Run13 Local Polarimetry

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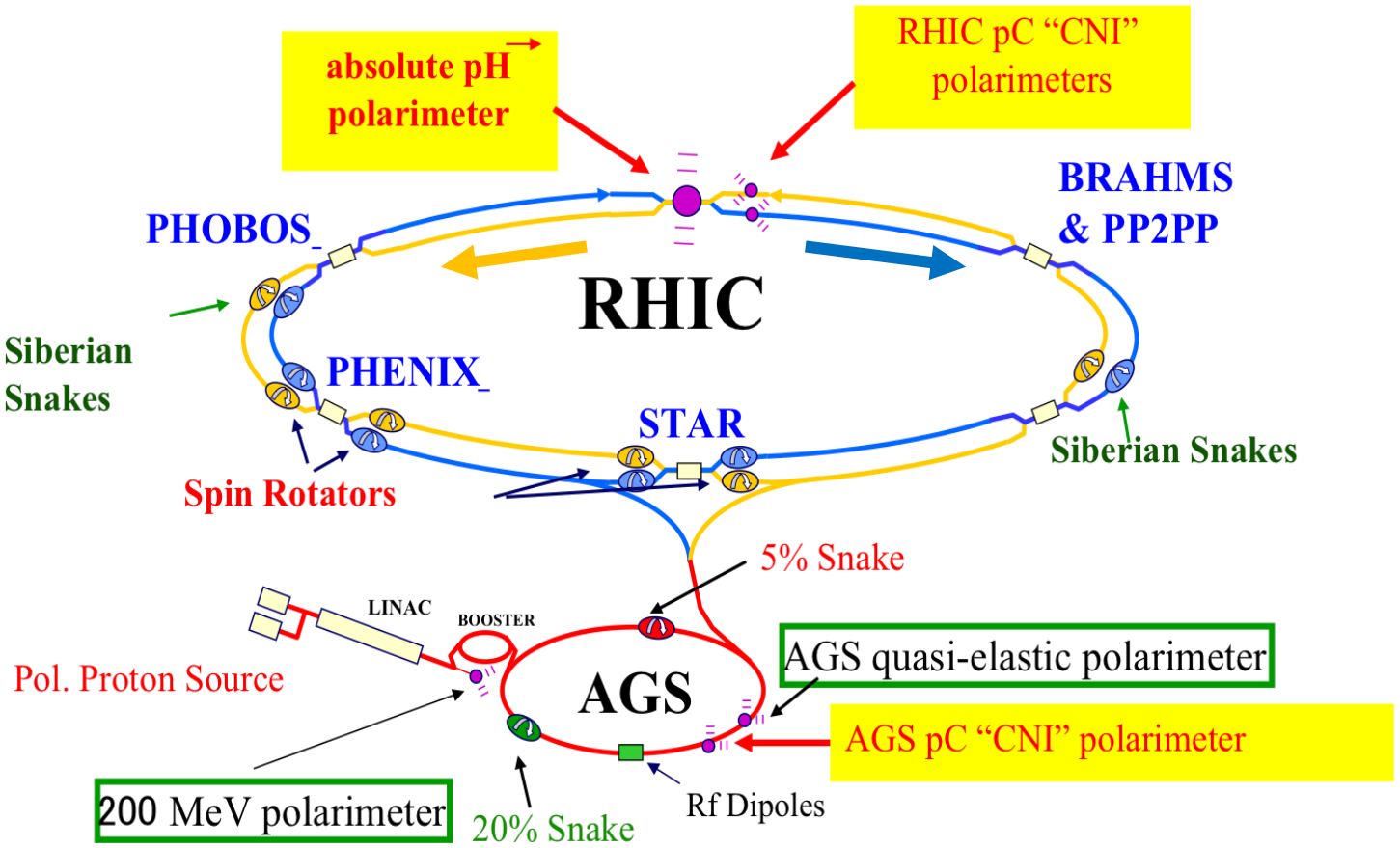
Japan-Korea PHENIX Collaboration Workshop

Minjung Kim
for the PHENIX collaboration
Department of Physics and Astronomy
Seoul National University

Polarization at RHIC



- Provides various spin patterns
- Hydrogen gas target polarimeter and carbon target polarimeter to measure polarization
- Clockwise beam: blue beam
- Counter-clockwise beam: yellow beam

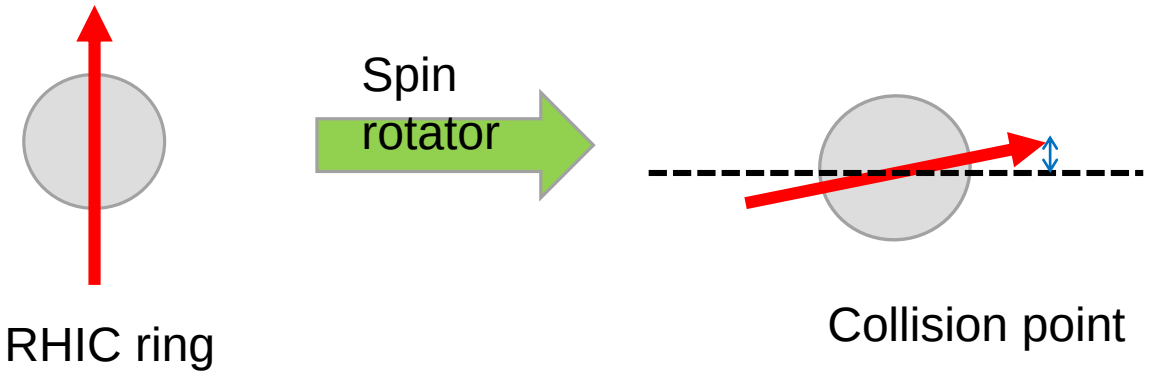
Why Local polarimeter is needed?

- Beam polarization direction:

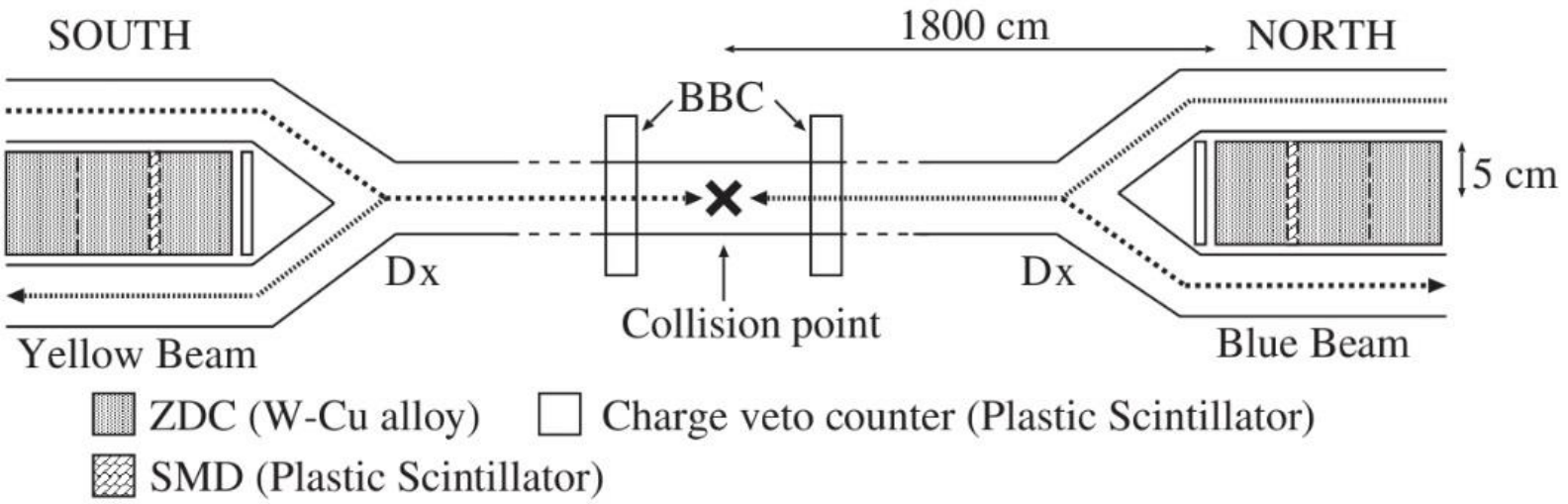
  Vertical in RHIC except experiment hall

  Longitudinal at the experiment hall –
  for A_{LL} measurements

- Need to know transverse component of polarization which gives systematic error



Local Polarimeter at PHENIX



Measure transverse component of polarization from neutron's production single transverse spin asymmetry at the very forward region

Downstream of Dx magnet in order to avoid charged particles from collision.

