JAGIELLONIAN UNIVERSITY
IN KRAKOW

Study of the η meson production with polarized proton beam

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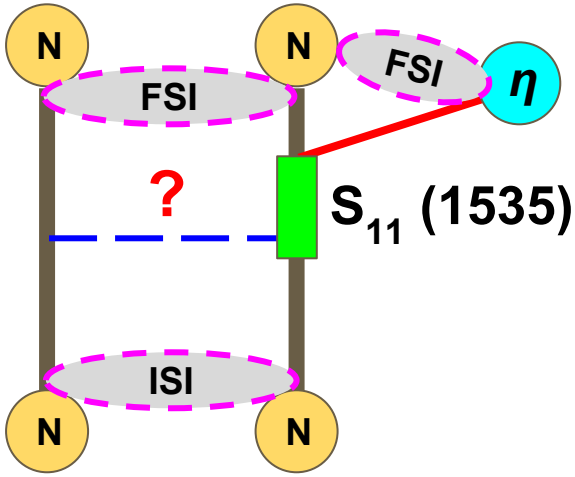
From Vacuum to the Universe,
Kitzbühel, June 28, 2016

Motivation for the η meson studies

Why study such rare particle like η ?

- **Determine the mechanism of the η meson production which is still puzzling.**
- **Learn about the interaction of the η meson with nucleons.**
- **Study the strong interaction in the low energy region.**

Motivation for the η meson studies



How to learn about the η production mechanism ?

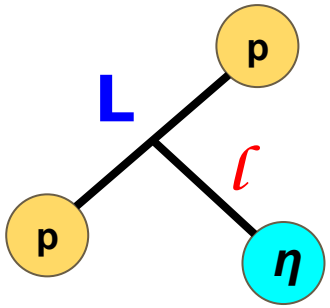
Use polarization observables such as analyzing power A_y

$$\sigma(\theta,\varphi) = \sigma_0(\theta) \cdot (1 + \sum_{i=1}^{3} P_i A_i(\theta,\varphi)) \quad \Leftarrow \quad P \neq 0$$

Theoretical predictions for the A_y value are sensitive to the assumption on the type of the production mechanism.

Motivation for the η meson studies

How to learn about the η interaction with nucleons ?



L : 0 1 2 …
S P D …

ℒ : 0 1 2 …
s p d …

Partial waves contribution

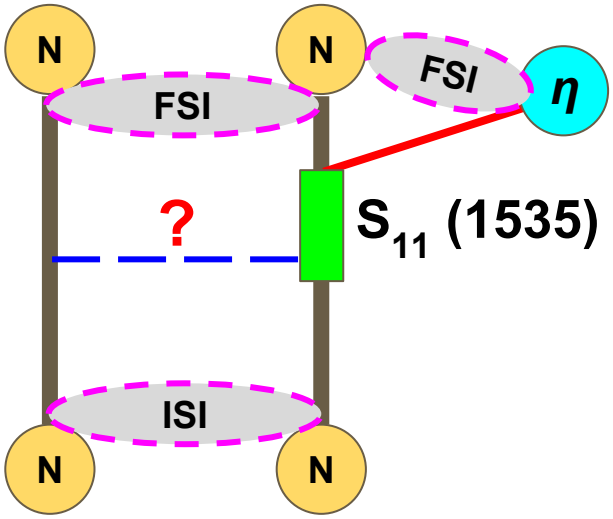
$$\frac{d\sigma}{d\Omega} \cdot A_y(\theta) \sim \mathrm{Im}\{A_{Ss} A_{Sd}^*\} \sin\theta_\eta \cos\theta_\eta$$

$$\frac{d\sigma}{d\Omega} \cdot A_y(\theta) \sim \mathrm{Im}\{A_{Ps} A_{Pp}^*\} \sin\theta_\eta$$

Polarization observables can probe the interference terms between various partial amplitudes

$^{2S^i+1}L^i_j \rightarrow$	$^{2S^f+1}L^f_j, \ell$
$^1S_0 \rightarrow$	$^3P_0 s$
$^3P_0 \rightarrow$	$^1S_0 s$
$^1D_2 \rightarrow$	$^3P_2 s$
$^3P_0 \rightarrow$	$^3P_1 p$
$^3P_1 \rightarrow$	$^3P_0 p$
$^3P_1 \rightarrow$	$^3P_1 p$
$^3P_2 \rightarrow$	$^3P_1 p$

