Double Helicity Asymmetry measurements with PHENIX Detector@RHIC

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Why RHIC?

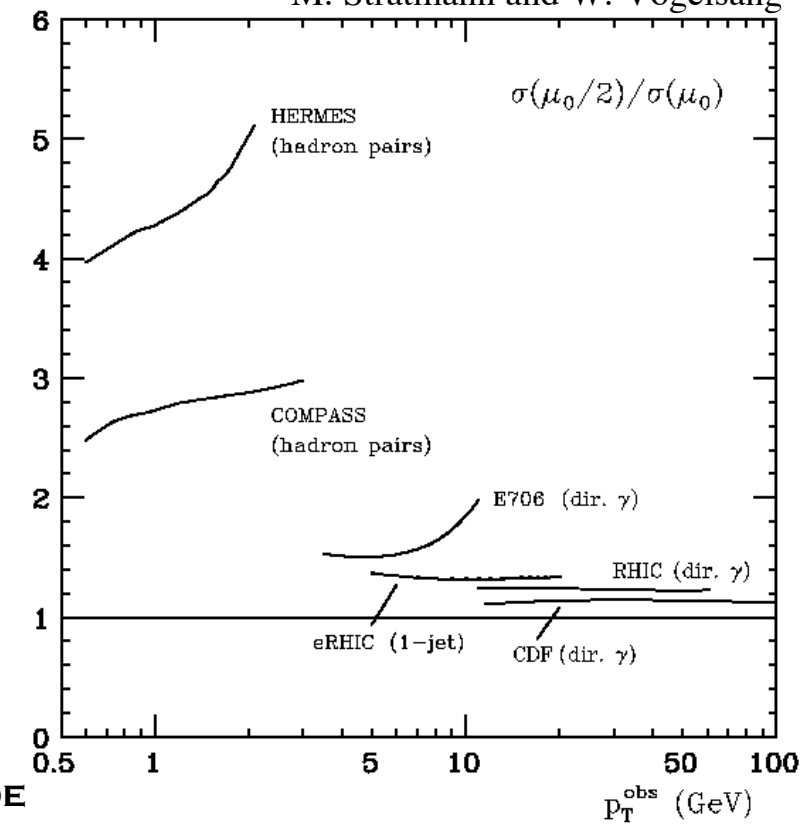
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

- Most of our knowledge of the nucleon spin presently comes from Deep Inelastic Scattering (DIS) Fixed Target Experiments
  - EMC (Nucleon Spin Crisis), SMC, SLAC (E80, E131, E142-E155x), *HERMES, COMPASS, Jlab ==> Still active*
  - Discovered the possibly large significance of polarized gluon distribution to this problem: **relying on NLO pQCD analysis** or **di-hadron production from photon-gluon-fusion** events

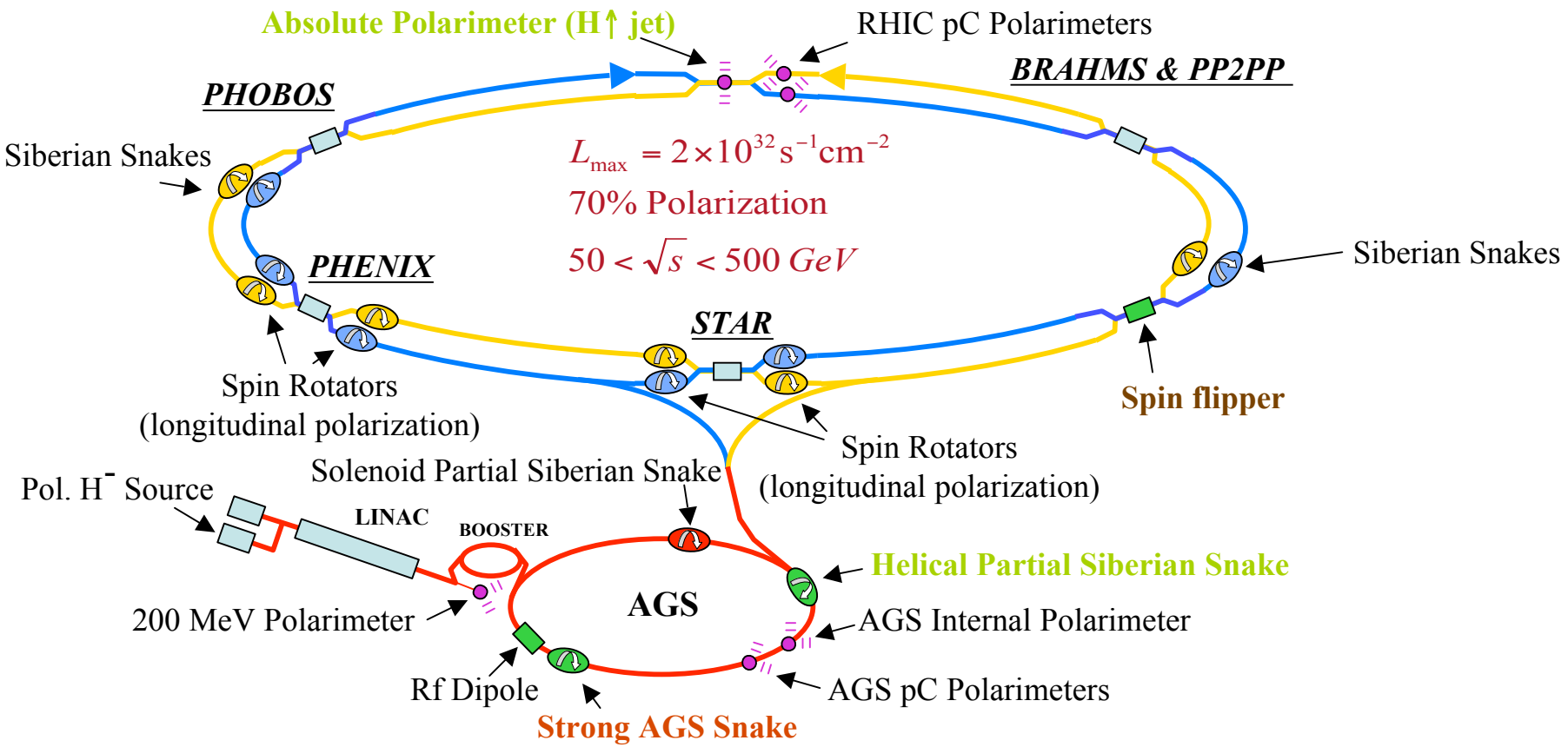
- Message from 1990s:
  - Measure ΔG by **"direct"** methods
  - To allow interpretation of asymmetries in terms of polaized gluon distributions, **keep the experimental measurements at high scales/scales**

- **RHIC accommodates both these requirements naturally**
- Future measurements at eRHIC (Saturday morning)

