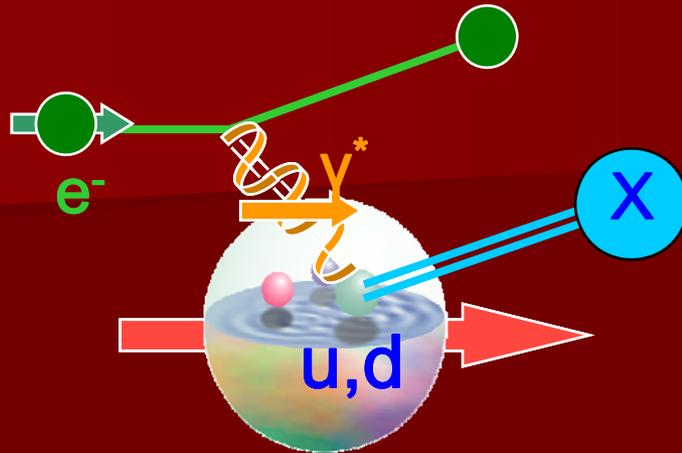


Probing the Proton Spin Structure with W bosons at PHENIX

Todd Kempel -- Iowa State University
for the PHENIX Collaboration

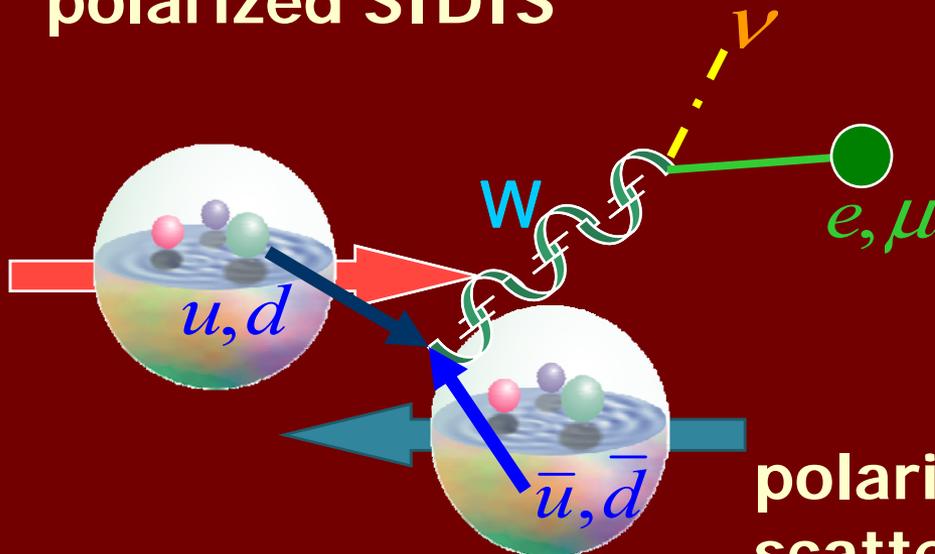
Probes Sensitive to Quark Flavor in Polarized Protons



Advantage: Only probing one proton

Disadvantage: Need to know Fragmentation Functions very well.

polarized SIDIS



Advantage: No Fragmentation Function

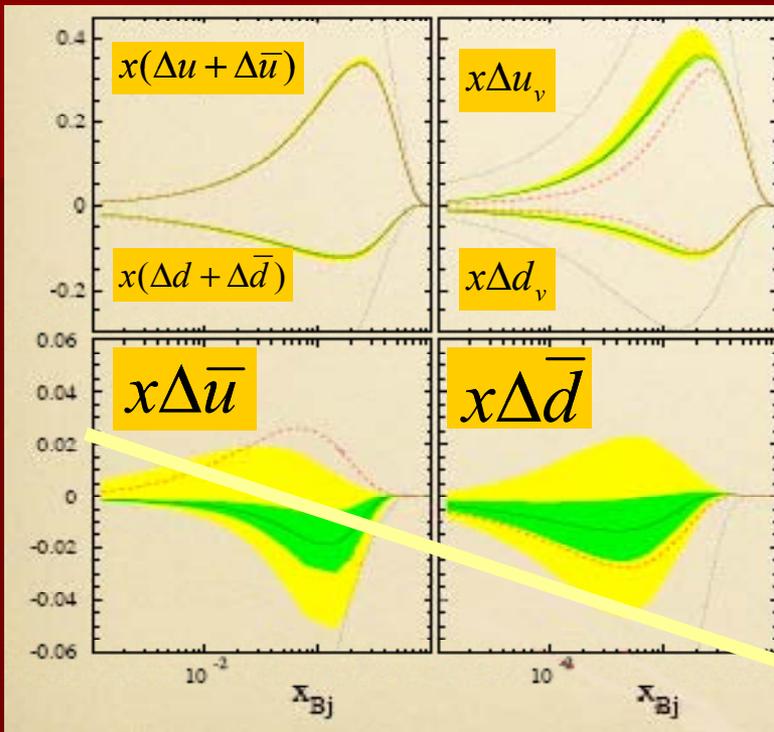
Disadvantage: Probing 2 protons. Can't measure W directly.

polarized pp scattering

Complementary Measurements!

