

PHENIX Run5pp Analysis

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for the PHENIX collaboration

In this talk

We'd like the workshop to be a "brainstorming" session regarding getting as much physics as possible out of the Run-05 dataset.

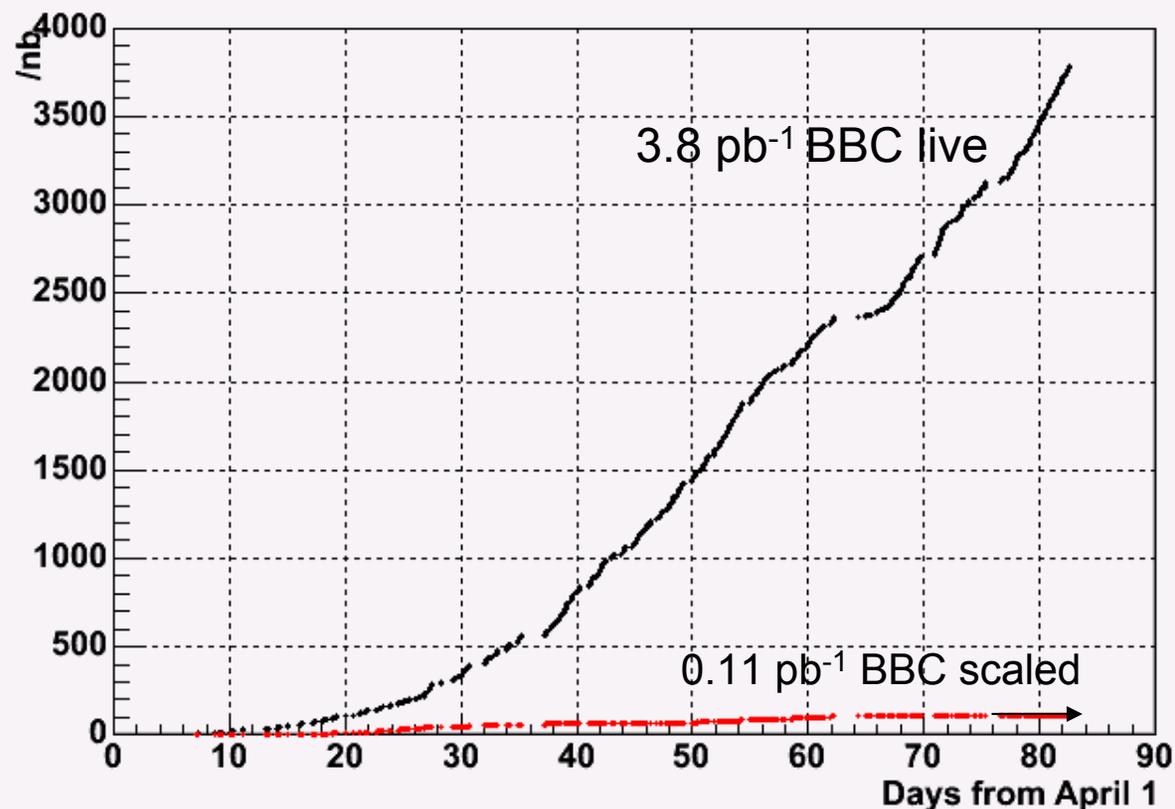
By the organizer

I will give a short sketch of PHENIX analysis with Run5 proton+proton data discussed in Spin physics working group.

----- luminosity and triggers -----

Recorded luminosity

#(BBC live)/22mb



Estimated using #BBC live triggers with $\sigma_{\text{BBC}}=22\text{mb}$

Longitudinal pol : $\sim 4\text{pb}^{-1}$
Transverse pol : 0.16pb^{-1}
With $\sim 50\%$ pol

Run3: $0.22 [\text{pb}^{-1}]$, 27% pol

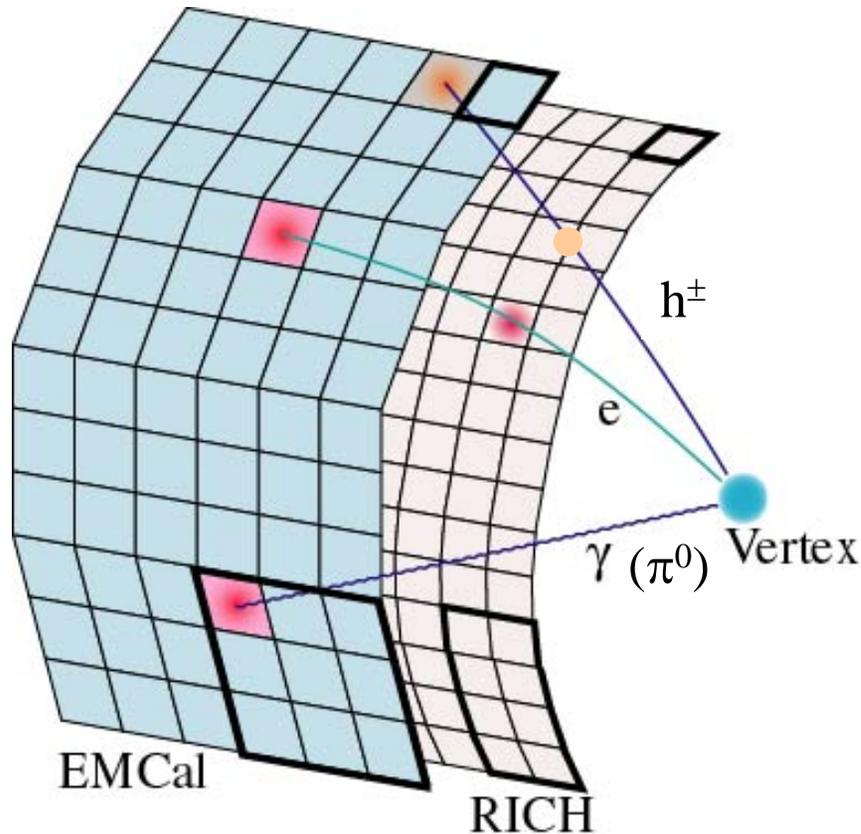
Triggers:

Photon
Electron
Muon

Min bias (pre-scaled)

Central arm trigger

Central arm $|\eta| < 0.35$, $2x(\phi = \pi/2)$



—“Photon” trigger

for π^0 , η , direct photon, Jet, etc

4x4c with BBC threshold $\sim 1.4\text{GeV}$

4x4b without BBC threshold $\sim 2.8\text{GeV}$

—“Electron” trigger

for J/psi, open charm, high $p_T \pi^\pm$

with RICH hit threshold $\sim 0.6\text{GeV}$

(for electron)

Muon arm trigger

Muon arms $|\eta|=(1.2-2.4)$, $\phi=2\pi$
 $E_{\min}\sim 2\text{GeV}$

An example from run control log. (A run with BBCLL1 rate = 60kHz)

	Trigger_name						Rate[Hz]	
○	MUIDLL1_N1D&BBCLL1	0x00004000	0	Enabled	758384	725584	725584	218.09
○	MUIDLL1_S1D&BBCLL1	0x00008000	0	Enabled	419730	402084	402084	120.85
	MUIDLL1_N1S&BBCLL1	0x00010000	9999999	Enabled	3102371	2982082	0	0.00
	MUIDLL1_S1S&BBCLL1	0x00020000	9999999	Enabled	2440916	2347487	0	0.00
●	MUIDLL1_N1D1S&BBCLL1	0x00040000	0	Enabled	64833	61754	61754	18.56
●	MUIDLL1_S1D1S&BBCLL1	0x00080000	0	Enabled	14125	13424	13424	4.03

○ Single muon trigger

● Dimuon trigger : J/psi

----- Local polarimetry -----

Which direction does the polarization align?

For the double longitudinal spin asymmetry analysis

$$A_{LL} = \frac{1}{P_B \cdot P_Y} \cdot \frac{N_{++} - N_{+-} R}{N_{++} + N_{+-} R} \quad \text{R: relative luminosity}$$

$$\delta A_{LL} = \frac{1}{P^2} \cdot \frac{1}{\sqrt{N}} + (\text{dilution effect}) + (\text{error of R})$$

