RHIC-spin program for the next several years

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JPS/DNP Fall meeting, 2009

Introduction

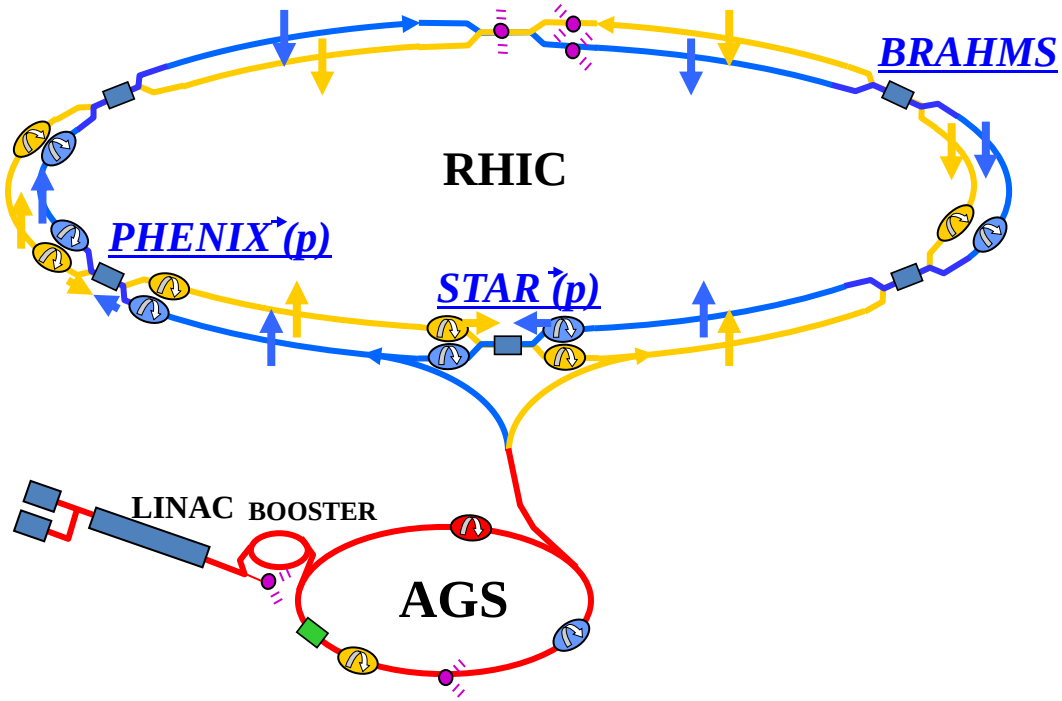
RHIC:

The polarized p+p collider

High energy ($\sqrt{s}$ is up to 500GeV)

Longitudinal and transverse with the spin rotator

Alternative spin direction to reduce the systematics



The first polarized p+p collision was in 2002. (Run2)

Spin Physics at RHIC

3 main topics and others

- Gluon spin component (ΔG program)
- Anti-quark spin flavor decomposition (W at $\sqrt{s}$=500GeV)
- Transverse spin structure

From the organizer

The talk

(A) should not be a review of RHIC spin results

(**Session 2WG** Workshop on Transverse Spin
and the Transverse Structure of the Nucleon.)

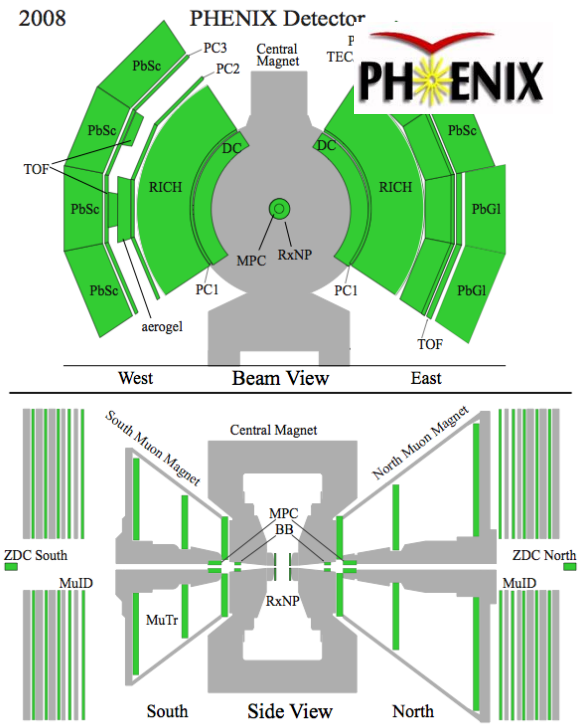
(**Session LA** Spin Structure of the Nucleon)

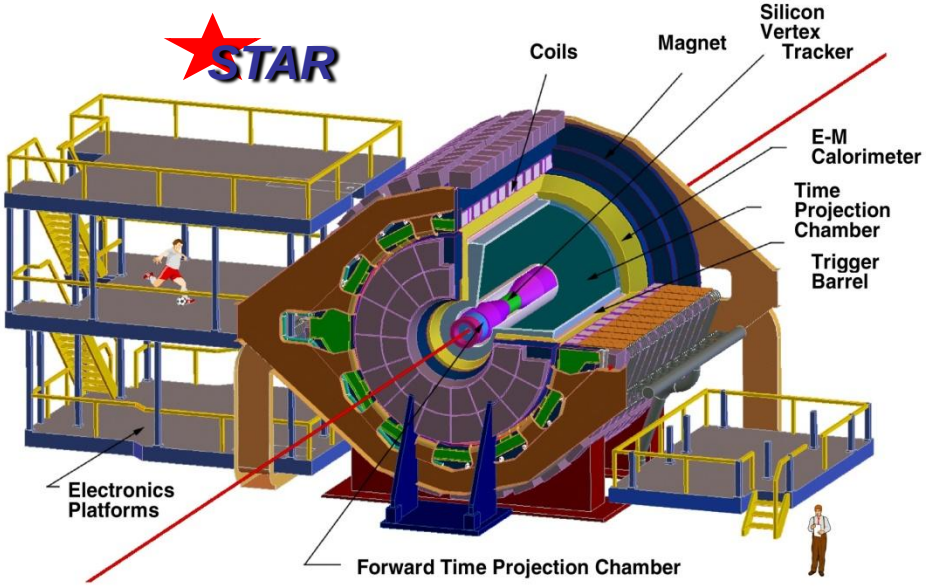
(B) should show what comes out in the next several years.

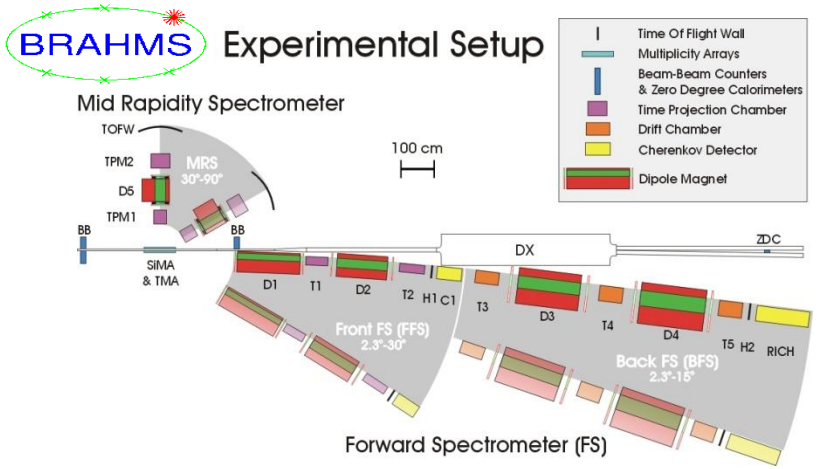
Players in this talk

PHENIX : **Fast DAQ, rare probes, photons.**
STAR : **Large coverage**
BRAHMS : **Small acceptance, but good hadron ID.**

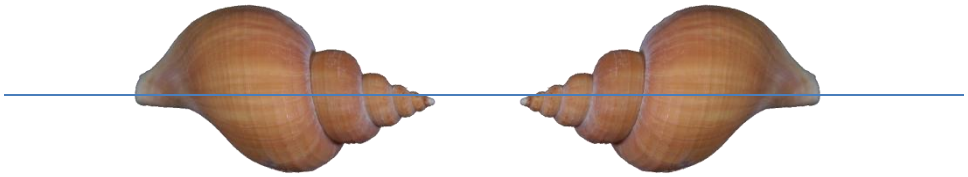
And they are all on the RHIC collider accelerator.







Gluon spin component (ΔG)



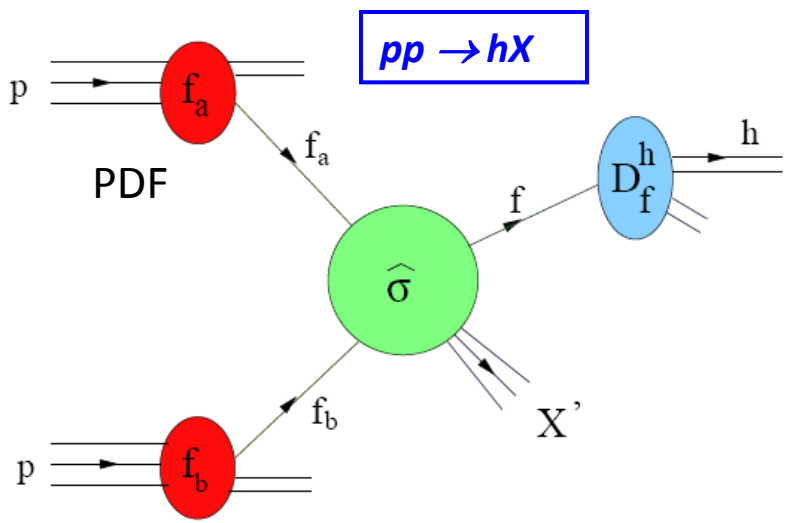
(longitudinal structure)

