Monte Carlo studies for the unpolarized SIDIS measurements at COMPASS

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- unpolarized distributions (→ this presentation)
  MC used mainly to evaluate the apparatus acceptance

MC is not used for the extraction of the spin asymmetries the standard COMPASS MC chain

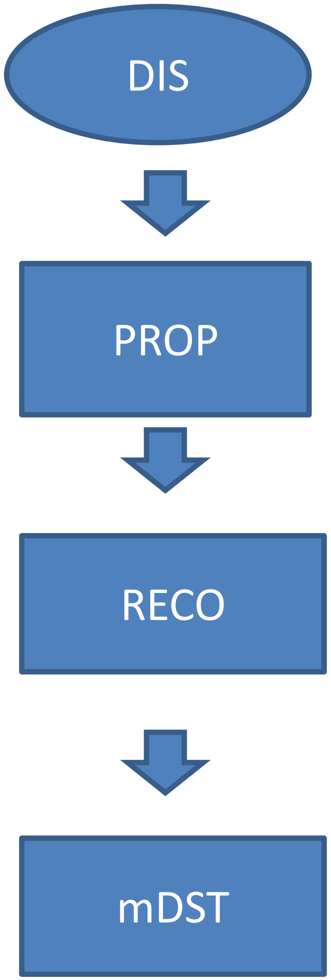
COMPASS MC chain

• **generation**
  Lepto *(pythia for tests on exclusive processes)*
  DIS events simulation

• **propagation**
  COMGEANT
  simulates the interaction and the propagation
  of the particles inside the spectrometer
  magnets, materials, detectors,triggers, ...
  different setups are individually described

• **reconstruction**
  CORAL (program for the data reconstruction)
  vertices, tracking, momentum,
  the same program used in MC and real data

• files with the reconstructed quantities are produced
  in the same format as for the real data



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***fine tuning** can be*
different** for **each analysis

indeed huge work
has been done in order to
optimize the description of the real data conditions

MC for the measurement of the unpolarized distributions (at COMPASS)

- transverse momentum dependence of the hadron multiplicities
  (quark transverse momentum extraction)

- hadron multiplicities for identified hadrons
  (strange FF extraction)

- unpolarized azimuthal asymmetries
  (cahn and boer-mulders)

transverse momentum dependence of the hadron multiplicities

the measured distributions are corrected for the acceptance

Q2 > 1

0.1 < y < 0.9

0.2 < z < 0.8

$$Acc_{dis} = \frac{{}^{rec}_{MC}N_{dis}}{{}^{gen}_{MC}N_{dis}} \qquad Acc = \frac{{}^{rec}_{MC}N_{h}}{{}^{gen}_{MC}N_{h}}$$

$$N_{dis}^{corr} = N_{dis}^{meas} \;/\; Acc_{dis} \qquad N_{h}^{corr} = N_{h}^{meas} \;/\; Acc$$

$$M = \frac{N_h^{corr}}{N_{dis}^{corr}} \Longrightarrow \propto e^{-\frac{P_T^{h\,2}}{< P_T^{h\,2} >}}$$

the measured distributions are corrected for the acceptance

by **weighting** in the **chosen kinematical bin** Δ *(ijkl)*

$$\int N_h^{corr}(Q^2,\, y;\, P_T^{lab},\, \vartheta_h^{lab})\, d\Delta \;=\; \int \frac{N_h^{meas}(Q^2,\, y;\, P_T^{lab},\, \vartheta_h^{lab})}{Acc(Q^2,\, y;\, P_T^{lab},\, \vartheta_h^{lab})}\, d\Delta$$

$$\Downarrow$$

$$^{ijkl}N_h^{corr} = \sum_{n=1,N}^{N=hadrons} \frac{1}{Acc(Q_n^{\,2},\, y_n;\, P_T^{lab}{}_n,\, \vartheta_h^{lab}{}_n)}$$

$$^{ij}N_{dis}^{corr} = \sum_{n=1,N}^{N=events} \frac{1}{Acc_{dis}(Q_n^{\,2},\, y_n)}$$

$$\Downarrow$$

$$^{ijkl}M = \frac{^{ijkl}N_h^{corr}}{^{ij}N_{dis}^{corr}}$$

i = bin in x

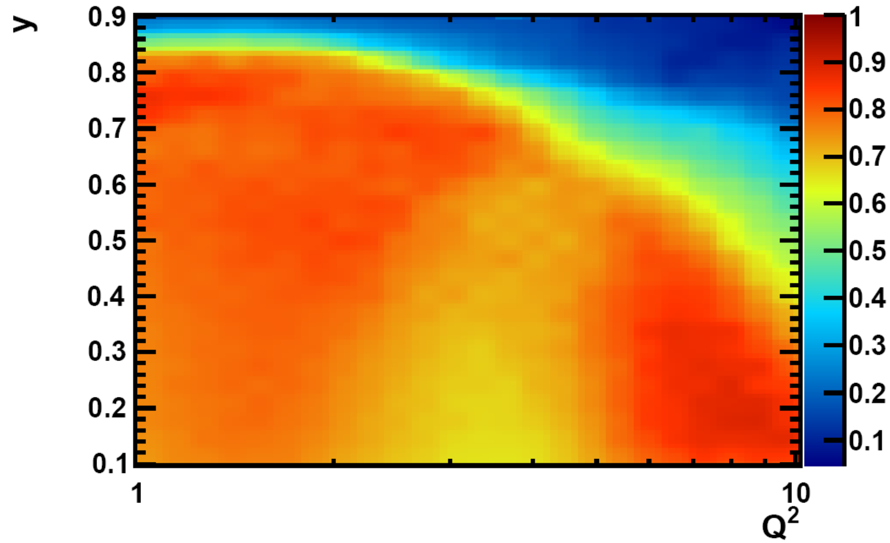
j = bin in Q^2

k = bin in z

l = bin in P_T^h

3 acceptance tables produced

- dis acceptance table $Acc_{dis}(Q^2, y)$



- hadron positive $Acc_{h+}(P_T^{lab}, \vartheta_h^{lab})$
- hadron negative $Acc_{h-}(P_T^{lab}, \vartheta_h^{lab})$

$$Acc(Q^2, y; P_T^{lab}, \vartheta_h^{lab}) = Acc_{dis}(Q^2, y) \cdot Acc_h(P_T^{lab}, \vartheta_h^{lab})$$

results obtained:

- correcting by the acceptance tables and **factorizing** dis and hadrons **acceptances**,

- correcting by the **acceptance** calculated in the **4 dimensions**,

$$N_h^{corr}(Q^2,\ y;\ P_T^{lab},\ \vartheta_h^{lab}) = \frac{N_h^{meas}(Q^2,\ y;\ P_T^{lab},\ \vartheta_h^{lab})}{Acc(Q^2,\ y;\ P_T^{lab},\ \vartheta_h^{lab})}$$

$${}^{ijkl}N_h^{corr} = {}^{ijkl}N_h^{meas} \ / \ {}^{ijkl}Acc$$

are the same !

