Longitudinal polarization of Λ and $\bar{\Lambda}$ in DIS at COMPASS

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DIS-09, Madrid

Physical motivation

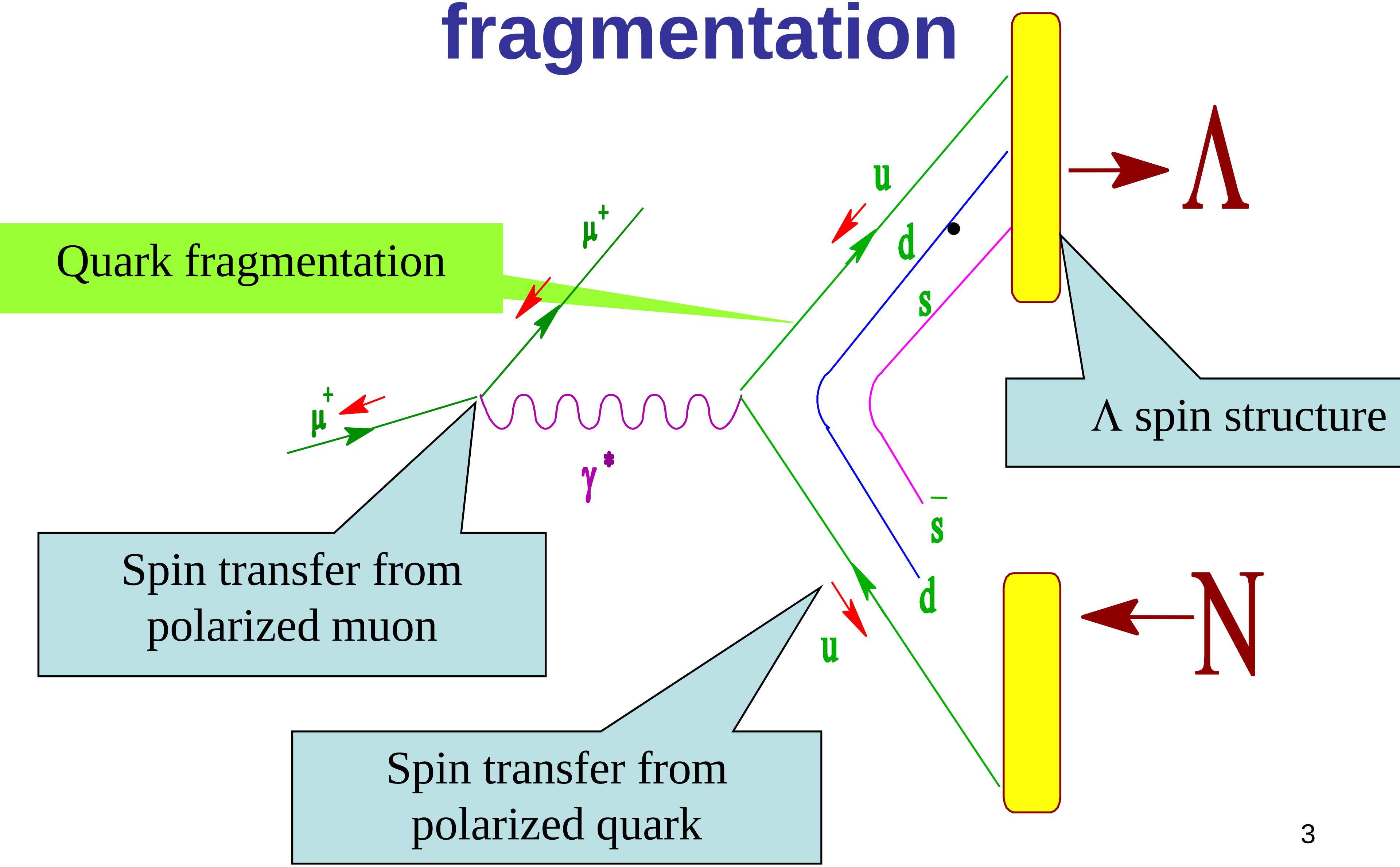
Longitudinal polarization of Λ and $\bar{\Lambda}$ in DIS is sensitive to:

- s(x), $\bar{s}$(x)
- polarization of strange quarks Δs

$$\Delta s = \int dx [s_\uparrow(x) - s_\downarrow(x) + \bar{s}_\uparrow(x) - \bar{s}_\downarrow(x)]$$

- Λ spin structure

Λ production in DIS, quark fragmentation



Λ spin structure

- **SU(6) quark model:** $\Delta s_\Lambda = 1, \Delta u_\Lambda = \Delta d_\Lambda = 0$

  100% polarization to **u** or **d** quarks is no influence on polarization of Λ

  P(Λ) - 0 (for u –quarks dominance)
- **Burkardt-Jaffe:** $\Delta u_\Lambda = \Delta d_\Lambda = -0.23$

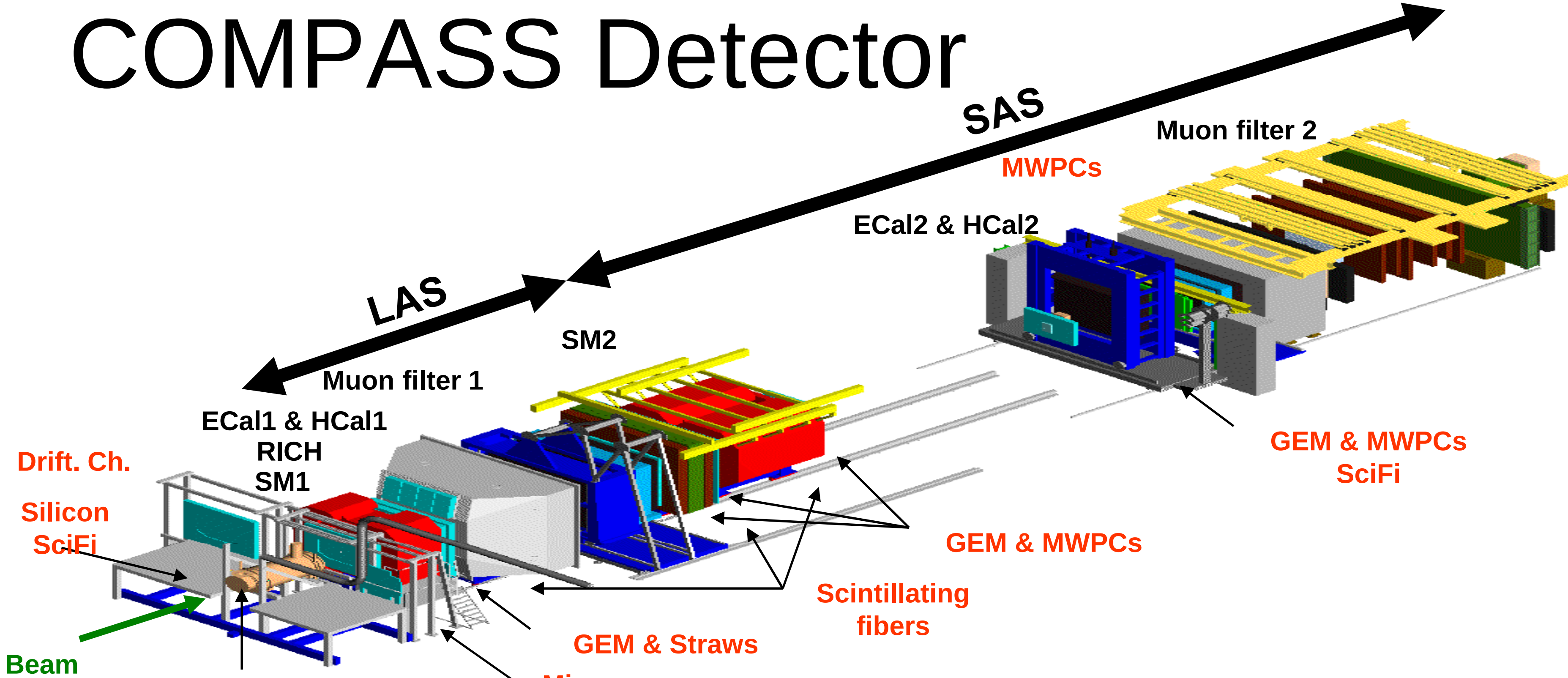
  P(Λ) – negative
- **B.Q.Ma et al.:** $\Delta u_\Lambda = \Delta d_\Lambda = \Delta s_\Lambda$

  P(Λ) – positive
- **Lattice calculations:** $\Delta u_\Lambda = \Delta d_\Lambda \sim 0, \Delta s_\Lambda = 0.68$

  P(Λ) ~ 0

- **Production** [redacted]
- **Spin transfer to** [redacted]

COMPASS Detector

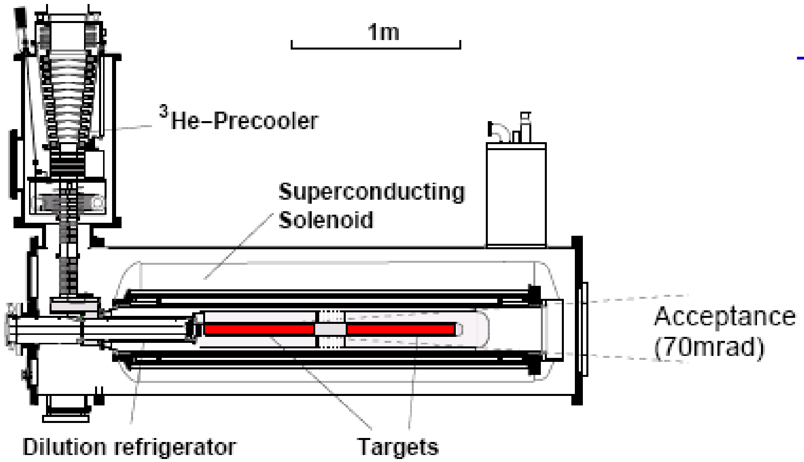


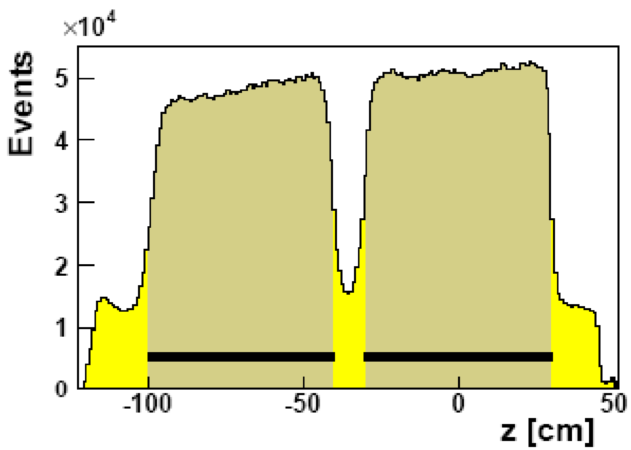
Polarized target

160 GeV μ^+ beam
$2.8 \cdot 10^8$ μ/spill (4.8 s)

P_b = -0.76±0.04 - 2003
P_b = -0.80±0.04 - 2004

Polarized ^{6}LiD target (2002-2004)