Consists of

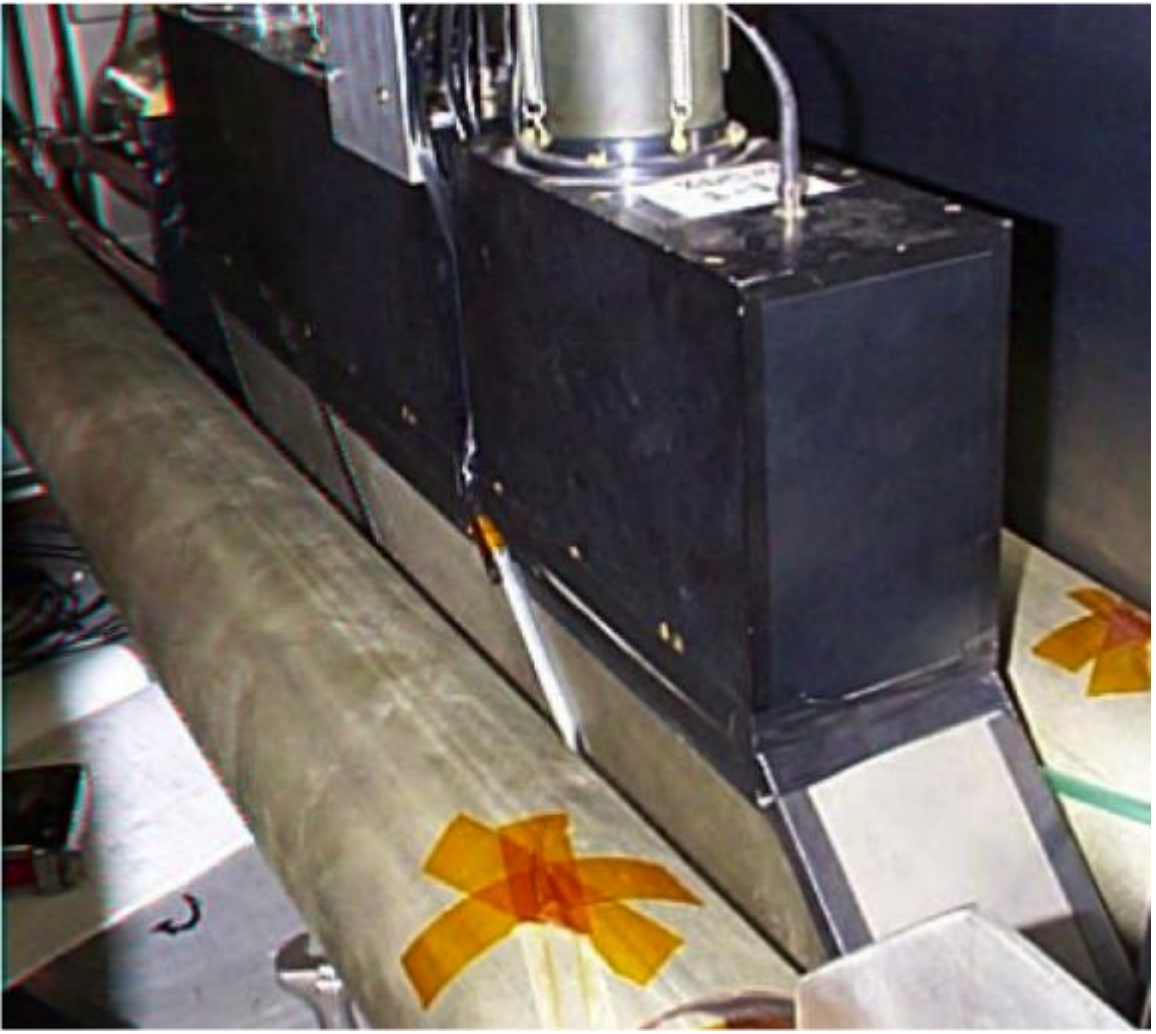
Zero Degree Calorimeter (ZDC) and Shower Max Detector (SMD)

Neutron Asymmetry Results

- IP12 experiment at 12'o clock at RHIC (2001-2002)
- Measured single transverse spin asymmetry of several particles to establish local polarimeter system.
- Large value of transverse single spin asymmetry for very forward neutron production was obtained.

	forward	backward
neutron	$-0.090 \pm 0.006 \pm 0.009$	$0.003 \pm 0.004 \pm 0.003$
photon	$-0.009 \pm 0.015 \pm 0.007$	$-0.019 \pm 0.010 \pm 0.003$
π^0	$-0.022 \pm 0.030 \pm 0.002$	$0.007 \pm 0.021 \pm 0.001$

Local Polarimeter Hardware

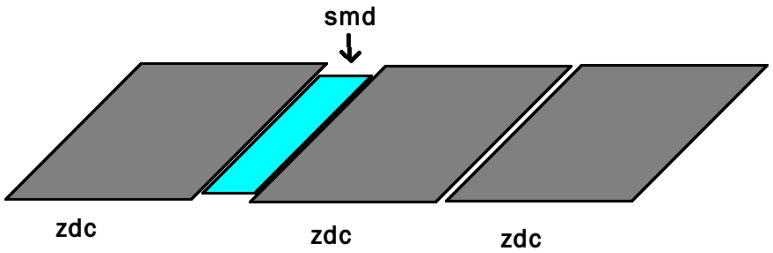


Zero Degree Calorimeter:

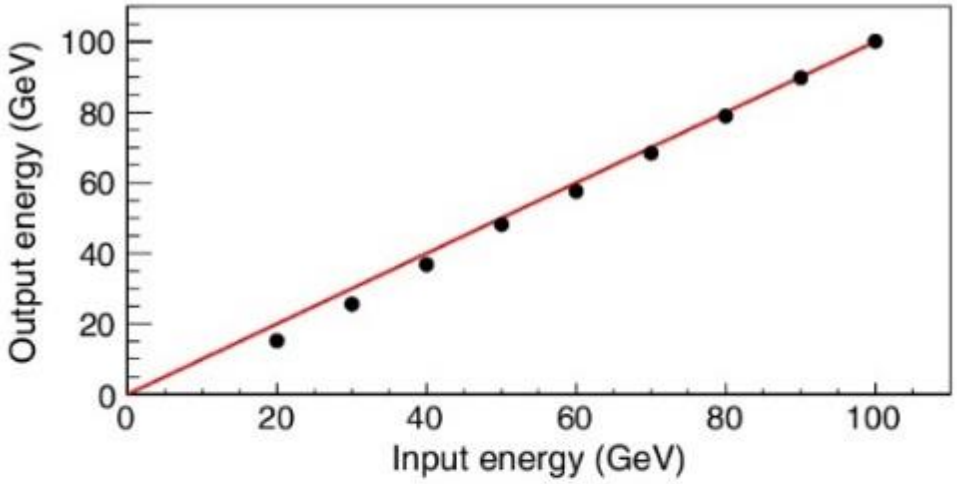
- Hadron calorimeter consists of Cu-W alloy and optical fibers

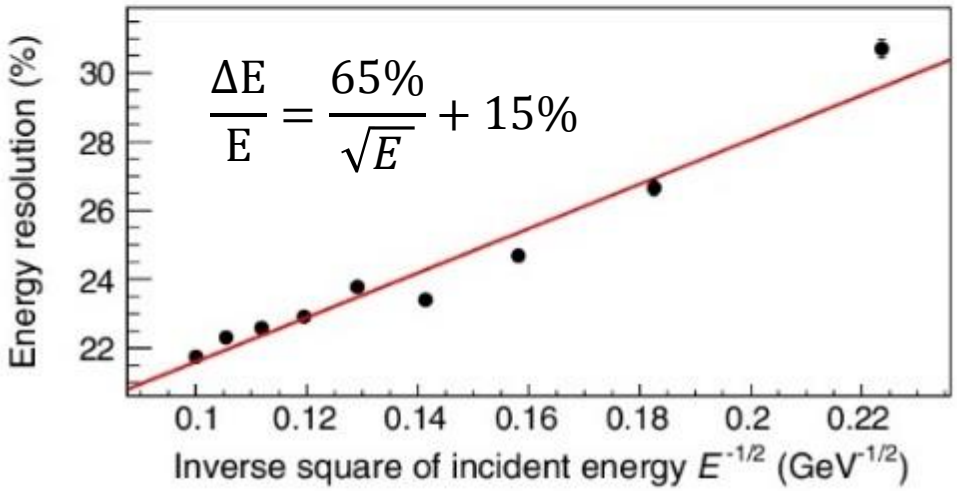
Shower Max Detector:

- X-y scintillator strip hodoscopes



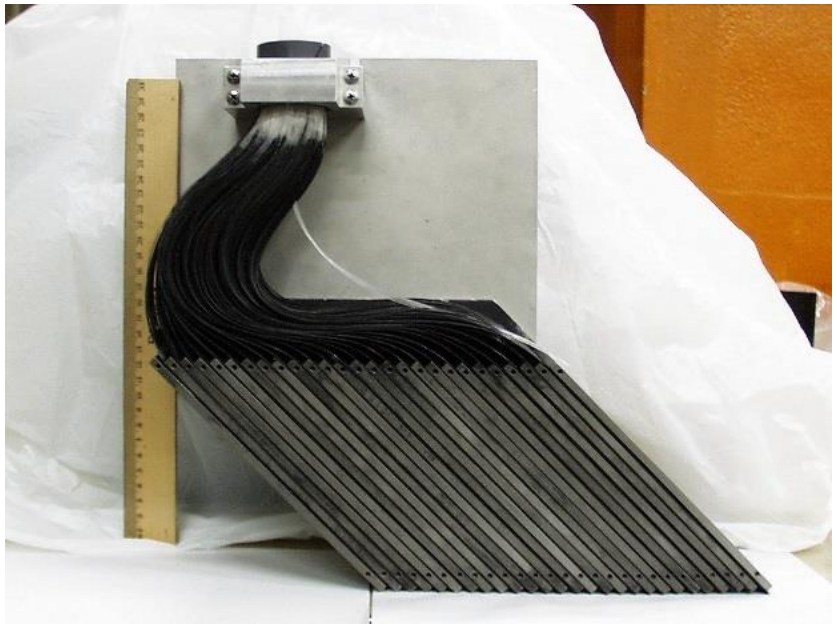
Zero Degree Calorimeter (ZDC)



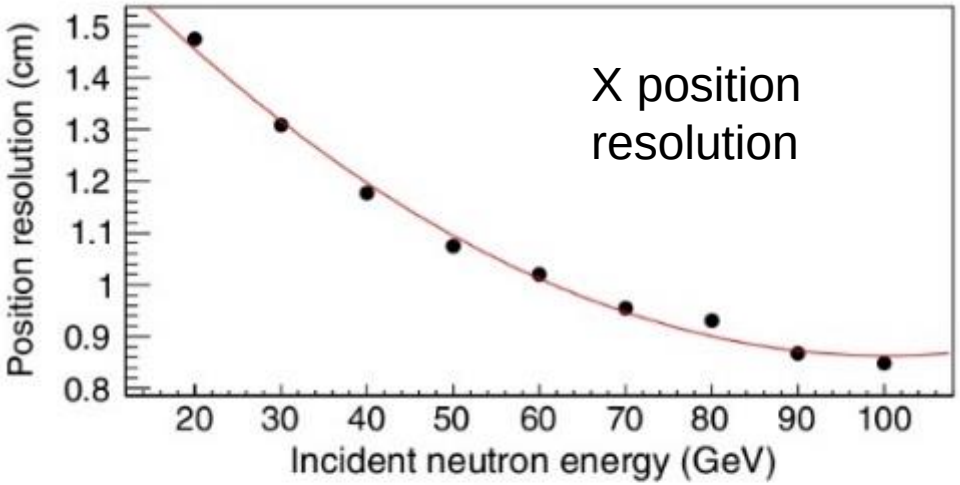


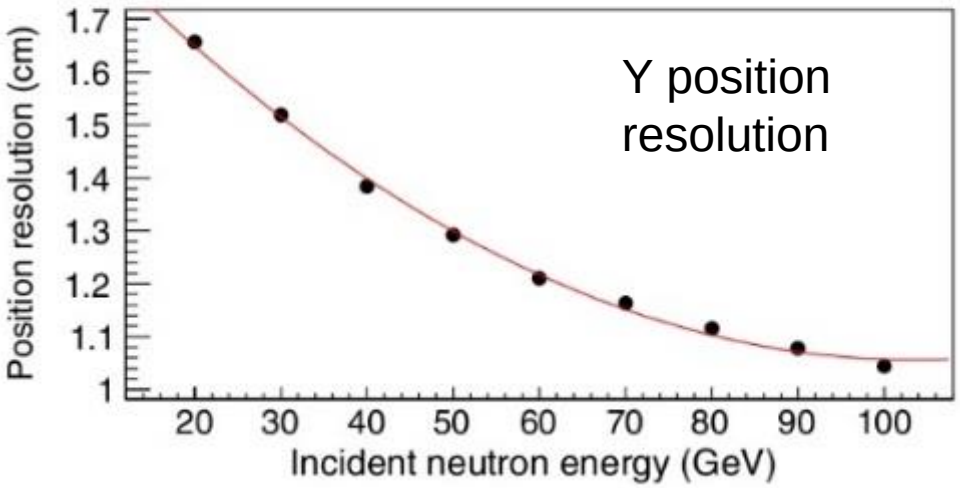
1.7 nuclear interaction length & 51 radiation length x 3 modules

Collect Cherenkov light from charged particles from neutron shower via optical fiber



Shower Max Detector (SMD)





- Measure energy from neutron shower, calculate position with centroid method
- Position resolution: ~1 cm for 100GeV neutron

How to get transverse component?

$$A_N = \frac{e_N}{p_T}$$

-Get A_N from transverse run

-In longitudinal run, transverse component $\frac{p_T}{p} = \frac{1}{p}\frac{e_N}{A_N}$

e_N: measured raw asymmetry with sqrt formula

p: beam polarization of RHIC

p_T : transverse component at the collision point calculated from measured asymmetry in the Local polarimeter

Analysis Cut

Event selection optimization ongoing

Tentative cut:

ZDC energy

-Min: 70 GeV to reject noise

-Max: 300 GeV (255 GeV + ~50 GeV resolution at 255 GeV)

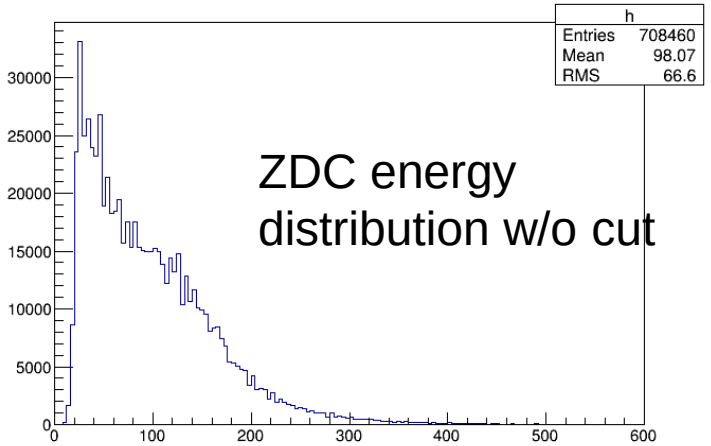
SMD

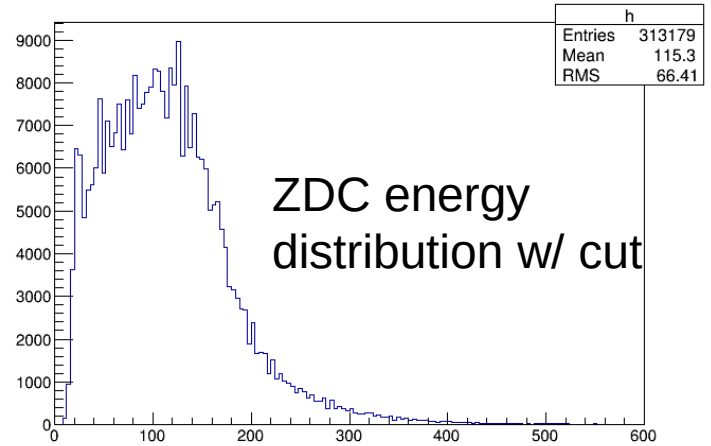
-# of scintillator: >=2 for horizontal && vertical

