Transverse Λ & $\overline{\Lambda}$ polarization with a transversely polarized target in COMPASS

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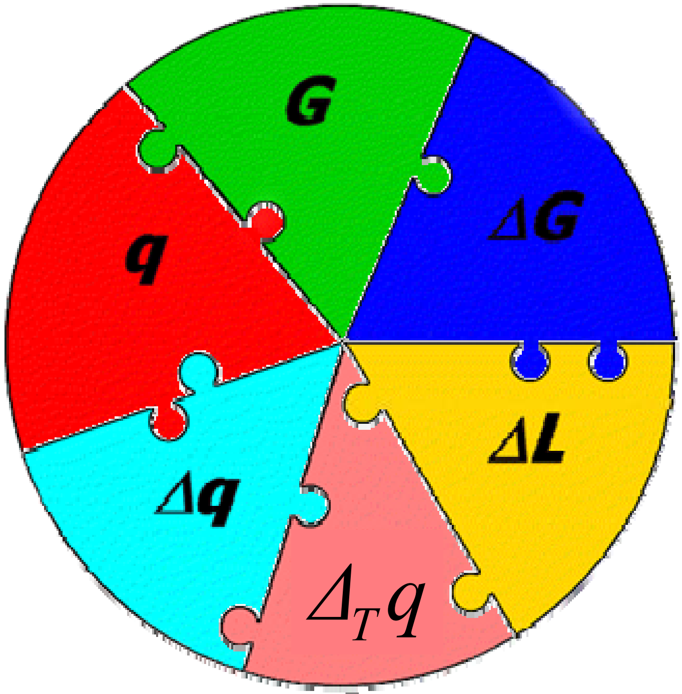
on behalf of the COMPASS collaboration

- Motivation
- Transverse Λ polarization
- Results of transverse Λ & $\overline{\Lambda}$ polarization
- Conclusion

Spin of nucleon



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

$$< s_z >= \frac{1}{2}\hbar = \frac{1}{2}\Delta\Sigma + L_q + \Delta G + L_g$$

$$\Delta u + \Delta d + \Delta s = 0.35 \pm 0.06$$

$$\Delta u_V + \Delta d_V = 0.41 \pm 0.08$$

$$\Delta \bar{u} + \Delta \bar{d} + \Delta \bar{s} = -0.08 \pm 0.06$$

$$\Delta G = 0.2 \sim 0.3$$

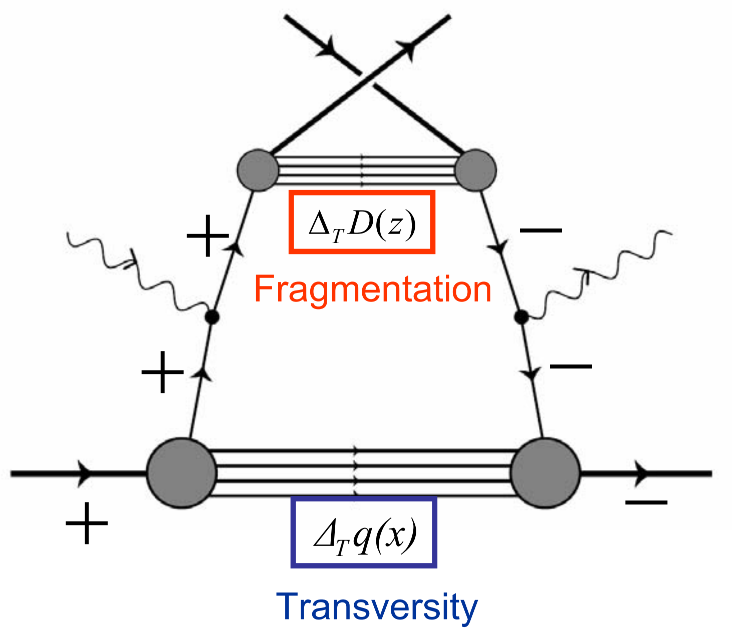
NMC,SMC,SLAC,HERMES,COMPASS…

still unknown

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

Measurement of transversity in SIDIS

SIDIS @ $Q^2 > 1$ (GeV/c^2)



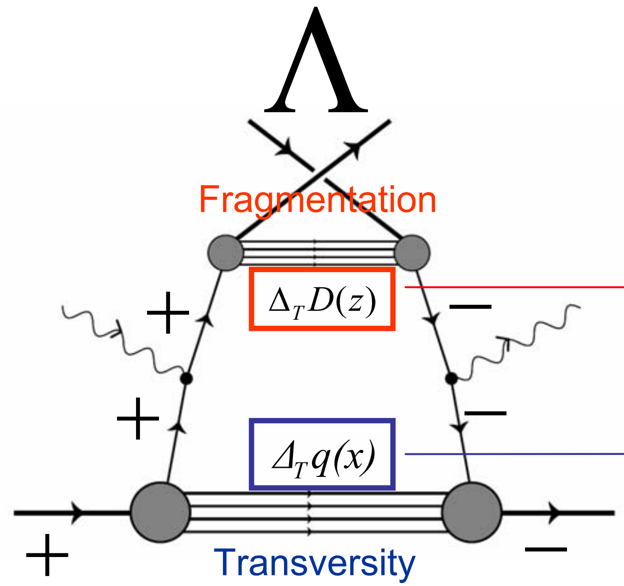
To measure chiral odd $\Delta_T q(x)$, requires another chiral-odd partner

Accessible by production of

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

Transversity can be measured in SIDIS on a transversely polarized target via “quark polarimetry Λ”

Transverse Λ polarization



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

Differentiate between factorization terms $\Delta_T D(z)$ and $\Delta_T q(x)$ by their different parameters?

Transverse Λ polarization in a transversely polarized target

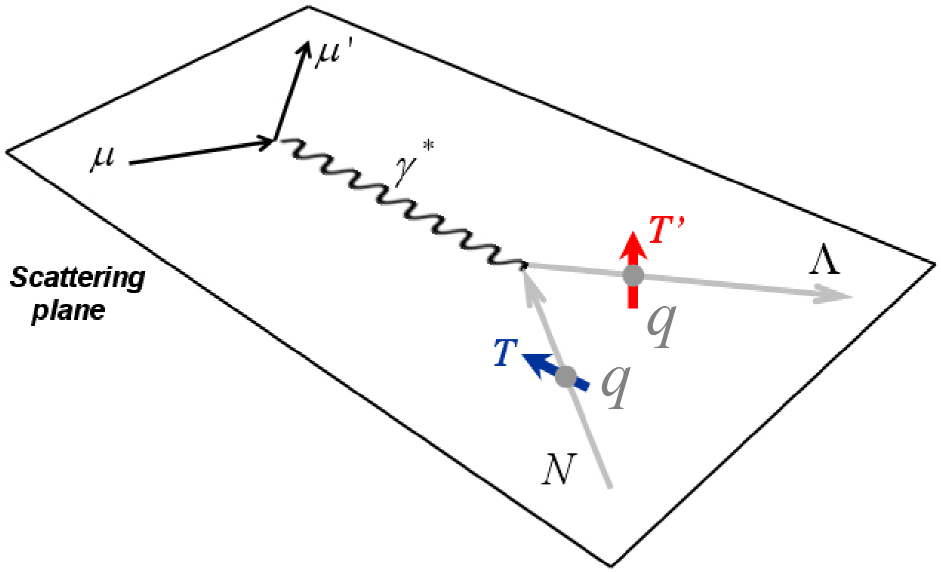
$$P_T^{\Lambda} = \frac{d\sigma^{lN^{\Uparrow} \rightarrow l'\Lambda^{\Uparrow} X} - d\sigma^{lN^{\Uparrow} \rightarrow l'\Lambda^{\Downarrow} X}}{d\sigma^{lN^{\Uparrow} \rightarrow l'\Lambda^{\Uparrow} X} + d\sigma^{lN^{\Uparrow} \rightarrow l'\Lambda^{\Downarrow} X}} = f\, P_T \frac{2(1-y)}{1+(1-y)^2} \frac{\sum_q e_q^2 \Delta_T q(x) \Delta_T D_q^{\Lambda}(z)}{\sum_q e_q^2 q(x) D_q^{\Lambda}(z)}$$

