Nuclear Dependent Analyzing Power of Charged Pion in polarized p+A Collision

Korea Univ.

Jaehee Yoo

The Proton Spin Structure

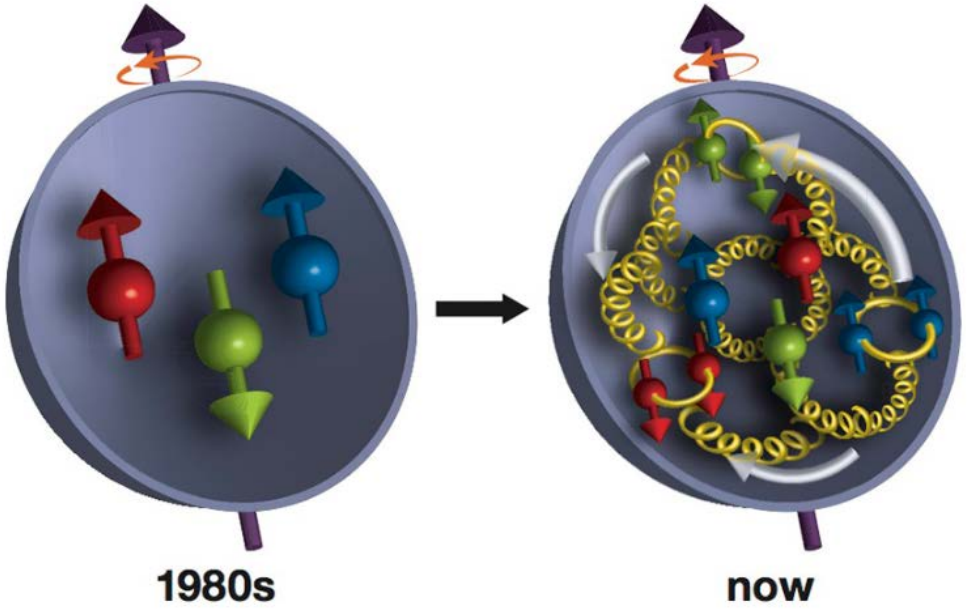
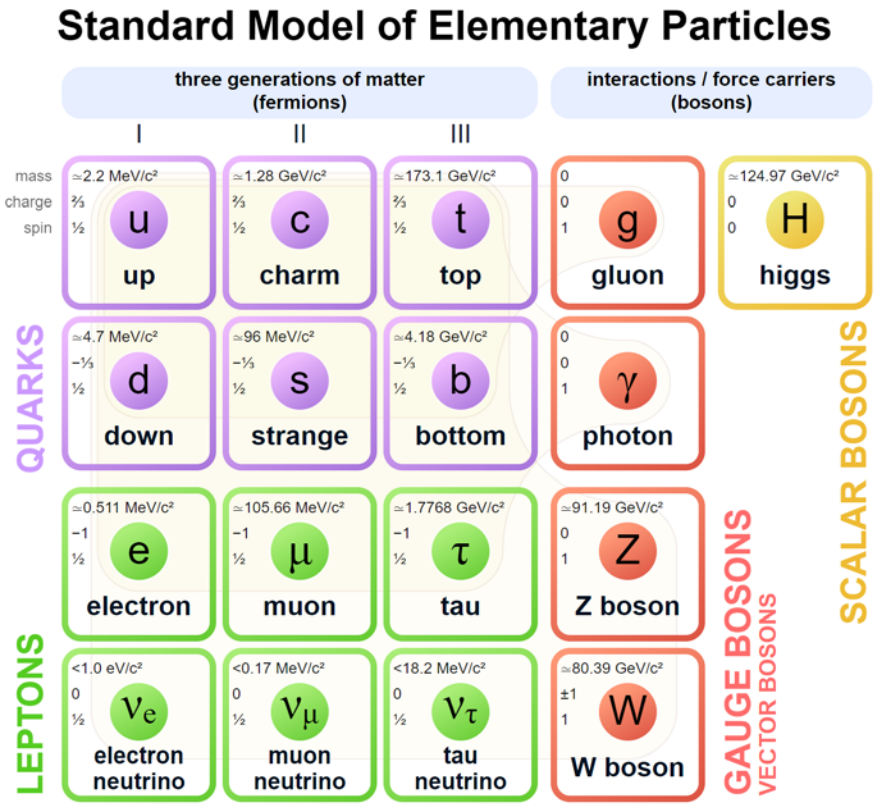


Image courtesy of Brookhaven National Laboratory



In the 1980s, scientists discovered that a proton's three valance quarks (red, green, blue) account for only a fraction of the proton's overall spin. New measurements from RHIC's PHENIX experiment reveal that gluons (yellow corkscrews) contribute as much as or possibly more than the quarks.

