Study of the η meson production with the polarized proton beam

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Plan

1. Motivation
2. Analyzing power
3. WASA-at-COSY
4. Asymmetry measurement
5. Vertex position studies
6. Polarization
7. Eta meson
8. Outlook

Motivation

- dynamics of the η meson production in pp->ppη reaction
- interaction of the η meson with nucleons

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

We would like to learn about it from the measurements of A_y

Analyzing Power

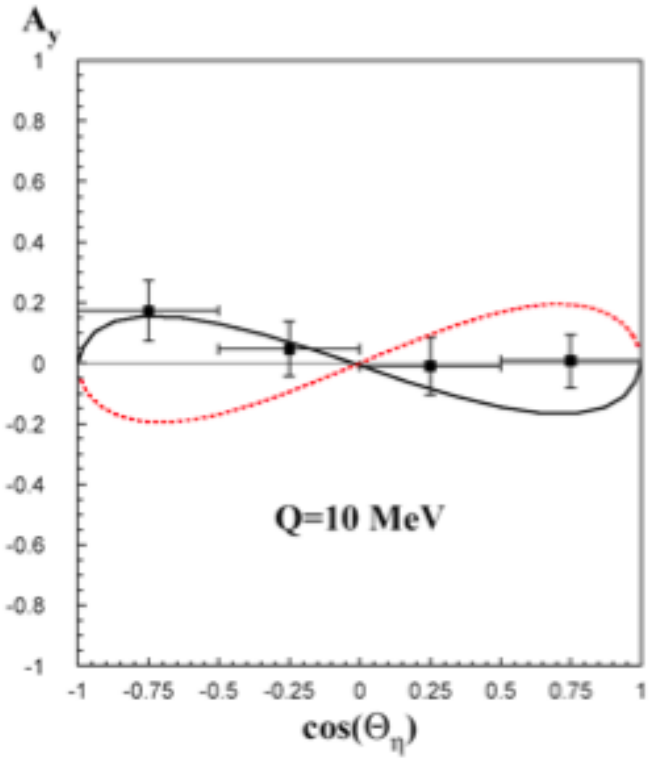
$$\sigma(\theta,\varphi) = \sigma_0(\theta) \cdot (1 + \sum_{i=1}^{3} P_i A_i(\theta,\varphi))$$ ⟸ **P ≠ 0**

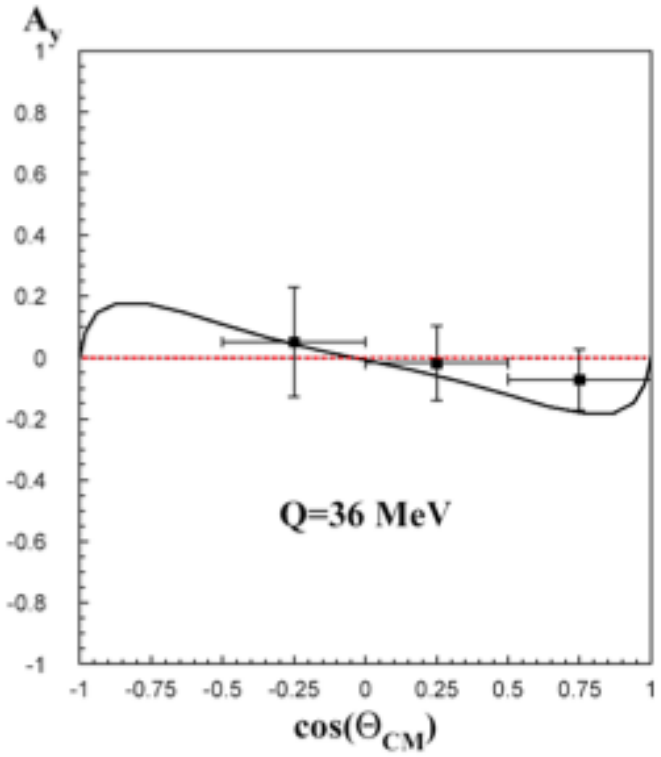
$\sigma(\theta,\varphi)$ Differential cross section with polarisation
$\sigma_0(\theta,\varphi)$ Differential cross section without polarisation

$$\sigma(\theta,\varphi) = \sigma_0(\theta)$$ ⟸ **P = 0**

- A_y vector analyzing power may be understood as a measure of the relative deviation between the differential cross section for the experiments with and without polarized beam.

COSY-11 result



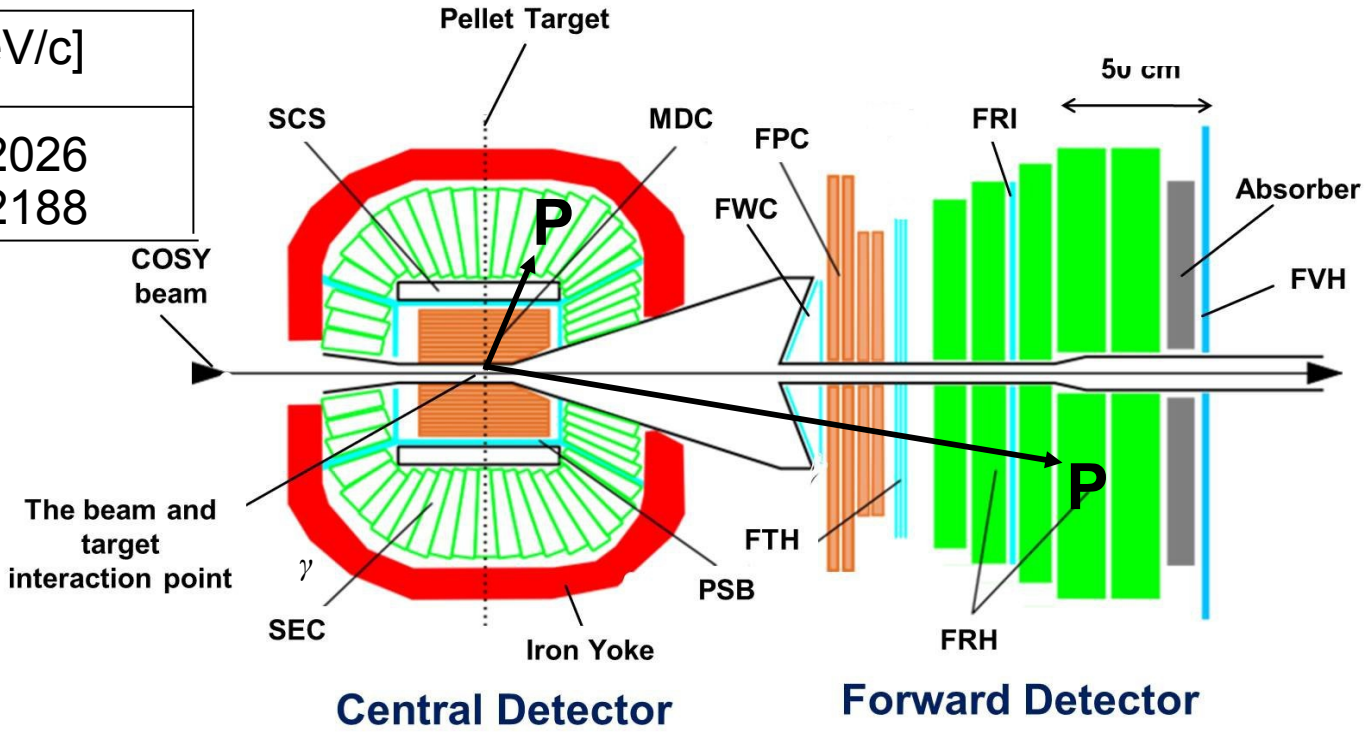


- The best result so far..**2000 events**.
- Current experiments at COSY are either **limited** by acceptance or resolution for the extension of the meson production studies.

P. Winter and R. Czyz˙ykiewicz et al., e-print arXiv: nucl-ex/0406034.
R.Czyzykiewicz at al., Phys.Rev.Lett. **98**, 122003 (2007)

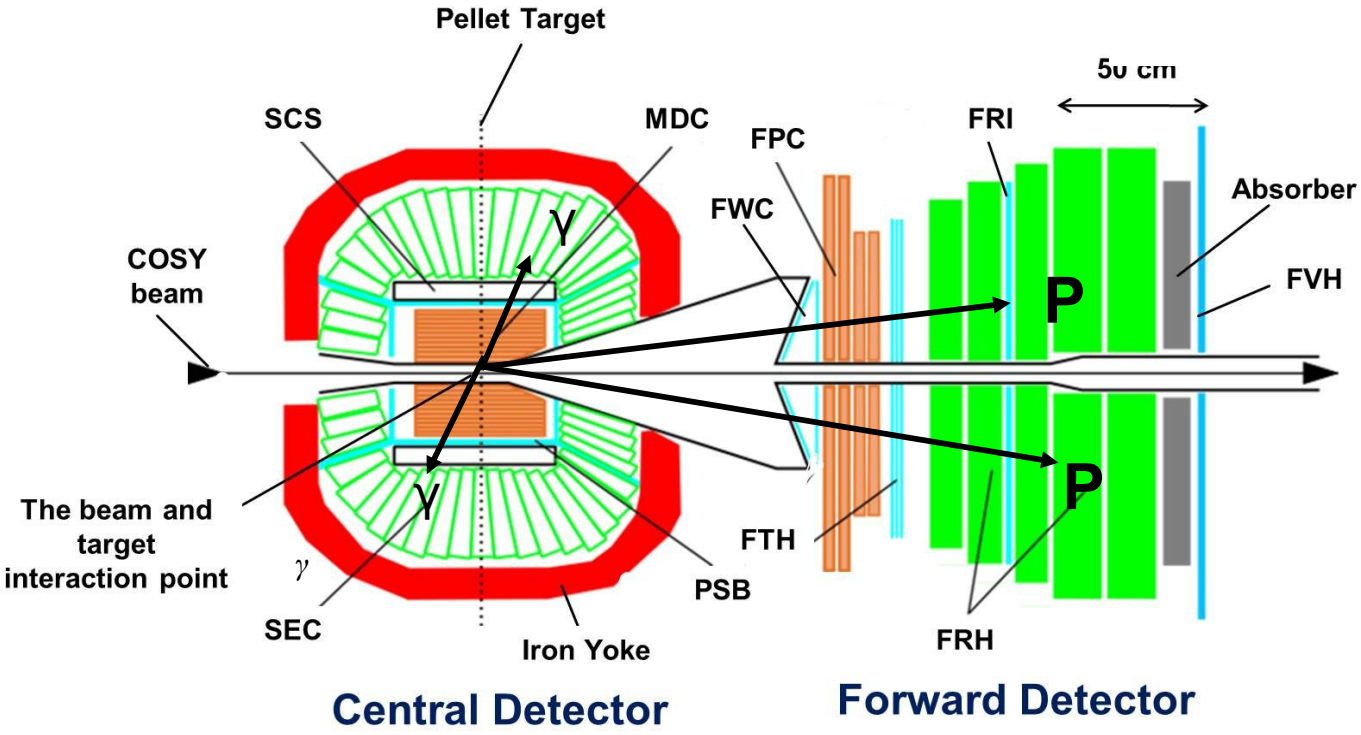
WASA Detector

Q [MeV]	P [MeV/c]
15	2026
72	2188



Protons from the pp->pp reaction are registered in the FD and CD

WASA Detector



Protons from the pp->ppη reaction are registered in the Forward Detector (FD), and photons from η meson decay are detected in the electromagnetic calorimeter(CD)

Analysis steps

1 For $\vec{p}p$ -> pp: we know A_y (EDDA)

we calculate Polarization P

2 For $\vec{p}p$ ->ppη: we measure

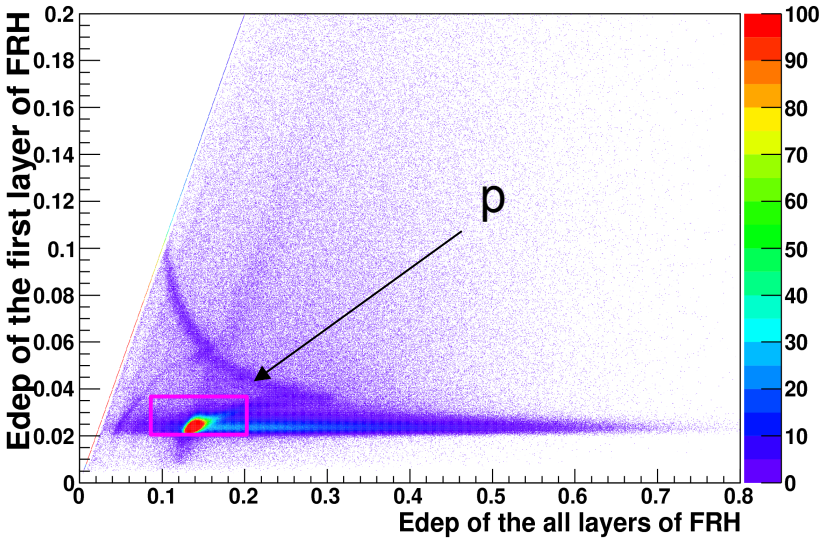
$N_\eta(\theta, \varphi)$ $N_\eta(\theta, \varphi + \pi)$

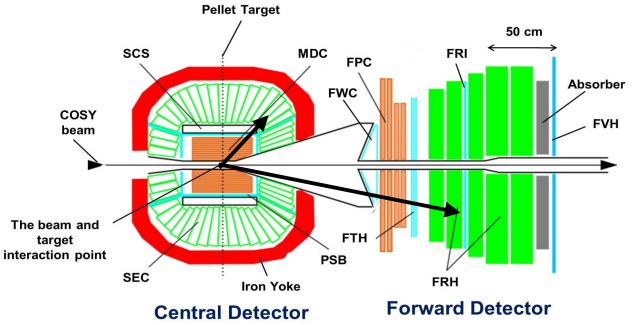
we calculate A_y

$$A_y(\theta) \equiv \frac{1}{P cos\varphi} \cdot \frac{N(\theta, \varphi) - N(\theta, \varphi + \pi)}{N(\theta, \varphi) + N(\theta, \varphi + \pi)}.$$

