COMPASS results: new measurements of transverse-spin asymmetries in two-hadron inclusive production

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on behalf of the COMPASS collaboration

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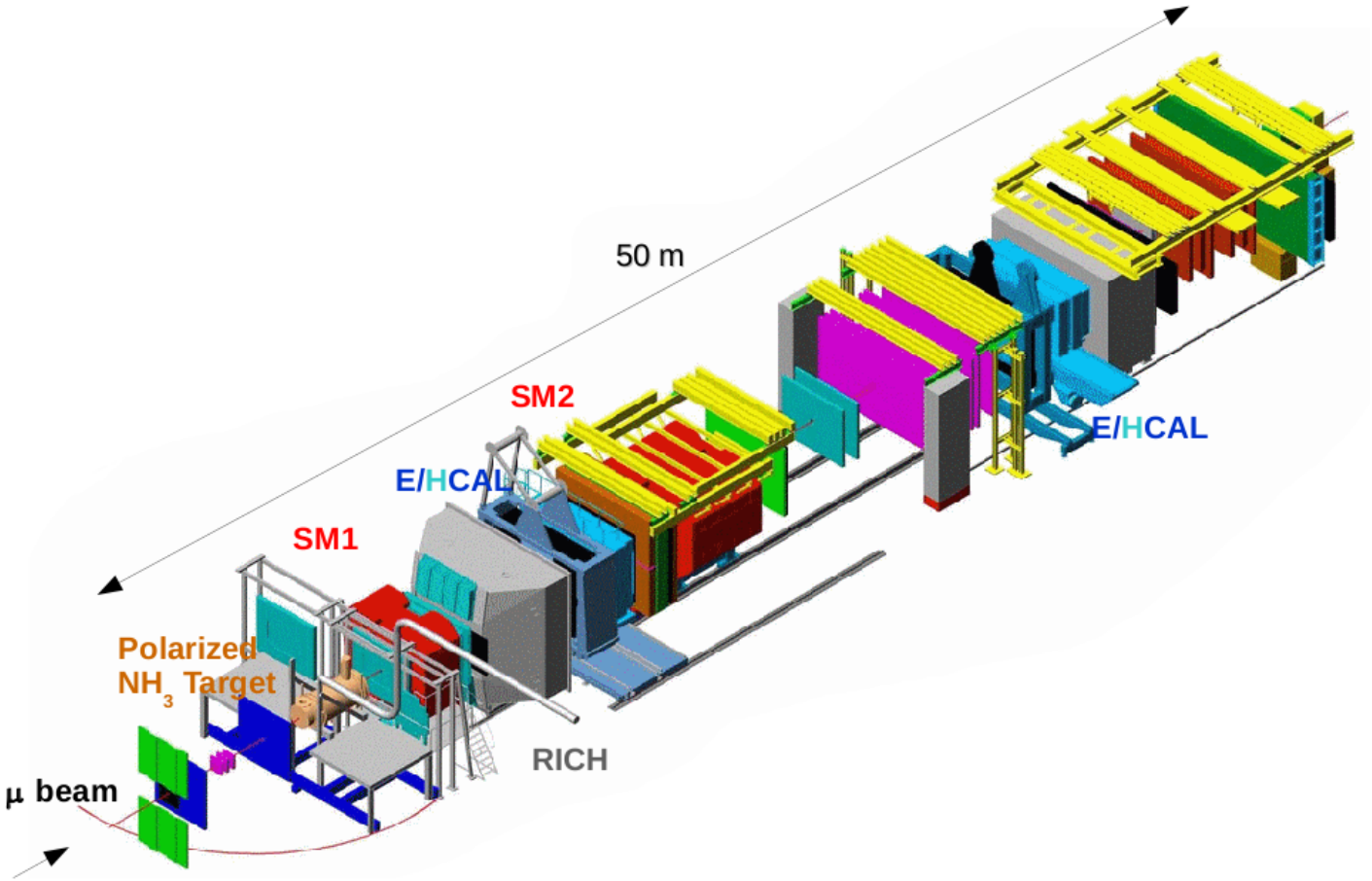
Veli Lošinj - Croatia

Outline

The COMPASS experiment at CERN

The COMPASS experiment



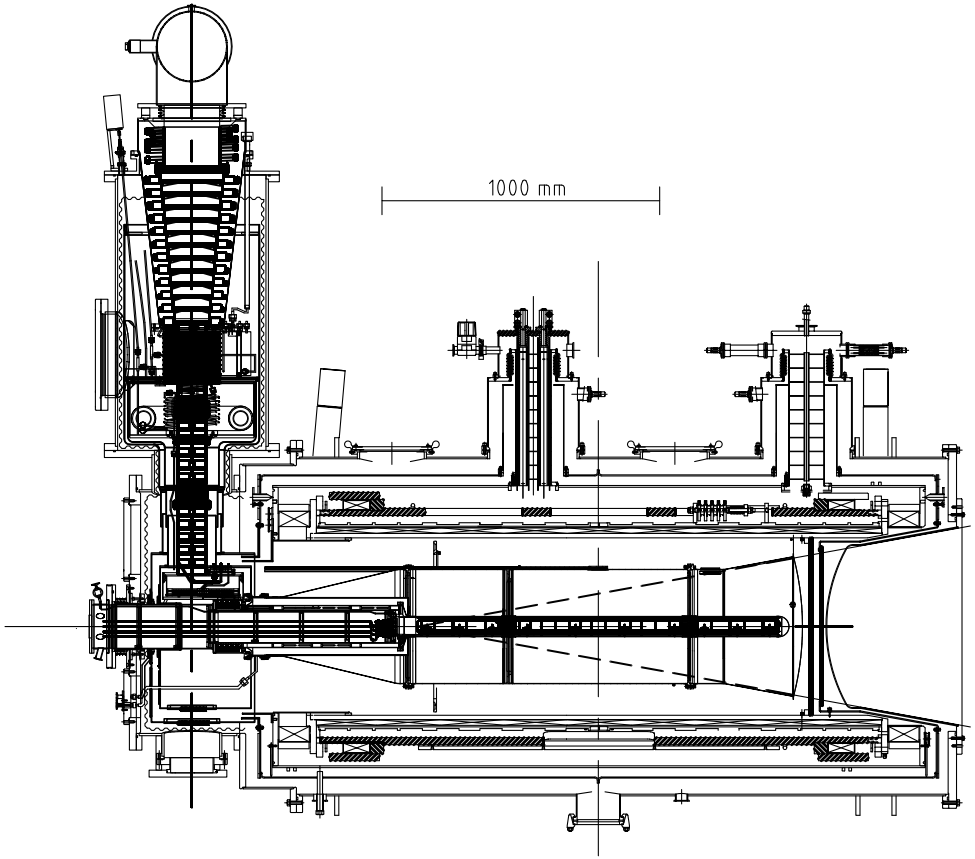
COMPASS setup 2007

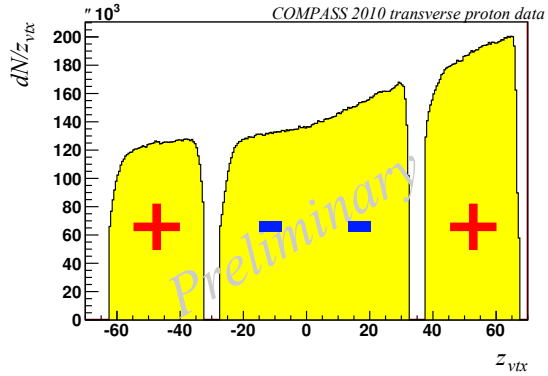
- Beam: $160\,GeV/c$
- Intensity: $2 \times 10^8 \mu^+$/spill
- Luminosity: $5 \times 10^{32} cm^{-2} s^{-1}$

- Two stage spectrometer
- Longitudinal polarized μ^+-beam
- 2002-2004 polarized ^{6}LiD (deuterium) target
- 2007 & 2010 polarized NH_3 (proton) target

- Tracking
- Calorimetry
- PID (RICH)

The COMPASS target system



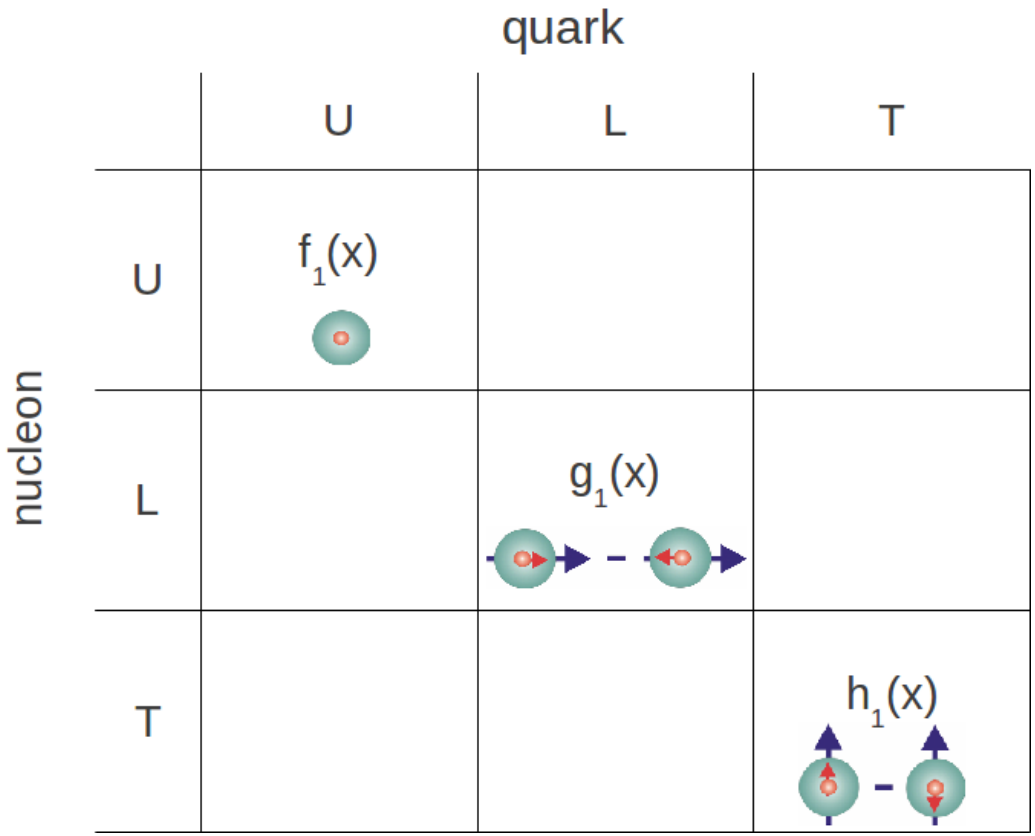


- Upgrade of target system in 2005
- Three cells with opposite polarization
- 180 mrad geometrical acceptance
- Transverse polarization reversed every week via microwave

- ^{6}LiD (deuteron):
  - polarization $\approx 48\%$
  - dilution factor ≈ 0.38
- NH_3 (proton):
  - polarization $\approx 90\%$
  - dilution factor ≈ 0.15

Spin structure → Transversity

Three distribution functions are necessary to describe the spin structure of the nuclean in LO:

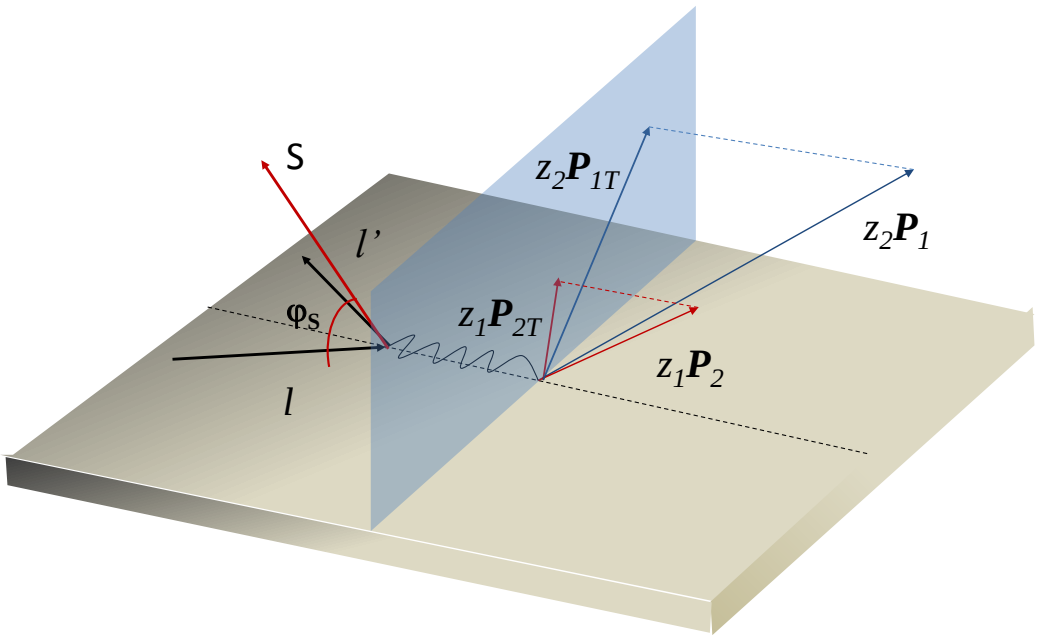


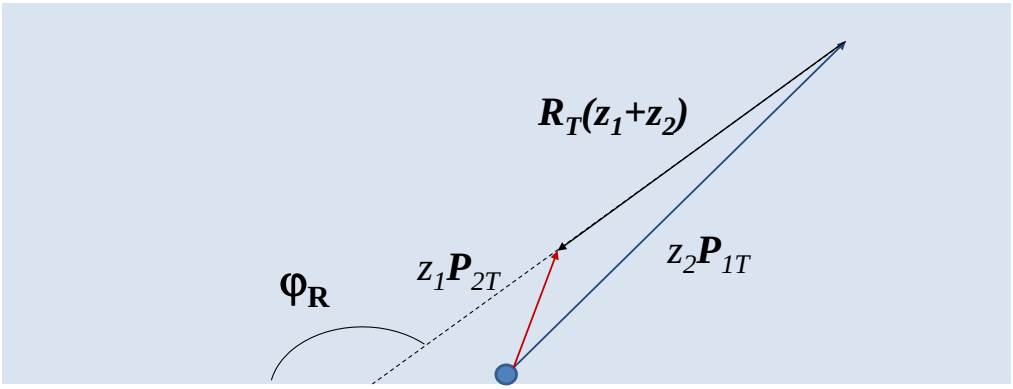
Quark distribution
$f_1(x) = q^+(x) + q^-(x)$

Helicity distribution
$g_1(x) = q^+(x) - q^-(x)$

Transversity distribution
$h_1(x) = q^{\uparrow\uparrow}(x) - q^{\uparrow\downarrow}(x)$
$lN^\uparrow \to l'hX$ Collins FF
$lN^\uparrow \to l'hhX$ Interference FF
$lN^\uparrow \to l'\Lambda X$ FF of $q^\uparrow \to \Lambda$

Theoretical motivations: angle definitions





$lP^{\uparrow} \rightarrow l' h_1 h_2$

Fragmentation of transversely polarized quark into two unpolarized hadrons

- $z_i = \frac{\mathbf{P_i}}{\mathbf{P_{tot}}}$
- $\mathbf{R_T} = \frac{z_1\mathbf{P_{2,T}} - z_2\mathbf{P_{1,T}}}{z_1+z_2}$
- $\hat{\mathbf{q}} = \hat{\mathbf{z}}$
- Azimuthal angle of $\mathbf{R_T}$:

  $\cos\Phi_R = \frac{\hat{\mathbf{q}}\times\mathbf{l}}{|\hat{\mathbf{q}}\times\mathbf{l}|} \cdot \frac{\hat{\mathbf{q}}\times\mathbf{R_T}}{|\hat{\mathbf{q}}\times\mathbf{R_T}|}$
- Φ_S azimuthal angle of the spin of the fragmenting quark

Theoretical motivations: two-hadron cross section

While integrating over $\mathbf{P_{h,T}}$ ($\mathbf{P_h} = \mathbf{P_1} + \mathbf{P_2}$) the two-hadron cross section is:

$$\frac{d^7}{d\zeta dM_h^2 d\Phi_R dz dx dy d\Phi_S} = \frac{2\alpha^2}{4\pi s x y^2} A(y) q(y) D_1^{\sphericalangle q}(z, M_h^2)$$
$$+ B(y) |S_\perp| \frac{|R_T|}{M_h} \sin(\Phi_R + \Phi_S - \pi) h_1(x) H_1^{\sphericalangle q}(z, M_h^2)$$

Where $h_1(x)$ is the Transversity PDF and $H_1^{\sphericalangle q}(z, M_h^2)$ is the two-hadron Interference FF, which describes the Fragmentation of a transversely polarized quark into two unpolarized hadrons (results from BELLE *talk of A.Vossen*, models from Radici et al. & Ma et al.).

Theoretical motivations: asymmetries extraction

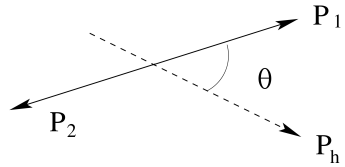
$$N^{\pm}_{2h}(\Phi_{RS}) = N^{0}_{2h}(1 \pm f P_T D_{NN} A_{2h} \sin\Phi_{RS} \sin\Theta)$$

with $\sin\Phi_{RS} = \sin(\Phi_R + \Phi_S - \pi)$

$$A_{2h} = \frac{\sum_q e_q^2 h_1(x) H_1^{\sphericalangle q}(z, M_h^2)}{\sum_q e_q^2 q(x) D_1^{\sphericalangle q}(z, M_h^2)}$$

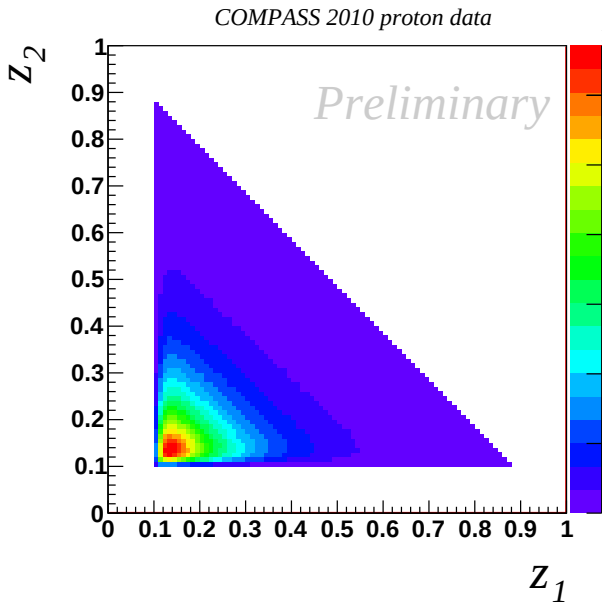
$\pm$ indicates nucleon spin orientation
f = target dilution factor
P_T = target polarization
$D_{NN} = \frac{1-y}{1-y+\frac{y^2}{2}}$ = transv. spin transfer coef.

h^+h^- center of mass frame



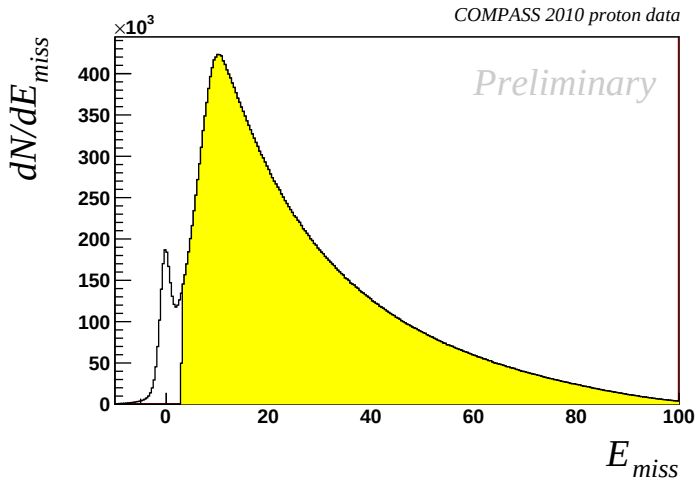
Data selection

- Vertex with at least **3** outgoing tracks:
  $\hookrightarrow$ All h^+h^- pair combinations are taken into account
- $Q^2 > 1$ GeV^2
- $0.1 < y < 0.9$
- $W > 5$ GeV



Specific cuts for two-hadron analysis:

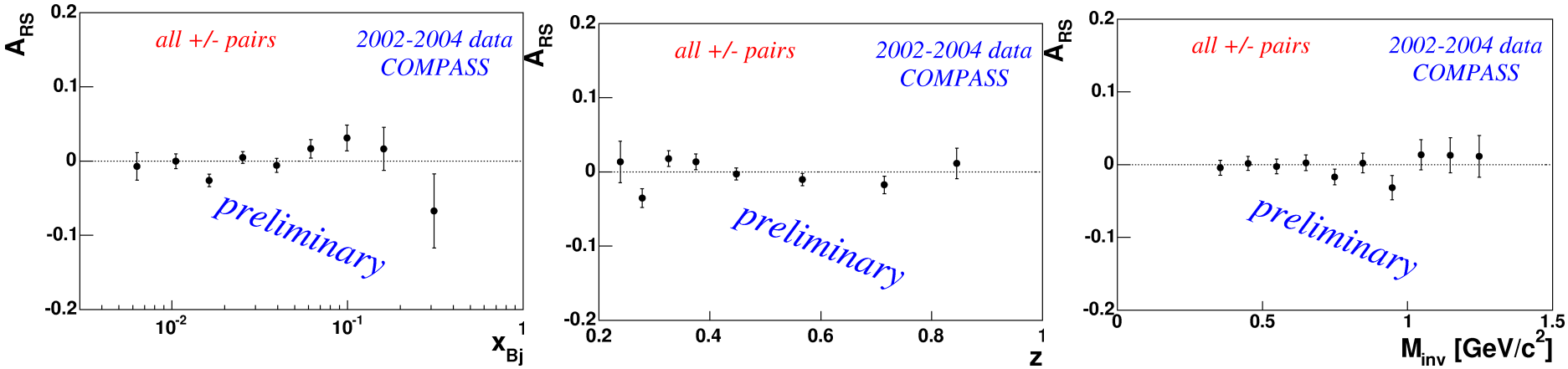
- $z > 0.1$ for each hadron
- $x_F > 0.1$ for each hadron
- $E_{miss} > 3$ GeV for each pair
- $R_T > 0.07$ GeV for each pair



two-hadron asymmetries:

deuteron data 2002 - 2004

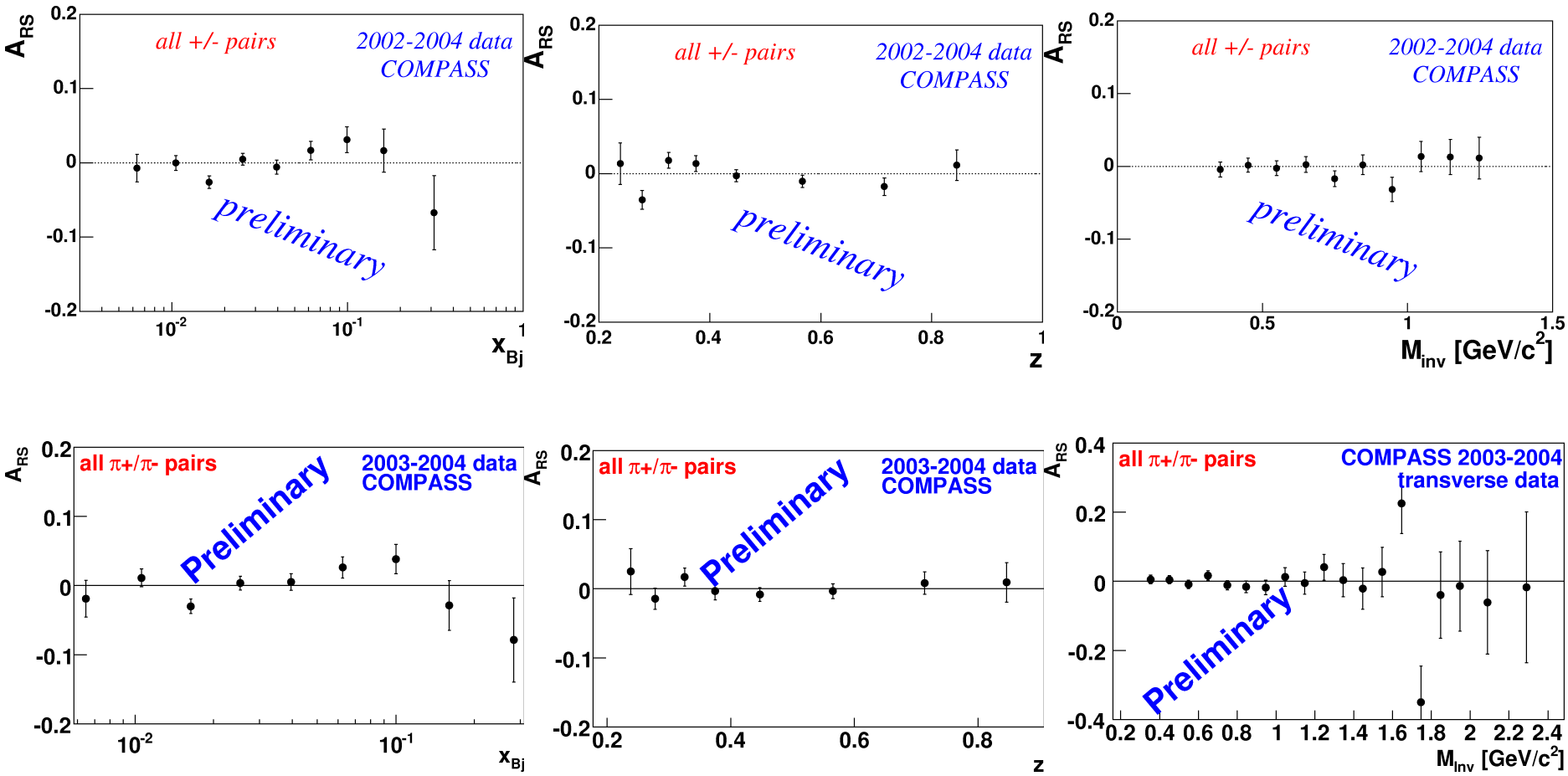
two-hadron asymmetries: deuteron data 2002 - 2004



2002 - 2004 deuteron data two-hadron asymmetries of h^+h^- pairs:

$\hookrightarrow$ all asymmetries are small, compatible with zero

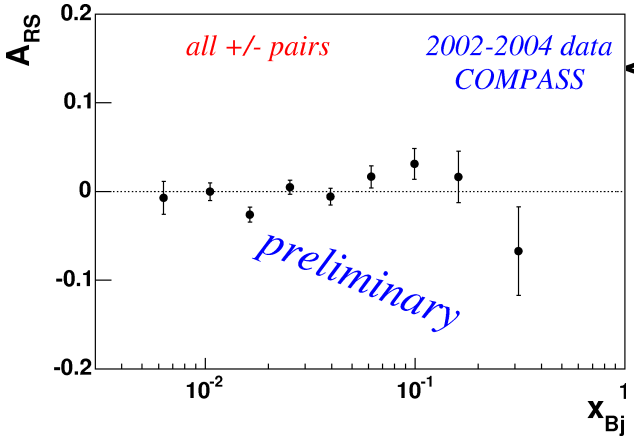
deuteron data 2002 - 2004: $\pi^+\pi^-$ pairs

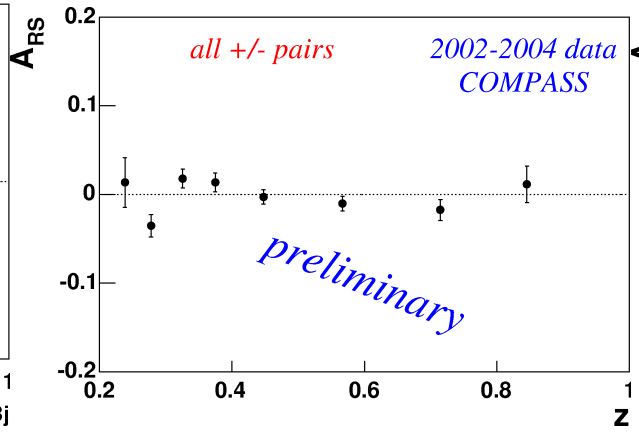


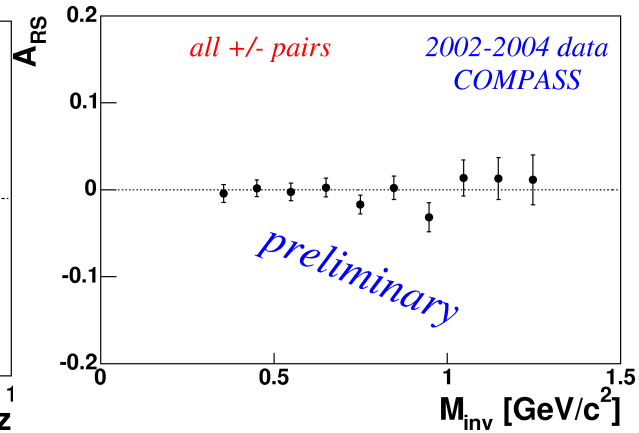
2002 - 2004 deuteron data two-hadron asymmetries: all h^+h^- pairs (top), $\pi^+\pi^-$ pairs (bottom)

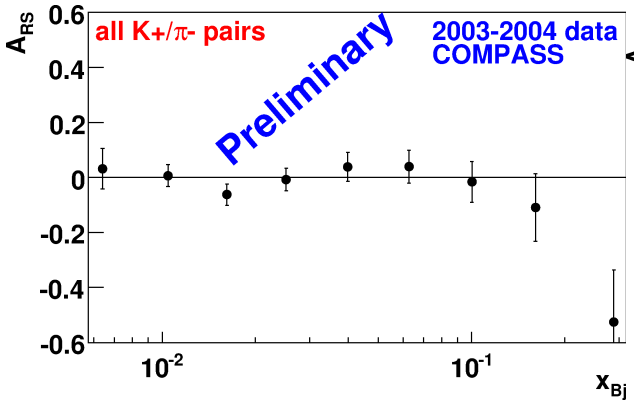
$\hookrightarrow$ $\pi^+\pi^-$ signal determines most of the unidentified asymmetries

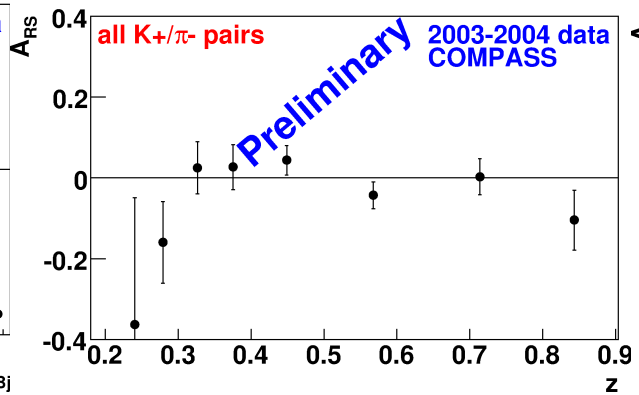
deuteron data 2002 - 2004: $K^+\pi^-$ pairs

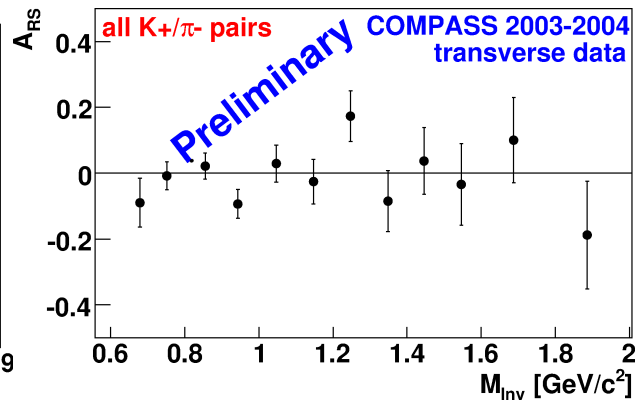






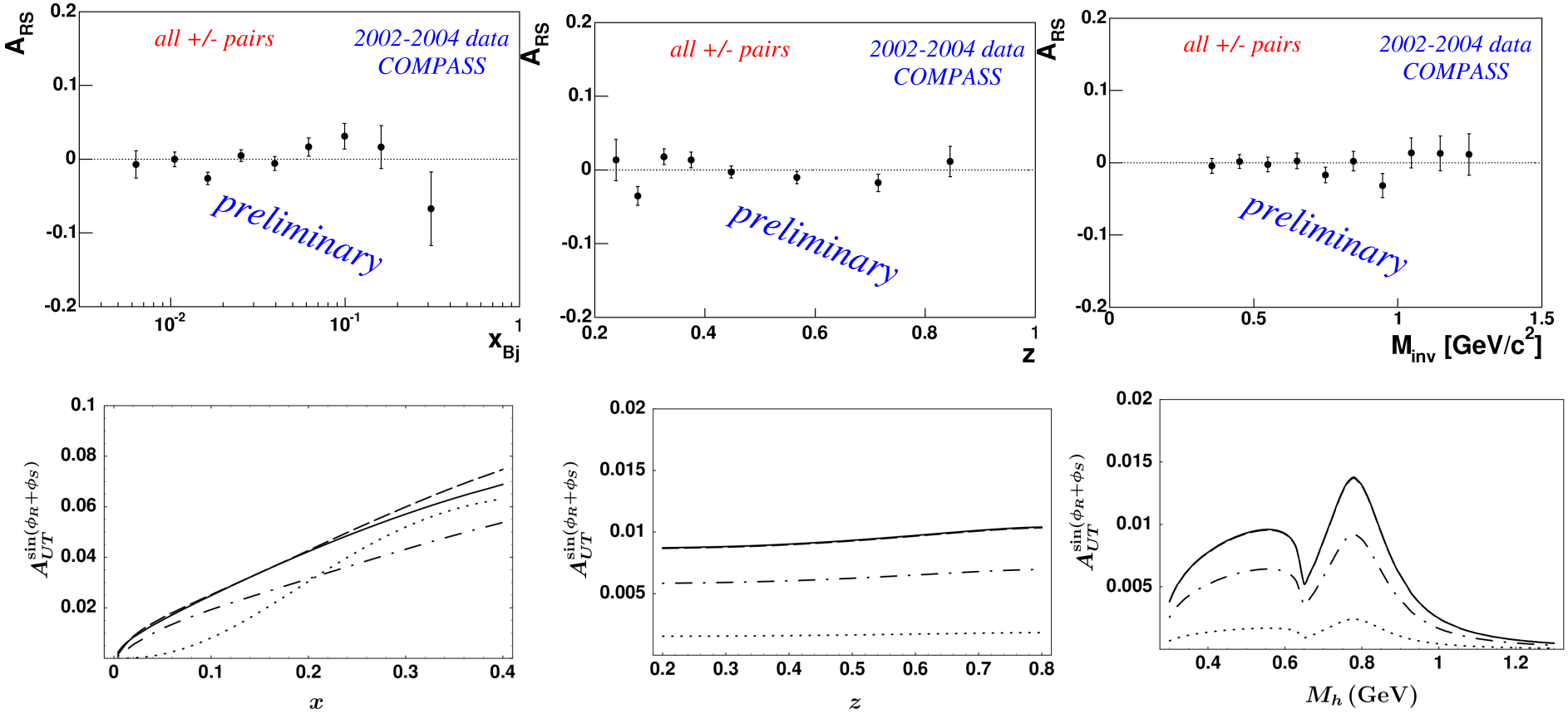






2002 - 2004 deuteron data two-hadron asymmetries: all h^+h^- pairs (top), $K^+\pi^-$ pairs (bottom)

deuteron data 2002 - 2004 comparison with model predictions



A. Bacchetta, hep-ph/0708037

Different lines correspond to different models of $h_1(x)$.

