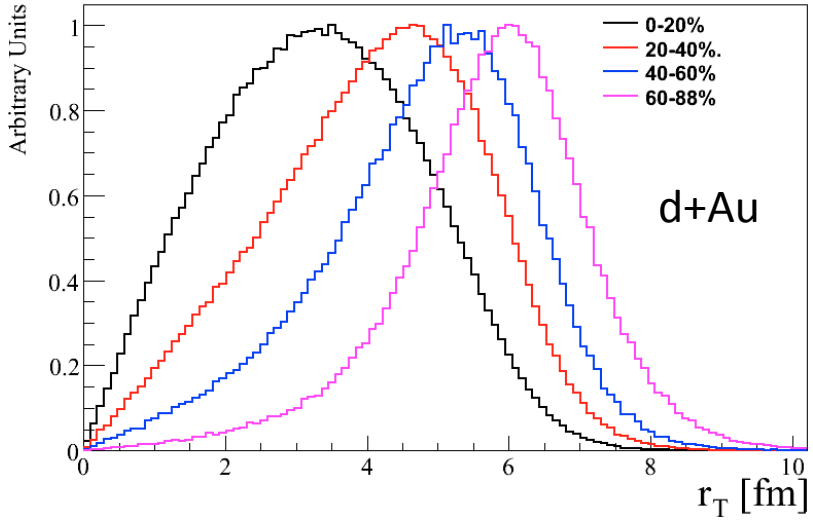
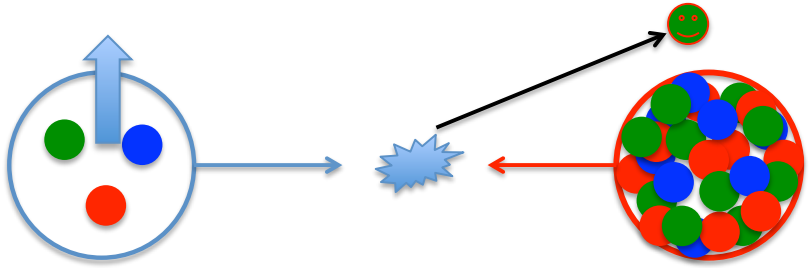
What is "NEW" in polarized p+A @RHIC ?

Ming Liu

- "Large" transverse spin asymmetry
  - Physics origins under study
- "Significant hints" of small-x gluon saturation in heavy A
  - Needs further experimental clarification
- Key observables
  - A-scan
  - Centrality dependence in p+A
  - A_N vs centrality, A …
  - Some other observables?

