ΔG Measurement at RHIC-PHENIX

Pacific Spin, Seattle

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for The PHENIX Collaboration

PHENIX

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Access to ΔG

A_{LL} (=double longitudinal spin asymmetry) is the probe.

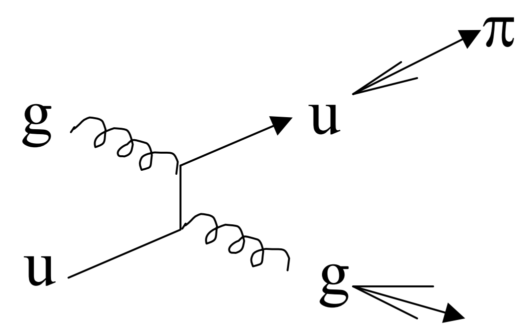
$$A_{LL} \equiv \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_1 P_2} \cdot \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$$

N : Physics observables

$R \equiv \frac{L_{++}}{L_{+-}}$: Relative luminosity: parallel to anti-parallel

For example, π^0 production

$$A_{LL} \sim \hat{a}_{LL}(ug \to ug) \cdot \frac{\Delta G(x_1)}{G(x_1)} \cdot \frac{\Delta u(x_2)}{u(x_2)}$$



(mixed with gg and qq interaction.
The fragmentation function also contributes.)

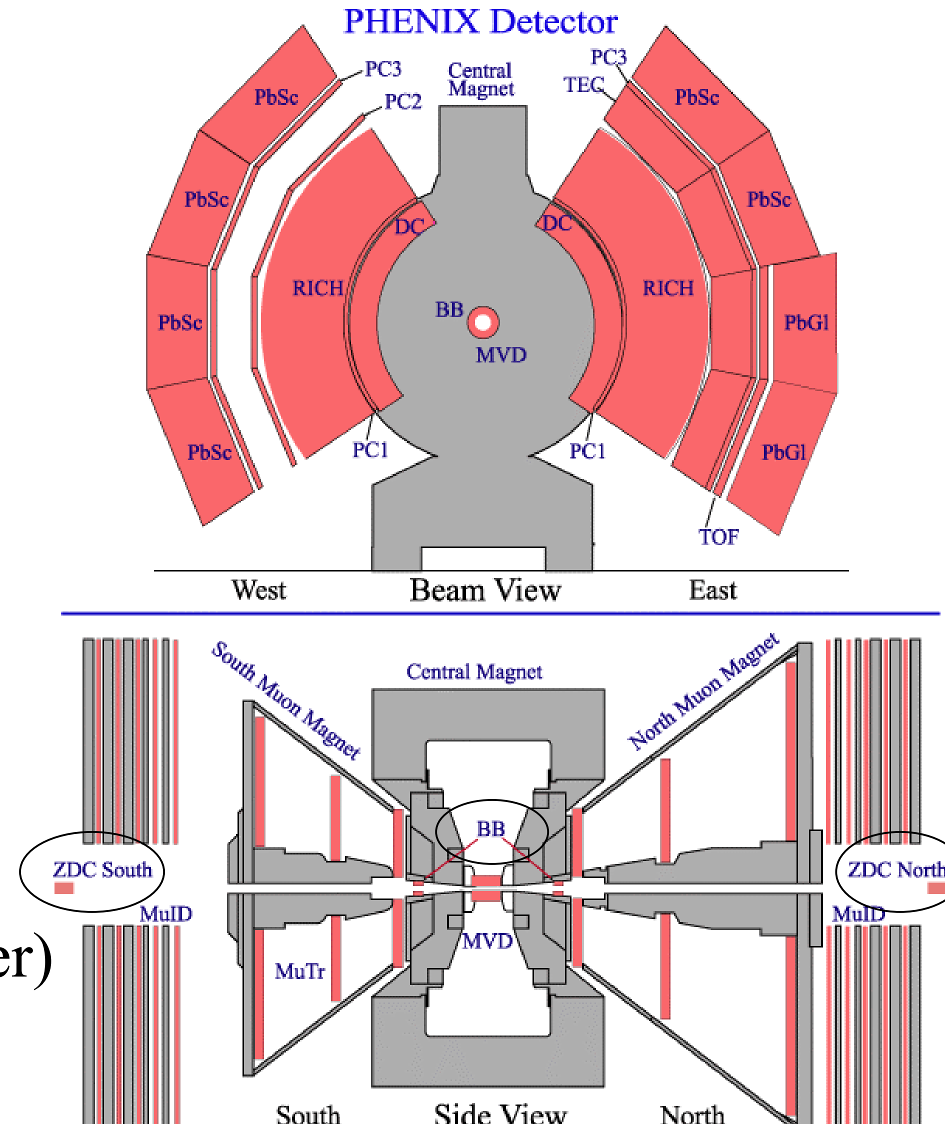
- **Jet (or leading hadron) production : high yield, high sensitivity to ΔG.**
- **Direct photon production : qg dominates, precision measurement of ΔG.**
  High luminosity is required.
- **Charm or Beauty via lepton : gg interaction. can reach smaller x.**

