hermes measurement of the Collins and Sivers asymmetries from a transversely polarized hydrogen target

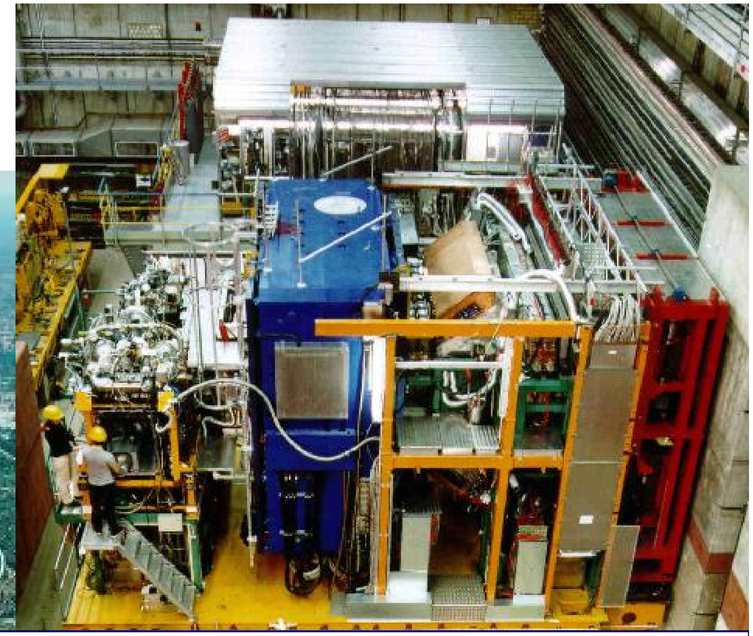
Francesca Giordano
INFN sez. Ferrara
Università degli studi di Ferrara

For the hermes collaboration

HERa MEasurement of Spin

HERA storage ring @ DESY

HERa MEasurement of Spin



Electron beam (27.6GeV/c) off

a transversely polarised

atomic hydrogen target

<P>~74±3%

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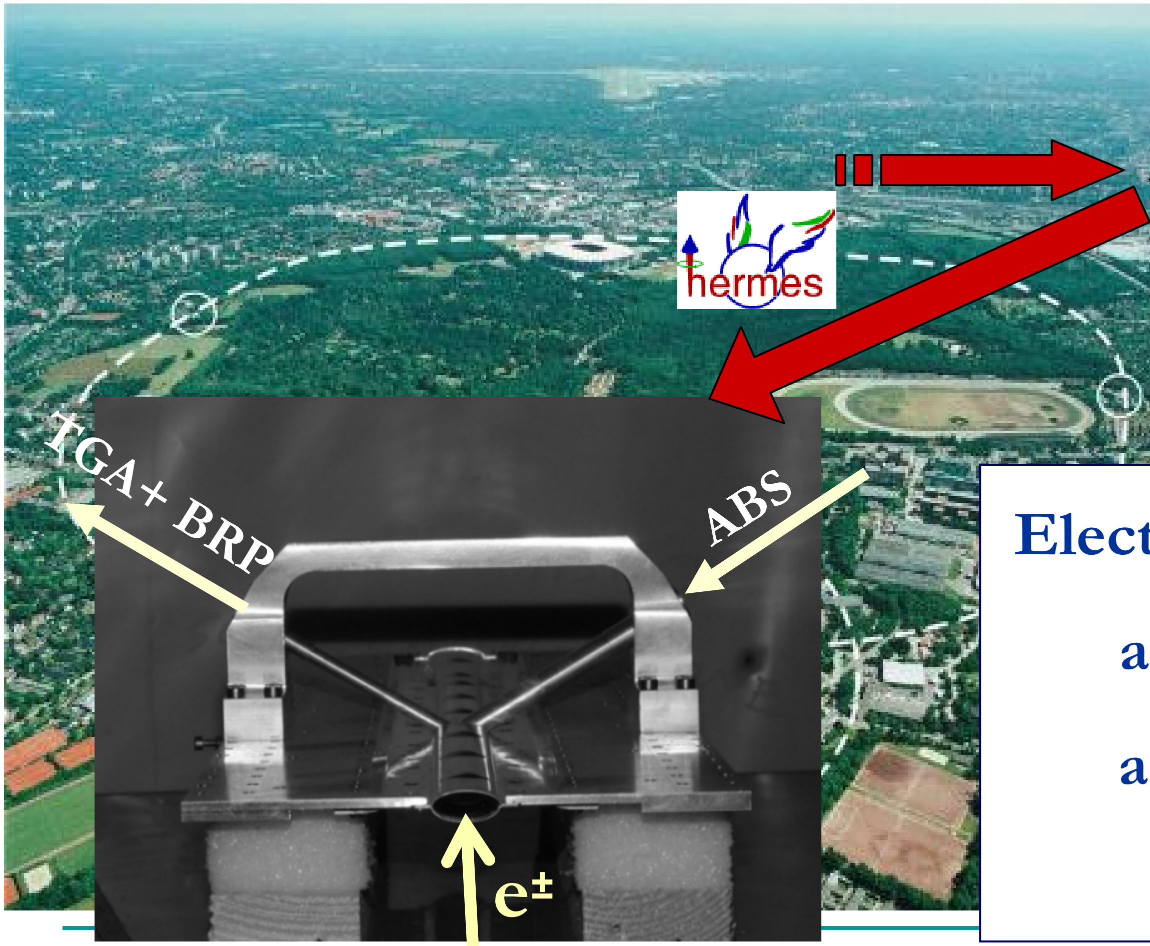

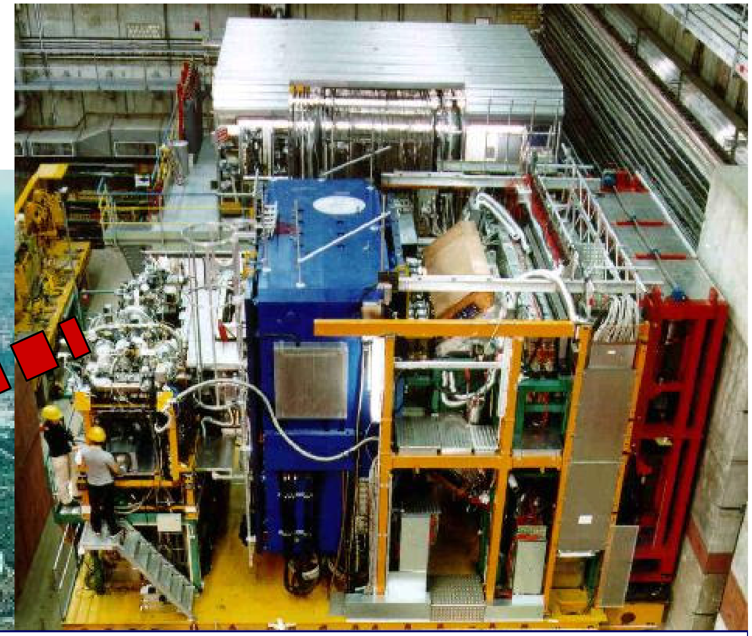

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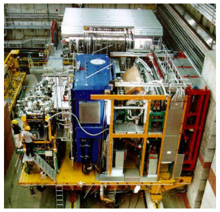
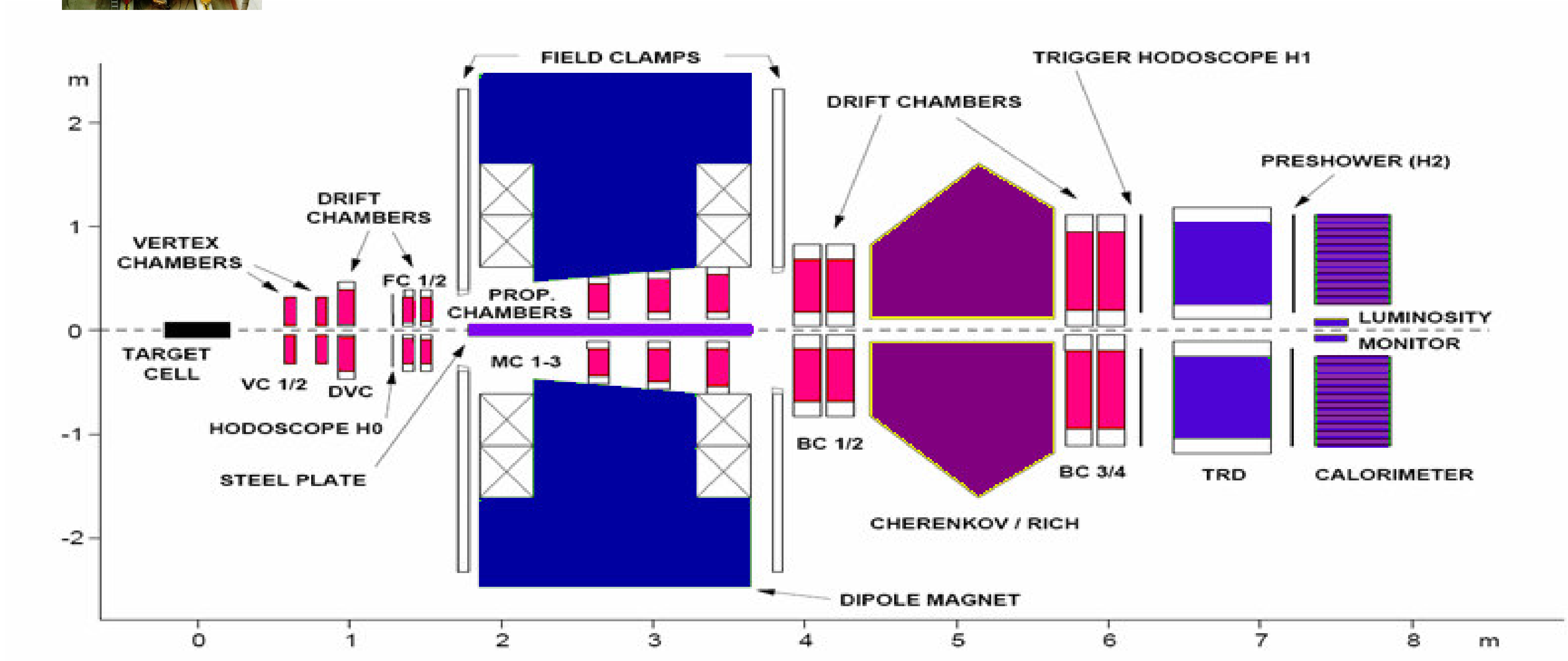


