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Physics of more than 11 years of COSY-11 – history, status, achievements, plans

Joanna Przerwa, Dieter Grzonka, Paweł Klaja,
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- The Westfälische Wilhelms–University Münster
- The Institute of Nuclear Physics in Cracow
- The Institute of Physics of the Silesian University in Katowice
- The Departments of Infrastructure of the Research Centre Jülich (ZEL, ZAT, ZAM, EM-E, EM-MAT)
- The Laboratory for Detectors at the Physics Institute of the Jagellonian University
- The workshops of the different institutions
- The COSY operation team
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The success of COSY–11 was only possible due to the support, encouragement and patronage of many persons and personalities directly or representing an agency or foundation. We appreciate the enormous help given to us and to our research which will be summarized and documented in this booklet and the upcoming proceedings of the symposium held in Cracow/Poland, June 16 – 20, 2007 (http://confer.uj.edu.pl/COSY-11/07/).

Contents

1. Physics

The COSY-11 installation was designed for a high precision study of meson production reactions in the vicinity of the production threshold in order to investigate the hadronic interaction between mesons and baryons in an energy domain where the perturbative description with the quantum chromo dynamics (QCD), the theory relevant for the strong interaction, is not applicable [1].

At relativistic energies the strong interaction can be well described by free quarks and gluons and their interaction can be considered as a small pertubation which allows a straightforward calculation. When reducing the energy this picture is not valid any more due to the self interaction of the exchange bosons of the strong force the gluons. At energies below a few GeV, the region to be investigated at COSY, the relevant degrees of freedom are the color neutral confined quarks: the ($q\overline{q}$) pairs - the mesons, and 3 quarks systems (qqq) - the baryons, and their interaction can be described by meson exchange. A reasonable understanding of these interaction processes including the possible influence of quark degrees of freedom requires very precise measurements of the most elementary system reduced to a low number of reaction mechnisms which is given by hadron-hadron induced meson production close to threshold where the number of contributing partial waves are very much reduced limited mostly to pure s-wave processes.

Meson production studies in the hadron–hadron interaction at threshold began in the fifties when sufficient energies of accelerated protons were available. A strong interdependence between developments in accelerator physics, detector performance and theoretical understanding led to a unique vivid field of physics. Early experiments performed with bubble chambers revealed already typical ingredients of threshold studies, which were superseded by more complete meson production investigations at the nucleon beam facilities TRIUMF, LAMPF, PSI, LEAR and SATURNE. With the advent of the cooler rings as IUCF, CELSIUS and COSY the field was entering a new domain of precision and the next step of further progress. COSY–11 devoted its research just to this field. The analysis of such data in the short range limit permits a more fundamental consideration and a quantitative comparison of the production processes for different mesons in the few–body final states. The interpretation of the data takes advantage of the fact that production reactions close–to–threshold are characterized by only a few degrees of freedom between a well defined combination of initial and exit channels. Deviations from predictions of phase–space controlled one–meson–exchange models are indications of new and exciting physics. Precision data on exitation functions, differential cross sections, isospin and spin observables were taken by a few experiments, especially by the COSY–11 collaboration, where a comprehensive overview of this field of hadronic threshold production studies will be given in the proceedings to this meeting and references therein.

The complexity of the hadronic structure is one of the actual and topical fields of physics concerning the microscopic scale. Different, complementary as well as competing experimental approaches are used to attack the challenge of the hadronic spectroscopy.

A detailed understanding of the strong interaction dynamics on the symmetries of QCD

[1] This chapter is based upon the Prog. Part. Nucl. Phys. 49 (2002) 1, and references therin

is a fundamental aim of hadron physics. At high energies the QCD serves as a reliable theory whereas at low energies non–perturbative QCD phenomena must be investigated. Here calculations are performed in an effective field theory of hadrons represented by the chiral effective Lagrangian, a theory of Goldstone bosons coupled to the octet of baryons and vector mesons. The QCD Lagrange function is written as: $L_{QCD} = \bar{q}\,(i\gamma^{\mu}\partial_{\mu} - M)\,q + L_{gluon} + L_{quark-gluon}$, where q describes the column vector of the quarks u, d, s, c, b, t with each of them represented by a spinor, analogous to the Dirac equation for spin–$\frac{1}{2}$ electrons. At energies in the few GeV range only the first three quarks are of any relevance, M represents the diagonal of the matrix for the quark current masses. Data of high quality and precision on hadronic processes at low and intermediate momenta are necessary in order to verify the systematic low energy expansion of the Chiral Perturbation Theory (χPT), which has already enforced an important insight into the structure and dynamics of nucleons and mesons.It is known that the current masses of the lightest three quarks are significantly smaller than the typical hadronic energy scale, represented by the proton mass of $m_p \approx 1\,\mathrm{GeV/c^2}$. This is the reason why in first order the quark masses of the light quarks are neglected in theoretical considerations and the spin–$\frac{1}{2}$ fields can be separated into two independent left– and right–handed parts, reflected by the chiral symmetry. The QCD Lagrangian separates into two identical images: $L_{QCD}[\bar{q}, q] = L_{QCD}\,[\bar{q}_{left}, q_{left}] + L_{QCD}\,[\bar{q}_{right}, q_{right}]$.

Left–handed quarks do not communicate with right–handed quarks and *vice versa*. There is no Lorentz transformation which can change the handedness of a mass–less quark or particle. This symmetry of the Lagrange function is not the symmetry of the spectrum of the particles since otherwise each hadron should have a partner of equal mass but inverted parity. Consequently there would be a second proton with negative parity which does not exist. There are no parity–doublets in the spectrum of the strong interacting particles and therefore the symmetry is spontaneously broken. Due to this breaking the mass–less so–called Goldstone bosons, the pseudoscalar π, K and η mesons appear. The restriction of the interaction of these particles among each other and with other hadrons can be used to analyze consequences of the chiral symmetry and its breaking in the framework of an effective field theory.

In reality the lightest hadrons — the Goldstone bosons — are by no means mass–less, which can be understood by an explicit breaking of the chiral symmetry including a term for the quark masses. For each massive Fermion there exists a Lorentz transformation which transforms a left–handed to a right–handed field. The effect of this explicit breaking now can be treated perturbatively since the masses of the light quarks are much smaller than the typical hadronic mass.

Predicting the low–energy properties of nuclear and particle physics, χPT plays an important role in understanding hadron physics in the non–perturbative regime. Therefore it is very important to know the properties of the mesons, their structure and interaction in the hadronic environment. The physics program at the medium energy hadron accelerators was and is focusing on studies of the production and the decay of light mesons and baryon resonances and the conservation or violation of symmetries.

COSY–11 studied the production of mesons and meson pairs at threshold with the questions depicted by the interaction view of figure 1.1 where in the nucleon–nucleon (NN) scattering a meson X is created in a one–boson–exchange model. For the particular case the questions have to be answered: how is the distortion of the incident NN waves (ISI) included, which mesons contribute to the exchange process, is there an intermediate baryon resonance, how significant are rescattering contributions of the exchange mesons and what is a reasonable treatment of the NN and NX final state interactions (FSI)? Especially for the

NN–interaction the FSI is crucial because of the nearby poles in the S–wave amplitudes corresponding to the deuteron bound state in the $^3S_1$ channel or the $^1S_0$ virtual state.These poles and the phase–space factors tend to determine much of the energy dependence of the total cross section for meson production. Furthermore, in any region where these poles dominate, it is possible to link quantitatively meson production in cases where the two nucleons emerge separately or as a bound deuteron state.

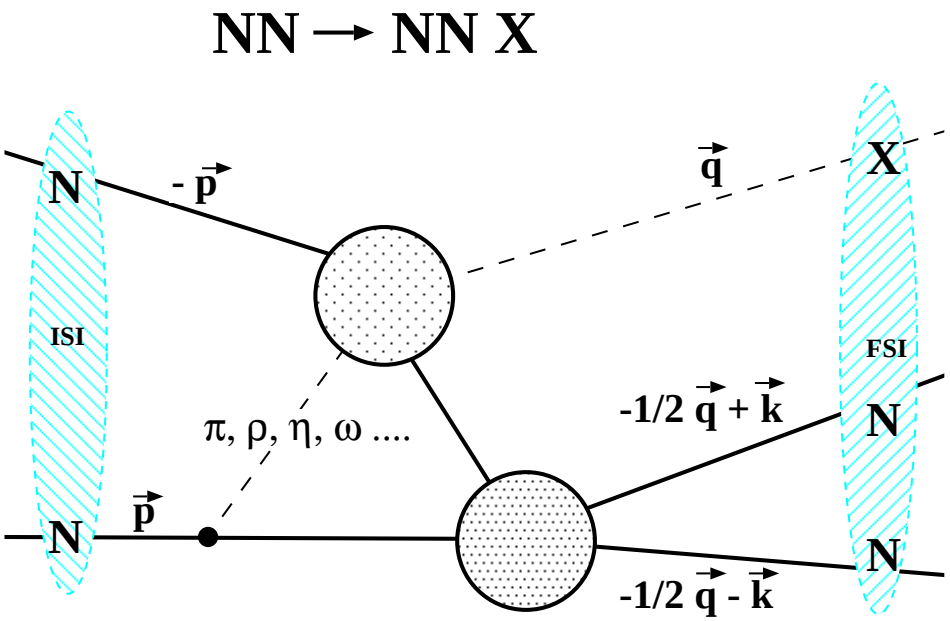

Figure 1.1: Diagrammatic view of the one–boson–exchange meson production process. Produced meson = X, nucleon momentum = $\vec{p}$, meson momentum = $\vec{q}$, relative NN momentum = $2\vec{k}$.

Even at threshold, the reaction mechanism of the basic process for the interrelation between real pions and virtual exchange meson currents is still not fully understood. Though first data suggested that s–wave pions were produced in a heavy–meson–exchange process, later measurements resulted in an interpretation of an interference among transition amplitudes as Ss, Ps, Pp, Sd and Ds, where the capital letter indicates the NN final state wave and the small letter the angular momentum between the two nucleons and the meson produced. In addition, it has been concluded that for higher partial waves π exchange rather than a heavier meson exchange is more significant.
Double meson production processes with both mesons being either identical (e.g. $\pi^0\pi^0$ or $K^0\overline{K^0}$) or different (e.g. $\pi\eta$) are in principle similar to the single ones, however, the possibly associated baryon resonances as intermediate states differ significantly.
As long as only S–wave processes are involved, which is the privilege of threshold production studies, scattering length and effective range approaches are used to describe the interaction sign and strength.

In case of strong attractive interactions a distinction between the final state scattering and the formation of a baryonic resonance leading to bound or quasi–bound states cannot be made uniquely. Such investigation have been studied by COSY–11.
Threshold production experiments are characterized by excess energies which are significantly smaller than the produced masses. Consequently, in fixed target experiments the momenta of the final state particles transverse with respect to the direction of the incoming beam are small compared to the longitudinal components. Thus, ejectiles are confined to a narrow forward cone in the laboratory system around the centre–of–mass movement and — close–to–threshold — an experimental acceptance covering the full solid angle is feasible with comparatively small dedicated detector arrangements as COSY–11.
Small relative momenta in the final state effectively limit the number of partial waves contributing, simplifying the theoretical interpretation of experimental results. As first described by Watson, with two strongly interacting particles in the final state, the energy dependence of the total cross section close–to–threshold is essentially determined by the (three–body) phase–space and the energy dependence of the on–shell final state interaction (FSI). Due to small relative velocities FSI effects are inherent to the experimental observables. Thus, the interpretation of data in terms of reaction dynamics requires a correct treatment of both initial (ISI) and final state interactions. On the other hand, FSI effects might provide access to low–energy scattering parameters, which are difficult to obtain otherwise in case of unstable particles.
Meson production at threshold implies high momentum transfers in the range of 0.37 GeV/c to 1.10 GeV/c for π^0 and ϕ meson production, threshold production probes with corresponding distances between 0.53 fm and 0.18 fm the short range part of the nucleon–nucleon interaction. Consequently, the energy dependence of the primary production amplitude is expected to be weak, motivating Watson's approach.
Theoretical studies have been carried out mainly within the framework of hadronic meson exchange models, i.e. with baryons and mesons as effective degrees of freedom. Chiral perturbation theory has been applied for the description of data on π production close–to–threshold. However, in view of the characteristic distances mentioned above, QCD inspired models with constituent quarks and gluons or instantons as relevant degrees of freedom, might turn out to be appropriate. High quality exclusive data on close–to–threshold meson production in the energy range of non–perturbative strong interaction physics will be crucial for exploring the boundary between effective meson exchange models and (so far phenomenological) approaches based on quark–gluon degrees of freedom.
It seems that the χPT is of limited value once strangeness is involved in the hadronic systems and non–perturbative coupled–channel considerations beyond χPT are presently available. High quality data on the meson $(\pi, \eta, \eta', \omega, K^+, K^-)$ production at threshold have been and are being produced at the hadronic beam cooler rings using the baryon number $B = 2$ systems (essentially pp and pn) as studied by COSY–11. A comparison of the meson production in the fundamental process to productions on heavier nucleons would give constraints to eliminate uncertainties in the basic interactions. As outlined by W. Weise and U.–G. Meißner, precise measurements of such processes set the necessary constraints for the effective Lagrangian of low–energy QCD with strange quarks. Its detailed knowledge has impacts on several other important issues, such as the strange quark content of the nucleon.

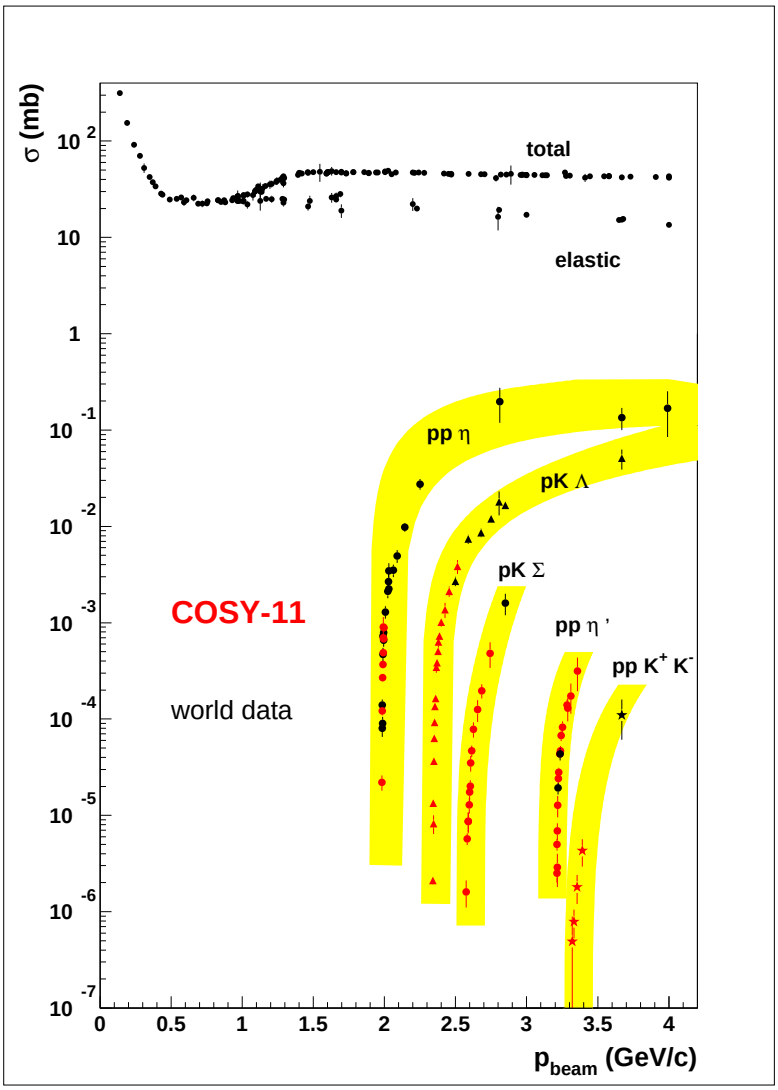

Figure 1.2: Proton–proton cross sections for different reactions of the light meson production in the threshold region. For comparison also the total and elastic cross sections of proton–proton scattering are shown.

Total cross sections of the meson production are very small in the threshold region down to eight orders of magnitude compared to the total yield. Due to the rapid growth of the phase–space volume they increase by orders of magnitudes in a few MeV range of excess energy. This implies that investigations of the near threshold meson production requires a precise determination of the beam momentum as well as of the momenta of ejectiles. Such studies have been made possible only due to the low emittance and small momentum spread proton beams available at the storage ring facilities. Figure 1.2 demonstrates threshold production measurements of light mesons in the proton–proton interaction, COSY–11 contributed significantly to these data.

2. Detection system

In this chapter we will present the main parts of the COSY-11 detection system with a general overview of it as displayed in figure 2.1.

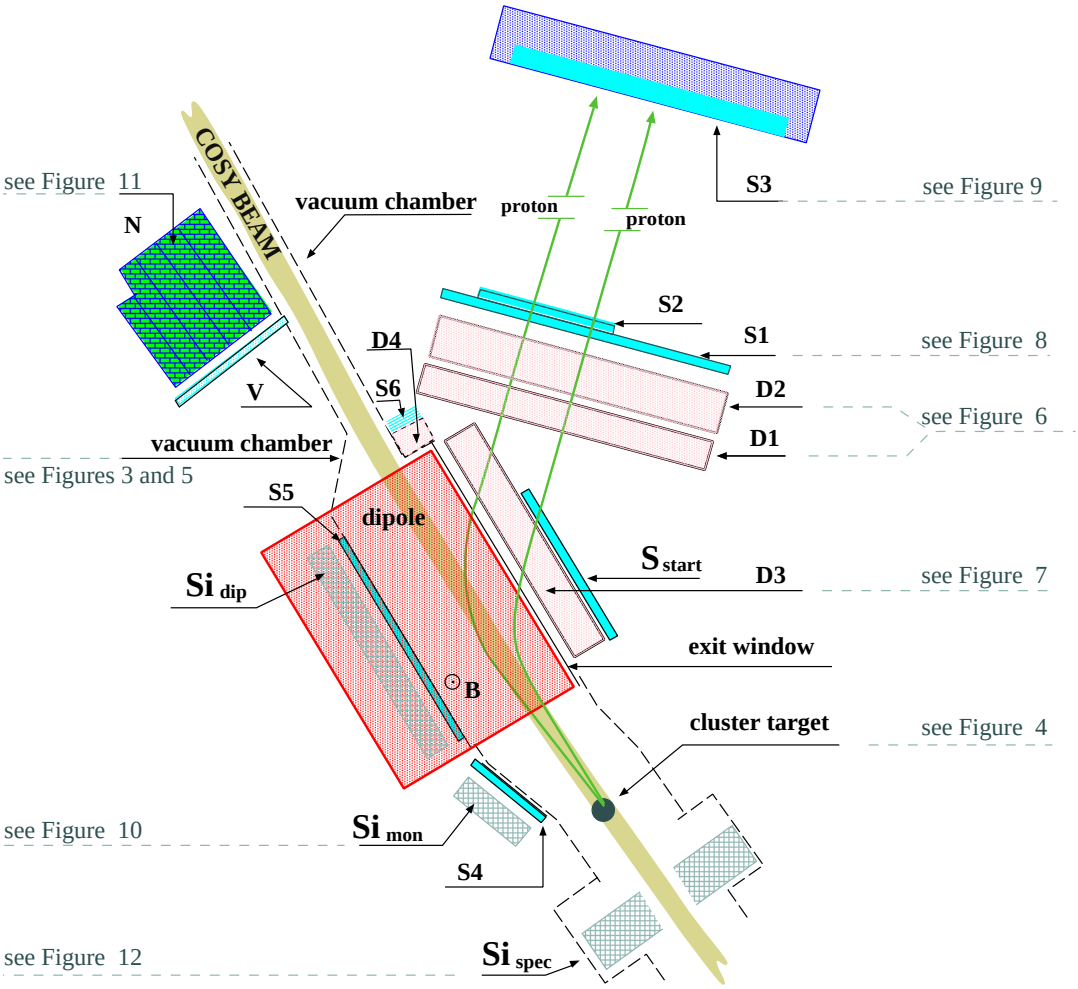

Figure 2.1: A drawing of the COSY–11 facility for close-to-threshold measurements

The COSY beam enters into the experiment from the bottom, it passes between the silicon detectors (Si_{spec}) and hits the cluster target where the reactions occur. The beam continues through the dipole magnet and proceeds into the COSY beam pipe. Reaction products (here two protons) exit through a thin window and are registered in drift-chambers (D1, D2, D3 or

D4) and scintillation counters (S_{start}, S1 – S6, V). Inside the dipole magnet are silicon pad and scintillation detectors (Si_{dip}, S5). For neutral particles the veto (V) and the scintillator lead sandwich (N) detectors are installed. The two detectors S4 and Si_{mon} serve for monitoring of the luminosity and of the beam-target overlap via elastic scattering.
A photo from the early stage of the experiment is shown in figure 2.2 and can easily be compared to figure 2.1.

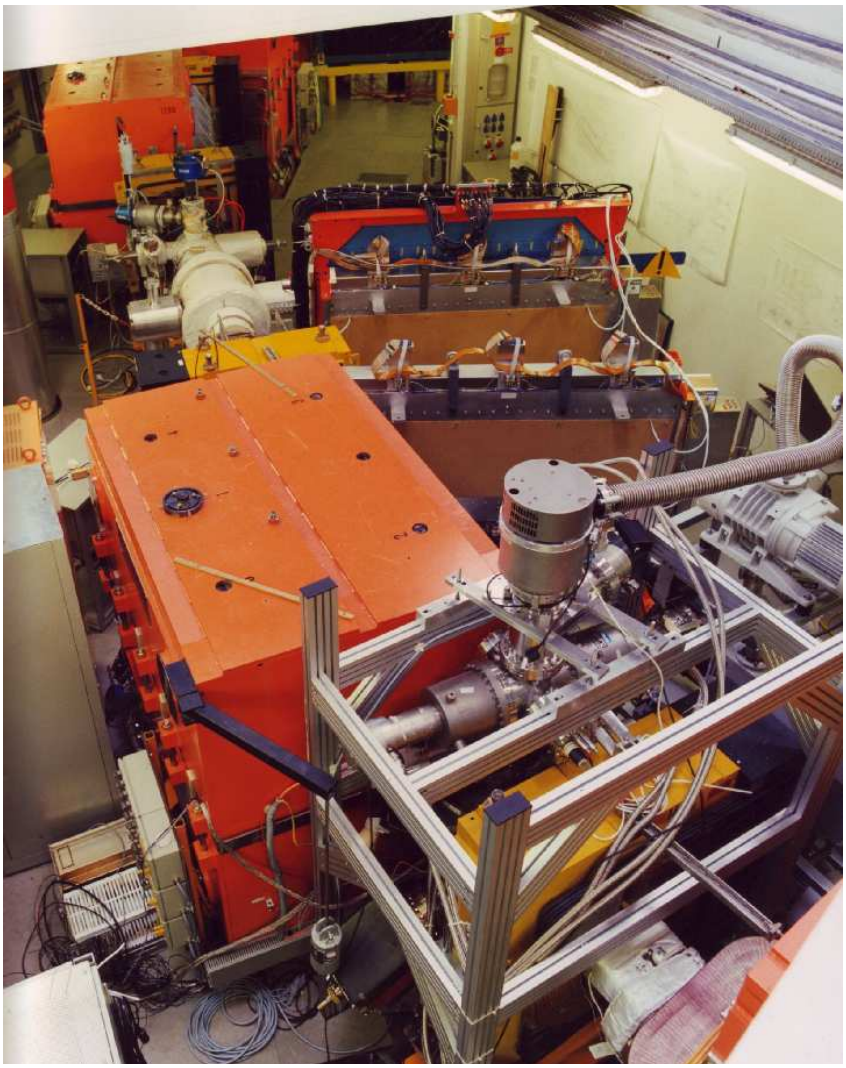

Figure 2.2: The COSY–11 detection system, showing the arrangement for the cluster target (bottom, right) the regular COSY dipole magnet (center, left) and the drift chambers and the scintillation detectors (top, right).

The COSY-11 facility was designed for close-to-threshold reaction studies where the relative momenta between the reaction particles are very small and all particles are focussed into a narrow forward cone resulting in a high detection efficiency achievable by still using rather small detection systems.
There is a special interest in the near threshold region because the final state interaction between the outgoing reaction products is best visible and the contributing partial waves are strongly limited mostly to pure s-waves which simplifies the theoretical description.
Due to the very strong energy dependence at threshold it is important to have a precise knowledge of the beam momentum and a very good momentum resolution of the beam particles.
COSY-11 was an internal magnetic spectrometer using a COSY machine dipole to separate the charged reaction products from the circulating beam. A photo taken during the installation work of the experiment COSY–11 is shown in figure 2.3.

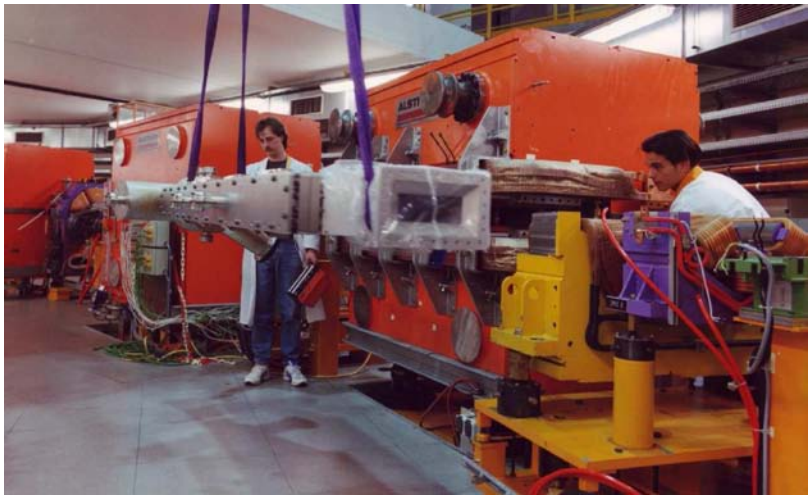

Figure 2.3: The special COSY–11 vacuum chamber during installation.

