Study of the η meson production with the polarized proton beam

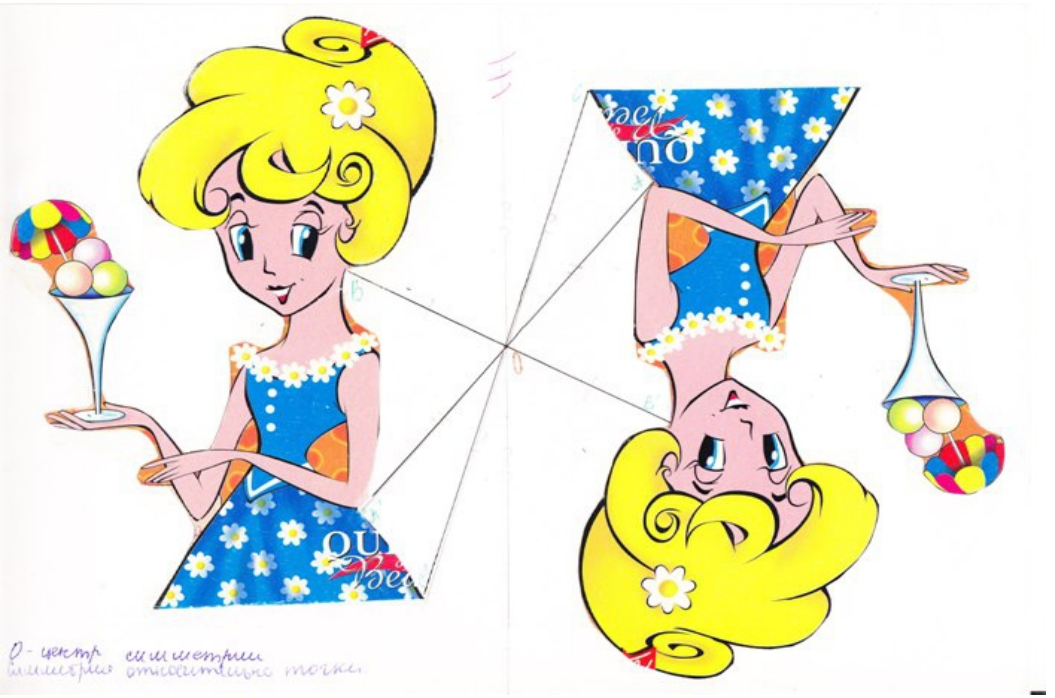
Iryna Schätti-Ozerianska

Institute of Physics, Jagiellonian University
Krakow, Poland

|| Symposium on applied nuclear physics and innovative technologies

Plan

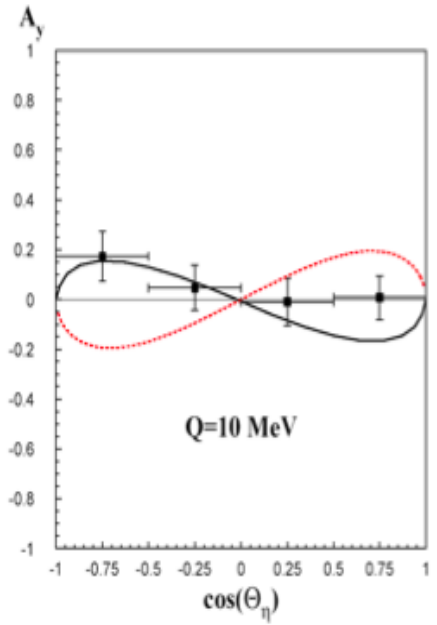
1. Motivation
2. Analyzing power
3. WASA-at-COSY
4. Asymmetry measurement
5. Vertex position studies
6. Polarization
7. Eta meson
8. Outlook

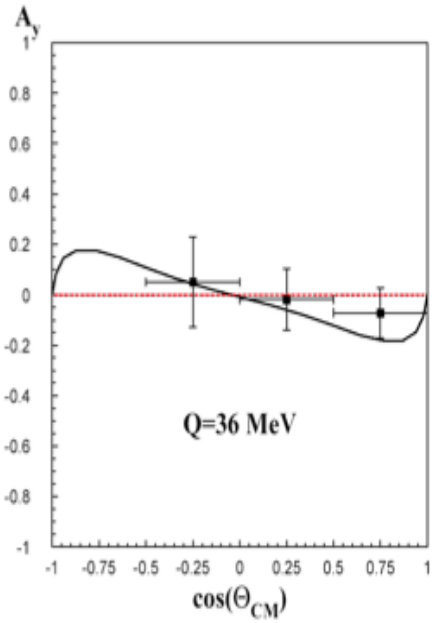


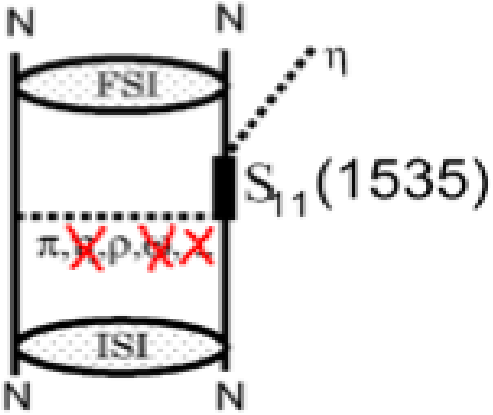
η meson production in pp collisions

dynamics of the η meson production in pp->ppη

CELSIUS
COSY
SATURNE





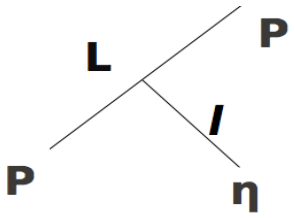


⇒ η meson production via exchange of isovector mesons

Compare with previous experiment COSY 11, (reconstructed η=2000 events only) Now, number of η on disk 500 000 events!

Partial Wave Analysis

interaction of the η meson with nucleons



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

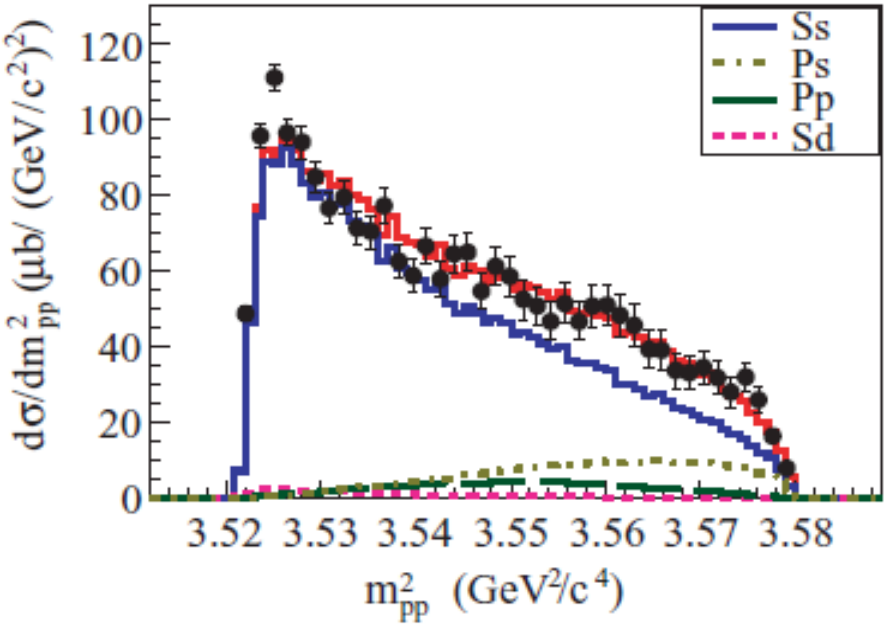
l: 0 1 2 ...
Wave: s p d ...

- 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

Analyzing Power

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

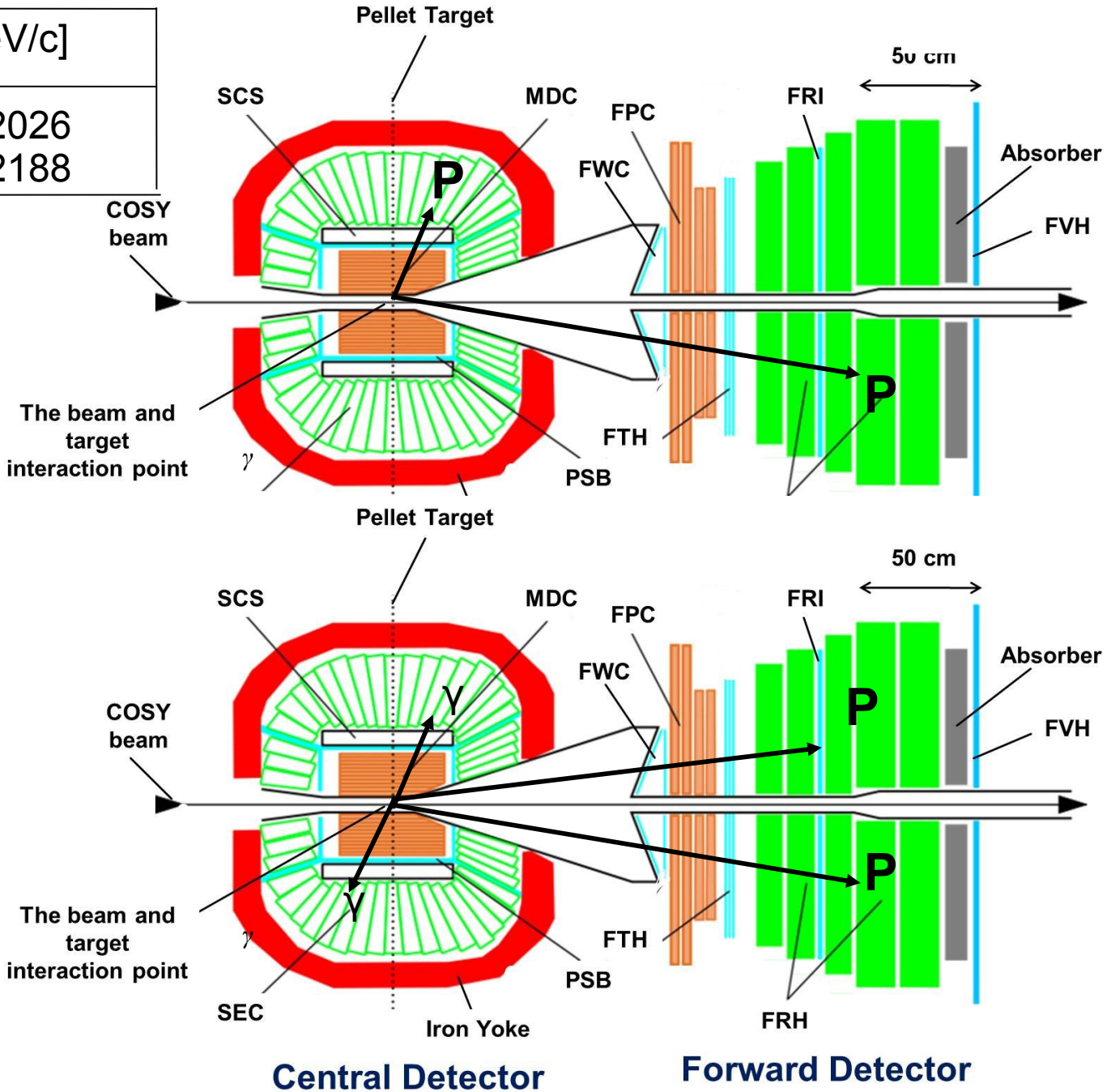
$\sigma(\theta,\varphi)$ Differential cross section with polarisation
$\sigma_0(\theta,\varphi)$ Differential cross section without polarisation

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

WASA Detector

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



Analysis steps

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

we calculate Polarization P

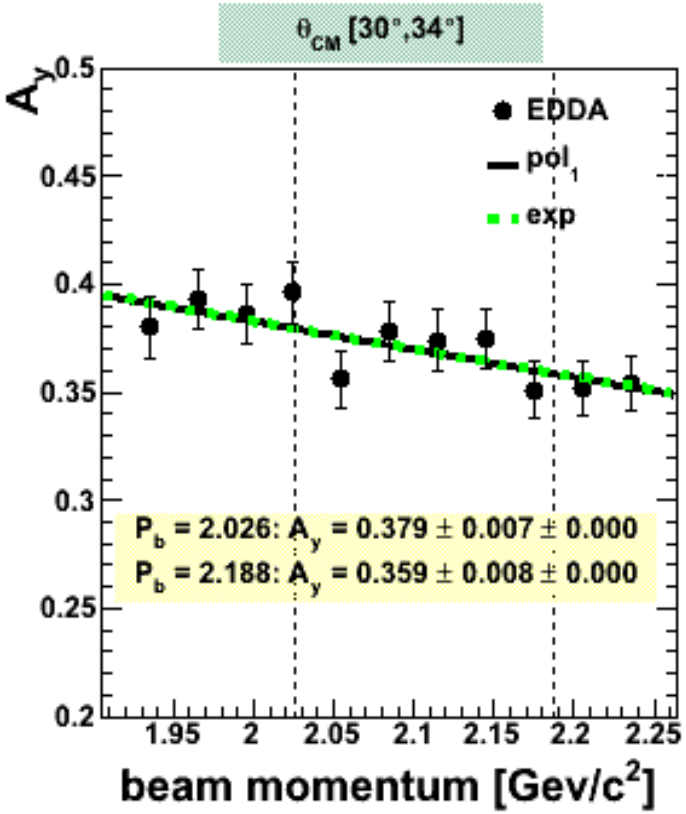
2 For $\vec{p}p$ ->ppη: we know

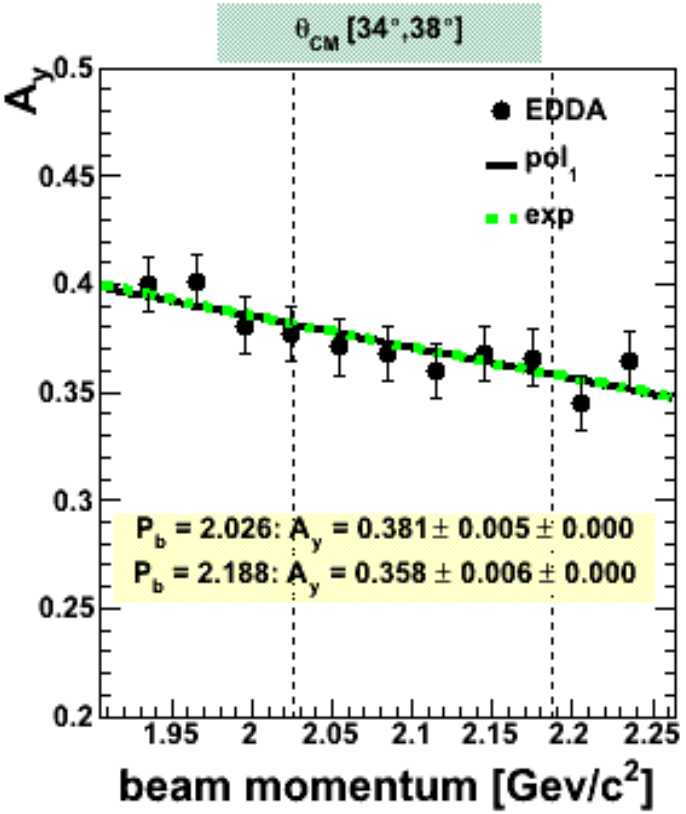
$$N(\theta,\varphi)=\sqrt{\frac{N^{\uparrow}(\theta,\varphi)\cdot N^{\downarrow}(\theta,\varphi+\pi)}{\epsilon^{\uparrow}\cdot L^{\downarrow}\cdot\epsilon^{\downarrow}\cdot L^{\uparrow}}} \qquad N(\theta,\varphi+\pi)=\sqrt{\frac{N^{\downarrow}(\theta,\varphi)\cdot N^{\uparrow}(\theta,\varphi+\pi)}{\epsilon^{\uparrow}\cdot L^{\downarrow}\cdot\epsilon^{\downarrow}\cdot L^{\uparrow}}}$$