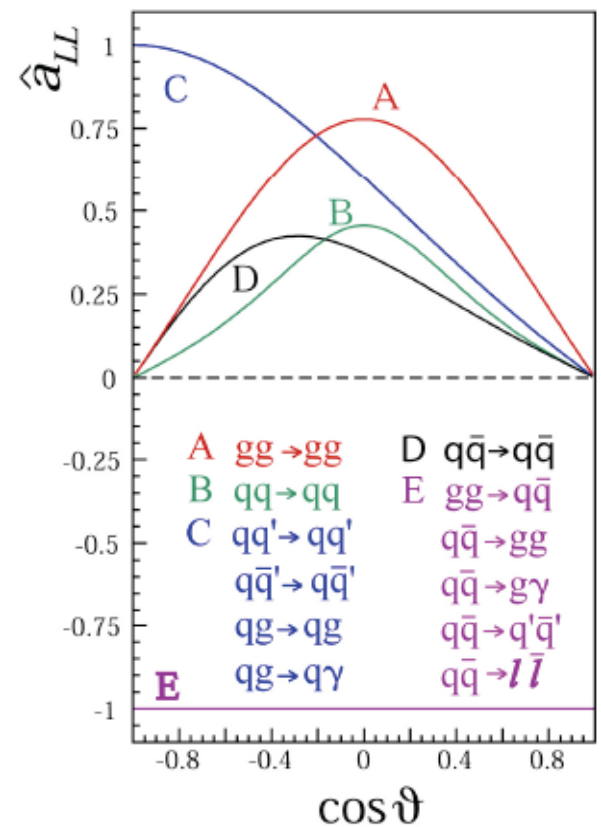
Probing ΔG

Double longitudinal spin asymmetry (A_{LL}) is sensitive to ΔG

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

$\hat{\sigma}$ Spin dependence

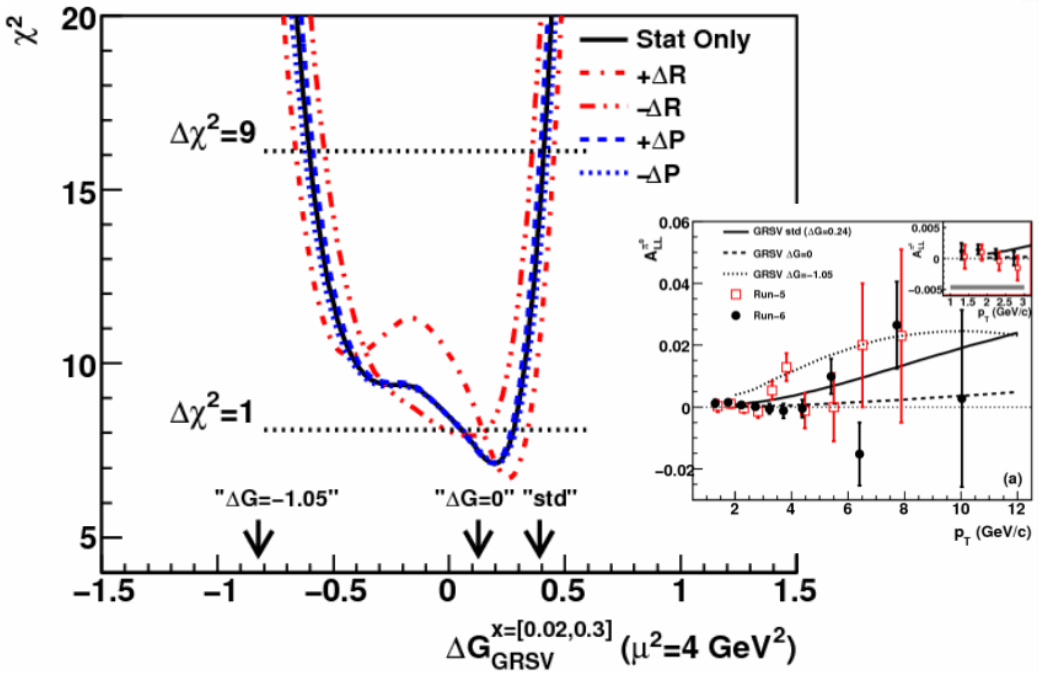




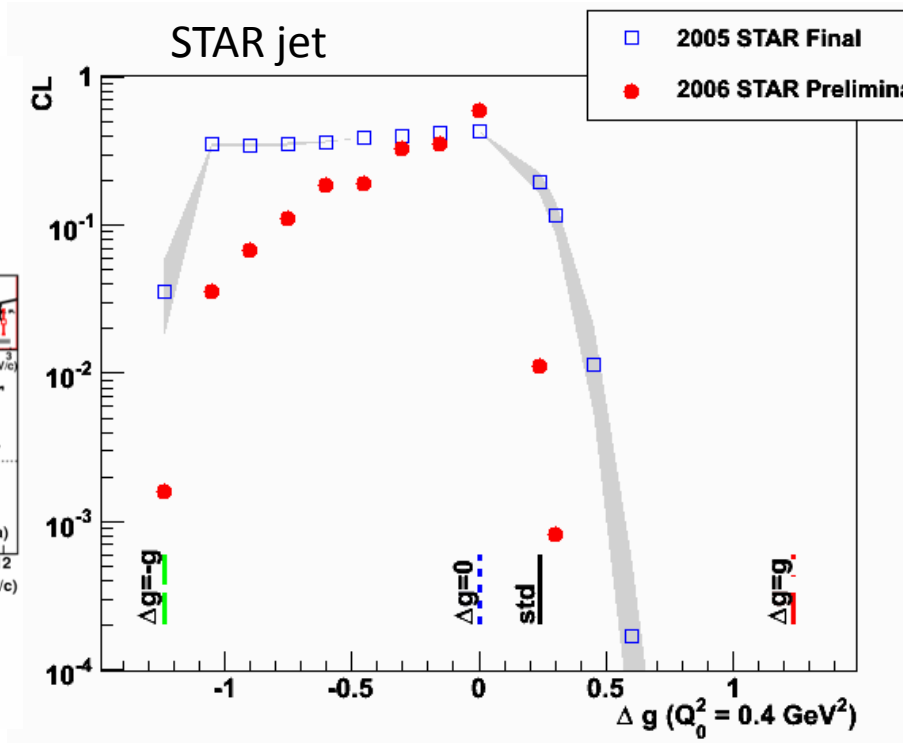
What we have learned

We found the asymmetry (A_{LL}) is small.
Under a model of the pol gluon PDF (GRSV), we can determine the ΔG value.

PHENIX pi0



STAR jet



PHENIX

$$\text{Stat.error}: \Delta G_{GRSV}^{x=[0.02,0.3]}\left(\mu^2 = 4GeV^2\right) = 0.2 \pm 0.1\,(1\sigma) \quad \text{and} \quad 0.2^{+0.2}_{-0.8} \quad (3\sigma)$$

$$\text{Syst.exp.error}: \pm 0.1$$

Is the spin puzzle solved?

From PHENIX

$$\text{Stat.error}: \Delta G_{GRSV}^{x=[0.02,0.3]}\left(\mu^2 = 4GeV^2\right) = 0.2 \pm 0.1\ (1\sigma) \quad \text{and} \quad 0.2^{+0.2}_{-0.8} \quad (3\sigma)$$

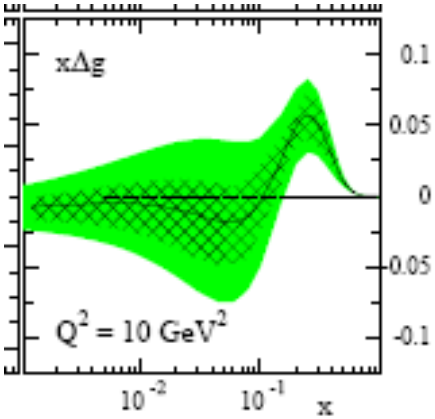
$$\text{Syst.exp.error}: \pm 0.1$$

No, the very large ΔG hypothesis is excluded. But it still have a large uncertainty.

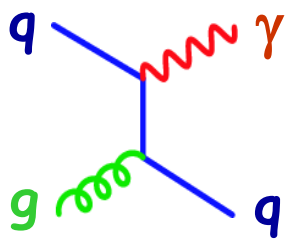
— More data accumulation.
With the same channel, it's difficult to reduce this range. FOM=P^4L
Other channels, especially for the negative polarization

— The chi2 plot is based on a model (GRSV).
We'd like to map out the x_{Bj} dependence.

DSSV arXiv:0904.3821
A global fit including RHIC results
Does Δg have a node?