to reject photon background

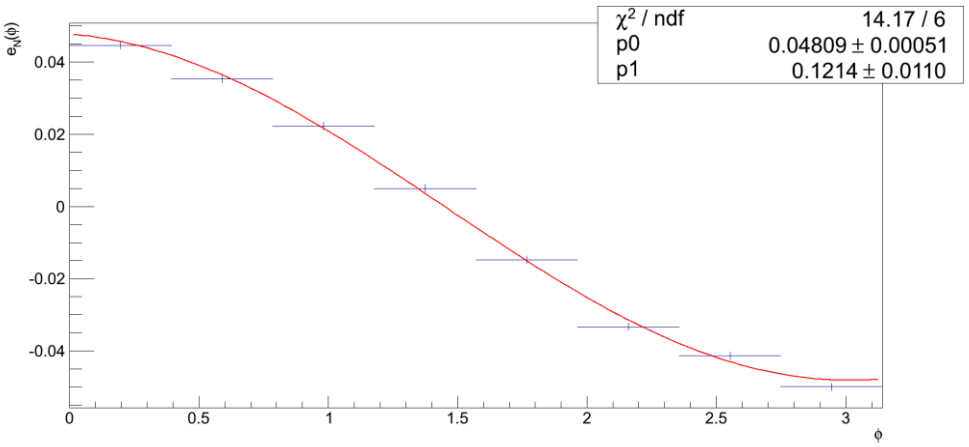
-Acceptance: 0.5< r <4.0 cm

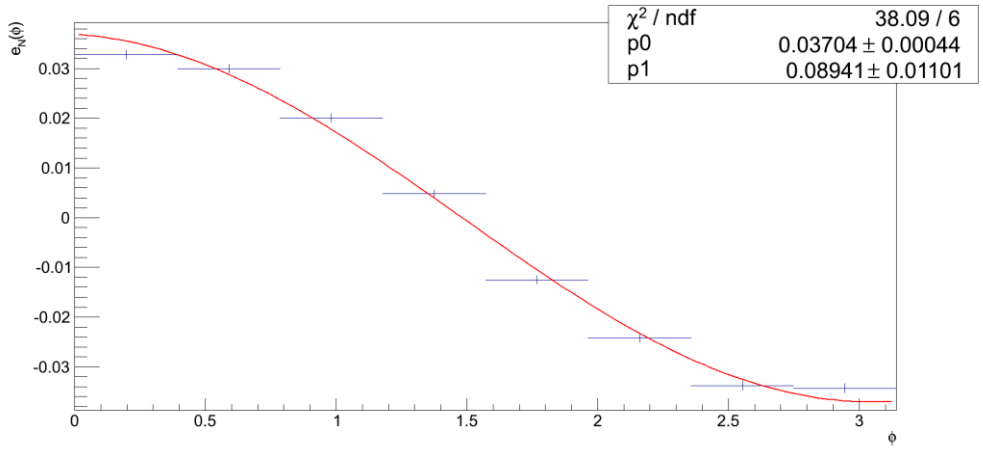
to avoid smearing effect of left-right separation around center & shower leakage at the edge





Transverse commissioning fill





Raw asymmetry results (up: blue beam , down: yellow beam)

RHIC polarization:

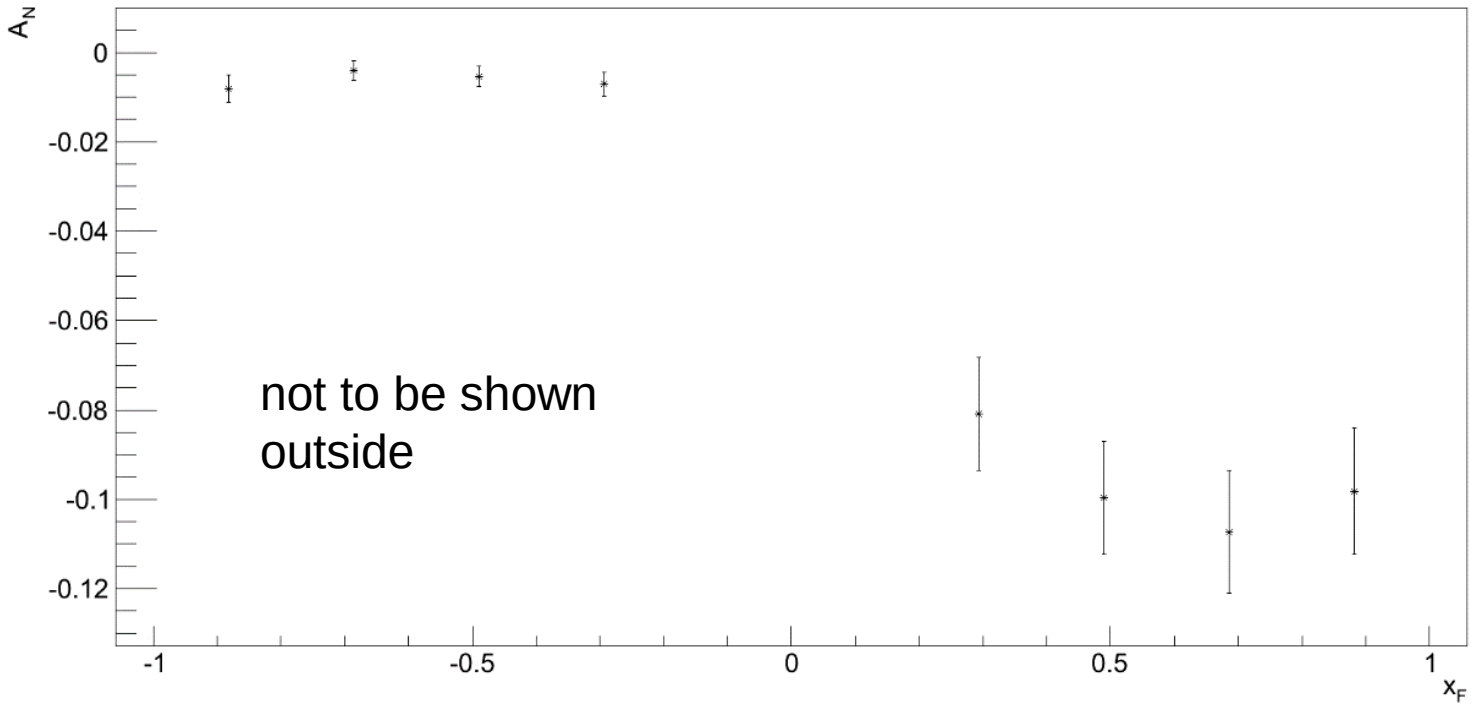
p = 0.502 $\pm$ 0.054 for blue

p = 0.369 $\pm$ 0.061 for yellow

A_N= -0.096 $\pm$ 0.012 for blue

A_N= -0.100 $\pm$ 0.018 for yellow

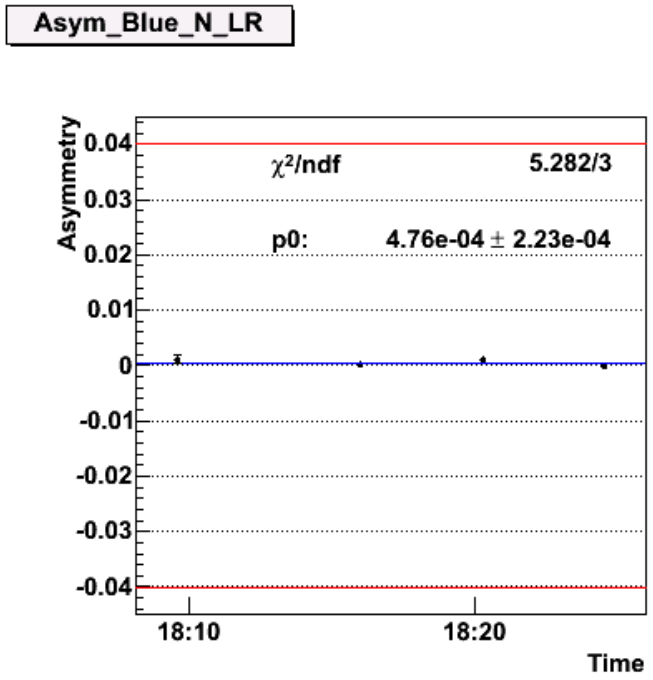
Energy dependence of A_N

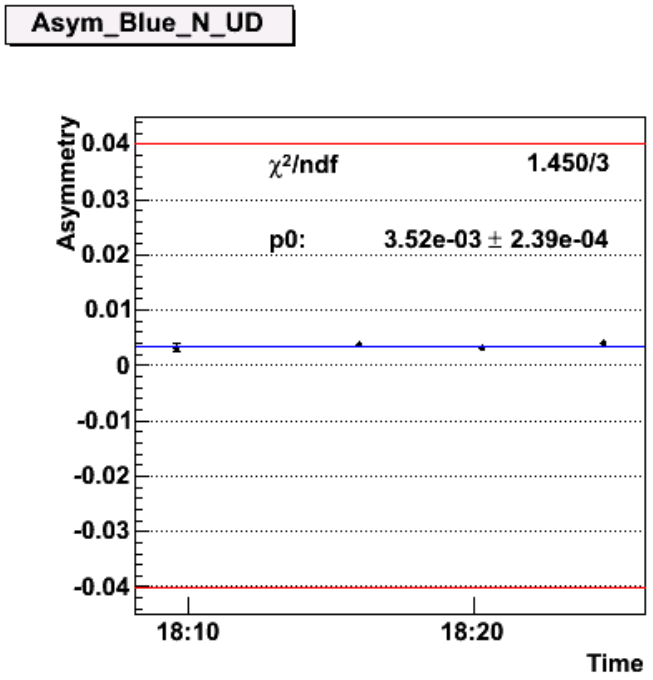


No energy dependence on A_N

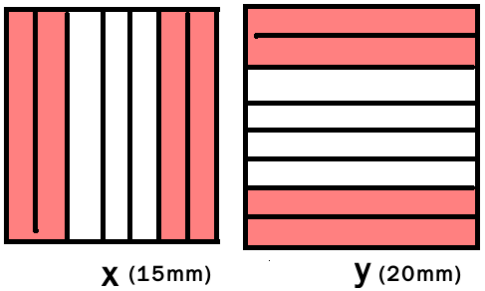
Forward A_N ~ -0.1, no large asymmetry in backward

Online monitor





↑Online monitor plot - raw asymmetry



-Count outer 2 SMD scintillators' hits every 5 minutes

-Get raw asymmetry from the counts

Spin rotator tuning

To find current with minimum transverse component of polarization

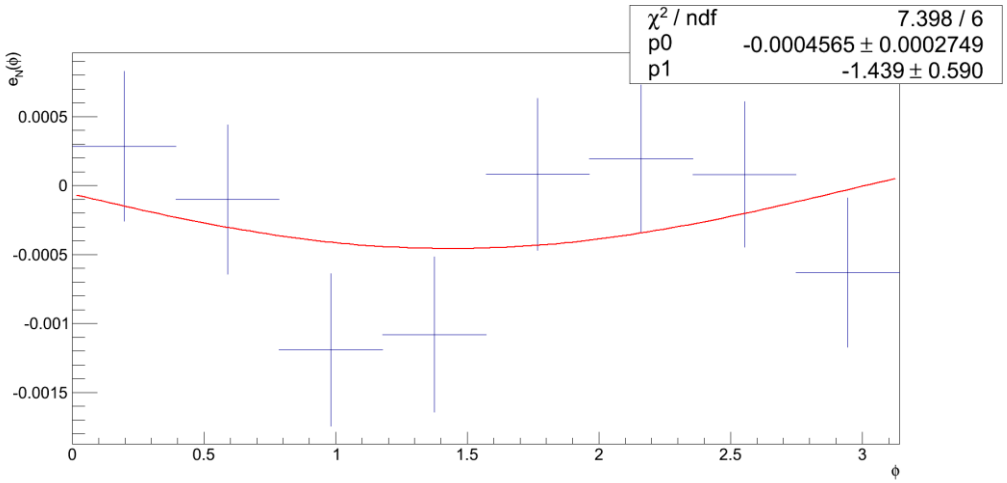
Local Polarimeter used to monitor during rotator tuning

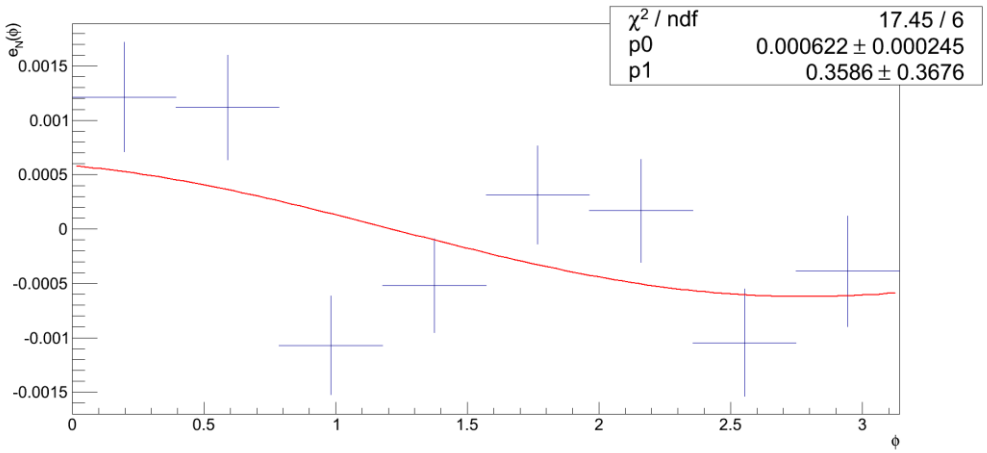
In run 13 Local Polarimeter commissioning, transverse fill -> rotator tuning -> longitudinal fill

runnumber	Inner current	Outer current	$\frac{p_T}{P}$ B	$\Delta\frac{p_T}{P}$ B	$\frac{p_T}{P}$ Y	$\Delta\frac{p_T}{P}$ Y
386227	0	0	0.06	0.01	0.01	0.01
386239	+5	0	0.04	0.01	0.06	0.01
386230	-5	0	0.11	0.01	0.08	0.01
386235	0	+5	0.09	0.01	0.09	0.01
386239	0	-5	0.1	0.01	0.07	0.01
386240	+5	+5	0.07	0.01	0.11	0.01
386241	-5	-5	0.15	0.01	0.07	0.01

+(-) current increased (decreased) from last year's current

Longitudinal commissioning fill





Raw asymmetry results plots (up: blue beam, down: yellow beam)

Relatively very small vertical scale

Transverse component:

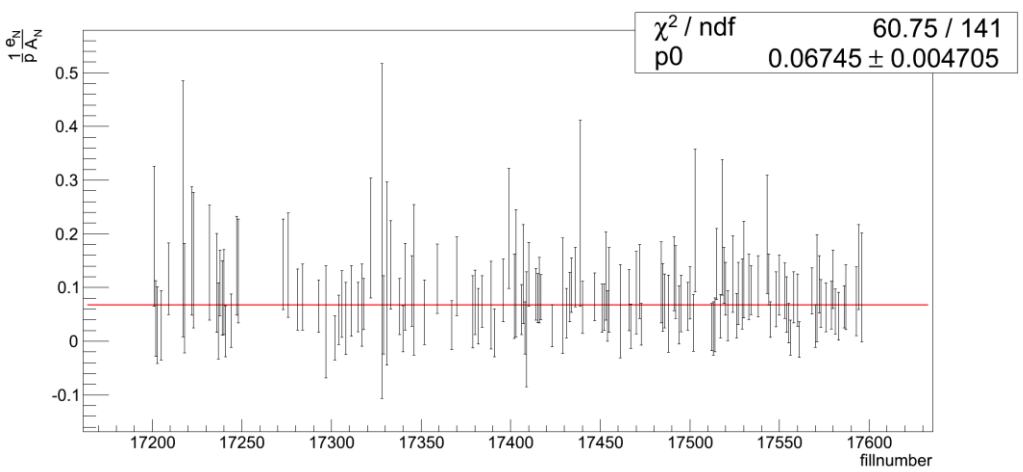
$\frac{p_T}{P}$ =0.010 $\pm$ 0.008 for blue

