Lambda asymmetries

Andrea Ferrero - for the COMPASS collaboration

Transversity2005 Workshop

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Outline:

- Λ polarization & transversity
- Method of extraction of P^{Λ}
- P^{Λ} vs. x_{Bj} in 2002+2003 data
- Conclusions

Why Lambdas?

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

The Λ polarization P_S^Λ 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 θ^* is the proton emission angle wrt. $\overrightarrow{\mathbf{S}}$ in the Λ rest frame

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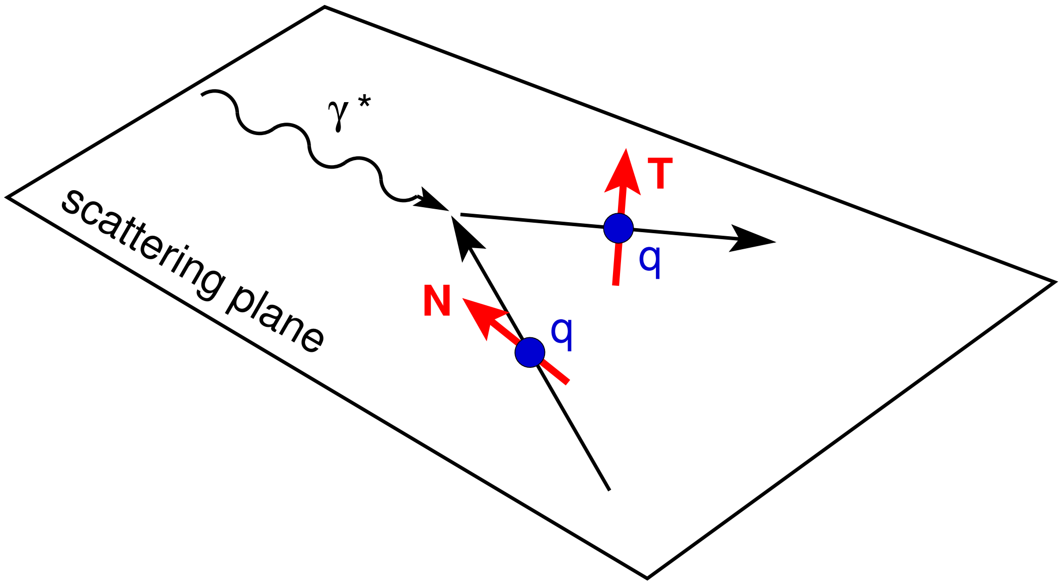
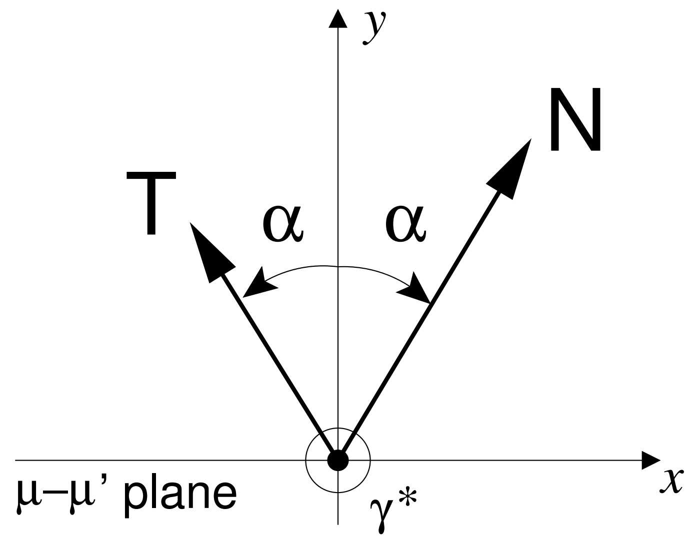
In general, the proton angular distribution is distorted by the non-ideal experimental acceptance:

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

Definition of the Λ polarization axis





N: component of target spin perpendicular to p_{γ^*}

T: symmetric of N wrt. the normal to the scattering plane,
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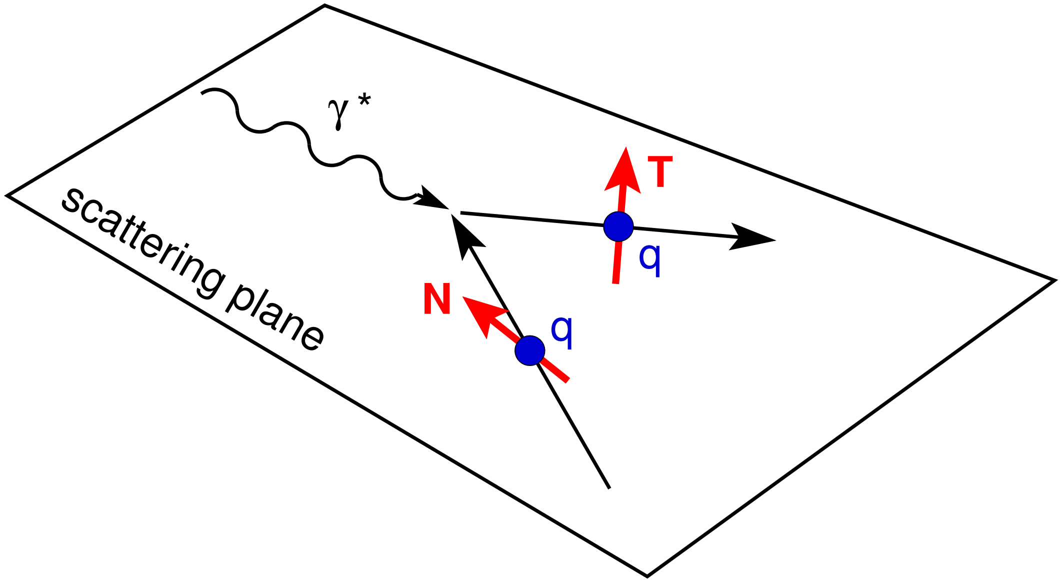

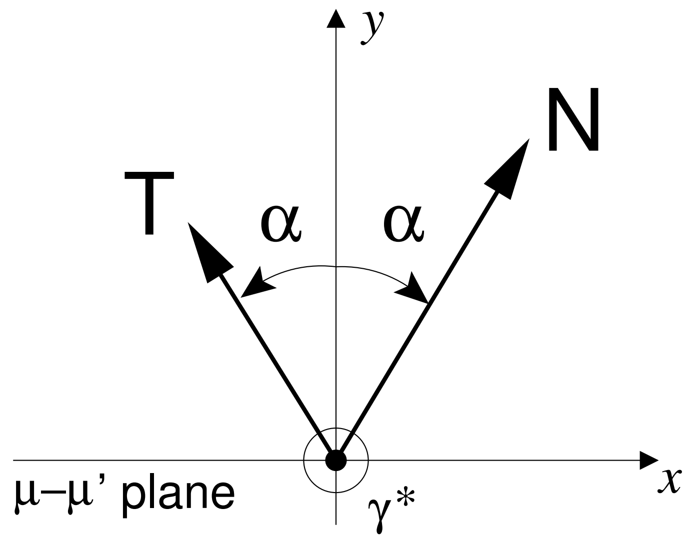

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If q fragments into a Lambda hyperon, then the measurement of P_T^Λ gives information about the initial quark polarization in the nucleon