PHENIX Detector

Central arm spectrometer
(West arm + east arm)
+
Muon arm spectrometer

In the beam forward and backward
BBC (Beam-beam counters)
ZDC (Zero degree counters)

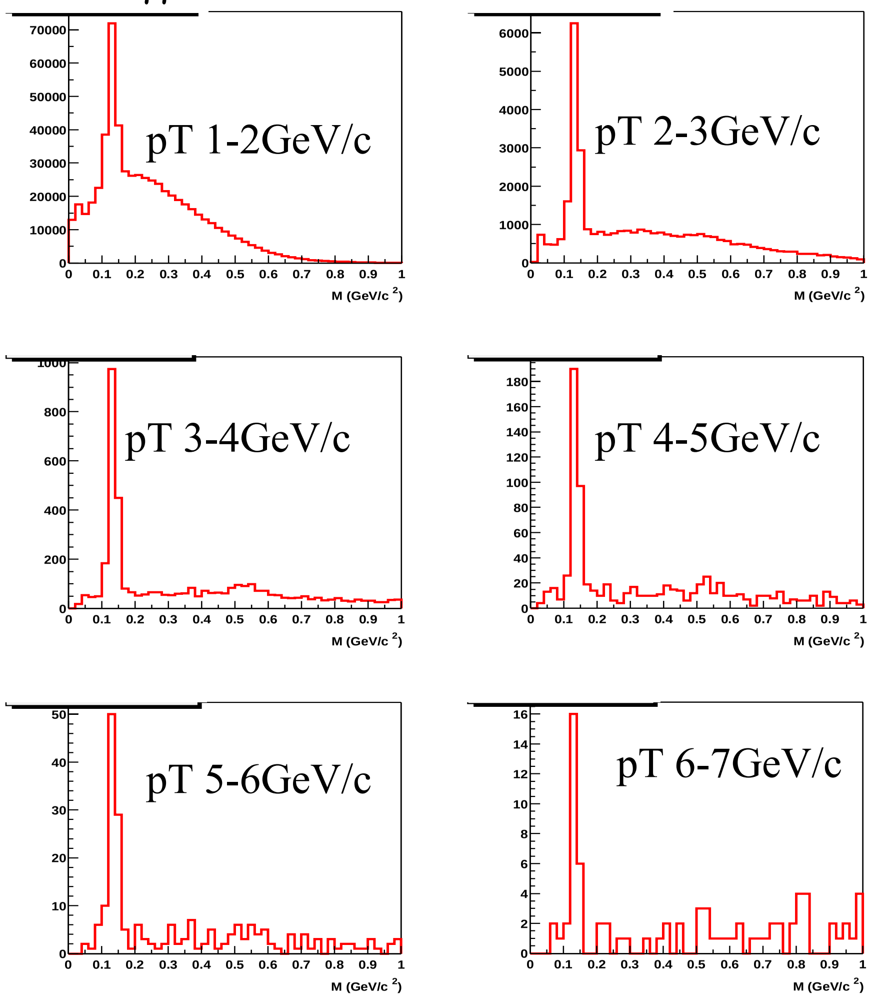
Advantages for π^0 measurement :
Fine-grained EMCal
(Electromagnetic Calorimeter)
Photon Trigger