Cesar da Silva pA@RHIC





Zhongbo Kang pA@RHIC

projectile: $x_1 \sim \frac{p_\perp}{\sqrt{s}} e^{+y} \sim 1$ valence

target: $x_2 \sim \frac{p_\perp}{\sqrt{s}} e^{-y} \ll 1$ gluon

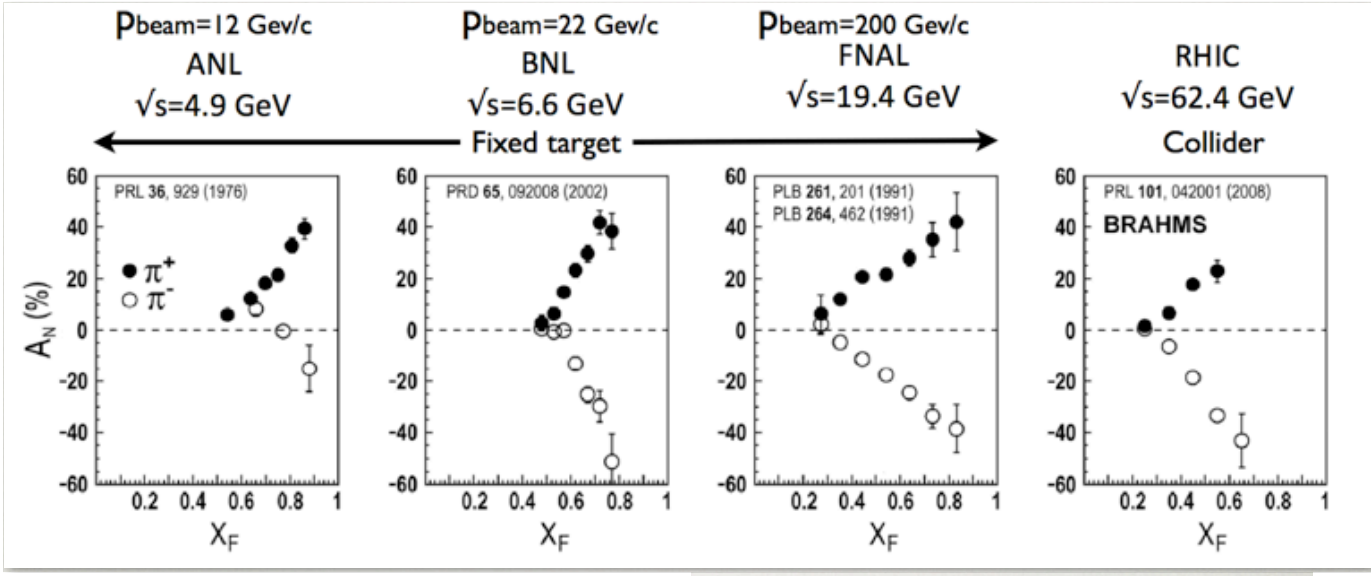
