Gluon sivers and experimental considerations for TMDs

Thomas Burton

DIS 2012

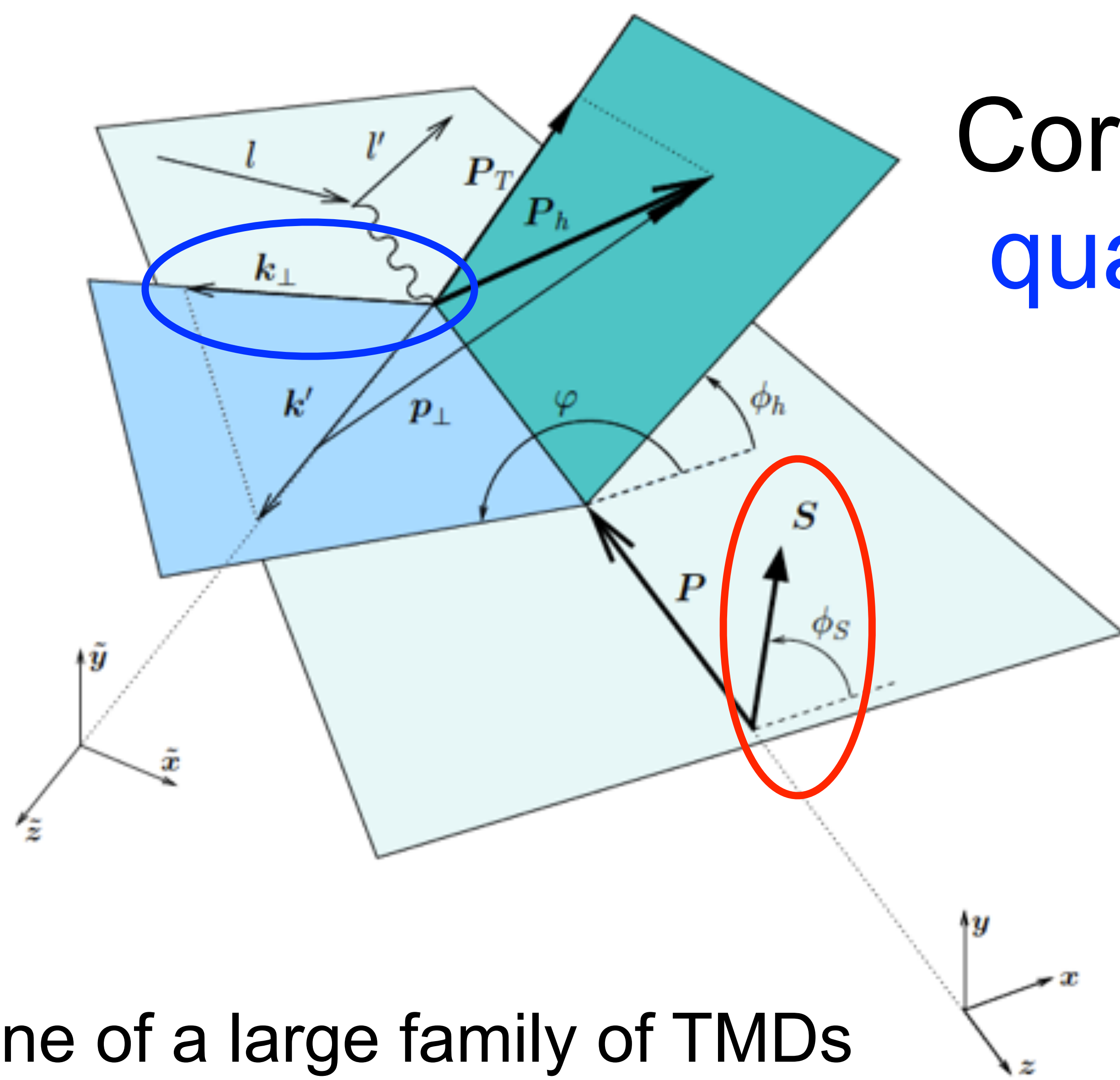
Tue 27th March

BROOKHAVEN NATIONAL LABORATORY

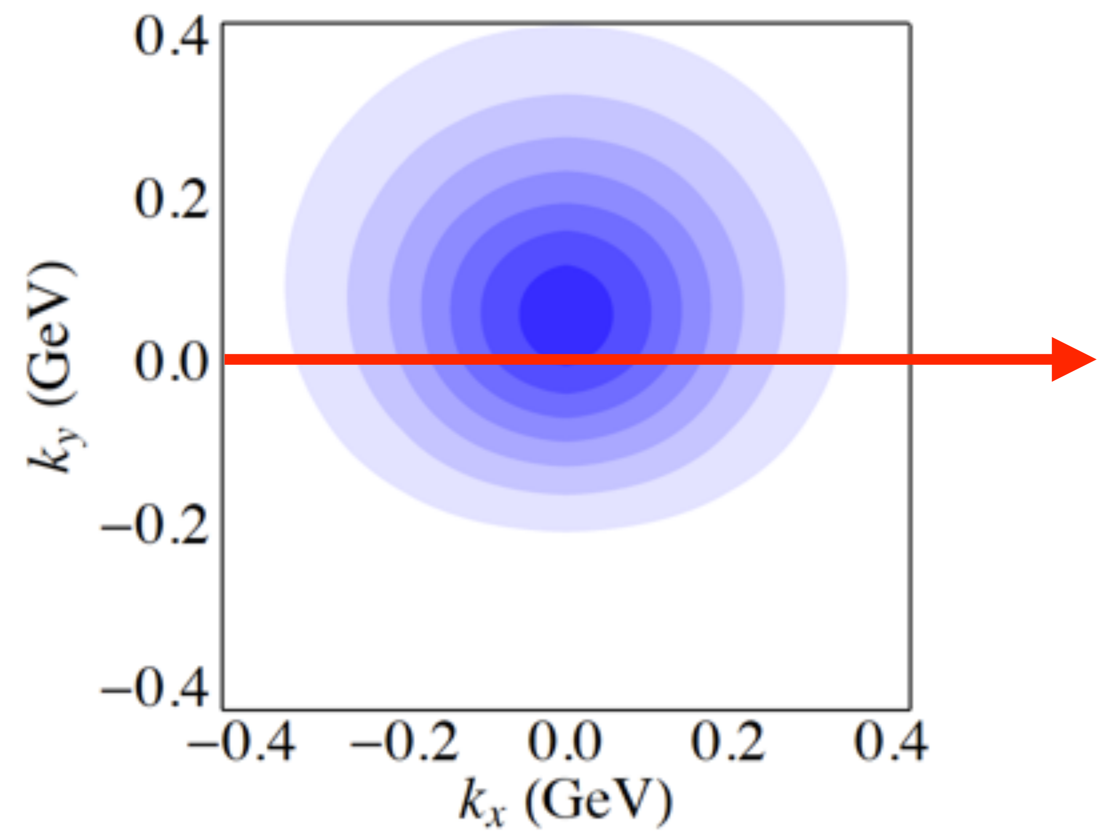
Overview

- Sivers function and gluons
  - ➡ Measurement using D^0 pairs
- PYTHIA simulation
  - ➡ Event selection
- Results and summary

