MEASUREMENT OF TRANSVERSITY AT COMPASS

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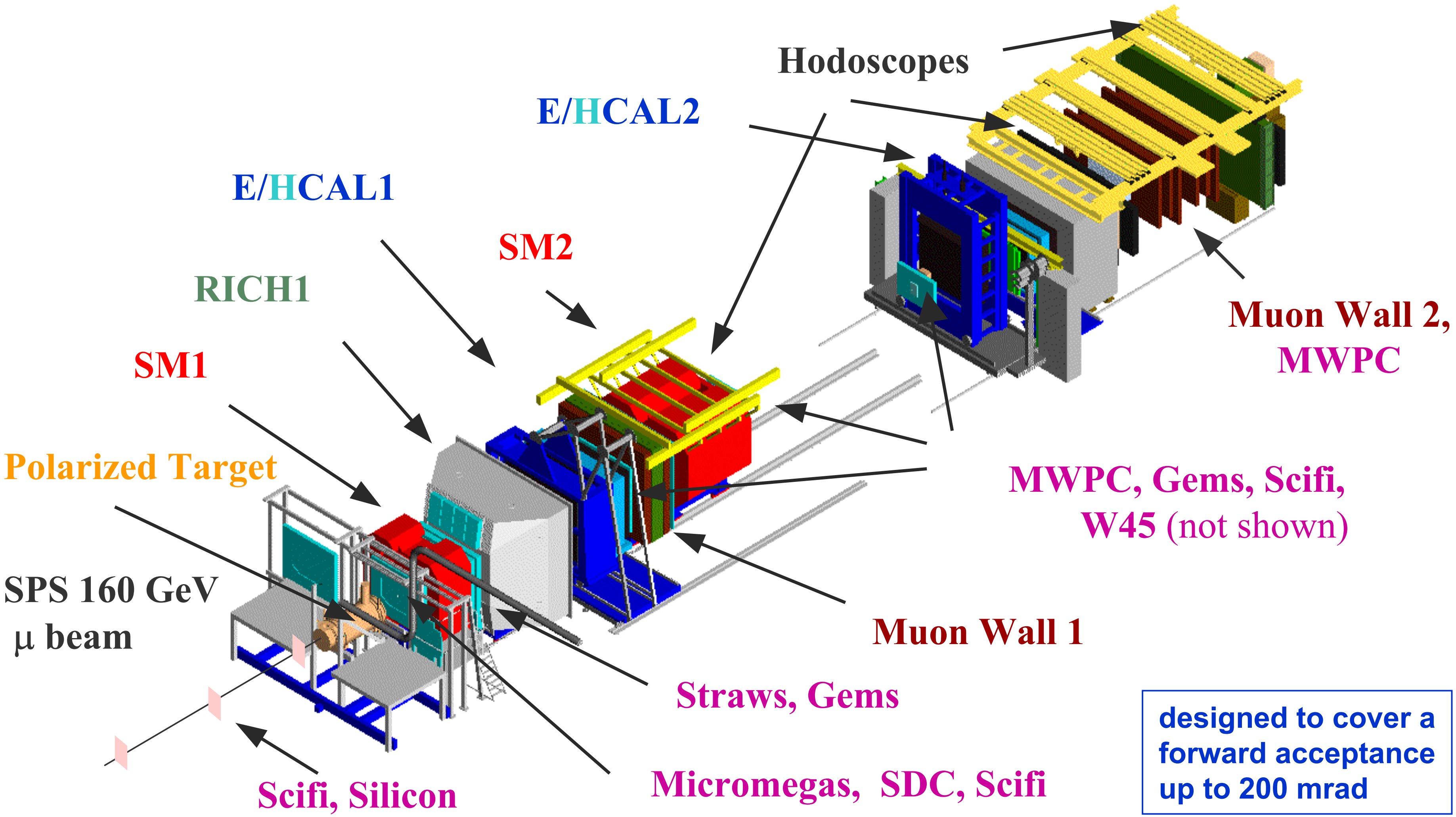
on behalf of the COMPASS Collaboration

- **The COMPASS spectrometer**
- **Transversity at COMPASS**
- **The 2002 data**
- **First results**
- **The future**

Paris, March 1, 2004

The Spectrometer

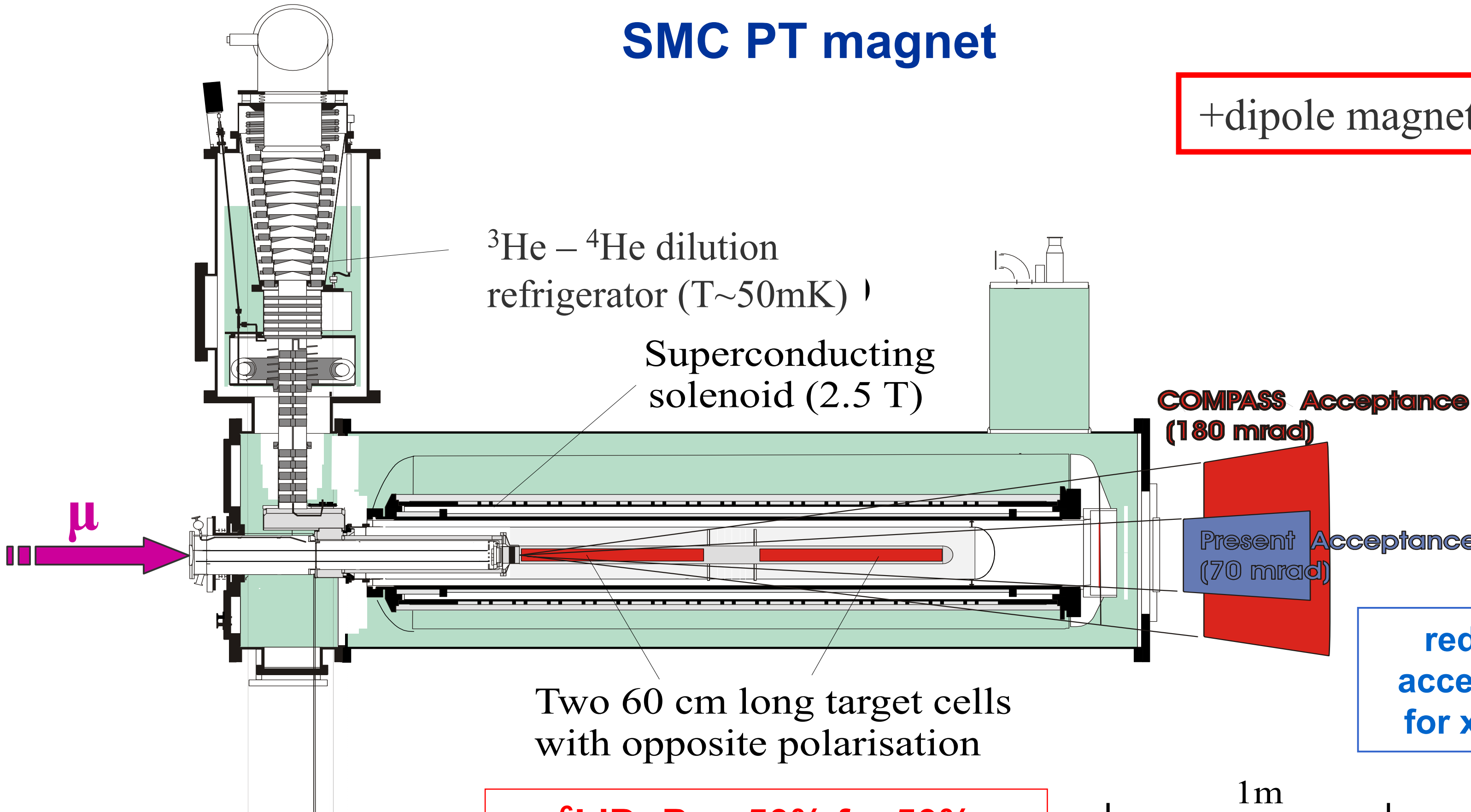


designed to cover a forward acceptance up to 200 mrad

The Target System in 2002 and 2003

SMC PT magnet

+dipole magnet (0.5T)



