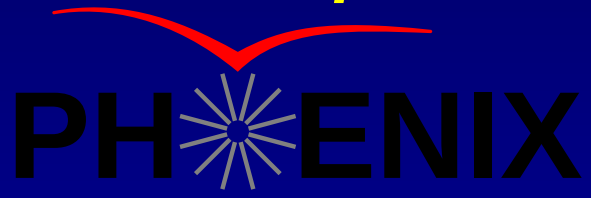
Looking Toward a Global Analysis of Helicity Distributions Including Data from



Christine Aidala
Columbia University

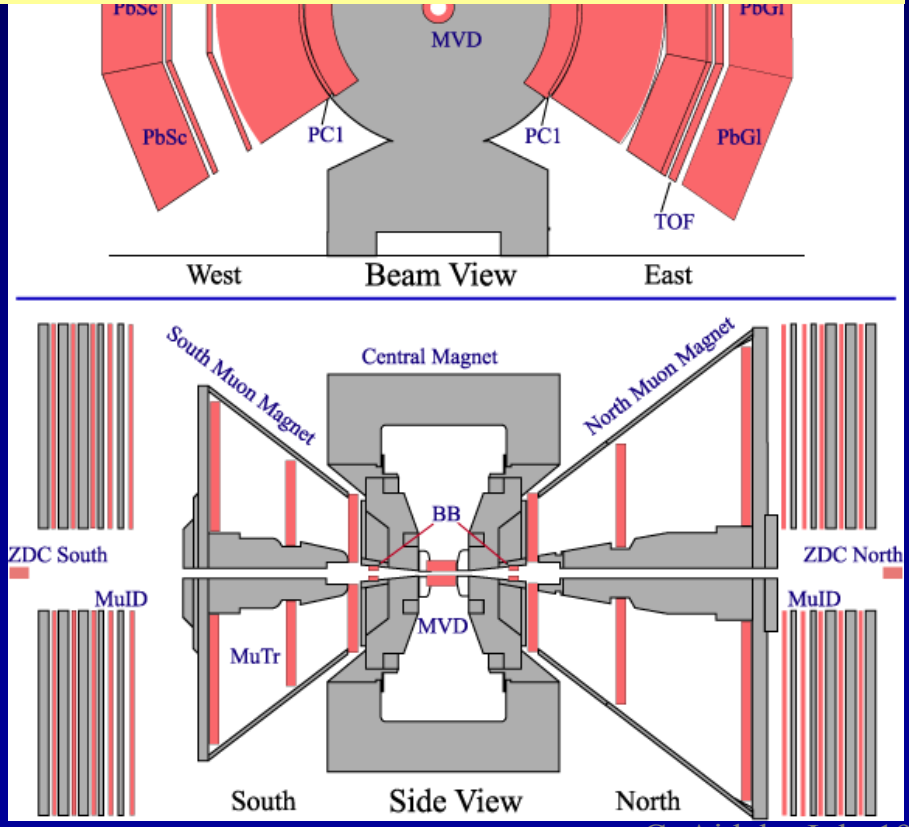
July 19, 2005

PHENIX

The PHENIX detector

Philosophy:

- ✓ High rate capability & granularity
- ✓ Good mass resolution and particle ID
- ➢ Sacrifice acceptance



Central Arms

$|\eta| < 0.35$

$\Delta\phi = 180$ degrees

Photons

(EMCal: Lead-glass and lead scintillator)

Charged tracks

(Beam-Beam, Drift Chamber, Pad Chambers)

