Study of η'-Meson Production in the Reaction pd$\rightarrow{}^3$He η' at COSY-11

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Extension of the COSY-11 proposal 62.1

1 Abstract

We propose to continue our investigations on the reaction pd$\rightarrow{}^3$He η' near threshold using the COSY-11 installation. The identification of the outgoing ^{3}He nuclei and the determination of their four momentum vectors will be provided by using drift chambers and scintillation walls. With this information it is possible to calculate the missing mass of the unobserved particle X of the reaction pd$\rightarrow{}^3$He X, which leads to a full event reconstruction in case of the two particle final state of interest. Since the installation COSY-11 takes advantage of the internal cluster target (single particle interaction, no target windows) in combination with a stochastically cooled beam, in view of its high luminosities this experimental setup is suited well for taking high precision data in the near threshold region.

2 Introduction

The near threshold production of mesons in nucleon-nucleon collisions is of fundamental interest and provides a possibility to study various theoretical models of production processes. Close to threshold only few partial waves are involved and due to the low relative momenta of the ejectiles, final state interactions can be studied in more detail.
At the cooler synchrotron COSY various near threshold measurements have been performed using the internal installation COSY-11 [1]. In case of the η-meson production in proton-proton collisions, measurements have been performed at excess energies from below threshold up to Q = 5.4 MeV [2] and the obtained cross sections are in very good agreement with existing data [3, 4, 5, 6]. In case of the η'-meson data have been taken in proton-proton collisions

at excess energies ranging from Q = 1.5 MeV up to Q = 46.6 MeV [7, 8, 9]. These data sets in the near threshold region are valuable for the development of theories on η- and η'-meson production in the elementary nucleon-nucleon scattering and the verification of their predictions, which may also be important in the context of understanding the production processes for these mesons in heavy ion collisions. Furthermore, total cross section data on the η' production are expected to probe the still controversially discussed glue content in the η'-meson [10, 11, 12].
In addition to the elementary nucleon-nucleon reactions the production of mesons on heavier targets provides the possibility to study reaction processes with more than only one involved target nucleon. A suitable reaction channel for this is pd$\rightarrow{}^3$He X with X being the produced meson(s). One aim of the physics program of the COSY-11 collaboration is to extend the previously discussed data by using deuterium as target and to study both the η and the η' production in pd collisions.
In earlier beam times the COSY-11 collaboration already took data on the reaction channel pd$\rightarrow{}^3$He η at excess energies of Q = 5 MeV, 11 MeV, 15 MeV, 20 MeV and 40 MeV. At all of these excess energies clear signals of the η production could be extracted. Currently the data are under final evaluation and total and differential cross section data will be available in the near future and are expected to illuminate the still open question of the relevant production process [13, 14] and the magnitude of the ^{3}He η final state interaction.
Furthermore, during one of these beam times pilot measurements to study the feasibility of investigations on the η'-meson production in pd collisions have been carried out successfully at excess energies of Q = 10 MeV and Q = 40 MeV. Since data in the near threshold region of this reaction are still missing except for one total cross section obtained at an excess energy of Q = 0.4 MeV [15], measurements on the η' production in pd collisions are of special interest and the continuation of the COSY-11 physics program on this topic is desirable. Therefore, to determine the energy dependence of the total cross section close to threshold accurately, and to study angular distributions, we ask for three weeks of beam time in total.

3 Experiment

3.1 Particle detection and identification

At COSY-11, measurements on the η- and η'-meson production in proton-proton scattering have been extended recently by production measurements in the proton-deuteron interaction, i.e. studies on the reaction channels pd$\rightarrow{}^3$He η (η') [16, 17]. Although the COSY-11 data base of the η production in pd collisions is by far in a better shape, in this proposal we will restrict ourselves only to the COSY-11 results from the two days measurement on the η'-production obtained at an excess energy of Q = 10 MeV in order to prove the feasibility of the planned measurements.

