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Division of Nuclear Physics
Chicago

Probing the gluon polarization in the polarized proton at the PHENIX experiment at RHIC

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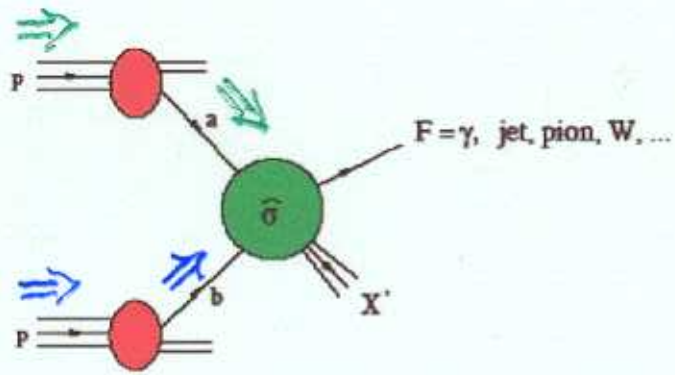
We present a new measurement of the beam helicity asymmetry A_{LL} for inclusive π^0 production, which is sensitive to the gluon polarization in the proton.

Hard scattering in polarized hadron collisions

$$p_T^3 \frac{d\Delta\sigma}{dp_T d\eta} = \Bigg|$$

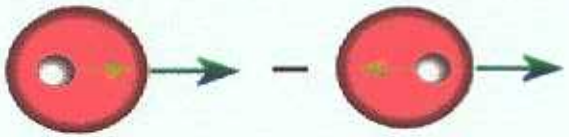


$$\Bigg|^2 + \mathcal{O}\left(\frac{\lambda}{p_T}\right)^n$$

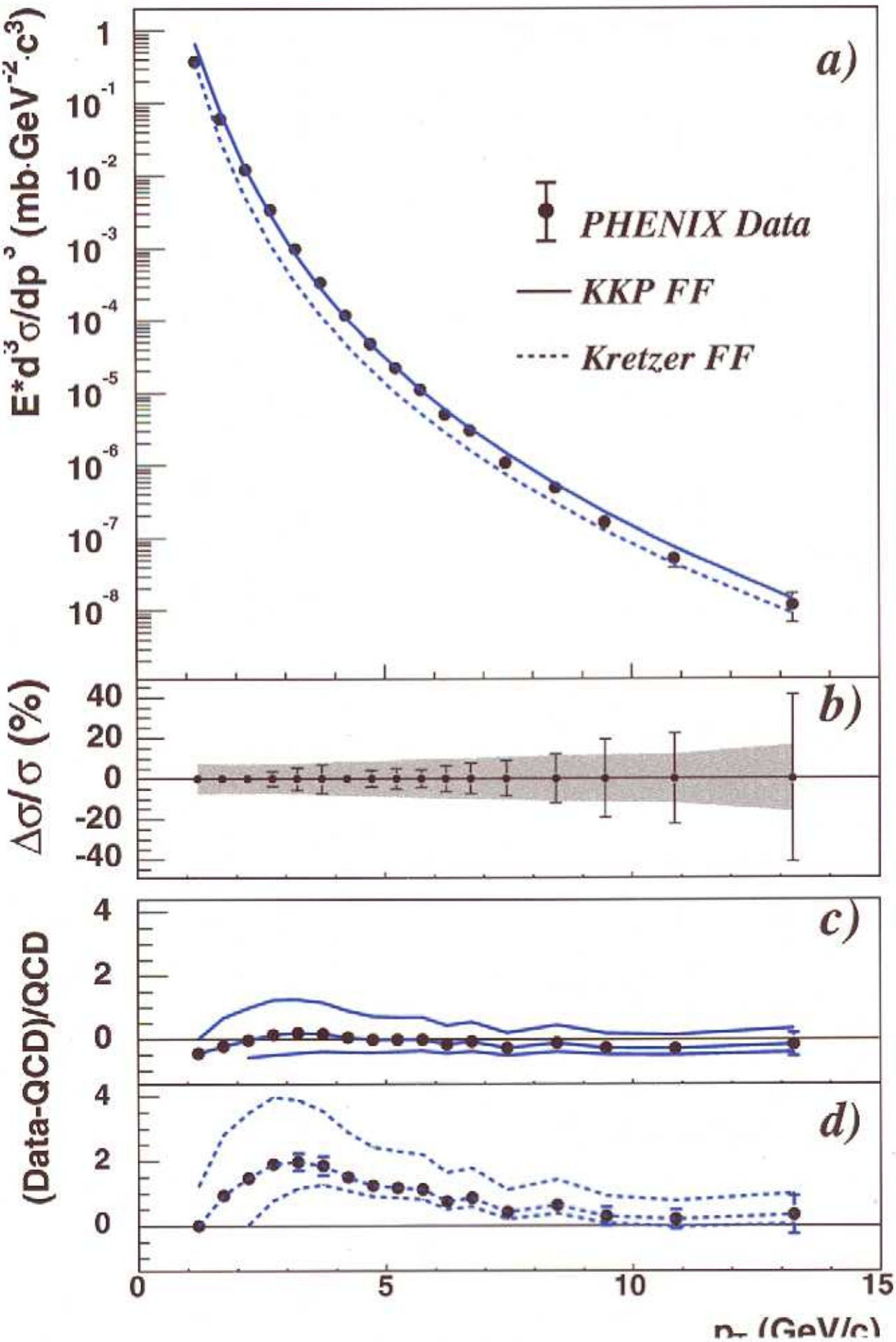
$$p_T^3 \frac{d\Delta\sigma^{pp\to \mathrm{F}X}}{dp_T d\eta} = \sum_{abc} \int dx_a\, dx_b\, \Delta f_a(x_a,\mu)\, \Delta f_b(x_b,\mu)$$
$$\times\, p_T^3 \frac{d\Delta\hat{\sigma}^{ab\to \mathrm{F}X'}}{dp_T d\eta}(x_a P_a, x_b P_b, P^{\mathrm{F}}, \mu) \;+\; \text{P.C.}$$

$$\Delta\sigma = \sigma_{++} - \sigma_{+-}$$

$\Delta\hat{\sigma}^{(0)} + \alpha_s \Delta\hat{\sigma}^{(1)} + \ldots$ perturb.

