Probing spin-structure of proton with the PHENIX Central Arm Detectors

K.Okada (RBRC)
for the PHENIX collaboration
Dubna Spin 05
September 28, 2005

Introduction

Our most familiar particle : proton
We even don't know its structure, especially for spin.

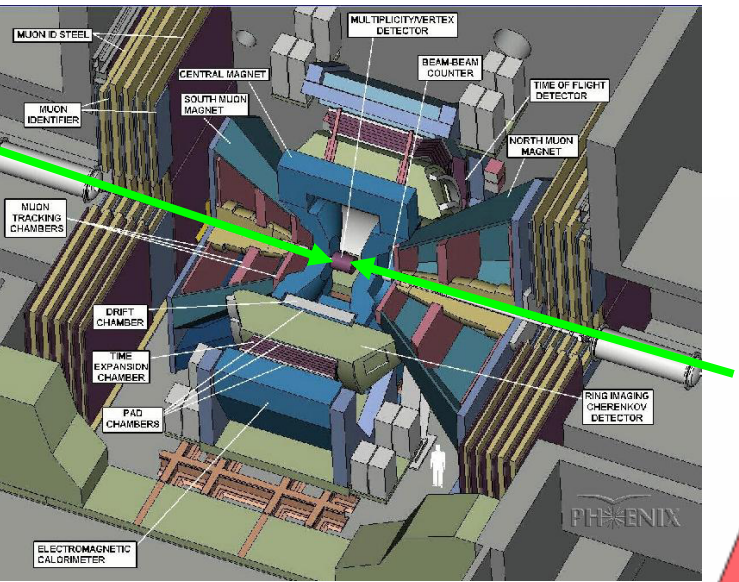
Longitudinal spin collisions
- —Gluon polarization
- —Quark flavor decomposition through Weak interactions.

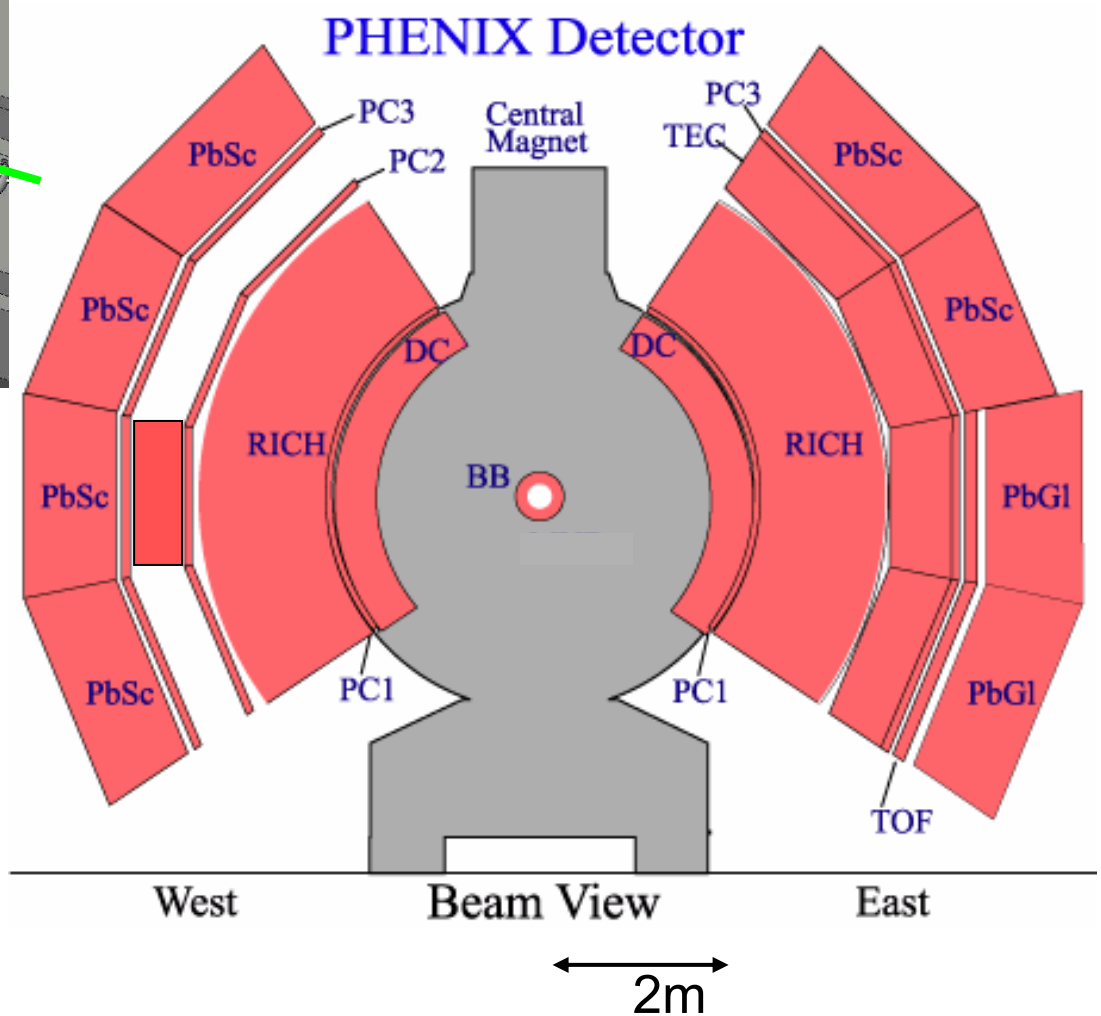
Transverse spin collisions
- —Origin of SSA in the forward region.
- —Collecting more experimental data.

At RHIC, we have an unique opportunity to access its spin information.

I will discuss the possibility with PHENIX central arm detectors.