As a target a very thin (10^{14} atoms/cm^2) beam of clusters of up to 10^5 atoms was developed. The energy loss of the COSY beam circulating through such thin target could be compensated by the stochastic cooling system of COSY which guarantees a precise beam momentum over the whole measurement cycle. The design of the COSY-11 target was based on comparable targets operating at CERN with the typical structure of a cluster source unit where the target-gas is pre-cooled, passes a nozzle and clusters in the nozzle exit; the clusters cross the COSY beam and finally are caught in a cluster–beam dump attached to the accelerator vacuum via a sequence of differential pumping stages. Figure 2.4 shows the compact construction of the cluster target arrangement.
The gas load appears at both ends of the system but several pumping stages separated by small apertures reduce the gas load for the ultra high vacuum of the accelerator to a very small level. Only the gas clusters can be transported from the cluster source to the dump since – due to their large mass – they are not scattered out of the cluster beam direction when hitting a gas particle. At COSY we had severe space limitation for the target. The equipment

had to fit into a gap of about 30 cm and therefore the concepts with other cluster targets with huge turbomolecular pumps could not be used. However, with the development of special cryopumps the COSY-11 cluster target could be realized.

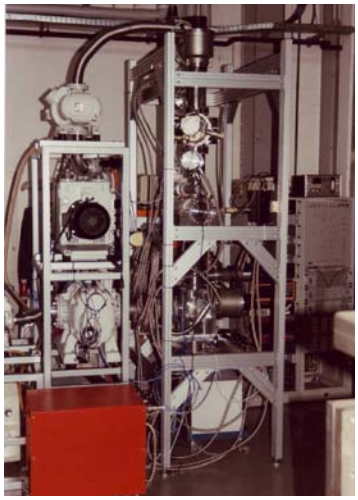

Figure 2.4: The arrangement of the cluster target before installation at COSY–11.

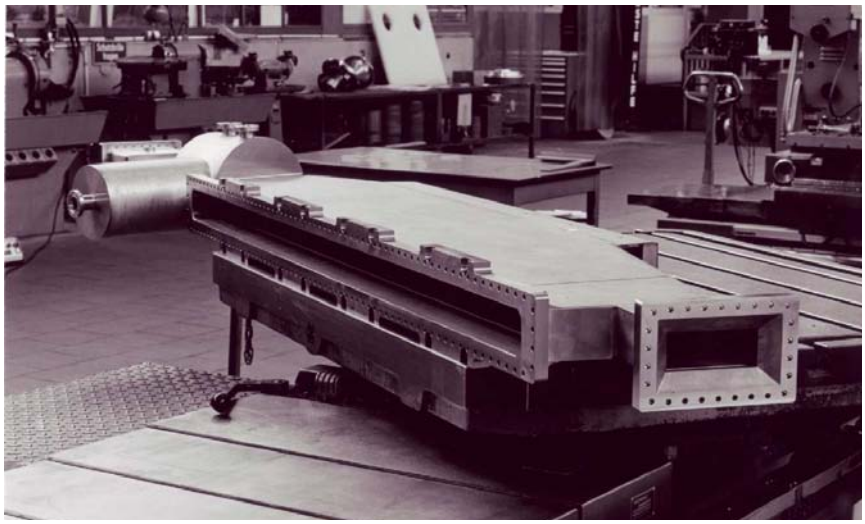

Figure 2.5: The COSY–11 vacuum chamber during construction at the ZAT of the Research Center Jülich.

In order to optimize the performance a special vacuum chamber was constructed and is shown in figure 2.5 with an increased free height compared to the standard COSY dipole chambers. The reaction products should leave the vacuum system as undisturbed as possible.

Therefore the vacuum chamber was equipped with an exit foil made of carbon fiber and a thin aluminum foil at the inside over the full length of the dipole (about 2 meters) without any support. The chamber was fixed to the dipole which was not straight forward because the ramping of the magnet changes slightly the gap height. All these effects were investigated in detail before the final solution was realized.

Figure 2.6: Three different views of the drift chambers, front and side view before installation (top), after installation next to the COSY dipole (bottom).

The main component of the detection system were two drift chamber sets with 6 and 8 layers of vertical and inclined wires. Three views of the drift chambers are shown in figure 2.6. The achieved position resolution was about 100 μm in horizontal and 200 μm in vertical coordinates which transfers to a missing mass resolution of less than 300 keV FWHM for e.g. the η-meson production. The chambers have been operating during the full measurement period of 15 years without any repair due to broken wires or any other problems. For special reaction channels an additional chamber with a hexagonal cell structure – which is nearly insensitive to magnetic fields – was positioned close to the exit foil of the magnet. Because the material budget in the way of the particles has to be as small as possible the chamber was designed with a fork structure without supports and is shown in figure 2.7.

Figure 2.7: Drift chamber with a hexagonal cell structure in front of the COSY dipole.

For the reconstruction of the momenta of the ejectiles the tracks of the particles are back-tracked from the drift chambers to the target through the realistic dipole field which was measured in 3 dimensions and included in our data analysis software. The target diameter was typical 9 mm which limits somewhat the precision in the reconstruction. When a higher precision was requested (as it was the case for the determination of the width of the η' meson) smaller target dimensions could be adjusted, increasing resolution according to expectations. To select candidates for desired events already on the trigger level, various scintillation detectors were installed. Behind the drift chambers was a hodoscope, named S1, consisting of 17 scintillator bars with a width of 10 cm each, readout on both sides, as shown in figure 2.8.

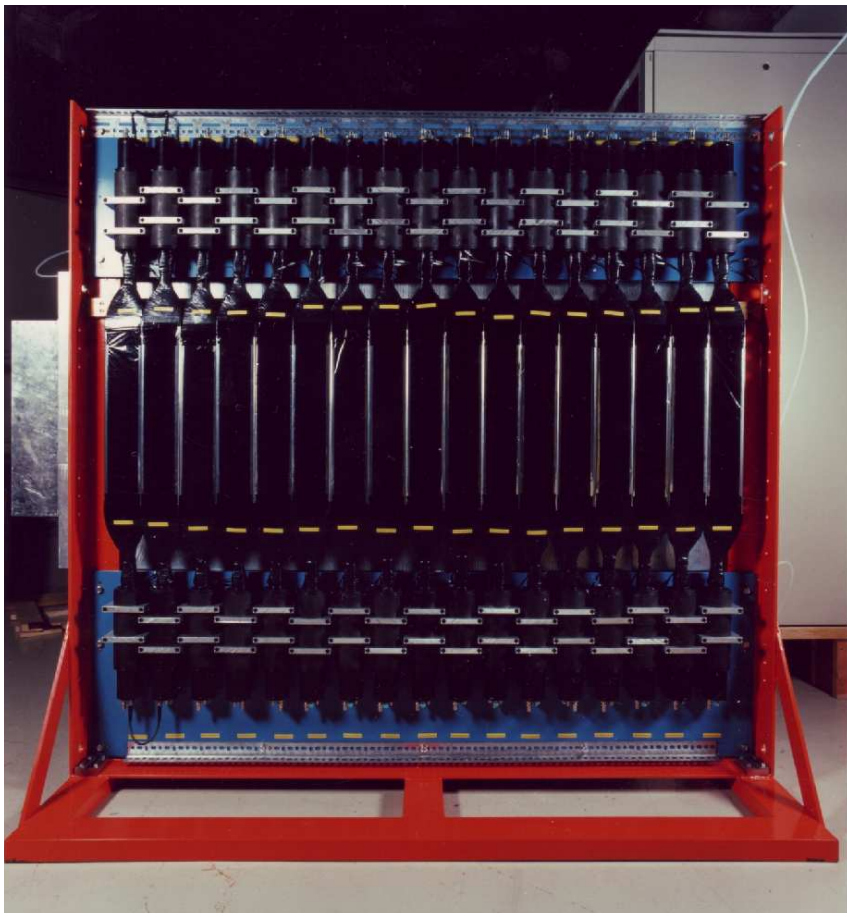

Figure 2.8: The COSY–11 hodoscope before installation consisting of 17 scintillator bars and readout on both sides.

Because the trigger did not only include the multiplicity but also the signal amplitude an electronic unit was developed to sum up the upper and lower photomultiplier signals of the individual modules which then provides energy loss information independent of the hit position. The same concept was used for a second scintillator hodoscope with 16 smaller strips of 1 cm width positioned directly behind S1 in the region where the outgoing particles were expected to be very close together. For the particle identification a time-of-flight method was used with a stop scintillator (S3) installed nine meters apart from the S1 counter. Here another concept was followed. It consisted of one large scintillator wall 2.2 m $\times$ 1 m which was observed from the rear by 217 photomultipliers, as shown in figure 2.9. The PM's were not directly coupled to the scintillator but there was a small gap such that only photons within a forward cone, i.e. the direct photons which went straight into the direction of the PM's were measured. Such solution permitted to achieve an optimal time resolution.

Figure 2.9: The COSY–11 large scintillator wall (S3, ”AMADEUS”) before installation (left: rear view) and at COSY–11 (right: front view).

In the dipole gap there was no space for tracking detectors for negatively charged particles but at least a silicon pad detector could be installed combined with a scintillator. Part of this detector is displayed in figure 2.10.

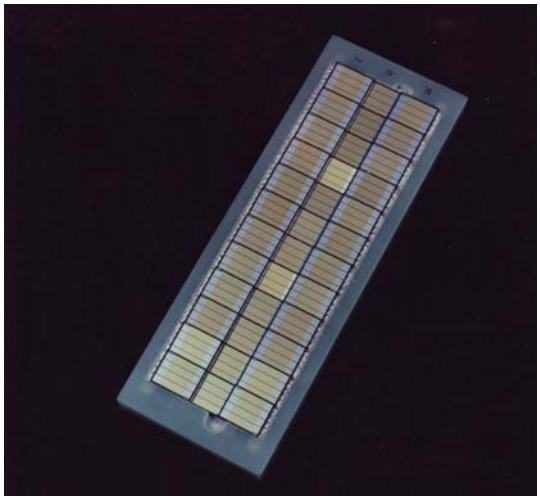

Figure 2.10: One module of the COSY-11 silicon pad detector consisting of 144 independent detection units.

It determines the position of a charged particle within a binning of a few millimeters and drastically reduces the background in the K^+K^- production studies.

Other detector components were used for special purposes like a system of scintillator and proportional wire chambers in forward direction above and below the vacuum chamber to measure the luminosity and determine the polarisation during measurements with polarized beam. For investigations where neutrons were produced in the reaction using a deuteron beam or a deuteron target a neutron detector (shown in figure 2.11) consisting of alternating

lead and scintillator sheets was developed covering a small forward cone behind the dipole.

Figure 2.11: The detector for neutral particles at COSY–11.

Furthermore an array of Si-pad detectors was mounted inside of the vacuum chamber surrounding the target point to measure the spectator protons in reactions on a neutron. This detector is displayed in figure 2.12 and was given to COSY-11 by Tord Johansson from the Uppsala University.

Figure 2.12: The array of Si-pad detectors surrounding the target region.

A more detailed description of the detector components and performance can be found in our publication: **"COSY–11, an internal experimental facility for threshold measurements"** *Nucl. Inst. & Meth. A 376 (1996) 397* as well as in the Diploma and PhD theses prepared at COSY-11 and listed in this booklet.

3. Methods

In course of the close to eleven years of experiments at COSY-11 many different methods were developed in order to fully identify the reactions under investigation. In this chapter we will briefly give account on the techniques of the unique determination of the registered particles.

Time-of-flight, energy loss, tracking in the magnetic field

Positively charged ejectiles were identified by independent measurements of their momenta and velocities or momentum and energy losses. Neutrons and gamma quanta were identified via indirect measurements of their velocity vectors and spectator protons by measurements of their kinetic energies and directions of motion.
For all reactions with a production of mesons like e.g. $pp \rightarrow ppX$ or $dp \rightarrow dpX$ the charged ejectiles were separated from the circulating beam in the magnetic field of the dipole. For these reactions the hardware trigger, based on signals from scintillation detectors, was adjusted to register all events with at least two positively charged particles. Tracking back the trajectories from the drift chambers through the dipole magnetic field to the target point allowed to determine the momenta of the particles. Having the momentum and the velocity of one particle, the latter measured using scintillation detectors, it is possible to identify the mass of the particle. As an example, figure 3.1 shows the squared mass of two simultaneously detected particles for the $pp \rightarrow A^+B^+X$ (left panel) and the $dp \rightarrow A^+B^+X$ reaction (right panel). Measured reactions can be grouped according to the type of ejectiles. The reaction with two protons, proton and pion, proton and deuteron, pion and deuteron and two pions were separated very clearly. In the above example the velocities of protons, deuterons and pi-

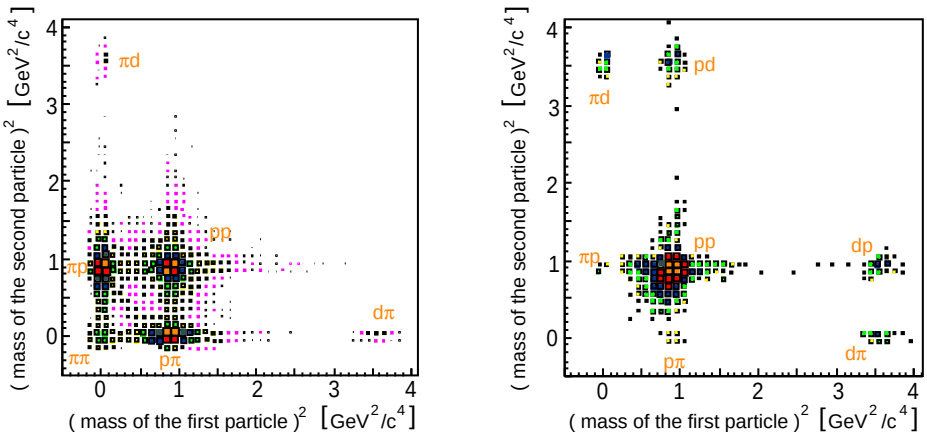

Figure 3.1: Left: Squared masses of two positively charged particles measured in coincidence in the $pp \rightarrow A^+B^+X$ reaction. **Right:** Squared masses of two positively charged particles measured in coincidence in the $dp \rightarrow A^+B^+X$ reaction. The size and colours of boxes correspond to the number of entries expressed in logarithmic scale.

ons were determined from the time-of-flight between the S1 and S3 scintillation hodoscopes. However, in the case of particles with a significantly lower lifetime (e.g. K^+ mesons), most of them would decay between the detectors rendering this method inefficient. Therefore, for kaons the velocity was determined from their time-of-flight between the target and the S1 detector. Here the time when the reaction took place at the target (t_0) was derived from the measurement of velocities and trajectories of the associated particles registered in the scintillation hodoscopes S1 and S3. The velocity of a K^+ meson is than given by the time difference of t_0 and the time measured by the S1 detector. An example of a spectrum is presented in figure 3.2 (left). Similarly, particles registered by the drift chamber D4 are identified via an

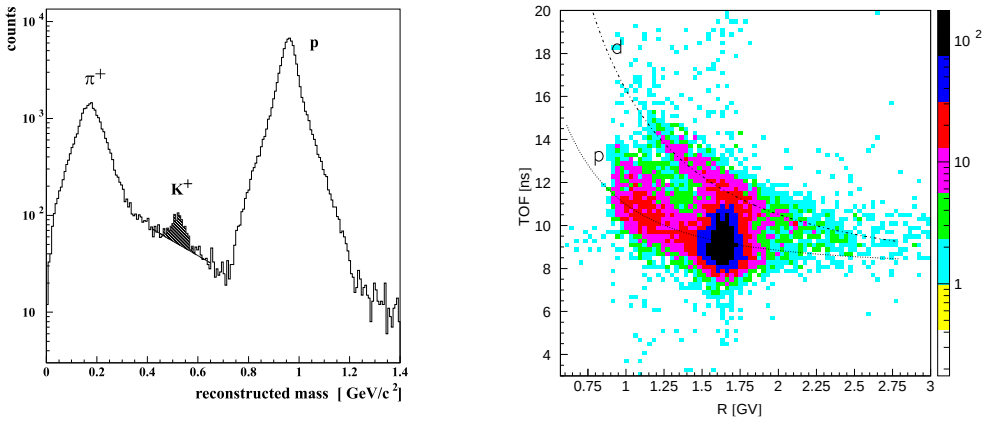

Figure 3.2: Left: Invariant mass distribution for events with three reconstructed tracks. Between the maxima from protons and pions a signal from the K^+ meson shows up. **Right:** Dependence of the time of flight on the magnetic rigidity for particles registered in the drift chamber D4. The time of flight was measured between the target and the scintillation hodoscope installed behind the D4 chamber. Lines indicates expectations for protons and deuterons. A significant enhancement of the yield of the protons is due to the spectator protons from the quasi-free neutron-proton reactions.

indirect determination of the time-of-flight between the target and the scintillation hodoscope S6. The momenta of particles registered in the D4 drift chamber, analogously as in the case of objects measured in the drift chambers D1 and D2, are established by the reconstruction of their trajectory in the magnetic field of the COSY dipole to the known reaction point. An example of a spectrum is presented in figure 3.2 (right). In the case of final ^3He nuclei and slow protons the identification was based on energy losses in the scintillator and semi-conductor detectors, respectively. The slow protons from the deuteron target were registered in the silicon pad detector installed close to the target, backward to the beam direction. Two layers of the spectator detector permitted to measure the kinetic energy of protons from 0,5 to 9 MeV and to distinguish them from fast particles which cross both detection layers whereas slow protons are stopped in the first or second detection plane (see figure 3.3 (left)).
The energy loss method was also successfully applied for the identification of ^3He nuclei (figure 3.3 (right)). Due to the large ionizing power these were clearly separated from protons, deutrons and pions by the energy loss in the S1 counter built out of plastic scintillator material with a thickness of 4 mm. In the case of ^3He nuclei it was also possible to measure its time-of-flight (TOF) on a nine meter path between S1 and S3 detectors (see figure 3.4 (left)). The combination of the TOF and energy loss method resulted in clean nearly background free

samples of events with ^3He nuclei.

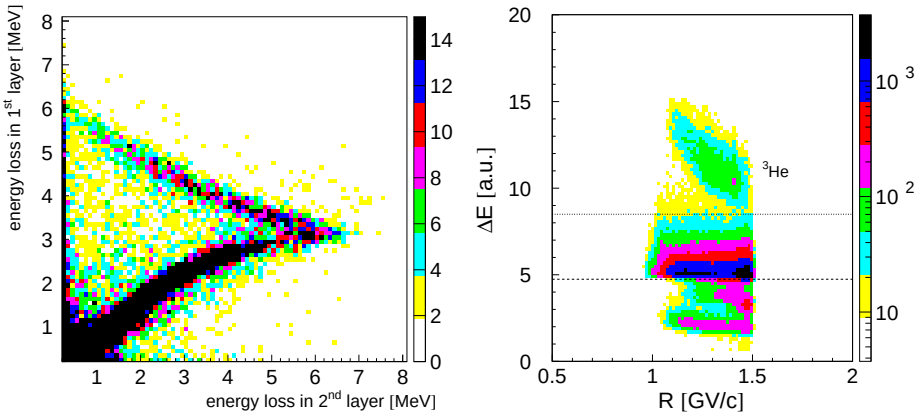

Figure 3.3: Left: Energy losses in the first versus the second layer of the silicon pad detector (spectator detector). The data were taken with a deuteron target and a proton beam with a momentum of 3.365 GeV/c. **Right:** Energy loss in the 4 mm thick plastic scintillator of the S1 hodoscope shown as a function of the magnetic rigidity. The lines indicate a hardware and software cut on the energy loss used in the analysis of the $dp \rightarrow {}^3He\eta$ reaction.

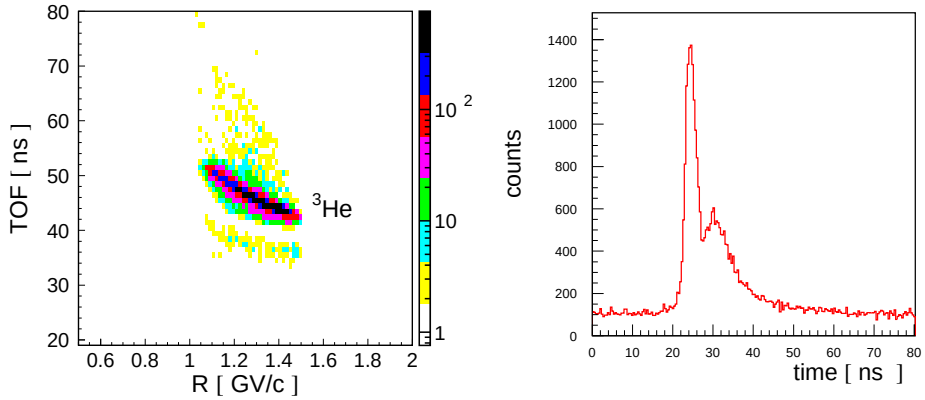

Figure 3.4: Left: Time-of-flight, measured on the path of 9.3 m between the scintillator hodoscopes S1 and S3, as a function of the magnetic rigidity. The figure shows only particles with an energy loss in the S1 scintillator larger than a value indicated by the dotted line in figure 3.3 (right). **Right:** Time of flight determined for the neutral particles between the target and the neutron detector.

The extension of the COSY-11 setup by a neutral particle detector opened a broad range of reactions with neutrons in the final state. The neutral particle detector delivers information about the time at which the registered neutron or gamma quantum induced correspondingly a hadronic or electromagnetic reaction. This information together with the time of the reaction t_0 allows to calculate the time-of-flight between the target and the neutron detector and to determine the absolute momentum of the registered particle, provided that they could have been identified. The time of the reaction in the target can be calculated from the time when other ejectiles of the same reaction crossed the S1 scintillator and from their reconstructed momenta and trajectories. Figure 3.4 (right) presents the time-of-flight distribution for neutral particles measured between the target and the neutral particle detector. The spectrum

was obtained under the condition that in coincidence with a signal in the neutral particle detector two charged particles were registered in the drift chambers D1 and D2. A clear signal originating from the gamma rays is seen (at about 24 ns) over a broader enhancement from neutrons centered at 30 ns. This histogram shows that a discrimination between signals originating from gamma quanta and slower neutrons can be done by a cut on the time-of-flight.

Missing mass method

For the identifications of the production of short-lived mesons or hyperons we made use of the missing mass technique. The investigated reaction channels can be found in the abstracts of the publications as well as in the Diploma and PhD theses of the COSY-11 collaboration. As a first example we consider the η–meson production via the reaction $pp \rightarrow pp\eta$. Knowing the beam momentum and measuring both outgoing reaction protons allows to calculate the "missing mass" by applying energy and momentum conservation. A missing mass squared spectrum is shown in figure 3.5 (left).

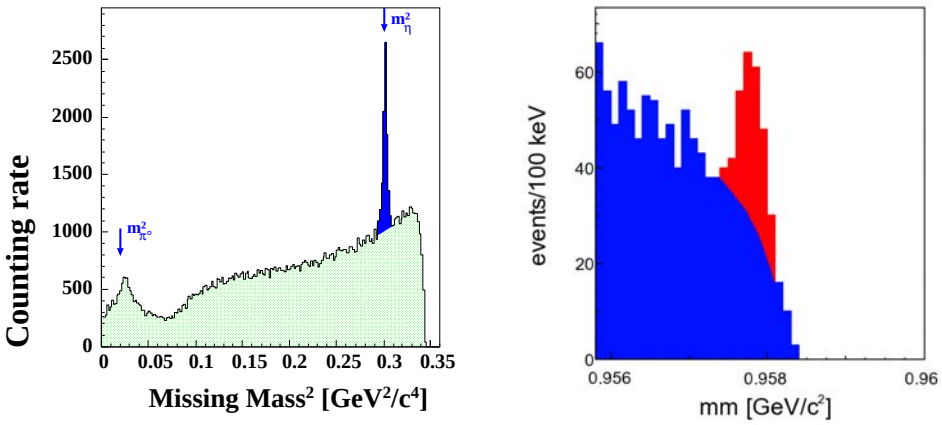

Figure 3.5: Left: Distribution of the squared missing mass for the $pp \rightarrow ppX$ reaction measured near the η production threshold. **Right:** Missing mass distribution close to the η' production thresholds determined with the target of 1 mm diameter. The FWHM of the signal amounts to 400 keV/c^2. The width is due to the convolution of the experimental mass resolution of the COSY-11 setup ($\sim$ 300 keV/c^2) and the natural mass distribution of the η' meson (200 - 300 keV/c^2).

Figure 3.5 (right) demonstrates the achieved missing mass resolution for the $pp \rightarrow ppX$ reaction measured close to the η' meson production threshold, at the COSY-11 detection system, when using a stochastically cooled beam and a cluster target with a diameter of 1 mm. It is worth noting that the precision of the mass determination is comparable with the natural width of the η' meson, and, to our best knowledge, it is by one order of magnitude better than ever achieved in experimental studies of hadrons.

Ramping– and super-cycle–mode of COSY

In order to study the energy dependence of the production cross section the beam momentum is varied and the number of produced mesons is counted by the content in the missing mass peak. In most of the experiments conducted by COSY-11 the beam momentum was

fixed at a given value to collect a required statistical accuracy before changing it to another value. However, in some cases, when the decrease of the systematical errors was particularly important, we took advantage of the possibility of the cooler synchrotron COSY to operate in the ramping mode permitting a continuous slow variation of the beam momentum during each measurement cycle.

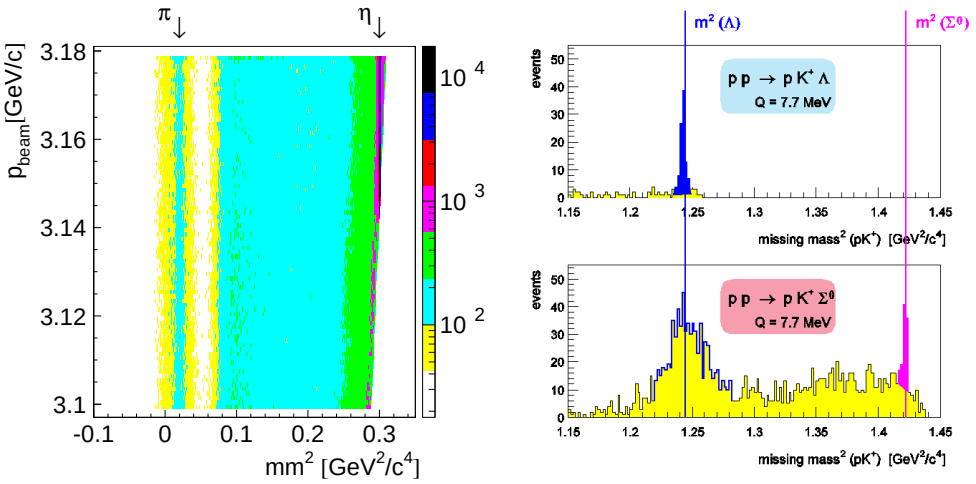

Figure 3.6: Left: Missing mass squared (x-axis) as a function of the beam momentum (y-axis). Results of the measurement conducted with the continuous change of the momentum of the deuteron beam around the threshold for the η meson production via $dp \rightarrow {}^3He\eta$ reaction. A signal from π^0 production spreads over the entire range of the scanned momentum. Above the η meson production threshold (for P_{beam} larger than 3.14 GeV/c) a sharp signal from the η meson is clearly visible. **Right:** Missing mass spectra to the $pp \rightarrow pK^+X$ reaction determined in the supercycle mode for the excess energy of 20 MeV above the production threshold of the Λ (upper picture) and Σ hyperon (lower picture).