The Proton Spin Structure

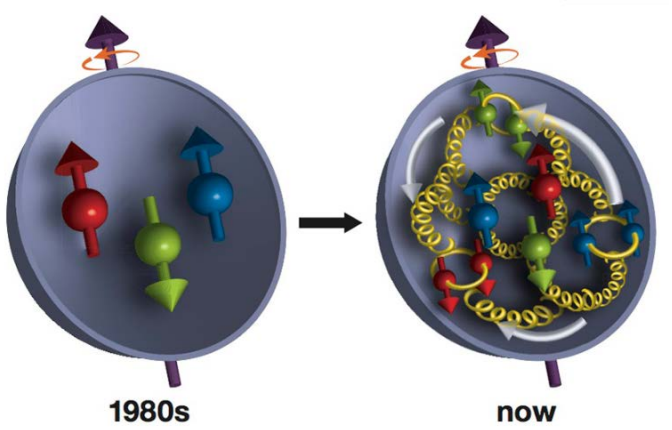


Image courtesy of Brookhaven National Laboratory

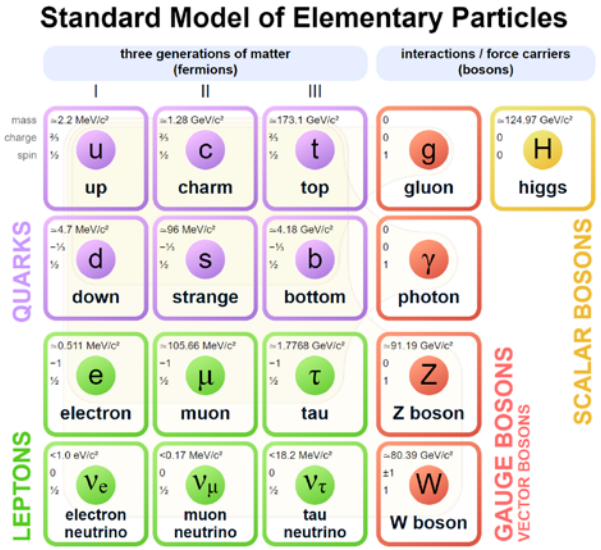
1988 EMC measured:

$\Sigma = 0.123 \pm 0.013 \pm 0.019$ $\Longrightarrow$ Spin Puzzle!

$$S_{proton} = \frac{1}{2} = \frac{1}{2}\Delta q + \Delta G + L_{q,g}$$

$$\frac{1}{2} = \frac{1}{2}\left(\Delta u_v + \Delta d_v + \underbrace{\Delta q_s}\right) + \Delta G + L_q + L_g$$

$$\Delta u_v + \Delta d_v + \Delta q_s + \Delta \bar{u}_s + \Delta \bar{d}_s + \Delta \bar{s}_s$$

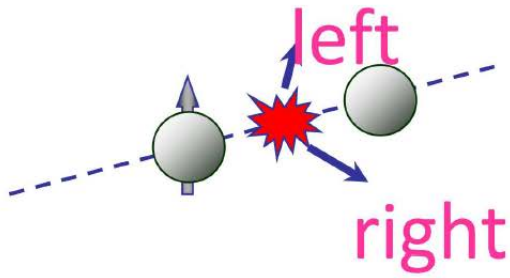


Full description of proton's spin needs
orbital angular momentum

How is proton's spin correlated with the motion of quarks and gluons?
-> Transverse Momentum Dependent (TMD) Functions

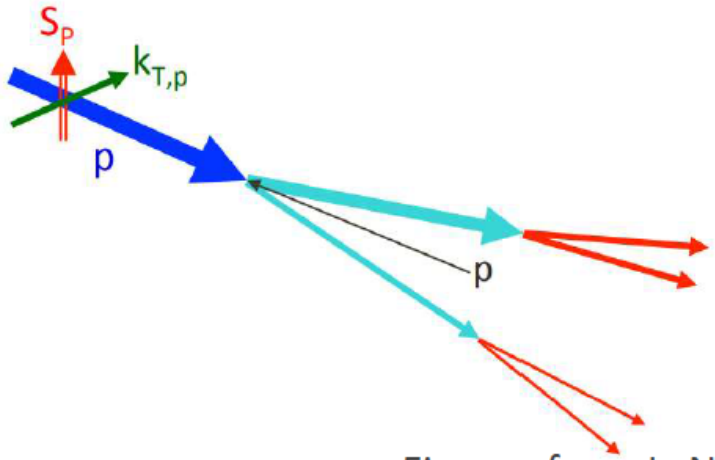
Transverse Single Spin Asymmetry

$$A_N = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$$

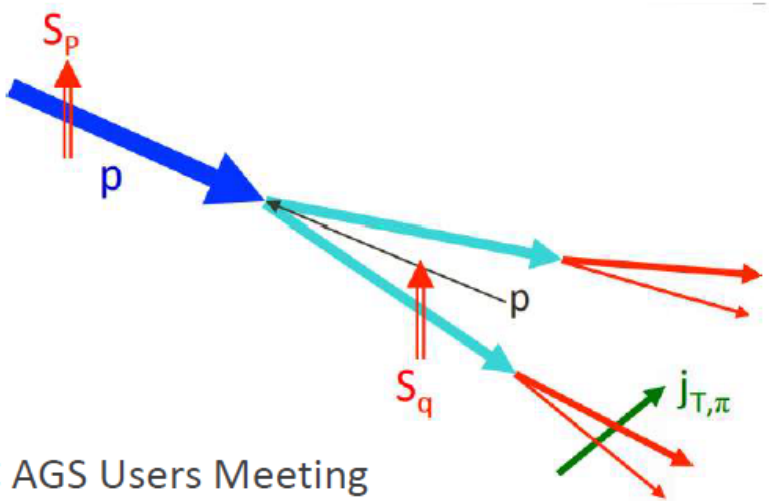


Sources of Transverse SSA's

Initial State Effects:
For example Sivers functions: correlation between proton spin and parton k_T



