A_N of heavy flavor decay muons in the PHENIX experiment at RHIC

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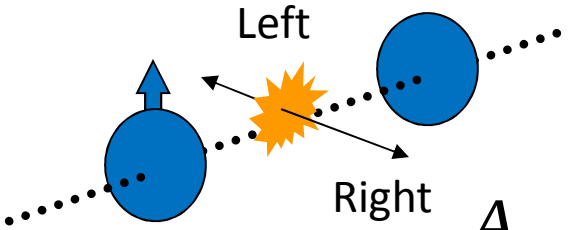
Sponsored by DOE, Office of Science

A brief history…



$$A_N = \frac{1}{P}\frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$$

Theory Expectation (twist-2):

Small asymmetries at high energies

(Kane, Pumplin, Repko, PRL 41, 1689–1692 (1978))

$$A_N \propto \frac{m_q}{\sqrt{s}}$$

A_N ~O(0.1%) Theory

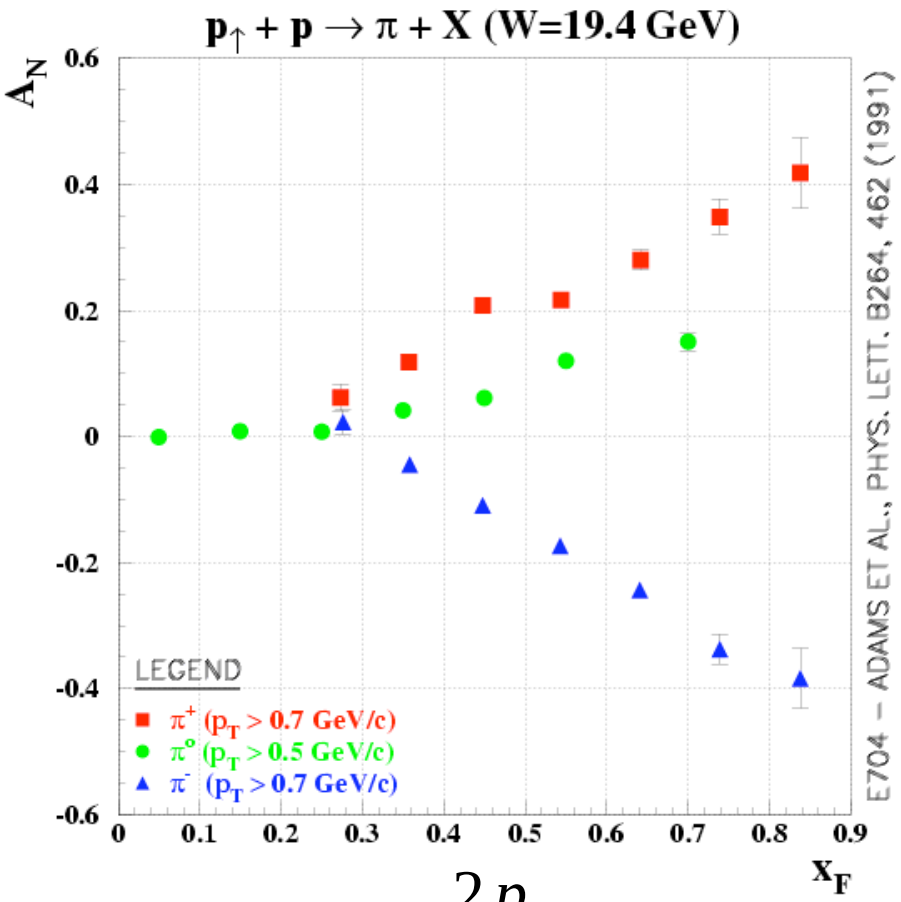
Experiment:

(E704, Fermi National Laboratory, 1991)

$$p p^{\uparrow} \rightarrow \pi + X$$

$$\sqrt{s} = 20\,\mathrm{GeV}$$

A_N ~O(10%) Measured



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

Theoretical efforts

- The Sivers Effect

  Transverse momentum dependent quark and gluon distributions give rise to correlation between transverse proton spin and the transverse momentum k_T of quarks and gluons

