Azimuthal asymmetries in SIDIS off unpolarized targets at COMPASS

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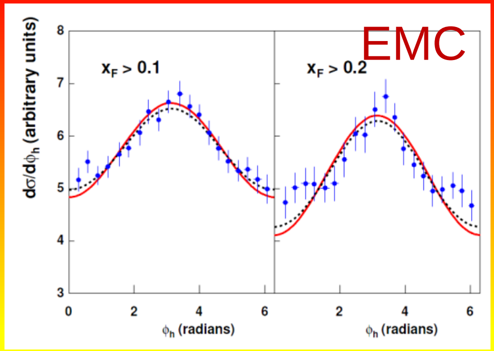
On behalf the COMPASS collaboration

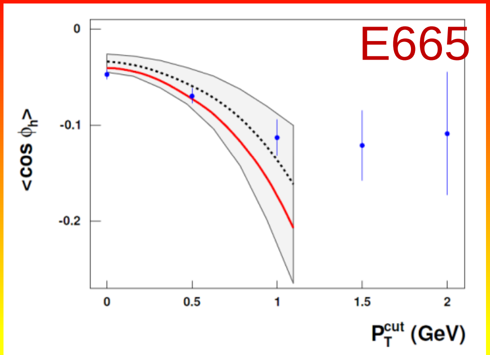
Outline

- Introduction
- The COMPASS experiments
- Analysis and extraction of the asymmetries
- Results
- Conclusions

Experimental status

- Azimuthal modulations in $lp \rightarrow l'hX$ measured by
  - EMC
  - E665





Fits from M. Anselmino, V. Barone, E. Boglione,U. D'Alesio, F. Murgia, A. Prokudin, A. Kotzinian, and C. Turk

- Large modulations up to 40% for $\cos\phi$, while $\cos 2\phi \sim 5\%$

  (with ϕ or ϕ_h the the hadron azimuthal angle in GNS)

  - More recently ZEUS in the high-pT (pQCD region)

Since last year, new data from COMPASS and HERMES

Cahn effect – just a reminder

The unpolarized SIDIS cross section is:

$$d\sigma^{lp\to l'hX} = \sum_q f_q\left(x,Q^2\right) \otimes d\sigma^{lp\to l'q} \otimes D_q^h\left(z,Q^2\right)$$

with f the PDF and D the FF

In collinear PM than the elementary xSection is

$$d\sigma^{lp\to l'q} \propto \hat{s}^2 + \hat{u}^2 \propto x\left(1+(1-y)^2\right)$$

i.e. no dependence on ϕ_h. Taking into account the parton transverse momentum in the kinematics leads to:

$$\hat{s} = sx\left[1-\frac{2k_T}{Q}\sqrt{1-y}\cdot\cos\phi\right]+O\left(\frac{k_T^2}{Q}\right) \qquad \hat{u} = sx(1-y)\left[1-\frac{2k_T}{Q\sqrt{1-y}}\cdot\cos\phi\right]+O\left(\frac{k_T^2}{Q}\right)$$

Resulting in the cos ϕ_h and cos $2\phi_h$ modulations observed in the azimuthal distributions

Unpolarised target SIDIS cross-section

COMPASS

$$\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} =$$

$$\frac{\alpha^2}{xyQ^2}\,\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T}+\varepsilon F_{UU,L}+\sqrt{2\,\varepsilon(1+\varepsilon)}\,\cos\phi_h\,F_{UU}^{\cos\phi_h}$$

$$+\,\varepsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h}+\lambda_e\,\sqrt{2\,\varepsilon(1-\varepsilon)}\,\sin\phi_h\,F_{LU}^{\sin\phi_h}$$

$$F_{LU}^{\sin\phi_h}=\frac{2M}{Q}\,\mathcal{C}\left[-\frac{\hat{h}\cdot k_T}{M_h}\left(xe\,H_1^\perp+\frac{M_h}{M}\,f_1\frac{\tilde{G}^\perp}{z}\right)+\frac{\hat{h}\cdot p_T}{M}\left(xg^\perp D_1+\frac{M_h}{M}\,h_1^\perp\frac{\tilde{E}}{z}\right)\right]$$

Cahn effect

Cahn effect + Boer-Mulders DF

Boer-Mulders DF

$$F_{UU}^{\cos\phi_h}=\frac{2M}{Q}\,\mathcal{C}\left[-\frac{\hat{h}\cdot k_T}{M_h}\left(xh\,H_1^\perp+\frac{M_h}{M}\,f_1\frac{\tilde{D}^\perp}{z}\right)-\frac{\hat{h}\cdot p_T}{M}\left(xf^\perp D_1+\frac{M_h}{M}\,h_1^\perp\frac{\tilde{H}}{z}\right)\right]$$

he

nucleon spin in an unpolarised

cleon

$$F_{UU}^{\cos 2\phi_h}=\mathcal{C}\left[-\frac{2\,(\hat{h}\cdot k_T)\,(\hat{h}\cdot p_T)-k_T\cdot p_T}{M\,M_h}\,h_1^\perp H_1^\perp\right]$$