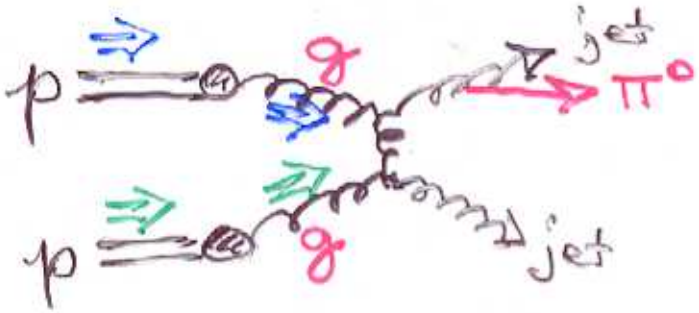
$\Delta f =$ 

$pp \to \pi^0 + X$ PRL 91, 241803 (2003)



Using π^0 to probe $\Delta G/G$

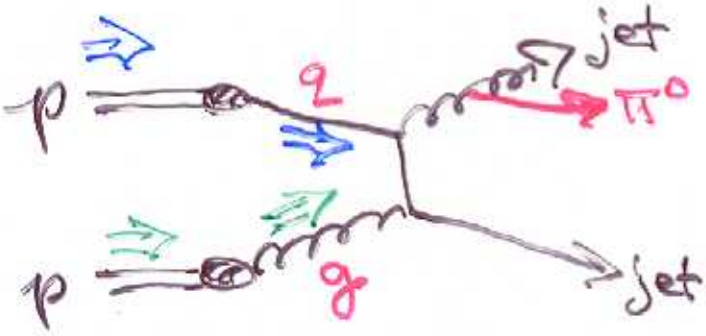
$$A_{LL} \equiv \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$