π^0 Detection

$\pi^0 \rightarrow \gamma\gamma$

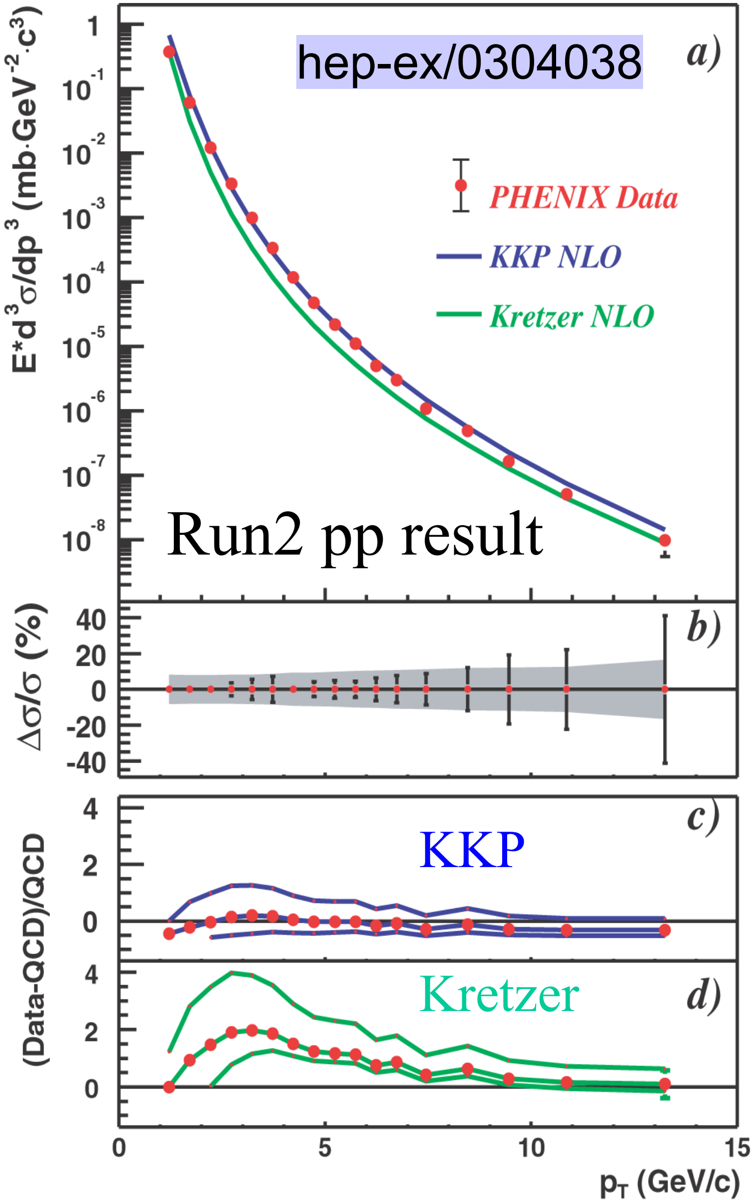
$M_{\gamma\gamma}$ distribution



Clear π^0 mass peak can be seen.

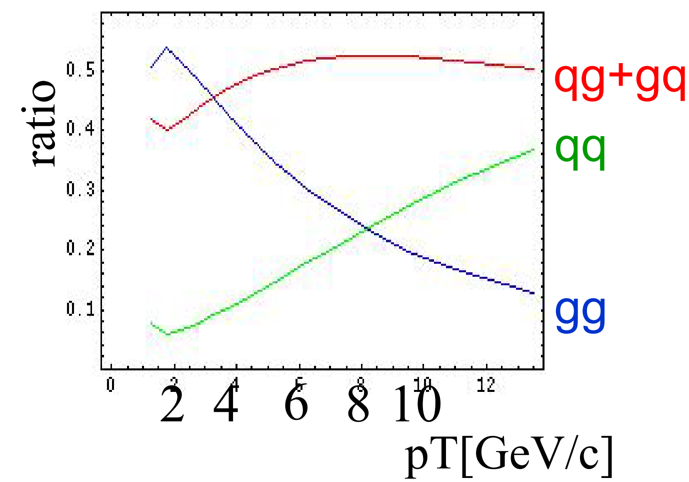
Combinatorial background contamination is smaller in higher p_T region.

π^0 cross section from Run2



We established the analysis method in Run2 (2002).

pQCD calculation agrees well with our result



qg gg contribution is dominant at pT< ~10GeV/c

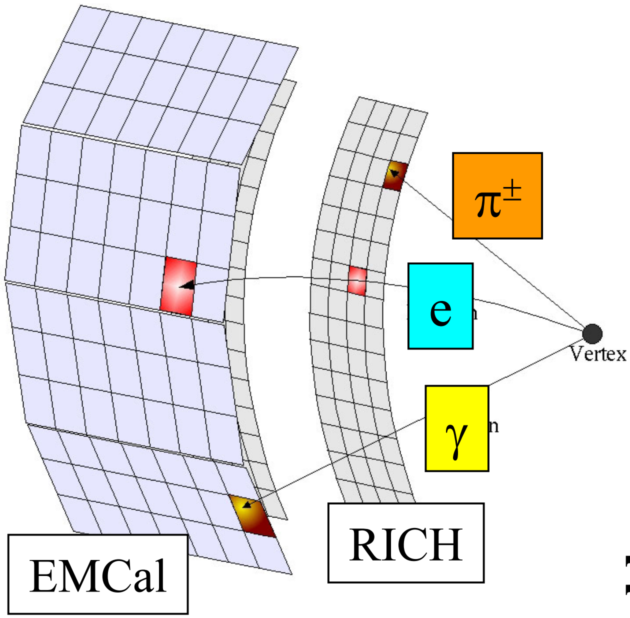
Run3 pp run (May 2003)

$\sqrt{s}$=200GeV

The first <u>longitudinally</u> polarized proton collisions

Integrated luminosity : ~350nb^{-1} from 6.6×10^{9} triggers
Average polarization : ~27%

