The simulation of the azimuthal asymmetry measurement with the BBC SPD.

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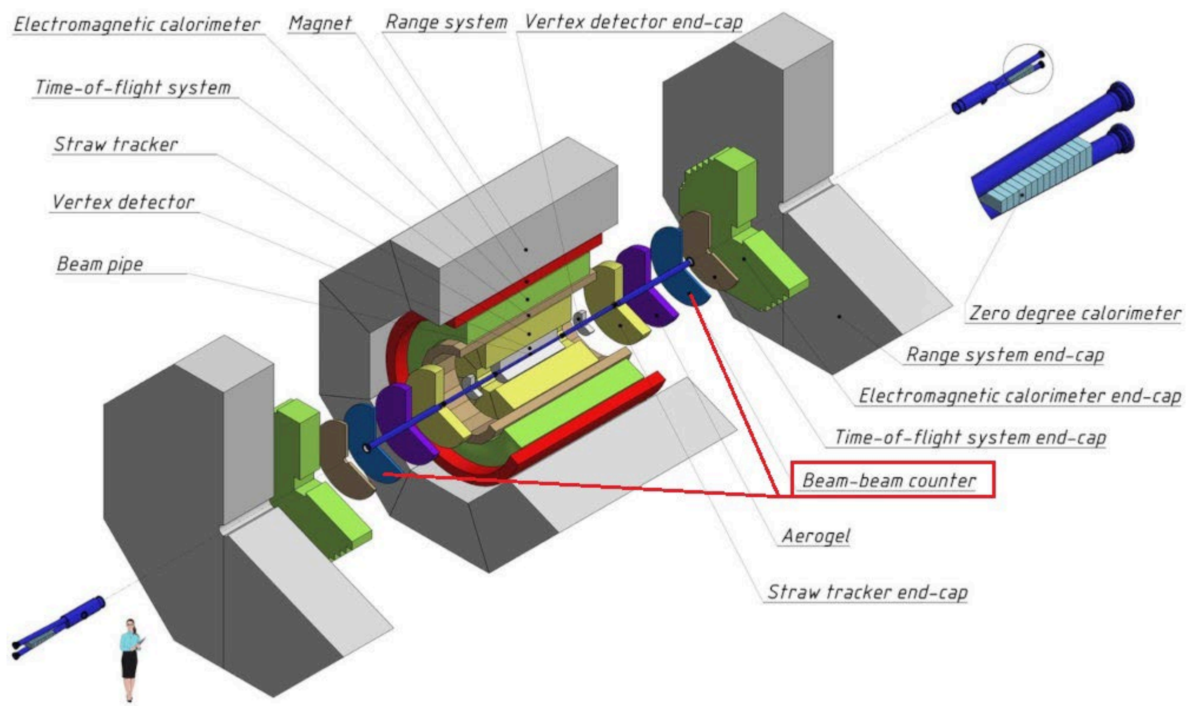
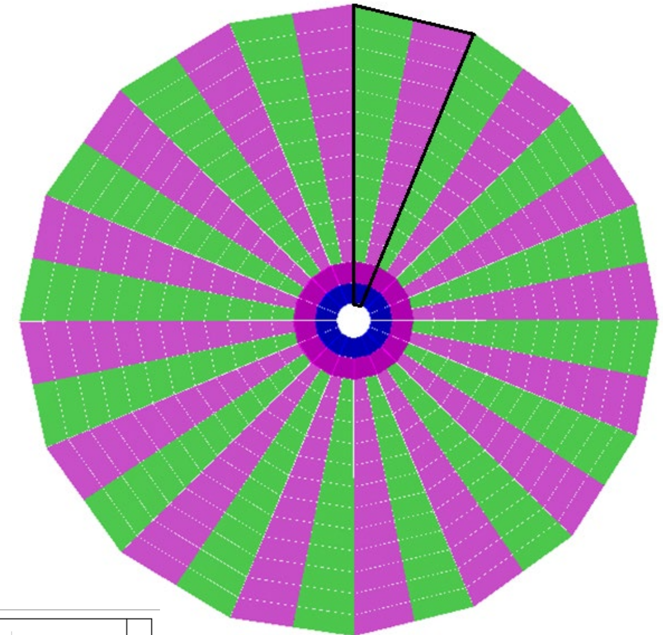
Beam-Beam Counters

The two Beam-Beam Counters (BBC) are components of the Spin Physics Detector (SPD) at the NICA collider. They will be installed in to end-caps parts of SPD and are designed to perform local polarimetry of the colliding polarized proton and deuteron beams and luminosity control in the beam interaction region. BBCs detect all the charged particles produced in the forward direction within their acceptance.