Boer- Mulders x Collins FF

+ Cahn effect

and R. Sassot. PR D71

COMPASS

COmmon **M**uon and **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

NA58

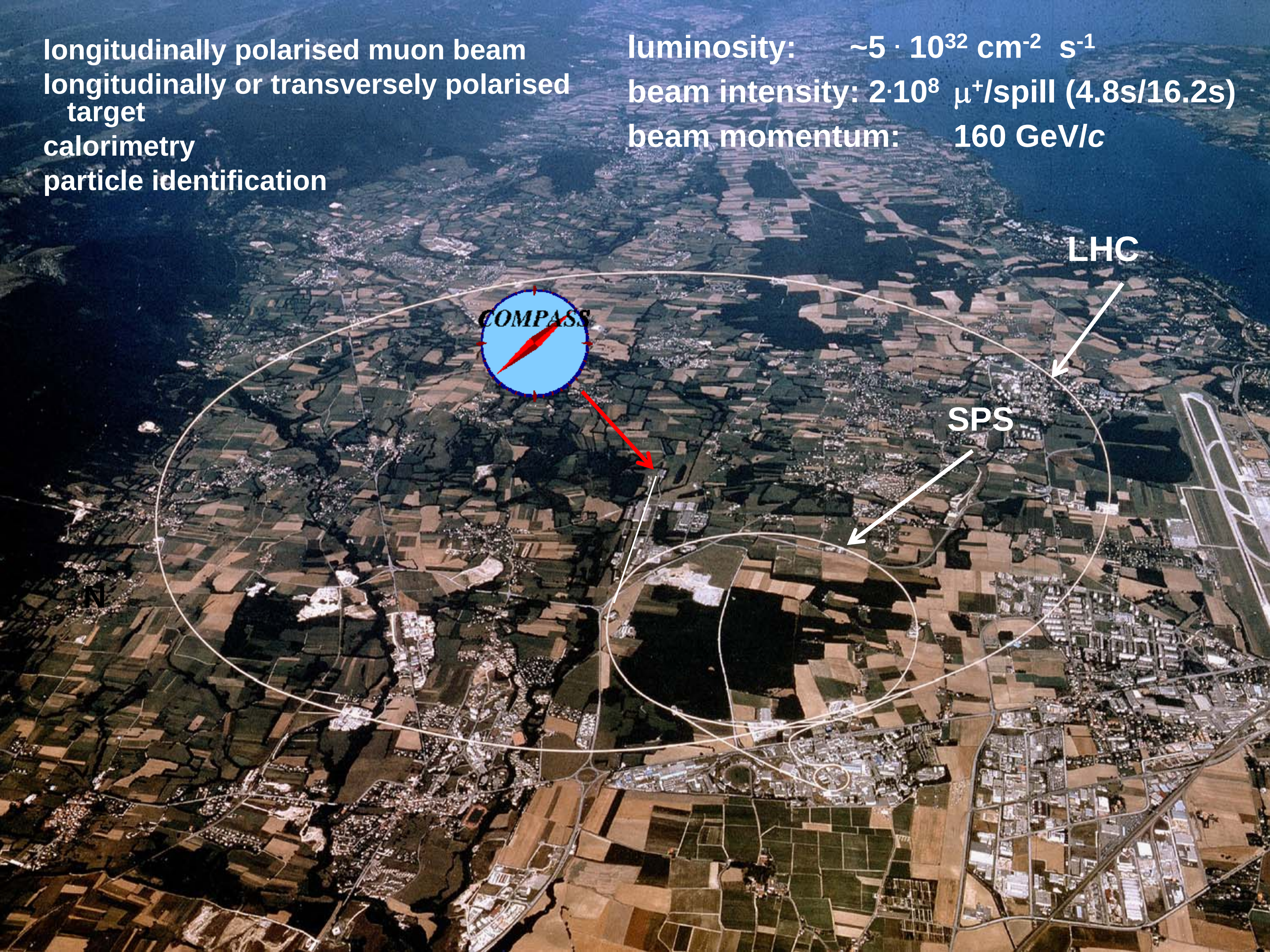
Czech Republic, Finland, France, Germany, India, Israel, Italy, Japan, Poland, Portugal, Russia

Bielefeld, Bochum, Bonn, Burdwan, Calcutta, CERN, Dubna, Erlangen, Freiburg, Heidelberg, Helsinki, Lisbon, Mainz, Miyazaky, Moscow, Munich, Prague, Protvino, Saclay, Tel Aviv, Torino, Trieste, Warsaw,Yamagata