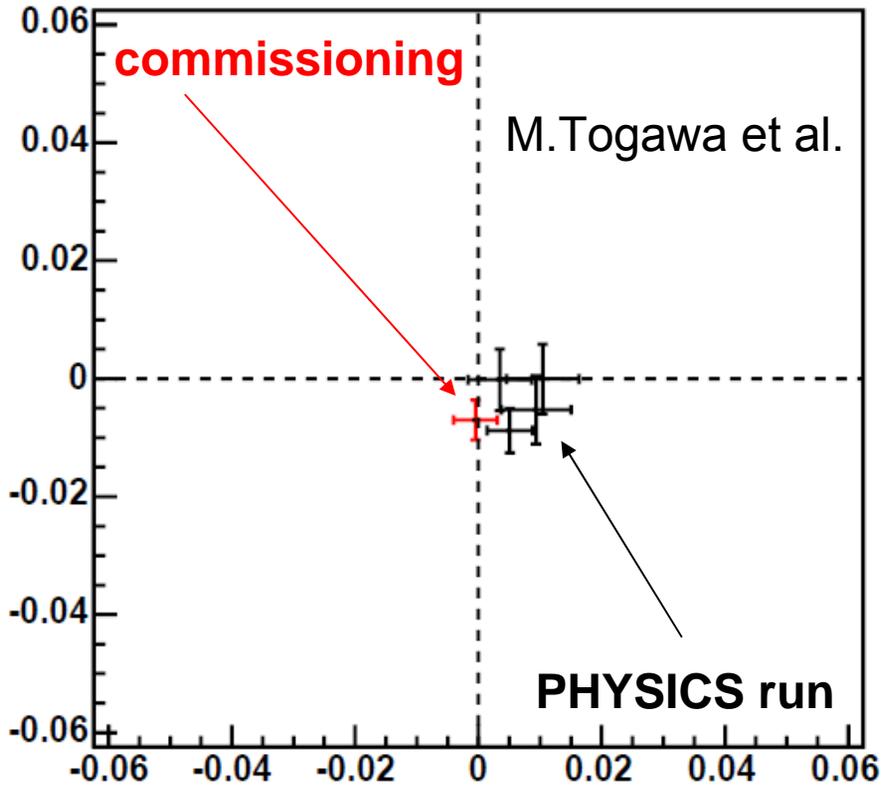
Dilution effect

- Random background
- Contamination of other physics
- A_{TT} component through remaining transverse polarization

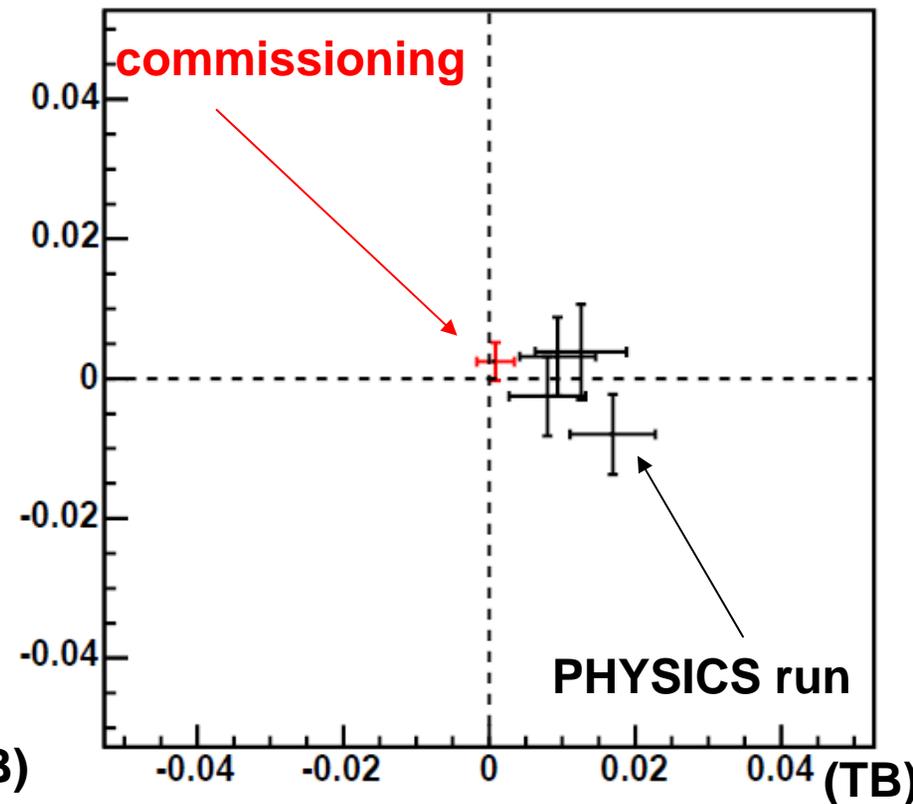
The forward neutron left-right asymmetry was used to measure the transverse polarization component.

Transverse component (200GeV)

(LR) **BLUE** ($A_N = 6.24\%$)



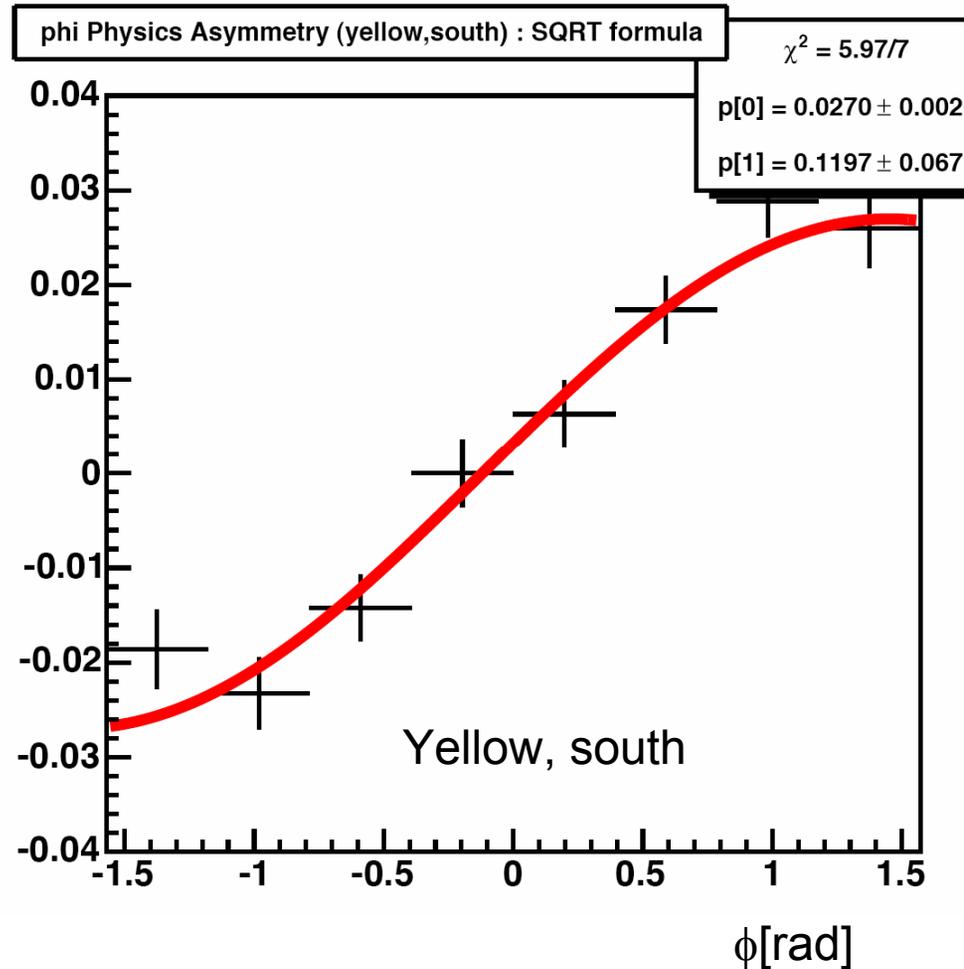
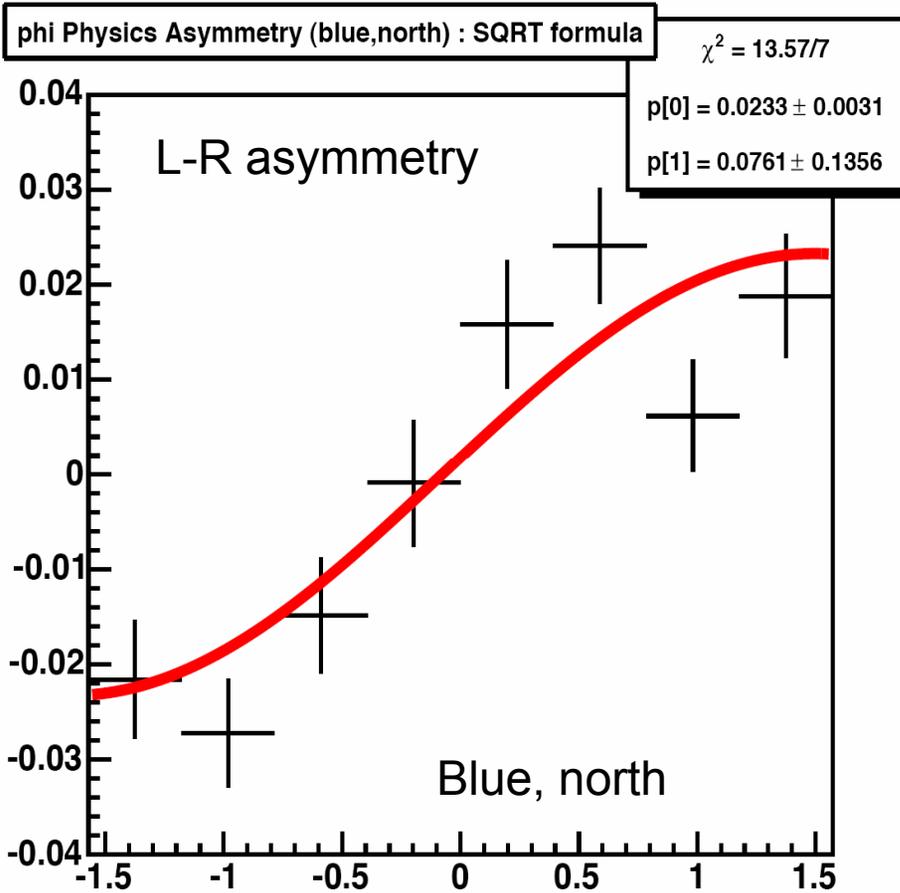
(LR) **YELLOW** ($A_N = 5.27\%$)



- Commissioning period
- ~250Hz in physics run

There is a little (10-20% fraction of total spin) transverse components remained

Forward Neutron Asymmetry Persists at $\sqrt{s}=410$ GeV



We can use it in the future as a tool.
Physics of the forward neutron asymmetry.

