A study on the pol. Gluon PDF with π^0 production at RHIC-PHENIX

K.Aoki for the PHENIX Collaboration

Kyoto Univ. / RIKEN Nishina Center

Introduction

Since it is a session for nucleon structure,
I'll skip most of the introduction..

- This study aims at ΔG

  (gluon spin contribution to the proton)

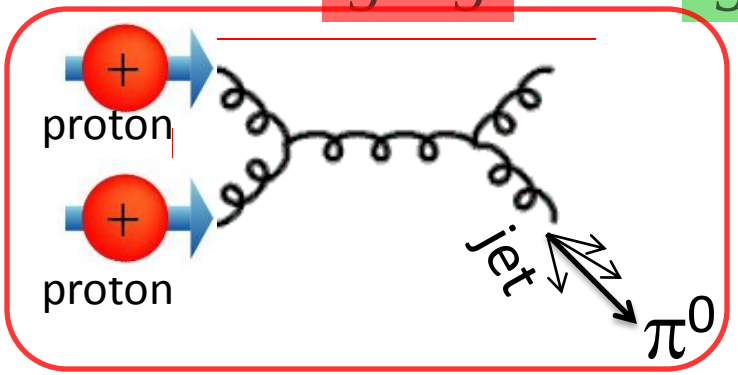
- Through "Double Helicity Asymmetry" (A_{LL}) of π^0 in pol *pp* collisions
  - gluons participate in leading order. suitable to probe gluon spin!

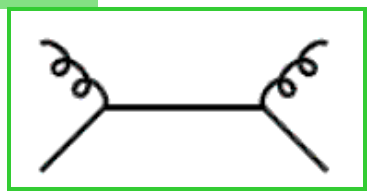
A_{LL} of π^0 in pol. *pp* collisions

- Theoretically

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} \sim \int dx_1 dx_2 \hat{a}_{LL}^{gg} \frac{\Delta g}{g}\frac{\Delta g}{g} + \hat{a}_{LL}^{qg} \frac{\Delta g}{g}\frac{\Delta q}{q} + \hat{a}_{LL}^{qq} \frac{\Delta q}{q}\frac{\Delta q}{q}$$

Proton's helicity





These two processes dominates
In our sensitive p_T region.

- Experimentally

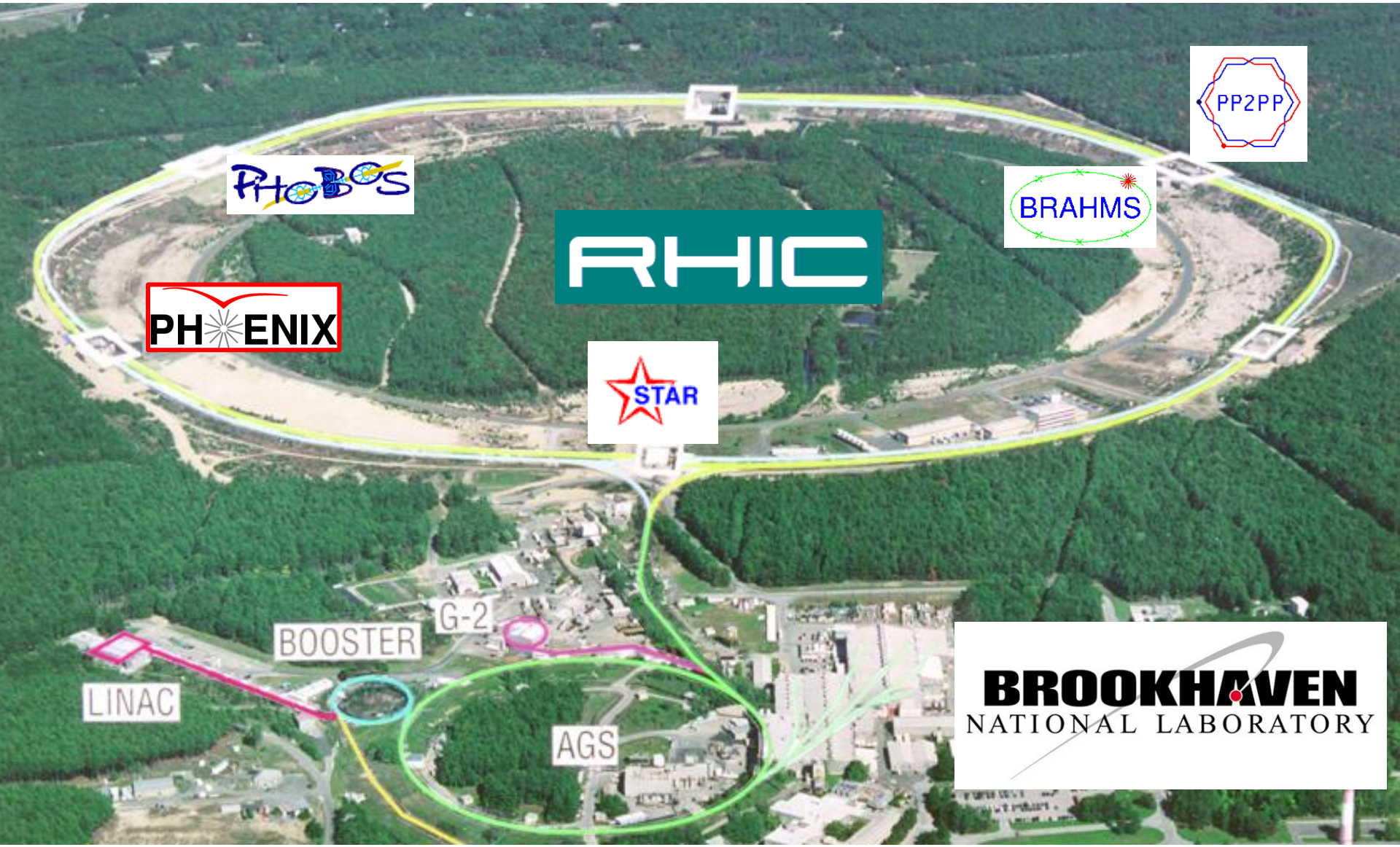
$$A_{LL} = \frac{1}{P_1 P_2} \frac{N_{++}^{\pi} - R \cdot N_{+-}^{\pi}}{N_{++}^{\pi} + R \cdot N_{+-}^{\pi}} \quad R \equiv \frac{L_{++}}{L_{+-}}$$

- N: particle yield
- P: polarization of beams
- R: Relative Luminosity

strategy

- X-section measurement to confirm pQCD applicability
- A_{LL} measurement to extract Δg

RHIC – the world's first pol pp collider



RHIC – the world's first pol pp collider

FOM: Figure of Merit

Longitudinal spin program

RUN	√s GeV	FOM = P^4L $10^{-3}pb^{-1}$	Int. Lumi (pb^{-1})	Pol.
2003 (RUN3)	200	1.9	0.35	27%
2004 (RUN4)	200	3.1	0.12	40%
2005 (RUN5)	200	170	3.4	47%
2006 (RUN6)	200	970	7.5	60%
	62.4	5.3	0.1	48%

Transverse spin program

RUN	√s GeV	FOM = P^2L $10^{-3}pb^{-1}$	Int. Lumi (pb^{-1})	Pol.
2002(RUN2)	200	3	0.15	15%
2005(RUN5)	200	33	0.15	47%
2006 (RUN6)	200	290	2.7	57%
	62.4	1	0.02	48%
2008(RUN8)	200	1100	5.2	46%