Here, the MC simulation of the BBC operation for proton-proton collisions is presented. The simulations are performed at the center-of-mass energies 10 and 27 GeV using the SpdRoot framework.



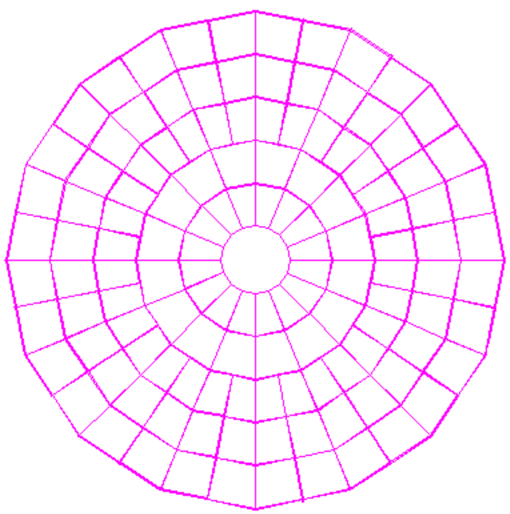
TDR design 2023

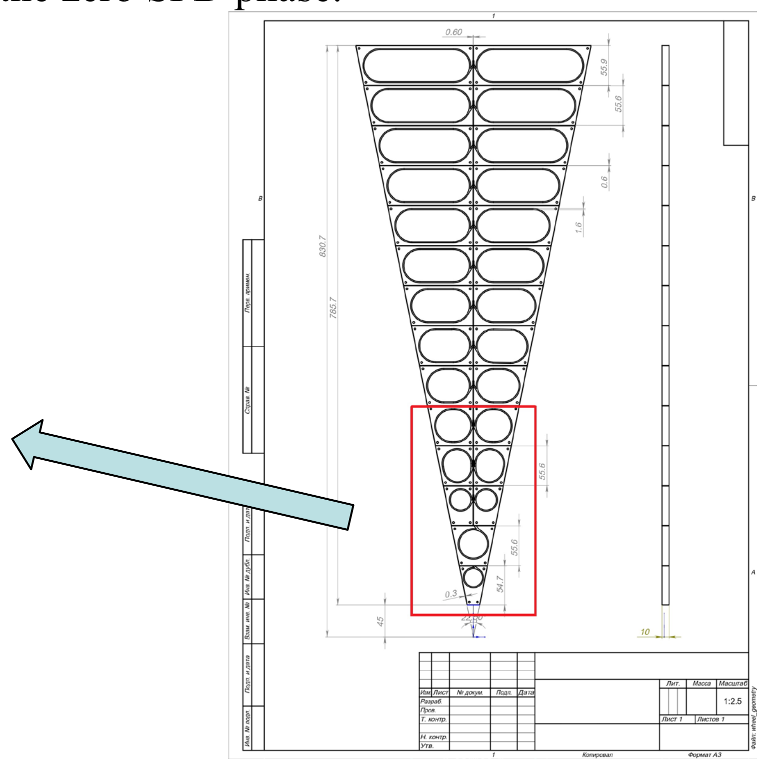


BBC - detector

- 416 scintillation tiles
- 14 concentric layers with 16 azimuthal sectors each
- The distance between tiles is equal 1 mm.
- The tile thickness is equal 10 mm.
- The diameter will be equal about 1650 mm.
- The distance between each detector and SPD center is equal Z = 1716 mm.
- The uncertainty of location of the interaction point is expected to be ΔZ ~ ±300 mm.

The BBC prototype will be used in the zero SPD phase.





PP – scattering simulation

Estimation of the BBC performance in the azimuthal asymmetry measurements are presented. How can be observed the polarization effect with BBC? The "visible A_N" in each BBC layer are interested.

The weighting procedure is used. The analysis of the azimuthal φ - distributions for each BBC layer is required.

FTF model, SpdRoot full simulation, $\sqrt{s}$ = 10 and 27 GeV, 10^7 interactions, B = 0.

Weighting procedure

$$w = 1 + p \cdot A_N(x_F,p_T) \cdot \cos(\varphi), \qquad p = 1$$

Mode polarization: ↑ (N^+) and ↓ (N^-)

Weighting procedure:

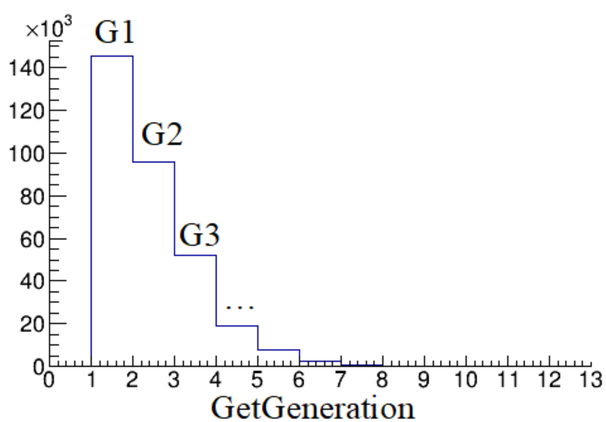
N^+: $w = 1 + p \cdot A_N(x_F,p_T) \cdot \cos(\varphi)$

