JAGIELLONIAN UNIVERSITY
IN KRAKOW

# Study of the η meson production with polarized proton beam

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WASA-at-COSY Collaboration

SPIN 2014, Beijing, October 21st, 2014

# *Motivation for η studies*

*Why study such particle like η ?*

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# *Motivation for η studies*

*Why study such particle like η ?*

1. Determine the mechanism of the η meson production

2. Learn about the interaction of the η meson with nucleons

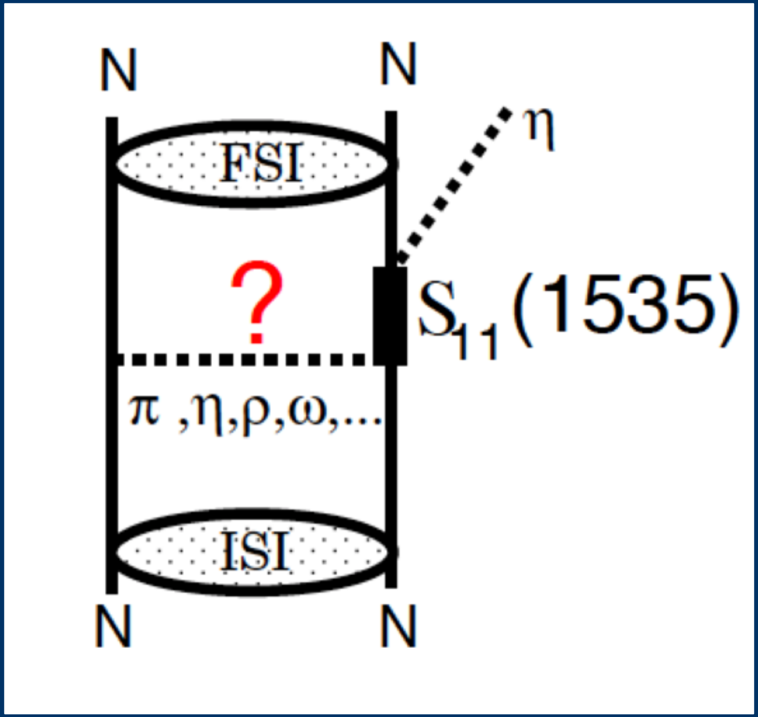
- Gives an unique opportunity to study the strong interaction in the low energy region

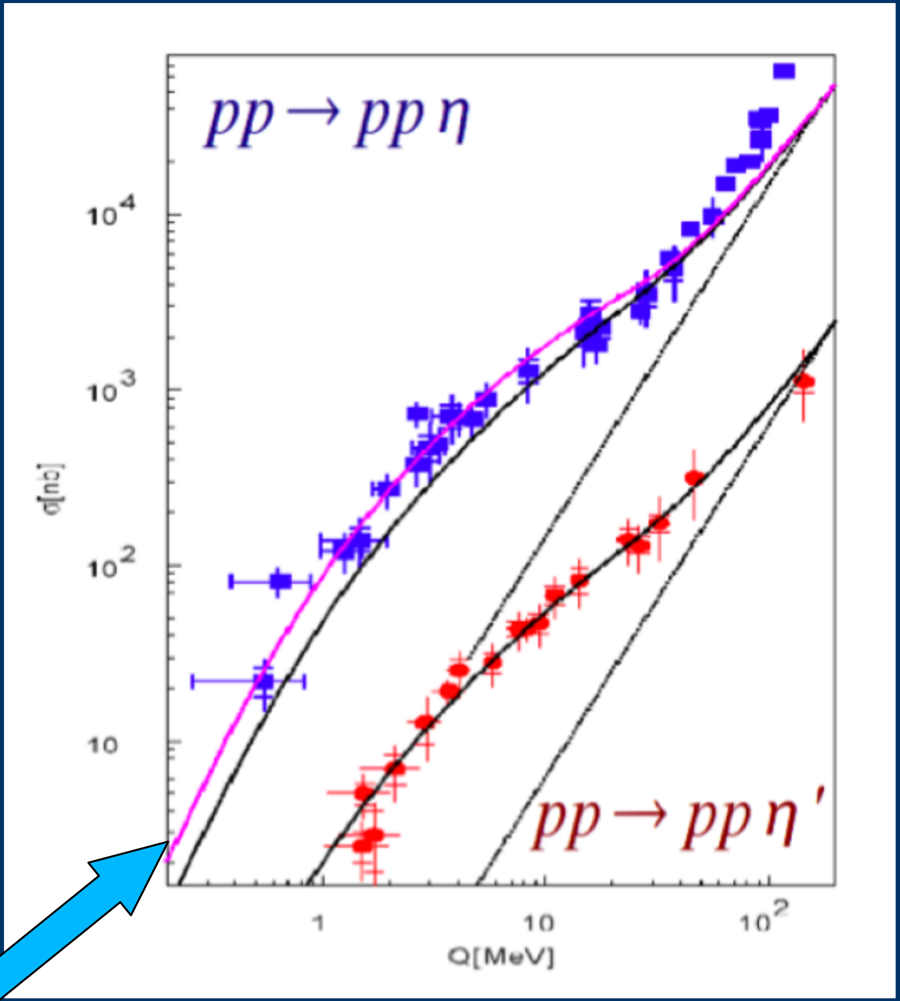
- η meson is a still an „exotic” particle with many intriguing questions

# η production in pp interactions

***pp → pp η***

Possible mechanisms:
1) pseudo-scalar meson exchange
2) vector meson exchange model




Excitation function does not give any hint on the production dynamics

# *How to learn about the mechanism ?*

Use polarization observables such as analyzing power $A_y$

Theoretical predictions for the $A_y$ value are sensitive to the assumption on the type of exchanged meson.