Combining Measurements with Global Fits

2005 DNS Global Fit

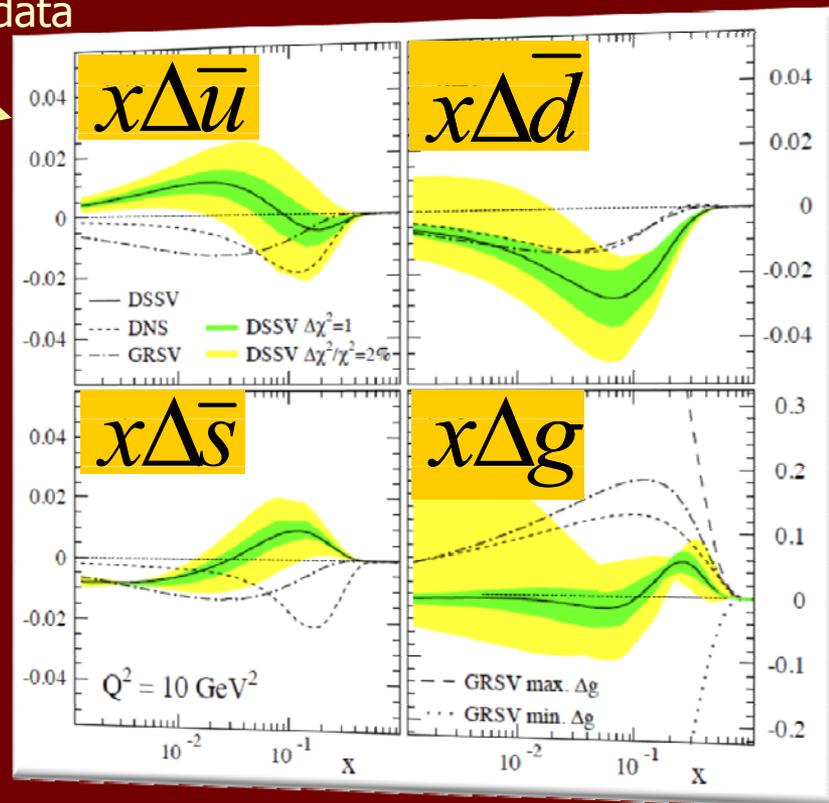


New DSS FF which include
RHIC and HERMES
unpolarized data

polarized RHIC data

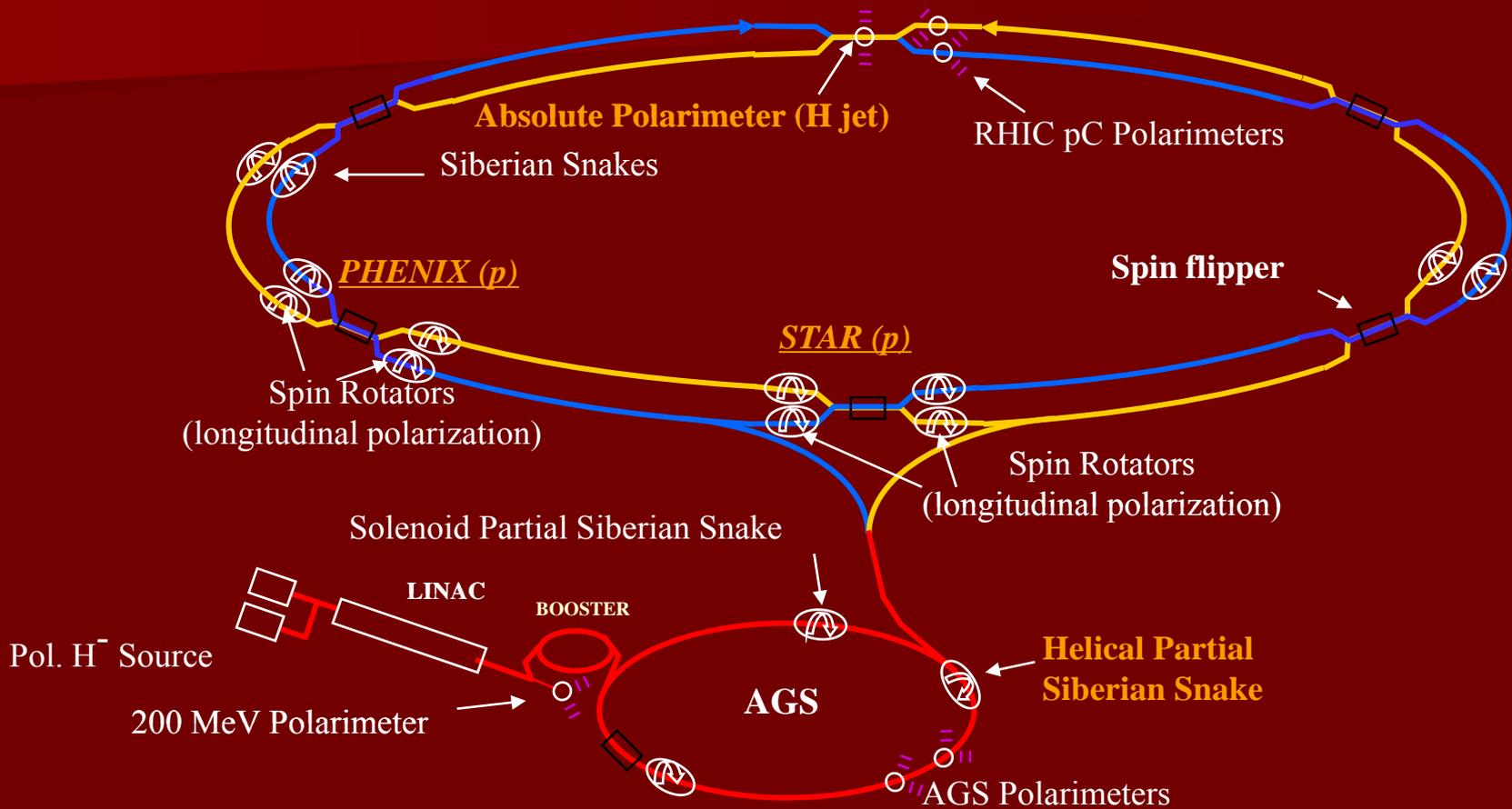
more SIDIS data

2008 DSSV Global Fit

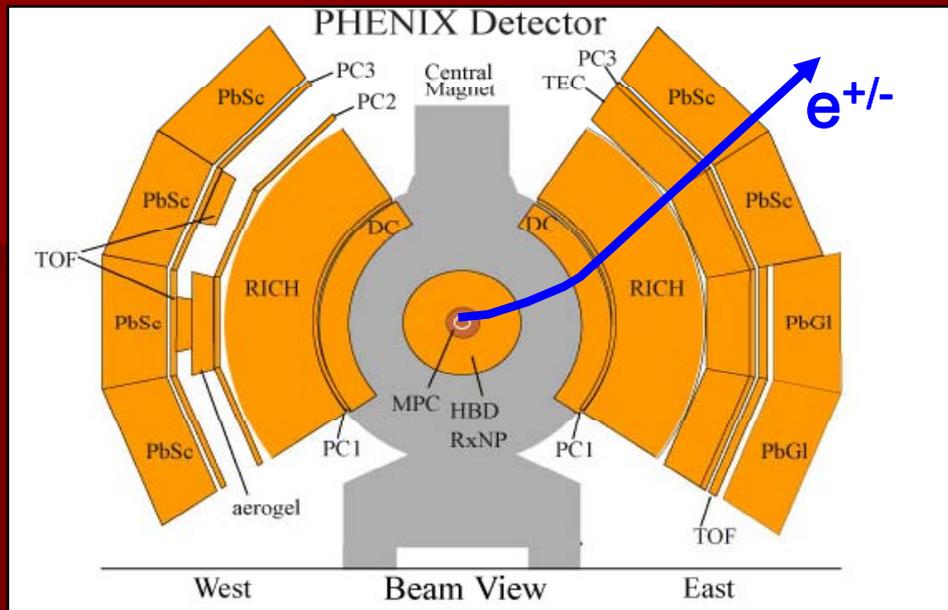


anti-u and anti-d distributions
small, but not well constrained
(positive? negative? nodes?)

The RHIC $\vec{p} + \vec{p}$ Collider



The PHENIX Experiment



Rapidity: $|\eta| < 0.35$
 $\Delta\phi = 2 * (\pi/2)$

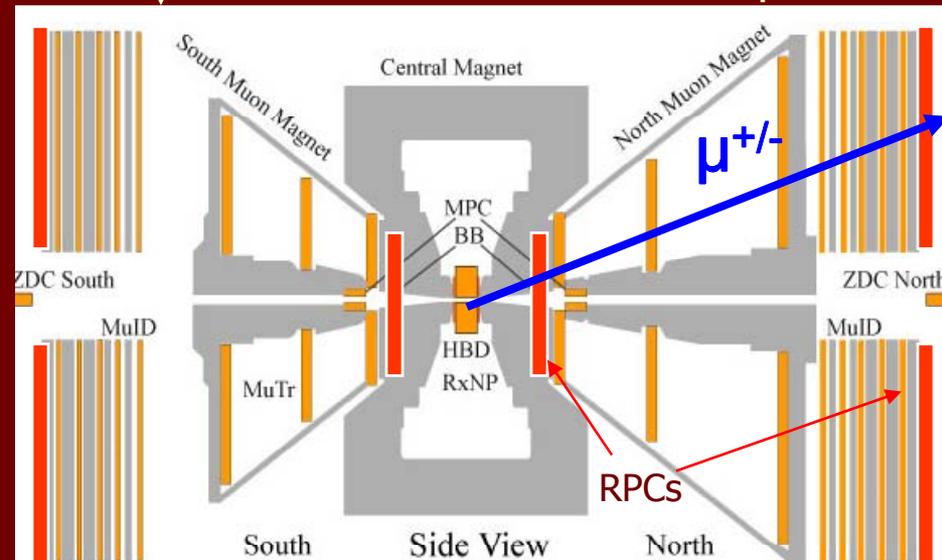
- $\pi^0/\gamma/\eta$ Electromagnetic Calorimeter
- π^+/π^- Drift Chamber
- Ring Imaging Cherenkov Counter
- e^+/e^- HBD

Philosophy (initial design):

