International Journal of Modern Physics A
Vol. 22, Nos. 2 & 3 (2007) 528–532

World Scientific
www.worldscientific.com

NEAR THRESHOLD η MESON PRODUCTION IN dp COLLISIONS

C. Piskor-Ignatowicz[⋆,*], J. Smyrski[⋆], P. Moskal[⋆], H.-H. Adam[#], A. Budzanowski[$], E. Czerwiński[⋆], R. Czyżykiewicz[⋆], D. Gil[⋆], D. Grzonka[%], M. Janusz[⋆], L. Jarczyk[⋆], B. Kamys[⋆], A. Khoukaz[#], P. Klaja[⋆,%], J. Majewski[⋆,%], W. Oelert[%], J. Przerwa[⋆,%], J. Ritman[%], T. Rożek[+], T. Sefzick[%], M. Siemaszko[+], A. Täschner[#], P. Winter[×], M. Wolke[%], P. Wüstner[%], W. Zipper[+]

[⋆] *Institute of Physics, Jagiellonian University, Cracow, Poland*
[#] *IKP, Westfälische Wilhelms-Universität, Münster, Germany*
[$] *Institute of Nuclear Physics, Cracow, Poland*
[%] *IKP, ZEL, Forschungszentrum Juelich, Juelich, Germany*
[+] *Institute of Physics, University of Silesia, Katowice, Poland*
[×] *Department of Physics, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA*

COSY-11 Collaboration

Preliminary results of recent measurements of the near threshold η meson production in the $dp \rightarrow dp\eta$ reaction are presented. The experiment was performed at the COSY-Juelich accelerator with the use of the COSY-11 detection system. Data were taken for three values of deuteron beam momenta corresponding to excess energies of 3.2, 6.1 and 9.2 MeV. The energy dependence of the total cross section confirms a strong effect of the final state interaction.

Keywords: η meson, near threshold production.

1. Introduction

The three nucleon system is the simplest system for study of the multi-nucleon interaction and, in particular, of inelastic processes in nuclear matter. From experimental point of view, the most suitable for these studies are the pd (or dp) collisions due to the high quality of proton (deuteron) beams available at particle accelerators. Recently the $d-\eta$ and $^3\mathrm{He}-\eta$ interaction was intensively studied on the theoretical ground. This interaction is of special interest due to the possible existence of the η-nucleus bound or quasi-bound states. From the experimental point of view, the η meson production near threshold in the three nucleon system is much less explored as compared to the two nucleon system[1,2,3]. The database for the $pd \rightarrow {}^3\mathrm{He}\eta$ reaction[4,5,6,7,8] has improved recently, however, for the reaction $pd \rightarrow dp\eta$ close to threshold there exist only data measured with the SPESIII spectrometer at SATURNE[9] for two excess energies namely $Q = 1.1$ and 3.3 MeV. Unfortunately, the uncertainty of the excess energy of theses data points of $\Delta Q = \pm 0.6$ MeV is

* E-mail address: c.piskor-ignatowicz@fz-juelich.de

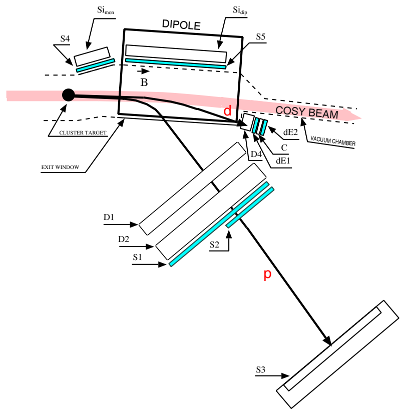

Fig. 1. Detection setup of the COSY-11 experiment[16]. Protons from the $dp \to dp\eta$ reaction are measured in the drift chambers D1, D2, as well as in the scintillator hodoscopes S1, S3. For detection of the outgoing deuterons, small drift chamber D4 with hexagonal cells[17], two scintillator detectors dE1, dE2 and Cerenkov threshold counter were installed.

very large when taking into account the rapid rise of the cross section near threshold. At higher energies, for $Q \geq 14$ MeV, the total and differential distributions of the cross section were determined by the PROMICE/WASA collaboration[10,11]. The aim of the present experiment was determination of the $dp \to dp\eta$ cross sections near threshold in order to study the interaction between the particles in the final state. The energy dependence of the total cross section is expected to be very sensitive to the $d - \eta$ interaction. Even much weaker $p - \eta$ interaction significantly modifies this shape as observed in the $pp \to pp\eta$ reaction[12,13].