PHENIX Central Arm



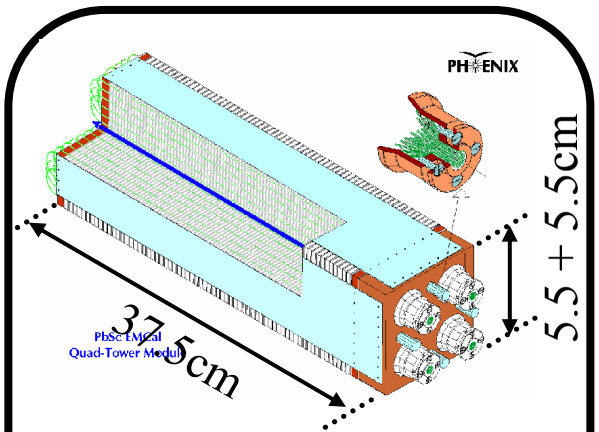


Acceptance :

η : ± 0.35

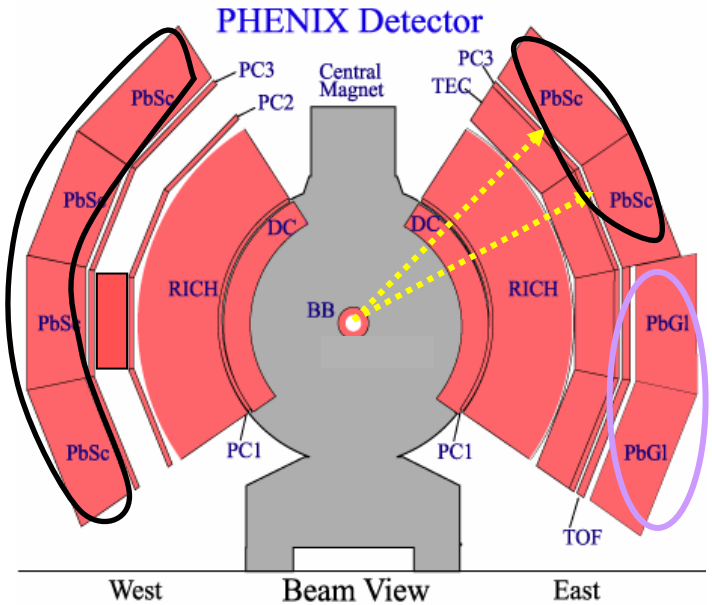
ϕ : 0.5π *2arms

Electromagnetic Calorimeter



Lead Scintillator Type

(PbSc Type)



Fine Segment ~0.01 [rad]

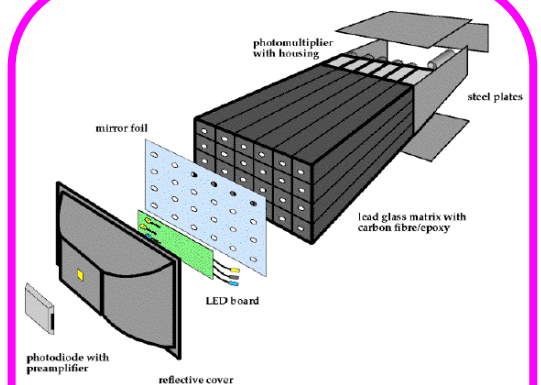
(π^0 photon separation up to ~20GeV/c)

Calibration is done by

—MIP

—Electron

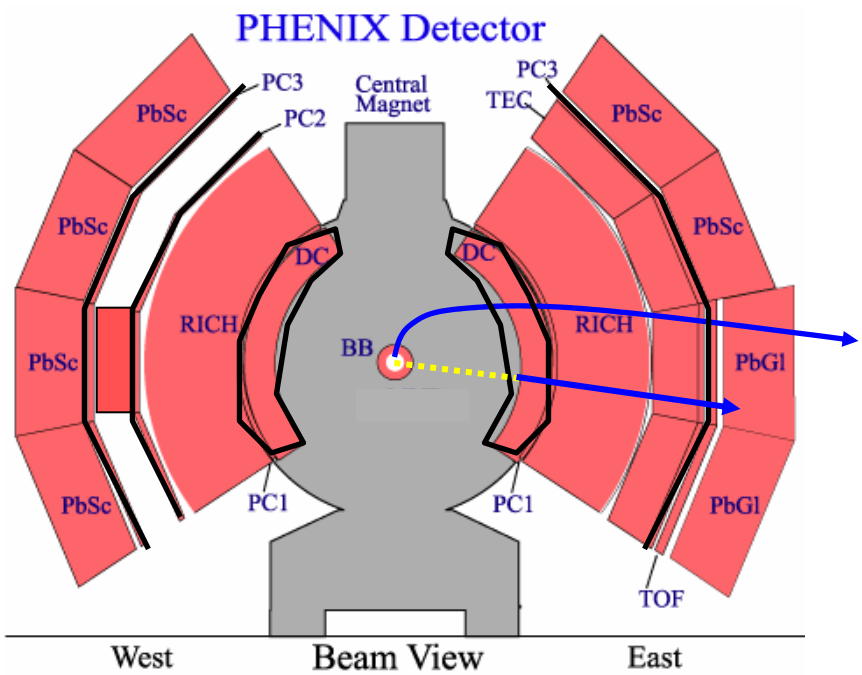
—π^0 peak position, width



Lead Glass Type

(PbGl Type)