$\frac{p_T}{P}$ = 0.018 $\pm$ 0.012 for yellow

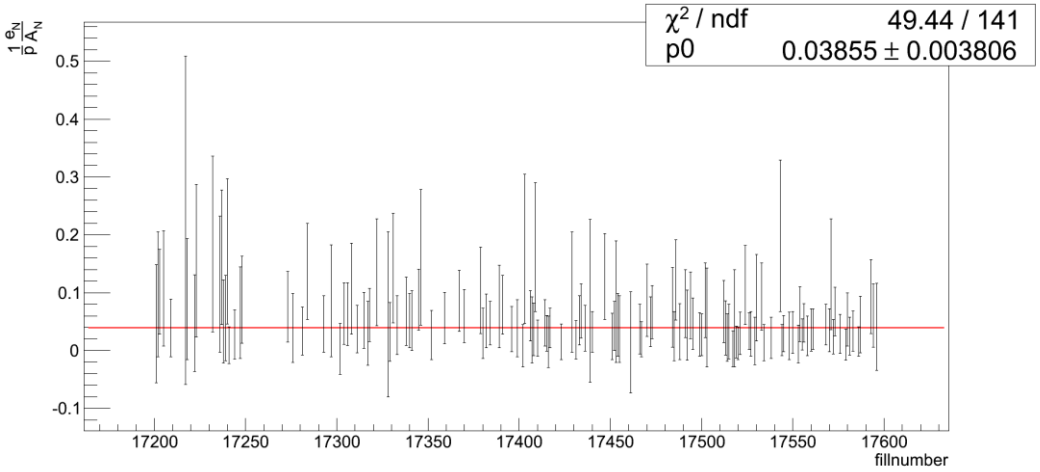
->Beam is longitudinal

PHYSICS Fill's $\frac{p_T}{P}$

BLUE BEAM



YELLOW BEAM



Blue beam average ~0.07, Yellow beam average ~0.04
->Longitudinally polarized

Summary and Prospect

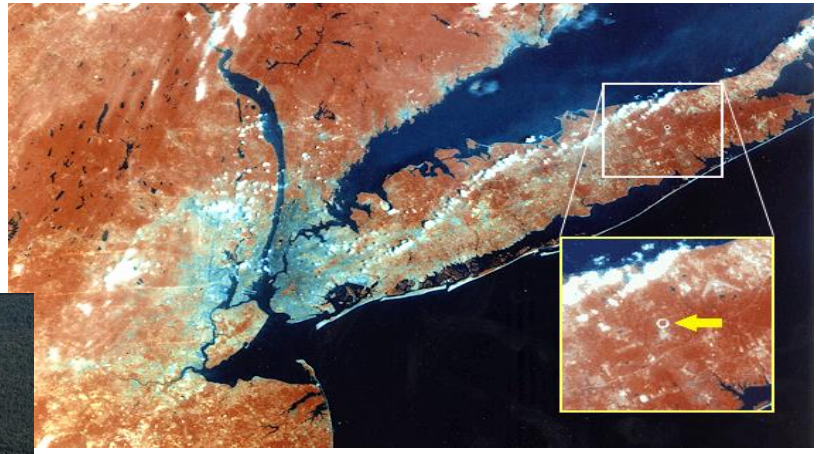
- The Local polarimeter is used to monitor transverse component of beam polarization of longitudinally polarized beam
- Event selection optimization ongoing
- Transverse component of longitudinal commissioning fill is about 1% or less.
- Physics runs' has small transverse component in average.

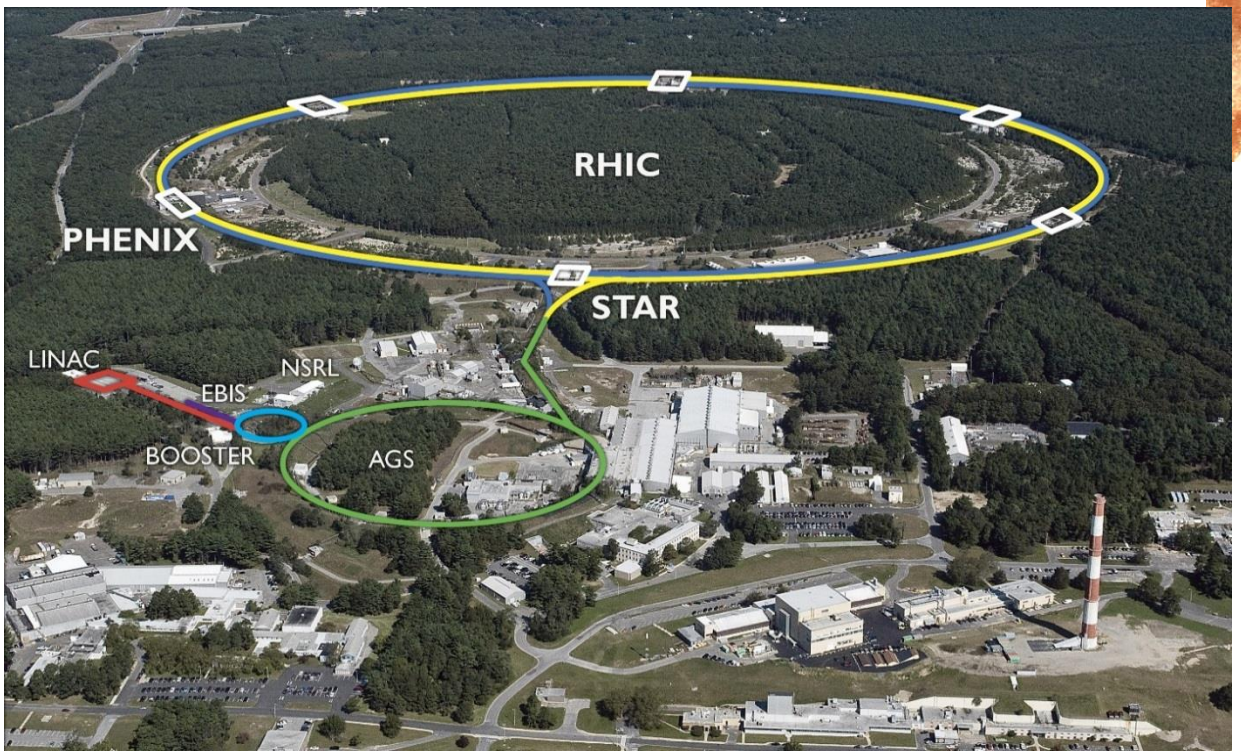
- Systematic uncertainty to be estimated


