Measurement of double helicity asymmetries in $\pi^{\pm}$ production at mid-rapidity at PHENIX

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Motivation

- Jaffe-Manohar Sum Rule:

$$Proton\ Spin\ = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \boxed{\Delta G} + L_q + L_g$$

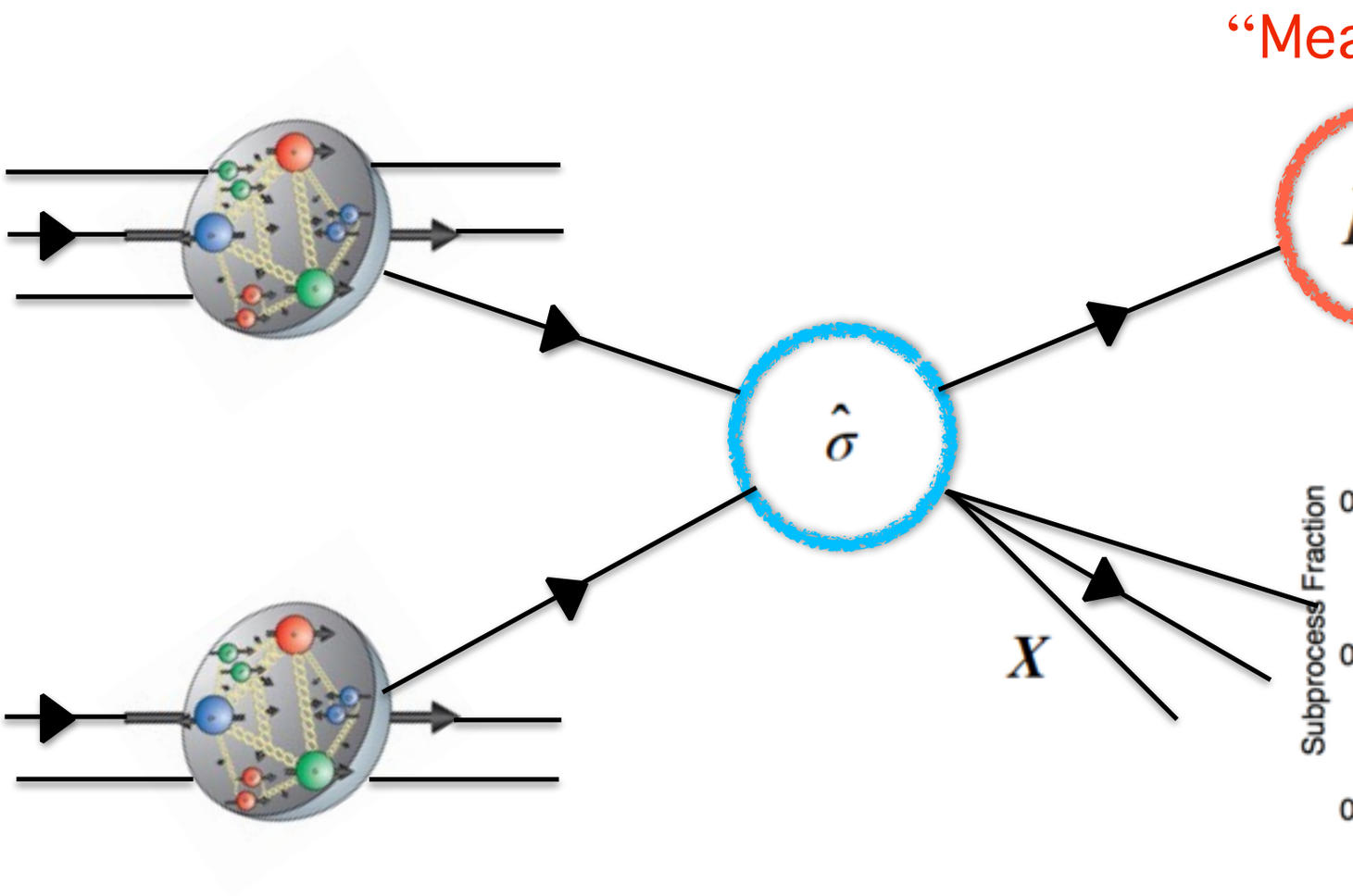
  - ΔΣ: reasonably well measured. only 30% of proton spin.
  - Where is the missing part? (spin crisis)

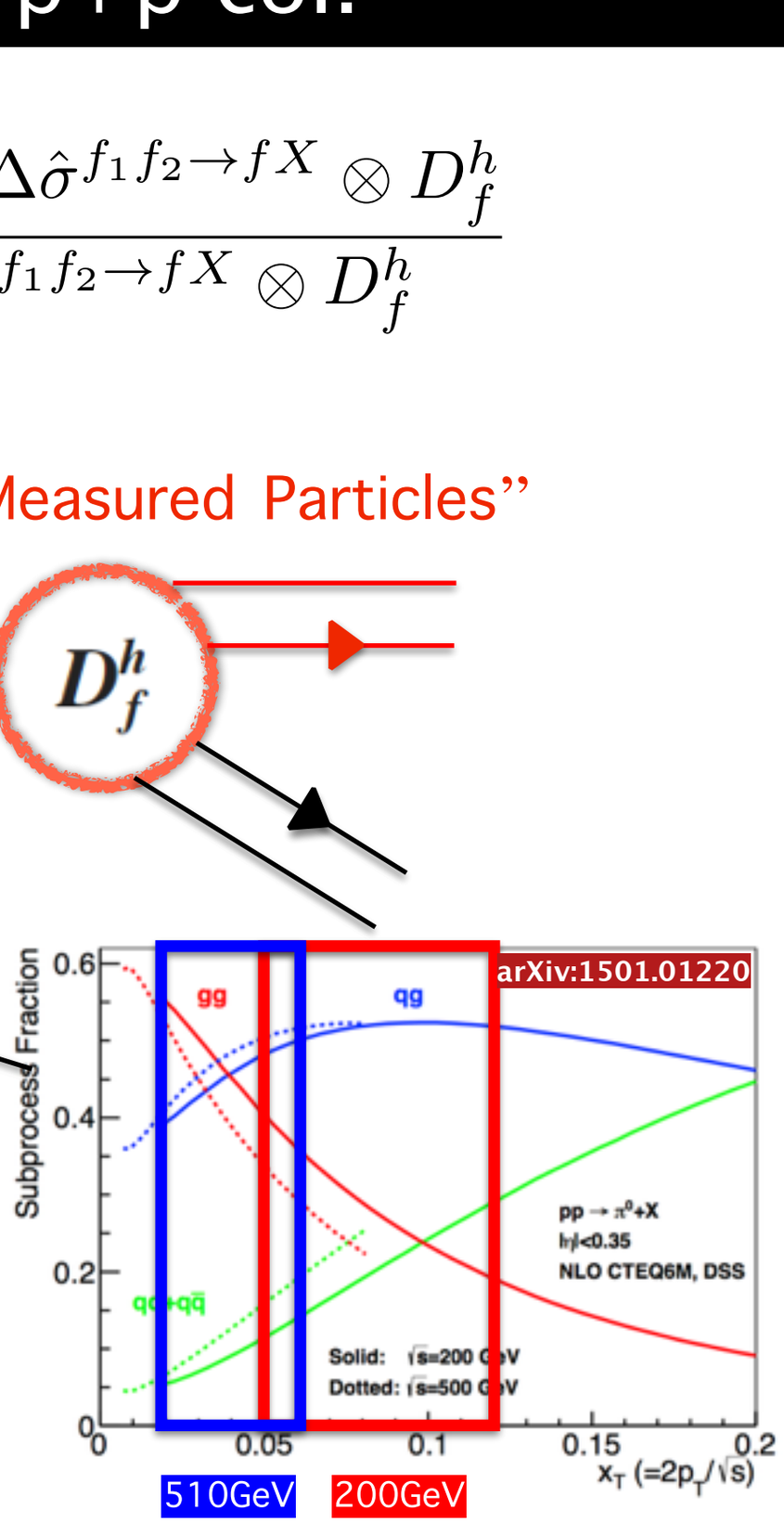
- Many experimental endeavors to measure ΔG:

  - Polarized DIS (evolution), SIDIS (high pT hadrons/charmed mesons)
  - Polarized p+p collisions at RHIC and A_{LL} measurement:
  - PHENIX π/η A_{LL}: PRD 93 011501 (2016), PRD 91 032001 (2015), PRD 90 012007 (2014), PRL 103 012003 (2009) and so on.
  - STAR Jet/Di-jet A_{LL}: PRL 115 92002 (2015), PRD 95 71103 (2017)

Motivation: Accessing ΔG via A_{LL} in p+p col.

