Transverse Spin Asymmetries for inclusive ρ^0 muoproduction at COMPASS

Andrea Moretti

on behalf of the COMPASS Collaboration

Motivation

Transverse Spin Asymmetries (TSA) in Semi-Inclusive DIS (SIDIS) measured since 2005:

***COLLINS** asymmetries - **SIVERS** asymmetries - **DIHADRON** asymmetries*

measured at
- HERMES (p target, 27.5 GeV e^+/e^- beam)
- **COMPASS** (p, d target, 160 GeV μ beam)
- JLab (^{3}He target, 6 GeV e^- beam)

for unidentified charged hadrons and for $\pi^+, \pi^-, \pi^0, K^+, K^-, K^0, p$

→ well known results, used to extract transversity and Sivers functions…

TSA for vector mesons: never measured so far

low statistics, high background

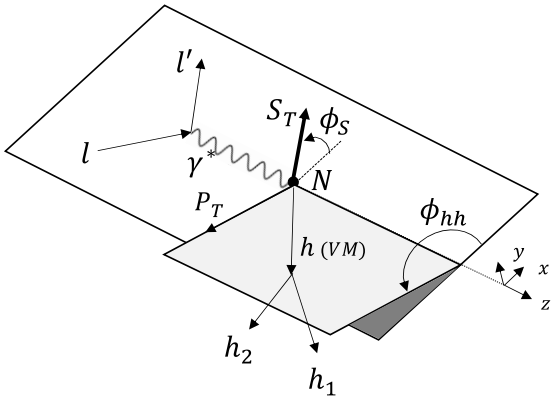
important insight on the quark fragmentation process to spin-1 particles

Cross-section and model predictions

SIDIS cross-section for VM production in the one-photon exchange approximation

[A. Bacchetta & P. Mulders, *Phys.Rev.D* 62 (2000) 114004]

$$\frac{\mathrm{d}^5\sigma}{\mathrm{d}x\,\mathrm{d}Q^2\mathrm{d}z\,\mathrm{d}\varphi_{hh}\mathrm{d}P_T^2} \propto 1 - \boldsymbol{A_{UT}^{\sin(\phi_{hh}+\phi_S-\pi)}} D_{NN}|\boldsymbol{S_T}|sin(\overbrace{\phi_{hh}+\phi_S-\pi}^{\phi_{Coll}}) + \boldsymbol{A_{UT}^{\sin(\phi_{hh}-\phi_S)}}|\boldsymbol{S_T}|sin(\underbrace{\phi_{hh}-\phi_S}_{\phi_{Siv}}) + \cdots$$



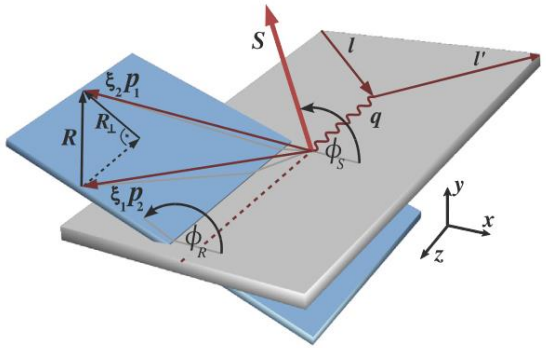
Collins asymmetry $A_{UT}^{sin(\phi_{hh}+\phi_S-\pi)} \sim h_1^q \otimes FF_{Collins}$

Sivers asymmetry $A_{UT}^{\sin(\phi_{hh}-\phi_S)} \sim f_{1T}^{\perp} \otimes FF_{unpolarized}$

<u>*Not to be confused with the dihadron asymmetries!*</u>

In that case, instead of ϕ_{hh} one uses ϕ_R :

that is, the azimuthal angle of the vector $\boldsymbol{R} = \frac{z_2\,\boldsymbol{p_1} - z_1\,\boldsymbol{p_2}}{z_1+z_2}$



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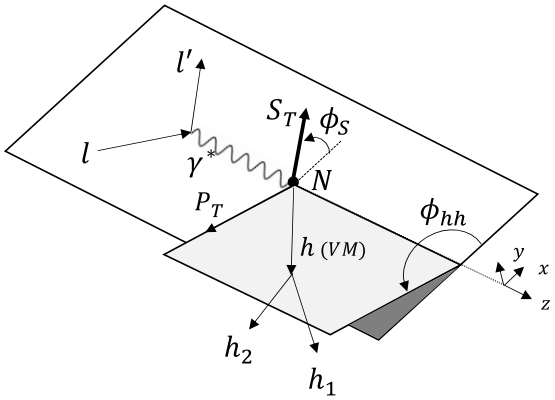

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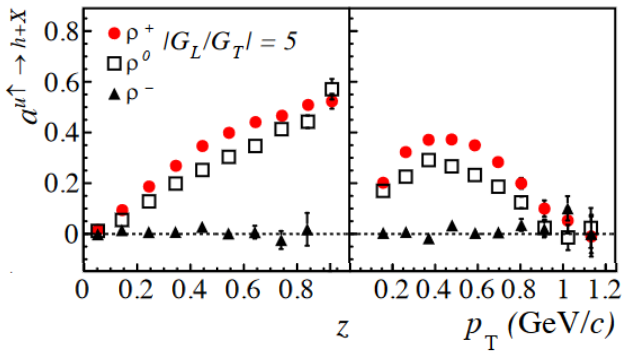
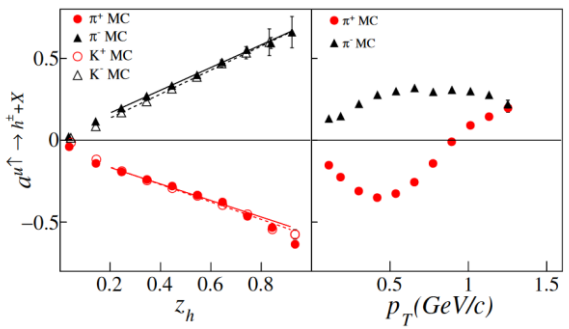
Vector Mesons are expected to have an opposite and smaller Collins asymmetry w.r.t. the π^+

[J. Czyzewski, *Acta Phys.Polon. 27* (1996) 1759-1766; X. Artru, *Proc. DSPIN2009*; string+3P0 model]



[A. Kerbizi et al., *hep-ph*: 2109.06124]



[A. Kerbizi et al., *Phys.Rev.D* 97 (2018) 7, 074010]

