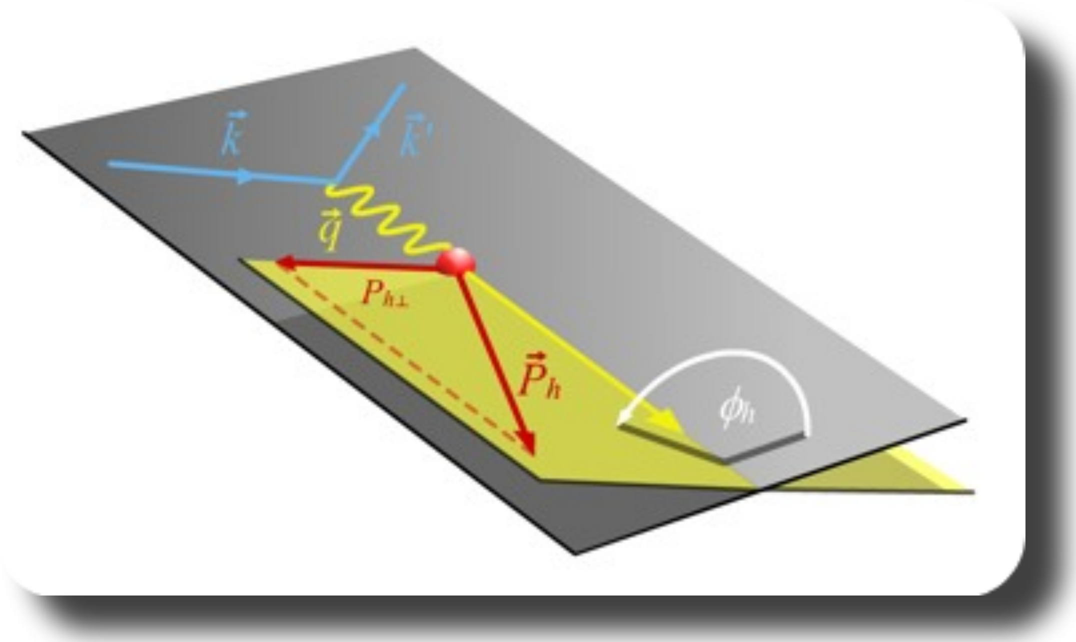
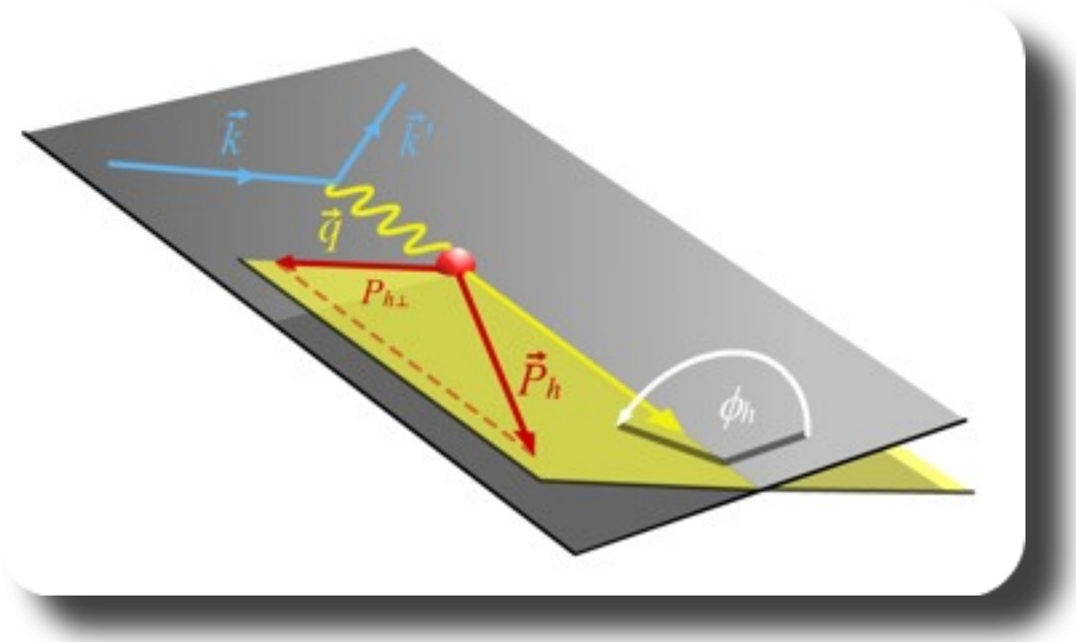
Kaon Azimuthal cosine modulations in SIDIS unpolarized cross section

Francesca Giordano
Rebecca Lamb

PSHP2010, Frascati
18th-21st October 2010



Semi Inclusive Deep Inelastic Scattering



target polarization

$$F_{XY,Z} = F_{XY,Z}(x, y, z)$$

beam polarization

virtual photon polarization

Collinear case

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

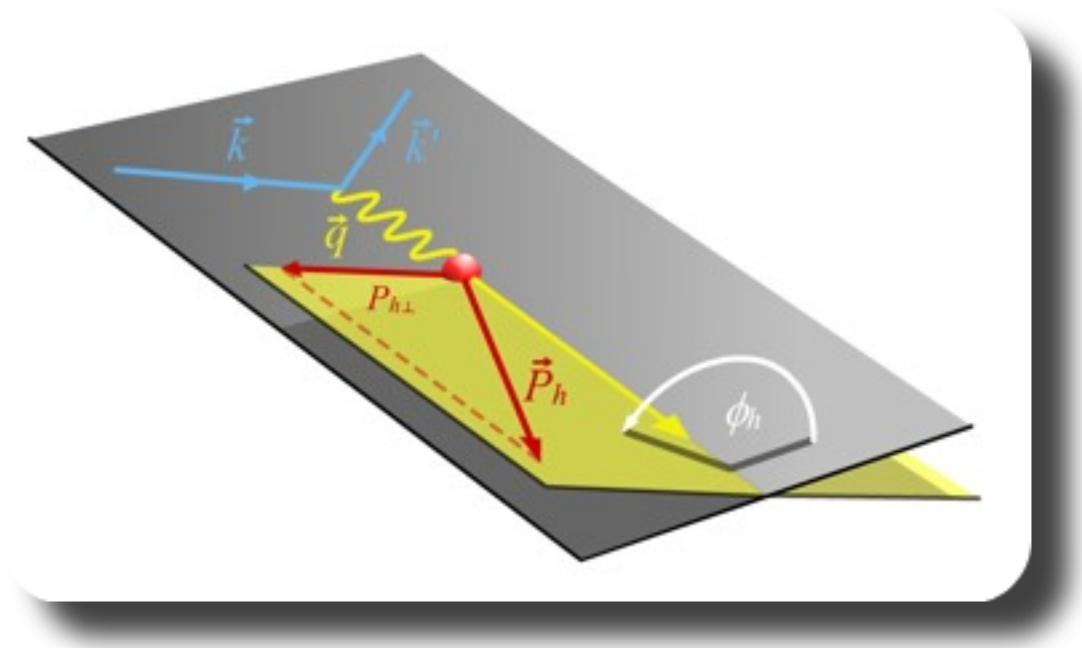
Q^2 **Negative squared 4-momentum transfer to the target**

y **Fractional energy of the virtual photon**

x **Bjorken scaling variable**

z **Fractional energy transfer to the produced hadron**

Semi Inclusive Deep Inelastic Scattering



target polarization

$$F_{XY,Z} = F_{XY,Z}(x, y, z, P_{h\perp})$$

beam polarization

virtual photon polarization

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

$$+C(y)\cos\phi_h F_{UU}^{\cos\phi_h} + B(y)\cos 2\phi_h F_{UU}^{\cos 2\phi_h}\}$$

Q^2	**Negative squared 4-momentum transfer to the target**
y	**Fractional energy of the virtual photon**
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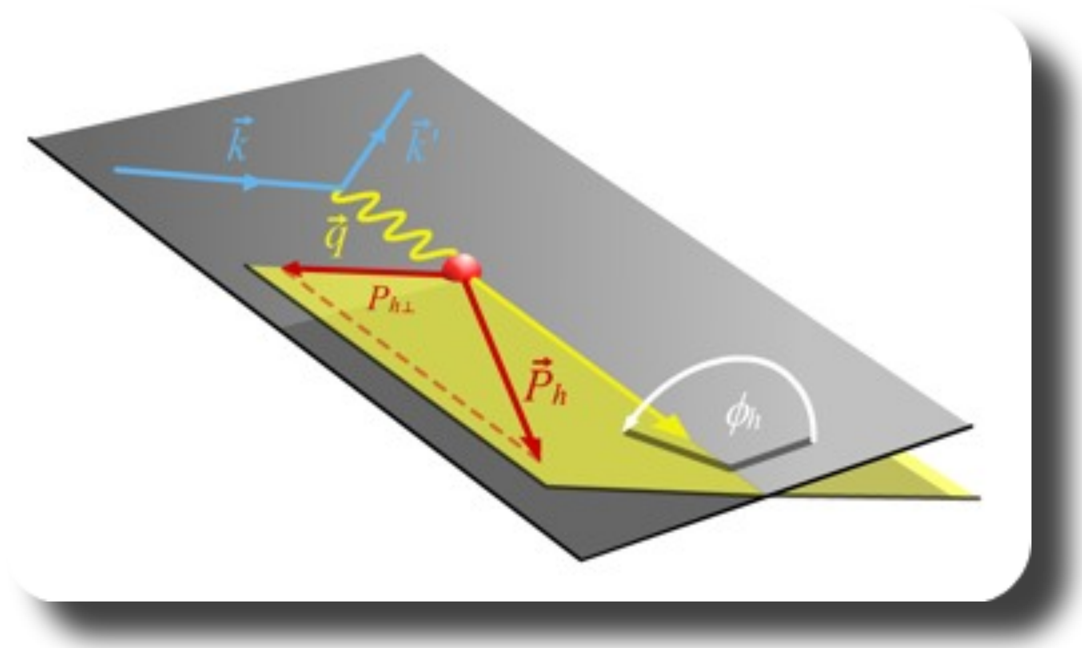
Semi Inclusive Deep Inelastic Scattering



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Q^2 **Negative squared 4-momentum transfer to the target**

y **Fractional energy of the virtual photon**

x **Bjorken scaling variable**

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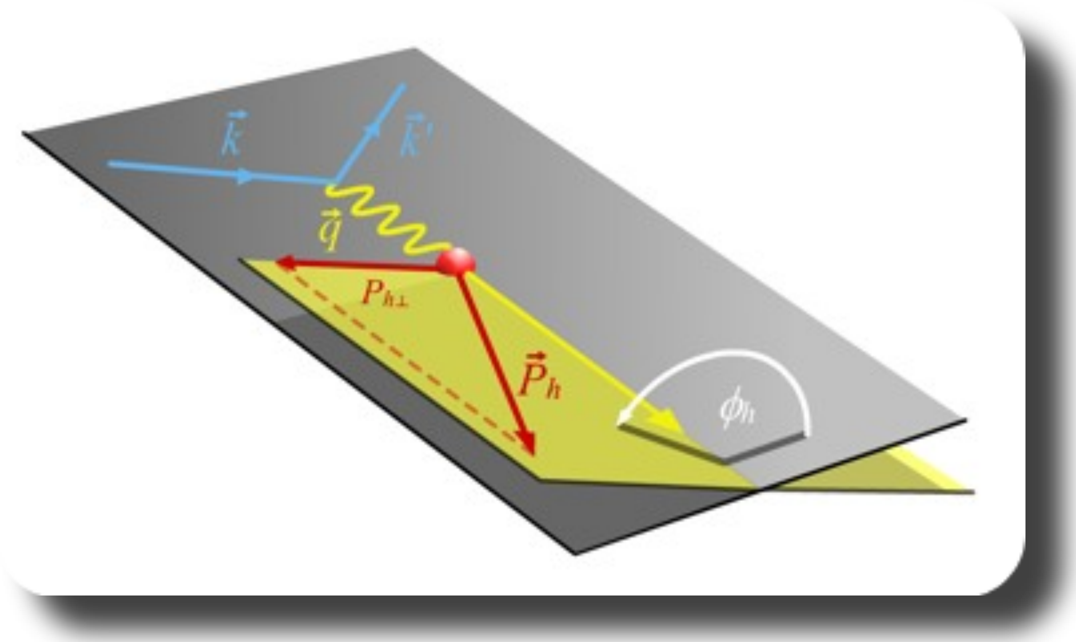
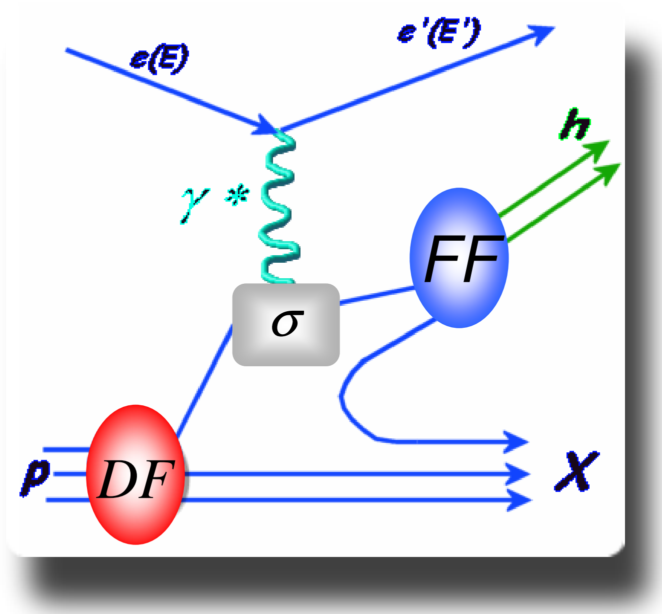
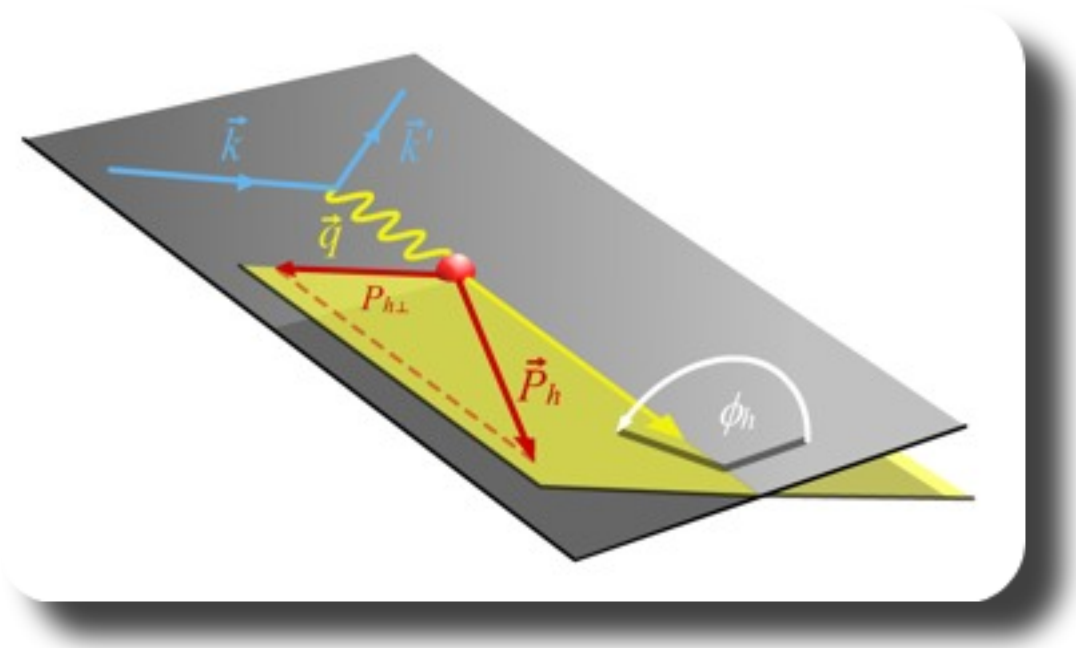
$$\langle\cos n\phi_h\rangle = \frac{\int \cos n\phi_h \frac{d^5\sigma}{dx\,dy\,dz\,d\phi_h\,dP_{h\perp}^2} d\phi_h}{\int \frac{d^5\sigma}{dx\,dy\,dz\,d\phi_h\,dP_{h\perp}^2} d\phi_h}$$

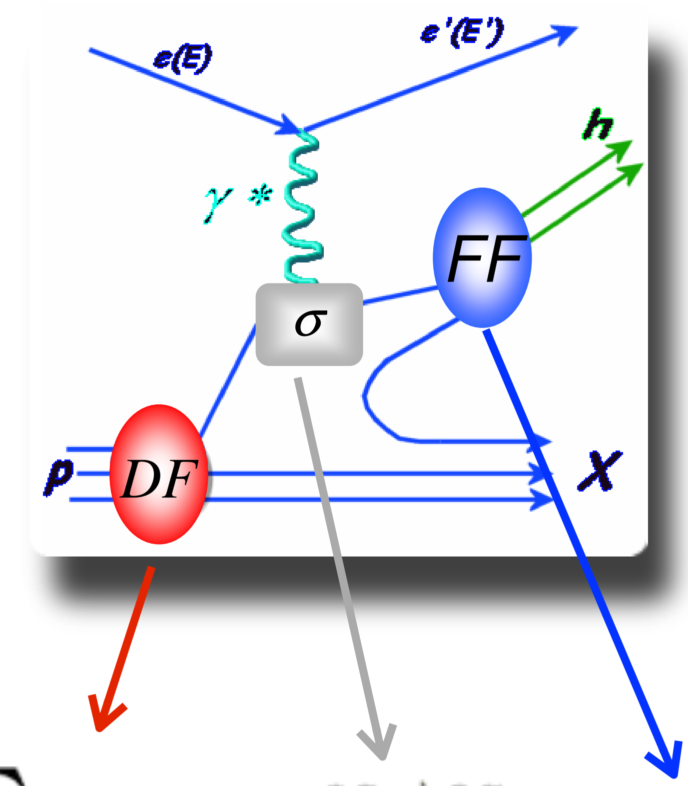
Semi Inclusive Deep Inelastic Scattering





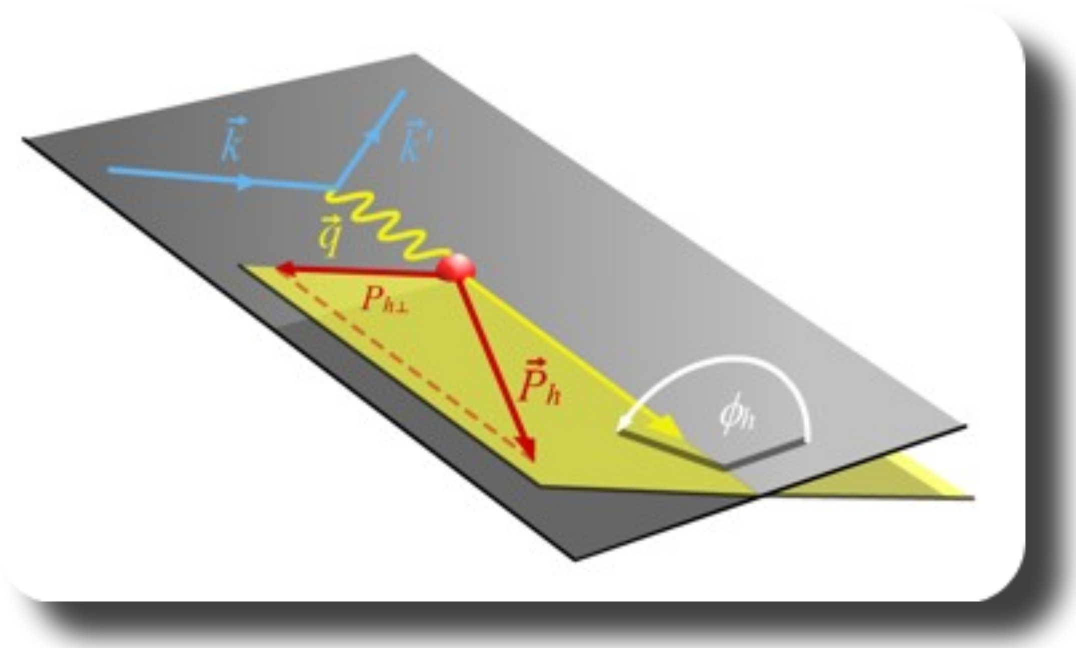
Factorization Theorem

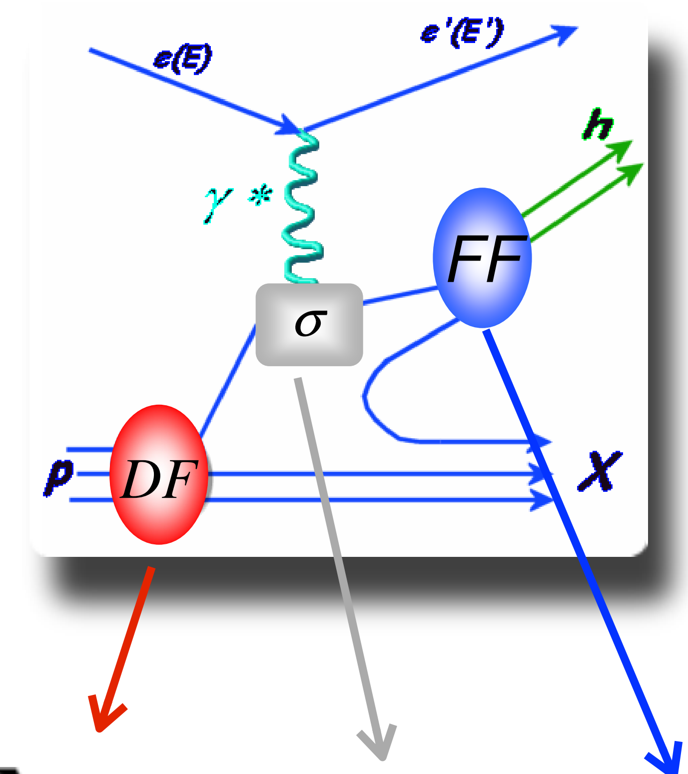




$$\sigma^{ep\to ehX} = \sum_q DF \times \sigma^{eq\to eq} \times FF$$

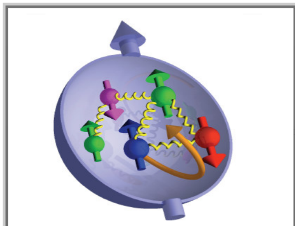
Factorization Theorem



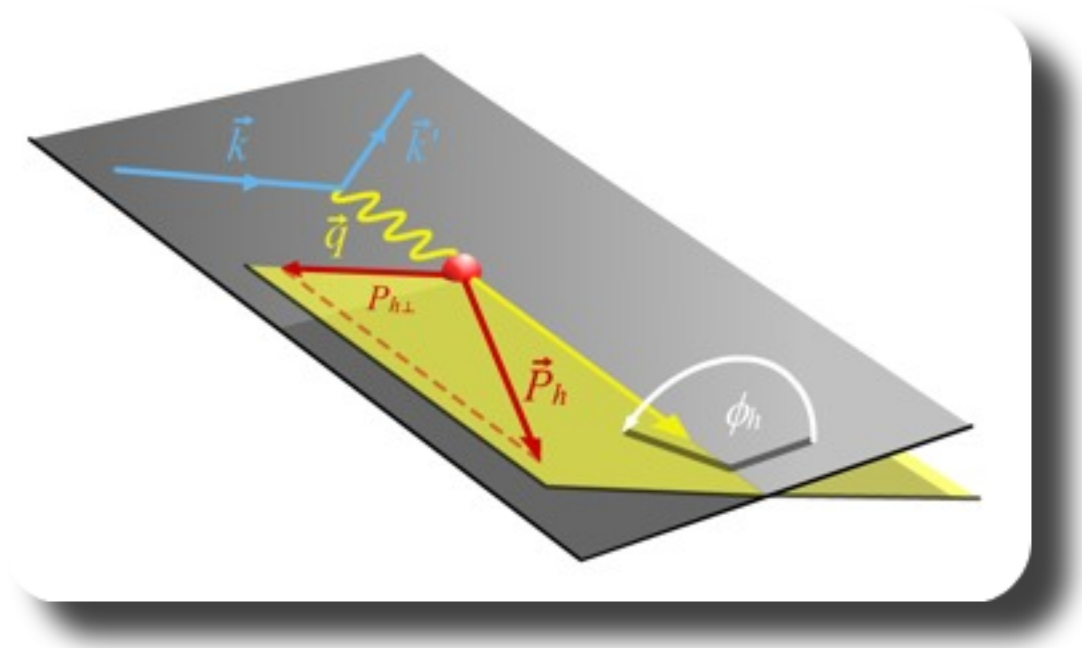


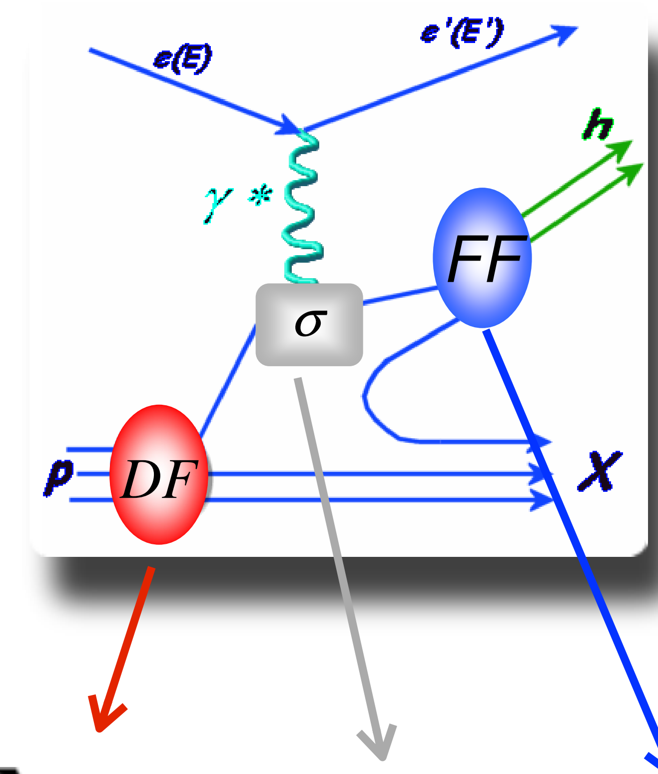
$$\sigma^{ep\to ehX} = \sum_q DF \times \sigma^{eq\to eq} \times FF$$

distribution functions

		quark		
		U	L	T
nucleon	U	f_1		$h_1^\perp$
	L		g_1	$h_{1L}^\perp$
	T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

Factorization Theorem





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distribution functions

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nucleon	U	f_1		$h_1^\perp$
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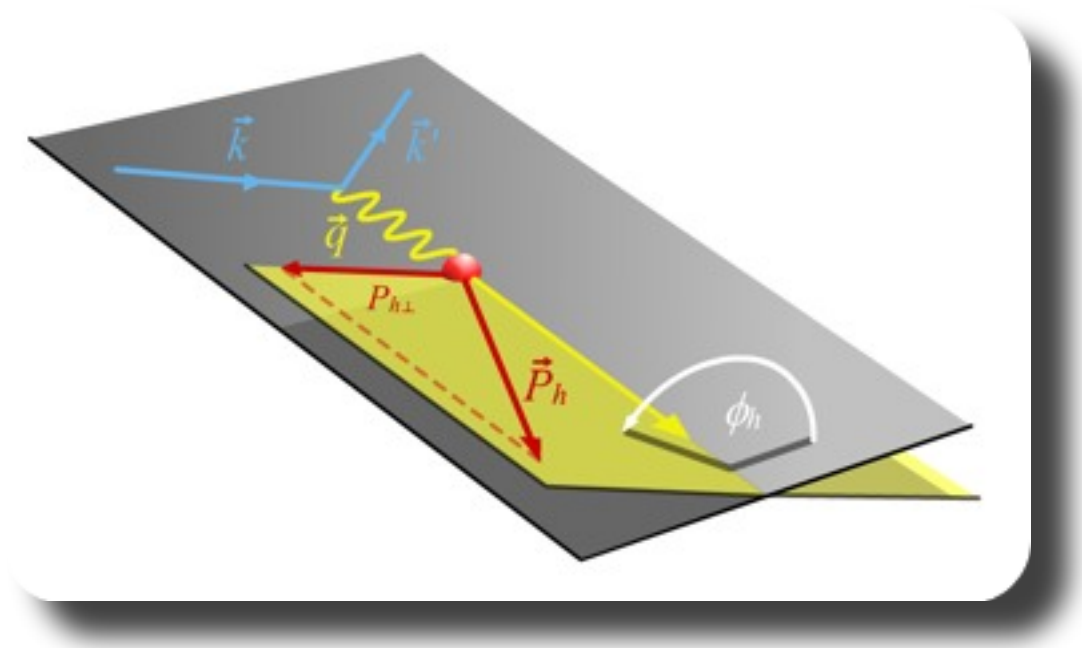
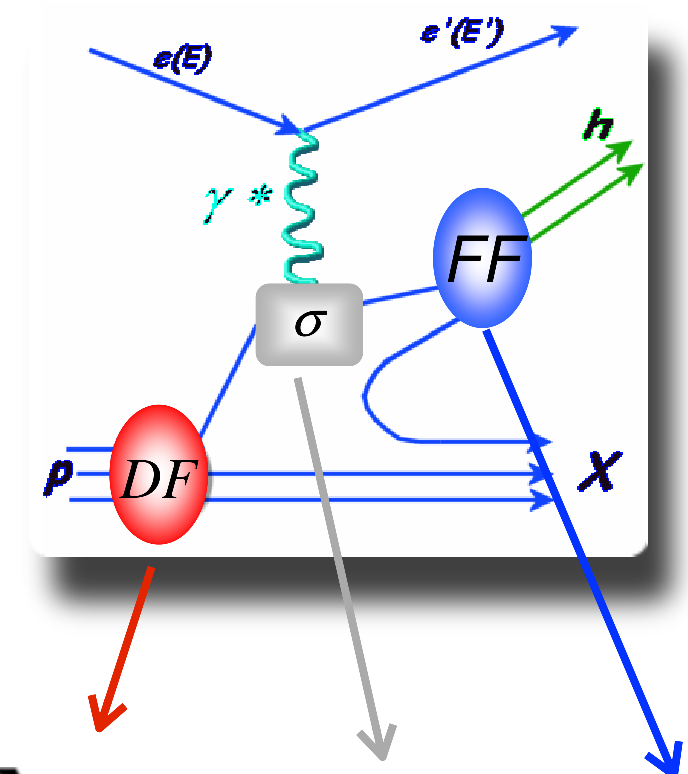
	T	$f_{1T}^\perp$	$g_{1T}^\perp$	$h_1 \quad h_{1T}^\perp$

fragmentation functions

		quark		
		U	L	T
had.	U	D_1		$H_1^\perp$

Factorization Theorem





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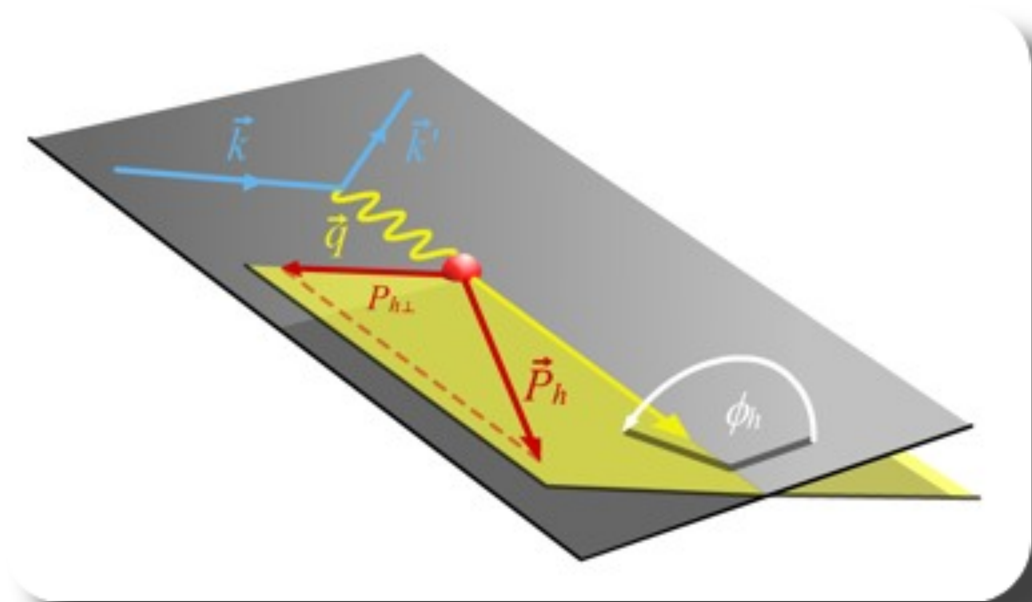
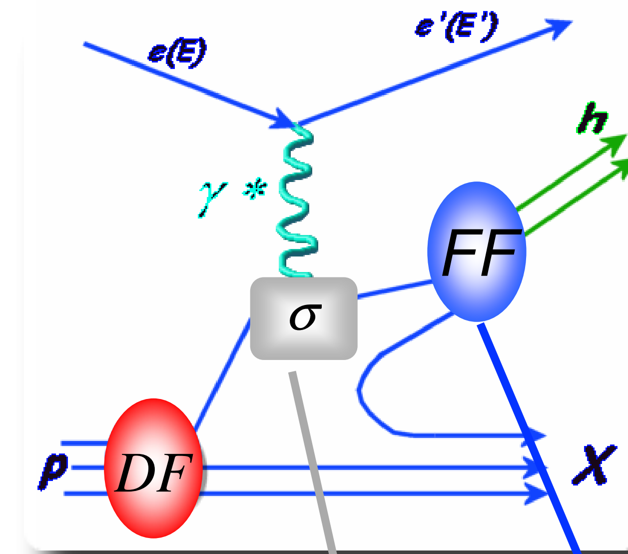
Factorization Theorem





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distribution functions

(nucleon)		quark U	quark L	quark T
nucleon	U	f_1		$h_1^\perp$
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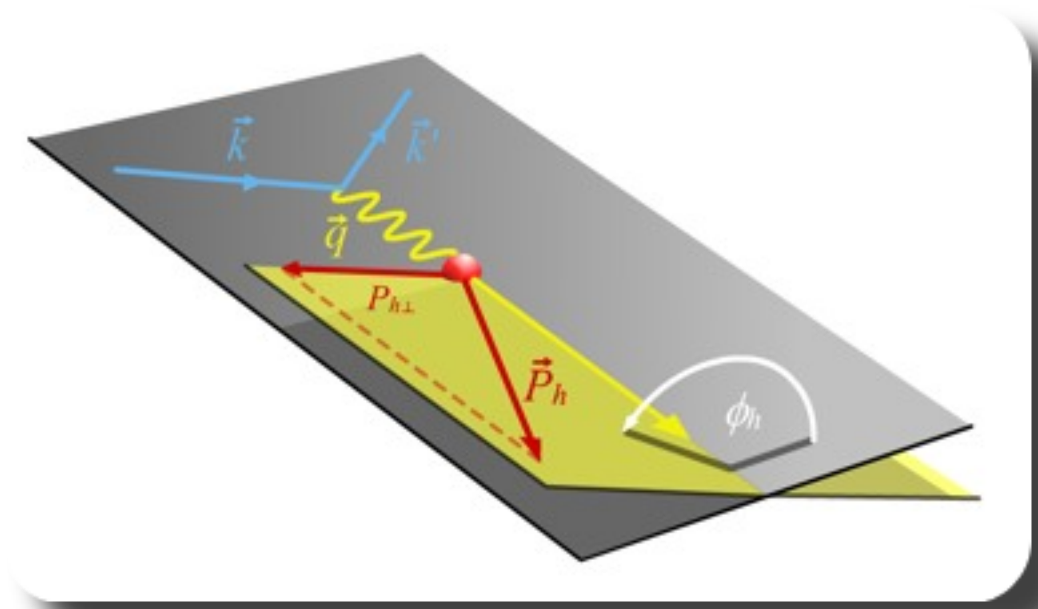
nucleon	T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

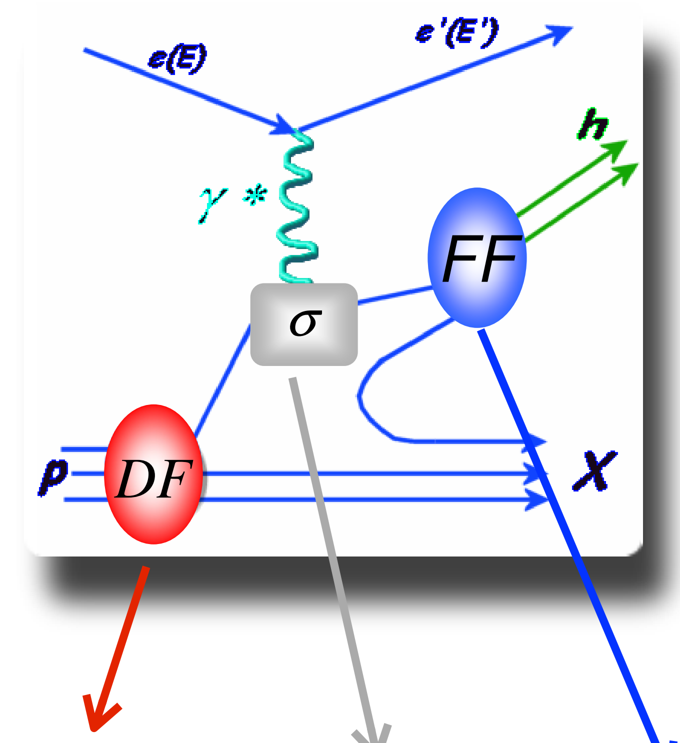
Boer-Mulders DF

fragmentation functions

		quark U	quark L	quark T
had.	U	D_1		$H_1^\perp$

Factorization Theorem





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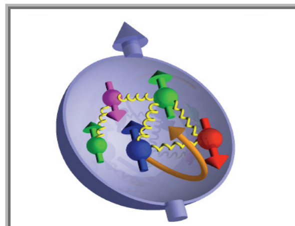		quark		
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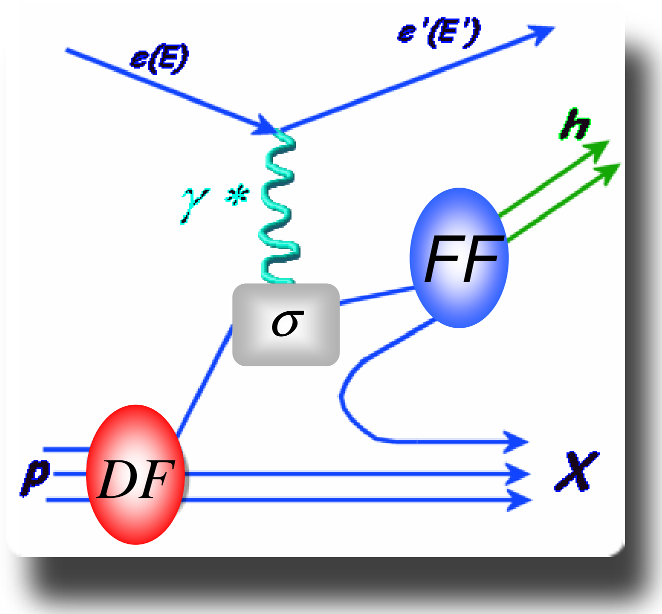
Boer-Mulders DF