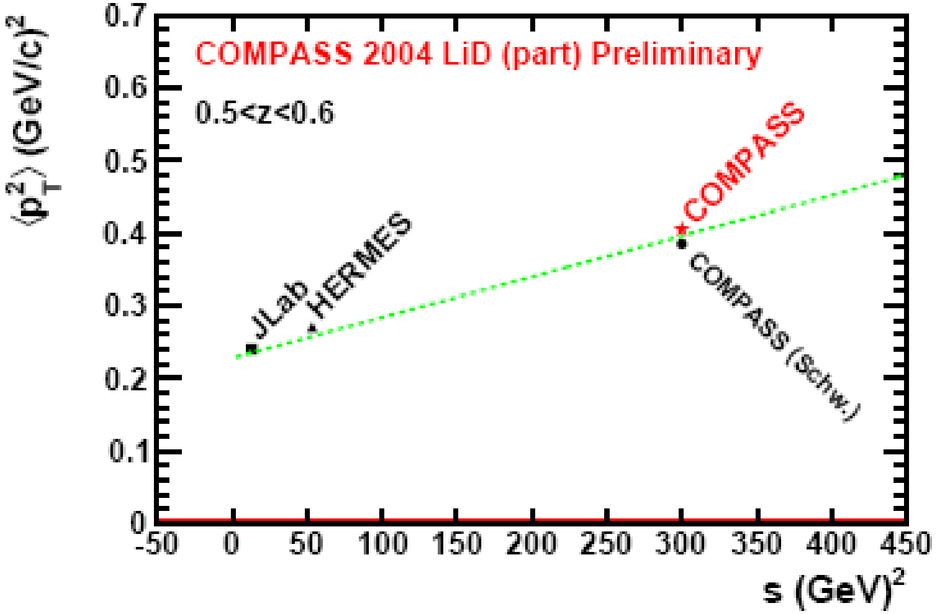
the **acceptance of the COMPASS spectrometer** has been studied on the whole kinematical range

the dependence on the kinematical variables is smooth

(no big holes in the apparatus acceptance)

as also confirmed by the **small difference** between the **measured < $(P_T^h)^2$>**

and the one corrected by the acceptance



identified hadron multiplicities

$Q^2 > 1$
$0.1 < y < 0.9$
$0.2 < z < 0.85$

i = bin in x or Q^2
k = bin in z

$$ {}^{ik}A = \frac{{}^{ik}M^{MC,rec}}{{}^{ik}M^{MC,gen}} $$

$$ {}^{ik}M^{MC,rec} = \frac{{}^{ik}N_h^{MC,rec}}{{}^{i}N_{dis}^{MC,rec}} $$

$$ {}^{ik}M^{MC,gen} = \frac{{}^{ik}N_h^{MC,gen}}{{}^{i}N_{dis}^{MC,gen}} $$

$Q^2 > 1$
$0.1 < y < 0.9$
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i = bin in x or Q^2
k = bin in z

$$ {}^{ik}M = \frac{{}^{ik}M^{meas}}{{}^{ik}A} $$

$$ {}^{ik}M^{meas} = \frac{{}^{ik}N_h^{meas}}{{}^{i}N_{dis}^{meas}} $$

multiplicities **corrected for the smearing** due to the spectrometer resolution and evaluated with the MC, **have been also calculated**

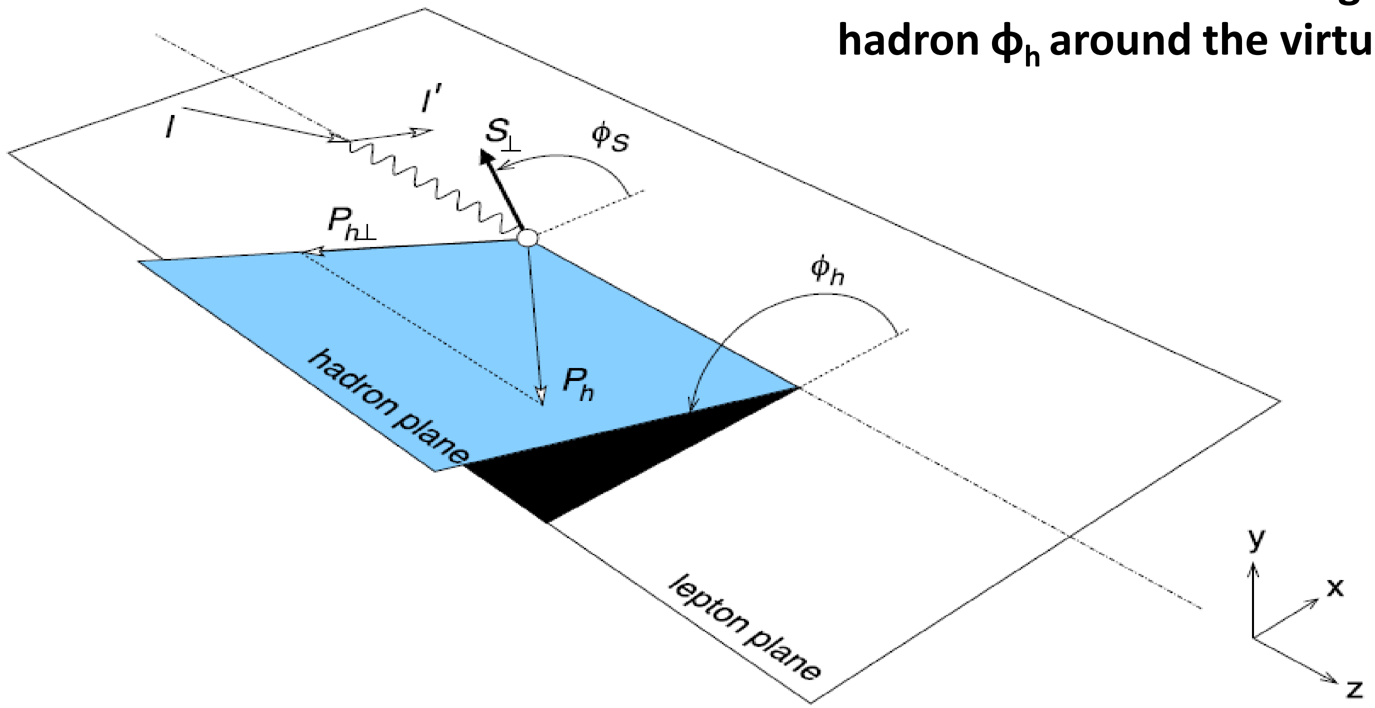
they are the same ! (smearing effect negligible)

hadron identification ⟵ tables produced from the real data using the RICH information (no MC info used)

unpolarized azimuthal asymmetries

$$N(\phi_h) \propto N_0 \cdot (1 + \varepsilon_1 A^{UU}_{\cos\phi_h} \cos\phi_h + \varepsilon_2 A^{UU}_{\cos 2\phi_h} \cos 2\phi_h + \lambda_l \varepsilon_3 A^{LU}_{\sin\phi_h} \sin\phi_h)$$

3 independent azimuthal modulations on the distribution on the **angle of the hadron ϕ_h around the virtual photon direction**



- azimuthal amplitudes are extracted **binning alternatively in x, z, P_T^h**

- the measured azimuthal distributions are corrected for the apparatus acceptance Acc

- Acc is calculated from MC

$Q^2 > 1$
$0.2 < y < 0.9$
$0.2 < z < 0.85$
$P_T^h < 1$

$$Acc_{ijk} = \frac{R_{ijk}^{MC}}{G_{ijk}^{MC}}$$

i = bin in $\boldsymbol{\phi_h}$

k = bin in $\mathbf{x_1}$
(where $x_1 = x$, z or P_T^h)

j = bin in $\mathbf{x_2}$
(where $x_2 = x$, y, θ_γ^{lab} , z, P_T^h , ...)

