International Workshop on Transversity:
New Developments in Nucleon Spin Structure

Transversity Measurements at COMPASS

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on behalf of the

COMPASS Collaboration

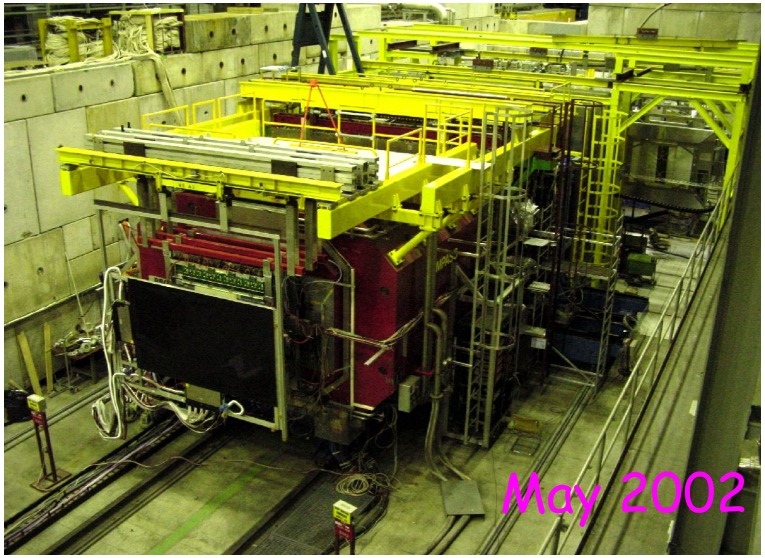
ECT*, Trento, June 13-18

COMPASS – History

COMPASS:

<u>THE</u> 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
- 2005 no beam (LHC installation)
- In long range planning @CERN at least until 2010

The COMPASS Collaboration
(230 Physicists from 12 Countries)

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

Lisboa

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

Warsaw (SINS), Warsaw (TU)

Prag

CERN

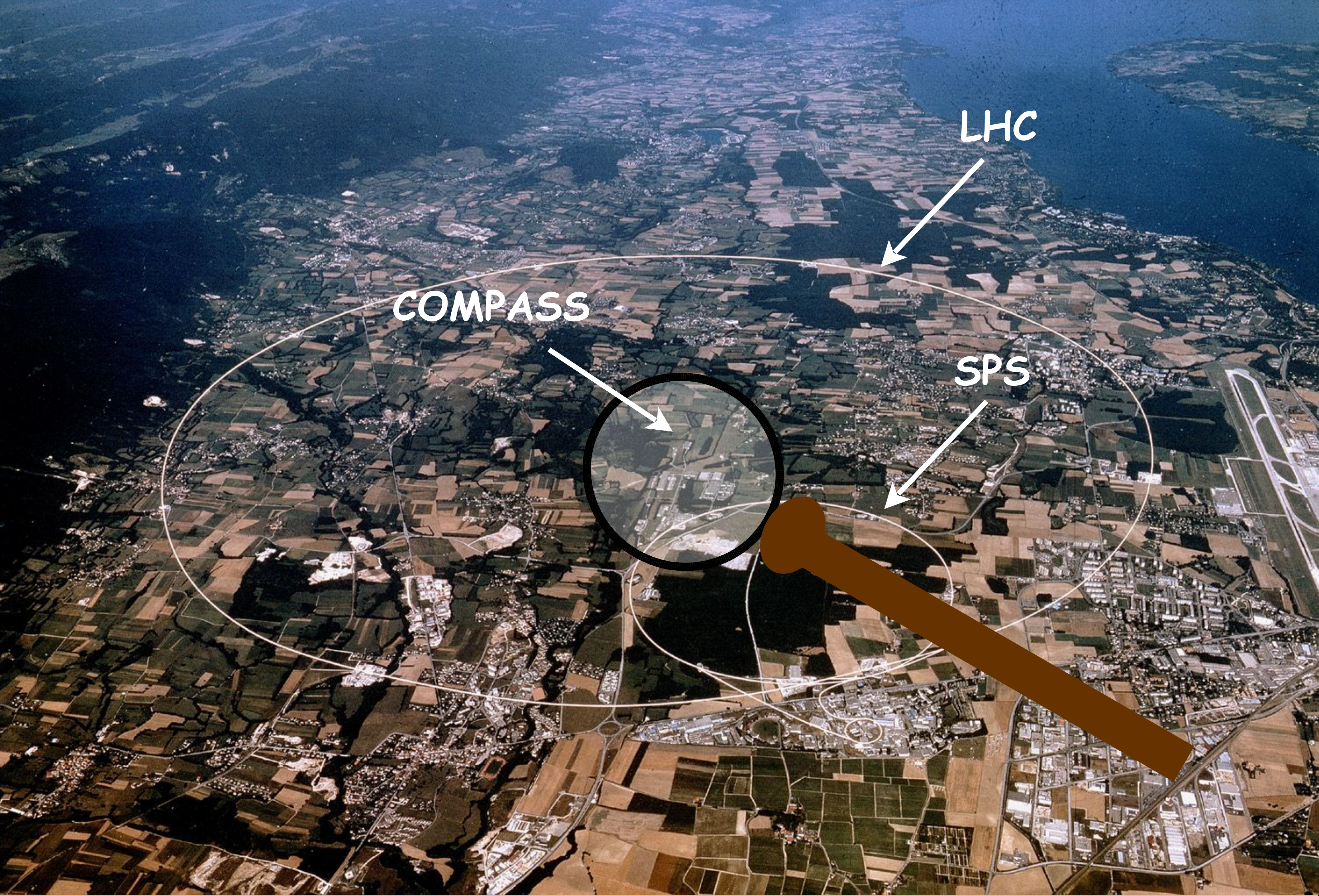
Nagoya

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

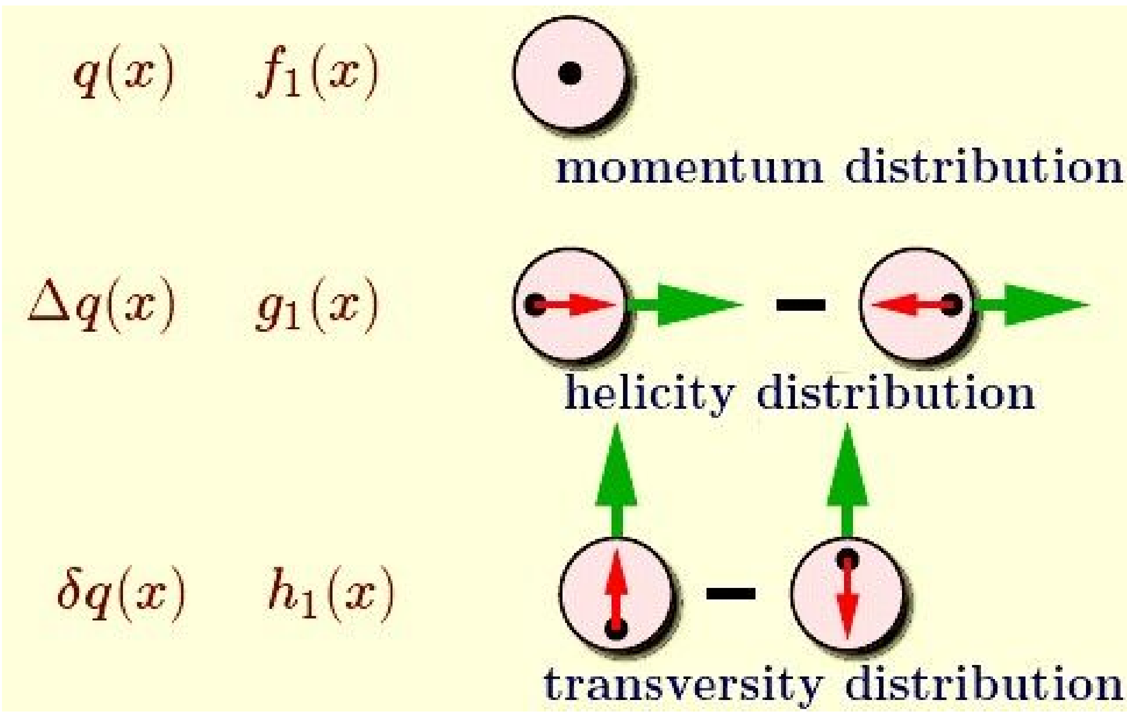
- **Gluon Polarization $\Delta G/G$**
- **Transverse spin structure function $h_1(x)$**
- Flavor dependent polarized Quark helicity densities $\Delta q(x)$
- Spin dependent fragmentation functions ΔD^{Λ}_{q}
- Diffractive VM-Production

Nucleon spectroscopy

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

Transverse Spin Physics

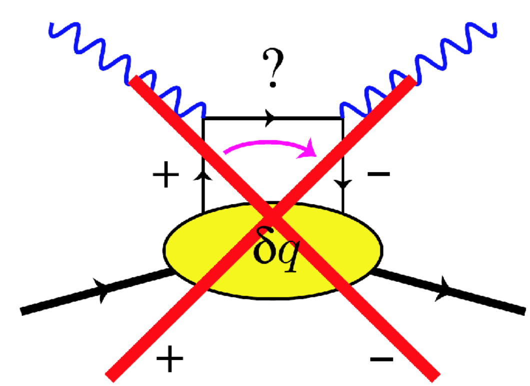
3 distribution functions are necessary to describe the spin structure of the nucleon at LO:



All of equal importance!