Cross-section and model predictions

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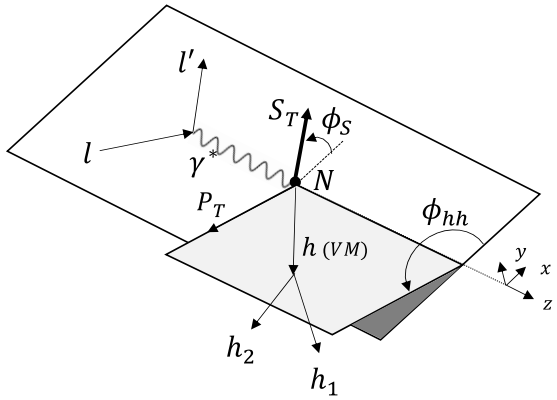

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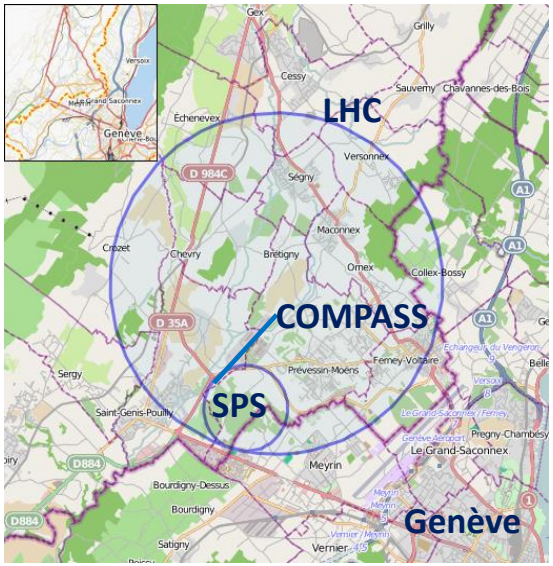
Collins and Sivers asymmetries for ρ^0 vector mesons MEASURED IN COMPASS FOR THE FIRST TIME

in this talk: preliminary results

The COMPASS experiment at CERN

COMPASS: COmmon Muon Proton Apparatus for Structure and Spectroscopy

- 24 institutions from 13 countries (about 220 physicists)
- a fixed target experiment
- located in the CERN North Area, along the SPS M2 beamline

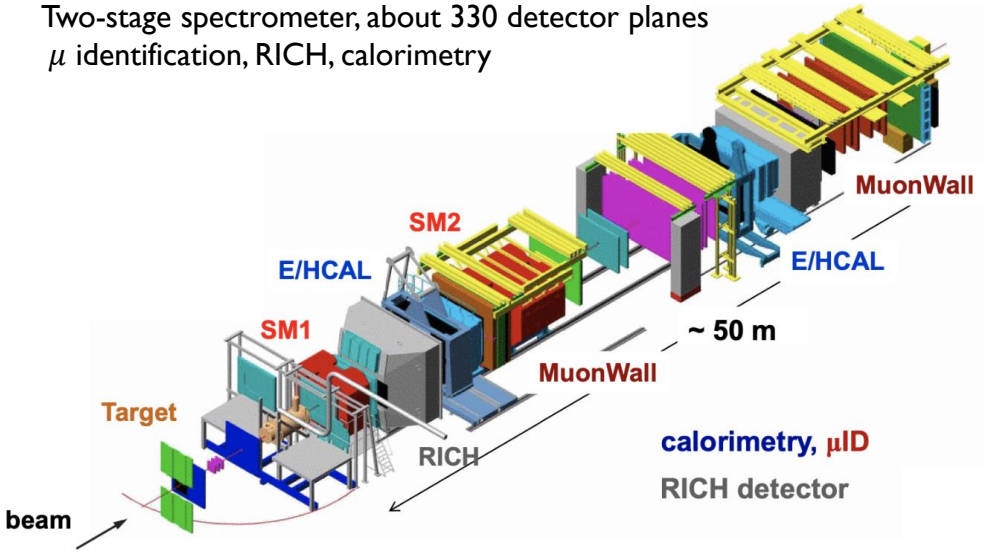


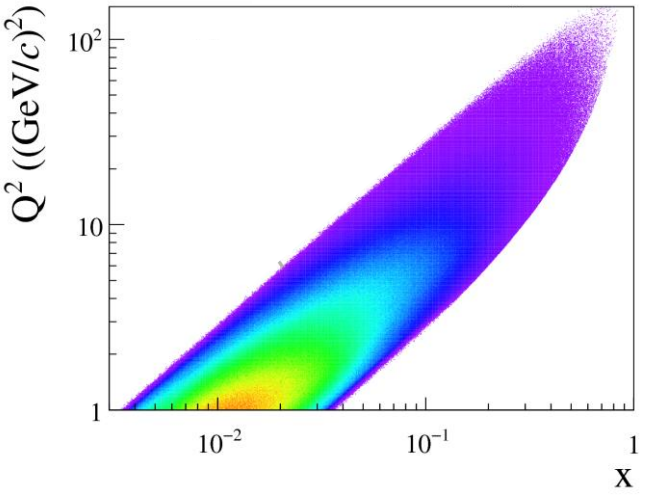
Broad research program:

- SIDIS with μ beam, with (un)polarized deuteron or proton target.
- Hadron spectroscopy with hadron beams and nuclear targets
- Drell-Yan measurement with π^- beam with polarized target
- Deeply Virtual Compton Scattering (DVCS)
- …

A multipurpose apparatus:

- Two-stage spectrometer, about 330 detector planes
- μ identification, RICH, calorimetry





Selection of ρ^0 events

Data sample: data collected in 2010 with a transversely polarized NH_3 (proton) target

DIS events selection

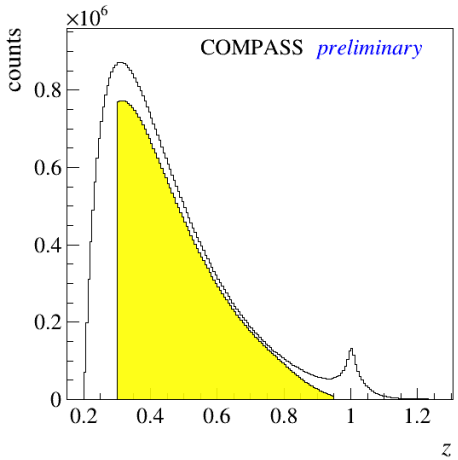
$$Q^2 > 1\ (\mathrm{GeV}/c)^2, \qquad W > 5\ \mathrm{GeV}/c^2, \qquad 0.003 < x < 0.700, \qquad 0.1 < y < 0.9$$

