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First close-to-threshold measurement of the analyzing power A_y in the reaction $\vec{p}p \to pp\eta$

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Abstract. At the internal facility COSY-11 a first measurement of the reaction $\vec{p}p \to pp\eta$ near the production threshold has been performed. Results for the analysing power will be presented and a comparison with one meson exchange models will be discussed.

PACS. 12.40.Vv Vector-meson dominance – 13.60.Le Meson production – 13.88.+e Polarization in interactions and scattering – 24.70.+s Polarization phenomena in reactions – 24.80.+y Nuclear tests of fundamental interactions and symmetries – 25.10.+s Nuclear reactions involving few-nucleon systems

1 Introduction

Triggered by an extensive database on η meson production in *NN* collisions through measurements of total [1–6] as well as differential cross sections [7–11] lots of theoretical investigations have been performed in this field of physics over the last years. Several one meson exchange models – differing mainly in the assumptions for the production mechanism – reproduce the existing data quite well so that additional measurements are needed. Polarisation observables – analysing powers or spin correlation coefficients – present a powerful tool because they are sensitive to the influence of higher partial waves.

2 Experiment

The measurement was performed at the internal facility COSY-11 [12,13] at the COler SYnchrotron COSY [14] in Jülich with a beam momentum of $p_{beam} = 2.096\,\mathrm{GeV/c}$ corresponding to an excess energy of $Q = 40\,\mathrm{MeV}$. The reaction takes place in a cluster target [15] mounted in front of a COSY dipole magnet. A set of drift chambers and a time-of-flight measurement with scintillation detectors allows for a four momentum determination of positively charged ejectiles. An identification of the unregistered meson succeeds with the missing mass method (see Figure 1).

Besides a clear signal from the η meson there is a broad background due to multi pion reactions. The rising shape of this background results from the acceptance behaviour of the detection system. A subtraction of the background with a polynomial fit allows the determination of the number of η-events. An efficiency correction for the polar and azimuthal angle of the relative proton-proton momentum in the pp-rest system was ap-

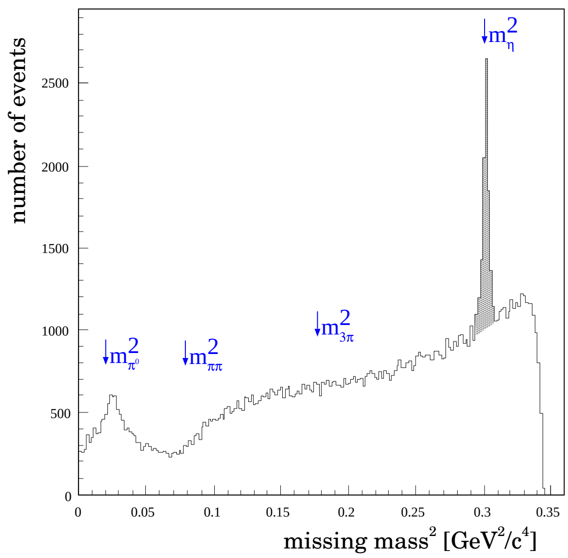

Fig. 1. Missing mass spectrum of events with two identified protons in the exit channel.

Table 1. Averaged beam polarisation obtained with the simultaneous measurement at the EDDA experiment

	time block 1	time block 2
$P_\uparrow$	0.381 ± 0.007	0.497 ± 0.006
$P_\downarrow$	-0.498 ± 0.007	-0.572 ± 0.007

plied. This is necessary for an extraction of interference terms from contributing partial waves. The detailed analysing procedure is described in [16,17].

3 Results

For later purposes, Figure 2 depicts the definition of the used polar- (θ) and azimuthal angle (φ). The indices p and q refer to the pp rest-system and the η meson in the CMS, respectively. The angle θ_p is chosen such, that $0 \leq \theta_p \leq \pi/2$. This choice guarantees that all observables are invariant under the transformation $\vec{p} \to -\vec{p}$ as required by the identity of the two protons in the final state.