gg dominates at lower p_T

$\hat{a}_{gg} \approx .75$

$$A_{LL} \approx .75 \times \left(\frac{\Delta G}{G}\right)^2$$



gq dominates for $p_T > 10$ GeV/c

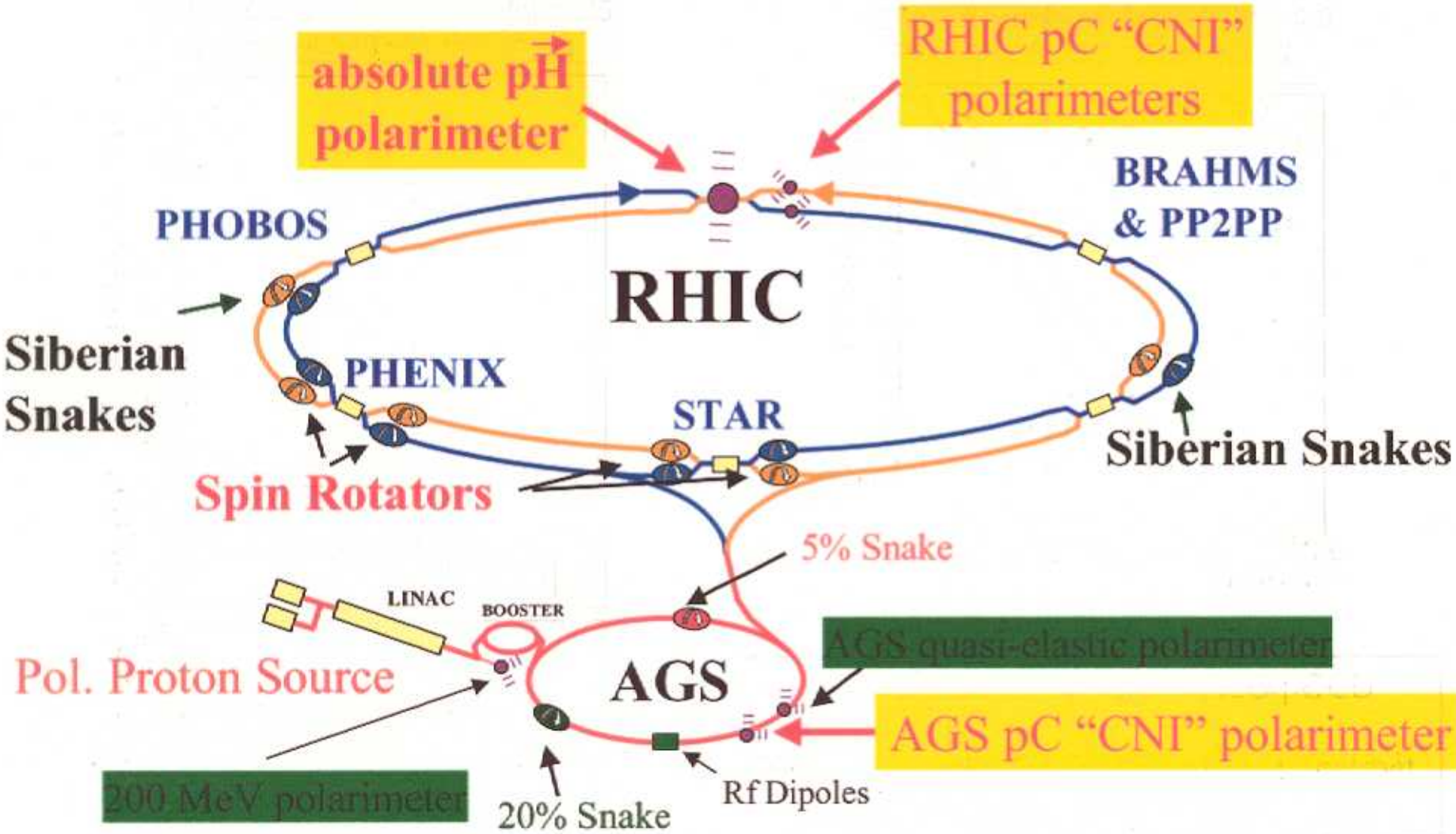
$\hat{a}_{gq} \approx .6$

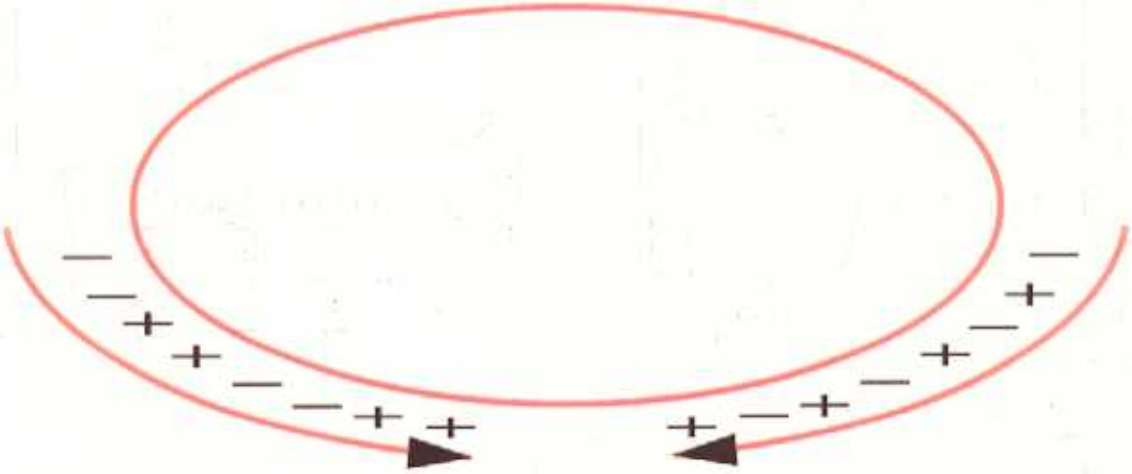
$$A_{LL} \approx .6 \times \frac{\Delta G}{G} \times \frac{\Delta q}{q}$$

$\sqrt{s} = 200$; mid-rapidity

$x_1 \approx x_2 \approx \frac{p_T}{100}$

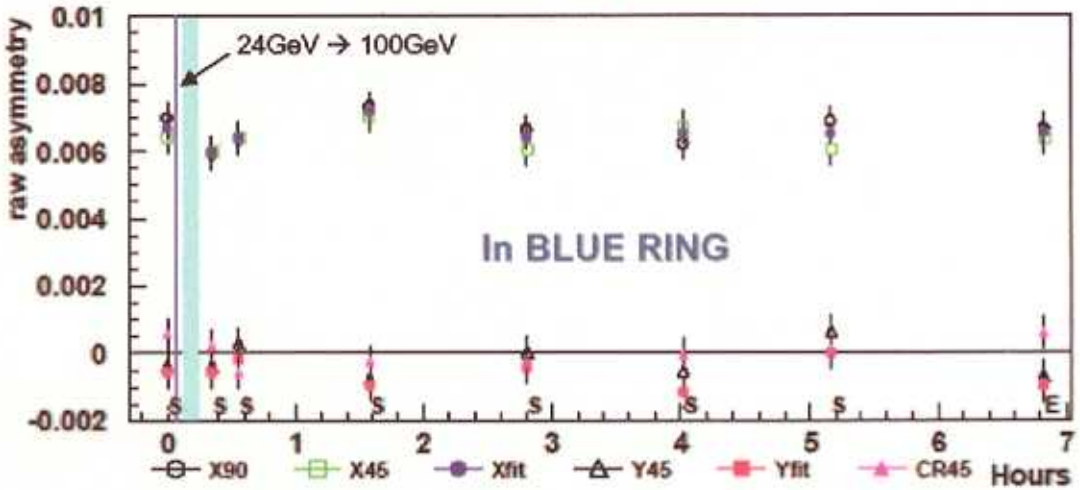
RHIC *pp* accelerator complex & Polarimeters

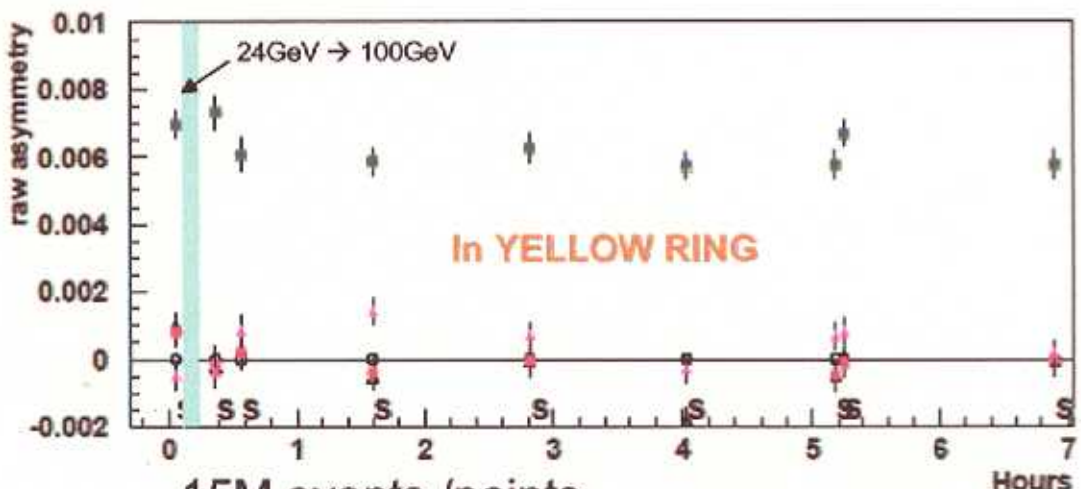




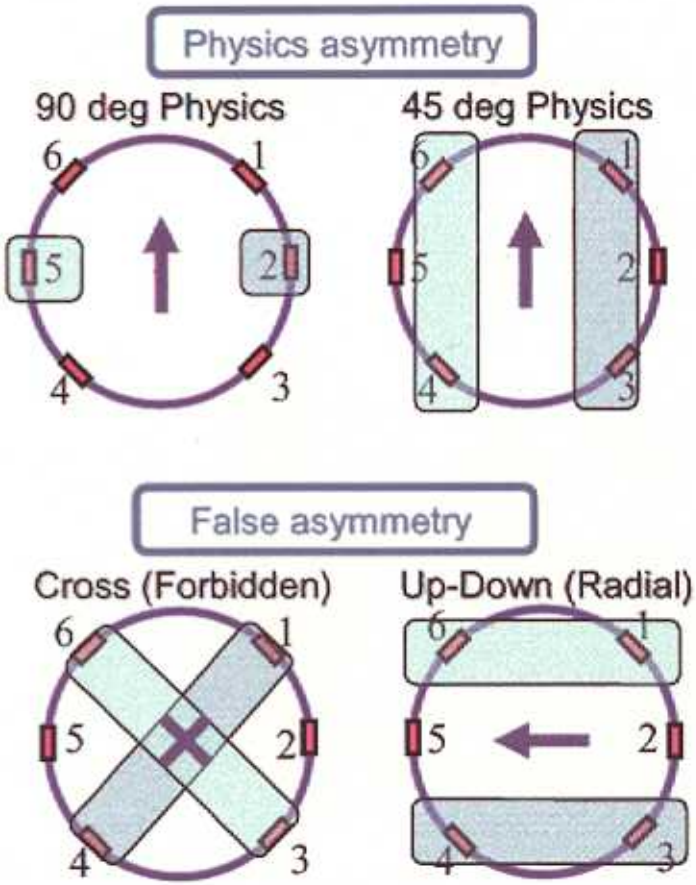
Polarization measurements during RHIC fill

