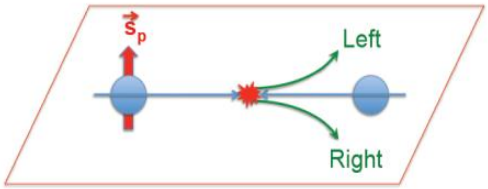
Transverse target single-spin asymmetry in inclusive electroproduction of charged pions and kaons

Luciano L. Pappalardo

University of Ferrara

Understanding Left-Right asymmetries in $p^{\uparrow}p$ scattering



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Collinear pQCD predicts $A_N \approx 0$

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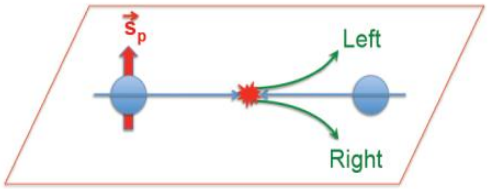

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- **mirror symmetric for π^+ and π^- vs. $x_F \sim \langle z \rangle P_{jet}/P_L$**
- **reporuced by various exp. over 35 years**
- **persistent with energy ($\sqrt{s}$ from 5 to 200 GeV !)**

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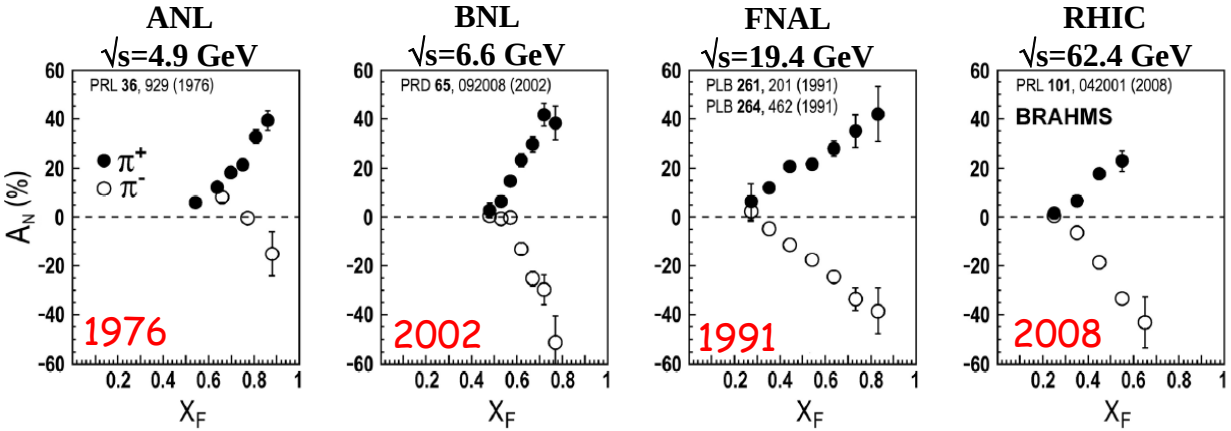

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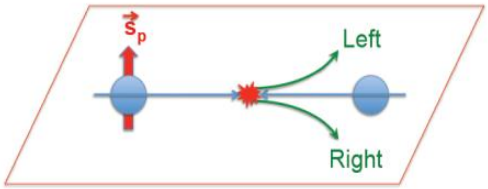

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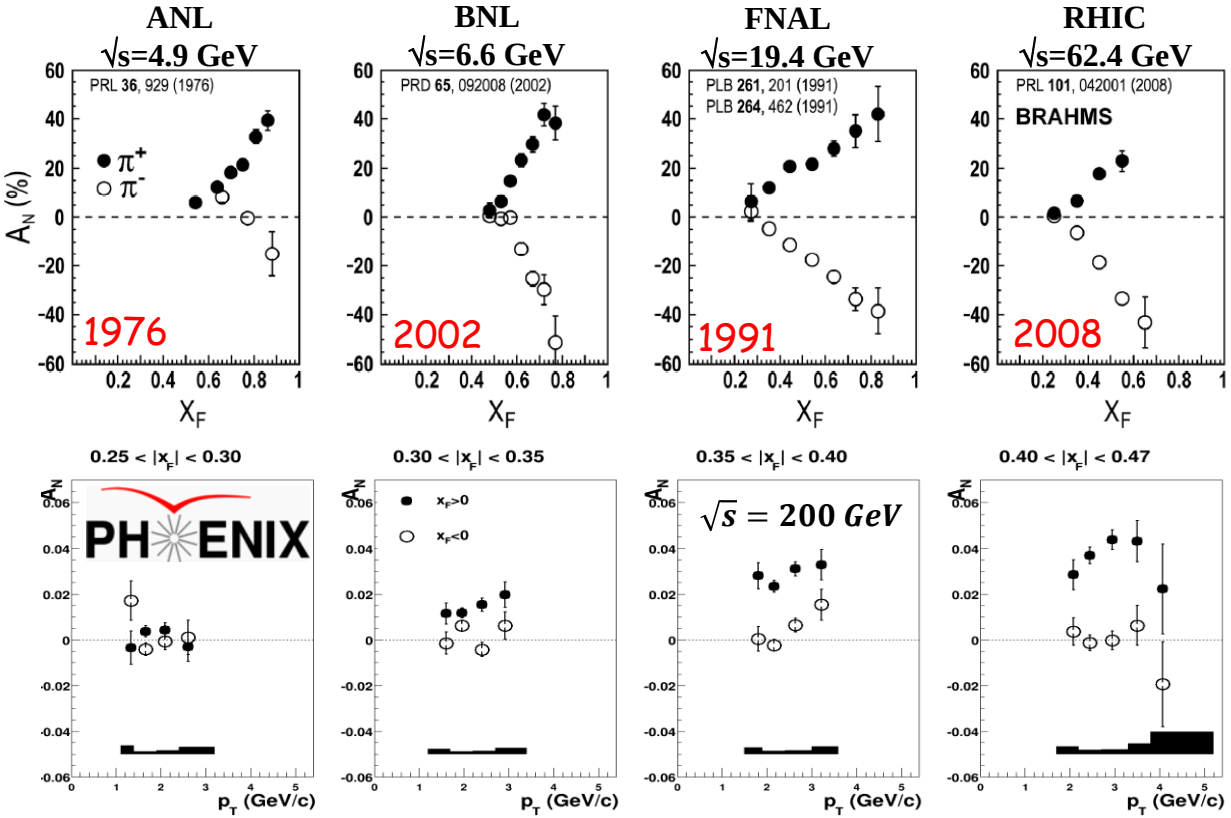

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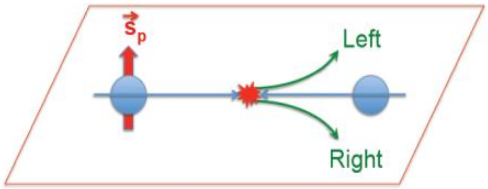

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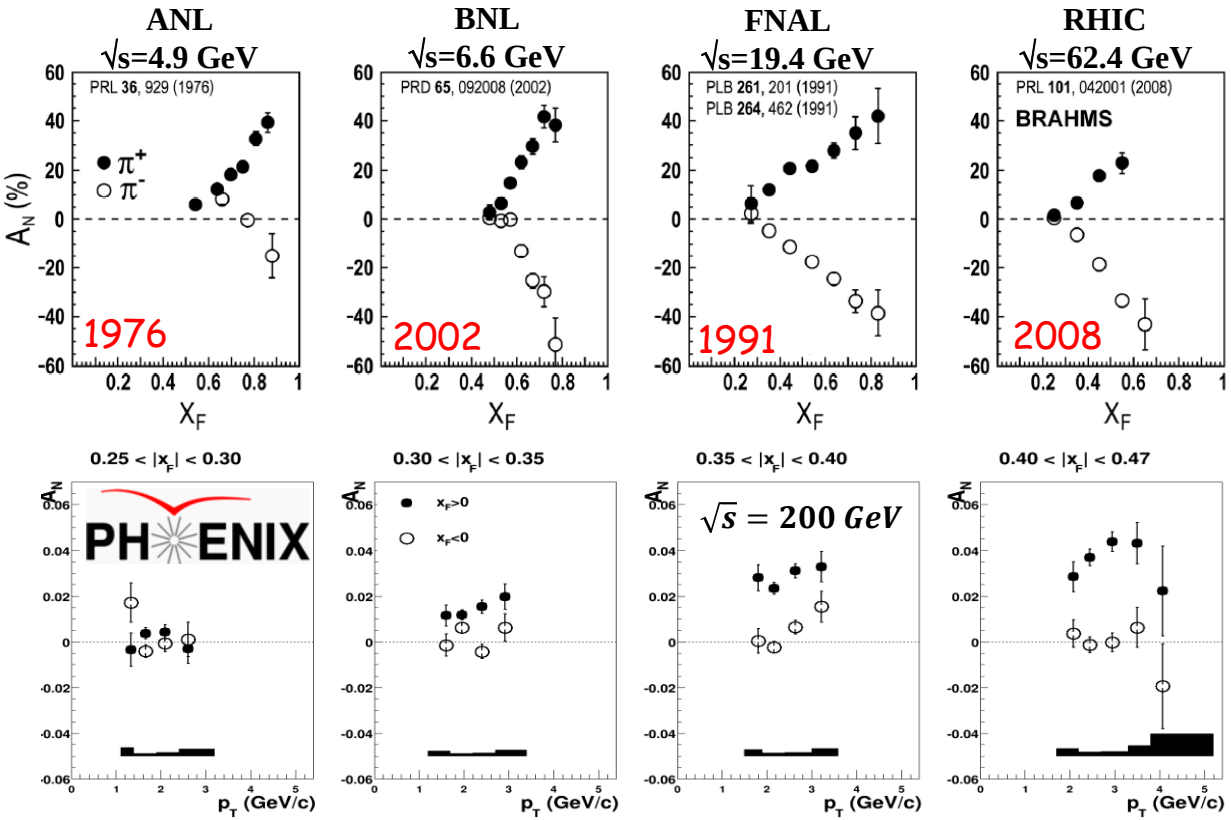

Cannot be interpreted using the standard leading-twist framework based on collinear factorization

- **Collinear framework:**
  - Higher-twist effects ? (could not be sufficient)
- **Non-collinear framework**
  - Requires intrinsic transverse momentum in fragmentation (Collins effect) or distribution function (Sivers effect)
  - Both measured in SIDIS
  - Combination of above ?

