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

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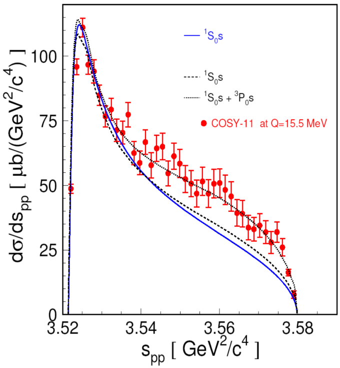
# Motivation

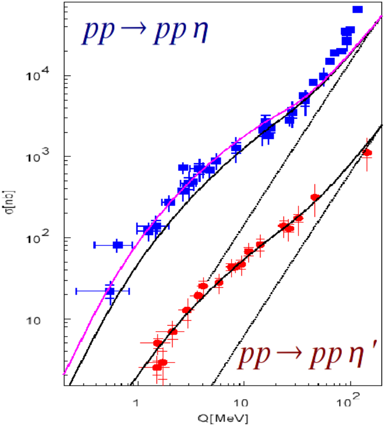
- the existence of the $\eta$-mesic nuclei depends on the nucleon-$\eta$ interaction
- studies of this interaction via the $pp \to pp\eta$ reaction show enhancements seen in the $pp$ and $p\eta$ invariant masses
- are this enhancements due to the nucleon-$\eta$ interaction or higher partial waves?

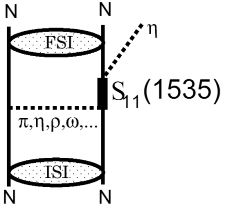



For the studies, a precise knowledge about the contribution from different partial waves is required.

# $\eta$ meson production in pp collisions






CELSIUS

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WASA/CELSIUS: H. Calen et al., Phys. Rev. Lett. 79 (1997) 2642.

COSY

COSY11:A. Khoukaz et al., Eur. Phys. J. A 20 (2004) 345.

COSY11:P. M. et al., Phys. Rev. C 69 (2004) 025203.

COSY11:P. M. et al., Phys. Lett. B 482 (2000) 356.

COSY11:P. M. et al., Phys. Lett. B 474 (2000) 416.

COSY11:J. Smyrski et al., Phys. Lett. B 474 (2000) 182.

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SATURNE

DISTO/SATURNE: F. Balestra et al.., Phys. Lett. B 491 (2000) 29.

SPES/SATURNE: F. Hibou et al.., Phys Lett. B 438 (1998) 41.

PINOT/SATURNE: E. Chiavassa et al.., Phys. Lett. B 322 (1994) 270.

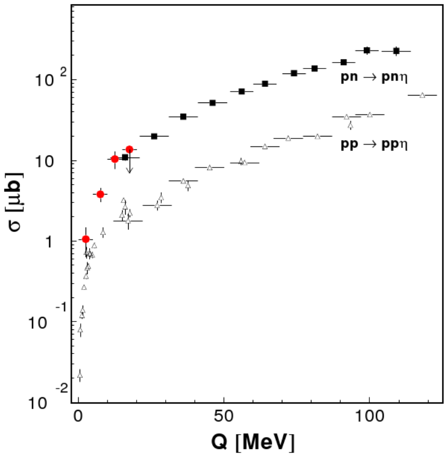
SPES/SATURNE: A. M. Bergdold et al.., Phys. Rev. D 48 (1993) R2969.

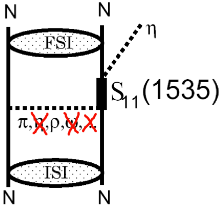
SPES/SATURNE: R. Wurzinger et al.., Phys. Lett. B 374 (1996) 283.

$\Rightarrow$ $\eta$ meson production in resonant current process

# $\eta$ 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
Phys. Rev. C 69, 035206 (2004): A.Deloff

- in $pp \to pp\eta$ 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:
  - $A_y \sim \text{Im} A_1 A_2^*$
  - differential cross sections, correlation coefficient $\sim \text{Re} A_1 A_2^*$

# 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:
  - $A_y \sim \mathrm{Im}\{A_{Ss}A^{*}_{Sd}\}\sin\theta_\eta\cos\theta_\eta$
  - $A_y \sim \mathrm{Im}\{A_{Ps}A^{*}_{Pp}\}\sin\theta_\eta$