Transversity & Λ polarization

- Informations on $\Delta_T q(x)$ (or $h_1(x)$) can be accessed in the process

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$$P^{\Lambda}_{T,exp} = \frac{d\sigma^{\mu N^{\uparrow}\rightarrow\mu'\Lambda^{\uparrow}X} - d\sigma^{\mu N^{\downarrow}\rightarrow\mu'\Lambda^{\uparrow}X}}{d\sigma^{\mu N^{\uparrow}\rightarrow\mu'\Lambda^{\uparrow}X} + d\sigma^{\mu N^{\downarrow}\rightarrow\mu'\Lambda^{\uparrow}X}} = f P_N D(y) \frac{\sum_q e_q^2 \Delta_T q(x) \Delta_T D_{\Lambda/q}(z)}{\sum_q e_q^2 q(x) D_{\Lambda/q}(z)}$$

f = target dilution factor, P_N = target polarization,

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- Alternative approach to Collins or Drell-Yan processes
- The chiral-odd partner of $\Delta_T q(x)$ is the fragmentation function

$$\Delta_T D_{\Lambda/q}(z) = D_{\Lambda^{\uparrow}/q^{\uparrow}}(z) - D_{\Lambda^{\downarrow}/q^{\uparrow}}(z)$$

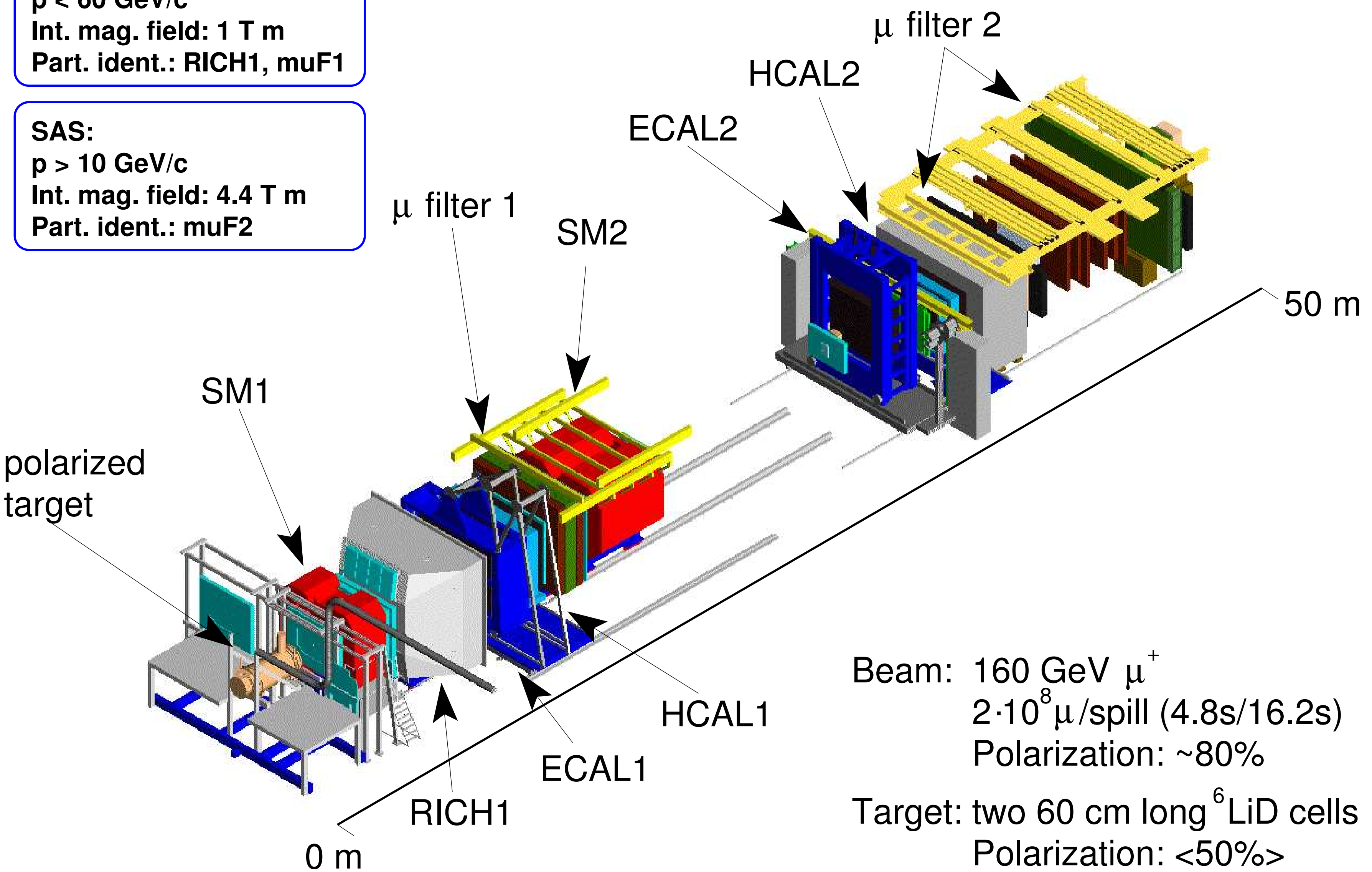
Literature on P_T^Λ measurement

- 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^Λ value comes from the almost unknown properties of the fragmentation functions $\Delta_T D_{\Lambda/q}(z)$

COMPASS spectrometer (2002 setup)