- polarisation: $> \mathbf{50\%}$
- dilution factor: $\sim \mathbf{0.4}$
- Dynamic Nuclear Polarization
- solenoid field: 2.5 T
  acceptance: 70 mrad
- ^{3}He/^{4}He: $T_{min} \approx 50\,\mathrm{mK}$
- two 60 cm long target cells with opposite polarisation
- regular polarisation reversal by field rotation

Production of $\Lambda(\bar{\Lambda})$

$$\vec{\mu}^{+} + d \rightarrow \mu^{+} + \Lambda + X$$

$$\Lambda \rightarrow p + \pi^{-}$$

No PID used

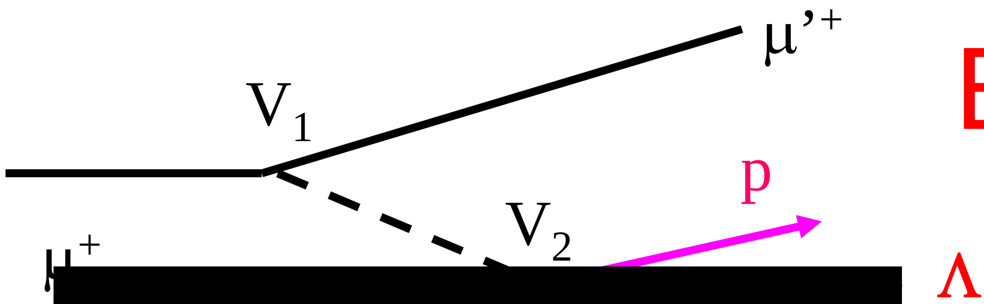
$$\vec{\mu}^{+} + d \rightarrow \mu^{+} + \bar{\Lambda} + X$$

$$\bar{\Lambda} \rightarrow \bar{p} + \pi^{+}$$

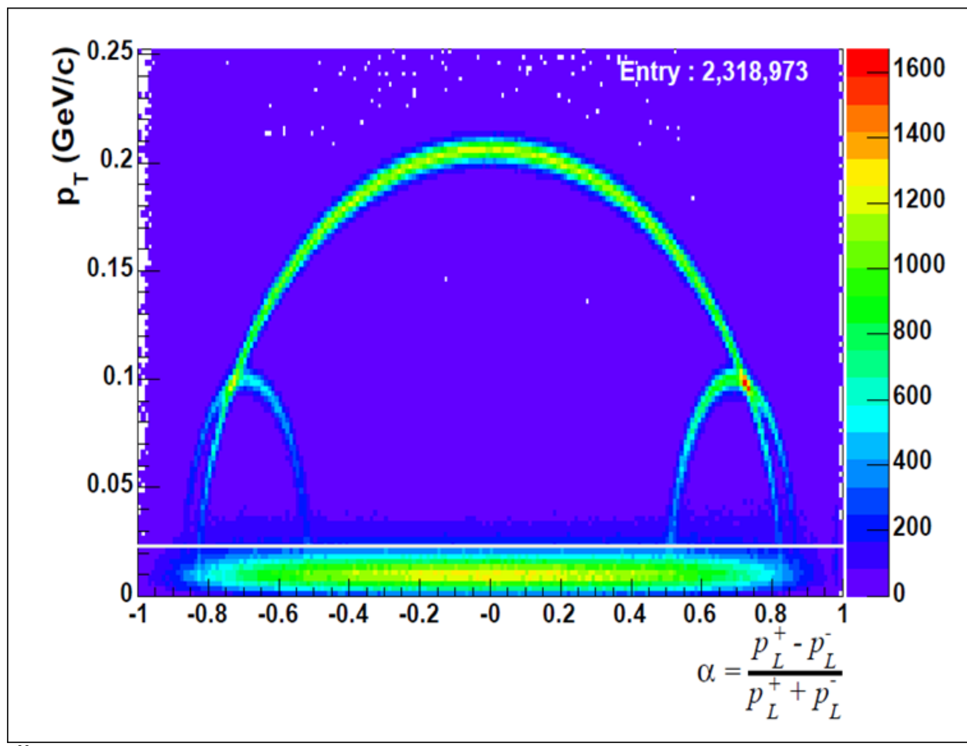
$$\vec{\mu}^{+} + d \rightarrow \mu^{+} + K_S + X$$

$$K_S \rightarrow \pi^{+} + \pi^{-}$$

Event selection

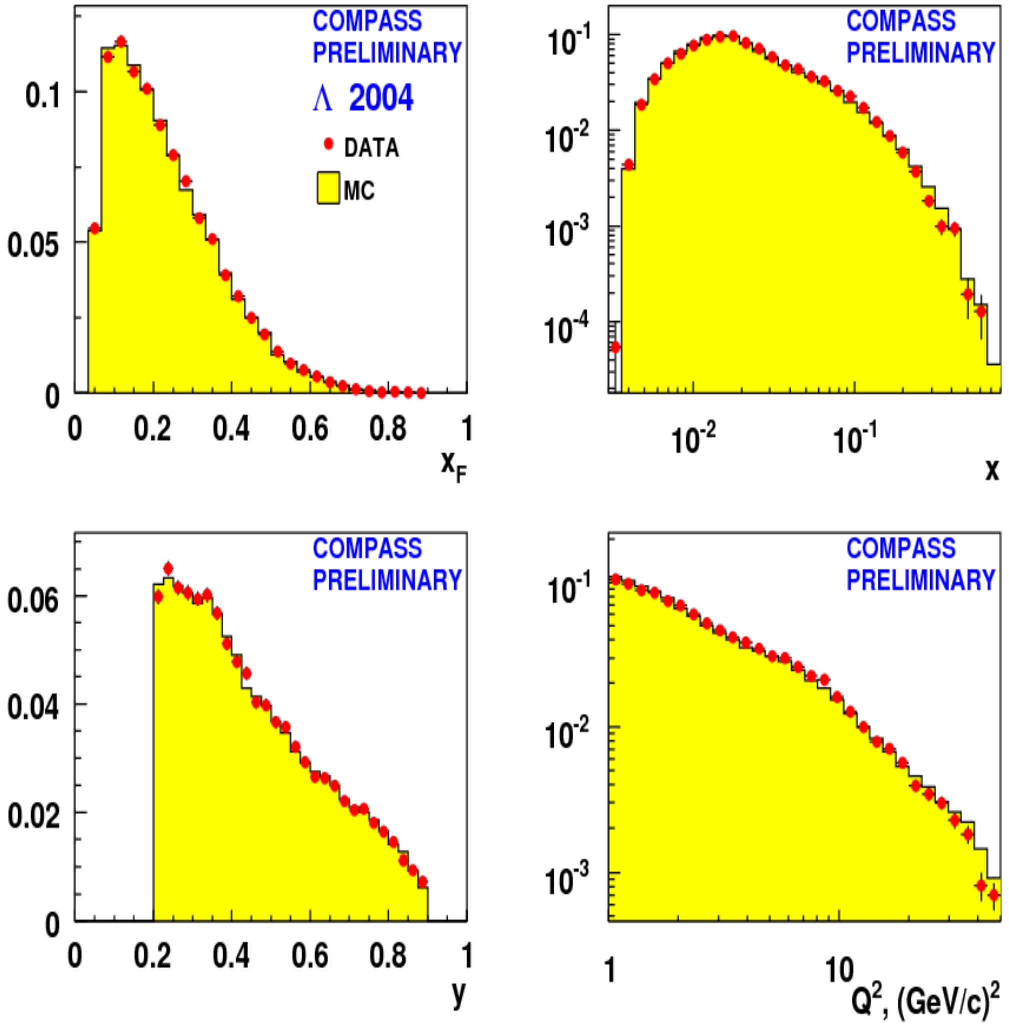


[redacted]



Comparison with other experiments

	N(Λ)	N($\bar{\Lambda}$)
E665	750	650
NOMAD	8 087	649
HERMES, 1996-2000	7 300	1 687
RHIC	30 000	24 000
COMPASS, 2003,2004	70 000	42 000