----- Luminosity Measurement -----

(Absolute and Relative)

Absolute luminosity

For cross section measurements,

Vernier scans

In Run5, we took at least 10 scans including an angle scan.
(We had only a couple of them in the past runs.)

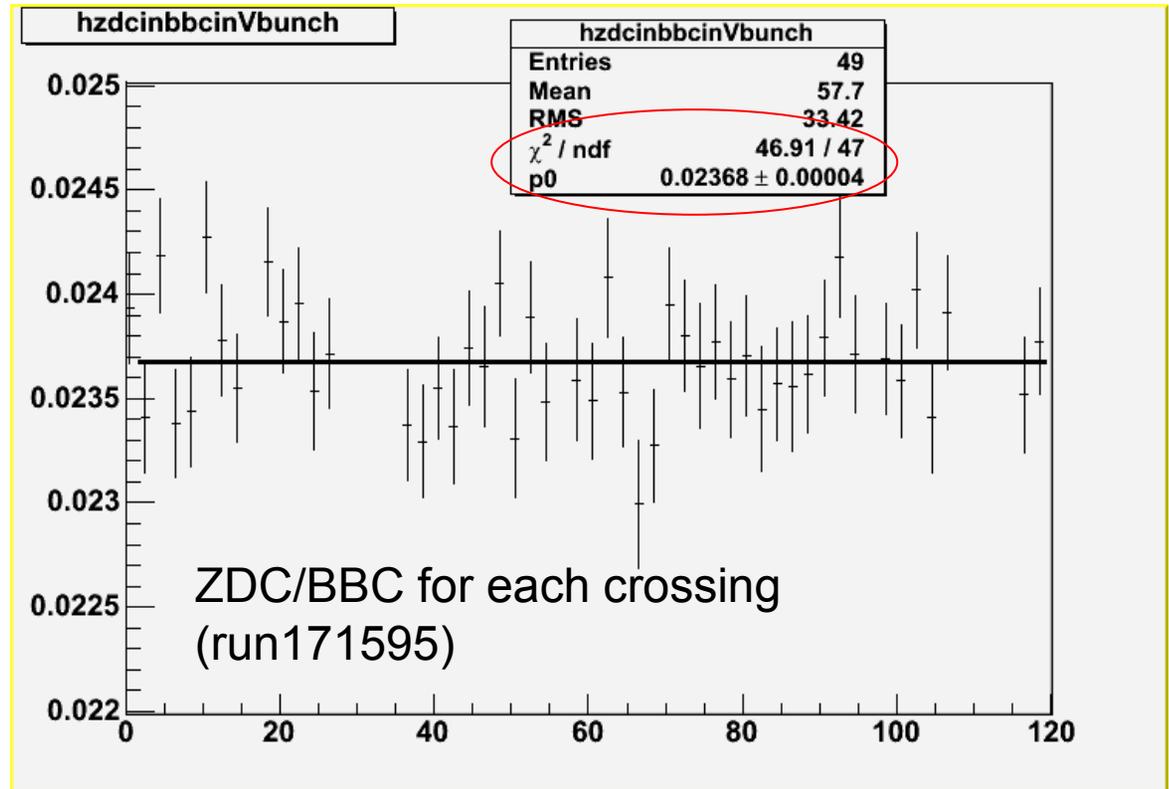
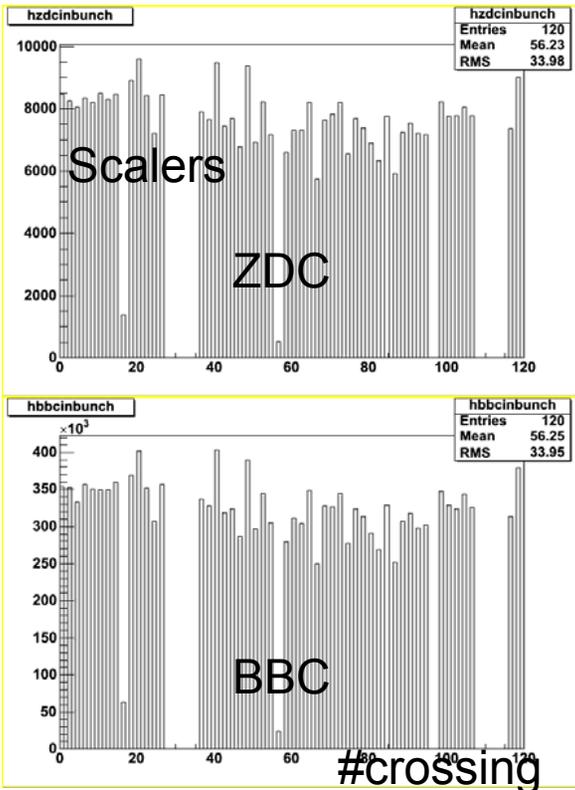
Bunch by bunch analysis is also on going

Relative luminosity

For double spin asymmetry measurements, relative luminosity error δR works as

$$\delta A_{LL} \sim \frac{\delta R}{2P_B P_Y}$$

A systematic uncertainty is checked by consistency between BBC and ZDC counts, those are placed completely different kinematical regions.



The vertex width fluctuation appears to be small unlike in the past runs. Analysis is on going.

Multi collision effects?

> Probability of more than one collision in a single bunch crossing

BBC maximum rate without vtx cut $200\text{kHz} / 0.5 (= \epsilon_{\text{bbc}}) / (84/120\text{bunches}) / 10\text{MHz}$
~ 6% at most

—To the absolute luminosity

It is less than the error of vernier scan measurement

—To the relative luminosity

It should be negligible, since its variation matters.

In the future

It will become a critical issue.

The new scaler will play an important role.

(It was installed and already functioning in this run.)

----- Observables -----

Run5pp topics discussed in Spin PWG

Cross section

C Pi0, Charged pion
Direct photon
eta
Single electron, J/psi

M J/psi

Helicity ++ and +-

C Jet correlation (kT)

A_N

C Charged hadron, pi0
Jet correlation (kT)

L Neutron asymmetry
(200,400GeV)

A_LL (A_TT)