Collins FF

fragmentation functions

		quark		
		U	L	T
had.	U	D_1		$H_1^\perp$

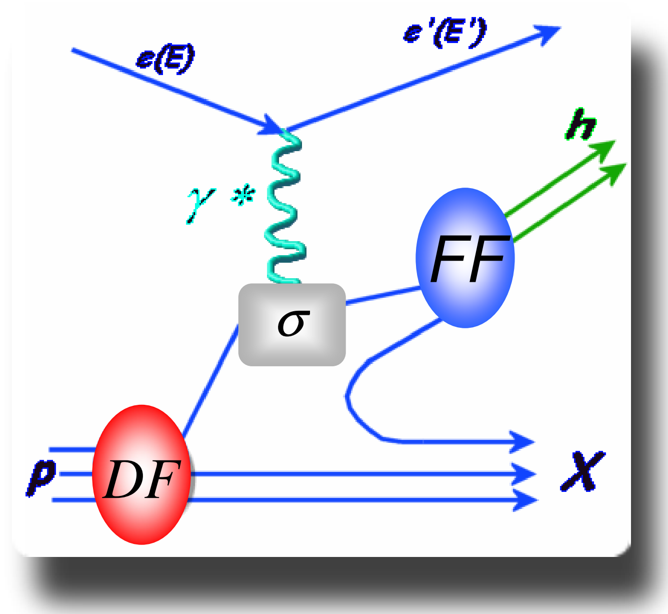
Factorization Theorem



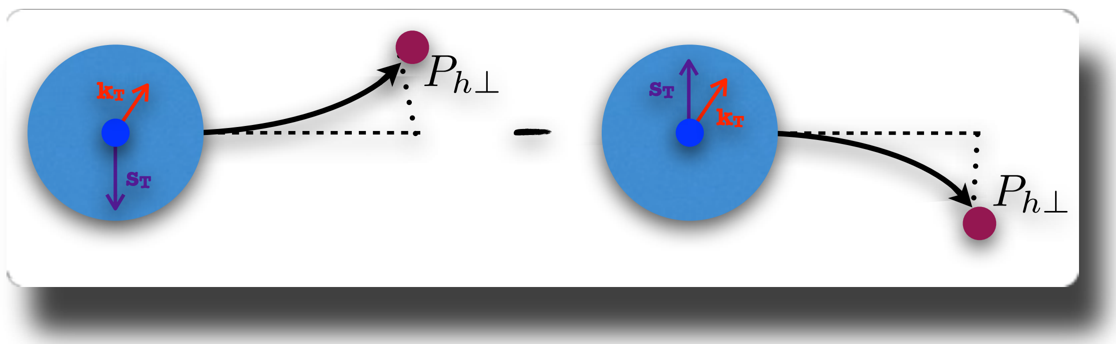
$$F_{UU}^{\cos 2\phi_h} \propto C[-\frac{2(\hat{P}_{h\perp}\cdot\vec{\kappa}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{\kappa}_T\cdot\vec{p}_T}{MM_h} h_1^\perp H_1^\perp]$$

implicit sum over quark flavors

Leading Twist Terms



Boer-Mulders effect



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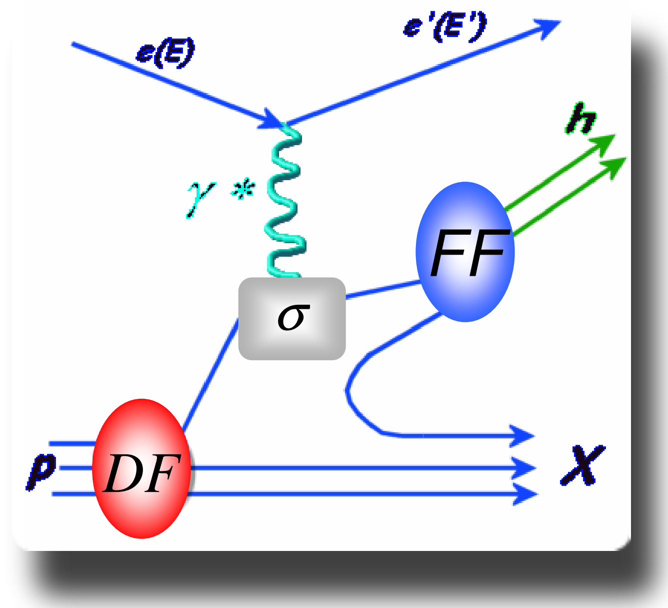
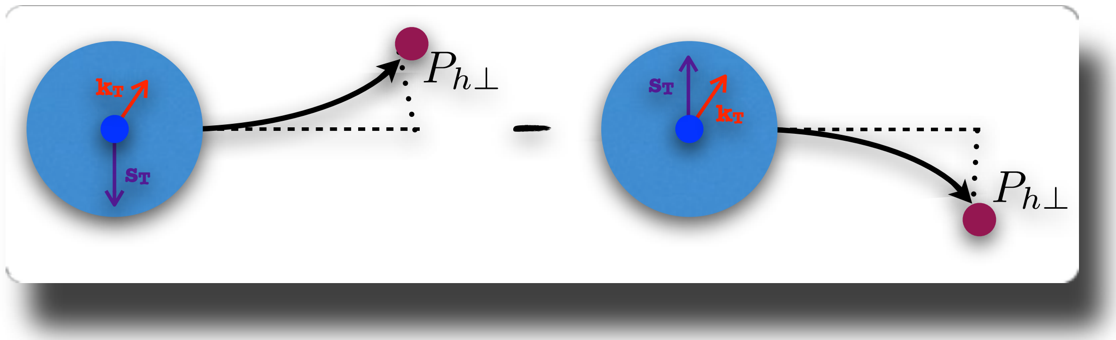


Boer-Mulders effect



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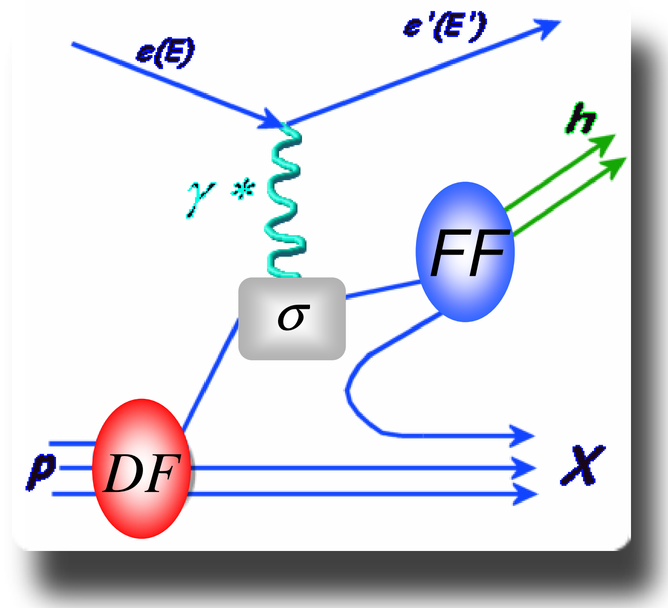
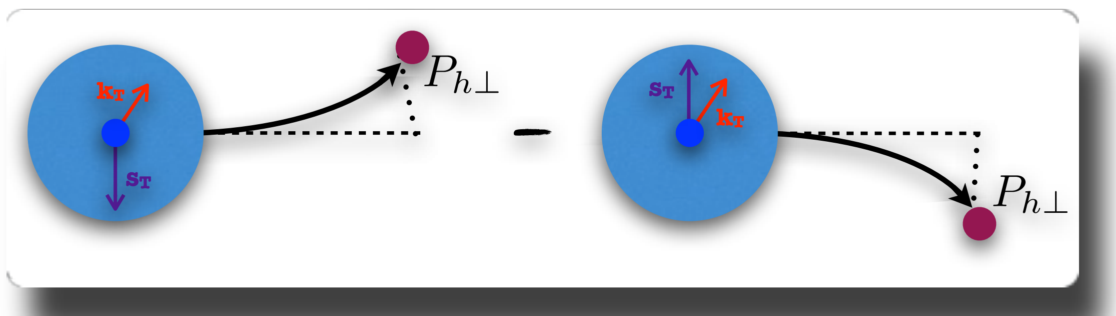
implicit sum over quark flavors

Leading And Next-to-Leading Twist Terms



Boer-Mulders effect



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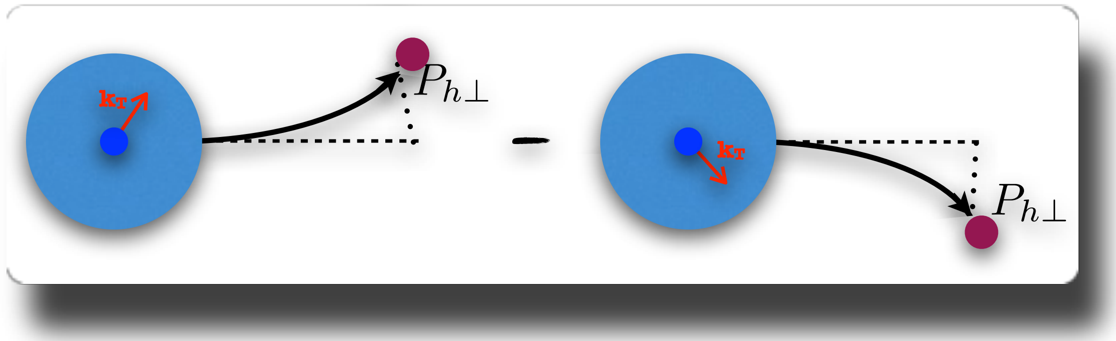
$$F_{UU}^{\cos \phi_h} \propto \frac{2M}{Q} C[-\frac{\hat{P}_{h\perp}\cdot\vec{p}_T}{M_h} x h_1^{\perp} H_1^{\perp} - \frac{\hat{P}_{h\perp}\cdot\vec{\kappa}_T}{M} x f_1 D_1 + ...]$$

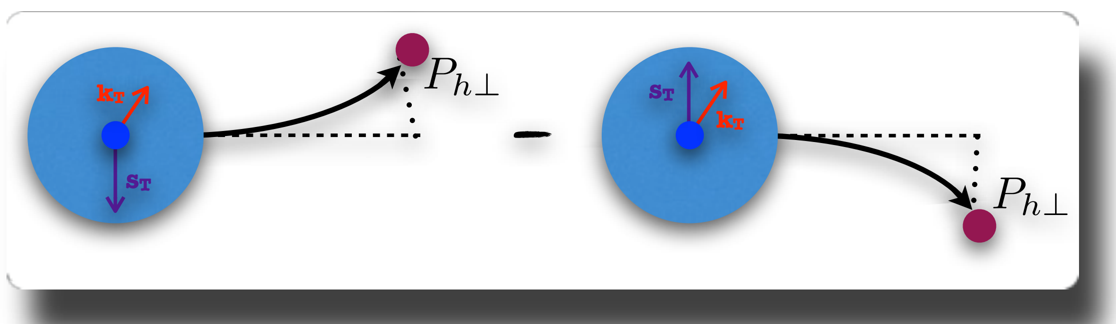
implicit sum over quark flavors

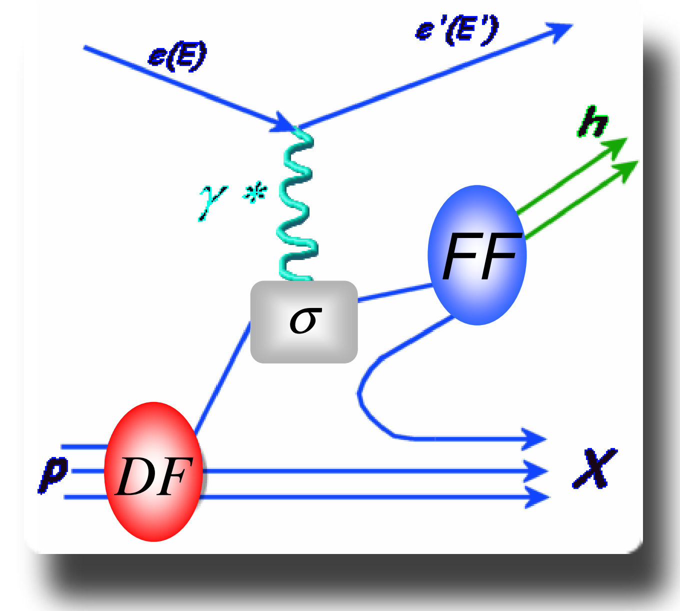
Leading And Next-to-Leading Twist Terms

Cahn effect



Boer-Mulders effect





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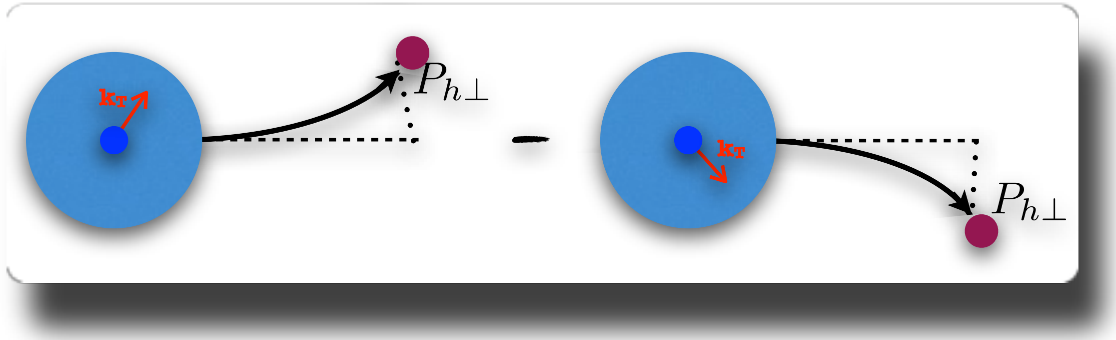
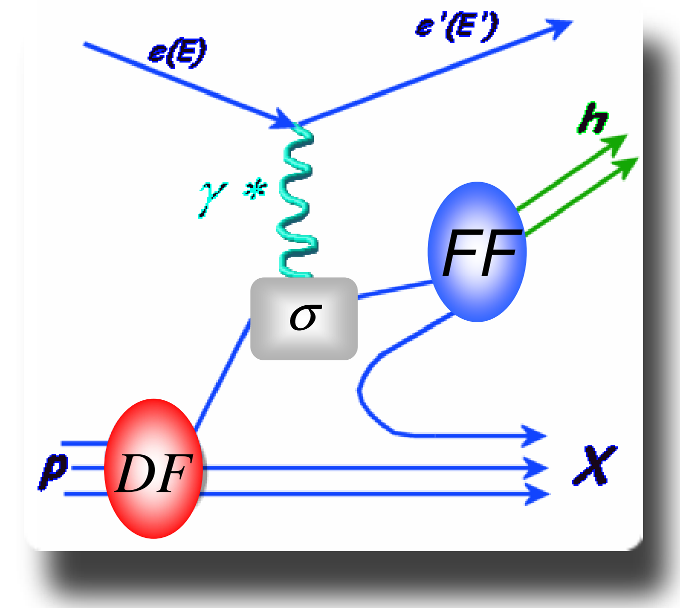
implicit sum over quark flavors

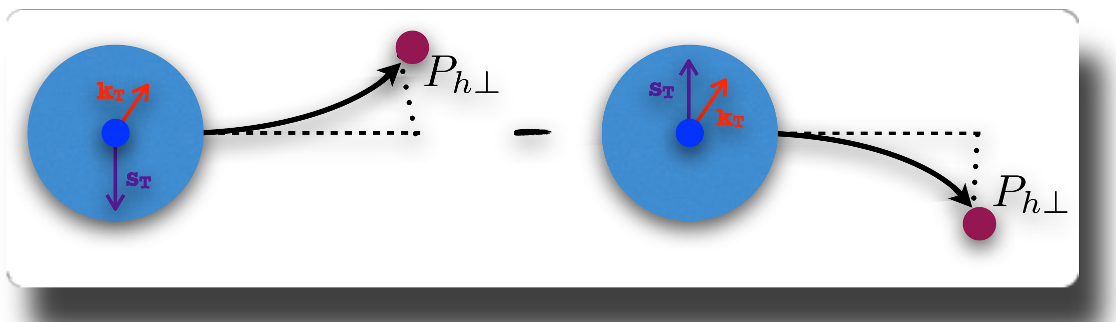
Leading And Next-to-Leading Twist Terms

Cahn effect





Boer-Mulders effect



$$F_{UU}^{\cos 2\phi_h} \propto C\left[-\frac{2(\hat{P}_{h\perp}\cdot\vec{\kappa}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{\kappa}_T\cdot\vec{p}_T}{M M_h} h_1^{\perp} H_1^{\perp}\right]$$

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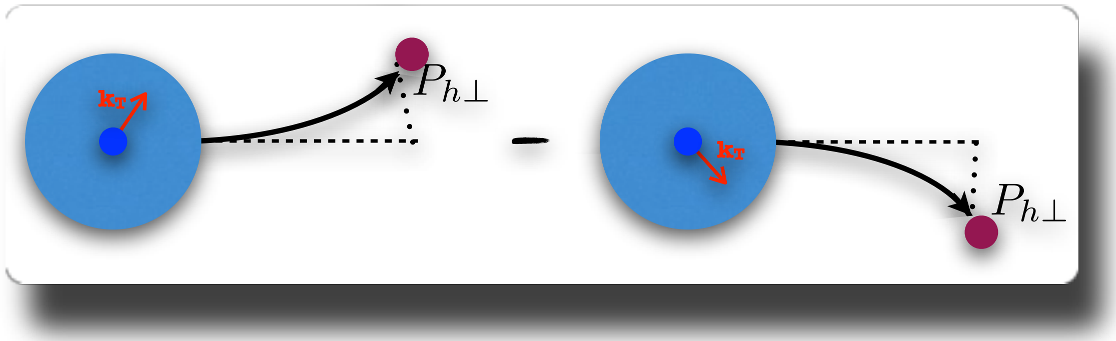
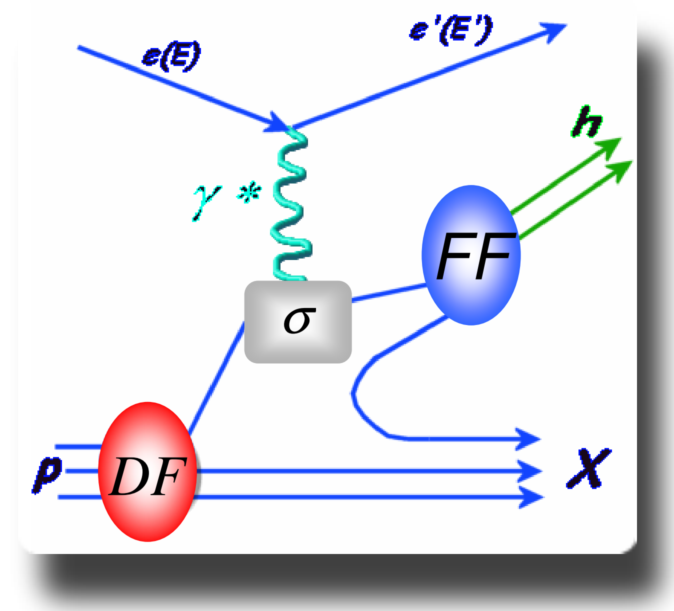
implicit sum over quark flavors

interaction dependent terms neglected

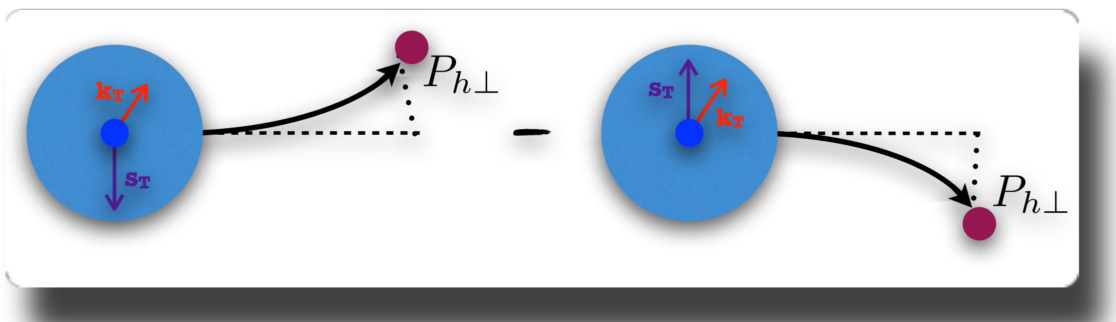
Leading And Next-to-Leading Twist Terms

Cahn effect





Boer-Mulders effect



$$F_{UU}^{\cos 2\phi_h} \propto C\left[-\frac{2(\hat{P}_{h\perp}\cdot\vec{\kappa}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{\kappa}_T\cdot\vec{p}_T}{M M_h} h_1^{\perp} H_1^{\perp}\right] + \frac{M^2}{Q^2} C\left[\frac{\kappa_T^2}{M^2} f_1 D_1 + \ldots\right]$$

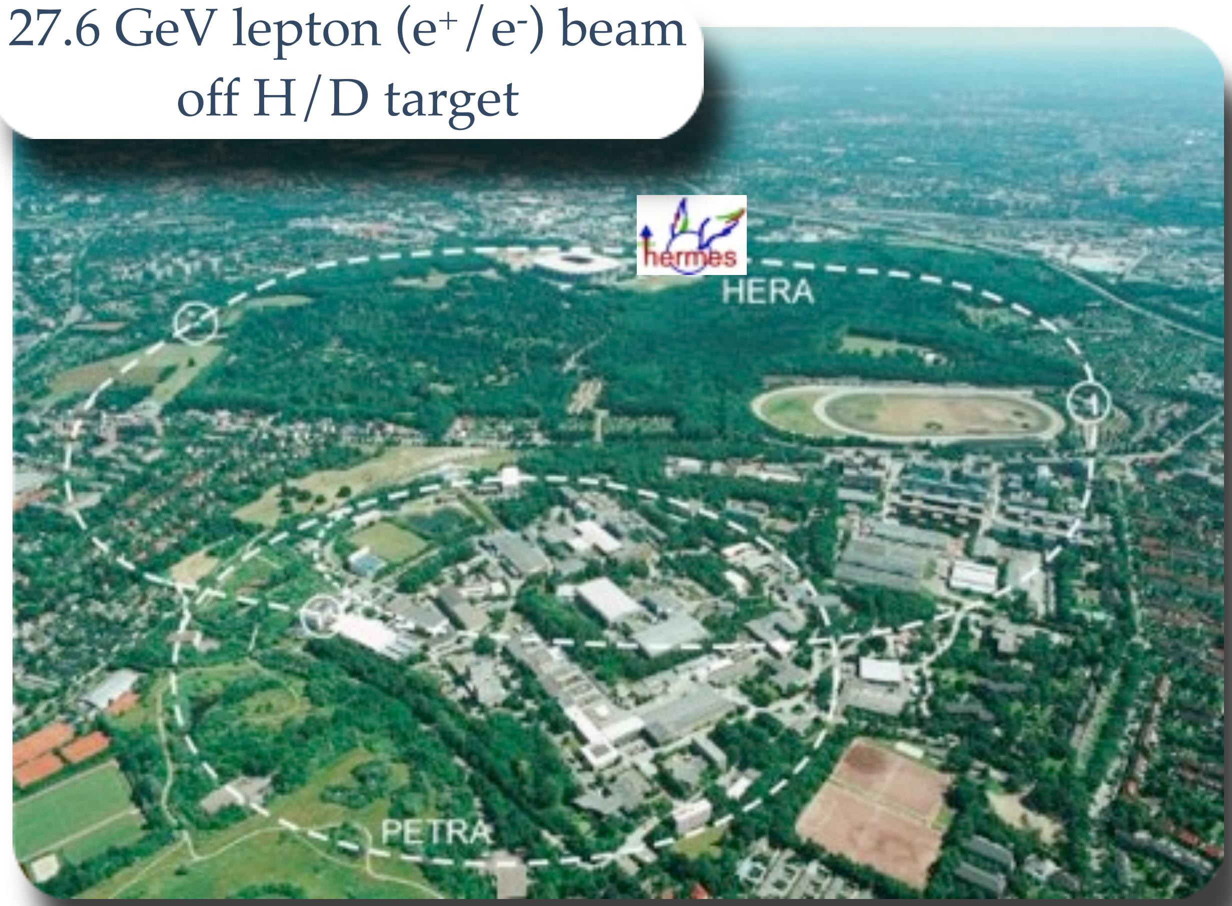
$$F_{UU}^{\cos\phi_h} \propto \frac{2M}{Q} C\left[-\frac{\hat{P}_{h\perp}\cdot\vec{p}_T}{M_h} x h_1^{\perp} H_1^{\perp} - \frac{\hat{P}_{h\perp}\cdot\vec{\kappa}_T}{M} x f_1 D_1 + \ldots.\right]$$

implicit sum over quark flavors

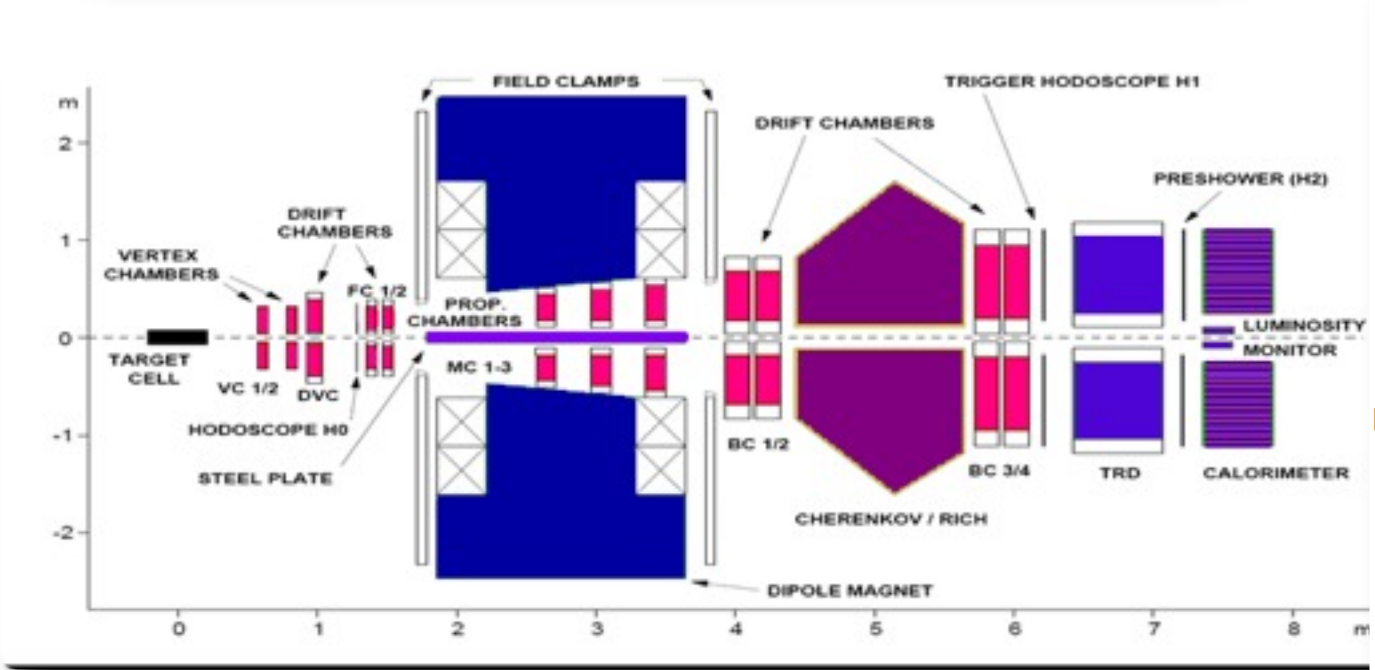
interaction dependent terms neglected

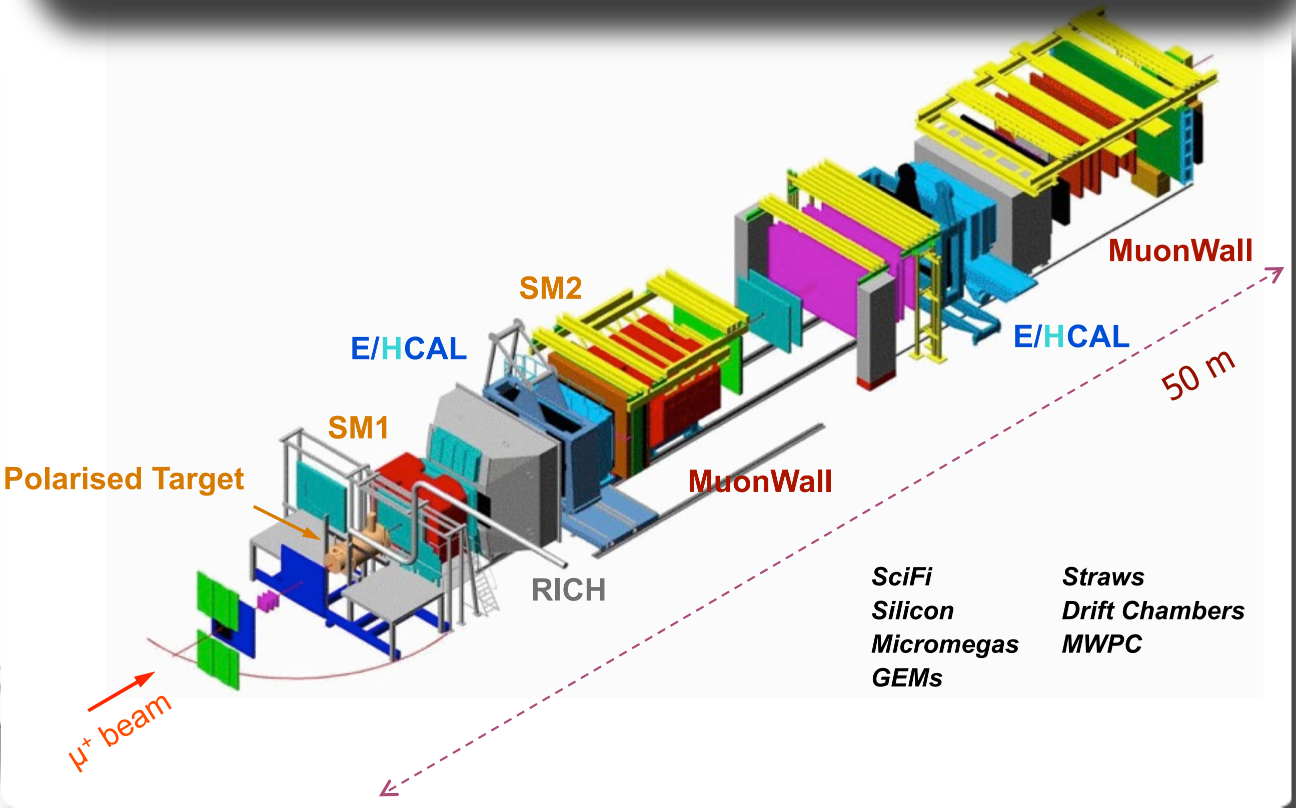
Leading And Next-to-Leading Twist Terms

27.6 GeV lepton (e^+/e^-) beam off H/D target



160 GeV μ^+ beam off ^{6}LiD target





HERMES@DESY

COMPASS@CERN

27.6 GeV lepton (e^+/e^-) beam
off H/D target

160 GeV μ^+ beam
off ^{6}LiD target

$$Q^2 > 1\,GeV^2$$
$$0.023 < x < 0.27$$
$$0.3 < y < 0.85$$
$$W^2 > 10\,GeV^2$$
$$0.2 < z < 0.75$$
$$0.05 < P_{h\perp} < 1\,GeV$$

$$Q^2 > 1\,GeV^2$$
$$0.003 < x < 0.13$$
$$0.2 < y < 0.9$$
$$W^2 > 5\,GeV^2$$
$$0.2 < z < 0.85$$
$$0.1 < P_{h\perp} < 1\,GeV$$

HERMES@DESY

COMPASS@CERN

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HERMES@DESY

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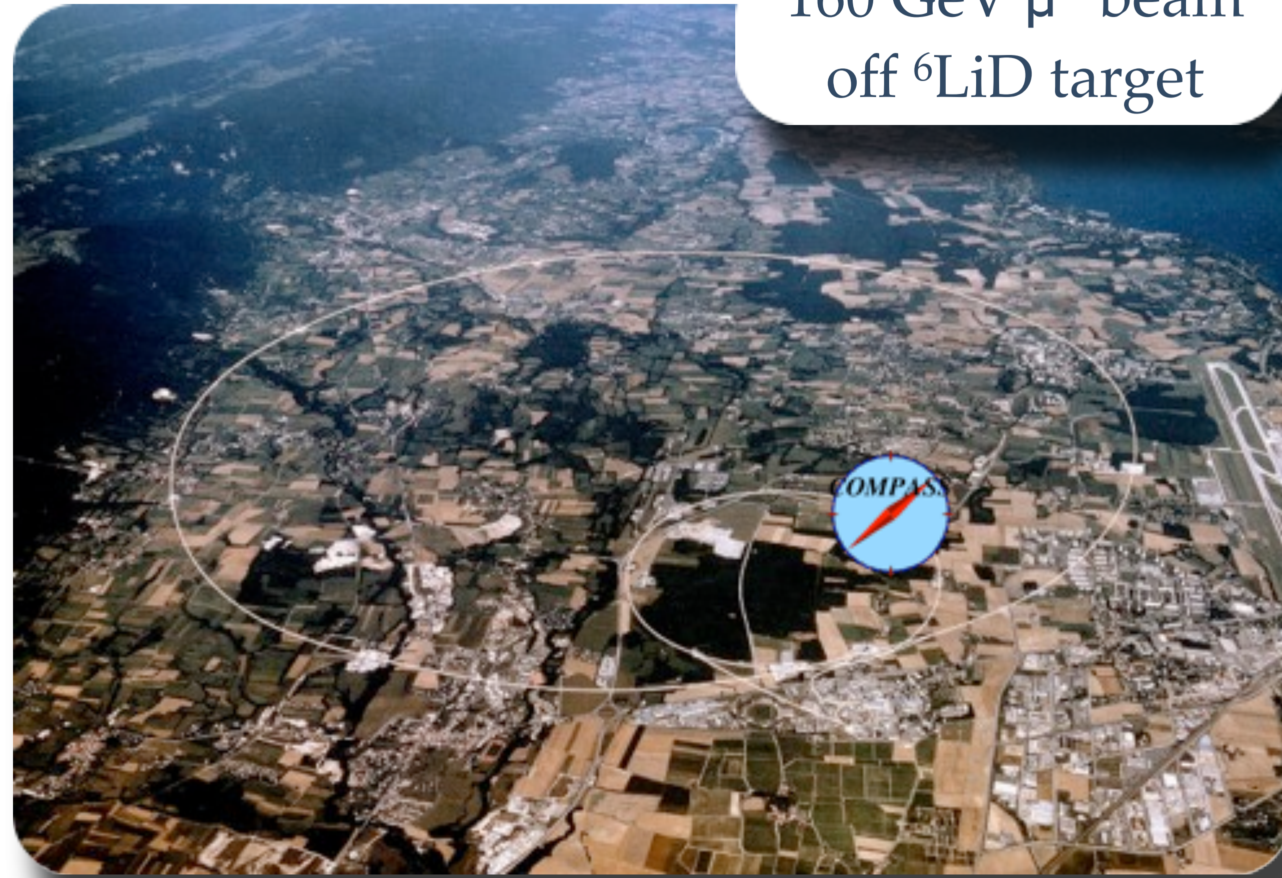

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$$h^+,\ h^-$$

COMPASS@CERN

27.6 GeV lepton (e^+/e^-) beam
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160 GeV μ^+ beam
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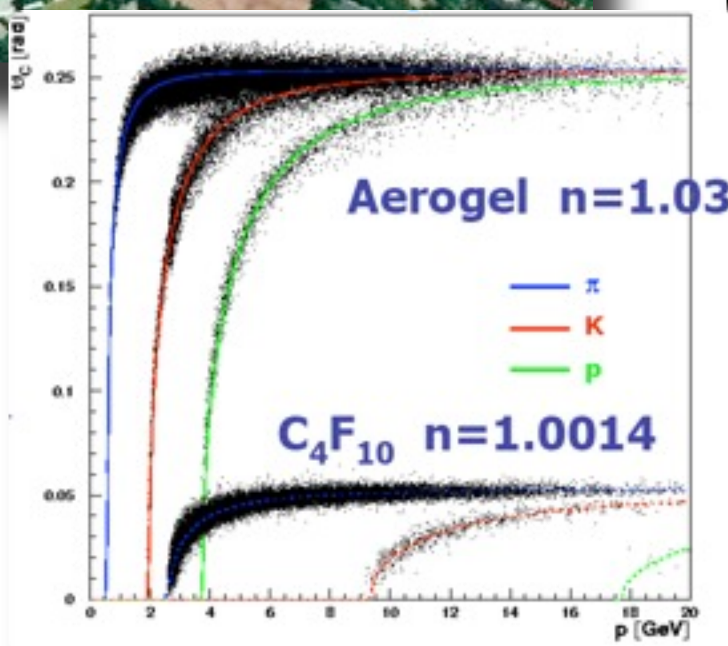

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$$\pi^+,\ \pi^-,\ K^+,\ K^-$$

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$$h^+,\ h^-$$

HERMES@DESY

COMPASS@CERN

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

$$n = \int L\sigma_w^0[1 + 2\langle\cos\phi_h\rangle_w + 2\langle\cos 2\phi_h\rangle_w]\epsilon_{w,\phi_h}^{acc}\epsilon_{w,\phi_h}^{rad}dw$$

Acceptance Correction

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

$$n = \int L\sigma_w^0[1 + 2\langle\cos\phi_h\rangle_w + 2\langle\cos 2\phi_h\rangle_w]\epsilon_{w,\phi_h}^{acc}\epsilon_{w,\phi_h}^{rad}dw$$

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

$$n = \int L\sigma_w^0[1 + 2\langle\cos\phi_h\rangle_w + 2\langle\cos 2\phi_h\rangle_w]\epsilon_{w,\phi_h}^{acc}\epsilon_{w,\phi_h}^{rad}dw$$

Acceptance Correction

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

$$n = \int L\sigma_w^0[1 + 2\langle\cos\phi_h\rangle_w + 2\langle\cos 2\phi_h\rangle_w]\epsilon_{w,\phi_h}^{acc}\epsilon_{w,\phi_h}^{rad}dw$$

Acceptance Correction

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

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$$n_{MC} = \int L\sigma^0_w\epsilon^{acc}_{w,\phi_h}\epsilon^{rad}_{w,\phi_h}dw$$

Acceptance Correction

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

$$n = \int L\sigma_w^0 [1 + 2\langle \cos\phi_h \rangle_w + 2\langle \cos 2\phi_h \rangle_w] \epsilon_{w,\phi_h}^{acc} \epsilon_{w,\phi_h}^{rad} dw$$

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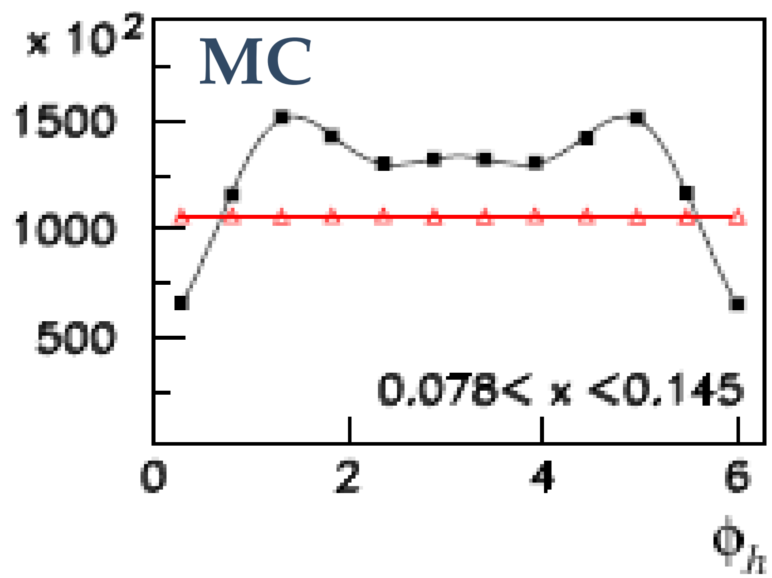


Generated in 4π

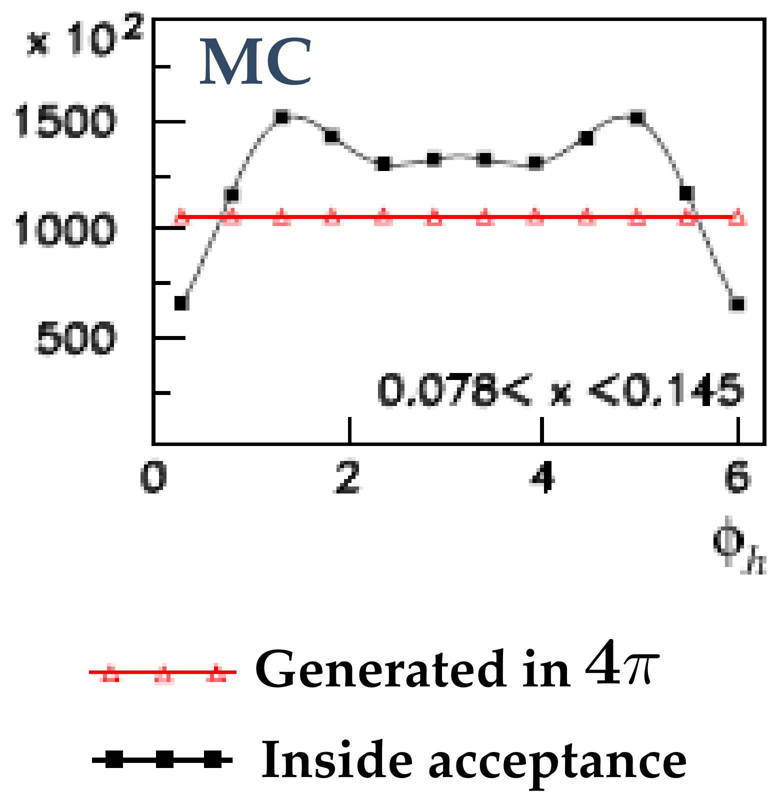
Inside acceptance

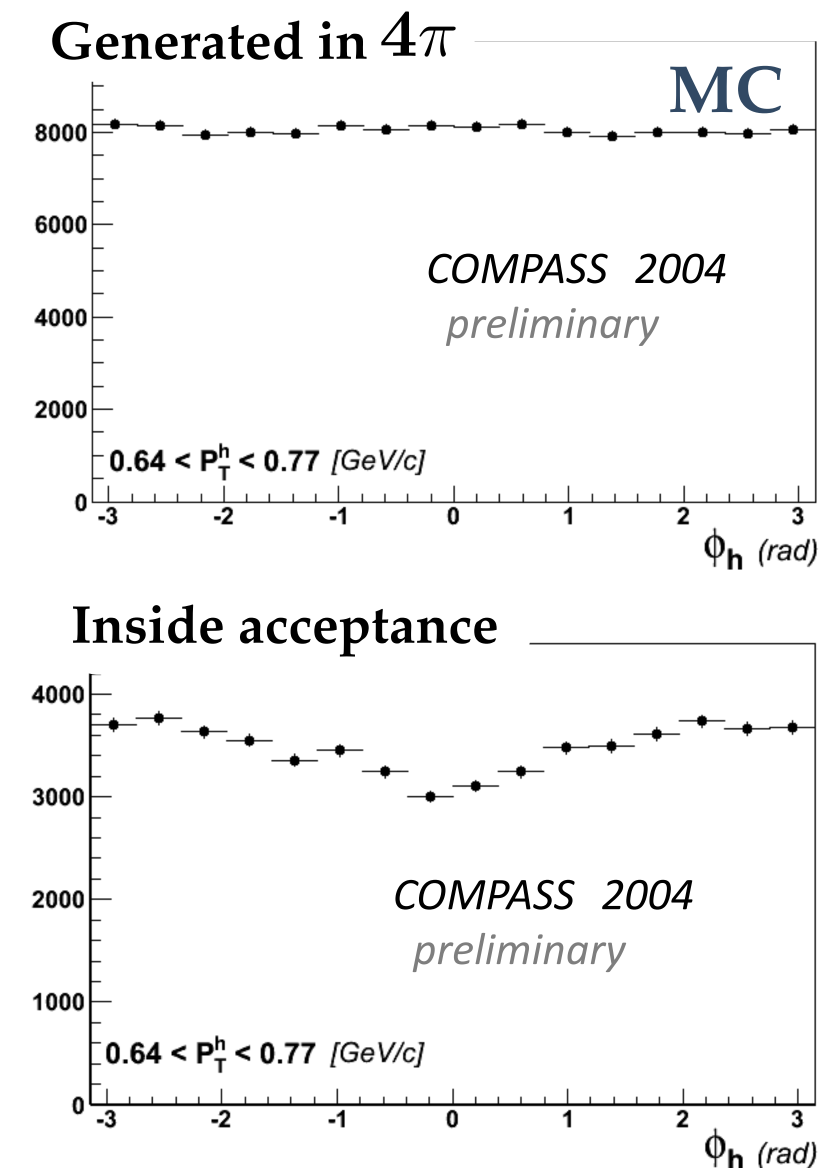
Acceptance Correction

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

$$n = \int L\sigma_w^0 [1 + 2\langle\cos\phi_h\rangle_w + 2\langle\cos 2\phi_h\rangle_w]\epsilon_{w,\phi_h}^{acc}\epsilon_{w,\phi_h}^{rad} dw$$

$$n_{MC} = \int L\sigma_w^0 \epsilon_{w,\phi_h}^{acc}\epsilon_{w,\phi_h}^{rad} dw$$





