Transverse Λ and $\overline{\Lambda}$ polarization with a transversely polarized proton target

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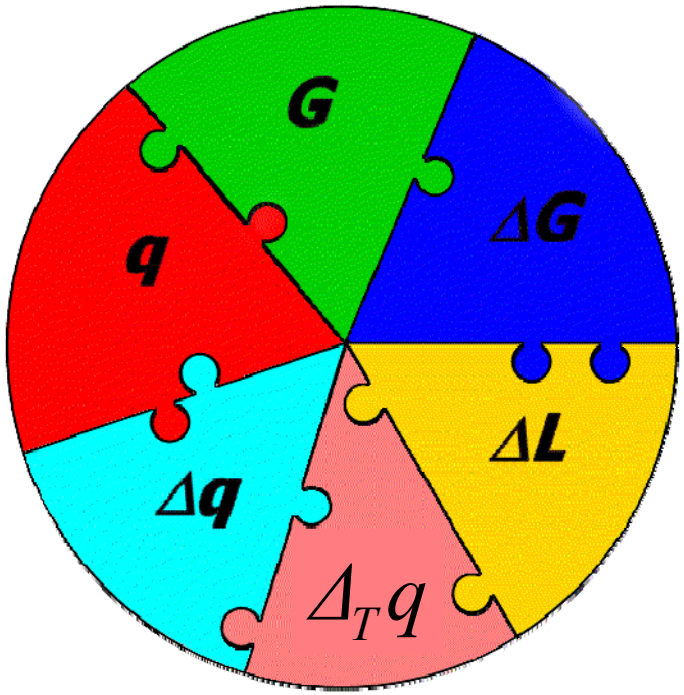
- Introduction
- COMPASS experiment
- Transversity from transverse Λ & $\overline{\Lambda}$ polarization
- Conclusion & outlook

bmb+f - Förderschwerpunkt COMPASS Großgeräte der physikalischen Grundlagenforschung

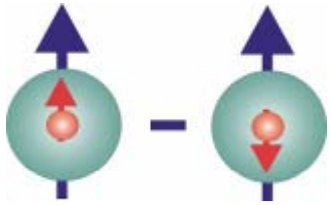
DPG spring meeting
20.März 2009, Bochum

Spin of nucleon



The spin puzzle of nucleon is going to be completed ...

Transversity distributions are also need to completely describe the spin structure of the nucleon.



$$\Delta_T q = q^{\uparrow\uparrow} - q^{\uparrow\downarrow}$$

Measurement of transversity in SIDIS

Semi-Inclusive Deep Inelastic Scattering (SIDIS) :

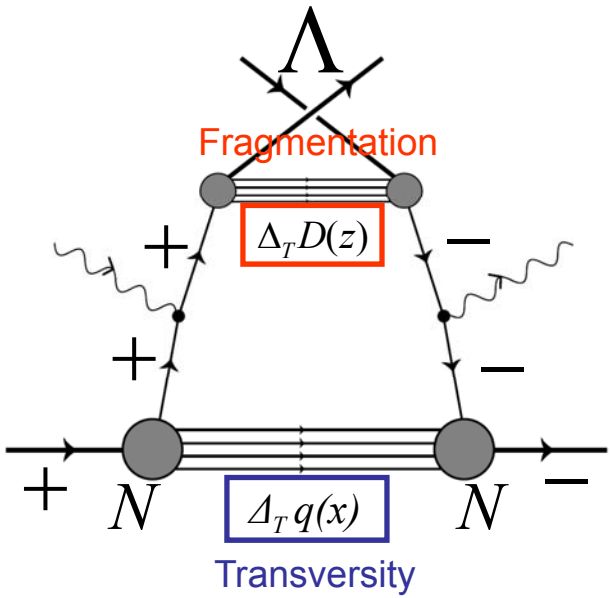
To measure chiral-odd $\Delta_T q$, requires another chiral-odd partner : polarized fragmentation function $\Delta_T D$

Accessible by production of

- $lN^{\Uparrow} \to l' hX$: Collins function
- $lN^{\Uparrow} \to l' h_1 h_2 X$: Interference fragmentation function
- $lN^{\Uparrow} \to l' \Lambda^{\Uparrow} X$: Λ production

Transversity $\Delta_T q(x)$ can be measured in SIDIS on a transversely polarized target via "Λ polarization"

Transverse Λ polarization



$$\mu N^{\Uparrow} \rightarrow \mu' \Lambda^{\Uparrow} X$$ @ DIS ($Q^2 > 1$ (GeV/c)^2)

Factorizations of $\Delta_T q(x)$ and $\Delta_T D(z)$ by their different parameters :

$$x_{Bj} = \frac{Q^2}{2M\nu}, \quad z = \frac{E_\Lambda}{E_\mu - E_{\mu'}}$$

Transverse Λ polarization from transversely polarized target

$$P_\Lambda = \frac{d\sigma^{lN^{\Uparrow}\rightarrow l'\Lambda^{\Uparrow}X} - d\sigma^{lN^{\Uparrow}\rightarrow l'\Lambda^{\Downarrow}X}}{d\sigma^{lN^{\Uparrow}\rightarrow l'\Lambda^{\Uparrow}X} + d\sigma^{lN^{\Uparrow}\rightarrow l'\Lambda^{\Downarrow}X}} = f\, P_T D_T(y) \frac{\sum_q e_q^2 \Delta_T q(x) \Delta_T D_q^\Lambda(z)}{\sum_q e_q^2 q(x) D_q^\Lambda(z)}$$