+ RICH rings

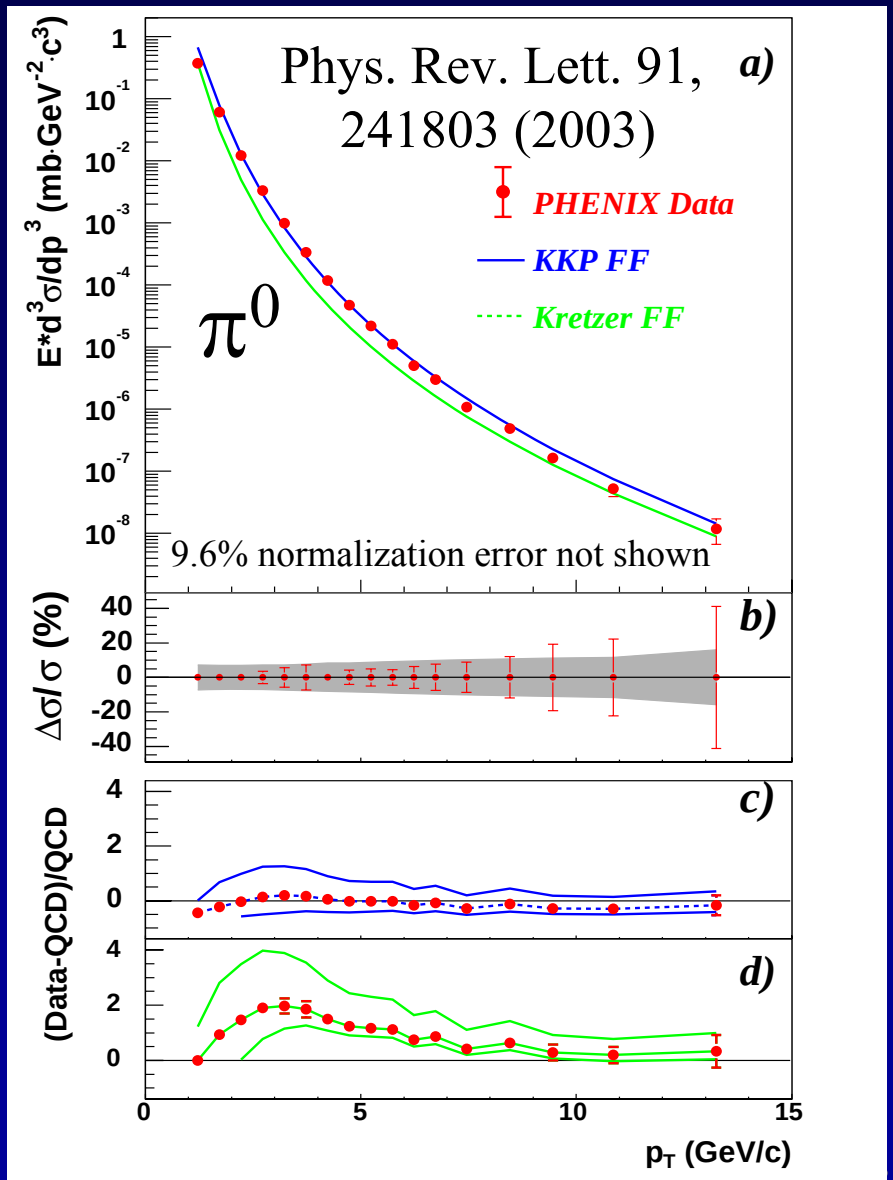
+ EMCal clusters

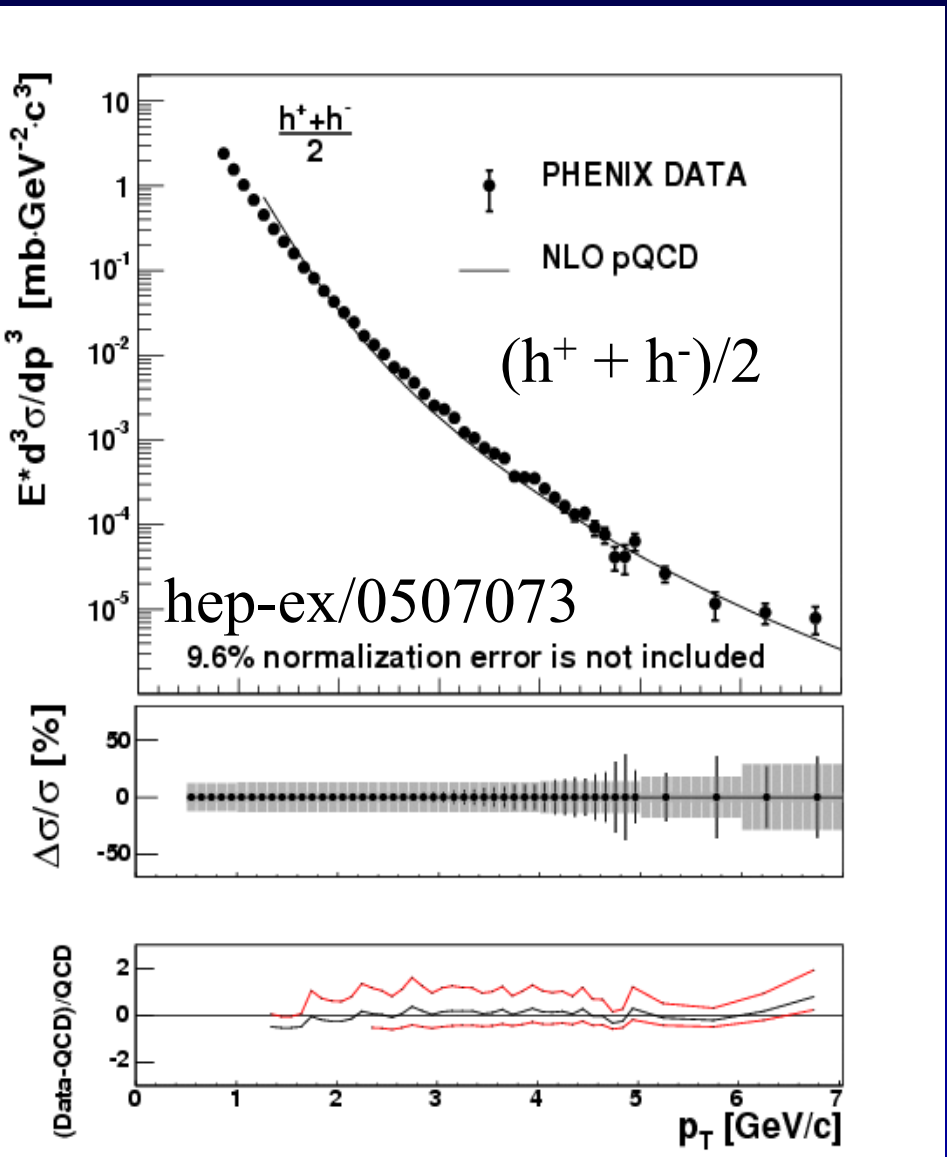
Forward Muon Arms

$1.2 < |\eta| < 2.4$

$\Delta\phi = 2\pi$

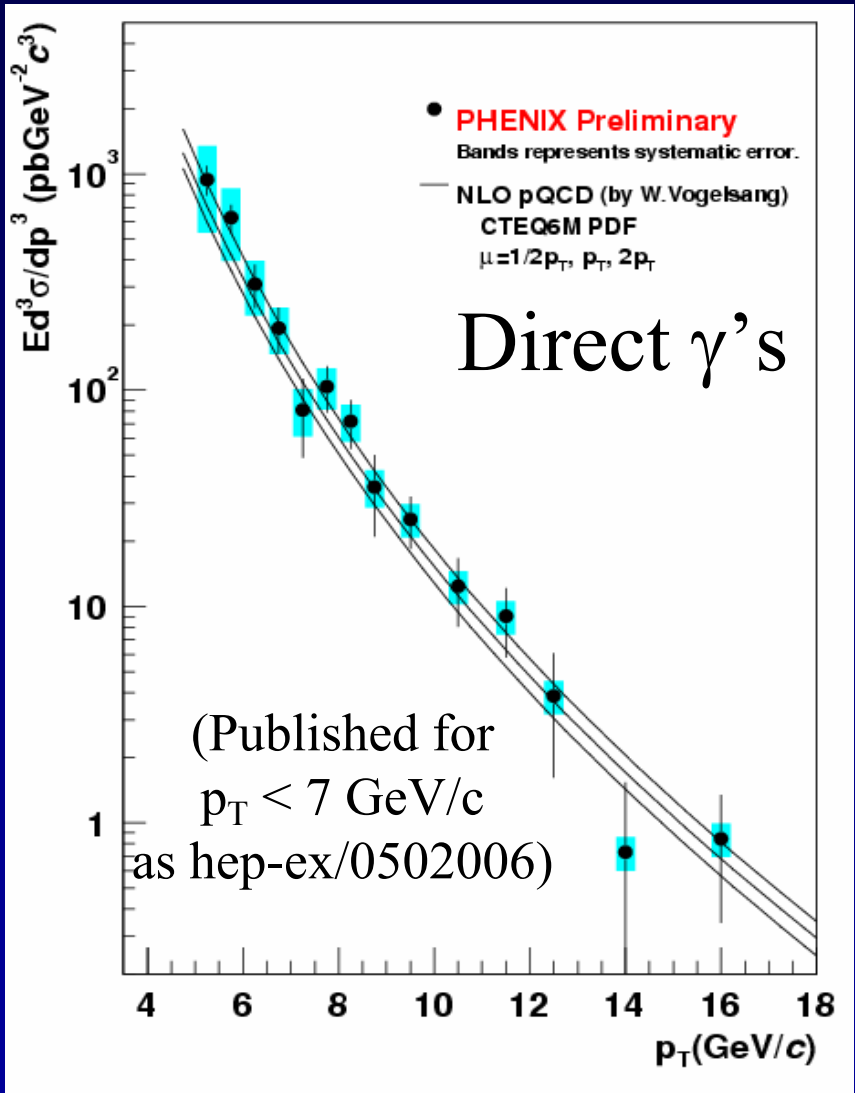
