Measurements of unpolarized azimuthal asymmetries at COMPASS

Wolfgang Käfer,
on behalf of the COMPASS collaboration

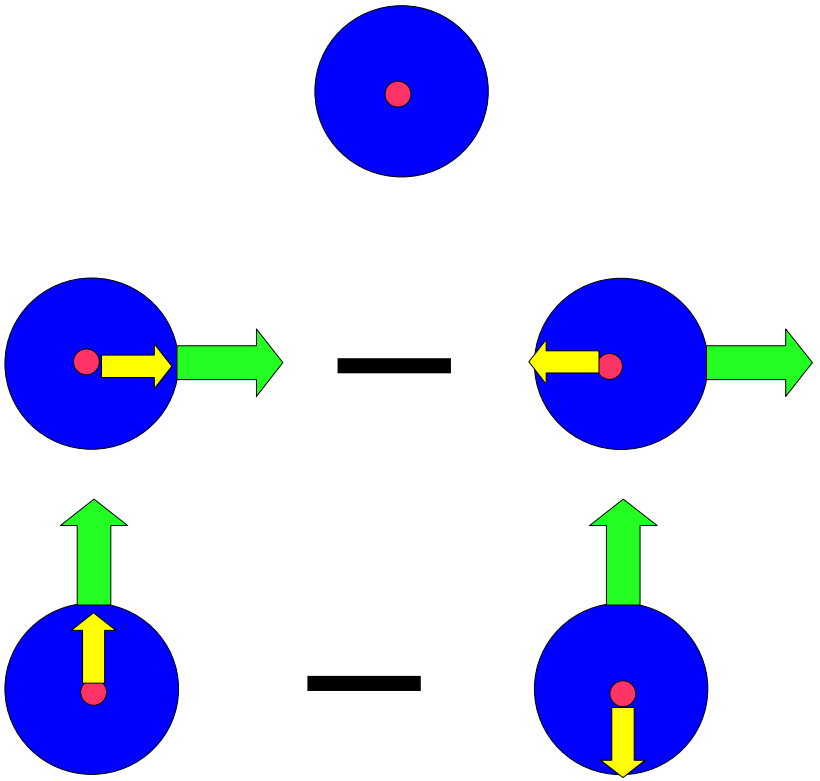
Transversity 2008, Ferrara

Outline

- **Theoretical motivation**
- **Extraction of Asymmetries**
- **First Results on unpolarized Asymmetries from COMPASS**
- **Systematics**
- **Summary and Outlook**

k_T independent SIDIS

3 PDFs describe the nucleon:



unpolarized distribution
very well measured

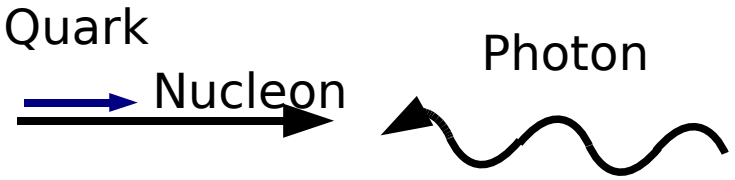
helicity distribution
well measured

transversity
measured

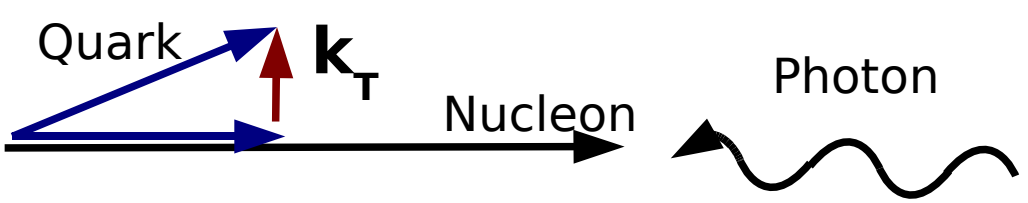
Quark Transverse Momentum k_T

- **Quark transverse momentum k_T**

QPM



intrinsic quark motion

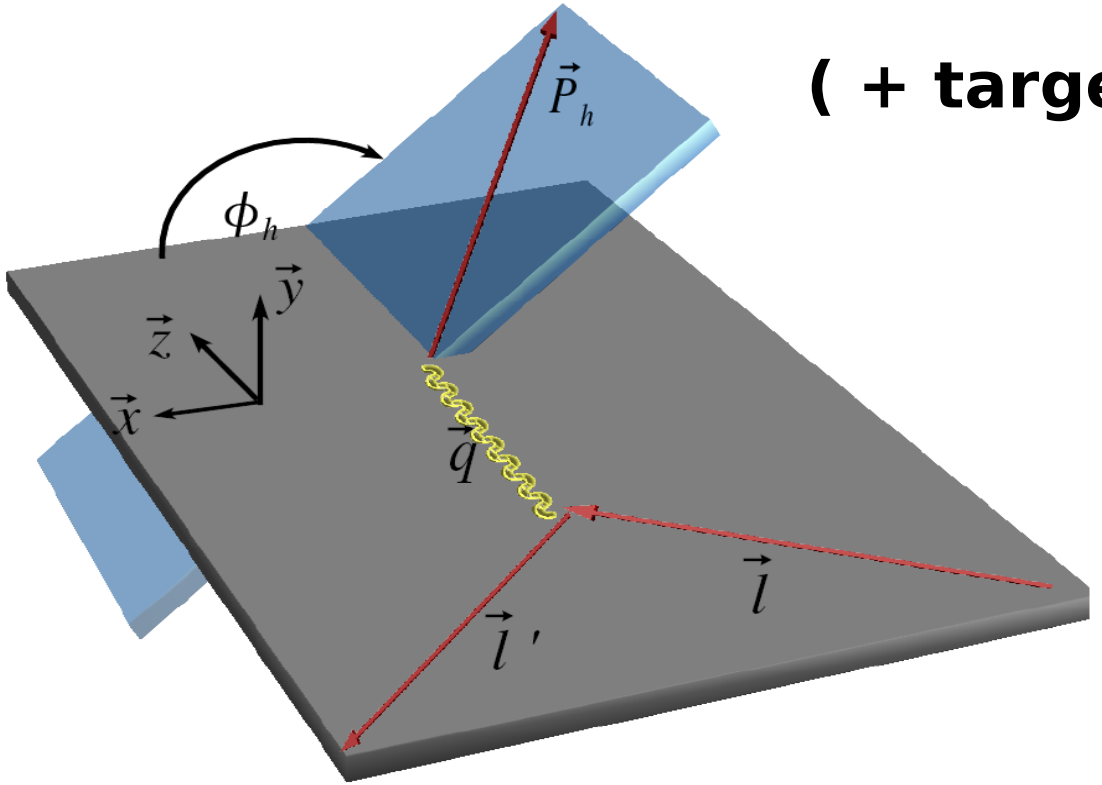


- **additional physics**
  - **Cahn Effect (kinematics)**
  - **Additional PDFs, e.g. Boer-Mulders $h_1^{\perp}(x, k_T)$**

SIDIS cross section

$$\frac{d^5\sigma}{dx\,dQ^2\,dy\,dz\,dP_t^2\,d\phi_h} \propto F_{UU} + F_{UU}^{\cos\phi_h} D_{\cos\phi_h}(y)\cos\phi_h + F_{UU}^{\cos 2\phi_h} D_{\cos 2\phi_h}(y)\cos 2\phi_h + P_{Beam} F_{LU}^{\sin\phi_h} D_{\sin\phi_h}(y)\sin\phi_h$$

(+ target polarization terms)



$$D_{\cos\phi_h}(y) = \frac{(2-y)\sqrt{(1-y)}}{1+(1-y)^2}$$

$$D_{\cos 2\phi_h}(y) = \frac{(1-y)}{1+(1-y)^2}$$

$$D_{\sin\phi_h}(y) = \frac{y\sqrt{(1-y)}}{1+(1-y)^2}$$

$$Q^2 = -q_\lambda q^\lambda \qquad x = \frac{Q^2}{2M_N(E_l - E_{l'})} \qquad y = \frac{E_l - E_{l'}}{E_l} \qquad z = \frac{E_h}{E_q}$$

SIDIS cross section

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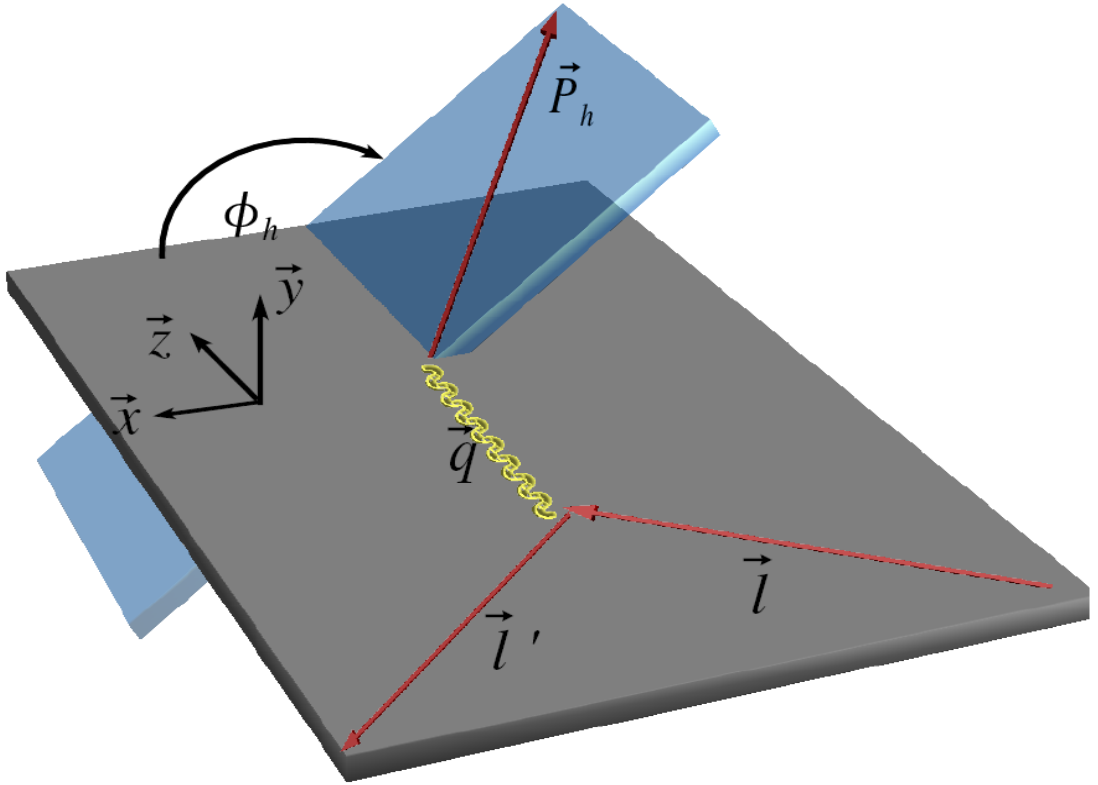

