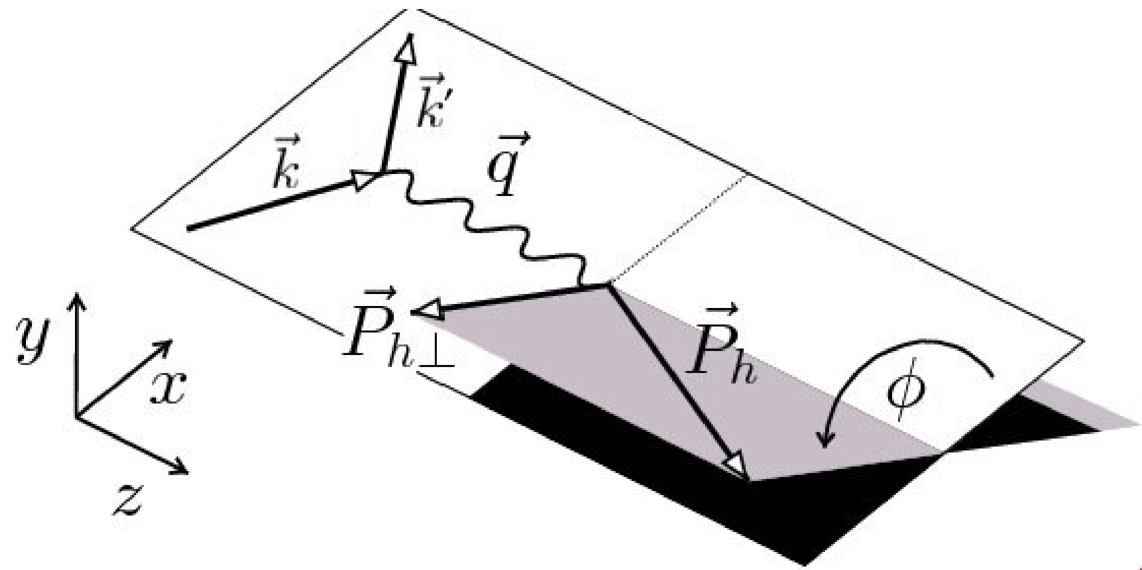
Università degli studi di Ferrara

Measurement of azimuthal asymmetries of the unpolarized cross-section at HERMES

Francesca Giordano

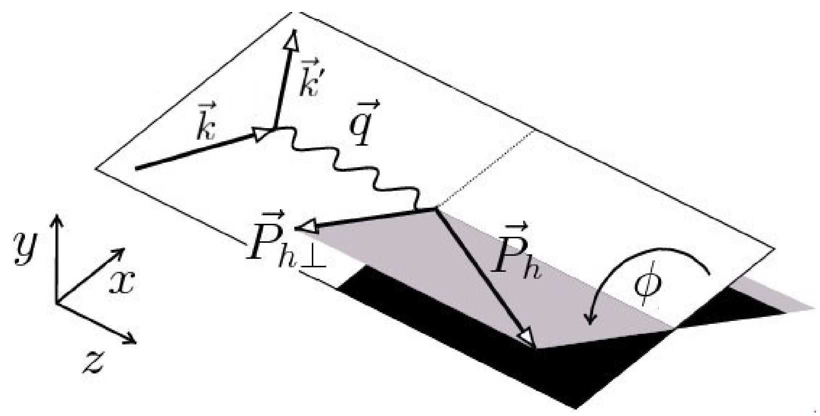
Ferrara, Transversity 08

Unpolarized Semi Inclusive DIS (SIDIS)



Unpolarized SIDIS :

<u>collinear approximation</u>



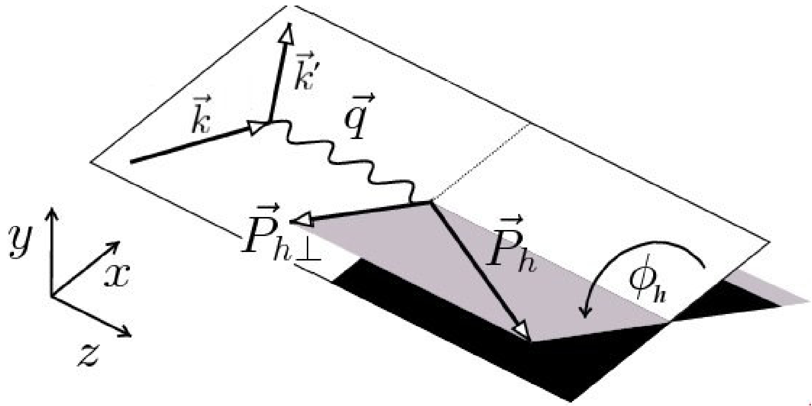
$$\frac{d^3\sigma}{dx\ dy\ dz} = \frac{\alpha^2}{xyQ^2}\left(1+\frac{\gamma^2}{2x}\right)\left\{A(y)\ F_{UU,T} + B(y)\ F_{UU,L}\right\}$$

$$F_{...} = F_{...}(x, Q^2, z)$$

$$A(y) \approx (1 - y + 1/2y^2)$$
$$B(y) \approx (1 - y)$$

Unpolarized SIDIS :

non-collinear cross-section



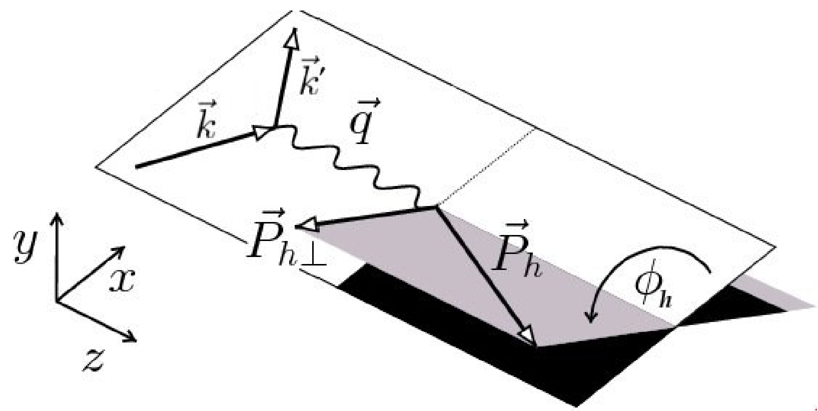
$$\frac{d^5\sigma}{dx\,dy\,dz\,d\phi\,dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\left(1+\frac{\gamma^2}{2x}\right)\Big\{A(y)\;F_{UU,T} + B(y)\;F_{UU,L}$$

$$+C(y)\;\cos\phi\,F_{UU}^{\cos\phi} + B(y)\;\cos 2\phi\,F_{UU}^{\cos 2\phi}\Big\}$$

$$F_{\dots} = F_{\dots}(x, Q^2, z, P_{h\perp})$$

$$A(y) \approx (1 - y + 1/2\,y^2)$$
$$B(y) \approx (1 - y)$$
$$C(y) \approx (2 - y)\sqrt{1 - y}$$

Unpolarized SIDIS :
non-collinear cross-section



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$$+C(y)\ \cos\phi\, F_{UU}^{\cos\phi} + B(y)\ \cos 2\phi\, F_{UU}^{\cos 2\phi}\Big\}$$

$$\langle \cos n\phi \rangle = \frac{\int \cos n\phi\ d^5\sigma}{\int d^5\sigma}$$

$$\int d^5\sigma = \int dx\ dy\ dz\ dP_{h\perp}^2 d\phi \frac{d^5\sigma}{dx\ dy\ dz\ dP_{h\perp}^2 d\phi}$$

Leading twist expansion

Distribution Functions (DF)			
N / q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	$h_1, h_{1T}^\perp$

Fragmentation Functions (FF)	
q/h	U
U	D_1
T	$H_1^\perp$

Leading twist expansion

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T	$f_{1T}^{\perp}$	$g_{1T}^{\perp}$	$h_1, h_{1T}^{\perp}$

$$F_{UU,T} \propto f_1 \otimes D_1$$

f_1 ↓ **DF**

D_1 ↓ **FF**

Fragmentation Functions (FF)	
q/h	U
U	D_1
T	$H_1^{\perp}$

Leading twist expansion

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$h_1^\perp$ = **Boer-Mulders function**

CHIRAL-ODD

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$h_1^{\perp}$ = **Boer-Mulders function**

CHIRAL-ODD

$$h_1^{\perp} \otimes H_1^{\perp}$$

chiral-odd DF — **chiral-odd FF**

CHIRAL-EVEN!

Structure functions expansion at leading twist

$$F_{UU}^{\cos 2\phi} = C\left[-\frac{2(\hat{h}\cdot\vec{k}_T)(\hat{h}\cdot\vec{p}_T) - \vec{k}_T\cdot\vec{p}_T}{MM_h} \underline{h_1^{\perp} H_1^{\perp}} \right]$$

Structure functions expansion at twist 3

$$F_{UU}^{\cos 2\phi} = C\left[-\frac{2(\hat{h}\cdot\vec{k}_T)(\hat{h}\cdot\vec{p}_T) - \vec{k}_T\cdot\vec{p}_T}{MM_h} \underline{h_1^{\perp} H_1^{\perp}} \right]$$

$$F_{UU}^{\cos\phi} = \frac{2M}{Q} C\left[-\frac{\hat{h}\cdot\vec{p}_T}{M_h}\left(xhH_1^{\perp} + \frac{M_h}{M} f_1 \frac{\tilde{D}^{\perp}}{z} \right) - \frac{\hat{h}\cdot\vec{k}_T}{M}\left(xf^{\perp} D_1 + \frac{M_h}{M} h_1^{\perp} \frac{\tilde{H}}{z} \right) \right]$$

Structure functions expansion at twist 3

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$$F_{UU}^{\cos\phi} = \frac{2M}{Q} C\left[-\frac{\hat{h}\cdot\vec{p}_T}{M_h}\Big(\overbrace{xhH_1^{\perp}}^{x\tilde{h} + \frac{\kappa_T^2}{M^2} h_1^{\perp}} + \frac{M_h}{M} f_1 \frac{\tilde{D}^{\perp}}{z}\Big) - \frac{\hat{h}\cdot\vec{k}_T}{M}\Big(\overbrace{xf^{\perp}D_1}^{x\tilde{f}^{\perp} + f_1} + \frac{M_h}{M} h_1^{\perp} \frac{\tilde{H}}{z}\Big)\right]$$

Cahn and Boer-Mulders effects

$$F_{UU}^{\cos 2\phi} = C\left[-\frac{2(\hat{h}\cdot\vec{k}_T)(\hat{h}\cdot\vec{p}_T)-\vec{k}_T\cdot\vec{p}_T}{MM_h}\,\underline{h_1^{\perp}H_1^{\perp}}\right]$$

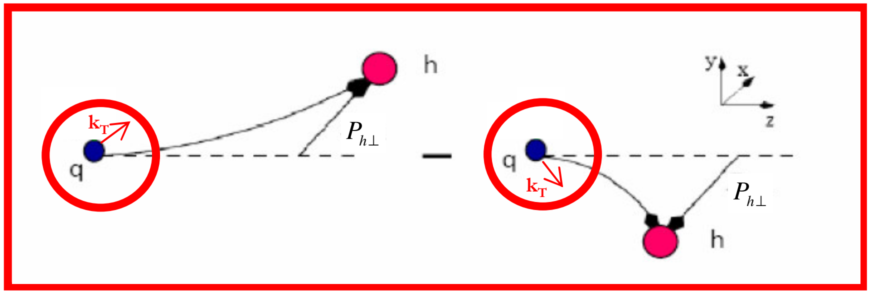
$$F_{UU}^{\cos\phi} = \frac{2M}{Q}C\left[-\frac{\hat{h}\cdot\vec{p}_T}{M_h}\,x\,\underline{h_1^{\perp}H_1^{\perp}}-\frac{\hat{h}\cdot\vec{k}_T}{M}\,x\,\underline{f_1D_1}\right]$$

