Transversity @ COMPASS

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(On behalf of the COMPASS collaboration)

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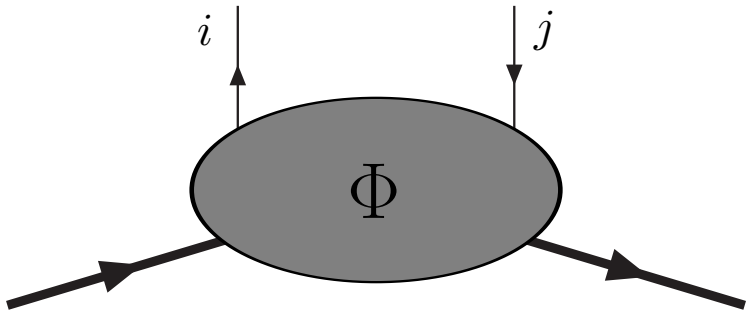
DIS 2003 International Workshop

The Parton Distribution Functions



The quark-quark correlation matrix:

$$\Phi_{ij}(k,P,S) = \int d^4\xi\, \mathrm{e}^{\mathrm{i}k\cdot\xi}\, \langle PS|\bar{\psi}_j(0)\psi_i(\xi)|PS\rangle$$

traced by:

$$\mathrm{Tr}(\Gamma\Phi) = \int d^4\xi\, \mathrm{e}^{\mathrm{i}k\cdot\xi}\, \langle PS|\bar{\psi}(0)\,\Gamma\,\psi(\xi)|PS\rangle\,,$$

where Γ is generally expressed as linear combination of the Dirac basis:

$$\Gamma = \left\{1,\ \gamma^\mu,\ \gamma^\mu\gamma^5,\ \mathrm{i}\gamma^5,\ \mathrm{i}\sigma^{\mu\nu}\gamma^5\right\}$$

The complete tree level result:
P. J. Mulders and R. D. Tangerman
The complete tree-level result up to order 1/Q for polarized deep-inelastic leptoproduction. Nucl. Phys., B461:197–237, 1996; Erratum-ibid.B484:538-540,1997.

At the leading twist:

$$\Phi(x) = \frac{1}{2}\left\{f_1(x) + \lambda_N\, g_1(x)\,\gamma_5 + h_1(x)\,\gamma_5\,\not{S}_\perp\right\} n_+$$

Transversity

The structure function h_1:

verifies the Soffer bound:

$$|h_1(x)| \leq (f_1(x) + g_1(x));$$

is chirally odd and not accessible in inclusive polarized DIS;

has non-relativistic limit:

$$h_1(x) = g_1(x);$$

has NOT yet been measured!

Possible channels:

1. polarized hadron - hadron collisions (Drell-Yan, single spin asymmetries);
   - RHIC, BNL (New York, USA)
2. lepton - nucleon SI-pDIS (Collins effect, Interference fragmentation, Λ polarimetry).
   - SPS, CERN (Geneva, CH)
   - HERA, DESY (Hamburgh, D)

Transversity in SI-pDIS (Collins effect)

At leading twist:

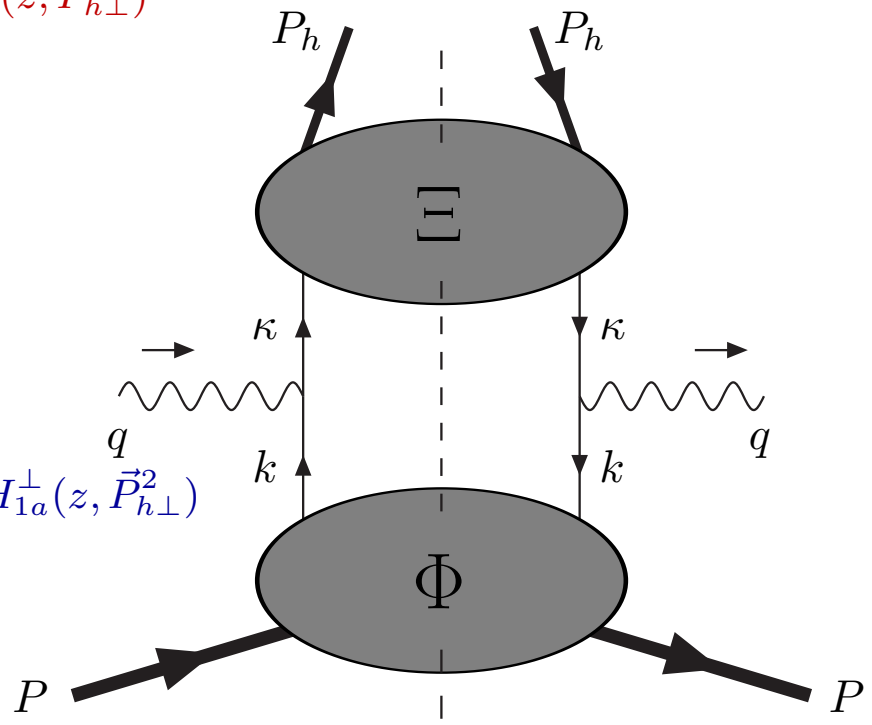
$$l^+ + N_{\uparrow\downarrow} \rightarrow l'^+ + X + \pi$$

