Collins Effect in polarized SIDIS and e^+e^- Data

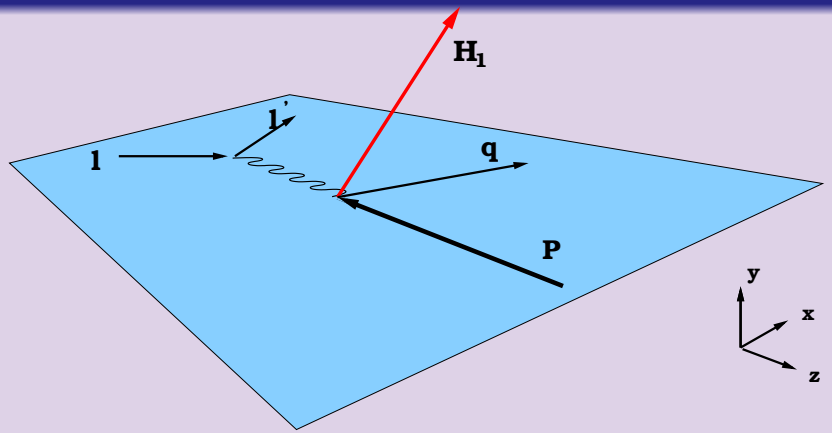
Alexei Prokudin

Università di Torino and INFN Sezione di Torino

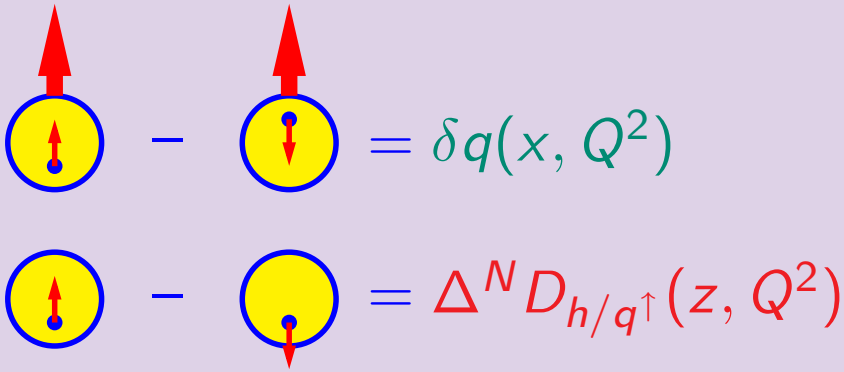
In collaboration with M. Anselmino, M. Boglione, U. D'Alesio, F. Murgia, A. Kotzinian and C.Turk

SIDIS and e^+e^- annihilation

SIDIS $lN \to l' H_1 X$

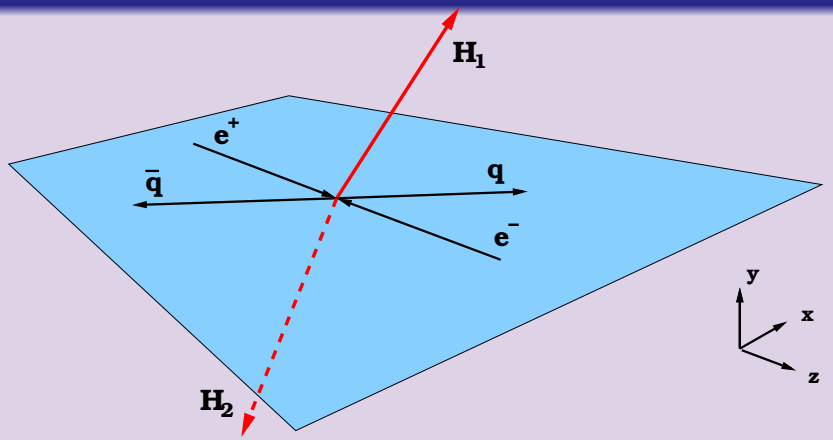


Collins effect gives rise to an azimuthal Single Spin Asymmetry



J. C. Collins, *Nucl. Phys.* **B396** (1993) 161

$e^+e^- \to H_1 H_2 X$



Collins effect gives rise to an azimuthal asymmetry, q and $\bar{q}$ Collins functions are present in the process:

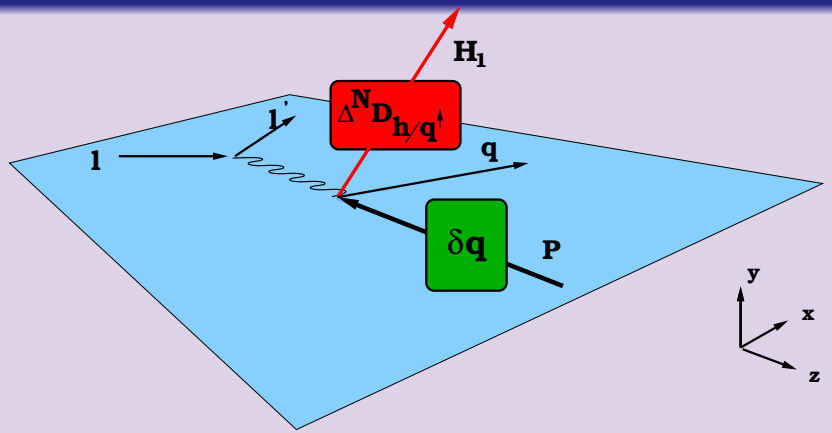
$\Delta^N D_{h/q^\uparrow}(z_1, Q^2)$

$\Delta^N D_{h/\bar{q}^\uparrow}(z_2, Q^2)$

D. Boer, R.Jacob and P. J. Mulders *Nucl. Phys.* **B504** (1997) 345

SIDIS and e^+e^- annihilation

SIDIS $lN \to l' H_1 X$

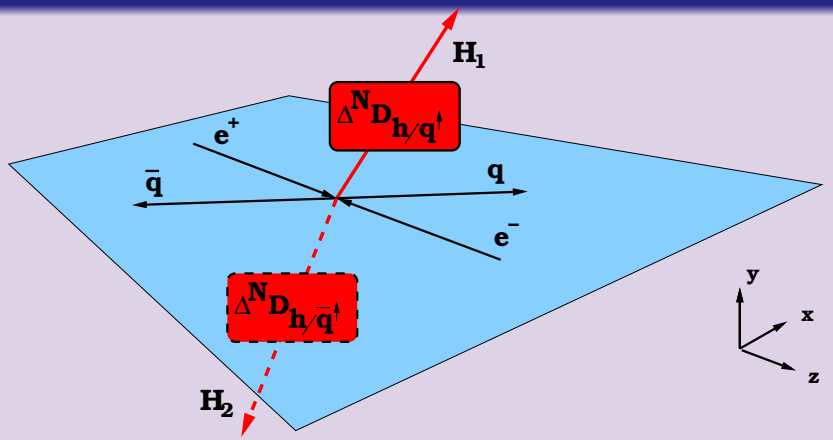


Cross Section $\sim sin(\phi_H + \phi_S) \cdot$
$\delta q(x, Q^2) \otimes \Delta^N D_{h/q^\uparrow}(z, Q^2)$

?