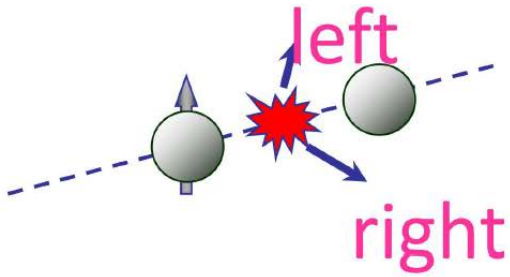
Final State effects:
Collins Function: spin momentum correlation in a Fragmentation Function

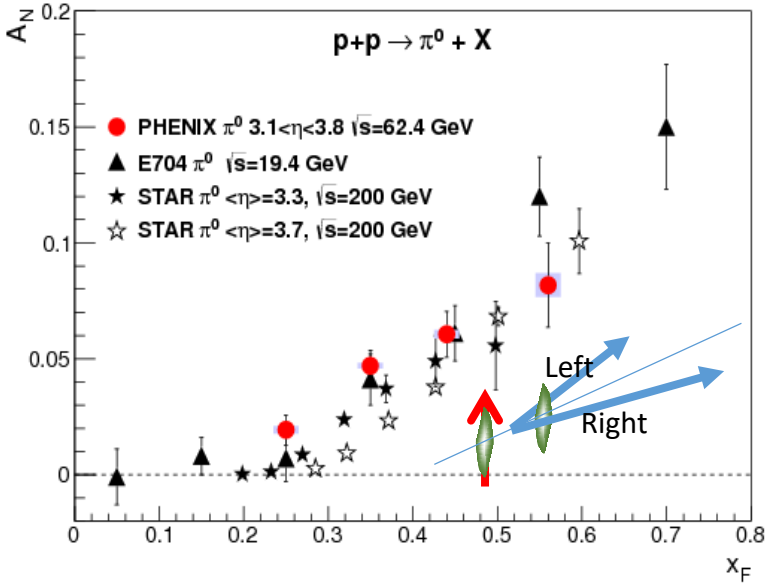


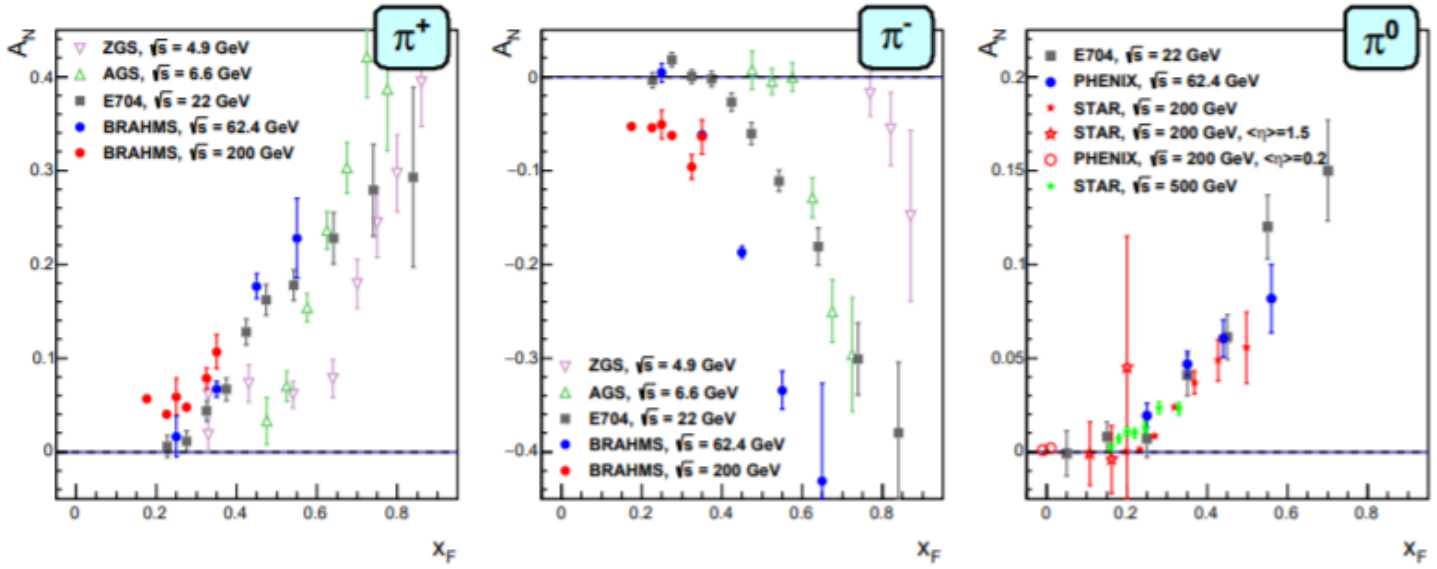
Figures from L. Nogach 2006 RHIC AGS Users Meeting