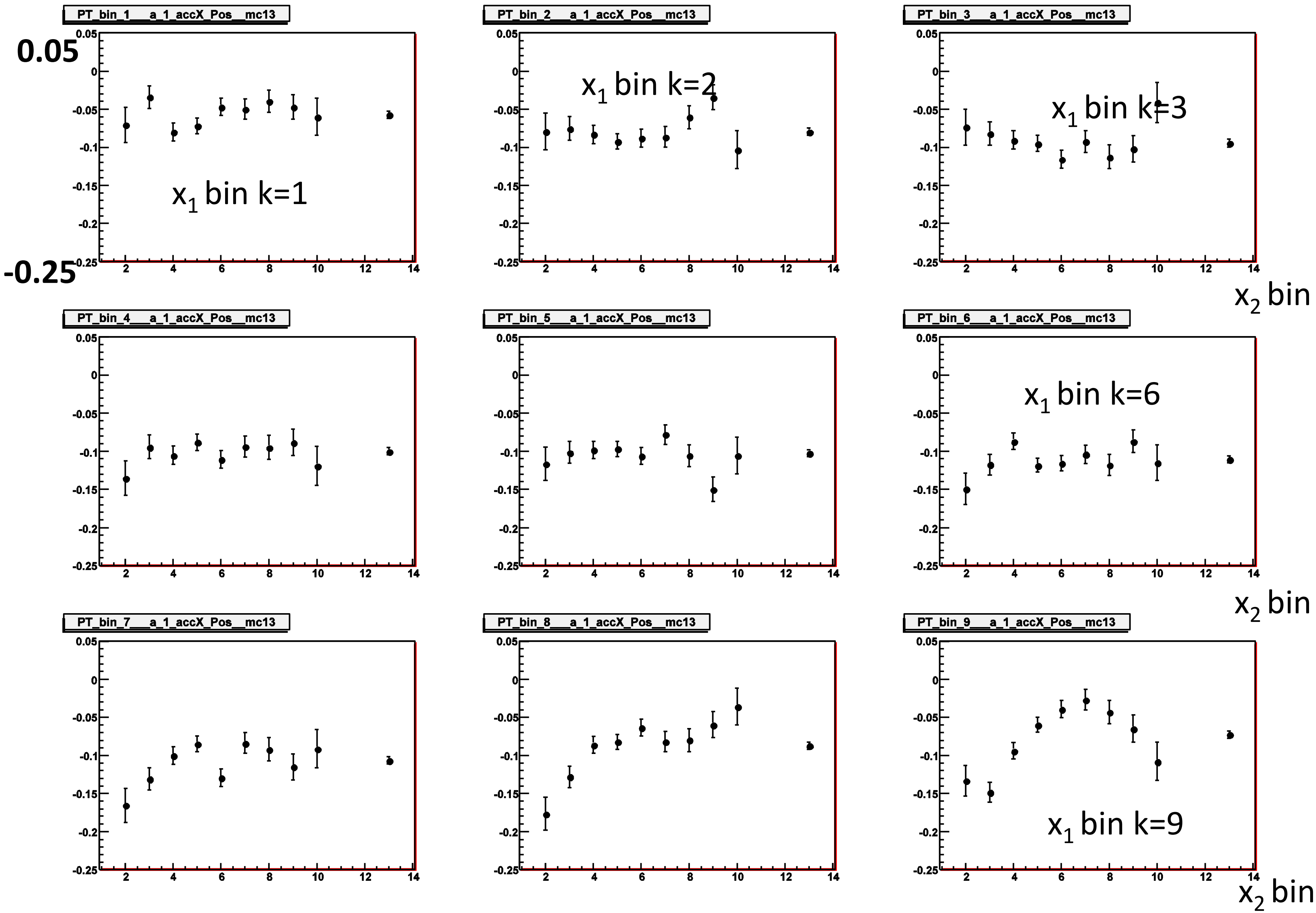
$$Acc_k(x_2, \phi_h) = a_0^k(x_2) \cdot (1 + a_1^k(x_2) \cos \phi_h + a_2^k(x_2) \cos 2\phi_h + \\ + a_3^k(x_2) \sin \phi_h + a_4^k(x_2) \cos 3\phi_h)$$

