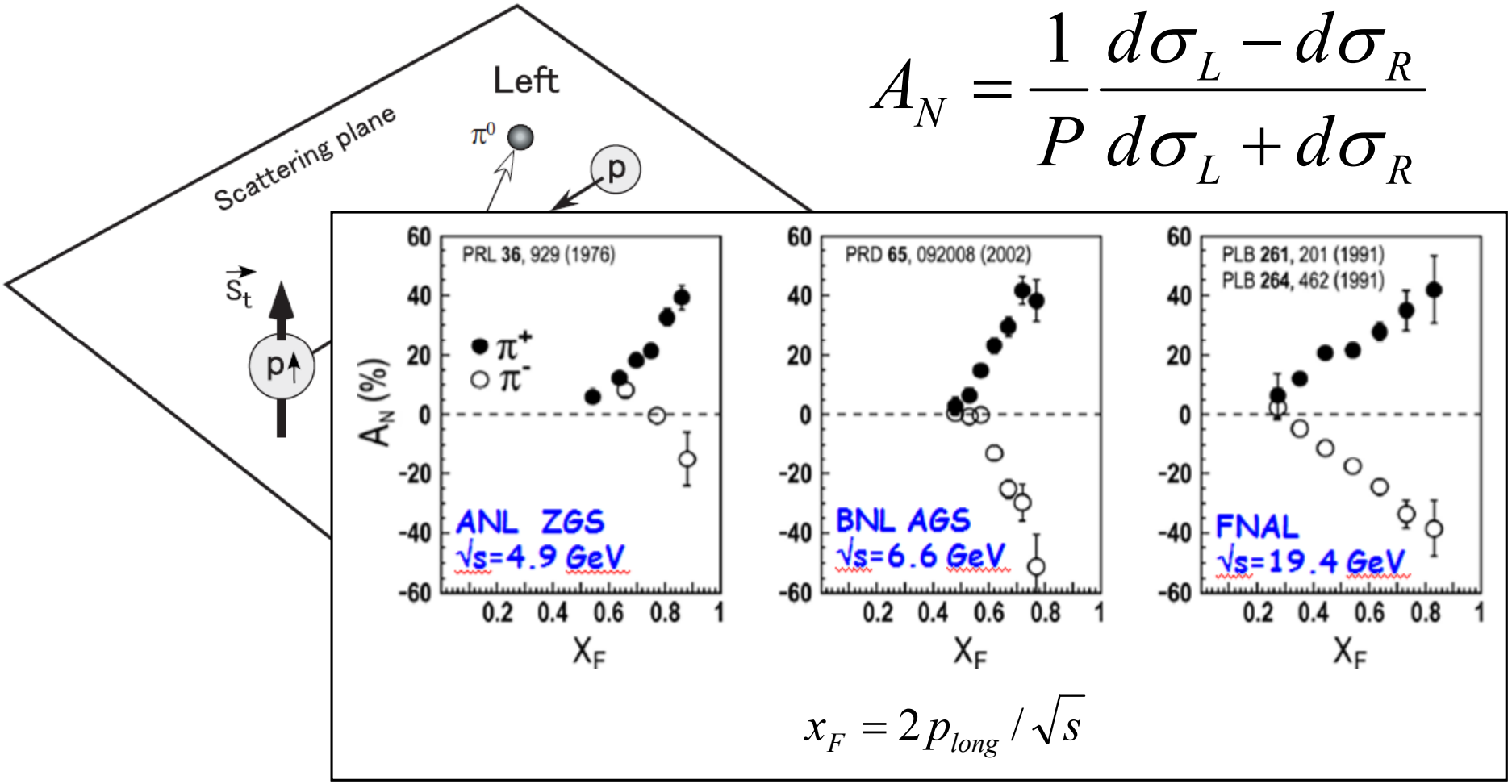
Recent Results of Transverse Spin Physics in PHENIX

K. Oleg Eyser
UNIVERSITY OF CALIFORNIA
UC RIVERSIDE

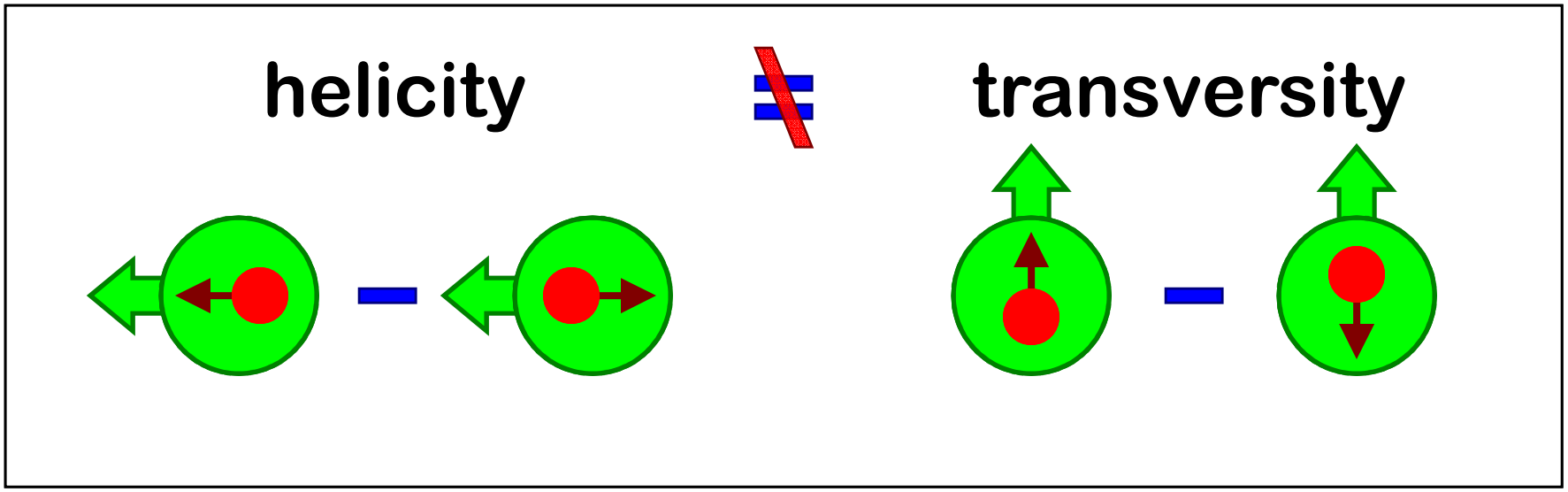
Transverse Asymmetries

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



$$x_F = 2p_{long}/\sqrt{s}$$

Three major questions



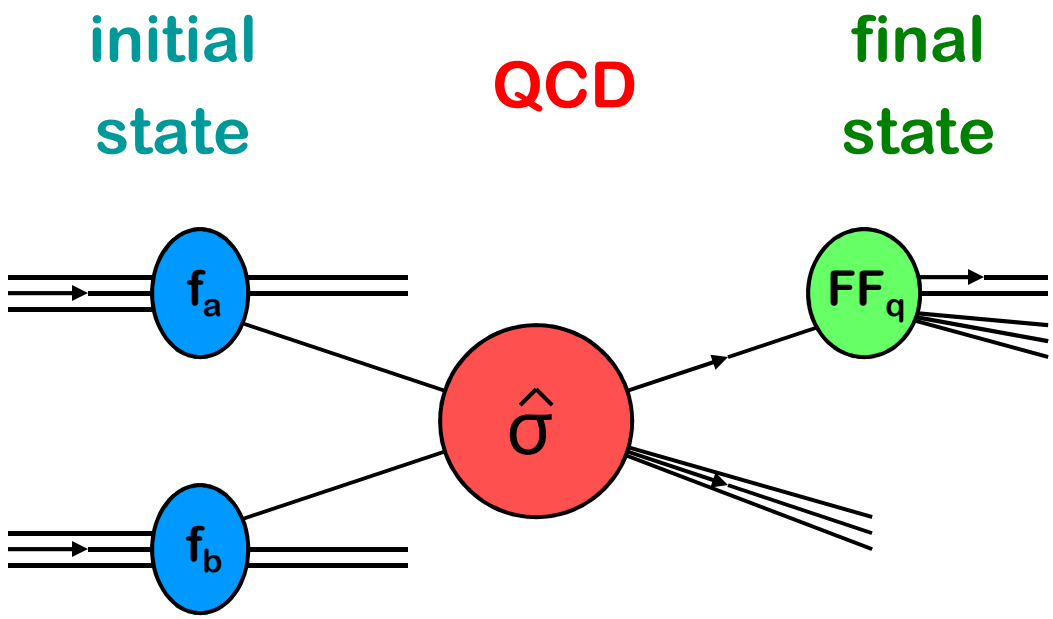
- What are the origins of transverse-spin phenomena in QCD?
  - Transversity
  - Connections to orbital angular momentum

