

COMPASS results on transverse spin asymmetries in two-hadron production in SIDIS

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on behalf of the COMPASS collaboration

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Related Subjects, March 29th 2012



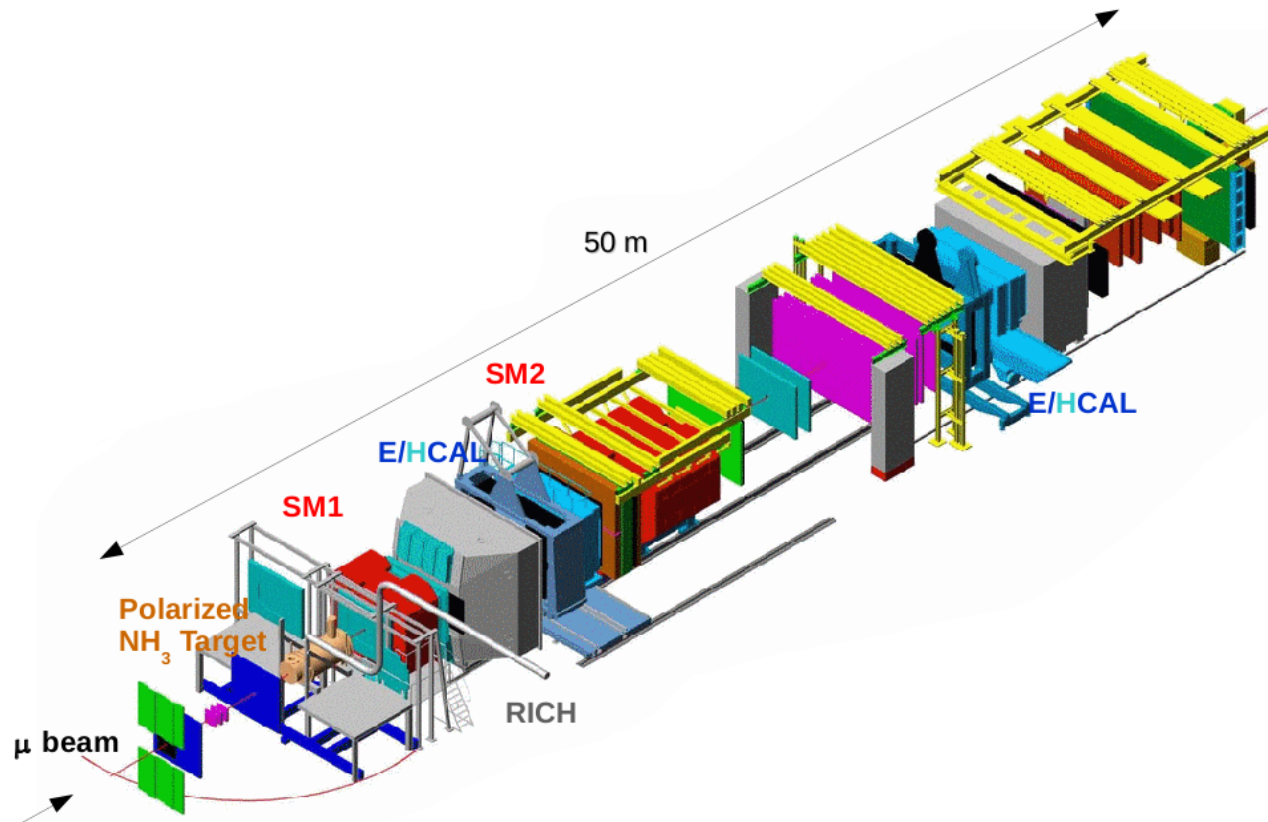
Outline

- 1 The COMPASS experiment
- 2 Theoretical framework
- 3 Data selection 2010
- 4 Two-hadron asymmetries: deuteron data 2002-04
- 5 Two-hadron asymmetries: proton data 2007
- 6 Two-hadron asymmetries: proton data 2010
- 7 Conclusions & outlook

The COMPASS experiment at CERN



The COMPASS experiment

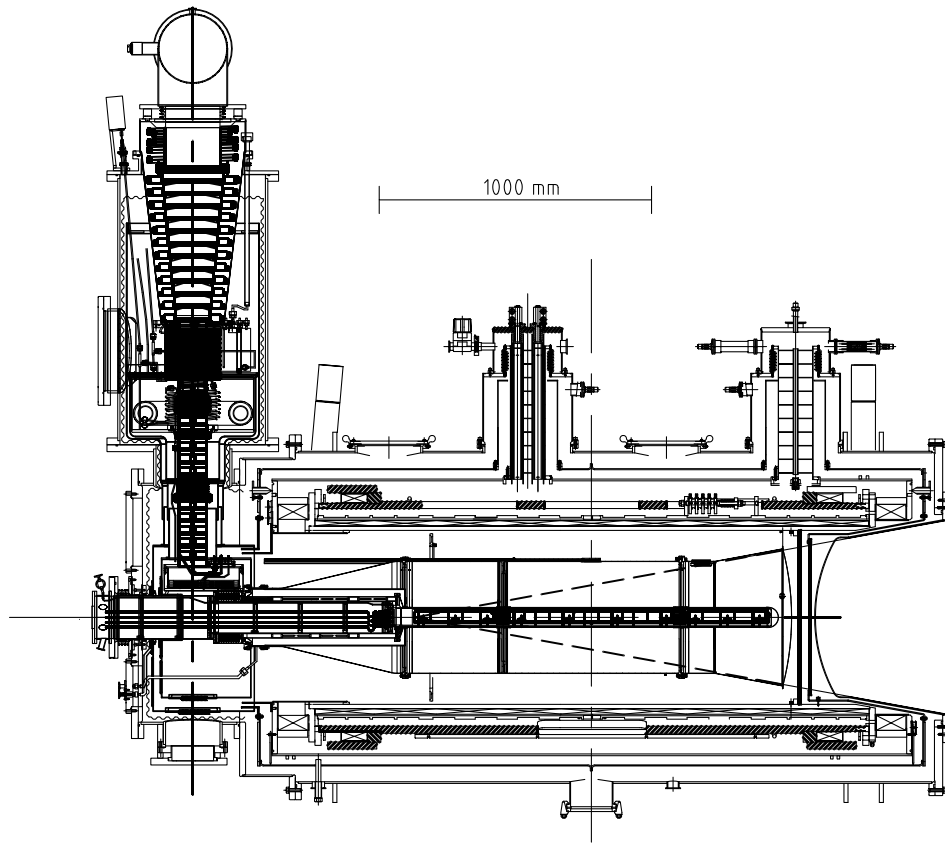


e.g.

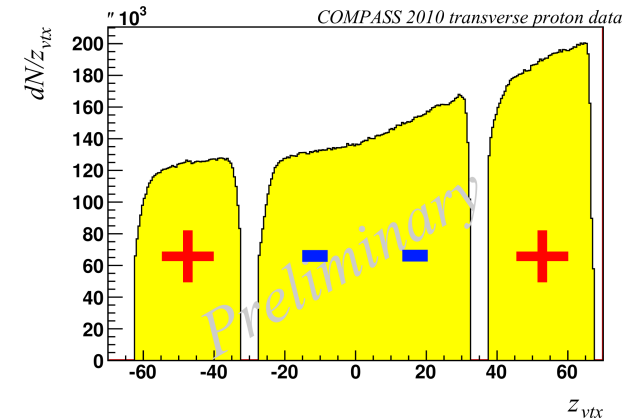
COMPASS setup 2007

- Beam:
 $160 \text{ GeV}/c$
- Intensity:
 $3.0 - 3.5 \cdot 10^8 \mu^+ / \text{spill}$
- Luminosity:
 $5 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- Tracking
- Calorimetry
- PID (RICH)
- Two stage spectrometer
- Longitudinal polarized μ^+ -beam
- 2002-04 polarized deuterium (^6LiD) target
- 2007 & 2010 polarized proton (NH_3) target

The COMPASS target system





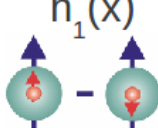
- Upgrade of target system in 2005
- Three cells with opposite polarization
- ± 180 mrad geometrical acceptance
- Transverse polarization reversed every week via microwave



- deuteron ${}^6\text{LiD}$:
 - ▶ polarization $\approx 47\%$
 - ▶ dilution factor ≈ 0.38
- proton NH_3 :
 - ▶ polarization $\approx 90\%$
 - ▶ dilution factor ≈ 0.15

Theoretical framework: from spin structure to Transversity

Three independent parton distribution functions (PDF) are necessary to describe the spin structure of the nucleon in leading order:

		quark		
		U	L	T
nucleon	U	$f_1(x)$ 		
	L		$g_1(x)$ 	
	T			$h_1(x)$ 

Quark distribution:

$$f_1(x_{bj}) = q^+(x_{bj}) + q^-(x_{bj})$$

Helicity distribution:

$$g_1(x_{bj}) = q^+(x_{bj}) - q^-(x_{bj})$$

Transversity distribution:

$$h_1(x_{bj}) = q^{\uparrow\uparrow}(x_{bj}) - q^{\uparrow\downarrow}(x_{bj})$$

Collins FF $lN^\uparrow \rightarrow l'hX$

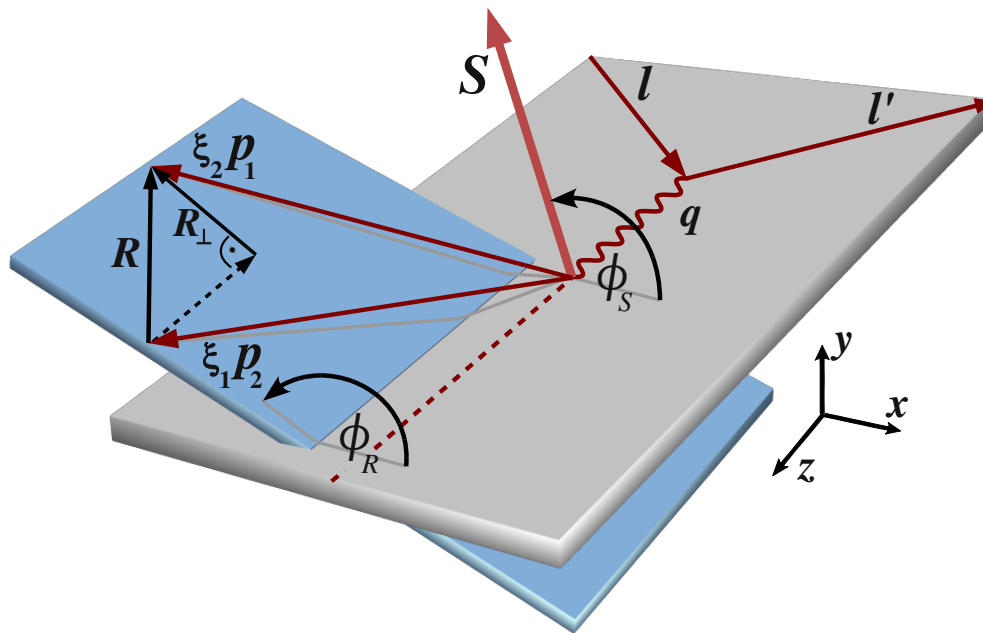
Interference FF $lN^\uparrow \rightarrow l'hhX$