C Pi0, Charged pion
Direct photon
eta, Lambda
Jet
Single electron

M J/psi

Spin transfer

C Lambda

Production mechanism

M J/psi polarization

C : with Central arm
M : with Muon arm
L : with Local poralimotor

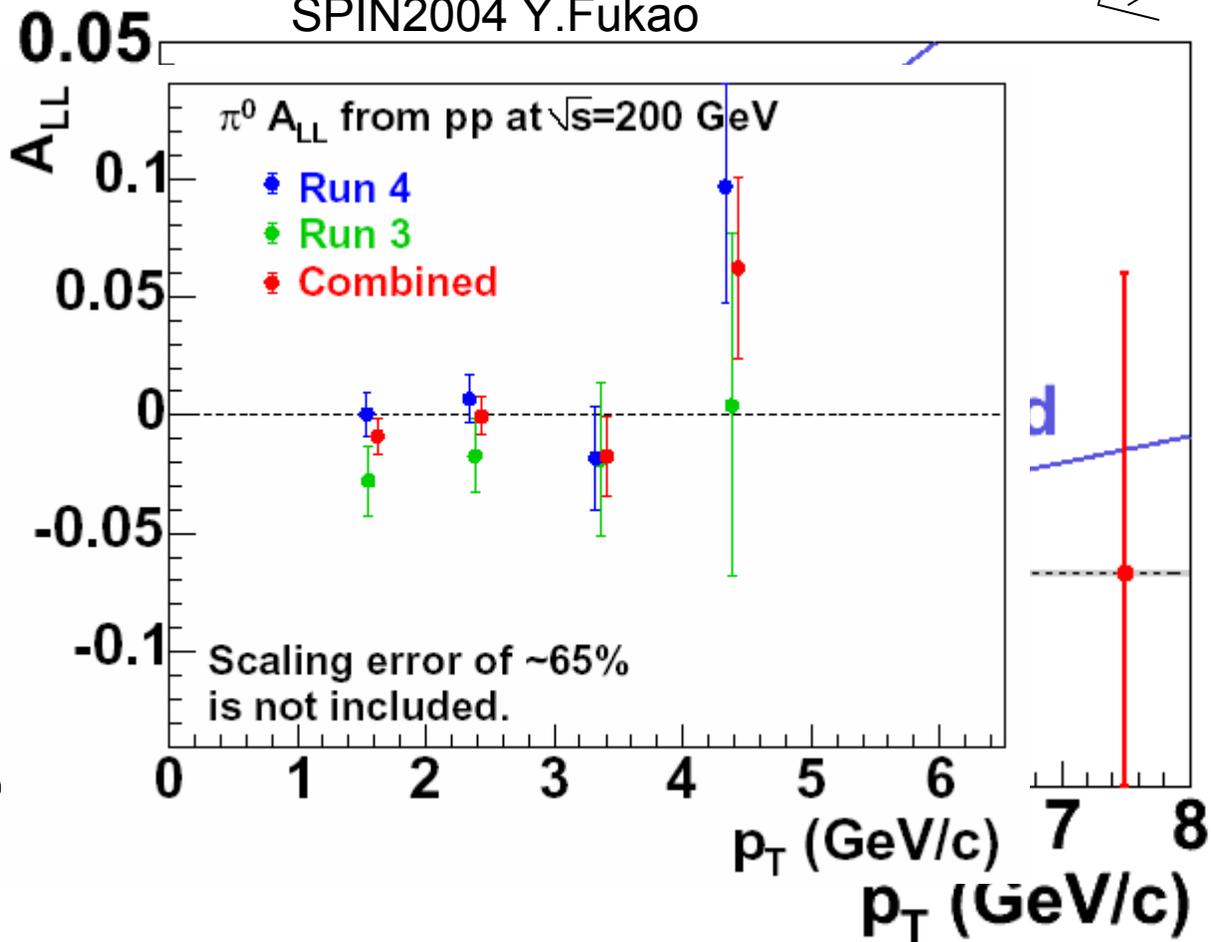
π^0

A_{LL} for Delta-g measurement

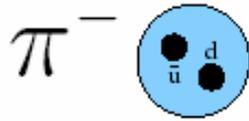
Favored by "photon" trigger

$\pi^0 A_{LL}$

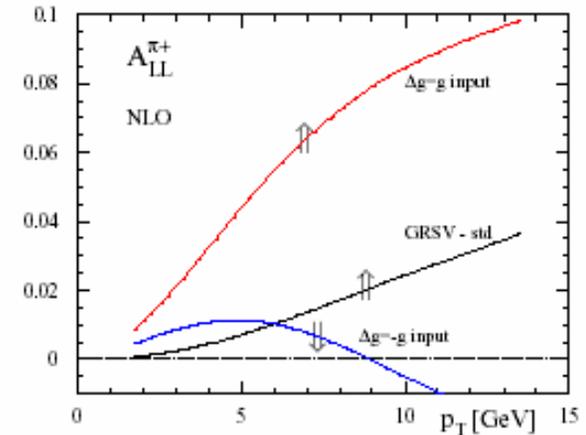
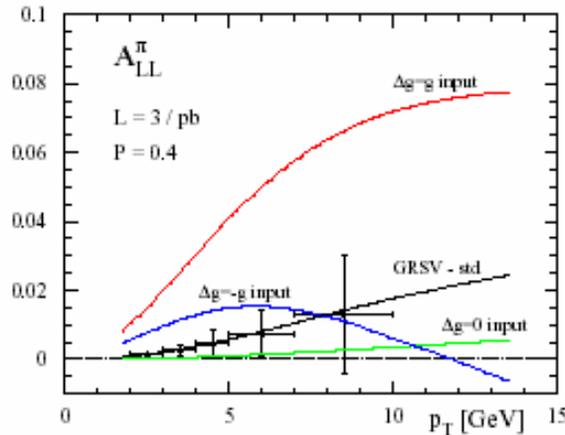
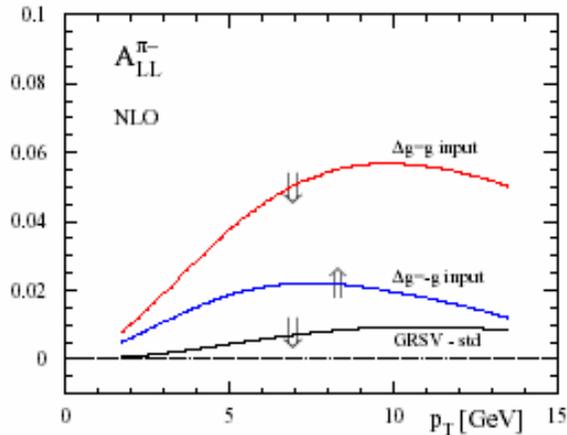
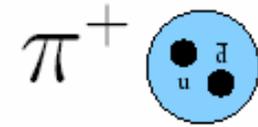
SPIN2004 Y.Fukao



Charged pions 1



π^0



idea: qg starts to dominate for $p_T \gtrsim 5 \text{ GeV}$ 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 pions 2

We identify charged pions with RICH

(Cherencov (RICH) threshold for π^\pm is $p > 4.7 \text{ GeV}/c$)

“electron” trigger collects them.

Compared to π^0

Backgrounds from conversion electrons (mimic high pT tracks in PHENIX apparatus)

> needs some EMCal energy cut

(In Run3, $E > 0.3 + 0.15 * p$ (by JJia) was applied.
Efficiency is about 50%.)

Sqrt(2) larger error is expected.

Direct photon 1

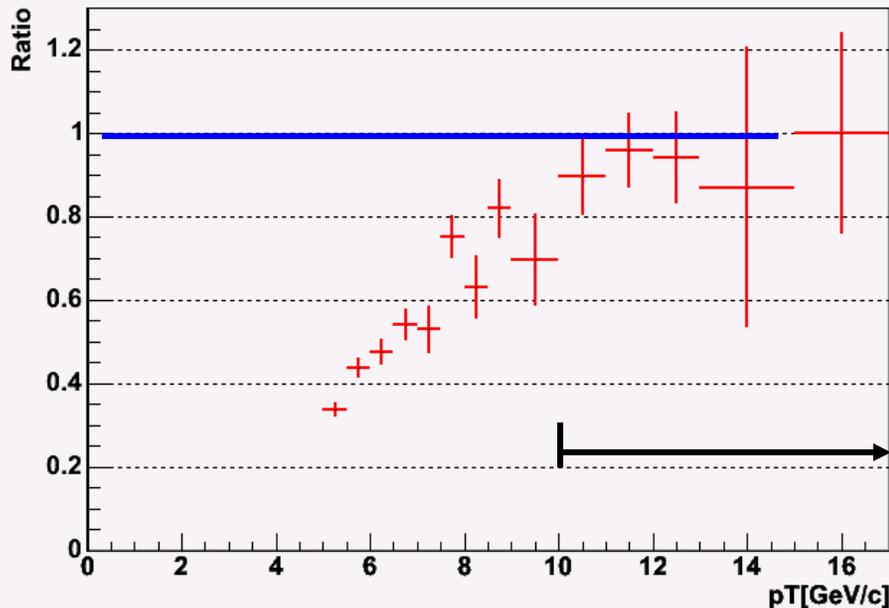
A_{LL} for Delta-g measurement
Favored by the photon trigger

With Run3 data, two methods are developed in the cross section measurement.

Subtraction method : Subtract BG from total photons

Isolation method : Apply an isolation cut requiring small energy in a cone around the photon

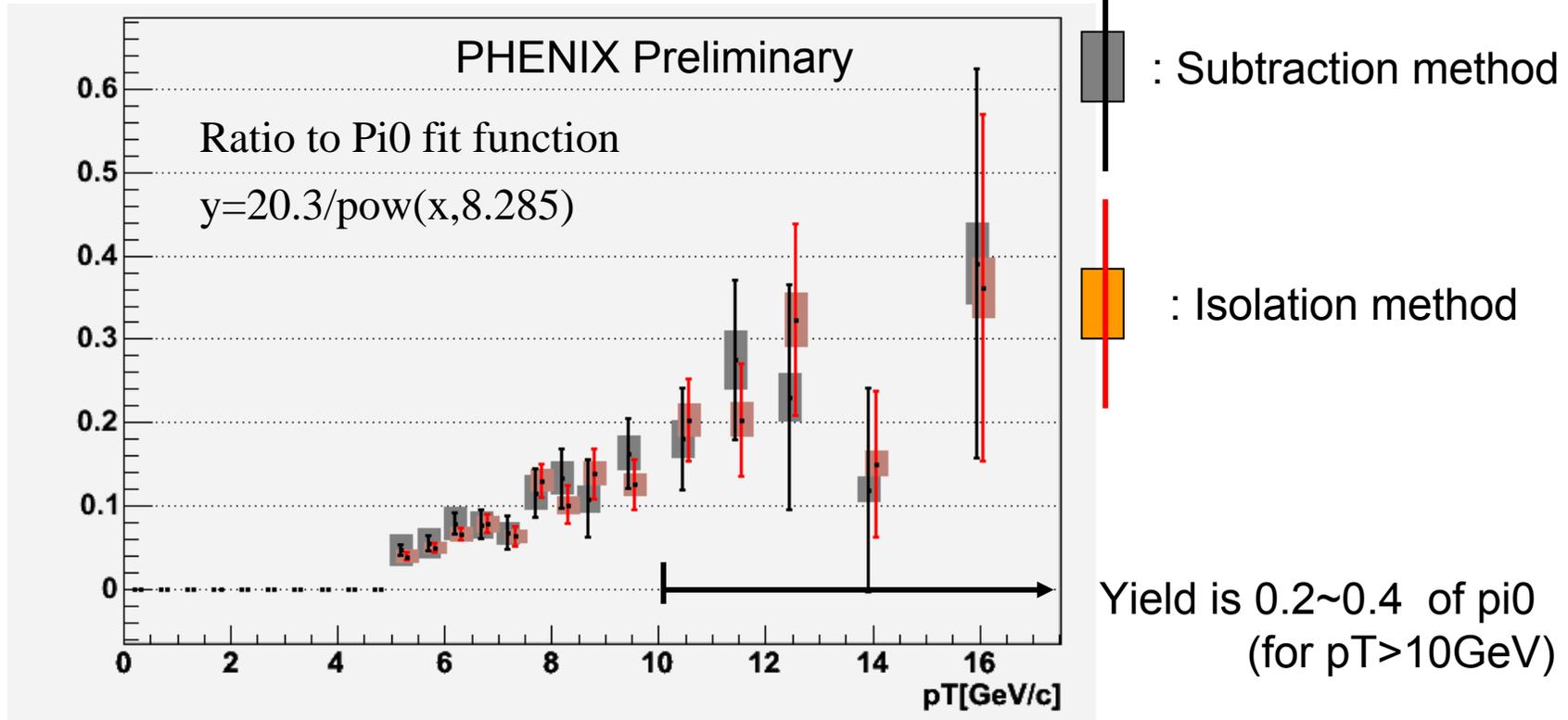
Purity (#direct photon signal / #inclusive isolated photon)



$p_T > \sim 10 \text{ GeV}$ would be a golden region.