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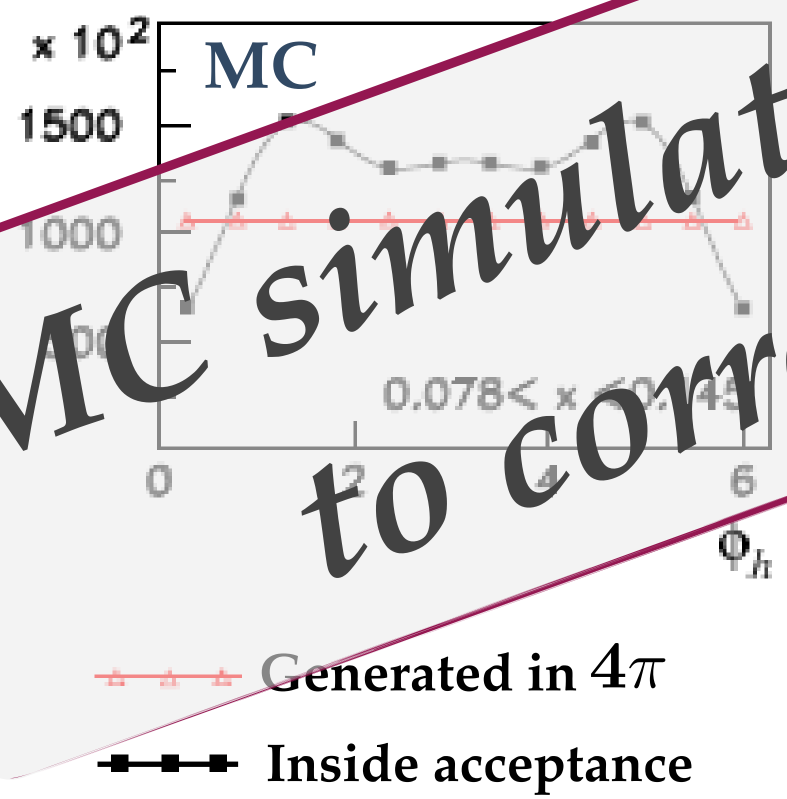
Acceptance Correction

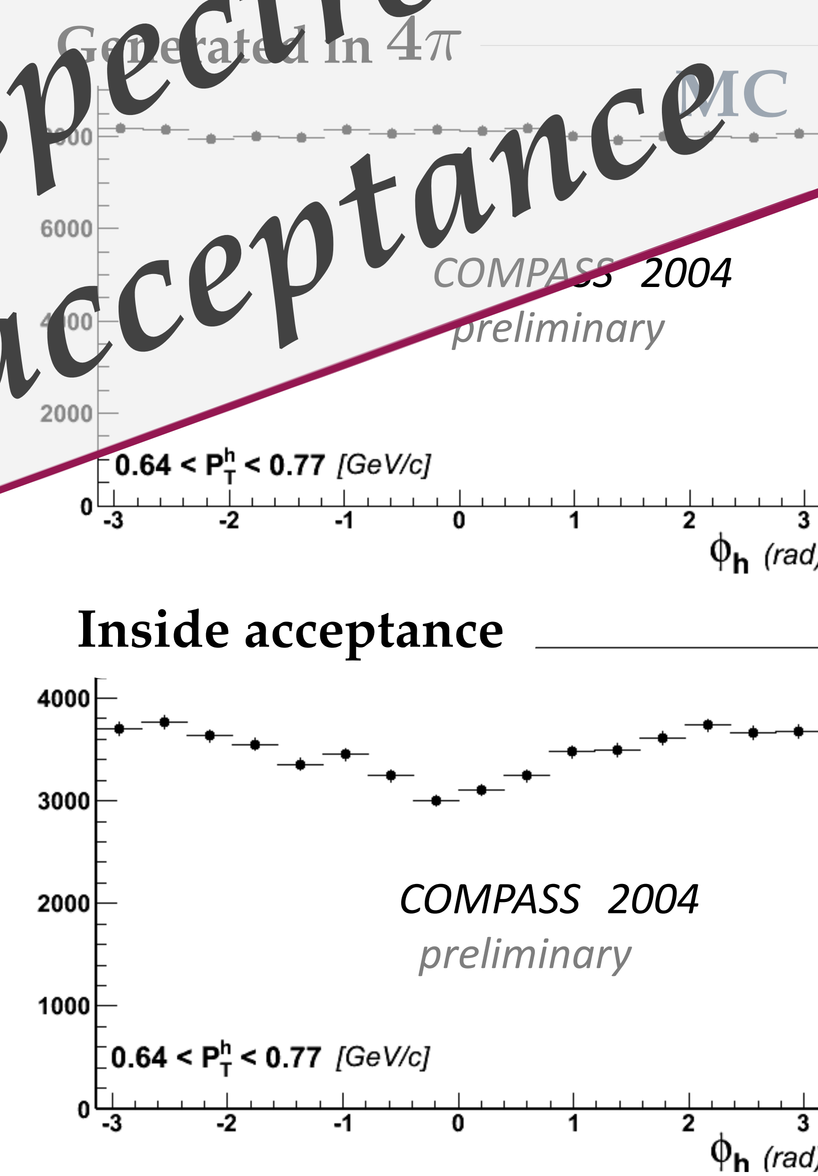
$$w = (x, y, z, P_{h\perp})$$

$$n = \int L\sigma_w^0 [1 + 2\langle \cos\phi_h \rangle_w + 2\langle \cos 2\phi_h \rangle_w] \epsilon_{w,\phi_h}^{acc} \epsilon_{w,\phi_h}^{rad} \, dw$$

$$n_{MC} = \int L\sigma_w^0 \epsilon_{w,\phi_h}^{acc} \epsilon_{w,\phi_h}^{rad} \, dw$$

MC simulation of spectrometers to correct for acceptance





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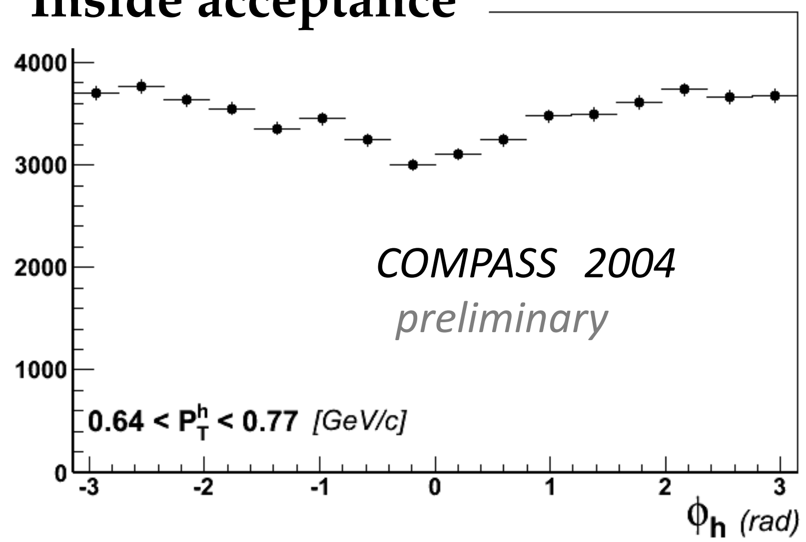
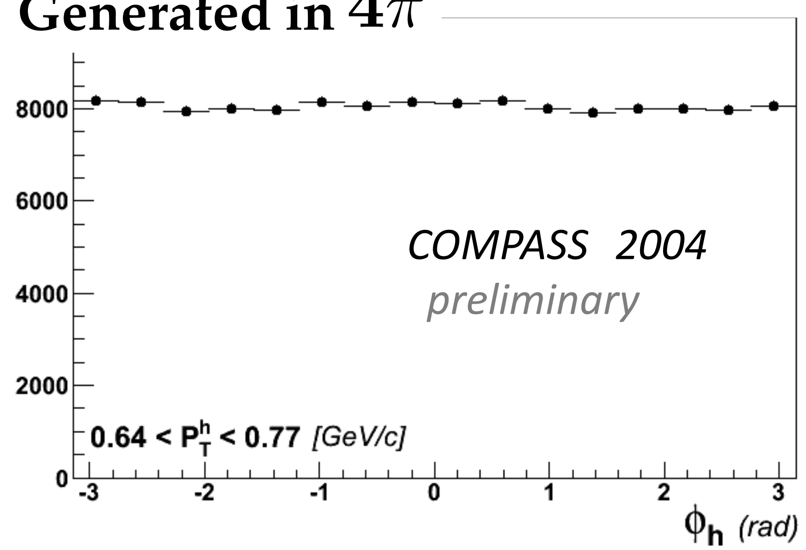
Acceptance Correction

Inside acceptance

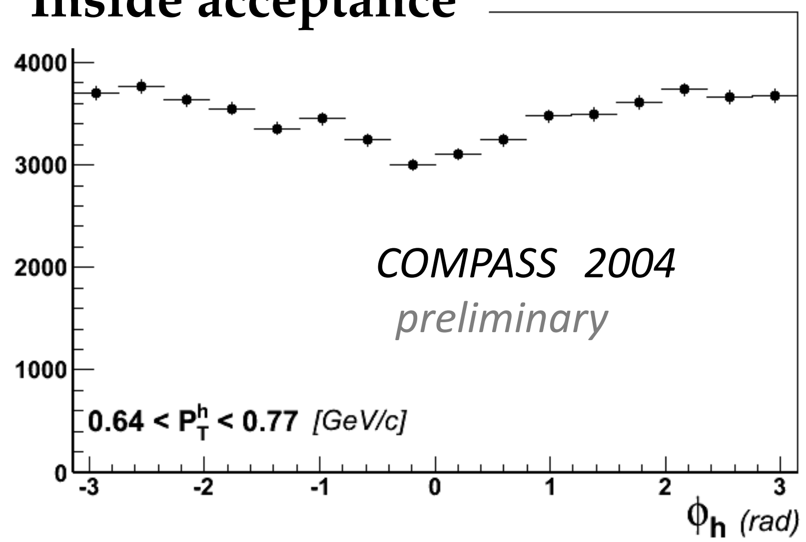


Generated in 4π

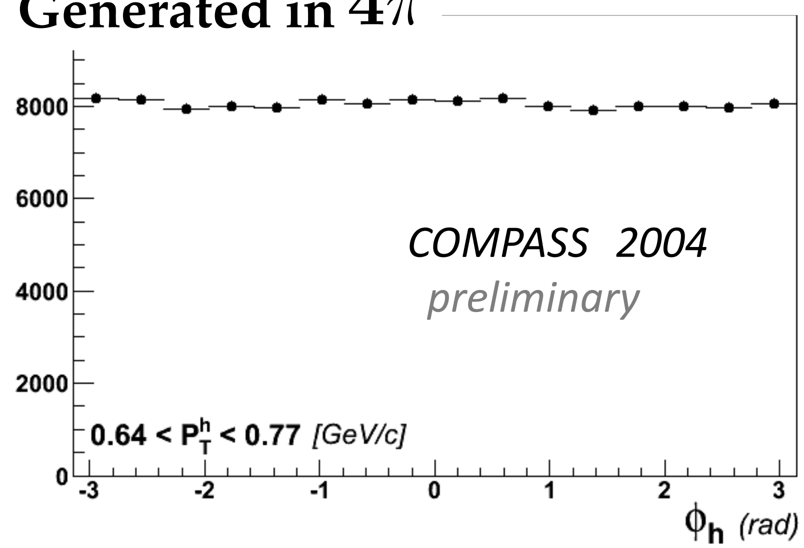


COMPASS Extraction

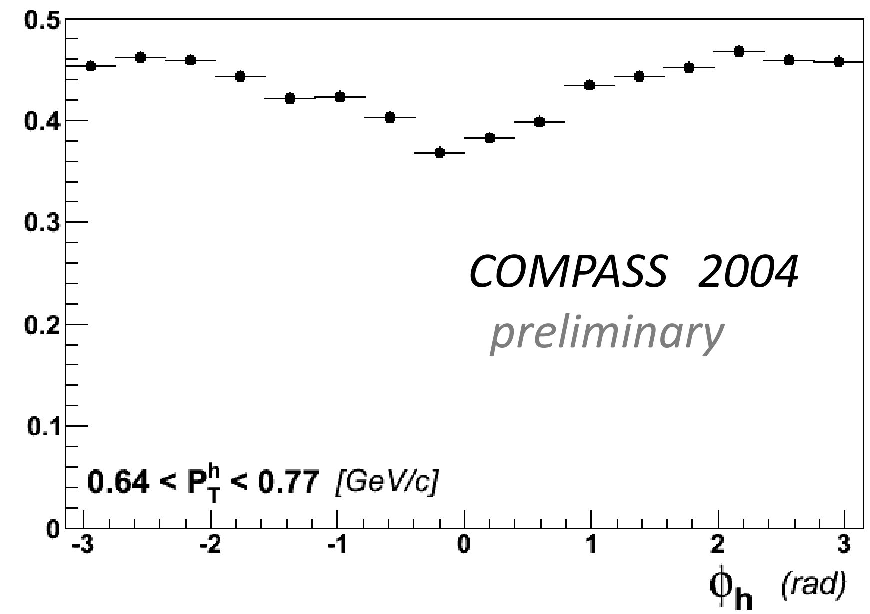
Inside acceptance



Generated in 4π



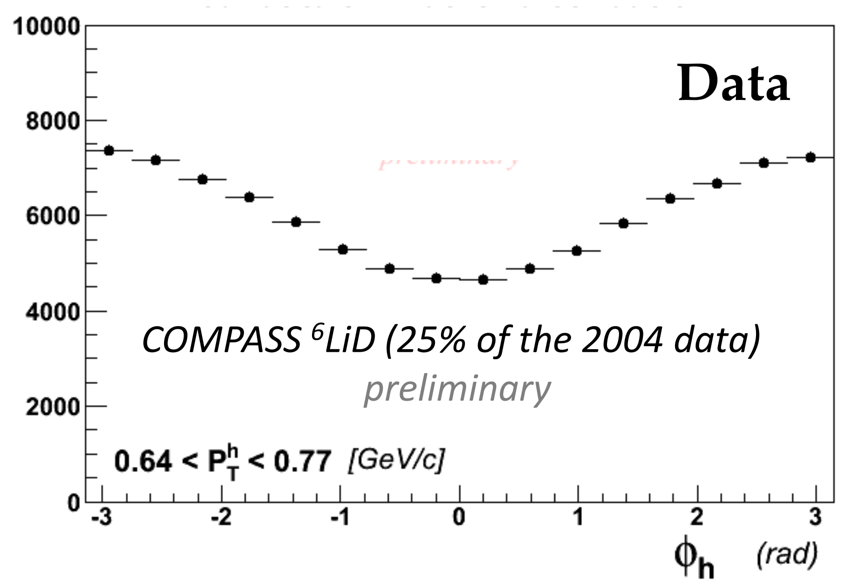
azimuthal acceptance



$$Acc_k(\phi_h) = \frac{R_k^{mc}(\phi_h)}{G_k^{mc}(\phi_h)}$$

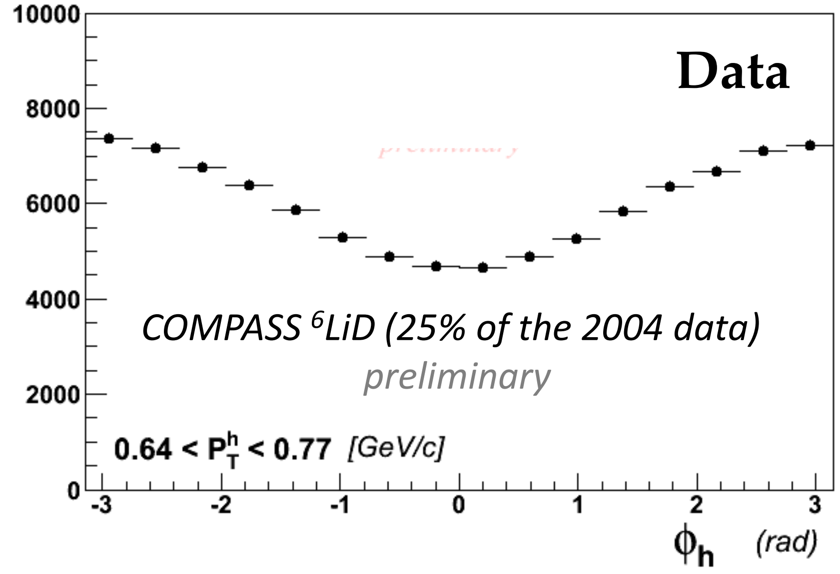
COMPASS Extraction

measured azimuthal distribution

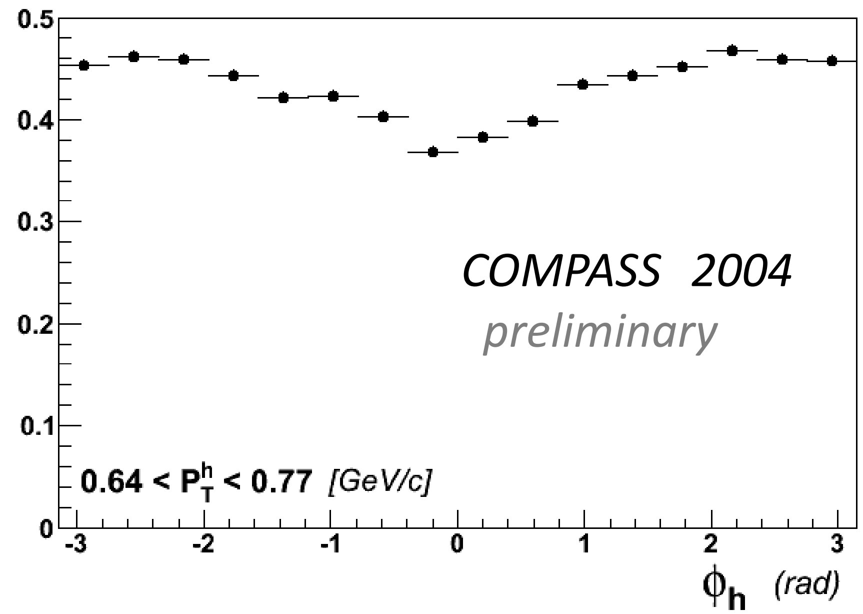


COMPASS Extraction

measured azimuthal distribution

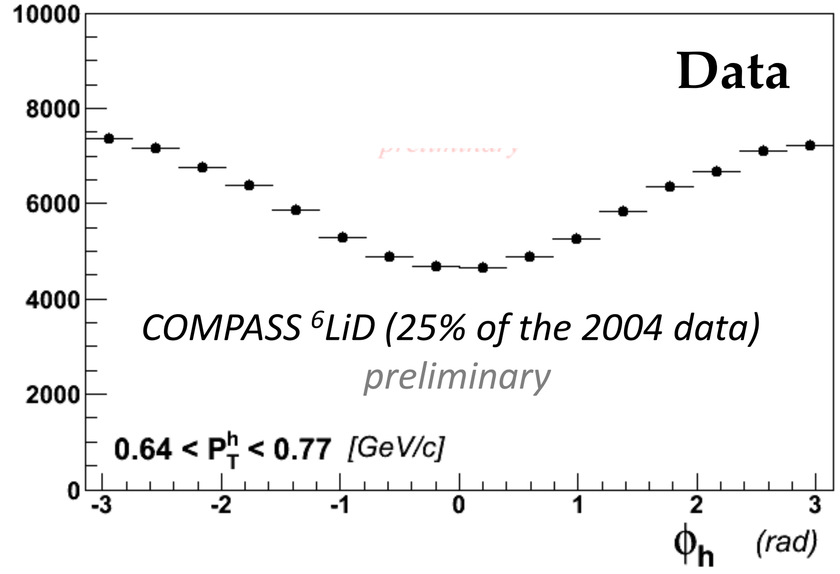


azimuthal acceptance



COMPASS Extraction

measured azimuthal distribution



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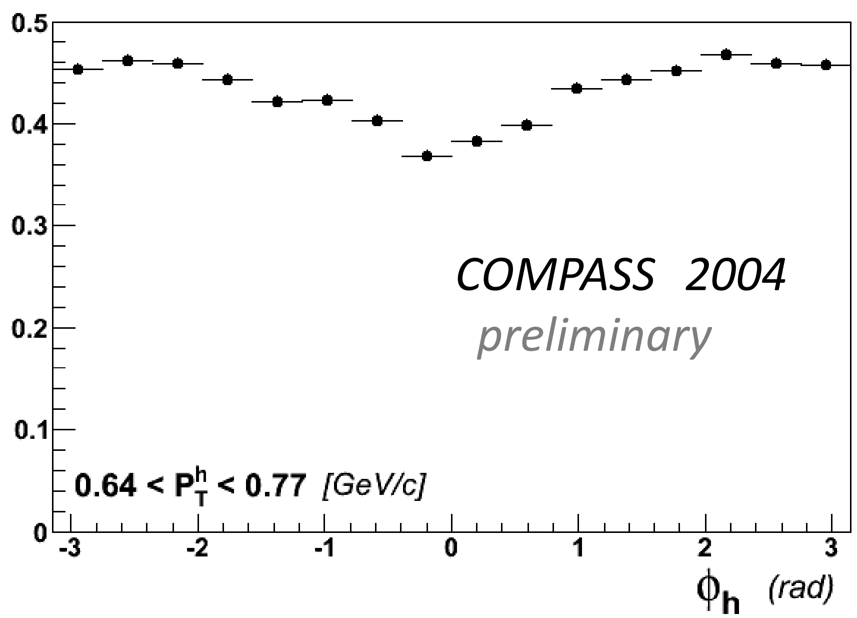
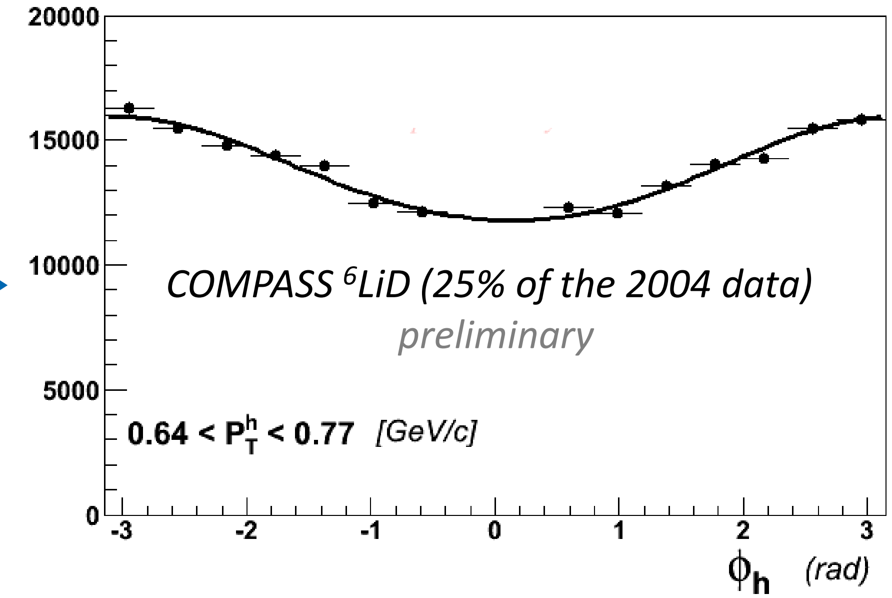
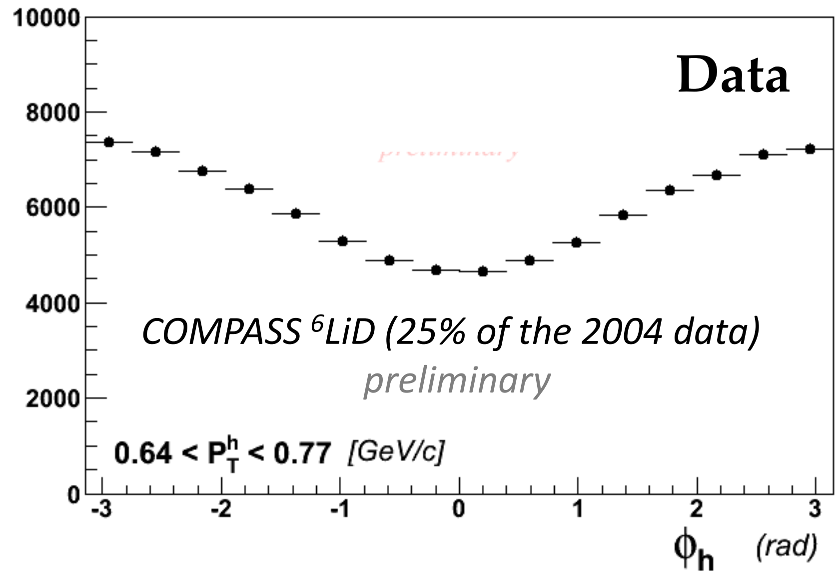


measured azimuthal distributions corrected by the acceptance

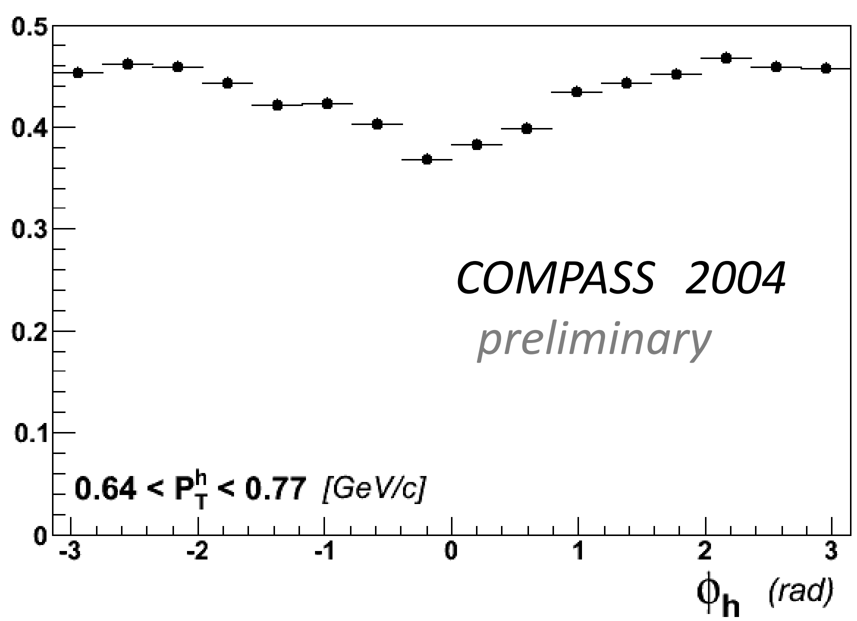


COMPASS Extraction

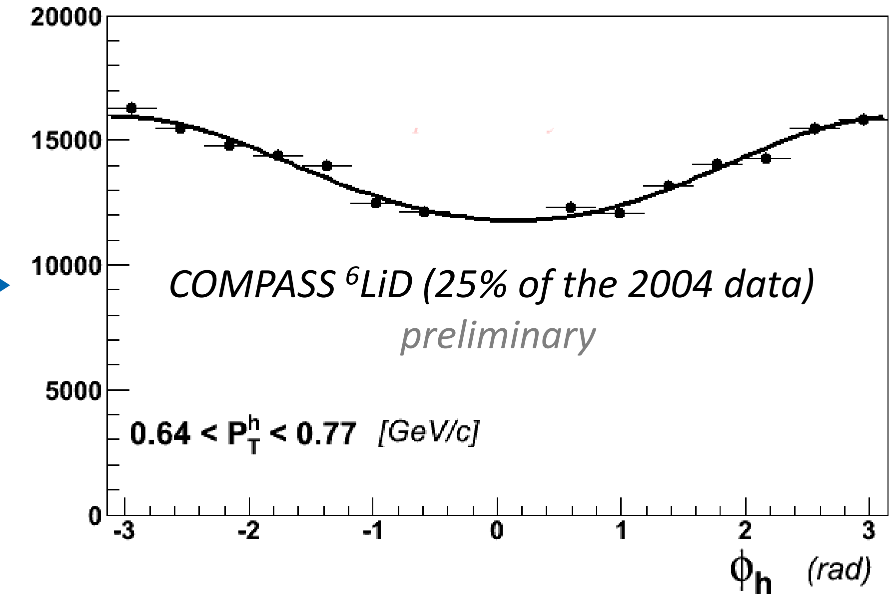
measured azimuthal distribution



azimuthal acceptance



measured azimuthal distributions corrected by the acceptance



$$p_0 \cdot (1 + p_1 \cdot \cos\phi_h + p_2 \cdot \cos 2\phi_h + p_3 \cdot \sin\phi_h)$$

COMPASS Extraction

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

$$n = \int L\sigma_w^0 [1 + 2\langle \cos\phi_h \rangle_w + 2\langle \cos 2\phi_h \rangle_w] \epsilon_{w,\phi_h}^{acc} \epsilon_{w,\phi_h}^{rad} dw$$

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$$n_{born} = S^{-1}[n - B]$$

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

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$$n_{born} = S^{-1}[n - B]$$

describes the acceptance & smearing between adjacent bins

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

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$$n_{born} = S^{-1}[n - B]$$

S^{-1}: describes the acceptance & smearing between adjacent bins

B: events smeared in the sample from outside the acceptance

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

$$n = \int L\sigma_w^0 [1 + 2\langle \cos\phi_h \rangle_w + 2\langle \cos 2\phi_h \rangle_w] \epsilon_{w,\phi_h}^{acc} \epsilon_{w,\phi_h}^{rad} dw$$

$$n_{born} = S^{-1}[n - B]$$

S^{-1}: describes the acceptance & smearing between adjacent bins

B: events smeared in the sample from outside the acceptance

Multi-dimensional (w) unfolding

Binning 900 kinematic bins x 12 ϕ_h-bins								
Variable	Bin limits							#
x	0.023	0.04	0.078	0.145	0.27	0.6		5
y	0.2	0.3	0.45	0.6	0.7	0.85		5
z	0.2	0.3	0.4	0.5	0.6	0.75	1	6
$P_{h\perp}$	0.05	0.2	0.35	0.5	0.7	1	1.3	6

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

$$n = \int L\sigma_w^0 [1 + 2\langle\cos\phi_h\rangle_w + 2\langle\cos 2\phi_h\rangle_w]\epsilon_{w,\phi_h}^{acc}\epsilon_{w,\phi_h}^{rad} dw$$

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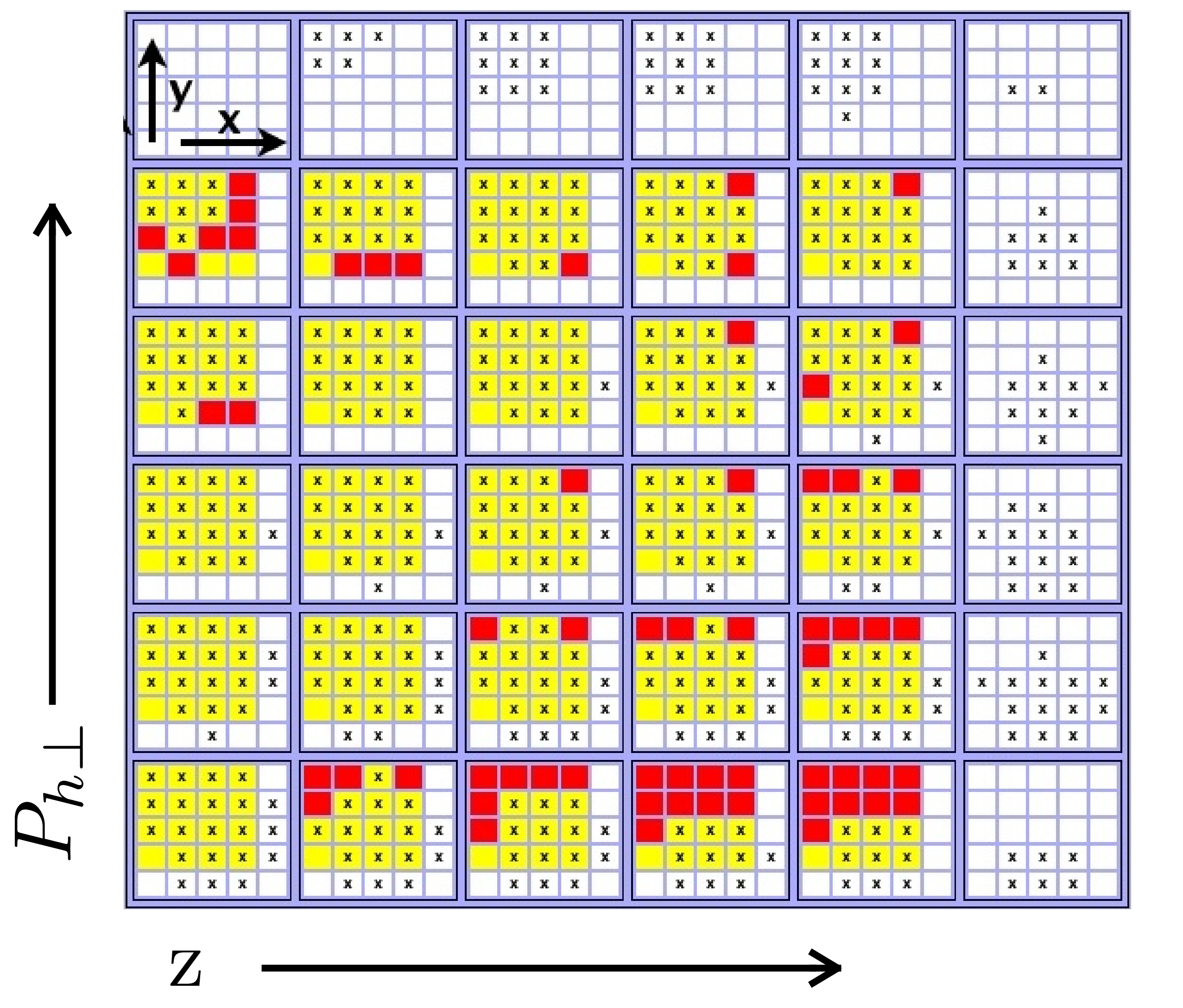
$P_{h\perp}$	0.05	0.2	0.35	0.5	0.7	1	1.3	6

$$A(1 + B\cos\phi_h + C\cos 2\phi_h)$$

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

$$n = \int L\sigma_w^0 [1 + 2\langle\cos\phi_h\rangle_w + 2\langle\cos 2\phi_h\rangle_w]\epsilon_{w,\phi_h}^{acc}\epsilon_{w,\phi_h}^{rad} dw$$



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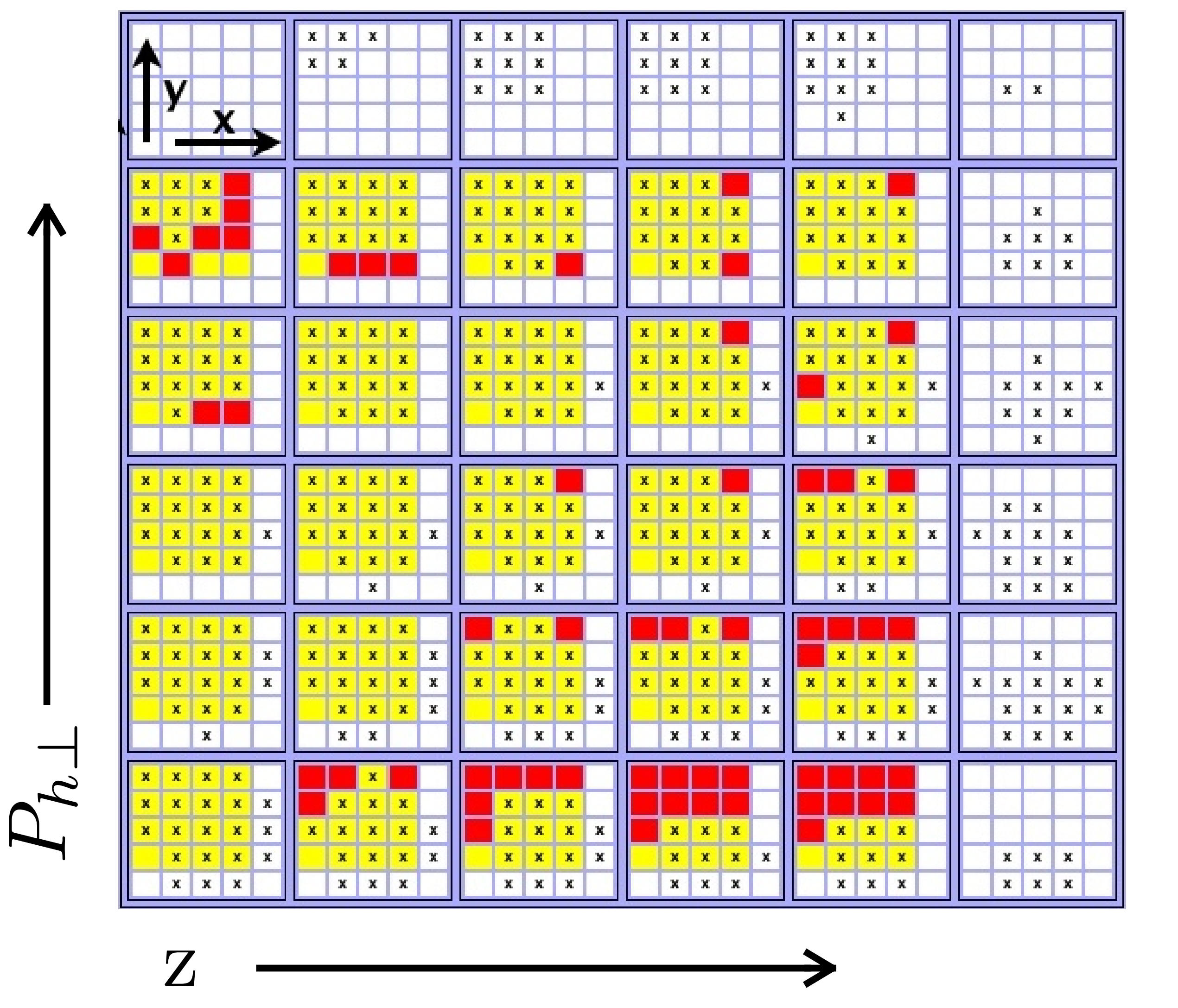
Projection Versus The Single Variable

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

$$n = \int L\sigma_w^0 [1 + 2\langle \cos\phi_h \rangle_w + 2\langle \cos 2\phi_h \rangle_w] \epsilon_{w,\phi_h}^{acc} \epsilon_{w,\phi_h}^{rad} dw$$



Multi-dimensional (w) unfolding

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Projection Versus The Single Variable