Cahn Effect

Boer Mulders

pQCD

Beam polarization

$$Q^2 = -q_\lambda q^\lambda \qquad x = \frac{Q^2}{2M_N(E_l - E_{l'})} \qquad y = \frac{E_l - E_{l'}}{E_l} \qquad z = \frac{E_h}{E_q}$$

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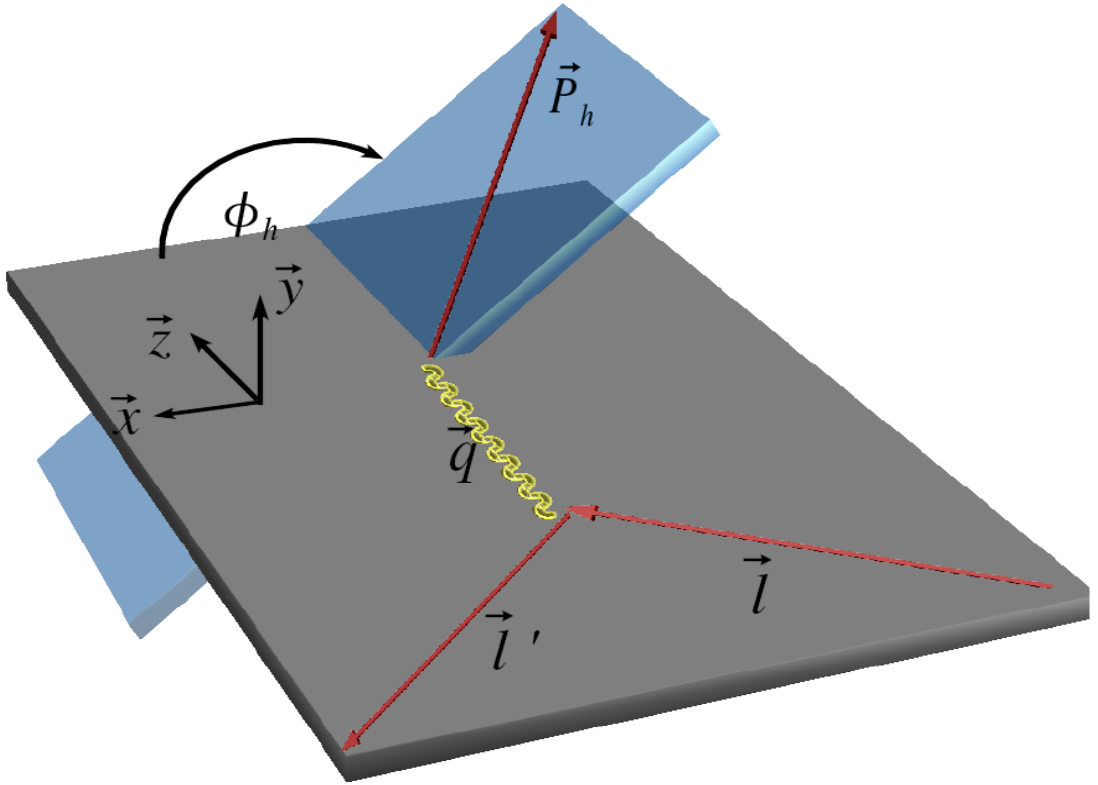

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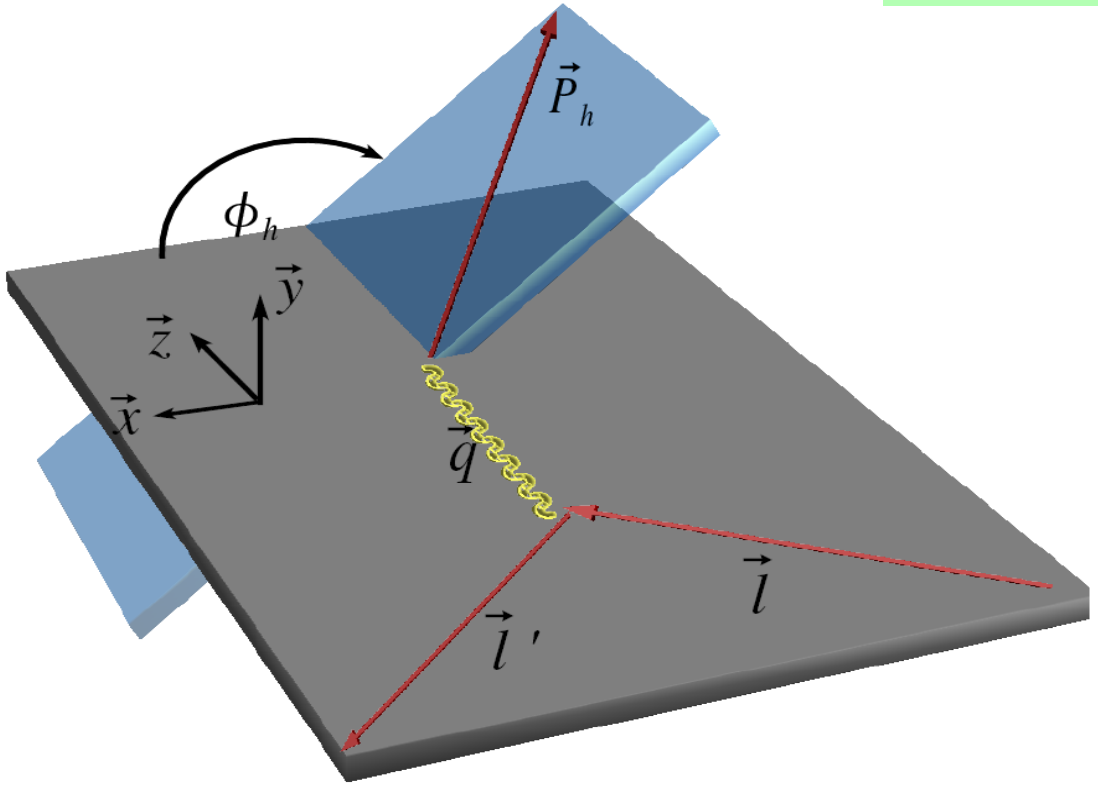

Cahn Effect

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Beam polarization

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Cahn Effect

- **Kinematical effect**
- **Leading order QED with $k_T \neq 0$**
- **Quark-lepton scattering:**

$$\frac{d\sigma}{d\phi_q} \propto 1 - 2\frac{k_t}{Q} D_{\cos\phi_h}(y) \cos\phi_q + \left(\frac{k_t}{Q}\right)^2 D_{\cos 2\phi_h}(y) \cos 2\phi_q$$

- **after fragmentation**

$$\frac{d\sigma}{d\phi_h} \propto 1 - 4\frac{\langle k_t^2 \rangle z P_t}{Q \langle P_t^2 \rangle} D_{\cos\phi_h}(y) \cos\phi_h + \ldots$$

- **$\langle k_T^2 \rangle \approx 0.25$ (GeV/c)^2**

R. N. Cahn. PL B78 (1978) 269-273

...

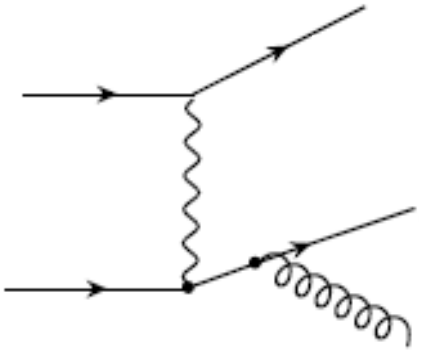
M. Anselmino et al. PR. D71 (2005) 074006

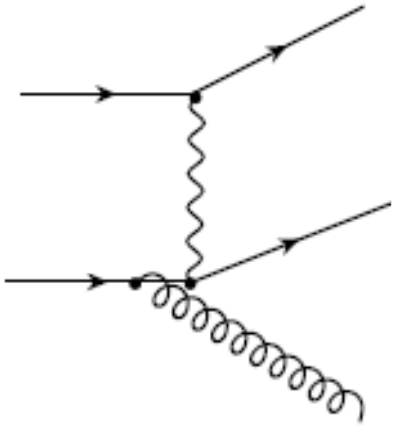
Boer – Mulders Function

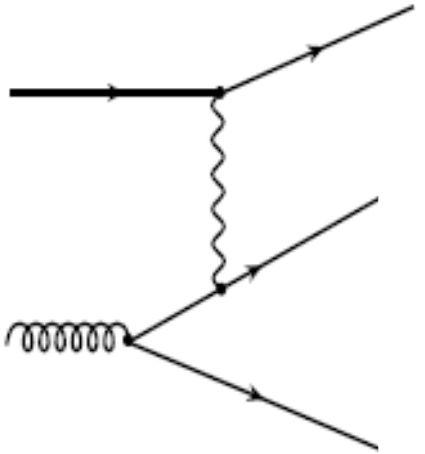
- **leading Twist**
- **contributes to cos ϕ_h and cos $2\phi_h$, convoluted with Collins fragmentation function $H_1^{\perp}$**
  - **for cos ϕ_h large Cahn effect**
  - **for cos $2\phi_h$ Boer-Mulders and Cahn effect might be of similar magnitude**
- **not measured**
- **also under investigation in Drell-Yan processes**

Pertubative QCD

- **important at P_t > 1GeV/c**







$O(\alpha_s^1)$:

H. Georgi and H. D. Politzer. PRL 40 (1978) 3-6
A. Mendez. NP B145 (1978) 199-220.

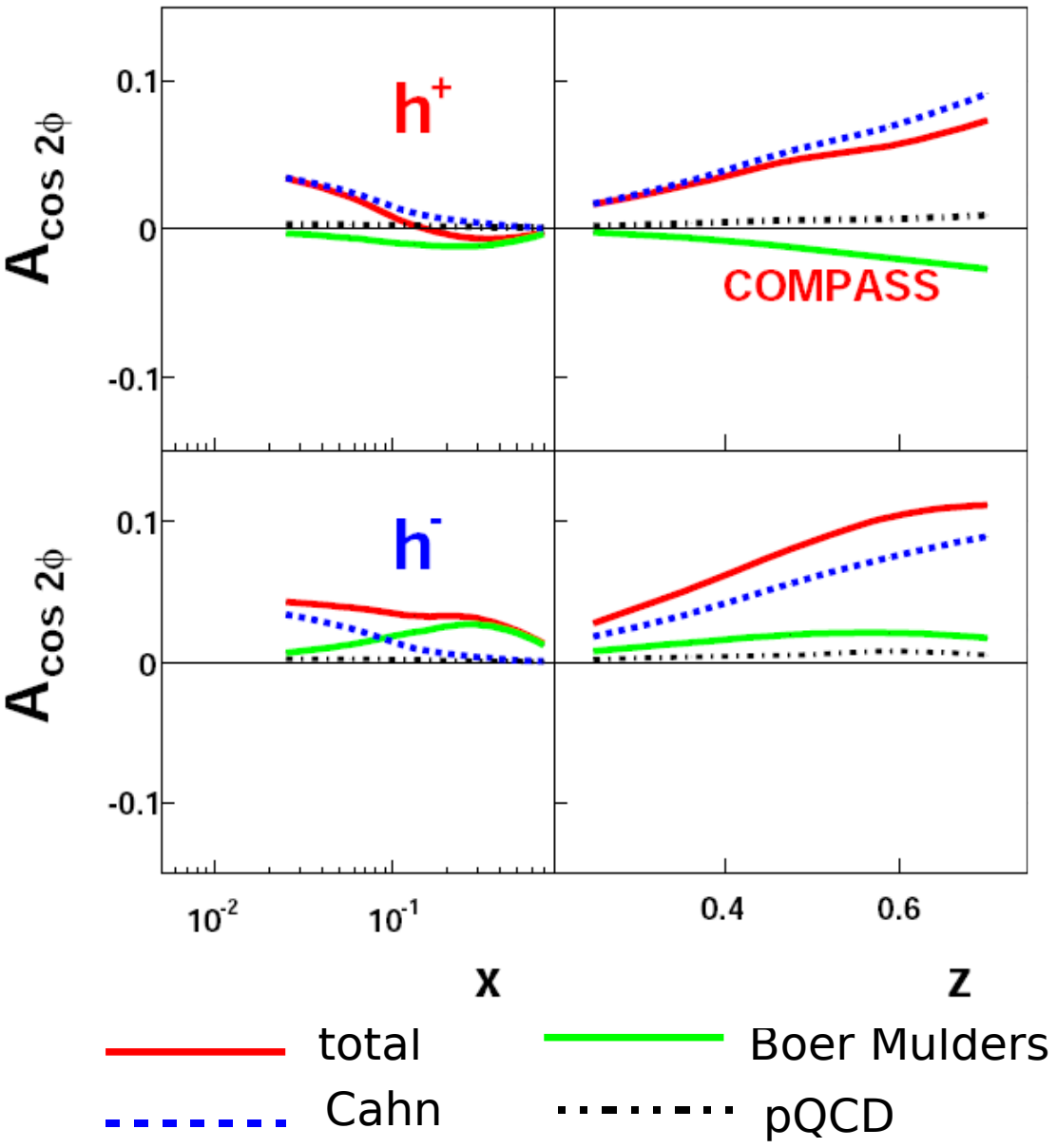
$O(\alpha_s^2)$:

A. Daleo, D. de Florian, and R. Sassot. PR D71 (2005) 034013.

Predictions for COMPASS kinematics

- **pQCD charge independent**
- **Cahn: charge independent**

  (if $k_T^u = k_T^d$)
- **Boer - Mulders: charge dependence**



V.Barone, A.Prokudin, B.Q.Ma
arXiv:0804.3024 [hep-ph]

Present experimental status

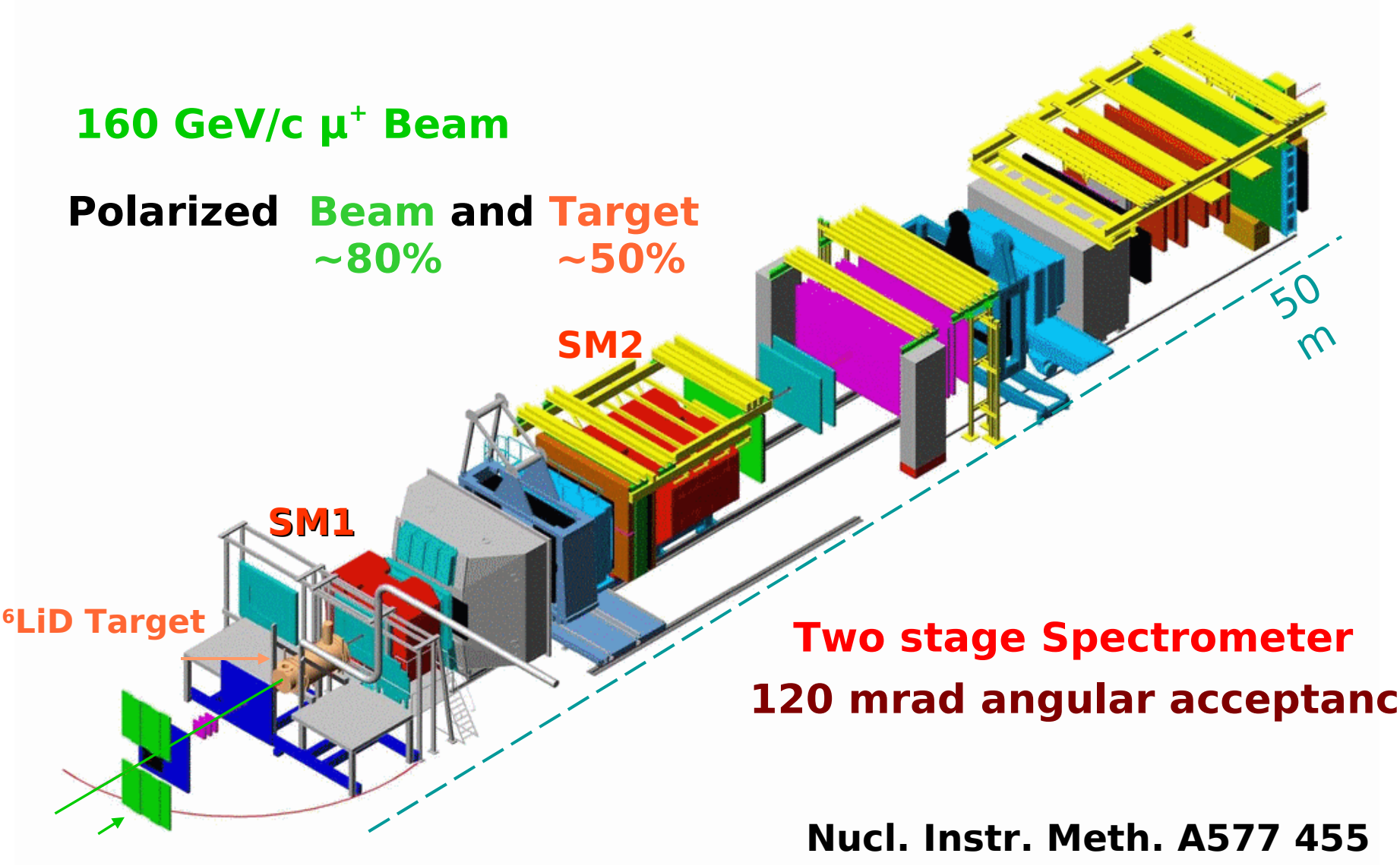
- **EMC** PL B 130 (1983) 118; ZP C34(1987) 277
- **E665** PR D48 (1993) 5057

→ large cos ϕ_h effect (up to 40% amplitude), cos $2\phi_h$ small (~5%)