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

$P \neq 0$

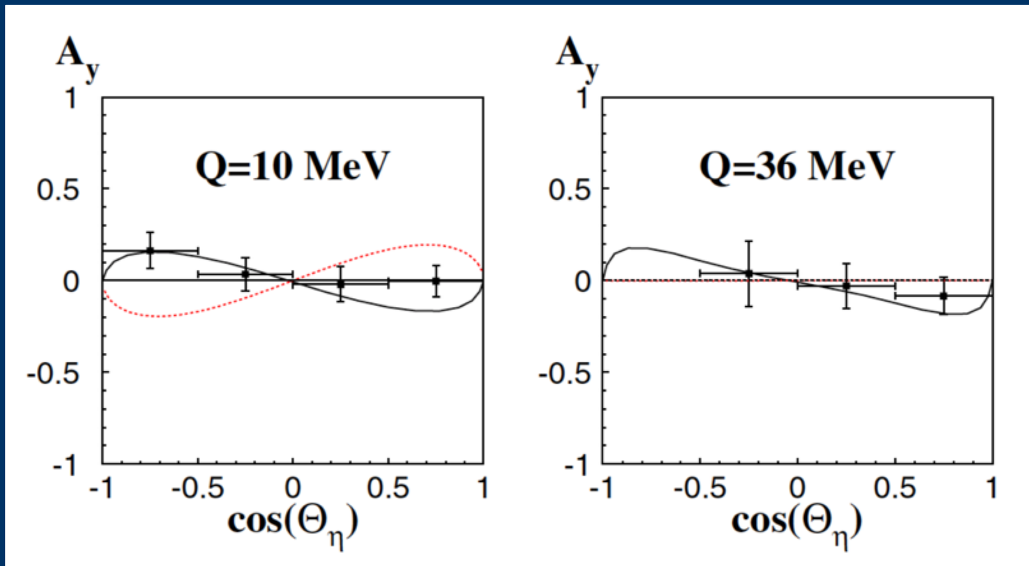
polarization

Analyzing power

Cross section without polarization

Cross section with polarization

# Results from COSY-11 experiment

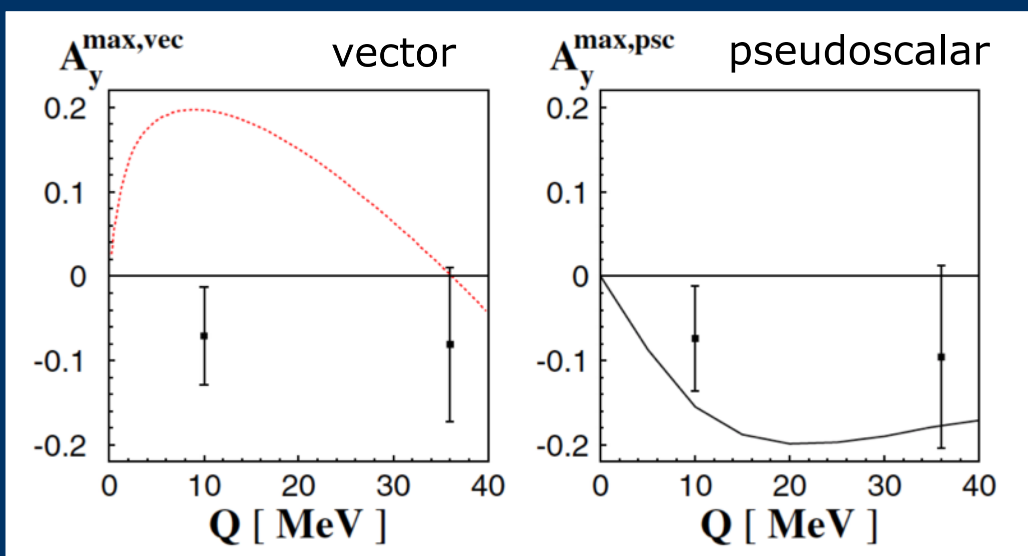



Data sample contained 2000 η mesons

G. Fäldt and C. Wilkin, Phys. Scr. **64**, 427 (2001).

$$A_y(\theta_\eta) = A_y^{\max,\mathrm{vec}} \sin 2\theta_\eta,$$

Prediction for Ay value in vector meson exchange model




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

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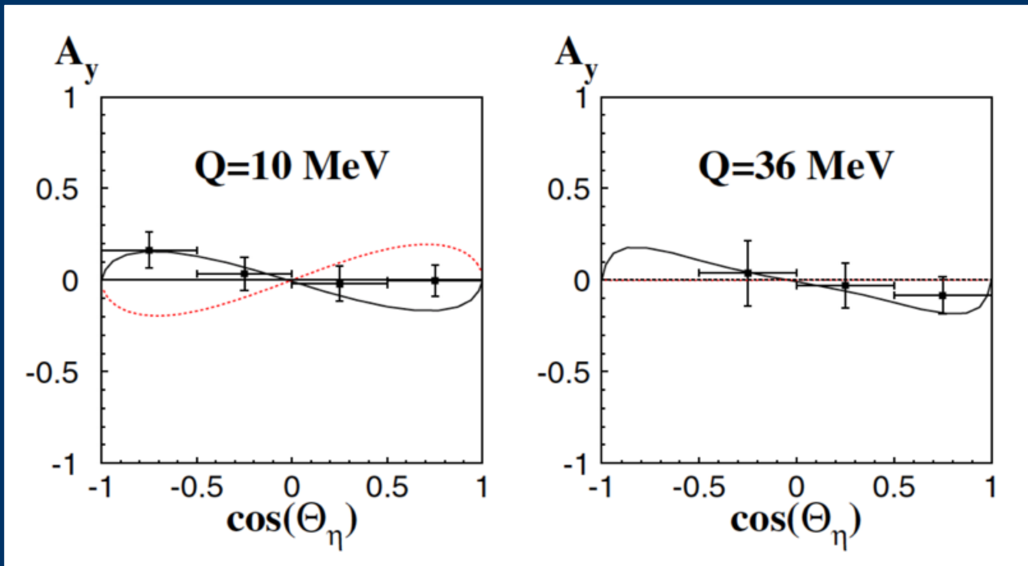


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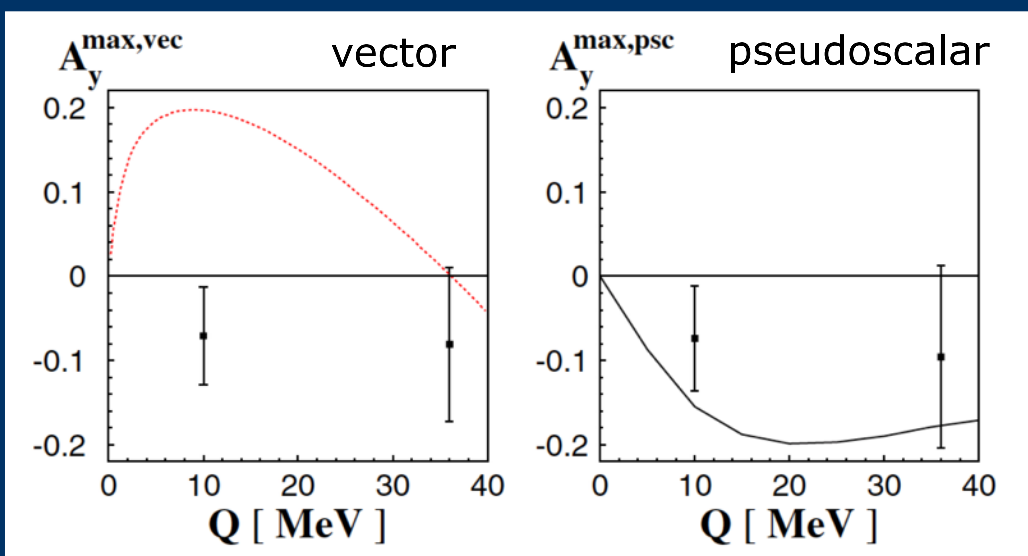


## Qualitative conclusion (only):

1) Most probably one can exclude the mechanism with the vector meson exchange and the mechanism is dominated with pion exchange.

2) The Ay values are with in calculated uncertainty equal zero therefore the η meson is predominantly produced in s wave

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

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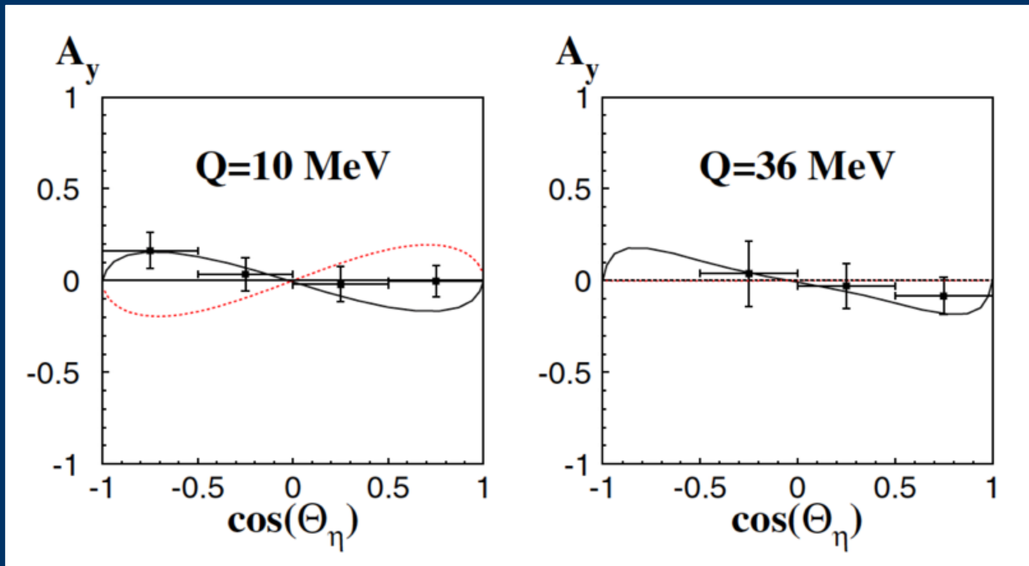


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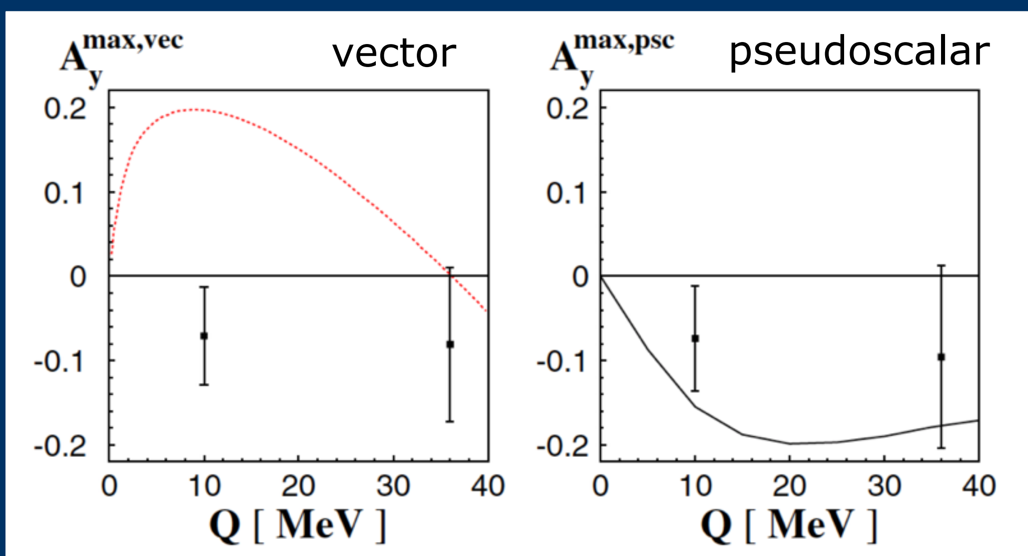


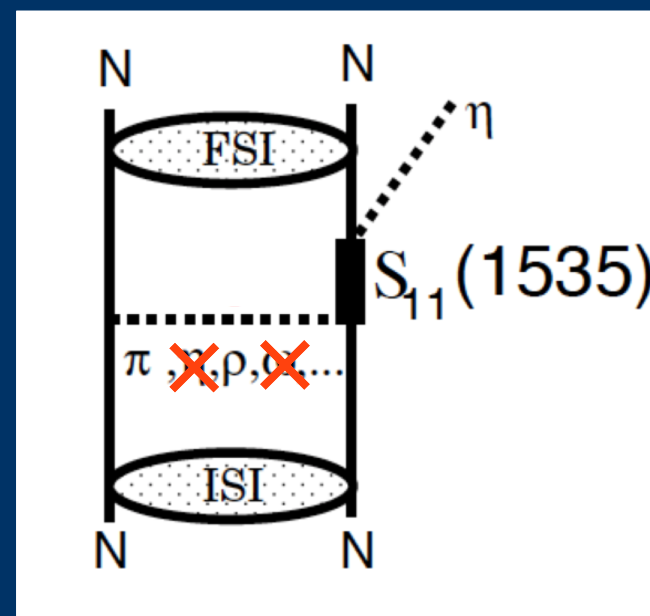


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# *How to improve and learn more about η production ?*

