Longitudinal polarisation of Λ and $\bar{\Lambda}$ hyperons in deep-inelastic scattering at COMPASS.

On behalf of the COMPASS Collaboration

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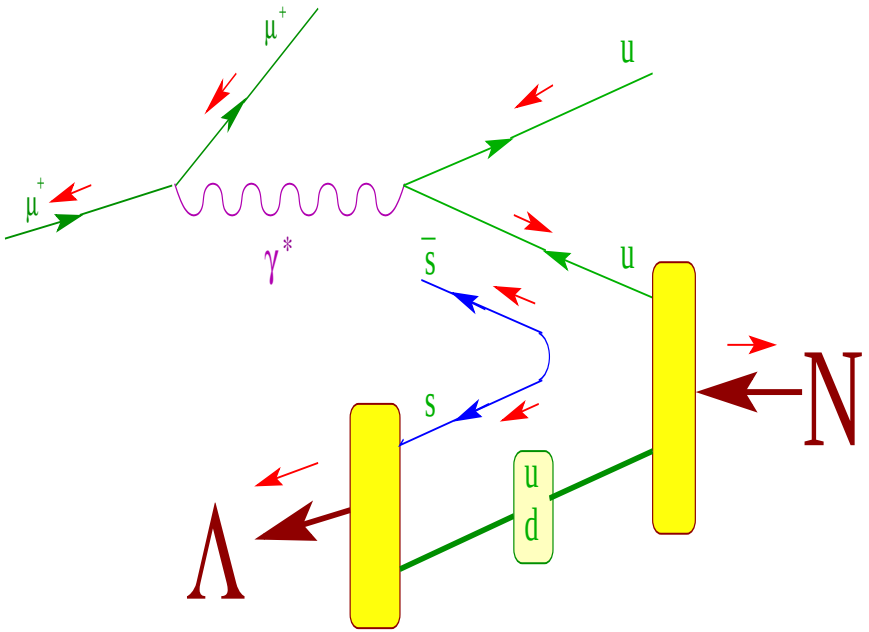
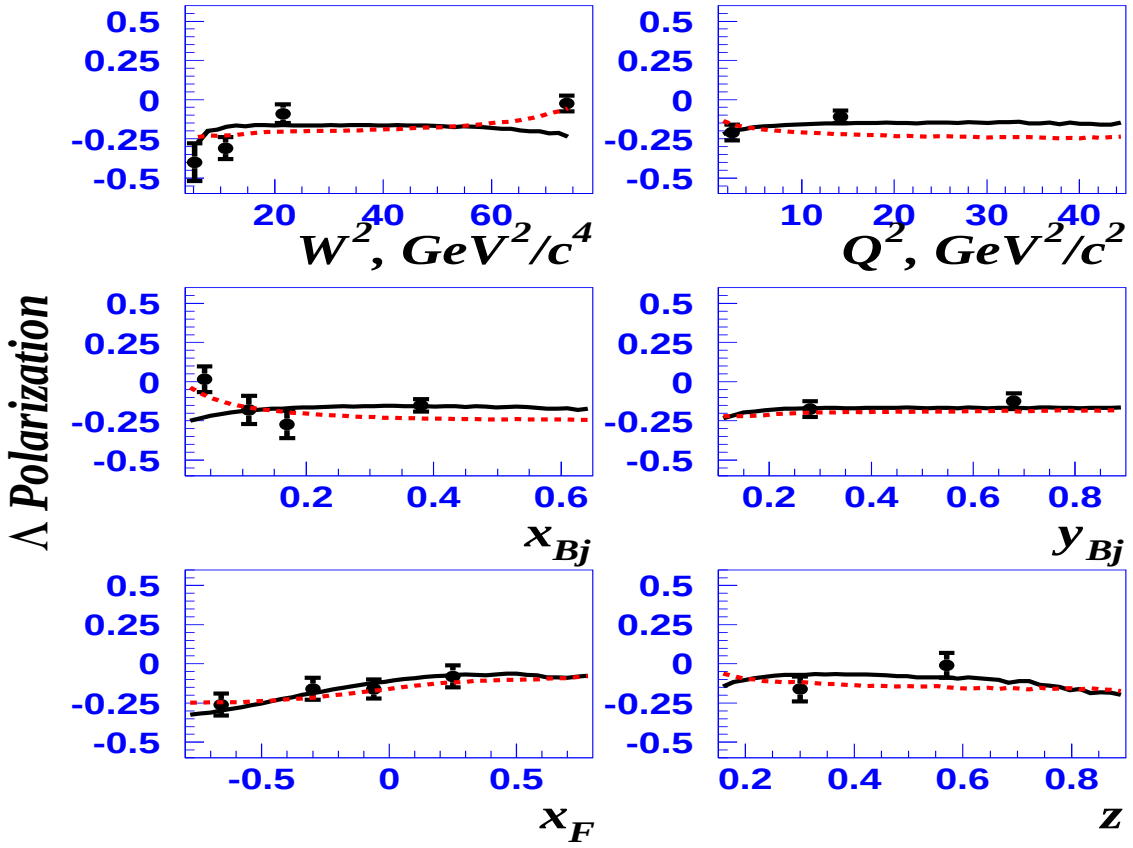
JINR, Dubna

Physics motivations

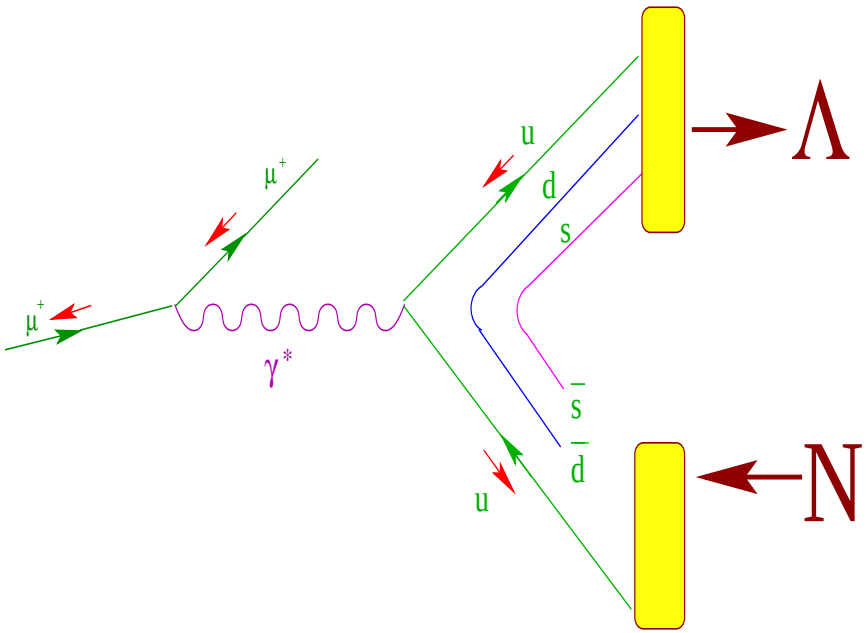


- Target fragmentation region (TFR) $x_F < 0$
  - J. Ellis, D. Kharzeev, A. Kotzinian (Z.Physik C69 (1996) 467) predict negative longitudinal polarisation of Λ hyperons (within polarised nucleon intrinsic strangeness model)

J. Ellis, A. Kotzinian, D. Naumov (Eur.Phys.J., C25 (2002) 603)



The predictions of polarised nucleon intrinsic strangeness model for the polarization of Λ hyperons produced in ν_μ charged-current DIS interactions off nuclei. The points with error bars are from NOMAD experiment.