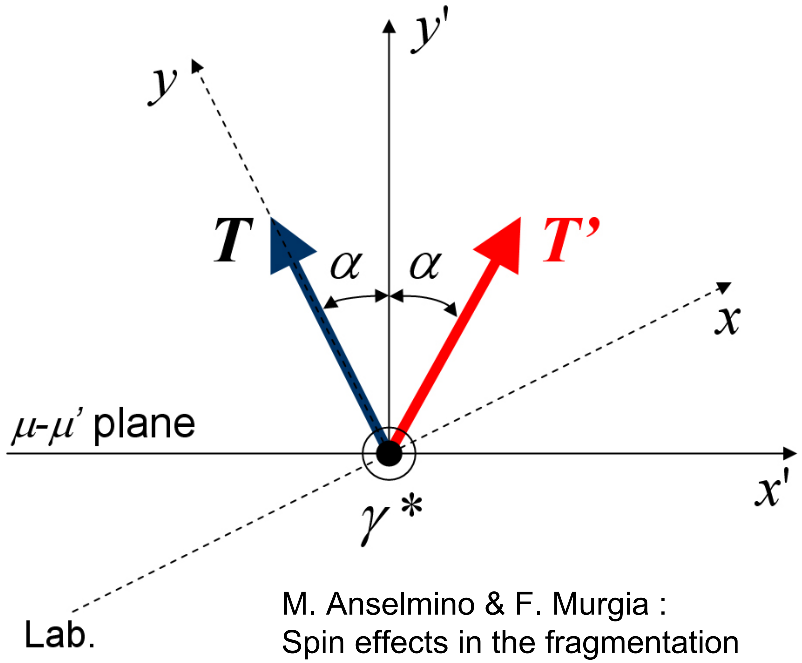
$\Delta_T q(x)$ = transversely polarized quark distribution
$q(x)$ = unpolarized quark distribution function
$\Delta_T D_q(z)$ = transversely polarized fragmentation
$D_q(z)$ = unpolarized fragmentation function

P_T = Target polarization
f = Dilution Factor
$D(y)$ = Depolarization factor

Coordinate system

Spin quantization axis for the measurement of transverse Λ polarization





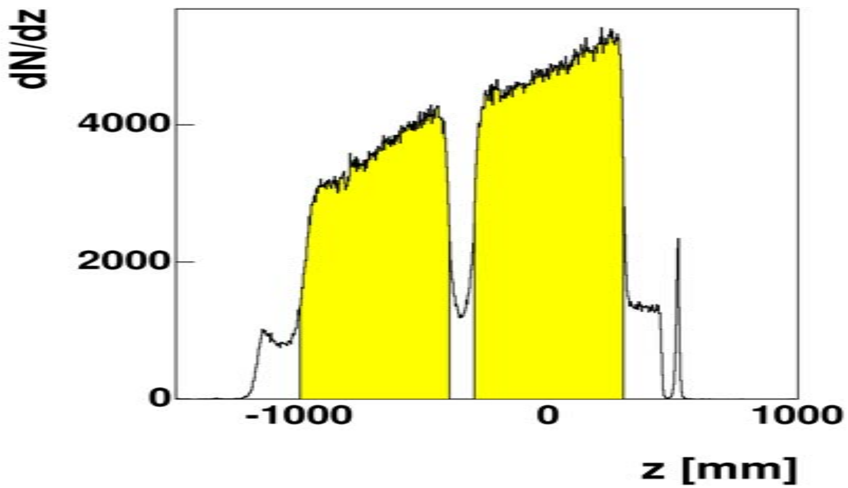
M. Anselmino & F. Murgia :
Spin effects in the fragmentation
of a transversely polarized quark,
Physics Letters B 483 (2000) 74-86

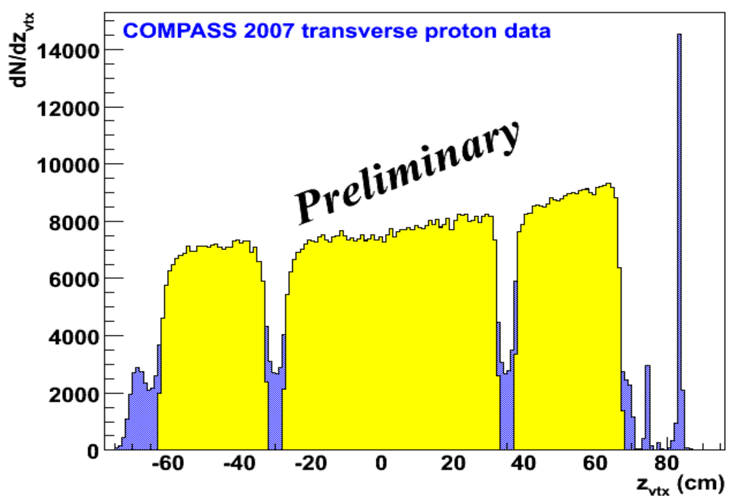
$\boldsymbol{T}$: component of target spin perpendicular to γ^* (y-axis)
$\boldsymbol{T'}$: symmetric of the $\boldsymbol{T}$ w.r.t. the normal to the scattering plane (y'-axis)

If q fragments into a Λ hyperon, then the measurement of P^{Λ} wrt. $\boldsymbol{T'}$ gives information about the initial quark polarization in the nucleon.

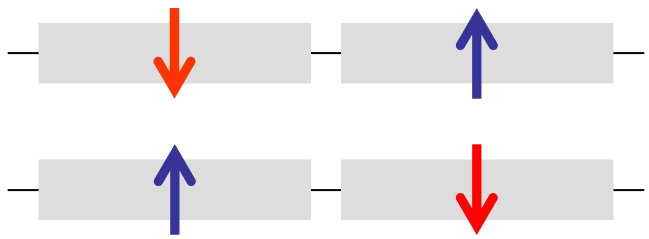
Polarized Target

In transversity-Mode: weekly reversal of polarization → period 1 and 2

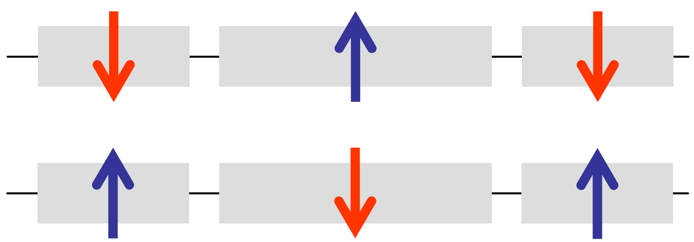




2002-2004 deuteron target ^{6}LiD :
Two 60 cm long target cells
with opposite polarizations