Los Alamos NATIONAL LABORATORY EST.1943

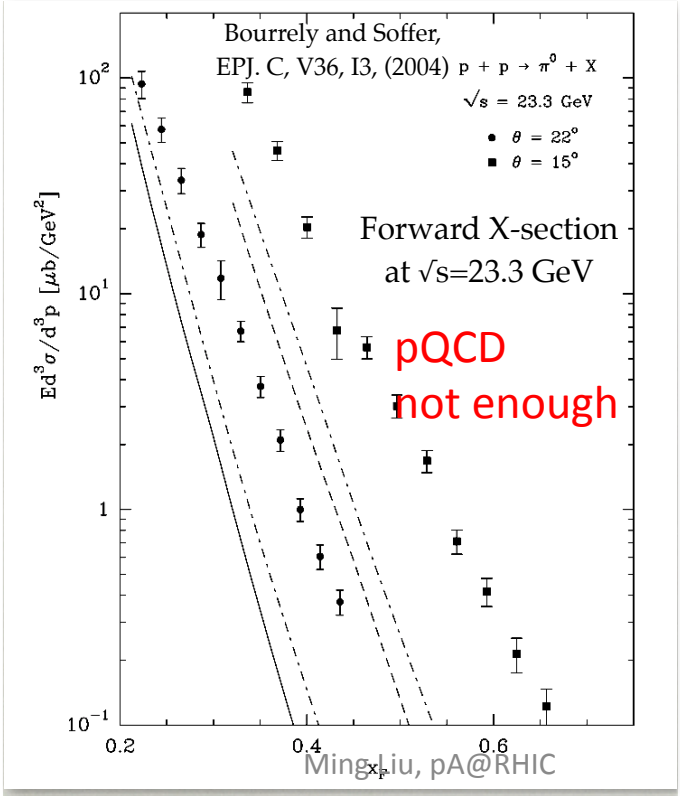
$$N = S + B$$

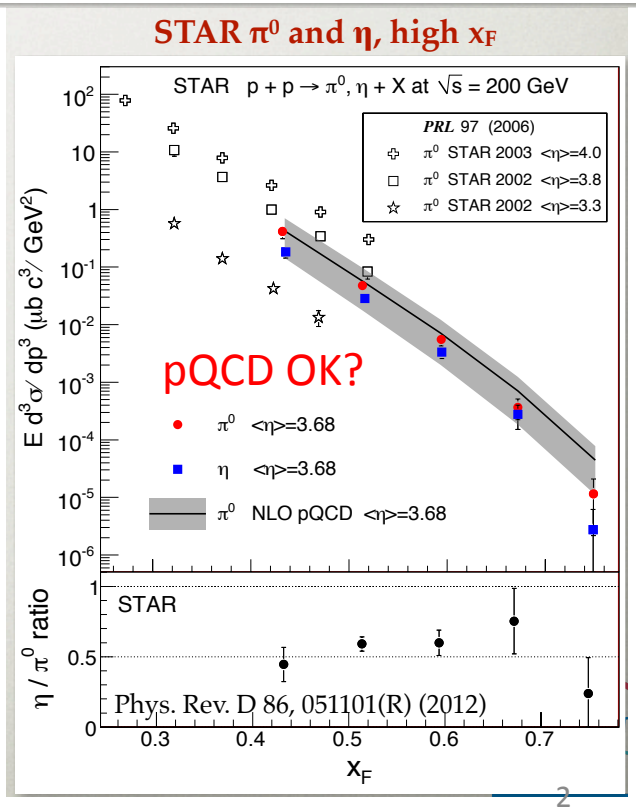
$$A = \frac{\Delta N}{N} = \frac{\Delta S}{S+B} = \frac{\Delta S}{S} \cdot \left(\frac{S}{S+B}\right)$$

