Single-spin asymmetries in inclusive hadron electroproduction at HERMES

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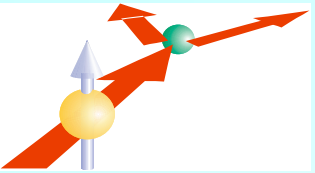
Outline

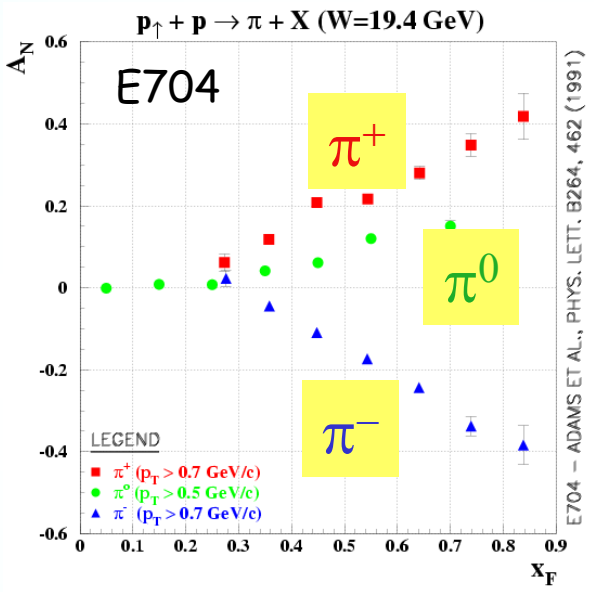
- Motivation: A_N in inclusive $p^{\uparrow}p$ scattering
- HERMES
- Results
- Comparison to $pp^{\uparrow}$, DIS and model predictions
- Summary

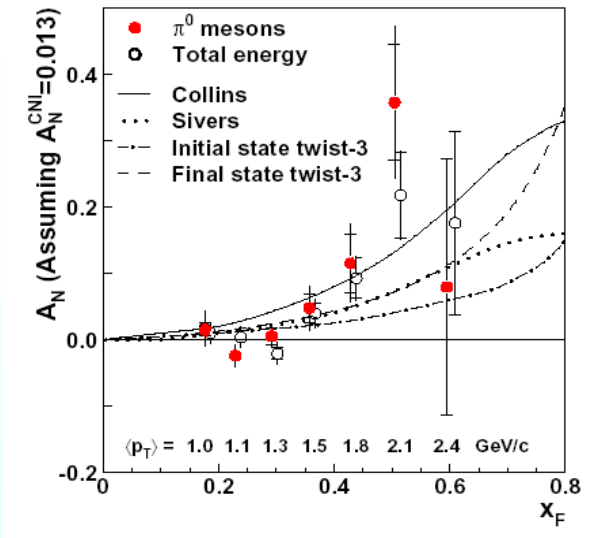
A_N in $p^{\uparrow}p$



$$A_N = [\sigma(\uparrow)-\sigma(\downarrow)]/[\sigma(\uparrow)+\sigma(\downarrow)]$$

- Large A_N has been observed in $\overset{(-)}{p}{}^{\uparrow}\, p \rightarrow h\, X$ reactions at ANL, BNL, FNAL, RHIC for $\sqrt{s}$ = 4.9–200 GeV
- Possible origins:
  - Sivers DF (was invented to explain A_N)
  - Collins FF + transversity DF
  - Twist-3
  - Combinations of above
- Possible connection to orbital angular momentum **L** ?
- For consistent partonic description: Need flavor dependent $A_N(E, x_F, p_T)$,

