International Workshop on Transversity:
New Developments in Nucleon Spin Structure

COMPASS

Transversity Measurements at COMPASS

Rainer Joosten, University of Bonn

on behalf of the

COMPASS Collaboration

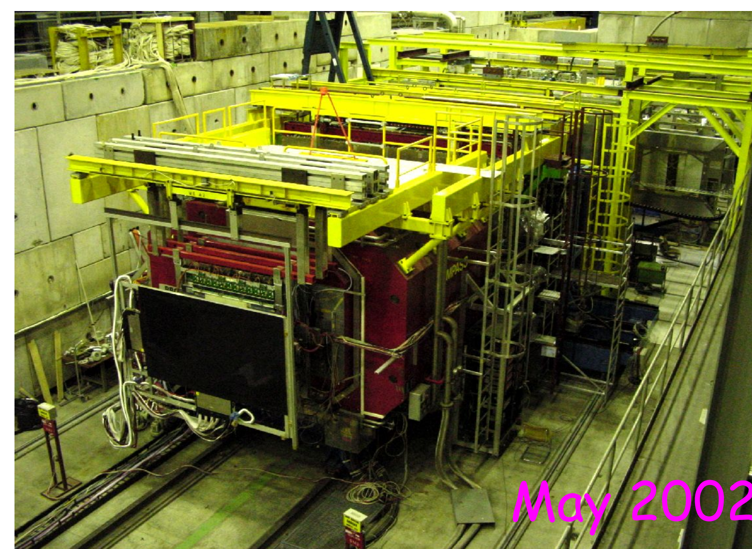
ECT*, Trento, June 13-18

HISKP

COMPASS – History

COMPASS:
THE new fixed target facility at CERN!

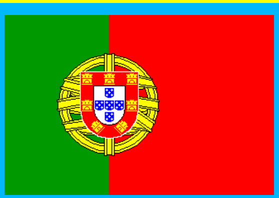
- 1996 COMPASS proposal
- 1997 conditional approval
- 1998 MoU
- 1999 – 2001 construction & installation
- 2001 technical run



- 2002, 2003, 2004 data taking
- In long range planning @CERN at least until 2010

The COMPASS Collaboration
(230 Physicists from 11 Countries)

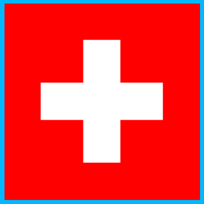
Dubna (LPP and LNP), Moscow (INR, LPI, State University), Protvino



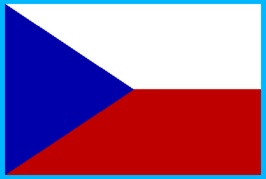
Lisboa

Bielefeld, Bochum, Bonn (HISKP & PI), Erlangen, Freiburg, Heidelberg, Mainz, München (LMU & TU)

Warsaw (SINS), Warsaw (TU)

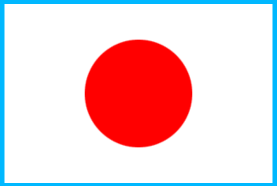


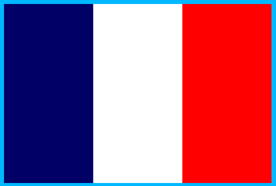
CERN



Prag

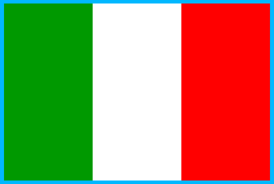
Nagoya





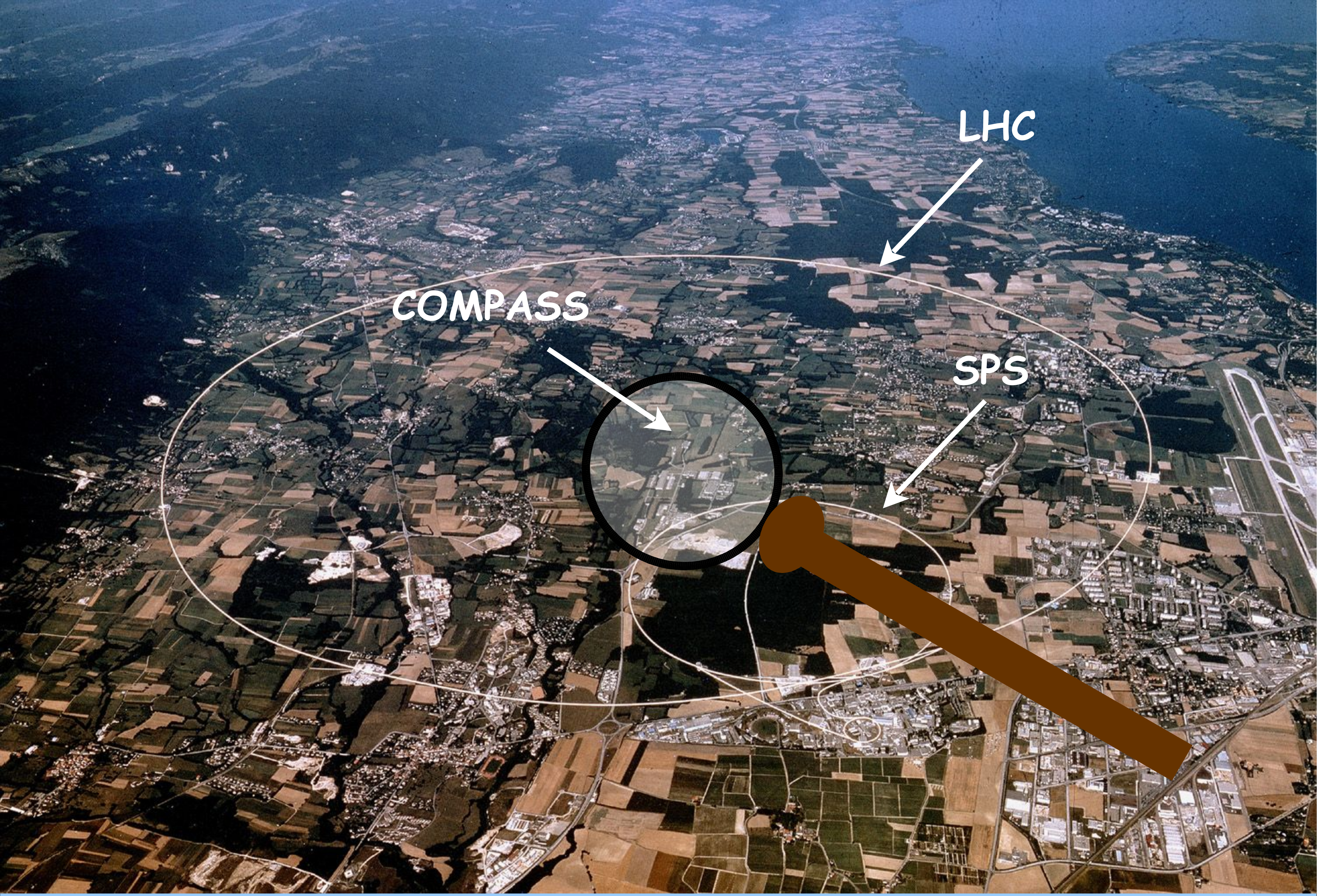
Saclay

Torino(University,INFN), Trieste(University,INFN)



Burdwan, Calcutta

Tel Aviv


LHC
COMPASS
SPS

Physics Goals

Contribute to the understanding of the non-perturbative physics of the nucleon

Nucleon spin structure

(in SIDIS with polarized muon beam and target)

- Gluon Polarization $\Delta G/G$
- Transverse spin structure function $h_1(x)$
- Flavor dependent polarized Quark helicity densities $\Delta q(x)$
- Spin dependent fragmentation functions ΔD^{Λ}_{q}
- Diffractive VM-Production

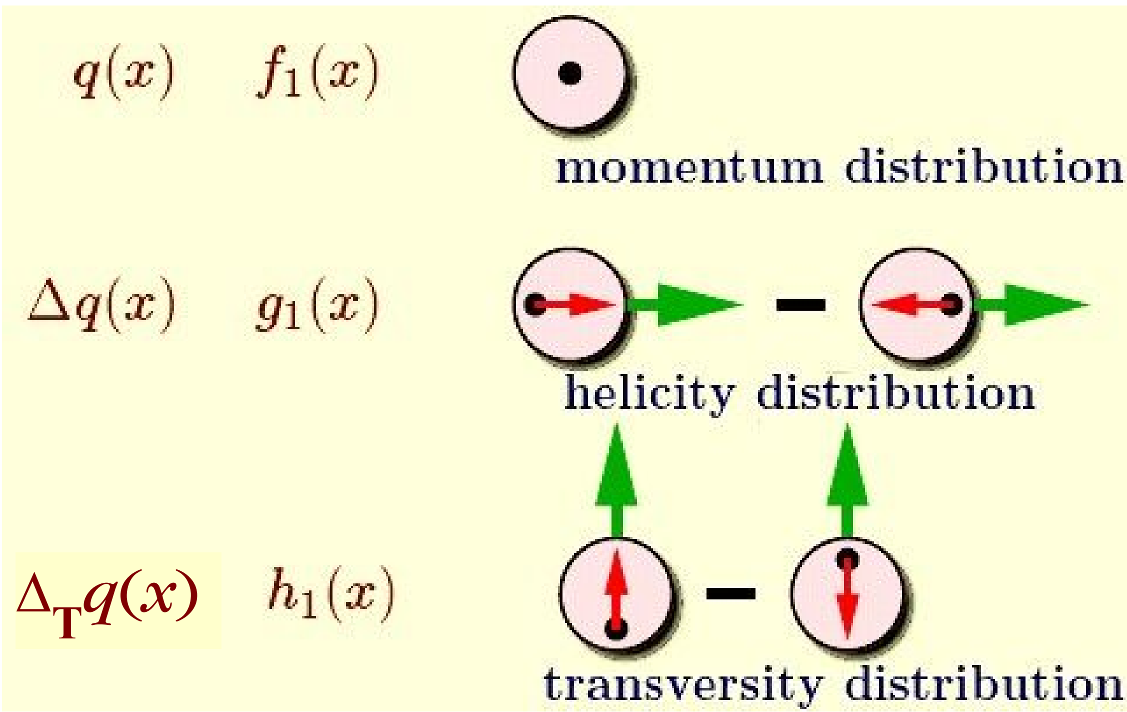
Nucleon spectroscopy

(hadron beams)

- Primakoff-Reactions
  - Polarizability of π and K
- Glueballs and hybrids
- Charmed mesons and baryons
  - semi-leptonic decays
  - double-charmed baryons

Transverse Spin Physics

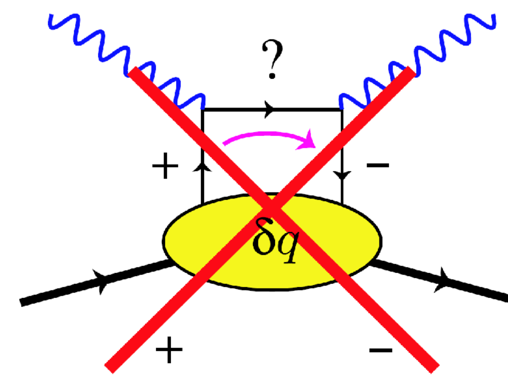
3 distribution functions are necessary to describe the spin structure of the nucleon at LO:



All of equal importance!