we calculate A_y

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

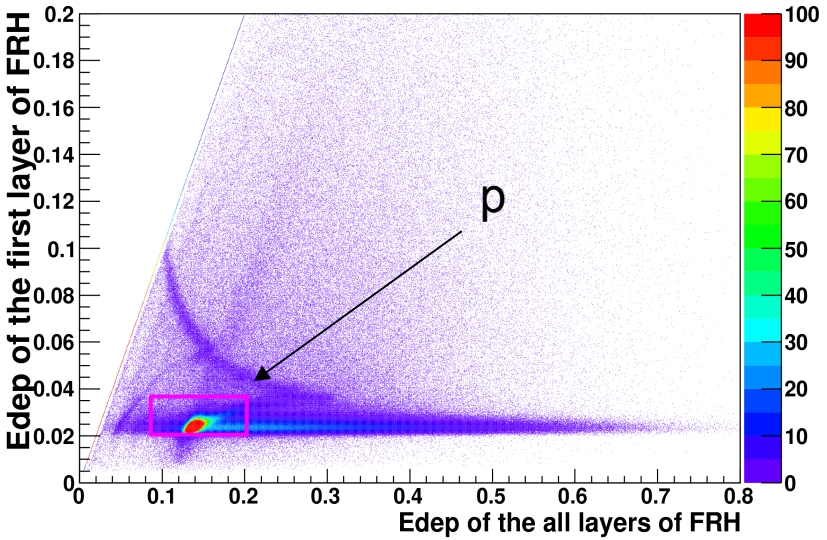
A_y from EDDA

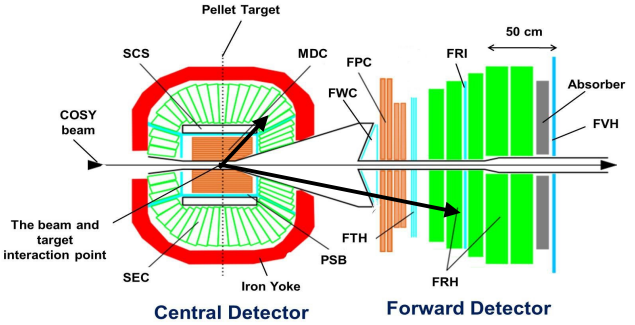

θCM [30°,34°]
Ay
EDDA
pol1
exp
Pb = 2.026: Ay = 0.379 ± 0.007 ± 0.000
Pb = 2.188: Ay = 0.359 ± 0.008 ± 0.000
beam momentum [Gev/c2]


θCM [34°,38°]
Ay
EDDA
pol1
exp
Pb = 2.026: Ay = 0.381 ± 0.005 ± 0.000
Pb = 2.188: Ay = 0.358 ± 0.006 ± 0.000
beam momentum [Gev/c2]

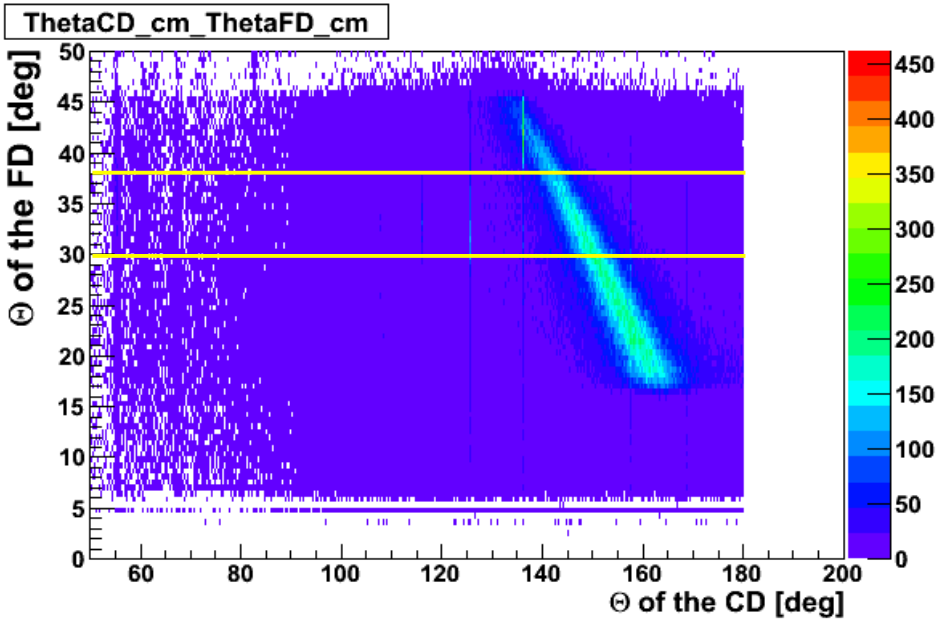
Determination of the *pp* elastic scattering

