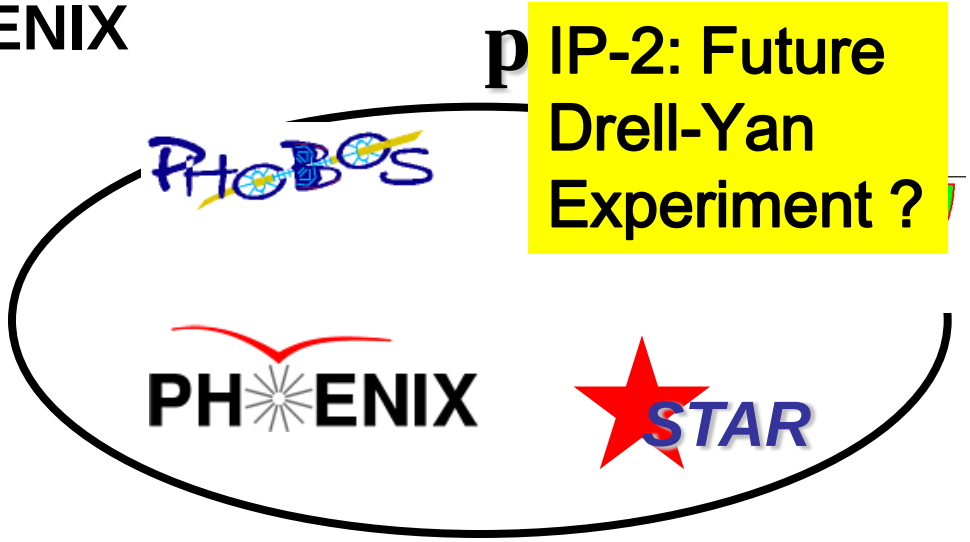
Future Drell-Yan Collider Experiments at RHIC

- **RHIC Spin**
  - Transverse Spin, RHIC Status and Plans
- **Drell-Yan in STAR and PHENIX**
  - Projections for A_{UT}
- **Drell-Yan at IP-2**
  - Internal Target
    - ➔ Yuji Goto's Talk
  - Collider Experiment



Transverse Spin Program at RHIC is Luminosity Limited

Physics channel	Luminosity Available
A_N	very good
A_N(back-to-back)	good
A_T (Collins FF)	fair
A_T (Interference FF)	limited
A_{TT} (Jets)	not studied
A_T (Jet-Photon)	marginal
A_T(Drell-Yan)	not by 2014
A_{TT} (Drell-Yan)	---

RHIC by 2014 at 500 GeV with longitudinal polarization:

$\int$Ldt ~950pb^{-1} delivered

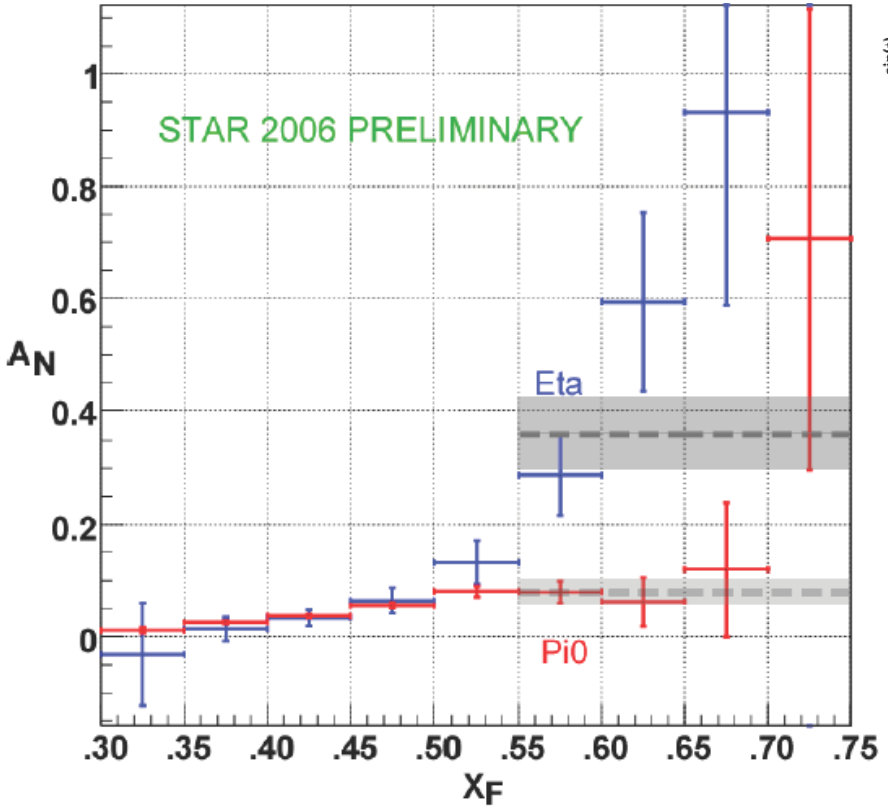
$\int$Ldt ~300pb^{-1} accepted (eg. PHENIX: vertex cut, trigger efficiencies, duty factor) all needed for W with longitudinal spin !

