Dihadron production in SIDIS experiments

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2nd Workshop on Probing Strangeness in Hard Processes,
November 12th 2013, Frascati National Laboratories, Italy

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

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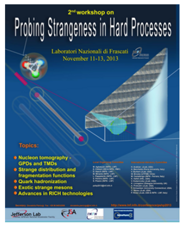
INFN Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati



Outline

The experiments

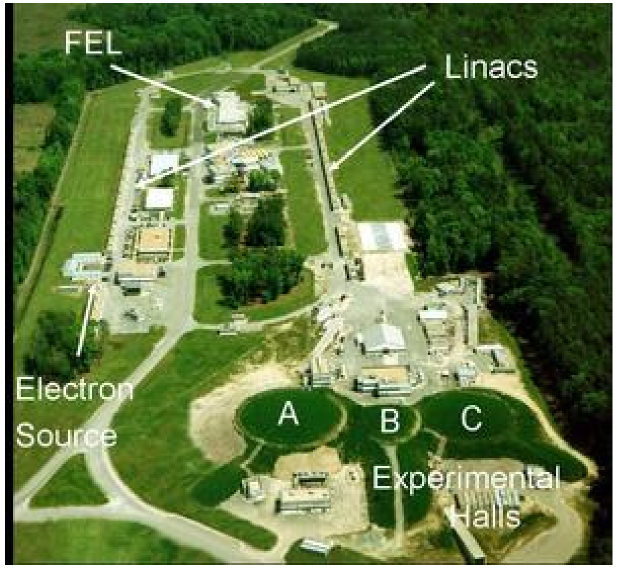
The experiments ▶ overview

COMPASS

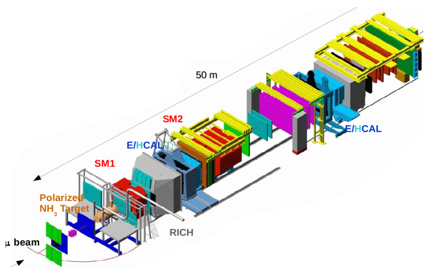
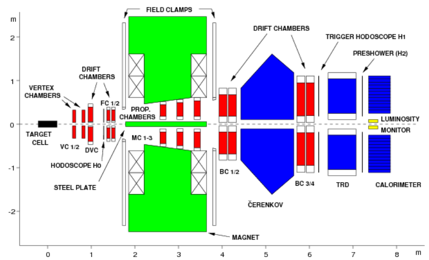
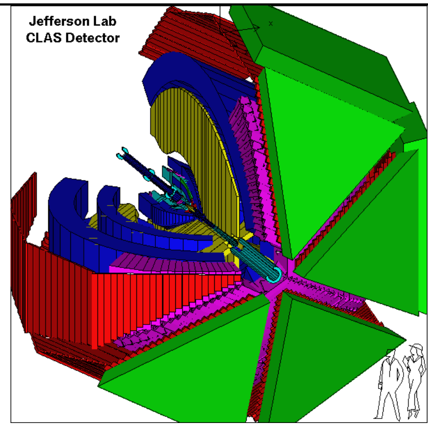
HERMES

CLAS Hall-B

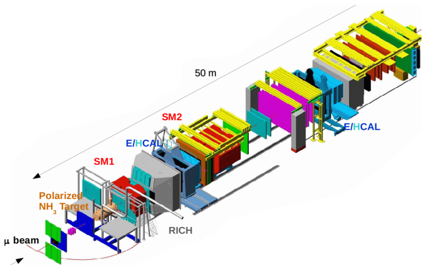
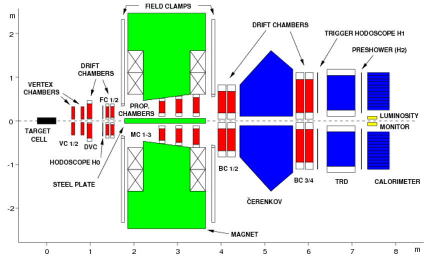
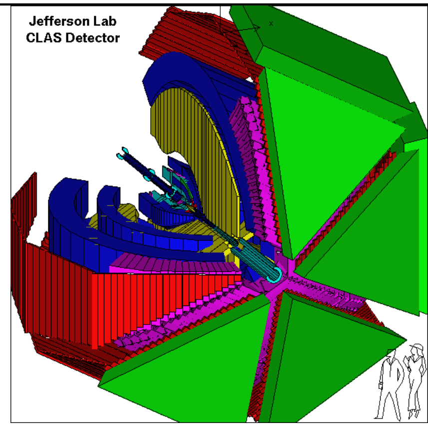
Jefferson Lab
Thomas Jefferson National Accelerator Facility



The experiments ▶ beams and targets

	COMPASS	HERMES	CLAS Hall-B
			
beam type	μ^+	$e^\pm$	e^-
beam pol.	longitudinally	longitudinally	longitudinally
$\langle\lambda\rangle(\%)$	≈ 80	?	$75-85$
beam energy	$160\,\mathrm{GeV}/c$	$27.6\,\mathrm{GeV}/c$	$5.5-6.0\,\mathrm{GeV}/c$
target type	solid state	gaseous	liquid & solid
target mat.	proton (NH_3)	proton (H_2)	proton (H_2)
	deuteron (^6LiD)		proton (NH_3)
target pol.	transversely	transversely	longitudinally
$\langle P_T\rangle(\%)$	≈ 47 and ≈ 90	≈ 74	≈ 80
$\langle f\rangle$ dilution factor	≈ 0.40 and ≈ 0.16	1	≈ 0.16

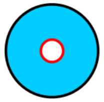
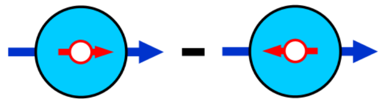
The experiments ▶ particle ID

	COMPASS	HERMES	CLAS Hall-B
			
momenta $\pi^\pm$	$1.5 - 50\,\mathrm{GeV}/c$	$2 - 15\,\mathrm{GeV}/c$	$0.3 - 2\,\mathrm{GeV}/c$
purity $\pi^\pm$	$\approx 99\,\%$	$> 98\,\%$	very high for π^+
momenta $K^\pm$	$9.5 - 50\,\mathrm{GeV}/c$	$2 - 15\,\mathrm{GeV}/c$	good for π^-
purity $K^\pm$	$> 90\,\%$	$> 98\,\%$	–

Theoretical framework

Theoretical framework ▶ leading twist PDFs 1

3 independent parton distribution functions (PDFs) are necessary to describe the spin structure of the nucleon in leading twist in the collinear case:

nucleon	**quark** U	L	T
U	f_1 number density 		
L		g_1 Helicity 	
T			h_1 Transversity 

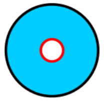
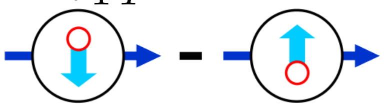
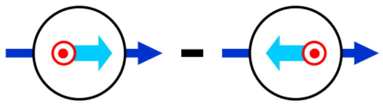
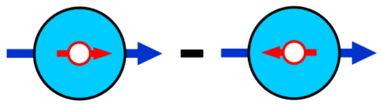
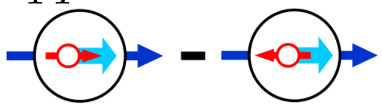
Theoretical framework ▶ leading twist PDFs 2

Taking into account the quark intrinsic transverse momentum k_T, at leading twist in total 8 PDFs are needed:

nucleon \ quark	U	L	T
U	f_1 number density		$h_1^\perp$ Boer-Mulders
L		g_1 Helicity	$h_{1L}^\perp$ Worm-gear L
T	$f_{1T}^\perp$ Sivers	g_{1T} Worm-gear T	h_1 Transversity $h_{1T}^\perp$ Pretzelosity

Theoretical framework ▶ subleading twist PDFs

Envolving to subleading twist adds another 16 PDFs:

nucleon	**quark**		
	U	L	T
U	number density f_1 		$h_1^\perp$ Boer-Mulders 
sub	$f^\perp$	$g^\perp$	h, e
L		Helicity g_1 	$h_{1L}^\perp$ Worm-gear L 
sub	$f_L^\perp$	$g_L^\perp$	h_L, e_L
T	$f_{1T}^\perp$ Sivers 	g_{1T} Worm-gear T 	h_1 Transversity  $h_{1T}^\perp$ Pretzelosity 
sub	f_T, $f_T^\perp$	g_T, $g_T^\perp$	h_T, e_T, $h_T^\perp$, $e_T^\perp$

Bacchetta A. & Radici M. arXiv:hep-ph/0311173 (2003)

Theoretical framework ▶ dihadron cross section

Selection of relevant parts of the full dihadron cross section:

$$d^7\sigma_{UT} =$$
$$\frac{\alpha^2}{2\pi Q^2 y}\left|\vec{S}_\perp\right|\sum_a e_a^2 B(y)\sin(\phi_R+\phi_S)\frac{\left|\vec{R}_T\right|}{M_{hh}}h_1^a(x)H_1^{\sphericalangle,a}(z,\xi,M_{hh}^2)+\ldots$$

$$d^7\sigma_{UL} =$$
$$\frac{\alpha^2}{2\pi Q^2 y}\vec{S}_L\sum_a e_a^2 V(y)\sin\phi_R\frac{\left|\vec{R}_T\right|}{Q}\frac{M}{M_{hh}}x h_L^a(x)H_1^{\sphericalangle,a}(z,\xi,M_{hh}^2)+\ldots$$

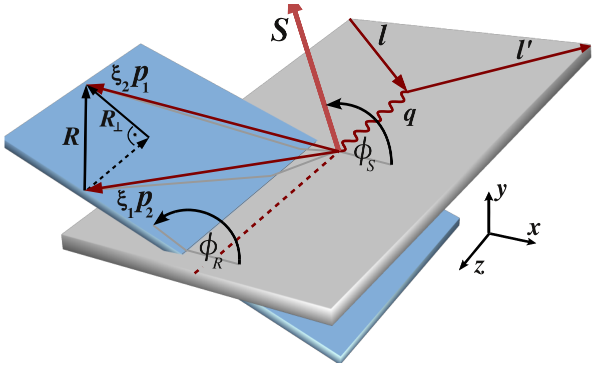
$$d^7\sigma_{LU} =$$
$$\frac{\alpha^2}{2\pi Q^2 y}\lambda\sum_a e_a^2 W(y)\sin\phi_R\frac{\left|\vec{R}_T\right|}{Q}\frac{M}{M_{hh}}x e^a(x)H_1^{\sphericalangle,a}(z,\xi,M_{hh}^2)+\ldots$$

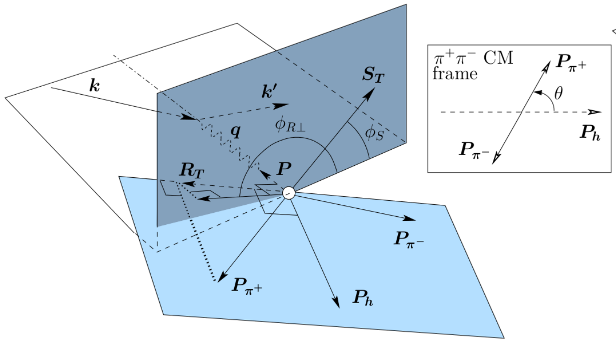
h_1 Transversity PDF
h_L subleading twist PDF of transv. polarized quark in long. polarized nucleon
e subleading twist PDF of transv. polarized quark in unpolarized nucleon
$H_1^{\sphericalangle}$ Interference Fragmentation Function (IFF)

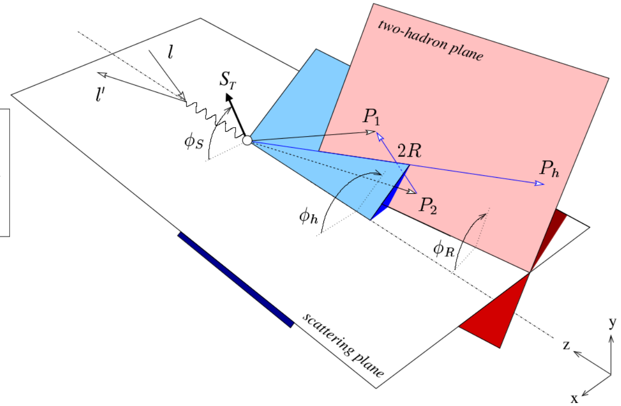
Bacchetta A. & Radici M. arXiv:hep-ph/0311173 (2003)

$$\ell + N^{\uparrow} \rightarrow \ell' + h_1 + h_2 + X$$

Fragmentation of a transversely polarized quark into a pair of unpolarized hadrons

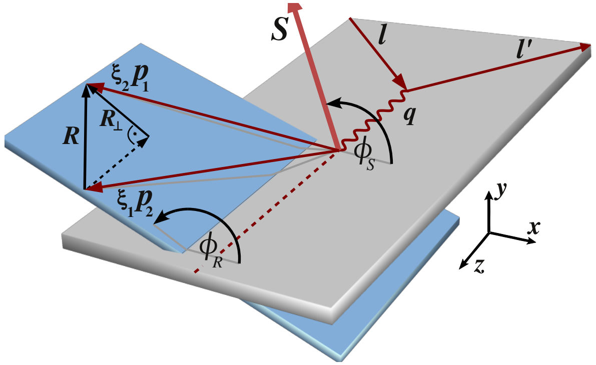


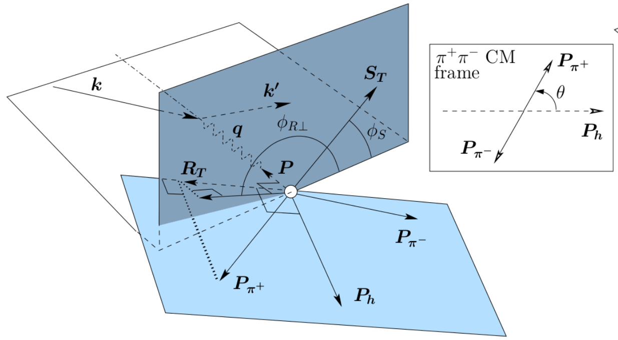


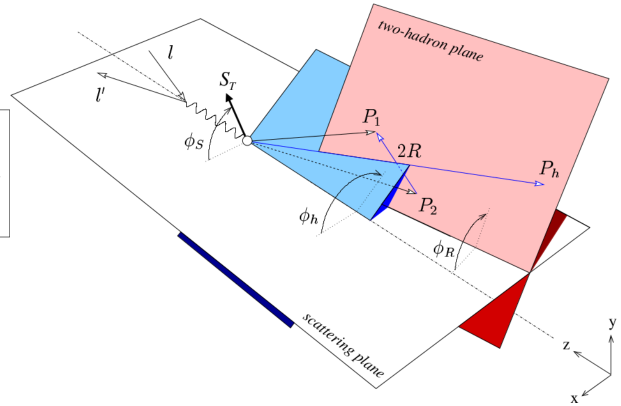


- $\boldsymbol{k}$, $\boldsymbol{k'}$ and $\boldsymbol{q}$ are 3-momenta of incoming, scattered lepton and virtual photon
- ϕ_S azimuthal angle of the spin $\boldsymbol{S}$ of the fragmenting quark
- $\boldsymbol{p_i}$ is the 3-momenta of h_i
- z_i is the fraction of the virtual-photon energy carried by h_i
- $\boldsymbol{P_h}$ is the sum of $\boldsymbol{p_1}$ and $\boldsymbol{p_2}$

Theoretical framework ▶ kinematics 2







- Definition of relative vector of the two hadrons slightly different between HERMES and COMPASS:
  - HERMES: $\boldsymbol{R} = (\boldsymbol{p_1} - \boldsymbol{p_2})/2$, $\boldsymbol{R_T} = \boldsymbol{R} - (\boldsymbol{R} \cdot \hat{\boldsymbol{P}}_{\boldsymbol{h}})\hat{\boldsymbol{P}}_{\boldsymbol{h}}$ thus $\boldsymbol{R}_T$ is the component of $\boldsymbol{p_1}$ orthogonal to perp. to $\boldsymbol{P_h}$ and $\phi_{R(\perp)}$ the zimuthal angle of $\boldsymbol{R}_T$ about the γ^* direction
  - COMPASS: $\boldsymbol{R} = \frac{z_2 \boldsymbol{p_1} - z_1 \boldsymbol{p_2}}{z_1 + z_2}$, which is invariant against boosts in the γ^* direction[1]