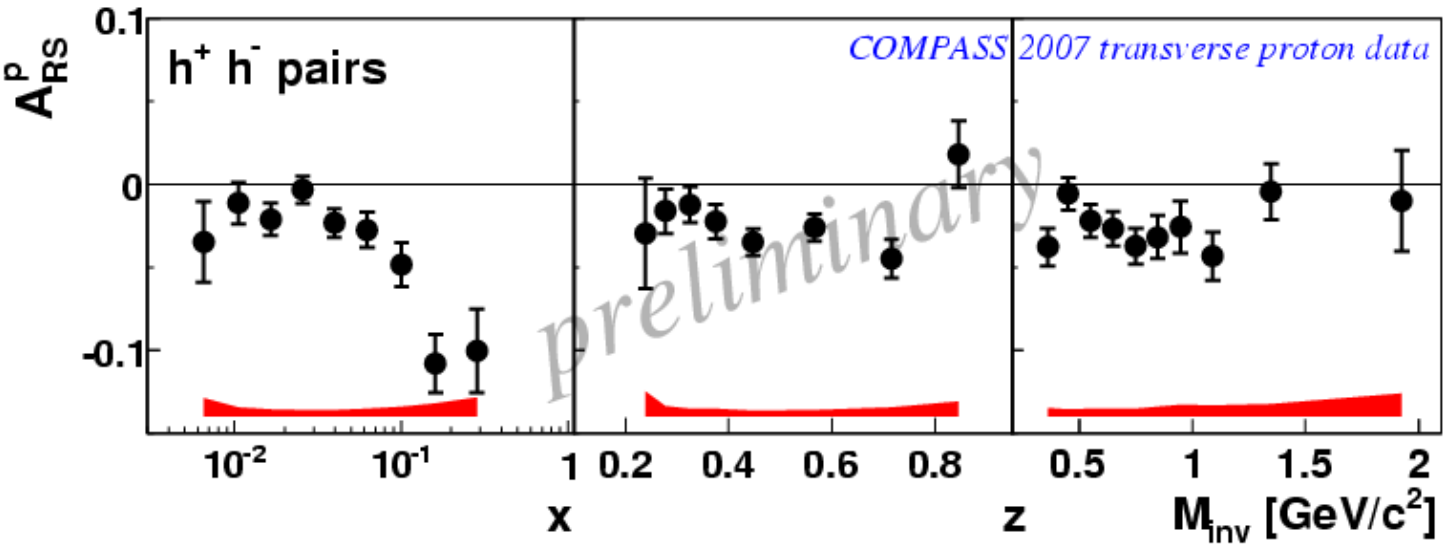
Different definition of Φ_S w.r.t. COMPASS

↪ rather agreement with model predictions

two-hadron asymmetries:

proton data 2007
unidentified hadron pairs

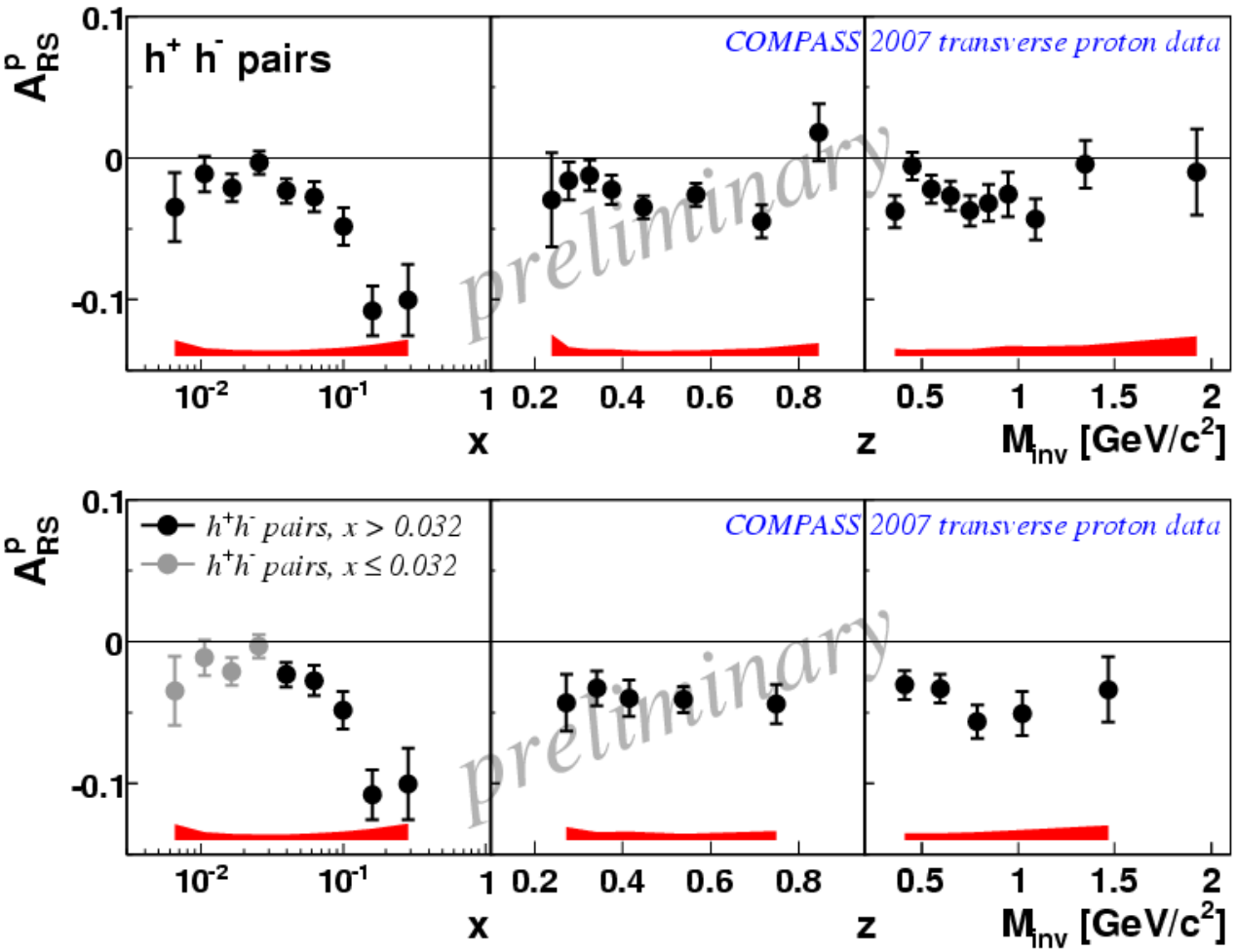
two-hadron asymmetries: proton data 2007



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

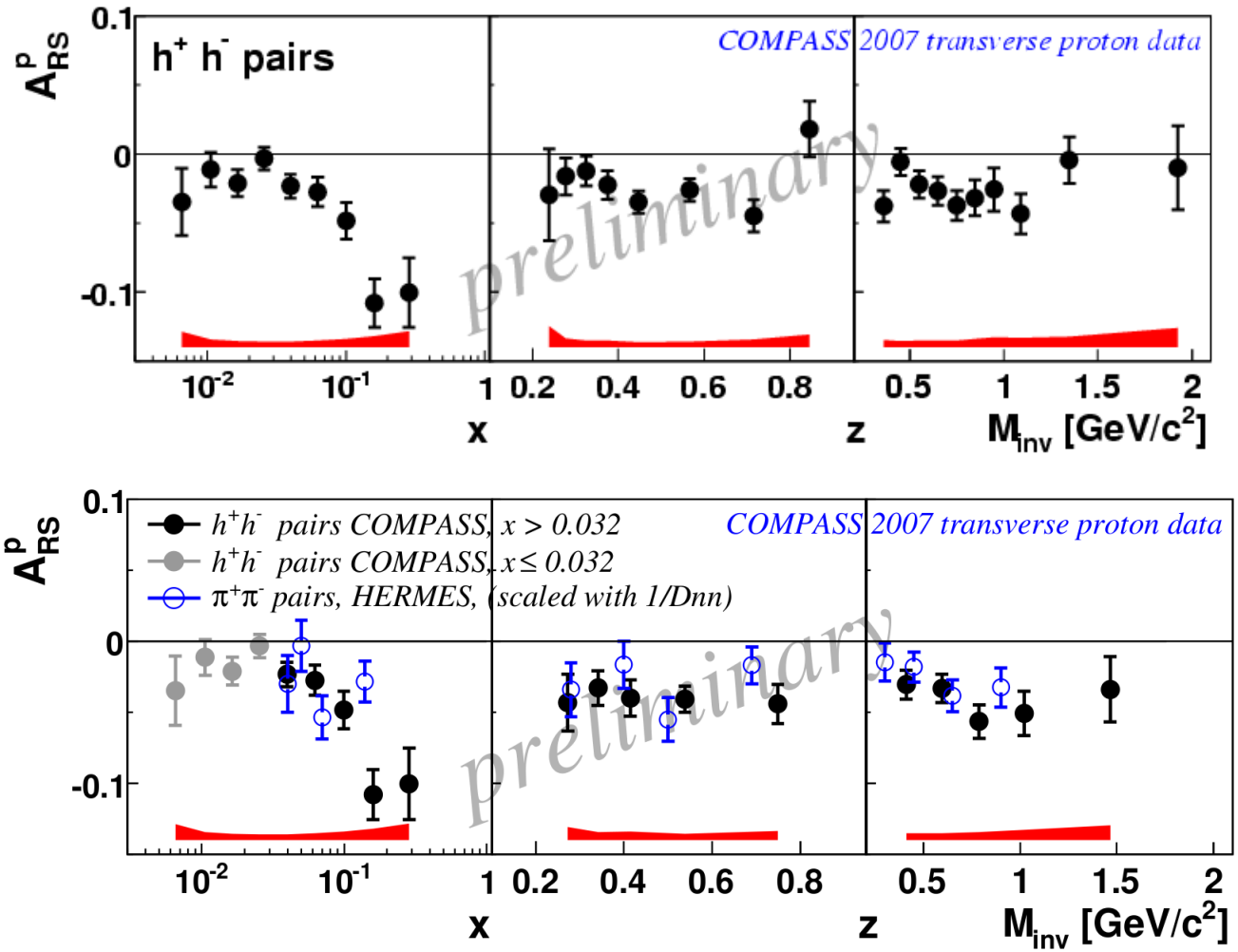
$\hookrightarrow$ Large asymmetries for proton up to $5 - 10\%$

proton data 2007: $x > 0.032$



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

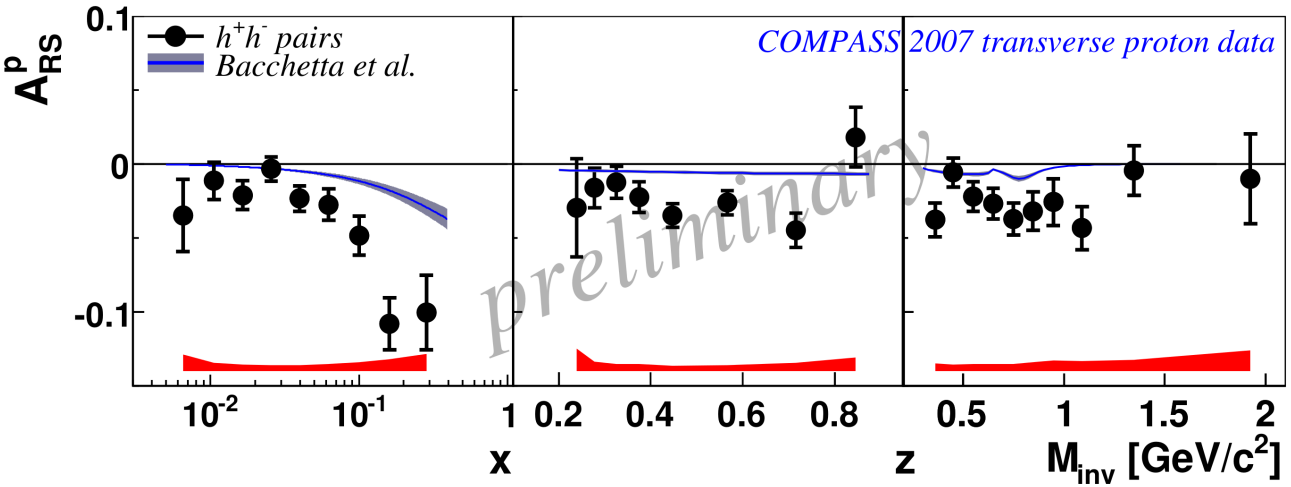
proton data 2007: comparison with HERMES data