N^-: $w = 1 - p \cdot A_N(x_F,p_T) \cdot \cos(\varphi)$

$$\Rightarrow R = \frac{N^+ - N^-}{N^+ + N^-} \Rightarrow$$

Fit function:

$P_0 \cdot \cos(\varphi + P_1)$



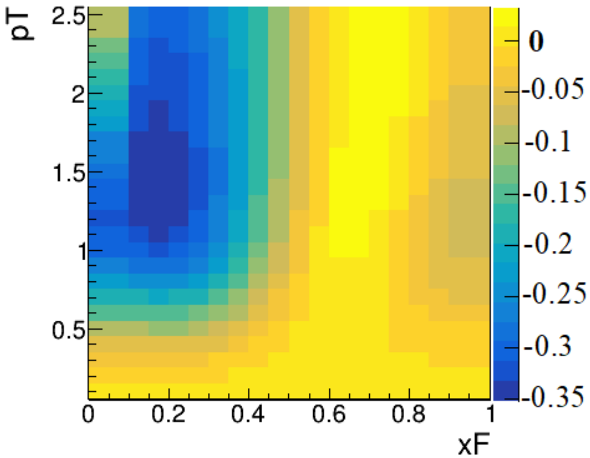
G1: $w = 1 + p \cdot A_N(x_F,p_T) \cdot \cos(\varphi)$

G2,G3…: $w = 1$

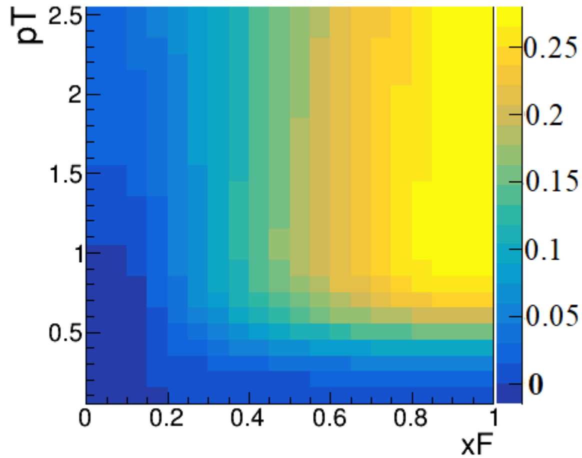
CPQ model

$A_N = f(x_F, p_T)$, $\sqrt{s} = 27$ GeV

Protons

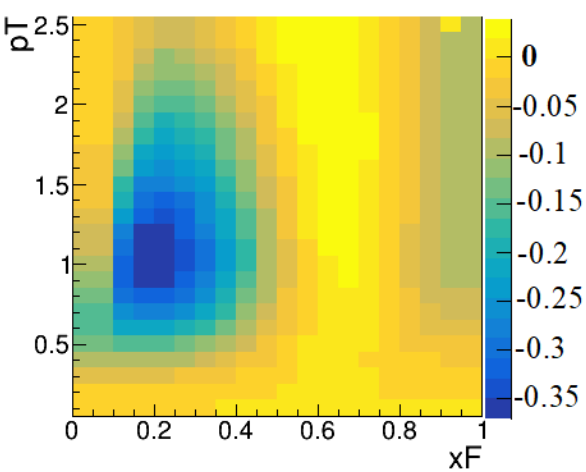


π^+

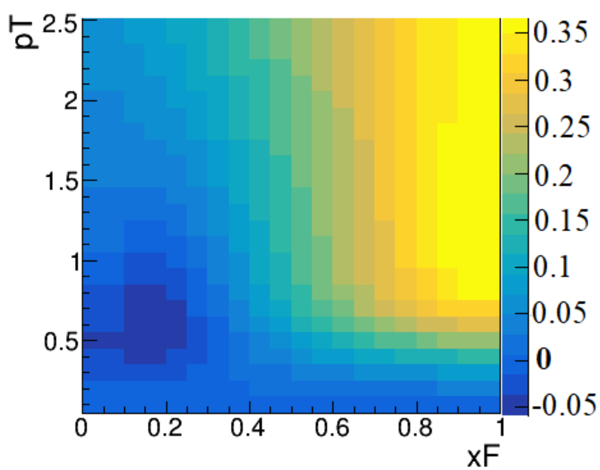


$A_N = f(x_F, p_T)$, $\sqrt{s} = 10$ GeV

Protons



π^+



$$p + p \to p + X$$
$$p + p \to \pi^+ + X$$
$$p + p \to \pi^- + X$$
$$p + p \to K^+ + X$$
$$p + p \to K^- + X$$