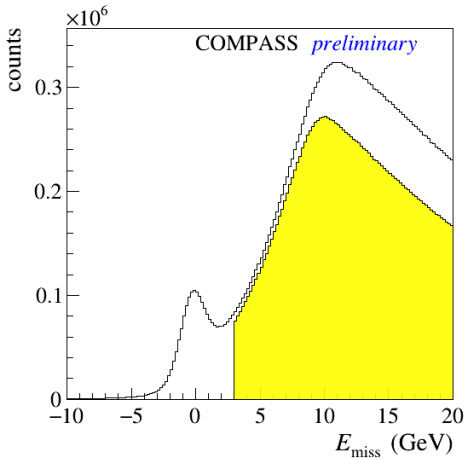
Two oppositely-charged hadrons selection

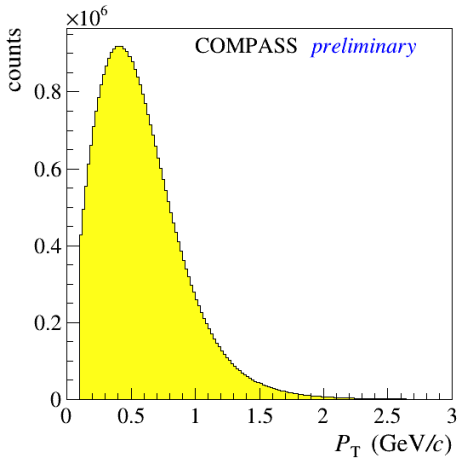
$$z_{h_{1(2)}} > 0.1, \qquad P_{h_{1(2)}T} > 0.1\ \mathrm{GeV}/c$$

Further cuts

$0.30 < z = z_{h_1} + z_{h_2} < 0.95$	fractional energy of the pair
$E_{miss} = (M_X^2 - M_p^2)/(2M_p) > 3\ \mathrm{GeV}$	missing energy
$0.1 < P_T\ /\ (\mathrm{GeV}/c) < 4.0$	transverse momentum of the pair
$0.35 < M_{hh}\ /\ (\mathrm{GeV}/c^2) < 3.00$	invariant mass







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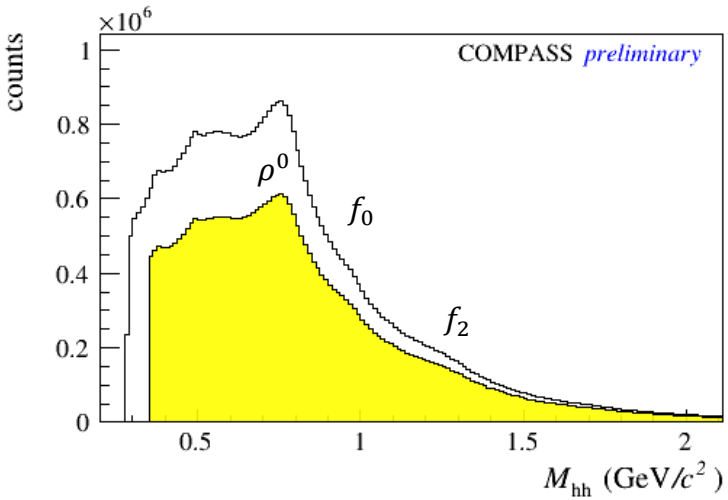


Combinational background under the ρ^0 peak

Procedure for the extraction of the asymmetries

The Collins and Sivers TSAs for inclusive ρ^0 are extracted **in four steps**

1) Background-uncorrected TSA for h^+h^- pairs $\boldsymbol{a_{UT}^{\sin\phi_X}}$

2) Fraction $\boldsymbol{f_s}$ of ρ^0 events

3) TSA for the background $\boldsymbol{A_{UT,bg}^{\sin\phi_X}}$

4) Subtract the TSA for the background from the background-uncorrected TSA

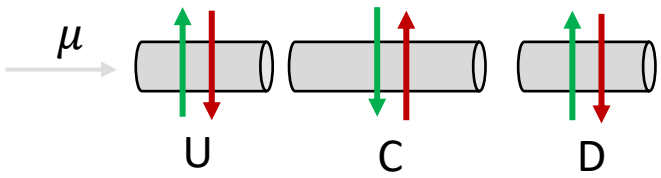
$$\boldsymbol{A_{UT}^{\sin\phi_X} = \frac{1}{f_s}\left[a_{UT}^{\sin\phi_X} - (1-f_s)A_{UT,bg}^{\sin\phi_X}\right]}$$

$\phi_X = \phi_{Coll}, \phi_{Siv}$

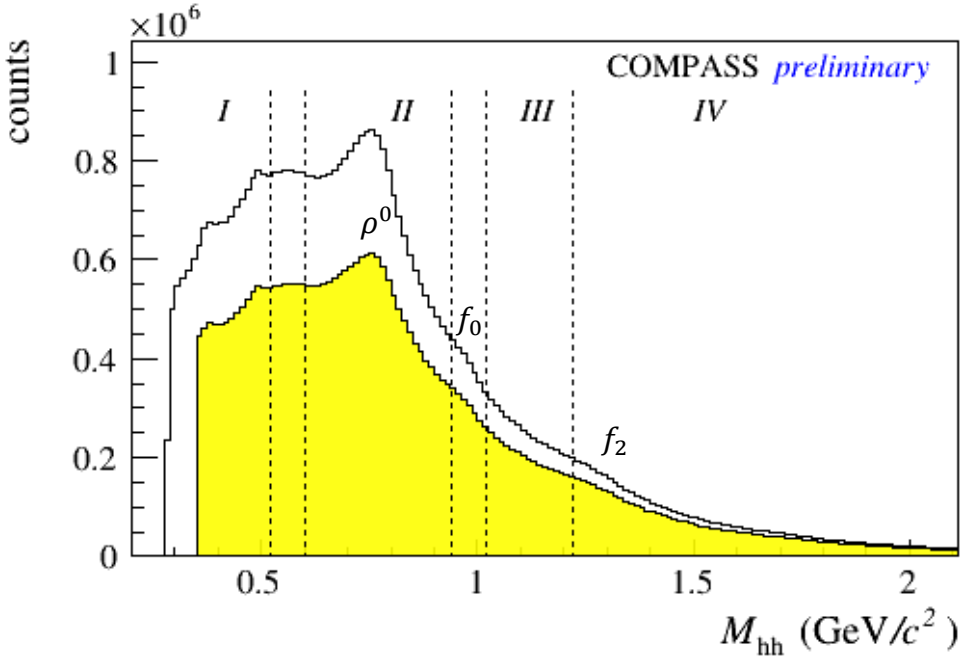
Extraction of the asymmetries

Standard COMPASS methods applied for the extraction of the asymmetries [COMPASS, *Nucl. Phys. B765* (2007) 31–70]