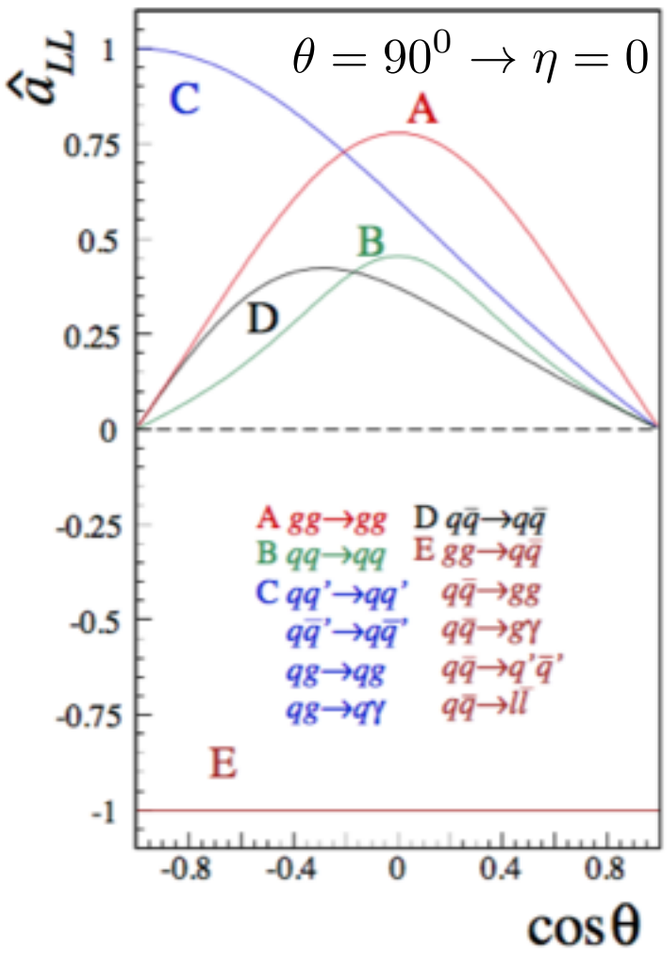
$$A_{LL} = \frac{d\Delta\sigma}{d\sigma} = \frac{\sum_{f_1,f_2=q,\bar{q},g} \Delta f_1 \otimes \Delta f_2 \otimes \Delta\hat{\sigma}^{f_1 f_2 \to f X} \otimes D_f^h}{\sum_{f_1,f_2=q,\bar{q},g} f_1 \otimes f_2 \otimes \hat{\sigma}^{f_1 f_2 \to f X} \otimes D_f^h}$$





Motivation: "Directly" access the sign of ΔG

PRL 113, 012001 (2014)

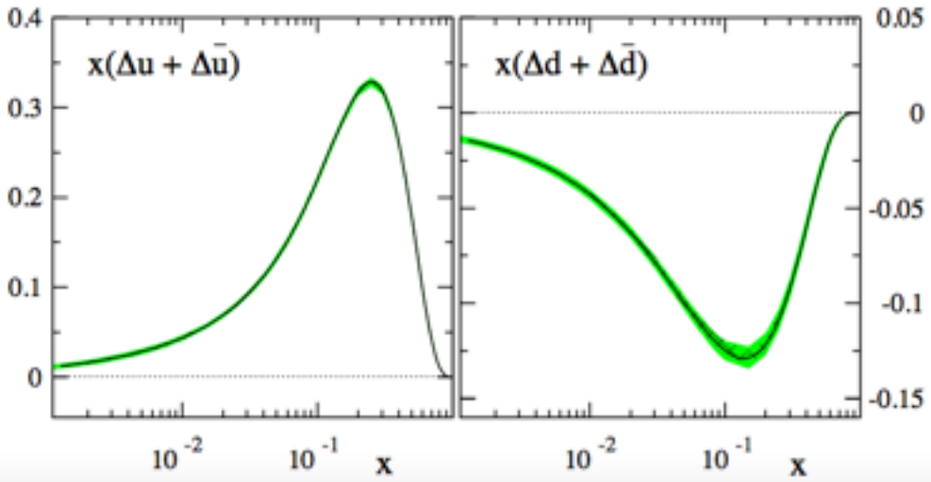


- q-g scattering starts to dominate at RHIC p_T above ~5GeV/c.
- Preferential fragmentation of u to π^+ and d to π^-.

$$A_{LL}^{\pi^+} \approx a_{gg}\Delta g\Delta g + \underbrace{a_{ug}}_{>0}\underbrace{\Delta u}_{>0}\Delta g$$

$$A_{LL}^{\pi^-} \approx a_{gg}\Delta g\Delta g + \underbrace{a_{dg}}_{>0}\underbrace{\Delta d}_{<0}\Delta g$$

Phys. Rev. D 80, 034030 (2009)