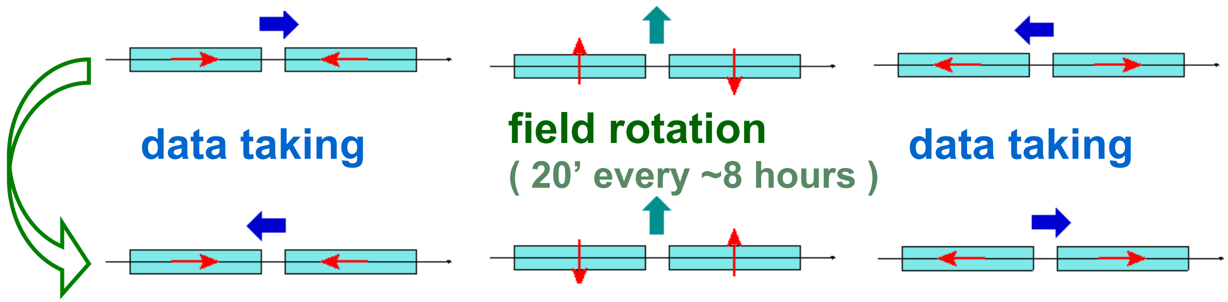
reduced acceptance for x_{Bj}> 0.1

^{6}LiD: P_T ~ 50% f ~ 50%
(NH_3, P_T ~90%, f ~17%)

Operation of the polarized target

Operation in longitudinal mode

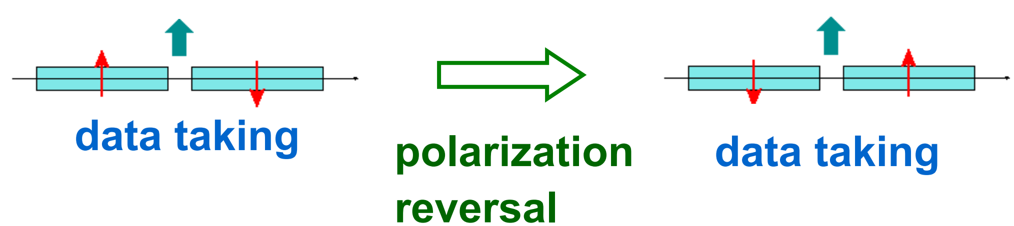
polarization reversal with respect to m.f.
(24h needed, once every ~2 weeks)



Operation in transverse mode

In principle, transverse polarization data can be taken at each field rotation
→ change of sign every 8 hours
In practice, some beam magnets and beam detectors have to be displaced (dipole field)

→ data taken in blocks of ~ 1 week, with polarization reversal in between



Collected statistics

2002 run **1 period ~ 12 days ~ 1.1 · 10^9 events**

(July 31- Aug. 6; Aug. 8- Aug. 12)

1 period ~7 days ~ 0.7 · 10^9 events

(Sept. 11- Sept.1 3; Sept. 15- Sept. 18)

50 TB of raw data

2003 run **1 period ~14 days ~1.4 · 10^9 events**

(Aug. 20 - Aug. 26; Aug. 28 - Sept. 3/9 4)

44 TB of raw data

~ as in 2002 but with a more efficient high Q^2 trigger

2004 run ***we expect to collect ~ the same statistics of 2002+2003***

Transversity signals in COMPASS

Several channels have been proposed for looking at transversity signals

stronger effects expected with a transversely polarised target:

- Collins effect for leading pions *
- Collins effect for all current fragmentation mesons *
- Relative Collins effect between leading and subleading mesons
- Λ polarimetry *
- …

with longitudinally polarized target

- single spin asymmetries *

Transversity at CERN

HELP CERN/LEPC 93 -14 LEPC/ P7 September 29, 1993,
a proposal for an internal jet-target experiment at LEP
L. Dick, A. Penzo, B. Vauridel, ….

the case for transversity

X. Artru, J. Collins, A. Kotzinian, …
Workshop in Geneva organised by R. Hess (March ’93)

taken up in 1994 by HMC

LoI CERN/SPSLC 95 -27 SPSC/I204 March 28, 1995

and then by COMPASS

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presently being investigated by HERMES

an important part of the RHIC programme

Collins effect for leading pions

spelled out in our Proposal

the fragmentation function of a quark of flavor a in an hadron h can be written as

$$D_a^h(z,\vec{p}_T^{\,h}) = D_a^h(z,p_T^h) + \Delta D_a^h(z,p_T^h)\cdot \sin\Phi_C$$

spin dependent part

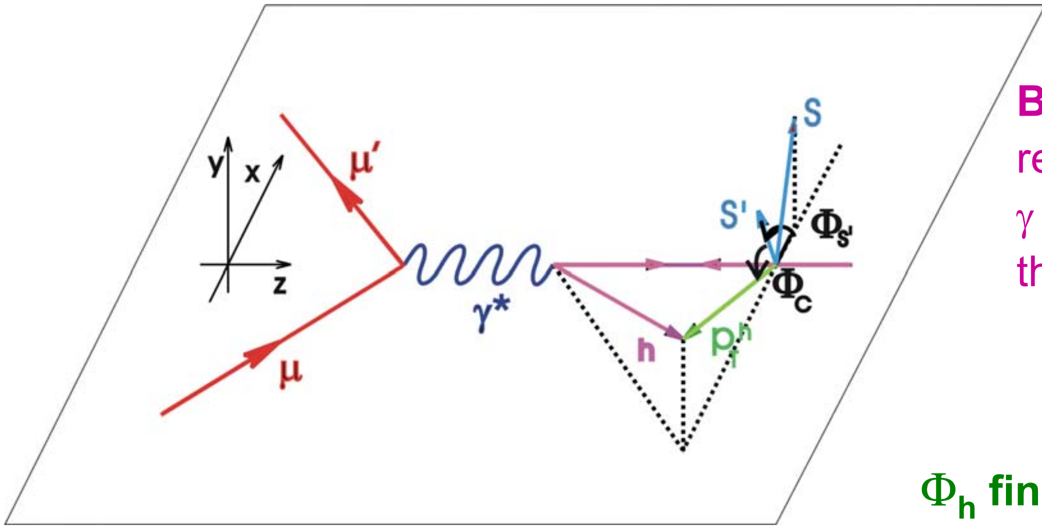
where

- $\vec{p}_T^{\,h}$ is the final leading hadron* transverse momentum with respect to the quark direction (the virtual photon direction)
- $z = E_h/(E_\mu - E_{\mu'})$
- $\Phi_C = \Phi_h - \Phi_{s'}$ is the "Collins angle"

for sub-leading particle opposite sign

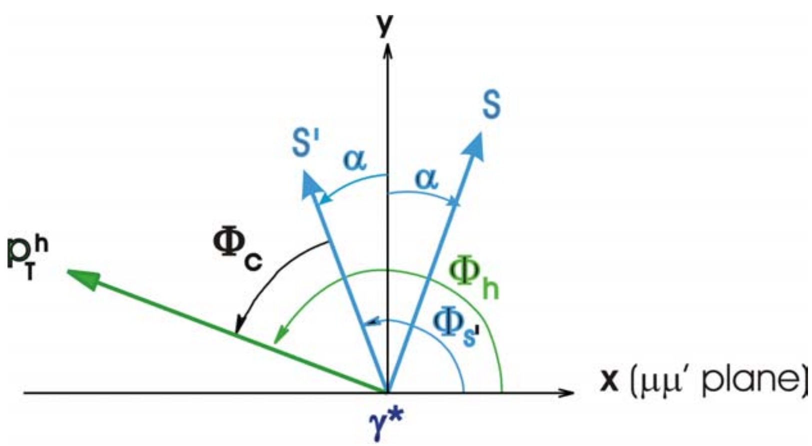
* experimentally, the leading hadron is the most energetic hadron produced in the event

Collins angle $\Phi_C = \Phi_h - \Phi_{s'}$



Breit frame:
ref. system with z axis defined by γ direction and x-z plane defined by the scattering plane

Φ_h final leading hadron azimuthal angle around the final quark direction



Φ_s is the azimuthal angle of the initial quark's spin in the Breit frame

$\Phi_{s'}$ azimuthal angle of the final quark transverse spin around the quark direction

$\Phi_{s'} = \pi - \Phi_s$

Collins effect for leading pions (cont.)