Determination of the pp elastic scattering

FD: - one charge particle

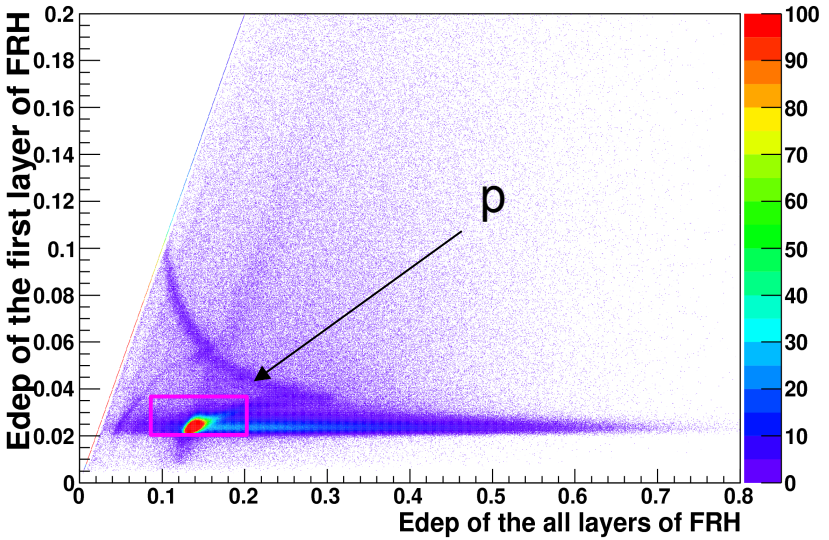


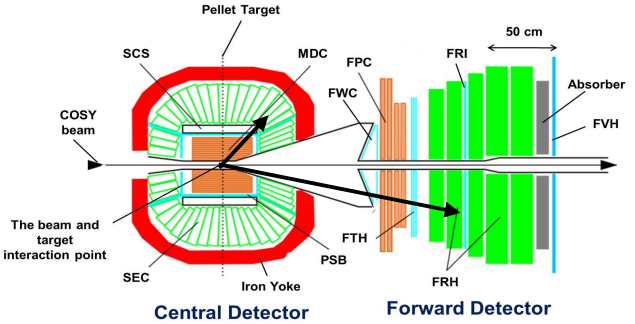


CD: - one charge particle

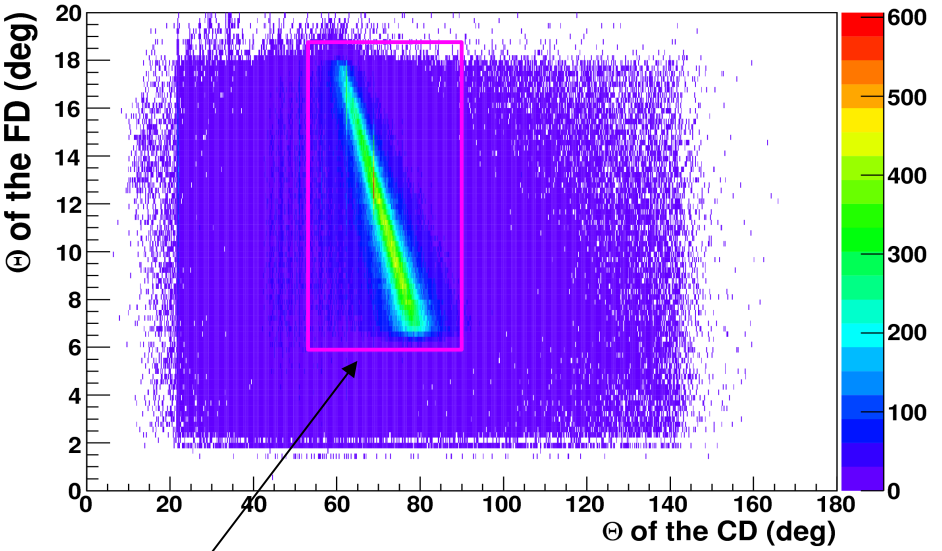
Determination of the pp elastic scattering

FD: - one charge particle



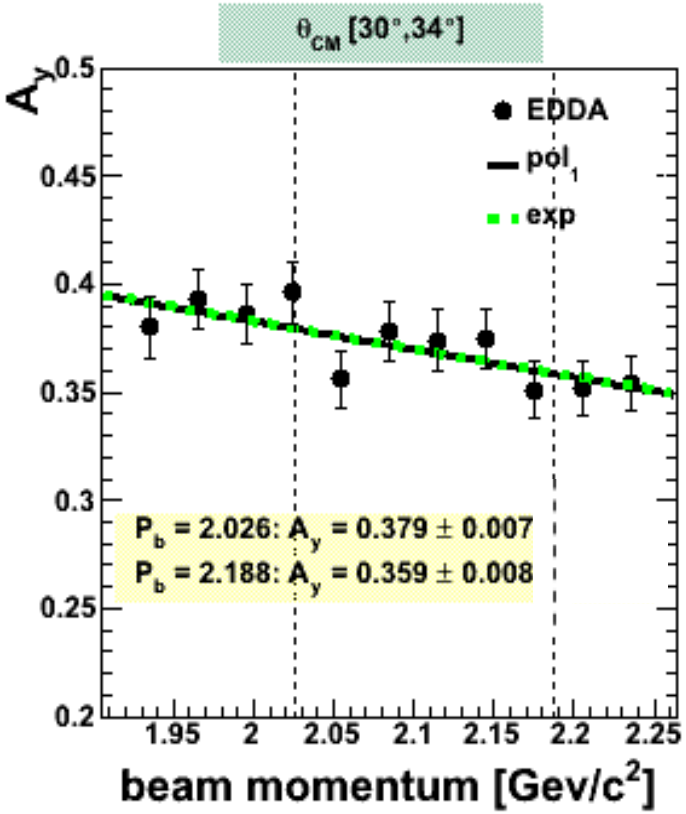


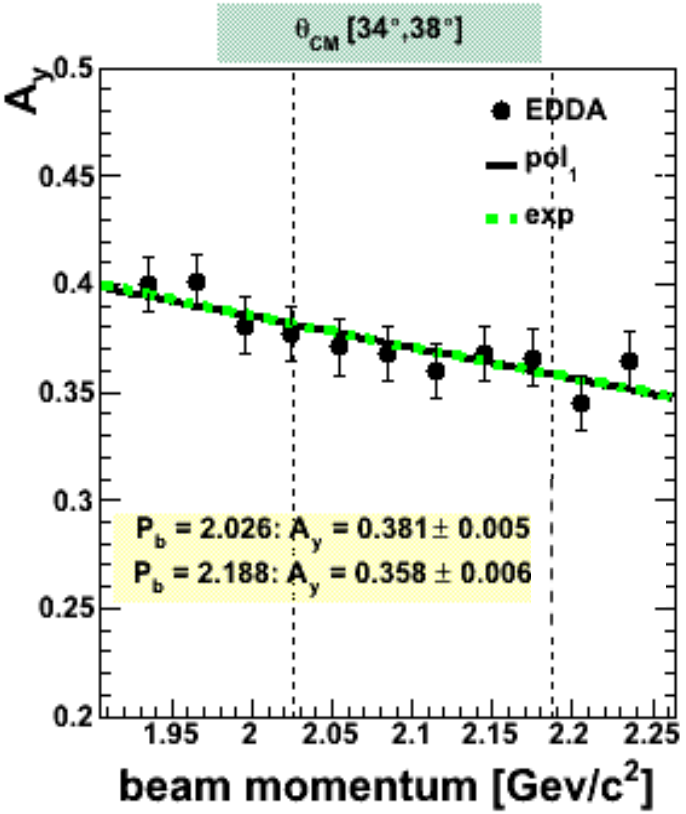
CD: - one charge particle



Elastic scattered protons

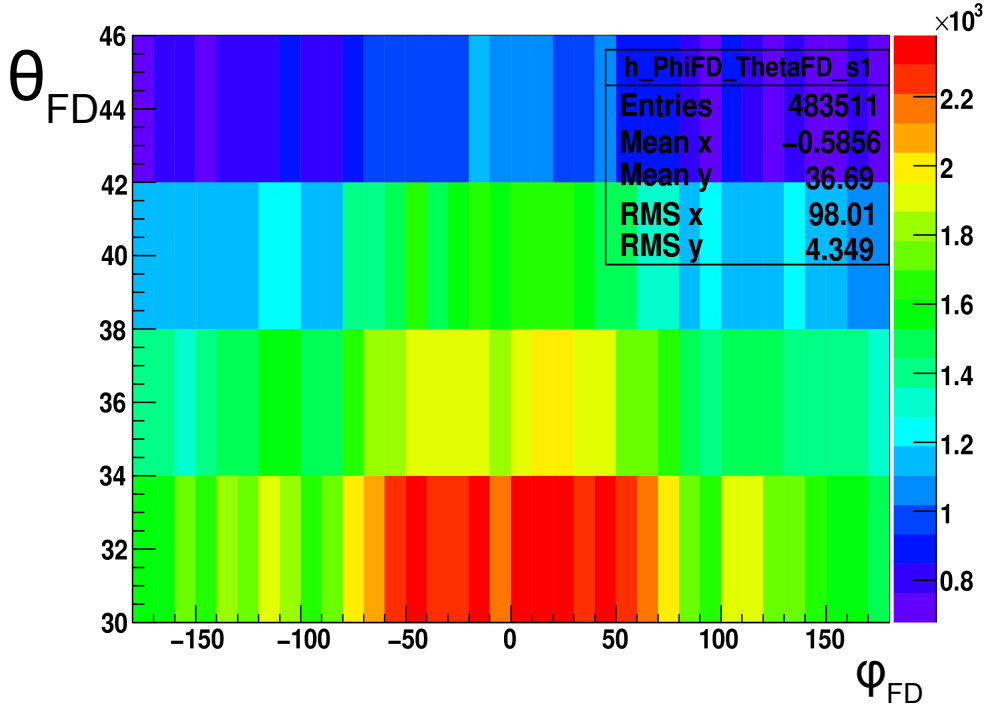
A_y from EDDA


θCM [30°,34°]
Ay
EDDA
pol1
exp
Pb = 2.026: Ay = 0.379 ± 0.007
Pb = 2.188: Ay = 0.359 ± 0.008
beam momentum [Gev/c2]

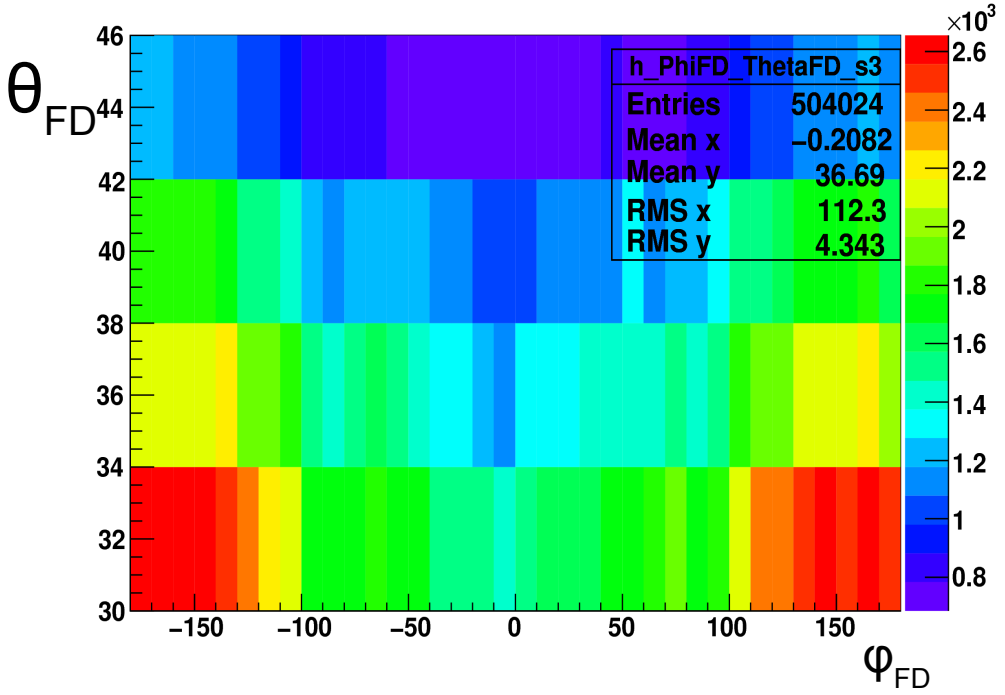

θCM [34°,38°]
Ay
EDDA
pol1
exp
Pb = 2.026: Ay = 0.381 ± 0.005
Pb = 2.188: Ay = 0.358 ± 0.006
beam momentum [Gev/c2]