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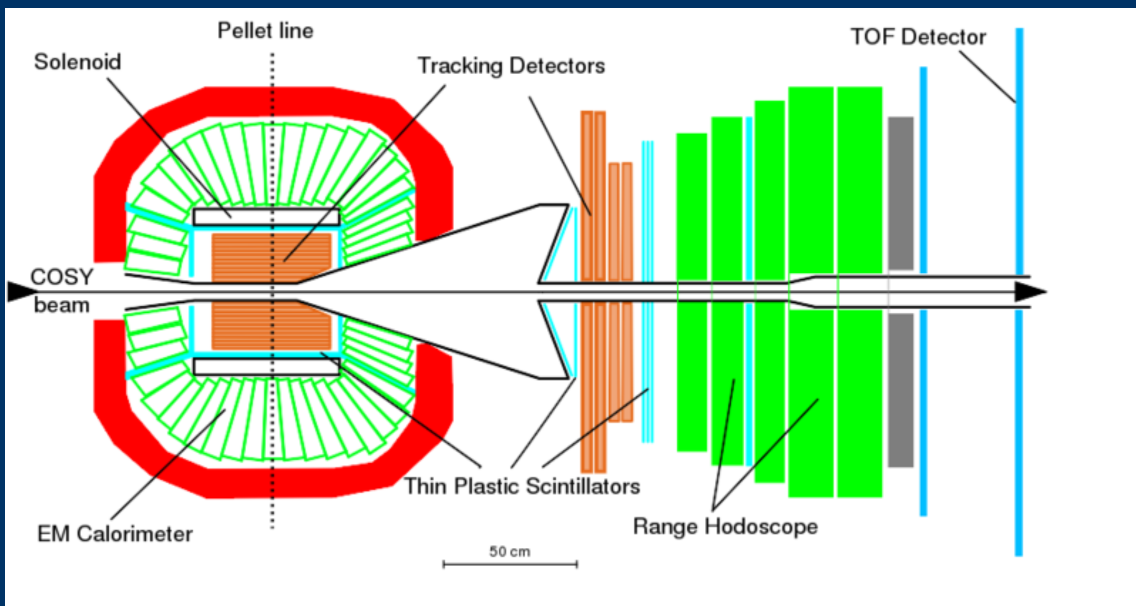


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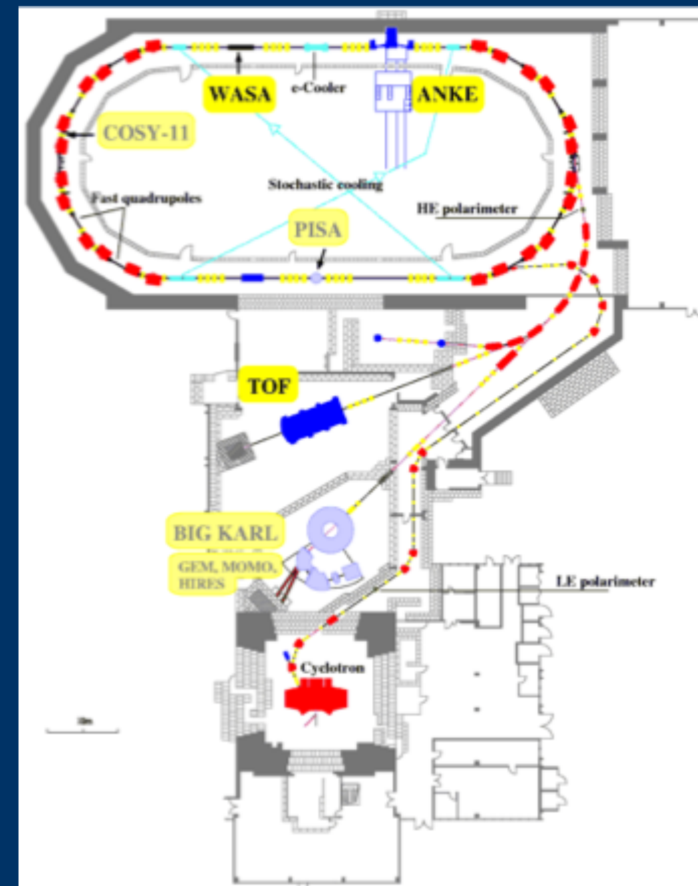



WASA-at-COSY

(azimuthally symmetric detector)

# Experiment with WASA at COSY

Reaction of polarized proton beam and unpolarized proton target:

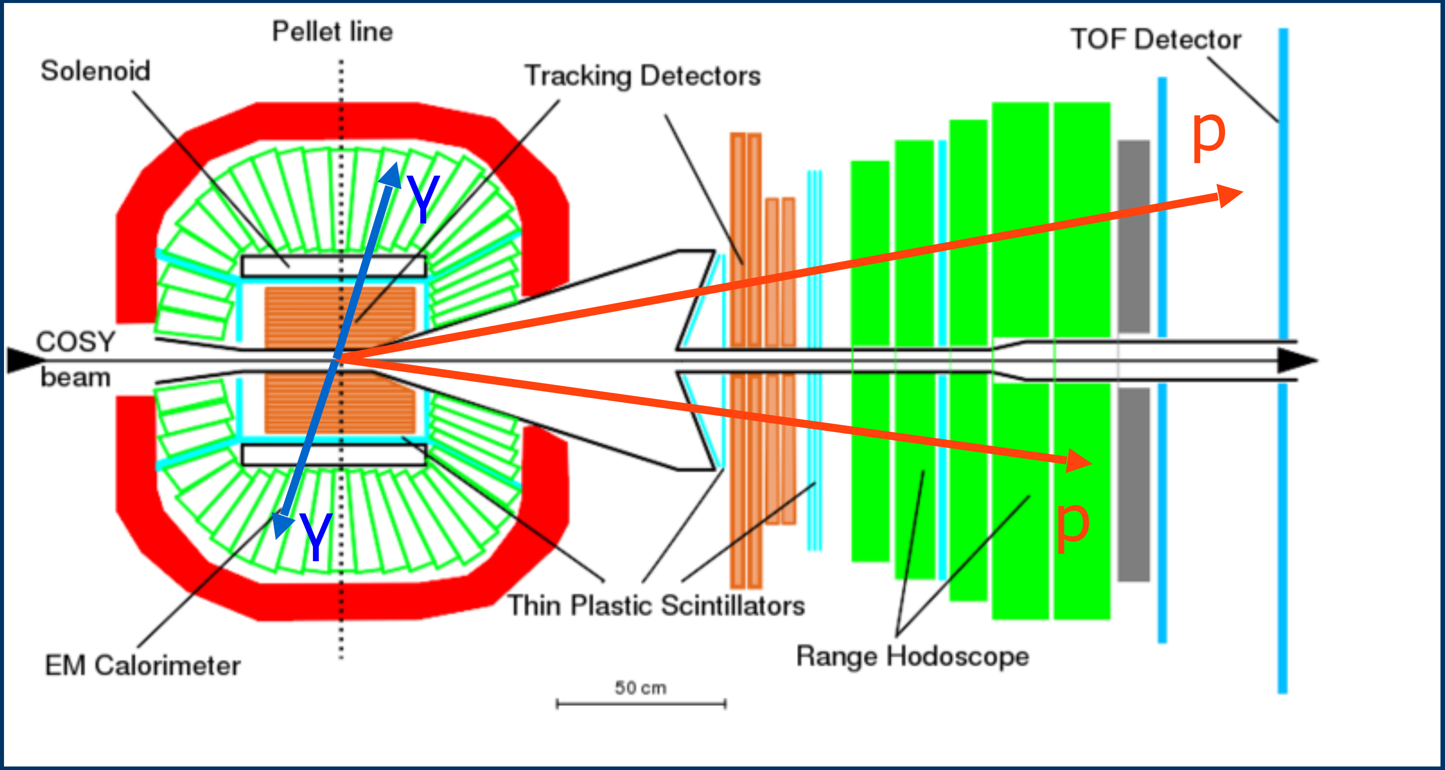
| P beam (MeV/c) | Q (MeV) |
|---|---|
| 2026 | 15 |
| 2188 | 72 |

Two reactions measured at the same time:

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

$\vec{p}p \longrightarrow pp$

(elastic scattering)




Two spin modes (up and down) and additional control runs without polarization.

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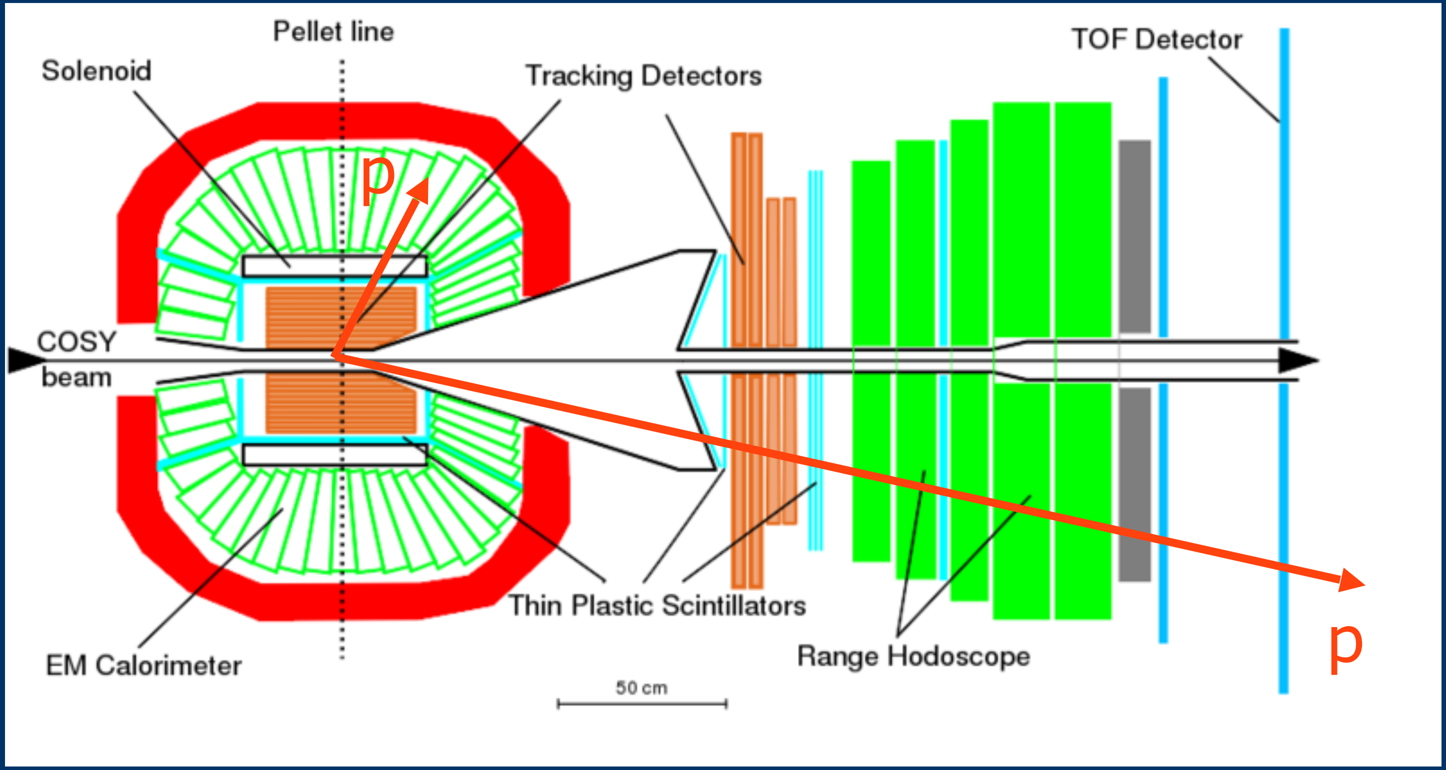


Two spin modes (up and down) and additional control runs without polarization.