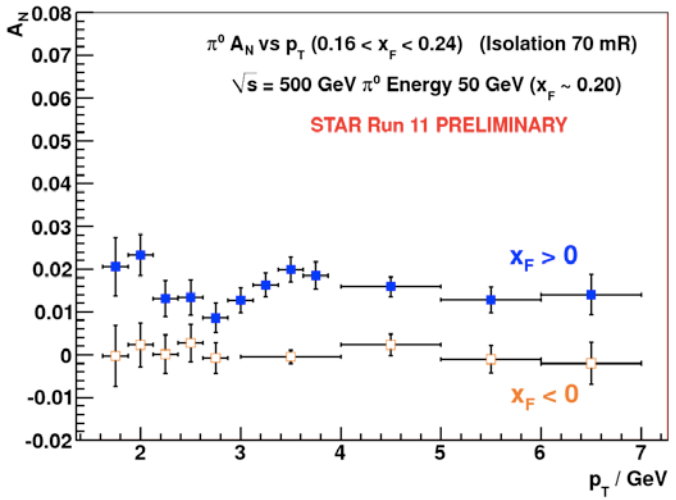
Transverse Single Spin Asymmetry

$$A_N = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$$









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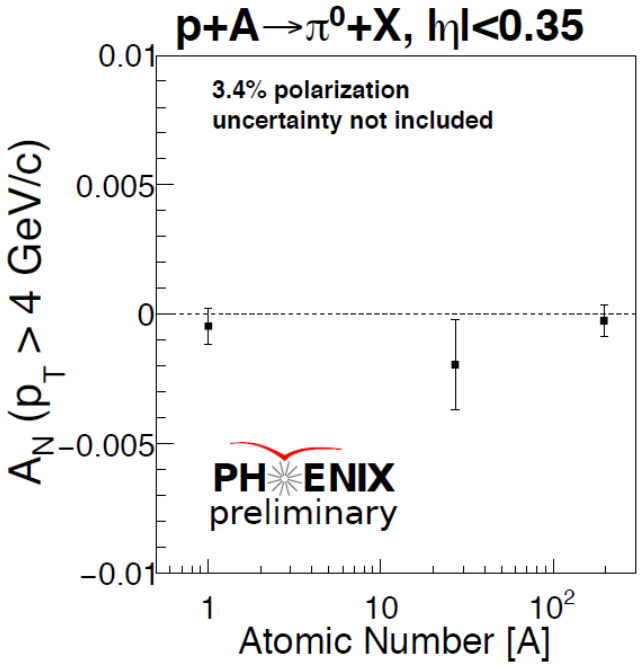
Motivation

Nuclear Dependent Analyzing Power of Charged Pion in polarized p+A Collision

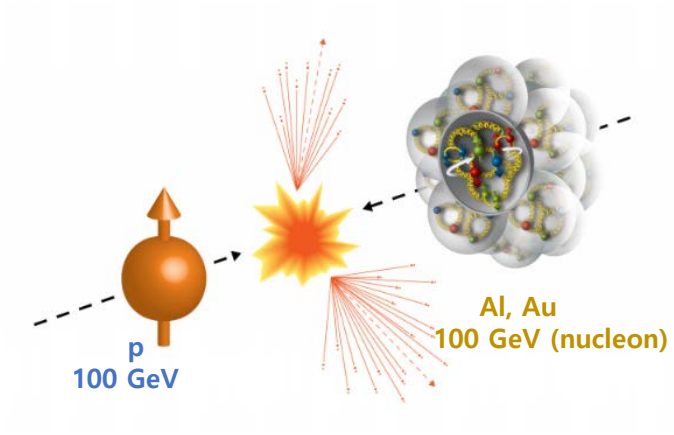
Asymmetry in mid-rapidity

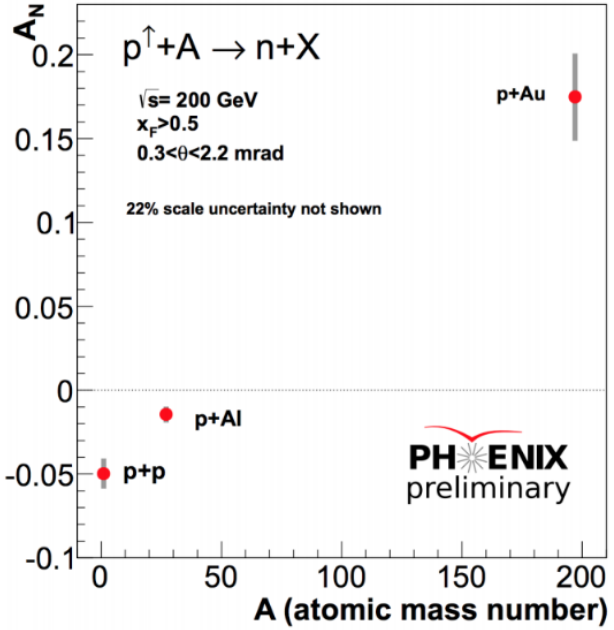


Phys. Rev. Lett. 123, 122001

How does it change from p+p to p+A collision?