➔ $\int$Ldt ~ 50pb^{-1} transverse by 2014

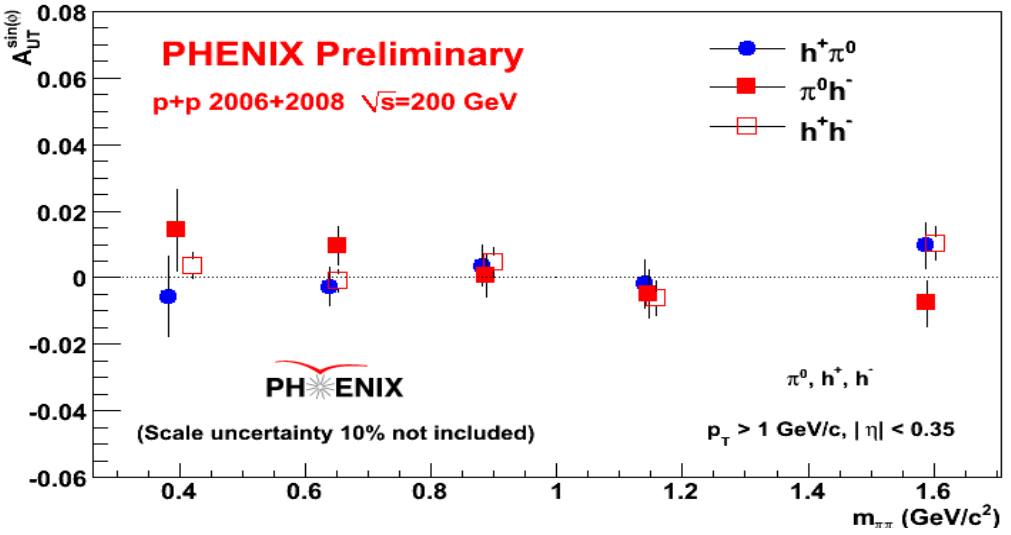
➔ Drell-Yan in PHENIX & STAR needs ~ 250pb^{-1} experiment for transverse

A_N in Inclusive Hadron Production and A_T in Interference Fragmentation at RHIC

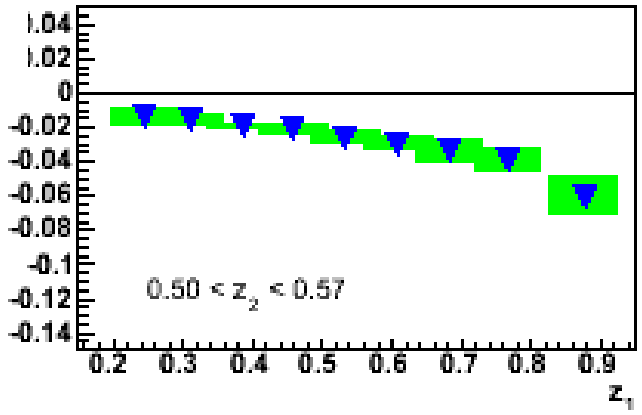
STAR A_N for π^0 and η



PHENIX A_{UT} in IFF



BELLE IFF



Drell-Yan: Clean Access to TMDs with very High Luminosity …

Transversity : correlation between transverse proton spin and quark spin

$\int Ldt \sim 1\ fb^{-1}$

$$A_{TT} \propto \delta q(x_1)\,\delta q(x_2)$$

Sivers : correlation between transverse proton spin and quark transverse momentum

$\int Ldt \sim 0.2\ fb^{-1}$

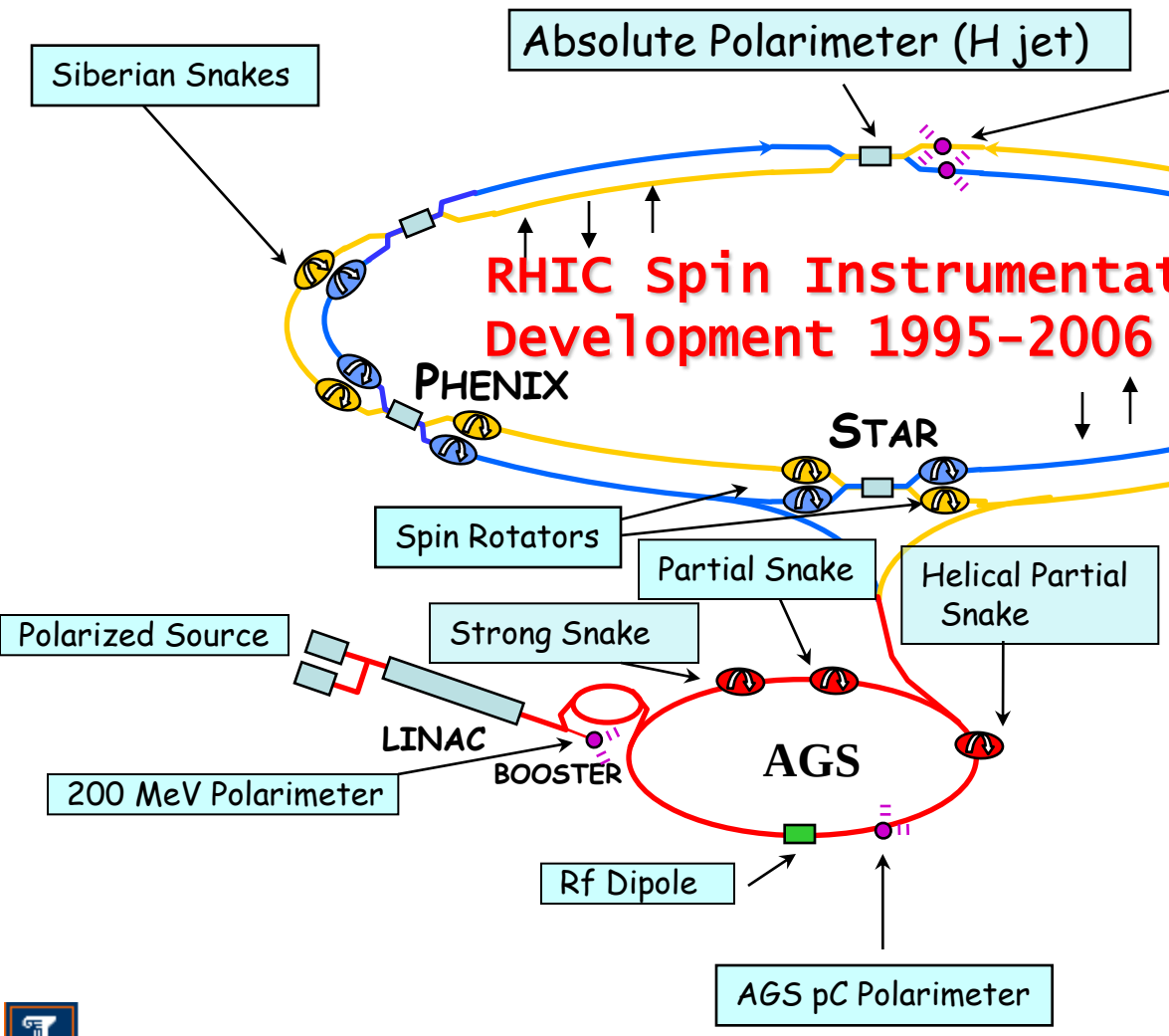
$$A_T \propto q(x_1) \cdot \bar{f}_{1T}^{\perp q}(x_2, k_\perp^2) \cdot \frac{(\hat{P} \times \vec{k}_T) \cdot \vec{S}_P}{M}$$