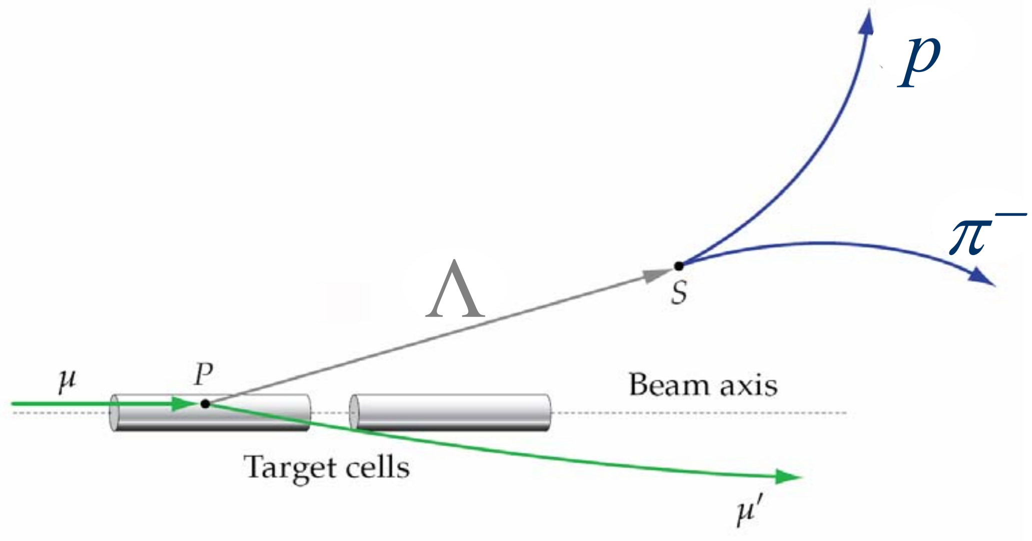


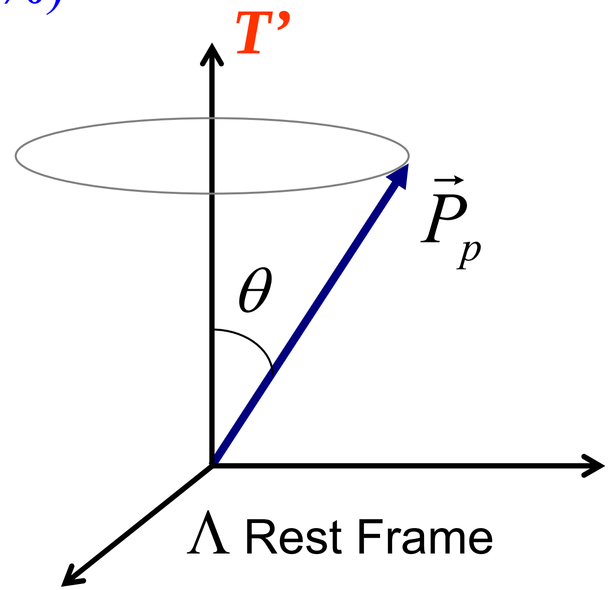
2007 proton target NH_3 :
Three target cells to reduce
possible false asymmetries



What is the Λ polarization?

Self-analyzing weak decay : $\Lambda \rightarrow p\pi^{-}$ (BR ≈ 64%)





Λ polarization P^{Λ} with respect to spin analyzer T' reveal itself in the angular distribution of decay proton :

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

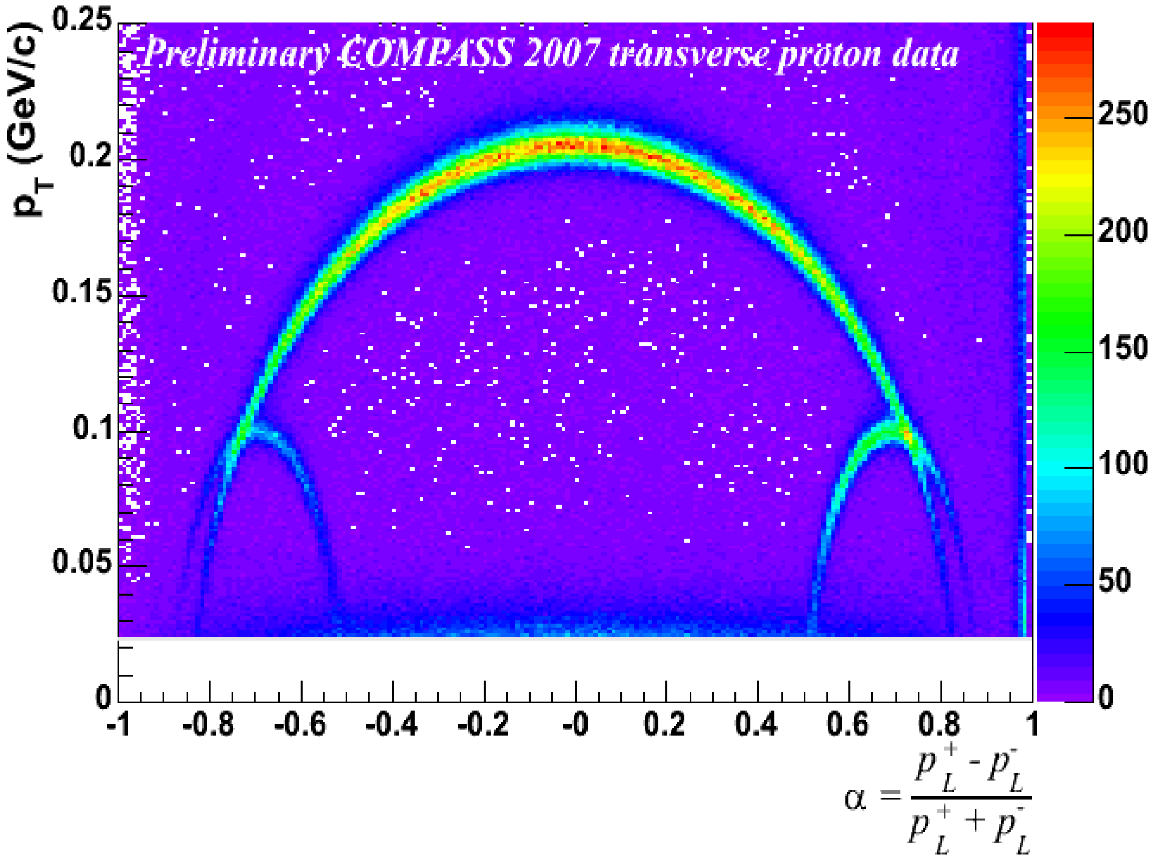
θ : angle of proton decay w.r.t ***T’*** in Λ rest frame
α = ± 0.643 (asymmetry parameter of Λ and $\bar{\Lambda}$)