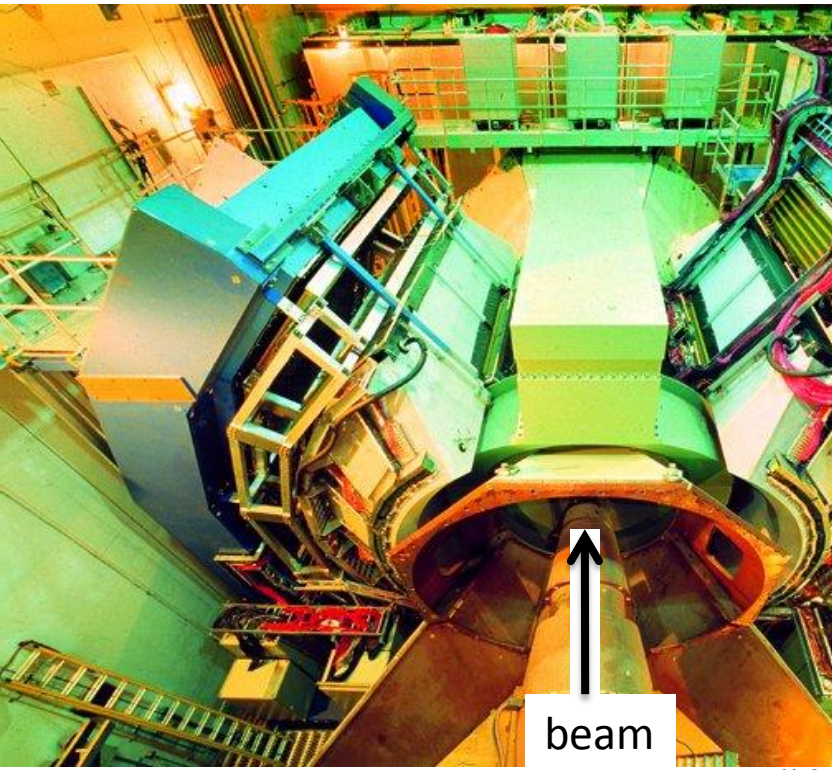
→We discuss RUN6 improvement, compared to RUN5.

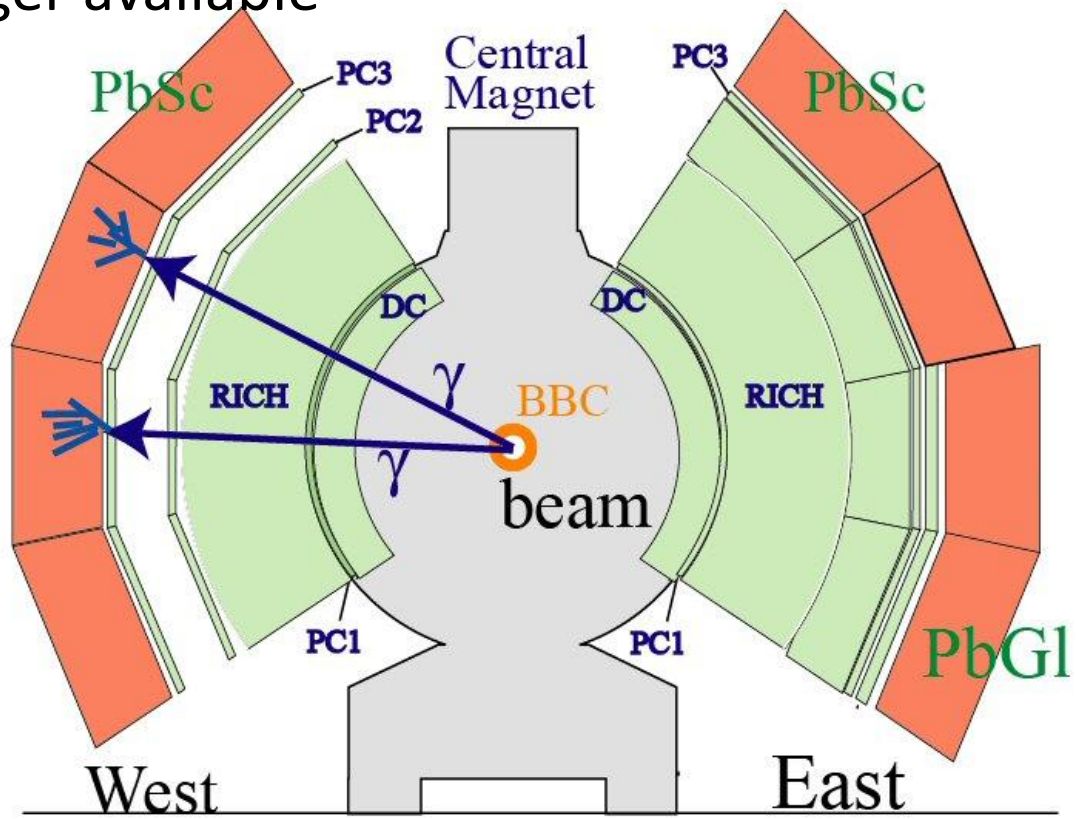
PHENIX Detector

- PHENIX has ability to detect various final state particles such as π^0,π^{+-},γ,e^{+-} and μ^{+-}. Here I concentrate on π^0(or γ) detection.

Central Arm

- $|\eta|$<0.35, $\Delta\phi$ ~ 2 x 90deg
- EMCal(PbSc,PbGl) for γ measurement. π^0 detected via $\gamma\gamma$ decay.
- High energy photon trigger available





cross section – pQCD applicability

RUN5 200GeV -- π^0

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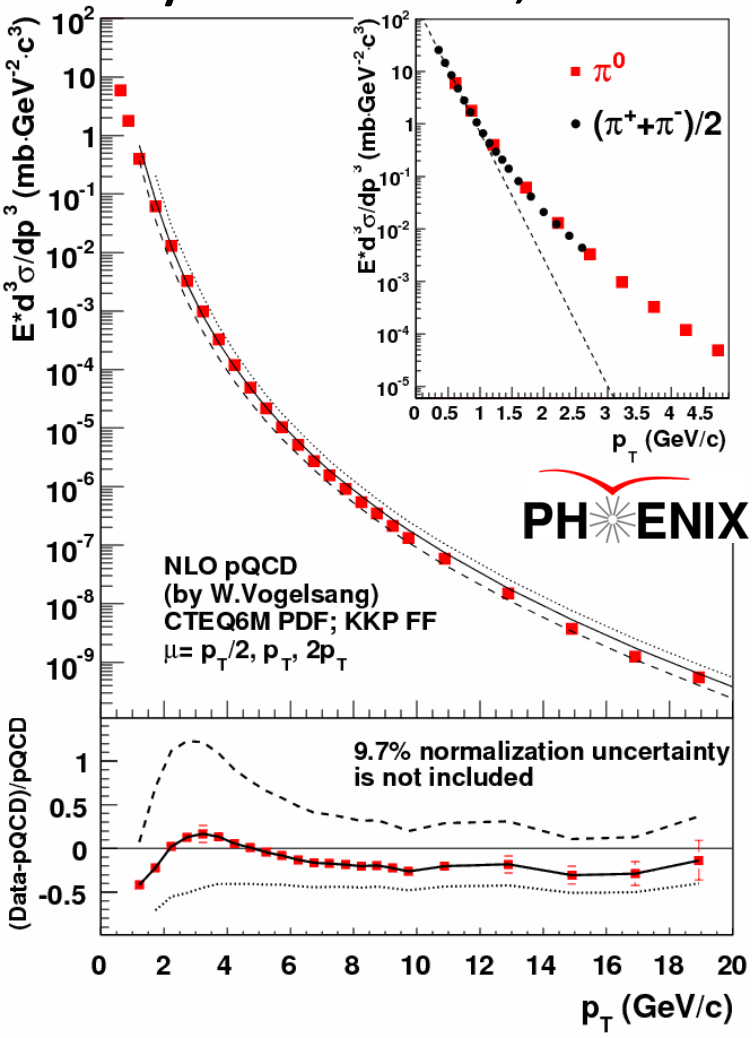
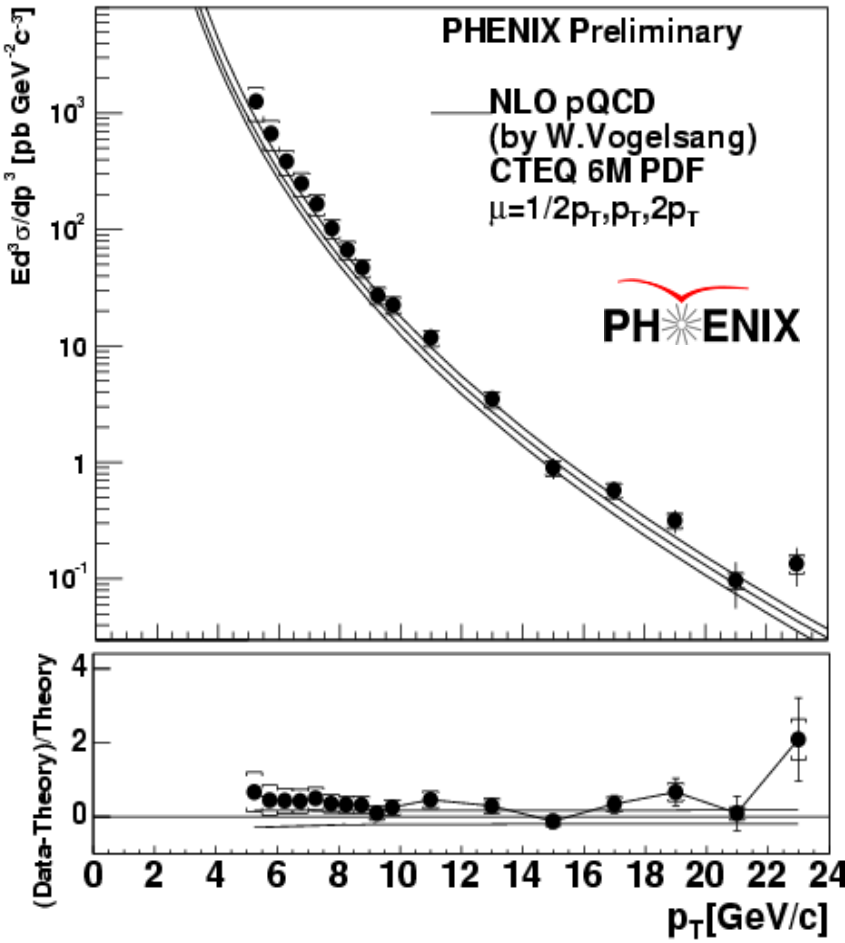