Photon Trigger



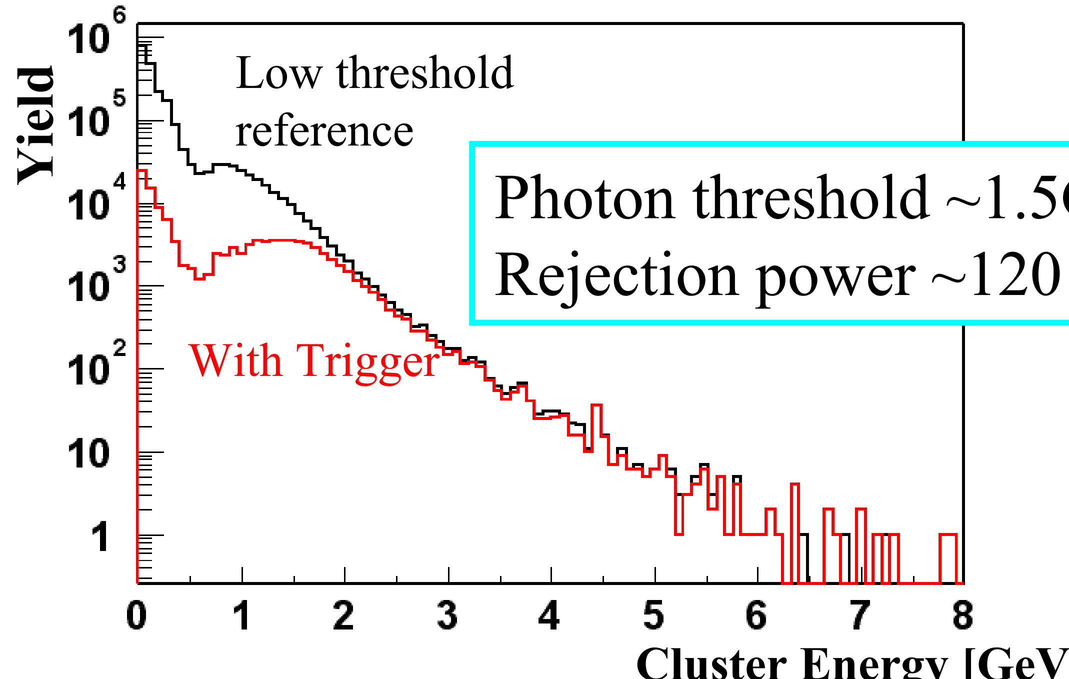
A part of EMCal-RICH trigger (for electron, photon)

Requirement ~75kHz (collision rate)

→ ~1kHz (Data acquisition rate)

Trigger for photons and electrons with the segmented EMCal and RICH.

We can set 4 EMCal trigger energy thresholds.



Photon threshold ~1.5GeV

Rejection power ~120

Sensitivity of A_{LL}

$$A_{LL} \equiv \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_1 P_2} \cdot \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}} \qquad R \equiv \frac{L_{++}}{L_{+-}}$$

There are 3 terms which determine the sensitivity

$$\delta A_{LL} = \frac{1}{P^2 \sqrt{N}}$$ **: π^0 yield**

$$\oplus \frac{\delta R}{2P^2}$$ **: relative luminosity**

$$\oplus \left(2 A_{LL} \cdot \frac{\delta P}{P} \right)$$ **: polarization measurement**