by fitting the dependence on x_2

amplitudes of **cosϕ_h** modulations given by the a**cceptance** $a_1^k(x_2)$

x_1 *(k bin)* = P_T^h

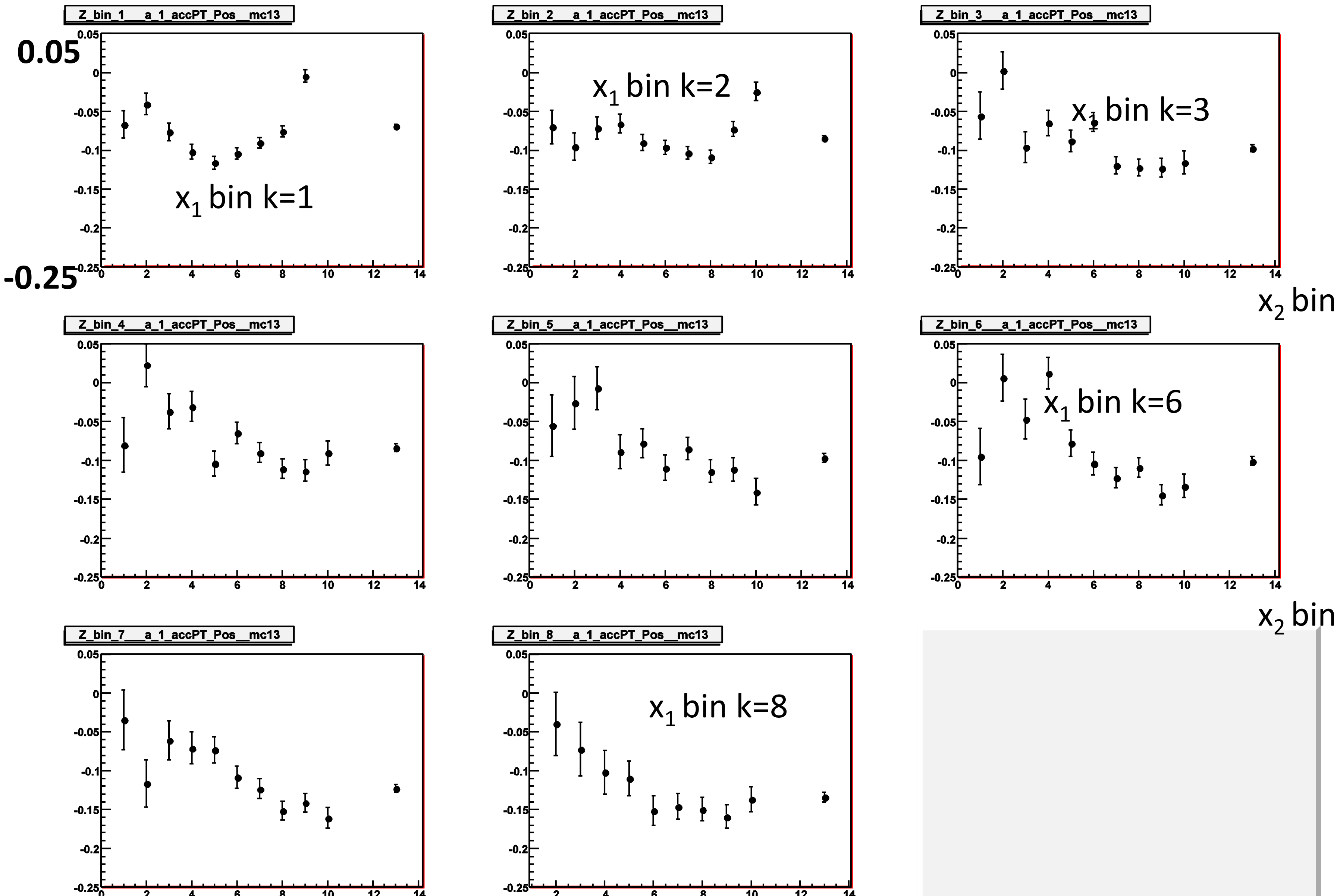
x_2= x



amplitudes of **cosφ$_h$** modulations given by the a**cceptance** $a_1^k(x_2)$

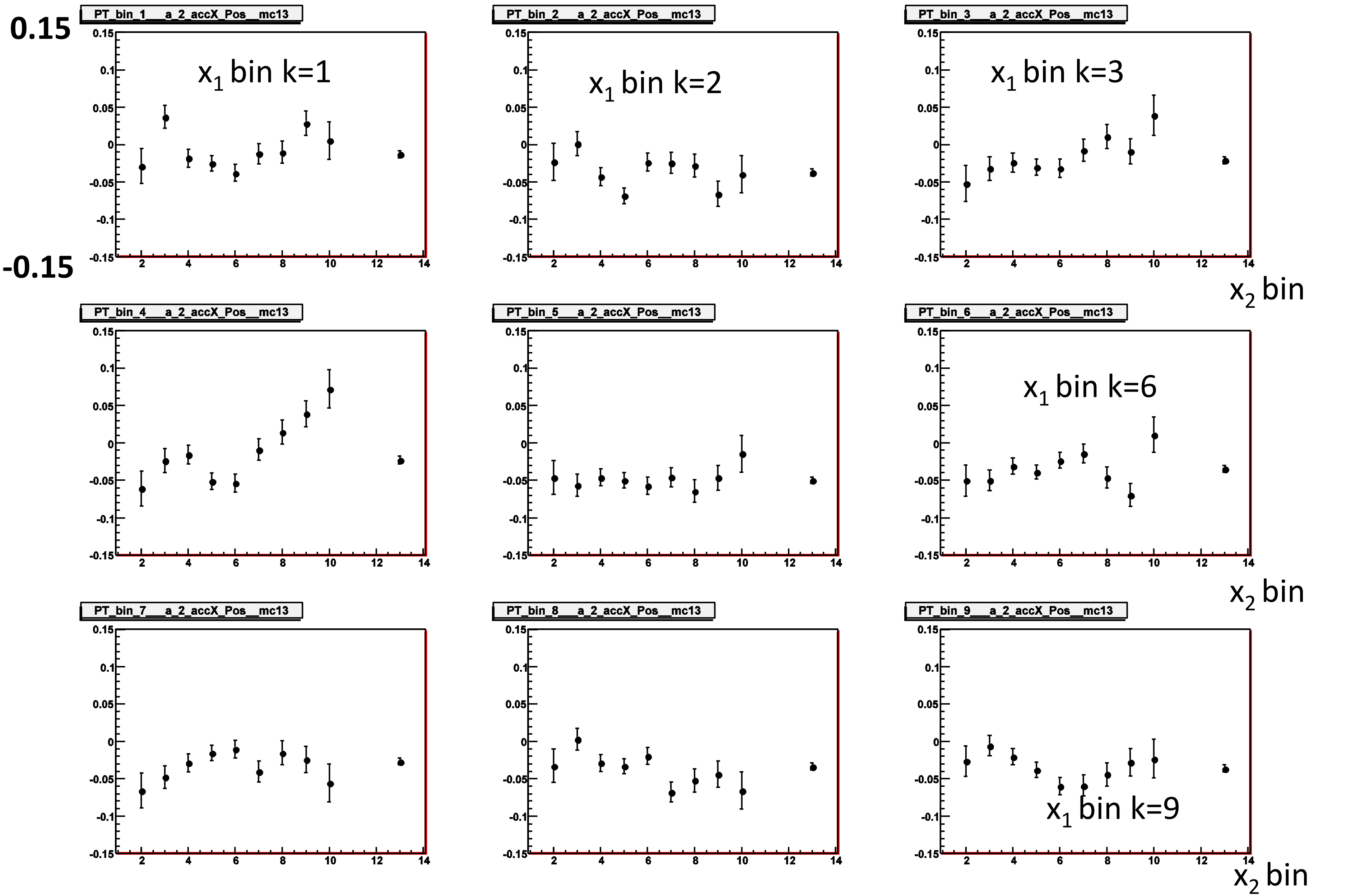
x_1 *(k bin)* = z

x_2= P_T^h



amplitudes of $\mathbf{cos2\phi_h}$ modulations given by the a**cceptance** $a_2^{\,k}(x_2)$ x_1 *(k bin)* = $P_T^{\,h}$

$x_2 = x$



$$Acc_{ijk} = \frac{R_{ijk}^{MC}}{G_{ijk}^{MC}}$$

i = bin in $\boldsymbol{\phi_h}$

k = bin in $\mathbf{x_1}$
(where x_1 = x, z or P_T^h)

j = bin in $\mathbf{x_2}$
(where x_2 = x, y, θ_γ^{lab} , z, P_T^h , ...)