pQCD works

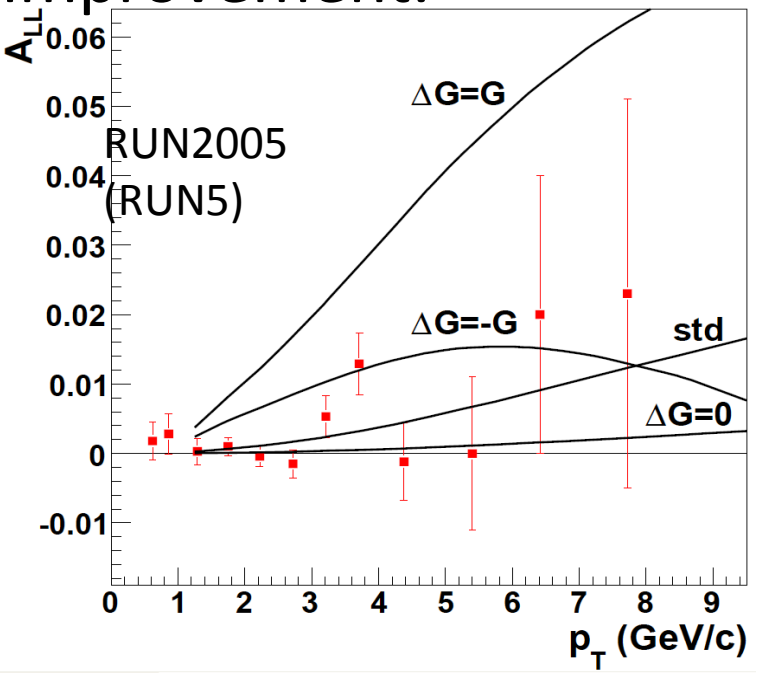
RUN5 200GeV – direct γ

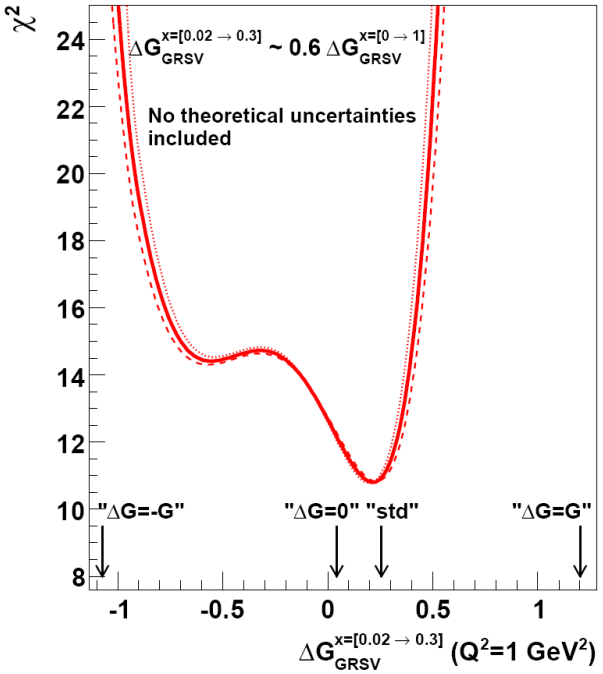


RUN5 π^0 results

- PHENIX measured π^0 A_{LL} at 200GeV (RUN2005)
  - Among four GRSV models, allowed by DIS,
    - ΔG=+G,-G are rejected.

    measured ***x*** range (0.02—0.3)
  - Need more statistics (for straight forward) improvement.