Sivers function



Correlates proton spin and quark intrinsic transverse momentum

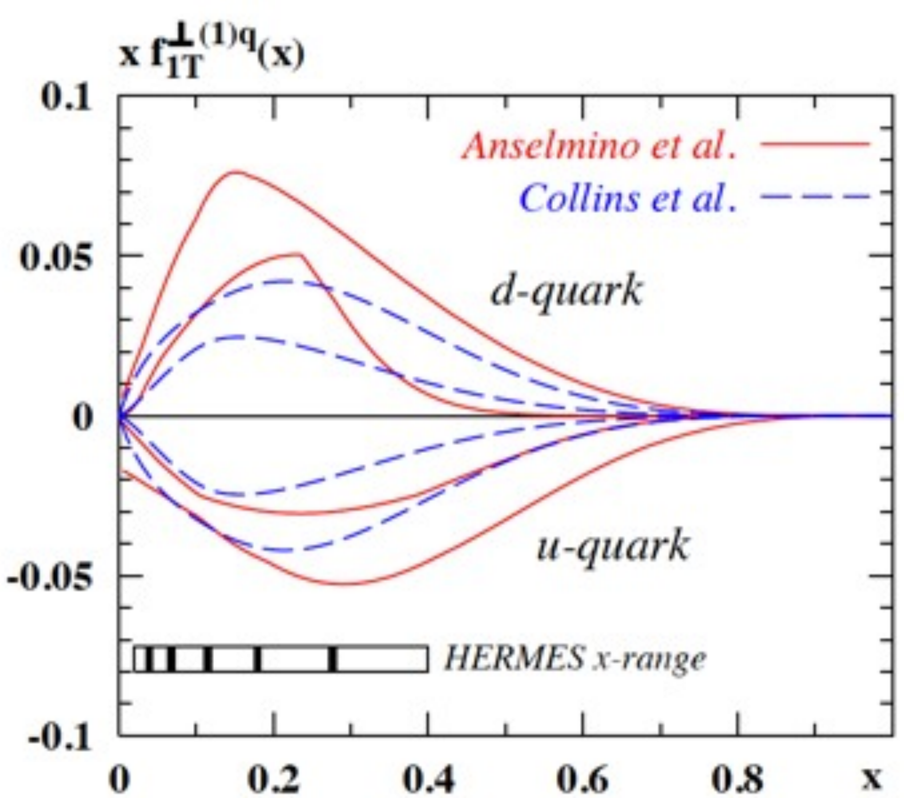


One of a large family of TMDs

EIC will map sea quark Sivers in (x, Q^2, z, p_T)

Gluon Sivers function

- Identical features to quark case
  Proton spin ↔ **gluon** k_T
- Harder than for quarks in ep
  No direct $\gamma \leftrightarrow$ g coupling



Why not p+p?

e.g. dijet correlations?

2 initial-state hadrons → factorisation fails

e + p: factorisation remains valid

Gluon Sivers function

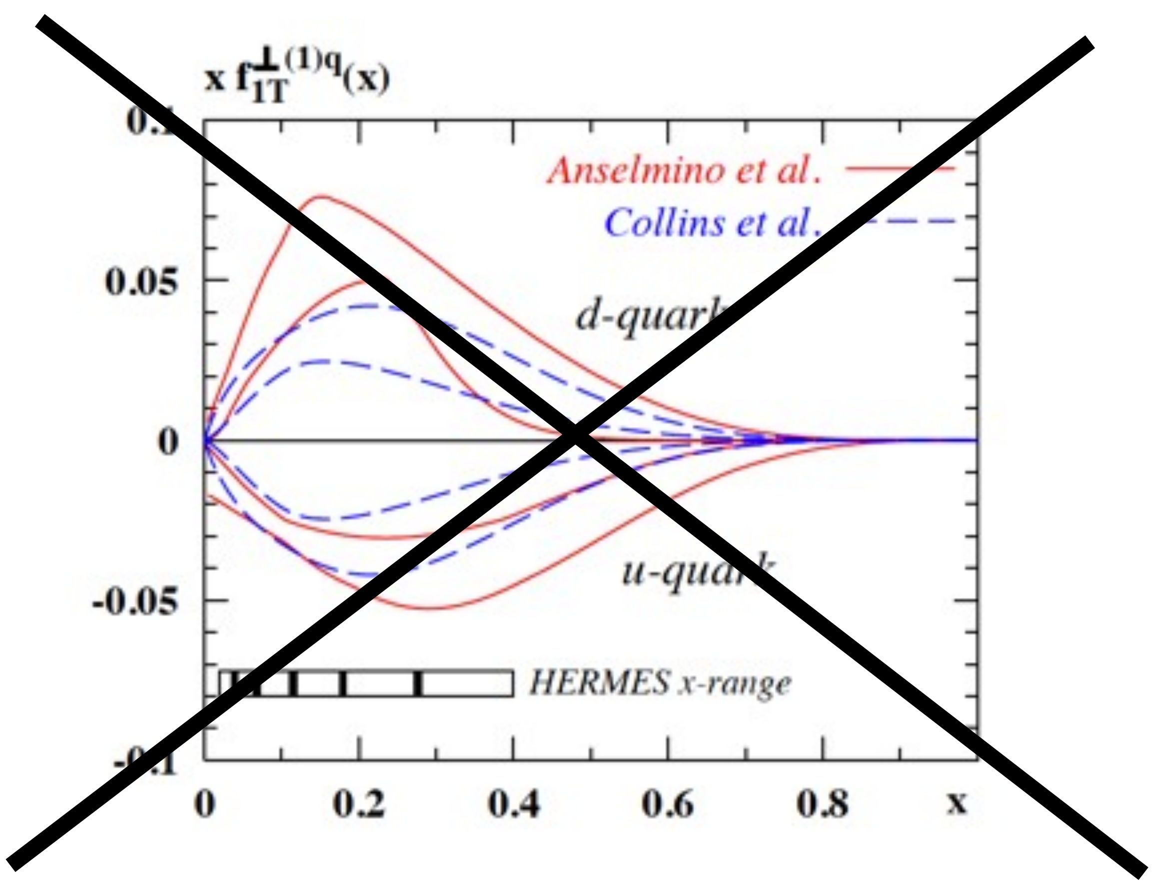
- Identical features to quark case

  Proton spin ↔ **gluon** k_T

- Harder than for quarks in ep

  No direct $\gamma \leftrightarrow$ g coupling

No existing extractions



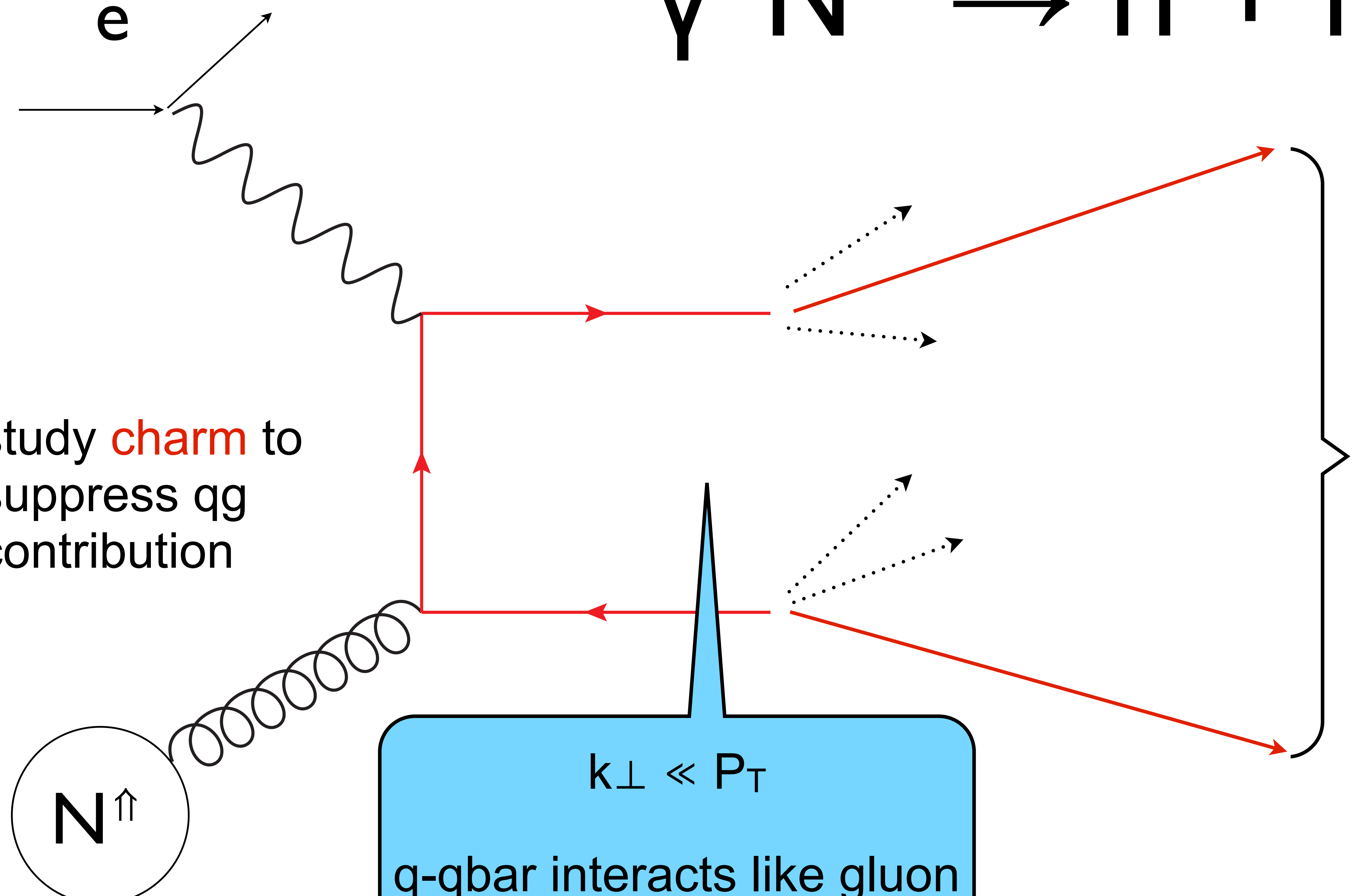
Why not p+p?