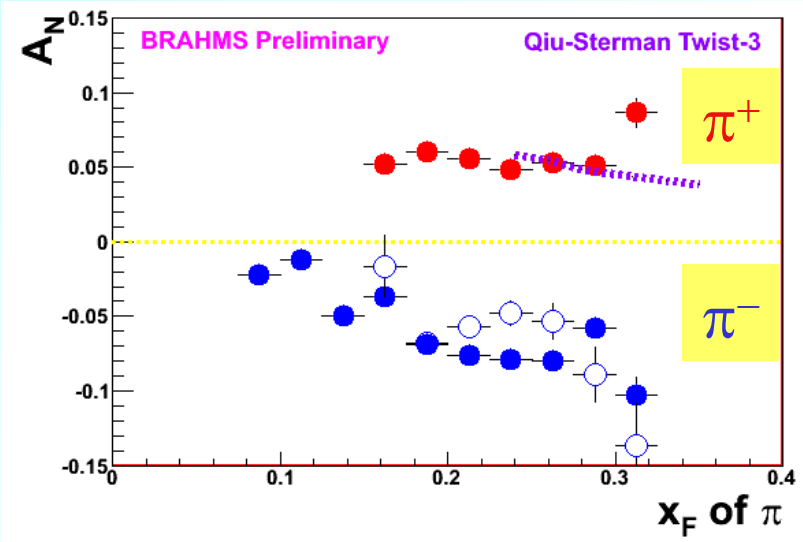


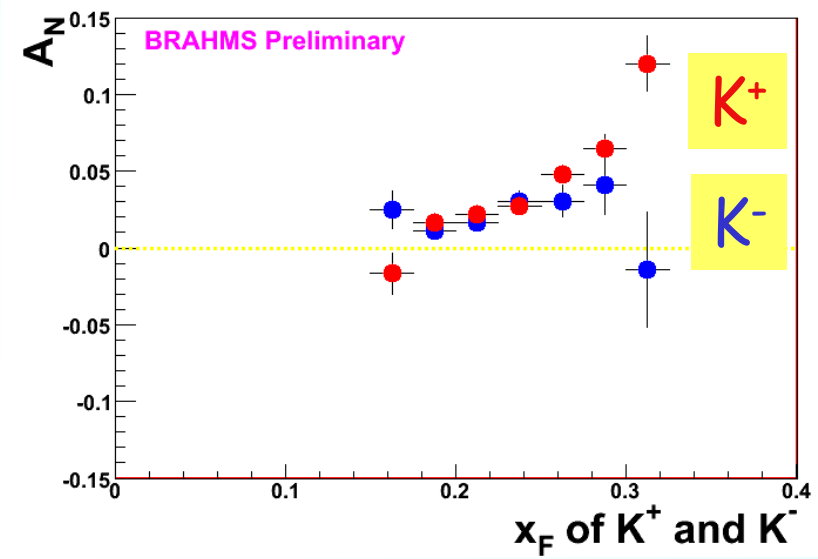


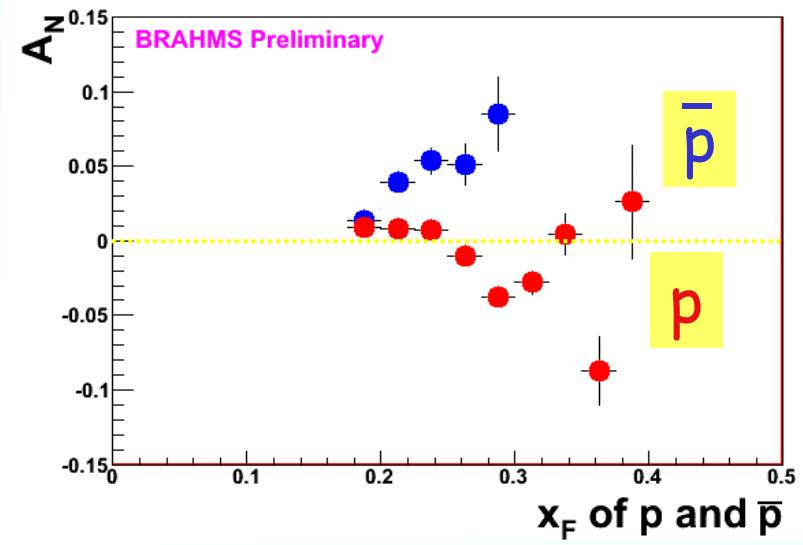
$$x_F^{CMS} = p_{long}/p_{long,max}$$

A_N for identified hadrons in p↑p

$\sqrt{s}$ = 200 GeV



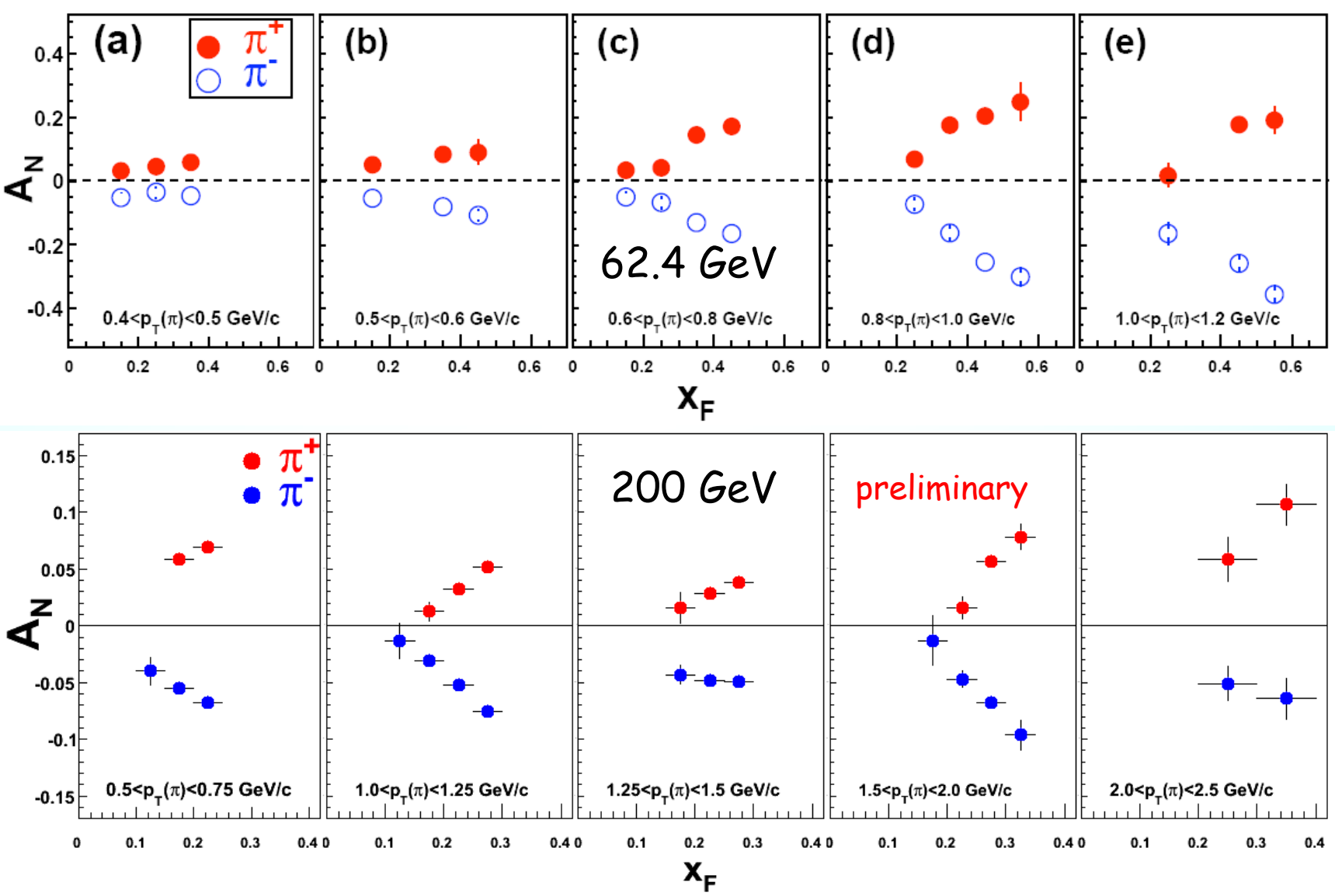




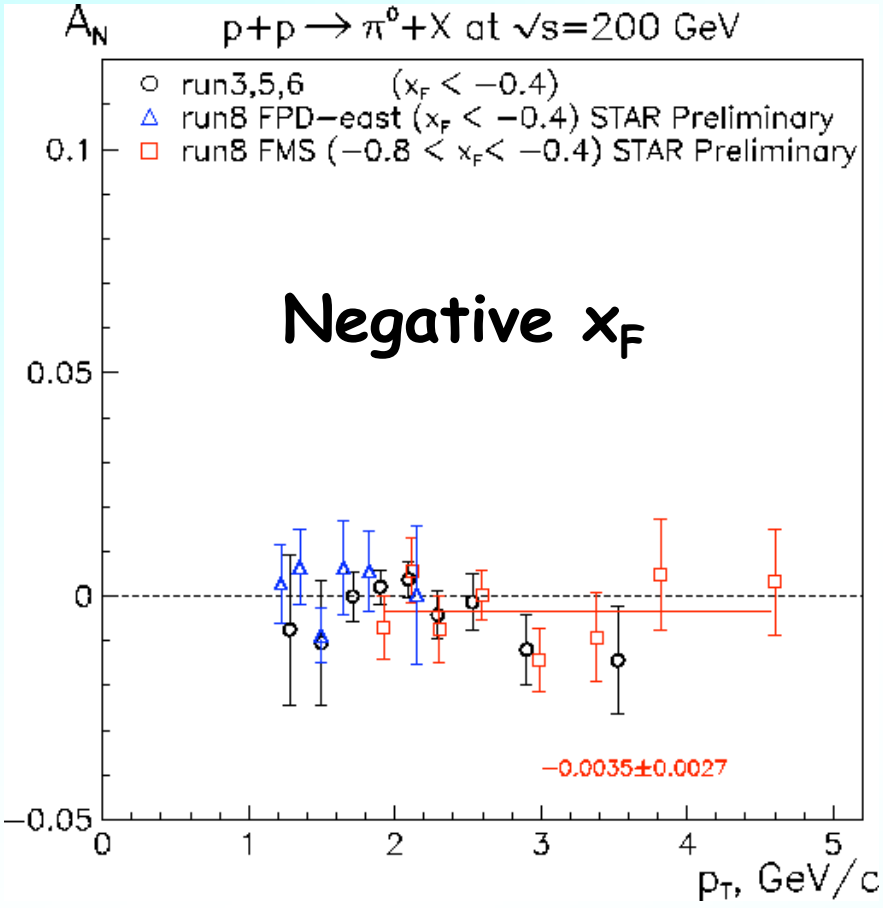
- $A_N(\pi^+)$ positive ≅ - $A_N(\pi^-)$ negative
- $A_N(K^+)$ ≅ $A_N(K^-)$ positive
  (in disagreement with expectation from valence quark fragmentation)
- $A_N(p)$ ≅ 0, $A_N(\bar{p})$ positive
- More data and theoretical input needed