$h_1(x)$ decouples from leading twist DIS because helicity of quark must flip

No mixture with Gluons in evolution - Valence like behavior



Transverse Spin Physics

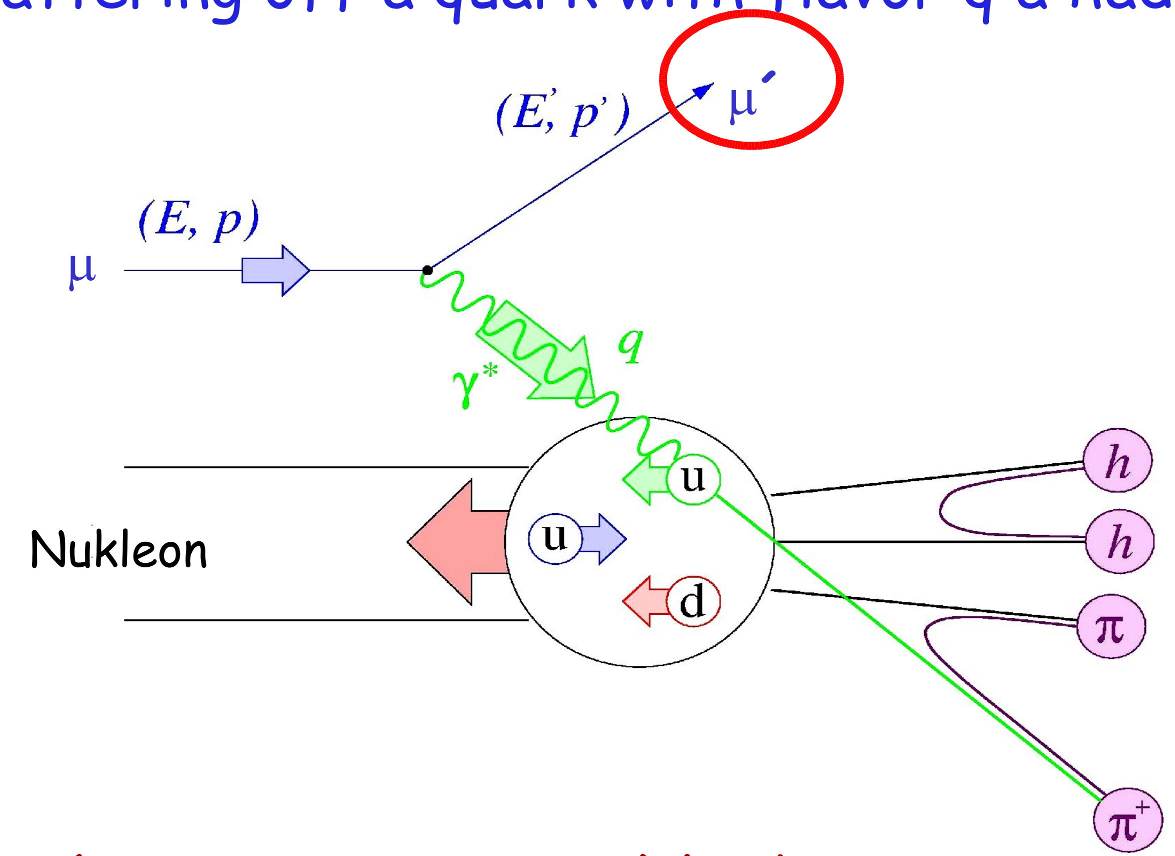
3 possible quark polarimeters suggested:

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

Transverse Spin Physics

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!

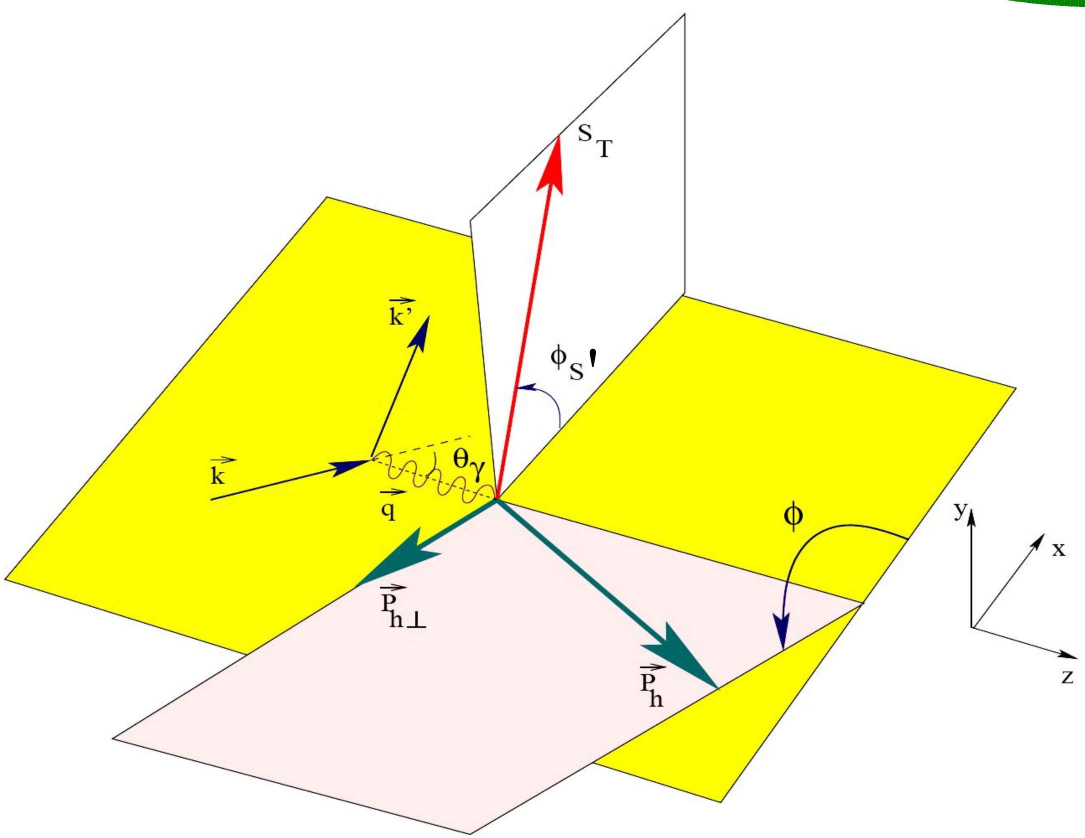
Transverse Spin Physics

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

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

Φ_C = Collins angle

spin dependent part



With $z = E_h/(E_\mu - E_{\mu'})$

and in the Breit system:

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

ϕ_h = azimuthal angle of hadron

$\phi_C = \phi_h - \phi_{S'} = \phi_h + \phi_S - \pi$

Measuring method

With one given polarization we measure:

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

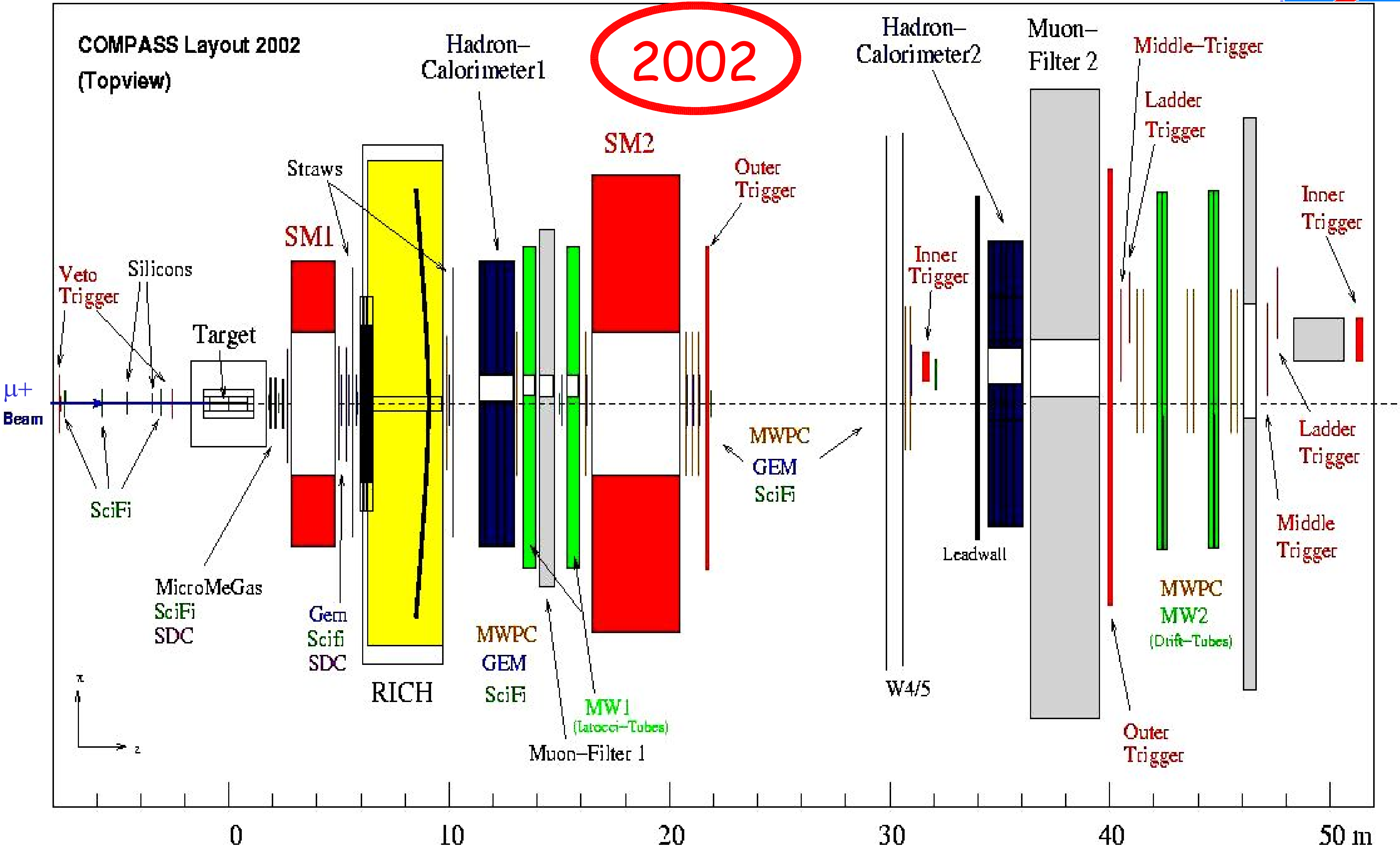
To get rid of the acceptance function F_{acc} we measure with opposite spins and subtract the normalized data-sets.
The acceptance cancels if it was stable during the data taking periods.