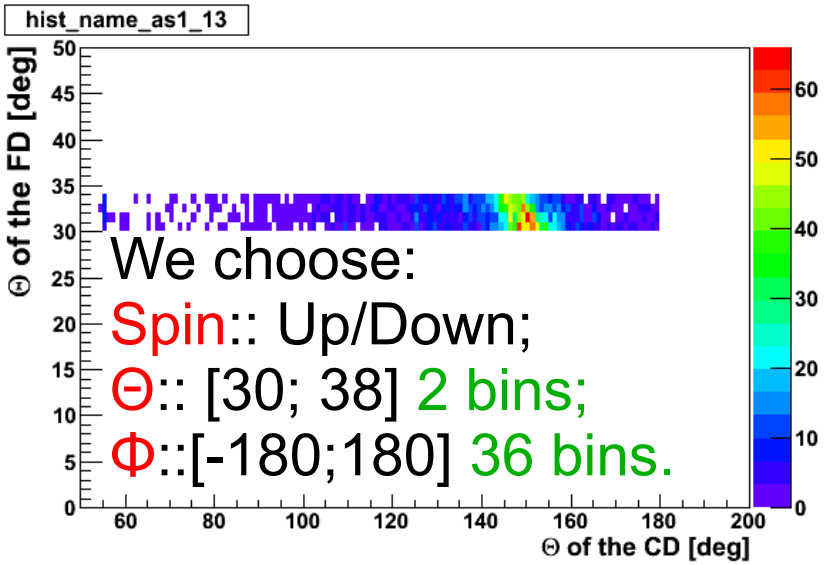
FD: - one charge particle

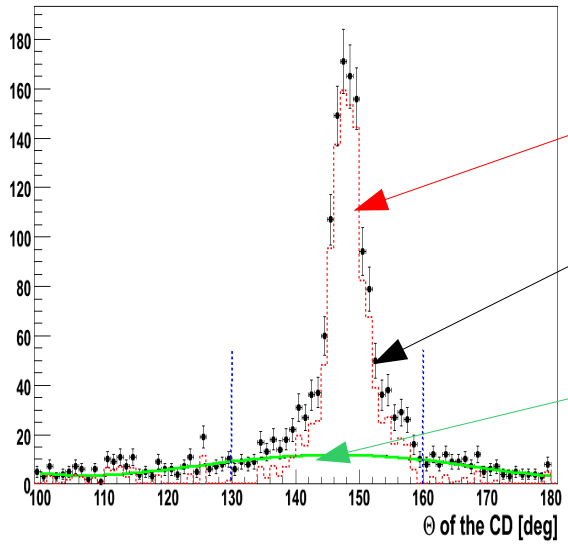




Determination of the *pp* elastic scattering



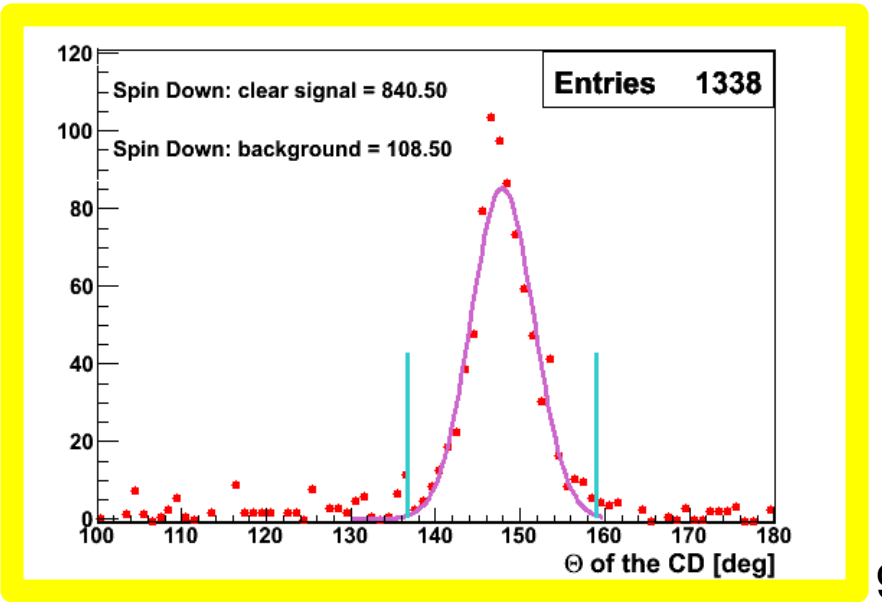




clear signal

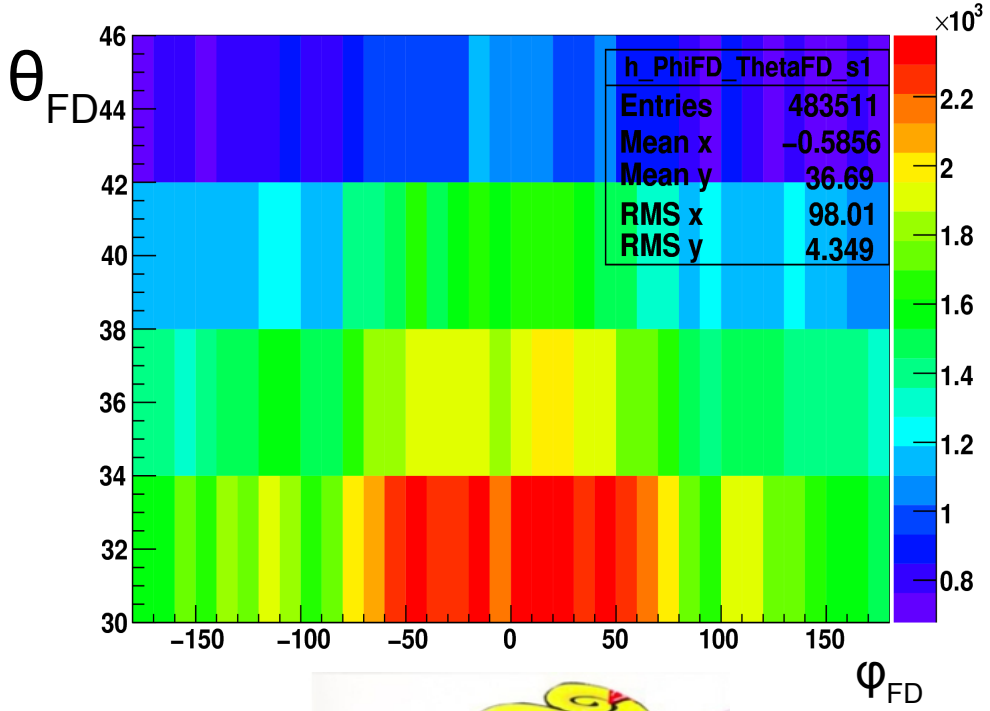
Data points

background

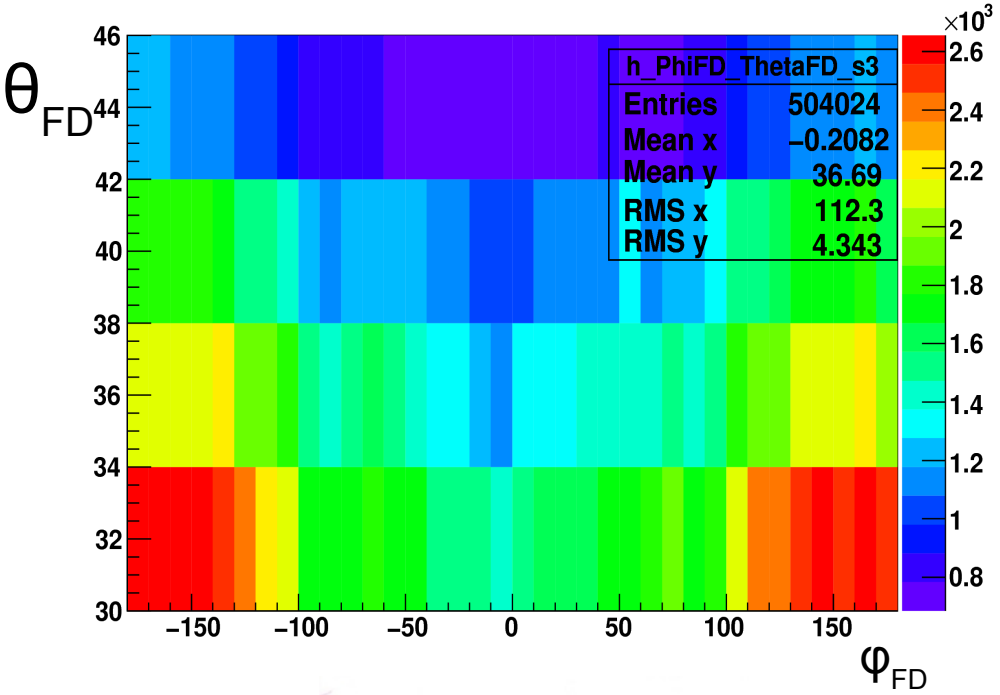


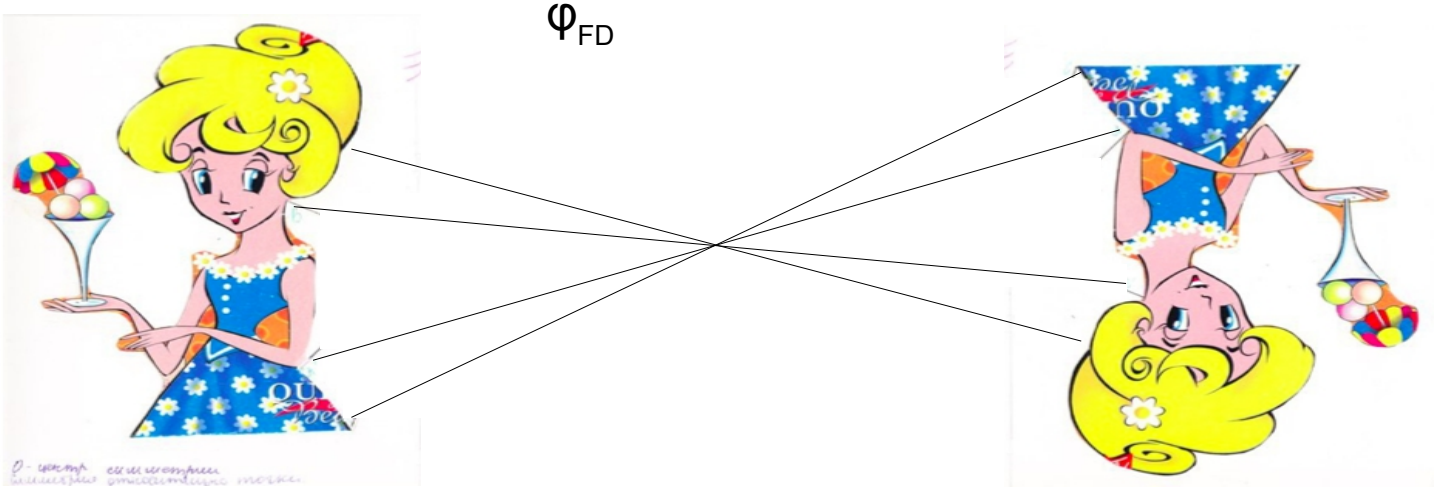
Spin Up/Down measurements

Spin Up

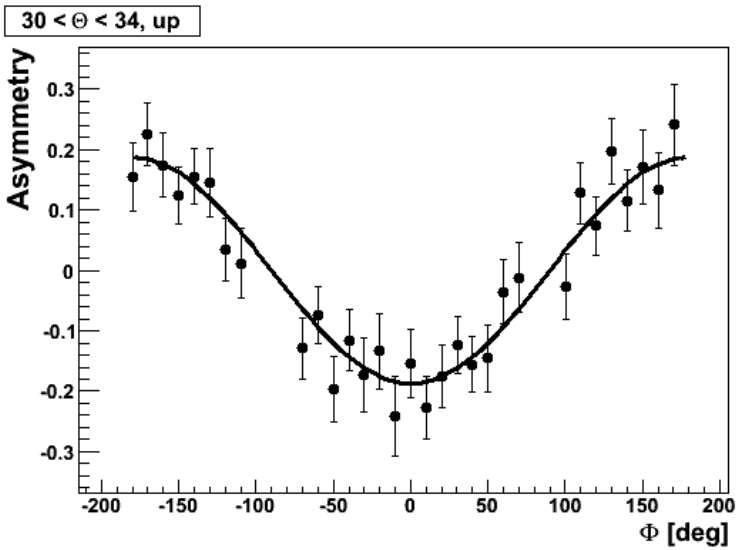


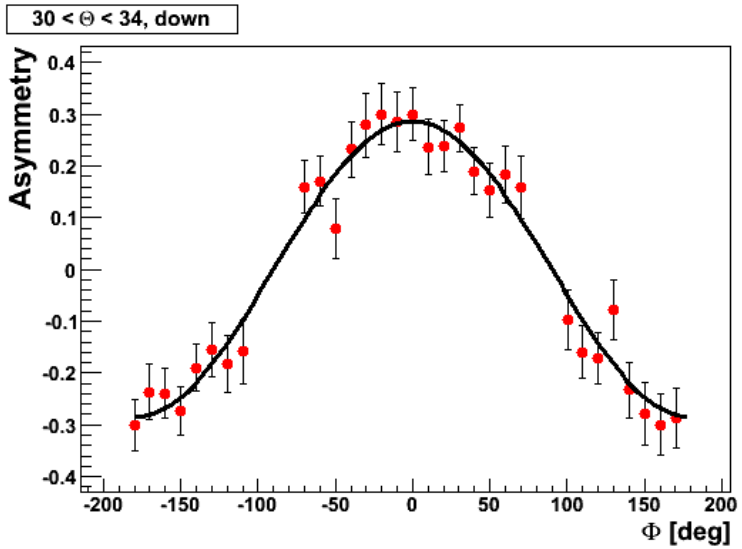
Spin Down





Asymmetry





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

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

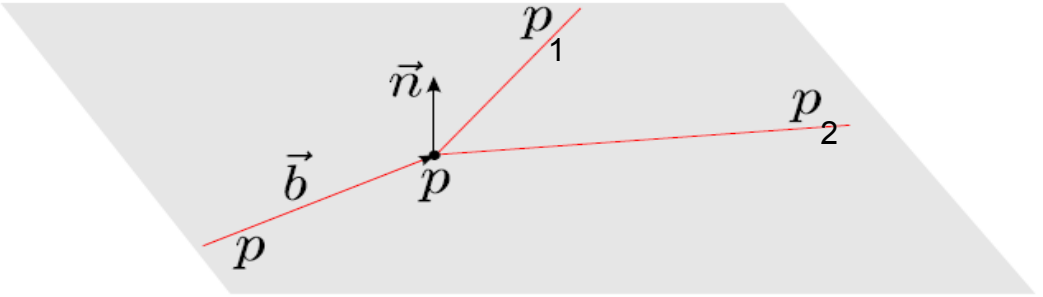
$$Asymmetry \equiv a \cdot cos\varphi + b$$

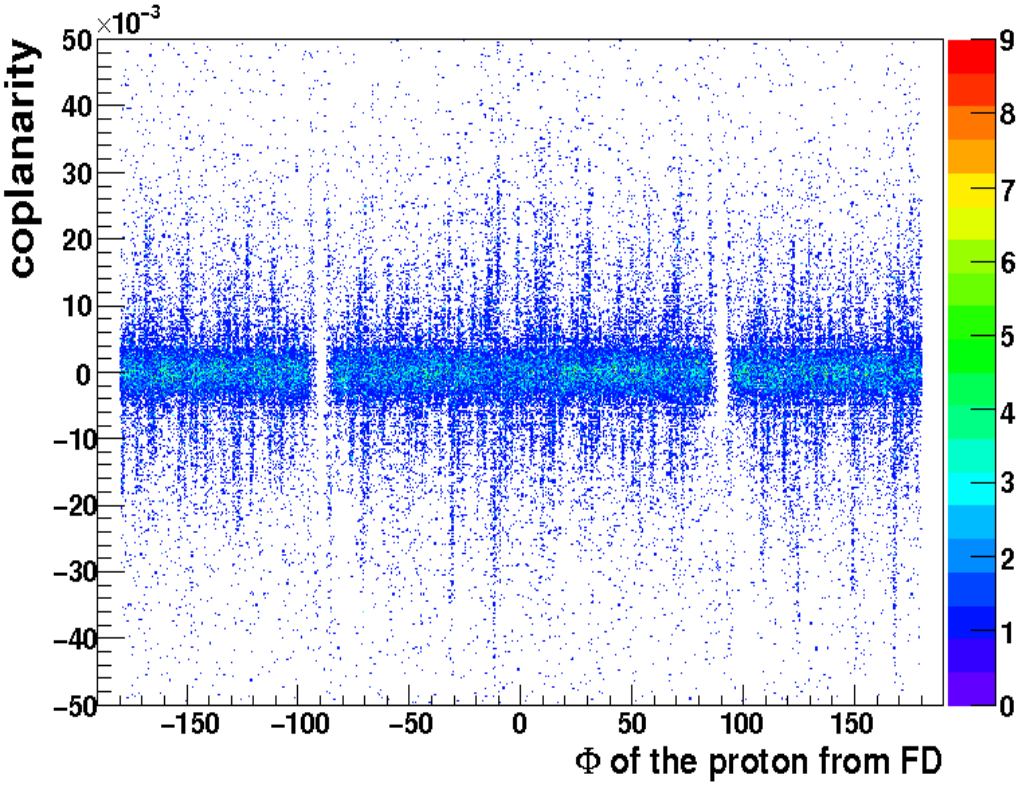
$$a \equiv A_y \cdot P$$

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

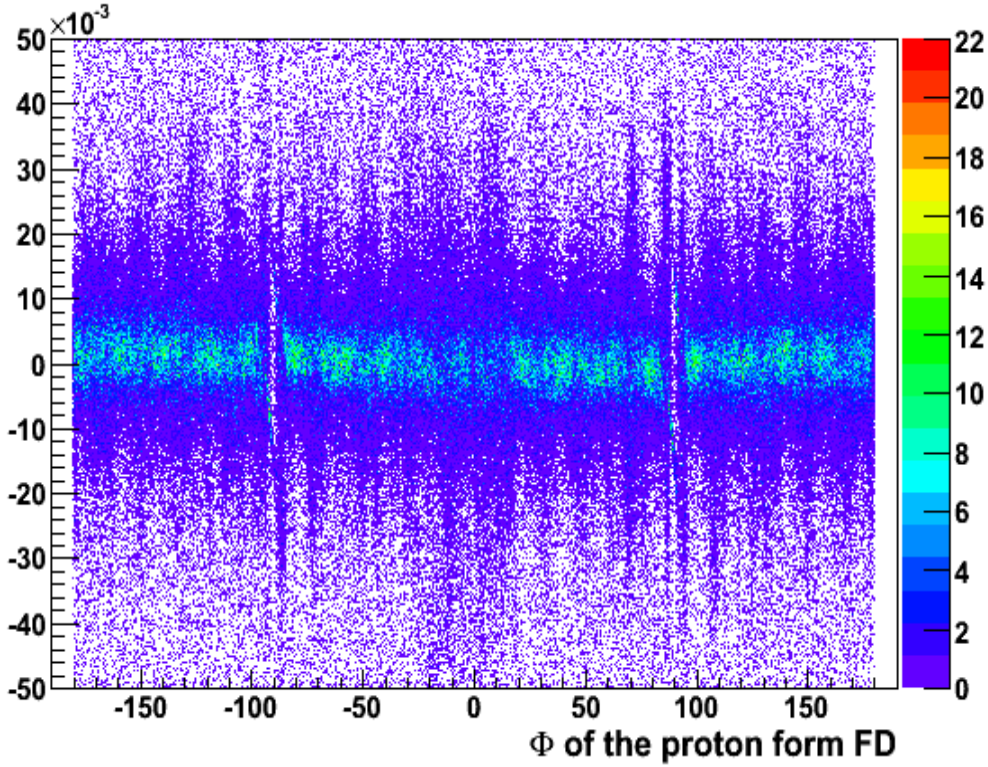
Vertex position determination:
coplanarity