FF of $q^\uparrow \rightarrow \Lambda$ $lN^\uparrow \rightarrow l'\Lambda X$

Theoretical framework: angle definitions

$$l p^\uparrow \rightarrow l' h_1 h_2$$

Fragmentation of transversely polarized quark into two unpolarized hadrons



in courtesy of H. Wollny

- l , l' and q are 3-momenta of incoming, scattered lepton and virtual photon
- Φ_S azimuthal angle of the spin of the fragmenting quark S
- $z_i = \frac{\mathbf{p}_i}{\mathbf{p}}$
- $\mathbf{R} = \frac{z_2 \mathbf{p}_1 - z_1 \mathbf{p}_2}{z_1 + z_2} = \xi_2 \mathbf{p}_1 - \xi_1 \mathbf{p}_2$
- \mathbf{R}_T is the component of \mathbf{R} perpendicular to \mathbf{q}
- Azimuthal angle of \mathbf{R} :

$$\Phi_R = \frac{(\mathbf{q} \times \mathbf{l}) \cdot \mathbf{R}}{|(\mathbf{q} \times \mathbf{l}) \cdot \mathbf{R}|} \arccos \left(\frac{(\mathbf{q} \times \mathbf{l}) \cdot (\mathbf{q} \times \mathbf{R})}{|\mathbf{q} \times \mathbf{l}| |\mathbf{q} \times \mathbf{R}|} \right)$$

Theoretical framework: two-hadron cross section

The differential two-hadron cross section is:

$$\frac{d^7\sigma}{d\cos\theta dM_h^2 d\Phi_R dz dx dy d\Phi_S} =$$

$$\frac{\alpha^2}{2\pi Q^2 y} \left(\left(1 - y + \frac{y^2}{2}\right) \sum_q e_q^2 f_1^q(x) D_{1,q}(z, M_h^2, \cos\theta) \right.$$

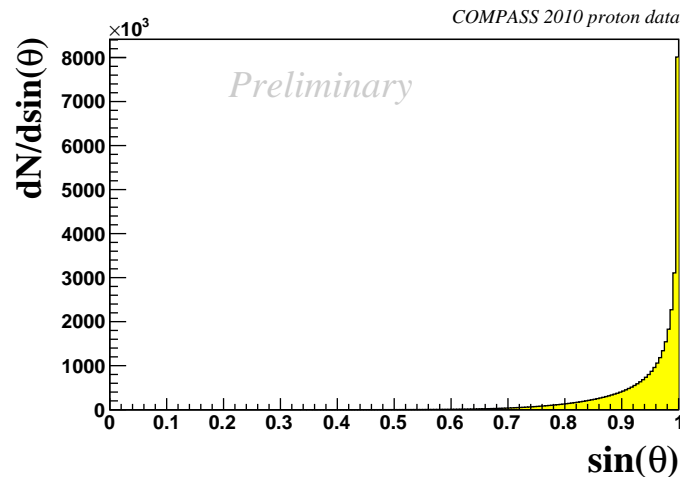
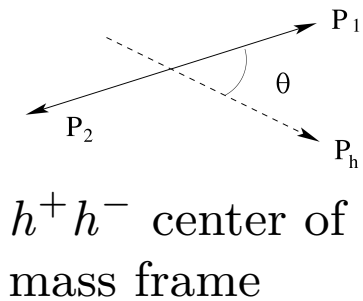
$$\left. + (1 - y) S_\perp \sum_q e_q^2 \frac{|\mathbf{p}_1 - \mathbf{p}_2|}{2M_h} \sin(\theta) \sin(\Phi_{RS}) h_1^q(x) H_{1,q}^\triangleleft(z, M_h^2, \cos\theta) \right)$$

$$\text{with } \Phi_{RS} = \Phi_R + \Phi_S - \pi$$

Where $h_1(x)$ is the Transversity PDF and $H_{1,q}^\triangleleft$ is the two-hadron Interference FF, which describes the Fragmentation of a transversely polarized quark into two unpolarized hadrons. $D_{1,q}$ is the unpolarized two-hadron fragmentation function which is measured at *e.g.* BELLE.

Theoretical framework: asymmetries extraction

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



$\langle \sin \theta \rangle = 0.943$
 \Rightarrow can be neglected

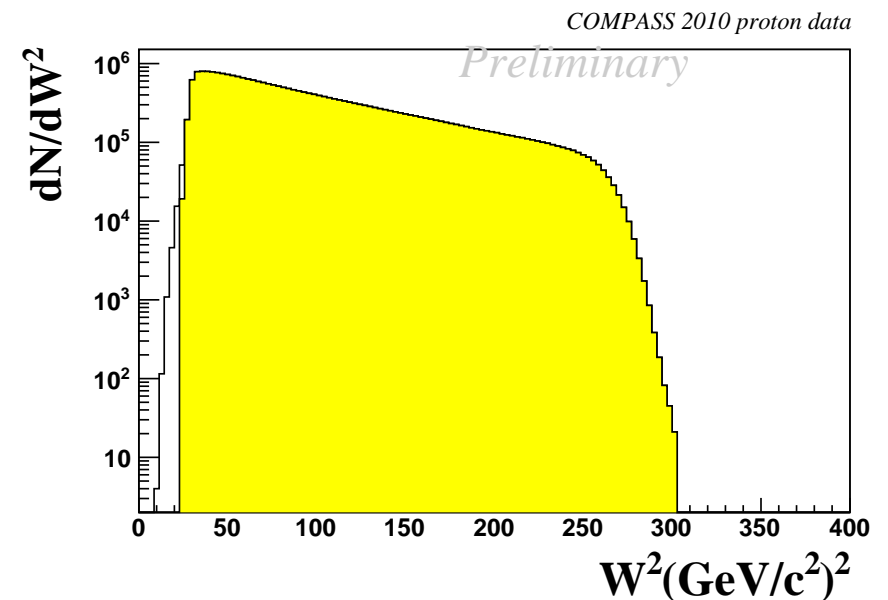
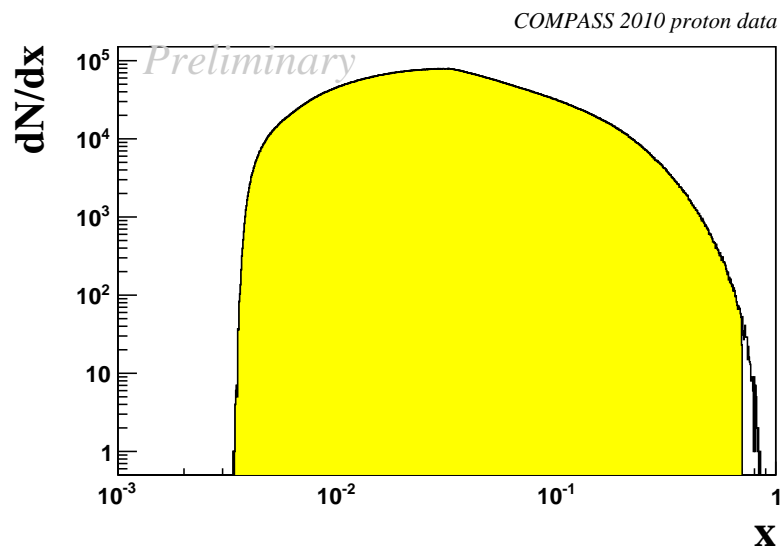
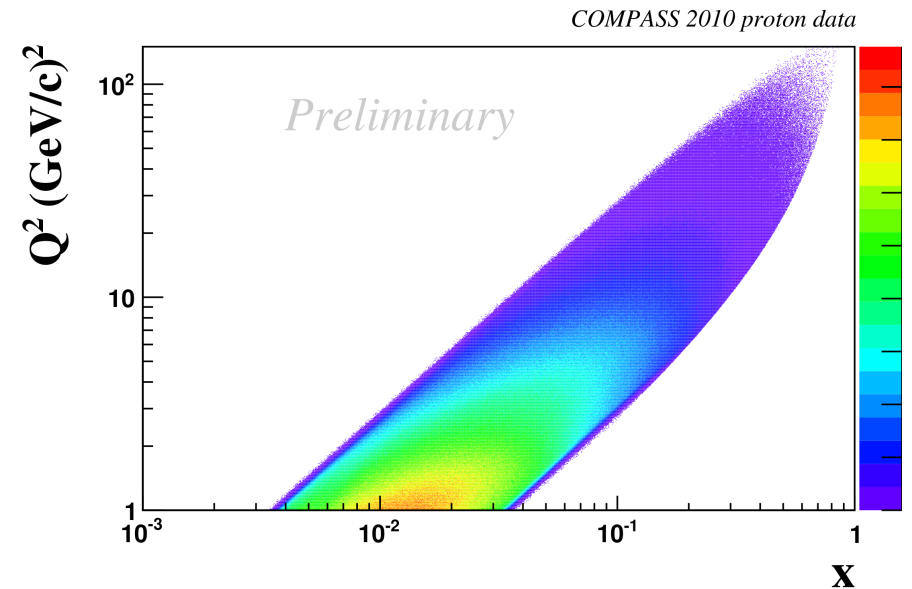
σ_{UU} = unpolarized cross section
 \pm indicates nucleon spin orientation
 f = target dilution factor
 P_T = target polarization
 D_{NN} = transv. spin transfer coef.
 $D_{NN} = \frac{1-y}{1-y+\frac{y^2}{2}}$

$$A_{UT}^{\sin \Phi_{RS}} = \frac{|\mathbf{p}_1 - \mathbf{p}_2|}{2M_h} \frac{\sum_q e_q^2 \cdot h_1^q(x) \cdot H_{1,q}^{\leftarrow}(z, M_h^2, \cos \theta)}{\sum_q e_q^2 \cdot f_1^q(x) \cdot D_{1,q}(z, M_h^2, \cos \theta)}$$

Data selection 2010: DIS cuts

DIS cuts are in common with single hadron analysis:

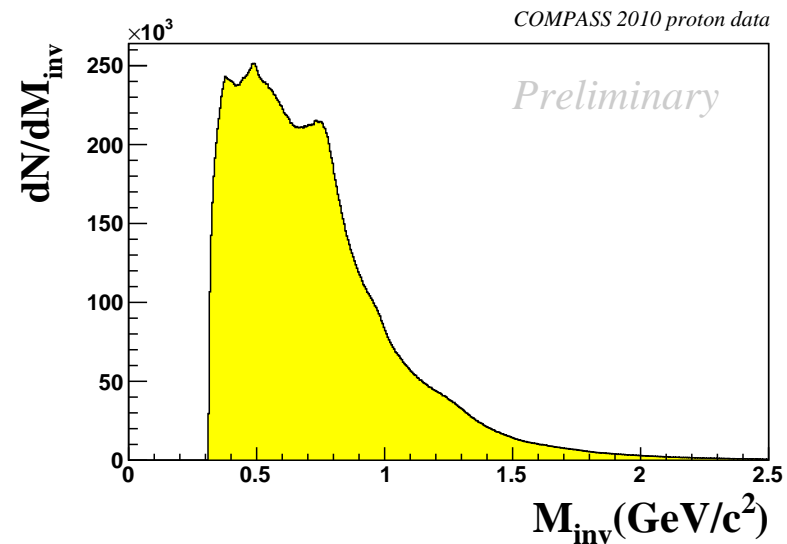
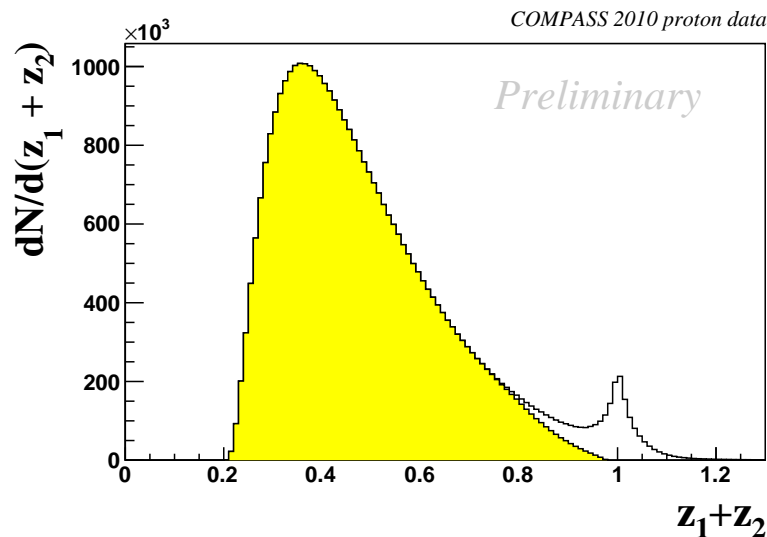
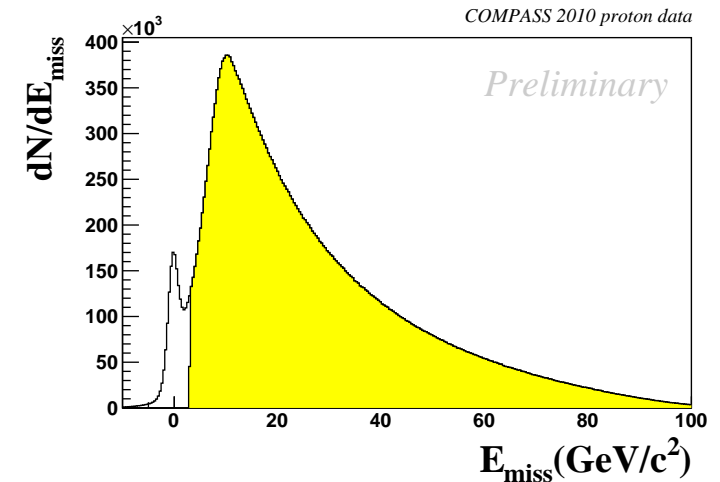
- $Q^2 > 1 \text{ (GeV/c)}^2$
 - $0.1 < y < 0.9$
 - $W > 5 \text{ GeV/c}^2$
-
- spectrometer acceptance:
 $0.003 < x_{bj} < 0.7$