It doesn't affect the statistical significance of non-zero ΔG

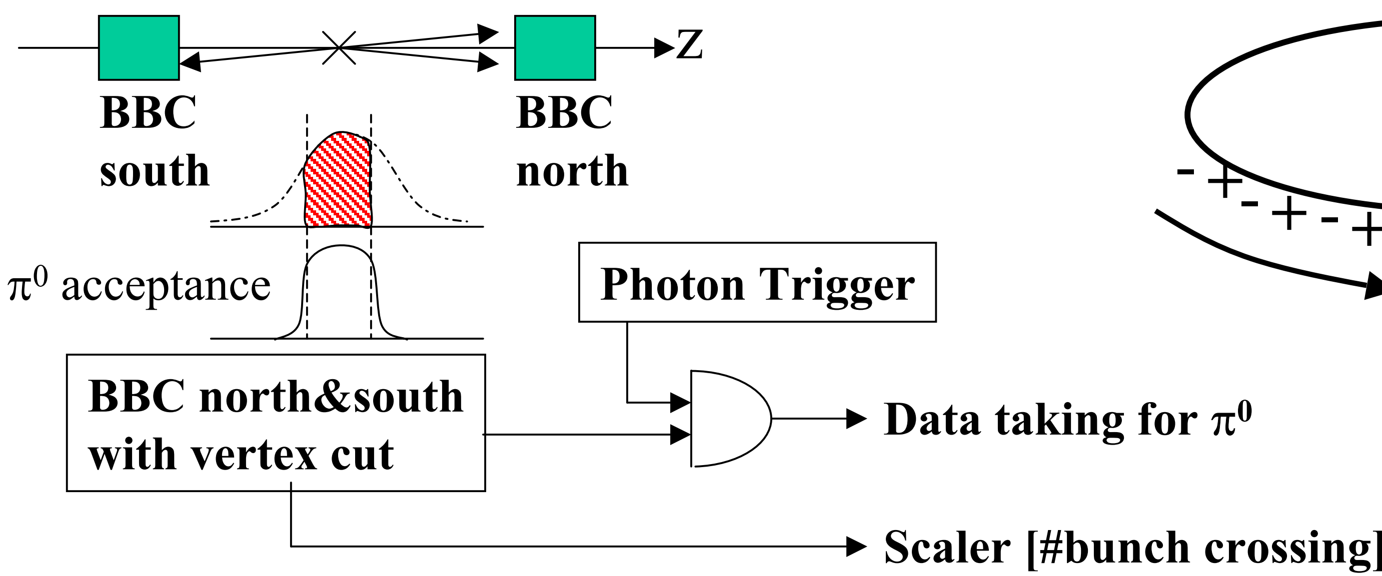
Relative Luminosity

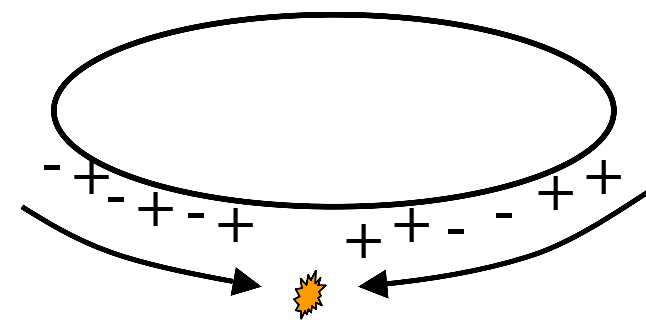
$$A_{LL} \equiv \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_1 P_2} \cdot \frac{N_{++} - R N_{+-}}{N_{++} + R N_{+-}} \qquad R \equiv \frac{L_{++}}{L_{+-}}$$

Each bunch has specific polarization sign (up to 120 bunch crossings)

Luminosity measurement is based on collision scaler value for each bunch crossing

- The vertex acceptance should be matched to the π^0 acceptance.
- Assumes collision scaler value ∝ luminosity. (no spin dependence)

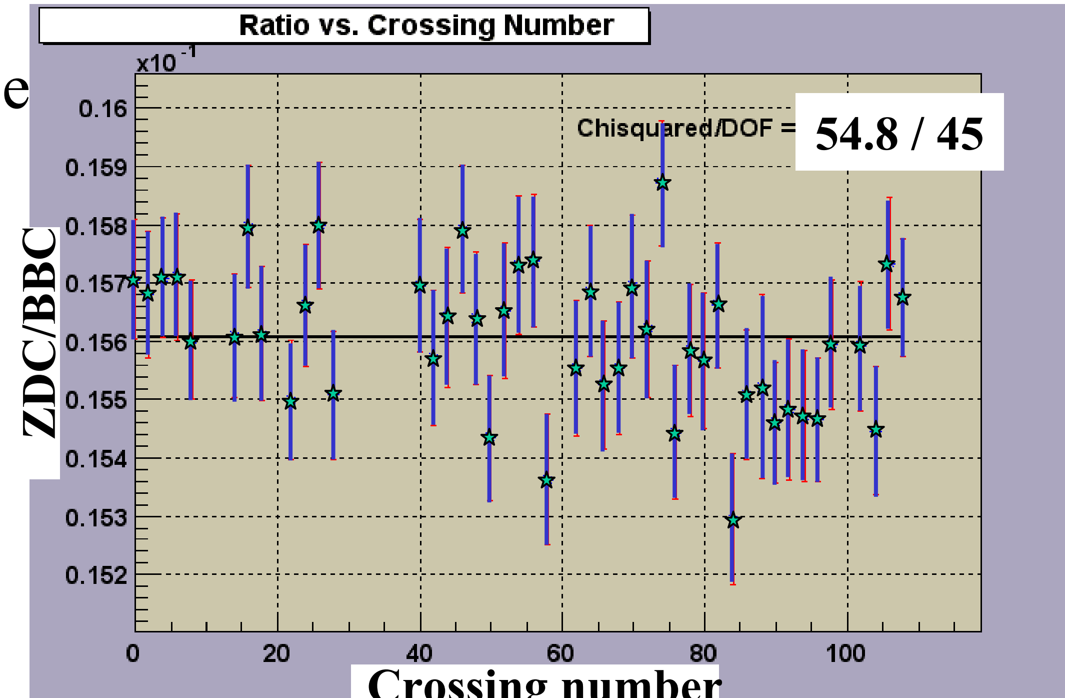




Relative Luminosity

One of the checks for the systematic error (e.g. possible spin dependence of luminosity monitors) is comparing 2 different luminosity monitors.

Different kinematical acceptance
BBC : $37 < \theta < 90$ [mrad]
ZDC : $\theta < 2$ [mrad]