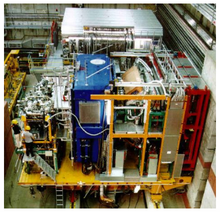
HERMES spectrometer



Resolution: $\Delta p/p \sim$ 1-2% $\Delta\theta$ <~0.6 mrad

Electron-hadron separation efficiency ~ 98-99%

Hadron identification with dual-radiator RICH



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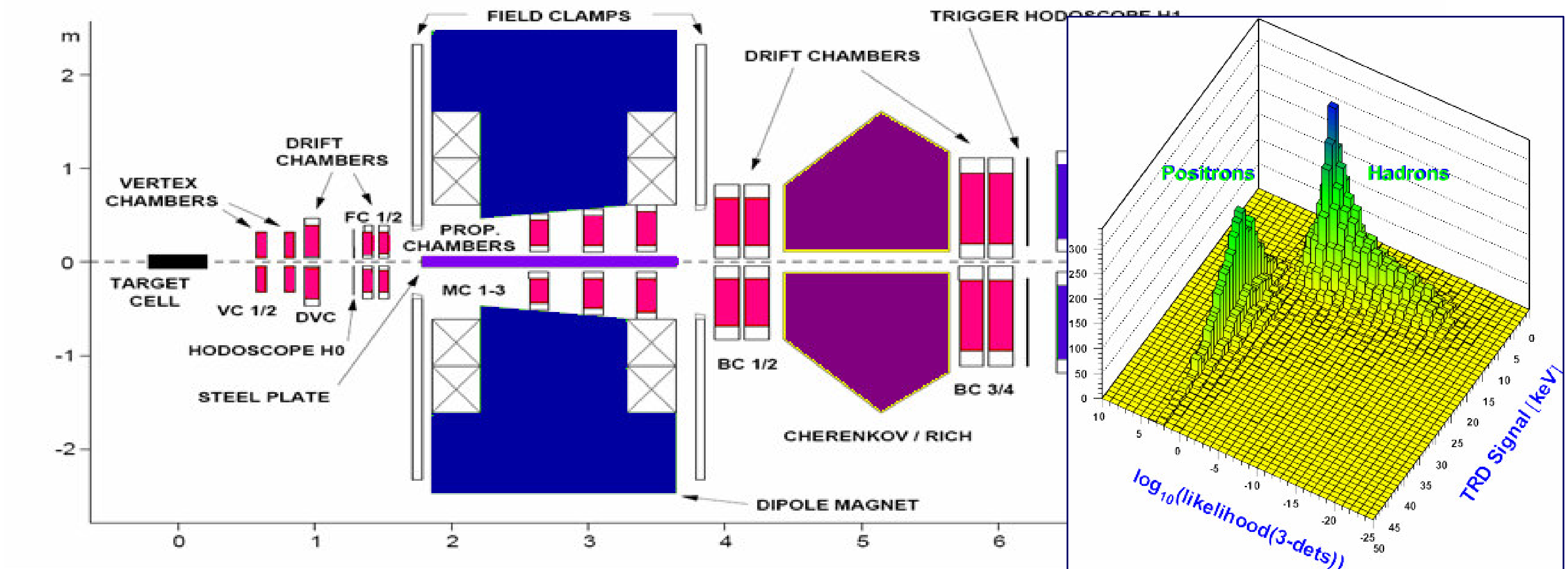

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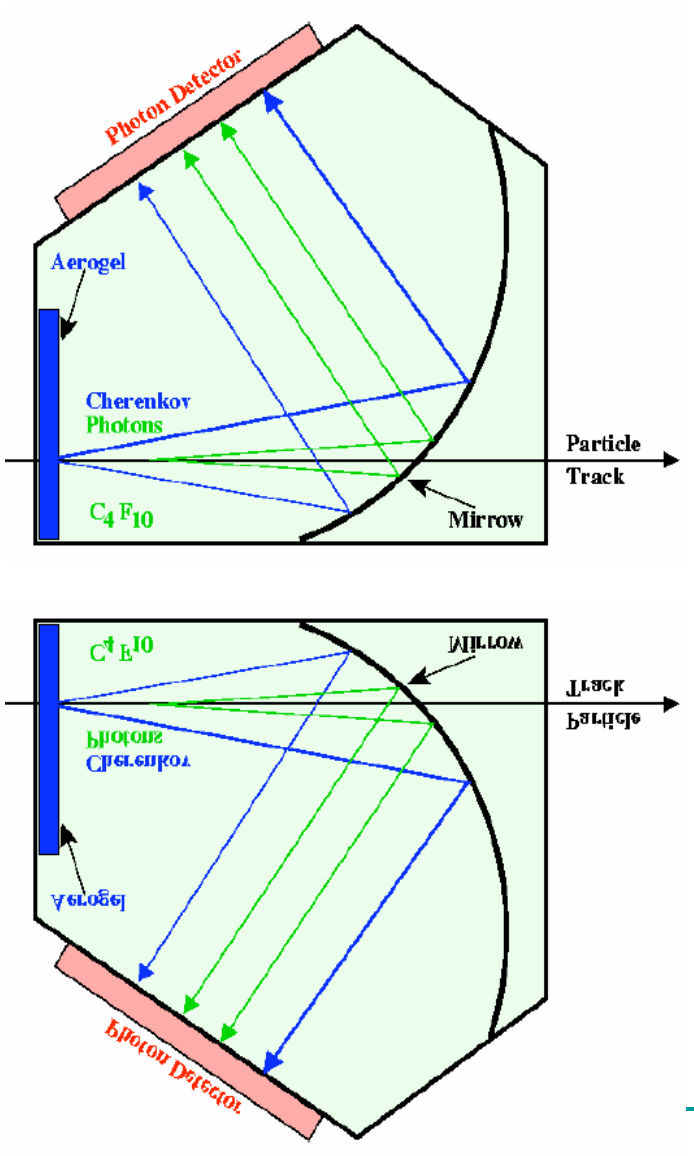

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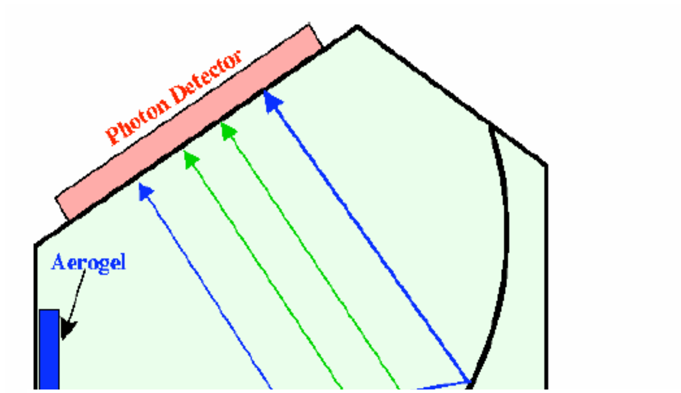
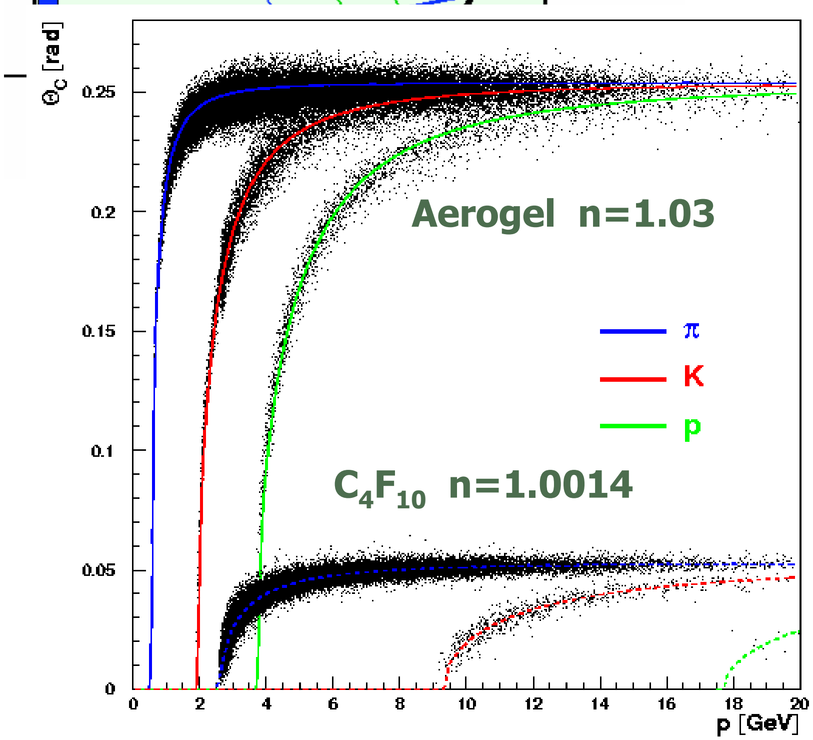
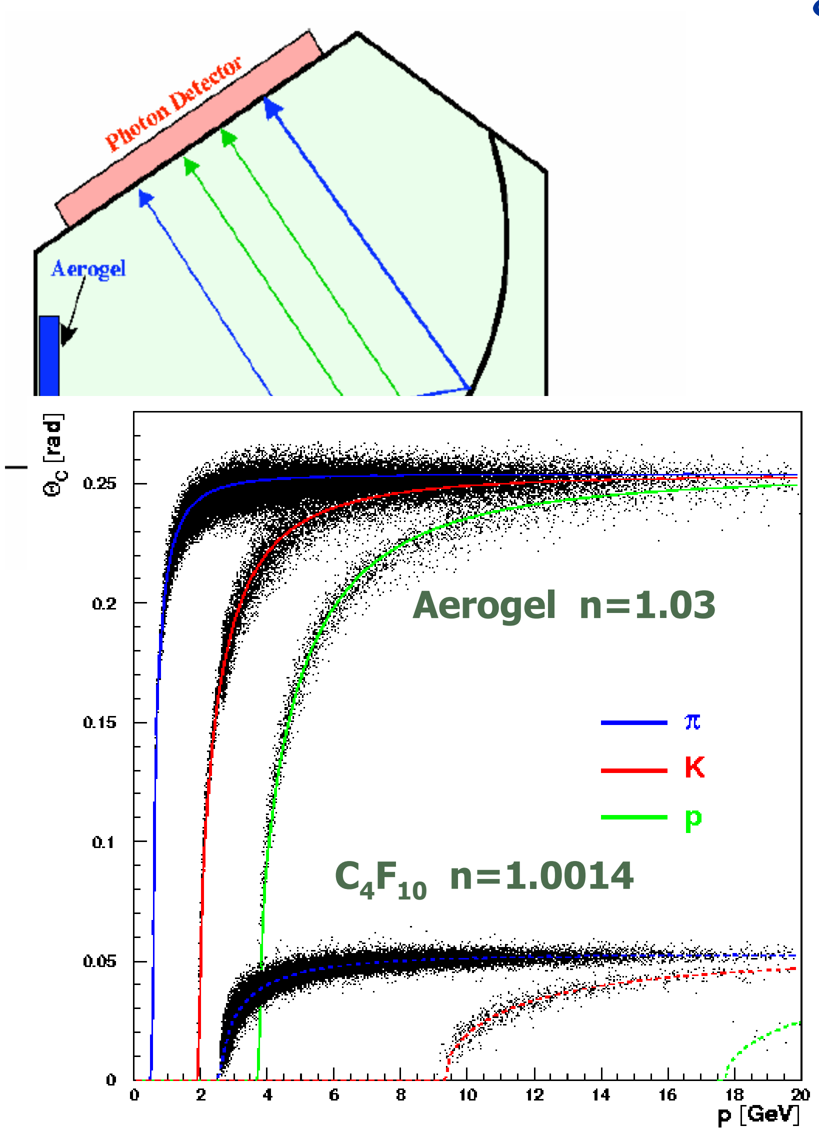
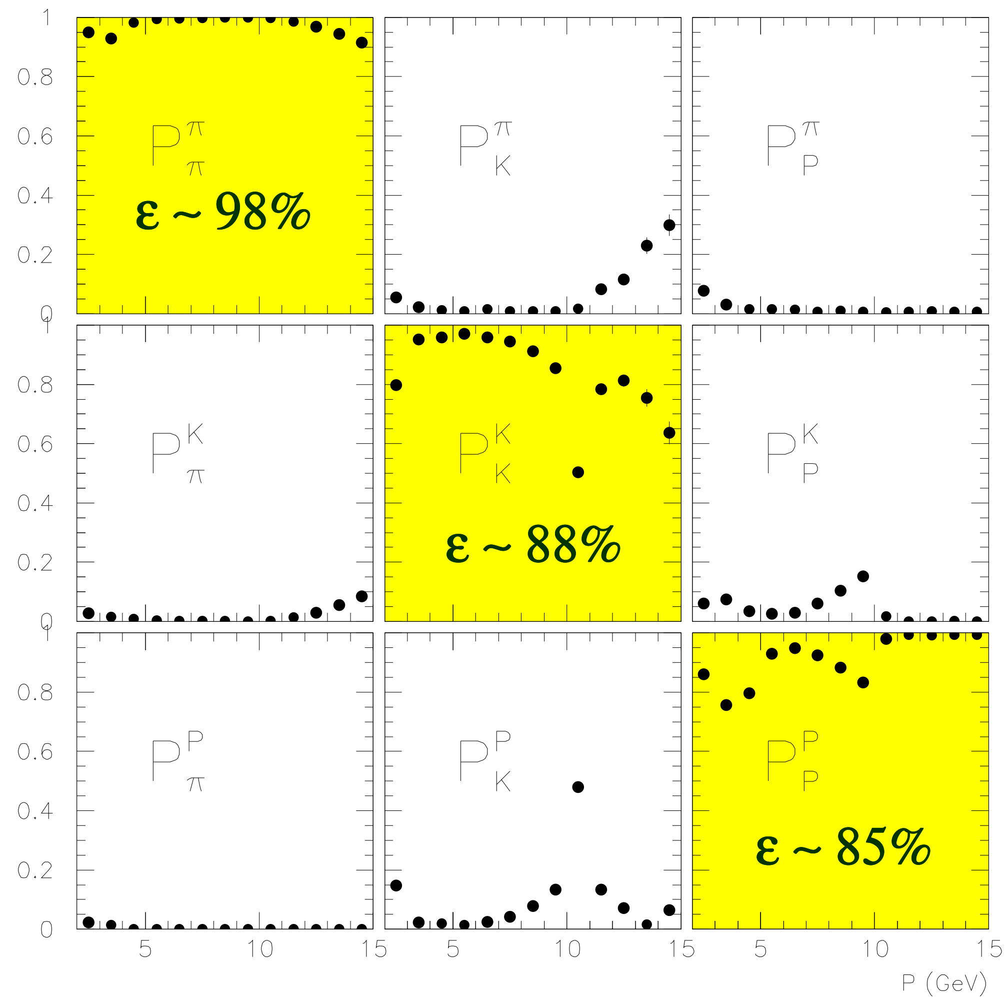