- The Collins Effect

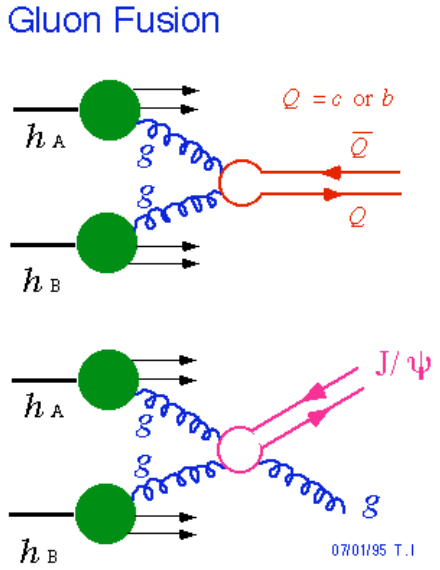
  Transversity distributions + spin dependent fragmentation functions

- Higher-Twist Effects (Quark gluon field interference)
  - Sterman and Qiu ⟹ Initial State Twist 3
  - Koike ⟹ Final State Twist 3
  - Explain RHIC experimental results very well

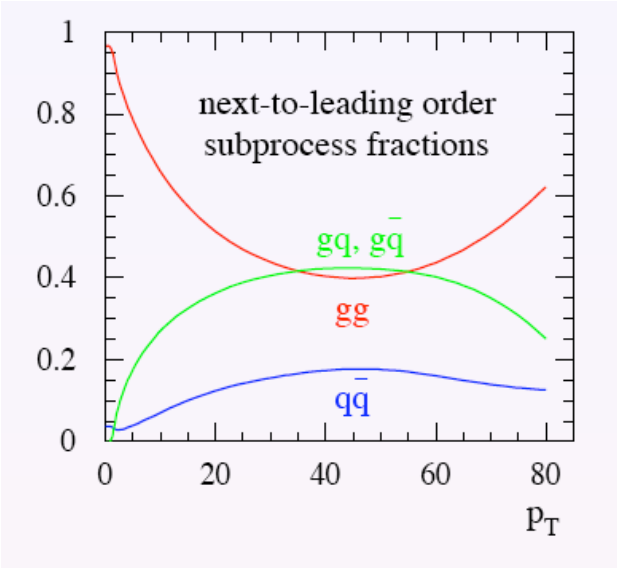
A coherent treatment of the Sivers effect and quark gluon correlations at higher twist has been provided by Ji, Qiu, Vogelsang and Yuan (**PRL97**:082002,2006)

Motivation of probing heavy flavor

- Eliminate the Collin's effects
  - heavy flavor production dominated by gluon gluon fusion at RHIC energy
  - Gluon has no transversity



- A perfect channel for gluon Sivers function
  - Gluon's orbital angular momentum