Charged Particle Tracking



Magnetic field is inside the DC radius

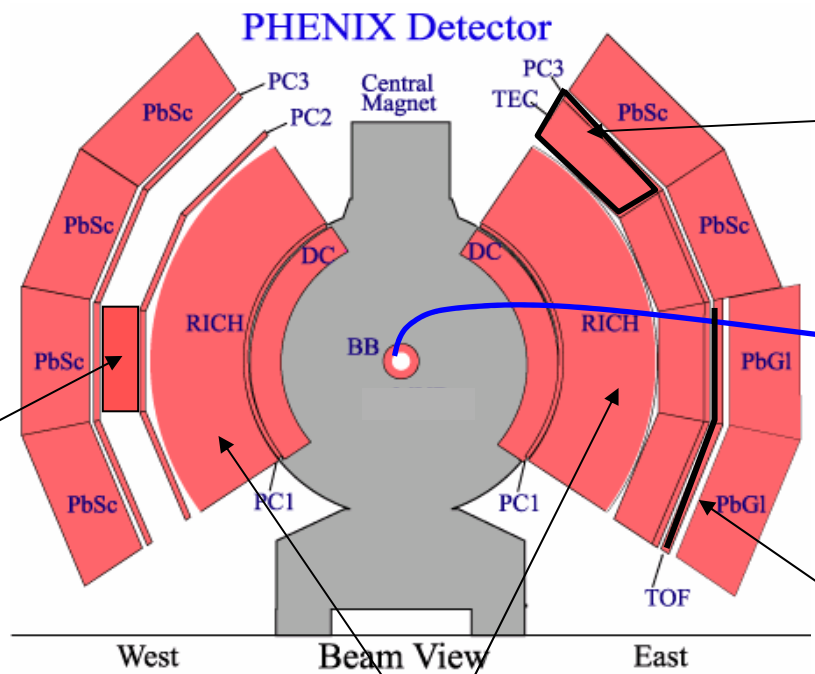
Vertex position
+ Drift chamber
+ Pad chamber

Calibration is done by

—No magnetic field run
—PID mass (TOF-Flight path length)

Fake momentum track
(e.g. conversion electron)
is one of background sources.

PID detectors



TEC/TRD

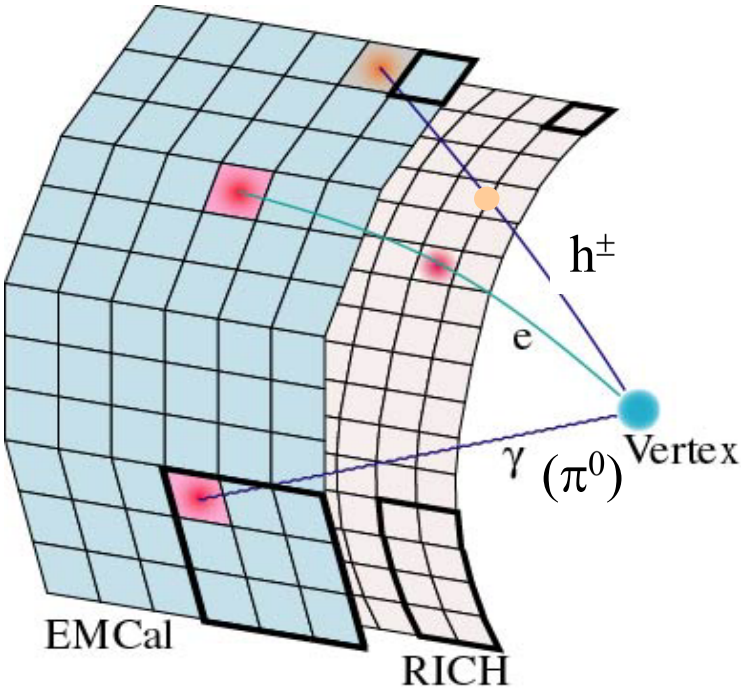
Aero gel counter

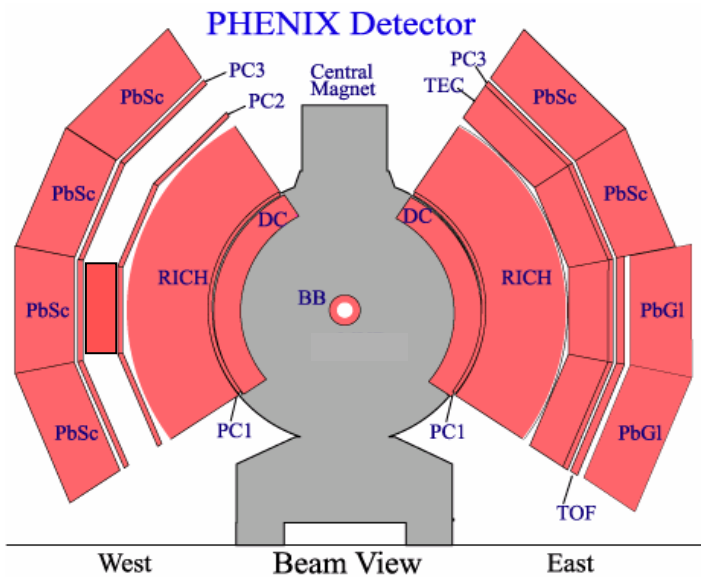
Time of Flight (TOF)

Ring Image Cherencov (RICH)