We used also the opportunity to change the energy in discrete steps from cycle to cycle. This so-called super-cycle mode was especially important for a detailed comparison of the production cross sections of the Λ and Σ hyperons. Figure 3.6 presents an example of the missing mass spectra obtained in both kind of mentioned experiments.

Reduction and subtraction of the physical background

Usage of the missing mass technique is unavoidably connected with the presence of a physical background originating from multi-particle production processes. In course of the analysis we have used several methods for the subtraction of this background. In the case of the $pp \rightarrow ppK^+K^-$ reaction we have required a signal in the silicon-pad counter at the position where the trajectory calculated for the K^- was crossing the detection plane. Such consistency check lead to an essentially background free spectrum corresponding to the $pp \rightarrow ppK^+K^-$ reaction solely. Figure 3.7 presents an example of the missing mass spectra before and after the reduction of the background.

In the case of the short-lived hyperons or mesons like Λ or η, respectively, the reduction of the background was not possible since the decay products of these particles could not be registered at COSY-11 with high enough efficiency. Therefore, the background could only

be subtracted via a statistical procedure. Here very important was i) the precision of the determination of the momenta of the measured ejectiles, ii) the small spread of the beam momentum and iii) the negligible secondary scattering effects in the extremely thin target ($\sim 10^{14}$ atoms/cm^2). The listed features resulted in the suppression of the background due to the small width of the missing mass peaks and therefore high signal to noise ratios.

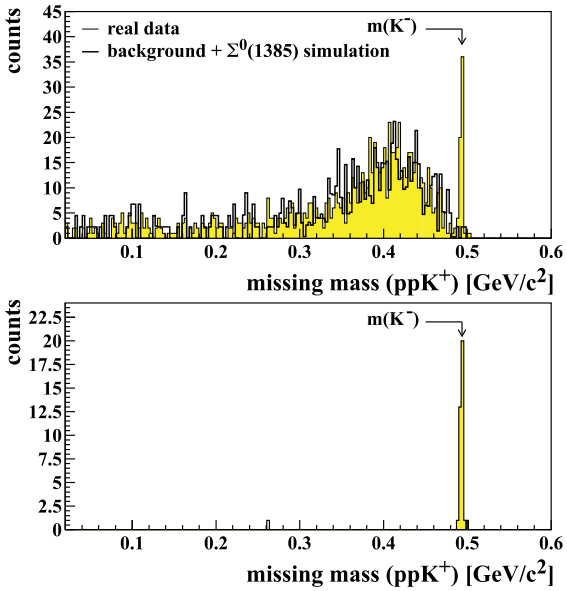

Figure 3.7: Missing mass distribution of the ppK^+ system at an excess energy of 17 MeV above threshold. The picture on the top presents events with identified protons and K^+ meson (thin solid line). The spectrum indicated by the thick solid line is a reproduction of the background distribution. The lower spectrum represents events with an additional hit in the silicon pad detector, at the position expected for the K^- meson.

The background was estimated either by determining its shape below the production threshold (see figure 3.8 (left)) or by determining its shape from Monte-Carlo studies (see figure 3.8 (right)). In the letter case the precision was always biased by the knowledge of the production mechanism of all background channels. However, as can be concluded from the consistency between the simulated and experimental distribution, visible in figure 3.8 (right), we have achieved a high level of understanding of the detectors functioning and the background distributions. In the case of the hyperon production we dealt also with another kind of the background which was due to the misidentification of kaons. In this case we applied the so called "side-band" technique making a conscious misidentification of pions with the reconstructed masses close to the mass of the kaon, and treating them in the analysis as they were true kaons.

As the last example of the missing mass analysis we present a spectrum (see figure 3.9) obtained for the quasi free $pn \rightarrow pnX$ process. In this case the distributions are broader than previously discussed for the case of pd or pp reactions. This is due to the lower accuracy in the determination of the momentum of the outgoing neutron as well as the lower accuracy in the determination of the momentum of the neutron inside the deuteron target.

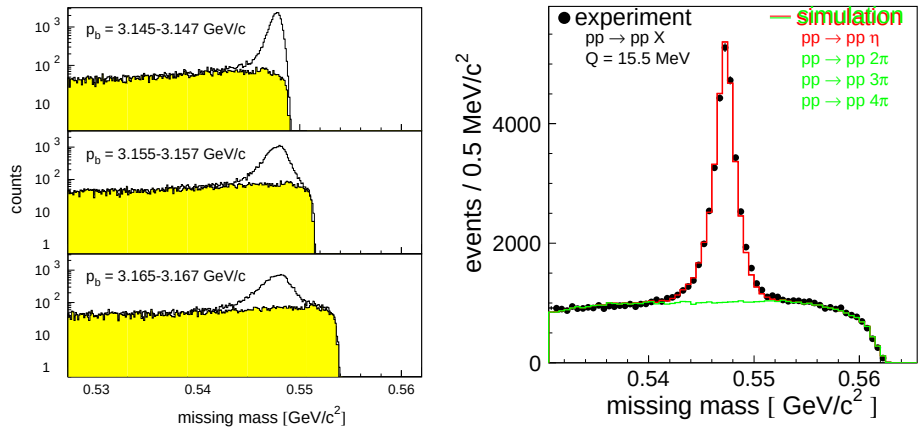

Figure 3.8: Left: Missing mass spectra for three different intervals of the deuteron beam momentum above the η production threshold. The shaded areas represent the multi-pion background measured below threshold which is scaled according to the luminosity and shifted to the kinematical limit of the missing mass. **Right:** Missing mass spectrum for the $pp \rightarrow ppX$ reaction determined in the experiment at a beam momentum of 2.0259 GeV/c. The superimposed histograms present the simulation for $pp \rightarrow pp\eta$ reaction, and for the reactions $pp \rightarrow pp2\pi$, $pp \rightarrow pp3\pi$ and $pp \rightarrow pp4\pi$. The simulated histograms were fitted to the data varying only the magnitude.

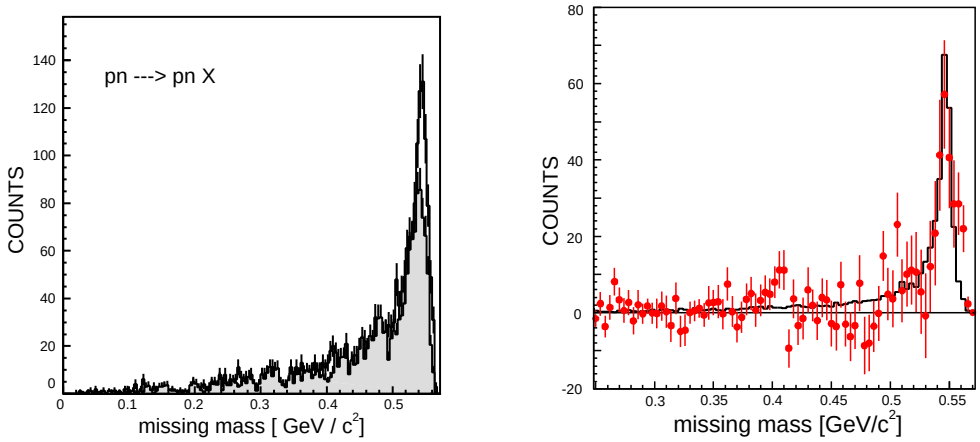

Figure 3.9: Left: The solid line shows the missing mass distribution of the $pn \rightarrow pnX$ process determined for $Q > 0$ with respect to the $pn \rightarrow pn\eta$ reaction. The shaded histogram depicts the missing mass spectrum determined for $Q < 0$. **Right:** The points denote the experimental missing mass spectrum for $Q > 0$ after subtraction of the multi-pion background. The superimposed solid line, normalised in amplitude to the data points, results from a Monte-Carlo simulation.

For the realisation of the proton-neutron reactions we used a deuteron target and analysed the data under the assumption of the spectator model. The momentum of a neutron inside a deuteron at the time of the reaction was inferred from the measurement of the momentum

vector of the spectator proton. The achieved mass resolution was, however, satisfactory, and even in the first test run (see figure 3.9) we succeeded to observe a statistically significant difference between the spectra determined below and above the threshold. This allowed us to extract a signal from the $pn \rightarrow pn\eta$ reaction.

Absolute normalisation

The integrated luminosity was established from the angular distributions of the number of the elastic scattering protons or deuterons which were registered in parallel to the investigated reactions. The elastically scattered particles were identified via distributions on the momen-

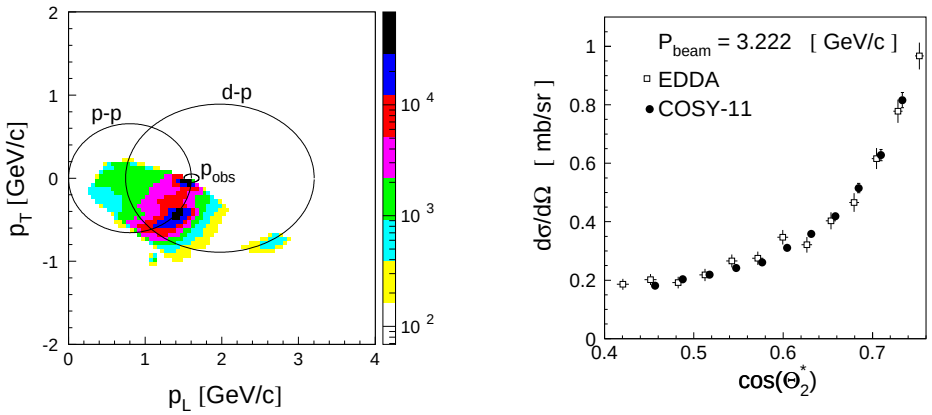

Figure 3.10: Left: Momentum plot of charged particles originating from the reactions of the deuteron beam with a proton target. Shown are perpendicular versus parallel momentum components with respect to the beam direction. Clear signals from proton-proton quasi-elastic scattering, deuteron-proton elastic scattering and from the protons "spectators" of the quasi-free neutron-proton processes. Solid lines indicate expected momentum ellipses. The number of entries per bin is shown logarithmically. **Right:** Differential cross sections for the elastic proton-proton scattering measured using the proton target and the proton beam with momentum of 3222 GeV/c. The COSY-11 points (full circles) were fitted in the overall normalization to the cross sections measured by the EDDA collaboration (open squares). To be better distinguishable the EDDA and COSY-11 points were shifted from each other in the horizontal direction by a half size of the point.

tum plot where – due to the two-body kinematics – the points should form corresponding kinematical ellipse. The momentum vector was determined for the forward scattered particles, whereas for the recoil protons the scattering angle was established from the signals in the position sensitive monitor detector.

In the case of the proton-deuteron reactions we detected both proton-deuteron elastic scattering as well as the quasi elastically scattered protons. An example of the spectrum is shown in figure 3.10 (left). Figure 3.10 (right) presents a comparison between the COSY-11 and EDDA results of the angular distribution for the proton-proton elastic scattering. The COSY-11 data were normalized to the cross sections determined by the EDDA collaboration with the luminosity as the only free parameter.

4. Total beam time

The following table summarizes the data taking at COSY–11.

Run #	Date of beam time	Reaction	Time granted
1)	April 1995	$pp \to pp\eta$	3/2 days
2)	June 1995	$pp \to pp\pi^+\pi^-$	10 days
3)	August 1995	$pp \to pp\pi^+\pi^-$	7 days
4)	August 1995	$pp \to pp\eta$	3 days
5)	October 1995	$pp \to pp\eta'$	7 days
6)	November 1995	$pp \to ppK^+K^-$	11 days
7)	April 1996	$pp \to ppK^+K^-$	10 days
8)	April 1996	$pp \to pK^+\Lambda$	2 days
9)	May 1996	$pp \to pp\phi$ $pp \to pp\omega$	4 days 2 days
10)	July 1996	$pp \to d'\pi^+$	9 days
11)	September 1996	$pp \to pp\eta'$	14 days
12)	October 1996	$pp \to pp\eta$	5 days
13)	December 1996	$pp \to ppK^+K^-$	6 days
14)	January 1997	$pp \to pK^+\Lambda$ $pp \to pK^+\Sigma^0$	12 days 2 days
15)	March 1997 April 1997	$pp \to ppK^+K^-$ $pp \to ppK^+K^-$	9 days 10 days
16)	May 1997	$pp \to pK^+\Sigma^0$	12 days
17)	June 1997	$pd \to X$	3 days
19)	June 1997	$pp \to pK^+\Sigma^0$	7 days
20)	October 1997	$pp \to pK^+\Sigma^0$	10 days
21)	February 1998	$pp \to pp\eta'$	14 days
22)	March 1998	$pp \to pK^+\Lambda/\Sigma^0$	9 days
23)	September 1998	$pp \to ppK^+K^-$	21 days
24)	November 1998	$pp \to pp\omega$	10 days
25)	February 1999	$pp \to pp\eta'$	7 days
26)	May 1999	$pp \to pp\omega/\phi$ $pd \to {}^3HeX$	7 days 1/2 day
27)	May 1999	$pp \to ppK^+K^-$	7 days
28)	July 1999	$pd \to {}^3He\eta(\eta')$	7 days
29)	December 1999	$pp \to pK^+\Lambda/\Sigma^0$	14 days
30)	March 2000	$pp \to pp\eta$	18 days
31)	July 2000	$pp \to pK^+\Lambda/\Sigma^0$	15 days

Run #	Date of beam time	Reaction	Time granted
32)	August 2000	$pp \to ppK^+K^-$	17 days
33)	January 2001	$\vec{p}p \to pp\eta$	11 days
34)	March 2001	$pp \to ppK^+K^-$	25 days
		$pp \to pn\pi^+$	1 day
35)	January 2002	$pp \to ppK^+K^-$	14 days
35)	March 2002	$pd \to {}^3He\eta'$	10 days
36)	May 2002	$pd \to {}^3He\eta'$	25 days
37)	June 2002	$pn \to pn\eta$	8 days
38)	September 2002	$\vec{p}p \to pp\eta$	18 days
39)	January 2003	$dp \to dp\eta$	10 days
40)	March 2003	$pp \to nK^+\Sigma^+$	11 days
41)	April 2003	$\vec{p}p \to pp\eta$	17 days
41)	September 2003	$pp \to pp\eta'$	23 days
42)	August 2004	$pn \to pn\eta'$	24 days
43)	April 2005	$dp \to {}^3He\pi^0/t\pi^+$	23 days
44)	September 2005	$pp \to ppK^+K^-$	18 days
45)	October 2005	$\vec{p}p \to pK^+\Lambda$	18 days
46)	February 2006	$pn \to d\eta'$	21 days
47)	September 2006	$pp \to pp\eta'$	28 days

SUM 1995-2006	608 days

5. The COSY–11 Collaboration

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1. *Excitation function of the $dp \rightarrow {}^3He\pi^0$, reaction near the ${}^3He\eta$ threshold*
   submission planned in summer 2007

2. *Close to threshold cross sections of the $pn \rightarrow pn\eta$ reaction*
   submission planned in summer 2007

3. *Proton-proton correlation function for the $pp \rightarrow pp\eta$ reaction at Q = 15.5 MeV*
   submission planned in summer 2007

4. *Study of the $p\eta$ interaction: Dalitz plot and invariant mass distributions of the $pp \rightarrow pp\eta$ reaction at Q = 10 MeV and Q = 36 MeV*
   submission planned in winter 2007

5. *Close to threshold excitation function of the $dp \rightarrow dp\eta$ reaction*
   submission planned in winter 2007

6. *Precise determination of the η' meson width*
   submission planned in spring 2008

7. *Close to threshold cross sections of the $pn \rightarrow pn\eta'$ reaction*
   submission planned in spring 2008

8. *Study of the $p\eta'$ interaction: High statistics invariant mass distributions of two-paricles subsystems for the $pp \rightarrow pp\eta'$ reactions measured at Q = 15.5 MeV: Comparison to the analogous spectra for the $pp \rightarrow pp\eta$ at the same excess energy*
   submission planned in spring 2008

9. *Near threshold total cross section for the $pd \rightarrow {}^3He\eta'$ reaction*
   submission planned in summer 2008

10. *Determination of the p-Λ scattering length via $\vec{p}p \rightarrow pK^+\Lambda$ reation*
    submission planned in summer 2008

11. *Total cross section of the $pp \rightarrow ppK^+K^-$ reaction very close to threshold*
    submission planned in winter 2008

12. *Close to threshold cross sections of the $pn \rightarrow d\eta'$ reaction*
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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

COSY-11, an internal experimental facility for threshold measurements

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Abstract

The COSY-11 installation is an internal experiment at the cooler synchrotron and storage ring COSY Jülich. It has been designed for full geometrical acceptance close to threshold for meson production studies, especially in the 1 GeV/c^2 mass range. The experimental setup makes use of a regular C-type COSY dipole magnet, following a cluster target, to separate reaction products from the beam and to analyze their momenta, thus allowing the observation of charged reaction products at small angles with beam energies close to threshold. Resonances will be identified by missing mass reconstructions from measured four-momenta of two outgoing protons in the predominantly studied $pp \rightarrow ppX$ reaction. In addition, charged mesons either produced directly or from decays of X will be detected. The different components of the experimental facility are presented.

1. Introduction

Although of fundamental nature, the production of single mesons and mesonic states with and without strangeness in a mass range from the π^0 to the $\Phi(1020)$ meson offers a broad field of unsolved questions in medium energy physics.

This holds especially for the 1 GeV/c^2 region, where the $\Phi(1020)$ is generally believed to be of rather pure $s\bar{s}$ quark content, whereas the structure of the $\eta'(958)$ is still being discussed. In case of the scalar mesons $f_0(975)$ and $a_0(980)$ existing data lead to differing interpretations: For instance, a two-quark two-antiquark state, a simple $s\bar{s}$ nature and a $K\bar{K}$ molecule structure are suggested in case of the f_0 [1–6].

Data of high precision and sufficiently large statistics, in case of small resonances especially in the threshold region, are needed to discriminate between these contradicting interpretations of mesonic states and resonances, which are to be explained on the general basis of QCD.

Threshold meson production necessarily implies vanish-

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PHYSICS LETTERS B

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Λ-hyperon production via the $pp \longrightarrow pK^+\Lambda$ reaction 2 MeV above threshold

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Abstract

The $pp \longrightarrow pK^+\Lambda$ reaction was measured at COSY with a proton beam momentum of 2.345 GeV/c, i.e. with an excess energy of 2 MeV above threshold. The total cross section was determined to be 8.2 ± 1.8 nb. The present data point close to the production threshold indicates, that existing phenomenological parametrizations of the total kaon production cross section are insufficient.

PACS: 14.20.Jn; 14.40.Aq
Keywords: Threshold measurement; Strangeness production; Final state interaction; Baryon-hyperon scattering length

1. Introduction

The associated strangeness production is an excellent tool to study reaction mechanisms and hadron dynamics in the nonperturbative region of strong interaction physics. Such investigations might relate quark model concepts to descriptions in terms of mesonic and nucleonic degrees of freedom. The (s–$\bar{s}$) quark pair creation provides a clean signal of the reaction dynamics since there are no strange valence quarks in the proton-proton entrance channel. Variation of the experimental input parameters such as projectile-target combinations, beam momenta, and incident spin states provides complementary information needed for a complete analysis.

Inclusive Λ-hyperon production experiments [1] using the high energy (200 GeV/c) proton beam have shown that spin effects are more important than predicted by perturbative QCD calculations. Spin effects are also being investigated at much

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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The Münster cluster target for internal storage ring experiments

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Abstract

The Münster cluster target has been built as a flexible device for internal storage ring experiments. To meet the particular spatial requirements of the COSY-ring at the KFA Jülich special cryopumps have been developed. Cluster beams of all gases except helium can be produced. Density profiles of the cluster beam can be measured on-line by means of a 5 keV electron scattering monitor system. An easy adaption of the cluster target to other installations is possible because of its compact modular design. During several beam times the target has successfully been operated within the COSY-11 experiment using hydrogen clusters. Cluster beam densities of up to $\rho \sim 10^{14}$ atoms/cm^3 have been reached.

Keywords: Cluster target; Internal target; Hydrogen clusters; Nozzle; Laval nozzle; Cryopump

1. Introduction

With the advent of storage rings using electron or stochastic cooling, high quality particle beams have become available leading to an increased precision in scattering experiments. To make full use of these advantages thin internal targets are necessary. One group of internal targets are gaseous targets like gas cells, gas-jet, cluster and atomic beam targets.

A supersonic gas-jet is generated when gas passes a Laval type nozzle under high pressure. Close to the nozzle high densities of up to 10^{17} atoms/cm^2 can be achieved in such a gas-jet target [1], but due to the scattering of the gas particles the density distribution perpendicular to the beam is very broad and approaches the density of the residual gas within some cm. Because of its high background of typically 10^{-3}–10^{-2} mbar this type of target cannot be used in a synchrotron ring with UHV conditions.

A molecular beam with densities of typically 10^{10}–10^{11} atoms/cm^2 can be prepared by cutting out the central part of a gas-jet by a special orifice, the skimmer. As a consequence, all of the atoms in this beam nearly move parallel to each other. Such a beam can pass a scattering chamber without influencing the pressure if it is caught in a beam dump.

Retaining a similar experimental arrangement, a much higher density is achieved by using a cluster beam instead of a molecular beam. It consists of formations of typically 10^3–10^4 atoms [2]. A cluster beam is produced by expanding gas in a nozzle at an appropriate temperature. During the expansion the temperature of the gas is reduced below the condensation point and the clustering starts. The typical densities of cluster targets are in the range of 10^{14} atoms/cm^3.

Compared to solid state targets gaseous targets have a number of advantages. First of all the target is extremely pure and there are no irradiation damages of the target material because of the continuous refreshing. Moreover losses of beam particles due to Coulomb scattering are negligible and the probability for secondary reactions is low. As a consequence the measurement of extremely low cross sections is possible.

Some basic parameters of existing cluster targets are given in Table 1. All cluster target devices consist of the two main parts, the cluster source and the cluster beam dump. The cluster target built in Münster, which is based on earlier studies [6], has drastically reduced geometrical dimensions compared to other existing devices. This was achieved by reducing the pumping capacities to a minimum.

2. Experimental arrangement

The cluster target has been designed for measurements with the cooler synchrotron COSY at the KFA Jülich within the COSY-11 experiment. COSY-11 is an internal experimental arrangement for meson production studies in p-p interactions close to threshold. The target is located in front of a machine dipole acting as a magnetic separator for the

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PHYSICS LETTERS B

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Total cross section of the reaction $pp \to pK^+\Lambda$ close to threshold

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Abstract

The energy dependence of the total cross section for the $pp \to pK^+\Lambda$ reaction was measured in the threshold region covering the excess energy range up to 7 MeV.

Existing model calculations describe the slope of the measured cross sections well, but are too low by a factor of two to three in rate.

The data were used for a precise determination of the beam momentum of the COSY-synchrotron. © 1998 Elsevier Science B.V.

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Keywords: Threshold measurement; Strangeness production; Final state interaction; Baryon-hyperon scattering length; Coulomb distortion corrections

1. Introduction

The associated strangeness production in pp collisions is of fundamental interest and provides a possibility to study various theoretical models of the strangeness dissociation mechanism [1].

In this contribution we present data on the production of the hyperon-kaon pair via the $pp \to pK^+\Lambda$

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η' Production in Proton-Proton Scattering Close to Threshold

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The $pp \to pp\eta'(958)$ reaction has been measured at the cooler synchrotron COSY at Jülich using the internal beam and the COSY-11 facility. The total cross sections at the four different excess energies $Q = 1.5$, 1.7, 2.9, and 4.1 MeV have been evaluated to be $\sigma = 2.5 \pm .5$, 2.9 ± 1.1, 12.7 ± 3.2, and 25.2 ± 3.6 nb, respectively. In this region of excess energy the $\eta'(958)$ cross sections are much lower compared to those of the π and η production. [S0031-9007(98)05794-9]

PACS numbers: 14.40.Cs, 13.75.Cs, 25.40.Ve

The first experimental evidence of the η' meson has been seen in the $K^- + p \to \Lambda +$ neutrals reaction channels in 1964 [1,2]. Nowadays, the $\eta'(958)$ is well established as the heaviest member of the ground state pseudoscalar meson nonet with quantum numbers $I^G(J^{PC}) = {}^+(\ {}^{-+})$. The physics of the η' meson is related to one of the most intricate phenomena in particle physics. In quark models [3] a nearly massless flavor singlet partner η' to the well established octet of pseudoscalar Goldstone bosons must exist. With the advent of quantum chromodynamics (QCD), however, the situation changed dramatically and there is no necessity [4] for a massless η'. Without this U(1) anomaly [5], the η' would be unacceptably light: $m^2_{\eta'} \leq 3m^2_\pi$. Consequently, 't Hooft [6] has stimulated an extensive dispute on how the U(1) anomaly and QCD instantons effect the mass spectrum of the $J^P = {}^-$ mesons [7–11]. The issues of (i) η-η' mixing, (ii) possible nonquarkonic component within the η' meson, and (iii) coupling of the η' to gluons have attracted much attention, but the situation is far from being settled [12–14]. Recently the CLEO [15] Collaboration reported an anomalously large branching ratio for the inclusive decay of beauty particles $B \to \eta' + X$, which is vitally discussed as evidence for strong coupling of η' meson to gluonic components [16–21].