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



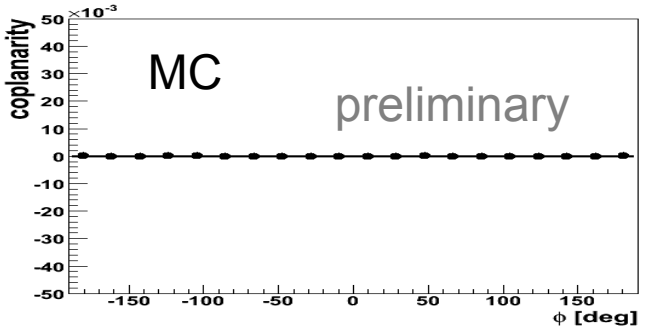


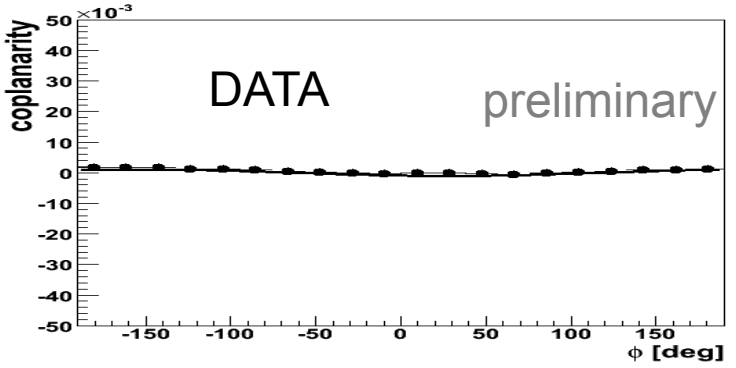
MC



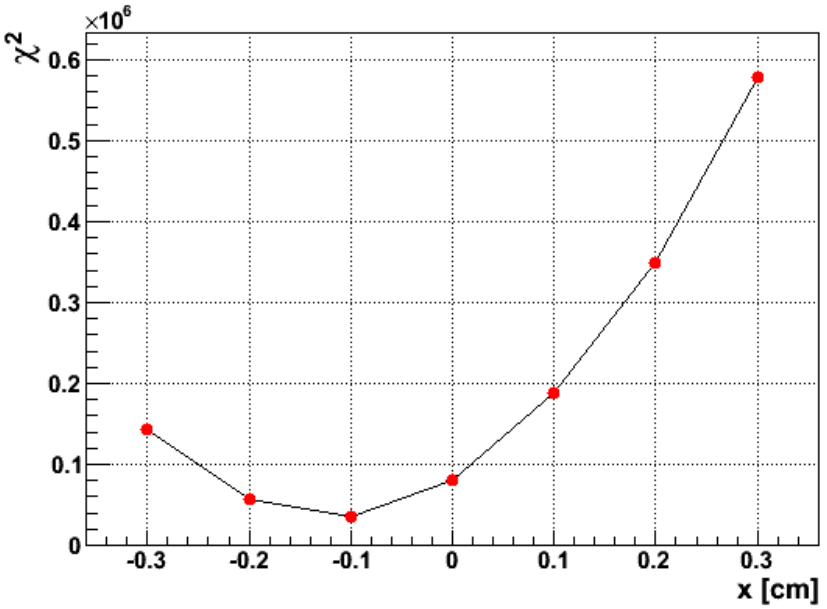
DATA

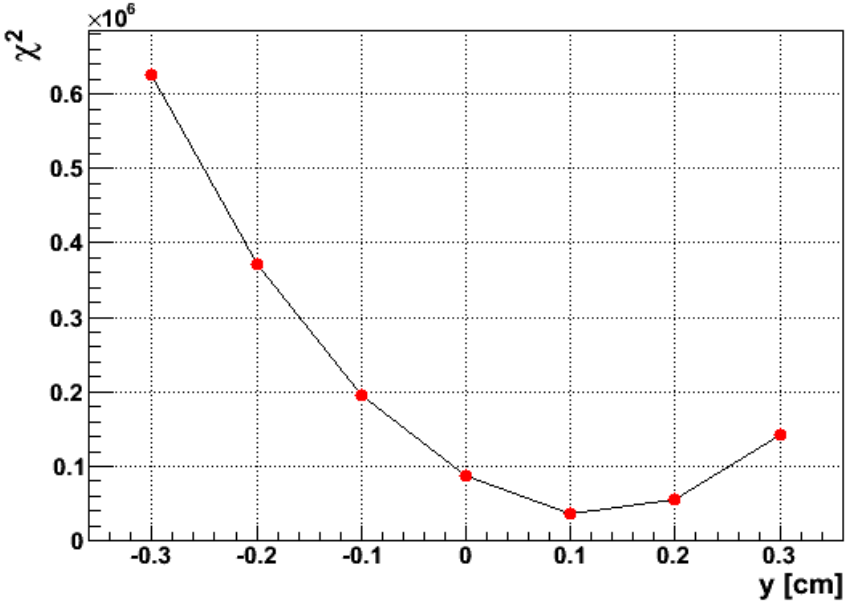
Vertex position determination:
coplanarity



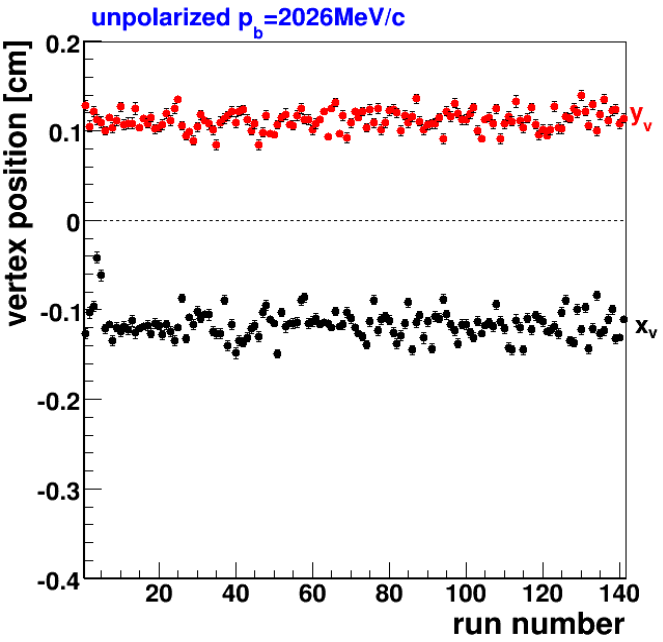


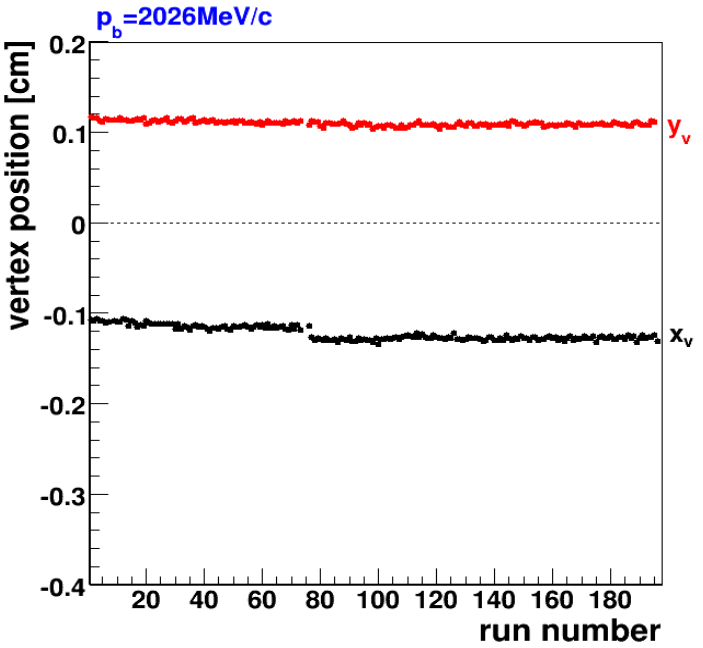
$$\chi^2 = \sum_i \frac{(M_i^{MC} - M_i^{exp})^2}{(\sigma_i^{exp})^2}$$