e.g. dijet correlations?

2 initial-state hadrons → factorisation fails

e + p: factorisation remains valid

$\gamma^* N^{\Uparrow} \rightarrow h + h + X$



study charm to suppress qg contribution

Measure a pair of **D** mesons

Statistically challenging

$k_\perp \ll P_T$

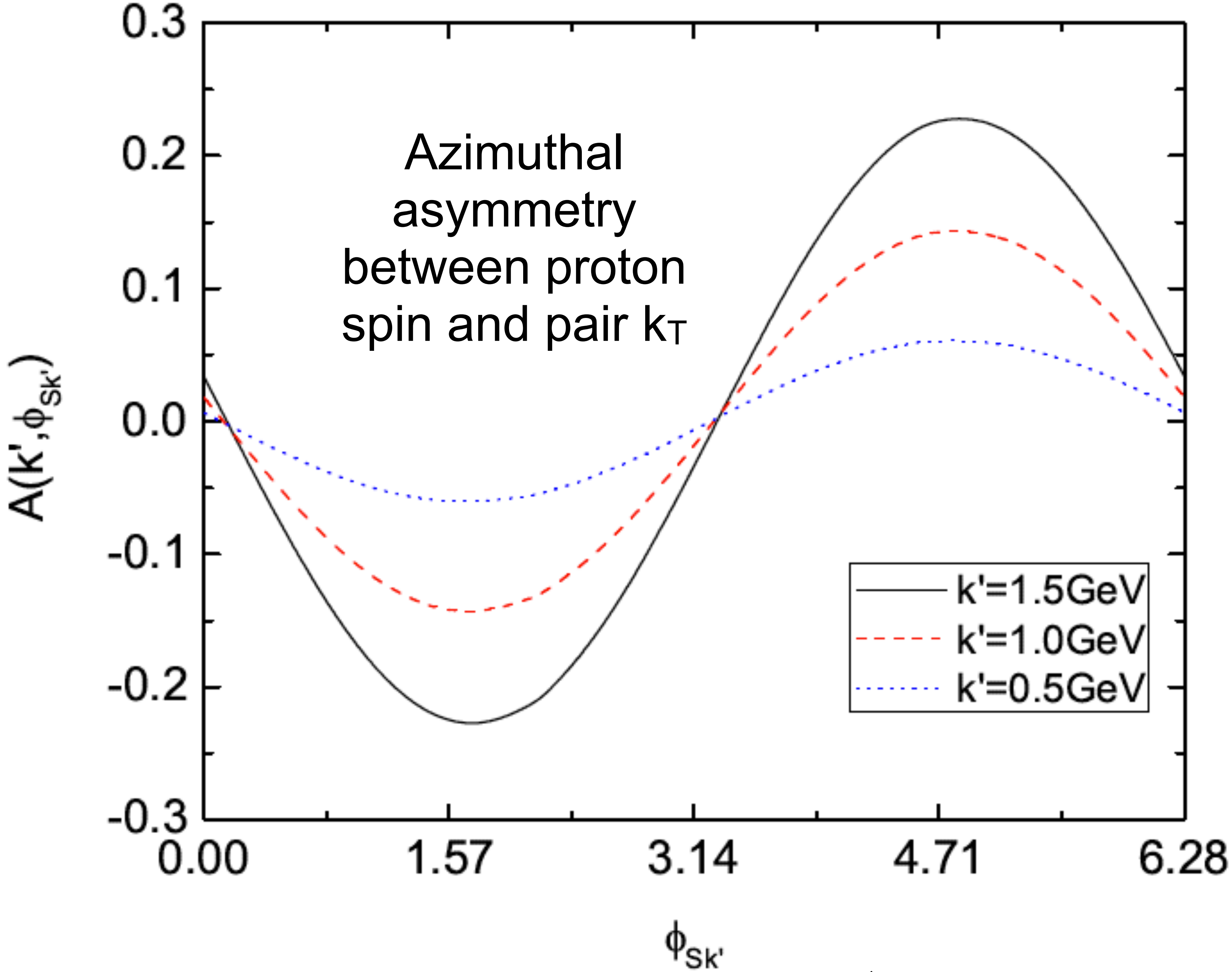
q-qbar interacts like gluon

"Correlation limit"

$k_\perp = |k_{1T} + k_{2T}|$

$P_T = (k_{1T} - k_{2T}) / 2$

$$A(k'_\perp, \phi_{Sk'}) = \frac{d\sigma(k'_\perp, \phi_{Sk'}) - d\sigma(k'_\perp, \phi_{Sk'} + \pi)}{d\sigma(k'_\perp, \phi_{Sk'}) + d\sigma(k'_\perp, \phi_{Sk'} + \pi)}$$



EIC INT proceedings
arXiv:1108.1713v1
section 2.3

Simulation

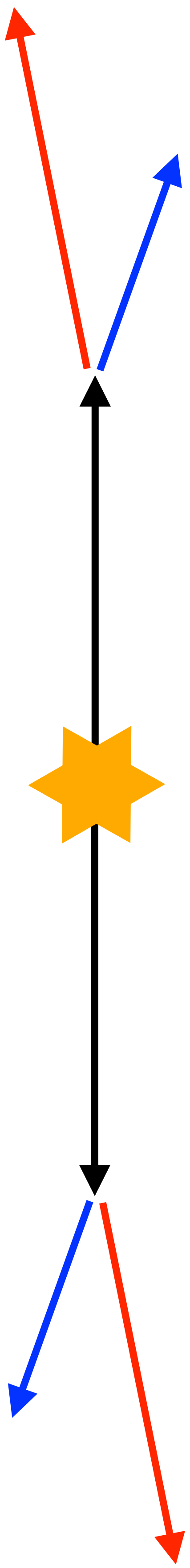
20 x 250 GeV most favourable: luminosity cross section

E_e	E_p	$\sqrt{s}$ (GeV)	L (10^{33} cm^{-2} s^{-1})	σ_{cc} (nb)
5	100	45	0.62	7.7
5	250	71	9.7	13.3
20	250	141	9.7	25.2

- PYTHIA 6.416
- Unpolarised
  - statistics, not asymmetry
- CT10 PDF (LHAPDF)
- No radiative corrections
- No detector resolution

	INT	PYTHIA
W	100	-
Q^2	16	1 to 10
y	-	0.05 to 0.95

D pair selection



- Both D^0 and D^0-bar $\rightarrow$ π K
  - Easily reconstructed
  - Branching ratio 3.87%
- $k_\perp / P_T < 0.5$ for "correlation limit"