- $\Delta_T q_a(x) = q_a^{\uparrow\uparrow}(x) - q_a^{\uparrow\downarrow}(x) \qquad q_a(x) = q_a^{\uparrow\uparrow}(x) + q_a^{\uparrow\downarrow}(x)$
- **+** and **–** indicate target polarization direction in the lab system "up" and "down"
- calculating Φ_C as if the target polarization "up"

$$N_{h,a}^{\pm} \propto q_a^{\uparrow\uparrow}(D_a^h \pm \Delta D_a^h \cdot \sin\Phi_C) + q_a^{\uparrow\downarrow}(D_a^h \mp \Delta D_a^h \cdot \sin\Phi_C)$$

$$\propto q_a \cdot D_a^h \pm \Delta_T q_a \cdot \Delta D_a^h \cdot \sin\Phi_C$$

Summing on quark flavors and introducing

f = polarized target dilution factor, P_T = target nucleon polarization,
$D = (1-y)/(1-y-y^2/2)$

we measure $\quad N_h^{\pm}(\Phi_C) = N_h^0 \cdot [1 \pm A_1 \cdot \sin\Phi_C]$

and thus

$$A_1 = f \cdot P_T \cdot D \cdot A_{Coll} = f \cdot P_T \cdot D \cdot \frac{\sum_a e_a^2 \cdot \Delta_T q_a \cdot \Delta D_a^h}{\sum_a e_a^2 \cdot q_a \cdot D_a^h}$$

Collins effect for leading pions (cont.)

For $\pi^{\pm}$, assuming $D_1 = D_u^{\pi^+} = D_d^{\pi^-} = D_{\bar{u}}^{\pi^-} = D_{\bar{d}}^{\pi^+}$ $\quad D_2 = D_u^{\pi^-} = D_d^{\pi^+} = D_{\bar{u}}^{\pi^+} = D_{\bar{d}}^{\pi^-}$

1. with a proton polarized target, combining π^+ and π^- we can measure

$$A_1^{p1} = f_p \cdot P_T^p \cdot D \cdot \underbrace{\frac{4\Delta_T u + \Delta_T \bar{d} + 4\Delta_T \bar{u} + \Delta_T d}{4u + \bar{d} + 4\bar{u} + d}}_{2x \cdot h_1(x)/F_2(x)} \cdot \frac{\Delta D_1 + \Delta D_2}{D_1 + D_2}$$

$$A_1^{p2} = f_p \cdot P_T^p \cdot D \cdot \frac{4\Delta_T u_v - \Delta_T d_v}{4u + \bar{d} + 4\bar{u} + d} \cdot \frac{\Delta D_1 - \Delta D_2}{D_1 + D_2}$$

2. With a deuteron target

$$A_1^{d1} = f_d \cdot P_T^d \cdot D \cdot \frac{\Delta_T u + \Delta_T \bar{d} + \Delta_T \bar{u} + \Delta_T d}{u + \bar{d} + \bar{u} + d} \cdot \frac{\Delta D_1 + \Delta D_2}{D_1 + D_2}$$

$$A_1^{d2} = f_d \cdot P_T^d \cdot D \cdot \frac{3(\Delta_T u_v + \Delta_T d_v)}{5(u + \bar{d} + \bar{u} + d)} \cdot \frac{\Delta D_1 - \Delta D_2}{D_1 + D_2}$$

a smaller signal is expected

Analysis of 2002 data

- Data selection
- Event selection
- Preliminary results
- Monte Carlo studies
- Systematics

Data selection

Many tests to check the stability of the apparatus during data taking:

after a first filtering of the data on logbook basis,

- profiles on the tracker planes
- track reconstruction and vertex reconstruction
- angular distributions and kinematical variable distributions dividing the data taking periods in blocks of ~ 10 h

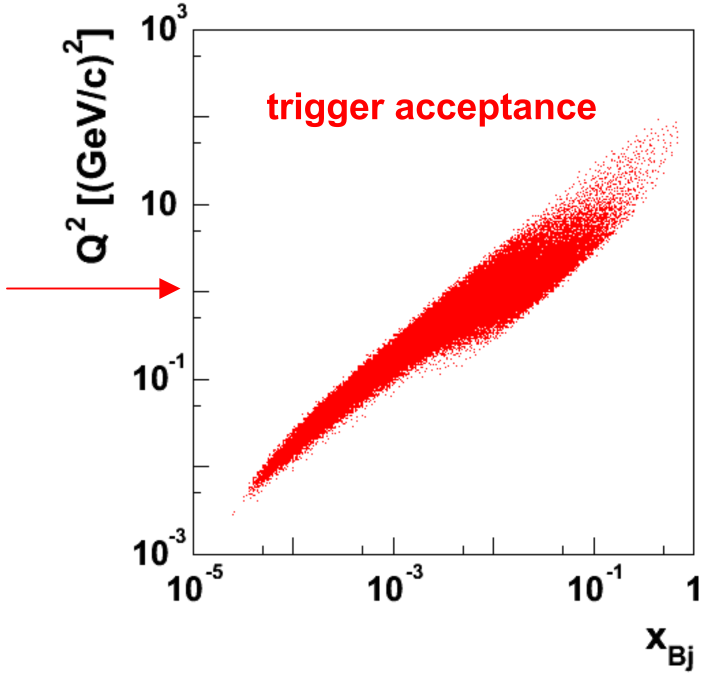
13 runs / 470 runs rejected (~3% of the events)

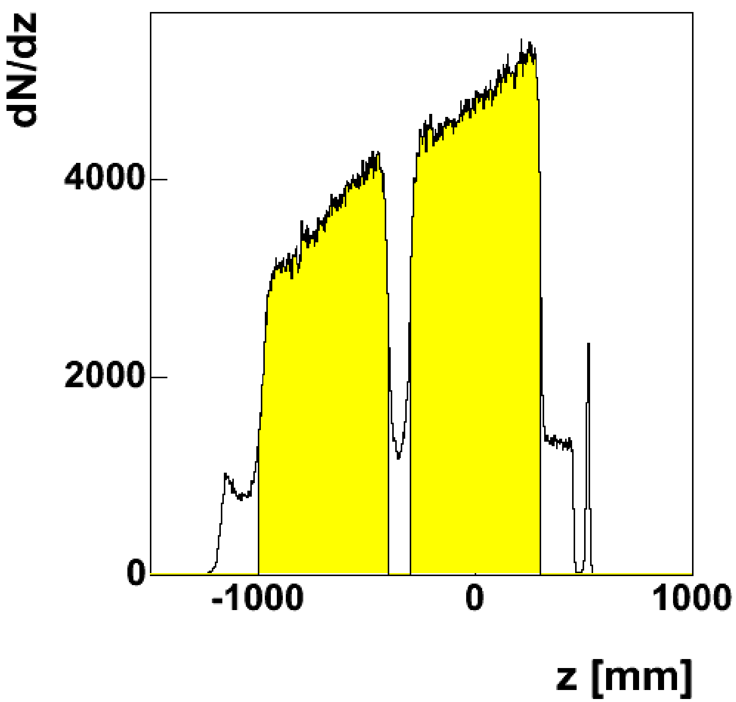
separate analysis for the 2 periods of data taking

