STUDY OF η MESON PRODUCTION WITH A POLARIZED PROTON BEAM

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1.1 Introduction

In the low energy regime of Quantum Chromodynamics, the interaction between quarks and gluons cannot be treated perturbatively and so far the understanding of the processes governed by the strong forces is unsatisfactory. Therefore, it is essential to carry out measurements involving the production and decay of hadrons and to interpret them in the framework of effective field theories experiencing recently an enormous development in applications to the description of meson decays and production. In this contribution we concentrate on the η meson. The progress in understanding of the production processes of the η meson will strongly rely on the precise determination of spin and isospin observables. So far these observables have been determined only for few excess energies and with low statistics [1-5].

1.2 Partial waves

For an unambiguous understanding of the production process relative magnitudes from the partial waves contributions must be well established. This may be achieved by the measurement of the analysing power which would enable to perform the partial wave decomposition with an accuracy by far better than resulting from the measurements of the distributions of the spin averaged cross sections [6, 7]. Analysing power A_y may be understood as a measure of the relative deviation between the differential cross section for the experiment with and without polarized beam (σ and σ_0 respectively):

$$\sigma(\theta,\varphi) = \sigma_0(\theta,\varphi) \cdot [1 + A_y(\theta) \cdot P \cdot \cos(\varphi)] \tag{1.1}$$

where P denotes the beam polarization.

1.3 Studies of A_y with the WASA detector at COSY

Using the WASA-at-COSY detector [8] we intend to determine the energy and the angular dependence of $A_y(Q,\theta)$ and the total and differential cross sections for the $\vec{p}p \to pp\eta$ reaction in the excess energy range from the threshold up to 100 MeV. In November 2010 first measurements for Q = 15 MeV and Q = 72 MeV have been conducted [9]. From Table 1.1 we can see the beam parameters and the expected number of events for each excess energy.

Q [MeV/c]	P [MeV/c]	$\sigma_{tot}[\mu b]$	Acceptance	$N_{\eta\to\gamma\gamma}$	$N_{\eta\to 3\pi^0}$
15	2026	10^3	0.55	99770	81861
72	2188	$5 \cdot 10^3$	0.63	447739	375580

Table 1.1: Estimate of the number of produced η mesons

Protons from the $\vec{p}p \to pp\eta$ reaction are registered in the forward part of the detector and photons from the η meson decay are detected in the Electromagnetic Calorimeter of the central part. Simultaneously to the $\vec{p}p \to pp\eta$ reaction elastically scattered protons were registered. The $\vec{p}p \to pp$ reaction will be used for monitoring of the polarization degree, luminosity and the detector

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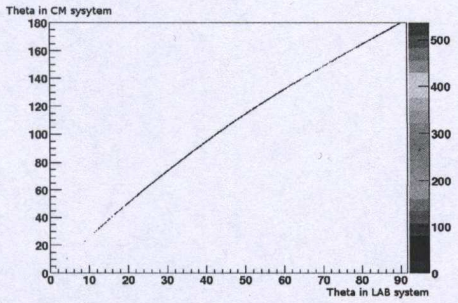
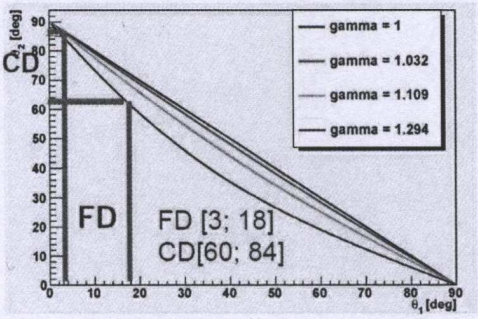
performance. In the case of the $\vec{p}p \to pp$ reaction one proton is registered in the Forward Detector and the other in the Central Detector.

Within the geometrical acceptance of the Forward Detector (from 3° to 18°), the Central Detector covers proton scattering angle from 60° to 84°. In the center of mass system that corresponds to a scattering angle in the range of 30° to 46° as seen in Fig. 1.1a.

In Fig. 1.1b the scattering angle of one proton is depicted as a function of the scattering angle of the second proton. The first proton is registered in the Central Detector, the second one in the Forward Detector. Colored lines are predictions for different beam momenta. The blue line corresponds to a beam momentum of 2 GeV/c, close to the experimental value.