Boer/Mulders: correlation between transverse quark spin and quark transverse momentum

$\int Ldt \sim 0.2\ fb^{-1}$

$$N(\phi) \propto h_1^{\perp q}(x_1, k_\perp^2) \cdot \frac{(\hat{P} \times \vec{k}_\perp) \cdot \vec{S}_q}{M} \cdot h_1^{\perp \bar{q}}(x_2, \bar{k}_\perp^2) \cdot \frac{(\hat{P} \times \vec{\bar{k}}_\perp) \cdot \vec{S}_{\bar{q}}}{M}$$

RHIC Polarized Protons: Status



--- Run-2009 ---

√s	P	∫Ldt
200 GeV	56%	16pb^{-1}
500 GeV	35%	13pb^{-1}

first 500 GeV run!

RHIC Polarized Protons: Plans

Assume: polarized proton running 2011 to 2014 for W-physics with longitudinal polarization at STAR and PHENIX

	2009	2011	2012	2013	2014	Design
Polarization	35%	50%	55%	60%	65%	70%
<Luminosity> in $10^{32}cm^{-2}s^{-1}$	0.6	1.0	1.5	2.0	2.5	2.0
		longitudinal spin for W-physics and ΔG with $\int Ldt \sim 300\ pb^{-1}$				

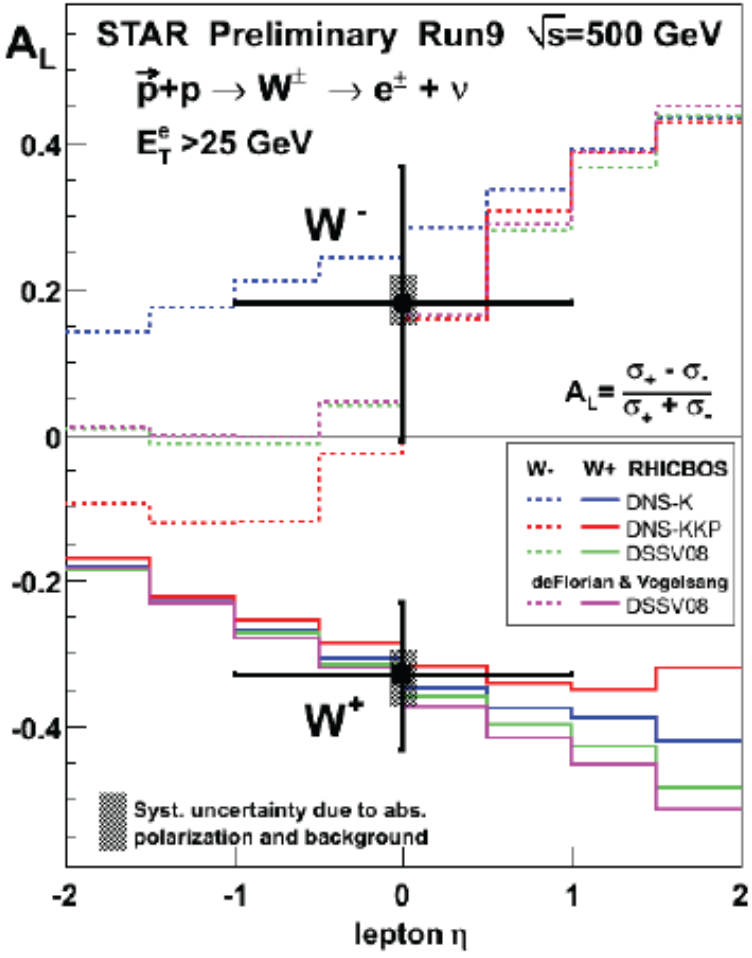
➔ (1) Drell-Yan Program with transverse spin in STAR and PHENIX will not start before run 15 (starting late 2014).