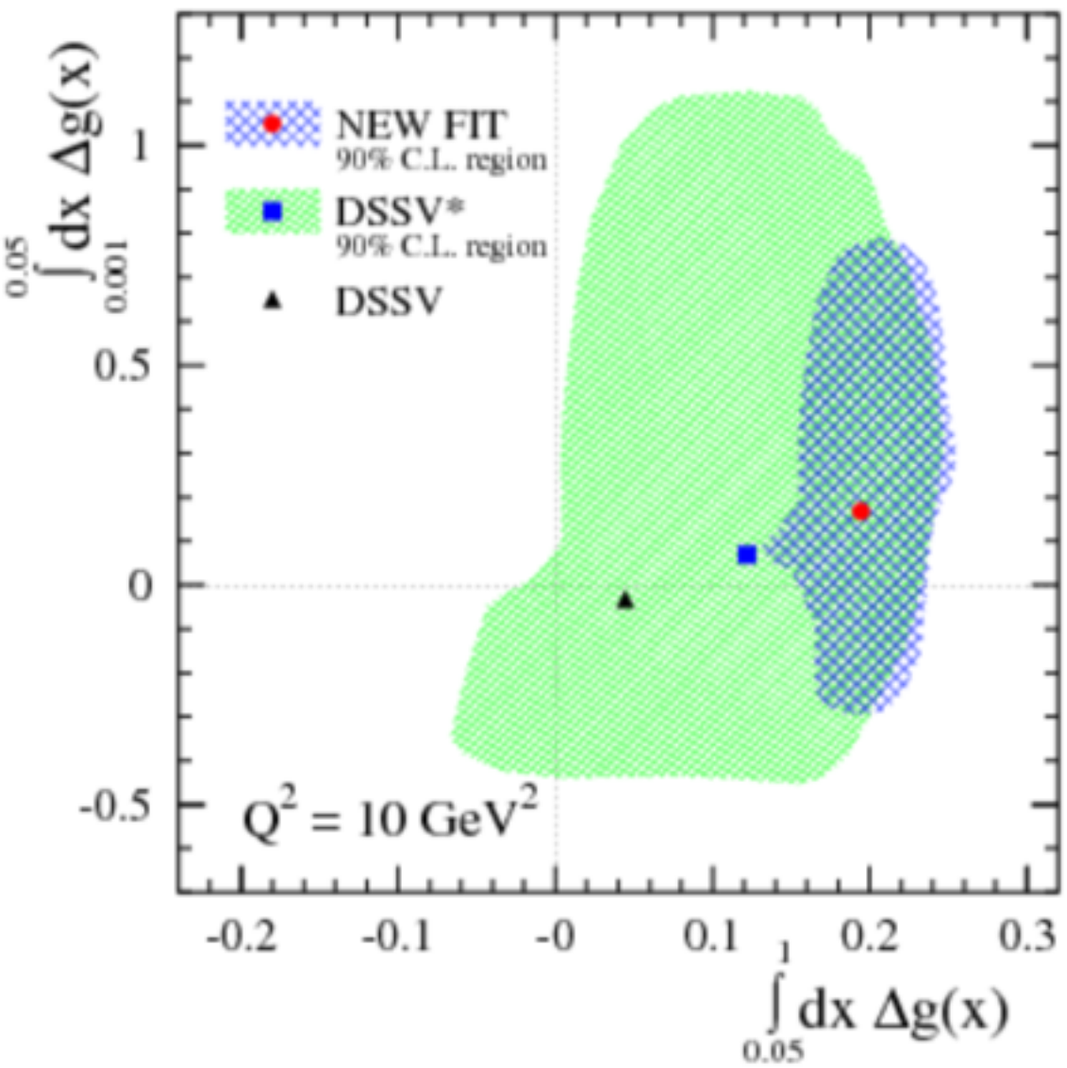


$$\Delta g > 0 \rightarrow A_{LL}^{\pi^+} > A_{LL}^{\pi^-}$$

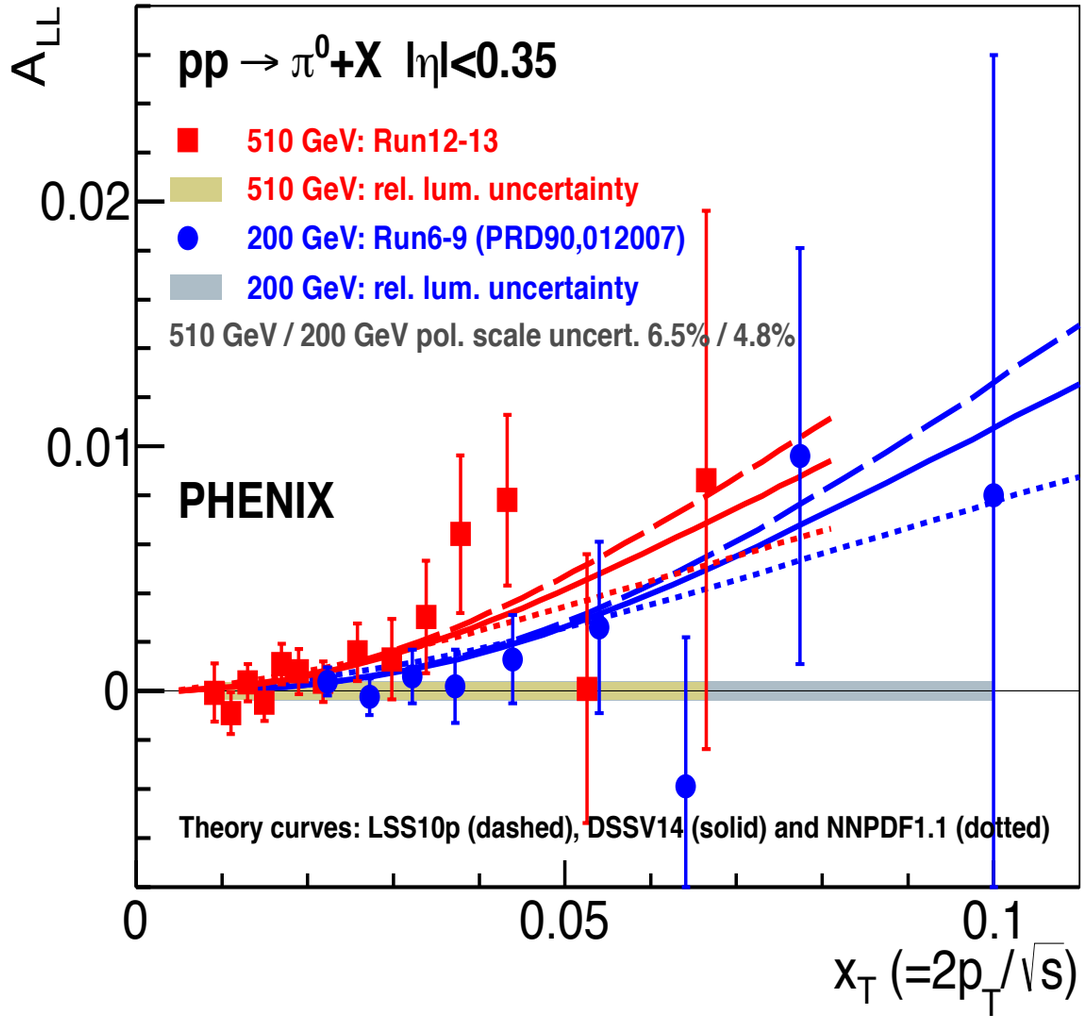
and vice versa

Current understanding

PRL 113, 012001 (2014)



PRD 93, 011501 (2016)



- The uncertainties have been reduced for x > 0.05 based on RHIC data up to Run-2009.
- Expanding experimental sensitivity to lower x region, x < 0.05, with PHENIX π^0 at 510 GeV.
- Confirms non-zero gluon polarization via hadron production.
- $\pi^{\pm}$ as potential direct indicator for the sign of Δg via pion A_{LL} ordering.

Data recoding and trigger set in Run-9 and Run-13

PHENIX Longitudinal Run

Year	*Sqrt(s) [GeV]*	*Int. L [pb^{-1}]*	*P (%)*	*FoM (LP^4)*
2009	*200*	*14*	*57*	*1.4*
2013	*510*	*150*	*55*	*14*

PHENIX EMCal-RICH Trigger (ERT) Set

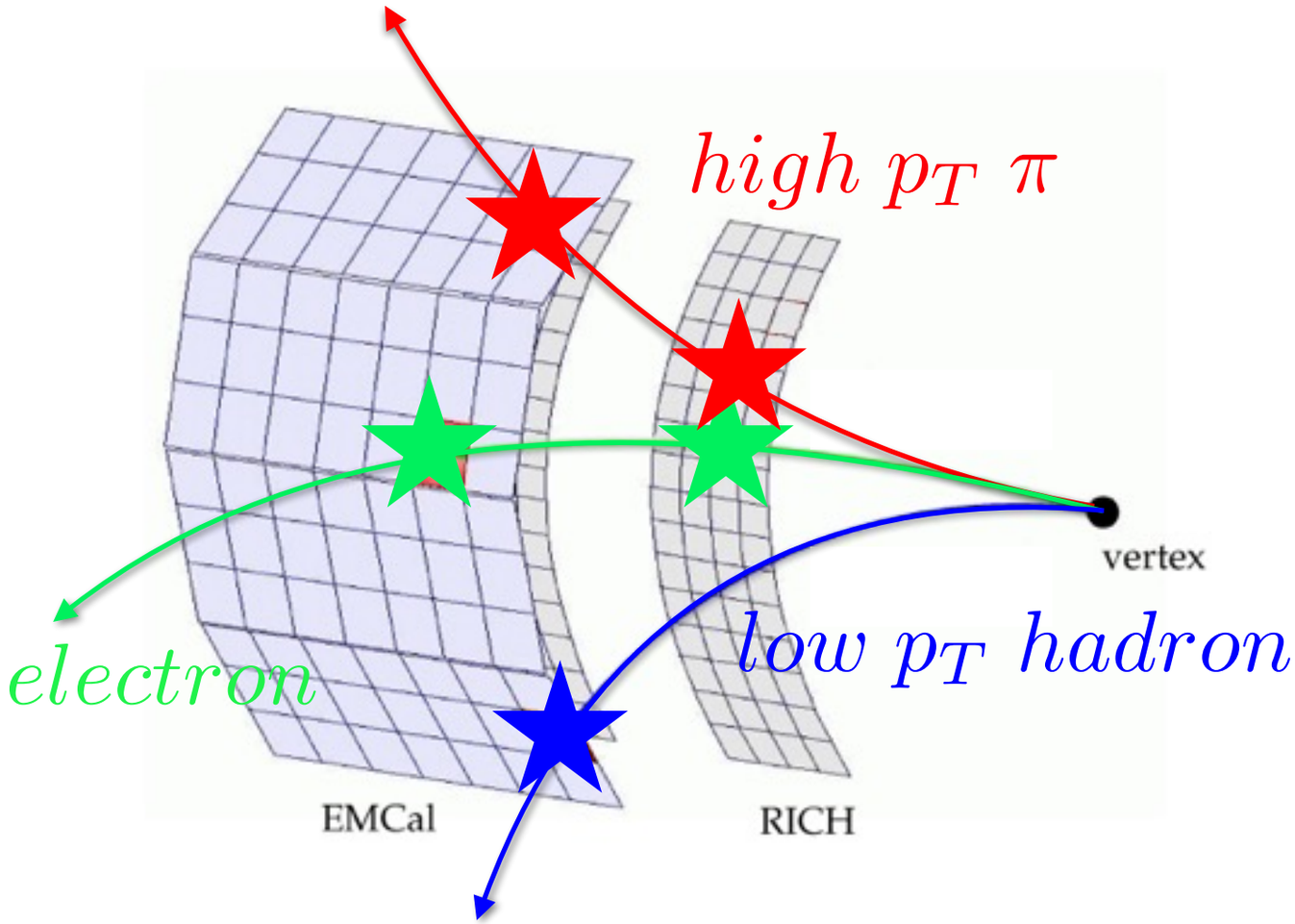
	Trigger Name and Threshold [GeV]			
Year	*4x4A*	*4x4B*	*4x4C*	*2x2E*
2009	*2.1*	*2.8*	*1.4*	*0.6*
2013	*4.7*	*5.6*	*3.7*	*2.2*