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

From this we get $$\frac{A_{UT}^{\sin\phi}}{D_{NN} \cdot f \cdot P} = A_{Coll} \propto \frac{\sum_q e_q^2 h_1^q(x,Q^2) \cdot H_1^{\perp(1)q}(z,Q^2)}{\sum_q e_q^2 f_1^q(x,Q^2) \cdot D_1^q(z,Q^2)}$$

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

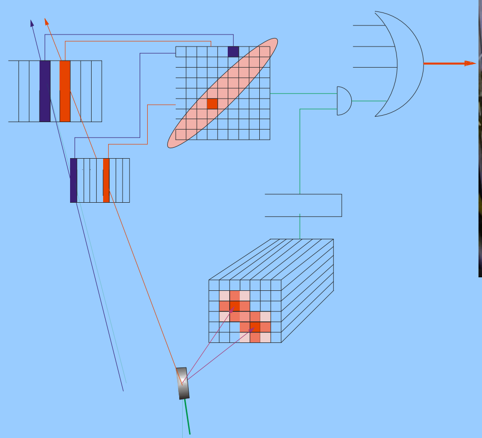
Das COMPASS Experiment



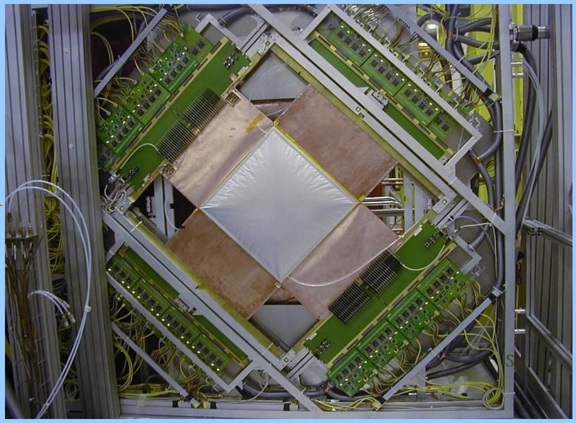
Beam: $2 \cdot 10^{8}$ μ^{+}/ spill (4.8s / 16.2s)
Luminosity: $\sim 5 \cdot 10^{32}$ cm^{-2} s^{-1}

Beam momentum: 160 GeV/c
Beam polarization: -76%

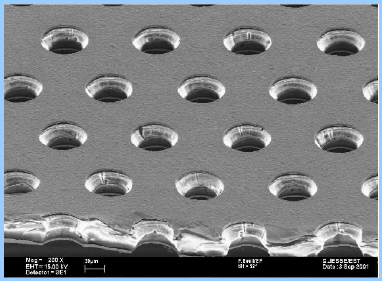
Many new technologies for tracking and PID