$$\sim \frac{\Delta S}{S} \cdot \left(\frac{S}{B}\right); \quad if \quad S << B$$

1. Known "knowns"
2. Known "unknowns"
3. Unknown "unknowns"







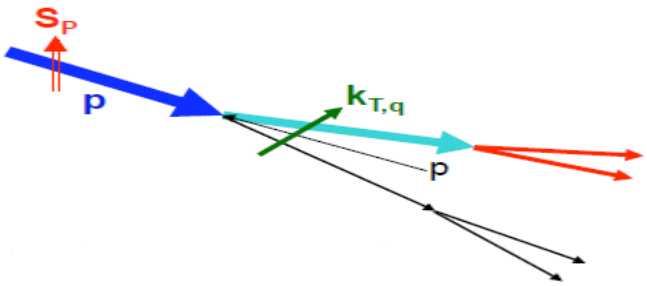
Sources of Transverse SSA's

"Sivers effect"

TMD: Correlation between nucleon spin and parton k_T.

Phys. Rev. D **41**, 83 (1990)
Phys. Rev. D **43**, 261, (1991)

$$d\sigma^{\uparrow} \propto \underbrace{\bar{f}_{1T}^{\perp q}(x,k_{\perp}^2)}_{\text{Sivers distribution}} \cdot D_q^h(z)$$



Twist-3: Quark-gluon correlations in polarized hadron

Phys. Rev. D **59**, 014004 (1998)

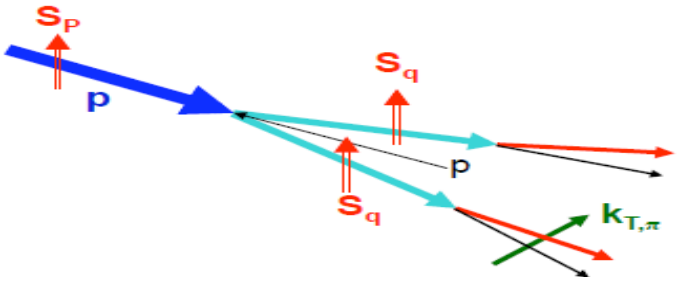
$$gT_{q,F}(x,x) = -\int d^2k_{\perp} \frac{|k_{\perp}|^2}{M} f_{1T}^{\perp q}(x,k_{\perp}^2)$$

"Collins effect"

TMD: Transversity distributions + Spin dependent fragmentation functions

Nucl. Phys. B 396, 161 (1993)

$$d\sigma^{\uparrow} \propto \underbrace{\delta q(x)}_{\text{Transversity}} \cdot \underbrace{H_1^{\perp}(z_2,\bar{k}_{\perp}^2)}_{\text{Collins FF}}$$

