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STUDY OF THE PRODUCTION MECHANISM OF THE η MESON BY MEANS OF ANALYSING POWER MEASUREMENTS

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

[⋆] *Institute of Physics, Jagellonian University, Cracow, Poland*
[%] *IKP, Forschungszentrum Jülich, Jülich, Germany*
[#] *IKP, Westfälische Wilhelms-Universität, Münster, Germany*
[$] *Institute of Nuclear Physics, Cracow, Poland*
[±] *Institut für Strahlen- und Kernphysik, Rheinische Friedrich-Wilhelms-Universität, Germany*
[+] *Institute of Physics, University of Silesia, Katowice, Poland*
[×] *Department of Physics, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA*
[⊗] *ZEL, Forschungszentrum Jülich, Jülich, Germany*

COSY-11 Collaboration

Information about the production mechanism of the η meson in proton-proton collisions can be inferred by confronting the experimental studies on the analysing power for the $\vec{p}p \to pp\eta$ reaction with the theoretical predictions of this observable. The determined analysing powers for Q=10 MeV and Q=36 MeV are consistent with zero. Results show that the predictions of pure pseudoscalar meson exchange model fairly describe the experimental data, while the predictions of pure vector meson exchange dominance model disagree with the data at the level of 4.3 σ.

Keywords: η meson, close-to-threshold production, analysing power.

1. Introduction

After a test measurement of the analysing power for the $\vec{p}p \to pp\eta$ reaction at excess energy Q=40 MeV[1], two additional measurements at Q=10 and Q=36 MeV have been done. The experiments have been performed in the Research Center Jülich (Germany), using the polarised proton beam of the medium-energy storage ring COSY[2] and a H_2 cluster target[3]. For the particle detection the COSY-11 detector setup[4] has been used. In this experiment the missing mass technique has been applied in order to identify events in which the η mesons have been produced. The goal of this experiment was to determine the main contribution to the production mechanism of the η meson.

From the near-threshold measurements of the cross sections for the $pp \to pp\eta$ reaction[5,6,7] it was concluded that the production of this meson proceeds via a two-

* E-mail address: r.czyzykiewicz@fz-juelich.de

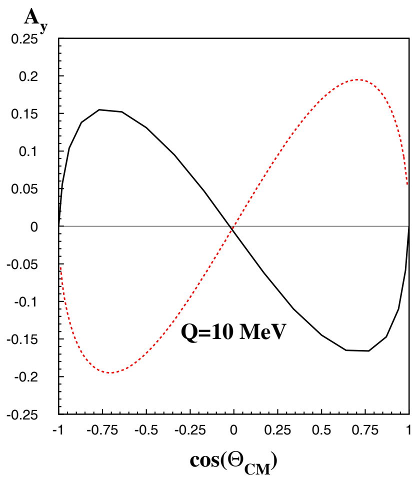

Fig. 1. Predictions of the analysing power for the $\vec{p}p \rightarrow pp\eta$ reaction at Q=10 MeV as a function of the center-of-mass (CM) polar angle of the η meson emission (Θ_{CM}). For the explanations of curves see text.

step process, namely the excitation of the $S_{11}(1535)$ resonance and its subsequent decay into a proton-η pair[8,9,10,11]. There exist, however, many possibilities leading to the excitation of the resonant state of the nucleon in this reaction. The simplest way to answer the question whether the excitation of the $S_{11}(1535)$ proceeds via the exchange of the pseudoscalar- or vector mesons (or exchange of both types of mesons) is the measurement of the analysing power for the $\vec{p}p \rightarrow pp\eta$ reaction. In Figure 1, predictions for two scenarious mentioned above are depicted for the excess energy Q=10 MeV.

The solid line in Fig. 1 is a prediction for the pseudoscalar meson exchange model[8,14], where the excitation of the $S_{11}(1535)$ resonance is dominated by the exchange of pseudoscalar mesons, whereas the dotted line represents the results of the calculations based on vector meson exchange[15]. Significant differences in the sign and the magnitude of the analysing power predicted basing upon different assumptions show the sensitivity of the analysing power to the production mechanism.