$h_1(x)$

- decouples from leading twist DIS because helicity of quark must flip
- not observable in inclusive DIS
- No mixture with Gluon (1/Q)



$\Rightarrow$ SIDIS

Transverse Spin Physics

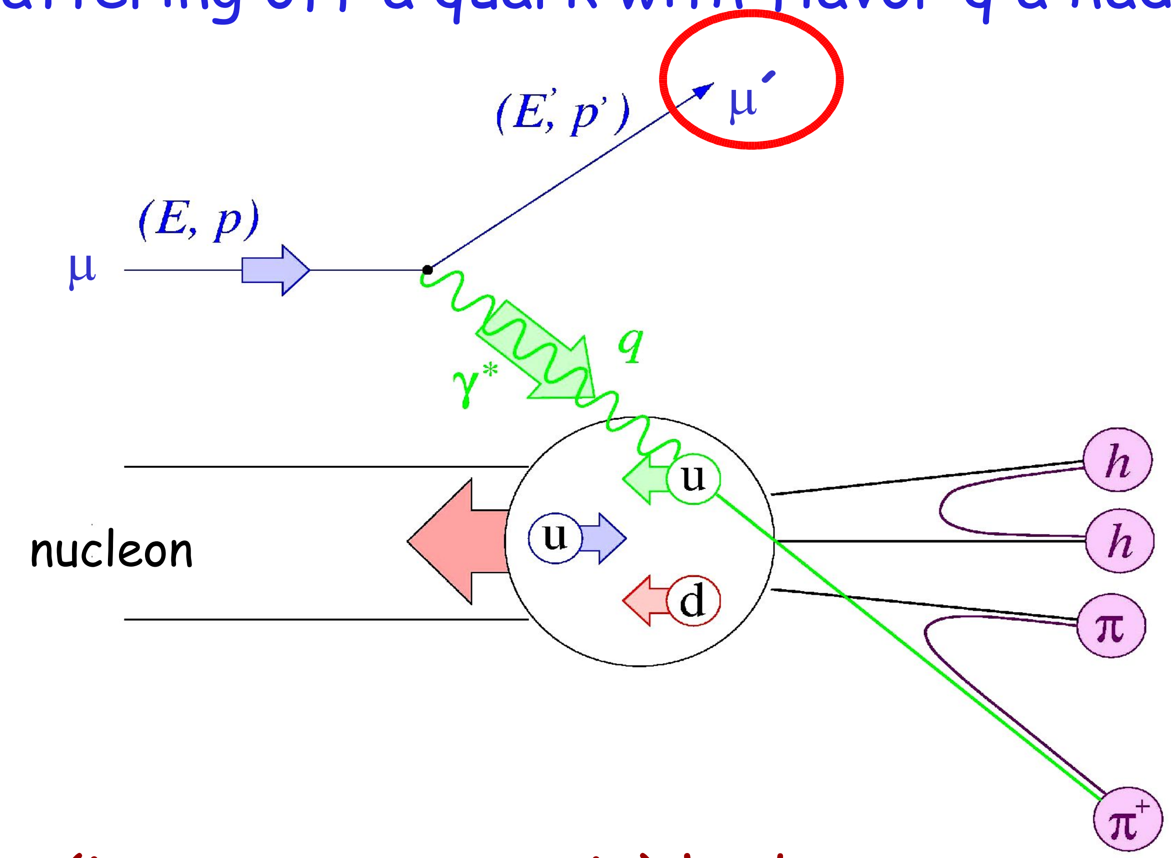
3 possible quark polarimeters suggested using SIDIS:

- Measure transverse polarization of Λ
- Azimuthal dependence of the plane containing leading & next to leading hadrons
- Azimuthal distribution of leading hadrons ← Results!
  - Collins effect

Transverse Spin Physics in SIDIS

General:

The fragmentation function $D_q^h(z, Q^2)$ describes the probability that by scattering off a quark with flavor q a hadron h is produced

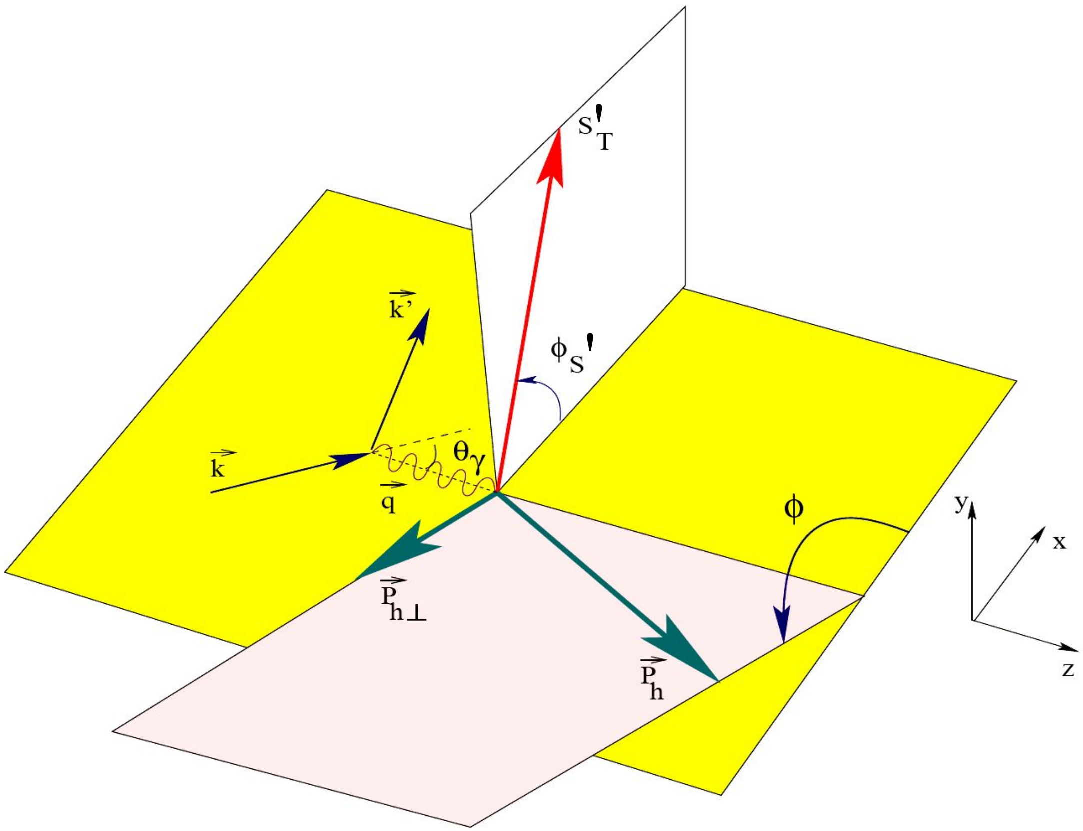


The leading (i.e. most energetic) hadron contains most probably the scattered quark → FILTER!

The coordinate system

Breit frame where:

- z is the virtual photon direction
- the x-z plane is the lepton scattering plane



$\phi_{S'}$ = azimuthal angle of spin vector of **fragmenting** quark with $\phi_{S'} = \pi - \phi_S$ (spin flip)

ϕ_h = azimuthal angle of hadron

The Collins angle is defined by

$$\phi_C = \phi_h - \phi_{S'}$$

$$= \phi_h + \phi_S - \pi$$

Transverse Spin Physics

COMPASS

The fragmentation function of a quark q into a hadron h can be written as:

spin dependent part

$$D_q^h(z, p_T^h) + \Delta_T D_q^h(z, p_T^h) \sin\Phi_C$$

$\Phi_C = \Phi_h - \Phi_{S'}$

Collins angle

Causing a count rate difference:

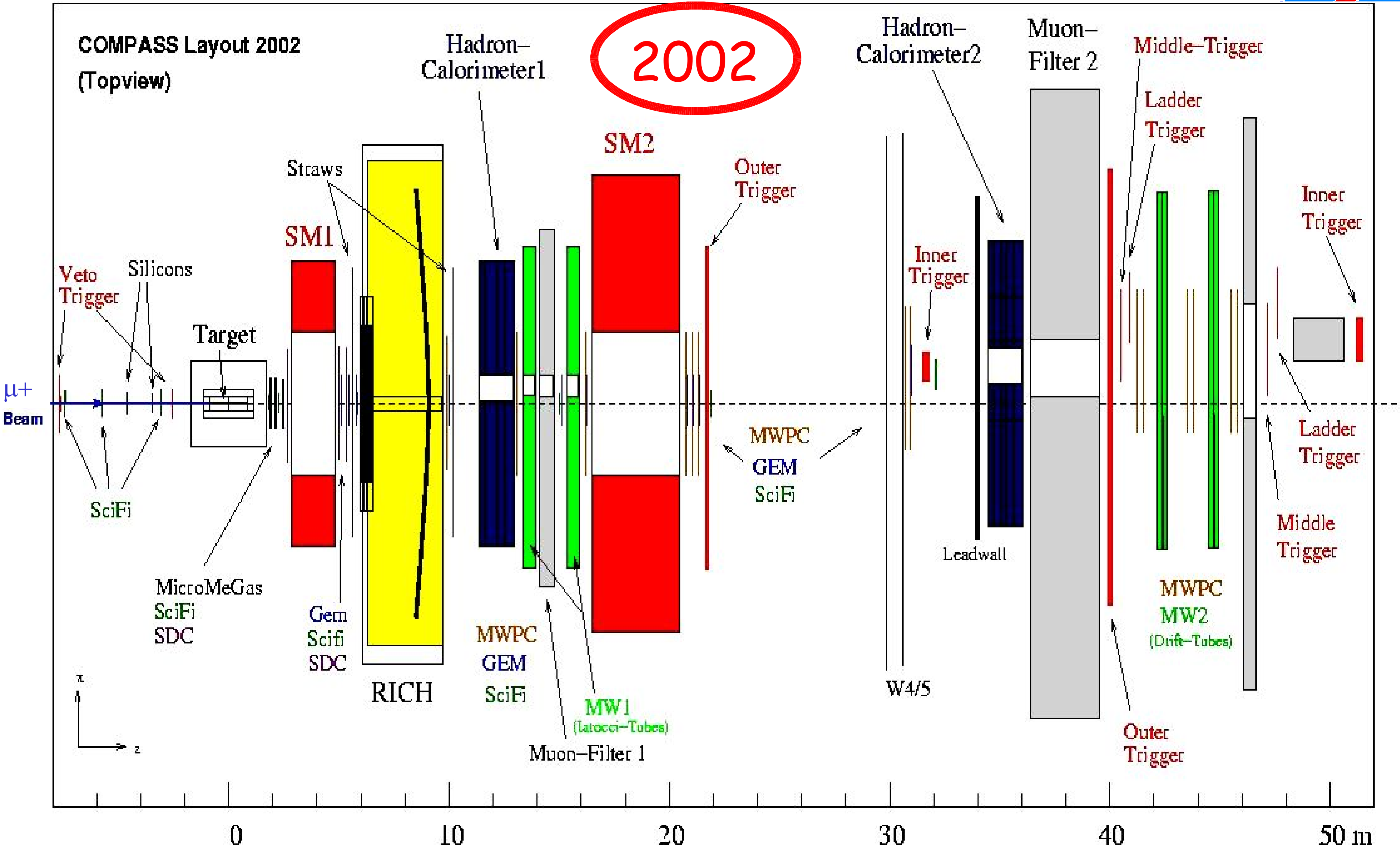
$$\frac{N^+(\Phi_C) - N^-(\Phi_C)}{N^+(\Phi_C) + N^-(\Phi_C)} = A_{UT}^{\sin\phi} \cdot \sin\Phi_C$$

From this we get:

$$\frac{A_{UT}^{\sin\phi}}{D_{NN} \cdot f \cdot P} = A_{Coll} = \frac{\sum_i e_i^2 \Delta_T q_i(x) \Delta_T D_i^h(\vec{z}, P^2_{h\perp})}{\sum_i e_i^2 q_i(x) D_i^h(z, \vec{P}^2_{h\perp})}$$

f dilution factor; P target polarization; $D_{NN} = (1-y)/(1-y-y^2/2)$ Depolarization factor

The COMPASS experiment



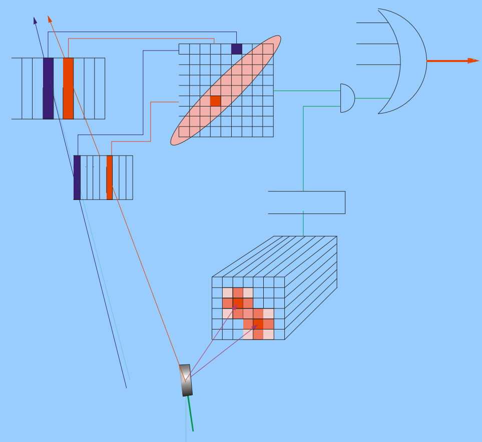
<u>Beam:</u> $2 \cdot 10^8$ μ^+/ spill (4.8s / 16.2s)

<u>Beam momentum:</u> 160 GeV/c

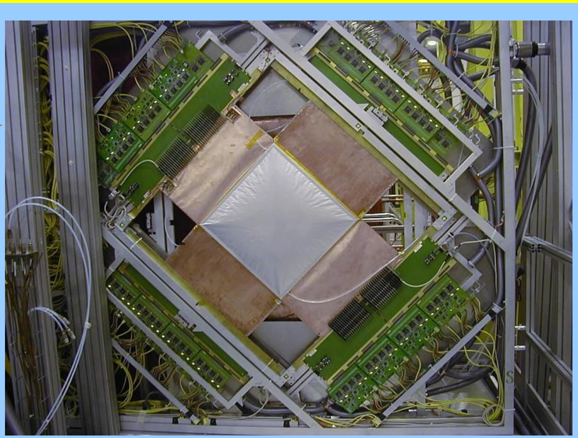
<u>Luminosity:</u> $\sim 5 \cdot 10^{32}$ cm^{-2} s^{-1}