Dual radiator **R**ing **I**maging **CH**erenkov

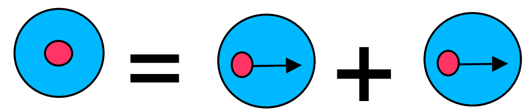




Nucleon quark structure

At leading twist there are 3 fundamental quark distribution functions:

Momentum distribution ***q(x)***



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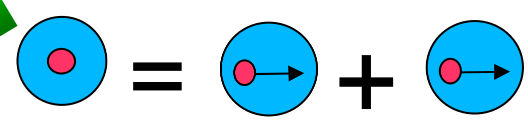

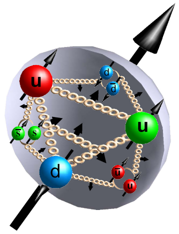

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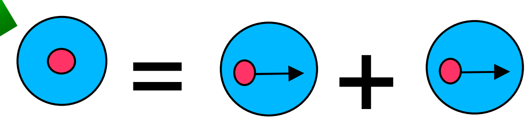
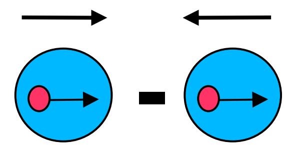
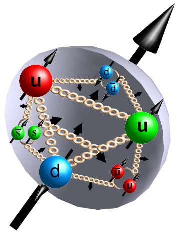


Helicity distribution ***Δq(x)***





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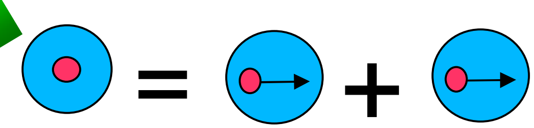

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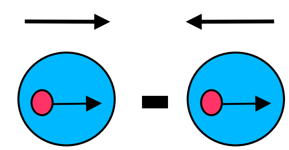

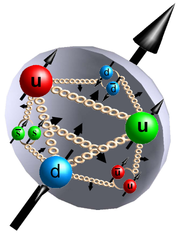

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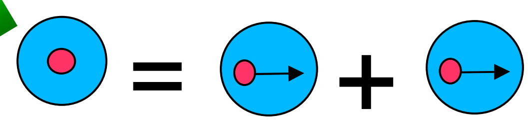

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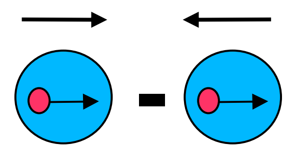
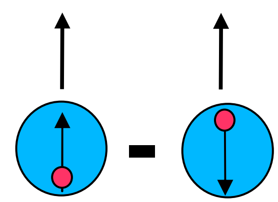
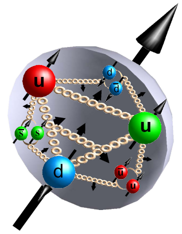


Transversity distribution ***δq(x)***





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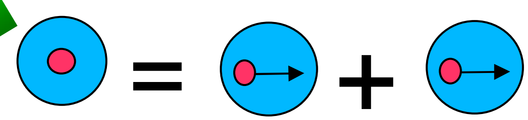

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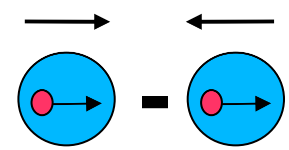
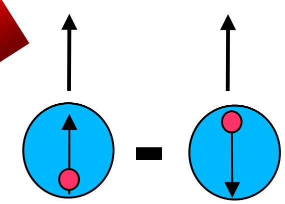
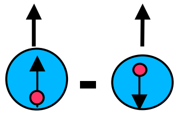
KNOWN



Transversity distribution ***δq(x)***

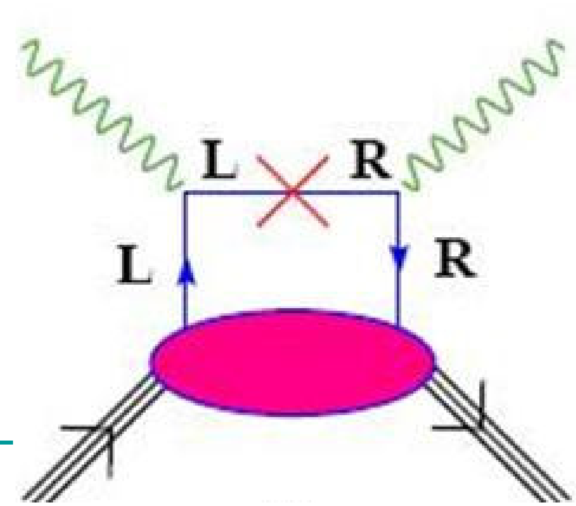
FIRST HINT !

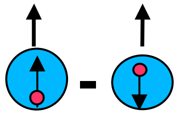




Transversity

The transversity distribution function is associated with an helicity flip of the struck quark. For this reason it is known as a **chiral-odd** function, and it cannot be probed in Inclusive Deep Inelastic Scattering.





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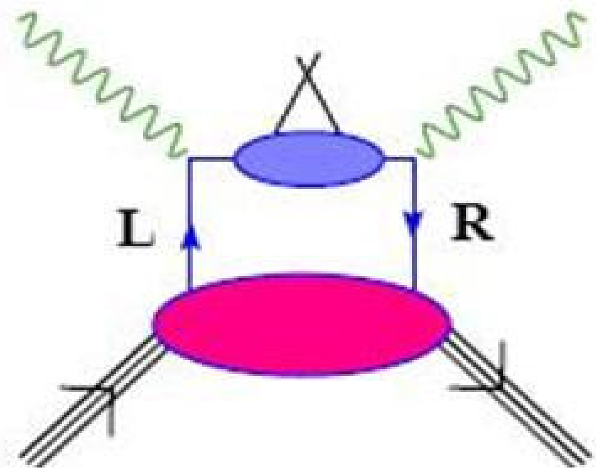
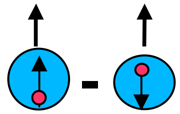
Semi **I**nclusive **D**eep **I**nelastic **S**cattering**:** transversity is coupled to a chiral-odd **F**ragmentation **F**unction;





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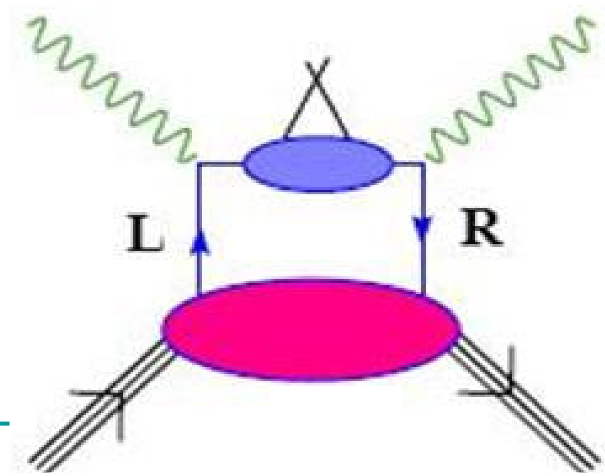
$$\delta q \quad \otimes \quad FF^{q \to h}$$

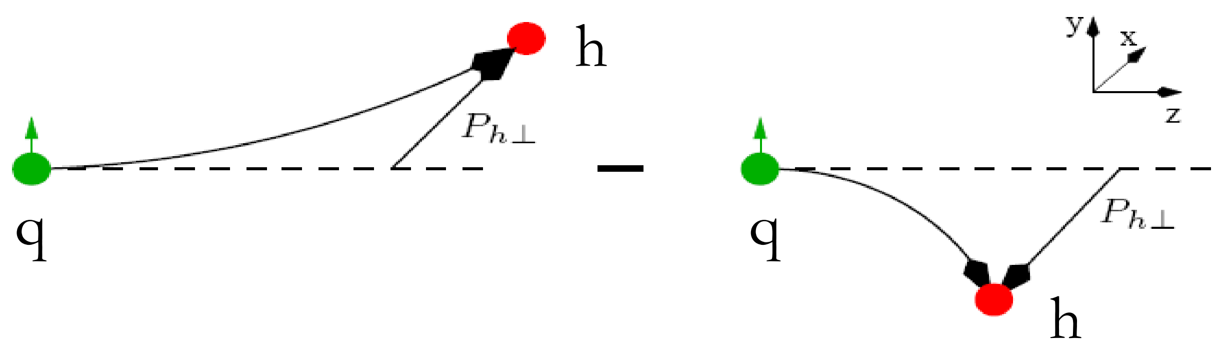
chiral-odd DF — **chiral-odd FF**

CHIRAL-EVEN!