↪ The azimuthal angle of $\phi_{R(\perp)}$:

$$\phi_{R(\perp)} = \frac{(\boldsymbol{q} \times \boldsymbol{k}) \cdot \boldsymbol{R_{(T)}}}{|(\boldsymbol{q} \times \boldsymbol{k}) \cdot \boldsymbol{R_{(T)}}|} \arccos\left(\frac{(\boldsymbol{q} \times \boldsymbol{k}) \cdot (\boldsymbol{q} \times \boldsymbol{R_{(T)}})}{|\boldsymbol{q} \times \boldsymbol{k}||\boldsymbol{q} \times \boldsymbol{R_{(T)}}|}\right)$$

$$\phi_S = \frac{(\boldsymbol{q} \times \boldsymbol{k}) \cdot \boldsymbol{S_{(T)}}}{|(\boldsymbol{q} \times \boldsymbol{k}) \cdot \boldsymbol{S_{(T)}}|} \arccos\left(\frac{(\boldsymbol{q} \times \boldsymbol{k}) \cdot (\boldsymbol{q} \times \boldsymbol{S_{(T)}})}{|\boldsymbol{q} \times \boldsymbol{k}||\boldsymbol{q} \times \boldsymbol{S_{(T)}}|}\right)$$

[1] *cf.* Artru & Collins, Z.Phys. **C69** (1996) 277-286

Theoretical framework ▶ asymmetry extraction *e.g.* A_{UT}

$$N_{h^+h^-}(x, y, z, M_{hh}^2, \cos\theta, \phi_{RS}) \propto$$
$$\sigma_{UU}(1 \pm f P_T D_{NN} A_{UT}^{\sin\phi_{RS}} \sin\theta \sin\phi_{RS})$$

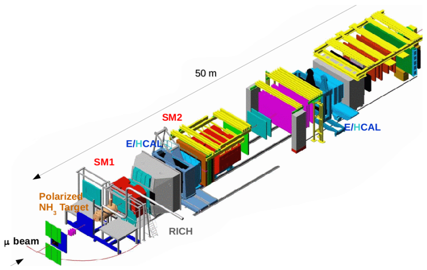
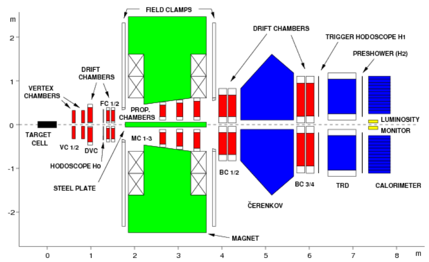
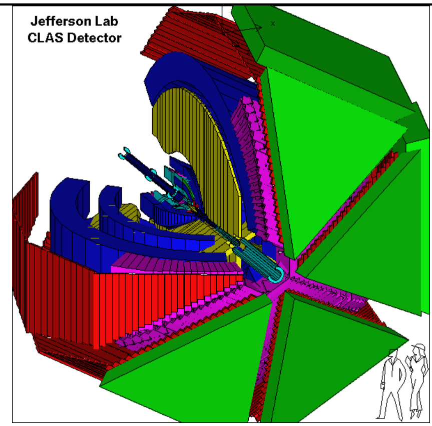
- ϕ_{RS} $= \phi_{R(\perp)} + \phi_S$ (COMPASS uses additional phase of $-\pi$ leading to sign change)
- θ polar angle of h_1 in the dihadron rest frame w.r.t. the $\boldsymbol{P_h}$ direction
- σ_{UU} unpolarized cross section
- $\pm$ indicates nucleon spin orientation
- f target dilution factor
- P_T target polarization
- $D_{NN}(y)$ transv. spin transfer coef.

$$A_{UT}^{\sin\phi_{RS}\sin\theta} \propto \frac{\sum_q e_q^2\, h_1^q(x)\, H_{1,q}^{\sphericalangle}(z, M_h^2, \cos\theta)}{\sum_q e_q^2\, f_1^q(x)\, D_{1,q}(z, M_h^2, \cos\theta)}$$

- f_1 number density
- D_1 unpolarized Interference Fragmentation Function

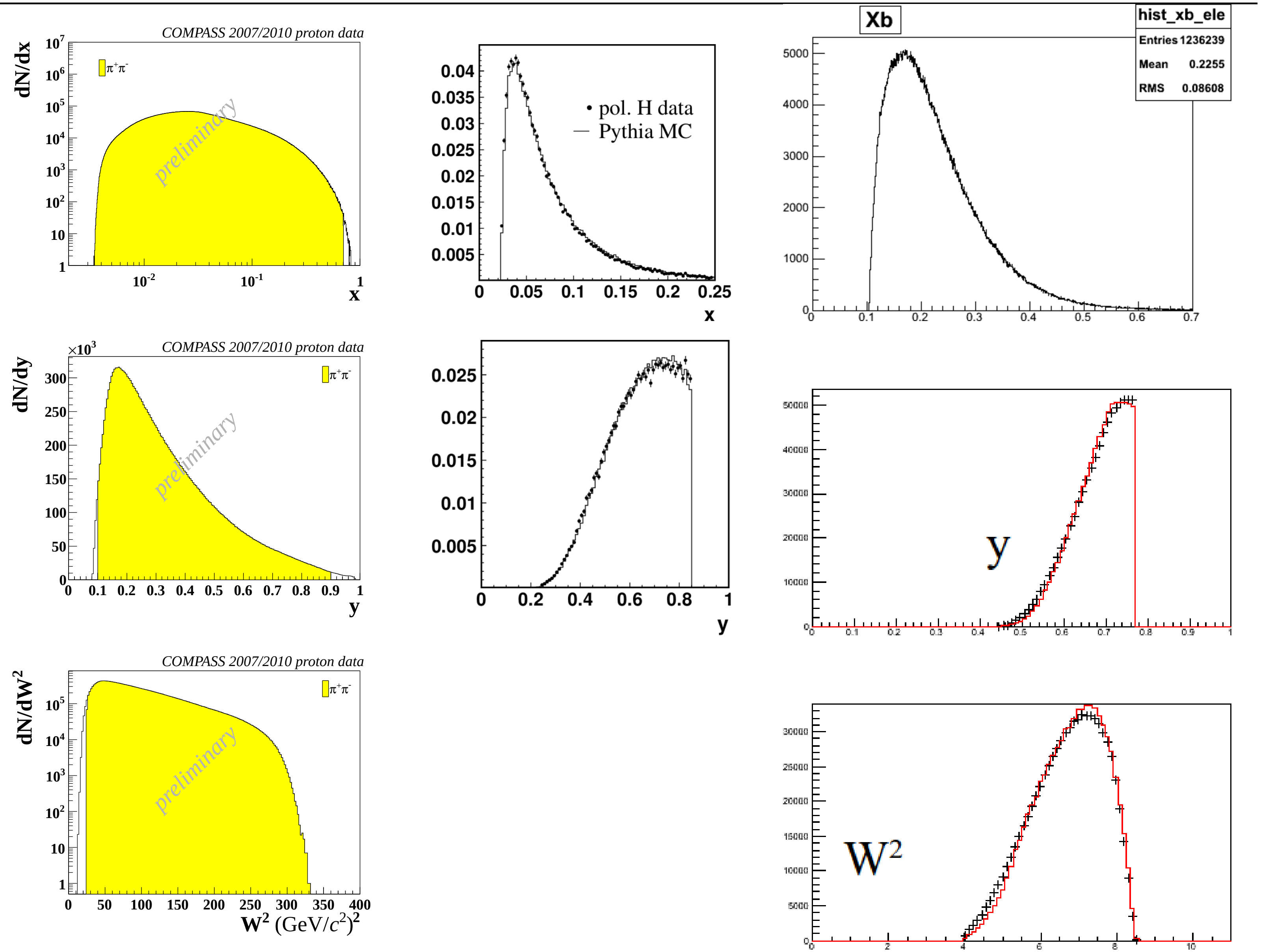
Data selection

Data selection ▶ cuts

	COMPASS	HERMES	CLAS Hall-B
			
DIS cuts & acceptance:			
$Q^2(\mathrm{GeV}^2/c^2)$	> 1	> 1	> 1
y	$0.1 - 0.9$	$0.1 - 0.85$	$0.44 - 0.77$
$W(\mathrm{GeV}/c^2)$	> 5	> 3.16	> 2
x	$0.003 - 0.7$	$0.023 - 0.4$	$0.1 - 0.7$
hadron & pair cuts & acceptance:			
z of each hadron	> 0.1	> 0.0	$0.15 - 0.76$
x_F of each hadron	> 0.1	> 0.0	> 0.0
$E_{miss}(\mathrm{GeV})$	> 3.0	> 0.0	> 1.5
$\boldsymbol{R}_T(\mathrm{GeV}/c)$	> 0.07	> 0.0	> 0.0
$M_{hh}(\mathrm{GeV}/c^2)$	$0.3 - 2.5$	$0.5 - 1.0$	$0.24 - 1.4$

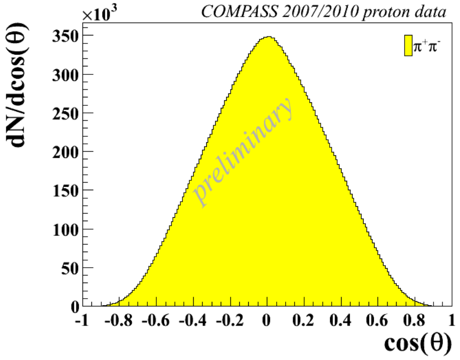
Data selection ▶ kinematic distributions 1

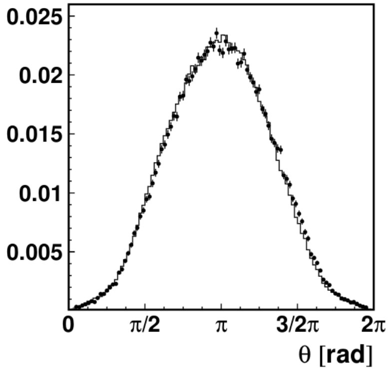
COMPASS	HERMES	CLAS Hall-B

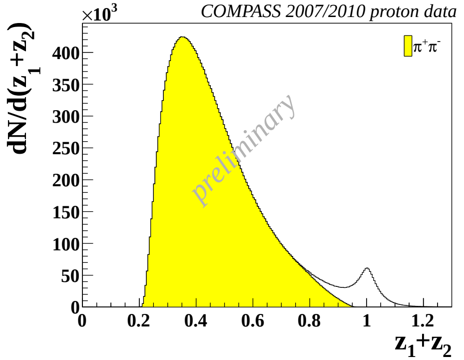


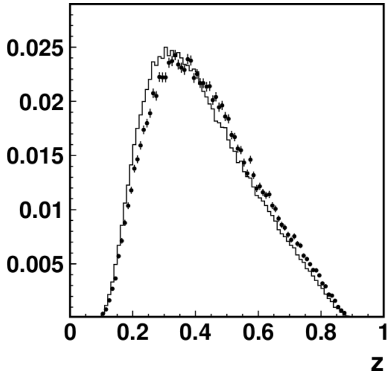
Data selection ▸ kinematic distributions 2

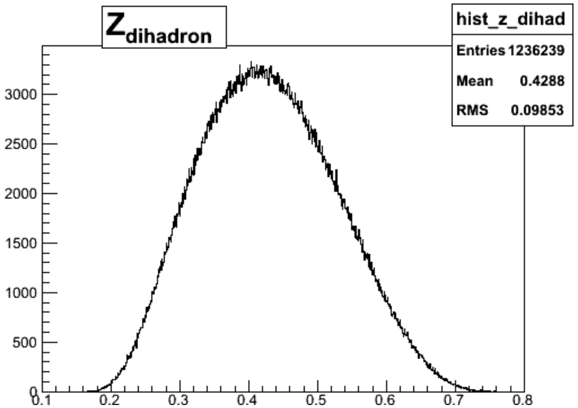
COMPASS	HERMES	CLAS Hall-B

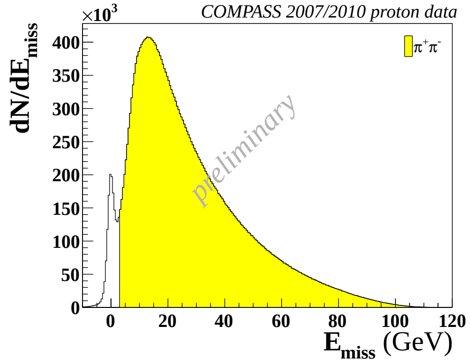


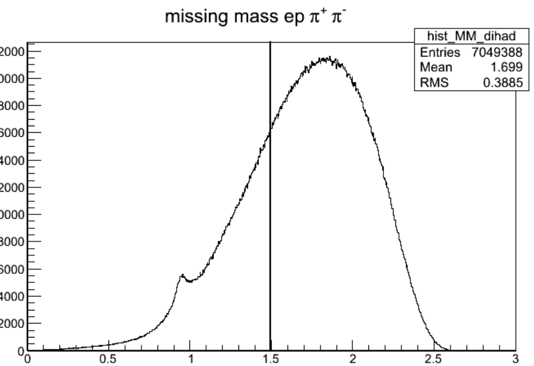




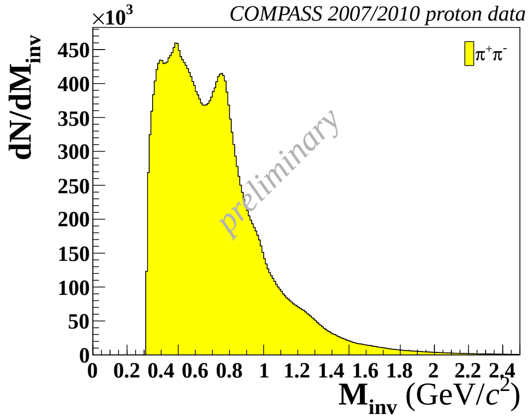
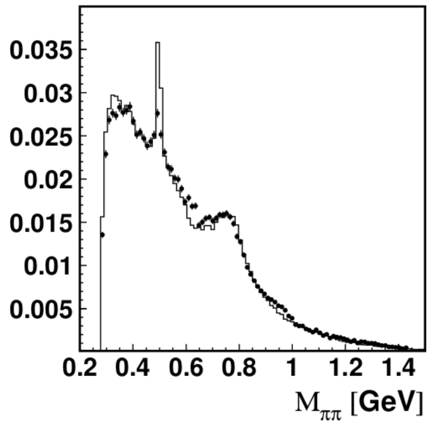
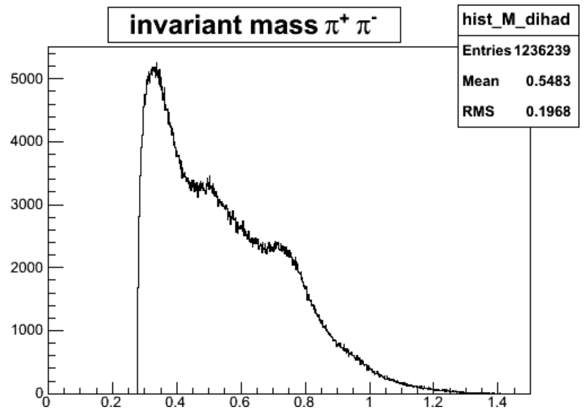








Data selection ▶ kinematic distributions 3

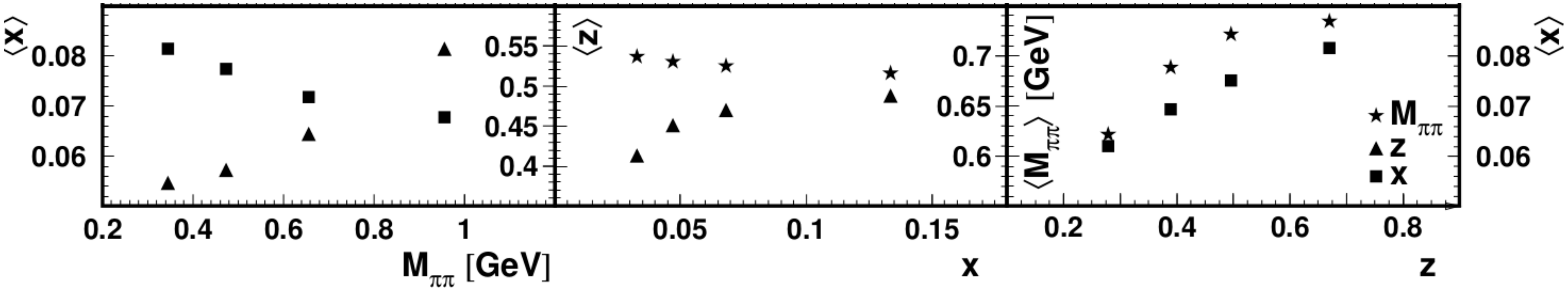
COMPASS	HERMES	CLAS Hall-B
		

Clear contributions from resonance decay in the invariant mass distribution in the data of all three experiments