Online Results

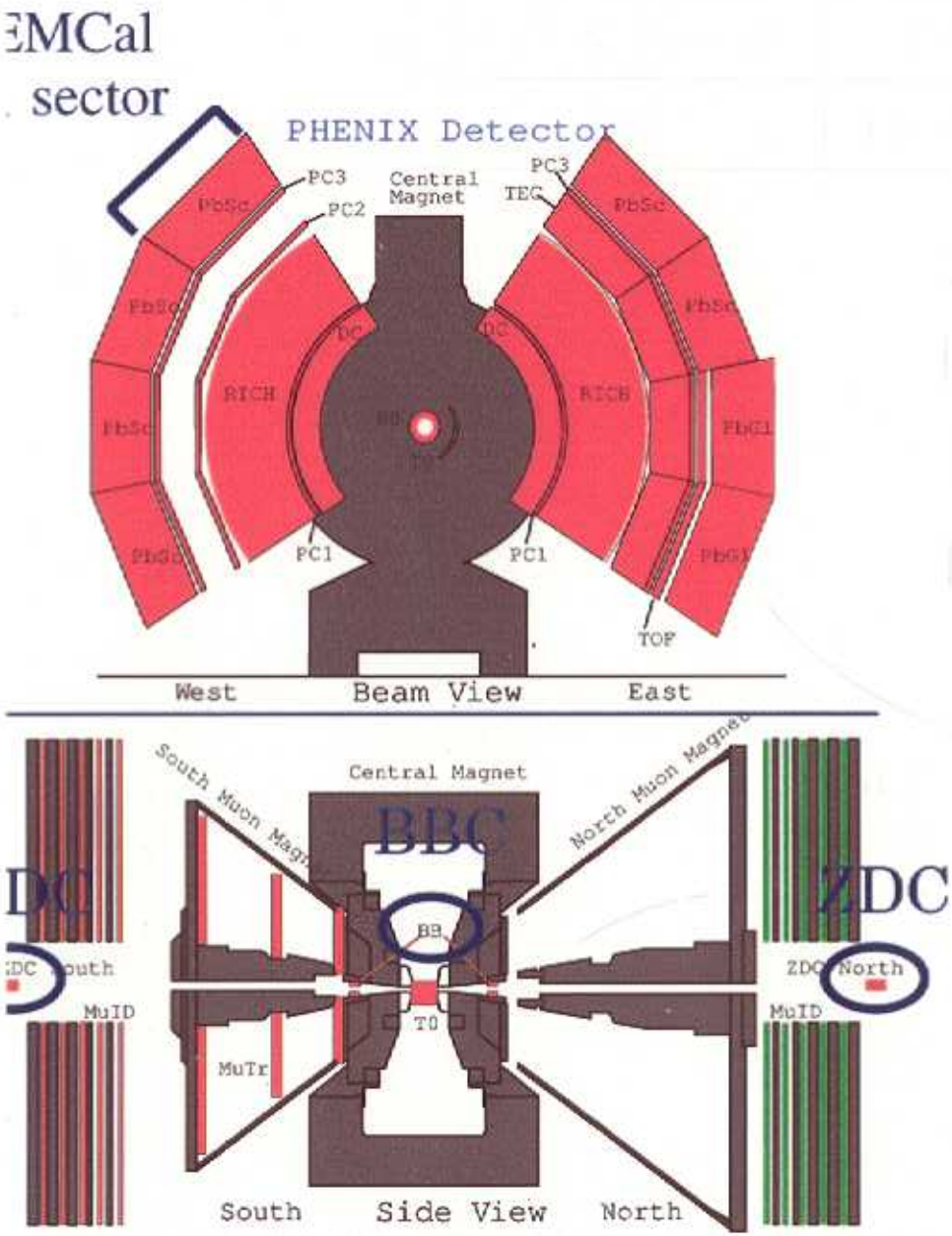




15M events /points



PHENIX detector



Electromagnetic Calorimeter (EMCal)

> Measure photon energy and position. ($\pi^0 \to \gamma$

> Acceptance

5m far from collision point.

$|\eta| < 0.35$, ϕ : 90+90 degree.

> PbSc(6 sectors) and PbGl(2 sectors).

Fine segmented. ($\Delta\eta \cong \Delta\phi \cong 0.01$)

> Energy resolution

PbSc : $8.1\%/\sqrt{E(\mathrm{GeV})} \oplus 2.1\%$

PbGl : $5.9\%/\sqrt{E(\mathrm{GeV})} \oplus 0.8\%$

> Position resolution

PbSc : $5.7\mathrm{mm}/\sqrt{E(\mathrm{GeV})} \oplus 1.6\mathrm{mm}$

PbGl : $8.4\mathrm{mm}/\sqrt{E(\mathrm{GeV})} \oplus 0.2\mathrm{mm}$

Beam-Beam Counter (BBC)

> Used for relative luminosity measurement.