$\delta q(x, Q^2) \neq 0$?
$\Delta^N D_{h/q^\uparrow}(z, Q^2) \neq 0$?

$e^+e^- \to H_1 H_2 X$



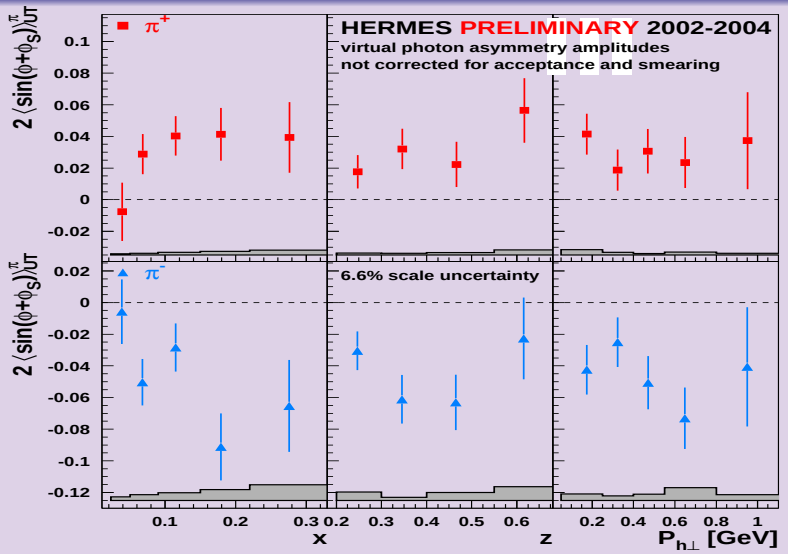
Cross Section $\sim cos(\phi_{H_1} + \phi_{H_2}) \cdot$
$\Delta^N D_{h/q^\uparrow}(z_1) \otimes \Delta^N D_{h/\bar{q}^\uparrow}(z_2)$

?

$\Delta^N D_{h/q^\uparrow}(z_1, Q^2) \neq 0$?
$\Delta^N D_{h/\bar{q}^\uparrow}(z_2, Q^2) \neq 0$?

SIDIS and e^+e^- annihilation

SIDIS $lN \to l' H_1 X$



HERMES, proton target,

$p_{lab} = 27.5$ (GeV)

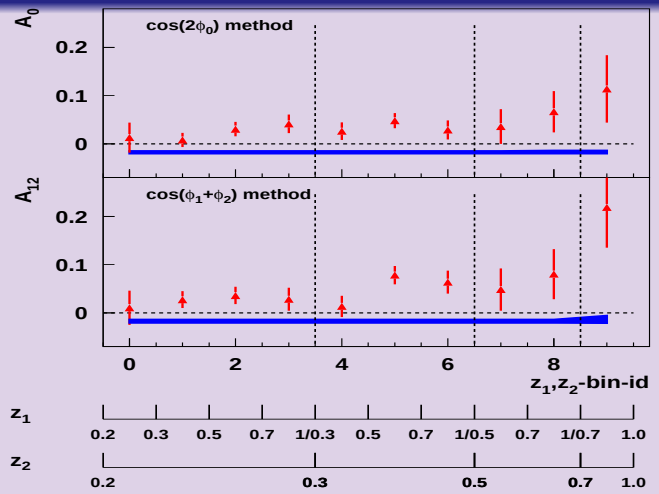
HERMES

$\delta q(x, Q^2) \neq 0$!

$\Delta^N D_{h/q^\uparrow}(z, Q^2) \neq 0$!

HERMES Collaboration, A. Airapetian *et al.* *Phys. Rev. Lett.* **94** 94 (2005) 012002

$e^+e^- \to H_1 H_2 X$



BELLE, $\sqrt{s} = 10.52$ (GeV),

BELLE

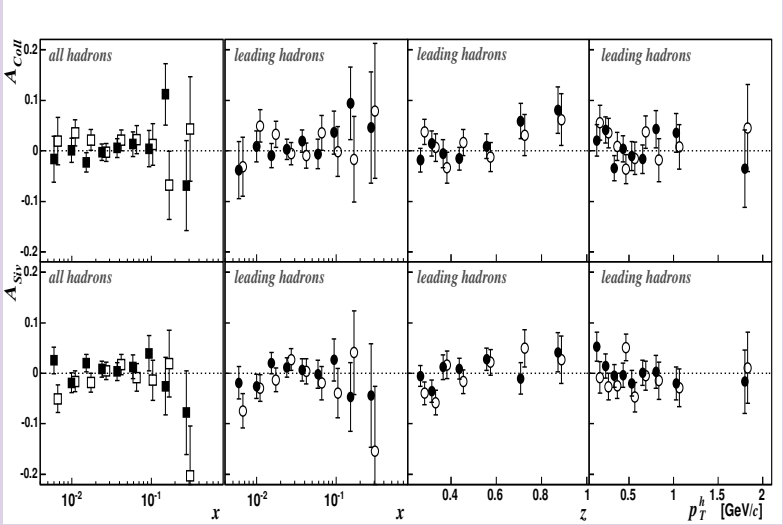
$\Delta^N D_{h/q^\uparrow}(z_1, Q^2) \neq 0$!

$\Delta^N D_{h/\bar{q}^\uparrow}(z_2, Q^2) \neq 0$!

Belle Collaboration, K. Abe *et al.*, *Phys. Rev. Lett.* **96**(2006)232002

SIDIS and e^+e^- annihilation

SIDIS $lN \to l' H_1 X$



COMPASS, deutron target

$p_{lab} = 160$ (GeV)

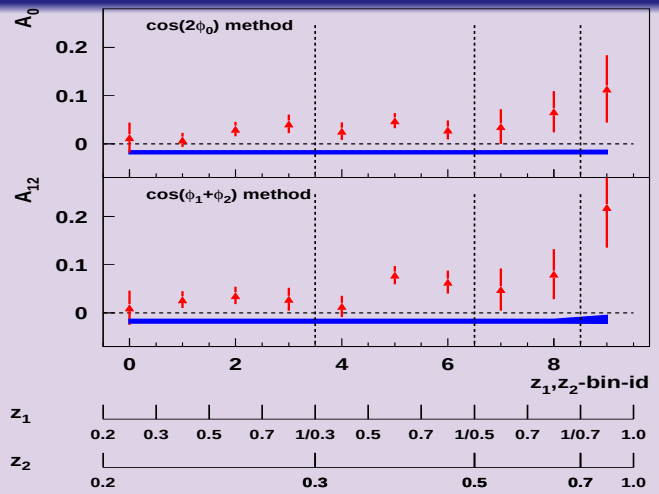
COMPASS

$\delta q(x, Q^2) \neq 0$?

$\Delta^N D_{h/q^\uparrow}(z, Q^2) \neq 0$?