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

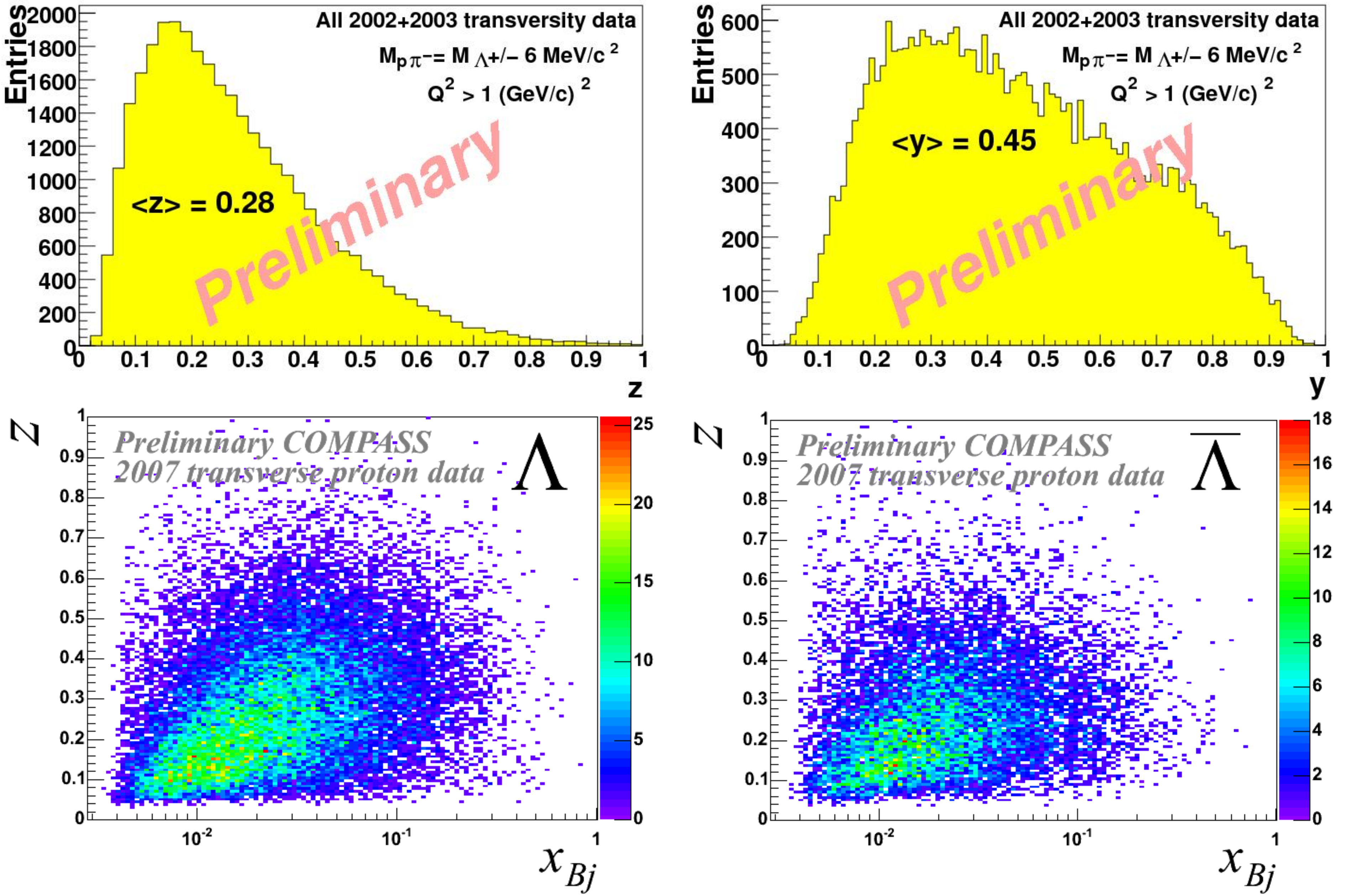
Data Selection

- Deuteron target in 2002-2004
  Proton target in 2007
- V^0 vertex must be downstream of primary vertex.
- P_T > 23 MeV/c to exclude e^+e^- pair-production
- P_{decay} > 1 GeV/c for proton and pion
- Collinearity angle θ_{col} < 10 mrad
- Q^2 > 1 $(GeV/c)^2$ (DIS event)
- $0.1 < y < 0.9$
- Application of RICH in 2007