There is no direct experimental information on the strength of the η' coupling to nucleons: $g_{\eta' NN}$. The smallness of the SU(3) singlet axial charge current extracted from deep inelastic scattering data suggests a small $\eta' NN$ coupling constant [22]. On the other hand, the η'-nucleon coupling constant $g_{\eta' NN}$ can put constraints on the theoretical quark models [23,24]. Because there are no known "doorwaylike" $N\eta'$ resonances close to the production threshold, measurements of the cross sections for the $pp \to pp\eta'$ reaction at such energies give an opportunity to determine the value of $g_{\eta' NN}$. In the case of the η production, however, a reaction mechanism mediated by the intermediate resonance N^* [$S_{11}(1535)$] is known to be important [25,26], making an extraction of the η-nucleon coupling constant $g_{\eta NN}$ very difficult.

Recently data were published concerning the $\eta'(958)$ meson production in the $pd \to {}^3\mathrm{He} + X$ reaction performed at SATURNE using the SPES4 spectrometer [27]. Assuming a pure s-wave phase space distribution, the measured differential cross section $d\sigma_{\eta'}/d\Omega^* = 13$ pb/sr results in a total cross section of $\sigma_{\eta'} \approx .16$ nb at a mean excess energy of $Q = .5$ MeV. No data are published concerning the production of η' at threshold in proton-proton collisions. There are only preliminary results from measurements at SATURNE [28]. Thus, the η' is the last nonstrange meson of the pseudoscalar nonet for which cross sections for the production in the elementary proton-proton scattering are unknown close to threshold.

Measurements of the η' production in the pp interaction were performed at the cooler synchrotron COSY-Jülich [29] using an internal cluster target [30] in front of a regular C-shaped COSY dipole magnet acting as a magnetic spectrometer. The η' mesons were not directly identified but their four-momentum vectors were determined via the missing mass method. The two outgoing protons were registered in a set of two drift chamber stacks followed by a scintillator hodoscope arrangement, and a large area scintillator wall placed 9 m downstream. Tracing the proton tracks back through the known three dimensional magnetic field into the target spot results in a definite momentum determination. With the measured time of flight a unique particle identification is possible and, therefore, the four-momentum vector components

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THE EUROPEAN PHYSICAL JOURNAL A

Low-energy Λ–p scattering parameters from the $pp \to pK^+\Lambda$ Reaction

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Abstract. Constraints on the spin-averaged Λp scattering length and effective range have been obtained from measurements of the $pp \to pK^+\Lambda$ reaction close to the production threshold by comparing model phase-space Dalitz plot occupations with experimental ones. The data fix well the position of the virtual bound state in the Λp system. Combining this with information from elastic Λp scattering measurements at slightly higher energies, together with the fact that the hyperdeuteron is not bound, leads to a new determination of the low energy Λp scattering parameters.

PACS. 12.38.Qk Experimental data – 13.85.Hd Inelastic scattering: many-particle final states – 25.40.Ve Other reactions above meson production thresholds (energies >400 MeV)

1 Introduction

The existence of light hypernuclei, such as ${}^{3}_{\Lambda}$He, shows the low energy Λ-p interaction to be strongly attractive, though not sufficient to bind the two-baryon hyperdeuteron. The Λ-p interaction is of especial interest since it is influenced by the strange quark content of the Λ-hyperon. However, in contrast to the nucleon-nucleon case, due to the short lifetime of the Λ, direct measurements of low-energy Λ-p scattering are sparse and the resulting parameters rather poorly known.

Bubble chamber measurements [1–3], based on samples of a few hundred secondary events, have allowed determinations of the elastic cross section down to Λ laboratory momenta ≈ 130 MeV/c. In the low energy region, where only S-waves are important, the spin-averaged total cross section is of the form

$$\sigma_{\Lambda p\to\Lambda p} = \frac{\pi}{q^2 + (-1/a_s + \frac{1}{2}r_s q^2)^2} + \frac{3\pi}{q^2 + (-1/a_t + \frac{1}{2}r_t q^2)^2}. \quad (1)$$

Here q is the Λp centre-of-mass momentum and $a_{s(t)}$ and $r_{s(t)}$ are, respectively, the S-wave scattering lengths and effective ranges in the Λp spin-singlet and triplet states. Separate values of these parameters have been claimed for the two spin states [1,2] and these are shown in Fig. 1. However, the error bars are large, strongly and systematically correlated and hard to quantify, since such data should really only support the determination of an average scattering length ā and effective range r̄ [3]. Already for laboratory momenta ≈ 300 MeV/c, the differential cross section is significantly non-isotropic, indicating the presence of P or higher waves [1,2], and so it is not surprising that the S-wave parameters deduced from such experiments depend upon the upper momentum cut assumed.

Values of the scattering length and effective range have also been deduced through the study of the Λp final state interaction (FSI) in the $K^-d \to \pi^- p\Lambda$ reaction with stopped K-mesons [4]. Here it is the shape of the Λp effective mass spectrum near the kinematic limit which is sensitive to the parameters. In impulse approximation the amplitude for this process is proportional to that for $K^-n \to \pi^-\Lambda$ and, if the Fermi motion in the target deuteron is neglected, the reaction is purely s-wave with no spin-flip. The final Λp system is therefore in the same spin-triplet state as the np pair in the deuteron and the values a_t and r_t so determined, which are also shown

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Comparison of Λ and Σ^0 Production near Threshold in Proton-Proton Collisions

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Threshold measurements of the associated strangeness production reactions $pp \to pK^+\Lambda$ and $pp \to pK^+\Sigma^0$ are presented. The most remarkable feature of the data is that at the same excess energy the total cross section for the Σ^0 production appears to be about a factor of 28^{+6}_{-9} smaller than for the Λ particle. It is concluded that strong $\Sigma^0 p$ final state interactions, and in particular the $\Sigma N \to \Lambda p$ conversion reaction, are the likely cause of the depletion in the Σ signal. This hypothesis is in line with other experimental evidence in the literature.

PACS numbers: 13.75.Ev, 14.20.Jn, 25.40.Ve, 29.20.Dh

The COSY–11 facility [1], at the Cooler Synchroton COSY [2], was designed for the study of meson production in proton-proton collisions near threshold. We report here experimental data on both the $pp \to pK^+\Lambda$ and $pp \to pK^+\Sigma^0$ reactions at excess energies $Q \leq 12.9$ MeV. At intermediate energies, and especially in the threshold region, the physics of strange particle production is most appropriately described in terms of meson exchange. In such models both strange and nonstrange exchanges, with or without intermediate isobar excitation, may be present. Even considering just the π- and K-exchange contributions, see, e.g., Refs. [3–6], model predictions of Λ and Σ^0 production cross sections may differ enormously due to uncertainties in the coupling constants. For example, the ratio $g^2_{\Lambda NK}/g^2_{\Sigma NK}$, as extracted from different reactions involving hyperons, varies between 0.08 and 27 [4–13]. In addition, the exchange of heavier nonstrange and strange mesons and their interference effects might also have an influence on strangeness production [14]. Strong final state interactions (FSI), especially between the hyperon and proton, are also likely to be very significant.

The four-momenta of the proton and K^+ are measured in COSY-11 [1], leaving the neutral hyperon to be identified from the missing mass in the reaction. The two emerging positively charged particles from the $pp \to pK^+X$ reaction are momentum analyzed in a C-shaped COSY-dipole magnet, placed downstream of the internal hydrogen cluster target [15]. Two sets of drift chambers are placed close to the magnet gap such that the ejectiles of interest (p and K^+) cross them almost at right angles, allowing the positions and directions of the particle trajectories to be determined. The particle momenta can then be fixed by ray tracing through the known magnetic field back to the target. Particle identification is performed by measuring the time of flight (TOF) between start and stop scintillators.

The present investigation was designed to measure Σ^0 production and compare it with Λ production near threshold. Total cross sections for $pp \to pK^+\Sigma^0$ are presented at seven energies in the range $3.0 < Q < 12.9$ MeV. Three extra Λ points at higher Q are added to our published set from $Q = 0.68$ to 6.68 MeV [16]. COSY was used in the "supercycle" mode, which allows the repetition of a sequence of spills with different beam momenta. In view of the large difference between the cross sections for the production of the two hyperons, 10 or 20 spills with momenta above the Σ^0 threshold were followed by one at the corresponding value of Q above the Λ threshold. The spill length was typically five minutes and the sequence repeated for a total running time of two to three days at each beam momentum. The supercycle mode compares similar processes under similar conditions, thus reducing possible errors due to shifts in accelerator and/or detector components.

To isolate the hyperon production channels in the off-line analysis, all two-track events containing candidates for K^+ and p pairs were selected. After determining the three-momenta and times of flight for both particles, invariant mass spectra were extracted which showed clear signals for pions, kaons, and protons above a moderate background. For events with particle 1 identified as a

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PHYSICS LETTERS B

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Near-threshold η meson production in proton–proton collisions

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Abstract

The production of η mesons has been measured in the proton-proton interaction close to the reaction threshold using the COSY-11 internal facility at the cooler synchrotron COSY. Total cross sections were determined for eight different excess energies (ϵ) in the range from $\epsilon = 0.5$ MeV to $\epsilon = 5.4$ MeV. The energy dependence of the total cross section is well described by the available phase–space volume weighted by FSI factors for the proton–proton and proton–η pairs. © 2000 Elsevier Science B.V. All rights reserved.

PACS: 13.60.Le; 13.75.-n; 13.85.Lg; 25.40.-h; 29.20.Dh

1. Introduction

Over the last few years, creation of mesons near threshold in the elementary nucleon–nucleon collision has become an important field for studies of meson production mechanisms as well as of meson–nucleon interactions. Measurements at the new generation of medium energy proton accelerators, storage rings with phase-space cooling of the beam as the IUCF-ring, CELSIUS and COSY, delivered high precision values of cross sections for the production of various mesons in the mass region up to 1 GeV/c^2. The experimental information gained so far is consistent with approximately constant production matrix elements when the final state interaction (FSI) is factored out. The pion production cross sections are described very precisely including only the proton–proton FSI, since the pion–proton interaction is comparatively weak close to threshold. Contrary, in the η meson production in proton–pro-

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Energy dependence of the near-threshold total cross-section for the $pp \to pp\eta'$ reaction

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Abstract

Total cross sections for the $pp \to pp\eta'$ reaction have been measured in the excess energy range from $Q = 1.53$ MeV to $Q = 23.64$ MeV. The experiment has been performed at the internal installation COSY-11 [1] using a stochastically cooled proton beam of the COoler SYnchrotron COSY [2] and a hydrogen cluster target [3,4]. The determined energy dependence of the total cross section weakens the hypothesis of the S-wave repulsive interaction between the η' meson and the proton [5,6]. New data agree well with predictions based on the phase-space distribution modified by the proton-proton final-state-interaction (FSI) only.

PACS: 13.60.Le; 13.75.-n; 13.75.C; 13.85.Lg; 25.40.-h; 29.20.Dh

Recently, total cross sections for the production of the η' meson in the collision of protons close to the reaction threshold have been published [7,8] for the first time. Two independent experiments performed at the accelerators SATURNE and COSY have delivered consistent results. The data has triggered off an interest in explaining the unknown dynamics of the $pp \to pp\eta'$ reaction [9–14]. The determined total cross sections are about a factor of thirty smaller than the ones for the $pp \to pp\eta$ reaction [7,15–18] at the corresponding values of excess energy. Trying to explain this large difference Hibou et al. [7] showed that calculations within a one-pion exchange model, where the parameters were adjusted to fit the total cross section for the $pp \to pp\eta$ reaction, underestimate the η' cross sections by about a factor of two.

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PHYSICS LETTERS B

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S-wave η'-proton FSI; phenomenological analysis of near-threshold production of π^0, η, and η' mesons in proton-proton collisions

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Abstract

We describe a novel technique for comparing total cross sections for the reactions $pp \to pp\pi^0$, $pp \to pp\eta$, and $pp \to pp\eta'$ close to threshold. The initial and final state proton-proton interactions are factored out of the total cross section, and the dependence of this reduced cross section on the volume of phase space is discussed. Different models of the proton-proton interaction are compared. We argue that the scattering length of the S-wave η'-proton interaction is of the order of 0.1 fm. © 2000 Elsevier Science B.V. All rights reserved.

PACS: 13.60.Le; 13.75.-n; 13.85.Lg; 25.40.-h; 29.20.Dh

New results on η and η' meson production in the reaction $pp \to ppX$, measured very recently at the COSY-11 facility [1,2], together with previous data [3–8], determine the energy dependence of the near-threshold total cross section with a precision comparable to the measurements of the reaction $pp \to pp\pi^0$ [9,10]. These new data encouraged us to perform a phenomenological analysis similar to those of Refs. [11–13]. Here we concentrate on π^0, η, and η' meson production, and complete the analysis of these references by taking into account the interaction between the incident protons, and by introducing a new representation of the data. The production rates of π^0, η, and η' mesons will be compared as a function of the available phase space. We will study the phase-space dependence of the quantity $|M_0|$

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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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Monitoring of the accelerator beam distributions for internal target facilities

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Abstract

We describe a direct method for monitoring the geometrical dimensions of a synchrotron beam at the target position for internal target installations. The method allows for the observation of the proton beam size as well as the position of the beam relative to the target. As a first demonstration of the technique, we present results obtained by means of the COSY-11 detection system installed at the cooler synchrotron COSY. The influence of the stochastic cooling on the COSY proton beam dimensions is also investigated.

PACS: 29.20.Dh; 29.27.−a; 29.27.Fh; 25.40.Cm

Keywords: Beam monitoring; Internal target; Stochastic cooling

1. Introduction

Internal cluster target facilities—such as COSY-11 [1] installed at the cooler synchrotron COSY-Jülich [2]—permit the study of the production of mesons in the proton–proton interaction with high luminosity (10^{31} cm^{-2} s^{-1}) in spite of very low target densities ($\approx 10^{14}$ atoms cm^{-2}). Such conditions minimize changes in the ejectiles' momentum vectors due to secondary scattering in the target, and hence facilitate the precise study of reactions with cross-sectional values at the nanobarn level.

An exact extraction of absolute cross-sections from the measured data demands a reliable estimation of the acceptance of the detection system. This in turn crucially depends on the

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Near threshold K^+K^- meson-pair production in proton–proton collisions

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Abstract

The near threshold total cross section and angular distributions of K^+K^- pair production via the reaction $pp \to ppK^+K^-$ have been studied at an excess energy of $Q = 17$ MeV using the COSY-11 facility at the cooler synchrotron COSY. The obtained cross section as well as an upper limit at an excess energy of $Q = 3$ MeV represent the first measurements on the K^+K^- production in the region of small excess energies where production via the channel $pp \to pp\Phi \to ppK^+K^-$ is energetically forbidden. The possible influence of a resonant production via intermediate scalar states $f_0(980)$ and $a_0(980)$ is discussed.

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Keywords: Near-threshold meson production; Antikaon; Kaon pairs

1. Introduction

Recently, detailed measurements on the K^+ meson production in proton–proton collisions have been performed in the previously unexplored near threshold region of the reaction channels $pp \to pK^+\Lambda$ and $pp \to pK^+\Sigma^0$ [1–4]. On the other hand, there is a lack of data on the elementary K^- meson production in the proton–proton scattering, especially in the region of low excess energies. The reaction channel with the lowest threshold energy is given by the associated K^+K^- meson pair production via the reaction channel $pp \to pp\,X$, $X = K^+K^-$. Therefore, measurements on the threshold production of negatively charged kaons ($m(K^\pm) = 493.677\,\mathrm{MeV}/c^2$ [5]) have to be carried out in the mass range of $m(X) \sim 1\,\mathrm{GeV}/c^2$. A study of this mass range is stimulated by the continuing discussion on the nature of the

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On the close to threshold meson production in neutron–neutron collisions

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Abstract

A method of measuring the close to threshold meson production in neutron–neutron collisions is described where the momenta of the colliding neutrons can be determined with the accuracy obtainable for the proton–proton reaction. The technique is based on the double quasi-free $nn \to nnX^0$ reaction, where deuterons are used as a source of neutrons. © 2001 Elsevier Science B.V. All rights reserved.

PACS: 13.60.Le; 13.75.-ni; 13.75.Cs

In the last decade close to threshold production of mesons has attracted a lot of experimental and theoretical effort (see, for instance, [1,2]). Experiments performed at the accelerators CELSIUS [3–7], COSY [8–15], IUCF [16–19], SATURNE [20–25], and TRIUMF [26–31] delivered precise data on the pseudoscalar (π, η, η', K) and vector (ω, ϕ) meson production in proton–proton and proton–deuteron collisions. A secondary neutron beam with a spread in energy smaller than 1 MeV focussed onto liquid hydrogen targets ($\sim 10^{23}$ atoms/cm^2) permitted also precise investigations of the π meson production in the neutron–proton reactions [26,27,29].

Close to threshold meson production in proton–neutron collisions were also investigated by means of a technique based on a quasi-free scattering of the proton off the neutron bound in the deuteron. Thin windowless internal deuterium cluster targets ($\sim 10^{14}$ atoms/cm^2) make a detection of an undisturbed spectator proton and a precise determination of the reacting neutron momentum — and hence of the excess energy — possible.

Pioneering experiments of the π^0 meson creation in the proton–neutron reaction with the simultaneous tagging of the spectator proton resulted in a resolution

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Close-to-threshold Meson Production in Hadronic Interactions

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Abstract

Studies of meson production at threshold in the hadron–hadron interaction began in the fifties when sufficient energies of accelerated protons were available. A strong interdependence between developments in accelerator physics, detector performance and theoretical understanding led to a unique vivid field of physics. Early experiments performed with bubble chambers revealed already typical ingredients of threshold studies, which were superseded by more complete meson production investigations at the nucleon beam facilities TRIUMF, LAMPF, PSI, LEAR and SATURNE. Currently, with the advent of the new cooler rings as IUCF, CELSIUS and COSY the field is entering a new domain of precision and the next step of further progress.

The analysis of this new data in the short range limit permits a more fundamental consideration and a quantitative comparison of the production processes for different mesons in the few–body final states. The interpretation of the data take advantage of the fact that production reactions close–to–threshold are characterized by only a few degrees of freedom between a well defined combination of initial and exit channels. Deviations from predictions of phase–space controlled one–meson–exchange models are indications of new and exciting physics. Precision data on differential cross sections, isospin and spin observables — partly but by no means adequately available — are presently turning up on the horizon. There is work for the next years and excitement of the physics expected. Here we try to give a brief and at the same time comprehensive overview of this field of hadronic threshold production studies.

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PHYSICS LETTERS B

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Analysing power A_y in the reaction $\vec{p}p \to pp\eta$ close to threshold

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Abstract

Measurements of the η meson production with a polarised proton beam in the reaction $\vec{p}p \to pp\eta$ have been carried out at an excess energy of $Q = 40$ MeV. The dependence of the analysing power A_y on the polar angle θ_η^* of the η meson in the center of mass system (CMS) has been studied. The data indicate the possibility of an influence of p- and d-waves to the close to threshold η production.

PACS: 12.40.Vv; 13.60.Le; 13.88.+e; 24.70.+s; 24.80.+y; 25.10.+s

1. Introduction

Several measurements on the η meson production in the proton–proton interaction covering a 100 MeV excess energy range were performed at different accelerators. The determined total cross sections [1–6], as well as their differential distributions [7–10] triggered intensive theoretical investigations aiming to understand the production mechanism on the hadronic and quark–gluon level.

In the theoretical descriptions of the η-production in nucleon–nucleon collisions the excitation of the $S_{11}(1535)$ resonance plays a decisive role. The hitherto performed studies with the aim to describe the total cross section show a dominance of this virtual S_{11} nucleon isobar in the close-to-threshold production of the η meson. The excitation of this intermediate state

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Upper limit for the cross-section of the overlapping scalar resonances $f_0(980)$ and $a_0(980)$ produced in proton–proton collisions in the range of the reaction threshold

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Abstract
Utilizing a missing mass technique we investigate the $pp \to ppX$ reaction scanning beam energies in the range permitting to create a mass close to that of the $f_0(980)$ and $a_0(980)$ scalar resonances, but still below the K^+K^- threshold where they decay dominantly into $\pi\pi$ and $\pi\eta$ mesons, respectively. Prior to the data analysis we introduce a notion of the close to threshold total cross-section for broad resonances. We estimated for the overlapping mesons a_0 and f_0 the total cross-section to be smaller than 430 nb at excess energy of $Q = 5$ MeV. The experiment has been performed at the Cooler Synchrotron (COSY) using the COSY-11 facility.

1. Introduction

A study of the 1 GeV/c^2 mass range is motivated by the continuing discussion on the nature of the scalar resonances $f_0(980)$ and $a_0(980)$, which have been interpreted as exotic four quark states [1], conventional $q\bar{q}$ states [2, 3] or molecular such as $K\bar{K}$ bound state [4, 5].

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THE EUROPEAN PHYSICAL JOURNAL A

Energy dependence of the Λ/Σ^0 production cross-section ratio in p-p interactions

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Abstract. The production of the Λ- and Σ^0-hyperons has been measured via the $pp \to pK^+\Lambda/\Sigma^0$ reaction at the internal COSY-11 facility in the excess energy range between 14 and 60 MeV. The transition of the Λ/Σ^0 cross-section ratio from about 28 at $Q \leq 13$ MeV to the high-energy level of about 2.5 is covered by the data showing a strong decrease of the ratio between 10 and 20 MeV excess energy. Effects from the final-state interactions in the p-Σ^0 channel seem to be much smaller than in the p-Λ channel. Estimates of the effective range parameters are given for the $N\Lambda$ and the $N\Sigma$ systems.

PACS. 13.75.-n Hadron-induced low- and intermediate-energy reactions and scattering (energy $\leq$ 10 GeV) – 13.75.Ev Hyperon-nucleon interactions – 13.85.Lg Total cross-sections – 25.40.Ep Inelastic proton scattering

1 Introduction

In the kinematical threshold region the strangeness production is commonly described by both non-strange and strange meson exchange with or without explicit inclusion of an intermediate resonance as depicted in the four graphs of fig. 1. While the exchange of the lightest mesons, namely π and K^+, is expected to be dominant in the Λ and Σ^0 production [1–7] there could also be a contribution arising from the exchange of heavier non-strange or strange mesons [8–11]. In addition, proton-hyperon final-state interactions (FSI) play an important role when comparing the $pK^+\Lambda$ and $pK^+\Sigma^0$ reaction channels.

Since the quark structures of the two neutral Λ and Σ^0 hyperons are similar, one can expect similar production mechanisms. In such a case the cross-section ratio $\mathcal{R}_{\Lambda/\Sigma^0} \equiv \frac{\sigma(pp\to pK^+\Lambda)}{\sigma(pp\to pK^+\Sigma^0)}$ should be mainly determined by the isospin relation which leads to $\mathcal{R}_{\Lambda/\Sigma^0} \sim 3$, in good agreement with the value $\mathcal{R}_{\Lambda/\Sigma^0} \approx 2.5$ observed in proton-proton scattering experiments at excess energies $Q \geq 300$ MeV [12]. It is interesting to note that a comparable cross-section ratio was determined in antiproton-proton annihilation experiments leading to $\bar{\Lambda}$-Λ, $\bar{\Sigma}^0$-Λ + c.c. and $\bar{\Sigma}^{\pm}$-$\Sigma^{\mp}$ as performed by the PS185 collaboration at LEAR [13,14].

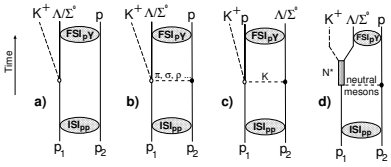

Fig. 1. Examples of possible graphs for the Λ- or Σ^0-hyperon production with inclusion of proton-proton initial (ISI) and proton-hyperon final-state interactions (FSI).

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Experimental study of $pp\eta$ dynamics in the $pp \to pp\eta$ reaction

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A high statistics measurement of the $pp \to pp\eta$ reaction at an excess energy of $Q=15.5$ MeV has been performed at the internal beam facility COSY-11. The stochastically cooled proton beam and the used detection system allowed to determine the momenta of the outgoing protons with a precision of 4 MeV/c (σ) in the center-of-mass frame. The determination of the four-momentum vectors of both outgoing protons allowed to derive the complete kinematical information of the ηpp system. An unexpectedly large enhancement of the occupation density in the kinematical regions of low proton-η relative momenta is observed. A description taking the proton-proton and the η-proton interaction into account and assuming an on-shell incoherent pairwise interaction among the produced particles fails to explain this strong effect. Its understanding will require a rigorous three-body approach to the $pp\eta$ system and the precise determination of contributions from higher partial waves. We also present an invariant mass spectrum of the proton-proton system determined at $Q=4.5$ MeV. Interestingly, the enhancement at large relative momenta between protons is visible also at such a small excess energy. In contrast to all other determined angular distributions, the orientation of the emission plane with respect to the beam direction is extracted to be anisotropic.

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I. MANIFESTATION OF THE ηpp INTERACTION

Due to the short life time of the flavor-neutral mesons (e.g., π^0, η, η'), the study of their interaction with nucleons or with other mesons is at present not feasible in direct scattering experiments. One of the methods permitting such investigations is the production of a meson in the nucleon-nucleon interaction close to the kinematical threshold or in kinematics regions where the outgoing particles possess small relative velocities. A mutual interaction among the outgoing particles manifests itself in the distributions of differential cross sections as well as in the magnitude and energy dependence of the total reaction rate.

In the last decade major experimental [1–8] and theoretical [9–13] efforts were concentrated on the study of the creation of π^0, η, and η' mesons via the hadronic interactions [14–16]. Measurements have been made in the vicinity of the kinematical threshold where only a few partial waves in both initial and final states are expected to contribute to the production process. This simplifies significantly the interpretation of the data, yet it appears to be challenging due to the three-particle final state system with a complex hadronic potential.

The determined energy dependences of the total cross section for η' [1,2] and η [2–6] mesons in proton-proton collisions are presented in Fig. 1. Comparing the data to the arbitrarily normalized phase-space integral (dashed lines) reveals that the proton-proton FSI enhances the total cross section by more than an order of magnitude for low excess energies. One recognizes also that in the case of the η' the data are described very well (solid line) assuming that the on-shell proton-proton amplitude exclusively determines the phase-space population. This indicates that the proton-η' interaction is too small to manifest itself in the excitation function within the presently achievable accuracy. In case of the η meson the increase of the total cross section for very low and very high energies is much larger than expected from the $^1S_0$ final state interaction between protons (solid line), though for both the $pp \to pp\eta$ and $pp \to pp\eta'$ reactions the dominance of the $^3P_0 \to {}^1S_0 s$ transition[1] is expected up to an excess energy of about 40 MeV and 100 MeV, respectively [14]. The excess at higher energies can be assigned to the

[1]The transition between angular momentum combinations of the initial and final states are described according to the conventional notation [8] in the following way:

$$^{2S'+1}L^{i}_{J'} \to {}^{2S+1}L_J, l, \tag{1}$$

where superscript i indicates the initial state quantites. S denotes the spin of the nucleons, and J stands for their overall angular momentum. L and l denote the relative angular momentum of the nucleon-nucleon pair and of the meson relative to the NN system, respectively. The values of orbital angular momenta are commonly expressed using the spectroscopic notation ($L=S,P,D,\ldots$, and $l=s,p,d,\ldots$).