COMPASS Collaboration, V. Y. Alexakhin *et al.* *Phys. Rev. Lett.* **94**(2005)202002

$e^+e^- \to H_1 H_2 X$



BELLE, $\sqrt{s} = 10.52$ (GeV),

BELLE

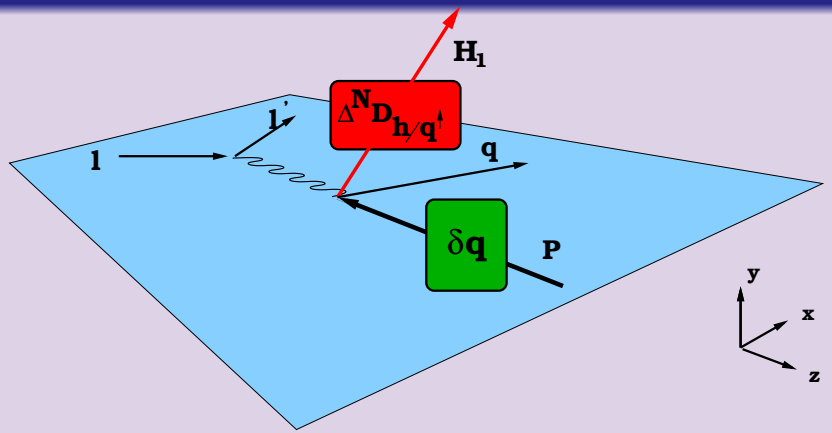
$\Delta^N D_{h/q^\uparrow}(z_1, Q^2) \neq 0$!

$\Delta^N D_{h/\bar{q}^\uparrow}(z_2, Q^2) \neq 0$!

Belle Collaboration, K. Abe *et al.*, *Phys. Rev. Lett.* **96**(2006)232002

SIDIS and e^+e^- annihilation

SIDIS $lN \to l' H_1 X$

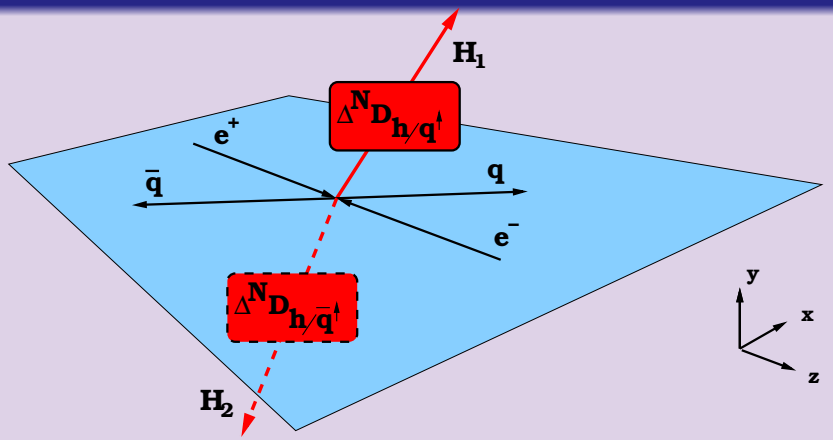


?

Are HERMES and COMPASS data compatible?

We fit HERMES data only and check if we can describe COMPASS data.

$e^+e^- \to H_1 H_2 X$



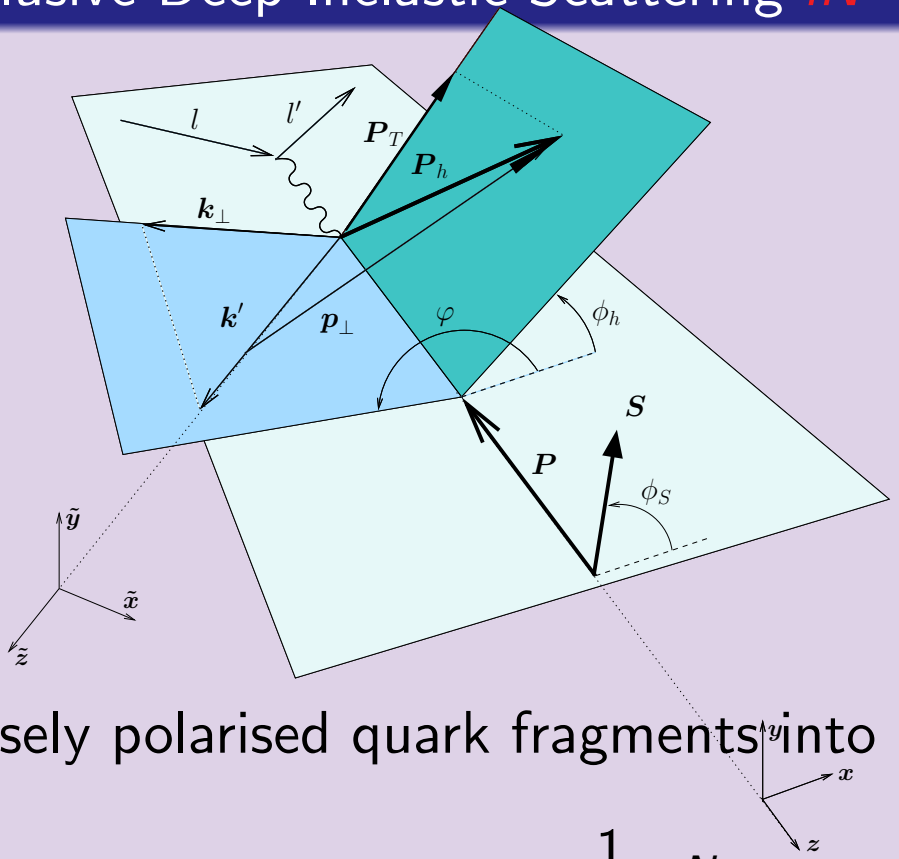
?

$$\Delta^N D^{SIDIS}_{h/q^\uparrow}(z) = \Delta^N D^{e^+e^-}_{h/q^\uparrow}(z) \ ?$$

We use Collins Fragmentation Functions obtained by fit to HERMES data give predictions for BELLE.

Collins function

Semi inclusive Deep Inelastic Scattering $lN \to l'hX$



Transversely polarised quark fragments into an unpolarised hadron:

$$D_{h/q^\uparrow}(z, \mathbf{p}_\perp) = D_{h/q}(z, |p_\perp|) + \frac{1}{2}\Delta^N D_{h/q^\uparrow}(z, |p_\perp|)\; S_{q'} \cdot (\hat{p}_{q'} x \hat{\mathbf{p}}_\perp),$$

$\Delta^N D_{h/q^\uparrow}(z, |p_\perp|) \Longrightarrow$ we use factorization of z & $p_\perp$ and Gaussian dependence on $p_\perp$

Collins fragmentation function

Positivity bound:

$$\frac{1}{2}|\Delta^N D_{h/q^\uparrow}(z,\mathbf{p}_\perp)| \leq D_{h/q}(z,\mathbf{p}_\perp)$$

Collins fragmentation function is parametrized in the form

$$\Delta^N D_{h/q^\uparrow}(z,\mathbf{p}_\perp) \equiv 2h(p_\perp)H(z)D_{h/q}(z,\mathbf{p}_\perp),$$

$$h(p_\perp) \equiv p_\perp\sqrt{\frac{2e}{\langle p_{\perp 1}^2\rangle}}exp(-p_\perp^2/\langle p_{\perp 1}^2\rangle) \leq 1,$$

$$|H(z)| \equiv |N_q z^{\alpha_q}(1-z)^{\beta_q}\frac{(\alpha_q+\beta_q)^{(\alpha_q+\beta_q)}}{\alpha_q^{\alpha_q}\beta_q^{\beta_q}}| \leq 1,$$

$$\delta q(x,k_\perp) \equiv \delta q(x)\frac{exp(-k_\perp^2/\langle k_{\perp h1}^2\rangle)}{\pi\langle k_{\perp h1}^2\rangle}$$

We use either $\delta q(x) \equiv (q(x)+\Delta q(x))/2$ or $\delta q(x) \equiv \Delta q(x)$

where N_q, α_q, β_q, $\langle p_{\perp 1}^2\rangle$ and $\langle k_{\perp h1}^2\rangle$ are parameters.