$$\frac{d\sigma}{dxdydzd^2\vec{P}_{h\perp}} = \sigma_0 + \sum_a x\, h_{1a}(x)\, H_{1a}^{\perp}(z, \vec{P}_{h\perp}^2)$$

At twist-3:

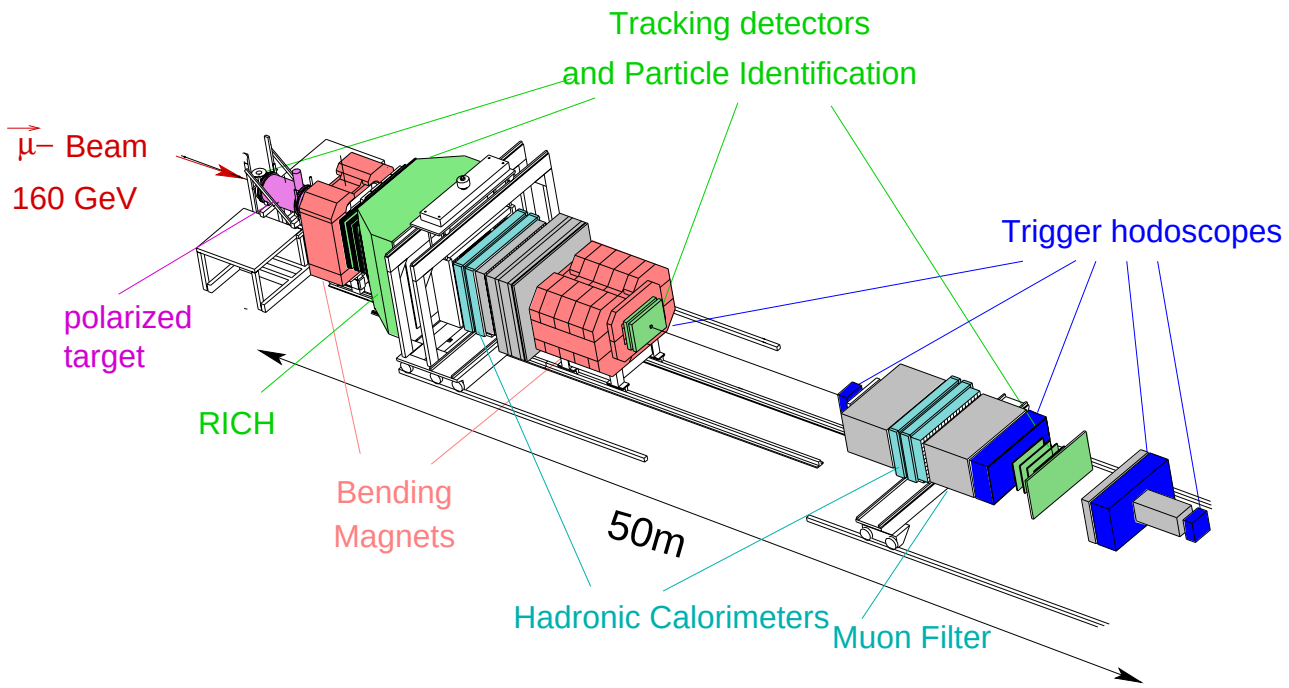
$$l^+ + \overrightarrow{\overleftarrow{N}} \rightarrow l'^+ + X + \pi$$

$$\frac{d\sigma}{dxdydzd^2\vec{P}_{h\perp}} = \sigma_0 + \frac{1}{Q}\sum_a x\, h_{1a}(x)\, H_{1a}^{\perp}(z, \vec{P}_{h\perp}^2) + \ldots + \ldots$$