(2) 11-14: Drell-Yan with longitudinal polarization using "W-sample"

(3) Initial ideas for dedicated Drell-Yan experiment at IP-2

W-physics: First Results (mid-rapidity)

From Jan Balewski, MIT, APS Meeting Washington February 2010



$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

STAR Preliminary Run 9

$$A_L(W^+) = -0.33 \pm 0.10(\text{stat.}) \pm 0.04(\text{syst.})$$

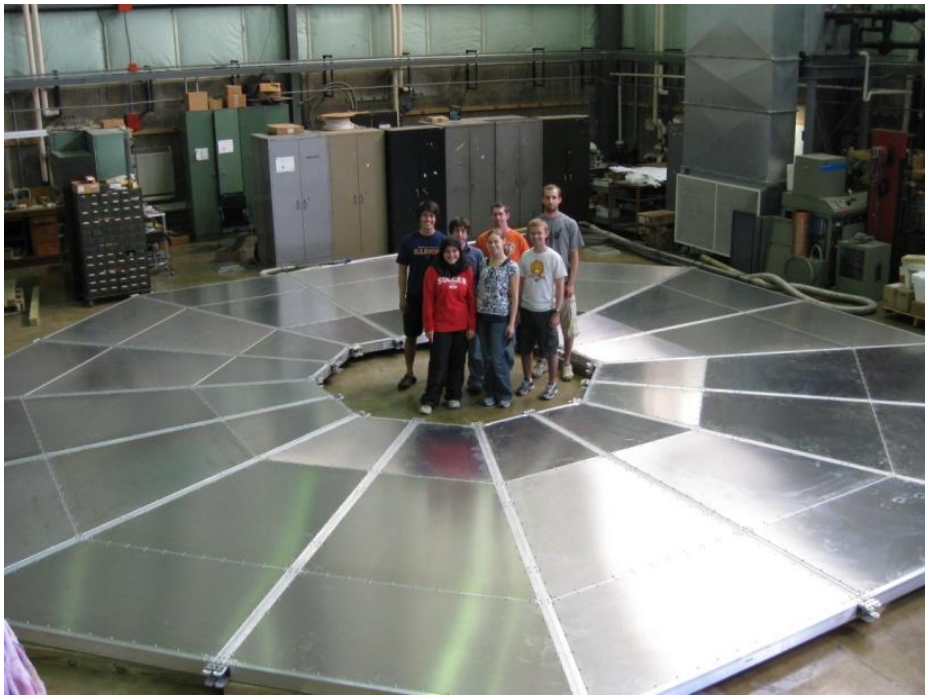
$$A_L(W^-) = 0.18 \pm 0.19(\text{stat.}) \; ^{+0.04}_{-0.03}(\text{syst.})$$

Summary
(for mid rapidity leptons)

- $A_L(W^+)$ negative, as predicted, **3.3 sigma <0**
- $A_L(W^-)$ central value positive, as expected
- systematic errors of A_L under control
- TPC charge separation works up to ET~50 GeV

W-physics & Drell-Yan: Exp. Readiness at Forward Rapidity

STAR: GEM tracker in endcap EMC acceptance, $1.0 < \eta < 2$ (run 12)
PHENIX: trigger upgrade +FVTX in muon spectrometer $1.2 < \eta < 2.4$ (run 11/12)



PHENIX trigger RPC pre-assembly at UIUC

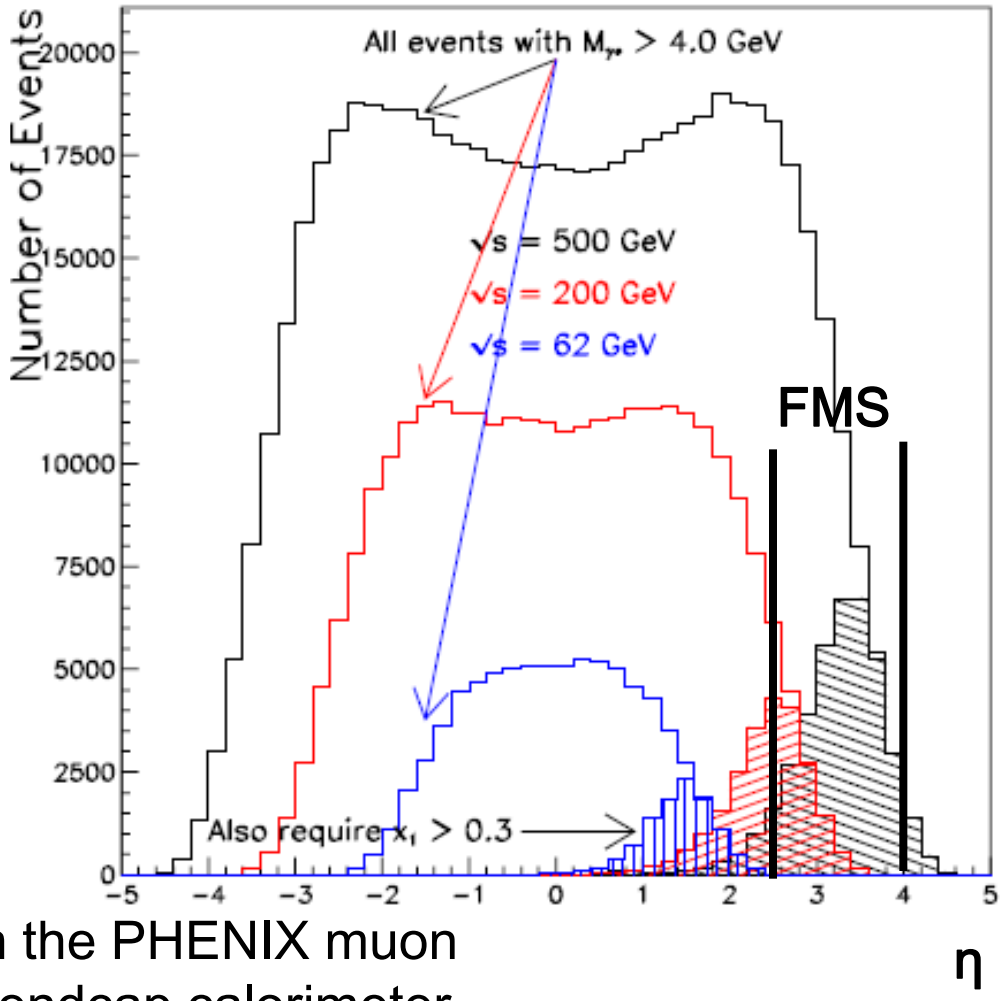
November-2009 RPC-3 north installation completed in PHENIX!