M. Stratmann and W. Vogelsang

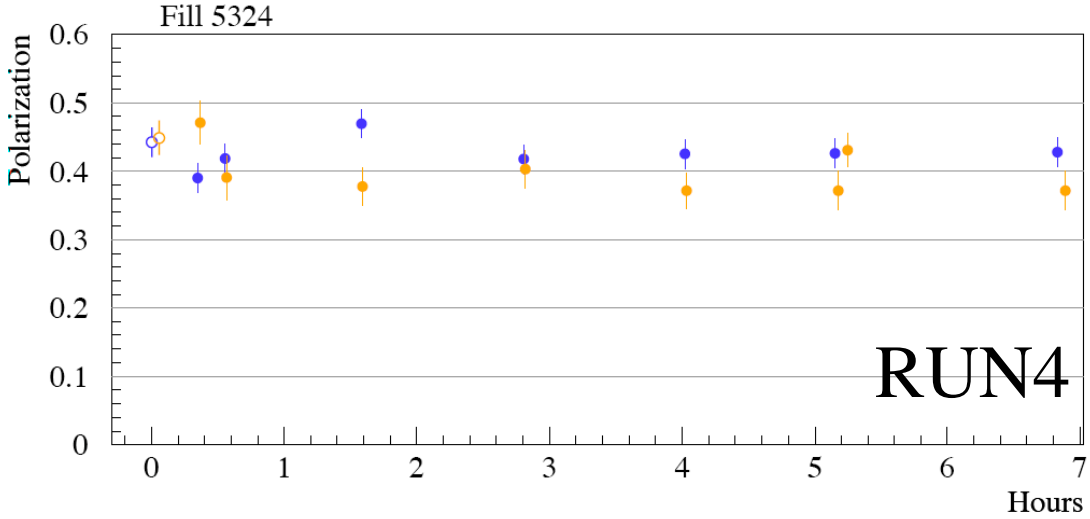


RHIC Polarized Collider



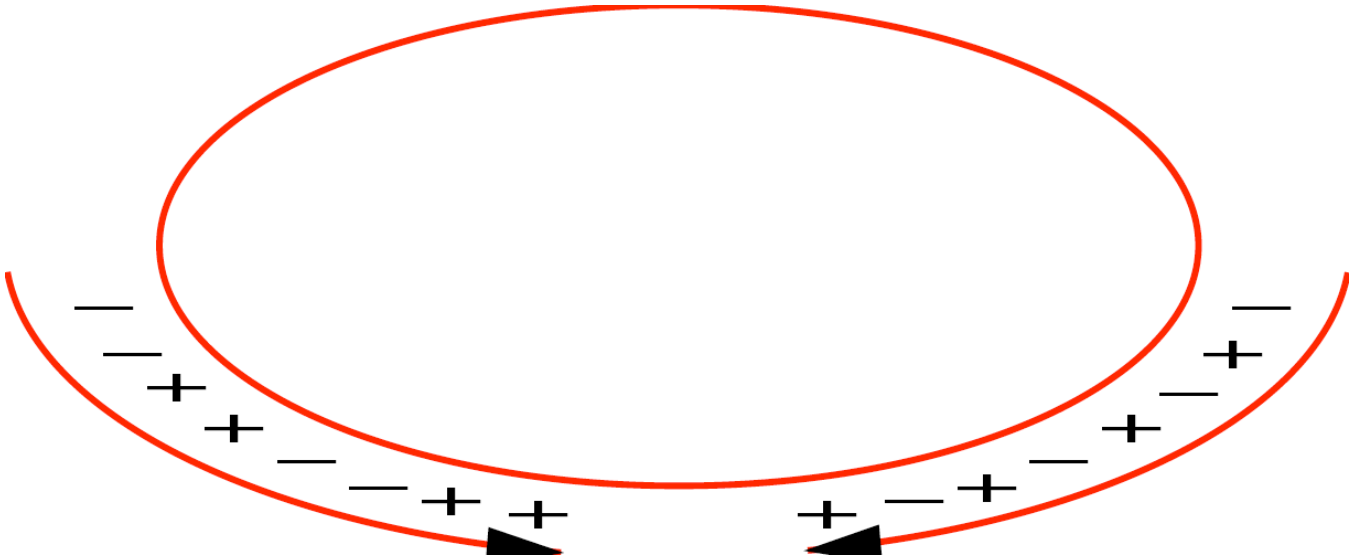
- Installed and commissioned during FY04 run
- Plan to be commissioned during FY05 run
- Installed and plan to be commissioned during FY05 run

Polarization in RHIC



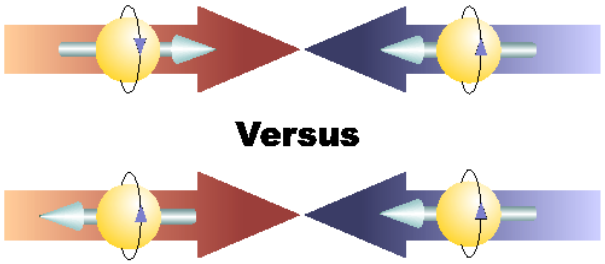
- RUN 4 RHIC pp average polarization (0.39 +/- 0.03)
- Last week 45-50% polarization seen **fill-after-fill** for a luminosity of 0.4 x 10^{31} cm^{-2} $sec^{-1,}$ with luminosity life times of 7-9 hrs.
- AGS cold snake installed March 2005 (few weeks ago):
  - Commissioning in Run-5 (on going)
  - Expected polarization in Run-6 for Physics >65%