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THE EUROPEAN PHYSICAL JOURNAL A

Total and differential cross-sections for the pp → ppη' reaction near threshold

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Abstract. The η'-meson production in the reaction $pp \to pp\eta'$ has been studied at excess energies of $Q = 26.5$, 32.5 and 46.6 MeV using the internal beam facility COSY-11 at the cooler synchrotron COSY. The total cross-sections as well as one angular distribution for the highest Q-value are presented. The excitation function of the near-threshold data can be described by a pure s-wave phase space distribution with the inclusion of the proton-proton final-state interaction and Coulomb effects. The obtained angular distribution of the η'-mesons is also consistent with pure s-wave production.

PACS. 13.60.Le Meson production – 13.75.-n Hadron-induced low- and intermediate-energy reactions and scattering (energy $\leq$ 10 GeV) – 13.85.Lg Total cross-sections – 25.40.-h Nucleon-induced reactions

1 Introduction

Measurements on the production of η'-mesons, the heaviest representative of the multiplet of pseudoscalar mesons, allow to study the properties and the structure of this isoscalar meson, which are still far from being well known. Since states with the same quantum numbers IJ^P can mix, the physically observable particles η and η' are considered to be mixed states of the $I = 0$ members of the ground-state pseudoscalar octet and singlet, commonly denoted as η_8 and η_1. In case of an ideal mixing, the η-meson would have a pure non-strange content ($u\bar{u}+d\bar{d}$), while the η' would show up as a pure $s\bar{s}$ state, corresponding to a mixing angle of $\theta_{\rm ideal} = -\arctan\sqrt{2} \approx -54.7°$. This value is in contrast to the experimentally still inaccurately determined mixing angle θ_P, which has been subject of several investigations [1–12] and was found to be between $-9°$ and $-20°$.

Furthermore, studies on the production of η'-mesons are also important with respect to still controversially discussed topics like possible $c\bar{c}$ or gluonic components in the structure of the η'-meson [8,13–19] or the understanding of the unexpected high mass, which is discussed in the context of the $U(1)_A$ anomaly [17,20,21]. The gluonic contribution to the cross-section for the $NN \to NN\eta'$ reaction may be inferred by the comparison of the η' production in different isospin channels [18,19,22].

Recently, detailed measurements on the η'-meson production in the reaction channel $pp \to pp\eta'$ have been performed in the previously unexplored region close to threshold up to an excess energy of $Q = 24$ MeV [23–26] as well at a higher excess energy of $Q = 144$ MeV [27]. In this publication, we present new results on this reaction channel at intermediate excess energies of $Q = 26.5$, 32.5 and 46.6 MeV, filling the gap between the available data sets.

Due to the small relative momenta of the ejectiles in the region of low excess energies, only partial waves of the lowest order participate in the exit channel. Therefore, total- and differential-cross-section data yield nearly unscreened information on relevant production mechanisms and allow to study final-state interactions (FSI) of the participating particles. Consequently, these new data became subject of several model calculations and comparisons with the related reaction channels on the π^0- and η-meson production [28–30].

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Drift chamber with a c-shaped frame

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Abstract

We present the construction of a planar drift chamber with wires stretched between two arms of a c-shaped aluminum frame. The special shape of the frame allows to extend the momentum acceptance of the COSY-11 detection system towards lower momenta without suppressing the high-momentum particles. The proposed design allows for construction of tracking detectors covering small angles with respect to the beam, which can be installed and removed without dismounting the beam-pipe. For a three-dimensional track reconstruction a computer code was developed using a simple algorithm of hit pre-selection.

PACS: 29.40.Cs; 29.40.Gx

Keywords: Drift chamber; Hexagonal cell; Track reconstruction

1. Introduction

The drift chamber which is described in this report was built for the COSY-11 experimental

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A method to disentangle single- and multi-meson production in missing mass spectra from quasi-free pn → pn$X$ reactions

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Abstract

The separation of contributions from multi- and single-meson production in the missing mass spectrum of the quasi-free pn → pn$X$ reaction constitutes a challenging task when the reaction is studied close to the threshold. This is especially true if the resolution of the mass determination is comparable with the excess energy and if the investigated signal appears close to the kinematical limit. In this paper, we outline a method which permits the extraction of the signal originating from the creation of a single meson without the necessity of conducting model-dependent simulations. For the pd → pn$X$p$_{\mathrm{spectator}}$ reactions, the method allows one to combine events corresponding to multi-meson production at various excess energies with respect to the pn → pn *meson* process, and hence leads to an increase of the statistics needed for the determination of the shape of the multi-meson background. As an example of the application of the method, we demonstrate that the evaluation of the data from the pd → pn$X$p$_{\mathrm{sp}}$ process according to the described technique enables one to extract a signal of the pn → pnη reaction whose shape is consistent with expectations, supporting the correctness and usefulness of the method introduced.

(Some figures in this article are in colour only in the electronic version)

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Kaon pair production close to threshold

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Abstract

The total cross section of the reaction $pp \to ppK^+K^-$ has been measured at excess energies $Q = 10$ MeV and 28 MeV with the magnetic spectrometer COSY-11. The new data show a significant enhancement of the total cross section compared to pure phase space expectations or calculations within a one boson exchange model. In addition, we present invariant mass spectra of two particle subsystems. While the K^+K^- system is rather constant for different invariant masses, there is an enhancement in the pK^- system towards lower masses which could at least be partially connected to the influence of the $\Lambda(1405)$ resonance.

PACS: 13.60.Hb; 13.60.Le; 13.75.-n; 25.40.Ve

Keywords: Kaon; Antikaon; Strangeness; Near-threshold meson production

1. Introduction

The strength of the kaon–antikaon interaction appears to be very essential with respect to different physics topics. It is an important parameter in the ongoing discussion on the nature of the scalar resonances a_0 and f_0 in the mass range of $\sim$1 GeV/c^2. Besides the interpretation as a $q\bar{q}$ meson [1], these resonances were also proposed to be $qq\bar{q}\bar{q}$ states [2], $K\bar{K}$ molecules [3,4], hybrid $q\bar{q}$/meson–meson systems [5] or even quark-less gluonic hadrons [6]. Especially for the formation of a molecule, the strength of the $K\bar{K}$ interaction is a crucial quantity and it can be probed in the $K\bar{K}$ production close to threshold [7].

Due to the unavailability of kaon targets for the analysis of $K\bar{K}$ scattering, the kaon pair production in multi particle exit channels like $pp \to ppK^+K^-$ is the only possibility to study this interaction by selecting the appropriate kinematic region of the phase space distribution. Besides the $K\bar{K}$ subsystem, information about the KN system is of equal importance especially in view of the actual discussion on the structure of the excited hyperon $\Lambda(1405)$ which is considered as a 3 quark system or a KN molecular state [8]. Up to now the scattering length a_{K^-p} has been mainly determined on kaonic hydrogen. But the situation is not yet clarified since first, the results of former measurements [9–12] and preliminary results at DEAR [13,14] are in disagreement and second, it has been shown that

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Threshold hyperon production in proton–proton collisions at COSY-11

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Abstract

The Σ^+ hyperon production was measured at the COSY-11 spectrometer via the $pp \to nK^+\Sigma^+$ reaction at excess energies of $Q = 13$ MeV and $Q = 60$ MeV. These measurements continue systematic hyperon production studies via the $pp \to pK^+\Lambda/\Sigma^0$ reactions where a strong decrease of the cross section ratio close-to-threshold was observed. In order to verify models developed for the description of the Λ and Σ^0 production we have performed the measurement on the Σ^+ hyperon and found unexpectedly that the total cross section is by more than one order of magnitude larger than predicted by all anticipated models. After the reconstruction of the kaon and neutron four momenta, the Σ^+ is identified via the missing mass technique. Details of the method and the measurement will be given and discussed in view of theoretical models.

PACS: 13.60.Hb; 13.75.-n; 25.40.Ve; 28.20.-n

Keywords: Strangeness; Kaon; Near threshold hyperon production; Sigma production; COSY-11

1. Introduction

The study of the hyperon production in hadron induced multi particle exit channels like $pp \to NKY$ includes several aspects. The nucleon–hyperon interaction can be extracted by analyzing the NY subsystem in the appropriate kinematical region. Closely related to that is the issue of the reaction mechanisms of the hyperon production which have to be clarified for an unambiguous interpretation of the data. If the hyperon production is due to the excitation and a subsequent decay of intermediate nucleon resonances it allows to extract information about the structure of the relevant resonances.

The $pp \to pK^+\Lambda$ excitation function close-to-threshold shows a clear deviation from the pure phase space distribution and a proton–hyperon final state interaction (FSI) has to be included to describe the data [1–4]. In the $pp \to pK^+\Sigma^0$ channel the pY FSI seems to be negligible and the pure phase space calculations follow reasonably well the data points. The cross section ratio $\sigma(pp \to pK^+\Lambda)/\sigma(pp \to pK^+\Sigma^0)$ below excess energies of $Q \sim 20$ MeV is in the order of 28 [2,3] in contrast to the value of about 2.5 determined for excess energies higher than $Q = 300$ MeV [5] (see Fig. 1). This value is in good agreement with the Λ/Σ^0 isospin relation. The question arises if this drastic cross section increase close-to-threshold is

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Hadronic ^{3}Heη production near threshold

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Measurements of η meson production in proton-deuteron collisions have been performed using the COSY-11 facility at COSY (Jülich). Results on total and differential cross sections for the $pd \to {}^3\mathrm{He}\eta$ reaction are presented at five excess energies between $Q = 5.0$ and $Q = 40.6$ MeV. The angular distributions show a transition from an almost isotropic emission close to threshold to a highly anisotropic distribution at higher excess energies. The total cross sections reveal a strong η-^{3}He final state interaction, corresponding to a scattering length of $|\Re(a)| = (4.2 \pm 0.5)$ fm and $\Im(a) = (0.4 \pm 1.9)$ fm.

DOI: 10.1103/PhysRevC.75.014004 PACS number(s): 25.40.Ve, 13.60.Le, 13.75.−n, 14.40.Aq

I. INTRODUCTION

Within the field of particle interactions, the formation of bound or quasibound states between an η meson and a nucleon or nucleus, creating so-called η-mesic nuclei, has attracted a lot of both theoretical and experimental interest. Predicted by Haider and Liu [1], the interaction of the η with a nucleus is expected to be attractive, as in the elementary η-N interaction [2–4], and therefore allows for the formation of a bound state. Recently, it was argued that the η bound state will deliver information about the singlet component of the η meson [5]. Although the strength of the attractive potential is supposed to increase with the mass of the nucleus, the answer to the question as to which is the lightest η-mesic nucleus is still unknown.

Therefore, close-to-threshold data on the $pd \to {}^3\mathrm{He}\eta$ reaction are of great interest for studying the strong η-nucleus final state interaction at low energies, which may provide a signal for the existence of quasibound η-nucleus states [6]. As observed close to threshold at the SPES-IV and SPES-II spectrometers at the SATURNE laboratory [7,8], the η-production cross section in the $pd \to {}^3\mathrm{He}\eta$ reaction reveals remarkable features. In addition to the unexpectedly large cross section for this channel as compared to, e.g., $pd \to {}^3\mathrm{He}\pi^0$, the excitation function has a maximum very close to the production threshold and a significant drop of the production amplitude with increasing energy within only a few MeV, which is in complete contrast to expectations based upon phase space. Furthermore, the center-of-mass angular distributions of the η mesons emitted near threshold were reported to be consistent with s-wave production and to exhibit no major contributions from higher partial waves. This behavior differs from the corresponding data on the π^0-production cross section, where a strong p-wave contribution is present even very close to threshold [9].

In order to describe this near-threshold behavior, a classical two-step mechanism was proposed by Kilian and Nann [10]. However, quantum mechanical calculations by Fäldt and Wilkin [11] within this model only succeeded in reproducing the square of the production amplitude at threshold to within a factor of 2.4. Moreover, to describe the observed rapid drop of the production amplitude with increasing energy, the two-step approach had to include a strong η-^{3}He final state interaction (FSI) with a large η-^{3}He scattering length.

Further measurements, performed at a higher excess energy of ∼50 MeV by the COSY-GEM Collaboration [12], yielded a highly nonisotropic angular distribution. The description using the refined two-step model prediction [12], adjusted to fit to the data at energies very close to threshold, significantly underestimates the value of the total cross section. Therefore, a different reaction mechanism, based on the excitation of the $N^*(1535)$ resonance, has been suggested. However, this model

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Mechanism of Near-Threshold Production of the η Meson

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Measurements of the analyzing power for the $\vec{p}p \to pp\eta$ reaction have been performed at excess energies of $Q = 10$ and 36 MeV. The determined analyzing power is essentially consistent with zero, implying dominance of the s wave at both excess energies. The angular dependence of the analyzing power, combined with the isospin dependence of the total cross section for the η meson production in nucleon-nucleon collisions, reveal that the excitation of the nucleon to the $S_{11}(1535)$ resonance is predominantly due to the exchange of the π meson between the colliding nucleons.

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The strong interaction responsible for the existence of hadrons has been studied intensively for more than half a century. At high energies, it is well described by QCD in a perturbative approach with quarks and gluons as the relevant degrees of freedom. However, in the low energy regime where the interaction between quarks and gluons cannot be treated perturbatively, there exists no clear understanding of the processes governed by the strong forces. The phenomena in this regime are not calculable using the particles and fields of the standard model. Here hadrons become the relevant degrees of freedom, and the interaction between hadrons may be described by meson exchange processes. Therefore, in order to understand the behavior of the strong interaction in systems such as nucleons which make up most of the matter surrounding us, it is essential to perform measurements involving the production and decay of hadrons and interpret them in the framework of the effective theories [1].

In this Letter, we focus on the hadronic production mechanism of the η meson and interpret the empirical observations in the framework of meson exchange models. We report on the determination of the angular dependence of the beam analyzing power for the $\vec{p}p \to pp\eta$ reaction. We also demonstrate that the confrontation of predictions based upon different scenarios, involving exchanges of various mesons, with the so far determined unpolarized observables and with results on the analyzing power, permits one to single out the dominant process and, hence, to understand details of the η meson production close to the kinematical threshold.

From precise measurements of the total cross sections of the η meson production in the $pp \to pp\eta$ reaction [2–9], it was concluded [10–17] that this process proceeds through the excitation of one of the protons to the $S_{11}(1535)$ state, which subsequently deexcites via the emission of the η meson (see Fig. 1). In practice, within the meson exchange picture, the excitation of the intermediate resonance can be induced by exchange of any of the pseudoscalar or vector ground state mesons between the nucleons [18–20]. Based only on the excitation function, it was, however, impossible to disentangle the contributions to the production process originating from the π, η, ω, or ρ meson exchange.

More constraints to theoretical models [10–17] have been deduced from the measurement of the isospin dependence of the total cross section by the WASA/PROMICE Collaboration [21,22]. The comparison of the η meson production in proton-proton and proton-neutron collisions inferred that the η meson is by a factor of 12 more copiously produced when the total isospin of the nucleons is zero with respect to the case when it is one. As a consequence, only an isovector meson exchange is con-

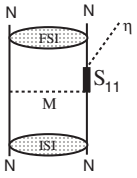

FIG. 1. The mechanism of the η meson production in nucleon-nucleon collisions. M denotes an intermediate pseudoscalar or vector meson, e.g., π, η, ω, or ρ. ISI and FSI indicate initial and final state interaction between the nucleons.

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Measurement of the $dp \to {}^3\mathrm{He}\eta$ reaction near threshold

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Abstract

Total and differential cross sections for the $dp \to {}^3\mathrm{He}\eta$ reaction have been measured near threshold for ^{3}He center-of-mass momenta in the range from 17.1 MeV/c to 87.5 MeV/c. The data were taken during a slow ramping of the COSY internal deuteron beam scattered on a proton target detecting the ^{3}He ejectiles with the COSY-11 facility. The forward–backward asymmetries of the differential cross sections deviate clearly from zero for center-of-mass momenta above 50 MeV/c indicating the presence of higher partial waves in the final state. Below 50 MeV/c center-of-mass momenta a fit of the final state enhancement factor to the data of the total cross sections results in the ^{3}He–η scattering length of $|a| = 4.3 \pm 0.5$ fm.

PACS: 14.40.-n; 21.45.+v; 25.45.-z

Keywords: Meson production; Final state interaction; Eta-mesic nucleus

1. Introduction

Measurements of the $dp \to {}^3\mathrm{He}\eta$ reaction near the kinematical threshold performed at the SPES-4 [1] and SPES-2 [2] spectrometers raised high interest due to a rapid increase of the total cross section very close to threshold. This increase, corroborated recently by the COSY-11 and ANKE groups [3,4], can be explained by the final state interaction (FSI) in the ^{3}He–η system. The relatively large strength of this interaction led to the suggestion of a possible existence of a ^{3}He–η bound state [5].

The measurements of the $dp \to {}^3\mathrm{He}\eta$ reaction are insensitive to the sign of the scattering length and thus they do not allow to draw definite conclusions about possible bound states. However, they permit to determine the absolute value of the real part of the scattering length and the value of its imaginary part providing hints whether the necessary condition for the formation of a bound state ($|\mathrm{Re}(a)| > \mathrm{Im}(a)$) [6] is fulfilled.

The principal possibility for the creation of a η-mesic nucleus [7] attracts a lot of interest [8] still after twenty years of investigations. Present theoretical considerations reveal that the observation of such state would also deliver information about the flavour singlet component of the η meson [9]. Indications for the η-nucleus bound state were reported from the γ-^{3}He measurements [10], however, the data do not allow unambiguous conclusions [11].

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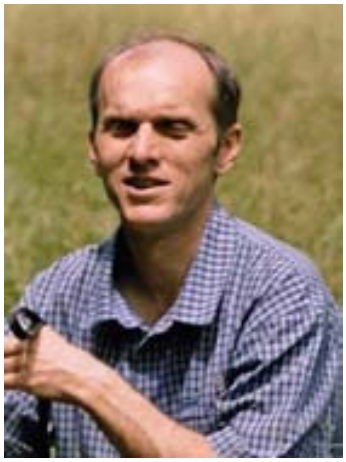
7. Habilitations

Jerzy Smyrski
Near-Threshold Meson Production in Proton-Proton Collisions
Jagellonian University, Kraków, Poland, 1998

Alfons Khoukaz
Near Threshold Production of Mesons in Hadronic Interactions
Westfälische Wilhelms-Universität Münster, Germany, 2002

Paweł Moskal
Hadronic interaction of η *and* η' *mesons with protons*
Jagellonian University, Kraków, Poland, 2004



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Near–Threshold Meson Production in Proton-Proton Collisions

Kraków, 1998

Abstract:

In the present paper, results of experimental studies of near-threshold meson production in the reactions $pp \to d\pi^+$, $pp \to pp\eta'$, $pp \to pK^+\Lambda$, and $pp \to ppK^+K^-$ are presented.

The experiments were performed at the new cooler synchrotron COSY-Jülich. The first of the above reactions was measured by using the external magnetic spectrometer BIG KARL, and the three remaining reactions were studied at the internal COSY–11 facility, resulting in the first world data on near-threshold cross sections in these reactions. In both experiments, the magnetic field of dipole magnets was used for separating the ejectiles from the beam and for reconstructing their momentum vectors at the target point. This experimental method allowed measurements with high detection acceptance very close to threshold, at excess energies of the order of 1 MeV. At higher energies, detection efficiency was drastically limited by the height of the gaps in dipole magnets. Particle trajectories were measured with built in Cracow drift chambers and, in the off line analysis, they were traced back through the magnetic field to the target which allowed us to determine the momentum vectors at the target point. Particle identification proceeded via the time-of-flight measurement combined with the information on particle momenta. The missing-mass method was applied to identify unobserved ejectiles. High missing-mass resolution, achieved thanks to precise particle momenta reconstruction, allowed us to extract signals of the measured reaction from the background of other possible processes, even for reaction cross sections at the level of 1 nbarn.

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Near Threshold Production of Mesons in Hadronic Interactions

Münster, 2002

Abstract:
Main focus of the present work is the study of the production of mesons in the hadron-hadron scattering and to investigate their interactions. For this purpose the near threshold production of mesons and meson-pairs in the mass range up to μ = 1 GeV/c^2 is studied in elementary proton-proton interactions as well as in proton-deuteron interactions. Experiments have been performed at the internal beam installations COSY-11 and PROMICE/WA-SA, placed at the cooler synchrotrons COSY and CELSIUS, respectively. Both storage rings have been designed to provide beams of light ions with a high momentum resolution in order to enable precision measurements on nucleon-nucleon, nucleon-nucleus and nucleus-nucleus interactions. The availability of special beam cooling devices like electron cooling or stochastic cooling systems enable to improve the beam momentum resolution down to $\Delta p/p \sim 10^{-4}$, which is of major interest for the meson and hyperon production close to the production thresholds. The use of internal cluster targets allows to benefit from these advantages and guarantee highest luminosities and precisely known kinematical conditions in the input channel in combination with single particle interactions within the target beam. The mentioned cooling mechanisms allow to compensate for beam heating effects caused by beam-target interactions, leading to long life times of the accelerated beam ($\sim$ hours) and constant beam conditions during the experiment.

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Hadronic interaction of η and η' mesons with protons

Kraków, 2004

Abstract:

We present results of investigations aiming to determine the hadronic interaction of η and η' mesons with nucleons. Inferences are based on comparisons of both the differential cross sections and the close-to-threshold excitation functions for the $pp \to pp\eta$ and $pp \to pp\eta'$ reactions with predictions based on the assumption that the kinematically available phase space is homogeneously populated. We discuss the phenomenology of the initial and final state interaction, relevance of the hadronic and quark-gluon degrees of freedom for the reaction dynamics, and explain in detail the experimental techniques used for the measurement of the meson production in free and quasi-free collisions of nucleons

8. PhD theses

Michael Rook
Strangeness-Erzeugung in der p p und pbar p Streuung
Rheinische Friedrich-Wilhelms-Universität Bonn, Germany, 1994

Alfons Khoukaz
Messungen zur schwellennahen Produktion geladener Pionenpaare in der Proton-Proton-Streuung
Westfälische Wilhelms-Universität Münster, Germany, 1996

Magnus Wolke
Schwellennahe assoziierte Strangeness-Erzeugung in der Reaktion $pp \to ppK^+K^-$ *am Experiment COSY-11*
Rheinische Friedrich-Wilhelms-Universität Bonn, Germany, 1998

Georg Schepers
Assoziierte Strangeness-Erzeugung an der Produktionsschwelle in der Reaktion $pp \to pK^+\Lambda$ *am Experiment COSY-11 mit einer optimierten Strahloptik*
Westfälische Wilhelms-Universität Münster, Germany, 1998

Paweł Moskal
η' *meson production in the* $pp \to pp\eta'$ *reaction near threshold*
Jagellonian University, Kraków, Poland, 1998

Peter Wüstner
Die Produktion des η*-Mesons am Jülicher Beschleuniger COSY und Entwicklung eines optimierten Datenaufnahmesystems*
Ruhr-Universität Bochum, Germany, 1999

Thomas Lister
Untersuchung der Reaktion $pp \to ppK^+X$ *in Nähe der* $f_0(980)$*-Resonanz*
Westfälische Wilhelms-Universität Münster, Germany, 1999

Swen Sewerin
Schwellennahe Hyperonproduktion in den Reaktionskanälen $pp \to pK^+\Lambda$ *und* $pp \to pK^+\Sigma^0$ *am Experiment COSY-11*
Rheinische Friedrich-Wilhelms-Universität Bonn, Germany, 2000

Christoph A. Quentmeier
Untersuchung der Reaktion $pp \to ppK^+K^-$ *nahe der Produktionsschwelle*
Westfälische Wilhelms-Universität Münster, Germany, 2001

Piotr Kowina
Production of the neutral Λ and Σ hyperons in proton-proton interactions at COSY-11
University of Silesia, Katowice, Poland, 2002

Peter Winter
Schwellennahe Kaonenproduktion im Proton-Proton Stoss am Experiment COSY-11
Rheinische Friedrich-Wilhelms-Universität Bonn, Germany, 2005

Tomasz Rożek
Threshold hyperon production in proton-proton collisions at COSY-11
University of Silesia, Katowice, Poland, 2006

Rafał Czyżykiewicz
Study of the production mechanism of the η meson in proton-proton collisions by means of analysing power measurements
Jagellonian University, Kraków, Poland, 2007

Cezary Piskor-Ignatowicz
Near threshold η-meson production in dp collisions
Jagellonian University, Kraków, Poland

Heinz-Hermann Adam
Untersuchung der $\eta - {}^3He$ - Endzustandswechselwirkung im Reaktionskanal $pd \rightarrow {}^3He\eta$ nahe der Erzeugungsschwelle
Westfälische Wilhelms-Universität Münster, Germany

Aleksander Täschner
Produktion von Mesonen in hadronischen Wechselwirkungen unter Verwendung von Clusterjet-Strahlen hoher Dichte
Westfälische Wilhelms-Universität Münster, Germany

Joanna Przerwa
Isospin dependence of the η' meson production in nucleon-nucleon collisions
Jagellonian University, Kraków, Poland

Paweł Klaja
Correlation femtoscopy for studying η and η' mesons production mechanism
Jagellonian University, Kraków, Poland

Damian Gil
Kaon pair production in pp collisions
Jagellonian University, Kraków, Poland

Eryk Czerwiński
Determination of the total width of the η' meson
Jagellonian University, Kraków, Poland

Barbara Rejdych
η' meson production in quasi-free $pn \rightarrow d\eta'$ reaction near threshold
Jagellonian University, Kraków, Poland

Michael Rook
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Strangeness-Erzeugung in der p p und pbar p Streuung

Bonn, 1994

Abstract:
Monte-Carlo Rechnungen zu dem in der Aufbauphase befindlichen Experiment COSY-11 belegen die Durchführbarkeit der Messung des Reaktionstyps $pp \rightarrow ppX$ für ein Meson X im 1 GeV/c2 Massenbereich in der Nähe der Reaktionsschwelle. Aus der Massgabe minimaler Akzeptanzbeschränkung für diesen Reaktionstyp folgt die Dimensionierung der Detektorkomponenten. Die erwarteten Zähl- und Triggerraten für den festgelegten Detektoraufbau stellen keine Begrenzung für die Lebensdauer der Detektorkomponenten sowie die Kapazität des Datenaufnahmesystems dar. Für den schwellennahen Messbereich ergibt sich für die ppX-Reaktion eine Akzeptanz von über 90%.