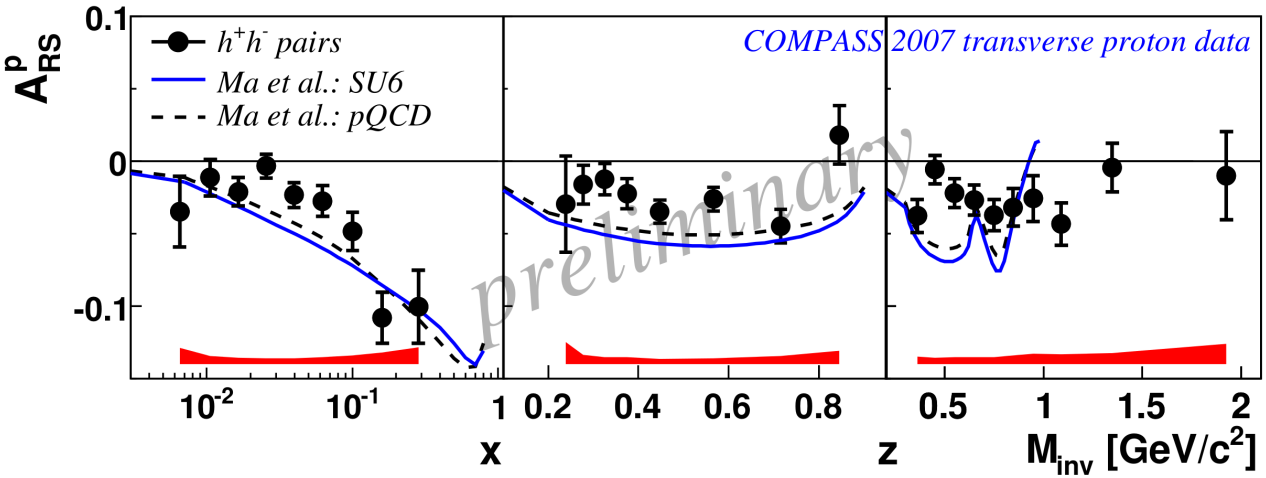
HERMES data scaled with $1/D_{nn}$

↪ Good agreement with HERMES data within the error bars

proton data 2007: comparison with model predictions



Bachetta & Radici, hep-ph/0608037



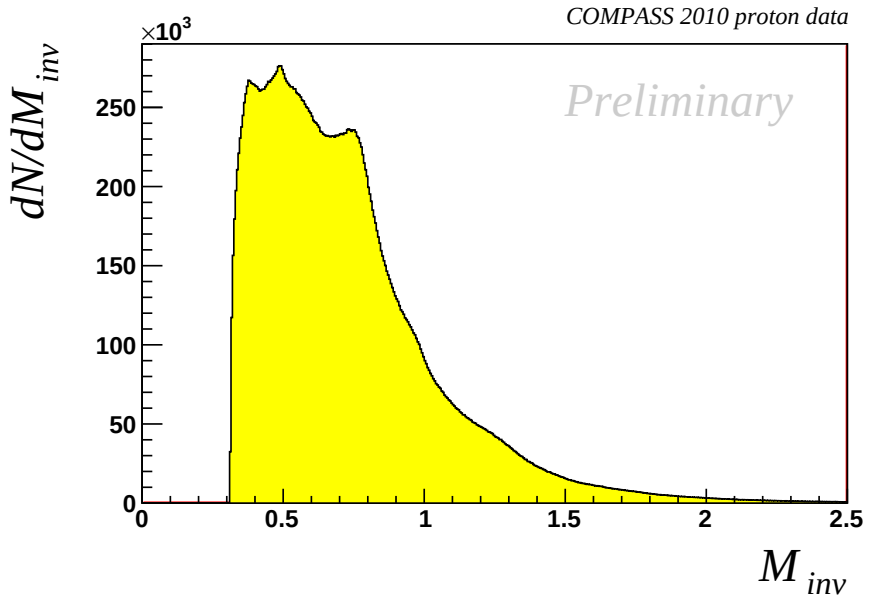
Ma et al., arXiv:0711.0817

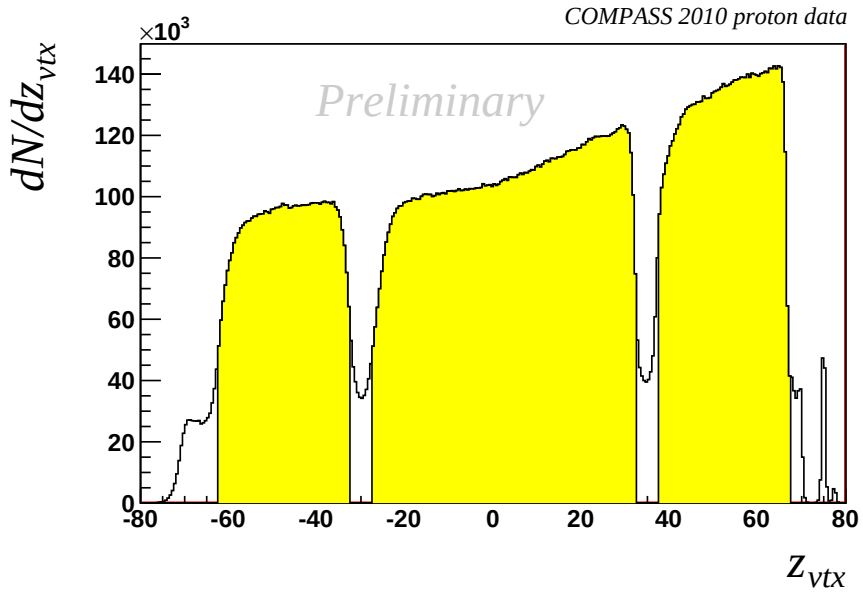
↪ Model predictions in agreement with data

two-hadron asymmetries:

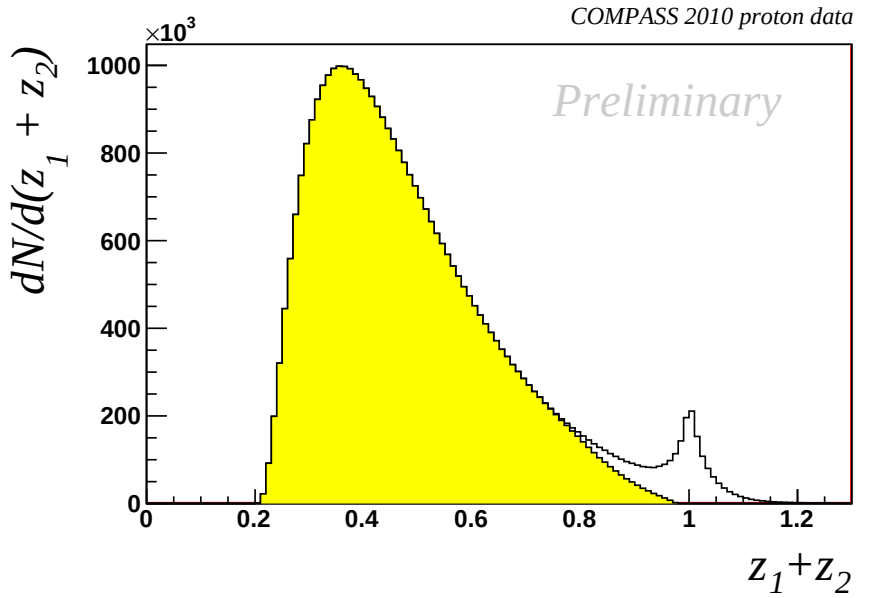
proton data 2010
unidentified hadron pairs

two-hadron asymmetries: proton data 2010

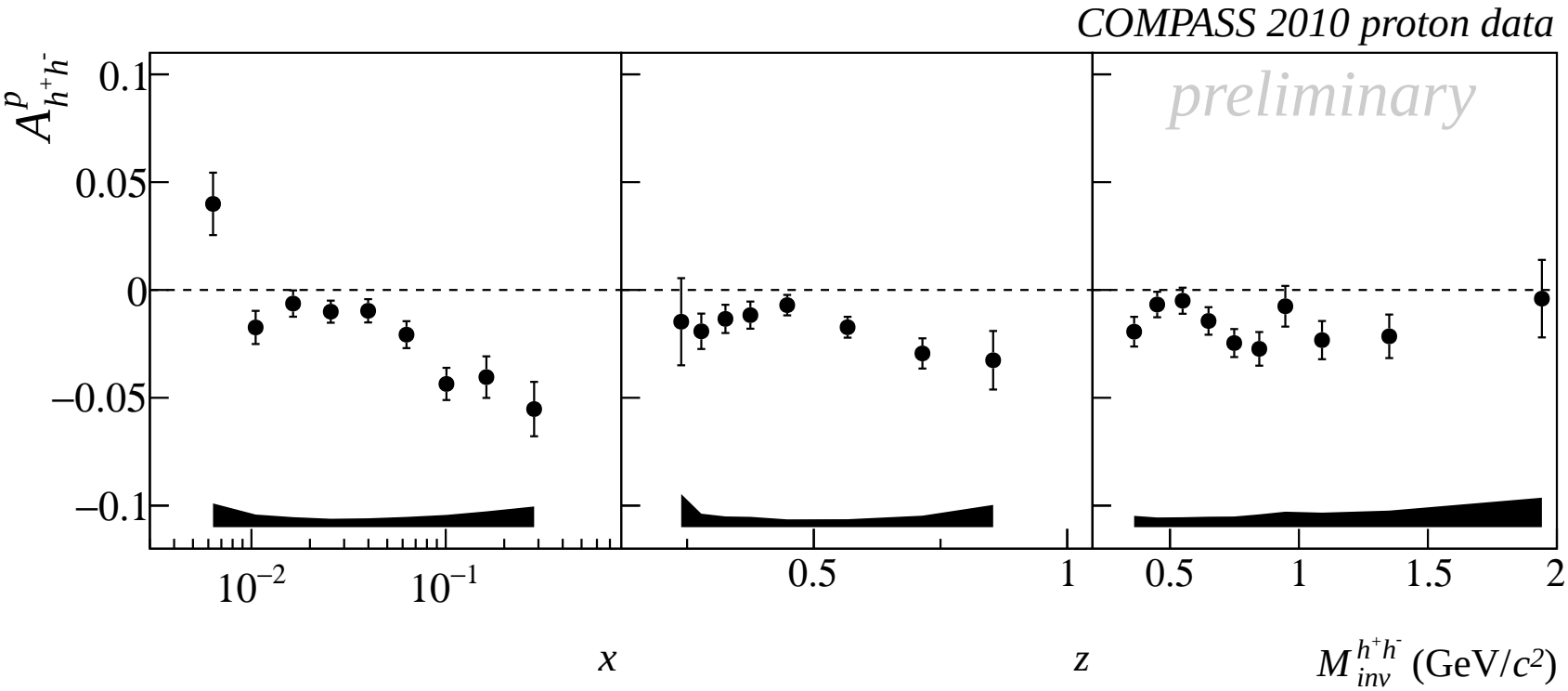




M_{inv} (top left), z-coordinate of the vertex (top right) and $z_1 + z_2$ distribution (bottom right) for proton 2007 data