Cross section measurements

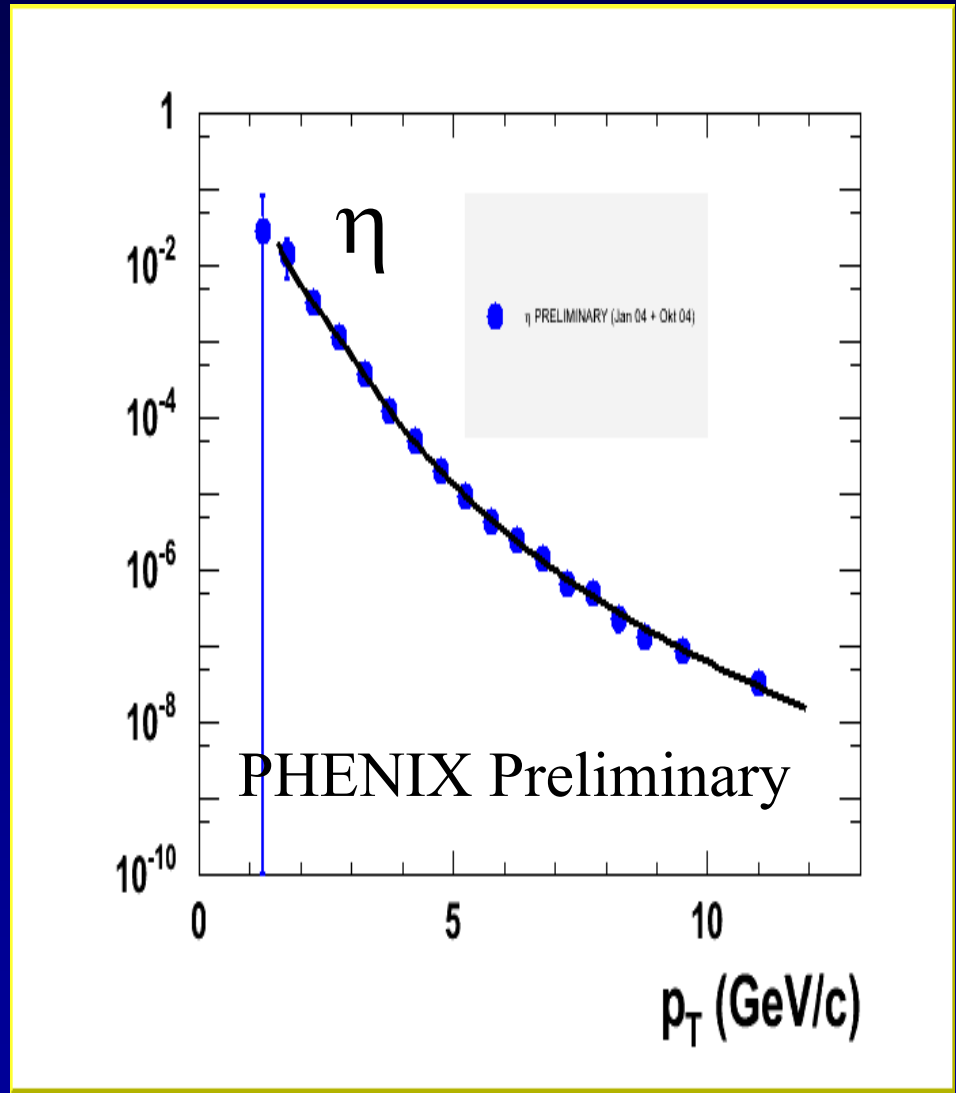




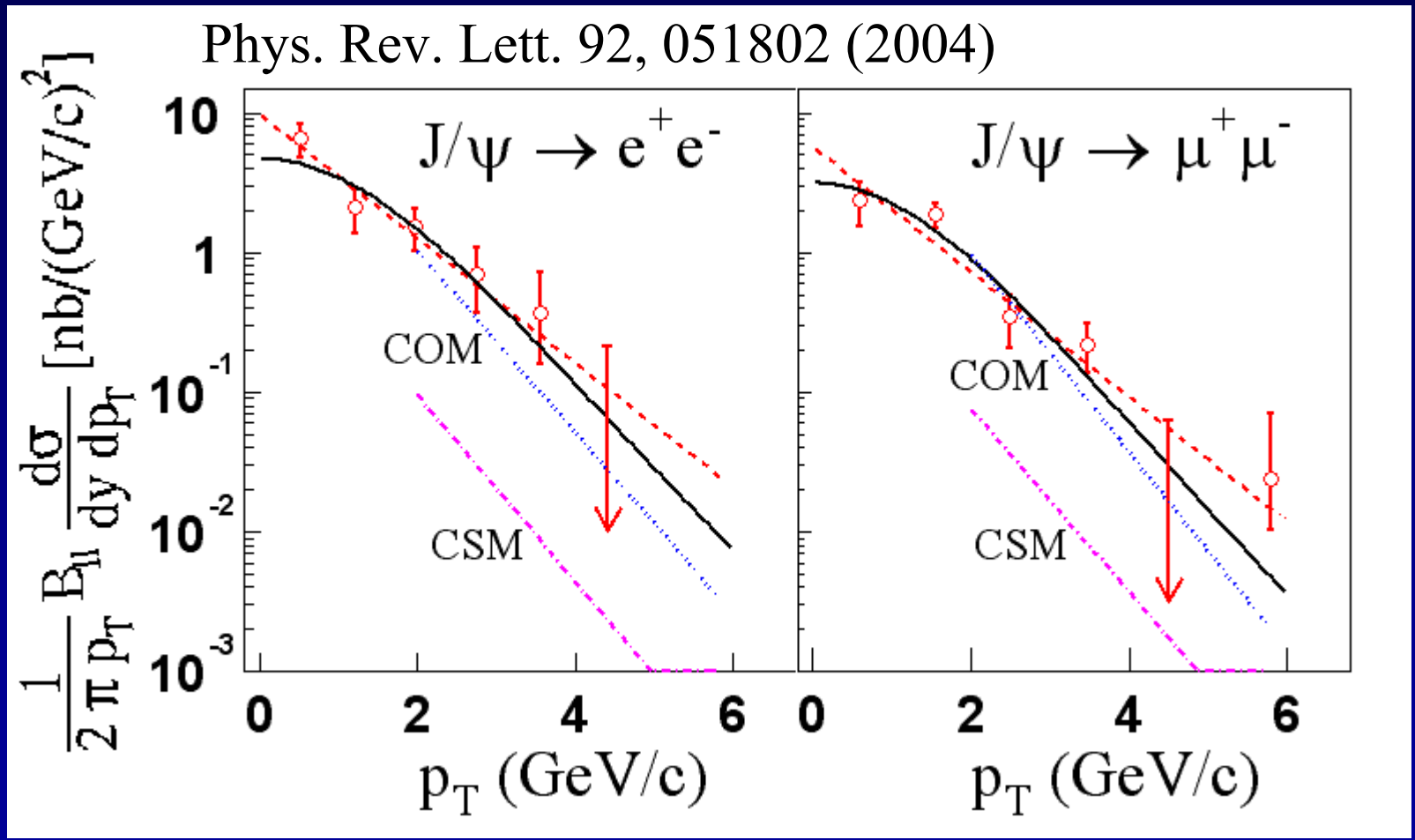
PHENIX

Cross section measurements (cont.)





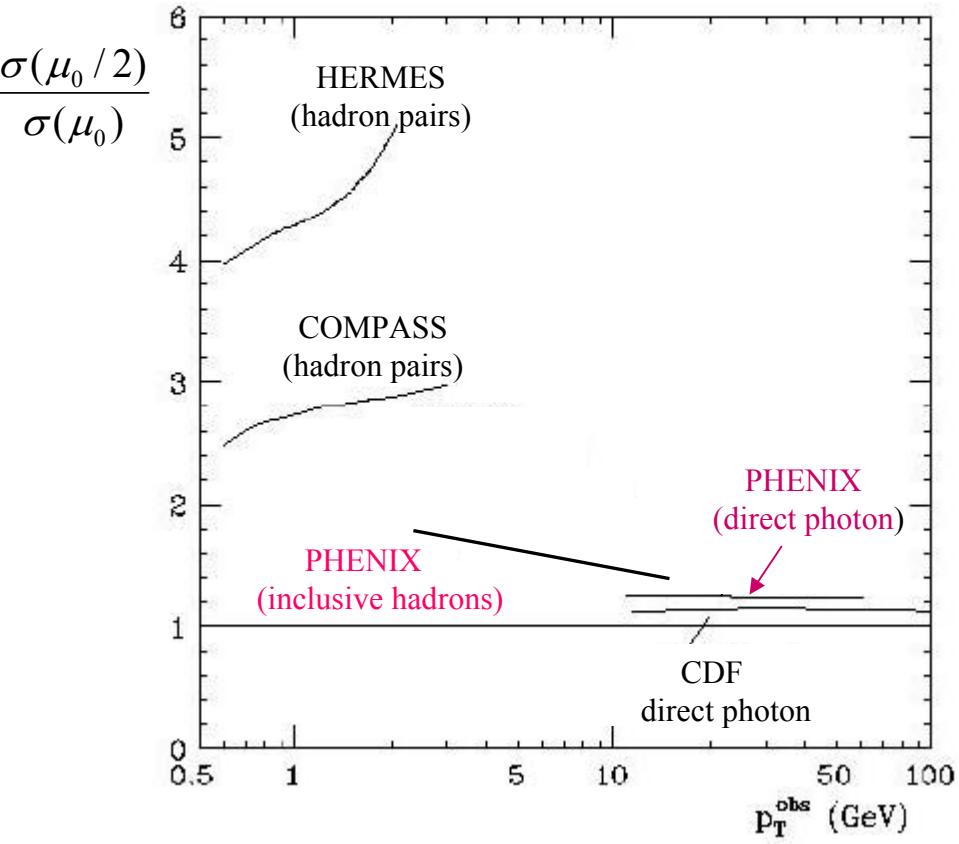
Cross section measurements (cont.)