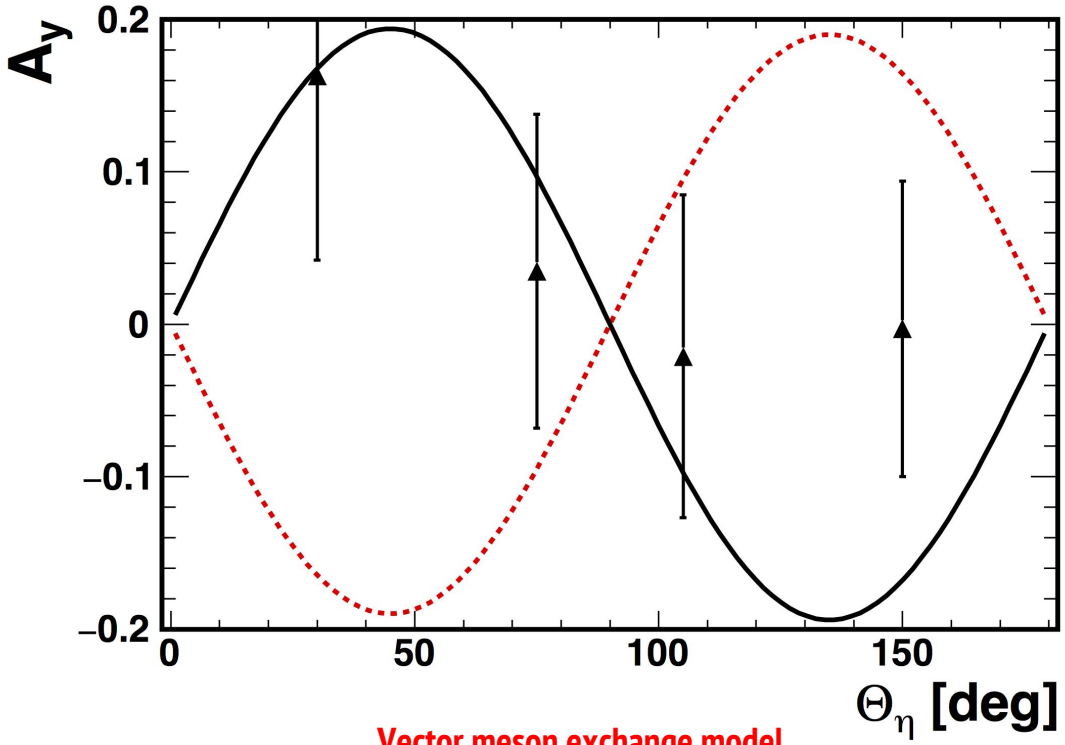
Previous studies and results



COSY-11 data
based on ~ 2000 events

$\vec{p}p \rightarrow pp\,\eta$

(Q = 10 MeV)



Vector meson exchange model
(G. Fäldt and C. Wilkin, Phys. Scripta 64 (2001) 427)

Pseudoscalar meson exchange model
(K. Nakayama et al., Phys. Rev. C 65 (2002) 045210)

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

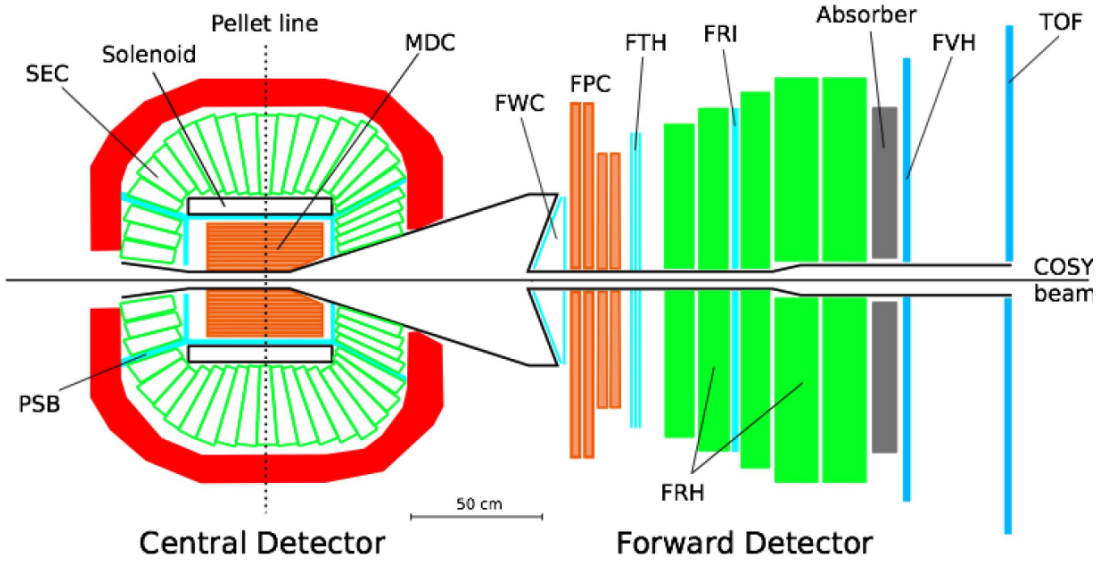
How to improve and learn more about η production ?

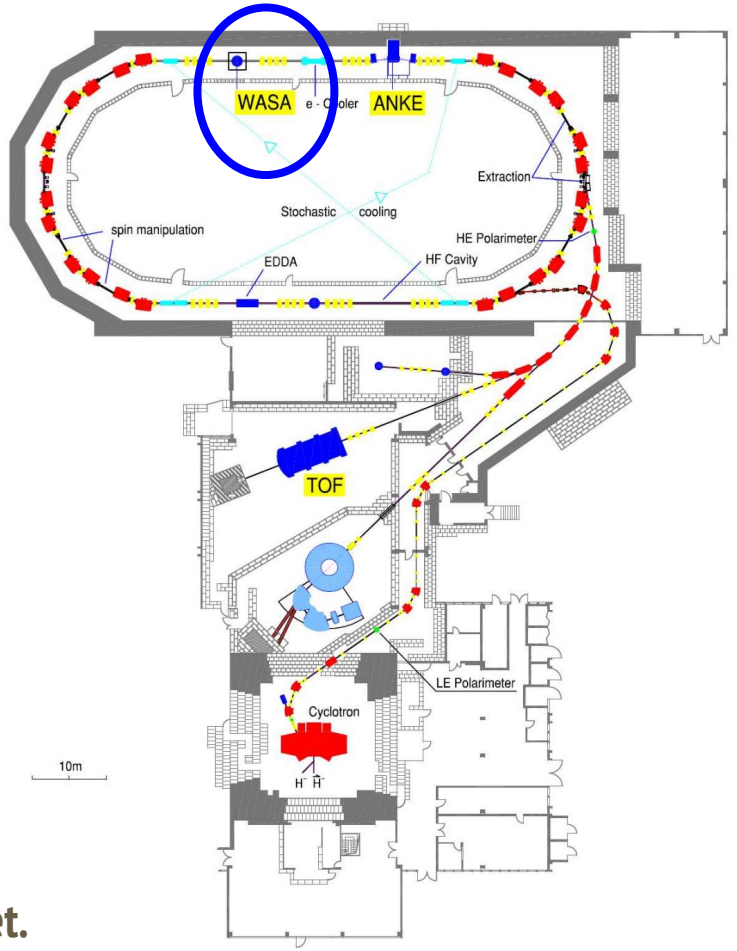
Do more precise and high statistics experiments !