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

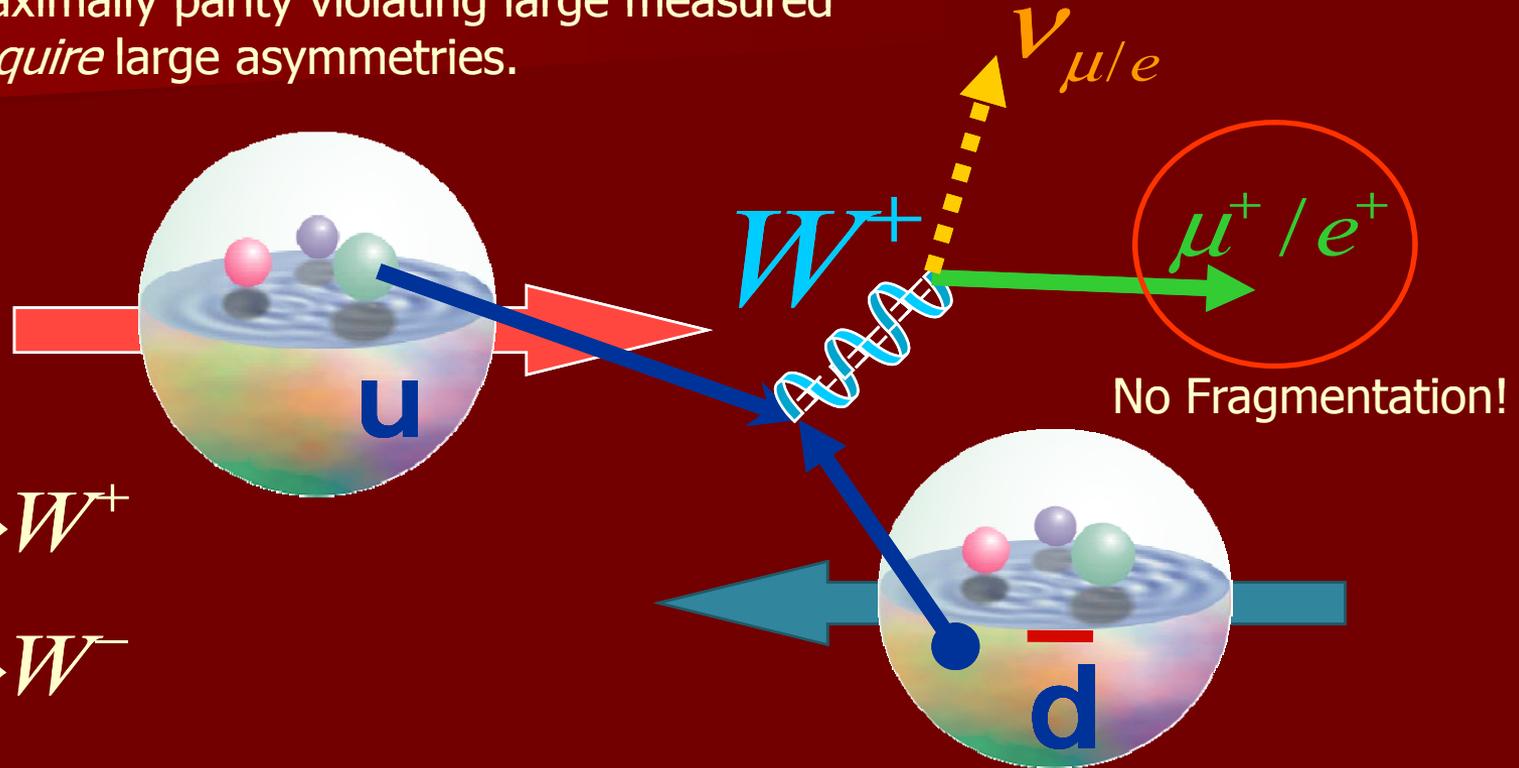
μ^+/μ^-
 Muon Tracking Detector
 Muon Identifier

Rapidity: $1.2 < \eta < 2.2$ (2.4)
 $\Delta\phi = 2\pi$



W Production Basics

Since W is maximally parity violating large measured Δu and Δd *require* large asymmetries.



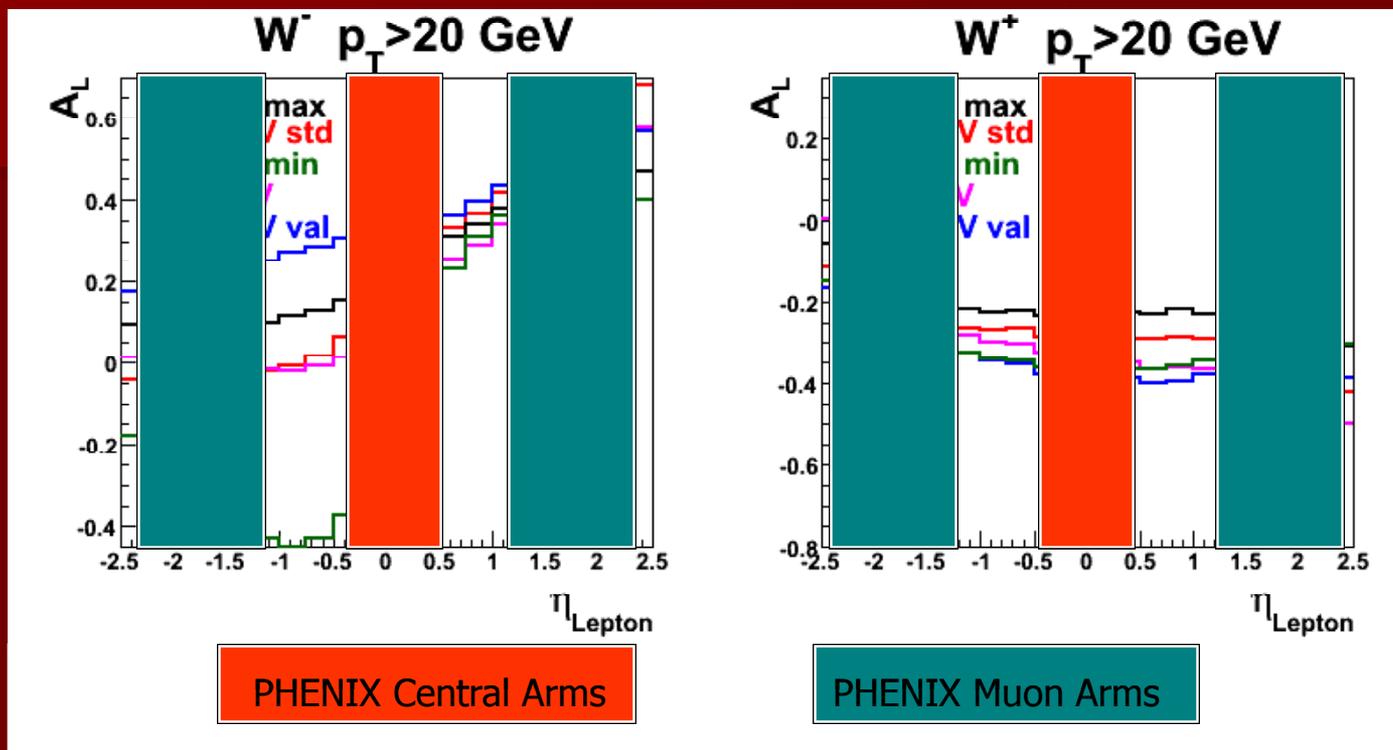
$$u\bar{d} \rightarrow W^+$$

$$d\bar{u} \rightarrow W^-$$

$$A_L^{W^+} = \frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow} \propto \frac{\Delta\bar{d}(x_1)u(x_2) - \Delta u(x_1)\bar{d}(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}$$

Similar expression for W^- to get $\Delta\bar{u}$ and Δd ...

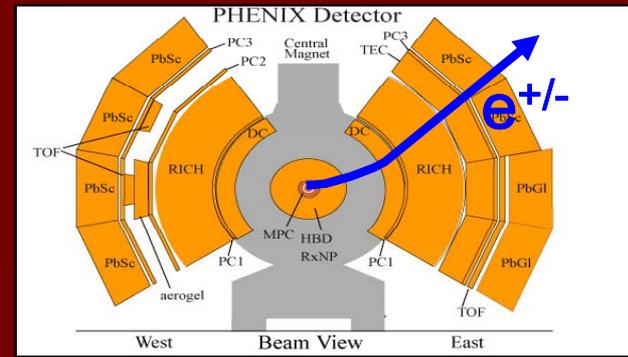
W's in the PHENIX Acceptance



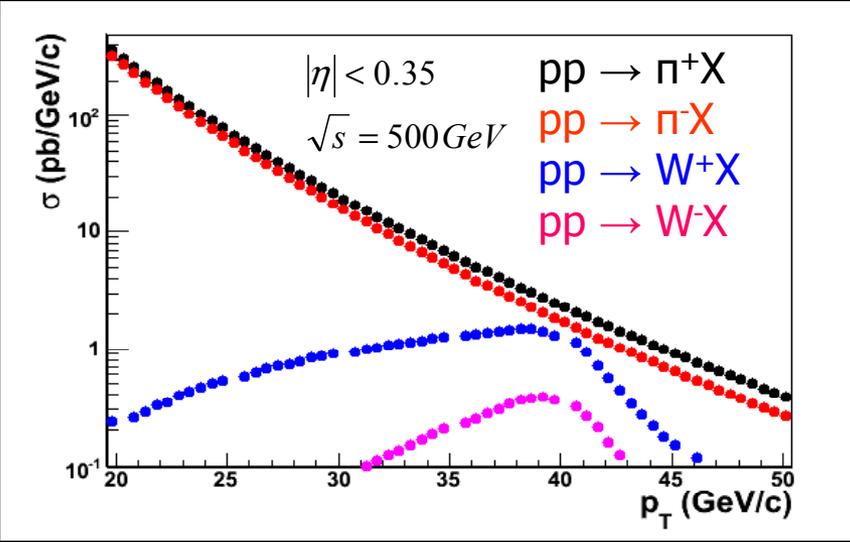
Central Arms are ready to Measure W's!