Cahn and Boer-Mulders effects

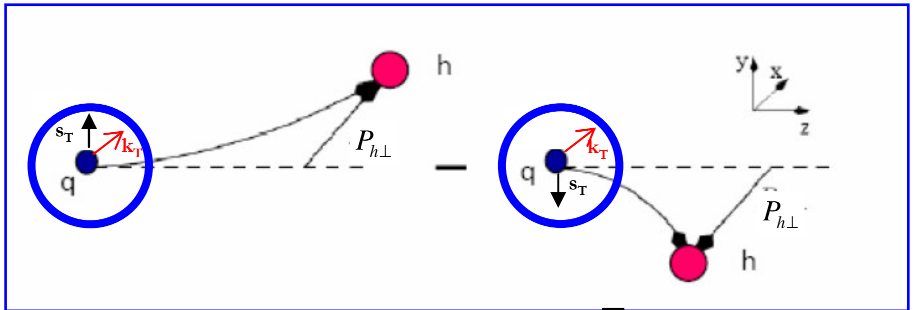
$$F_{UU}^{\cos 2\phi} = C\left[-\frac{2(\hat{h}\cdot\vec{k}_T)(\hat{h}\cdot\vec{p}_T) - \vec{k}_T\cdot\vec{p}_T}{MM_h} h_1^{\perp} H_1^{\perp} \right]$$

CAHN EFFECT

$$F_{UU}^{\cos\phi} = \frac{2M}{Q} C\left[-\frac{\hat{h}\cdot\vec{p}_T}{M_h} x\ h_1^{\perp} H_1^{\perp} - \frac{\hat{h}\cdot\vec{k}_T}{M} x\ f_1 D_1 \right]$$



Cahn and Boer-Mulders effects



BOER-MULDERS EFFECT

$$F_{UU}^{\cos 2\phi} = C\left[-\frac{2(\hat{h}\cdot\vec{k}_T)(\hat{h}\cdot\vec{p}_T) - \vec{k}_T\cdot\vec{p}_T}{MM_h} h_1^{\perp} H_1^{\perp} \right]$$

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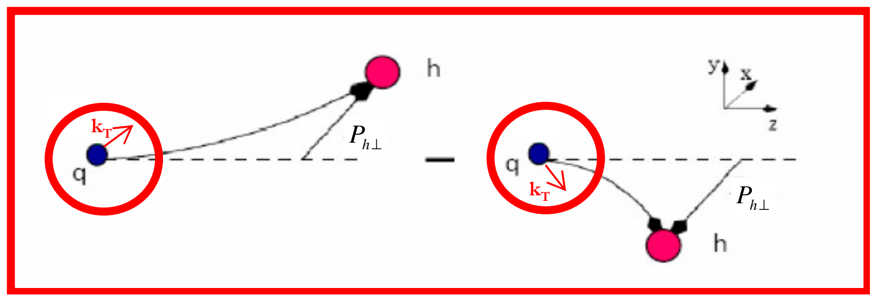
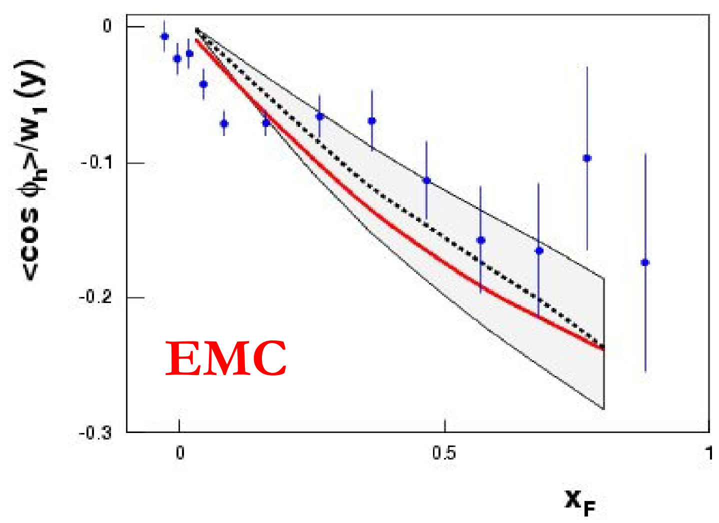
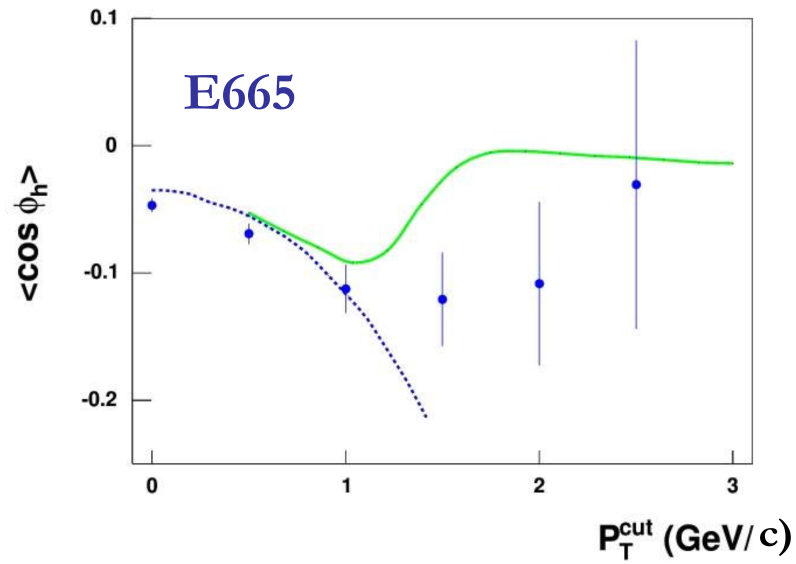
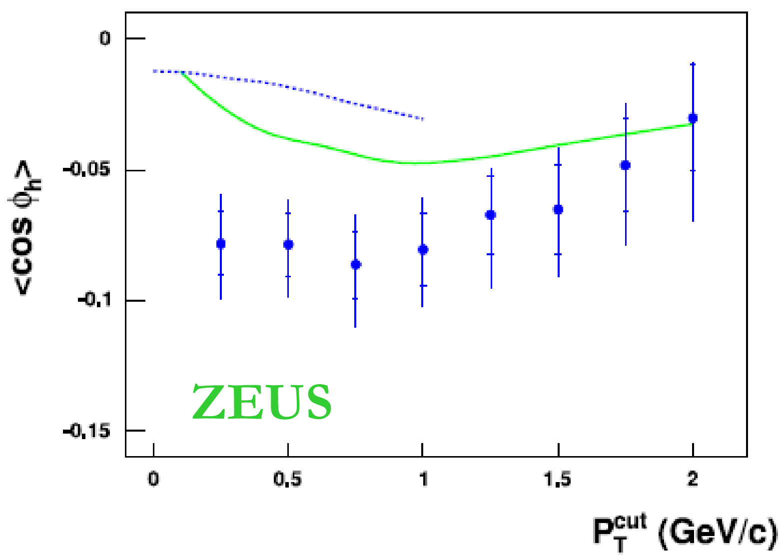


Experimental status: $\langle \cos\phi \rangle$

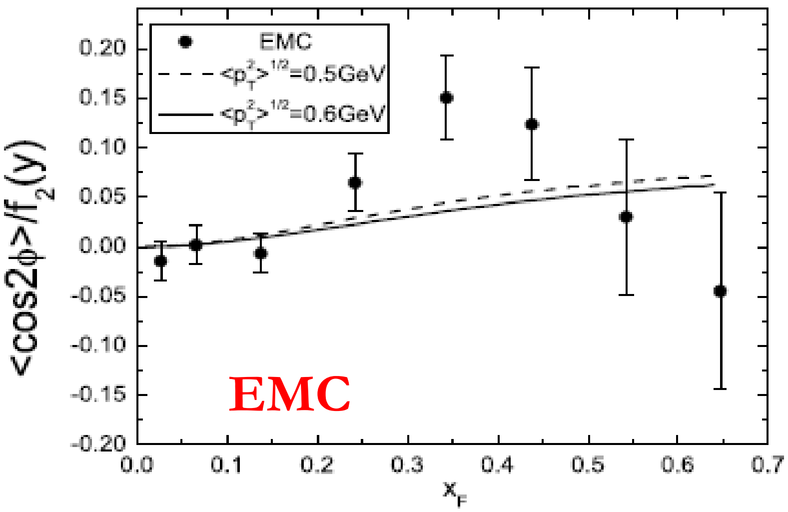


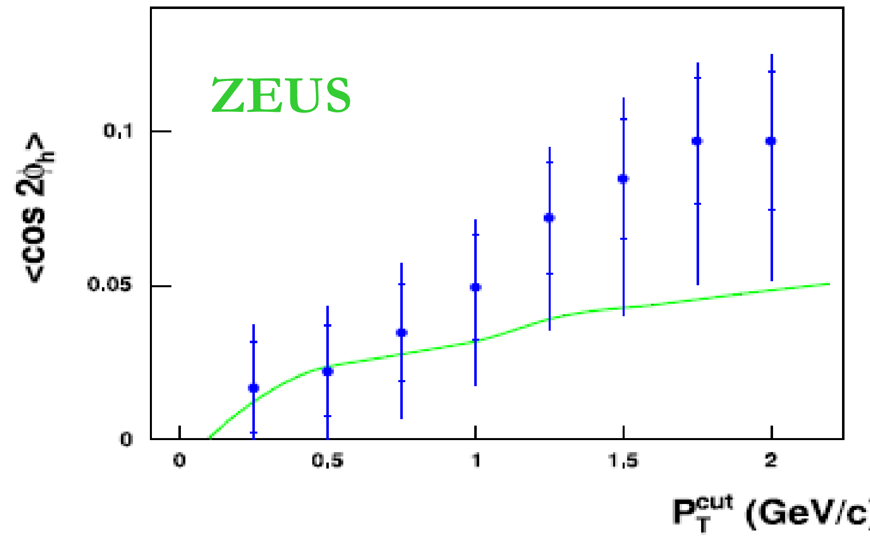




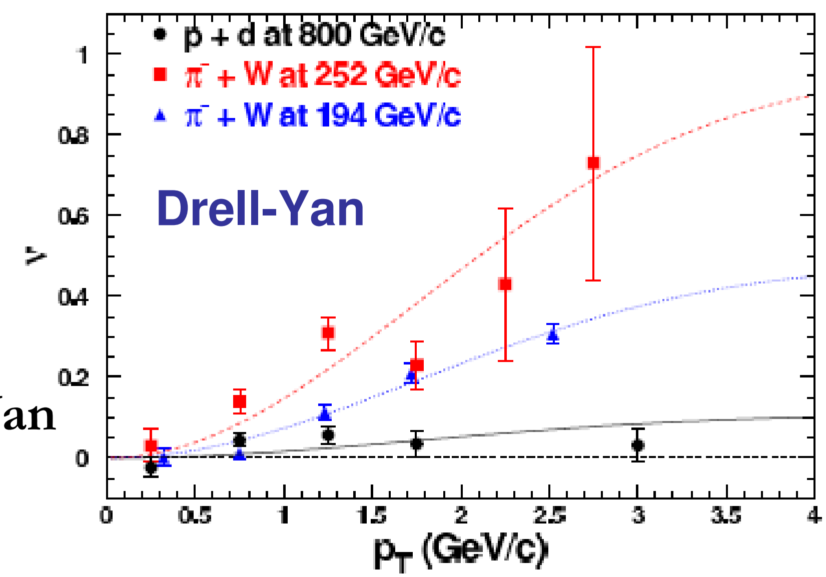
- Negative results in all the existing measurements
- No distinction between hadron type or charge

Experimental status: $\langle \cos 2\phi \rangle$



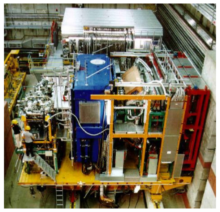


- Positive results in all the existing measurements
- No distinction between hadron type or charge (in SIDIS experiments)
- Indication of small Boer-Mulders function for the sea quark (from Drell-Yan experiments)