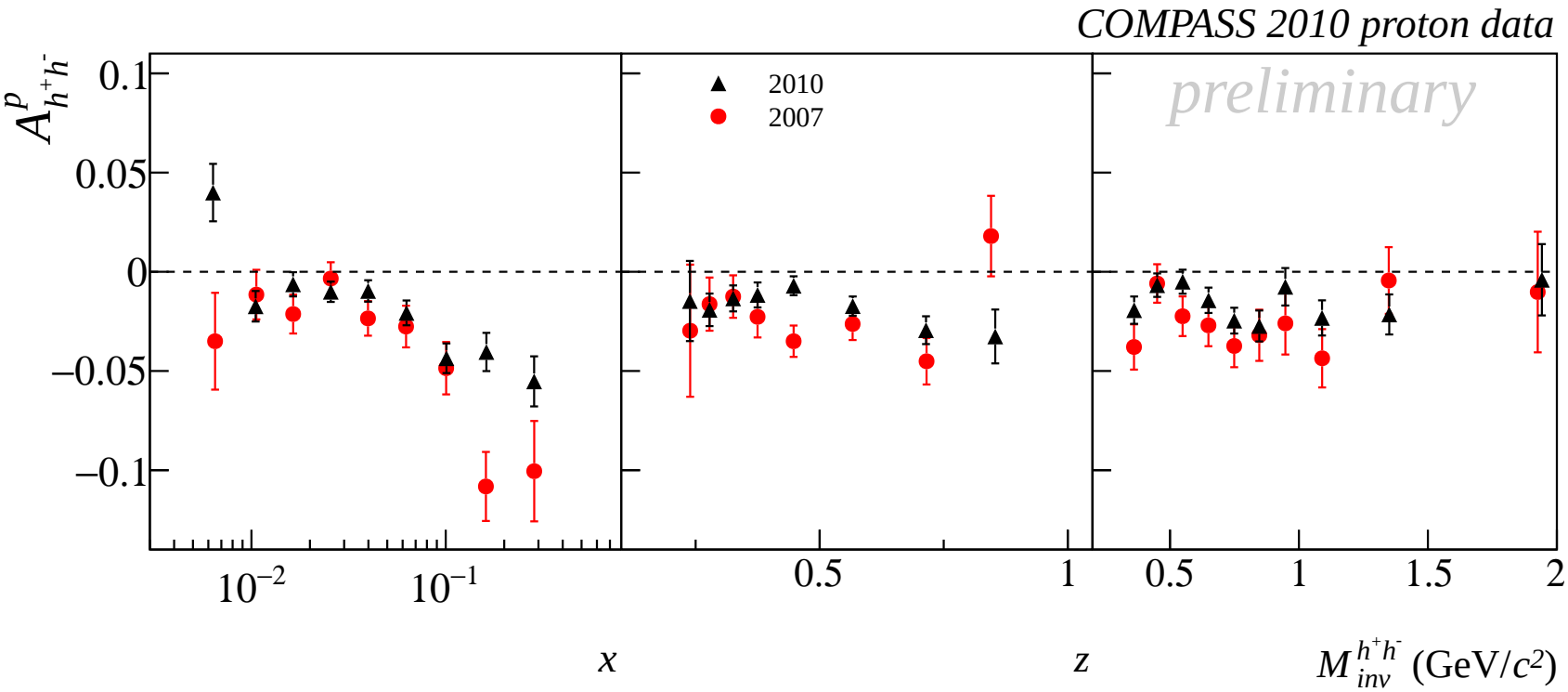
two-hadron asymmetries: proton data 2010



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

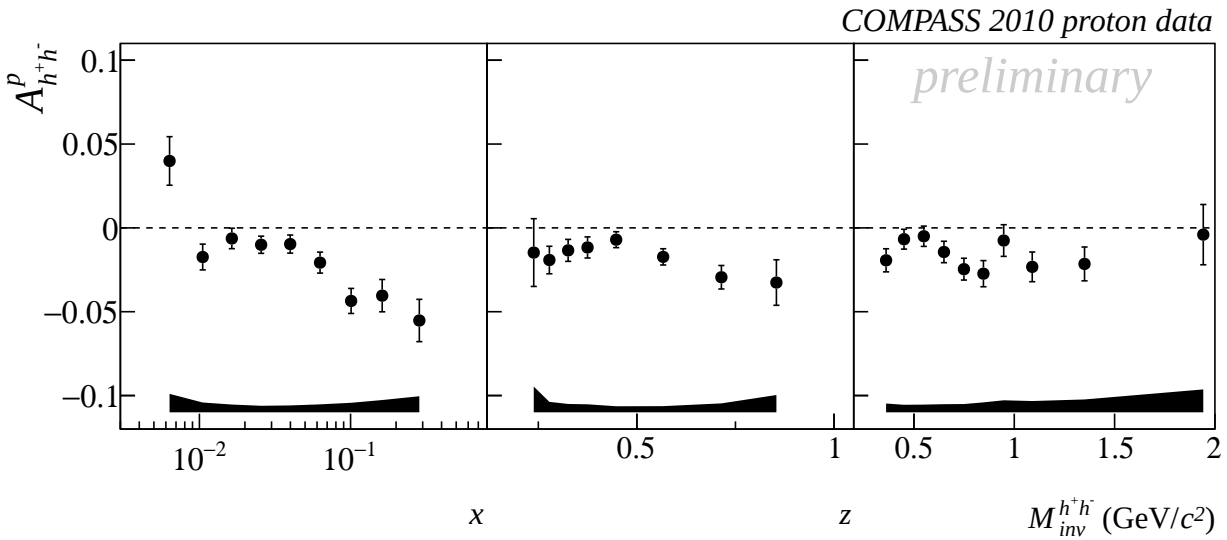
↪ Clear asymmetries for proton with improved errors

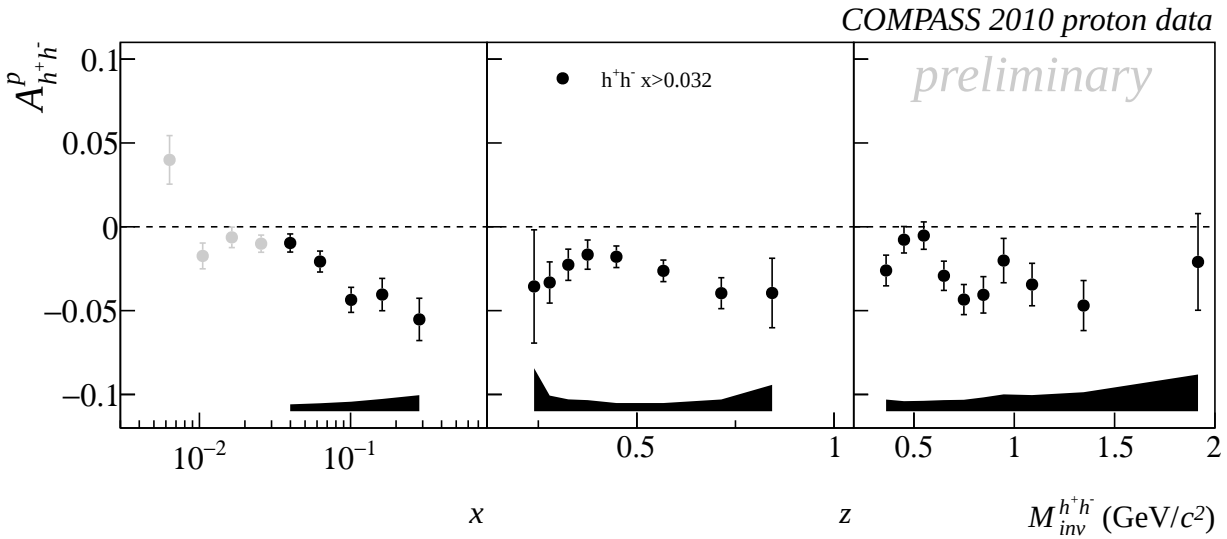
two-hadron asymmetries: comparison 2010 and 2007 proton data



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

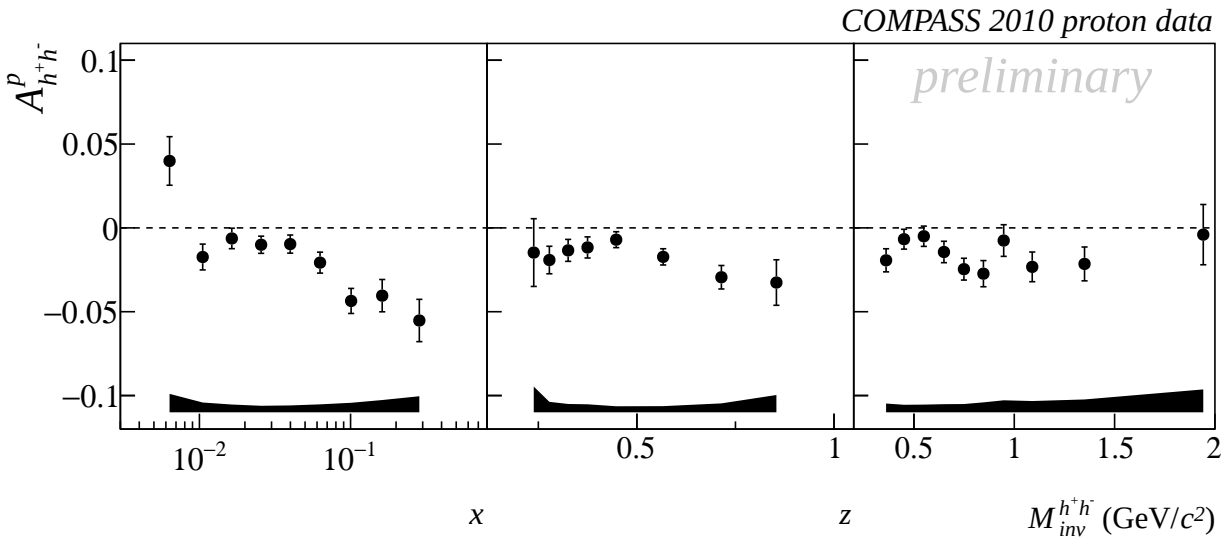
two-hadron asymmetries: proton data 2010 $x_{bj} > 0.032$