Weighting

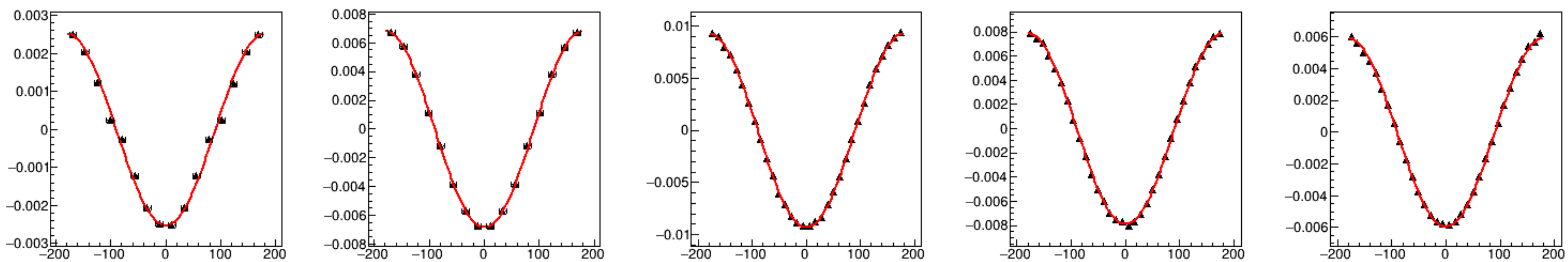
FTF model, B = 0 **p = 1, $A_N(x_F,p_T)$ = CPQ data.**

$$\text{p} \pm 1 \Longrightarrow R = \frac{N^+ - N^-}{N^+ + N^-} \Longrightarrow \textbf{Fit function: } P_0 \cdot \cos(\varphi + P_1)$$

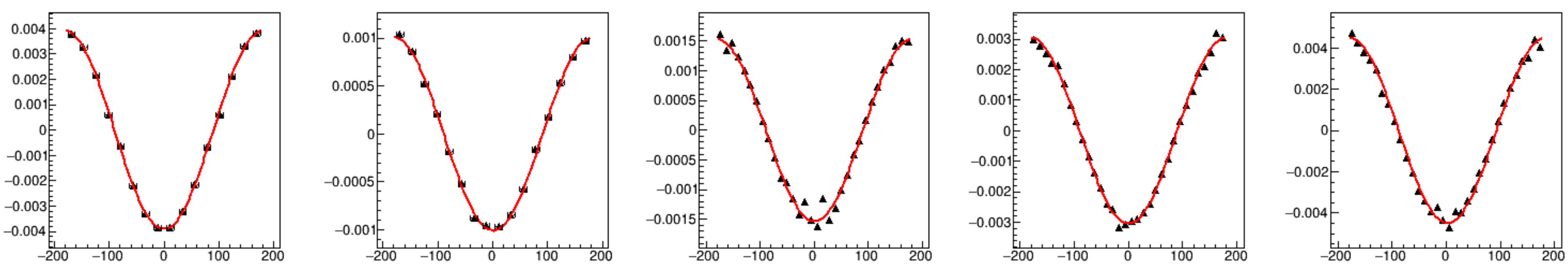
$$\Delta R \sim 1/\sqrt{2N^{+(-)}} \Longrightarrow \text{For } 1\cdot 10^7 \text{ interaction } \Delta R \sim R$$