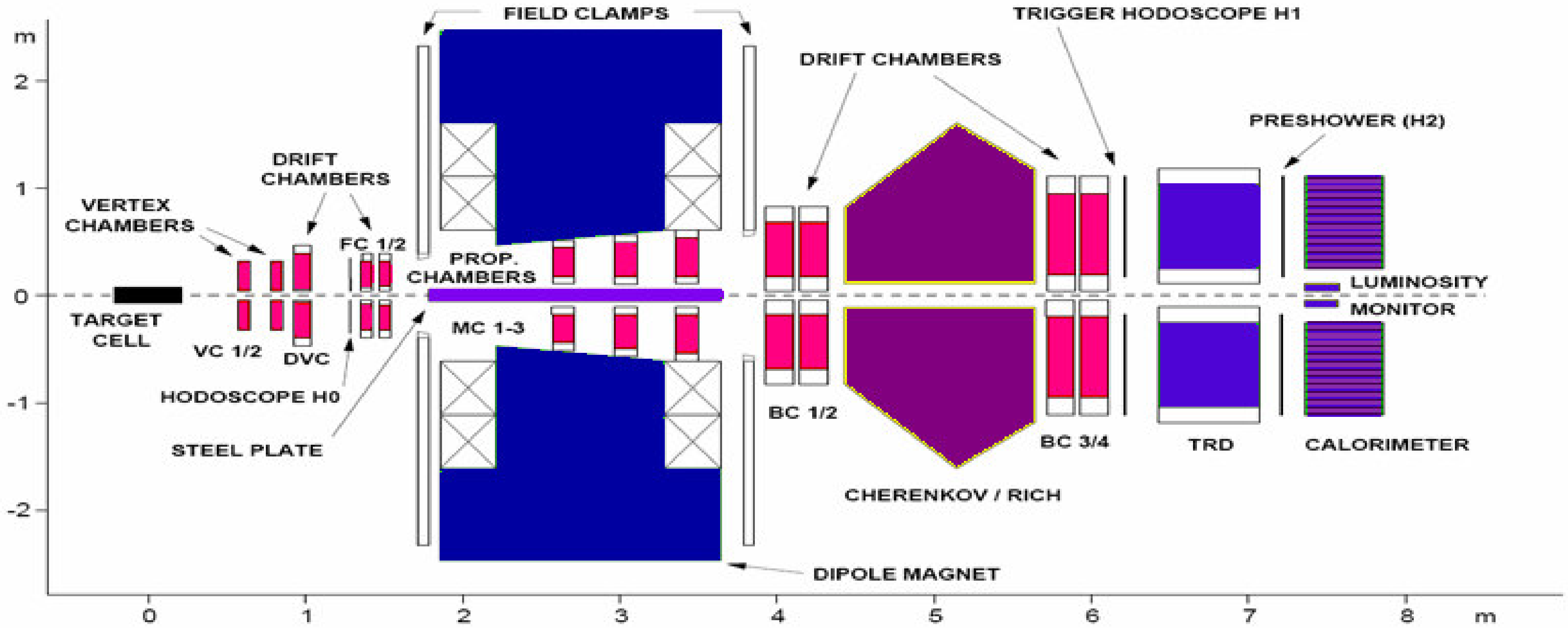


HERa MEasurement of Spin

HERA storage ring @ DESY



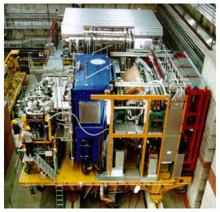
HERMES spectrometer



Resolution: $\Delta p/p \sim$ 1-2% $\Delta\theta$ <~0.6 mrad

Electron-hadron separation efficiency ~ 98-99%

Hadron identification with dual-radiator RICH



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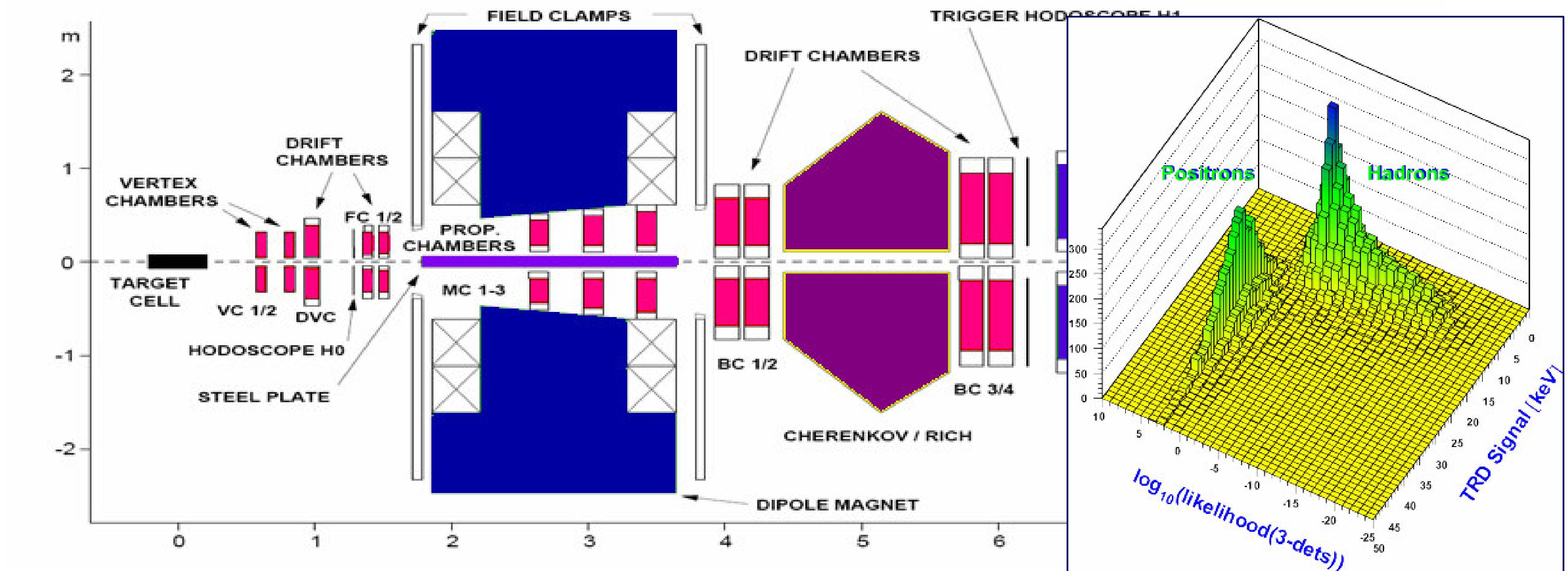

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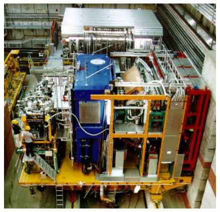

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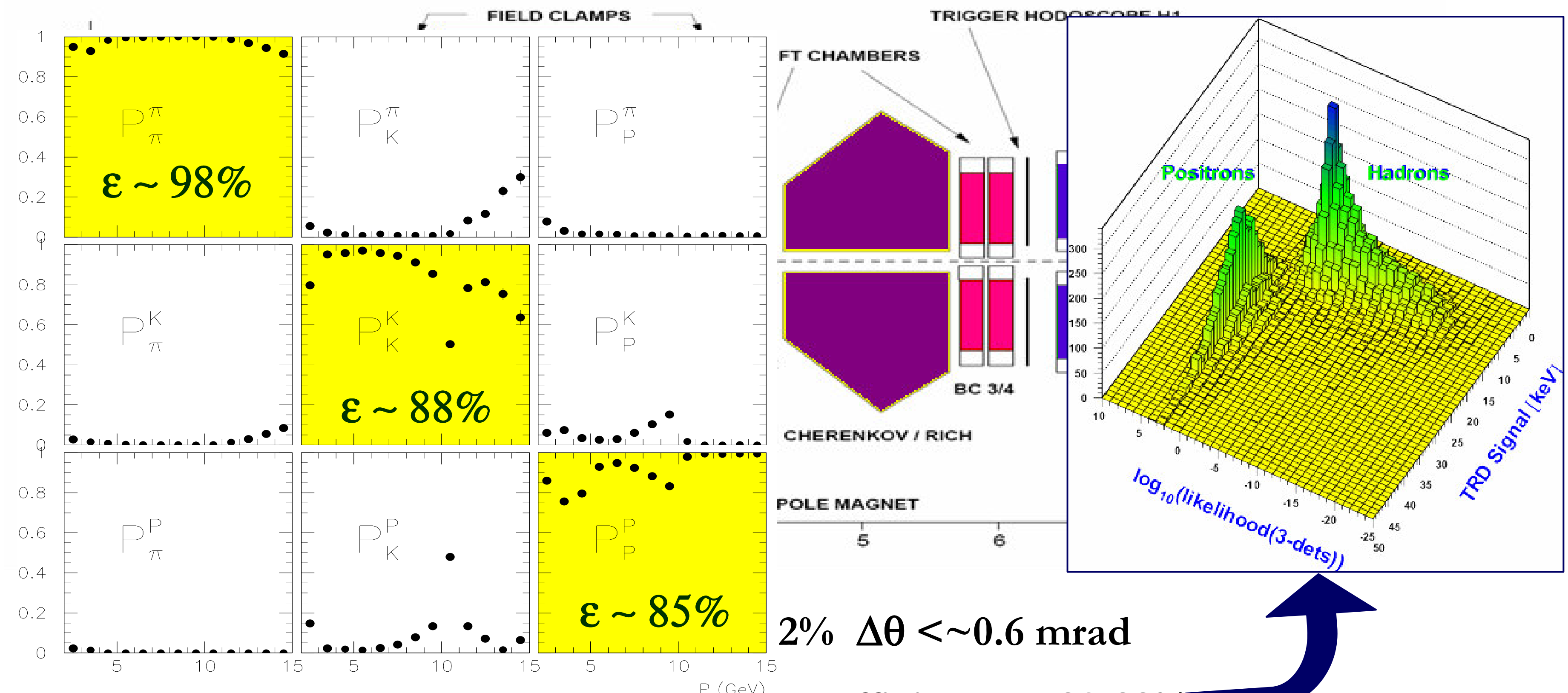

2% Δθ <~0.6 mrad

Electron-hadron separation efficiency ~ 98-99%

Hadron identification with dual-radiator RICH

Possible Measurements @ hermes

- **Flavour sensitive results:**
  - Distinction of hadron type and charge (thanks to the RICH identification)
  - Results from scattering off different targets (Hydrogen, Deuterium,….)

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Information about the Boer-Mulders distribution function

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Possible access to quark intrinsic transverse momenta via the cahn effect

Information about the Boer-Mulders distribution function

Possible sensitivity to functions related to graphs with an additional gluon ($\tilde{f}^{\perp}, \tilde{D}^{\perp}, \tilde{h}, \tilde{H}$)

Extraction method

$$n^{EXP} = \int \sigma_0 L(1 + A\cos\phi + B\cos 2\phi)$$

$$A = 2\langle \cos\,\phi \rangle$$

$$B = 2\langle \cos\,2\phi \rangle$$

Extraction method

$$n^{EXP} = \int \sigma_0 L(1 + A\cos\phi + B\cos 2\phi)\, \varepsilon_{acc}(\phi)\varepsilon_{RAD}(\phi)$$

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$$n^{EXP} = \int \sigma_0 L(1 + A_{F_{UU}})\varepsilon_{acc}\varepsilon_{RAD}$$

$$n^{MC} = \int \sigma_0^{MC} L^{MC} \varepsilon_{acc}^{MC} \varepsilon_{RAD}^{MC}$$

Extraction method

Monte Carlo check

$$n^{EXP} = \int \sigma_0 L (1 + A\cos\phi + B\cos 2\phi)\ \varepsilon_{acc}(\phi)\varepsilon_{RAD}(\phi)$$

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$$n^{CAHN} = \int \sigma_0 L \, (1 + A\cos\phi + B\cos 2\phi) \; \varepsilon_{acc}(\phi)\varepsilon_{RAD}(\phi)$$

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Model for the 'Cahn effect' in Monte Carlo

