# Transverse $\Lambda$ and $\overline{\Lambda}$ polarization at COMPASS

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on behalf of the COMPASS collaboration

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# Outline

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1. Introduction
2. Spontaneous $\Lambda$ and $\overline{\Lambda}$ polarization
   - Method of extraction of polarization
   - Results
3. $\Lambda$ and $\overline{\Lambda}$ polarization from a transversely polarized target
   - Definition of Polarization axis
   - Kinematics and available statistics
   - Results

# Why Lambdas?

Self-analyzing weak decay: $\Lambda \rightarrow p\,\pi^-$, B.R. $\simeq$ 64%

The $\Lambda$ polarization $P_S^\Lambda$ along a certain direction $\overrightarrow{\mathbf{S}}$ is measured from the angular distribution of the decay proton:

$$W(\theta^*) \propto 1 + \alpha P_S^\Lambda \cos(\theta^*),$$

where $\theta^*$ is the proton emission angle wrt. $\overrightarrow{\mathbf{S}}$ in the $\Lambda$ rest frame

In general, the proton angular distribution is distorted by the non-ideal experimental acceptance:

$$W_{exp}(\theta^*) \propto (1 + \alpha P_S^\Lambda \cos(\theta^*)) \cdot Acc(\theta^*)$$

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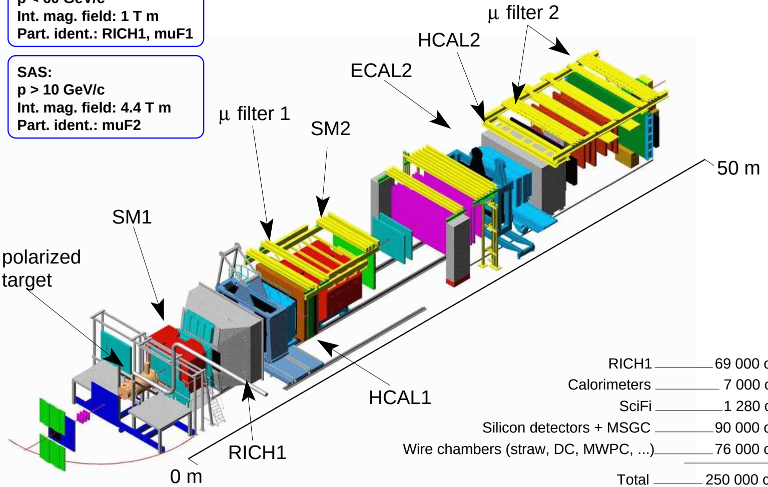
# The COMPASS Experimental Setup (2004 Layout)

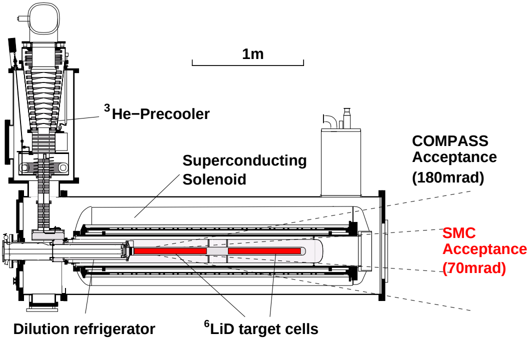
**LAS:**
**p < 60 GeV/c**
**Int. mag. field: 1 T m**
**Part. ident.: RICH1, muF1**

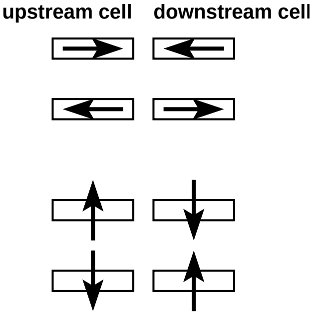
**SAS:**
**p > 10 GeV/c**
**Int. mag. field: 4.4 T m**
**Part. ident.: muF2**




| | |
|---|---|
| RICH1 | 69 000 channels |
| Calorimeters | 7 000 channels |
| SciFi | 1 280 channels |
| Silicon detectors + MSGC | 90 000 channels |
| Wire chambers (straw, DC, MWPC, ...) | 76 000 channels |
| Total | 250 000 channels |

# The Polarized Target




60 cm long $^6$LiD target cells, $< P_N > \sim \pm 50\%$, dilution factor $f \sim 0.4$

The equivalent of an unpolarized target is obtained by adding data from opposite polarization configurations and both cells