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Messungen zur schwellennahen Produktion geladener Pionenpaare in der Proton-Proton-Streuung

Münster, 1996

Abstract:
Das Münsteraner Clustertarget als internes Target am Protonensynchrotron COSY der KFA-Jülich wurde eingebaut und in Betrieb genommen. In ersten Messungen wurde die Funktionstüchtigkeit nachgewiesen, wobei die erreichten Kammerdrücke nahezu alle den angestrebten Werten entsprachen. Der Clusterstrahl ist räumlich schaft umgrenzt und besitzt eine homogene Dichteverteilung mit einer mittleren Flüchendichte von $3 \times 10^{13}\ Atomen/cm^{-2} \pm 33\%$.
In ersten Messungen an der COSY-11-Installation wurden Untersuchungen zur Bestimmung der absoluten Wirkungsquerschnitte der Reaktionen $pp \to pp\eta$ und $pp \to pp\pi^+\pi^-$ in der Nähe der Produktionsschwellen durchgeführt. Dabei konnte die Funktionsfähigkeit sowohl des Detektorsystems als auch der Auswertesoftware gezeigt werden. Bei der Auswertung der im Rahmen dieser Arbeit durchgeführten Messungen zur $\pi^+\pi^-$–Produktion konnten weder oberhalb noch unterhalb der Produktionsschwelle Ereignisse gefunden werden, die die Forderung erfüllten, dass sowohl zwei Protonen nachgewiesen wurden als auch in beiden Pionendetektoren Treffer detektiert wurden. Datengrundlage bildeten dabei ca. 25.5 Millionen aufgezeichnete Ereignisse. Somit konnte eine obere Grenze für den Querschnitt dieser Reaktion bestimmt werden:

P(beam)	WQ	CL
1.224 GeV/c	$\leq 9.9nb$	90%
1.222 GeV/c	$\leq 29.4nb$	90%

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Schwellennahe assoziierte Strangeness-Erzeugung in der Reaktion $pp \rightarrow ppK^+K^-$ am Experiment COSY-11

Bonn, 1998

Abstract:

Im Mittelpunkt des Experimentes COSY-11 am Beschleuniger und Speicherring COSY des FZ-Jülich steht das Studium der Produktion von Mesonen geringer Massenbreite in der Proton-Proton-Wechselwirkung im Schwellenbereich. Besonderes Augenmerk verdient dabei die Dynamik der assoziierten Produktion des im Valenzbereich des Eingangskanals nicht enthaltenen Quarkflavours der Strangeness. Mit der Reaktion $pp \rightarrow ppK^+K^-$ wird die zugehörige elementare Reaktion ohne Änderung des Quarkgehaltes beteiligter Baryonen studiert. Wirkungsquerschnitte dieses Ausgangskanals sind in der Nähe der Reaktionsschwelle bislang nicht bekannt. Indem mit der Schwellenproduktion von Mesonen hohe Impulsüberträge zwischen den beteiligten Baryonen verbunden sind, erscheint dieser experimentelle Zugang zugleich als Sonde der kurzreichweitigen Nukleon-Nukleon-Wechselwirkung. Eine Messung der Anregungsfunktion kann zudem über die Stärke der K-Kbar-Wechselwirkung Aufschluss geben, deren Kenntnis besonders durch die Diskussion der Natur skalarer Resonanzen im Massenbereich um 1 GeV/c2 motiviert ist. In Vorbereitung der Messungen an der COSY-11-Installation wurde die FASTBUS-Komponente des Datenaufnahmesystems in Betrieb genommen. Ein optimiertes Zeitverhalten mit Totzeiten unterhalb einer Millisekunde garantiert eine bestmögliche Ausnutzung der experimentell verfügbaren Luminosität. Durch eine kinematisch vollständige Rekonstruktion des Vierteilchen-Endzustandes wird ein erster totaler Wirkungsquerschnitt der Reaktion $pp \rightarrow ppK^+K^-$ nahe der Schwelle bestimmt. Bei einer Überschussenergie von 6.1$\pm$1.6 MeV ergibt sich ein Wert von 490 +400/-370 pb, der trotz seiner geringen Grösse über die am internen Target erreichte Luminosität durch den Nachweis zweier Ereignisse zugänglich wird. Die Normierung der gemessenen Zählrate beruht auf der simultanen Messung der elastischen Proton-Proton-Streuung als Referenzreaktion. Die Ereignisselektion des (ppK^+K^-)–Endzustandes und des elastischen Kanals verbunden mit einer Bestimmung der Luminosität werden in diesem Zusammenhang diskutiert. Unter Berücksichtigung des Vierkörper-Phasenraumes sowie der Final-State-Wechselwirkung des Proton-Proton-Systems sind erste Vorhersagen in Bezug auf die Anregungsfunktion im Schwellenbereich möglich.

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Assoziierte Strangeness-Erzeugung an der Produktionsschwelle in der Reaktion $pp \rightarrow pK^{+}\Lambda$ am Experiment COSY-11 mit einer optimierten Strahloptik

Münster, 1998

Abstract:

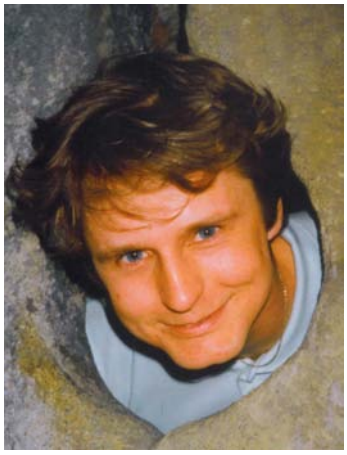
Using the experimental setup of the COSY-11 facility the energy dependence of the total cross section for the $pp \rightarrow pK^{+}\Lambda$ reaction was measured in the threshold region covering the excess energy range up to 7 MeV. The slope of the measured cross sections is described well by model calculations, but the rate is underestimated by a factor of two to three.

A special and precise determination of the proton beam momentum of the COSY-synchrotron using the measured data themselves was performed.

Investigations of the differential cross sections show that s-wave production is dominant in the $pp \rightarrow pK^{+}\Lambda$ reaction near threshold.

By comparing model phase-space Dalitz plot occupations with the experimental ones, constraints on the spin-averaged $\Lambda - p$ scattering length and effective rang have been obtained. The low energy Lambda p scattering parameters could be determined when combining the position of the virtual bound state in the Lambda p system with data from elastic Λp scattering measurements, together with the fact that the hyperdeuteron is not bound.

A major intension was given for the development and installation of a special magnet optics for the COSY-synchrotron to get optimal proton beam conditions for the COSY-11 experiment. Varying the focussing and defocussing strength of the quadrupoles in both of the arcs of the cooler ring the dimensions of the proton beam was reduced to the size of the cluster target beam. The change of the optics from the normal COSY one to this special COSY-11 optics combines a high resolution measurement (due to the small size of the reaction zone) with a high luminosity (due to the maximized overlap of proton beam and target).



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η' meson production in the $pp \to pp\eta'$ reaction near threshold

Kraków, 1998

Abstract:

The η' meson belongs to the ground state pseudoscalar meson nonet. According to the SU(3) classification its quark composition is similar to the structure of the η meson. However, due to the small pseudoscalar mixing angle ($\Theta_{PS} \approx 15^o$) the η' meson is predominantly a flavour singlet state and hence can comprise a significant amount of gluons. A possible gluon admixture would be reflected in the production mechanism of the η' meson in the elementary proton-proton reaction, it would modify an η' pp coupling constant which determines the direct production amplitude, and it would also influence the potential of the proton-eta$'$ meson interaction. These issues make the investigations of the eta$'$ meson very interesting.

The total cross section for the production of the η' meson in the $pp \to pp\eta'$ reaction has been measured close to the kinematical threshold. The experiment has been carried out at the cooler synchrotron COSY using the internal proton beam and the hydrogen cluster target. The ejected charged particles were registered using the COSY-11 detection system, which allow for an unique identification of positively charged particles and determination of their four-momentum vectors. Events with the creation of the η' meson were identified by means of the missing mass technique.

The obtained cross sections for the η' meson production are by about a factor of fifty smaller that the cross section for the production of the η meson at the same center of mass excess energies. Such large difference suggests that these mesons are produced in a rather different way.

Comparison of the measured cross section values with calculations based on the effective Lagrangian approach yields an upper limit for the $\eta' pp$ coupling constant. The analysis of the energy dependence of the total cross section for the $pp \to pp\eta'$ reaction suggests that either the primary production amplitude decreases very close to threshold or that the proton-η' interaction is repulsive.

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Die Produktion des η-Mesons am Jülicher Beschleuniger COSY und Entwicklung eines optimierten Datenaufnahmesystems

Bochum, 1999

Abstract:

Das interne Experiment COSY-11 am Cooler-Synchrotron COSY im Forschungszentrum Jülich ermöglicht ein Studium der Mesonenproduktion in Reaktionen der Art $pp \rightarrow ppX$ in der Nähe der Produktionsschwelle mit grosser Akzeptanz.

In dieser Arbeit wird die Produktion des η-Mesons bei einer Überschussenergie von 0 bis 7 MeV/cš im Schwerpunktsystem untersucht. Dabei wurde der Strahlimpuls in Rampen von 5 Minuten Länge von 1972 auf 2002 MeV/c erhöht. Gegenüber einer Messung von Einzelpunkten hat dies den Vorteil, daSS die zur Zeit unvermeidbare absolute Ungenauigkeit der Strahlimpulseinstellung von etwa 2 MeV/c keinen Einfluss auf die Differenzen zwischen verschiedenen gemessenen Impulsen hat. Die Erfahrungen mit dem Datenaufnahmesystem von COSY-11 wurden genutzt, um ein neues verbessertes Datenaufnahmesystem aufzubauen. Es wird im Frühjahr 1998 in einem anderen Experiment eingesetzt werden und ist dort bereits erfolgreich im Testbetrieb. Es erlaubt Eventraten von mehreren zehntausend pro Sekunde (einer Totzeit von $100\mu s$ pro Event entsprechend) bei einem maximalen Datendurchsatz von 4 Megabyte pro Sekunde.

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Untersuchung der Reaktion $pp \rightarrow ppK^+X$ in Nähe der $f_0(980)$-Resonanz

Münster, 1999

Abstract:

Im Rahmen dieser Arbeit wurden Messungen zur assoziierten Strangenesserzeugung in der Nähe der Masse der $f_0(980)$-Resonanz im Proton-Proton-Stoss analysiert. Die Auswertungen hinsichtlich der Reaktionskanäle $pp \rightarrow ppK^+K^-$, $pp \rightarrow pK^+\Sigma^0(1385)$ und $pp \rightarrow pK^+\Lambda(1405)$ ergaben, dass, bedingt durch die geringen Wirkungsquerschnitte in Verbindung mit der experimentell bedingten Methode der inklusiven Messung, lediglich obere Grenzen der Wirkungsquerschnitte ermittelt werden können.

Die aus den Analysen von Zweispurereignissen ermittelten absoluten Wirkungsquerschnitte der Reaktionen $pp \rightarrow pK^+\Lambda$, $pp \rightarrow pK^+\Sigma$, $pp \rightarrow pp\omega(782)$ und $pp \rightarrow pp\eta'(958)$ ergänzen die in Schwellennähe existierenden Daten und können trotz der grossen Messungenauigkeiten Hinweise über den Verlauf der jeweiligen Anregungsfunktion liefern. Die Auswertung der Ereignisse mit einem Proton und einem K^+ im Endzustand belegen die Möglichkeit des Nachweises aller positiv geladenen Produkte der zu untersuchenden Reaktionen. Da dabei keine Signaturen des $\Sigma^0(1385)$ und des $\Lambda(1405)$ gefunden werden konnten, können auch diese Analysen nicht zur Klärung der Anteile der unterschiedlichen Reaktionskanäle an der Zahl der gefundenen (ppK^+)–Ereignisse beitragen.

Da zur K^+K^-– ebenso wie zur $\Lambda(1405)$–Produktion lediglich obere Grenzen für die Wirkungsquerschnitte ermittelt werden konnten, künnen aus den hier vorgestellten Messungen keine Informationen sowohl über die innere Struktur der skalaren Mesonen $f_0(980)$ und $a_0(980)$ als auchüber die des Hyperons $\Lambda(1405)$ getroffen werden. Weitere Messungen an COSY-11 zwischen der K^+K^-– und der $\Lambda(1405)$- sowie zwischen der $\Lambda(1405)$ - und der $\Sigma^0(1385)$-Produktionsschwelle können möglicherweise Aufschluss über die Anregungsfunktionen zur Erzeugung dieser beiden Hyperonen geben. Eventuell können so die Anteile der verschiedenen Reaktionskanäle an der Zahl der gefundenen (ppK^+)-Ereignisse geklärt werden.

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Schwellennahe Hyperonproduktion in den Reaktionskanälen $pp \to pK^+\Lambda$ und $pp \to pK^+\Sigma^0$ am Experiment COSY-11

Bonn, 2000

Abstract:

At the internal experiment COSY-11 the near threshold production of the two neutral hyperons Λ and Σ^0 has been investigated in proton-proton collisions. In the measured energy region of up to 13 MeV excess energy it was found that the cross section of the Λ-production exceeds that of the Σ^0-production by a factor of 28. This ratio of the cross sections is in contrast to measurements at higher excess energies, where a ratio of 2-3 has been determined. As one explanation of this result a $N\Sigma \to N\Lambda$-conversion is discussed, which is known in the literature as the so called cusp-effect. At near threshold measurements of the Σ^0-production simultanously the lighter Λ-particle is produced. These reactions at about 80 MeV excess energies were also analysed and compared to other measurements at similar excess energy.

Christoph A. Quentmeier
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Untersuchung der Reaktion $pp \rightarrow ppK^+K^-$ nahe der Produktionsschwelle

Münster, 2001

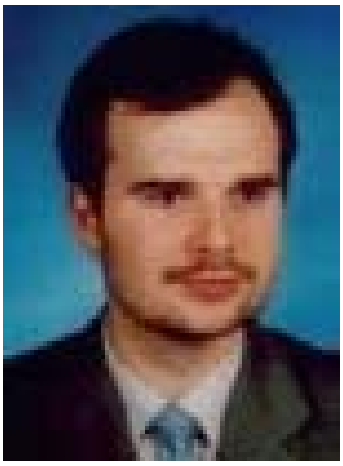
Abstract:

Die vorliegende Arbeit stellt die Ergebnisse der Analyse von Daten vor, die die COSY-11-Kollaboration bei Strahlimpulsen von p_{Strahl} = 3.292, 3.311 und 3.356 GeV/c aufgenommen hat.

Im Mittelpunkt der Untersuchungen steht die assoziierte Strangenesserzeugung in der Reaktion $pp \rightarrow ppK^+K^-$. Bei einer Überschussenergie (bezogen auf die freie K^+K^-–Produktion) von Q = +3 MeV wurden zwei Ereignisse gefunden. Unterhalb der Produktionsschwelle (Q = -3 MeV) trat erwartungsgemäss kein Kandidat auf. Beim höchsten gemessenen Strahlimpuls (entspr. Q = 17 MeV) wurden 61 +0/-5 Ereignisse mit dem K^+K^-–Endzustand identifiziert, von denen 35 +0/-1 zusätzlich ein klares K^-–Signal aufweisen.

Die identifizierten K^+K^-–Endzustände können sowohl aus der freien Erzeugung als auch aus der resonanten Produktion über die skalaren Resonanzen $f_0(980)$ und $a_0(980)$ stammen. Die Winkelverteilungen der Teilchen im Ausgangskanal lassen darauf schliessen, dass die freie K^+K^-–Produktion dominiert, wobei im Rahmen der vorliegenden Statistik ein Beitrag der skalaren Resonanzen nicht völlig ausgeschlossen werden kann.

Aus den im Rahmen dieser Arbeit analysierten Daten konnten zusätzlich Winkelverteilungen und Wirkungsquerschnitte zur ω- und η'-Erzeugung extrahiert werden. In beiden Fällen fügen sich die Datenpunkte gut in die Weltdaten ein.



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Production of the neutral Λ and Σ hyperons in proton-proton interactions at COSY-11

Katowice, 2002

Abstract:

Earlier measurements at COSY–11 of the near threshold Λ and Σ^0 hyperon production via the $pp \to pK\Lambda$ and $pp \to pK\Sigma^0$ reaction, respectively, have shown a strong discrepancy of the Λ/Σ^0 cross section ratio compared to the one observed at higher excess energies. Close to threshold at excess energies up to $Q \leq 13$ MeV the Λ/Σ^0 cross section ratio has been determined to be $28\ ^{+6}_{-9}$ which exceeds the value at high excess energies ($Q \geq 150$ MeV) of about 2.5 by one order of magnitude. Additional data have been taken between 14 MeV and 60 MeV, i.e. in an excess energy region where the ratio is expected to change from $\sim$28 to $\sim$2.5. The experiment has been performed at the **CO**oler **SY**nchrotron COSY using the internal proton beam and a hydrogen cluster target. The four-momentum vectors of the positively charged ejectiles were reconstructed by the COSY–11 facility and the appropriate software. Uncharged hyperons were identified by means of the missing mass technique. The analysis and the extracted results are presented and discussed in view of different theoretical interpretations. The analysis of the excitation function for the Σ^0 hyperon production suggests that either the proton-Σ^0 final state interaction (contrary to the p-Λ one) is very weak, or that the primary production amplitude is not constant.

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Schwellennahe Kaonenproduktion im Proton-Proton Stoss am Experiment COSY-11

Bonn, 2005

Abstract:

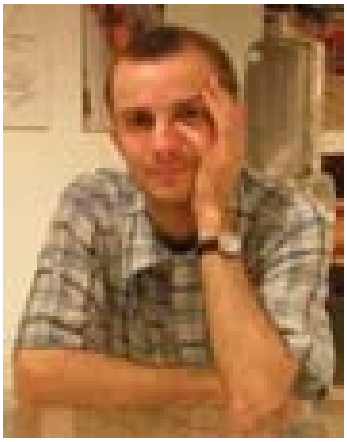
Measurements at the experiment COSY-11 at the synchrotron accelerator COSY in the Research Centre Jülich prioritise studies of near threshold meson production in nucleon-nucleon collisions. Due to the high momentum transfer between the baryons involved such experiments are sensitive on small distances and the relevant interactions in these regions. Experiments on meson production therefore enable to understand the fundamental hadronic interaction and the underlying reaction mechanisms.

A major part of the experimental studies at the detection system, which is designed as a magnetic spectrometer, consists of the associated strangeness production via the hyperon or K^+K^- channels. Near threshold cross sections for the specific reaction $pp \to ppK^+K^-$ are only scarcely available but show a strong enhancement when compared to the pure non relativistic phase space.

A detailed study of the excitation function at low Q-values was therefore extended by two new measurements. The kinematical complete reconstruction of the final state allowed to derive total cross sections of $\sigma = (0.787 \pm 0.178 \pm 0.082)$ nb at the excess energy of Q=10 MeV and $\sigma = (4.285 \pm 0.977 \pm 0.374)$ nb at Q=28 MeV. The absolute normalisation was performed by the simultaneous measurement of the elastic proton proton scattering.

Differential spectras are partly shown but due to the low statistics a detailed analysis is not performed. Nevertheless, mass spectra might play an important role in the near future. Here, especially the $\bar{K}-K$ and pK^- subsystems will be crucial with respect to the ongoing discussion about the nature of the scalar resonances and the influence of the Lambda(1405), respectively.

Within this work, the event selection of the reaction $pp \to ppK^+K^-$ and the elastic pp-scattering is explained and the full results are discussed. Their comparison with a model calculation as well as a parametrization of the strong pp final state interaction shows a still unexplained difference at low excess energies. It remains an open issue, whether new theoretical developments aill offer a satisfactory explanation of this enhancement.



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Threshold hyperon production in proton-proton collisions at COSY-11

Katowice, 2006

Abstract:

For the first time the $pp \to nK^+\Sigma^+$ reaction has been measured in the threshold region and the cross section was determined. The measurement was performed at the COSY-11 detection system at two beam momenta p = 2.6 GeV/c and 2.74 GeV/c, corresponding to excess energies Q = 13 MeV and 60 MeV. COSY-11 is an internal magnetic spectrometer experiment at the COoler SYnchroton and storage ring COSY in Jülich, Germany. It is equipped with scintillator hodoscopes and drift chambers for charged particle detection and a scintillator/lead sandwich detector for neutrons. Experimentally, the Sigma+ hyperon was identified via the missing mass technique, by detecting the remaining reaction products - K^+ meson and neutron. Extensive background studies in the missing mass spectra have been performed and the possible influence of the the higher partial waves on the detection efficiency discussed. The investigation on the Σ^+ production is a part of the long ongoing studies of the hyperons production performed by the COSY-11 collaboration. In the previous analysis of the Λ and Σ^0 hyperon production in the $pp \to pK^+\Lambda(\Sigma^0)$ reactions, respectively, the unexpectedly high cross section ratio $\sigma(\Lambda)/\sigma(\Sigma^0)$ in the close to threshold region was observed. To explain this behavior, various theoretical scenarios were proposed, but although they differ even in the dominant basic reaction mechanism, all more or less reproduce the data. In order to get more information for disentangling the contributing reaction mechanisms, data from an other isospin channel were taken, namely $pp \to nK^+\Sigma^+$. Within this thesis the method of the measurement and the data analysis is given. The total cross section is presented and the results are discussed in view of available theoretical models.

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Study of the production mechanism of the η meson in proton-proton collisions by means of analysing power measurements

Kraków, 2007

Abstract:

The analysing power measurements for the $\vec{p}p \rightarrow pp\eta$ reaction studied in this dissertation are used in the determination of the reaction mechanism of the η meson production in nucleon-nucleon collisions.

Measurements have been performed in the close-to-threshold energy region at beam momenta of p_{beam}=2.010 and 2.085 GeV/c, corresponding to the excess energies of Q = 10 and 36 MeV, respectively. The experiments were realised by means of a cooler synchrotron and storage ring COSY along with a cluster jet target. For registration of the reaction products the COSY-11 facility has been used. The identification of the η meson has been performed with the missing mass method. The results for the angular dependence of the analysing power combined with the hitherto determined isospin dependence of the total cross section for the η meson production in the nucleon-nucleon collisions, reveal a statistically significant indication that the excitation of the nucleon to the S_{11} resonance, the process which intermediates the production of the η meson, is predominantly due to the exchange of a π meson between the colliding nucleons.

The determined values of the analysing power at both excess energies are consistent with zero implying that the η meson is produced predominantly in the s-wave at both excess energies.

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Near threshold η-meson production in dp collisions

Kraków, completion planned for 2007

Abstract:

A deuteron-η interaction is of the special interest due to the possible existence of the η-nucleus bound or quasi-bound states. The η meson production near threshold in the three nucleon system is much less explored as compared to the two nucleon system. For the reaction $dp \rightarrow dp\eta$ near threshold there exist only data on the total cross section for two excess energies Q = 1.1±0.6 and 3.3±0.6 MeV measured with the spectrometer SPESIII at the SATURNE accelerator. The energy dependence of the total cross section for this reaction is expected to be very sensitive to the $d-\eta$ interaction since even much weaker $p-\eta$ interaction significantly modifies the shape of the excitation function as observed in the $pp \rightarrow pp\eta$ reaction. The aim of the experiment performed by the COSY-11 collaboration was determination of the $d-\eta$ interaction and study of the η production mechanism in the $dp \rightarrow dp\eta$ reaction. Data were taken for three values of deuteron beam momenta corresponding to excess energies of 3.2, 6.1 and 9.2 MeV. Protons from the $dp \rightarrow dp\eta$ reaction are measured in the drift chambers, as well as in the scintillator hodoscopes. Particle identification was based on the Time Of Flight (TOF) measured on the path of 9.3 m. The trajectories of deuterons were measured with a small drift chamber with hexagonal cells, placed in the area close to the beam pipe. Tracking particles trajectories through the magnetic field in the COSY-11 dipole magnet back to the target position allowed to determine their magnetic rigidity. For the deuterons identification three different methods were applied and they were based on: (i) energy losses in two scintillation detectors, (ii) signal (or lack of signal) in a threshold Cerenkov detector and (iii) TOF measured on the path of about 2.3 m. The integral luminosity for each beam momentum was determined from acceptance corrected numbers of elastic dp and quasi-elastic pp events measured simultaneously with $dp\eta$ channel. The determined $dp \rightarrow dp\eta$ total cross sections for three excess energies confirm a strong effect of the interaction in the $dp\eta$ meson final state. The enhancement of the near-threshold cross sections with respect to the phase-space behavior indicates for an effect of a strong interaction between the final state particles.

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Untersuchung der $\eta - {}^3He$ - Endzustandswechselwirkung im Reaktionskanal $pd \rightarrow {}^3He\eta$ nahe der Erzeugungsschwelle

Münster, completion planned for 2008

Abstract:

Measurements of η meson production in proton-deuteron collisions have been performed using the COSY-11 facility at COSY (Jülich). Results on total and differential cross sections for the $pd \rightarrow {}^3He\eta$ reaction are presented at five excess energies between Q = 5.0 and Q = 40.6 MeV. The angular distributions show a transition from an almost isotropic emission close to threshold to a highly anisotropic distribution at higher excess energies. The total cross sections reveal a strong $\eta - {}^3He$ final state interaction, corresponding to a scattering length of $|Re(a)| = (4.2 \pm 0.5)\,fm$ and $Im(a) = (0.4 \pm 1.9)\,fm$.