$\Delta_T q(x)$ = transversely polarized quark distribution
$q(x)$ = unpolarized quark distribution function
$\Delta_T D_q(z)$ = transversely polarized fragmentation
$D_q(z)$ = unpolarized fragmentation function

P_T = Target polarization
f = Dilution Factor
Depolarization factor :

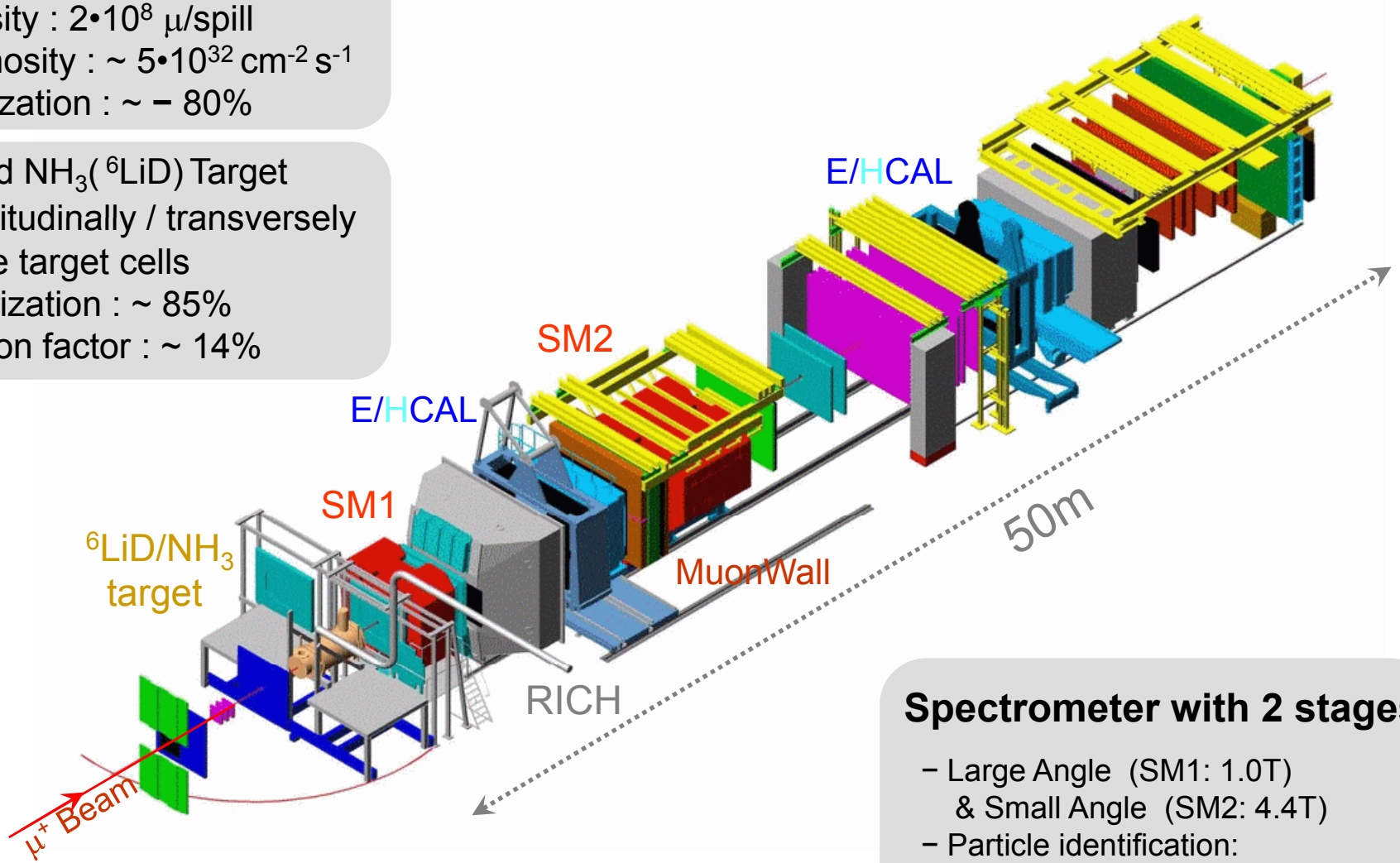
$$D_T(y) = \frac{2(1-y)}{1+(1-y)^2}$$

COMPASS spectrometer

Polarized μ^+ beam
- Energy : 160 GeV
- Intensity : $2 \cdot 10^8$ μ/spill
- Luminosity : ~ $5 \cdot 10^{32}$ cm^{-2} s^{-1}
- Polarization : ~ − 80%

Polarized NH_3(^{6}LiD) Target
- Longitudinally / transversely
- Three target cells
- Polarization : ~ 85%
- Dilution factor : ~ 14%

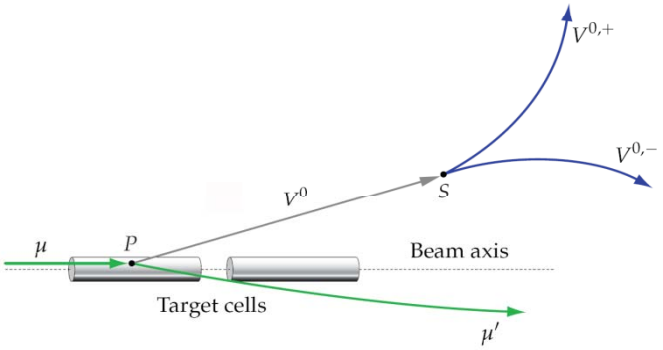
Common Muon and Proton Apparatus for Structure and Spectroscopy



