A_{LL} for Pion Production at STAR

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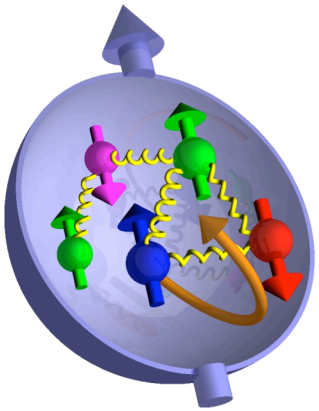
Collaboration
(for Bernd Surrow)

APS April Meeting

The Spin Puzzle



The proton is viewed as being a "bag" of bound quarks and gluons interacting via QCD

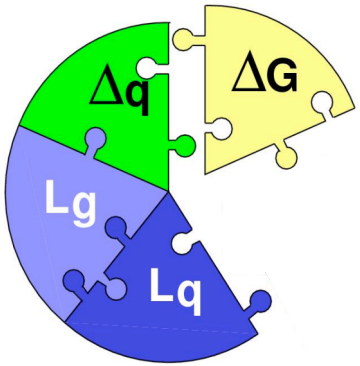
Spins + orbital angular momentum need to give the observed spin 1/2 of proton

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

Fairly well measured only ~30% of spin

Being measured at RHIC

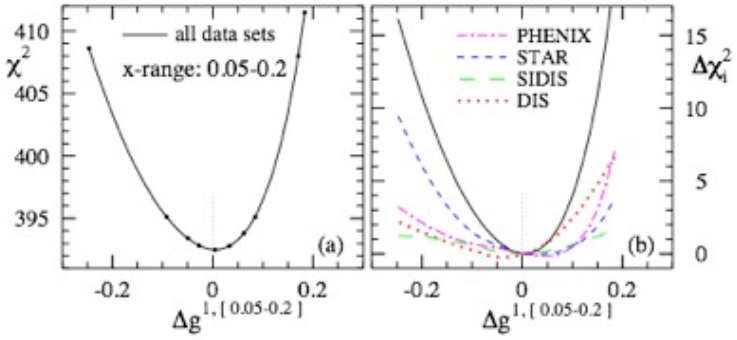
A future challenge

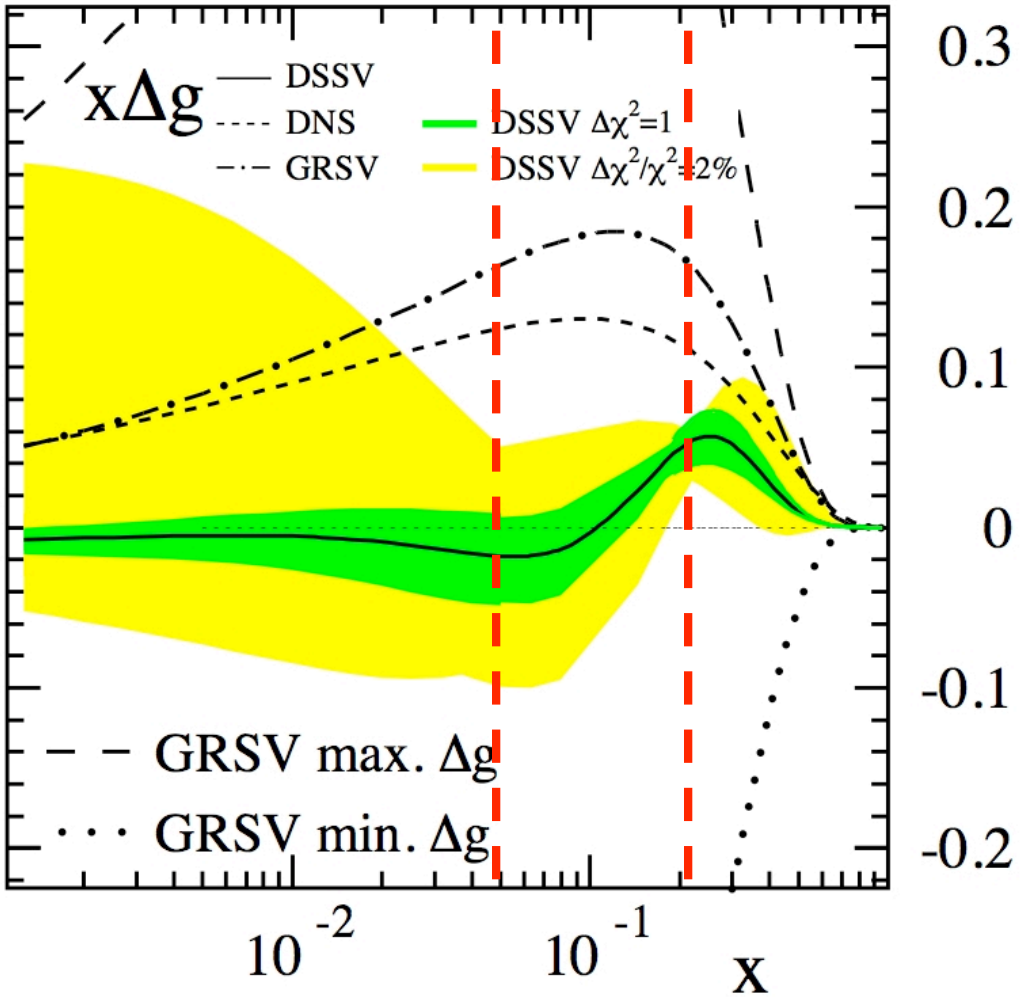


$$\Delta\Sigma = \int (\Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s} + \cdots)dx \qquad \Delta G = \int \Delta g dx$$

Current Picture of ΔG

With the inclusion of the RHIC and new DIS data the uncertainties on ΔG have been reduced drastically.