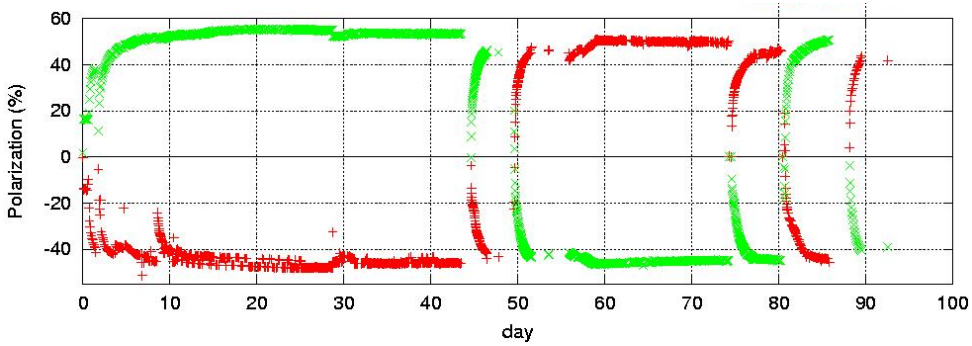
1. Product of two chiral-odd functions;
2. Possibility to observe the polarization of the struck quark from the leading hadron;
3. Asymmetry in a particular angle (known as Collins angle) in the Breit Frame.

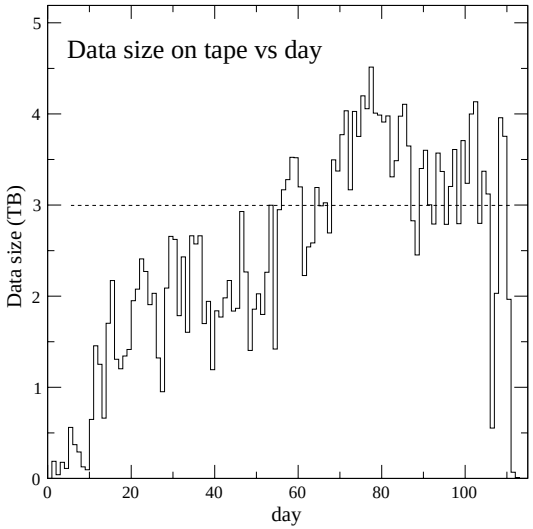
The COMPASS setup



- 160 GeV polarized muon beam;
- fixed target (presently ^{6}LiD, plans for NH_3);
- two-stages spectrometer;
- full Particle IDentification (PID):
  - Muon Filtering;
  - Ring Imaging CHerenkov detector;
  - Hadronic Calorimetry.

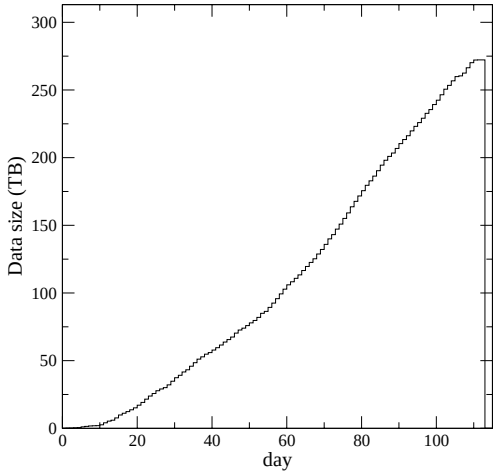
The 2002 run





- UPSTREAM CELL
- DOWNSTREAM CELL
- 80% of data collected in longitudinal polarized target configuration
- 20% of data collected in transverse polarized target configuration