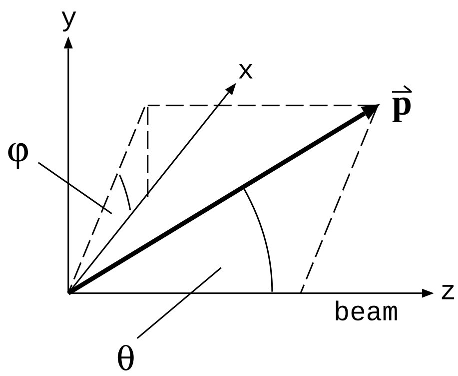

Fig. 2. Definition of the angles. θ is defined as the angle between momentum vector and the z-axis, φ between the x-axis and the projection of $\vec{p}$ onto the x-y-plane.

The determination of the analysing power needs the knowledge of the averaged beam polarisation $P_{\uparrow,\downarrow}$ for the cycles with spin up and down, respectively, the relative time-integrated luminosity $\mathcal{L}_{rel} := \int \mathcal{L}_\downarrow dt_\downarrow / \int \mathcal{L}_\uparrow dt_\uparrow$ and the number of events $N_{\uparrow,\downarrow}$.

Via a simultaneous measurement of the $\vec{p}$p-elastic scattering at the internal experiment EDDA [18,19] the beam polarisation was determined for two time blocks (see table 1). The slight increase between the two blocks was caused by improved tuning of the beam with respect to polarisation.

The relative luminosity was extracted from the comparison of the measured angular distribution of the elastically scattered protons with the distribution known from literature [18,19].

In order to account for the detection efficiency the data has been corrected on an event-by-event basis by the weighting factors determined via Monte-Carlo simulations [16,17]. Using a GEANT-3 code, 10^7 events were generated and for each event a detection system response was calculated. The simulated data

Table 2. Time-integrated relative luminosity $\mathcal{L}_{rel}$

	time block 1	time block 2
$\mathcal{L}_{rel}$	$1.004 \pm 0.004\,^{+0.002}_{-0.002}$	$0.949 \pm 0.004\,^{+0.001}_{-0.001}$

sample was analysed with the same programme which is used for the analysis of the experimental data.

The determined averaged values $\bar{A}_y(\cos\theta_q^*)$ of the analysing power for the $\vec{p}p \to pp\eta$ reaction are presented in table 3 as a function of the center of mass polar angle $\cos\theta_q^*$ of the η meson. Explicitely, $\bar{A}_y(\cos\theta_q^*)$ is defined via

$$\bar{A}_y(\cos\theta_q^*) := \quad (1)$$

$$\iiint \frac{d^2\sigma}{d\Omega_p d\Omega_q}(\xi)\, A_y(\xi)\, d\cos\theta_p d\varphi_p d\varphi_q^* \Big/ \frac{d\sigma}{d\cos\theta_q^*}\,, \quad (2)$$

where ξ denotes the set of the five variables which kinematically completely describe the exit channel, namely (θ_p, φ_p, θ_q^*, φ_q^*, E_{pp}). The kinetic energy E_{pp} of the two final protons in their CM system is given by $E_{pp} = \sqrt{s_{12}} - 2m_p$ with $\sqrt{s_{12}} = 2\sqrt{\vec{p}^2 + m_p^2}$ as the energy in the pp subsystem. θ_q^* and φ_q^* denote the angles of the η meson in the CMS.

Table 3. Analysing power as a function of the emission angle θ_q^* of the η meson in the CMS.

$\cos\theta_q^*$	$\bar{A}_y(\cos\theta_q^*)$
-0.75 ± 0.25	0.19 ± 0.21
-0.25 ± 0.25	-0.02 ± 0.09
0.25 ± 0.25	0.05 ± 0.06
0.75 ± 0.25	-0.05 ± 0.06

For the derivation of these values for the analysing power $\bar{A}_y(\cos\theta_q^*)$, we used an ansatz for the spin-dependent cross section as already applied in case of $\vec{p}\vec{p} \to pp\pi^0$ reaction [20]. With the inclusion of the efficiency correction, an integration gives (details can be reviewed in [16]):

$$\iint \frac{d^2\sigma}{d\Omega_p d\Omega_q}(\xi)\, A_y(\xi)\, d\cos\theta_p\, d\varphi_p =$$

$$2\pi \left(G_1^{y0} \sin\theta_q^* + (H_1^{y0} + I^{y0}) \sin 2\theta_q^* \right) \cos\varphi_q^*, \quad (3)$$

where G_1^{y0}, H_1^{y0} and I^{y0} described in [20] correspond to the explicit interference terms (PsPp), $(\mathrm{Pp})^2$ and (SsSd) of the partial wave amplitudes. Here, the relative angular momentum of the two outgoing protons in their rest system is denoted by capital letters $l_p = S, P, D \ldots$, the one of the η meson in the CMS by small letters $l_q = s, p, d \ldots$.