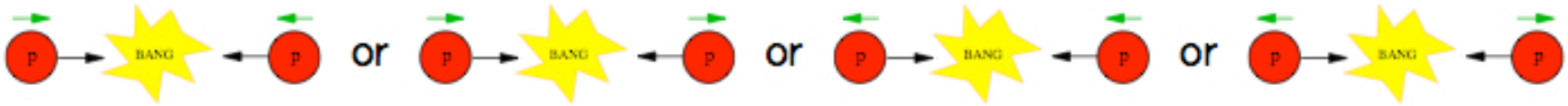




Region probed at sqrt(s)=200 GeV at RHIC

Helicity Asymmetries

Take the asymmetry of proton helicity configurations



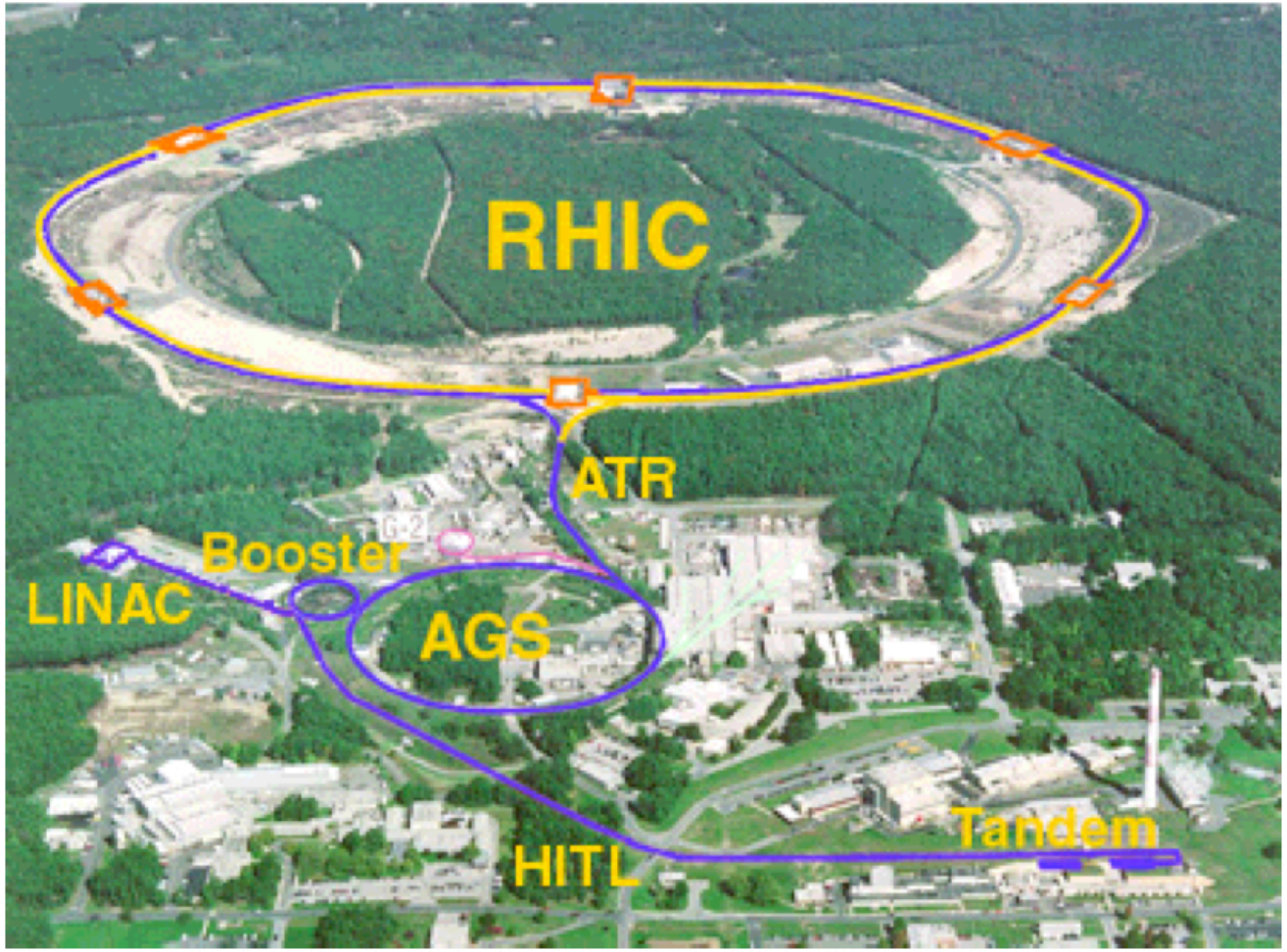
$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} = \frac{\sum_{a,b,c} \Delta f_a \otimes \Delta f_b \otimes d\hat{\sigma}^{f_a f_b \to f_c X} \cdot \hat{a}_{LL}^{f_a f_b \to f_c X} \otimes D_{f_c}^{h}}{\sum_{a,b,c} f_a \otimes f_b \otimes d\hat{\sigma}^{f_a f_b \to f_c X} \otimes D_{f_c}^{h}}$$