Back up

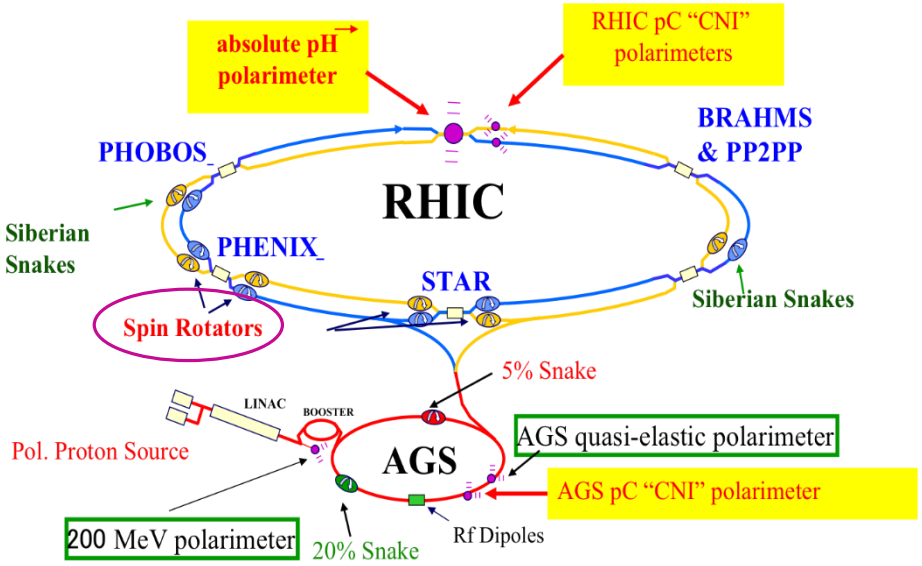
RHIC Overview

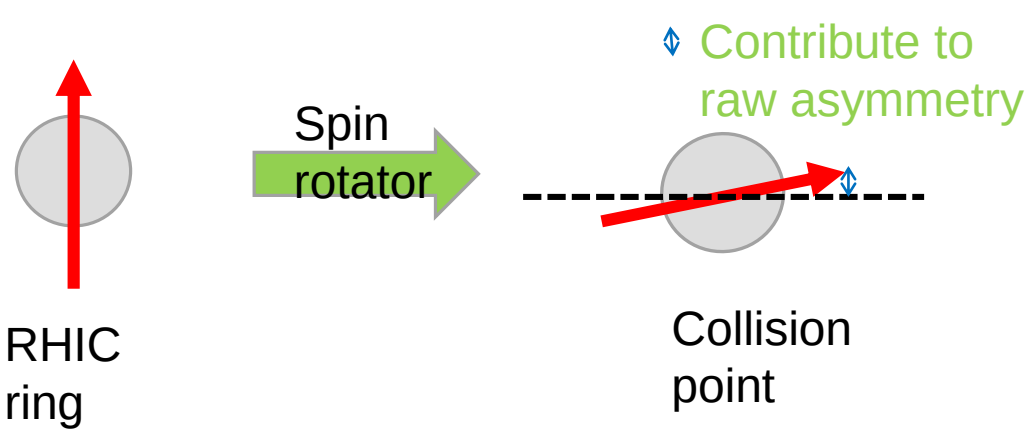
- Relativistic Heavy Ion Collider, in Brookhaven National Laboratory, NY, U.S.
- Capable of colliding high-energy beams of polarized protons
- $\sqrt{s}$ = 510 GeV p-p run in 2013





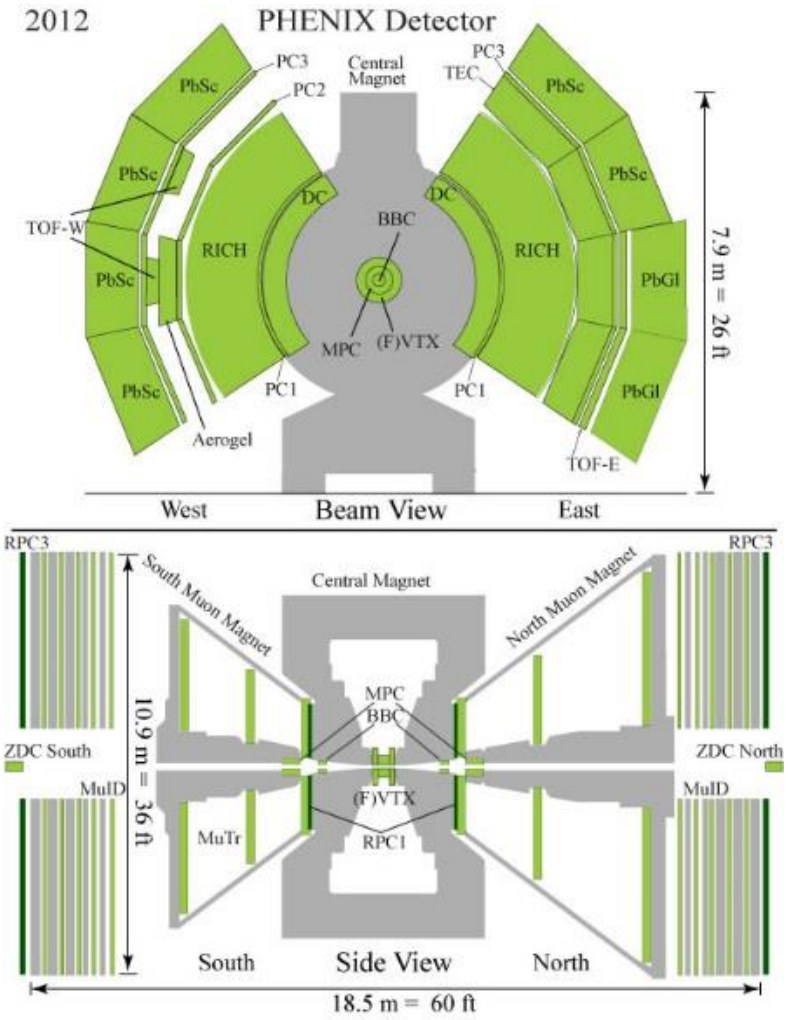
Why local polarimeter is needed?





- Stable beam polarization direction in RHIC is vertical.
- Longitudinal polarization is required to measure A_{LL}.
- Spin rotators change polarization to be longitudinal at the collision points.
- It is important to measure transverse component of beam polarization at the collision point since it will gives systematic error in analysis.
- Therefore, each experiment has local polarimeter to measure transverse component of beam polarization.

PHENIX detector



Neutron Production Experiments Results

ISR experiment in CERN

Neutron production cross section measurement with Variaous sqrt s and p_t

Shows peak at x_f~ 0.8 at p_t=0 GeV only regardless of sqrt s

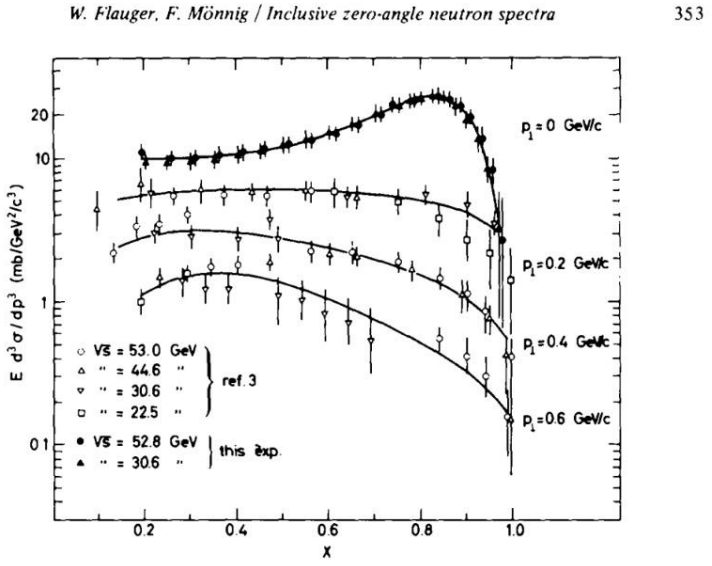


Fig. 3. The invariant cross sections for neutron production as a function of the scaling variable $x = p_{\parallel}/p_{max}$. The lines are hand drawn to guide the eye.

W. FLAUGER ET AL., NUCL. PHYS. B109, 347 (1976).

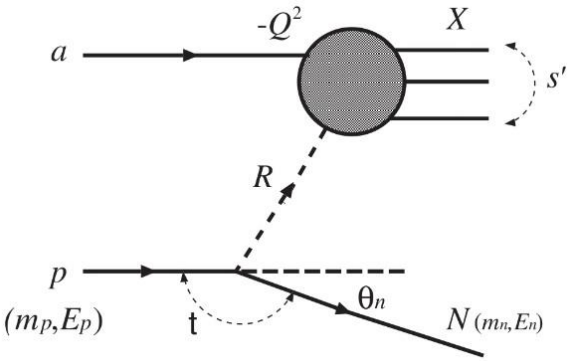
IP12 EXPERIMENT AT RHIC (2001-2002)

LOCATED AT 12'O CLOCK AT RHIC

TO MEASURE SINGLE TRANSVERSE SPIN ASYMMETRY TO ESTABLISH LOCAL POLARIMETER SYSTEM.

NEUTRON PRODUCTION TRANSVERSE SINGLE SPIN ASYMMETRY WAS MEASURED.

	forward	backward
neutron	$-0.090 \pm 0.006 \pm 0.009$	$0.003 \pm 0.004 \pm 0.003$
photon	$-0.009 \pm 0.015 \pm 0.007$	$-0.019 \pm 0.010 \pm 0.003$
π^0	$-0.022 \pm 0.030 \pm 0.002$	$0.007 \pm 0.021 \pm 0.001$



One pion exchange models describes cross sections: measured cross section showed a peak around x_F~0.8, and was found to have almost no sqrt s dependance.