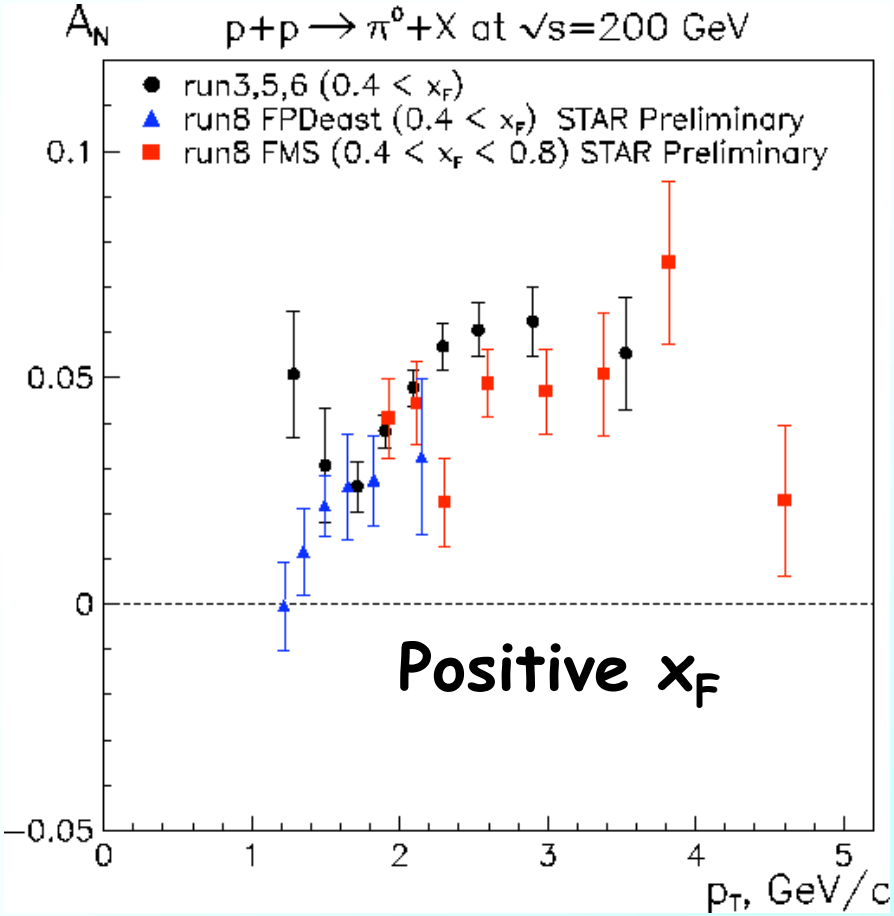
A_N for identified hadrons in p↑p

I. Arsene et al., Phys. Rev. Lett. 101 (2008) 042001



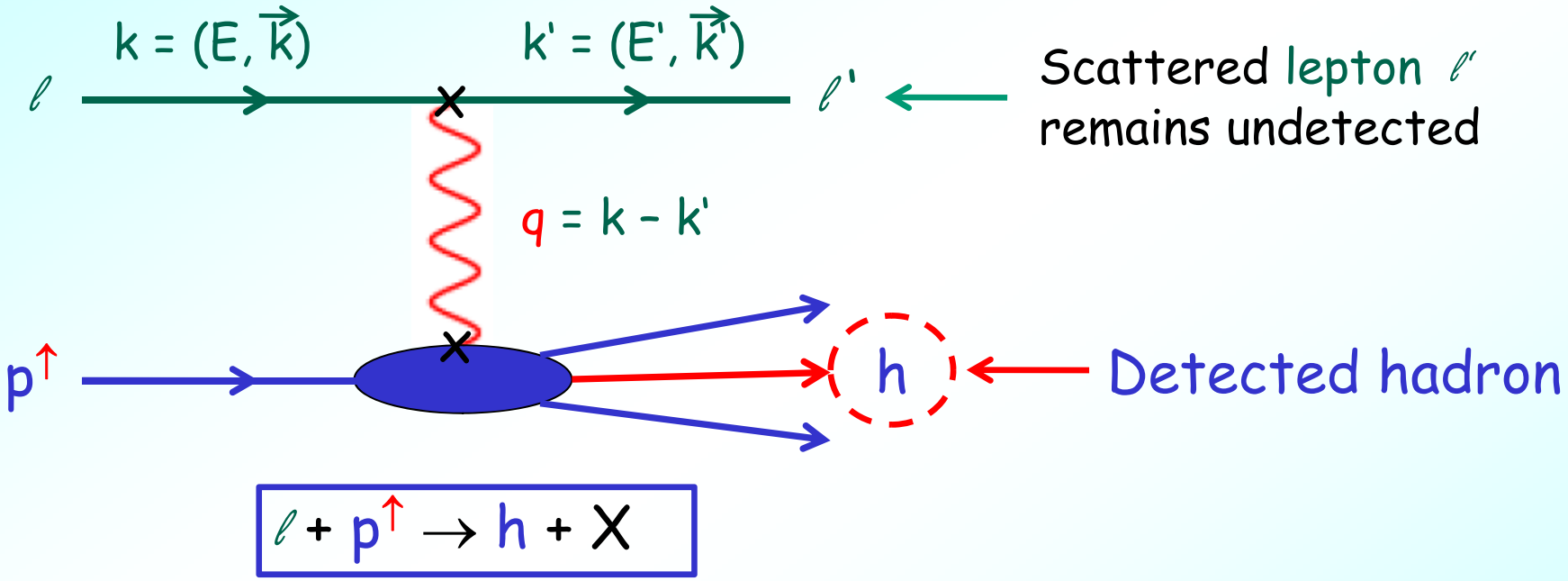
A_N for π^0 in p↑p





Consistent with zero for all p_T

Inclusive hadron electroproduction



Relevant kinematic variables:

- Feynman variable $x_F = p^h_{long}/p^h_{long,max}$ (in ep CMS)
- Transverse hadron momentum p_T (w.r.t e direction)

HERMES Experiment

Data taking: 1995-2007

27.6 GeV e+/e- beam of HERA
polarisation ≤ 60 %

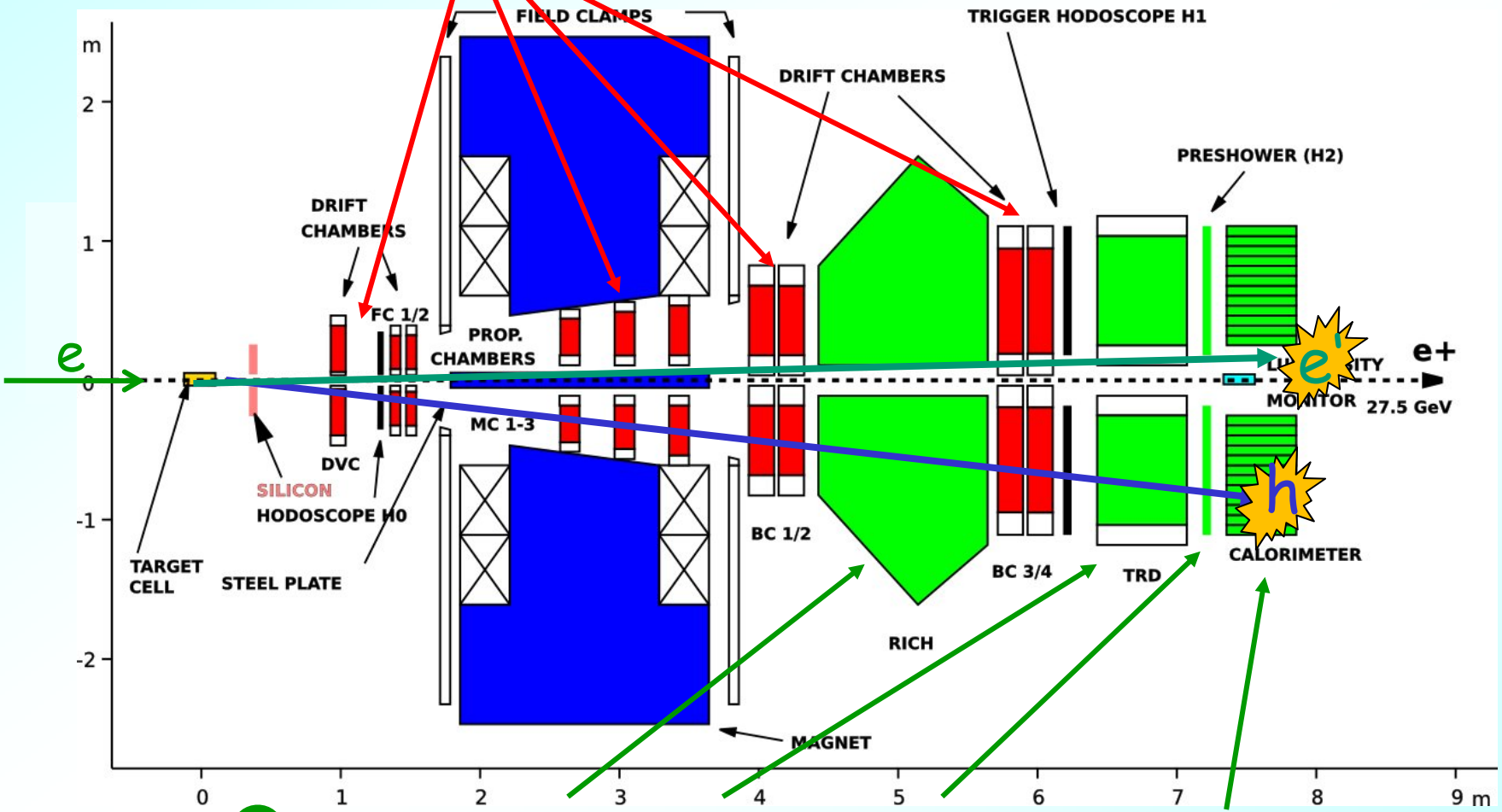
Internal gas targets

polarized : $\vec{}^{1}H$, $\vec{}^{1}H^{\uparrow}$, $\vec{}^{2}H$, $\vec{}^{3}He$