# *Analysis steps*

With the WASA detector we have gathered $5 \circ 10^5$ η mesons (for comparison with COSY-11 it was 2000 events).

$$A_y(\theta_\eta) = \frac{1}{P} \frac{N_+^{\uparrow}(\theta_\eta) - L_{\mathrm{rel}} N_-^{\downarrow}(\theta_\eta)}{N_+^{\uparrow}(\theta_\eta) + L_{\mathrm{rel}} N_-^{\downarrow}(\theta_\eta)}.$$

| 1 | 2 |
| --- | --- |
| | |

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| 1 $\vec{p}p \rightarrow pp$ | 2 |
|---|---|
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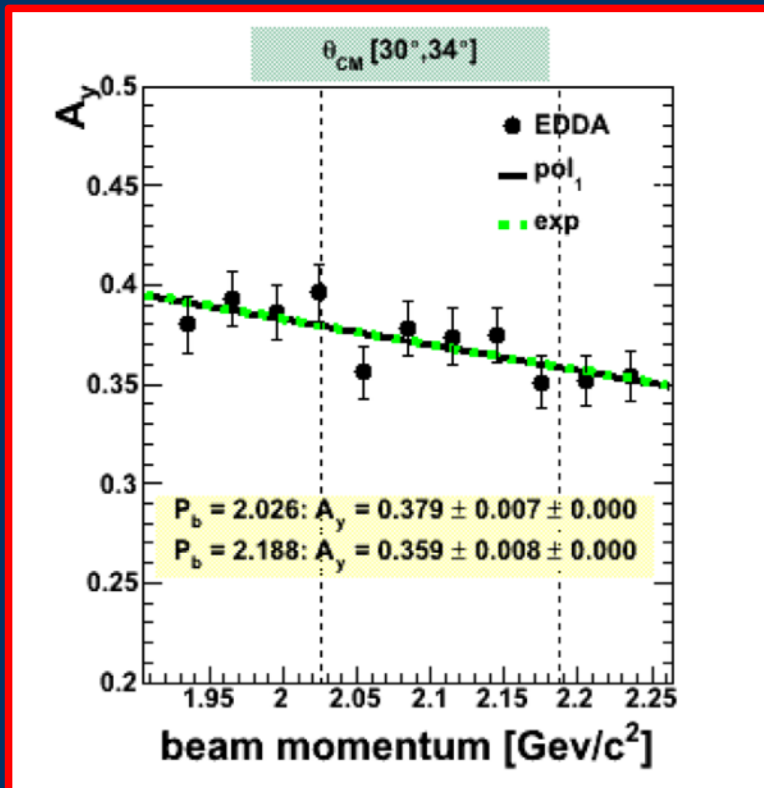
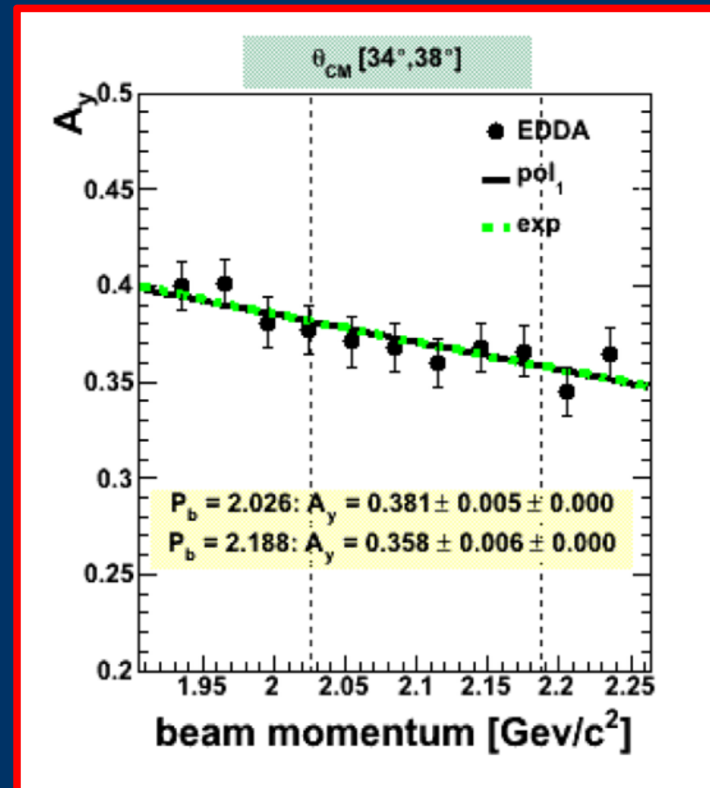
| 1 $\vec{p}p \to pp$ | 2 $\vec{p}p \to pp\,\eta$ |
|---|---|
| Using elastic scattering first we have to determine polarization,<br><br>and second step calculate the luminosity | Knowing the polarization and the luminosity one can calculate the analysing power as a function of the η emission angle |

# Step 1: polarization determination

(analyzing power for elastic scattering)

$pp \rightarrow pp$




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

Ay (from EDDA)

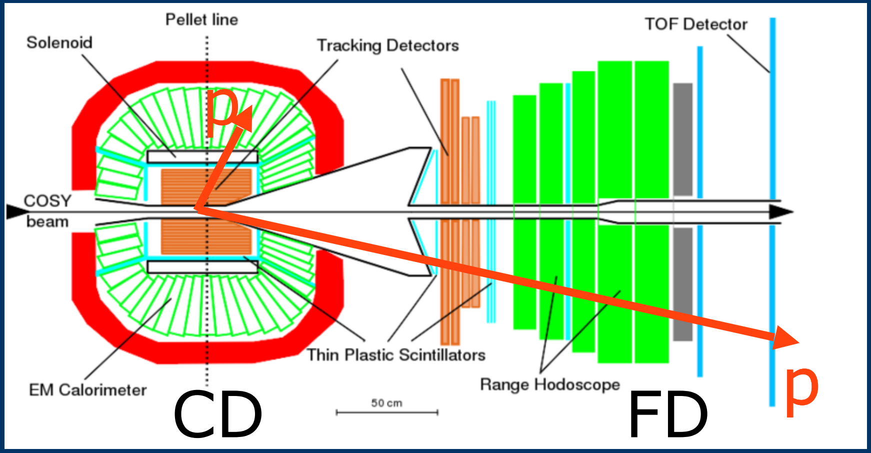
**M. Altmeier et al. (EDDA) *Eur. Phys. J.* A23, 351-364 (2005)**

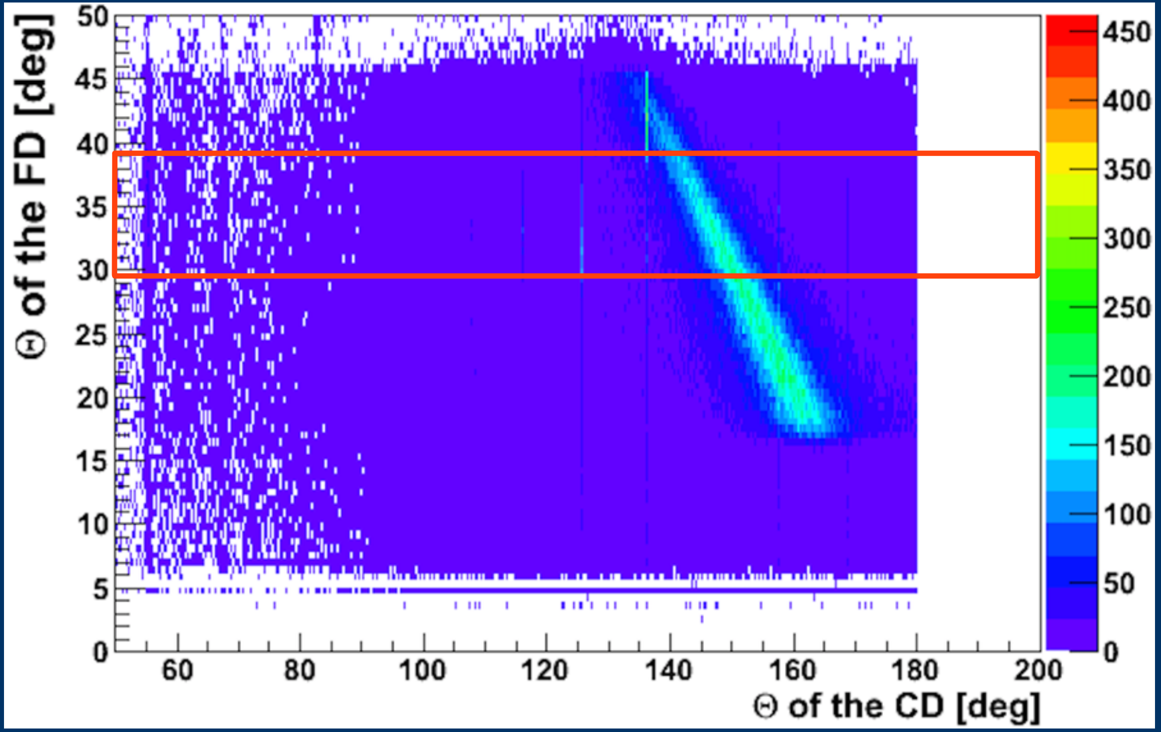
Database for cross sections
and analysing power
in elastic pp scattering