$R(\varphi)$ – distributions

$\sqrt{s}$ = **27** GeV, $1\cdot 10^7$ interaction

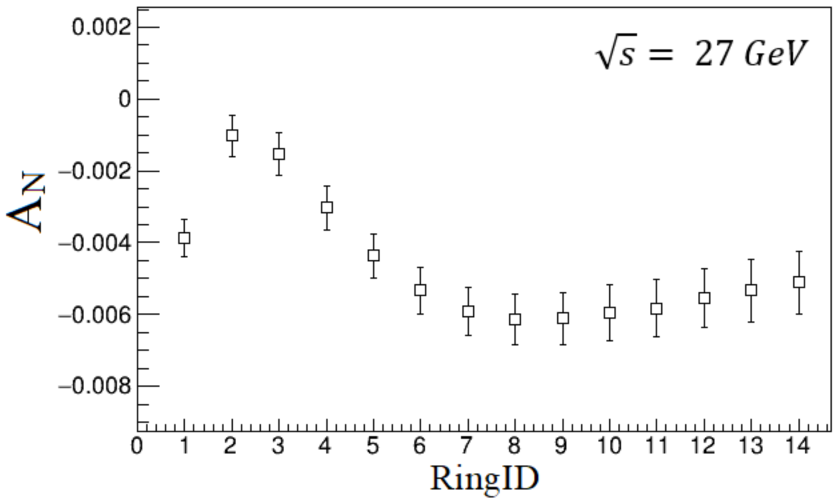


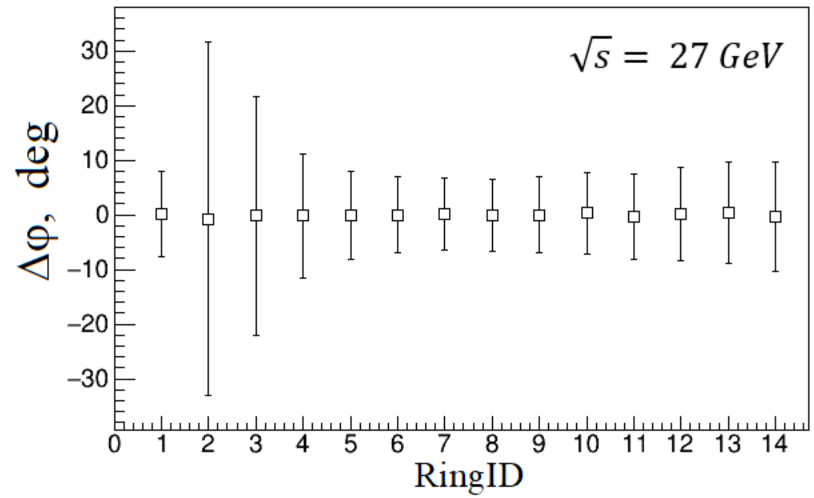
$\sqrt{s}$ = **10** GeV, $1\cdot 10^7$ interaction

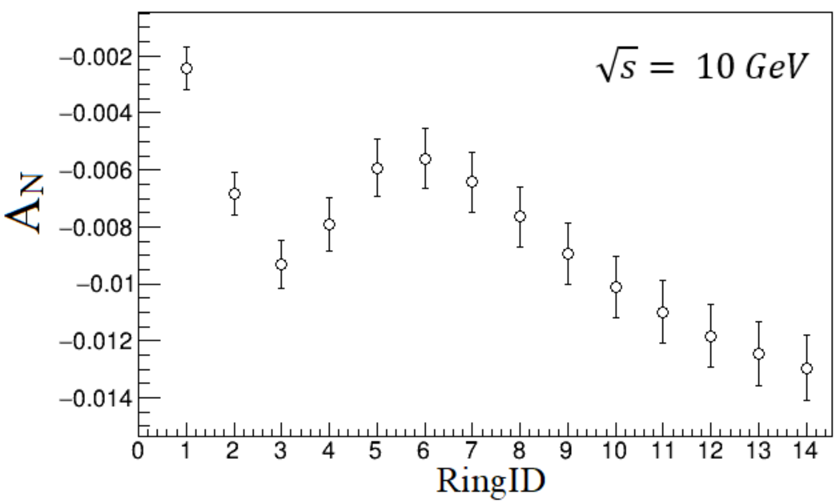


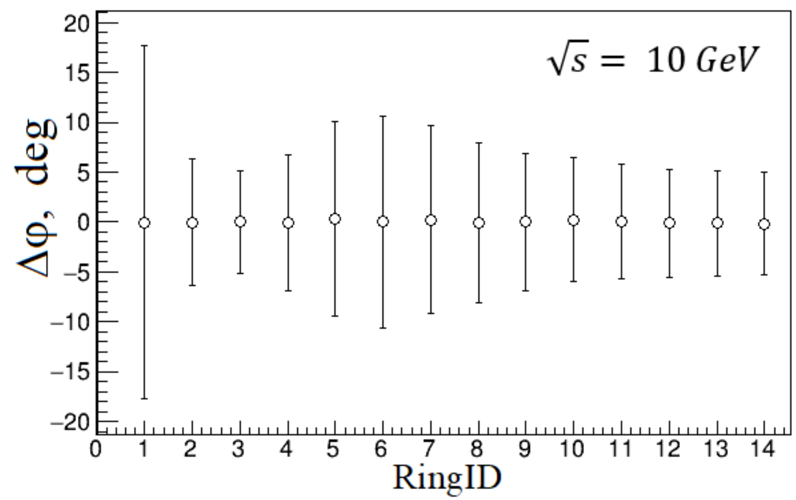
Analyzing power

$$R = \frac{N^{+} - N^{-}}{N^{+} + N^{-}} \Longrightarrow \textbf{Fit function: } P_0 \cdot \cos(\varphi + P_1) \Longrightarrow \begin{array}{l} P_0 = A_N \\ P_1 = \Delta\varphi \end{array}$$