unpolarized: ^{1}H, ^{2}H, ^{3}He, ^{4}He,
N, Ne, Kr, Xe

HERMES Spectrometer

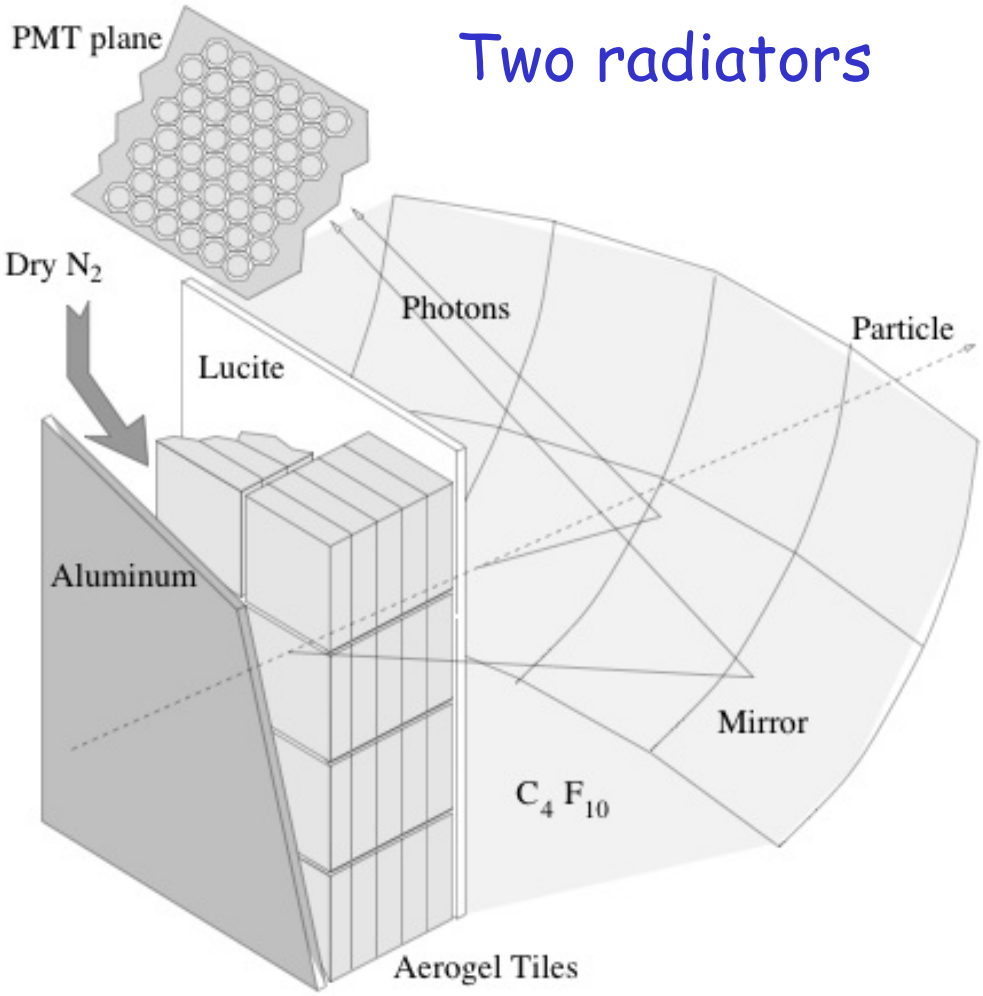
- tracking: $\delta p/p \sim 2\%$, $\delta\Theta < 0.6$ mrad, 40-220 mrad