and translating…

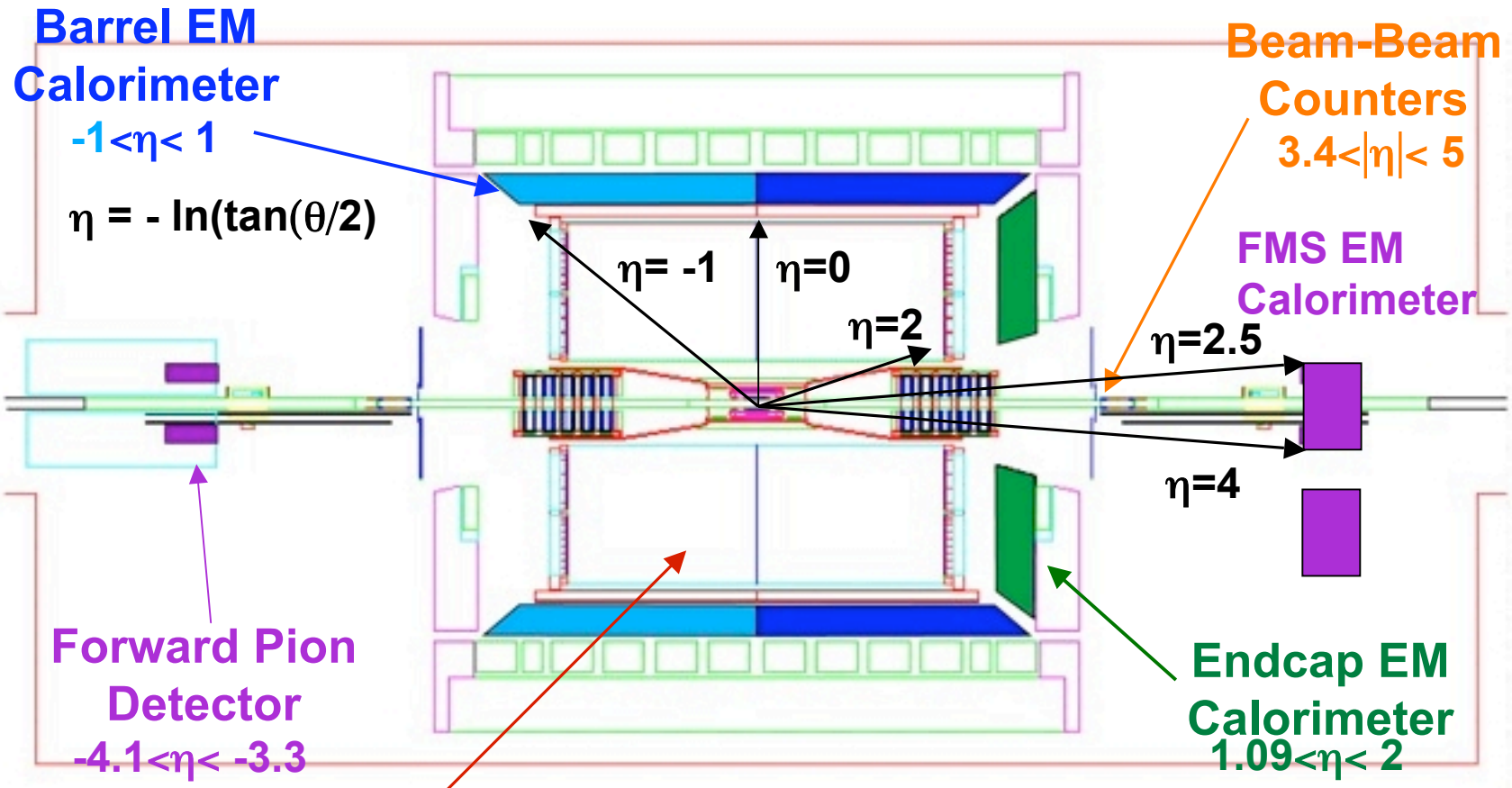
$$A_{LL} \approx a_{gg}\Delta g\Delta g + a_{qg}\Delta q\Delta g + a_{qq}\Delta q\Delta q'$$