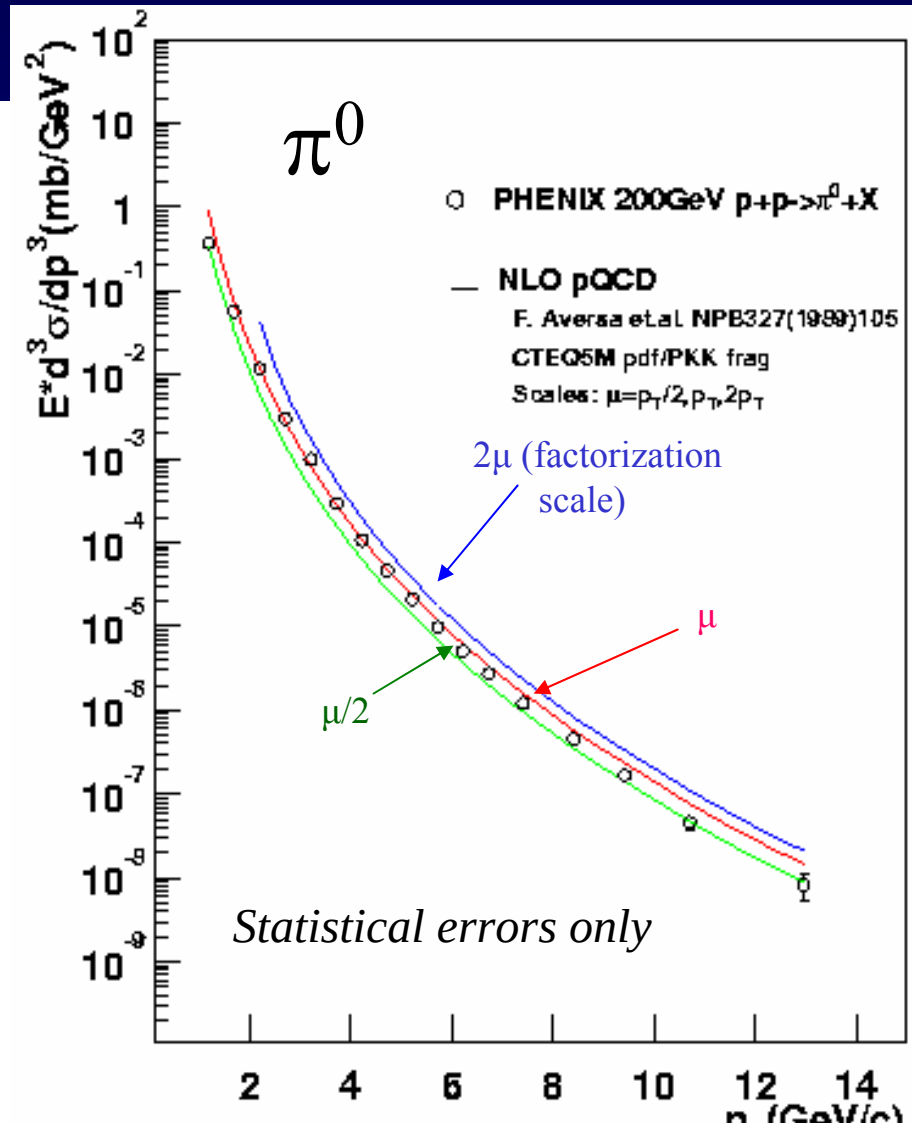


pQCD scale dependence at RHIC

Theoretical uncertainty of pQCD calculations in various channels:

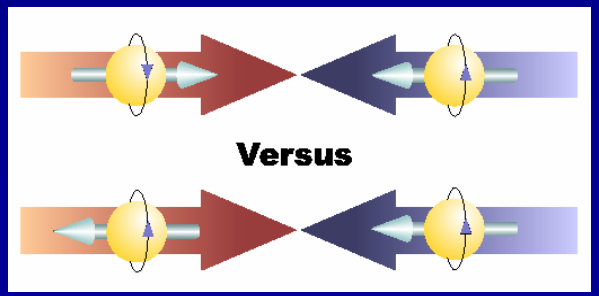
π^0 data vs pQCD with different factorization scales:

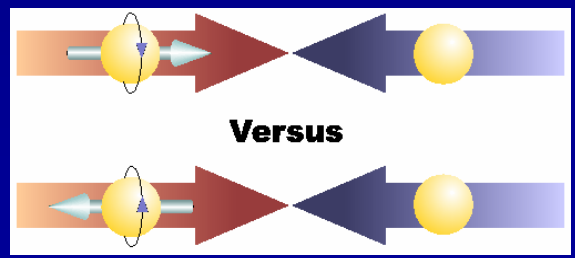


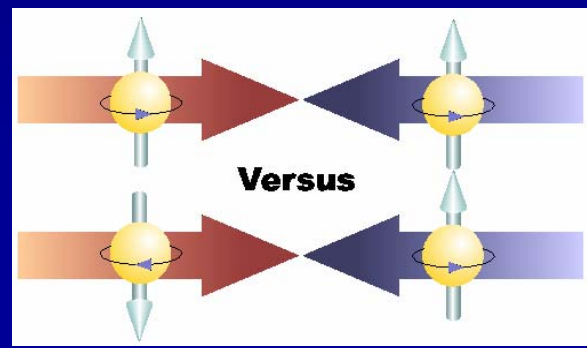


Overview of PHENIX spin structure program

Gluon Polarization ΔG	Flavor decomposition $\frac{\Delta u}{u}, \frac{\Delta \bar{u}}{\bar{u}}, \frac{\Delta d}{d}, \frac{\Delta \bar{d}}{\bar{d}}$	Transverse Spin
π Production $A_{LL}(gg, gq \to \pi + X)$	**W Production**	**Transversity δq:**
Prompt Photon $A_{LL}(gq \to \gamma + X)$	$A_L(u + \bar{d} \to W^+ \to l^+ + \nu_l)$	π^+, π^- Interference fragmentation: $A_T(p_\perp p \to (\pi^+, \pi^-) + X)$
Heavy Flavors $A_{LL}(gg \to c\bar{c}, b\bar{b} + X)$	$A_L(\bar{u} + d \to W^- \to l^- + \bar{\nu}_l)$	Drell Yan A_{TT}
		Single Asymmetries A_N