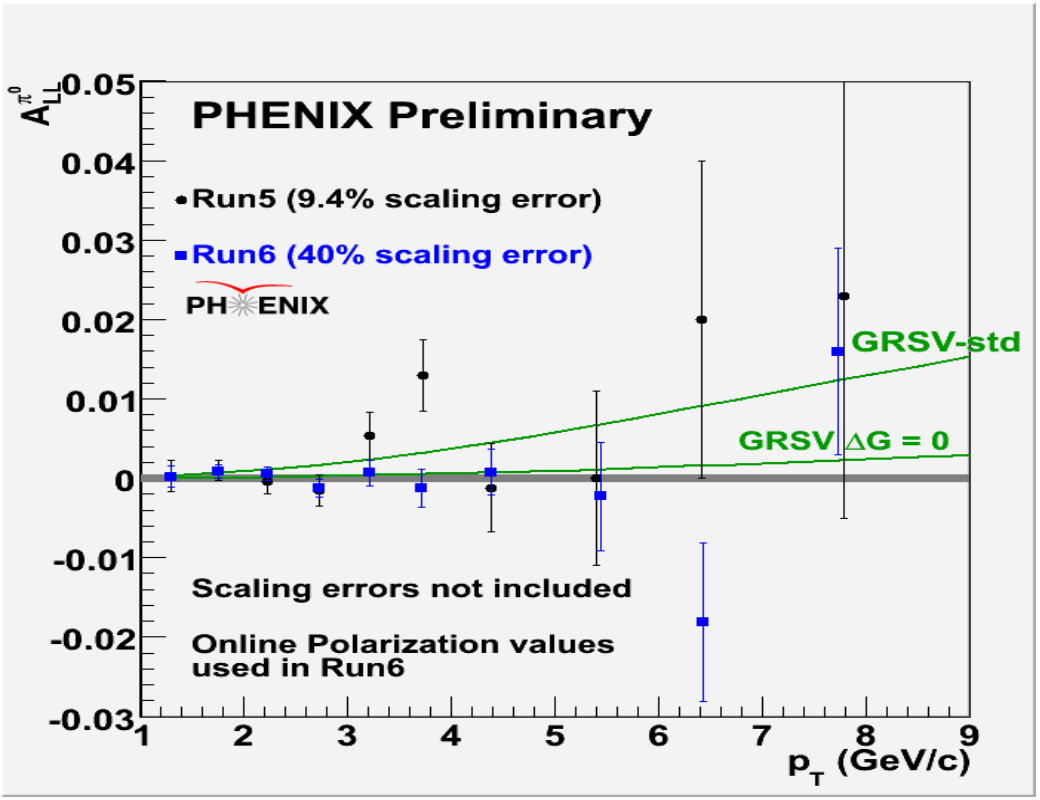


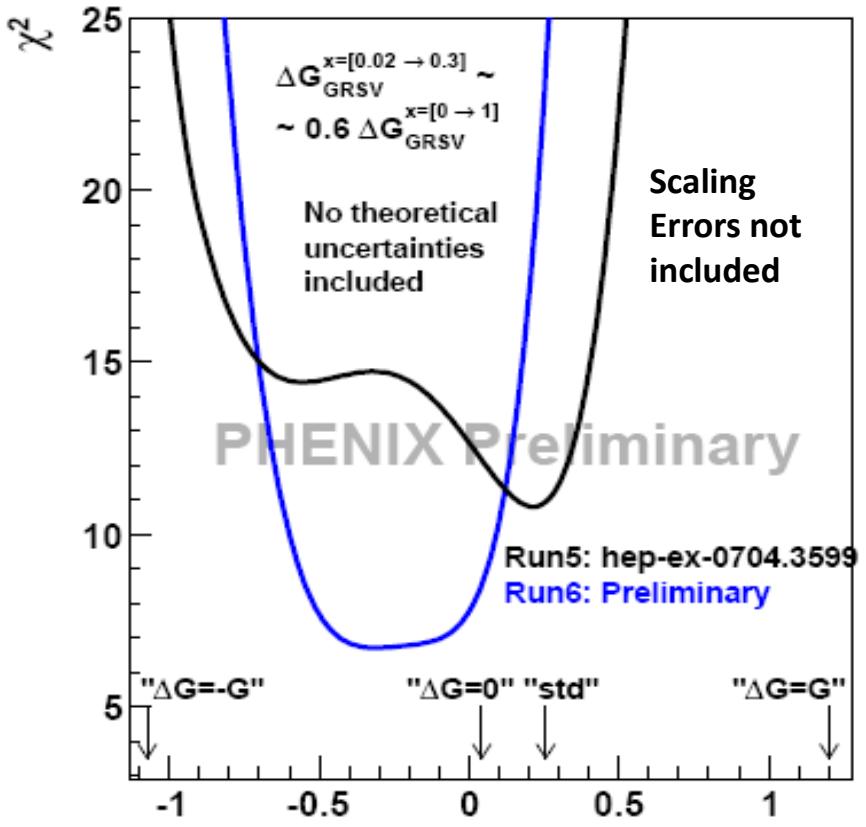
π^0 A_{LL} at 200GeV – RUN6 improvement

200GeV RUN5 2.5pb^{-1} (47%) ~10weeks

200GeV RUN6 6 pb^{-1} (60%) ~6weeks

- χ^2 test based on GRSV





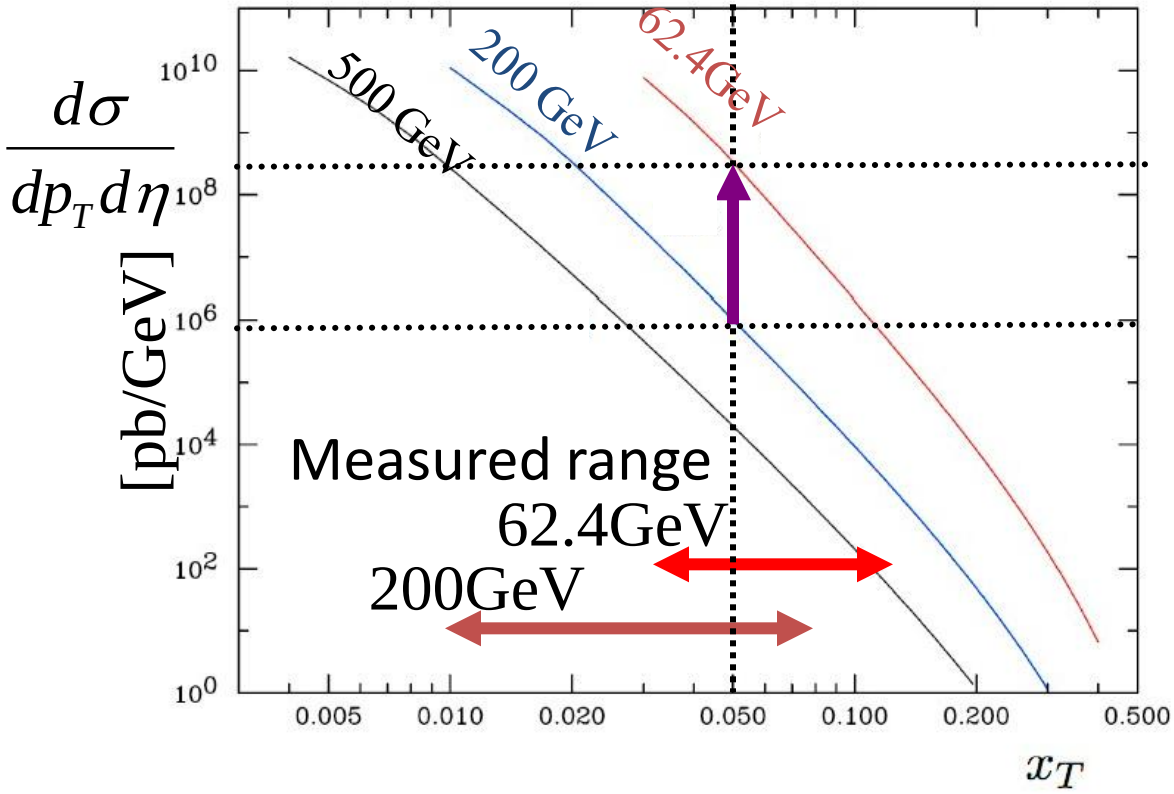
ΔG [x=0.02→0.3] (Q^2=1GeV^2)

- GRSV theory curves
  - Std: best fit to DIS data - rejected
  - ΔG=0 still allowed

Another way to improve access high x with lower energy

- Probed x scales with x_T.
- At fixed x_T, x-sec is 2 orders of magnitude higher at 62.4GeV than at 200GeV. → easier to access high x

$$x_T = \frac{2p_T}{\sqrt{s}}$$



cross section – pQCD applicability

RUN5 200GeV -- π^0

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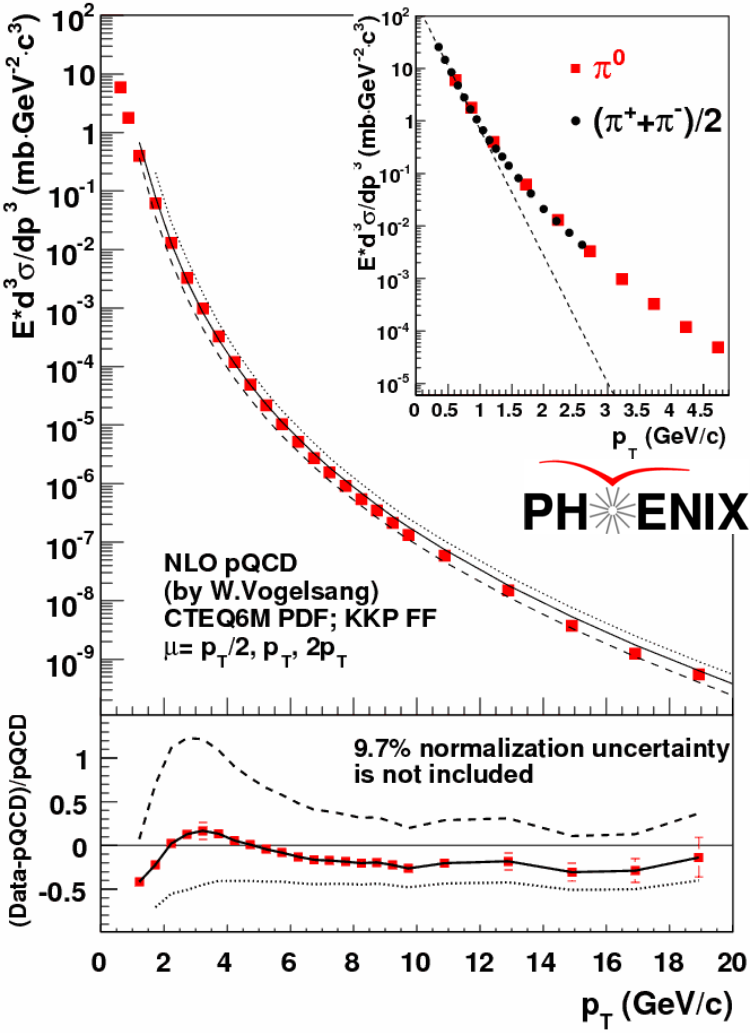
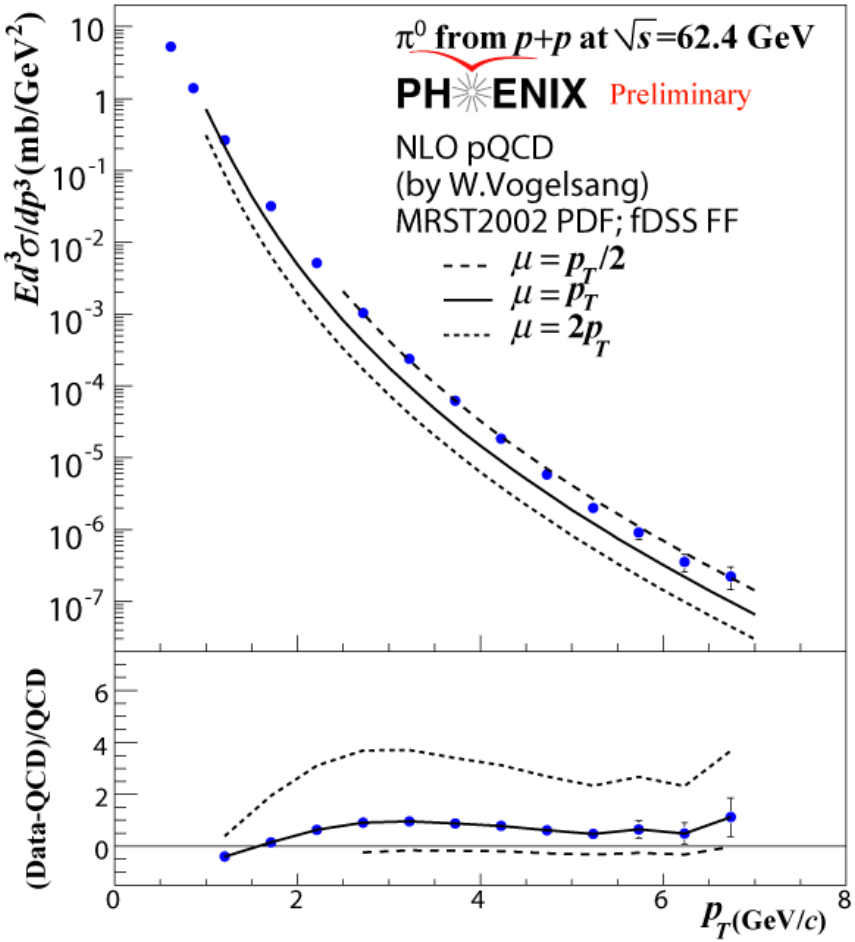
RUN6 62.4GeV -- π^0