- Λ

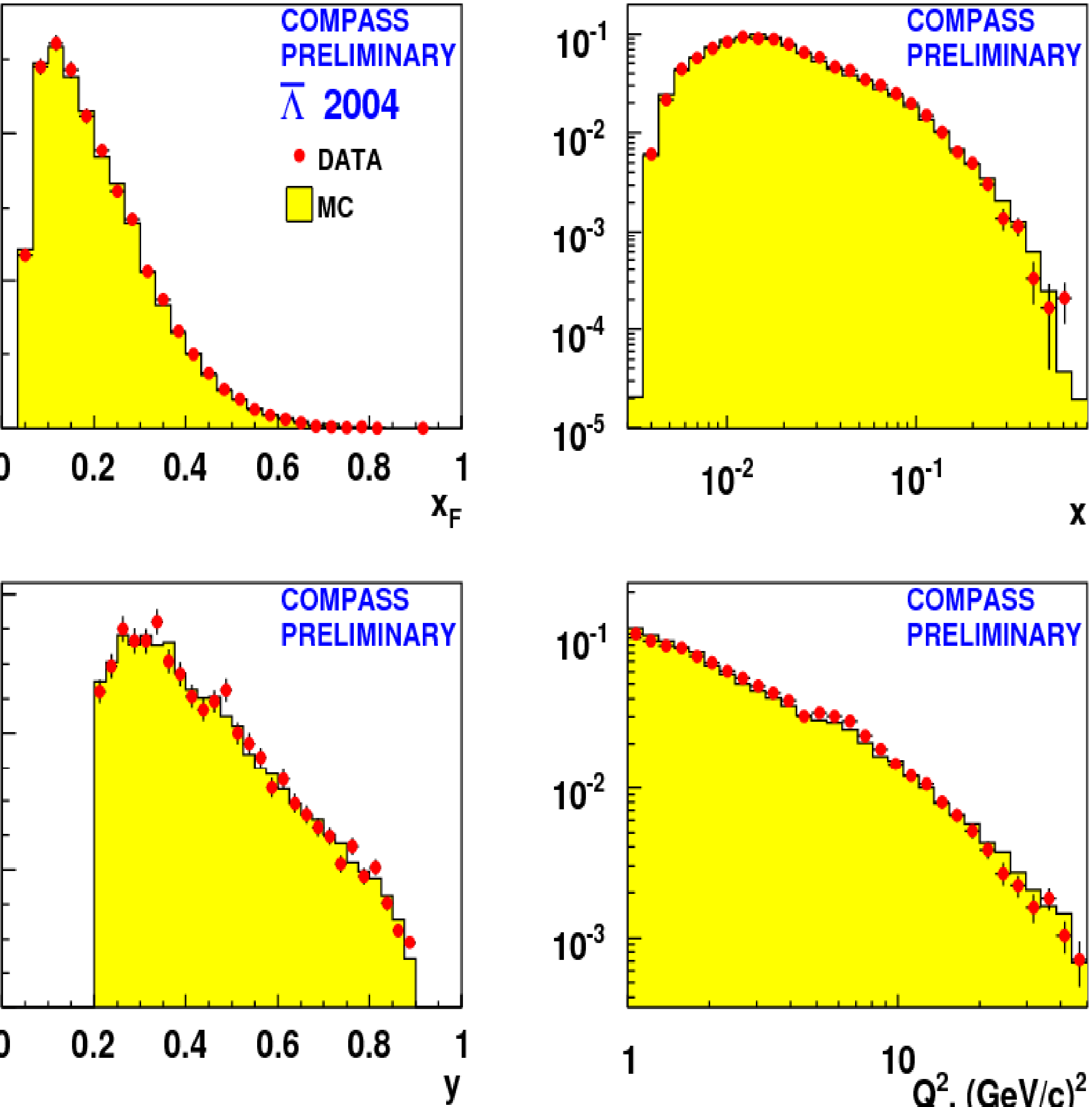
$\langle x_{Bj} \rangle = 0.05$

$\langle x_F \rangle = 0.23$

$\langle y \rangle = 0.46$

$\langle Q^2 \rangle = 3.31\ GeV^2$

Good agreement between data and MC



- $\bar{\Lambda}$

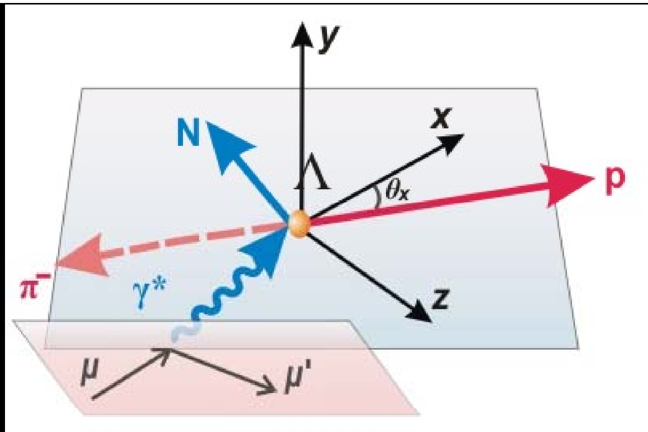
$\langle x_{Bj} \rangle = 0.050$

$\langle x_F \rangle = 0.22$

$\langle y \rangle = 0.48$

$\langle Q^2 \rangle = 3.27\ GeV^2$

Longitudinal polarization P_L



$$\frac{dN}{d\Omega} = \frac{N_{tot}}{4\pi}(1 + \alpha\vec{P}\vec{k})$$

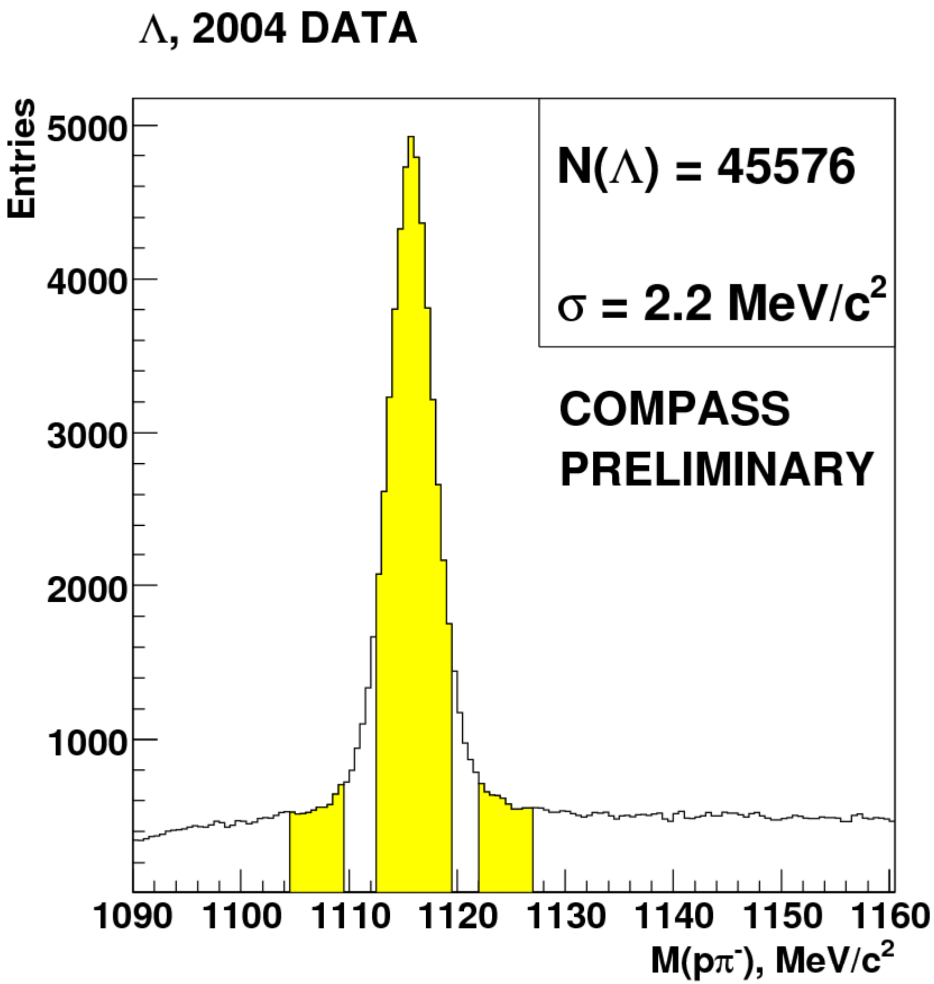
α=+(-)0.642 ±0.013 - Λ($\bar{\Lambda}$) decay parameter

P **- polarization vector**

k **- unit vector along the decay proton momentum**

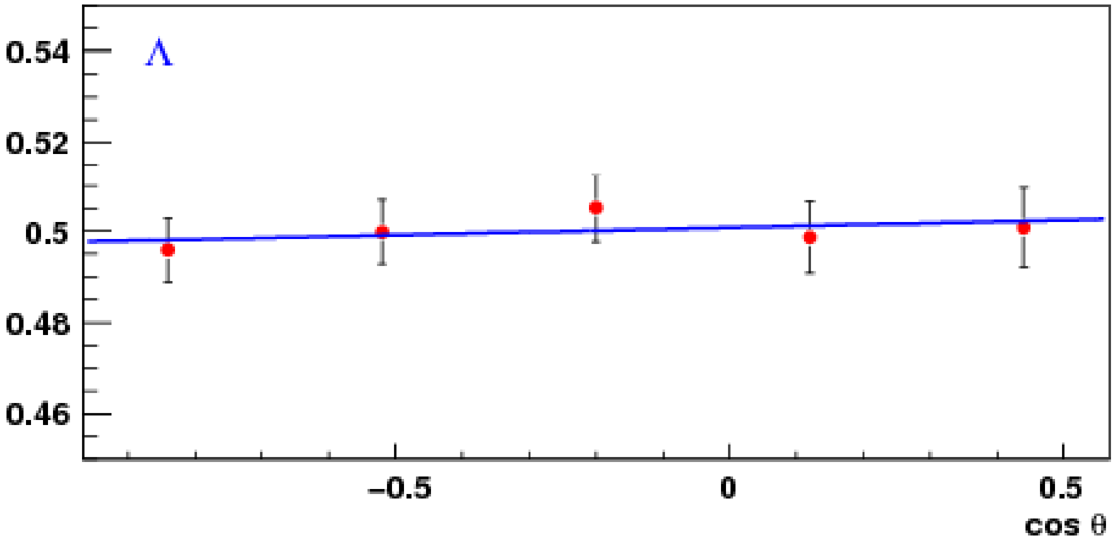
L-axis - along the momentum of virtual photon

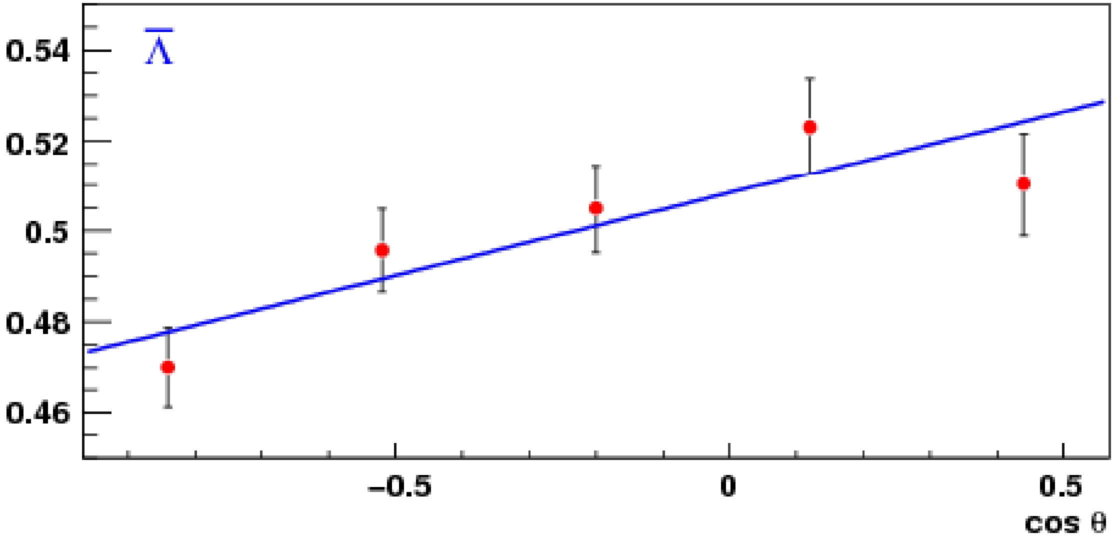
$$\frac{\text{[redacted]}}{N_{tot}^{obs}} \frac{\text{[redacted]}}{d\cos\theta} = \frac{1}{2}(1+\alpha \cdot P_L \cdot \cos\theta)$$



Determination of the angular distribution:

- sidebands subtraction





Angular distributions of Λ and $\bar{\Lambda}$ (run 2004)

Acceptance correction – using unpolarized MC

$P(K^0)=0.011\pm0.005$

Longitudinal spin transfer D_{LL}

$D_{LL'}$ - polarization of the struck quark along the axis L is transferred to the Λ along the secondary axis L'