- Current fragmentation region (CFR) $x_F > 0$
  - Study of the quark to baryon spin transfer processes $q \to \Lambda$
  - Λ spin structure
    NQM:$\Delta u^\Lambda = \Delta d^\Lambda = 0, \Delta s^\Lambda = 1$
    Burkardt and Jaffe:
    $g_1^\Lambda \Rightarrow \Delta u^\Lambda = \Delta d^\Lambda = -0.23,$
    $\Delta s^\Lambda = 0.58$
  - Test of the strange quark-antiquark symmetry of the nucleon sea
    $s(x) \neq \bar{s}(x)$?
    $\Delta s(x) \neq \Delta \bar{s}(x)$?

THE NUTEV ANOMALY

DATA...

NuTeV 2001 $\sin^2\theta_W(\mathrm{OS}) = 0.2272 \pm 0.0013(\mathrm{stat}) \pm 0.0009(\mathrm{syst}) \pm 0.0002(M_t, M_H)$

Global Fit 2003 $\sin^2\theta_W(\mathrm{OS}) = 0.2229 \pm 0.0004$

...VS. THEORY: THE PASCHOS-WOLFENSTEIN RELATION

$$
\begin{aligned}
R^- &= \frac{\sigma_{NC}(\nu) - \sigma_{NC}(\bar\nu)}{\sigma_{CC}(\nu) - \sigma_{CC}(\bar\nu)} \\
&= \left(\frac{1}{2} - \sin^2\theta_W\right) + 2\left[\frac{(u-\bar u) - (d-\bar d)}{u-\bar u + d - \bar d} - \frac{s-\bar s}{u-\bar u + d - \bar d}\right] \times \left[\left(\frac{1}{2} - \frac{7}{6}\sin^2\theta_W\right)\right. \\
&\qquad \left. + \frac{4}{9}\frac{\alpha_s}{2\pi}\left(\frac{1}{2} - \sin^2\theta_W\right) + O(\alpha_s^2)\right] + O(\delta(u-d)^2,\ \delta s^2)
\end{aligned}
$$

U,D...DENOTE MOMENTUM FRACTIONS CARRIED BY CORRESP. QUARK FLAVORS

- ISOSPIN VIOLATION $\rightarrow$ corrn. for non-isoscalar target included, but not $u^p \neq d^n$
- STRANGE ASYM. $\rightarrow$ strangeness must vanish, but not valence mom. fract.!
- QCD CORRECTIONS $\rightarrow$ tiny (only enter through sym. violating terms)

Strangeness of the nucleon: asymmetric?

F. Olness et al.,
hep-ph/0312323

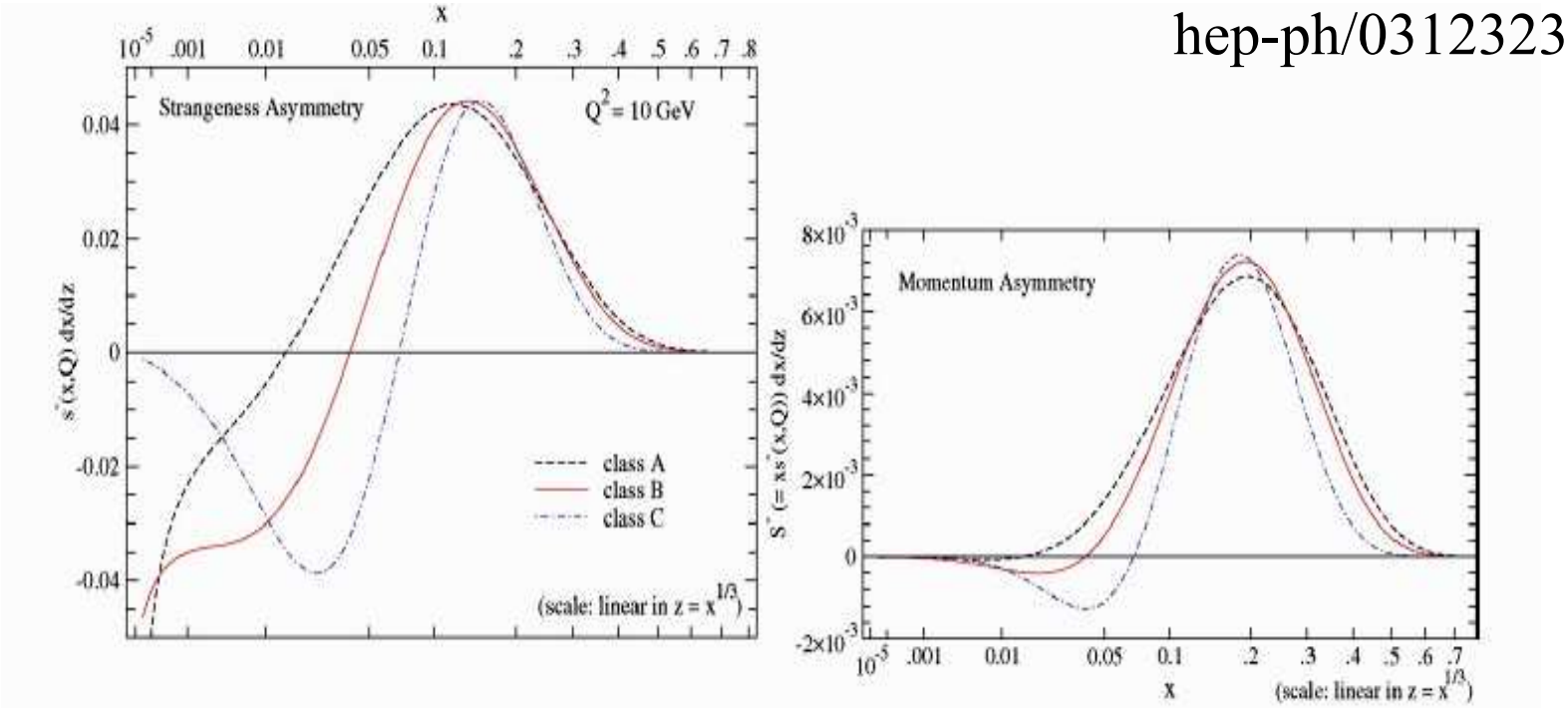
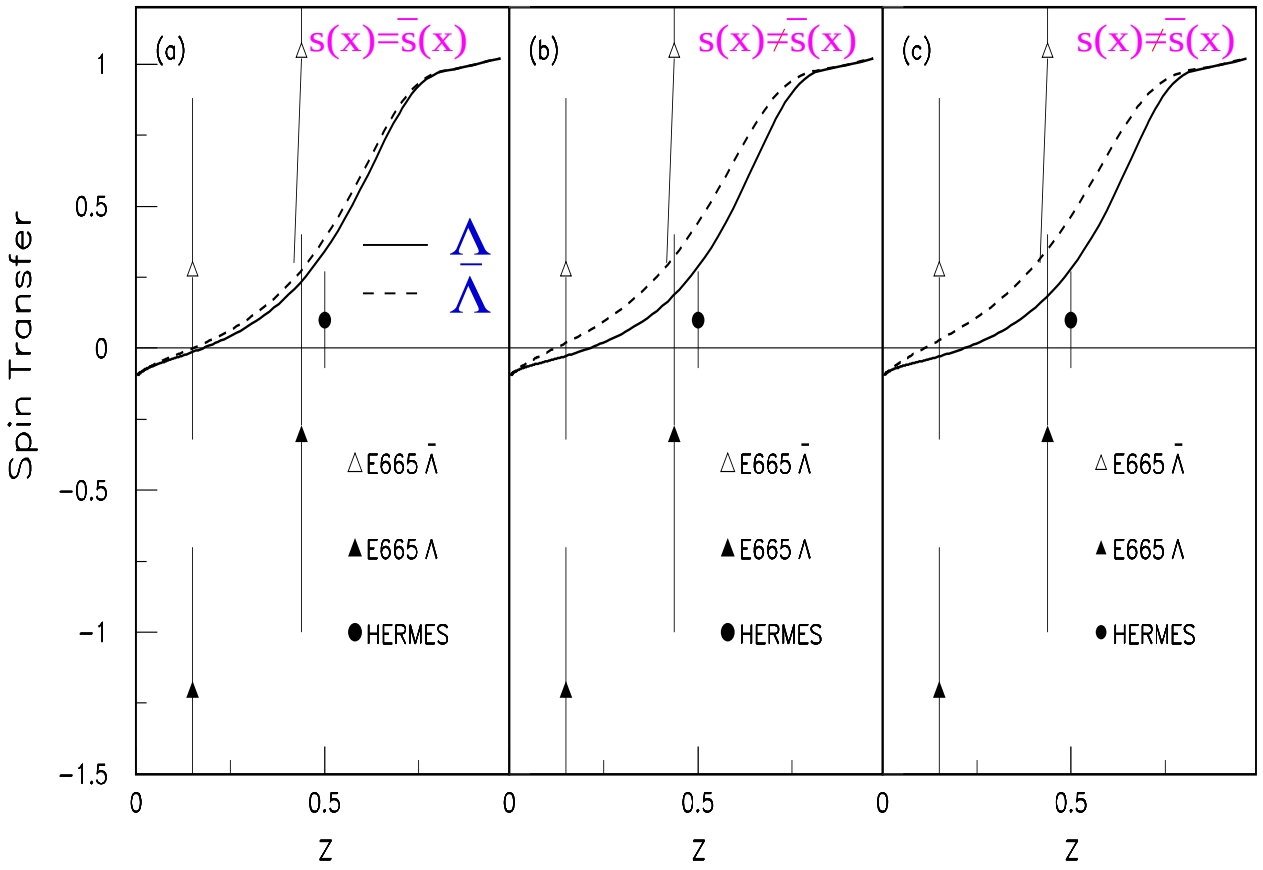