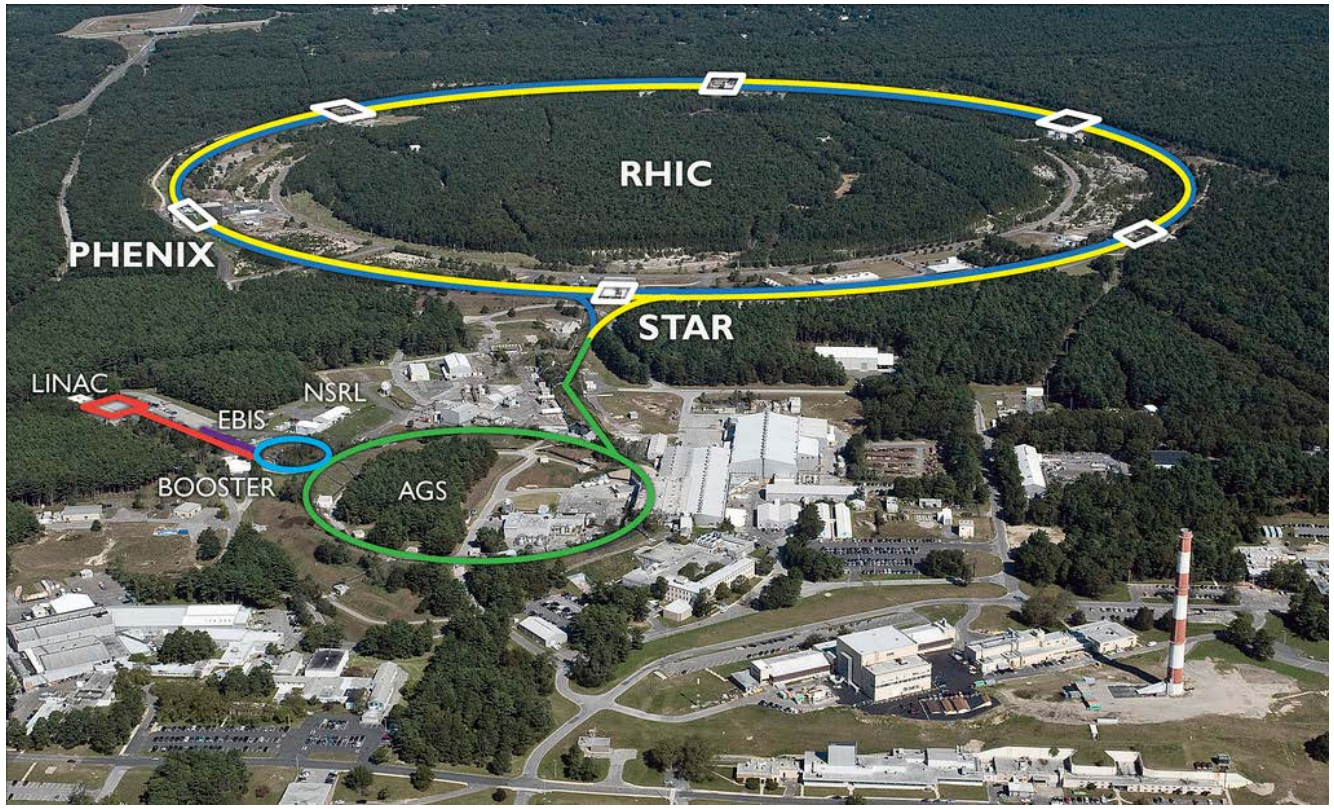
RHIC Run15
The world 1st high energy polarized proton+nucleus collision



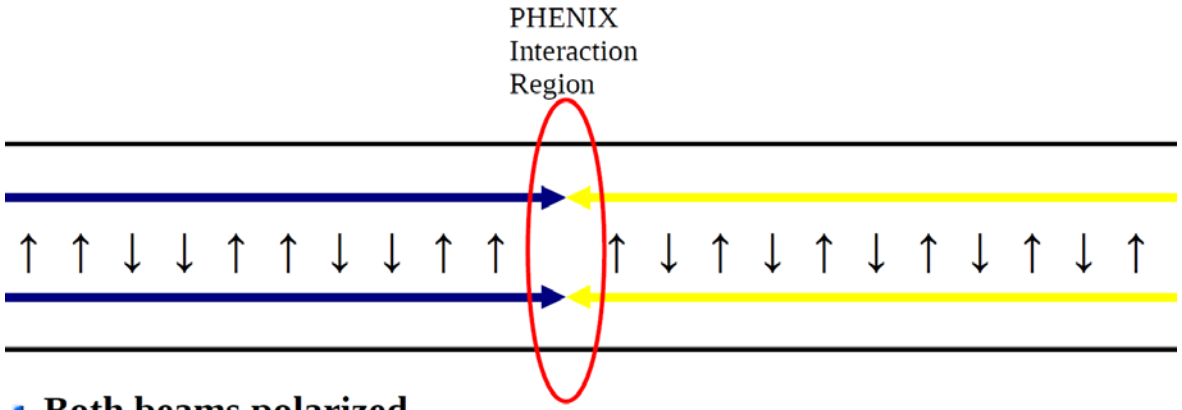


- The asymmetry of π^0 and η in midrapidity
  - Consistent with zero within errors