pQCD works



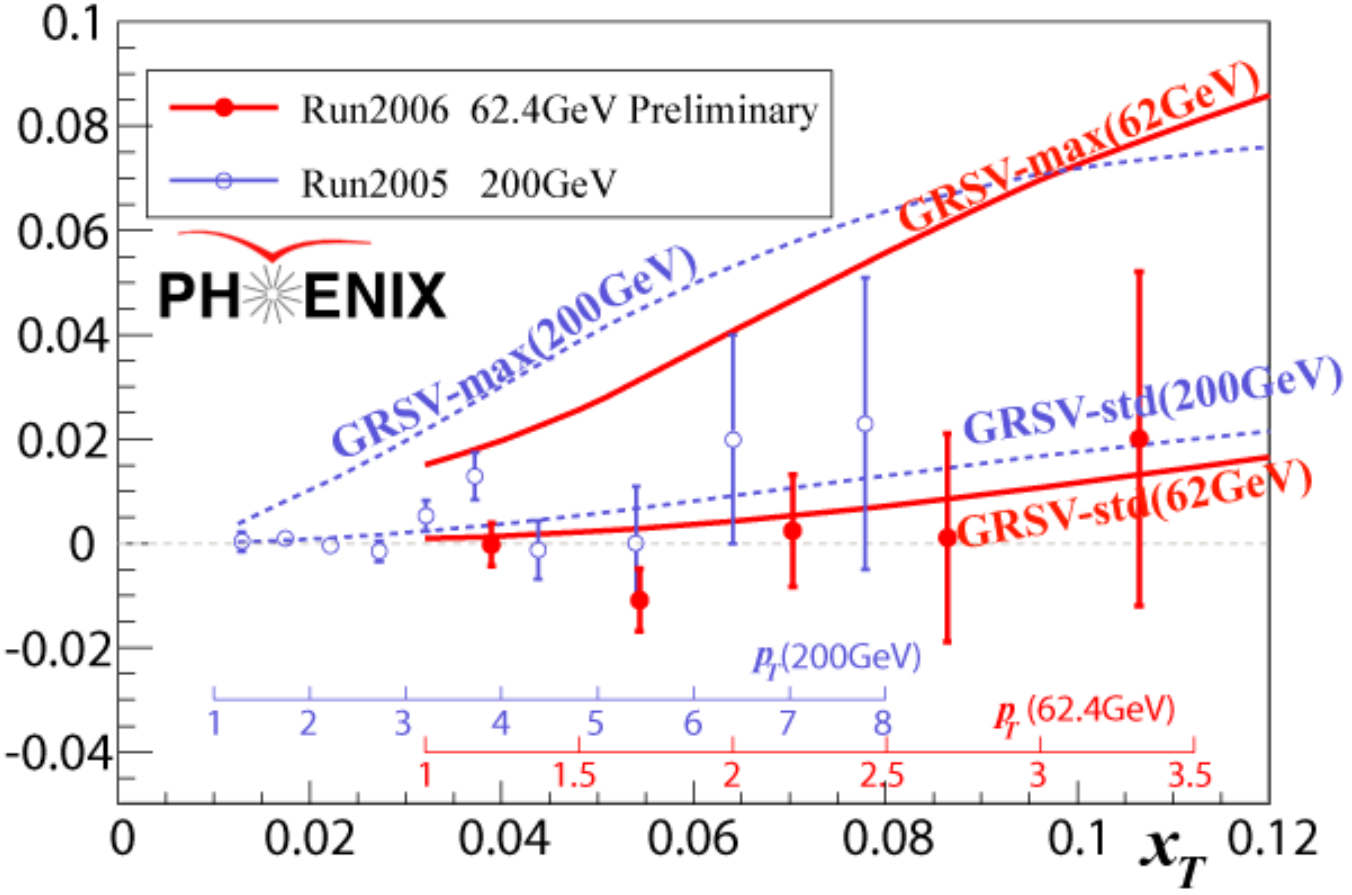
π^0 A_{LL} at 62.4GeV

- Significant statistical improvement in high x_T even with short data taking period (and small int.lumi)

		pol	
200GeV	2.5pb^{-1}	(47%)	~10weeks
62.4GeV	0.04 pb^{-1}	(48%)	~ 1week

$A_{LL}(\pi^0)$

GRSV – max is rejected also in higher x_T.