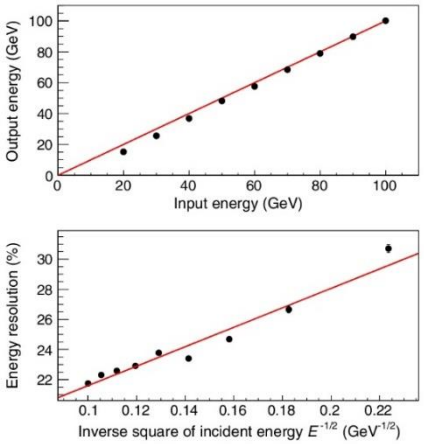
Zero Degree Calorimeter (ZDC)

Hadron calorimeter consists of Cu-W alloy absorbers with PMMA-based communication grade optical fibers

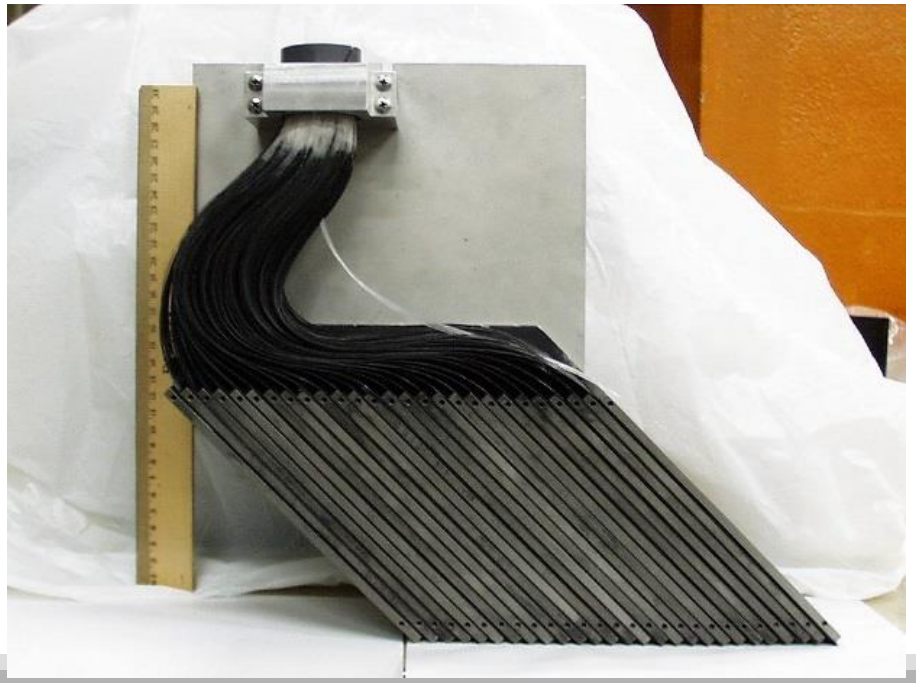
1.7 nuclear interaction length & 51 radiation length (1 module)

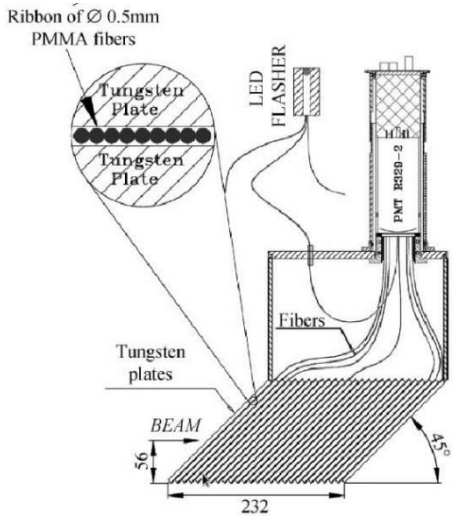
Collect Cherenkov light from charged particles from neutron shower via optical fiber (tilted 45 degree in order to maximize Cherenkov radiation)

22% energy resolution for the 100 GeV neutron dE/E=65%/sqrtE + 15%



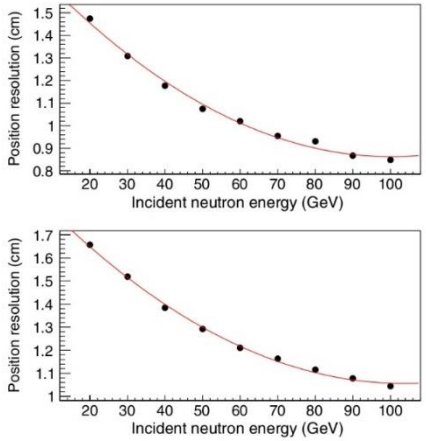
ZDC energy evaluation by simulation

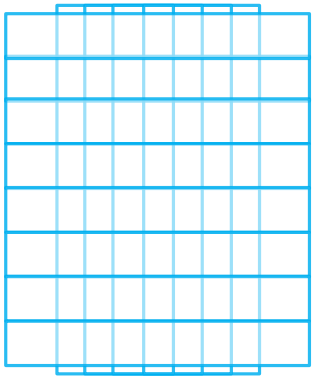


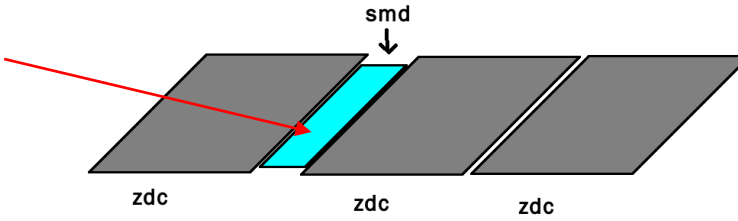


Shower Max Detector (SMD)

- X-y scintillator strip hodoscopes, inserted between 1st & 2nd ZDC modules
- 7 scintillator strips of 15mm width for x coordinate, 8 scintillator strips of 20mm width for y coordinate (105mm x110 mm)
- Neutron position is calculated with centroid method
- Position resolution is ~1cm for 100GeV neutron energy





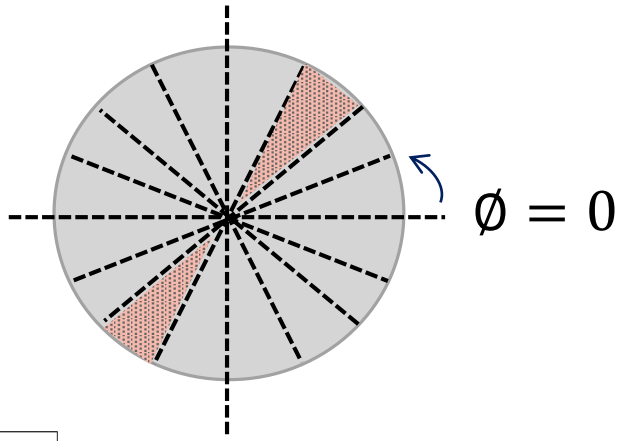


- SMD position resolution evaluated by simulation

Transverse run – get A_N

$$e_N = \frac{\sqrt{N_{\emptyset}^{\uparrow} N_{\emptyset+\pi}^{\downarrow}} - \sqrt{N_{\emptyset+\pi}^{\uparrow} N_{\emptyset}^{\downarrow}}}{\sqrt{N_{\emptyset}^{\uparrow} N_{\emptyset+\pi}^{\downarrow}} + \sqrt{N_{\emptyset+\pi}^{\uparrow} N_{\emptyset}^{\downarrow}}}$$

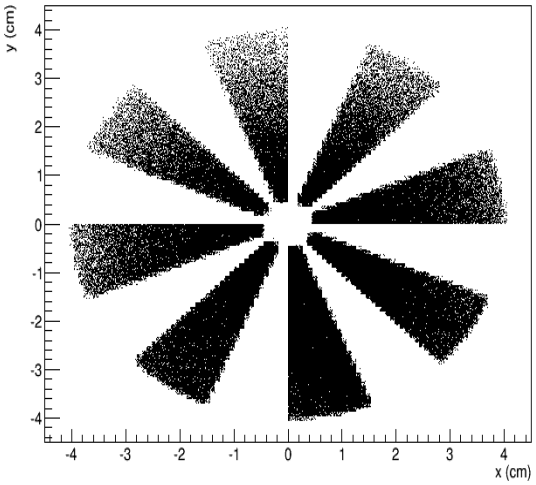
($N_{\emptyset}^{\uparrow}$ ($N_{\emptyset}^{\downarrow}$) = #of events with polarization up (down) producing neutrons to angle $\emptyset$)



p: given from RHIC polarimetry

$$A_N \cos(\emptyset - \emptyset_0) = \frac{e_N}{p}$$

-> Get A_N



Acceptance used (only showed half of acceptance)

Energy distribution: r<1cm