Muon Arms require a bit of work, but will be ready for the next 500GeV run

W's in the PHENIX Central Arms



Rapidity: $|\eta| < 0.35$



$$A_L = \frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow}$$

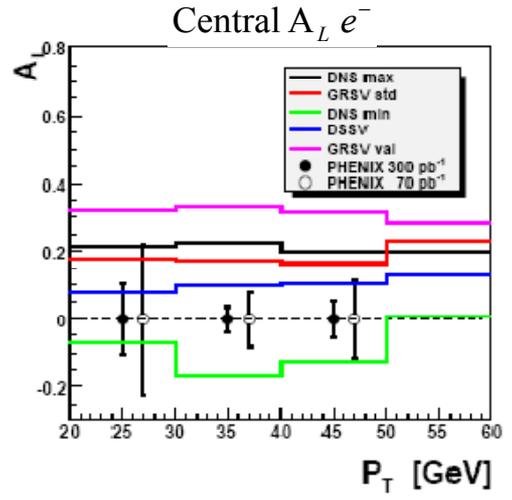
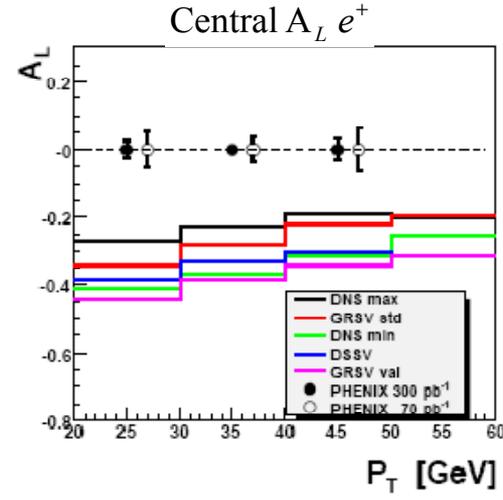
- 300 pb⁻¹
- 70 pb⁻¹

Pions: NLO pQCD Calculation from W. Vogelsang

W: RHICBOS (Nadolsky, Yuan)

Assumes 70% polarization

No background or detector resolution included



W's in the PHENIX Muon Arms

A bit of development necessary...

Design Luminosity

$$\sqrt{s} = 500 \text{ GeV} \quad \sigma = 60 \text{ mb}$$

$$L = 1.6 \times 10^{32} / \text{cm}^2 / \text{s}$$

Total X-sec rate = 9.6 MHz

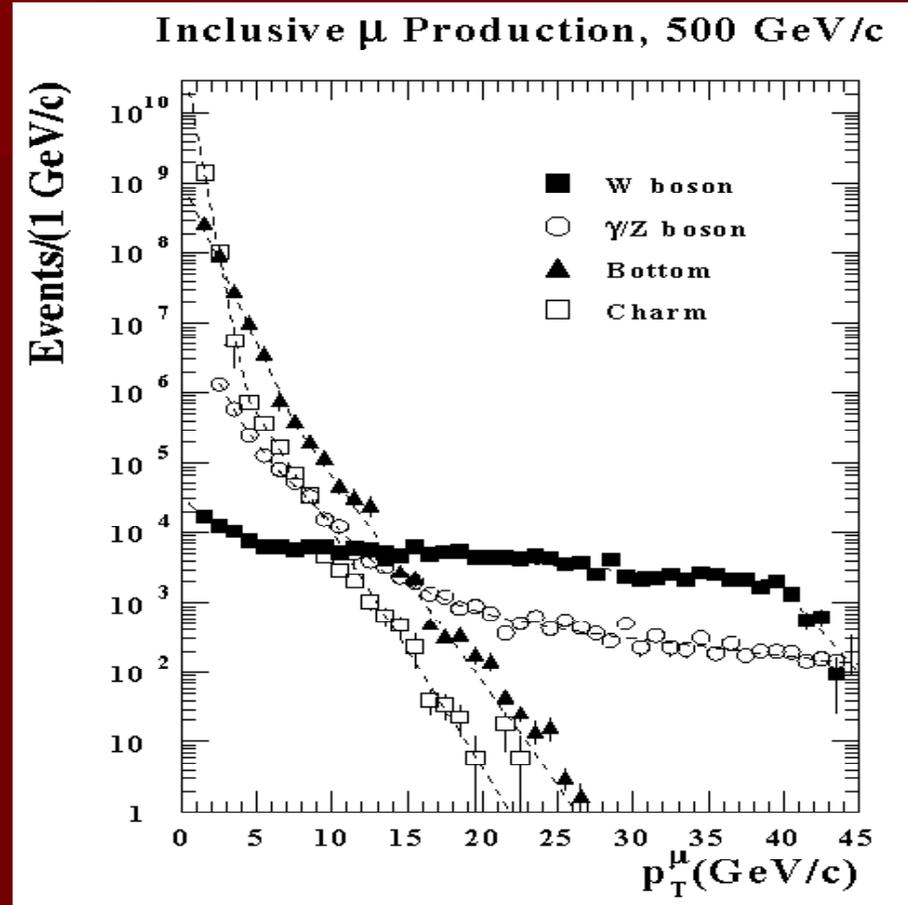
DAQ LIMIT

= 1-2 kHz (for μ arm)

Required RF
10,000

BUT

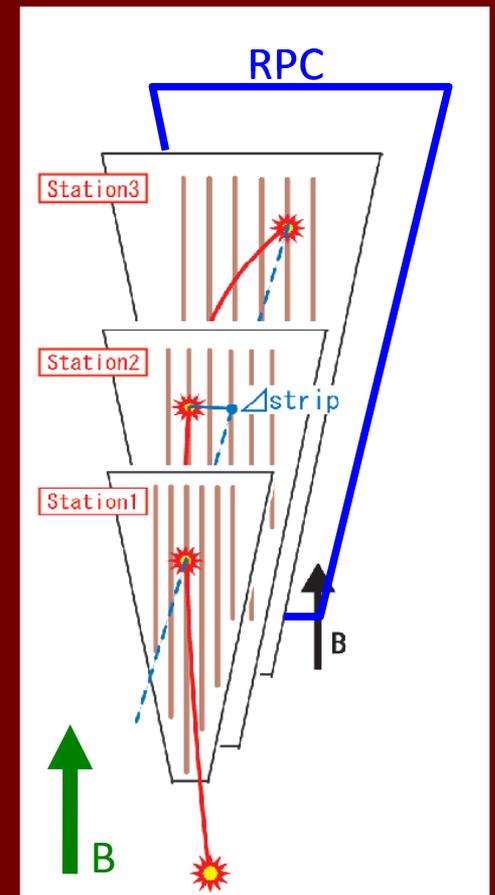
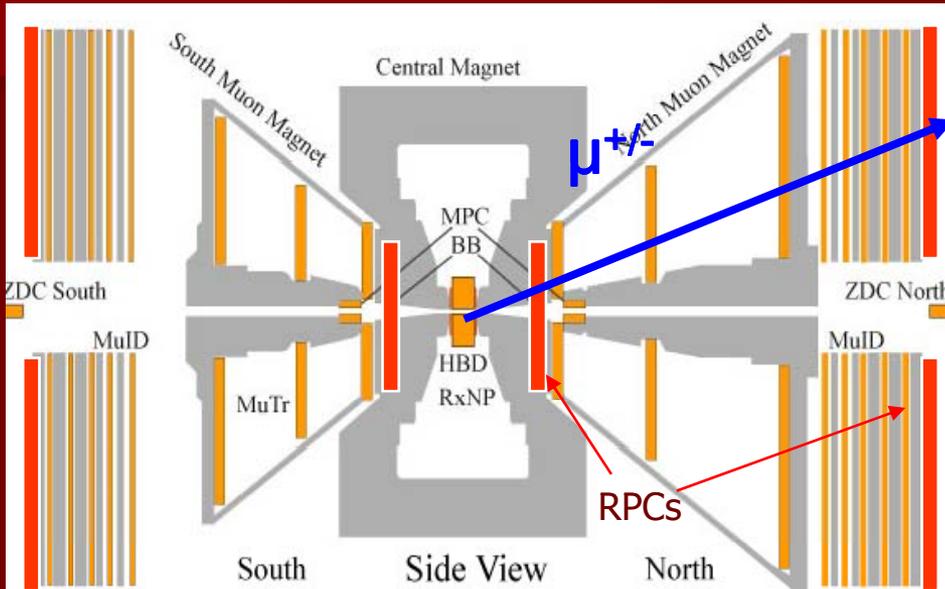
MuID LL1 (current trigger)
RF = 200 ~ 500



Need Momentum Selectivity in the LVL-1 Trigger

The PHENIX Muon Trigger

Rapidity: $1.2 < \eta < 2.2$ (2.4)



MUID

(only existing trigger)

No momentum selectivity!