WASA-at-COSY
Collaboration

New experiment

Fully symetric WASA-at-COSY detector





Collisions of polarized proton beam and unpolarized proton target.

P beam (MeV/c)	Q (MeV)
2026	15
2188	72

Beam Polarization	
	Up
	Down

Reaction	Decays
$pp \rightarrow pp\,\eta$	$\eta \rightarrow 2\,\gamma$
	$\eta \rightarrow 3\pi^0\,(6\,\gamma)$

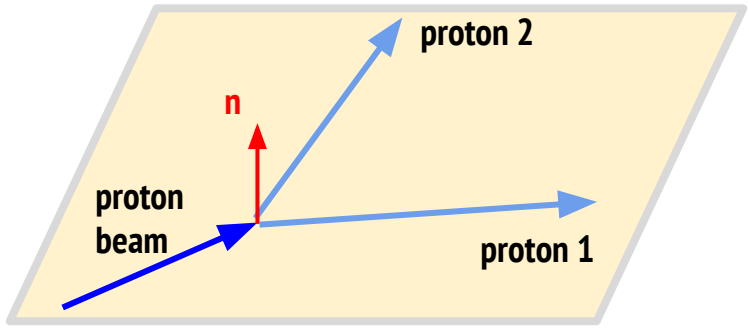
We have measured analyzing power of the η meson for the 4 independent cases, collecting more than 400 000 η events.

Interaction point (vertex) determination

For precise determination of the polarization the control over the vertex position is a crucial point.

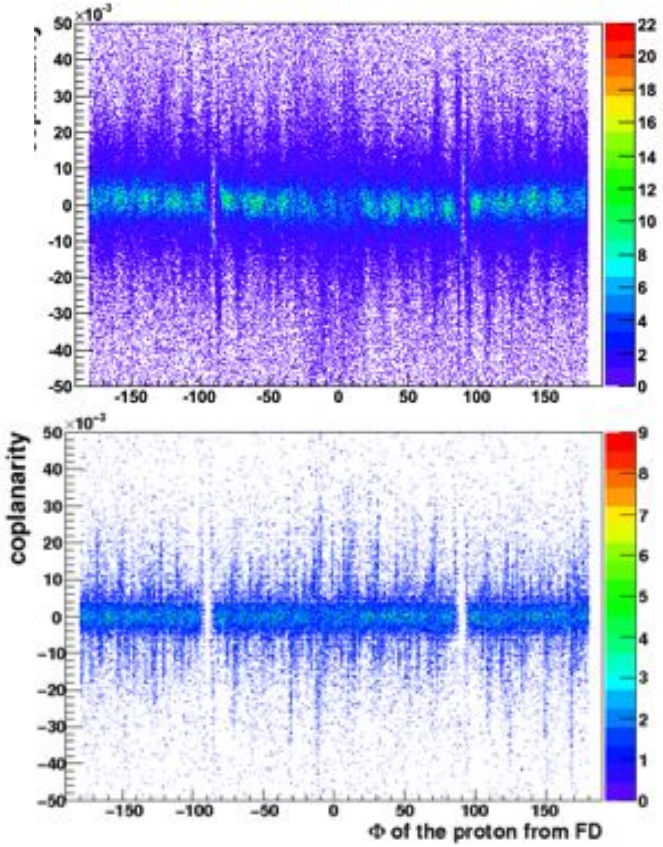
Coplanarity:

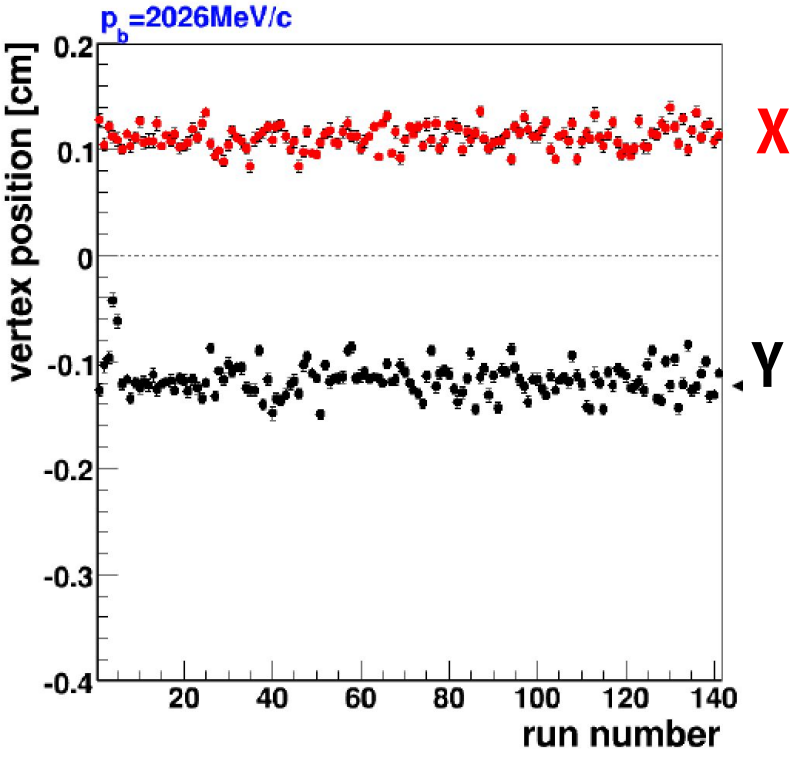
$$C = \frac{(\vec{p}_1 \times \vec{p}_2) \cdot \vec{p}_{beam}}{|\vec{p}_1 \times \vec{p}_2| \cdot |\vec{p}_{beam}|}$$