$$Acc_k(x_2, \phi_h) = a_0^k(x_2) \cdot (1 + a_1^k(x_2) \cos\phi_h + a_2^k(x_2) \cos 2\phi_h + $$
$$+ a_3^k(x_2) \sin\phi_h + a_4^k(x_2) \cos 3\phi_h)$$

$$^k N_h^{corr} = \sum_{i=1,..,N}^{N=hadrons} \frac{1}{Acc_k(x_2^i, \phi_h^i)}$$

measured distribtions
are corrected by
weighting for
the acceptance

$$ {}^{k}N_h^{corr} = \sum_{i=1,..,N}^{N=hadrons} \frac{1}{Acc_k(x_2^i, \phi_h^i)} $$

k = bin in $\mathbf{x_1}$

$x_1 = x$ $\quad$ $x_2 = z, P_T^h$

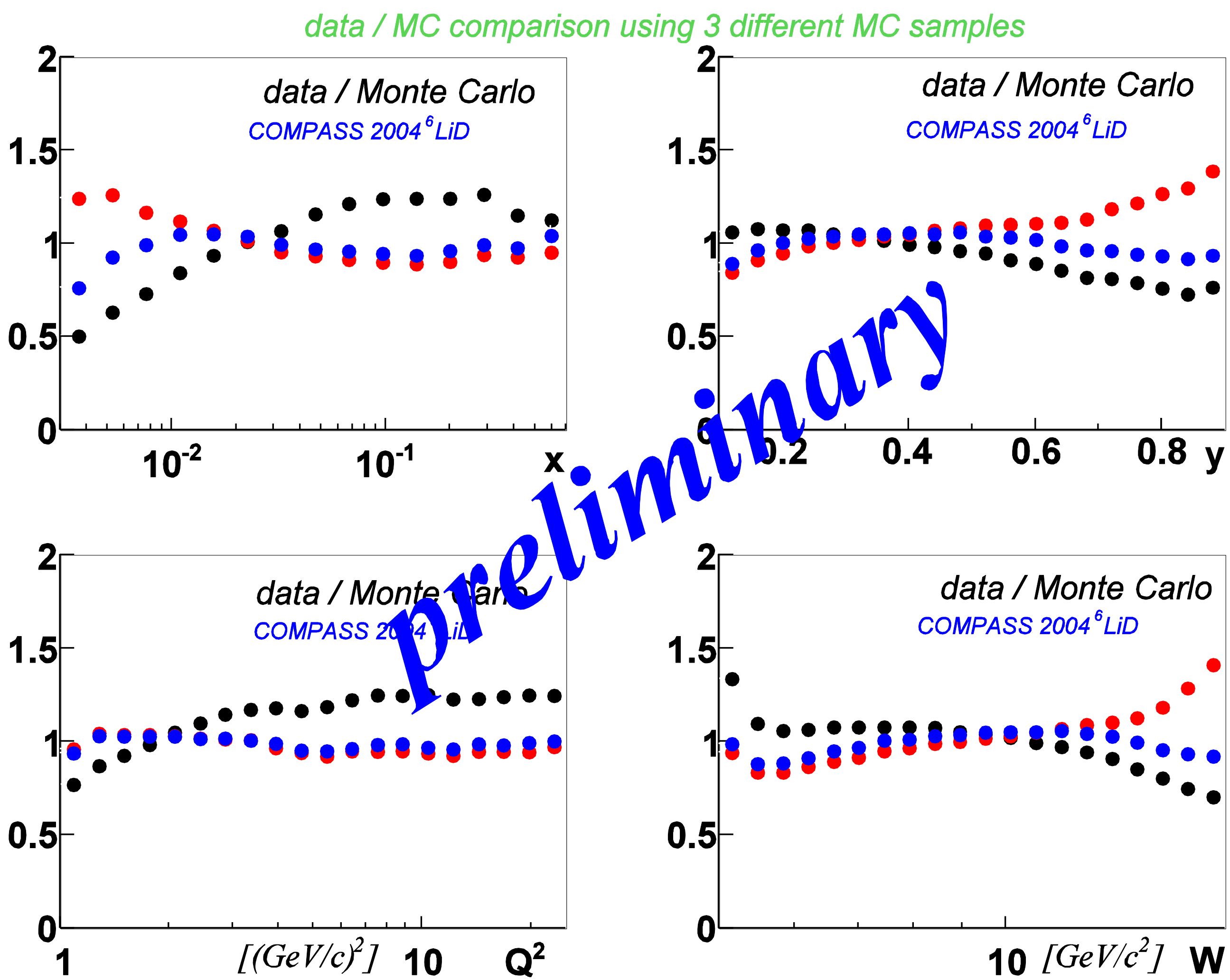
$x_1 = z$ $\quad$ $x_2 = x, P_T^h$

$x_1 = P_T^h$ $\quad$ $x_2 = x, z$

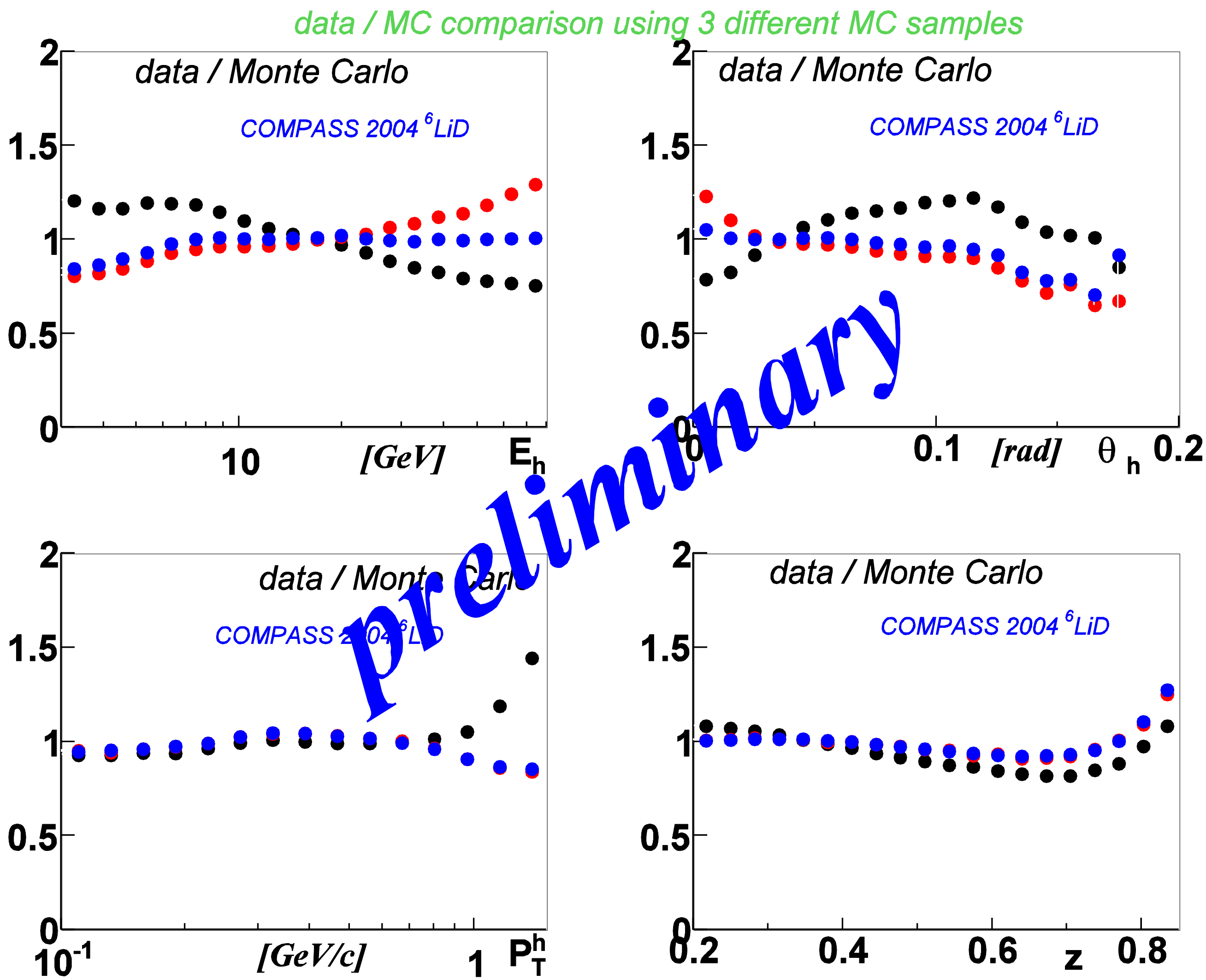
the **asymmetries** extracted using these set of varibles for x_1 and x_2 are the **same**