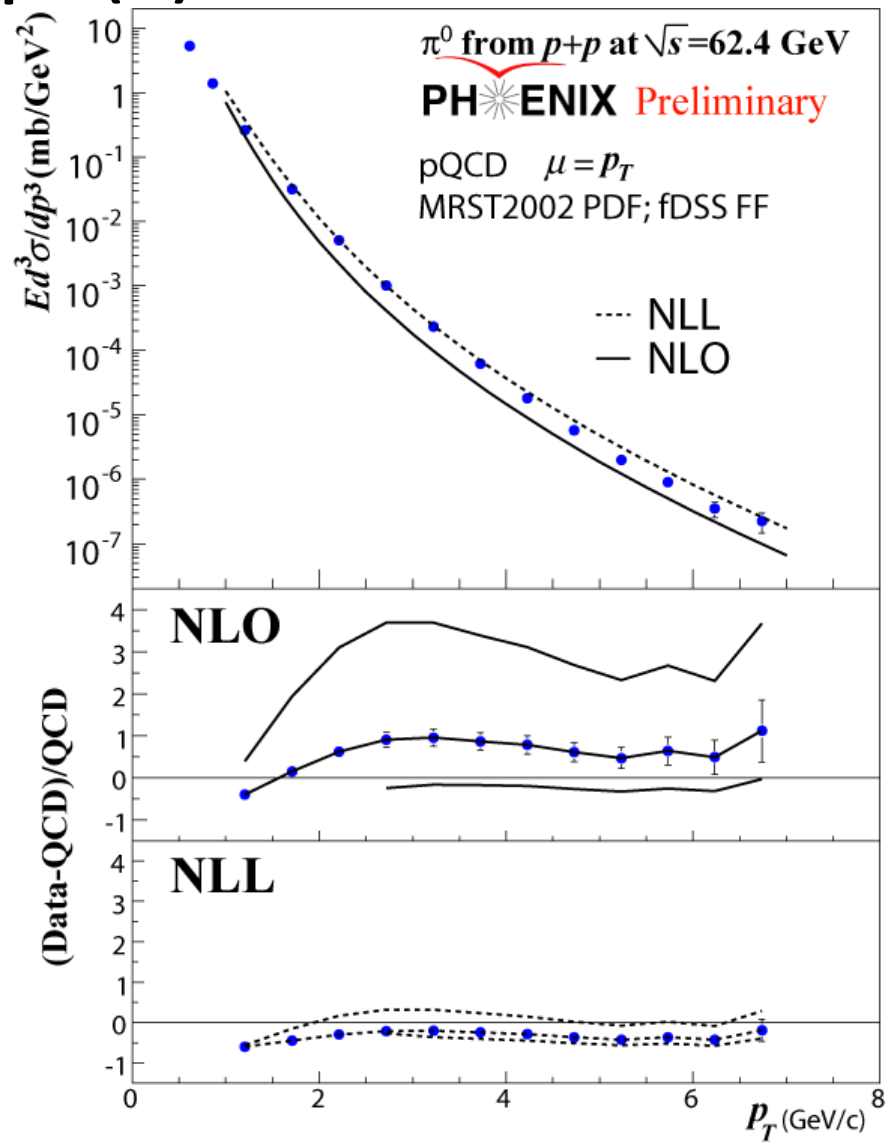


Scaling variable

$$x_T = \frac{2p_T}{\sqrt{s}}$$

Theoretical progress
NLO and NLL at sqrt(s)=62.4GeV

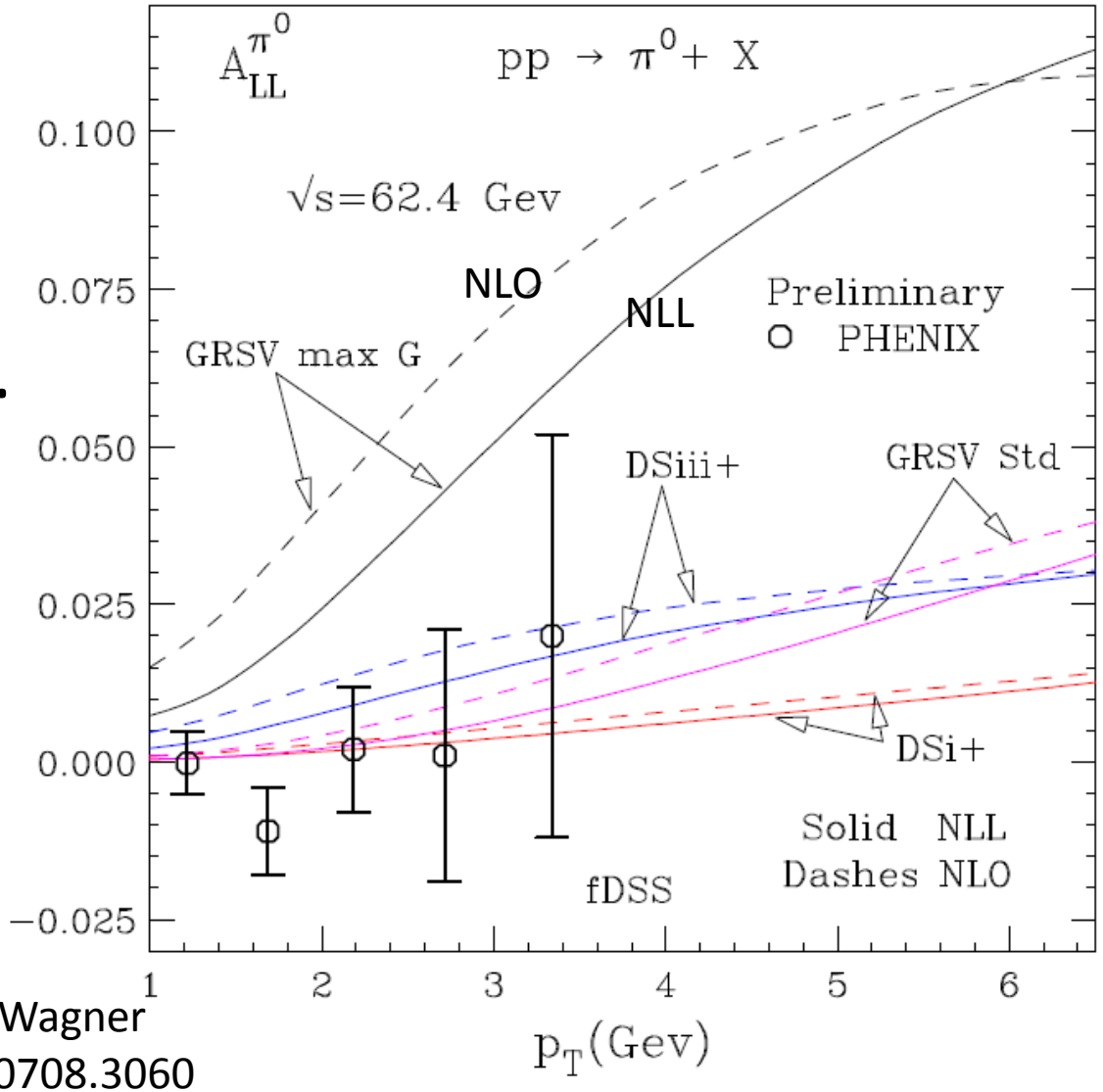
- NLL (Next-to-Leading Log) theory calculation available
- Improved agreement btw data and theory.
- Reduced scale dependence
- In Both NLO and NLL cases, data and theory agrees within theoretical uncertainty.



D. De Florian, W. Vogelsang, and F. Wagner
Phys.Rev.D76,094021(2007), arXiv:0708.3060

π^0 A_{LL} at 62.4GeV - NLL

- When we go NLL accuracy, GRSV-max A_{LL} decreases slightly.
- Still inconsistent with our data.



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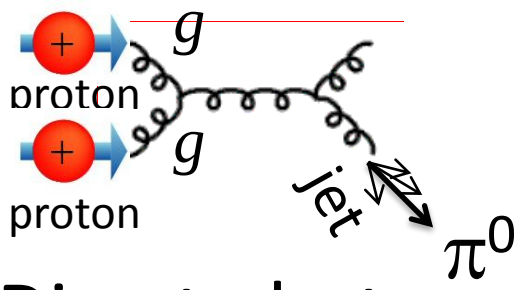
summary

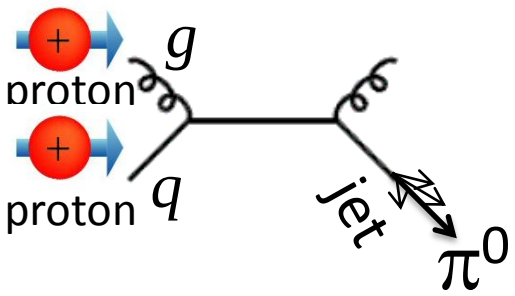
- Double Helicity Asymmetry A_{LL} of π^0 production is utilized for measurement of ΔG
- RUN2005 π^0 A_{LL} at sqrt(s)=200GeV put constraint on ΔG.
  - Needs more statistics for further improvement.
- Improvement obtained in RUN2006 in two ways
  - 200GeV: Collect more stat.
    - put significant constraint on ΔG
  - 62.4GeV : Lower energy to access higher x.
    - Improved higher x sensitivity with short data taking period
    - GRSV-max is rejected also in high x_T region in NLO.
    - Theory update - NLL
    - Our data is inconsistent with GSRV-max even in NLL.

- We are preparing a paper for 62.4GeV. Close to submission.

Various channels available at PHENIX to explore gluon pol.