Experimental data

Mont Carlo simulations



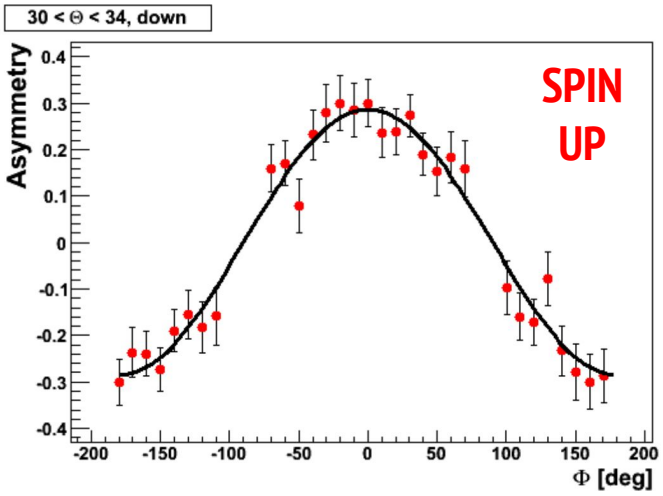


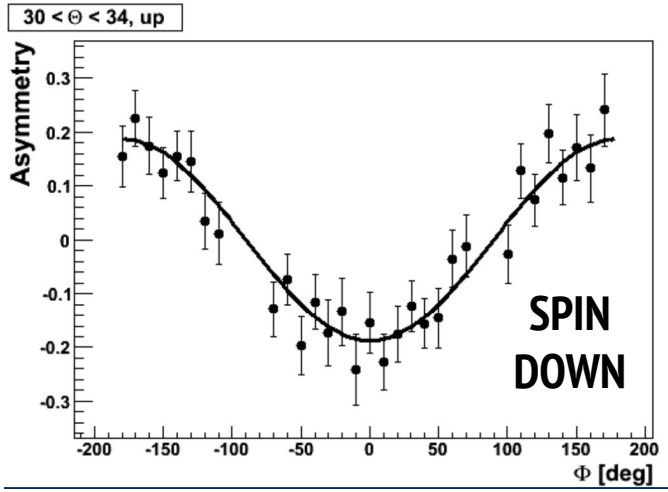
Asymmetry for the elastic scattering

$$\epsilon(\theta_{FD},\varphi_{FD}) = \frac{N(\theta_{FD},\varphi_{FD}) - N(\theta_{FD},\varphi_{FD}+\pi)}{N(\theta_{FD},\varphi_{FD}) + N(\theta_{FD},\varphi_{FD}+\pi)}$$

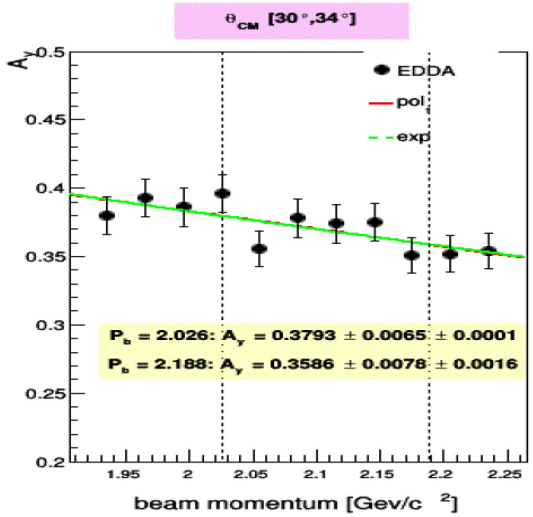
$$\epsilon(\theta_{FD},\varphi_{FD}) = P(\theta_{FD}) \cdot A_y(\theta_{FD}) \cdot cos(\varphi_{FD})$$