the **azimuthal amplitudes** are extracted
by **using 3 different MC simulations** describing equally well the apparatus
and obtained using different tunings of the generator

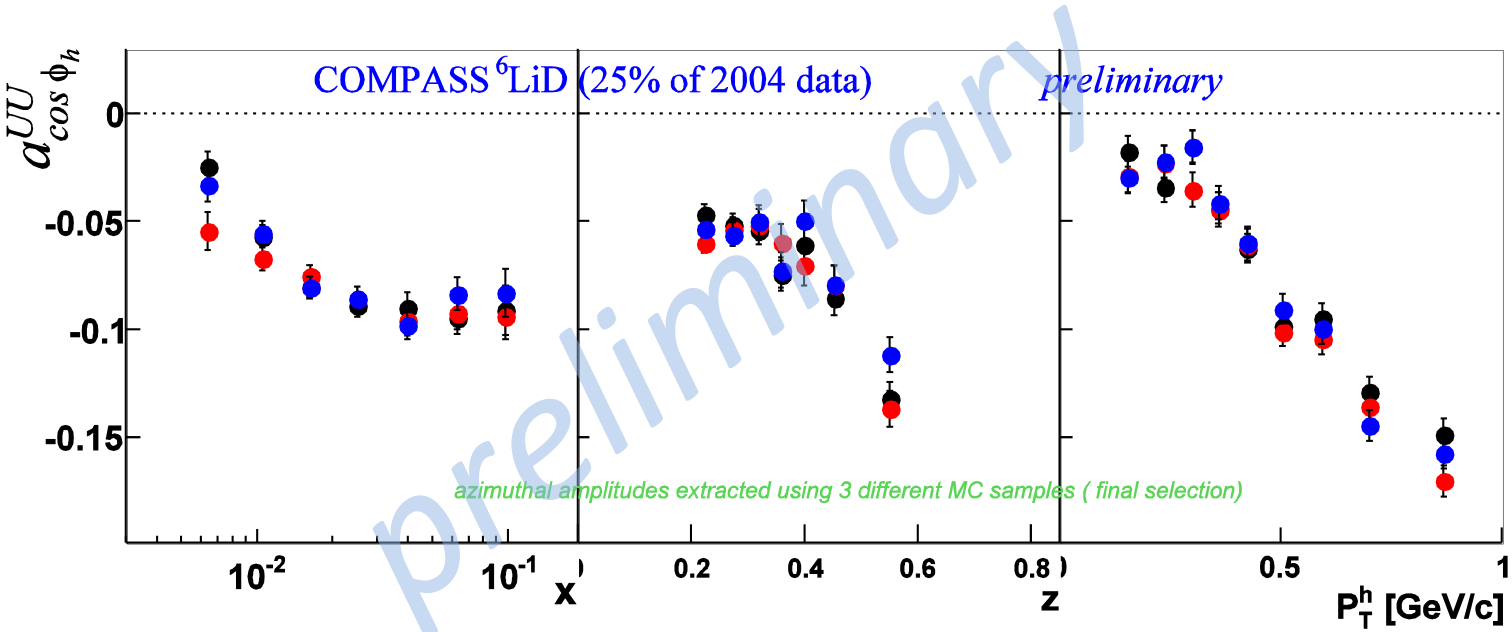
ratios between the RD and the 3 MC events



ratios between the RD and the 3 MC hadrons



in spite of the large difference in the kinematical distributions of the 3 MC the **results are very similar**



even the results obtained using the 1D acceptance $Acc_k(\phi_h)$ (release 2010)

instead of $Acc_k(x_2, \phi_h)$

in spite of the large difference in the kinematical distributions of the 3 MC the **results are very similar**

taken into account in the systematic errors

the results obtained using 1D or 2D acceptances are the same

as expected in case of flat acceptance

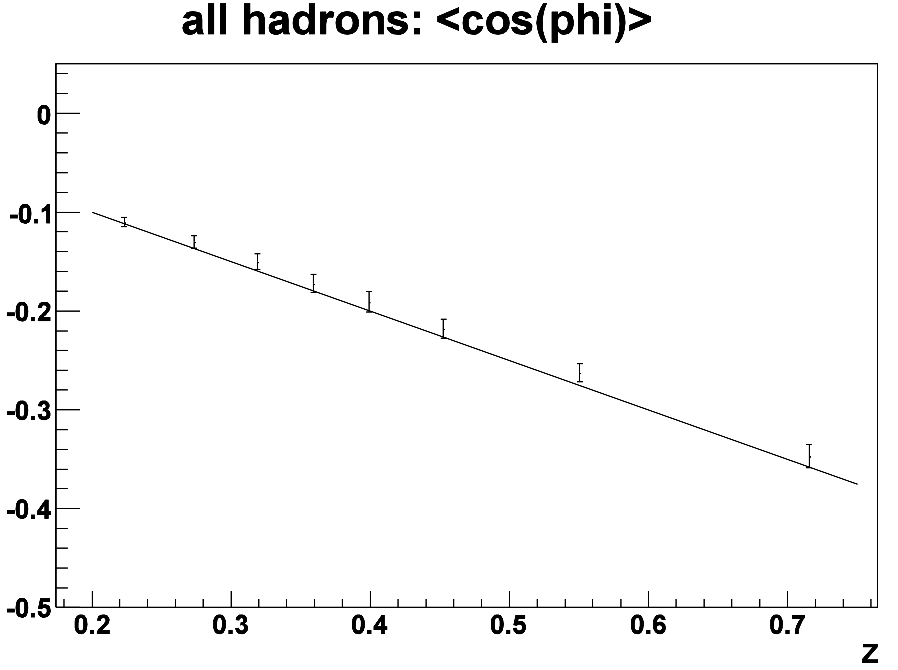
↓

the acceptance and the method have been thoroughly studied and we are confident of our results (paper in preparation) further tests:

- **smearing**
- **radiative effects**

smearing due to the spectrometer resolution

a large **cosϕ_h asymmetry** has been forced into the the **generated azimuthal distribution** (the **black line**) *(no cahn effect in lepto)*