Threshold type : Aero gel, RICH, TRD
Scintillator : TOF

Trigger and Data taking



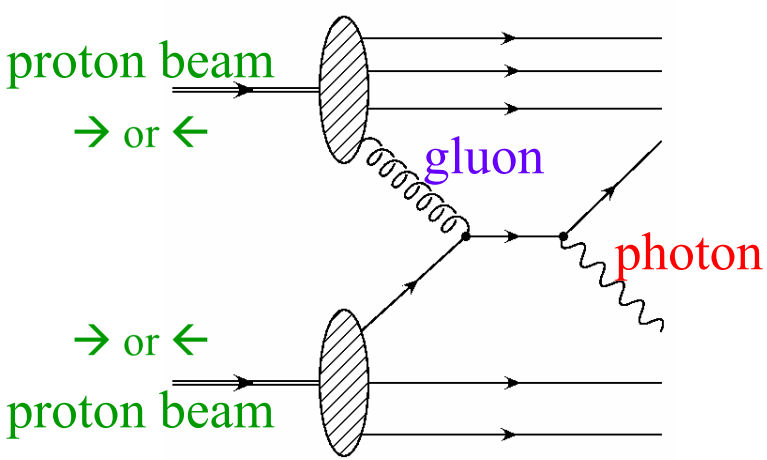


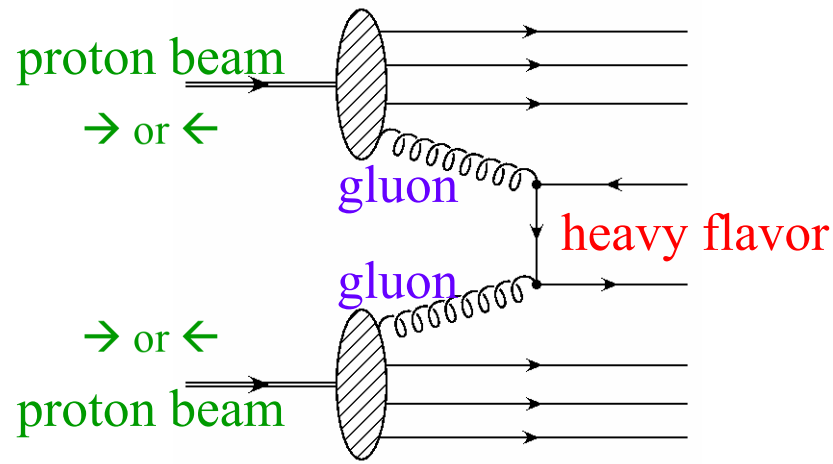
- EMCal and RICH are segmented.
  With their coincidence, “electron” trigger.
  Several EMCal cluster energy threshold

- Data taking rate of 5 kHz is achieved in 2005 p+p run.
  With the trigger, no loss of high pT physics.

Longitudinal double spin asymmetry

—Any reaction involves gluon brings information on gluon polarization





$$A_{LL} = \frac{d\sigma_{++} - d\sigma_{+-}}{d\sigma_{++} + d\sigma_{+-}}$$

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

High polarization (P) (it's squared)
High yield (N)
Precise measurement of (R)

Transverse single spin asymmetry (SSA)

SSA is observed at the forward region even at RHIC energy. (by STAR)

What mechanism explains this fact?

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

$$= \frac{1}{P} \cdot \frac{N_L^{\uparrow} - R \cdot N_L^{\downarrow}}{N_L^{\uparrow} + R \cdot N_L^{\downarrow}} \qquad R = \frac{L_{\downarrow}}{L_{\uparrow}}$$

Or

R can be omitted by using both arms.

—PHENIX central detector can provide information about mid-rapidity region.
—Two jet correlation measurements is also proposed.

Key items

Beam polarization

Relative Luminosity

What observables?
—Cross section
—2-particle correlation

Check our theoretical understandings (Cross section)

Detector upgrades

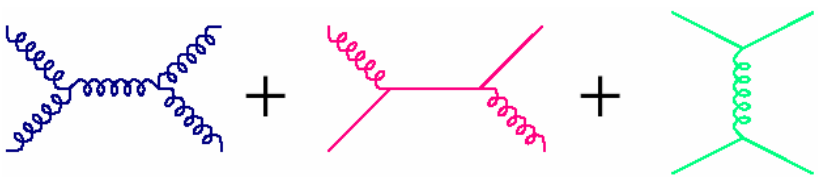
Asymmetry in cross section

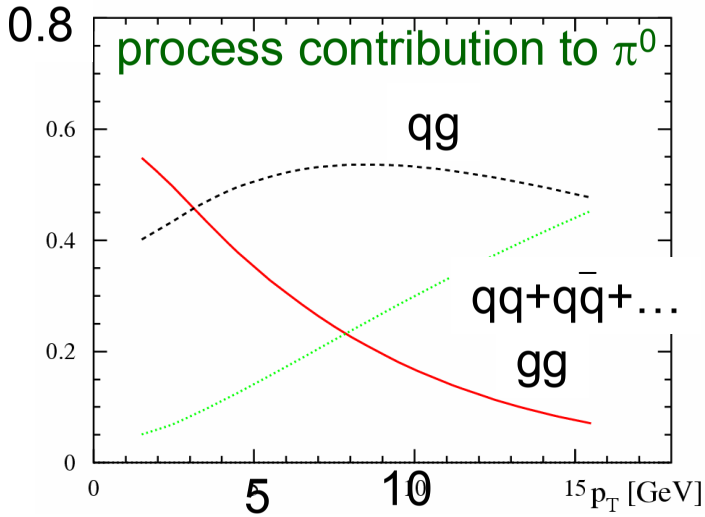
1. Physical interest :
2. Triggering (statistics) :
   —It needs to be matched to our data taking scheme.

3. Signal extraction :
   —It is not a good idea to extract signal independently in different spin configurations for the cancellation of systematic uncertainty.
   —Purity of the signal should be high.

4. Is the signal understood? :
   —The background contribution needs to be understood.
   —We need to understand the signal.