- Jet (or a component of jet)

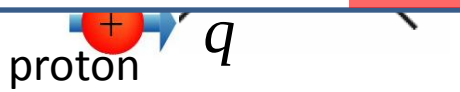




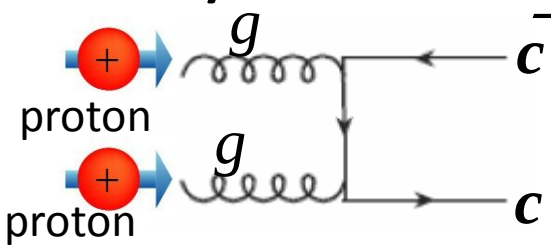
- π^0 , η $(\rightarrow \gamma\gamma)$
- π^{+-}
- *jet*-like cluster

$$A_{LL} \sim \int dx_1 dx_2 \hat{a}_{LL}^{gg} \frac{\Delta g}{g}\frac{\Delta g}{g} + \hat{a}_{LL}^{qg} \frac{\Delta g}{g}\frac{\Delta q}{q}$$

- γ



- Heavy Flavor

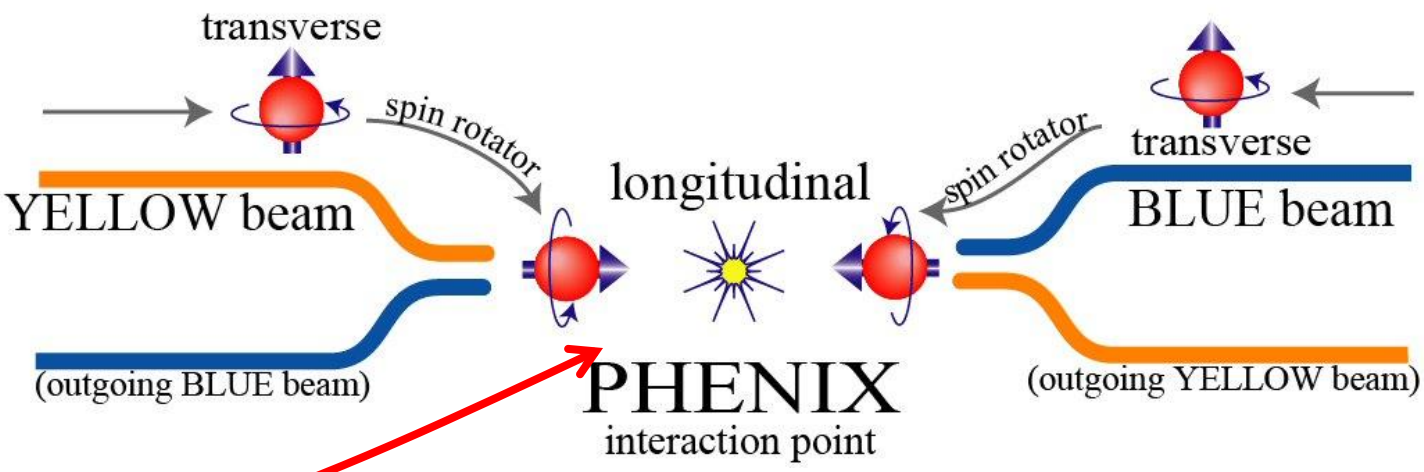


$\bar{c} \rightarrow D \rightarrow e$ or μ

or $\bar{c}c \rightarrow$ J/ψ

- e^{+-}
- μ^{+-}
- $J/\psi (\rightarrow e^+e^-, \mu^+\mu^-)$

RHIC beam at PHENIX IP



- Two independent beams(Blue / Yellow)
- Bunch structure (120 bunchs in ~106ns interval)
- Transverse→Longitudinal at IP (when we need it)
- Spin pattern

BLUE : + + - - ….
Yellow: + - + - ….

→ We can get all possible Collision patterns.

  - Syst. uncertainty from time-dep. of the det. eff. avoided.

PHENIX global detector

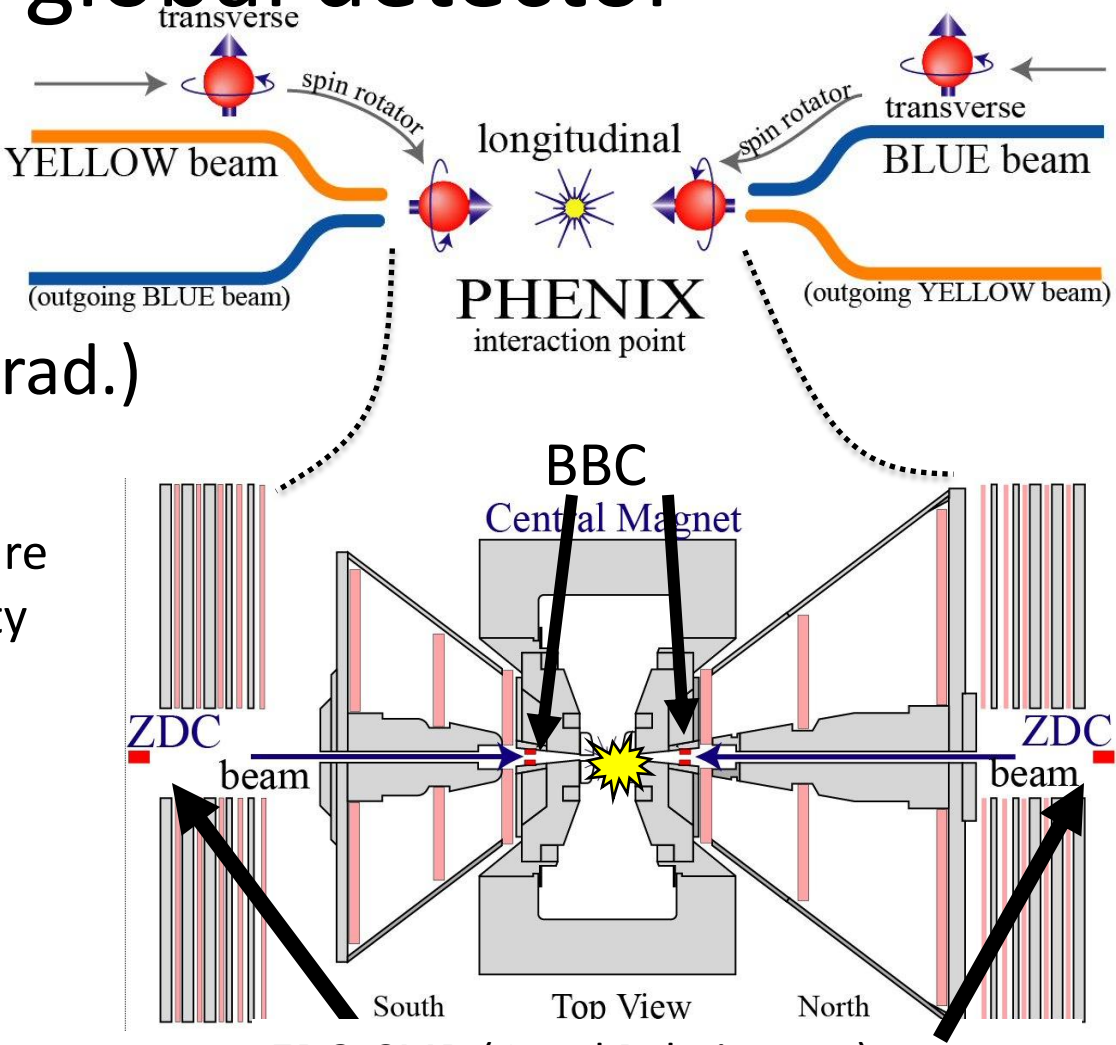
Luminosity Measure

- BBC 3.0<|η|<3.9
  - Quartz Cherenkov det.
- ZDC |η|>6.6 (+/- 2.8mrad.)
  - Hadron Calorimeter

These two independent lumi. measure are compared to find out uncertainty on Relative Lumi.

Local Polarimetry

- SMD (+ ZDC).
  - Scintillator hodoscopes.
  - Measures transverse component of beam through A_N of neutron.