Spin Up/Down measurements

Spin Up

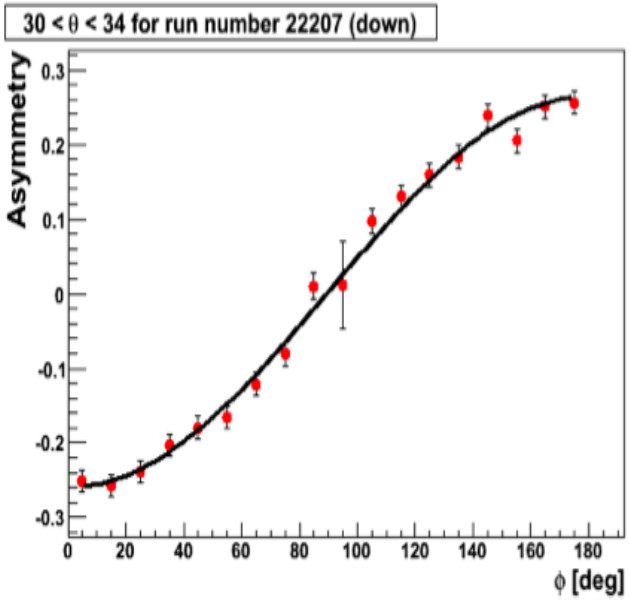


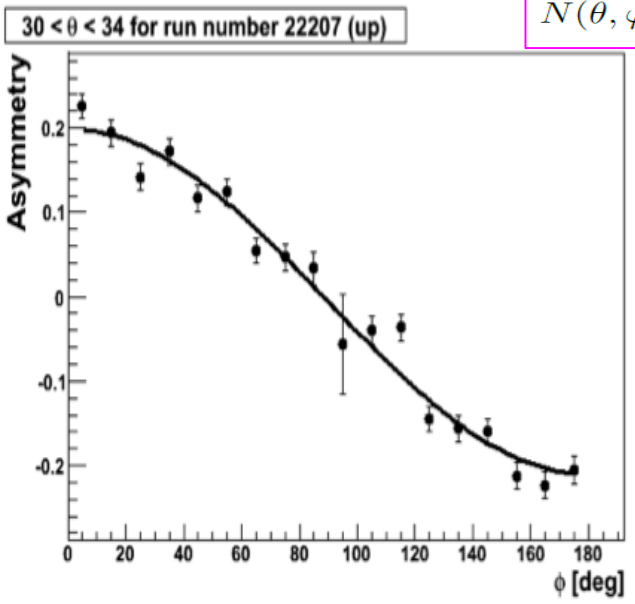
Spin Down

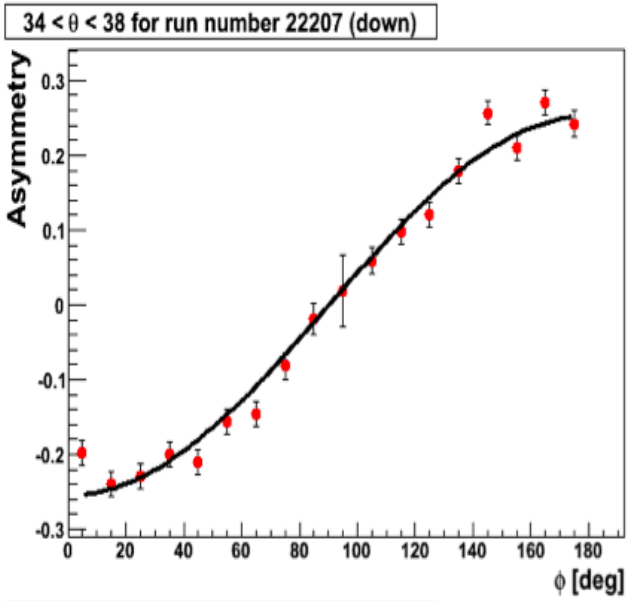


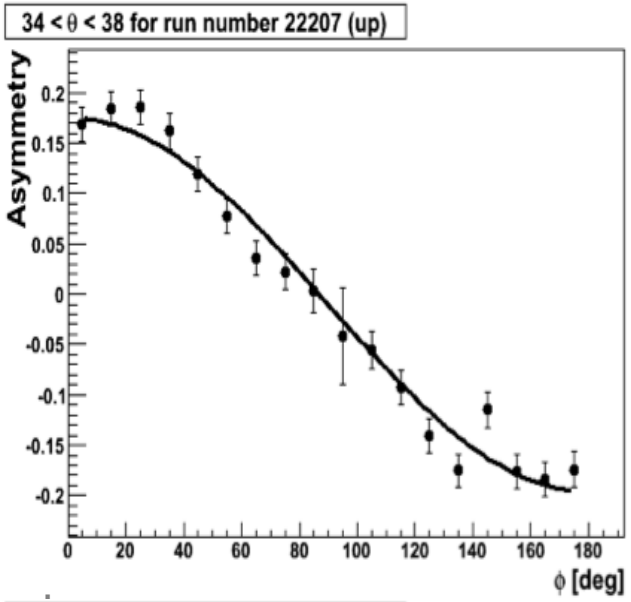
Asymmetry

$$\frac{N(\theta,\varphi) - N(\theta,\varphi+\pi)}{N(\theta,\varphi) + N(\theta,\varphi+\pi)} \equiv \epsilon(N(\theta,\varphi), N(\theta,\varphi+\pi))$$









$$Asymmetry \equiv P \cdot \cos\varphi \cdot A_y$$

$$Asymmetry \equiv a \cdot \cos\varphi$$

$$a \equiv A_y \cdot P$$

$$P \equiv \frac{a}{A_y}$$

preliminary

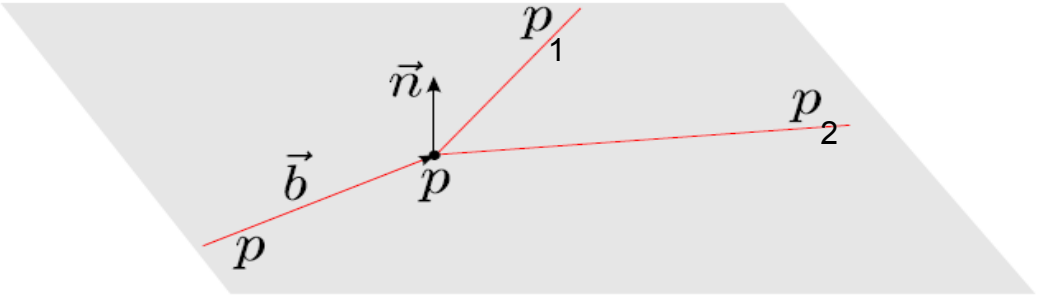
Vertex position (Systematics studies)

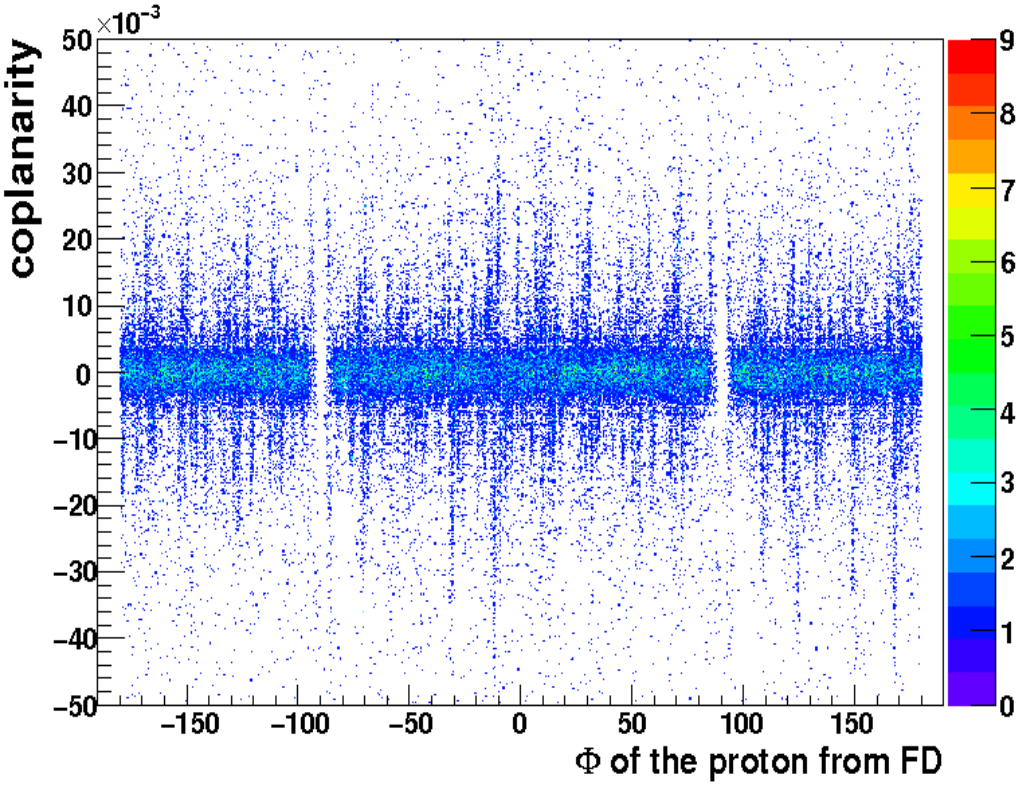
Coplanarity method

$d(\phi_d)$ method

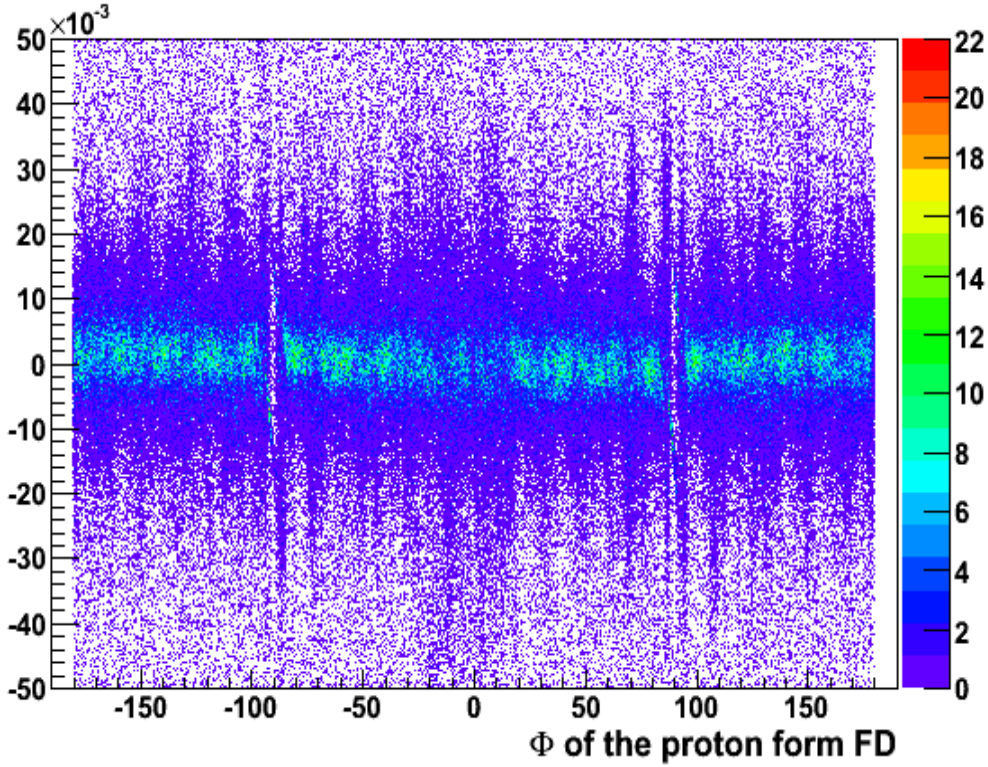
Vertex position determination:
coplanarity

Coplanarity: $C = \dfrac{(\vec{p}_1 \times \vec{p}_2) \cdot \vec{p}_{beam}}{|\vec{p}_1 \times \vec{p}_2| \cdot |\vec{p}_{beam}|}$,