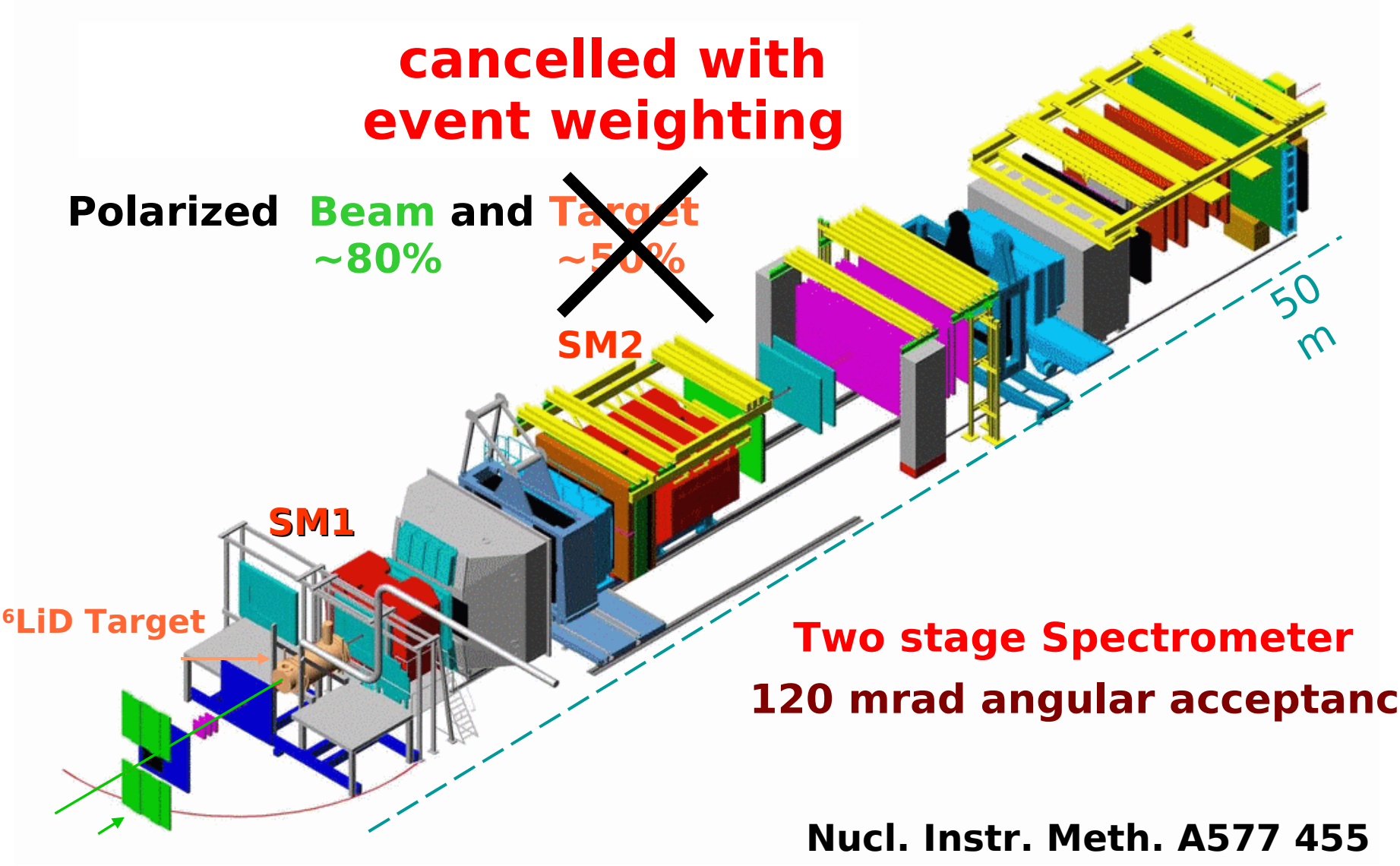
  - **no charge separation so far!**

- **Zeus (pQCD region)** PL B481 (2000) 199
- **sinϕ_h ~ 3% (CLAS)** PR D69 (2004) 112
- **today: First results from COMPASS**

The COMPASS-Experiment



The COMPASS-Experiment

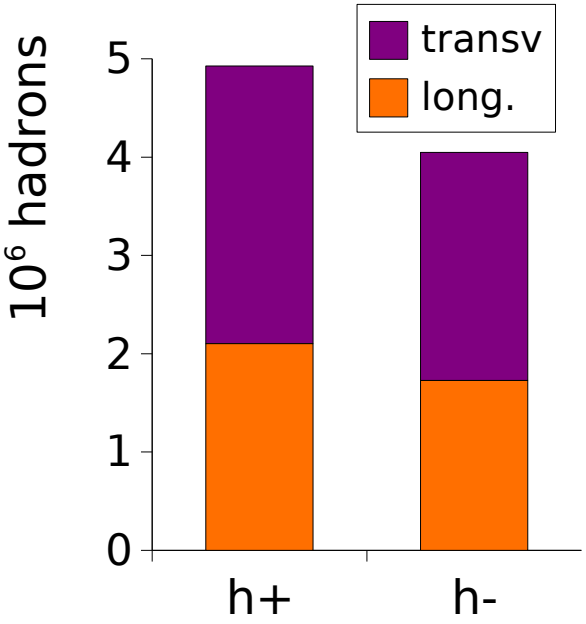


Data Sample

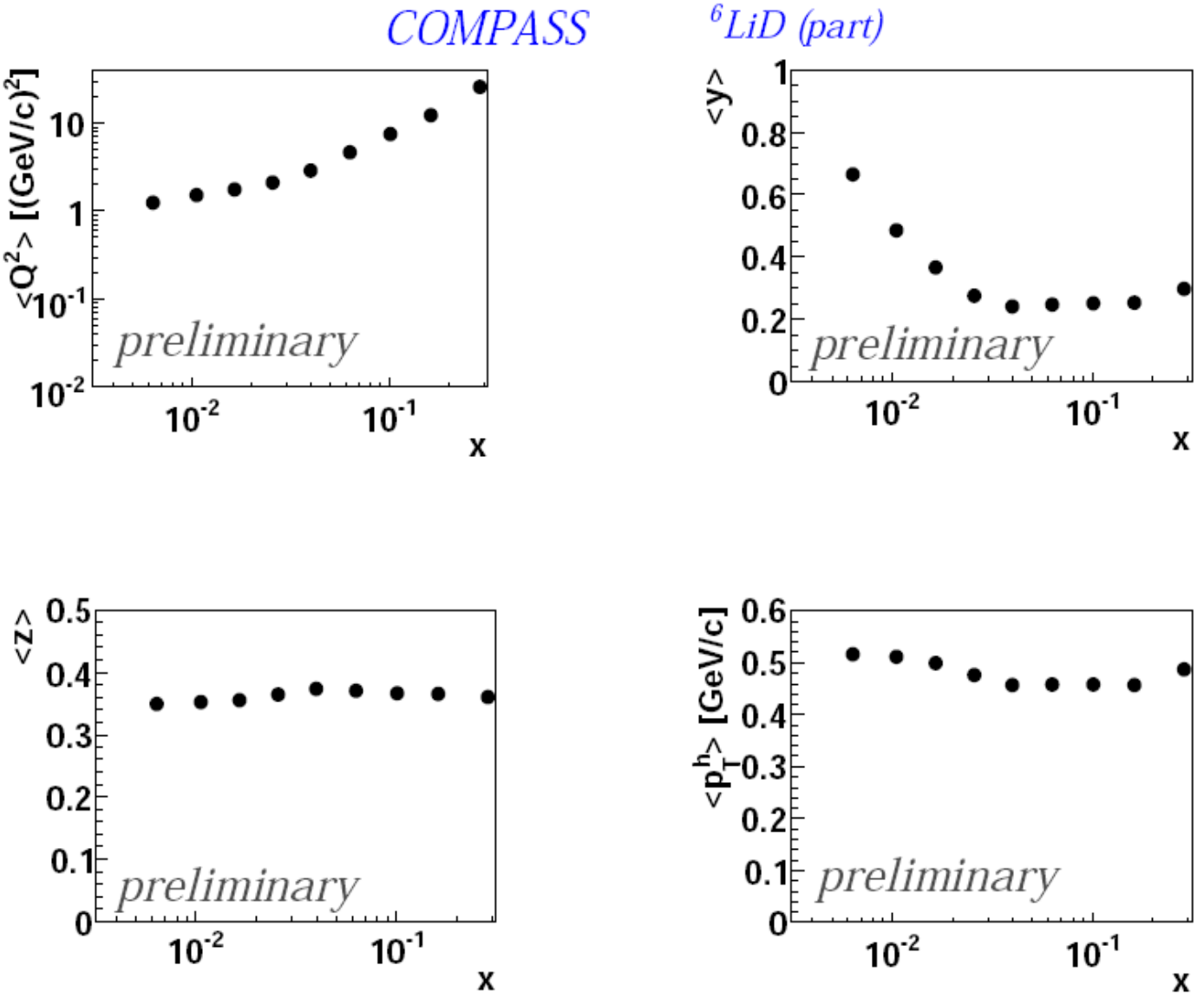
- **3 weeks with long. target polarization (2004, LiD target)**
- **4 weeks with transverse polarization (2004, LiD target)**

→ events weighted to cancel possible polarization dependencies

- **Kinematic region:**
  - **$Q^2>1(GeV/c)^2$**
  - **$0.1<y<0.9$**
  - **$0.2<z<0.85$**
  - **$0.1GeV/c<P_t<1.5GeV/c$**