Data selection 2010: hadron & pair cuts

Specific cuts for 2-hadron analysis:

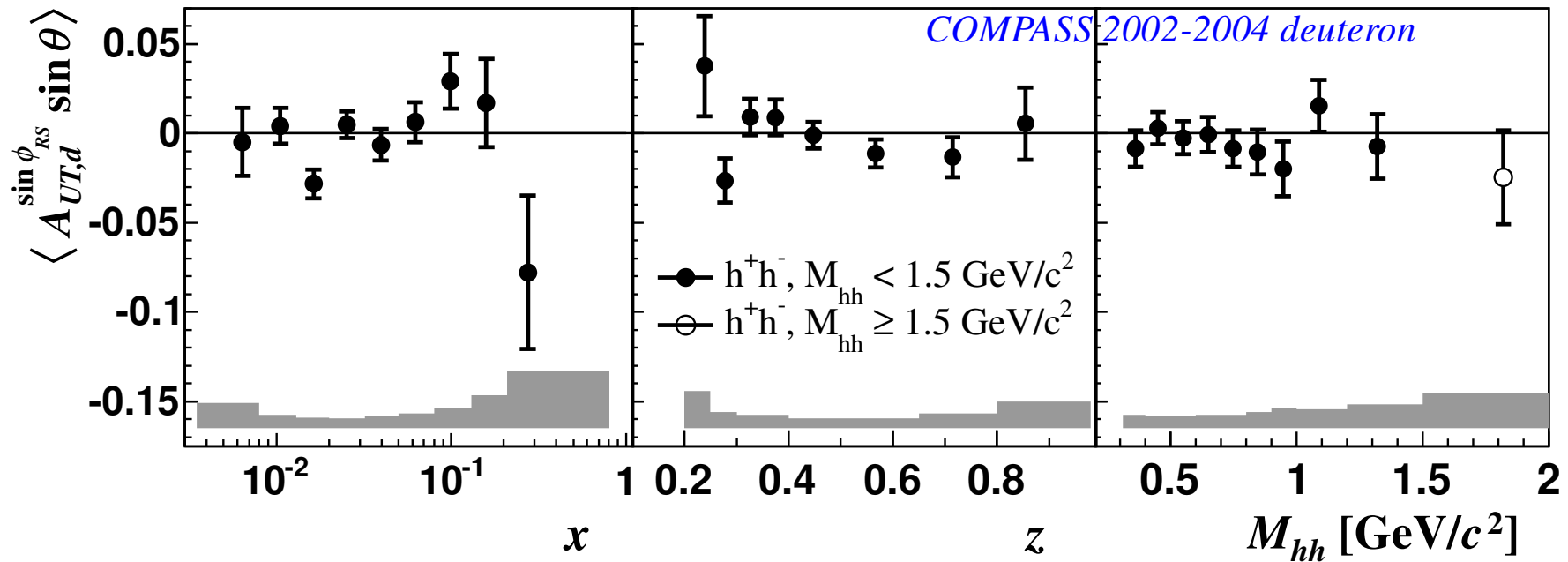
- Vertex with at least **3** outgoing tracks.
↪ All h^+h^- pair combinations are taken into account
- $z > 0.1$ for each hadron
- $x_F > 0.1$ for each hadron
- $E_{miss} > 3$ GeV for each pair
- $\mathbf{R}_T > 0.07$ GeV/ c for each pair



two-hadron asymmetries:

deuteron data 2002-04

deuteron data 2002-04: all h^+h^- pairs

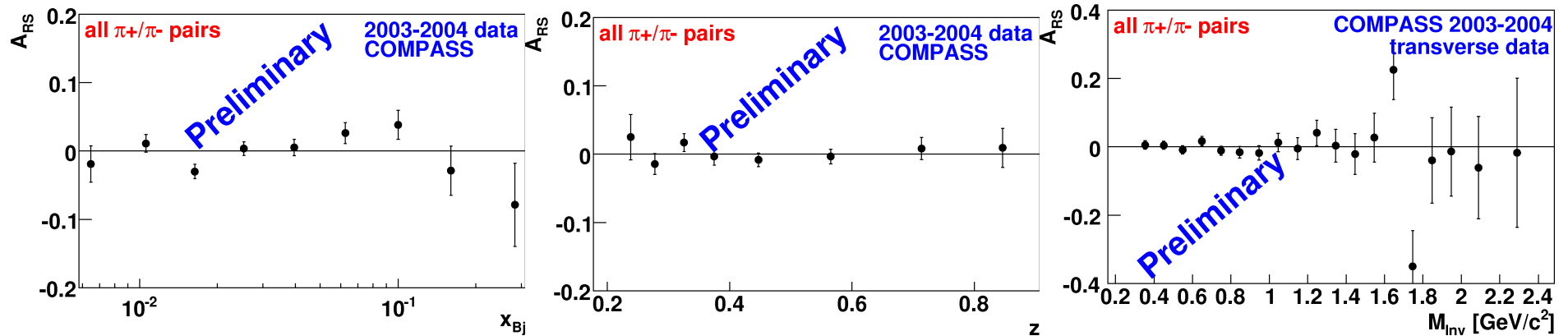
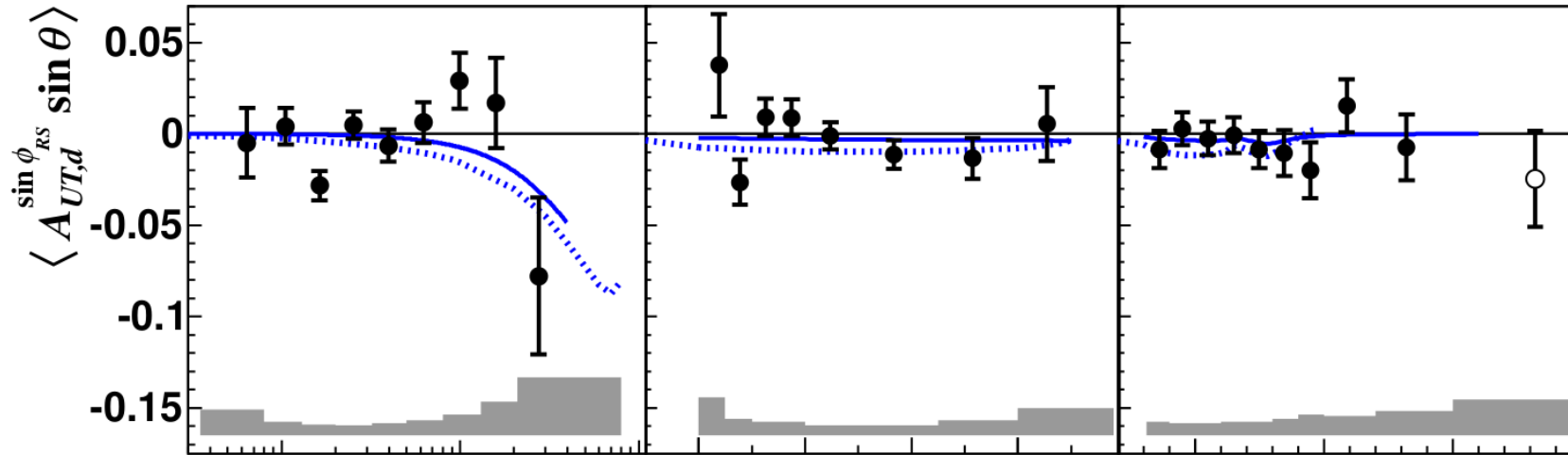


2002-04 deuteron data 2-hadron asymmetries of h^+h^- pairs:

NEWS: submitted to Phys. Lett. B: arXiv:1202.6150 [hep-ex]

↪ all asymmetries are small and compatible with zero

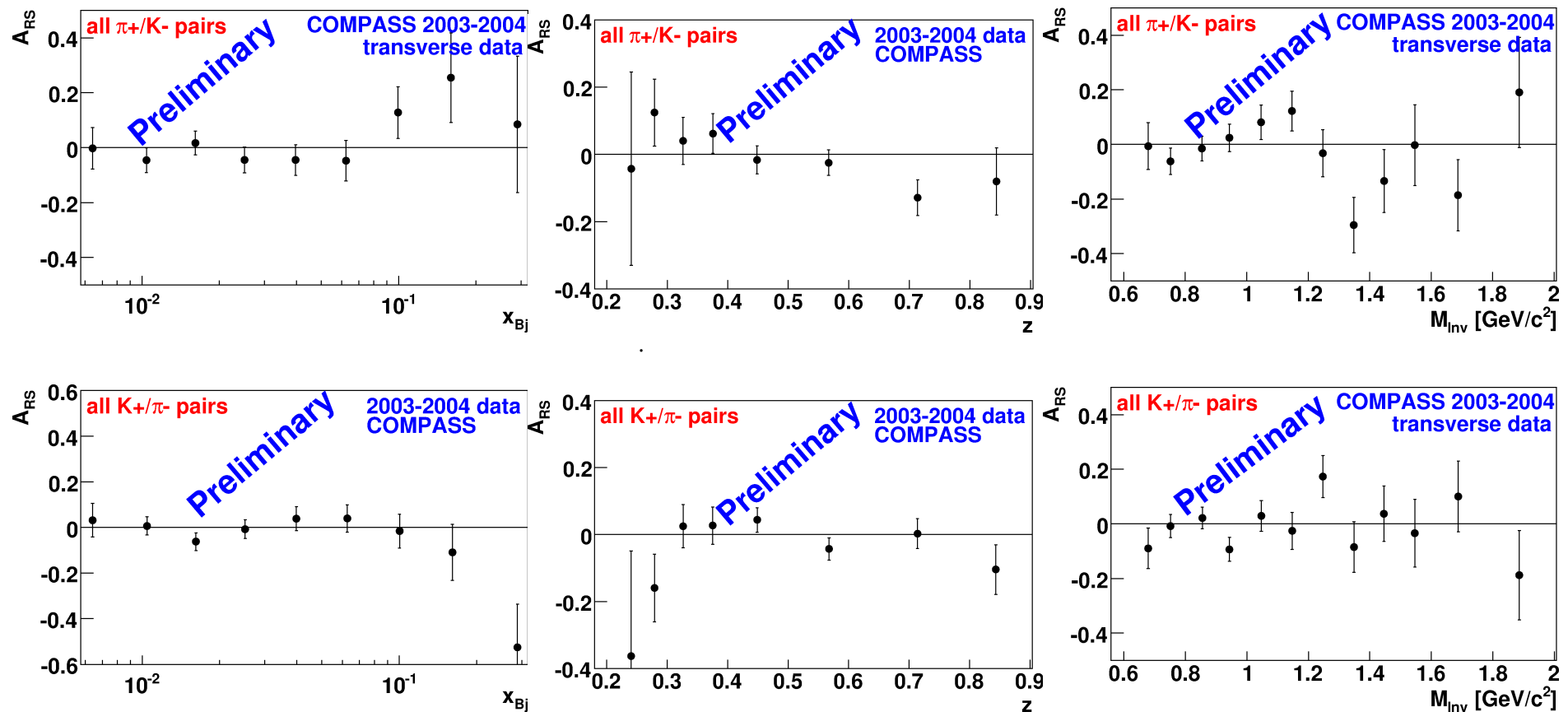
deuteron data 2002-04: $\pi^+\pi^-$ pairs



