Transversity signal in two hadron pair production at *COMPASS*

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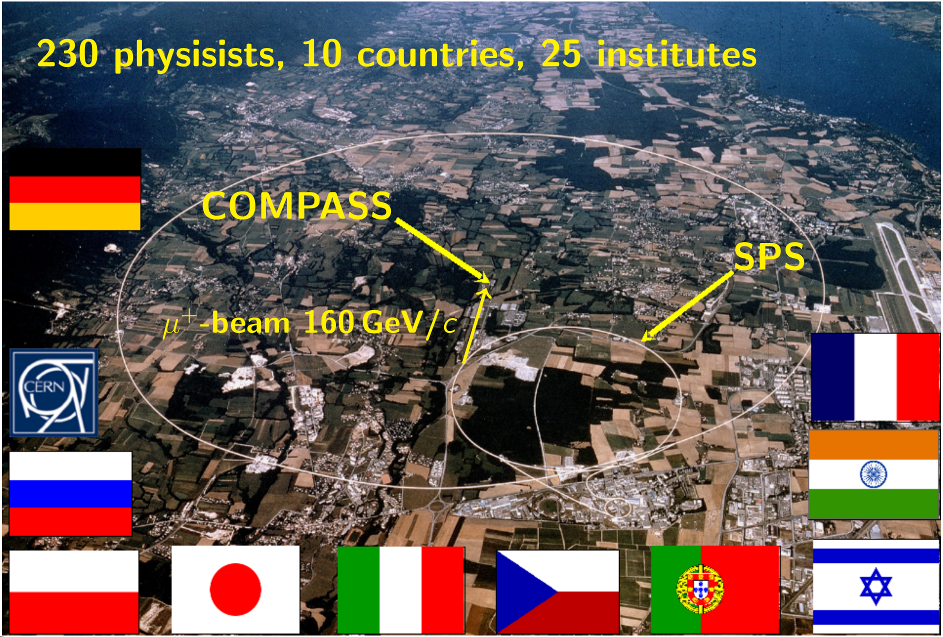
University of Freiburg
on behalf of COMPASS

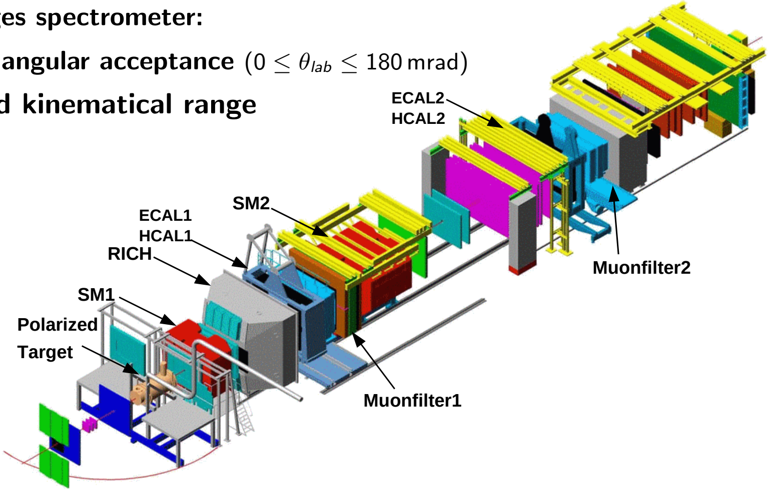
Outline:

- COMPASS experiment
- Transversity with Interference Fragmentation Function
- Results of 2007 Proton run

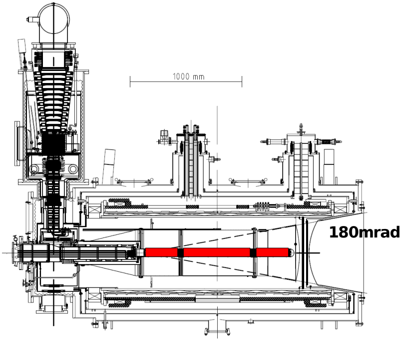
COMPASS Experiment

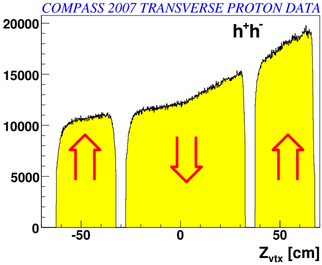


- high energy muon beam (160 GeV)
- high intensity beam ($2 \cdot 10^8 \mu^+ / spill$)
- two stages spectrometer:
  - $\rightsquigarrow$ large angular acceptance ($0 \leq \theta_{lab} \leq 180\,\mathrm{mrad}$)
  - $\rightsquigarrow$ broad kinematical range