With the equations (2) and (3), it can be shown that an extraction of the interference terms G_1^{y0} and $H_1^{y0} + I^{y0}$ is possible from the experimental data via

$$G_1^{y0} = \frac{1}{\pi^2} \sum_{\cos\theta_q^*} \frac{d\sigma}{d\cos\theta_q^*} \bar{A}_y \cdot \Delta\cos\theta_q^*$$

$$H_1^{y0} + I^{y0} = \frac{2}{\pi^2} \sum_{\cos\theta_q^*} \frac{d\sigma}{d\cos\theta_q^*} \bar{A}_y \cos\theta_q^* \cdot \Delta\cos\theta_q^* .$$

and results in

$$G_1^{y0} = (0.003 \pm 0.004)\,\mu\text{b}$$

and

$$H_1^{y0} + I^{y0} = (-0.005 \pm 0.005)\,\mu\text{b}.$$

4 Comparison with theory

Figure 3 shows a comparison of the data (triangles) with two model predictions taken from [21] (dotted line) and [22] (solid and dashed lines) for $Q = 10\,\text{MeV}$ and 37 MeV.

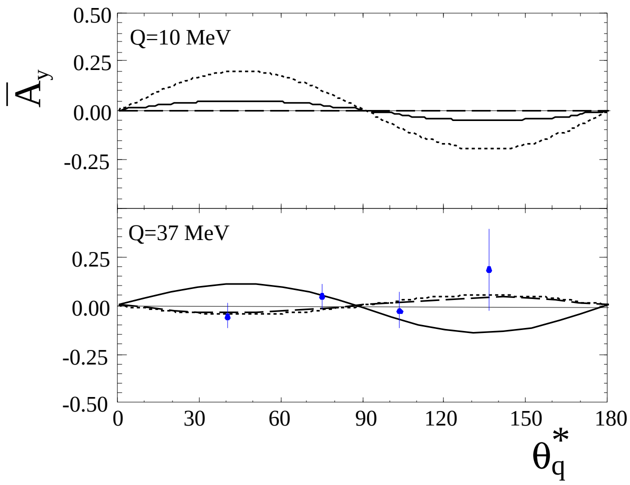

Fig. 3. Analysing power for the reaction $\vec{p}p \to pp\eta$ in dependence on θ_q^* for the two excess energies $Q = 10\,\text{MeV}$ and 37 MeV.

While Fäldt and Wilkin [21] conclude a dominant ρ meson exchange for the underlying production mechanism, the authors of reference [22] find a dominance of π and η-exchange (solid line). The dashed curve represents a reduction of their full model to a vector dominance model with an exclusion of π and η-exchange. It seems that the data favours slightly the vector dominance exchange models.

The observable structure of the experimental values show a slight deviation from the $\sin\theta_q^* \cos\theta_q^*$-dependence of both models. This deviation indicates a non-vanishing value of G_1^{y0}. As this corresponds to the (PpPs)-term, an influence of the P-wave must be suspected but right now the experimental result for G_1^{y0} is compatible with zero. A non-zero G_1^{y0} would imply that H_1^{y0} – describing the $(\text{Pp})^2$ interference – should have a non negligible contribution, too. For further detailed studies the data are not yet precise enough to disentangle the sum of H_1^{y0} and I^{y0}.

Therefore, new data at $Q = 37\,\text{MeV}$ has been taken in September 2002 in order to reduce the error bars by more than a factor of 2. The data analysis is currently in progress but it is already obvious that the much higher statistics and polarisation of $P \approx 80\%$ will enable to achieve a significant increase in precision.

Furthermore, additional measurements are scheduled in the first half of 2003 at $Q = 2,\ 10$ and $25\,\text{MeV}$ for tests on the predictions of the different models for the energy dependence of $A_y(\theta_q^*)$.

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