Drell-Yan with PHENIX & STAR

Large x → forward rapidity

Plot: η distributions of large x events for √s=62, 200 and 500 GeV

→ STAR FMS ($2.5 < \eta < 4.0$) would be ideal for √s=500 GeV. However, needs upgrade for background rejection!

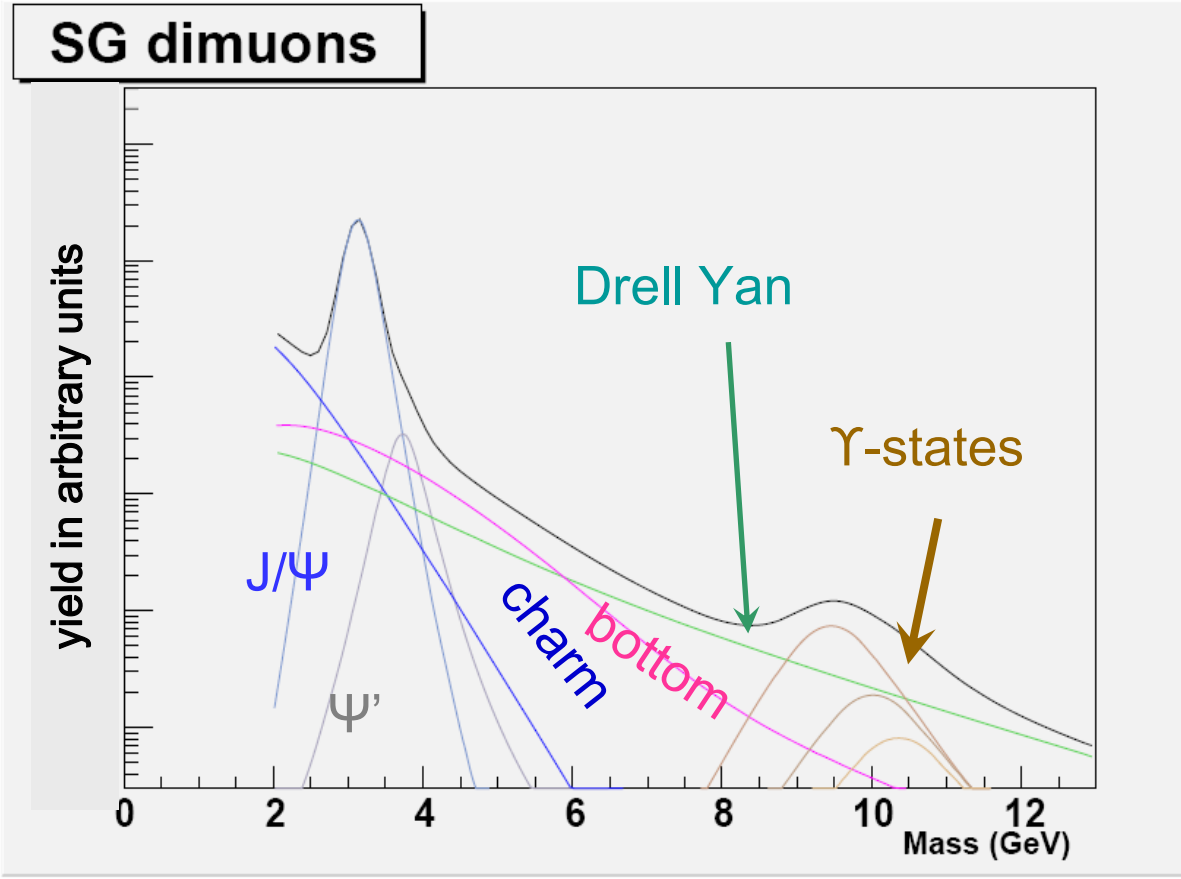


After completion of GEM upgrade in STAR and muon trigger & FVTX Upgrades in PHENIX Drell-Yan measurements will be possible with the PHENIX muon arms, $1.2 < \eta < 2.4$ and the STAR endcap calorimeter, $1 < \eta < 2$, in addition to the mid-rapidity detectors.