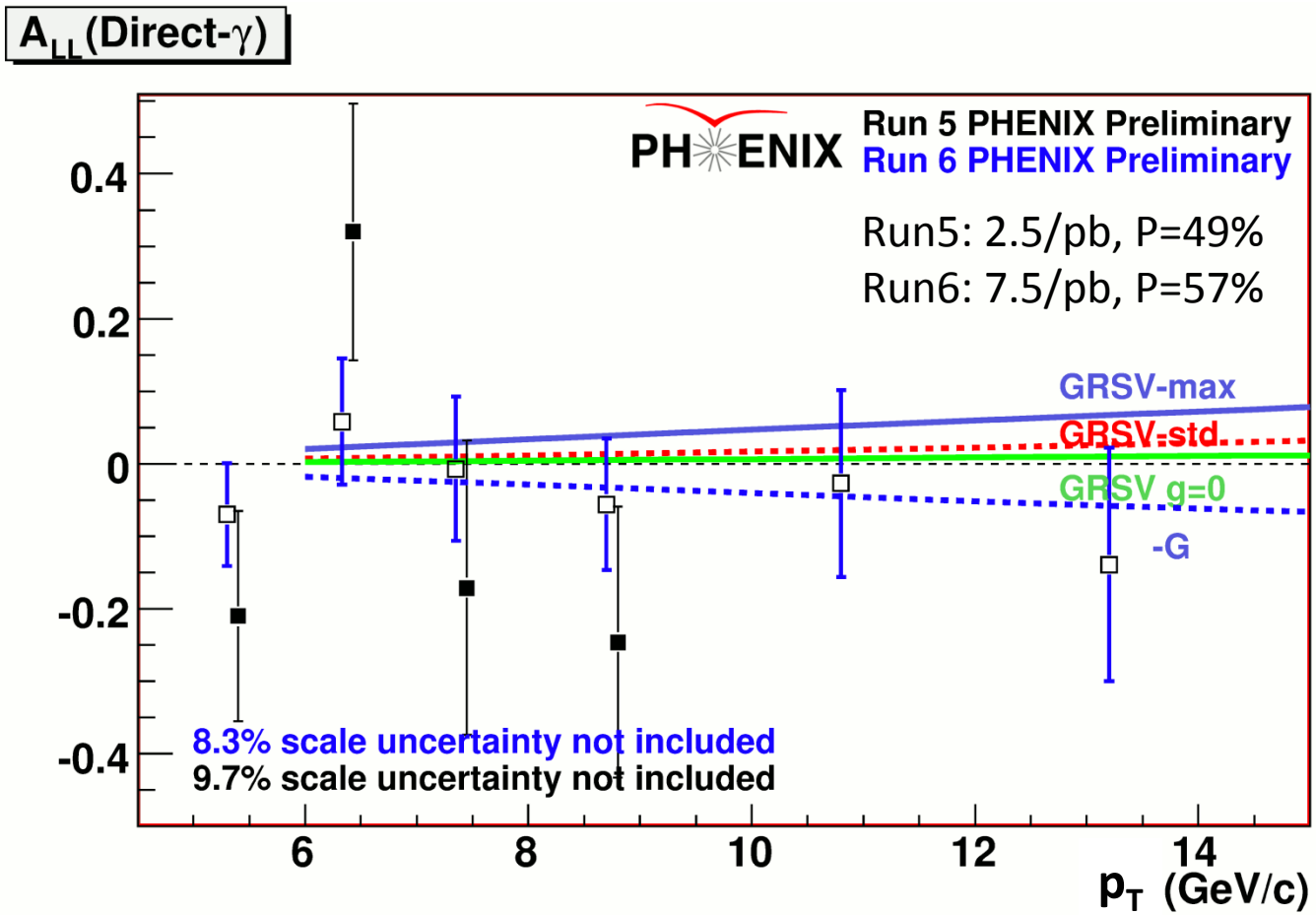


Direct photon A_{LL}



clean channel

sensitive to the sign of ΔG



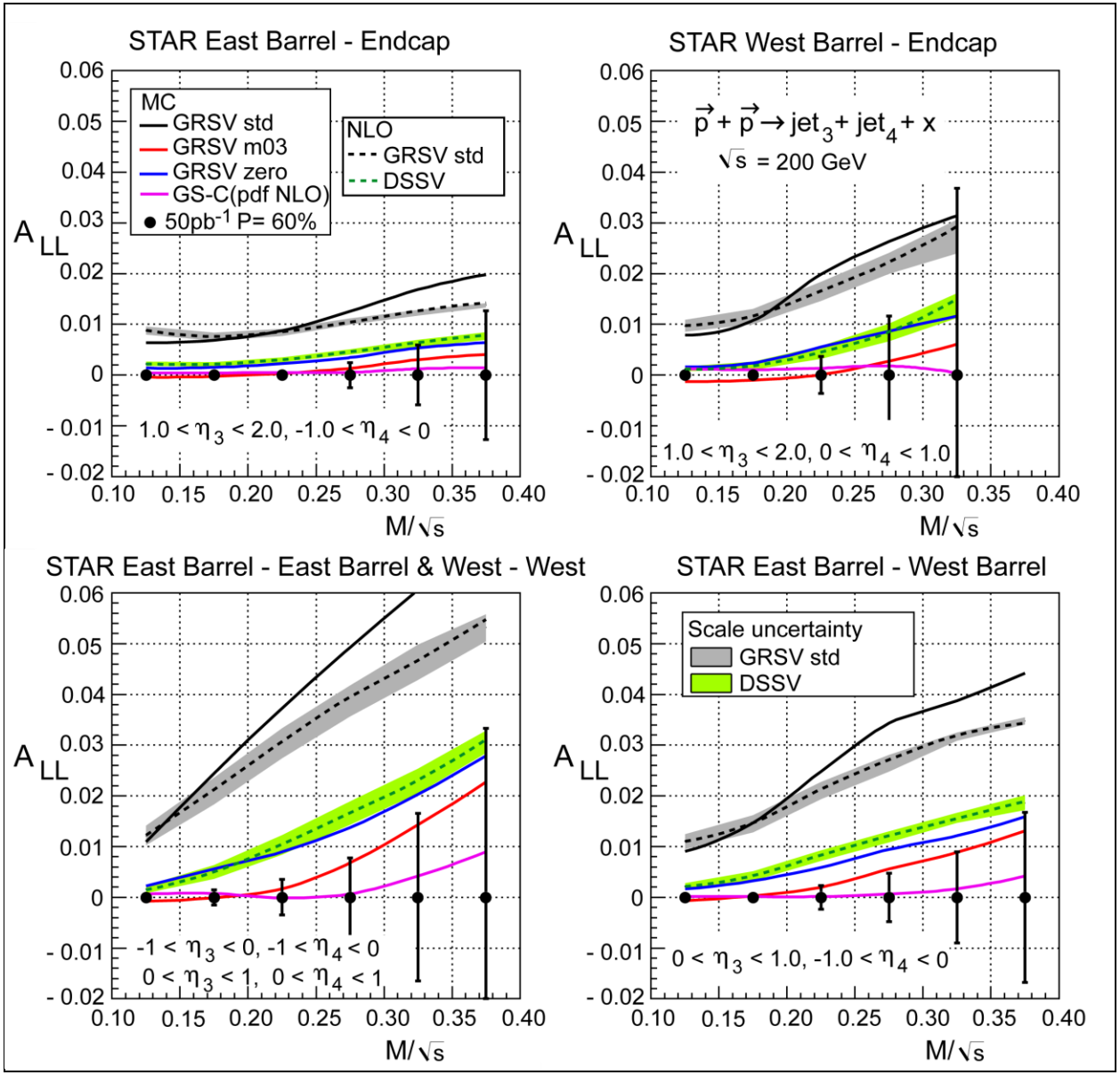
Currently statistically limited.

Better S/N in high pT

Important with a RHIC improvement. Hope FOM x~100

For the x dependence

Differential analysis



STAR

200 GeV projections

50 pb^{-1} P=60%

Di-jet divided into subsets. Each sensitive to different x region.

M//√s~√x1x2,
different x1/x2 bins

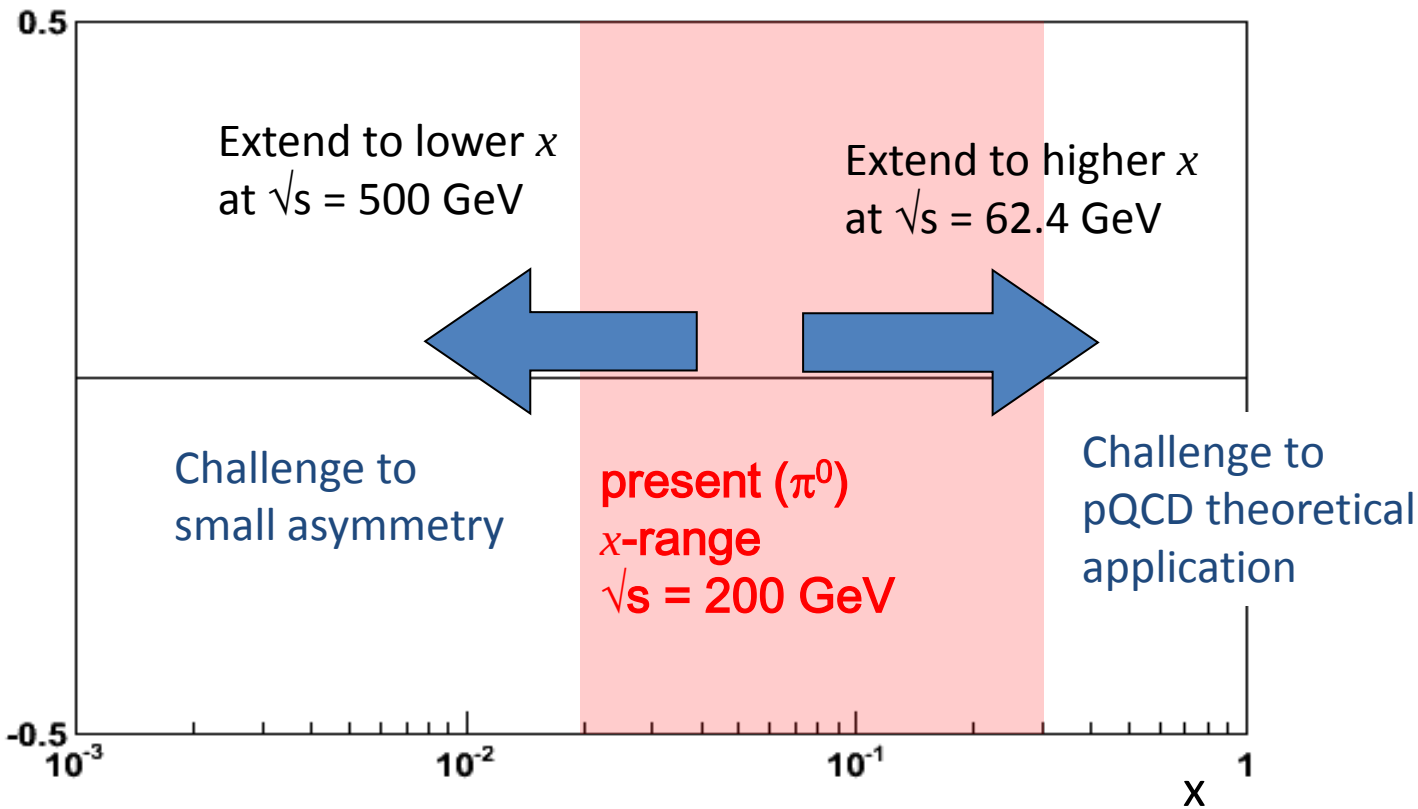
2009 run has 1/3 of FOM.

PHENIX upgrade :
the VTX detector
(inner barrel silicon detector)
increases the acceptance.

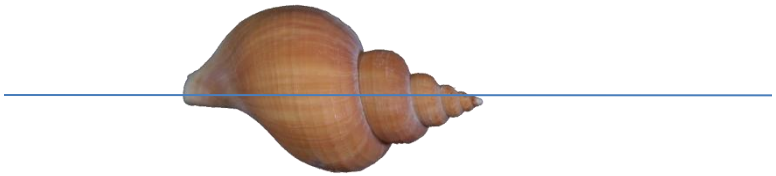
For the x dependence

Another option: different √s

- Varying √s in p+p collisions varies the x range for a given p_T bin.
- 2006 measured π^0 A_{LL} at √s=62.4 GeV (PHENIX).
- For W program, we need significant luminosity (~300 pb^{-1}) at √s=500 GeV, allowing access to lower x.