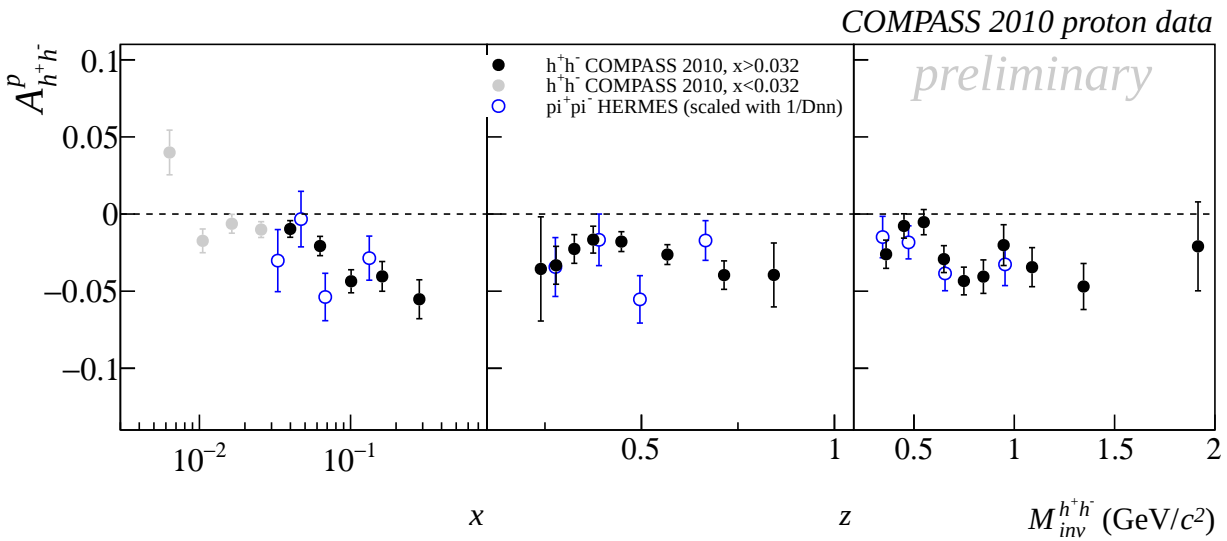




↪ Asymmetries in z and M_{inv} increase for $x > 0.032$ sample

Comparison with results from HERMES

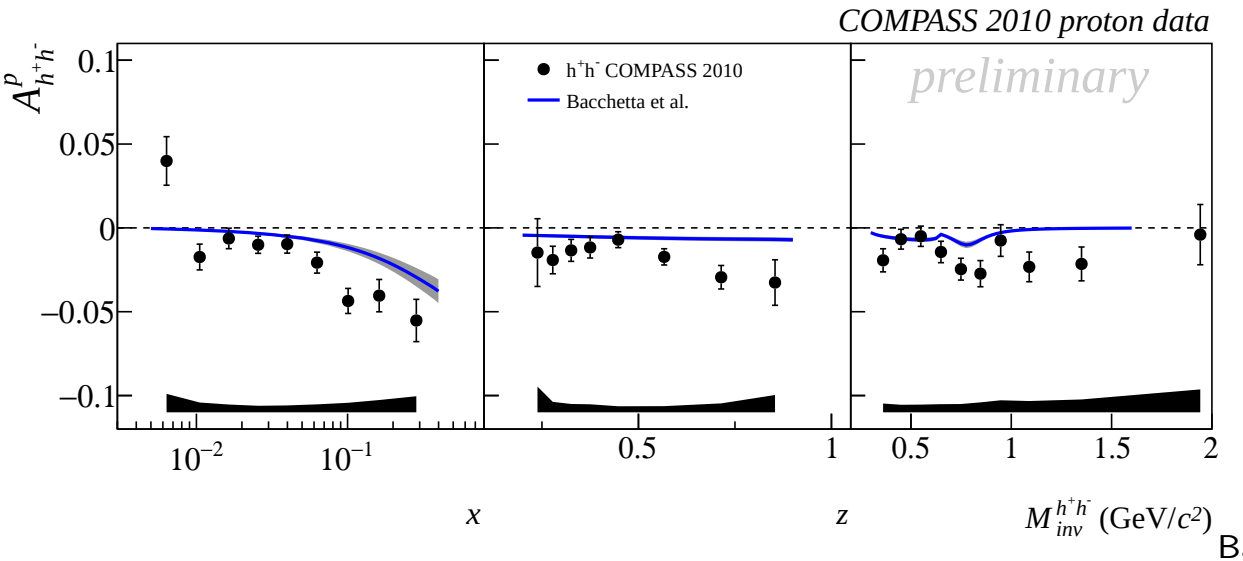




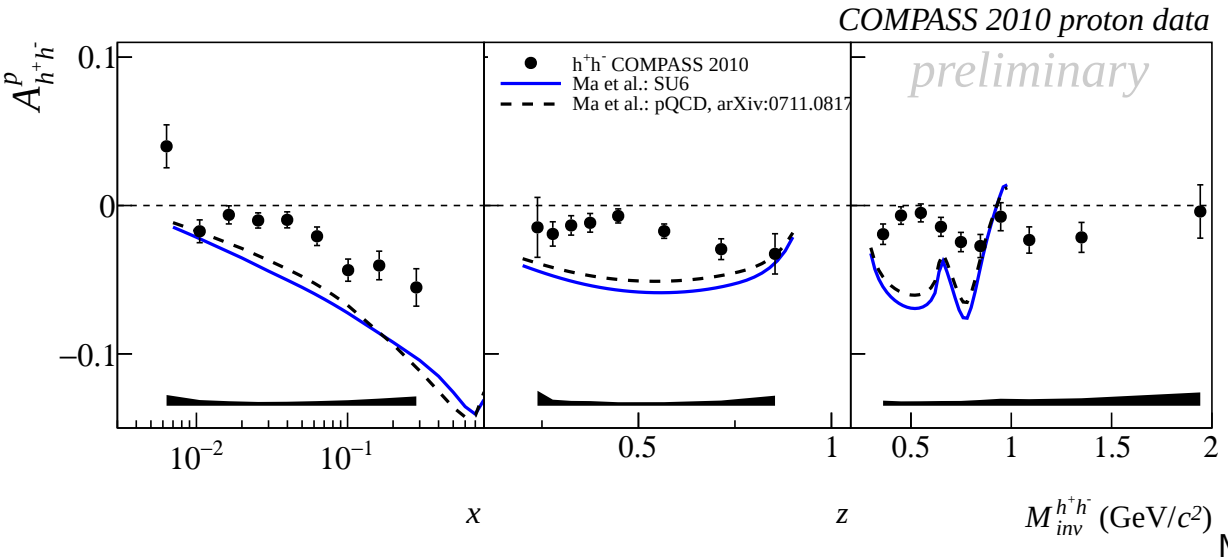
HERMES data scaled with $1/D_{nn}$

↪ Good agreement with HERMES data within the error bars

2010 proton data comparison with model predictions



Bachetta & Radici



Ma et al.

↪ level of agreement differs for x,z and M_{inv}

Conclusions & Outlook

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

$\hookrightarrow$ paper to be published soon

- **NEWS:** preliminary results for 2010 COMPASS proton data available:

1. Extensive **new** data
2. Small statistical and systematic uncertainty
3. Strong improvement with 2010 data
4. Agreement of independent COMPASS 2010 and 2007 proton measurements within the error bars
5. COMPASS data, with it's higher precision, is in agreement with HERMES data
6. Reasonable agreement with model predictions of Bacchetta & Ma

Outlook:

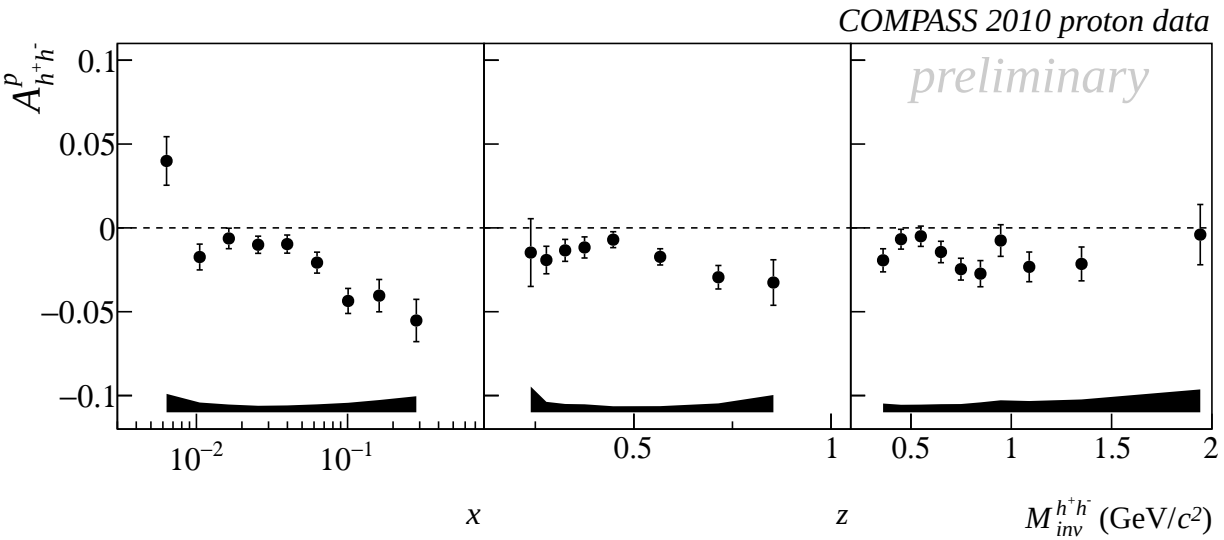
- Asymmetries for identified hadron pairs

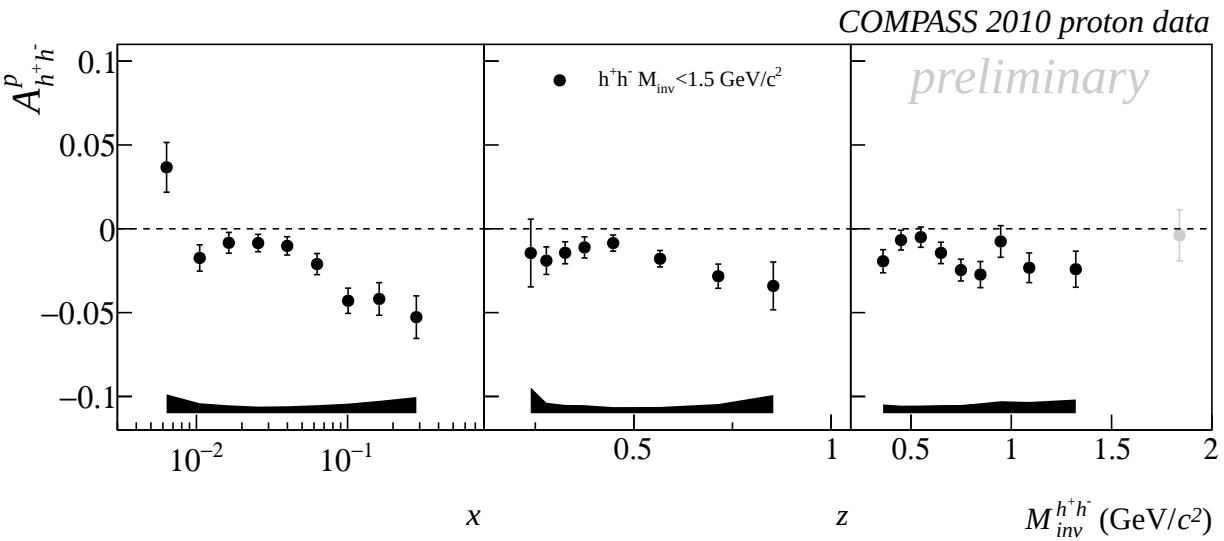
Thank You!