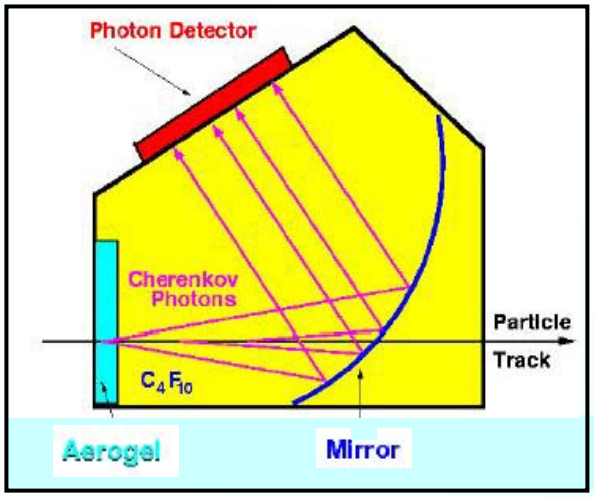


- PID: RICH, TRD, Preshower, Calorimeter
  lepton-hadron separation > 98%

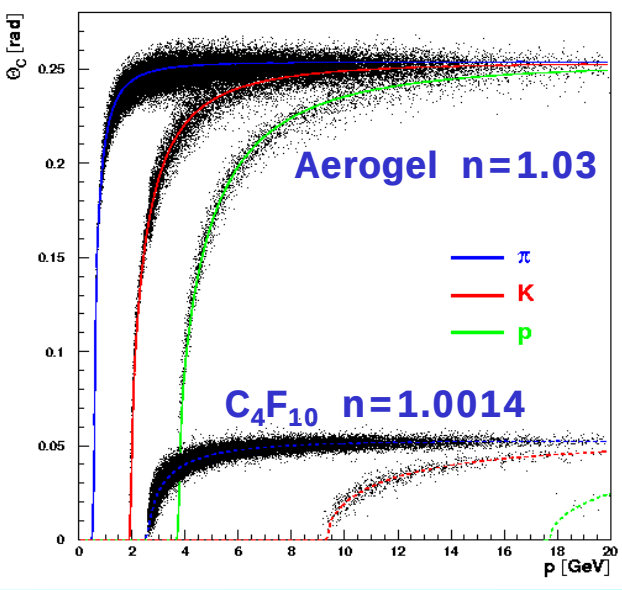
HERMES spectrometer - RICH

Two radiators



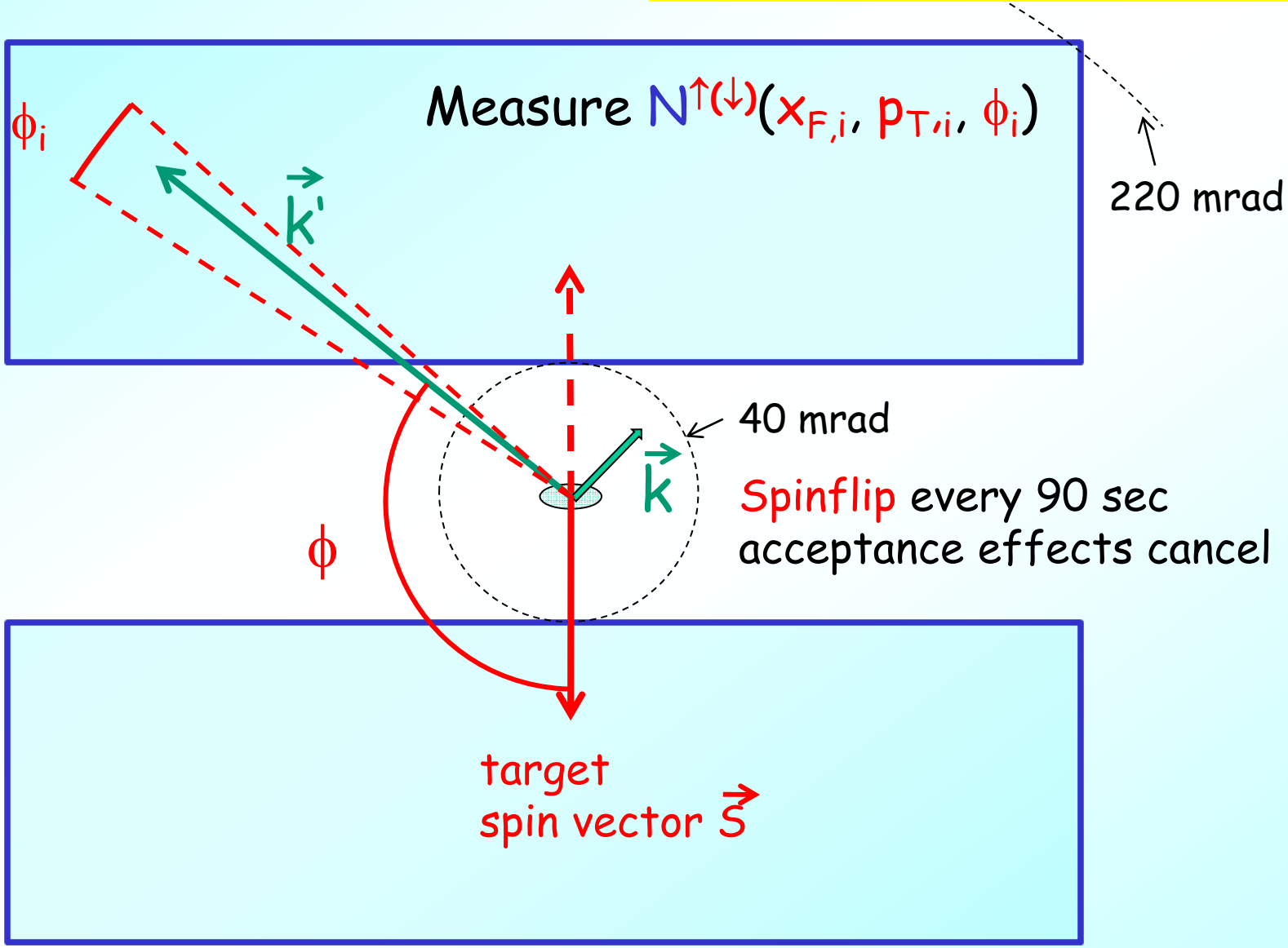


hadron separation



Hadron: π ~ 98%, K ~ 88% , P ~ 85%

HERMES front view



TSA in inclusive hadron electroproduction

TSA: Tranverse target single-spin asymmetry

Inclusive hadron electroproduction: $e^{\pm}\, p^{\uparrow} \rightarrow h\, X$

Scattered lepton not detected:
⟹ quasi-real photoproduction

π^+	π^-	K^+	K^-
66.4 M	56.8 M	5.5 M	3.0 M

Azimuthal asymmetry:

Asymmetry amplitude

$$A(x_F, p_T, \phi) = \frac{\sigma_{UT}(x_F, p_T, \phi)}{\sigma_{UU}(x_F, p_T)} = A_{UT}^{\sin\phi}(x_F, p_T)\sin\phi$$

A_{XY}: beam target polarisation

$$A_N = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = \frac{2}{\pi} A_{UT}^{\sin\phi}$$ (left-right asymmetry)

Single-spin azimuthal asymmetry

luminosity — polarisation-weighted luminosity — acceptance

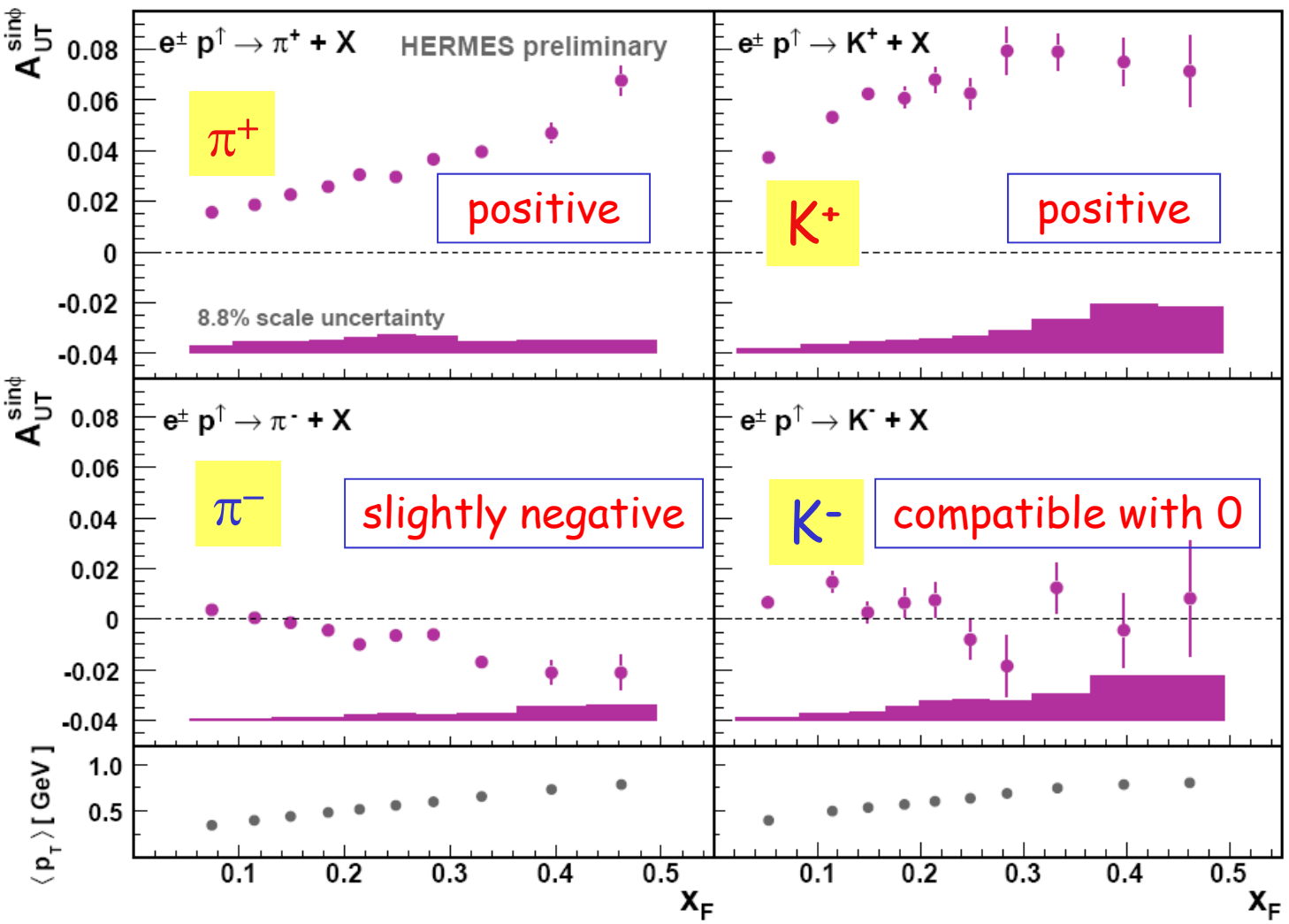
$$\frac{d^3N^{\uparrow(\downarrow)}}{dx_F\, dp_T\, d\phi} = [\, L^{\uparrow(\downarrow)}\, d^3\sigma_{UU} + (-)\, L_P{}^{\uparrow(\downarrow)}\, d^3\sigma_{UT}\,]\, \Omega(x_F, p_T, \phi)$$

$$= d^3\sigma_{UU}\, [\, L^{\uparrow(\downarrow)} + (-)\, L_P{}^{\uparrow(\downarrow)}\, A_{UT}{}^{\sin\phi}(x_F, p_T) \sin\phi\,]\, \Omega(x_F, p_T, \phi)$$

$$A_{UT}(x_F, p_T, \phi) = \frac{N^{\uparrow}/L_P{}^{\uparrow} - N^{\downarrow}/L_P{}^{\downarrow}}{N^{\uparrow}/L^{\uparrow} + N^{\downarrow}/L^{\downarrow}} \cong A_{UT}{}^{\sin\phi}(x_F, p_T) \sin\phi$$