2. Experiment

The experiment was performed using the stochastically cooled deuteron beam of the COoler SYnchrotron (COSY) in Juelich[14] scattered on internal proton target of the cluster jet type[15]. The charged reaction products were registered with the COSY-11 detection system which is schematically shown in Fig. 1. Protons from the $dp \to dp\eta$ reaction were measured in the drift chambers D1, D2 and in the scintillator hodoscopes S1, S3. Tracking their trajectories through the magnetic field in the COSY-11 dipole magnet back to the target position allowed to determine their magnetic rigidity. Particle identification was based on the Time Of Flight (TOF) measured on the path of 9.3 m between the scintillator hodoscope S1 and S3. Fig. 2 shows the TOF dependence on the magnetic rigidity with clearly separated protons, deuterons and ^{3}He. Due to setting of the triggering electronics, only a tail of pion TOF distribution was registered as can be seen in the figure. The outgoing deuterons from the $dp \to dp\eta$ reaction have about two times larger momenta than the outgoing protons and, consequently, their deflection in the magnetic field of the COSY-11 dipole magnet is two times smaller. Their trajectories were measured with a small drift chamber D4, placed in the area between the chamber D1 and the beam pipe, allowing for a three dimensional particle track reconstruction (see Fig. 1). Due to a huge background of spectator protons originating from the break-

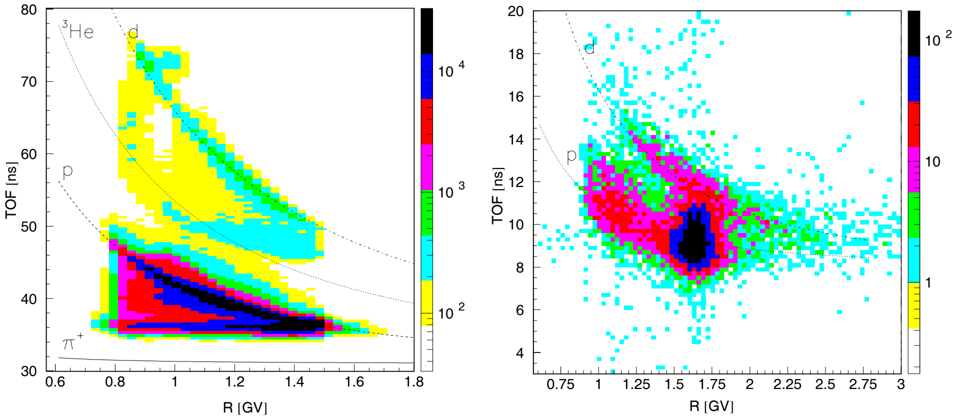

Fig. 2. Dependence of the TOF on magnetic rigidity for particles registered in the drift chambers D1, D2 (*left*) and for particles detected in the D4 chamber (*right*).

up of the deuteron beam interacting with the proton target, identification of the deuterons crossing the D4 chamber was a very difficult task. Therefore, for the particle identification three different methods were applied and they were based on: (i) energy losses in two scintillation detectors dE1 and dE2 with a thickness of 5 mm and 10 mm respectively, placed behind the D4 chamber, (ii) signal (or lack of signal) in a threshold Cerenkov detector made of 2 cm plexiglas plate and (iii) TOF measured on the path of about 2.3 m between the target and the dE1 detector. For the TOF determination, the time of the reaction at the target was derived from measurement of velocity of the associated particle registered in the scintillator hodoscopes S1 and S3 and from the time measured by the S1 detector. Dependence of the TOF on the magnetic rigidity for particles registered with the D4 drift chamber is shown in the right panel of Fig. 2. The η-mesons produced in the $dp \to dp\eta$ reaction were identified using the missing mass method.

The integral luminosity for each beam momentum was determined from acceptance corrected number of ^{3}Heη events measured simultaneously with $dp\eta$ channel. The $dp \to {}^3$Heη total cross section was taken from Ref. 4.