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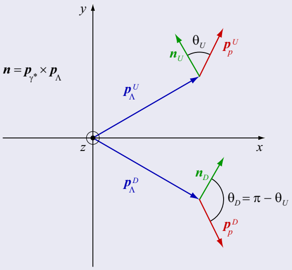
# Method of extraction of polarization

Quasi-real photoproduction, unpolarized beam and target
Polarization axis is choosen along $\overrightarrow{n} = \overrightarrow{p_{\gamma^*}} \times \overrightarrow{p_\Lambda}$

The distortion due to the apparatus acceptance is corrected using the up/down symmetry of the apparatus




G. Ohlsen and P. W. Keaton. Techniques for measurement of spin-$\frac{1}{2}$ and spin-1 polarization analyzing tensors. *Nucl. Inst. Meth.* **109**, 41 (1973)

$$\epsilon_n(\theta^*) = \frac{\sqrt{U_+D_+} - \sqrt{U_-D_-}}{\sqrt{U_+D_+} + \sqrt{U_-D_-}} = \alpha P_n \cos\theta^*$$

$U$: Lambda pointing upwards
$D$: Lambda pointing downwards

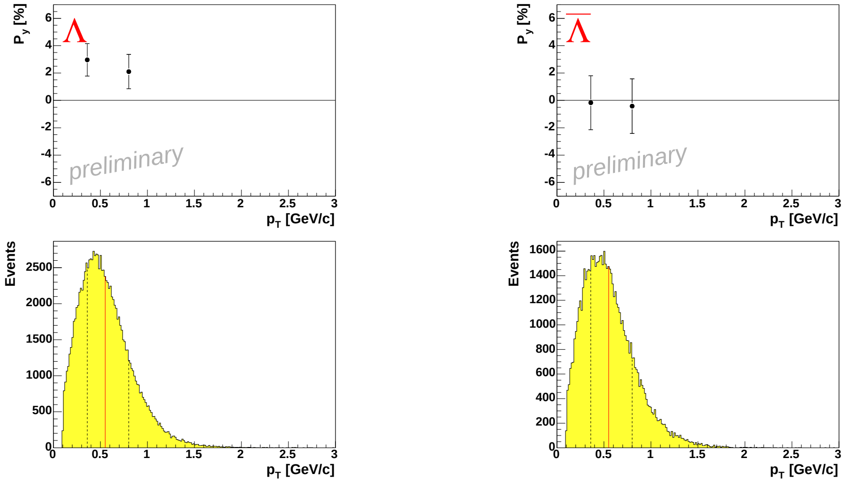
$$U_\pm = \frac{N_0^U}{2} A_U(\pm\cos\theta^*)(1 \pm \alpha P_n \cos\theta^*)$$
$$D_\pm = \frac{N_0^D}{2} A_D(\pm\cos\theta^*)(1 \pm \alpha P_n \cos\theta^*)$$

with the assumption

$$A_U(\cos\theta^*) = A_D(\cos(\pi - \theta^*)).$$

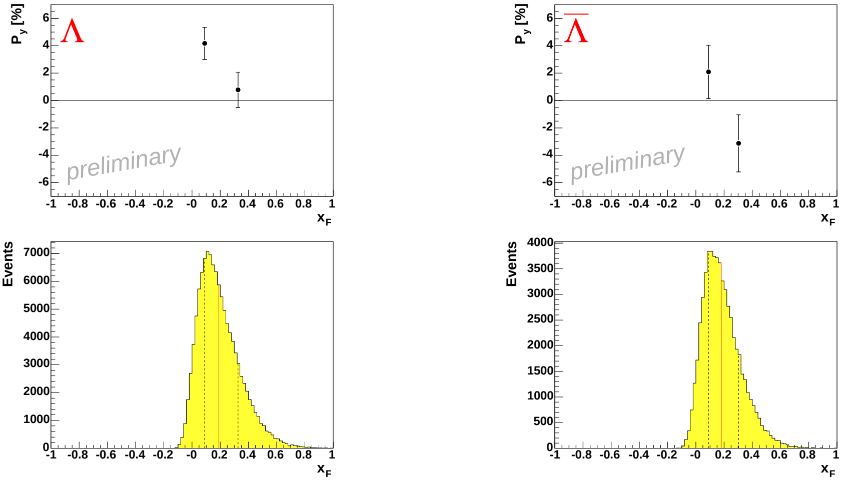
# Dependence of Λ and $\bar{\Lambda}$ polarization over $p_T$