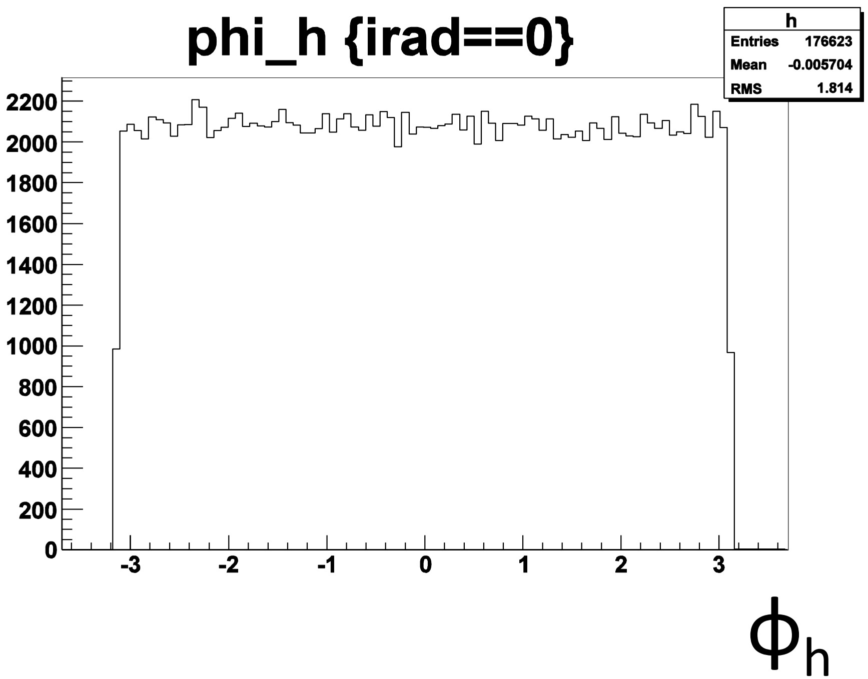
the **points** are the **values extracted from the MC using the reconstructed values** for the kinematical variables and ϕ_h

the effect on the extracted asymmetries is negligible : 0.01 (absolute)

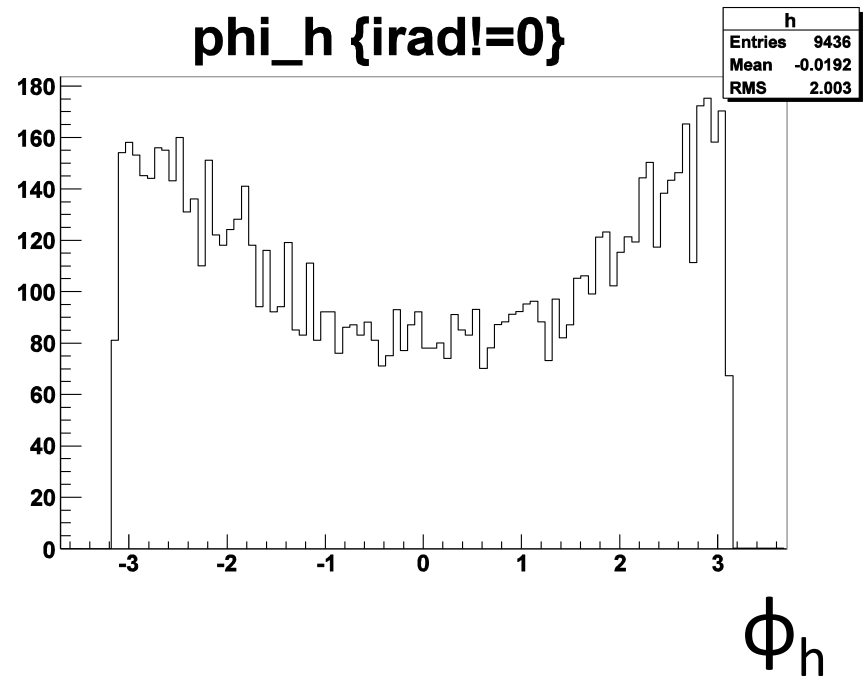
radiative effects

some tests done, using radgen (+lepto)

NO RAD events

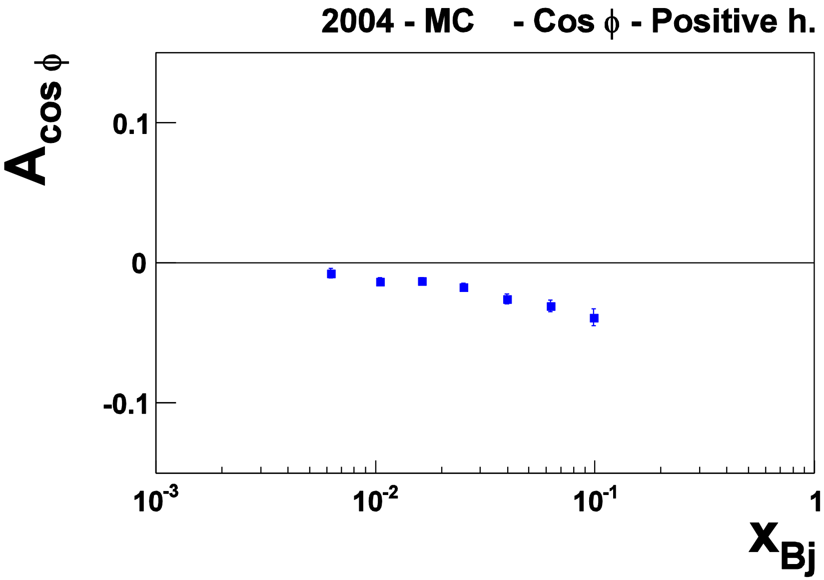


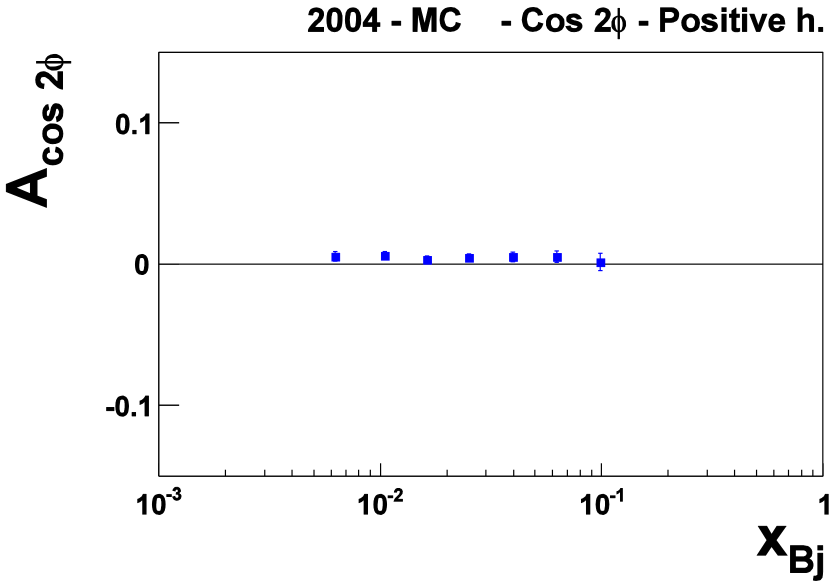
RAD events



the effect of the radiative events on the extracted asymmetries can be estimated from

