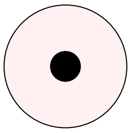
# Single Spin Azimuthal Asymmetries

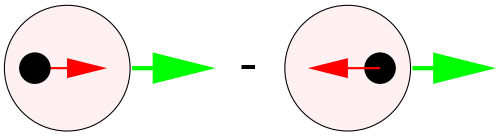
D. Hasch
INFN - Laboratori Nazionali di Frascati
for the HERMES Collaboration

- Motivation
- Cross section single spin azimuthal asymmetries (SSA)
- Weighted SSA
- Summary

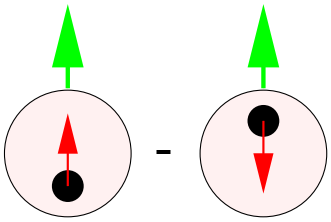
# parton distribution functions

$f_1$ = 

unpolarised quark in unpolarised nucleon

$g_{1L}$ = 

longitudinal polarised quark in longitudinal polarised nucleon

$h_1$ = 

transverse polarised quark in transverse polarised nucleon

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transverse quark polarisation densities accessible via
single spin azimuthal asymmetries

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chiral-odd DF

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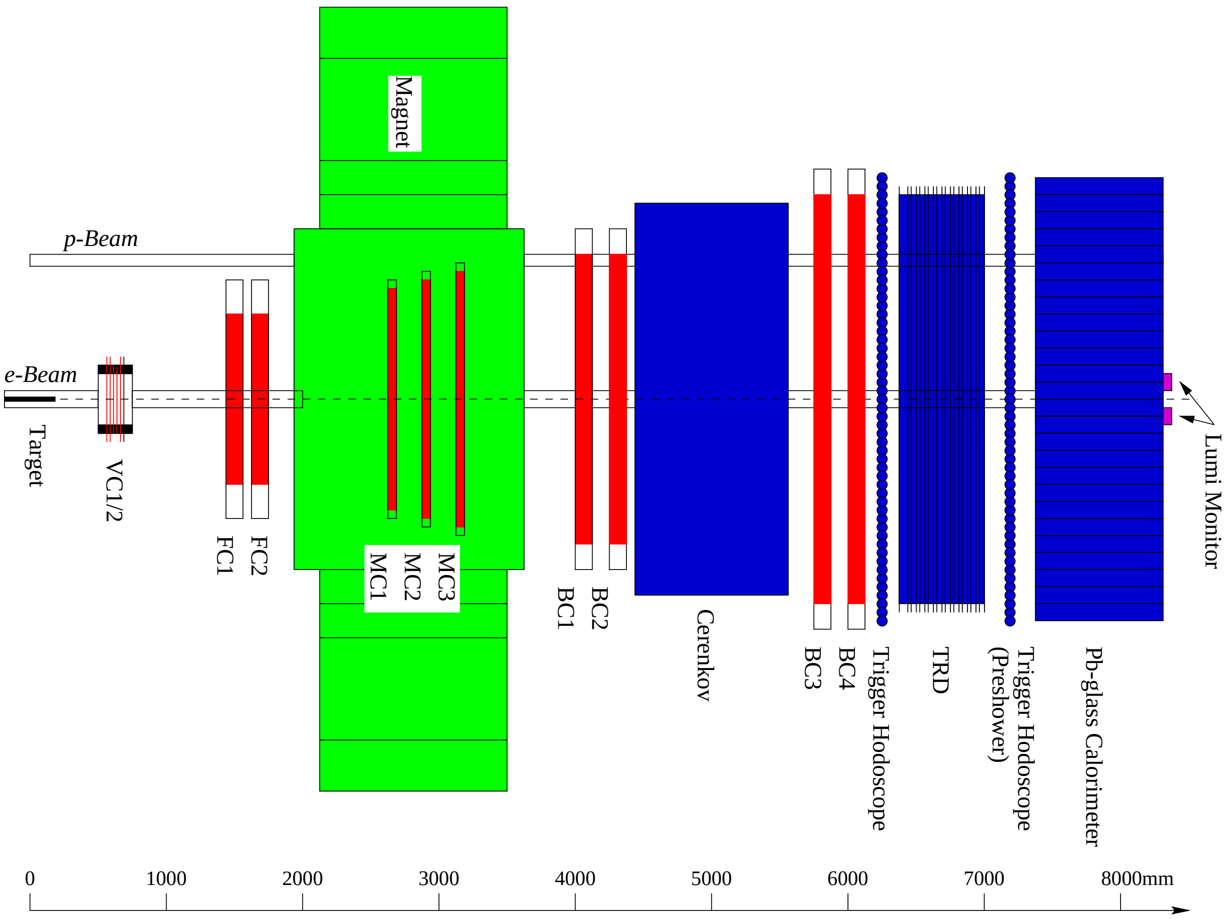
time-odd Collins FF