The COSY-11 standard procedure for particle identification is the track-reconstruction of positively charged particles through a well known magnetic field by means of a set of two drift chambers (D1, D2, see figure 1), yielding a precise momentum determination, followed by a time-of-flight measurement by a set of two scintillator hodoscopes (S1, S3). To separate detected ^{3}He nuclei from pions, protons and deuterons, two independent approaches are used at COSY-11. As demonstrated in figure 2, due to the comparatively large energy loss of ^{3}He nuclei in the scintillation detector S1, these ejectiles can clearly be separated from

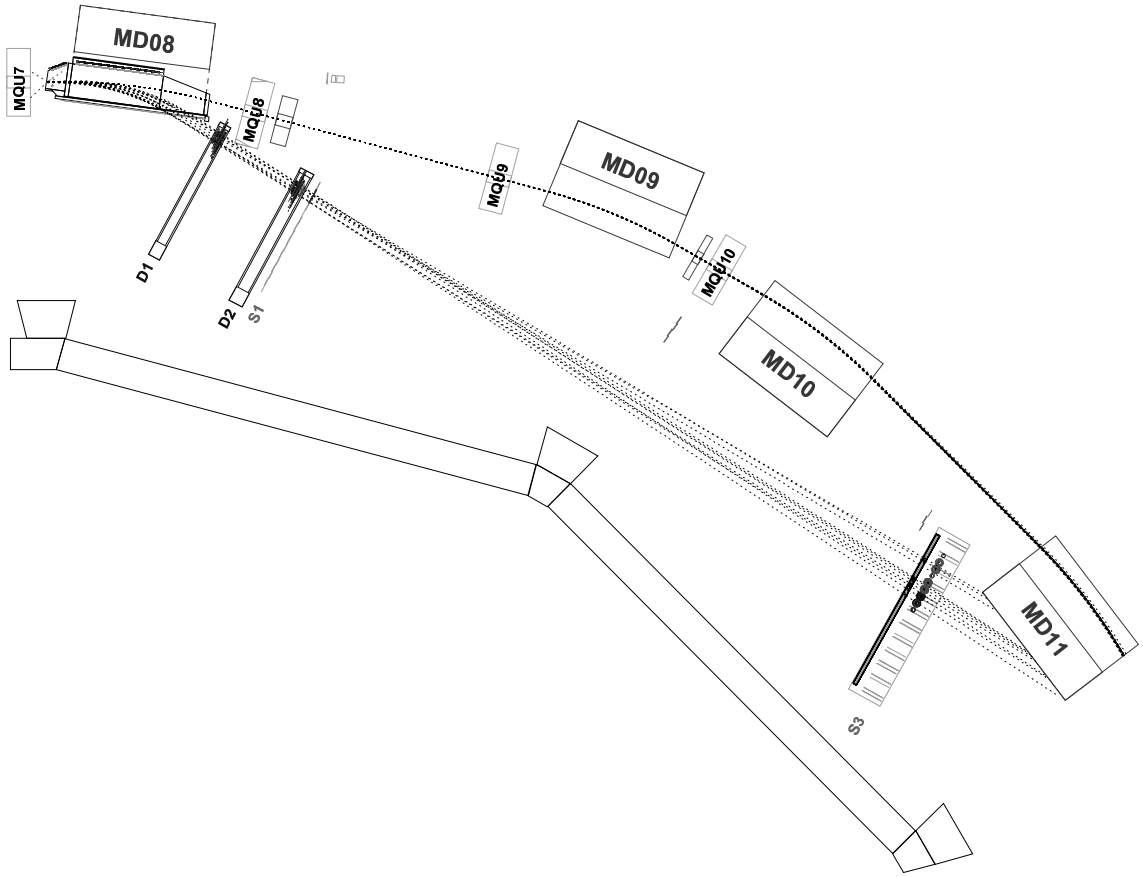

Figure 1: Sketch of the COSY-11 installation, including Monte-Carlo generated ^{3}He-tracks of the reaction pd$\rightarrow^3$He η' at an excess energy of Q = 10 MeV.