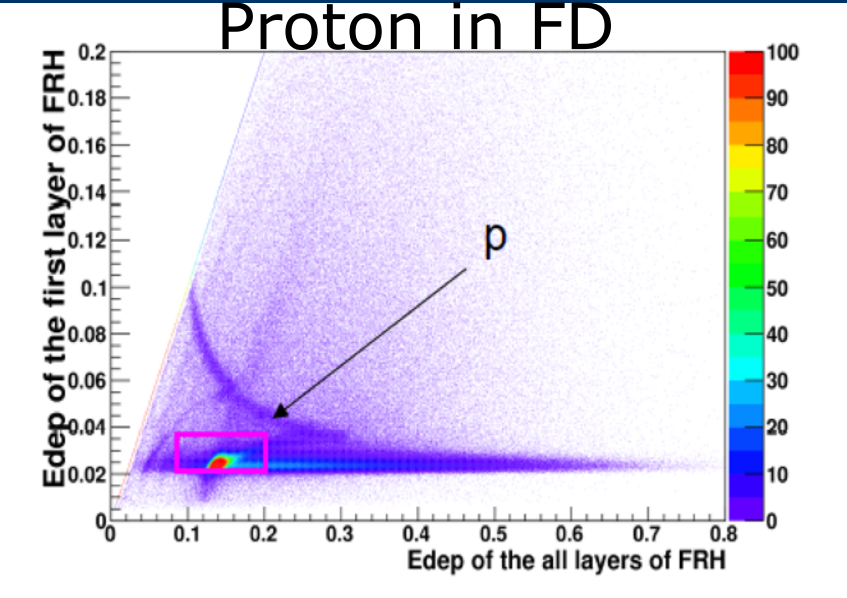
# Step 1: polarization determination

(elastic events selection)

*pp → pp*



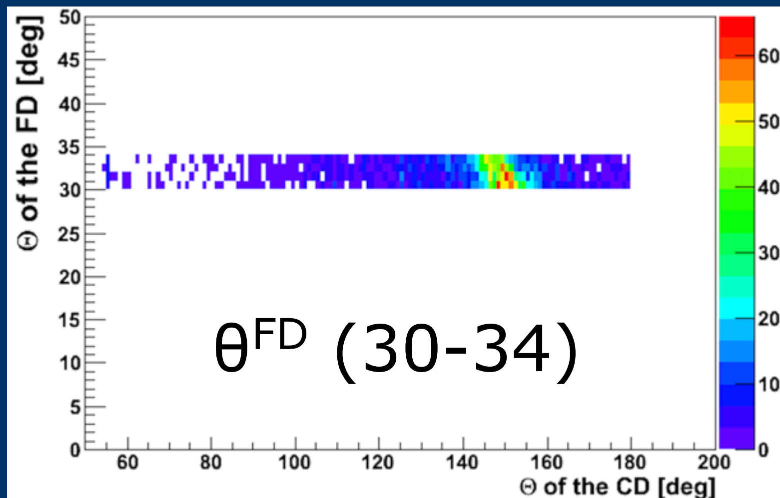



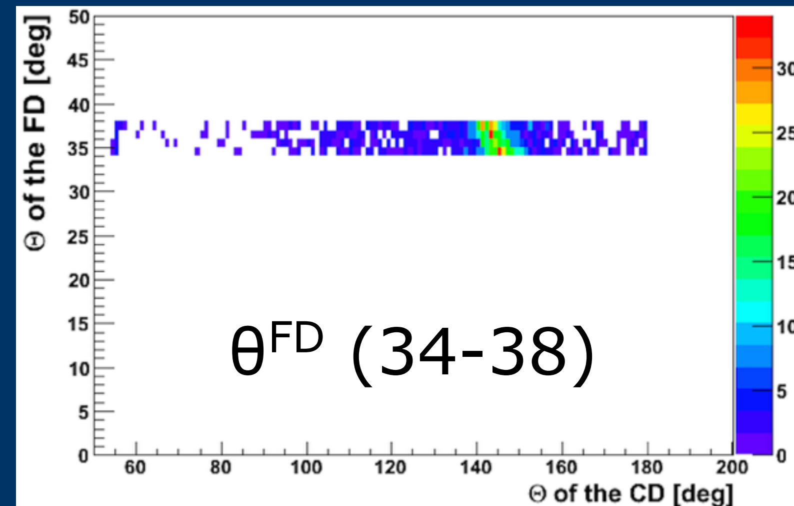




We use angular θ range 30-38 deg in CM, divided into two bins of 4 deg width each.

# Step 1: polarization determination

(asymmetry calculation)