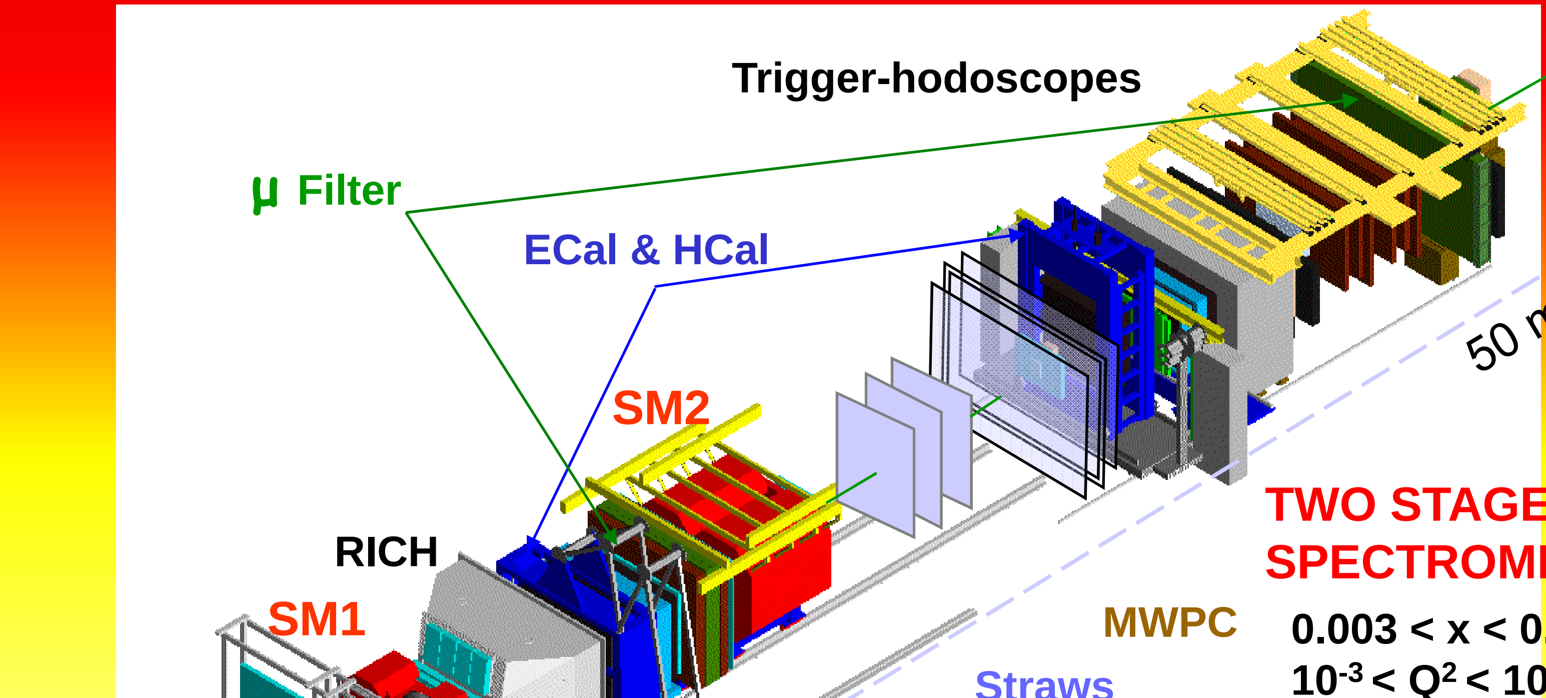
28 Institutes, ~230 physicists

longitudinally polarised muon beam
longitudinally or transversely polarised target
calorimetry
particle identification

luminosity: ~5 · 10^{32} cm^{-2} s^{-1}
beam intensity: $2 \cdot 10^{8}$ μ^{+}/spill (4.8s/16.2s)
beam momentum: 160 GeV/*c*



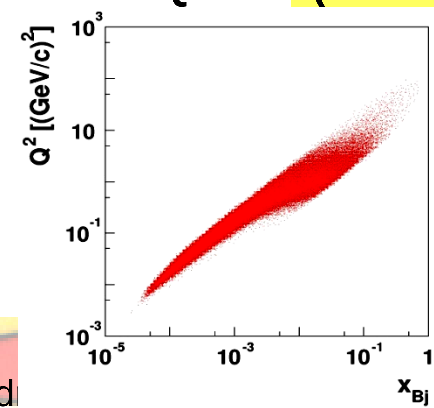
The Spectrometer for the Muon Programme



TWO STAGE SPECTROMETER:

$0.003 < x < 0.5$

$10^{-3} < Q^2 < 10$ (GeV/c



Data used for this analysis

- part of the 2004 (^{6}LiD target) data collected with longitudinal (L) and transverse (T) polarization
- with both target orientation configurations to cancel possible polarization effects

Event selection:

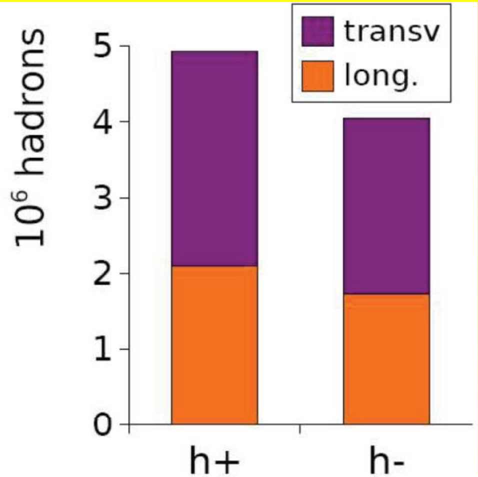
DIS events…

- $Q^2>1$ (GeV/c)^2
- $0.1<y<0.9$
- $W>5$ (GeV/c^2)