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

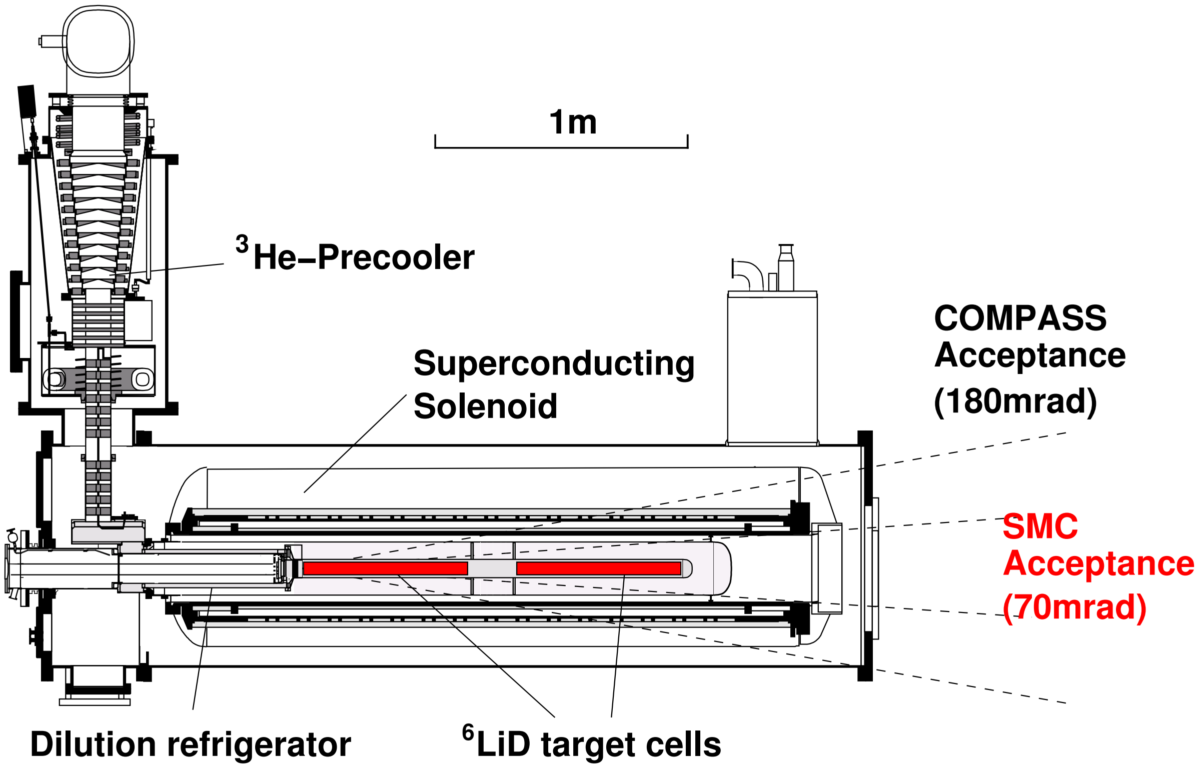
SAS:
p > 10 GeV/c
Int. mag. field: 4.4 T m
Part. ident.: muF2



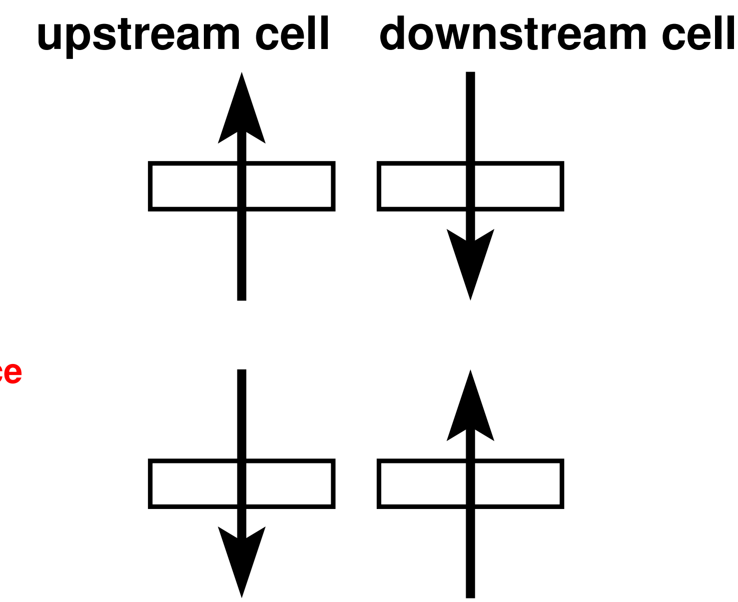
Beam: 160 GeV μ^+
$2 \cdot 10^8 \mu$/spill (4.8s/16.2s)
Polarization: ~80%