Exquisite Control Of Systematics



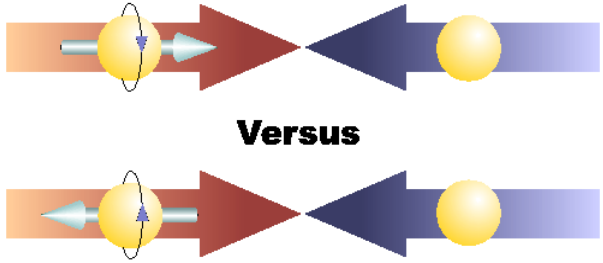
This talk

$$A_{LL} \rightarrow \frac{\Delta G}{G}$$



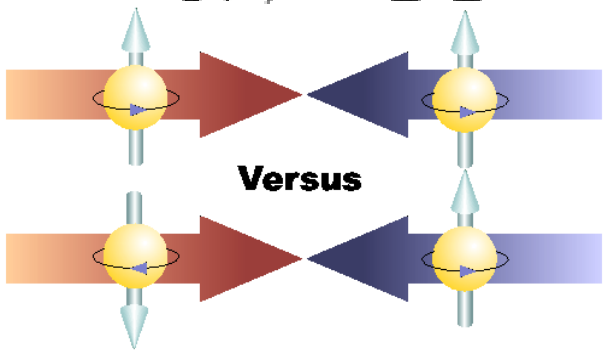
X. Wei

$$A_L^{W^\pm} \rightarrow \frac{\Delta q}{q}; \frac{\Delta \bar{q}}{\bar{q}}$$



M. Chiu

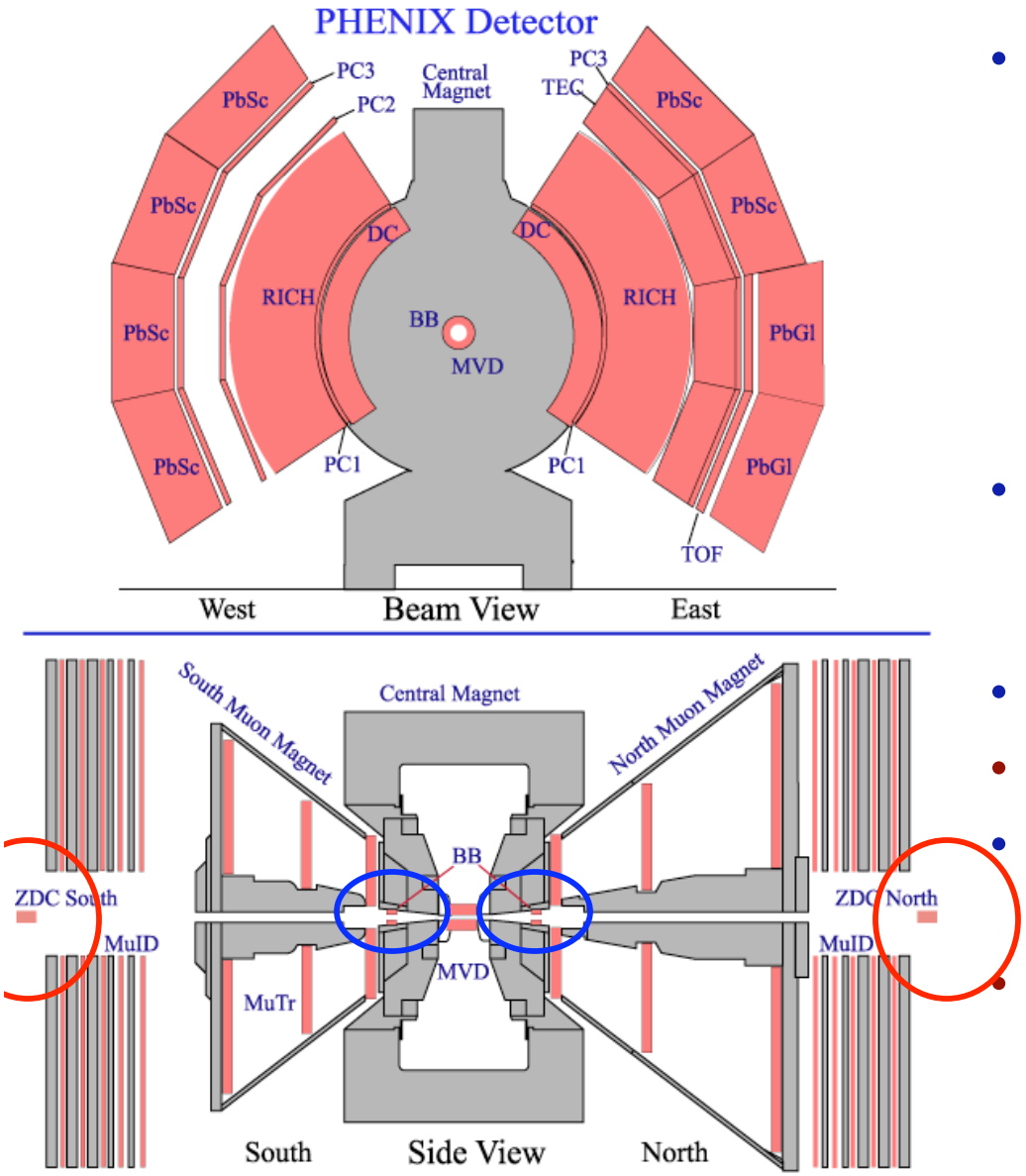
$$A_N, A_{TT}$$



12 Countries; 57 Institutions; 460 Participants

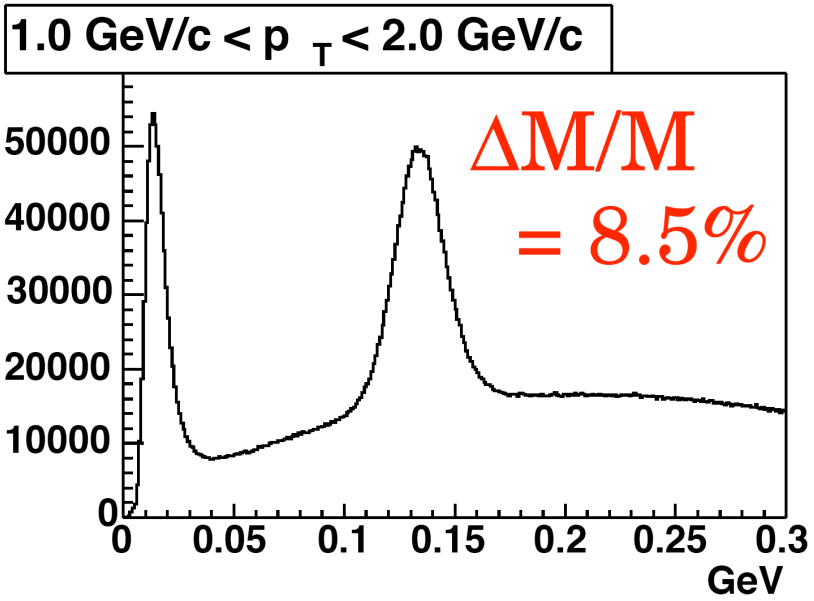
Brazil	University of São Paulo, São Paulo
China	Academia Sinica, Taipei, Taiwan
	China Institute of Atomic Energy, Beijing
	Peking University, Beijing
France	LPC, University de Clermont-Ferrand, Clermont-Ferrand
	Dapnia, CEA Saclay, Gif-sur-Yvette
	IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, Orsay
	LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau
	SUBATECH, Ecòle des Mines at Nantes, Nantes
Germany	University of Münster, Münster
Hungary	Central Research Institute for Physics (KFKI), Budapest
	Debrecen University, Debrecen
	Eötvös Loránd University (ELTE), Budapest
India	Banaras Hindu University, Banaras
	Bhabha Atomic Research Centre, Bombay
Israel	Weizmann Institute, Rehovot
Japan	Center for Nuclear Study, University of Tokyo, Tokyo
	Hiroshima University, Higashi-Hiroshima
	KEK, Institute for High Energy Physics, Tsukuba
	Kyoto University, Kyoto
	Nagasaki Institute of Applied Science, Nagasaki
	RIKEN, Institute for Physical and Chemical Research, Wako
	RIKEN-BNL Research Center, Upton, NY
	University of Tokyo, Bunkyo-ku, Tokyo
	Tokyo Institute of Technology, Tokyo
	University of Tsukuba, Tsukuba
	Waseda University, Tokyo
S. Korea	Cyclotron Application Laboratory, KAERI, Seoul
	Kangnung National University, Kangnung
	Korea University, Seoul
	Myong Ji University, Yongin City
	System Electronics Laboratory, Seoul Nat. University, Seoul
	Yonsei University, Seoul
Russia	Institute of High Energy Physics, Protovino
	Joint Institute for Nuclear Research, Dubna
	Kurchatov Institute, Moscow
	PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg
	St. Petersburg State Technical University, St. Petersburg
Sweden	Lund University, Lund
USA	Abilene Christian University, Abilene, TX
	Brookhaven National Laboratory, Upton, NY
	University of California - Riverside, Riverside, CA
	University of Colorado, Boulder, CO
	Columbia University, Nevis Laboratories, Irvington, NY
	Florida State University, Tallahassee, FL
	Georgia State University, Atlanta, GA
	University of Illinois Urbana Champaign, IL
	Iowa State University and Ames Laboratory, Ames, IA
	Los Alamos National Laboratory, Los Alamos, NM
	Lawrence Livermore National Laboratory, Livermore, CA
	University of New Mexico, Albuquerque, NM
	New Mexico State University, Las Cruces, NM
	Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
	Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY
	Oak Ridge National Laboratory, Oak Ridge, TN
	University of Tennessee, Knoxville, TN
	Vanderbilt University, Nashville, TN