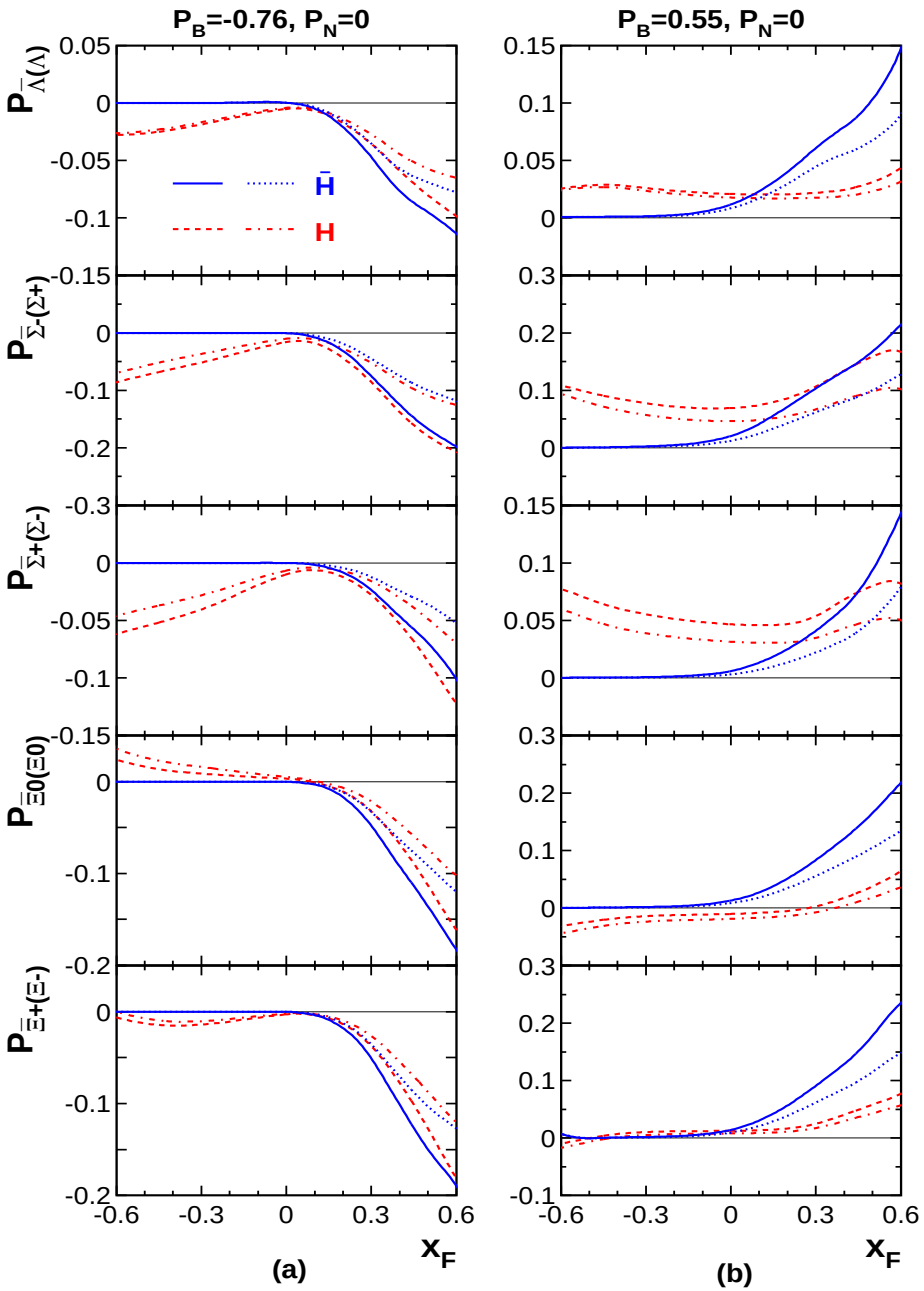
Fig. 2. Result of the CTEQ [3] fit to DIS data for $s^- = s(x) - \bar{s}(x)$ and S^-. The fit is not very sensitive to the small x region. The momentum sum appears to be positive, $S^- = 0.002^{+0.002}_{-0.003}$, in these fits.