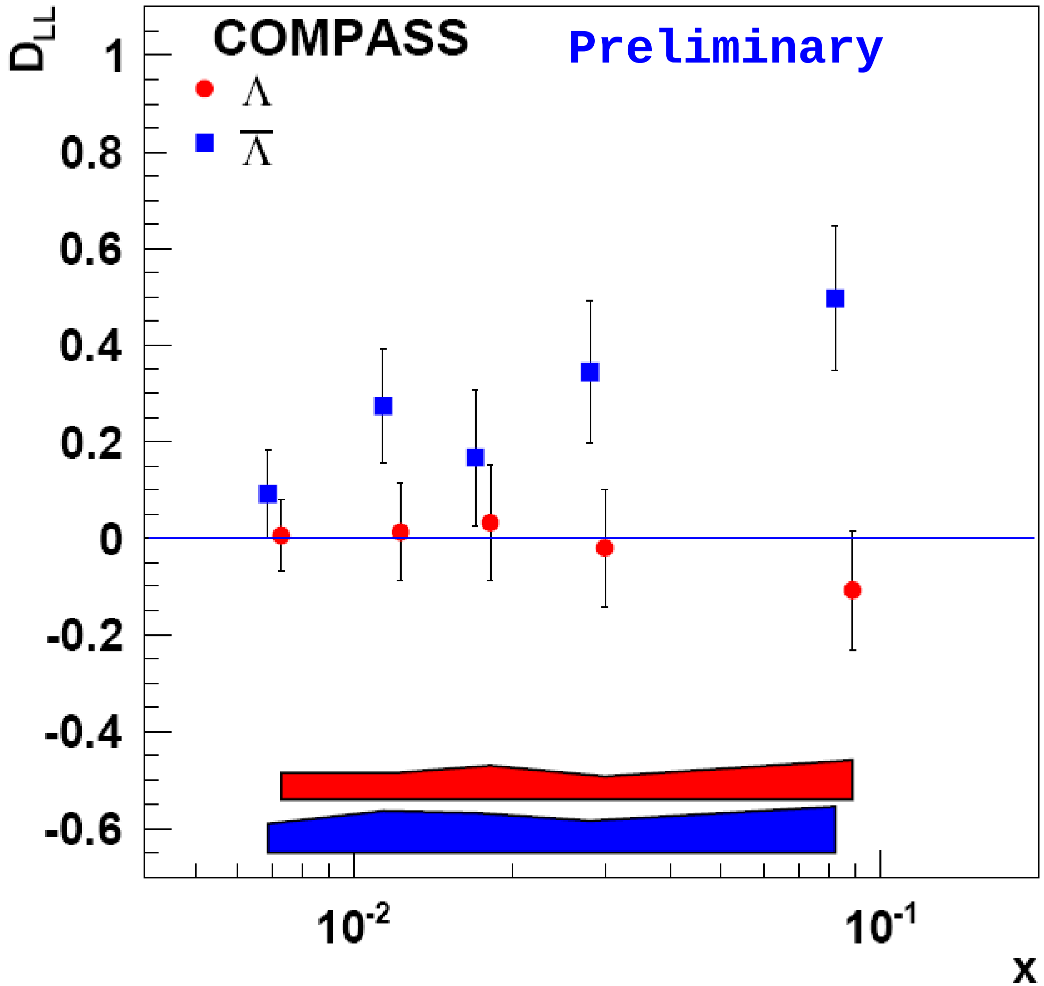
In our case: L=L'

$$P_L = D_{LL} P_b D(y)$$

P_b – beam polarization, D(y) – depolarization factor

$$D(y) = \frac{1-(1- \text{[redacted]}}{1+(1- \text{[redacted]}}$$

Comparison of Λ and $\bar{\Lambda}$: x



$D_{LL}(\Lambda) \neq D_{LL}(\bar{\Lambda})$

$D_{LL}(\Lambda)$ = -0.012 ± 0.047 ± 0.024

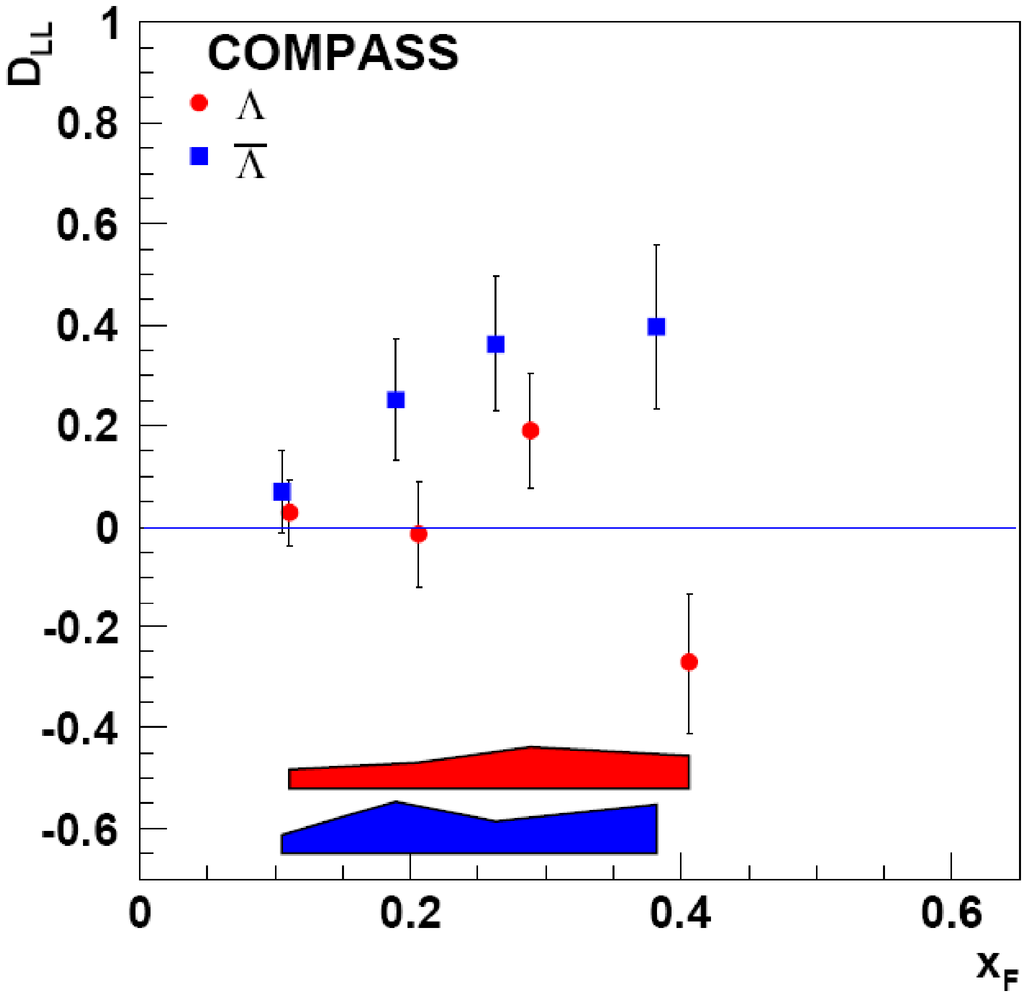
$D_{LL}(\bar{\Lambda})$ = 0.249 ± 0.056 ± 0.049

Table 2. Systematic errors for the spin transfer to Λ and $\bar{\Lambda}$.

	Λ	$\bar{\Lambda}$
Spin transfer to kaons, $\delta(K_S^0)$	0.016	0.016
Variation of the $\cos\theta$ cut, $\delta(\theta)$	0.016	0.044
Uncertainty of the ss-method, $\delta(ss)$	0.010	0.016
Uncertainty of the beam polarization, $\delta(P_b)$	0.0006	0.013
σ_{syst}	0.024	0.049

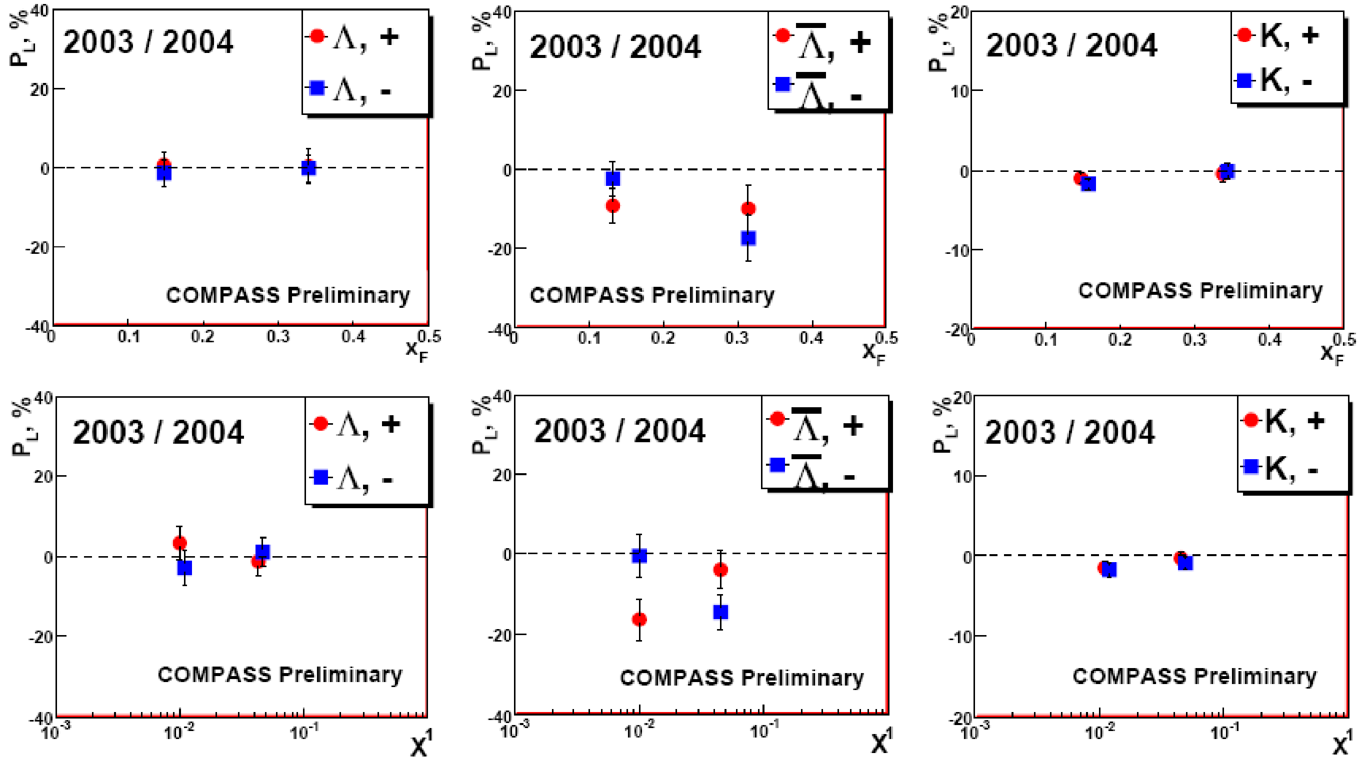
The results are averaged over target polarization