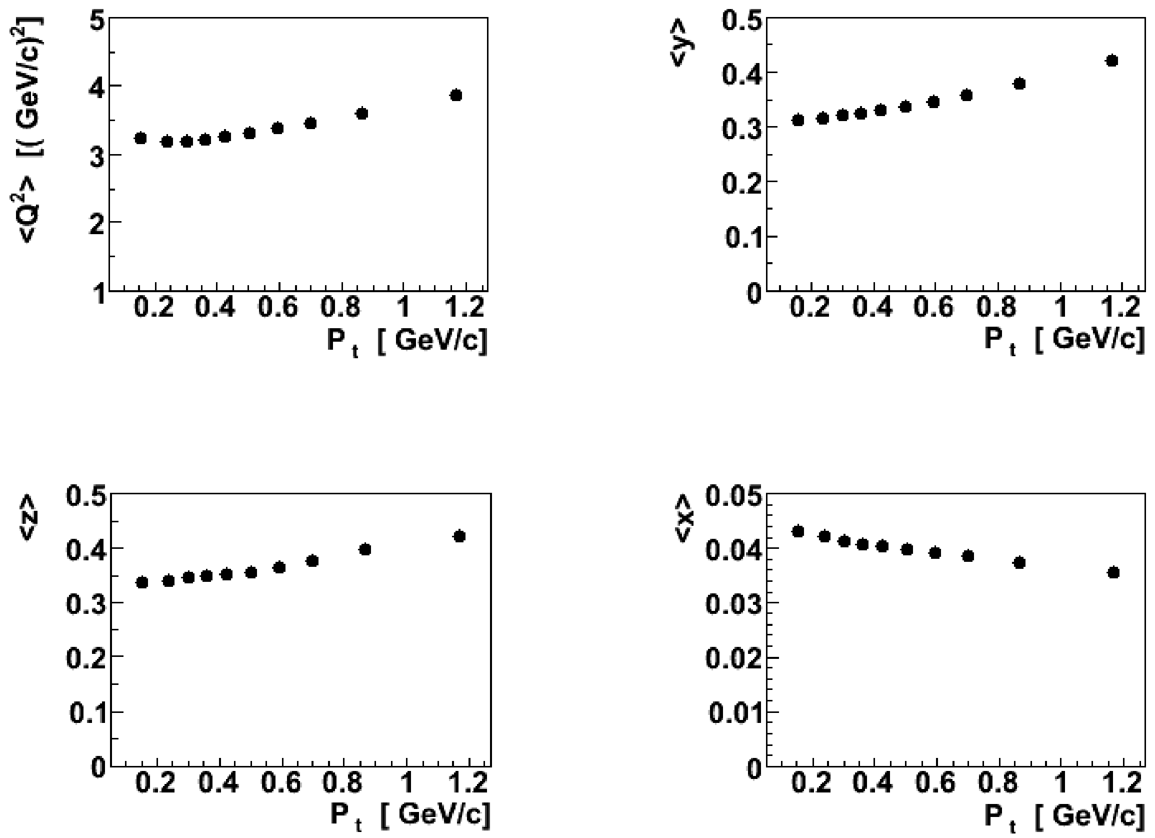
Hadrons

- $0.2< z < 0.85$
- $0.1<p_T<1.5$ (GeV/c)

Statistics of this analysis:



Mean kinematical values



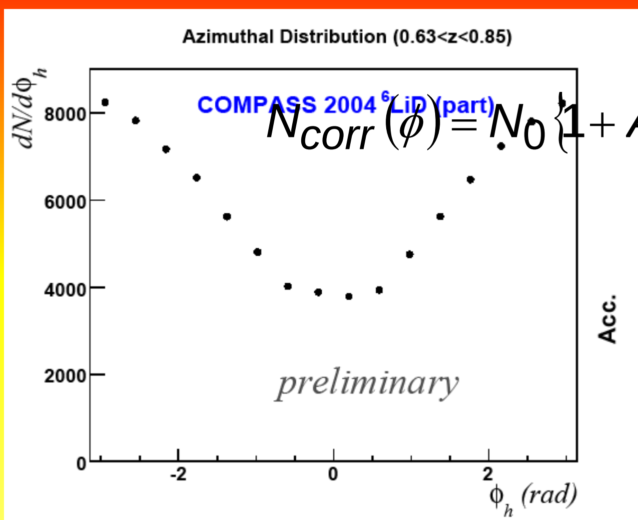
unpolarised target SIDIS cross-section

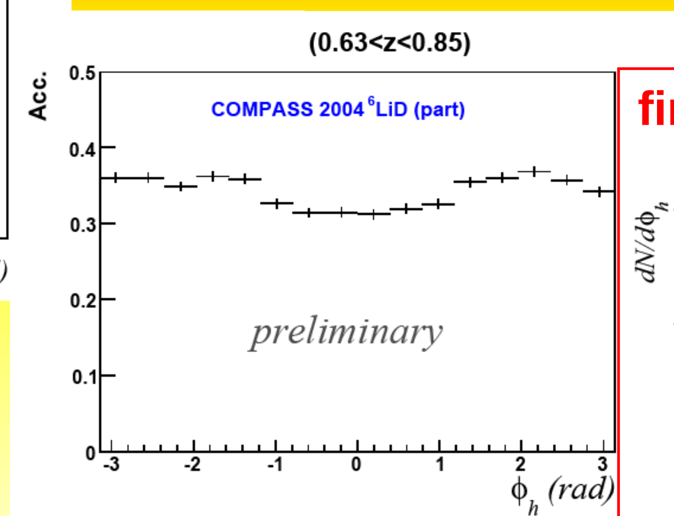
to extract the asymmetries the azimuthal distributions have to be corrected by the apparatus acceptance

→ dedicated MC simulations for L and T target polarisation data

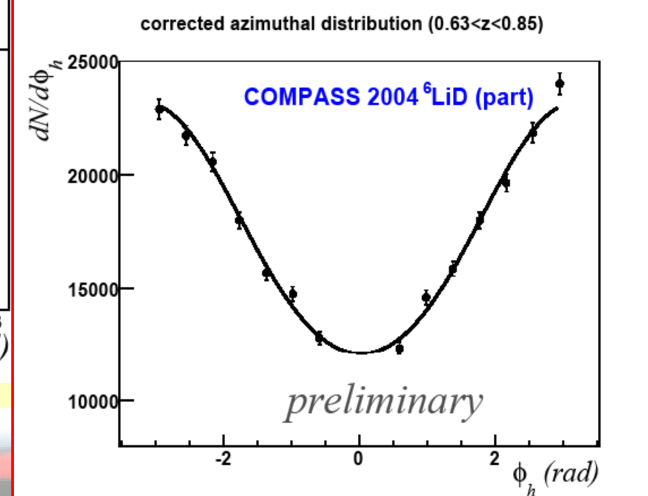
→ Final distributions fitted with the following function:

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





final azimuthal distribution



Systematic Error

- The systematic error is evaluated from:
  - compatibility of results with L and T target polarization (different experimental conditions, different MCs)
  - comparison of results obtained using two different MCs with different settings for each data set (LEPTO default, standard COMPASS high pt; ~extreme cases)
  - compatibility of results from subsamples corresponding to:
    - different periods
    - different geometrical regions for the scattered muon