Data from RHIC Transverse Runs

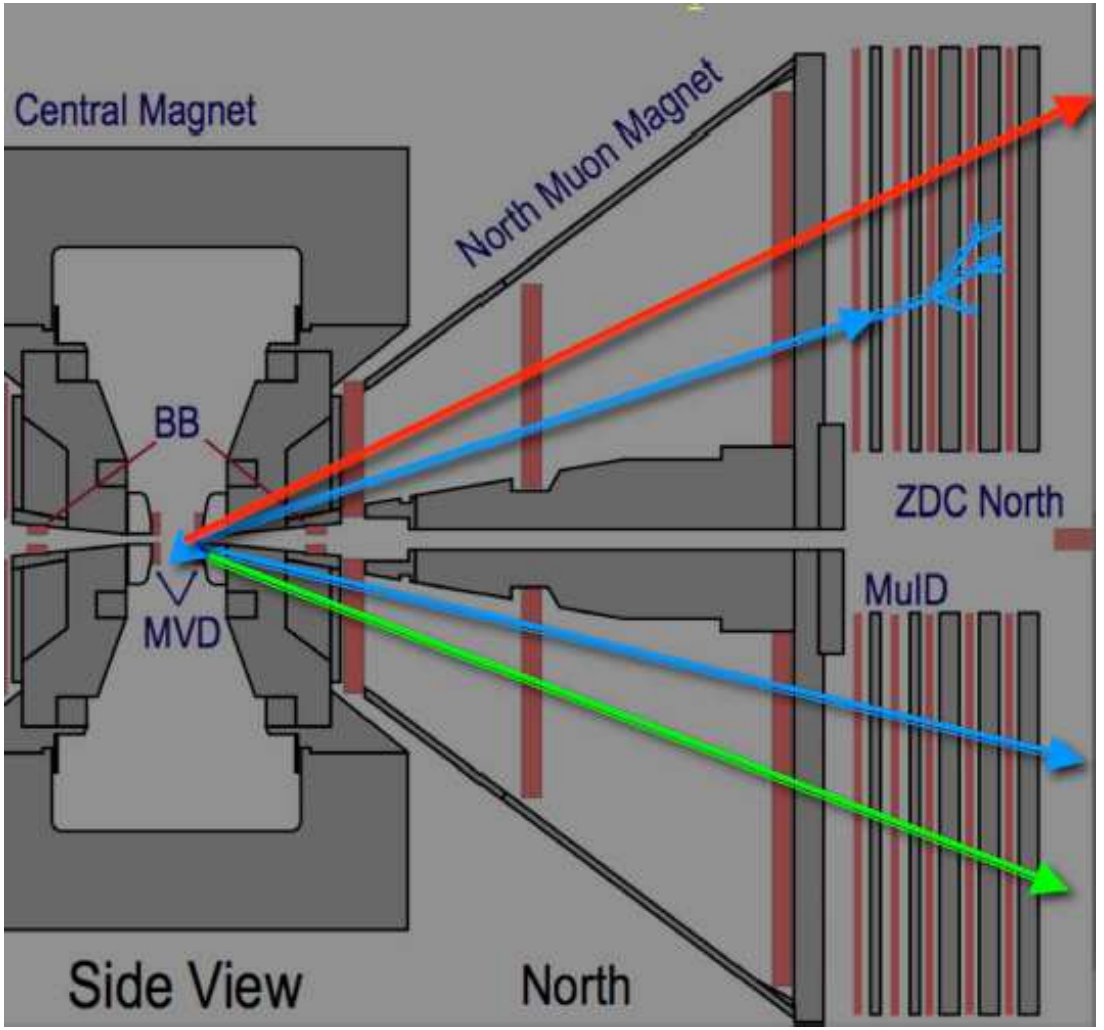
Year	√s (GeV)	L (pb-1)	P	FoM (P2L)
2002	200	0.15	15%	0.0034
2005	200	0.16	47%	0.035
2006	200	2.7	51%	0.7
2006	62.4	0.02	48%	0.0046
2008	200	5.2	46%	1.1
2012	200	9.2	58%	3.1

The Muon Spectrometer

North: $1.2<|\eta|<2.4$

South: $1.2<|\eta|<2.2$

Azimuthal: $\Delta\Phi=2\pi$



Tracks:

- Heavy Flavor decay muons
- Punch-through hadrons
- Hadron decay muons

} Inclusive muons

- Stopped hadrons ⟹ Distinguished background

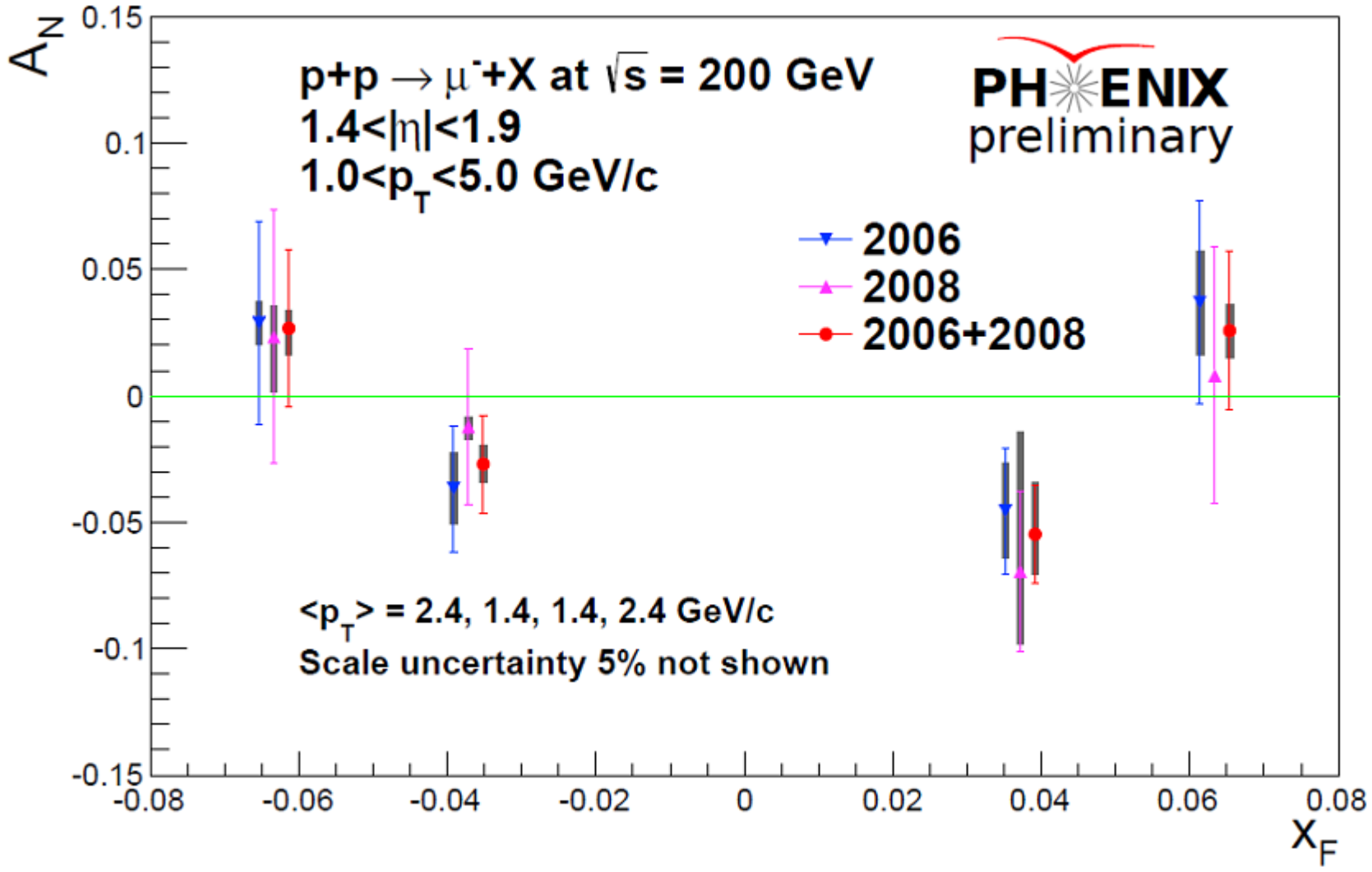
Physics Asymmetry

- Inclusive Muons: mixing signal and hadron background
- Stopped hadrons: used to estimate A_N from hadron background
- Physics Asymmetry can be calculated by:

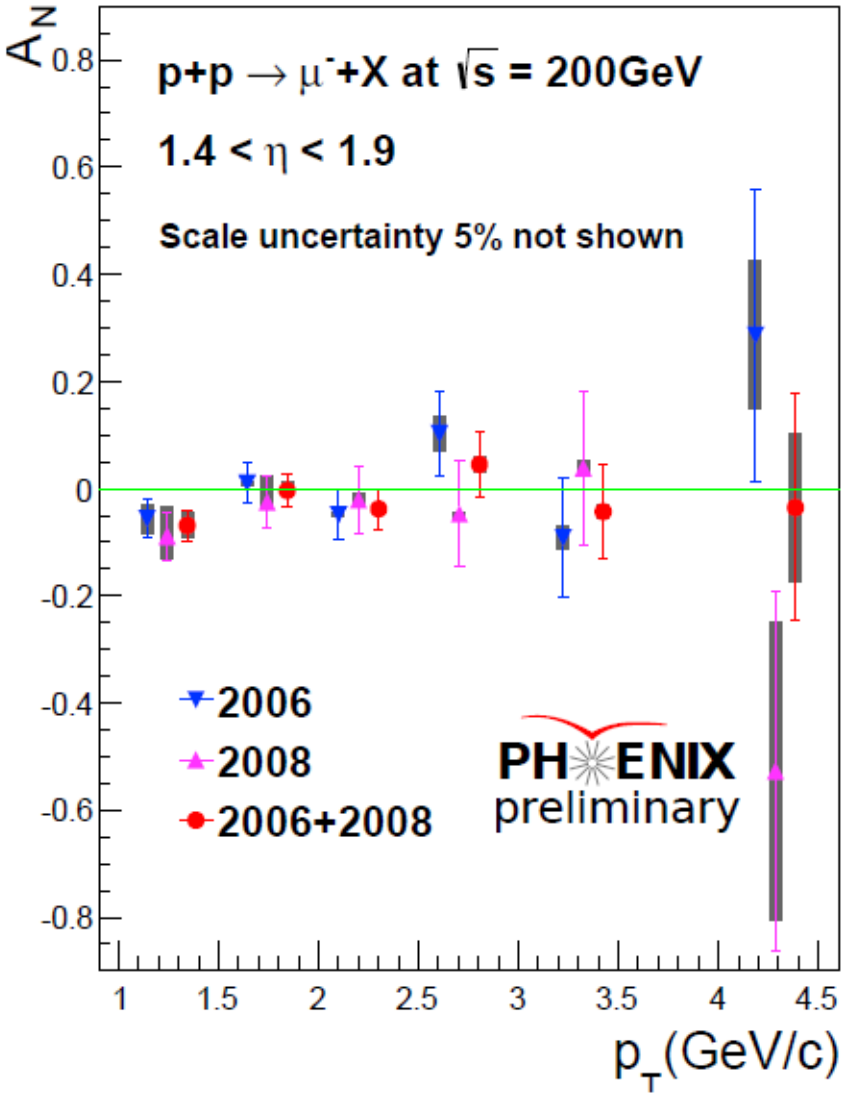
$$A_N^{Phys} = \frac{A_N^{Incl} - r \cdot A_N^{BG}}{1 - r}$$