RHIC

The world's first polarized proton collider

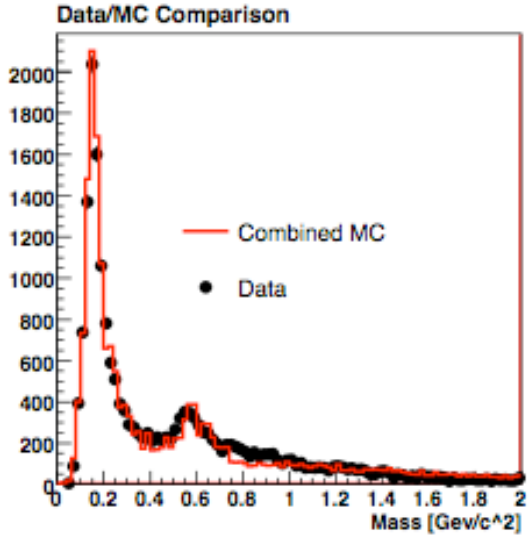


STAR

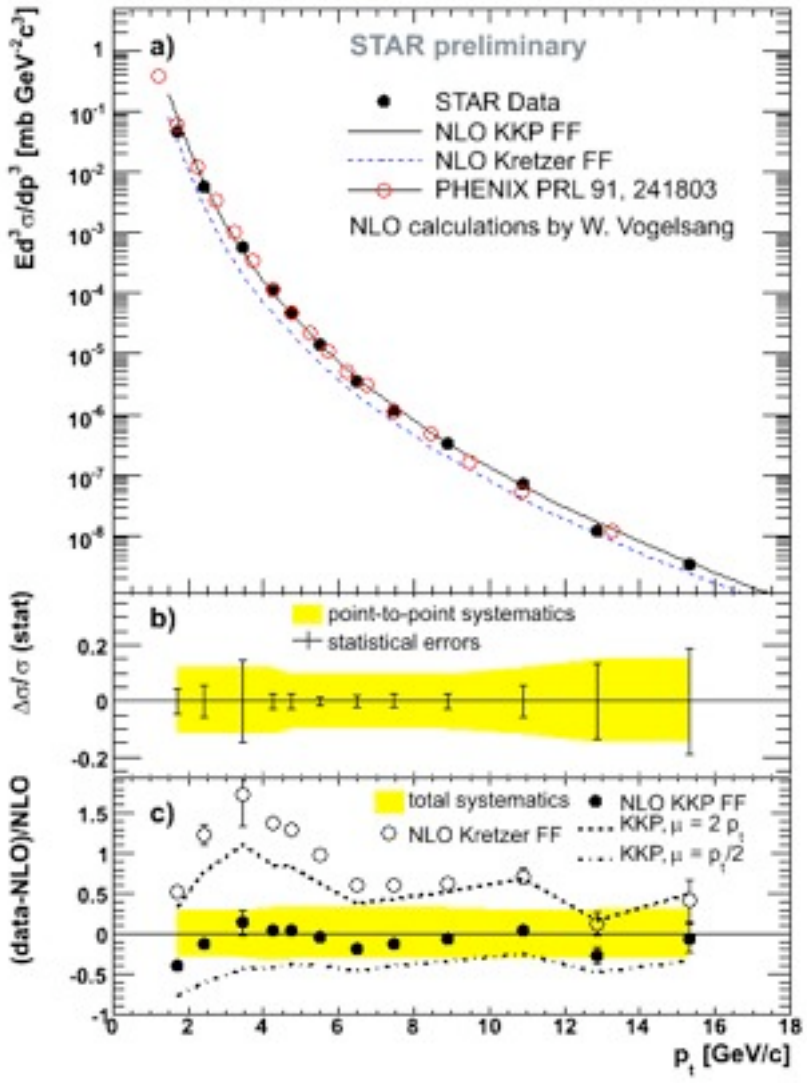

Barrel EM Calorimeter
-1<η< 1
η = - ln(tan(θ/2)
η= -1
η=0
η=2
Beam-Beam Counters
3.4<|η|< 5
FMS EM Calorimeter
η=2.5
η=4
Forward Pion Detector
-4.1<η< -3.3
Endcap EM Calorimeter
1.09<η< 2
Time Projection Chamber
-1.3<η< 1.3
Solenoidal Magnetic Field 5kG

2008

Neutral Pion Cross Section



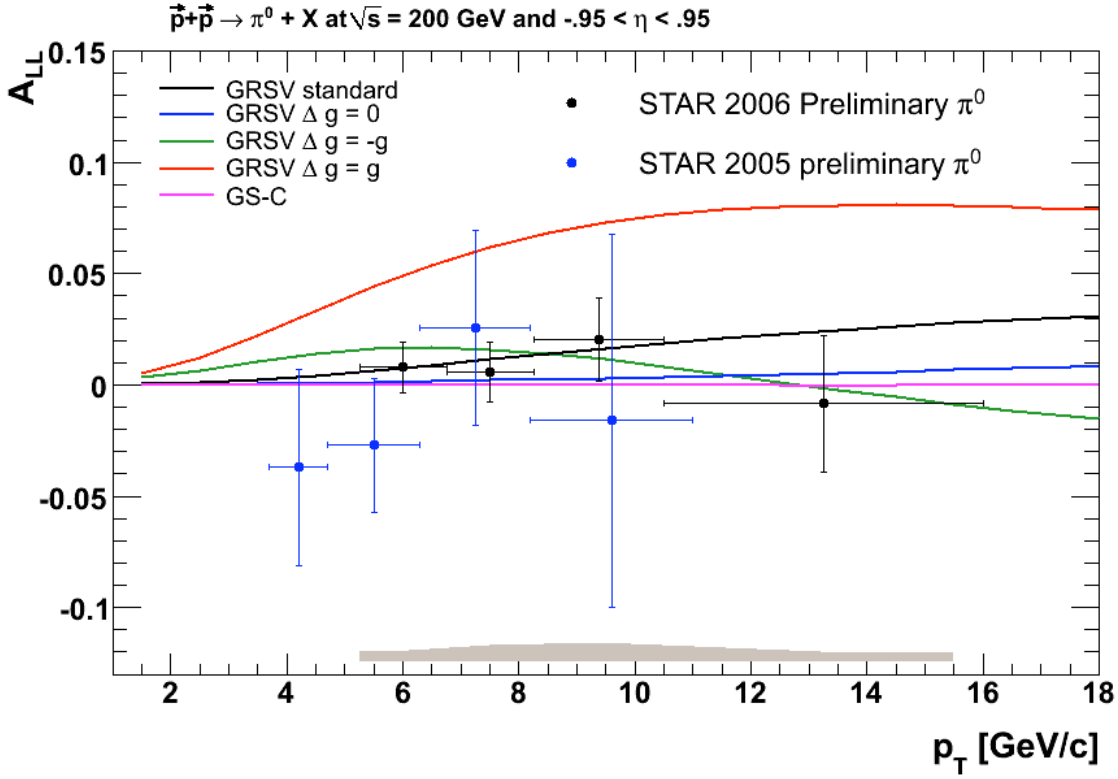
- The π^0 is reconstructed through the di-photon channel and tagged through its invariant mass
- The background is characterized in simulation.
- pQCD describes data well



Neutral Pion A_{LL} (2005+2006)

Maximum gluon polarization scenario (GRSV-Max) is ruled out

2006 preliminary result uncertainties are comparable to PHENIX at p_T~8 GeV/c and data extend to a higher p_T than PHENIX