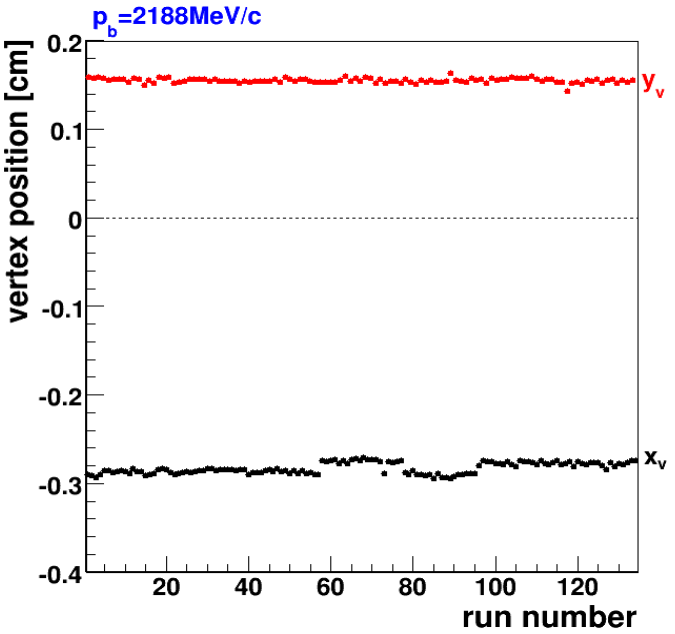




Result for the coplanarity method

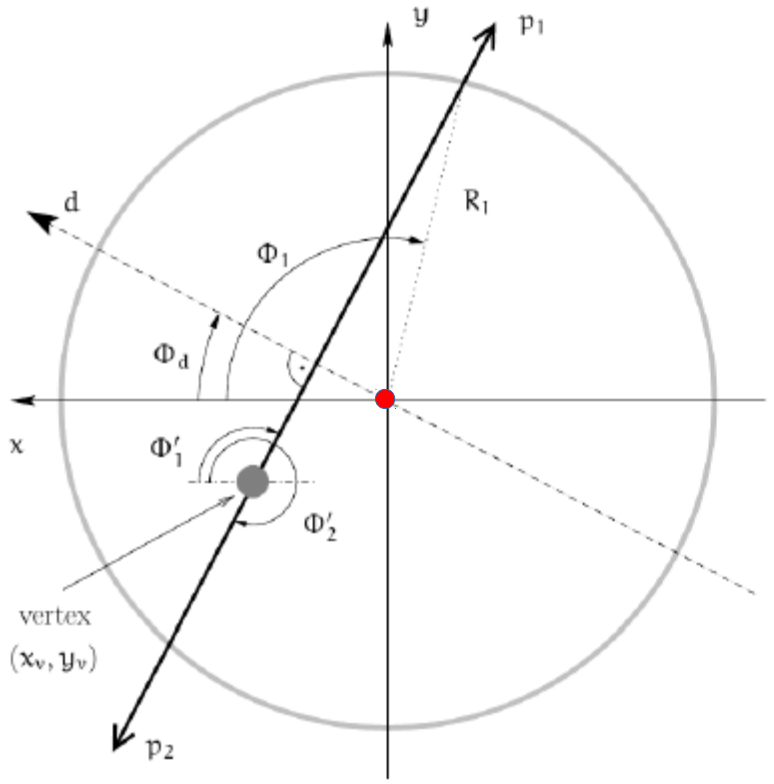






Vertex position determination: $d(\phi_d)$ method

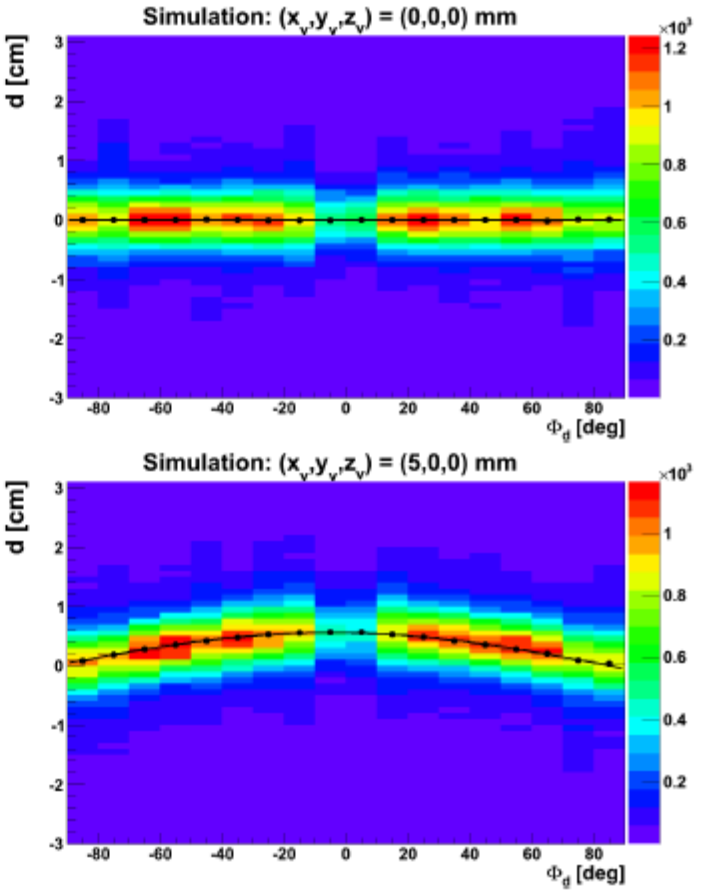
x and y vertex coordinates, the method



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

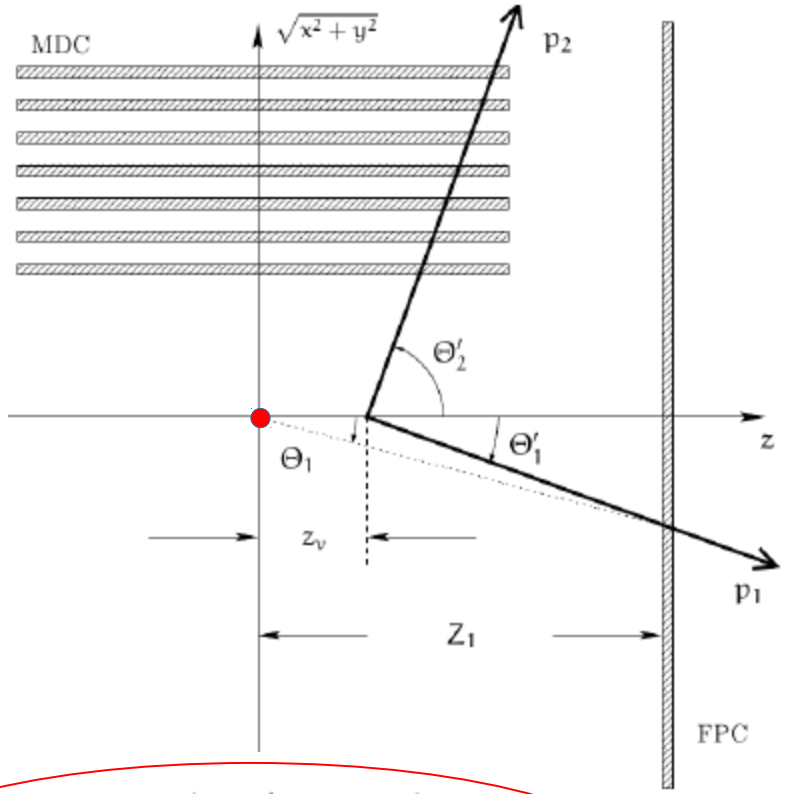
Fit

MC



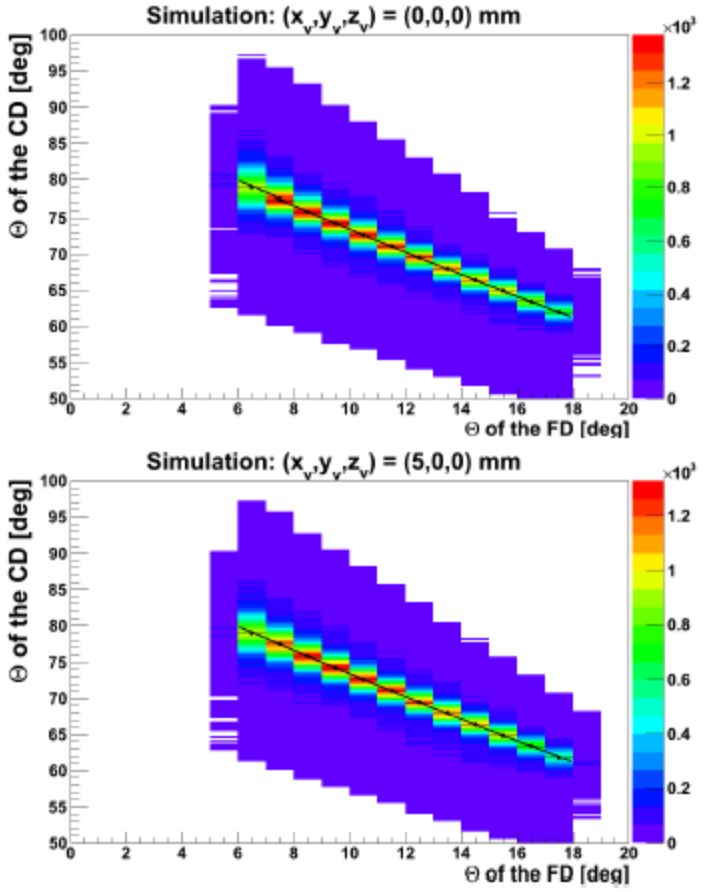
Vertex position determination: $d(\phi_d)$ method

z-vertex coordinate, the method



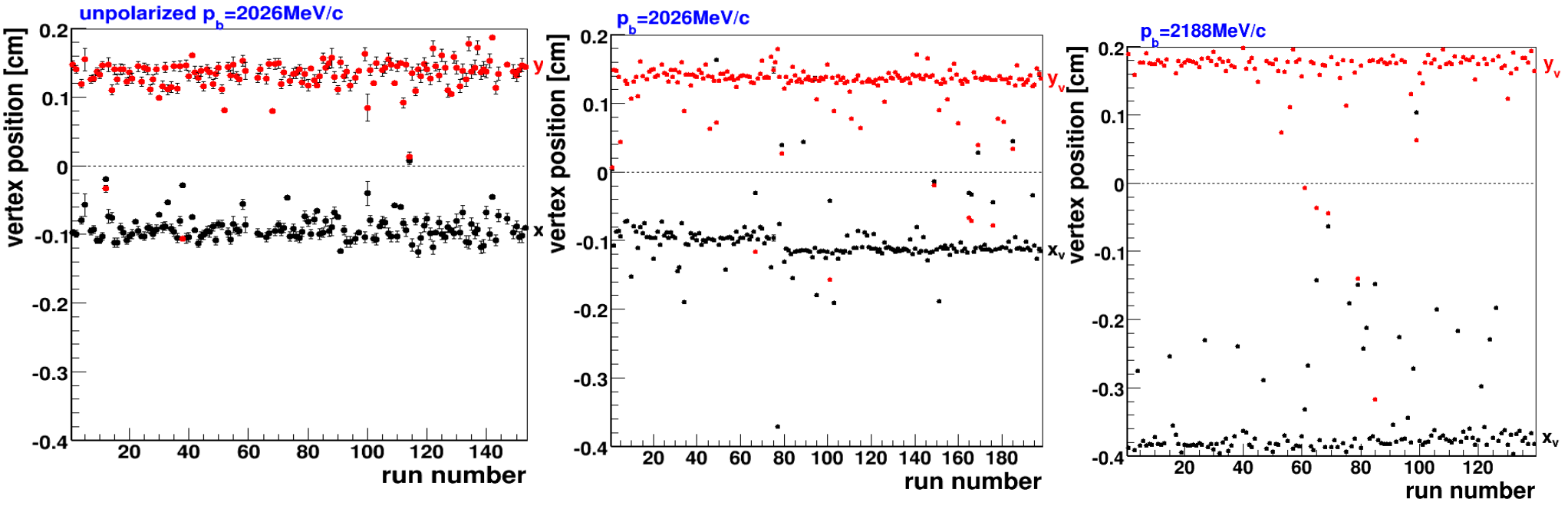
$$tg(\theta_2') = \frac{1-(z^{vertex}/z_{FTH})}{tg(\theta_1)} \bullet \gamma^2_{CMS}$$

MC



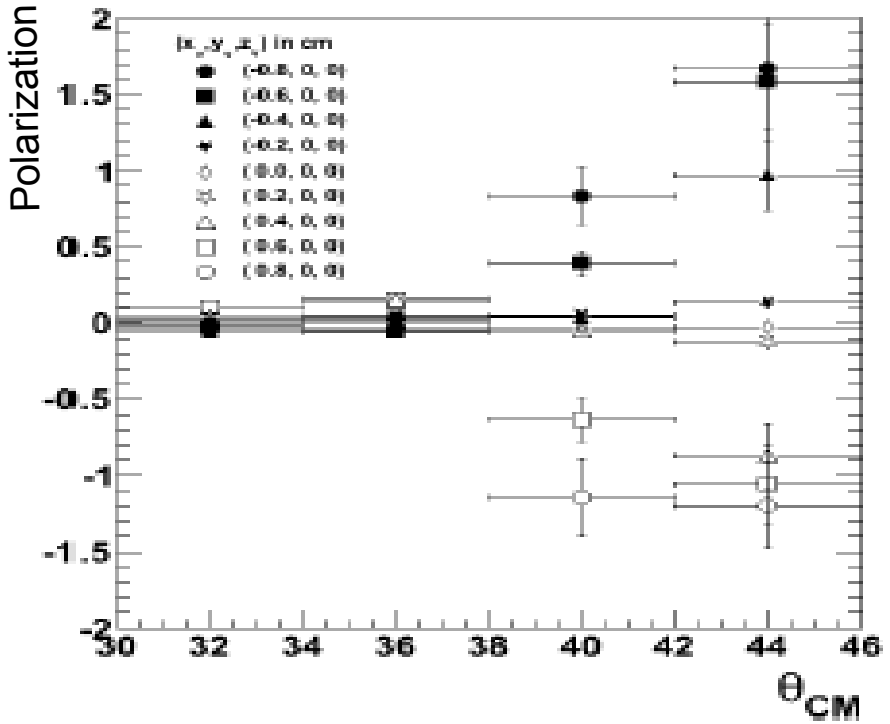
Fit

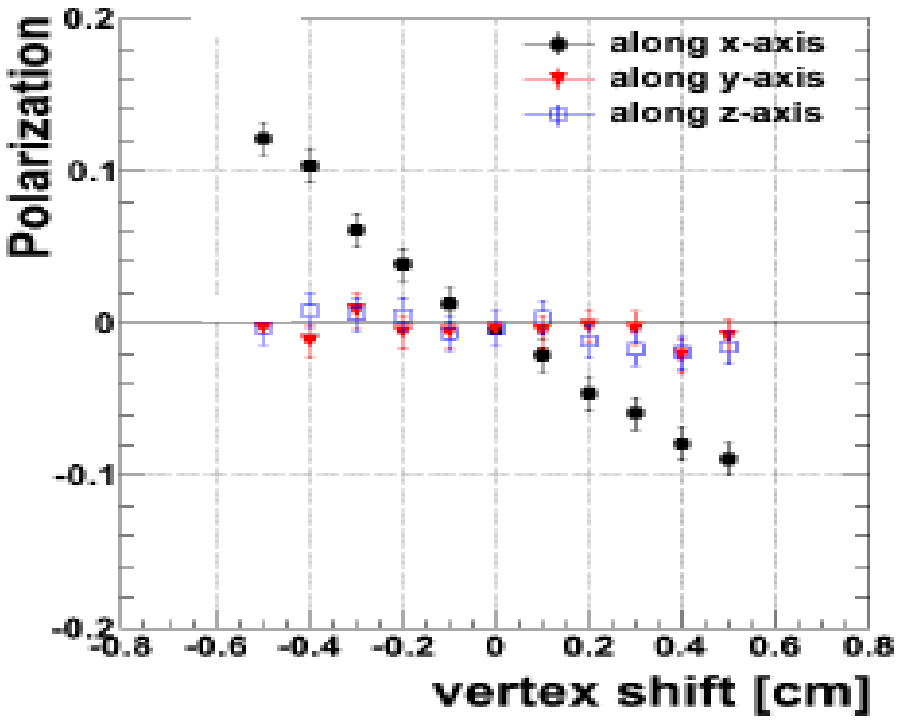
Result for the distance method



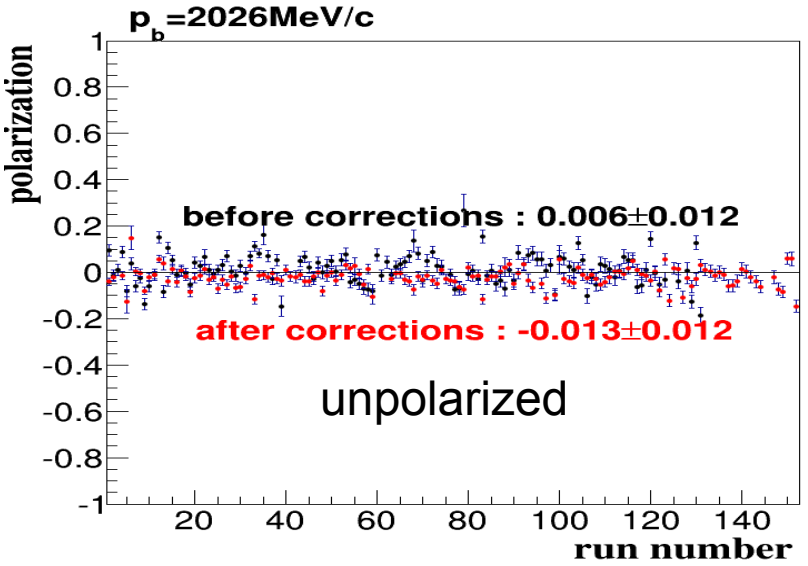
vertex	unpolarized P_{beam} = 2.026 Gev/c	P_{beam} = 2.026 Gev/c	P_{beam} = 2.188 Gev/c
The χ^2 method			
x_v	-0.1164±0.0052	-0.1230±0.0011	-0.2834±0.0010
y_v	0.1119±0.0052	0.1099±0.0011	0.1551±0.0010
The distance method			
x_v	-0.0908±0.0017	-0.0968±0.0012	-0.3755±0.0019
y_v	0.1386±0.0019	0.1369±0.0011	0.1793±0.0015

Study of the influence of the position of the interaction point for the beam polarization