Asymmetry — Polarization — Analysing Power



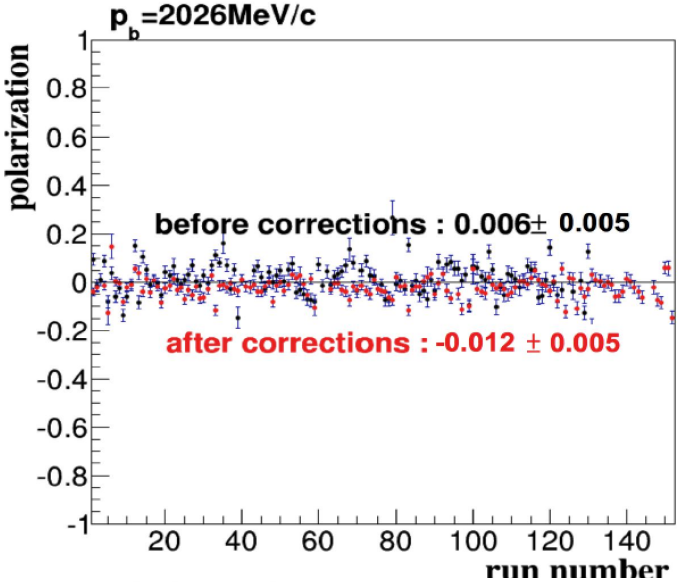


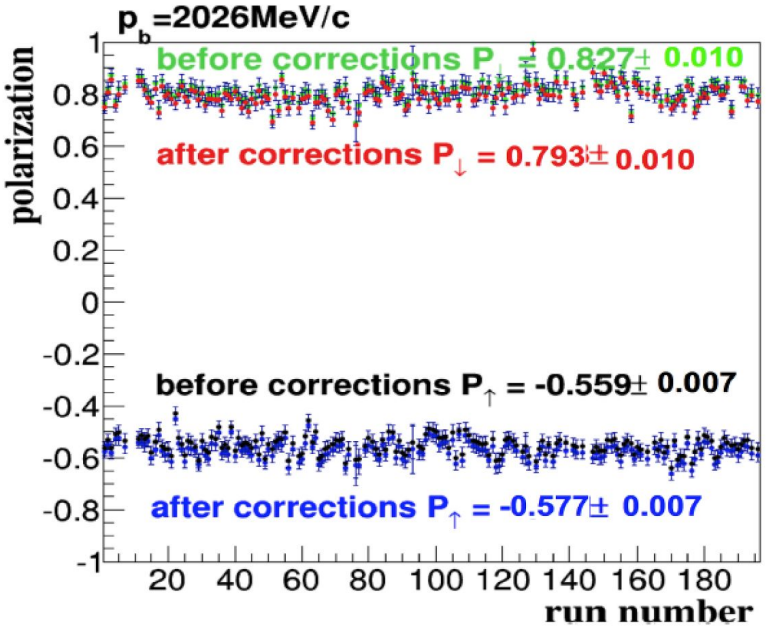
A_y for elastic scattering evaluated from EDDA Collaboration measurements



M. Altmeier et al. Phys. Rev. Lett., 85:1819 (2000)

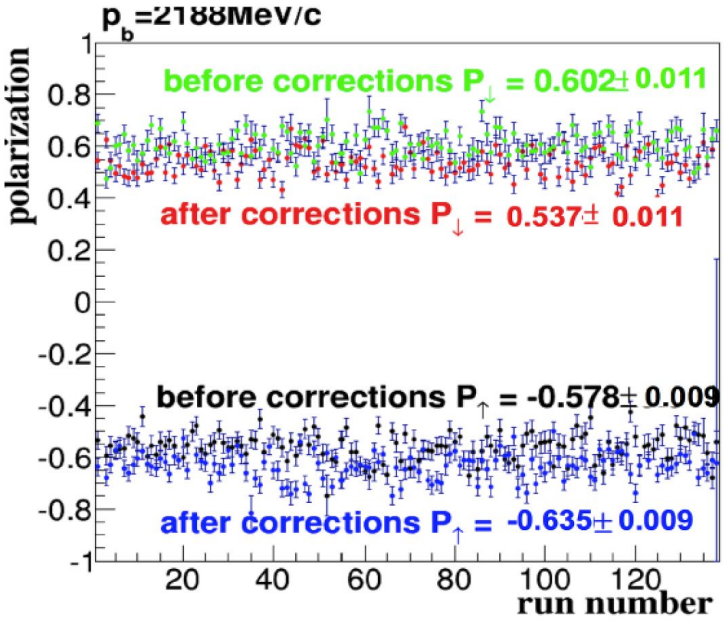
Polarization results





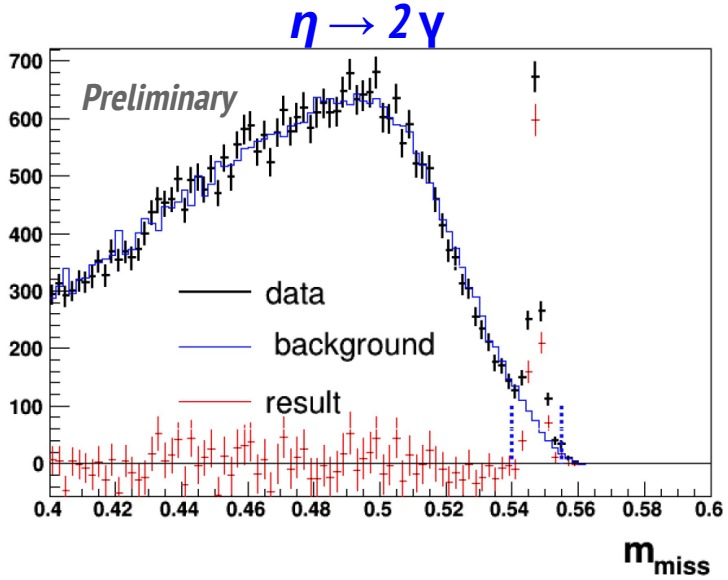
Not polarized control data sample in agreement with zero.

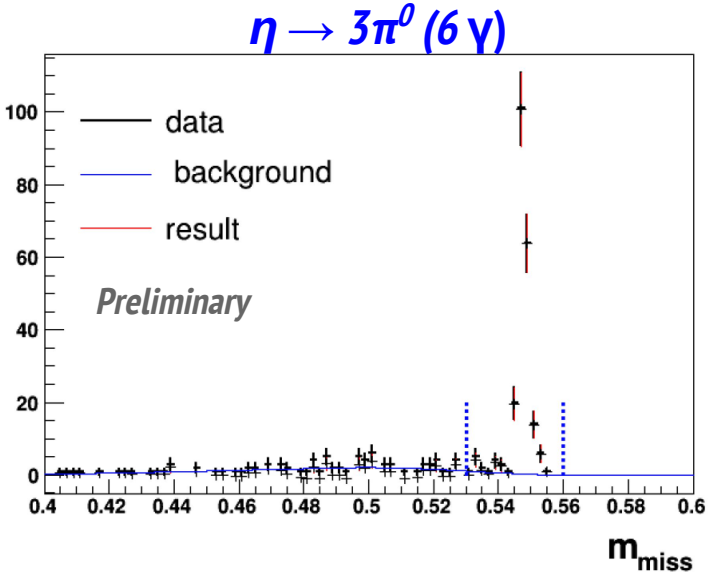
Polarization very stable over the whole beam run.