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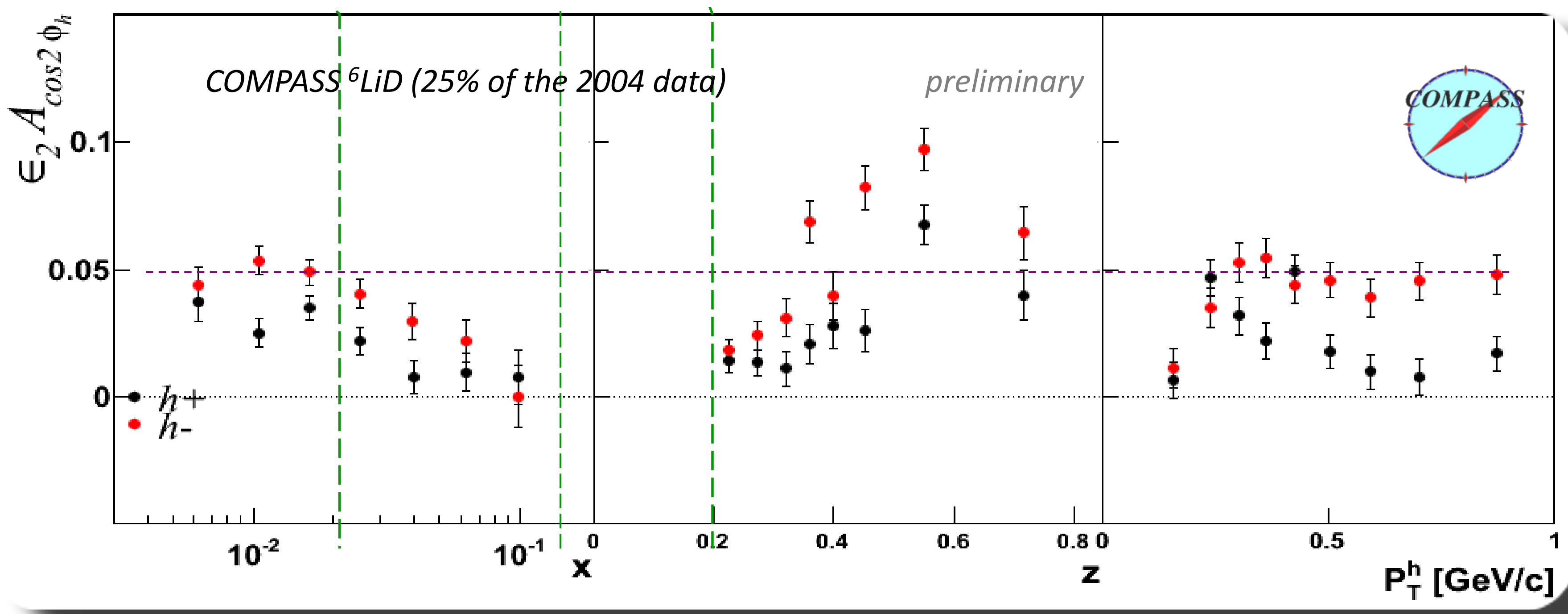
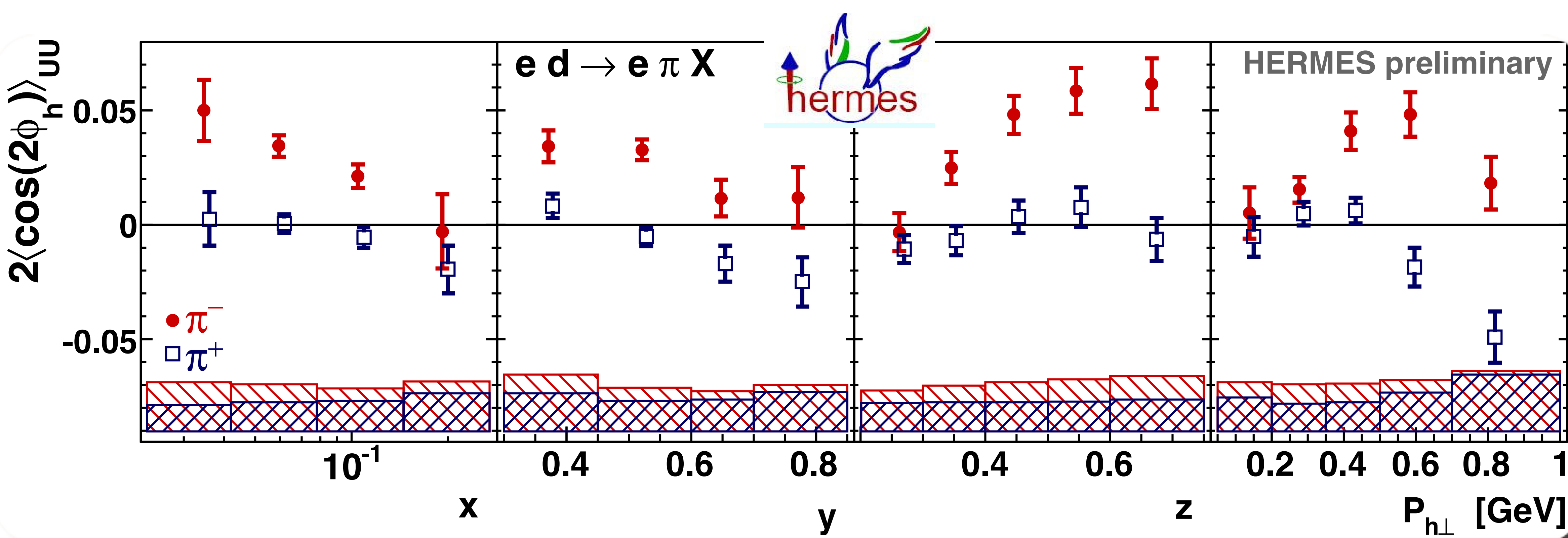
hadrons



pions



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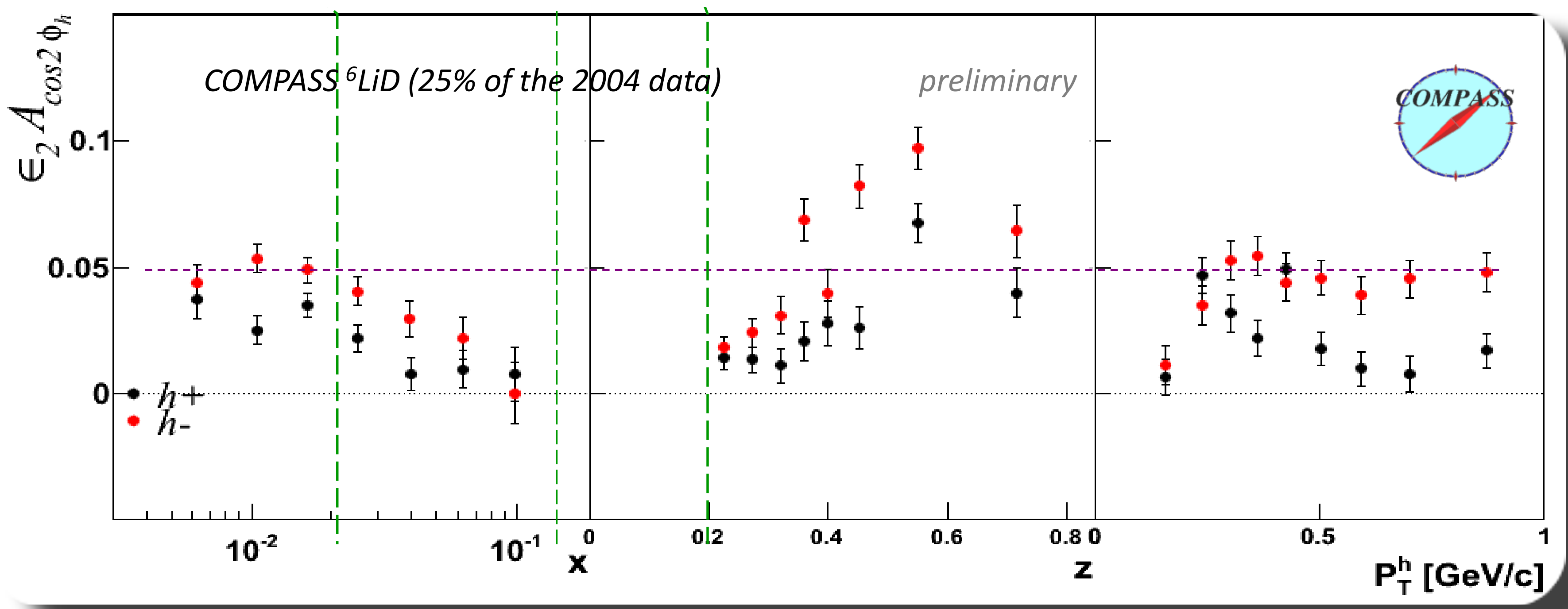
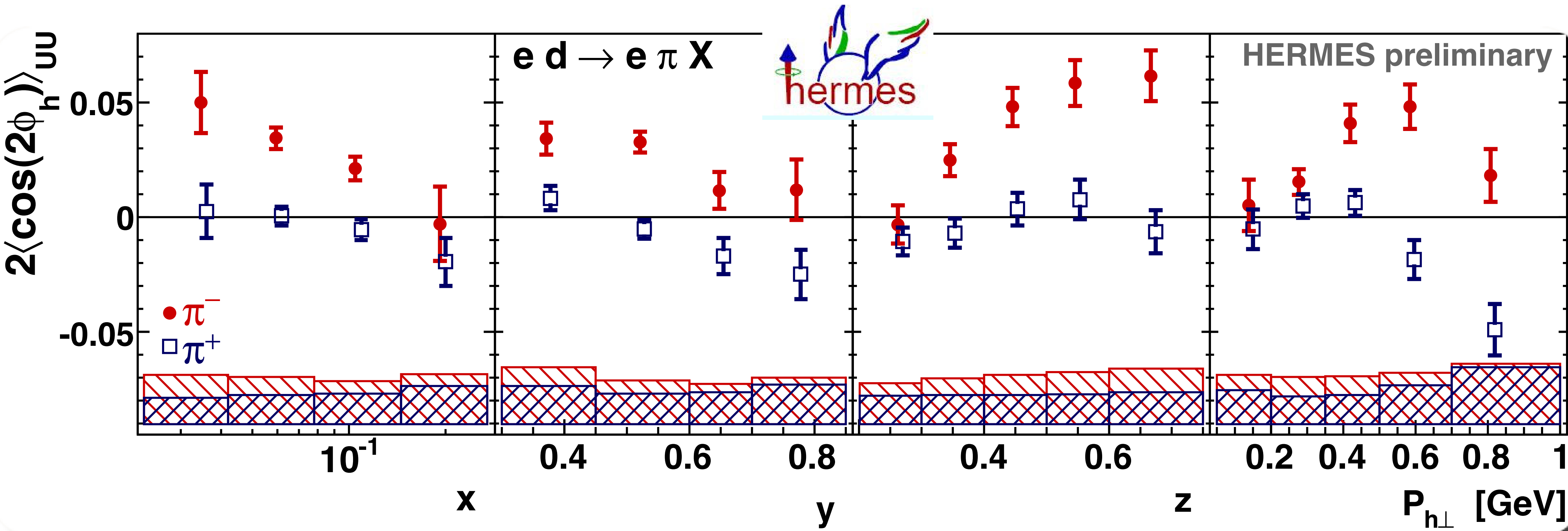
hadrons



$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

pions



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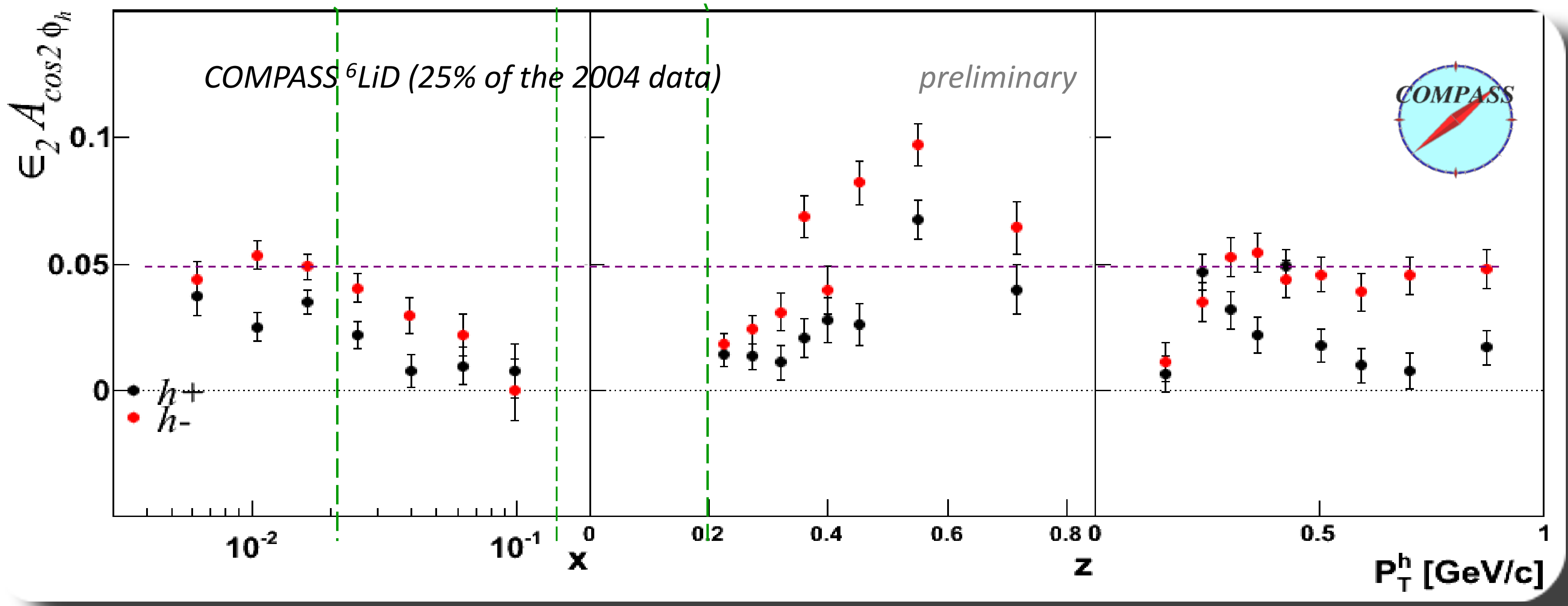
hadrons

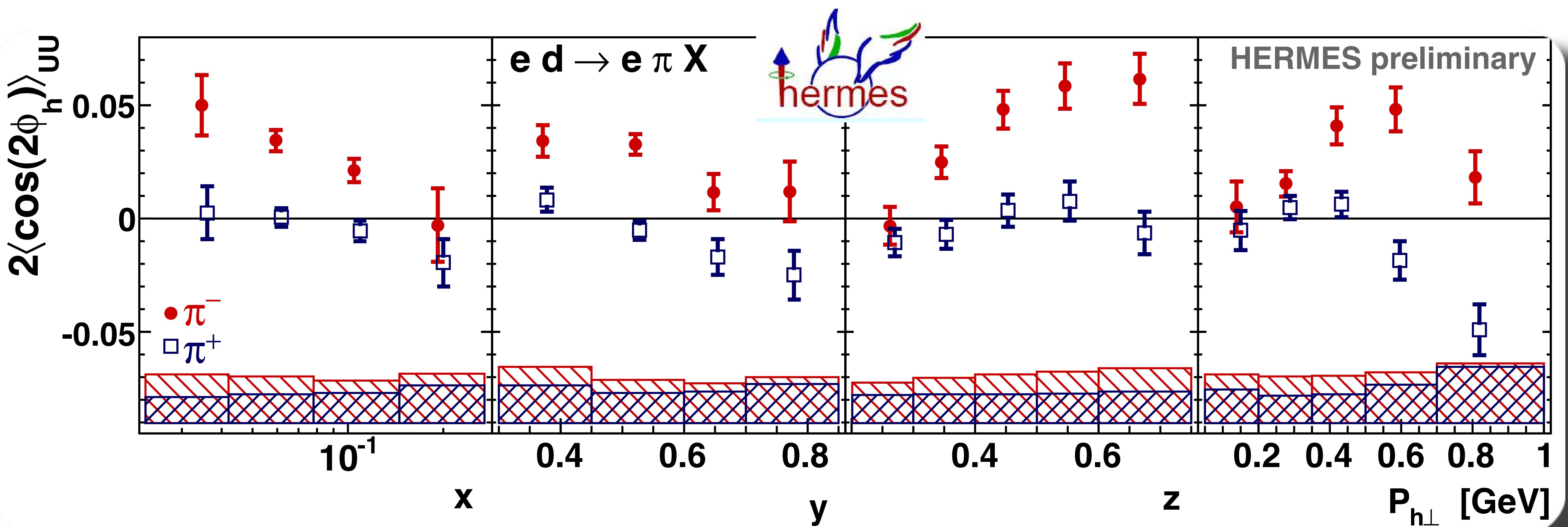


$$\propto C[-h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Cahn

Boer-Mulders

pions



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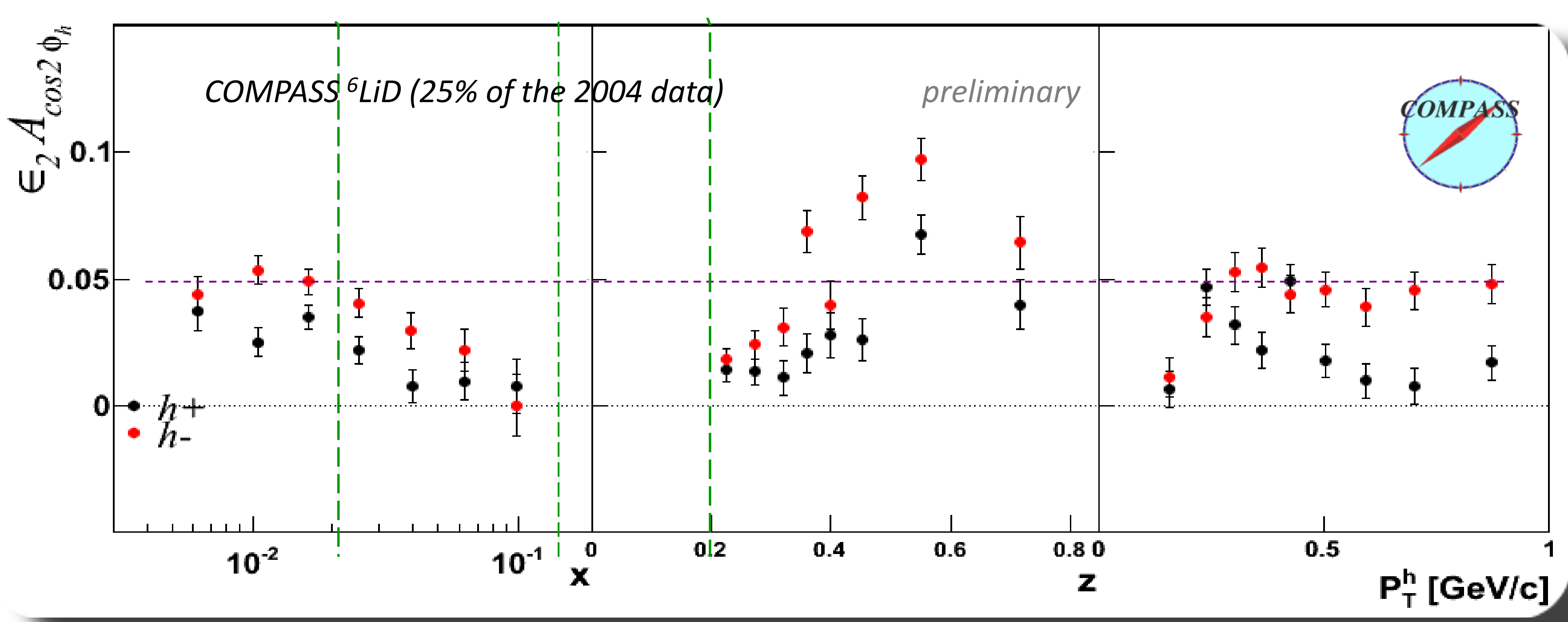
hadrons



Gamberg, Goldstein
Phys. Rev. D77:094016, 2008

Zhang et al
Phys. Rev. D78:034035, 2008

Barone et al
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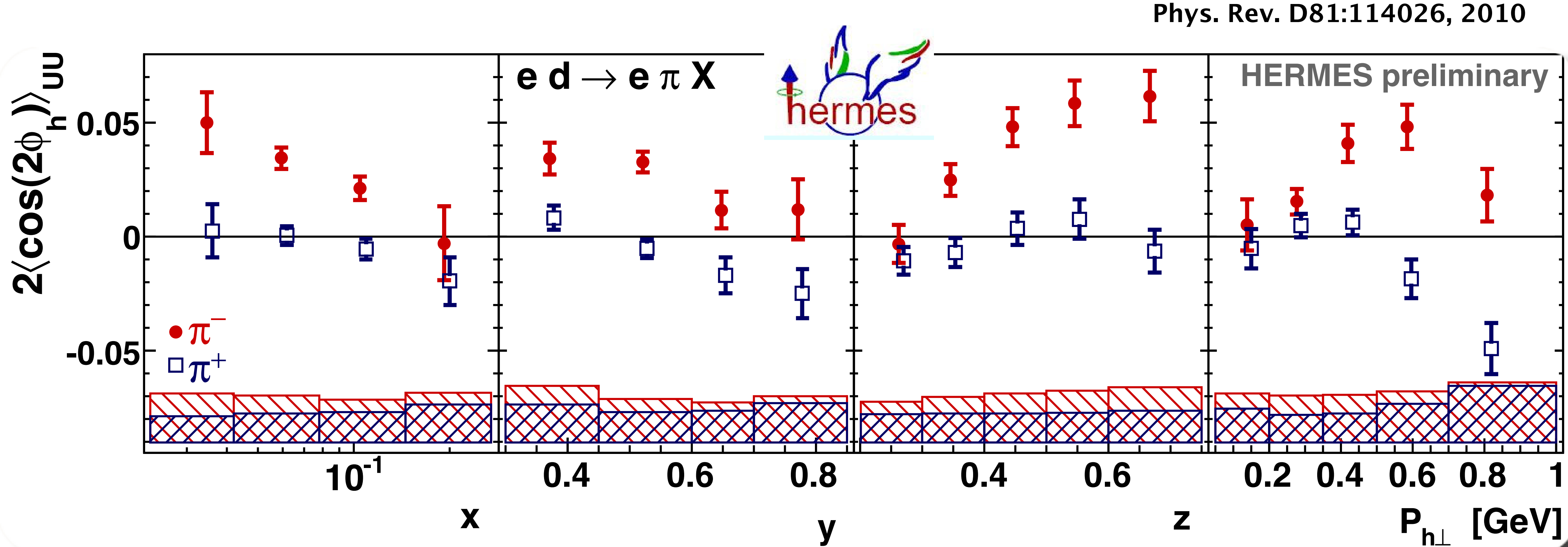
Barone, Melis, Prokudin
Phys. Rev. D81:114026, 2010

$$\propto C[\underbrace{-h_1^{\perp} H_1^{\perp}}_{\text{Boer-Mulders}} + \underbrace{\frac{\kappa_T^2}{Q^2} f_1 D_1}_{\text{Cahn}} + \ldots]$$

pions



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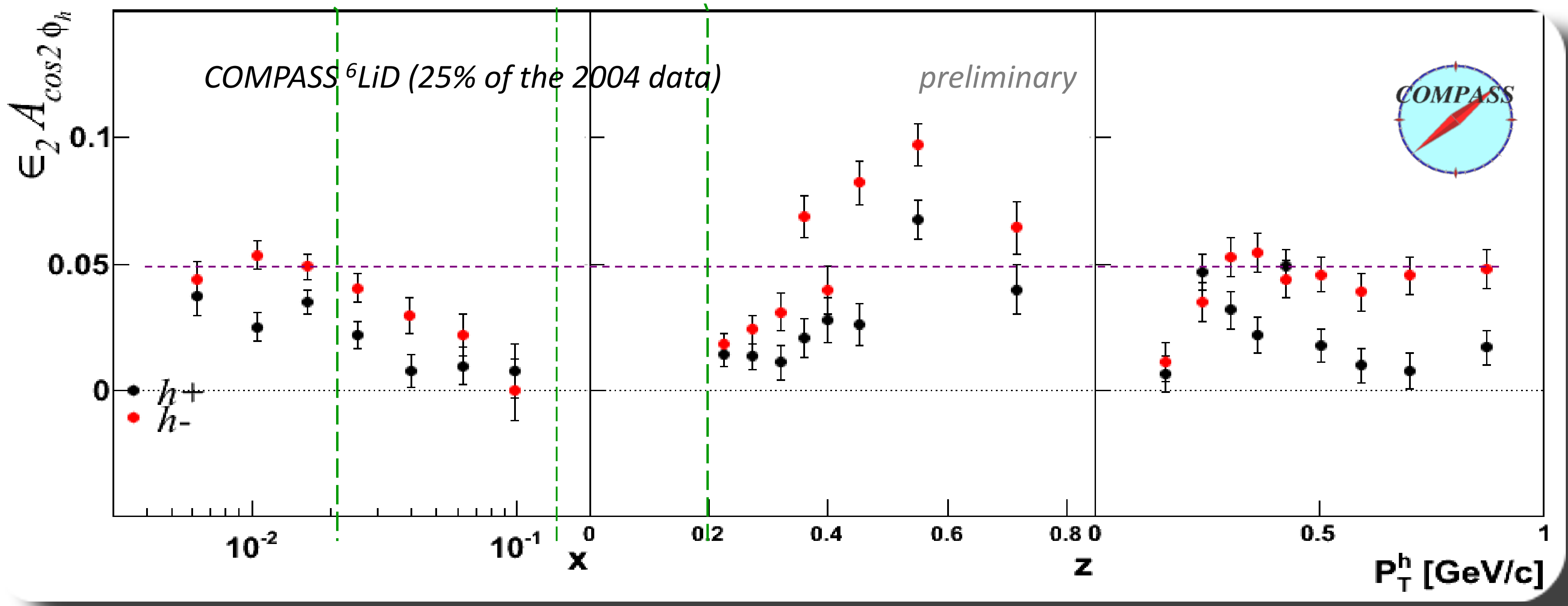

hadrons

Cahn expected flavor blind

$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots]$$

Boer-Mulders

Cahn

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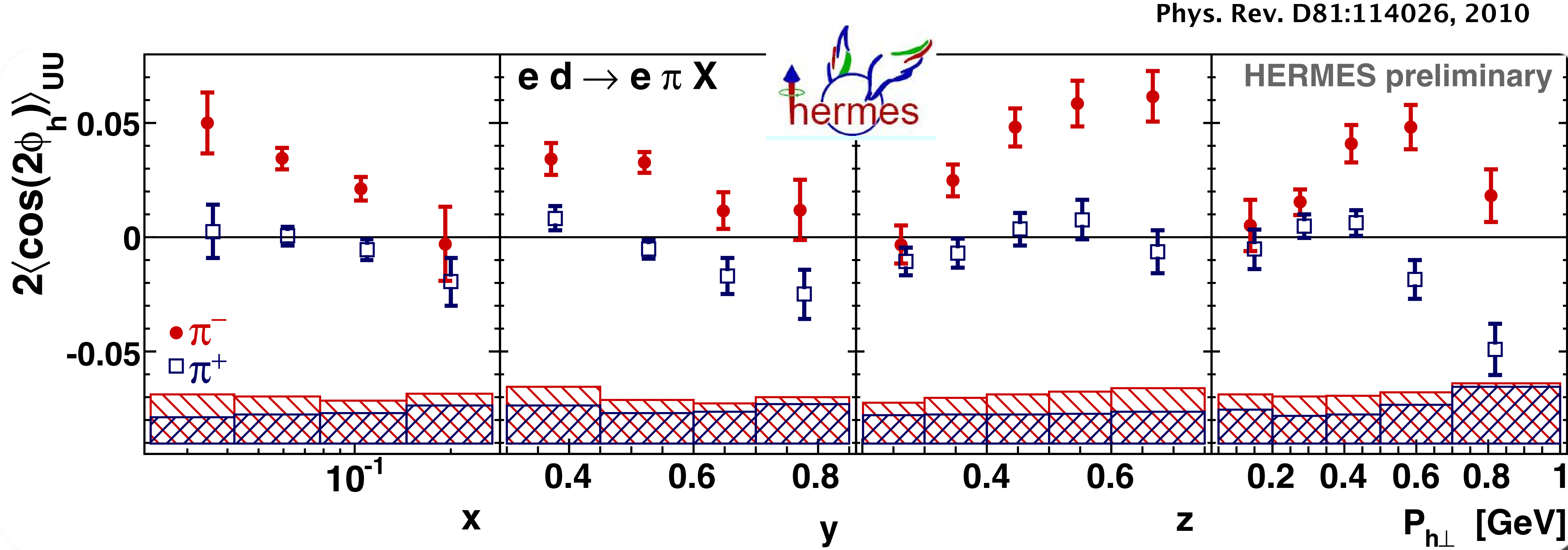
pions



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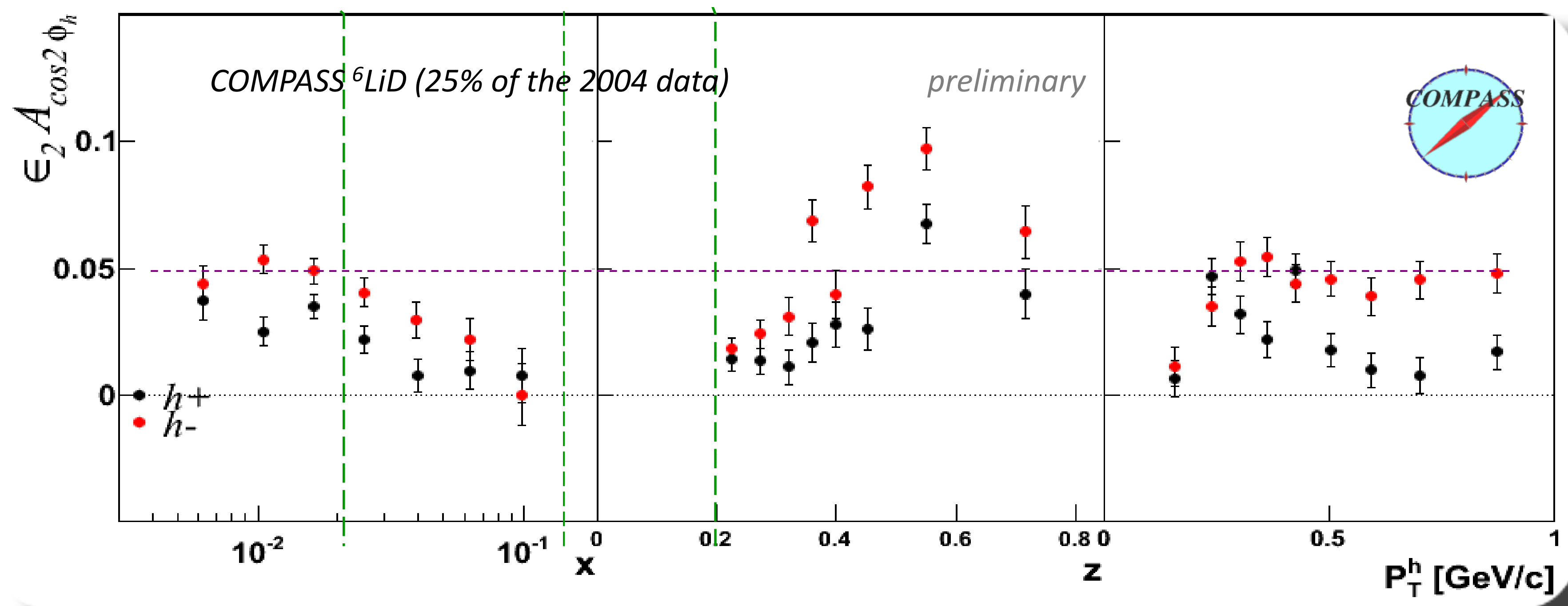

hadrons

Cahn expected flavor blind

different π^+/π^- amplitudes > Boer-Mulders effect

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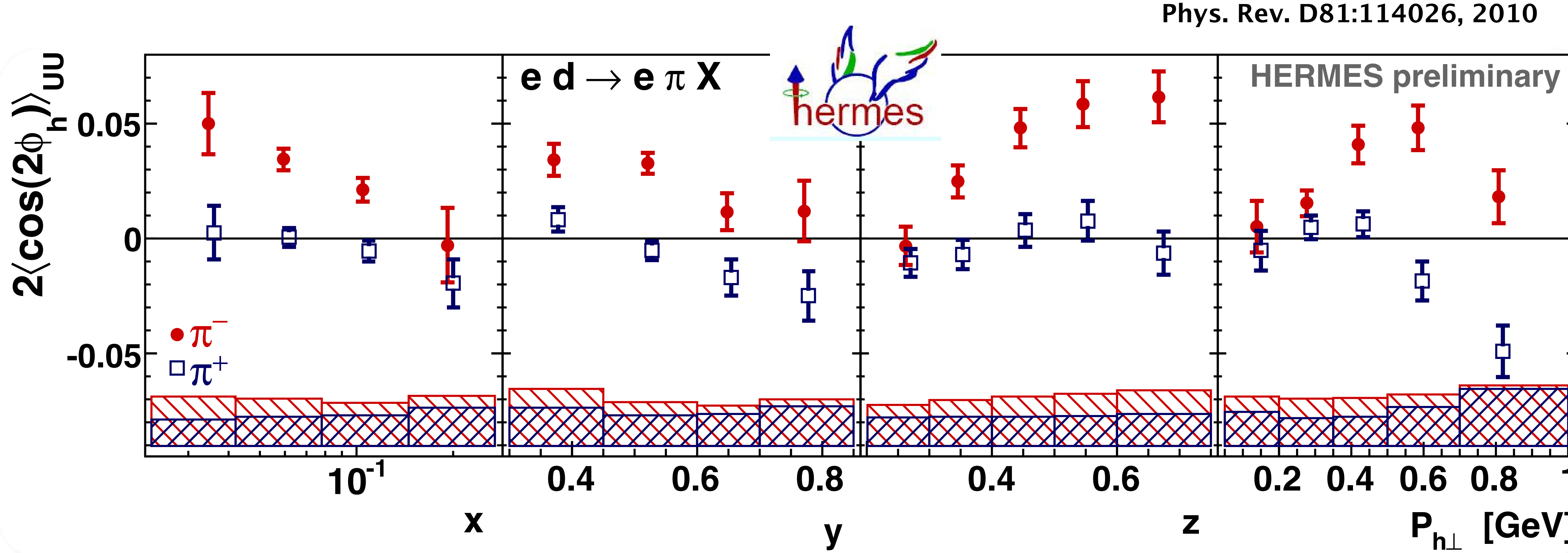
$$\propto C[\underbrace{-h_1^\perp H_1^\perp}_{\text{Boer-Mulders}} + \overbrace{\frac{\kappa_T^2}{Q^2} f_1 D_1}^{\text{Cahn}} + \ldots]$$

pions



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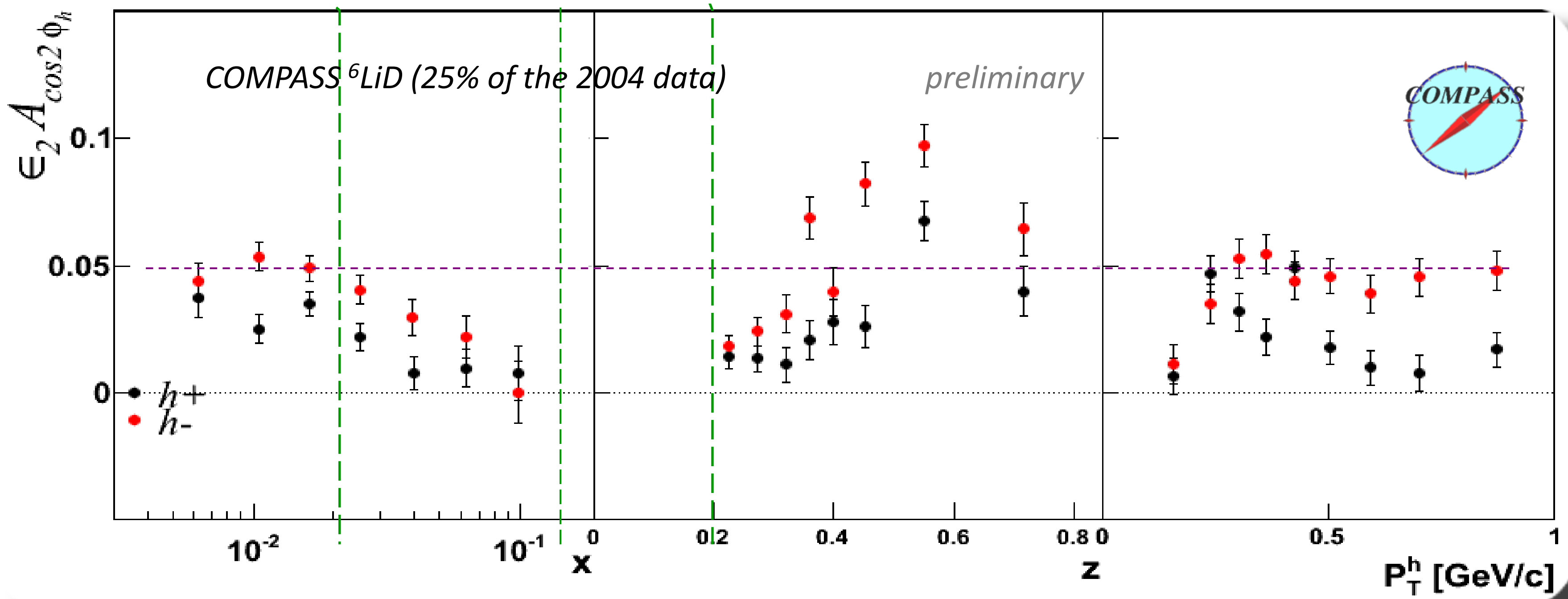

hadrons

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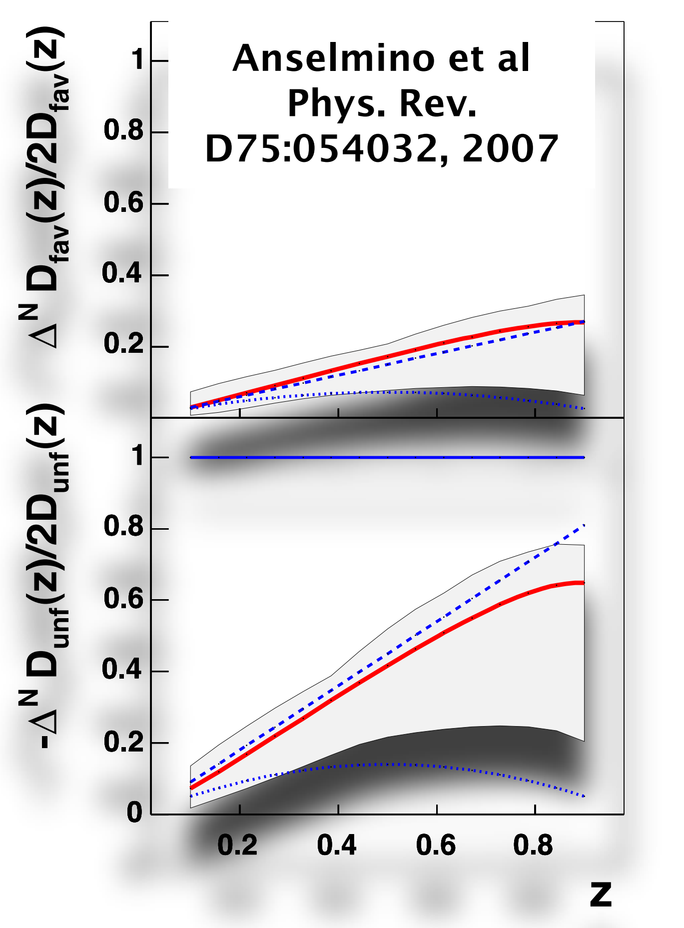
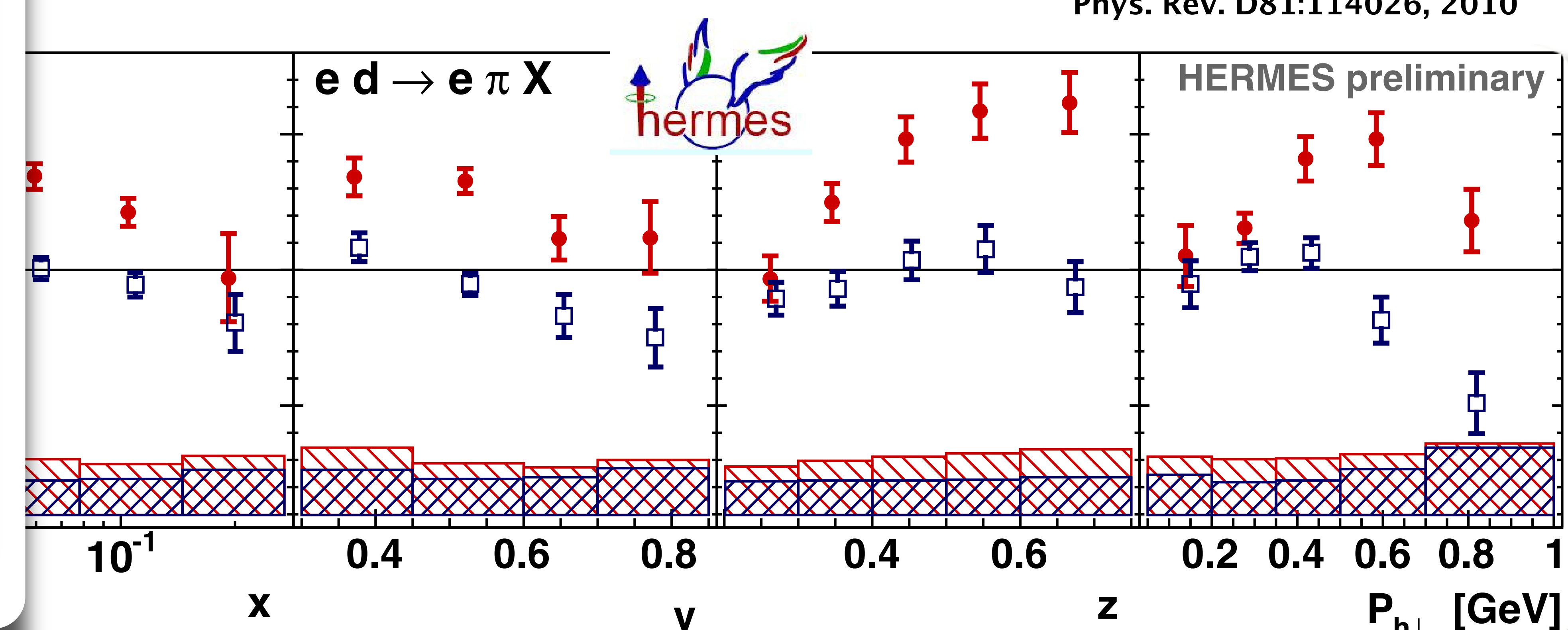
$$H_1^{\perp, u \to \pi^-} \approx -H_1^{\perp, u \to \pi^+}$$

$$\propto C[-h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots]$$

Boer-Mulders — Cahn





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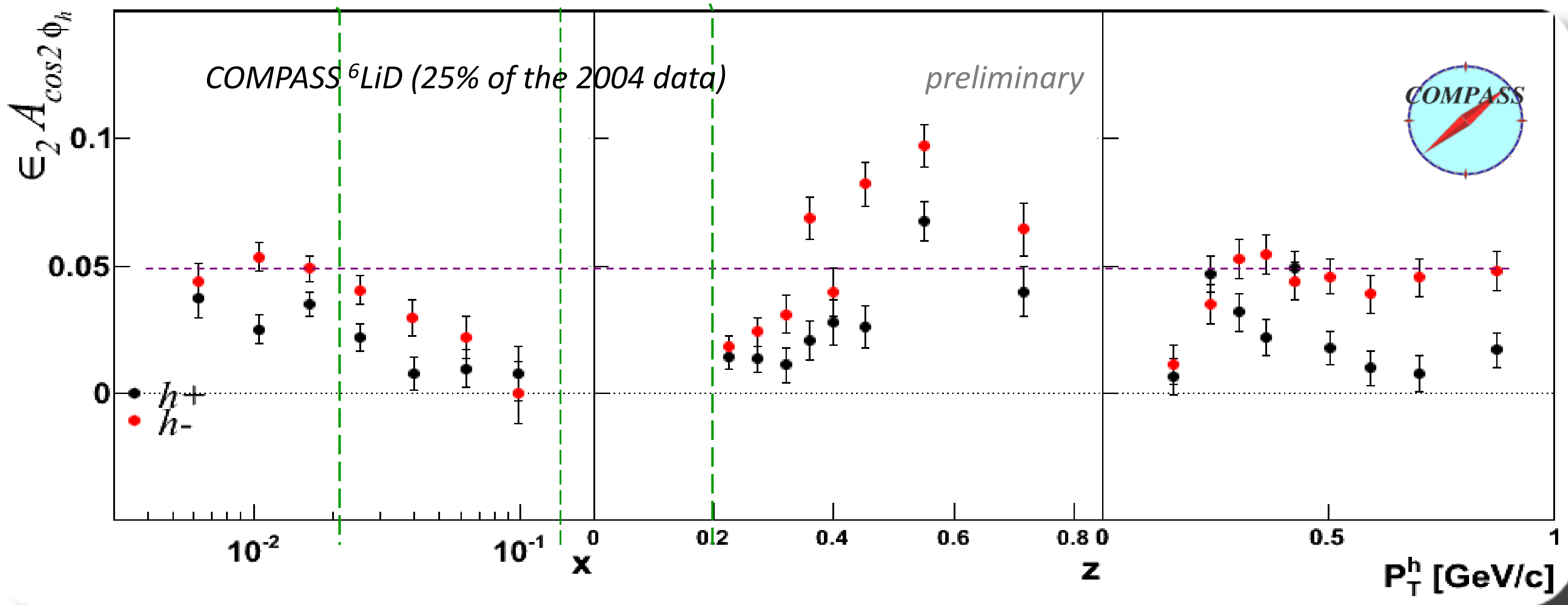
hadrons