Collins mechanism

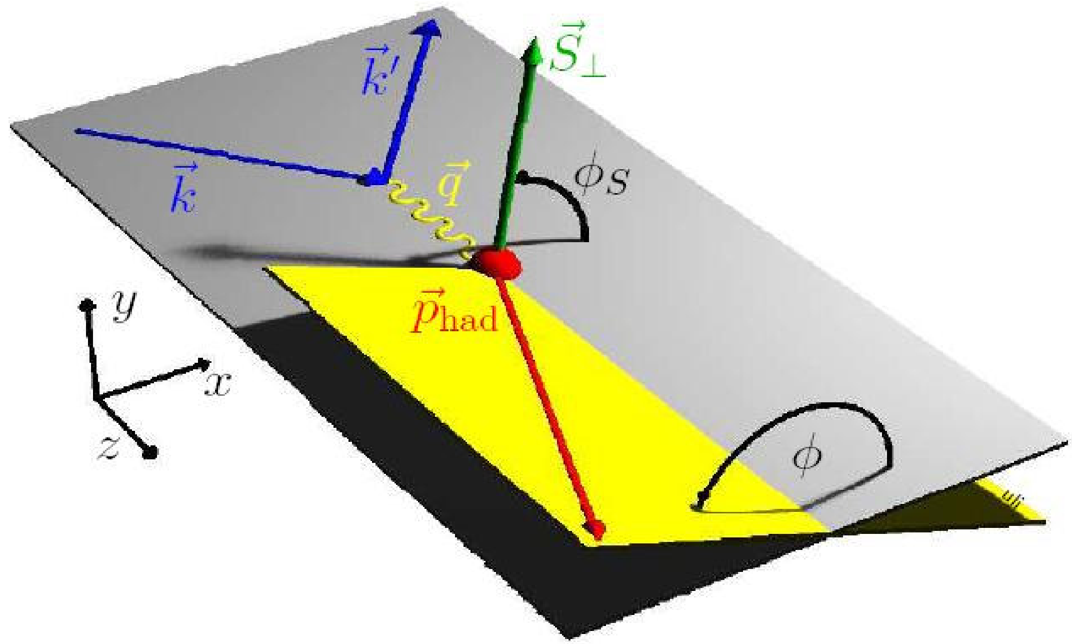
The Collins Fragmentation Function $H_1^{\perp}(z, k_T^2)$ describes the correlation between the transverse polarization of the struck quark and the transverse momentum of the produced unpolarised hadron

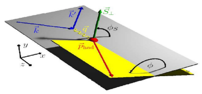


The Collins mechanism produces an **azimuthal asymmetry** in the direction of the outgoing hadrons

Azimuthal **S**ingle **S**pin **A**symmetries

$$A_{UT}^{h} = \frac{\sigma_h^{\uparrow\Downarrow} - \sigma_h^{\uparrow\Uparrow}}{\sigma_h^{\uparrow\Downarrow} + \sigma_h^{\uparrow\Uparrow}}$$



 Azimuthal **S**ingle **S**pin **A**symmetries

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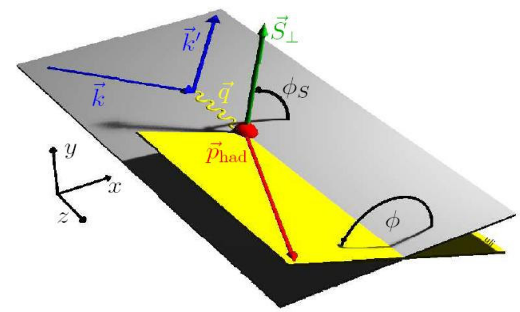

$$A_{UT}^{h} \propto 2\left|S_T\right| \sin\left(\varphi + \varphi_S\right) \frac{\sum_q e_q^2 \; I[\frac{(\vec{k}_T \cdot \hat{P}_{h\perp})}{M_h} \delta q(x, p_T^2) H_1^{\perp q}(z, k_T^2)]}{A(y) \sum_q e_q^2 q(x, k_T^2) D_1^q(z, k_T^2)}$$

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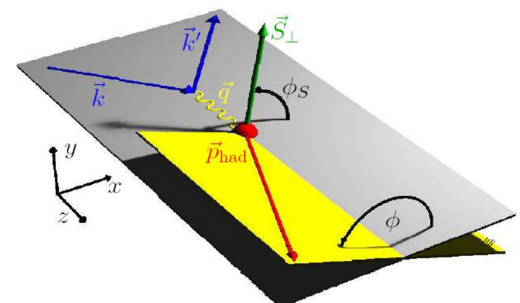

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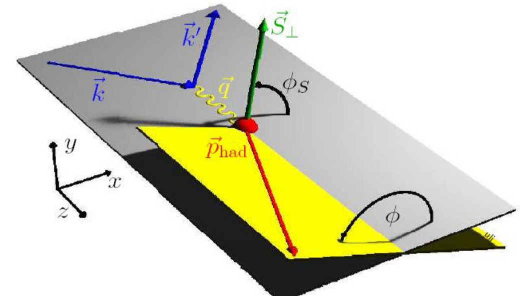

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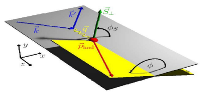
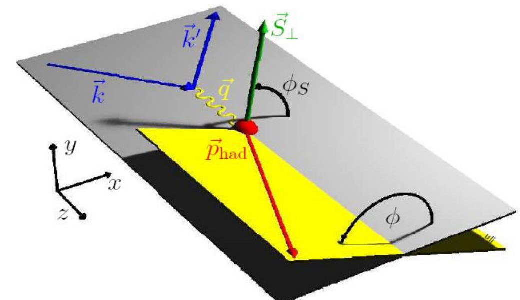
$$+ 2\left|S_T\right| \; \sin\left(\varphi - \varphi_S\right) \frac{\sum_q e_q^2 \; I[\frac{(\vec{p}_T \cdot \hat{P}_{h\perp})}{M} f_{1T}^{\perp q}(x, k_T^2) D_1^q(z, k_T^2)]}{A(y) \sum_q e_q^2 q(x, k_T^2) D_1^q(z, k_T^2)}$$



Azimuthal Single Spin Asymmetries

$$\boxed{A_{UT}^{h} = \frac{\sigma_h^{\uparrow\Downarrow} - \sigma_h^{\uparrow\Uparrow}}{\sigma_h^{\uparrow\Downarrow} + \sigma_h^{\uparrow\Uparrow}}}$$



$$A_{UT}^{h} \propto 2\left|S_T\right| \sin\left(\varphi + \varphi_S\right) \frac{\sum_q e_q^2 \, I\left[\frac{(\vec{k}_T \cdot \hat{P}_{h\perp})}{M_h} \boxed{\delta q(x, p_T^2) H_1^{\perp q}(z, k_T^2)]}\right.}{A(y) \sum_q e_q^2 q(x, k_T^2) D_1^q(z, k_T^2)}$$

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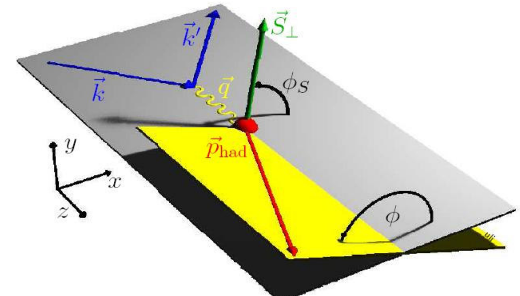

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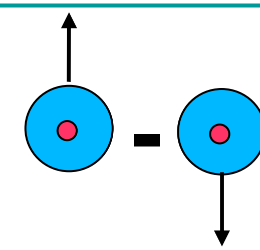
Collins signature

$$+2\left|S_T\right| \boxed{\sin\left(\varphi - \varphi_S\right)} \frac{\sum_q e_q^2\, I\left[\frac{(\vec{p}_T \cdot \hat{P}_{h\perp})}{M} \boxed{f_{1T}^{\perp q}(x, k_T^2) D_1^q(z, k_T^2)}\right]}{A(y)\sum_q e_q^2 q(x, k_T^2) D_1^q(z, k_T^2)}$$

Sivers signature

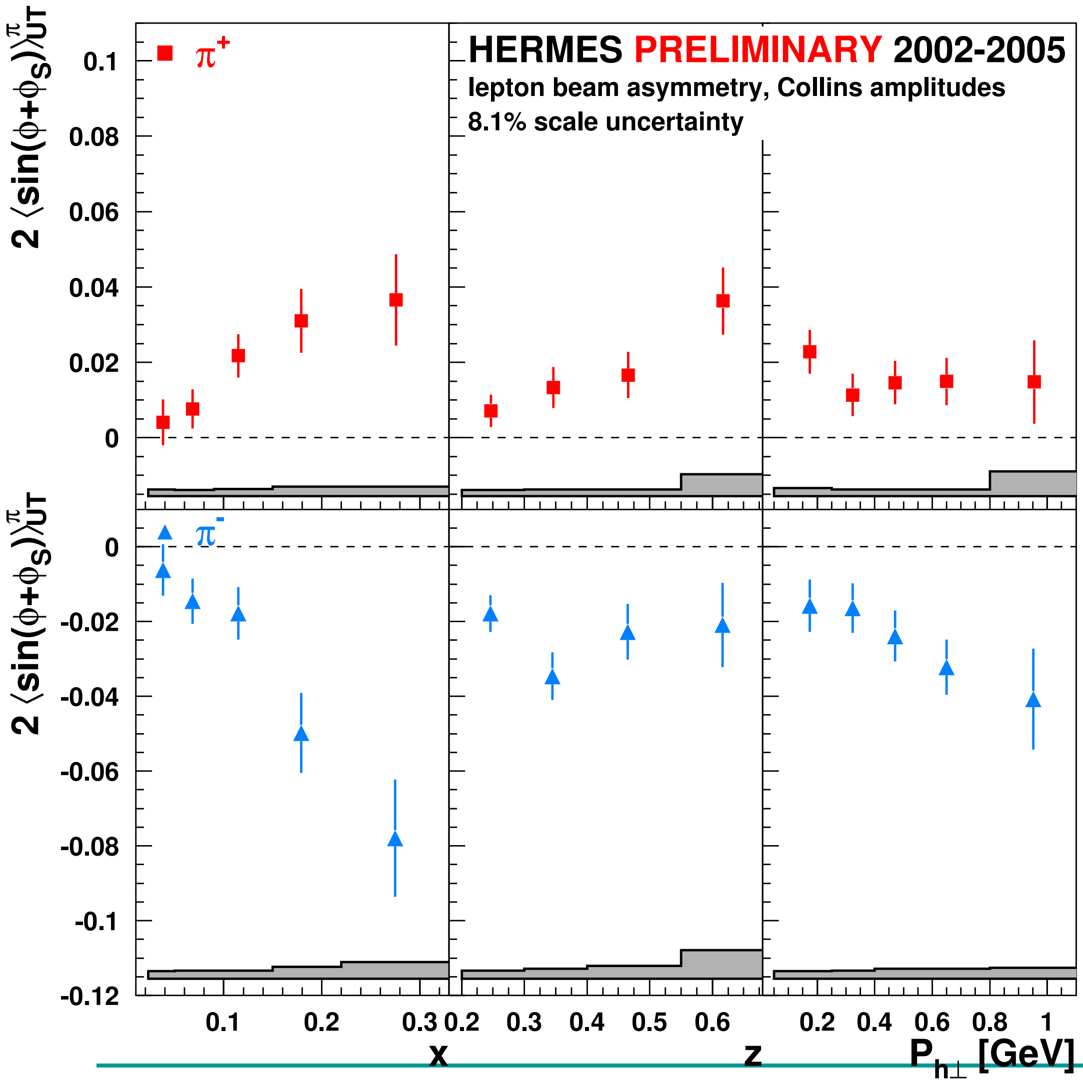
Sivers mechanism

$f_{1T}^{\perp q}(x, p_T^2)$ 

The Sivers function $f_{1T}^{\perp q}(x, p_T^2)$ describes the correlation between the transverse polarization of the nucleon and the transverse momentum of the quark within → **spin-orbit structure** of the nucleon

a non-zero Sivers function requires a **non-vanishing orbital angular momentum** inside the nucleon