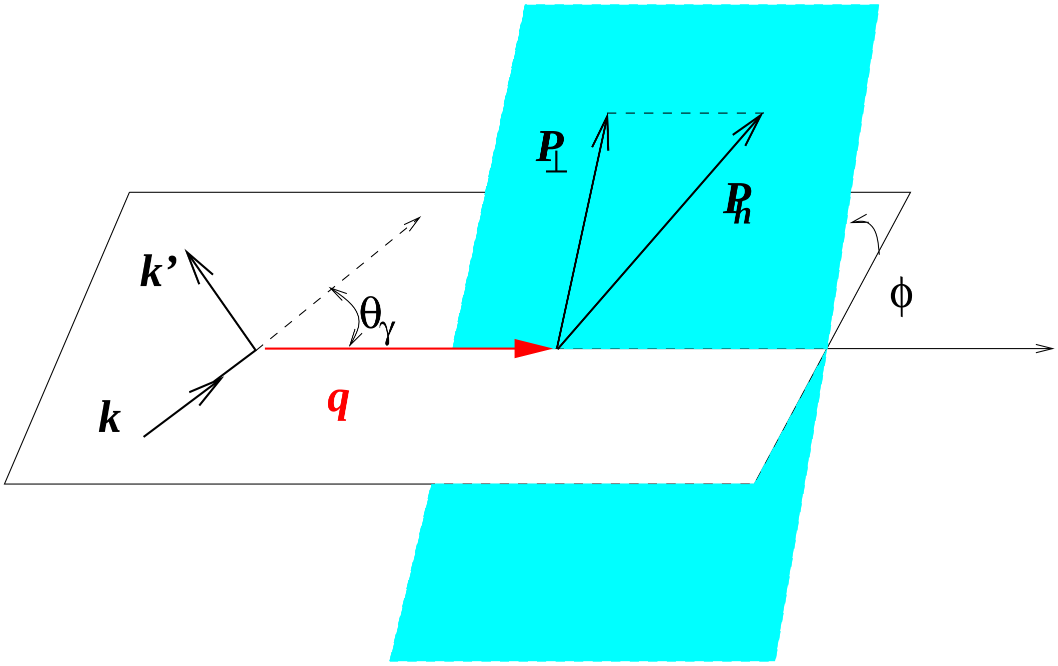
# HERMES -experiment




- beam: 27.5 GeV Hera polarised $e^+$
- target: internal storage cell gas target
- **tracking: 57 tracking planes**
  $\delta P/P = (0.7 - 1.3)\%$, $\delta\theta < 0.6$ mrad
- **particle identification: Čerenkov, TRD, Preshower, Calorimeter**

# study azimuthal distribution of semi-inclusive and exclusive $\pi$ production: ep$\rightarrow$ e$'\pi$X

good $\pi$ identification for $E_\pi = 5 - 14$ GeV




| | |
|---|---|
| $Q^2 = -q^2 = (k-k')^2$ | $>$ 1 GeV$^2$ |
| $\nu = E - E'$ | |
| $x = Q^2/(2M\nu)$ | 0.02 – 0.85 |
| $y = \nu/E$ | $<$ 0.85 |
| $z = E_\pi/\nu$ | $>$ 0.2 |
| $W^2 = 2M\nu + M^2 - Q^2$ | $>$ 4 GeV$^2$ |
| $P_\perp$ pion transverse momentum | |