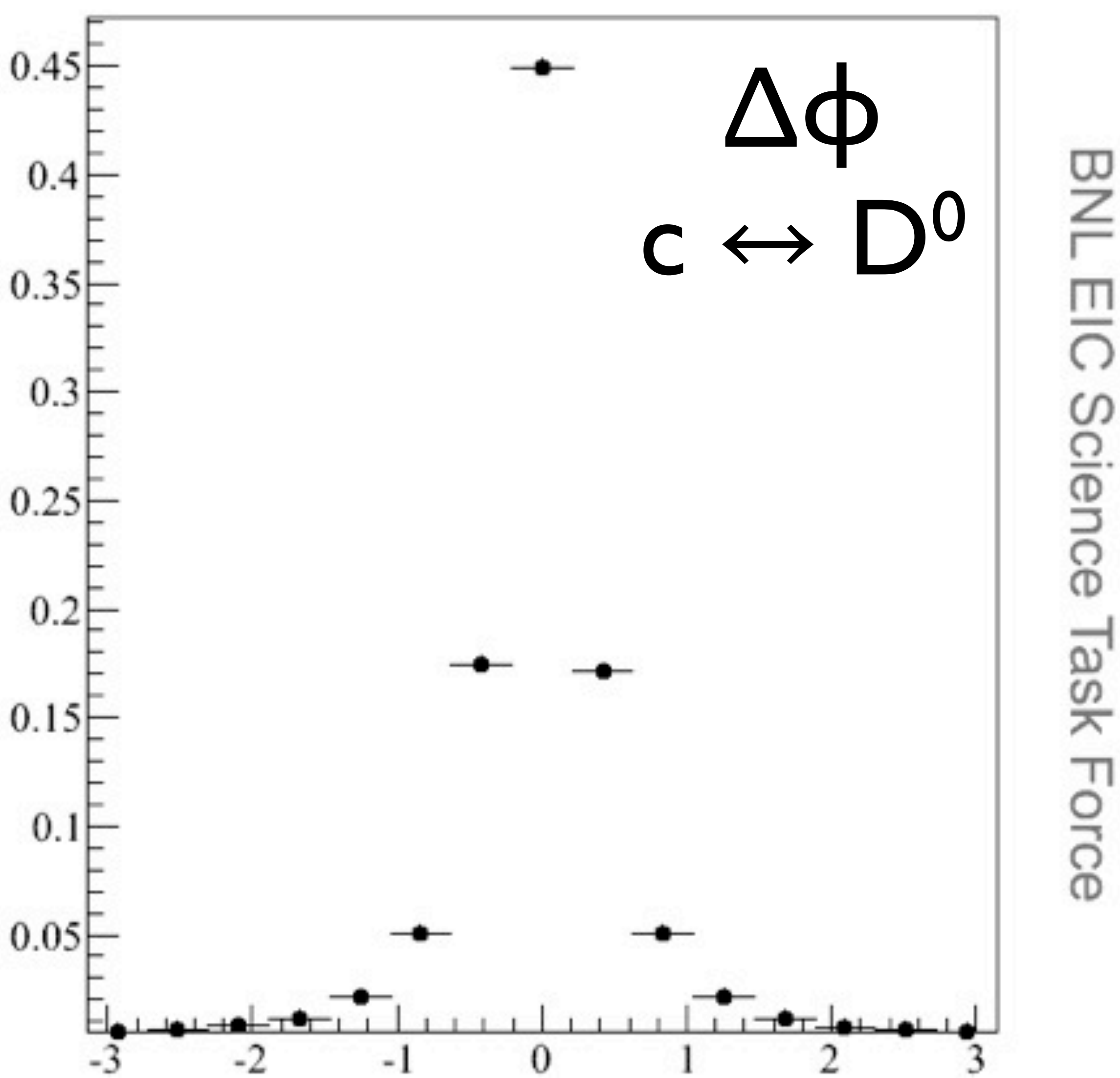
	INT	PYTHIA
P_T	5 to 40	-
z	> 0.25	> 0.25