Target: two 60 cm long ^{6}LiD cells
Polarization: <50%>

The polarized target



Two opposite spin configurations

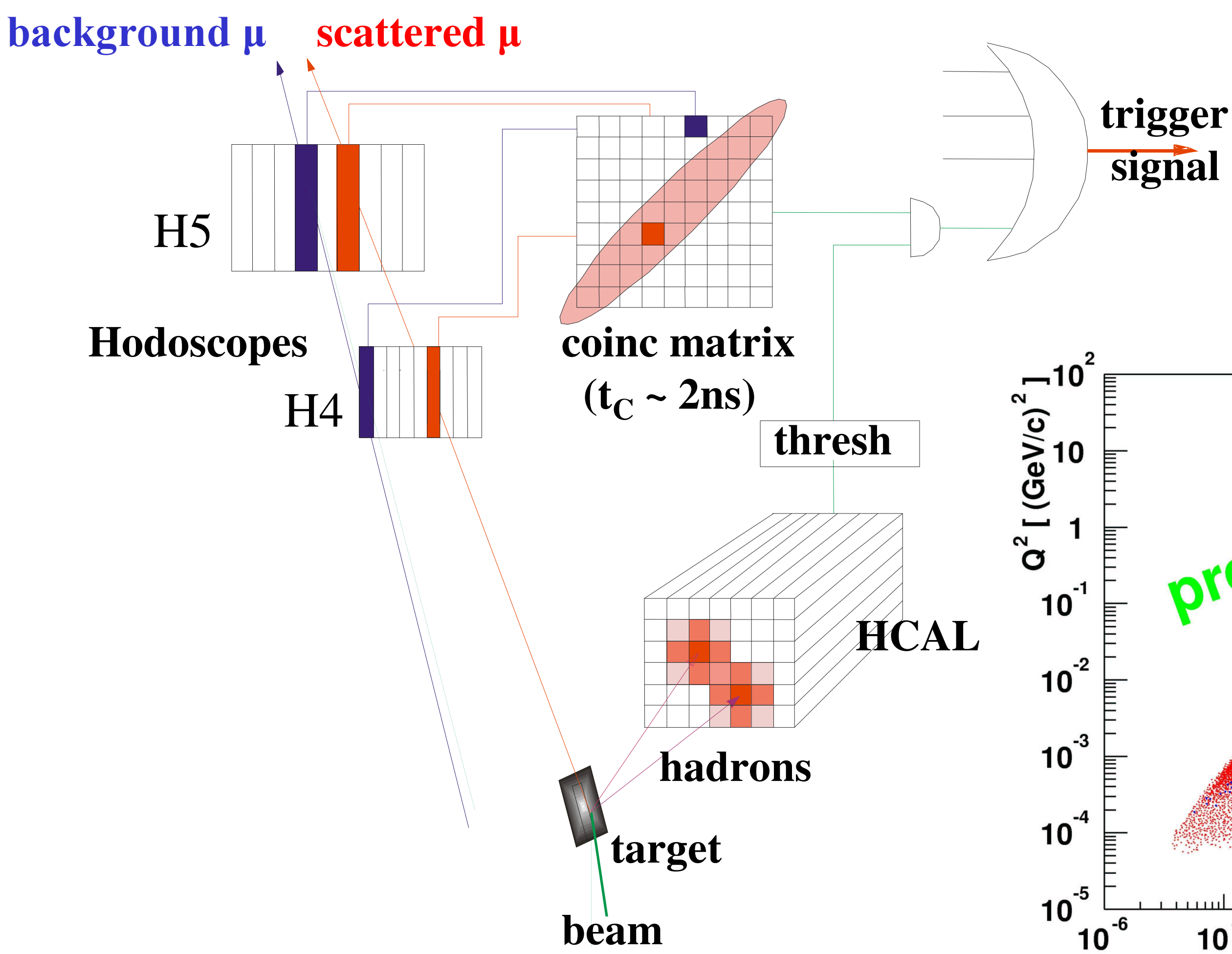


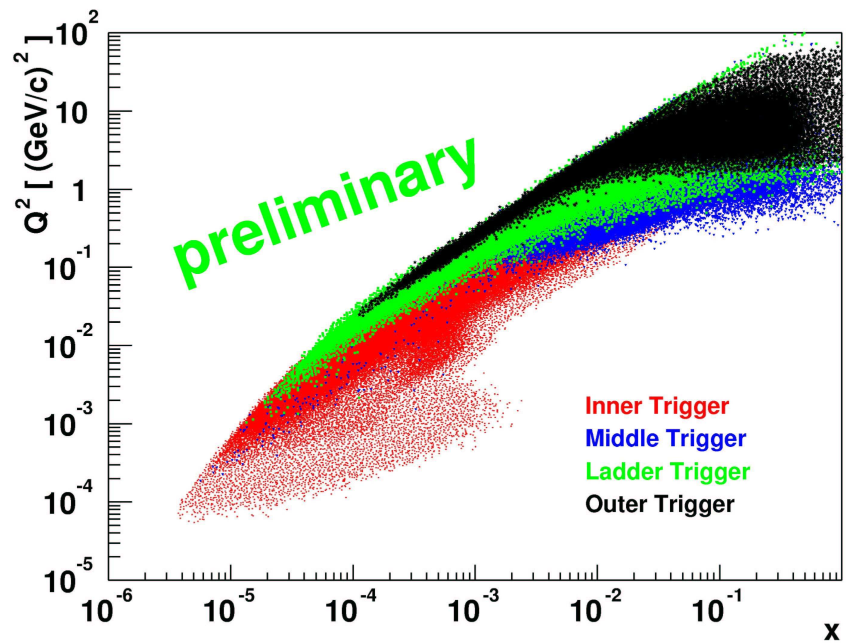
60 cm long ^{6}LiD target cells, $< P_N > \sim \pm 50\%$, dilution factor $f \sim 0.4$

A 0.5 T dipole magnetic field is used to maintain the transverse spin configuration

COMPASS trigger

Trigger : (H4 * H5) * (Hcal1 U Hcal2)

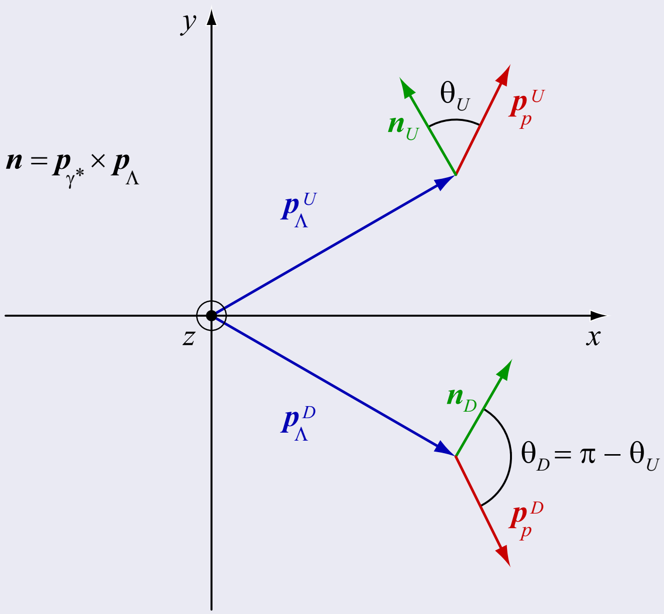




Extraction of the Λ polarization

The "familiar" case: polarization along $\vec{n} = \vec{p_\Lambda} \times \vec{p_{\gamma^*}}$

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)

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

where

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

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

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two cells (+ & -) and two spin configurations (1 & 2)

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$= \alpha P_T^\Lambda \cos\theta^*, \quad (= \alpha P_T^\Lambda/2$ if only 2 θ^* bins are considered)

where θ^* is the proton decay angle wrt. the **T** axis in the Λ rest frame,

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

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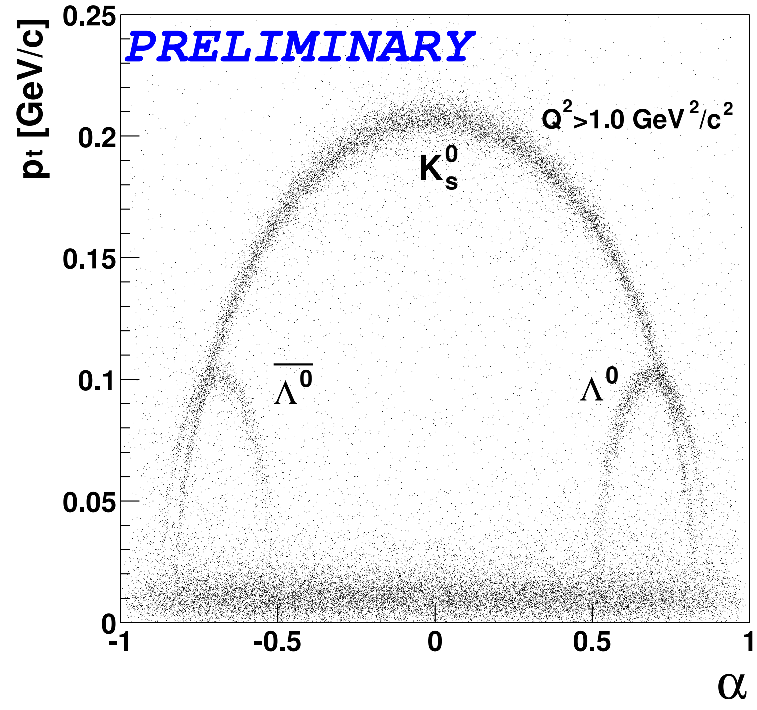
The only assumptions in the derivation are:

1. The target polarization is constant: $P_T^{(1)} = P_T^{(2)}$
2. The experimental acceptance does not change in time:
   $Acc_1^+(\theta^*) = Acc_2^-(\theta^*)$, $Acc_1^-(\theta^*) = Acc_2^+(\theta^*)$

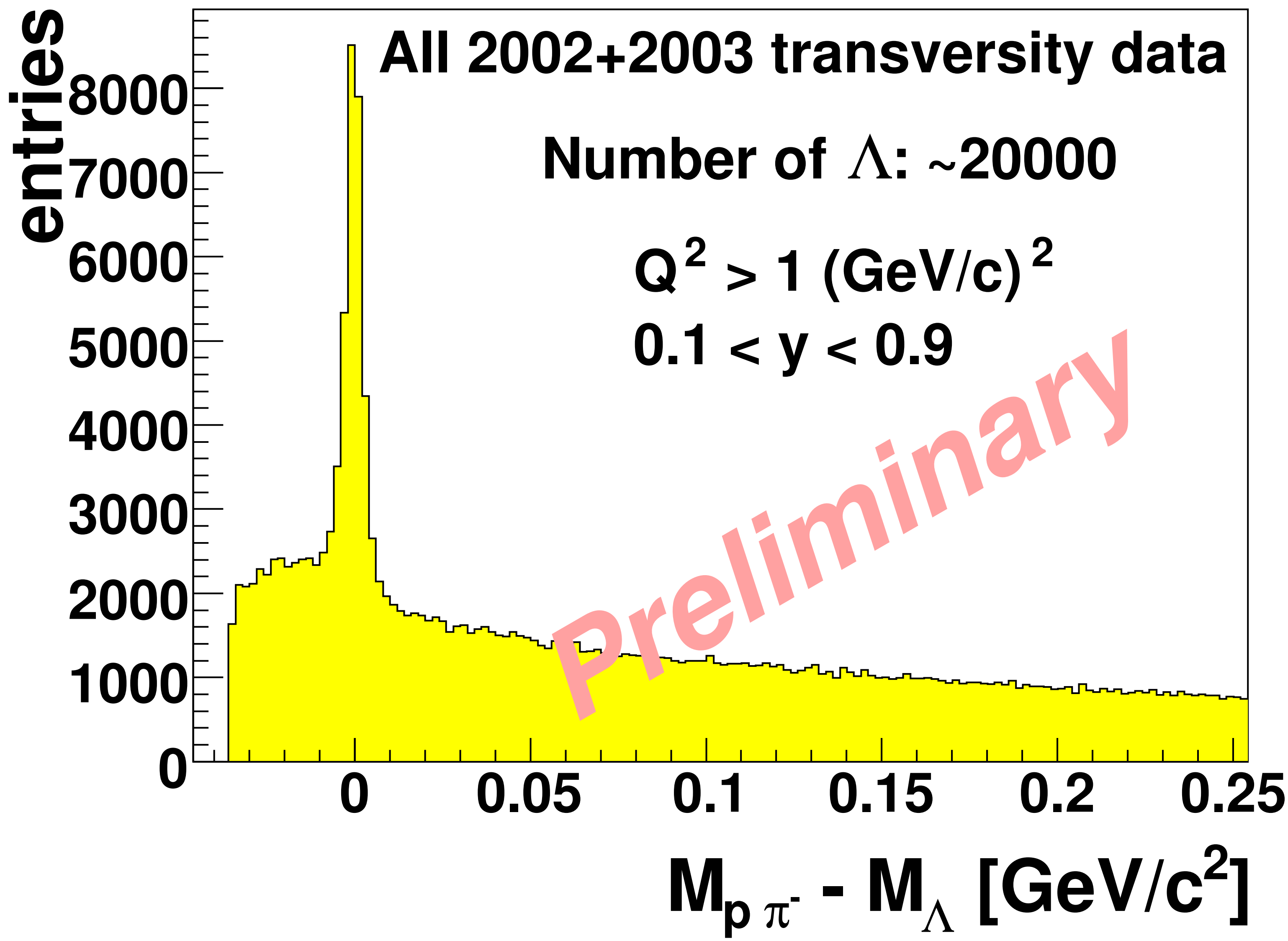
Selection of Λ events

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

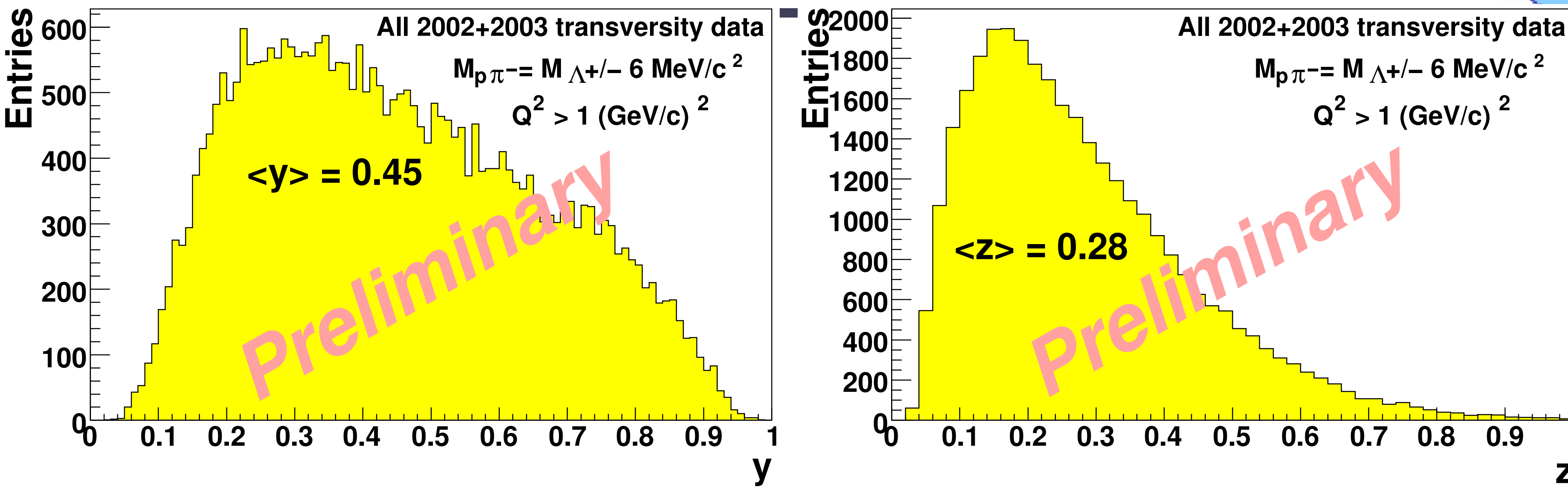


- The candidate Λ decay is downstream of the target and outside of it
- collinearity < 10 mrad
- Armenteros $p_T > 23$ MeV/c
- $0.1 < y < 0.9$