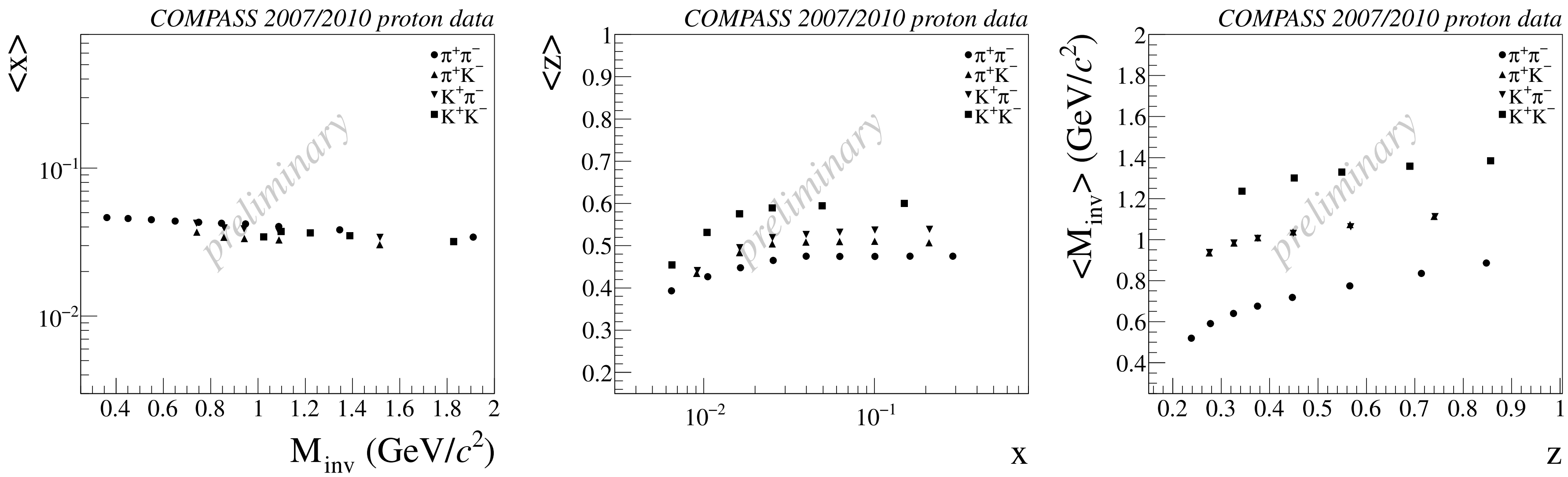
- η (548 GeV/c^2) and η' (958 GeV/c^2)
- ω (783 GeV/c^2)
- K^0 (498 GeV/c^2)
- ρ^0 (776 GeV/c^2)
- indication for higher mass resonances in COMPASS data

Data selection ▶ mean values 1

HERMES

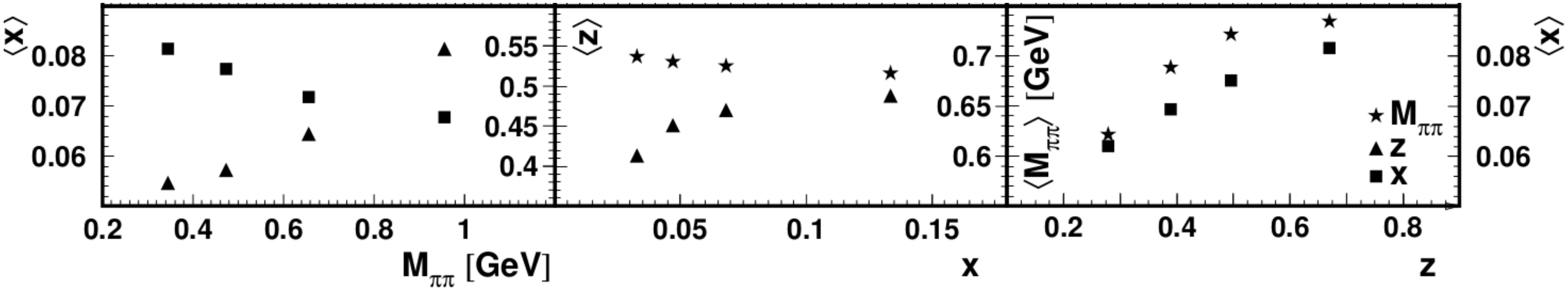


COMPASS

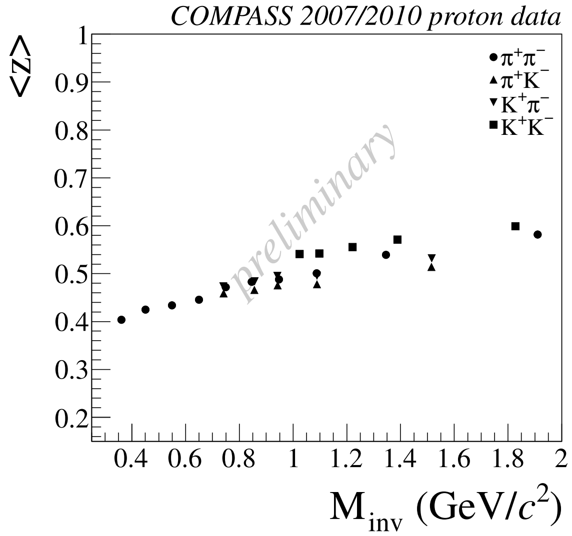


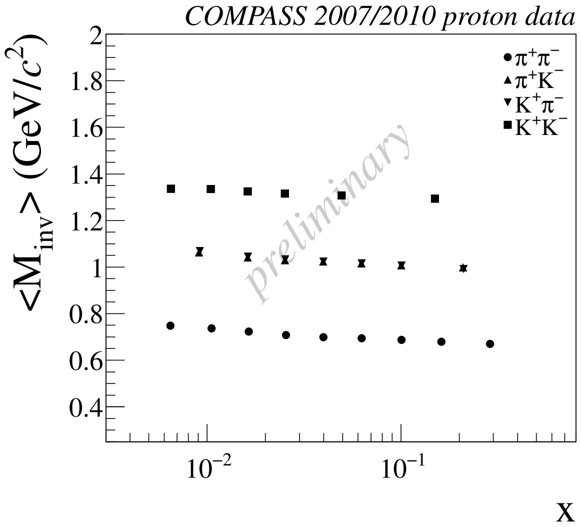
Data selection ▶ mean values 2

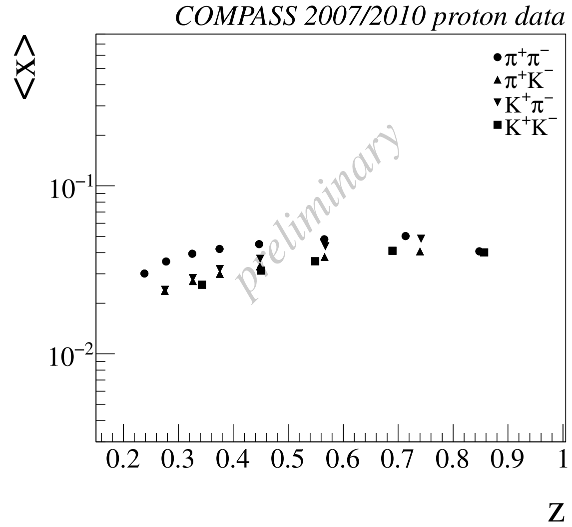
HERMES



COMPASS







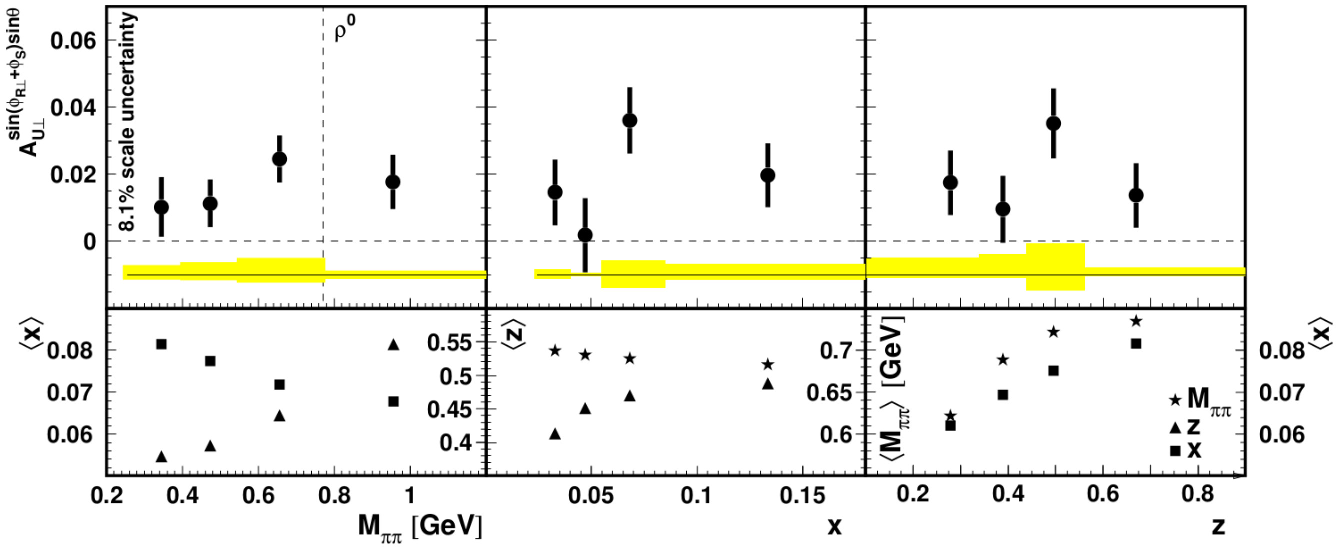
The asymmetries

A_{UT}

$\pi^+\pi^-$ pairs

HERMES and COMPASS

HERMES ▶ $\pi^+\pi^-$ dihadron asymmetries A_{UT}

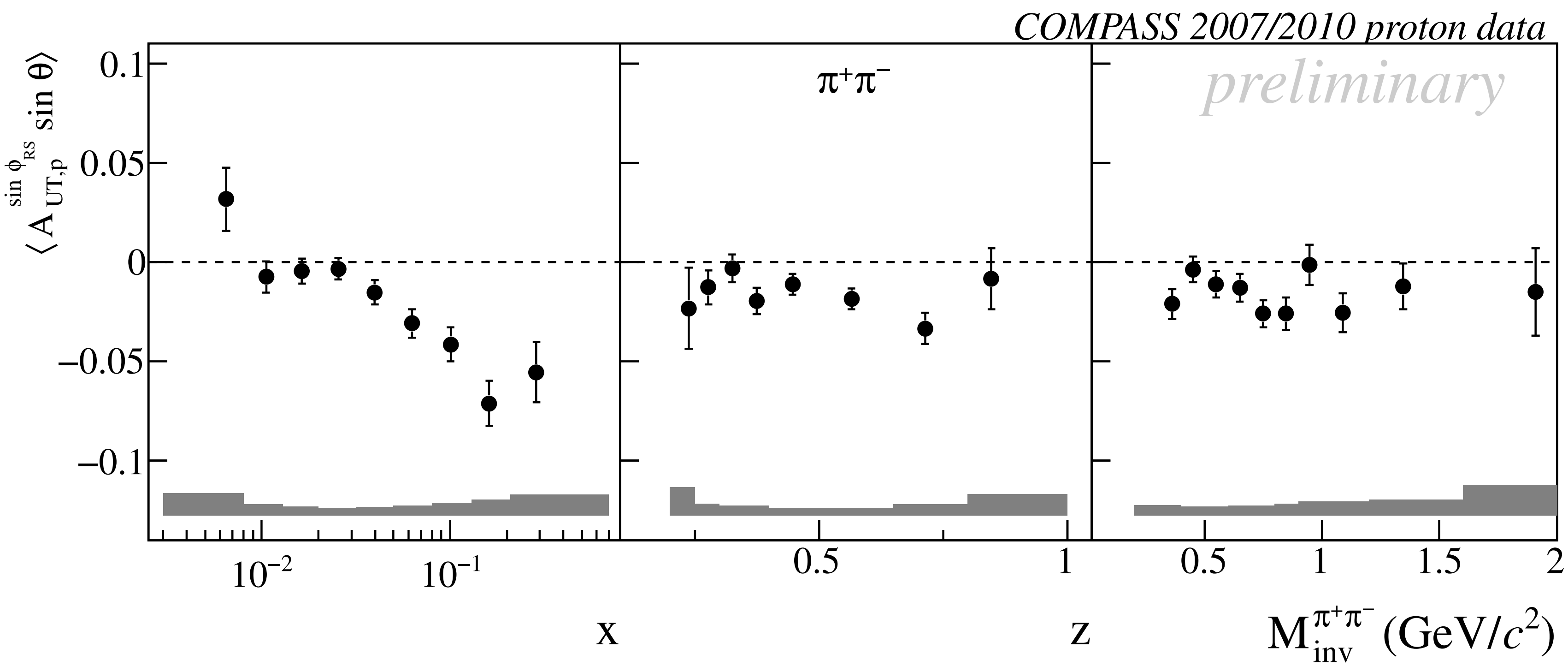


Clear non-zero asymmetry amplitudes in high x region and in ρ^0 mass bin

$\hookrightarrow$ First indication of a non-zero h_1 Transversity PDF and $H_1^{\sphericalangle}$ IFF

A. Airapetian *et al.* [HERMES Collaboration], JHEP **0806** (2008) 017

COMPASS ▶ $\pi^+\pi^-$ asymmetries A_{UT}

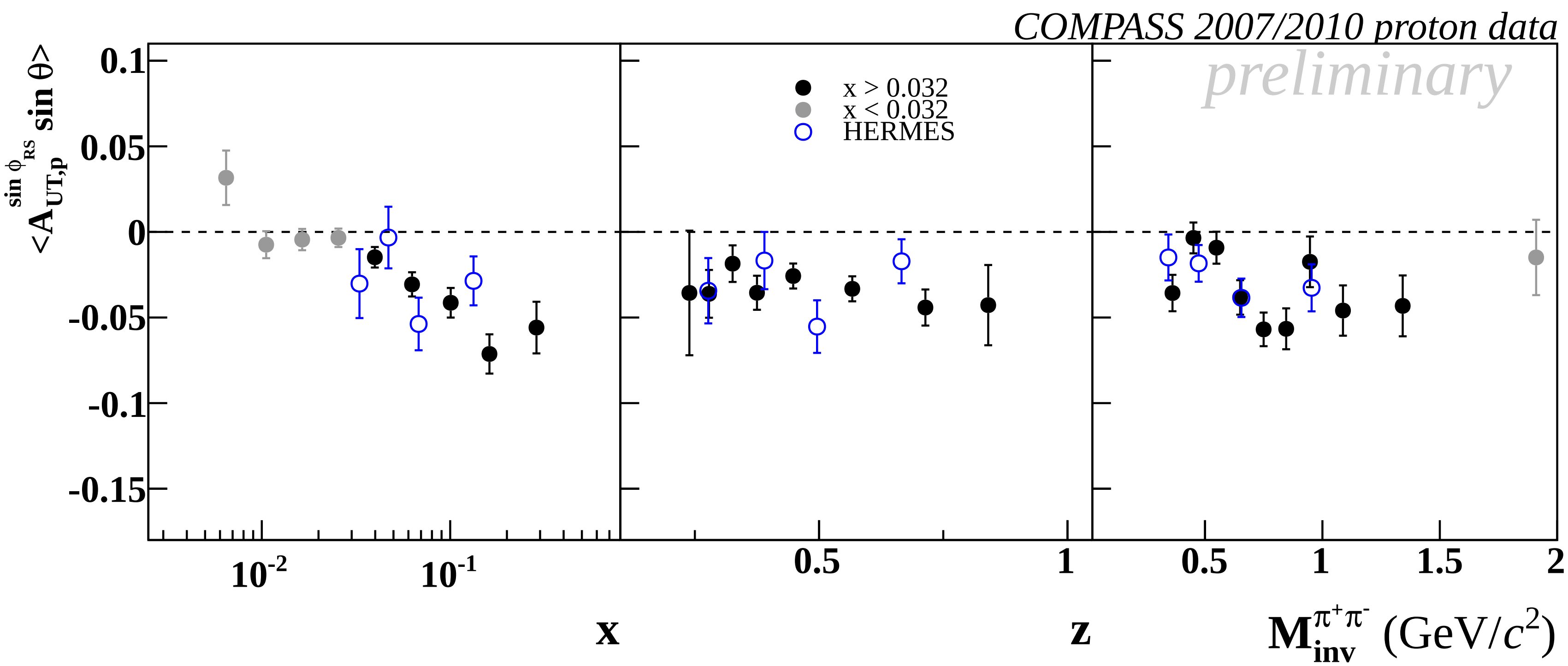


↪ Clear asymmetry amplitudes of $\pi^+\pi^-$ pairs in high x region and around the ρ^0 mass

↪ Confirmation of HERMES results with increased statistical precision in a larger kinematic range in x and M_{inv} with a higher $\langle Q^2 \rangle$.