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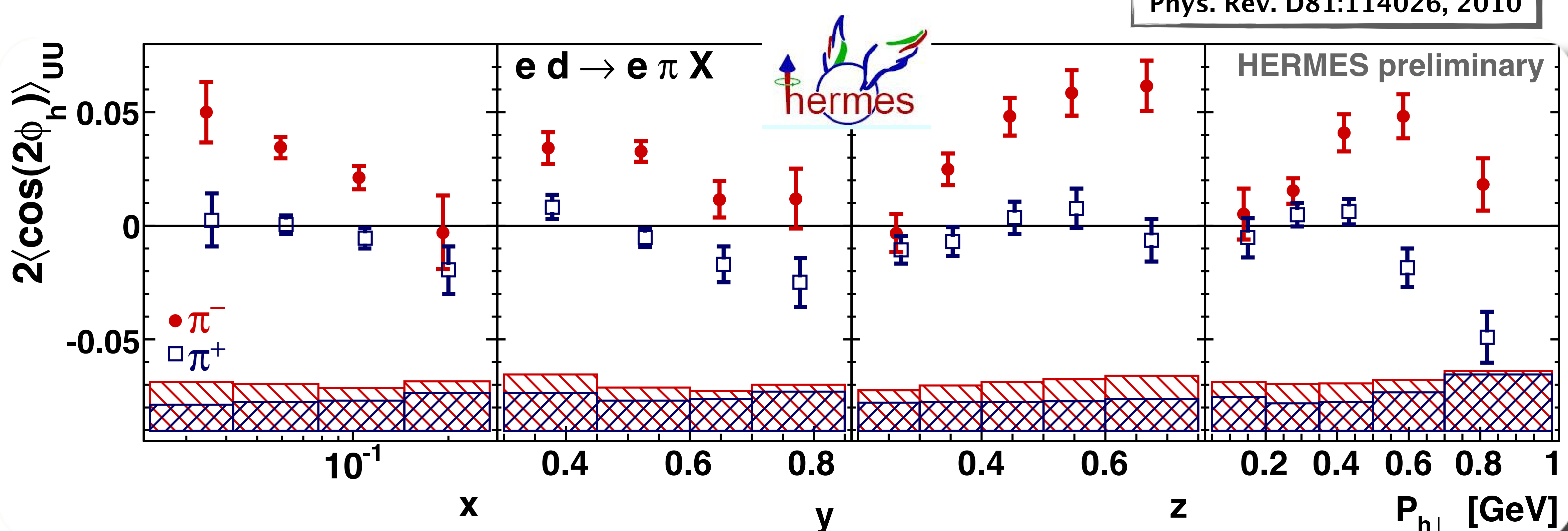
$$\propto C[-h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots]$$

Boer-Mulders   Cahn

pions



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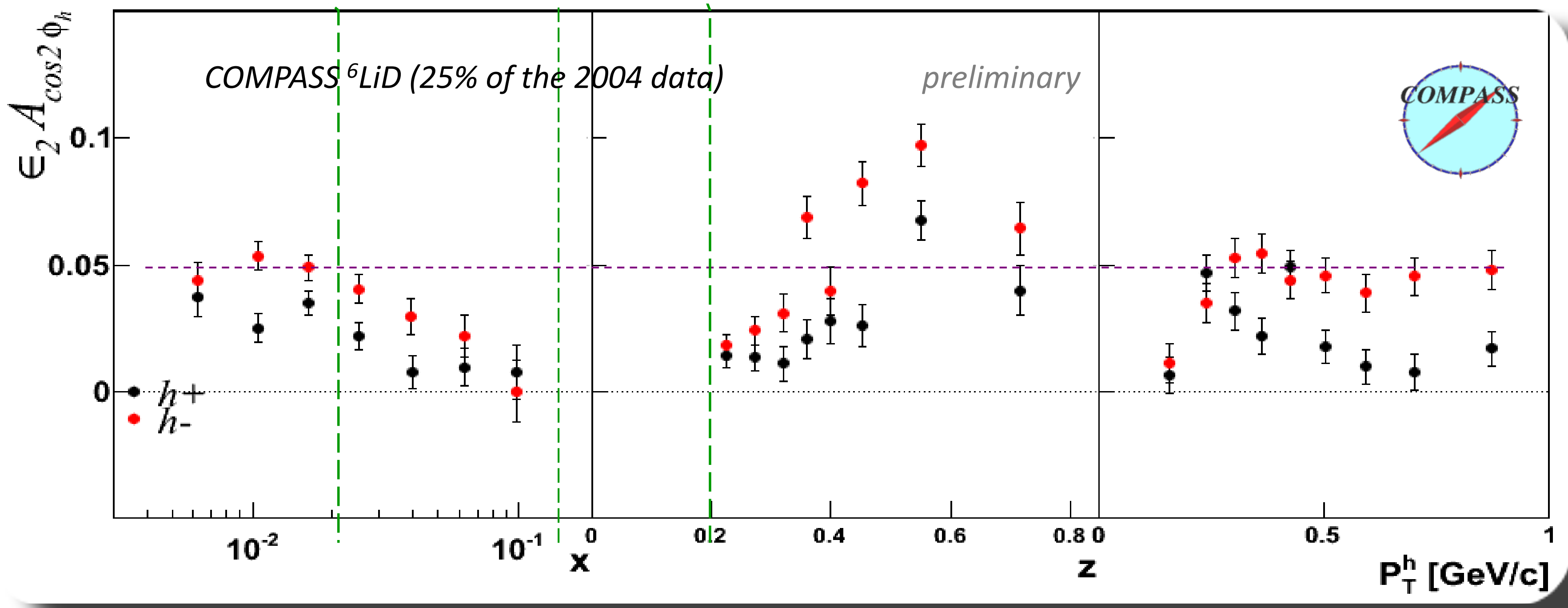
hadrons



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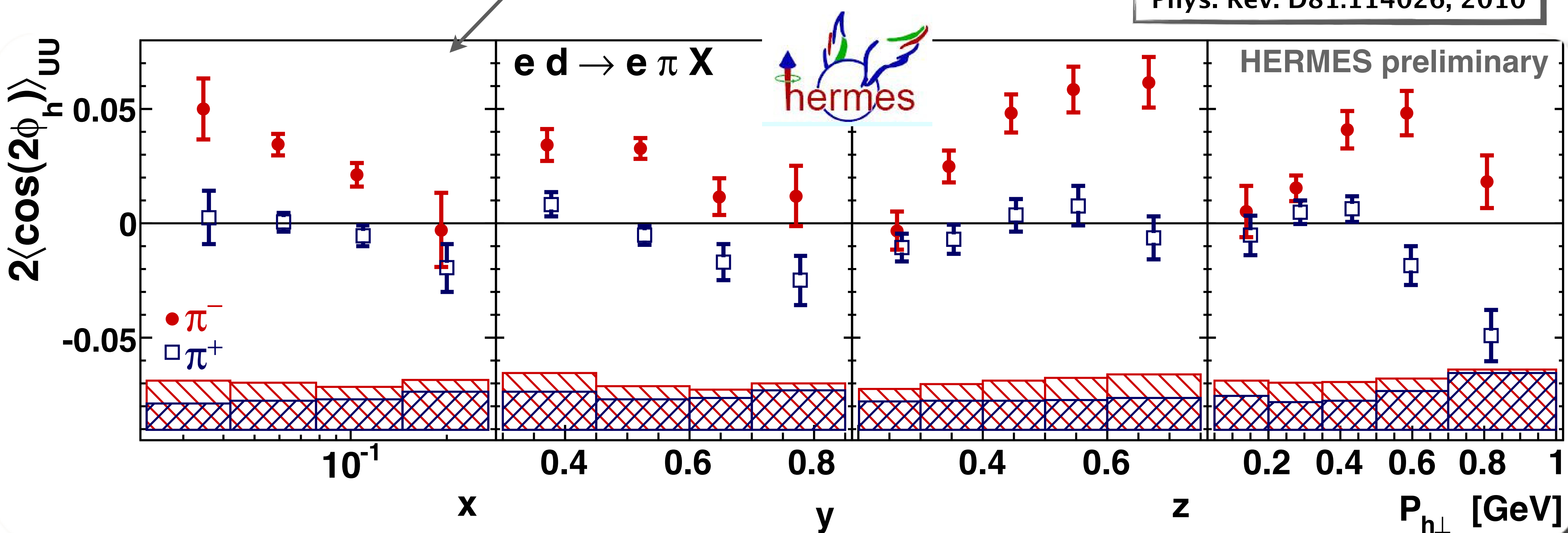
$$\propto C[-h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots]$$

Cahn

Boer-Mulders dominates

pions



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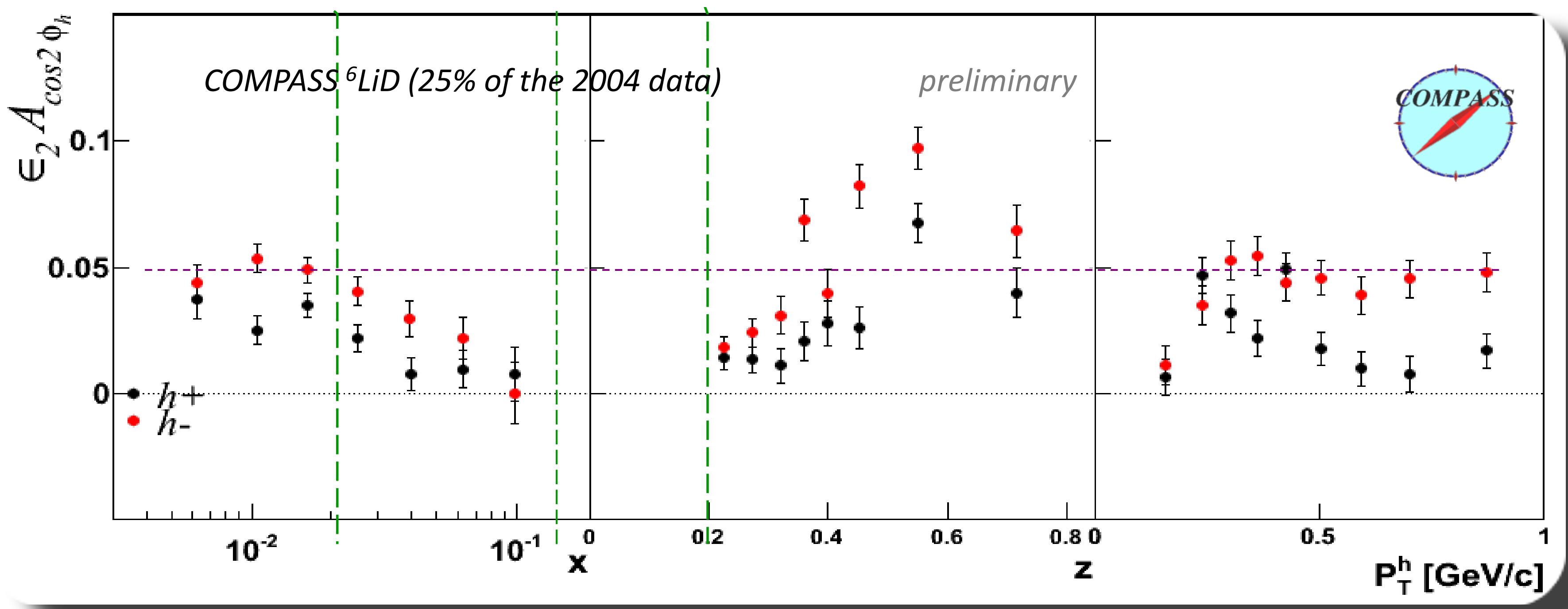

hadrons

dominates

Cahn

$$\propto C\left[-h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots\right]$$

Boer-Mulders
dominates

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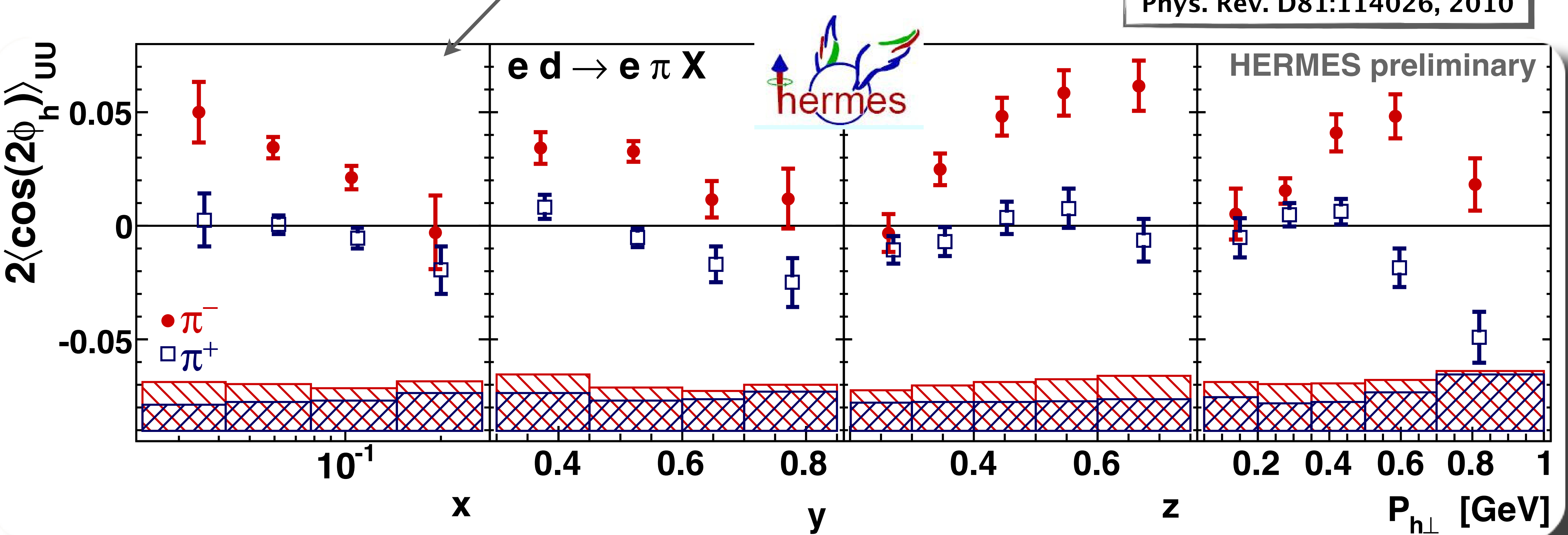
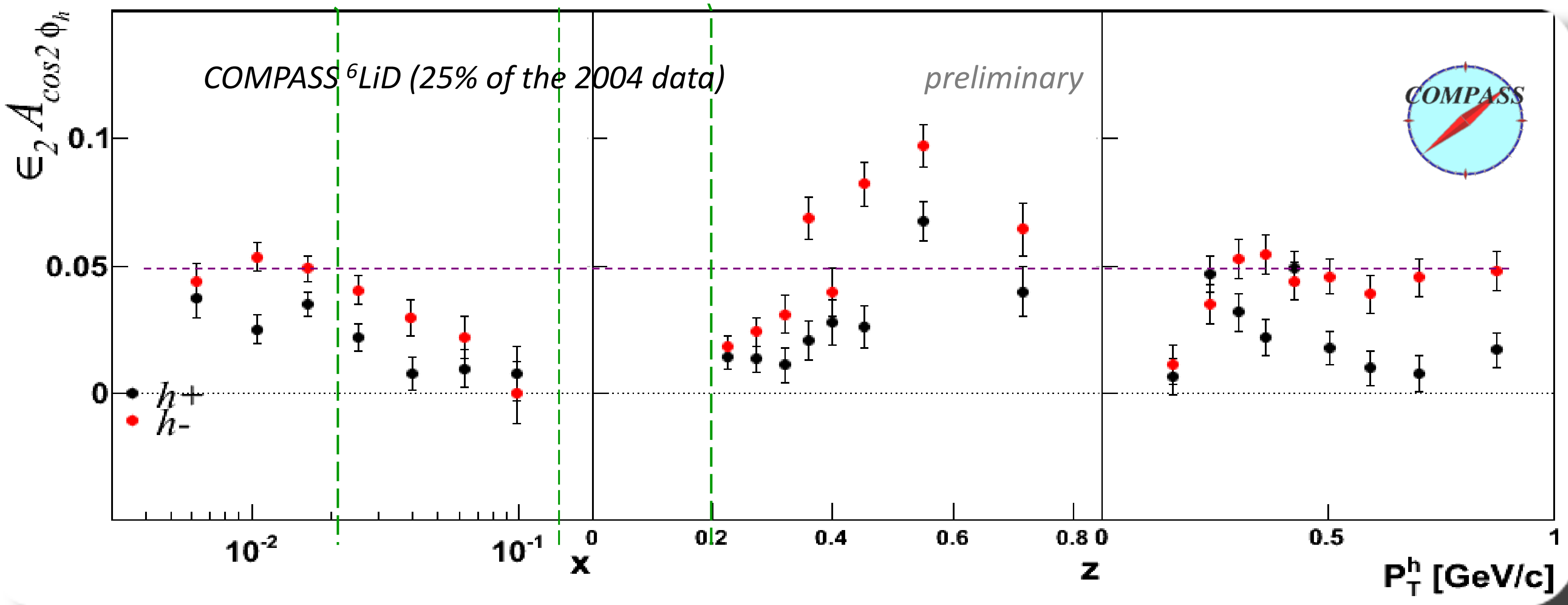
Phys. Rev. D81:114026, 2010

pions



G. Sbrizzai, Spin2010 conference

hadrons



dominates

Cahn

Gamberg, Goldstein
Phys. Rev. D77:094016, 2008

Zhang et al
Phys. Rev. D78:034035, 2008

Barone et al
Phys. Rev. D78:045022, 2008

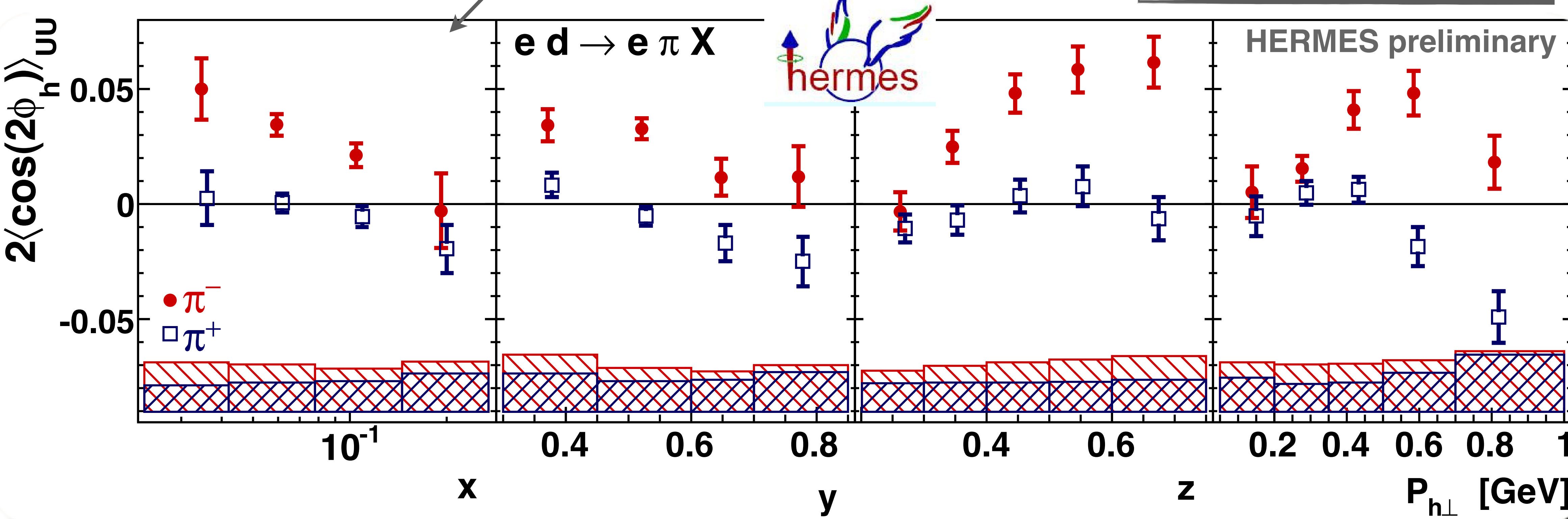
Barone, Melis, Prokudin
Phys. Rev. D81:114026, 2010

hermes $\langle \kappa_T \rangle$ < COMPASS $\langle \kappa_T \rangle$

$$\propto C\left[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots\right]$$

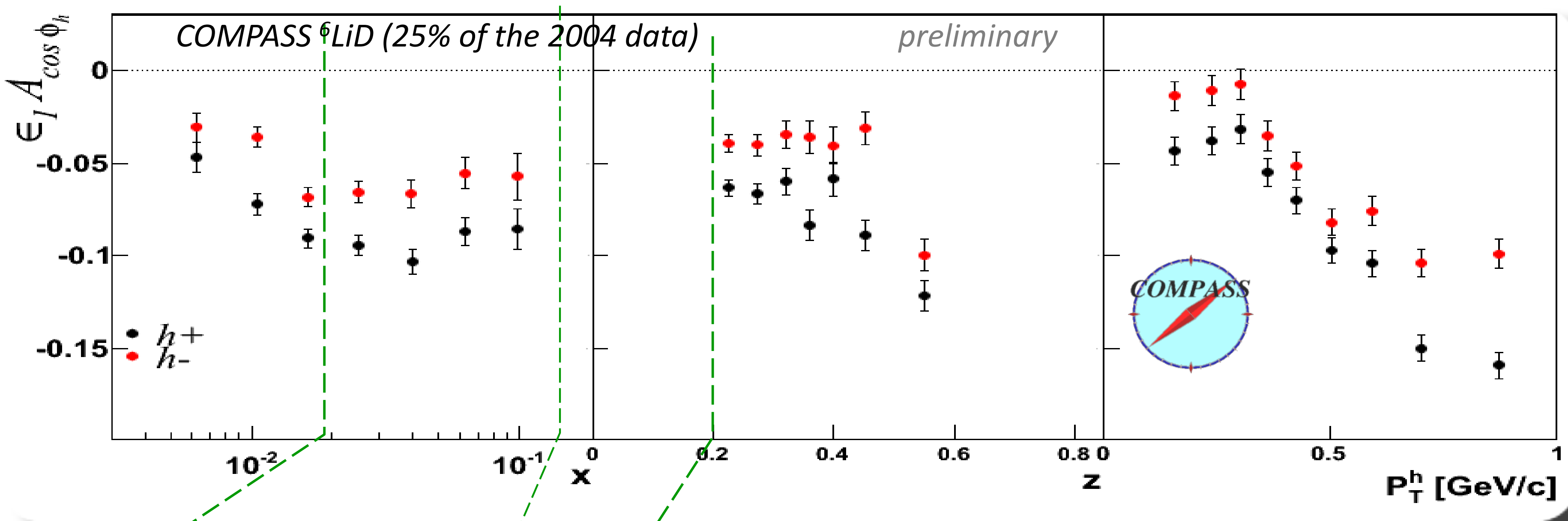
Boer-Mulders
dominates

pions

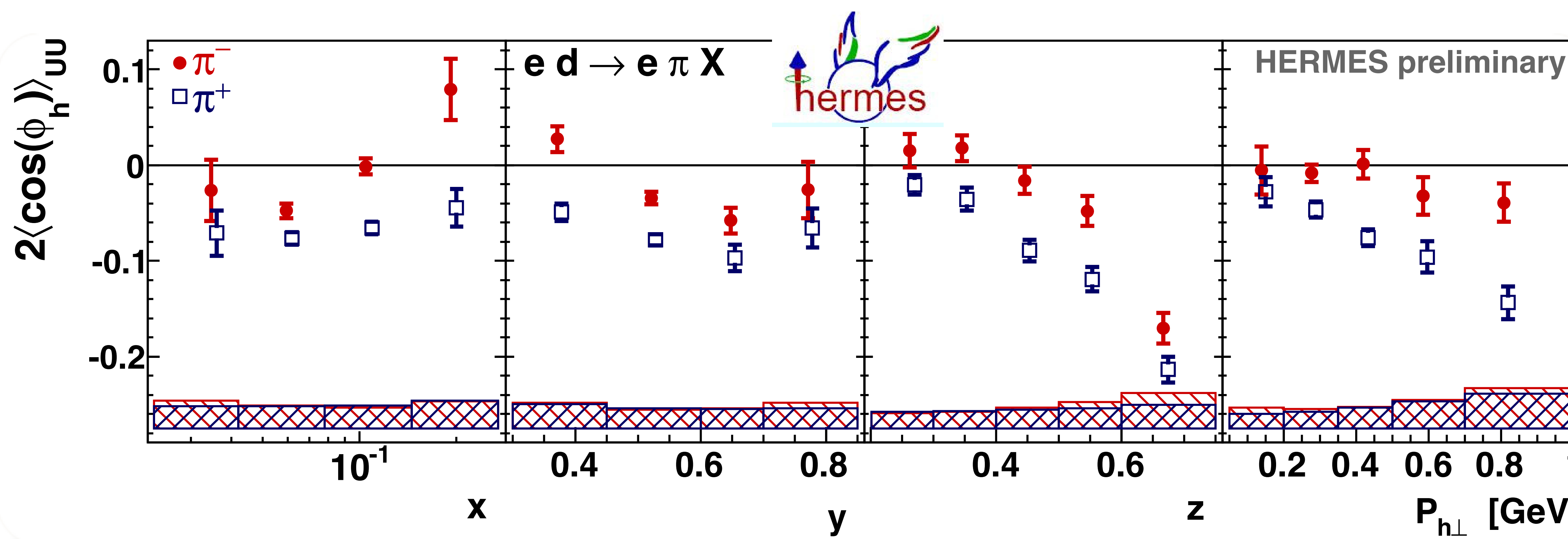


G. Sbrizzai, Spin2010 conference

hadrons

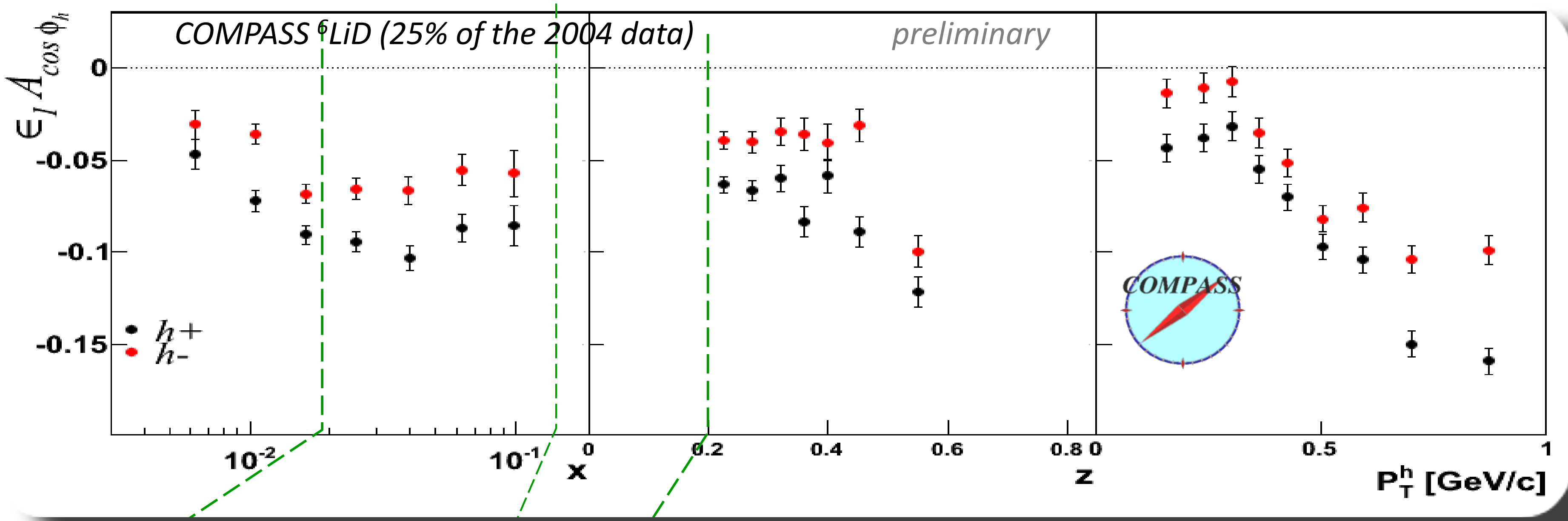


pions



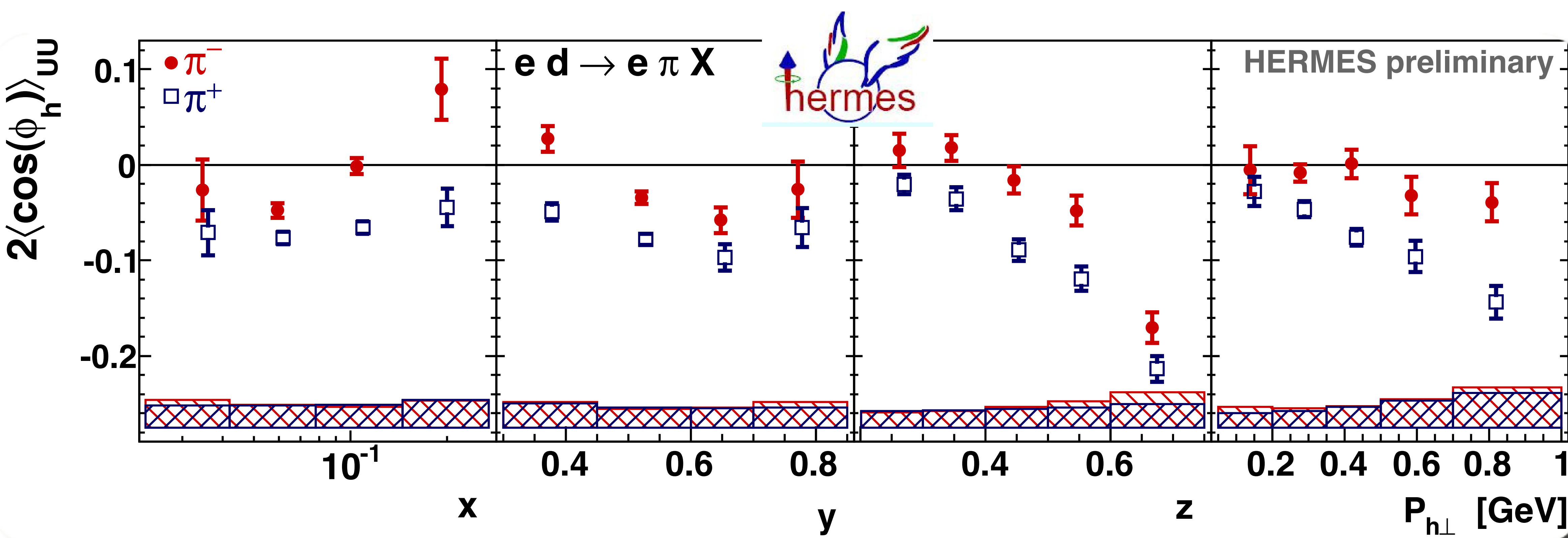
G. Sbrizzai, Spin2010 conference

hadrons



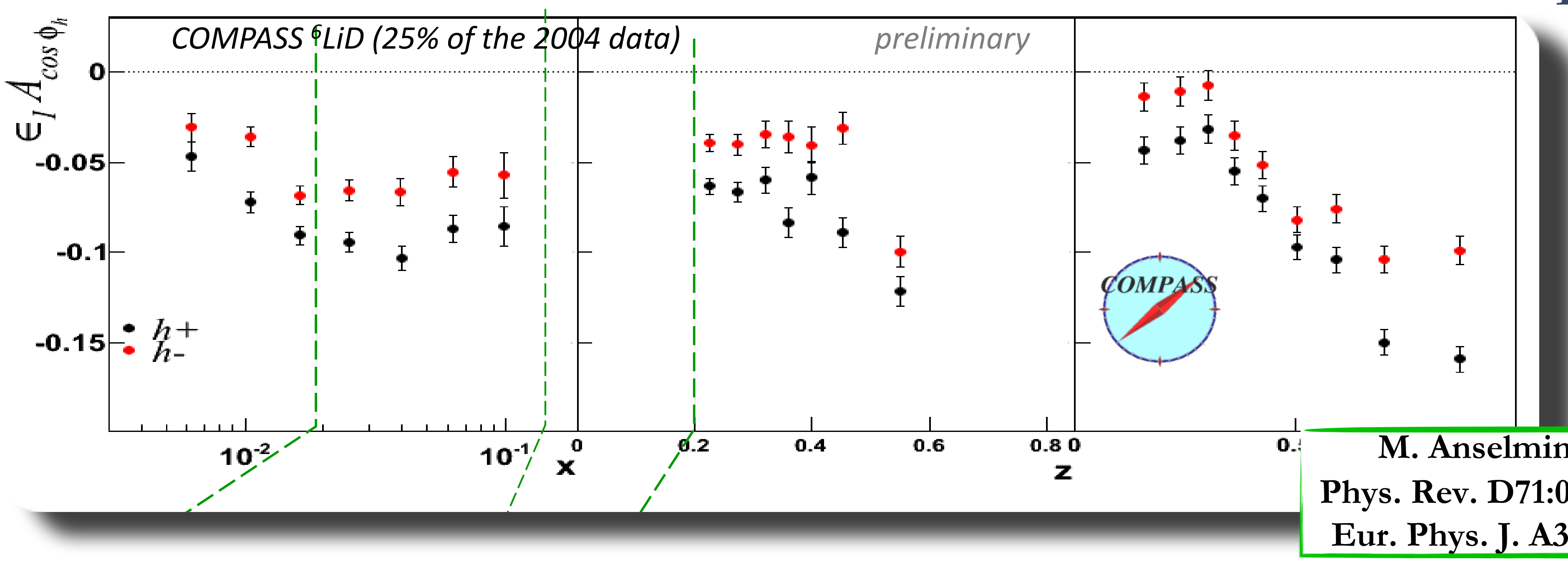
$$\propto \frac{2M}{Q} C[\underbrace{-h_1^\perp H_1^\perp}_{\text{Boer-Mulders}} - \overbrace{f_1 D_1}^{\text{Cahn}} + ...]$$

pions



G. Sbrizzai, Spin2010 conference

hadrons



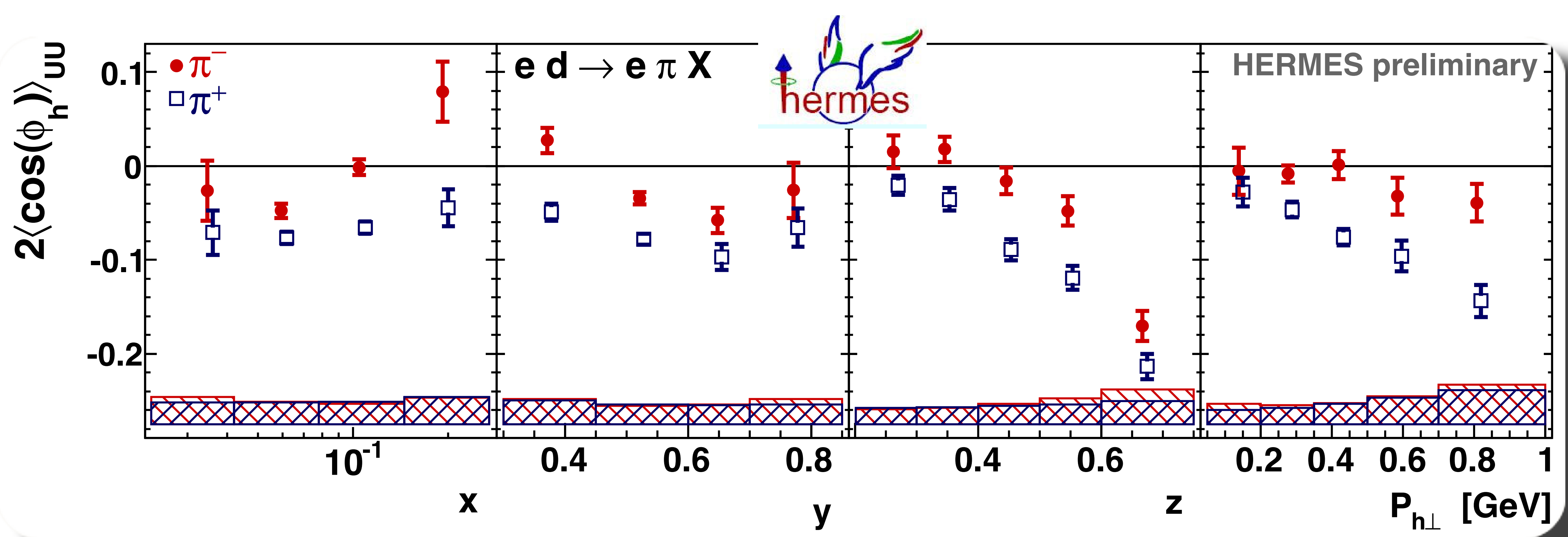
M. Anselmino et al.,
Phys. Rev. D71:074006, 2005
Eur. Phys. J. A31:373, 2007