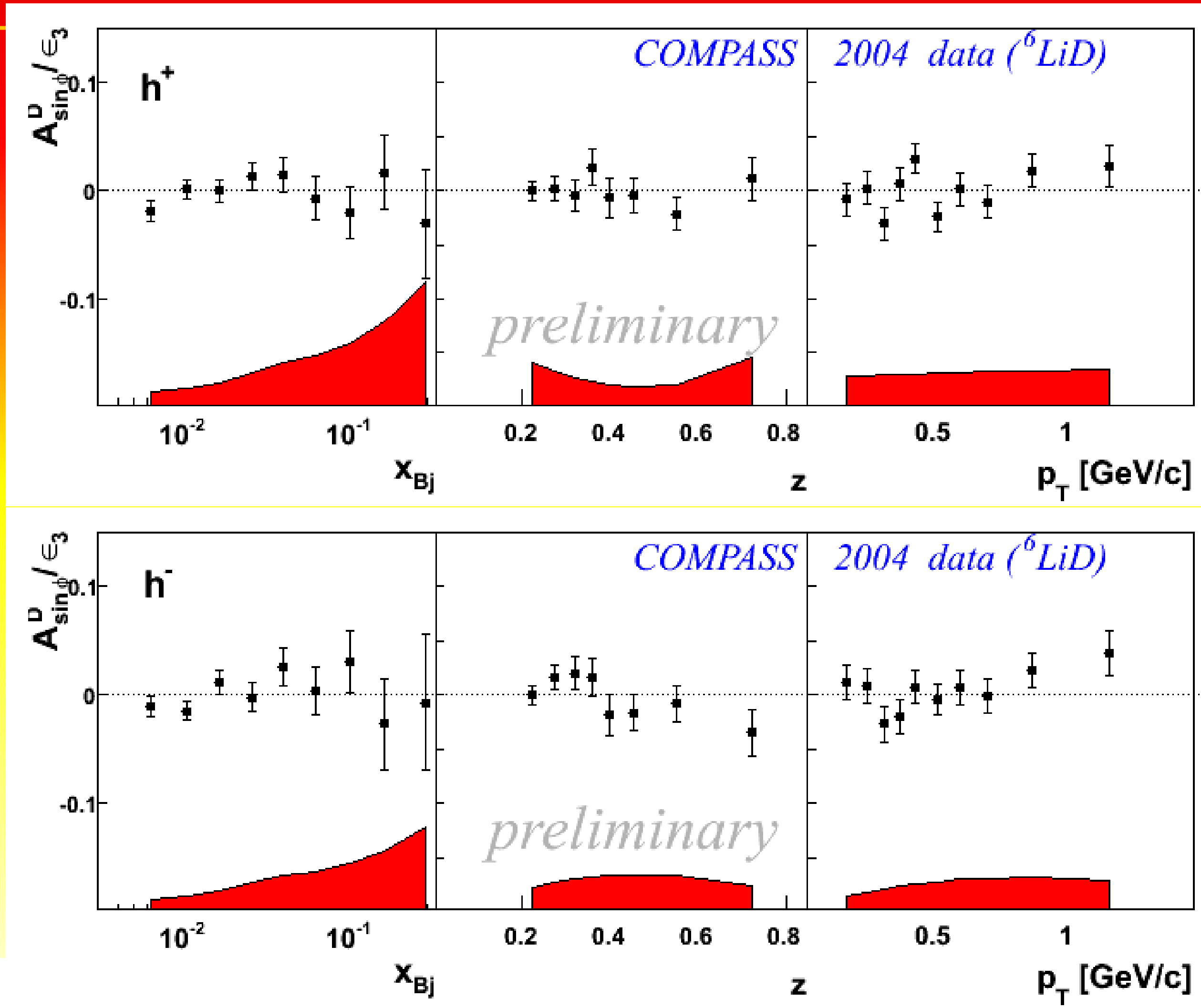
Results: sinϕ modulation

$$A_{\sin\phi} / \varepsilon_s$$