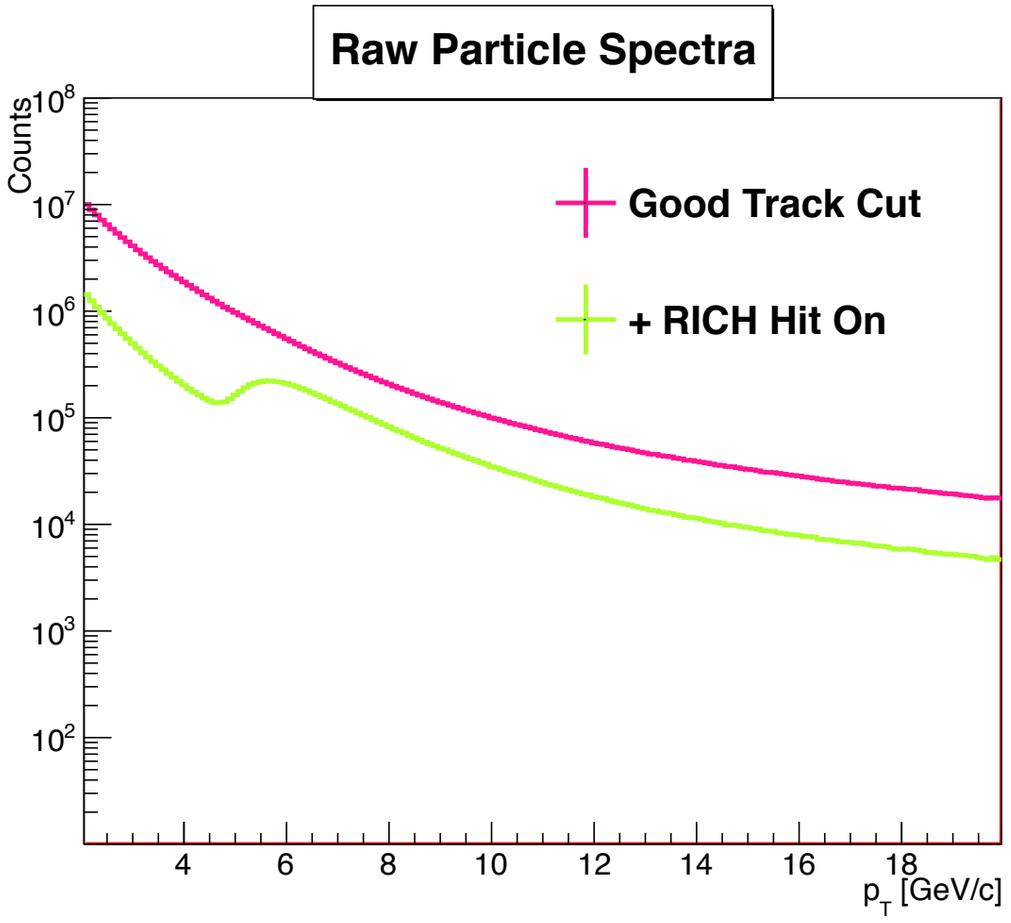
- 14 (150) pb^{-1} polarized p+p data available from dataset in 2009 (2013).
- Higher rate of Run-13 than that of Run-9.
- Due to the lack of hadron trigger in PHENIX, the statistical precision of the $\pi^{\pm}$ data is limited in both Run-9 and Run-13.
- Alternatively, high p_T γ triggers are used for high p_T $\pi^{\pm}$ analysis.

Particle ($\pi^{\pm}$) ID and background sources

- Trigger $\pi^{\pm}$ with a BBC and EMCal.
- Track can be divided into two categories according to RICH response at p_T 5~16GeV/c.
  - RICH Hit: $e^{\pm}$ and $\pi^{\pm}$.
  - No RICH Hit: $K^{\pm}$ and p(-bar).

Particle	*Electron*	*Pion*	Kaon	*Proton*
Threshold	*30MeV/c*	*4.7GeV/c*	*16GeV/c*	*30GeV/c*





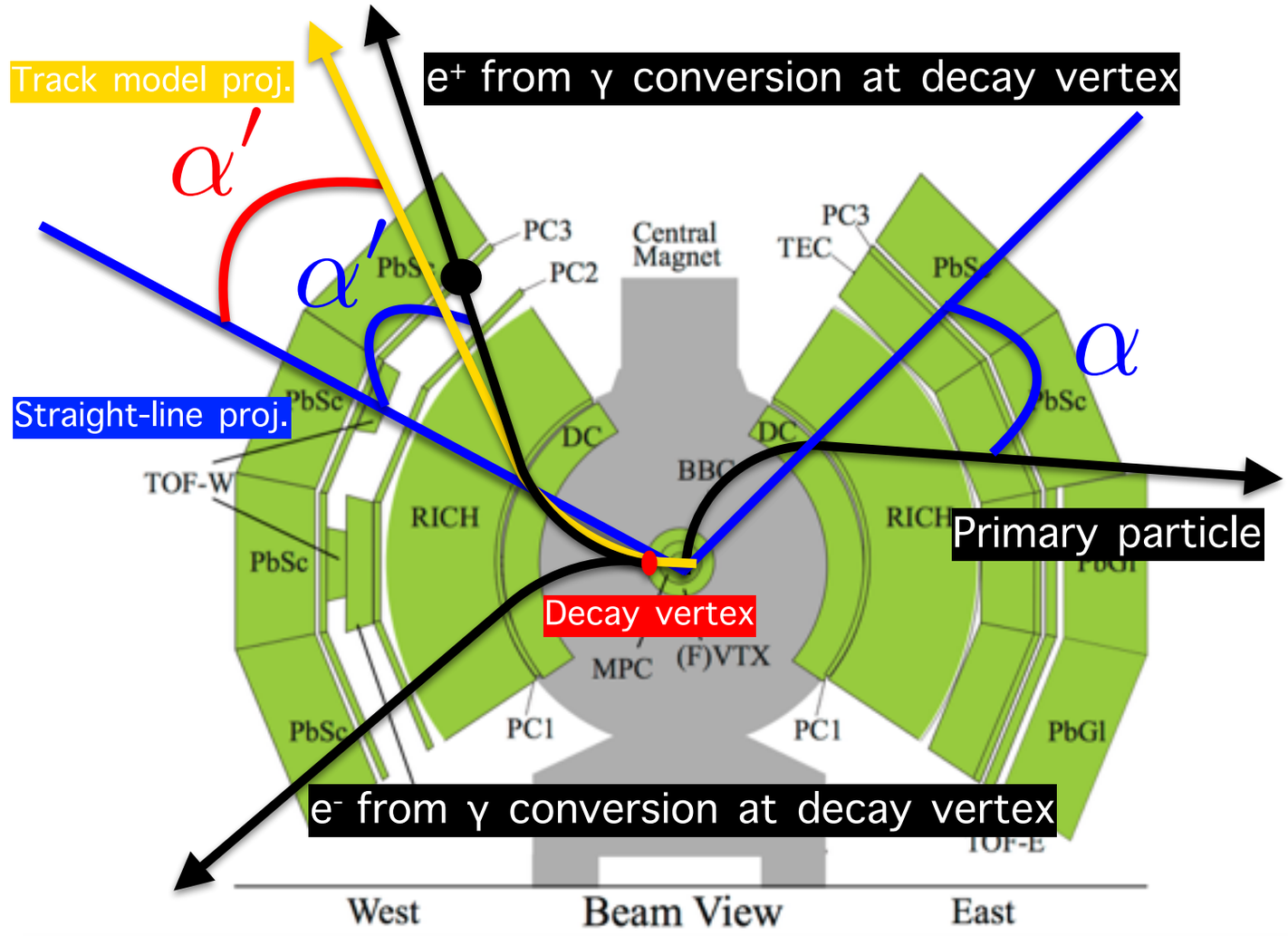
Particle (π±) ID and background sources (continued)

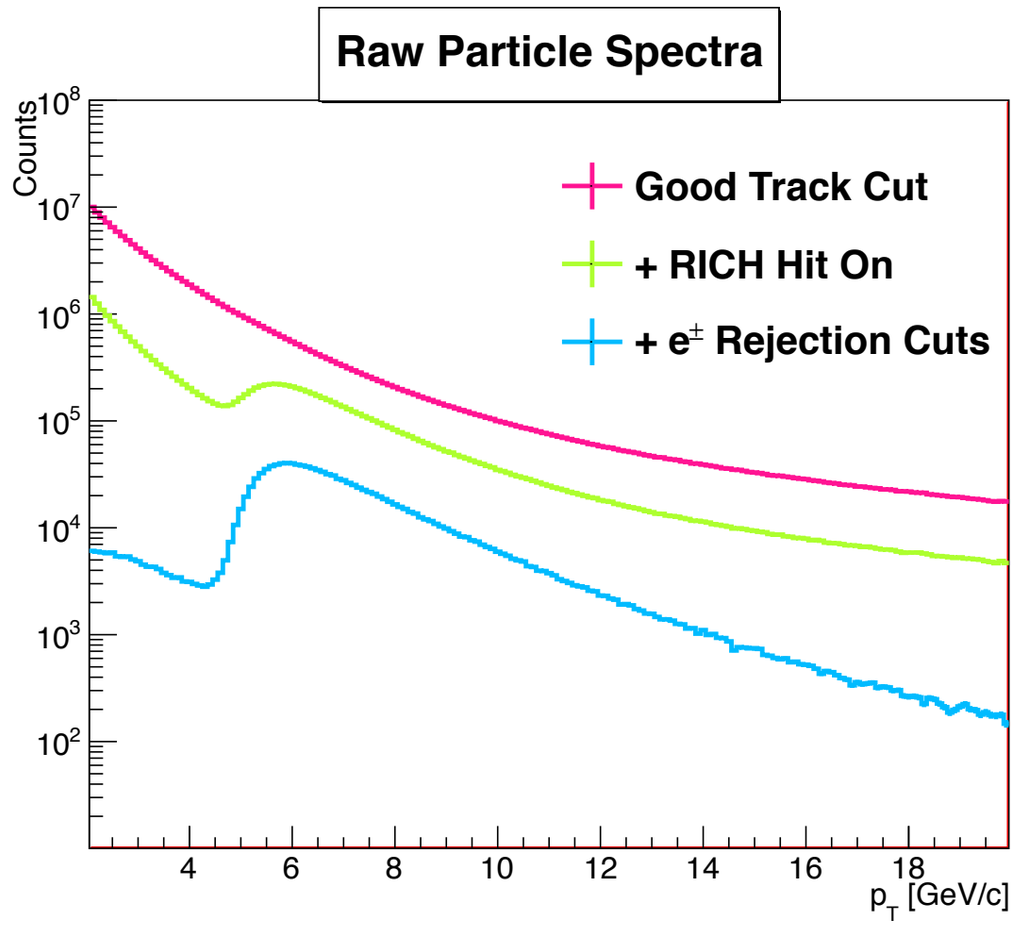
- $e^{\pm}$ backgrounds:

  - Primary $e^{\pm}$ easily removed with e/p and shower shape cuts.

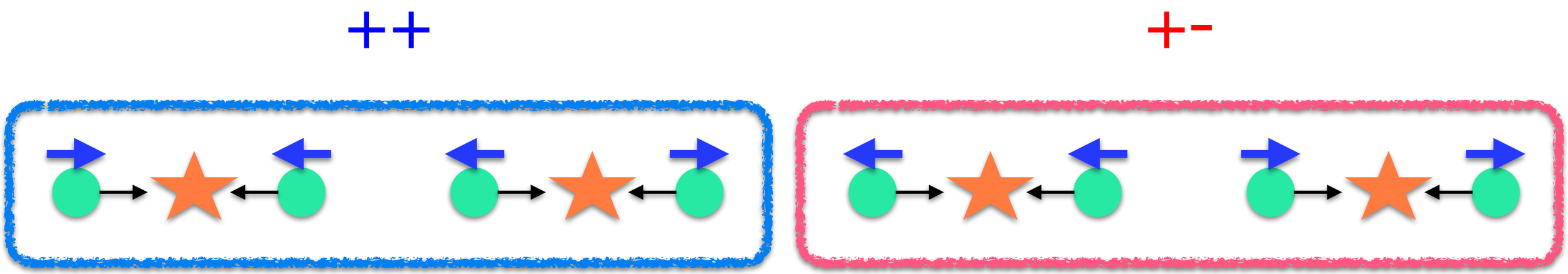
  - The tracking algorithm assumes that tracks originate from the vertex. Therefore, off-vertex tracks may be mis-reconstructed with an arbitrarily large momentum ($p_T \sim 1/\alpha$).

  - Conversion $e^{\pm}$ (decay-in-flight) removed by applying cuts on the deviation of the hit position from the track model projection (also shower shape cut and others).





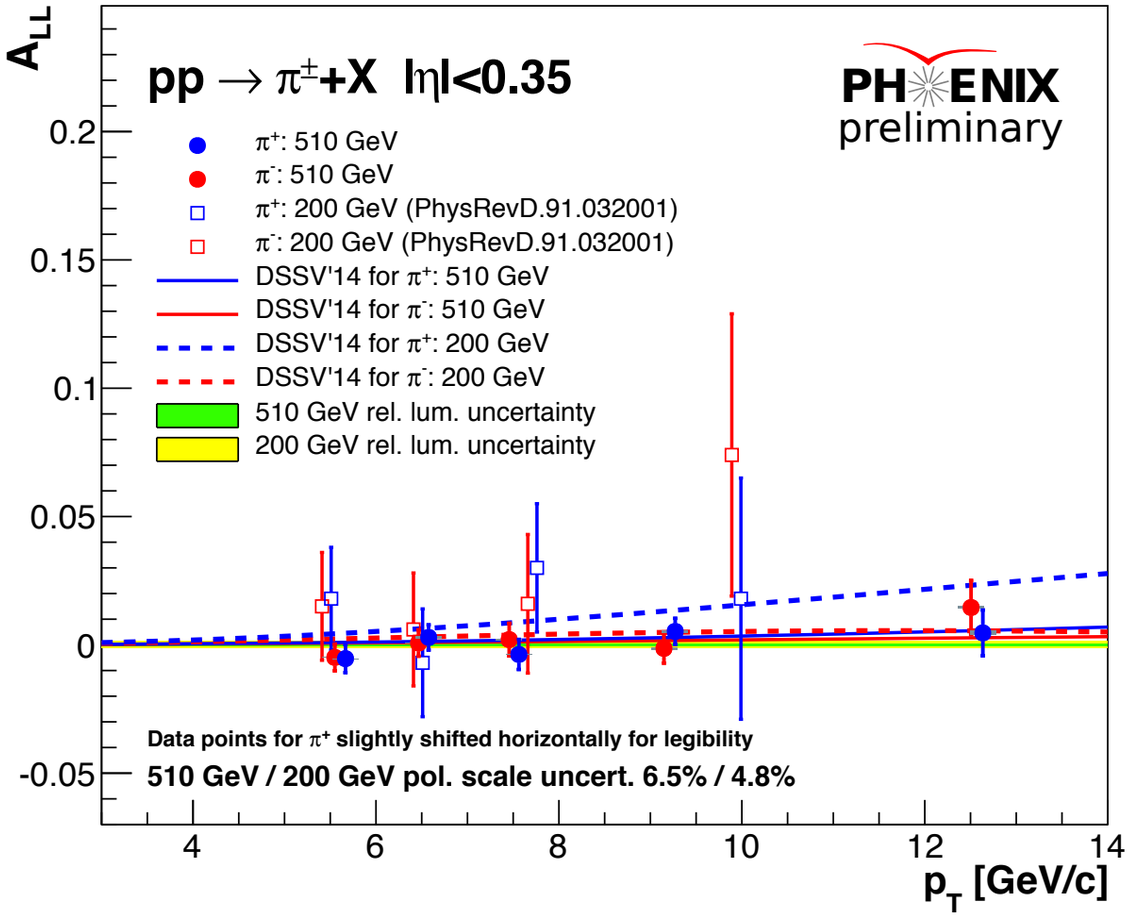
Measuring A_{LL} in experiment

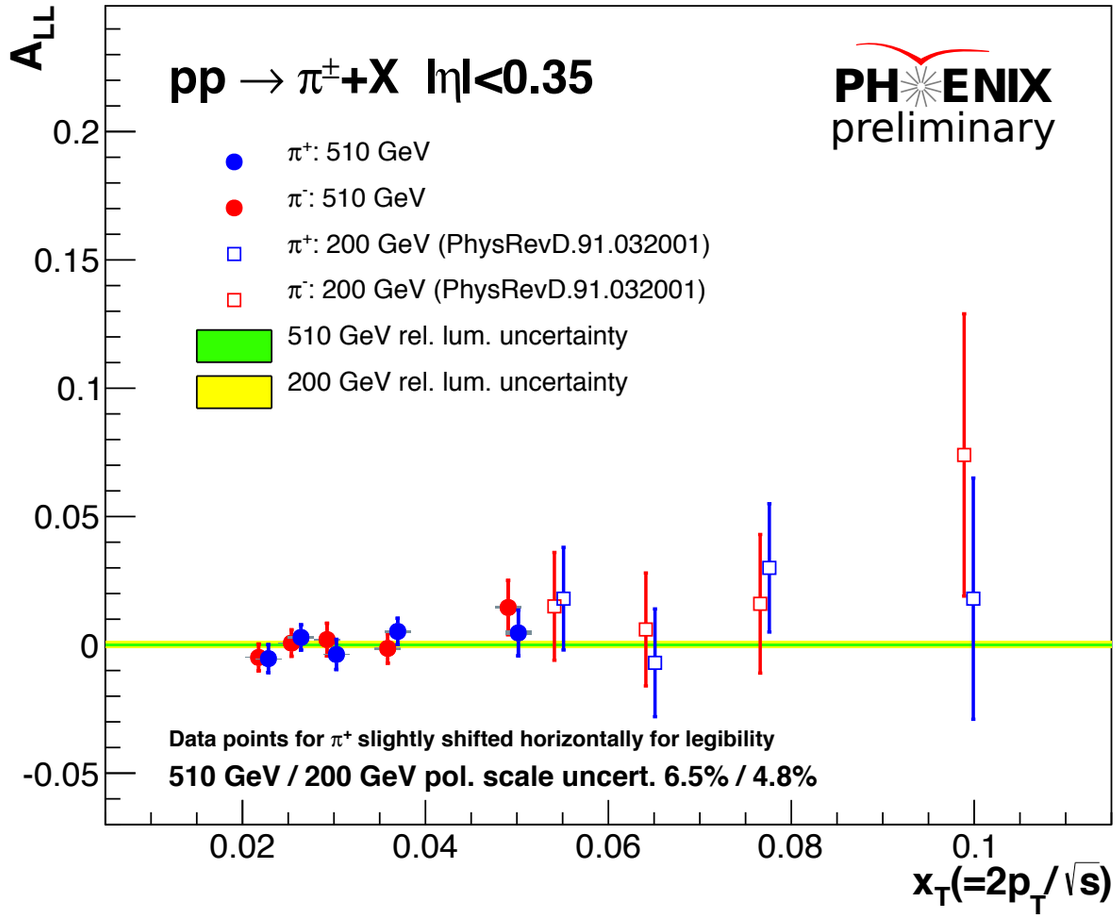


$$A_{LL}^{\pi} = \frac{d\Delta\sigma}{d\sigma} = \frac{1}{|P_B P_Y|} \frac{N_{++} - R N_{+-}}{N_{++} + R N_{+-}}$$