Quark-Antiquark Asymmetry of the Nucleon Sea

B.Q.Ma et al., Phys.Lett. B488 (2000) 254



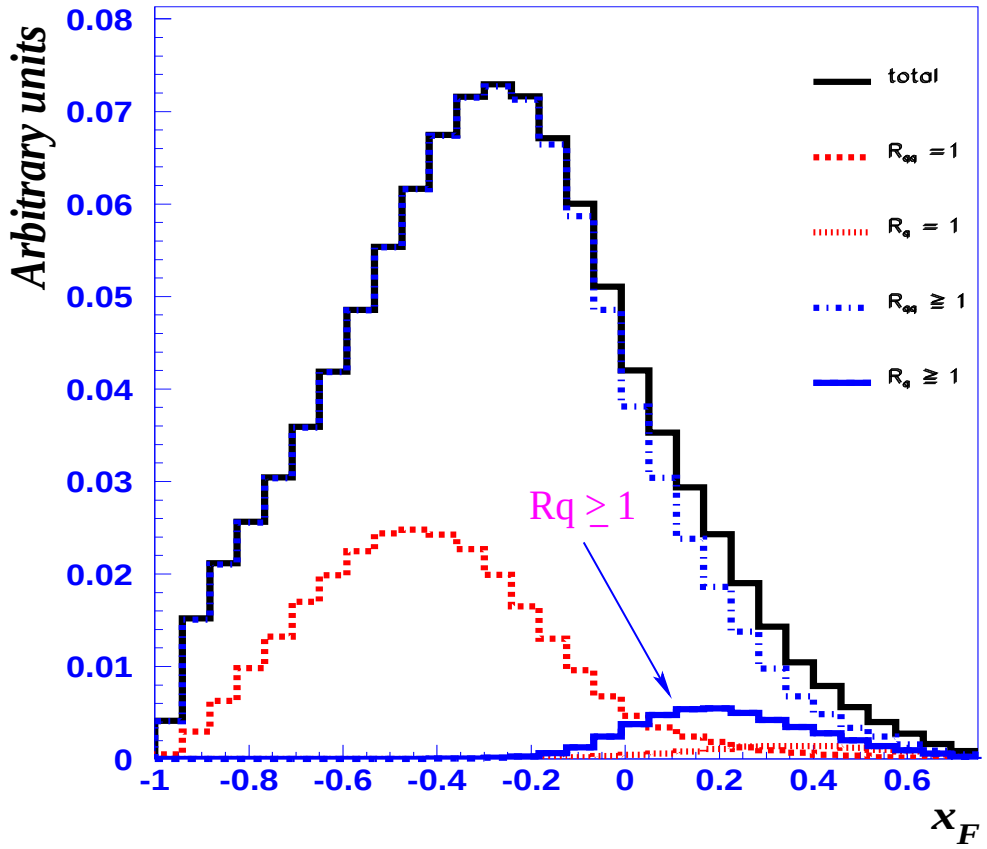
- The z-dependence of the Λ and $\bar{\Lambda}$ spin transfer in polarised charged lepton DIS on the nucleon.
- The solid and dashed curves correspond to the calculated results of Λ and $\bar{\Lambda}$ spin transfers with different parametrisations of quark distributions.
- Possibility of quark-antiquark asymmetries either in the quark to Λ fragmentation functions and/or in the quark and antiquark distributions of the target proton.



Liang Zuo-tang et. al.,
hep-ph/0506207

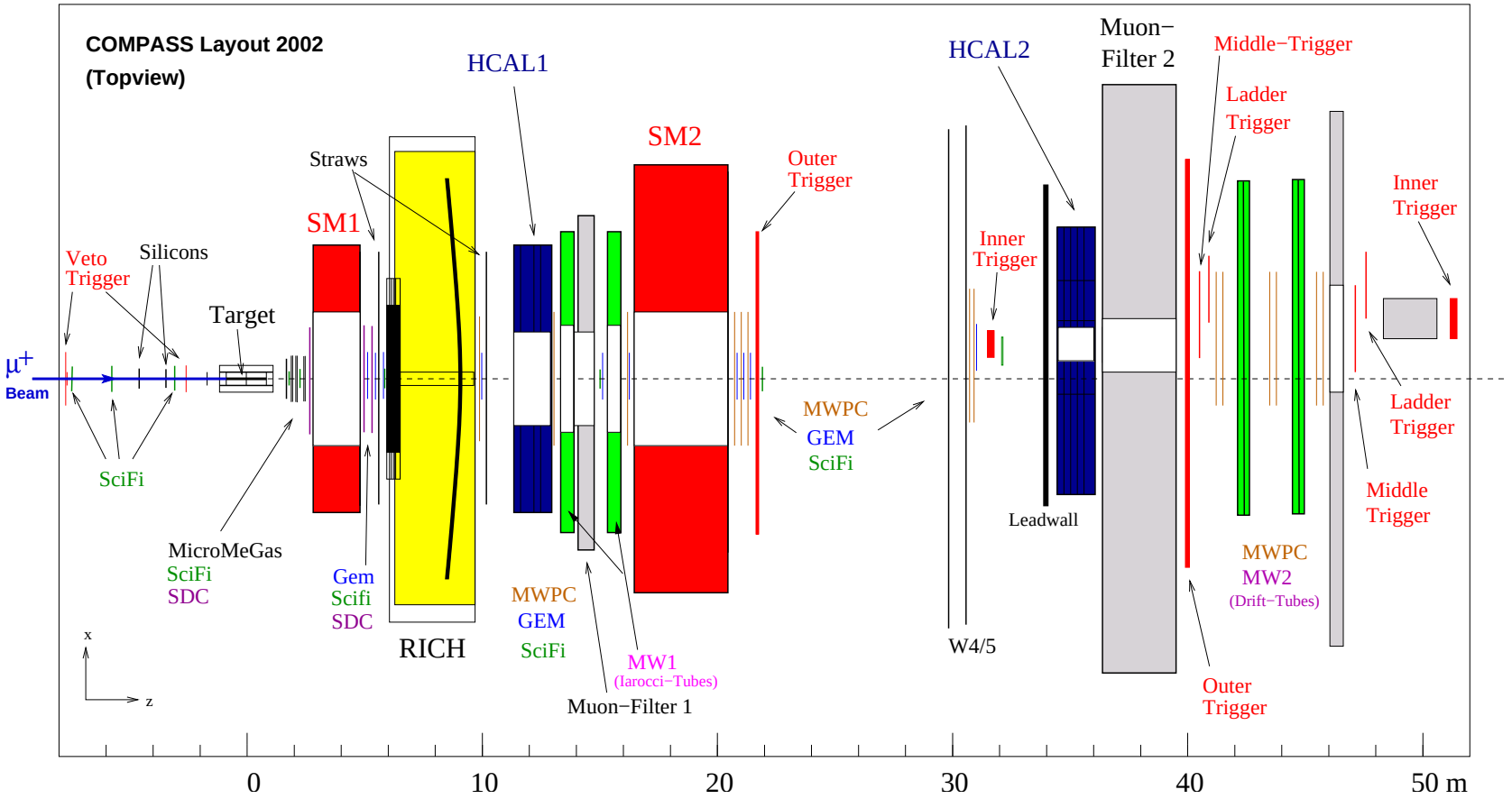
Comparison of the polarizations of anti-hyperons with those of the corresponding hyperons as functions of x_F. Left column for COMPASS conditions.
Both the contributions from the fragmentation of the struck quark and that of the nucleon remnant are taken into account. The solid and dashed lines denote the results obtained by using the SU(6) picture, while the dotted and dash-dotted lines denote those by using the DIS picture.
Polarisations are close to each other. Authors claim that diquark fragmentation is neglidgible.