Comparison of Λ and $\bar{\Lambda}$: x_F



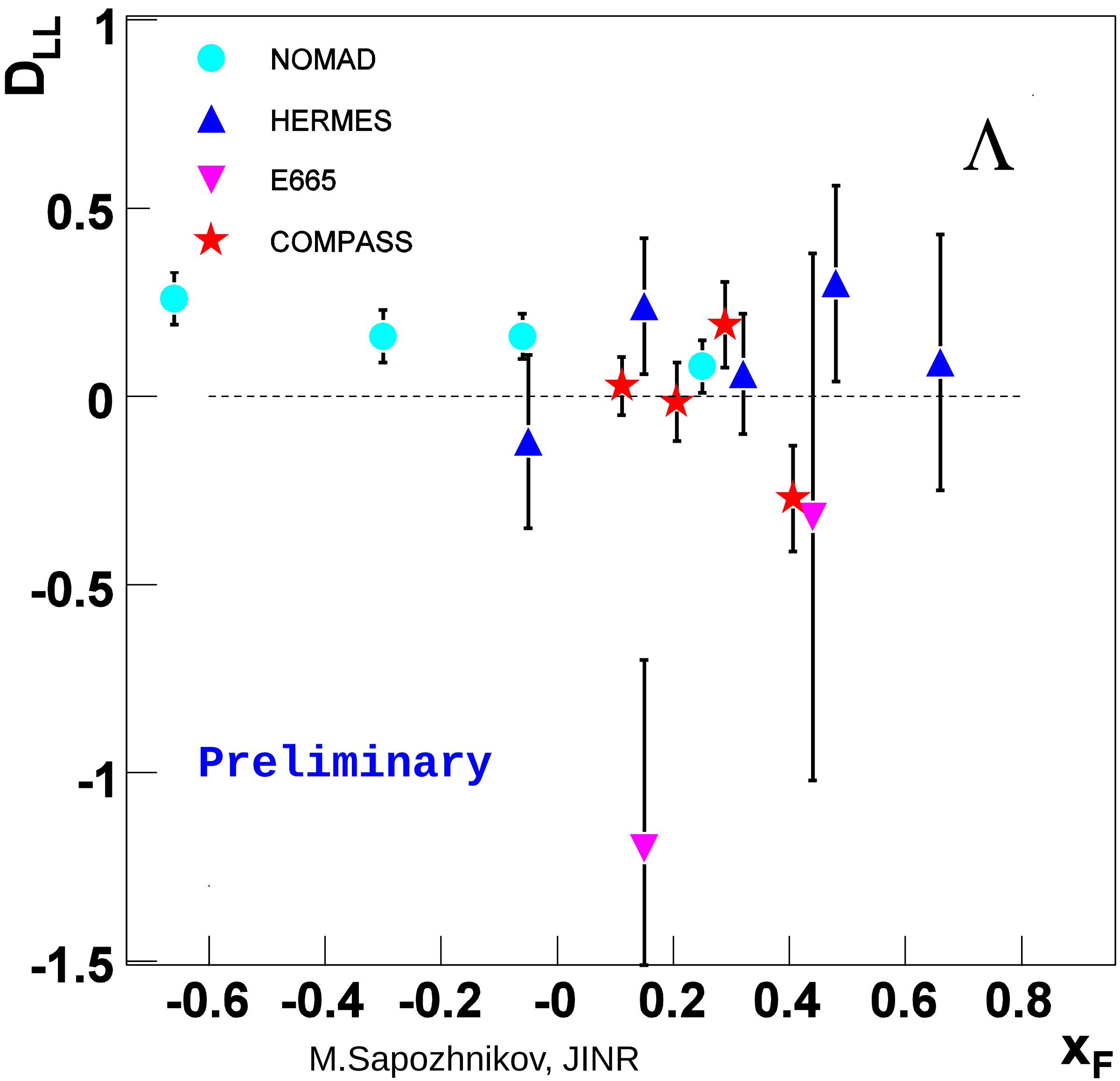
The results are averaged over target polarization

P_L: dependence on the target polarization

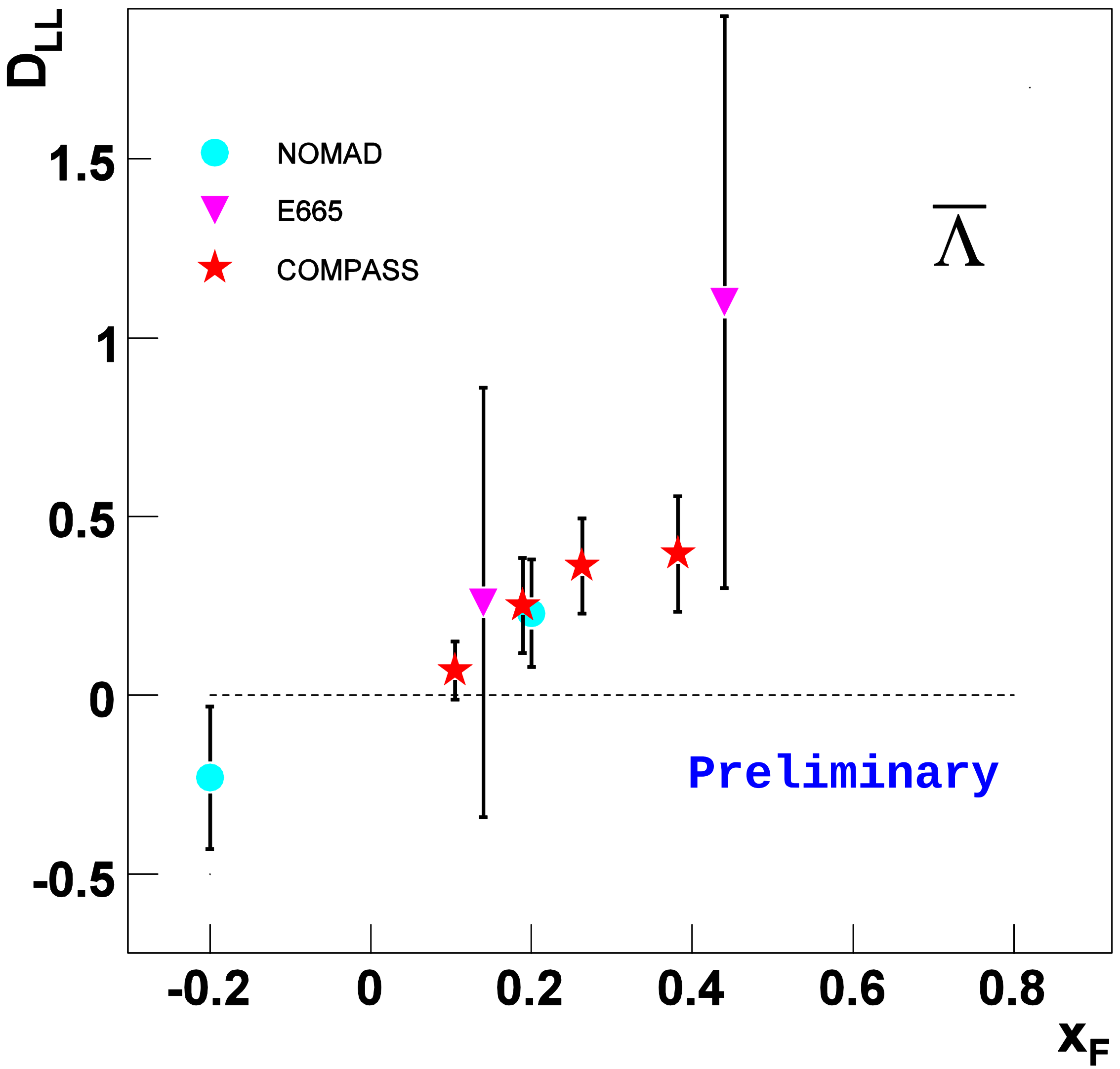


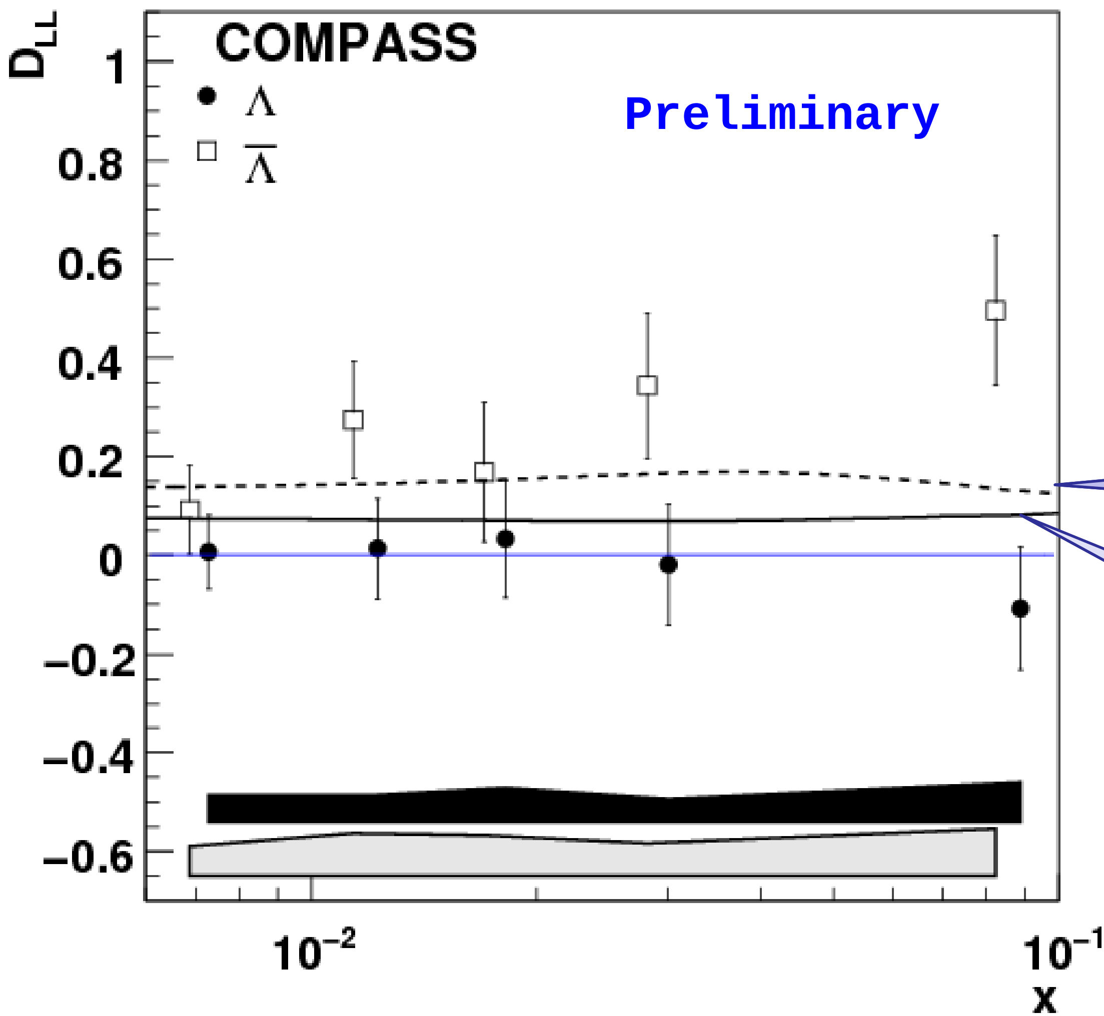
$$\Delta P = P_- - P_+ = -0.01 \pm 0.04, \qquad \Lambda$$
$$= 0.01 \pm 0.05, \qquad \bar{\Lambda}$$