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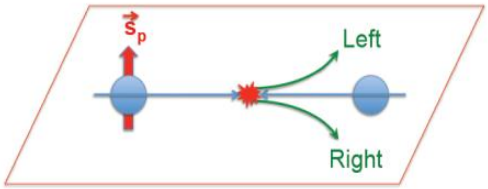

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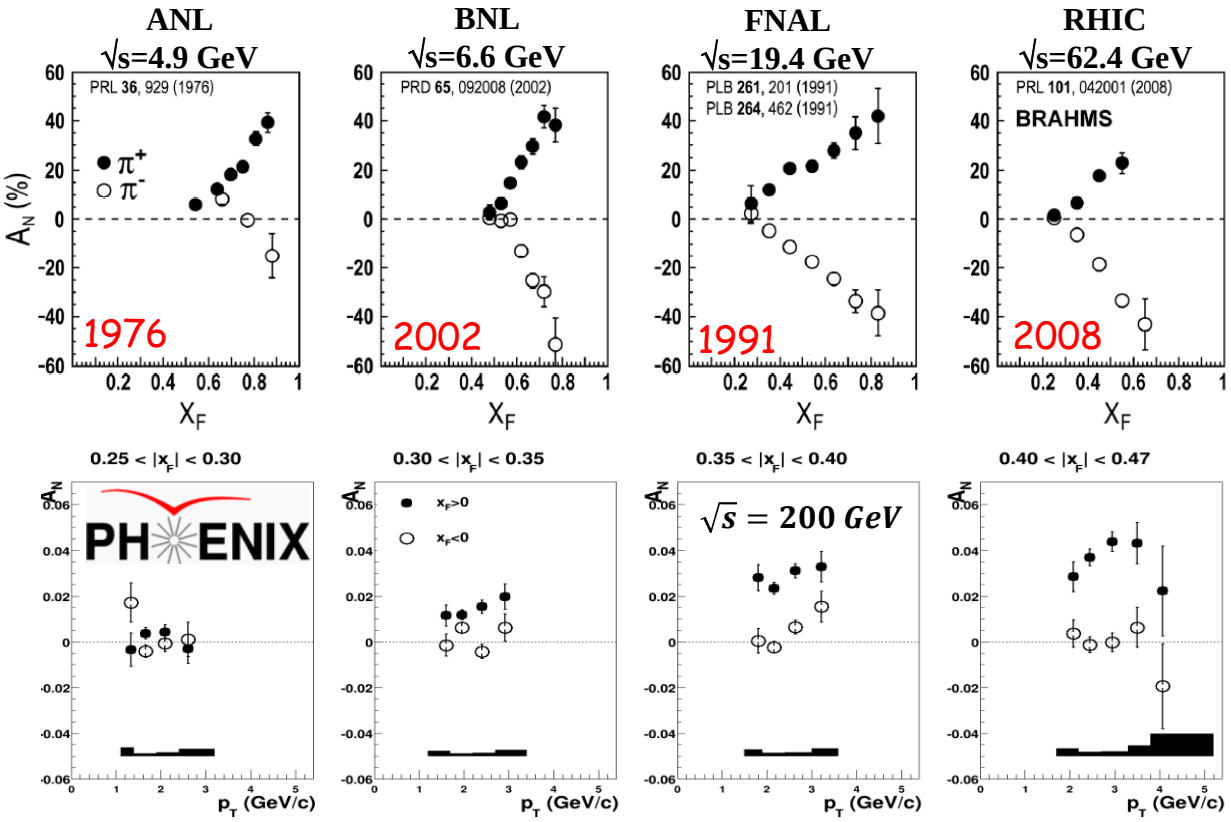

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Sign error invalidates agreement
Presently the interpretation is unsettled

How does A_N look in inclusive $e^{\uparrow}p \rightarrow$ hX processes? Can help the interpretation of A_N in $p^{\uparrow}p$?

Inclusive hadron electroproduction: motivation

- A_N can be measured in $ep^{\uparrow}$ inclusive scattering $(lp^{\uparrow} \rightarrow hX)$
- **The process is analogue to $\boldsymbol{p^{\uparrow}p}$ scattering: both have only one hard scale ($\boldsymbol{P_T}$)** and is much cleaner (electromagnetic probe)
- Can help understanding the large SSAs measured in $p^{\uparrow}p$ scattering
- **Important test for TMD factorization for processes with only one hard scale**

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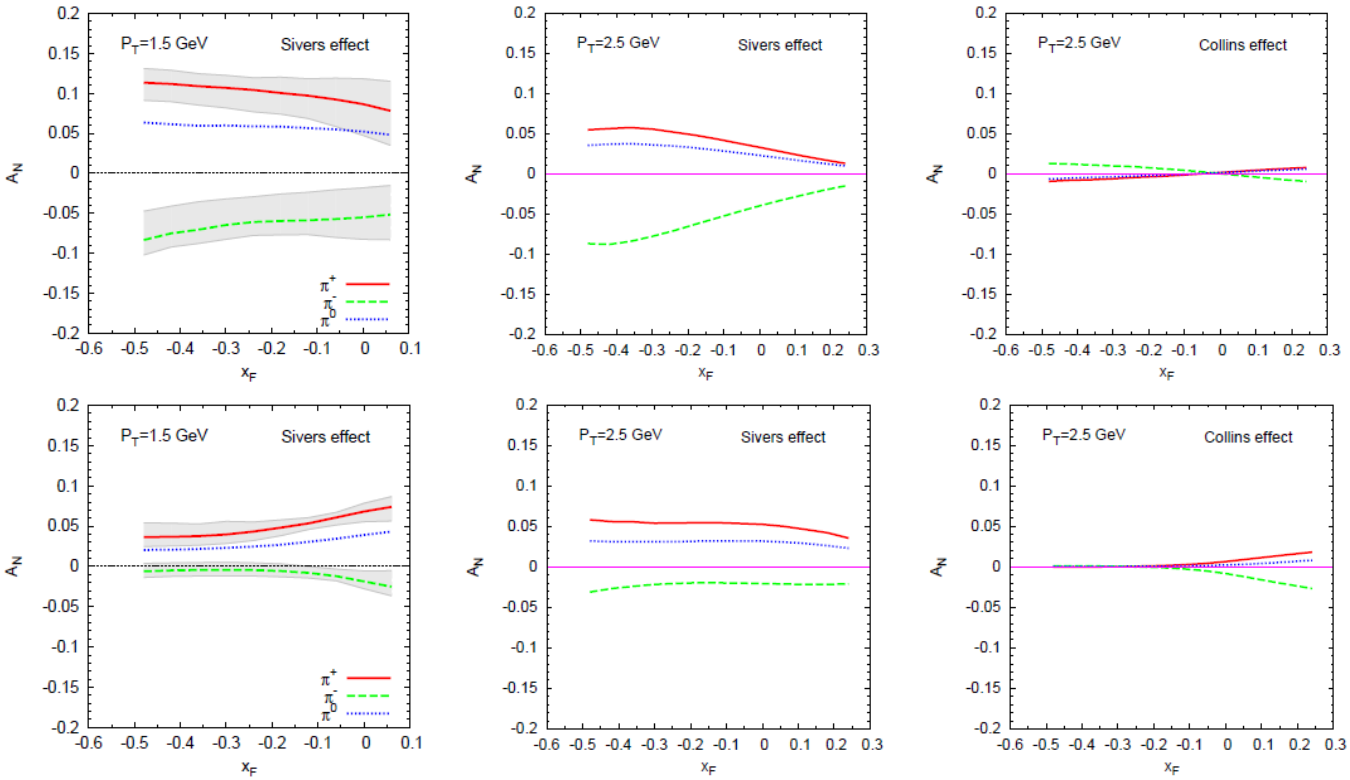
- Can help understanding the large SSAs measured in $p^{\uparrow}p$ scattering
- **Important test for TMD factorization for processes with only one hard scale**
- HERMES has a lot of good data for this investigation!
- Theoretical predictions are available (Torino group) → Sivers effects dominates over Collins effect

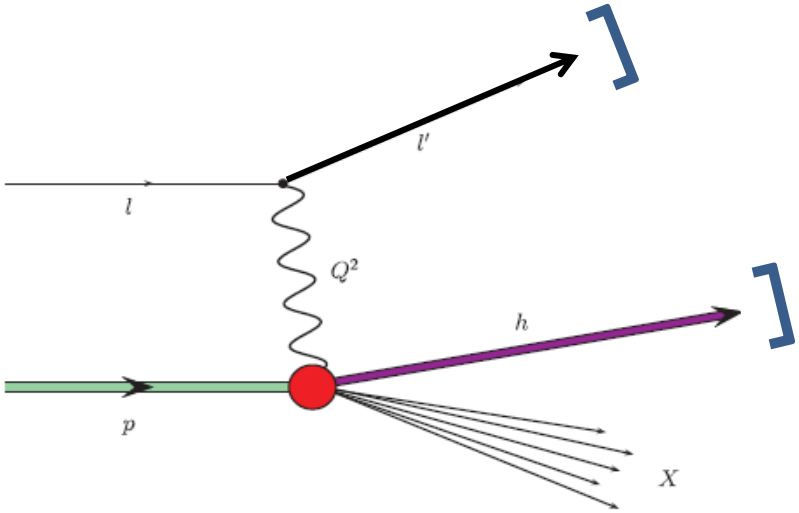
Anselmino et al., Phys. Rev. D81:034007, 2010