Difficulties in interpretation of experimental results due to:

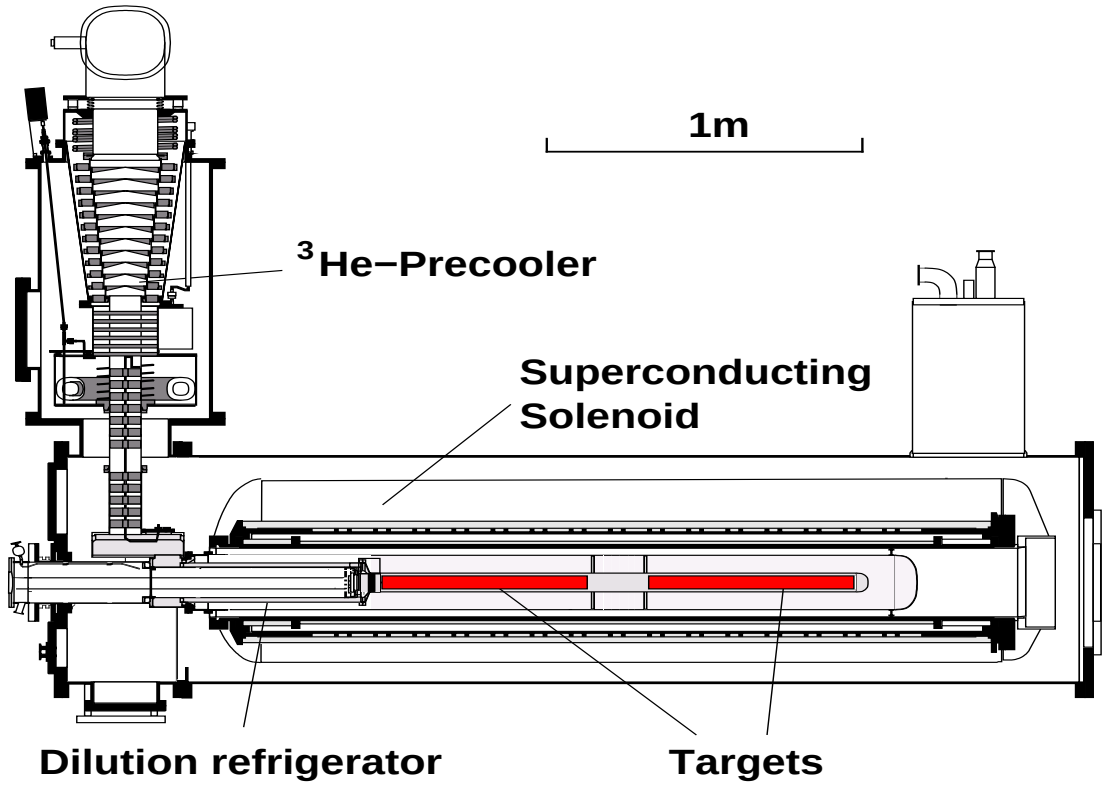


- large contribution from the diquark fragmentation
  (J. Ellis et al. Eur. Phys. J C25 (2002) 603)
  Rank counters R_{qq} and R_q correspond to particle rank from the diquark and quark ends of the string.
- significant fraction of Λ hyperons produced via decays of heavier strange particles

COMPASS experimental setup 2002

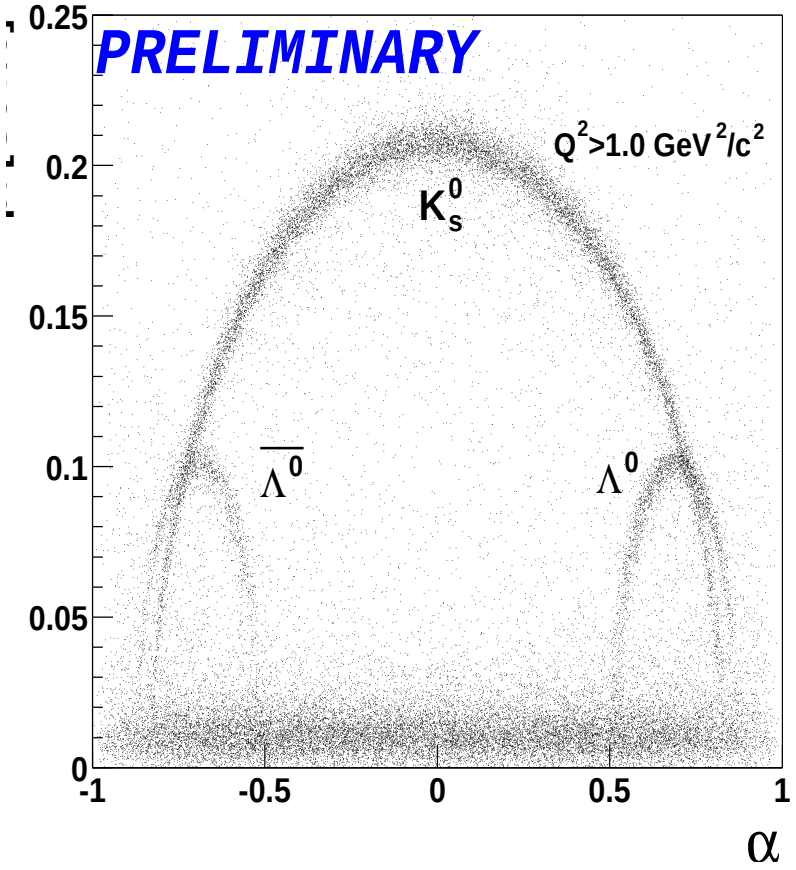


Polarised target



- Solenoidal field 2.5T
- 2×60 cm long cells
- ^6LiD material
- $P_T \approx 50\%$
- $f = 0.5$
- In this analysis data are averaged on target polarisation

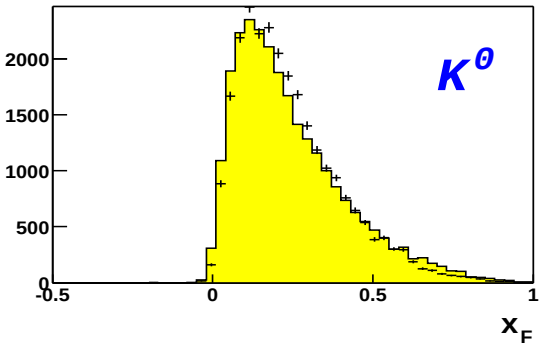
Selection cuts

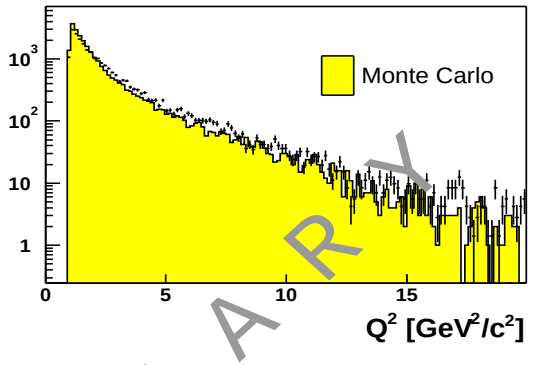


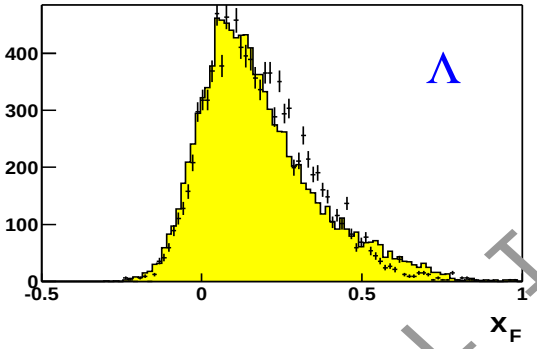
$$\alpha = \frac{p_L^+ - p_L^-}{p_L^- + p_L^+}$$

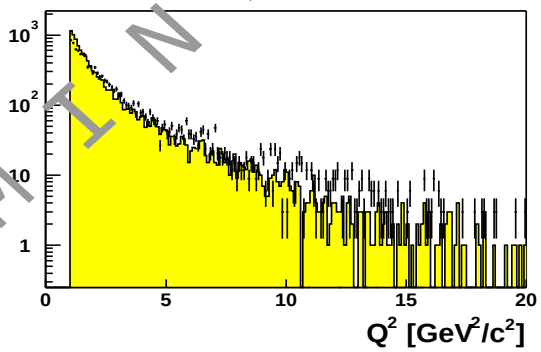
- Decay vertex (V^0) must be outside of the target.
- The angle between vector of V^0 momentum and vector between primary and V^0 vertices should be $\theta_{col} < 0.01$ rad.
- $p_t > 23$ MeV/c.
- $Q^2 > 1\ (GeV/c)^2$, $0.2 < y < 0.8$