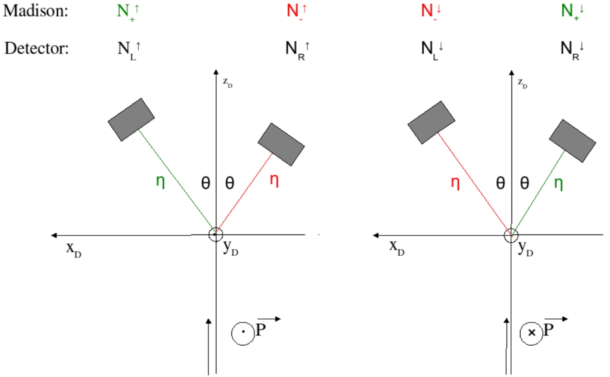
Our aim is to measure angular dependence of the analysing power

# Madison convention





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

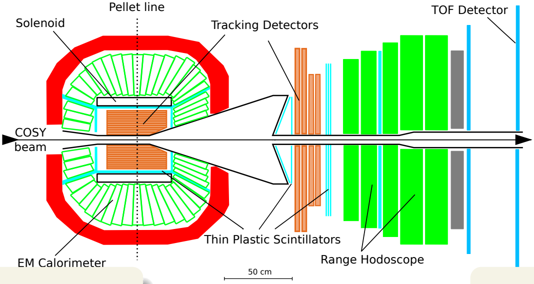


# $A_y$ with WASA-at-COSY





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

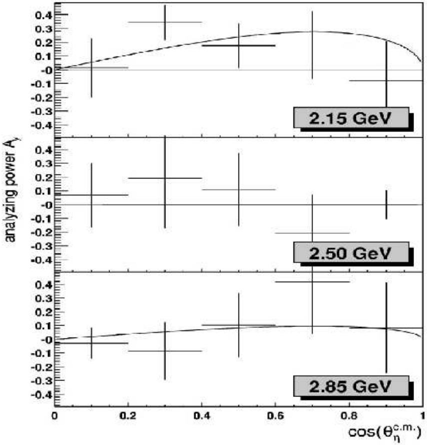



$$N_- = \sqrt{\frac{N_R^{\uparrow}}{\epsilon_R L^{\uparrow}}\frac{N_L^{\downarrow}}{\epsilon_L L^{\downarrow}}}$$

$$N_+ = \sqrt{\frac{N_L^{\uparrow}}{\epsilon_L L^{\uparrow}}\frac{N_R^{\downarrow}}{\epsilon_R L^{\downarrow}}}$$

# $A_y$ measurements - DISTO



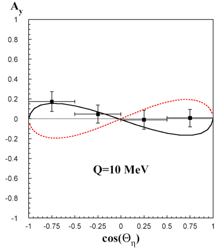


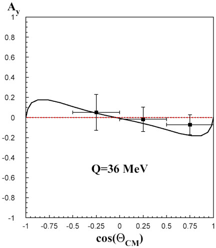

F.Balestra et al. Phys. Rev. **C69** (2004) 064003

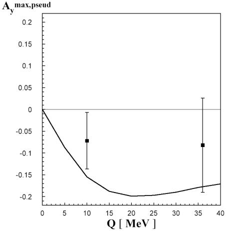
# $A_y$ measurements - COSY-11





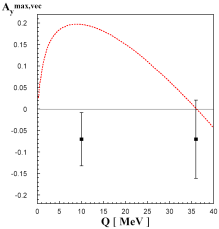



G.Fäldt, C.Wilkin:

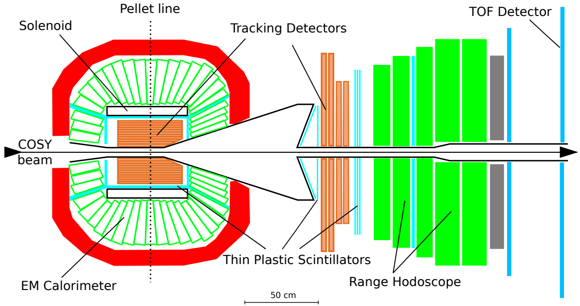
$$A_y(\theta_\eta)=A_y^{max}(Q)\sin(2\theta_\eta)$$

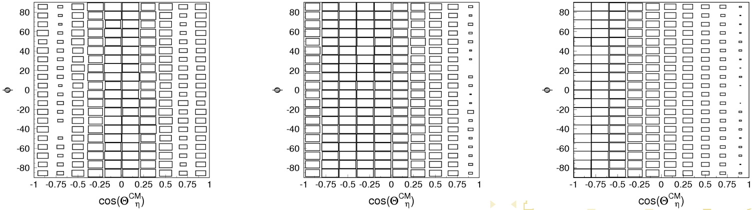



R.Czyżykiewicz et al., Phys.Rev.Lett. **98**, 122003 (2007)