Integrated data size on tape vs day



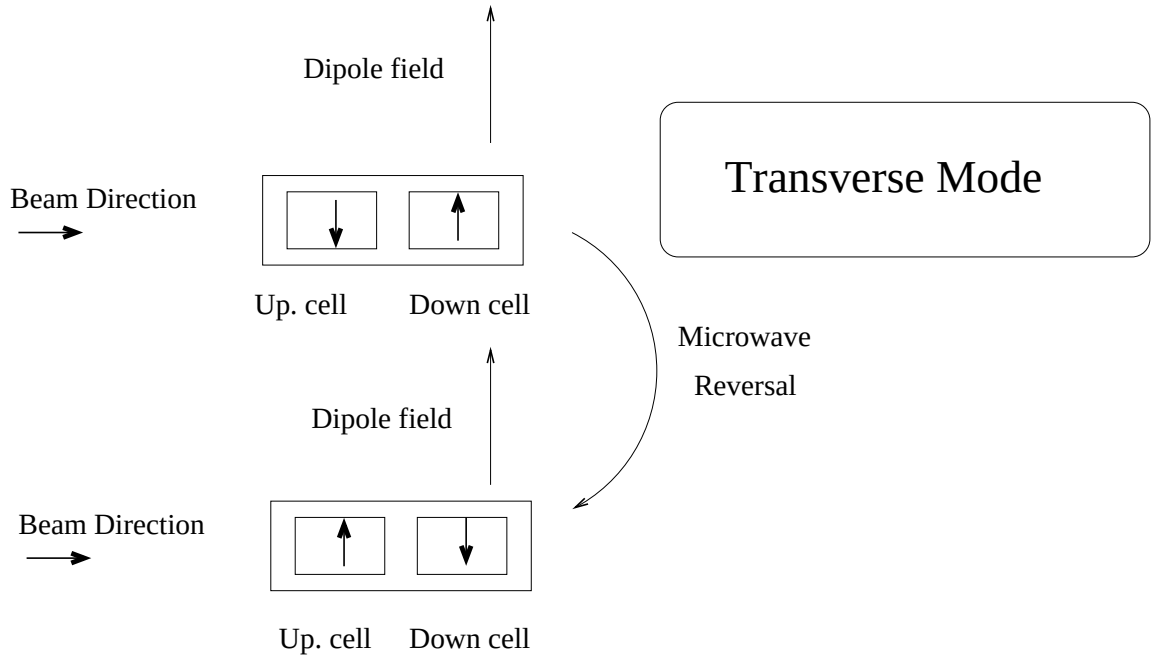
COMPASS measures Transversity

Data Taking in transverse spin configuration:

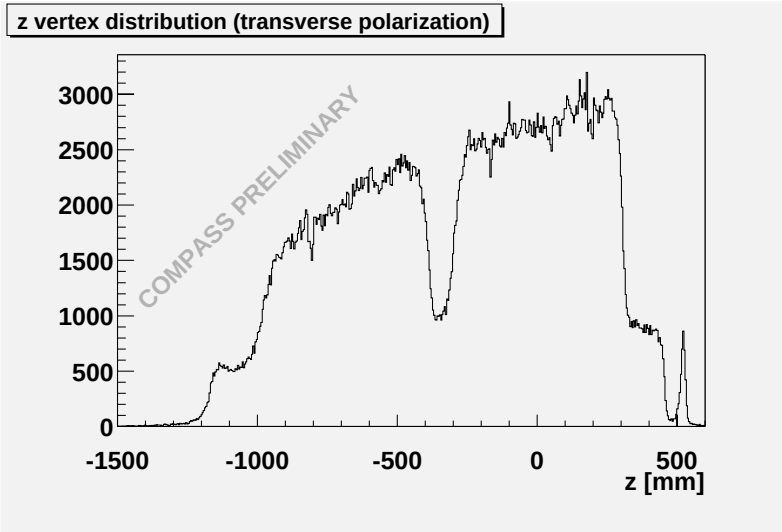
- duration: 3 weeks;
- size of raw data: more than 30 TBytes;
- integrated luminosity $L \simeq 1.9 \times 10^{38} cm^{-2}$.

Period			Pol. UP & DOWN	Good Runs
31/7/2002	$\longrightarrow$	6/8/2002	$\Downarrow \Uparrow$	114
8/8/2002	$\longrightarrow$	12/8/2002	$\Uparrow \Downarrow$	102
11/9/2002	$\longrightarrow$	18/9/2002	$\Downarrow \Uparrow + \Uparrow \Downarrow$	130

Spin rotation done by microwave reversal to pass from $\Downarrow\Uparrow$ to $\Uparrow\Downarrow$.