COMPASS Polarized Target





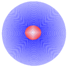
COMPASS target ($\geq$ 2006):

- 3 target cells
- acceptance: 180 mrad
- target material: NH_3
- dilution factor: $f \simeq 15\,\%$
- polarization: $P_T \sim 90\,\%$
- reversal of polarization every 4 - 5 days

Transverse Spin Physics

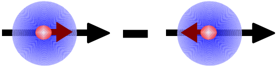
In leading order three parton distributions are needed to describe the structure of the nucleon:

$\mathbf{q}(x)$



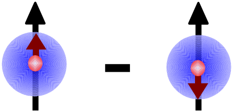
quark distribution
in unpolarized DIS
$\ell\, P \rightarrow \ell' X$

$\Delta\mathbf{q}(x)$



helicity distribution
in polarized DIS
$\vec{\ell}\,\vec{P} \rightarrow \ell' X$

$\Delta_T\mathbf{q}(x) = \mathbf{q}^{\uparrow\uparrow}(x) - \mathbf{q}^{\uparrow\downarrow}(x)$



transversity distribution
in polarized SIDIS

$\ell\, P^{\uparrow} \rightarrow \ell' hhX$ Interference FF
$\ell\, P^{\uparrow} \rightarrow \ell' hX$ Collins FF
$\ell\, P^{\uparrow} \rightarrow \ell' \Lambda X$ FF of $q^{\uparrow} \rightarrow \Lambda$

$\rightarrow$ A.Bressan on Wed.

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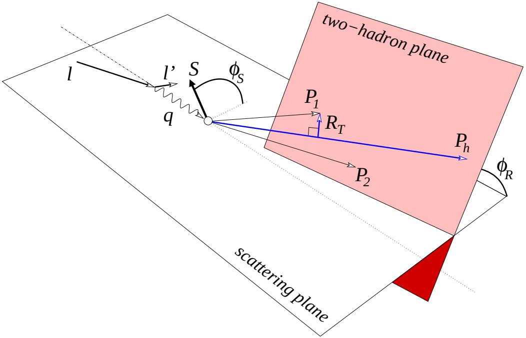
Measuring transversity with Two-Hadron-Interference-FF $H_1^{\sphericalangle}$:

$\rightsquigarrow$ azimuthal asymmetry:

$$N_{h^+h^-} \propto 1 \pm A \cdot \sin\phi_{RS} \cdot \sin\theta$$

$$\phi_{RS} = \phi_R + \phi_S - \pi$$



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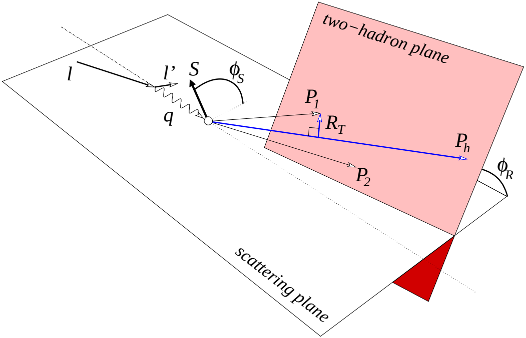

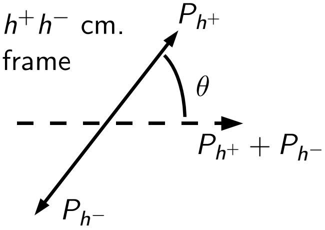

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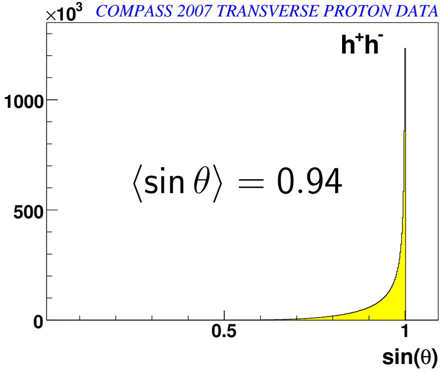