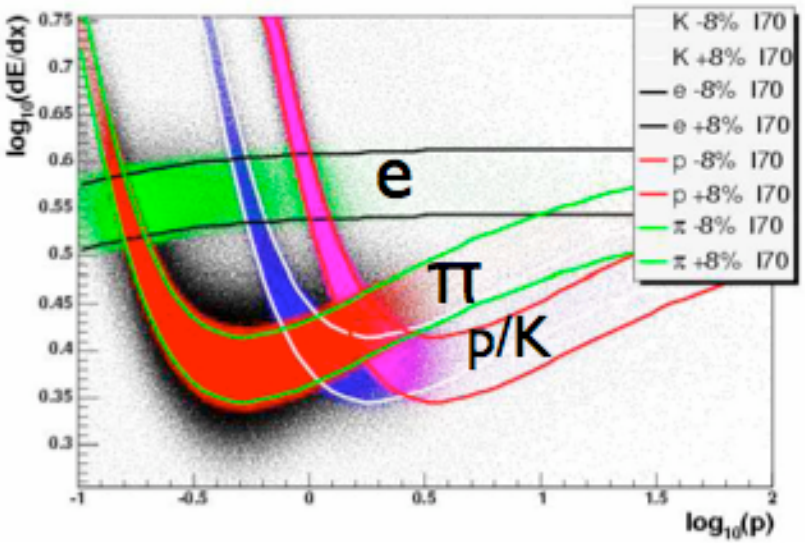


$\Delta G(Q^2 = 1GeV^2) \approx 1.8$

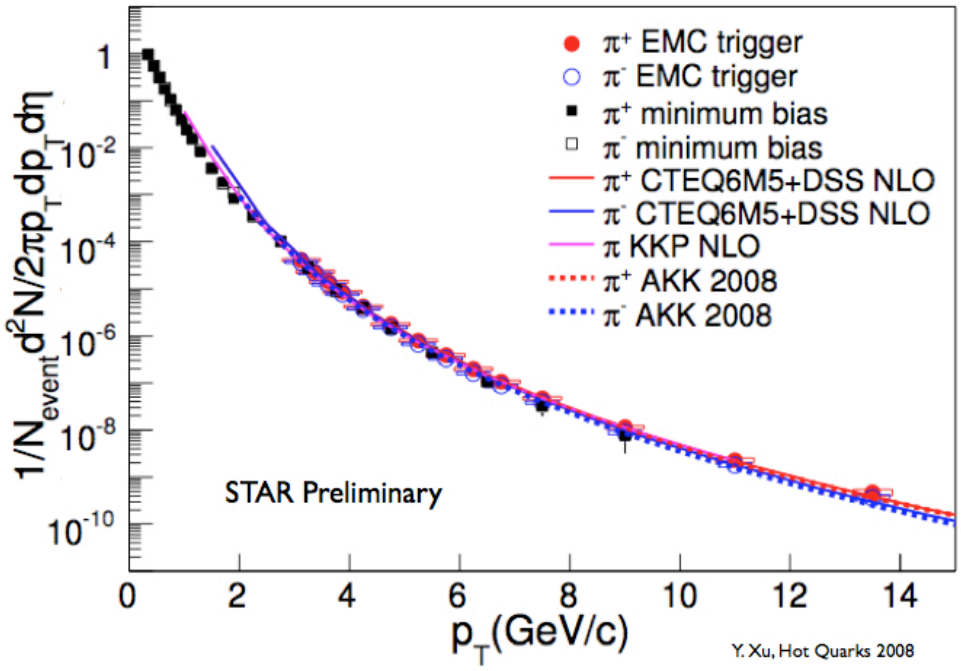
$\Delta G(Q^2 = 1GeV^2) \approx 0.4$

$\Delta G(Q^2 = 1GeV^2) \approx 1.0$

Charged Pion Cross Section



Phys.Lett.B637:161-169,2006



- Identified by the TPC which uses dE/dx from |eta|<1.3
- Provides a 1σ separation between K/p and pions
- pQCD describes data well

Charged Pion A_{LL} (2005)