@ **HERMES** kinematics

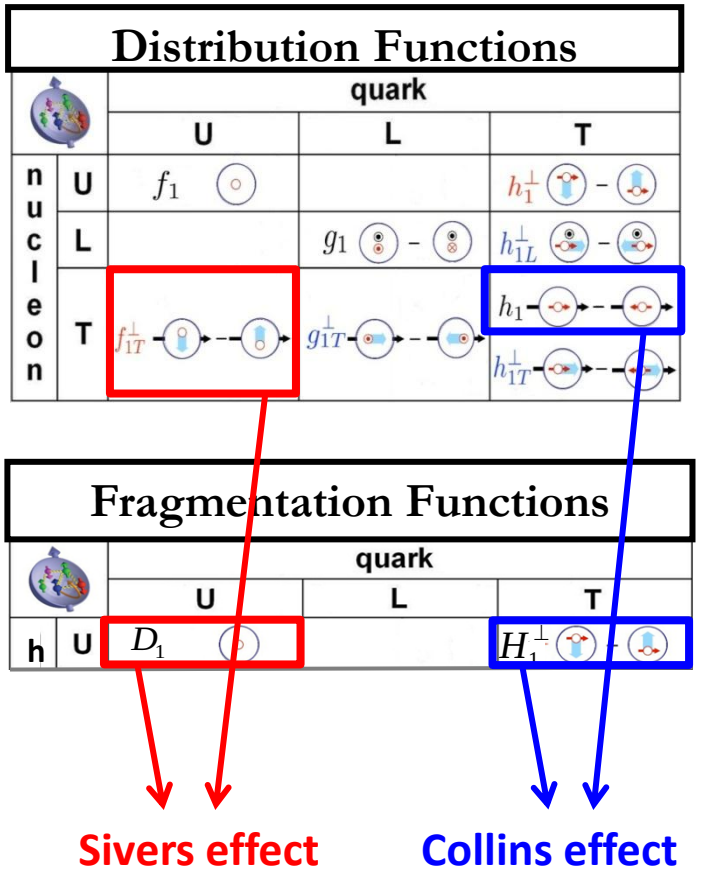
@ **COMPASS** kinematics

From SIDIS to inclusive hadron production



SIDIS: $lp^{\uparrow} \rightarrow l'hX$

- Hadron detected in coincidence with lepton
- DIS regime ($Q^2 > 1\ GeV^2$)
- Hard scales: Q^2, $P_{h\perp}$ (w.r.t. γ^*)
- Main variables: Q^2, x_B
- Factorization valid for ${P_{h\perp}}^2 \ll Q^2$



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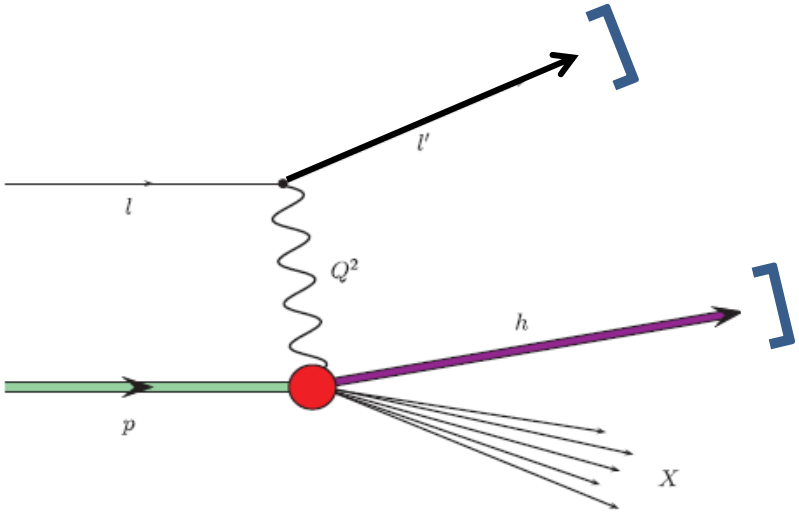

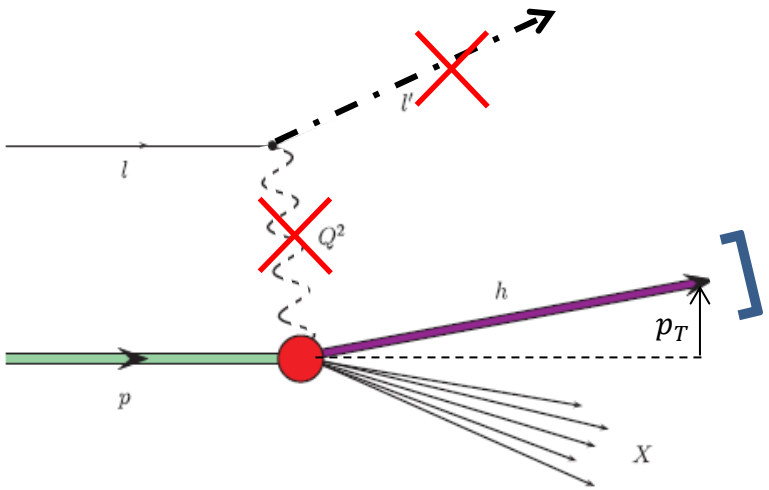

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  (quasi-real photoproduction regime)
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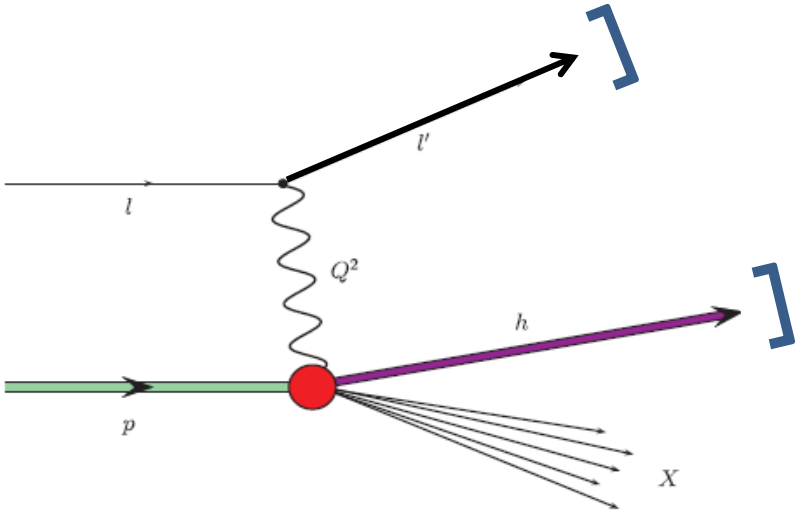
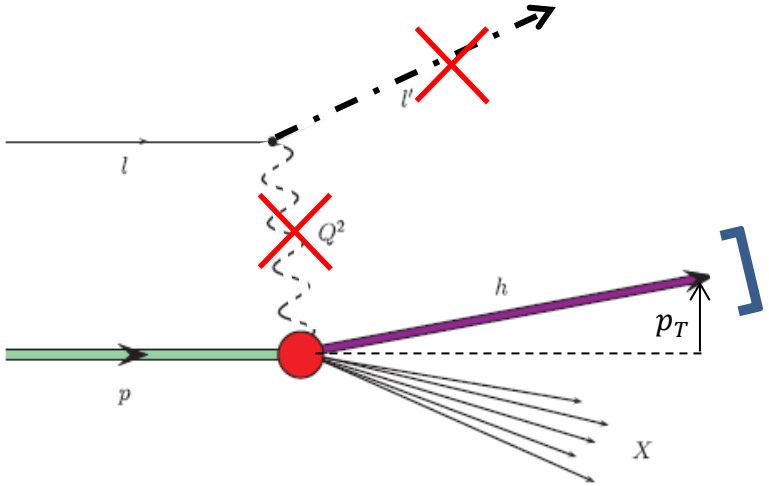
- Main variables: $x_F = 2\frac{P_L}{\sqrt{s}}$, p_T
- Factorization valid for large p_T?