Braun C. DIS2013

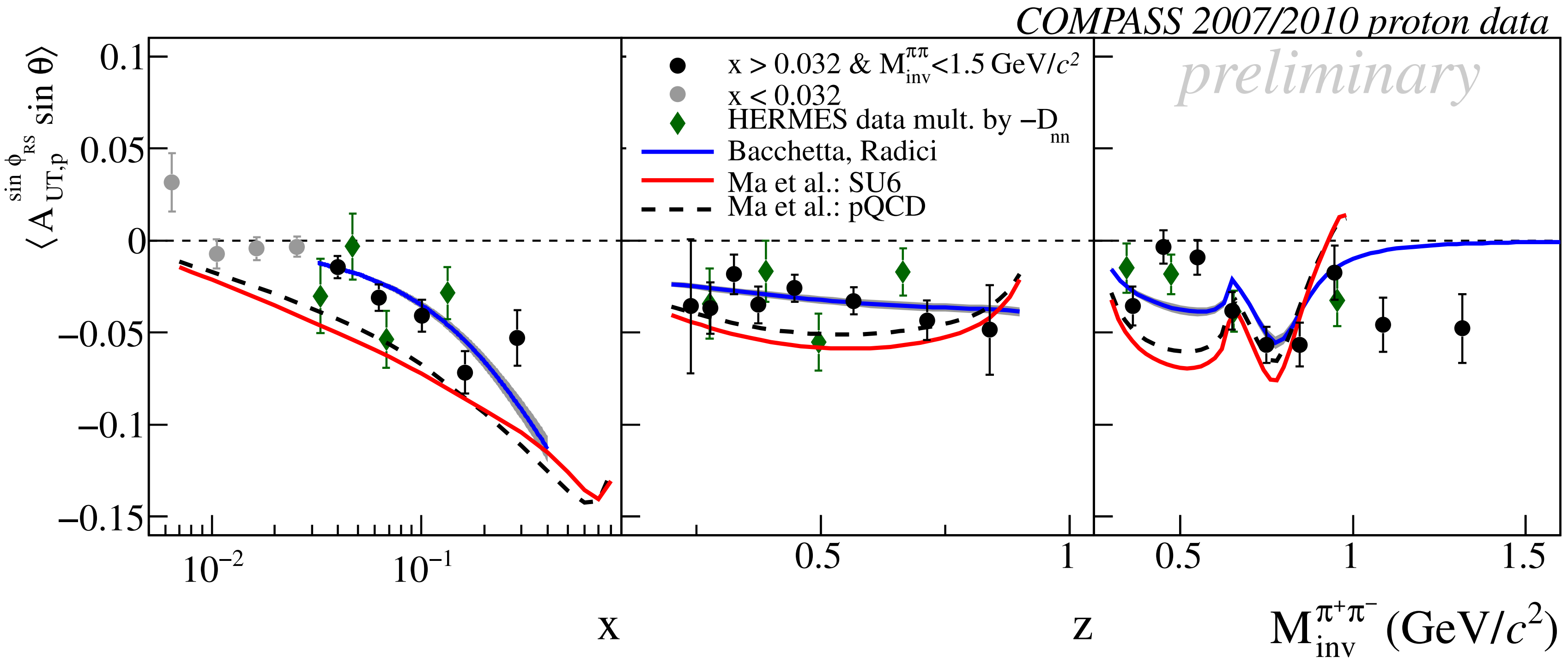
HERMES *vs.* COMPASS ▶ $\pi^+\pi^-$ asymmetries A_{UT}



↪ Good agreement between HERMES and COMPASS results within the uncertainties.

HERMES data scaled with $\frac{1}{D_{nn}} = \frac{1-y+y^2/2}{1-y}$ and sign changed

HERMES *vs.* COMPASS ▶ $\pi^+\pi^-$ asymmetries A_{UT}

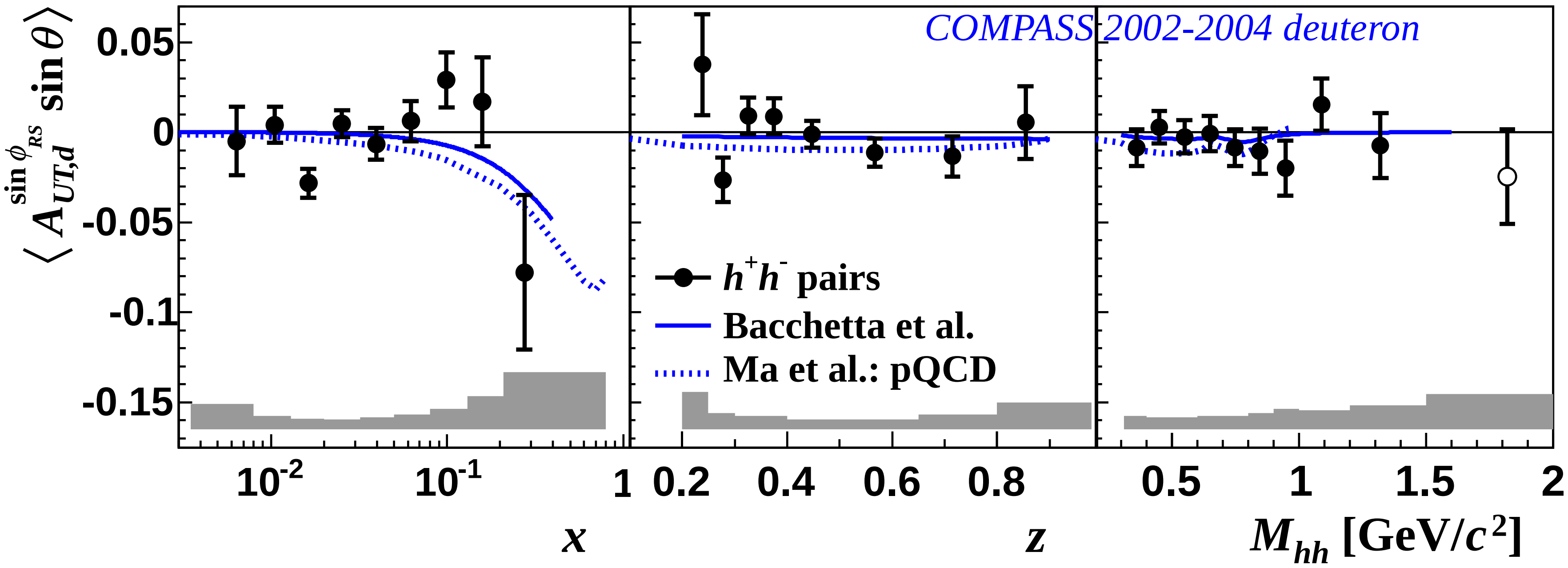


↪ Common trend of data and model predictions

- Good agreement in x and z dependence
- Very good agreement around ρ^0 mass in strength and shape
- No significant asymmetry amplitude from in η, η', K^0 and ω region?

Bacchetta A. and Radici M., Phys. Rev. D **74** (2006) 114007
Ma B.-Q. *et al.*, Phys. Rev. D **77** (2008) 014035

COMPASS ► h^+h^- asymmetries A_{UT}^d

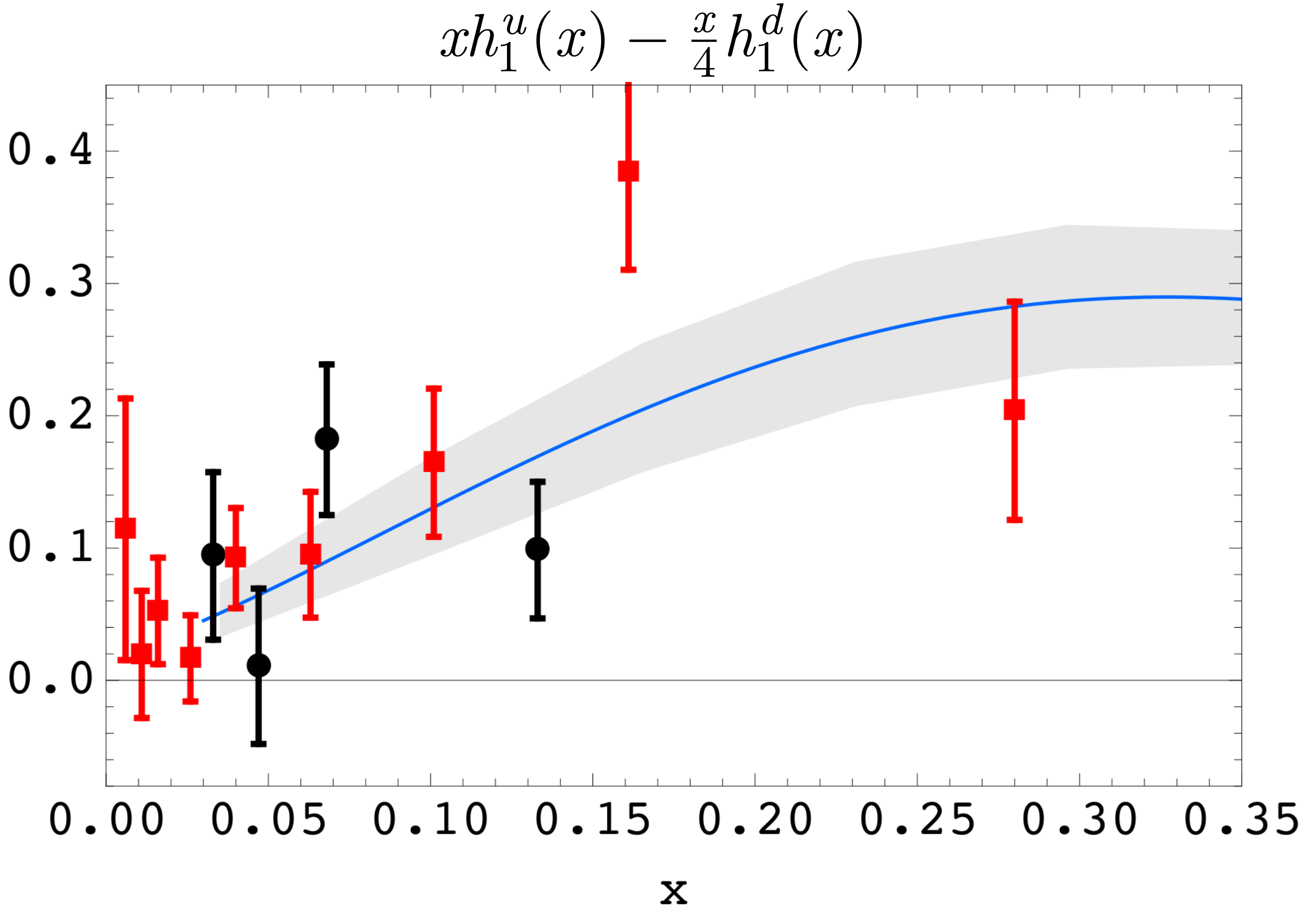


Adolph C. *et al.* [COMPASS Collaboration], Phys. Lett. B **713** (2012) 10
Bacchetta A. and Radici M., Phys. Rev. D **74** (2006) 114007
Ma B.-Q. *et al.*, Phys. Rev. D **77** (2008) 014035

↪ Asymmetries for deuteron target compatible with zero within the uncertainties

The models also predict a cancellation of the u and d quark transversity on the deuteron.

HERMES & COMPASS ▶ extraction of transversity



Combination of valence u, d flavors for the transversity distribution from:

black:
HERMES Airapetian *et. al.*, JHEP, **06** (2008) 017

red:
COMPASS Adolph *et. al.*, Phys. Lett. B **713** (2012) 10-16, arXiv:1202.6150

talk by A. Courtoy
A. Bachetta, A. Courtoy and M. Radici, PRL **107** (11), arXiv:1206.1836

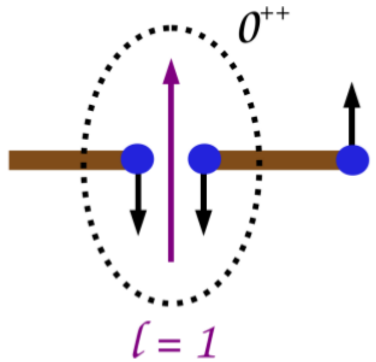
The asymmetries

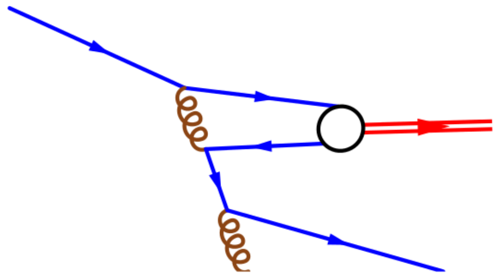
A_{UT}

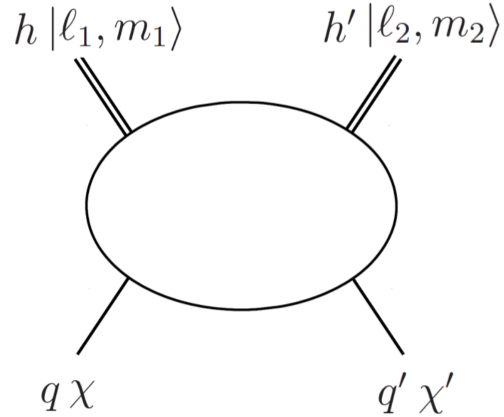
$\pi^+\pi^0$ and $\pi^-\pi^0$ pairs

HERMES

HERMES ▶ $\pi^+\pi^0$ & $\pi^-\pi^0$ new formalism 1







- Artru/Lund string fragmentation model cannot be easily related to the published notation
- D_1 is unpolarized FF with $(\chi = \chi')$
- $H_1^\perp$ is generalized Collins FF with $(\chi \neq \chi')$
- Fragmentation functions expanded into partial waves in the direct sum basis $|\ell, m\rangle$ (rather then direct product basis $|\ell_1, m_1\rangle\,|\ell_2, m_2\rangle$):

$$D_1 = \sum_{\ell=1}^{\infty} \sum_{m=-\ell}^{\ell} P_{\ell,m}(\cos\vartheta)\, e^{\imath m(\phi_R-\phi_k)}\, D_1^{|\ell,m\rangle}(z, M_{hh}, |\boldsymbol{k}_T|)$$

$$H_1^\perp = \sum_{\ell=1}^{\infty} \sum_{m=-\ell}^{\ell} P_{\ell,m}(\cos\vartheta)\, e^{\imath m(\phi_R-\phi_k)}\, H_1^{\perp|\ell,m\rangle}(z, M_{hh}, |\boldsymbol{k}_T|)$$

Gliske S. PhD thesis (2011)

HERMES ▶ $\pi^+\pi^0$ & $\pi^-\pi^0$ new formalism 2

$\frac{1}{2} \otimes \frac{1}{2} = 1 \oplus 0 = 1\,\mathrm{PSM} + 1\,\mathrm{long.\ VM} + 2\,\mathrm{transv.\ VM}$

- PSM $= |0,0\rangle$; long. VM $= |1,0\rangle$; transv. VM $= |1,\pm1\rangle$
- Artru/Lund: PSM asymmetry has opposite sign of transv. pol. VM (left *vs.* right) and $|1,0\rangle$ is zero
- Collins FF includes pairs of dihadrons: CG algebra $\rightarrow |2,\pm2\rangle$ with opposite sign as PS (*cf.* Collins π^+ *vs.* π^-)