Charged pions are useful for constraining ΔG

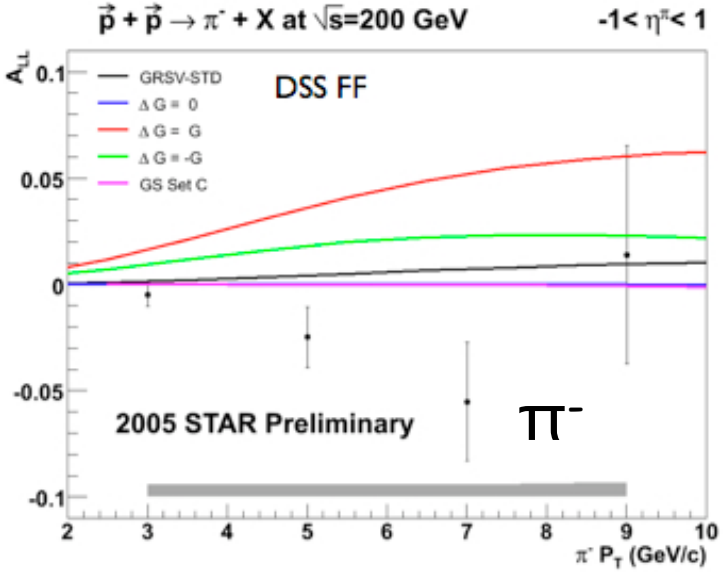
1. Can give the sign of Δg

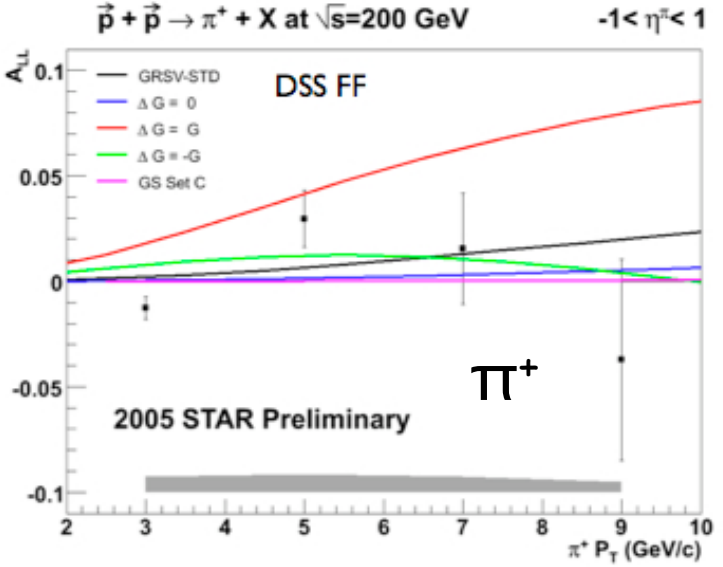
$$\Delta g > 0 \rightarrow A_{LL}^{\pi^+} > A_{LL}^{\pi^-}$$

$$\Delta g < 0 \rightarrow A_{LL}^{\pi^+} < A_{LL}^{\pi^-}$$

2. π^+ is a strong "lever-arm" for measuring Δg especially since Δg is small

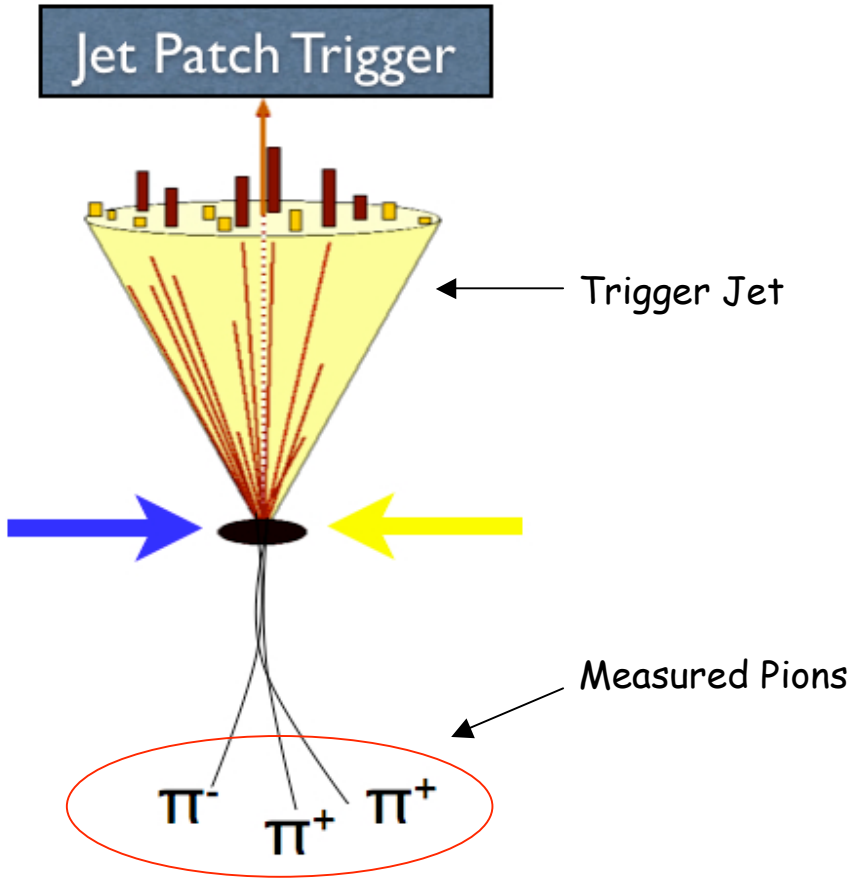
$$A_{LL}^{\pi^+} \propto \Delta g \Delta g + \Delta g \Delta u \rightarrow \Delta g \Delta u$$