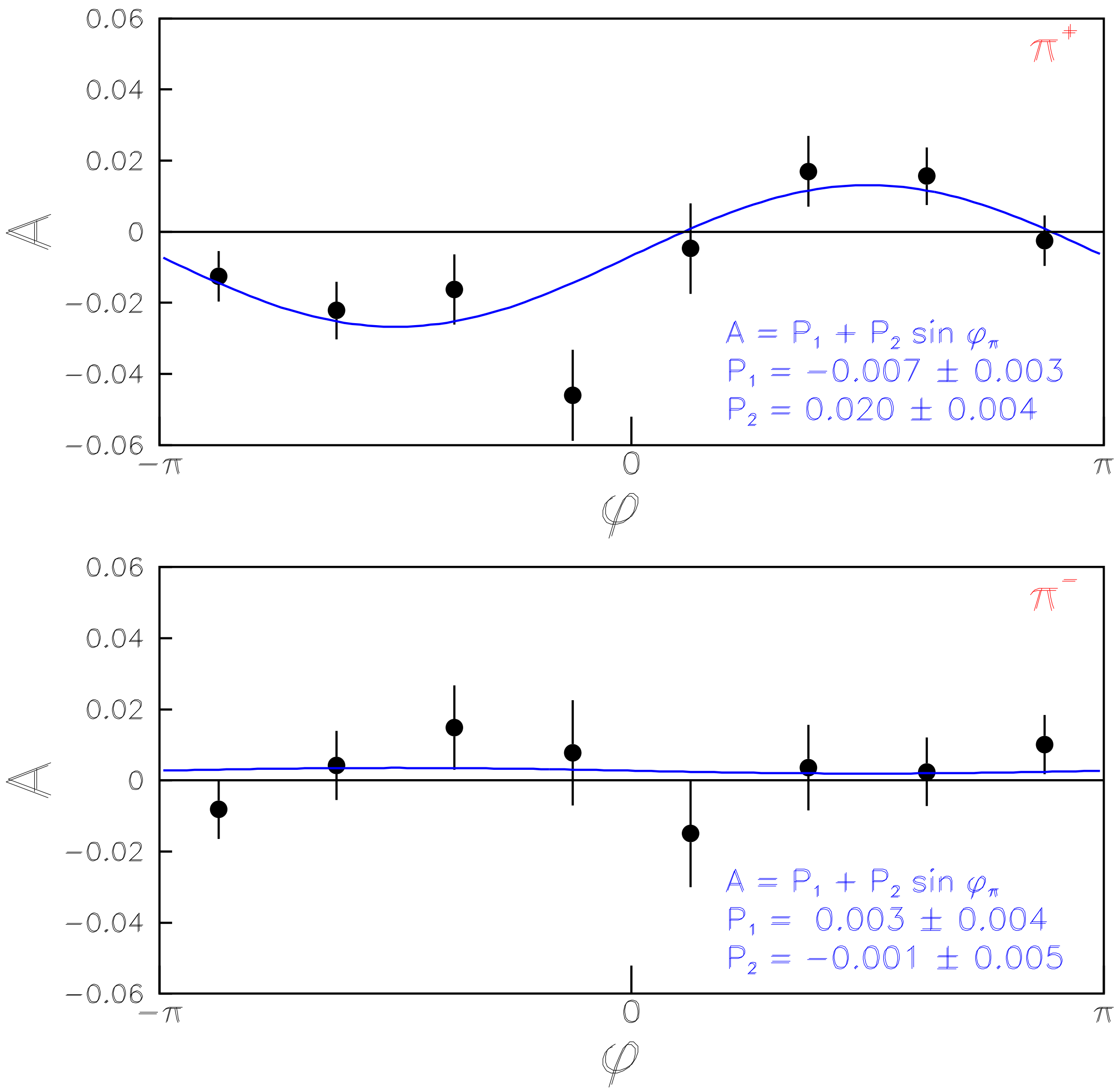
$\phi$ azimuthal angle of $\pi$ around the virtual photon direction

# cross section single spin asymmetry from longitudinal polarised target

$$A(\phi) = \frac{1}{\langle P \rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

$\langle P \rangle = 0.86$ average target polarisation

$\pm$ positive/negative target helicity



# extract $\sin\phi$ moment: azimuthally weighted asymmetries

$$A_{\mathrm{UL}}^{\sin\phi} = \frac{1}{P}\frac{\int_0^{2\pi}\sin\phi\,\mathrm{d}N_+ \; - \; \int_0^{2\pi}\sin\phi\,\mathrm{d}N_-}{\frac{1}{2}[\int_0^{2\pi}\mathrm{d}N_+ \; + \; \int_0^{2\pi}\mathrm{d}N_-]}$$
$$= 2 < \sin\phi >$$

$$< \frac{P_{\mathrm{T}}}{zM_{\mathrm{h}}}\sin\phi >_{\mathrm{UL}} \;\propto\; S_L \sum_{a,\bar{a}} e_a^2 x\, h_L^a(x)\; H_1^{\perp a}(z) + S_T \sum_{a,\bar{a}} e_a^2 x\, h_1^a(x)\; H_1^{\perp a}(z)$$

HERMES: longitudinal polarised target: $S_T << S_L$
NEVERTHELESS second term contributes with $\approx 30\%$