Direct photon 2

Statistics compared to pi0



The strategy of direct photon analysis in Run5

- To get more understandings of the production cross section. (With x20 luminosity)
- Calculate the asymmetry. Develop a dilution correction method.

A_{LL} of Jet

Even with a limited acceptance in PHENIX central arm, we can catch them.

→ Tag one photon, sum all energy in one arm.

Question :

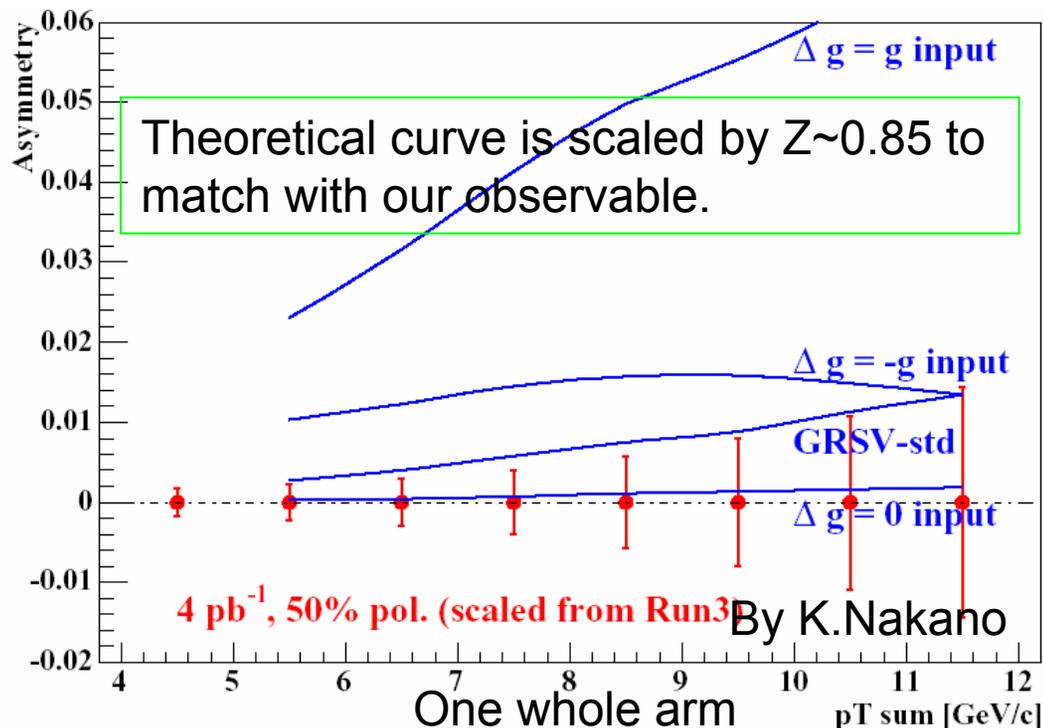
1. Are those really jets?
2. To estimate the original jet energy, how much fraction (Z) do we catch?
How much is its ambiguity (ΔZ)?

An attempt has been done with Run3 data:

Tune PYTHIA with several parameters, obtain Z value.

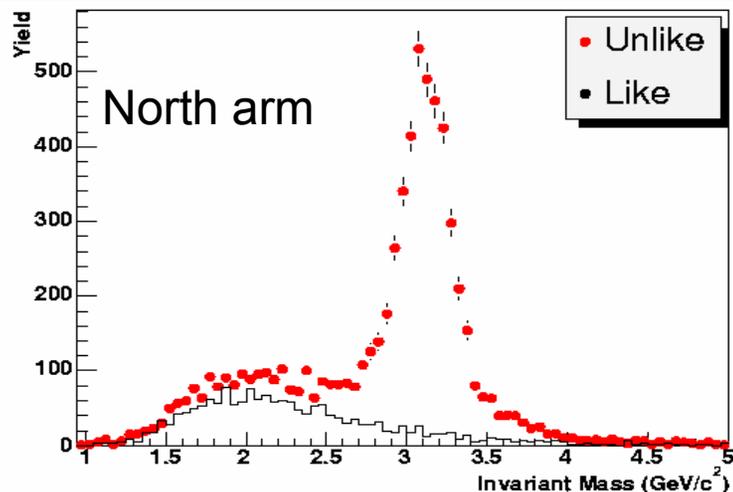
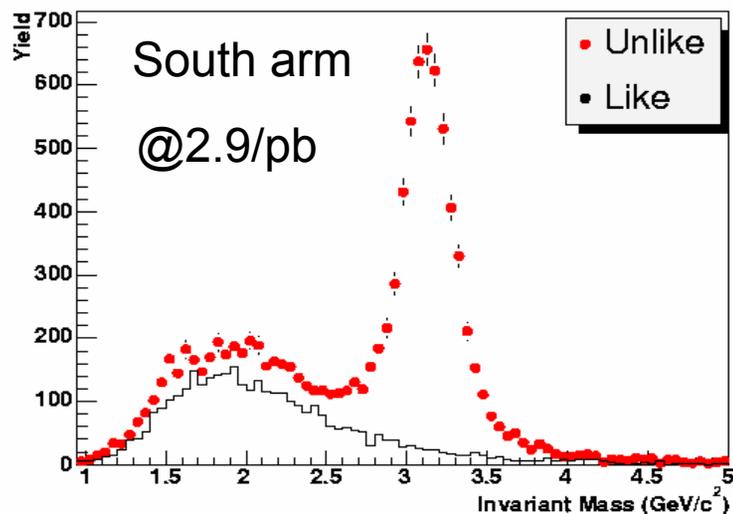
Compared to π^0 :

- Systematic uncertainty in the interpretation
- More statistics



J/psi in the muon arm

One approach to (gg \rightarrow cc-bar)

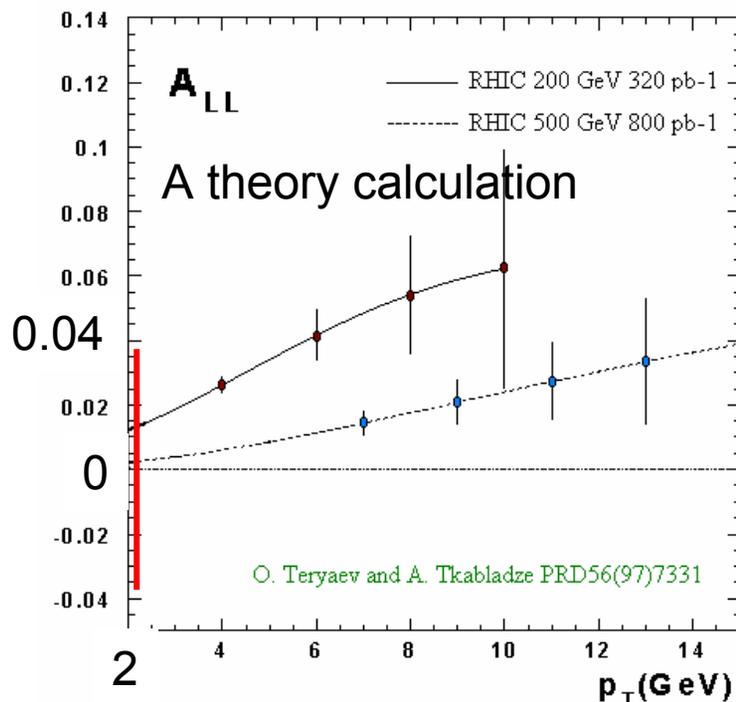


Statistics

~ 8000 J/psi in both arms (@2.9pb⁻¹)