$$R = \frac{L_{++}}{L_{+-}}$$

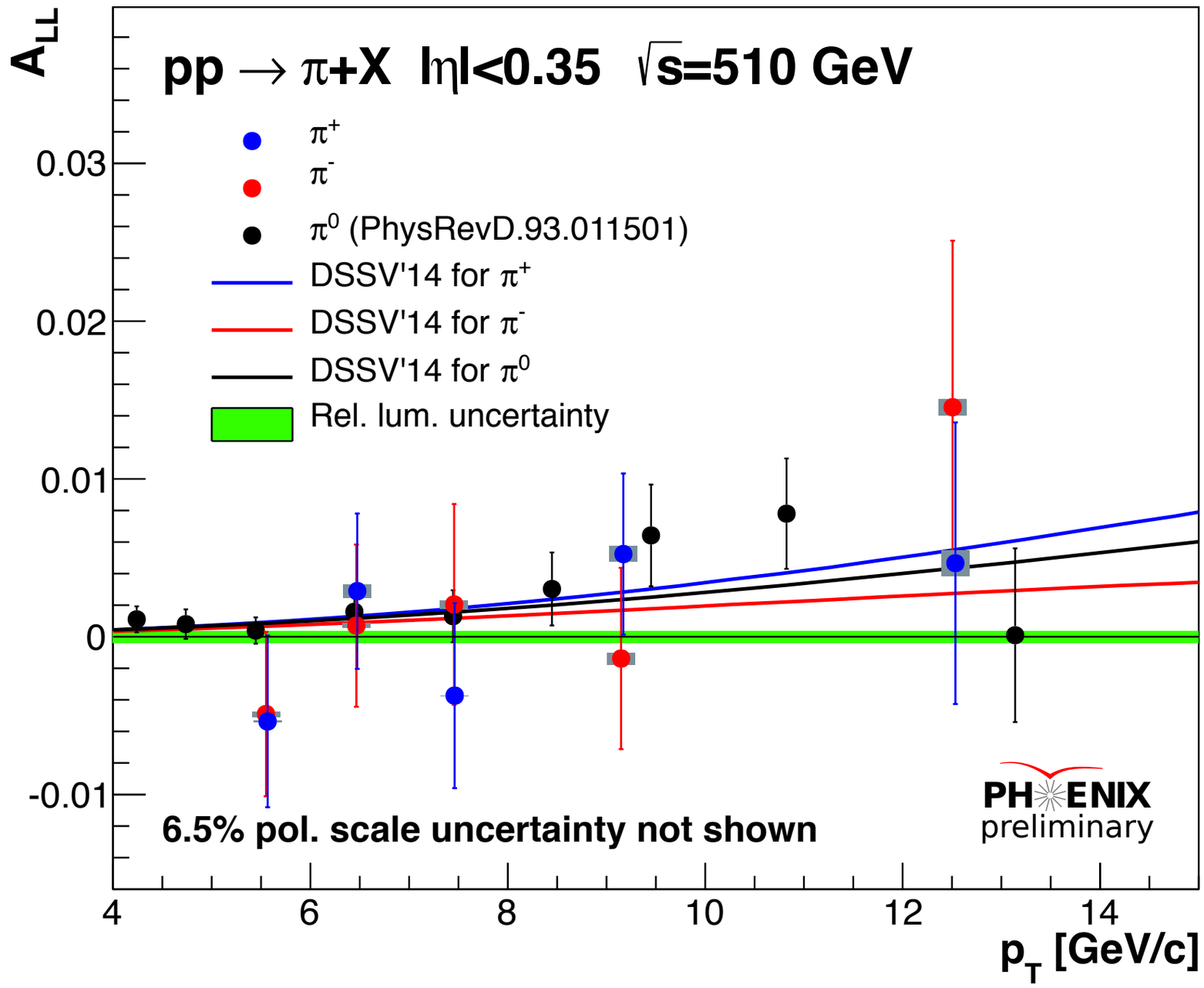
A_{LL} in $\pi^{\pm}$ production at 510 GeV and 200 GeV





- Improvement of statistical precision of $\pi^{\pm}$ A_{LL} in Run-13.
- Expanding experimental sensitivity to lower x_T region, < 0.05, with in Run-13.

A_{LL} in $\pi^{\pm}$ and π^0 production at 510 GeV



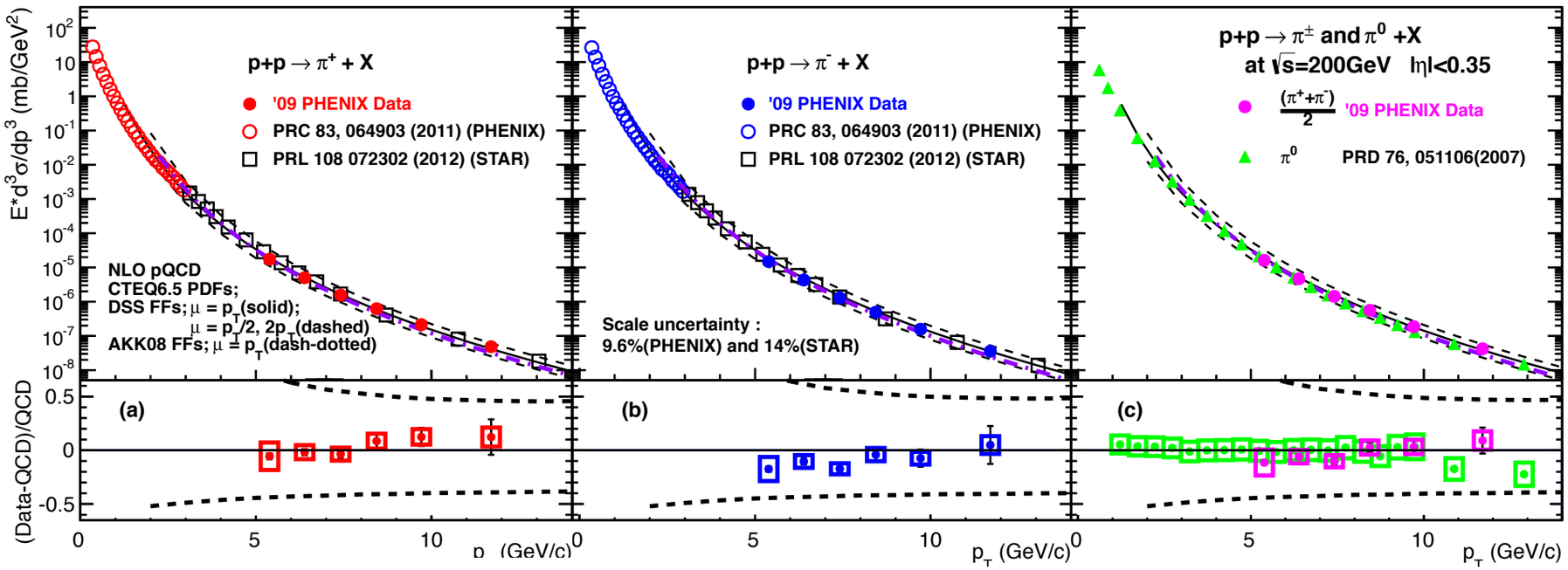
- Theory curves follow measured A_{LL} within statistical uncertainty.
- As a complementary probe, might help to double-check the sign of the gluon polarization.

Summary and outlook

- A_{LL} in $\pi^{\pm}$ production are sensitive to the sign of the gluon polarization.
- A_{LL} in $\pi^{\pm}$ production at 510 GeV has been measured for the first time in the world.
- As a complementary probe with improved statistics, might help to double-check the gluon polarization.