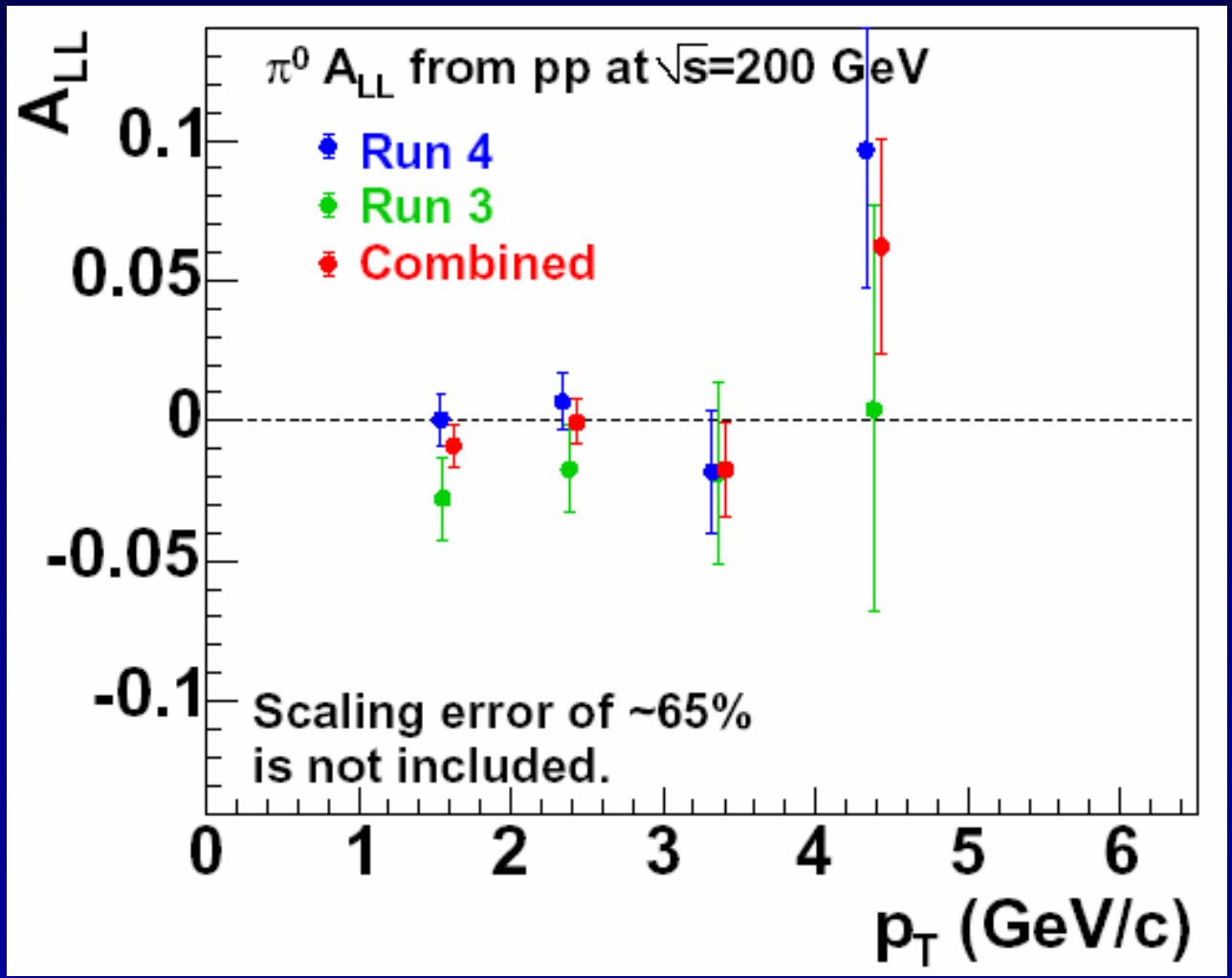




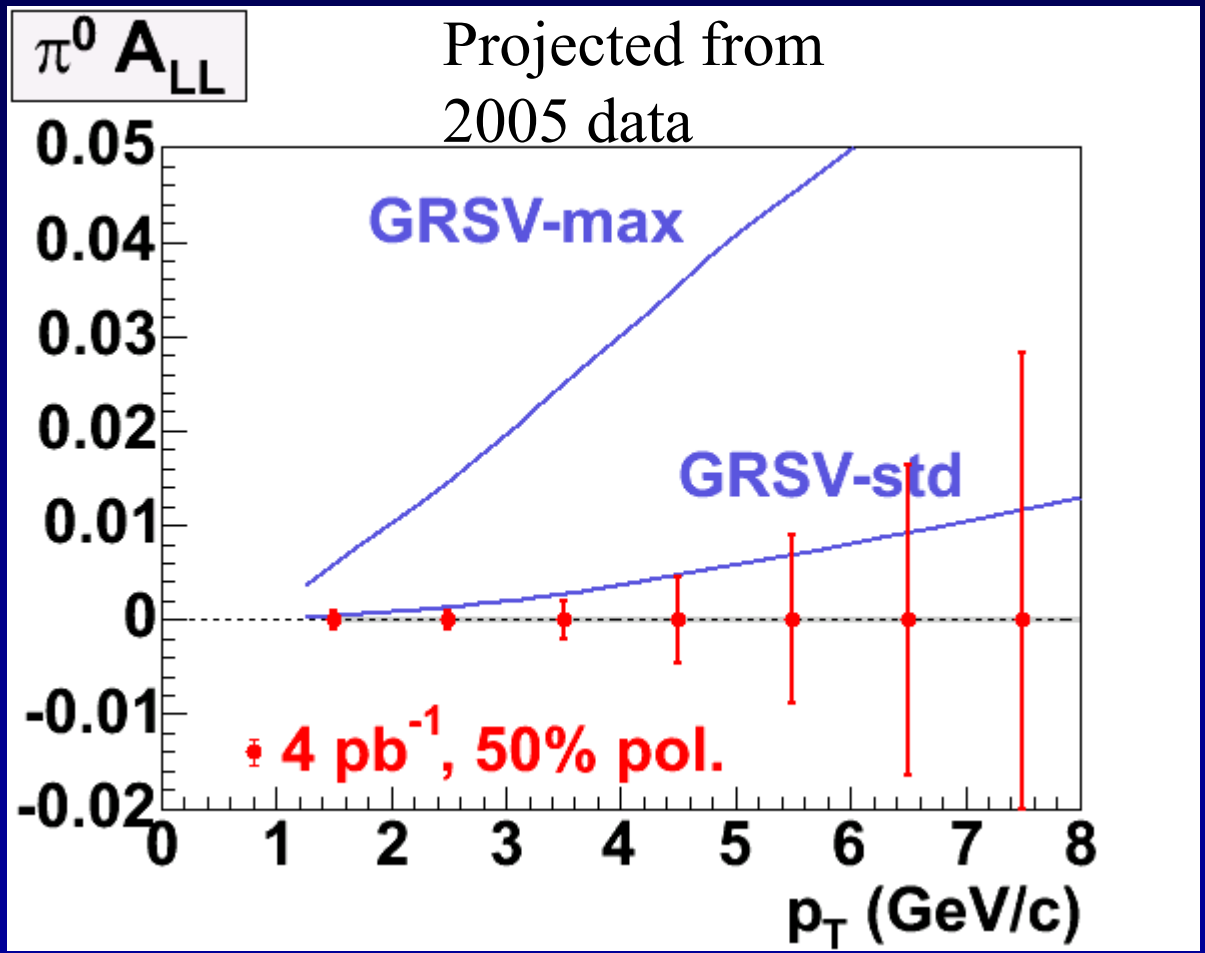
Probing Δg

- PHENIX is sensitive to Δg via double-longitudinal spin asymmetries in the production of mesons, photons, heavy flavor, and jets
  - First measurements have been made, and a number of additional measurements will become available in the next few years
  - Long-term, greater kinematic coverage and new processes will become accessible due to
    - Detector upgrades
    - Luminosity upgrades
    - Higher energy $\sqrt{s} = 200GeV \rightarrow 500GeV$

Pions: an abundant probe



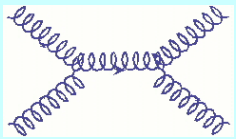
Neutral pion asymmetry projected from 2005 data



Sensitivity to partonic processes

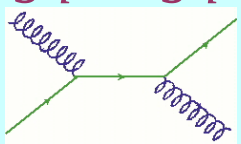
- Neutral pion as well as charged hadron production in the current p_T range dominated by gg and gq scattering
- Higher p_T will be more sensitive to q processes