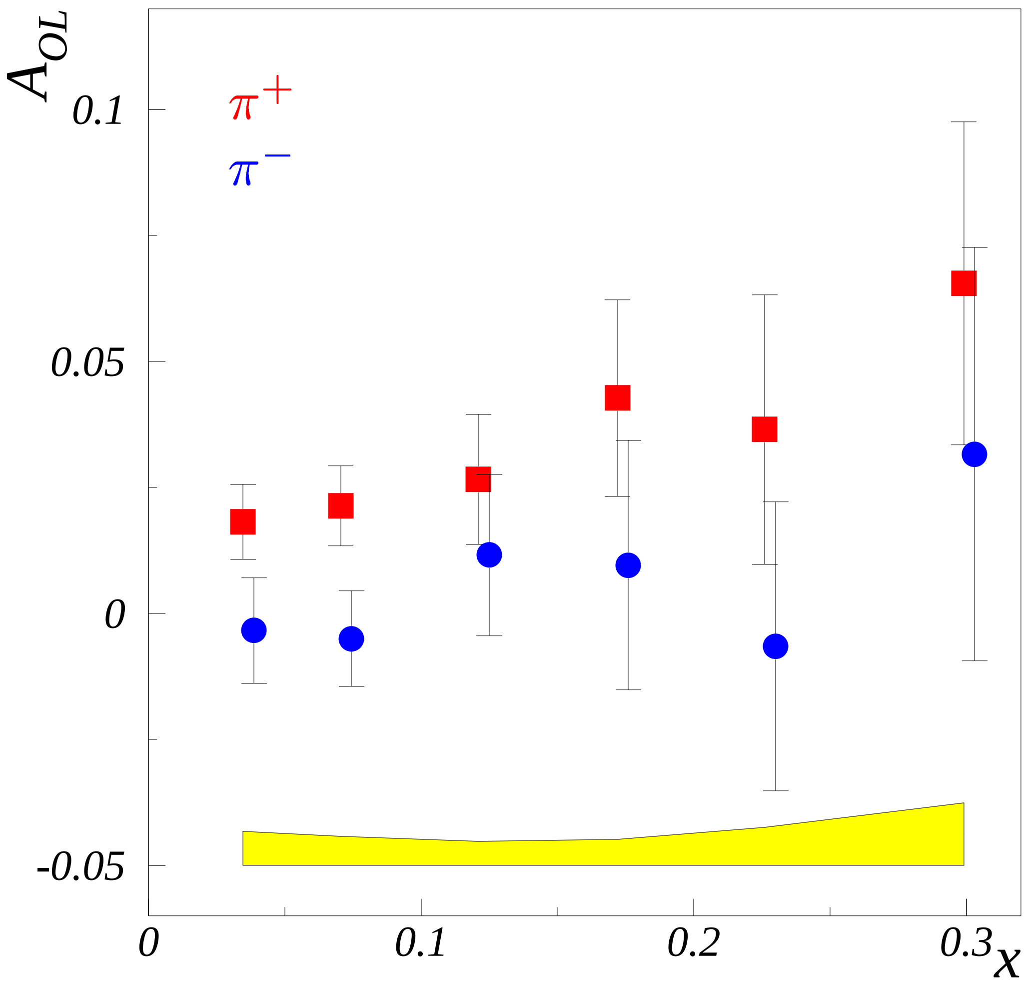
$h_L(x)$ twist-3 chiral-odd distribution function

$h_L(x) = 2x\int_x^1 \mathrm{d}y \frac{h_1(y)}{y^2}$ contains twist-2 part

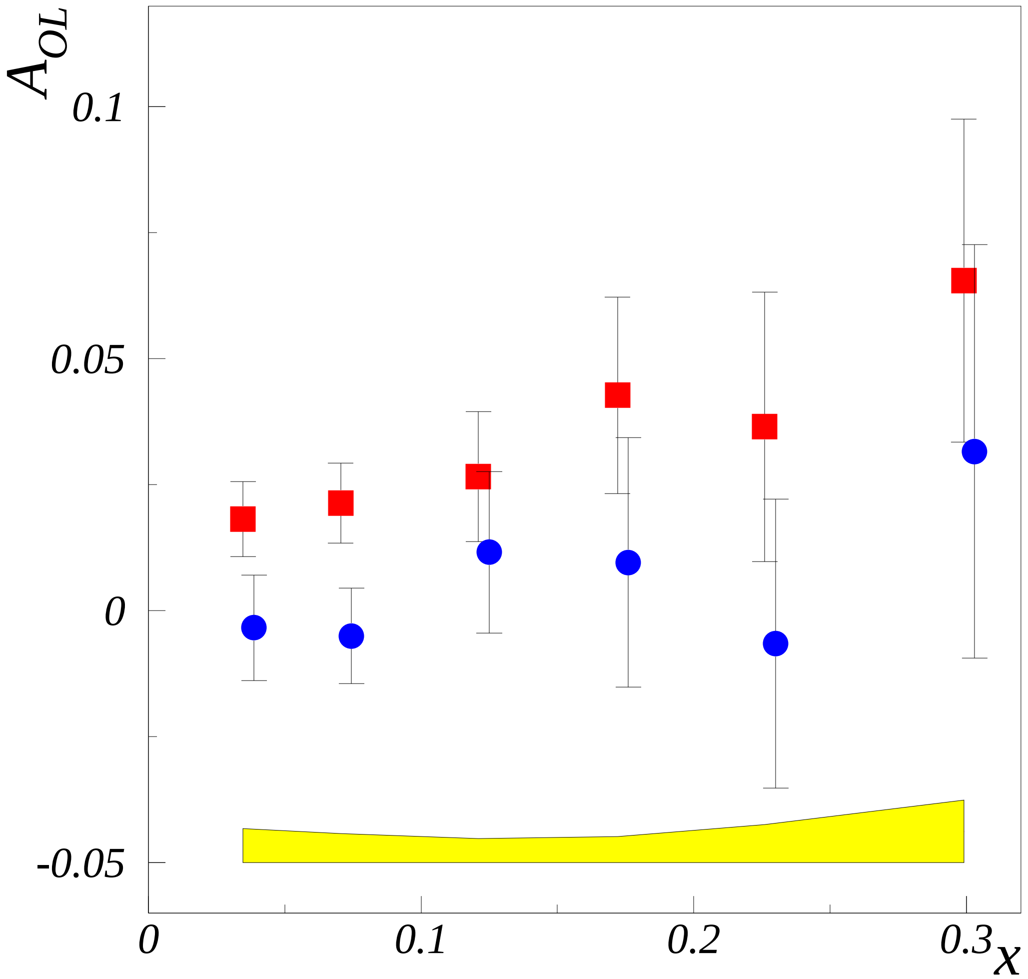
$H_1^{\perp a}(z)$ time-odd Collins spin dependent fragmentation function