Acceptance effects cancel for small bin size or asymmetry

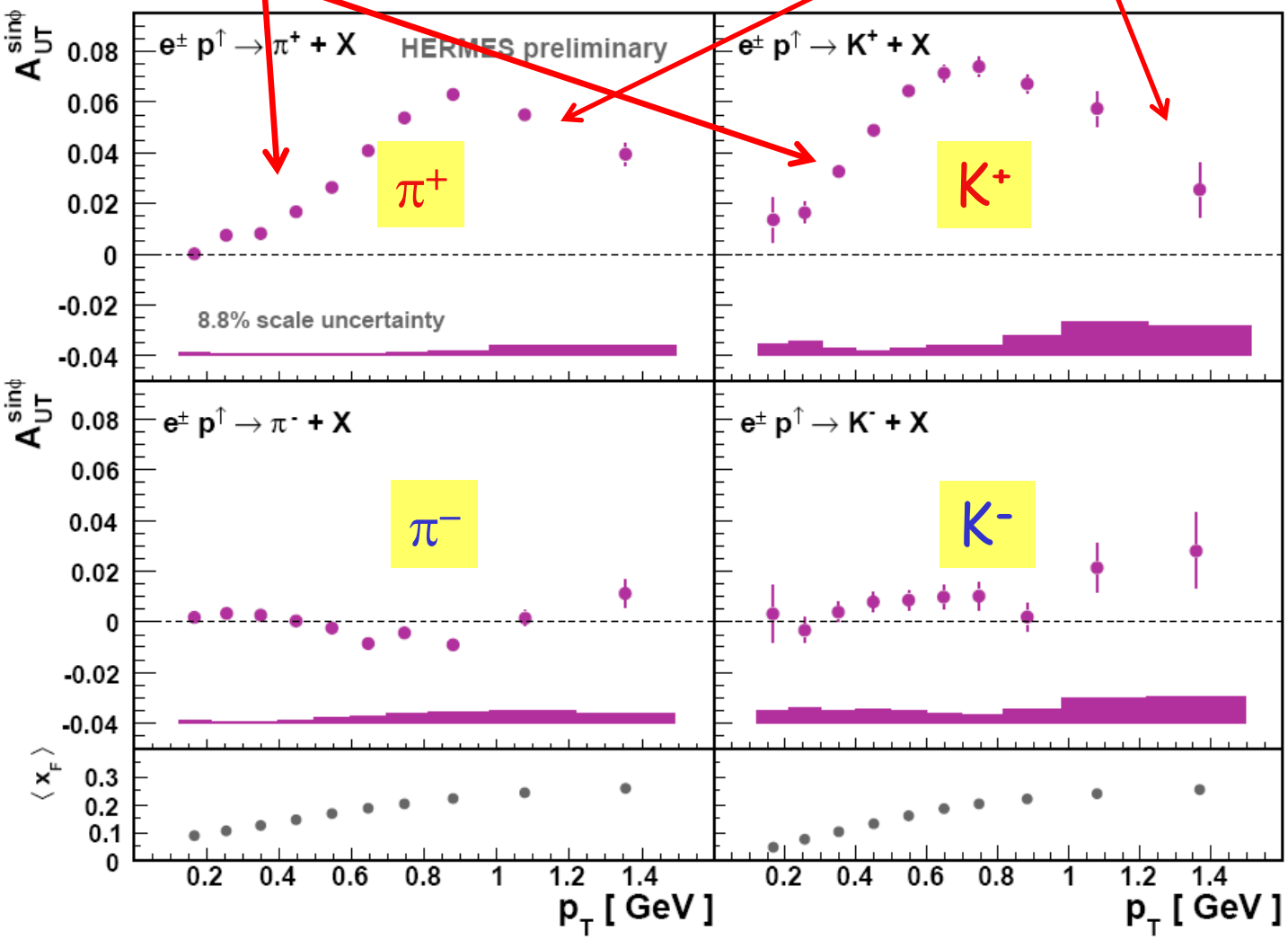
Inclusive hadron TSA



x_F dependence

Inclusive hadron TSA

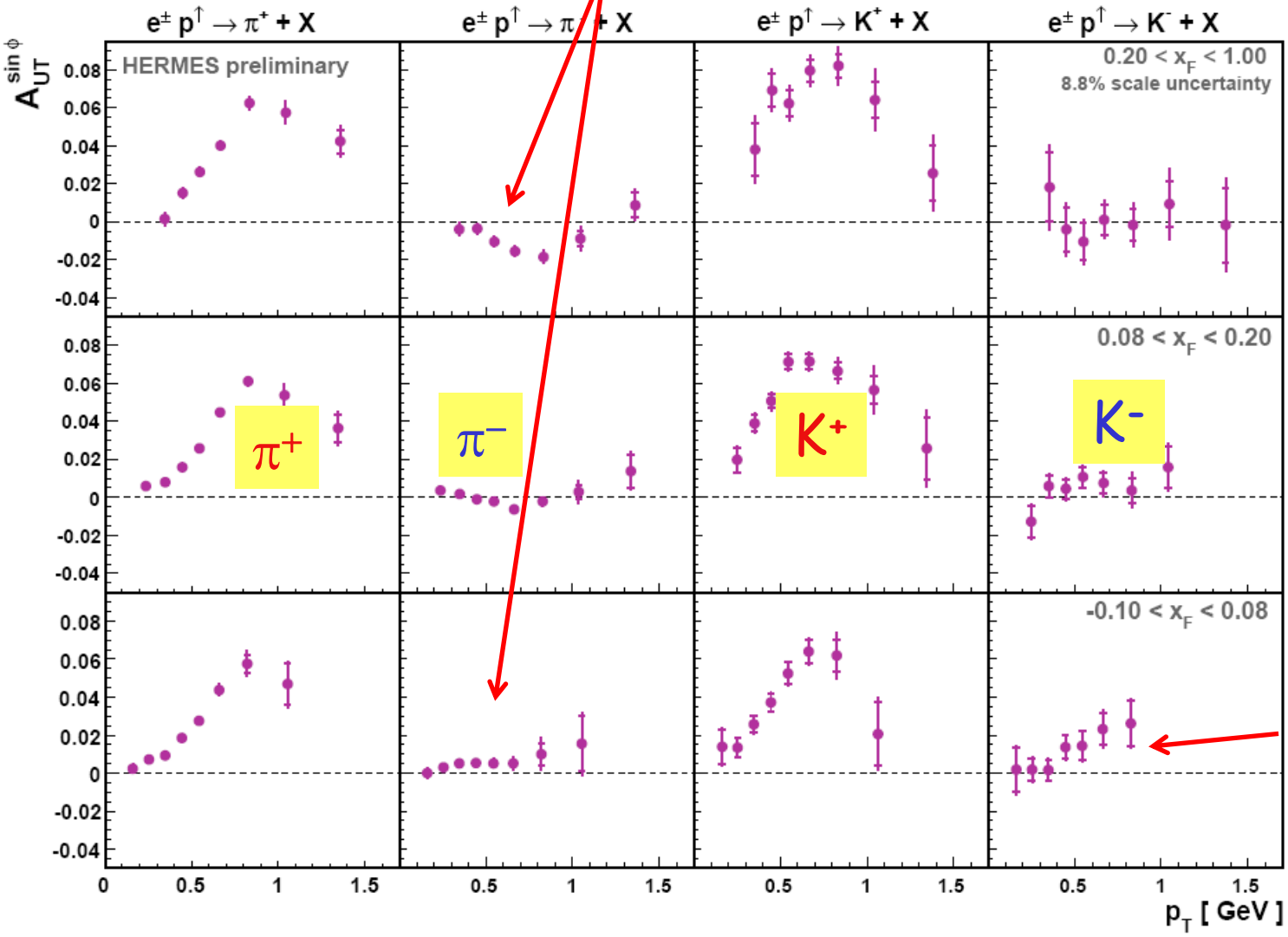
Increase with p_T at low p_T Decrease at high p_T