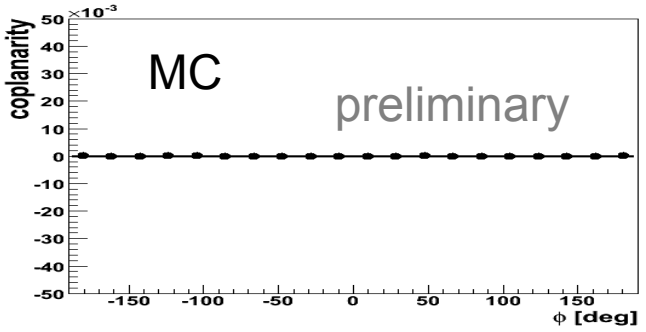


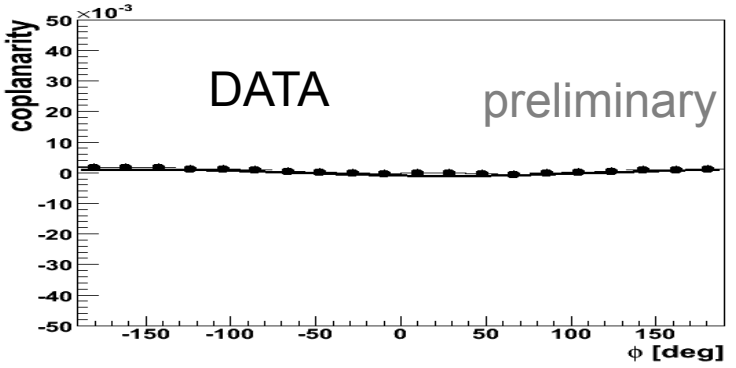
MC



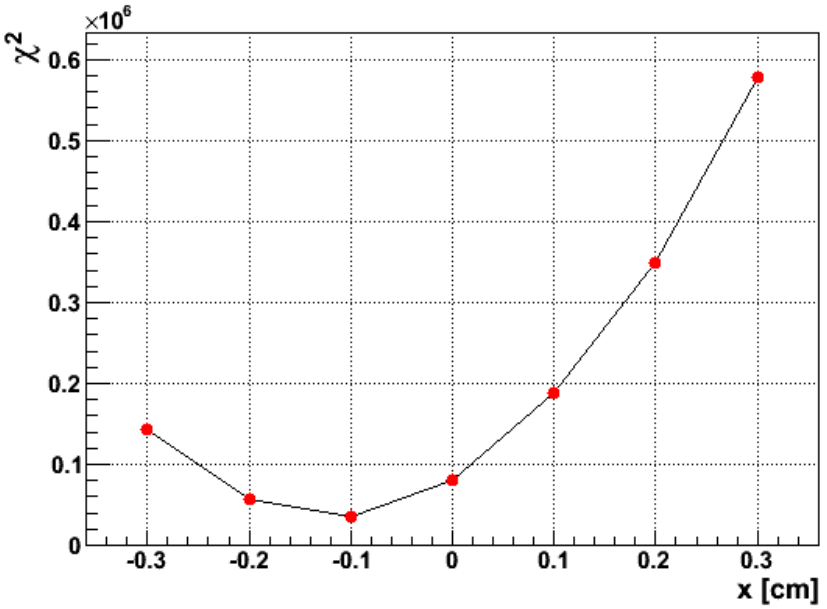
DATA

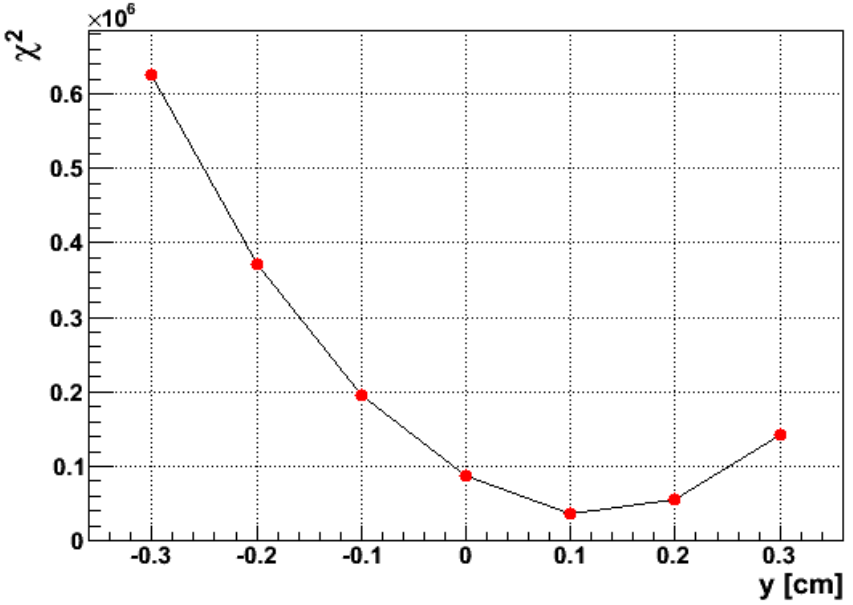
Vertex position determination:
coplanarity





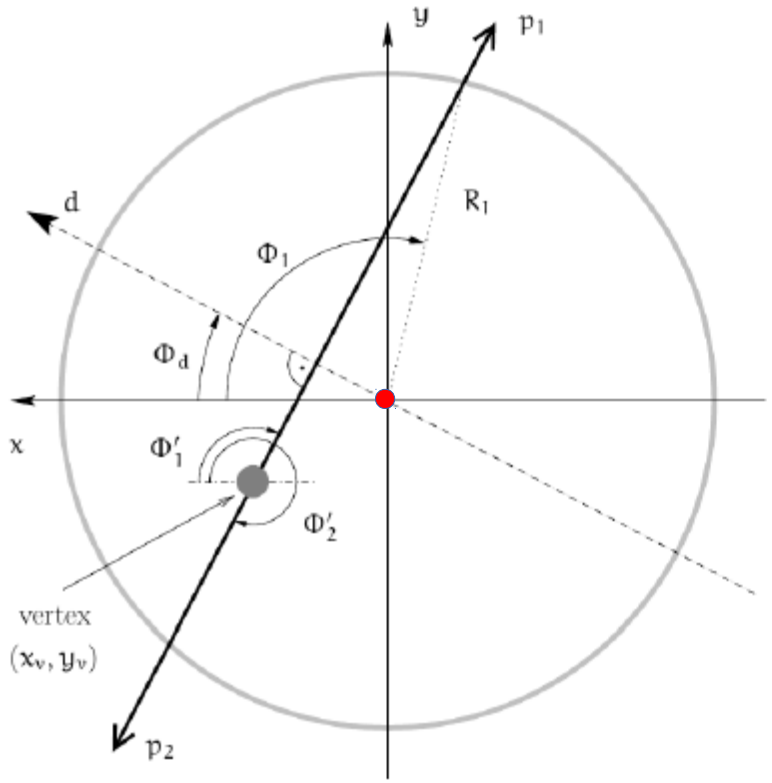
$$\chi^2 = \sum_i \frac{(M_i^{MC} - M_i^{exp})^2}{(\sigma_i^{exp})^2}$$





Vertex position determination: $d(\phi_d)$ method

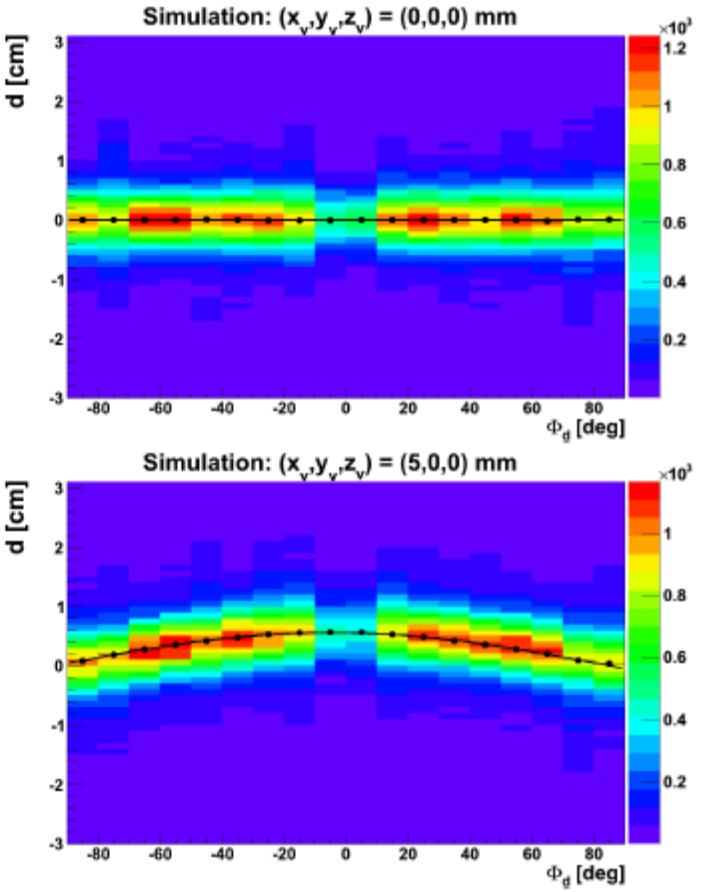
x and y vertex coordinates, the method



$$d = x^{vertex}\cos(\phi_d) + y^{vertex}\sin(\phi_d)$$

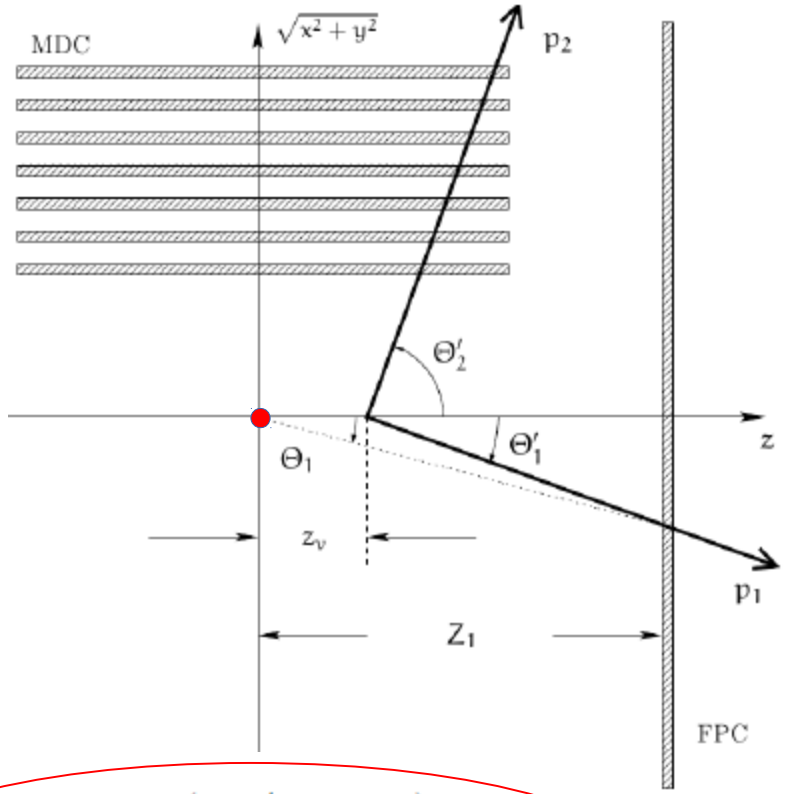
Fit

MC



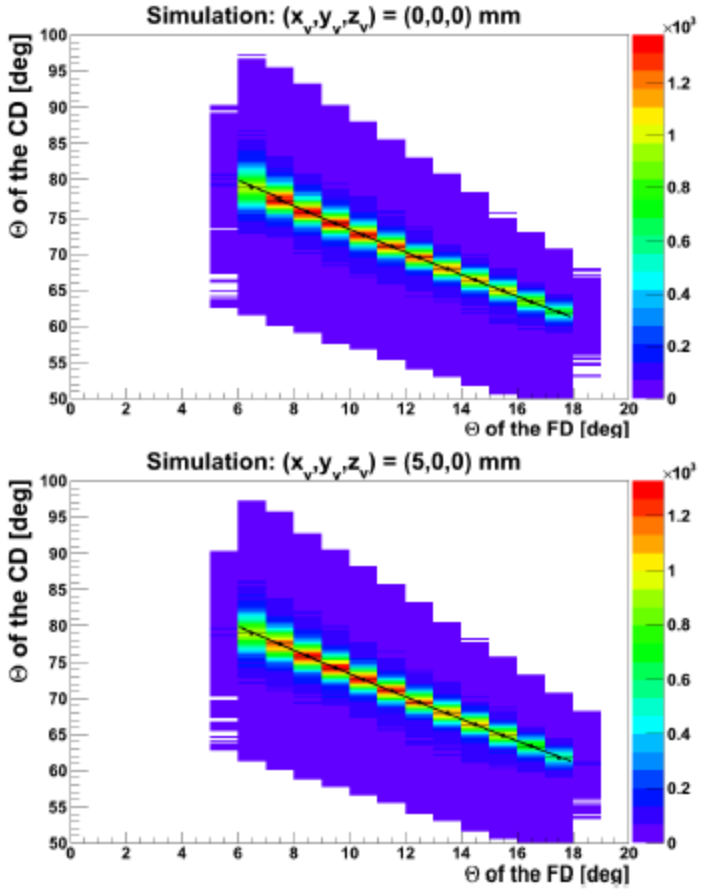
Vertex position determination: $d(\phi_d)$ method

z-vertex coordinate, the method



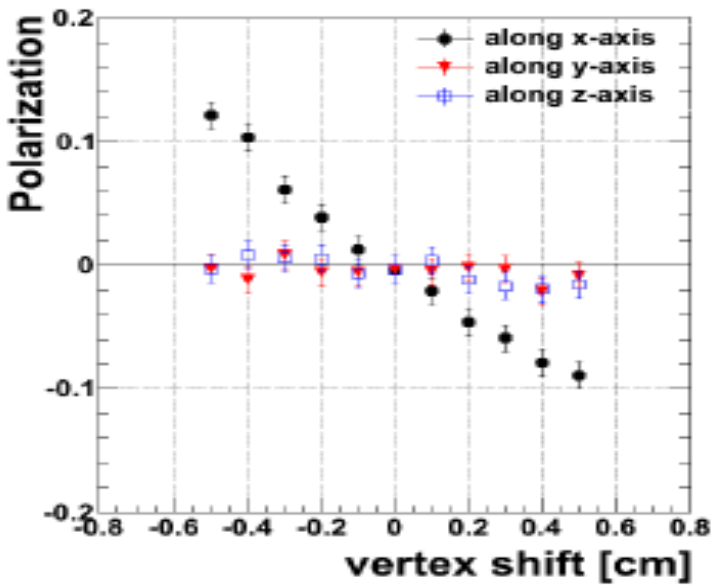
$$tg(\theta_2') = \frac{1-(z^{vertex}/z_{FTH})}{tg(\theta_1)} \bullet \gamma^2_{CMS}$$