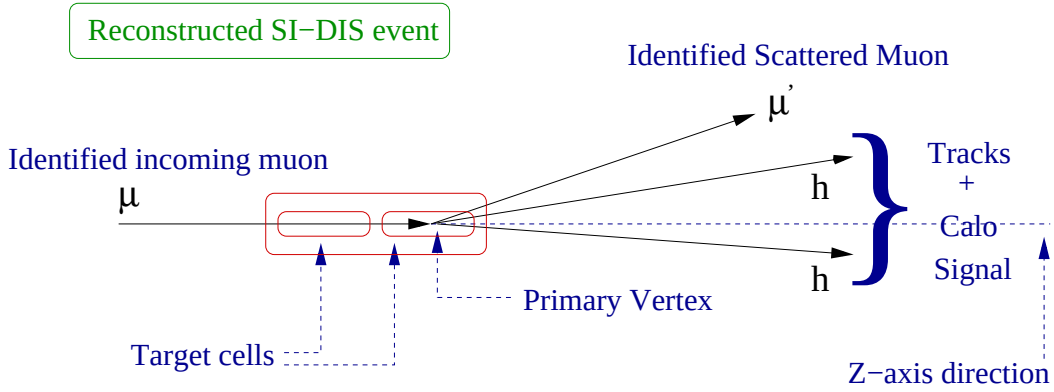


Reconstruction of SI-DIS events

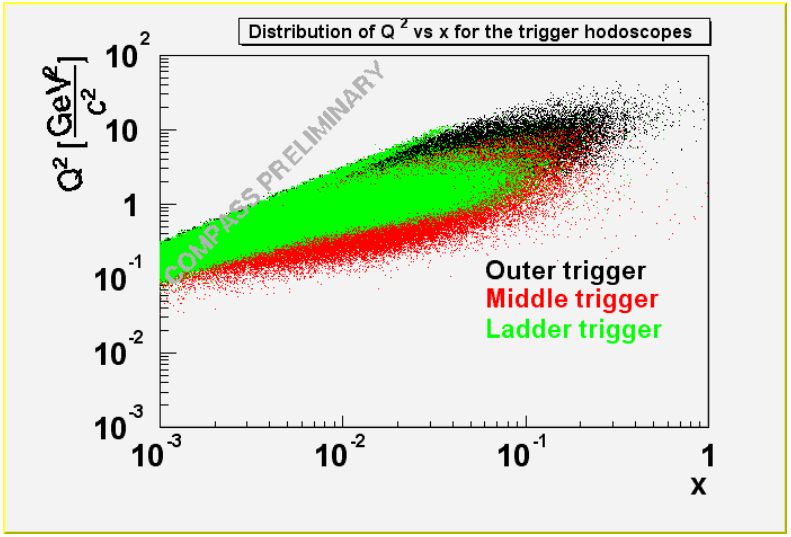


The data analysis:

- 2/3 of available statistics;
- SI-DIS events reconstructed requiring:
  - Beam muon ID;
  - Scattered muon ID;
  - Hadron signal in CALO.



Kinematics of SI-DIS events

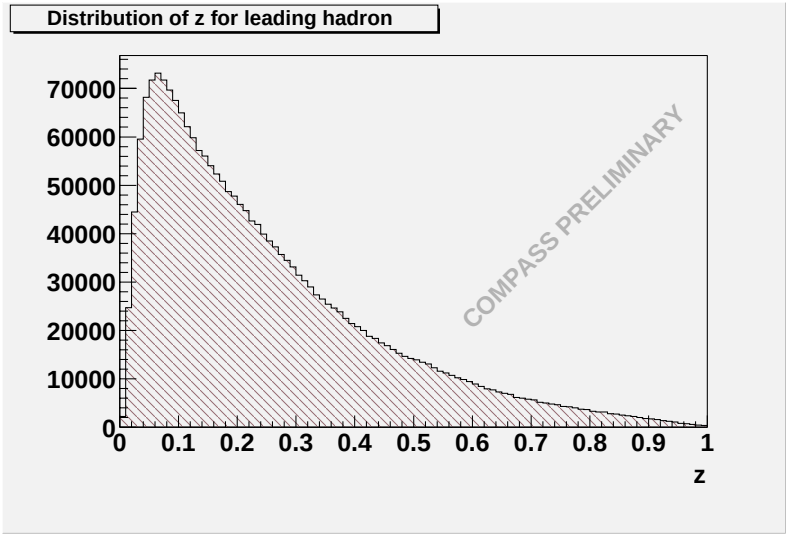


The $x - Q^2$ plane:

- large surface covered for different physics analysis purposes;
- large Q^2 event reconstruction not fully implemented;
- need to cut at high Q^2 to access DIS events.