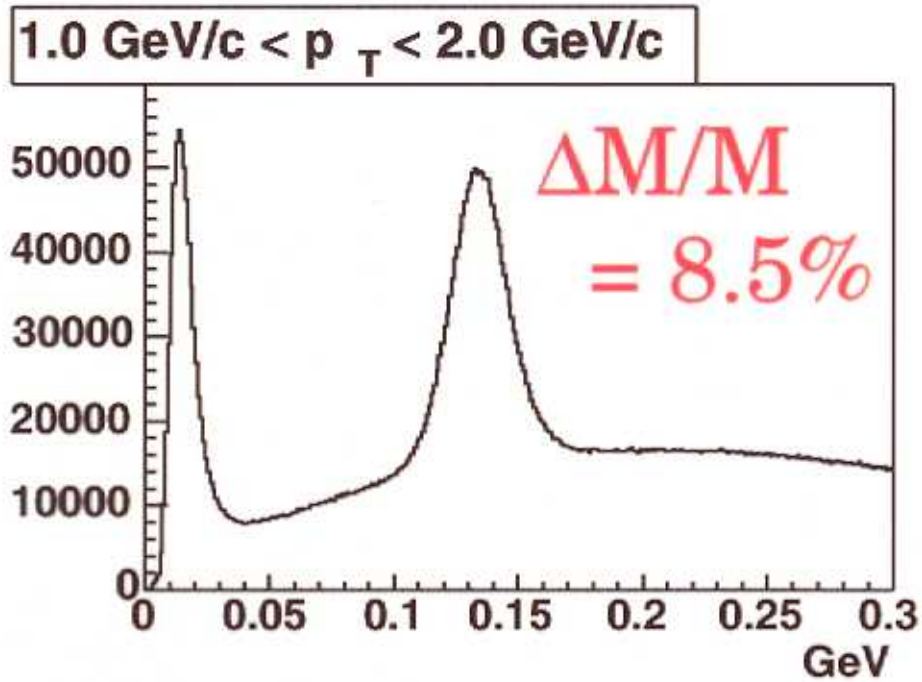
> Acceptance : $3.0 < \eta < 3.9$

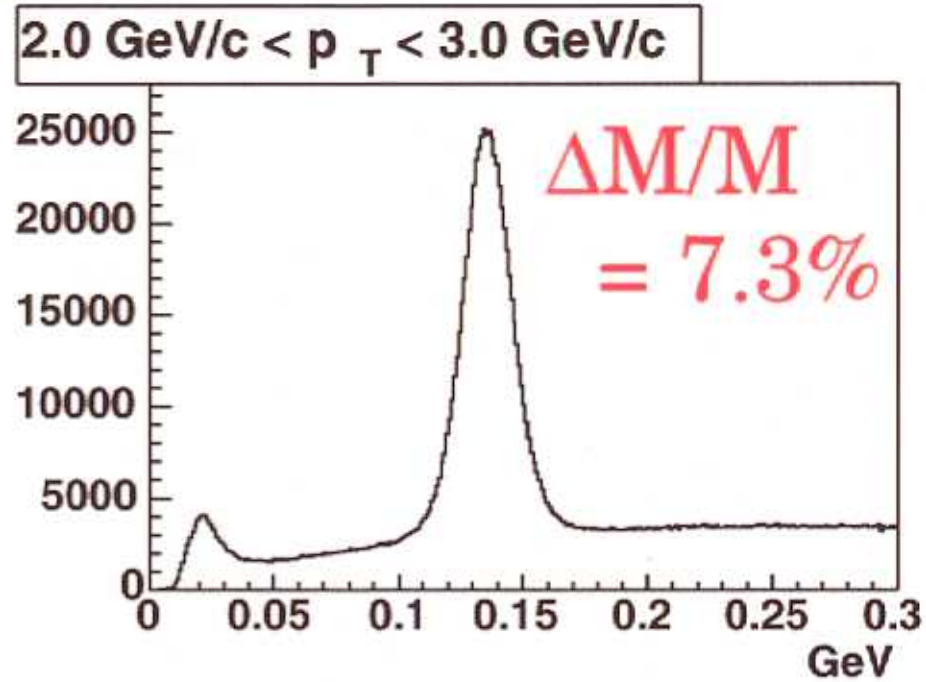
Zero Degree Calorimeter (ZDC)

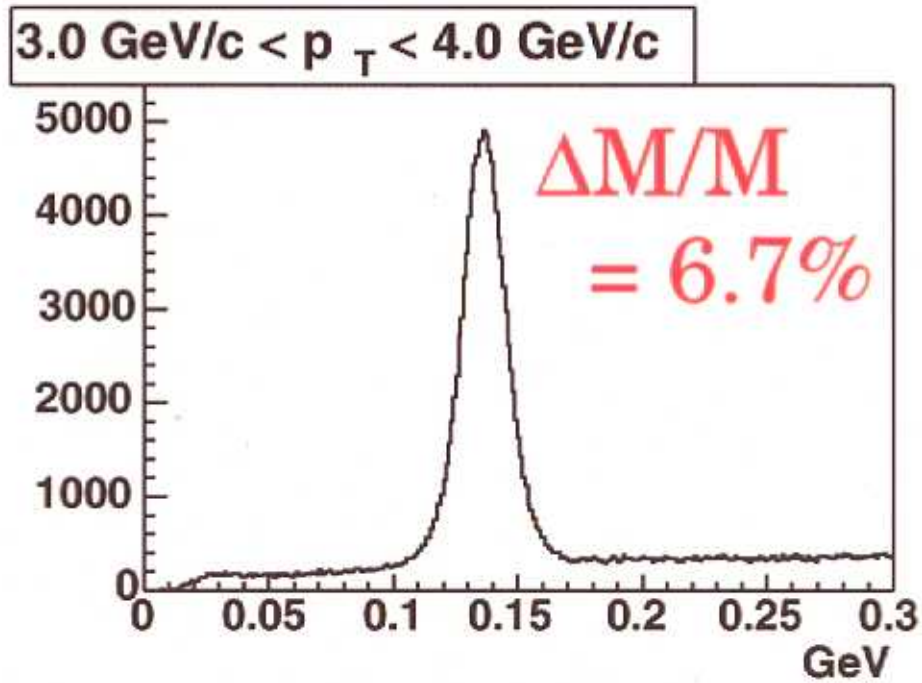
> Used for relative luminosity measurement.