Extraction method

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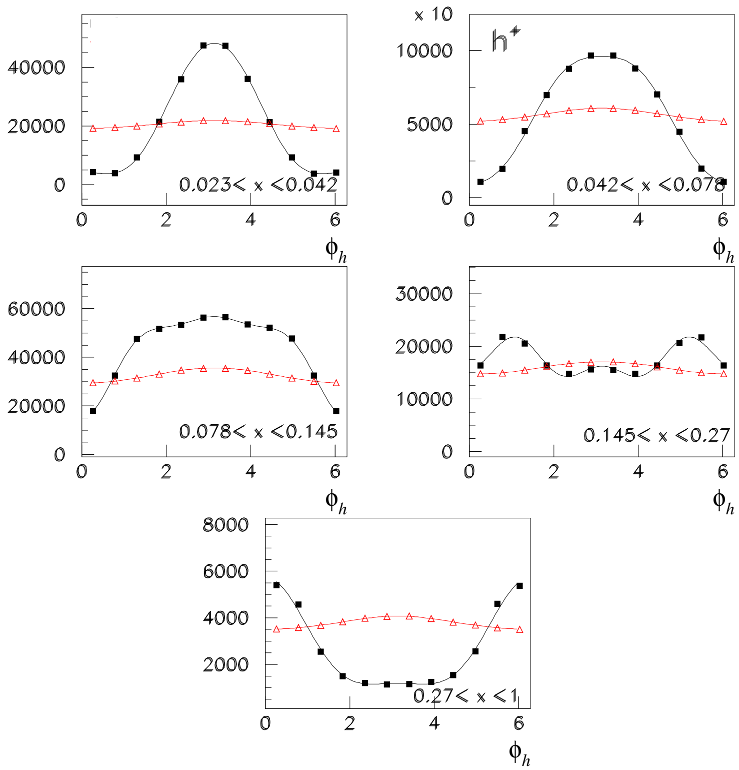
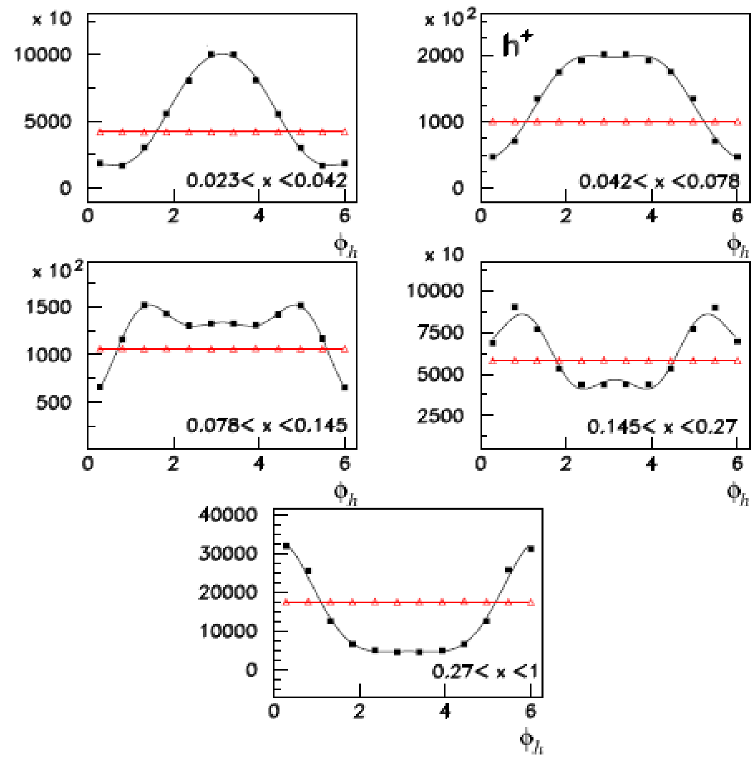
Monte Carlo + Cahn model



$$n^{MC} = \int \sigma_0^{MC} L^{MC} \varepsilon_{acc}^{MC} \varepsilon_{RAD}^{MC}$$

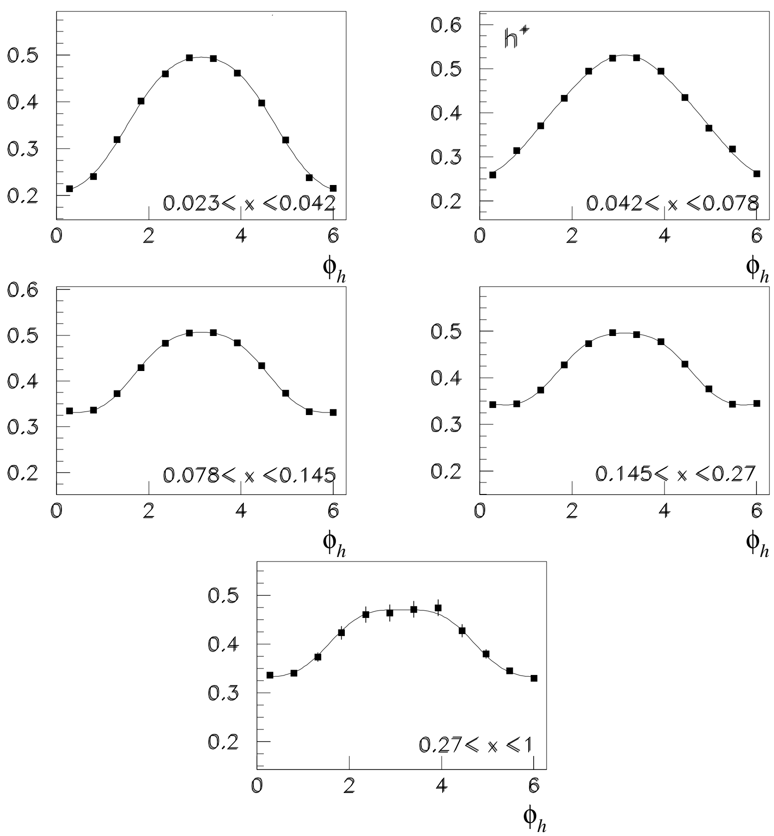
Standard Monte Carlo



Extraction method

$$\frac{n^{CAHN}}{n^{MC}} = \frac{\int \sigma_0 \varepsilon_{acc} \varepsilon_{RAD} L \left(1 + A\cos\phi + B\cos 2\phi\right)}{\int \sigma_0^{MC} \varepsilon_{acc}^{MC} \varepsilon_{RAD}^{MC} L^{MC}}$$

(MC+Cahn)/MC



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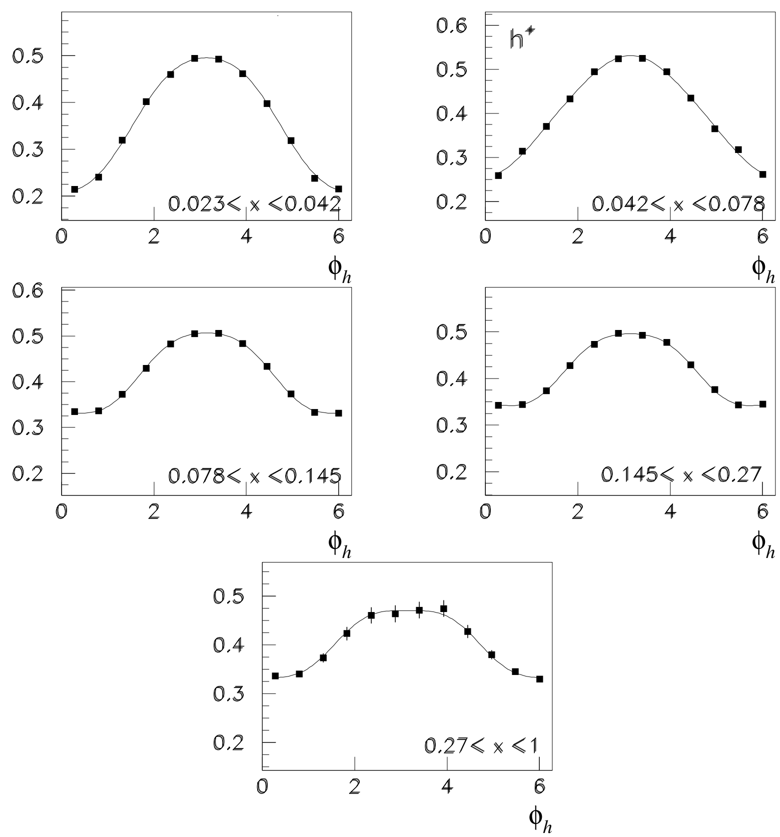

$$\sigma_0 = \sigma_0(\bar{x}) \qquad \varepsilon_i = \varepsilon_i(\bar{x})$$

$$A = A(\bar{x}) \qquad B = B(\bar{x})$$

$$\bar{x} = (x, y, z, P_{h\perp})$$

Extraction method

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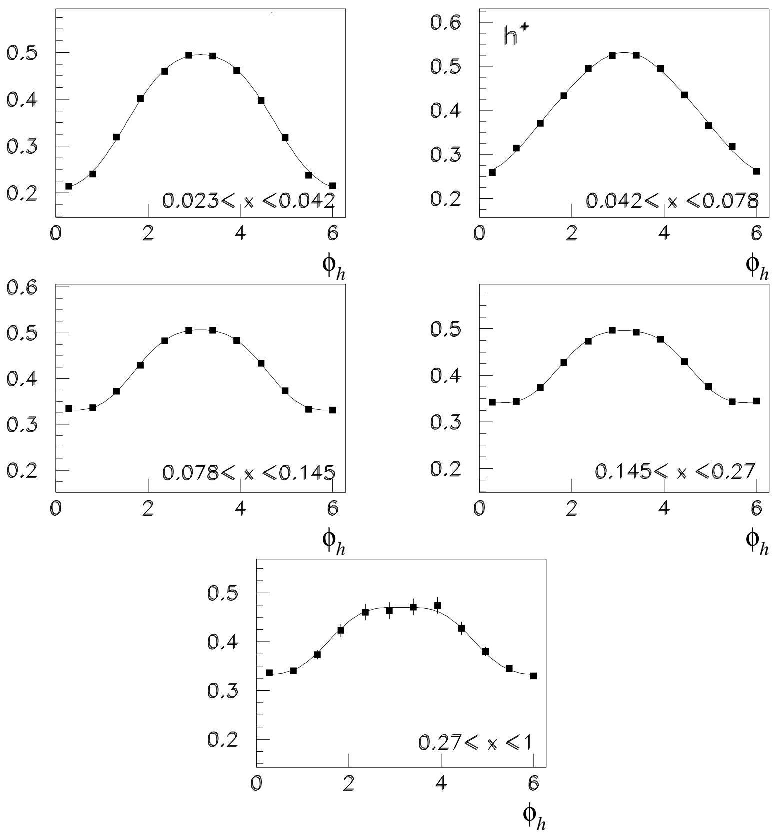