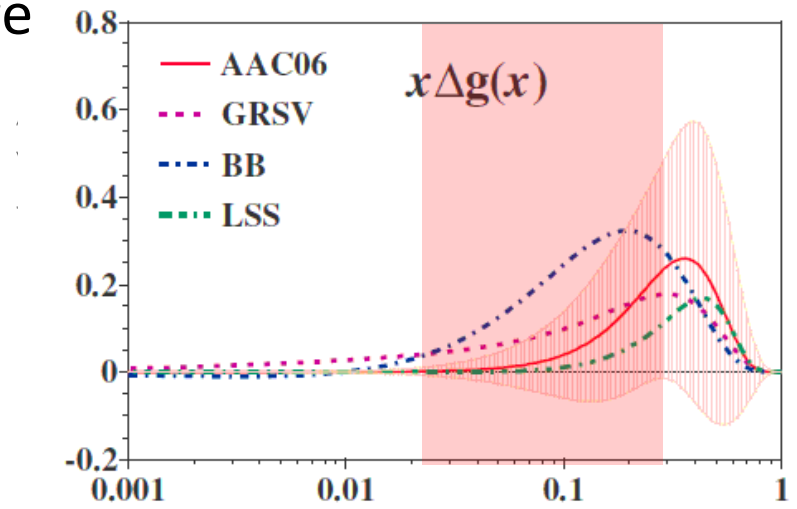


ZDC+SMD (Local Polarimeter)

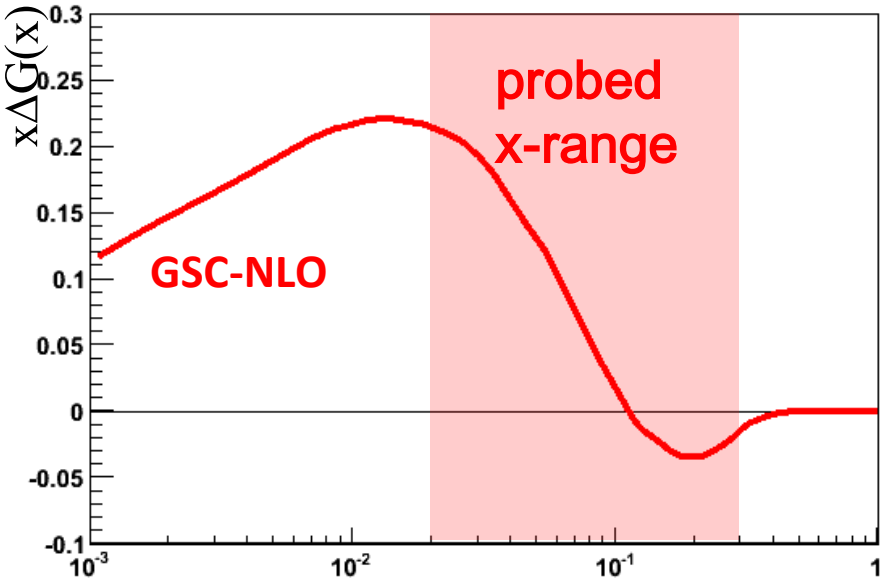
$$A_{LL} = \frac{1}{P_1 P_2} \frac{N^{\pi}_{++} - R \cdot N^{\pi}_{+-}}{N^{\pi}_{++} + R \cdot N^{\pi}_{+-}}$$

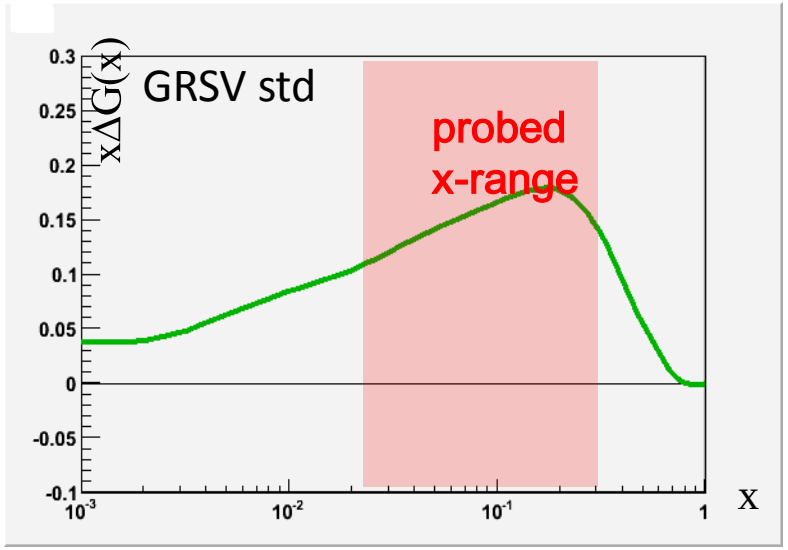
other PDF models

Should not satisfied with measured x range for model independent determination.
For furthur improvement, x range should be extended.



GSC-NLO: $\Delta G = \int \Delta G(x)dx = 1.0$

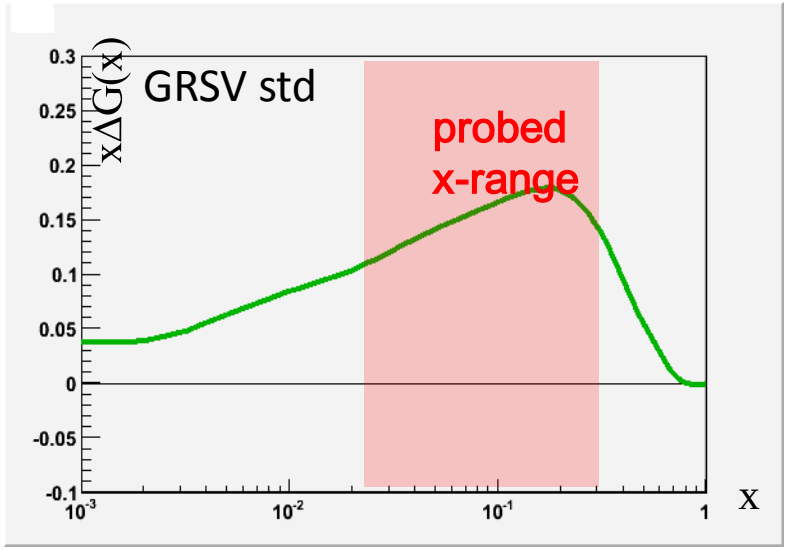




GSC-NLO: $\Delta G \overset{0.3}{=} \int_{0.02} \Delta G(x)dx \sim small \rightarrow 0$

other PDF models

- Should not be satisfied with measured x range for model independent determination.
- Measure different x region by
  - Go to different kinematics → Seishi's talk
  - Change sqrt(s): low energy – high x, high energy - low x
    - Sqrt(s)=500GeV for coming run.
    - We have sqrt(s)=62.4GeV in RUN2006



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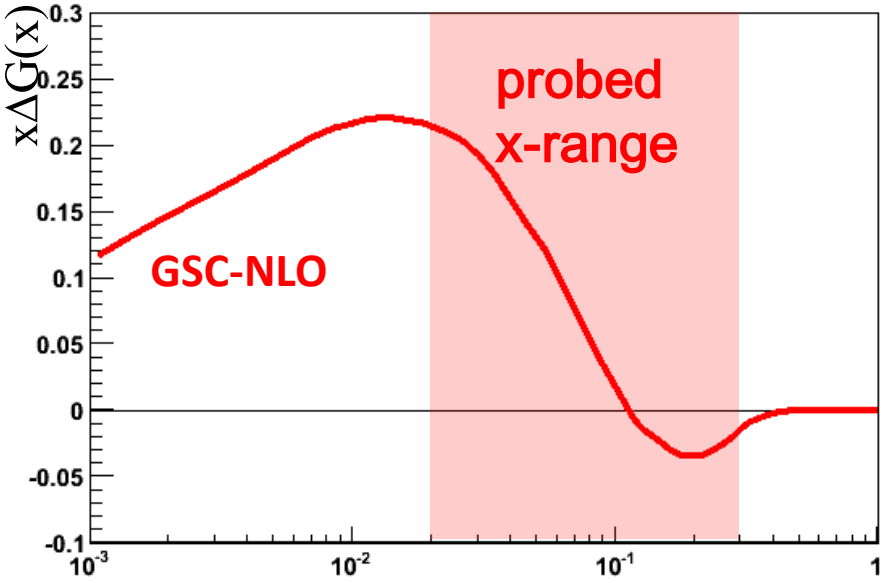

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