Highly segmented Muon Tracker. Currently being instrumented with triggering electronics

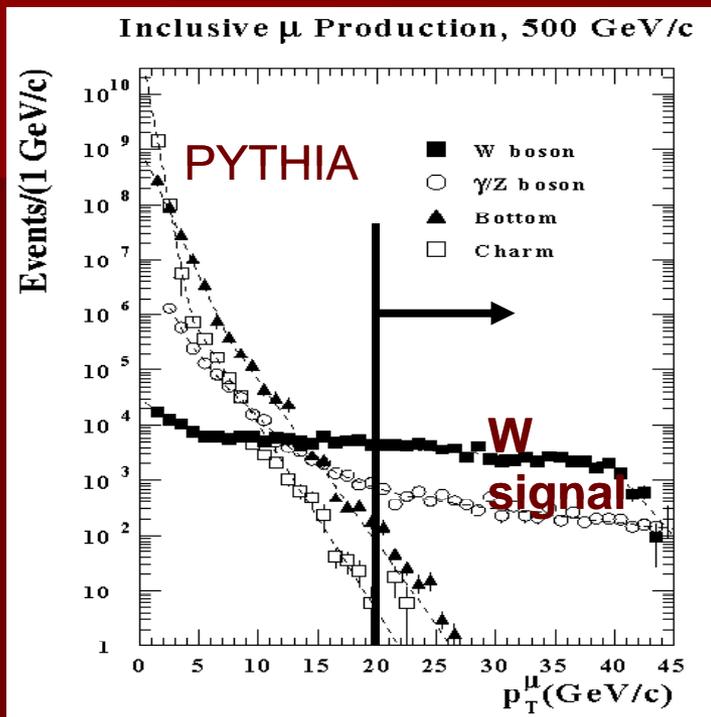
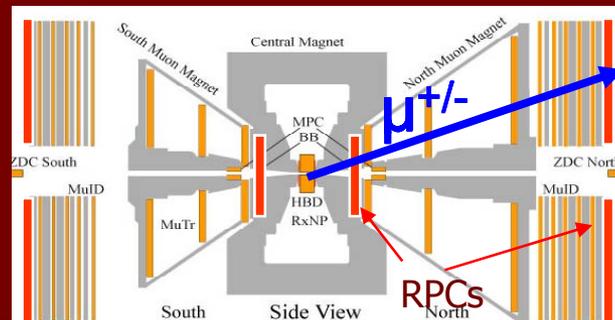
Upgraded Trigger Configuration

New Resistive Plate Chambers add better timing, less background sensitivity

Muon Tracker FEEs are currently being installed, and RPCs are now in production (!!)

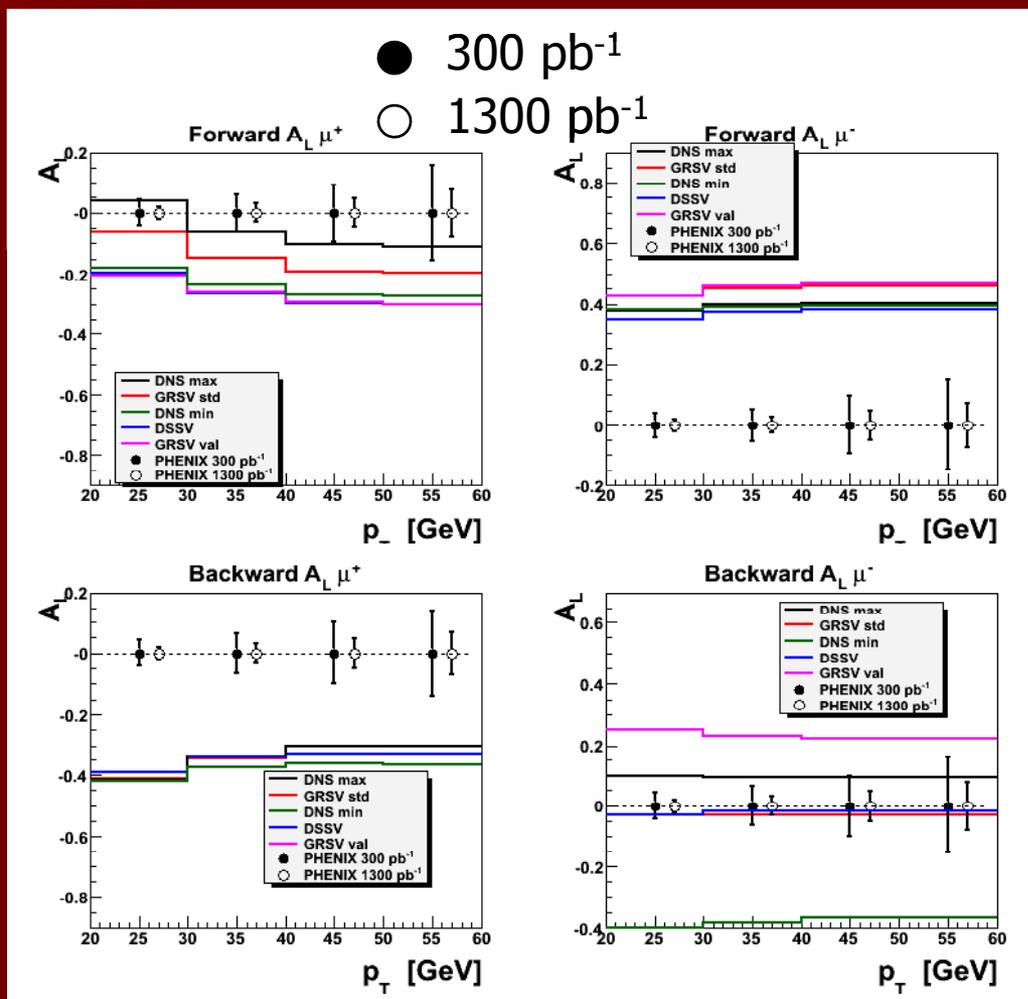
See talk by Yoshinori Fukao Wednesday 10:00 in the 'Future Facilities' session

W's in the PHENIX Muon Arms

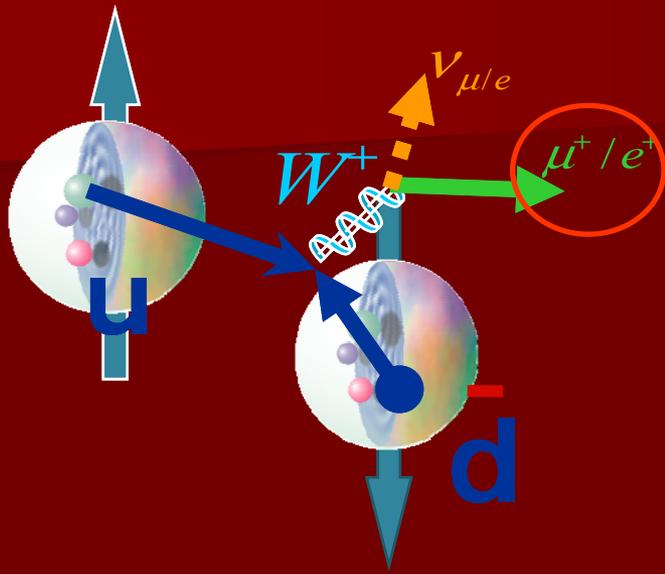


- full reconstruction, Backgrounds included, 70% polarization

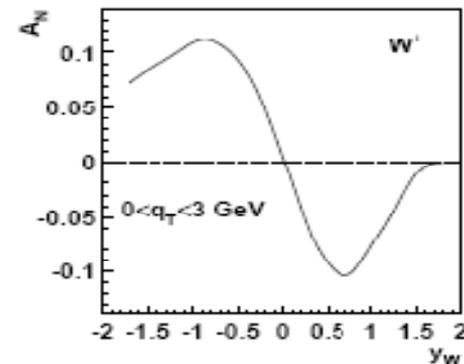
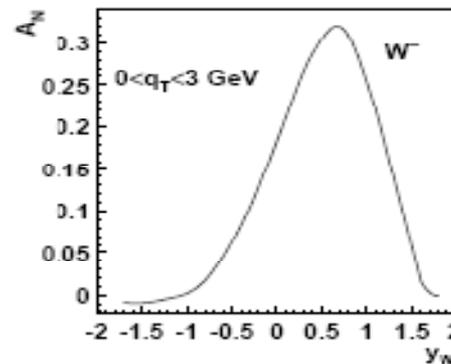
- Signal from RHICBOS (Nadolsky, Yuan)