Nucleon Collisions

Transversity & Collins fragmentation

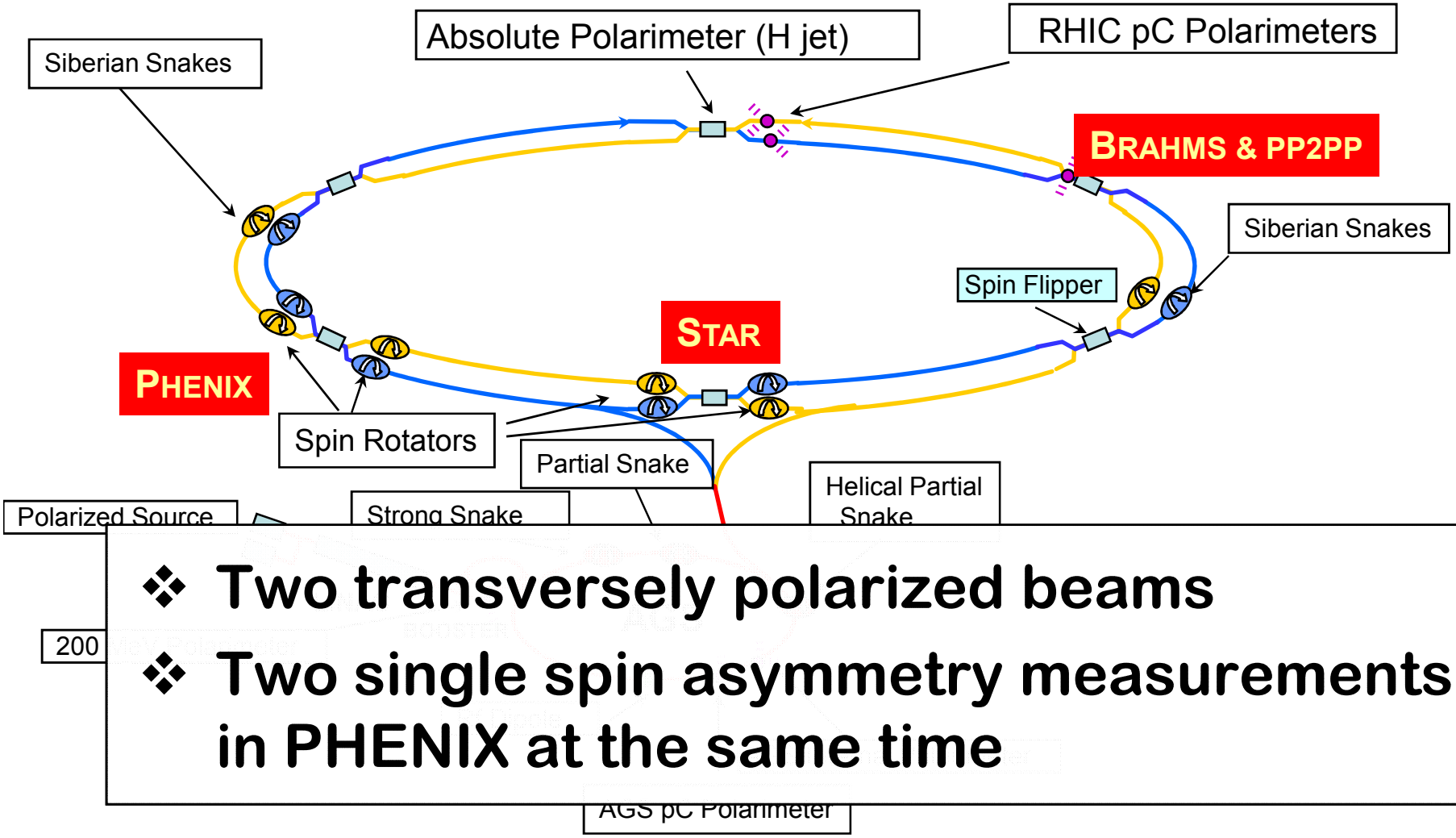
correlation between proton spin & quark spin + spin dependant fragmentation function

J. C. Collins, Nucl. Phys. B396, 161 (1993).



$$\propto \delta q(x) \cdot H_1^{\perp}(z_2, \bar{k}_{\perp}^2)$$

RHIC



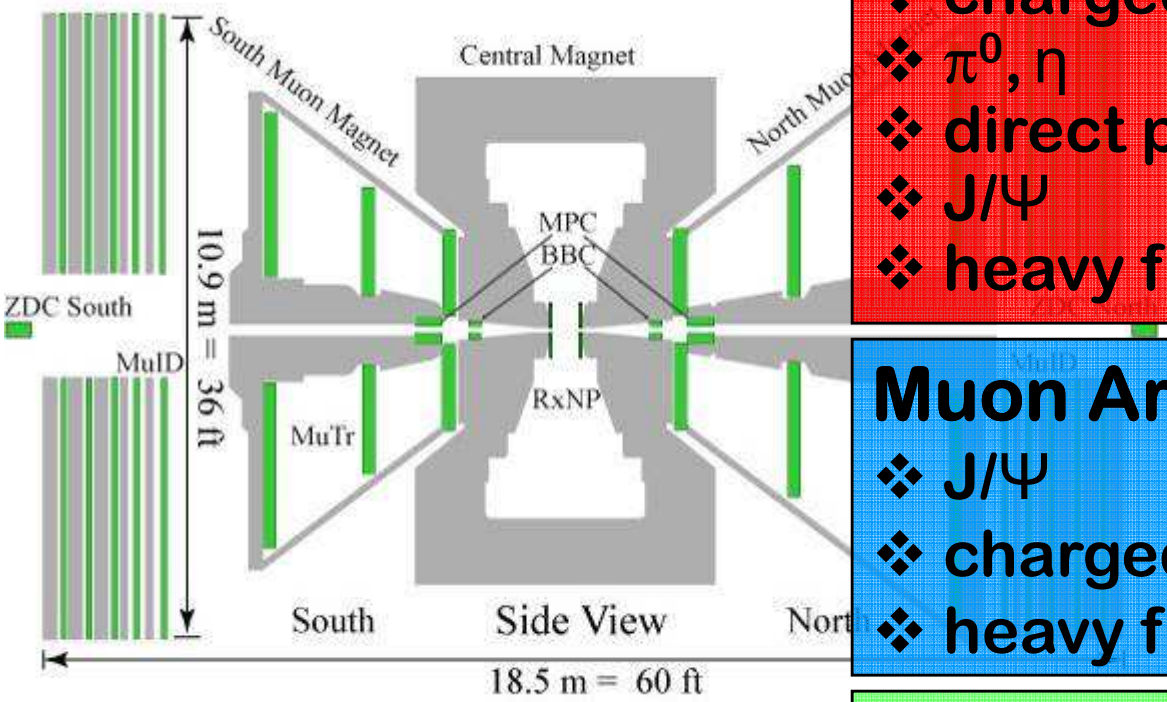
- Two transversely polarized beams
- Two single spin asymmetry measurements in PHENIX at the same time

Luminosity & Polarization

Year	Energy	Polarization	Longitudinal		Transverse	
	[GeV]	[%]	L [pb^{-1}]	LP^4 [pb^{-1}]	L [pb^{-1}]	LP^2 [pb^{-1}]
2002	200	15	-	-	0.15	3.4×10^{-3}
2003	200	27	0.35	1.9×10^{-3}	-	-
2004	200	40	0.12	9×10^{-3}	-	-
2005	200	49 (47)	3.4	2×10^{-1}	0.16	3.5×10^{-2}
2006	200	57 (51)	7.5	7.9×10^{-1}	2.7	7.0×10^{-1}
2006	62	48	0.08	4.2×10^{-3}	0.02	4.6×10^{-3}
2008	200	46	-	-	5.2	1.1×10^{0}
2009	500	35	14	2.1×10^{-1}	-	-
2009	200	55	16	1.5×10^{0}	-	-