Event selection

Requirements:

- **primary vertex with identified μ, μ'**
- **$Q^2 > 1\ (GeV/c)^2$**
- **$0.1 < y < 0.9$**
- **$W > 5\ GeV/c^2$**





- **incident muon inside the two target cells and primary vertex inside the target cells**

Event selection

Requirements (cont.):

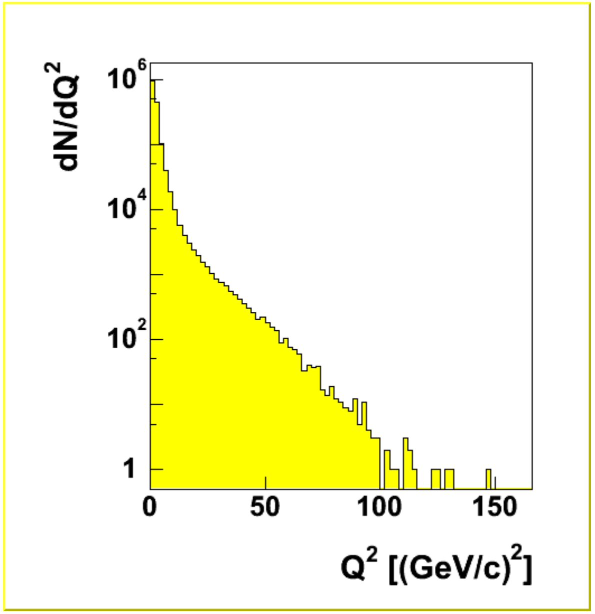
- **Leading hadron (l.h.):**
  - at least 1 charged hadron from primary vertex
    with less than 10 radiation lengths
  - energy deposit in HCALs > 5 or 8 GeV (if signal)
  - p_T > 0.1 GeV/c
  - if $z < 1 - z_{tot}$, no cluster in HCALs corresponding to particles with no associated track and energy larger than the candidate leading hadron
  - $z > 0.25$

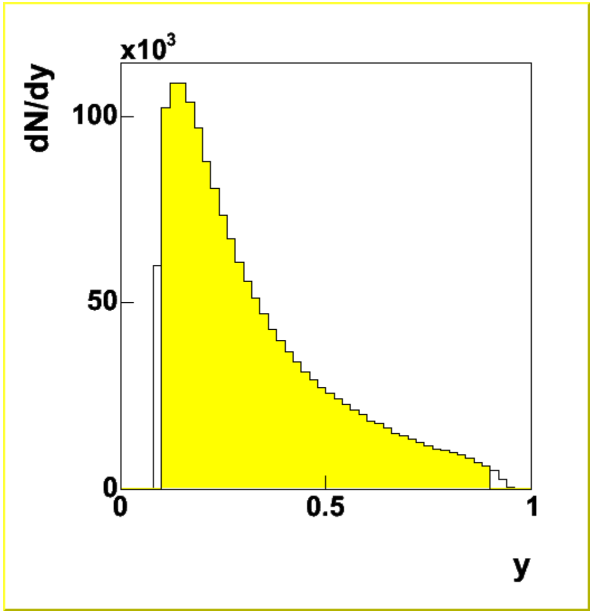
    to eliminate events with real leading hadron not detected:

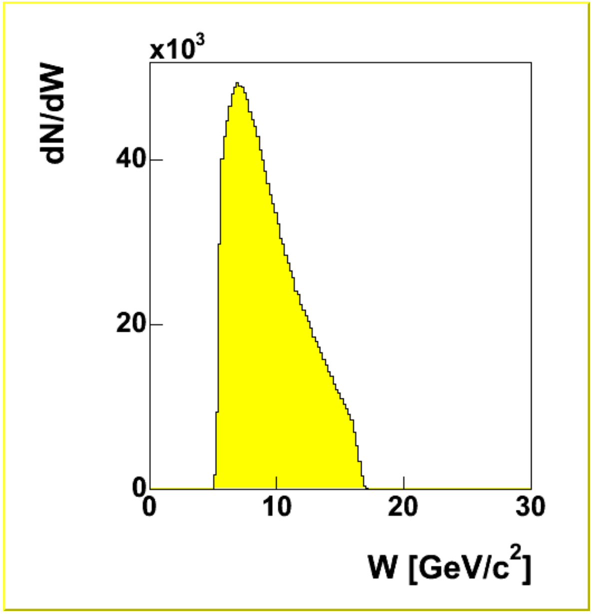
    neutral leading hadron, leading hadron not in acceptance, …