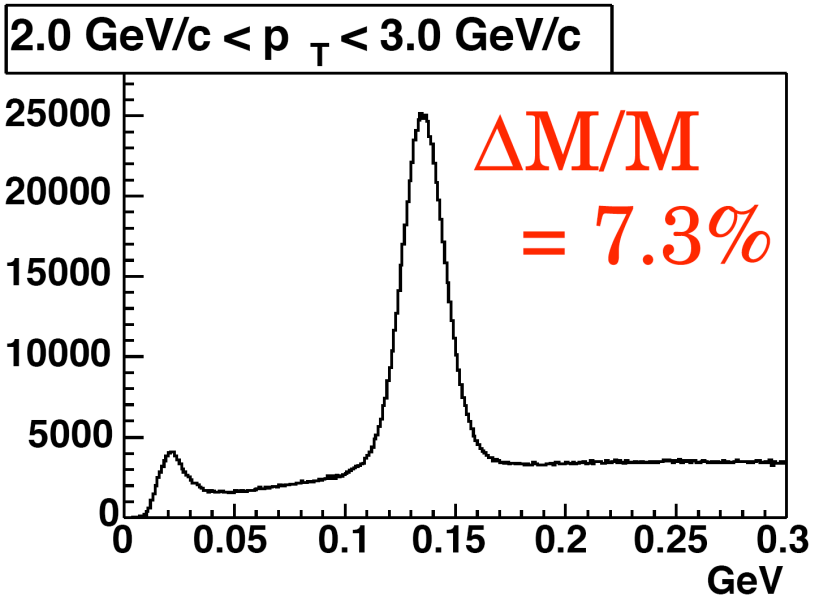
PHENIX Detector & Design Philosophy

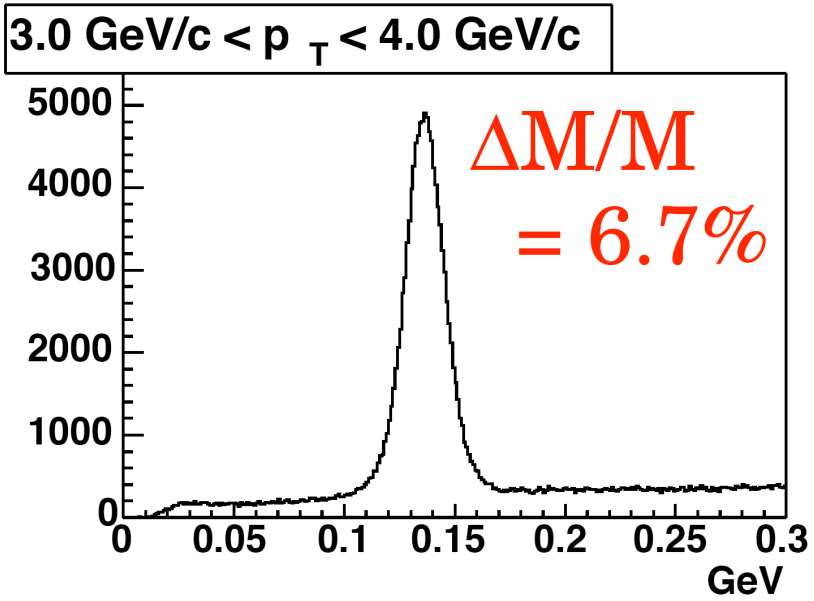


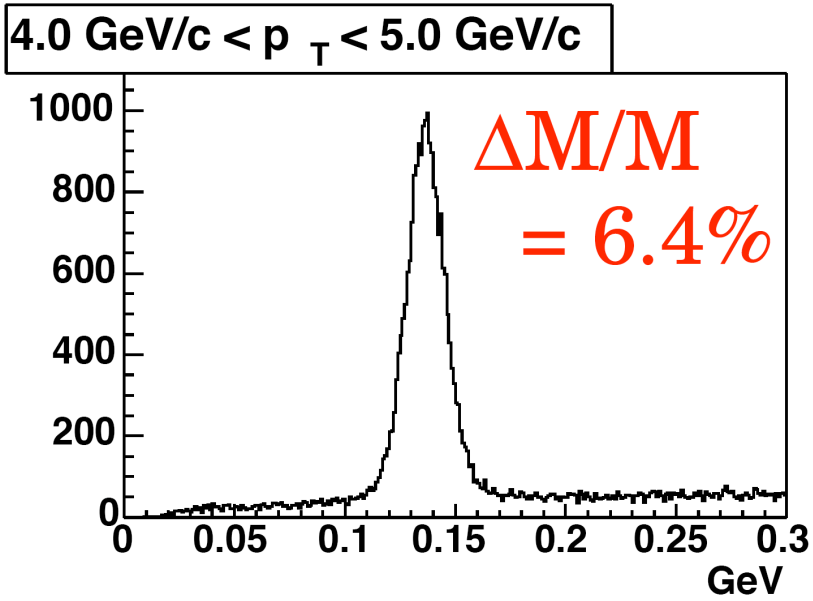
- **Philosophy:**
  - **High resolution** at the cost of acceptance
  - **High rate** capable DAQ
  - Excellent **trigger capability** for rare events
- **Central tracking**: Pad chamber, drift chamber, time expansion chamber
- **Forward tracking:** Muon tracker
- ***Central arm EM Calorimetry***
- Particle ID: Muon ID, RICH, TOF, TEC
- ***Global Detectors: Beam-Beam Counter, Zero-Degree-Calorimeter***

π^0 Reconstruction





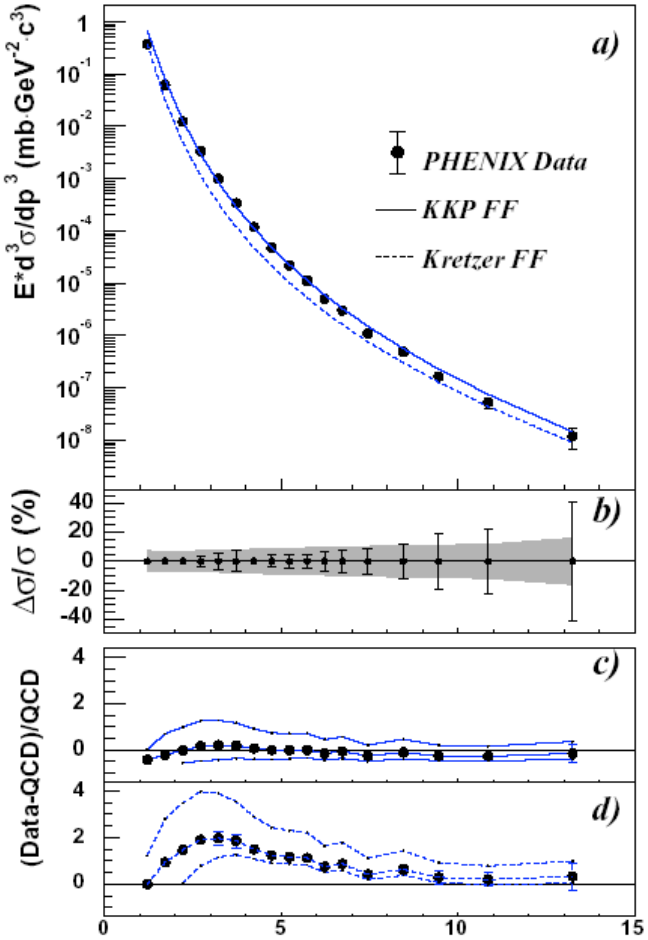




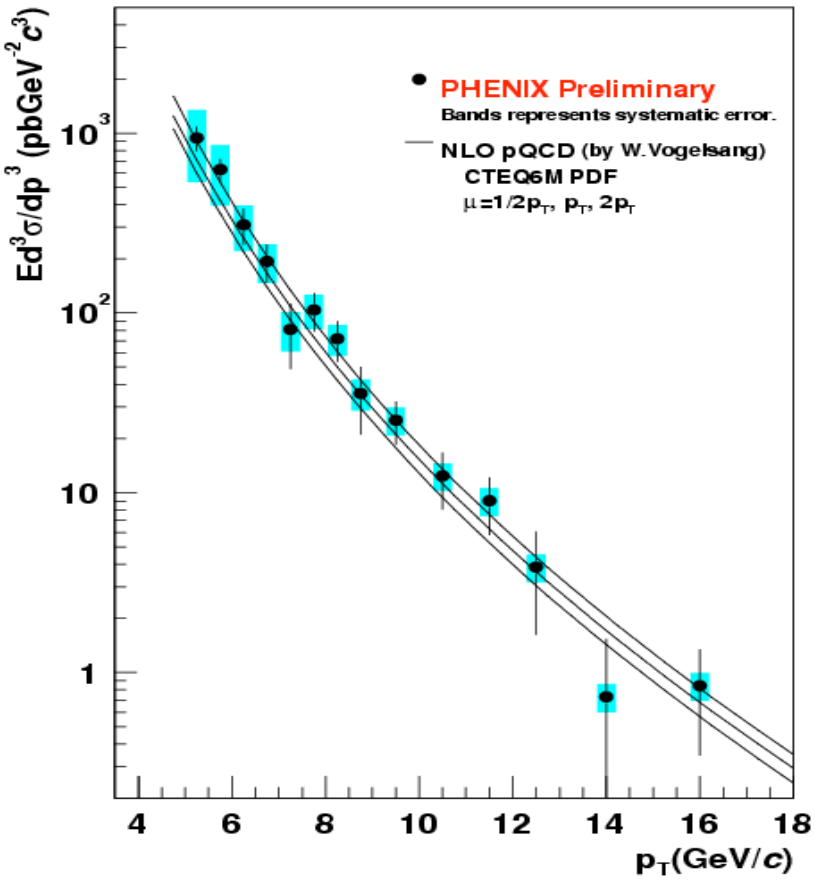
Cornerstone of RHIC Spin Program

- Measured un-polarized cross section at Sqrt(s)=200 GeV are well described by the **Next-to-Leading Order cross sections**