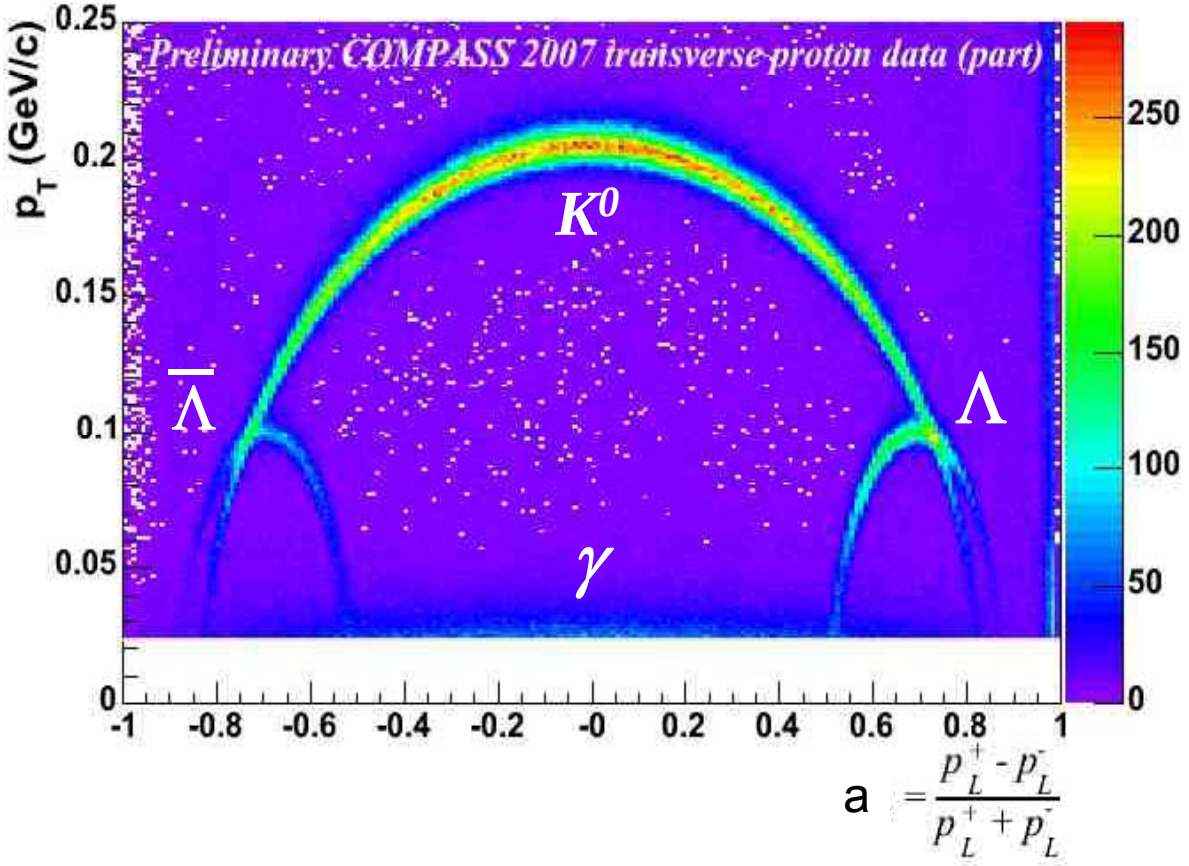
Spectrometer with 2 stages
- Large Angle (SM1: 1.0T) & Small Angle (SM2: 4.4T)
- Particle identification: RICH , μF, ECAL, HCAL

Identification of $\Lambda \to p\pi^-$, $\bar{\Lambda} \to \bar{p}\pi^+$, $K^0 \to \pi^+\pi^-$

Data Analysis in 2007



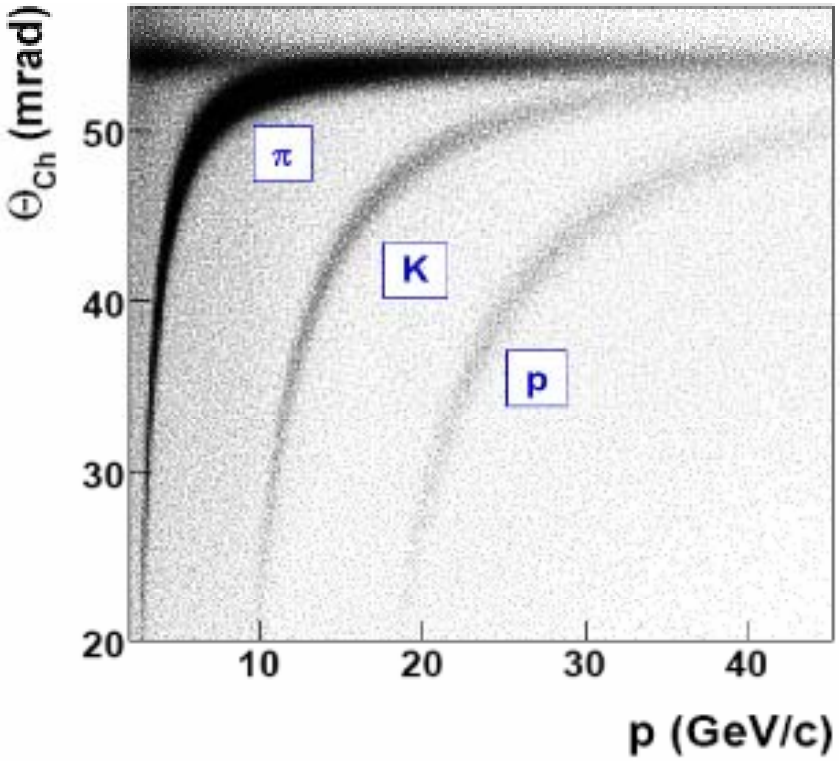
- 50% of time dedicated to transversity runs
- $Q^2 > 1$ (GeV/c)^2
- $0.1 < y < 0.9$
- $P_T > 23$ MeV/c to exclude e^+e^- pair-production
- Application of RICH