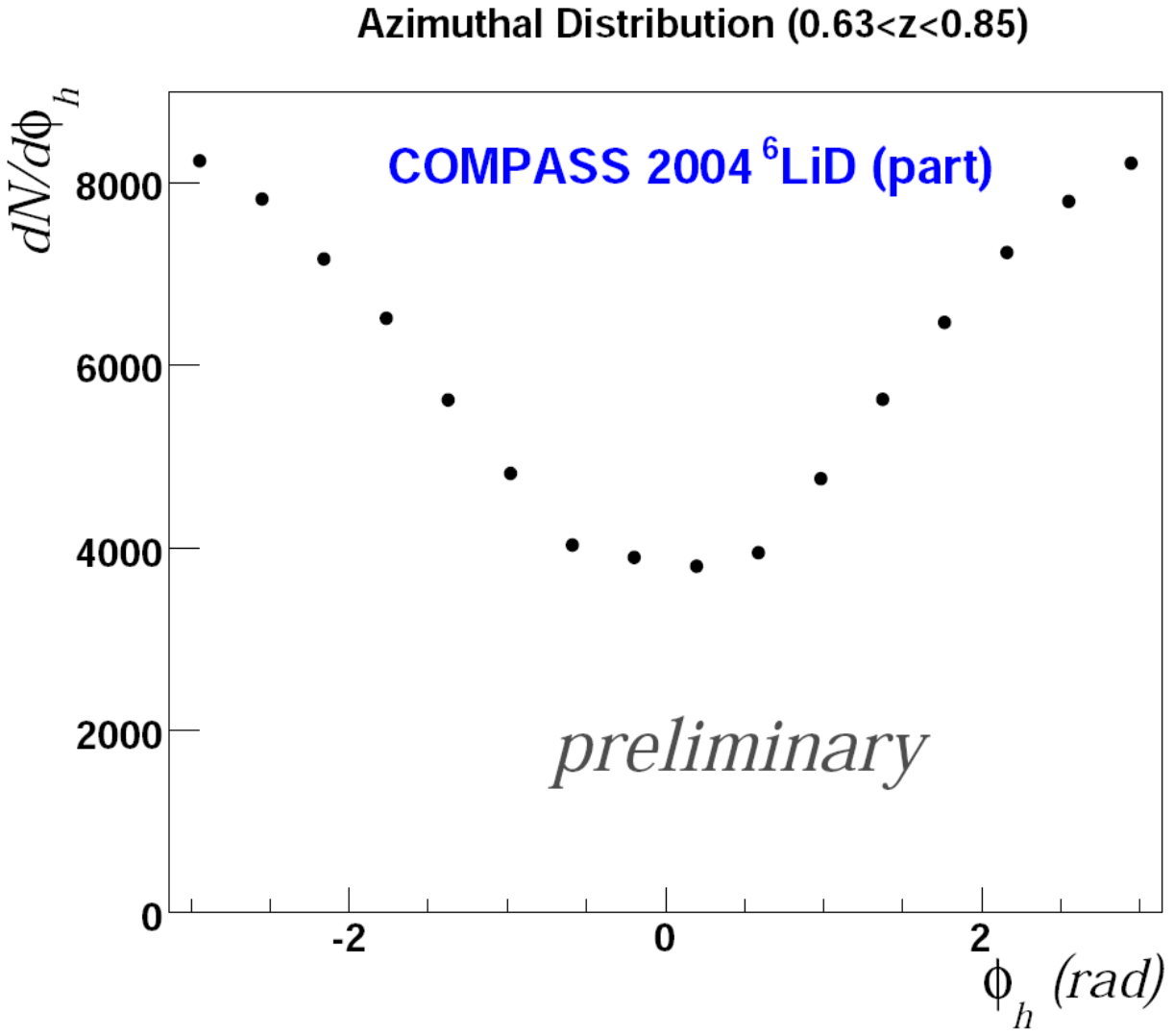
Mean kinematics



mean Q^2, y, z, and P_t as a function of x

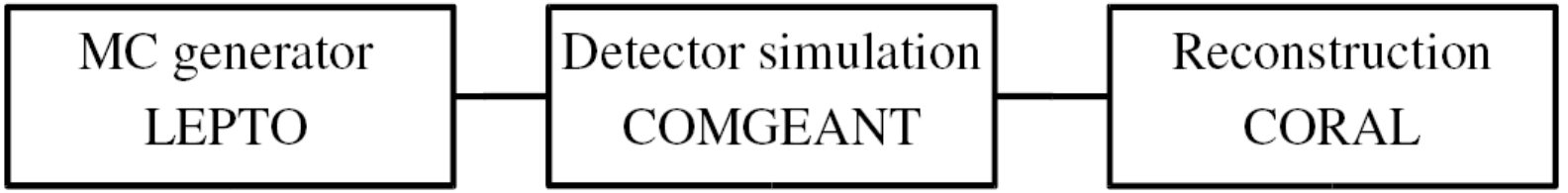
The method I

Measured ϕ_h distribution distorted by detector acceptance



The method II

- **Need to correct -> MC simulation**

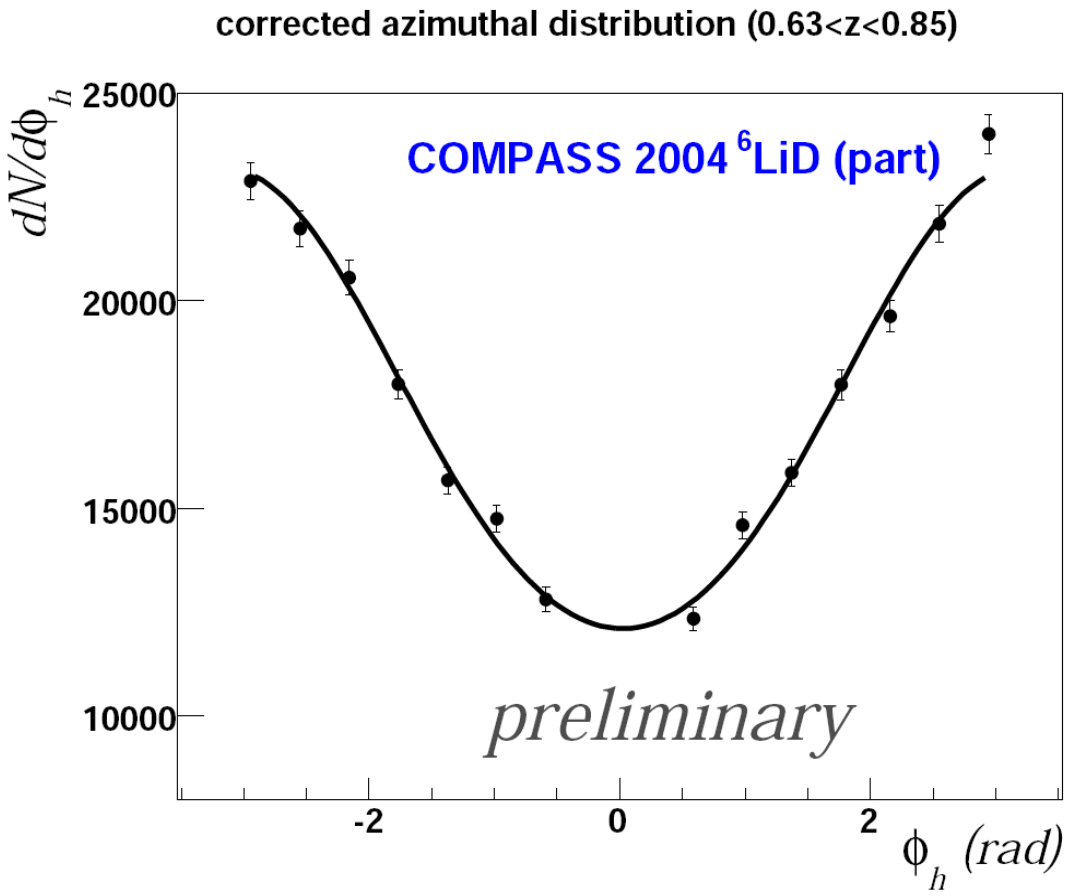


$$A(\phi_h)=\frac{N_{rec}(\phi_h)}{N_{gen}(\phi_h)} \qquad N_{corr}(\phi_h)=\frac{N_{meas}(\phi_h)}{A(\phi_h)}$$

- **amplitudes obtained with fit to N_{corr}**

$$N_{corr}(\phi_h)=N_0(1+A_{\sin\phi_h}\sin\phi_h+A_{\cos\phi_h}\cos\phi_h+A_{\cos 2\phi_h}\cos 2\phi_h)$$

After acceptance correction

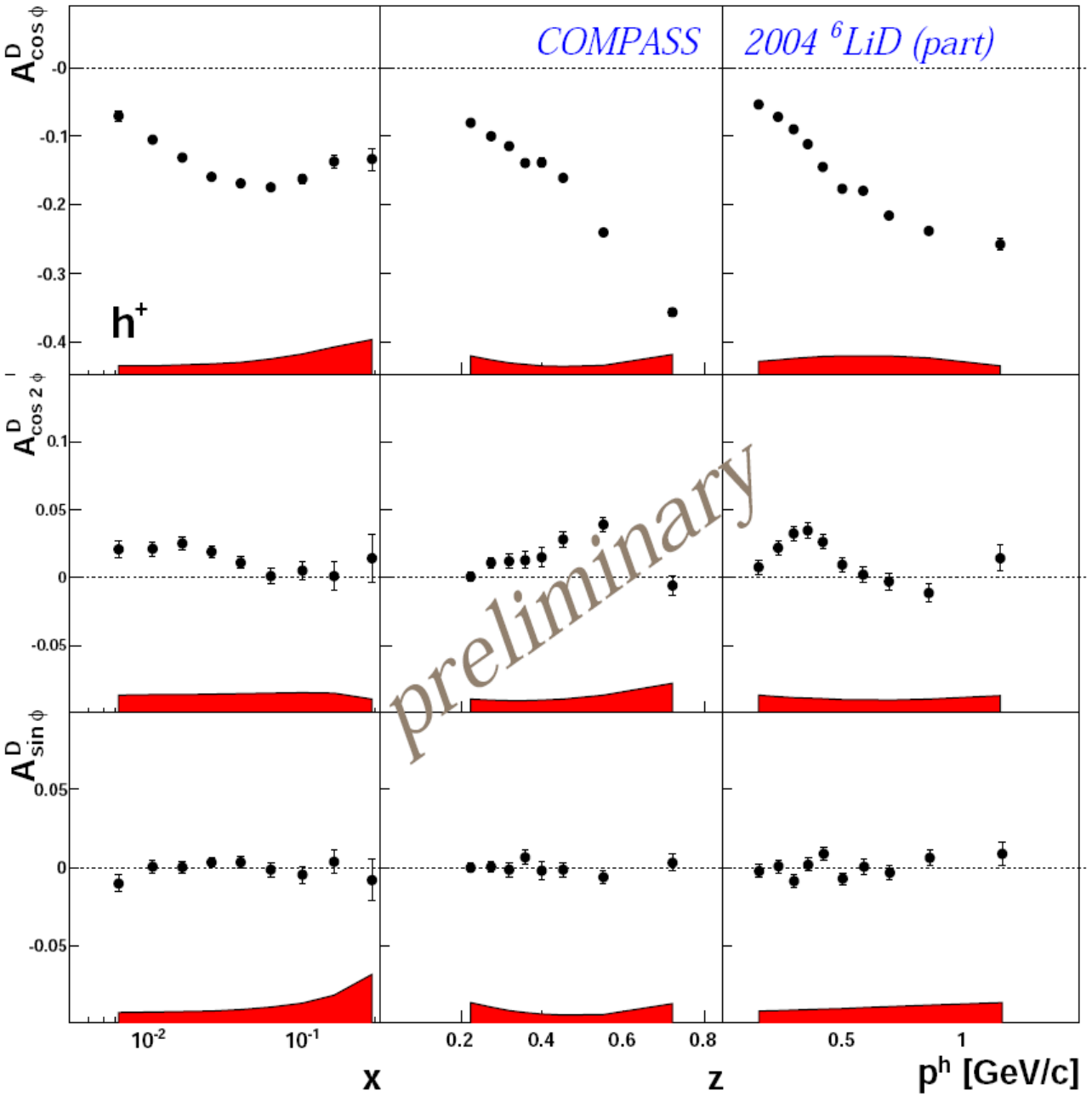


h+:

$A_{\cos\phi_h}$

$A_{cos2\,\phi_h}$

$A_{\sin\phi_h}$



Cahn (+Boer - Mulders)