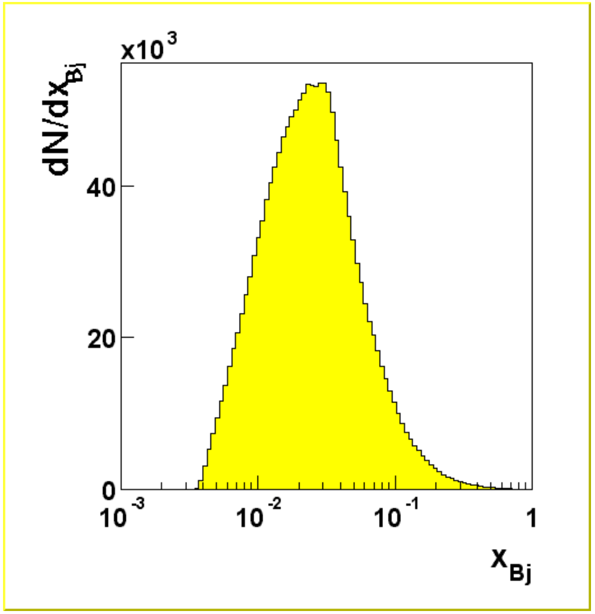
Final sample

Some distributions

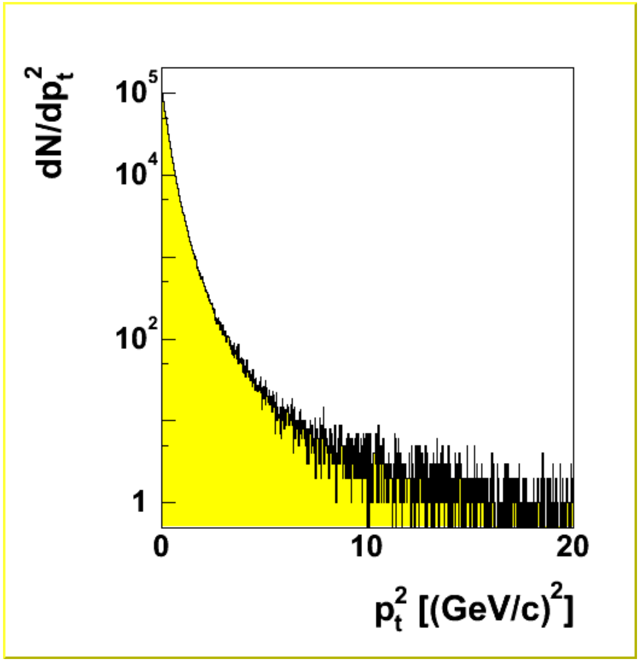


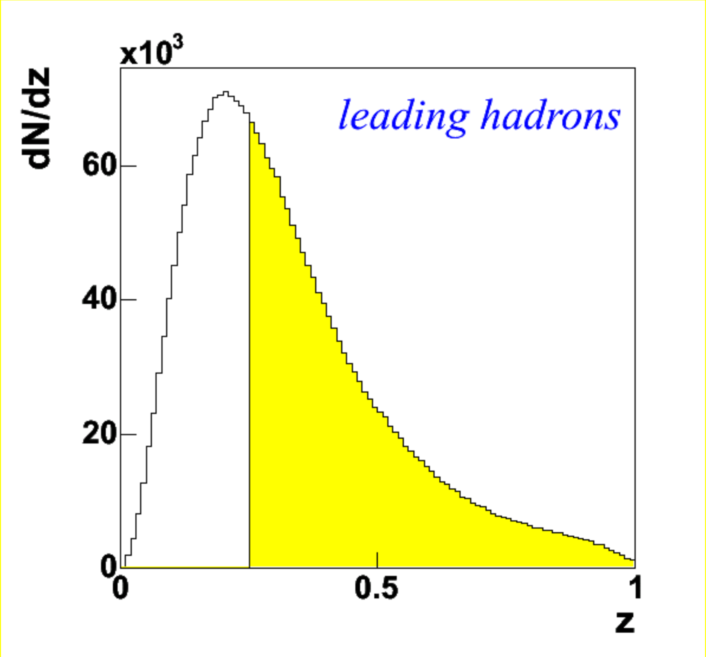






Final sample



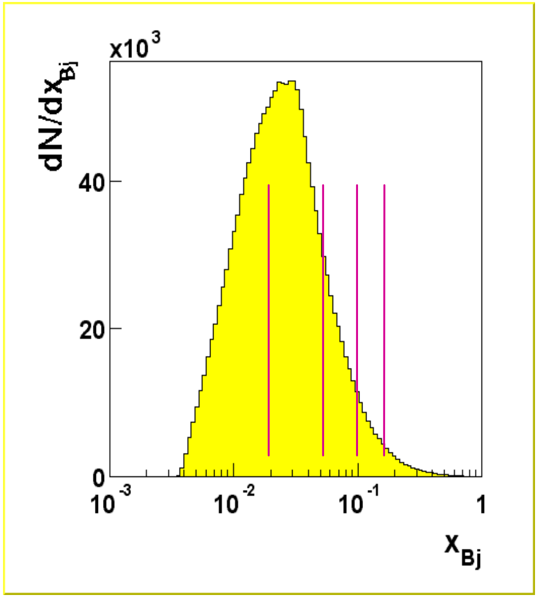


final statistics:

	1st period		2nd period	
	1st orientation	2nd orientation	1st orientation	2nd orientation
Cell 1	187k	203 k	102 k	173 k
Cell 2	257 k	278 k	138 k	233 k

Asymmetry calculation

The asymmetry has been calculated separately for the events with positive and negative charge leading hadrons



The data have been divided in 5 x_{Bj} bins

For each data taking period and each cell, the distributions

$$\frac{N^{+}(\Phi_c) - R\cdot N^{-}(\Phi_c)}{N^{+}(\Phi_c) + R\cdot N^{-}(\Phi_c)} \qquad \left(R = N^{+}_{tot}/N^{+}_{tot} \right)$$

have been fitted with the function

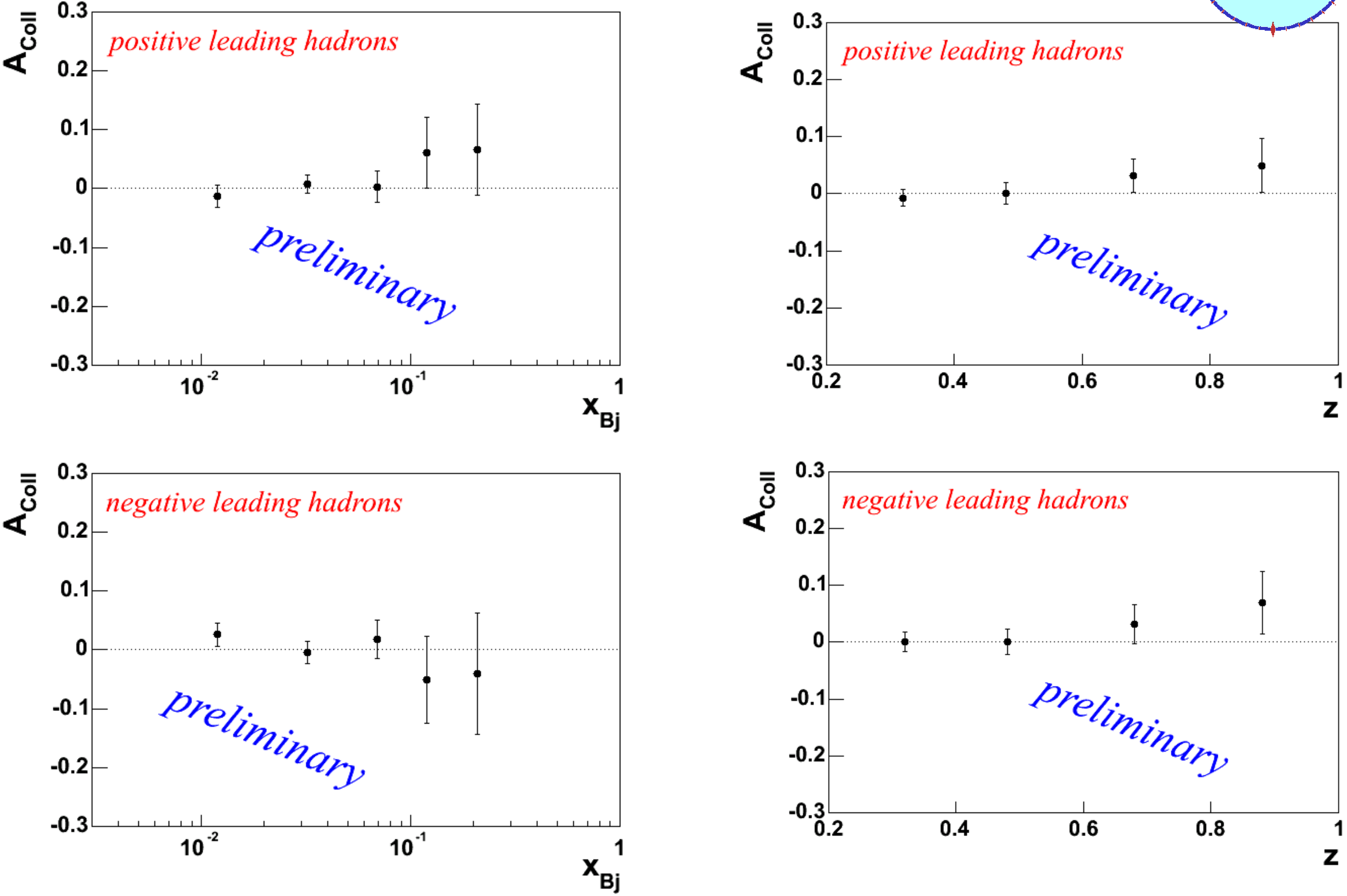
$$c\cdot\left(1 + A_1 \cdot \sin\Phi_C\right)$$

all the 4 values the A_1 are in good agreement

Finally, the "Collins" asymmetries $A_{Coll} = \frac{1}{f\cdot D\cdot P_T}\cdot A_1$