a : Asymmetry of longitudinal momentum component between + and – track

Λ selection using RICH

PID : RICH



Threshold momenta:

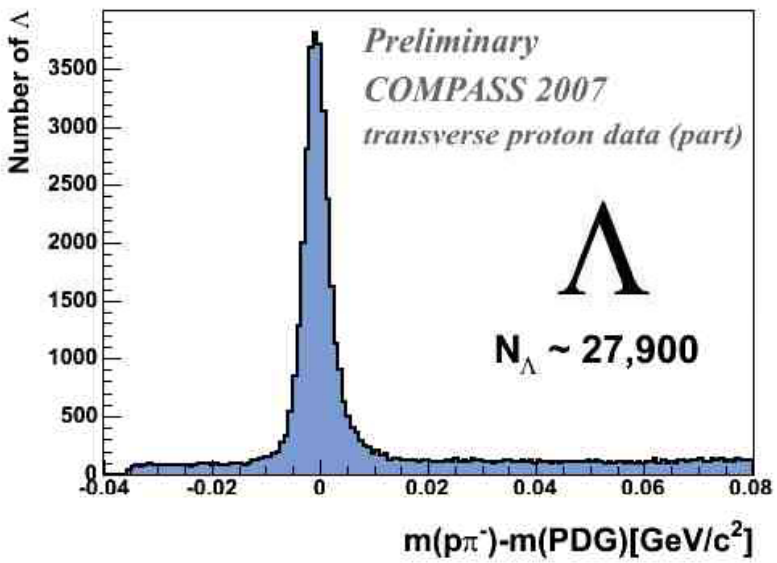
p_π ~ 2 GeV/c

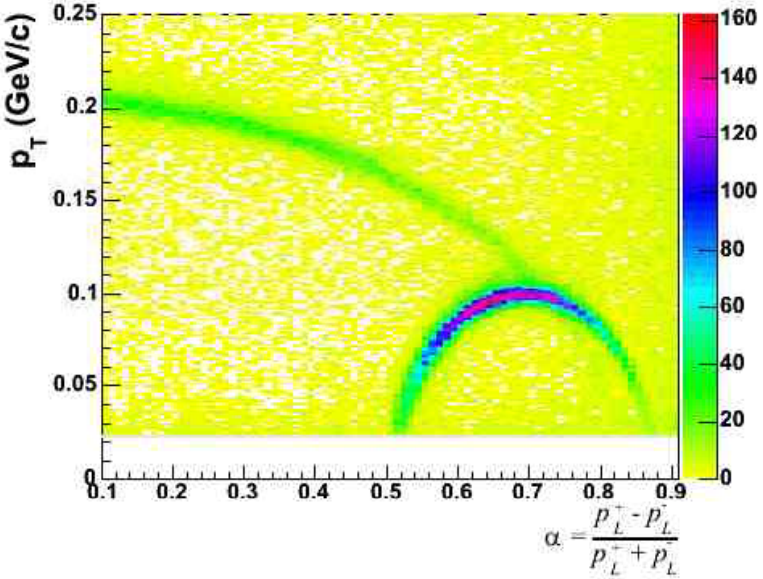
p_K ~ 9 GeV/c

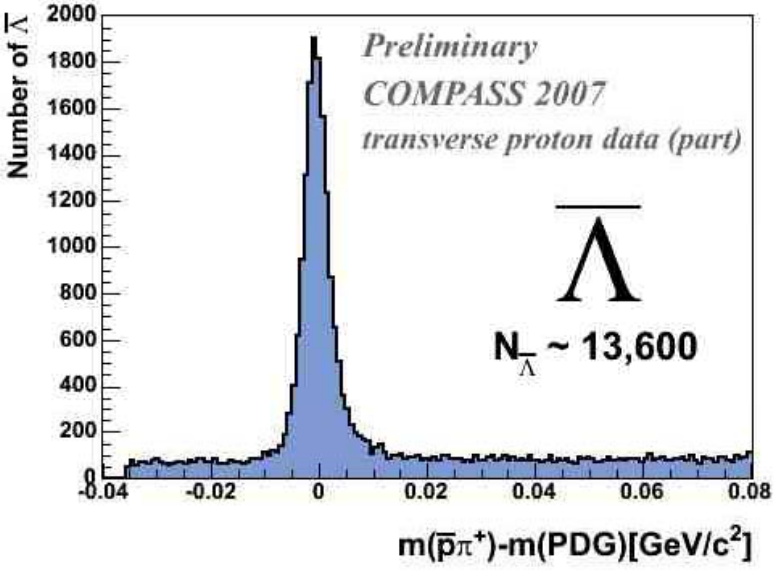
p_P ~ 17 GeV/c

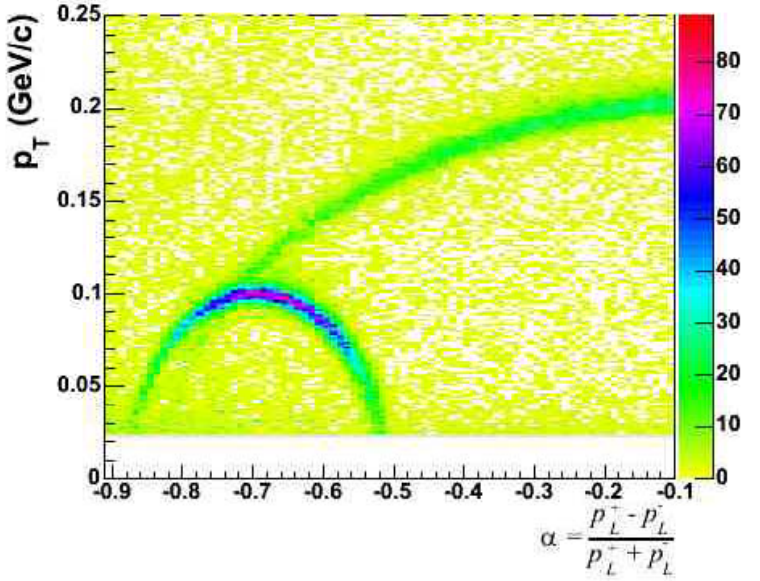
- Hadron masses calculated from the measured chêrenkov angle θ_{ch}
- Separation between π, K and p in the momentum range 2~50 GeV/c