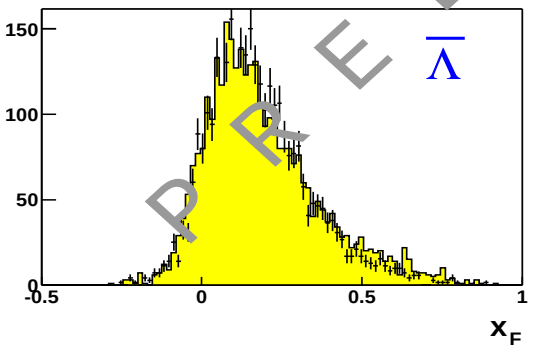
Kinematical characteristics

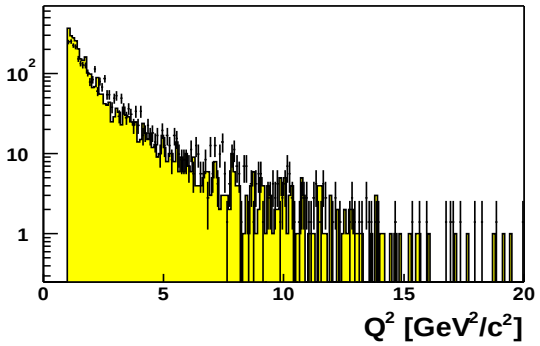












LEPTO 6.5.1 is used for event simulation.

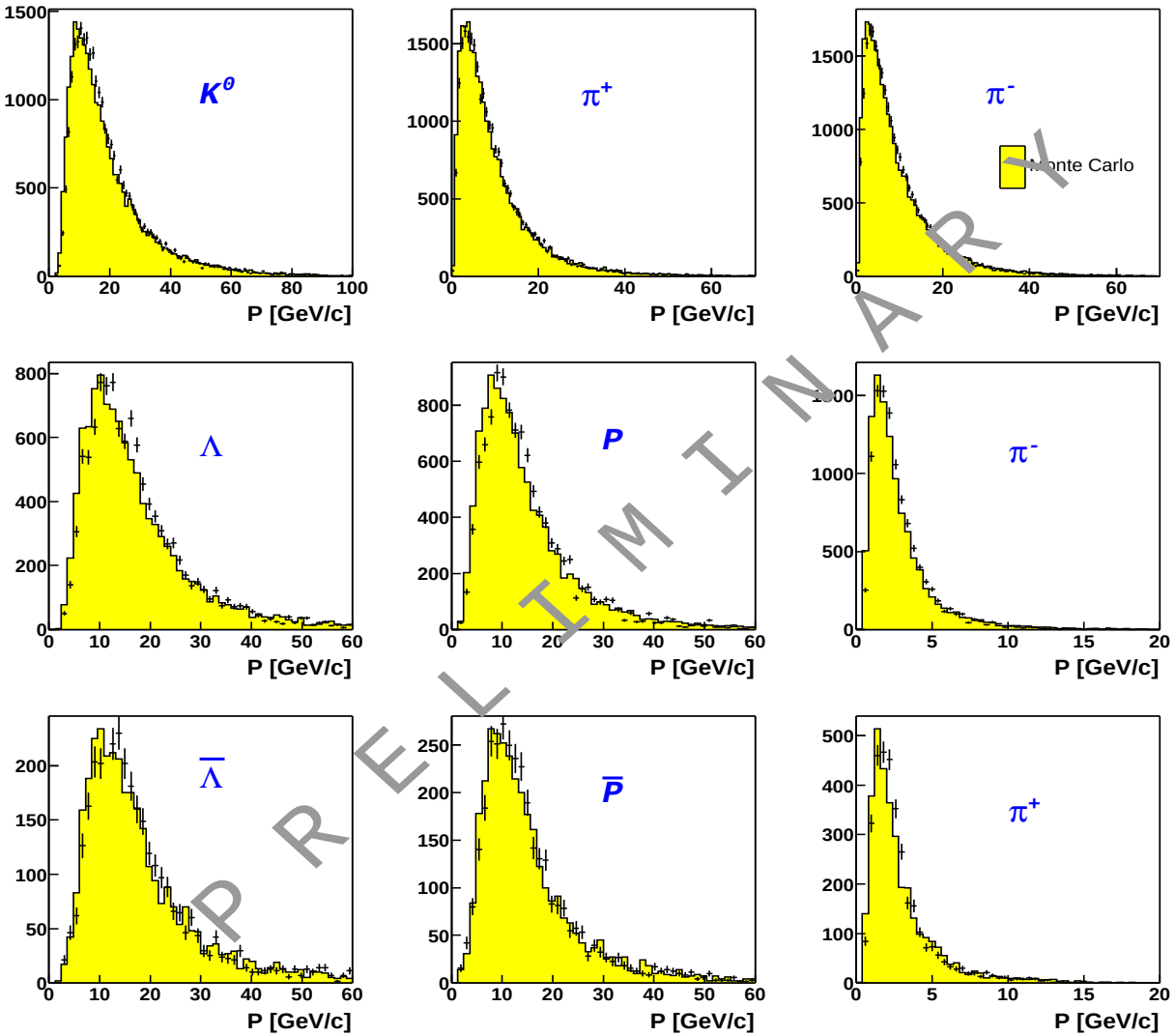
$< x_F >= 0.2$

$< y >= 0.45$

$< x_{Bj} >= 0.02$

$< Q^2 >= 2.62\ (GeV/c)^2$

Kinematical characteristics



$< P_\Lambda > \approx 12\ GeV/c$

$< P_\pi > \approx 2\ GeV/c$

Experiments on Λ and $\bar{\Lambda}$ production in DIS

	N(Λ)	N($\bar{\Lambda}$)
E665	750	650
NOMAD	8087	649
HERMES, 1996-2000	16900	2500
COMPASS, 2002	7919	5062

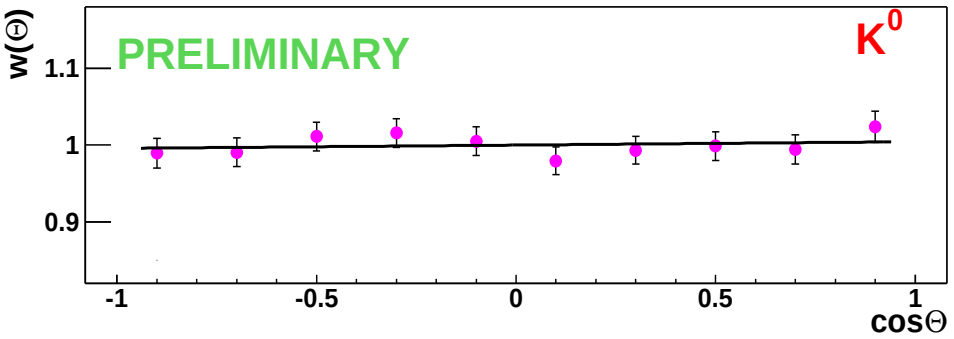
Angular distributions

- $\Lambda(\bar{\Lambda})$ hyperon polarisation is measured via angular asymmetry of decay protons in $\Lambda \to p\pi^-$ $(\bar{\Lambda} \to \bar{p}\pi^+)$ decays.
- Determine X- axis along the direction of the virtual photon in the V^0 rest frame.
- The angular distribution in the $\Lambda(\bar{\Lambda})$ rest frame is