* integrated luminosity for PHENIX central arm

PHENIX



Central Arms $|\eta| < 0.35$

- charged hadrons
- π^0, η
- direct photon
- J/Ψ
- heavy flavor

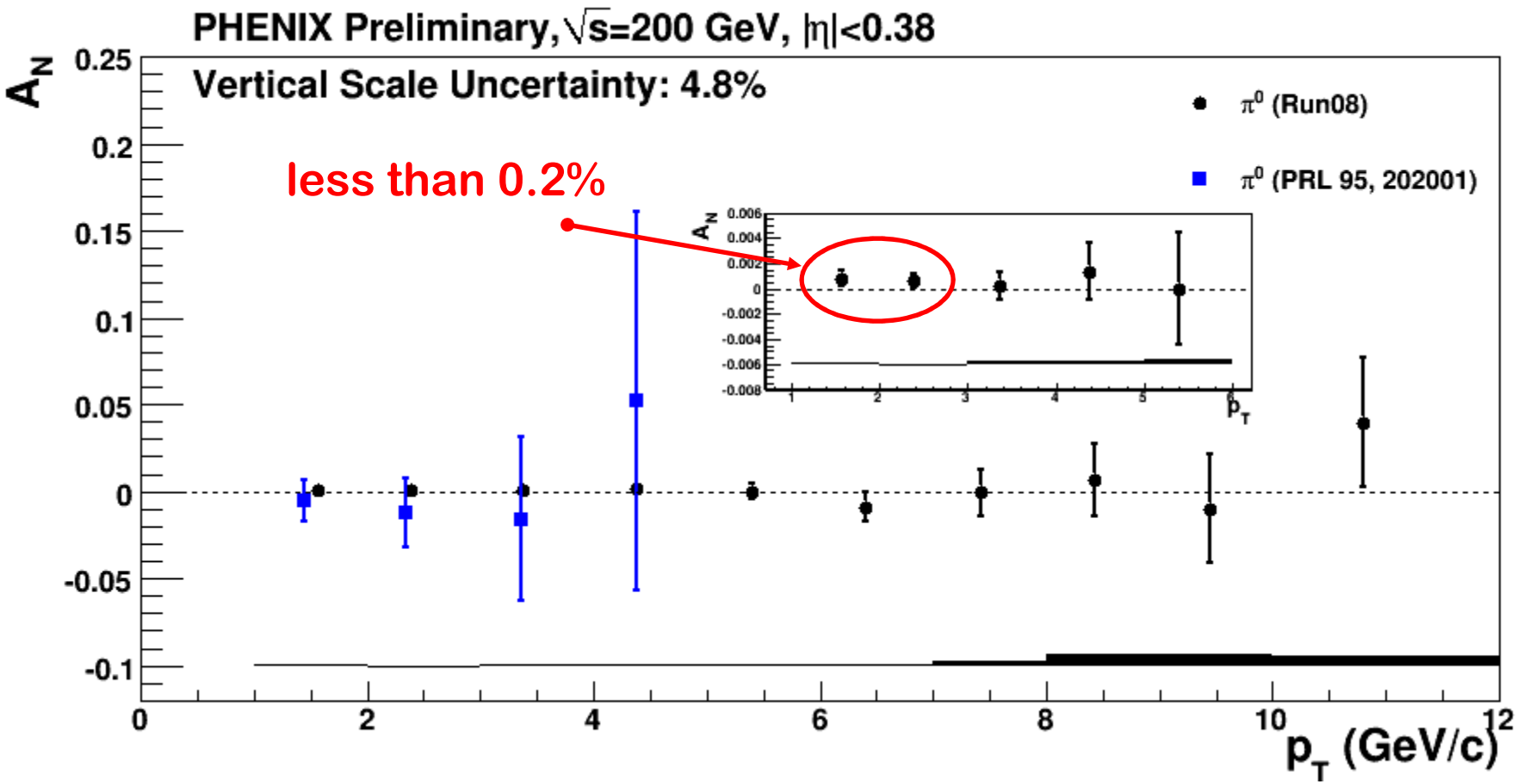
Muon Arms $1.2 < |\eta| < 2.4$

- J/Ψ
- charged hadrons
- heavy flavor

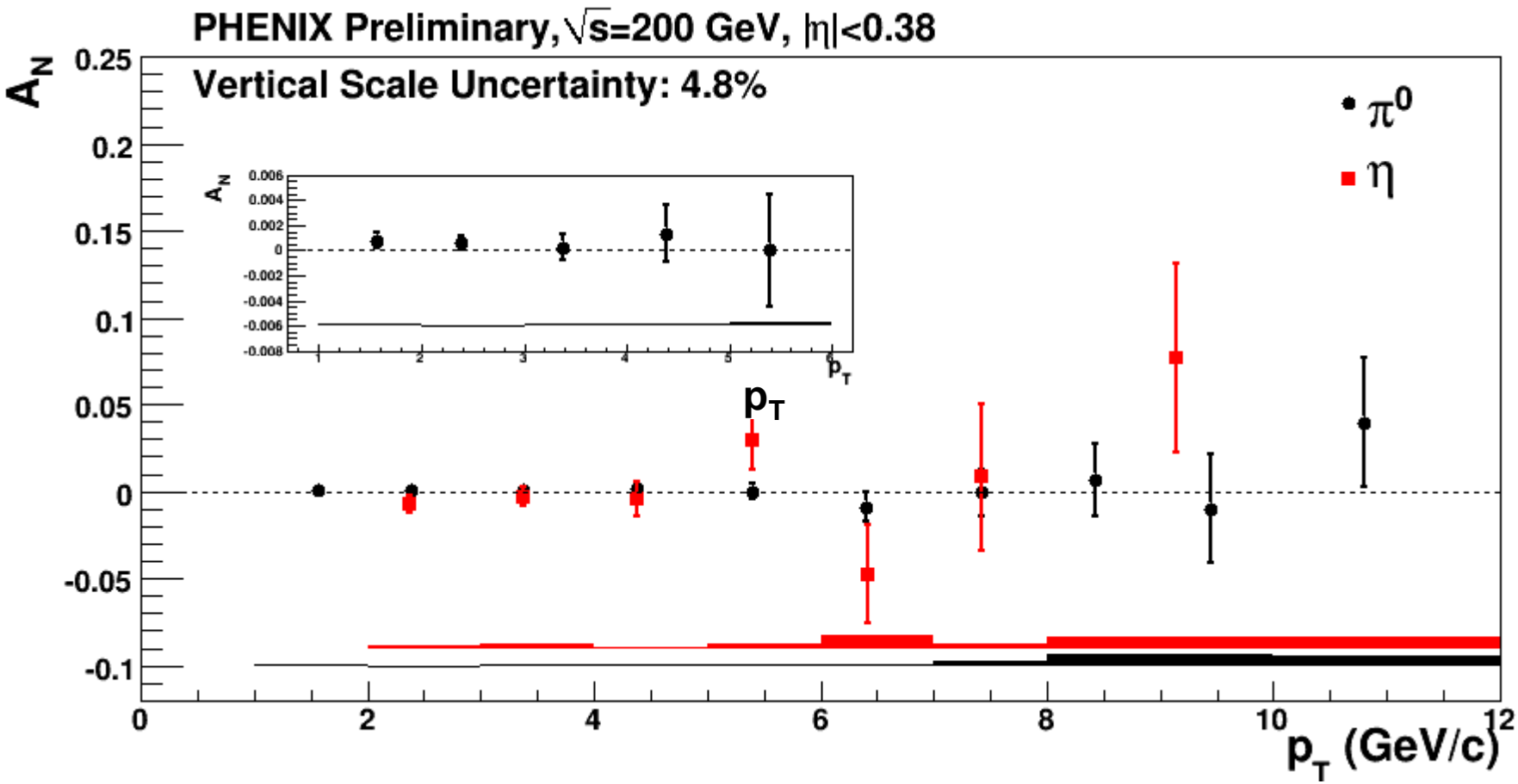
MPC $3.1 < |\eta| < 3.9$

- π^0, η

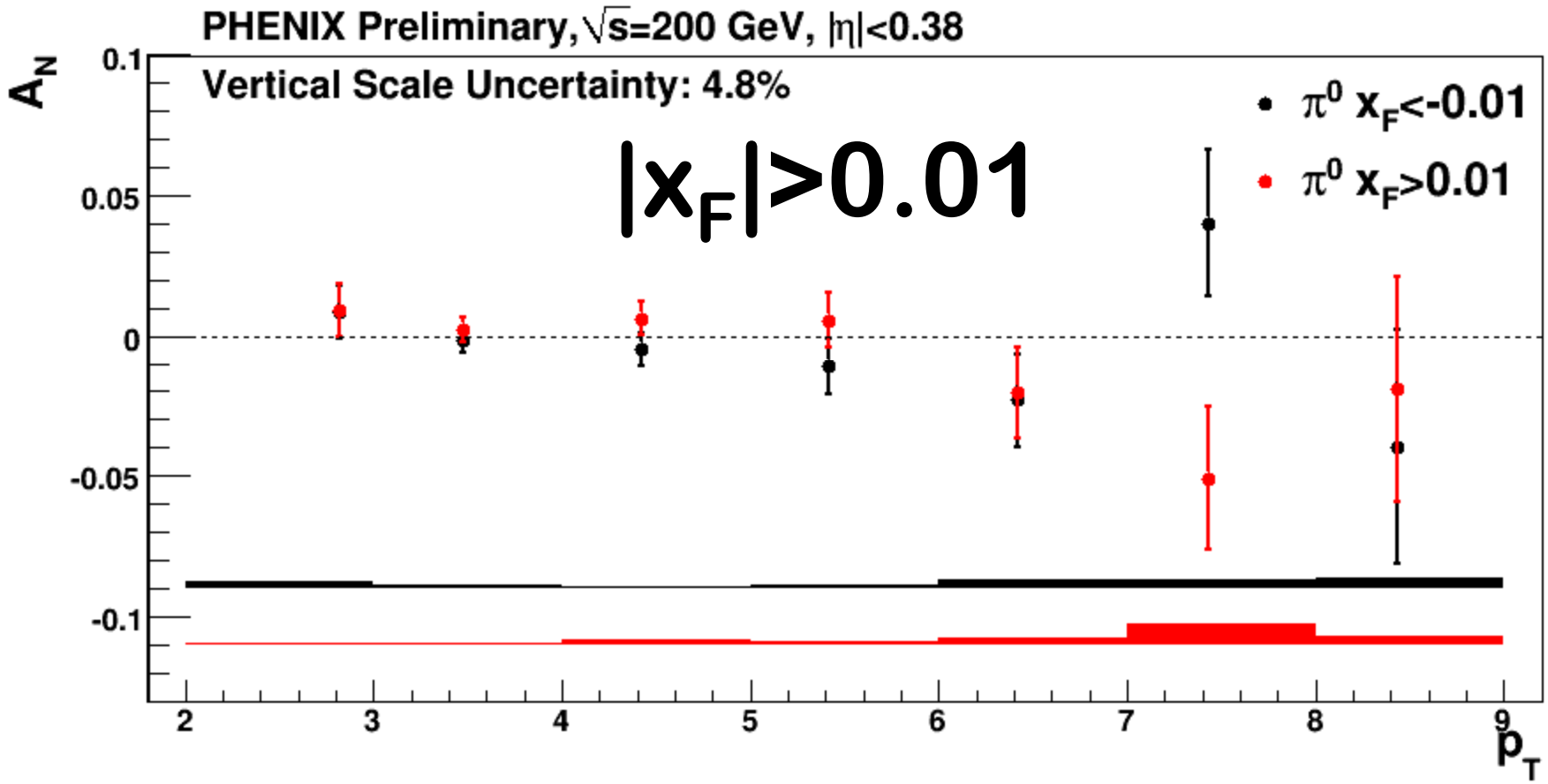
A_N: mid-rapidity π^0



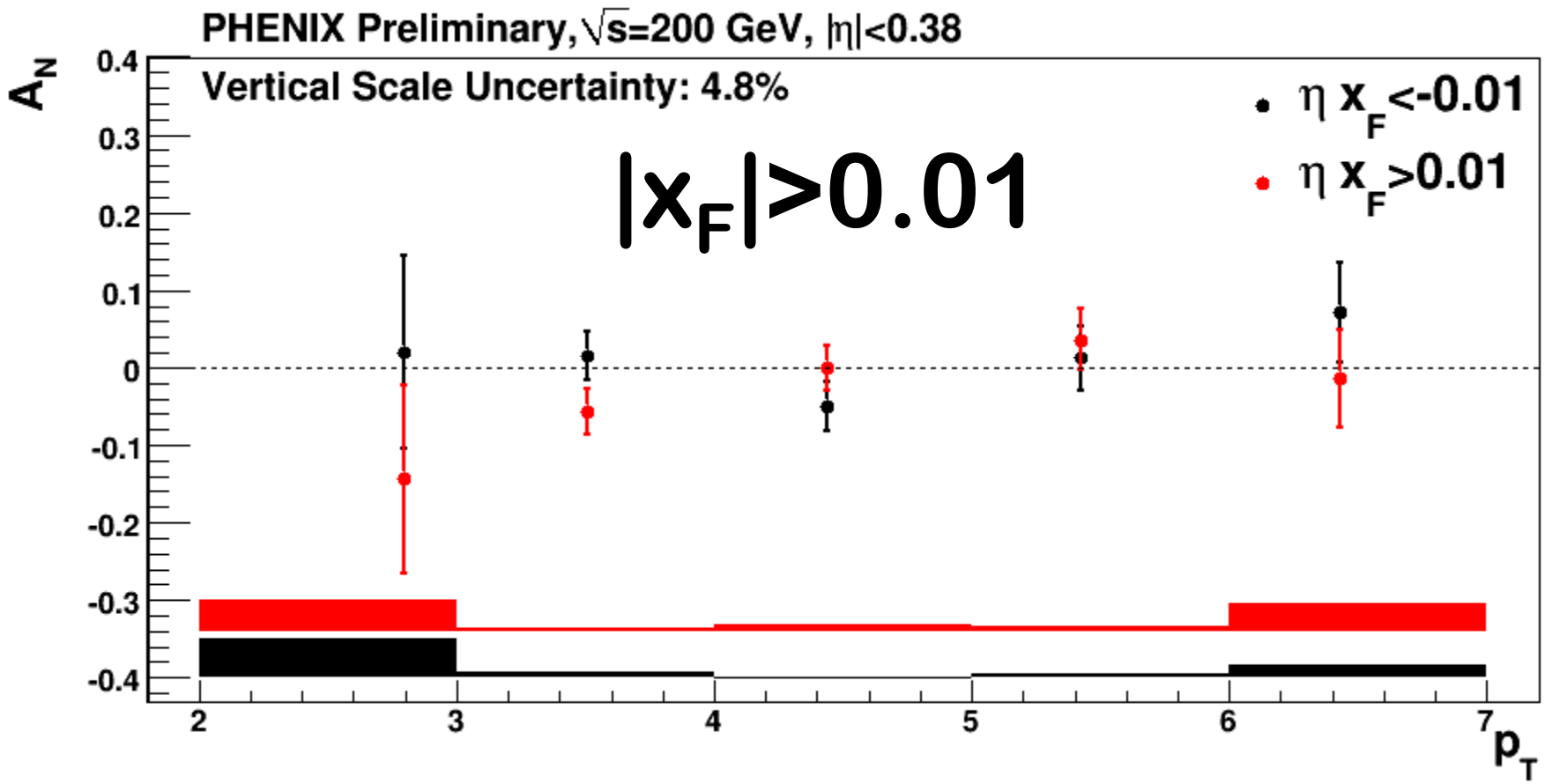