Drell-Yan Background in the PHENIX Muon Spectrometers

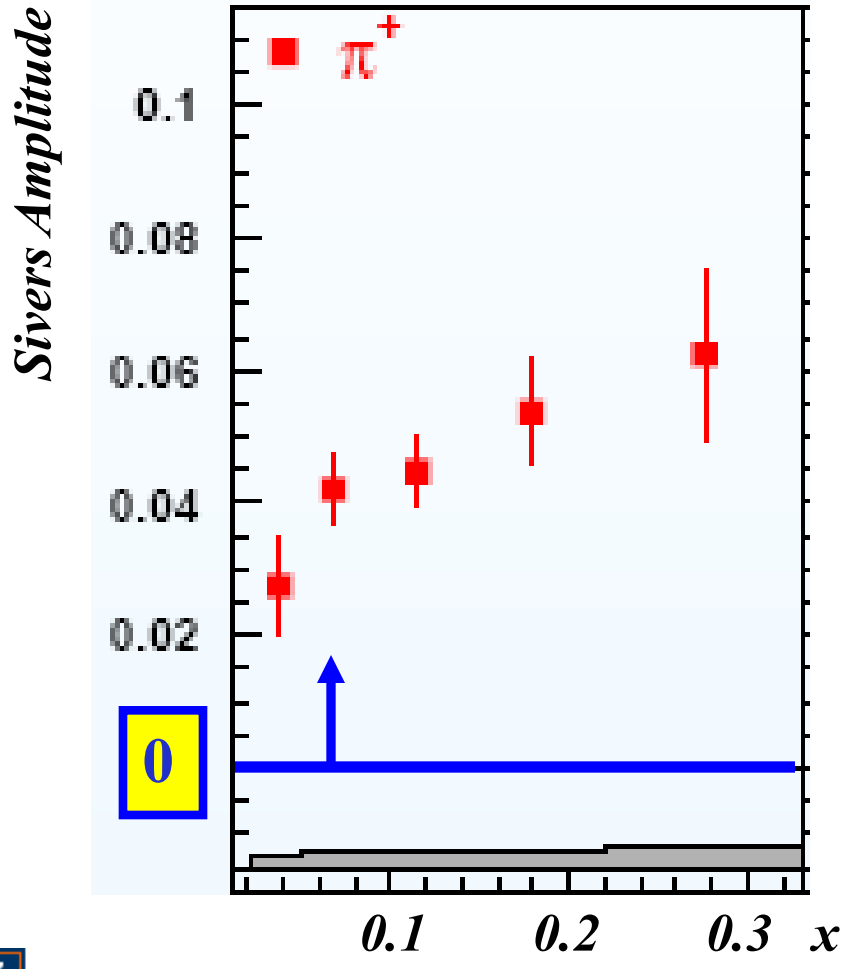
Example: Drell Yan with the PHENIX muon spectrometers and the new forward silicon detector (FVTX).

FVTX enables DY measure-ment by rejecting heavy flavor background. Best mass Region: 4 GeV < Q < 10 GeV