Description of $A_{UT}^{sin(\phi_h+\phi_S)}$

We use only HERMES data on $A_{UT}^{sin(\phi_h+\phi_S)}$ in the fitting procedure. Favoured and unfavoured fragmentation functions are defined as follows:

$$D^{fav}(z) \equiv D^{u\to\pi^+}(z) = D^{d\to\pi^-}(z) = D^{\bar{u}\to\pi^-}(z) = D^{\bar{d}\to\pi^+}(z)$$

$$D^{unfav}(z) \equiv D^{u\to\pi^-}(z) = D^{d\to\pi^+}(z) = D^{\bar{u}\to\pi^+}(z) = D^{\bar{d}\to\pi^-}(z)$$

The resulting set of parameters is the following:

$N_{fav} =$	-0.66 ± 0.52	$N_{unfav} =$	0.52 ± 0.12
$\alpha_{fav} =$	1.24 ± 0.90	$\alpha_{unfav} =$	3.2 ± 3.4
$\beta_{fav} =$	0 ± 4.0	$\beta_{unfav} =$	4.1 ± 5.5
$\langle p_{\perp 1}^2 \rangle =$	0.56 ± 0.15 GeV^2	$\langle k_{\perp h1}^2 \rangle =$	0.28 GeV^2
		$\chi^2/d.o.f =$	0.86

Table: Best values of the parameters of the Collins functions.

The results are compatible with results of

A. V. Efremov, K. Goeke and P. Schweitzer, Phys. Rev. D **73**, 094025 (2006)

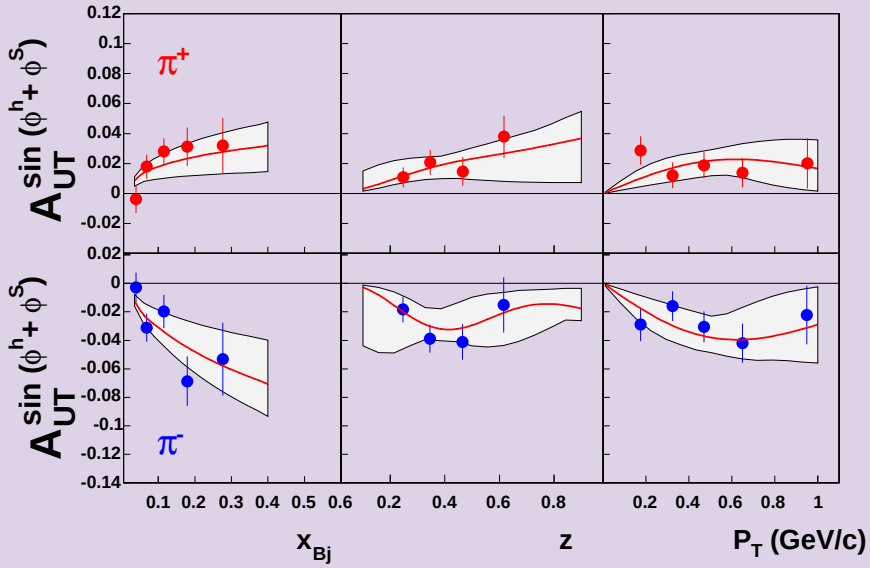
W. Vogelsang and F. Yuan, Phys. Rev. D **72**, 054028 (2005)

Description of HERMES and COMPASS data

PDF: GRV LO 1998, GRSV2000 FF: Kretzer,

HERMES

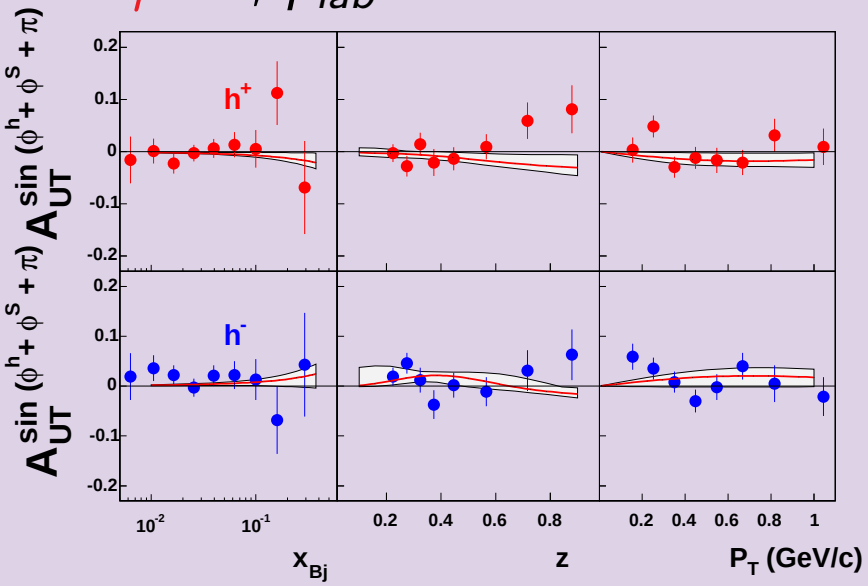
$ep \to e\pi X$, $p_{lab} = 27.57$ GeV.



FIT

COMPASS

$\mu D \to \mu hX$, $p_{lab} = 160$ GeV.