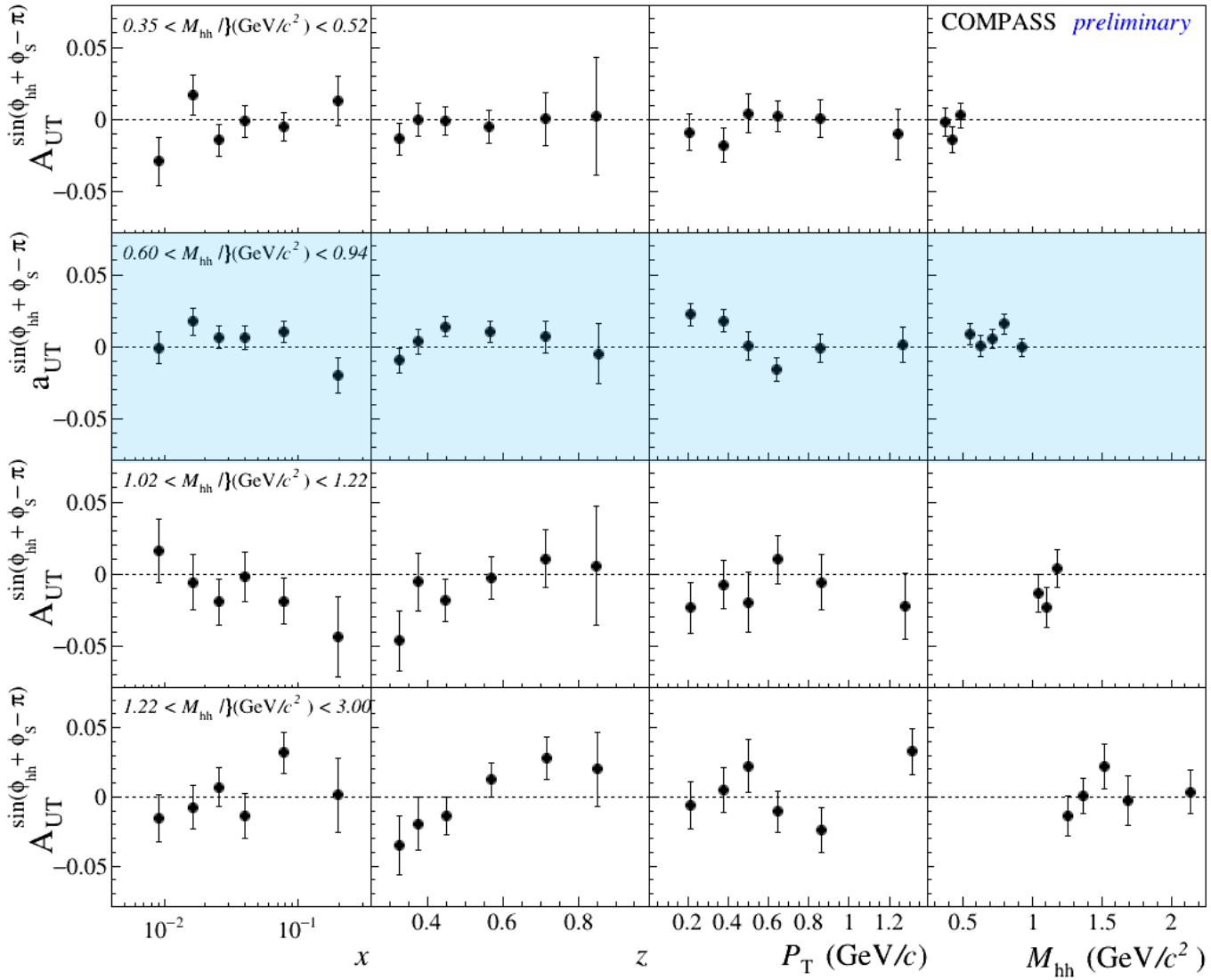
- Data taking organized in **(sub)periods**: polarization of the three target cells reversed → systematic effects minimized
- Asymmetries extracted for each of the 12 periods of data taking and then combined
- Six one-dimensional bins in x, z and P_T
- **Four invariant mass regions**



$I \quad 0.35 < M_{hh}/(\mathrm{GeV}/c^2) < 0.52$
$\boldsymbol{II \quad 0.60 < M_{hh}/(\mathrm{GeV}/c^2) < 0.94}$
$III \quad 1.02 < M_{hh}/(\mathrm{GeV}/c^2) < 1.22$
$IV \quad 1.22 < M_{hh}/(\mathrm{GeV}/c^2) < 3.00$



Collins asymmetries in four mass regions

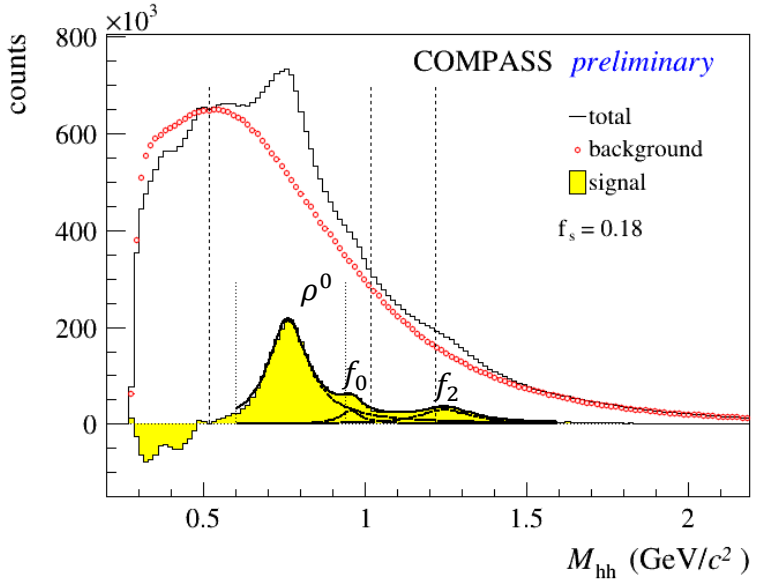


ρ^0 region

Indication for a positive Collins asymmetry at intermediate z and small P_T

Background Collins asymmetries: similar and compatible with zero in the three side regions

Signal fraction estimation



Shape of the background:
taken from the $h^+h^+ + h^-h^-$ distribution:

1) $h^+h^+ + h^-h^-$ distribution normalized at $M_{hh} \sim 0.50\ \mathrm{GeV}/c^2$