(a) The scattering angle in the centre of mass system is presented as a function of the scattering angle in the laboratory frame.



(b) The distribution of the scattering angle of proton registered in the Central Detector as a function of the scattering angle of the proton registered in the Forward Detector. For more details see the text.

Figure 1.1: The protons angular distributions in the Monte Carlo simulations of the $pp \to pp$ reaction.

1.4 Extraction of A_y from the experiment

In the first step we can obtain the value of the polarization, P, from the $\vec{p}p \to pp$ reaction using the analysing power already measured by the EDDA experiment [10]. In the second step, we will calculate the geometrical averages, $N_{\pm}$, of the number of η meson produced in direction (θ, φ) during the spin down $N^{\downarrow}$ and spin up $N^{\uparrow}$ modes, defined as follows:

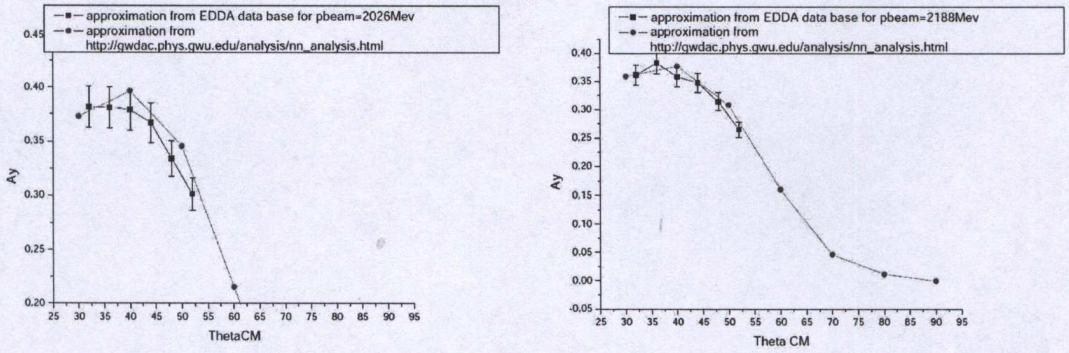
$$\begin{aligned} N_- &\equiv \sqrt{N_-^{\uparrow} N_-^{\downarrow}} = \sqrt{\frac{N_R^{\uparrow}}{\epsilon_R L^{\uparrow}} \cdot \frac{N_L^{\downarrow}}{\epsilon_L L^{\downarrow}}} \\ N_+ &\equiv \sqrt{N_+^{\uparrow} N_+^{\downarrow}} = \sqrt{\frac{N_L^{\uparrow}}{\epsilon_L L^{\uparrow}} \cdot \frac{N_R^{\downarrow}}{\epsilon_R L^{\downarrow}}} \end{aligned} \tag{1.2}$$

$N_-^{\downarrow}$ and $N_+^{\uparrow}$ can be determined according to the Madison convention[11]. Knowing the angles θ and φ of the outgoing η meson we can calculate the analysing power for the three particle final state using the following formula:

$$A_y(\theta) = \frac{1}{P cos\varphi} \cdot \frac{N_+(\theta,\varphi) - N_-(\theta,\varphi)}{N_+(\theta,\varphi) + N_-(\theta,\varphi)} \tag{1.3}$$

where the polarization P was calculated in the first step.

An A_y for the proton-proton elastic scattering at 2026 MeV and 2188 MeV beam momenta, based on the results of the EDDA experiment is shown in Fig. 1.2. We can conclude that values of A_y for Q=15 MeV and Q=72 MeV are within the range of [0.32-0.38].



$p_{beam} = 2026$ MeV $p_{beam} = 2188$ MeV

Figure 1.2: Distribution of A_y for $\vec{p}p \to pp$ reaction as a function of the protons scattering angle, θ, in the centre of mass system. Square points denotes data based on EDDA experiment [12] and superimposed line indicates results of Ref. [13].

Acknowledgements

This publication has been supported by COSY-FFE and by the European Commission under the 7th Framework Programme through the Research Infrastructures action of the Capacities Programme, Call: FP7-INFRASTRUCTURES-2008-1, Grant Agreement N. 227431 and by the Polish Ministry of Science and Higher Education under grants No. 2861/B/H03/2010/38 and 0320/B/H03/2011/40.

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