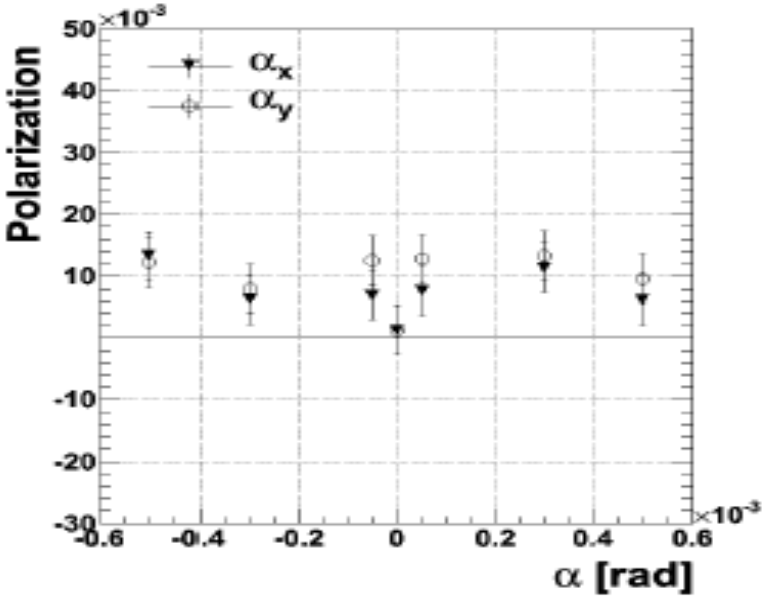
MC



Fit

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

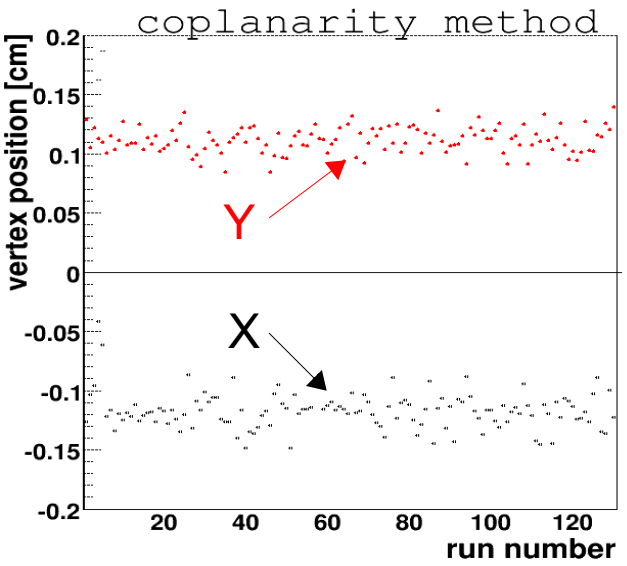




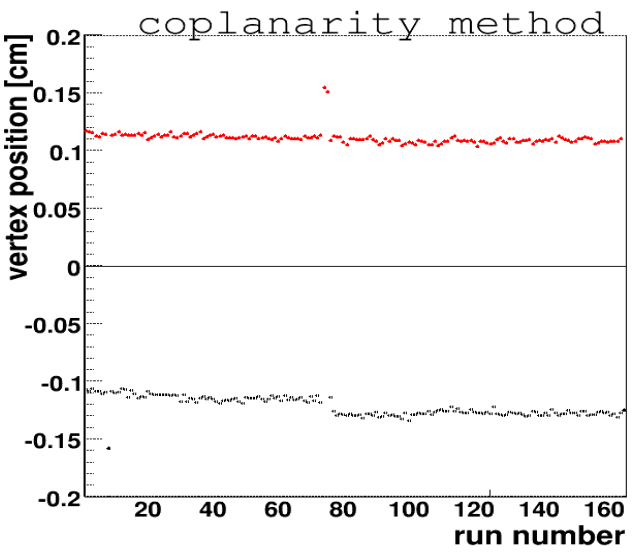
The study concluded that to have systematic uncertainty of the polarization smaller than 0.03, we need to control the position of the interaction point with a precision better than 1 mm