# $A_y$ on WASA-at-COSY

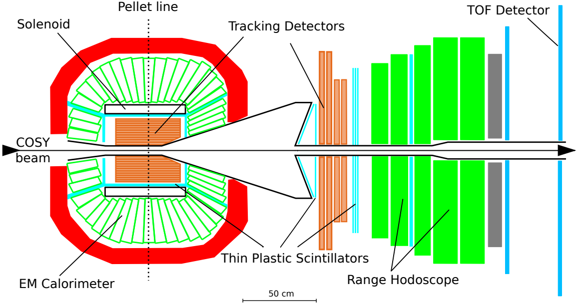




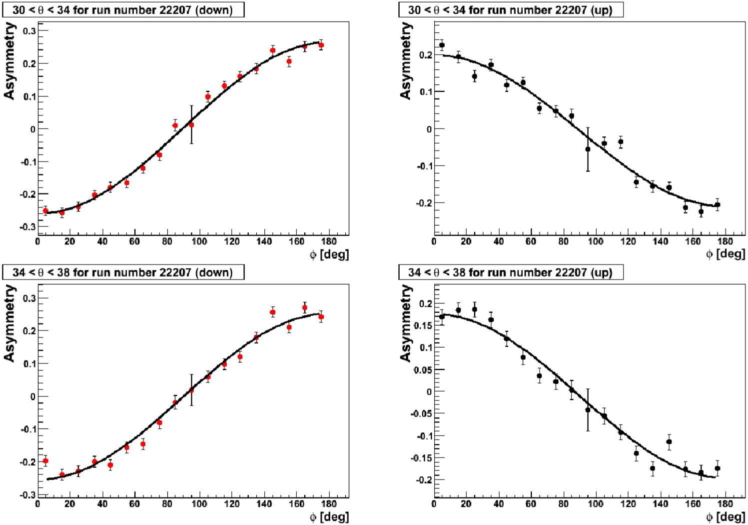
# $A_y$ on WASA-at-COSY





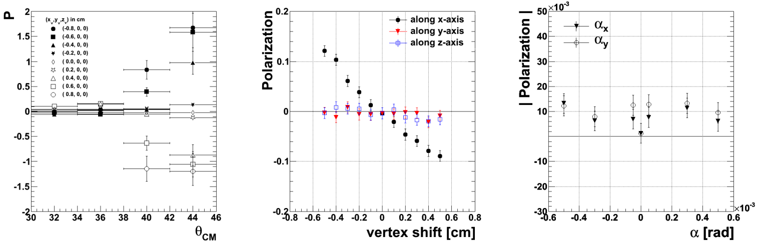

One week of beam time for the measurement was scheduled for November 2010 year. Whereas the previous studies are based on few thousands of events, at WASA about $10^6$ $pp \rightarrow pp\eta$ events has been collected.

# Determination of the beam polarization



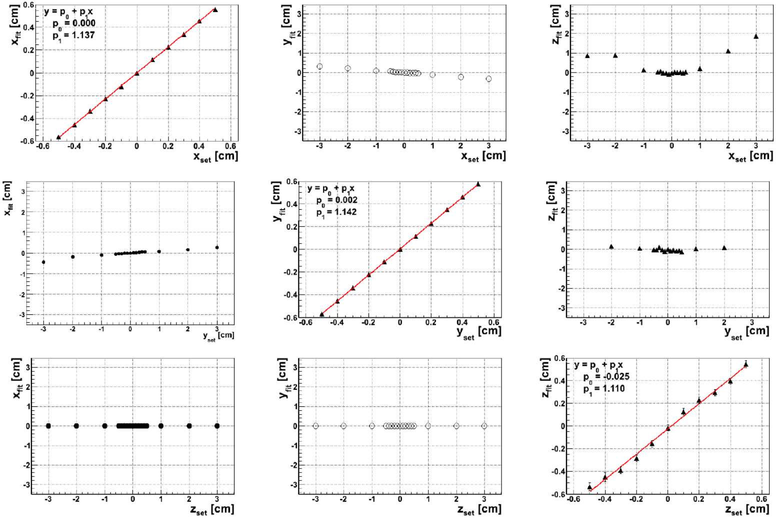
# Determination of the beam polarization

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



# Determination of the vertex position





# Summary



- near the threshold only S-wave, pp pairs production ($^3P_0 \to {}^1S_0 s$, 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 $38^{\circ}$.