# SSA $A_{\mathrm{UL}}^{\sin\phi}$: x dependence

$0.2 < z < 0.7$



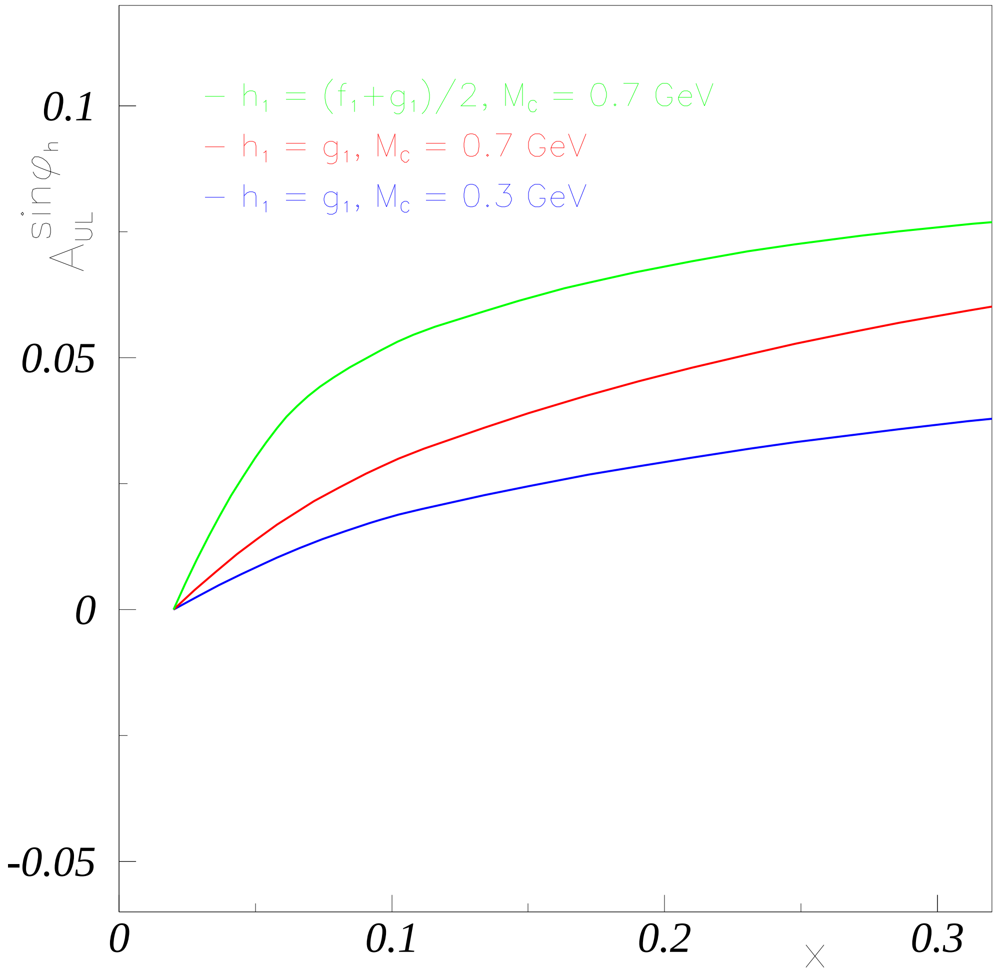

increase of $A_{\mathrm{UL}}^{sin\phi}$ with increasing $x$ agrees with existing interpretations