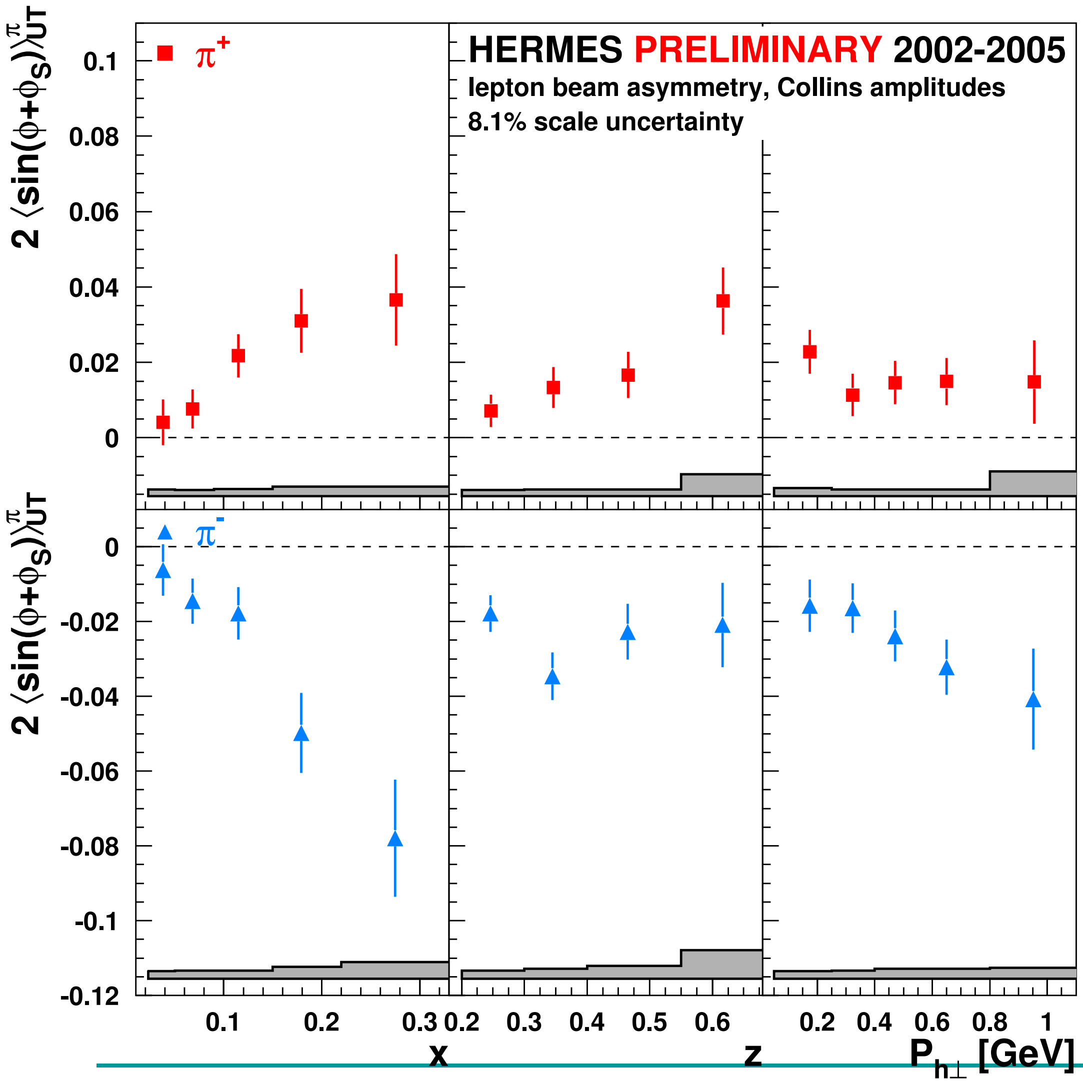
Collins amplitudes for charged pions



→ **Large positive for π^+**

→ **Large negative for π^-**

Collins amplitudes for charged pions



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$$\boxed{u \rightarrow \pi^+ \quad H_1^{\perp, fav}}$$

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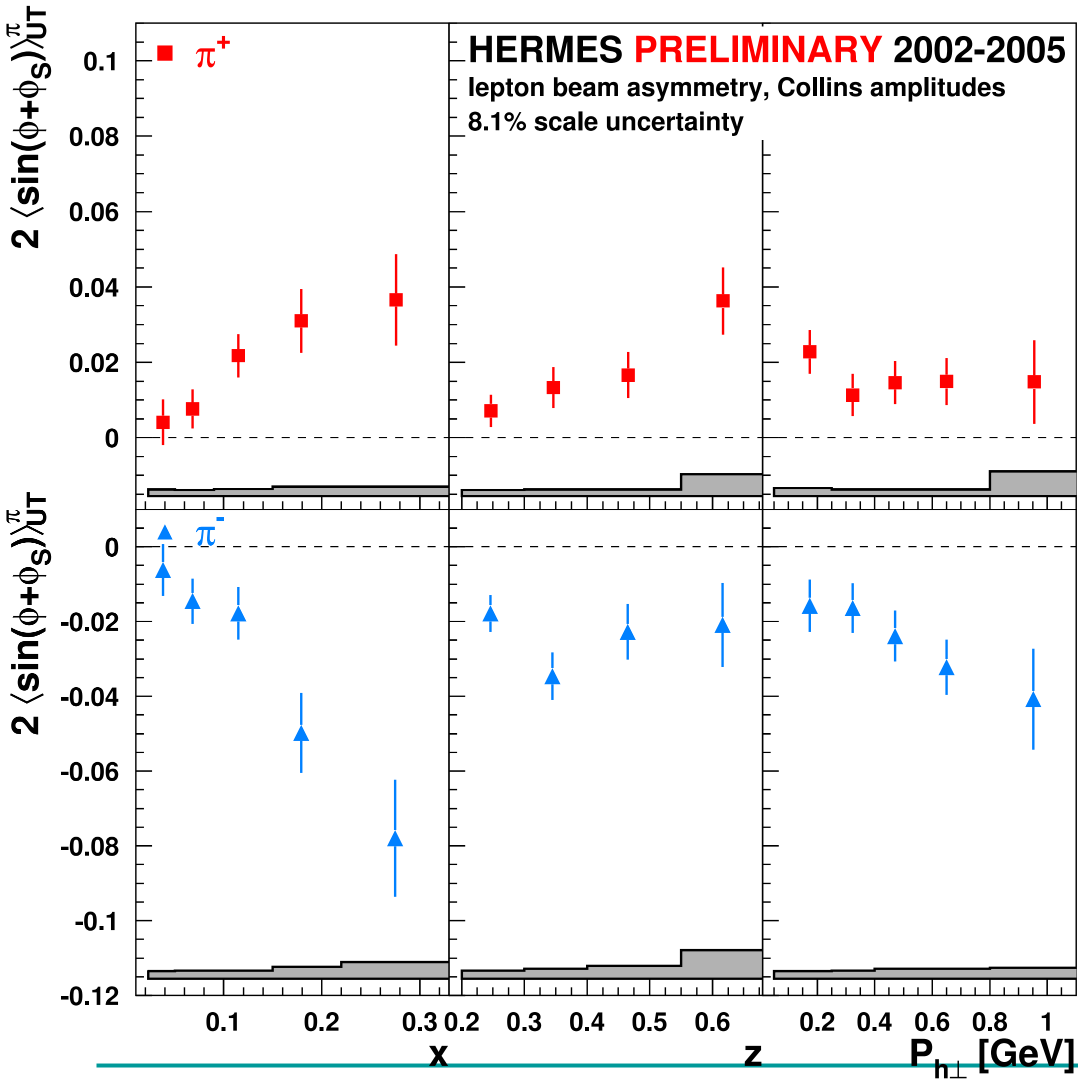

→ Large positive for π^+

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$$\boxed{u \rightarrow \pi^{+} \quad H_1^{\perp,\,fav}}$$

$$\boxed{u \rightarrow \pi^{-} \quad H_1^{\perp,\,unfav}}$$

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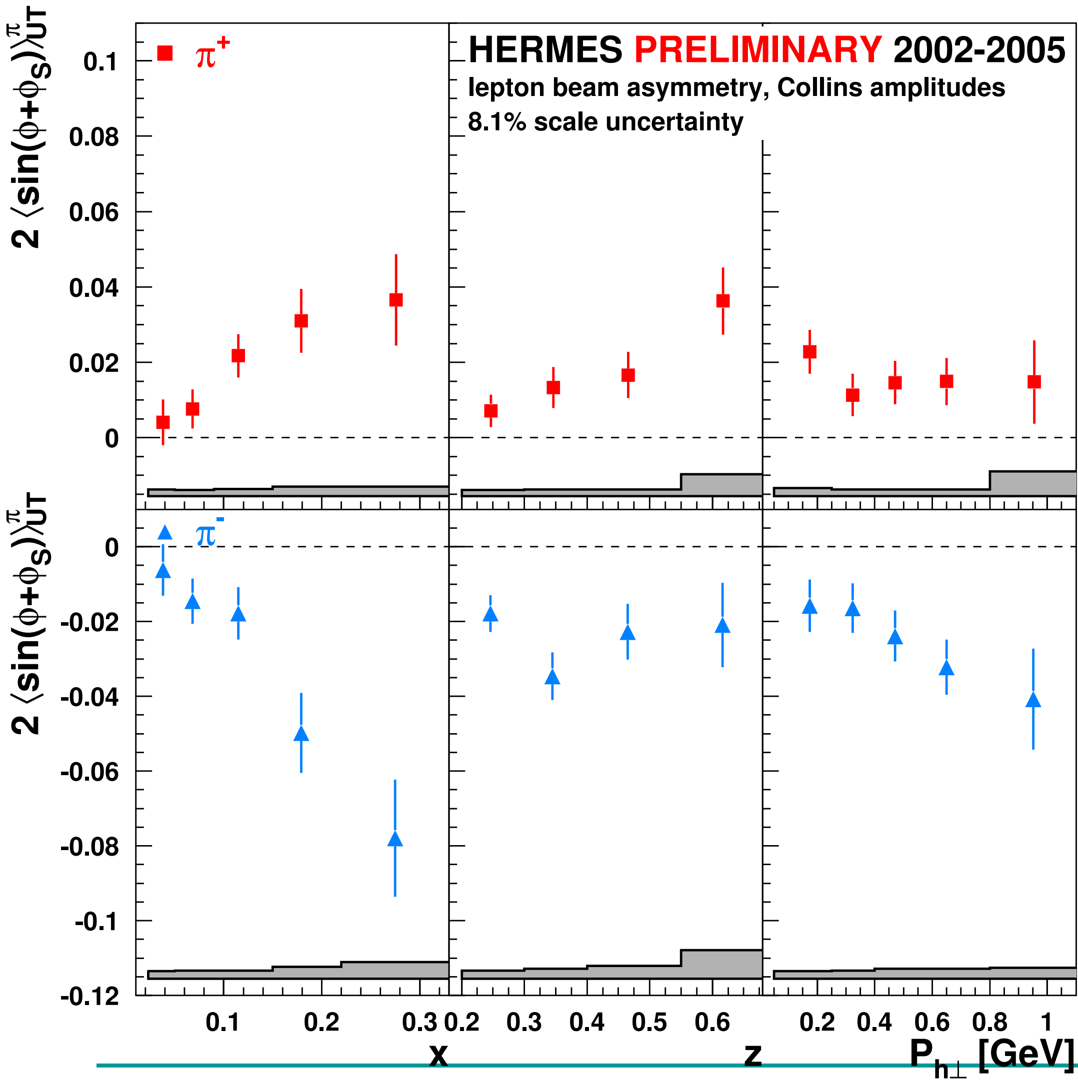