- π^+, K^+(π^-, K^-) veto for proton (anti-proton) candidate
- Likelihood methods are used to reject π and K for proton candidate in the decay of $\Lambda \to p\pi^-$ and $\overline{\Lambda} \to \bar{p}\pi^+$

Invariant mass of Λ and $\bar{\Lambda}$

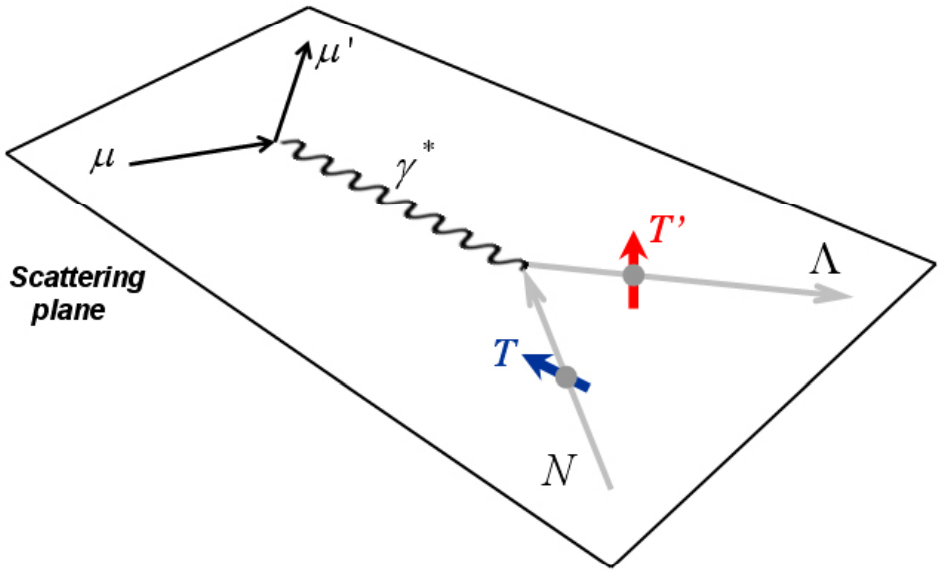


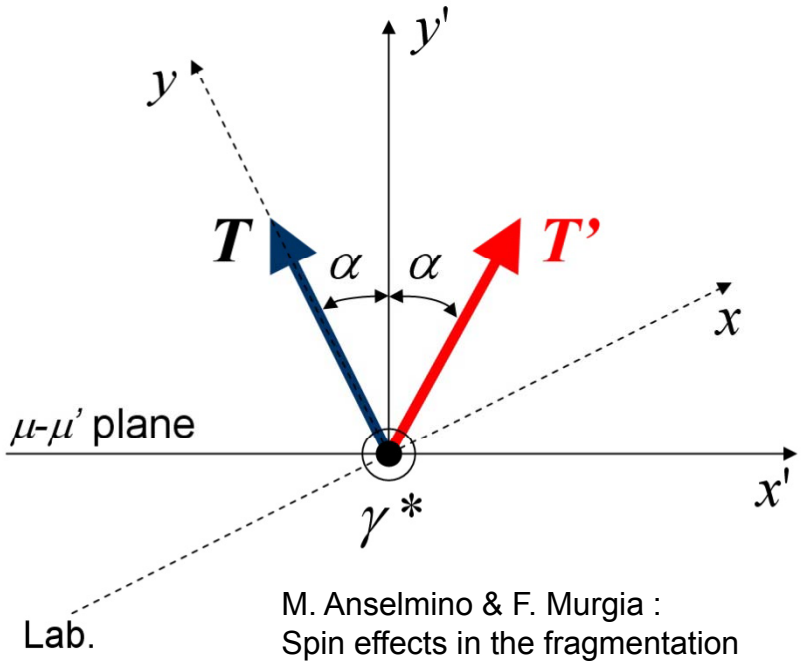






Coordinate system





M. Anselmino & F. Murgia :
Spin effects in the fragmentation
of a transversely polarized quark,
Physics Letters B 483 (2000) 74-86