Cahn+ Boer-Mulders

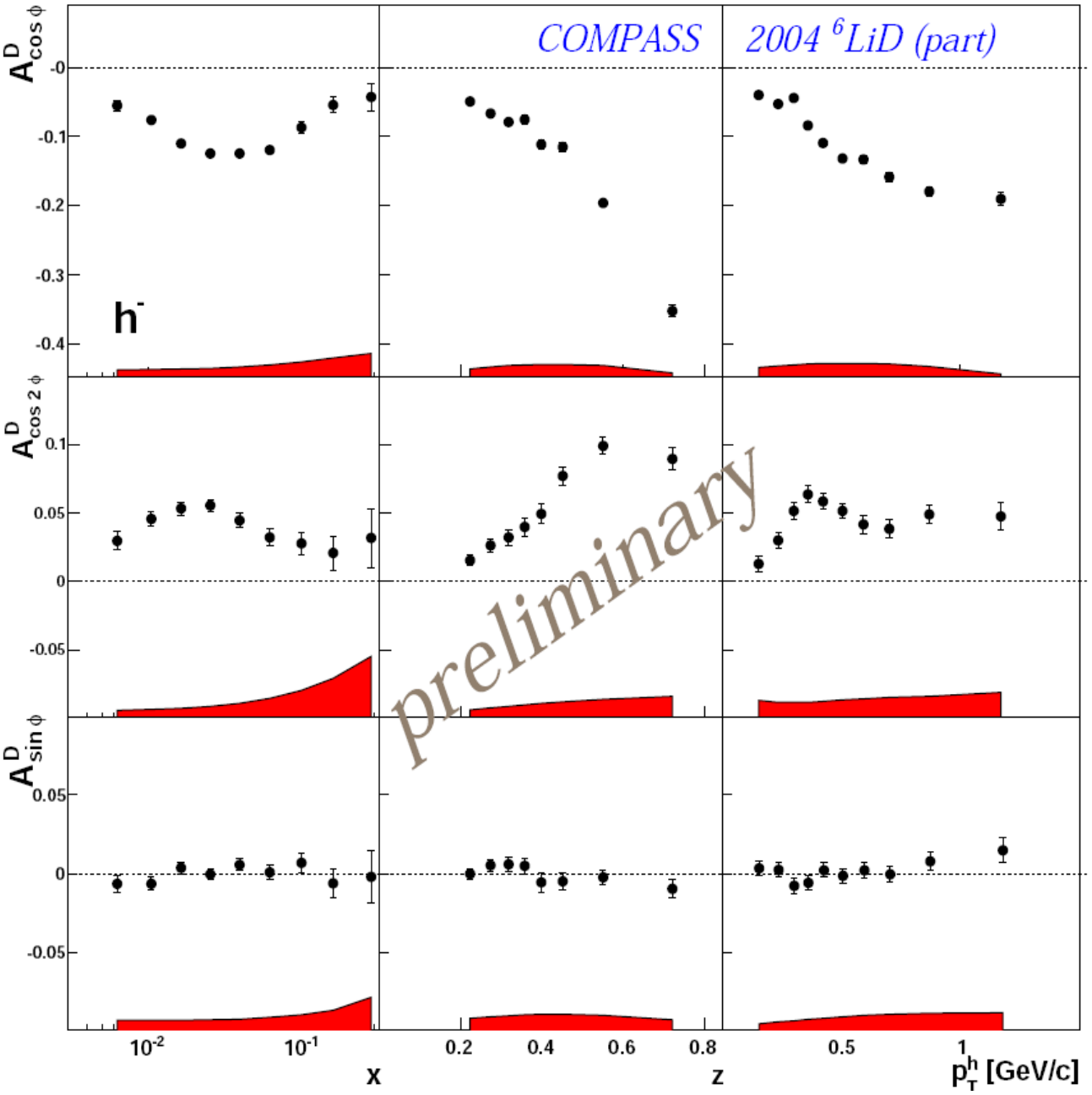
beam polarization

h-:

$A_{\cos\phi_h}$

$A_{cos2\,\phi_h}$

$A_{\sin\phi_h}$



Cahn (+Boer - Mulders)

Cahn+ Boer-Mulders

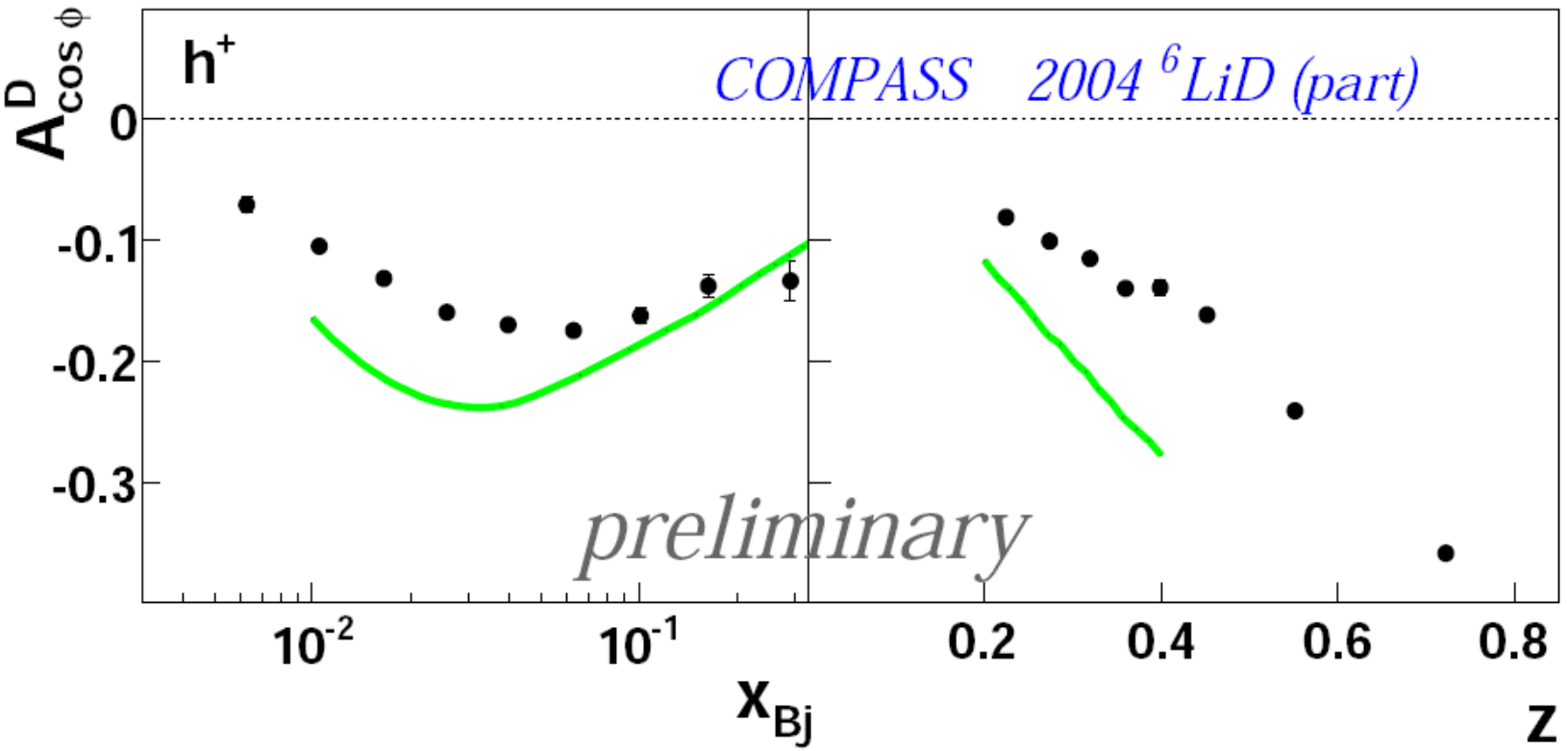
beam polarization

Concerning the Systematic Error:

- **data with longitudinal and transverse target polarization (different experimental conditions, different MCs)**
- **two MCs with different settings for each data set (LEPTO default, COMPASS high P_t)**
- **additional tests (sample splitted in time, event topology, target polarization):**

  here no significant contribution

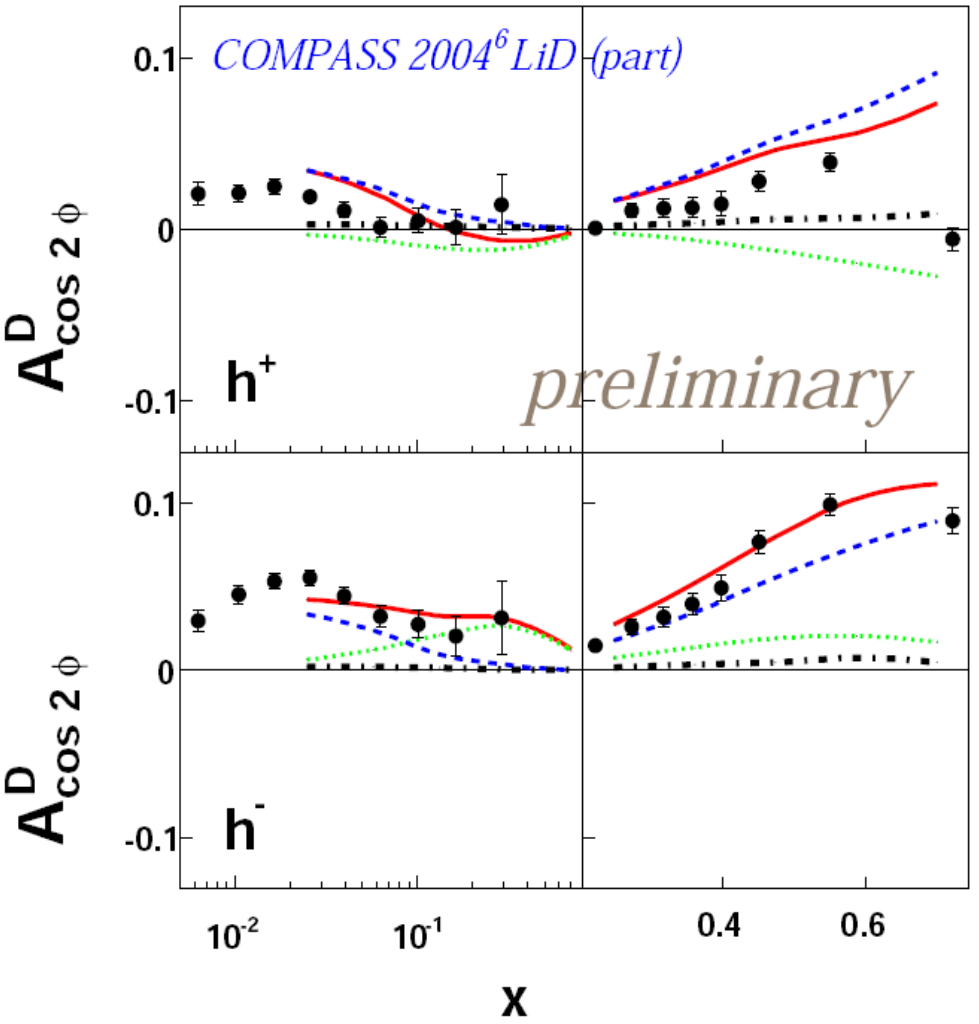
Comparison with Theory



errors shown are statistical only

M. Anselmino, M. Boglione, A. Prokudin, C. Türk
Eur. Phys. J. A 31, 373-381 (2007)
does not include Boer – Mulders contribution