Trigger-System

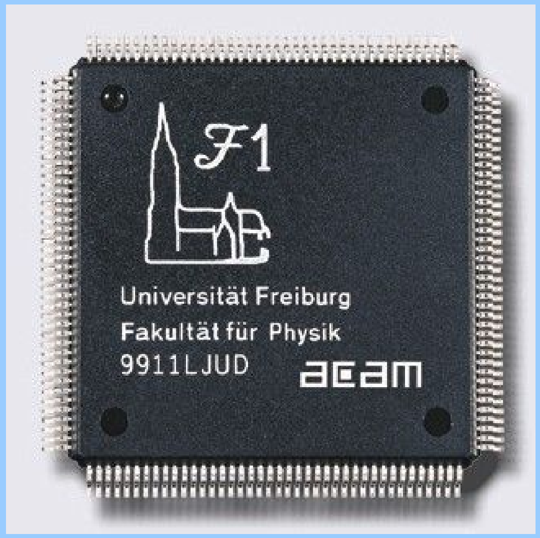


MicroMegas

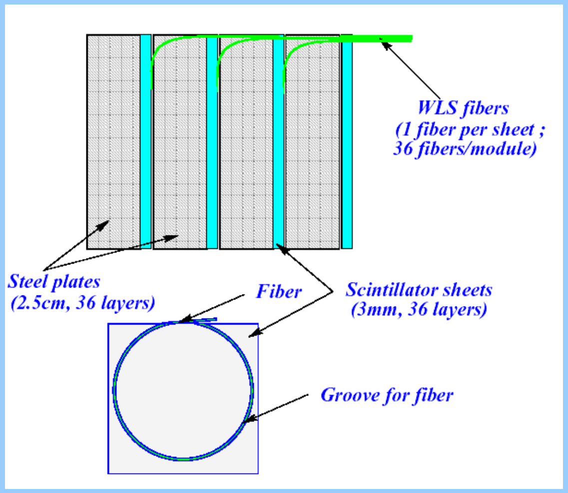


GEM

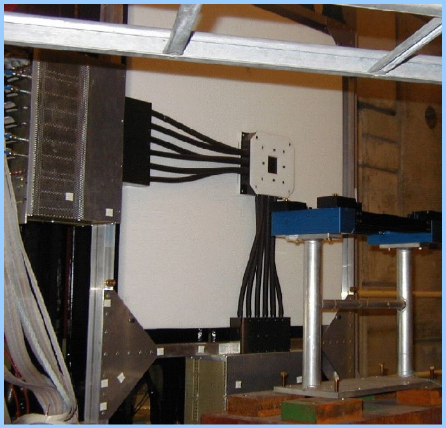
Straws



Readout electronics

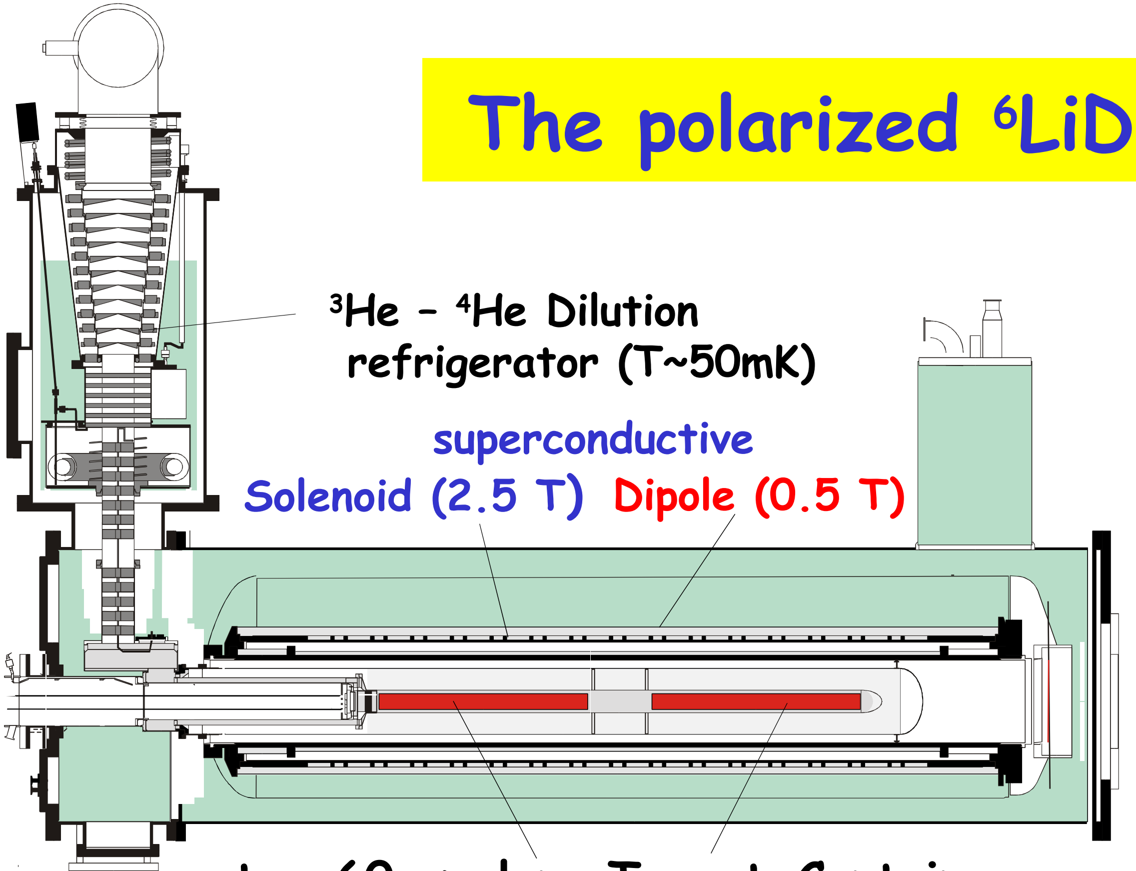


calorimeter readout



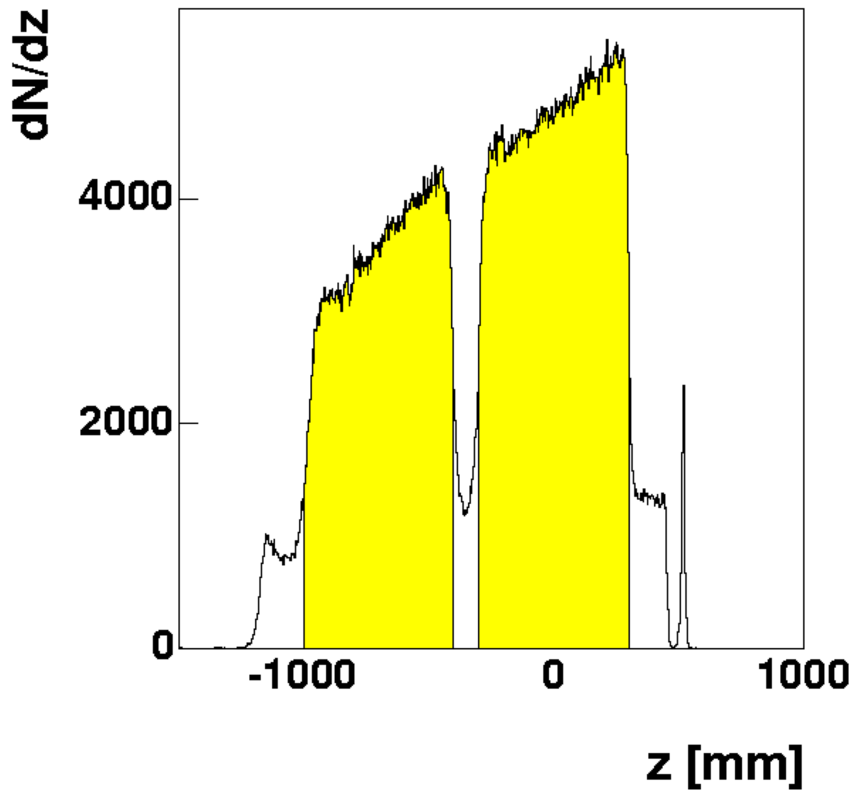
Scintillating fiber trackers

The polarized ^{6}LiD-Target



Polarization: 50%

Dilution factor: 0.38



During data taking for transversity

dipole field always on and ↑

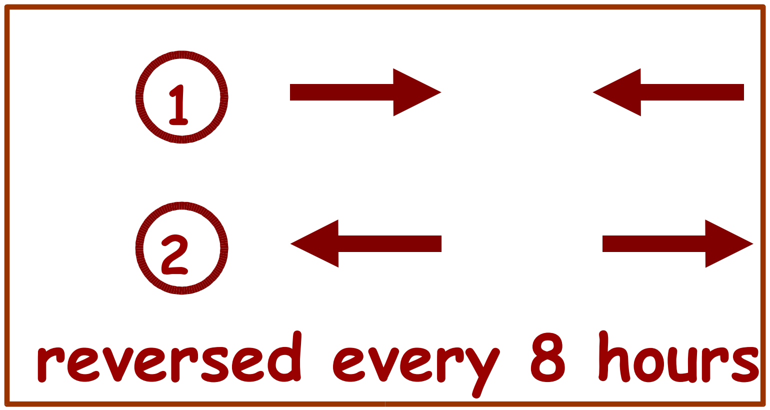
Relaxation time:

longitudinal running » measurable

transversal running > 2000 hrs

The polarized ^{6}LiD-Target

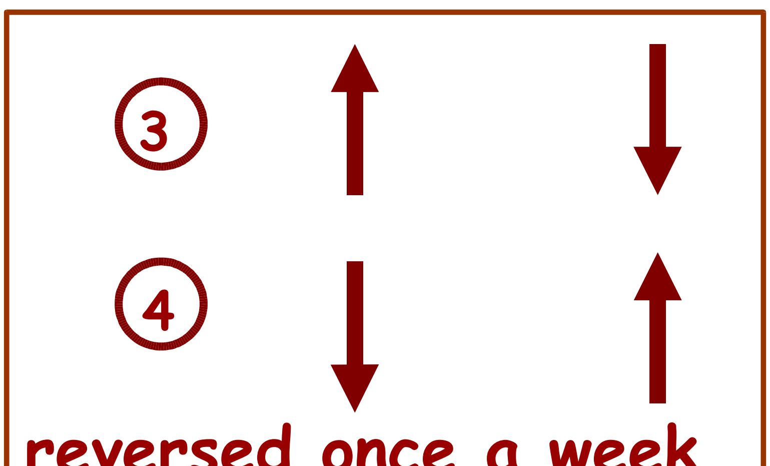
4 possible spin combinations:



Longitudinal running:

changed by field rotation

(~ 20 min)

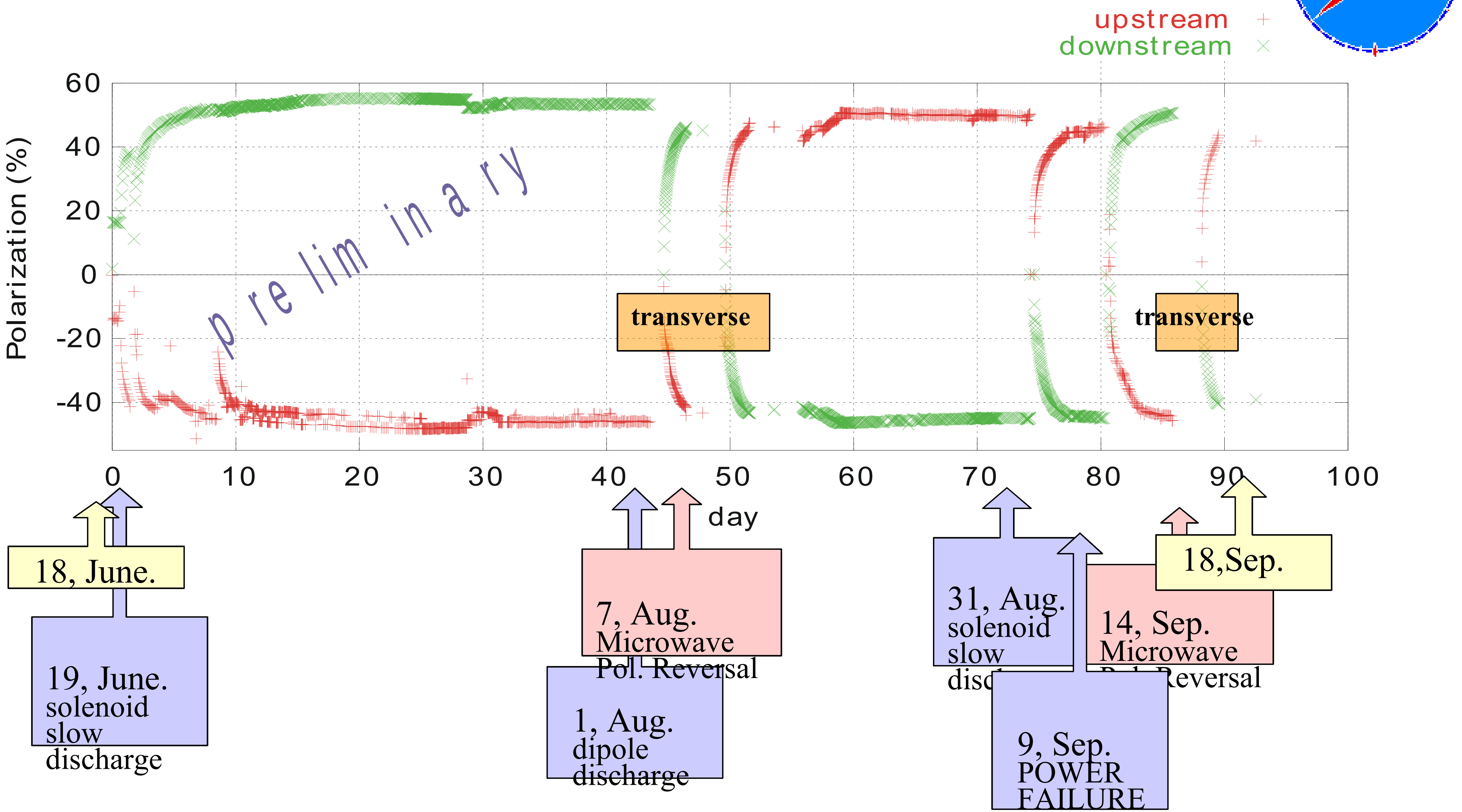


Transversal running:

changed by microwave reversal

(~ 24 h)

^{6}LiD-Target-Polarization 2002



Polarization: +56%, -47%

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)