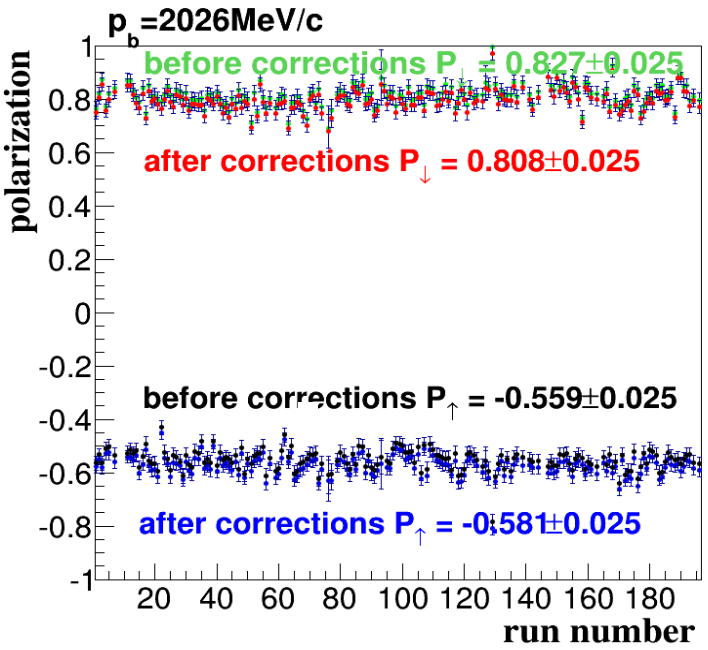


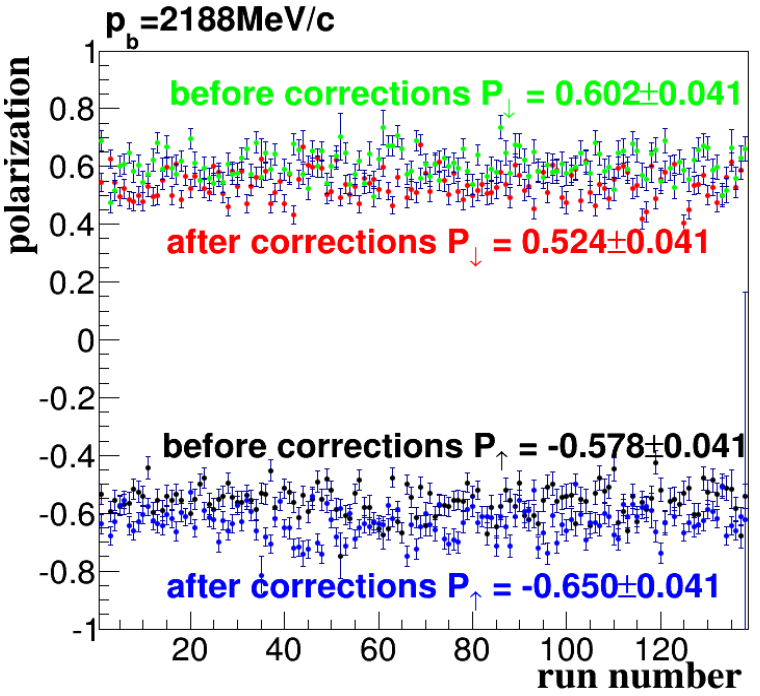


Polarization



Stable polarization
In time





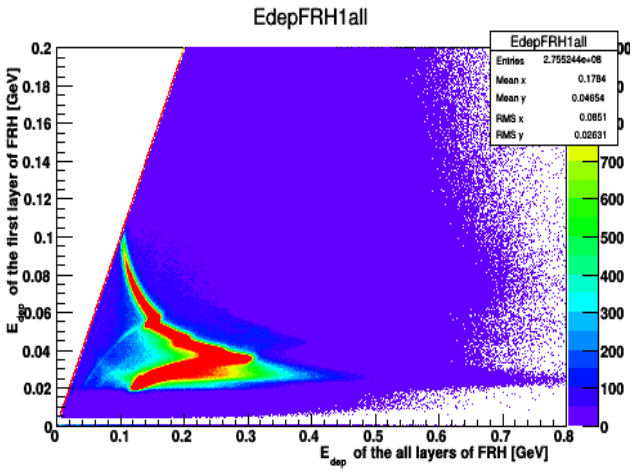
Eta meson

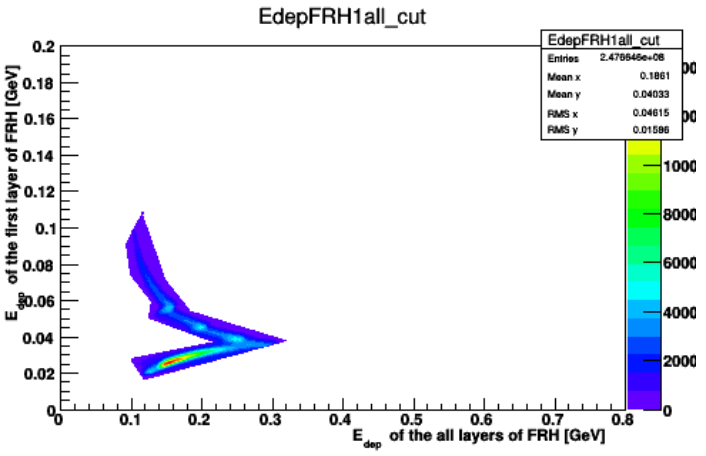
preselection

1. Only 2 charge in the FD;

2. More then 2 neutral in the CD;

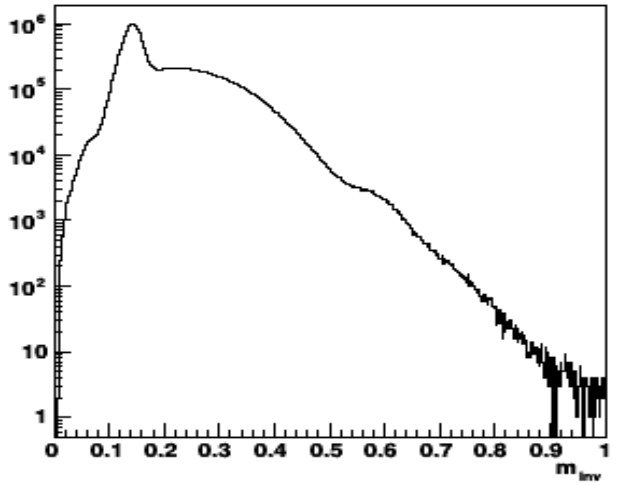
Cut for the protons

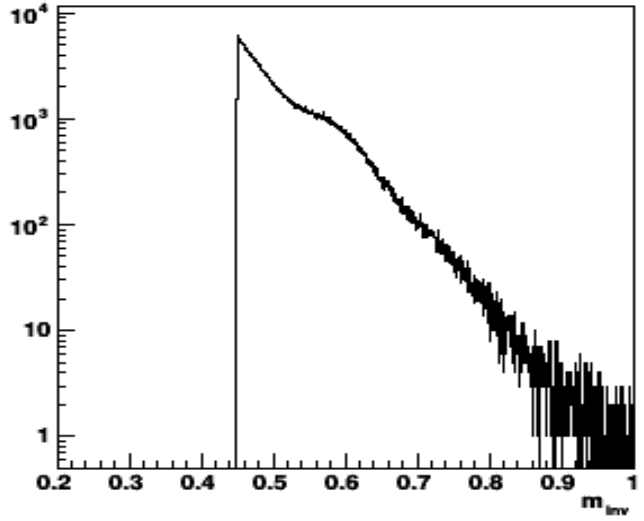




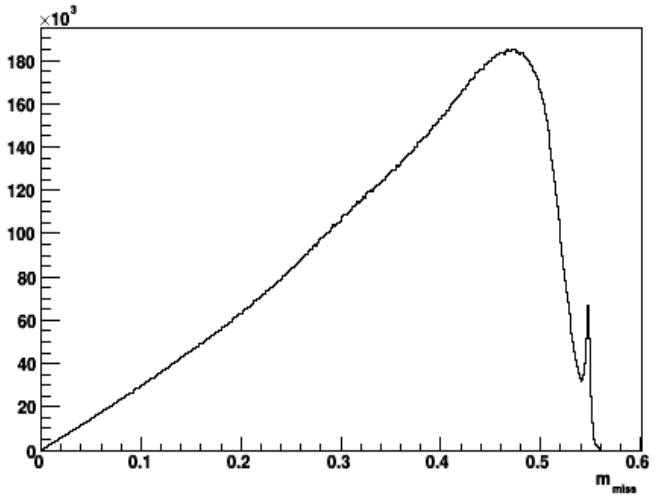
Eta meson

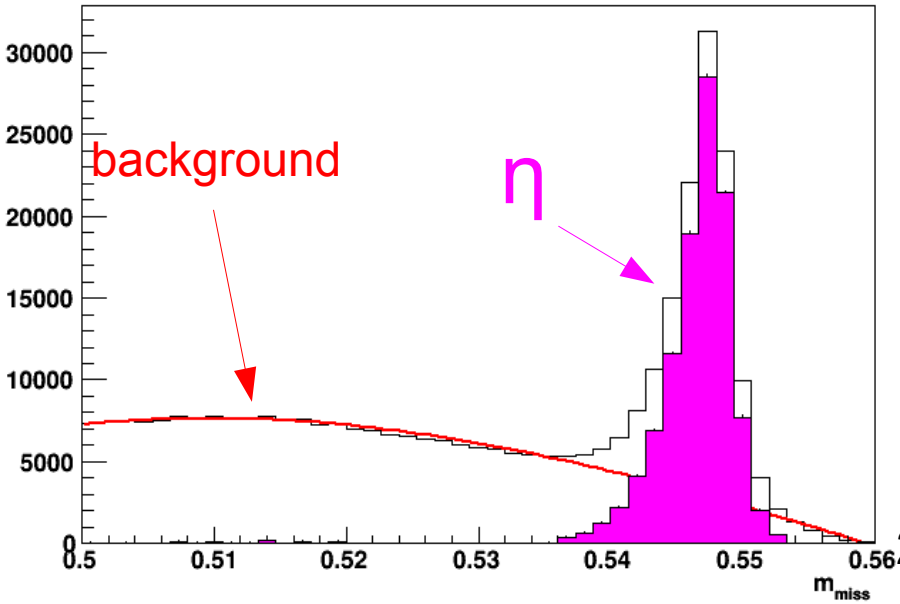
Invariant Mass of η-data





Missing Mass of pp data





Outlook

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

2. Luminosity

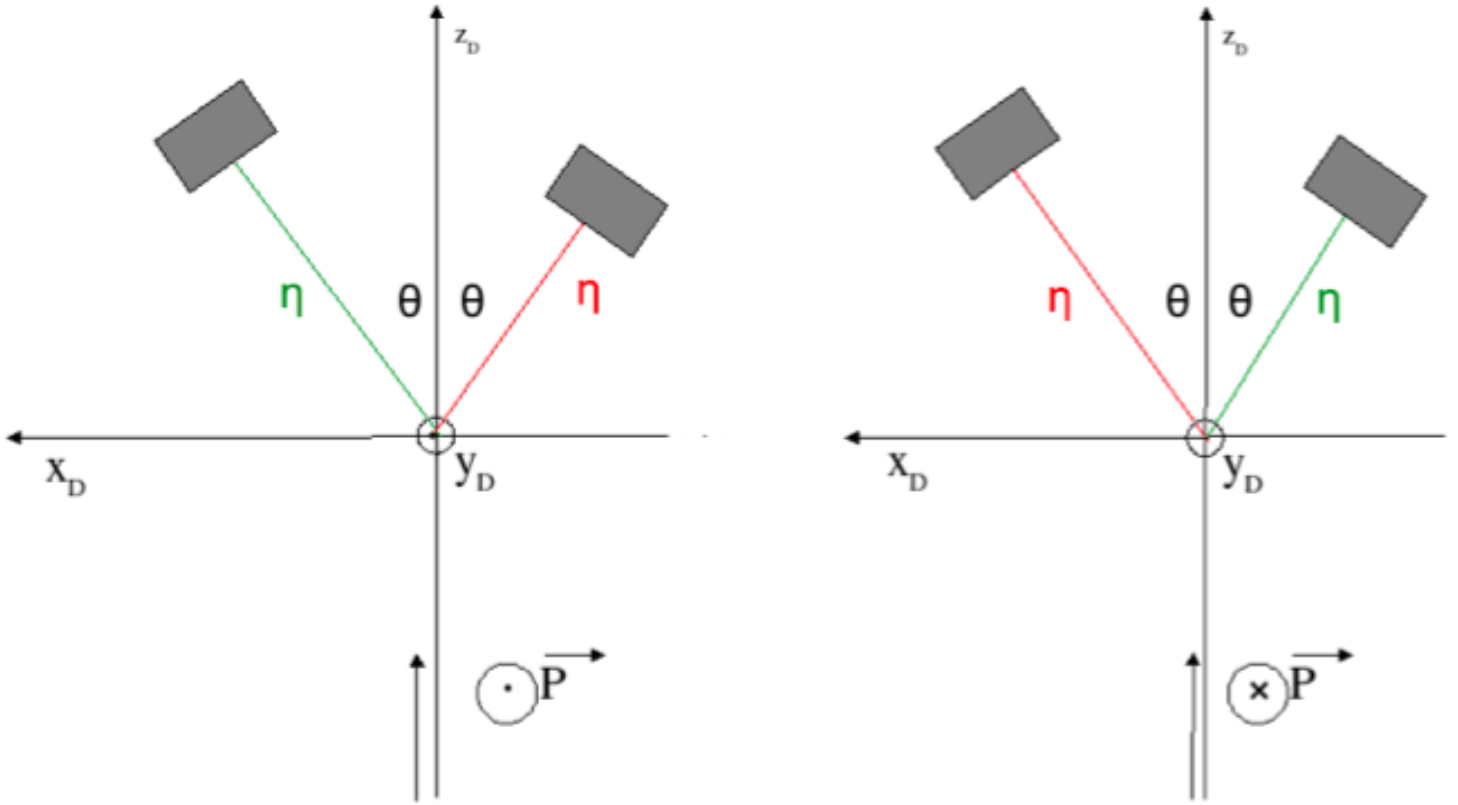
2. Interpretation of the result in the view of the production mechanism for $\vec{p}p$->ppη reaction

Thank You for Attention:)

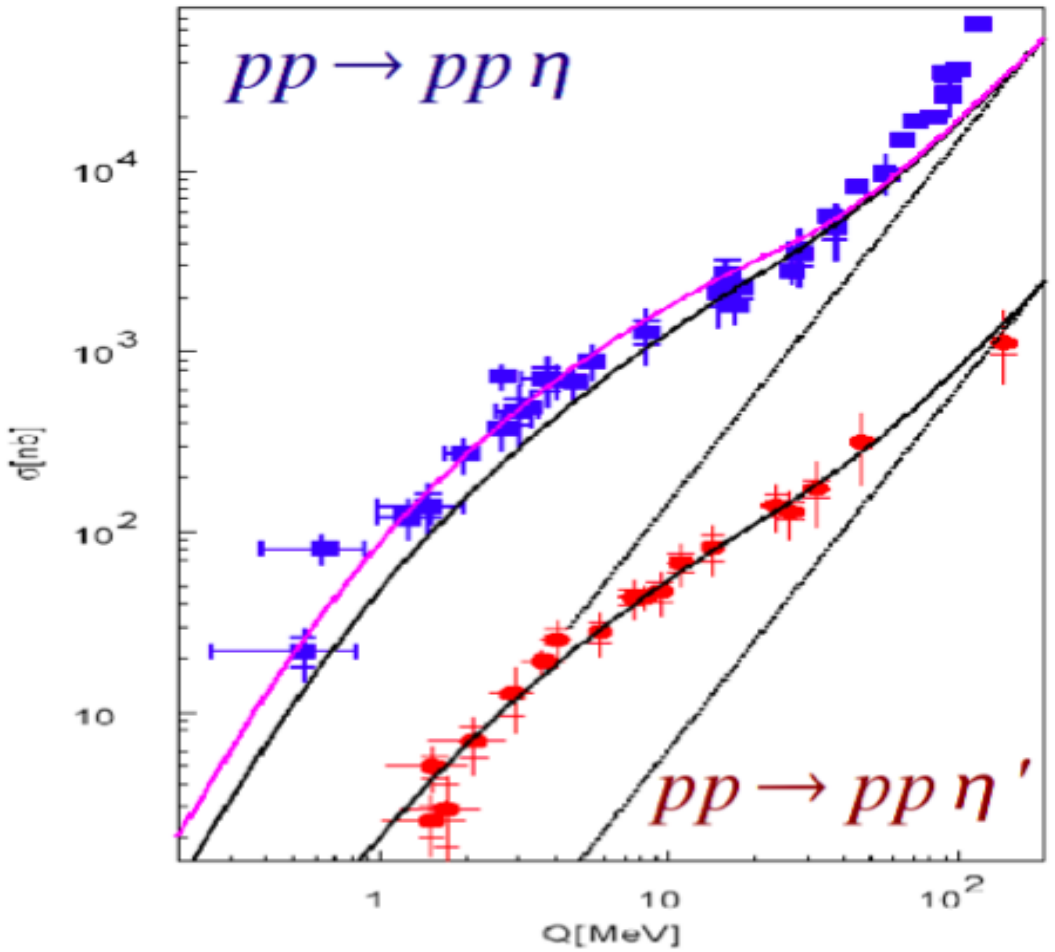
Madison convention

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

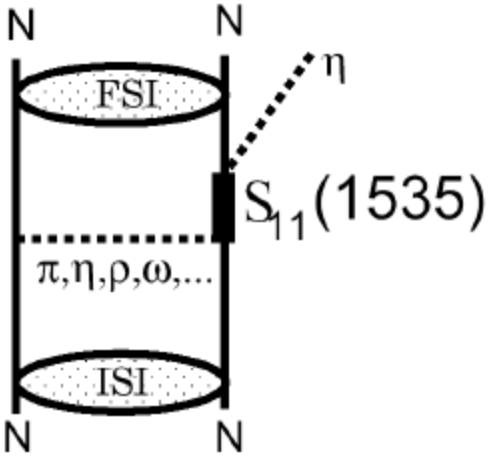
Detector: $N_L^{\uparrow}$ $N_R^{\uparrow}$ $N_L^{\downarrow}$ $N_R^{\downarrow}$