Application of the stochastic cooling to the COSY deuteron beam guarantees a high quality of the beam with the momentum smearing on the level of Δp/p $\approx 10^{-4}$. However, the absolute beam momentum determined on the basis of the accelerator frequency is know with accuracy of Δp/p $\approx 10^{-3}$ only. Therefore, for a more precise beam momentum determination, which is crucial in the present near threshold measurements, we used the center of mass momenta of the ^{3}He ions from the $dp \to {}^3$Heη reaction calculated from the analysis of ^{3}He momenta in the magnetic field of the COSY-11 dipole magnet. Resulting correction to the nominal beam momentum was -1.6$\pm$0.4 MeV and the uncertainty of the excess energy for the $dp \to dp\eta$ reaction was $\pm$0.1 MeV.

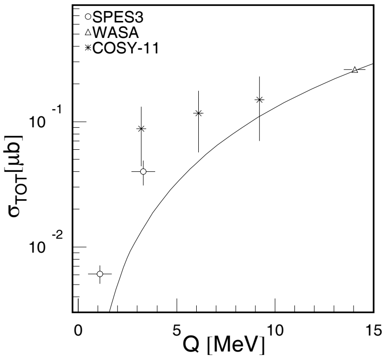

Fig. 3. Dependence of total cross section on the excess energy. The line indicates three body phase-space normalized to the PROMICE/WASA point[11]. Open circles shows data from Ref. 9, and stars denotes preliminary results determined by the COSY-11 group.

3. Preliminary Results

The measurement was done for three deuteron beam momenta above the $dp \to dp\eta$ threshold namely: 3177.4, 3189.4 and 3202.4 MeV/c and one momentum below the threshold equal to 3163.4 MeV/c. The measurement below the threshold was used for the background subtraction under the eta peak in the missing mass spectra. The determined $dp \to dp\eta$ total cross sections are shown in Fig. 3 together with the data measured at SATURNE and at WASA. The data 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. We expect that further analysis of the collected experimental data will allow to reduce substantially the relatively large uncertainties of our preliminary data points.

4. Acknowledgments

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" program (Hadron Physics and Hadron Physics-Activity -N4: EtaMesonNet contract number RII3-CT-2004-506078), of the FFE grants (41266606 and 41266654) from the Research Center Juelich, of the DAAD Exchange Programme (PPP-Polen), of the Polish State Committee for Scientific Research (grant No. PB1060/P03/2004/26).

References

1. P. Moskal *et al.*, *Prog. Part. Nucl. Phys.* **49**, 1 (2002).
2. C. Hanhart, *Phys. Rept.* **397**, 155 (2004).
3. G. Fäldt, T. Johansson, C. Wilkin, *Physica Scripta* **T99**, 146 (2002).
4. B. Mayer *et al.*, *Phys. Rev. C* **53**, 2068 (1996).
5. M. Betigeri *et al.*, *Phys. Lett. B* **472**, 267 (2000).
6. R. Bilger *et al.*, *Phys. Rev. C* **65**, 44608 (2002).
7. H.-H. Adam *et al.*, *Int. J. Mod. Phys. A* **20**, 643 (2004).
8. J. Smyrski *et al.*, *Acta Phys. Slovaca* **56**, 213 (2006).

9. F. Hibou *et al.*, *Eur. Phys. J. A* **7**, 537 (2000).
10. J. Złomańczuk *et al.*, *Physica Scripta* **T104**, 84 (2003).
11. R. Bilger *et al.*, *Phys. Rev. C* **69**, 014003 (2004).
12. P. Moskal *et al.*, *Phys. Rev. C* **69**, 025203 (2004).
13. P. Moskal, *ArXiv:hep-ph/0408162*.
14. R. Maier *et al.*, *Nucl. Instr. Meth.* **A390**, 1 (1997).
15. H. Dombrowski *et al.*, *Nucl. Instr. Meth.* **A386**, 228 (1997).
16. S. Brauksiepe *et al.*, *Nucl. Instr. Meth.* **A376**, 397 (1996).
17. J. Smyrski *et al.*, *Nucl. Instr. Meth.* **A541**, 574 (2005).