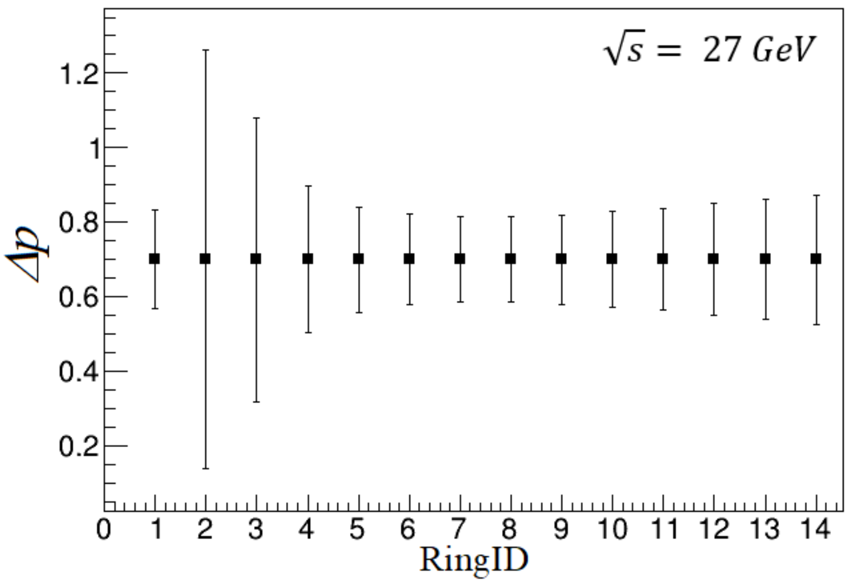


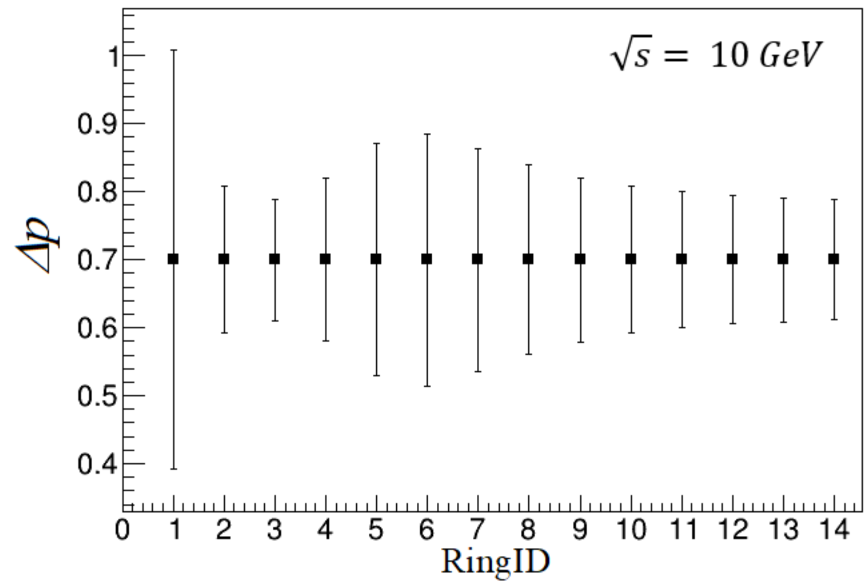


Uncertainty of polarization

$$R = \frac{N^+ - N^-}{N^+ + N^-} \Rightarrow \textbf{Fit function: } P_0 \cdot \cos(\varphi + P_1) \Rightarrow P_0 = p \cdot A_N \Rightarrow \Delta p = \frac{\Delta P_0}{A_N}$$

$p_{\text{input}} = 0.7$





$$\overline{\Delta p} = \sqrt{\frac{1}{\sum_{i=1}^{14} \frac{1}{\Delta p_i{}^2}}}$$