2. Preliminary Results

The experiments have been performed at the beam momenta p_{beam}=2.010 and 2.085 GeV/c, corresponding to the excess energies Q=10 and 36 MeV, respectively[12,13]. Analysing powers have been determined as functions of the center-of-mass polar angles of the η meson emission – Θ_{CM}. The preliminary results of the data analysis are depicted in Fig. 2.

In order to verify the correctness of the models the reduced χ^2 for both hypotheses have been calculated. In calculations the data point for Q=36 MeV and $\cos\Theta_{CM} = -0.75$ has been excluded due to the low statistics and problems with the background evaluation, resulting in large systematical error. The reduced value of the χ^2 for the pseudoscalar meson exchange model was found to be $\chi^2_{pseudoscalar} = 0.68$, which corresponds to the significance level $\alpha_{pseudoscalar} = 0.69$,

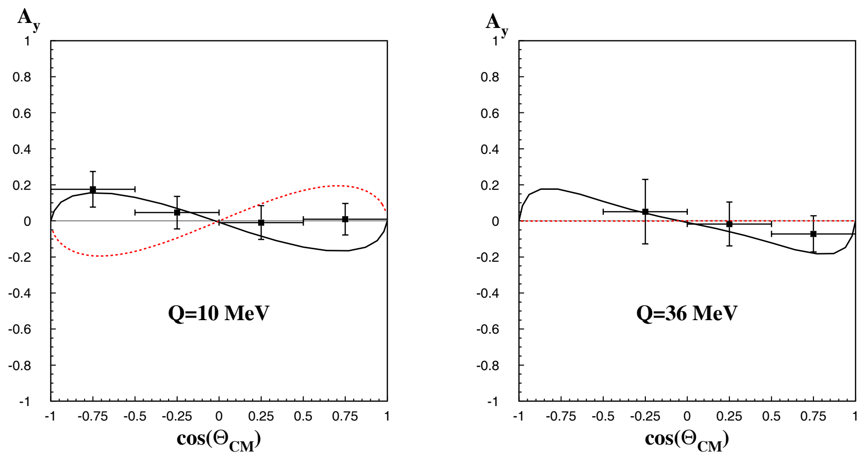

Fig. 2. *Left*: Analysing power function for the $\vec{p}p \to pp\eta$ reaction at Q=10 MeV. *Right*: The same, but for the excess energy Q=36 MeV. Vertical bars denote the statistical errors, whereas the horizontal bars are to visualize the ranges of averaging. Full lines are predictions of the pseudoscalar meson exchange model[8,14], whereas dotted lines are the predictions of vector meson exchange model[15]. For Q=36 MeV prediction of vector meson exchange model is consistent with zero. The size of the vertical axis has been chosen to cover the full range of the allowed values of A_y.

whereas for the vector meson exchange model $\chi^2_{vector} = 2.85$ resulting in the significance level $\alpha_{vector} = 0.006$.

In Ref. 15 the angular distribution of the analysing power is parametrized with the following equation:

$$A_y(\Theta_{CM}) = A_y^{max} \sin 2\Theta_{CM}, \tag{1}$$

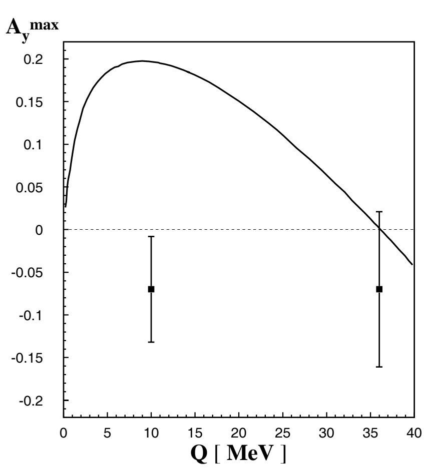

Fig. 3. The line denotes the energy dependence of A_y^{max} according to the vector meson exchange model[15]. Two points are the experimentally determined values of the A_y^{max} for Q=10 and 36 MeV.

where the amplitute A_y^{max} is a function of the excess energy Q, and its energy dependence is shown as the solid line in Fig. 3.