→ Large positive for π^+

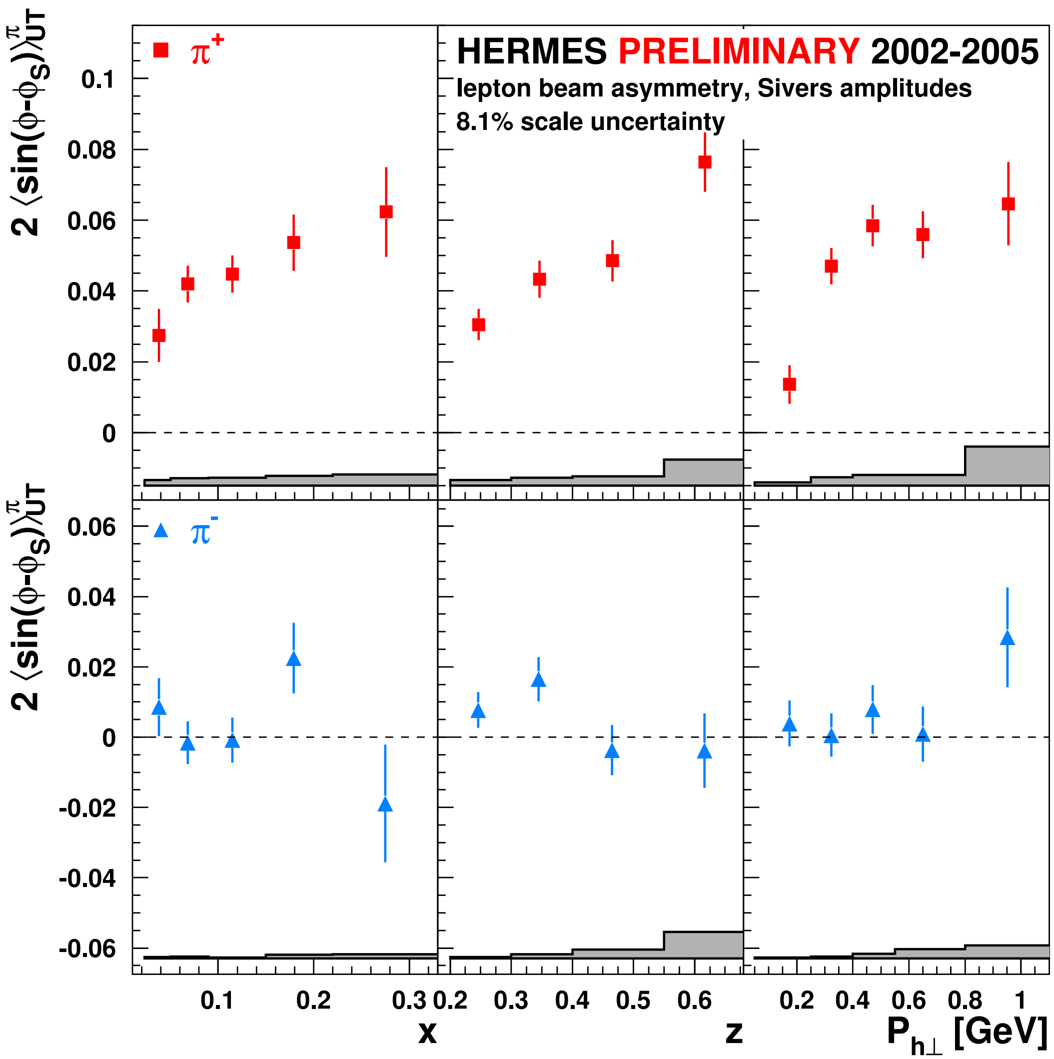
→ Large negative for π^-

$$u \rightarrow \pi^+ \quad H_1^{\perp, fav}$$

$$u \rightarrow \pi^- \quad H_1^{\perp, unfav}$$

$$\boxed{H_1^{\perp, unfav} \approx -H_1^{\perp, fav}}$$

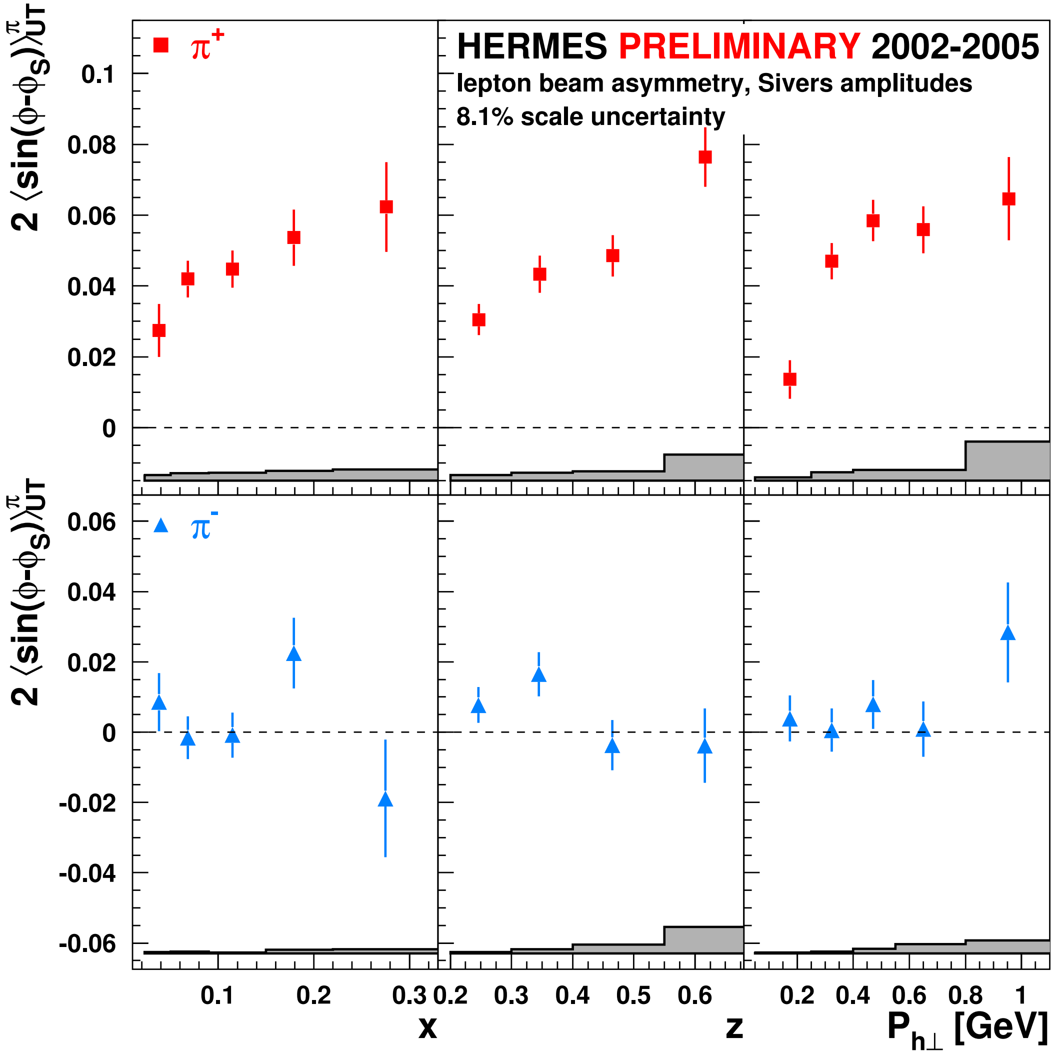
Sivers amplitudes for charged pions



→ Large positive for π^+

→ Consistent with zero for π^-

Sivers amplitudes for charged pions



→ Large positive for π^+

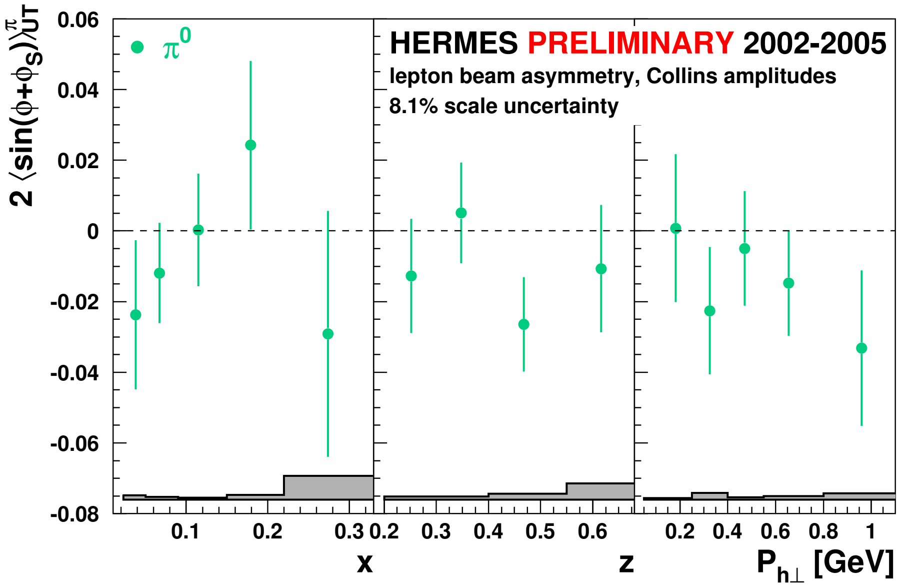
→ Consistent with zero for π^-

Non zero quark orbital angular momentum !