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Produktion von Mesonen in hadronischen Wechselwirkungen unter Verwendung von Clusterjet-Strahlen hoher Dichte

Münster, completion planned for 2008

Abstract:
Im Rahmen dieser Arbeit soll die Produktion von Mesonen nahe der Produktionsschwelle in der Proton-Deuteron-Streuung am Experiment COSY-11 mit dem Münster Clusterjet-Target untersucht werden. Darüber hinaus werden systematische Studien zur Wasserstoff-Clusterproduktion durchgeführt, mit dem Ziel, Targetstrahlen höchster Dichte für zukünftige Experimente auf dem Gebiet der Mesonenproduktion zur Verfügung zu stellen. In diesem Zusammenhang wird ein Prototyp-Target entworfen und aufgebaut, wie es z.B. am geplanten PANDA-Experiment an FAIR verwendet werden könnte.

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Study of the proton-η' interaction in the $pp \to pp\eta'$ reaction

Kraków, completion planned for 2008

Abstract:
The COSY-11 collaboration has performed measurements of $pp \to pp\eta$ and $pp \to pp\eta'$ reactions at the excess energy $Q = 15.5$ MeV. The determined pp and $p-meson$ invariant mass distributions will be used for comparative study of the interaction within $proton-meson$ system. The elaboration of the measurement of the $pp\eta$ system has been completed and results were published in [1].
The analysis of experimental data, taken during the $pp \to pp\eta'$ reaction measurement at beam momentum $p_B = 3.257$ GeV/c will be described in the dissertation.
The differential distributions of the invariant masses for two-particle subsystems (s_{pp} and $s_{p\eta'}$) in the $pp \to pp\eta'$ reaction will be presented and compared with theoretical predictions in view of still unknown interaction between the η' meson and the proton.
The dissertation will comprise also an evaluation of the two-proton correlation function for the $pp \to pp\eta'$ reaction which will be interpreted in the framework of the correlation femtoscopy used for the determination of the spatial size of the reaction volume.

[1] P. Moskal et al., Phys. Rev. **C 69** (2004) 025203.

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Isospin dependence of the η' meson production in nucleon-nucleon collisions

Kraków, completion planned for 2008

Abstract:

According to the quark model, the masses η and η' mesons should be almost equal. However, the empirical value of these masses differ by more than the factor of two. Similarly, though the almost the same quark-antiquark content, the total cross section for the creation of these mesons close to the kinematical thresholds of the $pp \to ppX$ reaction differs significantly. In particular the total cross sections for the $pp \to pp\eta'$ reaction close to the threshold are by about a factor of fifty smaller than the cross sections for the $pp \to pp\eta$ reaction.

Using the COSY-11 detection setup we intend to determine whether this difference will also be so significant in the case of the production of these mesons in the proton-neutron scattering.

The aim of this work is determination of the excitation function of the total cross section for the $pn \to pn\eta'$ reaction near the kinematical threshold. The comparison of the $pp \to pp\eta'$ and $pn \to pn\eta'$ total cross sections will allow to learn about the production of the η' meson in the channels of isospin I = 0 and I = 1 and to investigate aspects of the gluonium component of the η' meson.

The method of measurement of the quasi-free $pn \to pn\eta'$ reaction, as well as a way to disentangle single- and multi-pion production in the missing mass spectrum from $pn \to pnX$ reaction will be also described.

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Kaon pair production in pp collisions

Kraków, completion planned for 2009

Abstract:

Experimental results obtained at the COSY-11 installation, where the cross sections for the reaction $pp \rightarrow ppK^+K^-$ has been determined at four excess energies below the ϕ meson production threshold, reveal a significant enhancement compared to the expectations including only the proton-proton final state interaction.

Evaluation and interpretation of a new experimental data at Q = 3 MeV which have been collected in order to learn more about kaon pair interaction and production in the proton-proton collisions at a very threshold, will constitute the basis of the thesis.

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Determination of the total width of the η' meson

Kraków, completion planned for 2010

Abstract:

There are many theoretical expectations which try to explain atypical properities of the η' meson and one of the goals of experiments conducted at WASA-at-COSY, KLOE–2 and MAMI–C detection facilities will be to investigate structure of that meson. For the studies of branching ratios and, in general, of the η' decays the precise knowledge of the total width of the η' meson may be very important.

The aim of this work is to determine the natural width of the η' meson from data of the $pp \rightarrow pp\eta'$ reaction measured at the COSY–11 detection setup in October/November 2006. The total width of the η' will be obtained via missing mass spectra established from measured four-momentum vectors of protons. Part of the thesis will be devoted to describe the experimental method used and calibrations of detectors. Measurement at five different beam momenta allows to control systematical errors. Based on simulations and on-line spectra one can expect determination of the width of the η' meson with a precision of about 0.02 MeV/c^2 which is five times better than the best achieved till now.

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η' meson production in quasi-free $pn \to d\eta'$ reaction near threshold

Kraków, completion planned for 2010

Abstract:

Investigations of the η' meson production in the nucleon-nucleon collisions aim at the explanation of the reaction mechanism, structure of the η' meson, and its interaction with nucleons. The purpose of this work is the experimental determination of the near threshold excitation function for the $pn \to d\eta'$ reaction. This process may occur only if the isospin of the colliding nucleons is equal to zero. Thus the knowledge of the total cross section for this reaction will deliver a complementary results to studies of the production of the η' mesons via $pp \to pp\eta'$ and $pn \to pn\eta'$ reactions, where the nucleons collides in the total isospin I = 1 or in the mixture of states with I = 0 and I = 1, respectively. The determination of the isospin dependence of the η' meson production in the nucleon-nucleon interaction should reduce significantly ambiguities of theoretical descriptions of its production mechanism.

The $pn \to d\eta'$ reaction was induced by the proton beam with a momentum of 3.365 GeV/c in the deuteron target. The identification of the reaction is based on the determination of the four-momentum vectors of the outgoing deuteron and the spectator proton. The meson η' is identified via the missing mass technique.

Deuterons were registered by means of the drift chamber and scintillation hodoscope build out of five independent detection layers. The energy loss in these five detectors will be used for the seperation of deuterons from protons and pions.

The spectator protons were registered using a silicon-pad detectors. From the four-momentum vector of the spectator proton the four-momentum vector of the struck neutron will be derived allowing determination of the total energy of the colliding nucleons for each event.

The main result of the work will be the determination of the near threshold excitation function for the quasi-free $pn \to d\eta'$ reaction.

9. Diploma theses

Michael Rook
Aufbau und Inbetriebnahme einer Dipolfeldmeβmaschine zur Streufeldvermessung von COSY-Dipolen
University of Cologne, Germany, 1990

Alfons Khoukaz
Arbeiten zum Aufbau eines Wasserstoff-Clustertargets
Westfälische Wilhelms-Universität Münster, Germany, 1992

Paweł Moskal
Response Function of the Trigger Scintillator Detector for the COSY-11 Installation
Jagellonian University, Kraków, Poland, 1993

Magnus Wolke
A large area scintillation detector with matrix readout for experiments at COSY
Westfälische Wilhelms-Universität Münster, Germany, 1993

Werner Hamsink
Development of a computer-assisted control system for the COSY-11 clustertarget
Westfälische Wilhelms-Universität Münster, Germany, 1994

Stephan Brauksiepe
Die Effizienz des Zwei-Protonen-Triggers am internen Experiment COSY-11
Ruhr-Universität Bochum, Germany, 1996

Ruth M. Woodward
Erlangen Kaon Detector for the Reaction $pp \rightarrow pK^{+}$Lambda at COSY-11, Jülich
Imperial College of Science, Technology and Medicine, London, Great Britain, 1996

Christoph A. Quentmeier
Aufbau eines Clustertargets und systematische Untersuchungen zur Clusterproduktion
Westfälische Wilhelms-Universität Münster, Germany, 1997

Rüdiger Grossmann
Suche nach einer schmalen Dibaryon-Resonanz an COSY-11
Universität Tübingen, Germany, 1997

Dorota Wyrwa
Analysis of one and two track events in scintillation counters
Jagellonian University, Kraków, Poland, 1997

Isabell-Alissandra Pellmann
Luminositätsbestimmung am Experiment COSY-11: Vergleich verschiedener Methoden
Westfälische Wilhelms-Universität Münster, Germany, 1998

Virginie Bollini
Badanie produkcji mezonów w zderzeniach protonów z protonami przy energii 2.4 GeV
Jagellonian University, Kraków, Poland, 1999

Heinz-Hermann Adam
η-*Mesonenproduktion in der Reaktion* $pd \rightarrow {}^3He\,\eta$ *am Experiment COSY-11*
Westfälische Wilhelms-Universität Münster, Germany, 2000

Jacek Sobczyk
Komora dryfowa z celami sześciokątnymi do eksperymentu COSY-11
Jagellonian University, Kraków, Poland, 2000

Peter Winter
Erste Messung der Analysierstaerke Ay in der Reaktion $\vec{p}p \rightarrow pp\eta$ *am Experiment COSY-11*
Rheinische Friedrich-Wilhelms-Universität Bonn, Germany, 2002

Christian Kolf
Spurrekonstruktion in der Hexagonal-Driftkammer am Experiment COSY-11
Rheinische Friedrich-Wilhelms-Universität Bonn, Germany, 2002

Rafał Czyżykiewicz
η *and* η' *meson production in the quasi-free proton-neutron collisions at the COSY-11 facility*
Jagellonian University, Kraków, Poland, 2002

Siegfried Steltenkamp
Luminositätsbestimmung für Proton-Deuteron-Streureaktionen am Experiment COSY-11
Westfälische Wilhelms-Universität Münster, Germany, 2002

Paweł Klaja
Korelacje proton-proton w reakcji $pp \rightarrow ppX$
Jagellonian University, Kraków, Poland, 2003

Joanna Przerwa
Bremsstrahlung radiation in the deuteron - proton collision
Jagellonian University, Kraków, Poland, 2004

Michał Janusz
Wyznaczanie pędu Fermiego neutronu w reakcji $pd \to pnp\eta$
Jagellonian University, Kraków, Poland, 2004

Eryk Czerwiński
Symulacje komputerowe reakcji $pp \to pp\eta'$ w celu wyznaczenia szerokości naturalnej mezonu η' z pomiarów wykonanych układem detekcyjnym COSY–11
Jagellonian University, Kraków, Poland, 2006

Izabela Drągowska
Symulacje kwazi-swobodnej reakcji $nn \to d\pi^-$ w oddziaływaniu deuteronu z deuteronem
Jagellonian University, Kraków, Poland, 2006

Krzysztof Tajchman
Wyznaczenie świetlności w eksperymencie COSY-11 dla zdarzeń d+p
Jagellonian University, Kraków, Poland, 2006

Michał Silarski
Analysis of the differential cross-sections for the reaction $pp \to ppK^+K^-$ in view of the K^+K^- interaction
Jagellonian University, Kraków, Poland

Michael Rook
University of Cologne

Aufbau und Inbetriebnahme einer Dipolfeldmessmaschine zur Streufeldvermessung von COSY-Dipolen

Köln, 1990

Abstract:

Diese Arbeit befaßt sich mit dem Aufbau und der Inbetriebnahme einer Dipolfeldmeßmaschine zur Vermessung der Streufelder von Dipolen des COSY-Speicherrings. Die Feldmeßmaschine dient der Erstellung von 3-dimensionalen Feldkarten der COSY-Dipole mittels Hallsonden, mit denen eine Ortsauflösung in der Feldkarte von 0.1 mm erreicht wird. Die Feldauflösung liegt in der Größenordnung 10^{-4} T.

Der Meßaufbau ist so flexibel gestaltet, daß Feldkartenmessungen auch an anderen Multipolmagneten durchgeführt werden können. Die Steuerung des Meßprozesses sowie die Aufbereitung der Meßdaten wird von einem Steuerprogramm übernommen. Erste Meßergebnisse zeigen, daß eine Messung der Hauptkomponente eines Dipolfeldes mit genügender Genauigkeit durchgeführt werden kann, während die Bestimmung kleiner Feldkomponenten erst nach Verbesserung der Meßsondenhalterung zufriedenstellend erfolgen kann.

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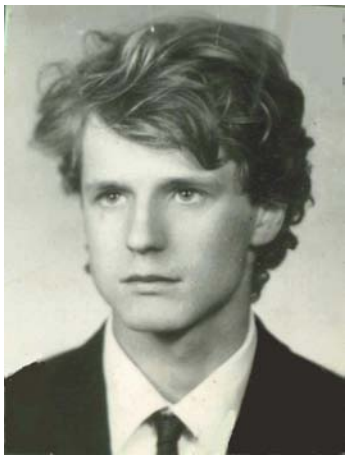
Arbeiten zum Aufbau eines Wasserstoff-Clustertargets

Münster, 1992

Abstract:
Im Rahmen der vorliegenden Arbeit wurden Komponenten für das Wasserstoff-Clustertarget für das Experiment COSY-11 aufgebaut, weiterentwickelt und in Betrieb genommen. Insbesondere wurde die Herstellung von aktivkohlebeschichteten Kaltblechen für Kryopumpen optimiert. Die relevanten Kenngrössen dieser Pumpen wurden anschliessend bestimmt und mit theoretischen Daten verglichen. Weiter wurde ein Monitorsystem zum Vermessen von Clusterstrahlprofilen, basierend auf der elastischen Streuung von Elektronenstrahlen an Clustern, aufgebaut. Mit diesem System gelang es, die relative Flächendichte von Wasserstoff-Clustern ortsaufgelöst aufzunehmen, ohne den Targetbetrieb bzw. die Vakuumbedingungen zu beeinträchtigen.



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Response Function of the Trigger Scintillator Detector for the COSY-11 Installation

Kraków, 1993

Abstract:

The COSY-11 experimental facility has been designed for studies of the near threshold mesons production in the proton-proton and proton-deuteron collisions. The identification of reactions is based on the registration of trajectories and velocities of the charged outgoing baryons and long lived mesons. The velocity of outgoing protons is measured using the scintillator hodoscope comprising the *start* and *stop* detectors seperated by a distance of nine meters. The fast signals from these counters are used also for the formation of the experimental trigger. The *start* counter is build out of sixteen independent detection units forming a scintillation array with the dimensions of 160 times 45 centimeters. Each detection unit consists of the fast plastic scintillator with the dimensions of 45 x 10 x 0.4 centimeters read out on two sides by photomultipliers.

The aim of this thesis was the determination of the response of a single detection unit of the *start* counter to ionizing particles. Investigations has been conducted using the secondary pion beam at CERN and also by means of electrons emitted from the ^{90}Sr source. The result of studies conducted is the determination of charge and time variations of signals as a function of the hit position. In particular it was established that the sum of charges for signals collected at both sides is fairly independend of the position of irradiation. This observation revealed a possibility of using the energy losses of registered particles for the triggering purposes. The work resulted also in the estimation of the resolution of the time and position determination, and on the elaboration of a method for the correction of the time walk effect due to the use of leading edge discriminators.

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A large area scintillation detector with matrix readout for experiments at COSY

Münster, 1993

Abstract:
Geometrical parameters of a large area scintillation wall with a matrix arrangement of the readout photomultipliers have been optimized by means of Monte Carlo simulation to meet the requirements of a time-of-flight measurement at the experiment E5 at the proton synchrotron COSY Juelich. A system based on short light pulses emitted by light diodes to monitor the photomultiplier gains has been adapted to this application and was successfully tested.
Experimental results for the pulse height function of the photomultipliers from a test measurement with minimum ionizing particles deviate for the prototype module from the Monte Carlo simulation. Neglecting the light guide connections of the photomultipliers in the simulation is likely to explain this deviation.
Experimental values for the time resolution of the prototype exceed the theoretical expectation by about 30with the hit position agrees with the theoretical prediction. A time-of-flight resolution of 240-260 ps depending on the hit position has been determined for minimum ionizing particles for the combination of start and stop scinitillators in the experiment E5. Thus, for protons with a momentum of about 1 GeV/c, a time-of-flight resolution of 195-220 ps is expected for the next stage of expansion of the detector setup, corresponding to an estimated momentum resolution of
The center-of-gravity method for the reconstruction of the hit position showed the expected behaviour of systematic deviations between true and reconstructed hit positions. Quantitatively, reconstructed positions are spread by 1.2 cm horizontally and 0.8 cm vertically. Consequently, the position resolution is much better than required by the experiment E5.
Until installation of the detector in its second and final stage of expansion, an absolute calibration of the PM tubes will be performed, and the gain monitoring system will be put into operation. A modified MC simulation describing the experimentally determined pulse height function can be used in future to study both systematic deviations of the reconstructed hit positions and their energy dependence and the double hit resolution of the detector.

Werner Hamsink
Westfälische Wilhelms-Universität

Development of a computer-assisted control system for the COSY-11 clustertarget

Münster, 1994

Abstract:
In this diploma thesis a complete control of the COSY-11 clustertarget was developed. The existing electronic was debugged and taken into operation. The computer control is based on an OS-9 operating system. This multitasking system allows to run parallel several processes that can exchange information. The control of the system via configuration files allows a flexible operation with the possibility to change the control software without changing the entire programme and requires little effort to understand the functioning of the programme. In the near future the system will be improved and documentation will be prepared to make sure that the system can be operated in the future.

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Die Effizienz des Zwei-Protonen-Triggers am internen Experiment COSY-11

Bochum, 1996

Abstract:

Für das Experiment COSY-11 wurde eine flexible und schnelle Triggerelektronik für die Untersuchung von Schwellenreaktionen aufgebaut und erfolgreich eingesetzt. Die Triggerlogik erlaubt die Aufnahme von Ereignissen unterschiedlicher Multiplizitäten mit einstellbaren Untersetzungsfaktoren bei beliebiger Verknüpfungsmöglichkeit. Die ersten Messdaten der COSY-11 Installation wurden analysiert und elastisch gestreute Protonen selektiert. Dabei wurde eine Rekonstruktion der Teilchenspuren in einer realen Magnetfeld-verteilung durchgeführt. Mit den Ereignissen der elastischen Streuung konnte eine Energie-verlusteichung des Monitordetektors und des Szintillationszählers S1 vorgenommen werden. Ausserdem erlaubt die Rekonstruktion der Protonen im Magnetfeld bei Kenntnis des Trefferortes des zweiten Protons im Monitordetektor die Bestimmung des Targetortes, wodurch der Überlapp von Target und COSY-Strahl ermittelt werden kann. Durch Monte-Carlo Simulationen wurde die Akzeptanz der Detektoranordnung für die elastische Streuung bestimmt, woraus die aktuelle Luminosität zu $6.2 \cdot 1028 cm^{-2} s^{-1}$ ermittelt werden konnte. Bei der ersten COSY-11 Messung zur $\pi^+\pi^-$ – Produktion bei einem Strahlimpuls von 1.224 GeV/c konnte mit der Triggerlogik für einen Zweiteilchennachweis die Zählrate durch die Szintillatoren S1 und S2, bei allen Multiplizitäten, von $\geq 4kHz$ auf eine Triggerrate von $\approx 100Hz$ gesenkt werden, bei einer Effizienz des Zwei-Protonen-Nachweises von über 99.99%.

Ruth M. Woodward
ICSTM

Erlangen Kaon Detector for the Reaction $pp \rightarrow pK^+\Lambda$ at COSY-11, Jülich

London, 1996

Abstract:
A large scintillator module with the dimensions of 65 cm $\times$ 24 cm was prepared by the Erlangen team with the aim of improving the K^+ identification and efficiency at COSY–11. Data were taken to study the performance of this detector in the actual experiment. The reaction $pp \rightarrow pK^+\Lambda$ was analyzed and compared to the standard COSY–11 setup, especially with respect to the K^+ detection.

Christoph A. Quentmeier
Westfälische Wilhelms-Universität

Aufbau eines Clustertargets und systematische Untersuchungen zur Clusterproduktion

Münster, 1997

Abstract:

Im Bereich der Kern- und Elementarteilchenphysik stellen Streuexperimente die wesentlichen Mittel dar, Zusammensetzung und Verhalten von Materie zu erforschen. Zu diesem Zweck können Teilchen, zum Beispiel Protonen, auf Energien von heute bis zu 1 TeV pro Nukleon beschleunigt und dann auf ein Target geschossen werden. Bei Experimenten mit einem Ringbeschleuniger besteht die Möglichkeit, entweder ein externes oder ein internes Target zu verwenden. Beim externen Target wird der Strahl aus dem Ring extrahiert und auf das Target geschossen. Teilchen, die nicht mit dem Target wechselwirken, gehen dabei für das Experiment verloren. Das interne Target befindet sich hingegen direkt in der Flugbahn der zirkulierenden Teilchen im Strahlrohr. Teilchen, die nicht mit dem Target wechselwirken, stehen nach einem weiteren Umlauf erneut für eine Reaktion zur Verfügung, so dass mit geringeren Targetdichten gearbeitet werden kann. Der Einsatz eines internen Targets ist daher besonders sinnvoll, wenn Reaktionen unter Einzelstossbedingungen untersucht werden sollen, gleichzeitig aber eine hohe Luminosität verlangt wird. Die Funktionsweise eines Clustertargets beruht darauf, dass das durch eine spezielle Düse strömende Gas adiabatisch expandiert und teilweise zu kleinen Mikro-Tröpfchen, den sogenannten Clustern, kondensieren kann. Ein Clustertarget zeichnet sich durch eine hohe, variable Targetdichte im Bereich von bis zu 1014 $Atomen/cm^3$ und eine kleine, wohldefinierte Targetregion unter Beibehaltung von UHV-Bedingungen in der Streukammer aus. Bei Proton-Proton Streuexperimenten, die an der KFA Jülich im Rahmen des COSY-11 Experiments, zum Beispiel zwecks Untersuchung der Produktionsmechanismen von Mesonen nahe der Schwelle, durchgeführt werden, wird ein Wasserstoff-Clustertarget mit grossem Erfolg eingesetzt. Basierend auf dem Konzept dieses Clustertargets, wurde ein weiteres entworfen. Ziel und Gegenstand dieser Arbeit war es, das Clustertarget aufzubauen und zu testen. In diesem Rahmen wurden systematische Untersuchungen zur Clusterproduktion durchgeführt. Im Besonderen wurden der Einfluss der Gastemperatur, des Gasdrucks und des Düsendurchmessers auf die Targetdichte detailliert untersucht. Dabei zeigte es sich, dass das Clustertarget besonders hohe Dichten erreichen kann, wenn sich das Gas vor der Expansion nicht mehr wie üblich im gasförmigen, sondern als unterkühltes Gas im flüssigen Zustandsbereich befindet. Darüber hinaus wurden bereits erste Testmessungen zur Produktion von Helium-Clustern durchgeführt.

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Suche nach einer schmalen Dibaryon-Resonanz an COSY-11

Tübingen, 1997

Abstract:

In Experimenten zum doppelten pionischen Ladungsaustausch (DCX) wurde bei niedrigen Pioneinschussenergien eine resonanzartige Struktur unterhalb der Delta-Resonanz gefunden. Diese Struktur kann beschrieben werden, wenn zusätzlich zum konventionellen DCX-Mechanismus auch ein Prozess über eine Dibaryon-Resonanz abläuft. Das Deuteron als triviales Dibaryon ist wohlbekannt, jedoch hat die hypothetische Dibaryon-Resonanz eine nicht-triviale Quarkkombination. In gewissem Sinne stellt sie einen angeregten Zustand des Deuterons dar und wird deshalb d' genannt. Da die Experimente zur DCX-Reaktion an Kernen durchgeführt wurden, ist die Möglichkeit nicht auszuschliessen, dass ein Kernmediumseffekt der Grund für diese resonanzartige Struktur ist. Um dies entscheiden zu können, muss man nach freien Dibaryonen suchen. Ein erstes Experiment zur Erzeugung von freien Dibaryonen in Proton-Proton Kollisionen wurde 1995 am CELSIUS-Speichering mit dem WASA-PROMICE-Detektor durchgeführt. Bei der Auswertung dieser Daten konnte tatsächlich eine schmale Struktur bei einer Masse von 2.063 GeV/c^2 gefunden werden. Ein weiteres Experiment wurde im Juli 1996 am Cooler-Synchrotron COSY mit dem COSY-11 Aufbau durchgeführt. Mit der Auswertung der in dieser Strahlzeit gewonnenen Daten beschäftigt sich diese Diplomarbeit. Das COSY-11 Experiment ist sehr gut geeignet, um Reaktionen an der Schwelle zu messen. Es wurden Daten bei 3 verschiedenen Strahlenergien aufgenommen, direkt an der Schwelle der hypothetischen d'-Resonanz (p_0=1.360 GeV/c), überhalb der Schwelle (p_0=1.374 GeV/c) und unterhalb der Schwelle (p_0=1.330 GeV/c). Die Existenz der d'-Resonanz konnte nach Auswertung der Daten mangels Statistik nicht nachgewiesen werden, jedoch wurden 3 Ereignisse mit je 2 Protonen und einem positiven Pion gefunden. Mit Monte-Carlo Simulationen konnte gezeigt werden, dass man bei der d'-Schwellenenergie jeweils ein Ereignis aus der konventionellen 2-Pion Produktion und ein Ereignis aus der d'-Resonanz erwarten würde. Dies ist in Einklang mit den Daten. Neben diesen identifizierten $pp\pi^+$–Ereignissen wurden auch 2-Spur-Ereignisse $(pp, p\pi^+$ und $\pi^+\pi^+)$ sowie 1-Spur-Ereignisse (π^+) untersucht. Im Allgemeinen stimmen diese Spektren recht gut mit Monte-Carlo Simulationenüberein.

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Analysis of one and two track events in scintillation counters

Kraków, 1997

Abstract:

In general, the aim of this work is to analyse the probability of distinguishing between two cases when one or two particles are passing through a scintillator. The main information about the mechanism of losing energy by the particles and also about the distribution of their energy loss are contained in the first chapter. In the second one the accordance of the experimental data to the Bethe-Bloch formula in the range up to 2 GeV is examined and in the third part the problem of the identification of very close tracks is considered. 'Close' means that the distance of two trajectories is so small that the drift chambers cannot resolve them. For measurements of the $pp \rightarrow ppX$ reactions very close to threshold the momenta of the protons are comparable and their trajectories are very close. With the drift chambers a resolution of two tracks as close as 3 mm is achieved. For closer tracks a separation via the drift chamber reconstruction is not possible, these are identified as a single track. But such events could be analysed if the particle multiplicity in the scintillator is known, the single track could be interpreted as two tracks with identical momenta and the missing mass of the system X could be calculated. A multiplicity signal is in principle given by the energy loss in the scintillator. Due to the energy loss distribution a clear separation of the multiplicity 'one' and 'two' is not efficient with a single scintillation dE/dx signal. The analysis of several scintillator elements is needed.