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

$\hookrightarrow h^+h^-$ asymmetries dominated by $\pi^+\pi^-$ signal

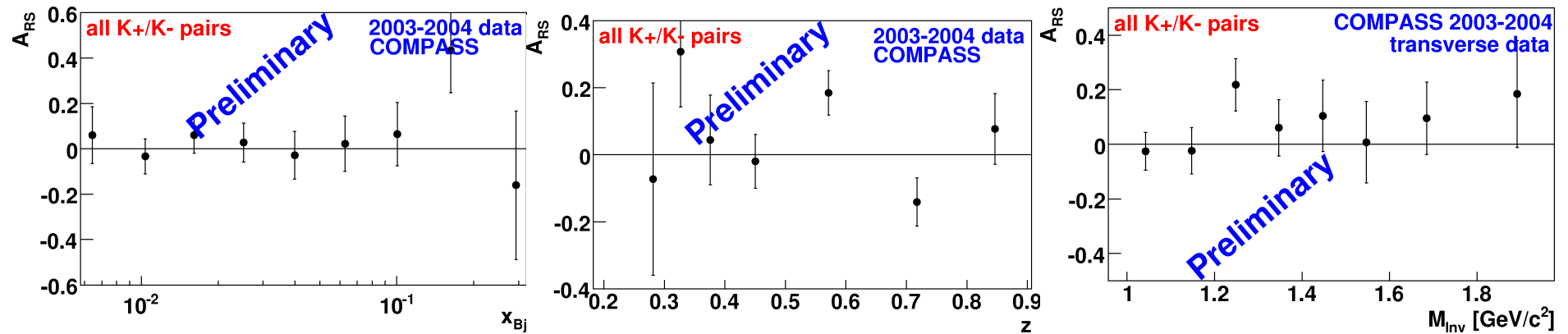
deuteron data 2002-04: $\pi^+ K^-$ & $K^+ \pi^-$ pairs



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

$\hookrightarrow \pi^+ K^-$ & $K^+ \pi^-$ signal compatible with zero
 \hookrightarrow opposite signs of mean values in x_{bj}

deuteron data 2002-04: K^+K^- pairs



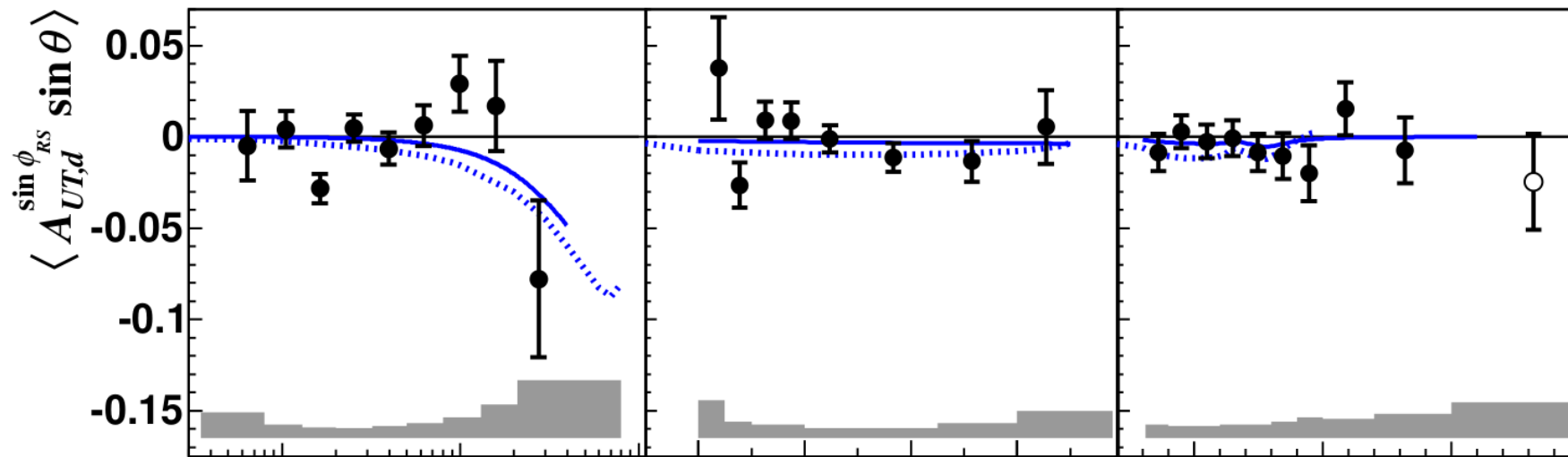
2002-04 deuteron data 2-hadron asymmetries: K^+K^- pairs

↪ K^+K^- no signal & low statistics

deuteron data 2002-04: comparison with model predictions

Bacchetta *et al.* hep-ph/0708037

Ma *et al.*, Phys. Rev. D77 (2008) 014035, arXiv:0711.0817 [hep-ph]

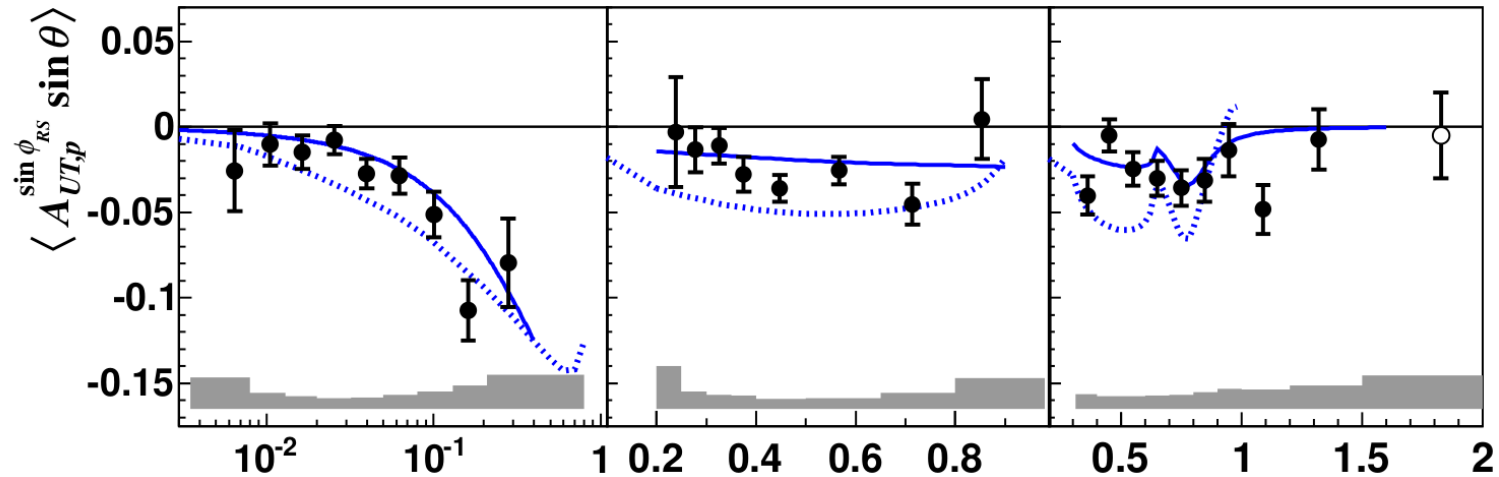


↪ good agreement with model predictions

two-hadron asymmetries:

proton data 2007

two-hadron asymmetries: proton data 2007

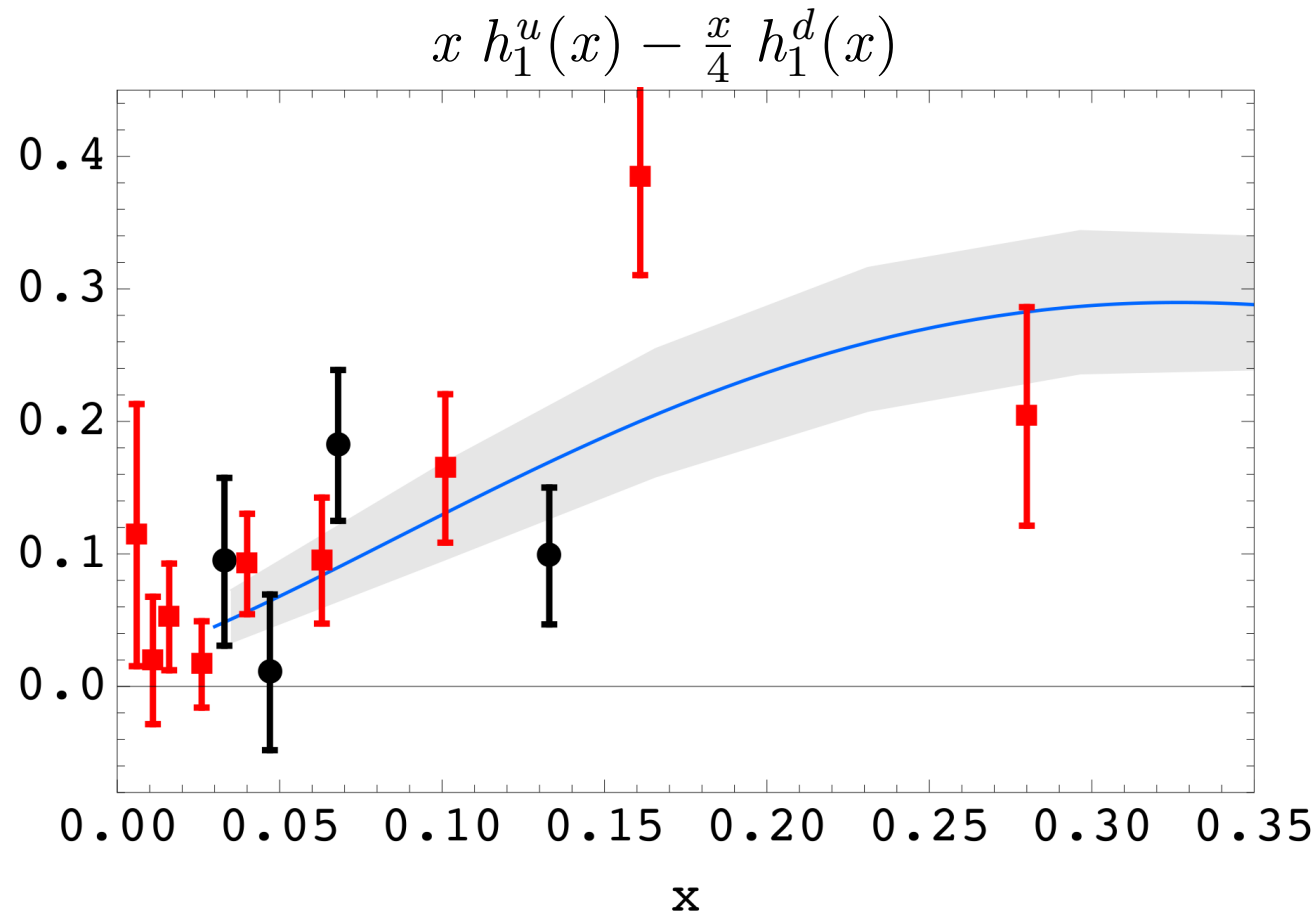


2007 proton data two-hadron asymmetries of h^+h^- pairs.