have been evaluated and their values have been averaged

Results from 2002 data



MonteCarlo studies

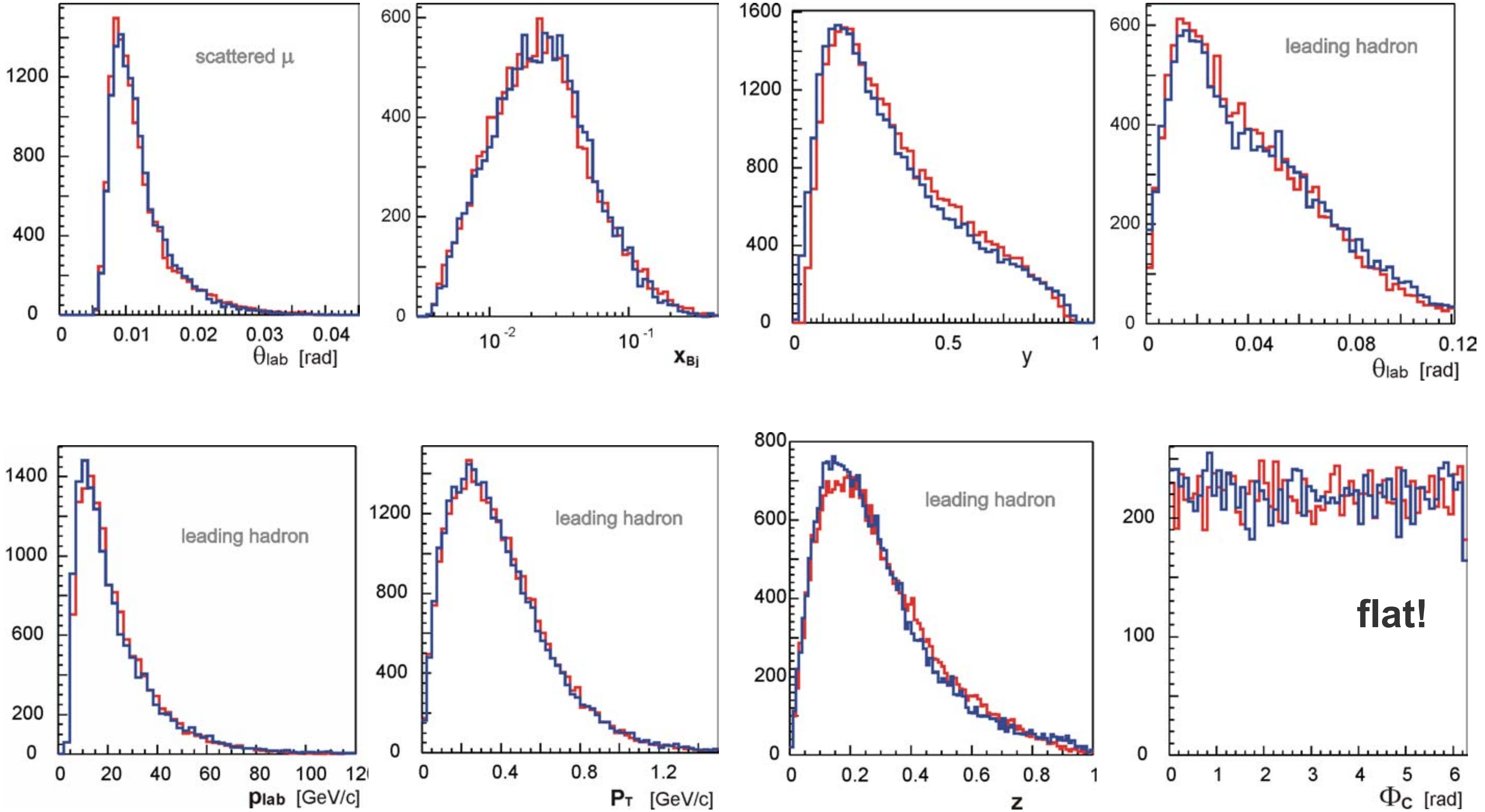
- to estimate the resolution in measured quantities
- to estimate the "contamination" of non leading hadrons in the final sample of reconstructed leading hadrons

MC events

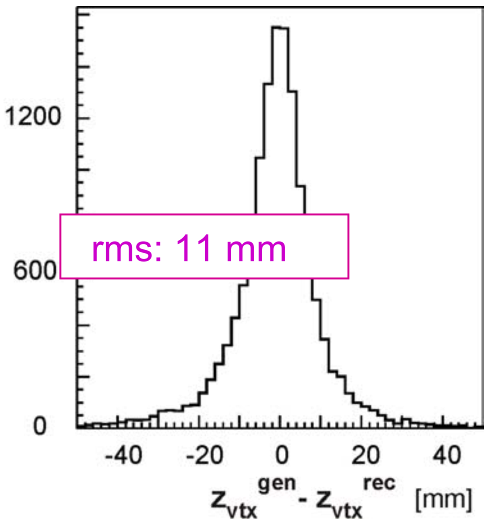
- generated with Lepto 6.5.1 and the last version of COMGeant (trigger geometry and mean efficiency of trackers included)
- reconstructed using the same CORAL version used for DST production
- standard analysis but:
  - μ' selection: only μ' in SAS
  - leading hadron selection:
    - no z_{tot} cut
    - HCALs not used

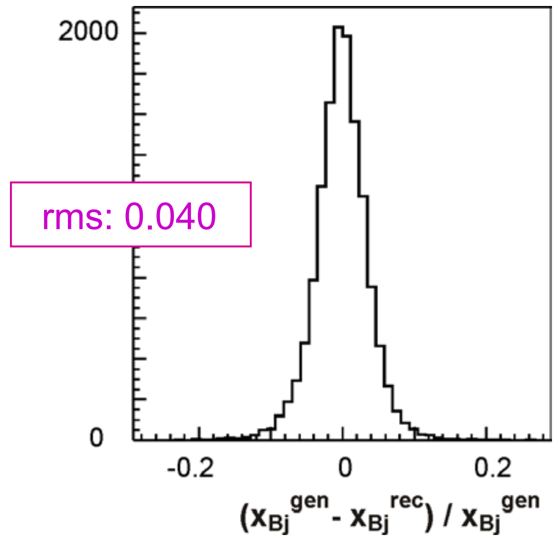
comparison with a small sample of real data

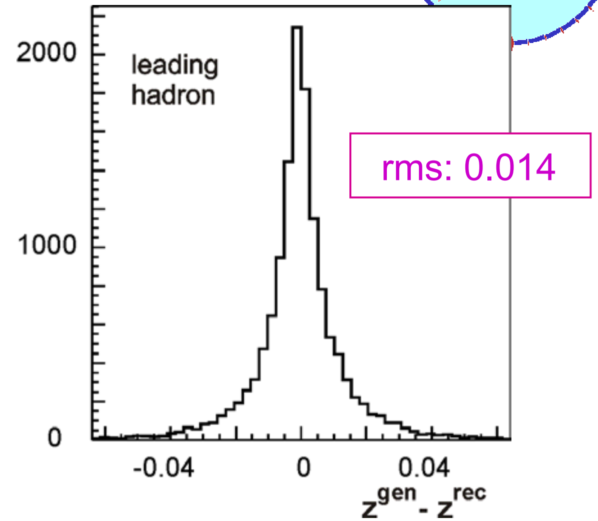
Comparison MC - data

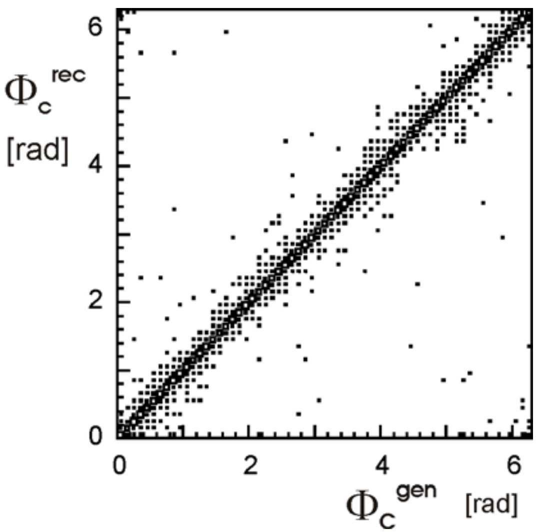


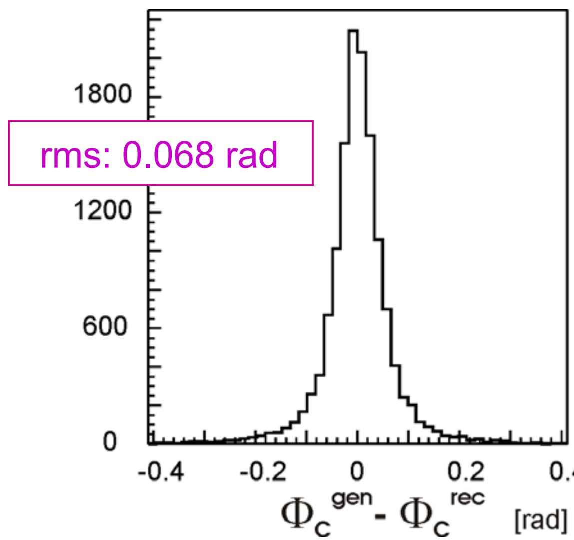
MC studies: resolution in measured quantities