RHIC



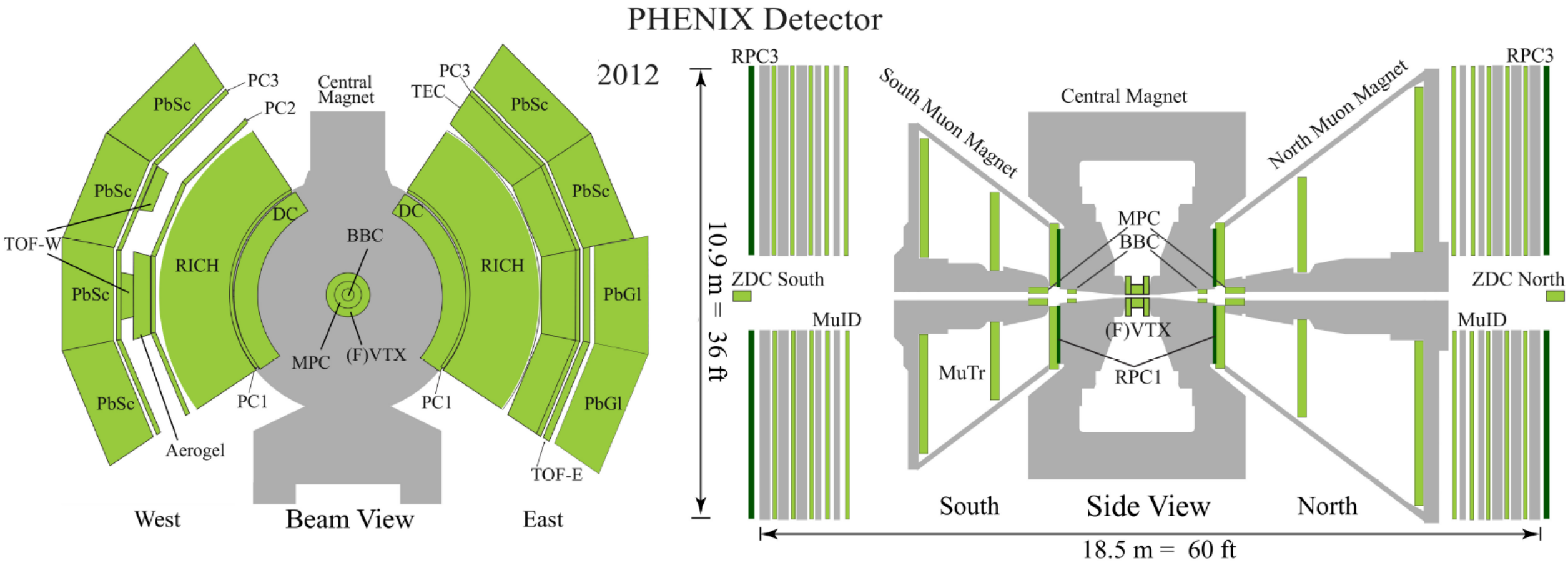
Polarized Beams



- **Both beams polarized**
- Variation of bunch polarization direction minimizes systematic uncertainties in measurement
- For transversely polarized beams, allows for two independent A_N measurements

View of the Brookhaven National Laboratory, NY, USA

PHENIX Detector System



2 central arm: Mid rapidity, $|\eta| < 0.35$

- Identified charged hadrons : π^0, η, direct photon, J/ψ, heavy flavor.

Analysis step

1. RunQA
2. Calibration
3. Data selection
4. Event cuts
5. Track cuts : π± identification
6. Simulation for Reconstruct eff.
7. Calculate Cross-Section
8. Calculate A_N

To measure the Cross-Section

$$E\frac{d^3\sigma}{dp^3}=\frac{1}{2\pi p_T}\frac{1}{L}\frac{\Delta N_{\pi^\pm}^{meas}}{\epsilon\,\Delta\eta\,\Delta p_T}$$

$$N_{\pi^\pm}^{meas}=\epsilon\,N_{\pi^\pm}$$

$$\epsilon_\eta=\epsilon_{geo}\wedge\epsilon_{det}\wedge\epsilon_{trig}=\epsilon_{reco}\wedge\epsilon_{trig}$$

- 1. Integrated Luminosity
- 2. Measured Yield
- 3. Efficiency of central arm detectors to measure an charged pion.

  3-1) Reconstruction Efficiency

  3-2) Trigger Efficiency

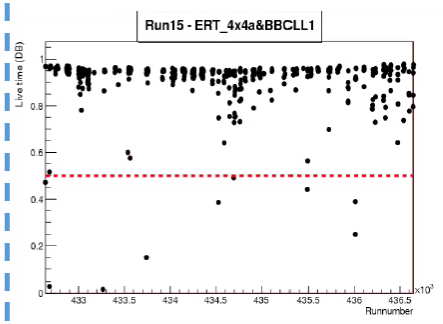
Integrated Luminosity

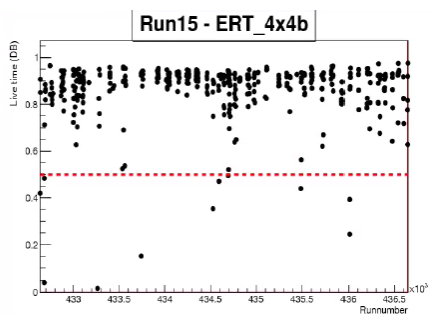
- I'm Using 204 runs in pAu.
- Int_Lumi : 1.113 pb^{-1}

Year	$\sqrt{s}$ (GeV)	Recorded Luminosity for longitudinally / transverse polarized p+p STAR	Recorded Luminosity for longitudinally / transverse polarized p+p PHENIX	<P> in %
2006	62.4	-- pb^{-1} / 0.2 pb^{-1}	0.08 pb^{-1} / 0.02 pb^{-1}	48
	200	6.8 pb^{-1} / 8.5 pb^{-1}	7.5 pb^{-1} / 2.7 pb^{-1}	57
2008	200	-- pb^{-1} / 7.8 pb^{-1}	-- pb^{-1} / 5.2 pb^{-1}	45
2009	200	25 pb^{-1} / -- pb^{-1}	16 pb^{-1} / -- pb^{-1}	55
	500	10 pb^{-1} / -- pb^{-1}	14 pb^{-1} / -- pb^{-1}	39
2011	500	12 pb^{-1} / 25 pb^{-1}	18 pb^{-1} / -- pb^{-1}	48
2012	200	-- pb^{-1} / 22 pb^{-1}	-- pb^{-1} / 9.7 pb^{-1}	61/56
	510	82 pb^{-1} / -- pb^{-1}	32 pb^{-1} / -- pb^{-1}	50/53
2013	510	300 pb^{-1} / -- pb^{-1}	155 pb^{-1}/ -- pb^{-1}	51/52
2015	200	52 pb^{-1} / 52 pb^{-1}	-- pb^{-1}/ 60 pb^{-1}	53/57
2015	200 p Au	total delivered Luminosity = 1.27 pb^{-1}		60
2015	200 p Al	total delivered Luminosity = 3.97 pb^{-1}		54