↪ Large asymmetries for proton up to 5 – 10%

proton data 2007: 1st extraction of transversity in collinear framework via DiFF

A. Bachetta, A. Courtoy and M. Radici, PRL **107** (11)



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

black:

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

red:

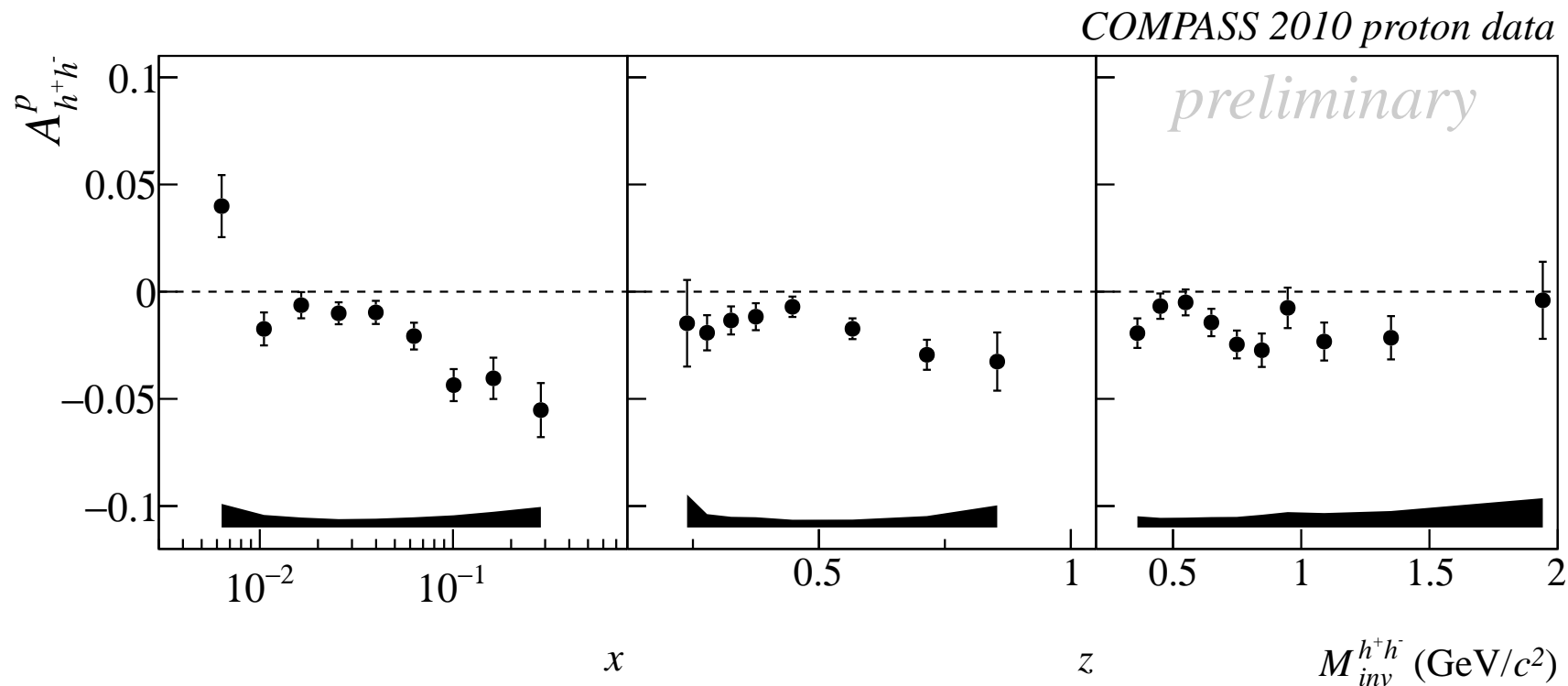
COMPASS Wollny *et al.*, arXiv:0907.0961

cf. A. Courtoy right after this talk!

two-hadron asymmetries:

proton data 2010

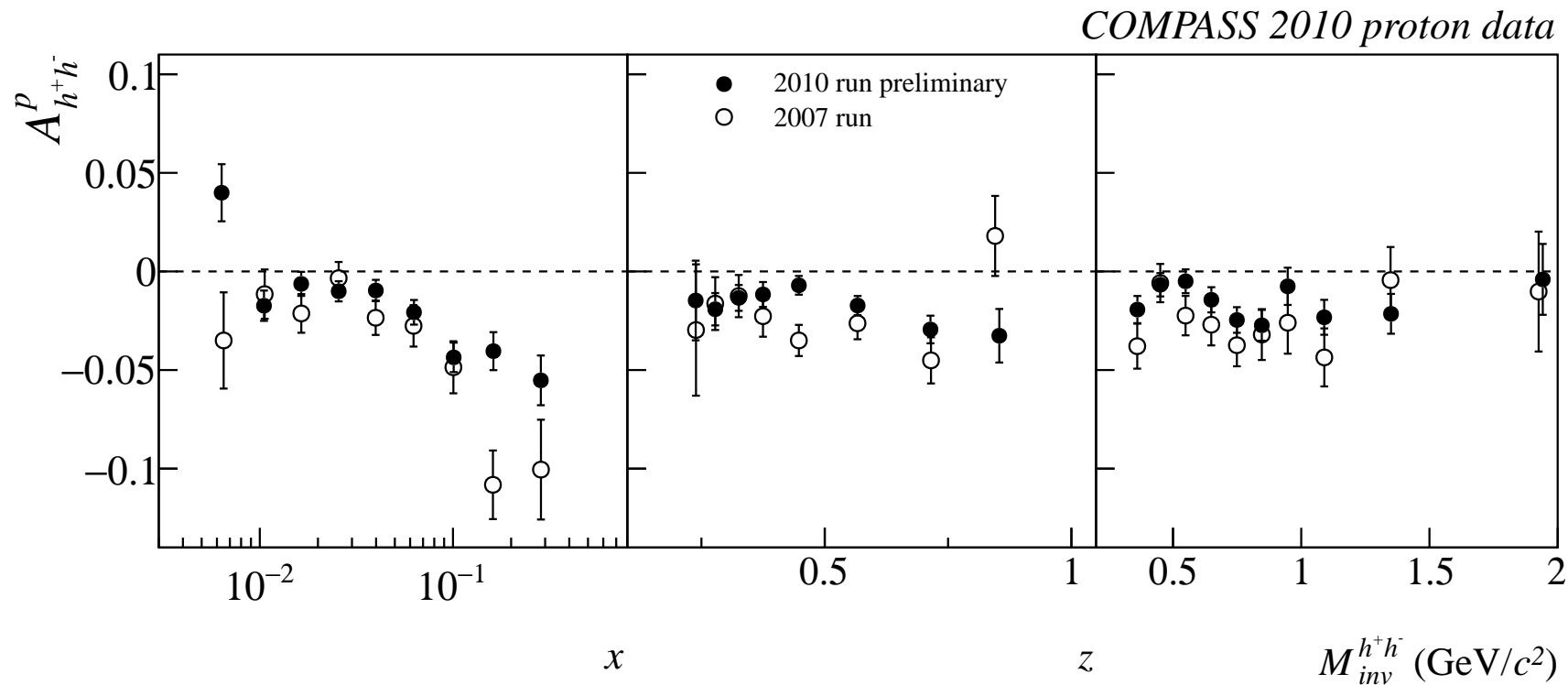
two-hadron asymmetries: proton data 2010



NEWS: The 2010 two-hadron asymmetries of h^+h^- pairs.

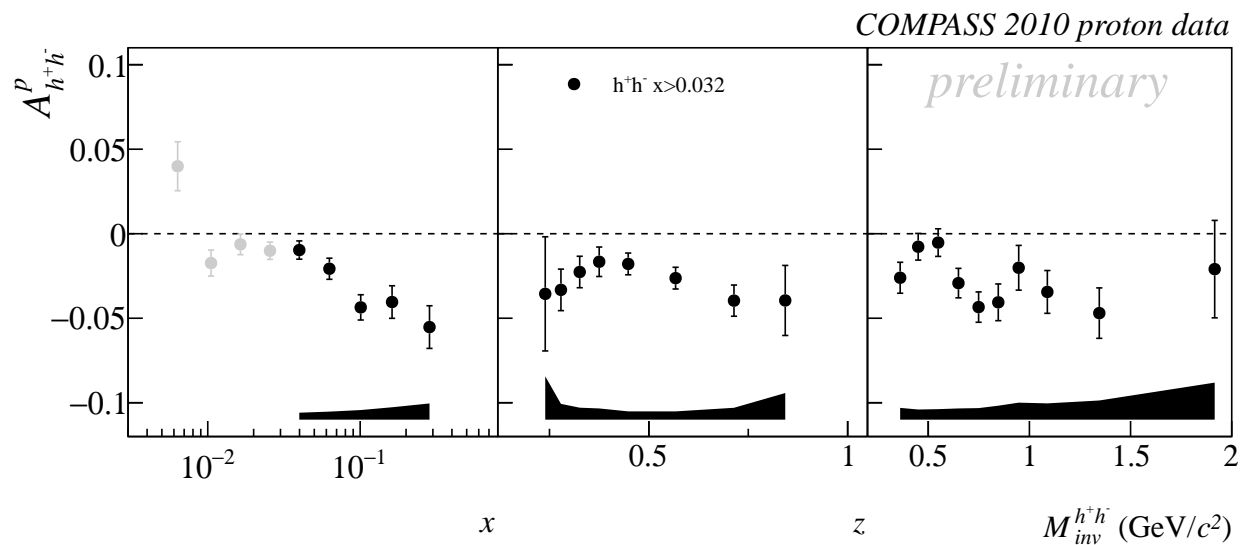
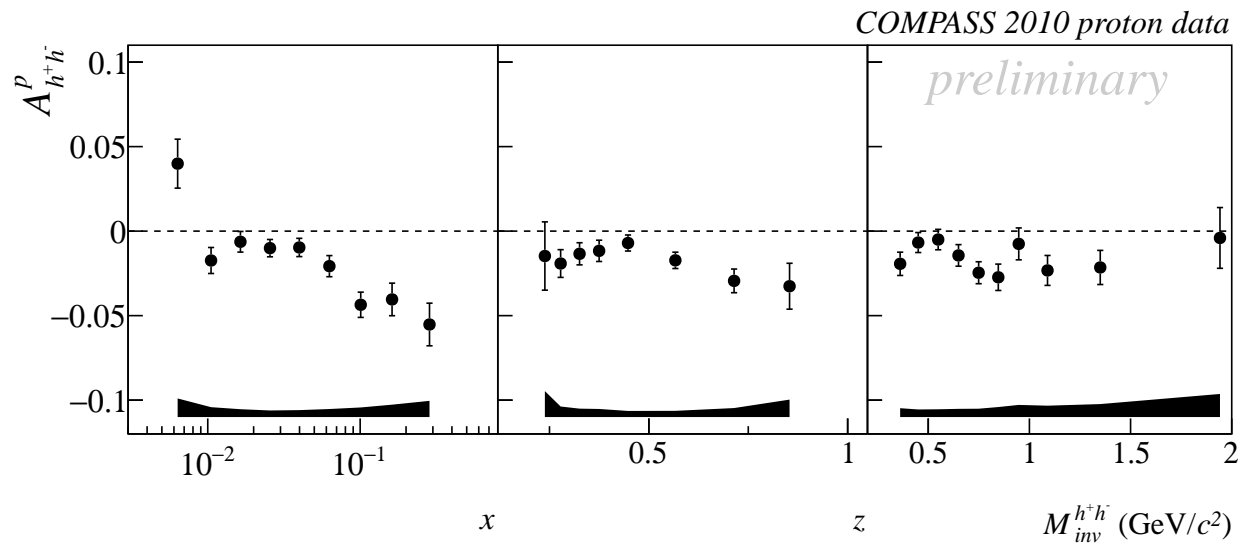
↪ Clear asymmetries for proton with improved errors