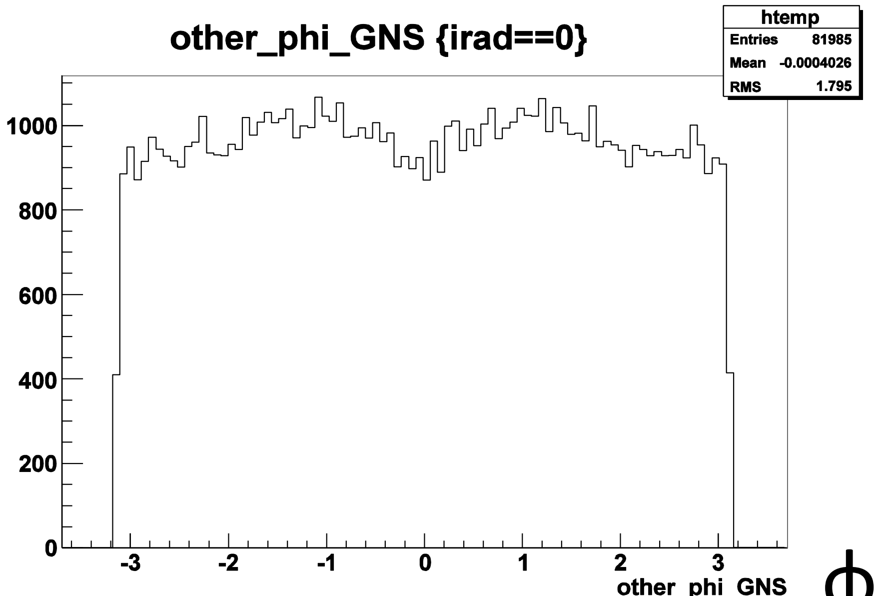
$$\frac{n^{gen}_{Lepto+Radgen}(\phi_h)}{n^{gen}_{Lepto}(\phi_h)}$$





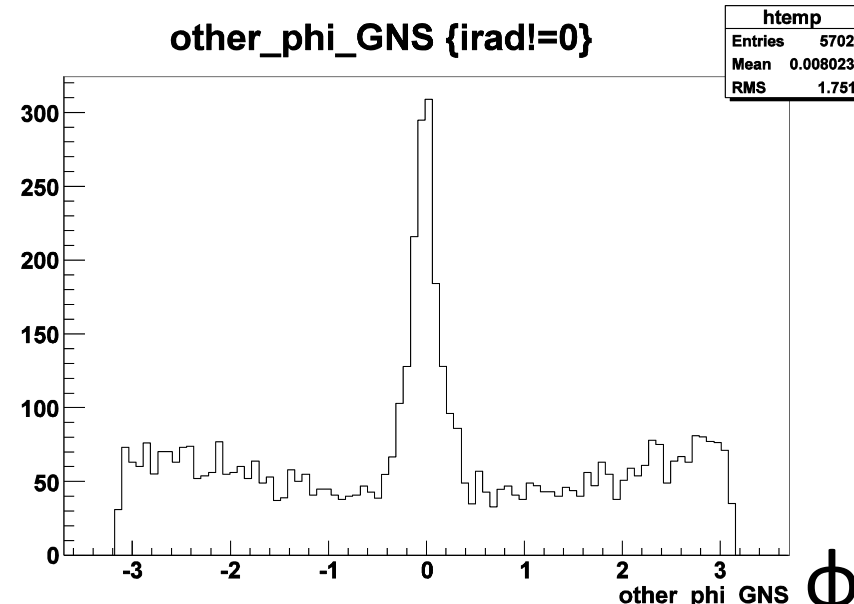
the sample (lepto + radgen) passed through the complete MC chain

NO RAD events



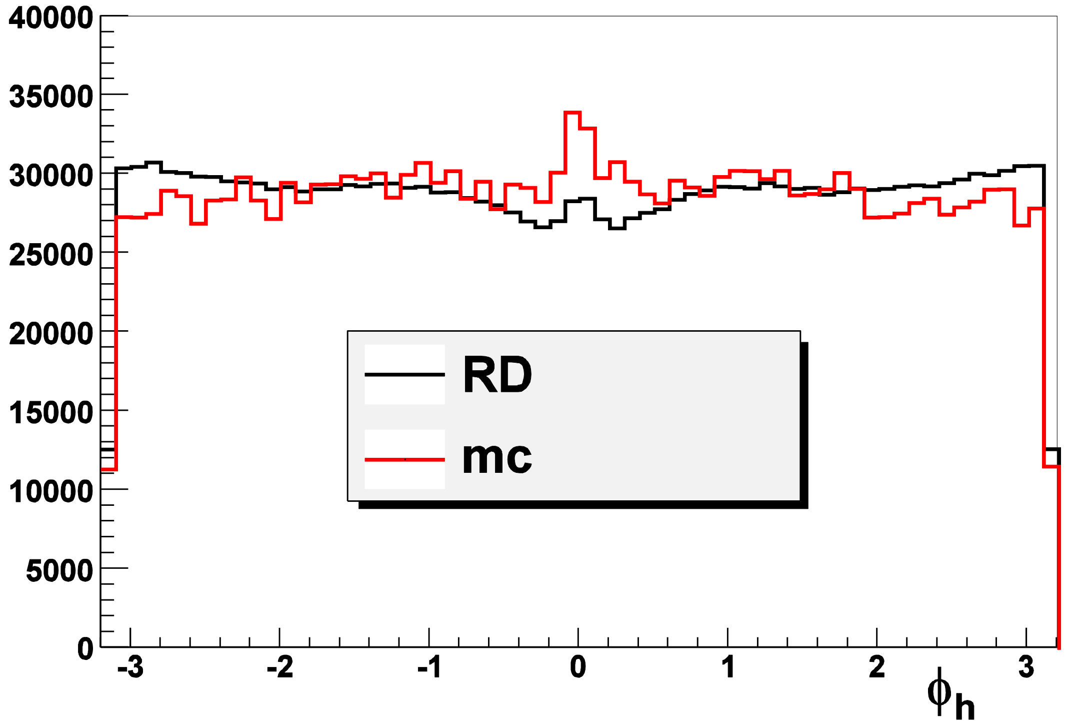
ϕ_h

RAD events



ϕ_h

e+e- produced by photon convertion inside the apparatus comparing the effect (the peak at ϕ_h=0) in RD and MC



it is found that the effect is **overestimated in the MC used**

the radiative effect in the MC are overestimated,
in agreement with

theoretical calculation
(Afanasev , invited talk at COMPASS Analysis Meeting Sept. 2010)

the effect on the measured amplitudes of the azimuhal modulations is evaluated to be less than 1%

better tools have tobe implented (B.Badelek) to precisely evaluate the effect on the asymmetries spares

PDFs used in Lepto

MRST04LO

MSTW2008LO

CTEQ05L