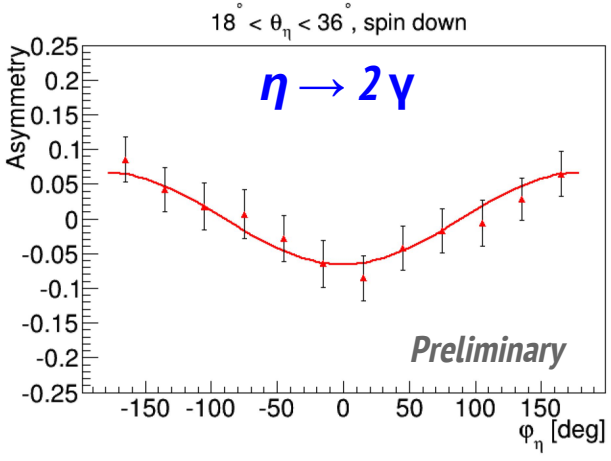


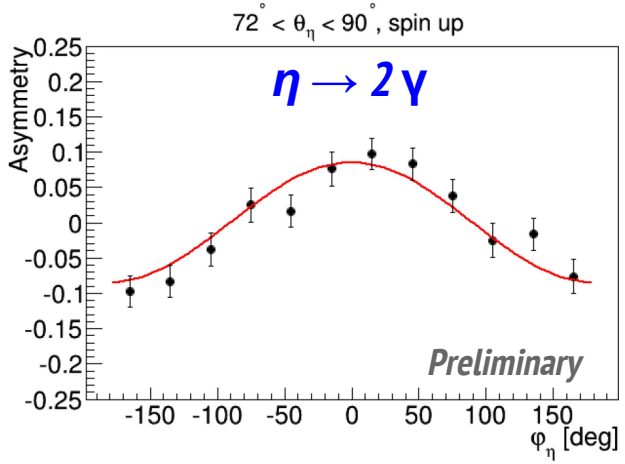
Identification and determination of the η meson

The number of the η mesons was determined based on the missing mass distributions, where the background was separated using the extended simulations of multipion production.

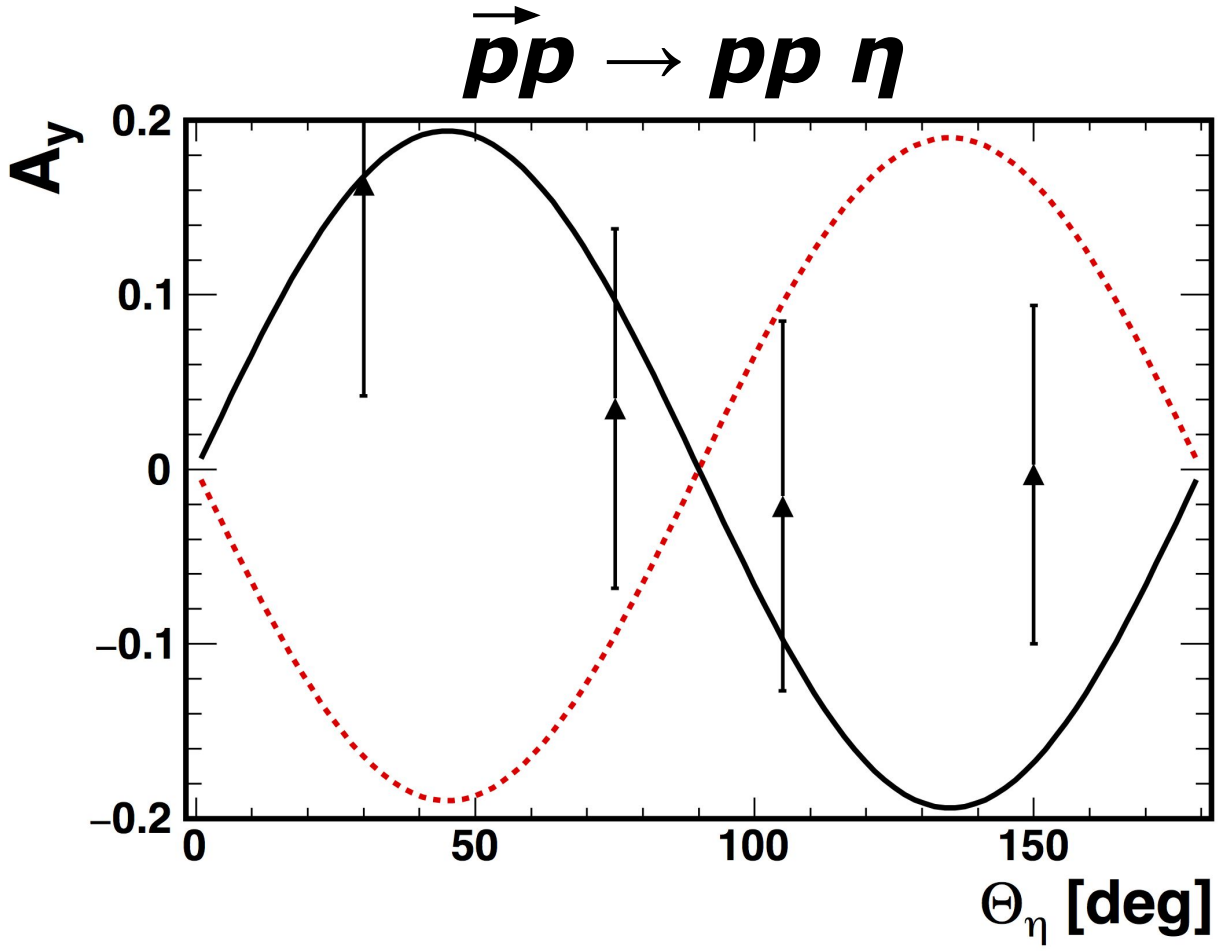








Result of the analsing power for the η meson



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▲ COSY-11 result for Q = 10 MeV