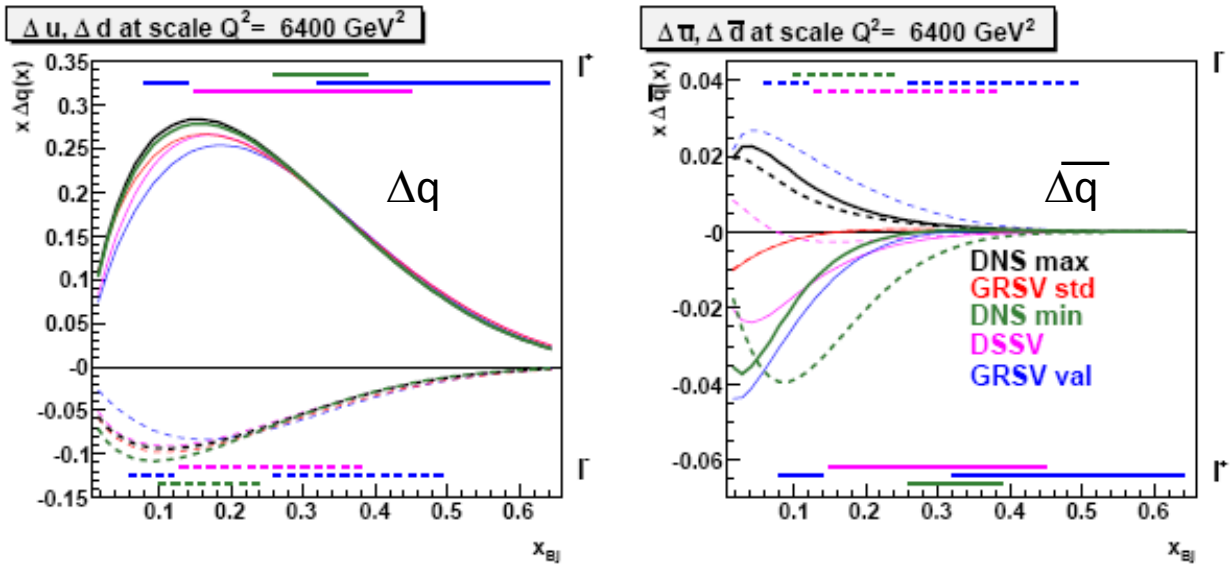


Anti-quark spin flavor decomposition



(anti) quark components

From SIDIS

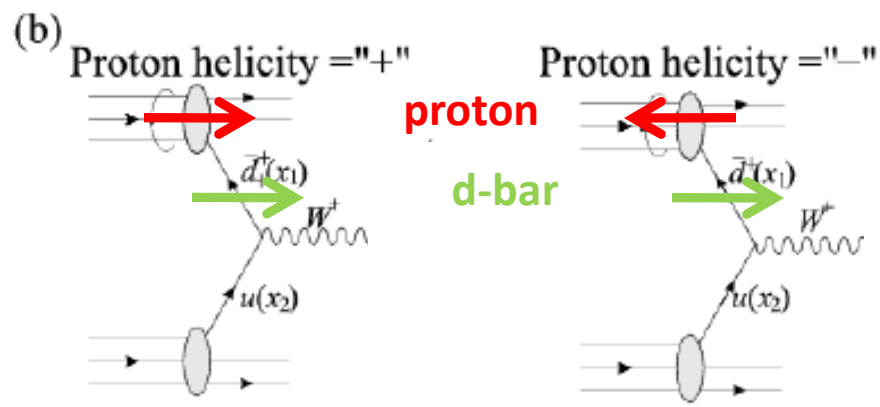


W program at RHIC

d-bar+u →W+

u-bar+d →W-

d-bar, u-bar is always positive helicity



W^+ A_L: Longitudinal single spin asymmetry information of d-bar in the proton

No fragmentation function needed.
Test at very high Q^2 (M_W^2=6460GeV^2)

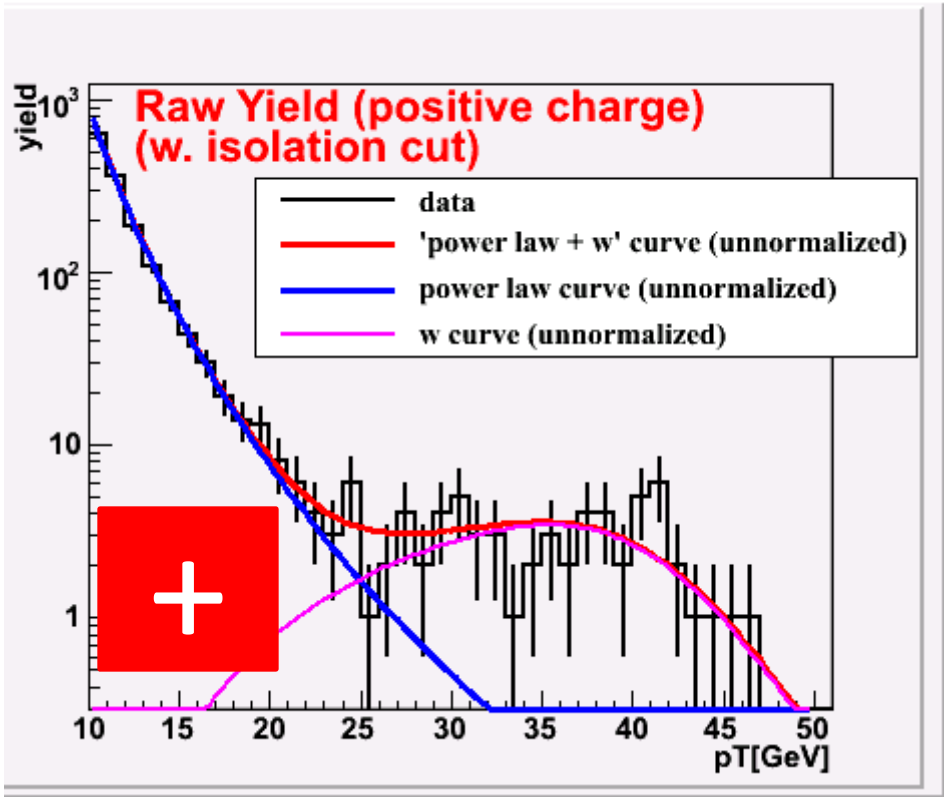
It has just begun in 2009run.

Road map

3 steps

1. Confirm our W signal. (~∫L=10/pb)
2. Confirm non zero asymmetry from quark pol. (~∫L=100/pb)
3. Constrain anti quark polarization. (~∫L=300/pb)

PHENIX electrons
(raw yield)

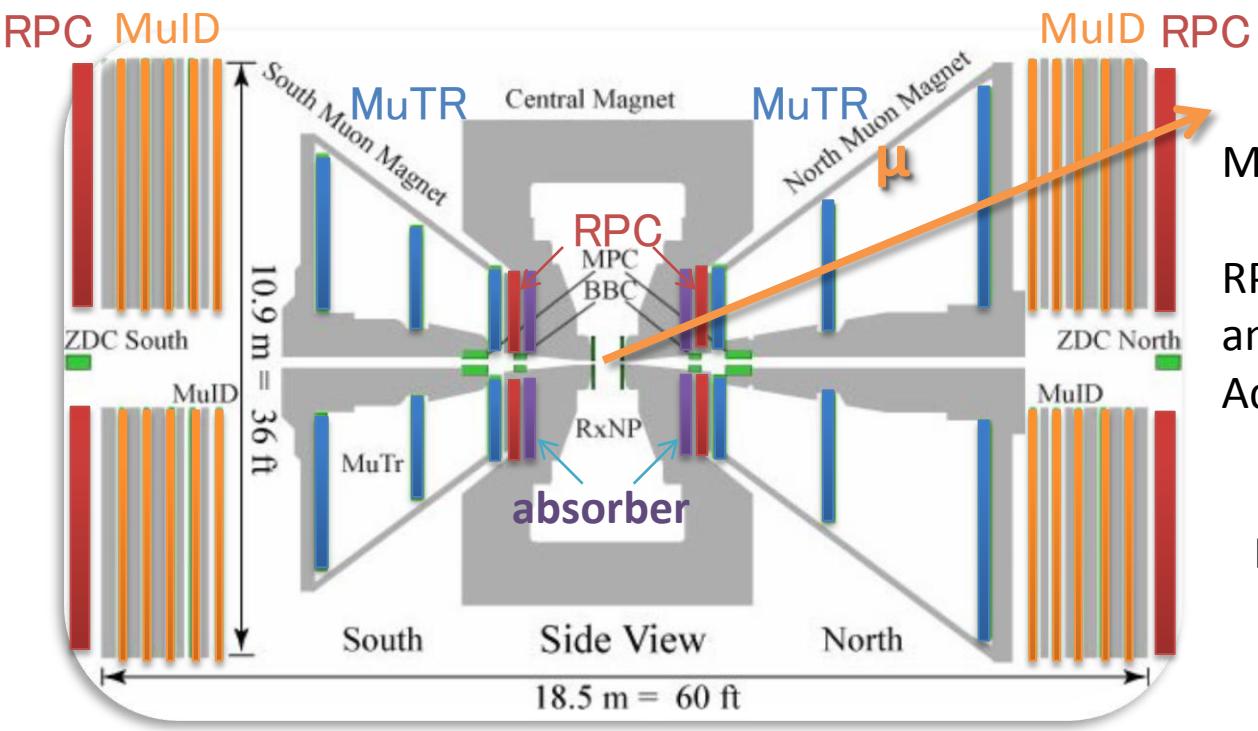


Experimental challenges

Trigger & charge separation

PHENIX

Central arm : electron channel, it should work with the current setting
Muon arm : muon channel, Triggering based on E loss → Momentum base