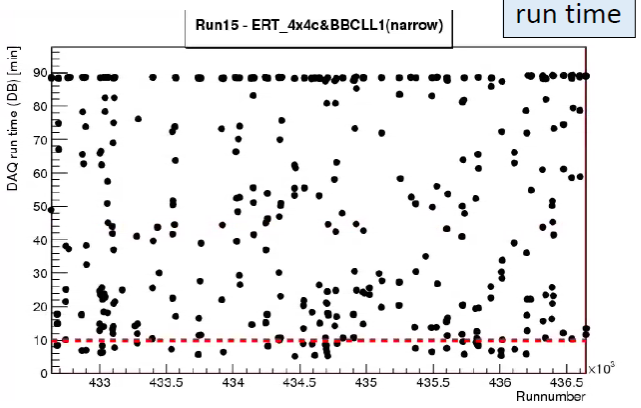
O : Trasversely polarized

- Trigger
  - ERTLL1_4x4a&BBCLL1
  - ERT_4x4b
  - ERT_4x4c&BBCLL1(narrow)
- Cut
  - DAQ Run time > 10 min
  - DAQ live time > 0.5

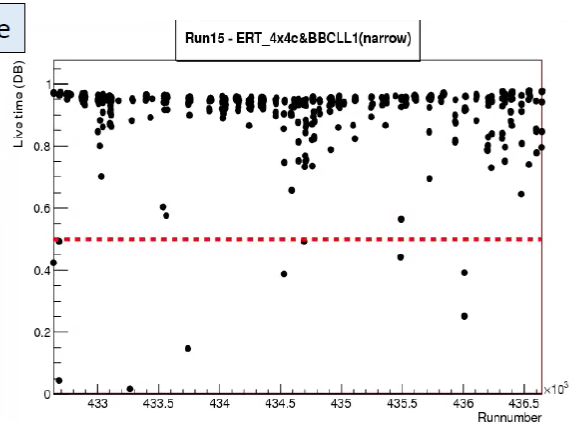




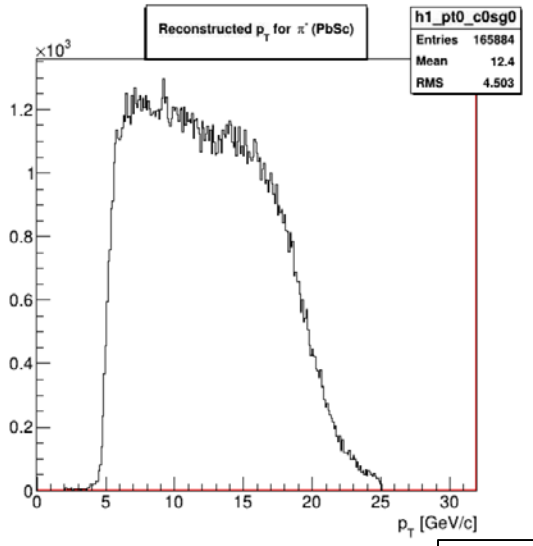
run time

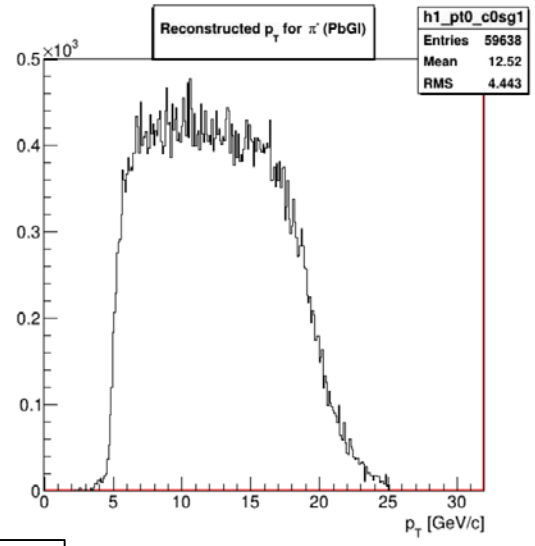


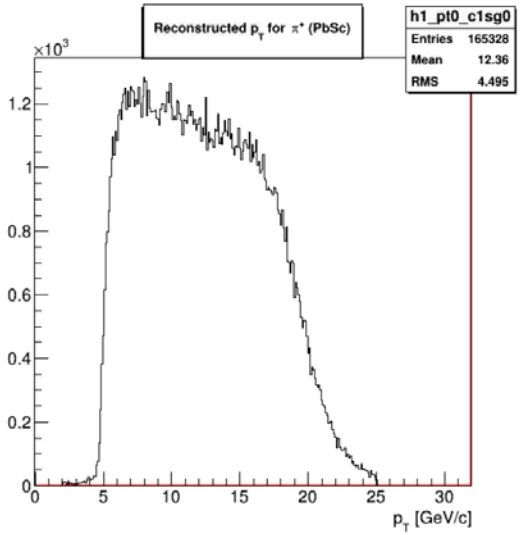
live time

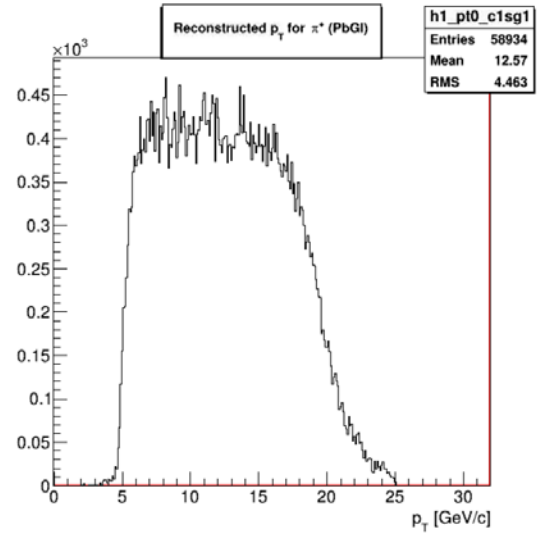


Reconstructed efficiency of pions

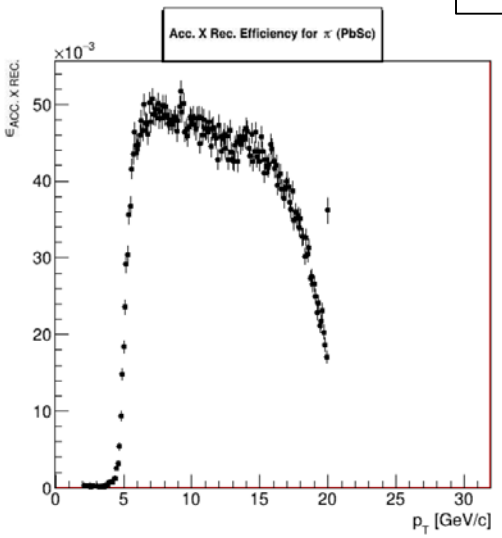