Result of vertex position

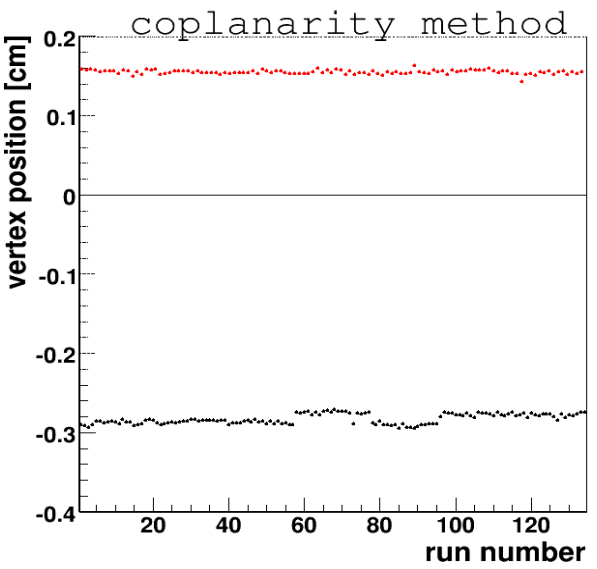
Unpolarized

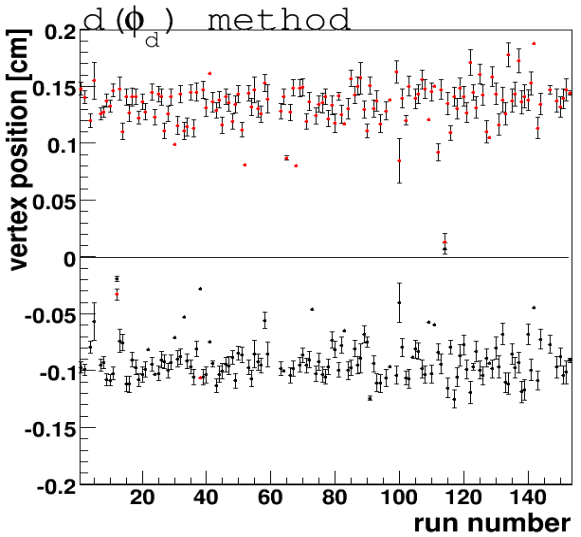


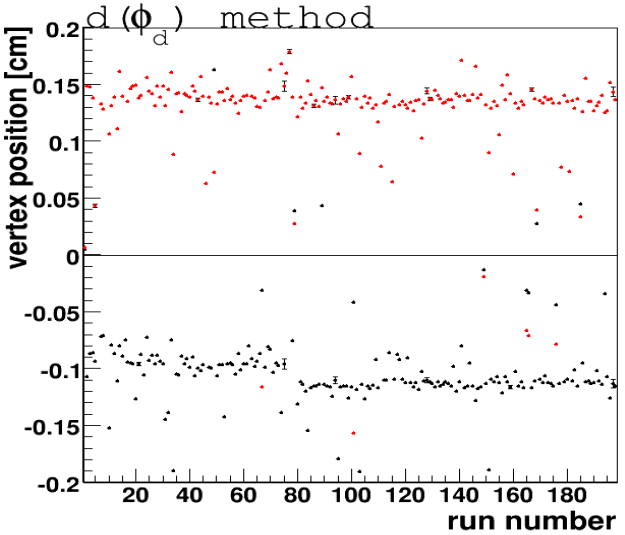
2026 MeV/c

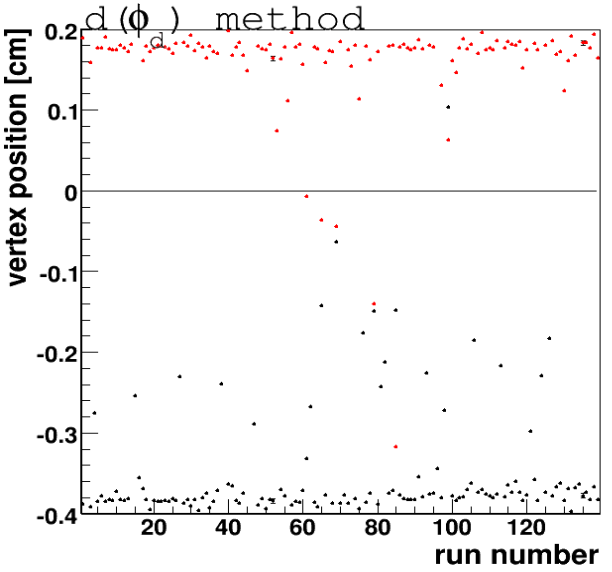


2188 MeV/c

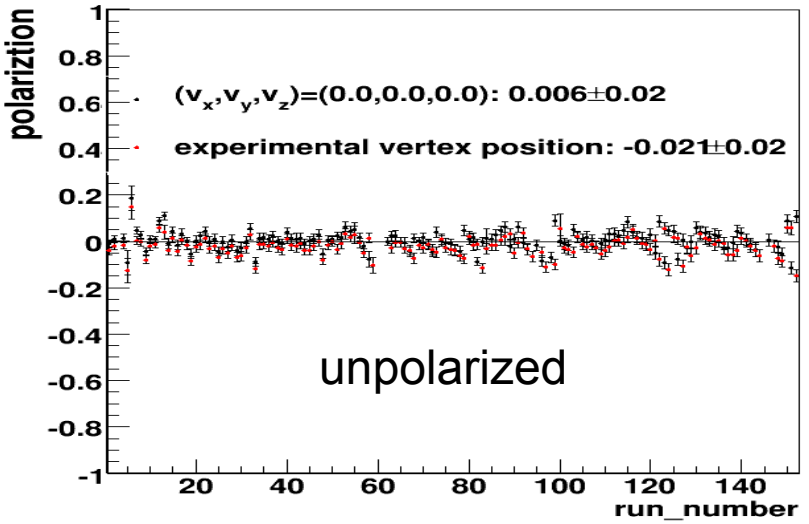




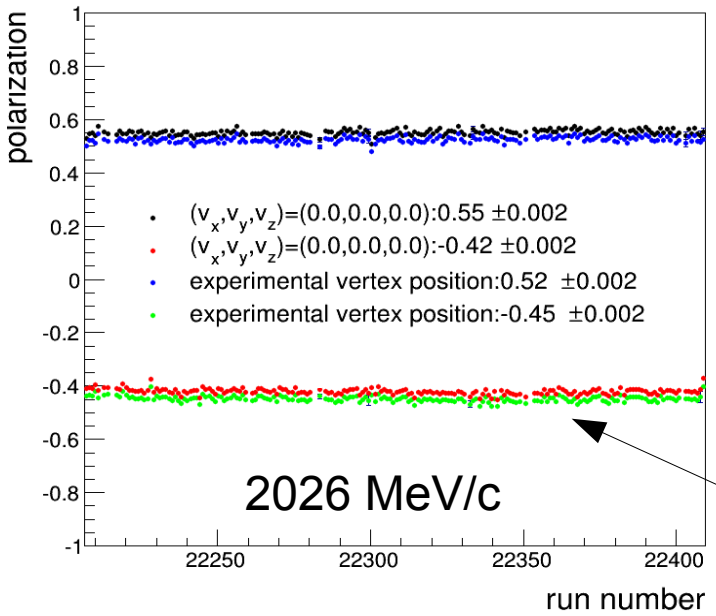




Polarization

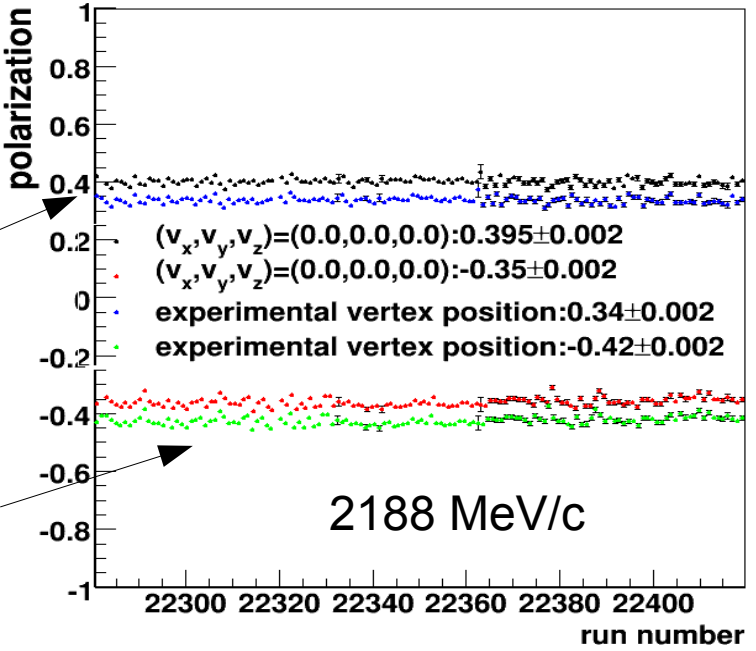


Stable polarization
In time



Spin up

Spin down



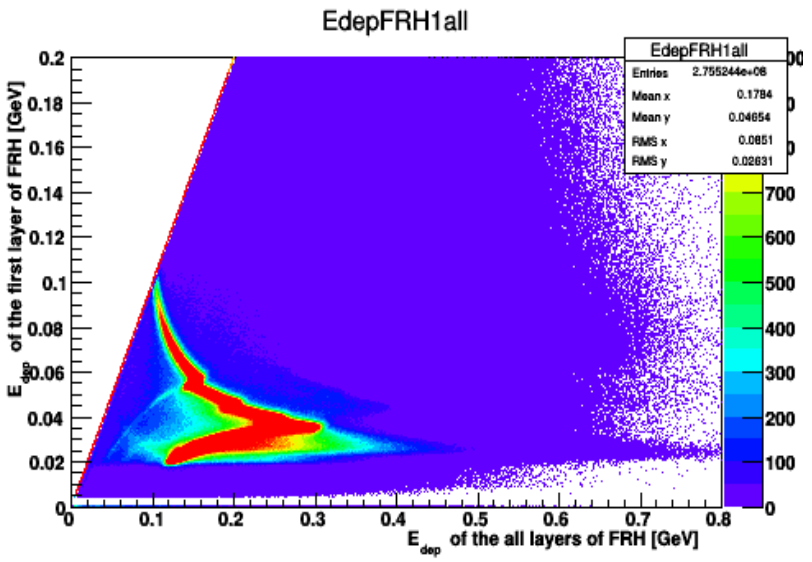
Eta meson

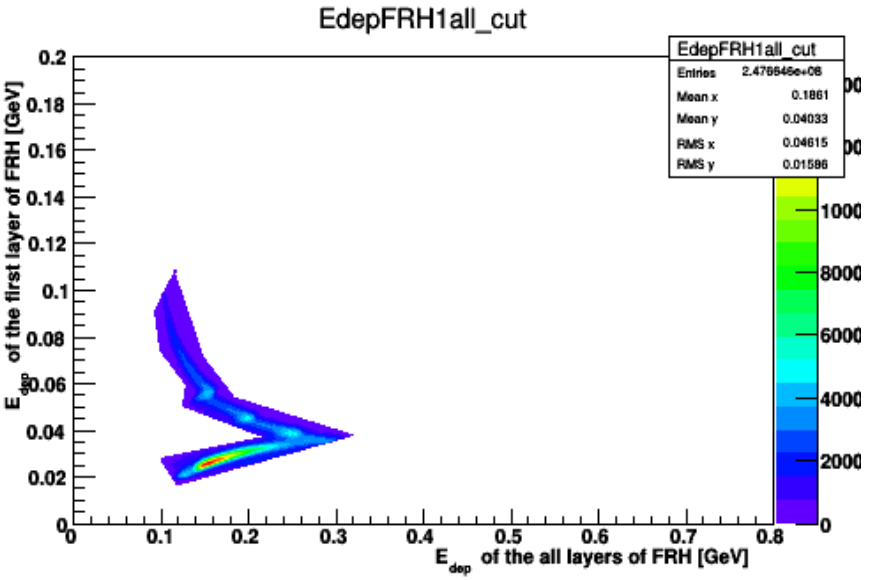
preselection

1. Only 2 charge in the FD;

2. More then 2 neutral in the CD;

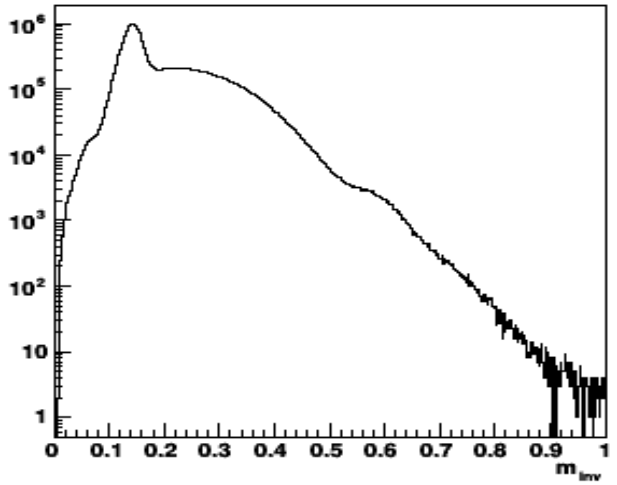
Cut for the protons

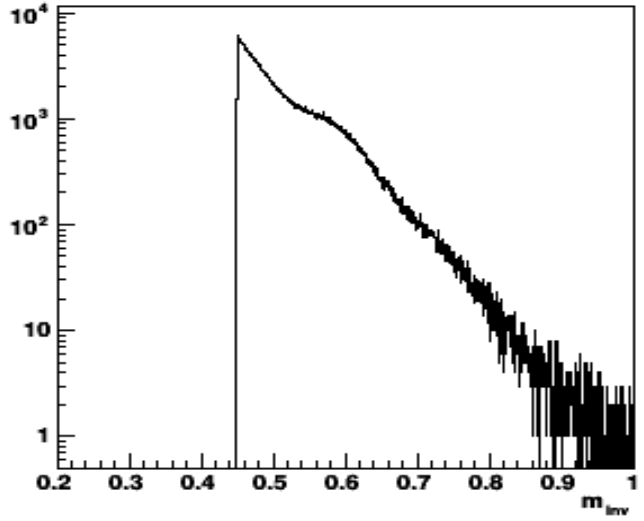




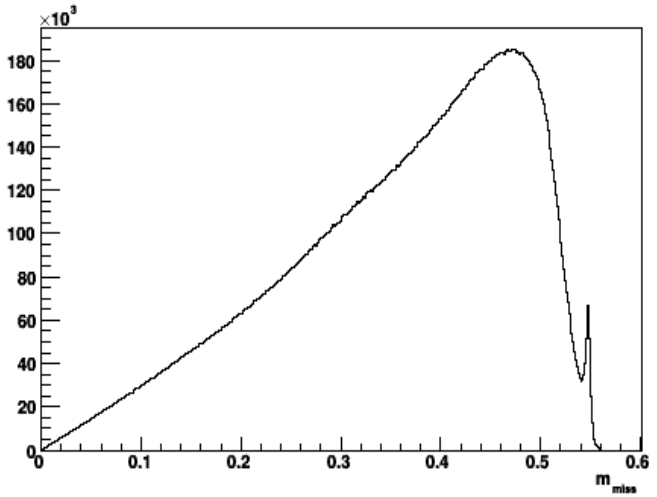
Eta meson

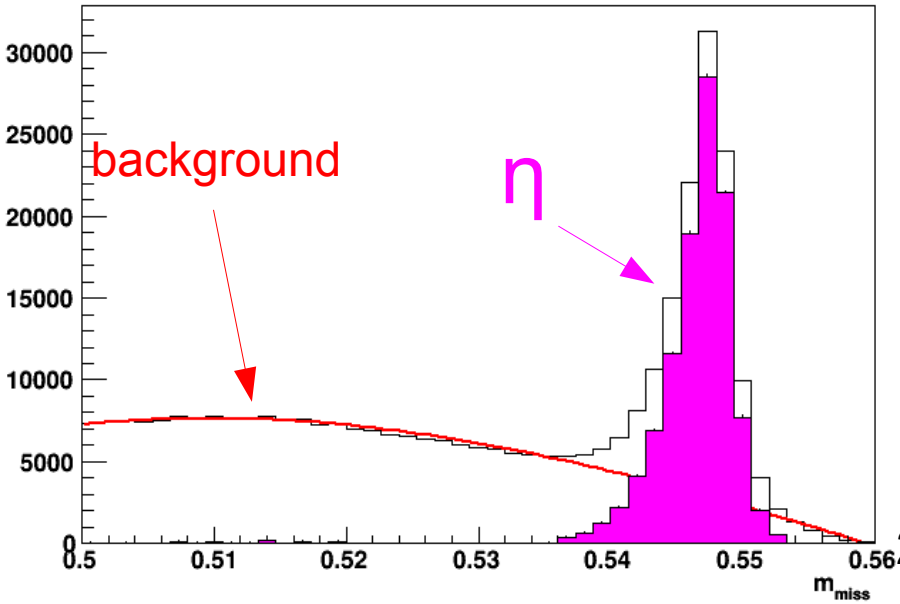
Invariant Mass of η-data





Missing Mass of pp data





With the respect to the previous experiment we have statistics by the factor 250 more!

WASA detector have 4π acceptance, which will improve result !

Outlook

1. Calculation of the Analysing Power, A_y, for the $\vec{p}p$->ppη reaction

2. Luminosity

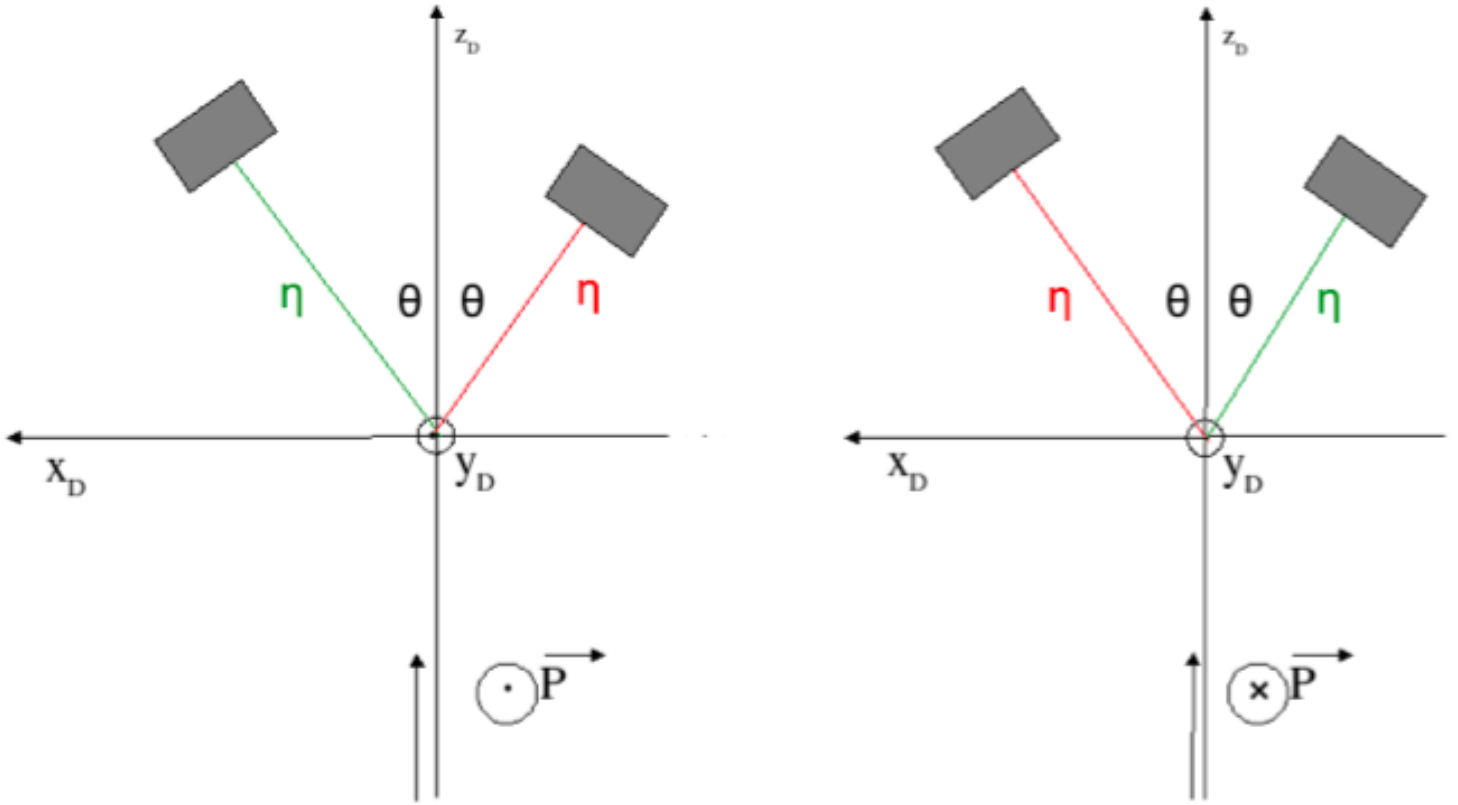
3. Interpretation of the result in the view of the production mechanism for $\vec{p}p$->ppη reaction

Thank You for Attention:)

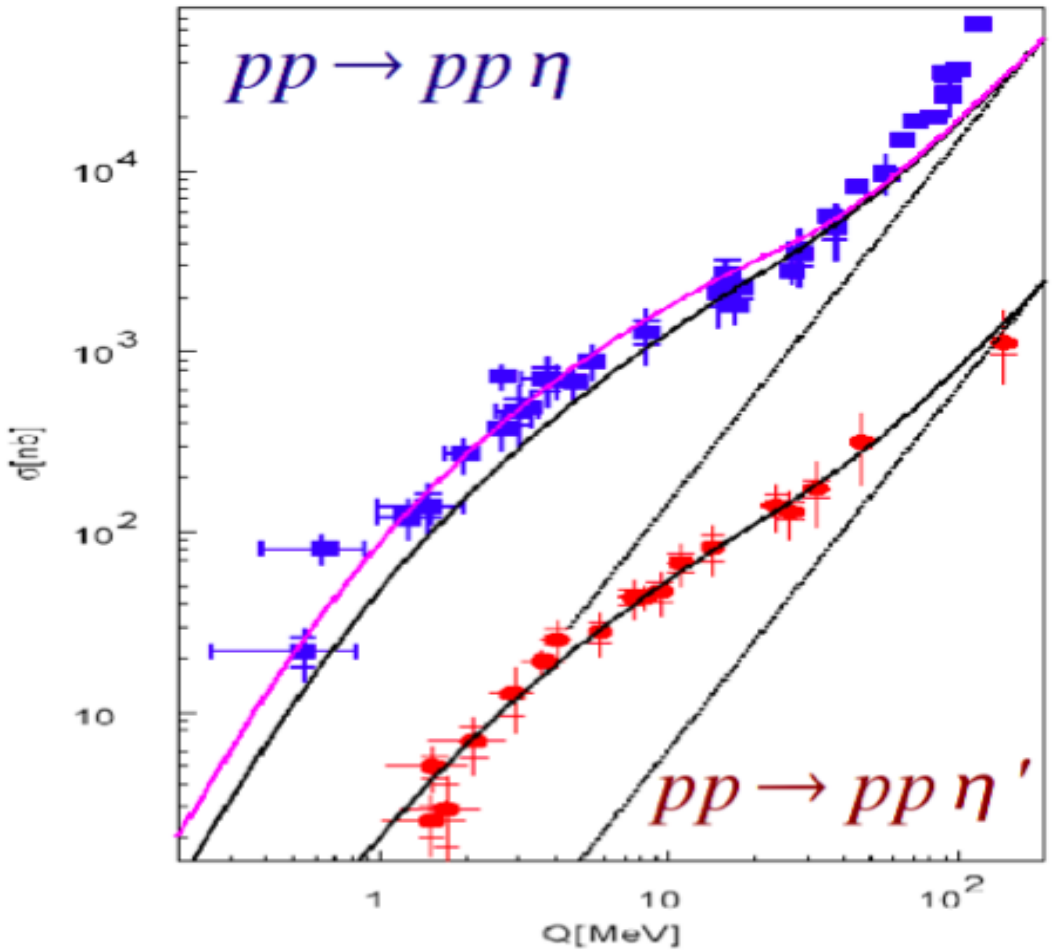
Madison convention

Madison: $N_+^{\uparrow}$ $N_-^{\uparrow}$ $N_-^{\downarrow}$ $N_+^{\downarrow}$

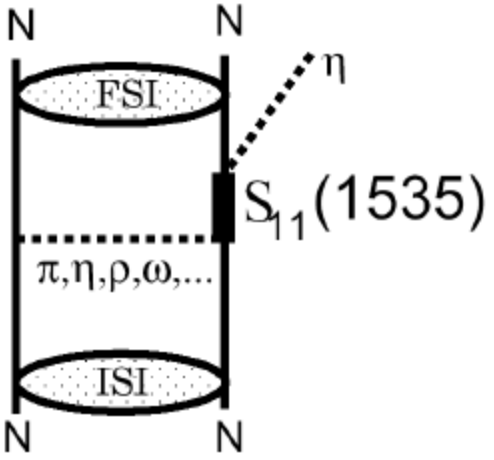
Detector: $N_L^{\uparrow}$ $N_R^{\uparrow}$ $N_L^{\downarrow}$ $N_R^{\downarrow}$