Overall available statistics



Kinematics of the Lambda production



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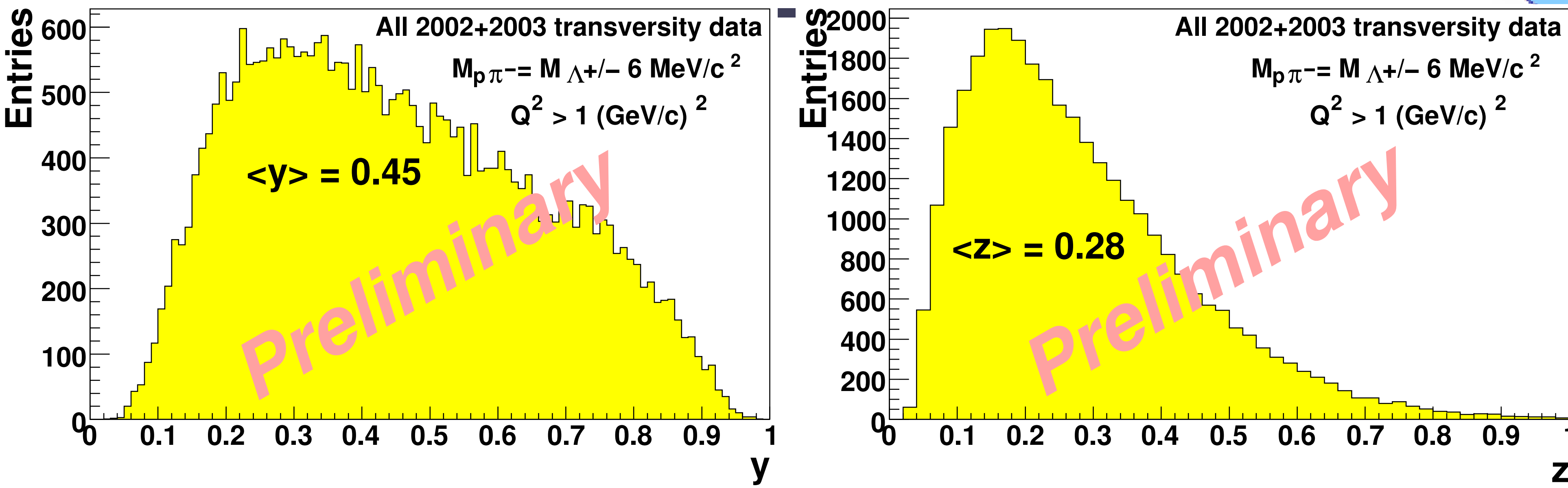

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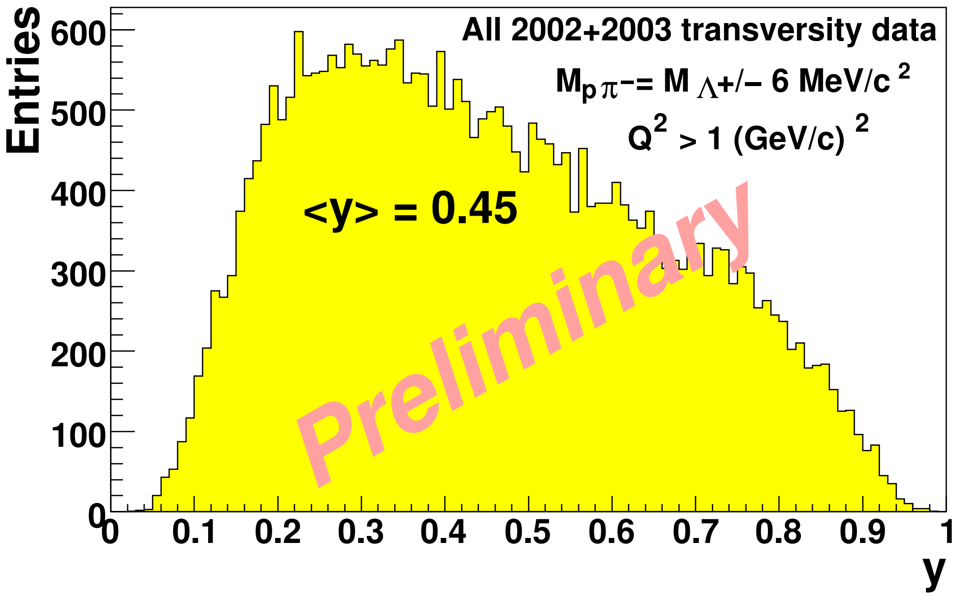