η meson production in pp collisions

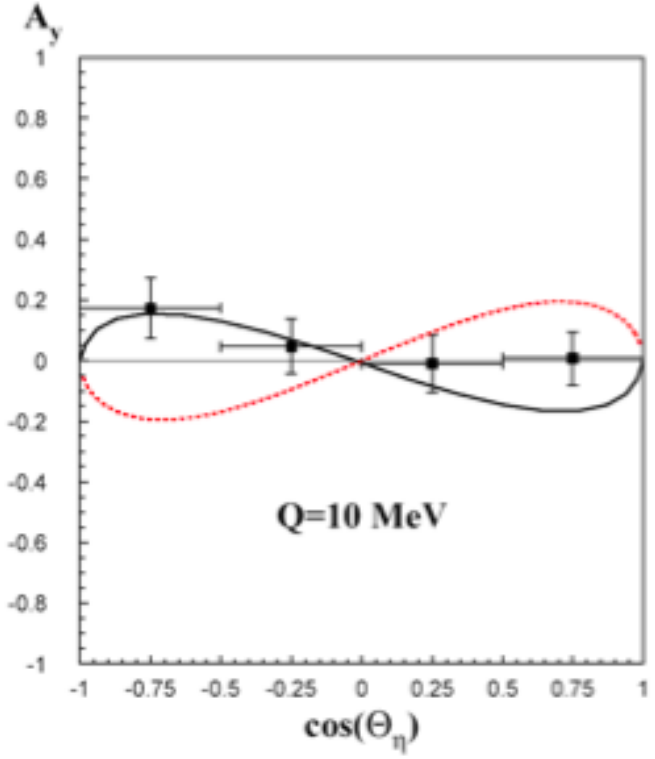


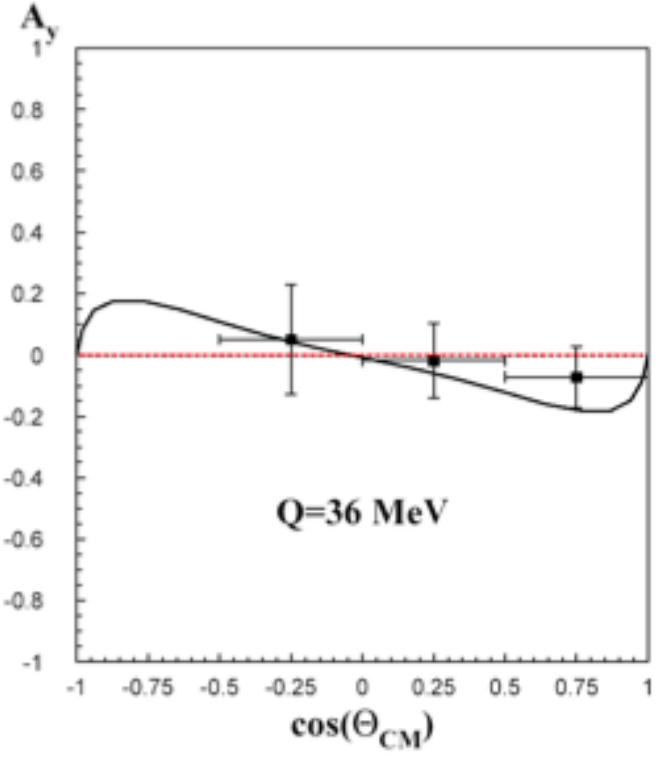
CELSIUS
COSY
SATURNE



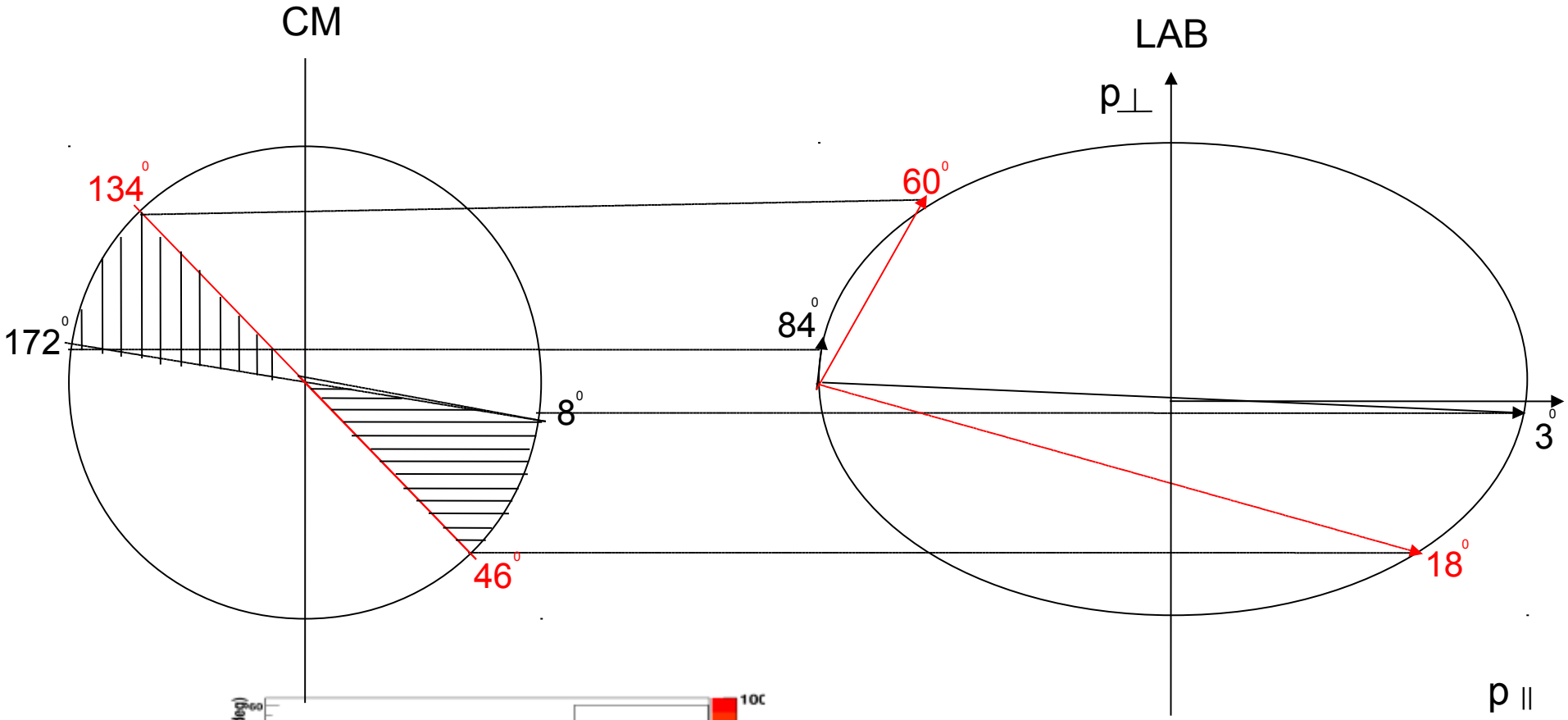
=> η meson production via exchange of isovector mesons

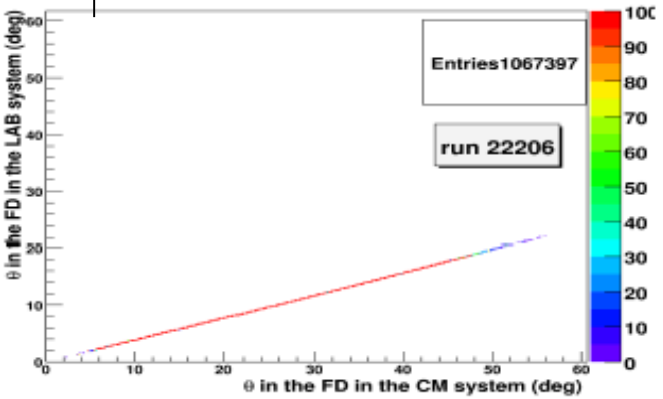
COSY-11


A_y
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
Q=10 MeV
cos(Θ_η)


A_y
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
Q=36 MeV
cos(Θ_CM)

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

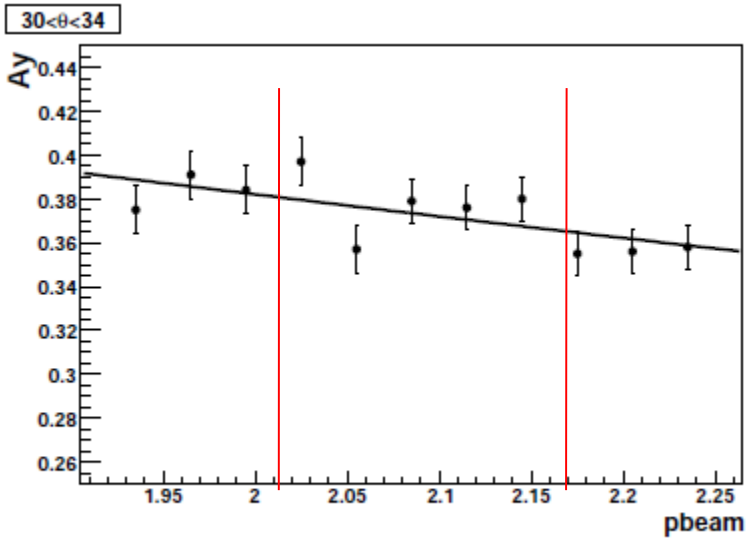
$$\overline{P} \equiv \frac{\sum_{n=1}^{4} \frac{p_n}{\sigma_n^2}}{\sum_{n=1}^{4} \frac{1}{\sigma_n^2}}$$