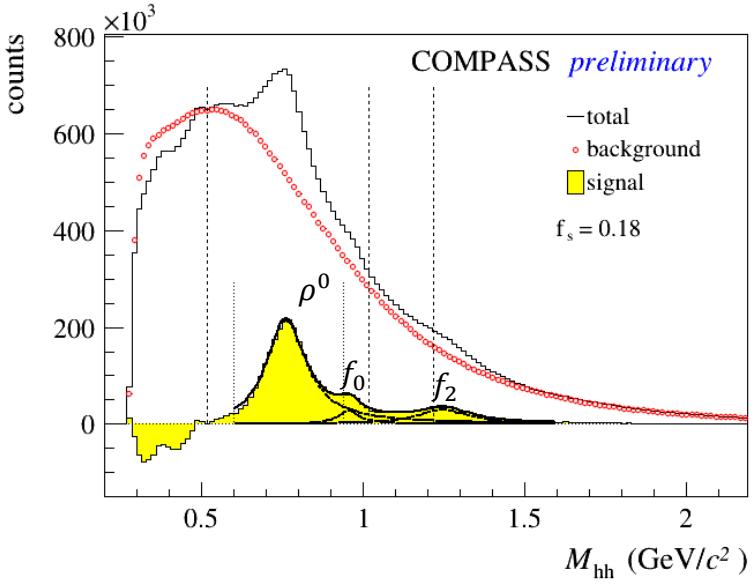
2) scaled $h^+h^+ + h^-h^-$ distribution subtracted from the h^+h^- one.

The signal distribution can be a fitted with the sum of three Breit-Wigner functions for ρ^0, f_0, f_2

3) Signal fraction calculated by counting the signal yields in ρ^0 region as

$$f_s = \frac{n_{\rho^0}}{n_{h^+h^-}}$$

Signal fraction estimation



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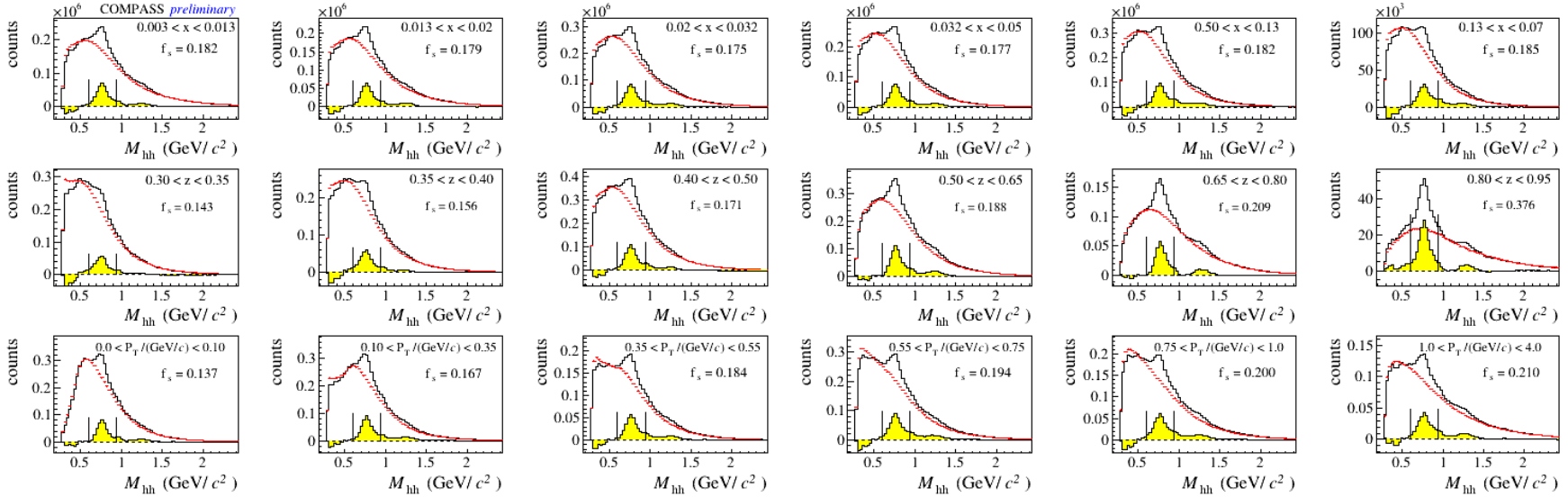
Same procedure in all x, z, P_T bins



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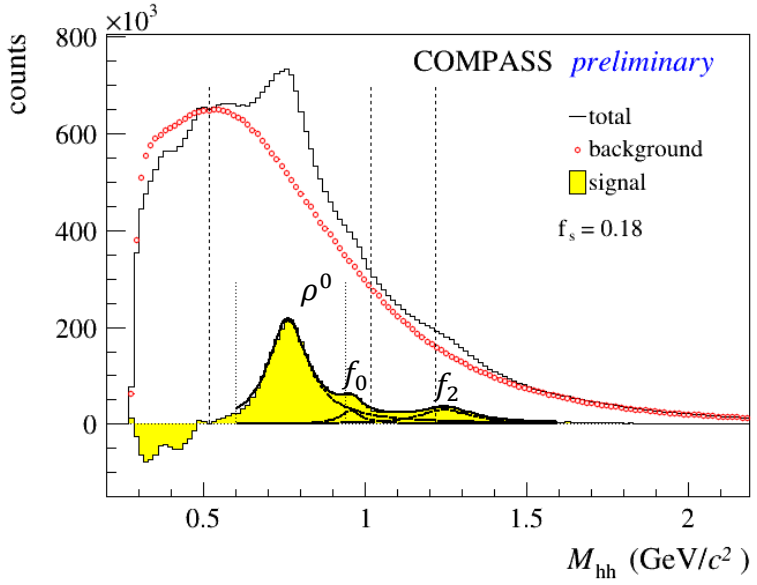