A_N: mid-rapidity π^0 and η



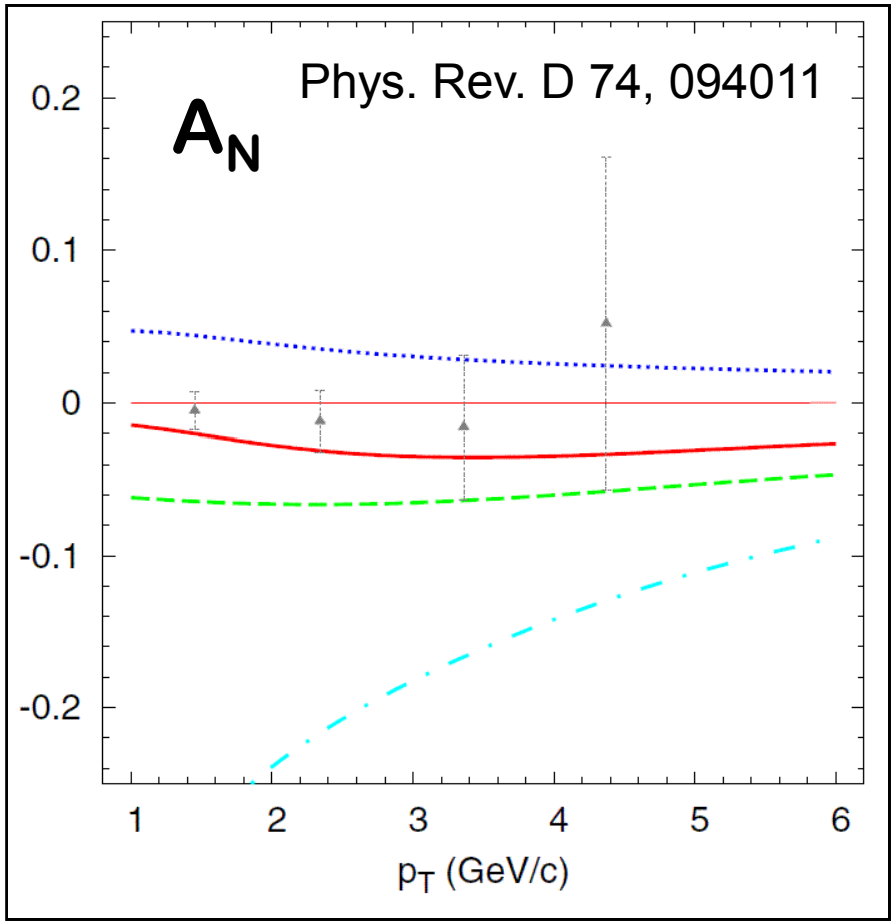
A_N: mid-rapidity π^0



A_N: mid-rapidity η



Limit on Gluon Sivers Function

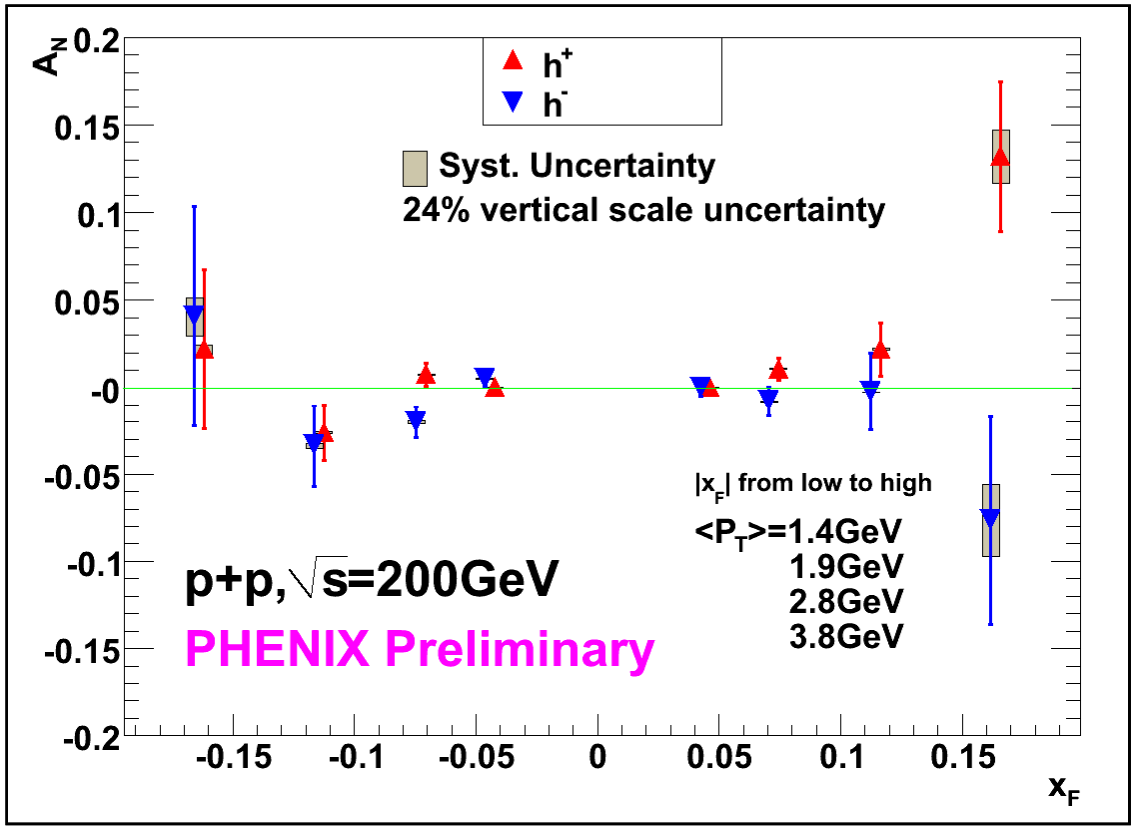


- gluon Sivers at positivity bound no sea quark Sivers
- gluon Sivers parameterized to be 1 sigma from PHENIX π^0 A_N
- sea quark maximized plus valence quarks
- gluon contribution

❖ **LO model-dependent constraints on gluon Sivers function from PHENIX data at SMALL x**