Armenteros

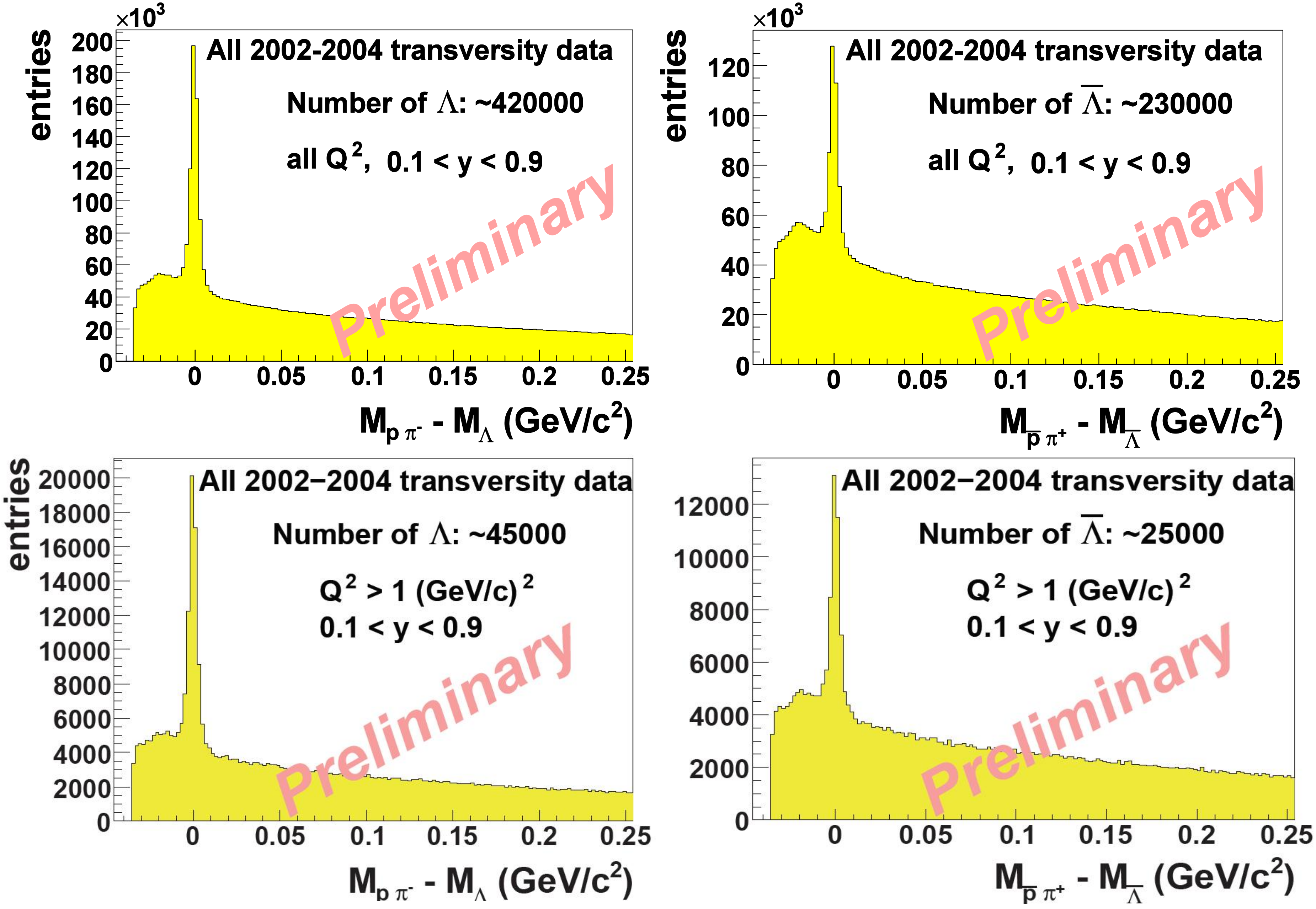


Kinematics

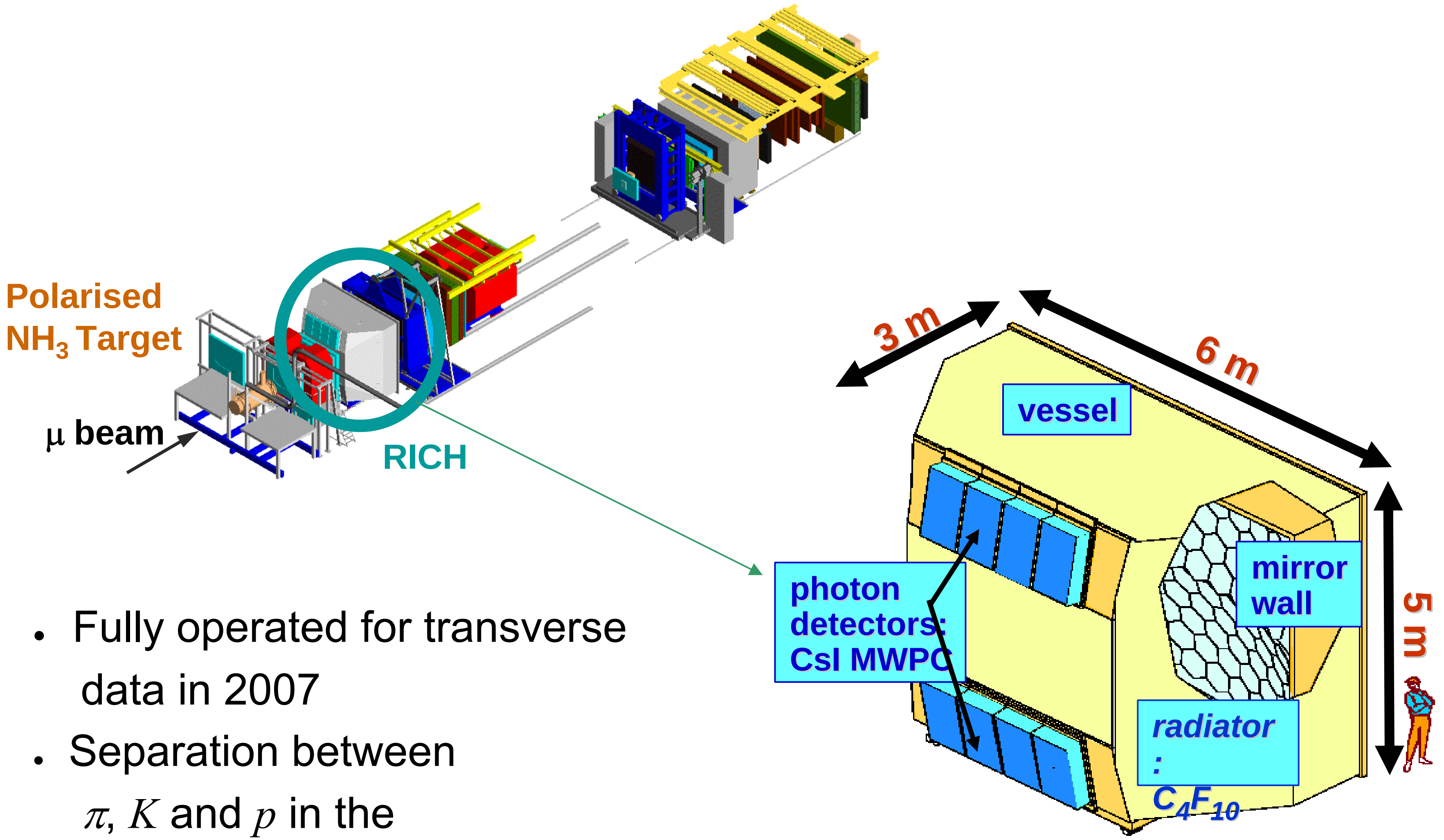


All 2002+2003 transversity data
$M_{p\pi^-} = M_\Lambda \pm 6$ MeV/c^2
$Q^2 > 1$ (GeV/c)^2
<z> = 0.28
Preliminary
Entries
z
<y> = 0.45
y
Preliminary COMPASS
2007 transverse proton data
Λ
$\bar{\Lambda}$
x_{Bj}

Invariant mass of Λ & $\bar{\Lambda}$ in 2002-2004

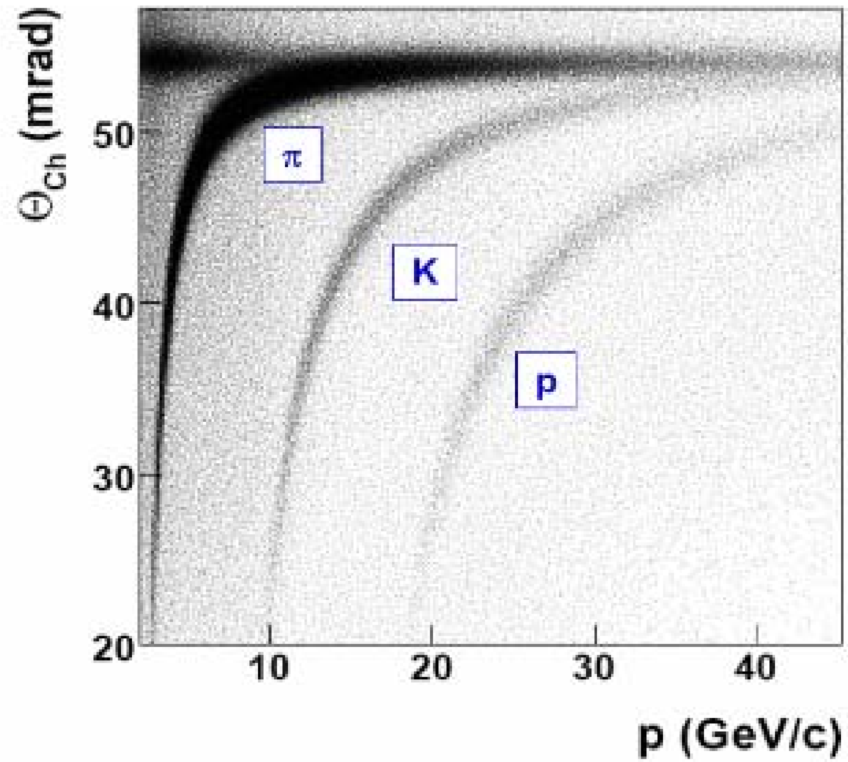


Λ selection using RICH in 2007



- Fully operated for transverse data in 2007
- Separation between π, K and p in the momentum range 3-50 GeV/c

Λ selection using RICH in 2007



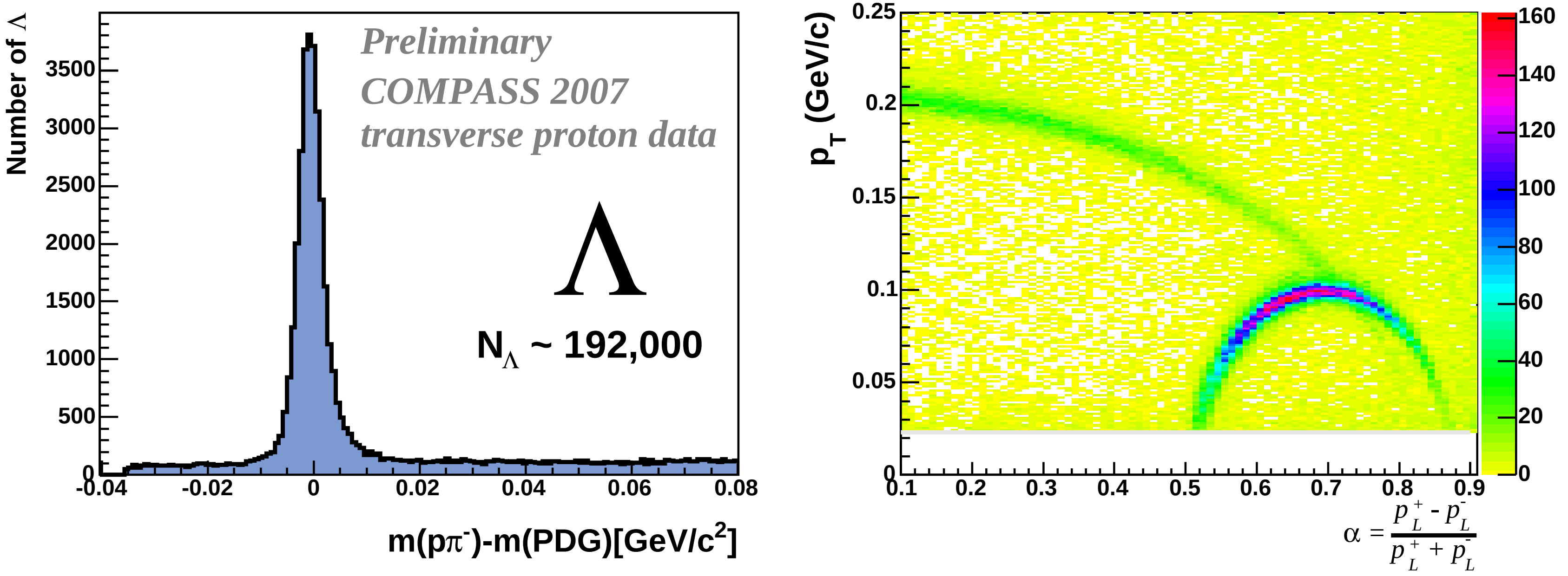
- Hadron masses calculated from the measured cherenkov angle θ_{ch}