$gg \rightarrow gg$



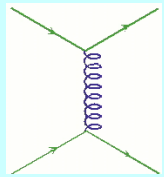
$\propto \frac{\Delta G}{G}\frac{\Delta G}{G}$

$gq \rightarrow gq$

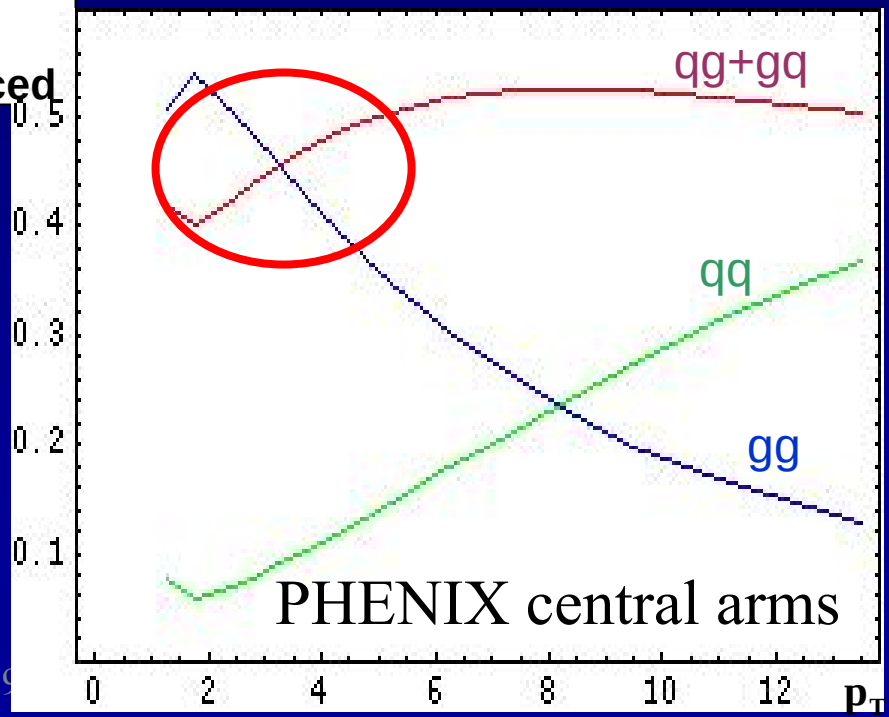


$\propto \frac{\Delta q}{q}\frac{\Delta G}{G}$

$qq \rightarrow qq$



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



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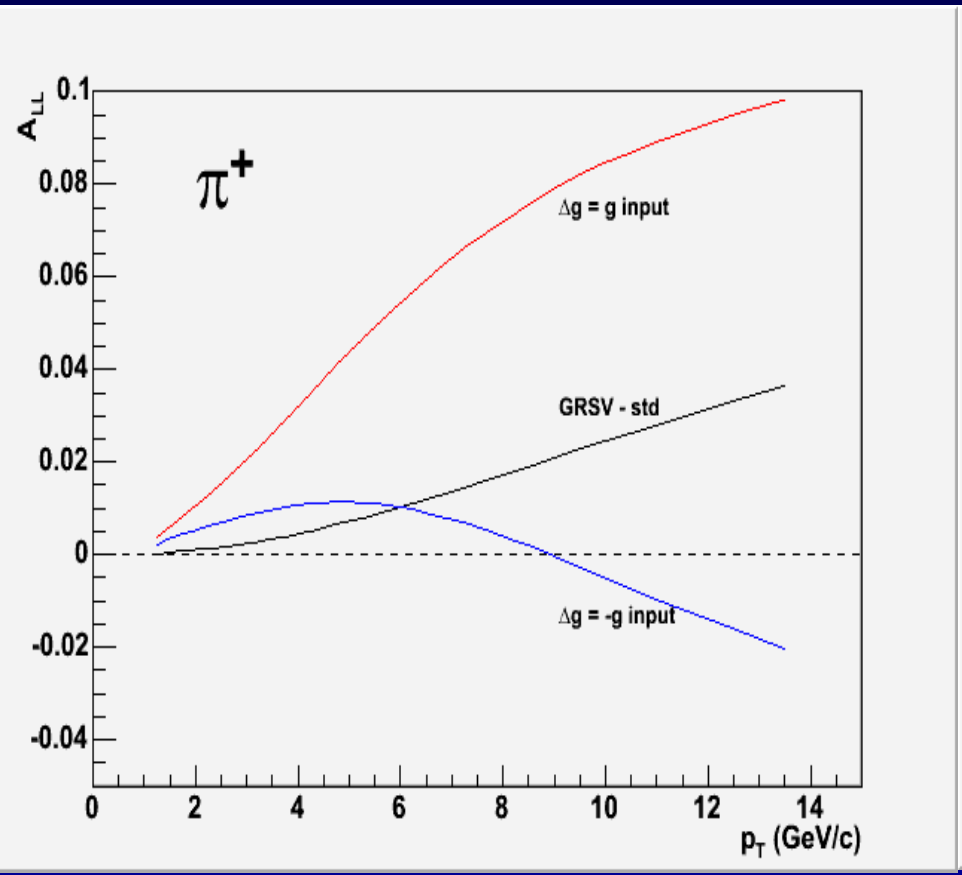
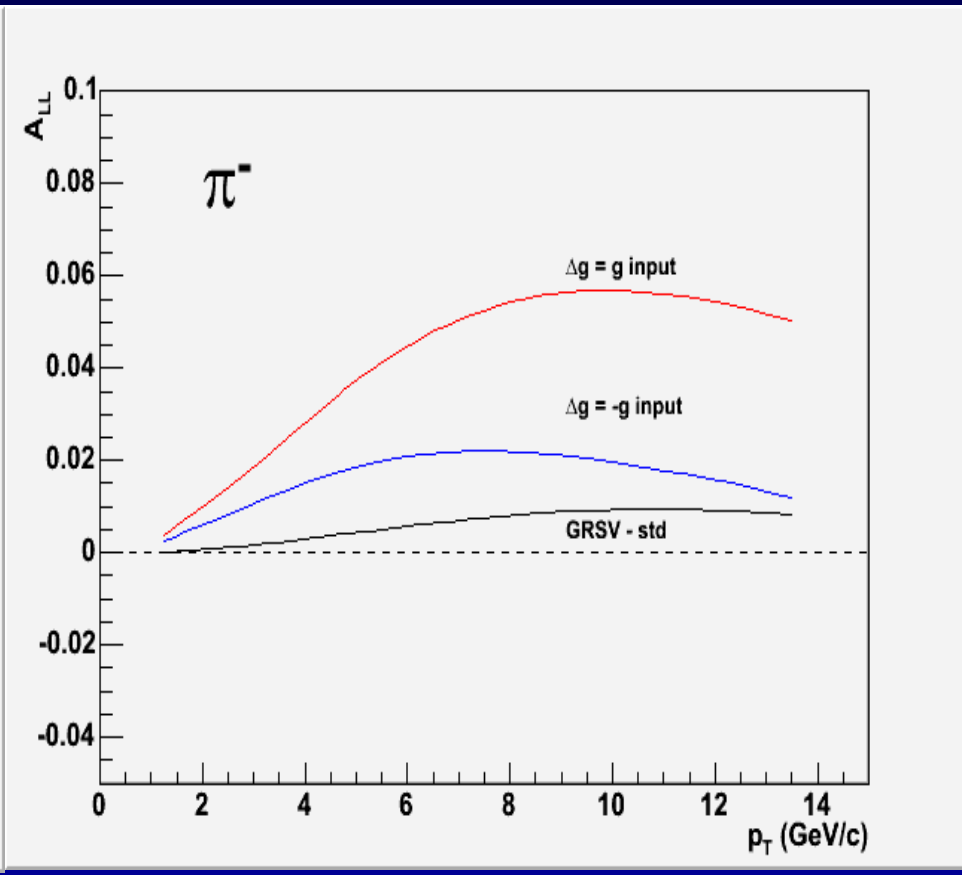
A_{LL} of charged pions: Determining the sign of Δg

- At higher transverse momentum (p_T > ~5 GeV/c), pions will be dominantly produced via qg scattering
- The tendency of π^+ ($u\bar{d}$) to fragment from an up quark and π^- ($d\bar{u}$) from a down quark and the fact that Δu and Δd have opposite sign will make A_{LL} of π^+ and π^- differ measurably
- This difference will allow us to determine the sign of Δg!