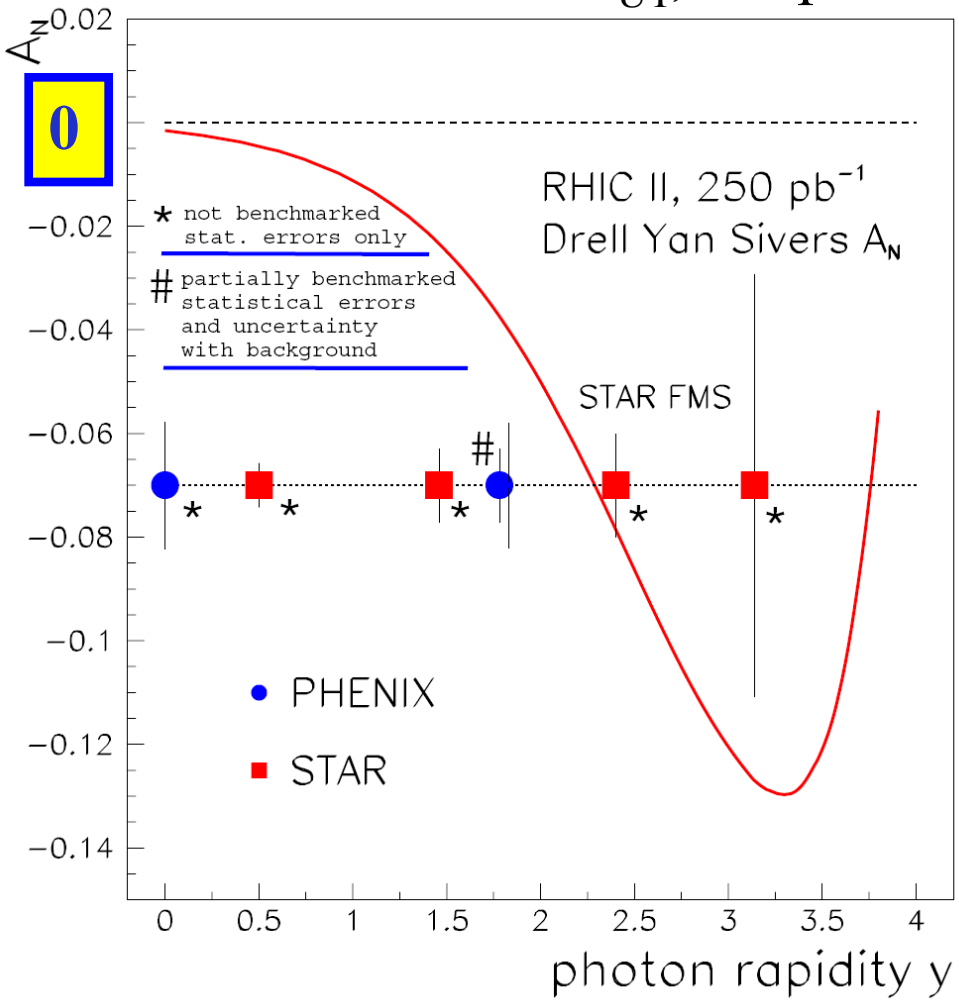


HERMES Sivers Result vs A_{UT} Projections for RHIC

HERMES Sivers Results



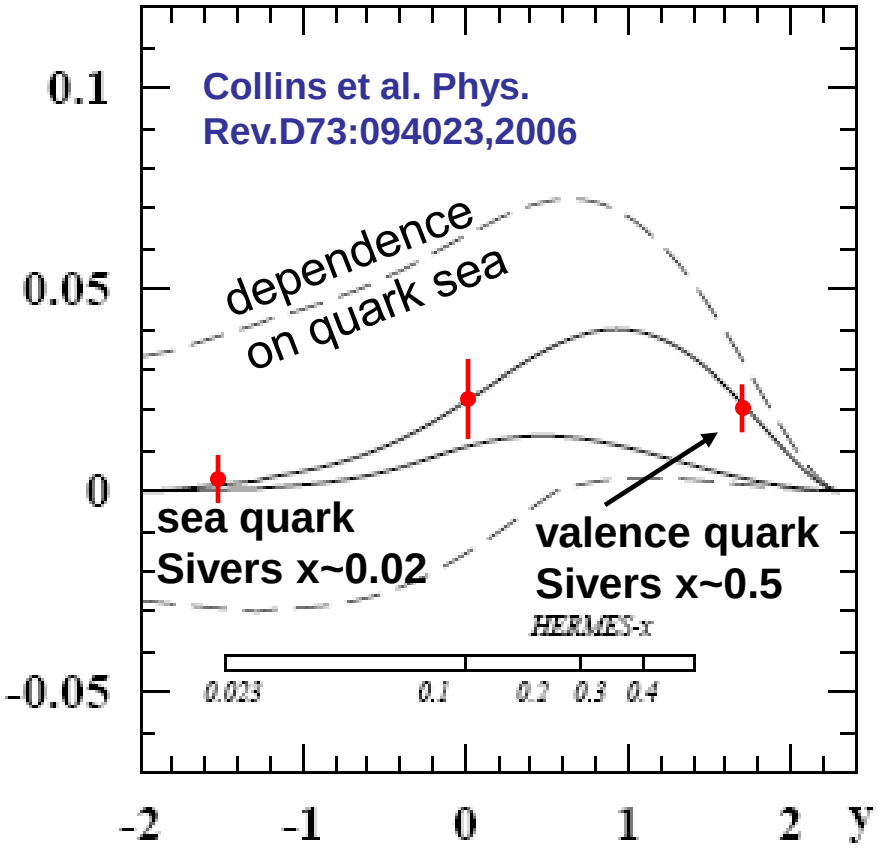
RHIC Drell-Yan A_{UT}, 250pb^{-1}



Sensitivity at RHIC to Sivers Effect for Anti-Quarks

Collins et al. Phys.Rev.D73:094023,2006

$A_{UT}^{\sin(\phi - \phi_S)}$ *in* $p^{\uparrow}p \to l^{+}l^{-}X$ *at RHIC* $Q=20GeV$



Sensitive to valence quark Sivers at large x and sea quark Sivers distributions at small x.

$$f_{1T_{\rm DY}}^{\perp(1)\bar{q}}(x) = \epsilon(x)\; f_{1T_{\rm DY}}^{\perp(1)q}(x)\;,$$

$$\epsilon(x) = \pm \begin{cases} 0.25 = \text{const} & \text{model I} \\ \dfrac{(f_1^{\bar{u}} + f_1^{\bar{d}})(x)}{(f_1^{u} + f_1^{d})(x)} & \text{model II} \end{cases}$$

Drell-Yan at IP-2

Can one utilize the large integrated luminosity for W-physics for transverse spin Drell-Yan?