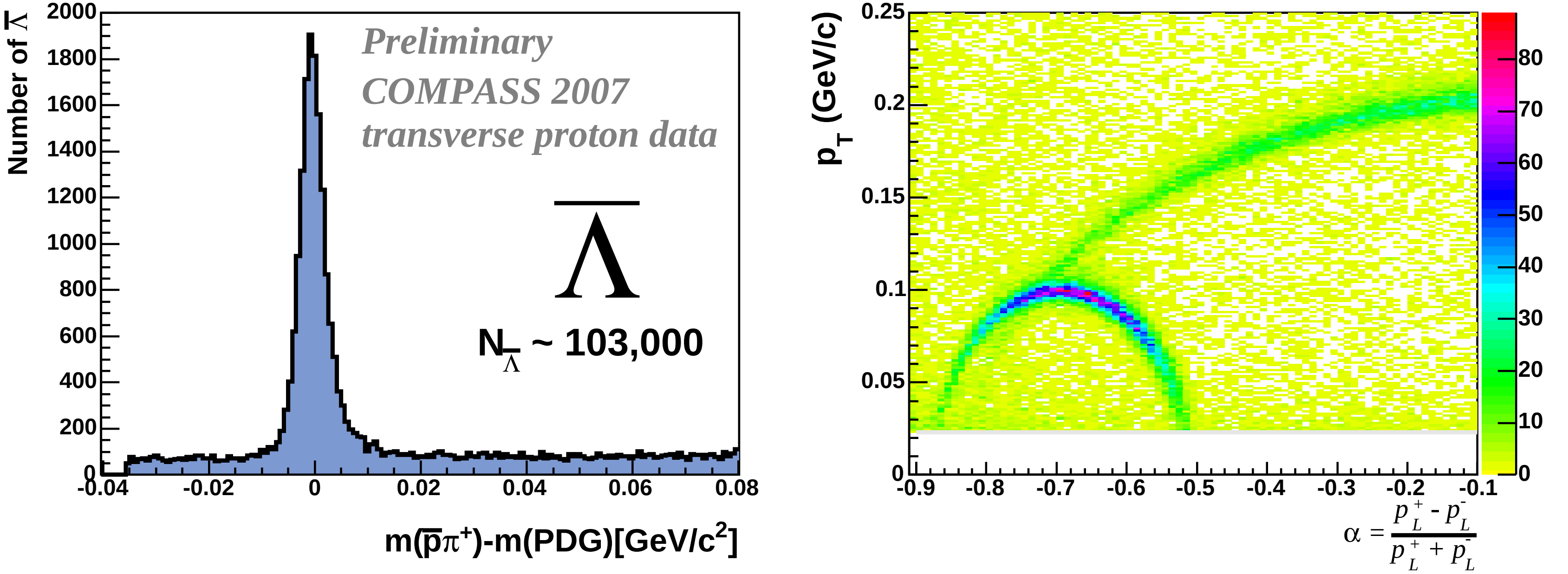
- Threshold momenta:

  P_{π} ~ 2 GeV/c
  p_K ~ 9 GeV/c
  p_P ~ 17 GeV/c

- Likelihood methods are used to reject pion and kaon for proton candidate in the decay of Λ ($\Lambda \to p\pi^-$) and $\overline{\Lambda}$ ($\overline{\Lambda} \to \overline{p}\pi^+$)

Invariant mass of Λ & $\bar{\Lambda}$ in 2007





Extraction of Λ polarization

Exploit symmetry

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

$$N_{\exp}(\theta) \propto \left[1 + \alpha\, P_T^{\Lambda} \cos(\theta)\right] \cdot Acc(\theta)$$

- Extract acceptance correction from data using up-down symmetry of angular distribution. Recombination of data samples from two (three) target cells and two target polarizations :

$$\frac{d\sigma^{lN^{\Uparrow}\to l'\Lambda^{\Uparrow}X} - d\sigma^{lN^{\Uparrow}\to l'\Lambda^{\Downarrow}X}}{d\sigma^{lN^{\Uparrow}\to l'\Lambda^{\Uparrow}X} + d\sigma^{lN^{\Uparrow}\to l'\Lambda^{\Downarrow}X}} \propto \frac{N^{lN^{\Uparrow}\to l'\Lambda^{\Uparrow}X} - N^{lN^{\Uparrow}\to l'\Lambda^{\Downarrow}X}}{N^{lN^{\Uparrow}\to l'\Lambda^{\Uparrow}X} + N^{lN^{\Uparrow}\to l'\Lambda^{\Downarrow}X}} \propto$$

$$\frac{[\sqrt{N_1^{\uparrow}(\theta)N_2^{\uparrow}(\theta)} + \sqrt{N_1^{\downarrow}(\pi-\theta)N_2^{\downarrow}(\pi-\theta)}] - [\sqrt{N_1^{\uparrow}(\pi-\theta)N_2^{\uparrow}(\pi-\theta)} + \sqrt{N_1^{\downarrow}(\theta)N_2^{\downarrow}(\theta)}]}{[\sqrt{N_1^{\uparrow}(\theta)N_2^{\uparrow}(\theta)} + \sqrt{N_1^{\downarrow}(\pi-\theta)N_2^{\downarrow}(\pi-\theta)}] + [\sqrt{N_1^{\uparrow}(\pi-\theta)N_2^{\uparrow}(\pi-\theta)} + \sqrt{N_1^{\downarrow}(\theta)N_2^{\downarrow}(\theta)}]}$$

where,

$\uparrow, \downarrow$: Target-spin orientations

$1,\ 2$: Periods of data taking

Extraction of Λ polarization

"Geometrical mean" method grants independence from acceptance effects with the assumption $Acc_{1(2)}^{\Uparrow}(\theta) = Acc_{2(1)}^{\Downarrow}(\theta)$

$$\varepsilon_T(\theta) = \frac{[\sqrt{N_1^{\uparrow}(\theta)N_2^{\uparrow}(\theta)} + \sqrt{N_1^{\downarrow}(\pi-\theta)N_2^{\downarrow}(\pi-\theta)}] - [\sqrt{N_1^{\uparrow}(\pi-\theta)N_2^{\uparrow}(\pi-\theta)} + \sqrt{N_1^{\downarrow}(\theta)N_2^{\downarrow}(\theta)}]}{[\sqrt{N_1^{\uparrow}(\theta)N_2^{\uparrow}(\theta)} + \sqrt{N_1^{\downarrow}(\pi-\theta)N_2^{\downarrow}(\pi-\theta)}] + [\sqrt{N_1^{\uparrow}(\pi-\theta)N_2^{\uparrow}(\pi-\theta)} + \sqrt{N_1^{\downarrow}(\theta)N_2^{\downarrow}(\theta)}]}$$

$$= \alpha\, P_T^{\Lambda} \cos\theta$$

If only two cosθ bins are used, P^{Λ} simplifies to

$$P_T^{\Lambda} = \frac{\varepsilon_T(\theta_i)}{\alpha\langle\cos\theta_i\rangle} \xrightarrow{i=2} P_T^{\Lambda} = \frac{\varepsilon_T(\theta)}{2\alpha}$$