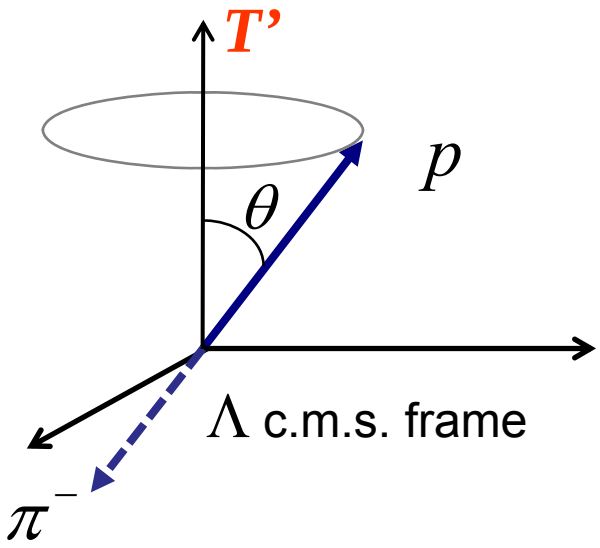
T (initial quark spin) : component of target spin perpendicular to γ*

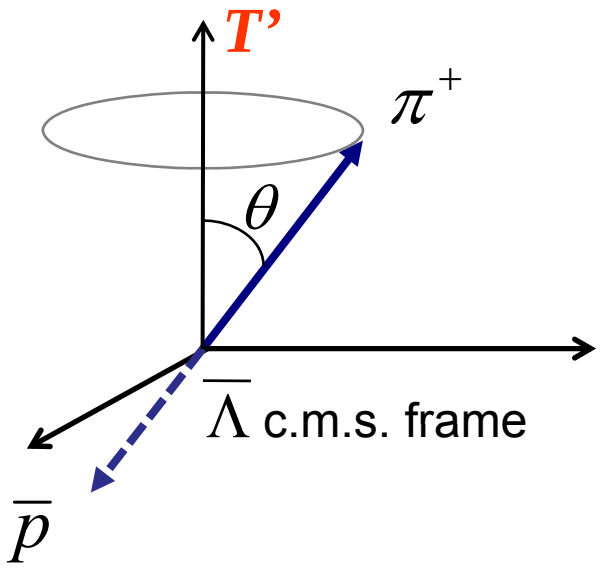
T' (final quark spin) : symmetric of the ***T*** w.r.t. the normal to the scattering plane

Quantization axis along *T'* → measurement of angular distribution w.r.t. *T'*

Angular distribution

Angular distribution of decay product :





- Decay violates parity → not isotropic

$$N(\theta) \propto (1 + \alpha\, P_T^{\Lambda} \cos\theta) \cdot Acc(\theta)$$

- Slope of the daughter baryon cosθ distribution is given by

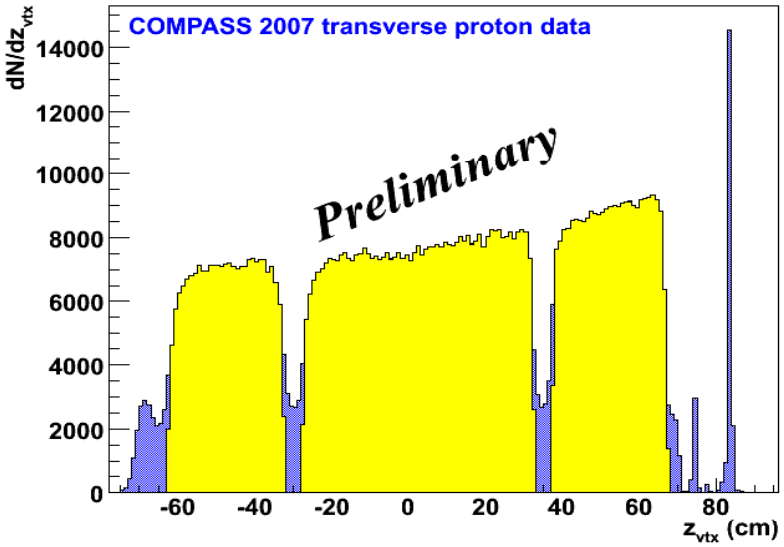
$$\alpha\, P_{\Lambda}^{T}$$

- Magnitude of asymmetry parameters are same for Λ and $\bar{\Lambda}$

$$\alpha = \pm 0.642 \pm 0.013$$

- Acceptance effect to be corrected

Bias cancellation



Three target cells with weekly reversal target polarizaiton :