Cahn

$$\propto \frac{2M}{Q} C[-h_1^\perp H_1^\perp - f_1 D_1 + ...]$$

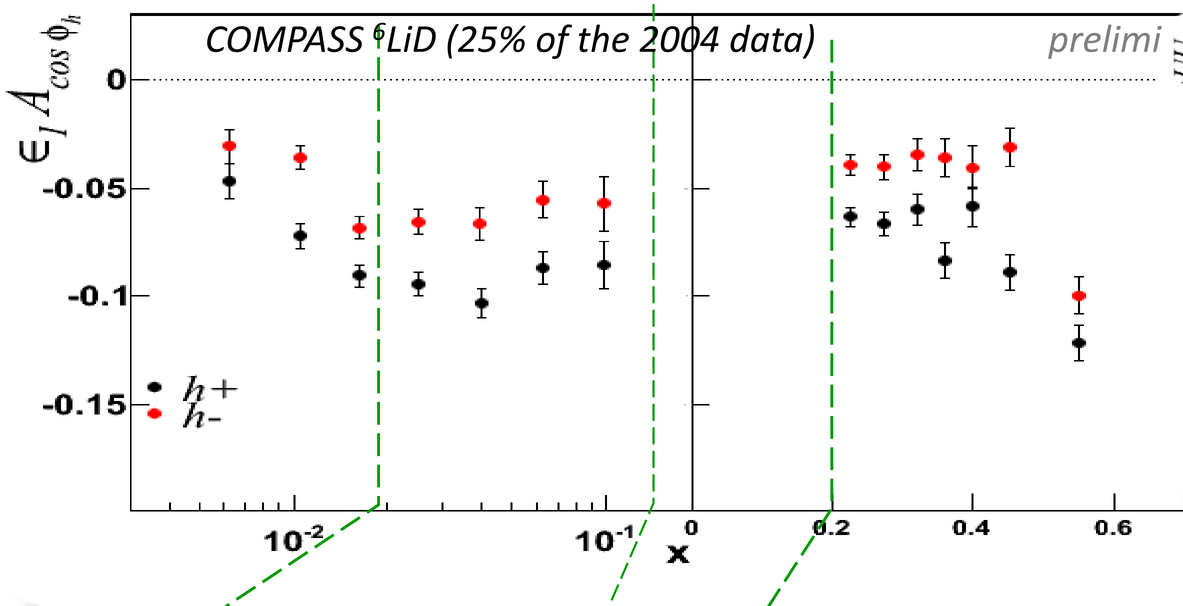
Boer-Mulders

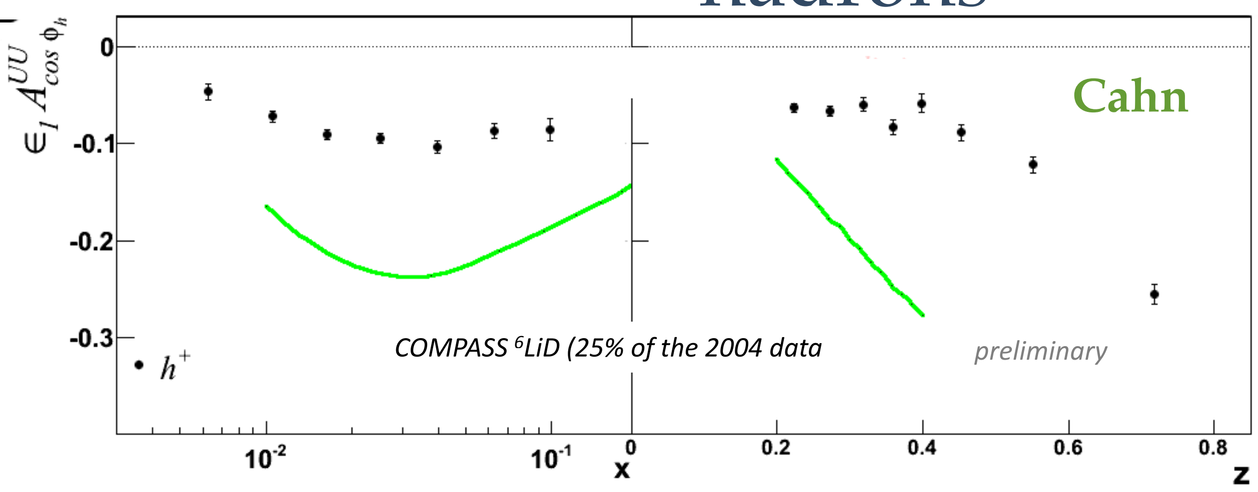
pions



G. Sbrizzai, Spin2010 conference

hadrons



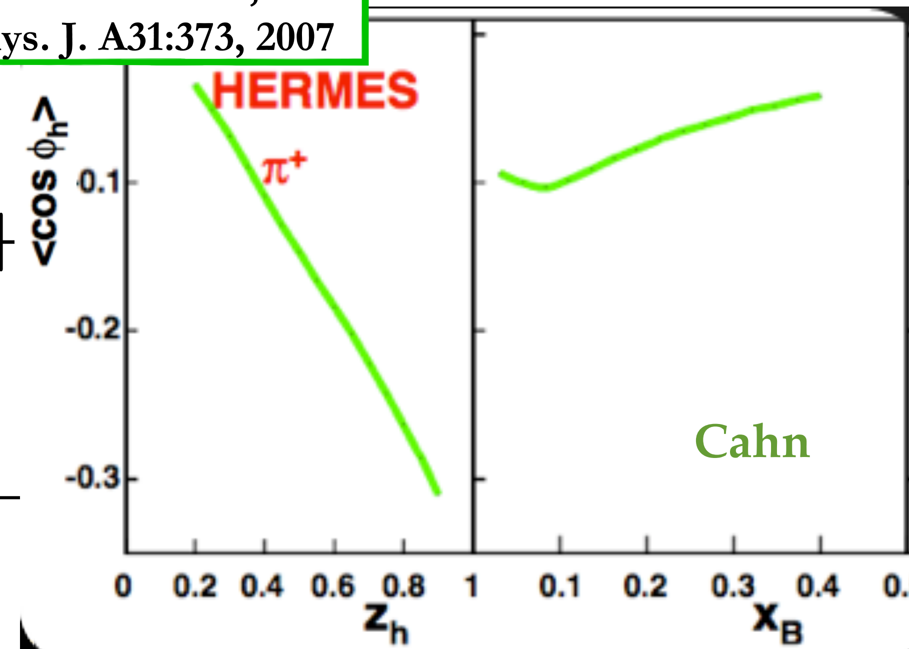


M. Anselmino et al.,
Phys. Rev. D71:074006, 2005
Eur. Phys. J. A31:373, 2007

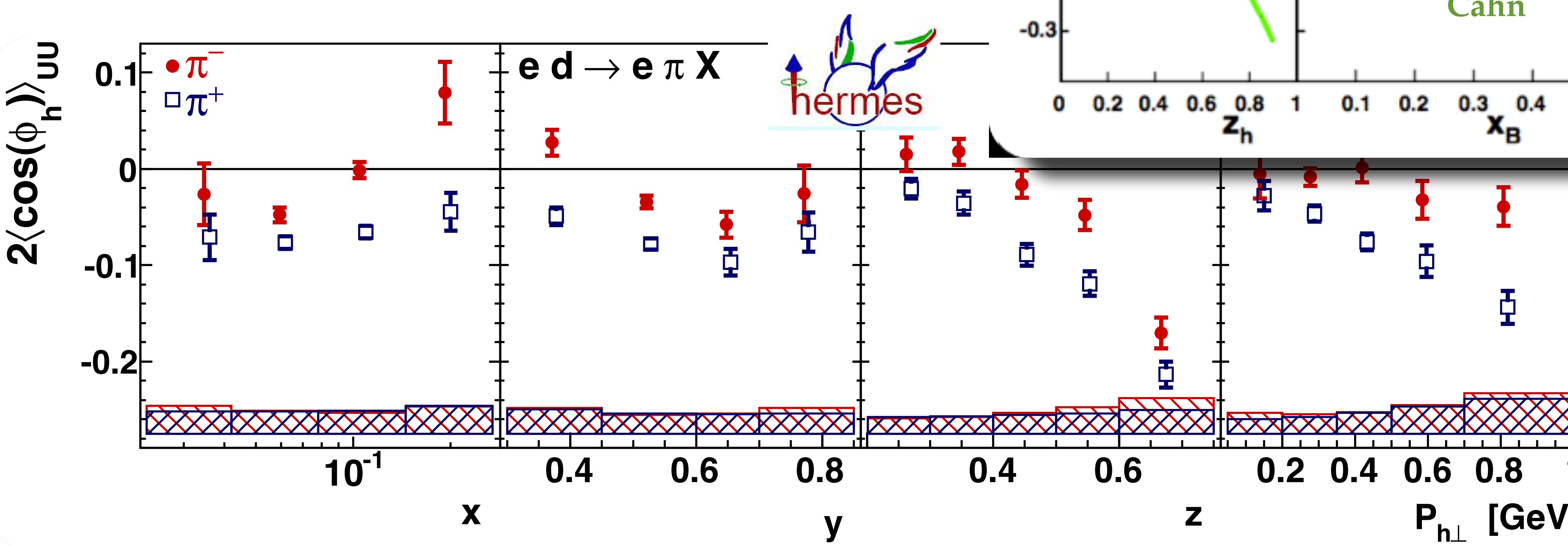
$$\propto \frac{2M}{Q} C[-h_1^{\perp} H_1^{\perp} - f_1 D_1 +$$

Cahn

Boer-Mulders

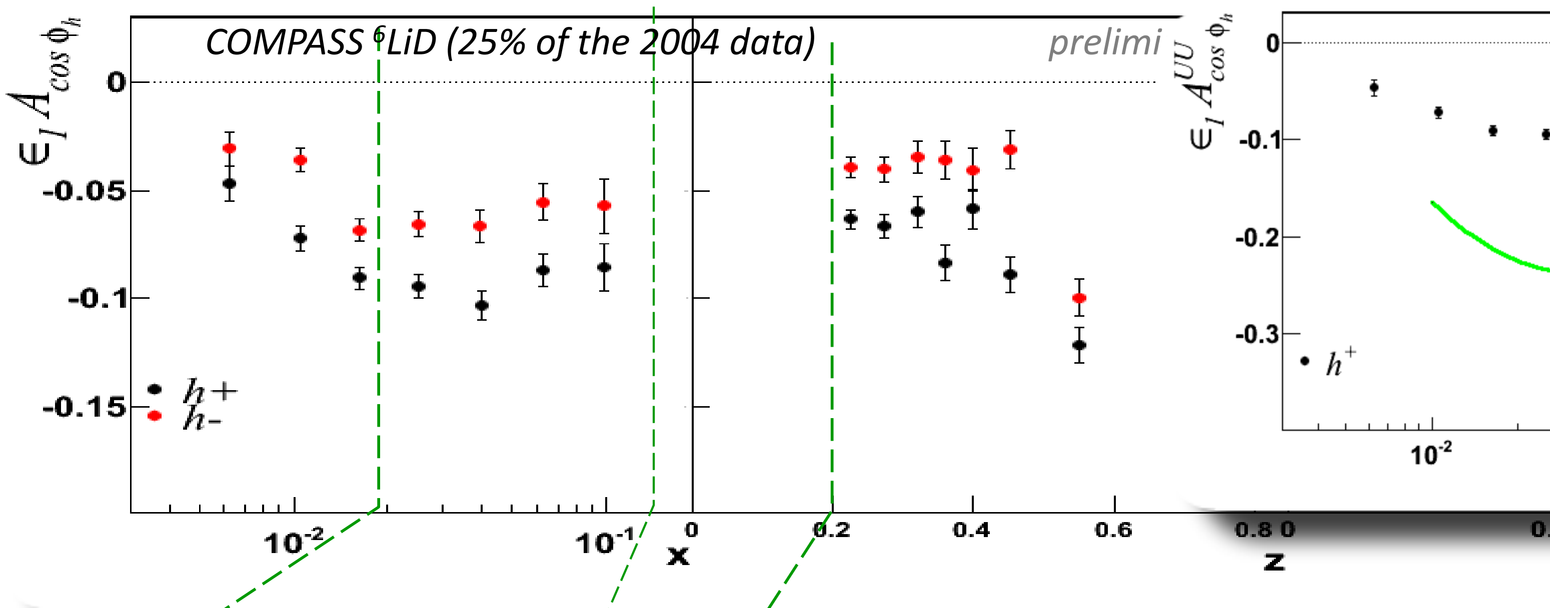


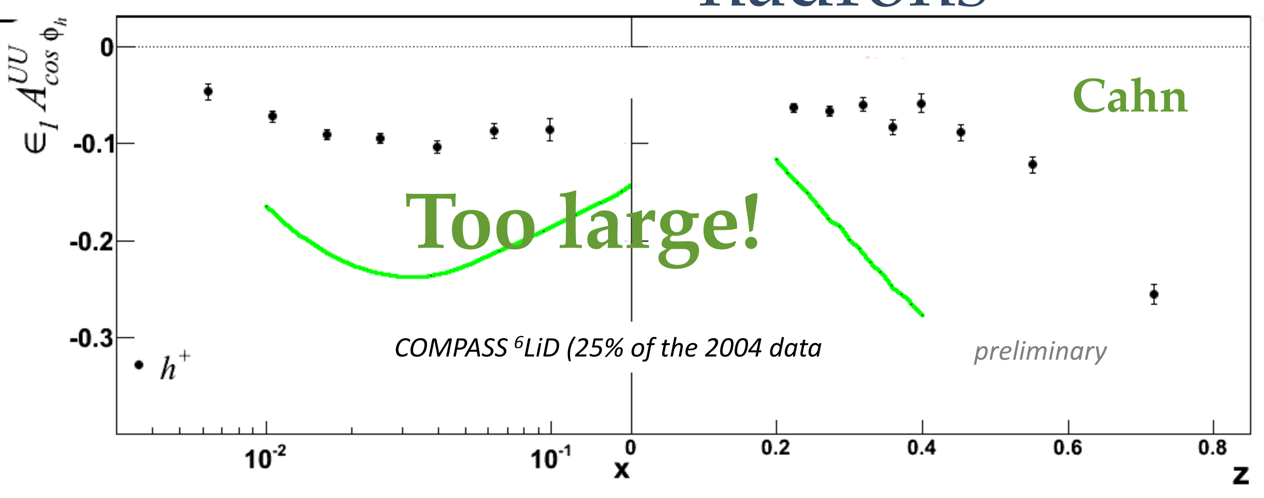
pions



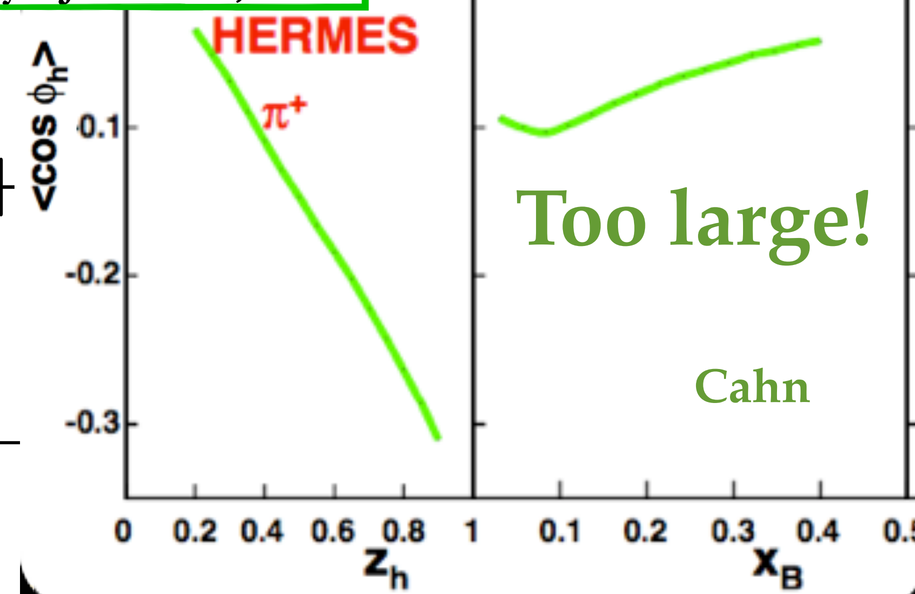
G. Sbrizzai, Spin2010 conference

hadrons





M. Anselmino et al.,
Phys. Rev. D71:074006, 2005
Eur. Phys. J. A31:373, 2007

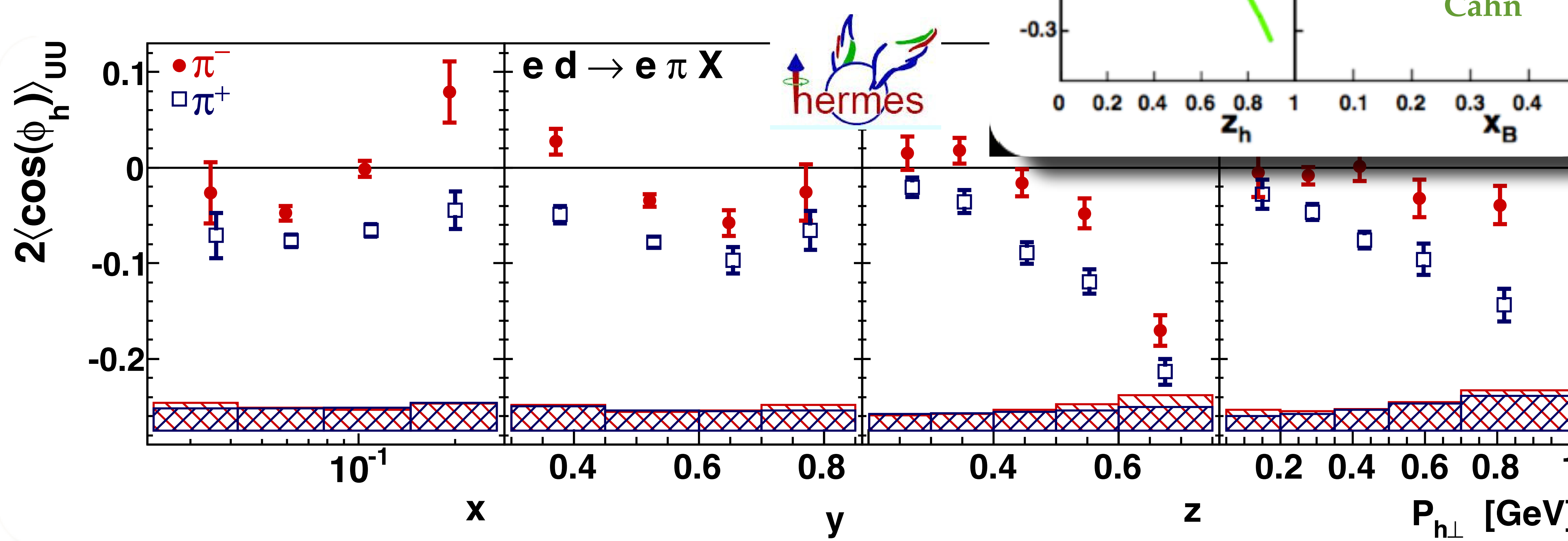


$$\propto \frac{2M}{Q} C[-h_1^{\perp} H_1^{\perp} - f_1 D_1 +$$

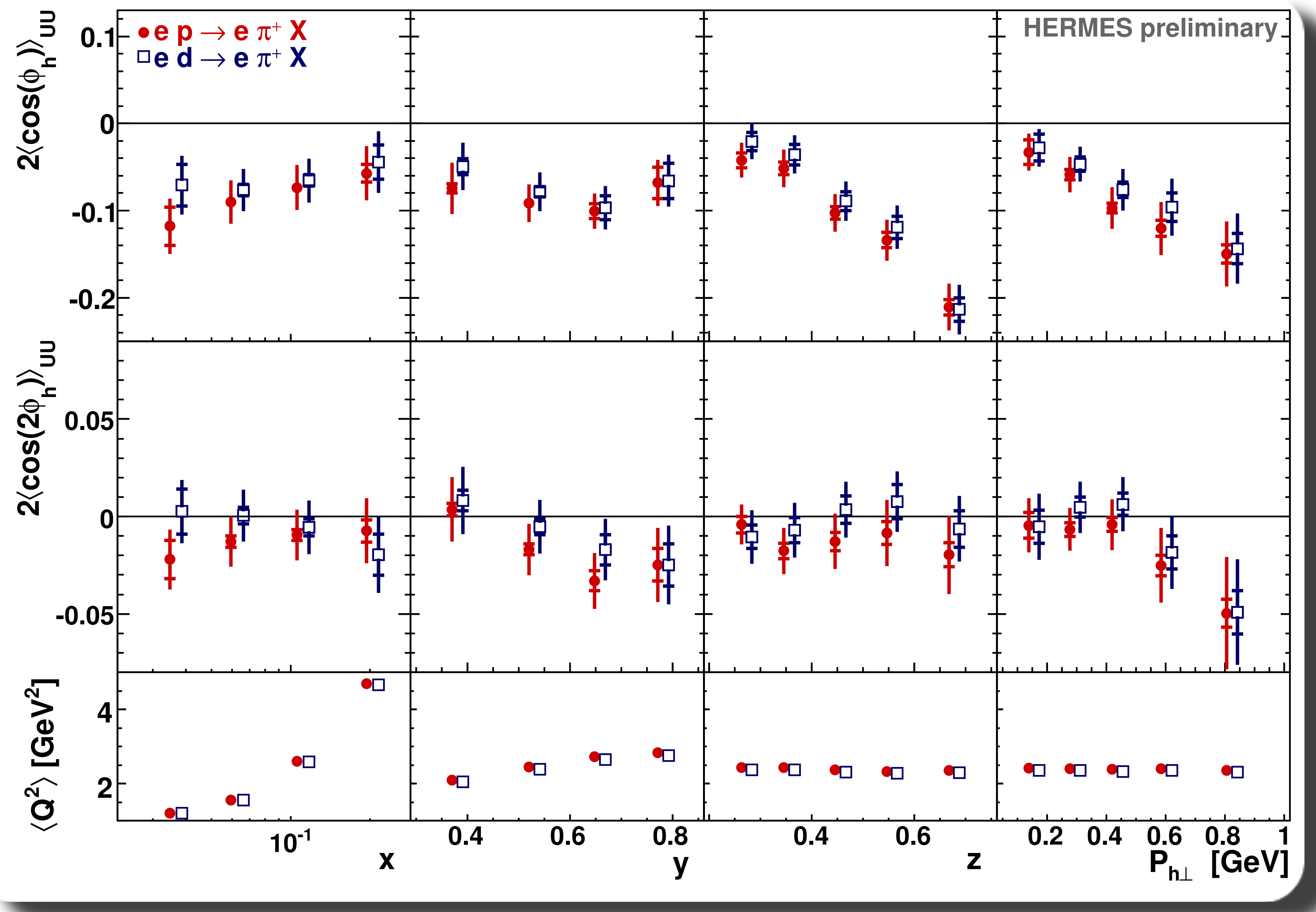
Cahn

Boer-Mulders

pions

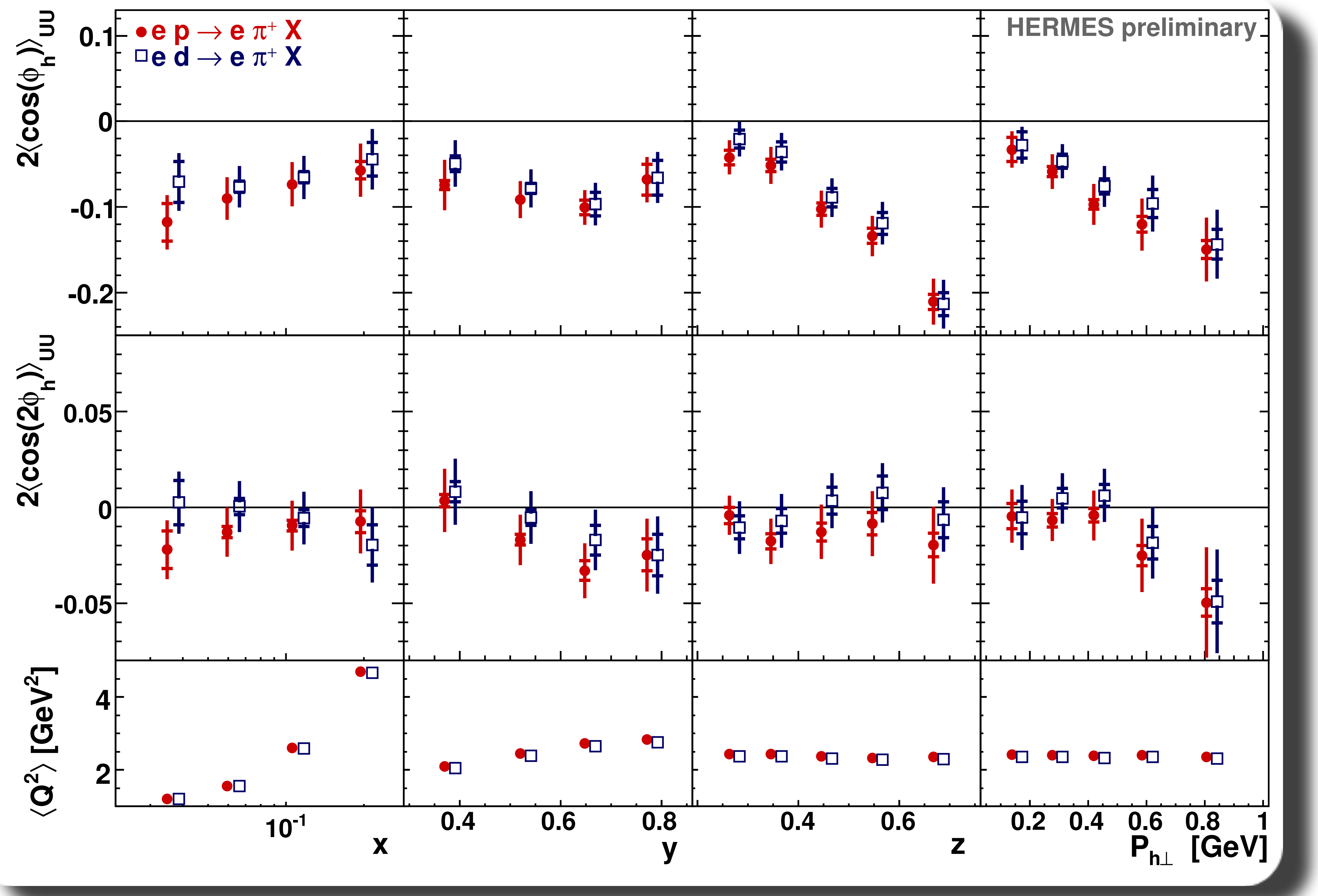


π^+



HERMES Results: Hydrogen vs. Deuterium

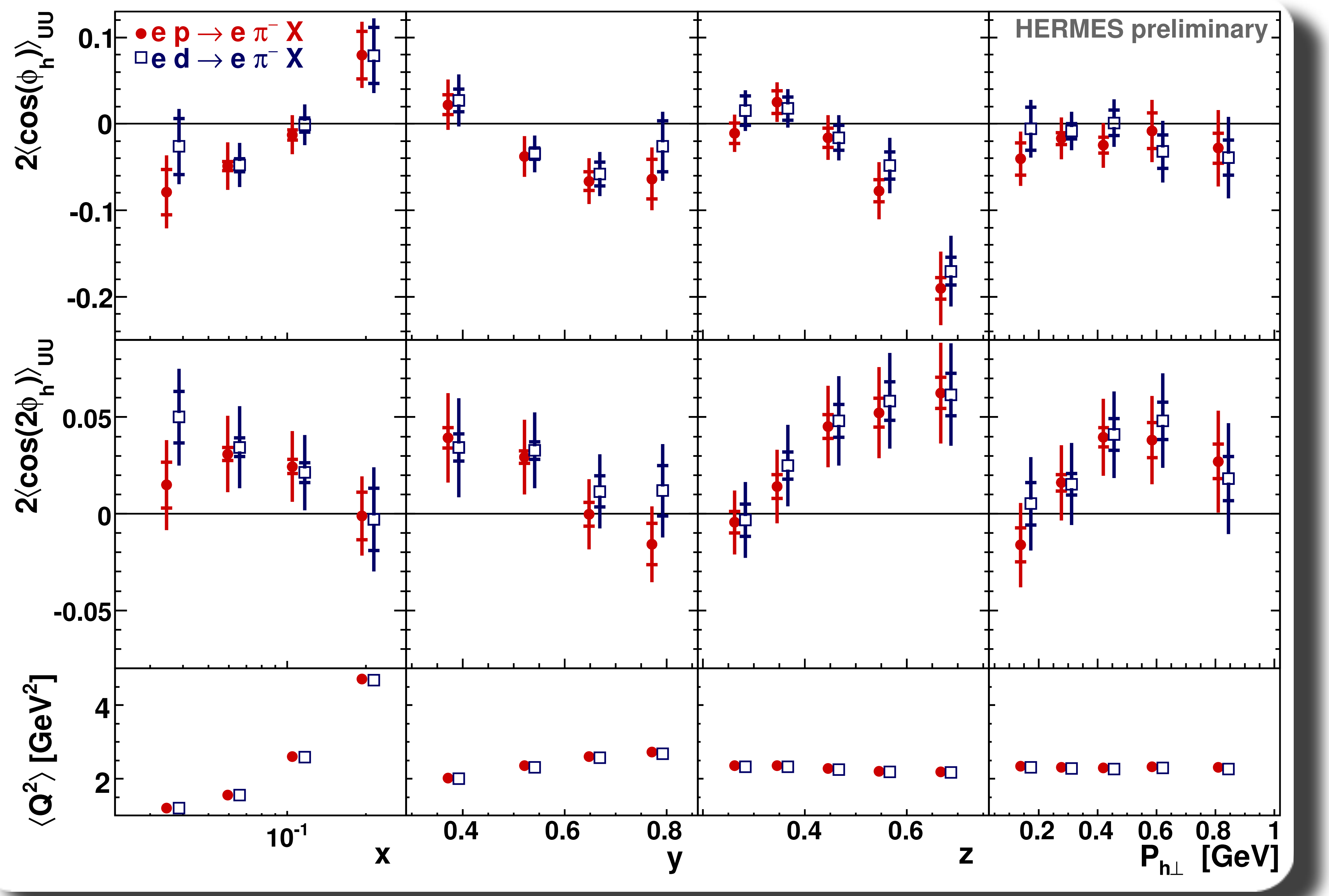
π^+



$$h_1^{\perp,u} \approx h_1^{\perp,d}$$

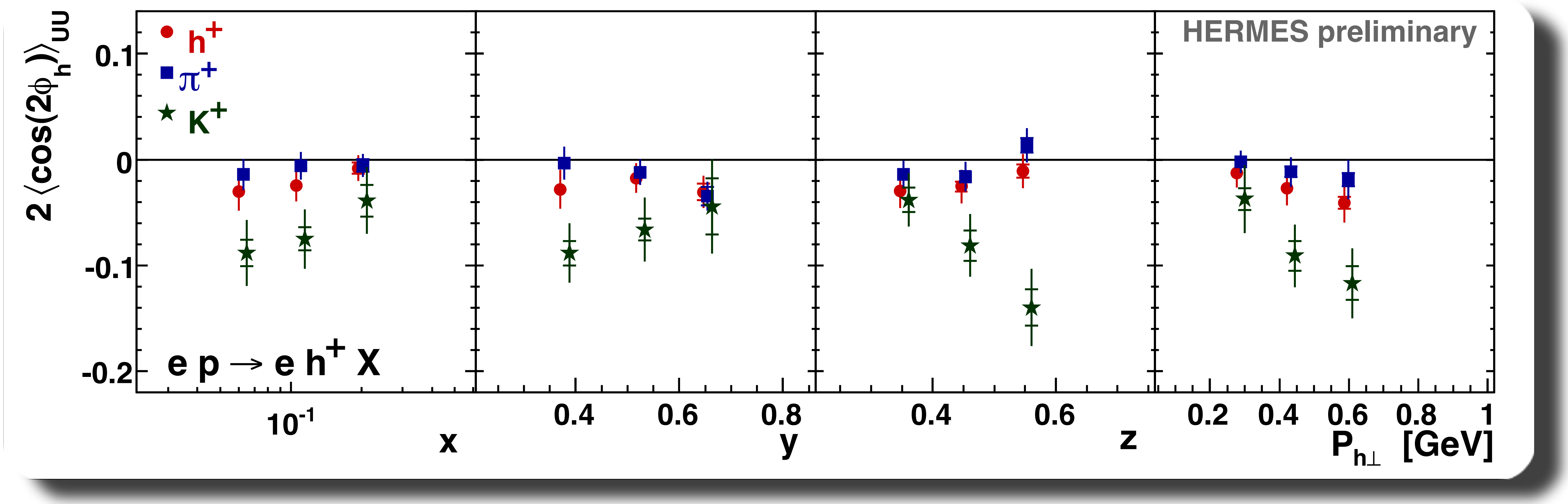
HERMES Results: Hydrogen vs. Deuterium

π^-

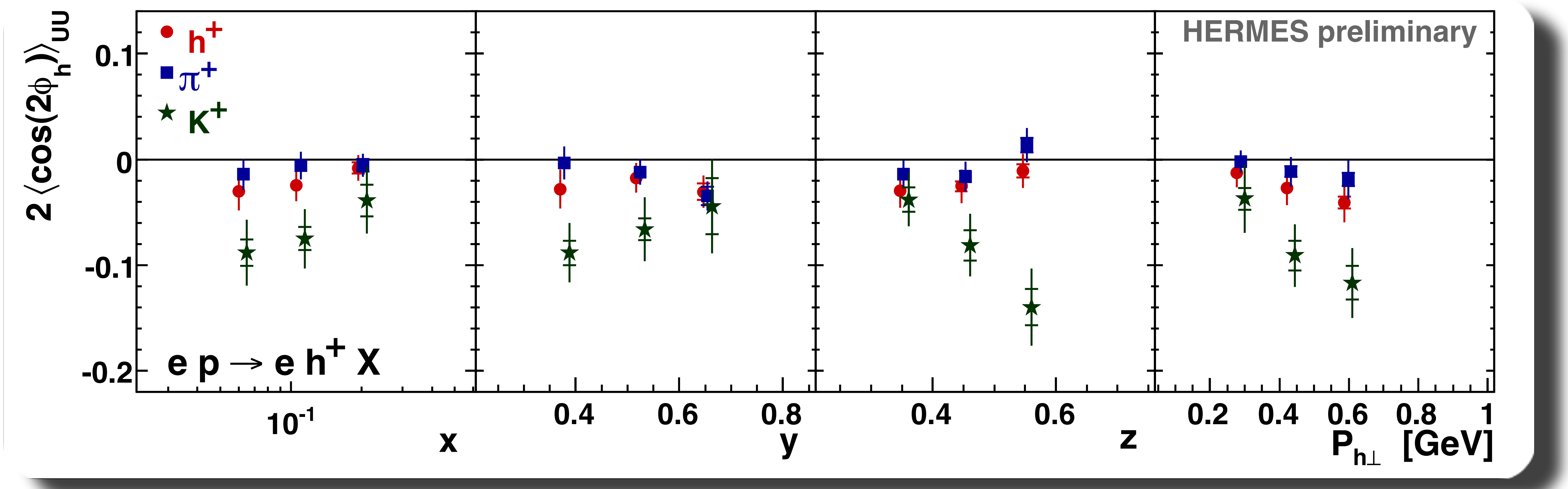


$$h_1^{\perp,u} \approx h_1^{\perp,d}$$

HERMES Results: Hydrogen vs. Deuterium



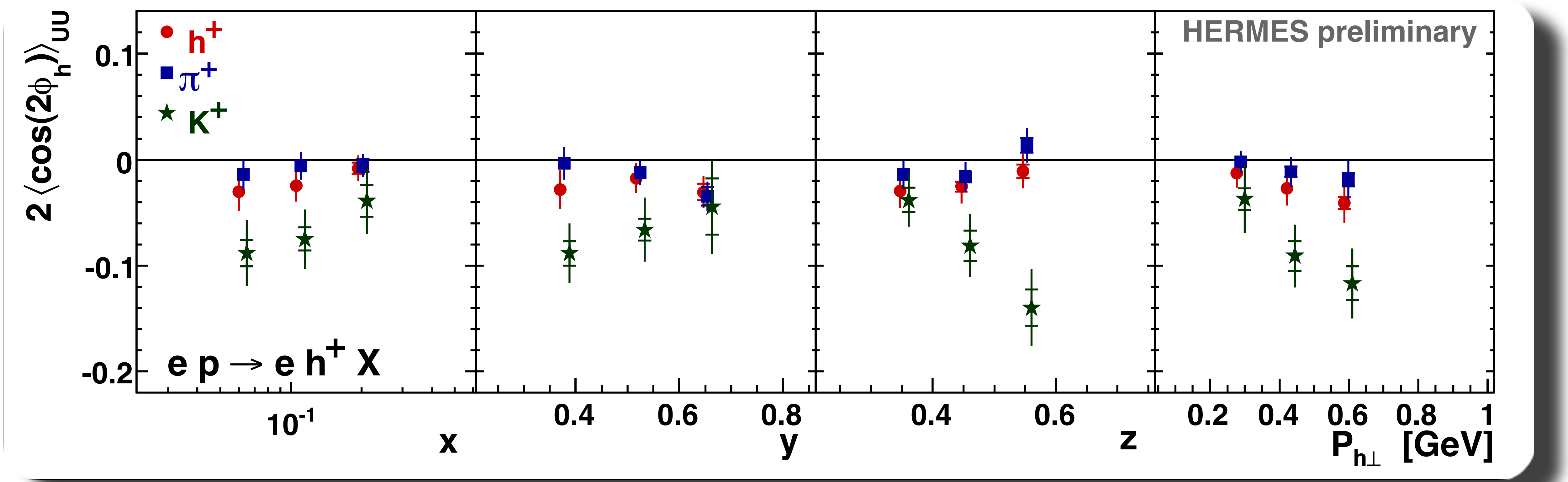
HERMES Results: Kaons, Hydrogen



$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots.]$$

Boer-Mulders — Cahn

HERMES Results: Kaons, Hydrogen

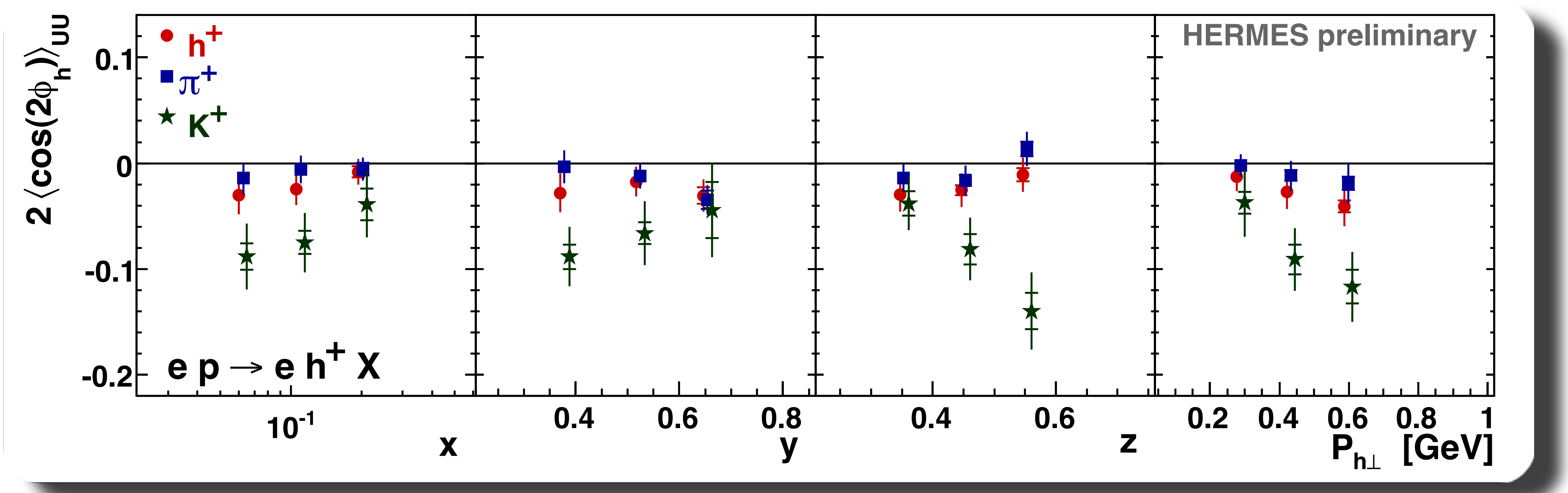


$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Boer-Mulders

Cahn

HERMES Results: Kaons, Hydrogen



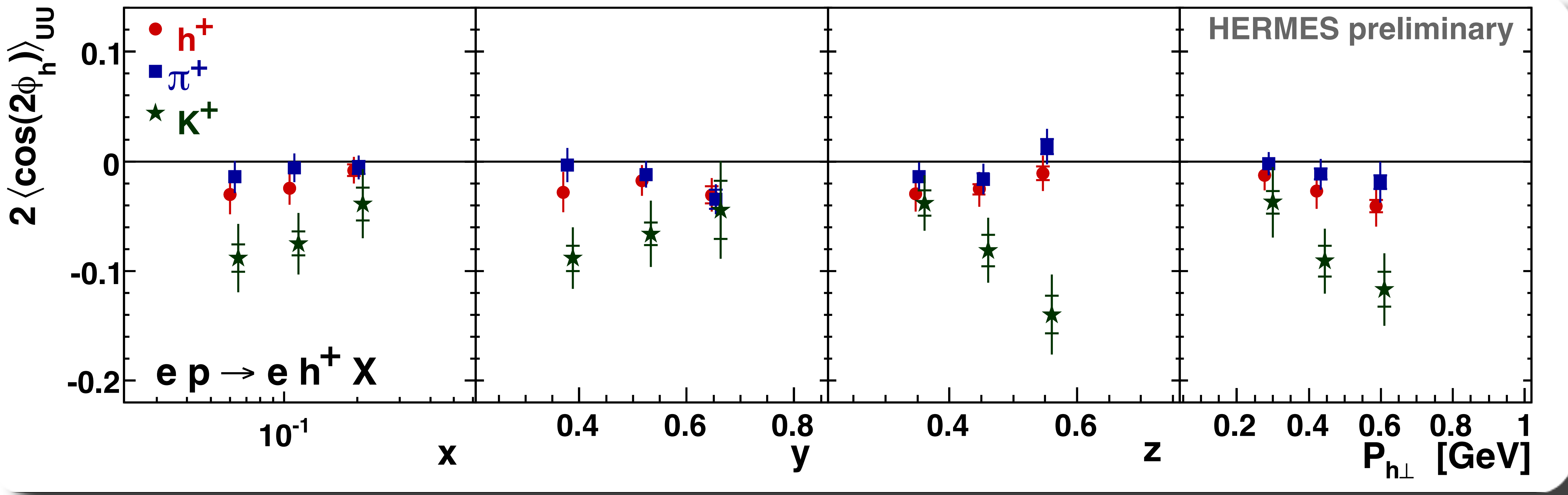
$$\propto C[-h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Boer-Mulders — Cahn