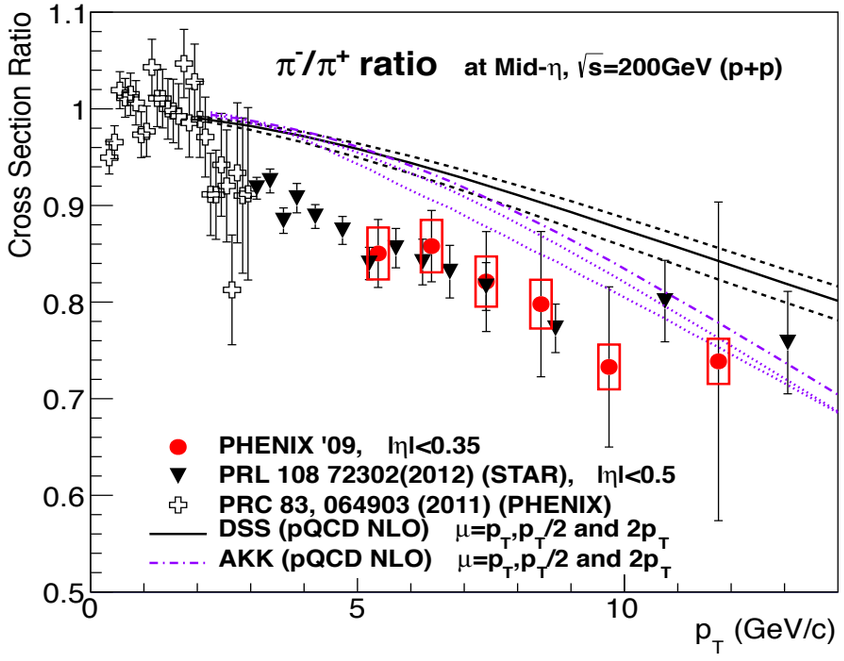
Thanks!

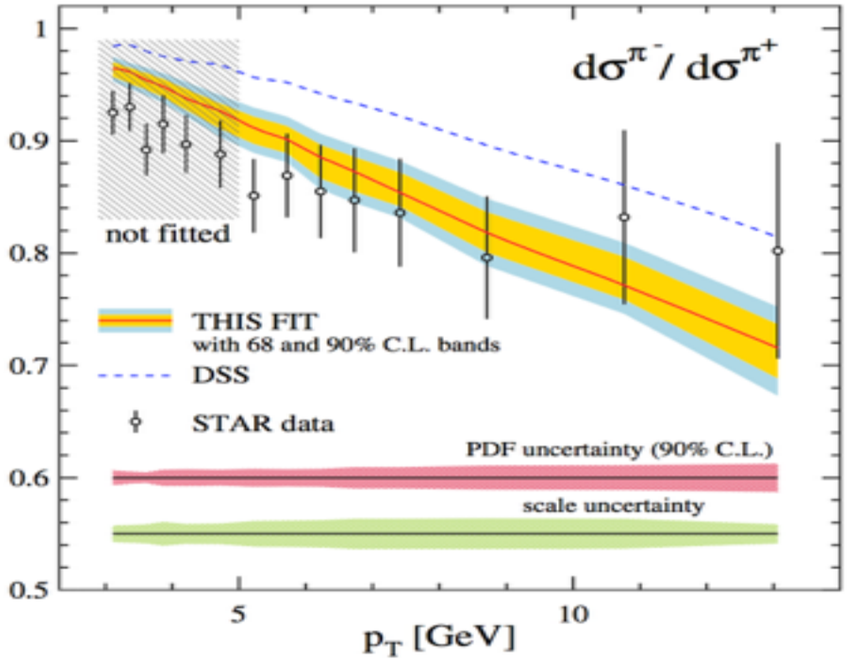
Latest π± X-section results at 200 GeV with Run-9 data



Phys. Rev. D 91, 032001 (2015)

Phys. Rev. D 91, 014035 (2015)

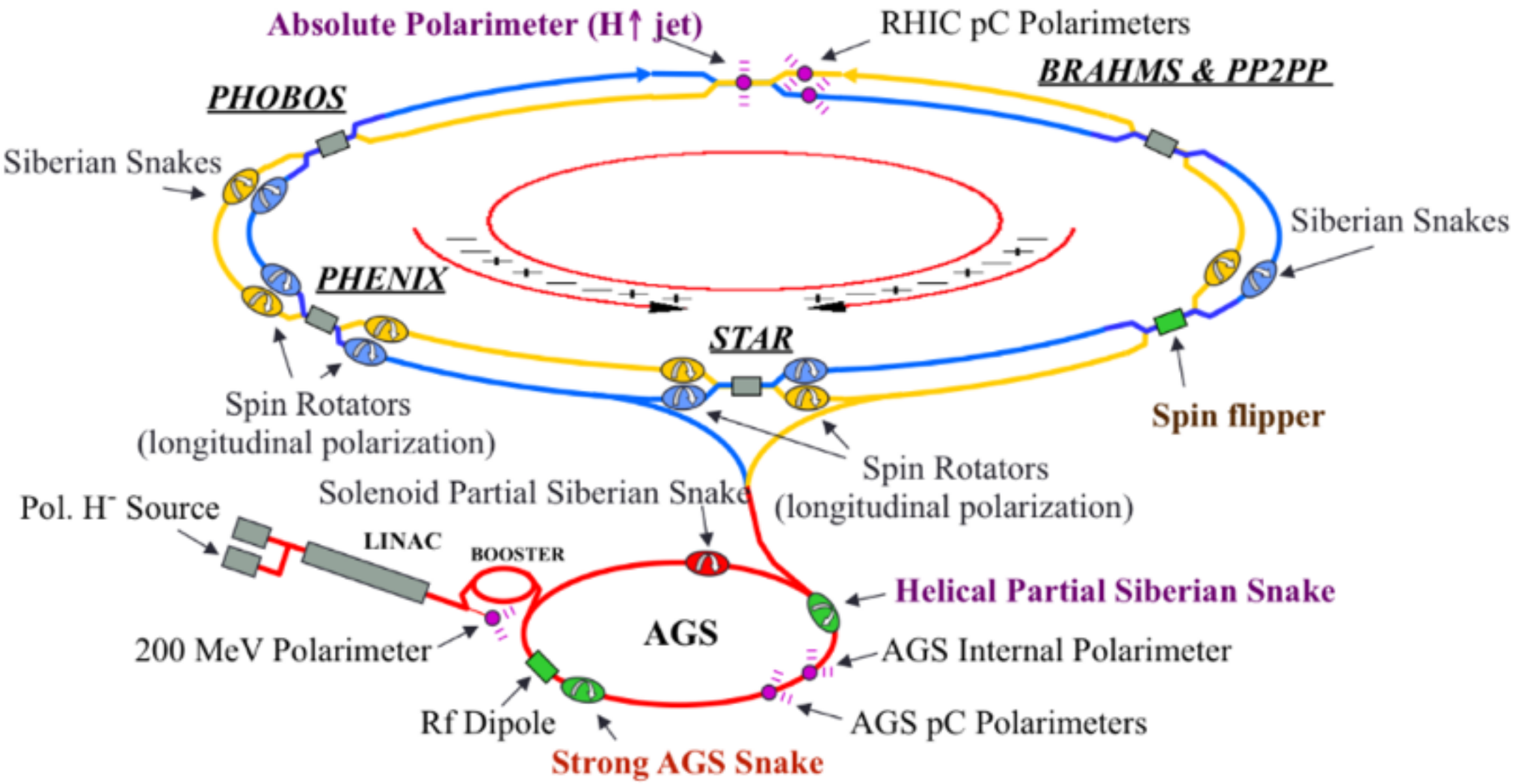




π± background < 2% averaged over the p_T range, thanks to the Hadron Blinder Detector (HBD).