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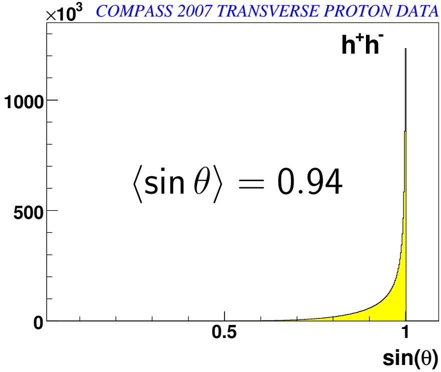

For this analysis:
$\sin\theta$ can be neglected

Measured asymmetry A is a convolution of

transversity $\Delta_T \mathrm{q}(x)$ and

Two-Hadron-Interference-FF $H_1^{\sphericalangle}$:

$$A_{RS} = \frac{A}{f\, P_T D_{nn}} = \frac{\sum_q e_q^2 \cdot \Delta_T q(x) \cdot H_1^{\sphericalangle}(z, M^2_{h^+h^-})}{\sum_q e_q^2 \cdot q(x) \cdot D_1(z, M^2_{h^+h^-})}$$

$$H_1^{\sphericalangle} = H_1^{\sphericalangle, sp} + \cos\theta\, H_1^{\sphericalangle, pp}$$

f target dilution factor

P_T target polarization

$D_{nn} = \frac{1-y}{1-y+y^2/2}$ depolarization factor

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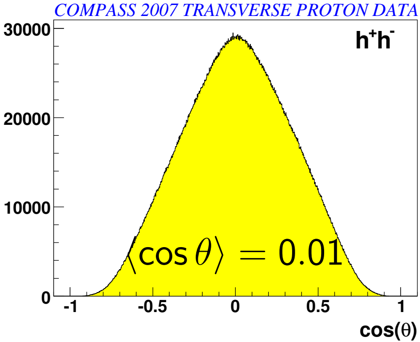


2007 Proton Run: Statistics

Data taking in 2007: May to November

$81.5 \cdot 10^{12}$ **muons on tape**

equally shared between transverse and longitudinal target polarization

Total statistics for transverse target polarization (after all cuts):

Proton target (NH_3) h^+h^- pairs	Deuteron target (^6LiD) h^+h^- pairs
$11.28 \cdot 10^6$	$6.1 \cdot 10^6$

Considering: $\langle f \cdot P_T \rangle_{NH_3} \simeq \frac{1}{\sqrt{2}} \langle f \cdot P_T \rangle_{^6LiD}$

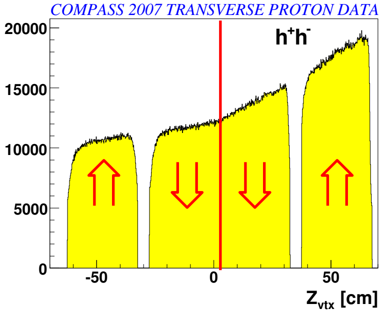
$\rightsquigarrow$ similar statistical precision

Asymmetry Extraction: Method

Splitting middle cell into two parts

$\rightsquigarrow$ two couples of cells with opposite polarization

$\rightsquigarrow$ two independent values for the asymmetries per period



Extraction: Extended Unbinned Maximum Log-Likelihood Fit:

$$P^{\uparrow\downarrow}(\phi_h, \phi_S) \;=\; a \cdot g^{\uparrow\downarrow}(\vec{A})$$

$^{\uparrow\downarrow}$ = sign of target polarization

a = acceptance

$g^{\uparrow\downarrow}(\vec{A})$ = 8 spin dependent modulations plus $\cos\phi_R$ and $\cos 2\phi_R$

$$\mathrm{LH} = \left(\prod_j P_j\right) \cdot e^{-\mu}, \qquad \text{'extended' factor:} \quad \mu = \int \mathrm{d}\phi_R \int \mathrm{d}\phi_S \, P^{\uparrow\downarrow}(\phi_h, \phi_S)$$

Asymmetry Extraction: Method

Separation of acceptance and spin dependent modulations:

Coupling of:

two cells (u,d)

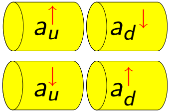
with opposite polarization $\uparrow\downarrow$ and

two periods (p1,p2)

with opposite target polarization:

period 1:

period 2:



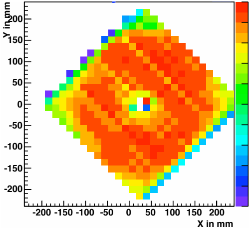
Fix acceptances with Assumption:

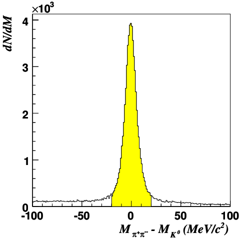
$$C_u = \frac{a_u^\uparrow}{a_u^\downarrow}; \; C_d = \frac{a_d^\downarrow}{a_d^\uparrow}$$

Data quality checks:

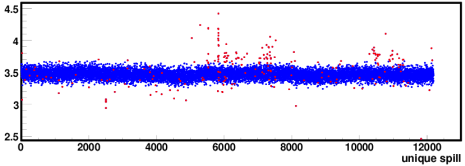
- detector profiles
- event reconstruction
- K^0-reconstruction (invariant mass)
- distributions of kinematical variables

$x_{bj}, Q^2, y, W, p_{\mu'}, \phi_{\mu'_{Lab}}, \theta_{\mu'_{Lab}}, p_{had}, p_{T_{had}}, z, \phi_{had_{Lab}}, \theta_{had_{Lab}}, \phi_h, \phi_S, Z_{vertex}$





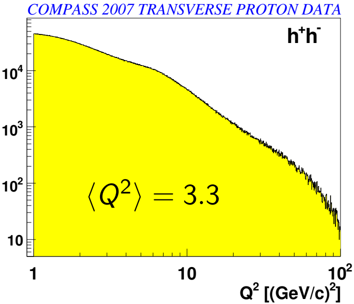
#tracks per primary vertex per spill

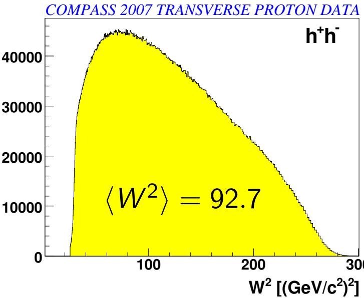


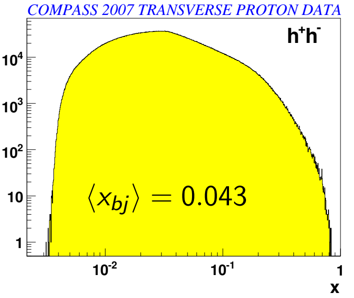
SIDIS Event Selection

DIS cuts:

- $Q^2 > 1\,(\mathrm{GeV}/c)^2$
- $0.1 < y < 0.9$
- $W > 5\,\mathrm{GeV}/c^2$







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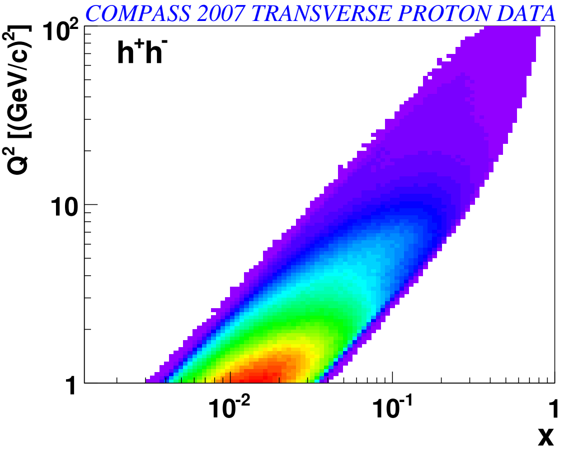
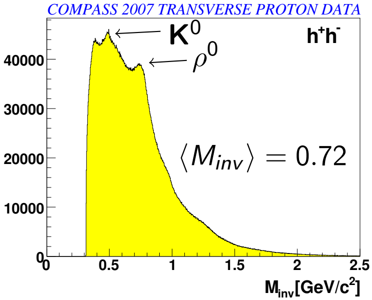
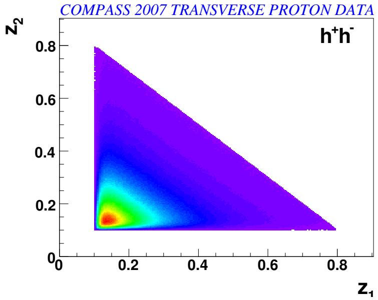