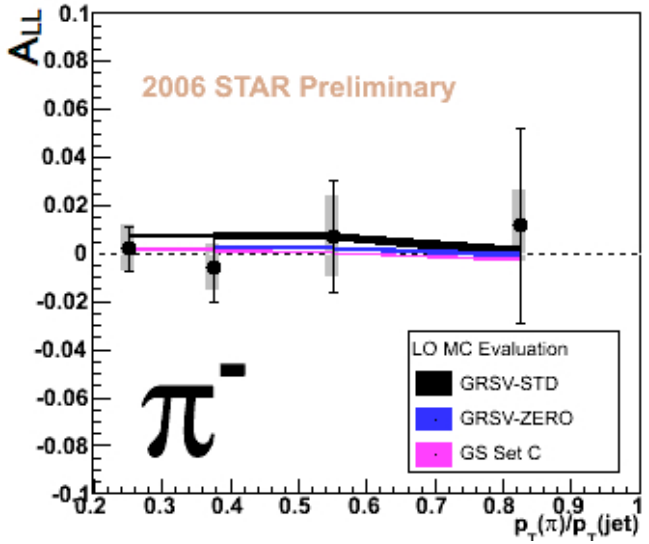


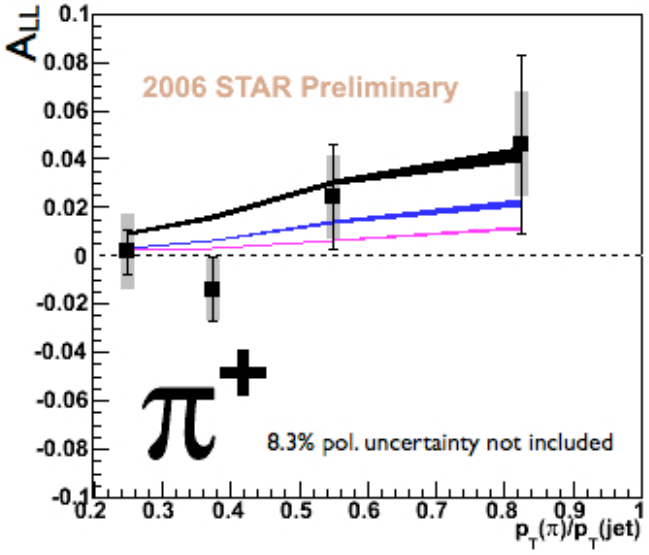


Charged Pion A_{LL} (2006)

A new way of measuring the charged pion. Triggering on a jet and measuring away side pion gives less trigger bias. Allows less biased measurement of something akin to z.

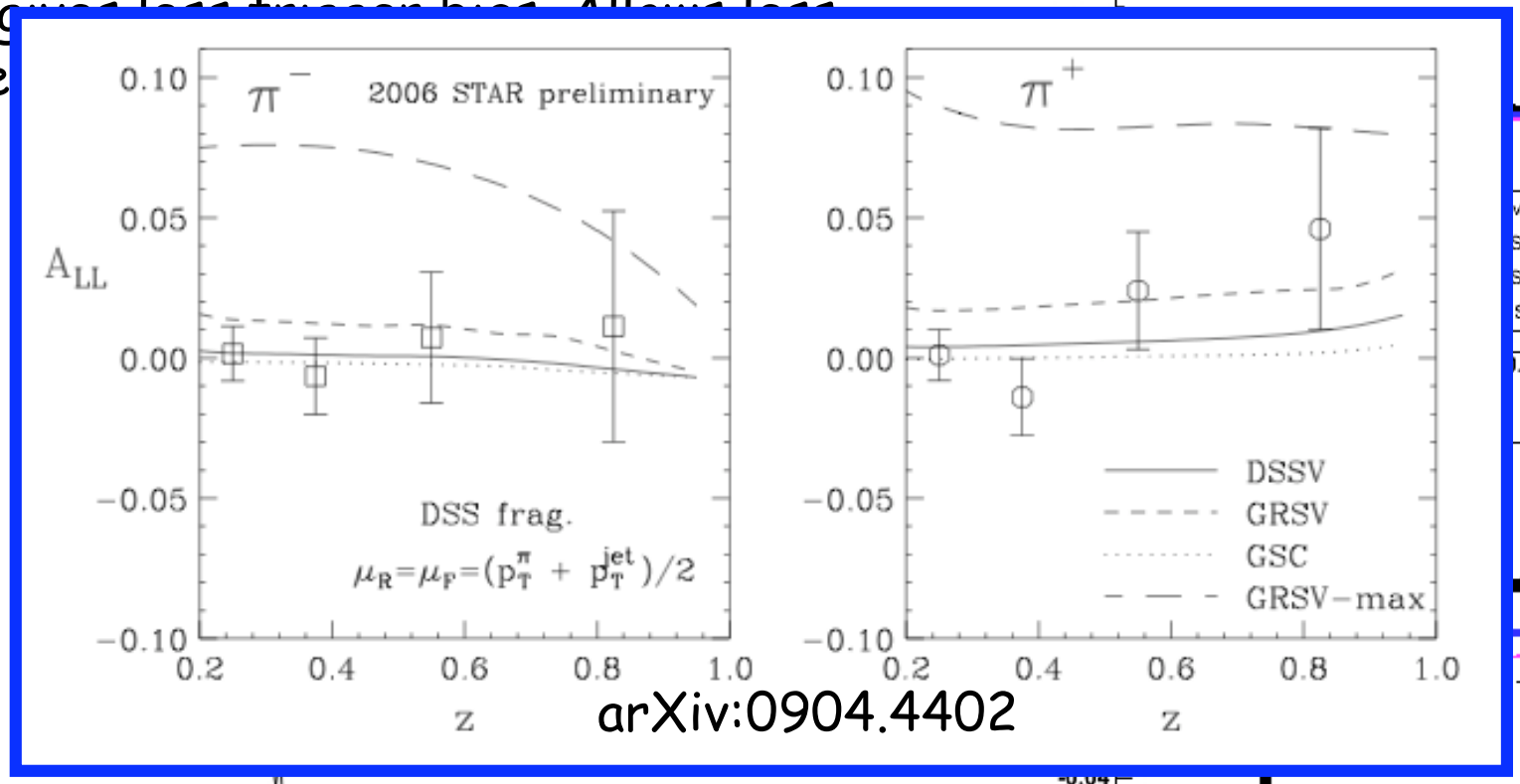




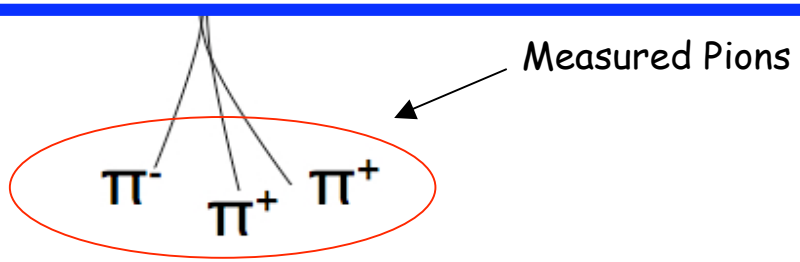


Charged Pion A_{LL} (2006)