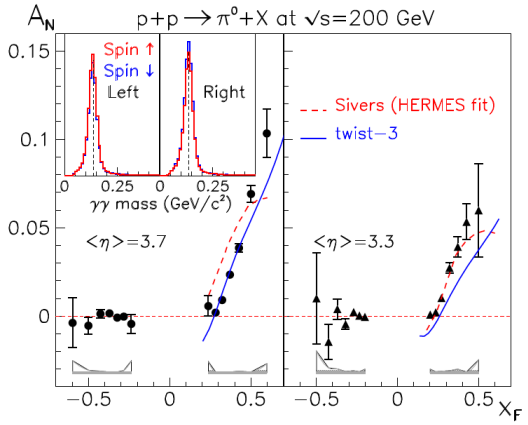


Twist-3: Transversity combined with twist-3 quark-gluon fragmentation function

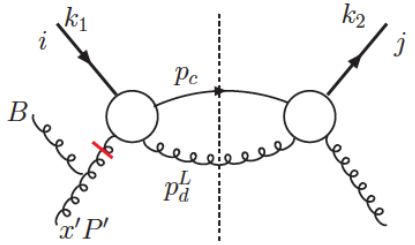
A New Challenge: A_N Sign Mismatch

Collins or Sivers?

- Twist-3 (RHIC) v.s. Sivers (SIDIS)

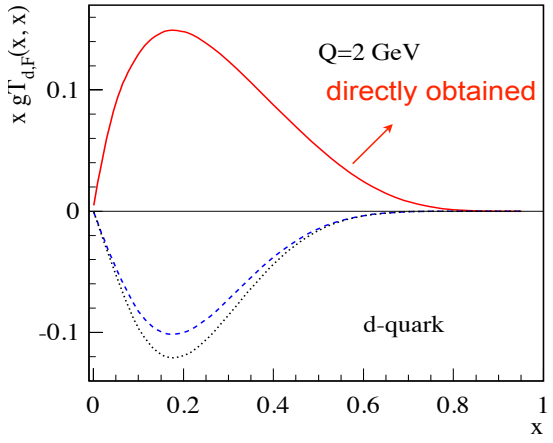


$$gT_{q,F}(x,x) = -\int d^2k_\perp \frac{|k_\perp|^2}{M} f_{1T}^{\perp q}(x,k_\perp^2)|_{\text{SIDIS}}$$

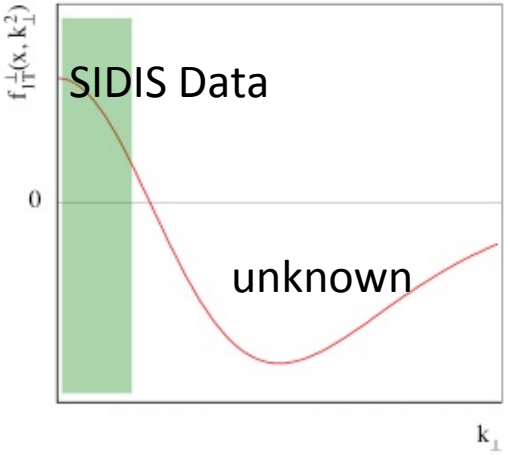


Qiu,Sterman
Kouvaris et al.
Kanazawa,Koike
Kang,Prokudin

Kang, Qiu, Vogelsang, Yuan PRD 2011

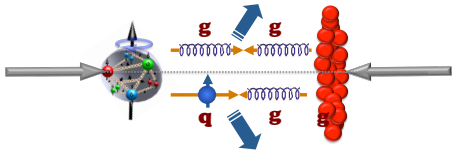


A possible solution? Kang, Prokudin PRD (2012)



Collins dominates?
U. D'Alesio@QCDN12

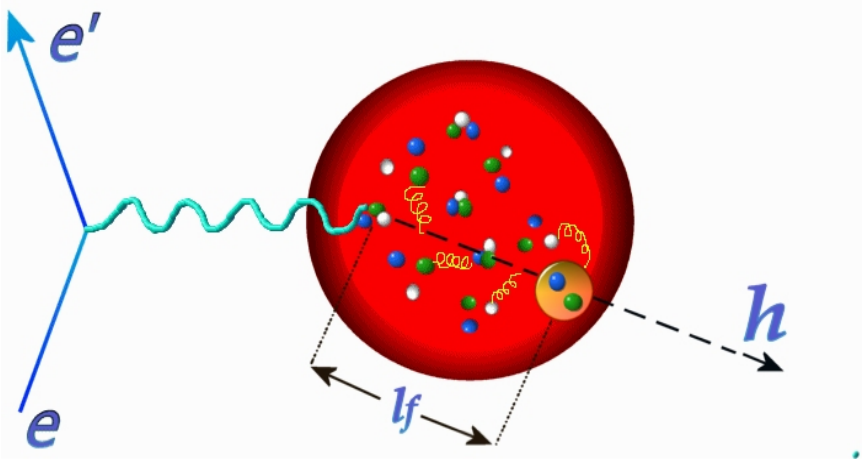
Need more data!