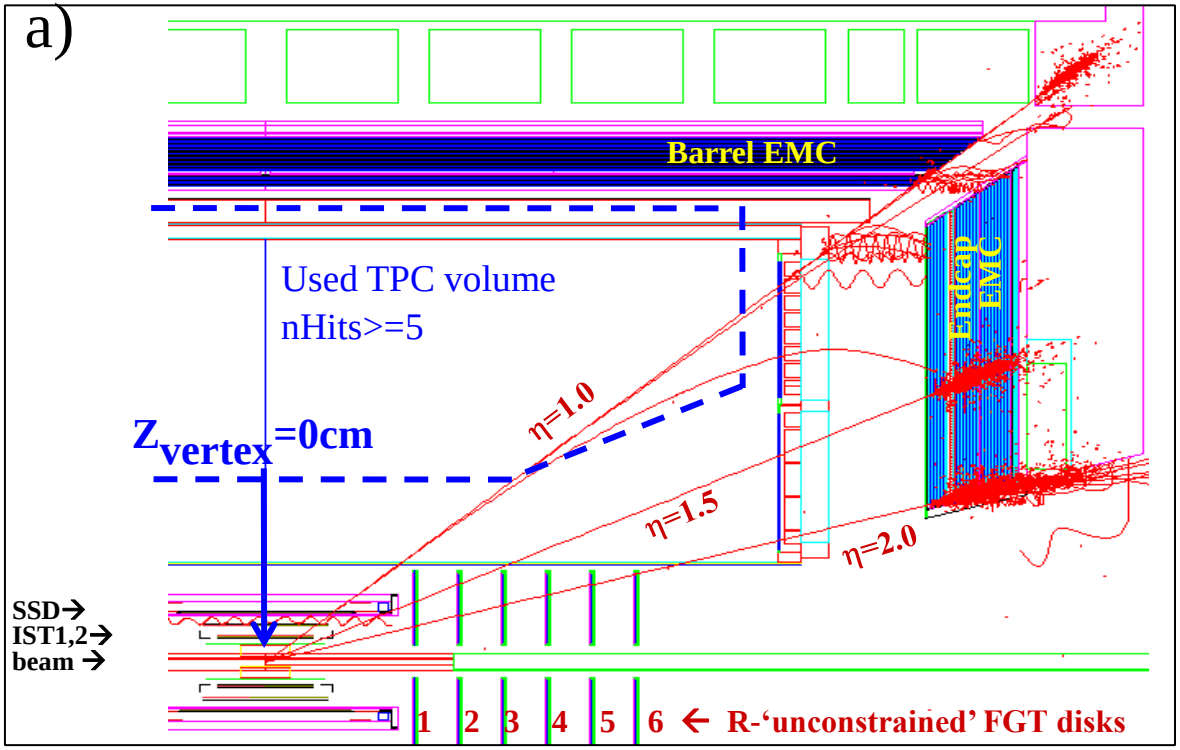
MuTR: 10% of charge sent to the trigger logic
RPC : provide the timing info. and
Additional absorber

Functional by 2011 run.

Experimental challenges

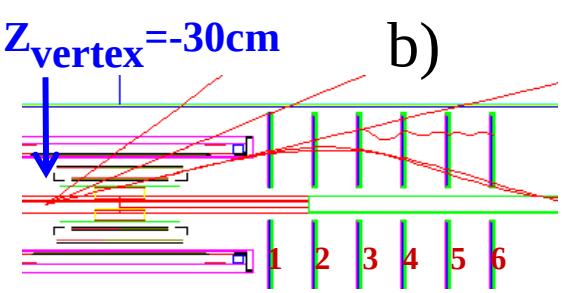
STAR

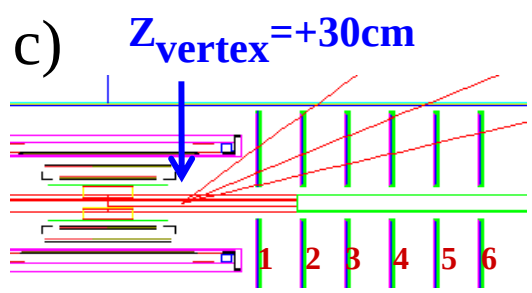
Forward electron tracking for charge separation.



FGT disks geometry:
Rin=7.5cm, Rout=41cm,
Z1…Z6=60…150cm, ΔZ=18cm

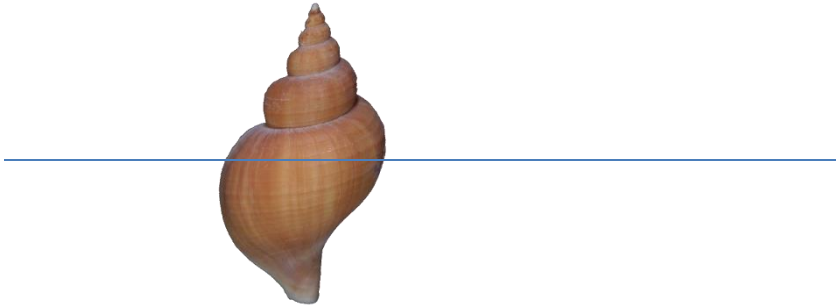
- 5 hits required for helix reco
- FGT sustains tracking if TPC provides below 5 hits
- use TPC, SSD,IST for Z_{vertex} <~0 and η<~1.3
- allow $Z_{vertex} \in [-30,+30]$cm





By 2012 run

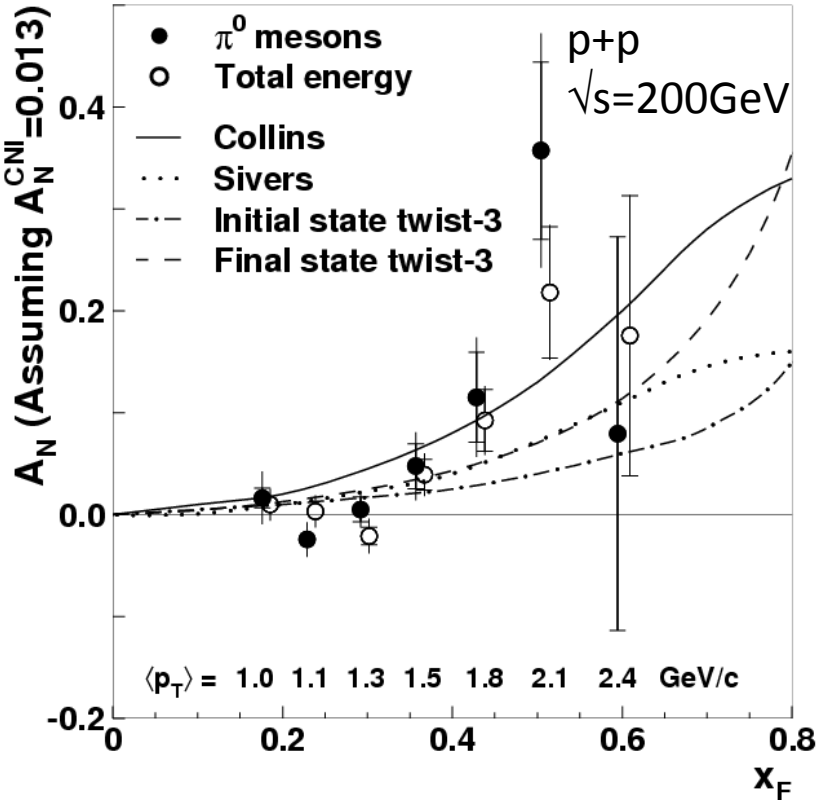
Transverse spin structure



In the theory community,
this is the most active field.

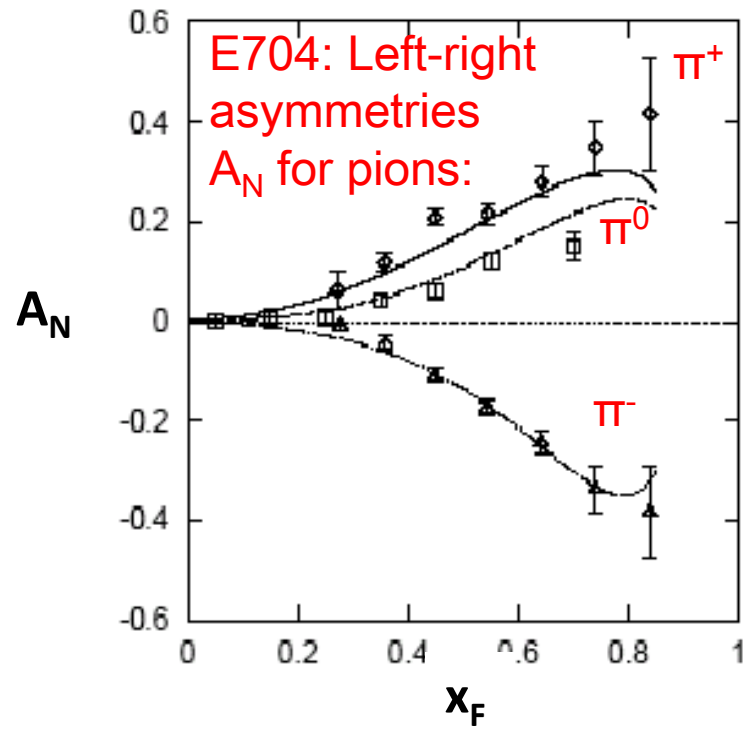
Experimental results lead the field

STAR PRL 92,171801, 2004



$$x_F = \frac{2p_L}{\sqrt{s}}$$

STAR measured a large single spin asymmetry. Qualitatively it looks very similar to the measurements by E704 in 1990's .



Possible mechanisms (ex.)

Sivers mechanism:

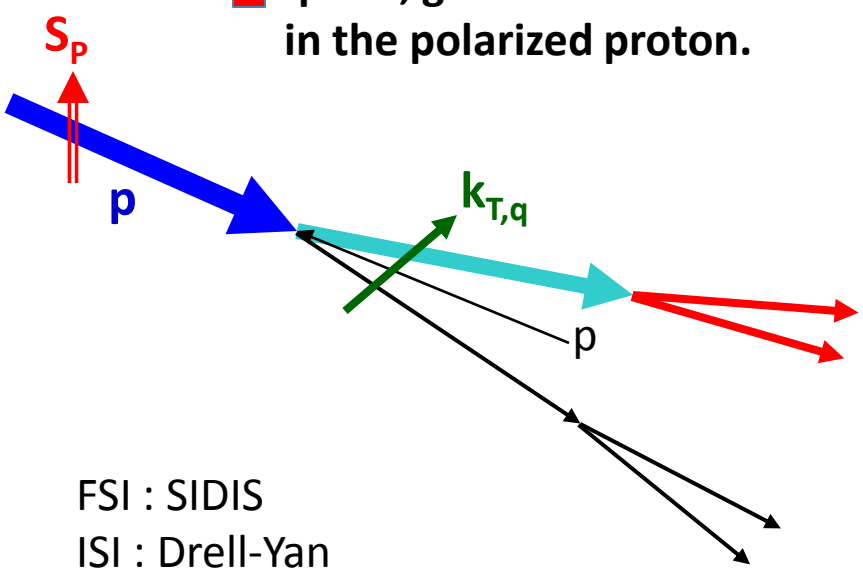
correlation between
proton spin & parton k_T

Collins mechanism:

parton spin & hadron kT
in the fragmentation process.