for i = 1,…,n = number of cosθ-bins

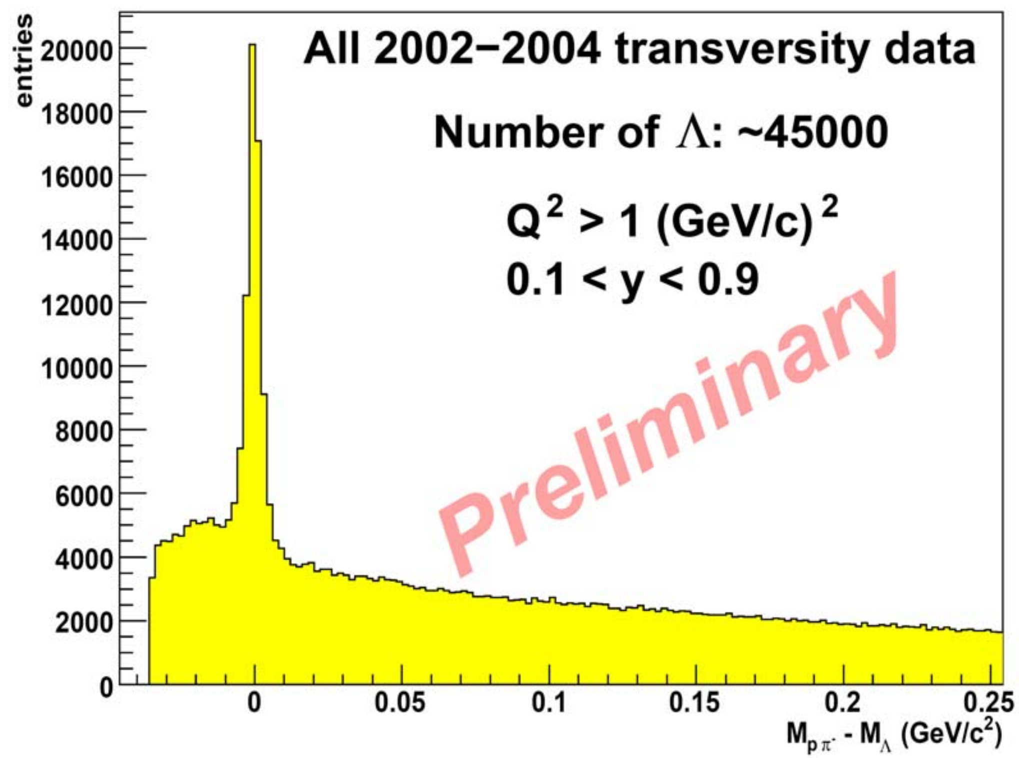
Extraction of Λ polarization

$$P_T^{\Lambda} = \frac{\varepsilon_T(\theta)}{2\alpha} = \frac{1}{2\alpha}\frac{[\sqrt{N_1^{\uparrow}(\theta)N_2^{\uparrow}(\theta)} + \sqrt{N_1^{\downarrow}(\pi-\theta)N_2^{\downarrow}(\pi-\theta)}] - [\sqrt{N_1^{\uparrow}(\pi-\theta)N_2^{\uparrow}(\pi-\theta)} + \sqrt{N_1^{\downarrow}(\theta)N_2^{\downarrow}(\theta)}]}{[\sqrt{N_1^{\uparrow}(\theta)N_2^{\uparrow}(\theta)} + \sqrt{N_1^{\downarrow}(\pi-\theta)N_2^{\downarrow}(\pi-\theta)}] + [\sqrt{N_1^{\uparrow}(\pi-\theta)N_2^{\uparrow}(\pi-\theta)} + \sqrt{N_1^{\downarrow}(\theta)N_2^{\downarrow}(\theta)}]}$$

- Fitting the reconstructed invariant mass provides N_{Λ} (# of Λ) for each data set, which are the disjoint samples with 8 subdivision

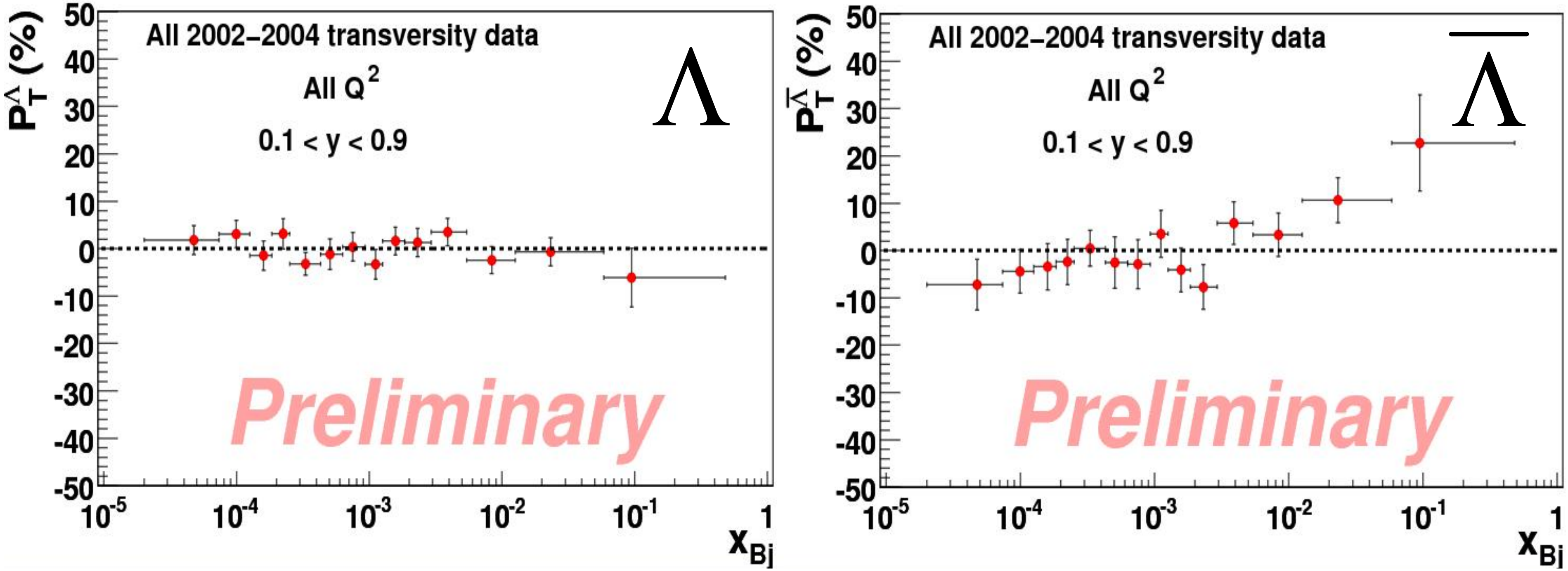
- Fit functions :

$$\frac{A}{\sqrt{2\pi\sigma}}\exp^{\frac{-(m-\bar{m})^2}{2\sigma^2}} + \text{pol}(3)$$



Transverse Λ & $\bar{\Lambda}$ Polarization in 2002-2004

- Only statistical errors are shown and systematic effects have been estimated not to be larger than the statistical errors
- Small tendency for $\bar{\Lambda}$, but not significant for deuteron target