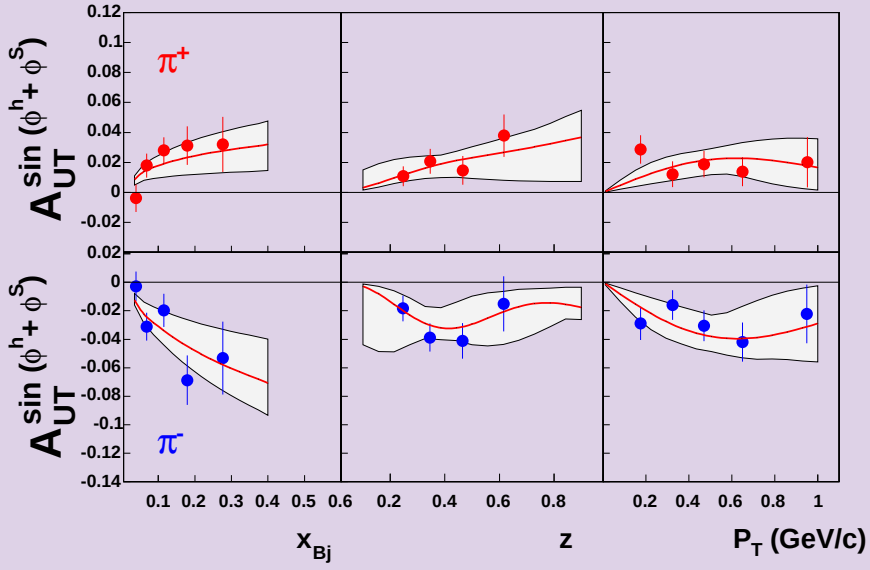
PREDICTIONS

Description of HERMES and COMPASS data

PDF: GRV LO 1998, GRSV2000 FF: Kretzer,

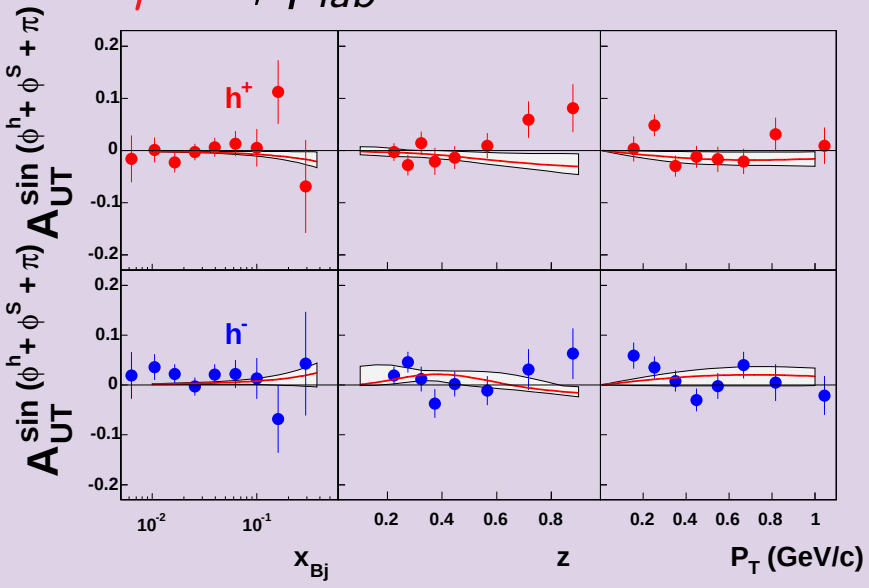
HERMES

$ep \to e\pi X$, $p_{lab} = 27.57$ GeV.



COMPASS

$\mu D \to \mu hX$, $p_{lab} = 160$ GeV.



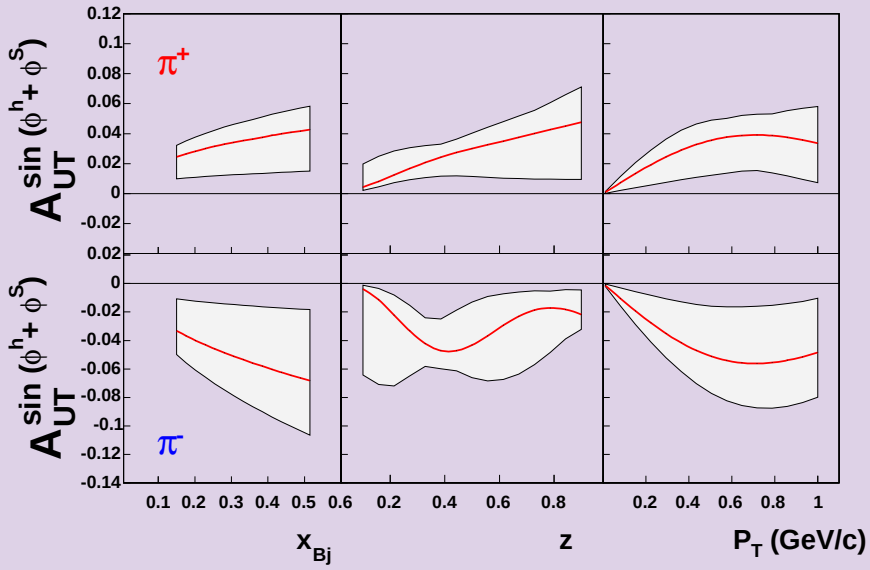
HERMES and COMPASS data are compatible

Predictions for JLab and COMPASS

PDF: GRV LO 1998, GRSV2000 FF: Kretzer,

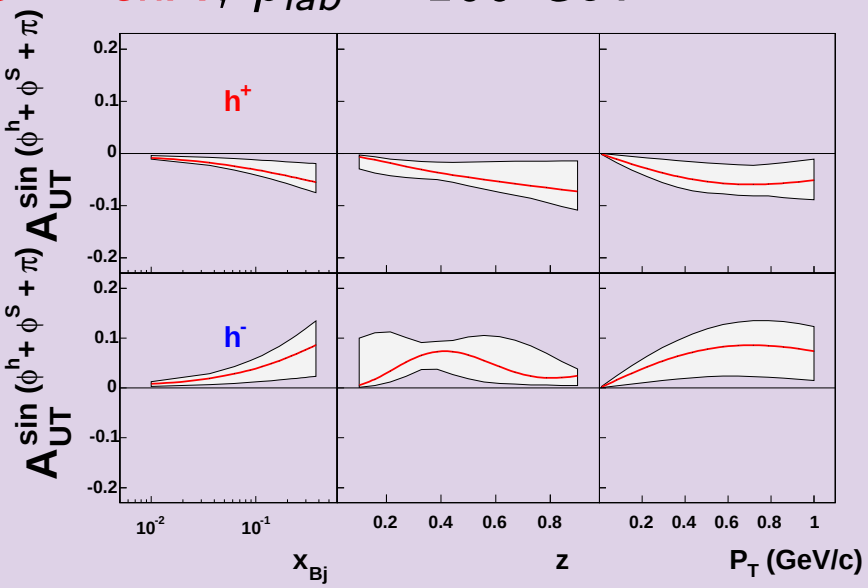
JLAB

$ep \to e\pi X$, $p_{lab} = 6$ GeV.