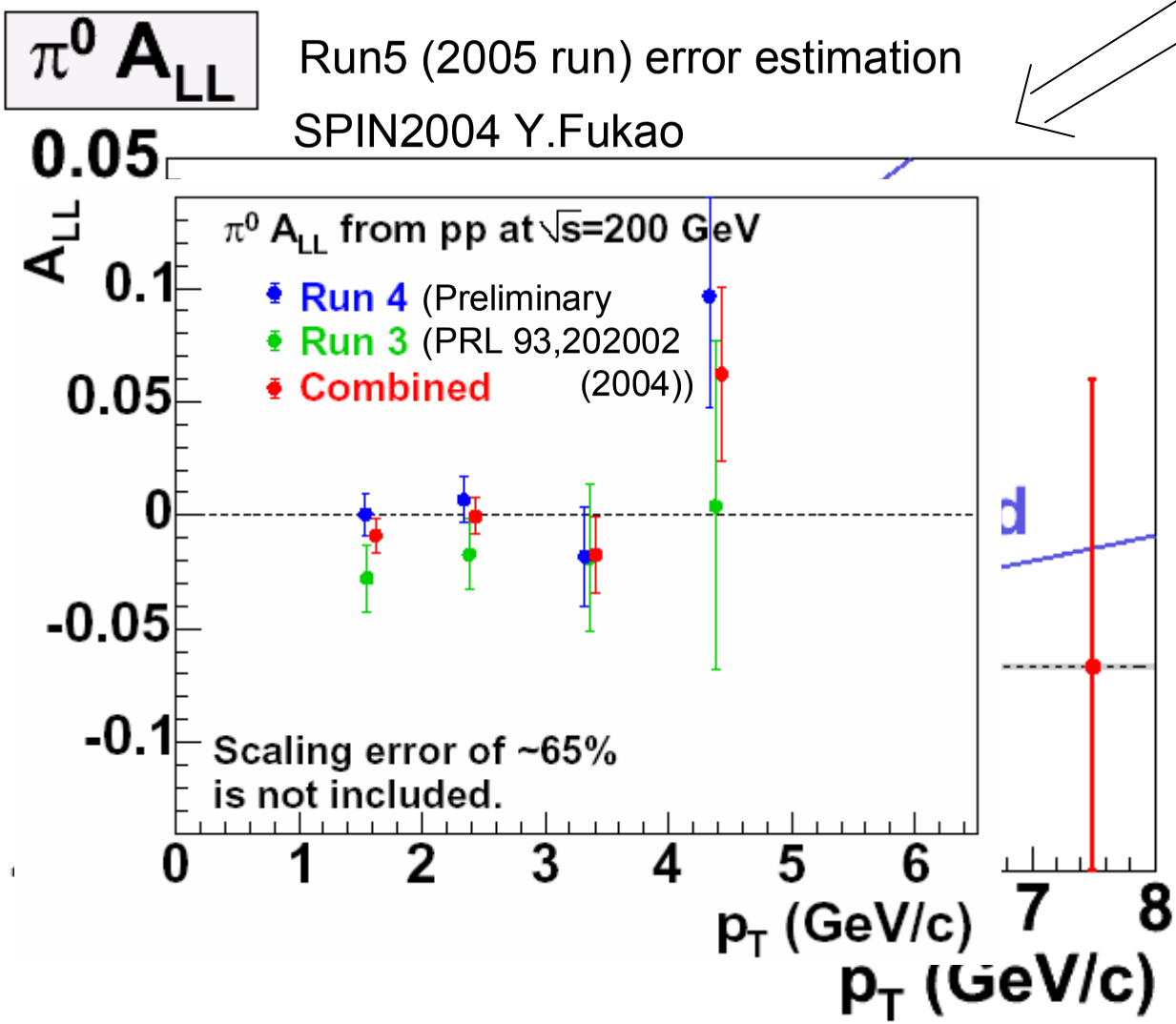
π^0 A_{LL}





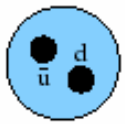
1. **Physical interest**
2. **Triggering (statistics) :**
   Favored. photons from π^0 are caught by EMCal trigger
3. **Signal extraction (purity) :**
   Count $M_{\gamma\gamma}$ pair in π^0 mass range.
   Combinatorial BG, 27%@1-2GeV/c, 8%@4-5GeV/c under the analysis condition published in 2004.
4. **Is the signal understood? :**
   NLO pQCD calculation describes our data well
   Asymmetry of combinatorial BG is estimated with the π^0 sidebands.

π^0 A_{LL}

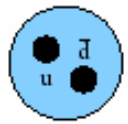

π^0 A_{LL}
Run5 (2005 run) error estimation
SPIN2004 Y.Fukao
π^0 A_{LL} from pp at $\sqrt{s}$=200 GeV
Run 4 (Preliminary
Run 3 (PRL 93,202002 (2004))
Combined
Scaling error of ~65% is not included.
A_{LL}
0.05
0.1
0.05
0
-0.05
-0.1
0
1
2
3
4
5
6
7
8
p_T (GeV/c)
p_T (GeV/c)

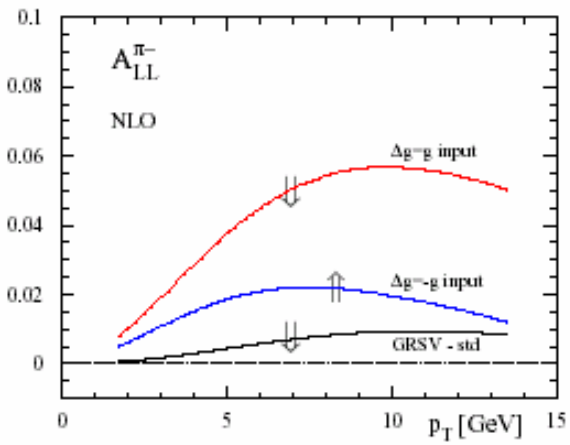
Charged π's

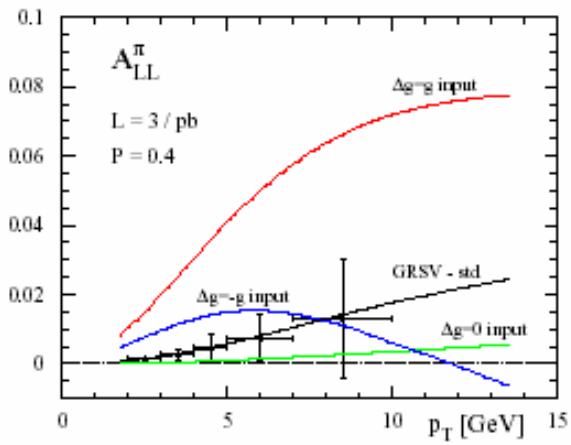
1. Physical interest

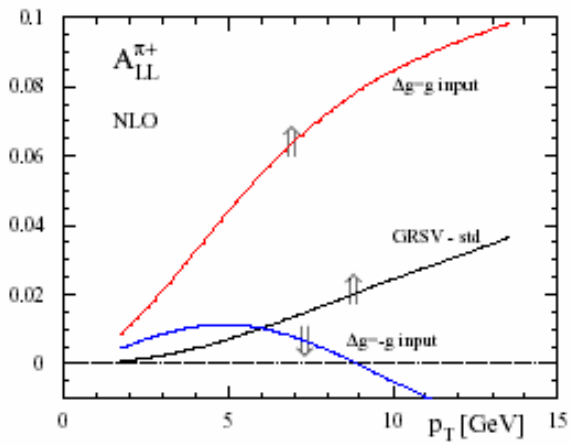
π^- 

π^0

π^+ 







idea: qg starts to dominate for $p_T \gtrsim 5\,\mathrm{GeV}$ and $D_u^{\pi^+} > D_u^{\pi^0} > D_u^{\pi^-}$, $D_g^{\pi^+} = D_g^{\pi^-}$

expect: sensitivity to sign of Δg, e.g., positive Δg: $A_{LL}^{\pi^+} > A_{LL}^{\pi^0} > A_{LL}^{\pi^-}$