The z distribution:

- presence of low energetic component;
- need to cut at high z:
  - recon. hadron $\equiv$ leading hadron.



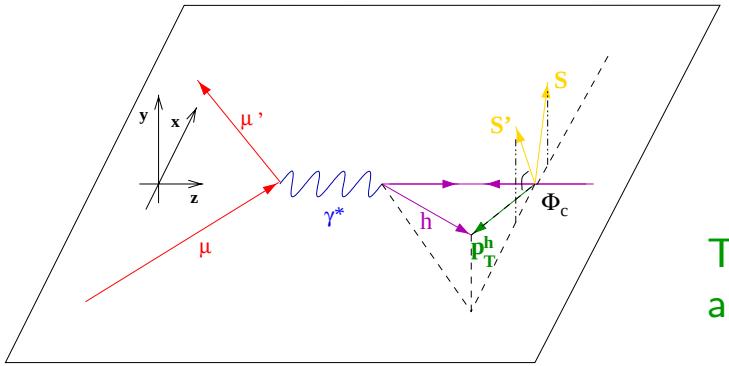
Kinematical cuts

Different kinematical cuts are necessary to access DIS.

Selection of DIS events
used by COMPASS in the preliminary analysis:

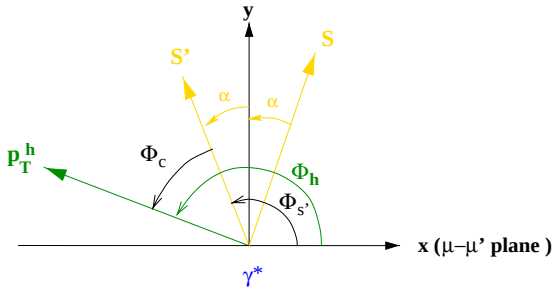
- $Q^2 > 1$ GeV^2;
- $0.1 < y < 0.9$;
- $z > 0.25$;
- $p_t^B > 0.1$ GeV/c.

The Collins effect



Go to the Breit frame;
Calculate the azimuthal angle of the outgoing hadron Φ_h;
Associate the azimuthal angle of the spin vector Φ_S;
Calculate the Collins angle $\Phi_C = \Phi_h + \Phi_S - \pi$;

The result for each target cell should show an oscillation along Φ_C:



$$N_{\uparrow\downarrow}(\Phi_C) = \alpha(\Phi_C) \cdot N_0 \left(1 \pm \epsilon \sin \Phi_C\right)$$

$$\epsilon = A_{UT} \cdot P_T \cdot f \cdot D_{NN}$$

$$A_{UT} \propto a_c(z) \cdot x\ h_1(x)$$

$$a_c = z \cdot p_q^h \cdot \frac{\sqrt{p_q^{h\,2} + M^2}}{M^2 + p_q^h \cdot \sqrt{p_q^{h\,2} + M^2}}$$

from the proposal

A_{UT} = amplitude of the asymmetry;

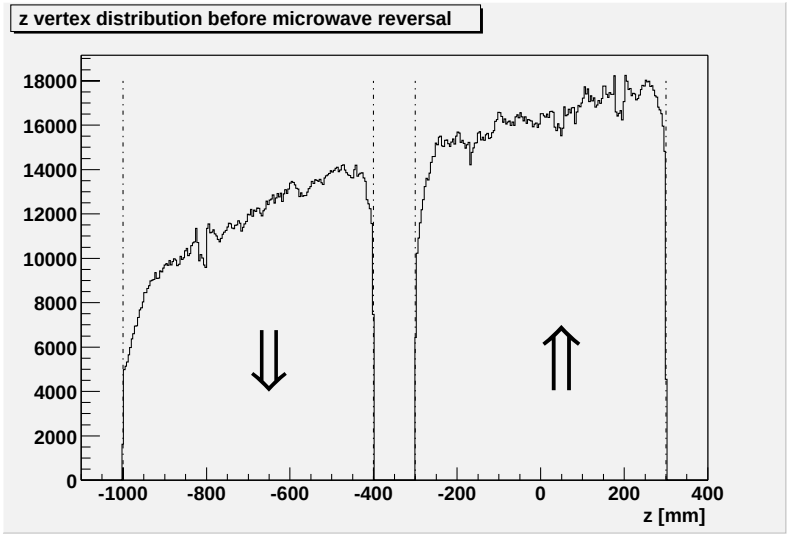
P_T = polarization of the target;