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Luminositätsbestimmung am Experiment COSY-11: Vergleich verschiedener Methoden

Münster, 1998

Abstract:
In dieser Arbeit werden verschiedene Methoden zur Luminositätsbestimmung am internen Experiment COSY-11 untersucht und miteinander verglichen. Die Luminosität kann aus Strahl- und Targeteigenschaften oder durch Analyse von Reaktionen mit bekanntem Wirkungsquerschnitt bestimmt werden. Sie ergibt sich dann aus der Zählrate, der Grösse des analysierten Raumwinkels und dem aus der Literatur bekannten differentiellen Wirkungsquerschnitt. Im Rahmen dieser Arbeit wurden die Reaktionen $pp \to pp$ und $pp \to d\pi^+$ untersucht. Die Analyse der letztgenannten Reaktion wurde in diesem Experiment zum ersten Mal zur Luminositätsbestimmung genutzt.
Zusätzlich wurde ein Luminositätsmonitor (Vieldrahtproportionalkammern in Verbindung mit Szintillatoren) entwickelt, mit dem sowohl die Luminosität online während der Strahlzeit überwacht als auch der Wechselwirkungspunkt von Strahl und Target in Projektion senkrecht zur Strahlrichtung bestimmt werden kann. Zur Analyse der Daten wurde ein Auswertungsprogramm entwickelt, mit dem sowohl reale Daten als auch Ergebnisse von Monte-Carlo-Simulationsrechnungen analysiert werden können. Erste Daten wurden bereits aufgenommen und bestätigen die volle Funktionsfähigkeit des Detektorsystems.

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Badanie produkcji mezonów w zderzeniach protonów z protonami przy energii 2.4 GeV

Kraków, 1999

Abstract:
Celem pracy jest analiza danych zebranych w pomiarach przyprogowej produkcji mezonu η' w zderzeniach protonu z protonem pod kątem produkcji innych mezonów na przykład mezonu ω czy K^+.
Aby sprawdzić czy aparatura COSY–11 pozwala na badanie reakcji w których produkowane są mezony ω czy K^+ dane przeanalizowano poszukując zdarzeń typu: $pp \to ppX$, $pp \to p\pi^+X$ oraz $pp \to pK^+X$. Identyfikacja zdarzeń pochodzących z reakcji $pp \to p\pi^+n$ pozwoliła na wykonanie wstępnej kalibracji nowo zainstalowanego detektora neutronowego.

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η-Mesonenproduktion in der Reaktion $pd \rightarrow {}^3He\,\eta$ am Experiment COSY-11

Münster, 2000

Abstract:

In der vorliegenden Arbeit wird die Produktion des η-Mesons in der Reaktion $pd \rightarrow {}^3He\eta$ bei einem Q-Wert von 10.8 MeV ($peta-Schwelle$ = 1.572 GeV/c, p_{Strahl} = 1.593 GeV/c) am COSY-11-Experiment untersucht. Diese Reaktion ist deshalb besonders interessant, weil mit ihr zwei konkurrierende Modelle zur η-Produktion getestet werden können. Dabei handelt es sich um das sogenannte Resonanzmodell und das Zwei-Stufen-Modell.

Bisherige Messungen an COSY (GEM), CELSIUS (WASA-PROMICE) und SATURNE (SPES2) konnten noch keine eindeutige Aussage für oder wider eines der beiden Modelle machen. Bei COSY-GEM existiert bisher nur ein Datenpunkt bei Q = 49.3 MeV, der mit dem Resonanzmodell in Einklang steht. Die Ergebnisse von WASA-PROMICE sind bisher nur vorläufig und können daher noch nicht eingeschätzt werden. Die Datenpunkte der SPES2-Kollaboration reichen nur bis zu einem Q-Wert von 7 MeV und werden durch das Zwei-Stufen-Modell gut beschrieben. Weitere Messungen nahe der Schwelle sind also zur Klärung notwendig.

Die COSY-11-Kollaboration plant daher Messungen bei einem Q-Wert im Bereich von 0 bis 50 MeV. Der in dieser Arbeit ermittelte Wirkungsquerschnitt bei Q = 10.8 MeV ist hierbei ein erster Schritt, weitere Daten für Q = 40 MeV stehen zur Analyse bereit. AuSSerdem sind Messungen zur Reaktion $pd \rightarrow {}^3He\eta'$ vorgesehen bzw. bereits vorgenommen worden.

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Komora dryfowa z celami sześciokątnymi do eksperymentu COSY-11

Kraków, 2000

Abstract:

Tematem pracy jest budowa nowej komory dryfowej do eksperymentu COSY-11 pracującego na akceleratorze COSY-Juelich. Komora te pozwala na rozszerzenie akceptancji COSY-11 na obszar niższych pędów. Jej szczególną cechą jest rama do mocowania drutów w kształcie litery U, umożliwiająca rejestrację torów cząstek w pobliżu jonowodu z pełną wydajnością. Komora zawiera cele sześciokątne ułożone w siedem płaszczyzn detekcyjnych pozwalających na trójwymiarową rekonstrukcję śladów. Druty katodowe wykonane są z aluminium, co znacząco ogranicza efekt rozpraszania kątowego cząstek. Wstępne testy komory przeprowadzono ze źródłem promieniotwórczym ^{55}Fe. Jako gaz roboczy zastosowano mieszankę gazową P10. Testy potwierdziły szczelność komory oraz prawidłowe działanie poszczególnych cel.

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First measurement of the analyzing power A_y in the reaction $\vec{p}p \rightarrow pp\eta$ at the experimental facility COSY-11

Bonn, 2002

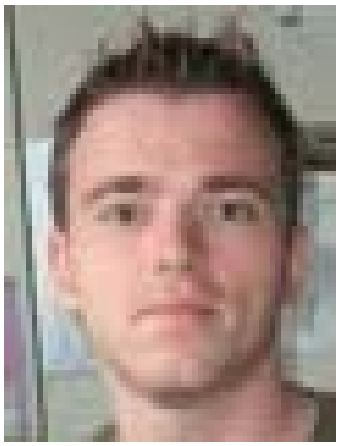
Abstract:

Measurements at the experiment COSY-11 at the synchrotron COSY in the Research Centre Jülich prioritise studies of near threshold meson production in nucleon-nucleon collisions. Due to the high momentum transfer between the baryons involved such experiments are sensitive on small distances and the relevant interactions in these regions. Experiments on meson production therefore enable to understand the fundamental hadronic interaction and the underlying reaction mechanisms.

A study of the influence of higher partial waves succeeds with polarization observables which are sensible thereon. The analyzing power represents besides the spin correlation coefficients one of these measurands. For its determination the polarization of one of the two colliding particles is necessary.

First results of the analyzing power are presented using data in the reaction $\vec{p}p \rightarrow pp\eta$ taken at the experiment facility COSY-11 with a beam momentum $p_{beam} = 2.096 GeV/c$ according to an excess energy Q = 40 MeV. A selection of the ppη final-state is done via a kinematical complete reconstruction of this three body system. The determination of the relative luminosity of both spin states is based on the simultaneous measurement of the elastic proton-proton scattering.

Individual interference terms of amplitudes of partial waves were determined and enables a comparison with theoretical forecasts.



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Spurrekonstruktion in der Hexagonal-Driftkammer am Experiment COSY-11

Bonn, 2002

Abstract:

The experimental facility COSY-11 at the cooler synchrotron and storage ring COSY at the Research Center Jülich investigates the production of small width mesons in the proton-proton- and proton-deuteron-interaction close to threshold. At COSY-11, the trajectories of positively charged ejectiles are measured by means of two planar drift chamber systems. In summer 2000, a drift chamber with hexagonal cells was added to the COSY-11 setup. Consequently, the acceptance for short-living, positively charged mesons like pions and kaons increases. The trajectories in the hexagonal chamber can be determined with the new track reconstruction software in three dimensions. With the data of the COSY-11 beamtime in March 2001 a calibration was performed. The position resolution, determined as the standard deviation of the experimental data, amounts to $350 \mu m$.

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η and η' meson production in the quasi-free proton-neutron collisions at the COSY-11 facility

Kraków, 2002

Abstract:

Both, the structure of the η' meson as well as its production mechanism are still under strong discussion and debate. The most possible hypothesis concerning the explanation of the almost three times larger mass for this meson observed experimentally relative to the theoretically calculated mass is a gluonium admixture to the η' wave function. This gluonium admixture should reflect itself in the production yield of the η' meson in proton-neutron collisions. Since the production of η' meson through the gluonium exchange is isospin independent, the ratio $R_{\eta'} = \sigma_{pn\to pn\eta'}/\sigma_{pp\to pp\eta'}$ close to threshold is expected to be $R_{\eta'} = 1$, after corrections for initial and final state interactions. The close to threshold η' production in proton-proton collisions has already been investigated at the COSY-11 facility. Cross section values in the threshold region have been measured. However, until now no data have been taken for the η' meson production in the proton-neutron collision. In order to investigate the η' production in proton-neutron collisions at the COSY synchrotron, the COSY-11 facility has been equipped with two new subsystems, namely the neutron detector and the spectator counter. The optimization of the topography for these additional detectors, the selection of the most suitable beam momentum and a discussion for the method of luminosity determination for the quasi-free $pn \to pn\eta(\eta')$ reactions are presented in this thesis. Rates for the production of η and η' mesons in proton-neutron collisions at COSY-11 have been estimated. For the calculations a special fast program has been written.

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Luminositätsbestimmung für Proton-Deuteron-Streureaktionen am Experiment COSY-11

Münster, 2002

Abstract:

Im Rahmen dieser Arbeit soll die integrierte Luminosität für die Bestimmung des Wirkungsquerschnittes der Reaktion $pd \rightarrow {}^3He\eta$ ermittelt werden. Als Referenzreaktion wurde die elastische Proton-Deuteron-Streuung simultan gemessen. Diese Arbeit befasst sich neben dem experimentellen Aufbau und einer kurzen theoretischen Einleitung zunächst mit der Simulation und Analyse von Daten der elastischen Proton-Deuteron-Streuung. In der Simulation beziehungsweise Analyse wird durch Vergleich von generierten und analysierten Daten eine Aussage über die Genauigkeit der Rekonstruktion gemacht. Hierzu wurden Ereignisse simuliert, bei denen verschiedene Aspekte, wie zum Beispiel der Einfluss des Targetdurchmessers oder der Einfluss einiger Störeffekte, genauer untersucht werden. Der zweite Teil der Arbeit befasst sich mit der Bestimmung der Luminosität für die gemessenen Strahlimpulse von 1,581 GeV/c, 1,593 GeV/c, 1,602 GeV/c, 1,612 GeV/c und 1,655 GeV/c. Die Bestimmung der Luminosität besteht aus zwei Schritten.

Im ersten Schritt werden die vom Untergrund separierten gemessenen Ereignisse der elastischen Proton-Deuteron-Streuung ausgezält. Über Monte-Carlo simulierte und analysierte Daten wird die Akzeptanz des Detektorsystems für die elastische Proton-Deuteron-Streuung bestimmt. Im zweiten Schritt müssen die Wirkungsquerschnitte der elastischen Proton-Deuteron-Streuung bei den untersuchten Strahlimpulsen aus den Literaturdaten bestimmt werden. Da keine Wirkungsquerschnitte bei den untersuchten Impulsen vorliegen, werden sie mittels der bekannten Literaturdaten interpoliert.

Zum Schluss wird aus den interpolierten Wirkungquerschnitten sowie aus der ermittelten Akzeptanz und den vom Untergrund getrennten gemessenen Ereignissen der Referenzreaktion die integrierte Luminosität bei den einzelnen Strahlimpulsen bestimmt.

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Korelacje proton-proton w reakcji $pp \rightarrow ppX$

Kraków, 2003

Abstract:

Praca poświęcona jest analizie danych z eksperymentu przeprowadzonego przez grupę badawczą COSY-11 w Centrum Badawczym Jülich w Niemczech. Celem tej pracy jest pokazanie jak korelacja pomiędzy parą protonów, których pędy mierzone są w reakcji $pp \rightarrow ppX$ pozwala określić mechanizm tej reakcji.

Szczególna uwaga poświecona jest produkcji mezonu η. Narzędziem pozwalającym dokonać takiej analizy są rozkłady koincydencji proton-proton. Badanie jakościowego i ilościowego zachowania tych rozkładów może pozwolić na wyciągniecie ciekawych wniosków o mechanizmach reakcji $pp \rightarrow ppX$.

W pracy opisane są własności mezonu η oraz mechanizmy produkcji mezonów (mezony π^0 i η) oraz przedstawiony jest teoretyczny opis rozkładów koincydencyjnych ze szczególnym uwzględnieniem funkcji korelacji.

Praca zawiera opis poszczególnych części układu detekcyjnego COSY-11 użytego do pomiaru reakcji $pp \rightarrow ppX$.

Analiza danych opisana w pracy, przedstawia jakościowe zachowanie rozkladów koincydencyjnych proton-proton dla reakcji $pp \rightarrow pp\eta$ zmierzonej przy pędzie wiazki 2.0259 GeV/c, oraz porównanie funkcji korelacji wyliczonej z danych doświadczalnych z modelowymi funkcjami korelacji dwóch założonych mechanizmów produkcji mezonu η.

Pomiary koincydencyjne i ich analiza pozwoliła otrzymać nowe, niedostępne w pomiarach inkluzywnych informacje o mechaniźmie produkcji mezonu η w zderzeniu proton-proton. Rozmiary źródła, z którego emitowane są protony przy produkcji mezonu η, są wyraźnie większe od rozmiarów źródła emisji protonów przy produkcji jednego lub dwu pionów. Kręt względny pomiędzy parą protonów a nierejestrowanymi cząstkami jest znacznie większy dla pionów (~ 6) niż dla mezonu η (~ 0).

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Bremsstrahlung radiation in the deuteron - proton collision

Kraków, 2004

Abstract:

Despite the fact that Bremsstrahlung has been observed many years ago, it is still the subject of interest of many theoretical and experimental groups. Due to the high sensitivity of the $NN \rightarrow NN$ gamma reaction to the nucleon-nucleon potential, Bremsstrahlung radiation is used as a tool to investigate details of the nucleon-nucleon interaction. Such investigations can be performed at the cooler synchroton COSY in the Research Centre Jülich, by dint of the COSY–11 detection system.

For the first time at the COSY–11 experiment signals from gamma-quanta were observed in the time-of-flight distribution of neutral particles measured with the neutral particle detector.

In this thesis the results of the identification of Bremsstrahlung radiation emitted via the $dp \rightarrow dp\gamma$ reaction in data taken with a proton target and a deuteron beam are presented and discussed.

The time resolution of the neutral particle detector and its timing calibration are crucial for the indentification of the $dp \rightarrow dp\gamma$ reaction. Therefore, methods of determining the relative timing between individual modules – constituting the neutron detector – and of the general time offset with respect to the detector components are described. Furthermore the accuracy of the momentum determination of the resistered neutron which defines the precision of the event reconstruction was extracted from the data.

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Wyznaczanie pędu Fermiego neutronu w reakcji $pd \rightarrow pnp\eta$

Kraków, 2004

Abstract:

Celem tej pracy jest wykonanie wstępnej analizy danych oraz wykonanie energetycznego cechowania detektora spektatora. Dotychczas kwaziswobodne pomiary przyprogowej produkcji mezonu η w reakcji $pd \rightarrow pnp_{sp}\eta$ pozwoliły zbadać zależność całowitego przekroju czynnego w zakresie całkowitej energii dostępnej w układzie środka masy Q od 16 - 109 MeV. W zakresie ciepła reakcji od 0 - 16 MeV nie wykonano jak dotąd pomiarów. W czerwcu 2002 grupa badawcza COSY–11 wykonała pomiar powyższej reakcji bardzo blisko nad progiem przy optymalnym pędzie wiązki protonowej wynoszącym 2.075 GeV/c. Analiza danych pozwoli na zbadanie całkowitego przekroju czynnego we wcześniej niepoznanym obszarze.

Bardzo interesującym problemem jest fakt oddziaływania badanego mezonu z nukleonem w stanie końcowym. Wykorzystując porównanie całkowitych przekrojów czynnych na produkcję mezonów η i η' w zderzeniach protonu z neutronem i protonu z protonem będzie możliwe uzyskanie informacji o strukturze mezonu η'. Informacje uzyskane podczas przeprowdzonego pomiaru produkcji mezonu η w reakcji $pn \rightarrow pnp_{sp}\eta$ wykorzystane zostaną do przygotownia podobnego eksperymentu z produkcją mezonu $\eta\prime$. Pomiar ten jest planowny na sierpień 2004 roku.

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Symulacje komputerowe reakcji $pp \to pp\eta'$ w celu wyznaczenia szerokości naturalnej mezonu η' z pomiarów wykonanych układem detekcyjnym COSY–11

Kraków, 2006

Abstract:

Zagadnienia fizyki związane z mezonem η' zyskały ostatnio duże zainteresowanie w związku z badaniami planowanymi na akceleratorach COSY, DAϕNE–2 oraz MAMI–C, gdzie mezon η' będzie wytwarzany w reakcjach odpowiednio hadronu z hadronem, elektronu z pozytonem oraz kwantu γ z hadronem. Badanymi obserwablami będą między innymi szerokości cząstkowe mezonu η' na rozpady z udziałem mezonów π oraz leptonów. Precyzja wyznaczenia szerokości cząstkowych w przypadku gdy możliwy będzie tylko pomiar stosunku rozgałęzienia, będzie zdeterminowana dokładnością z jaką znana jest całkowita szerokość naturalna $\Gamma_{\eta'}$.

Dotychczas $\Gamma_{\eta'}$ została wyznaczona jedynie w dwóch bezpośrednich pomiarach ze względną precyzją 30% oraz 50%. Średnia wartość z tych pomiarów wynosi 0.30 ± 0.09 MeV/c^2 i różni się znacząco od wartości 0.202 ± 0.016 MeV/c^2 określonej pośrednio ze stosunków rozgałęzień oraz kombinacji szerokości cząstkowych otrzymanych z przekrojów czynnych. Znacznie bardziej precyzyjny bezpośredni pomiar $\Gamma_{\eta'}$ rzuci nowe światło na tę rozbieżność.

Celem tej pracy jest określenie z jaką dokładnością można wyznaczyć szerokość naturalną $\Gamma_{\eta'}$ mezonu η' na podstawie reakcji $pp \to pp\eta'$ zmierzonej układem detekcyjnym COSY–11 oraz opracowanie planu przyszłego eksperymentu wraz z oszacowaniem czasu jego trwania, a takiże wskazanie w jaki sposób należy zmodyfikować aktualny układ pomiarowy, aby uzyskać znacząco lepszą dokładność (conajmniej o czynnik pięć) od obecnej. Opracowanie opiera się na informacjach uzyskanych z trzydniowego testowego pomiaru omawianej reakcji, który odbył się w październiku 2003 roku. Ponadto wykorzystane zostały całkowite przekroje czynne na reakcję $pp \to pp\eta'$, które zostały zmierzone w poprzednich latach przez grupę badawczą COSY–11 w oparciu o wyznaczenie masy brakującej produktów do reakcji $pp \to ppX$.

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Symulacje kwazi-swobodnej reakcji $nn \rightarrow d\pi^-$ w oddziaływaniu deuteronu z deuteronem

Kraków, 2006

Abstract:

Celem tej pracy było przeprowadzenie symulacji reakcji $nn \rightarrow d\pi^-$, zachodzącej jako kwazi-swobodny proces w zderzeniach deuteronów ($dd \rightarrow p_{sp}p_{sp}d\pi^-$), sprawdzenie akceptancji układu detekcyjnego COSY-11 na pomiar tego procesu oraz oszacowanie dokładności wyznaczenia masy brakującej i energii dostępnej w zderzeniach neutronów.

Symulacja była przeprowadzona dla pędu wiązki wynoszącego P_{beam} = 2600 MeV/c. W wyniku wykonanych obliczeń wykazałam, że najbardziej prawdopodobne jest, że proton spektator pochodzący od wiązki zostanie zarejestrowany przez detektor D3, natomiast układ dwóch komór dryfowych D1 i D2 zarejestruje deuteron, oraz że całkowita akceptancja systemu detekcyjnego COSY-11 na reakcję $nn \rightarrow d\pi^-$ realizowaną poprzez $dd \rightarrow p_{sp}p_{sp}d\pi^-$ wynosi A = 3.9 10^{-3}.

Następnie zakładając, że przekrój czynny na reakcję $nn \rightarrow d\pi^-$ jest taki sam, jak przekrój czynny na reakcję $pp \rightarrow d\pi^+$ oszacowałam, że za pomocą układu detekcyjnego COSY-11 i synchrotronu COSY będzie można rejestrować około 5000 reakcji $nn \rightarrow d\pi^-$ dziennie. Obliczona niepewność pomiarów wyznaczenia energii dostępnej na reakcję $nn \rightarrow d\pi^-$ wynosi 7 MeV (szerokość w połowie wysokości). Wynika ona z rozdzielczości pędowej pomiarów protonów spektatorów.

Z symulacji przedstawionej w tej pracy wynika, że pomiaru przekrojów czynnych na produkcję mezonu π w zderzeniach neutronów można dokonać za pomocą aparatury COSY-11 i synchrotronu COSY. Wykonane obliczenia wykazują, że w czasie kilkudniowego pomiaru będzie można zarejestrować ponad 10^4 zdarzeń.

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Wyznaczenie świetlności w eksperymencie COSY-11 dla zdarzeń d+p

Kraków, 2006

Abstract:

Tematem pracy jest wyznaczenie świetlności w pomiarach przyprogowej produkcji mezonów η w reakcjach $dp \to dp\eta$ oraz $dp \to {}^3He\eta$. Pomiary te przeprowadzone zostały na akceleratorze COSY z zastosowaniem systemu detekcyjnego COSY-11. Do wyznaczenia świetlności wykorzystany został proces elastycznego rozpraszania d-p oraz, niezależnie, proces rozpraszania kwazi-elastycznego p-p. Procesy te były rejestrowane równolegle z reakcjami produkcji mezonów η. W pracy przedstawione zostały dane literaturowe dotyczące różniczkowych przekrojów czynnych dla elastycznego rozpraszania d-p i p-p oraz opisano zastosowaną parametryzację przekrojów czynnych w funkcji pędu wiązki i przekazu czteropędu dla d-p oraz pędu wiązki i kąta rozproszenia dla p-p. Świetlność zintegrowana wyliczona została przez porównanie zarejestrowanych rozkładów kątowych dla liczby zliczeń z różniczkowymi przekrojami czynnymi opisywanymi przez zastosowane parametryzacje. Świetlność wyznaczona w oparciu o rozpraszanie elastyczne d-p jest o ok. 15% większa niż świetlność znaleziona w oparciu o rozpraszanie kwazi-elastyczne p-p. Rozbieżność tą można zrozumieć biorąc pod uwagę efekt zasłaniania protonu przez neutron w deuterze, co prowadzi do mniejszego przekroju czynnego na kwazi-elastyczne rozpraszanie p-p w porównaniu z przypadkiem rozpraszania elastycznego p-p.

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Analysis of the differential cross-sections for the reaction $pp \to ppK^+K^-$ in view of the K^+K^- interaction

Kraków, completion planned for 2008

Abstract:

Measurements of the $pp \to ppK^+K^-$ reaction, performed with the experiment COSY-11 at the Cooler Synchrotron COSY, show a significant difference between obtained excitation function and theoretical expectations including pp-FSI. The discrepancy may be assigned to the influence of K^+K^- or Kp interaction, which may manifest itself in the distributions of the differential cross-section. This thesis concerns analysis of the event distributions as a function of the invariant masses of two-particle subsystems. In particular the analysis will be based on generalization of the Dalitz plot proposed by Chodrow. In the investigation the experimental data, obtained from two measurements at excess energies of Q = 10 MeV and 28 MeV, will be compared to the results of Monte Carlo simulations generated with various parameters of the K^+K^- and Kp interaction.

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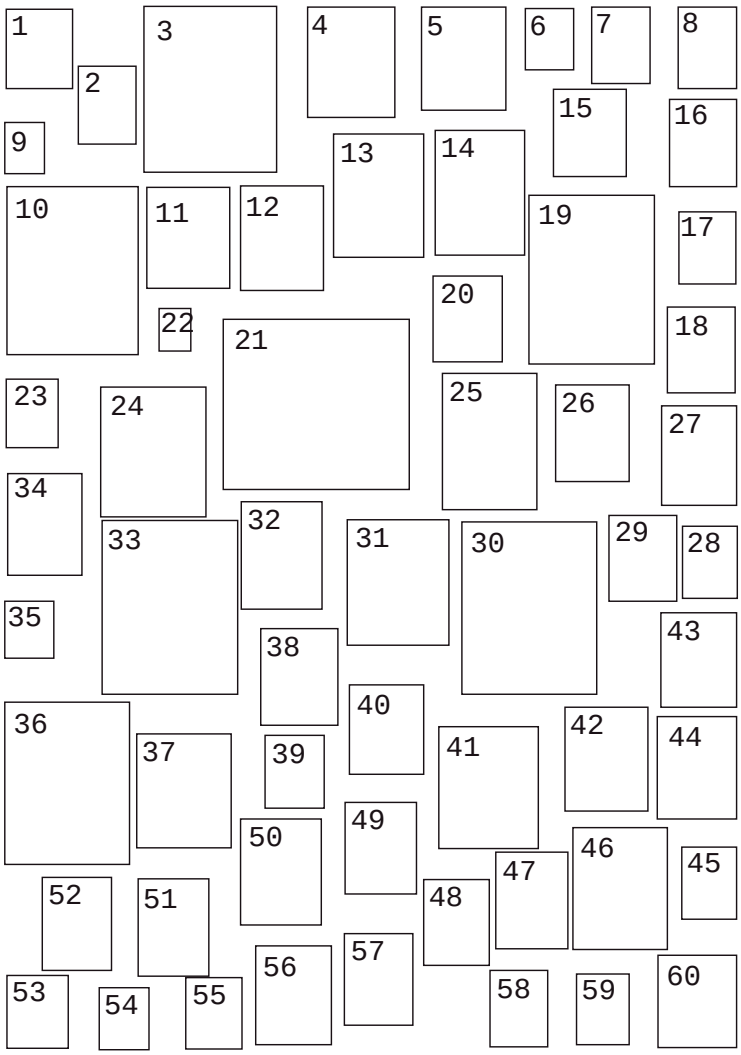

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