A new way of measuring the charged pion. Triggering on a jet and measuring away side pion g… biase…

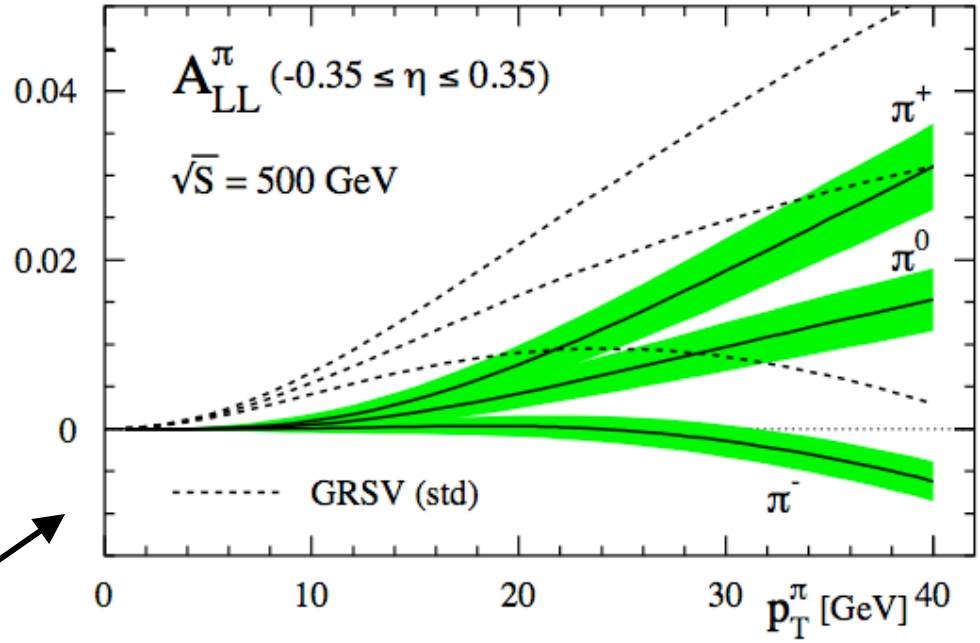


arXiv:0904.4402



Pions at 500 GeV

With RHIC now running at 500 GeV, a new region of lower-x will be able to be explored.



arXiv:0904.3821

Pseudorapidity range is for PHENIX, but the predictions should not vary much for the STAR acceptance

Solid lines are DSSV predictions and green bands are 1σ uncertainties from the polarized pdfs

Conclusions

- Helicity asymmetry measurements for hadron production in polarized proton-proton collisions are important to unraveling of the proton spin puzzle
- Comparison of the π^+, π^0, and π^- asymmetries will give information about the sign of Δg
- Future 500 GeV running will provide sensitivity of Δg at lower x

Backup Slides

Sign of ΔG from Charged Pions

In $5<p_T<10$ region

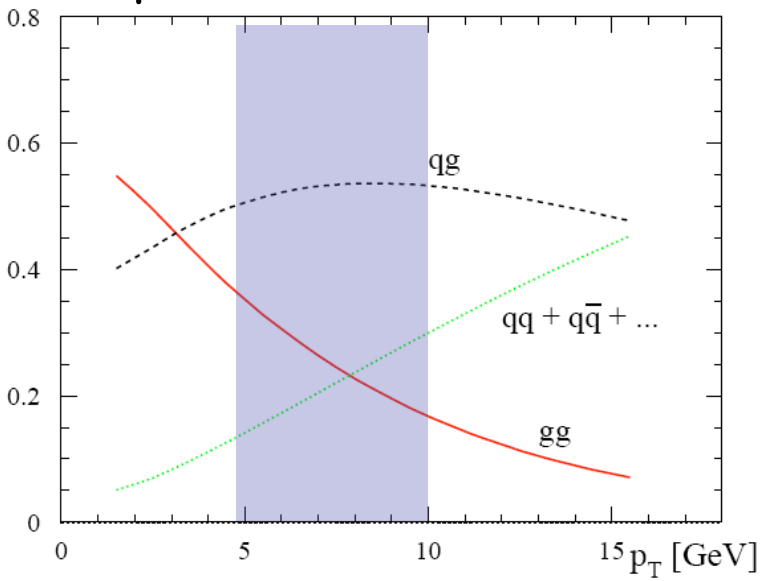
$$A_{LL} \propto a_{gg}\Delta g\Delta g + a_{qg}\Delta q\Delta g$$

If we also assume a favored fragmentation for π^+ and π^-

$$D^{\pi^+}_{u,\bar{d}} >> D^{\pi^+}_{\bar{u},d,s,\bar{s}} \quad \text{and} \quad D^{\pi^-}_{d,\bar{u}} >> D^{\pi^-}_{d,\bar{u},s,\bar{s}}$$

And that gluons fragment to π^+ and π^- with nearly the same magnitude

subprocess fraction for π^0



$$\rightarrow \quad A^{\pi^+}_{LL} \approx a_{gg}\Delta g\Delta g + a_{gu}\Delta g\Delta u \quad \text{and} \quad A^{\pi^-}_{LL} \approx a_{gg}\Delta g\Delta g + a_{gd}\Delta g\Delta d$$

And because

$$a_{gq} > 0$$
$$\Delta u > 0$$
$$\Delta d < 0$$

$$\rightarrow$$

$$\Delta g > 0 \rightarrow A^{\pi^+}_{LL} > A^{\pi^-}_{LL}$$
$$\Delta g < 0 \rightarrow A^{\pi^+}_{LL} < A^{\pi^-}_{LL}$$