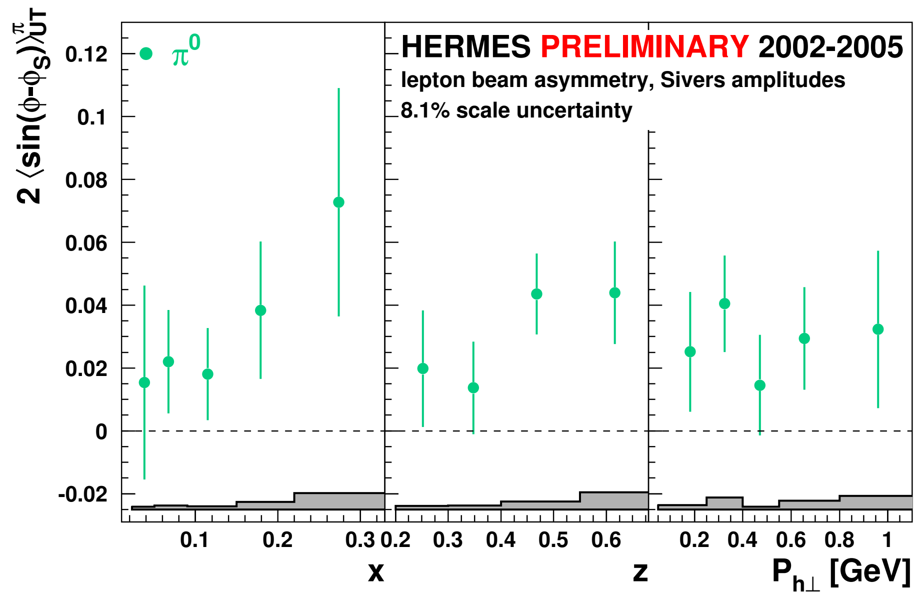
$\pi^0 \rightarrow \gamma\gamma$

The neutral pions

Collins amplitudes

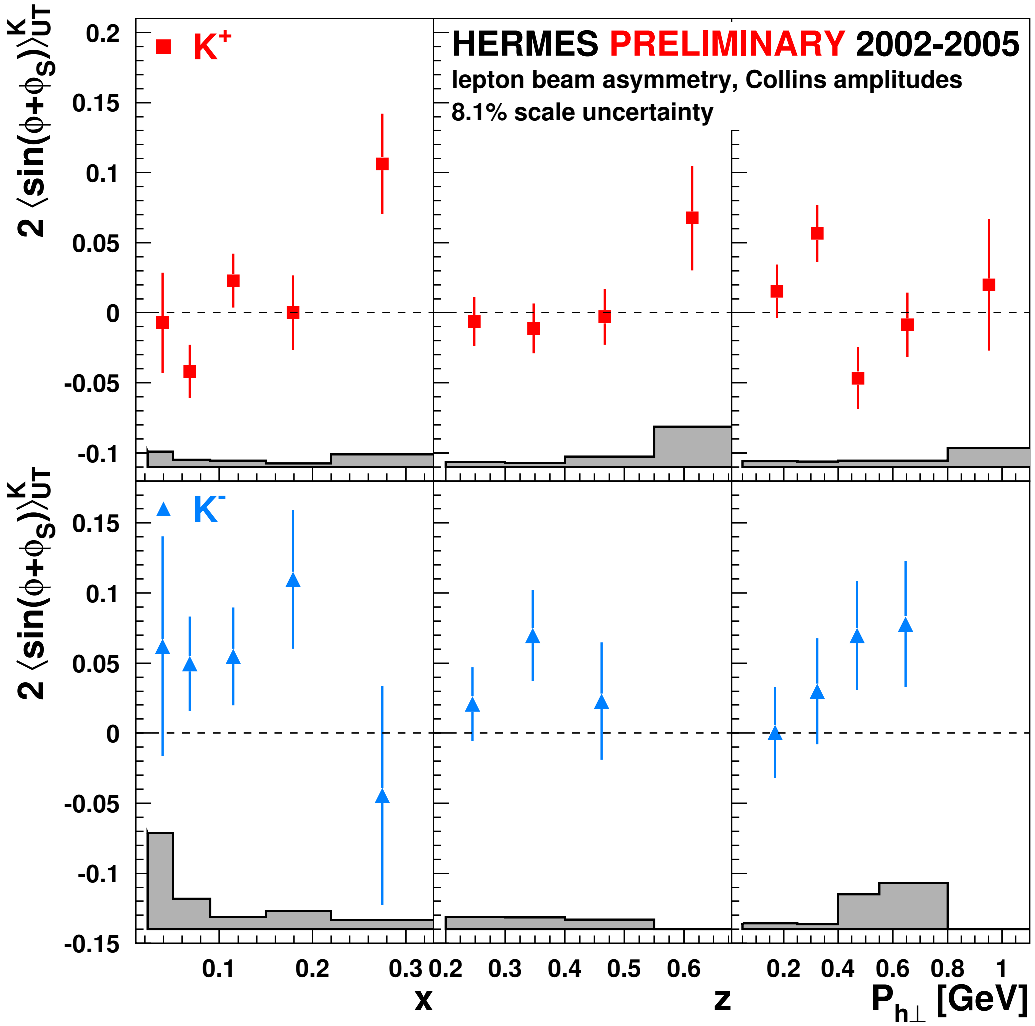


Sivers amplitudes



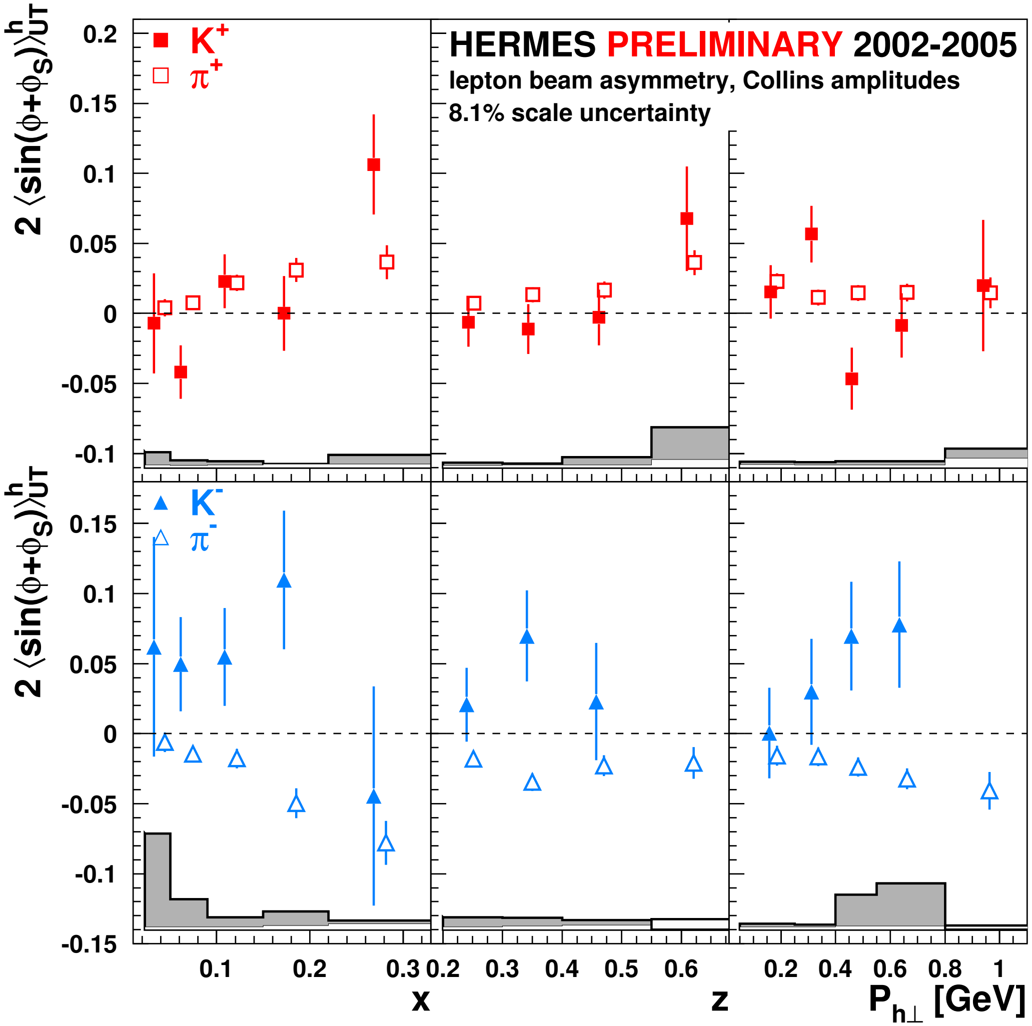
Isospin symmetry fulfilled for π-mesons SSA amplitudes!

