PROCEEDINGS OF SCIENCE

Determination of the analysing power for the $\vec{p}p \to pp\eta$ reaction using WASA-at-COSY detector system

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We report on the measurement of the analyzing power for the $\vec{p}p \to pp\eta$ reaction with beam momenta of 2026 MeV/c and 2188 MeV/c performed with the WASA-at-COSY detector at the Cooler Synchrotron COSY. The η meson from the $\vec{p}p \to pp\eta$ reaction was identified by the techniques of missing mass and invariant mass. The angular distribution of the determined analyzing power strongly disagrees with theoretical predictions. A comparison of the obtained A_y angular distribution with a series of associated Legendre polynomials revealed negligible contribution of the *Sd* partial wave at Q = 15 MeV. However, at Q = 72 MeV, a significant interference of the *Ps* and *Pp* partial waves was observed.

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1. Introduction

The production mechanism of the η meson and meson-nucleon final state interaction for the $\vec{p}p \to pp\eta$ reaction can be studied via measurements of the cross sections and analyzing power, $A_y(\theta)$. Up to now total and differential cross sections have been determined relatively precisely [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13], however so far A_y for the $\vec{p}p \to pp\eta$ reaction has been determined with rather large uncertainties [14, 15, 16, 17].

In November 2010 the high statistics sample of $\vec{p}p \to pp\eta$ reaction has been collected using the azimuthally symmetric WASA-at-COSY detector [18]. Measurements were taken with two beam momenta of 2026 MeV/c and 2188 MeV/c, corresponding to 15 MeV and 72 MeV excess energies, respectively.

Based on elastic scattering of protons, the vertex position of the real experiment were measured with two independent methods [23]. The spin flipping technique of the beam has been used to control the effect caused by potential asymmetries in the detector. Monitoring of the beam polarization was based on the $\vec{p}p \to pp$ reaction. The result shown stable polarization during whole experiment [27, 28].

2. Analyzing power for the η meson

The determination of the analyzing power for the η meson was carried out separately for spin up and spin down modes, and for each spin orientation the analyzing power was determined identifying the η meson via two decay channels: $\eta \to \gamma\gamma$ and $\eta \to 3\pi^0$.

After the identification of the final state particles the number of events corresponding to the $\vec{p}p \to pp\eta$ reaction, have been determined for each angular bin N(θ_η,φ_η) separately. θ_η and φ_η denote respectively the polar and the azimuthal angle of the eta meson emission in the center of mass system. An example of the missing mass distribution for a chosen spin mode of the beam momentum 2188 MeV/c is shown in Fig. 1.

The collected amount of the η events, about 400 000 events, significantly improves the statistical uncertainty of the analyzing power for the η meson compared to the previous COSY-11 experiments with about 2000 events only [14]. The systematic uncertainty was improved due to the axial symmetry of the WASA-at-COSY detector and its close to 4π acceptance which is by two orders of magnitude larger than the acceptance of the COSY-11 detector.

Assuming that p and d waves can occur for the η meson production, its analyzing power is given by:

$$A_y = \frac{\Im(A_{Ps}A^*_{Pp}) sin\theta_\eta + \Im(A_{Ss}A^*_{Sd}) 3cos\theta_\eta \sin\theta_\eta}{\frac{d\sigma}{d\Omega}}, \tag{2.1}$$

where $\Im(A_{Ps}A^*_{Pp})$ is the imaginary part of the interference term between the Ps and Pp waves, and $\Im(A_{Ss}A^*_{Sd})$ is the interference term between the Ss and Sd waves [32]. Figure 3 shows result obtained in this experiment with superimposed lines corresponding to the fit of the formula:

$$A_y \frac{d\sigma}{d\Omega} = C_1 \cdot sin\theta_\eta + C_2 \cdot cos\theta_\eta sin\theta_\eta \tag{2.2}$$

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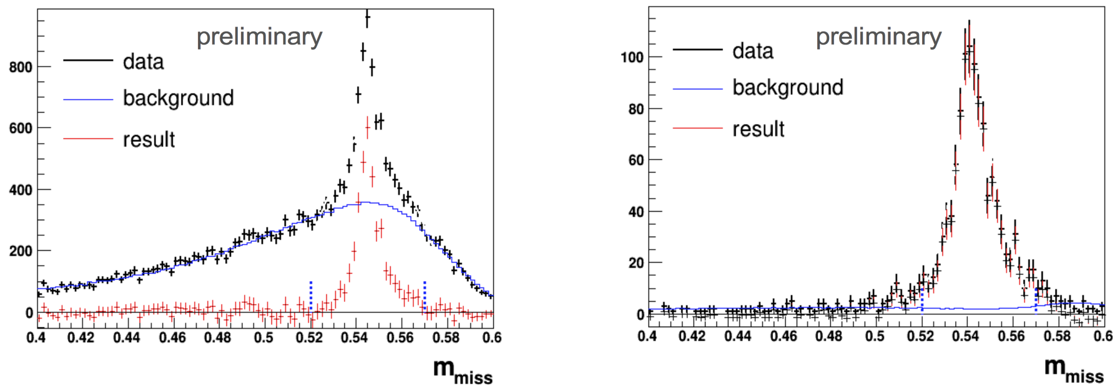

Figure 1: Missing mass distribution for the chosen range $70^\circ < \theta_\eta < 90^\circ$, $-180^\circ < \varphi_\eta < -170^\circ$ and spin "up" mode. Left: $\eta \to \gamma\gamma$. Right: $\eta \to 3\pi^0 \to 6\gamma$. Beam momentum: $p_{beam} = 2188$ MeV/c. Black crosses denote experimental data. Continuous blue lines show the sum of the simulated background for the $\pi^0, 2\pi^0, 3\pi^0$ and $4\pi^0$ production. Red points show the result of difference between the experimental data and simulated background. Dashed blue lines show the region of the extraction of the number of produced η meson.