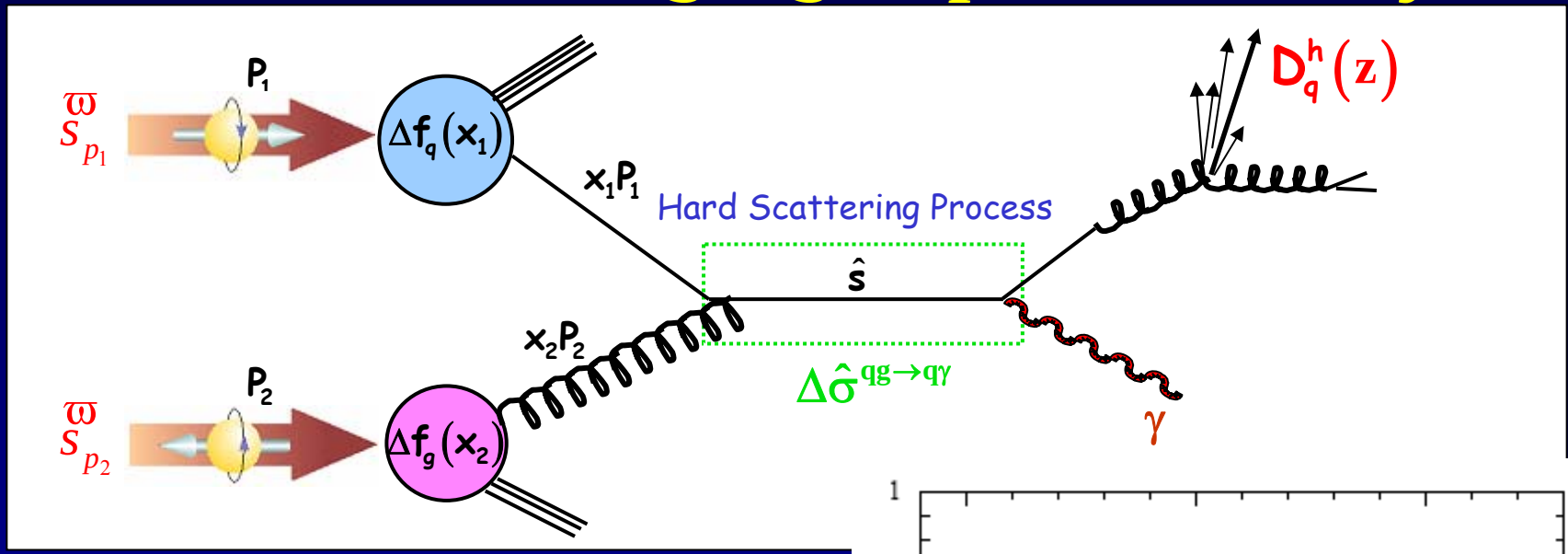
Charged pions (cont.)





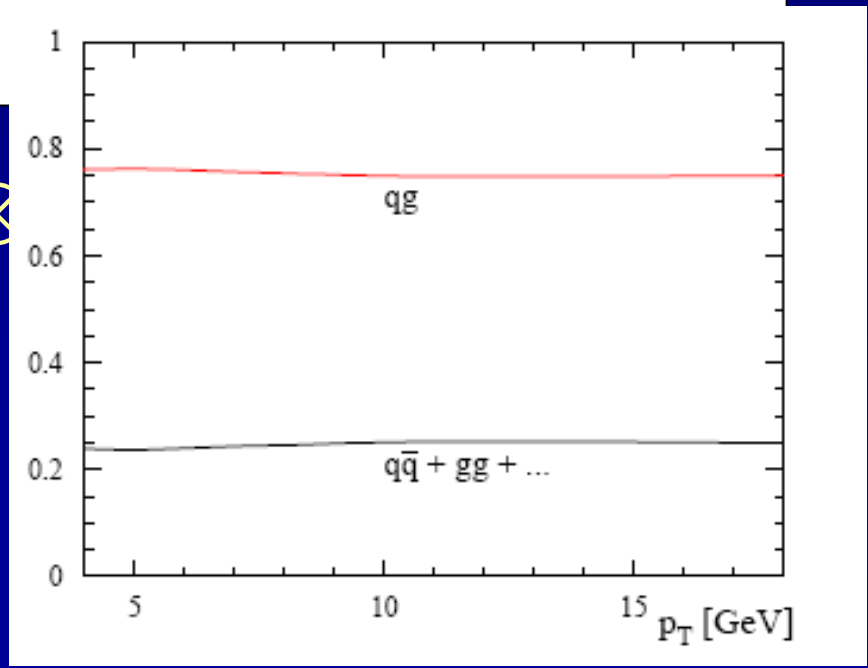
$$\Delta g > 0 \Rightarrow A_{LL}^{\pi^+} > A_{LL}^{\pi^0} > A_{LL}^{\pi^-}$$

Direct photons: Cleaner theoretically, more challenging experimentally



$$\Delta\sigma(pp \to \gamma X) \propto \Delta q(x_1) \otimes$$

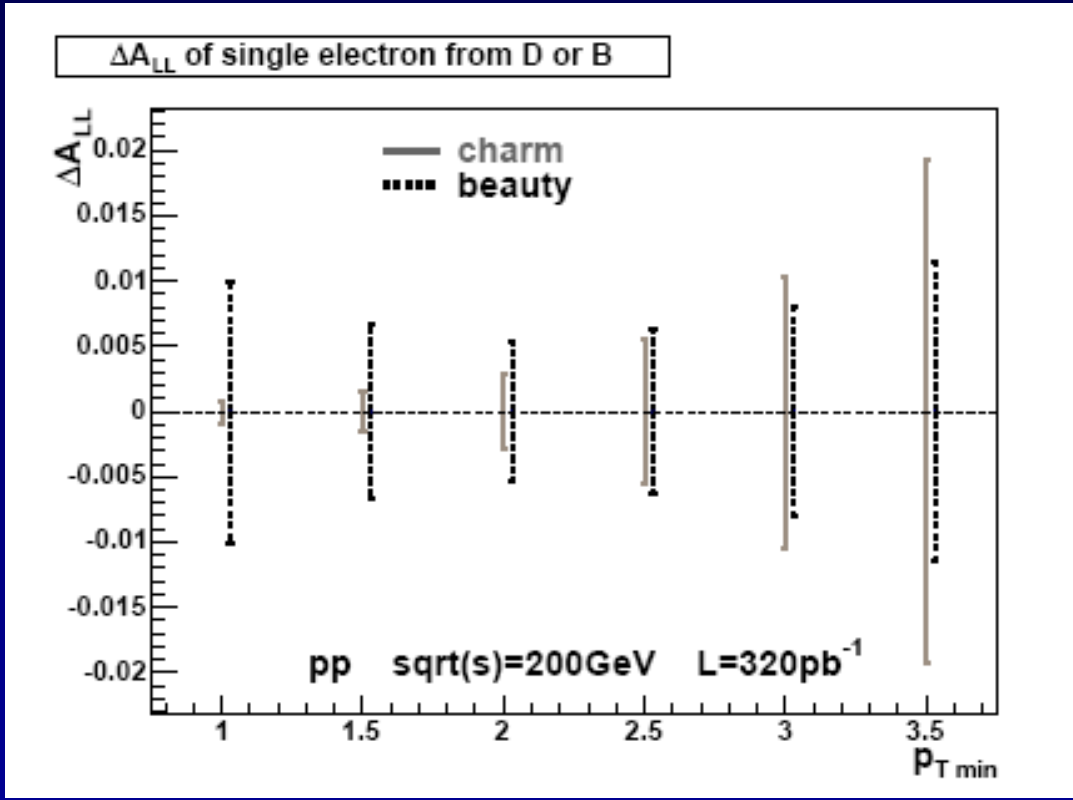
Gluon Compton scattering



PHENIX

Heavy flavor

- Largely from gluon-fusion (quadratic Δg)
- Leptons from 2-10 GeV/c predominantly from heavy flavor decays
- Forward measurements sensitive to gluons at lower x