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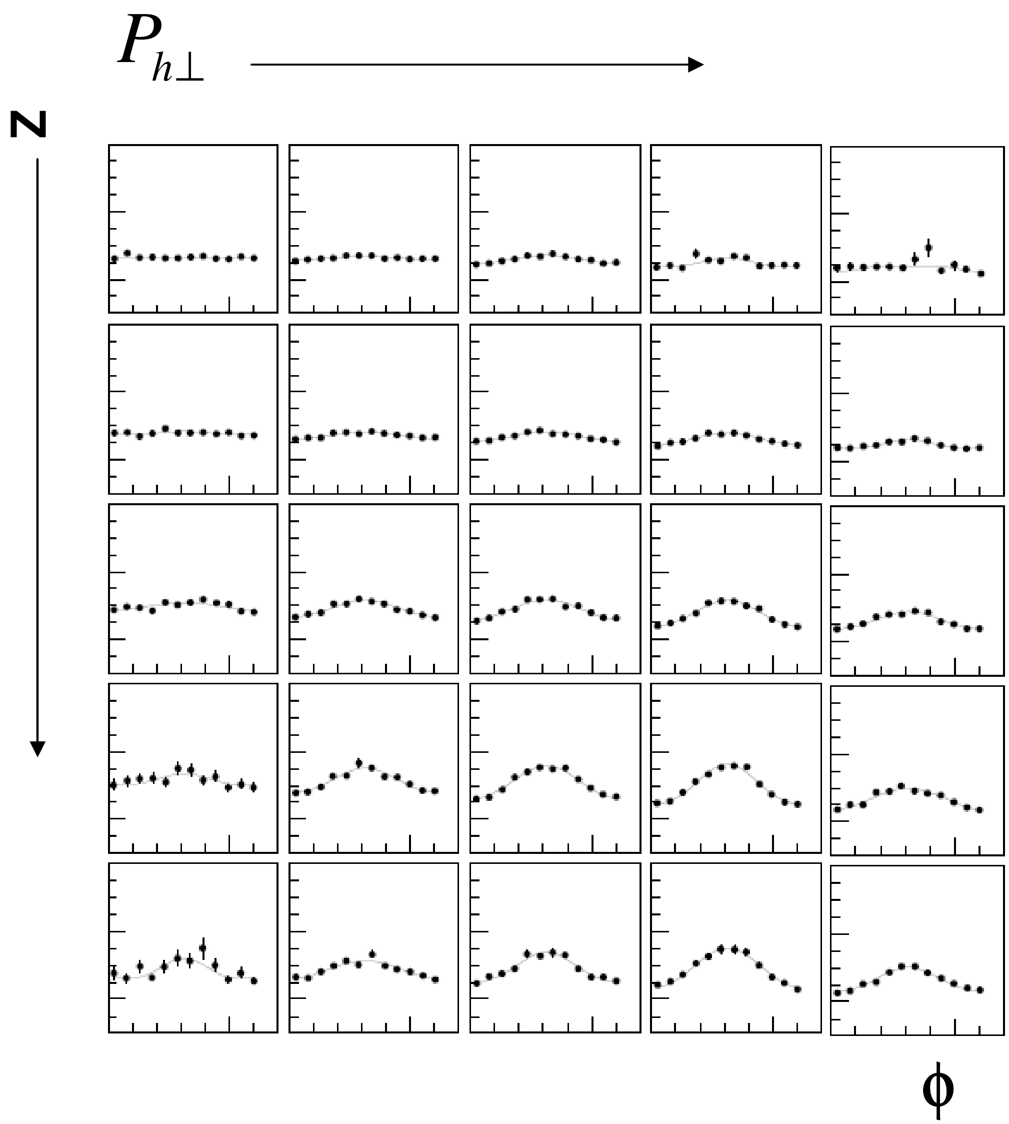
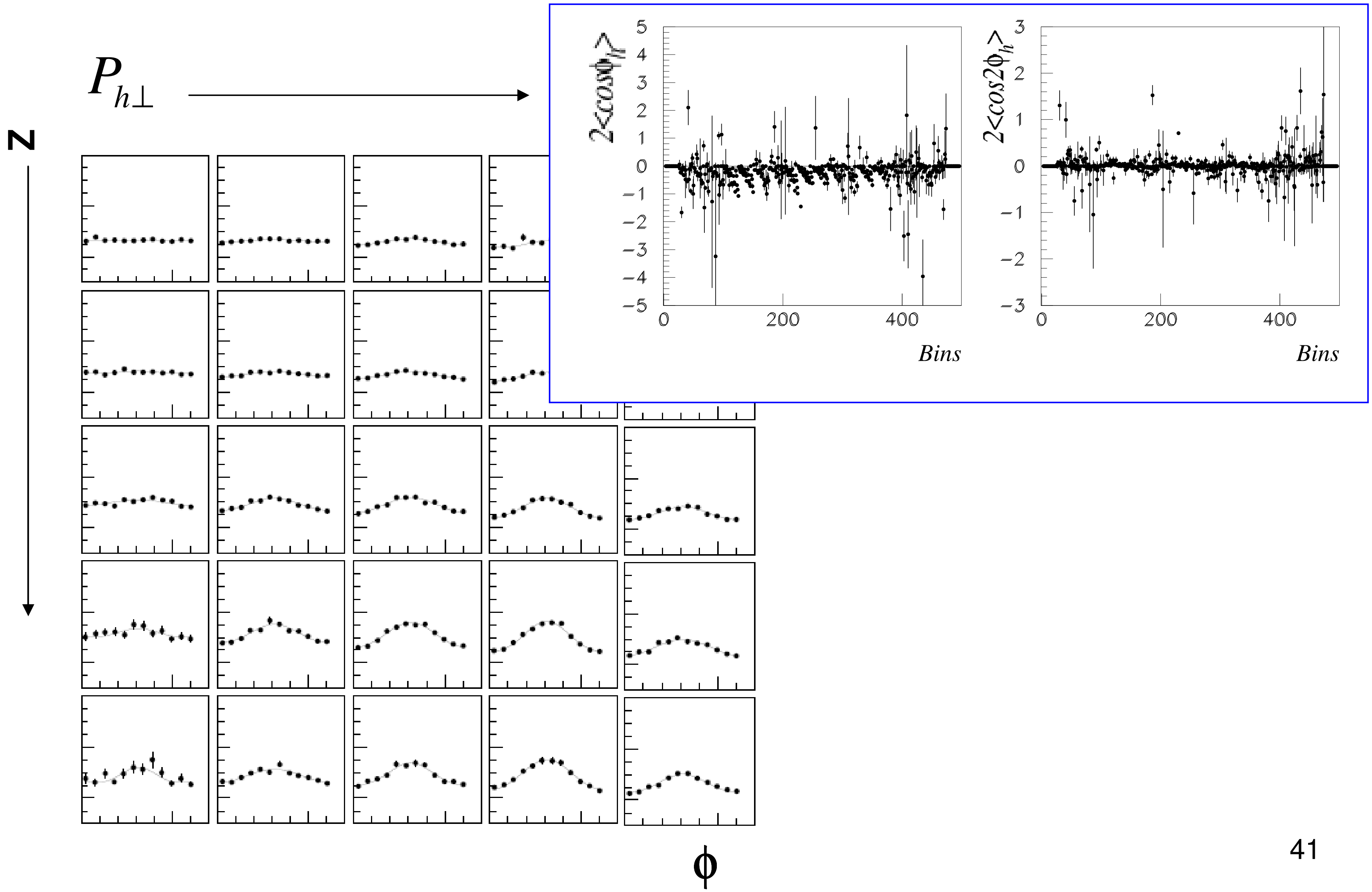
Fully differential analysis

BINNING 500 kinematical bins $\times$ 12 ϕ-bins							
Variable	Bin limits						#
x_{bj}	0.023	0.042	0.078	0.145	0.27	1	5
y_{bj}	0.3	0.45	0.6	0.7	0.85		4
z	0.2	0.3	0.45	0.6	0.75	1	5
P_{h_T}	0.05	0.2	0.35	0.5	0.75	1.41	5

The method

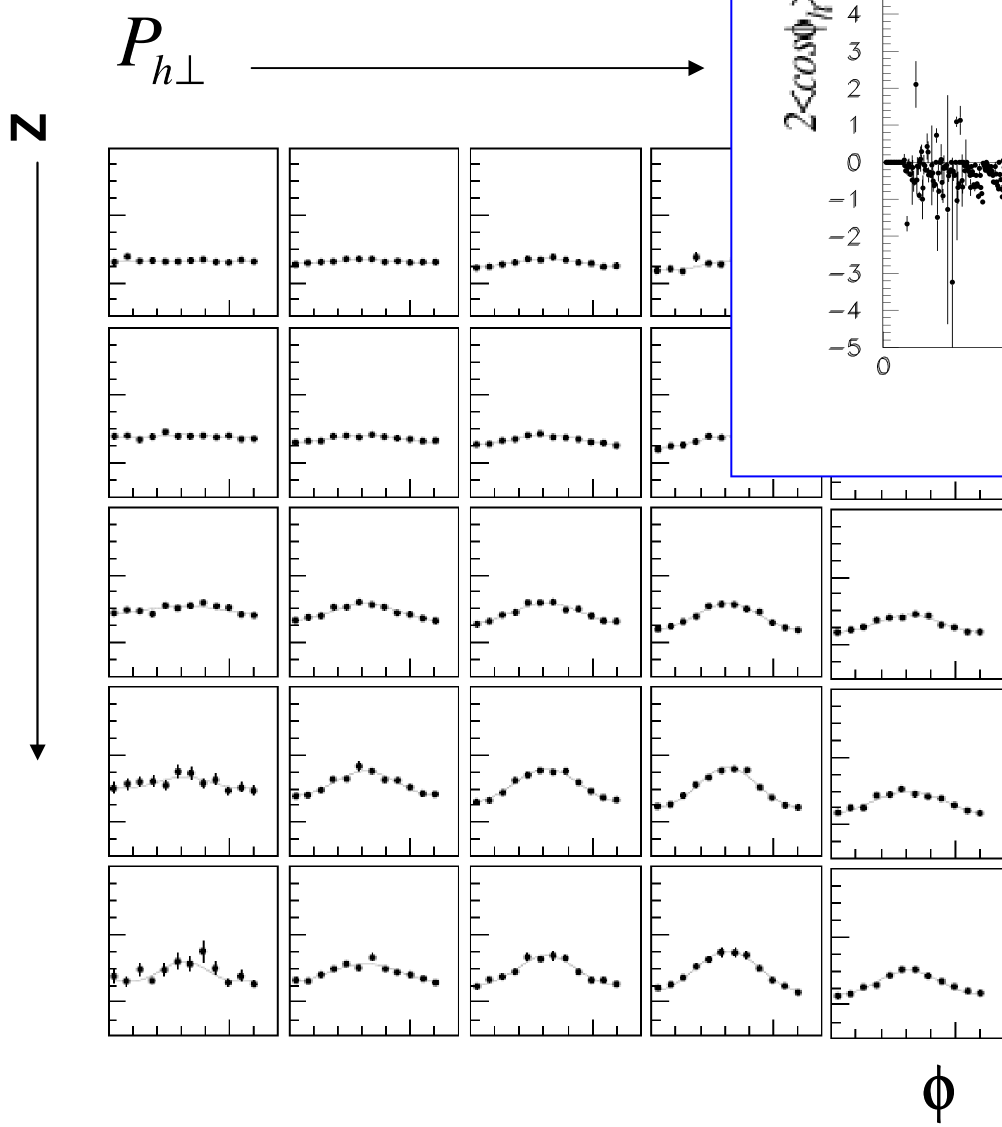


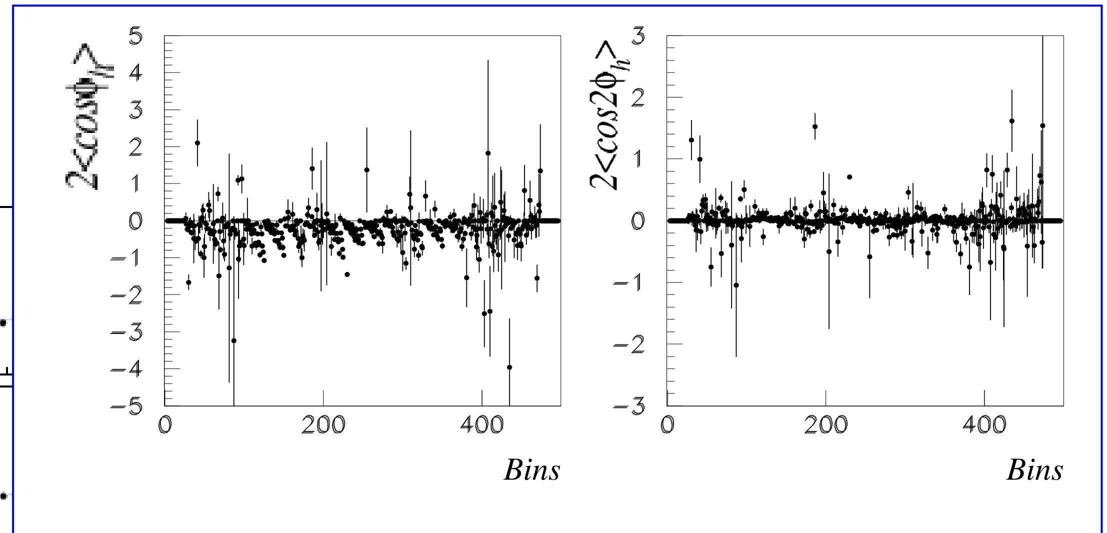
The method



$P_{h\perp}$
z
$2\langle cos\phi_h \rangle$
$2\langle cos2\phi_h \rangle$
Bins
Bins
ϕ