$|1,\pm1\rangle$ moments allow collinear access to the transversity PDF

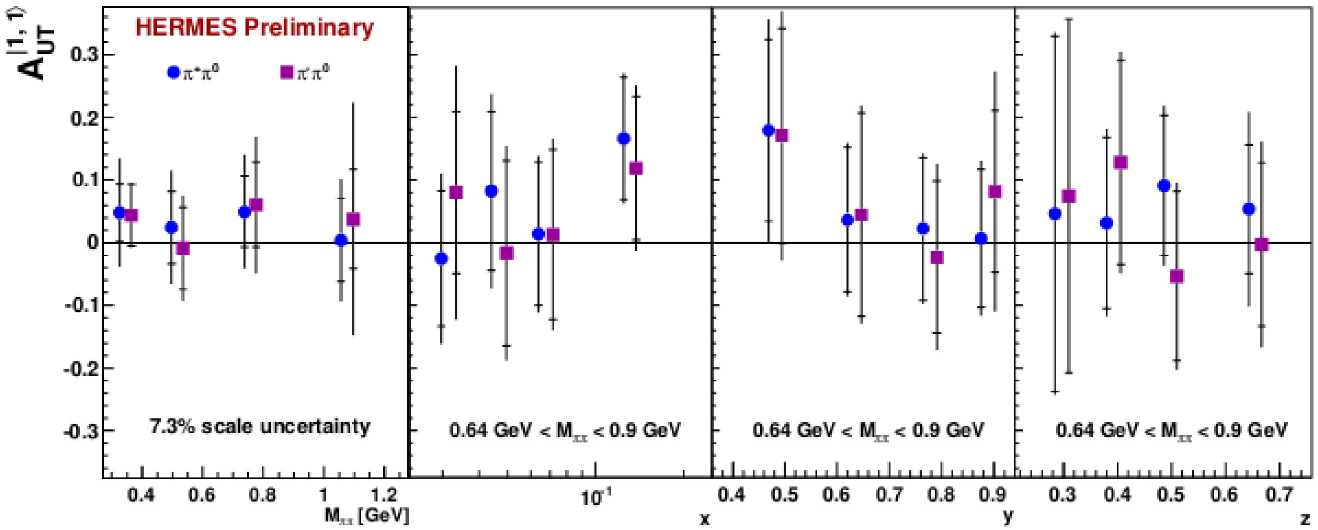
$\Rightarrow$ $H_1^{\perp|1,1\rangle}$ is related to usual IFF $H_1^{\sphericalangle}$ including also *pp* interference

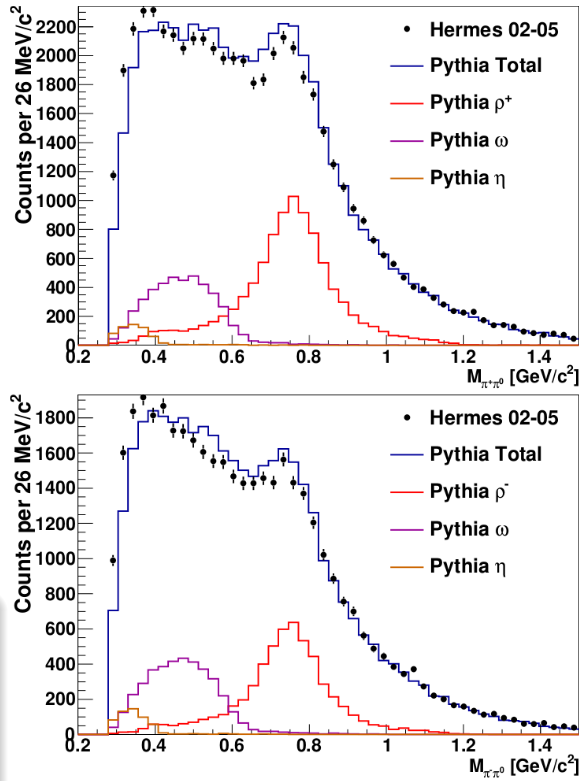
$|2,\pm2\rangle$ moments are transverse momentum dependent and related to string fragmentation models

$\Rightarrow$ Cross-section has direct access to $H_1^{\perp|2,\pm2\rangle}$

$\Rightarrow$ $H_1^{\perp|2,\pm2\rangle}$ should have opposite sign as pseudo-scalar $H_1^{\perp}$

HERMES ▶ $\pi^+\pi^0$ & $\pi^-\pi^0$ dihadron asymmetries $|1,1\rangle$





Gliske S. DIS2013

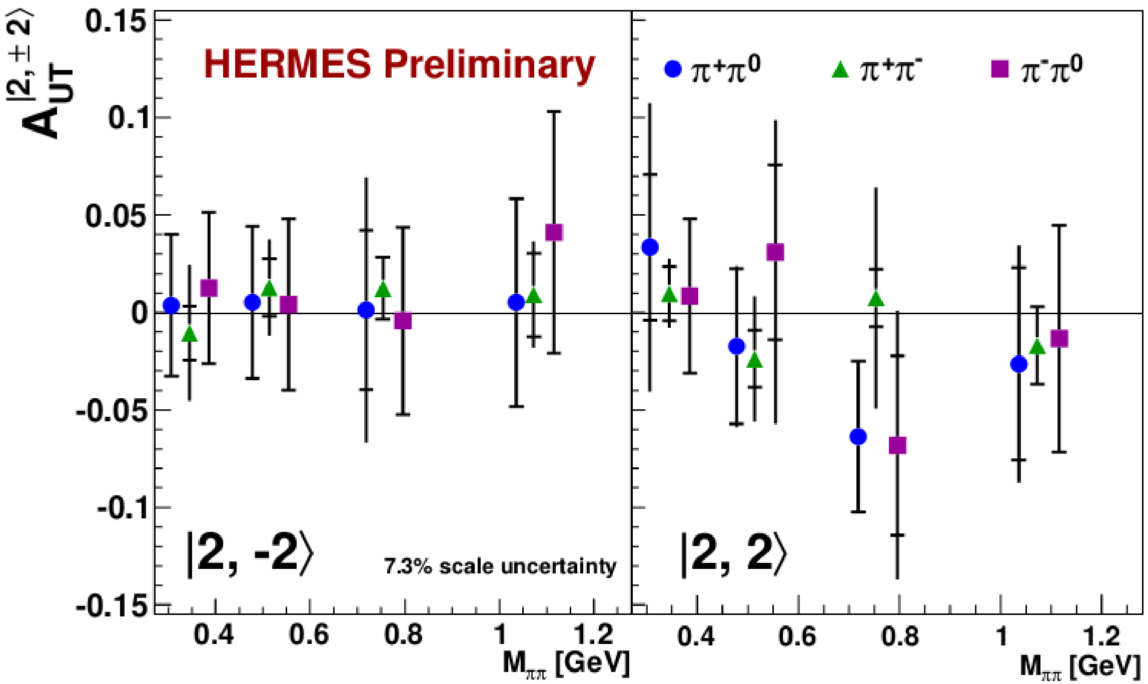
$$\phi_R = \pm \arccos\left(\frac{(\boldsymbol{q}\times\boldsymbol{k})\cdot(\boldsymbol{P}_h\times\boldsymbol{R_T})}{|\boldsymbol{q}\times\boldsymbol{k}||\boldsymbol{P}_h\times\boldsymbol{R_T}|}\right)$$

(difference is suppressed by $1/Q^2$)

$\hookrightarrow$ $|1,1\rangle$ limited statistics for $\pi^\pm\pi^0$

- still sizeable mean asymmetry
- consistent signs of all $\pi^\pm\pi^0$ pairs
- Despite uncertainties, may still help constrain global fits

HERMES ▶ $\pi^+\pi^-$, $\pi^+\pi^0$ & $\pi^-\pi^0$ dihadron asymmetries $|2, \pm 2\rangle$



Gliske S. DIS2013

↪ $|2, -2\rangle$ moment is compatible with zero for all combinations:

Transversity TMD causes frag. quark to have positive polarization → $|2, -2\rangle$ must be zero as this PW requires negative polarization

↪ $|2, +2\rangle$ moment is consistent with model expectations:

No indication of any signal outside the ρ mass bin → no non-resonant pion-pairs in p-wave

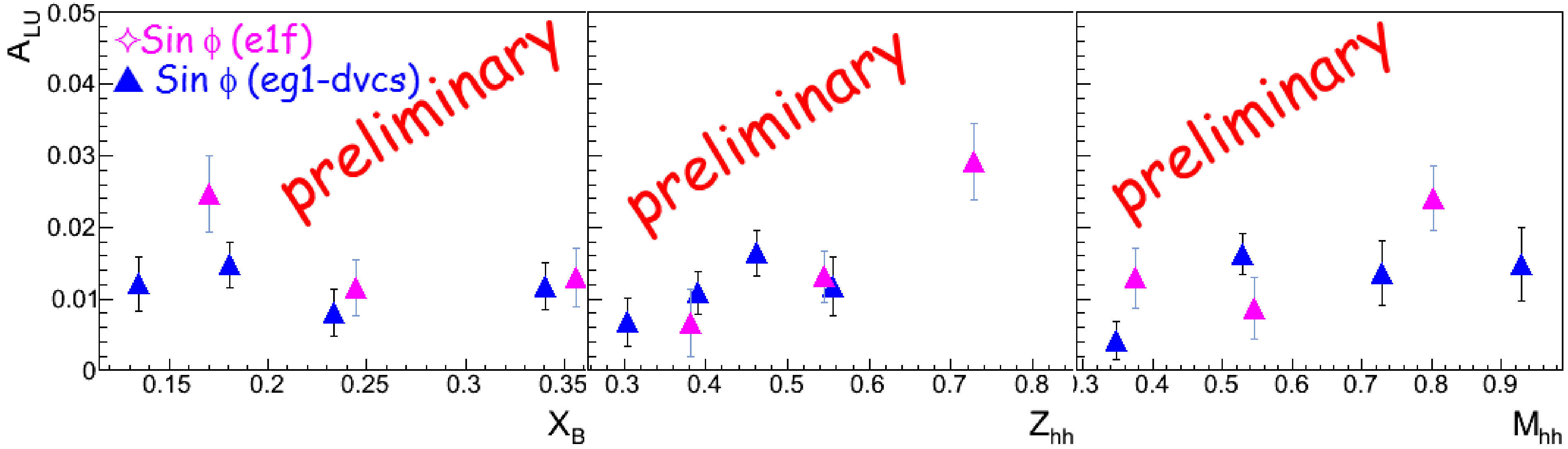
The asymmetries

A_{UL} and A_{LU}

$\pi^+\pi^-$ pairs

JLab

JLab ▶ $\pi^+\pi^-$ dihadron asymmetries A_{LU}

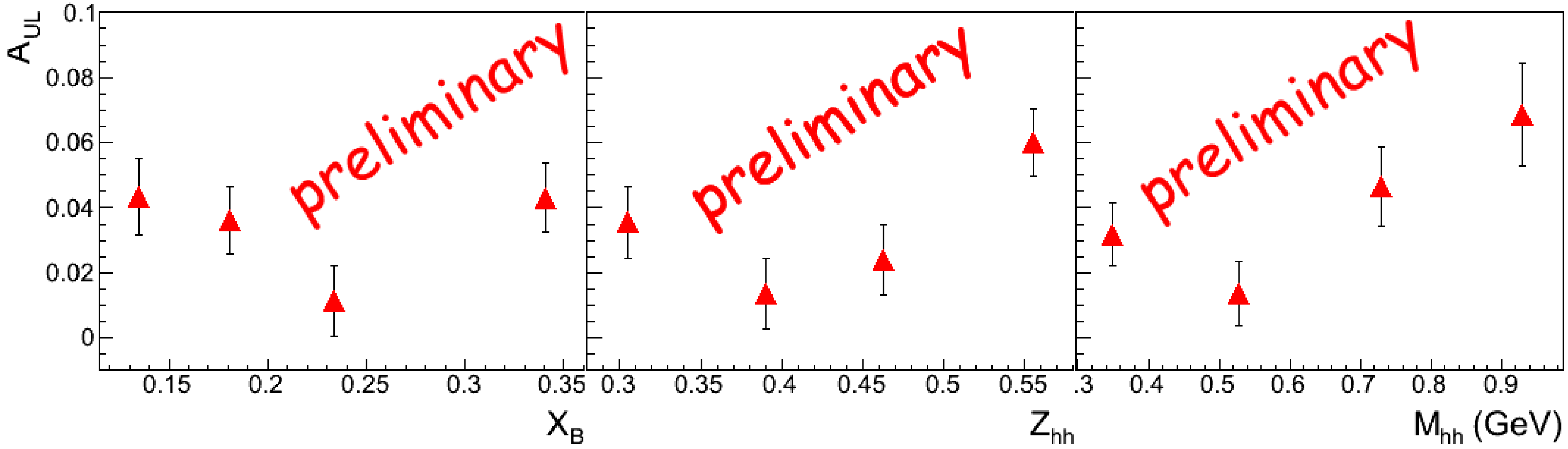


↪ Sizeable asymmetry amplitudes, from independent data sets
↪ Very small statistical uncertainties
⇒ Compatible results from 2 different setups

- e1f ($21\,\mathrm{fb}^{-1}$): unpol. liquid hydrogen target, $E_{beam} = 5.5\,\mathrm{GeV}$, $\langle\lambda\rangle = 75\,\%$
- eg1-dvcs ($50\,\mathrm{fb}^{-1}$): long. pol. NH_3 target, $E_{beam} = 5.967\,\mathrm{GeV}$, $\langle P_T\rangle = 80\,\%$, $\langle\lambda\rangle = 85\,\%$