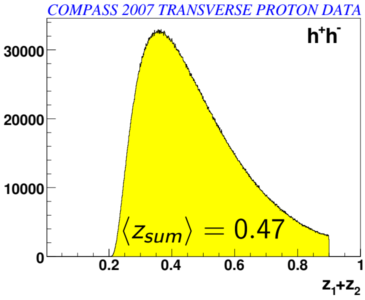
SIDIS Event Selection

hadron cuts:

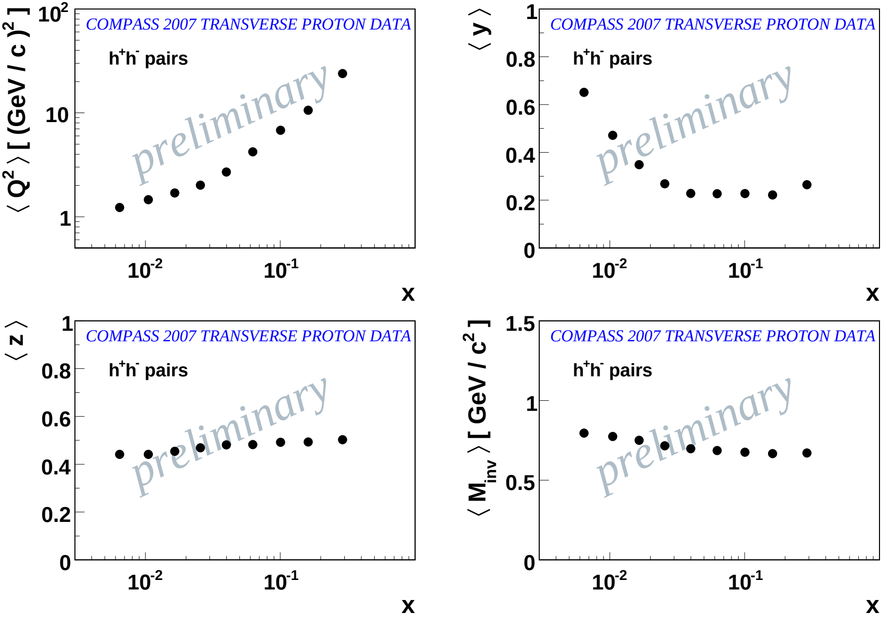
- $x_F > 0.1$
- $z_i > 0.1$
- $z_{sum} = z_1 + z_2 < 0.9$
- $R_T > 0.07\,\mathrm{GeV}/c$







Mean Kinematics - Proton Data 2007

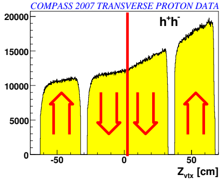


Systematic Tests

Tests for systematic errors:

- Splitting spectrometer into sectors:
  - Left / Right
  - Top / Bottom
- Splitting middle cell:

  two asymmetries per double period



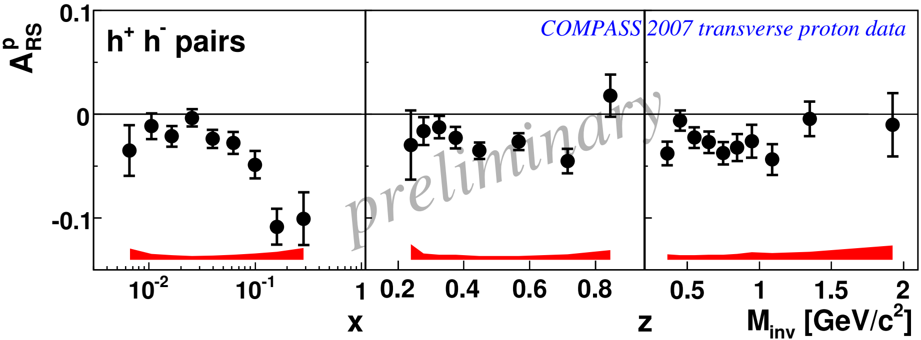
- Check for false asymmetries:

  Combination of cells with same polarization

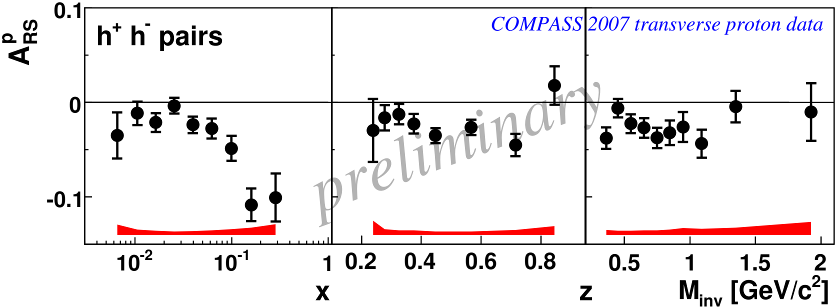
- Comparison of 4 estimators for asymmetry extraction

  1D and 2D double ratios, binned LH, unbinned LH

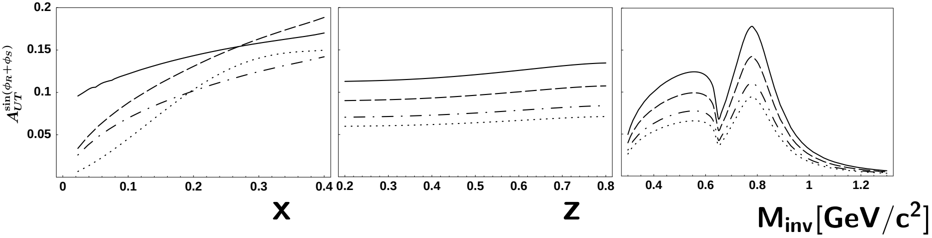
Results Proton 2007



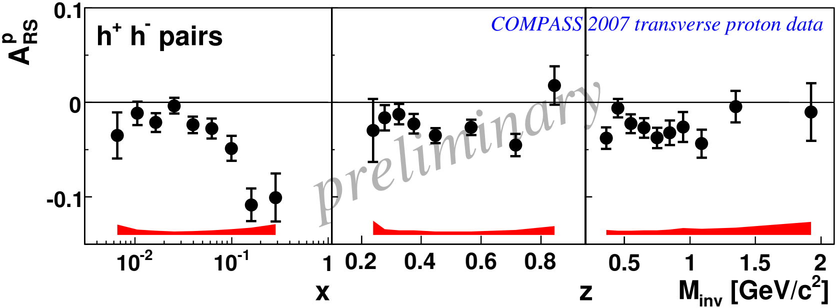
Results Proton 2007 and predictions



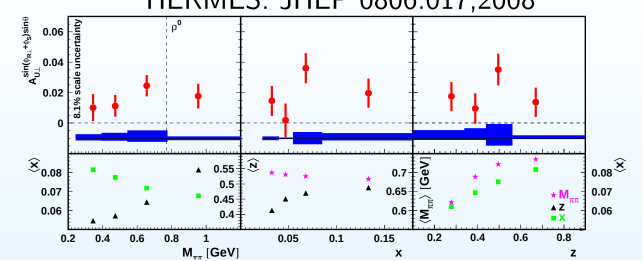
Bacchetta, Radici hep-ph/0608037



Results Proton 2007 and HERMES



HERMES: JHEP 0806:017,2008



- different definition of ϕ_S
- No D_{nn} correction

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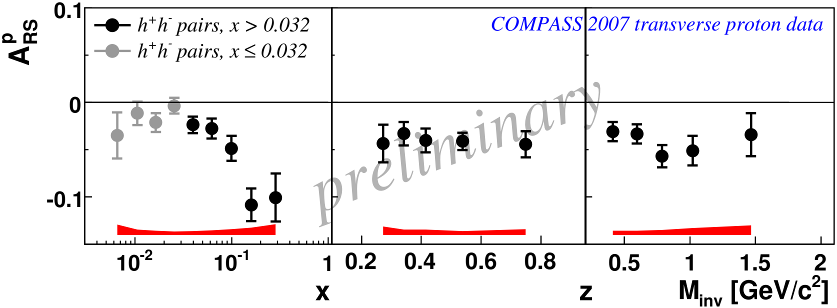