COMPASS proton target

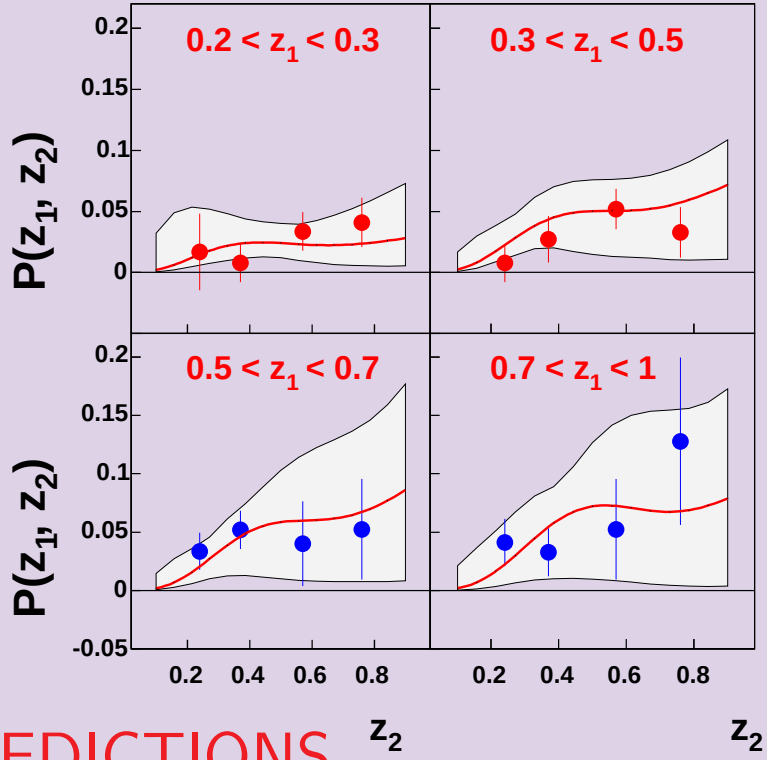
$ep \to ehX$, $p_{lab} = 160$ GeV.



Description of BELLE data

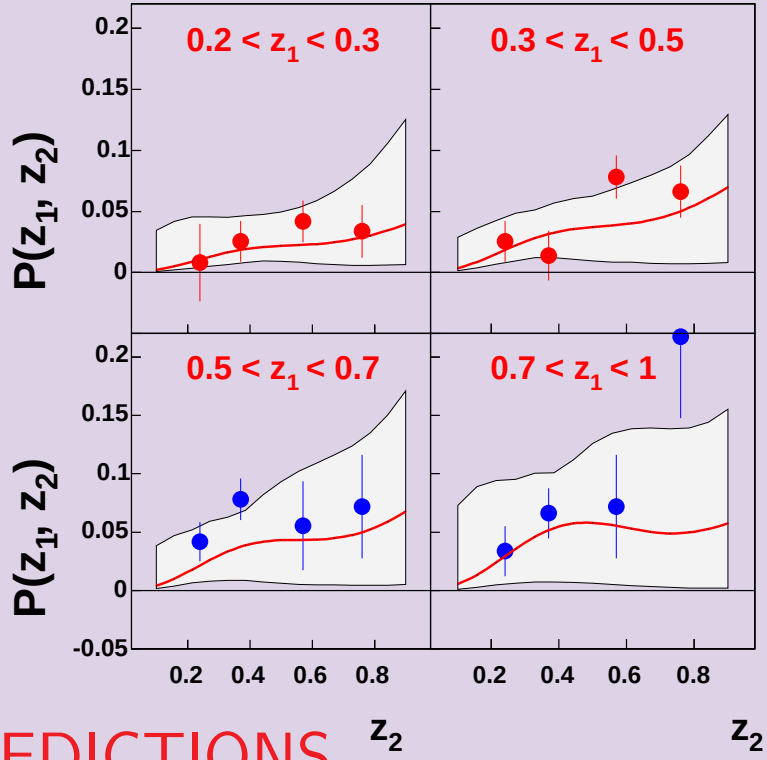
$\Delta^N D_{h/q^\uparrow}(z, |p_\perp|)$ from fit to SIDIS HERMES data