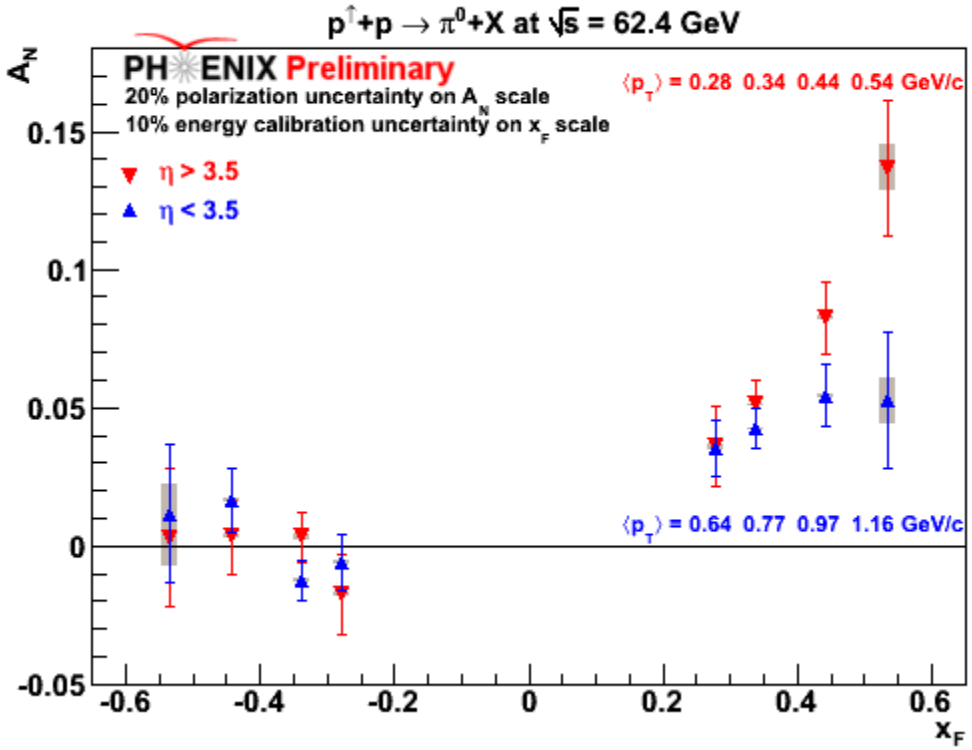
Forward A_N Charged Hadrons

- Unidentified charged hadron asymmetry
- Mid-rapidity results from 2002 & 2005
  - Increased statistics in 2008 data

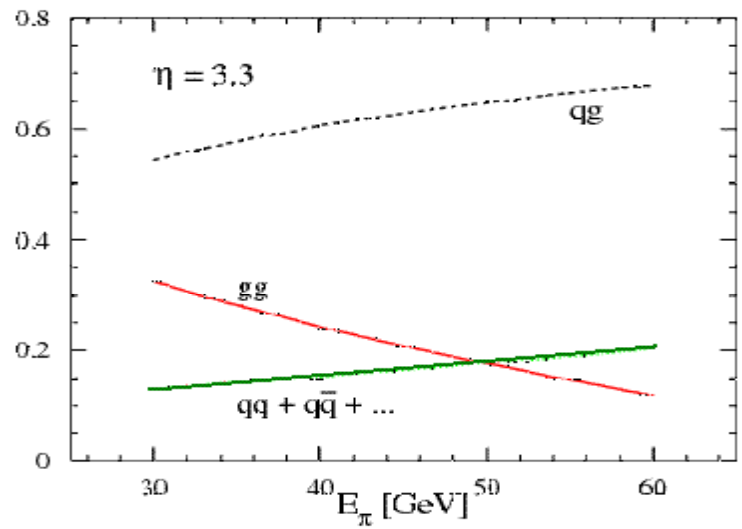


Forward A_N @ 62.4 GeV

- Neutral pions
- quark-gluon dominated



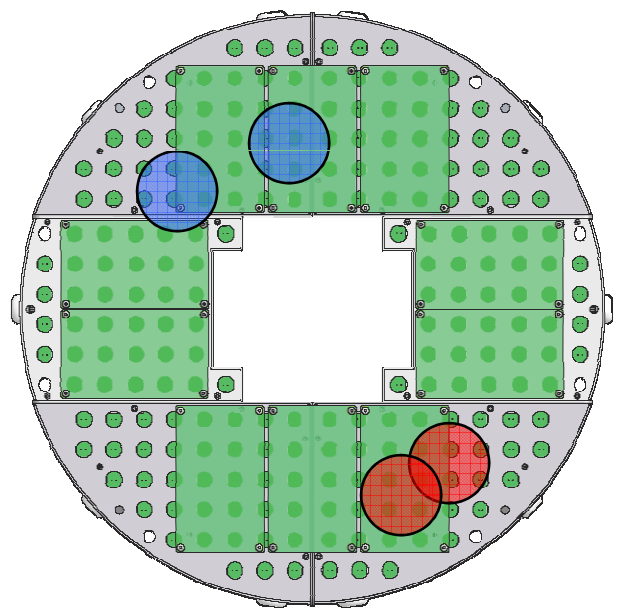
Processs contribution to pi0, eta=3.3, sqrt(s)=200 GeV
Guzey et al, PLB **603**,173 (2004)



- global analysis needed!

Forward A_N for Clusters

in the Muon Piston Calorimeter
clusters from pion decay photons
merge at high energies
(> 20 GeV)

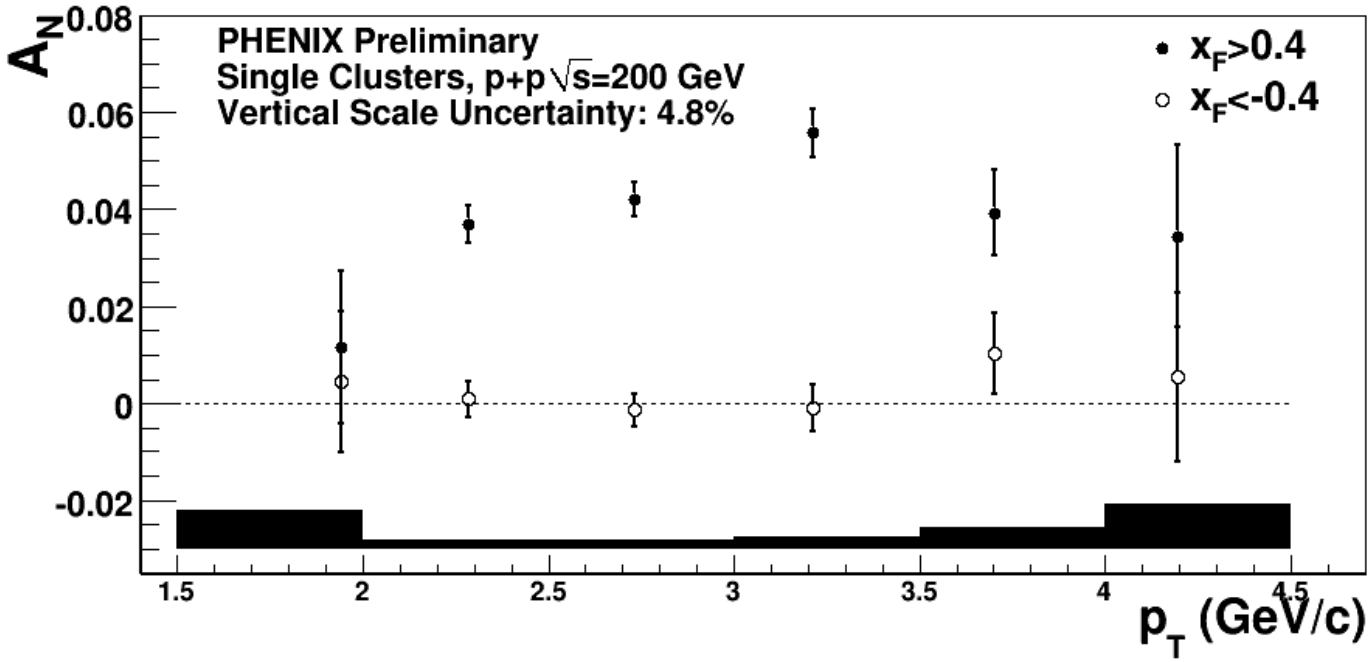


tower size
2.25^2 cm^2

220 cm
from vertex

$\sqrt{s}$ = 200 GeV

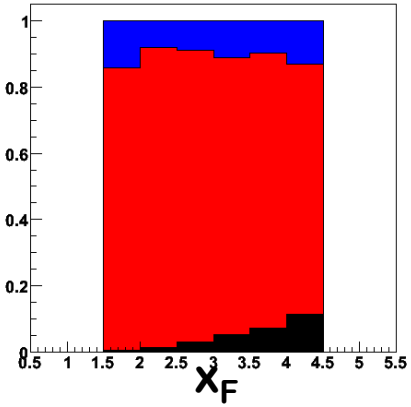
Forward A_N for Clusters



$\sqrt{s}$ = 200 GeV

Cluster contribution

- decay photon
- π^0
- direct photon

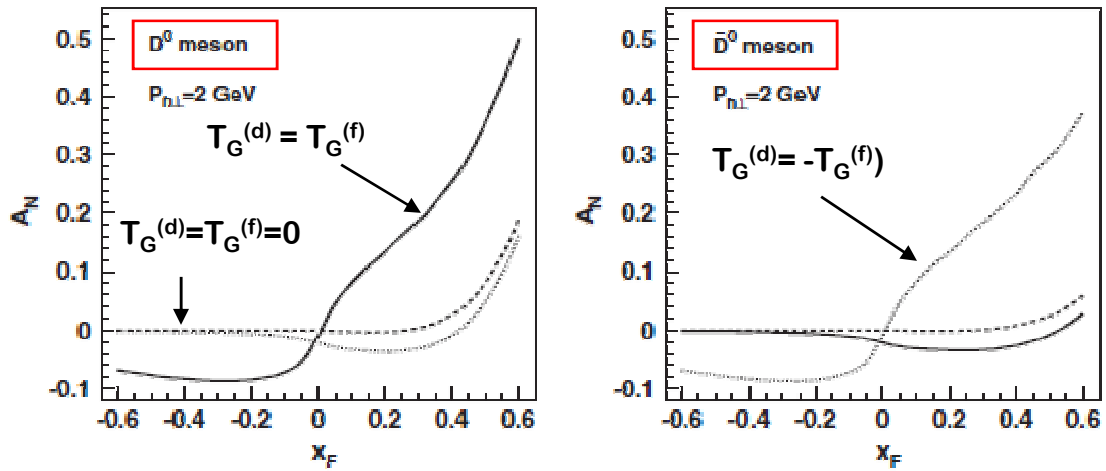


Heavy Flavor

$p^{\uparrow}p \rightarrow DX$

- dominated by glu
  gluon fusion
- No gluon transve
- Sensitive to gluo
  Sivers effect

PRD 78 114013 (2008)