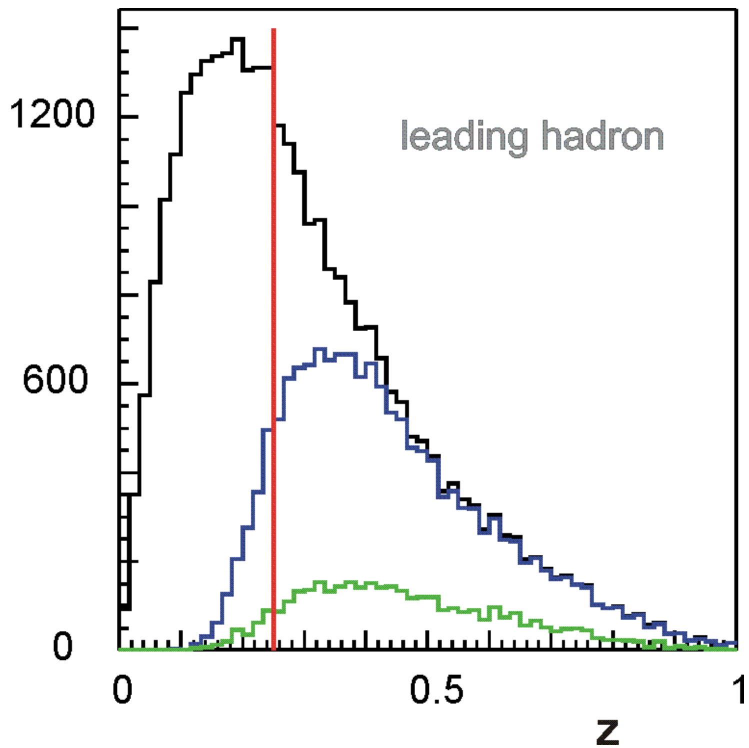
- **resolution in the different quantities as requested from the measurements**
- **no signal dilution due to the resolution in the Collins angle and in z_{vtx}**

MC studies:
"contamination" of non leading hadrons

non leading hadrons in the final sample *(wrongly reconstructed l.h.)*

due to acceptance, neutral leading hadrons

[Collins effect for subleading hadrons]



all rec. l.h.

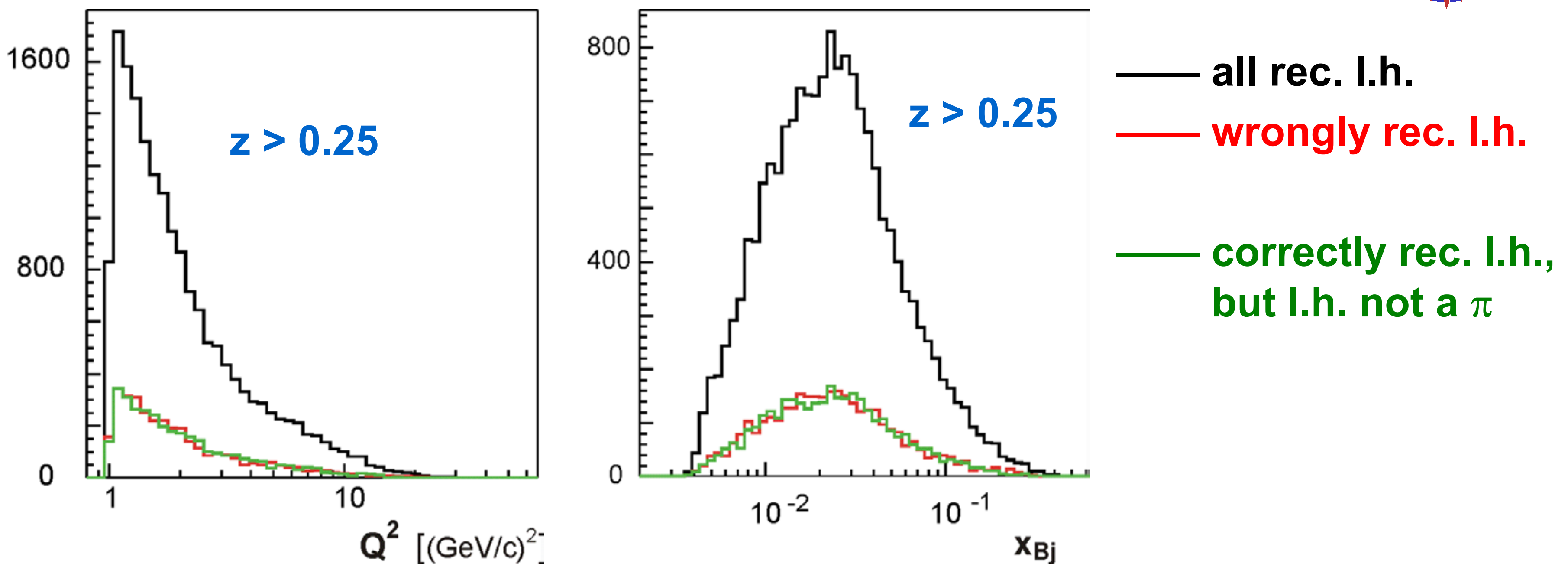
correctly rec. l.h.

correctly rec. l.h., but l.h. not a π

$z > 0.25$

still events with wrongly rec. l.h. at $z<0.45$

MC studies: "contamination" of non leading hadrons



wrongly reconstructed l.h.: ~ 20% of the final sample

SMALLER IN THE DATA: z_{tot} and HCAL cuts not applied to Monte Carlo events

correctly rec. l.h., but l.h. not a π: ~ 20% of the final sample

mainly K (and p): RICH1 not yet used in the analysis

Systematics

Several test have been perfomed to check the consistency of the result:

> it is free from acceptance effects only if the ratio of the acceptances and efficiencies in Φ_C for the two cells does not change from one orientation to the other

In particular

- Combining differently the cells
- Splitting of the cells in two parts
- Splitting the data in high and low hadron momenta
- Changing the Φ_C binning
- Use of a different estimator for A_1
- Check of possible variations of acceptance and efficiency
- ….