email: christopher.braun@cern.ch

Back Up

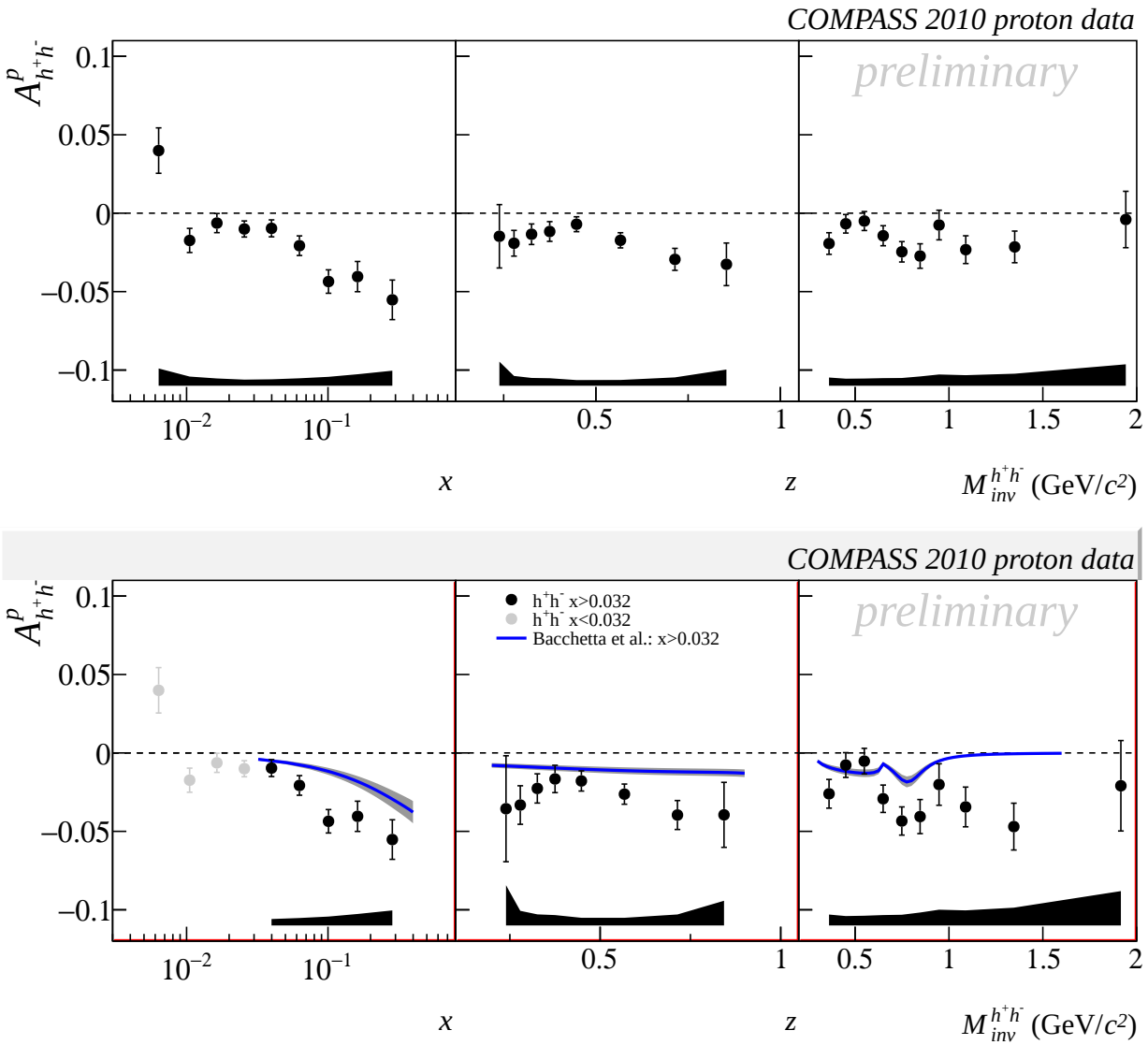
two-hadron asymmetries: proton data 2010 $M_{inv} < 1.5\,GeV/c^2$





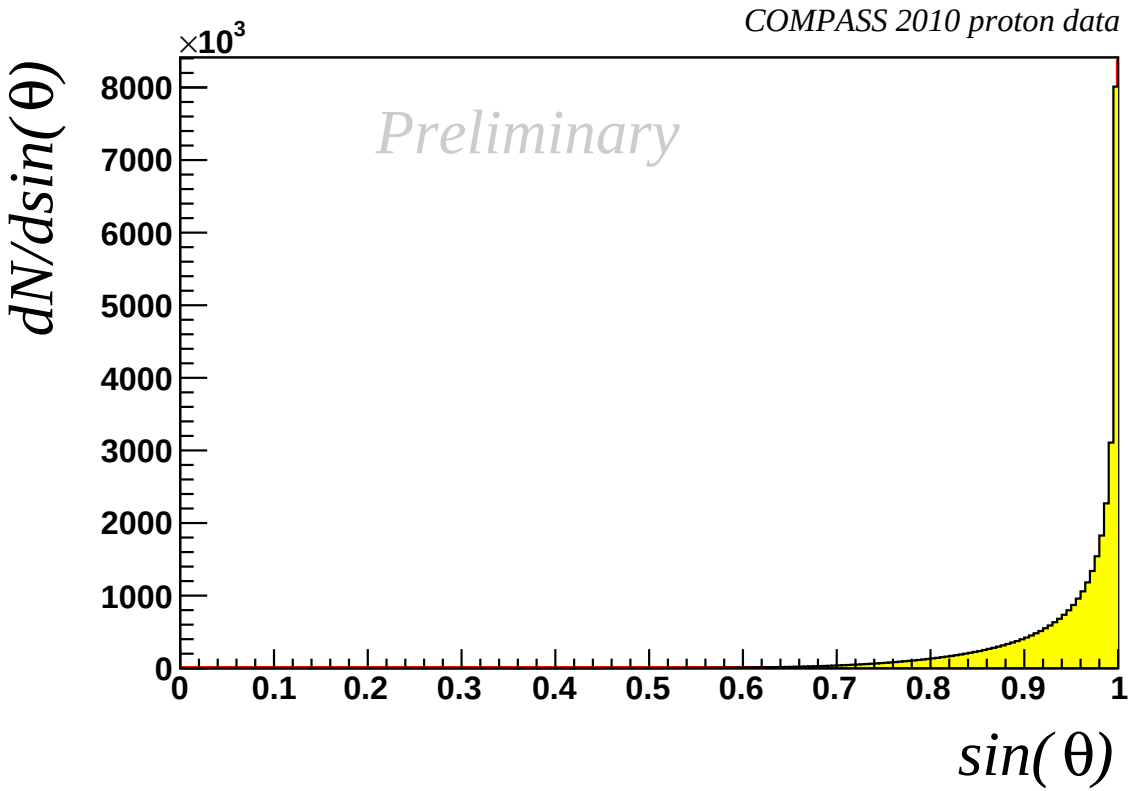
↪ No change in the asymmetries for $M_{inv} < 1.5\,GeV/c^2$

2010 proton data comp. with Bacchetta et al. $x_{bj} > 0.032$

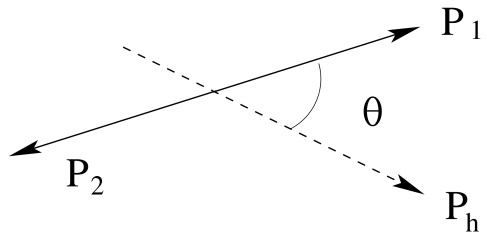


↪ Asymmetries of data and model prediction increase for $x > 0.032$

two-hadron: $\sin\Theta$



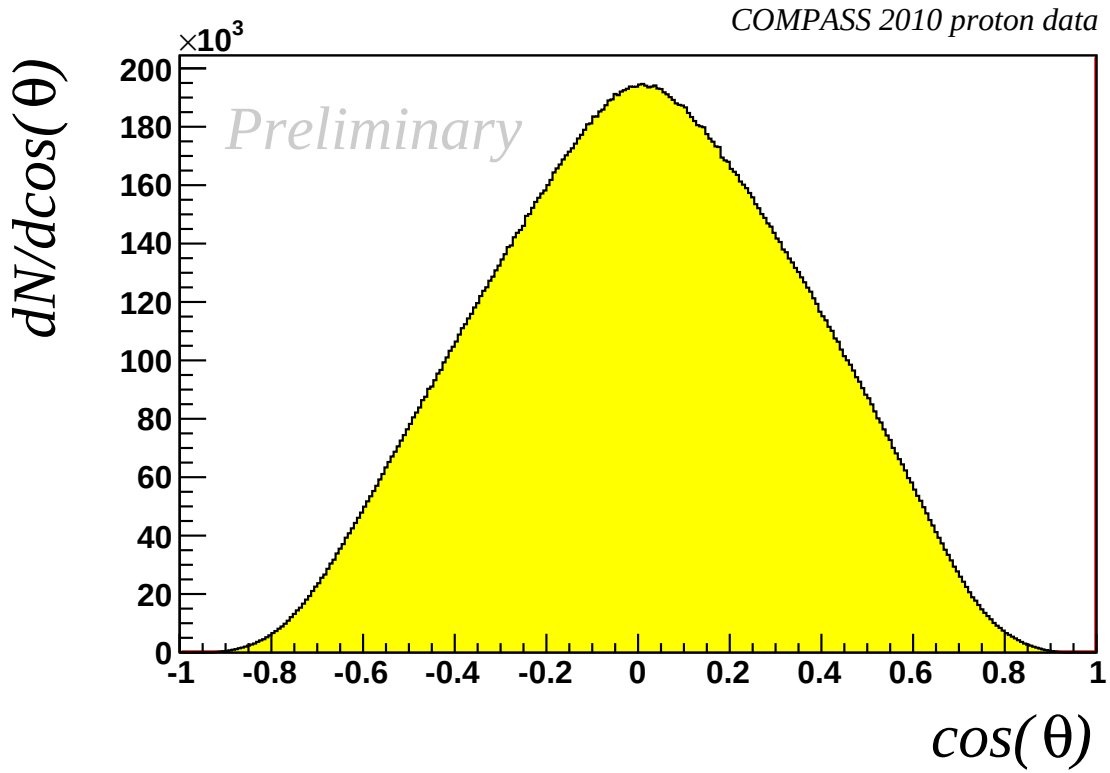
h^+h^- center of mass frame



$$\langle \sin\Theta \rangle = 0.943$$

$\sin\Theta$ can be neglected.

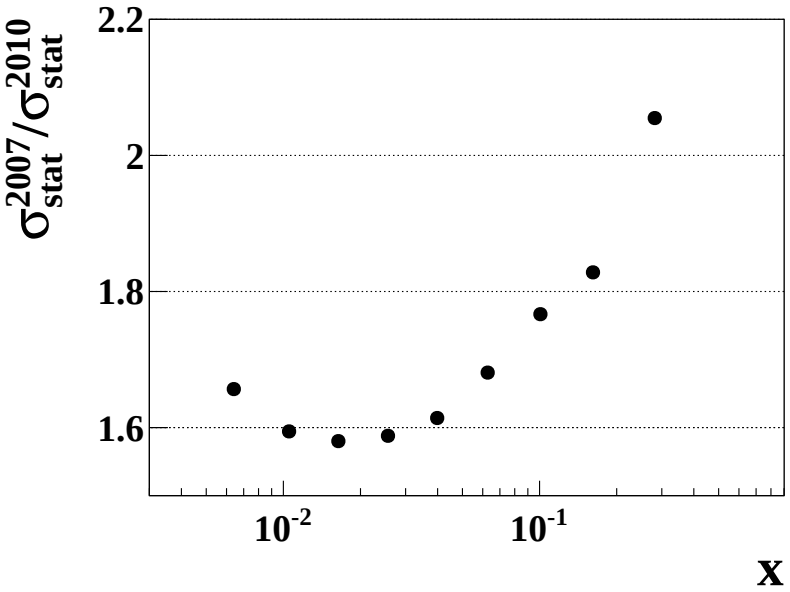
two-hadron: $\cos\Theta$



$$H_1^{\sphericalangle}(z, \cos\Theta, M_{inv}^2) = H_{1,0t}^{\sphericalangle}(z, M_{inv}^2) + H_{1,lt}^{\sphericalangle}(z, M_{inv}^2)\cos\Theta$$

$$\langle \cos\Theta \rangle = 0.01$$
$$\langle \cos^2\Theta \rangle = 0.1$$

Comparison of statistical errors 2007/2010



The ratio between the statistical error of 2007 on 2010 analysis, as a function of x bins.

The overall gain is around a factor of 1.7

deuteron data: data Selection

- μ'-recovery is used as a veto
- Wrong combinations of ECAL1, HCAL1 and HCAL2 clusters (~~ECAL2~~)
- 2002-04:
  - HCAL1: $P_{had} > 4.0 GeV/c \;\&\&\; E_{hcal1} < 0.3 \cdot P_{had}$
  - HCAL2: $E_{hcal2} < 0.24 \cdot P_{had} + 1 GeV$
- 2007:
  - HCAL1: $P_{had} > 5.0 GeV/c \;\&\&\; E_{hcal1} < 0.2 \cdot P_{had}$
  - HCAL2: $E_{hcal2} < 0.25 \cdot P_{had}$
- 2010: no calorimeter cuts

Comparison of systematic errors 2002-04/2007/2010

	2002-2004	2007	2010
	$\sigma_{sys}/\sigma_{stat}$	$\sigma_{sys}/\sigma_{stat}$	$\sigma_{sys}/\sigma_{stat}$
estimator	0.04	0.04	0.15
false asymmetrie	0.32	0.66	0.71
left/right and top/bottom	0.84	0.75	0.77
target ploarization	5.4%	2.2%	5.0%
total	0.90	1.00	0.76