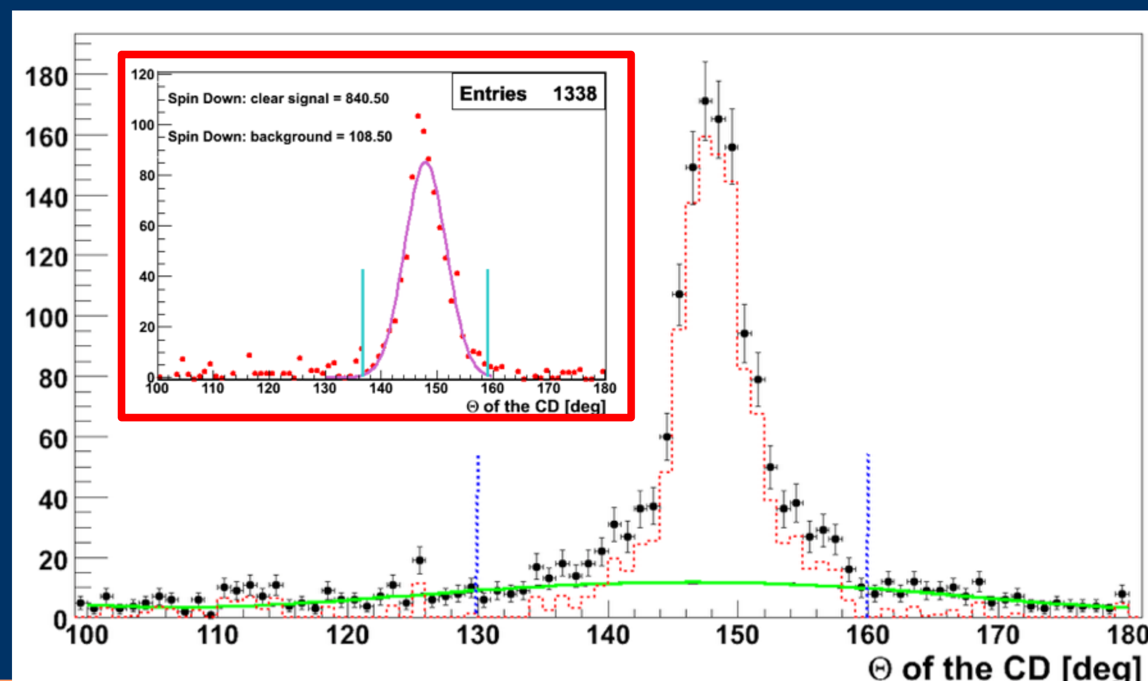



***pp → pp***

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

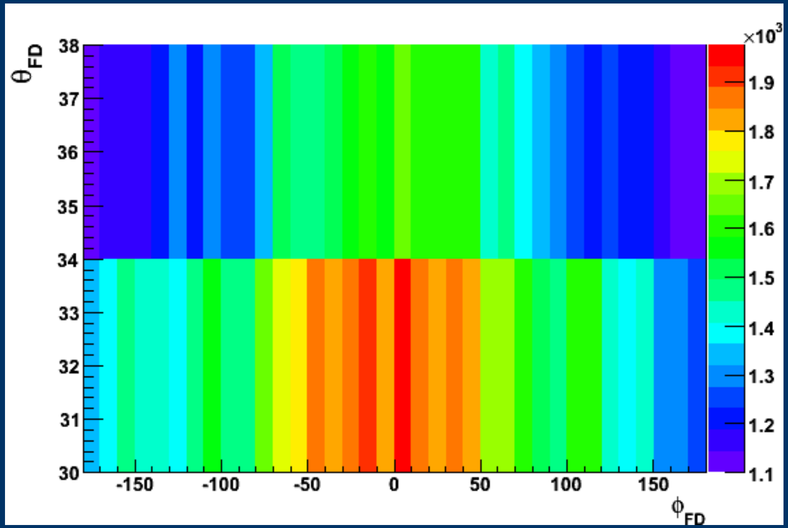
asymmetry



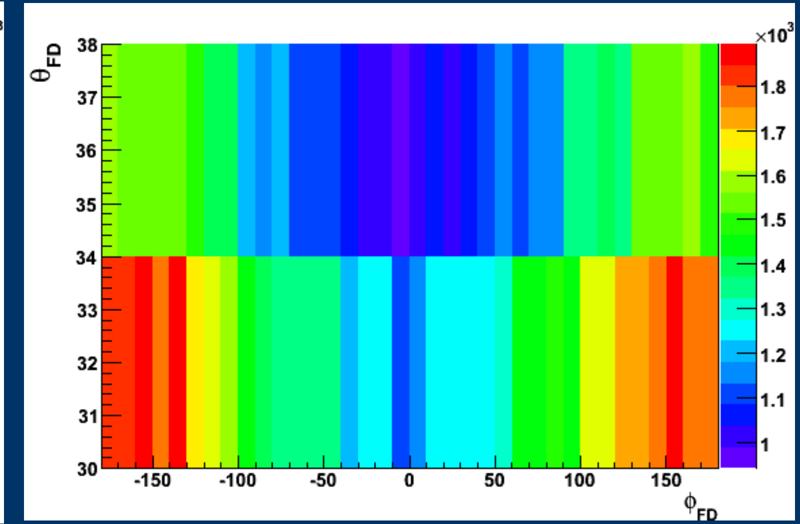
# Step 1 : polarization determination

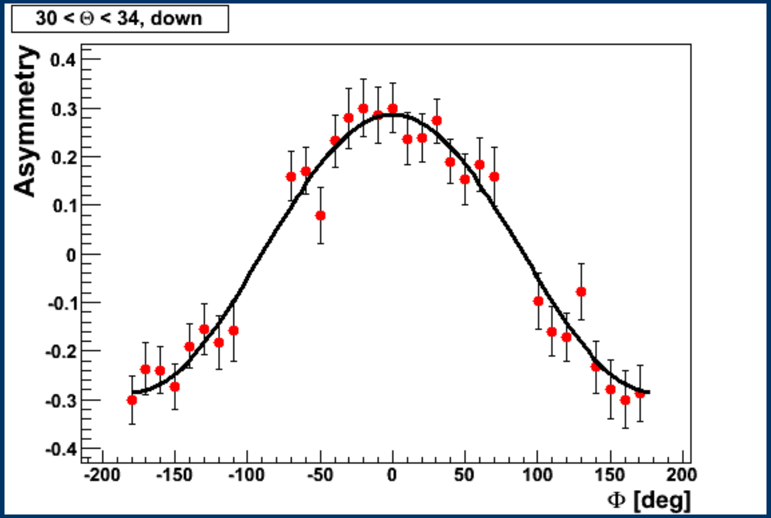
(asymmetry calculation – example plots)

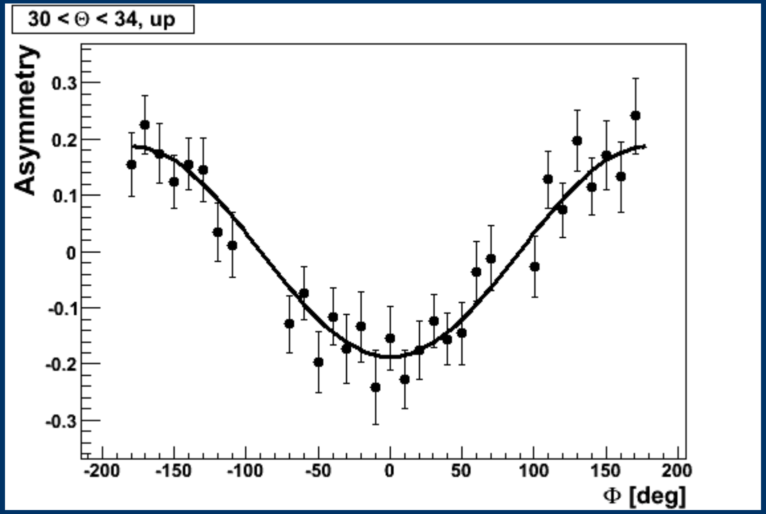
Spin UP mode



Spin DOWN mode



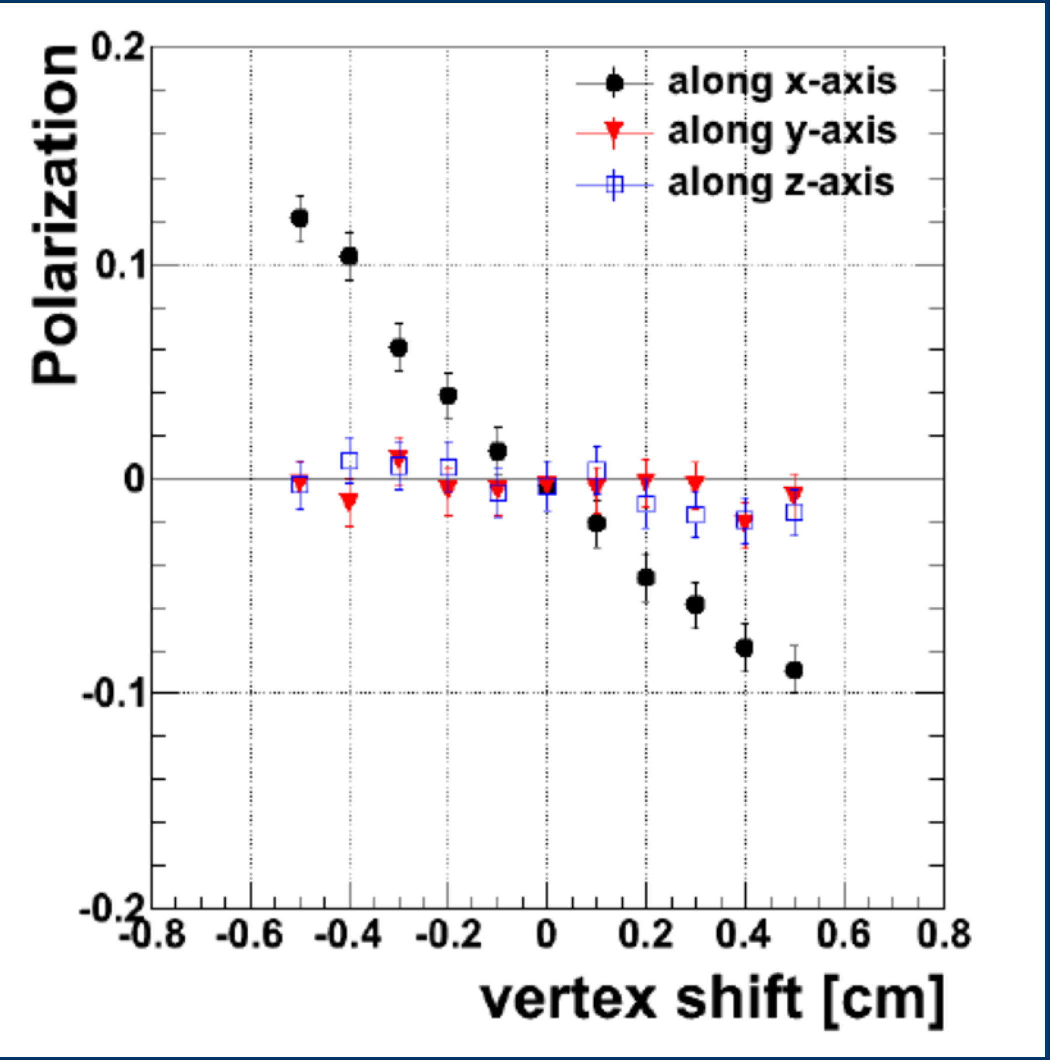


# Step 1 : polarization determination

(Vertex position – systematic effects studies)

Polarization value can change with the vertex position!



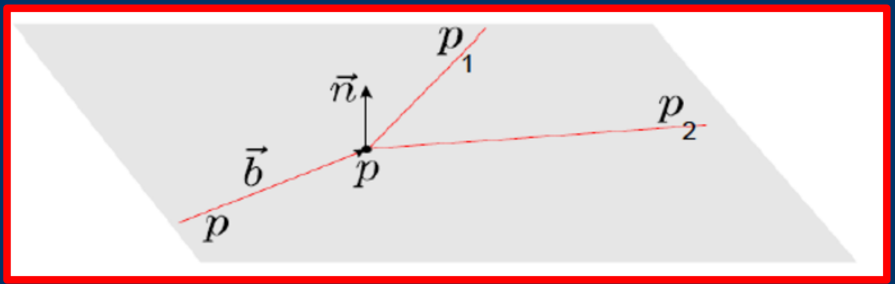

Monte Carlo simulations how the change of the vertex position influences the polarization value

# Step 1 : polarization determination

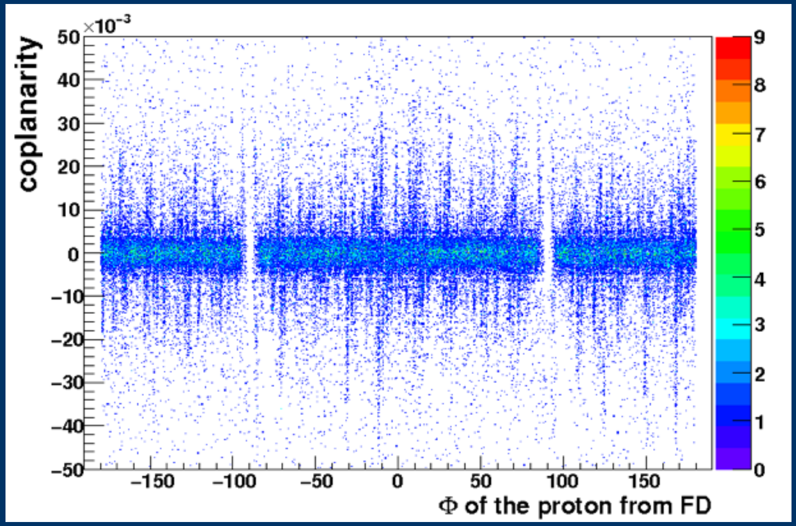
(Vertex position – systematic effects studies)

Polarization value can change with the vertex position!