Variations of efficiency and acceptance

expected distributions in Φ_C for each x_{Bj} bin

$$N_{1B}(\Phi_C) = c_{1B} \cdot a_{1B}(\Phi_C) \cdot [1 - A_1 \cdot \sin\Phi_C]$$
$$N_{2B}(\Phi_C) = c_{2B} \cdot a_{2B}(\Phi_C) \cdot [1 + A_1 \cdot \sin\Phi_C]$$
$$N_{1C}(\Phi_C) = c_{1C} \cdot a_{1C}(\Phi_C) \cdot [1 + A_1 \cdot \sin\Phi_C]$$
$$N_{2C}(\Phi_C) = c_{2C} \cdot a_{2C}(\Phi_C) \cdot [1 - A_1 \cdot \sin\Phi_C]$$

acceptance, efficiency

assuming $\frac{a_{2B}(\Phi_C)}{a_{1B}(\Phi_C)} = \frac{a_{2C}(\Phi_C)}{a_{1C}(\Phi_C)} = \alpha(\Phi_C)$

it is $R(\Phi_C) = \frac{N_{1C}(\Phi_C) \cdot N_{2C}(\Phi_C)}{N_{1B}(\Phi_C) \cdot N_{2B}(\Phi_C)} = \frac{c_{1C} \cdot c_{2C}}{c_{1B} \cdot c_{2B}} \cdot \left[\frac{a_{1C}(\Phi_C)}{a_{1B}(\Phi_C)}\right]^2$

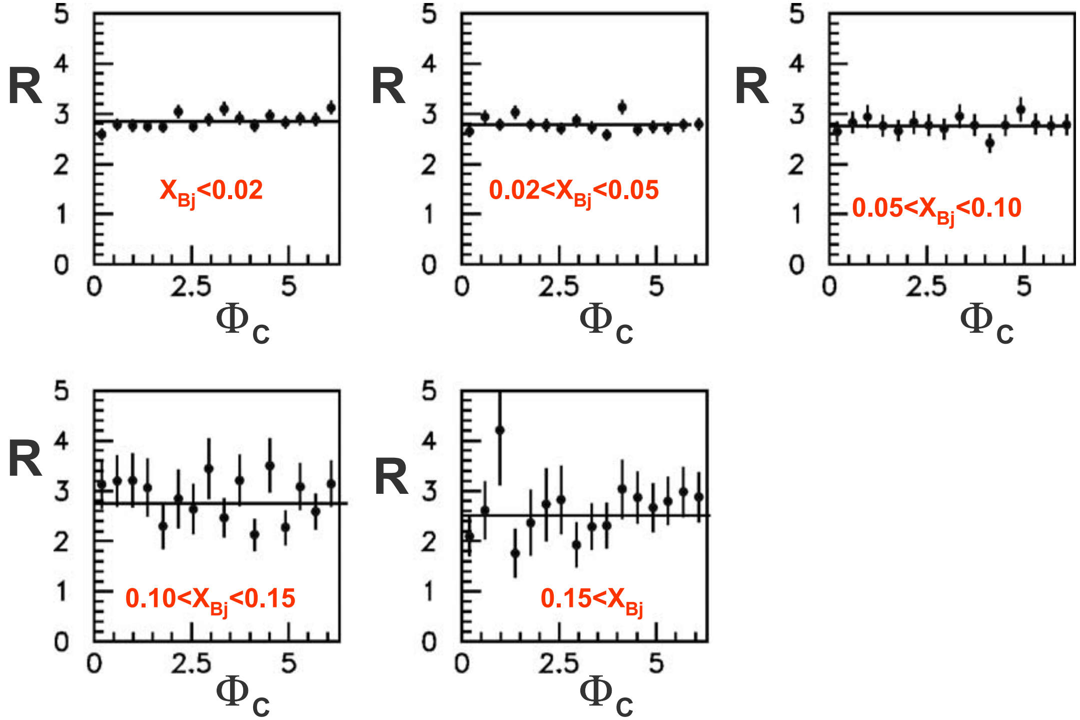
if R does not depend on Φ_C,

the hypothesis done in the standard analysis is correct

Variations of efficiency and acceptance (cont.)

Test on the dependence of R on Φ_C:

done for l.h.$^+$ and l.h.$^-$, for the two data taking periods

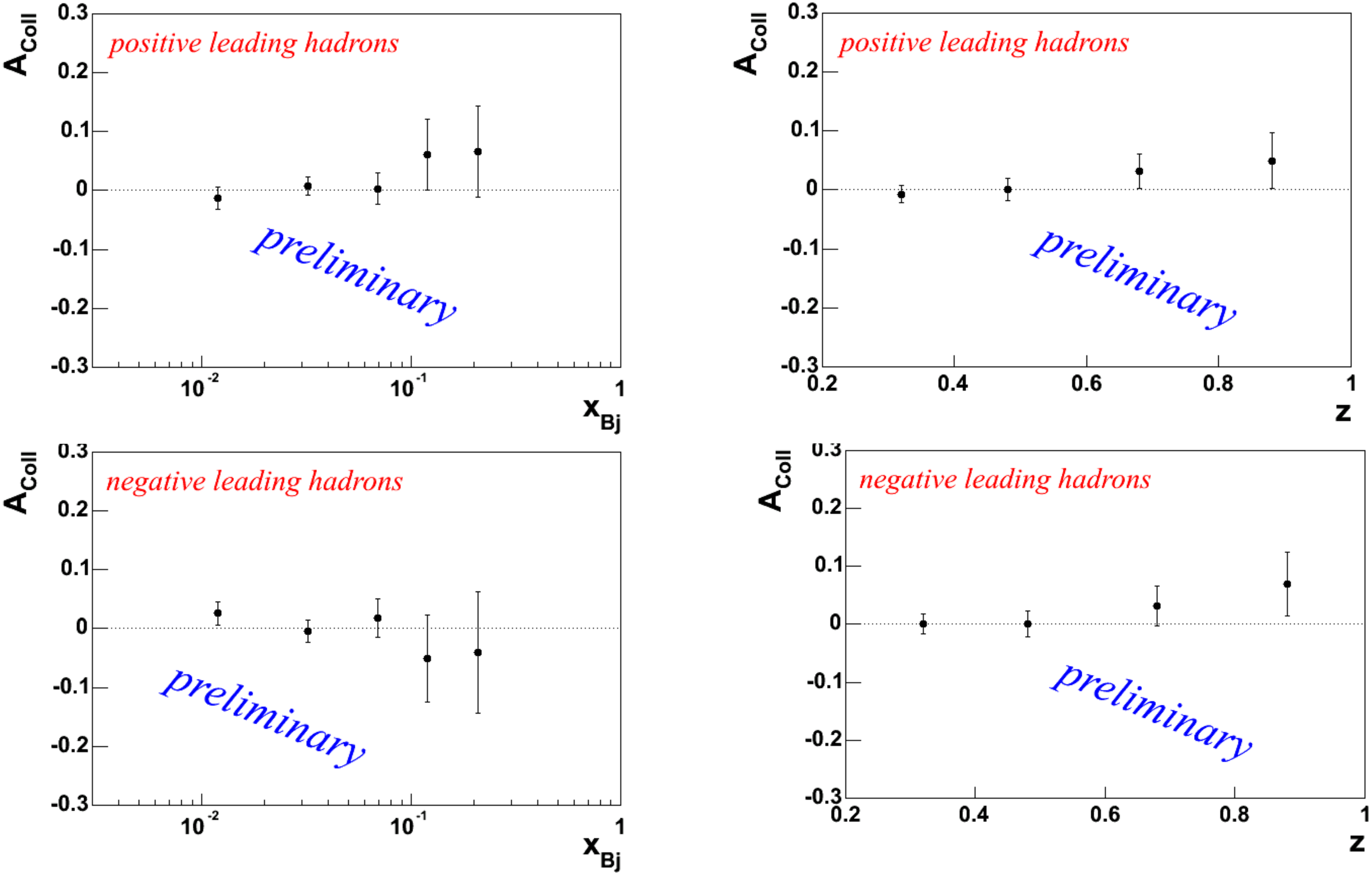


R does not depend on Φ_C inside statistical errors

Systematics: conclusion

All the tests we made are consistent with the fact that,

systematic effects, if present, are smaller than statistical errors



Conclusions and outlook

- COMPASS is in business !!!
- Within the statistics of the 2002 run, the measured Collins asymmetries for the leading hadron are compatible with zero
- Combining the data of 2002, 2003, and 2004, the sensitivity should improve by at least a factor of 2
- Systematic investigations of Collins (and Sivers) asymmetries for subleading hadrons still to be done

many results from deuteron target in the next future!

- Measurements with the polarized proton target from 2006