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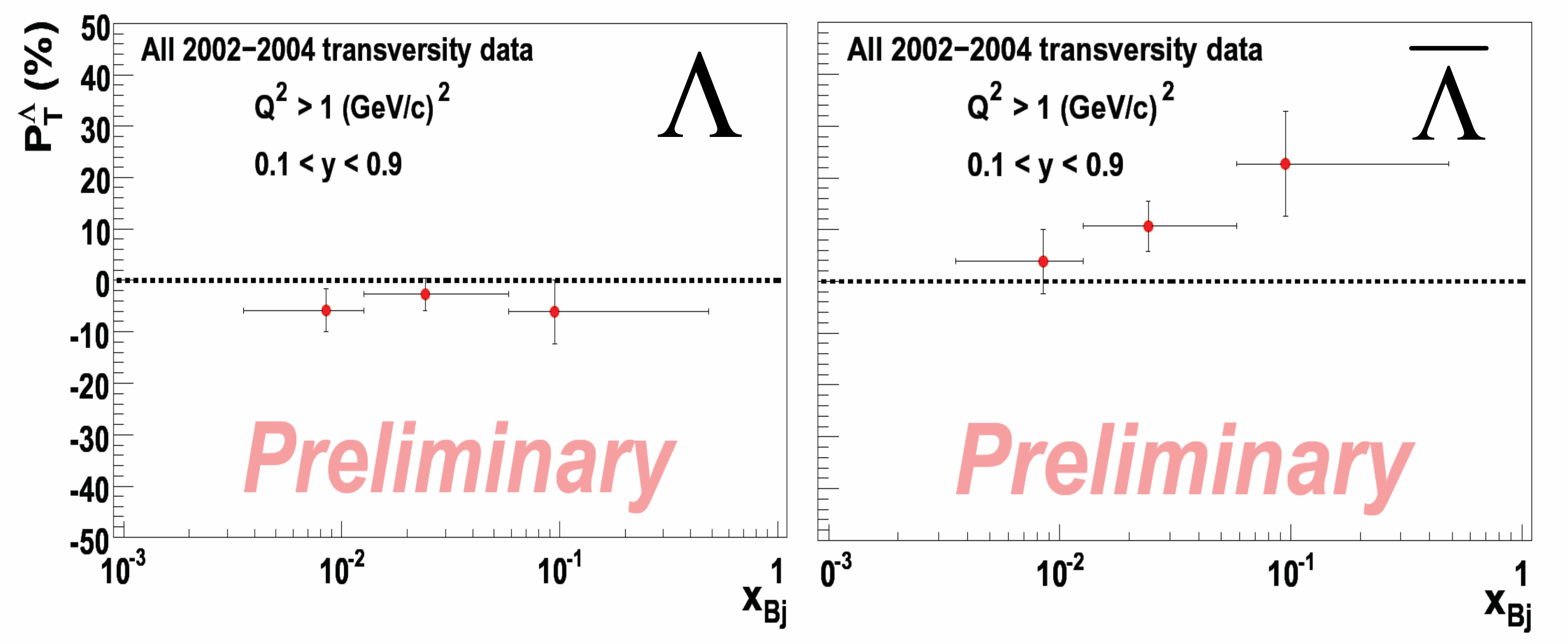
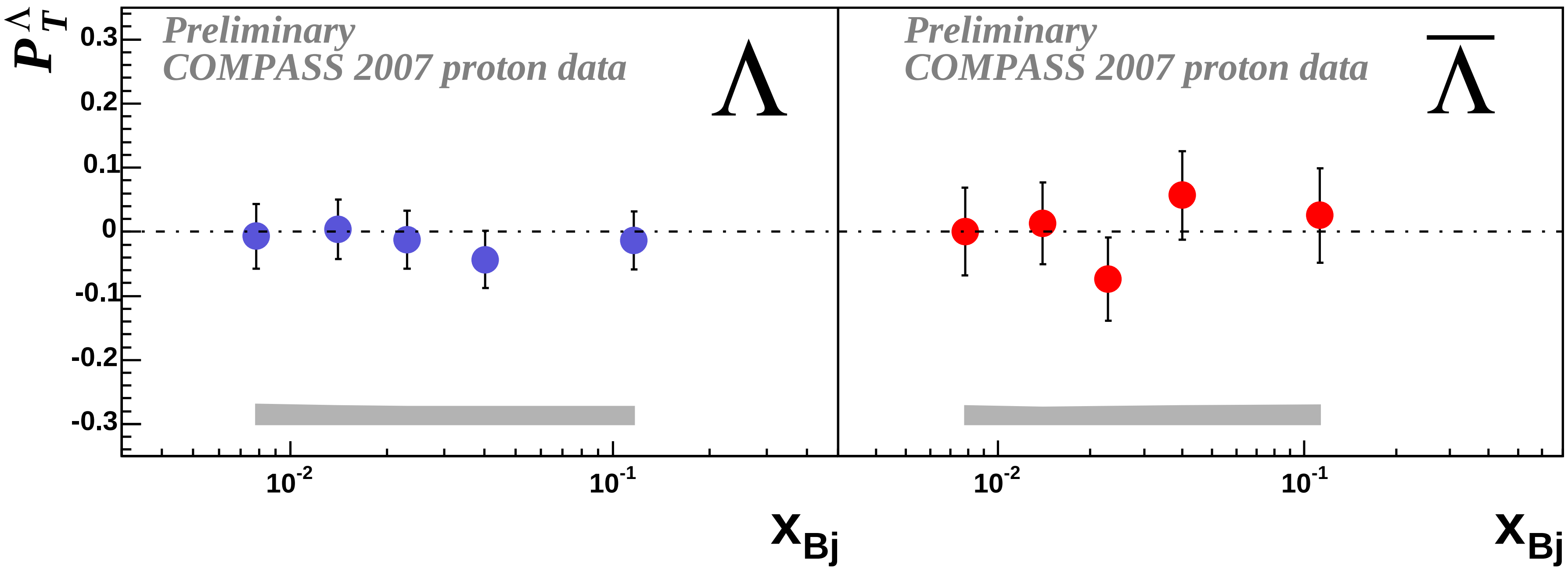


Transverse Λ & $\bar{\Lambda}$ Polarization in 2007

- With ~60% higher statistics than 2002-2004 and RICH identification, 5 x_{Bj} and z bins are possible for 2007 data (instead of 3 for 2002-2004).
- Systematic errors have been estimated to be smaller than statistical errors from false polarization.
- No dependence on x_{Bj} with proton target.



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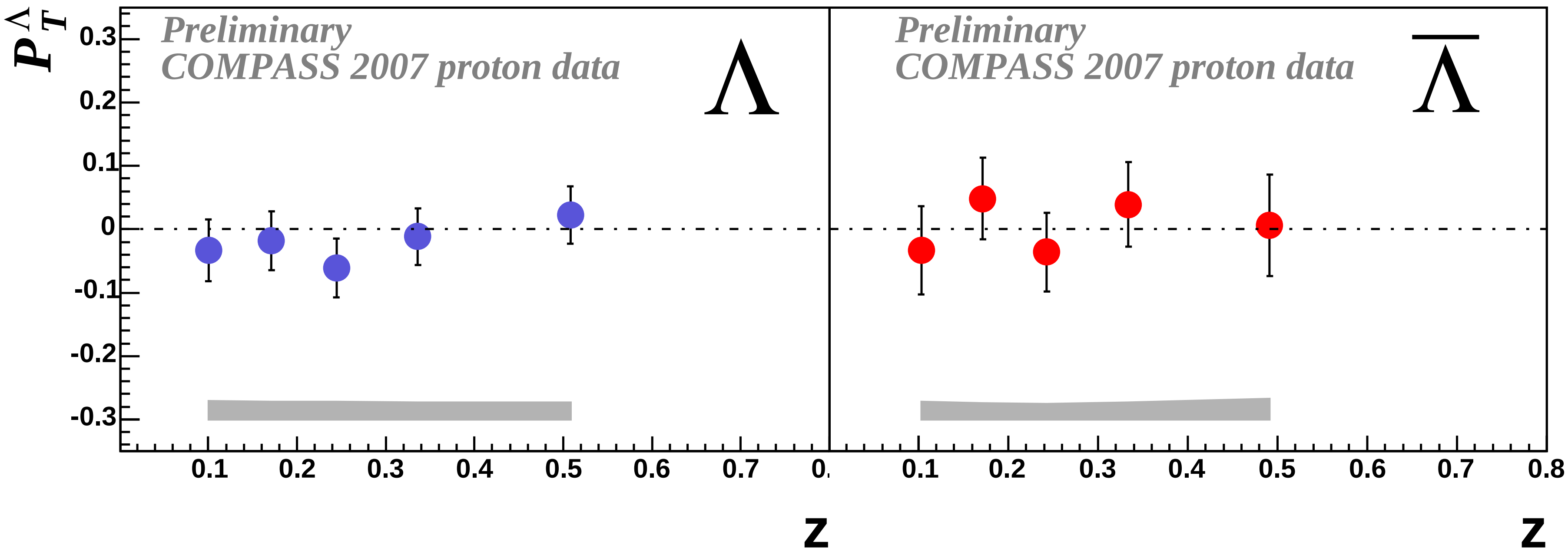

Conclusion and outlook

COMPASS preliminary results on transverse Λ polarization

- Data taking in 2002-2004 on ^{6}LiD target :
  Small, still with 0 compatible signal

- Data taking in 2007 on NH_3 target :
  50% of time dedicated to transverse measurements
  Very good working RICH
  Λ & $\overline{\Lambda}$ unpolarized, no dependence on x_{Bj} and z

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

Thank you !