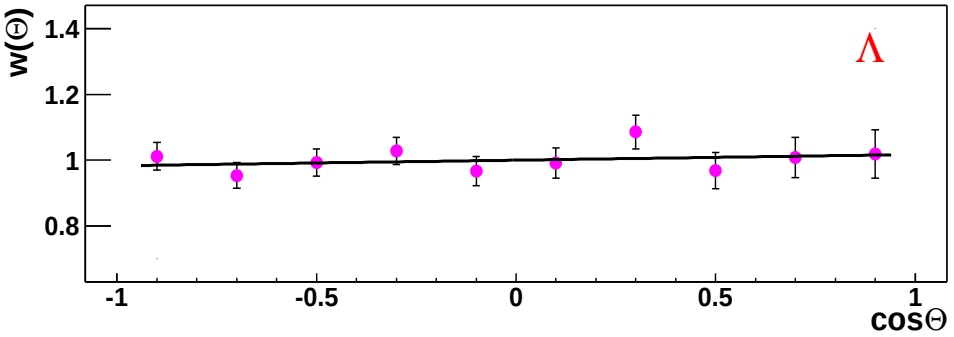
$$\frac{dN}{d\cos\theta_X} = \frac{N_{tot}}{2}(1 + \alpha P \cos\theta_X) \tag{1}$$

  where N_{tot} is the total number of events, $\alpha = 0.642 \pm 0.013$ is Λ decay parameter, P is the projection of the polarisation vector at the corresponding axis, θ_X is the angle between the direction of the positive decay particle (proton for Λ, pion - for $\bar{\Lambda}$).
- Background subtraction using bin-by-bin fit of the invariant mass distributions of $(p\pi^-)$ in $\cos\theta$ bins.
- The acceptance correction $A(\cos\theta)$ was determined using unpolarised Monte Carlo simulation.