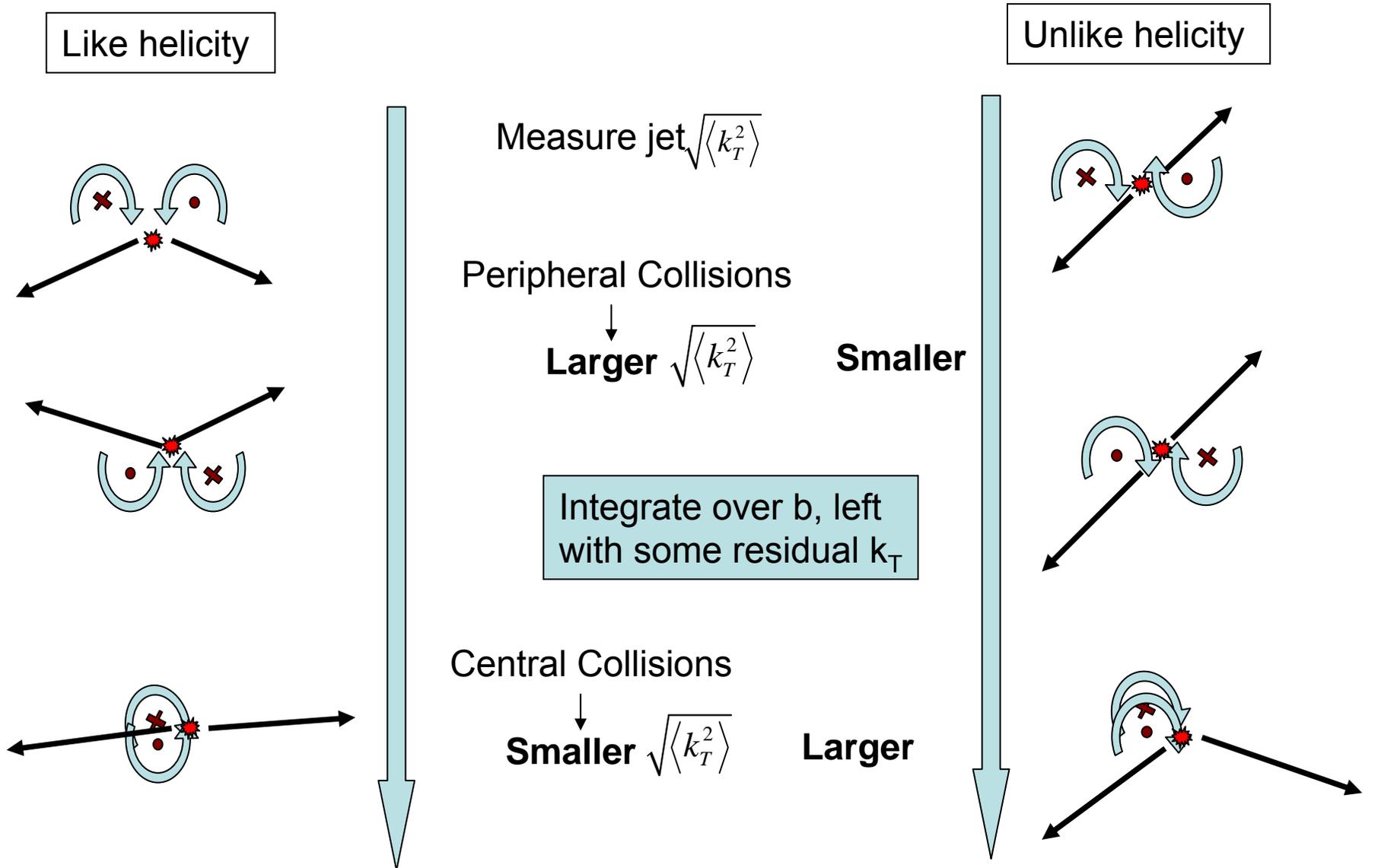
With 4pb⁻¹, total J/psi yield is ~10000.

$\Delta A_{LL} \sim 4\%$ (average pT ~2GeV/c)



We will see if something happens.

Angular momentum 1



From D.Fields's talk at SSA workshop

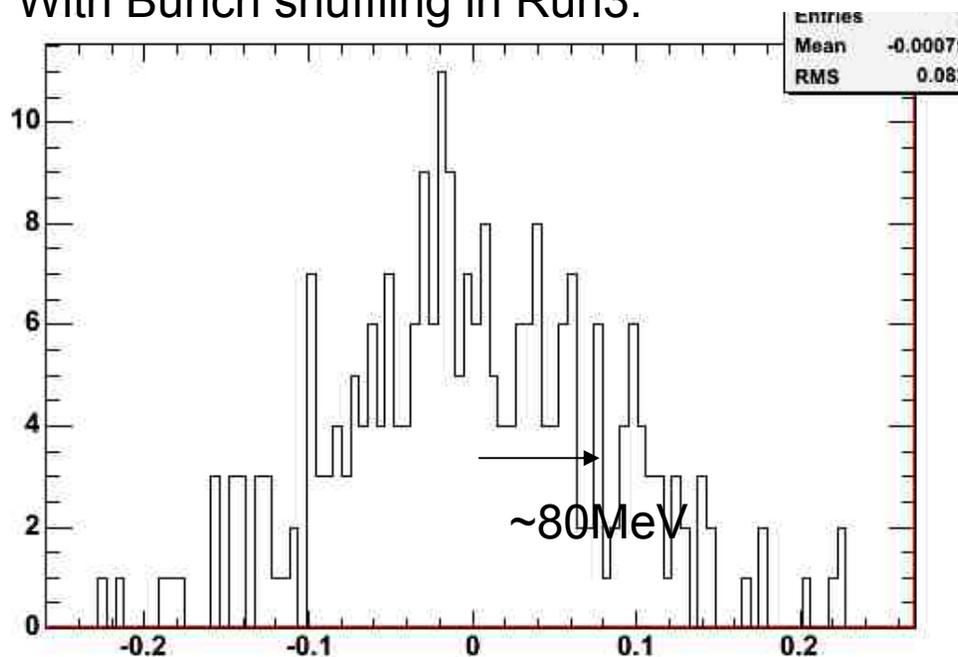
Angular momentum 2

How to measure $\langle k_T \rangle$ in PHENIX?

Di-hadron correlation (Far and Near side correlation)

$$\Delta \sqrt{\langle z_{trg}^2 k_T^2 \rangle} \longleftarrow \text{Calculated from } \langle p_{T,trig} \rangle, \langle p_{T,assoc} \rangle, \sigma_F, \sigma_N$$

With Bunch shuffling in Run3.



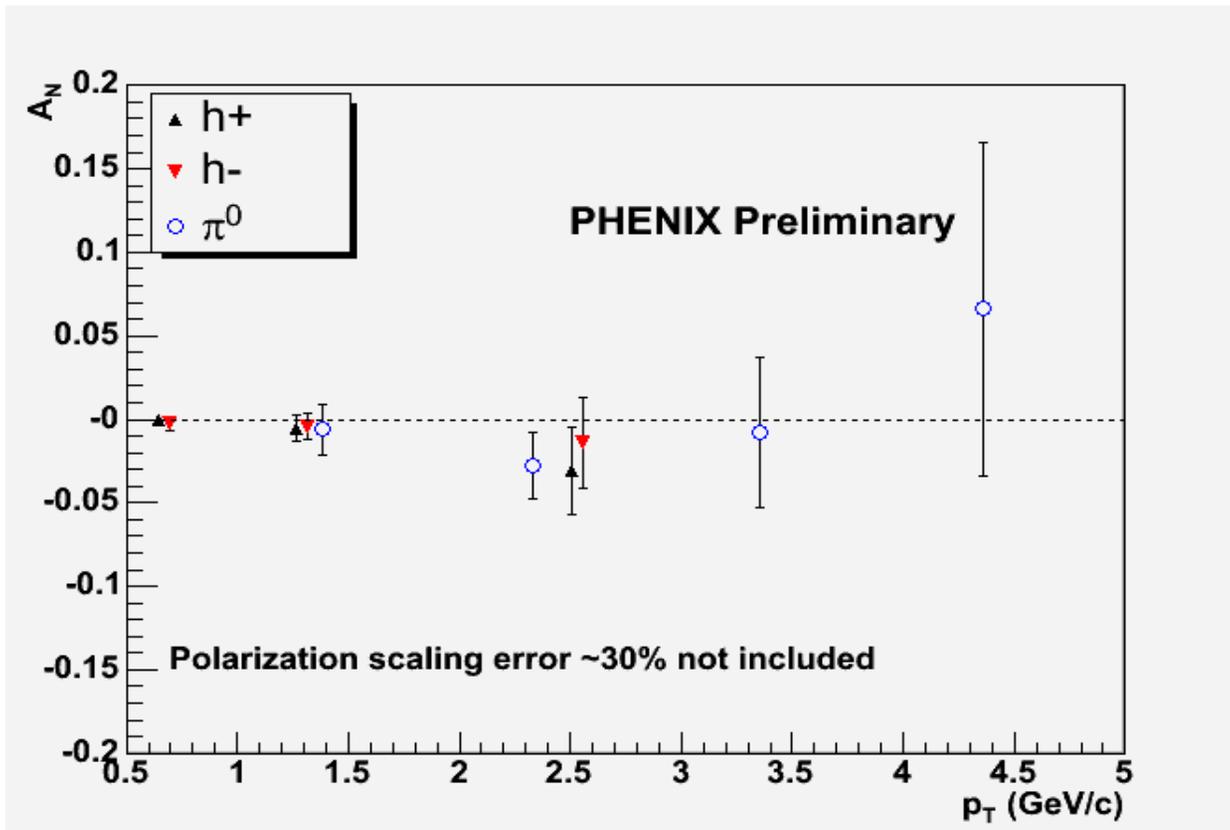
Let's see
in Run5, with higher polarization.