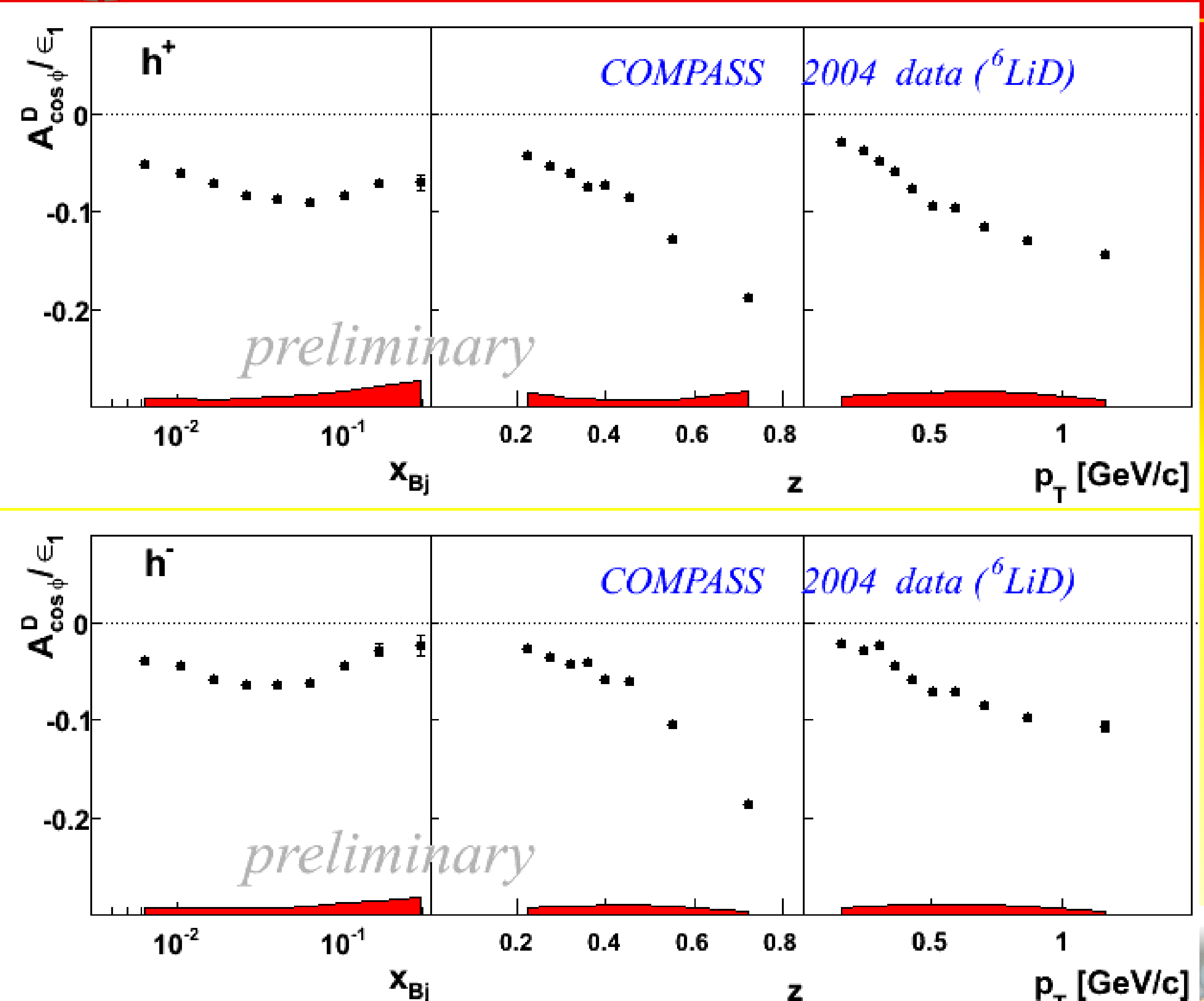
$$\varepsilon_s = \frac{2y\sqrt{1-y}}{1+(1-y)^2}$$