other ejectiles in a ΔE/p plot. Furthermore, the combination of the measured time of flight and the reconstructed momentum allows to reconstruct the invariant mass of the detected ejectiles which in turn enables to perform a particle identification. This situation is demonstrated in figure 3, presenting the reconstructed mass of particles, selected by the ΔE/p plot. Obviously, this method is well suited and, moreover, sufficient for a helium-identification. Therefore, the time of flight measurement is not needed, leading to an increased geometrical detection acceptance of the COSY-11 installation for the ^{3}He η' channel. In figure 4 the missing mass distribution of accepted events with one detected particle, identified as ^{3}He nucleus, is presented[1]. Close to the η' literature mass a clear signal of the pd$\rightarrow^3$Heη' production is obvious, corresponding to $\sim$ 340 detected η' mesons. Within a factor of $\sim$ 2 this number is in line with our estimated counting rate, presented in our previous proposal 62.1, where a total number of 145 events per two days has been estimated. However, in order to improve the background subtraction and to extract differential cross sections, at least 1000 events per excess energy are desired. Therefore, for our planned measurements an increase of the

[1] At this preliminary stage of data evaluation only cms ^{3}He-scattering angles in the range of $|cos\Theta^*| < 0.6$ have been considered.

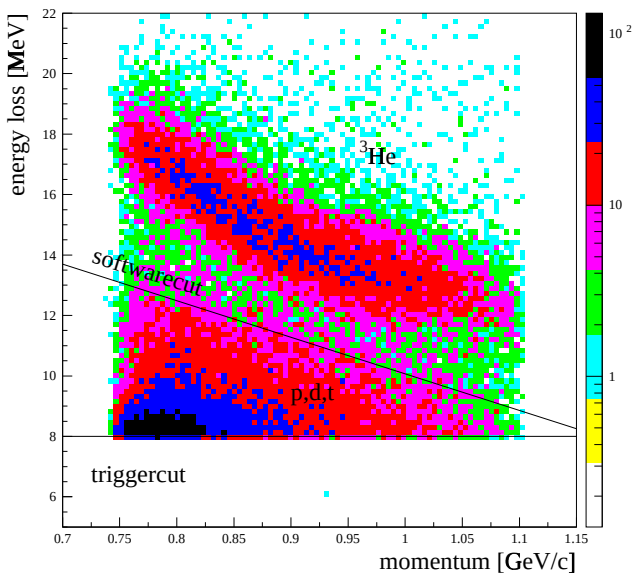

Figure 2: Energy loss of positively charged particles as function of the reconstructed momentum for the reaction pd$\rightarrow^3$He X, obtained at a beam momentum of p = 2.457 GeV/c (logarithmic z-axis). The cut at about 8 MeV is caused by the trigger used in the experiment. The ^{3}He nuclei are separated from other particles by the indicated software cut.

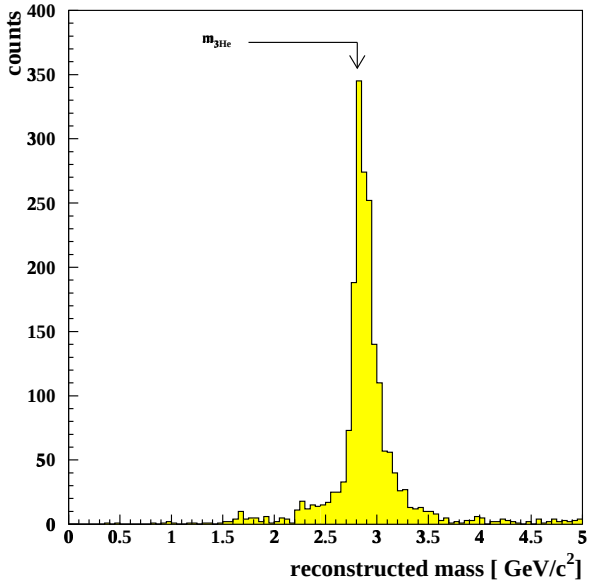

Figure 3: Reconstructed mass of detected ^{3}He nuclei using both the momentum reconstruction and the time of flight information.

statistics by a factor of three is required.
The high capability of the COSY-11 facility to measure angular distributions is shown in figure 5 for Monte-Carlo simulations, performed at an excess energy of Q = 20 MeV. Even at this energy the whole range of scattering angles is covered.