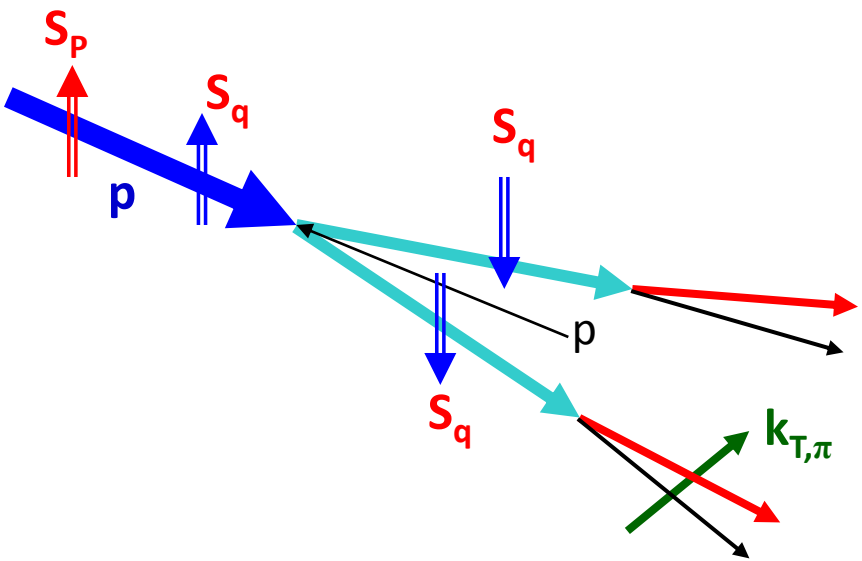
Transversity (quark polarization)
× jet fragmentation asymmetry

- **quark, gluon motion in the polarized proton.**

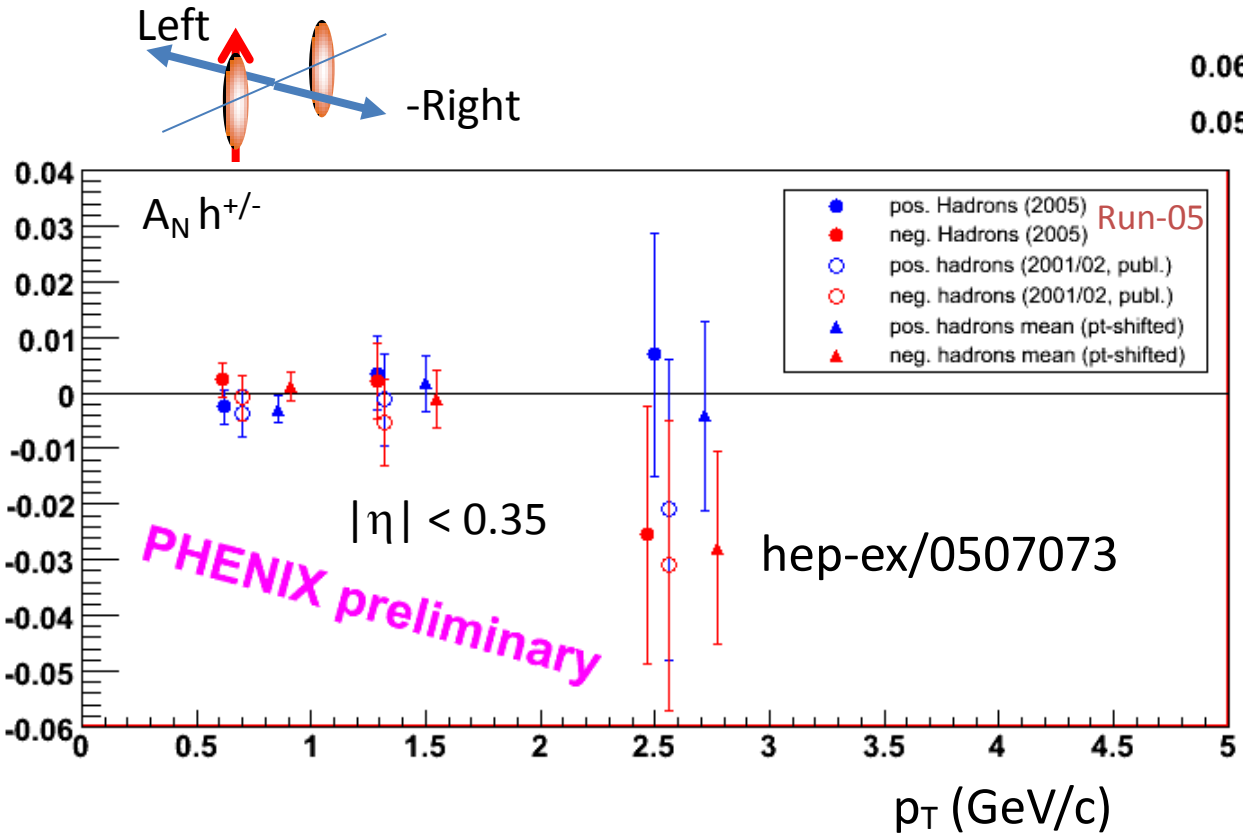


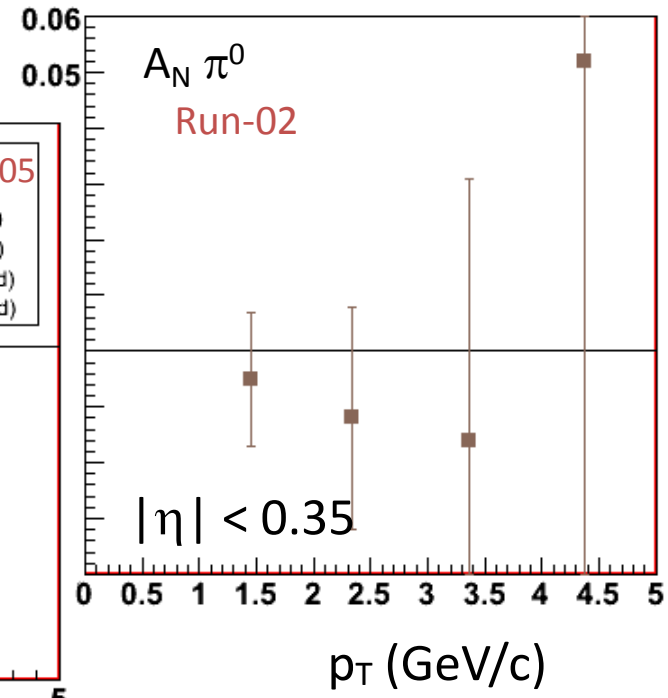
FSI : SIDIS
ISI : Drell-Yan

- **an analyzer for the quark transversity pol. (no gluon effect)**



Midrapidity hadron A_N



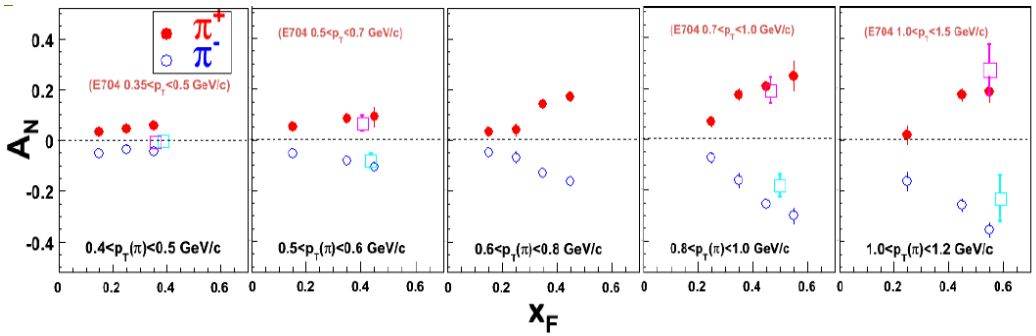


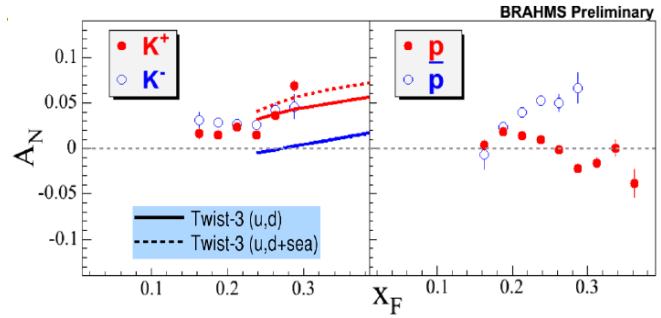
PRL 95, 202001 (2005)

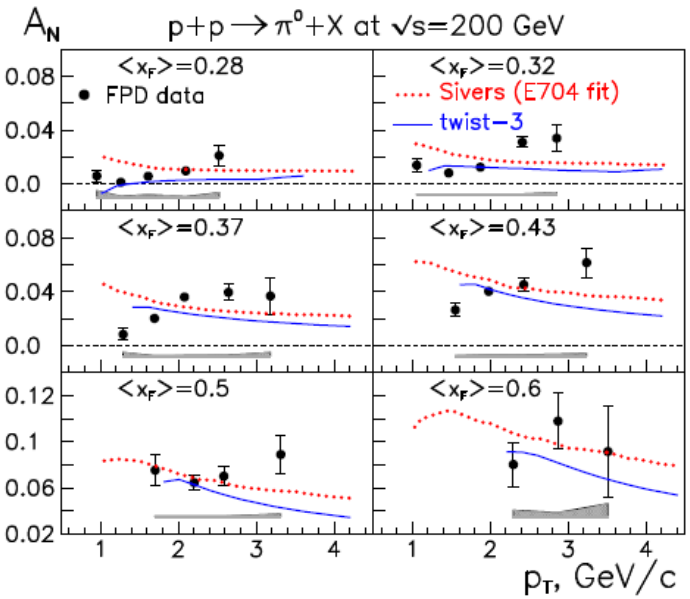
- A_N is zero within 1%
- It constrains Sivers distribution function for gluons. (Anselmino et al., PRD74, 094011 (2006))
- Updated π^0 result (with >10x smaller stat. uncertainty) is coming.