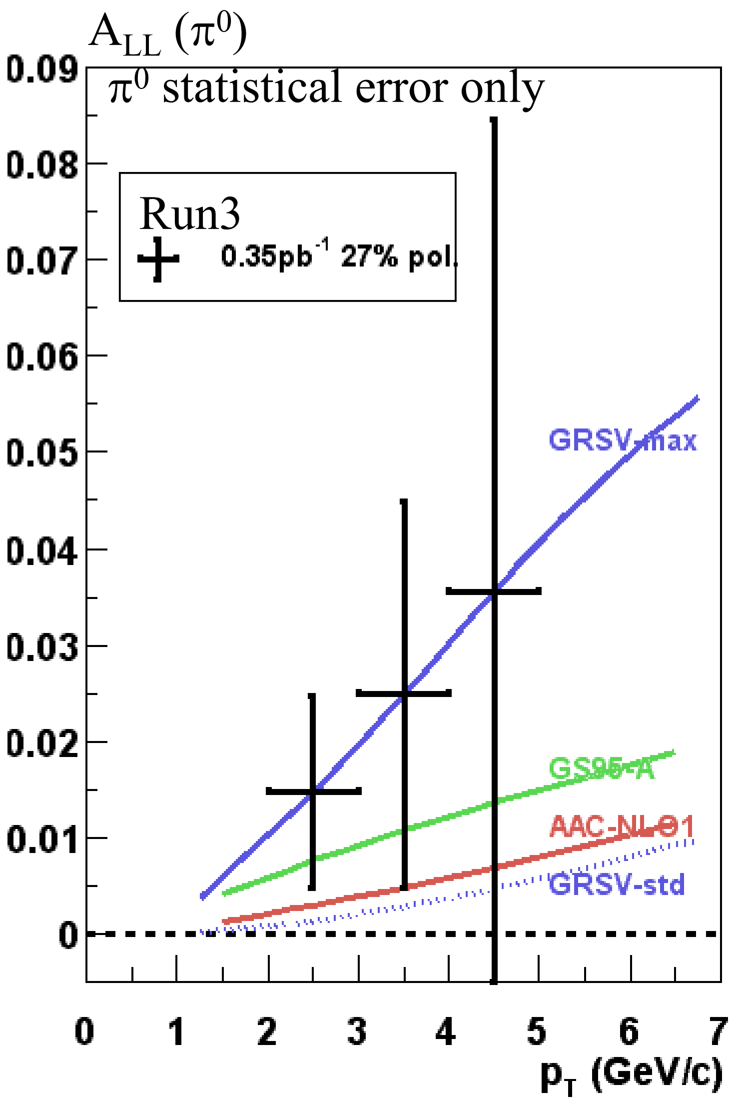
$\delta R/R < 0.06\%$
(less than 0.06%, because it's limited by run statistics, and BBC vertex cut is tuned to the π^0 acceptance.)

↓

$\delta R/2P^2 < 0.5\%$ (P=27%)

$$\delta A_{LL} = \frac{1}{P^2\sqrt{N}} \oplus \frac{\delta R}{2P^2} \oplus \left(2A_{LL} \cdot \frac{\delta P}{P}\right)$$

Projected Statistical Error of π^0 Yield



$$\delta A_{LL} = \frac{1}{P^2\sqrt{N}} \oplus \frac{\delta R}{2P^2} \oplus \left(2A_{LL} \cdot \frac{\delta P}{P} \right)$$

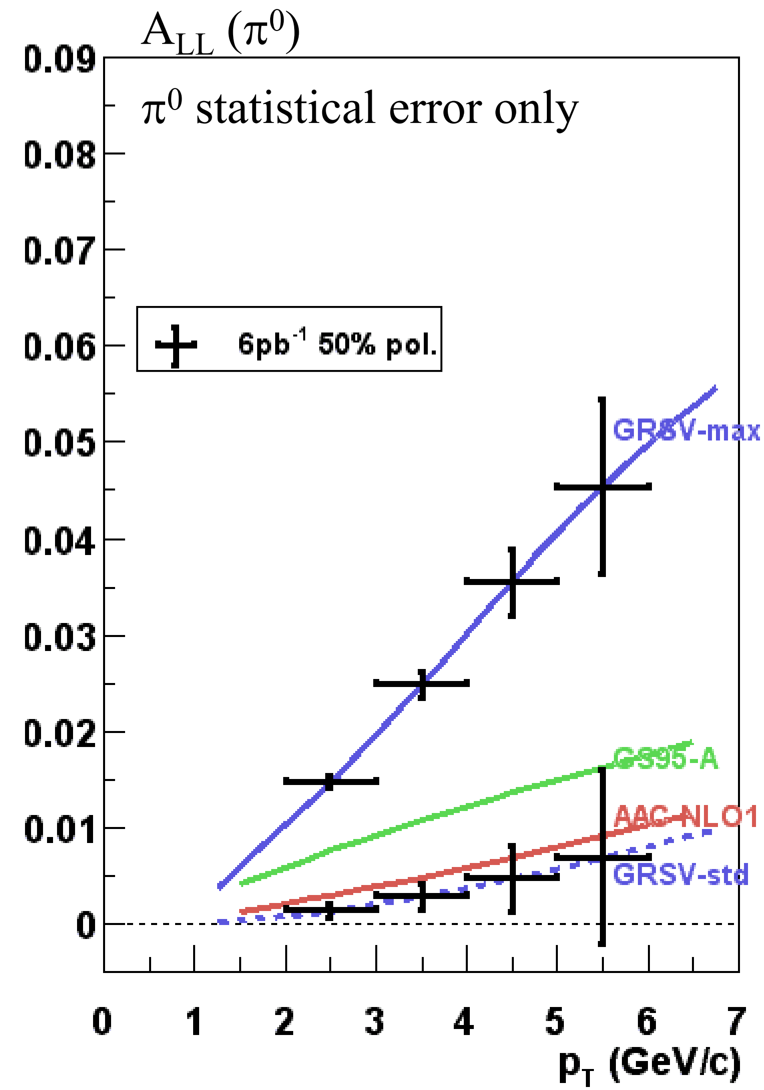
π^0 yield is calculated from Run2 result.