<u>Beam polarization:</u> -76%

Many new technologies for tracking and PID

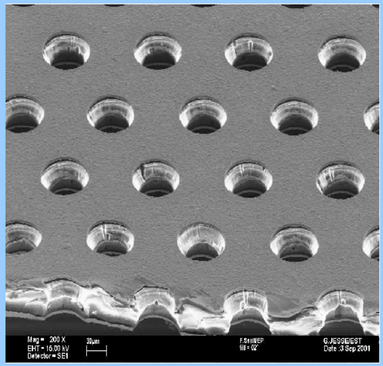


Trigger system

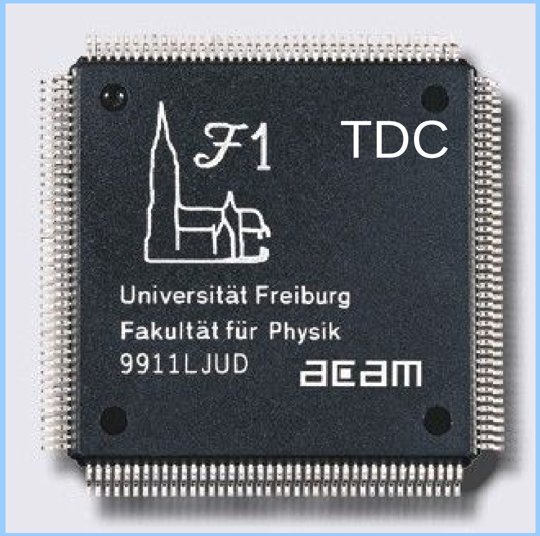


MicroMegas -position and track time

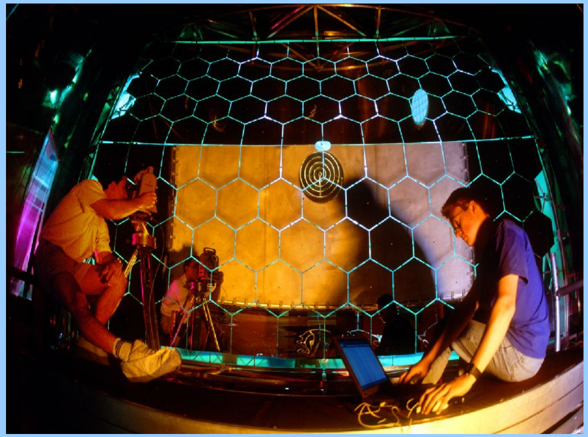
Straws -large area



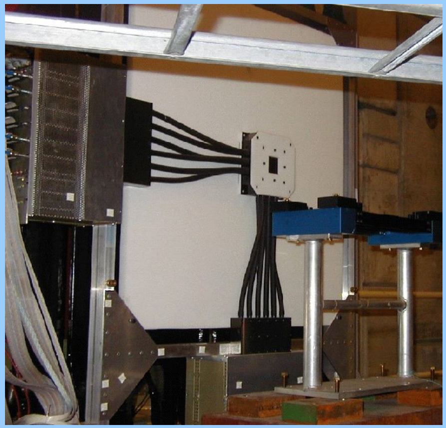
GEM -space resolution



Dead time free readout electronics

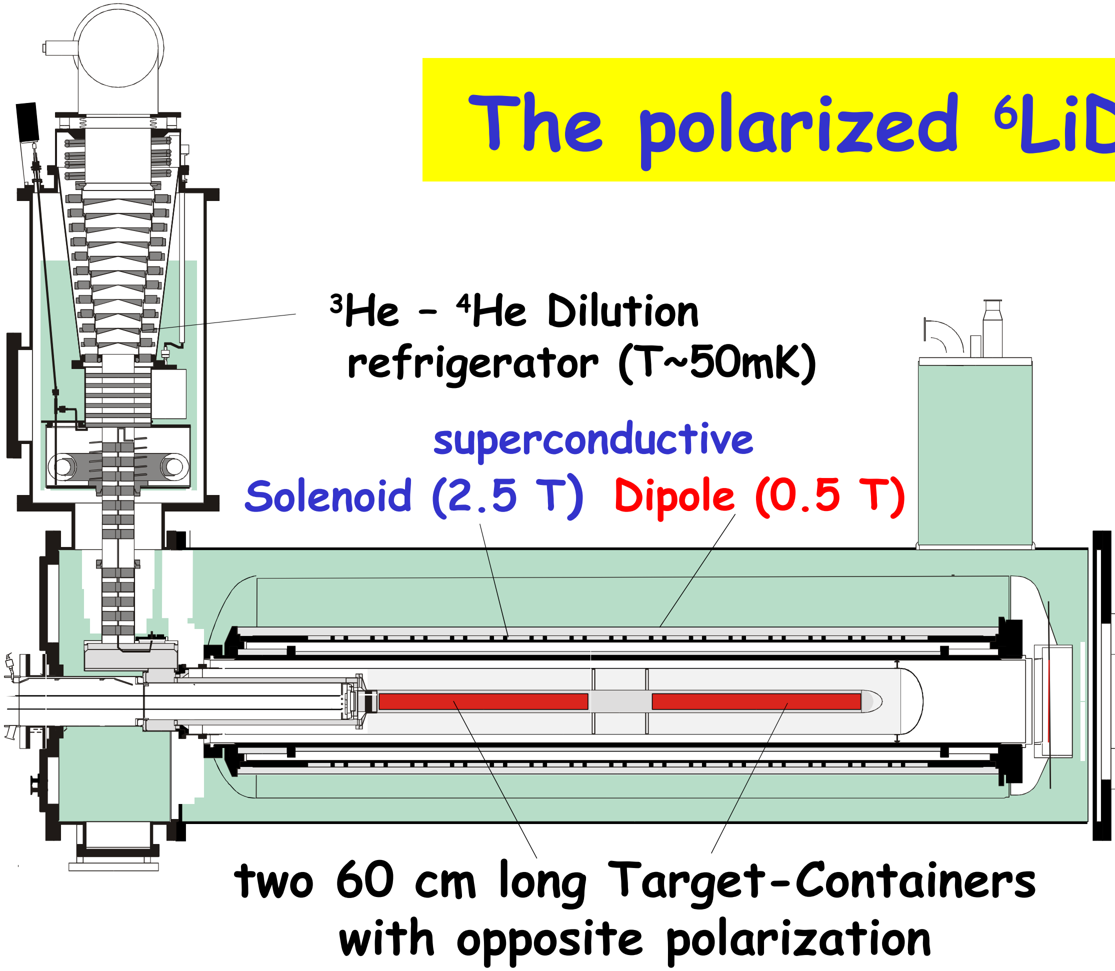


RICH
CsI & MWPC readout
Radiator: C_4F_{10}

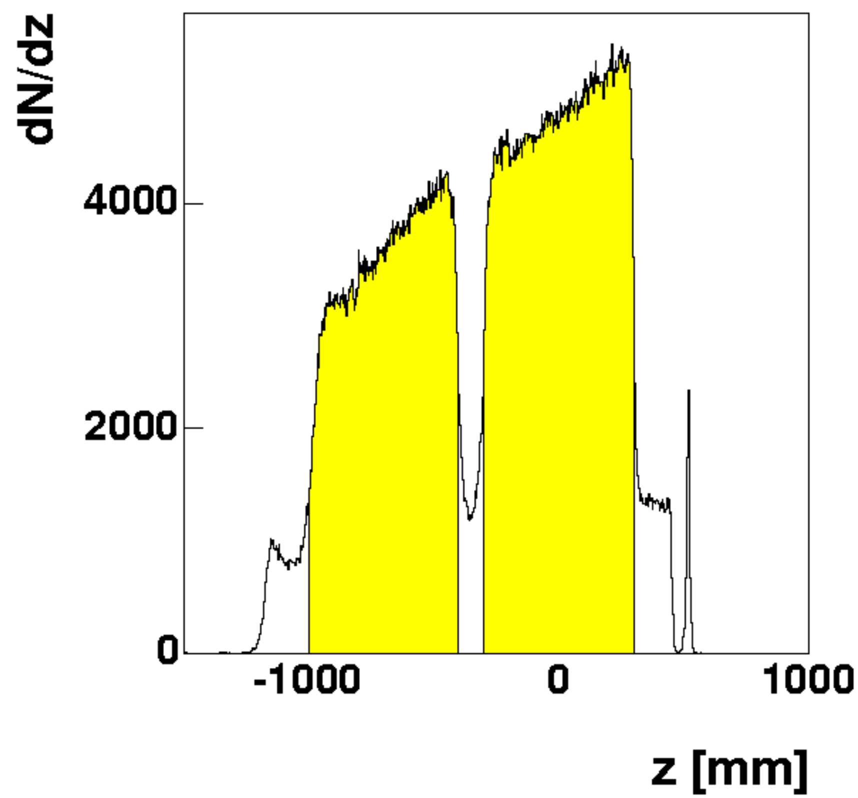


Scintillating fibre hodoscopes
- highest rates

The polarized ^{6}LiD-Target



Polarization: 50%
Dilution factor: 0.38



During data taking for transversity

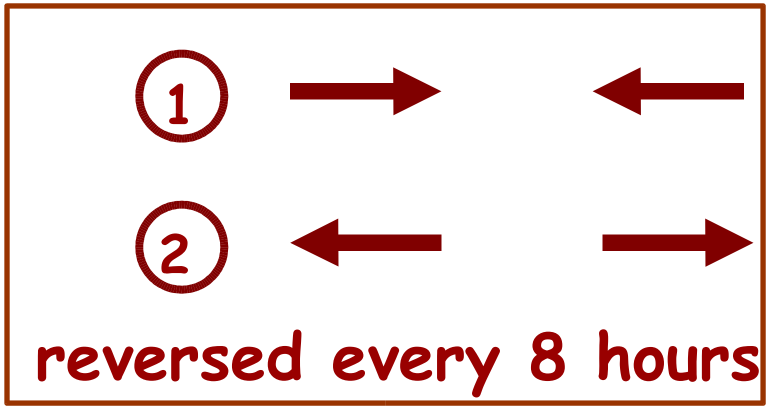
dipole field always on and ↑

Relaxation time:

longitudinal running » measurable
transversal running > 2000 hrs

The polarized ^{6}LiD-Target

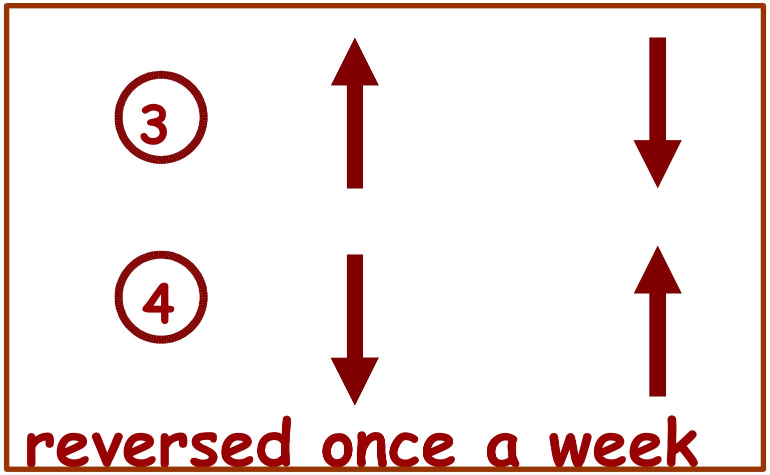
4 possible spin combinations:



Longitudinal running:

changed by field rotation

(~ 20 min)



Transversal running:

changed by microwave reversal

(~ 24 h)

Data Sample

2002: 12+7 days of data taking (total)
with transversely polarized ^{6}LiD target
(separate analysis for both periods of data taking)

- $1.8 * 10^9$ events
- $1.6 * 10^6$ events after all cuts (preliminary)

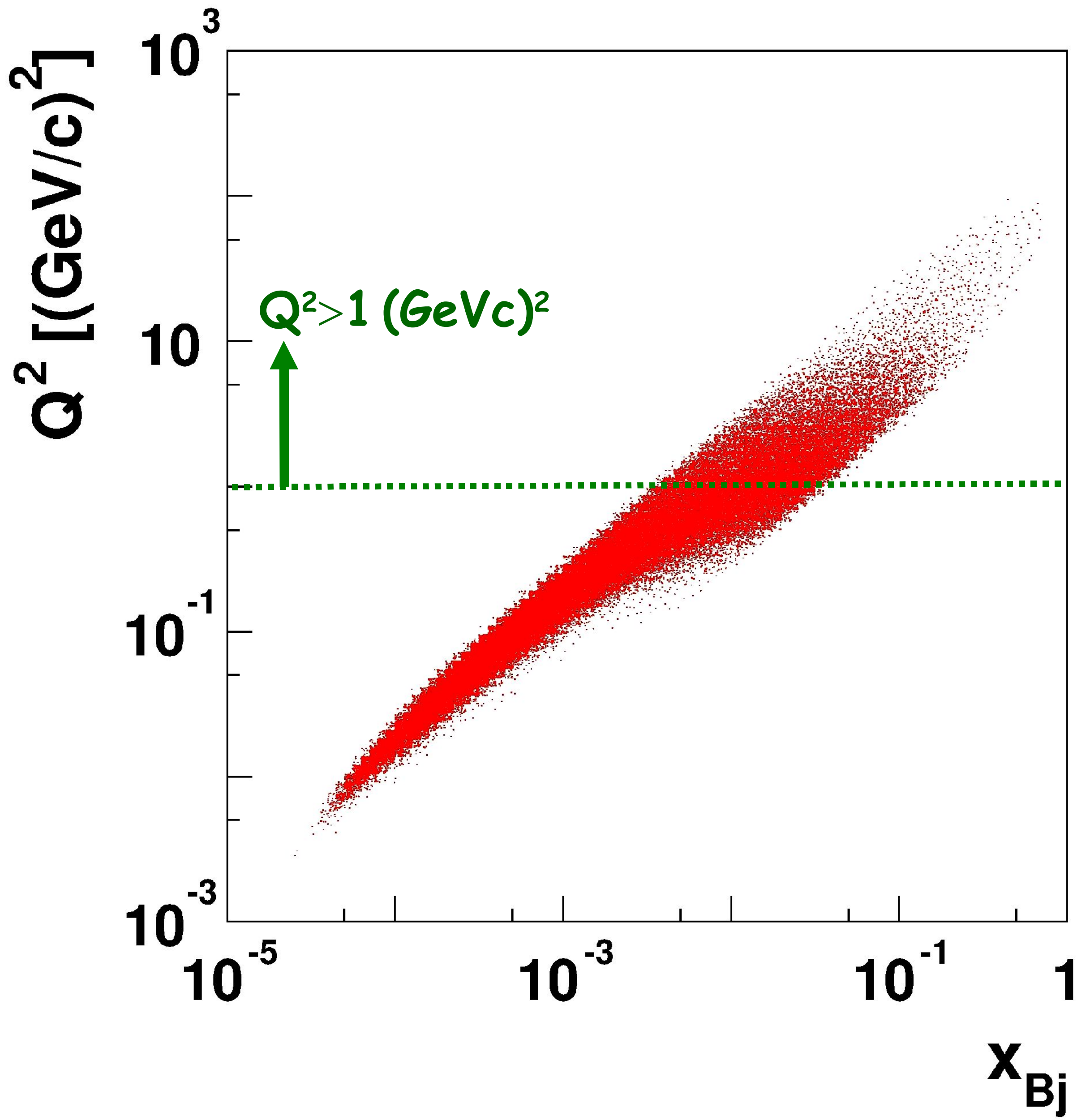
2003: 14 days of data taking
with transversely polarized ^{6}LiD target

+ 2003 trigger upgrade to gain sensitivity
on large x_{Bj} & large Q^2 events !