The current situation

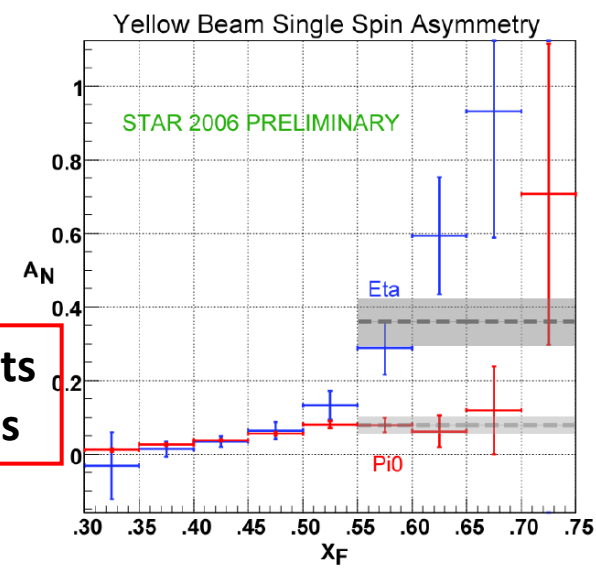
At SIDIS, COMPASS and HERMES disagree on Sivers asymmetry measurements.
At RHIC, there are measurements where the mechanism is not well understood.



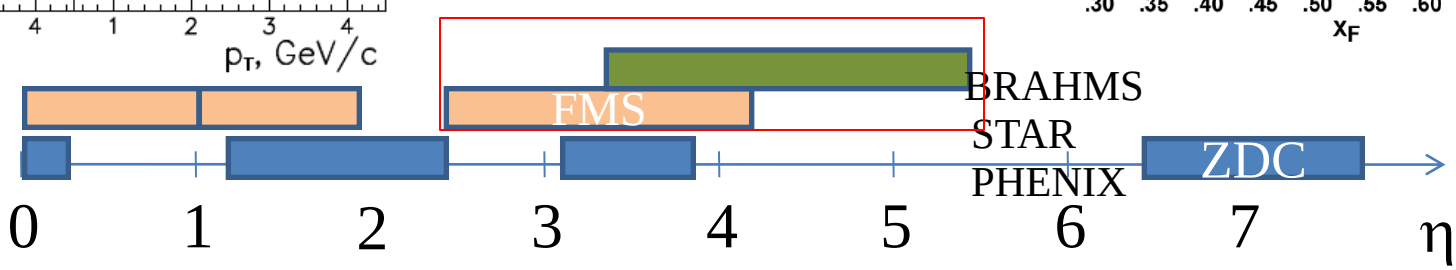




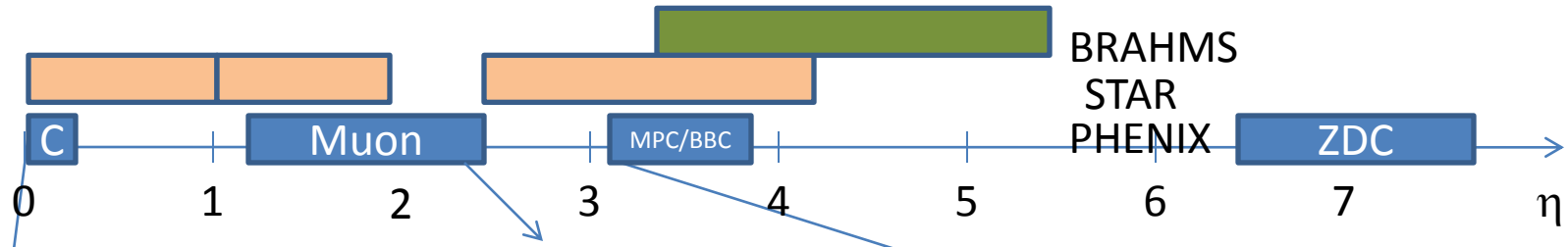
Particle dependence?
p_T dependence?



Complementary measurements will disentangle various effects



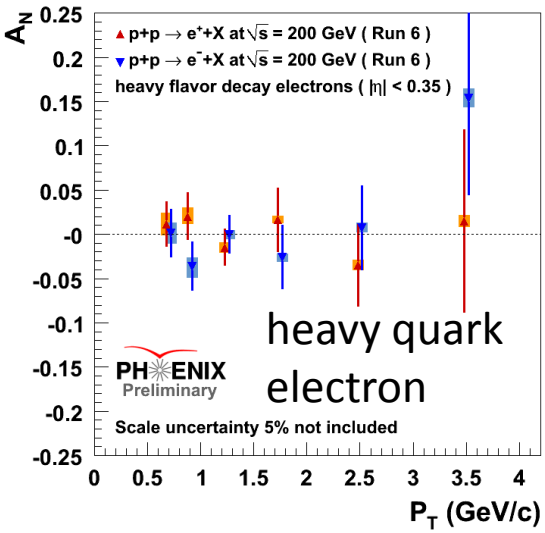
PHENIX single spin analysis catalogue

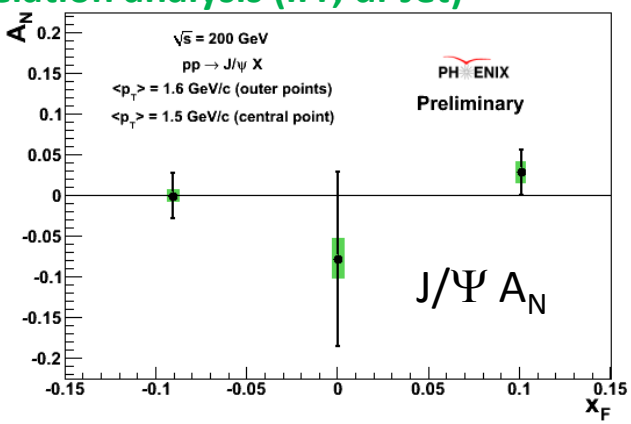


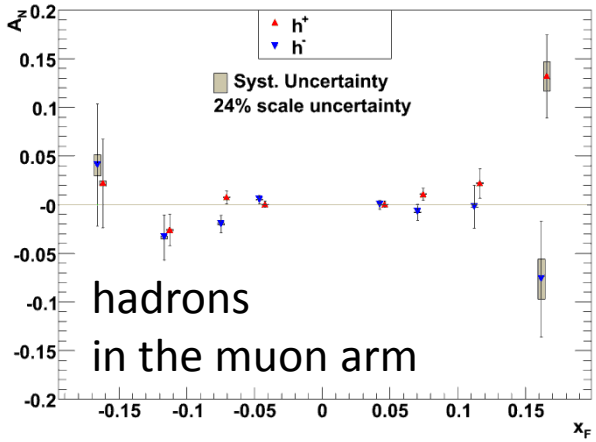
central arm pi0 A_N (Run8pp)
Heavy quark A_N
correlation analysis (IFF, di-Jet)

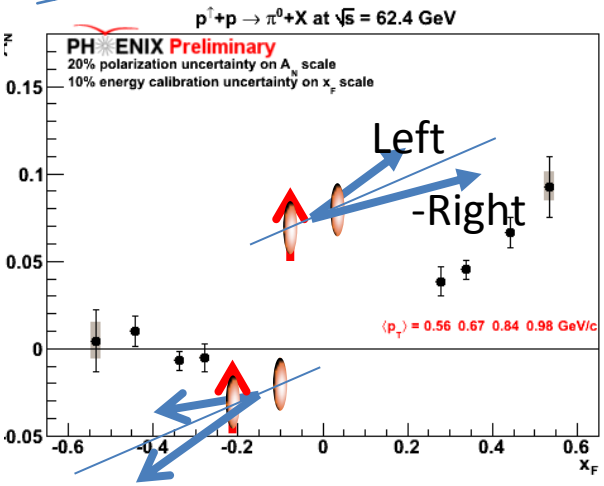
Heavy quark muon decay
punch through hadron
correlation analysis (IFF, di-Jet)