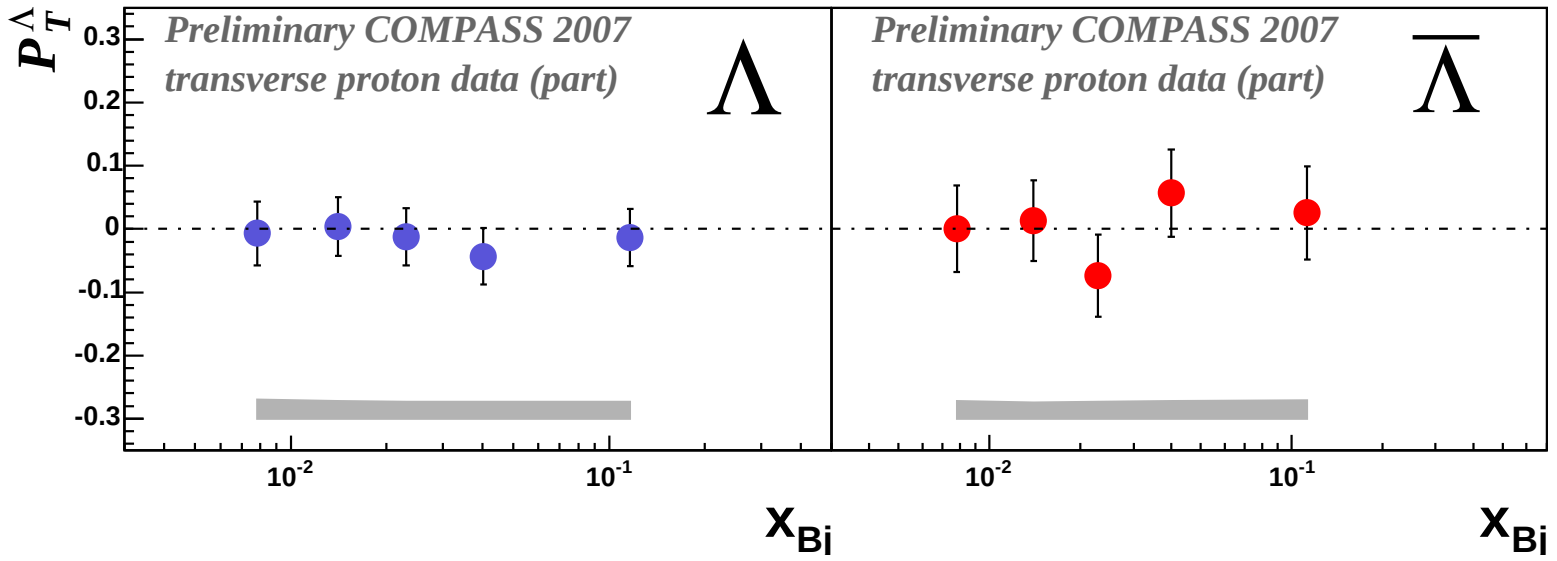
Period 1.

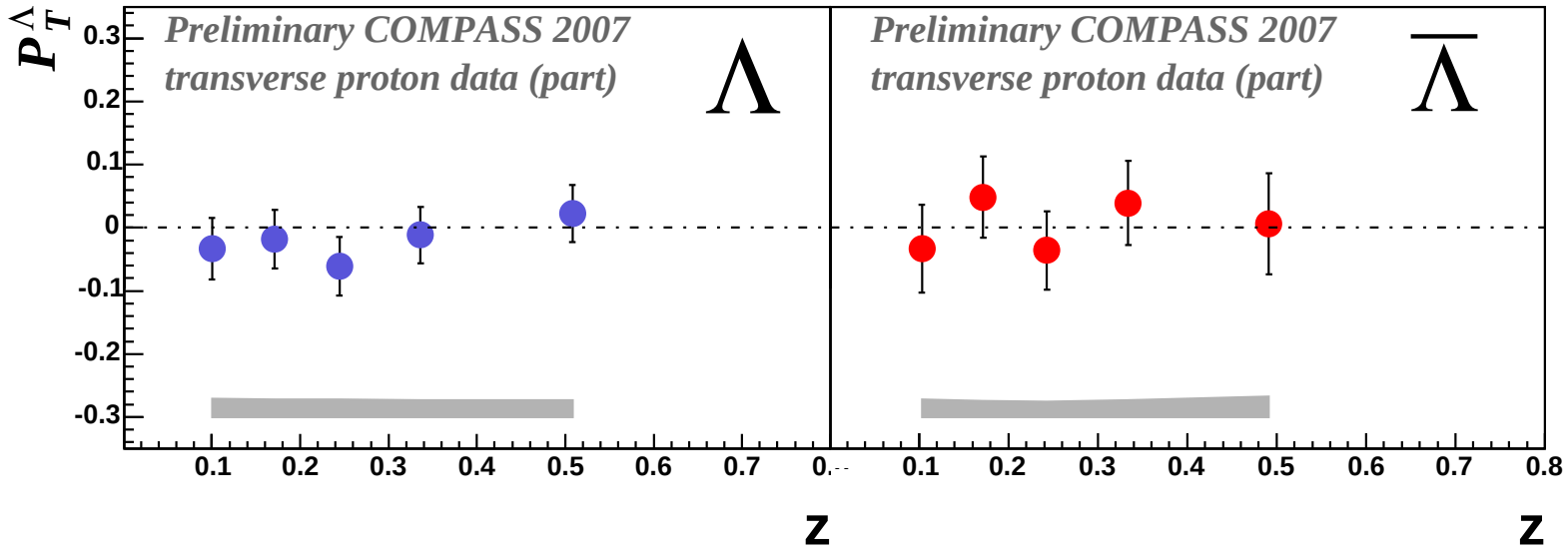
Period 2.