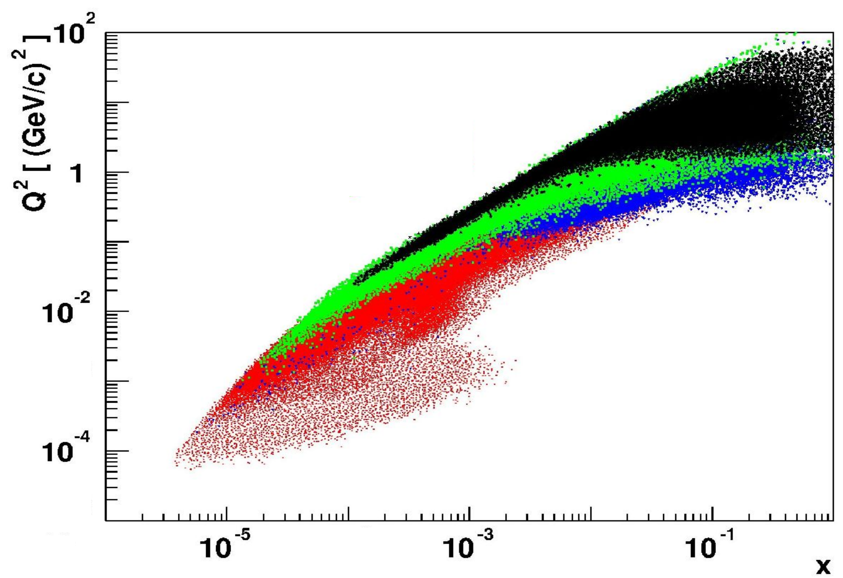
- 2002 data doubled

2004 expected: 2002+2003

Transversity Trigger



Standard trigger:

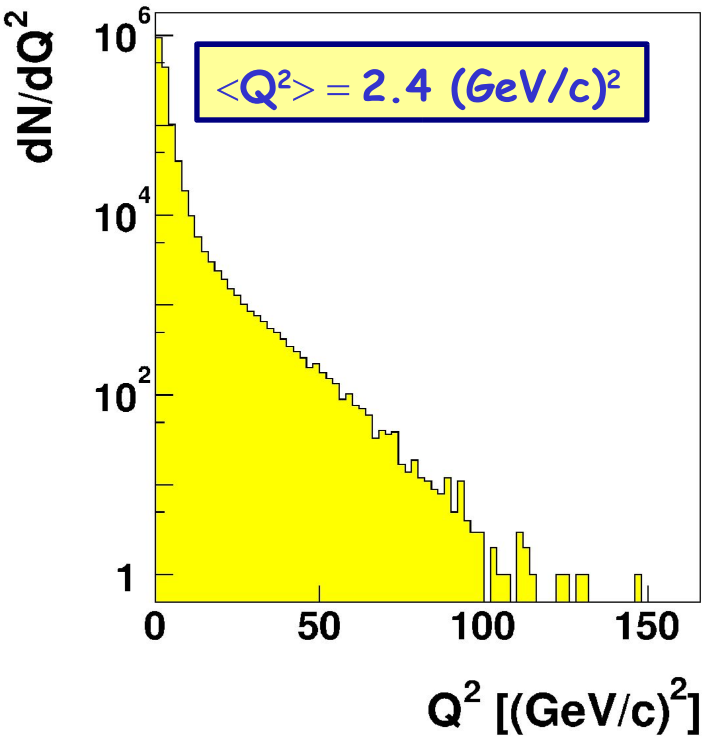


Event selection (1)

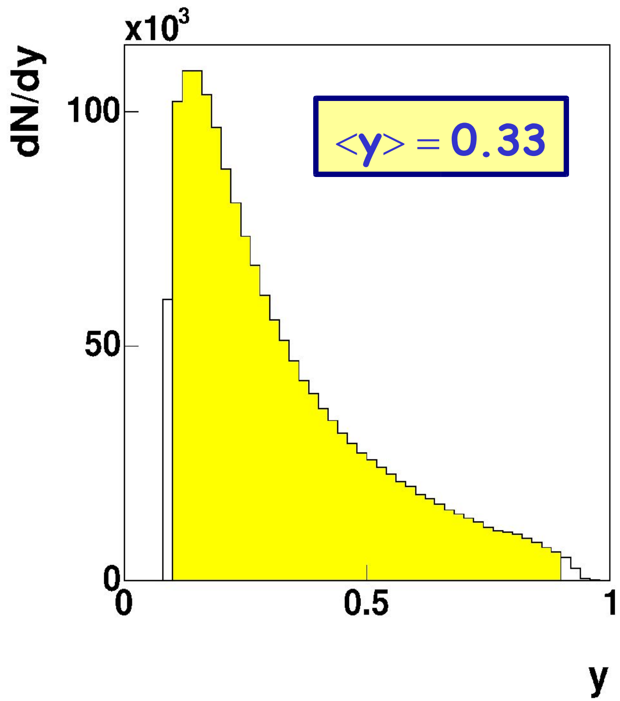
- Primary vertex with identified μ, μ' & hadron

Cuts on μ' based on kinematics:

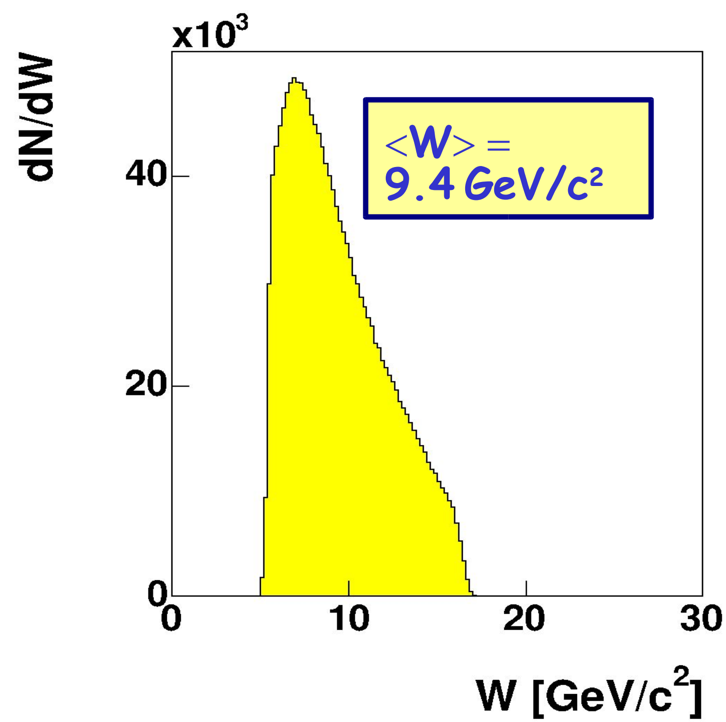
- $Q^2 > 1\ (GeV/c)^2$



- $0.1 < y < 0.9$



- $W > 5\ GeV/c^2$



Event selection (2)

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Selection of leading hadrons (lh):

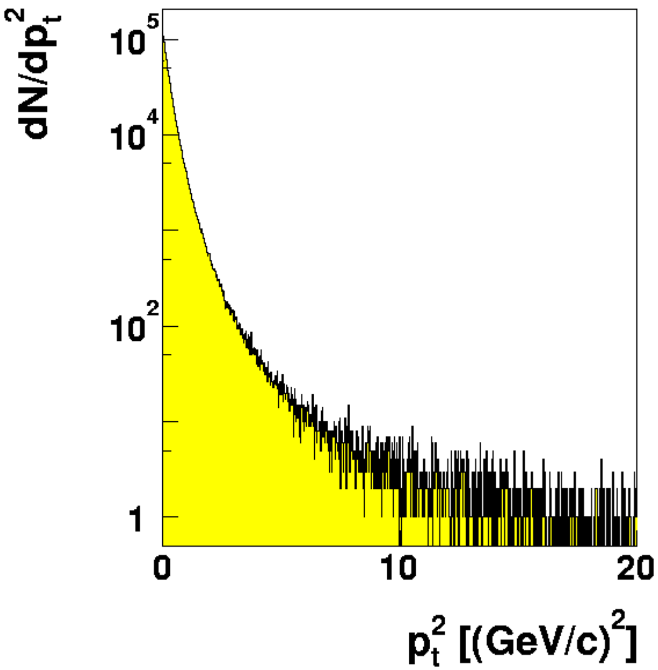
- energy deposit in hadron calorimeters > 5 GeV(HCAL 1) or > 8 GeV (HCAL 2)
- Penetration $< 10\ X_0$

Presently no π / K / p separation by RICH

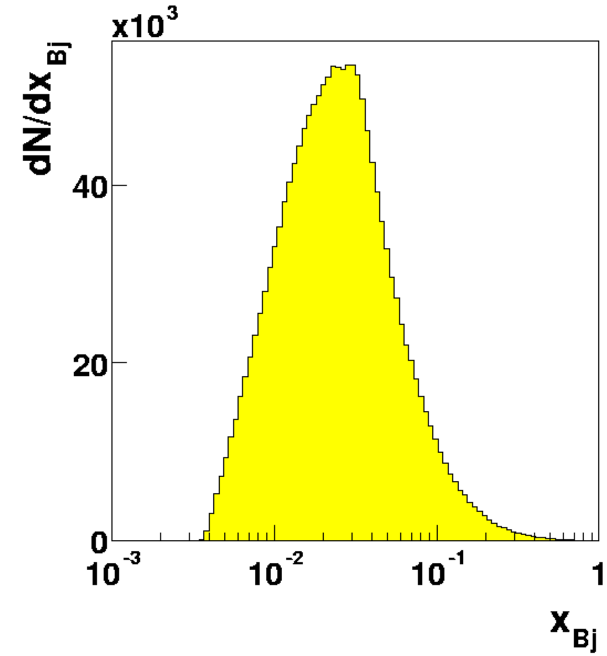
Cuts on lh based on kinematics:

- $p_T > 0.1$ GeV/c
- $z > 0.25$
- $z_{lh} > 1 - \Sigma z_i$

Final sample

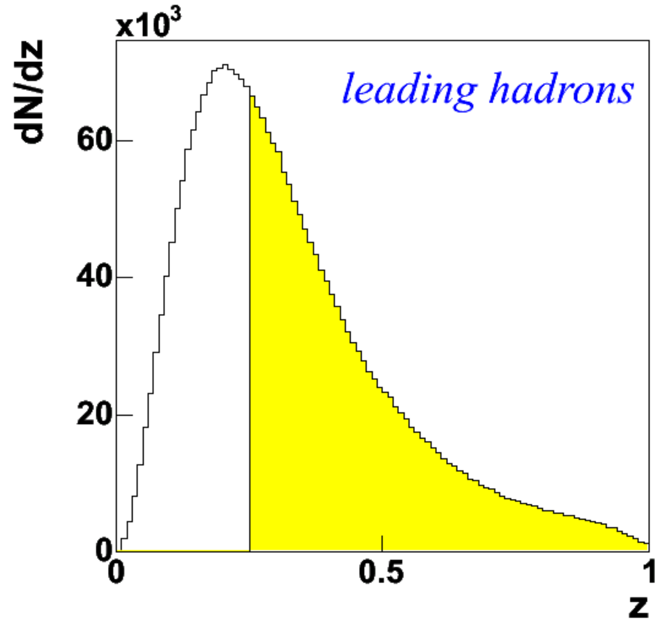


$\langle p_T^2 \rangle = 0.3$ (GeV/c)^2

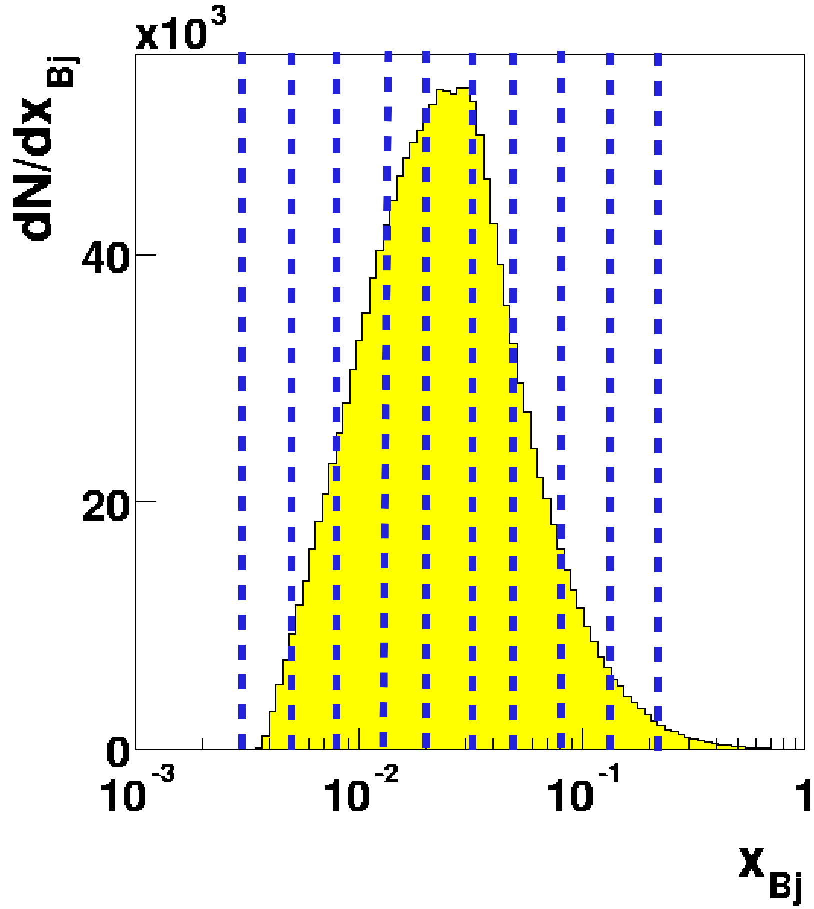


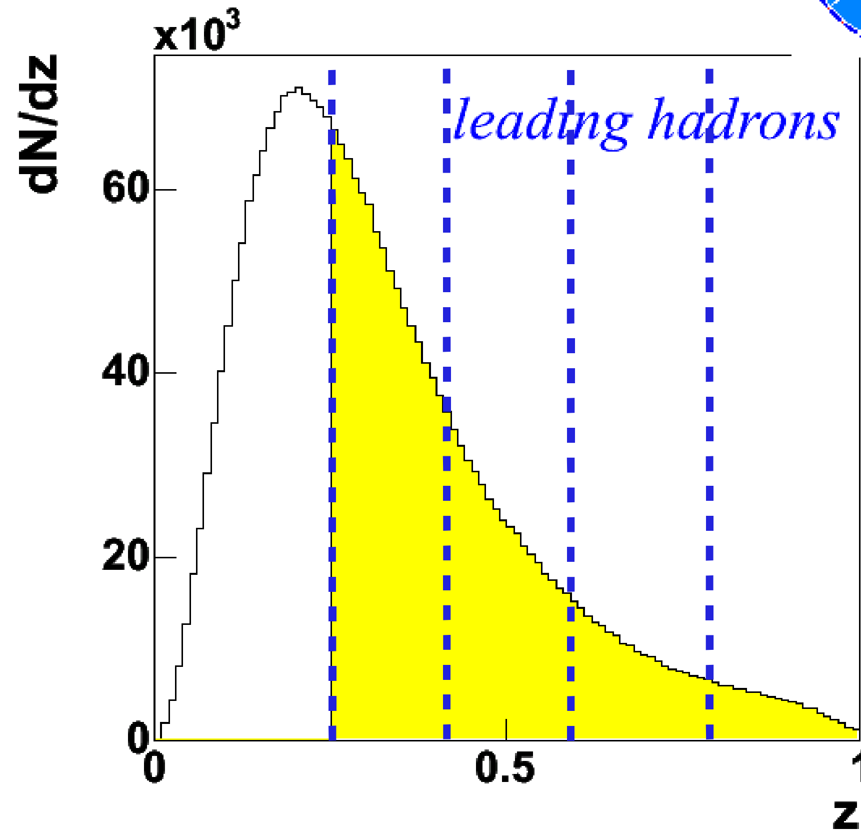
$\langle x_{Bj} \rangle = 0.035$

$\langle z \rangle = 0.45$



Final sample - binning





Final statistics:

	1st period		2nd period	
	1st orientation	2nd orientation	1st orientation	2nd orientation
cell1	187k (103/ 84)	203k (112/ 91)	102k(56/46)	173k(95/ 78)
cell2	257k (144/113)	278k (156/122)	138k(77/61)	233k(130/103)

Asymmetry calculation

COMPASS

For each polarization and target cell we measure:

$$N(\Phi_C) = N_0\{1 + A_{UT}^{\sin\phi} \cdot \sin\Phi_C\} \cdot F_{acc}(\Phi_C)$$

To cancel out the acceptance function F_{acc} we additionally measure with opposite spins and subtract the normalized data-sets.

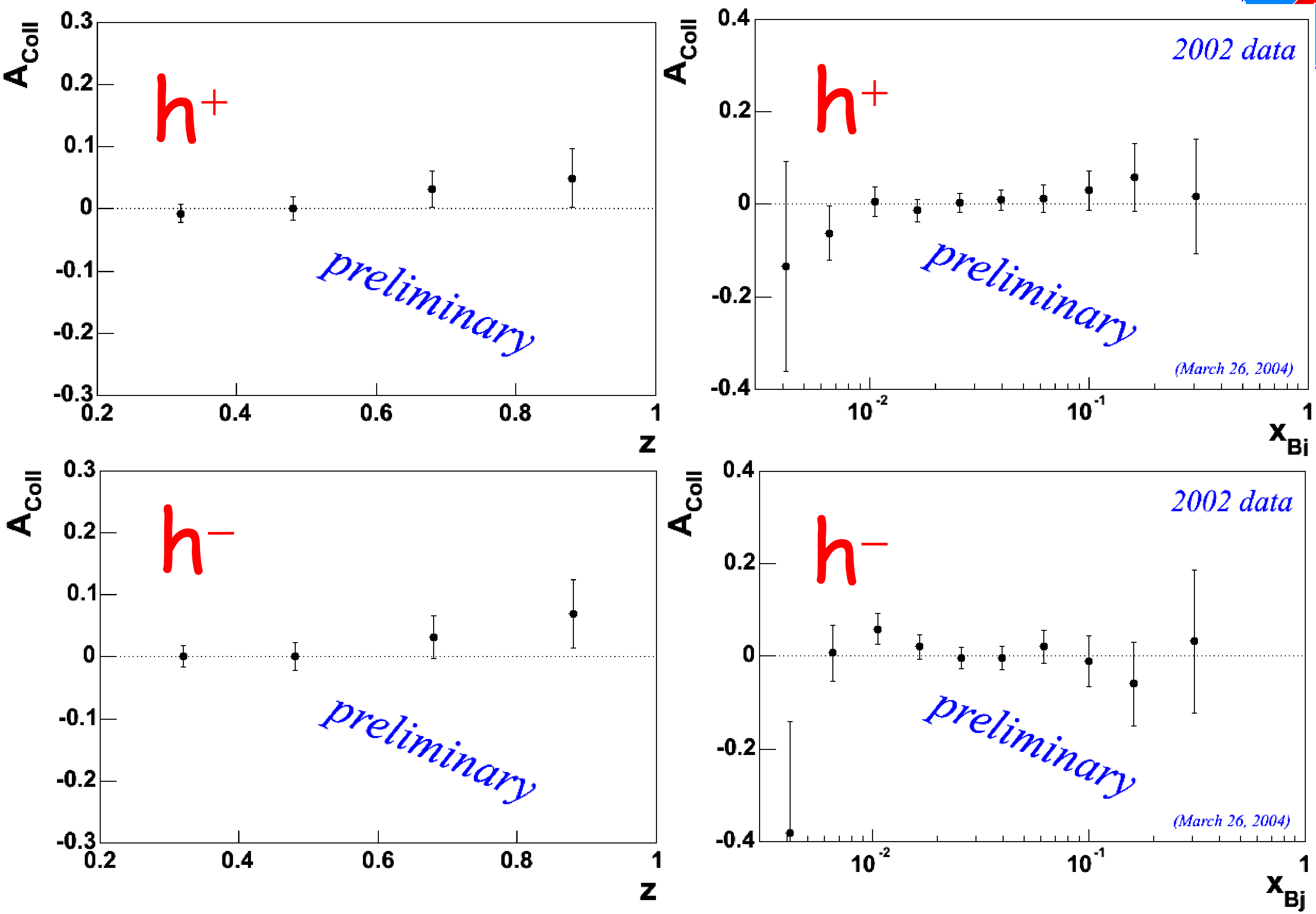
The counting rate asymmetry is then calculated for Φ_C bins by:

$$A_N(\Phi_C) = \frac{N^+(\Phi_C) - R \cdot N^-(\Phi_C)}{N^+(\Phi_C) + R \cdot N^-(\Phi_C)} \quad \text{where} \quad R = \frac{N^+_{tot}}{N^-_{tot}}$$