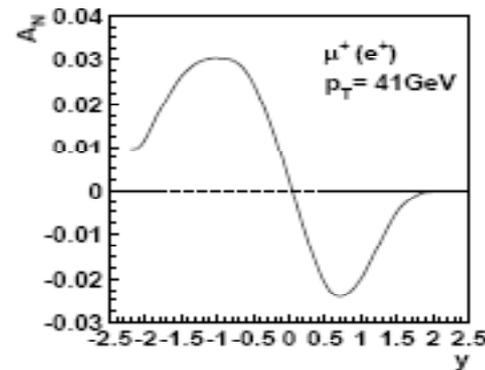
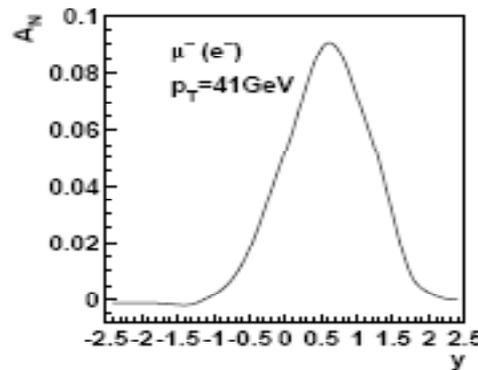
Transversely Polarized Protons



Fairly large predicted asymmetries for flavor separation of quark Sivers function!



W Asymmetries (can't be measured)



W → e Asymmetries (can be measured !!)

Sivers Function

$$f_{q/h^\uparrow}(x, k_\perp, \vec{S}) \equiv f_{q/h}(x, k_\perp) + \frac{1}{2} \Delta^N f_{q/h^\uparrow}(x, k_\perp) \vec{S} \cdot (\hat{p} \times \hat{k}_\perp)$$

Z. Kang, J.W. Qiu
arXiv:0903.3629

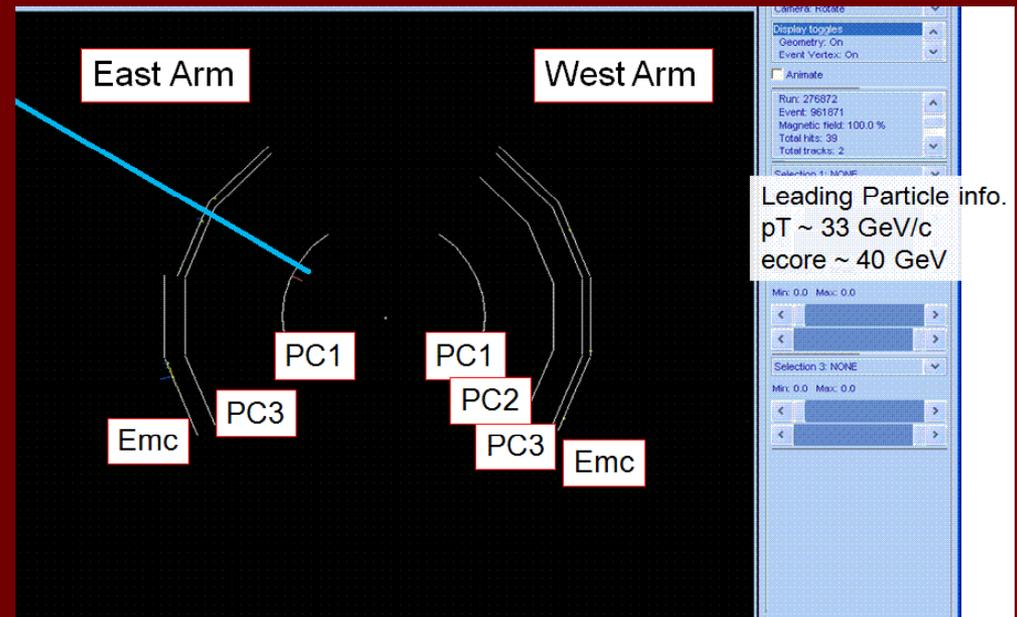
The work has already begun

2009 RHIC p+p run at $\sqrt{s} = 500 \text{ GeV}$

PHENIX recorded $\sim 10 \text{ pb}^{-1}$

Special streams of data were produced very quickly and are already being analyzed to sort out issues related to the higher energy and luminosity.

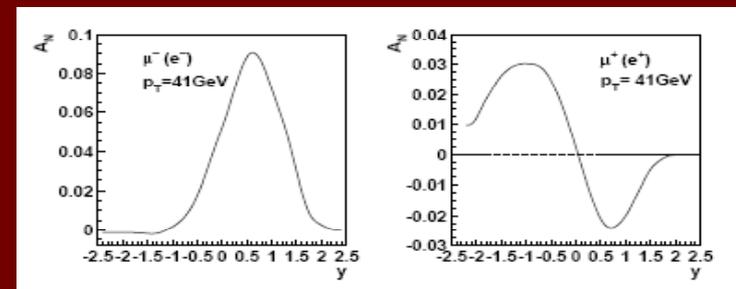
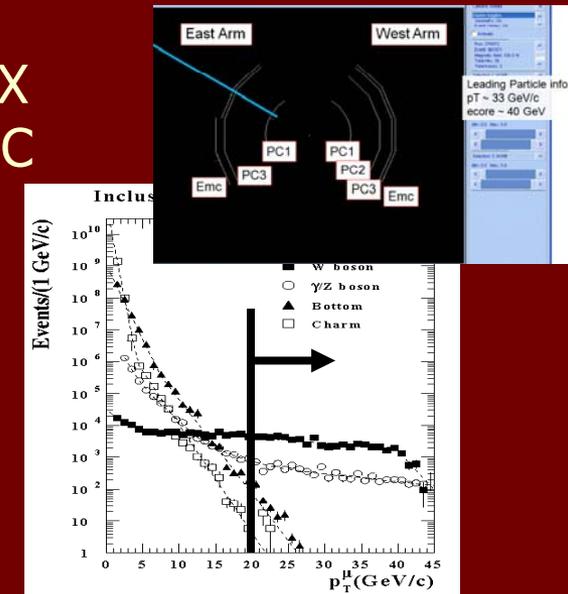
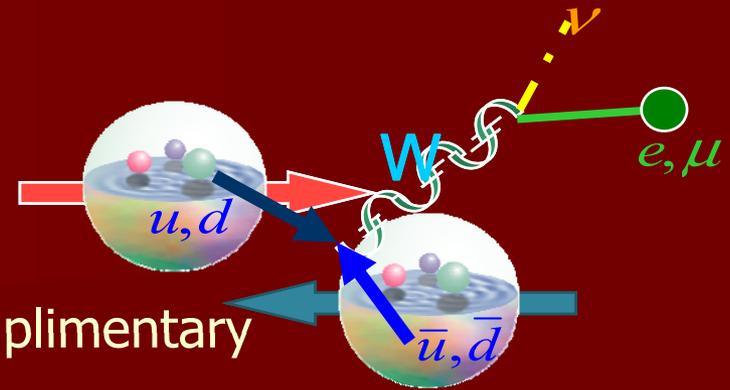
Stay Tuned!



Event Display of a Candidate W event

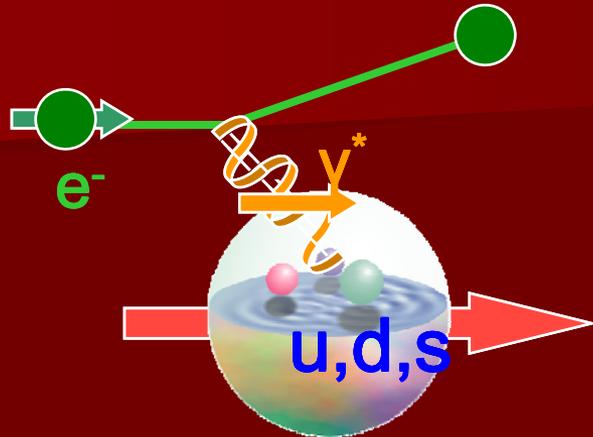
Summary

- W measurements at RHIC provide complimentary measurements to SIDIS data
- Measurements are already possible in the PHENIX central arms and analysis has started on 2009 RHIC data
- Upgrades are being tested and installed in the PHENIX muon arms to be ready for the next 500 GeV run
- W bosons provide exciting possibilities for other flavour separated measurements!