Assuming that the predictions of the vector meson exchange model regarding the shape of the angular dependence of the analysing power are correct, we have estimated the values of A_y^{max} comparing the experimental data with the predicted shape utilizing a χ^2 test. The values of A_y^{max} for Q=10 and 36 MeV have been determined, and are equal to -0.070±0.062 and -0.070±0.091, respectively. Results are presented in Fig. 3. The predicted A_y^{max} function, is at a distance of 4.3 σ from the data point for Q=10 MeV.

3. Conclusions

Our studies indicate that the predictions of the analysing power within the pure vector meson exchange models can be rejected with significance level of 0.006. On the other hand, predictions of the pseudoscalar meson exchange model, where π meson is the dominant meson in the internuclear exchange are in line with the experimental data with the statistical probability of 69 %. This suggests that the latter scenario is much more probable for the η meson production. However, the interference in the exchange of both types of mesons are not excluded and should be studied theoritically. It is also possible that the mesonic or nucleonic currents contribute to the η meson production more than it has been assumed in both models. Further theoretical analysis of this process is required.

The analysing powers for Q=10 MeV and Q=36 MeV are consistent with zero, within one standard deviation. This may suggest that the η meson is predominantly produced in the *s*-wave. This observation is in agreement with the results of the analysing power measurements performed by the DISTO collaboration[16] where, interestingly, in the far-from-threshold energy region the A_y were found to be consistent with zero within one standard deviation.

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References

1. P. Winter *et al.*, *Phys. Lett.* **B544**, 251 (2002); erratum-ibid. **553** 339 (2003).
2. R. Maier *et al.*, *Nucl. Instr. Meth.* **A390**, 1 (1997).
3. H. Dombrowski *et al.*, *Nucl. Instr. Meth.* **A386**, 228 (1997).

4. S. Brauksiepe *et al.*, *Nucl. Instr. Meth.* **A376**, 397 (1996);
P. Klaja *et al.*, *AIP Conf. Proc.* **796**, 160 (2005);
J. Smyrski *et al.*, *Nucl. Instr. Meth.* **A541**, 574 (2005).
5. A.M. Bergdolt *et al.*, *Phys. Rev.* **D48**, 2969 (1993);
E. Chiavassa *et al.*, *Phys. Lett.* **B322**, 270 (1994);
H. Calén *et al.*, *Phys. Lett.* **B366**, 39 (1996);
H. Calén *et al.*, *Phys. Rev. Lett.* **79**, 2642 (1997);
F. Hibou *et al.*, *Phys. Lett.* **B438**, 41 (1998);
J. Smyrski *et al.*, *Phys. Lett.* **B474**, 182 (2000).
6. M. Abdel-Bary *et al.*, *Eur. Phys. J.* **A16**, 127 (2003).
7. P. Moskal *et al.*, *Phys. Rev.* **C69**, 025203 (2004).
8. K. Nakayama *et al.*, *Phys. Rev.* **C65**, 045210 (2002).
9. C. Hanhart *Phys. Rept.* **397**, 155 (2004).
10. G. Fäldt, T. Johansson, C. Wilkin *Phys. Scripta* **T99**, 146 (2002).
11. P. Moskal *et al.*, *Prog. Part. Nucl. Phys.* **49**, 1 (2002).
12. R. Czyżykiewicz *et al.*, *Acta Phys. Slovaca* **56**, 387 (2006); *ArXiv:nucl-ex/0603018*.
13. R. Czyżykiewicz *Schriften des FZ-Jülich, Matter and Materials* **21**, 122 (2004).
14. K. Nakayama *et al.*, *Phys. Rev.* **C68**, 045201 (2003).
15. G. Fäldt, C. Wilkin *Phys. Scripta* **64**, 427 (2001).
16. F. Balestra *et al.*, *Phys. Rev.* **C69**, 064003 (2004).