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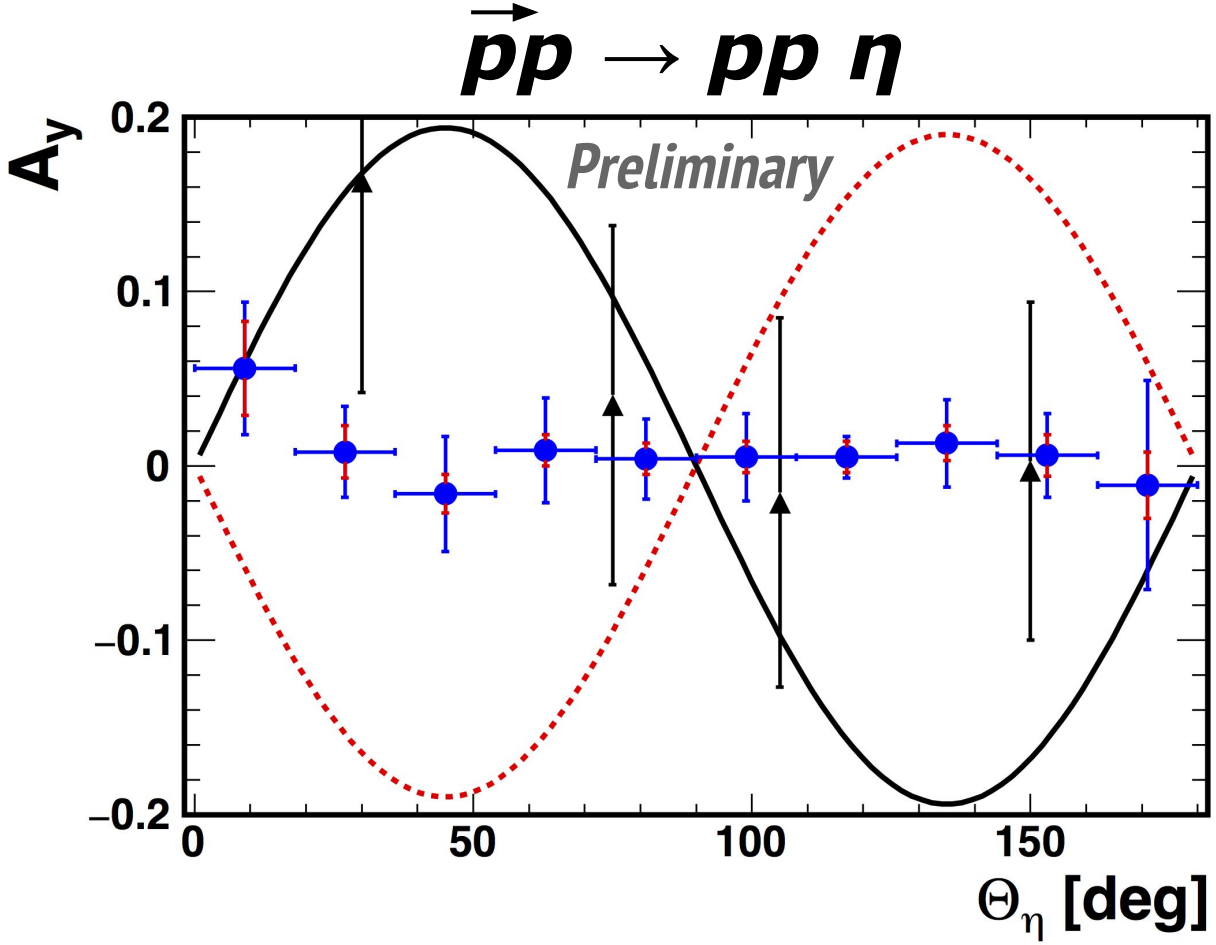

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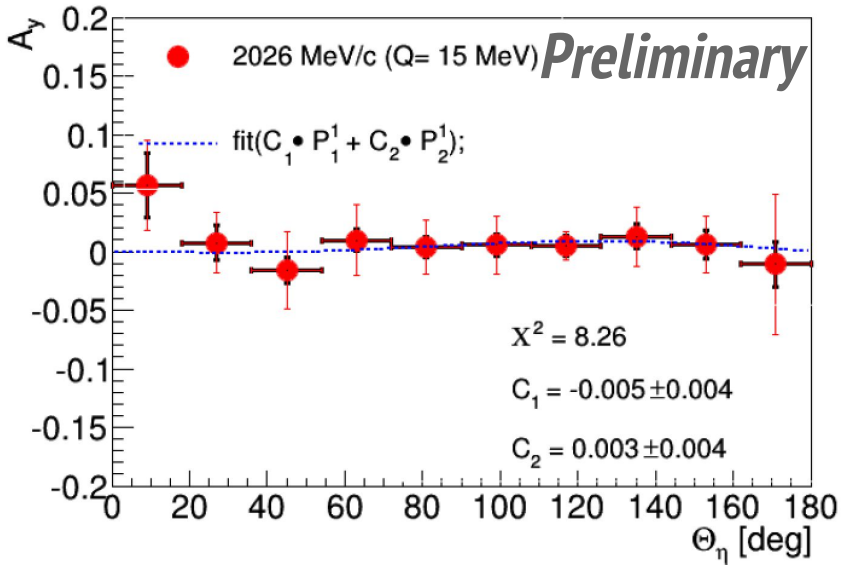
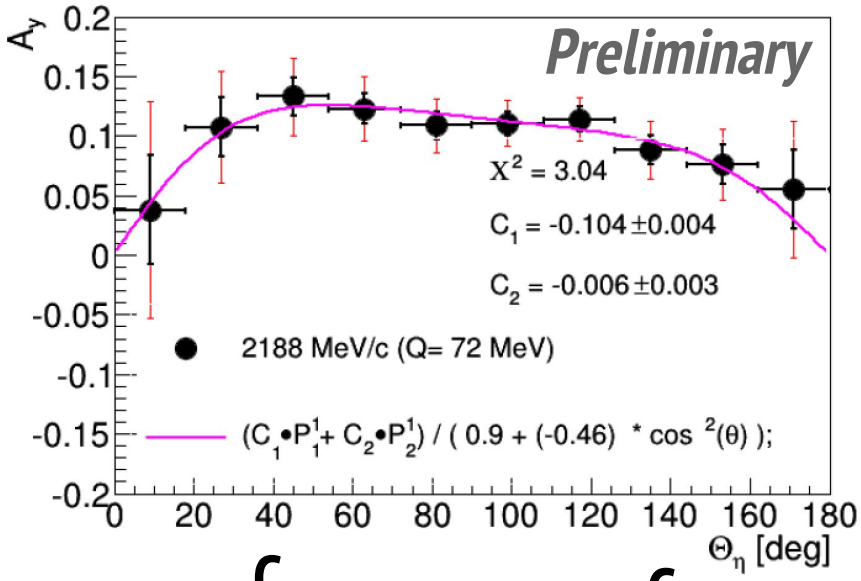
COSY-11 result for Q = 10 MeV