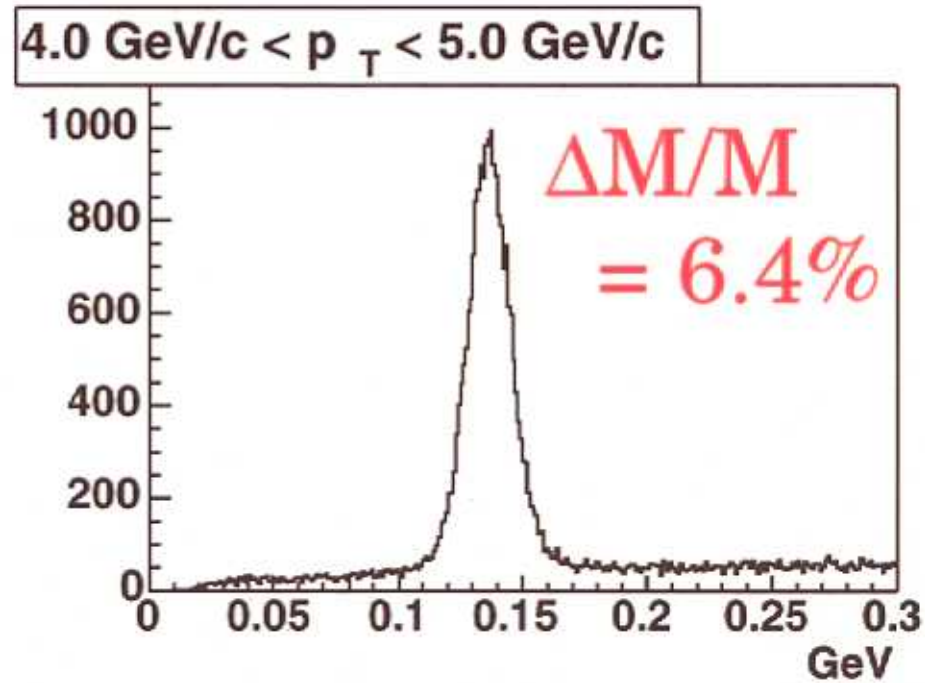
> Acceptance : ±2 mrad

π° mass spectrum

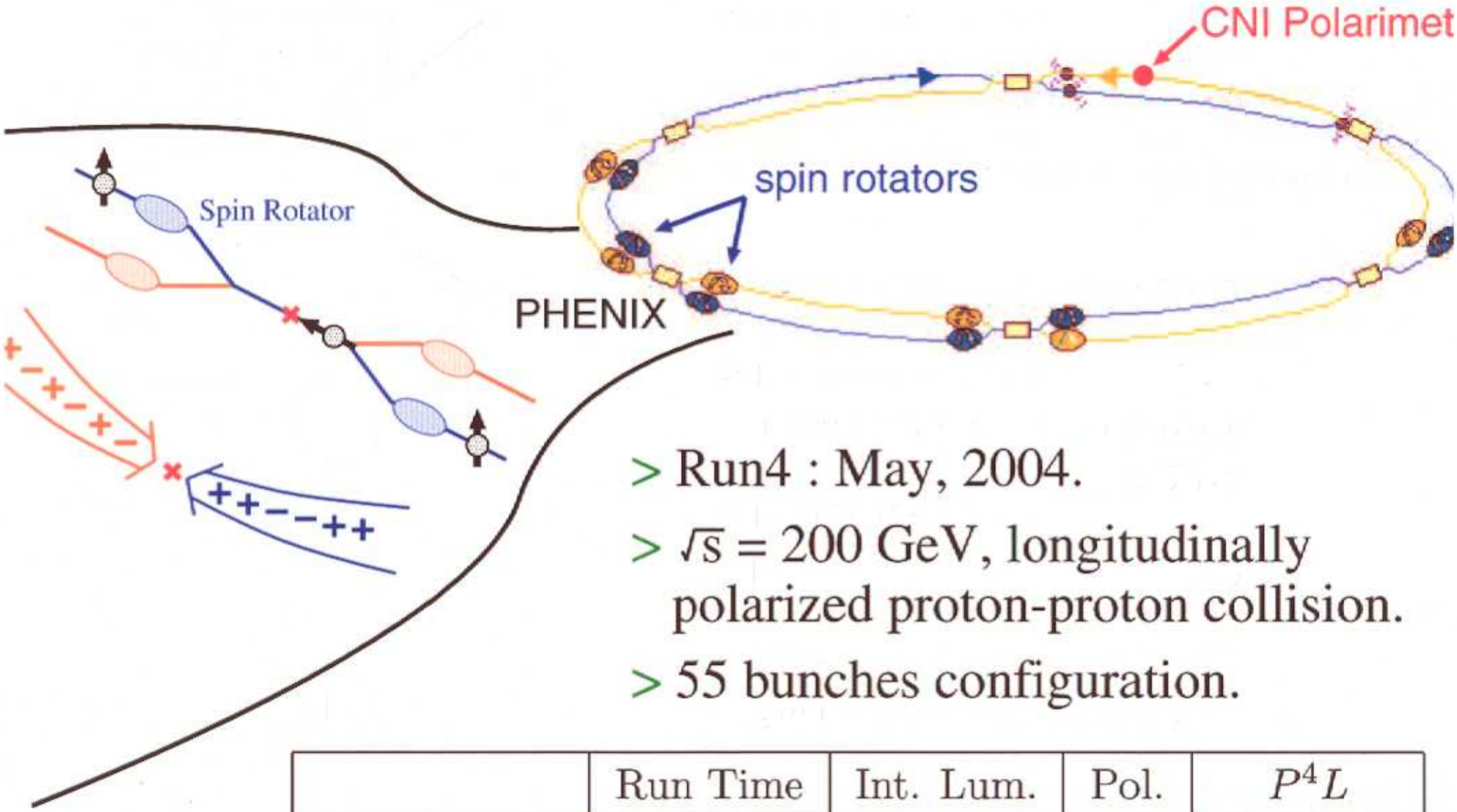








RHIC (Relativistic Heavy Ion Collider)



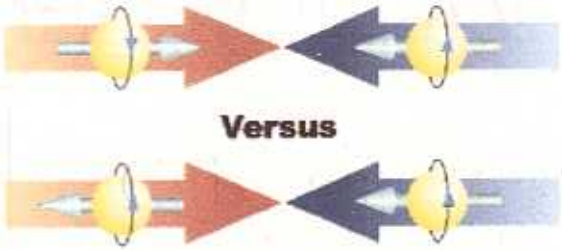
> Run4 : May, 2004.

> $\sqrt{s}$ = 200 GeV, longitudinally polarized proton-proton collision.

> 55 bunches configuration.