Comparison with other experiments : Λ

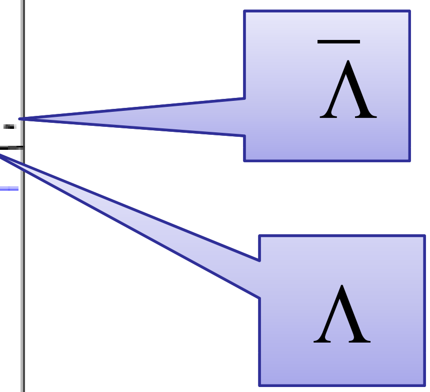


Comparison with other experiments : $\bar{\Lambda}$





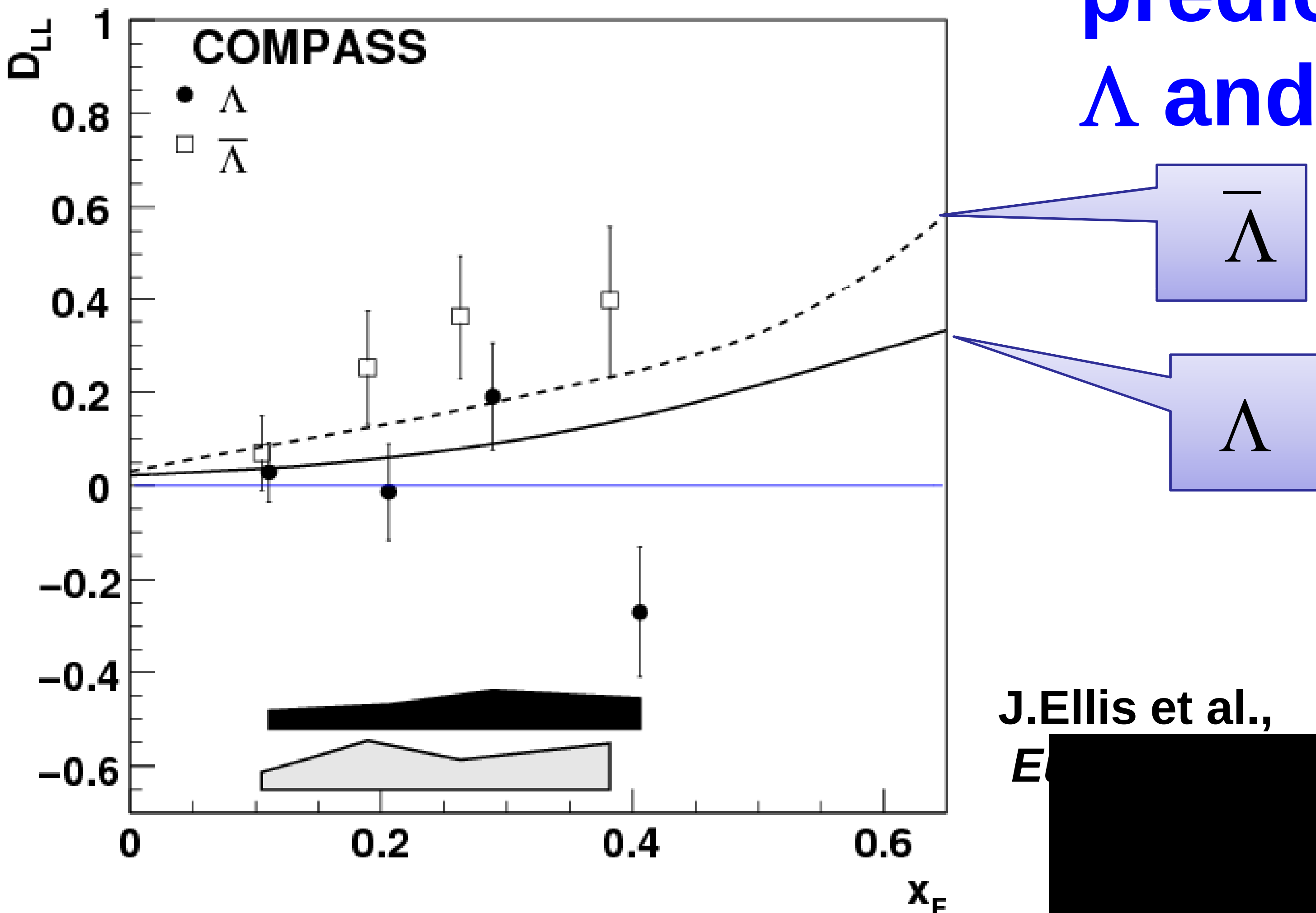
Theory predictions for Λ and $\bar{\Lambda}$



J.Ellis et al.,
Eur.Phys.J. C52 (2007) 603

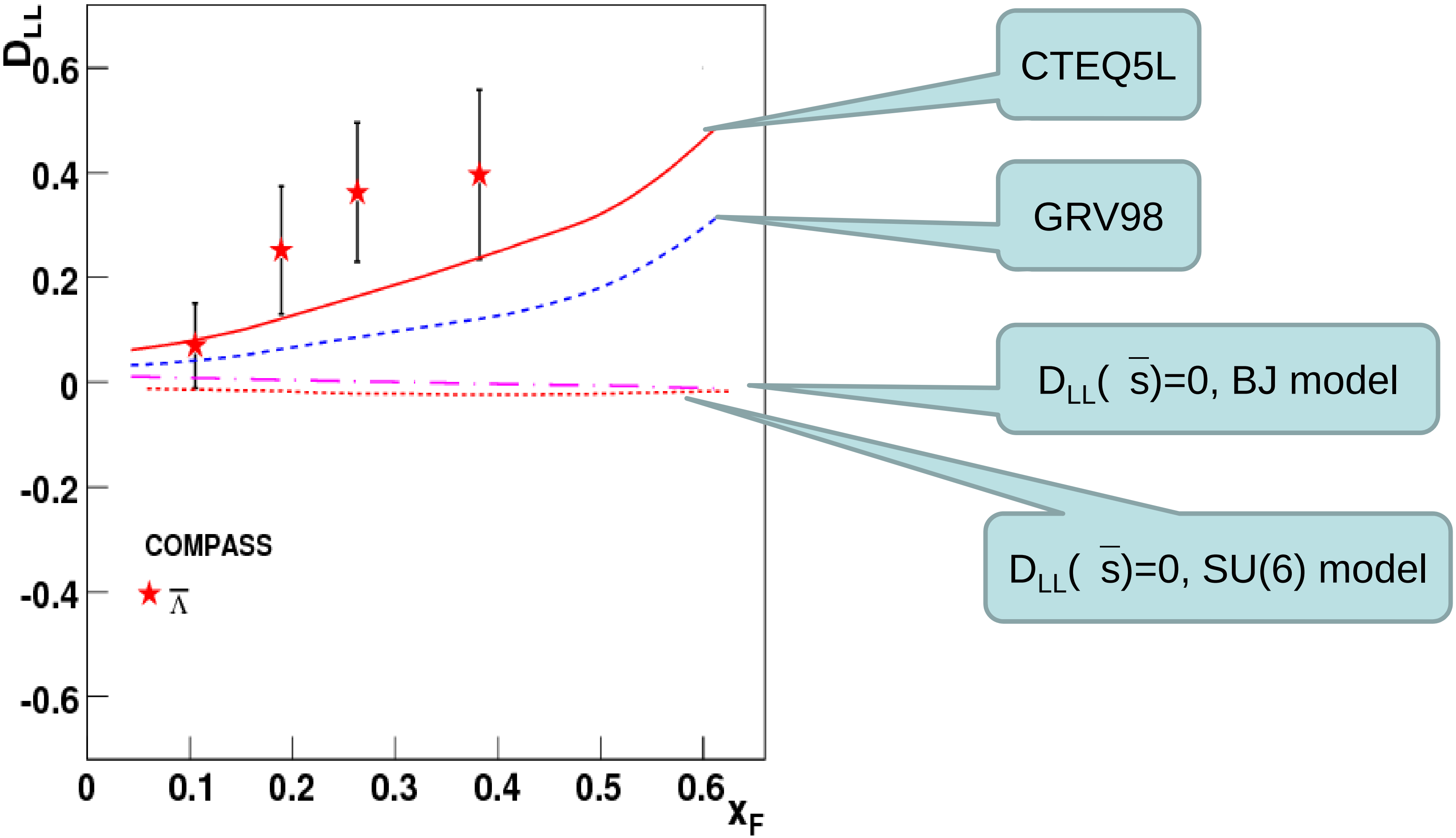
Theory predictions for Λ and $\bar{\Lambda}$

Preliminary

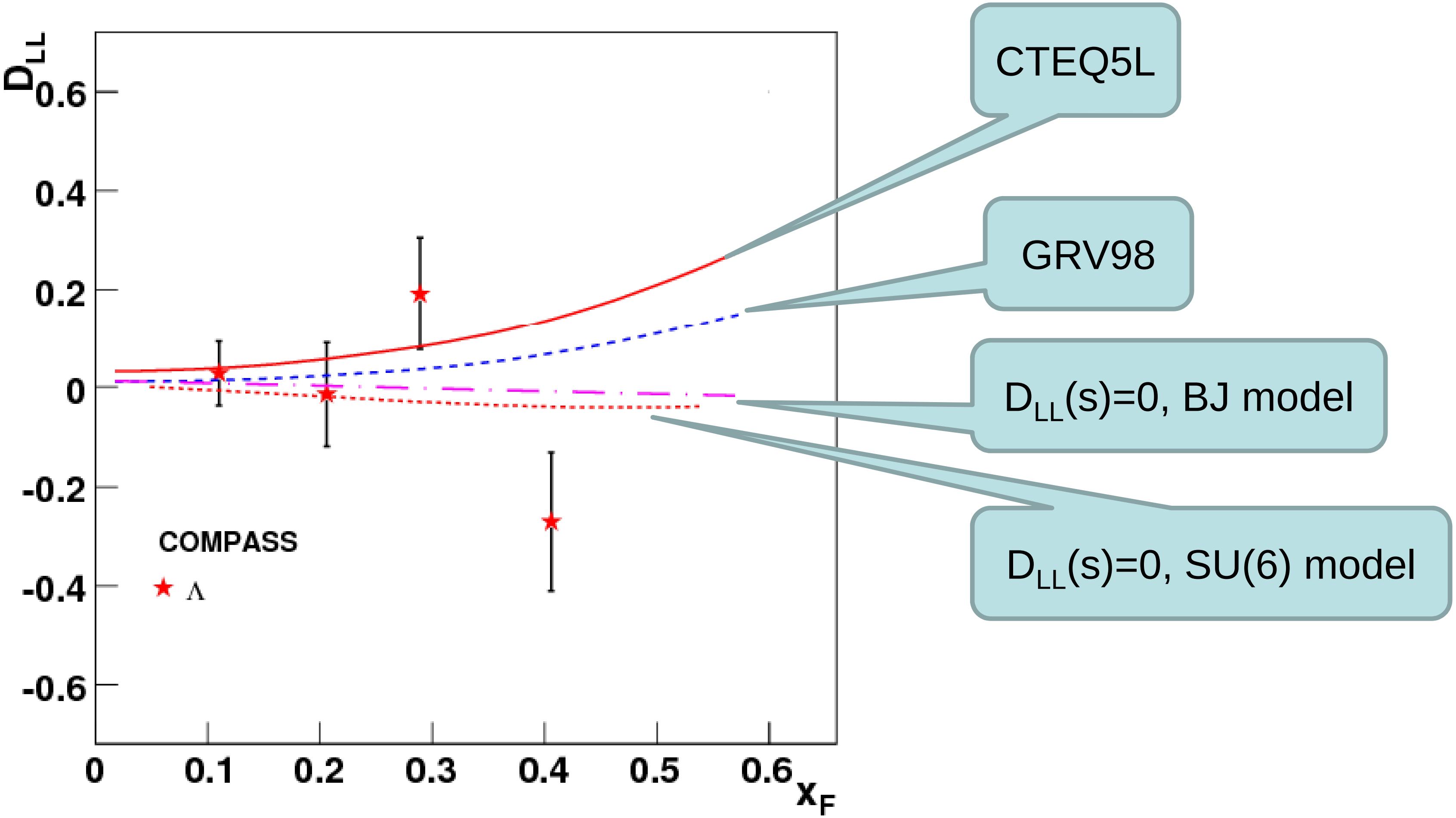


J.Ellis et al.,
E[redacted]