Need theoretical supports !!

At $\langle p_{T,trig} \rangle \sim 1.8 \text{ GeV}$

A_N measurement in the central arm

We recorded 0.16pb^{-1} with transverse polarized beam.



Run2 result, with $\sim 0.15\text{pb}^{-1}$, 15% pol, will be published soon.

Compared to Run2, we gain 9 times of figure of merit by virtue of higher polarization.

.....It will be beaten by only 3 days of Run5 data taking.

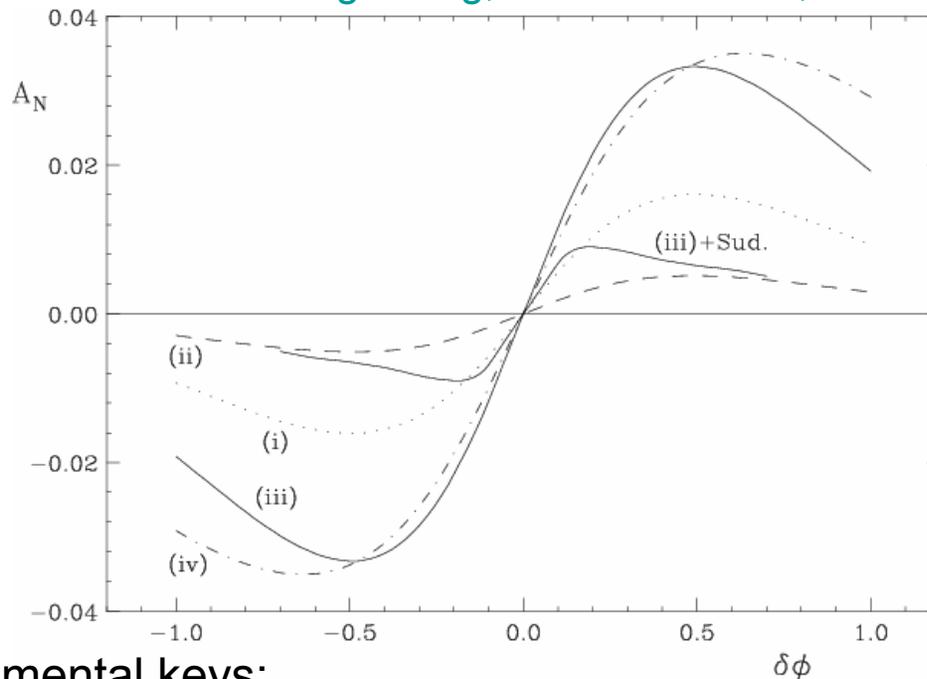
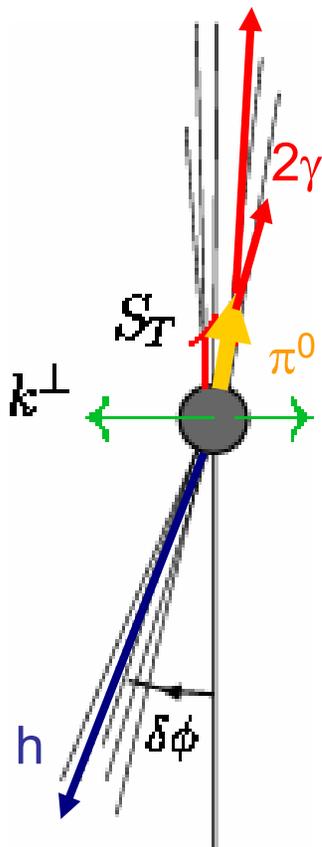
A_N of Jet k_T

A probe to access to Sivers functions.

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)

From M.Chiu's talk at SSA workshop

Summary

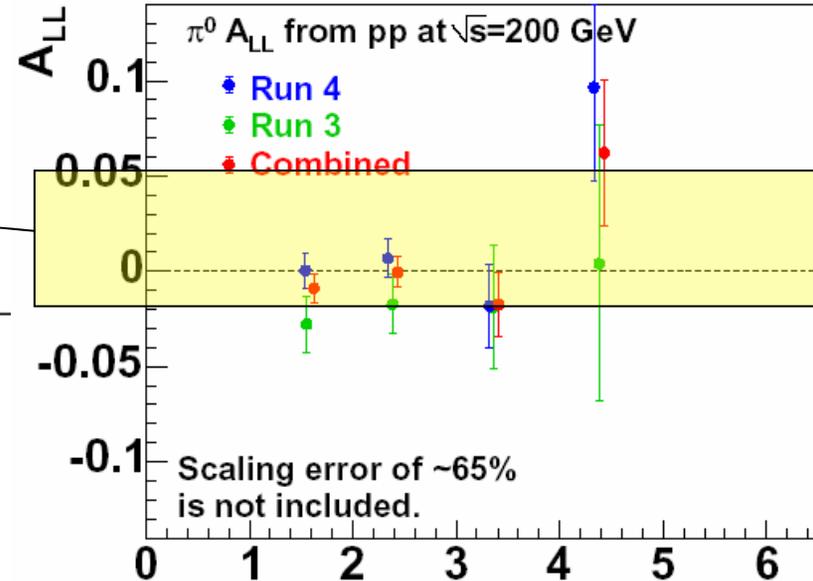
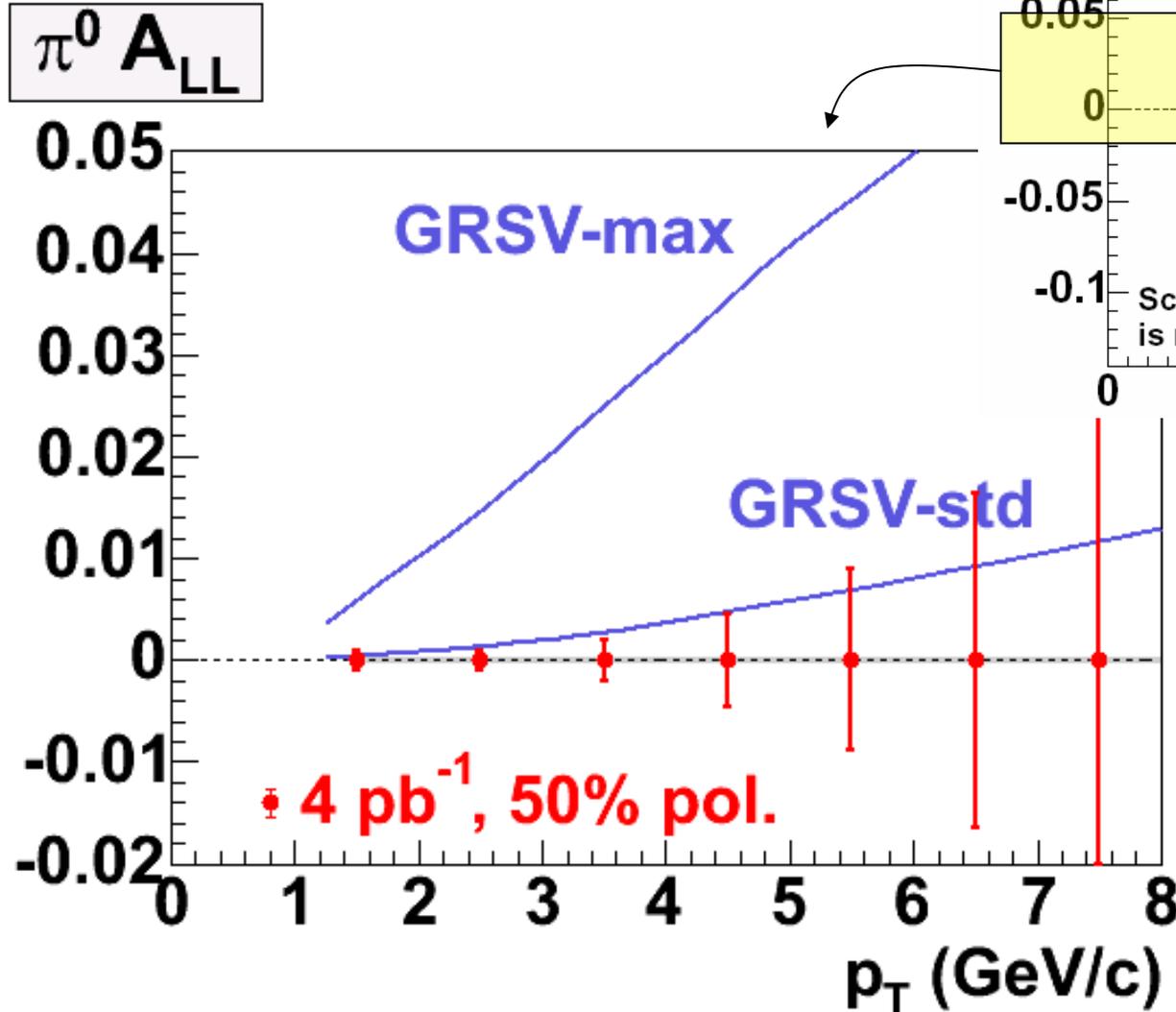
- PHENIX recorded $\sim 4\text{pb}^{-1}$ with the longitudinal polarization of average $\sim 50\%$ pol. It is **210 times** more figure of merit (P^4N) for the double spin asymmetry than in Run3.
- Luminosity of 0.16pb^{-1} is also recorded with the transverse polarization. It provides us a size of A_{TT} contamination to A_{LL} . For A_{N} measurement, it's a factor of 9 more than Run2's figure of merit (P^2N).
- Forward neutron asymmetry was confirmed in $\sqrt{s} = 410\text{GeV}$ collisions.
- The double longitudinal spin asymmetry of π^0 will be improved very much.
- We will measure particle production cross sections with increased statistics.
- Other probes will give hints for future measurements.

