NEAR THRESHOLD HEAVY MESON PRODUCTION IN PP- AND PD-COLLISIONS AT THE EXPERIMENT COSY-11

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Abstract

The near threshold production of heavy mesons in proton-proton and proton-deuteron collisions has been studied using the internal facility COSY-11 at COSY. Recent results on the exclusive total cross section for the reaction pp→ppK$^+$K$^-$ at an excess energy of Q = 17 MeV fix the scale of the strangeness dissociation into two kaons.
The production of η- and η'-mesons in proton-proton and proton-deuteron collisions has been measured at several excess energies close to threshold. Total cross sections for the proton-proton data and recent results on the proton-deuteron data will be presented and discussed.

1 Introduction

Experiments on the production of mesons in the elementary nucleon-nucleon scattering yield fundamental information on the production and the structure of mesons and baryons. They offer valuable information for several fields in physics like the physics of relativistic heavy-ion collisions or the physics of compact objects in astrophysics like neutron stars [1].Focussing on the close to threshold production, the relative momenta of the ejectiles get diminished and final state interactions of meson-meson, meson-baryon and baryon-baryon systems become predominant and can be studied in detail.
At the COSY-11 facility the production of η, η' and kaon pairs has been studied in pp scattering experiments. This installation is an internal facility at the proton cooler synchrotron COSY at Jülich [2] and has been designed for threshold meson and hyperon production studies. The detection system allows to determine the momenta and velocities and therefore the four momentum vectors of positively charged ejectiles. This yields a full event reconstruction for the reaction types pp→ pp X and pd→ ^{3}He X with $X = \{\eta, \eta', ...\}$ by detecting both outgoing protons and the ^{3}He, respectively, and identifying the X-particle using the missing mass method. Similar to this, for the K^+K^- production a

full event reconstruction is possible by detecting both the outgoing protons and the K^+-meson. Details to the installation can be found in [3].
The high mass of the produced mesons requires high momentum transfers between the interacting nucleons and allows therefore to study the short range part of the nucleon-nucleon interaction. Due to the s-quark content of the produced mesons, the reaction dynamics depends on the strangeness content of the interacting particles. Thus, these data can contribute to understand the strangeness content of the nucleons.
New data on the η- and η'-production at COSY-11 via the reaction pd$\rightarrow^3$He X scrutinize the effect of the presence of a second target nucleon. These data will help to study the role of possible two-step mechanismn and benefit the transition of results from the nuleon-nucleon to the nucleus-nucleus case.

2 Kaon-Pair Production near Threshold

Nucleon-nucleon production cross sections of kaons and kaon pairs are of high interest for the understanding of many topics like the still controversially discussed structure of the $f_0(980)$, the K^+K^- FSI or medium effects of kaon production in nuclear matter. Different to the K^+-meson, which can also be produced via hyperon resonances, up to now there exist no data for the production of K^--mesons in the nucleon-nucleon scattering near threshold. Therefore, measurements of the elementary production process $pp \rightarrow ppK^+X$ (X=K^-) were carried out COSY-11 at excess energies between Q =4.4 MeV and Q = 56.1 MeV [4, 5, 6].Monte Carlo simulations have shown that one of the measured protons may originate from the decay of heavy hyperons. Being aware of this background, the evaluation of the data allows to determine upper limits of the absolute cross sections for the K^+K^- production as well as for the hyperon production [4, 5]. However, new measurements with higher statistics show a clear signal of the K^+K^- production. Since the evaluation of the data is still going on, at this stage a preliminary estimation of the total cross section at an excess energy of Q = 17 MeV is possible and yields in cross sections slightly below 1 nb.

3 Production of η- and η'-Mesons in pp-Collisions

The η-meson production in NN interactions close to the production threshold has been studied in several theoretical works using one-boson exchange models. It is assumed to proceed dominantly through the excitation of the S_{11} nucleon resonance N*(1535) with a branching ratio N*(1535)$\rightarrow$ ηN of about 30-55%.