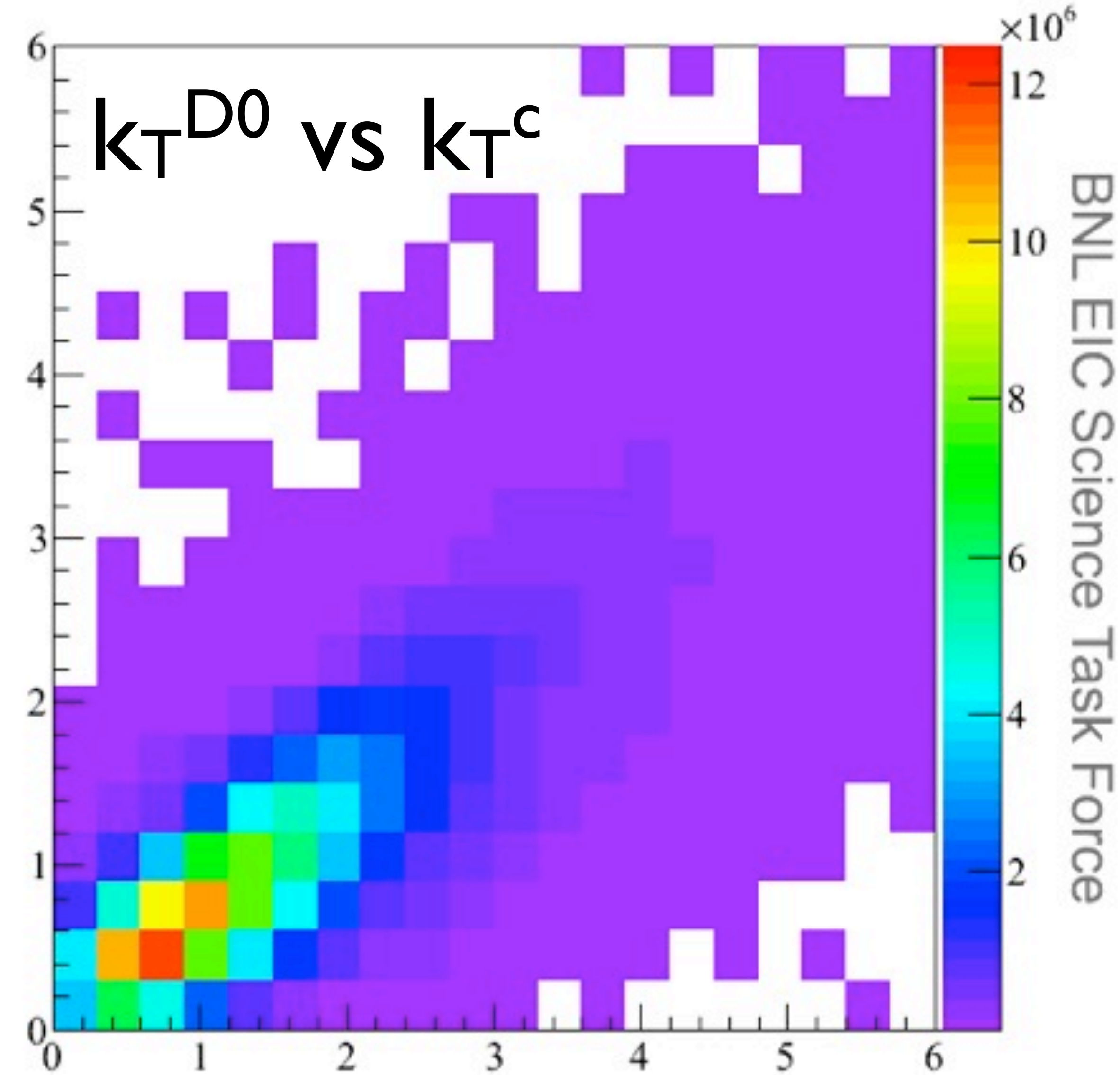
$k_\perp = |k_{1T} + k_{2T}|$

$P_T = (k_{1T} - k_{2T}) / 2$

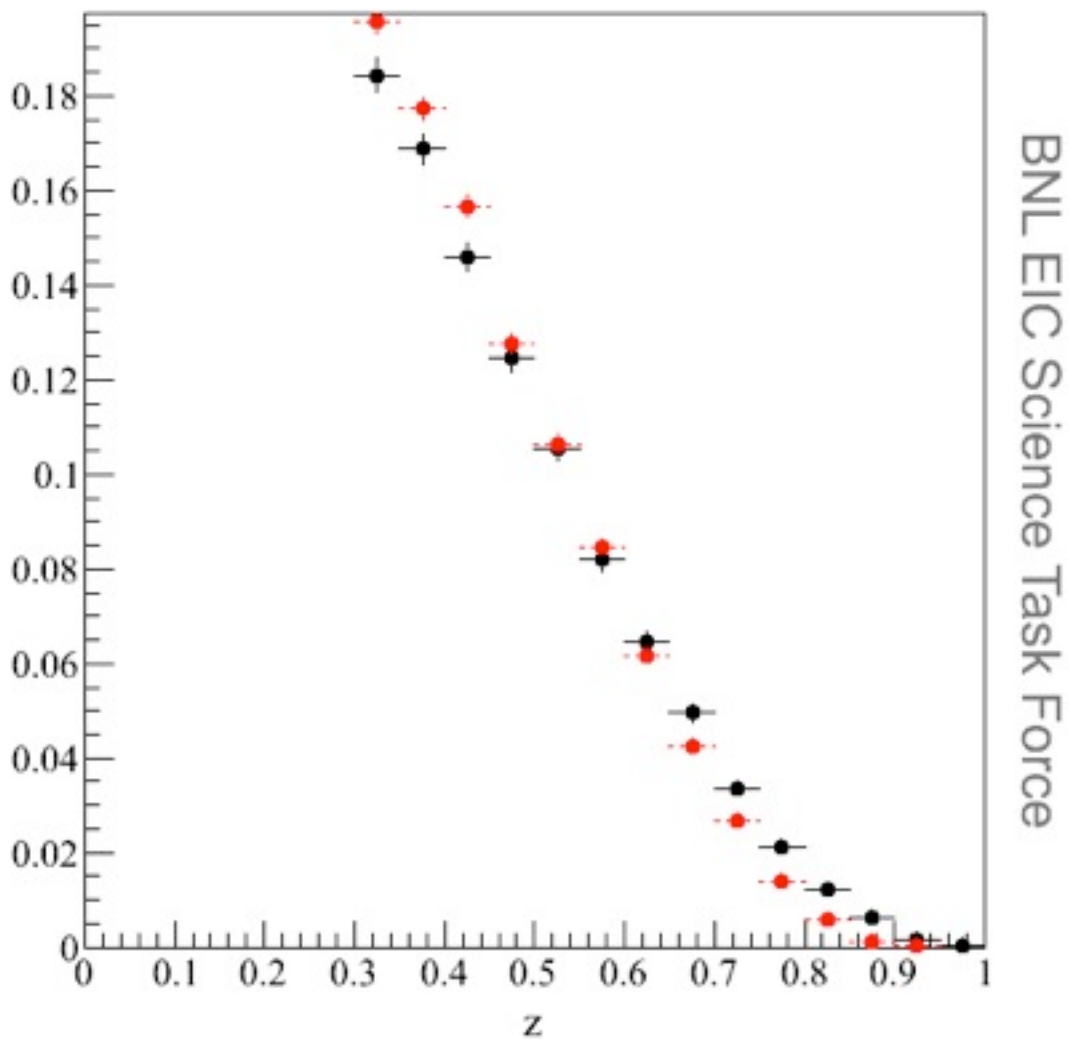
$c \leftrightarrow D$ correlation

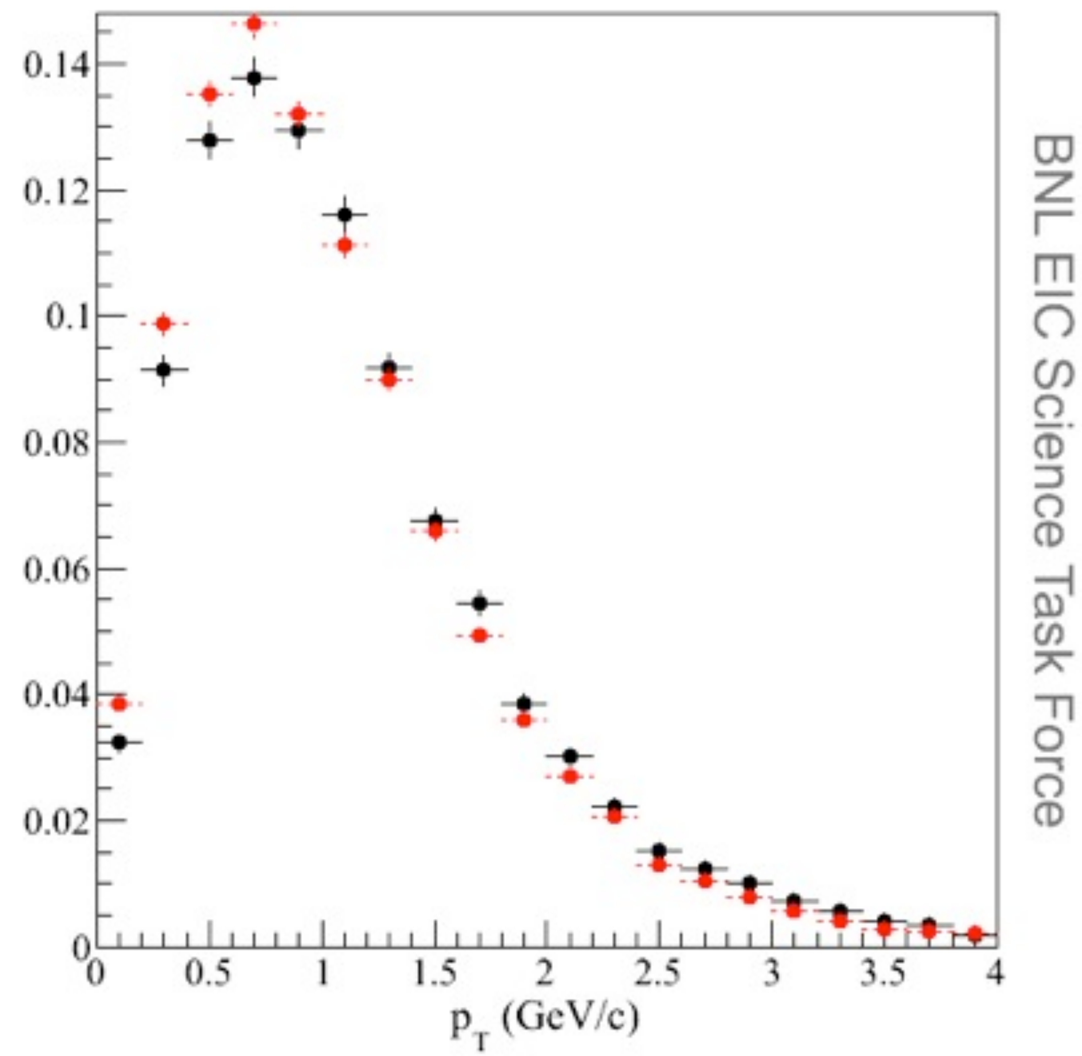
- c quarks aren't directly measurable:
  - ➡ D meson properties serve as "proxy"