Sensitivity to the strange distribution $\bar{s}(x)$



Sensitivity to the strange distribution s(x)



Conclusions

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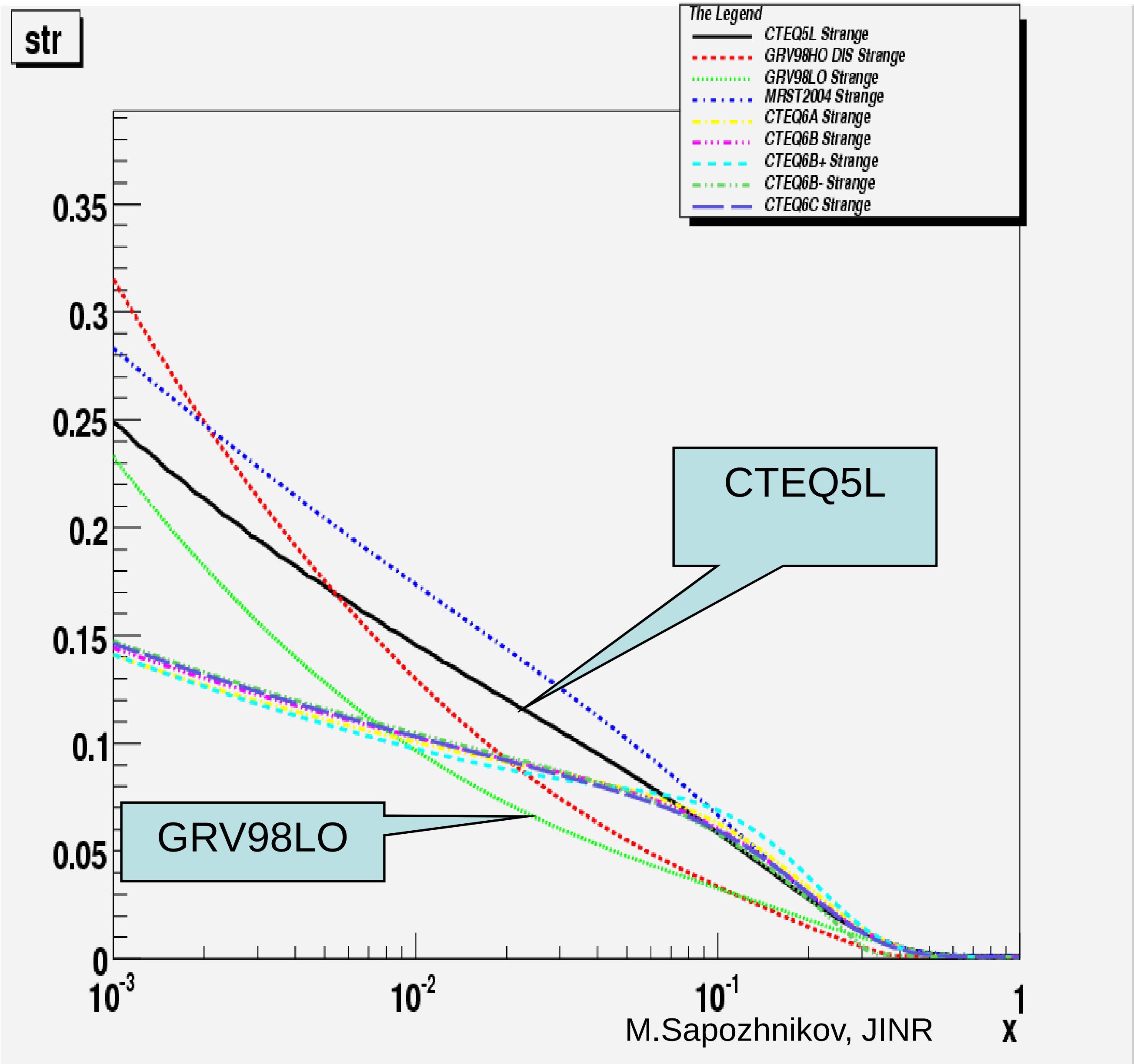
Backup slides



M.Sapozhnikov, JINR

- Influence to different PDF's

$Q^2 = 4\ GeV^2$

Polarization of Λ from quark fragmentation

Spin transfer from polarized muon

Spin transfer from polarized quark

$$P_\Lambda = \frac{\Sigma_q e_q^2 [P_b D(y) q(x) + P_T \Delta q(x)] \Delta D_q^\Lambda(z)}{\Sigma_q e_q^2 [q(x) + P_b P_T D(y) \Delta q(x)] D_q^\Lambda(z)}$$

$$\Delta D_q^\Lambda = D_q^{+\Lambda} - D_q^{-\Lambda} \qquad D_q^\Lambda = D_q^{+\Lambda} + D_q^{-\Lambda}$$

Polarization of Λ: $P_T = 0$

$$P_\Lambda = \frac{\Sigma_q e_q^2 P_b D(y) q\,(x) \Delta D_q^\Lambda(z)}{\Sigma_q e_q^2 q\,(x) D_q^\Lambda(z)}$$

$$\Delta D_u^\Lambda = \Delta D_d^\Lambda = 0;$$

$$\Delta D_{\bar{u}}^{\bar{\Lambda}} = \Delta D_{\bar{d}}^{\bar{\Lambda}} = 0;$$

$$D_{LL}^\Lambda = \frac{1}{9} \frac{s(x) \Delta D_s^\Lambda(z)}{\Sigma_q e_q^2 q\,(x) D_q^\Lambda(z)}$$

$$D_{LL}^{\bar{\Lambda}} = \frac{1}{9} \frac{\bar{s}(x) \Delta D_{\bar{s}}^{\bar{\Lambda}}(z)}{\Sigma_q e_q^2 q\,(x) D_q^{\bar{\Lambda}}(z)}$$

$D_{LL}(\bar{\Lambda}) > D_{LL}(\Lambda)$

$$D_{LL}^{\Lambda} = \frac{1}{9} \frac{s(x) \Delta D_s^{\Lambda}(z)}{\Sigma_q e_q^2 q\,(x) D_q^{\Lambda}(z)}$$

$$D_{LL}^{\bar{\Lambda}} = \frac{1}{9} \frac{\bar{s}(x) \Delta D_{\bar{s}}^{\bar{\Lambda}}(z)}{\Sigma_q e_q^2 q\,(x) D_q^{\bar{\Lambda}}(z)}$$

Even if $s(x) = \bar{s}(x)$, $D_{LL}(\bar{\Lambda}) > D_{LL}(\Lambda)$ due to difference of the denominator:

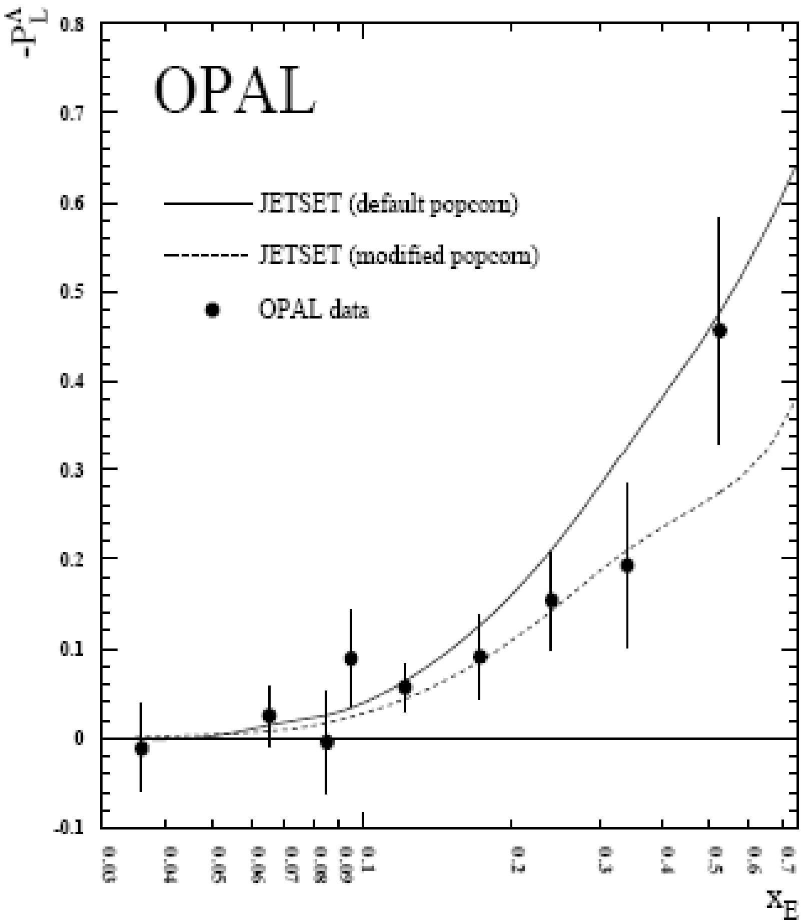
$D_{u,d}(\Lambda) > D_{u,d}(\bar{\Lambda})$

Independent quark fragmentation:

- **$D_{LL}(\bar{\Lambda}) > D_{LL}(\Lambda)$**
- **Sensitivity to s(x)**

Are these conclusions still valid in a more advanced model?