Pereira S.A. Como2013

JLab ▶ dihadron asymmetries A_{UL}



↪ Sizeable asymmetry amplitudes
↪ Very small statistical uncertainties

Pereira S.A. Como2013

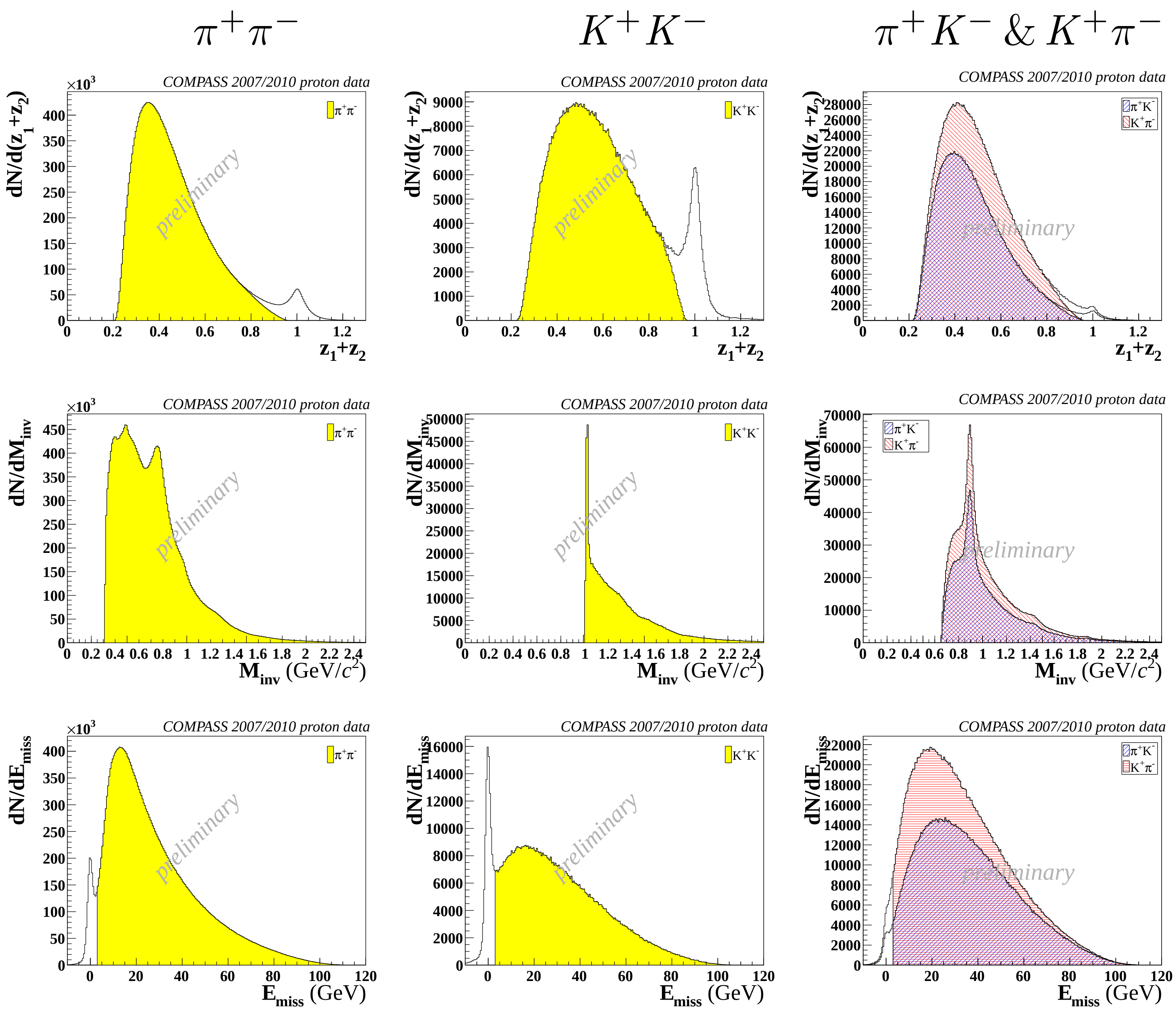
The asymmetries

A_{UT}

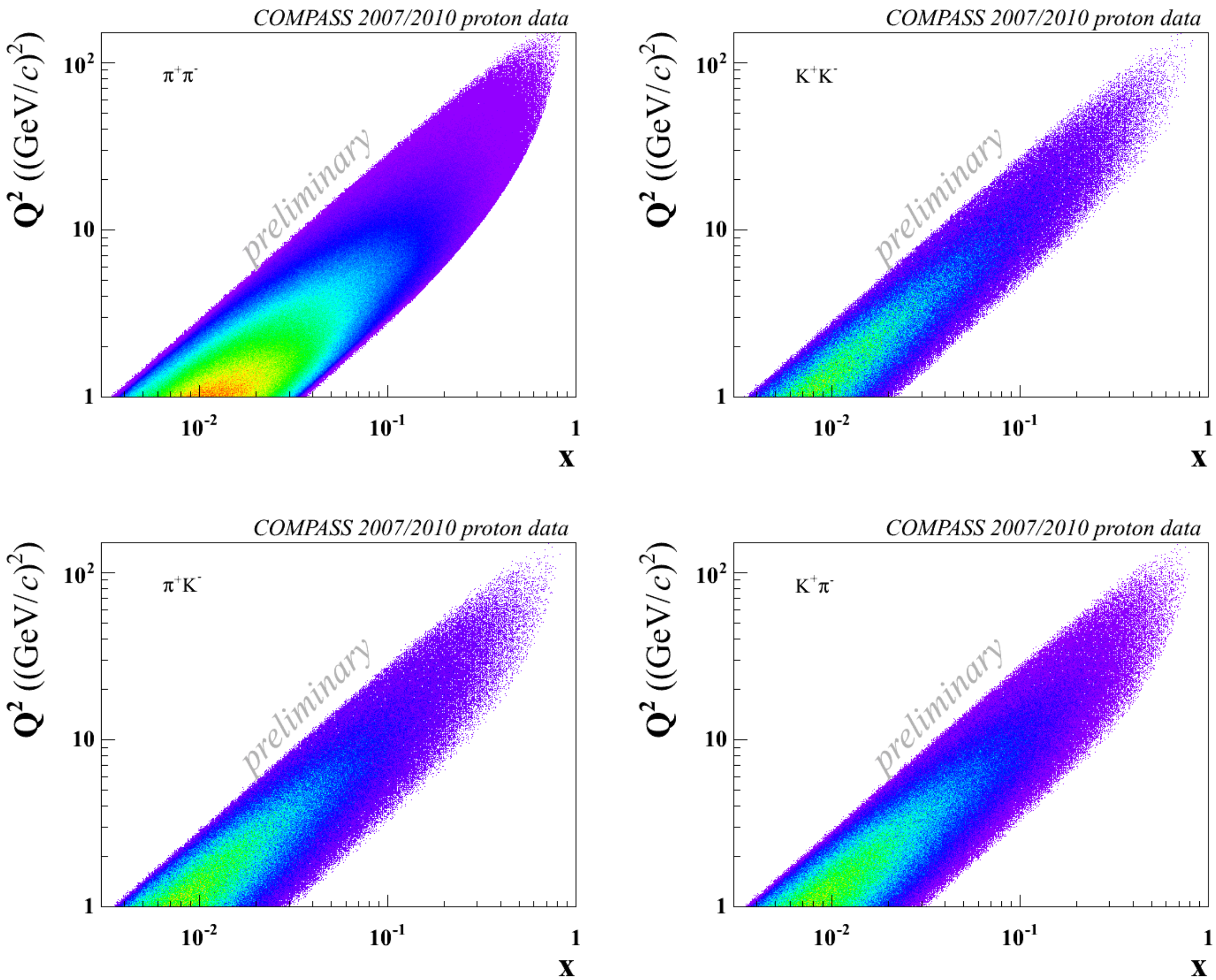
pairs with strangeness: K^+K^-, $K^+\pi^-$ and π^+K^-

HERMES & COMPASS

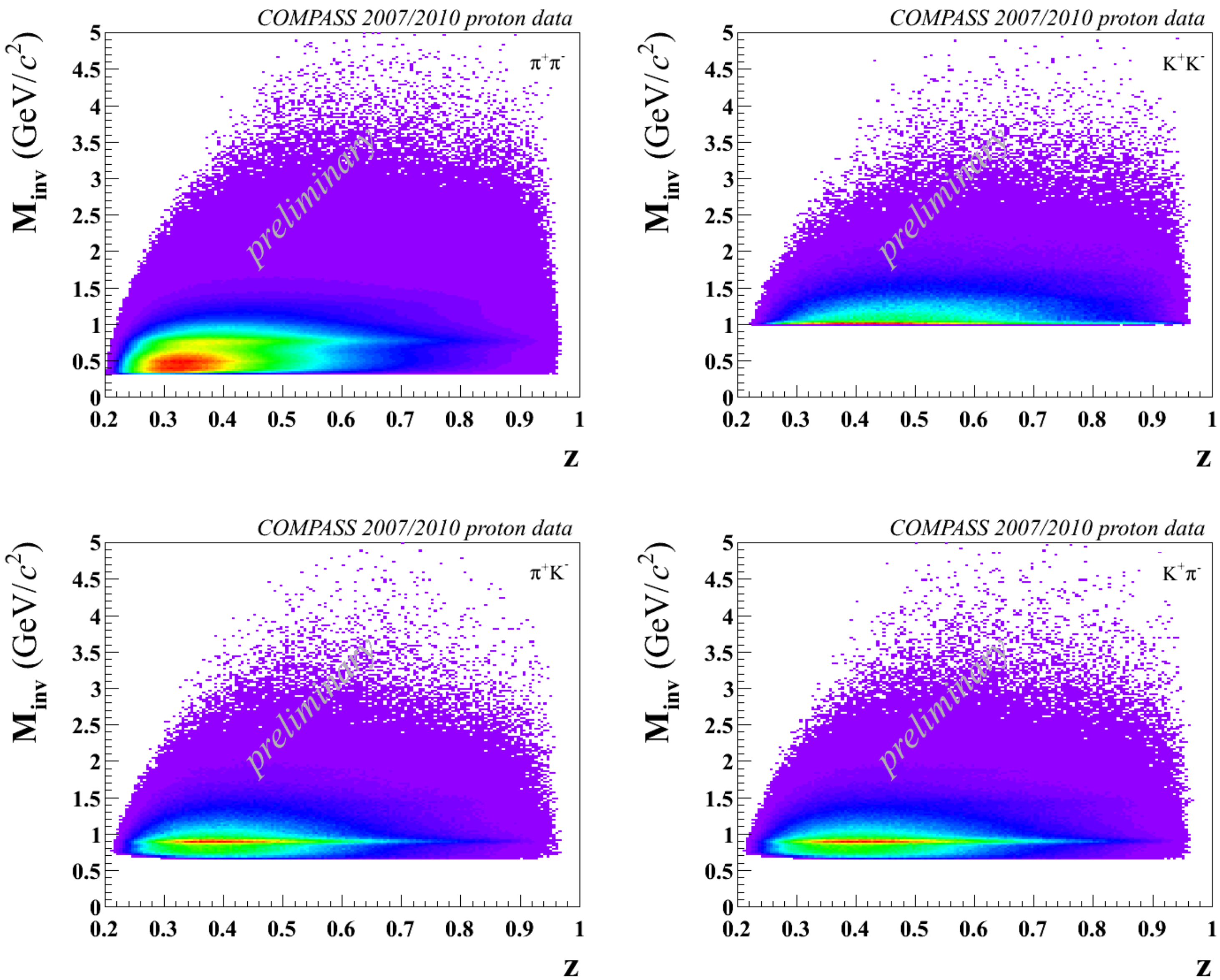
COMPASS ▶ $z_1 + z_2$, M_{inv} and E_{miss} distributions



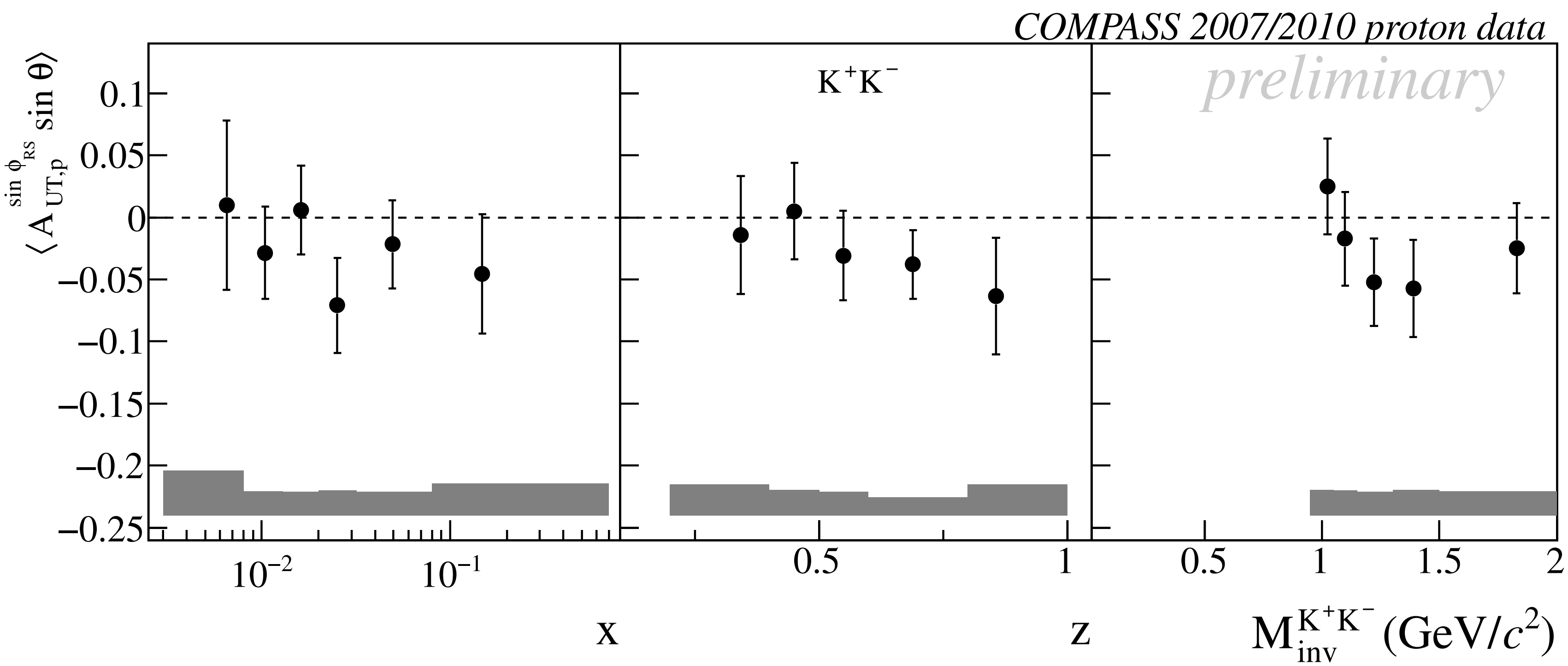
COMPASS ▶ Q_2 vs. x distributions



COMPASS ▶ M_{inv} vs. z distributions



COMPASS ▶ K^+K^- asymmetries A_{UT}

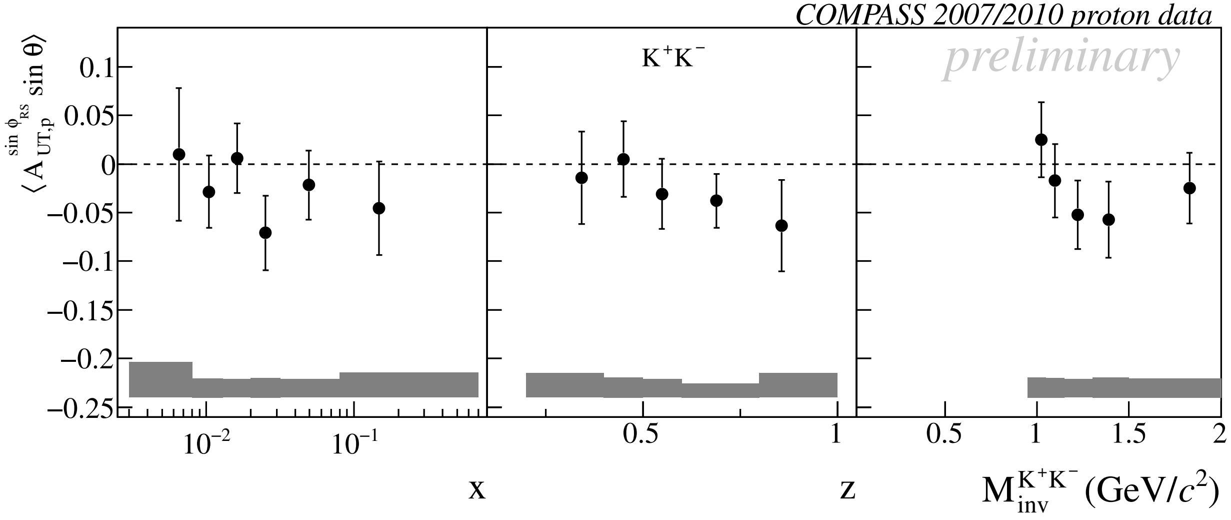


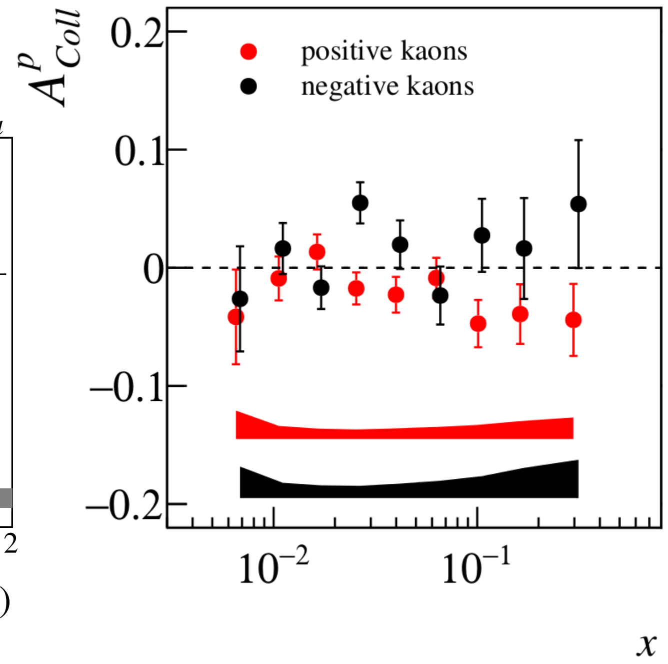
↪ no clear trend & large statistical uncertainties

- weak indication of a non-zero asymmetry at high x
- weak indication of a non-zero asymmetry at high z
- indication of a wide dip at $M_{inv} \approx 1.4\,\mathrm{GeV}/c^2$