Backups

Neutral pions

A_{LL} for Delta-g measurement

Favored by the photon trigger



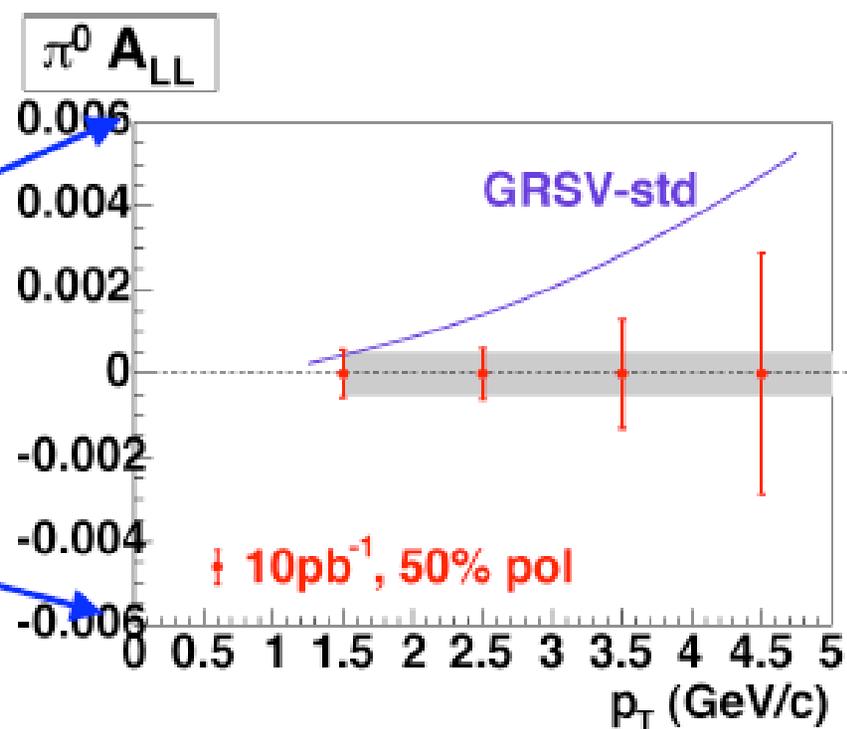
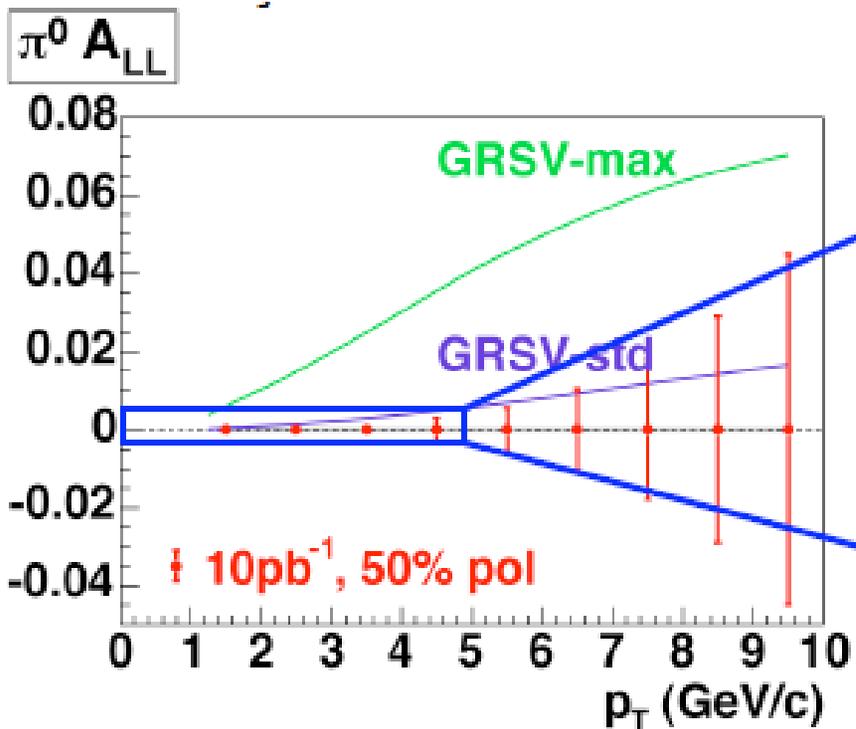
Scaled from Run3
by Y. Fukao

Manabu's slide

[https://www.phenix.bnl.gov/WWW/p/draft/togawa/pwg/spin/050601/
SpinPwg050601_MTogawa.ppt](https://www.phenix.bnl.gov/WWW/p/draft/togawa/pwg/spin/050601/SpinPwg050601_MTogawa.ppt)

$$A_{raw} \sim pol_L^2 \cdot A_{LL} + pol_T^2 \cdot A_{TT} \sim Pol^2 \left(A_{LL} + \frac{pol_T^2}{Pol^2} \cdot A_{TT} \right) = A$$

- Radial component, (weighted mean of 4 fills)
 - Blue : $10.3\% \pm 3.9\%$
 - Yellow : $21.5\% \pm 5.3\%$
- $\Delta(pol_T^2/pol^2) \sim 10^{-2}$
 - A_{TT} error should $< 10^{-1}$ to achieve 10^{-3} error.
- If thinking fill by fill analysis, $\Delta(pol_T^2/pol^2) \sim 1.7 \cdot 10^{-2}$
 - A_{TT} error should $< 0.5 \cdot 10^{-1}$ to achieve 10^{-3} error.



We can achieve $\pi^0 A_{TT}$ error $< 0.5 \cdot 10^{-1}$ with 0.1 pb^{-1} data taking until 5 GeV.

p_T	$\Delta A_{LL}(\%)$
1.0~2.0	0.92
2.0~3.0	1.01
3.0~4.0	2.19
4.0~5.0	4.91

Back up

$$x = \frac{pol_T}{Pol} = \frac{A_{ON}}{A_{OFF}} \quad A_{OFF} : \sim 0.06 \quad \text{-- analyzing power in PHENIX}$$

ON : spin rotator is ON ; **OFF** : spin rotator is OFF

$$\left(\Delta \frac{pol_T}{Pol} \right)^2 = \frac{1}{A_{OFF}^2} \left(\frac{1}{Pol_{ON}^2 N_{ON}} + x^2 \frac{1}{Pol_{OFF}^2 N_{OFF}} \right)$$

Transverse RUN
Commissioning RUN

$$\Delta \left(\frac{pol_T}{Pol} \right)^2 = \sqrt{2} x \Delta \left(\frac{pol_T}{Pol} \right) \propto \frac{1}{N_{ON}} \quad Pol^2 = pol_T^2 + pol_L^2$$

- **$\Delta (pol_T/Pol)^2$ should be $< 10^{-2}$**
 - other main uncertainty from relative luminosity ($\sim 10^{-3}$)
- In the transverse commissioning, statistics of necessity depends on pol_T/Pol value.
 - If $pol_T/Pol = 0.1$ (thinking RUN3 value), **1.6M evts are going to achieve $\Delta (pol_T/Pol)^2 < 10^{-3}$**
- **~ 30 min by 1kHz trigger is enough.**

Back up

$$\left(\Delta \frac{pol_T}{Pol} \right)^2 = \frac{1}{A_{OFF}^2} \left(\boxed{\frac{1}{Pol_{ON}^2 N_{ON}}} + x^2 \boxed{\frac{1}{Pol_{OFF}^2 N_{OFF}}} \right)$$

Transverse RUN
Commissioning RUN

$$\Delta \left(\frac{pol_T}{Pol} \right)^2 = \sqrt{2} x \Delta \left(\frac{pol_T}{Pol} \right) \propto \frac{1}{N_{ON}}$$

- $\Delta (pol_T/Pol)^2$ should be $< 10^{-2}$
 - If $pol_T/Pol = 0.1$ (thinking RUN3 value), **1.6M evts are going to achieve $\Delta (pol_T/Pol)^2 < 10^{-2}$**
 - **Data taking ~15 min by 2kHz trigger is enough.**

Back up

- Takes A_{TT} RUN in ΔA_{TT} less than 10%

– $\Delta A(\text{measure}) = \Delta(\text{pol}_T/\text{Pol})^2 \Delta A_{TT}$

→ $\Delta(\text{pol}_T/\text{Pol})^2 = 10^{-2}$ is enough for $\Delta A(\text{measure}) = 10^{-3}$.

- How much data is required for < 10%?

– We will achieve less than 10% till $p_T \sim 5 \text{ GeV}/c$ at 0.075 pb^{-1}

(see RUN4 table)

p_T	$\Delta A_{LL}(\%)$
1.0~2.0	0.92
2.0~3.0	1.01
3.0~4.0	2.19
4.0~5.0	4.91