It is the largest uncertainty, for now.

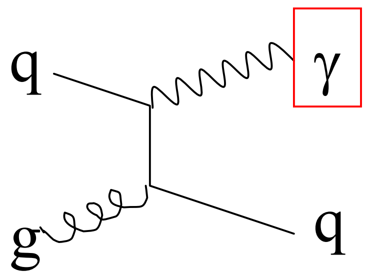
Projected A_{LL} sensitivity (RUN4 or 5)

Accelerator (AGS, RHIC) developments are going on for both luminosity and polarization.

In the next runs statistical error is expected to be 1/14 of Run3

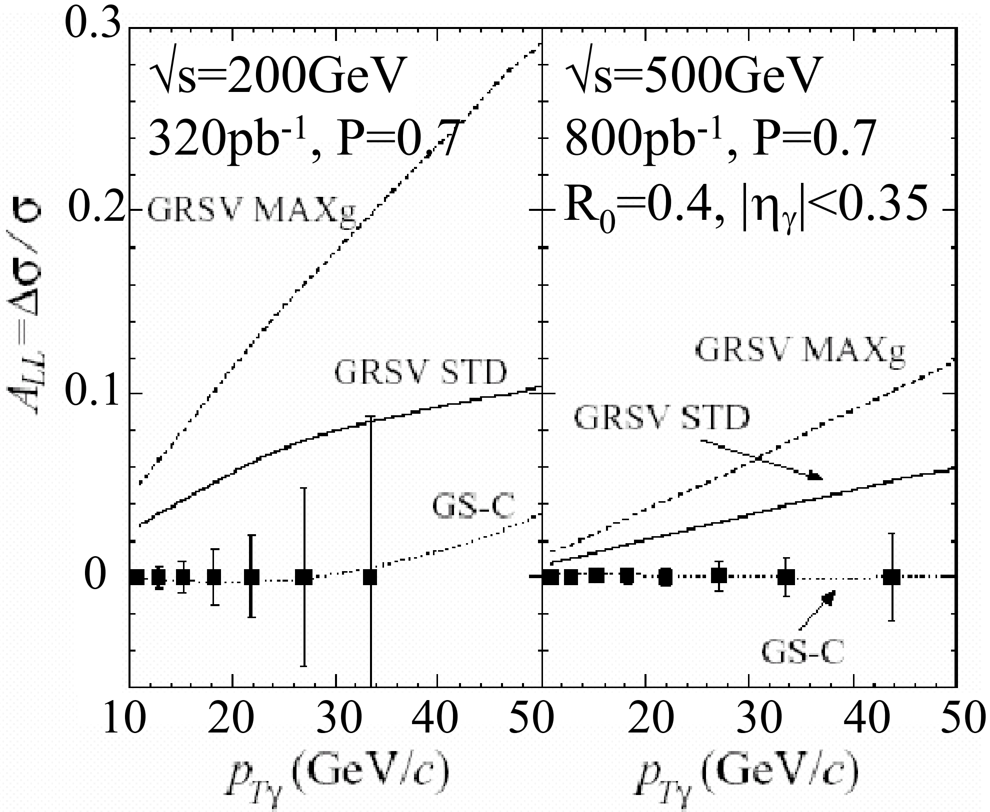


A_{LL} from Direct Photon Production



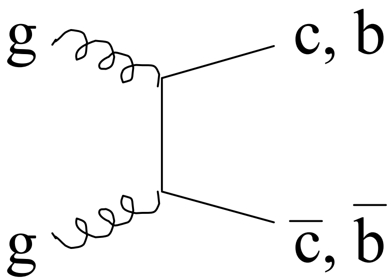
$$A_{LL} = \frac{\Delta G}{G} \cdot A_1^p \cdot \hat{a}_{LL}(gq \rightarrow \gamma q)$$

From polarized DIS experiments



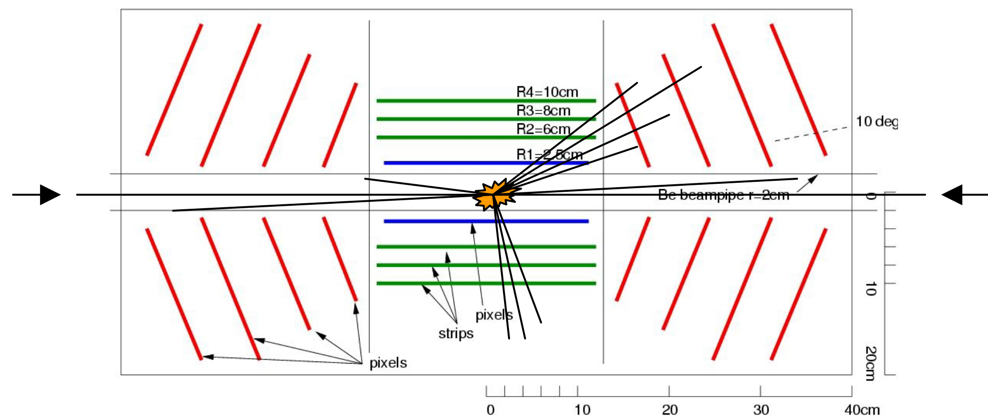
qg dominates, clean precision measurement of ΔG. High luminosity is required.