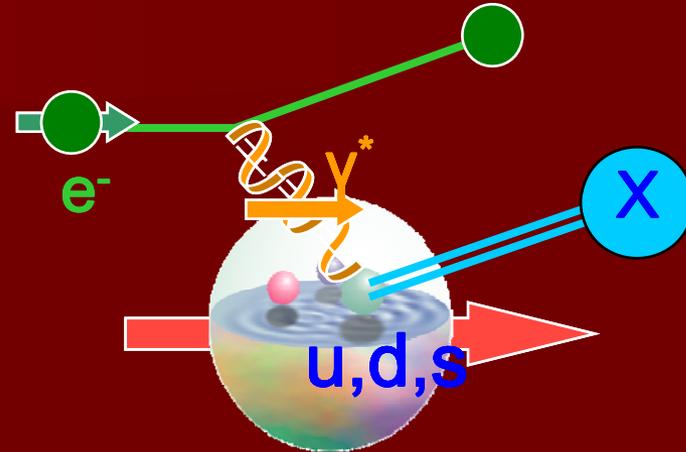


Backup

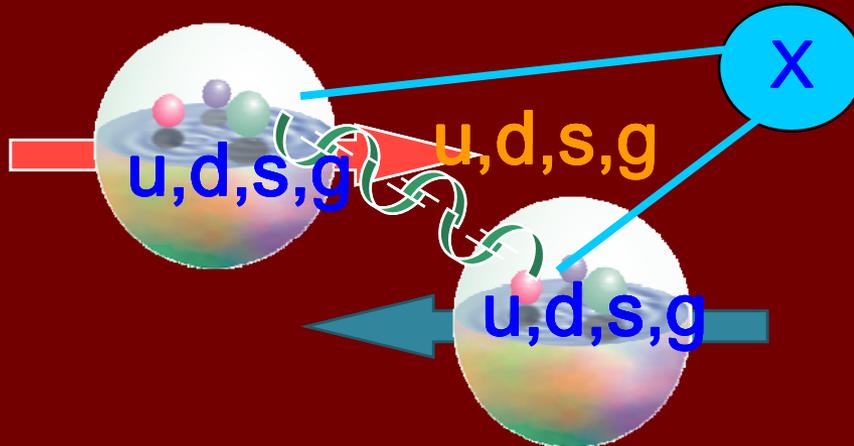
Probes to Study Polarized Proton Structure



polarized DIS



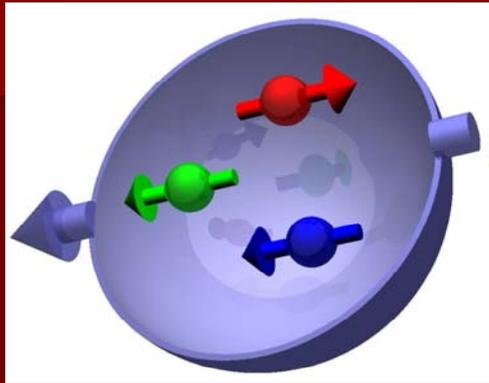
polarized SIDIS



polarized pp scattering

Structure of a Longitudinally Polarized Proton

The Past



Naïve parton model:

$$\frac{1}{2} = \frac{1}{2} (\Delta u_v + \Delta d_v)$$

1989 EMC (CERN):

$$\Delta\Sigma = 0.12 \pm 0.09 \pm 0.14$$

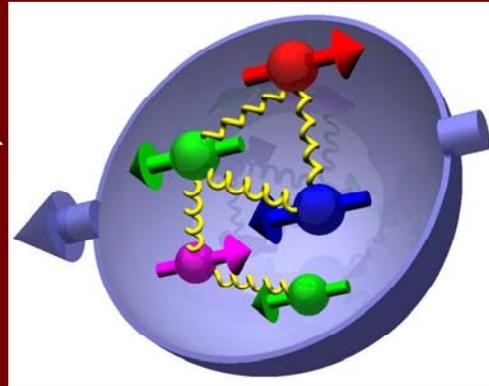
2005 COMPASS:

$$\Delta\Sigma = 0.33 \pm 0.03 \pm 0.05$$

$$\Delta\Sigma = \Delta u + \Delta d + \Delta s + \Delta \bar{u} + \Delta \bar{d} + \Delta \bar{s}$$

⇒ Spin Crisis

The Present
(and near future)

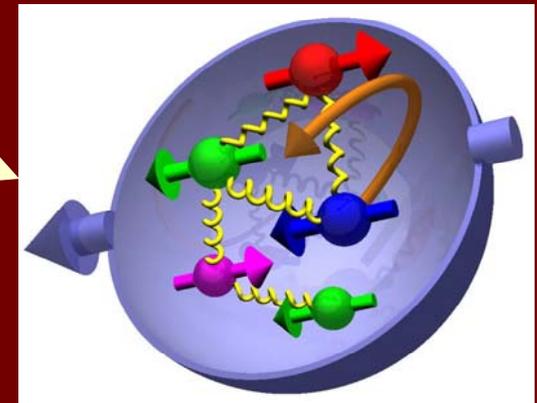


⇒ Gluons are polarized (ΔG)

⇒ Sea quarks are polarized:

$$\frac{1}{2} = \frac{1}{2} (\Delta q + \Delta \bar{q}) + \Delta G$$

The Future

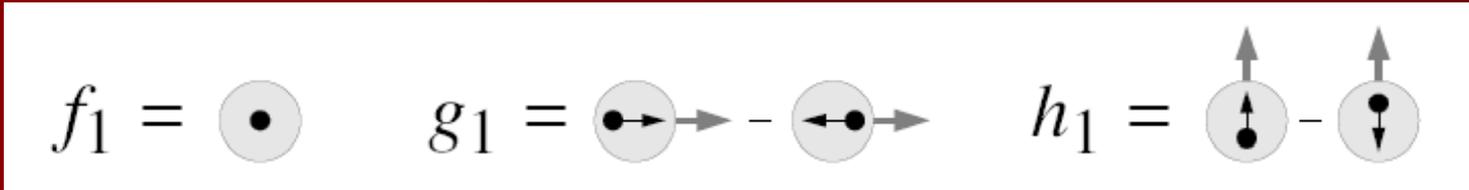


For complete description include parton orbital angular momentum L_Z :

$$\frac{1}{2} = \frac{1}{2} (\Delta q + \Delta \bar{q}) + \Delta G + L_Z$$

(Precise knowledge of L_z will require theoretical development...)

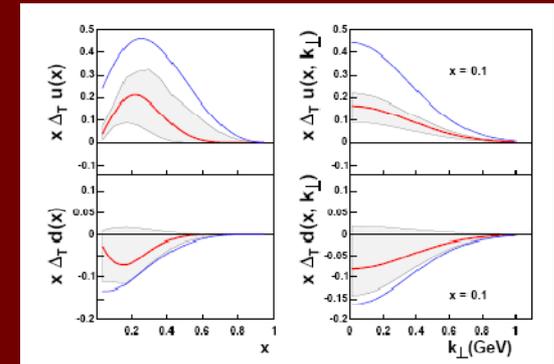
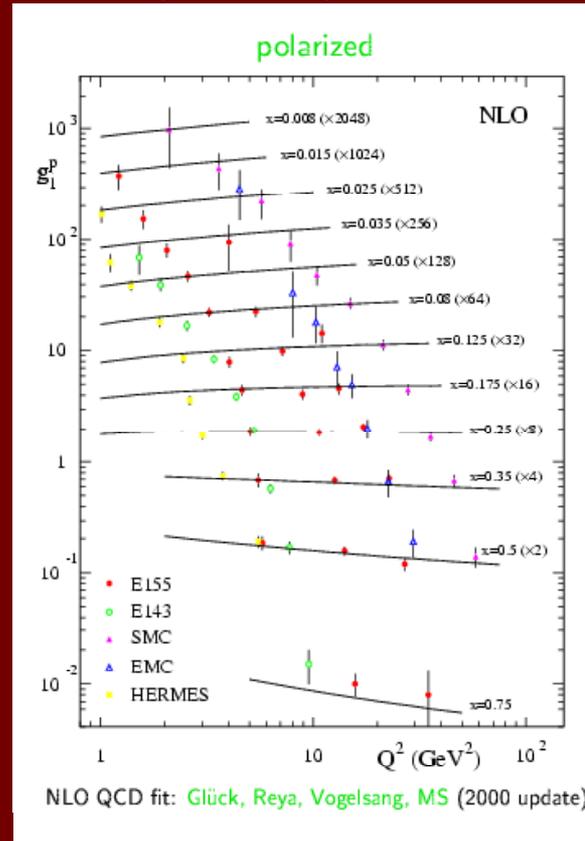
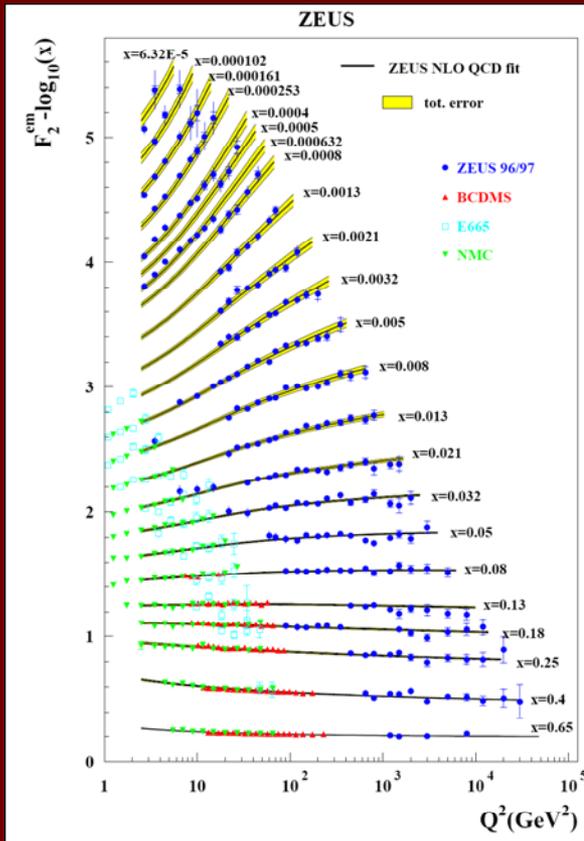
Current Status of Structure Functions