$cos(2\Phi_1)$ method



PREDICTIONS

$cos(\Phi_1 + \Phi_2)$ method

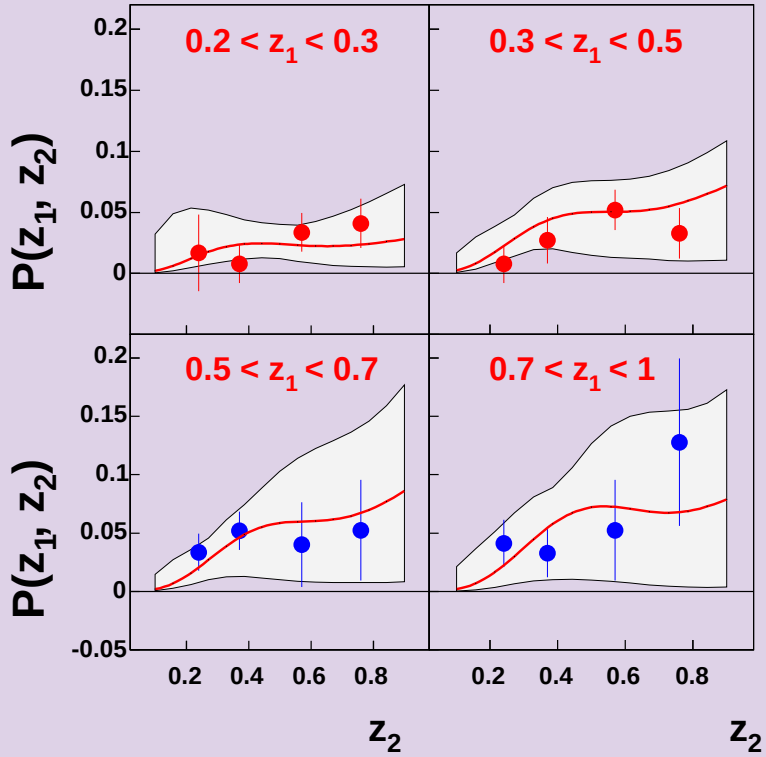


PREDICTIONS

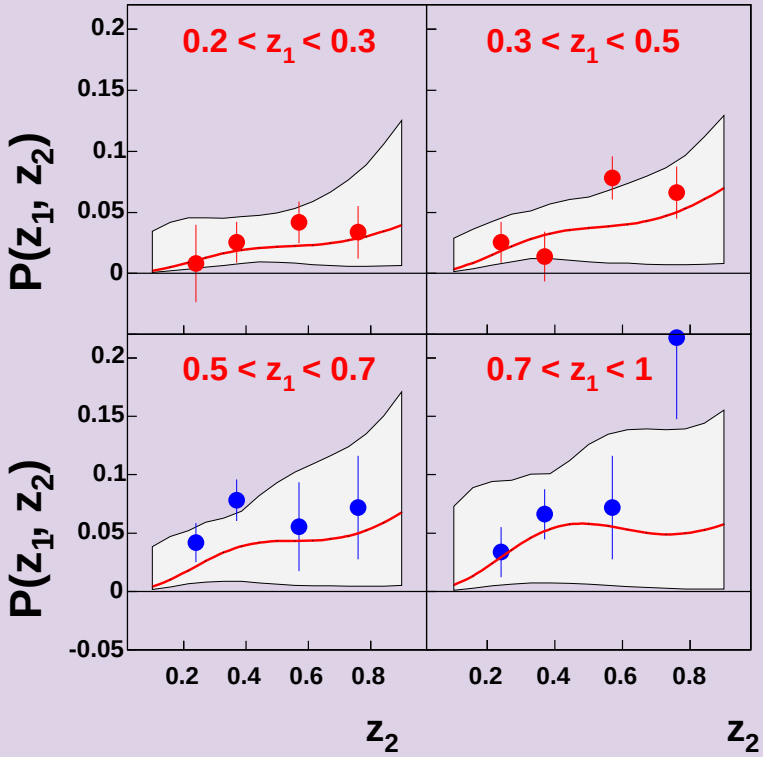
Description of BELLE data

$\Delta^N D_{h/q^\uparrow}(z, |p_\perp|)$ from fit to SIDIS HERMES data

$cos(2\Phi_1)$ method



$cos(\Phi_1 + \Phi_2)$ method

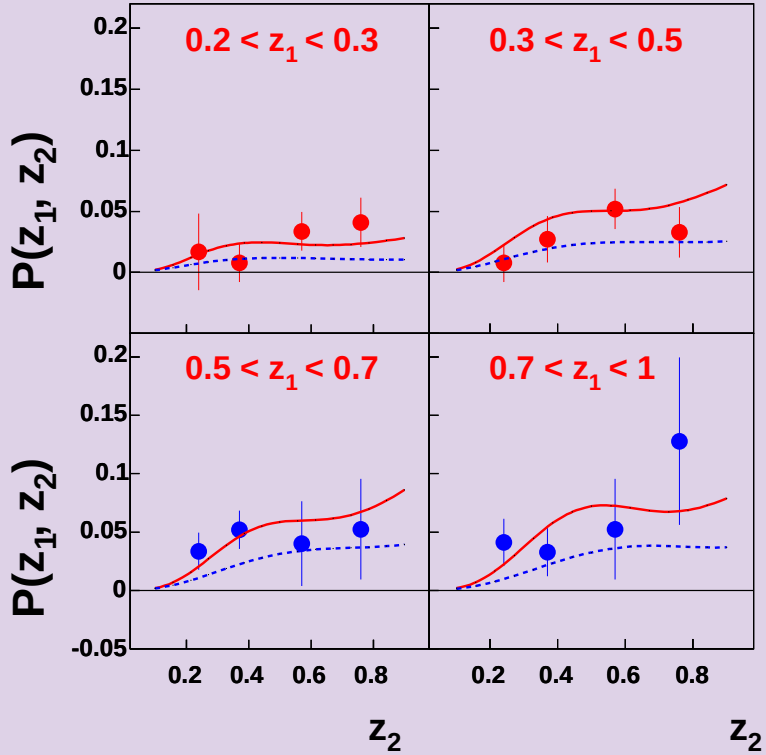


Collins FFs are the same in SIDIS and e^+e^-

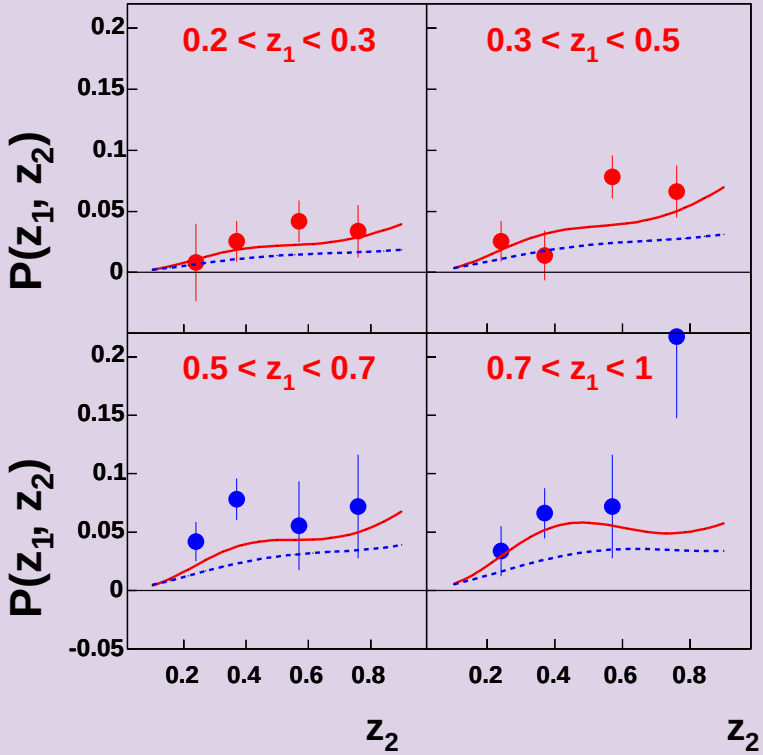
What do we know about transversity?

We use either $\delta q(x) \equiv (q(x) + \Delta q(x))/2$ (the dashed line) or $\delta q(x) \equiv \Delta q(x)$ (the solid line)