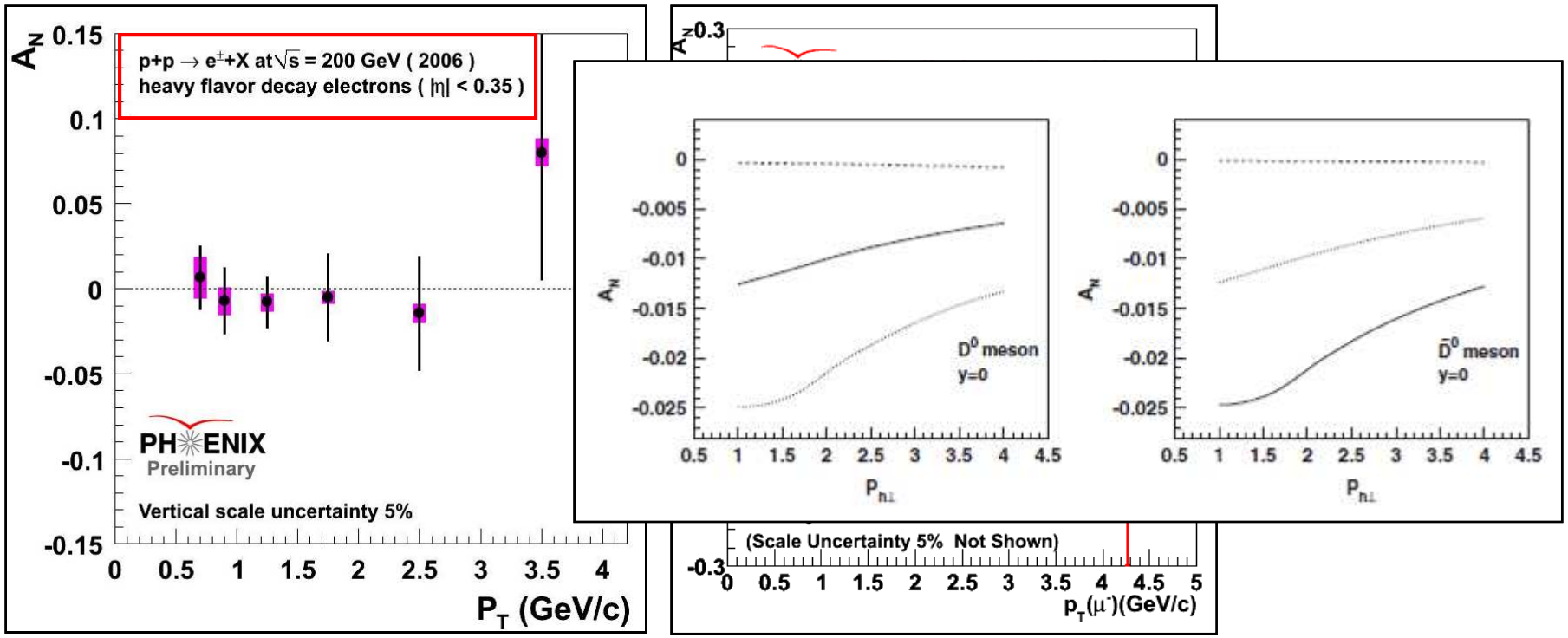


- Twist-3 gluon correlators $T_G^{(d)}$, $T_G^{(f)}$
- Disentangle effects in x_F range

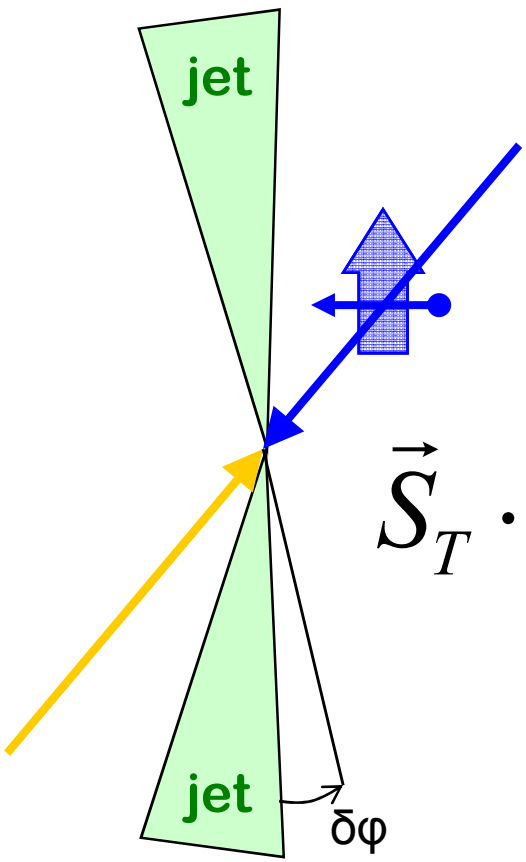
Heavy Flavor

single leptons

no full D-meson reconstruction

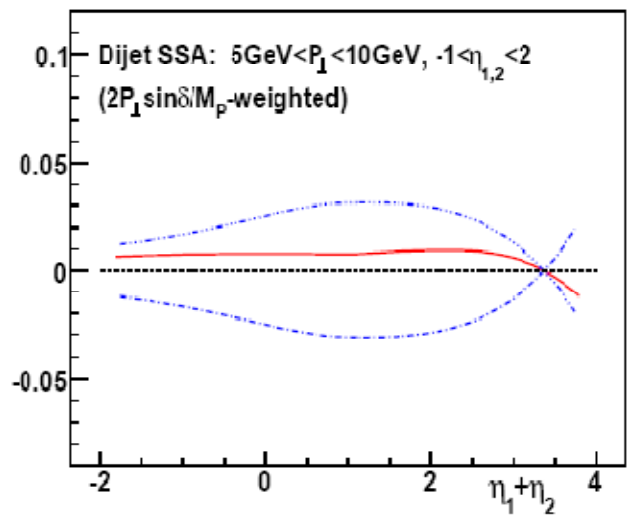


Back-to-back jets



The Sivers effect can manifest itself as an <u>azimuthal</u> asymmetry in back-to-back jets in polarized p+p collisions.

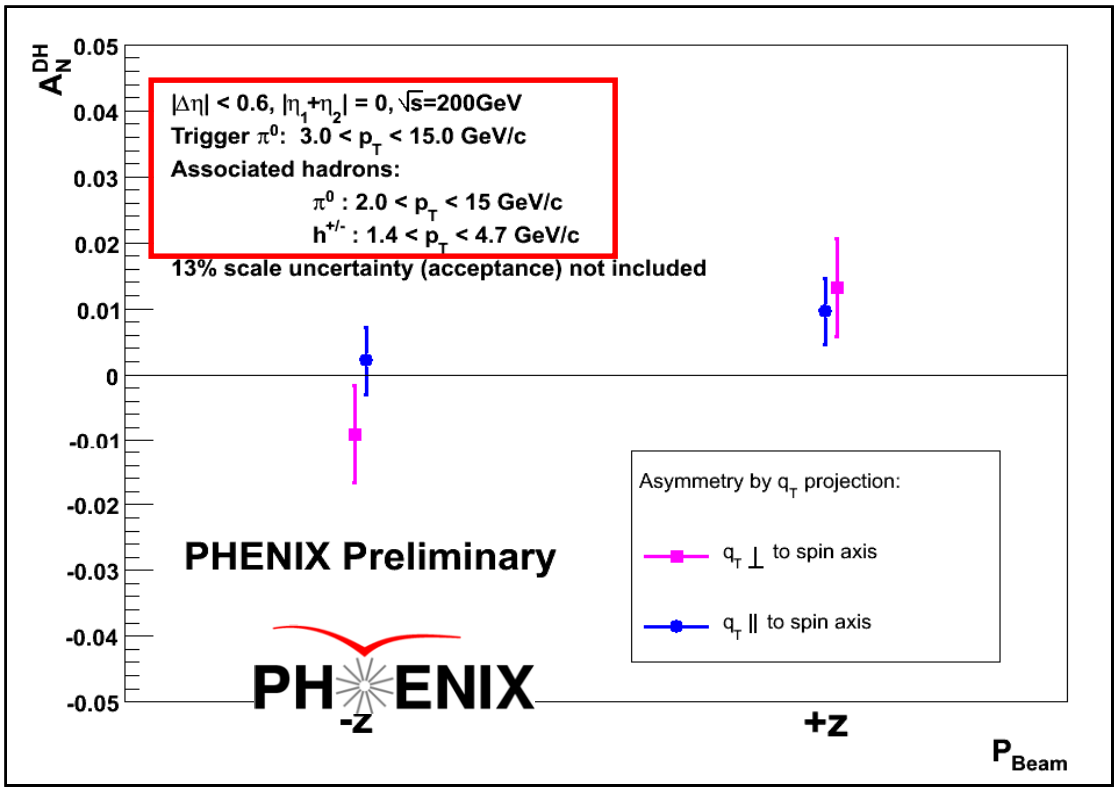
$$\vec{S}_T \cdot (\vec{p} \times \vec{k}_T)$$



Boer, Vogelsang
Phys. Rev. D 69, 094025

Bomhof, Mulder, Vogelsang and Yuan
PRD 75, 074019

Di-hadrons in PHENIX



- Sivers asymmetry ($q_T^{\perp}$)
- No asymmetry expected for $q_T^{\parallel}$
- Improved statistics for 2008 data set!