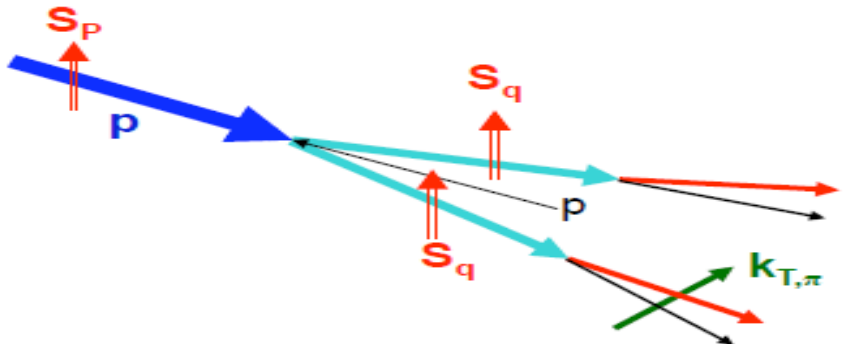


Could "A" affect Collins Fragmentation Function?

- Unpolarized quark fragmentation "is modified" in SIDIS
  - hadronization
- How about Collins polarized fragmentation functions in p+A?
  - Hadronization in CGC?

Kwatar Hafidi pA@RHIC

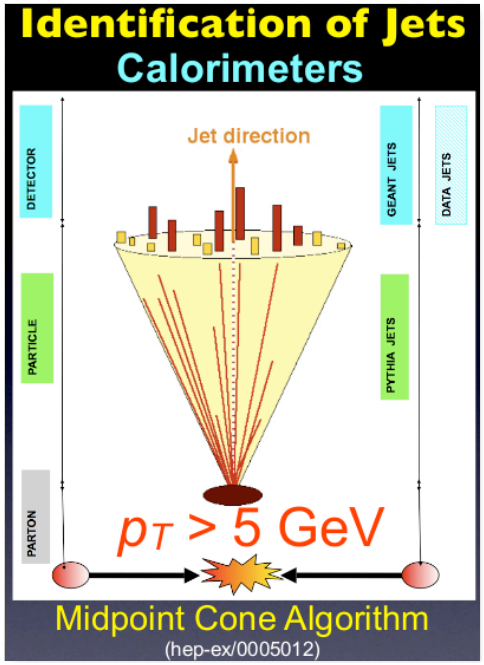


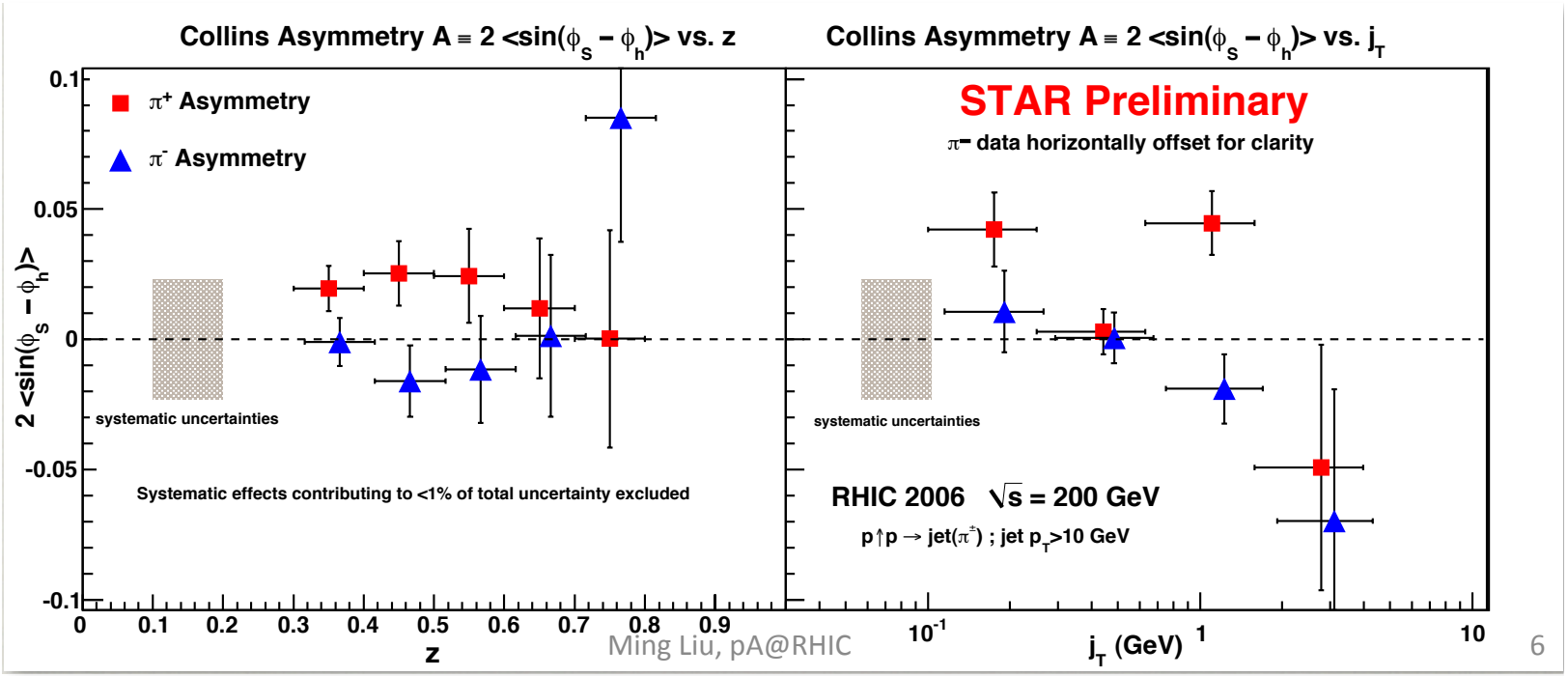


Key observables:
- Collins A_N asymmetry inside a Jet in p+A
- Centrality dependence, (pT, z, PID…)
- NO polarized e+"A", unique @RHIC