η meson production in pp collisions

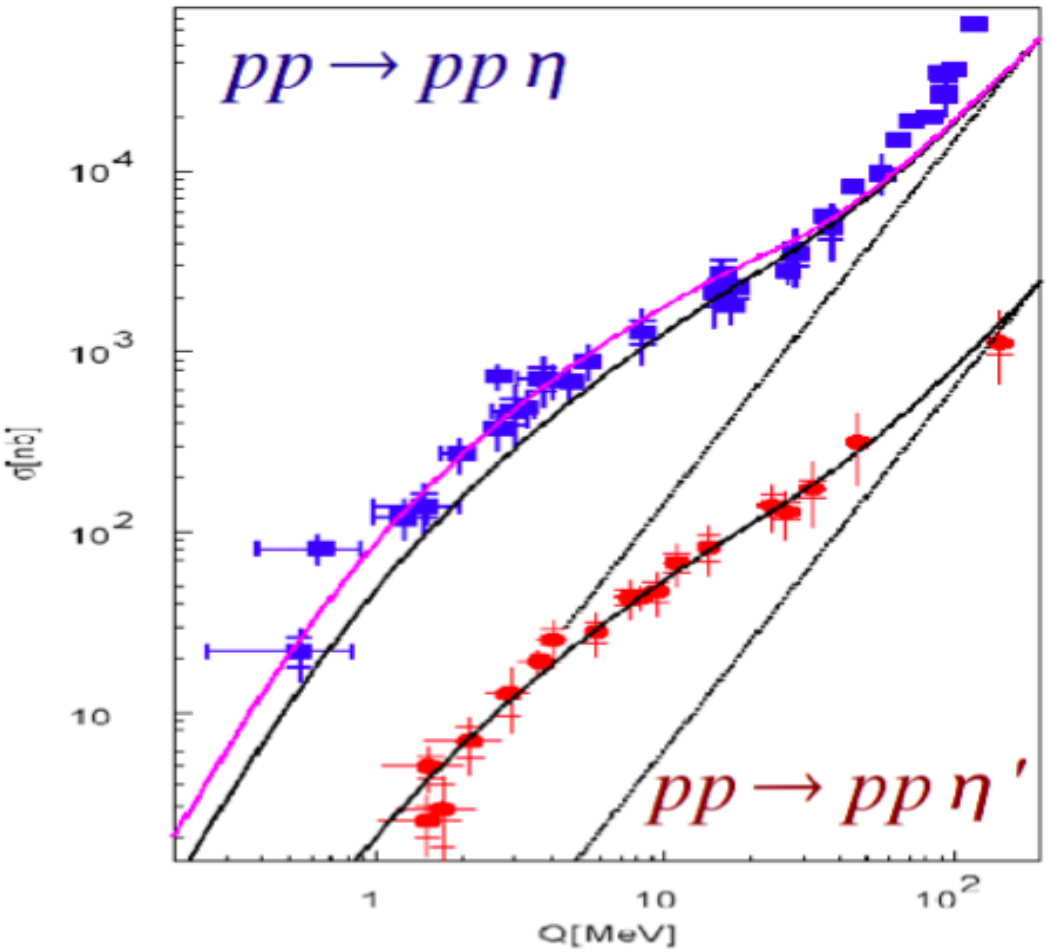


CELSIUS
COSY
SATURNE

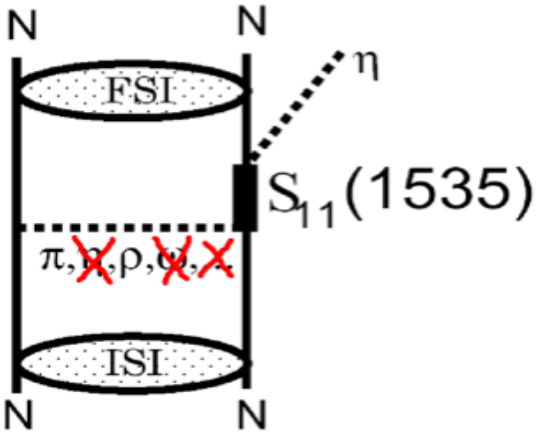


=> η meson production via exchange of isovector mesons

η meson production in pp collisions

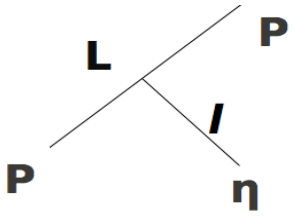


CELSIUS
COSY
SATURNE



=> η meson production via exchange of isovector mesons

Partial Wave Analysis



L: 0 1 2 ...
Wave: S P D ...

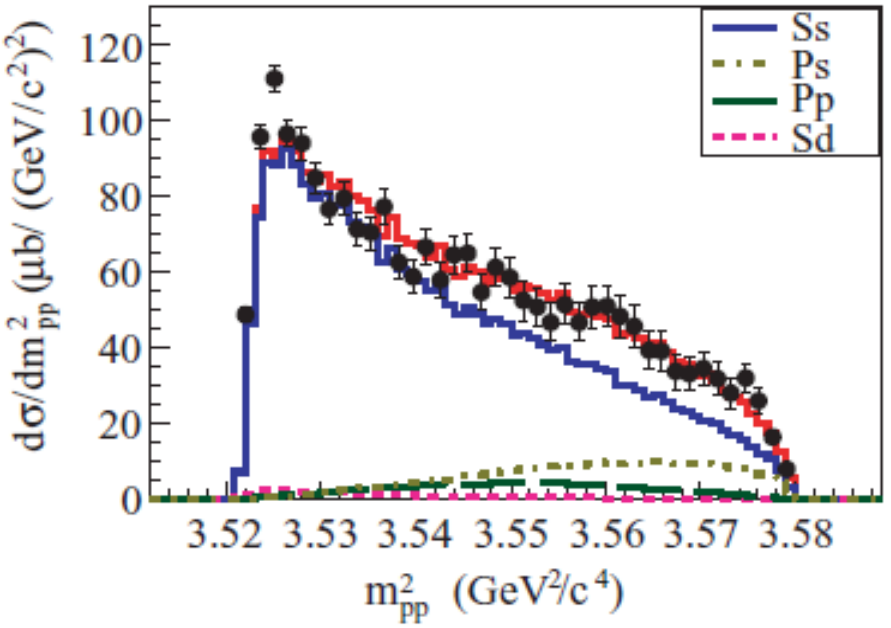
l: 0 1 2 ...
Wave: s p d ...

- 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, ..)

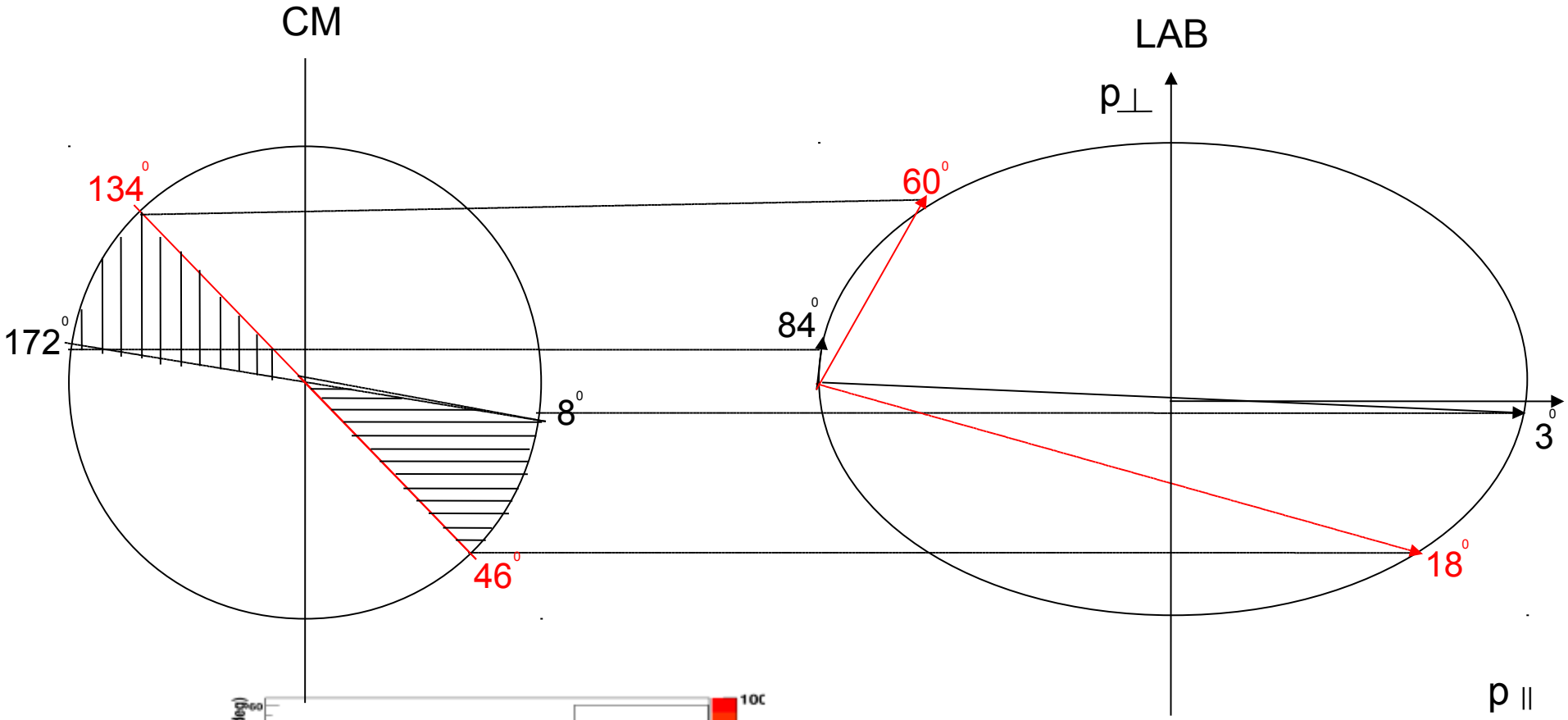
- analyzing power:
  - $A_y \sim \mathrm{Im}\{A_{Ss} A_{Sd}^*\} \sin\theta_\eta \cos\theta_\eta$
  - $A_y \sim \mathrm{Im}\{A_{ps} A_{Pp}^*\} \sin\theta_\eta$

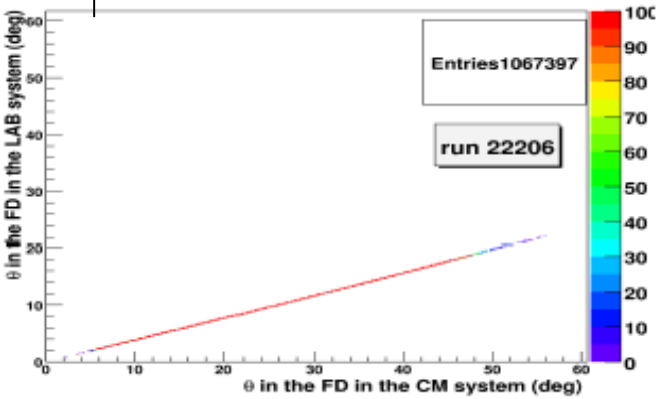


Our aim is to measure angular dependence of the analyzing power

COSY-11

Angular range of the detector (elastic scattering)





Theta LAB 11 deg = Theta 30 deg CM

EDDA data base Ay [32, 88]

Fit parameters for Asymmetry

Theta	A $\pm\sigma$A	B $\pm\sigma$B	P$\pm\sigma$P
$30 < \theta < 34$	0.2009±0.0058	-0.011±0.0042	0.5294±0.053
$34 < \theta < 38$	0.1997±0.0063	-0.0031±0.0045	0.5188±0.05
$38 < \theta < 42$	0.197±0.0070	-0.016±0.0050	0.5218±0.046
$42 < \theta < 46$	0.1925±0.0087	-0.008±0.0062	0.5218±0.051

Spin up

Theta	a $\pm\sigma$a	b $\pm\sigma$b	P$\pm\sigma$P
$30 < \theta < 34$	-0.255±0.0059	-0.0024±0.0043	-0.6719±0.066
$34 < \theta < 38$	-0.2427±0.0065	-0.0045±0.0046	-0.6306±0.06
$38 < \theta < 42$	-0.2417±0.0072	-0.0155±0.0052	-0.6403±0.055
$42 < \theta < 46$	-0.2341±0.0089	-0.0165±0.0064	-0.6346±0.06