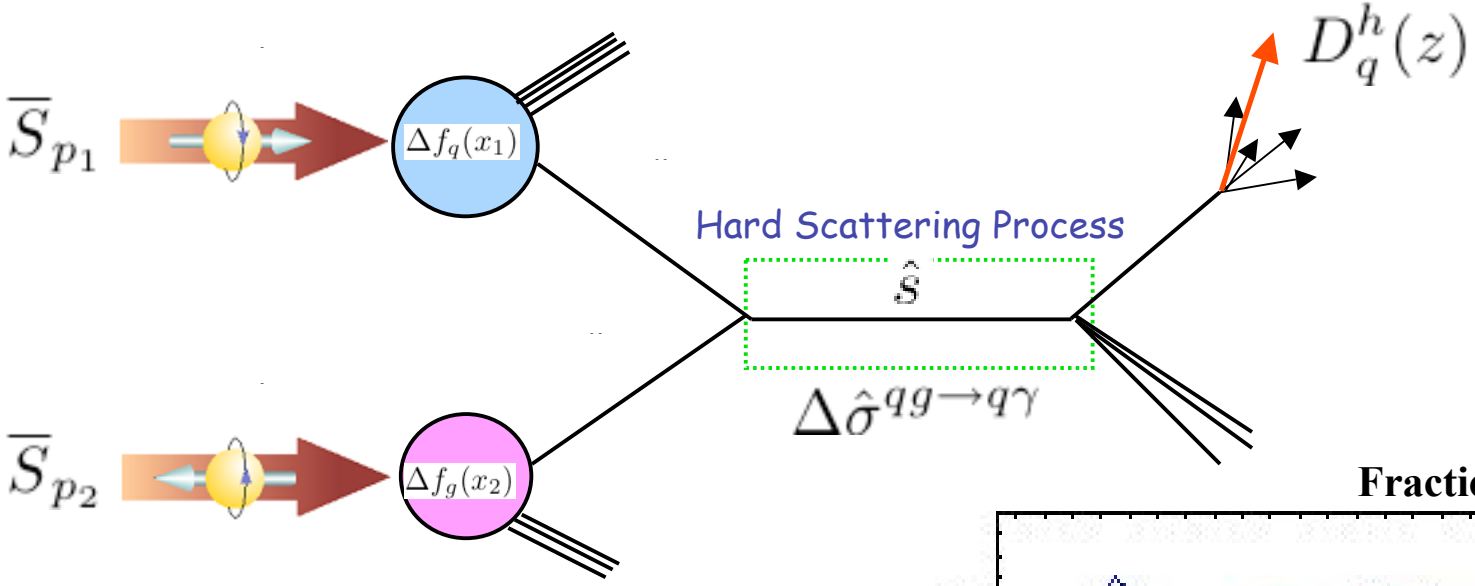
$pp \rightarrow \pi X$



$pp \rightarrow \gamma X$

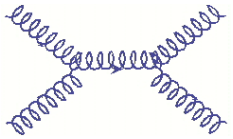


Double Spin: Leading hadrons



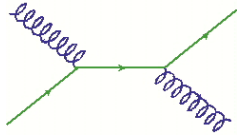
$h = \pi^0$

$gg \to gg$



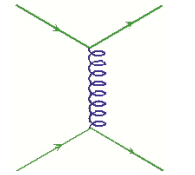
$\propto \frac{\Delta G}{G}\frac{\Delta G}{G}$

$gq \to gq$



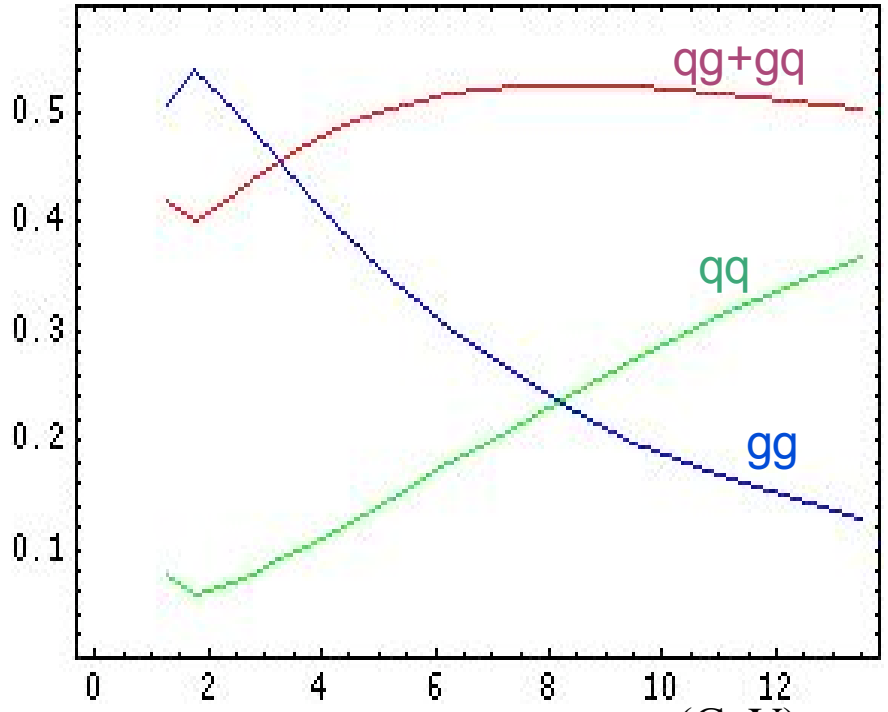
$\propto \frac{\Delta q}{q}\frac{\Delta G}{G}$

$qq \to qq$



$\propto \frac{\Delta q}{q}\frac{\Delta q}{q}$

Fraction of π^0 produced



A_{LL} & Background Subtraction

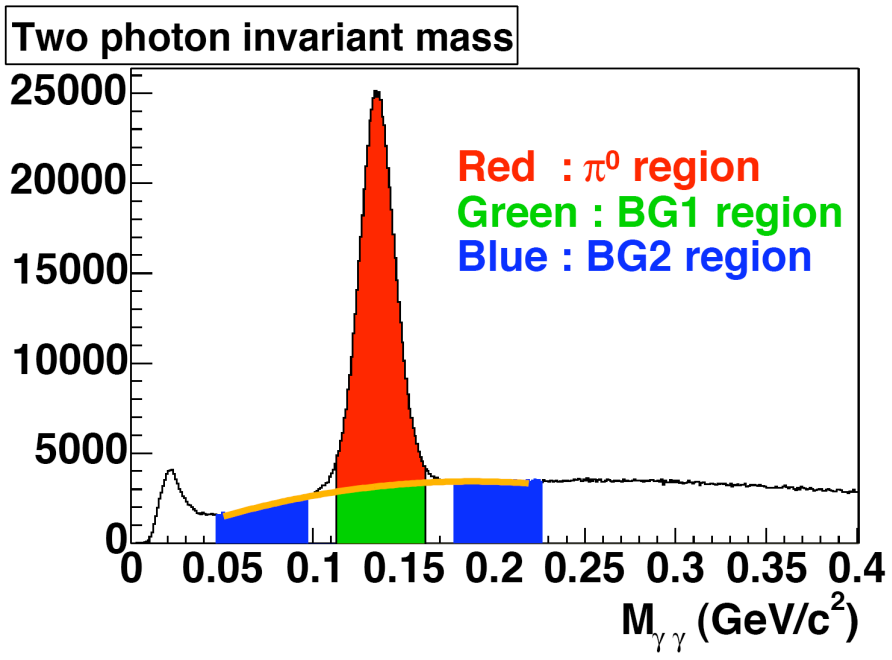
- Calculate A_{LL} (π^0 + BG1) and A_{LL}(BG2) independently

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P \cdot P} \cdot \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}} \text{where} R = \frac{L_{++}}{L_{+-}}$$

- Fit π^0 peak and get the correction factors

$$W_{BG} = 1 - W_{\pi^0} \quad \text{where} \quad W_{\pi^0} = \frac{\pi^0}{\pi^0 + BG1}$$

- Subtract A_{LL}(BG2) from A_{LL}(π^0 + BG1) to get A_{LL}(π^0)



p_T (GeV/c)	π^0 stat. (w_{BG})
1-2	1151k (31%)
2-3	510k (13%)
3-4	91k (7%)
4-5	17k (5%)

Gluon Spin Program has begun!

