Study of the $\eta$ meson production with the polarized proton beam

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for the WASA-at-COSY collaboration

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Motivation

η meson production mechanism

Partial waves

Analysing power

WASA-at-COSY

$A_y$ measurements

Analysis

Summary
Motivation

- the existence of the $\eta$-mesic nuclei depends on the nucleon-$\eta$ interaction
- studies of this interaction via the $pp \rightarrow pp \eta$ reaction show enhancements seen in the $pp$ and $p\eta$ invariant masses
- are these enhancements due to the nucleon-$\eta$ interaction or higher partial waves?

For the studies, a precise knowledge about the contribution from different partial waves is required.
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$pp \rightarrow pp \eta$
Partial waves
$A_\eta$
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$\eta$ meson production in $pp$ collisions

$pp \rightarrow pp \eta$

$pp \rightarrow pp \eta'$

CELSIUS

COSY

SATURNE

⇒ $\eta$ meson production in resonant current process
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$\eta$ meson production in $pp$ collisions

$\Rightarrow \eta$ meson production via exchange of isovector mesons
Partial waves

Few remarks and example based on
C.Wilkin, private communication
hepph/0311341: C.Hanhart

- in $pp \rightarrow pp\eta$ reaction, $\eta$ is produced mainly in the $s$-wave
- higher partial waves contributions from interference terms
- some interferences do not vanish only for the spin observables e.g. $A_y$
- generally:
  - $A_y \sim \text{Im}A_1A_2^*$
  - differential cross sections, correlation coefficient $\sim \text{Re}A_1A_2^*$
Partial waves

Example

- the lowest partial wave decomposition (S,P and s,p waves)
- few possibilities: Ss, Ps, Sp, Pp, Sd, ...
- two groups:
  - odd angular momentum (Pp, Ps,...)
  - even angular momentum (Ss, Sd,...)
- analysing power:
  - $A_y \sim \text{Im}\{A_{Ss}A_{Sd}^*\} \sin \theta_\eta \cos \theta_\eta$
  - $A_y \sim \text{Im}\{A_{Ps}A_{Pp}^*\} \sin \theta_\eta$

Our aim is to measure angular dependence of the analysing power.
Madison convention

\[ A_y(\theta) = \frac{1}{P \cos \phi} \frac{N_+(\theta, \phi) - N_-(\theta, \phi)}{N_+(\theta, \phi) + N_-(\theta, \phi)} \]

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$A_y$ with WASA-at-COSY

\[
A_y(\theta) = \frac{1}{P \cos \phi} \frac{N_+(\theta, \phi) - N_-(\theta, \phi)}{N_+(\theta, \phi) + N_-(\theta, \phi)}
\]

$A_y(\theta) = \frac{1}{P \cos \phi} \frac{N_+(\theta, \phi) - N_-(\theta, \phi)}{N_+(\theta, \phi) + N_-(\theta, \phi)}$

\[
N_- = \sqrt{\frac{N_R^\uparrow}{\epsilon_R L^\uparrow} \frac{N_L^\downarrow}{\epsilon_L L^\downarrow}}
\]

\[
N_+ = \sqrt{\frac{N_L^\uparrow}{\epsilon_L L^\uparrow} \frac{N_R^\downarrow}{\epsilon_R L^\downarrow}}
\]
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$A_y$ measurements - DISTO

$A_y$ measurements - COSY-11

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$A_y(\theta_\eta) = A_y^{max}(Q)\sin(2\theta_\eta)$

G. Fäldt, C. Wilkin:

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$A_y$ on WASA-at-COSY

\[ \cos(\Theta_{CM}) \]

50 cm
One week of beam time for the measurement was scheduled for November 2010 year. Whereas the previous studies are based on few thousands of events, at WASA about $10^6$ \( pp \rightarrow pp\eta \) events has been collected.
Determination of the beam polarization

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Determination of the beam polarization

$p p \rightarrow p p \eta$

$30 < \theta < 34$ for run number 22207 (down)

$34 < \theta < 38$ for run number 22207 (down)

$30 < \theta < 34$ for run number 22207 (up)

$34 < \theta < 38$ for run number 22207 (up)
Study of the influence of the position of the interaction point and tilt of the beam on the polarization:

- Determination of the beam polarization
- Study of the influence of the position of the interaction point and tilt of the beam on the polarization:

**Motivations**

- $pp \rightarrow pp \, \eta$

**Partial waves**

- $A_{\eta}$

**WASA-at-COSY**

**Measurements**

**Analysis**

**Summary**

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Determination of the vertex position

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- near the threshold only S-wave, pp pairs production \((^3P_0 \rightarrow ^1S_0 s, \text{transition})\),
- at higher energies \(\eta\) angular dependence is expected to come from the interference of the s- and d-wave amplitudes,
- s-d interference contributes significantly to the \(\eta\) analysing power,
- with WASA-at-COSY, \(A_y\) can be measured one order of magnitude more accurate than by experiments made so far,
- the statistics will allow us to obtain error of polarization lower than 1%. Therefore, we need to control the systematic uncertainty at least at the same level,
Summary and Outlook

- the systematical errors may be due to the wrong assumption of the vertex position (the systematic uncertainty of polarization), the systematic uncertainty of luminosity, production rates..., 
- in order to have systematic uncertainty of the polarization smaller than 1%, we need to control the position of the interaction point with the precision higher than 0.3 cm, 
- due to the large sensitivity of the result to the scattering angle it is better to calculate polarization taking into account the scattering angle not bigger than 38°.