two-hadron asymmetries: comparison 2010 and 2007 proton data



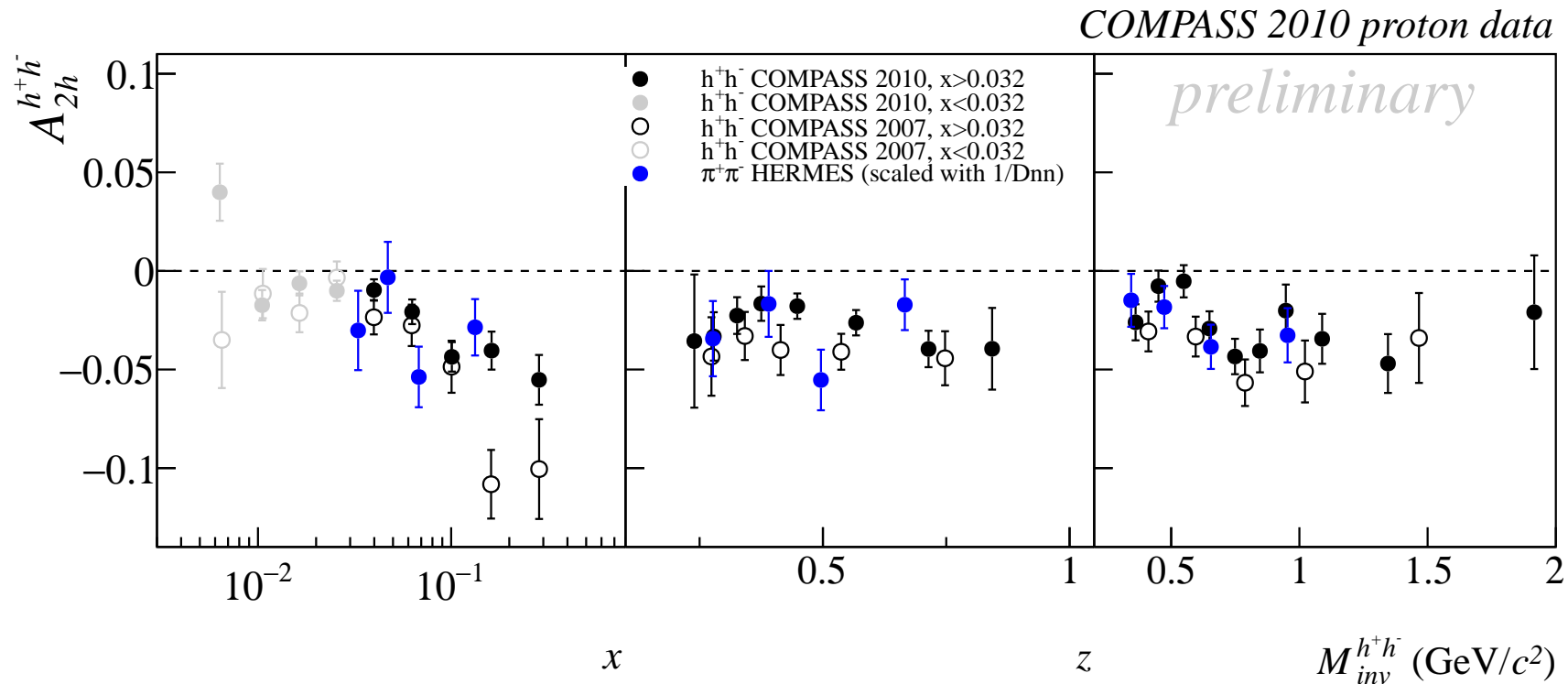
↪ Good agreement between 2007 and 2010 results within the error bars. Factor of gain in statistical err. ~ 1.7 & $\sigma_{sys}/\sigma_{stat} = 0.8$

two-hadron asymmetries: proton data 2010 $x_{bj} > 0.032$



↪ Asymmetries in z and M_{inv} increase for $x_{bj} > 0.032$ sample

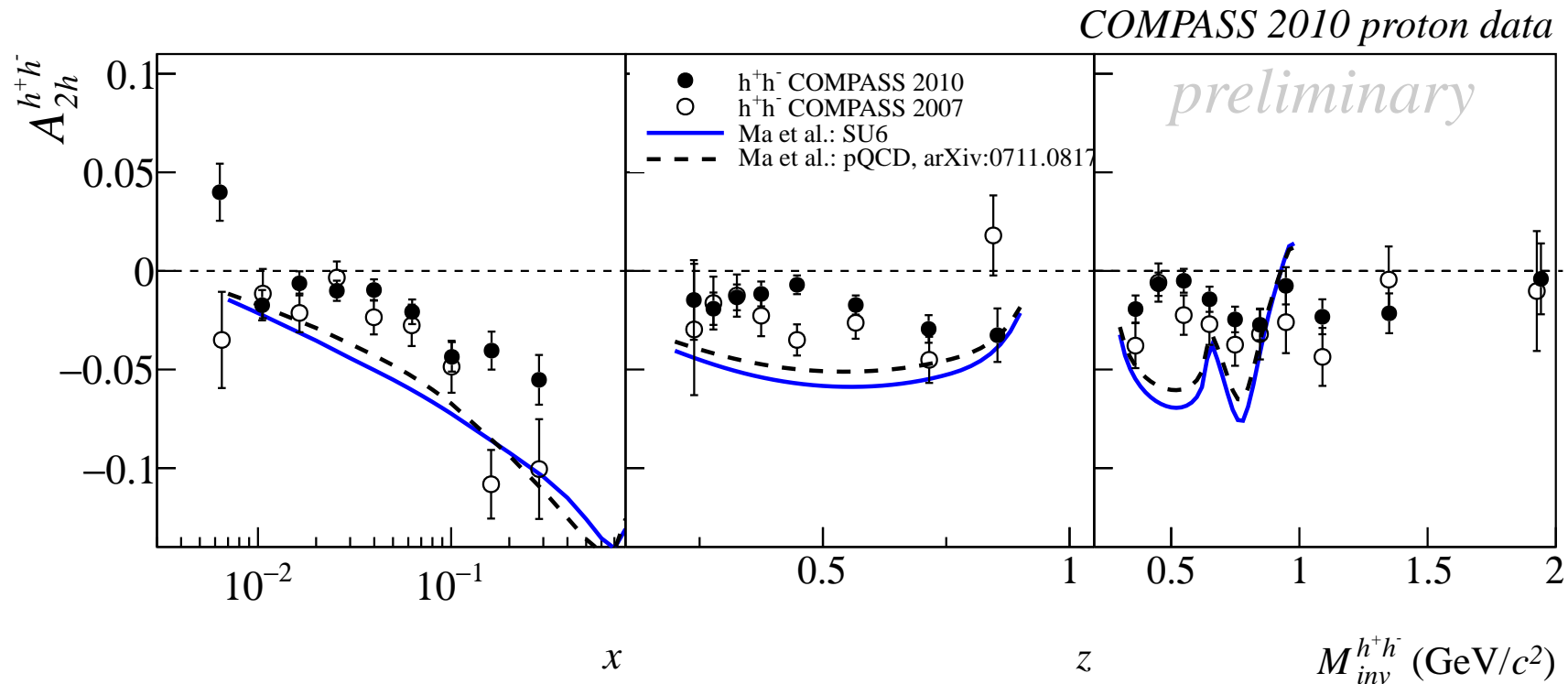
Comparison with results from HERMES



Airapetian *et. al.*, JHEP, **06** (2008) 017 scaled with $\frac{1}{D_{nn}}$

↪ Good agreement with HERMES data within the error bars

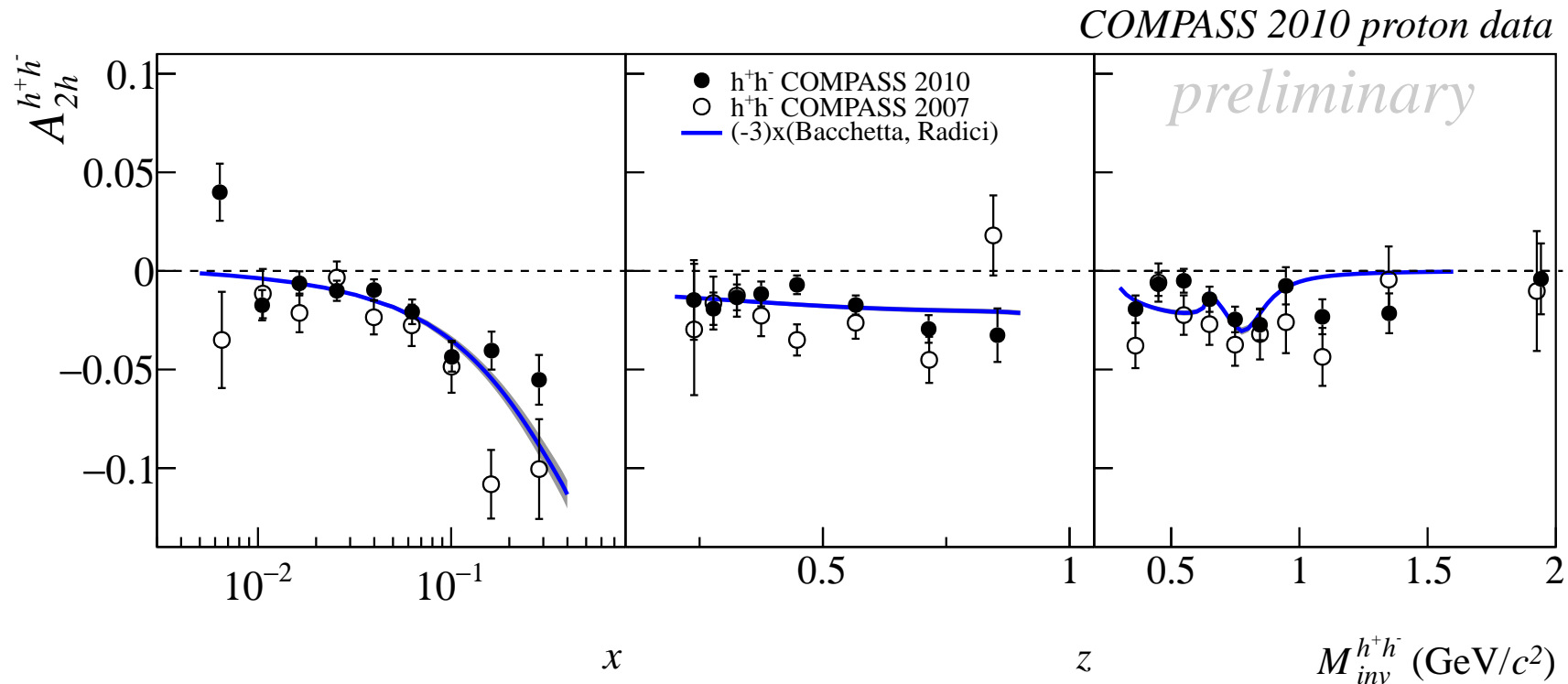
2010 proton data comparison with model predictions