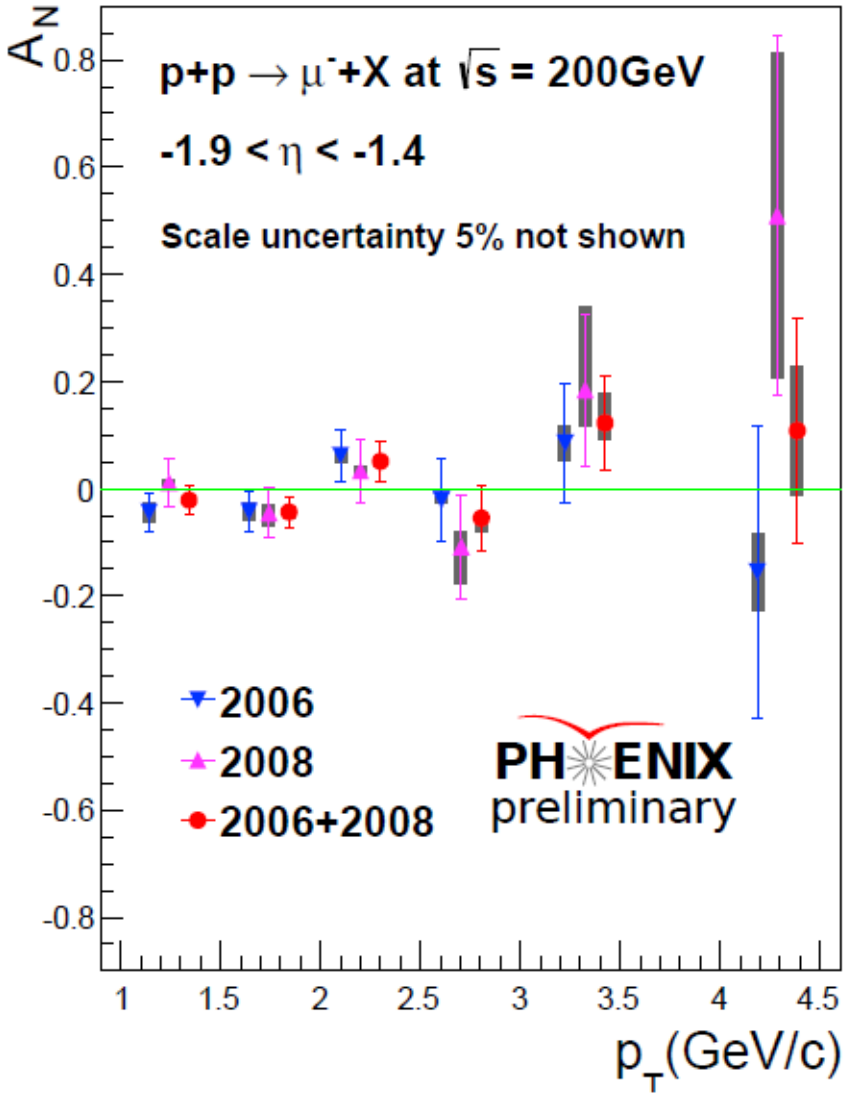
Where $r = \frac{N^{BG}}{N^{Incl}}$ is background fraction which was determined by simulation

A_N vs x_F


A_N
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
p+p → μ⁻+X at √s = 200 GeV
1.4<|η|<1.9
1.0<p_T<5.0 GeV/c
PHENIX
preliminary
2006
2008
2006+2008
<p_T> = 2.4, 1.4, 1.4, 2.4 GeV/c
Scale uncertainty 5% not shown
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
x_F

A_N vs p_T


A_N
p+p → μ⁻+X at √s = 200GeV
1.4 < η < 1.9
Scale uncertainty 5% not shown
2006
2008
2006+2008
PHENIX
preliminary
p_T(GeV/c)


A_N
p+p → μ⁻+X at √s = 200GeV
-1.9 < η < -1.4
Scale uncertainty 5% not shown
2006
2008
2006+2008
PHENIX
preliminary
p_T(GeV/c)