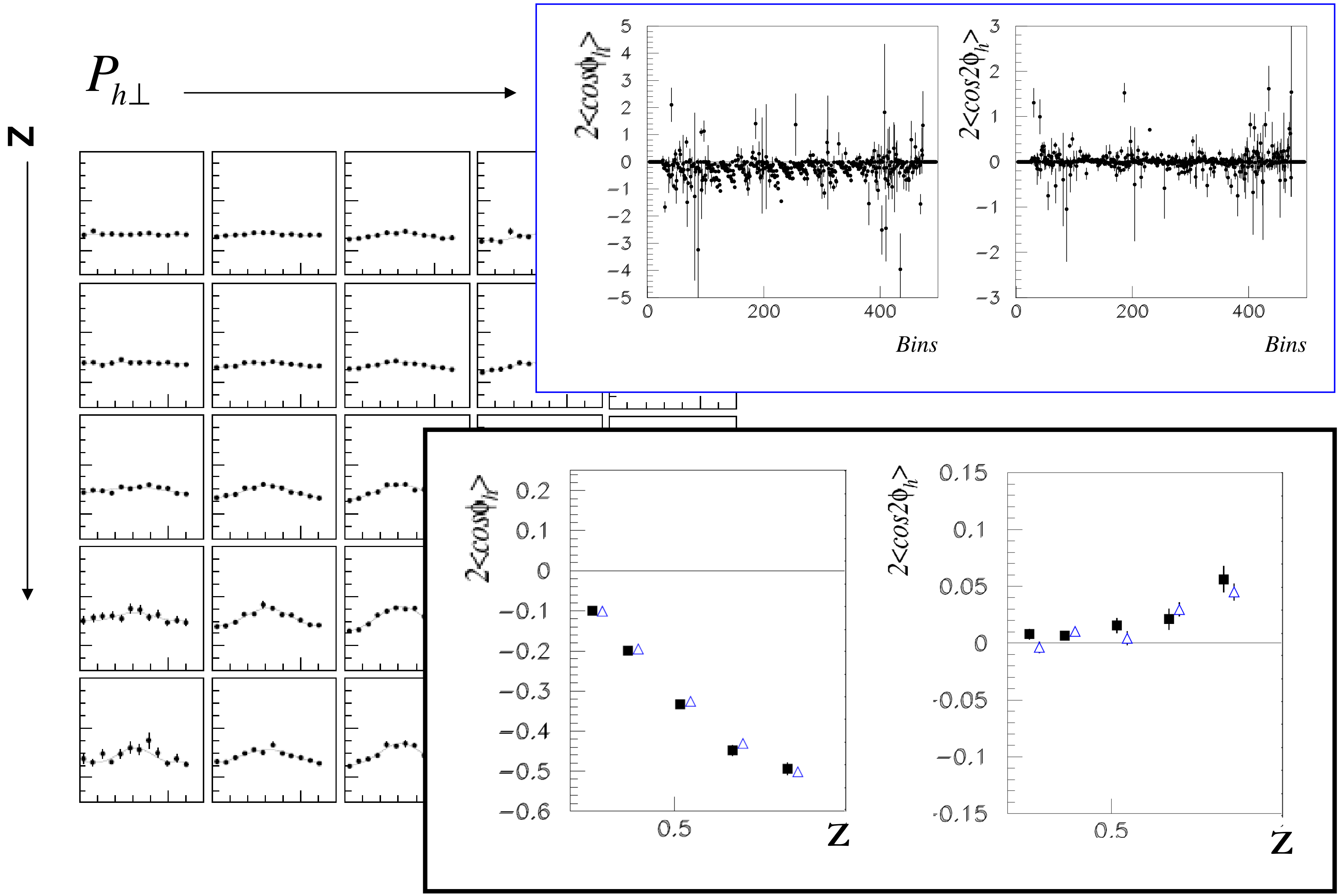
The method





$$\langle \cos\phi \rangle (x) = \frac{\sum_i \sigma_i^{4\pi}(x) \langle \cos\phi \rangle_i}{\sum_i \sigma_i^{4\pi}(x)}$$

The method



Fake asymmetries

$$\frac{n^{MC\,1}}{n^{MC\,2}} = \frac{\int \sigma_0^{MC\,1} \varepsilon_{acc}^{MC} \varepsilon_{RAD}^{MC} L^{MC\,1}}{\int \sigma_0^{MC\,2} \varepsilon_{acc}^{MC} \varepsilon_{RAD}^{MC} L^{MC\,2}}$$

Fake asymmetries

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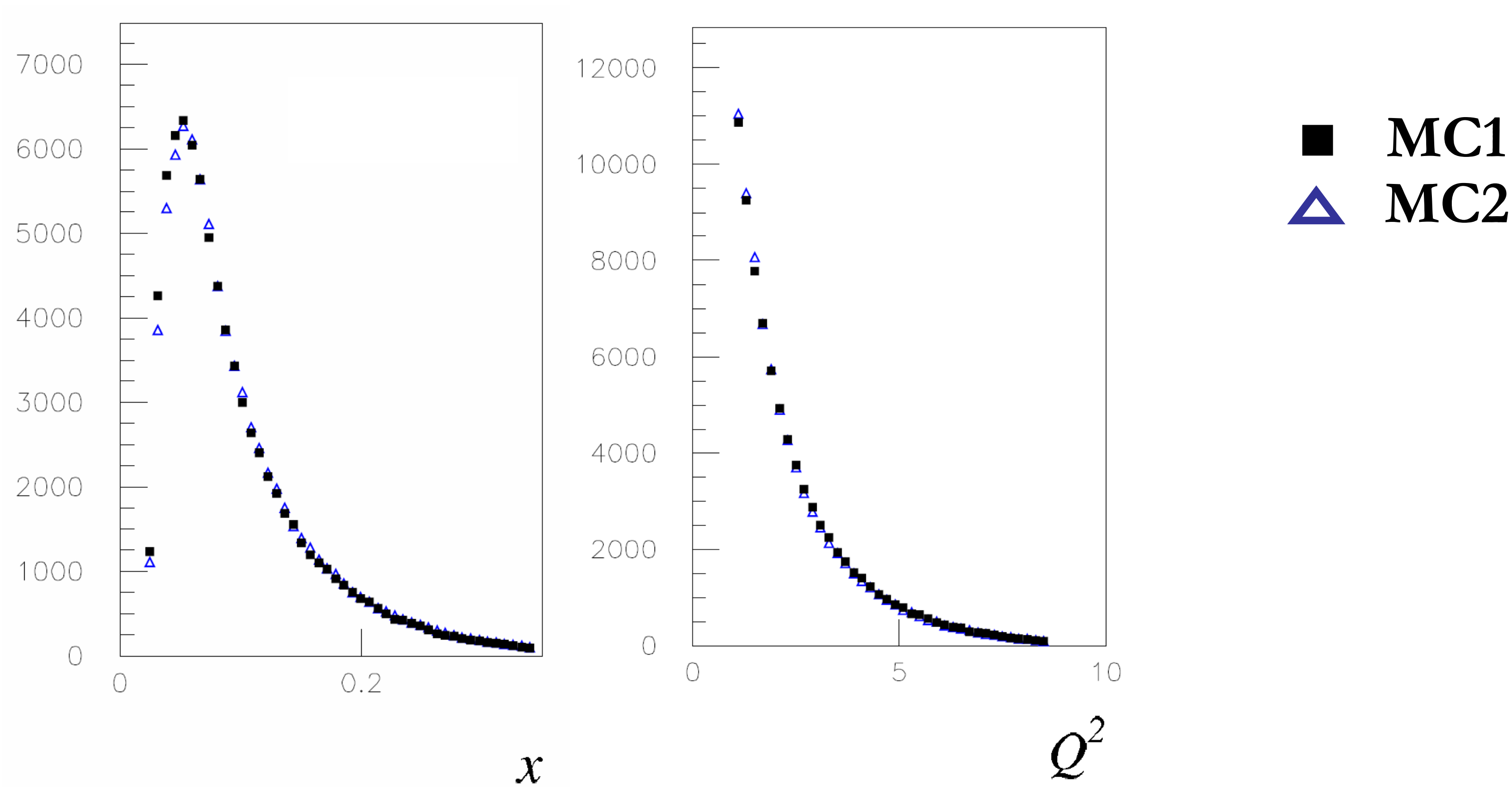

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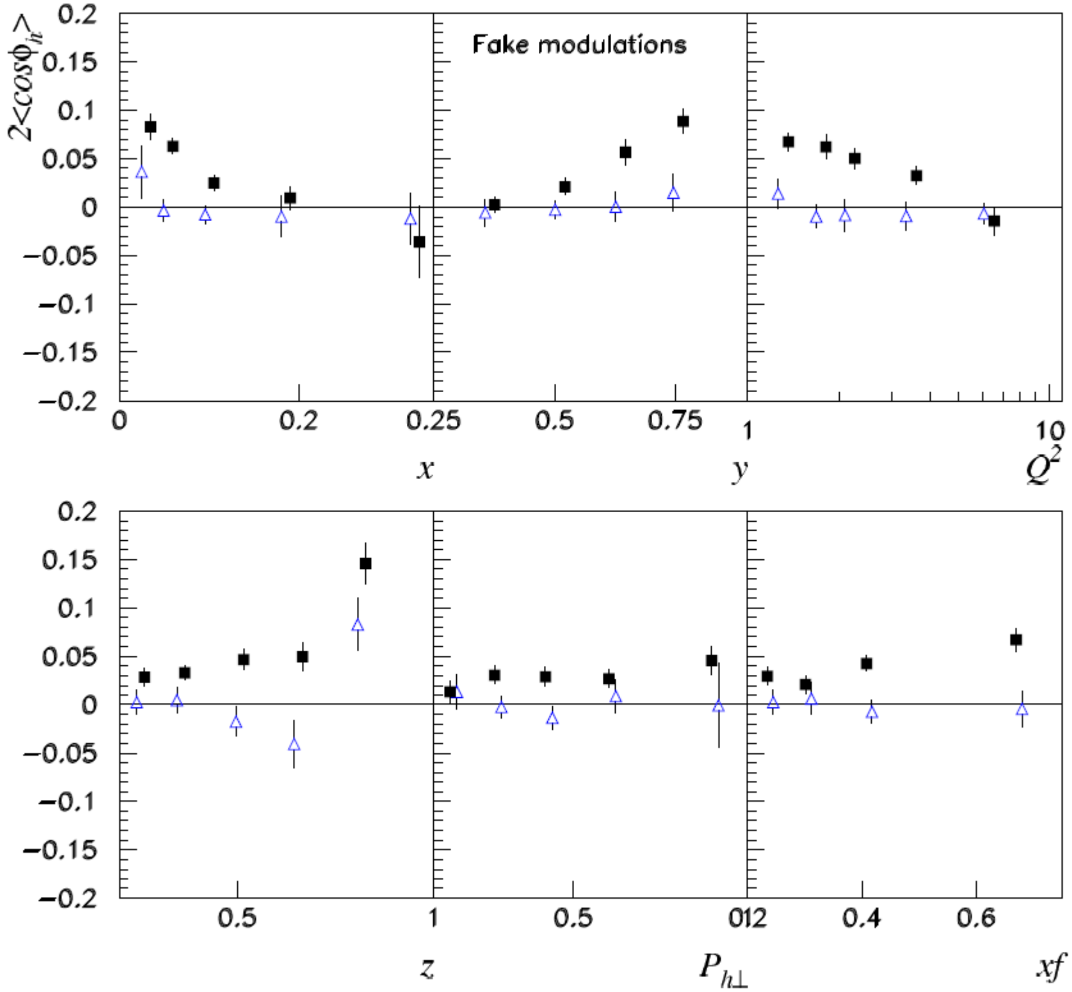