$$u - dominance$$

$$K^+\{u\bar{s}\} \qquad \pi^+\{u\bar{d}\}$$

HERMES Results: Kaons, Hydrogen



$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots]$$

Boer-Mulders   Cahn

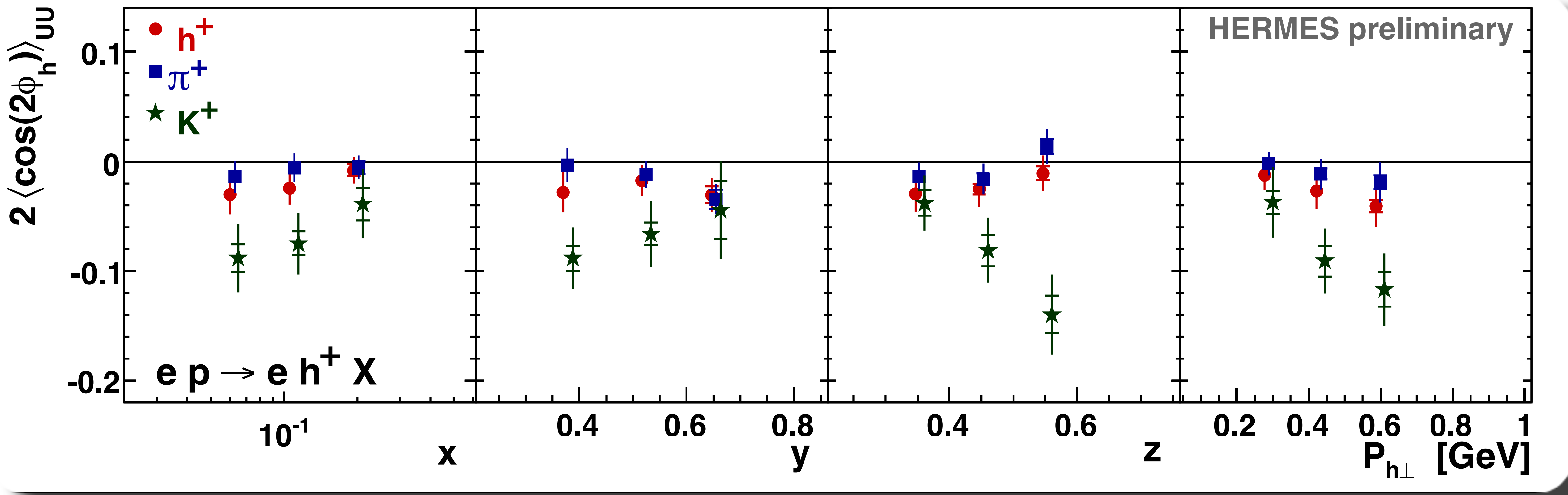
$u - dominance$

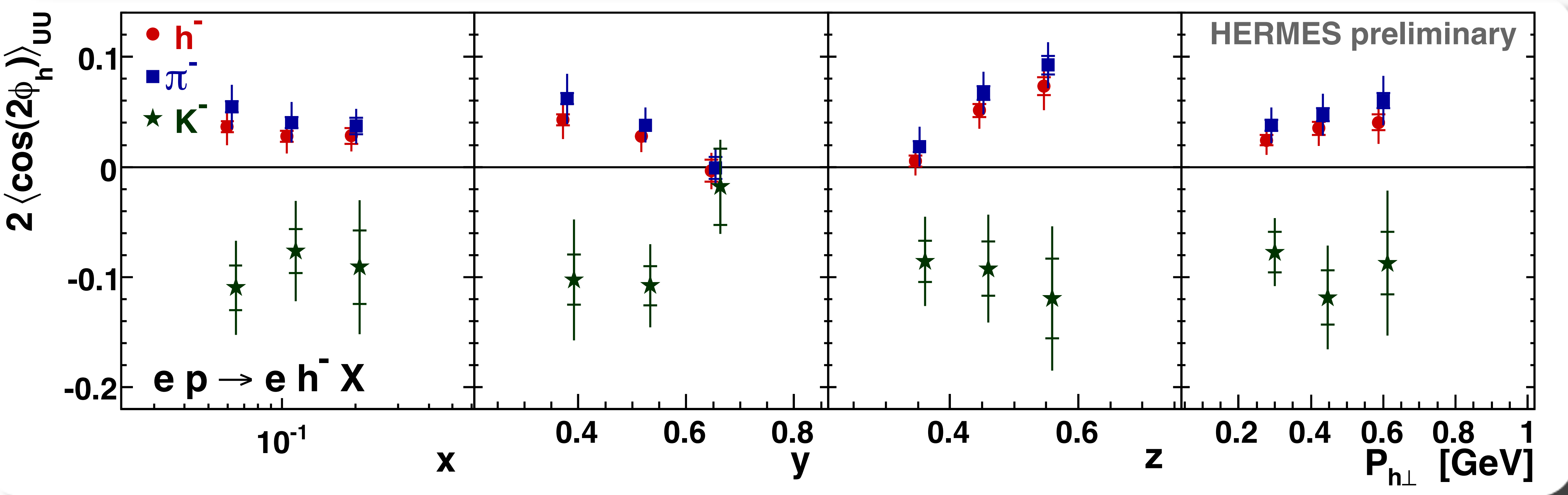
$K^{+}\{u\bar{s}\}$ $\pi^{+}\{u\bar{d}\}$

$$H_1^{\perp, u\to K^{+}} \overset{?}{>} H_1^{\perp, u\to \pi^{+}}$$

HERMES Results: Kaons, Hydrogen

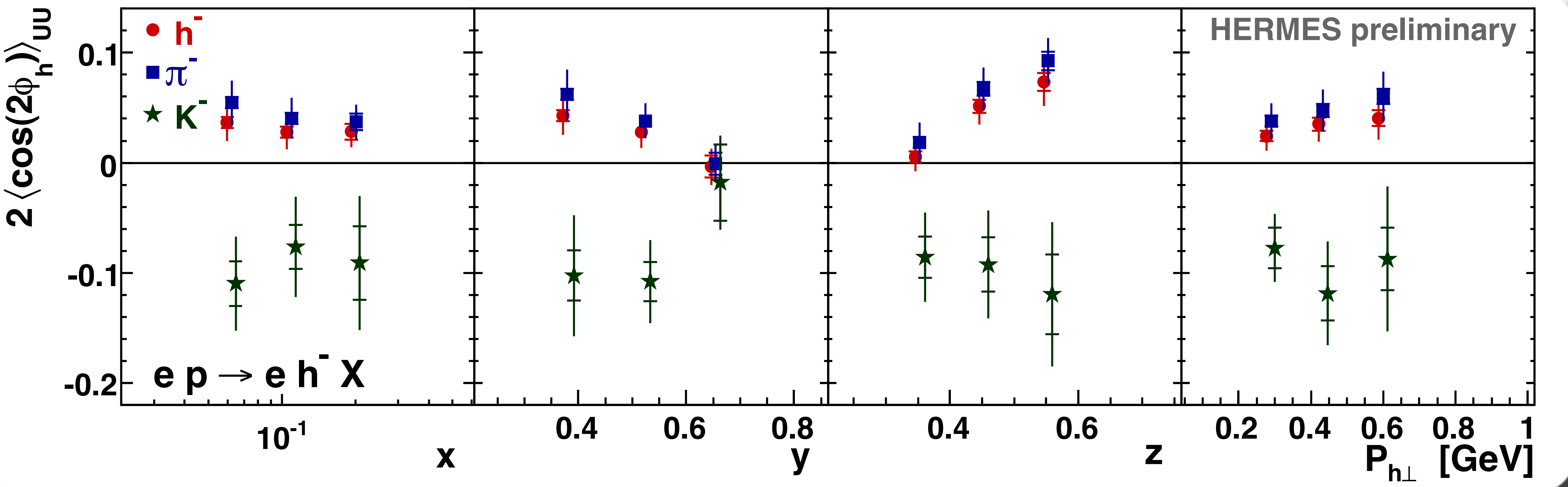
hermes





HERMES Results: Kaons, Hydrogen

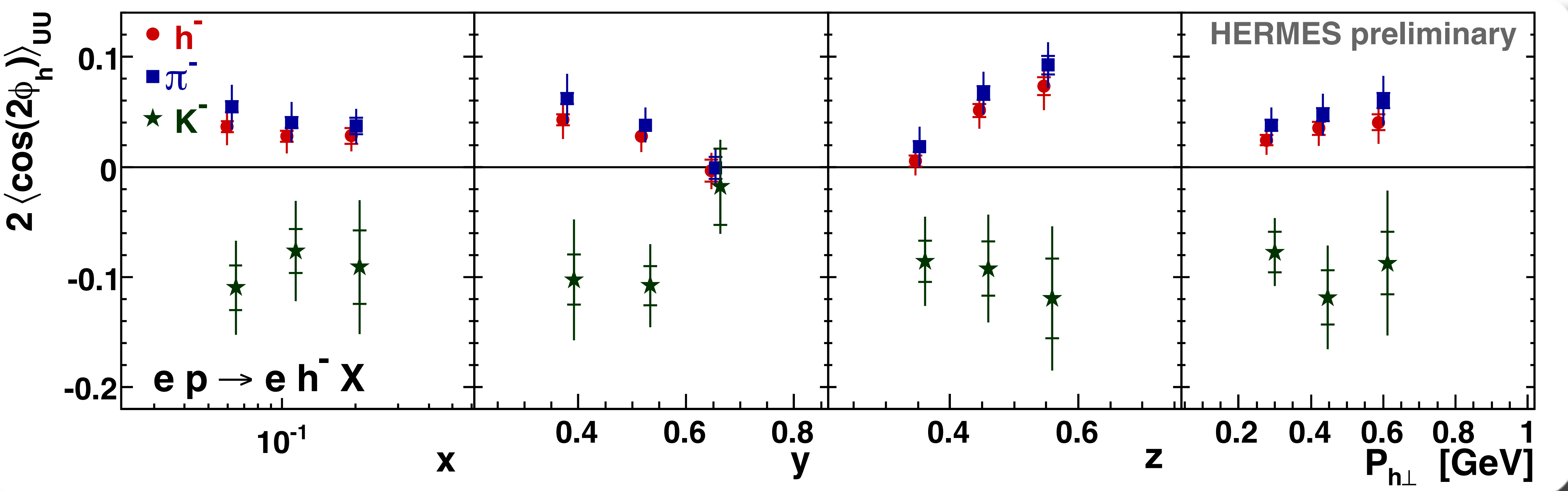
$$\propto C[\underbrace{-h_1^\perp H_1^\perp}_{\text{Boer-Mulders}} + \overbrace{\frac{\kappa_T^2}{Q^2} f_1 D_1}^{\text{Cahn}} + ...]$$



HERMES Results: Kaons, Hydrogen

$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Boer-Mulders — Cahn

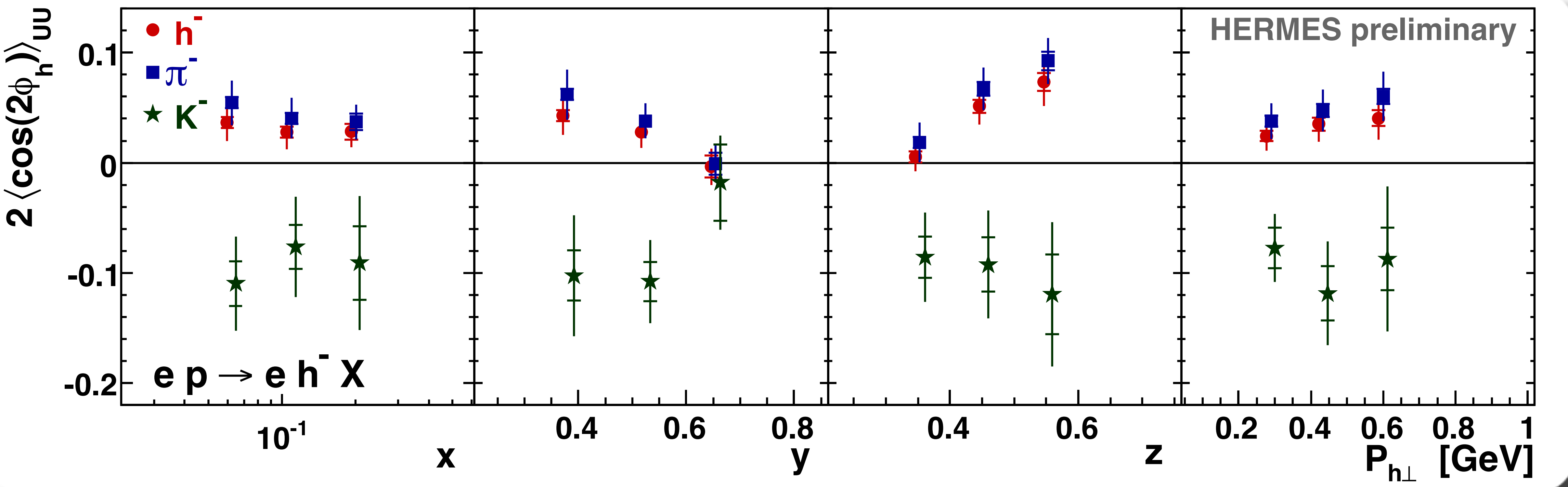


HERMES Results: Kaons, Hydrogen

$$\propto C[-h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Boer-Mulders   Cahn

$u - dominance$



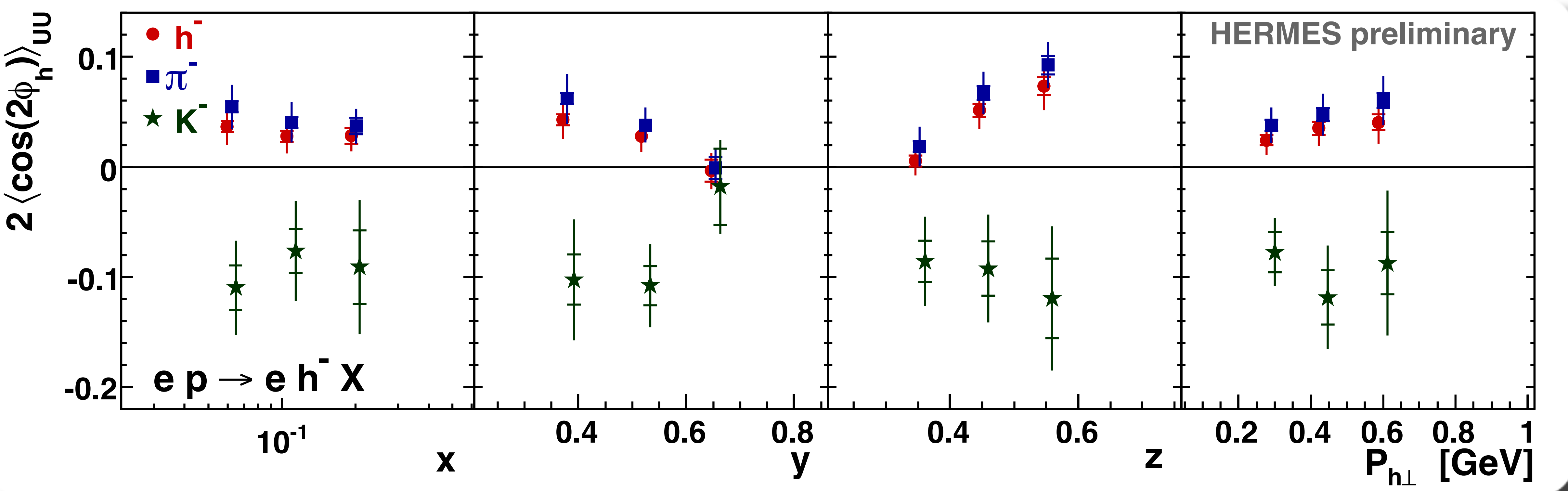
HERMES Results: Kaons, Hydrogen

$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Boer-Mulders   Cahn

$u - dominance$

$K^-\{s\bar{u}\}$ $K^+\{u\bar{s}\}$



HERMES Results: Kaons, Hydrogen

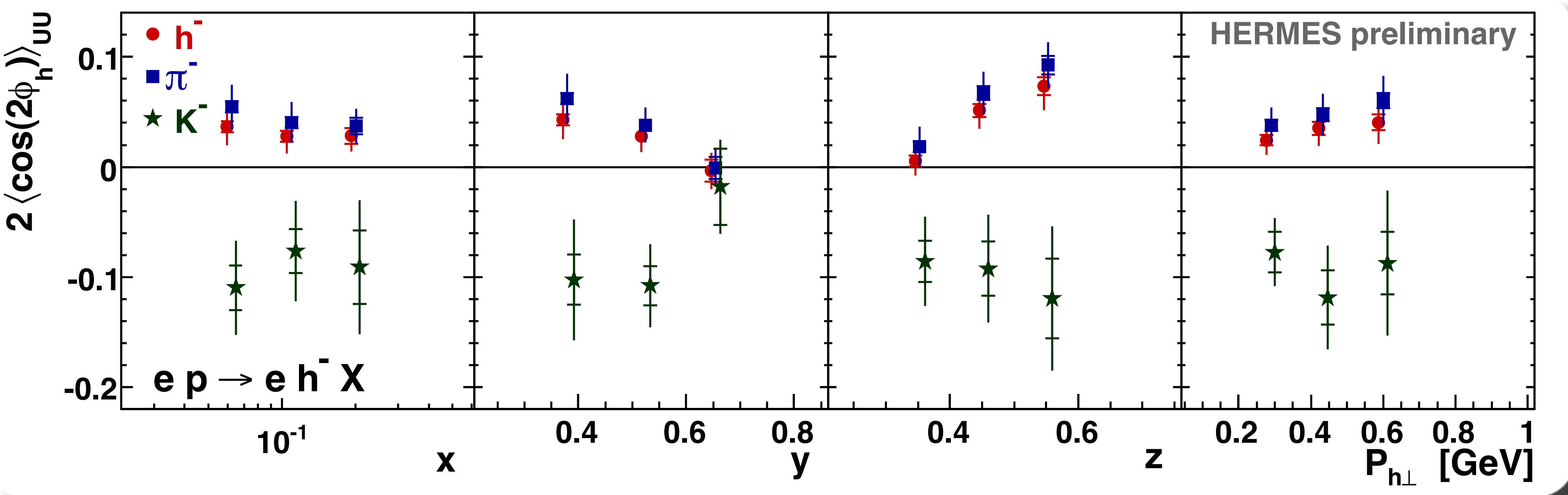
$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Boer-Mulders   Cahn

$u - dominance$

$K^-\{s\bar{u}\} \qquad K^+\{u\bar{s}\}$

$$H_1^{\perp,u\to K^-} \overset{?}{\approx} H_1^{\perp,u\to K^+}$$



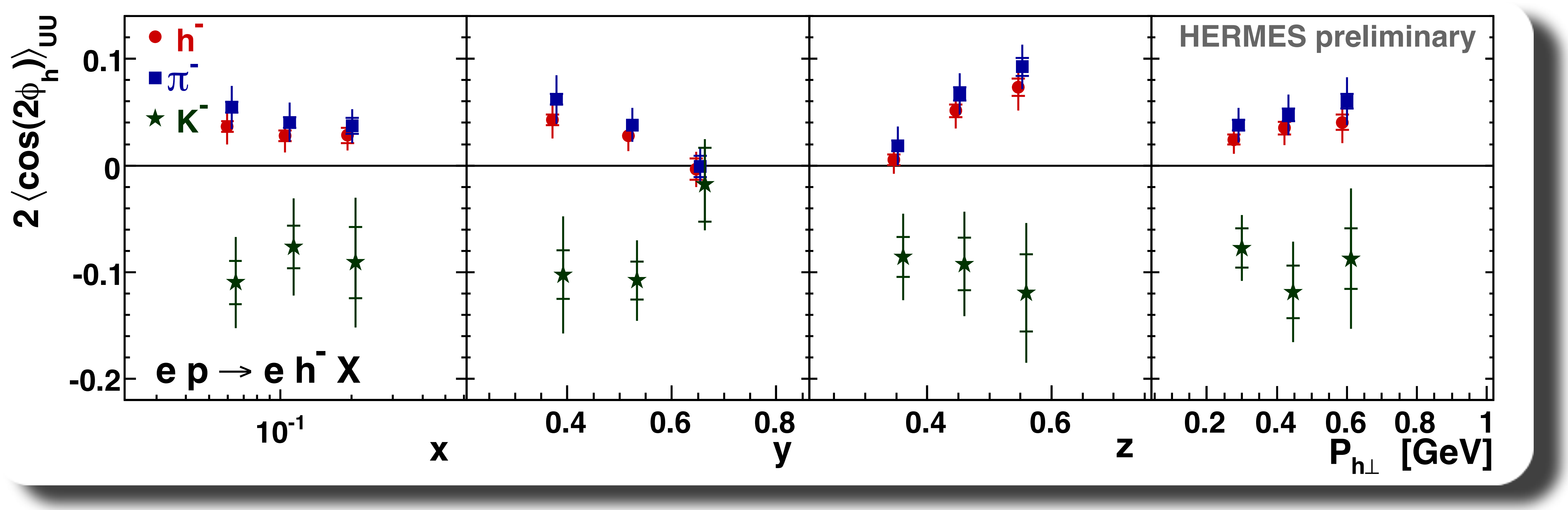
HERMES Results: Kaons, Hydrogen

$$\propto C[-\underbrace{h_1^\perp H_1^\perp}_{\text{Boer-Mulders}} + \overbrace{\frac{\kappa_T^2}{Q^2} f_1 D_1}^{\text{Cahn}} + ...]$$

$u - dominance$ **?**

$K^-\{s\bar{u}\} \qquad K^+\{u\bar{s}\}$

$$H_1^{\perp,u\to K^-} \overset{?}{\approx} H_1^{\perp,u\to K^+}$$



HERMES Results: Kaons, Hydrogen

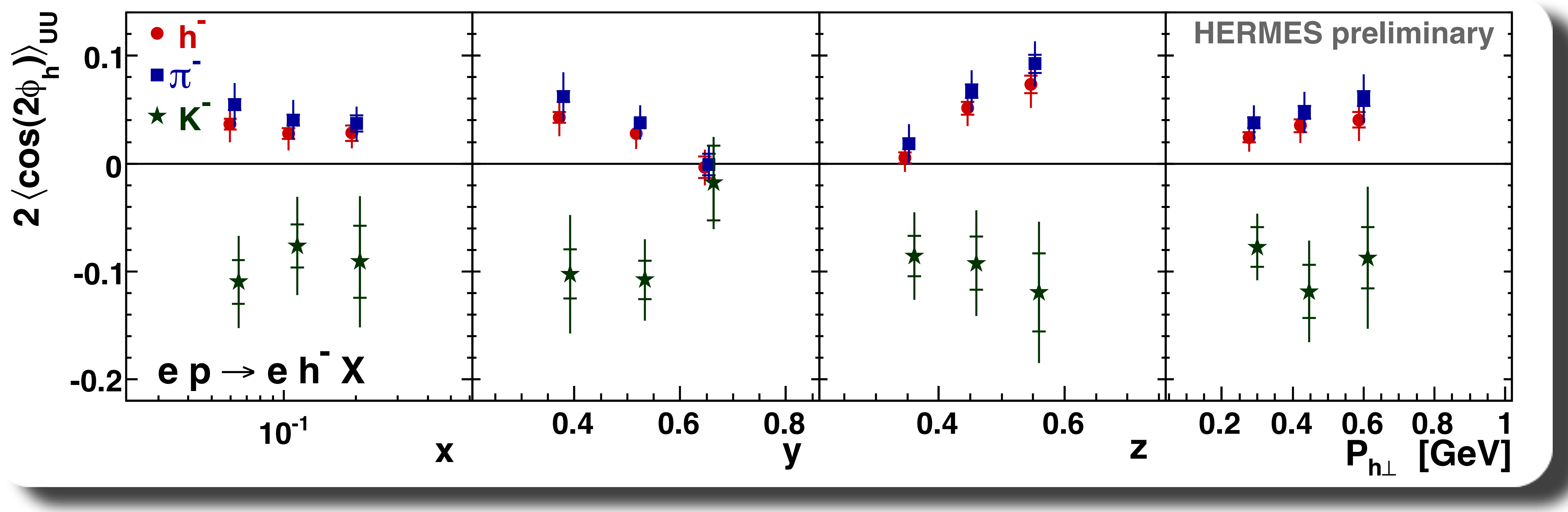
$$\propto C[-h_1^{\perp} H_1^{\perp} + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Boer-Mulders — Cahn

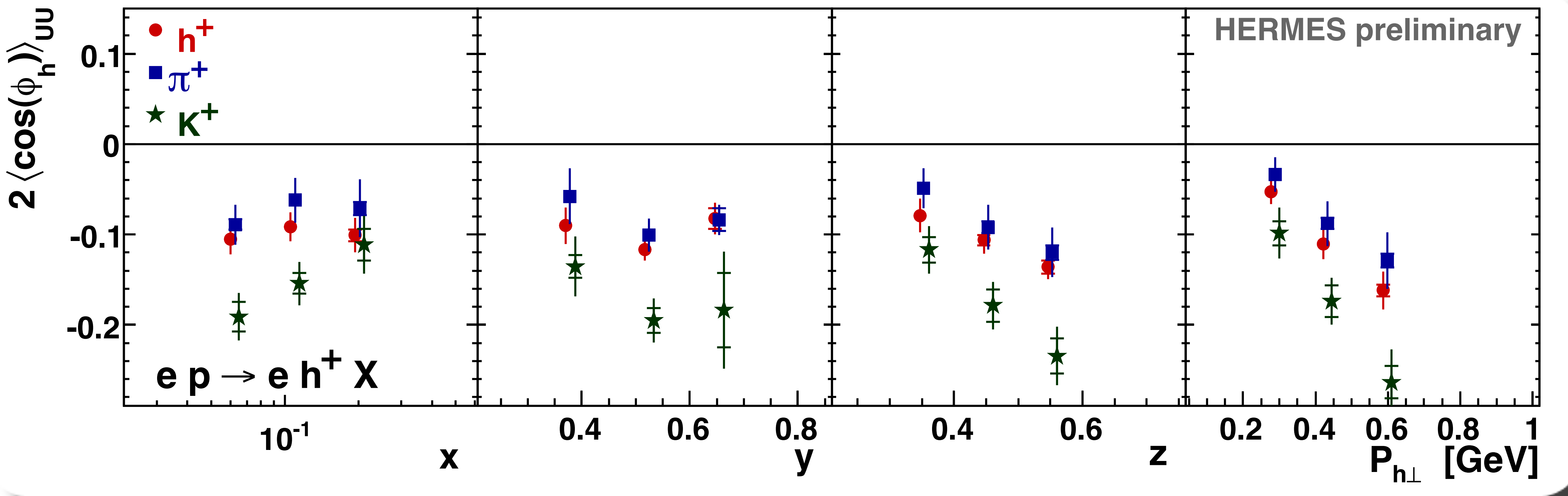
$u - dominance$ **?**

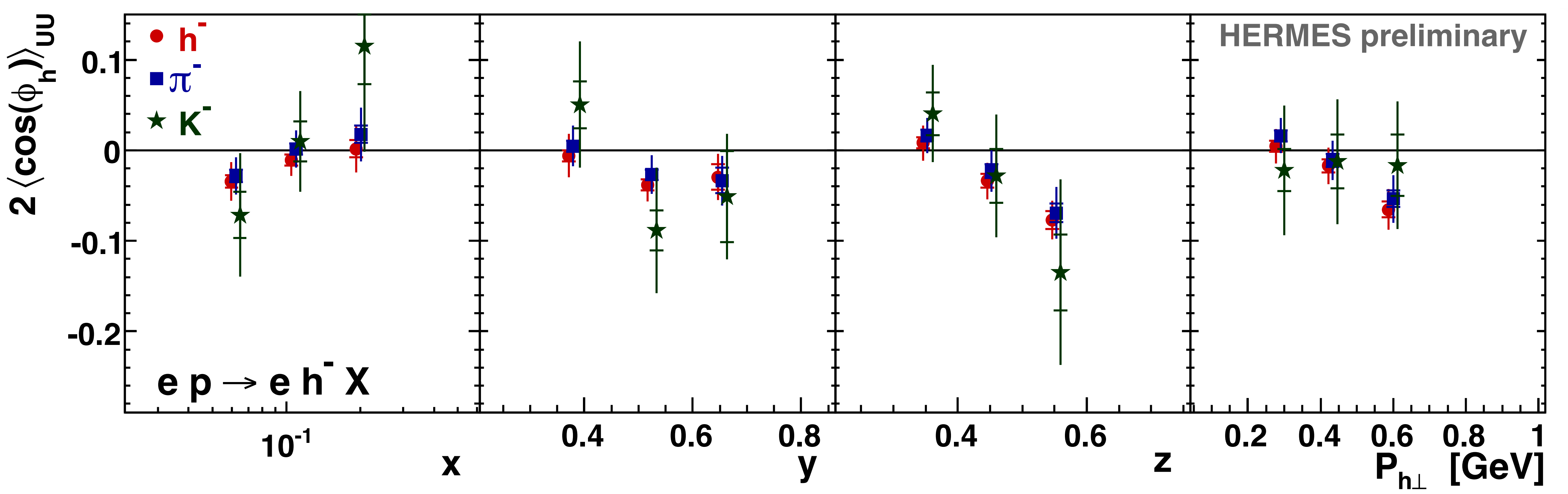
$K^-\{s\bar{u}\}$ $K^+\{u\bar{s}\}$ $K^-\{s\bar{u}\} \Longrightarrow full\, sea\, object$

$$H_1^{\perp, u\rightarrow K^-} \overset{?}{\approx} H_1^{\perp, u\rightarrow K^+}$$

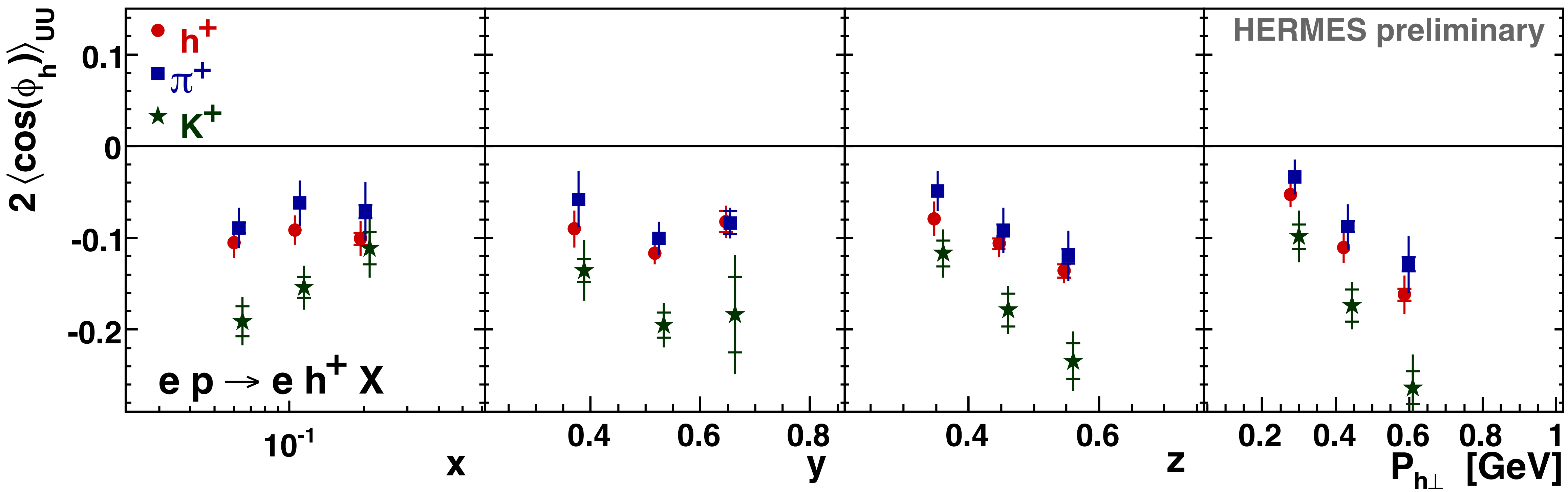


HERMES Results: Kaons, Hydrogen

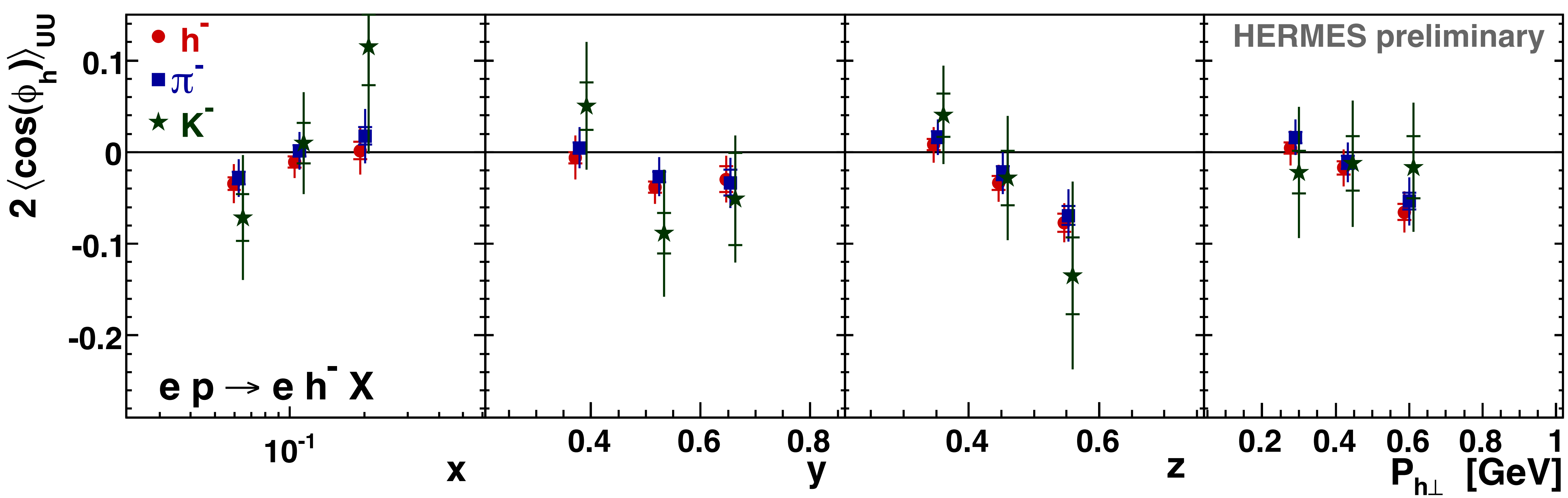




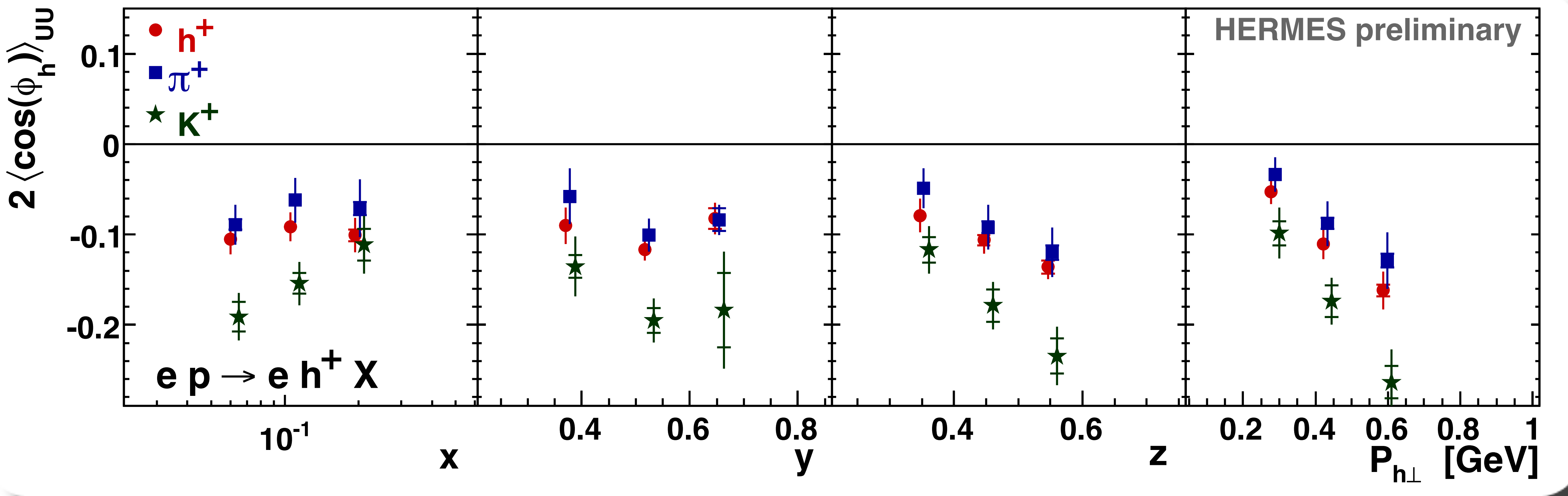
HERMES Results: Kaons, Hydrogen



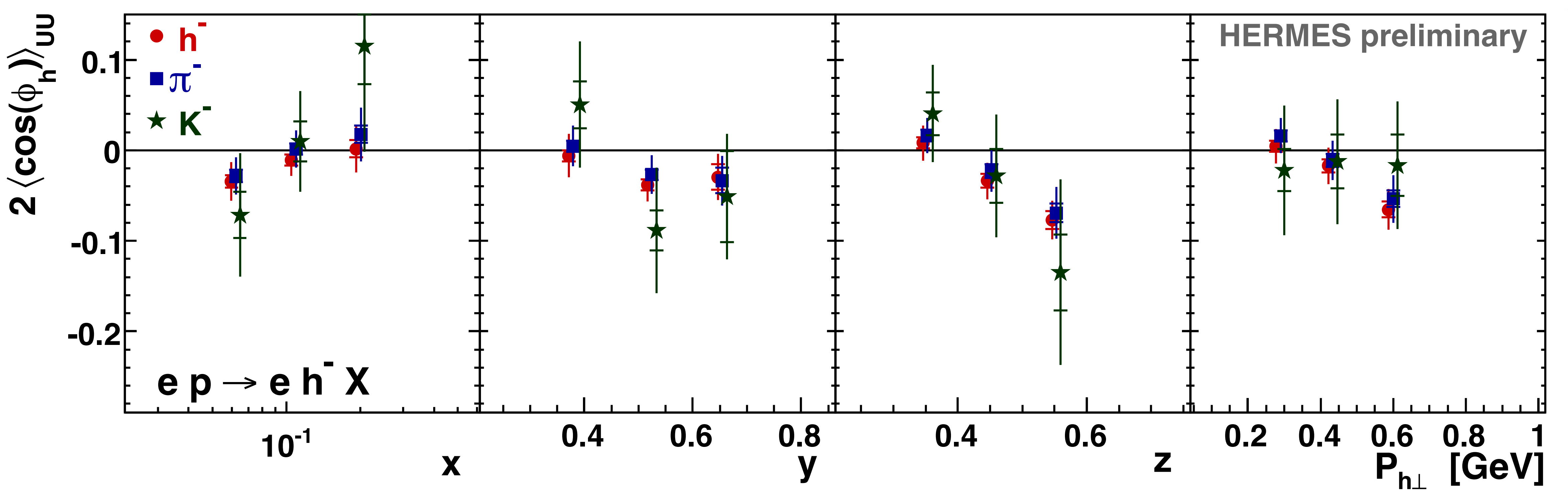
$$\propto \frac{2M}{Q} C[-h_1^\perp H_1^\perp - f_1 D_1 + ...]$$



HERMES Results: Kaons, Hydrogen

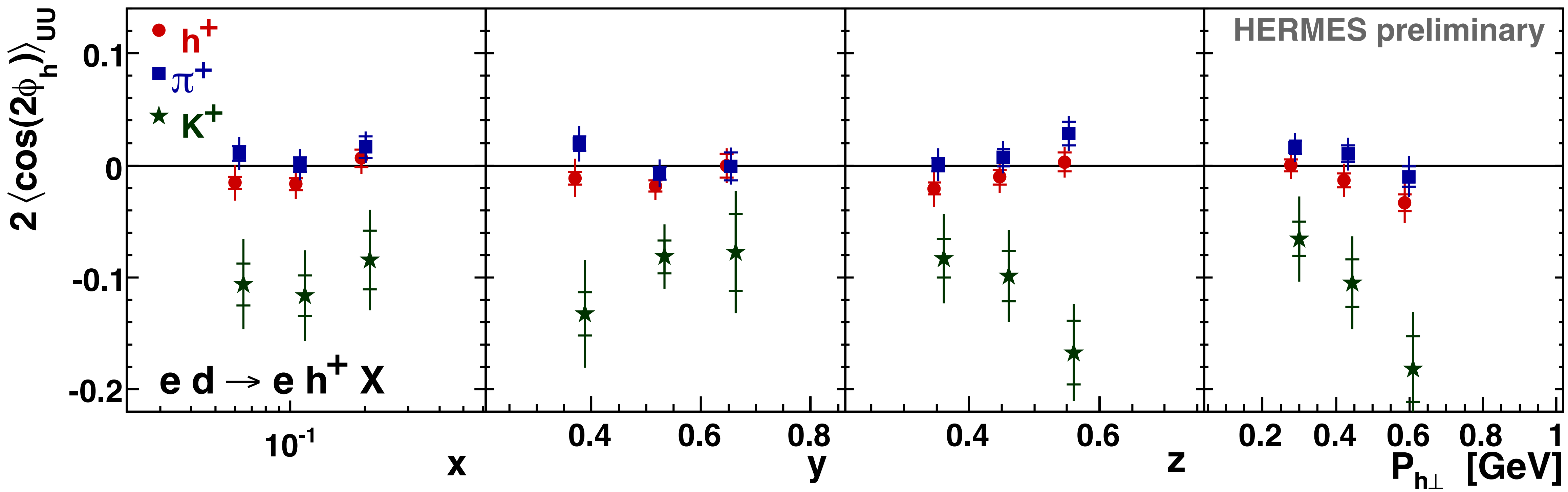


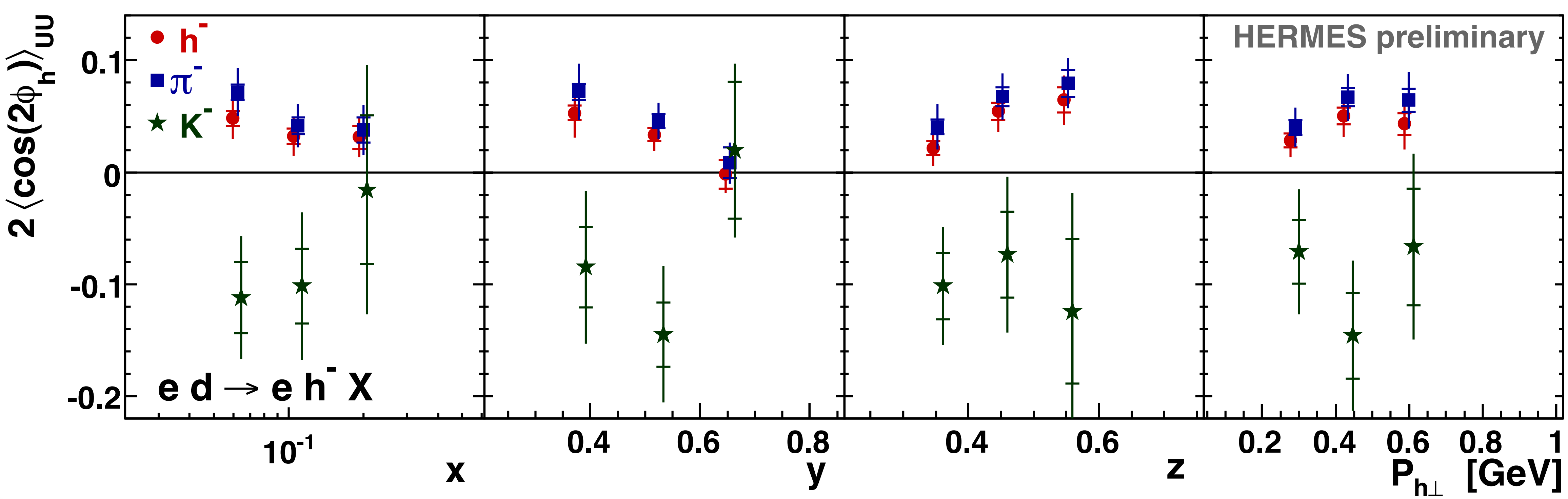
$$\propto \frac{2M}{Q}\, C[-h_1^{\perp} H_1^{\perp} - f_1 D_1 + ...] \qquad ?$$