Collins Asymmetry inside Jets

- Significant non-zero spin asymmetry observed @RHIC

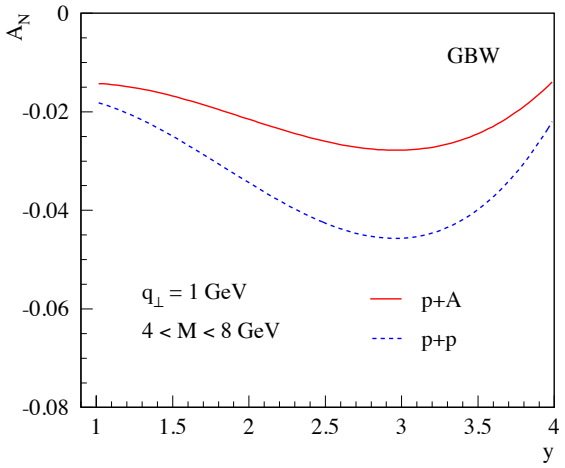


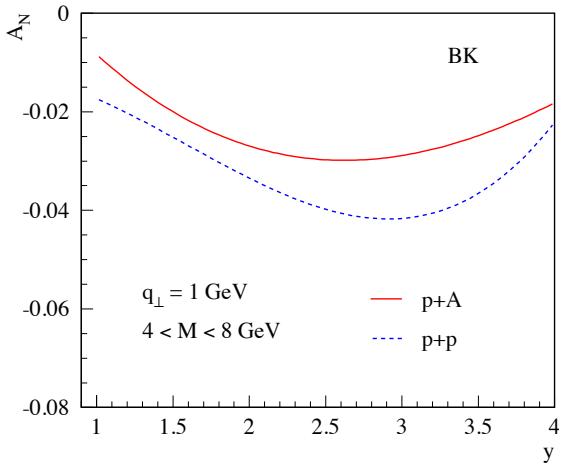


Sivers Asymmetry and CGC

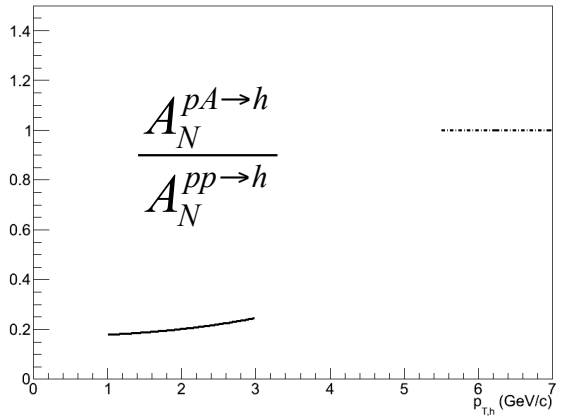
- Drell-Yan and Direct photon in p+A in "small-x"
- High luminosity possible
  - L = 15~ 35 pb^{-1}/wk x 20 wks = 300~750 pb^{-1} (Wolfram Fischer pA@RHIC)

Zhongbo Kang pA@RHIC



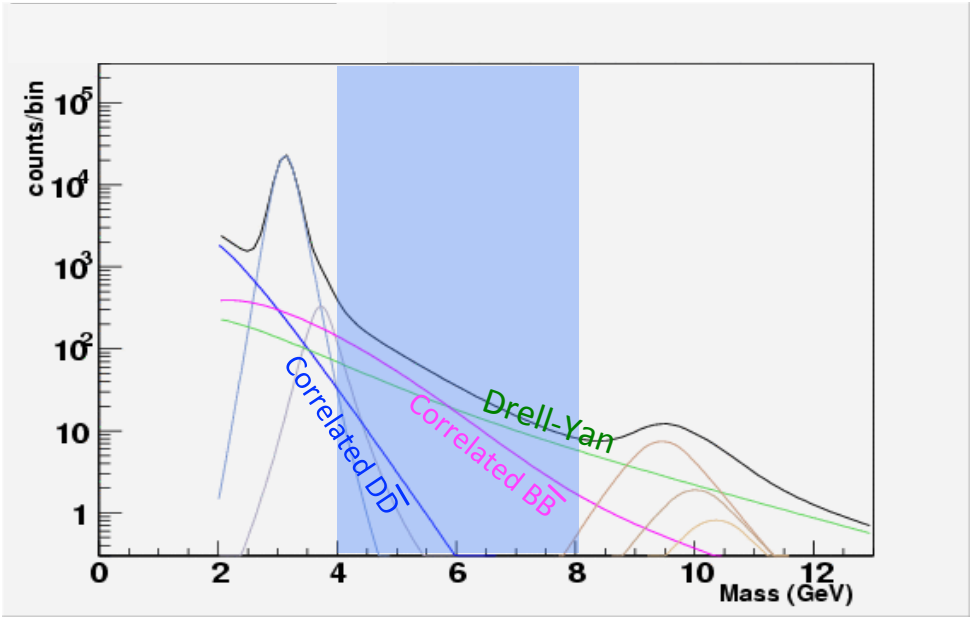


John Lajoie pA@RHIC

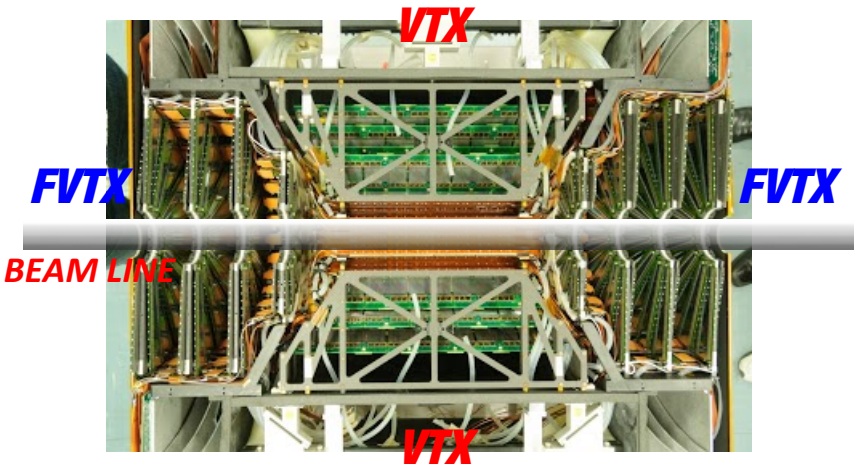


- The maximum happens at y~3, which corresponds to xp ~ 0.2 in the polarized proton (the Sivers function is largest at around this point)