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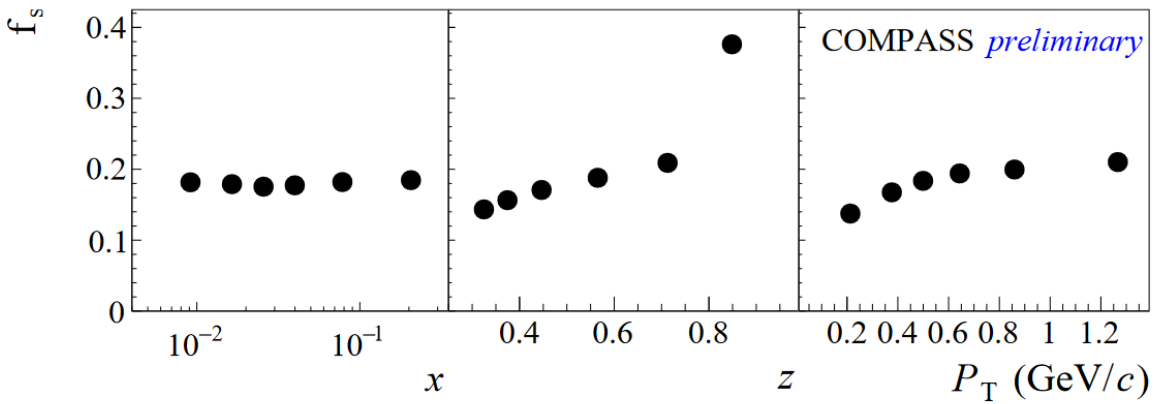
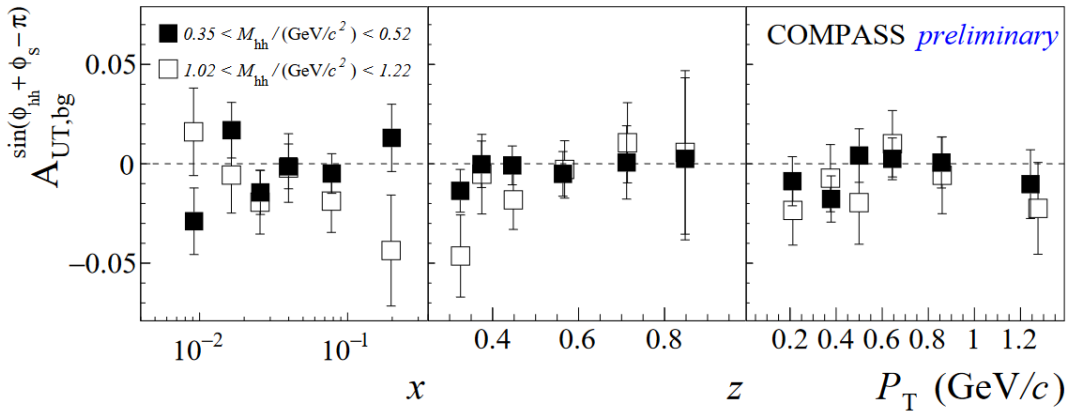


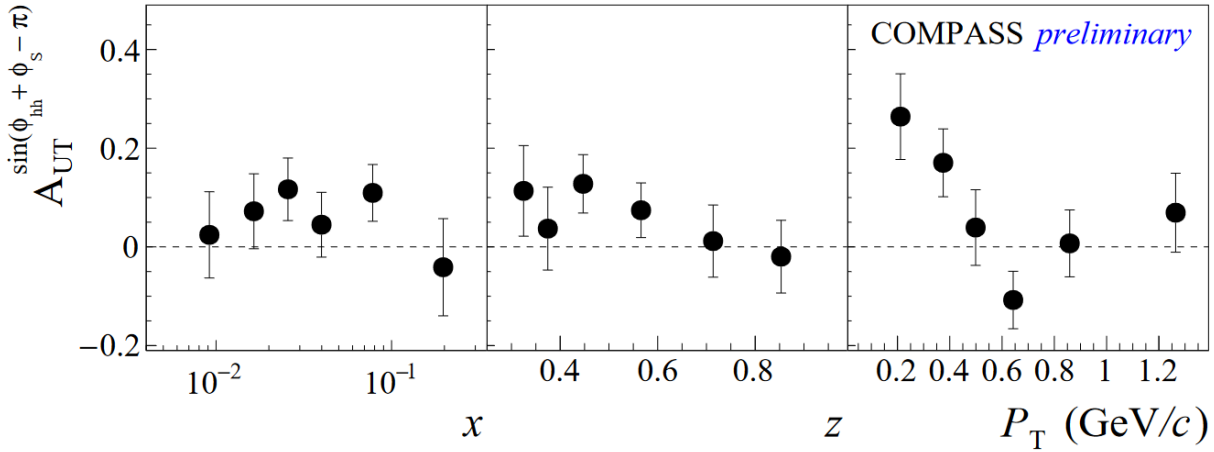
Signal fraction: about 18%
- increase with z up to 38%
- as expected e.g. in the string fragmentation model

Background- and corrected Collins asymmetries



Background asymmetry $A_{UT,bg}^{sin\,\phi_{hh}+\phi_S-\pi}$

arithmetic mean of asymmetries in regions I and III



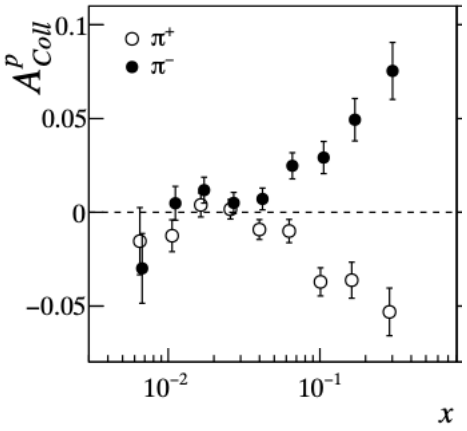
COLLINS ASYMMETRY FOR ρ^0

- indication for positive asymmetry
  opposite to π^+ as expected
- large at small P_T
- only statistical uncertainties
  $\sigma_{syst} = 0.3\sigma_{stat}$

Background- and corrected Collins asymmetries

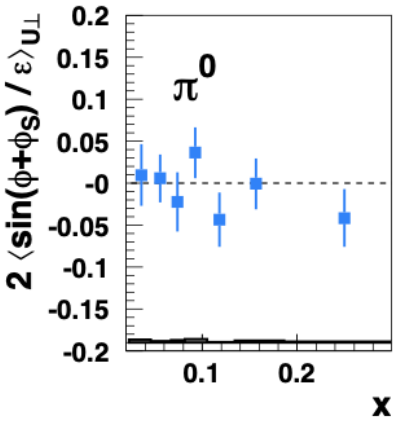
Collins asymmetry for π^+, π^-

[COMPASS, *Phys. Lett. B 744* (2015) 250]



Collins asymmetry for π^0

[HERMES, *JHEP 12* (2020) 010]



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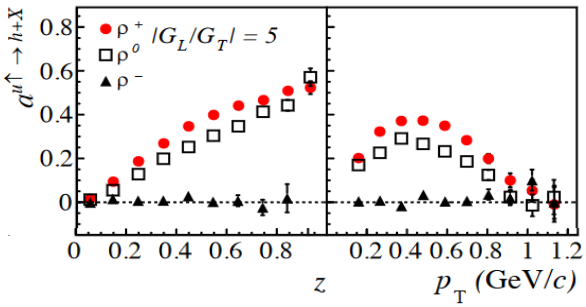