p_T dependence

Inclusive hadron TSA

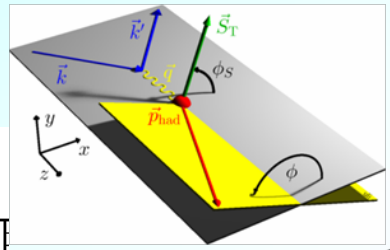
Sign change for π^-

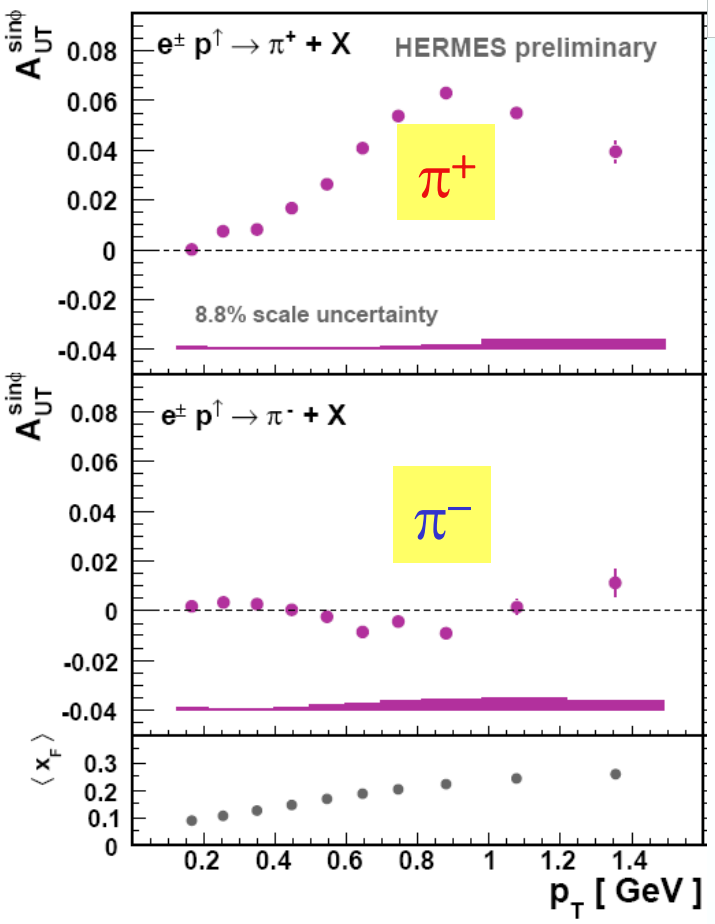


positive for $x_F \cong 0$

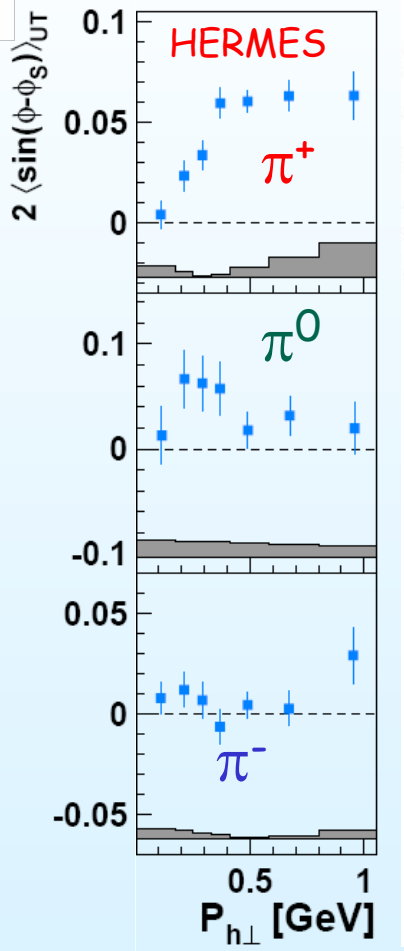
p_T dependence for different x_F intervalls

Comparison to DIS

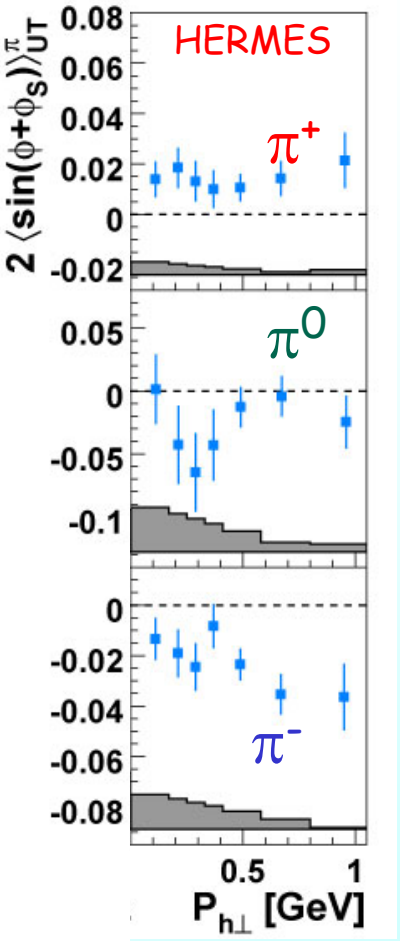




Sivers



Collins

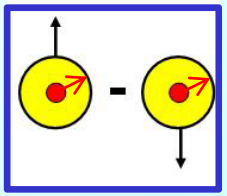


A_N resembles Sivers

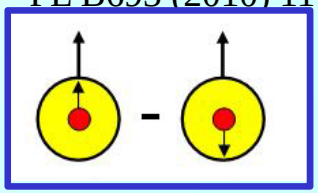
→ M. Diefenthaler (HERMES)

→ A. Richter (COMPASS)