D^0 feed-down





Direct D^0/D^0bar

D^0 from $D^{*+} \rightarrow \pi^+ D^0$

D^0bar from $D^{*-} \rightarrow \pi^- D^0$

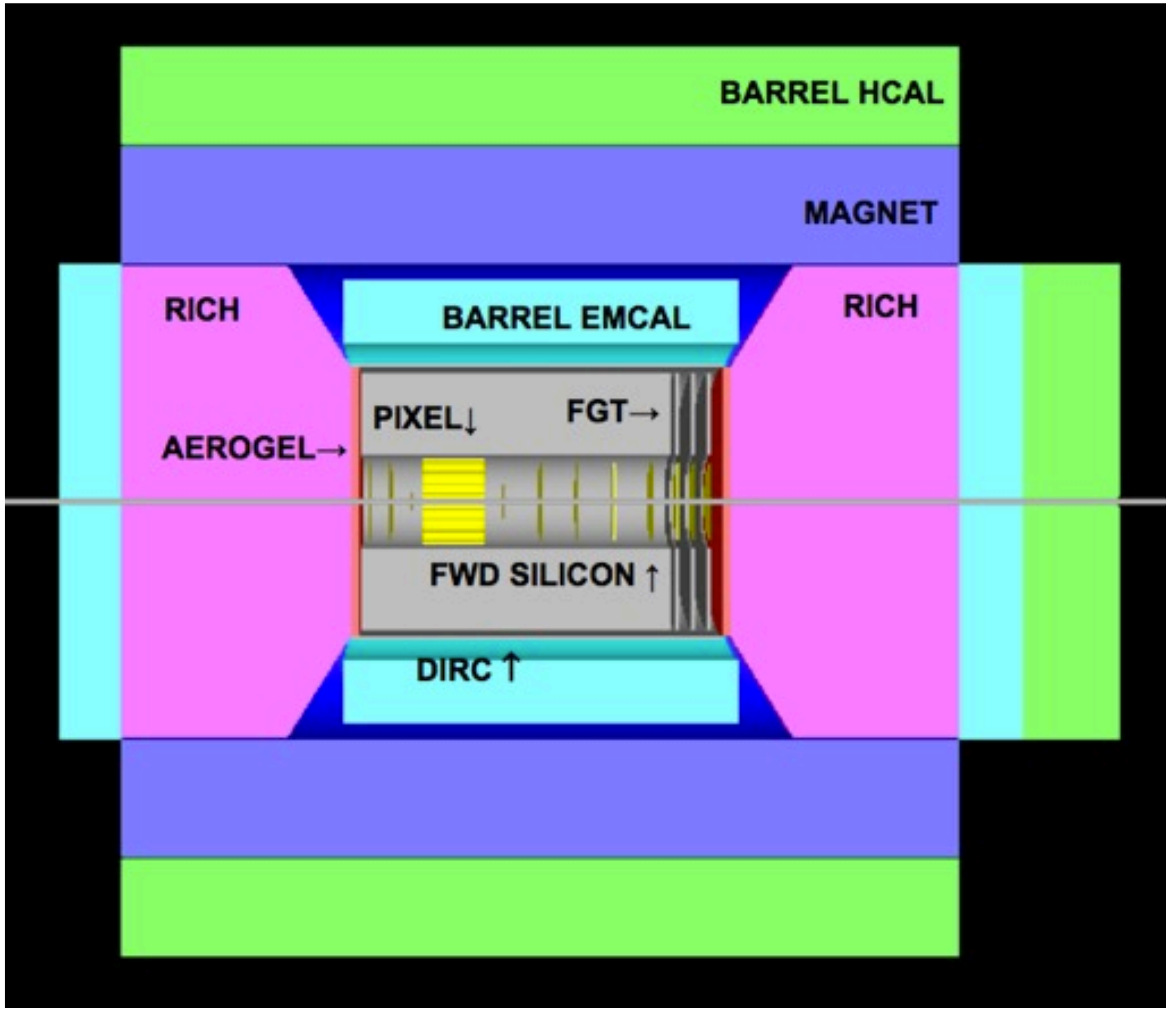
No significant different in momentum (or angle) - therefore analyse all D0s

Detector

Acceptance:

Scattered e^- > 1° from beam

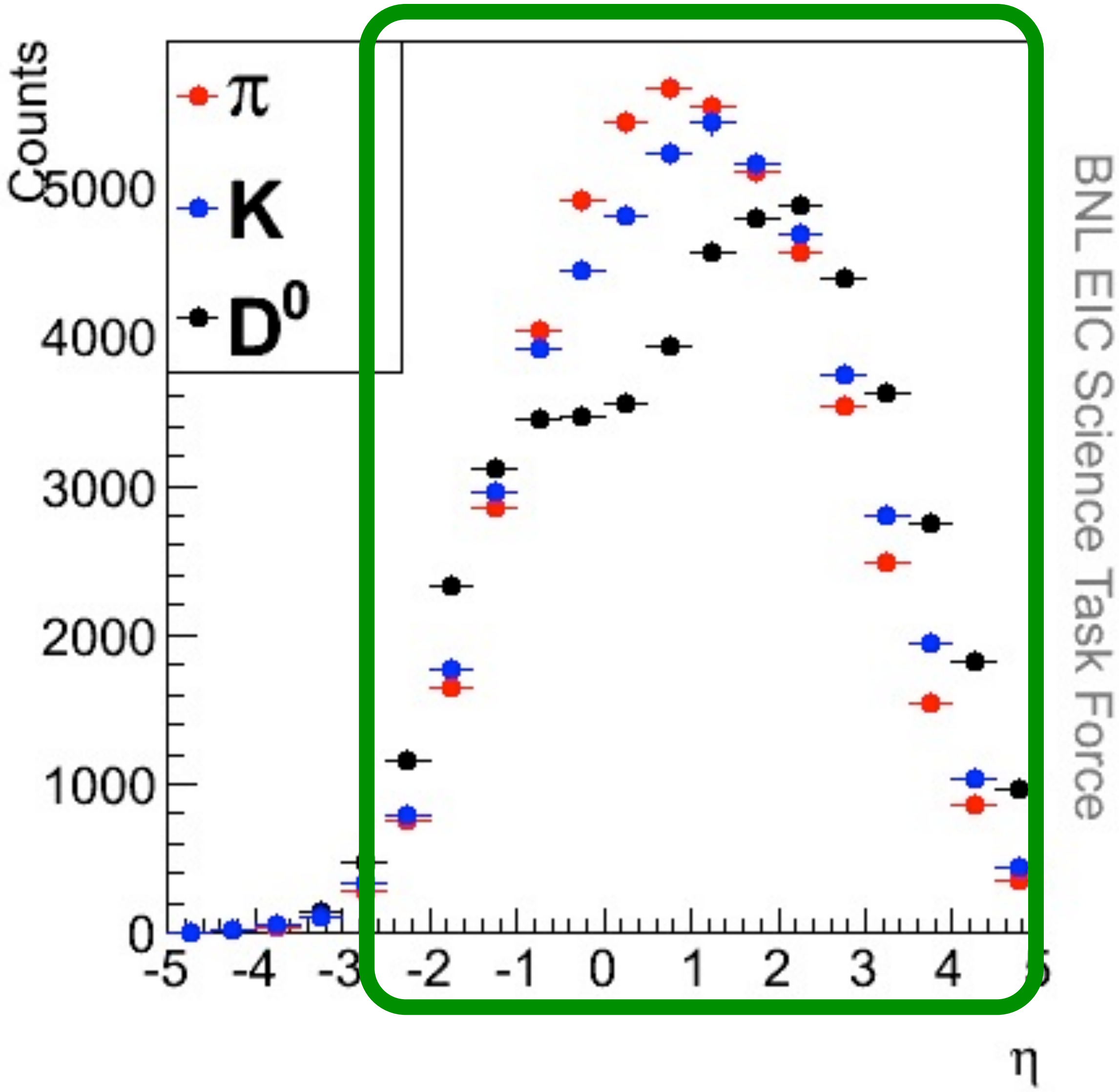
D^0 products > 1° from beam

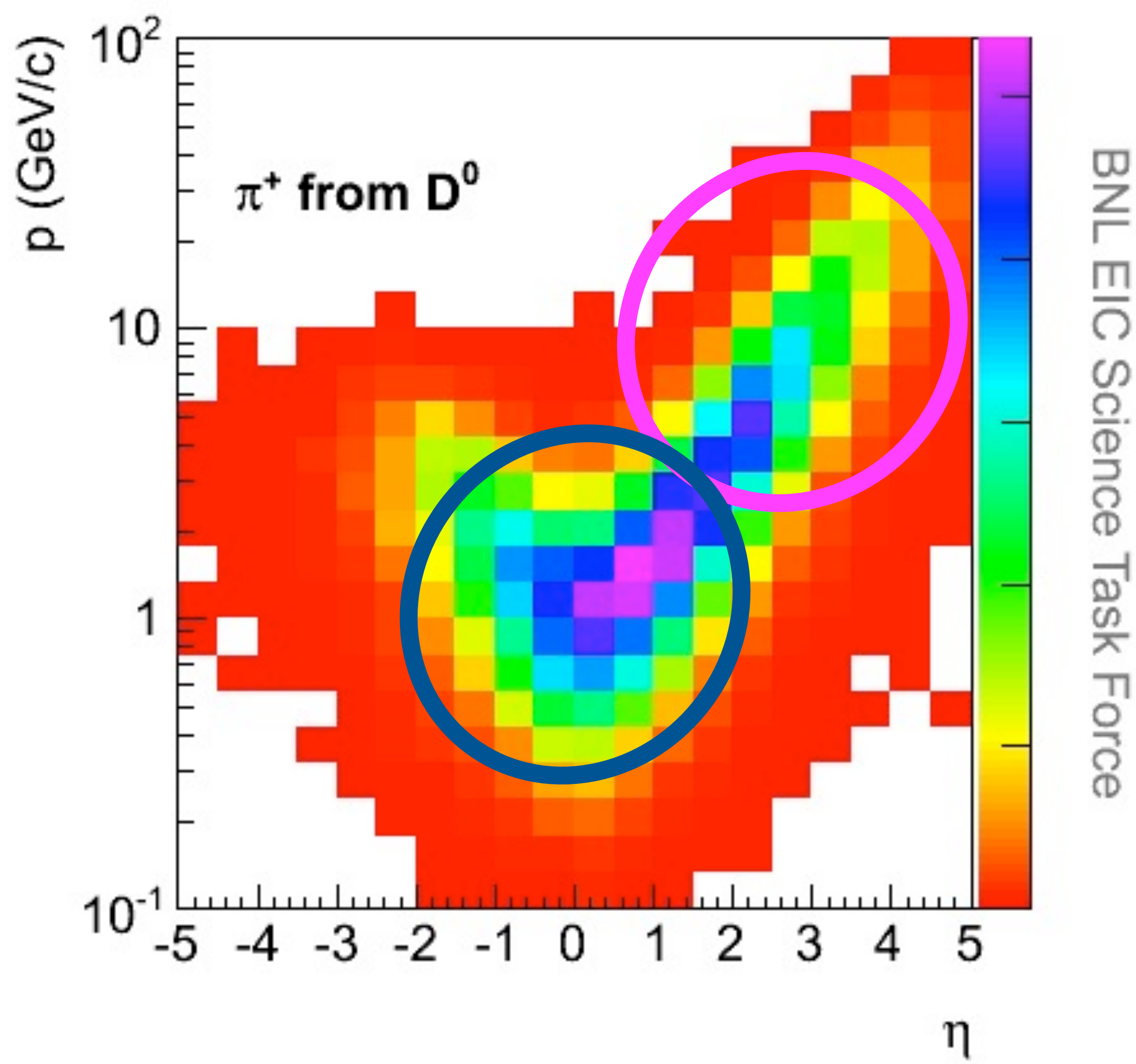


No account for resolution:

- Close to 4π PID
- Close to 4π tracking with good (p, θ) resolution

➡ effects assumed not to change "takeaway message"