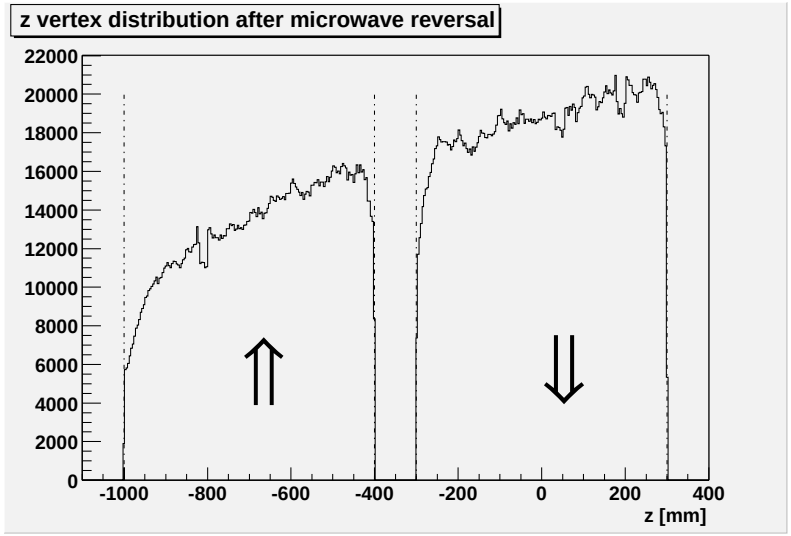
D_{NN} = spin transfer coefficient:

$$\gamma^* q_\uparrow \longrightarrow q'_\uparrow$$

f = dilution factor.

Combining the target cells





- Making use of the 2 periods with opposite polarization;
- Cutting on the Z vertex position to select the target cell;
- Calculating 2 independent asymmetries fitting by sinus function:
  - one for the upstream cell;
  - one for the downstream cell.

$$F^u(\Phi_C) = \frac{R^u \cdot N^u_\uparrow - N^u_\downarrow}{N^u_\downarrow + R^u \cdot N^u_\uparrow} \qquad R^u = \frac{N^{tot,\downarrow}_u}{N^{tot,\uparrow}_u}$$

$$F^d(\Phi_C) = \frac{N^d_\uparrow - R^d \cdot N^d_\downarrow}{N^d_\uparrow + R^d \cdot N^d_\downarrow} \qquad R^d = \frac{N^{tot,\uparrow}_d}{N^{tot,\downarrow}_d}$$

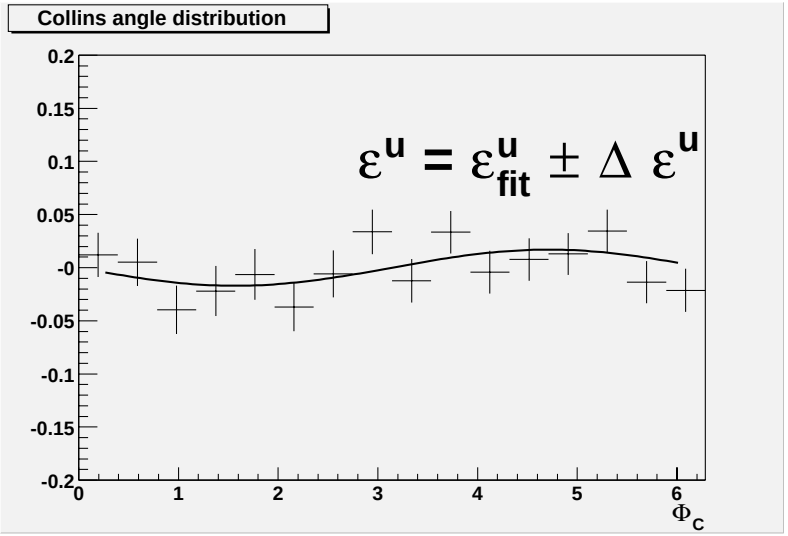
$$F^{u(d)}(\Phi_C) = \epsilon^{u(d)}_{fit} \sin\Phi_C$$

The value of the asymmetry

Dividing in bins of x:

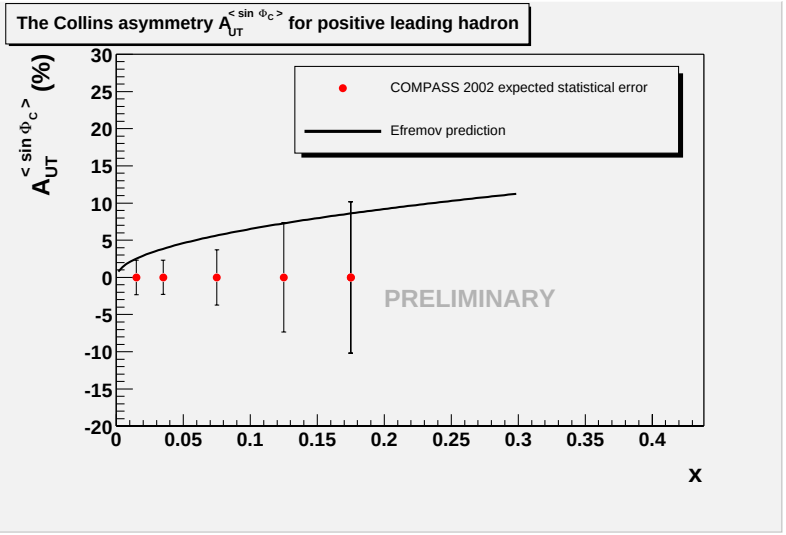
- $x < 0.02$;
- $0.02 < x < 0.05$;
- $0.05 < x < 0.10$;
- $0.10 < x < 0.15$;
- $x > 0.15$.

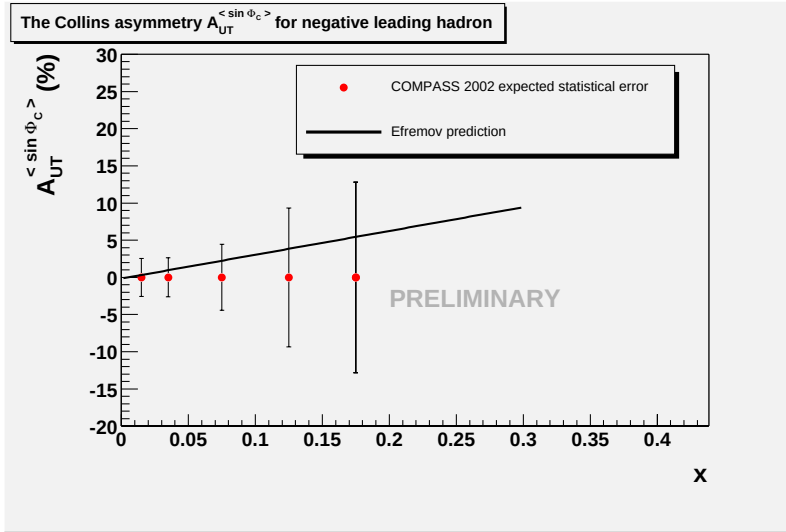
$$F^{u(d)}(\Phi_C) = \epsilon_{fit}^{u(d)} \sin\Phi_C$$



1. Treating separately the positive and negative leading hadrons;
2. Calculating the weighted mean from the two measurements: $\langle\epsilon\rangle = E(\epsilon^u_{fit}, \epsilon^d_{fit})$;
3. Rescaling the values by the experimental parameters: $A_{UT} = 1 \,/\, \langle f\rangle \langle P_T\rangle \langle D_{NN}\rangle$.

Projection of statistical errors





1. comparison with A_{UT} for deuterium
   by A. V. Efremov (COMPASS data analysis Workshop, March 3rd 2003, Dubna);
2. large statistic error, especially at large x:
   - alignment of Large Area Trackers not tuned;
   - μ ID in the first spectrometer not yet implemented;
   - preliminary version of reconstruction program used (DST3, Nov. 2002);
   - expected DST4 / DST3 efficiency gain $\sim$ 1.5.

Outlook

1. first 20 TB of transversity data have been processed;
2. algorithms to compute the Collins asymmetries have been implemented;
3. preliminary measurement of Collins asymmetries A_{UT} for π^+ and π^- available soon;
4. evaluation of systematic errors:
   - comparison MC/Real-Data ongoing.
5. possibility to check the Efremov calculation of Collins effect for COMPASS deuterated target;
6. new data to be taken in 2003 and 2004;
7. a lot of work in progress.