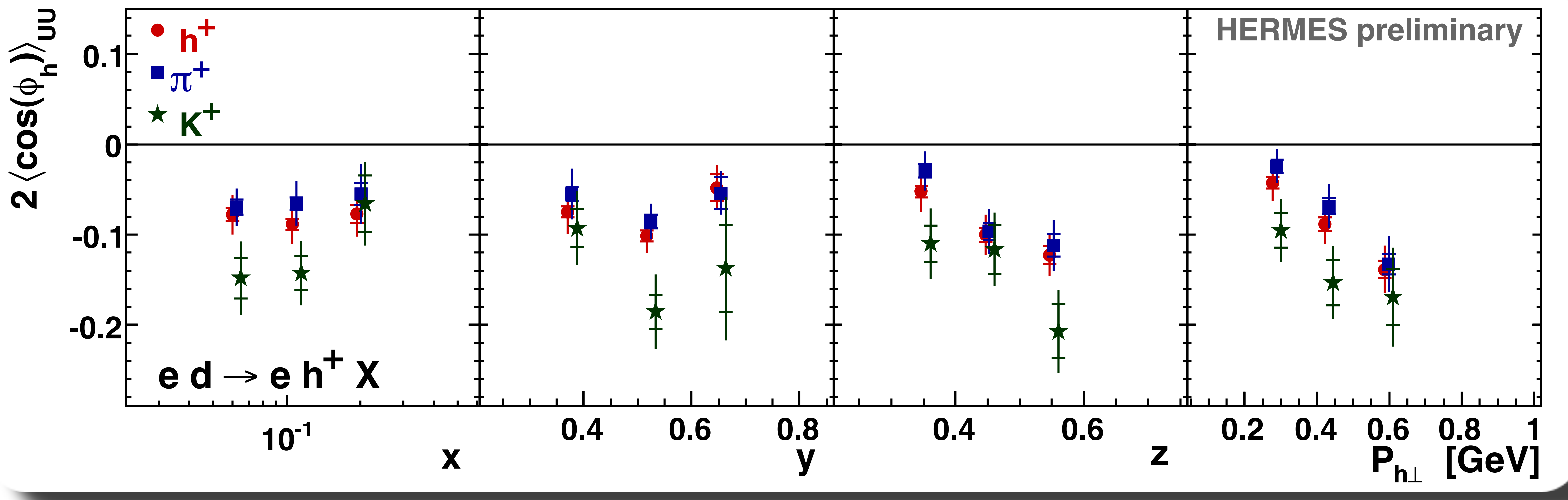
HERMES Results: Kaons, Hydrogen

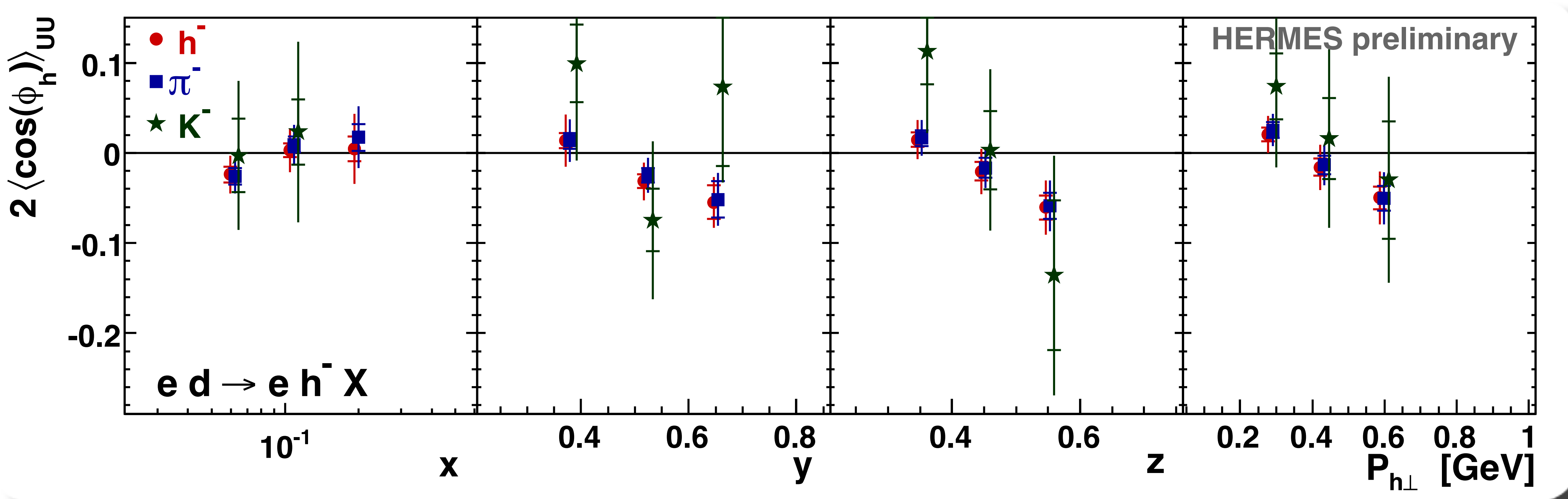
hermes





HERMES Results: Kaons, Deuterium





HERMES Results: Kaons, Deuterium

First flavor dependent measurement of cosine amplitudes in DIS reactions !

First flavor dependent measurements: separate results for h^+/h^-

2007

First measurements for identified π^+/π^- & K^+/K^-

2010

First flavor dependent measurement of cosine amplitudes in DIS reactions !

- $\cos 2\phi_h$:

  difference between π^+/π^- (hermes) h^+/h^- (COMPASS)

  ⇨ evidence of a non-zero Boer-Mulders function

  similar results for deuterium & hydrogen data (hermes)

  ⇨ suggest a Boer-Mulders function with same sign for *u* and *d* quark

  large signal and same sign for K^+/K^- (hermes)

  ⇨ (u-dominance?) same Collins for K^+/K^- ?

  ⇨ (no-u-dominance?) important sea contribution ?

- $\cos \phi_h$: (difficult to interpret, several contributions)

  difference between π^+/π^- (hermes) h^+/h^- (COMPASS)

  ⇨ evidence of a non-zero Boer-Mulders function

  large signal and same sign for K^+/K^- (hermes)

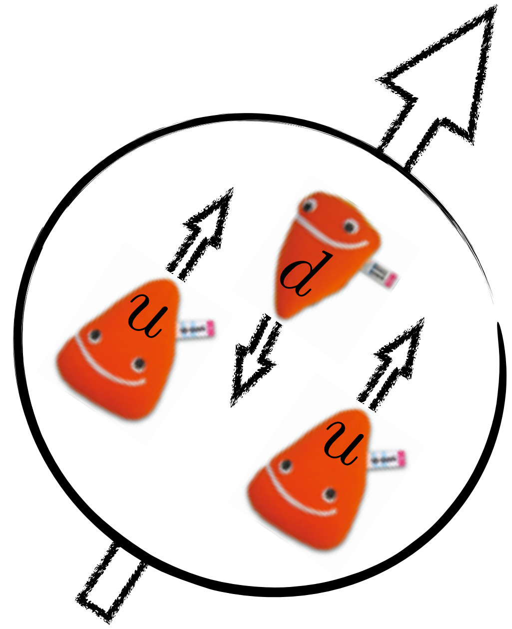
  ⇨ (u-dominance?) same Collins for K^+/K^- ?

  ⇨ (no-u-dominance?) important sea contribution ?

Summary

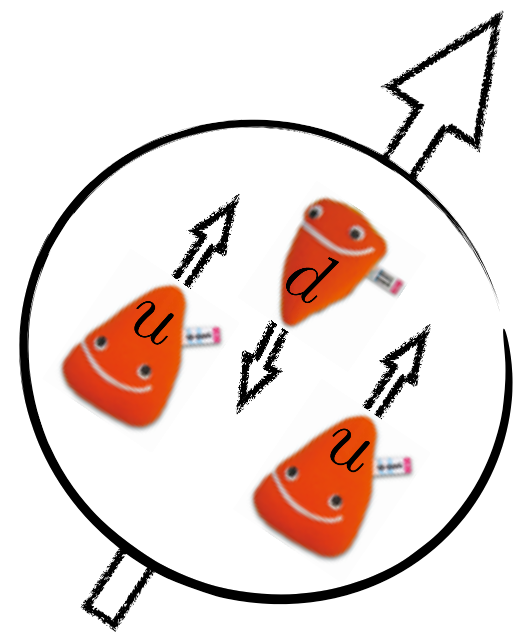
"You think you understand something? Now add spin…"   -- R. Jaffe

“You think you understand something? Now add spin…” -- R. Jaffe



http://www.particlezoo.net/

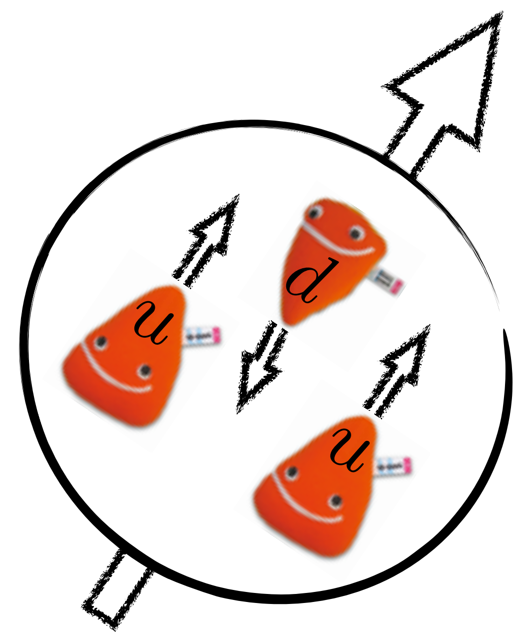
"You think you understand something? Now add spin…"   -- R. Jaffe



You think you understand something? Now add the strange!

http://www.particlezoo.net/

"You think you understand something? Now add spin…" -- R. Jaffe

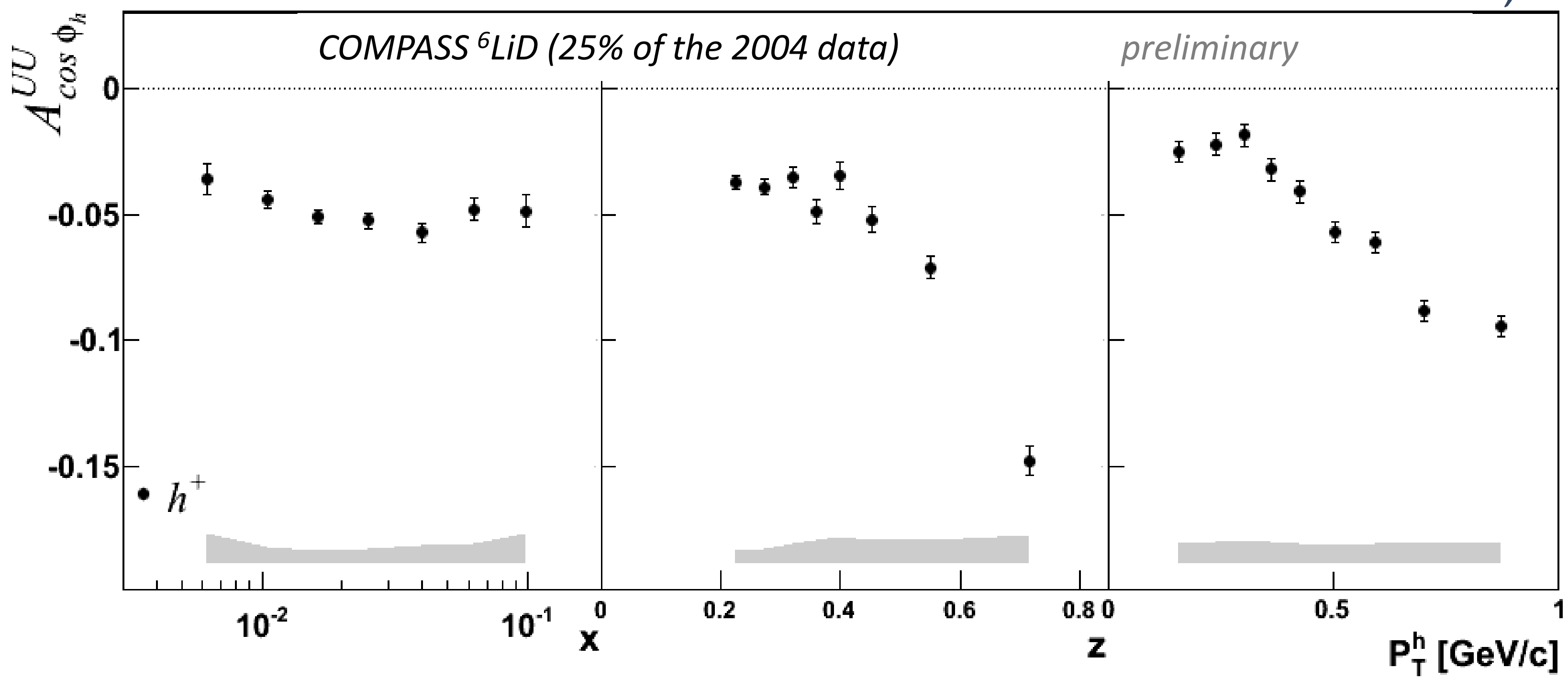


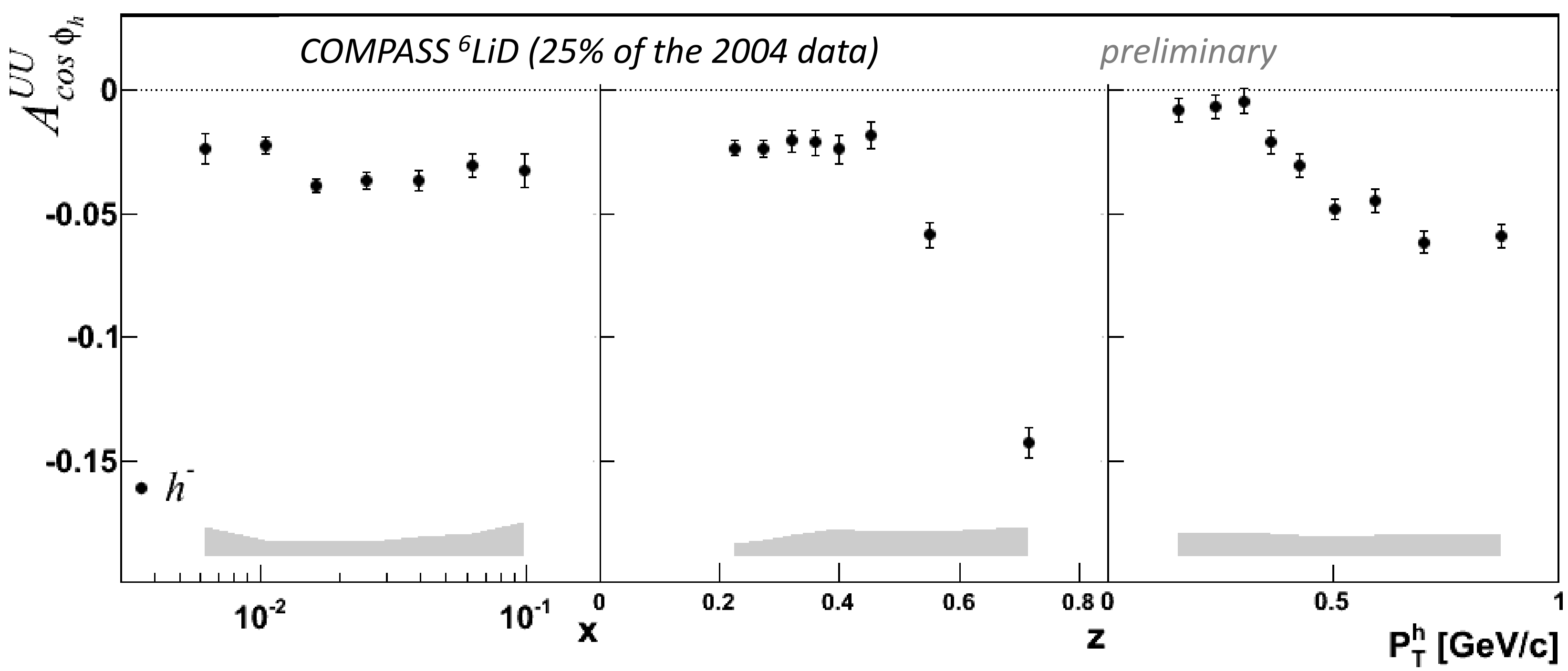
You think you understand something? Now add the strange!

Thank you!

http://www.particlezoo.net/

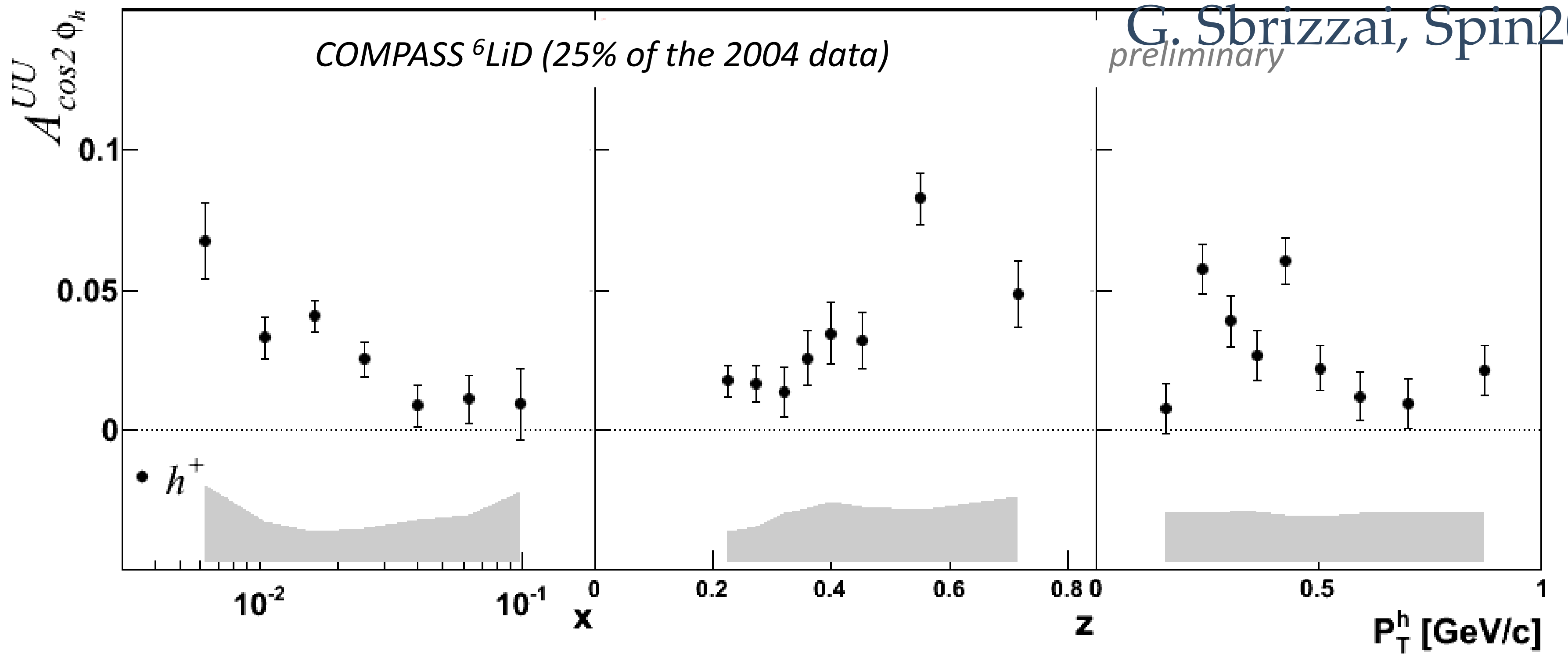
Backup

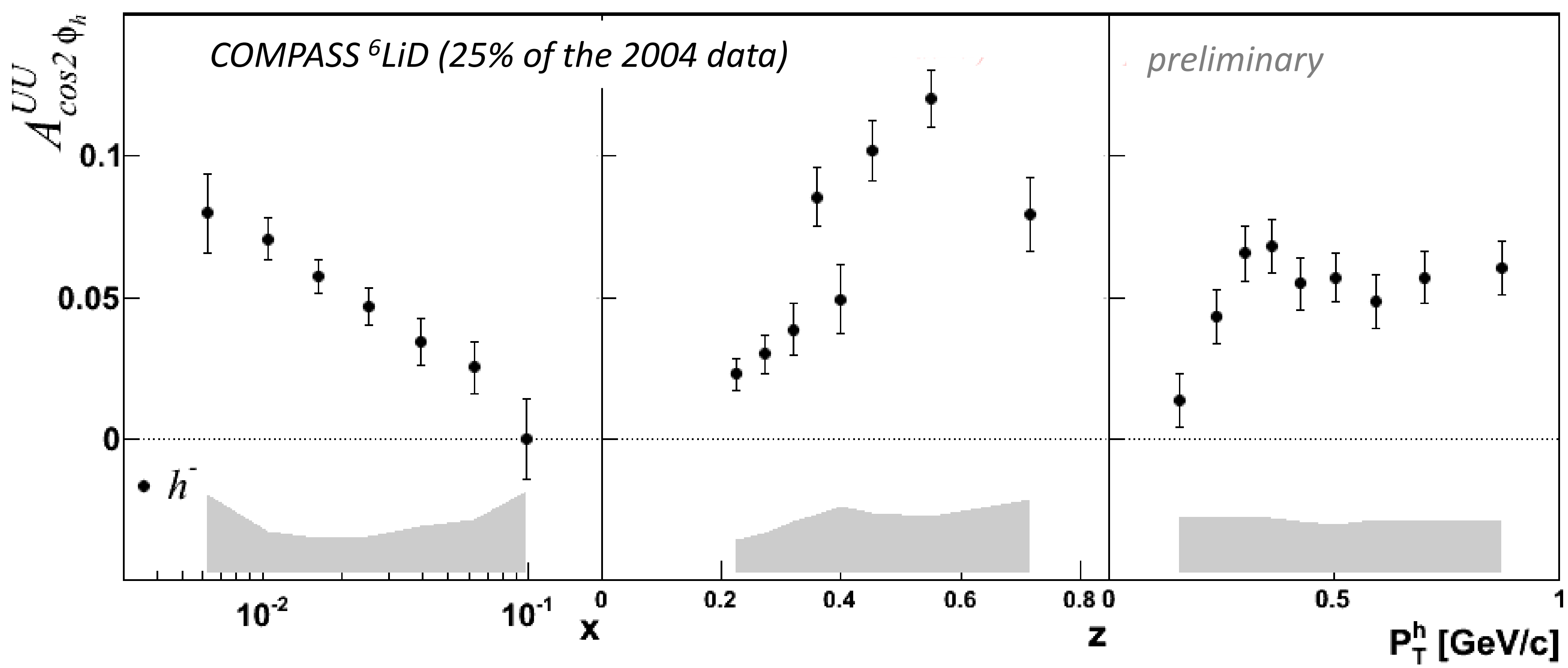




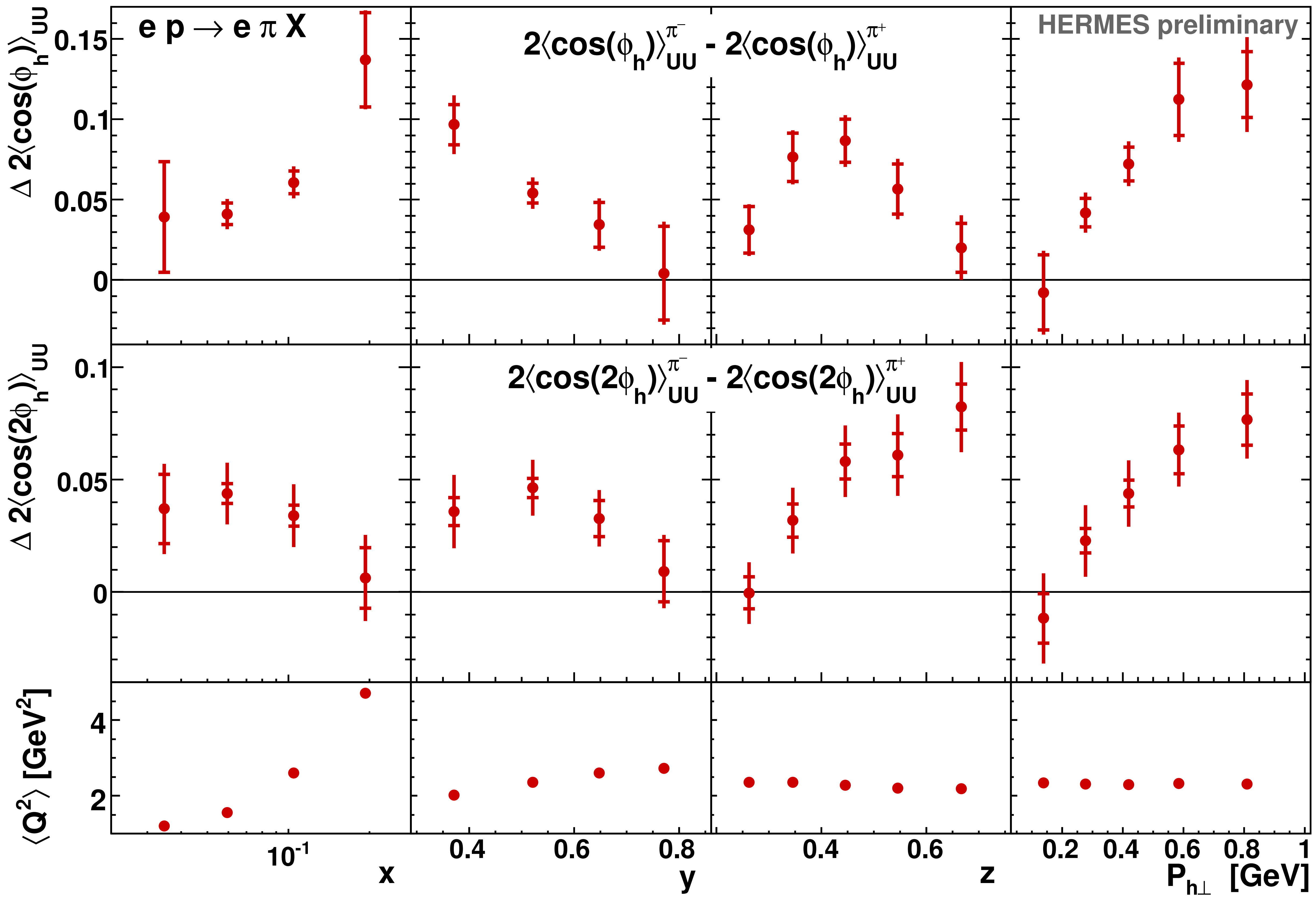
COMPASS Results

G. Sbrizzai, Spin2010 conference





COMPASS Results

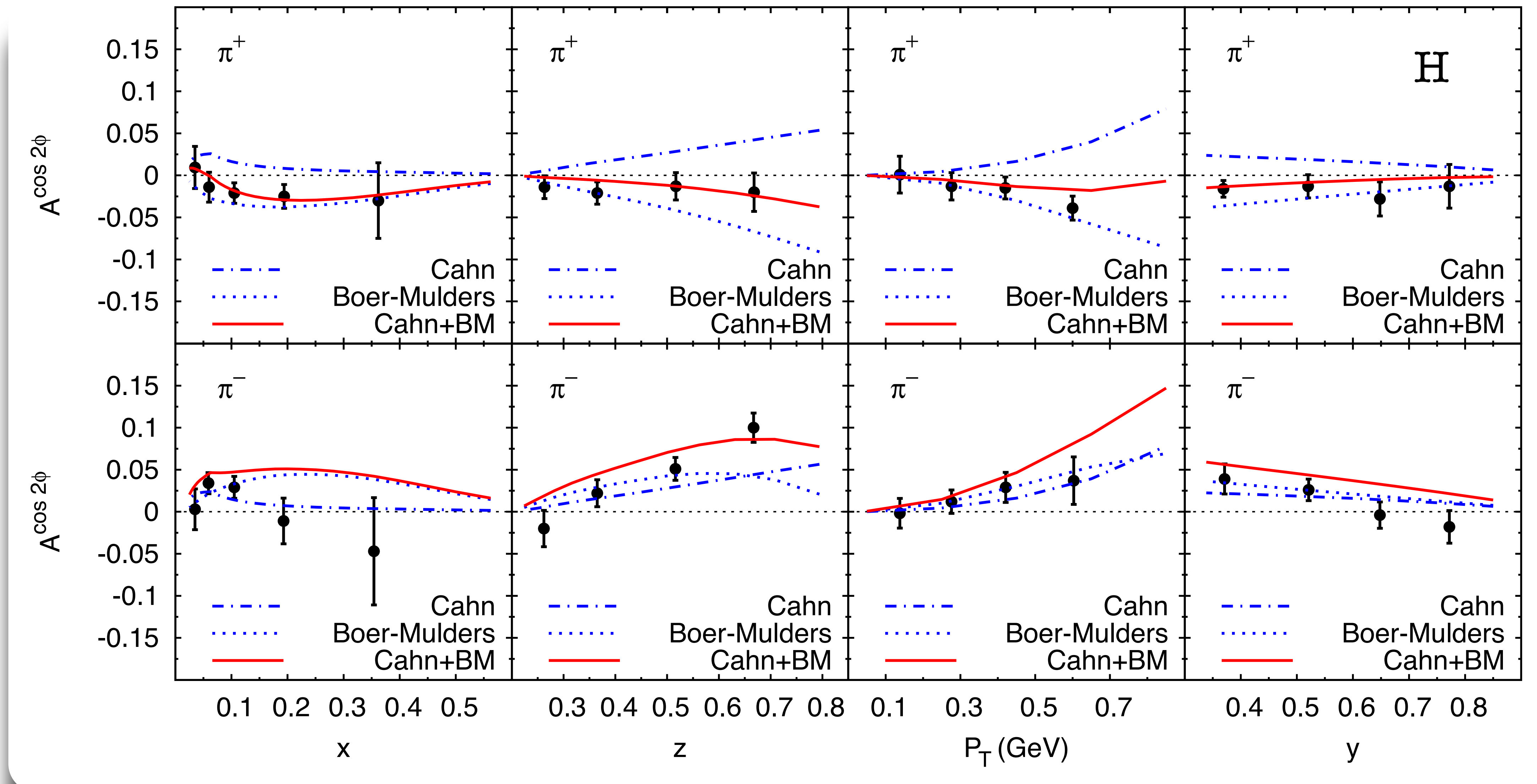


Pion difference

Barone, Melis, Prokudin
Phys. Rev. D81:114026, 2010

* subsample HERMES data

*



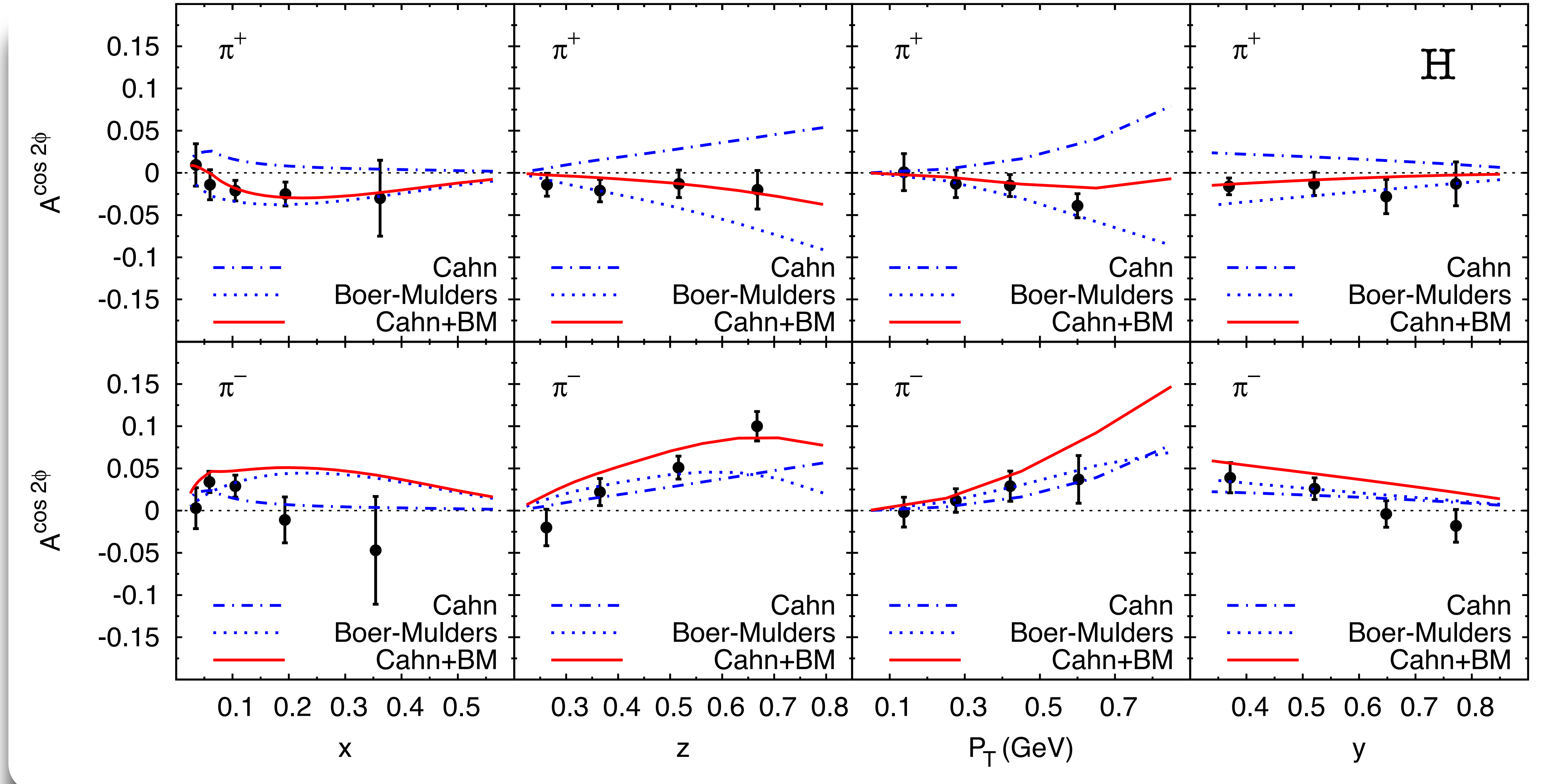
$$< k_T^2 > = 0.25\, GeV^2$$

Barone, Melis, Prokudin Phys. Rev. D81:114026, 2010

Barone, Melis, Prokudin
Phys. Rev. D81:114026, 2010

* subsample HERMES data

*

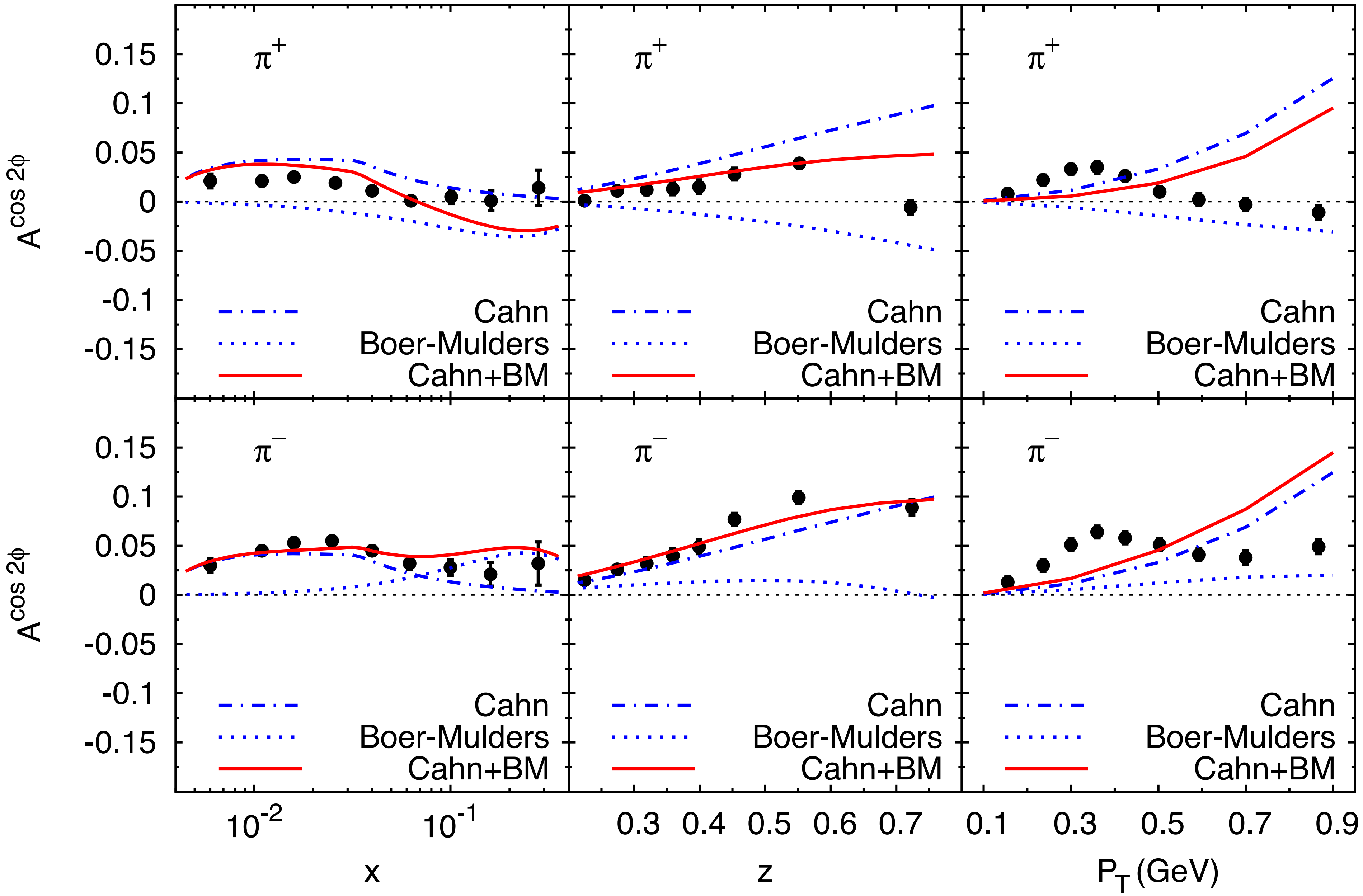


$$< k_T^2 > = 0.18 \, GeV^2$$

Extracted from a parametrization of HERMES spectrum

Barone, Melis, Prokudin Phys. Rev. D81:114026, 2010

Barone, Melis, Prokudin
Phys. Rev. D81:114026, 2010



Barone, Melis, Prokudin Phys. Rev. D81:114026, 2010

Systematic Checks

- ☑ RICH efficiency& contamination
- ☑ Binning effect
- ☑ Unfolding method
- ☑ Time stability

- ☑ Model dependence: different MC generators & cross section models

- ☐ Dipole Magnet effect on different charges tested > no effect

- ☑ Small radiative effects checked
- ☑ Detector inefficiencies
- ☑ Effect at spectrometer edges
- ☑ Compatibility between different experimental setups

- ☑ Model dependence: different MC generators & cross section models

- ☐ 2-D test of acceptance > no effect