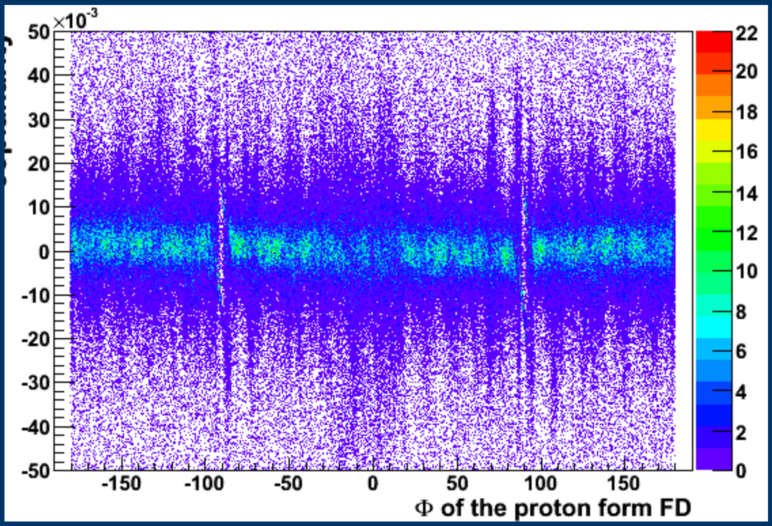
We used coplanarity method to determine the interaction region.




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




Monte Carlo simulations

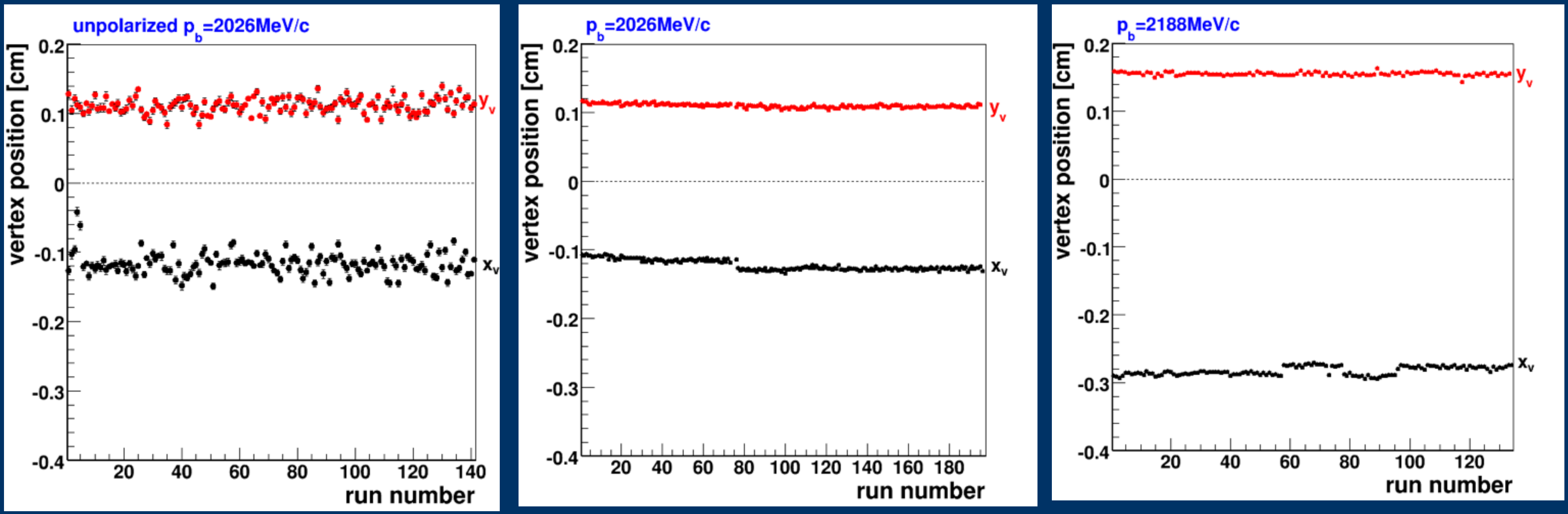



Experimental Data

# Step 1: polarization determination

(Vertex position – systematic effects studies)

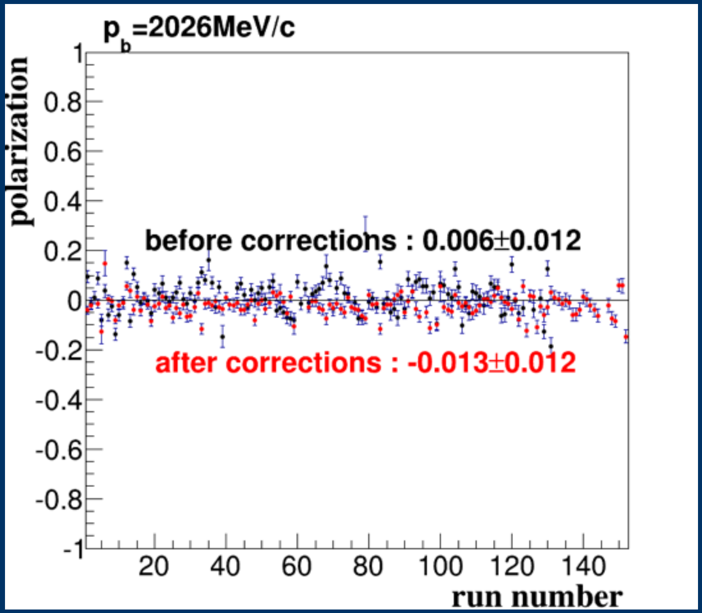
Based on the MC simulations we have determined the vertex position in our experiment.




Vertex position is stable for whole beam run

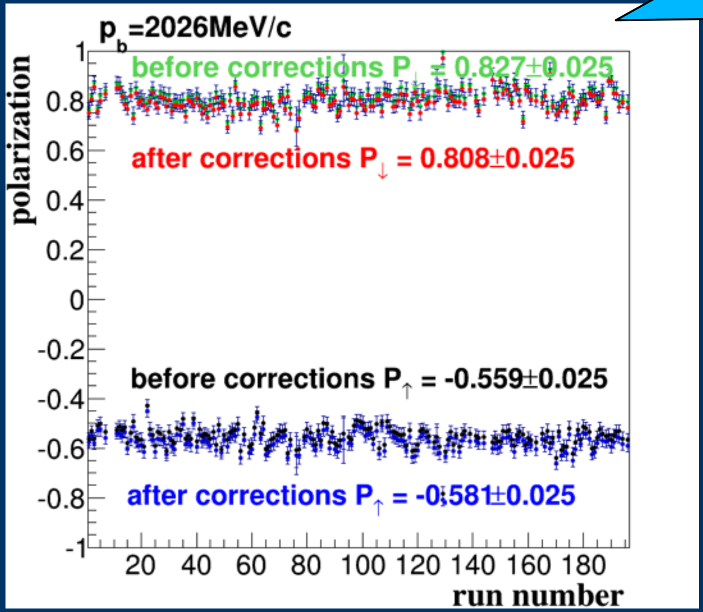
| vertex | unpolarized $P_{beam}$ = 2.026 Gev/c | $P_{beam}$ = 2.026 Gev/c | $P_{beam}$ = 2.188 Gev/c |
|---|---|---|---|
| $x_v$ | -0.1164±0.0052 | -0.1230±0.0011 | -0.2834±0.0010 |
| $y_v$ | 0.1119±0.0052 | 0.1099±0.0011 | 0.1551±0.0010 |

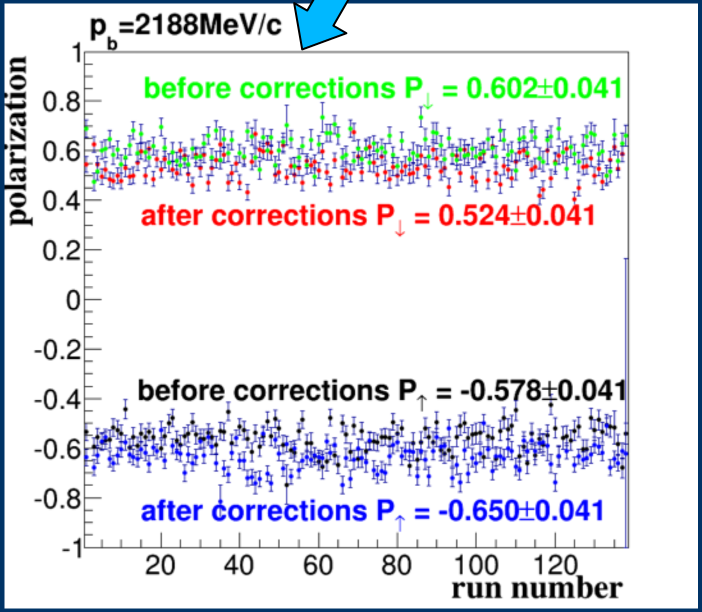
# Step 1 : Results for polarization




Not polarized control sample (P = 0)

Polarization very stable over the whole beam run (2 weeks)