■ One-dimensional analysis

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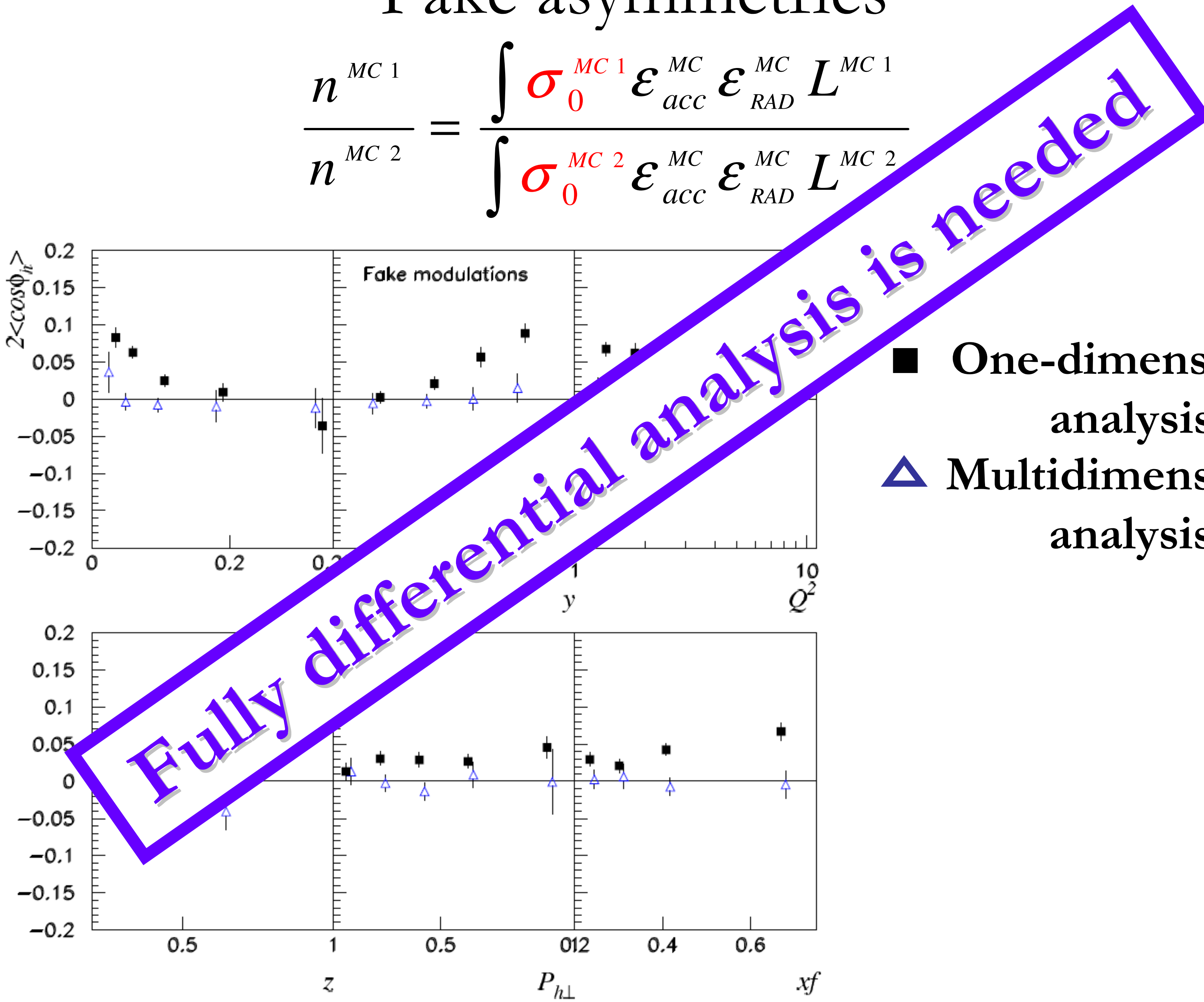

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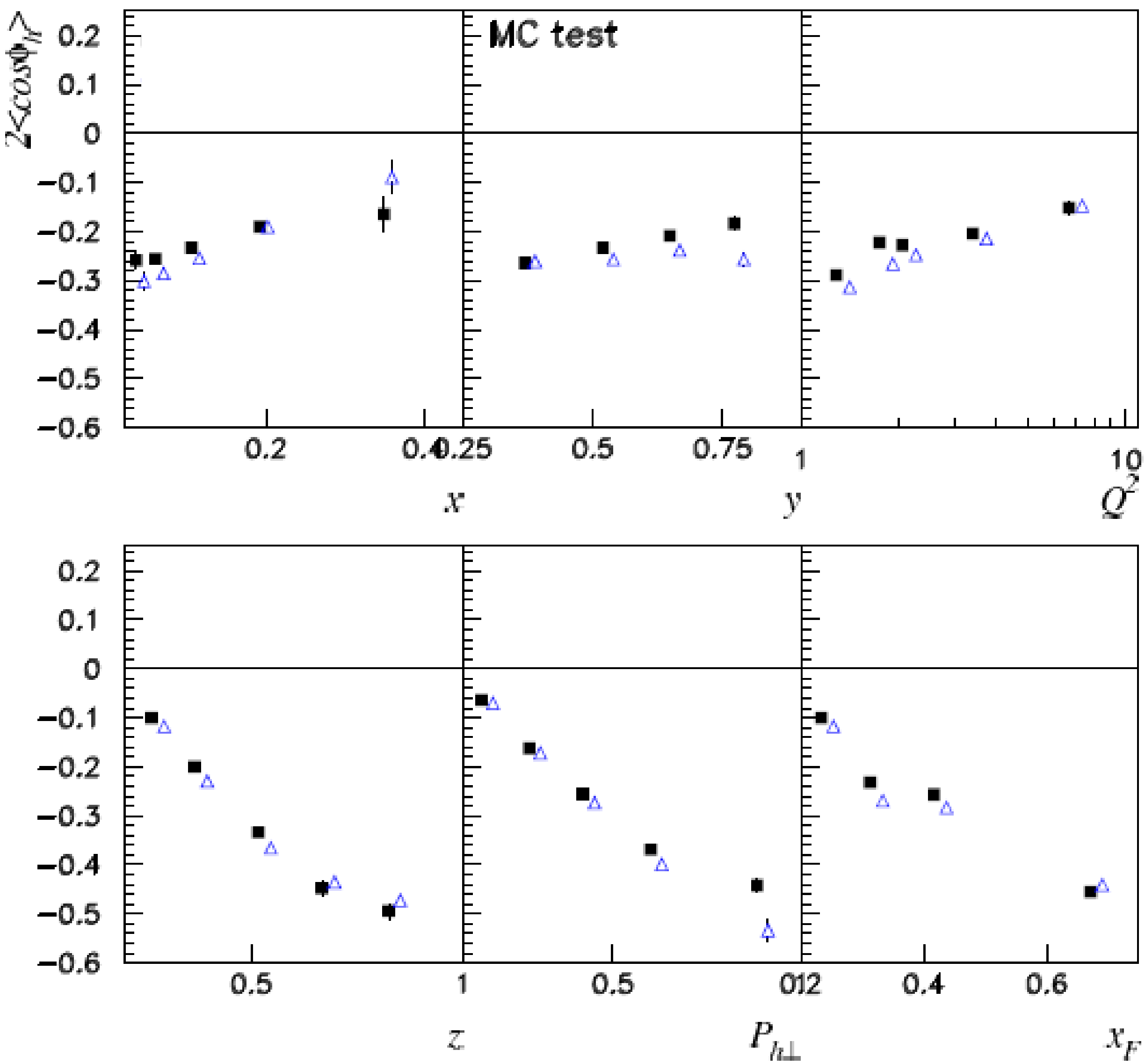
Monte Carlo check

$$\left.\frac{n^{CAHN}}{n^{MC}}\right|_{\overline{x}} = \frac{\sigma_0 \varepsilon_{acc} \varepsilon_{RAD} L}{\sigma_0^{MC} \varepsilon_{acc}^{MC} \varepsilon_{RAD}^{MC} L^{MC}} \left(1 + A\cos\phi + B\cos 2\phi\right)$$

Monte Carlo check: $\langle cos\phi \rangle$



■ **Cahn Model**

△ **Extracted values**

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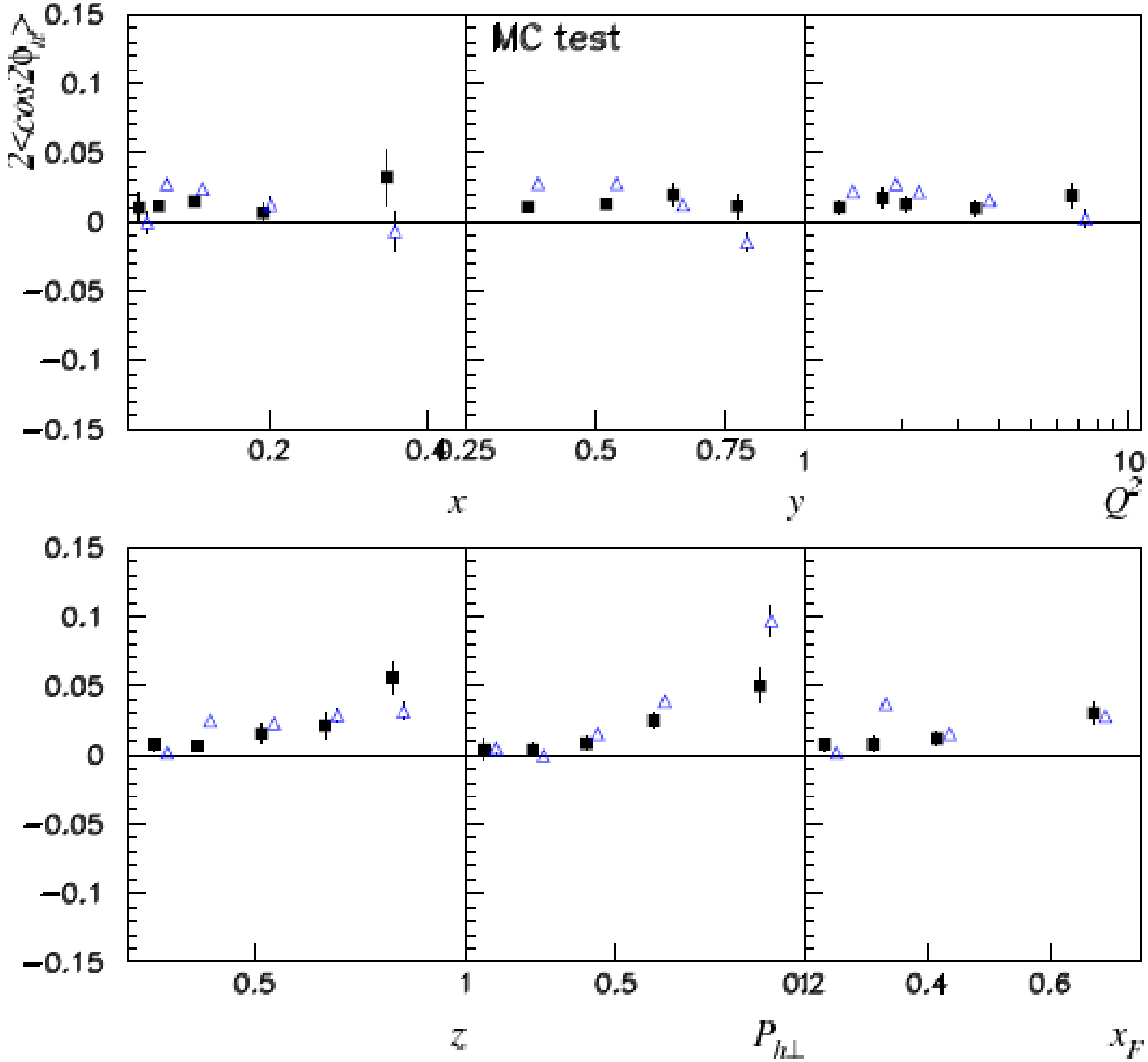