From SIDIS to inclusive hadron production





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Hadron yields for UT data

π^+	π^-	K^+	K^-
7.3 M	5.4 M	131 K	54 K

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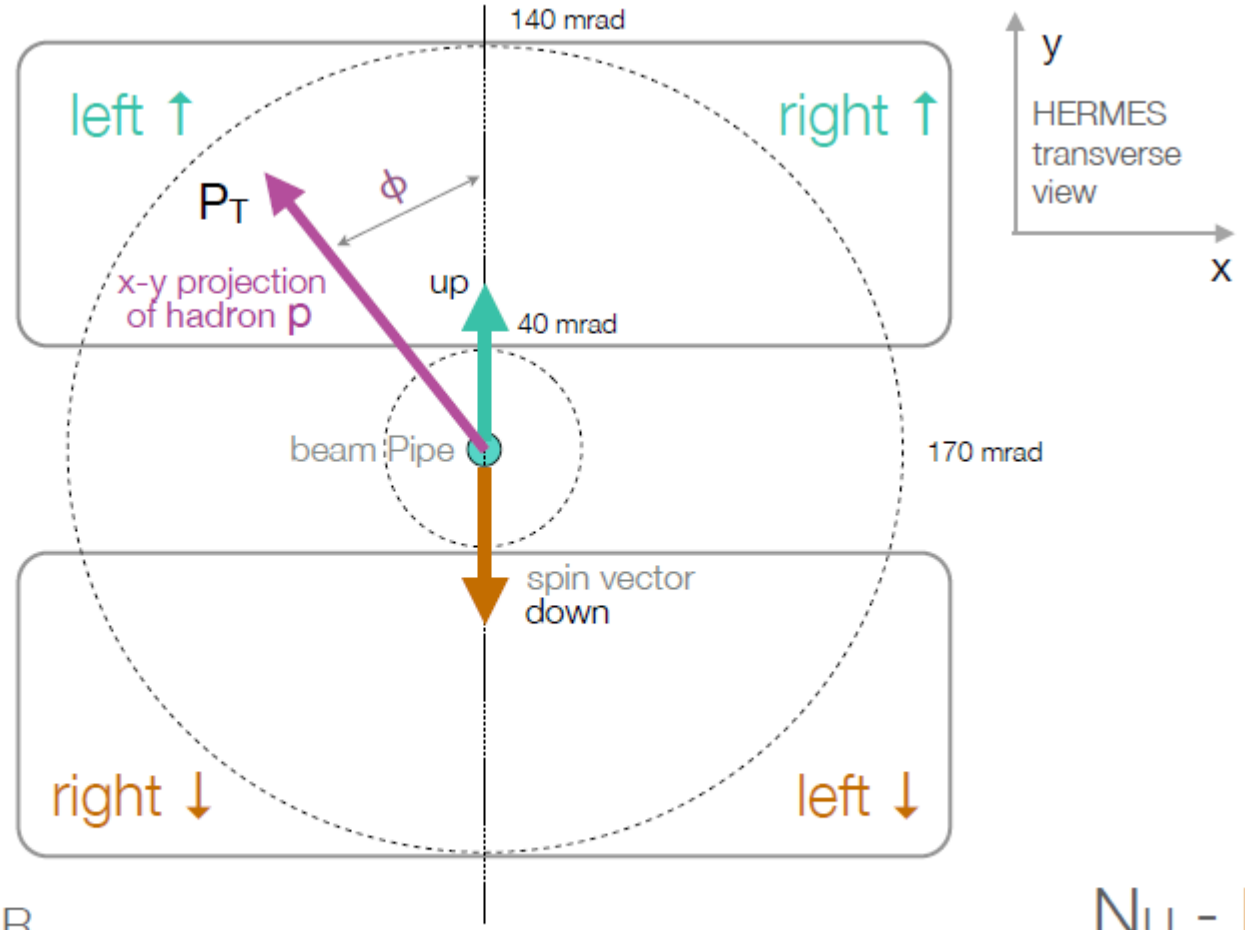
62 M	53 M	5.4 M	3.0 M

Acceptance at HERMES: A_N vs. A_{UT}



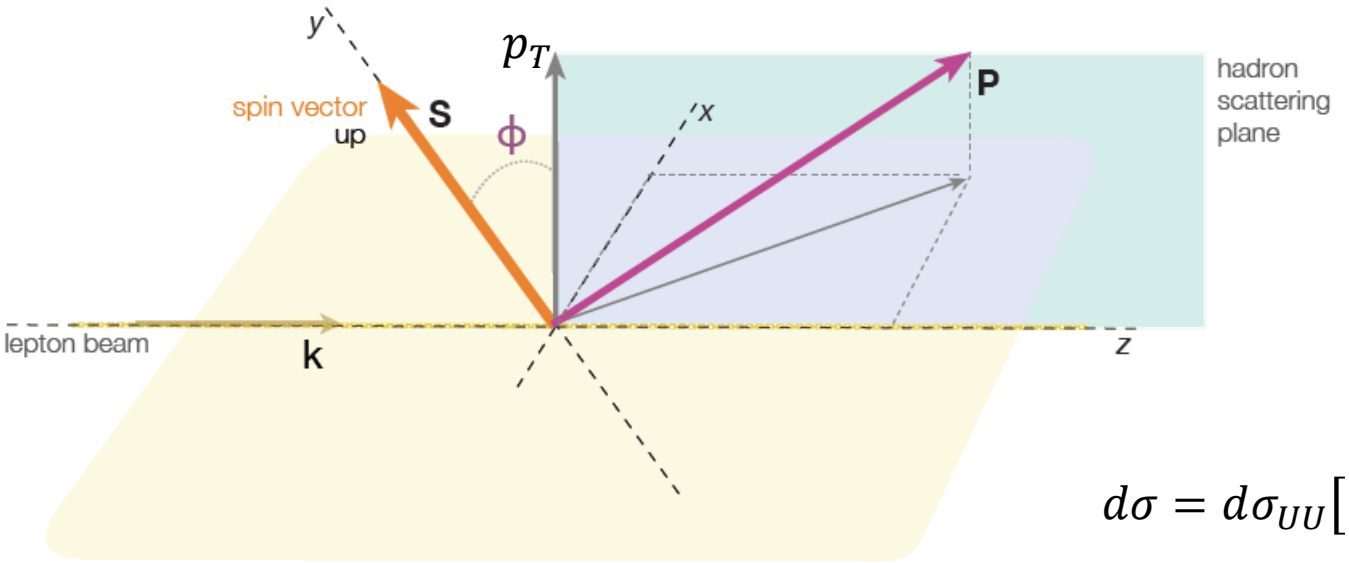
Highest sensitivity to Left-Right asymmetries is around the beam pipe → huge acceptance effects

$$A_N = \frac{N_L - N_R}{N_L + N_R}$$ (left-right)

Up-Down asymmetry is completely equivalent

$$A_{UT} = \frac{N_U - N_D}{N_U + N_D}$$ (p-down)

Cross section and azimuthal asymmetries



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

$$d\sigma = d\sigma_{UU}\left[1 + S_\perp A_{UT}^{\sin\phi} \sin\phi\right]$$

ϕ: azimuthal angle between the upwards target spin direction and hadron production plane

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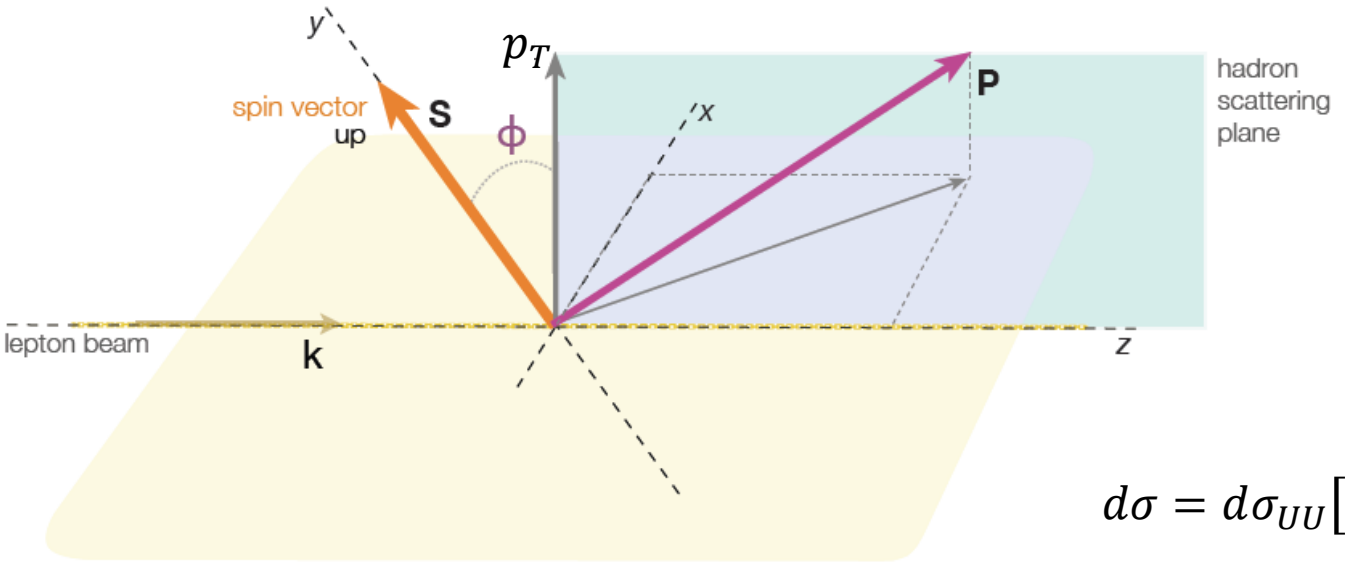

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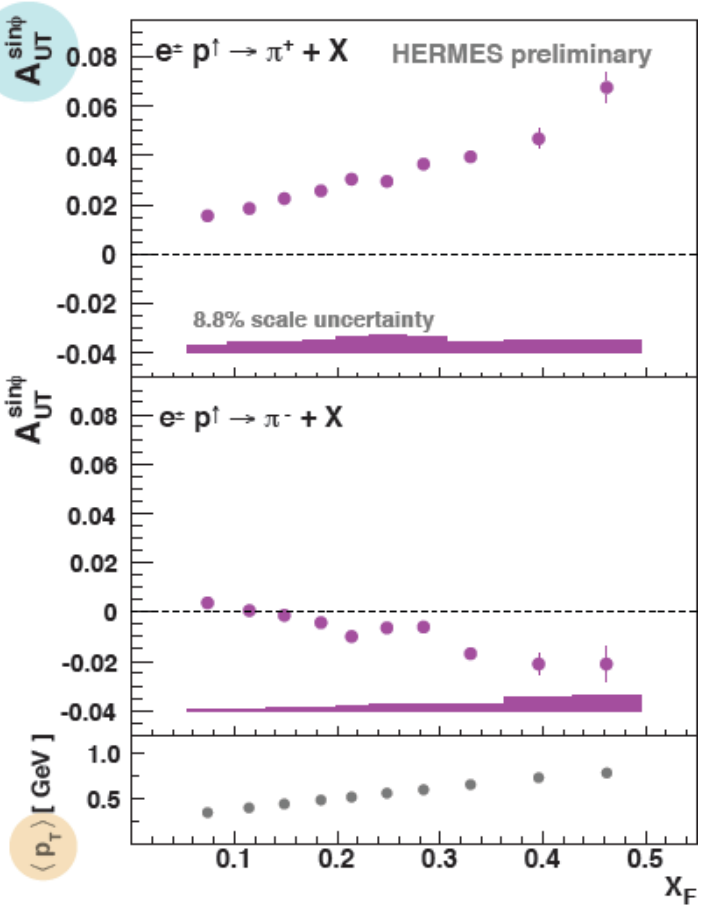
In each x_F and p_T bin the $A_{UT}^{\sin\phi}$ azimuthal amplitude is extracted a ML fit (unbinned in ϕ):

$$pdf(\phi;\alpha) = 1 + S_\perp\left(a + A_{UT}^{\sin\phi} \sin\phi\right) \quad \Rightarrow \quad \mathcal{L}(\alpha) = \prod_i^N pdf(\phi;\alpha)$$

$$A_N = \frac{\int_0^\pi d\phi\, \sigma_{UT} \sin\phi}{\int_0^\pi d\phi\, \sigma_{UU}} = \frac{2}{\pi} \cdot A_{UT}^{\sin\phi}$$