The result is then fitted by: $A_0 + A_{UT}^{\sin\phi} \cdot \sin\Phi_C$

So that we get: $$A_{Coll} = \frac{A_{UT}^{\sin\phi}}{D_{NN} \cdot f \cdot P}$$

Collins-Asymmetrie (Deuteron)

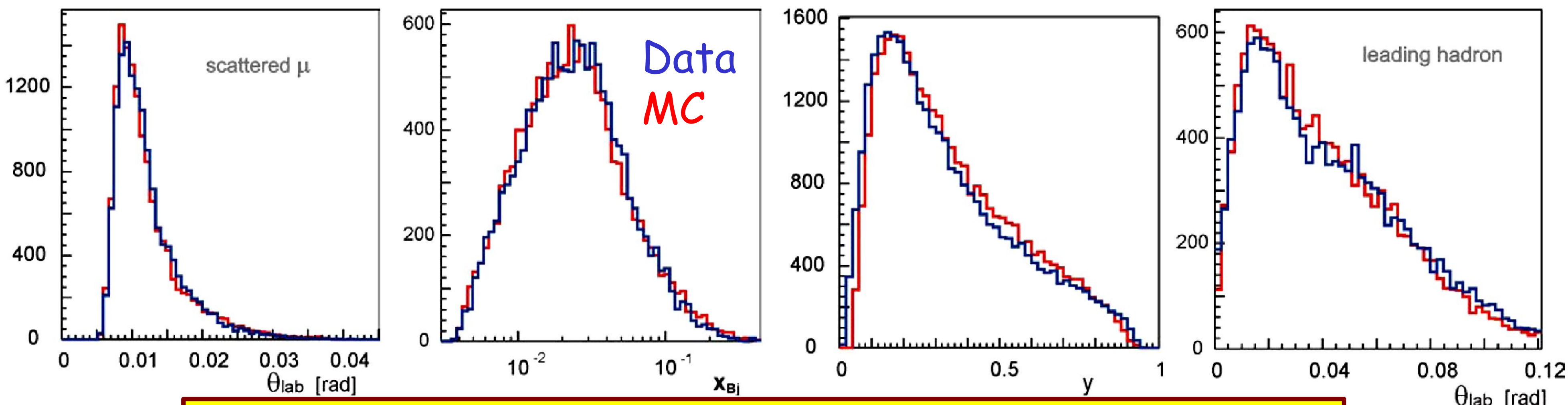


Monte Carlo studies (1)

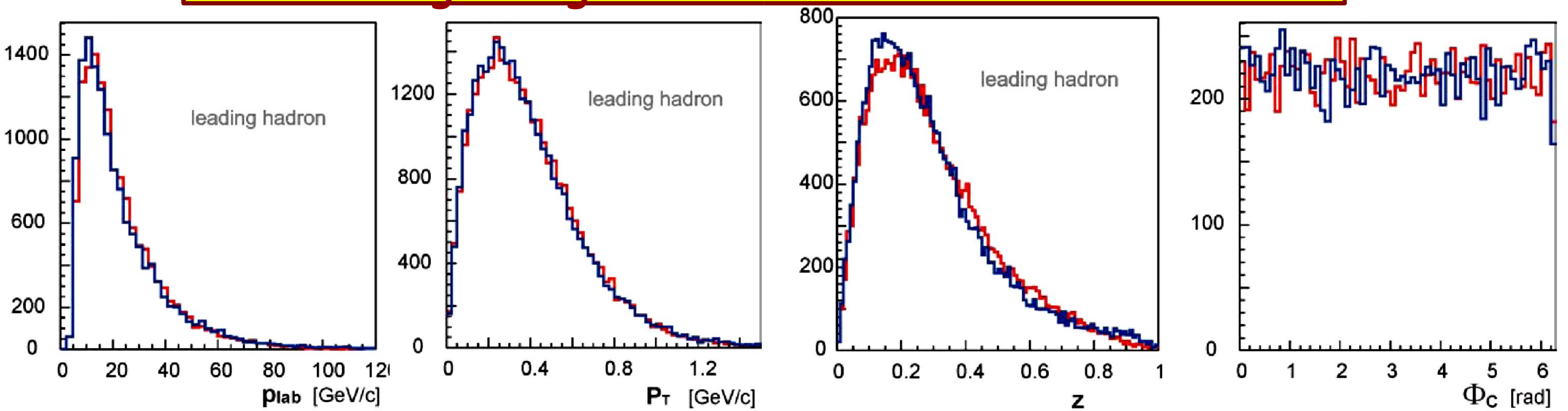
- MC events generated with Lepto 6.5.1

☑ Trigger geometry

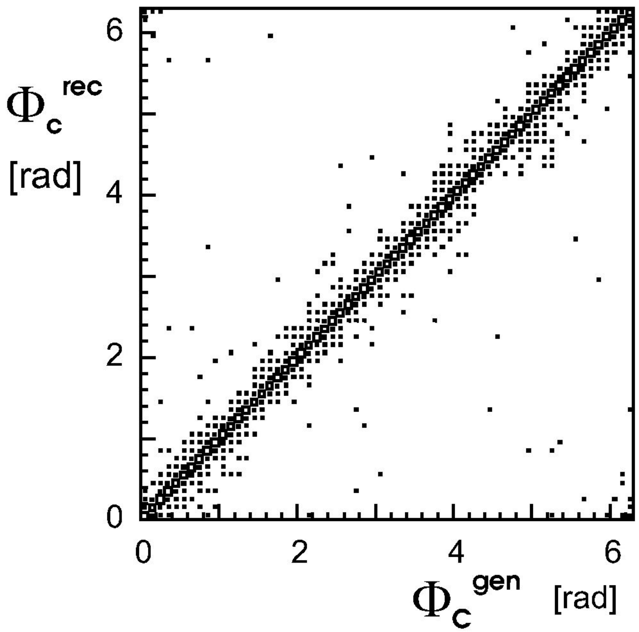
☑ Tracking efficiencies

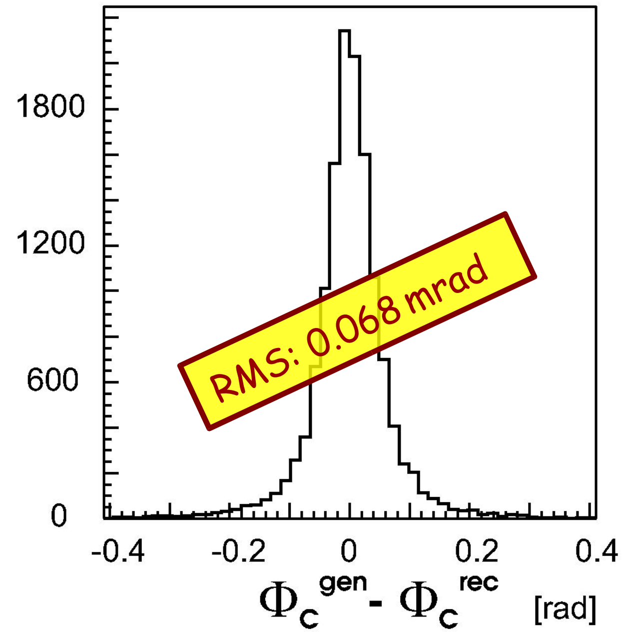


☑ **Overall good agreement between MC and real data**

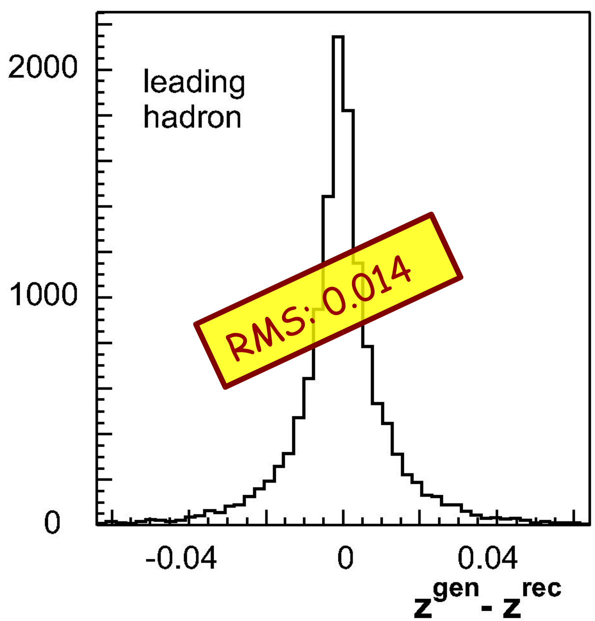


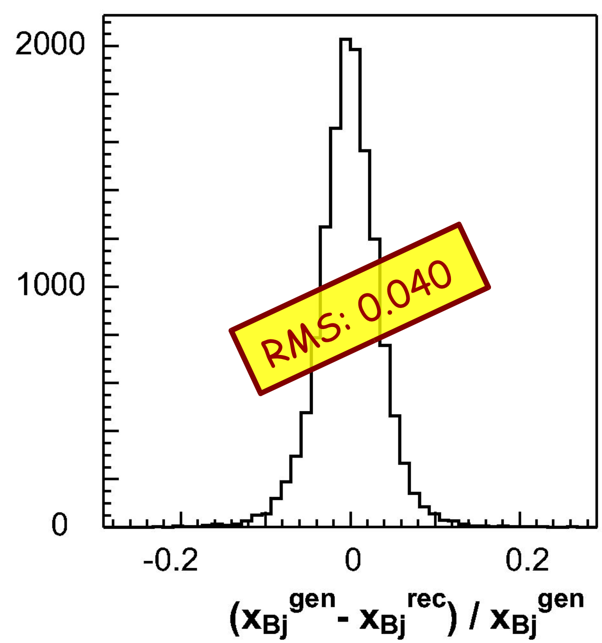
Monte Carlo studies (2)