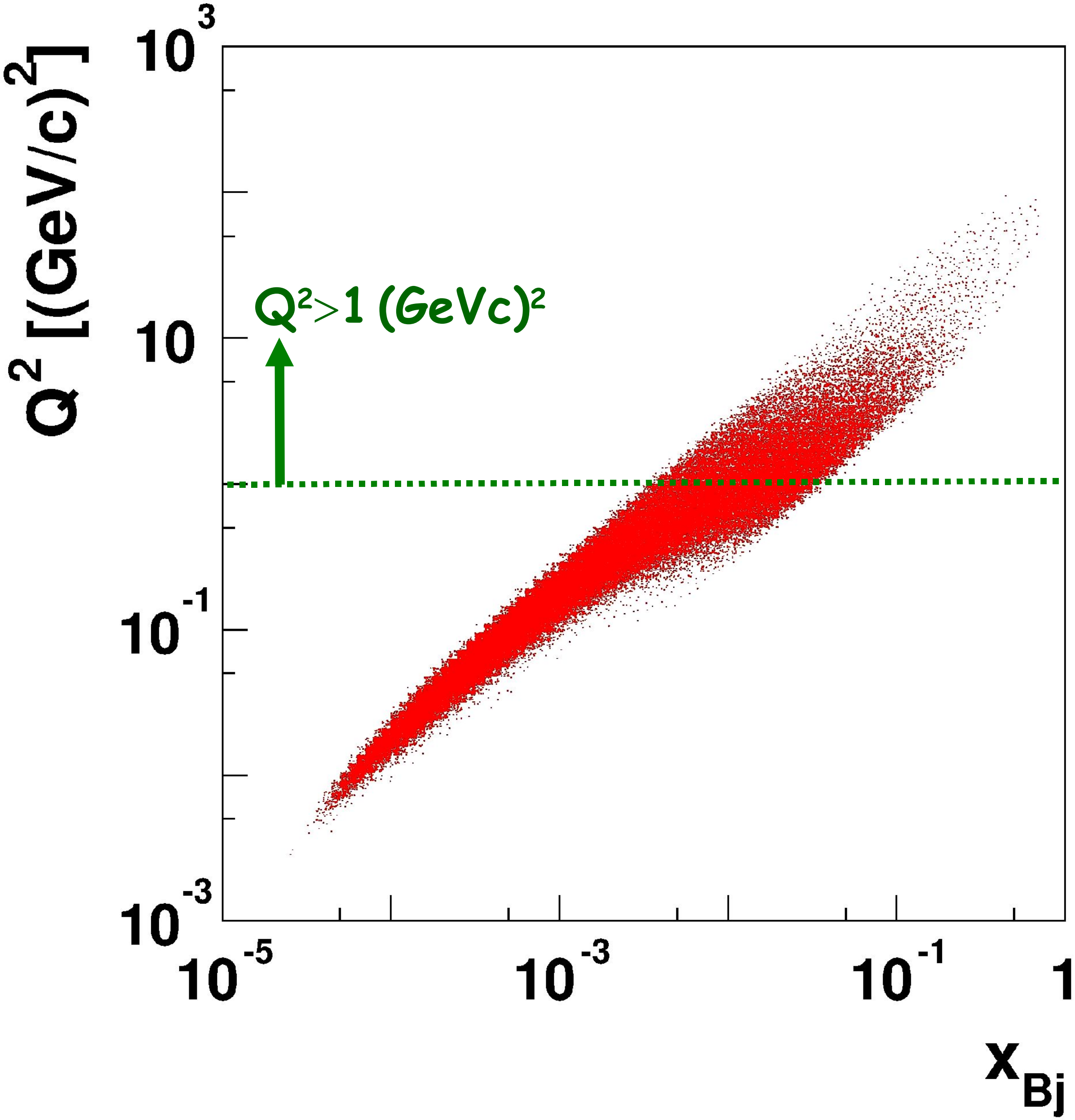
2003: 14 days of data taking
with transversely polarized ^{6}LiD target

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

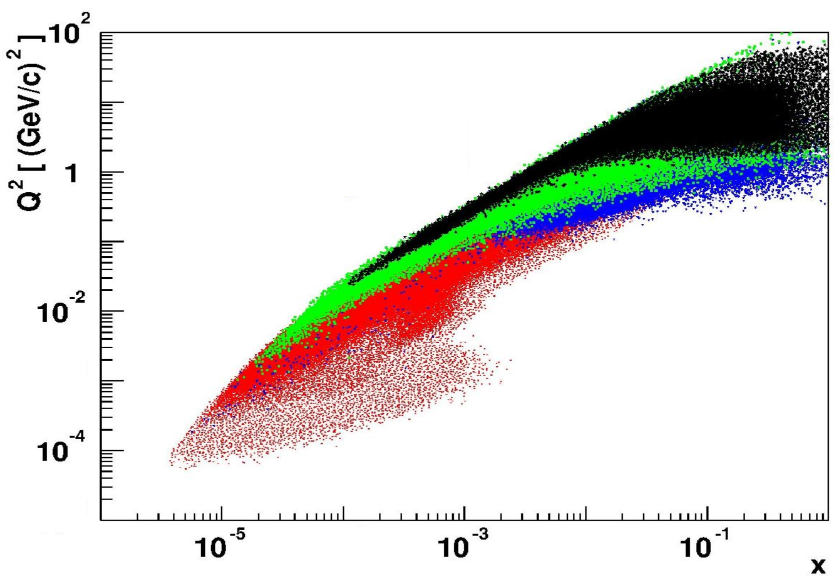
- 2002 data doubled

2004 expected: 2002+2003

Transversity Trigger



Standard trigger:

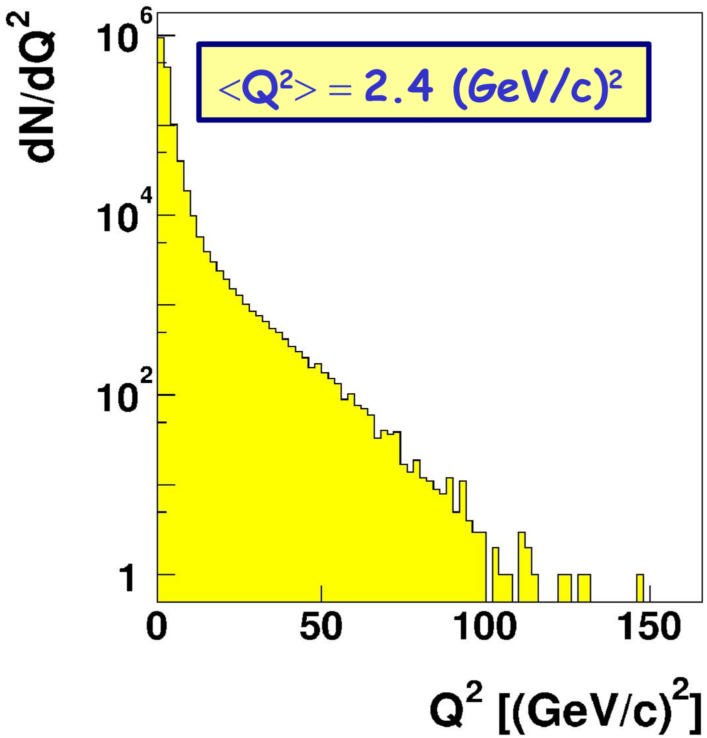


Event selection (1)

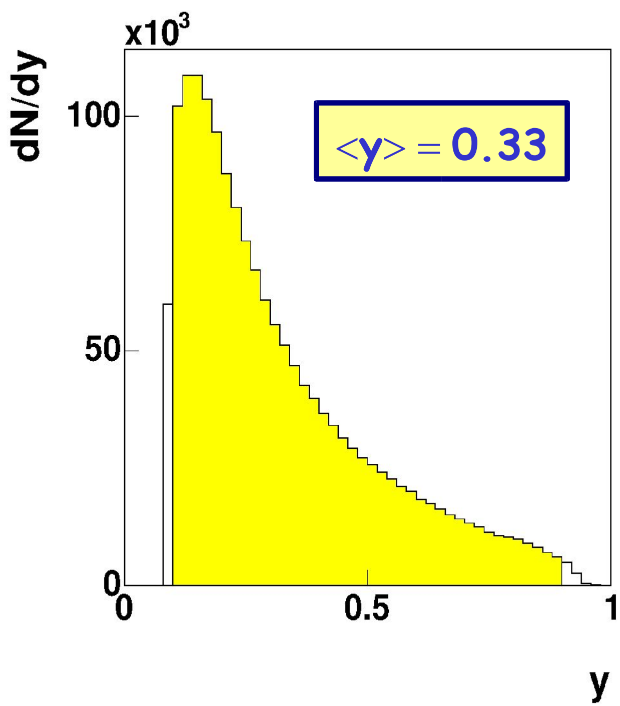
- Primary vertex with identified μ, μ' & hadron

Cuts on μ' based on kinematics:

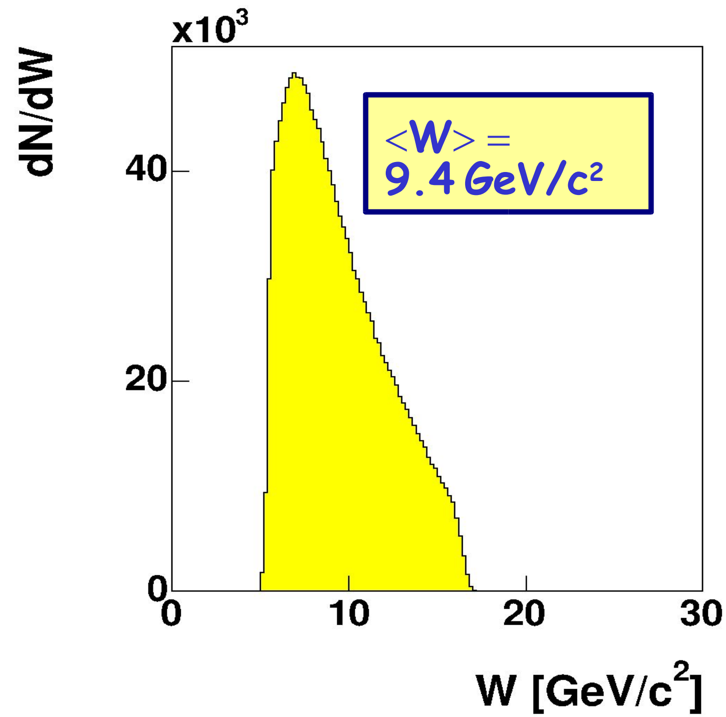
- $Q^2 > 1$ (GeV/c)^2



- $0.1 < y < 0.9$



- $W > 5$ GeV/c^2



Event selection (2)

COMPASS

Selection of leading hadrons (lh):

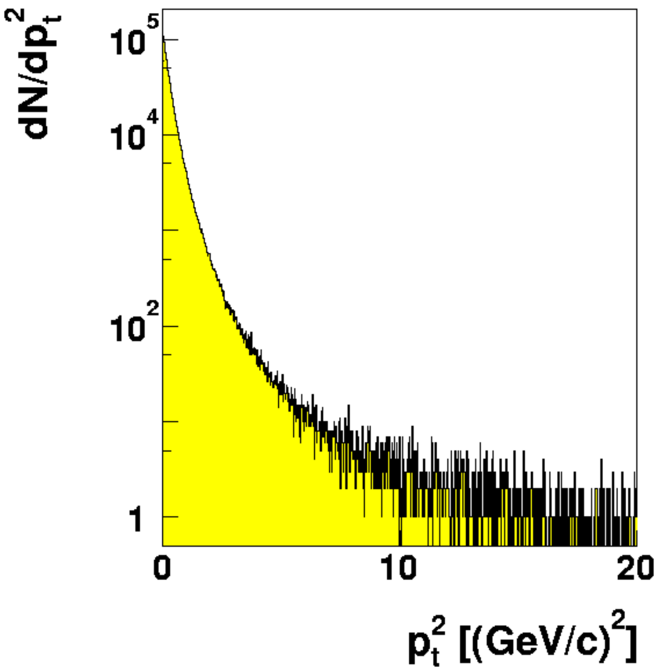
- energy deposit in hadron calorimeters
  > 5 GeV(HCAL 1) or > 8 GeV (HCAL 2)
- Penetration $< 10\ X_0$

Presently no π / K / p separation by RICH

Cuts on lh based on kinematics:

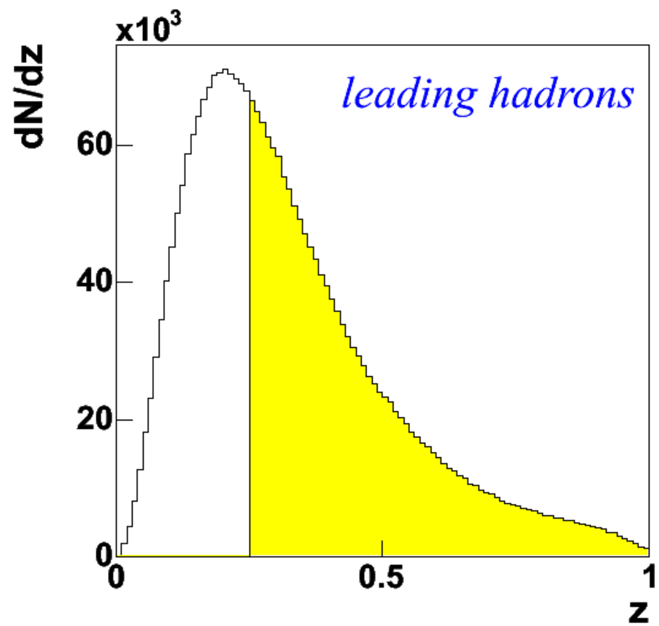
- $p_T > 0.1$ GeV/c
- $z > 0.25$
- $z_{lh} > 1 - \Sigma z_i$

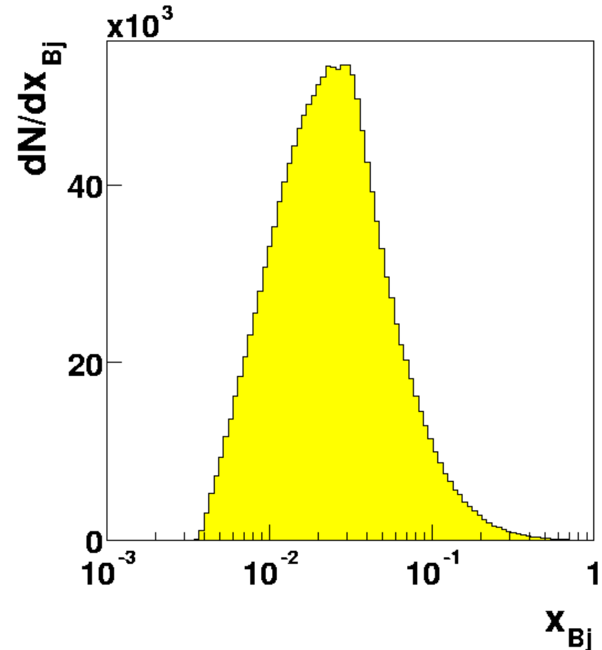
Final sample



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

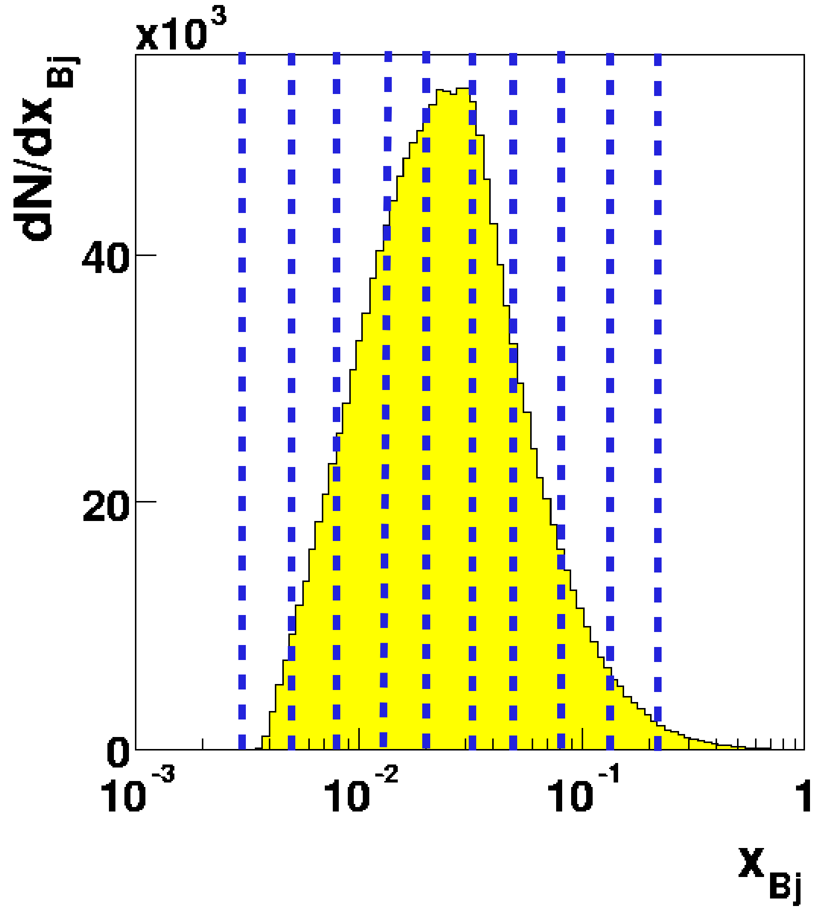
$\langle z \rangle = 0.45$

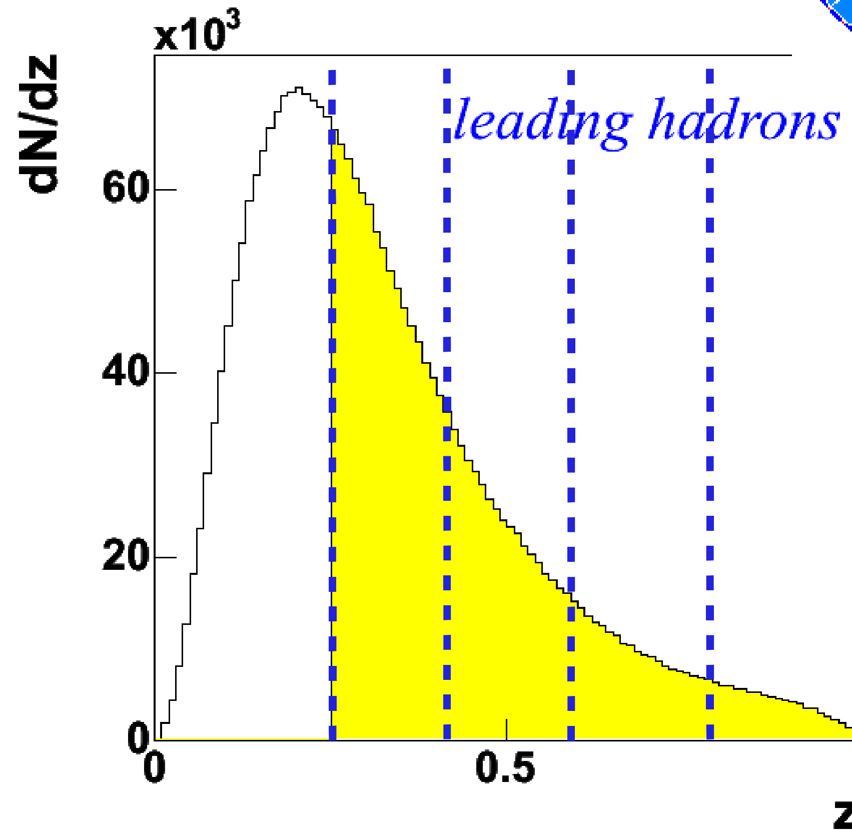




$\langle x_{Bj} \rangle = 0.035$

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

The asymmetry is calculated seperately for positive and negative leading hadrons in the 10 x_{Bj} and 4 z bins.