Spin down

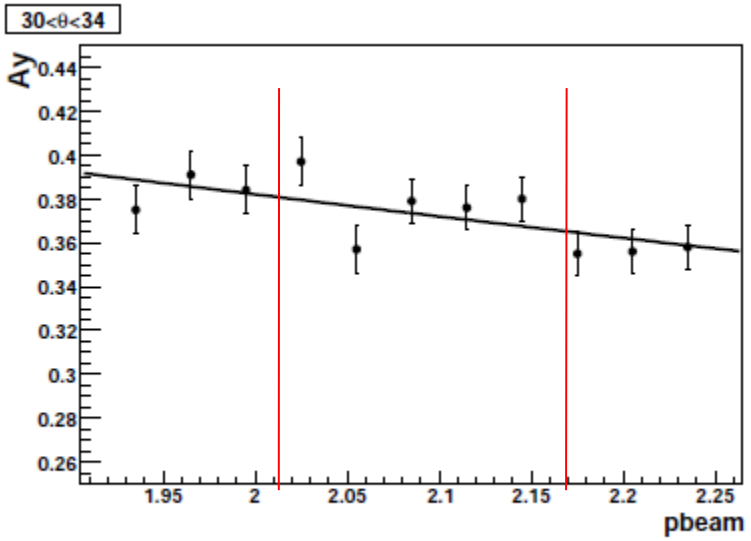
$$\overline{P} \equiv \frac{\sum_{n=1}^{4} \frac{p_n}{\sigma_n^2}}{\sum_{n=1}^{4} \frac{1}{\sigma_n^2}}$$

$$\sigma_{\overline{P}} \equiv \sqrt{\frac{1}{\sum_{n=1}^{4} \left(\frac{1}{\sigma_n^2}\right)}}$$

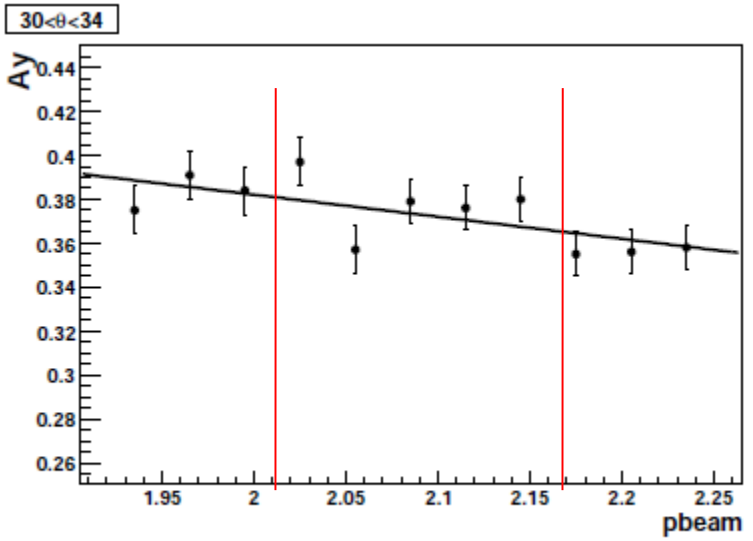
EDDA data base

$$A_y(p_{beam}) \equiv a \cdot p_{beam} + b$$

$$A_y(p_{beam}) \equiv \alpha \cdot e^{-\beta \cdot p_{beam}}$$

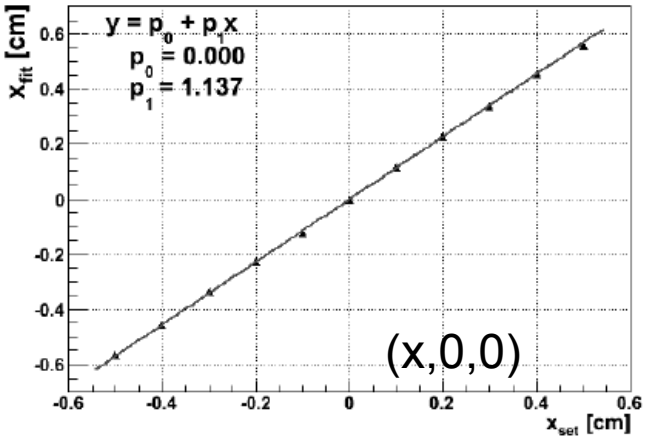


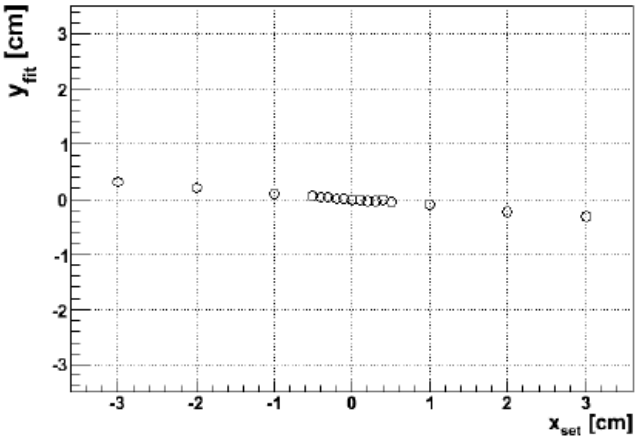
(a) exponential fit

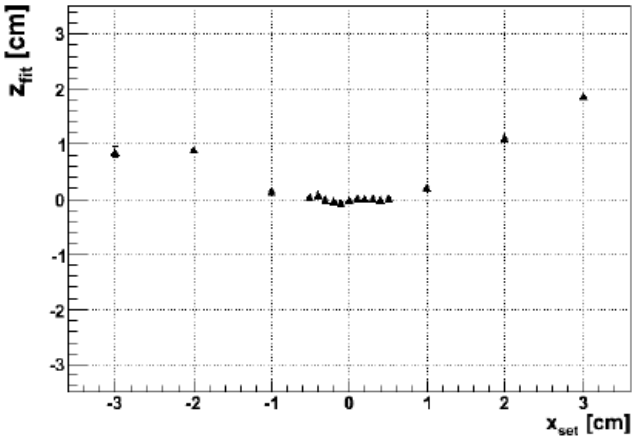


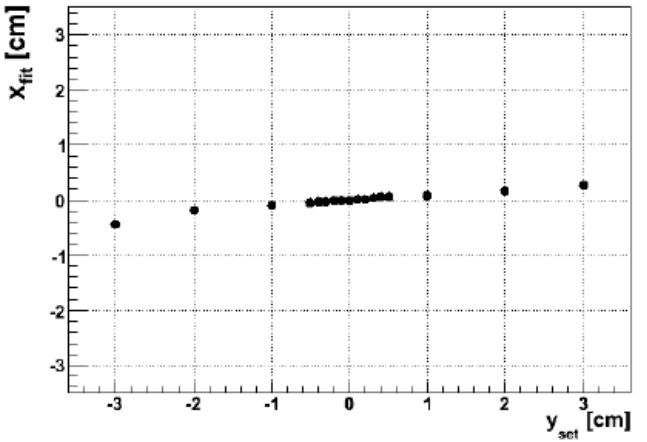
(b) line fit

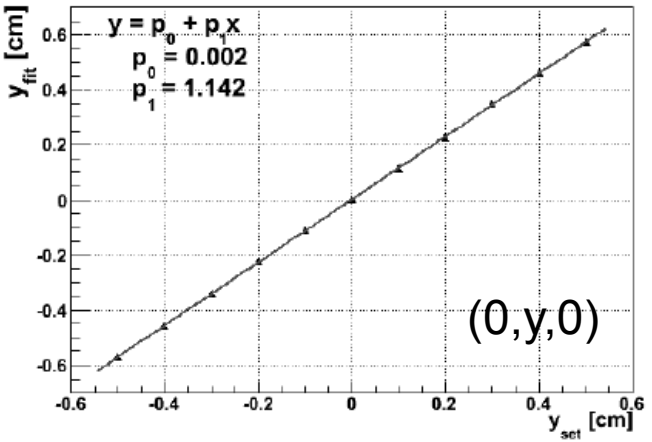
MC for the shift of vertex position

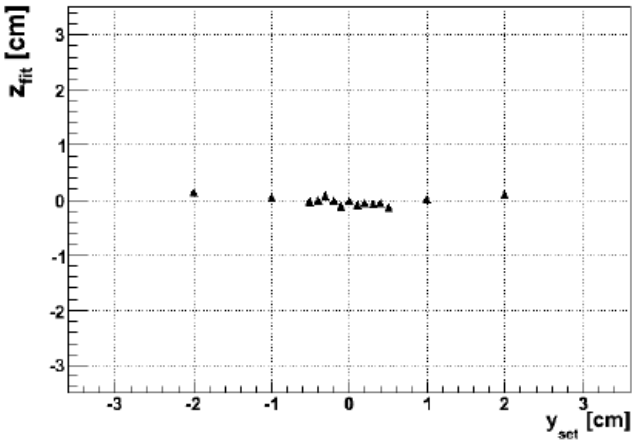


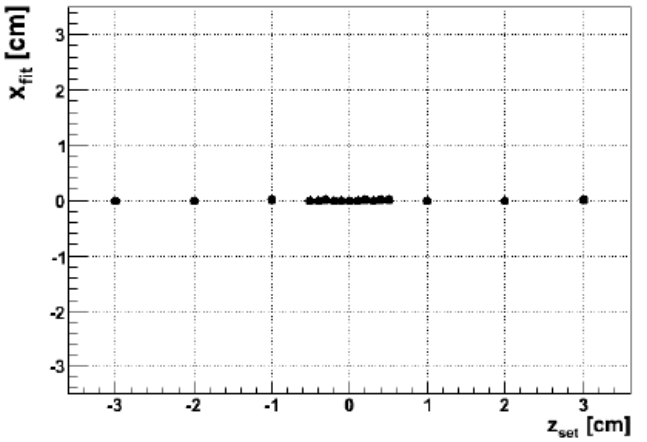


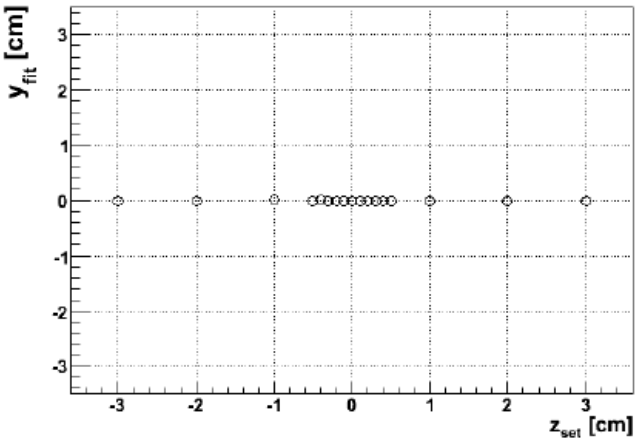


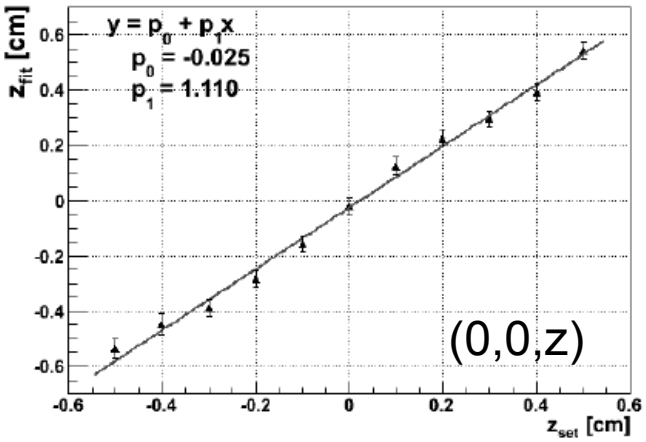












Hodana M. Moskal P. Ozerianska I. *http://arxiv.org/abs/1309.0430*

Calculations of the error bars for Asymmetry(δε)

$$\delta\epsilon \equiv \sqrt{\left(\frac{\delta\epsilon}{\delta N_+}\cdot\delta N_+\right)^2+\left(\frac{\delta\epsilon}{\delta N_-}\cdot\delta N_-\right)^2}$$

Ay from EDDA

$\theta_{CM}[^\circ]$	A_y	
	$p_{beam} = 2.026\,\mathrm{GeV/c^2}$	$p_{beam} = 2.188\,\mathrm{GeV/c^2}$
[30,34]	$0.380 \pm 0.007_{stat} \pm 0.002_{syst}$	$0.358 \pm 0.007_{stat} \pm 0.001_{syst}$
(34,38]	$0.382 \pm 0.004_{stat} \pm 0.001_{syst}$	$0.358 \pm 0.005_{stat} \pm 0.002_{syst}$
(38,42]	$0.376 \pm 0.005_{stat} \pm 0.001_{syst}$	$0.356 \pm 0.006_{stat} \pm 0.002_{syst}$
(42,46]	$0.366 \pm 0.006_{stat} \pm 0.002_{syst}$	$0.344 \pm 0.008_{stat} \pm 0.002_{syst}$

N	Theta	A_y	P Up	P Down
1	$28 < \theta < 32$	0.3817	0.56 ± 0.01	0.69 ± 0.01
2	$32 < \theta < 36$	0.3811	0.55 ± 0.02	0.68 ± 0.02
3	$36 < \theta < 40$	0.3788	0.56 ± 0.02	0.69 ± 0.02
4	$40 < \theta < 44$	0.3669	0.56 ± 0.03	0.69 ± 0.02
5	$44 < \theta < 48$	0.3339	0.55 ± 0.04	0.74 ± 0.04