error bars:
statistical errors

bands:
systematical errors



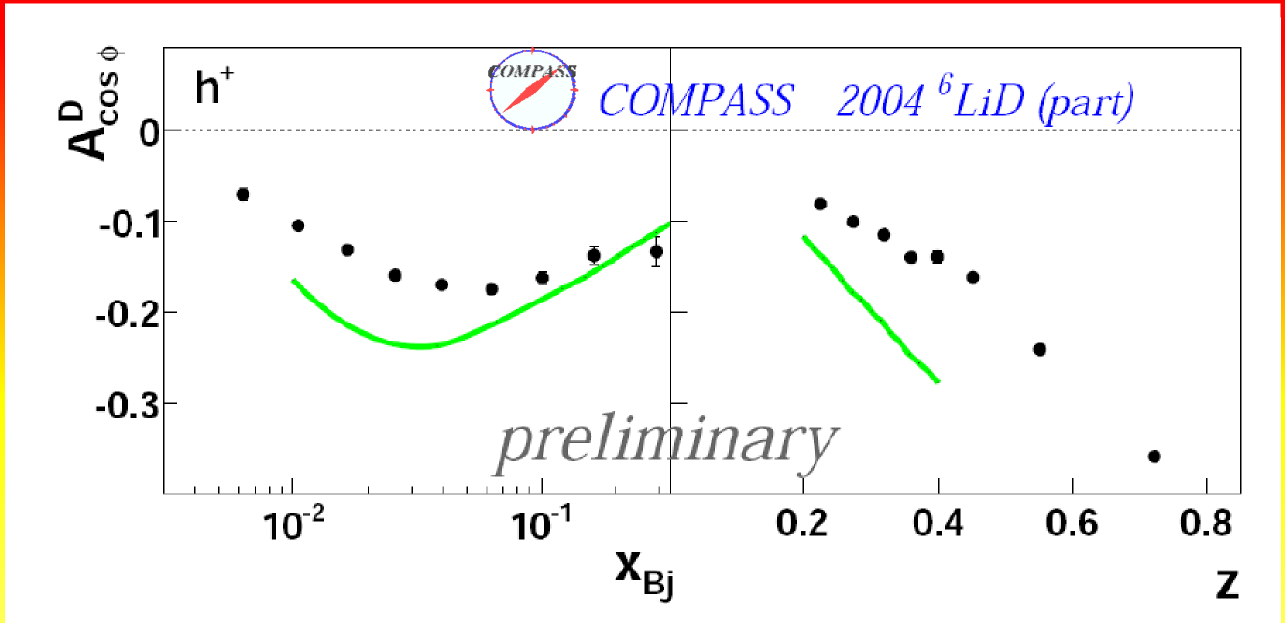
Results: cosϕ modulation



$A_{\cos\phi} / \varepsilon_c$

$$\varepsilon_c = \frac{2(2-y)\sqrt{1-y}}{1+(1-y)^2}$$

What was expected

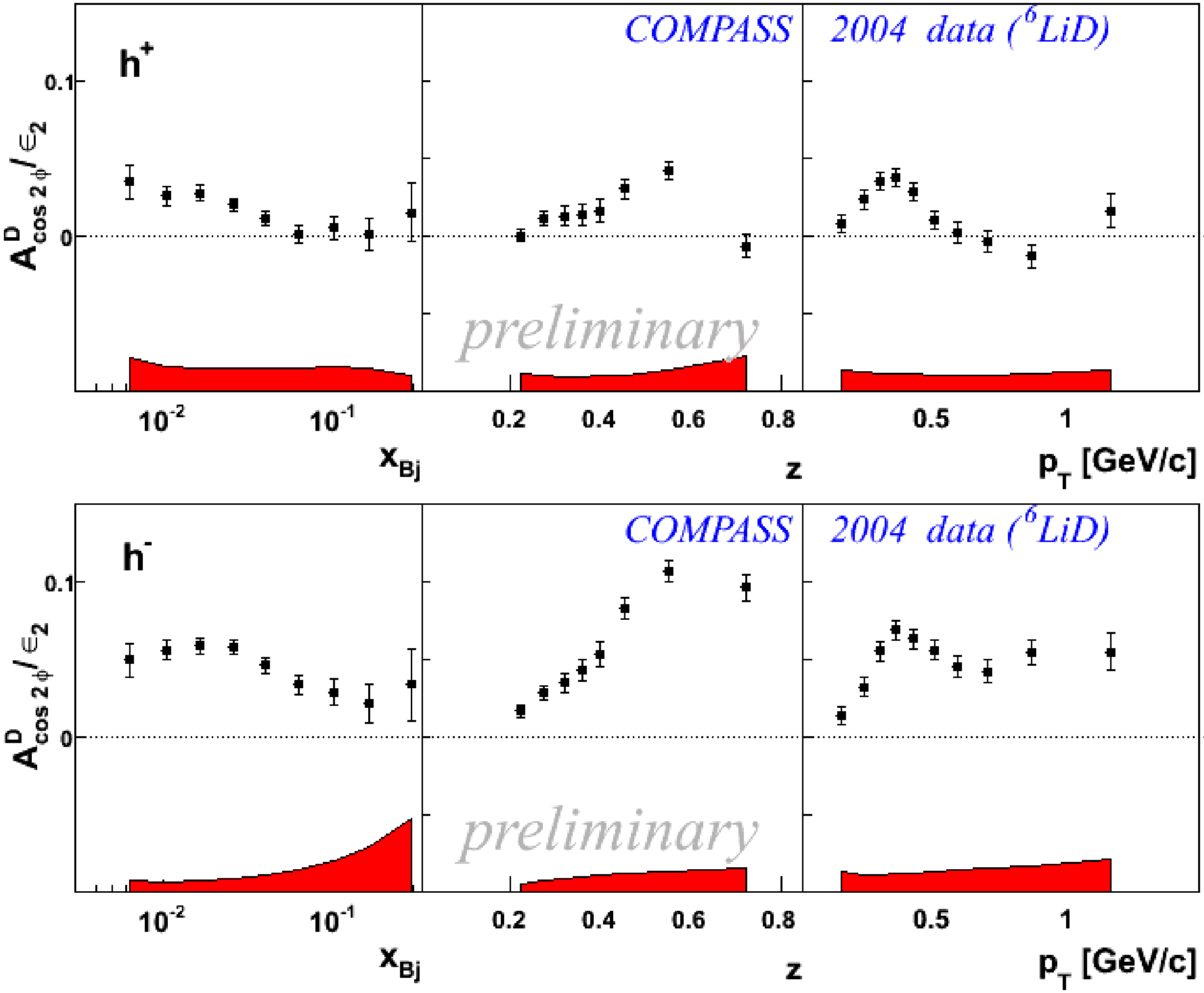


M. Anselmino, M. Boglione, A. Prokudin, C. Türk
Eur. Phys. J. A 31, 373-381 (2007)
does not include Boer – Mulders contribution