From lecture slide by Marco Stratmann
At 1st Summer School on QCD Spin Physics (RBRC)

Charged π's

2. Triggering (statistics) :

"electron" trigger (Cherencov (RICH) threshold for $\pi^{\pm}$ is p>4.7GeV/c)

3. Signal extraction (purity) :

Needs to apply EMCal energy cut to reject backgrounds. (ε~50%)

4. Is the signal understood? :

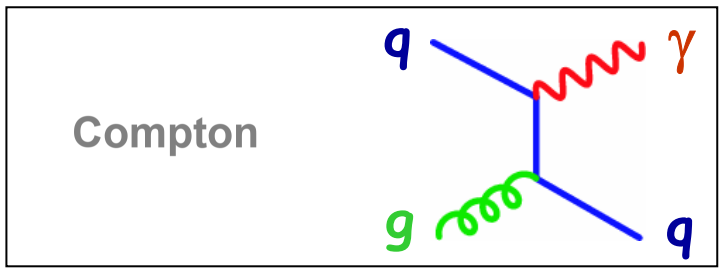
We need to prove the signal is really $\pi^{\pm}$. (efficiency study)

Since the target p_T range is more than 5GeV/*c*, statistics is limited currently.
But we can study the signal purity.

How about direct photon A_{LL}?

1. Physical interest

QCD Compton process is dominant.
A golden channel for the measurement of gluon polarization.



How about direct photon A_{LL}?

2. Triggering (statistics) :

Favored. photons are caught by EMCal trigger

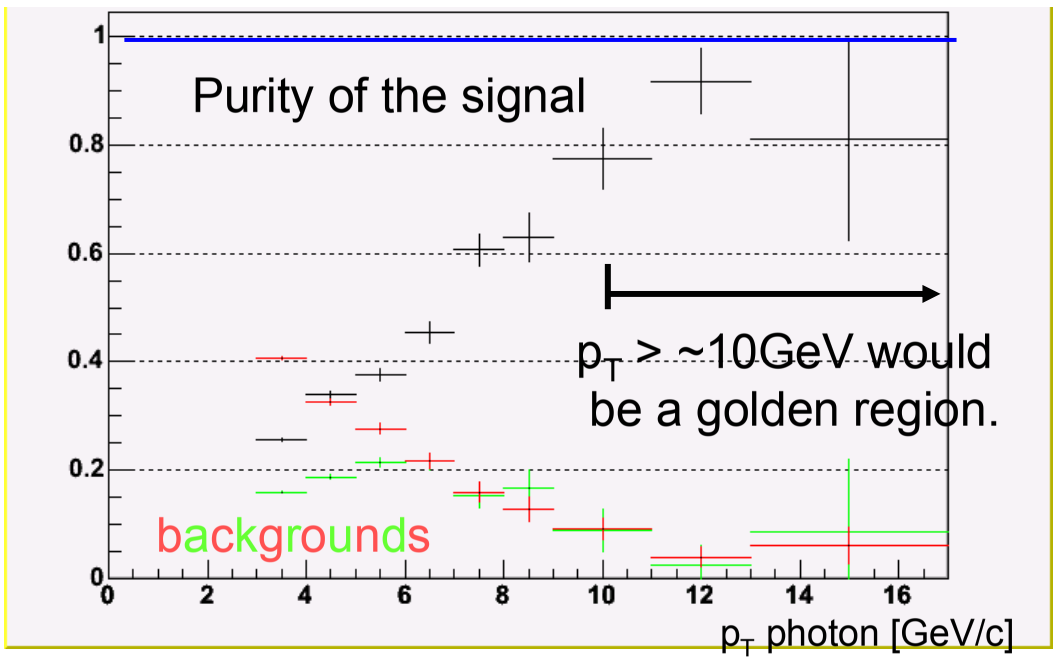
3. Signal extraction (purity) :

By applying the isolation cut, ~90% of all photon is the direct photon (see the plot)

4. Is the signal understood? :

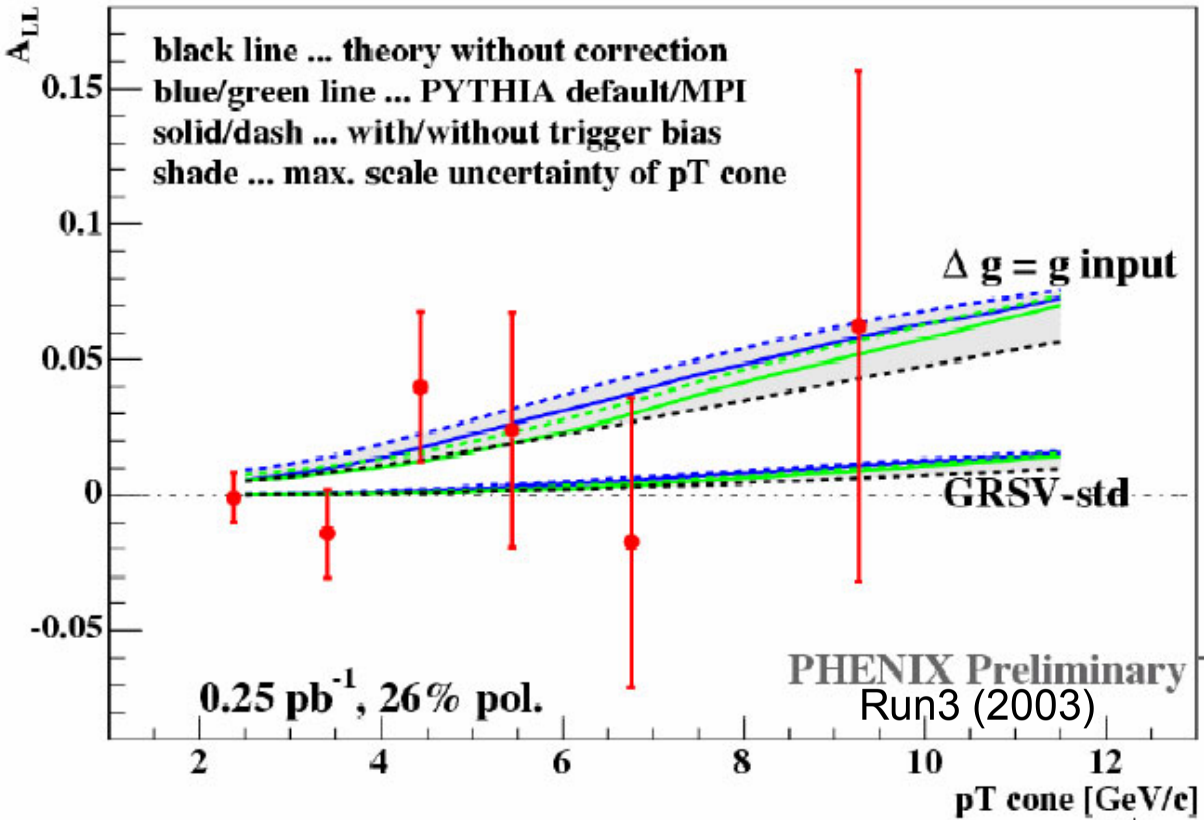
NLO pQCD agrees well to the cross section measurement