	Run Time	Int. Lum.	Pol.	P^4L
Run 3 (2003)	4 weeks	220 nb^{-1}	27%	1.17 nb^{-1}
Run 4 (2004)	4 days	75 nb^{-1}	40%	1.92 nb^{-1}

A_{LL}



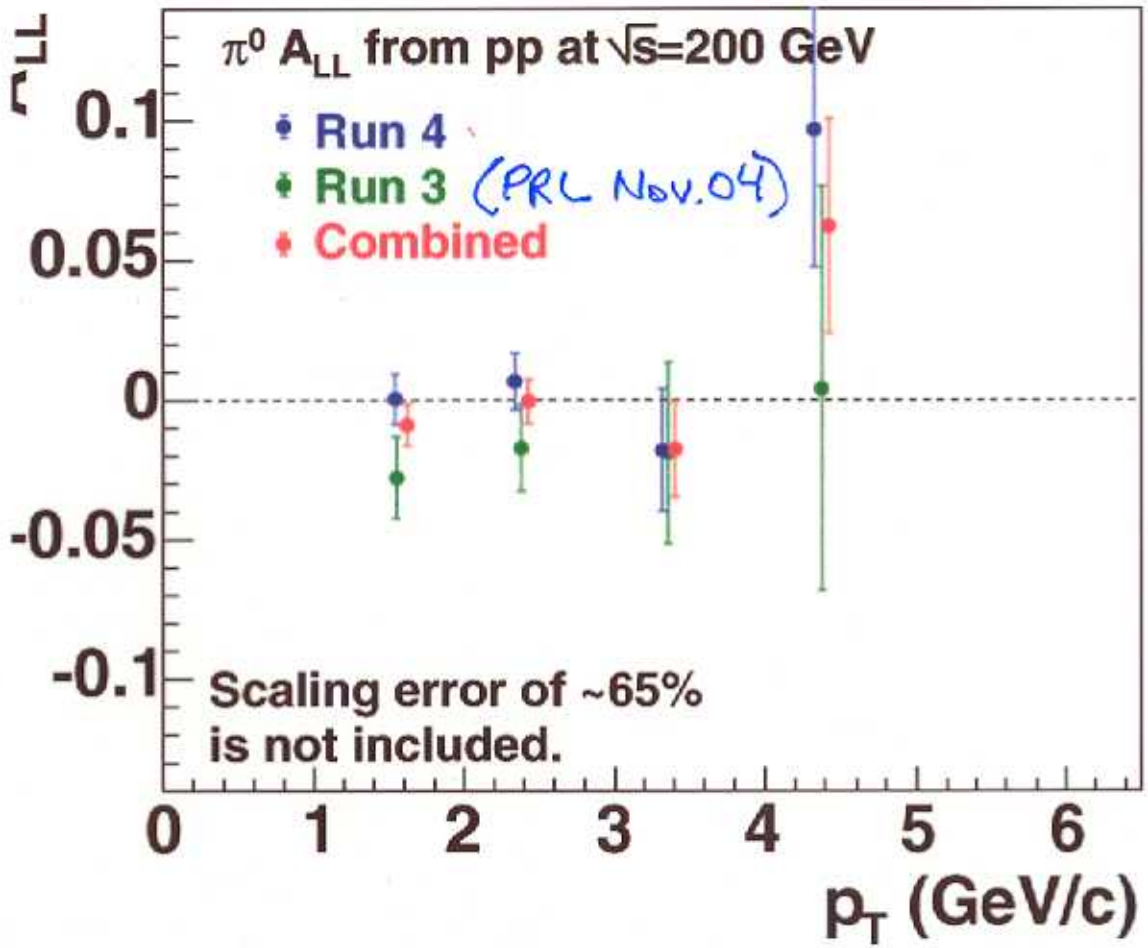
$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{|P_B P_Y|} \frac{N_{++}/L_{++} - N_{+-}/L_{+-}}{N_{++}/L_{++} + N_{+-}/L_{+-}}$$