(for an ideal detector with full 2π coverage in ϕ)

Preliminary results (1)



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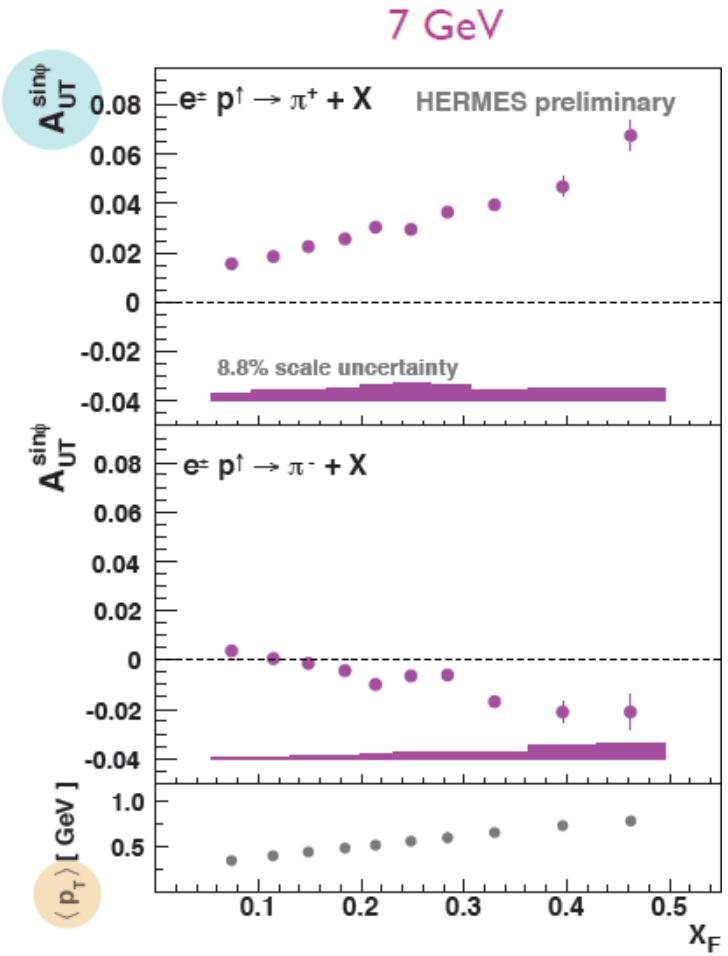

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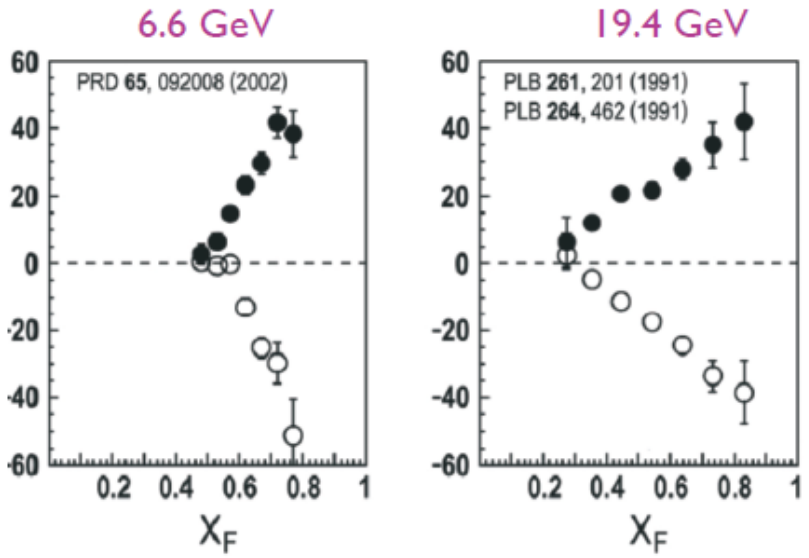

- A_N in $p^{\uparrow}p$ scattering is much larger and mirror symmetric for π^+ and π^-
- u-quark dominance in $ep^{\uparrow}$ scattering can explain the relatively smaller size for π^-

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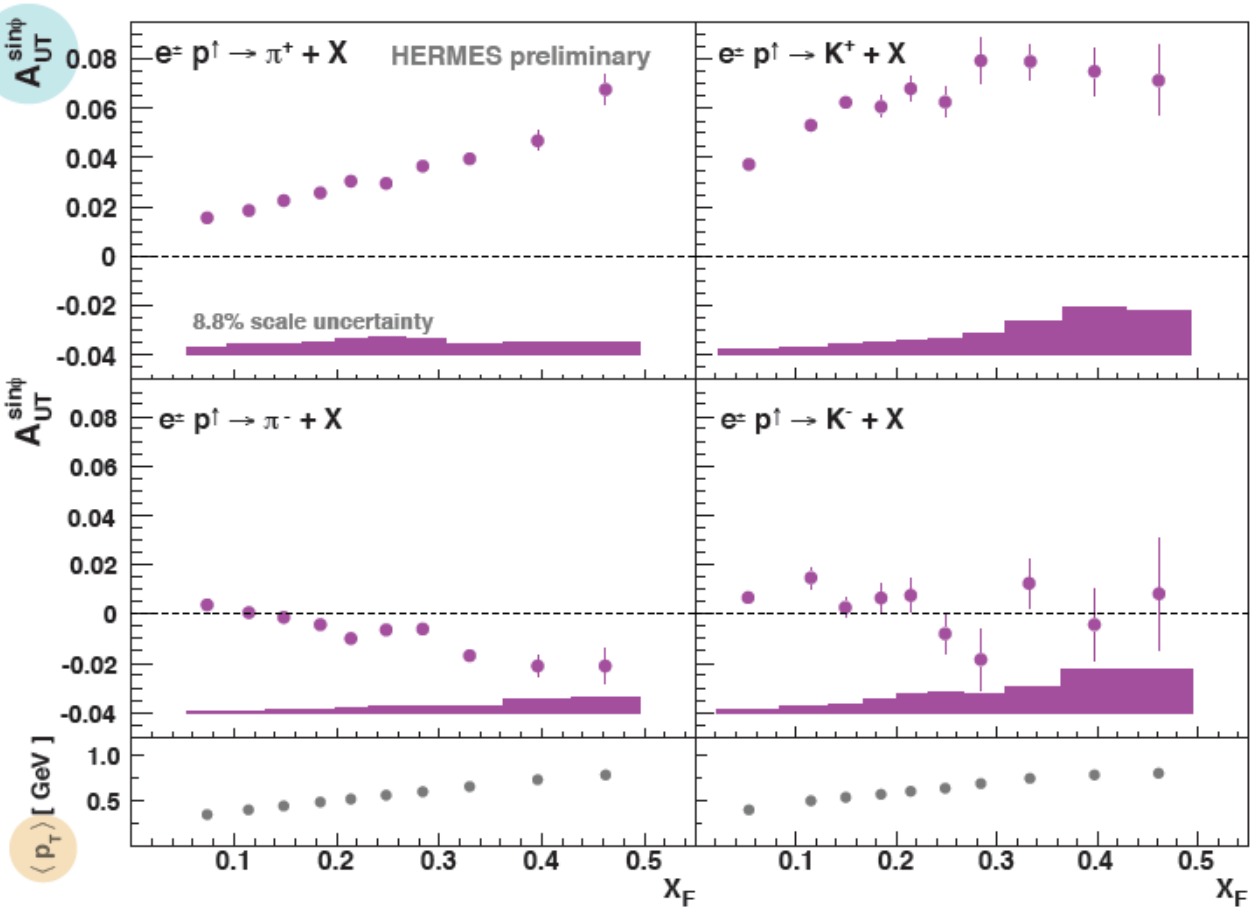
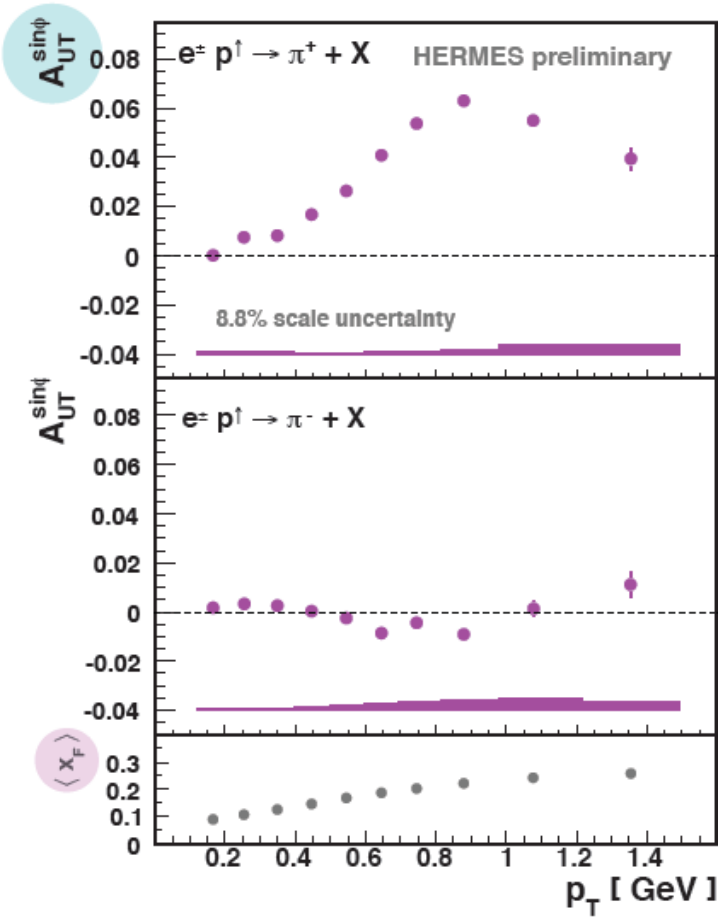


- K^+ amplitude up to 8%
  Small dependece on x_F
- K^- consistent with 0
- Strong correlation between x_F and p_T!