- Data taken in **4 weeks in Run 3** & **4 days of 2004**
- Longitudinal spin asymmetry measurement at PHENIX
  - *Beam polarization measurement using p-Carbon CNI polarimetry and Jet-Polarimetry (**See Sandro Bravar's talk**)*
  - *Forward neutron production based local polarimetry*
  - *Relative luminosity variations less than 2.5 x 10^{-4}*

Uncertainties improve As $P^2\mathrm{Sqrt}(L)$

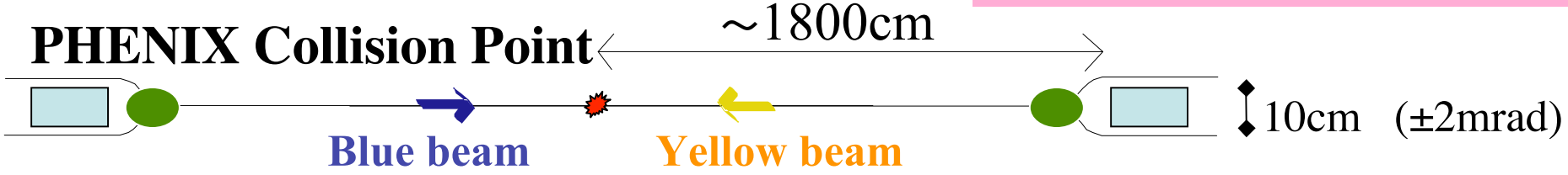
	Run Time	Int. Lum.	Pol.	P^4L
Run 3 (2003)	4 weeks	220 nb^{-1}	27%	1.17 nb^{-1}
Run 4 (2004)	4 days	75 nb^{-1}	40%	1.92 nb^{-1}

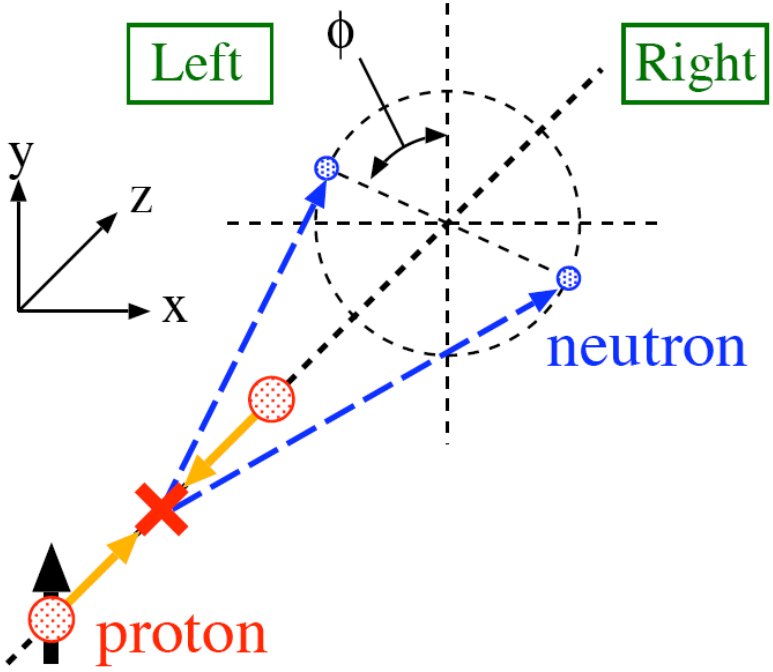
Double helicity asymmetry in inclusive mid-rapidity neutral pion production for polarized -pp collisions at Sqrt(s)=200 GeV hep-ex/0404027, Published: PRL 93, 202002 (2004)

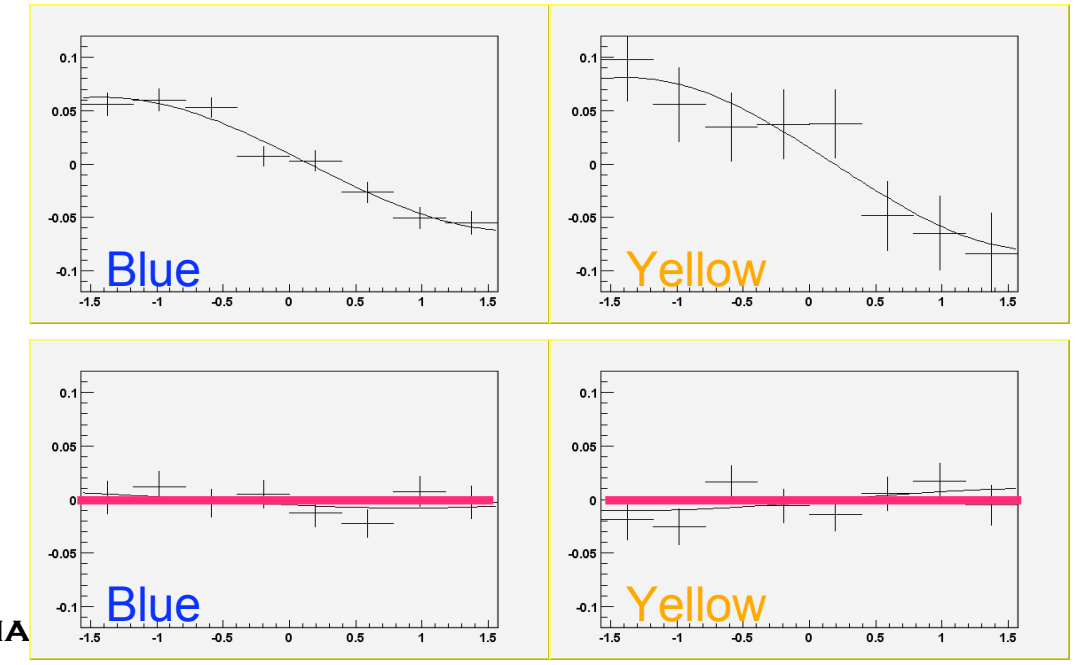
PHENIX Local Polarimeter

- Spin Rotator Magnets enable longitudinal collisions in IRs
- PHENIX discovered at low pT and high xF an analyzing power in neutron production in pp collisions at 100 GeV
- ZDC + Shower Max Detector