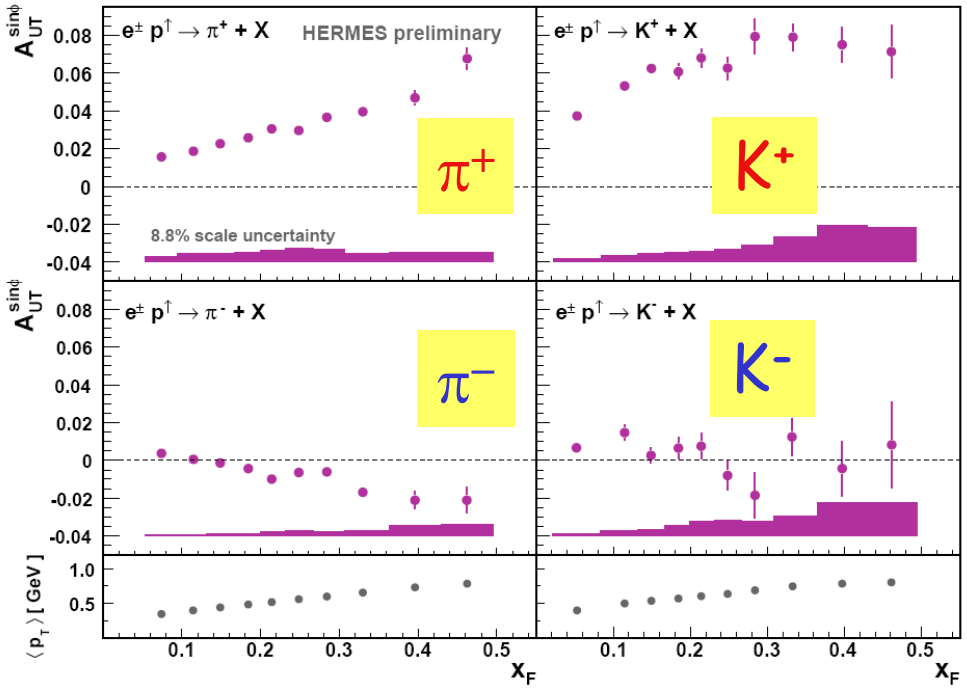
PRL 103 (2009) 152002

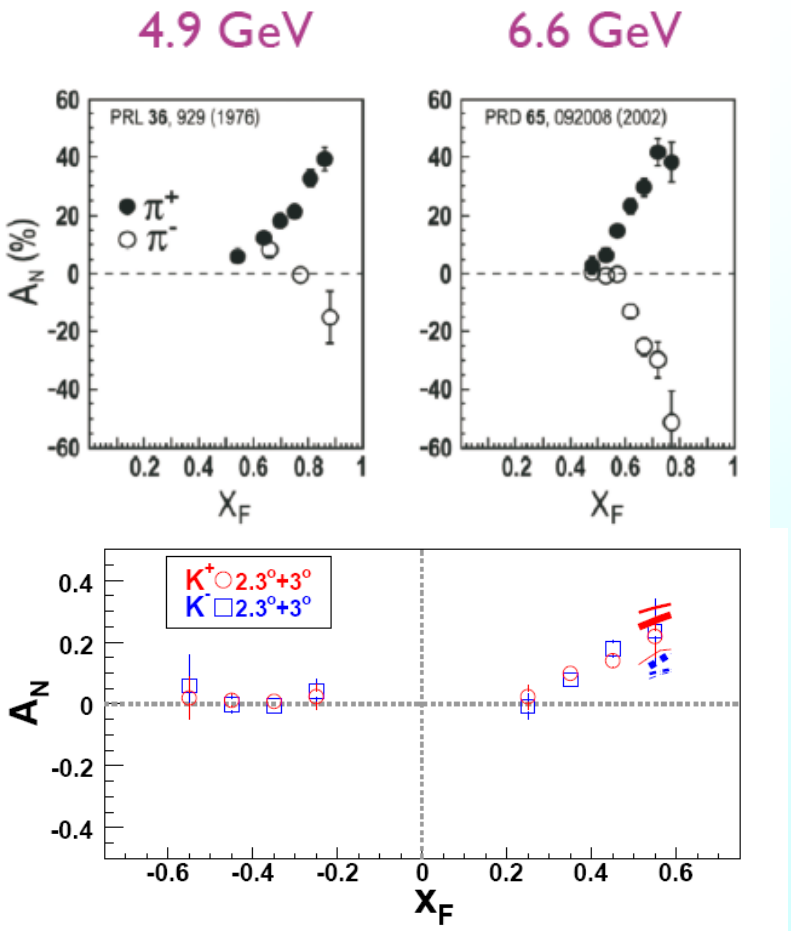


PL B693 (2010) 11



Comparison to pp





π^+, π^-, K^+: A_N similar to $p^{\uparrow}p$

K^-: A_N rather different from $p^{\uparrow}p$

Inclusive hadron TSA

Interpretation: non-trivial due to missing hard scale - except for high p_T (factorisation?)

Model predictions:

M. Anselmino et al., PRD 81 (2010) 034007

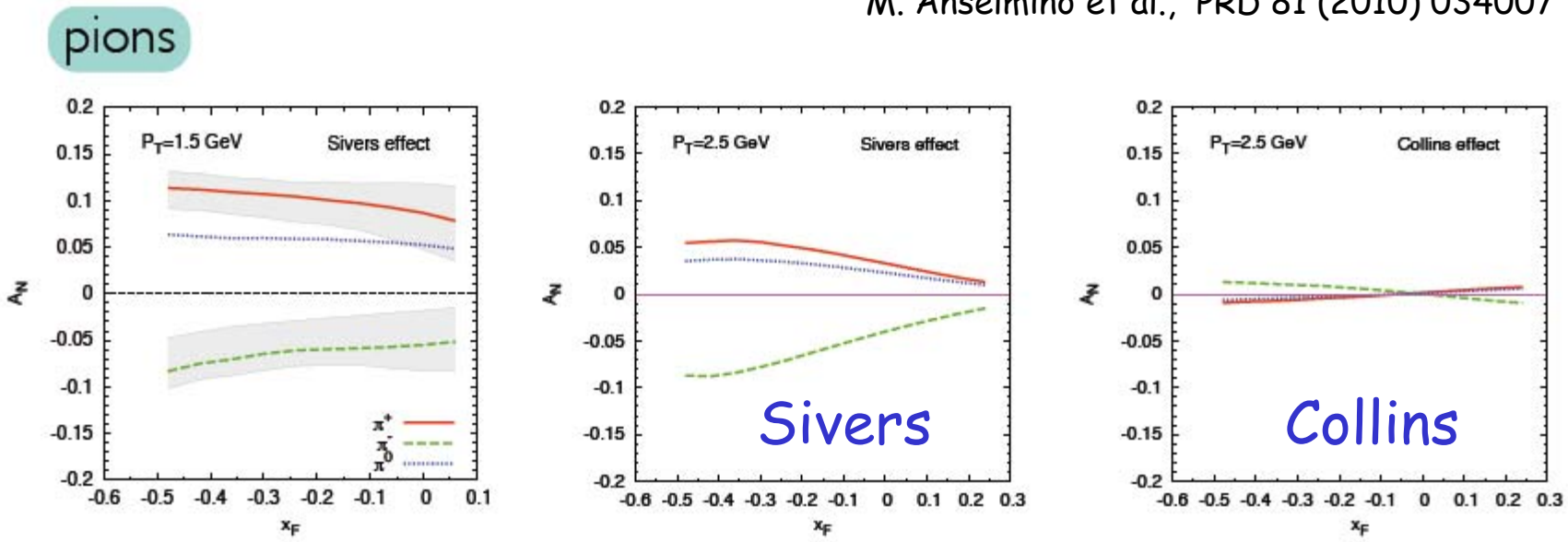
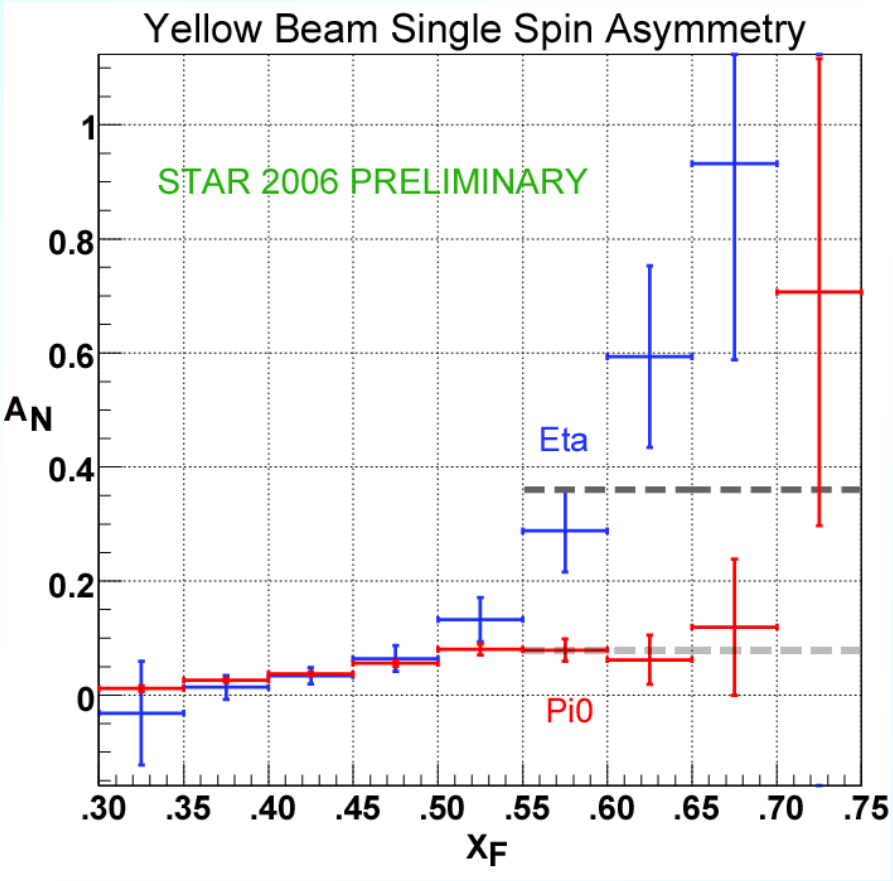


FIG. 2: Estimates of A_N vs. x_F for the $p^\uparrow \ell \to \pi X$ process at HERMES ($\sqrt{s} \simeq 7$ GeV). Left panel: Sivers effect at $P_T = 1.5$ GeV; central panel: Sivers effect at $P_T = 2.5$ GeV; right panel: Collins effect at $P_T = 2.5$ GeV.

Conclusion

- HERMES has measured with high precision single-spin asymmetries in inclusive hadron electroproduction, $e + p^{\uparrow} \rightarrow h + X$, from a transversely polarised proton target
- Substantial single-spin asymmetries are observed for positive pions and kaons
- Asymmetries for negative pions and kaons are small and show interesting dependence on x_F
- The dependence on p_T is similar to that observed in $p^{\uparrow}p$
- The dependence on p_T resembles the behaviour of the Sivers asymmetry in DIS

A_N for π^0 and η in p↑p



Very large asymmetry for η