- Acceptance correction from data using up-down symmetry of angular distribution
- Recombination of data samples with the assumption of $Acc^{\uparrow}_{1(2)}(\theta) = Acc^{\downarrow}_{2(1)}(\theta)$
- "Geometrical mean" grants independence from acceptance effects :

$$\frac{[\sqrt{N_1^{\uparrow}(\theta)N_2^{\uparrow}(\theta)}+\sqrt{N_1^{\downarrow}(\pi-\theta)N_2^{\downarrow}(\pi-\theta)}]-[\sqrt{N_1^{\uparrow}(\pi-\theta)N_2^{\uparrow}(\pi-\theta)}+\sqrt{N_1^{\downarrow}(\theta)N_2^{\downarrow}(\theta)}]}{[\sqrt{N_1^{\uparrow}(\theta)N_2^{\uparrow}(\theta)}+\sqrt{N_1^{\downarrow}(\pi-\theta)N_2^{\downarrow}(\pi-\theta)}]+[\sqrt{N_1^{\uparrow}(\pi-\theta)N_2^{\uparrow}(\pi-\theta)}+\sqrt{N_1^{\downarrow}(\theta)N_2^{\downarrow}(\theta)}]} = \alpha\, P_T^{\Lambda} \cos\theta$$

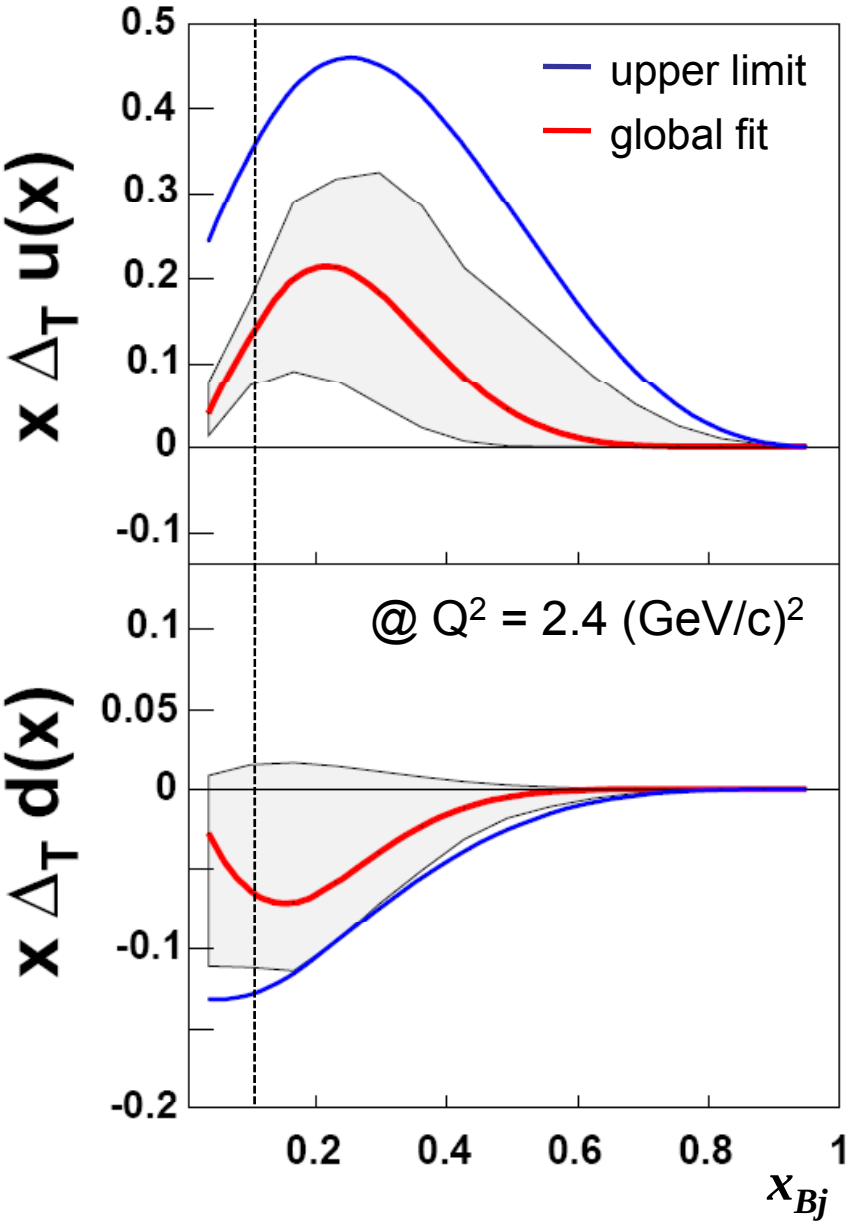
Transverse Λ & $\bar{\Lambda}$ polarization





Systematic errors have been estimated to be smaller than statistical errors

Interpretation of results



Anselmino et al: Phys. Rev. D 75, 054032 (2007)

- HERMES / COMPASS / BELLE combined results for collins asymmetry
- For proton target a positive $\Delta_T q(x)$ is expected :

$$2 \cdot \Delta_T u(x) + 1 \cdot \Delta_T d(x) > 0$$

- $\Delta_T D(z)$ seems to be very small in $0 < z < 0.5$:

  nearly no analyzing power

- Need extended kinematic :

  $x_{Bj} > 0.1$ and $z_\Lambda > 0.5$

Conclusions and Outlook

- Transverse Λ & $\overline{\Lambda}$ polarization with transversely polarized target have been studied to bring an information of transversity in the DIS region at COMPASS
  - Transverse Λ & $\overline{\Lambda}$ polarization are compatible with 0
- Λ & $\overline{\Lambda}$ have no clear x_{Bj} and z dependence of polarization with proton target
  - $\Delta_T q(x) \cdot \Delta_T D_q^{\Lambda}(z)$ is small

Very soon : Analysis of the whole 2007 proton data sample will allow to reduce considerably the statistical error

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