$cos(2\Phi_1)$ method



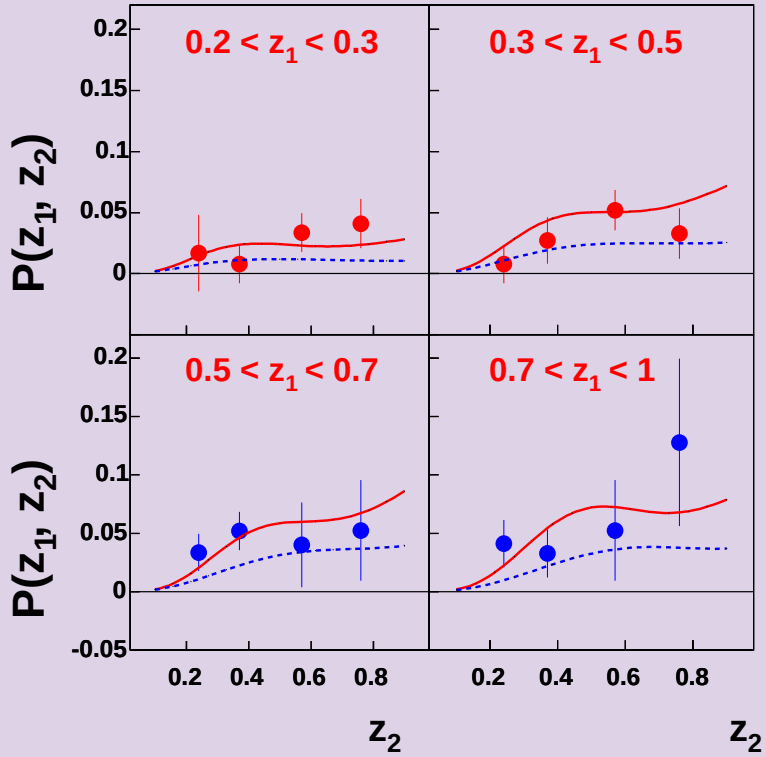
$cos(\Phi_1 + \Phi_2)$ method



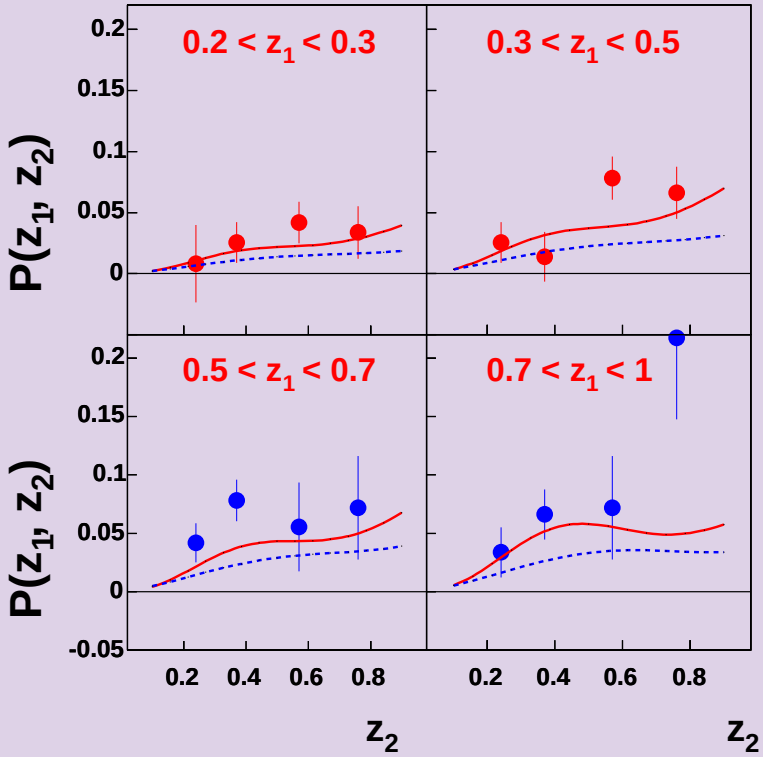
What do we know about transversity?

We use either $\delta q(x) \equiv (q(x) + \Delta q(x))/2$ (the dashed line) or $\delta q(x) \equiv \Delta q(x)$ (the solid line)

$cos(2\Phi_1)$ method



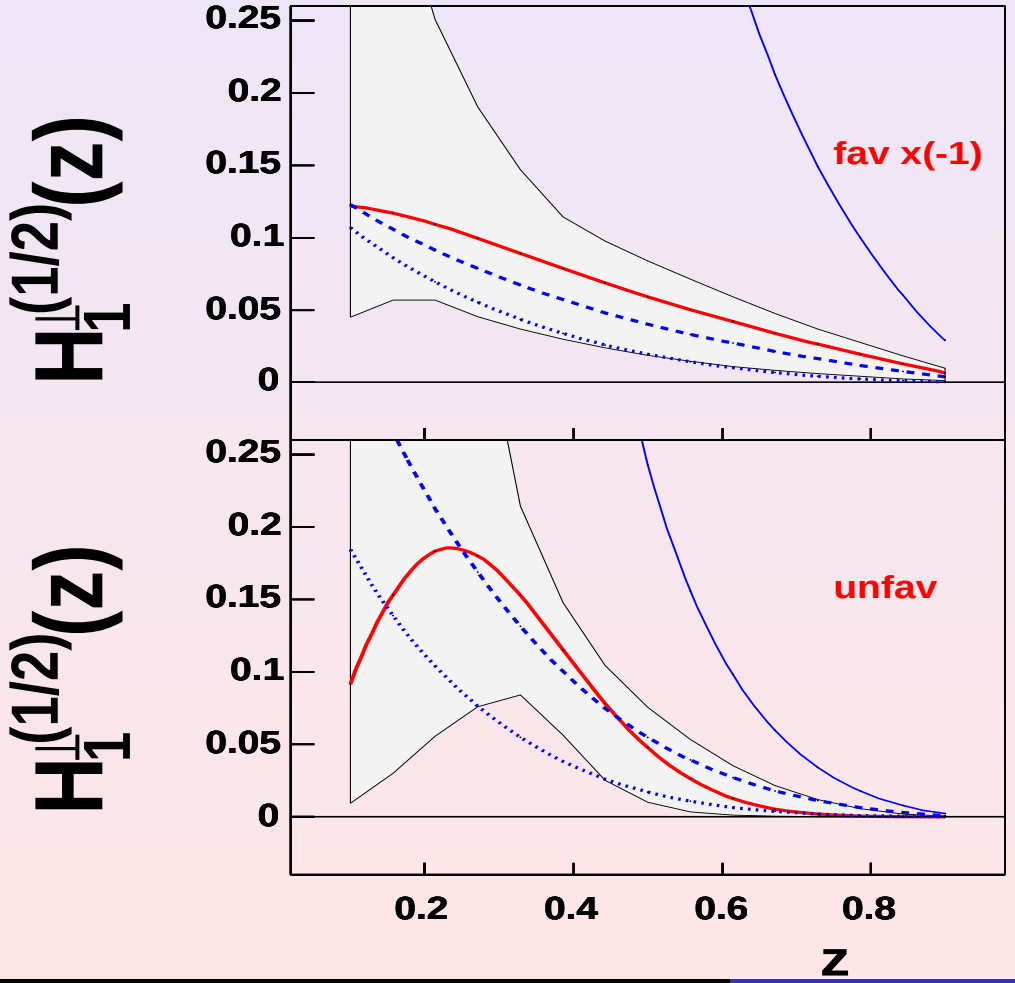
$cos(\Phi_1 + \Phi_2)$ method



Both scenarios are allowed by the existing data

Comparison with other models.

$$H_1^{\perp(1/2)}(z) = \int d^2\mathbf{p}_\perp \frac{|p_\perp|}{2zm_\pi} H_1^\perp(z,\mathbf{p}_\perp) \equiv \frac{1}{4}\int d^2\mathbf{p}_\perp \Delta^N D_{h/q^\uparrow}(z,\mathbf{p}_\perp)$$



The dashed line
A. V. Efremov, K. Goeke, and P. Schweitzer, Phys. Rev. D **73**, 094025 (2006)

The dotted line
W. Vogelsang and F. Yuan, Phys. Rev. D **72**, 054028 (2005)

CONCLUSIONS

- Estimates of the Collins functions for favoured and unfavoured fragmentation have been obtained by fitting to the HERMES data. These turn out to be definitely different from zero. Predictions for COMPASS show a very good agreement with the data.
- Collins effect at JLab and COMPASS (with the proton target) is expected to be sizable.
- Extracted Collins functions provide an exellent description of e^+e^- BELLE data. This allows us to conlude that Collins functions are equal in both cases. Thus we conclude that the origin of Collins effect is the same in SIDIS $lN \to l'hX$ and $e^+e^- \to h_1 h_2 X$.
- Transversity $\delta q(x)$ is modelled by either $\Delta q(x)$ or $(q(x) + \Delta q(x))/2$. Both scenarios are allowed by the existing data.

CONCLUSIONS

- Estimates of the Collins functions for favoured and unfavoured fragmentation have been obtained by fitting to the HERMES data. These turn out to be definitely different from zero. Predictions for COMPASS show a very good agreement with the data.
- Collins effect at JLab and COMPASS (with the proton target) is expected to be sizable

THANK YOU!

of

functions are equal in both cases. Thus we conclude that the origin of Collins effect is the same in SIDIS $lN \to l'hX$ and $e^+e^- \to h_1 h_2 X$.
- Transversity $\delta q(x)$ is modelled by either $\Delta q(x)$ or $(q(x) + \Delta q(x))/2$. Both scenarios are allowed by the existing data.