MPC pi0, eta A_N







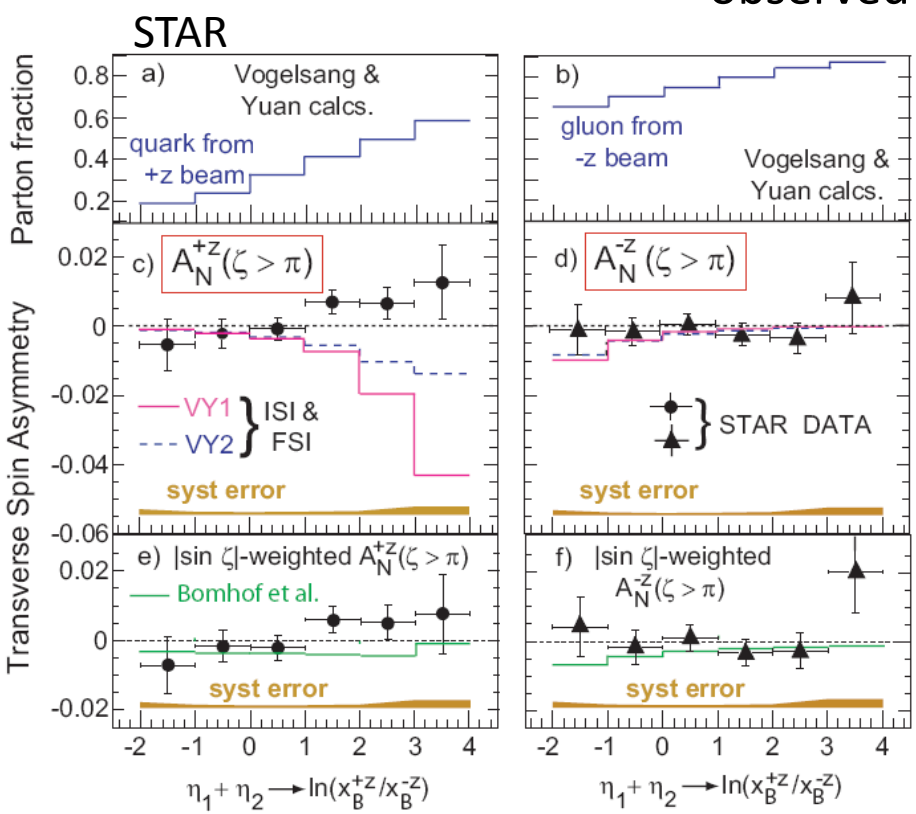


Other than A_N , example

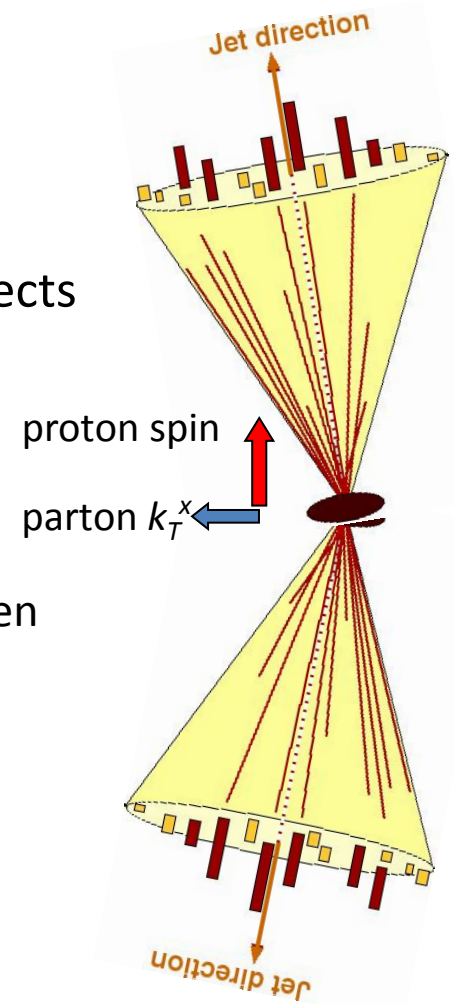
Sivers with di-Jets at Mid-rapidity

Initially thought could be large and give sensitivity to q and g orbital angular momentum

PRL 99 (2007) 142003
Observe small SSA
Much smaller than Sivers effects observed in SIDIS



Cancellation between
ISI vs FSI
and
u-quark vs d-quark



γ-Jet (only ISI)
leading flavor tag (u/d separation)

Prediction in the transverse spin

There is a prediction based on a solid theory background.

– **Sivers effect in Drell-Yan process (PLB536,43,… , arXiv:0901.3078)**

$$f_{1T}^{\perp}(x, k_T, \zeta)\big|_{\mathrm{DIS}} = -f_{1T}^{\perp}(x, k_T, \zeta)\big|_{\mathrm{DY}}.$$ FSI vs. ISI

A fundamental test of the QCD.

Direct photon (forward) + jet (mid-rapidity) :

The same trick with larger cross section. (PRL 99,212002)

STAR : FMS gamma + Central TPC Jet.

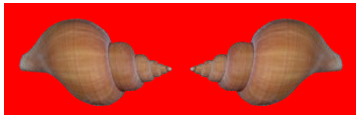
PHENIX : FOCAL gamma + central arm jet ?

RHIC schedule related to spin

2009 PAC recommendation

Year	Likely beam	Exp's upgrade	RHIC upgrade	Gain from RHIC upgrade	comments
FY10	AuAu				No spin data
FY11	AuAu low√s pp@500 UU	PNX-VTX PNX- mutrig	9MHz cavity AGS tune jump Spin flipper	short vtx width→ L Polarization Rel. Lum. systematic	W, step 1,2 Low x A_{LL}
FY12	AuAu@200 pp@500	PNX-FVTX STR-FGT STR-HFT proto	Electron lens Pol source	store lifetime → L Polarization	W, step 2,3 Low x A_{LL}
FY13	pp@200 AuAu	PNX-FOCAL?			pp ref for HI with new det. Transverse spin?

Summary



ΔG program

—More FOM, Other channels (other than g+g dominant process)
—Correlation analysis for the x-dependence
—Or different collision energies

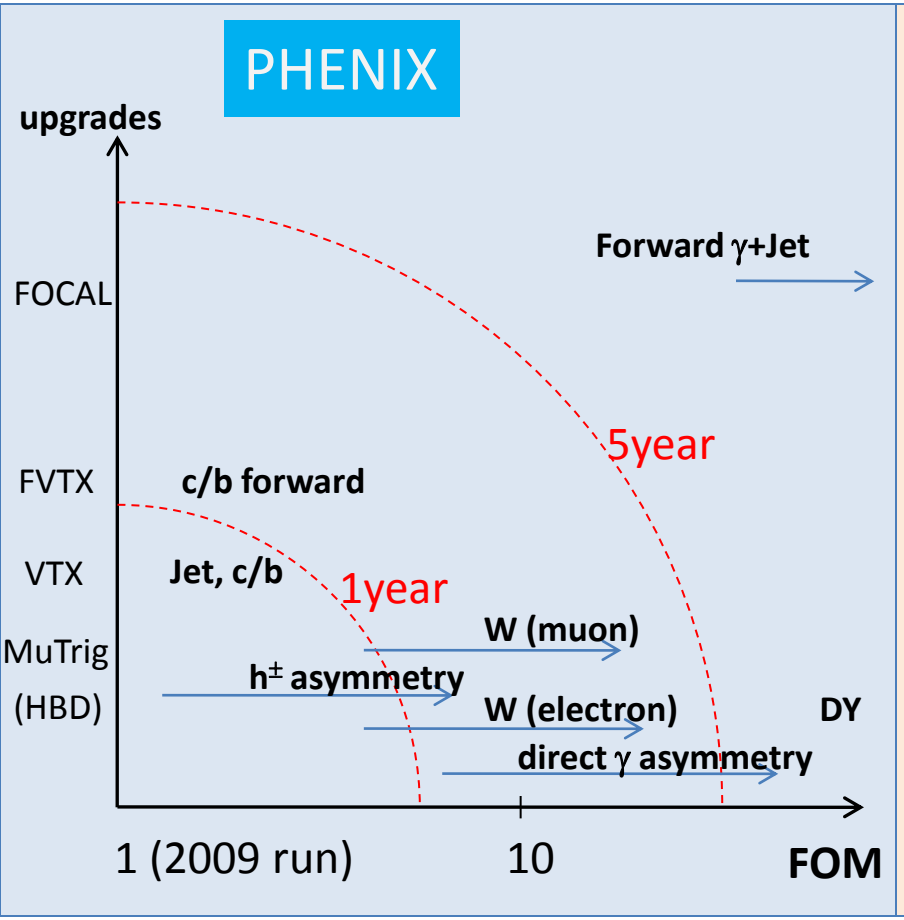
Anti-quark flavor decomposition

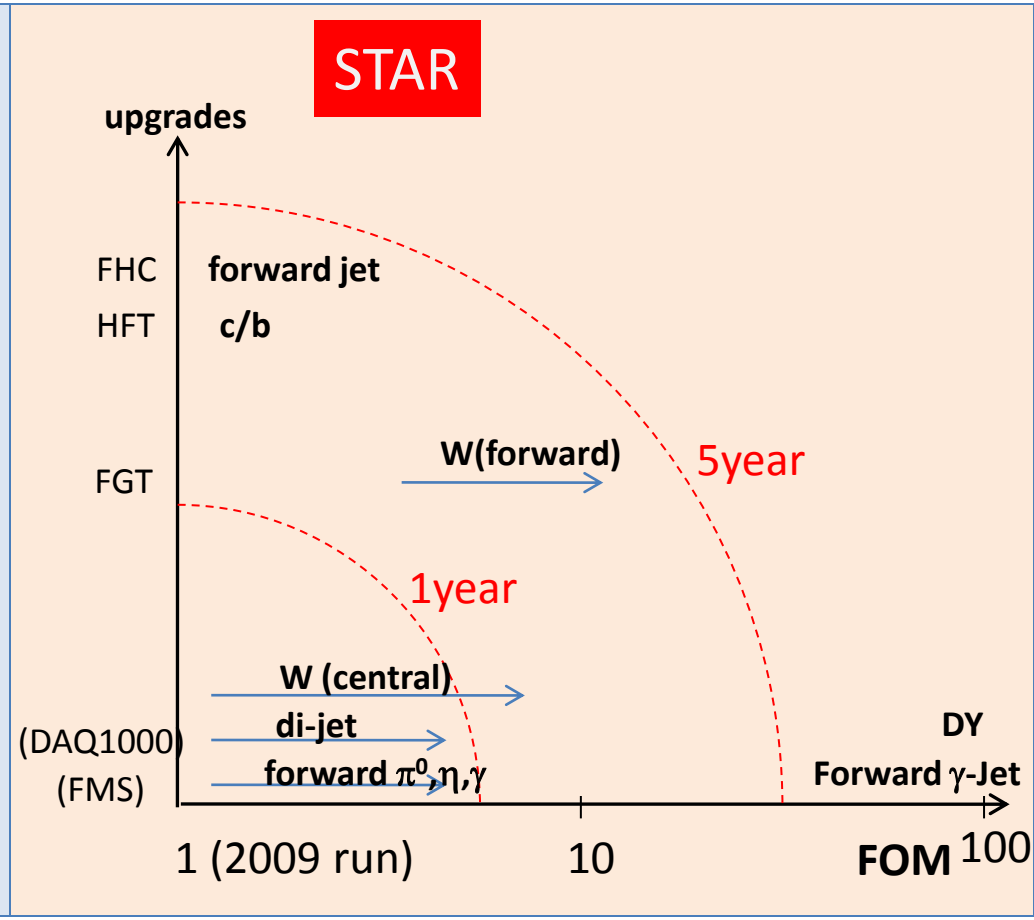
—This year, we collected the first $\sqrt{s}$=500GeV data.
—We will focus on this topic for the following few years.

Transverse spin structure

—Many results from RHIC remain unexplained.
—Correlation channels are also looked over.

The last slide : A very rough sketch





∗ Of course, not every physics channel is on the plot.
There are many challenges on going.