Collins amplitudes for charged kaons



→ **No significant non-zero Collins amplitudes for Kaons**

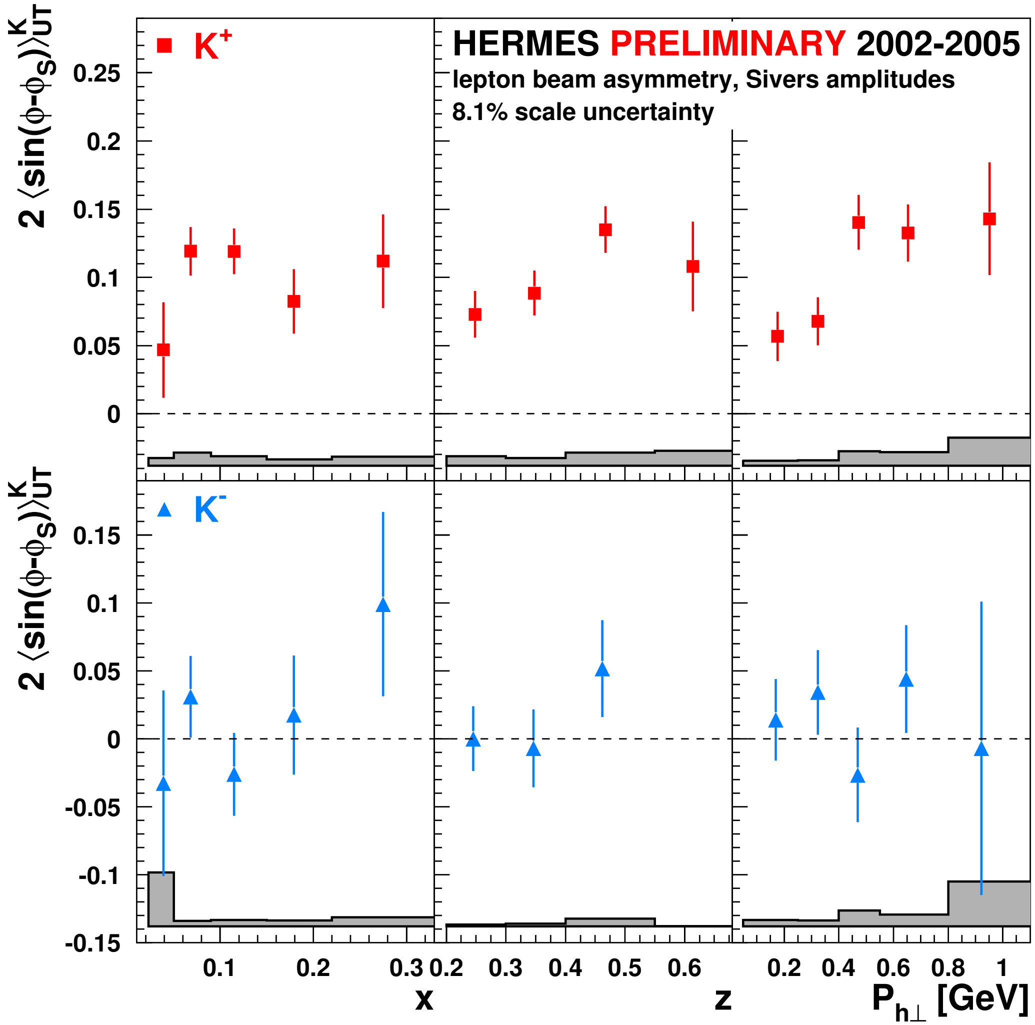
Collins amplitudes for charged kaons



→ No significant non-zero Collins amplitudes for Kaons

→ Collins amplitudes for K^+ compatible with π^+

Sivers amplitudes for charged kaons

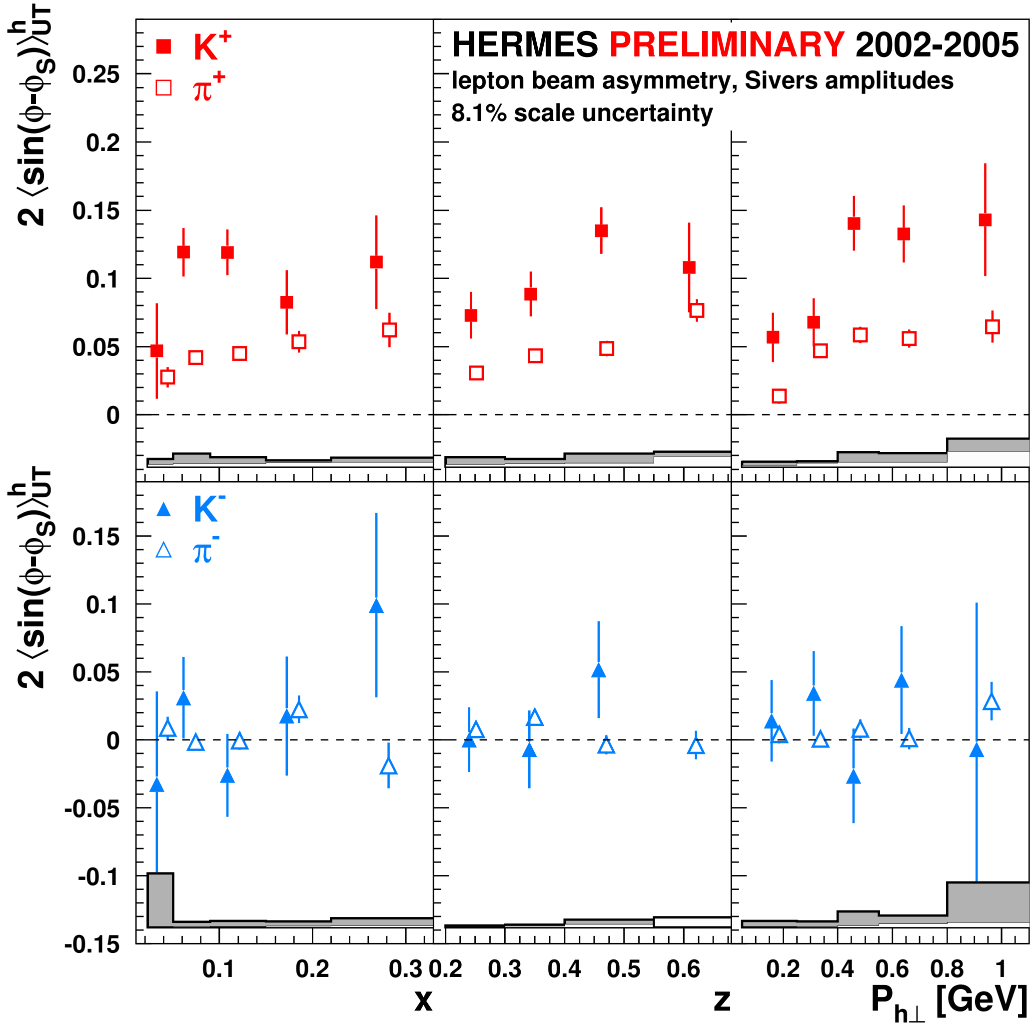


→ **Large positive for K^+**

→ **Consistent with zero for K^-**

but….

Sivers amplitudes for charged kaons

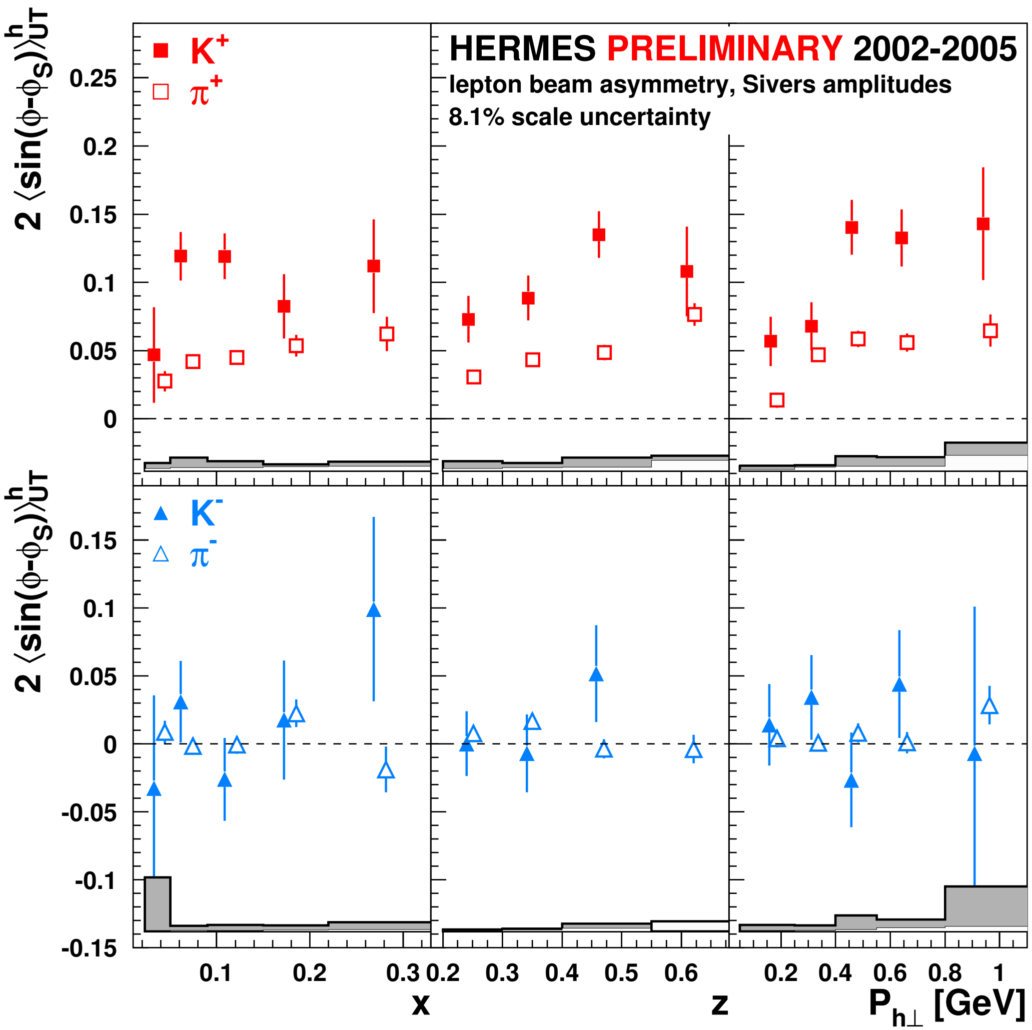


→ Large positive for K^+

→ Consistent with zero for K^-

→ K^+ amplitudes are larger than the π^+ amplitudes!

Sivers amplitudes for charged kaons



→ Large positive for K^+

→ Consistent with zero for K^-

→ K^+ amplitudes are larger than the π^+ amplitudes!

Significant sea quark contribution?

Conclusion

- **The first evidence of a significant SSA Collins amplitudes for π-mesons**

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$$\boxed{A_{UT}^{\sin(\varphi+\varphi_S)} \propto \delta q(x) \otimes H_1^{\perp q}(z)}$$

Conclusion

- **The first evidence of a significant SSA Collins amplitudes for π-mesons**

$$A_{UT}^{\sin(\varphi+\varphi_S)} \propto \delta q(x) \otimes H_1^{\perp q}(z)$$

R.Seidl et al.

Phys.Rev.Lett. 96,232002 (2006)

E.S.Ageev et al.

Nucl.Phys.B765,31 (2007)

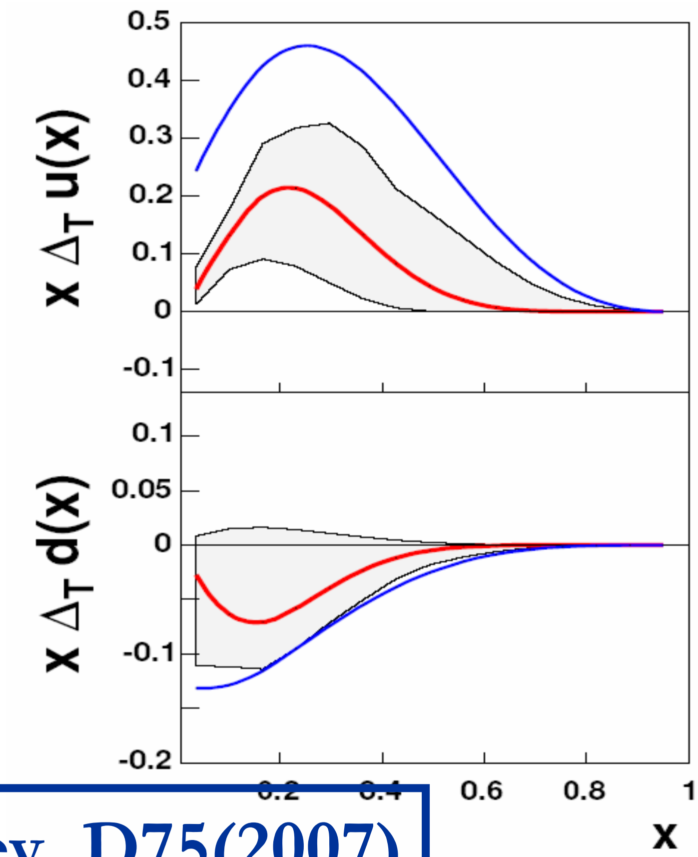
A.Airapetian et al.

Phys.Rev.Lett. 94,012002 (2005)

Conclusion

- The first evidence of a significant SSA Collins amplitudes for π-mesons

$$A_{UT}^{\sin(\varphi+\varphi_S)} \propto \delta q(x) \otimes H_1^{\perp q}(z)$$



First extraction of transversity!

Anselmino et al. Phys.Rev. D75(2007)

Conclusion

- **The first evidence of a significant SSA Collins amplitudes for π-mesons**

- **Significant SSA Sivers amplitudes for π^+ and K^+**

Conclusion

- The first evidence of a significant SSA Collins amplitudes for π-mesons

- Significant SSA Sivers amplitudes for π^+ and K^+

  $\Rightarrow$ non-zero quark orbital angular momenta!

Thanks!

Vector meson contributions