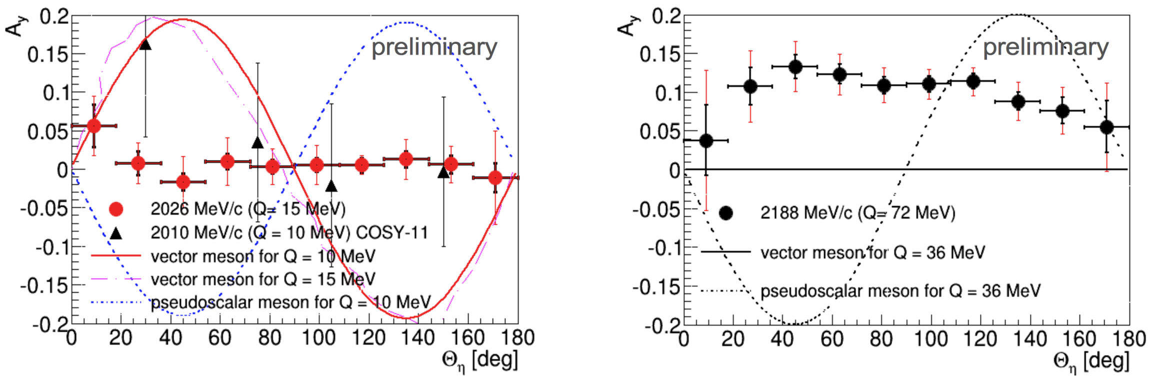

Figure 2: Analyzing power of the η meson as a function of θ_η. Superimposed lines indicate theoretical predictions (see legend) for Q = 15 MeV (left panel) and Q = 72 MeV (right panel).The dashed line shows the prediction of the analyzing power as a function of the η emission angle in the cener-of-mass for vector meson dominance model [29]. The solid line describes vector meson model [31] and the dotted line describe the pseudoscalar model [30]. Please note that the data at Q = 72 MeV are compared with theoretical predictions for Q = 36 MeV, which is the largest Q for which such predictions are available.

where C_1 and C_2 are treated as free parameters of the fit. For Q = 72 MeV the angular dependence of $d\sigma/d\Omega$ was determined by the parametrization of the data from reference [21], and for Q = 15 MeV it was assumed to be constant as determined in the experiments of COSY 11 [12] and COSY-TOF collaborations [22]. One can see in Fig. 3 that the associated Legendre polynomials of order $m = 1$ fully describe the existing data.

Thus, the analyzing power is zero for the beam momentum 2026 MeV/c, and there is no interference between A_{Ss} and A_{Sd} as well as between A_{Pp} and A_{Ps} amplitudes of the partial waves.

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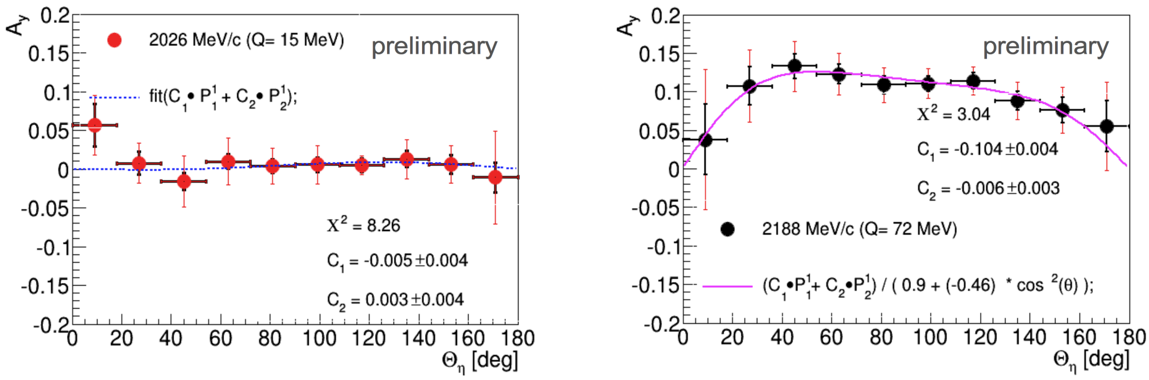

Figure 3: Analyzing power of the η meson as a function of θ_η. The fit of A_y with the sum of the two associated Legendre polynomials P_1^1 and P_2^1 is shown for the Q = 15 MeV (left) and for Q = 72 MeV (right).

3. Results

The comparison of the angular dependence of the analyzing power for the $\vec{p}p \to pp\eta$ reactions with the associated Legendre polynomials revealed that at Q=15 MeV there is no $Ss - Sd$ and no $Pp - Ps$ interference and that for the higher beam momentum 2188 MeV/c, the Sd partial wave contribution is small (consistent with zero within two standard deviations). On the other hand, the contribution of $Ps - Pp$ interference is large which means that both of these partial waves contribute at Q = 72 MeV (see Fig. 3).

The obtained angular dependence of the analyzing power agrees with the previous experiments, however it disagrees with the theoretical predictions based on the pseudoscalar or vector meson dominance models [25, 26].

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