$A_{OL}$
0.1
0.05
0
-0.05
0
0.1
0.2
0.3
x

# SSA $A_{\rm UL}^{\sin\phi}$: x dependence

$$0.2 < z < 0.7$$



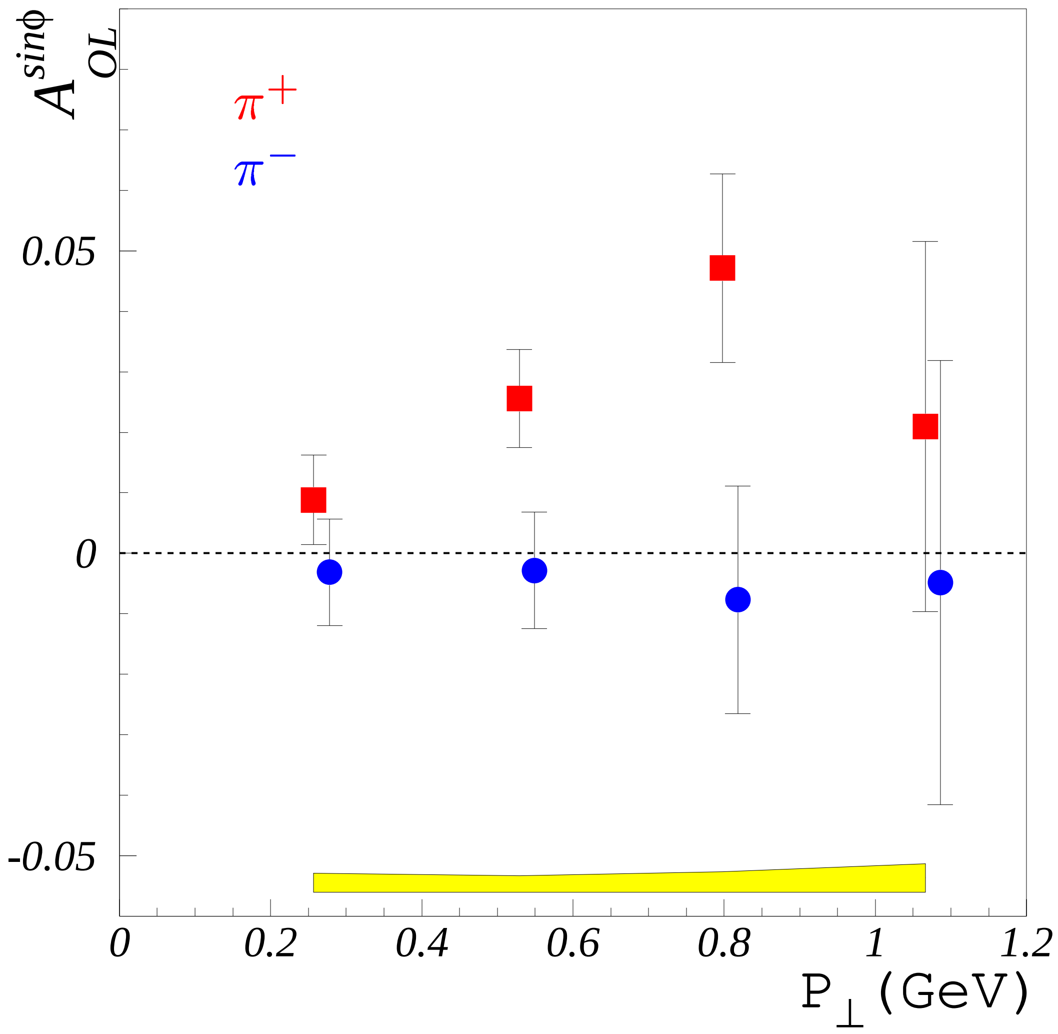

curves: `A.M. Kotzinian` *et al.* `hep-ph/9908466`
assuming:

$$h_{1L}^{\perp}(x) \sim h_L(x) \approx h_1(x) \approx g_1(x)$$

$$\Rightarrow \frac{\sigma_{UL}}{\sigma_{OO}} \propto x \frac{g_1(x)}{f_1(x)}$$

# SSA $A_{\mathrm{UL}}^{\sin\phi}$: $P_\perp$ dependence

$0.2 < z < 0.7$




dominance of the intrinsic quark transverse momenta for $P_\perp \leq 1$ GeV

# extension of kinematic range

- strong $z$–dependence of $H_1$ Collins FF for $z \rightarrow 1$
- $\pi^+$: for $z > 0.8$ pion pole contribution
- recently large SSA predicted for transverse polarised target