WASA-at-COSY preliminary result for Q = 15 MeV

Results for the partial wave contribution





$\frac{d\sigma}{d\Omega} \cdot A_y(\theta) \sim \mathrm{Im}\{A_{Ss}A_{Sd}^*\}\sin\theta_\eta\cos\theta_\eta$

$\frac{d\sigma}{d\Omega} \cdot A_y(\theta) \sim \mathrm{Im}\{A_{Ps}A_{Pp}^*\}\sin\theta_\eta$

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

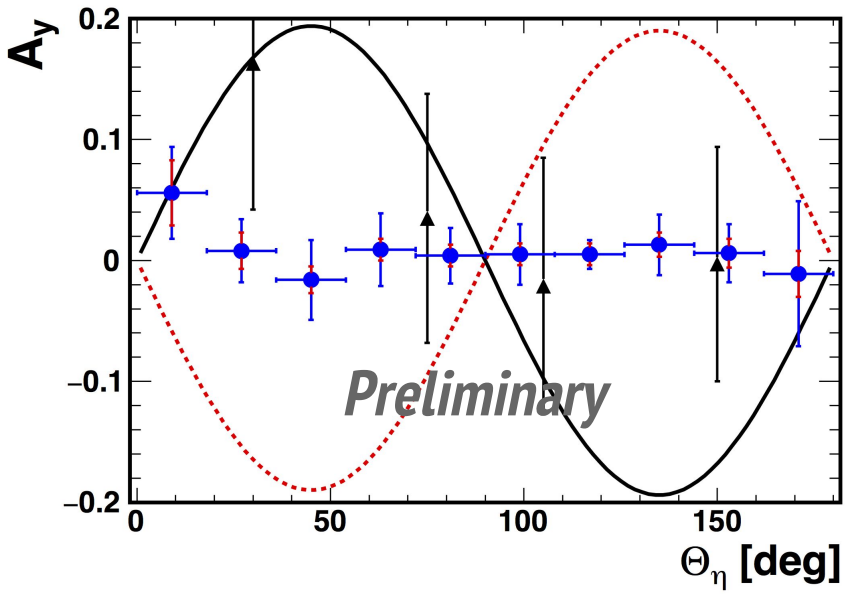
(C_1 multiplies the first term, C_2 multiplies the second term)

- The analyzing power is zero for the beam momentum 2026 MeV/c, no ***p*** and ***d*** waves for the η meson.

p_{beam}	$C_1^{final} \pm stat \pm syst$	$C_2^{final} \pm stat \pm syst$
2026 MeV/c	0.004 ± 0.003± 0.001	0.004± 0.003± 0.002
2188 MeV/c	-0.102± 0.003± 0.003	-0.003± 0.003± 0.003

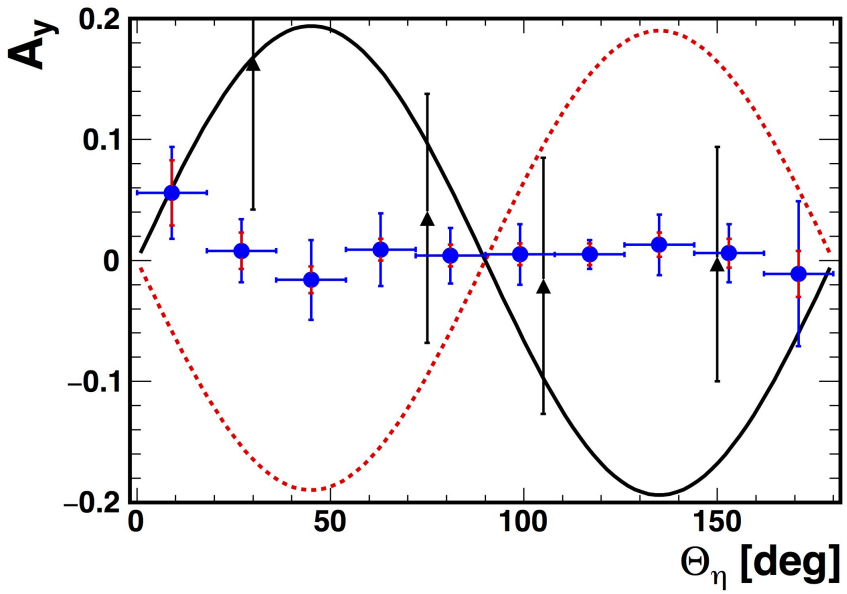
- For the beam momentum 2188 MeV/c there is enough excess energy available to produce not only ***s*** waves but also ***p*** waves, and indeed a strong interference between ***Ps*** and ***Pp*** partial waves was observed.

Conclusions



- Studies of the $pp \rightarrow pp\,\eta$ reaction was done for excess energies Q=15 MeV and Q=72 MeV.
- Analyzing power of the η meson was measured with precision of two order of magnitude higher than previously.
- The result shows that for the beam momentum 2188 MeV/c there is enough excess energy available to produce not only s waves but also p waves, and indeed a strong interference between Ps and Pp partial waves was observed.

Conclusions



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