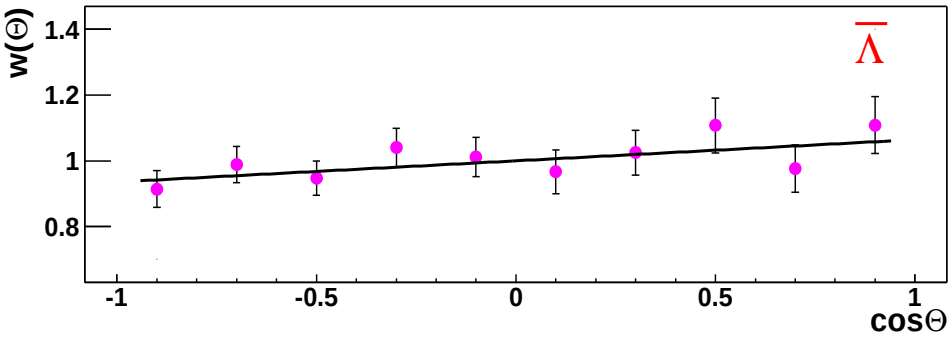
Corrected angular distributions



$$P_{K^0_s} = 0.007 \pm 0.017$$

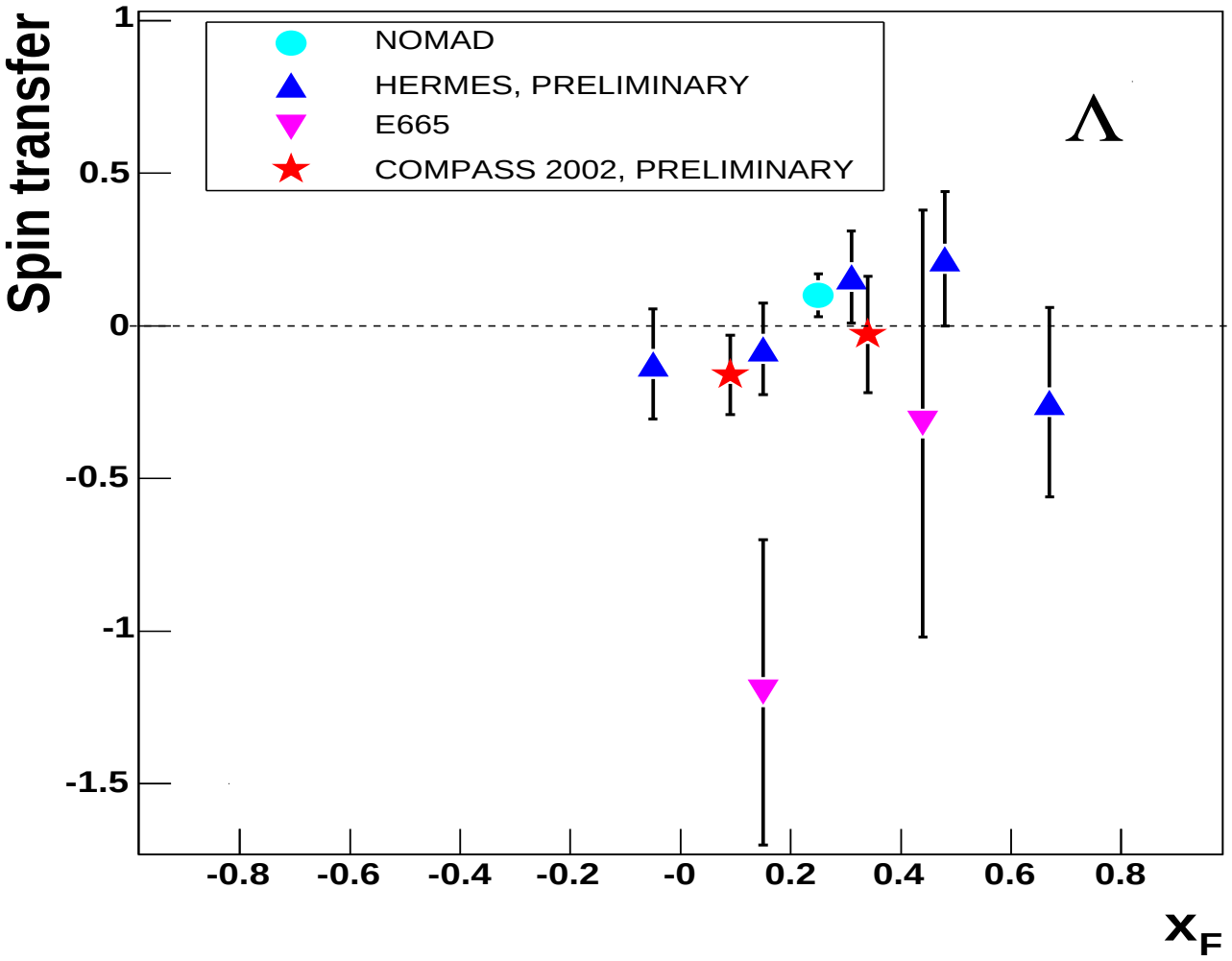


$$P_{\Lambda} = 0.03 \pm 0.04 \pm 0.04$$



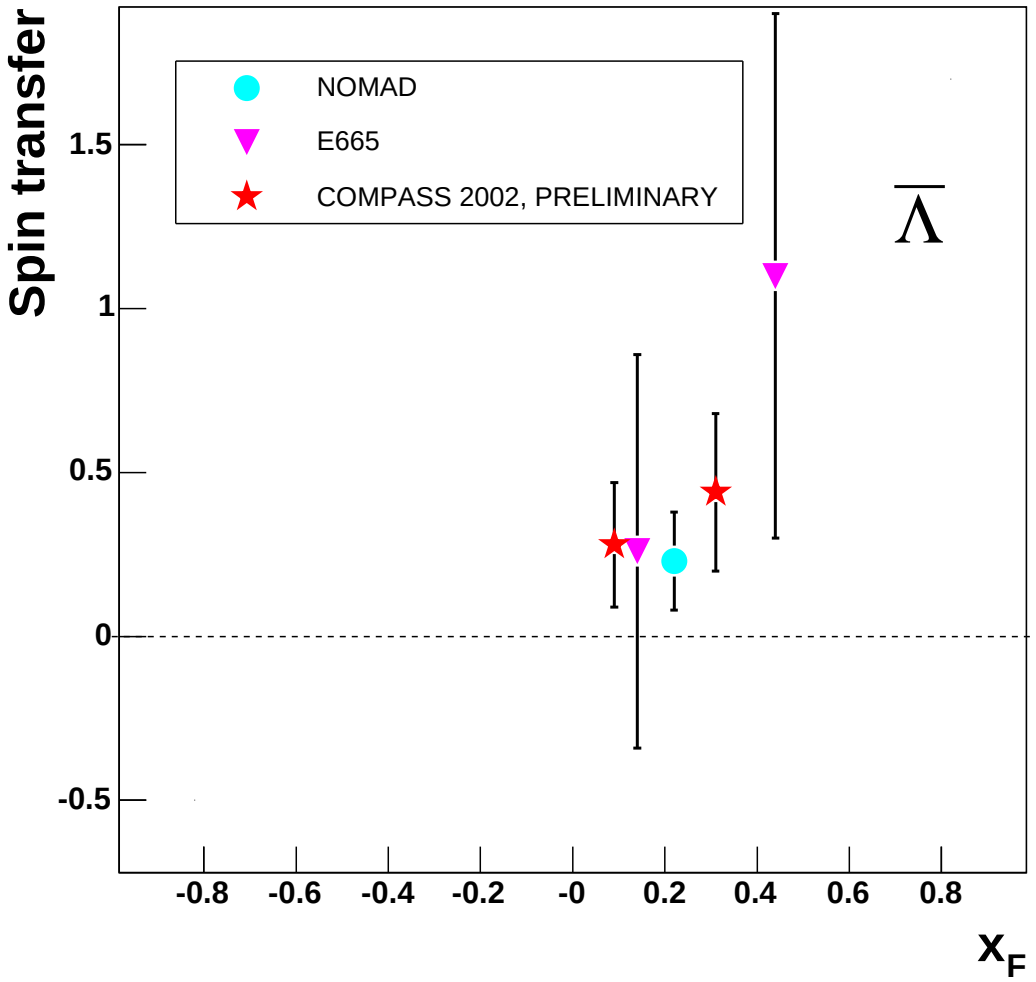
$$P_{\bar{\Lambda}} = -0.11 \pm 0.06 \pm 0.05$$

Spin transfer to Λ

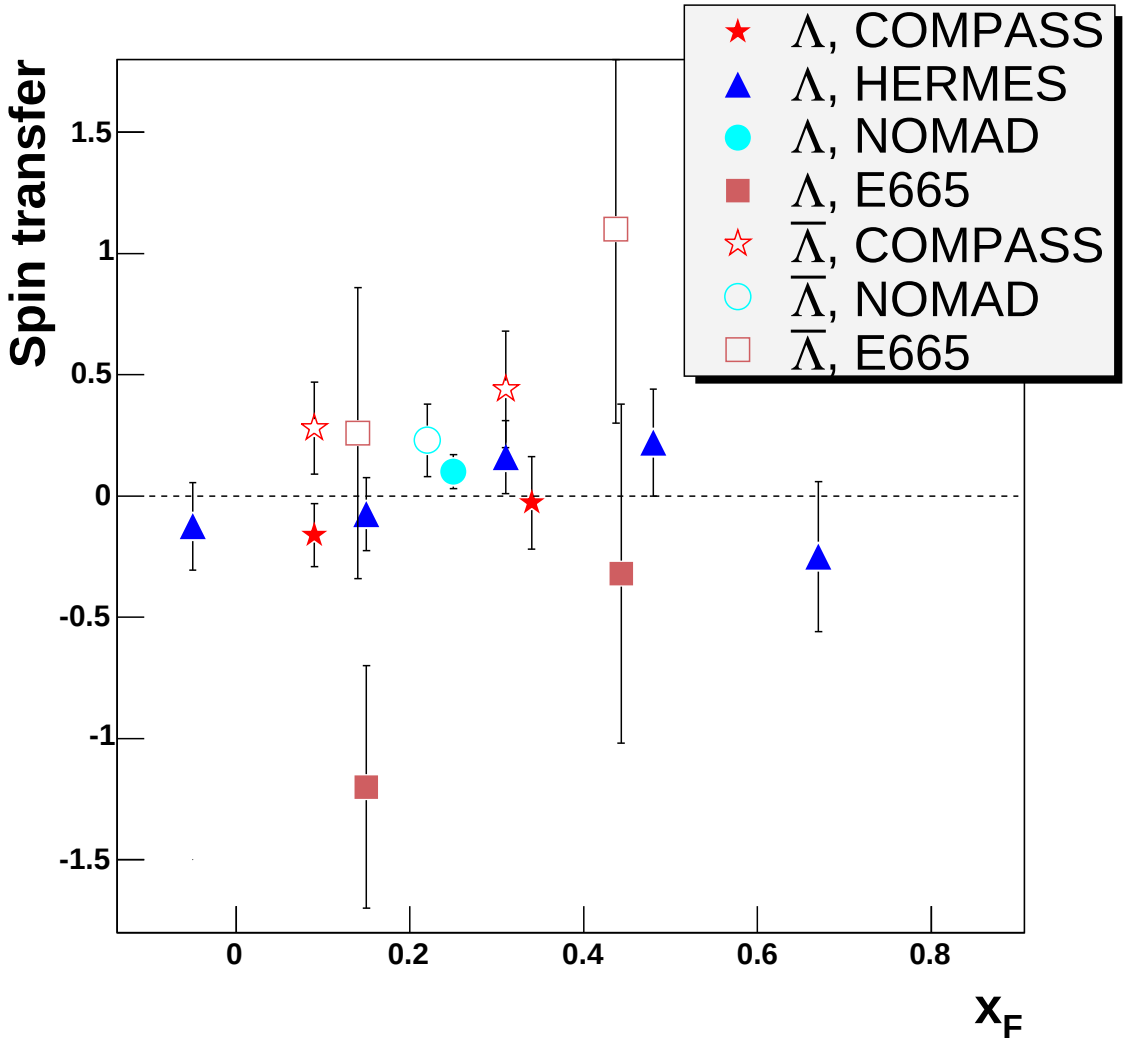


$$S = \frac{P_\Lambda}{P_B D}$$

Spin transfer to $\bar{\Lambda}$



Spin transfer to Λ and $\bar{\Lambda}$



Conclusion

- 2002 data statistics is about 8000 Λ and 5000 $\bar{\Lambda}$ with background subtraction and with cuts on $Q^2 > 1\ (GeV/c)^2$, $0.2 < y < 0.8$.
- 2002 data show good potential of COMPASS for Λ and $\bar{\Lambda}$ hyperons polarisation measurement.
- Data samples collected in 2003 and 2004 will significantly increase the statistics.