Comparison with Theory



V.Barone, A.Prokudin, B.Q.Ma
arXiv:0804.3024 [hep-ph]

total
Cahn
Boer Mulders
pQCD

errors shown are statistical only

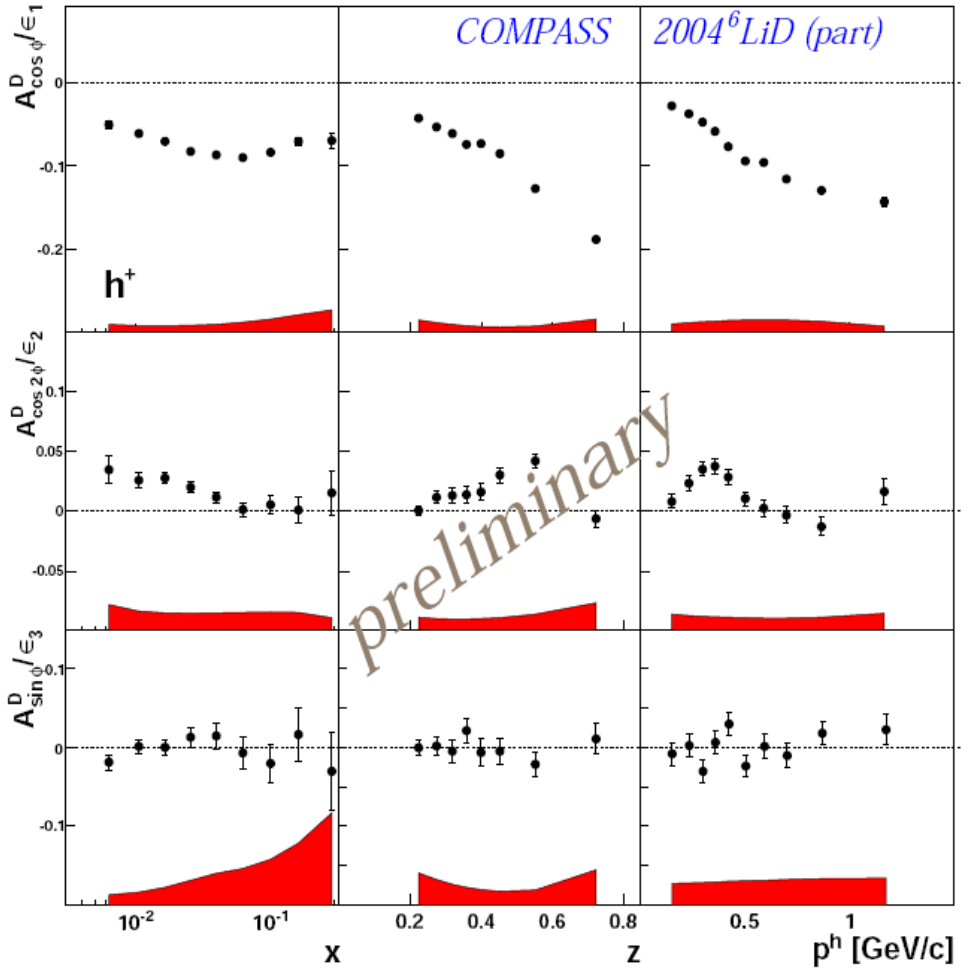
Summary and Outlook:

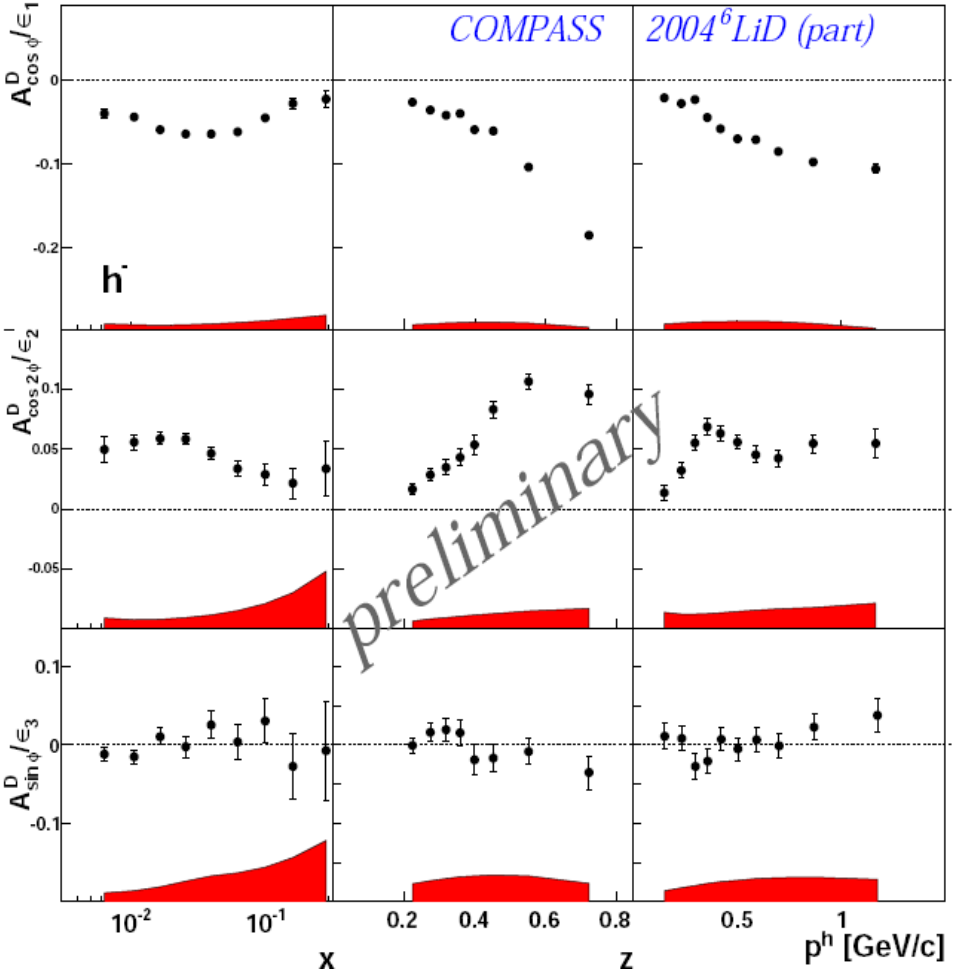
- **First results on unpolarized Asymmetries from COMPASS**
- **$\cos\phi_{h:}$ up to 40% asymmetry**
  - **not in agreement with prediction**
- **$\cos 2\phi_h$: up to 10%**
  - **Good agreement with prediction**
- **sin ϕ_h: compatible with 0**
- **2007 proton data will be analyzed as well**

BACKUP

BACKUP

Results corrected for kinematics

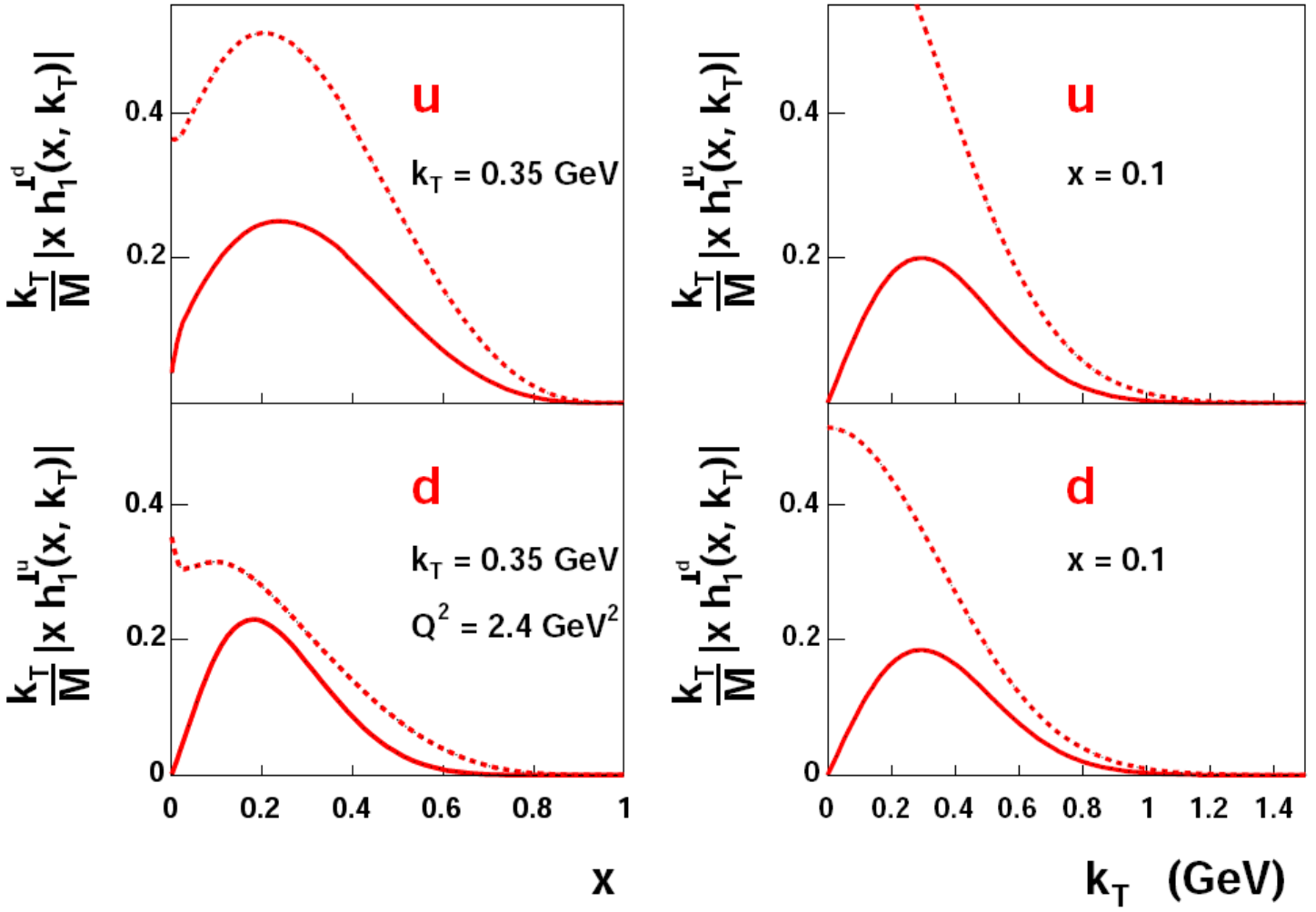




$$\epsilon_1 = \left\langle \frac{2(2-y)\sqrt{(1-y)}}{(1+(1-y)^2)} \right\rangle \qquad \epsilon_2 = \left\langle \frac{2(1-y)}{(1+(1-y)^2)} \right\rangle \qquad \epsilon_3 = \langle P_{\text{Beam}} \rangle \left\langle \frac{2y\sqrt{(1-y)}}{(1+(1-y)^2)} \right\rangle$$