Uncertainty projections for single electrons from D or B decay, including silicon vertex tracker upgrade (2008)

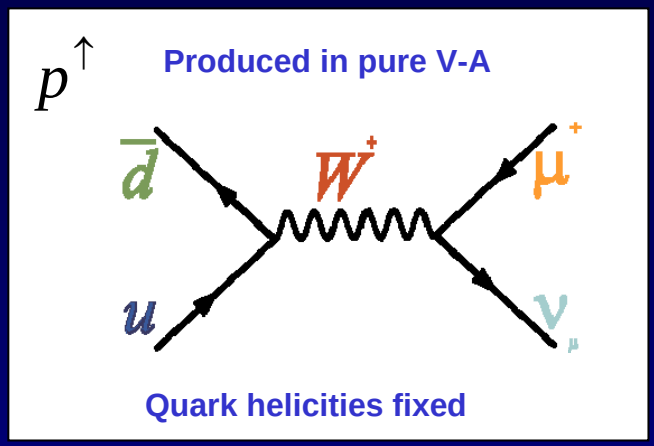
Probing quark and antiquark helicity distributions

- Quark helicity distributions—long-term
  - Gamma pairs from quark-antiquark annihilation (high luminosities required)
  - Drell-Yan (high luminosities required)
  - *W production (500 GeV, muon trigger upgrade, ~2010)*

W production to probe the flavor-separated helicity distributions of the sea

- W+ from $u\bar{d}$, W- from $d\bar{u}$ (some small contribution from charm/strange)
- Measure leptonic decay products of W's: forward muons (with identified charge)
- Maximally parity violating—look for *single-longitudinal* spin asymmetries A_L
- *Direct* measurement of flavors—no need to compare different isospin targets as in DIS
- No reliance on FF's

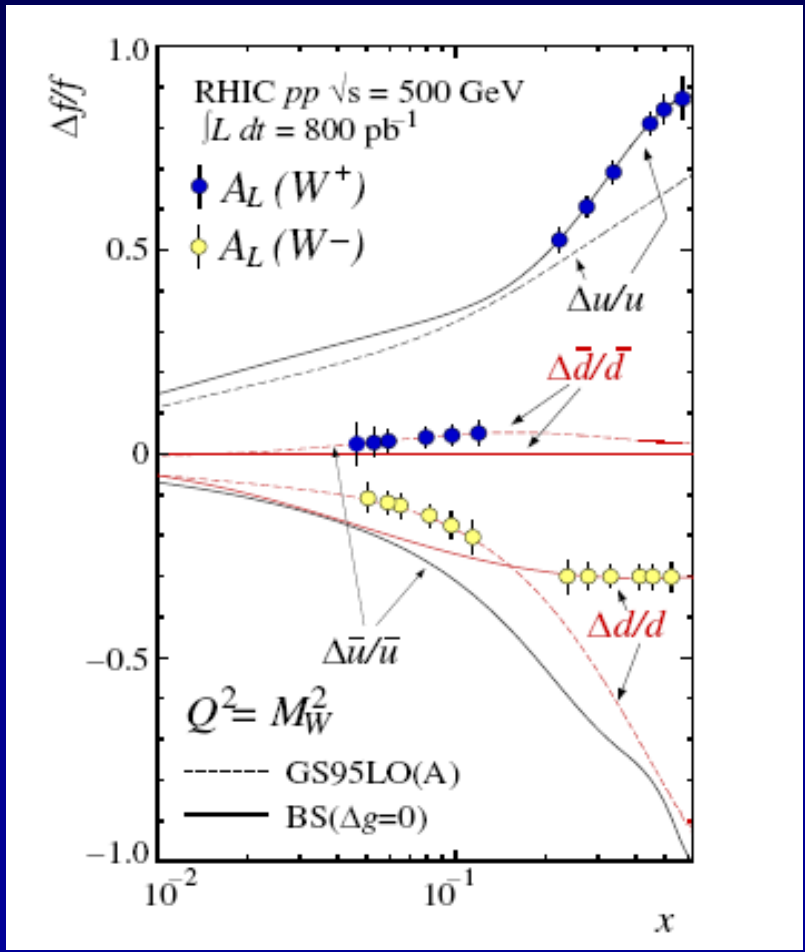
Flavor decomposition via W's (cont.)



$$A_L^{W+} = \frac{\Delta u(x_1)\bar{d}(x_2) - \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}.$$

- Looking at forward or backward rapidity with respect to the (single) polarized beam lets one select the polarized u or anti-d (in the case of W+)

Expected flavor sensitivity at RHIC



Expected sensitivity vs. x

Physics goals of detector upgrades

upgrade	channel	physics target	x coverage
muon trigger	$W^+ \to \mu^+$	$\Delta u(x)$, $\Delta d(x)$	$0.2 < x_{u,d} < 0.6$
	$W^- \to \mu^-$	$\Delta \bar{u}(x)$, $\Delta d(x)$	$0.04 < x_{\bar{u},\bar{d}} < 0.1$
silicon vertex tracker	$c \to e$		$0.01 < x_g < 0.1$
	$b \to e$		
	$D \to K\pi$	$\Delta g(x)$	$0.1 < x_g < 0.2$
	$B \to J/\psi$		$0.03 < x_g < 0.1$
	γ + jet		$0.02 < x_g < 0.1$
nose cone calorimeter	γ + jet	$\Delta g(x)$	$0.001 < x_g$

Summary

- PHENIX will measure a variety of channels in the near term that are sensitive to Δg
- Looking farther ahead (~2010), detector upgrades and higher energy will allow the x-dependence of Δg to be mapped out more systematically
- W production in future 500 GeV running will provide a new way of measuring the flavor dependence of the sea contributions to the spin of the proton

Extra slides

PHENIX spin running so far

- 2001-2
  - ***Transversely*** polarized collisions
  - Average polarization 15%
  - Integrated luminosity 0.15 pb^{-1}
- 2003
  - ***Longitudinally*** polarized collisions
  - Average polarization 27%
  - Integrated luminosity 0.220 pb^{-1}
- 2004
  - 5 weeks commissioning
  - 4 days longitudinal physics data
  - Average polarization 40%
  - Integrated luminosity 0.075 pb^{-1}
- 2005
  - Long run (10 wks)
  - P ~50%
  - ~10% of total integrated luminosity transverse

Planned PHENIX p+p analyses from 2005 data

- Cross sections
  - Improved: π^0, direct photons, η, J/ψ
  - New: π+/π-
- A_{LL} to probe Δg
  - π^0, direct photons, η, π+/π-, jets, J/ψ, single e+/e-, single μ+/μ-, Λ
- Transverse spin observables
  - A_N of π^0 and h+/h-
  - Back-to-back di-hadron asymmetry

Not all of these analyses may lead to publishable results from the current data set, but they all represent short-term goals (~1-2 years)

Direct photon projections