The counting rate asymmetry is 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: $A_0 + A_{UT} \cdot \sin\Phi_C$

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

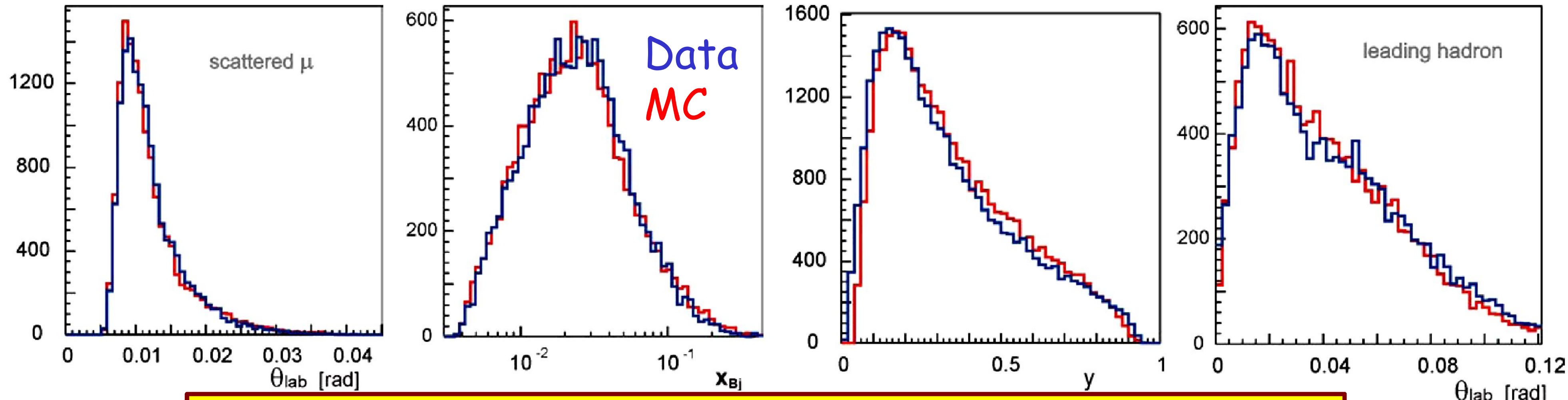
This was done for each data taking period and each target cell
The single results were finally averaged.

Monte Carlo studies (1)

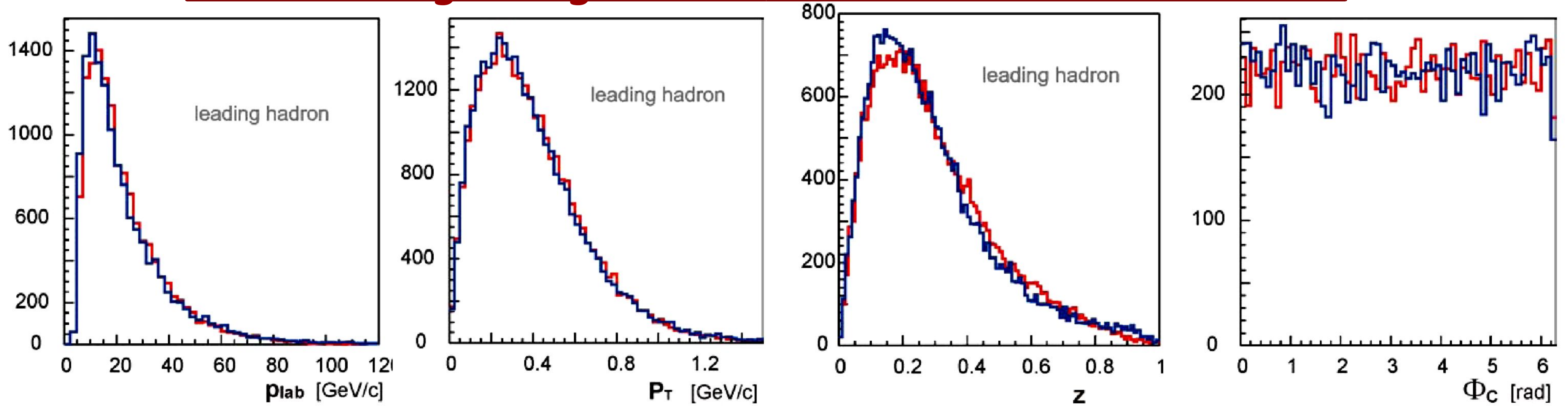
- MC events generated with Lepto 6.5.1

☑ Trigger geometry

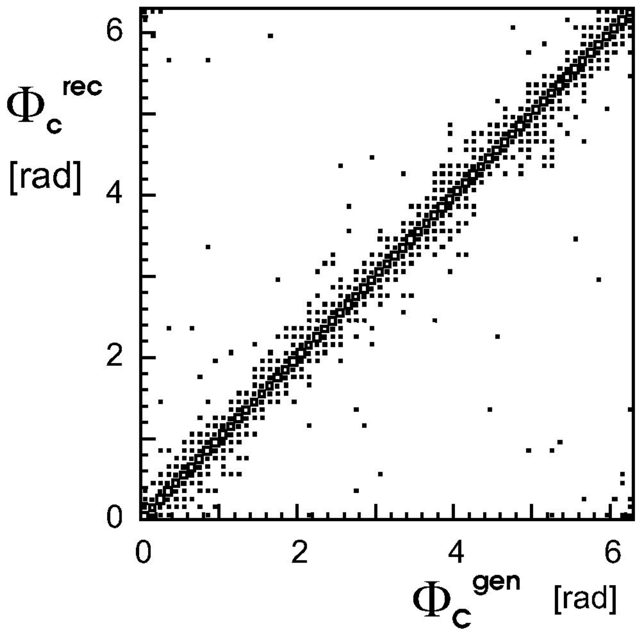
☑ Tracking efficiencies

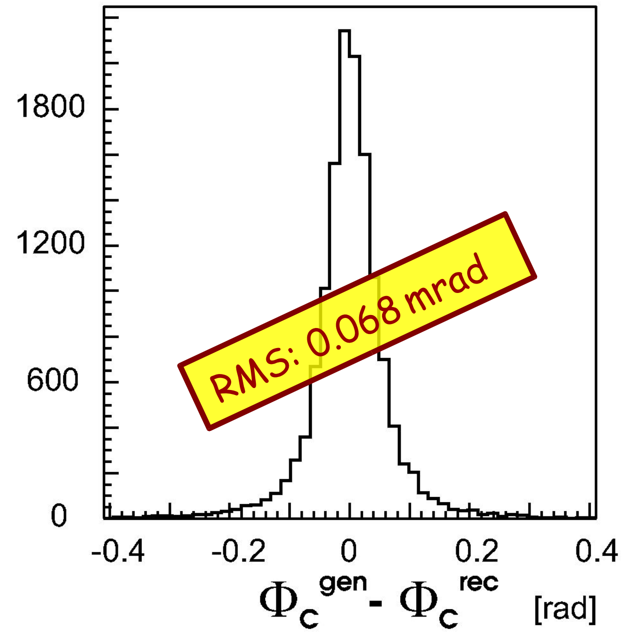


☑ **Overall good agreement between MC and real data**

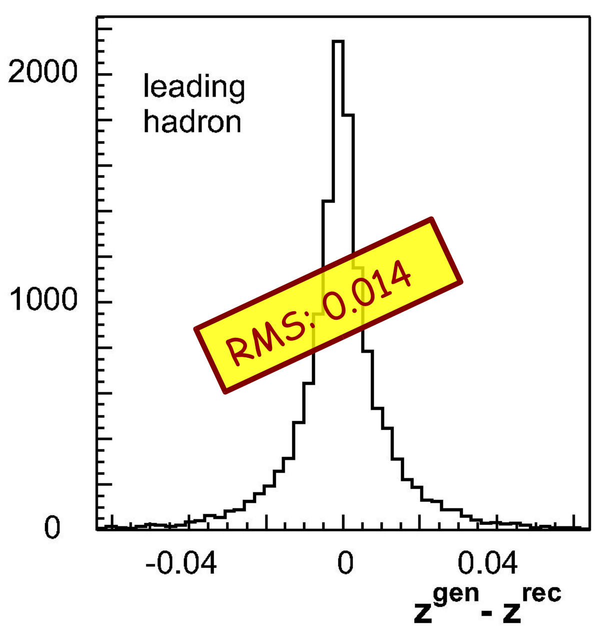


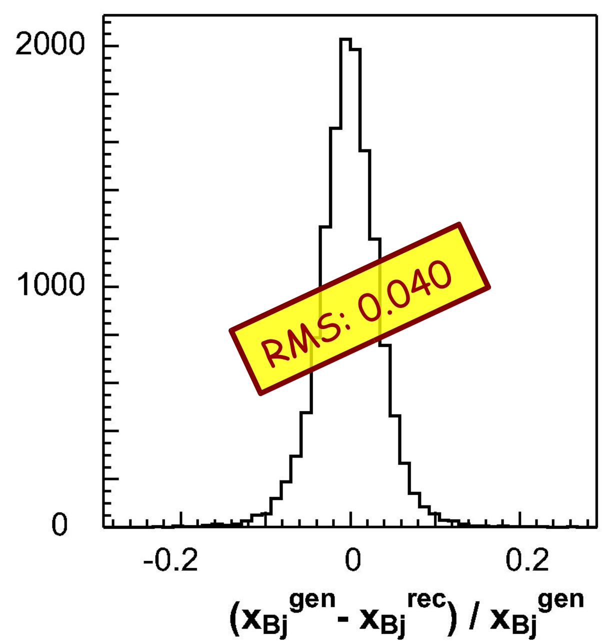
Monte Carlo studies (2)