Ma *et al.*, arXiv:0711.0817

- ↪ trend in x_{bj} confirmed
- ↪ rather agreement for z and M_{inv}

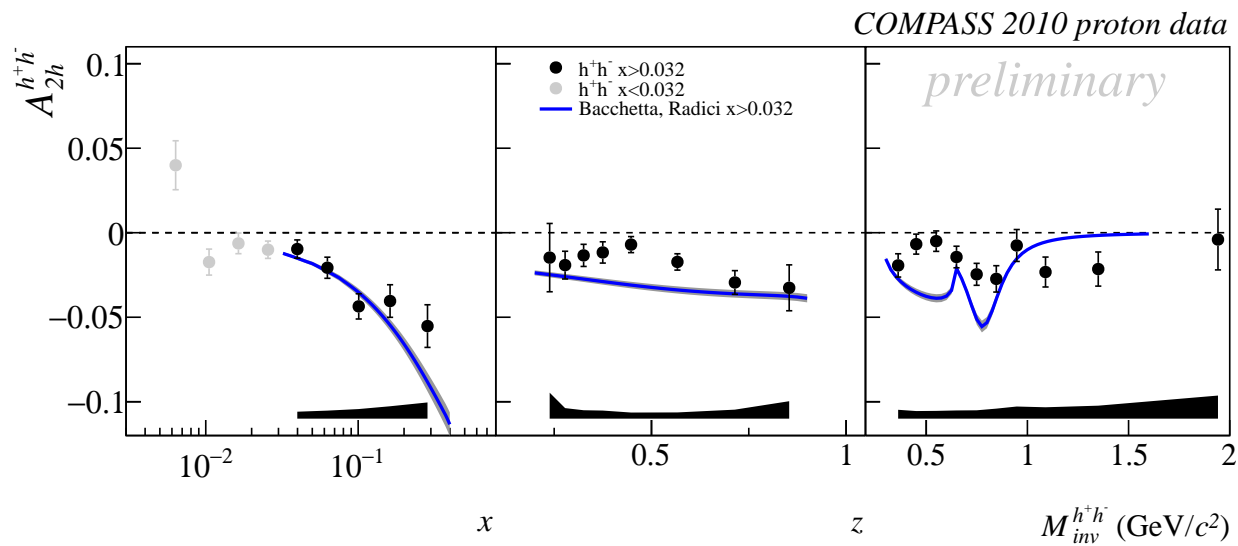
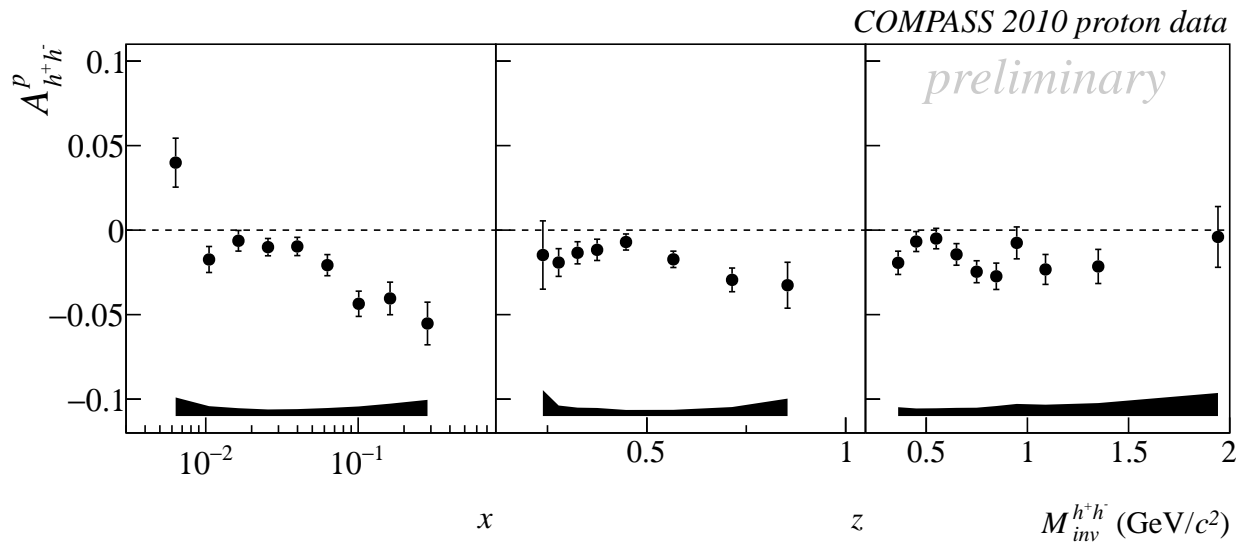
2010 proton data comparison with model predictions



Bacchetta *et al.*, hep-ph/0608037

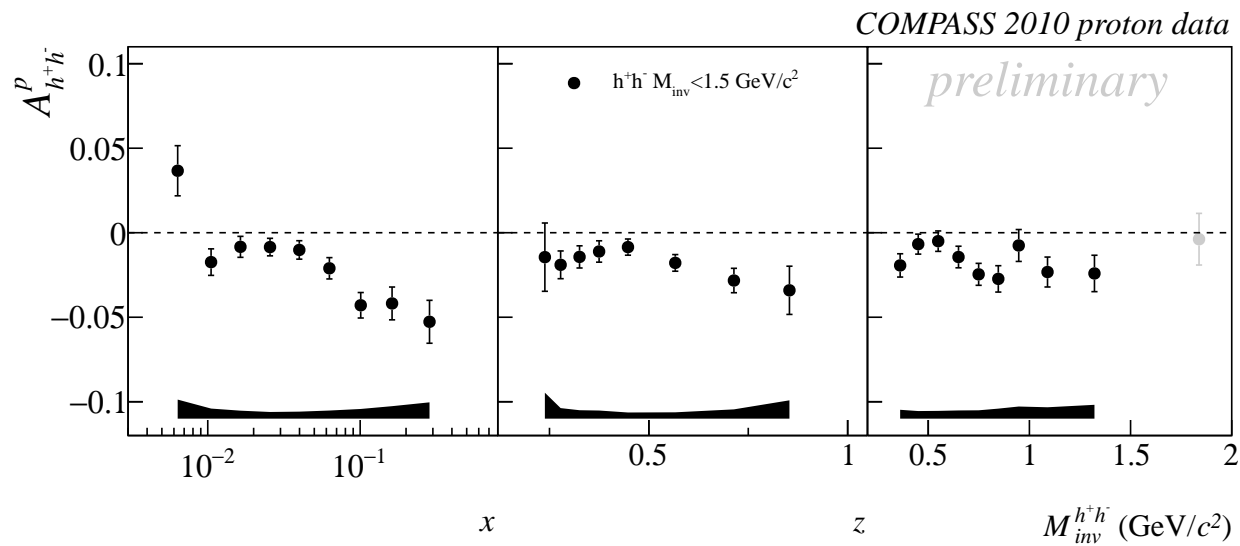
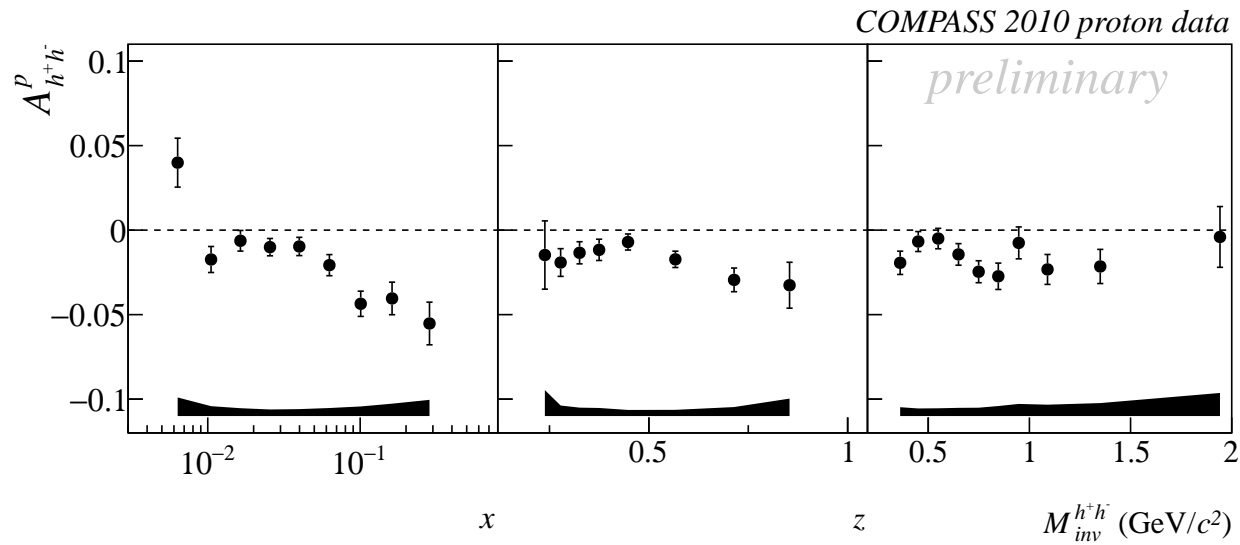
- ↪ good agreement for x_{bj} and z
- ↪ signal in ρ_0 mass region confirmed

2010 proton data comp. with Bacchetta *et al.* valence region



↪ data and model prediction increase for $x_{bj} > 0.032$

two-hadron asymmetries: proton data 2010 $M_{inv} < 1.5 \text{ GeV}/c^2$



to be used in PW analysis *cf.* Bachetta & Radici, hep-ph/0212300

Conclusions & Outlook

- Complete analysis of COMPASS deuteron data available
- COMPASS 2007 proton data available

↪ paper submitted to Phys. Lett. B: arXiv:1202.6150 [hep-ex]

- preliminary results for 2010 COMPASS proton data available:
 - 1 Small statistical and systematic uncertainty
 - 2 Strong improvement with 2010 data
 - 3 Agreement of independent COMPASS 2010 and 2007 proton measurements within the error bars
 - 4 COMPASS data, with it's higher precision, is in agreement with HERMES data
 - 5 Reasonable agreement with model predictions of Bacchetta & Ma

Outlook:

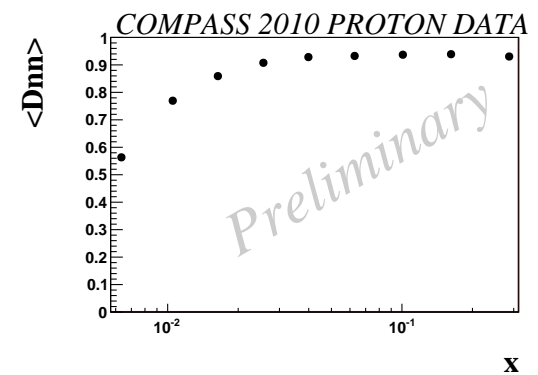
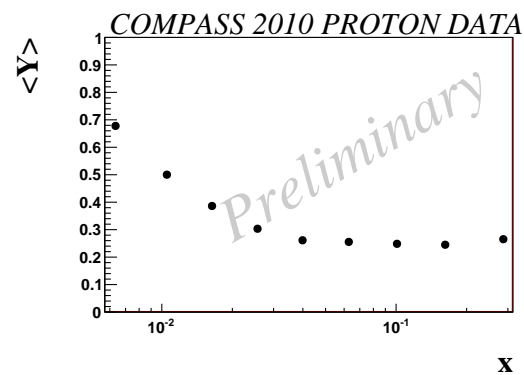
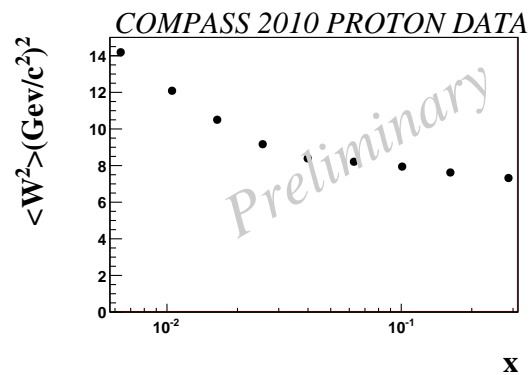
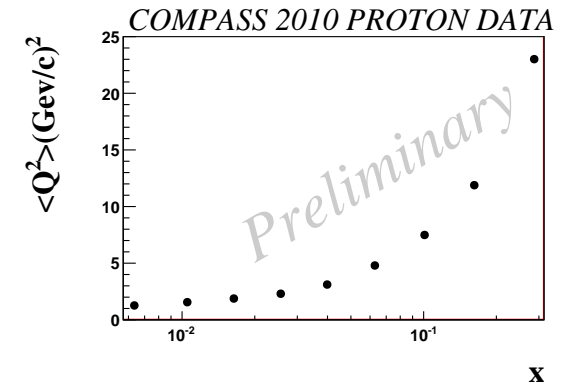
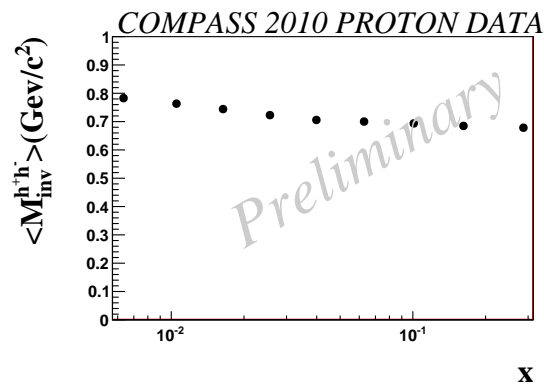
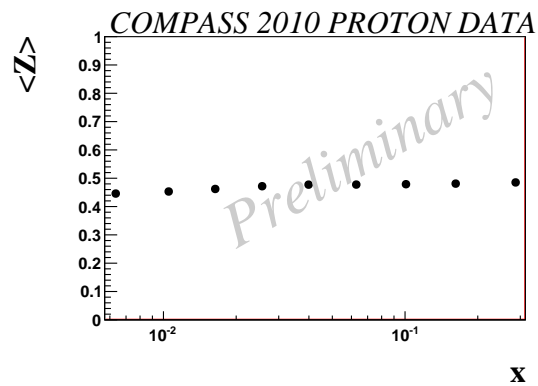
- Asymmetries for identified pairs: $\pi^+\pi^-$, K^+K^- , π^+K^- , $K^+\pi^-$