Preliminary results (2)



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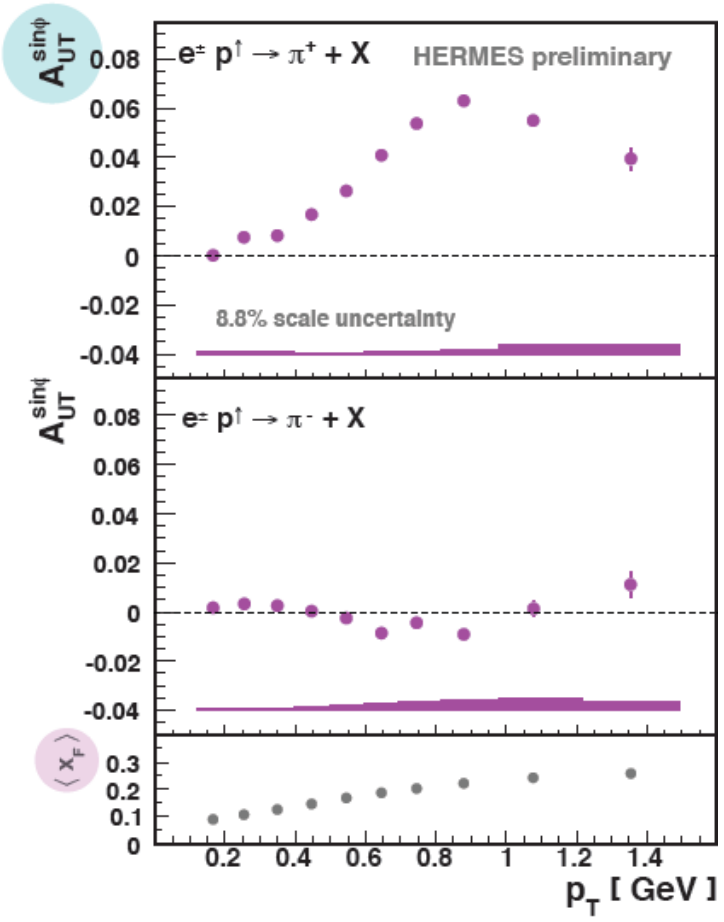

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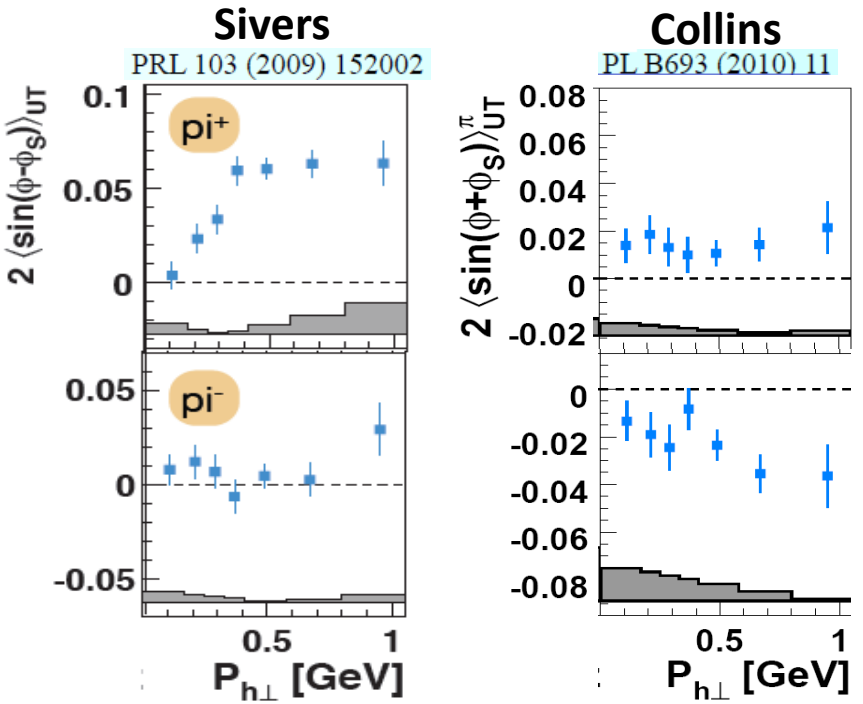

➢ **Inclusive pions amplitudes are very similar to Sivers amplitudes measured in SIDIS!**

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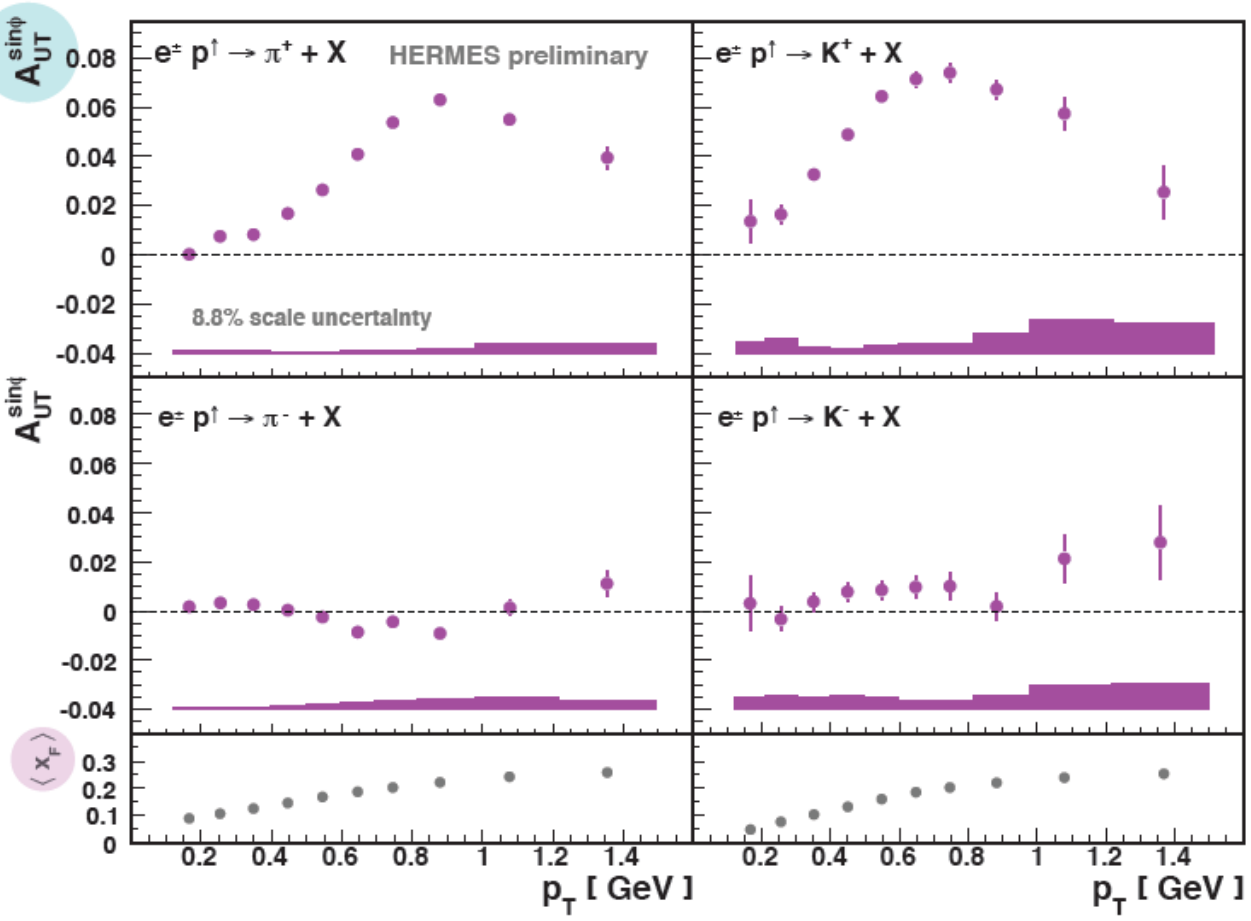
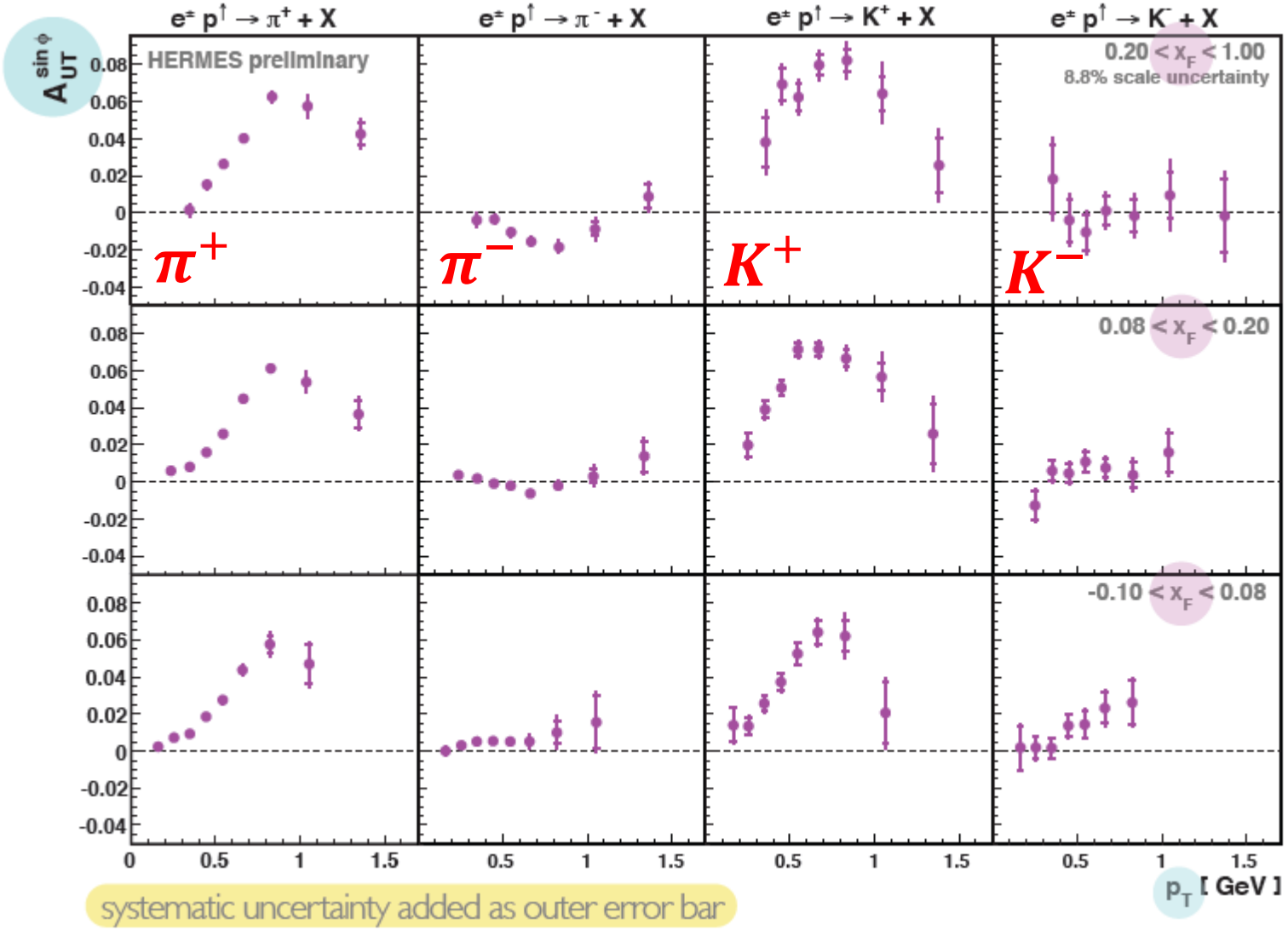