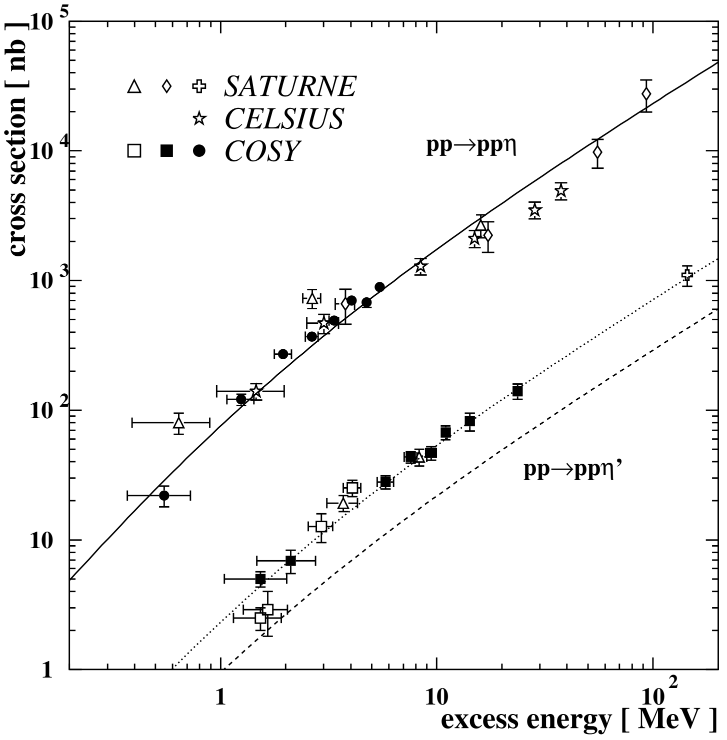

Figure 1: Total cross sections for the reactions pp→ppη and pp→ppη'. Open triangles, diamonds and crosses indicate measurements performed at SATURNE [7, 8, 9], open stars at CELSIUS [10] and filled circles, filled and open boxes at COSY [11, 12, 13]. The curves are described in the text.

However, at energies close to the η'-threshold no such resonance is known. Thus, it is not expected that the η' production via the excitation of baryonic resonances will be appreciable. To check different models, data especially close to threshold are needed. Therefore, the production of η- and η'-mesons in pp collisions has been studied at COSY-11 at excess energies of Q = 0 - 5.4 MeV (η) and Q = 1.5 - 23.6 MeV (η'), respectively.

The obtained total cross sections for the η production, shown in Figure 1, are in good agreement within the error bars with existing data. An evaluation of the center of mass angular distribution of the outgoing η-mesons results in a distribution consistent with pure s-wave production which agrees with expectations of low partial waves according to conservation laws. The drawn solid line was computed using a one-pion-exchange model including the proton-proton final state interaction [14] and adjusted to the shown η data points. In this model a π^0 is emitted by one proton and converts to an η on the second. Knowing the relevant amplitudes $|f(\pi^0 p \to p\eta)|^2$ and $|f(\pi^0 p \to p\eta')|^2$, a prediction for the corresponding excitation function for the η' production is possible. In the same figure the near threshold data on the η' production are shown as function of the excess energy. The order of magnitude of the total cross sections is reproduced within a factor of two by this prediction (dasded line). This discrepancy indicates that other effects like the exchange of heavier mesons may contribute to the production process. Scaling this prediction by a factor of ~ 2, the energy dependence of the excitacion function can be described well (dotted line). This is different to the η-meson case, where meson-nucleon final state interactions are not negligible.

4 Production of η- and η'-Mesons in pd-Collisions

Close to the η-threshold in the pd-scattering only few data are available and present a contradictory picture. Whereas available data below an excess energy of 7 MeV [15] are described well by calculations to a two-step model [16], a new data point at an excess energy of Q = 49.3 MeV [17] is in contradiction to these calculations. To clarify this situation, measurements have been performed at COSY-11 to the η-channel as well to the η'-channel for which only one data point near threshold is available [18, 19].