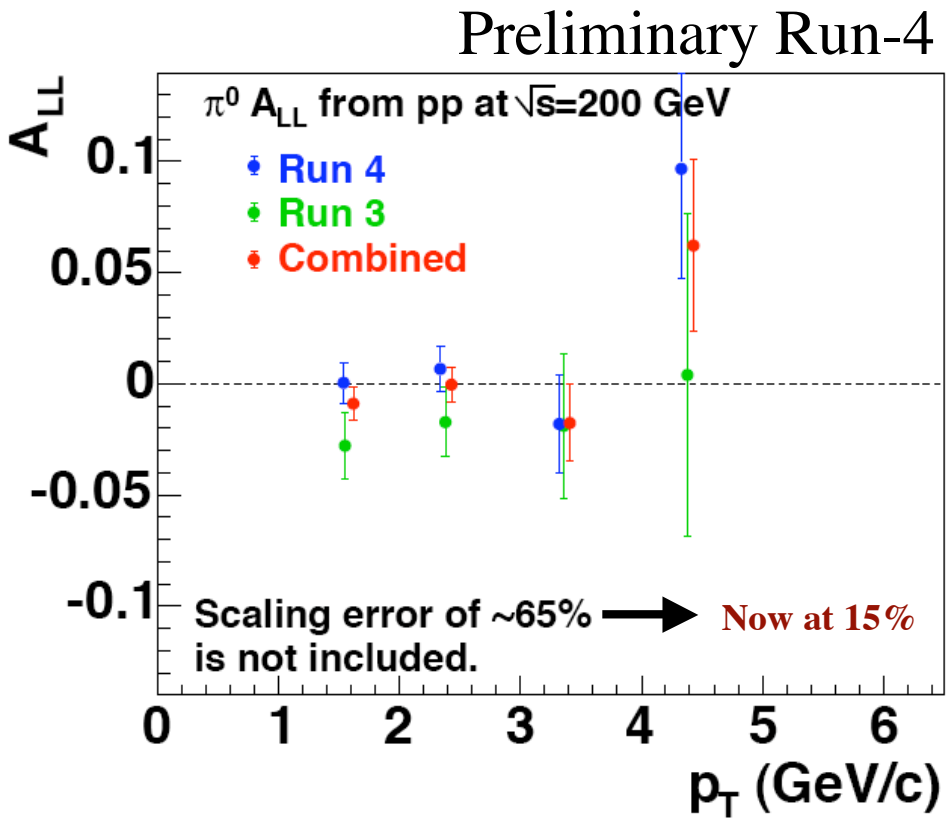
$P_L/P > 0.99$ blue & yellow







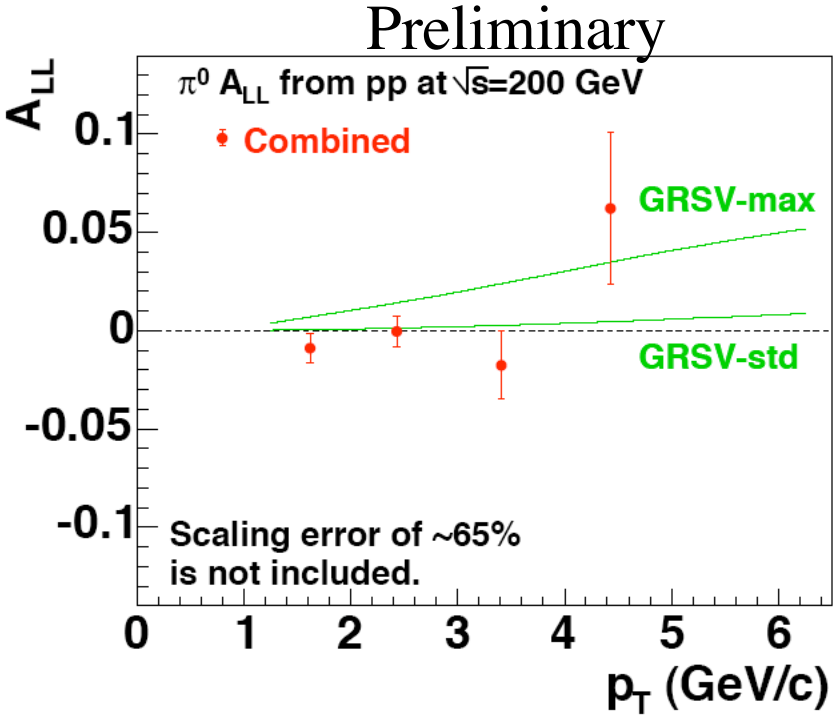
$A_{LL}(\pi^0)$: Run-3 & Preliminary Run-4



- Data from Run-3 and Run-4 consistent:
  - $Ch^2/DF = 5.7/4$
- Figure of merit of Run3 and Run4 are: 1.17 and 1.92, respectively
  - Uncertainties in Run-4 smaller in spite of significantly fewer events

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: best fit to DIS data

$$\int_0^1 \Delta G(x)dx \sim \ 0.7 \text{ at } \mathrm{Q}^2 \ 1 \ \mathrm{GeV}^2$$

- GRSV-max

$$\Delta G(x) = G(x) \text{ at } \mathrm{Q}^2_{\mathrm{input}} = \ 0.40 \ \mathrm{GeV}^2$$

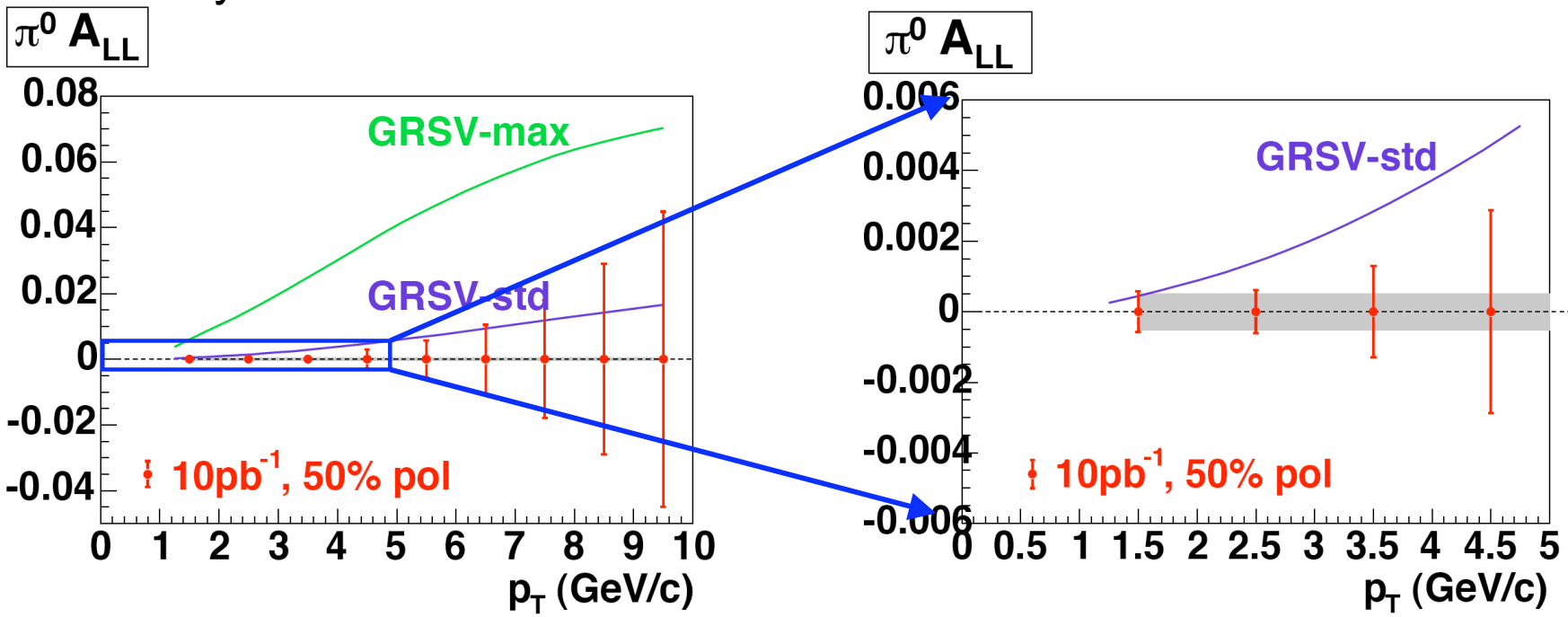
- Data prefers the GRSV-std curve (and hence the gluon distribution and its first moment)
  - B. Jaeger et al. Phys. Rev. D67, 054005 (2003)