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

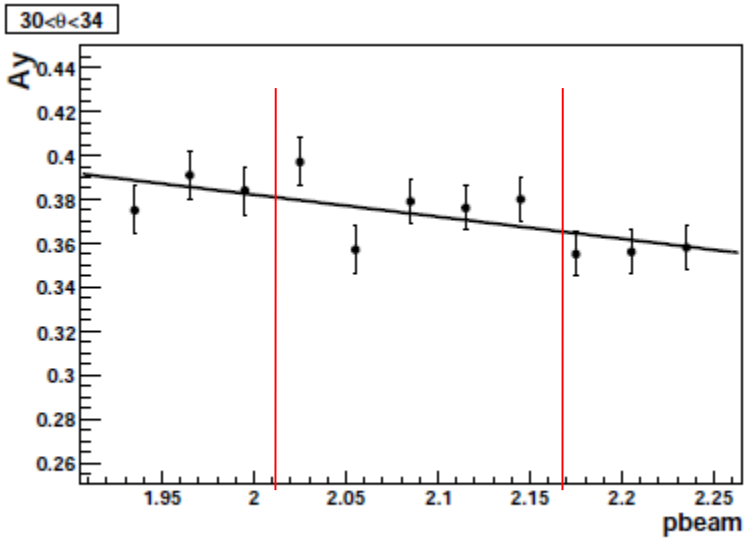
EDDA data base

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

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

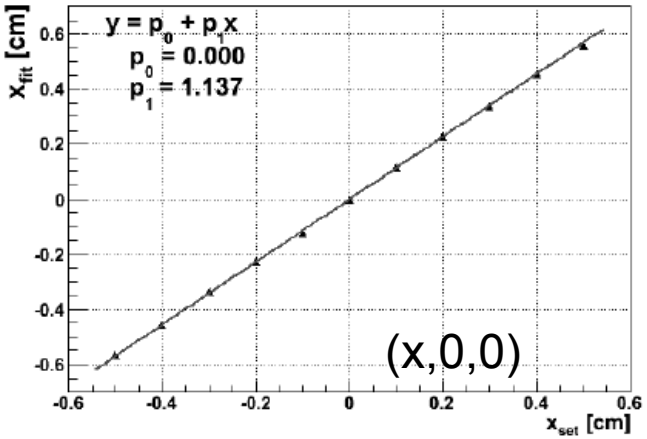


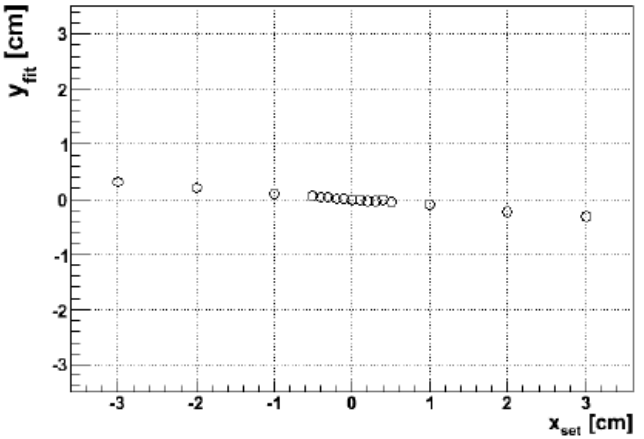
(a) exponential fit

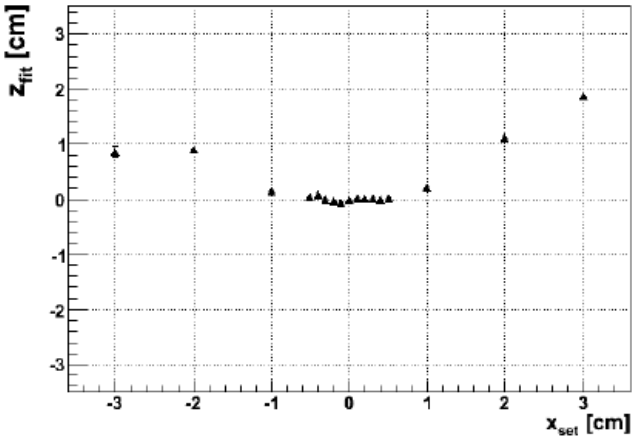


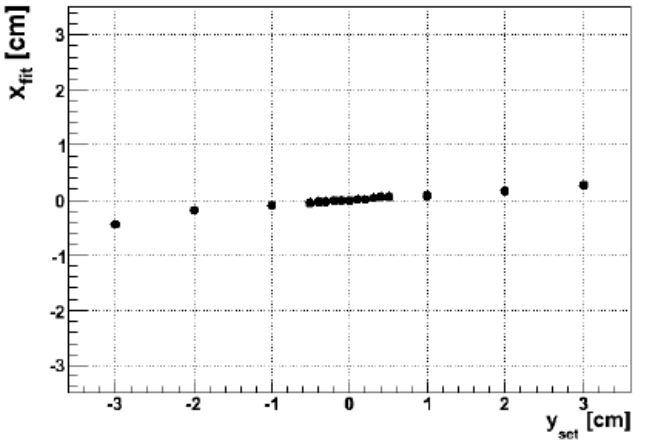
(b) line fit

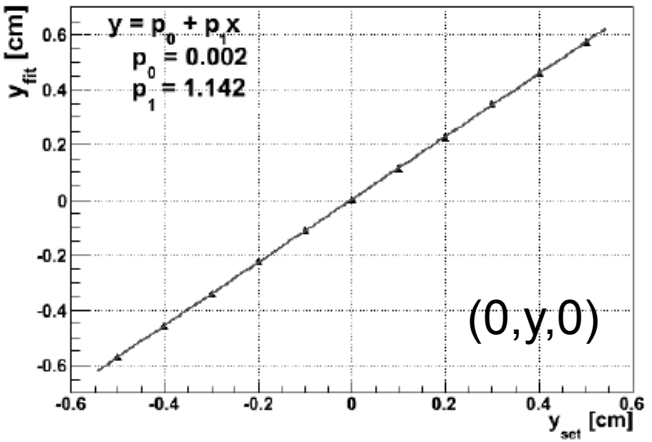
MC for the shift of vertex position

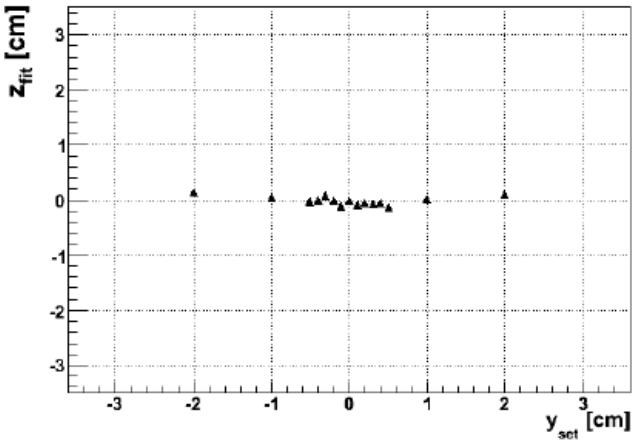


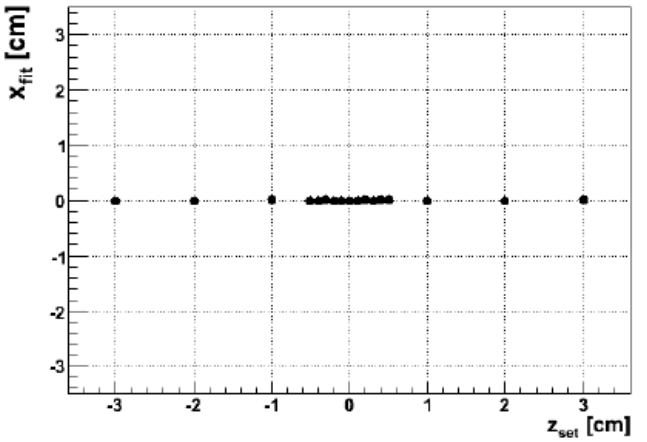


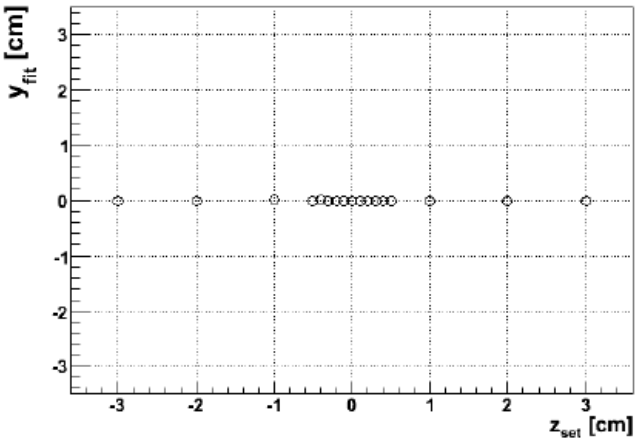


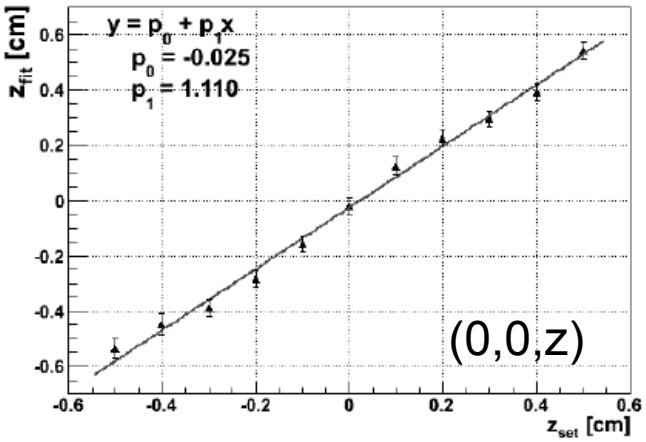












Hodana M. Moskal P. Ozerianska I. *http://arxiv.org/abs/1309.0430*

Calculations of the error bars for Asymmetry(δε)

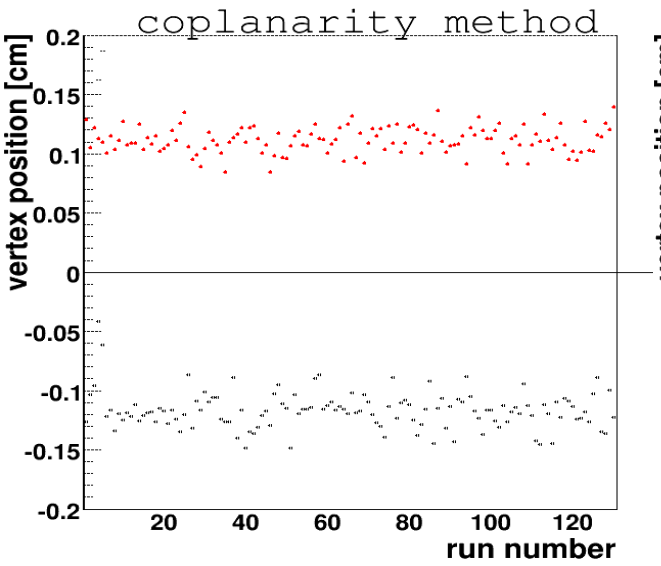
$$\delta\epsilon \equiv \sqrt{\left(\frac{\delta\epsilon}{\delta N_+}\cdot\delta N_+\right)^2+\left(\frac{\delta\epsilon}{\delta N_-}\cdot\delta N_-\right)^2}$$

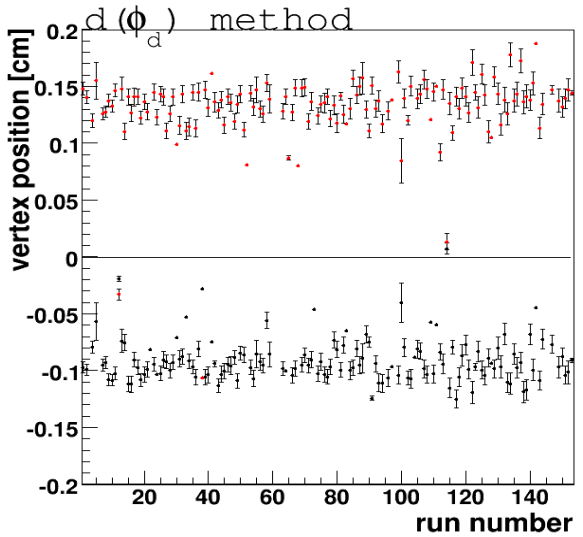
Ay from EDDA

$\theta_{CM}[^\circ]$	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]	$0.366 \pm 0.006_{stat} \pm 0.002_{syst}$	$0.344 \pm 0.008_{stat} \pm 0.002_{syst}$

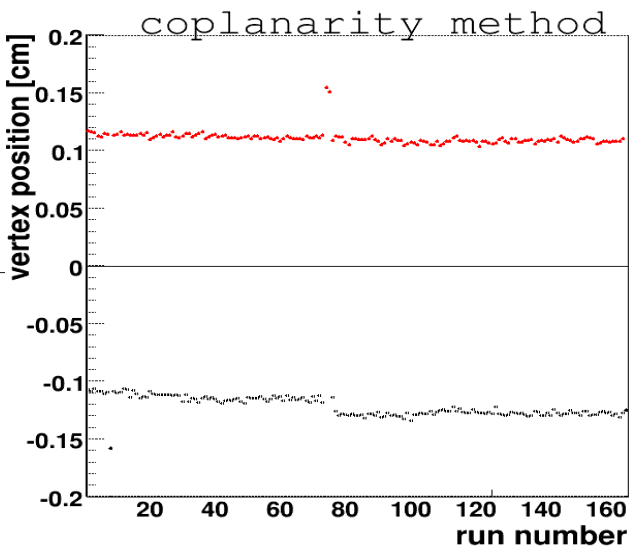
Result of vertex position

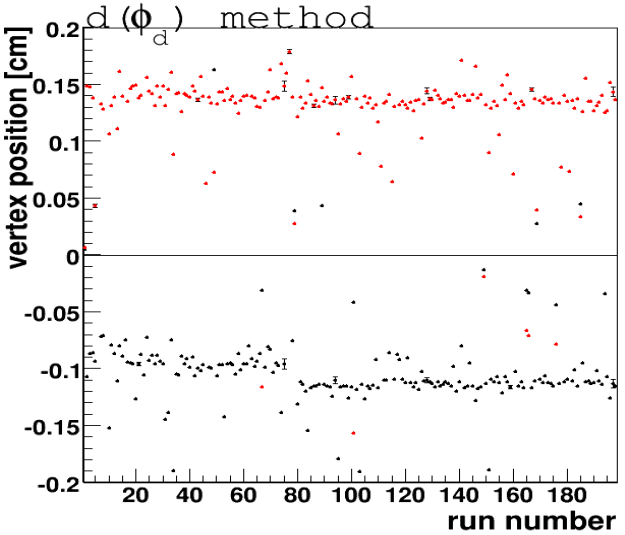
Unpolarized



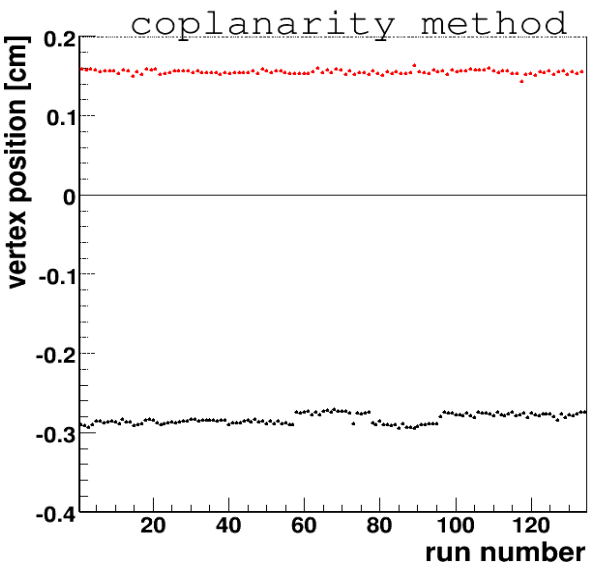


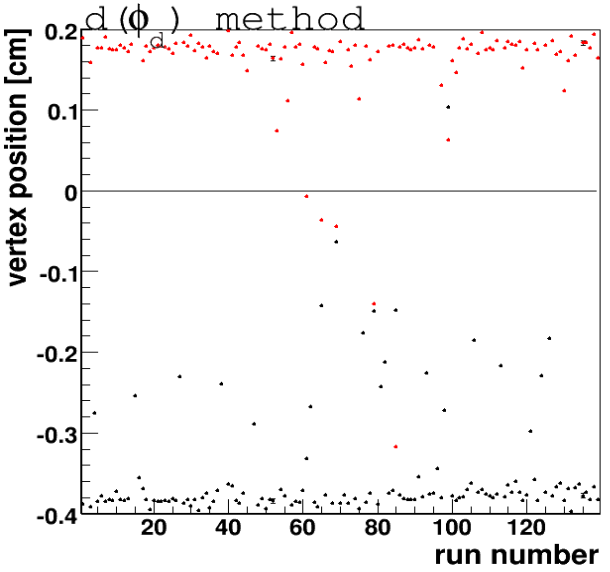
2026 MeV/c





2188 MeV/c





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