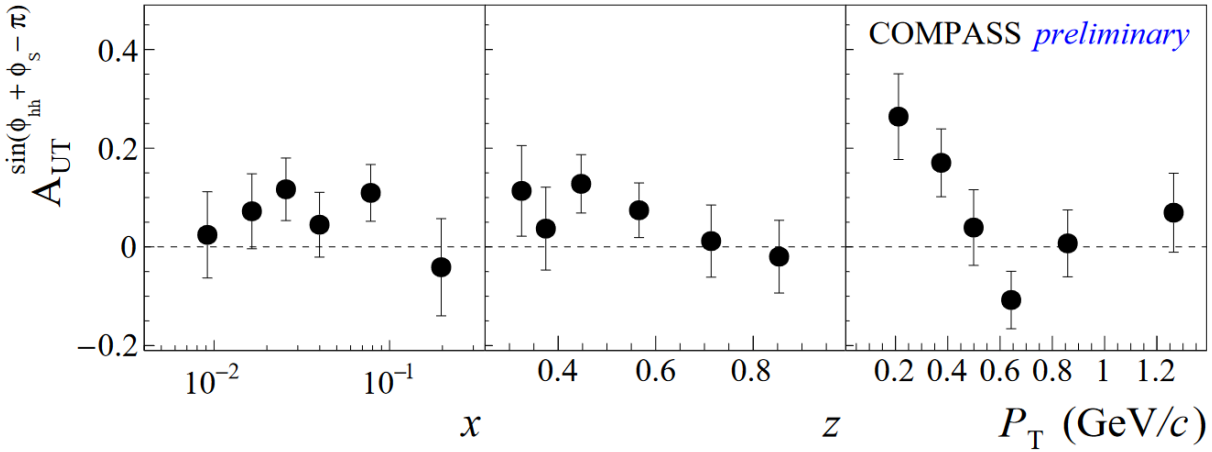

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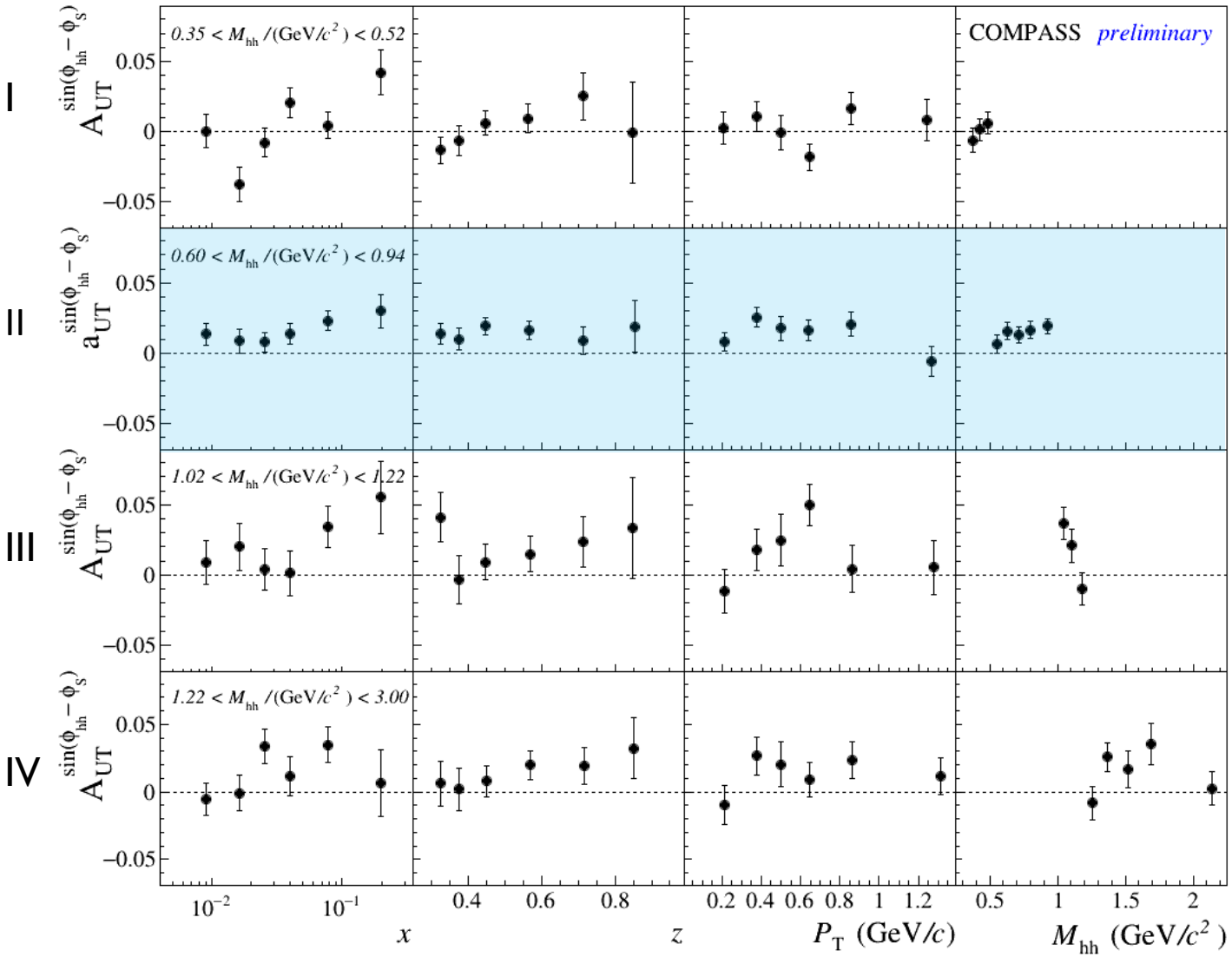
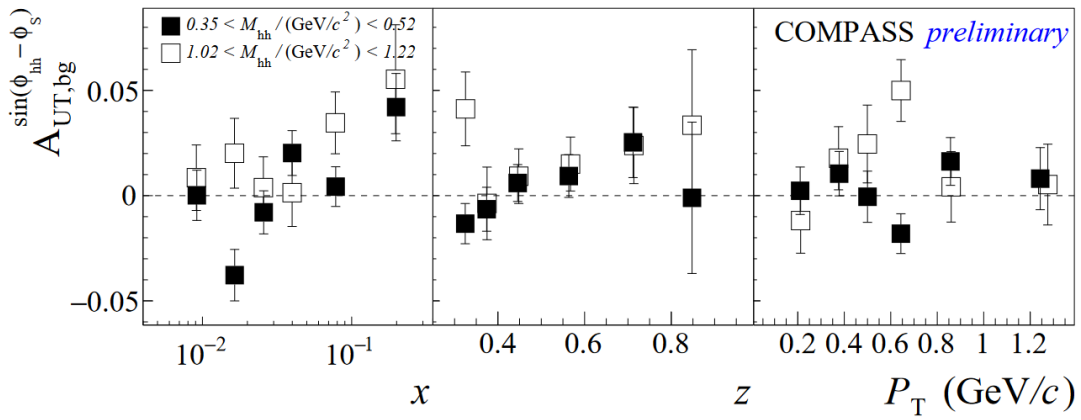
Sivers asymmetries in four mass regions