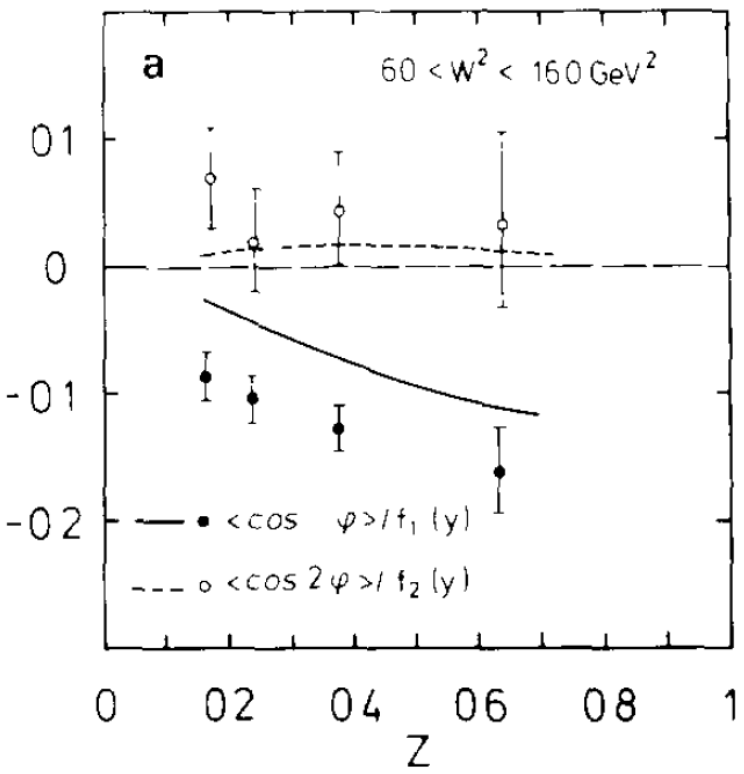
The Boer – Mulders Function

- **obtained from Sivers Function using Burkardts approach**



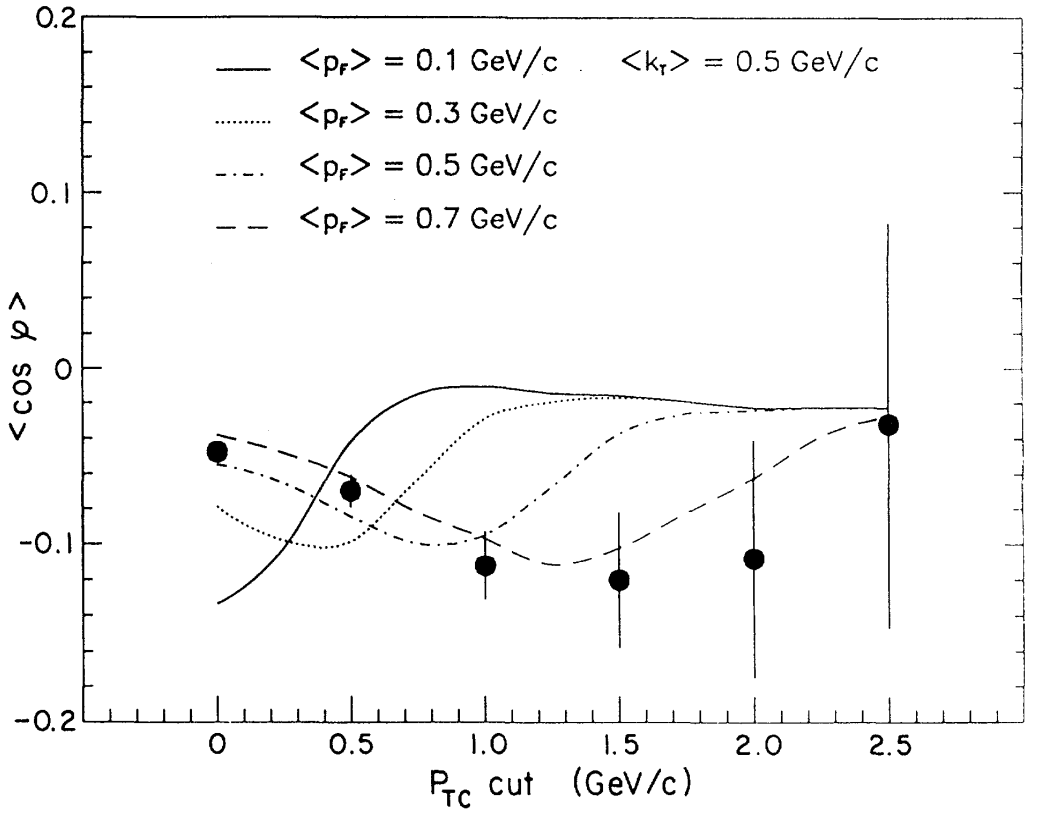
Previous experiments

EMC (120 GeV data)



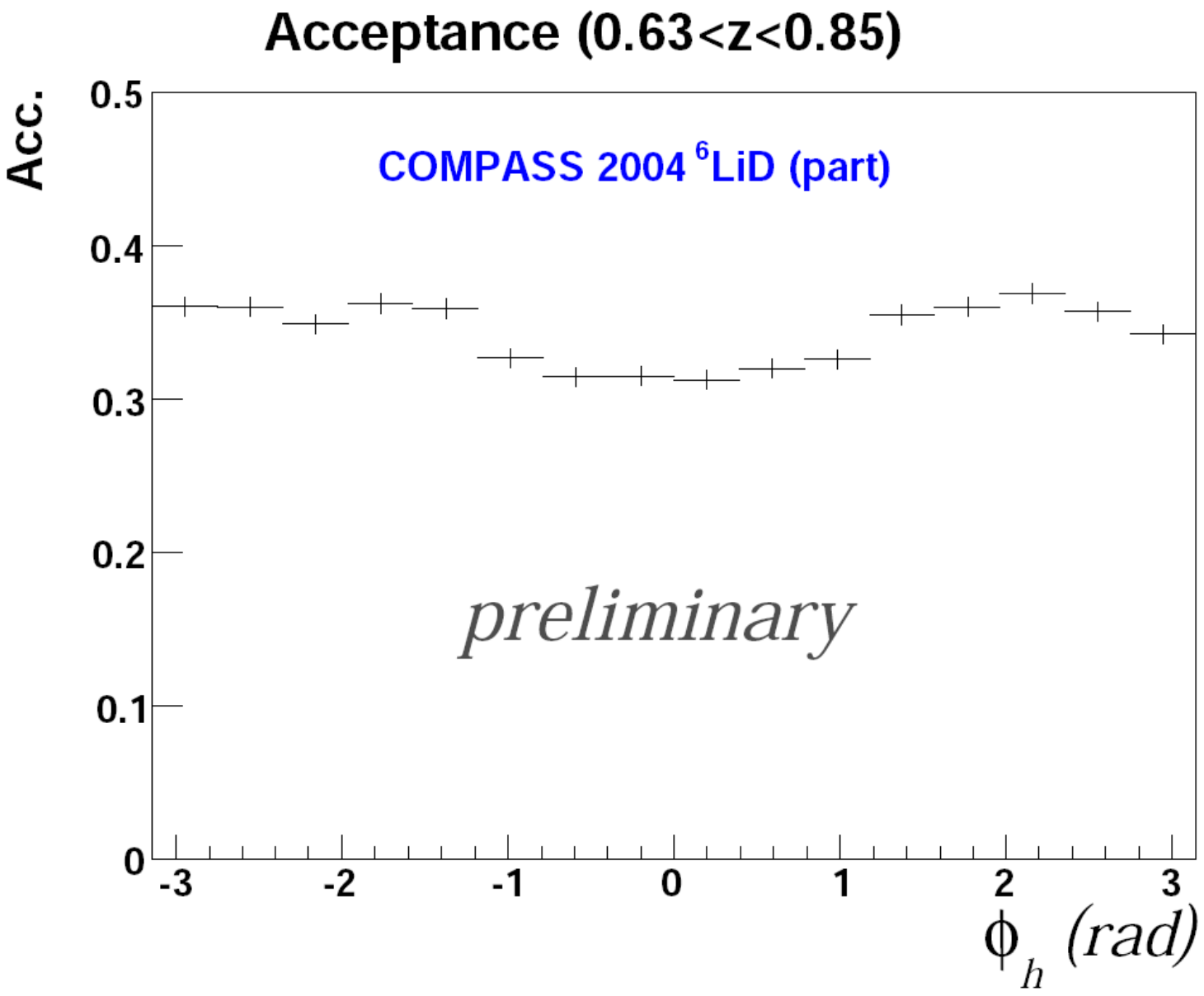
$$\frac{\langle \cos\phi_h \rangle}{f_1(y)} = \frac{A_{\cos\phi_h}}{\epsilon_1}$$

E665



$$\langle \cos\phi_h \rangle = \frac{A_{\cos\phi_h}}{2}$$

acceptance


Acceptance (0.63<z<0.85)
Acc.
0.5
0.4
0.3
0.2
0.1
0
COMPASS 2004 ^{6}LiD (part)
preliminary
-3
-2
-1
0
1
2
3
ϕ_h (rad)