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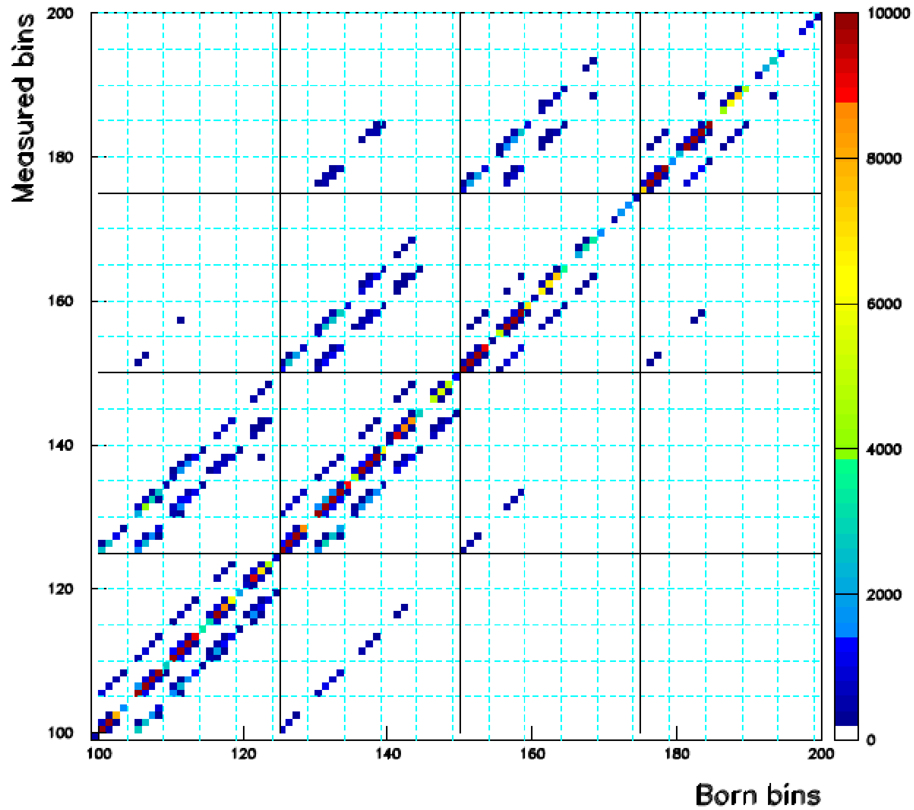

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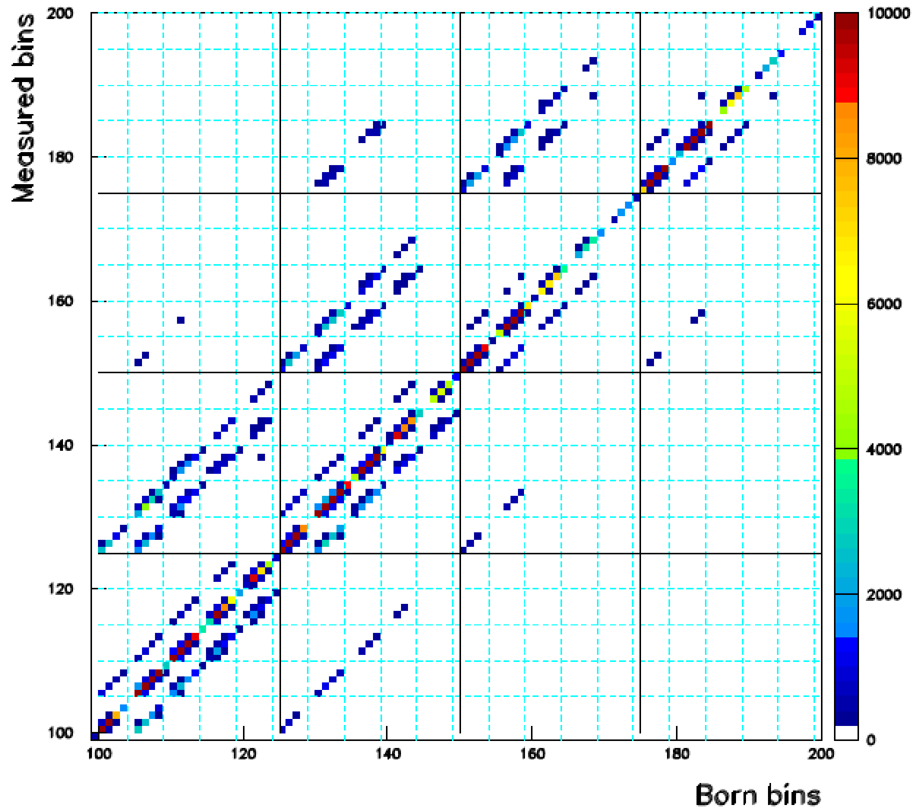

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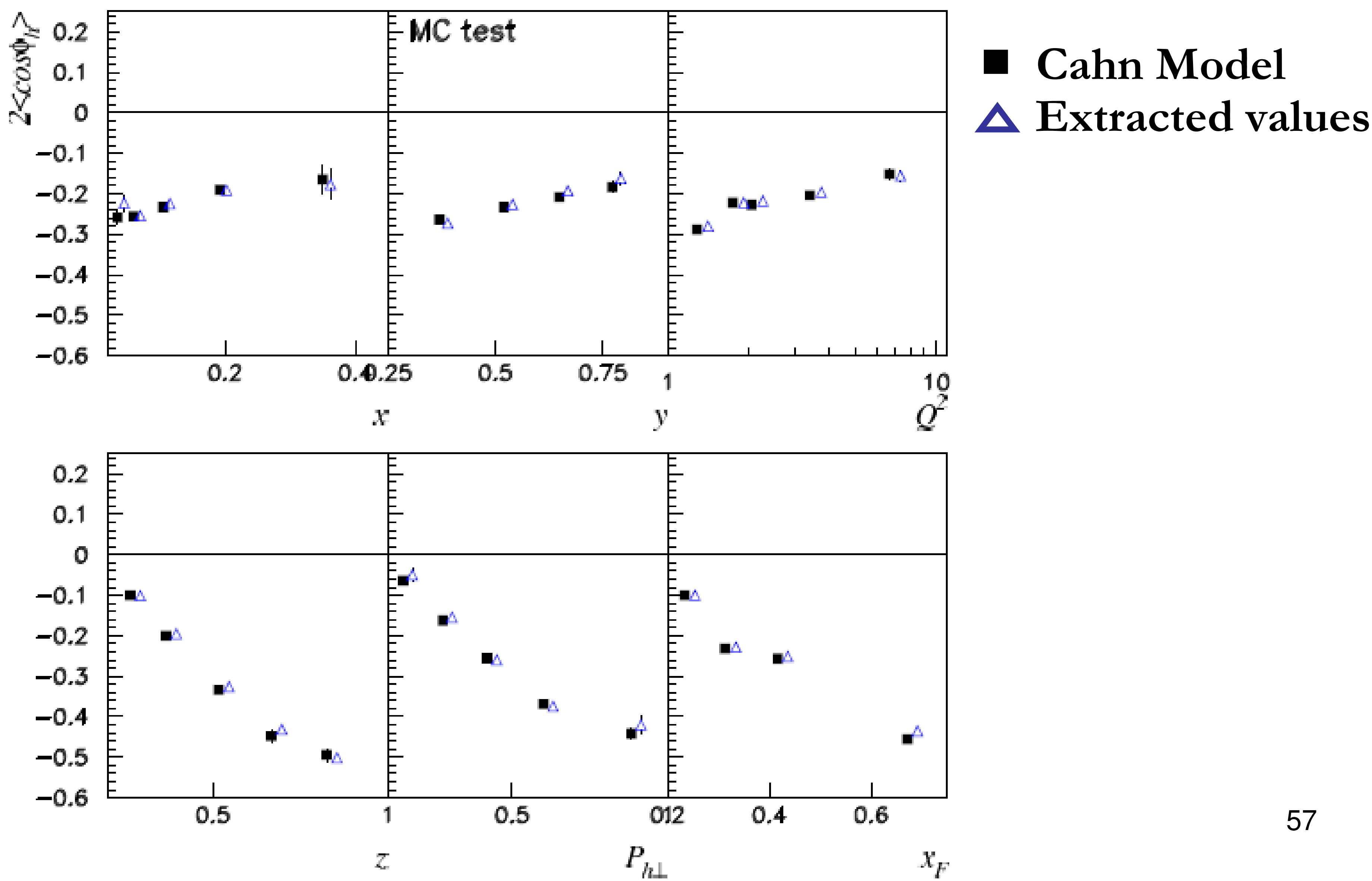

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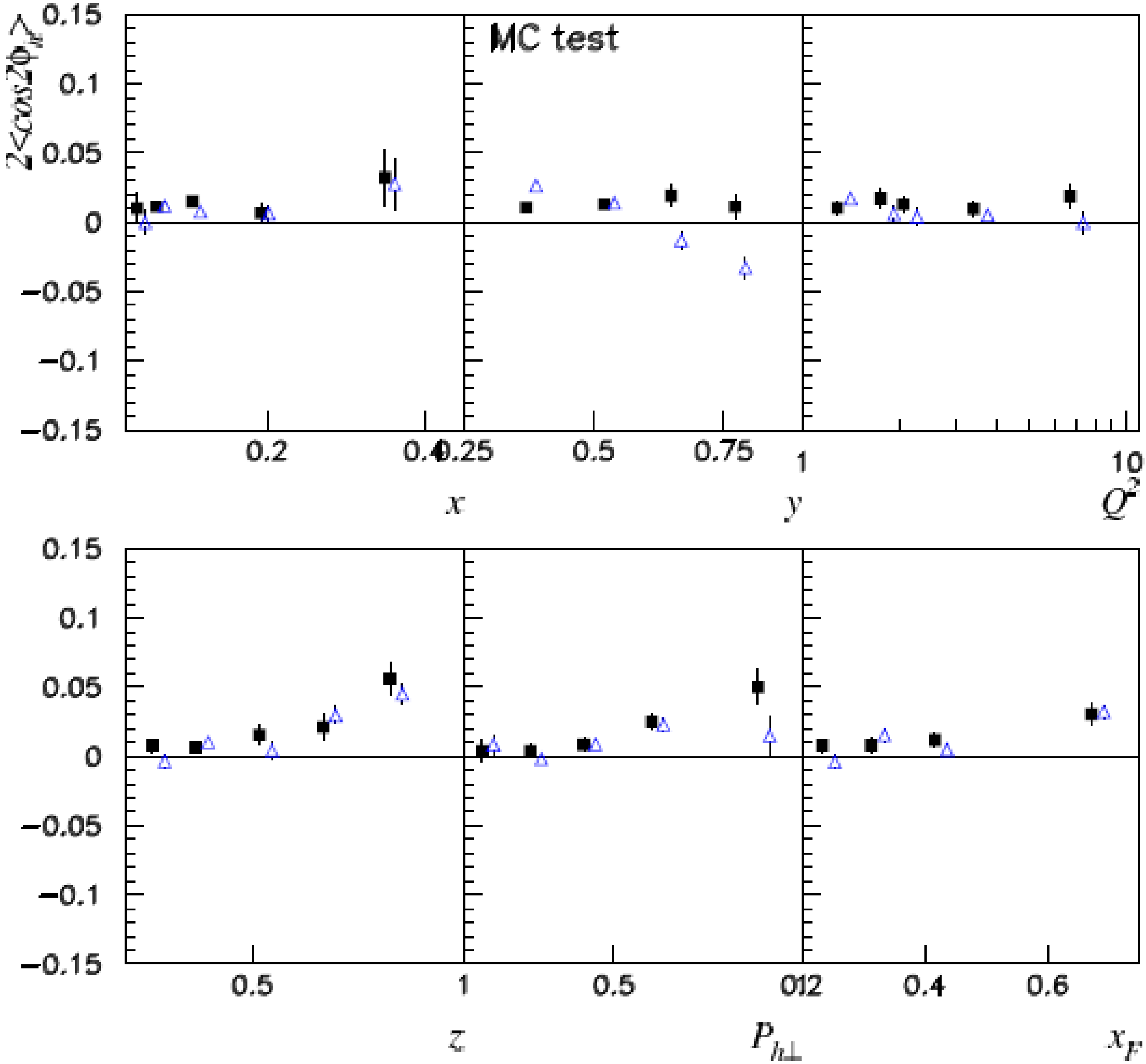

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  In particular it was stressed the existence of the

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