ρ^0 region
Clear positive asymmetry

Background asymmetries:
also large

Background- and corrected Sivers asymmetries



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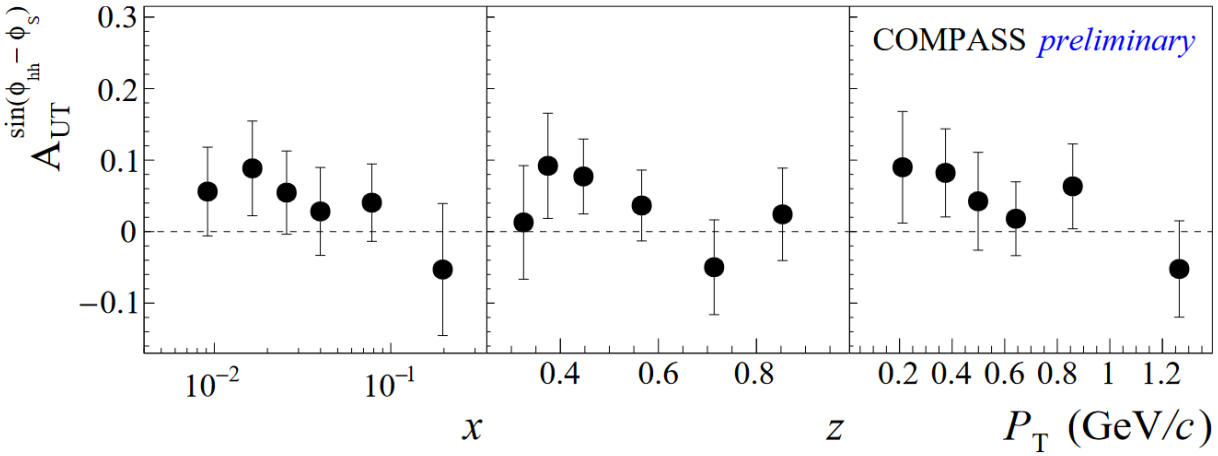

SIVERS ASYMMETRY FOR ρ^0

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Background- and corrected Sivers asymmetries

Sivers asymmetry for π^+, π^-

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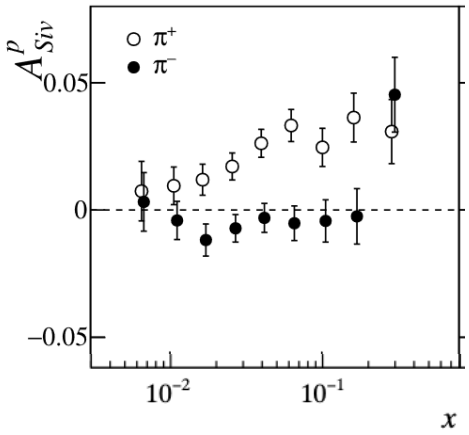
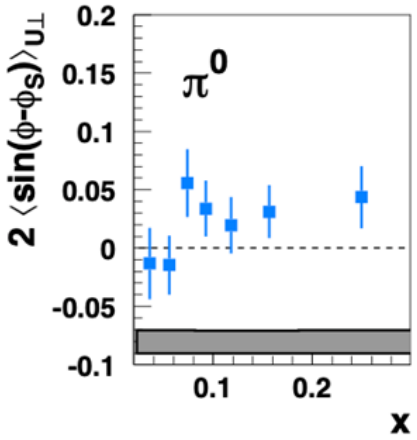
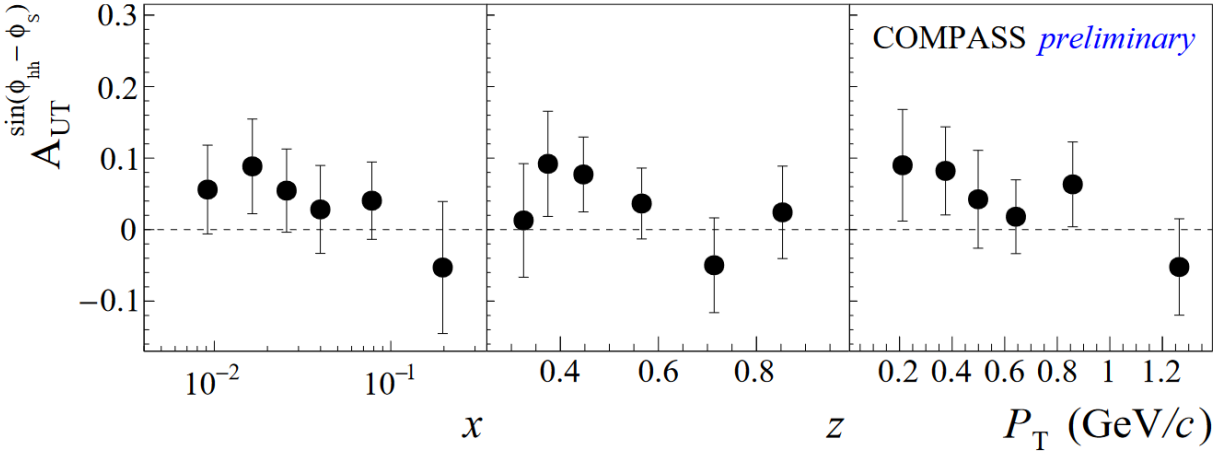


Sivers asymmetry for π^0

[HERMES, *JHEP 12* (2020) 010]





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Conclusions

COMPASS has measured the ***Collins and Sivers asymmetries for inclusively produced*** ρ^0 *for the first time*

- Indication for a positive *Collins asymmetry* for ρ^0
  opposite to the π^+ case, as expected from models

- Indication for a positive *Sivers asymmetry* for ρ^0
  also as expected

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Thank you