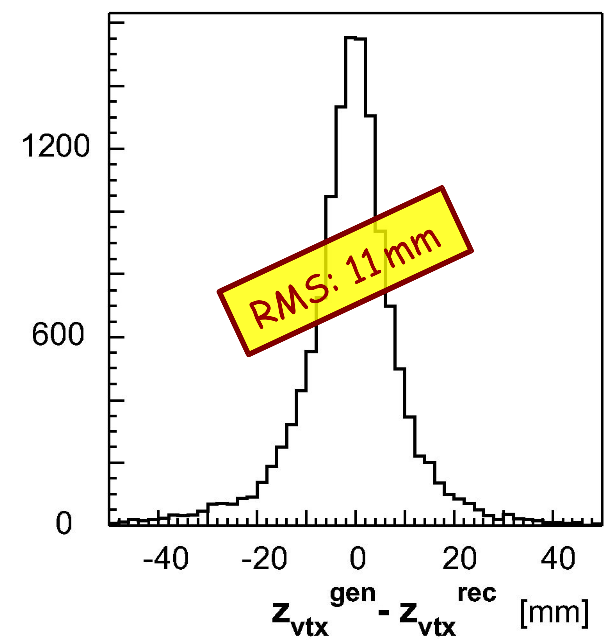




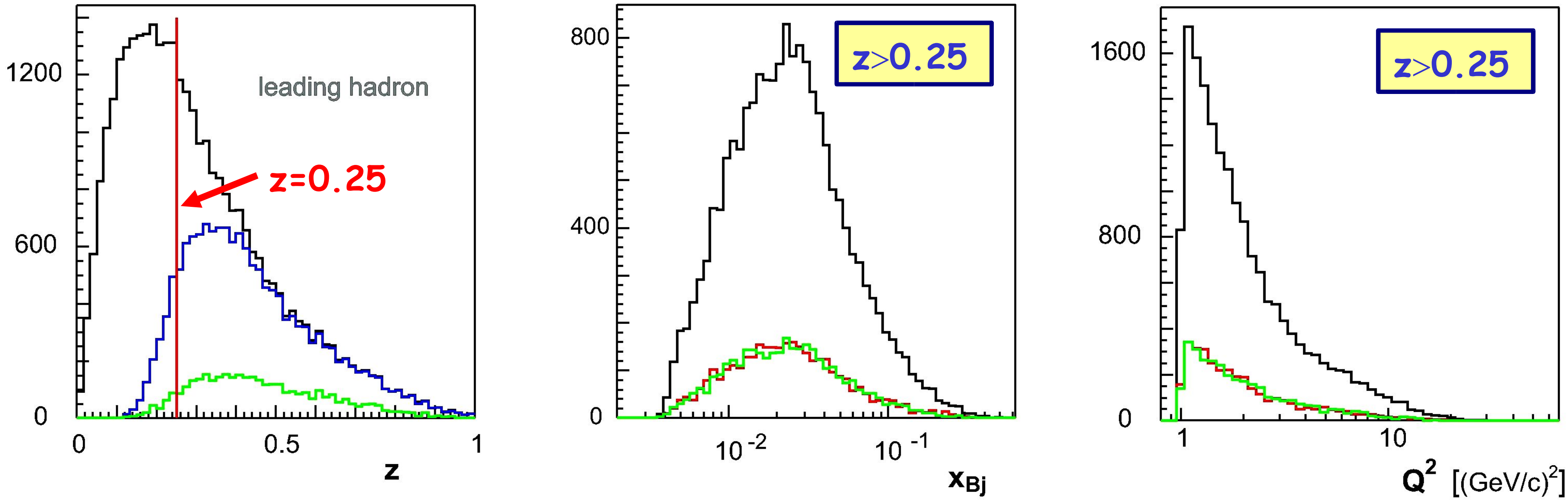
No signal dilution due to finite resolution!







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:

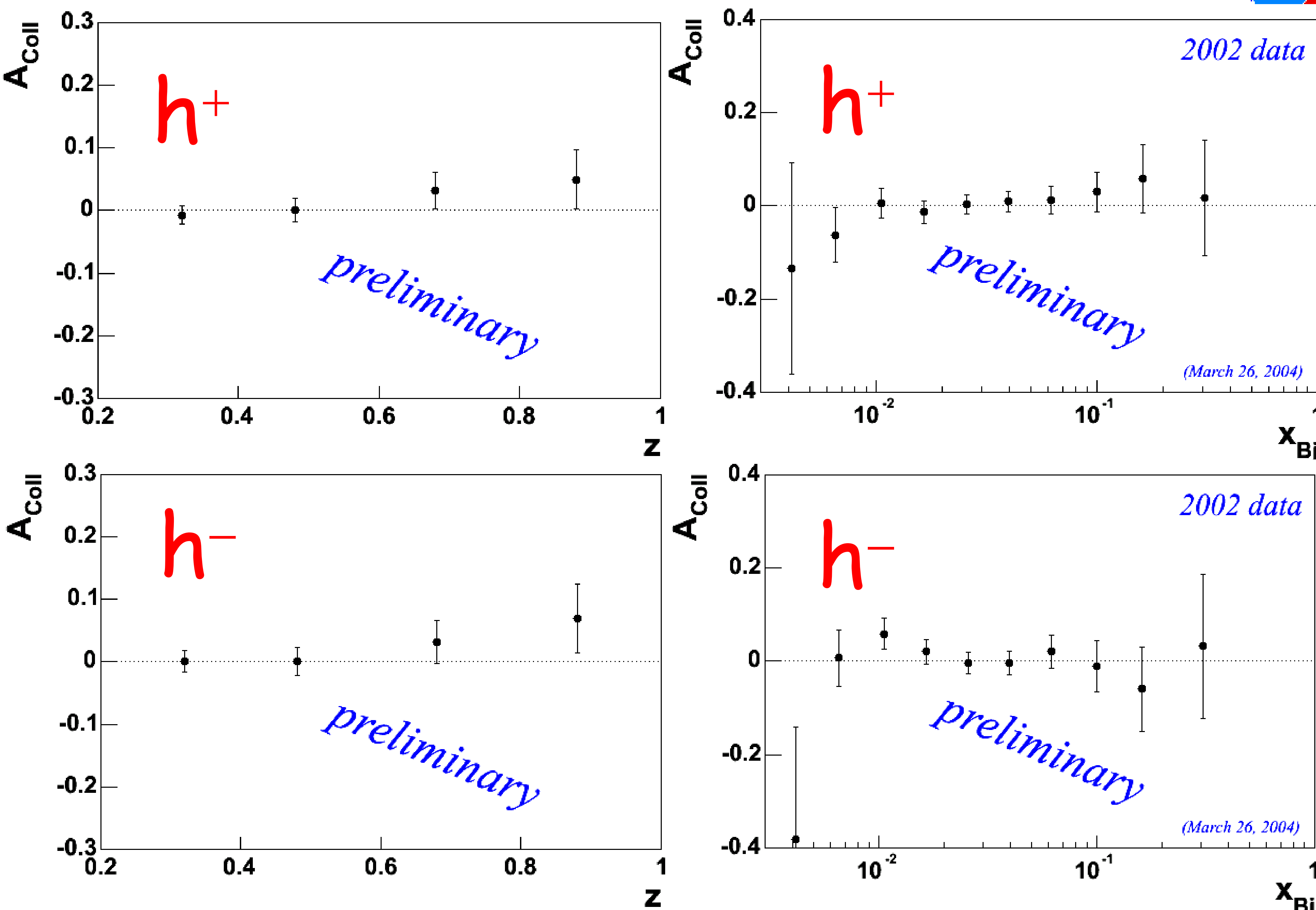
- The ratio of the acceptances and efficiencies for both target cells vs. Φ_C does not change between two spin orientations

- 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 !

Collins-Asymmetrie (Deuteron)



Conclusion & Outlook

- Within statistical error the measured Collins asymmetries for leading hadrons from a Deuteron target are compatible with zero
- Including 2003 & 2004 data
  → sensitivity improvement by factor >2 expected
- Extract Sivers asymmetries from our data
- Systematic investigations of Collins asymmetries for sub-leading hadrons still to be done
- Extract Collins asymmetries using independent quark polarimeters (Λ, leading hadron&next-to-leading hadron)

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

END of talk