Confidence Levels

	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%

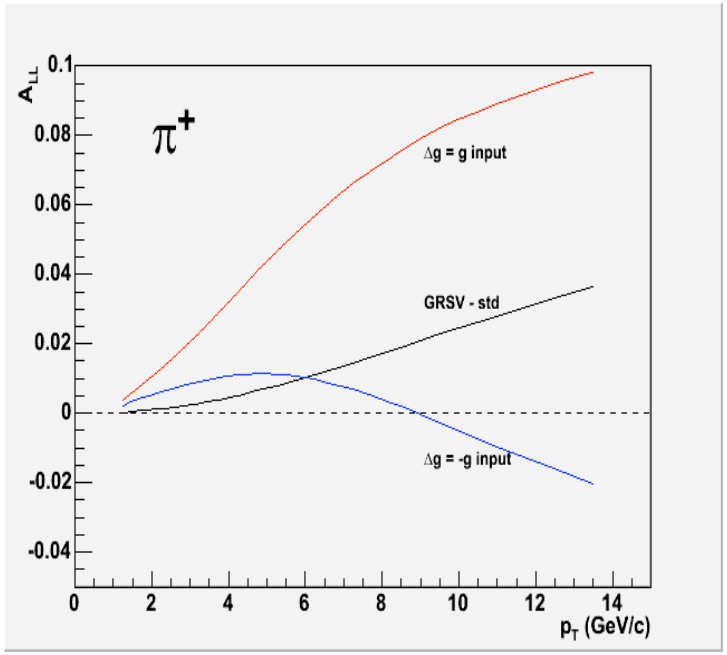
Run-5 Started April 19, 2005

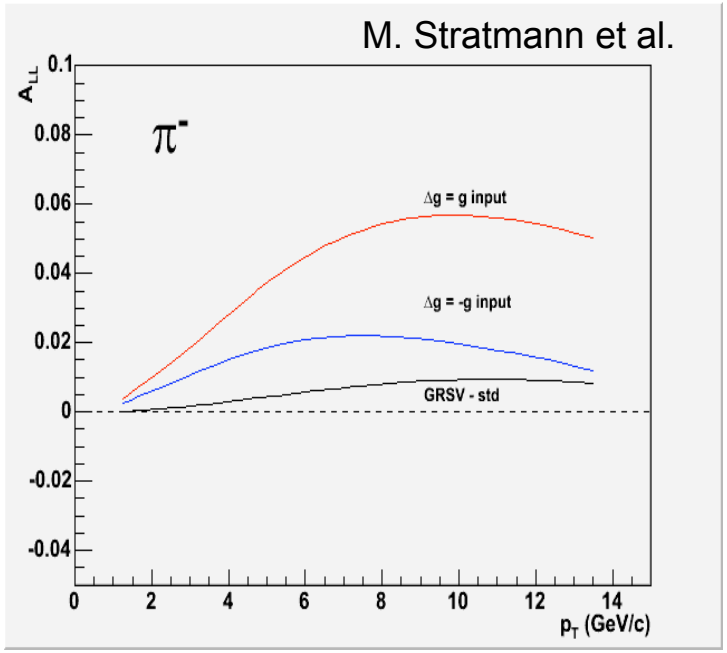
- Run ends June 25
- 8-9 Physics Weeks
  - Expect ~5-10 pb-1 with ~45% average beam polarization
  - **Status Last Week**: beam polarization > 45% last week, luminosity low by factor 3 so far



Near Term Outlook

- Run-6 a strong siberian snake to go in AGS:
  - Beam Polarization 50% ==> 65-70%
  - Luminosity expected to increase as well ~65 pb-1
- **Helicity asymmetry for π^0 at Higher pT (> 6 GeV/c)** and also *relative sizes of charged pion double spin asymmetries*





$$\Delta G > 0 \Rightarrow A_{LL}^{\pi^+} > A_{LL}^{\pi^0} > A_{LL}^{\pi^-}$$

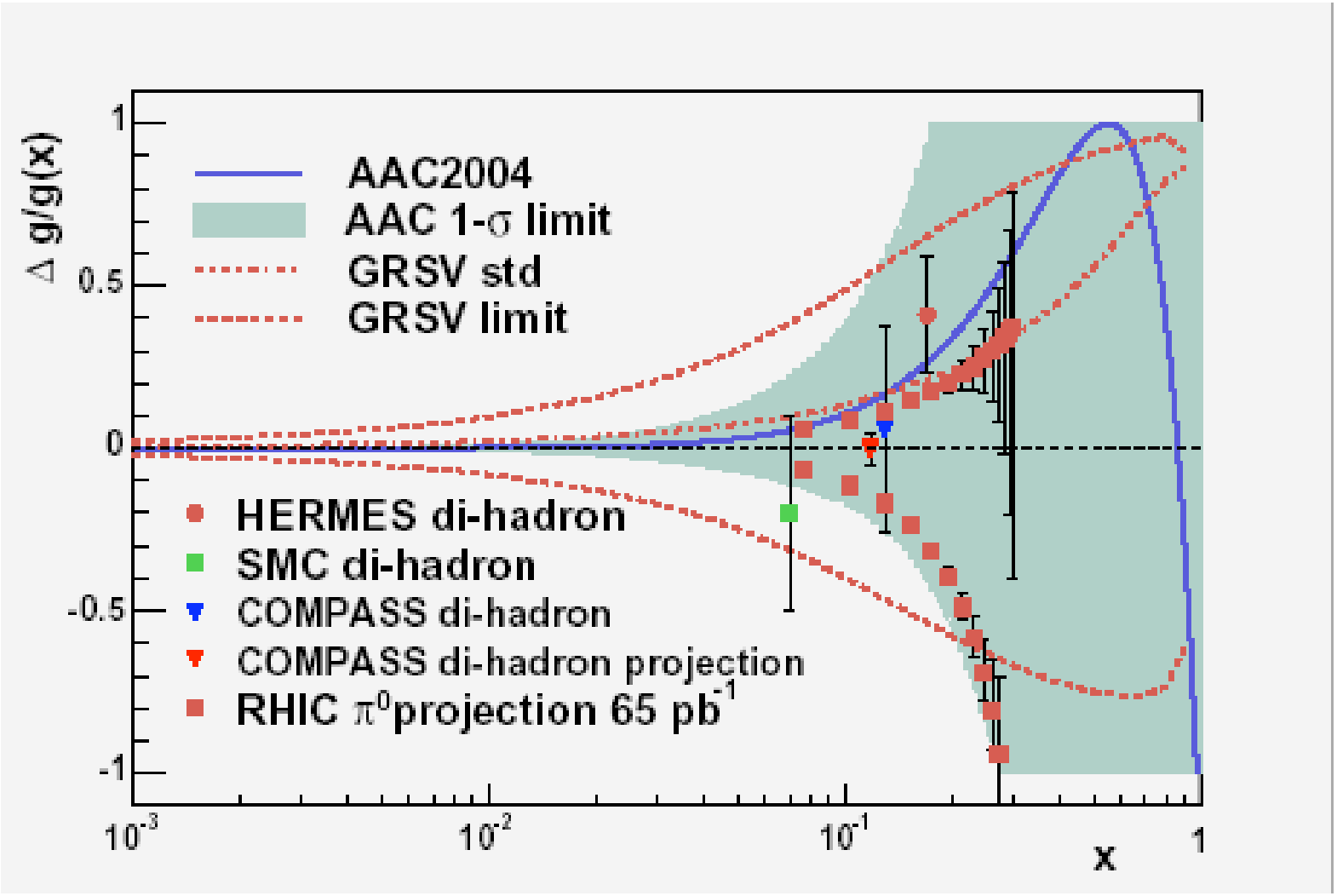
Summary & Outlook

- **Summary**
  - **First measurement of a double helicity asymmetry in neutral pion production from the RHIC spin program**
  - **ΔG measurements theoretically clean**
- **Outlook:**
  - ***Uncertainties are large but they will improve with P^2 Sqrt(L)***
  - > 45% polarization from store to store already demonstrated in Run-5
  - Luminosity development in progress this week
- **Upgrades:**
  - **Accelerator:** A significance run expected next year
    - **Run 6: Cold Snake Operational in AGS: Polarization 65-70%**
  - **PHENIX Detector**: Run 8,9 physics and detector upgrade
    - Forward Detector Upgrades for Parity Violating W production: **X.Wei's talk**
    - Silicon VTX detector in increase the **x range of $\Delta G/G$ coverage**

Research Plan for Spin Physics For RHIC, Feb. 2005 BNL 73798-2005

After Run-6

- Final inclusive π^0 production result at Sqrt(s)=200 GeV



Relative Luminosity

- Beam-Beam Counter (BBC) used as Relative Luminosity Monitor
  - Low background
  - High statistics
- Zero Degree Calorimeters (ZDC)s used as a cross check
  - ***Different kinematics and acceptance***
- Bunch by bunch comparison of ratio of multiplicities in BBC vs. ZDC

- **Achieved relative luminosity precision $\delta R = \delta(L^{++}/L^{+-}) < 2.5 \times 10^{-4}$**
  - Estimate limited by ZDC statistics (30 times lower than that of BBC)
- ***Relative luminosity contribution to $A_{LL}(\pi^0)$***
  - ***< 0.2% for Run3 (27% beam polarization)***
  - ***< 0.1% for Run4 (40% beam polarization)***
- A_{LL} for BBC relative to ZDC consistent with zero (< 0.1%)
  - Strongly indicates that both double spin asymmetries are zero