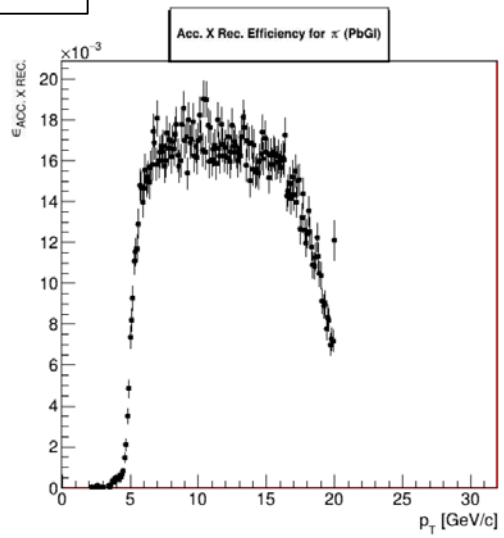




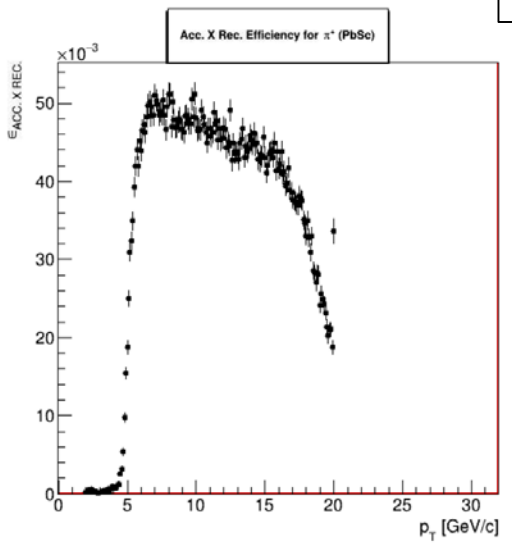


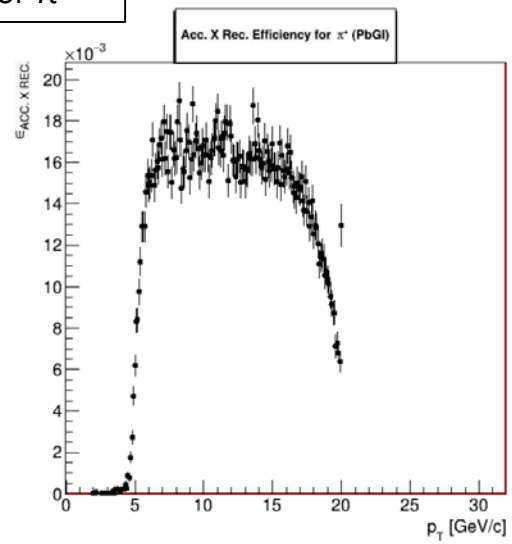
For π^-





For π^+





Trigger Efficiency

For π^-

For π^+

Summary

- The $\pi^{\pm}$ A_N in mid-rapidity in p+p, p+Au and p+Al collisions at sqrt(s) =200 GeV was measured by PHENIX.

- $\pi^{\pm}$ transverse asymmetry from p+p to p+A are comparable in mid –rapidity and π^0.

- The $\pi^{\pm}$ production in p+p vs p+A will answer outstanding question considering nuclear effects.

Thank you.