Heavy Quark Production

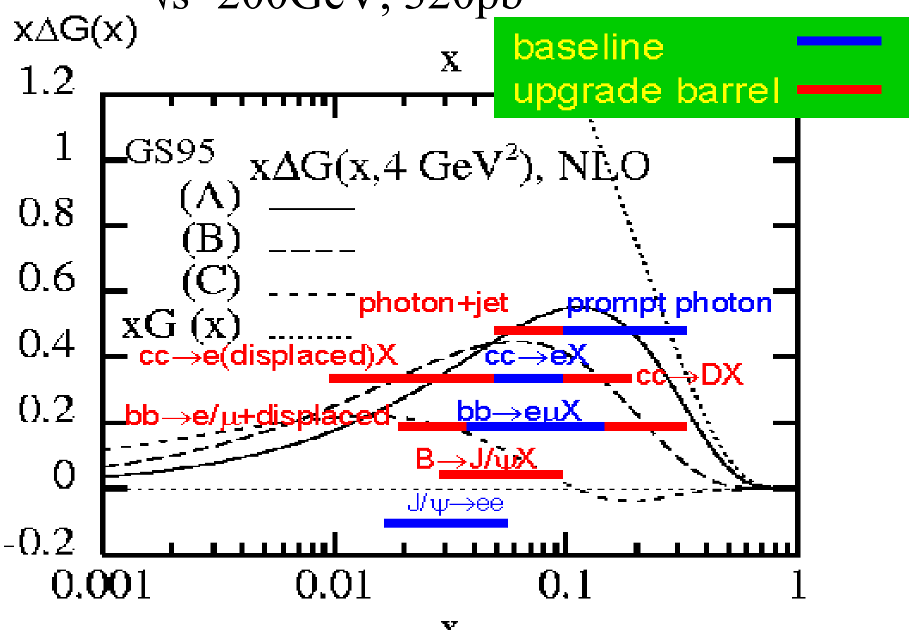


It can probe lower x region.

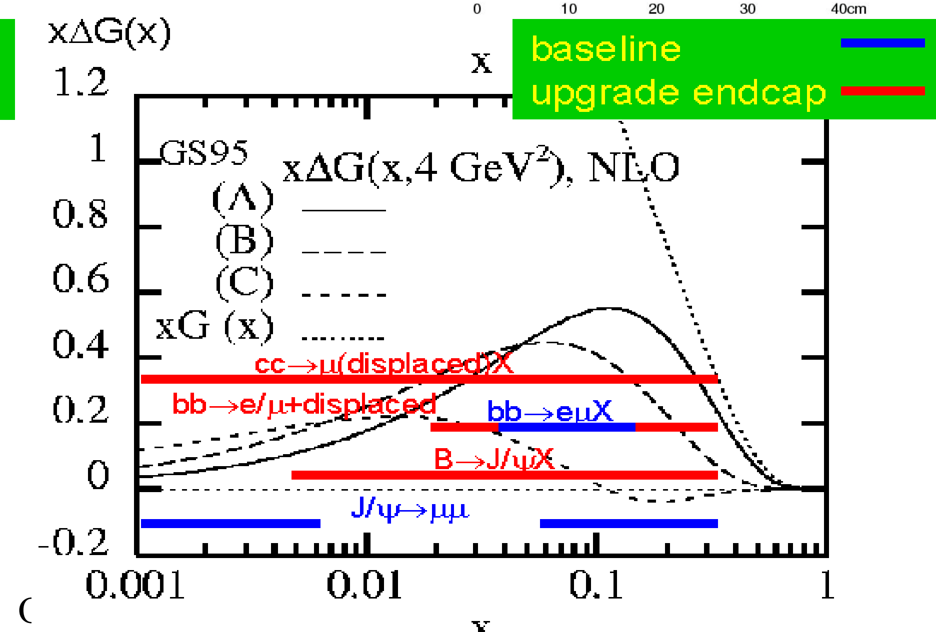
Silicon strip/pixel vertex detector is in PHENIX upgrade plan.



$\sqrt{s}$=200GeV, 320pb[-1]



Barrel



Endcap

Summary

- We took the first data of longitudinally polarized proton collisions.
- π^0 is a good probe to discover non-zero ΔG.
- PHENIX has a high granularity EMCal for good π^0 measurements.
- The first goal is A_{LL} measurement from π^0.

- The relative luminosity measurement error is confirmed to be small enough.
- The largest uncertainty is from the statistical error on the π^0 yield.

- Accelerator developments are going on to enhance both luminosity and beam polarization.
- With high luminosity and high polarization, direct photon production will be the probe for a precise measurement of ΔG.
- Access to Charm and Beauty probes is part of the detector upgrade plan.

- Run3 analysis is currently underway. PHENIX looks forward to measuring ΔG