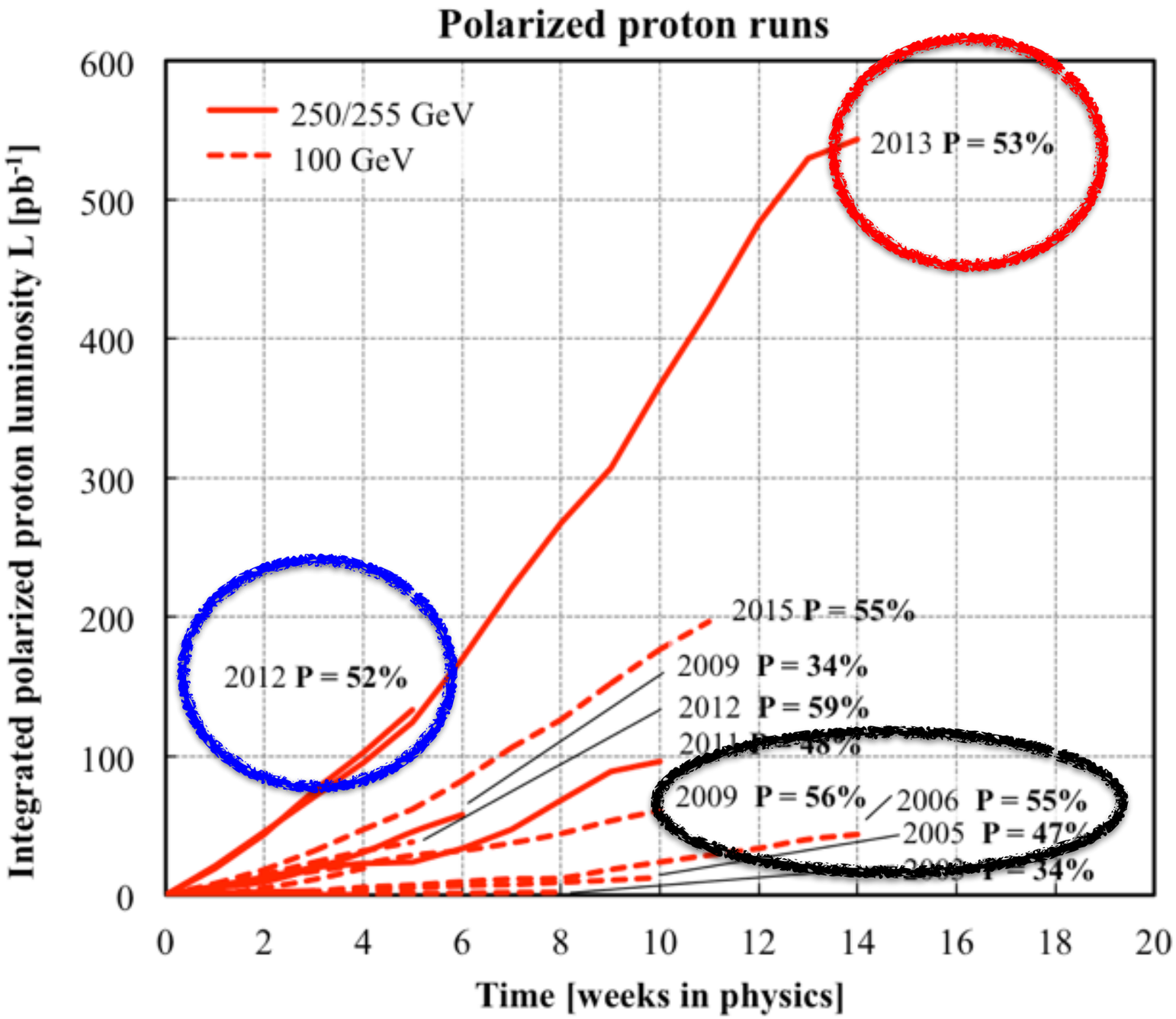
PHENIX π± are in good agreement with Star π± and the DSS14 recent global fit.

RHIC



- The world's only polarized p+p collider
  - Longitudinal or transverse polarization
  - Up to $\sqrt{s}$ = 510 GeV

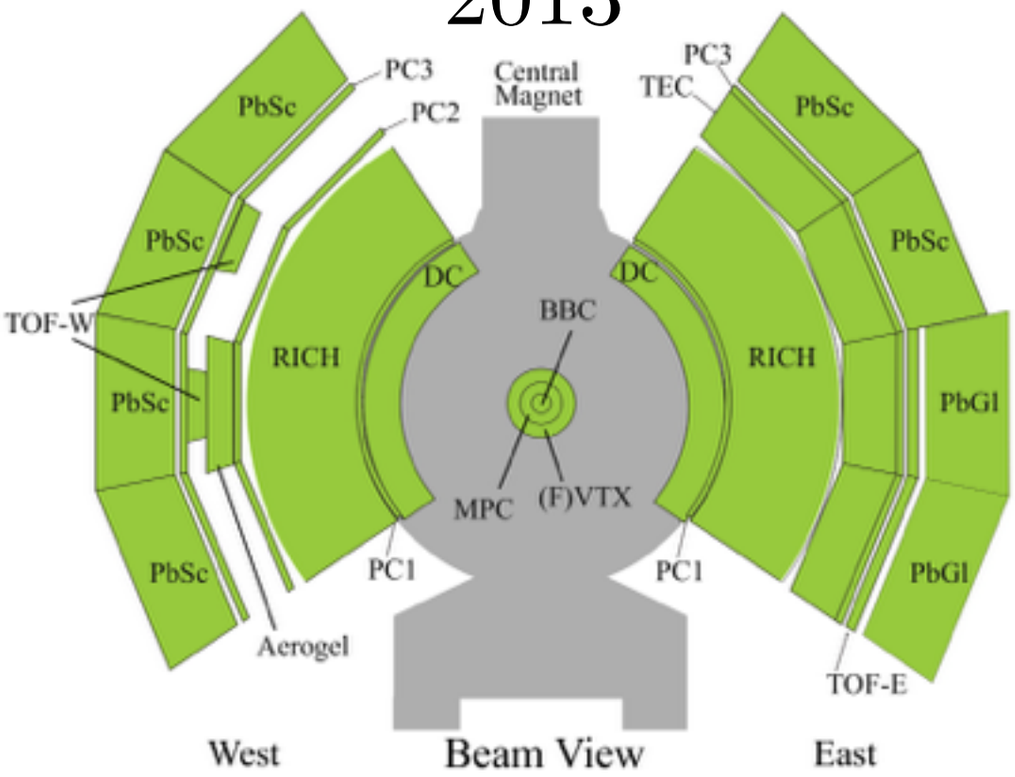
Dataset



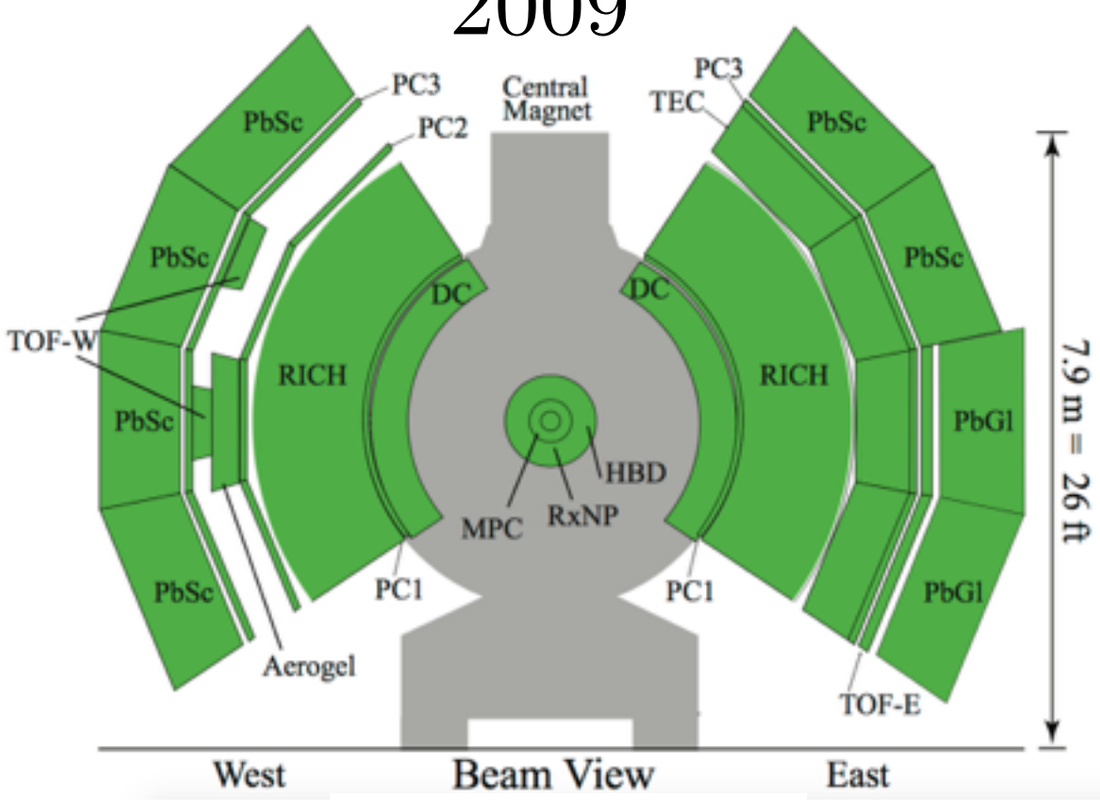
- 20(2012) and 108(2013) pb^{-1} polarized p+p data available.

PHENIX

2013



2009



- Tracking
  - Drift Chamber (DC)
  - Pad Chamber (PC1/PC3)
  - Silicon Vertex Tracker (VTX) in 2013
- $\pi^{\pm}$ Identification
  - Ring Imaging Cherenkov Detector (RICH)
  - Electromagnetic Calorimeter (PbSc/PbGl)
  - Hadron Blider Detector (HBD) in 2009
- Relative Luminosity
  - Beam Beam Counter (BBC)
  - Zero Degree Calorimeter (ZDC)
- Acceptance
  - $|\eta|<0.35$
  - $\Delta\phi = 2 \times \pi/2$