Unpolarized

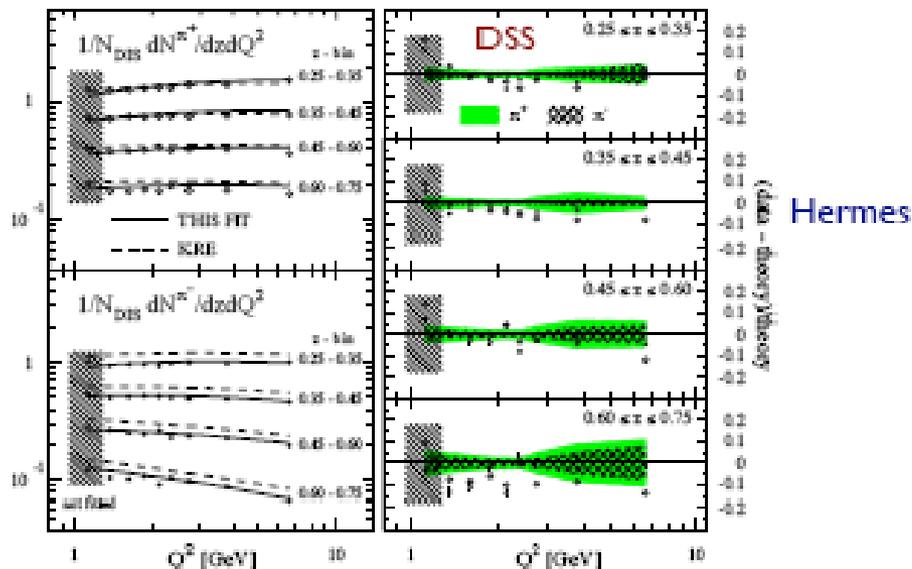
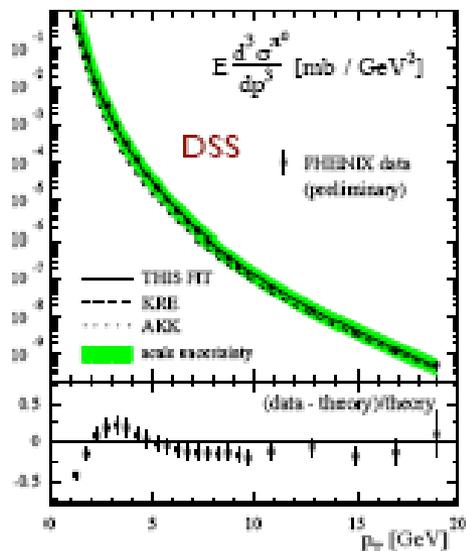
Longitudinally Polarized

Transversely Polarized



Another talk...

DSS Fragmentation Functions



✓ Pion production at RHIC OK

$$p_T^{\pi} \geq 1 \text{ GeV}$$

✓ SIDIS OK with DSS fragmentation functions

DdF, R.Sassot, M.Stratmann

DSS fragmentation functions extracted from a global fit that includes RHIC and HERMES unpolarized data!

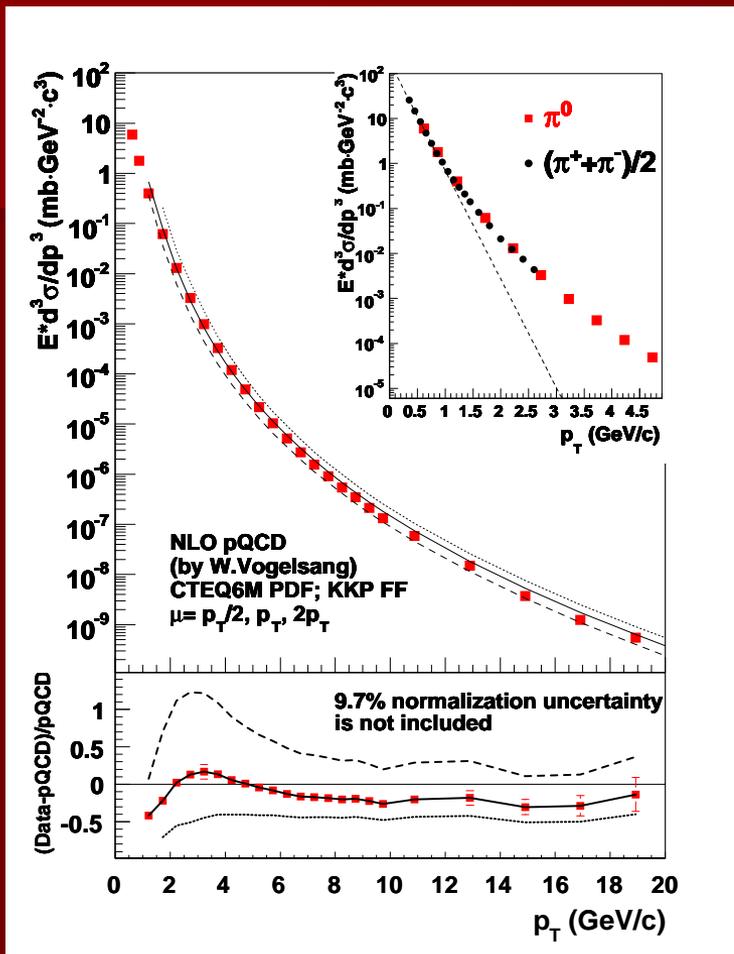
All other FF sets fail to reproduce Hermes data

Do not include: "high p_T " hadrons from Compass and Hermes

No NLO description available

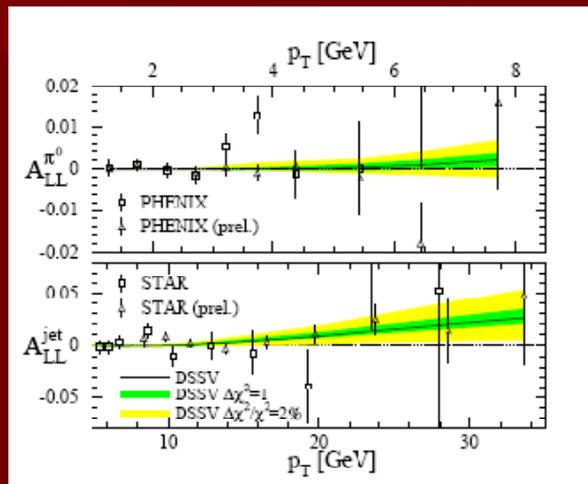
Not clear pQCD works well : check unpolarized

How has RHIC contributed?



NLO clearly works at RHIC!

PHENIX π^0 's and STAR jets provide the main constraint on ΔG



$$A_{LL} = \frac{d\sigma_{++} - d\sigma_{+-}}{d\sigma_{++} + d\sigma_{+-}}$$