- π^+ and K^+ ampl. have similar p_T dependence
- K^+ ampl. slightly lager

- K^- slightly positive

Preliminary results (3)



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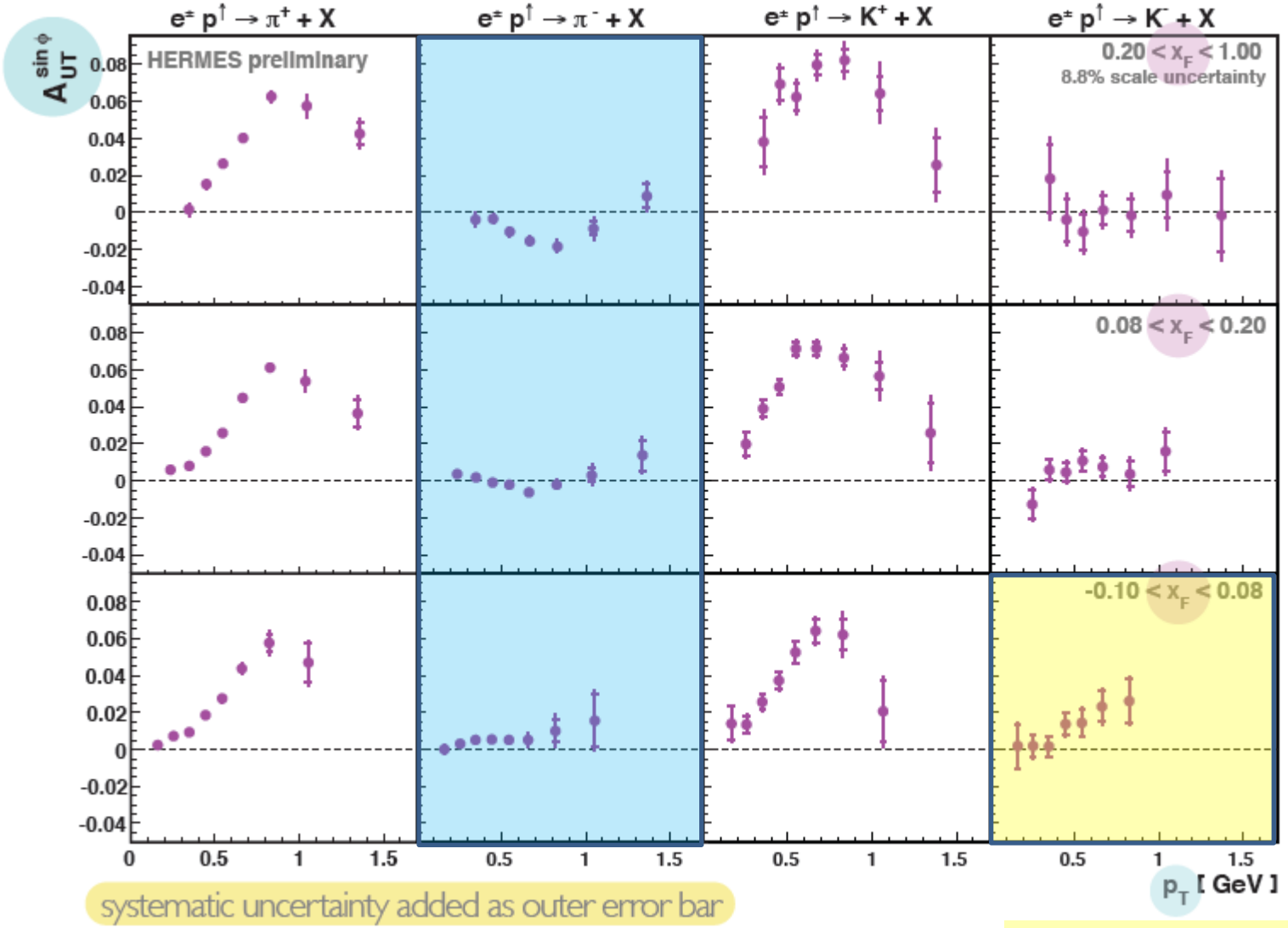
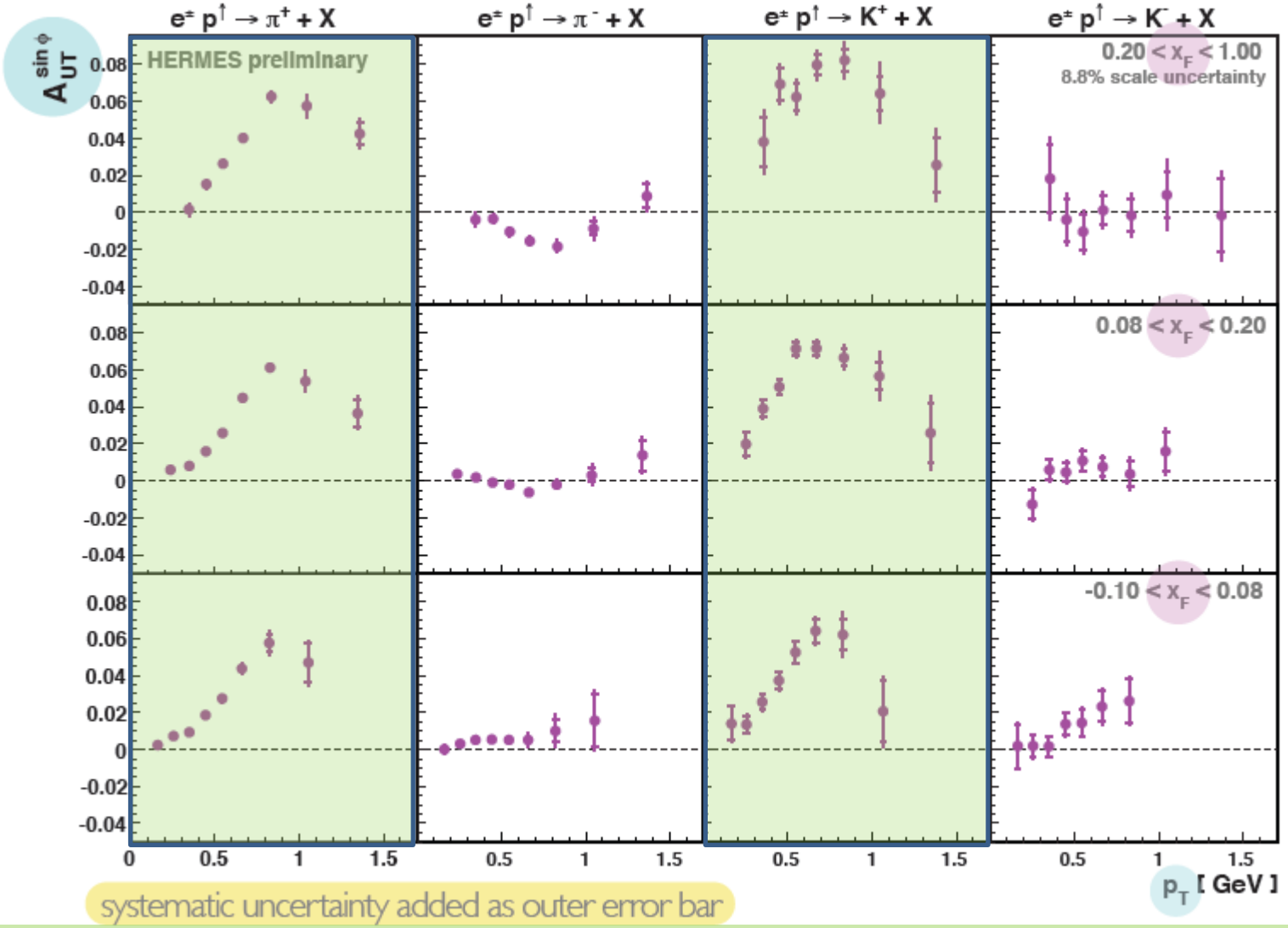


Sign change for π^-

K^- becomes positive at low x_F

Preliminary results (3)



For π^+ and K^+ the asymmetry is nearly independent on x_F, so the increase in magnitude in 1DIM plots vs. x_F reflects the underlying dependence on p_T (strongly correlated). Different for $p^{\uparrow}p$ scattering case!