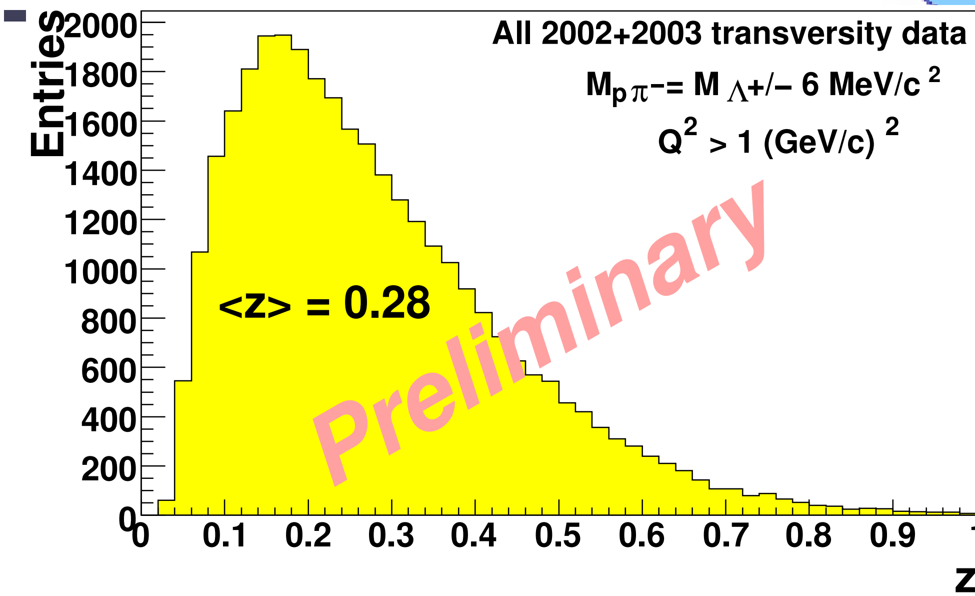

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  - $\sim 10^{-5} < x_{Bj} < 1$ *for all* Q^2
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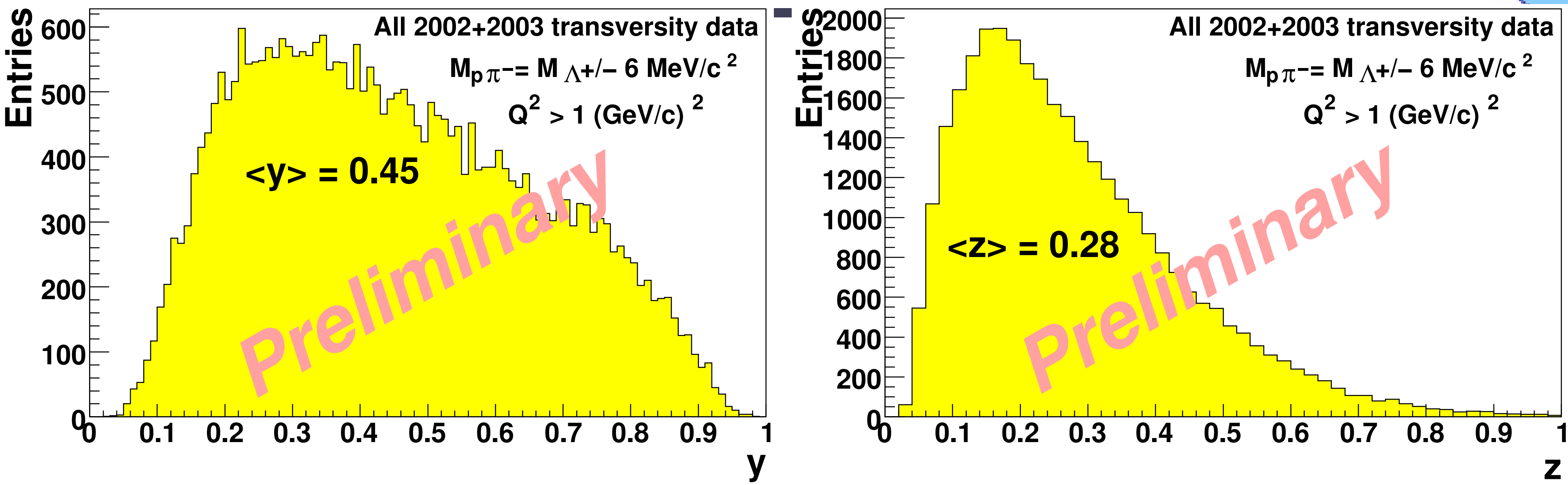

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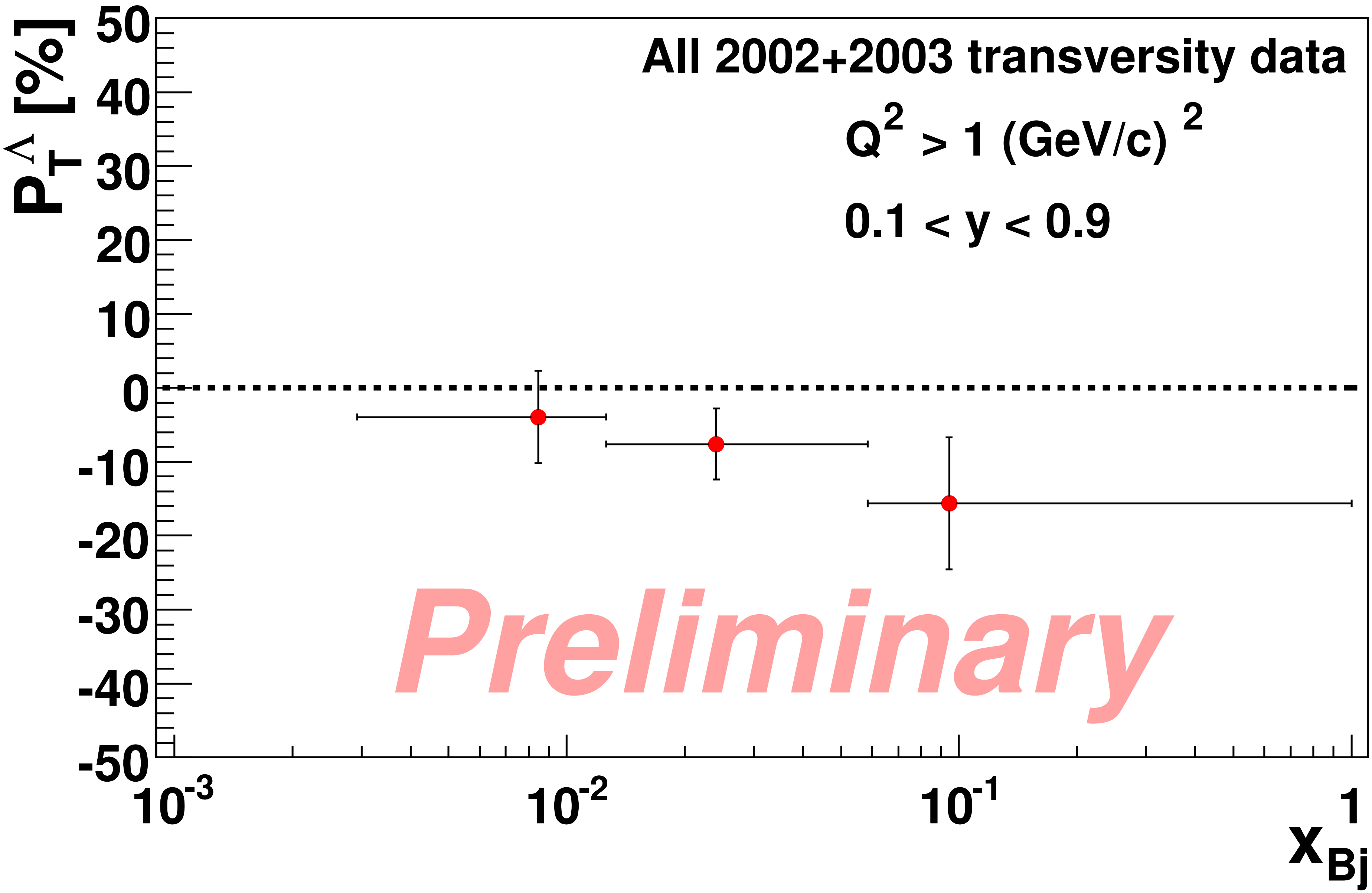
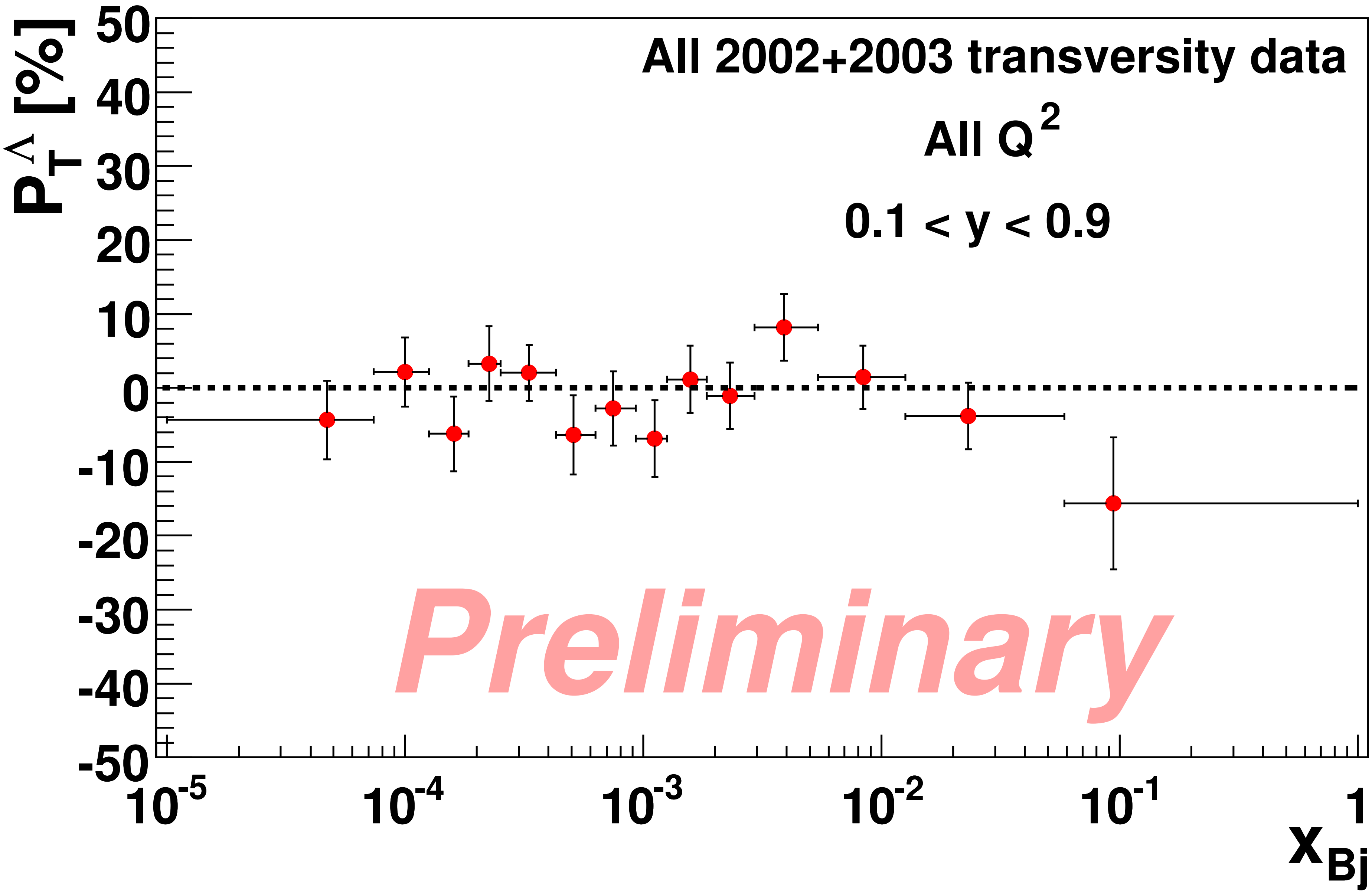
- A binning on x_{Bj} has been applied to study the x_{Bj}-dependence of P_T^Λ