In Figure 2 preliminary results on the η production via the the reaction

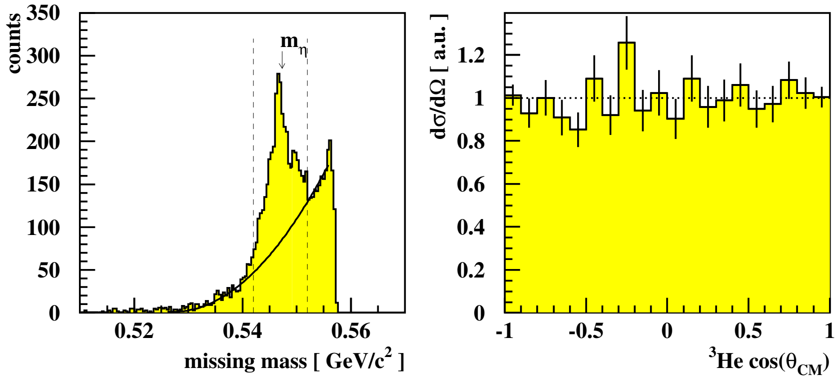

Figure 2: Missing Mass with respect to the ^{3}He system (left hand side) and differential cross section (right hand side) at an excess energy of 10 MeV above the pd$\to$^{3}Heη threshold.

pd$\to$^{3}Heη at an excess energy of Q = 10 MeV are shown [20]. The ^{3}He missing mass distribution (left hand side) shows a clear signal of the η-meson on a background caused by multi-pion production. The corresponding angular

distribution (right hand side of Figure 2) is consistent with s-wave production. This is in agreement with data at lower excess energies [15], while at Q = 49.3 MeV significant deviations from pure s-wave are appreciable [17].
For the next future it is planned to study both the η- and η'-production up to excess energies of Q = 50 MeV in pd-collisions to provide differential and absolute cross sections and to study relevant production processes.

References

[1] G.Q. Li et al., Nucl. Phys. **A625** (1997) 372.

[2] R. Maier, Nucl. Instr. & Meth. **A390** (1997) 1; R. Maier, Nucl. Phys. News, Int. **7** No. 4 (1997) 5.

[3] S. Brauksiepe et al., Nucl. Instr. & Meth. **A376** (1996) 397.

[4] M. Wolke, doctoral thesis, University Bonn (1998).

[5] T. Lister, doctoral thesis, University Münster (1998).

[6] C. Quentmeier, doctoral thesis (in preparation), University Münster (2000).

[7] F. Hibou et al., Phys. Lett. **B438** (1998) 41.

[8] E. Chiavassa et al., Phys. Lett. **B322** (1994) 270.

[9] Y. Bedfer et al., Acta Phys. Pol. **B29** (1998) 2973.

[10] H. Calen et al., Phys. Lett. **B366** (1996) 39.

[11] J. Smyrski et al., accepted for publication in Phys. Lett. **B** (2000); nucl-ex/9912011.

[12] P. Moskal et al., submitted to Phys. Lett. **B** (2000).

[13] P. Moskal et al., Phys. Rev. Lett.**80** (1998) 3202.

[14] J.-F. Germond, C. Wilkin, Nucl. Phys. **A518** (1990) 308.

[15] B. Mayer et al., Phys. Rev. **C53** (1996) 2068.

[16] K. Kilian and H. Nann, AIP Conf. No. 221 (1990) 185; G. Fäldt and C. Wilkin, Nucl. Phys. **A587** (1995) 769.

[17] M.G. Betigeri et al., nucl-ex/9912006.

[18] A. Kozela, Ph.D. thesis, Jagellonian University, Cracow (1994).

[19] R. Wurzinger et al., Phys. Let. **B374** (1996) 283.

[20] H.-H. Adam, diploma thesis (in preparation), University Münster (2000).