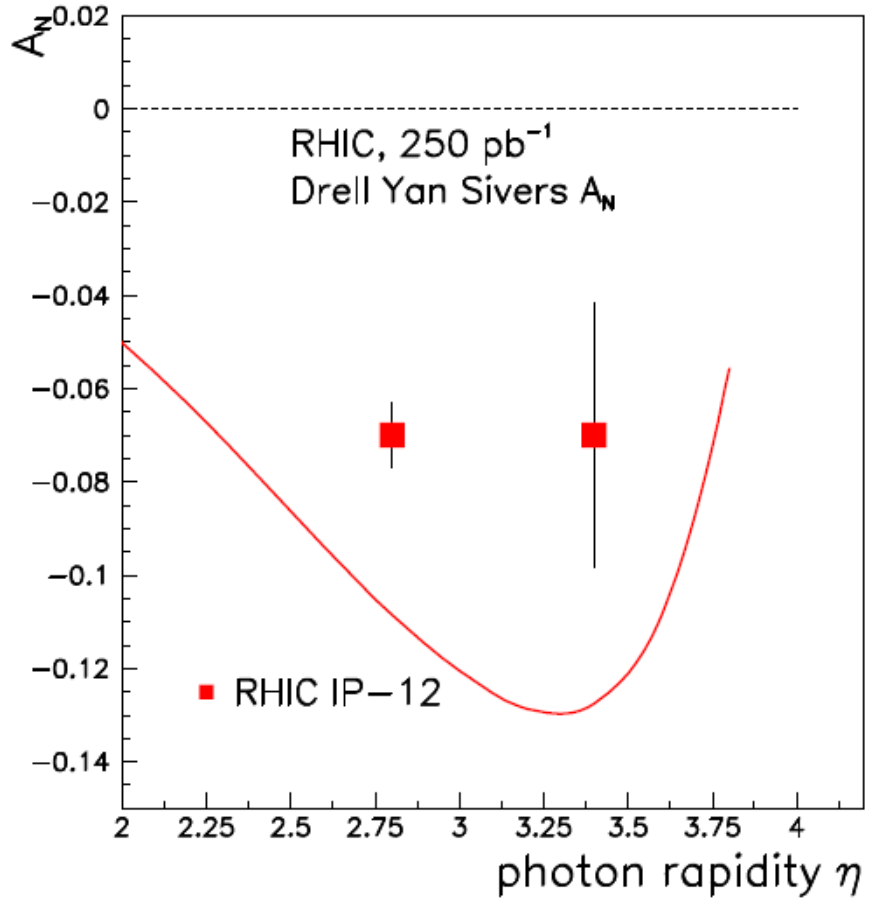
Yes, both the old PHOBOS and BRAHMS IPs, IP-2 and IP-10 have no spin rotators and therefore transverse spin while STAR and PHENIX can have longitudinal spin!

(I) Experiment using an internal gas target
➔ Yuji Goto

(II) Move STAR FMS to IP-2 and upgrade with hadronic calorimeter and/or charged tracking to improve background rejection! (Les Bland, Hank Crawford et al.)

➔ Both experiments are preparing to submit a LO to the RHIC PAC in June 2010

A_{UT} in Drell-Yan at IP-2



A_{UT} prediciton from Feng Yuan and Werner Vogelsang based on Hermes data.

Backgrounds not included.

Summary

White paper: "Transverse Spin Drell-Yan Physics at RHIC"
http://thy.phy.bnl.gov/~vogelsan/drellyan1/dy_final.pdf

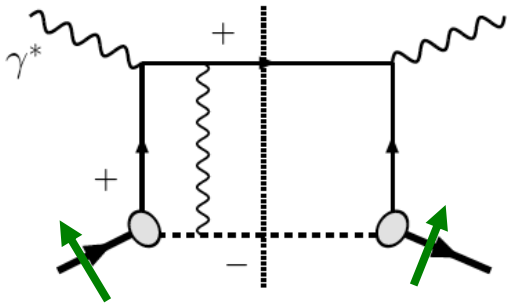
Increasing experimental evidence that Sivers mechanism plays an important role in accounting for single transverse spin asymmetries observed in hard scattering.

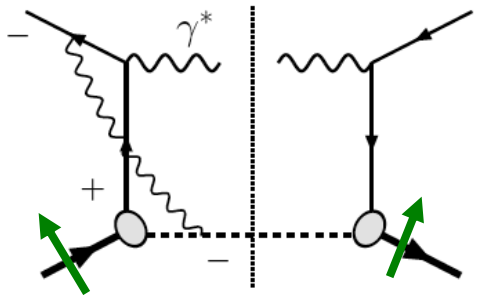
Gauge link formalism makes it possible to account for the presence of Sivers asymmetries. Fundamental test possible in Drell-Yan at RHIC.

A dedicated experiment at IP-2 would make it possible to take advantage of the full 300pb^{-1} W-physics data sample for transverse spin physics. A program based on STAR and PHENIX would take data after 2014.

Non-universality of Sivers Asymmetries: Unique Prediction of Gauge Theory !

Simple QED example:

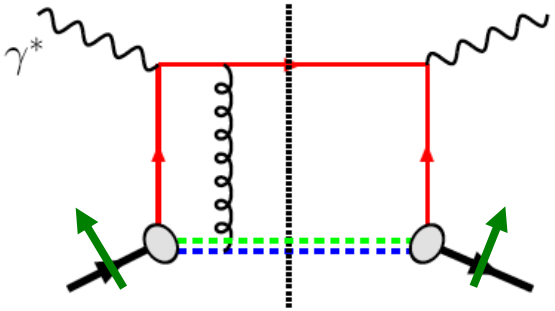


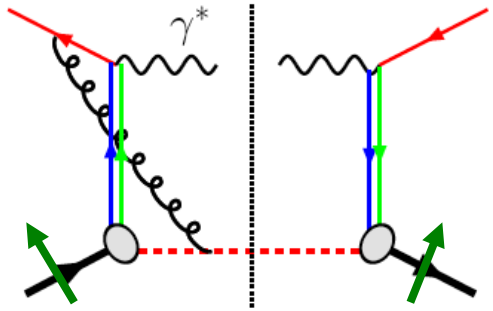


DIS: attractive

Drell-Yan: repulsive

Same in QCD:





As a result:

$$\text{Sivers}|_{\text{DIS}} = -\text{Sivers}|_{\text{DY}}$$