Thank you for your attention!

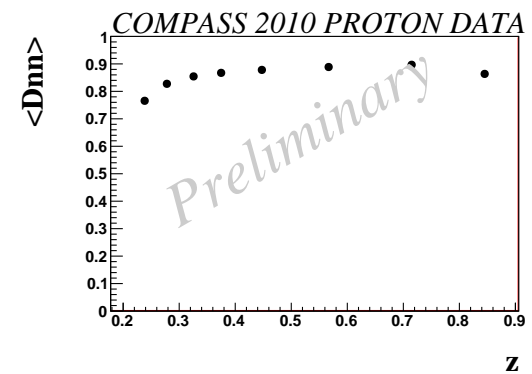
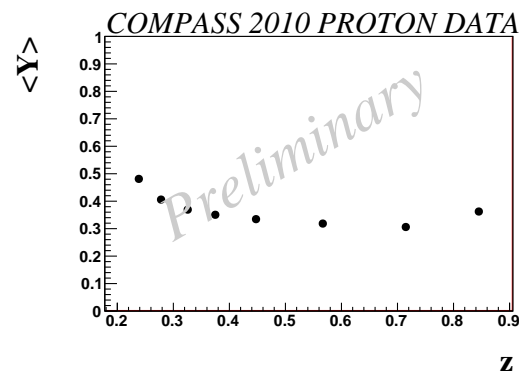
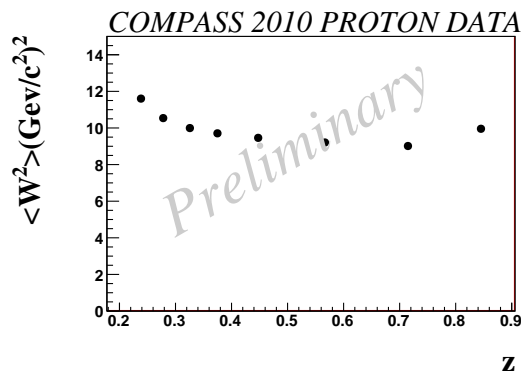
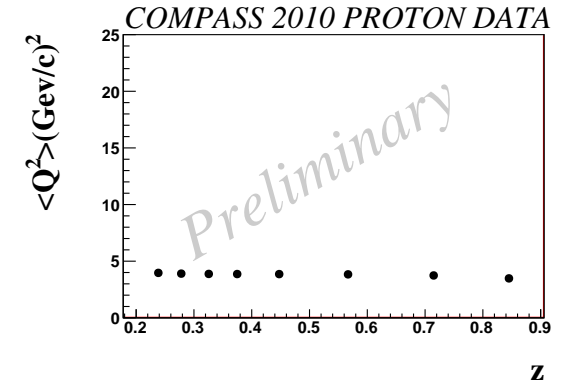
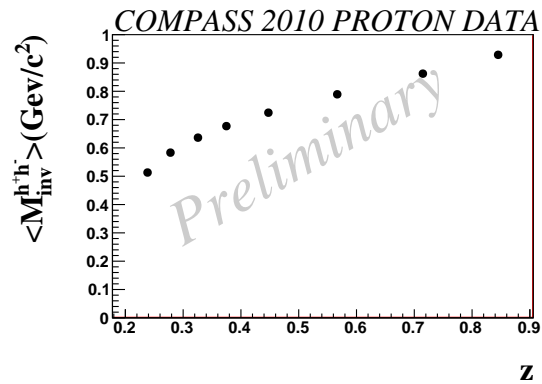
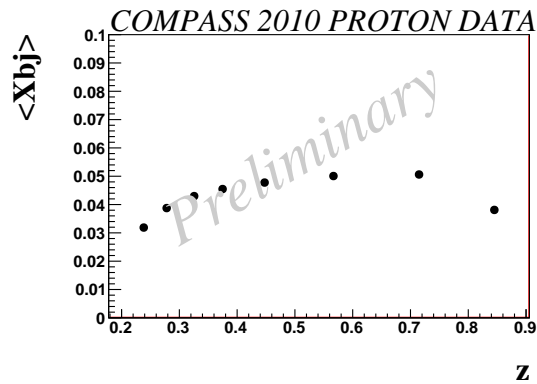
electronic address: christopher.braun@cern.ch

Back up

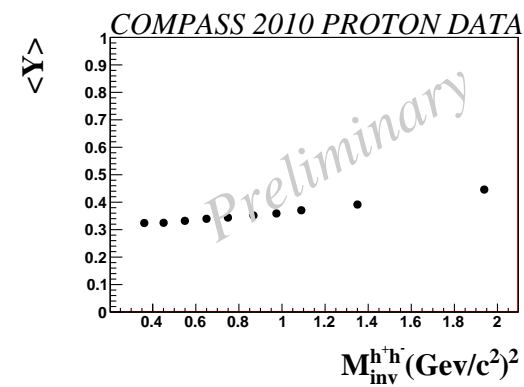
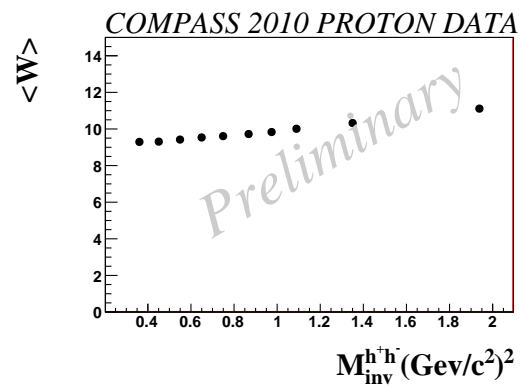
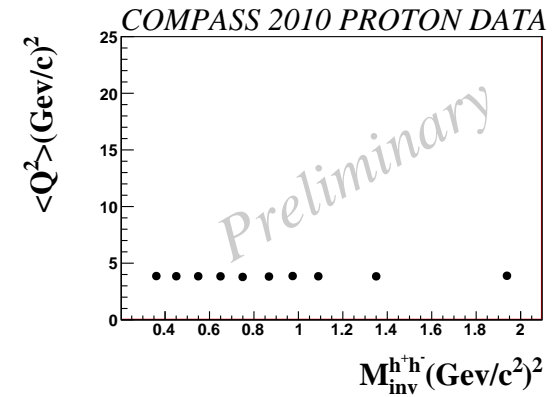
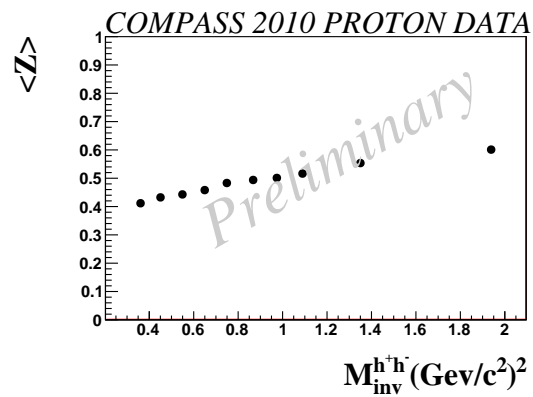
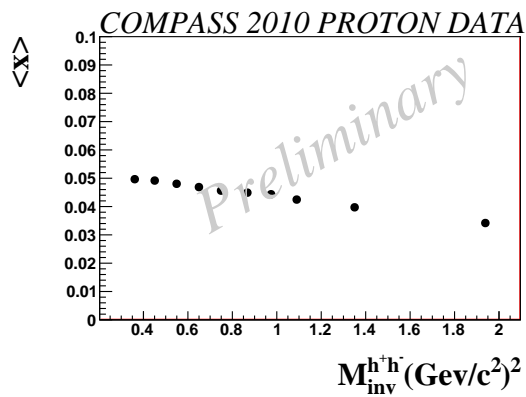
2010 proton data: kinematic mean values in x_{bj}



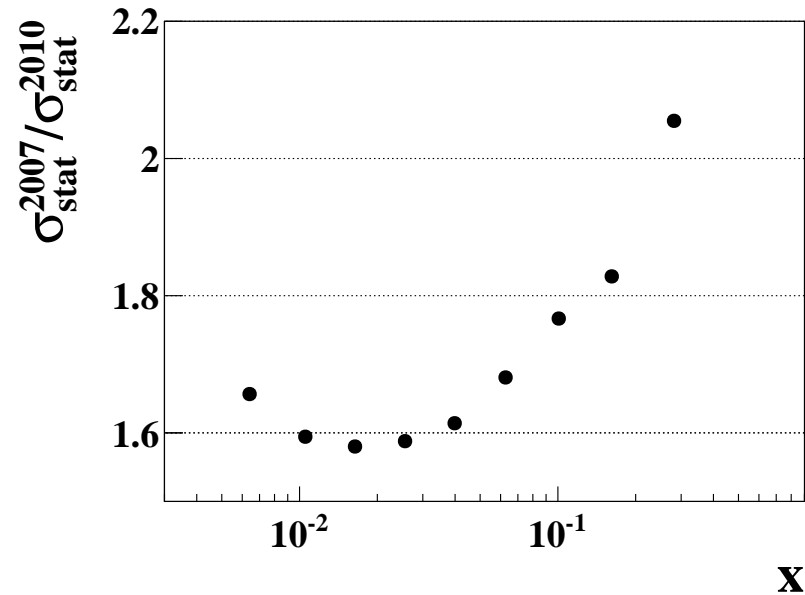
2010 proton data: kinematic mean values in z



2010 proton data: kinematic mean values in M_{inv}



Comparison of statistical errors 2007/2010



The ratio between the statistical error of 2007 on 2010 analysis, as a function of x_{bj} bins. The overall gain is around a factor of 1.7

two-hadron: final statistics

2010 proton data

	h^+h^- pairs
	$\cdot 10^6$
total	34.56

2007 proton data

	h^+h^- pairs
	$\cdot 10^6$
total	10.91

2002-04 deuteron data

	h^+h^- pairs
	$\cdot 10^6$
total	5.81

31.6 % of 2010 statistics

16.8 % of 2010 statistics