COMPASS 2002 data - only statistcal errors shown



# Dependence of Λ and $\overline{\Lambda}$ polarization over $x_F$

COMPASS 2002 data - only statistcal errors shown



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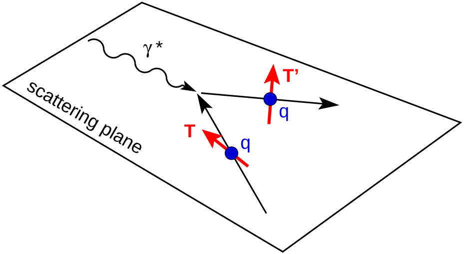
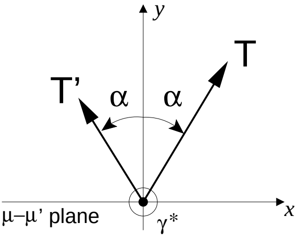
# Transversity & $\Lambda$ polarization




**T**: component of target spin perpendicular to $p_{\gamma^*}$

**T'**: symmetric of **T** wrt. the normal to the scattering plane, scaled by the spin trasfer coefficient $D(y) = \dfrac{2(1-y)}{1+(1-y)^2}$

If $q$ fragments into a Lambda hyperon, then the measurement of $P_T^{\Lambda}$ gives information about the initial quark polarization in the nucleon

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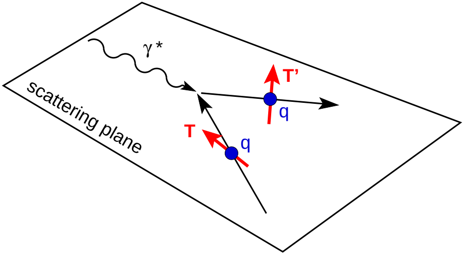


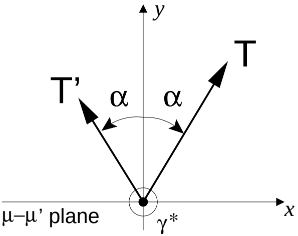


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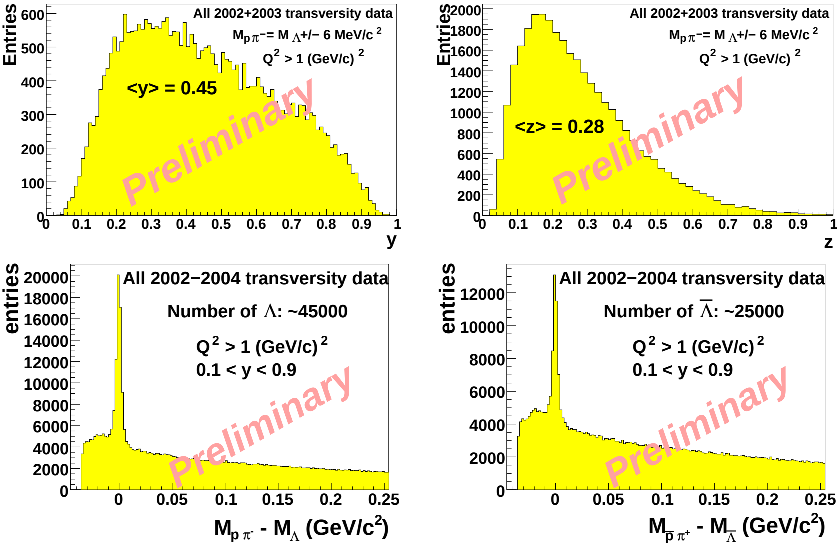
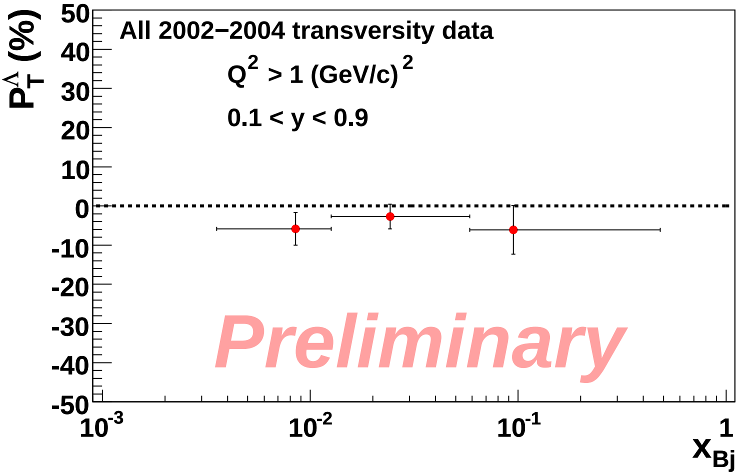
# Kinematics and available statistics