Similar analysis possible in different combinations of rapidity

η_{min}	-3.7	-2.4	-0.35	1.2	3.1
η_{max}	-3.1	-1.2	+0.35	2.4	3.9

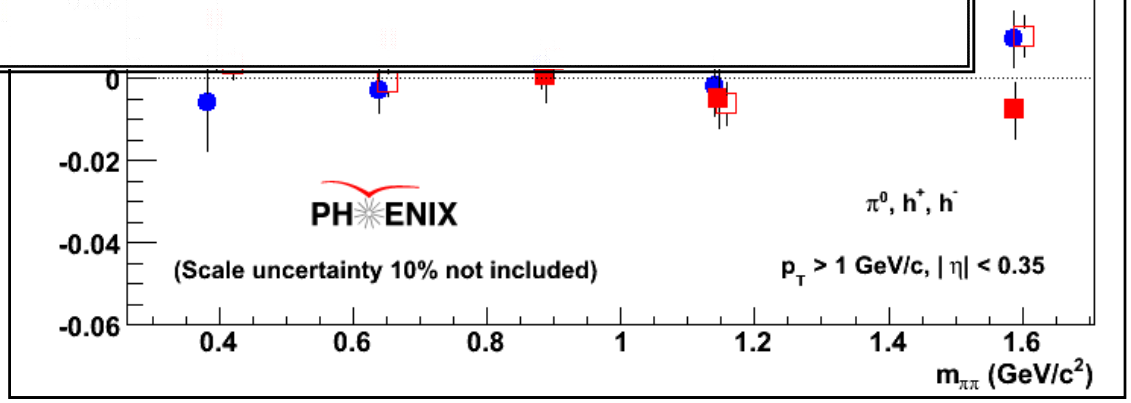
Works in progress...

Interference fragmentation

Matthias Große Perdekamp

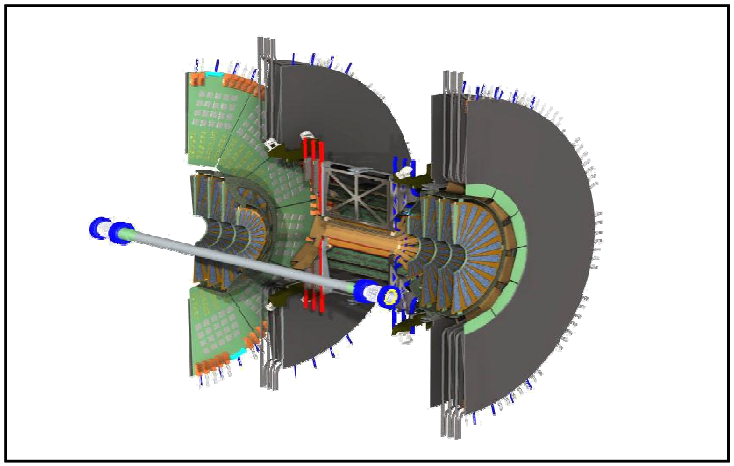
Interference fragmentation functions in pp and e^+e^- data

$$A_{UT,\phi}^{h_1,h_2} = \frac{\sigma_\phi^\uparrow - \sigma_\phi^\downarrow}{\sigma_\phi^\uparrow + \sigma_\phi^\downarrow}$$



Outlook

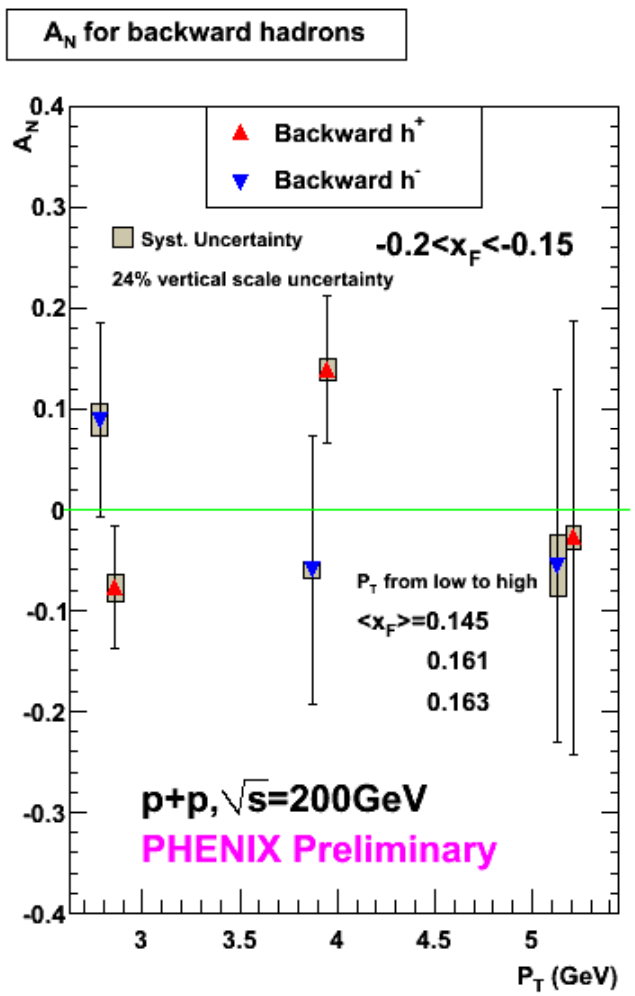
- Non zero asymmetries in forward direction
  - asymmetry for η-meson soon
- Sivers constraint possible with mid-rapidity data
- Di-hadron correlations for rapidity separated pairs
- Heavy flavor tagging with vertex detector upgrades
  - charm/bottom separation

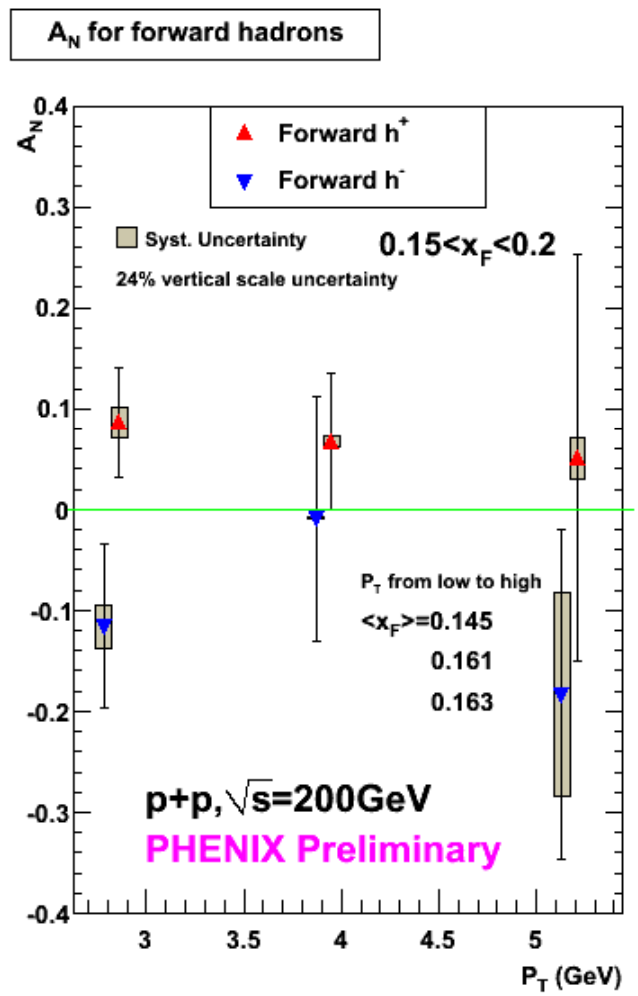


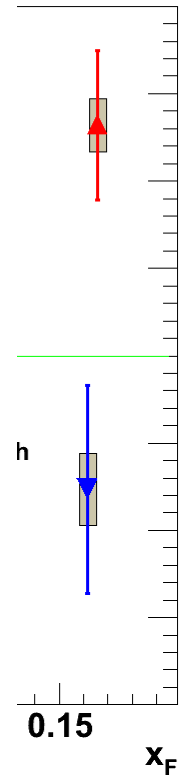
Backup

Forward A_N Charged Hadrons

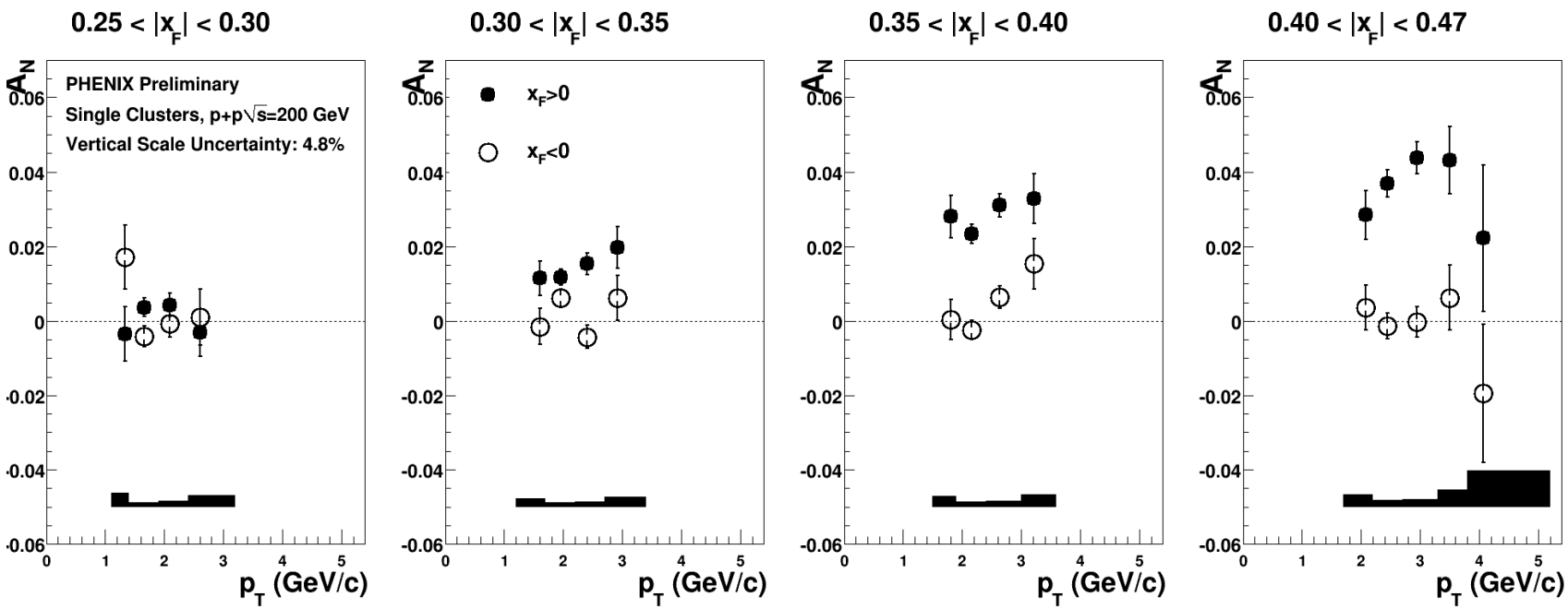
- Unidentif
- Asymme
sharing ar
magnet/ab
- Non-zero
pseudorap