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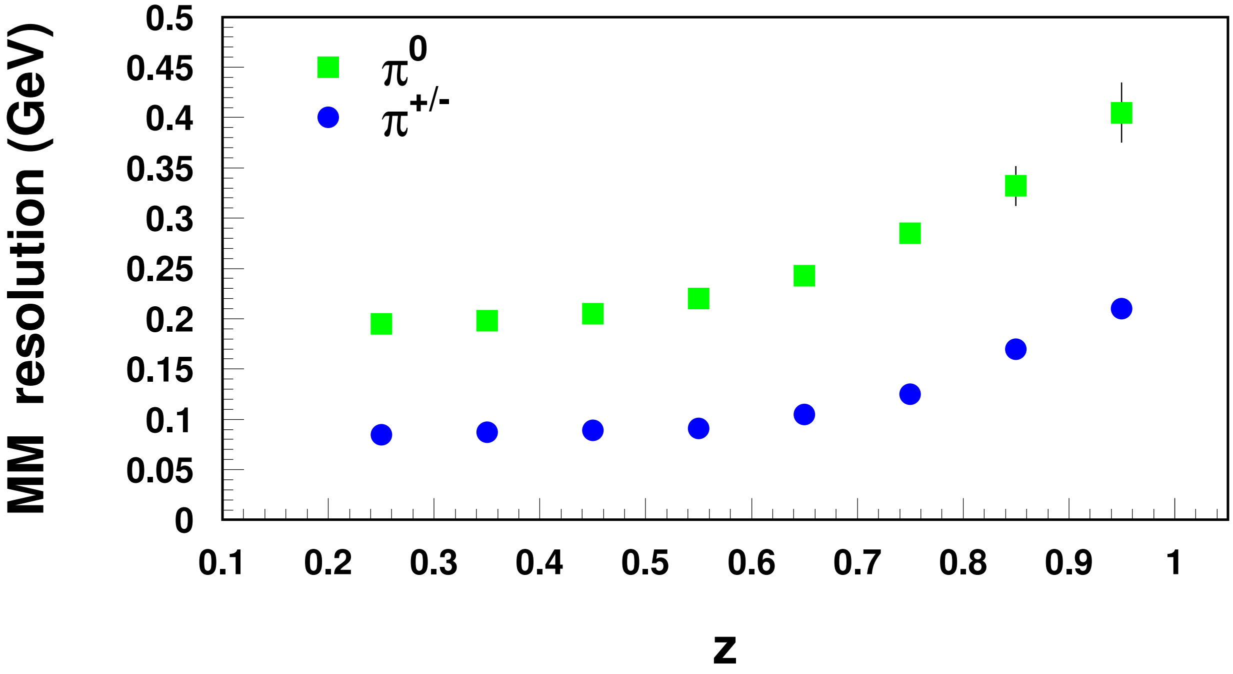
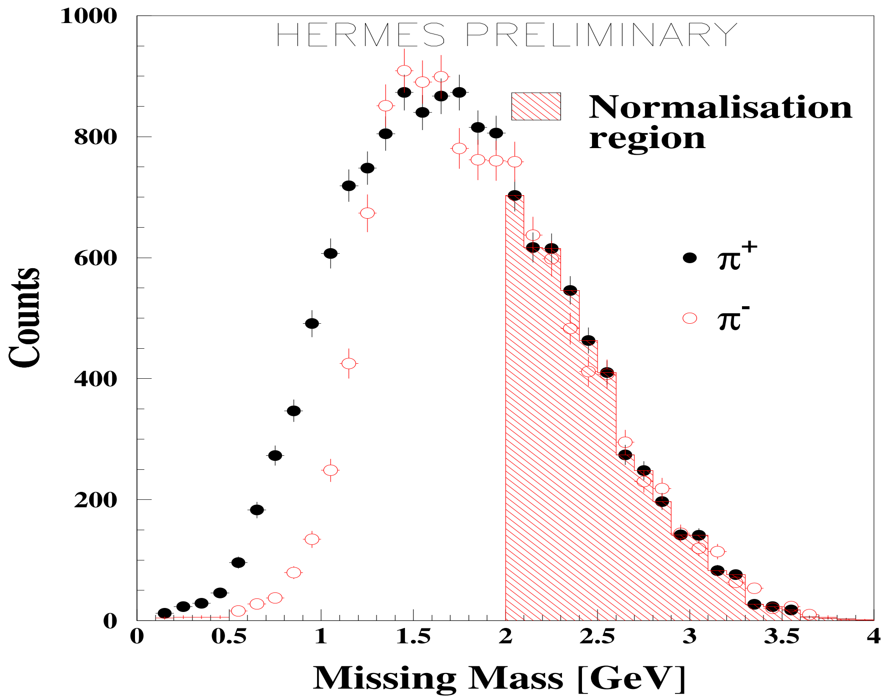
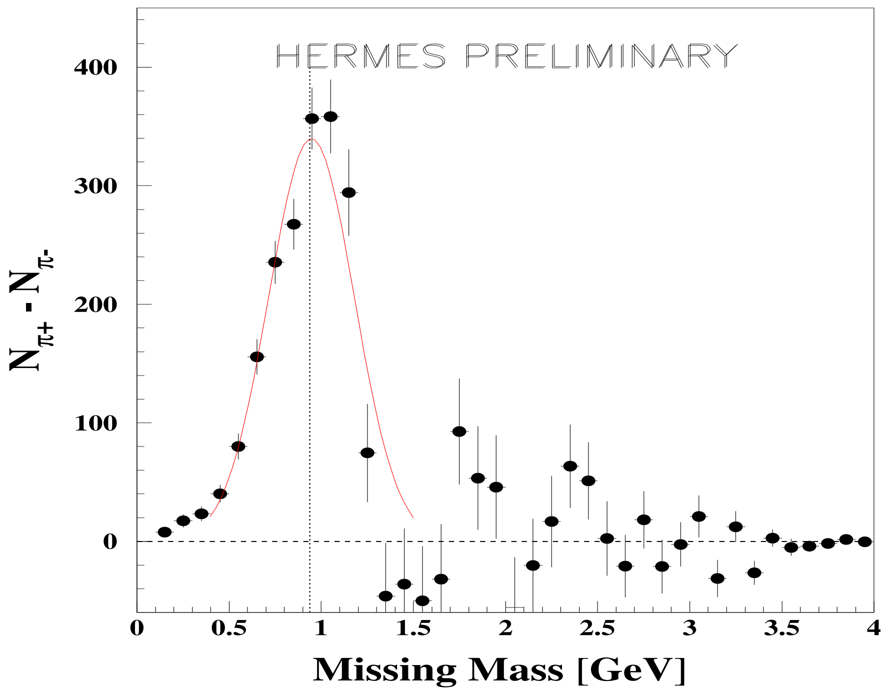
extension of kinematic range to $z \rightarrow 1$ for ep$\rightarrow$e$'\pi$X