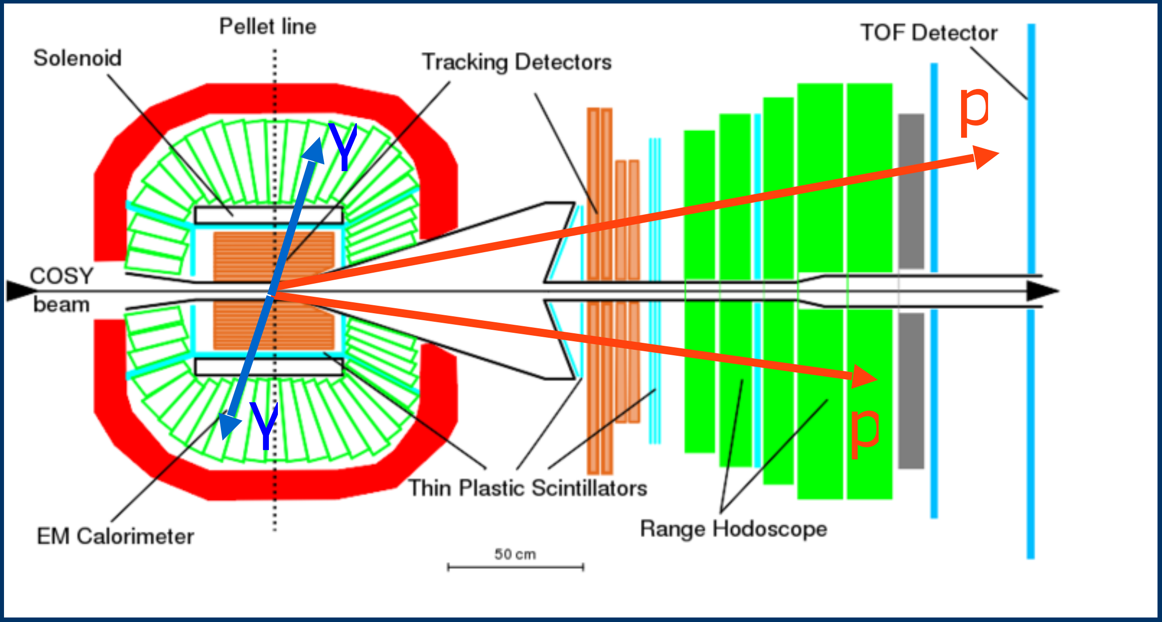
# Step 2 : η identification

Analysis has started. We search for the reaction chain:

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

We did the basic preselection of events under the condition:

2 charged particles in FD and >= 2 neutral particles in CD



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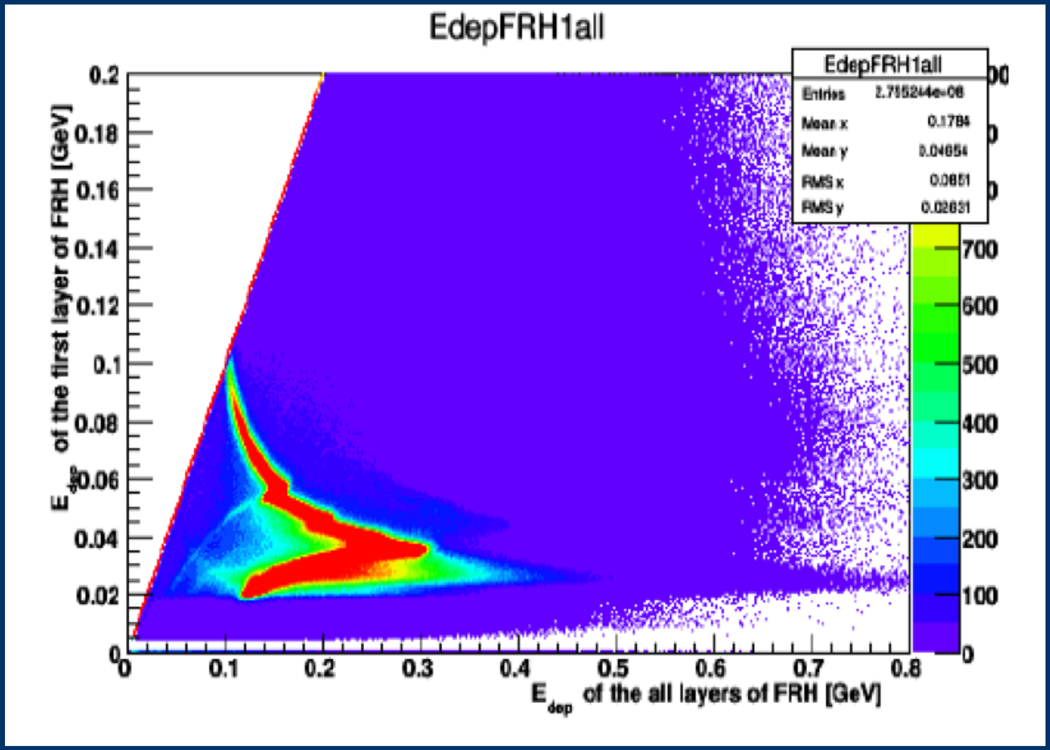
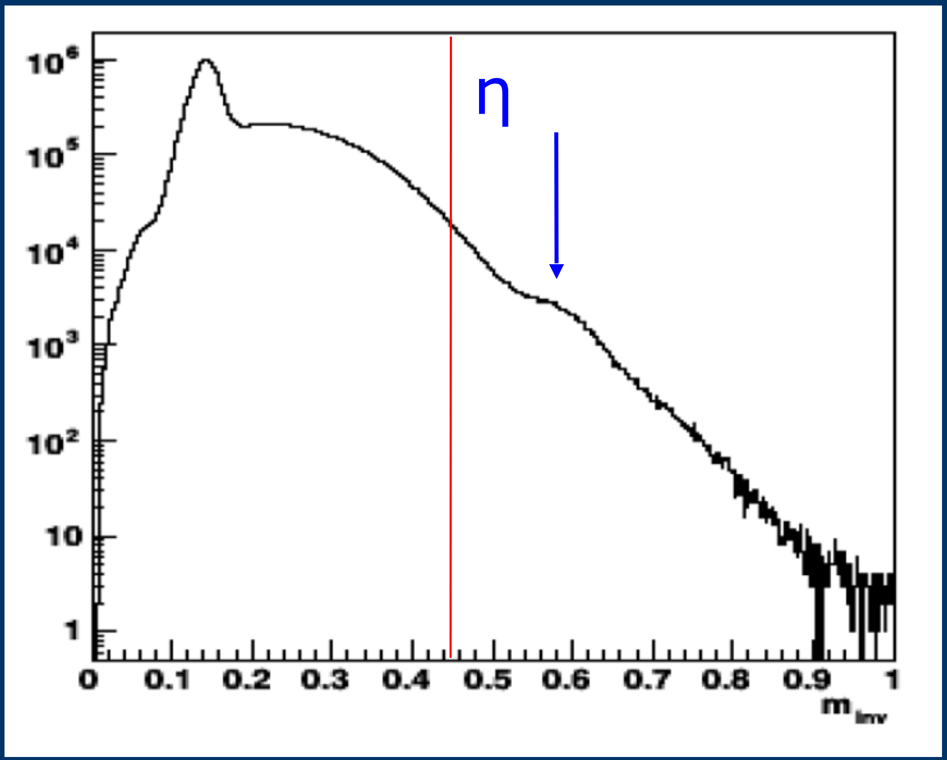


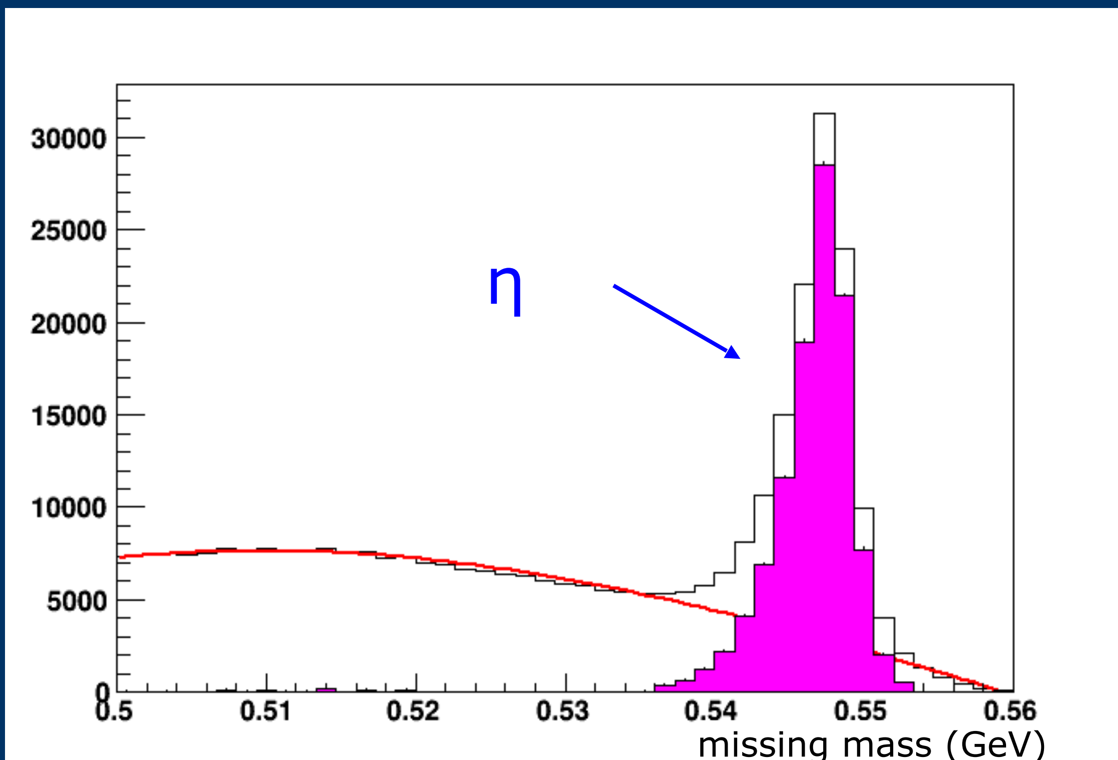

Selection of protons in FD (by dE-E method)




Selection of 2 gamma in CD (invariant mass)

# Step 2 : η identification

$\vec{p}p \longrightarrow pp\,\eta$ → Y Y




With COSY-11 we had 2000 η mesons

now

with WASA we have around **5◦10$^5$ η** mesons

Example missing mass from around 15% of all data

# *Outlook and perspective*

- The polarization studies are finished

- Now we are evaluating the luminosity

- and at the same time will be finishing the η selection

- Calculation of the Ay value

- Confrontation of the results with the theoretical prediction

Thank you!

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WASA-at-COSY
Collaboration

# Madison convention