++ same helicity
+– opposite helicity

(P) Polarization
(L) Relative Luminosity
(N) Number of pi0s

PHENIX

A_{LL} results

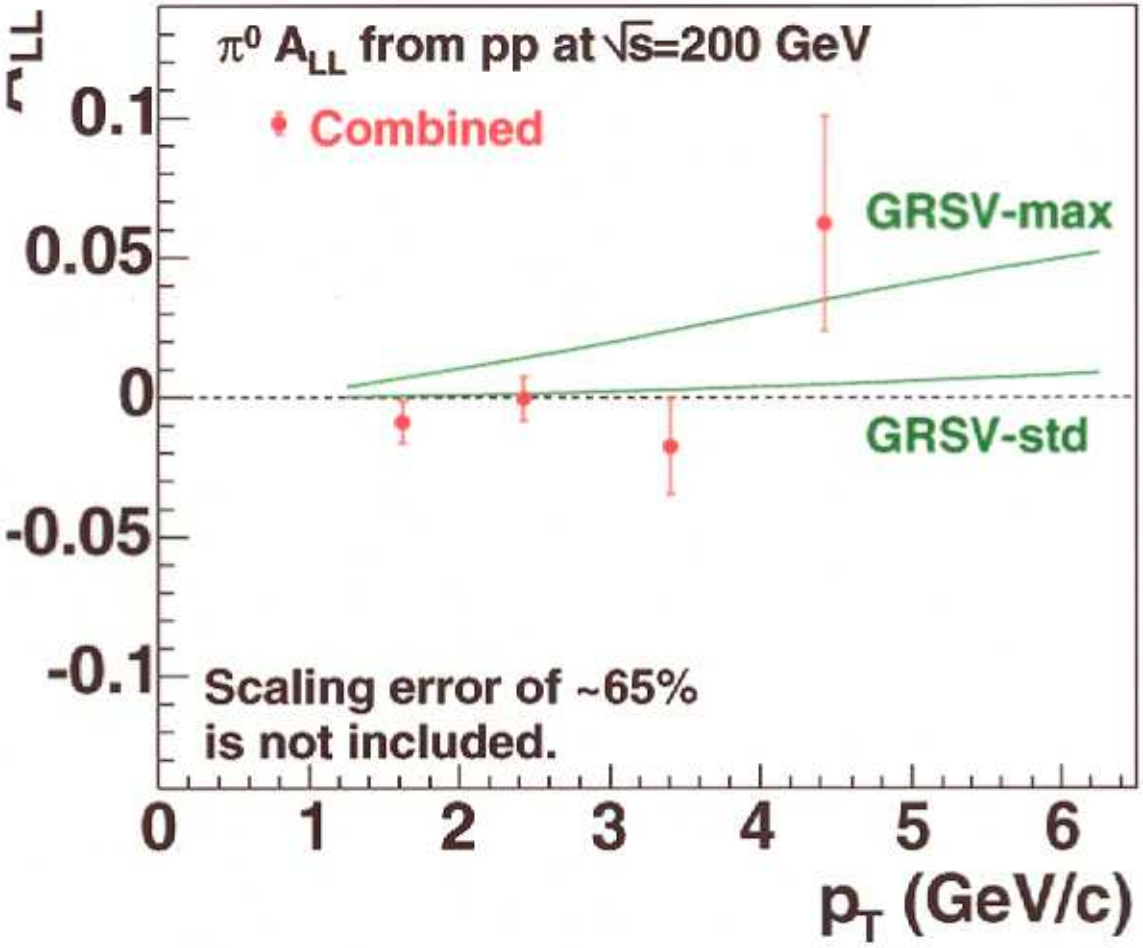


Chi-square test to check consistency between Run-3 and Run-4.
——> χ^2/NDF = 5.7 / 4

Figure of merit
Run-3 : 1.17
Run-4 : 1.92
——> A_{LL} uncertainty become smaller.

p_T (GeV/c)	$A_{LL}^{\pi^0}$ (Run 4) (%)	$A_{LL}^{\pi^0}$ (Run 3) (%)	$A_{LL}^{\pi^0}$ comb. (%)
1-2	0.0± 0.9	-2.7± 1.3	-0.9±0.7
2-3	0.7± 1.0	-1.3± 1.3	0.0±0.8
3-4	-1.8± 2.2	-1.7± 2.8	-1.8±1.7
4-5	9.7± 4.9	0.7± 6.2	6.2±3.8

Comparison with theory



GRSV-std :
$\int \Delta g \, dx = 0.7$ at $Q = 2.2$ GeV

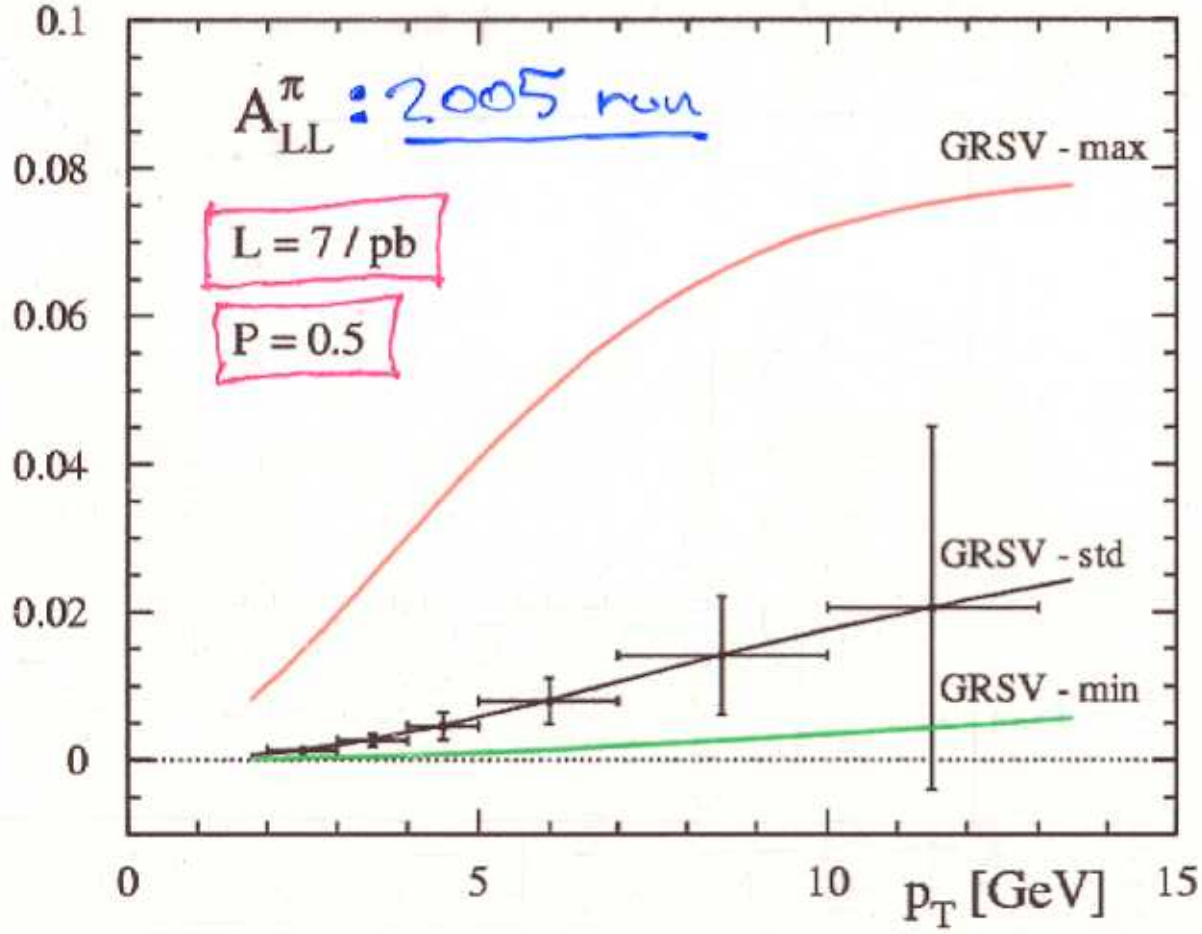
GRSV-max :
$\Delta g(x) = g(x)$ at the input scale.

Confidence level between theory and Run-3 & Run-combined data shows measurement supports GRSV-std model.
(B. Jager et.al., PHys. Re
D67, 054005 (2003))

	GRSV-std	GRSV-max
4 points (1-5 GeV/c)	21-24%	0.00-6%
3 points (2-5 GeV/c)	27-29%	0.01-13%

π^0 Production and ΔG

π^0 can be used to determine ΔG with limited L & P



Jager, Schafer, Stratmann, Vogelsang