Braun C. DIS2013

COMPASS ▶ K^+K^- asymmetries A_{UT}





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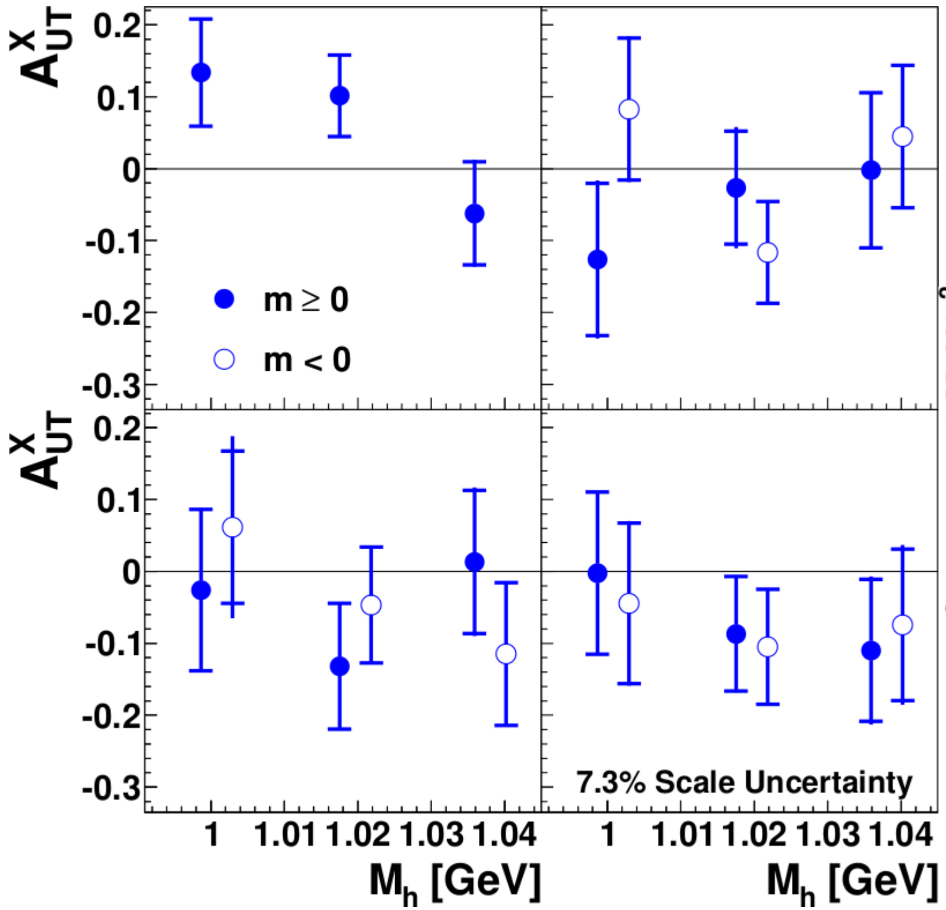
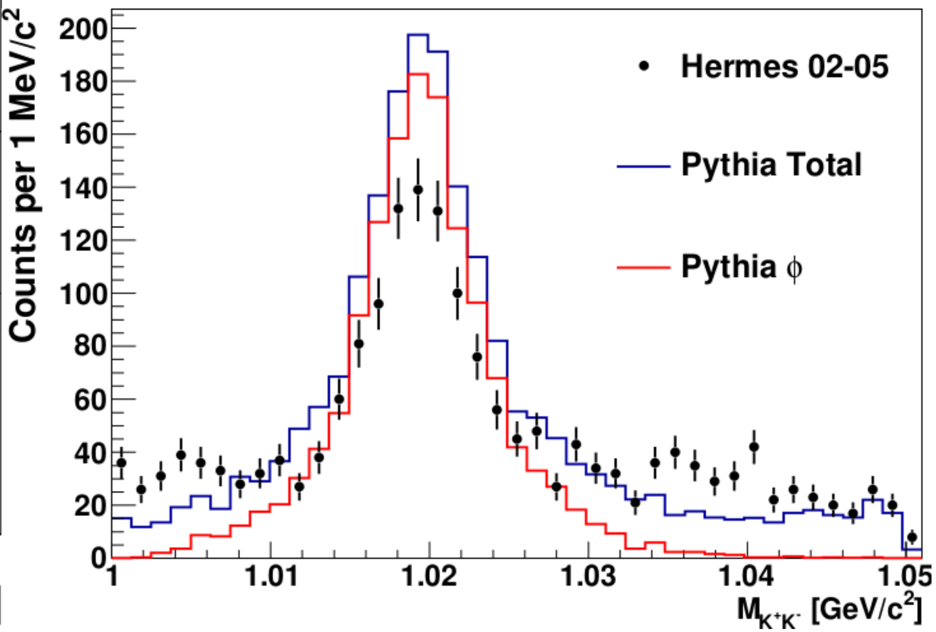
Braun C. DIS2013

COMPASS *vs.* HERMES ▶ K^+K^- asymmetries A_{UT}



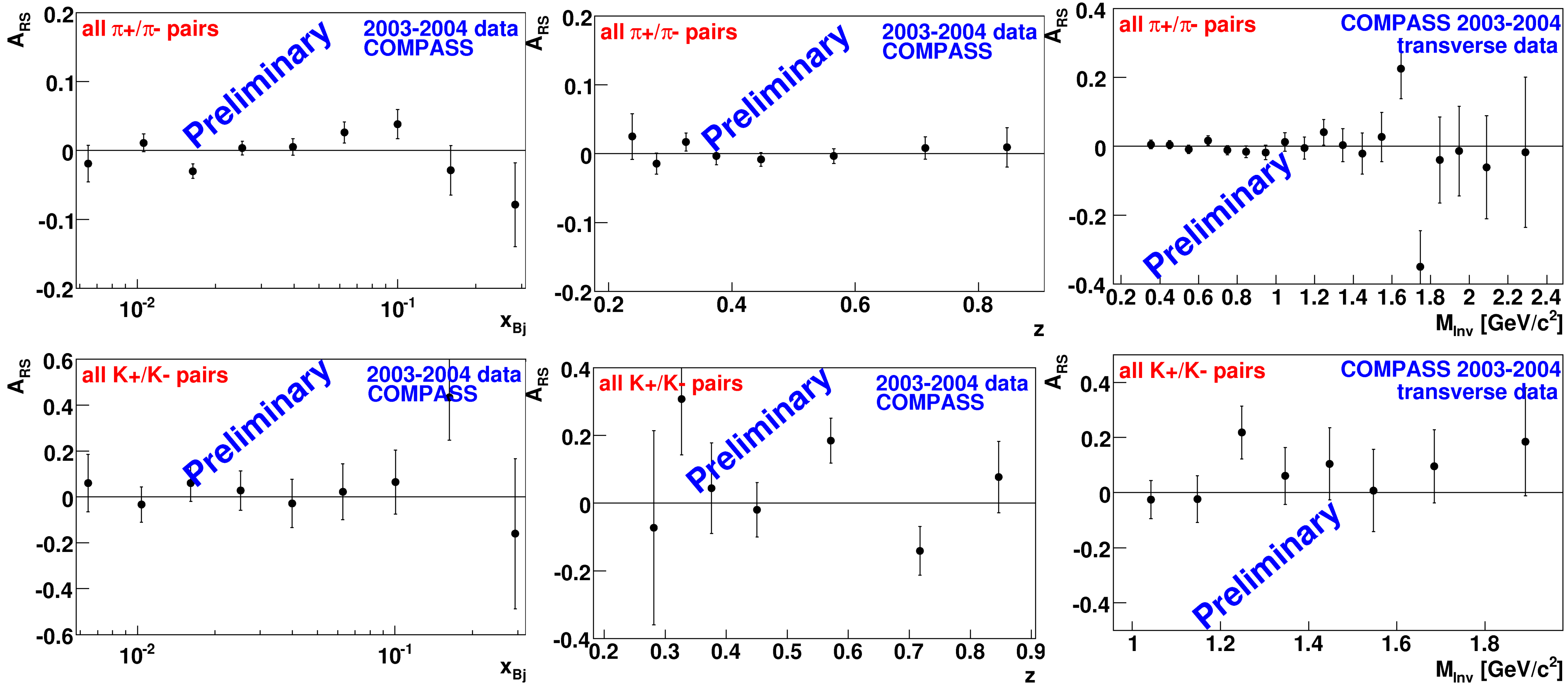


$\hookrightarrow$ indication of a signal

- top row: $|0,0\rangle$, $|1,\pm1\rangle$: signal in $\phi(1020)$ bin?
- bottom row: $|2,\pm1\rangle$, $|2,\pm2\rangle$: opposite signs to $|0,0\rangle$

from PhD thesis of Stephen Gliske, Univ. Michigan 2011

COMPASS ▶ $\pi^+\pi^-$ & K^+K^- asymmetries A^d_{UT}

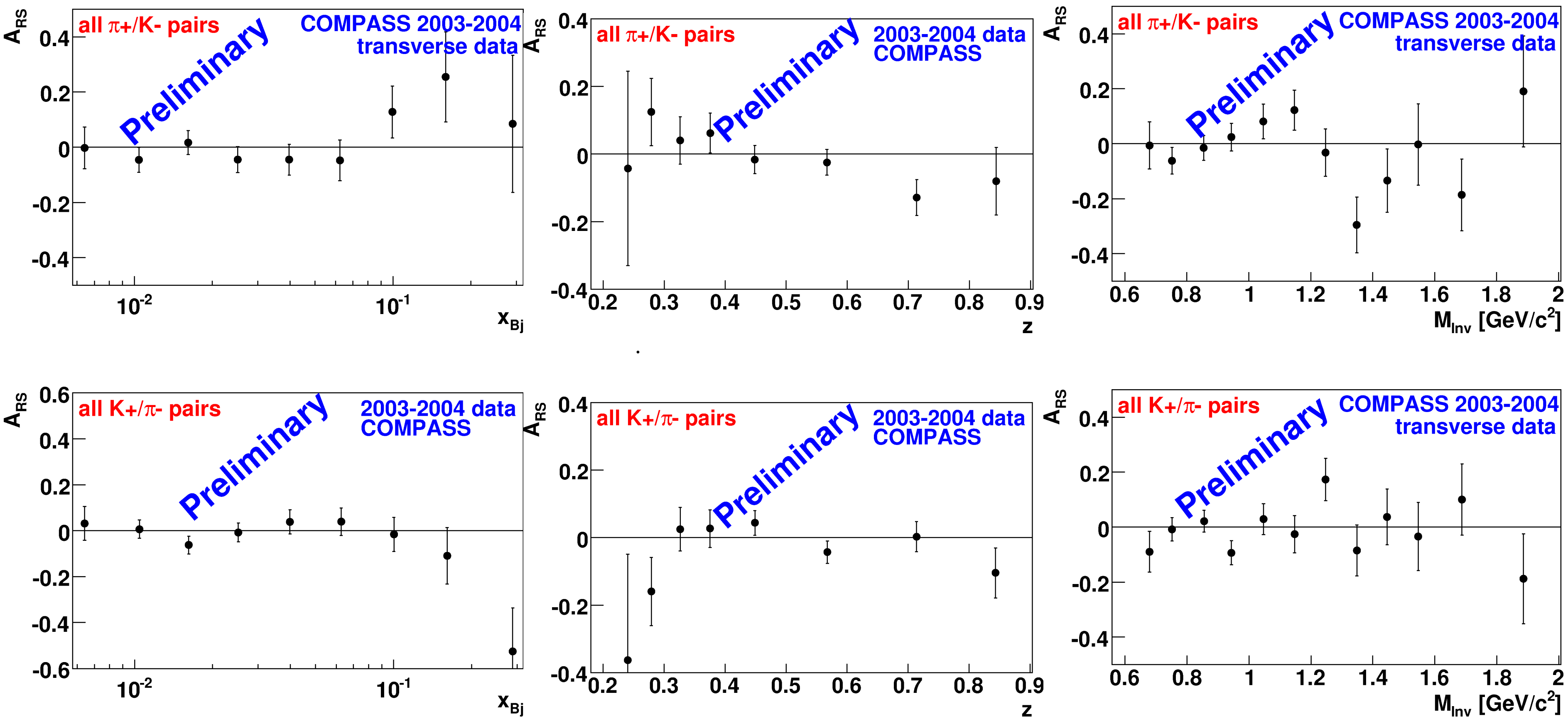


2002-04 deuteron data 2-hadron asymmetries: $\pi^+\pi^-$ pairs (top), K^+K^- pairs (bottom)

$\hookrightarrow$ h^+h^- asymmetries follow mostly $\pi^+\pi^-$ signal

$\pi^+\pi^-$ asymmetries are small and compatible with zero
K^+K^- no signal & low statistics

COMPASS ▶ π^+K^- & $K^+\pi^-$ asymmetries A^d_{UT}

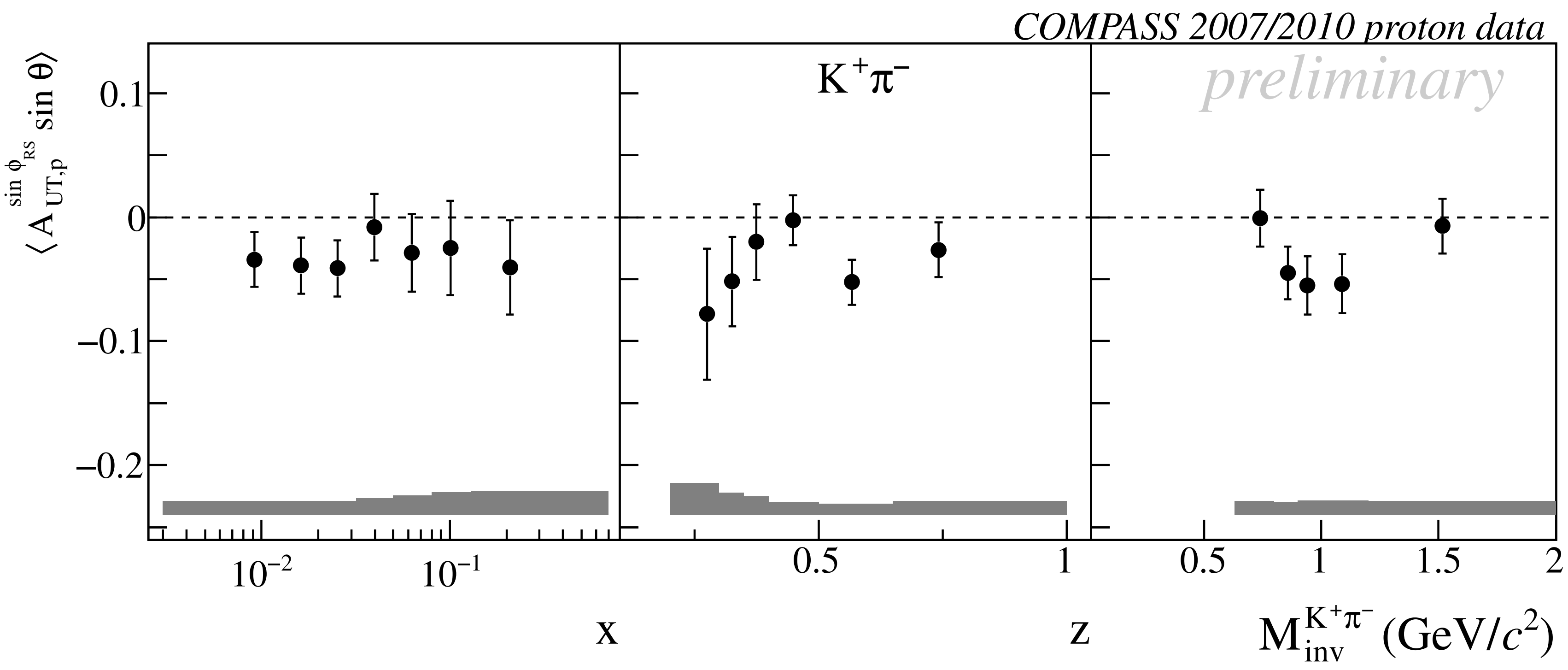


2002-04 deuteron data 2-hadron asymmetries: all π^+K^- pairs (top), $K^+\pi^-$ pairs (bottom)

$\hookrightarrow$ π^+K^- & $K^+\pi^-$ signal compatible with zero

weak indication of opposite sign of the signal in x dependence

COMPASS ▶ $K^+\pi^-$ asymmetries A_{UT}



- negative mean value with constant trend in x
- weak indication of a non-zero asymmetry at low and high z
- indication of a wide dip at $M_{inv} \approx 1.0\,\mathrm{GeV}/c^2$