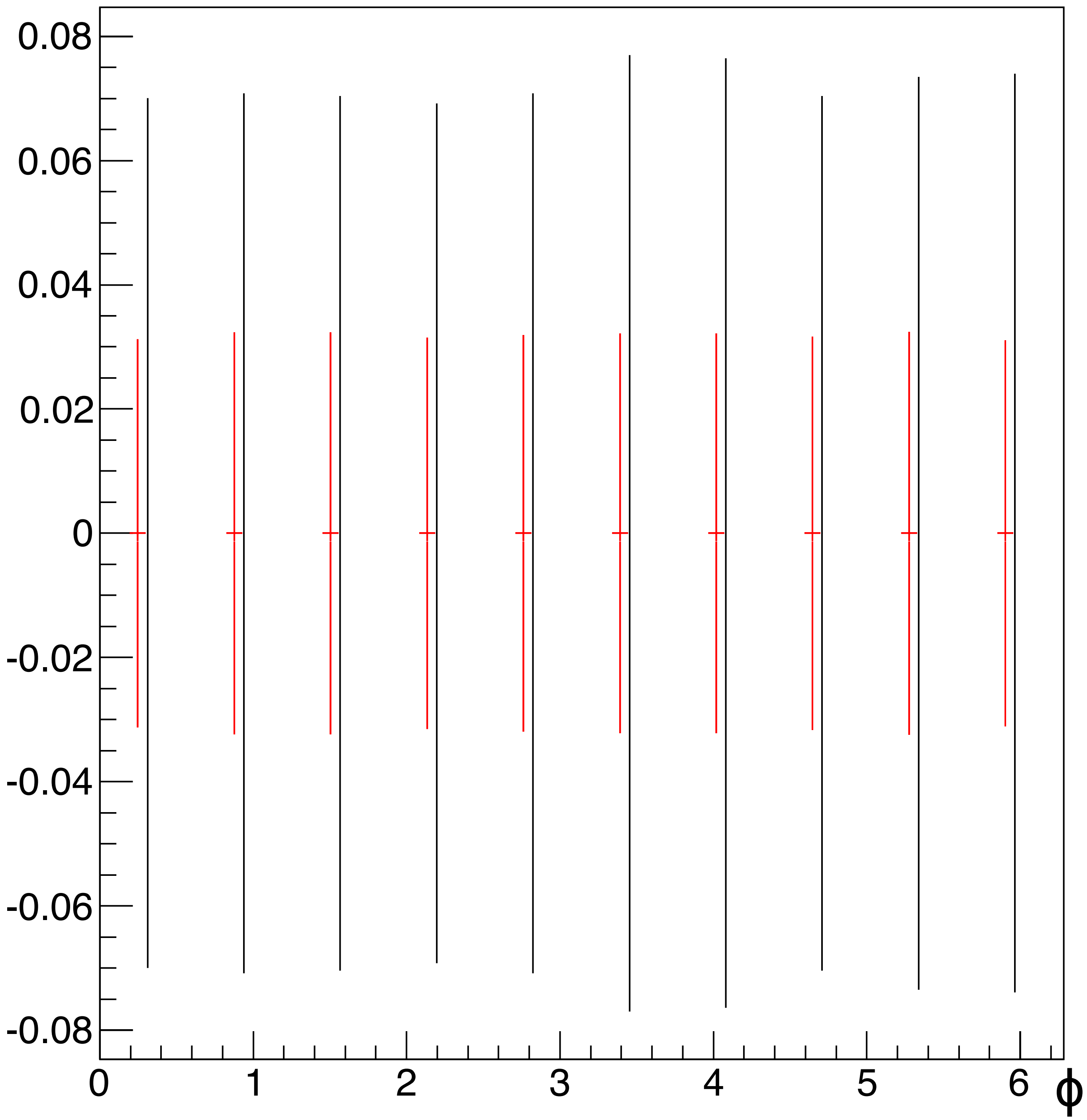


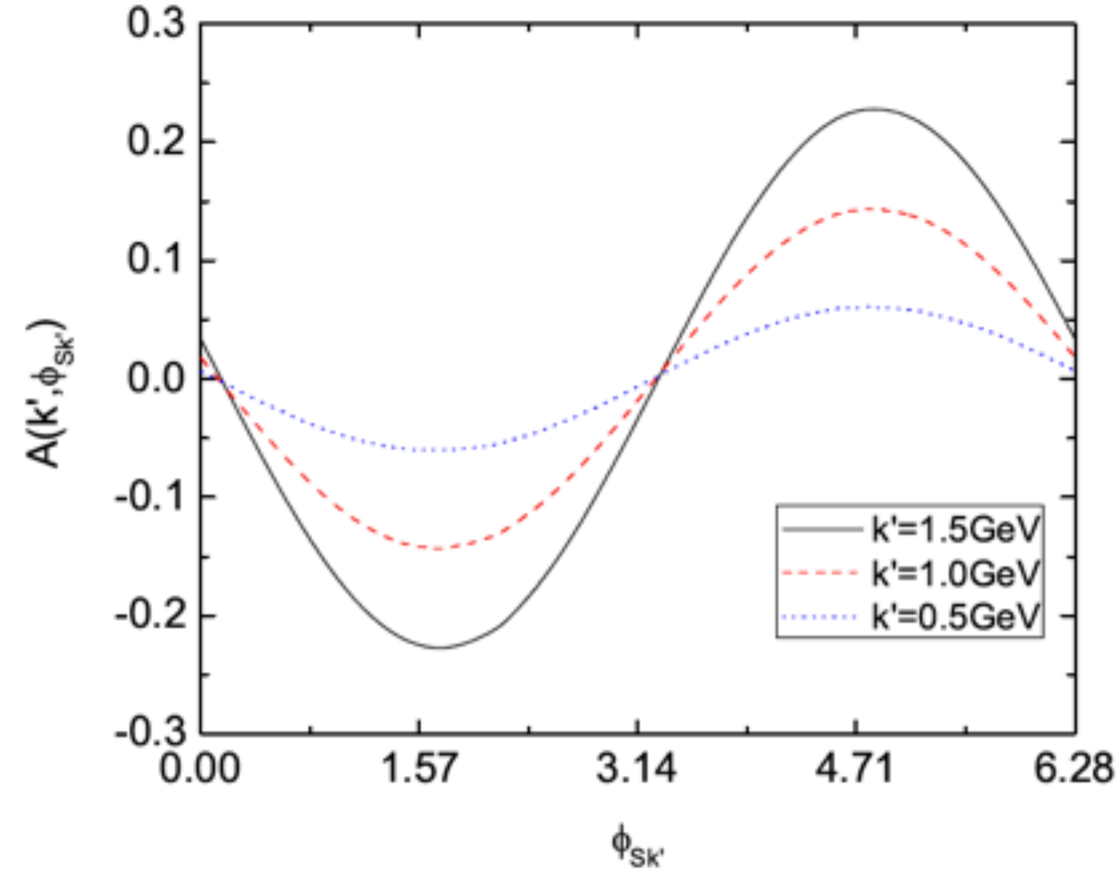
- **Wide η coverage** for PID and tracking
- PID up to **moderate p at mid η**
- PID up to **large p at forward η**
- $D^0 \rightarrow \pi K$: precise vertex reconstruction

See talk by K. Dehmelt, Thursday

Monte Carlo sample

- Strict cuts: D^0(bar) → πK ; z ; $k_\perp / P_T$
  - ➡ accept < 1 / 10^4 PYTHIA events
  - ➡ Filter events before writing to disk
- Generated 600 million PYTHIA events
  - ➡ 50,000 event sample for analysis





$0.5 < k_\perp < 1.0$

$1.0 < k_\perp < 2.0$

1/sqrt(N) error per (ϕ, $k_\perp$) bin, scaled for

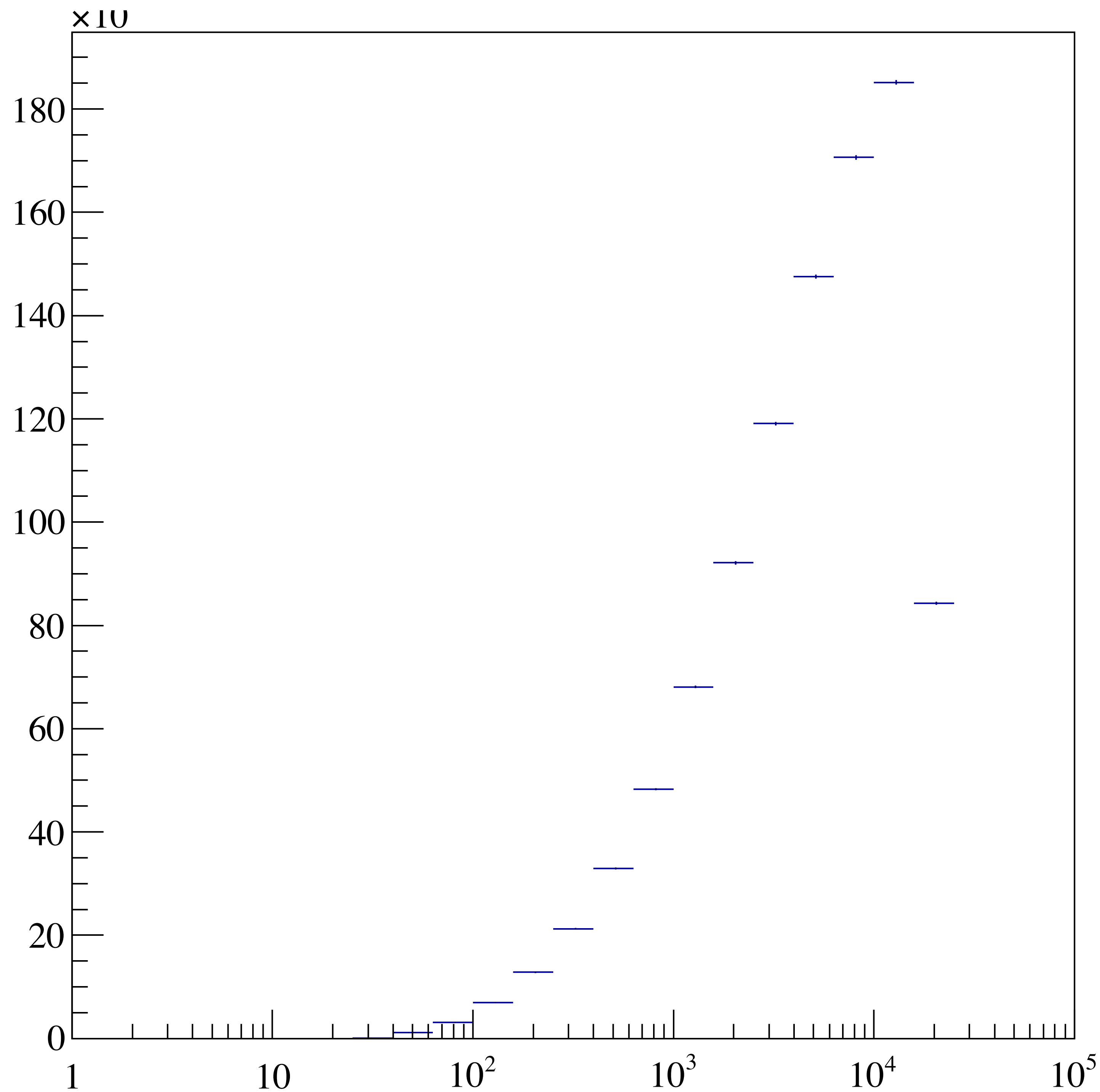
- 70% beam polarisation
- 100 fb^{-1} integrated luminosity

~8 months with 50% efficiency and L = $10^{34} cm^2 s^{-1}$

Summary

- Gluon Sivers is unique EIC measurement
  - e + p: theoretically treatable
  - high energy
  - high luminosity
- Accessible via D^0 pair production:
  - statistically challenging
  - feasible within current design
  - likely a multi-year goal

W^2 distribution



Q^2