Polarization vs. x_{Bj} - 2002+2003, $Q^2 > 1$



Polarization vs. x_{Bj} - 2002+2003, all Q^2



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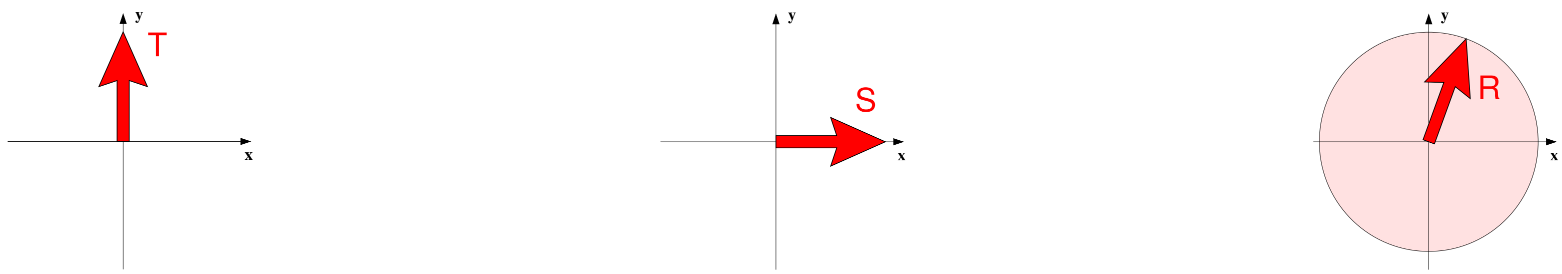

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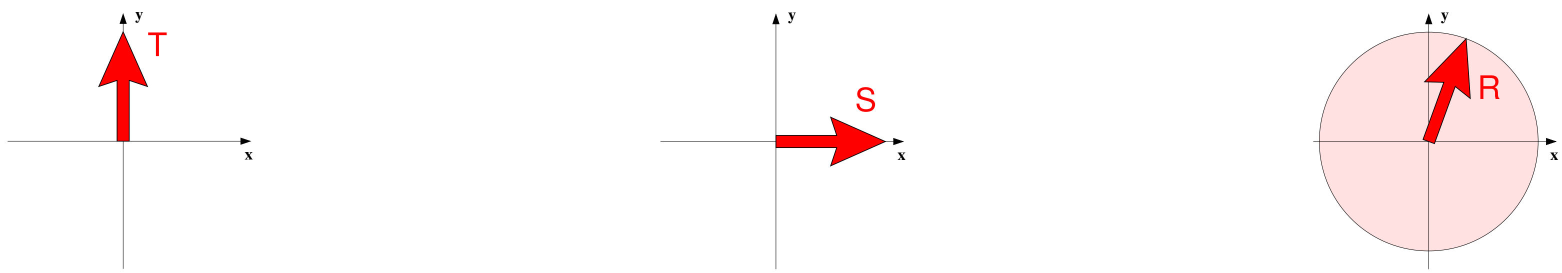

- The analysis shows that systematic effects are not larger than the statistical error

Conclusions

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- The x_{Bj} dependence does not show a significant deviation from zero, but the statistics in the most interesting region ($x_{Bj} \sim 0.1$) is still poor
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