Spin transfer from polarized quark to Λ



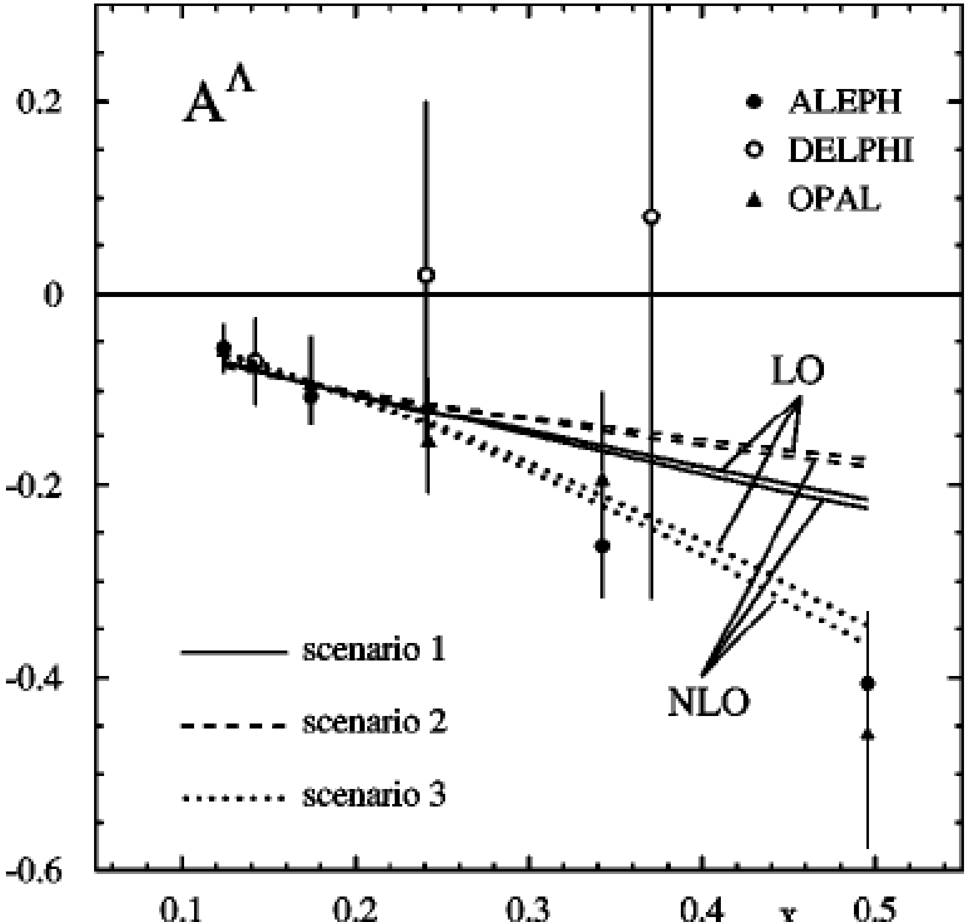
$$e^+e^- \to Z^0 \to s\bar{s}$$

$$P_s = -0.91$$

Polarized quarks, indeed, transfer the polarization to Λ.

Figure [illegible] The longitudinal polarization predicted using tuned versions of JETSET with different versions of the popcorn model of baryon production. The measurements are shown as solid points and the error bars are the statistical plus systematic errors, added in quadrature.

Impact of LEP data

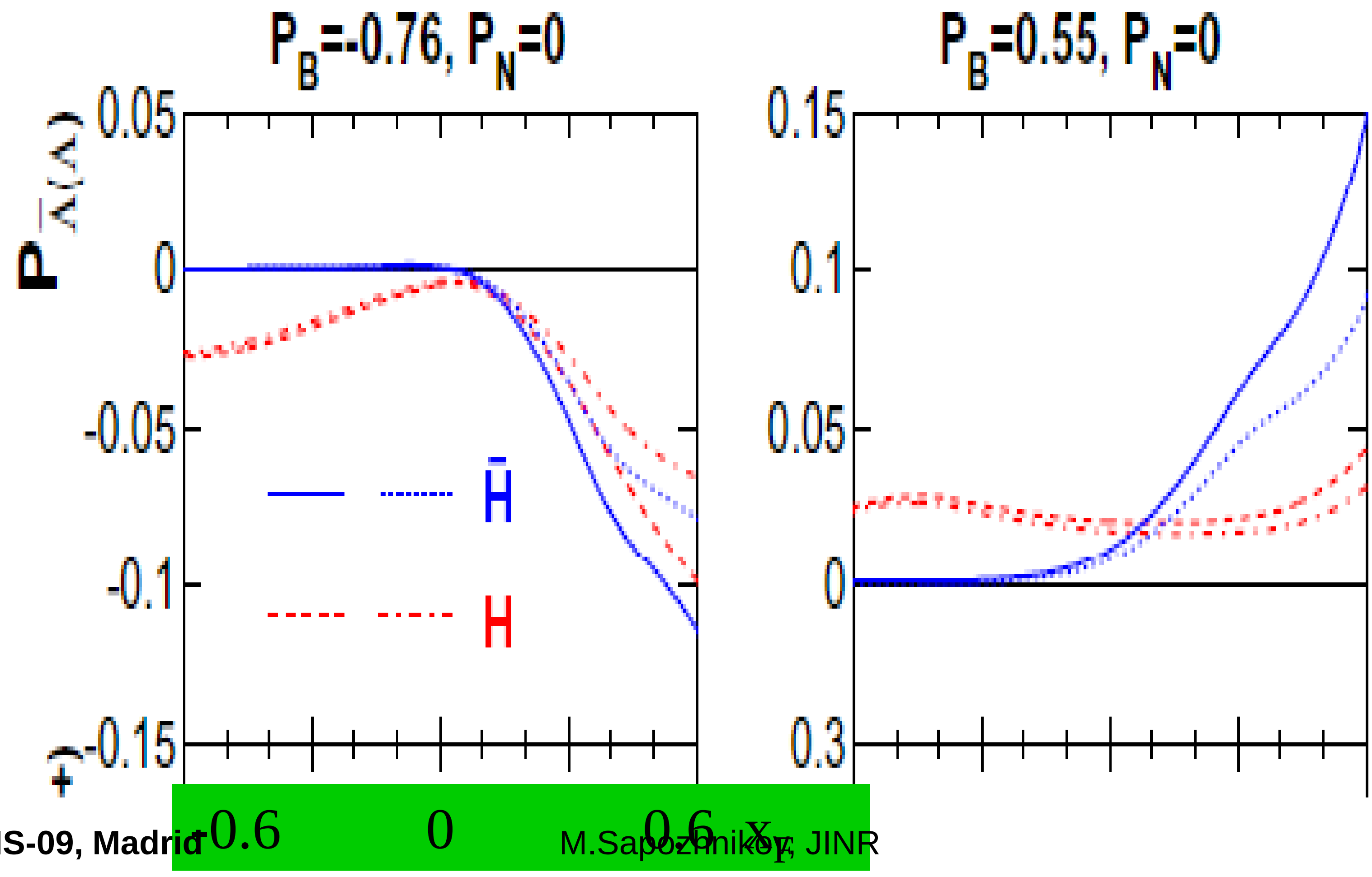


D. de Florian, M.Stratmann, W.Vogelsang, PRD 57(1998)5811

1- SU(6)
2 – BJ
3 - $\Delta u_{\Lambda} = \Delta d_{\Lambda} = \Delta s_{\Lambda}$

Theory predictions for $\Lambda / \bar{\Lambda}$

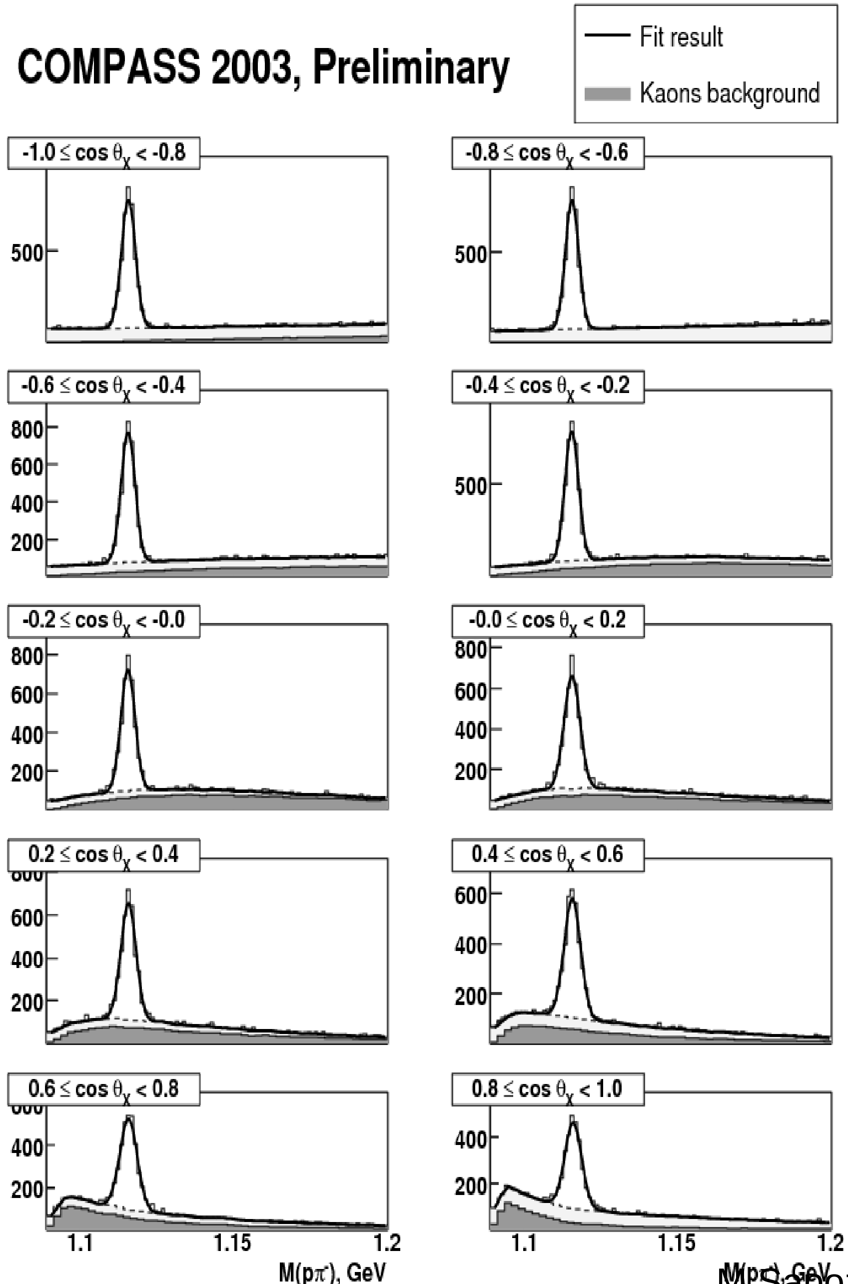
- Liang Zuo-tang et al. Phys.Rev.D72 (2005) 033006



Transverse polarization P_Y

First analysis on 2002 data, all Q^2

- 160,000 Λs and 85,000 $\overline{\Lambda}$s
- Small positive Λ polarization:
  $P_T^{\Lambda} = +2.7 \pm 0.9(\text{stat.}) \pm 1.1(\text{sys.})\ \%$
  - Sign opposite to Λ polarization in p and π^- beams
  - Same sign as in K^- beam
  - Much lower absolute value
- $\overline{\Lambda}$ unpolarized: $P_T^{\overline{\Lambda}} = -0.3 \pm 1.4(\text{stat.}) \pm 1.8(\text{sys.})\ \%$



- θ - between virtual photon and p in Λ c.m.s.

- Kaon background is important at large cosθ
- cut

  $-1 < \cos\theta < 0.6$