Summary & Outlook

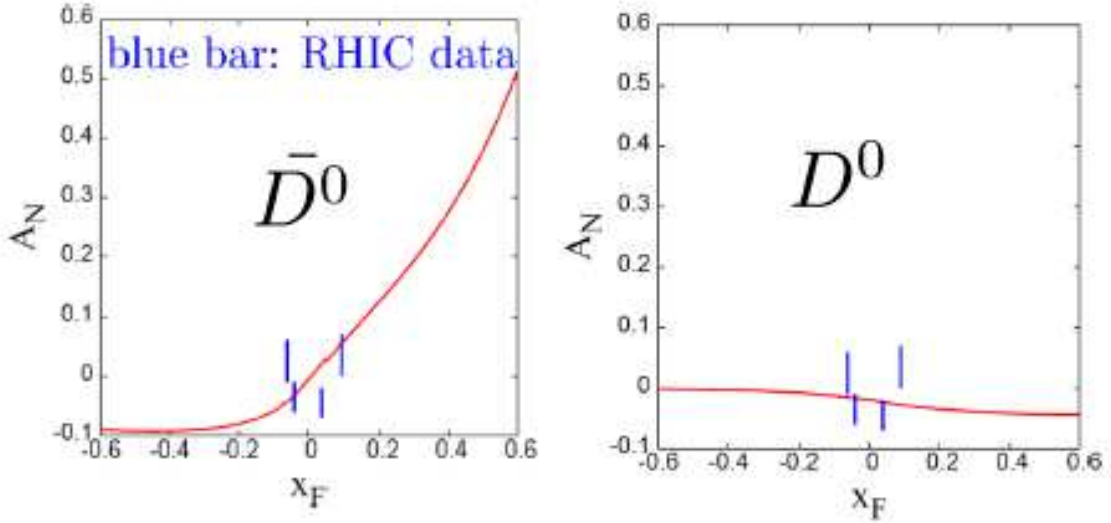
- PHENIX measured the transverse single spin asymmetries in heavy flavor production at 200GeV in 2006, 2008 and 2012 (in progress). At RHIC energy, open heavy flavor production are dominated by gluon-gluon fusion, so the A_N in heavy flavor production is only sensitive to the gluon's Sivers effect.
- With combining 2006 and 2008 preliminary results
  - A_N of heavy flavor decay muons is still consistent with zero
  - May indicate that the gluons Sivers function is smaller than the sensitivity of the present measurement
- FVTX detector will significantly enhance our physics search
  - FVTX was installed in 2012 and had a successful commission run.
  - Precise measurement of secondary vertex help exclude huge background
  - See Jeongsu Bok's talk at session "Instrumentation VI" on Saturday

Thank you

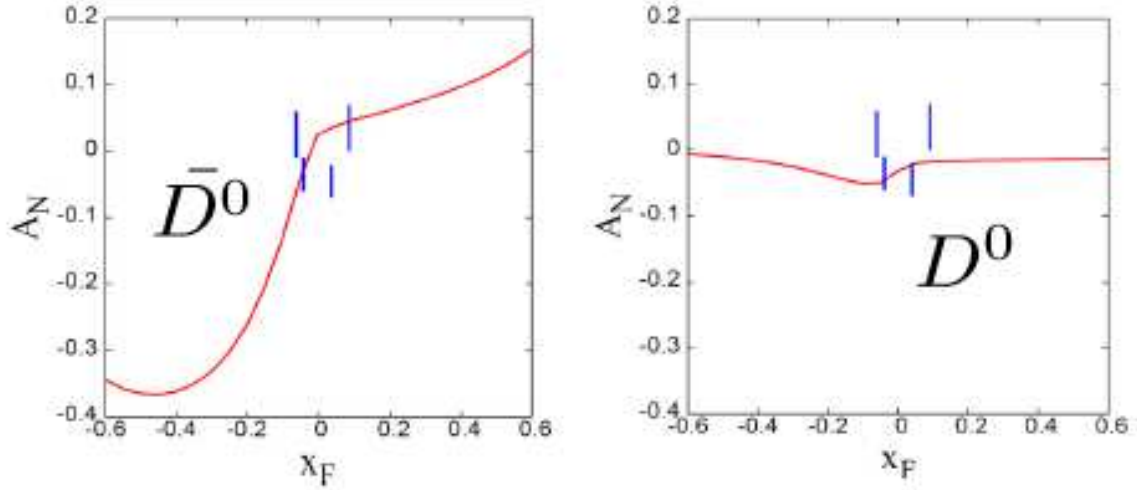
Prediction from Y. Koike

arXiv:**1104.3943**

Model 1:
$O(x) = 0.004xG(x)$



Model 2:
$O(x) = 0.001\sqrt{x}G(x)$



RHIC as Polarized Proton Collider