⇒ indication of signals from $K^*/K_{1/2}$ decays

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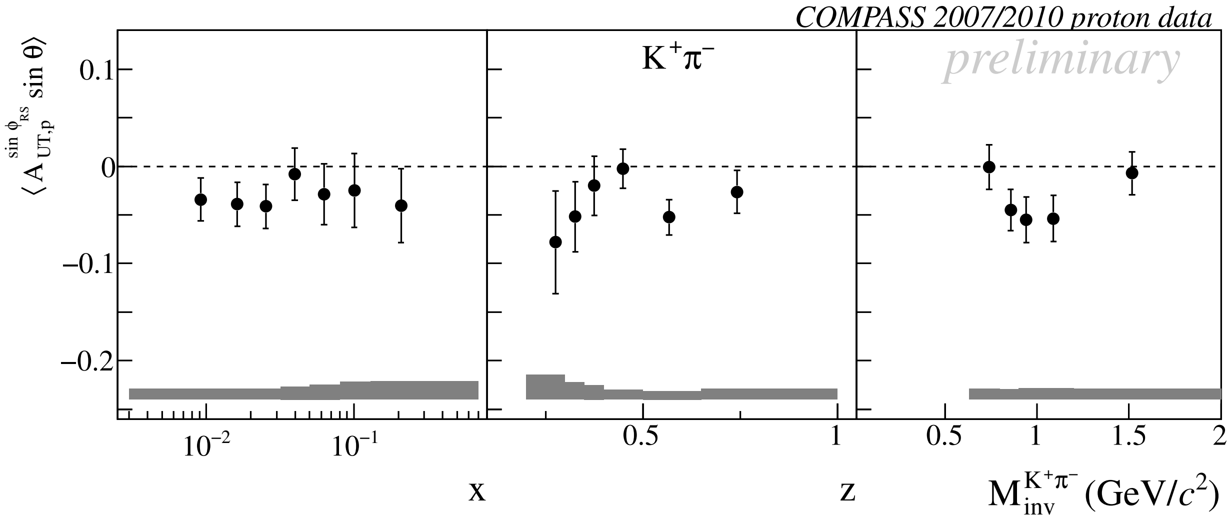
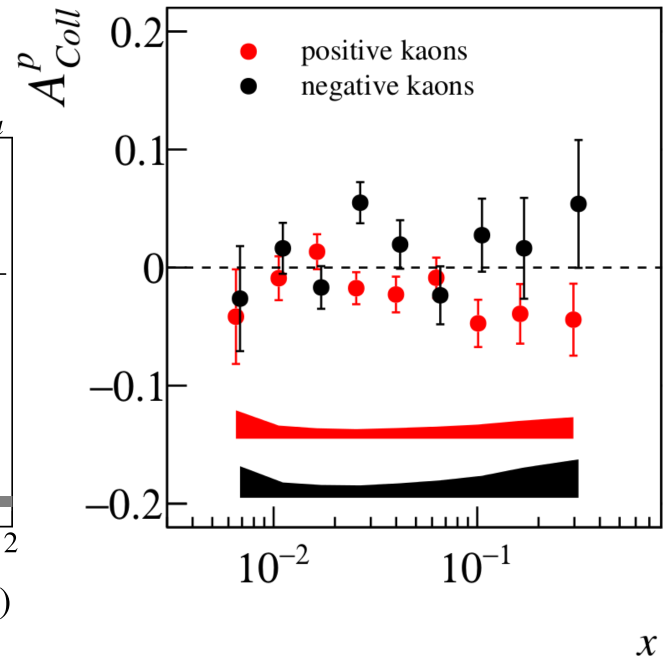
COMPASS ▶ $K^+\pi^-$ asymmetries A_{UT}





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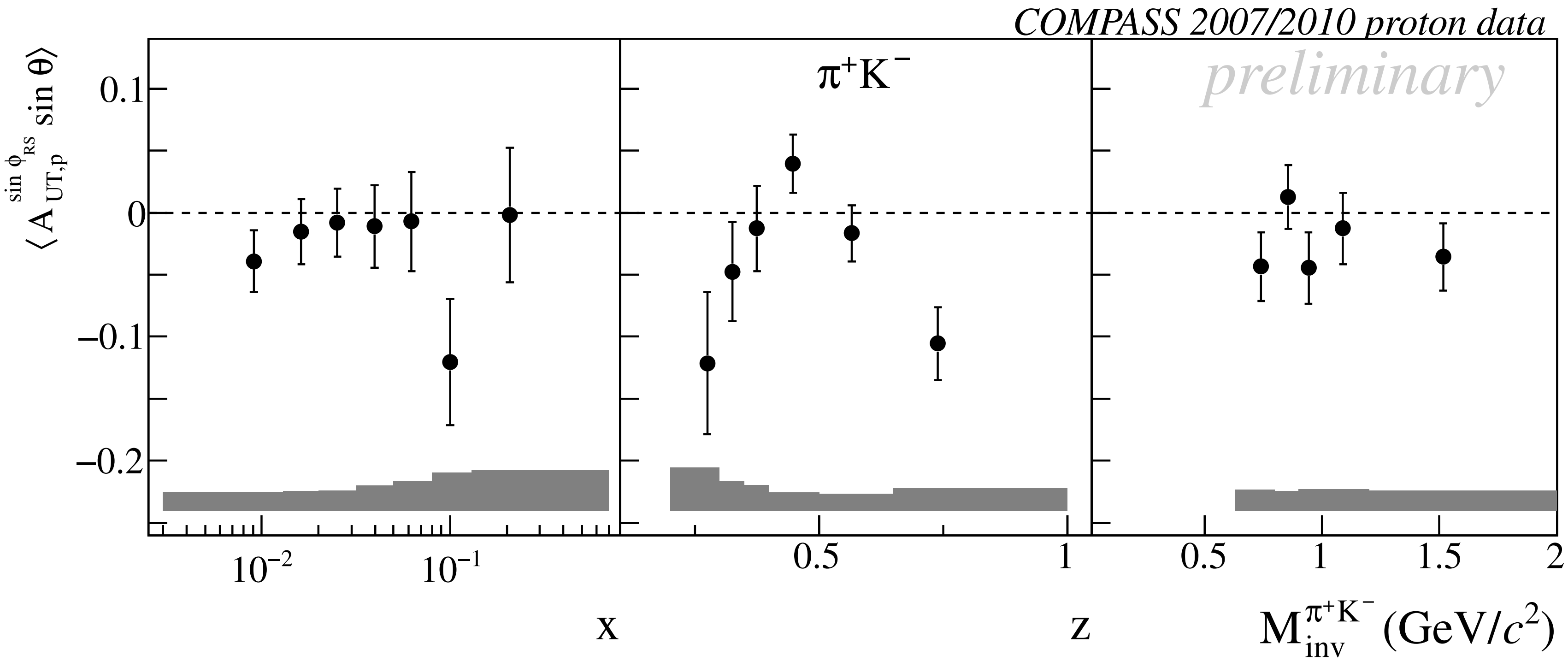
COMPASS ▸ π^+K^- asymmetries A_{UT}



- x no signal
- z significant slope with a relative maximum around 0.45
- M_{inv} no clear signal

⇒ No clear signal in mass range

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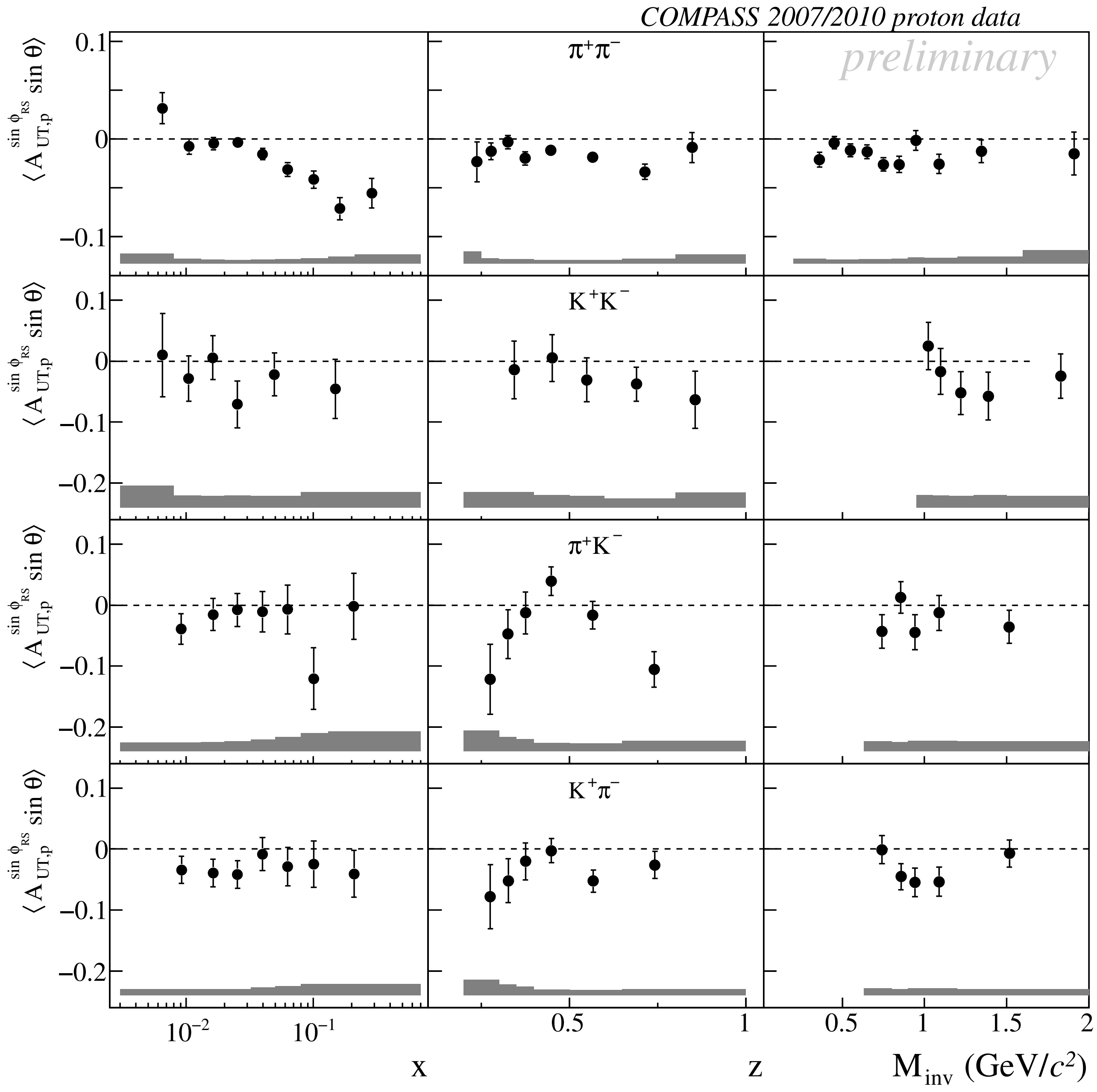
COMPASS ▶ all identified pairs A_{UT}



Conclusion and outlook

Conclusion and outlook ▶ Conclusion

General

- non-zero Transversity TMD PDF h_1 and IFF $H_1^{\sphericalangle}$

COMPASS

- Full set $\pi^+\pi^-$, K^+K^-, $K^+\pi^-$, π^+K^- from proton data

HERMES

- $\pi^\pm\pi^0$ pairs will assist in the u-d flavor separation
- Unique access to the TMD spin structure of fragmentation
- Testing the Lund/Artru model via $|2,\pm2\rangle$ moments
- $|2,-2\rangle$ must be zero if h_1 causes the fragmenting quark to have positive polarization as this partial wave requires negative polarization
- $|2,+2\rangle$ no non-resonant pion-pairs in p-wave, sizeable for $\rho^\pm$, zero for ρ^0

JLab 6 GeV

- sizeable A_{LU}, A_{UL} asymmetries of $\pi^+\pi^-$ with very small statistical uncertainties

Conclusion and outlook ▶ Outlook

COMPASS

- Reanalysis of deuteron data with homogeneous cuts, binning and methods *w.r.t.* proton 2007/2010 analyses for a full flavor separation incl. strangeness
- $\pi^{\pm}\pi^{0}$ pair asymmetries
- A_{UL}, A_{LL} asymmetries

HERMES

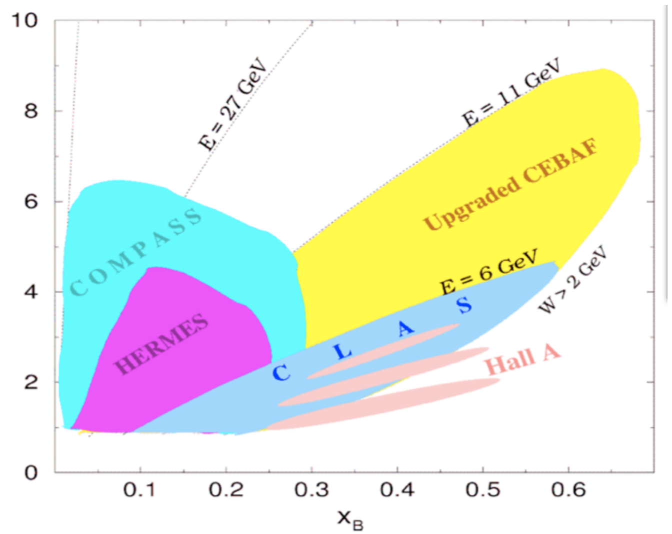
- $K^{+}K^{-}$ (some data near ϕ mass), $\pi^{+}\gamma\gamma$, $\pi^{-}\gamma\gamma$, $K^{+}\pi^{-}$, $\pi^{+}K^{-}$

JLab 6 GeV

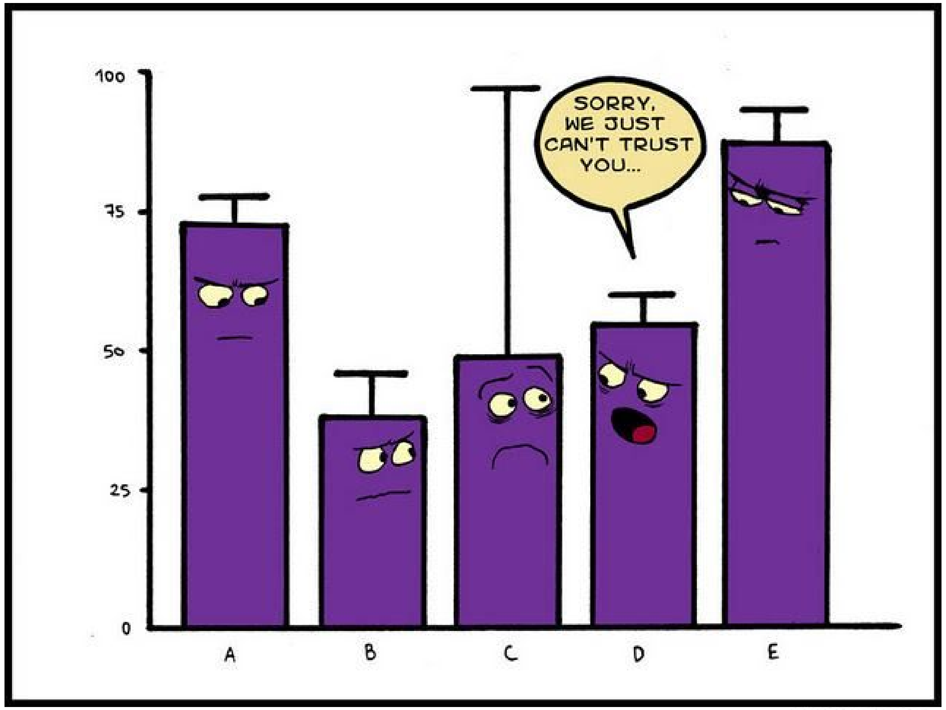
- $\pi^{+}\pi^{0}$ pair asymmetries
- double spin asymmetries

JLab 12 GeV

- larger Q^2 coverage
- data with x up to 0.6
- Kaon sample with π/K separation at $3-8\,\mathrm{GeV}/c \Rightarrow$ strangeness
- Transversal and longitudinally polarized H, D (CLAS12) and ^{3}He (SoIID) targets



Thank you for your attention!



electronic address: christopher.braun@cern.ch