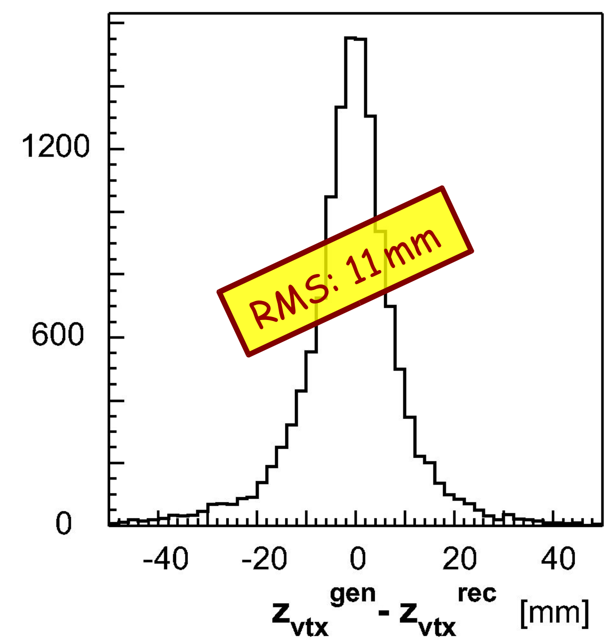




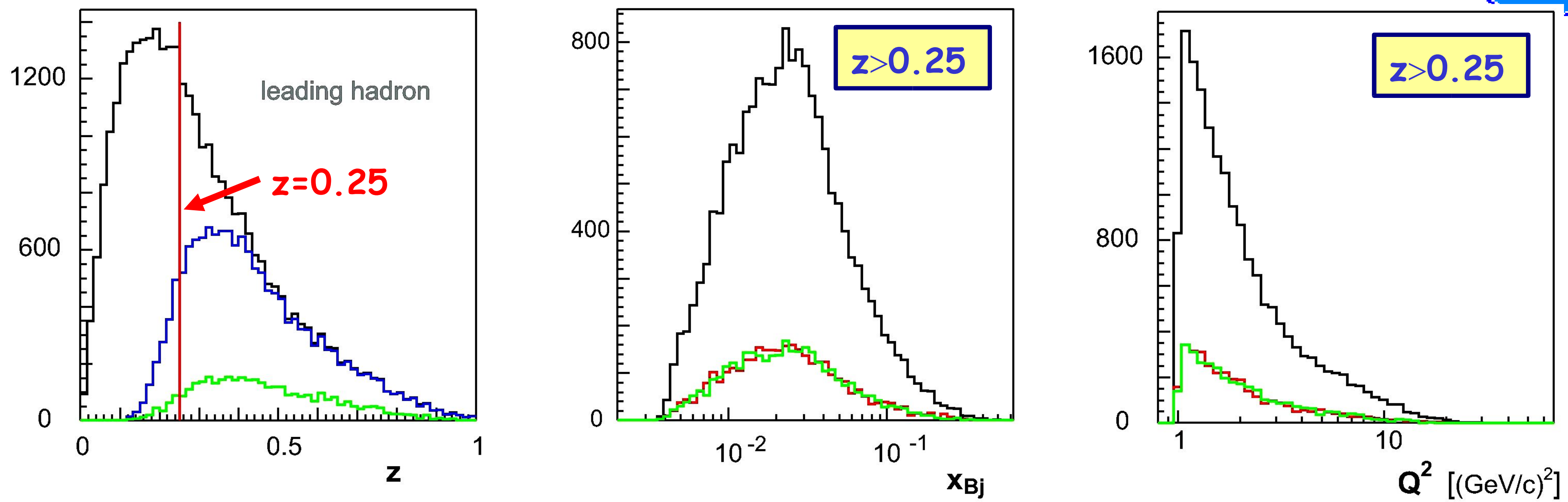
No signal dilution due to finite resolution!







Contamination of non-leading hadrons



all reconstructed hadrons

correctly reconstructed leading hadrons

correctly reconstructed leading hadron, but leading hadron is not π

~20% of the final sample, mainly K and p

(RICH analysis not applied to data presented today)

wrongly reconstructed leading hadrons

~20% of the final sample (probably smaller in the data because cuts on HCAL & $z_{lh}>1-\Sigma z_i$ not applied to MC events)

Stability checks

Tests performed:

- The ratio of the acceptances and efficiencies for both target cells vs. Φ_C does not change between two spin orientations

- The results were stable under the following actions:
  - Splitting the target cells in two parts
  - Splitting the data in high and low hadron momenta
  - Using a different method to extract $A_{UT}^{\sin\Phi}$
  - Changing the Φ_C binning

Conclusion:

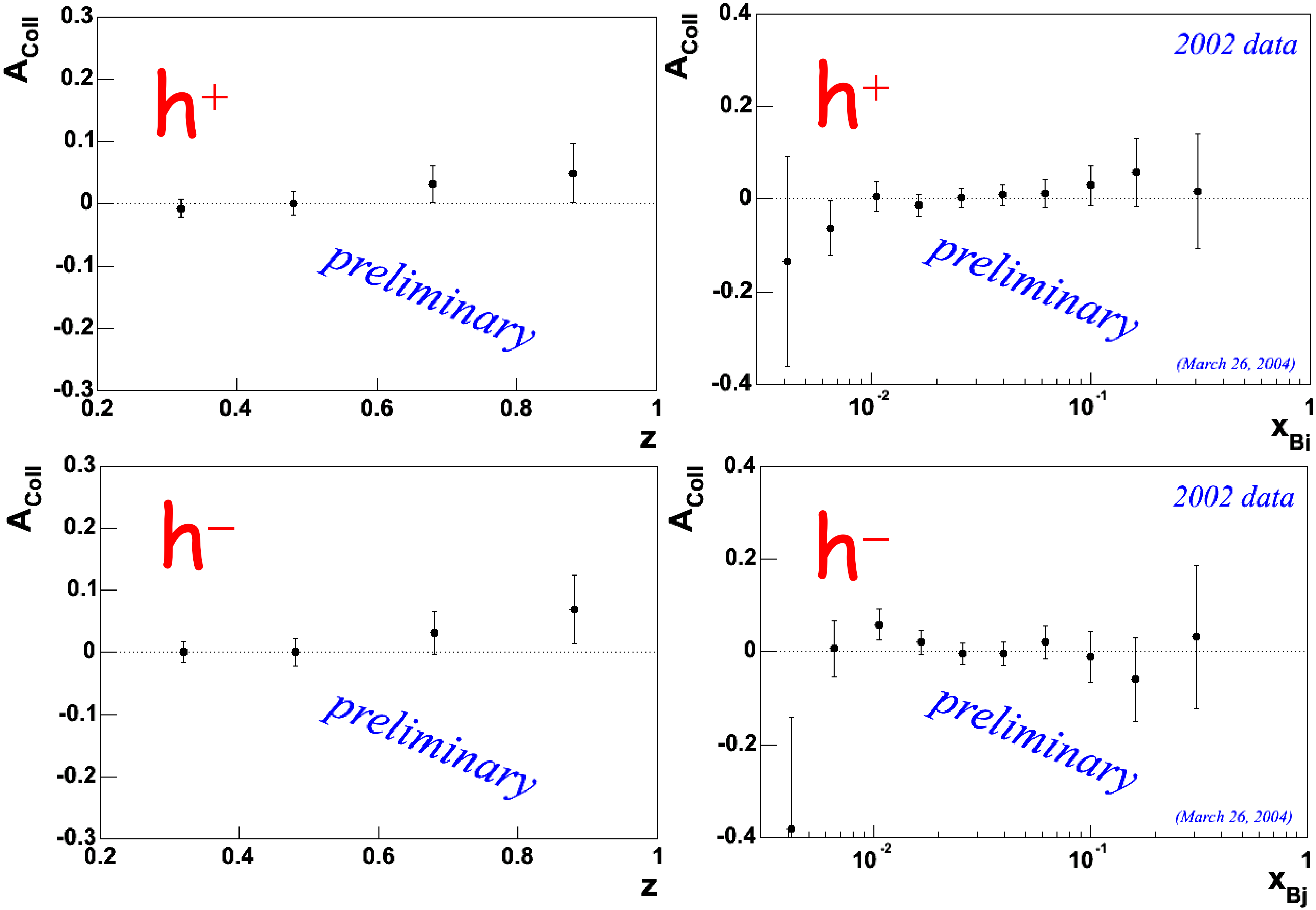
The results are stable with systematic effects smaller than the statistical errors !

Conclusion & Outlook

- A first measurementof Collins asymmetries has been performed with a polarized deuteron (^{6}LiD) target.
- The measured asymmetries are very small and compatible with the current statistical errors.
- Including 2003 & 2004 data
  → sensitivity improvement by factor >2 expected
- Extract Sivers asymmetries from our data
- Systematic investigations of Collins asymmetries for all sub-leading hadrons still to be done
- Extract Collins asymmetries using independent quark polarimeters (Λ, leading hadron&next-to-leading hadron plane)

Many results on transverse spin physics can be expected from COMPASS in the next future

Collins-Asymmetrie (Deuteron)



END of talk