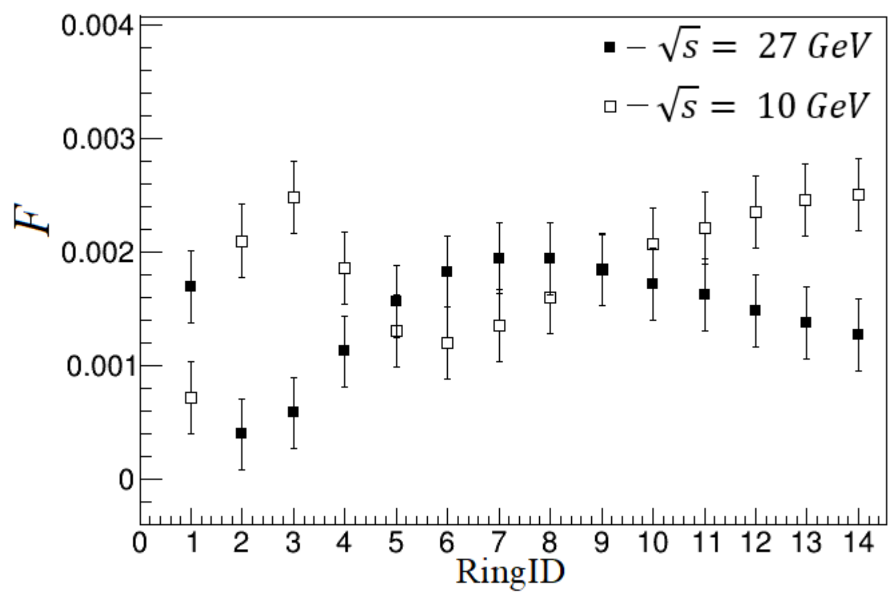
	N	$L,\ cm^{-2}c^{-1}$	$\sigma^{pp}_{tot},\ mb$	t, sec	$\overline{\Delta p}$
$\sqrt{s} = 27$ GeV	$1 \cdot 10^7$	10^{32}	40	2.5	0.039
$\sqrt{s} = 10$ GeV	$1 \cdot 10^7$	$3 \cdot 10^{30}$	38	87.7	0.031

$$\Delta p_i = \frac{(\Delta P_0)_i}{(A_N)_i}$$

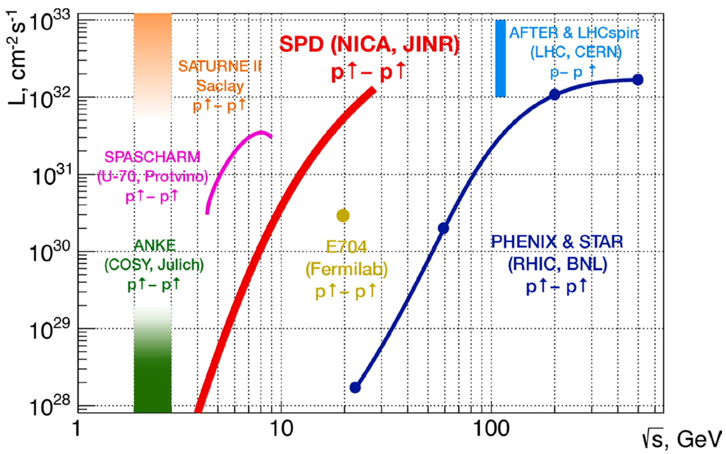
Figure of merit

$$F^{tot} = \sum_{i=1}^{14} F_i = \sum_{i=1}^{14} \sqrt{\frac{N_i^+ + N_i^-}{2 \cdot N_{tot}}} \cdot |A_N^i|$$

	N_{tot}	F^{tot}
$\sqrt{s} = 27$ GeV	$1 \cdot 10^7$	0.02
$\sqrt{s} = 10$ GeV	$1 \cdot 10^7$	0.026