Drell-Yan backgrounds and control with FVTX/VTX



√s = 200 GeV simulation, p+p pythia

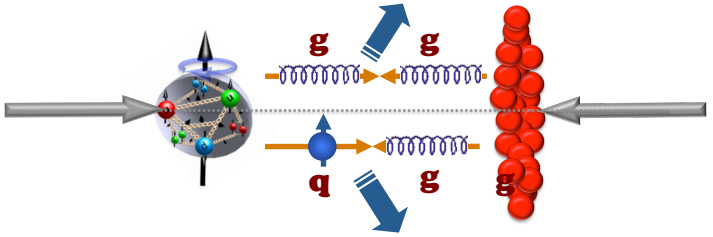


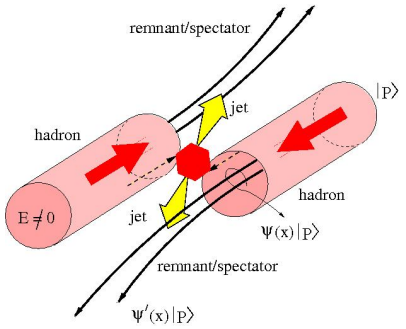
FVTX/VTX has been successfully installed and working since 2012/2011.

- Between 4 GeV/c^2 and 8 GeV/c^2 is thought to be dominated by Drell-Yan process and correlated $B\bar{B}$.
- We would separate Drell-Yan process and correlated $B\bar{B}$ which have different decay length, using silicon vertex detector, (F)VTX between 4 and 8 GeV/c^2.
- Would get order of a thousand events for each arm with FVTX with 50 pb^{-1}.

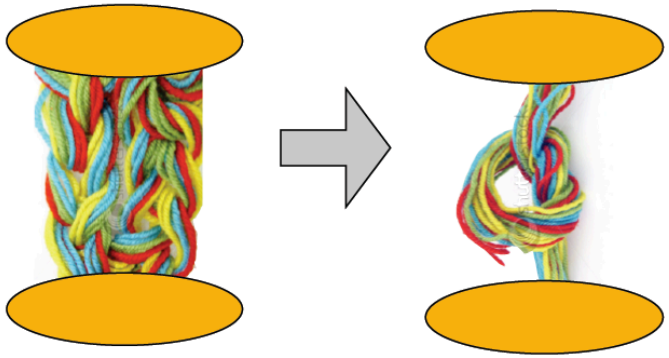
Could TMD "Restored" p+A Collisions?

- Theoretical challenges
  - validity of factorization, universality .
  - TMD, Twist-3…

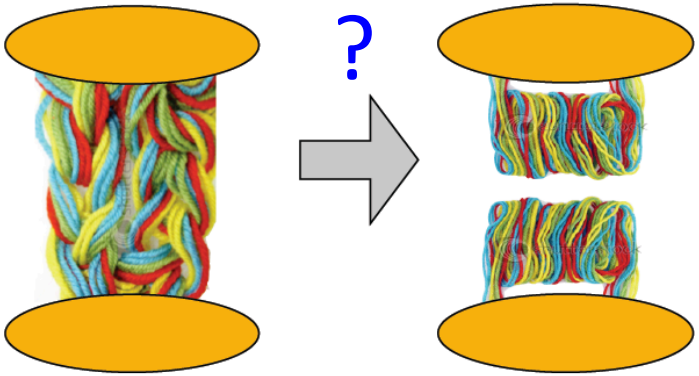




Bacchetta, Mulders@QCD-N12



TMD factorization does not work for pp to hadrons.



Breakdown of TMD in p+p

Possible restoration in p+A?

Polarized p+A @RHIC!

- High polarization
  - ~60%
- High luminosity
  - 15 ~ 35 pb^{-1}/wk
- Exciting Unique physics