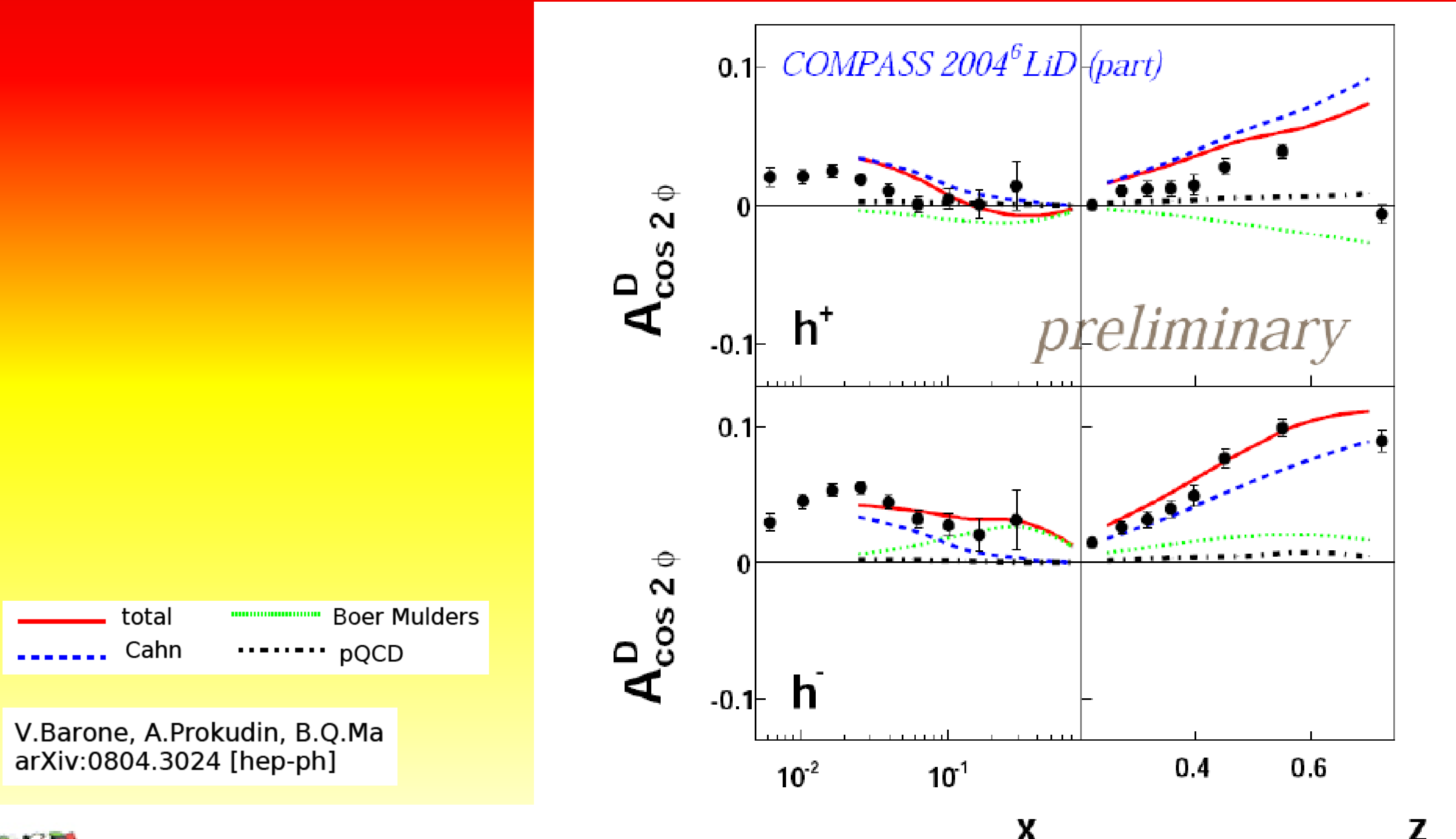
results: cos 2ϕ modulation

$$A_{\cos 2\phi} / \varepsilon_2$$

$$\varepsilon_2 = \frac{2(2-y)}{1+(1-y)^2}$$

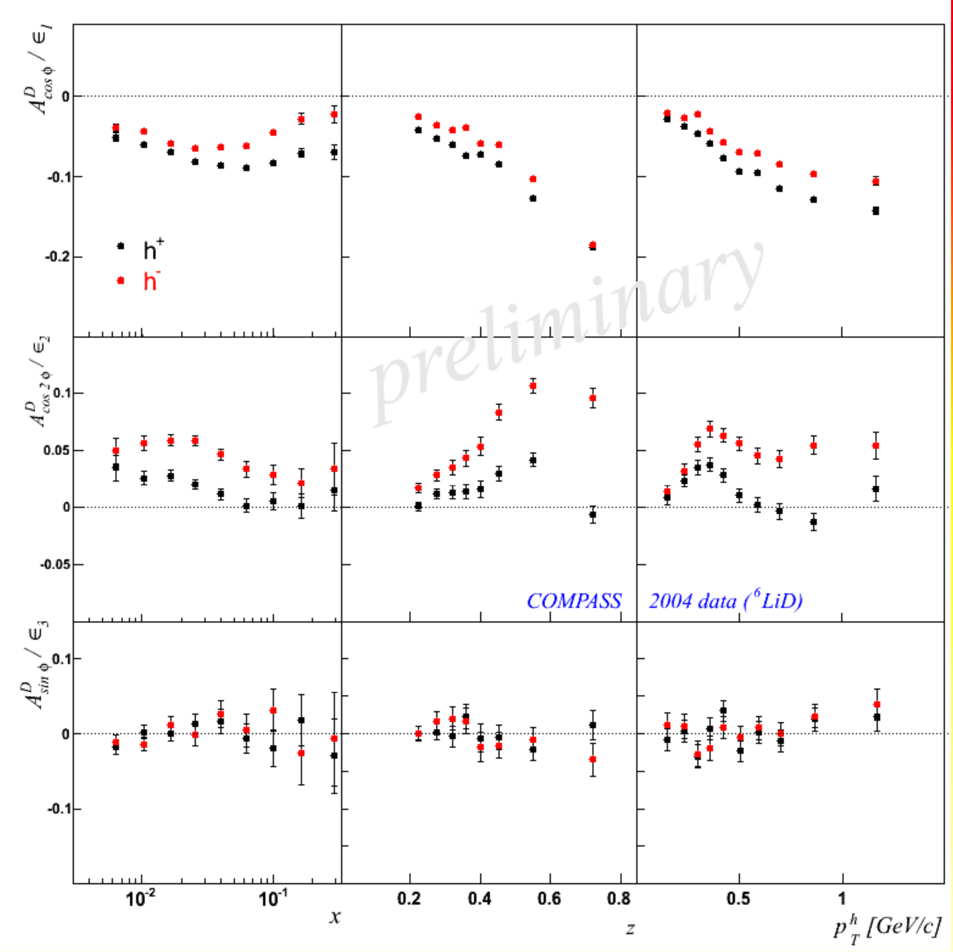


Predictions



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

Summary of the results



Summary

First results on unpolarized asymmetries:

- Results obtained separately for + and - hadrons
- $\sin\phi$ modulation compatible with 0
- $\cos\phi$ modulation up to 20% (for large z or p_T) and the overall trend is reproduced by the predictions
- $\cos 2\phi$ modulation smaller (10% at most). Overall good agreement with the predictions
- There is a difference between +h and –h asymmetries on $\cos\phi$/$\cos 2\phi$

All in all: new input for deeper understanding of the nucleon structure

Thank You