Uncertainty of polarization



$$\Delta p = \frac{\sqrt{2}}{F \cdot \sqrt{N_{inc}}}$$

$$N_{inc} = L \cdot \sigma_{tot} \cdot t$$

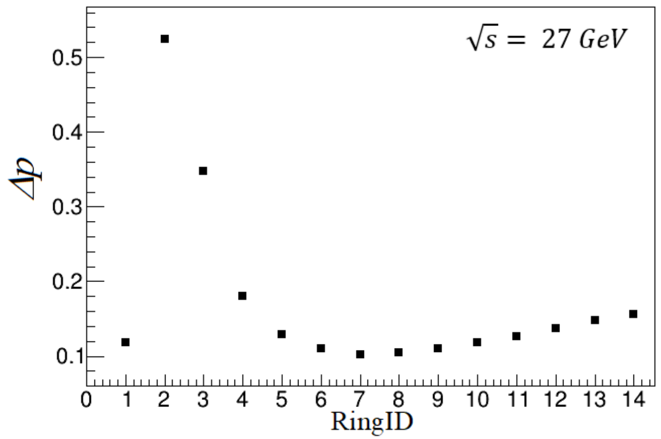
$$p = 0.7$$

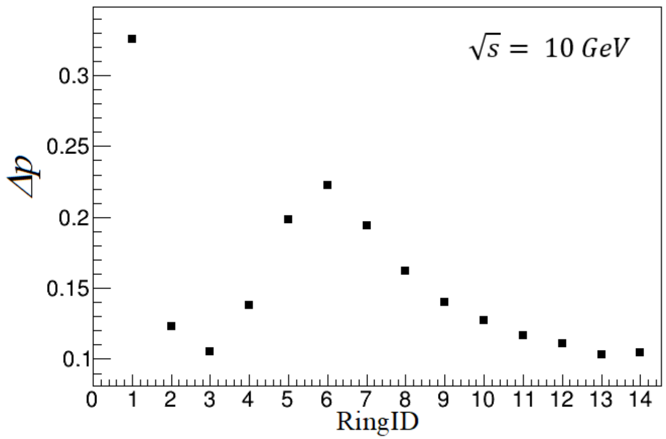
	$L,\ cm^{-2}c^{-1}$	$\sigma^{pp}_{tot},\ mb$	N_{tot}	F^{tot}	t, sec	$\overline{\Delta p}$	Δp
$\sqrt{s}$ = 27 GeV	10^{32}	40	$1\cdot10^7$	0.020	2.5	0.039	0.022
$\sqrt{s}$ = 10 GeV	$3\cdot10^{30}$	38	$1\cdot10^7$	0.026	87.7	0.031	0.017

Uncertainty of polarization

$$\Delta p = \frac{\sqrt{2}}{F \cdot \sqrt{N_{inc}}} \qquad N_{inc} = L \cdot \sigma_{tot} \cdot t \qquad p = 0.7$$

	$L,\ cm^{-2}c^{-1}$	$\sigma^{pp}{}_{tot},\ mb$	F^{tot}	Δp	t, sec
$\sqrt{s}$ = 27 GeV	10^{32}	40	0.020	0.01	12.5
				0.02	3.1
$\sqrt{s}$ = 10 GeV	$3 \cdot 10^{30}$	38	0.026	0.01	256 (4.3 min)
				0.02	65

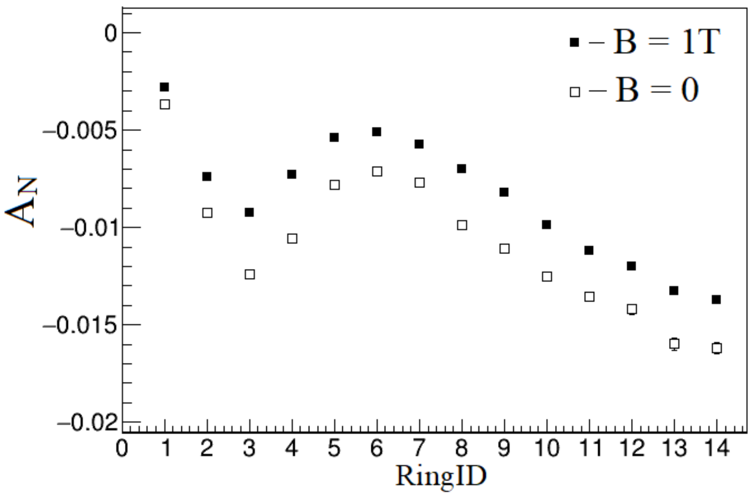


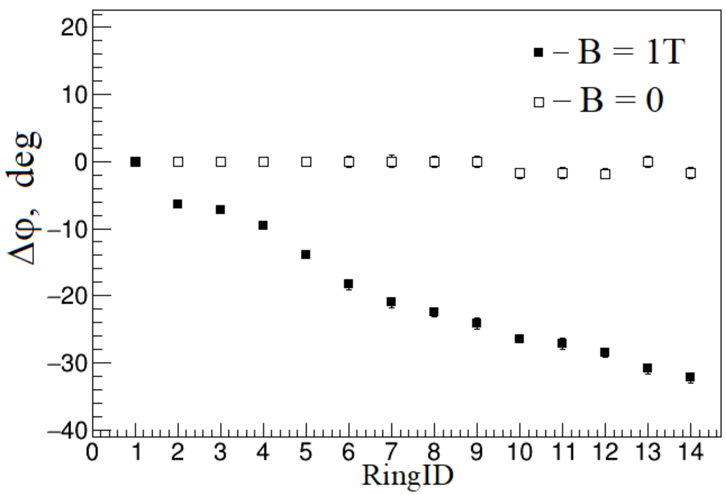


Analyzing power

B = 1T

$\sqrt{s}$ = 10 GeV





Results

- SpdRoot simulation with FTF model have been performed for pp-scattering at total energies 10 and 27 GeV.
- The weighting procedure has been applied for the azimuthal asymmetry measurements. The A_N data from CPQ model.
- The azimuthal asymmetry can be determined with the BBC in each layer.
- The estimation of the run time to approach of the polarization uncertainty 1-2% have been performed.
- The magnetic field influence to the measured asymmetry and phase was estimated. The expected account for analyzing power is up to 15%. The phase shift is increased with the BBC-layer increasing and is expected up to 40 degree.