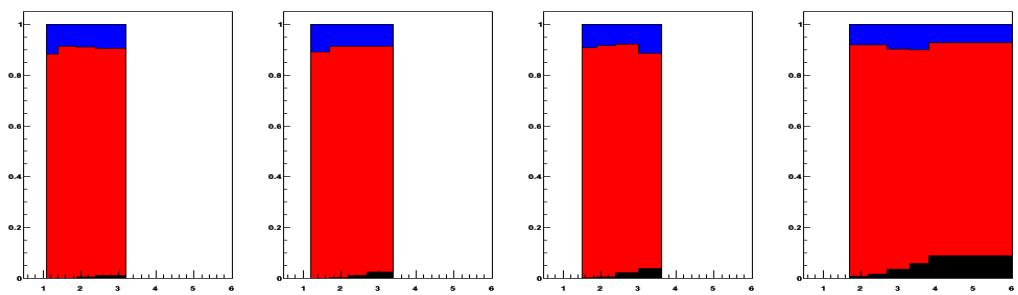






Forward A_N for clusters





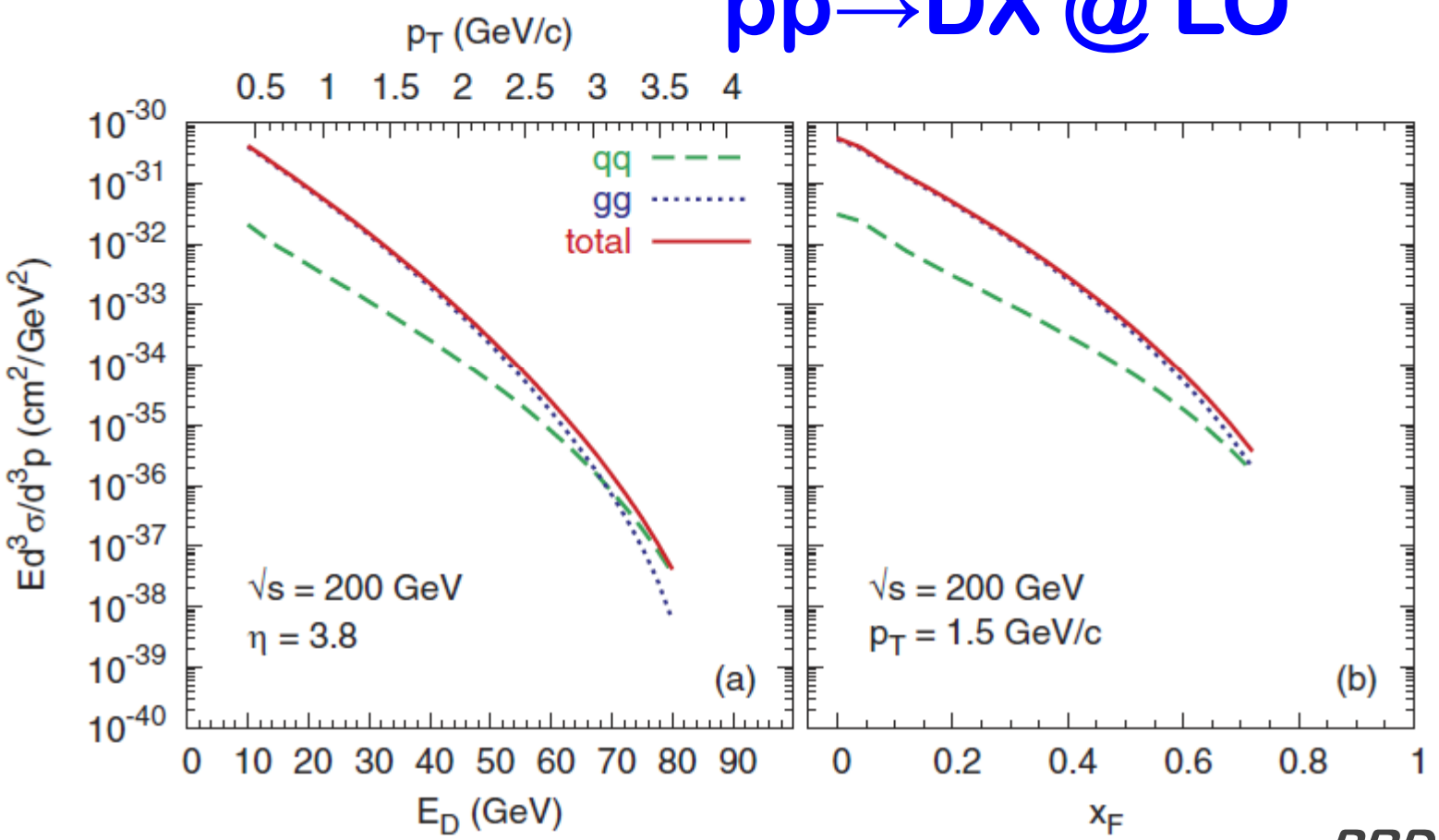
Decay photon

π^0

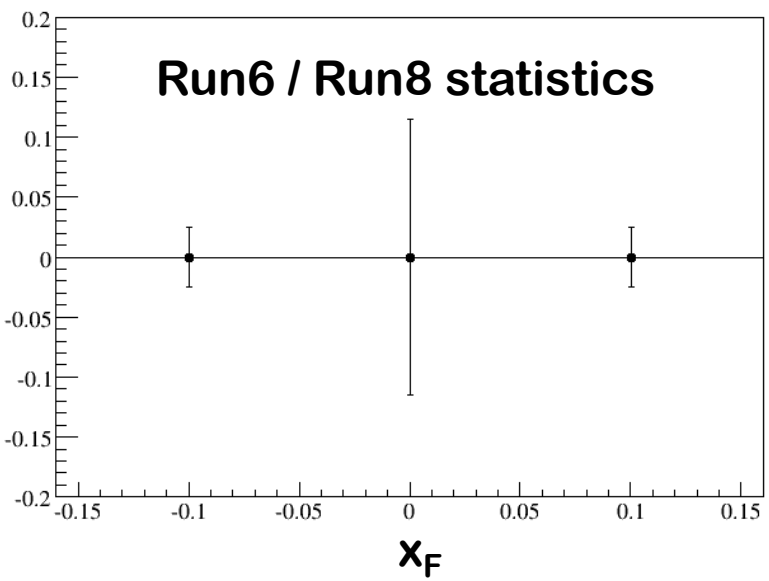
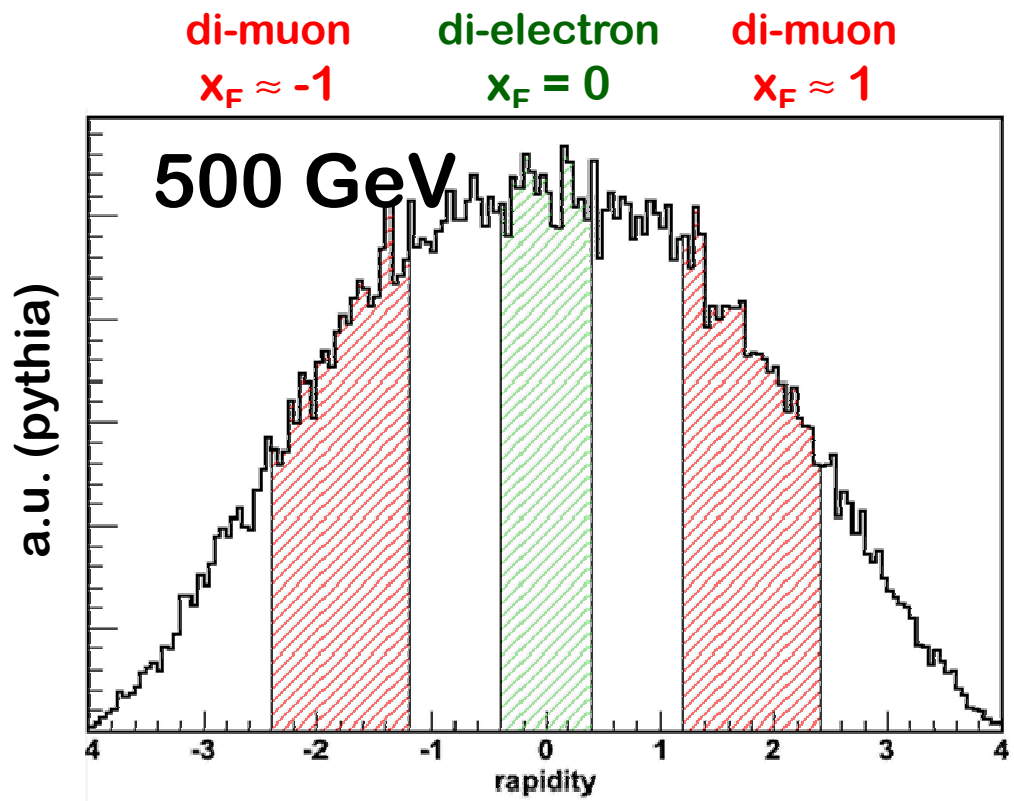
Direct photon

Heavy Flavor

pp→DX @ LO



PRD 70,074025

Heavy Flavor

- J/Psi single spin asymmetry
- production mechanism
- gluon dynamics
- larger x_F lever arm?