Interpretation

- The inclusive hadron electrorpoduction data set is a mixture of various contributions with different kinematic depdendences ⇒ Difficult to draw conclusions on the underlying physics from the observed kinematic dependences
- More insight may be gained by studying separately the asymmetries for different subsamples

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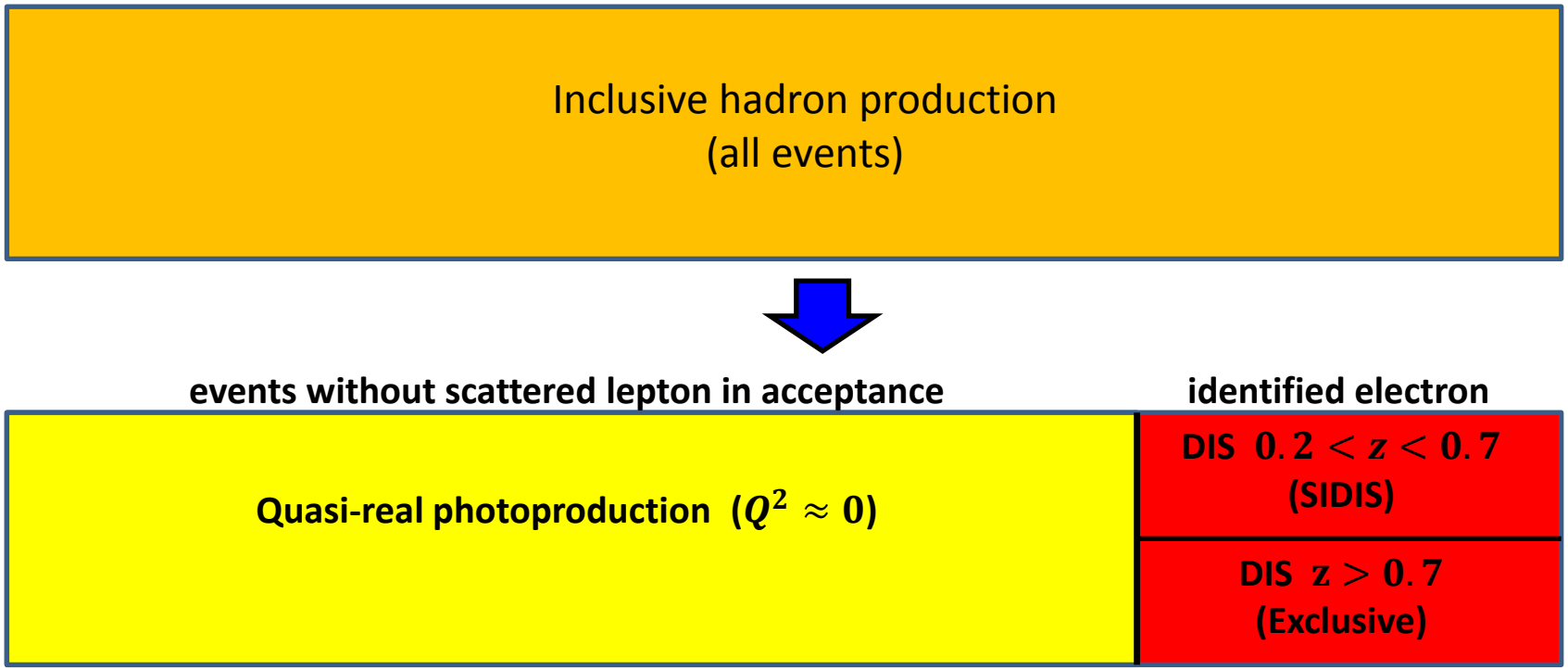


- Studies were performed and almost finalized. Results are very interesting!
- **To be published very soon! → stay tuned!!**

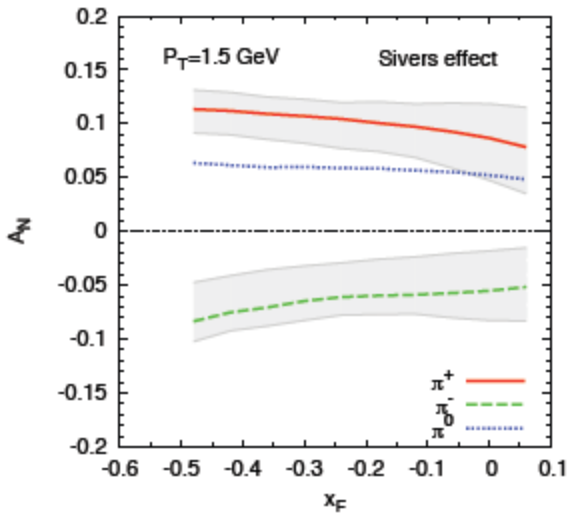
Conclusions

- **Inclusive hadron electroproduction was studied for the first time at Hermes**
- The process is analogue to $p^{\uparrow}p$ scattering: both have only one hard scale (hadron transverse momentum) and can help to understand the large asymmetries observed
- **Signicant $A_{UT}{}^{\sin\phi}$ asymmetry amplitudes for positively charged mesons** are observed at Hermes as a function of x_F and p_T.
- Differently from the $p^{\uparrow}p$ scattering case, the rise of the amplitudes with x_F is a reflection of the underlying dependence on p_T (strongly correlatated)
- **These preliminary results constitute the most precise measurement of inclusive hadron asymmetries in DIS experiments to date**
- Final results (extended to $p_T \approx 2\ GeV$) **will be published soon** along with detailed interpretation studies based on the analysis of different sub-samples.

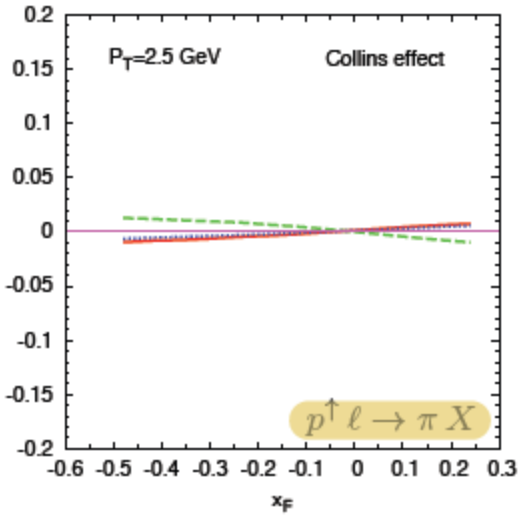
Backup

Comparison with predictions

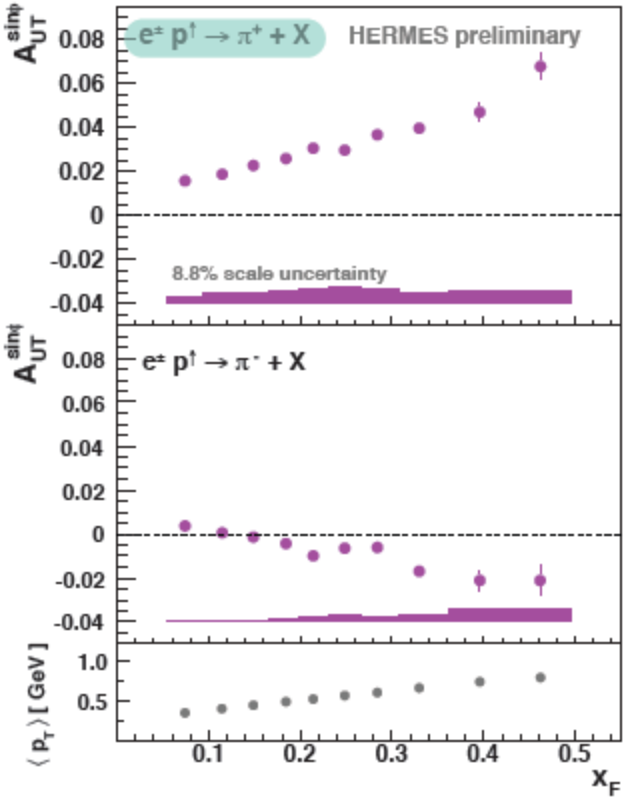
Sivers



Collins



inclusive Hadrons



- note different kinematical configuration :

$$A_N^{\ell p^\uparrow \to h(\text{jet})+X}(x_F, \boldsymbol{P}_T) = -A_N^{p^\uparrow \ell \to h(\text{jet})+X}(-x_F, \boldsymbol{P}_T)$$

electrons moving along the positive Z direction

protons moving along the positive Z direction