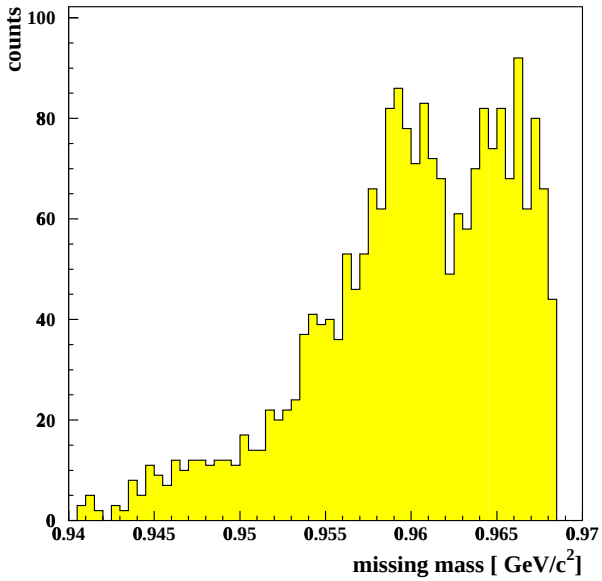

Figure 4: Missing mass spectrum of the reaction pd$\rightarrow{}^3$He X, obtained at an excess energy of Q = 10 MeV, integrated over a range of cms scattering angles of -0.6 $\leq cos\Theta^* \leq$ 0.6.

4 Beam time request

As shown, COSY-11 is ideally suited to study the reaction channel pd$\rightarrow{}^3$He η' near threshold and to extract differential and total cross section data. To complete our physics program on this reaction channel it is planned to determine both the scale and the shape of the excitation function as well as to investigate the angular distributions as function of the excess energy. For this purpose we propose to study the η' production in pd collisions at three additional excess energies, i.e. at Q= 7 MeV, 15 MeV and 20 MeV. On account of a new hardware trigger leaving out the time of flight measurement, the detection efficiency will be increased compared to former measurements. Taking into account the presented results of our measurements at Q = 10 MeV and assuming a mean luminosity of $3{\cdot}10^{30}$cm^{-2}s^{-1}, three weeks of beam time in total are required, including an appropriate amount of time (2 days) for a careful trigger adjustment and for the COSY beam optimization.
Therefore we ask for 21 days of beam time in order to complete our studies on the η'-production in the reaction pd$\rightarrow{}^3$He η'.

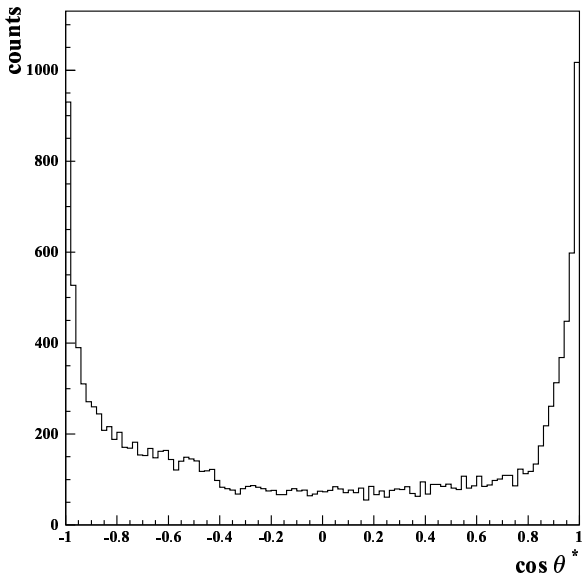

Figure 5: Angular distribution of Monte-Carlo generated ^{3}He-nuclei from the reaction pd$\rightarrow{}^3$He η' at an excess energy of 20 MeV. Only events with one reconstructed track in the drift chambers and a hit in the scintillator hodoscope S1 were selected.

excess energy	detection efficiency	time	expected events
7 MeV	31.6%	6 days	1200
15 MeV	18.2%	6 days	1000
20 MeV	15.1%	7 days	1100
adjustments and beam preparation		2 days	
total beam time		21 days	

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