We need to study about asymmetries of background photon (mainly from π^0 decay).

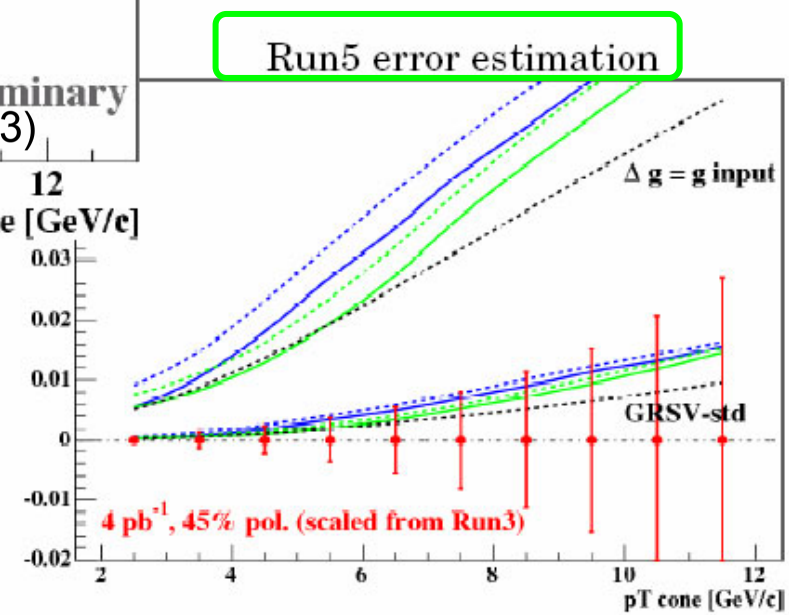


More luminosity, polarization!!