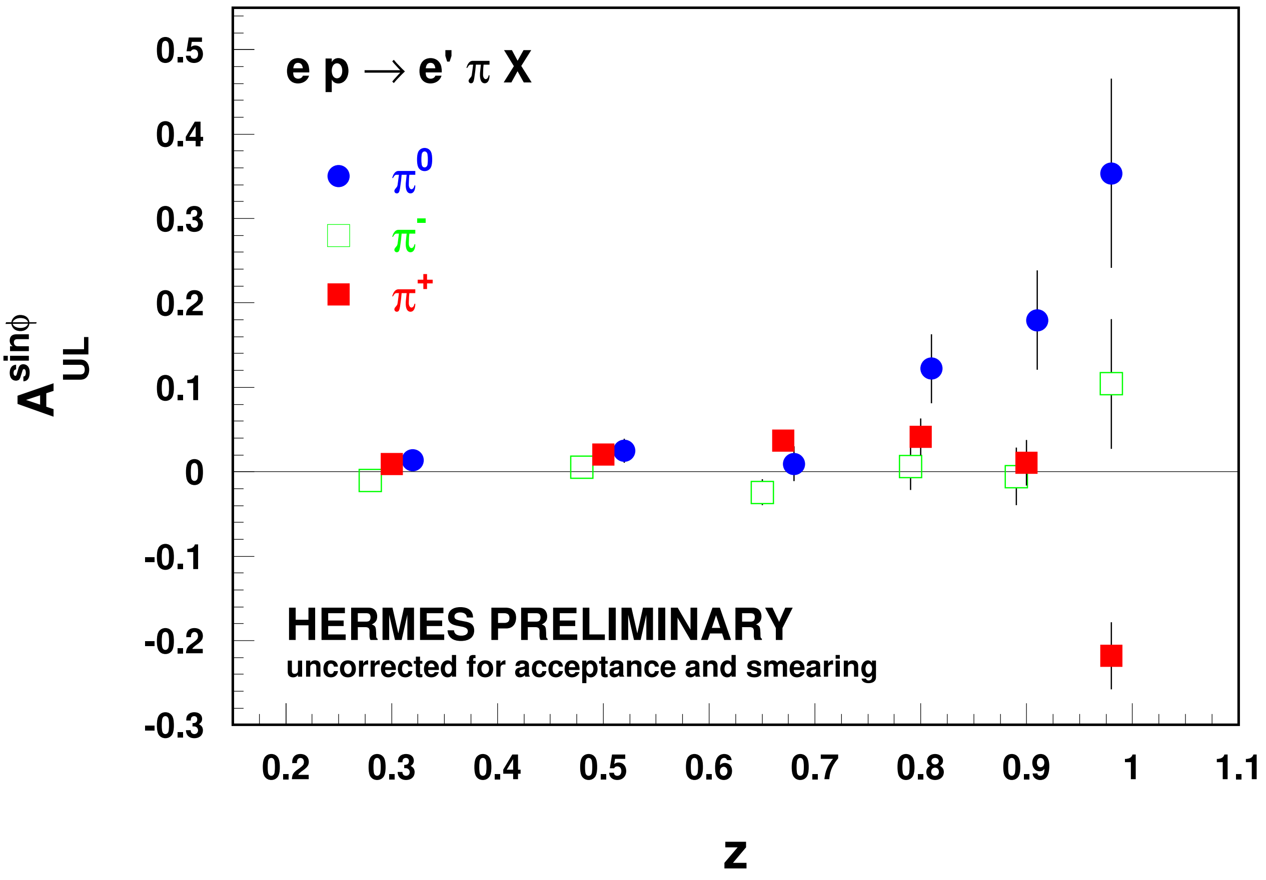


# exclusive channel: ep $\rightarrow$ e$'\pi^+$n



# extension of kinematic range
# SSA $A_{\rm UL}^{\sin\phi}$: z dependence



# Summary

first observation of a single spin azimuthal asymmetry for pions produced in DIS of a positron beam on a longitudinally polarised hydrogen target

$\underline{0.2 < z < 0.7}$

$$\pi^+ \quad A_{\rm UL}^{sin\phi} = 0.022 \pm 0.005(stat) \pm 0.003(syst)$$
$$\pi^- \quad A_{\rm UL}^{sin\phi} = -0.005 \pm 0.008(stat) \pm 0.004(syst)$$

[hep-ex/9910062], PRL *in press*

$\underline{z > 0.7}$

NEW PRELIMINARY RESULTS:

large $\pi^+$ and $\pi^0$ single spin azimuthal asymmetries has been measured for $z \rightarrow 1$

$\pi^+$ asymmetry changes sign in the high $z$ region

# SSA $A_{UL}^{\sin\phi}$: z dependence