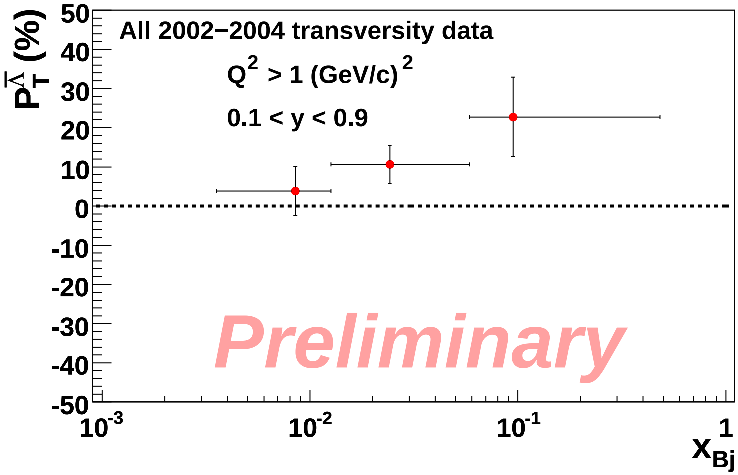


# Λ Polarization vs. $x$ - $Q^2 > 1$




Only statistical errors are shown. Sytematic effects have been estimated not to be larger than statistical errors.

# $\bar{\Lambda}$ Polarization vs. $x$ - $Q^2 > 1$

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# Conclusions

- Transverse $\Lambda$ and $\overline{\Lambda}$ polarization is being studied by COMPASS, using data from both unpolarized and transversely polarized targets.
- There is evidence of positive $\Lambda$ transverse polarization in unpolarized scattering, while $\overline{\Lambda}$ polarization is compatible with zero.
- No clear $p_T$ dependence of such polarization is observed in the presented data. More significant indications are expected to come from the analysis of the full 2002-2004 data sets.
- The correlation between $\Lambda$ and $\overline{\Lambda}$ polarization and the transverse target polarization was also studied as a function of $x$.
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# Literature on $P_T^\Lambda$ measurement

- An early proposal for this measurement can be found in Baldracchini *et al.*, Fortsch. Phys. 30 (1981) 505
- Also discussed in Artru and Mekhfi, Nucl. Phys. **A532** (1991) 351c, and by Artru in the proceedings of the SPIN-93 conference, LYCEN-93-53, without giving estimates of the expected Lambda polarization
- An estimate of $P_T^\Lambda \simeq 5\% - 6\%$ at $x_{Bj} \simeq 0.2$ is given in Kunne *et al.*, LNS-Ph-93-01, assuming a target polarization of 80% and $f = 1$
- A more recent proposal by M. Anselmino can be found in the proceedings of the "Future Physics at COMPASS" workshop
- A large uncertainty on the expected $P_T^\Lambda$ value comes from the almost unknown properties of the fragmentation functions $\Delta_T D_{\Lambda/q}(z)$

# Extraction of the polarization

Acceptance correction with "geometrical mean" method:

$$\epsilon_T(\theta_i^*) = \frac{\left[\sqrt{N_1^+(\theta_i^*)\cdot N_2^+(\theta_i^*)}+\sqrt{N_1^-(\pi-\theta_i^*)\cdot N_2^-(\pi-\theta_i^*)}\right]-\left[\sqrt{N_1^+(\pi-\theta_i^*)\cdot N_2^+(\pi-\theta_i^*)}+\sqrt{N_1^-(\theta_i^*)\cdot N_2^-(\theta_i^*)}\right]}{\left[\sqrt{N_1^+(\theta_i^*)\cdot N_2^+(\theta_i^*)}+\sqrt{N_1^-(\pi-\theta_i^*)\cdot N_2^-(\pi-\theta_i^*)}\right]+\left[\sqrt{N_1^+(\pi-\theta_i^*)\cdot N_2^+(\pi-\theta_i^*)}+\sqrt{N_1^-(\theta_i^*)\cdot N_2^-(\theta_i^*)}\right]} =$$

$$= \alpha P_T^\Lambda \cos\theta_i^*, \quad (= \alpha P_T^\Lambda/2 \text{ if only 2 angular bins are used})$$

where $N^\pm_{1(2)}(\theta_i^*) = \Phi^\pm_{1(2)} \left(\frac{d\sigma}{d\Omega}\right)^0 (1 \pm \alpha P_T^\Lambda \cos\theta_i^*) \cdot Acc^\pm_{1(2)}(\cos\theta_i^*)$