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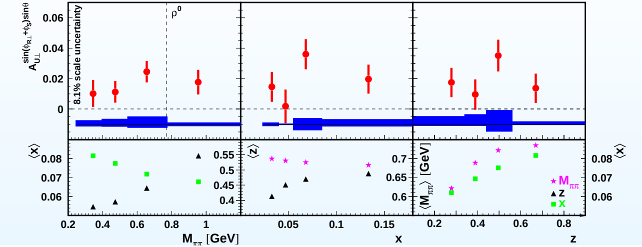

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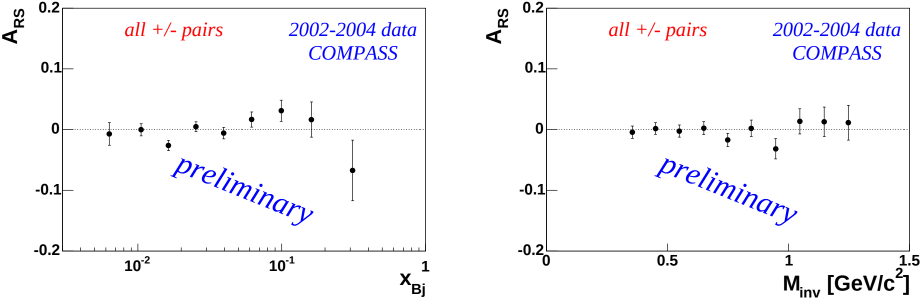
Results Deuteron 2002-2004



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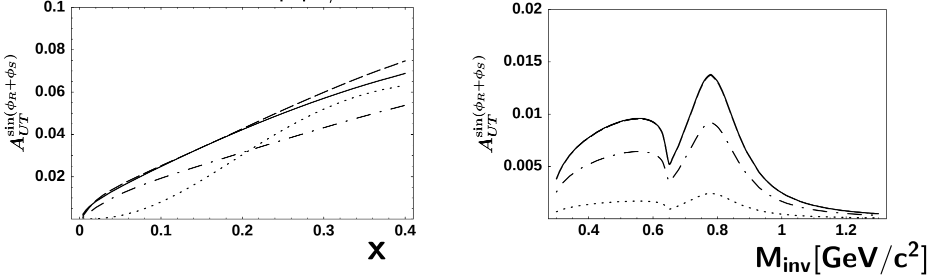

Summary

First result for asymmetry in two hadron pair production measured in COMPASS 2007 proton transverse run:

- **Measured Asymmetry:**
  - significantly different from zero
    - $\rightsquigarrow$ Two Hadron-Interference-FF and Transversity are non zero
  - in agreement with prediction
  - signal stronger than measured by HERMES

- **Outlook:**
  - **Identified hadron pairs**

Thank You

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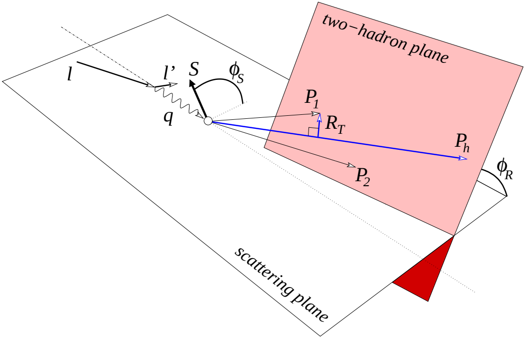
Back Up

Definition of R_T

$$\mathbf{R_T} = \frac{z_2 \mathbf{P_{1T}} - z_1 \mathbf{P_{2T}}}{z_1 + z_2}$$

$$\cos\phi_R = \frac{\vec{q}\times\vec{\ell}}{|\vec{q}\times\vec{\ell}|} \cdot \frac{\vec{q}\times\vec{R}_T}{|\vec{q}\times\vec{R}_T|}, \qquad \sin\phi_R = \frac{(\vec{\ell}\times\vec{R}_T)\cdot\hat{q}}{|\hat{q}\times\vec{\ell}||\hat{q}\times\vec{R}_T|}$$



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