Jet A_{LL}

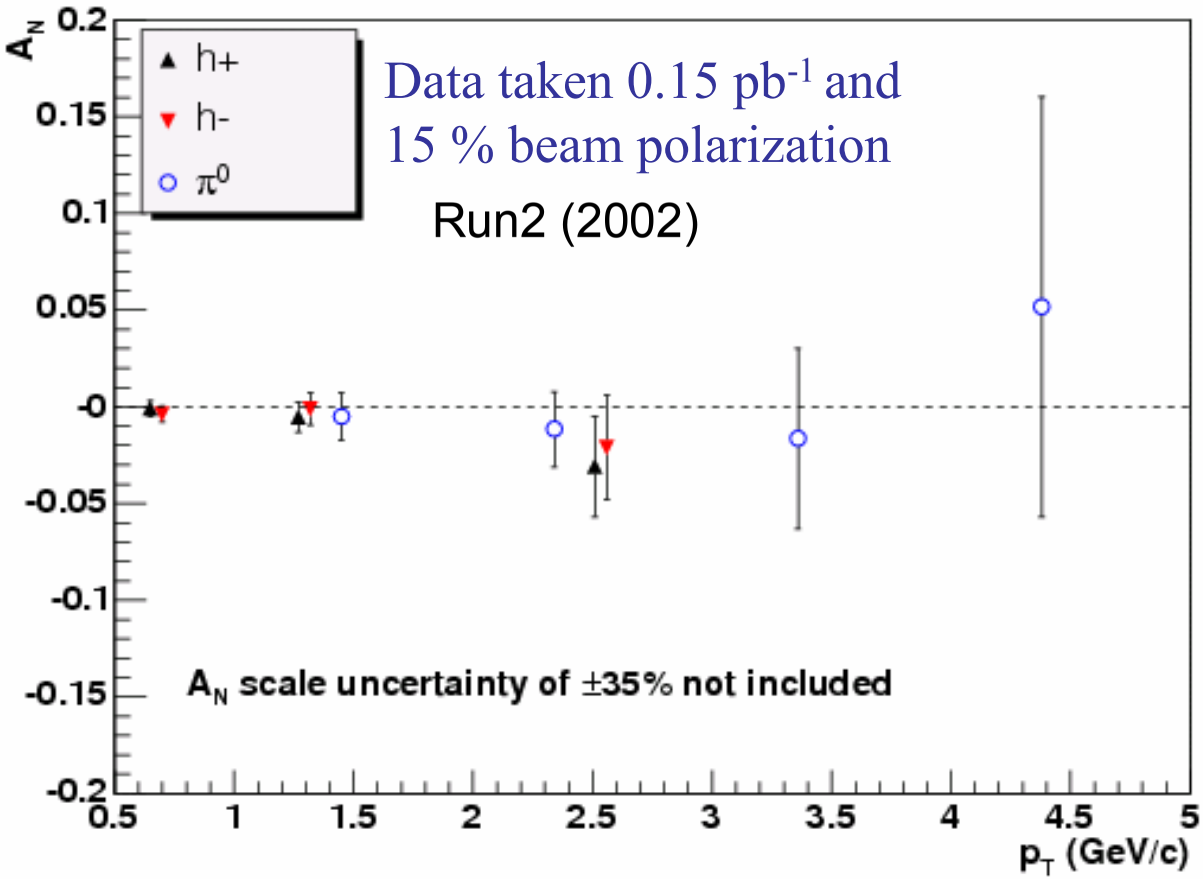


The motivation is similar to π^0's



- A_{LL} of jet-like cluster
  - even with a limited acceptance in PHENIX central arm, we can capture most of a jet
    - tag one photon, sum all observed energy/momentum in a cone

A_N in Mid-rapidity



hep-ex/0507073,
accepted by PRL a week ago

A_N for both charged hadrons and neutral pions consistent with zero at midrapidity.

In Run5 (2005 run),
almost same luminosity,
three times more polarization

Asymmetry in 2-particle correlations

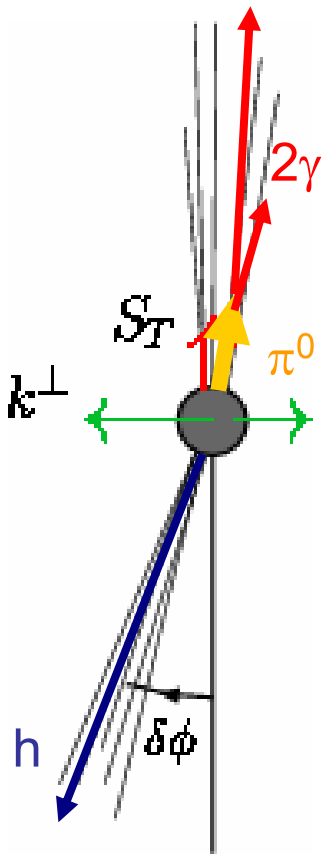
In PHENIX, 2-particle correlation is used as a representative of Jet correlation.

- **With transverse single spin asymmetry**
  $\rightarrow$ access to Sivers function

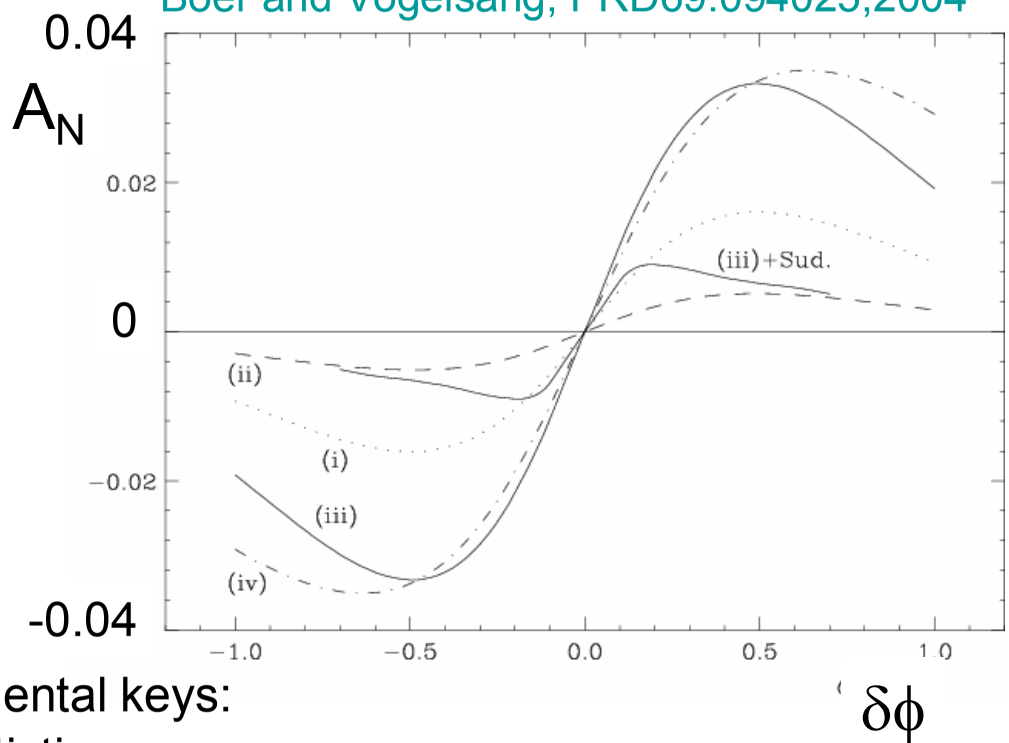
- **With longitudinal double spin asymmetry**
  $\rightarrow$ access to the orbital moment
  (it needs theoretical supports!)

A_N of Jet k_T

A probe to access to Sivers functions (=left/right asymmetry in the k_T of the partons).
Some possibilities in Run5 with the residual radial polarization component (?).
One of the topics in the future with radial polarized beam.



Boer and Vogelsang, PRD69:094025,2004



Experimental keys:
- —Statistics
- —Beam polarization
- —Smearing due to di-hadron analysis (instead of di-jet)

Main topic in Run6 ?

Summary

- With Run5 data
  - —Get non-zero gluon polarization from π^0/Jet.
  - —Extend p_T range of direct photon.
  - —A_{LL} of η, J/ψ is under analysis.
  - —The spin transfer to Λ^0 is another topic.
  - —Even with a short transverse period, precision of π^0,$h^{\pm}$ A_N is better than the published result.
- Future prospects
  - —Charged pion A_{LL} for the sign of gluon polarization
  - —Direct photon A_{LL} (Year 2008 run?)
  - —Measurement of Sivers function with 2-particle correlation with transverse spin run.

With silicon vertex detector upgrade

- —Determination of the kinematics
- —Open charm detection (related to gluon fusion process)