The only assumptions in the derivation are:

$$P_T^{(1)} = P_T^{(2)}$$

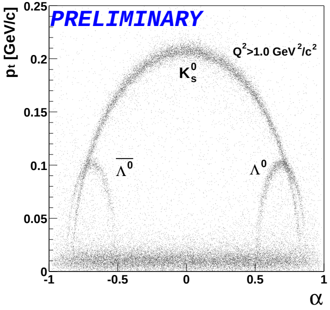
$$Acc_1^+(\theta_T^*) = Acc_2^-(\theta_T^*), \qquad Acc_1^+(\pi-\theta_T^*) = Acc_2^-(\pi-\theta_T^*)$$

$$Acc_1^-(\theta_T^*) = Acc_2^+(\theta_T^*), \qquad Acc_1^-(\pi-\theta_T^*) = Acc_2^+(\pi-\theta_T^*)$$

No up/down symmetry required!!!

# Selection cuts

- Primary vertex in target cell material,
  beam crossing both cells
- $\mu'$ traverses at least 30 radiation lengths
- Tracks of $p$ and $\pi^-$ candidates traverse at least the SM1 magnet
- momentum of both decay particles $> 1$ GeV/c




- The candidate $\Lambda$ decay is downstream of the target and outside of it

- collinearity $< 10$ mrad
- $0.1 < y < 0.9$
- Armenteros $p_T > 23$ MeV/c

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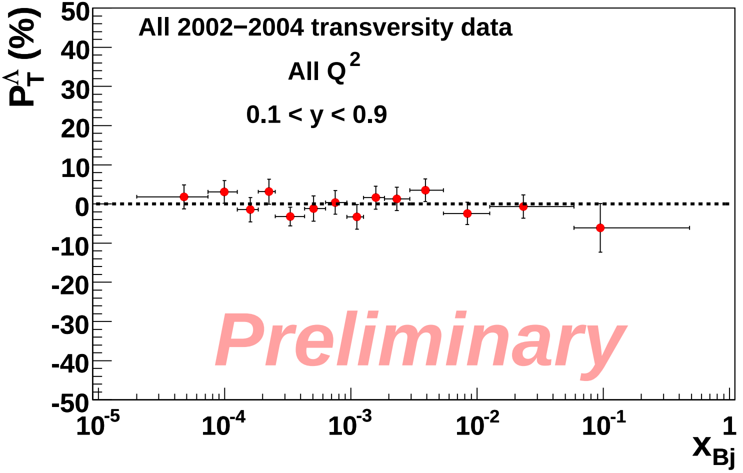


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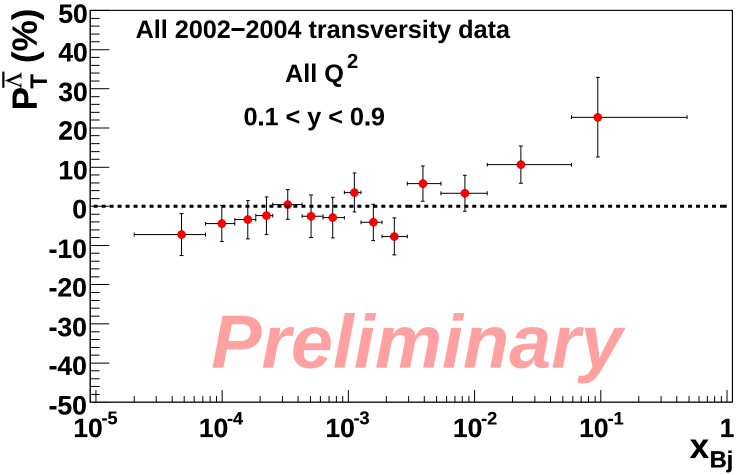
# $\overline{\Lambda}$ Polarization vs. $x$ - all $Q^2$

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