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Transverse spin asymmetries for inclusive ρ^0 production in SIDIS at COMPASS

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on behalf of the COMPASS Collaboration

COMPASS

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Transverse spin asymmetries for inclusive ρ^0 production in SIDIS at COMPASS

motivation

transverse spin asymmetries (TSA) in SIDIS are being measured since 2005,
in particular

Collins asymmetries, dihadron asymmetries, Sivers asymmetries

HERMES	(p target, 27.5 GeV/c beam)
COMPASS	(p, d target, 160 GeV/c beam)
JLab	(^{3}He, 5.6 GeV/c beam)

for h^+, h^-, π^+, π^- , π^0, K^+, K^-, K^0, p → relevant information on nucleon structure and FFs

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TSA for vector mesons (VM) not measured

challenging measurement: low statistics and high background

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TSA for vector mesons (VM) not measured

challenging measurement: low statistics and high background

but VM production is an interesting channel

spin-1, 3x3 spin density matrix

important insights on the fragmentation process

theory and model predictions

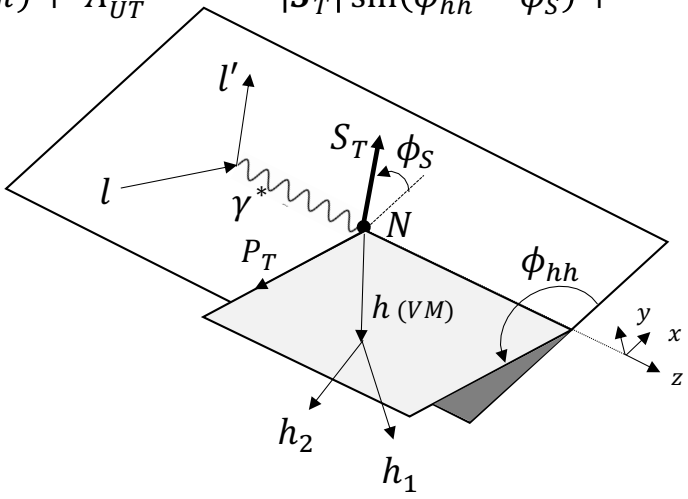
SIDIS cross section for VM production in the one-photon exchange approximation

*(Bacchetta & Mulders, PRD **62** (2000) 114004)*

$$\frac{d\sigma^{lN\to lh(VM)X}}{dzdxdQ^2P_T dP_T d\phi_{hh}} \propto 1 - A_{UT}^{\sin(\phi_{hh}+\phi_S-\pi)} D_{NN} |\boldsymbol{S}_T| \sin(\phi_{hh}+\phi_S-\pi) + A_{UT}^{\sin(\phi_{hh}-\phi_S)} |\boldsymbol{S}_T| \sin(\phi_{hh}-\phi_S) + \cdots$$

Collins asymmetry $A_{UT}^{\sin(\phi_{hh}+\phi_S-\pi)} \sim h_1^q \otimes \mathrm{FF}_{\mathrm{Coll}ins}$

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



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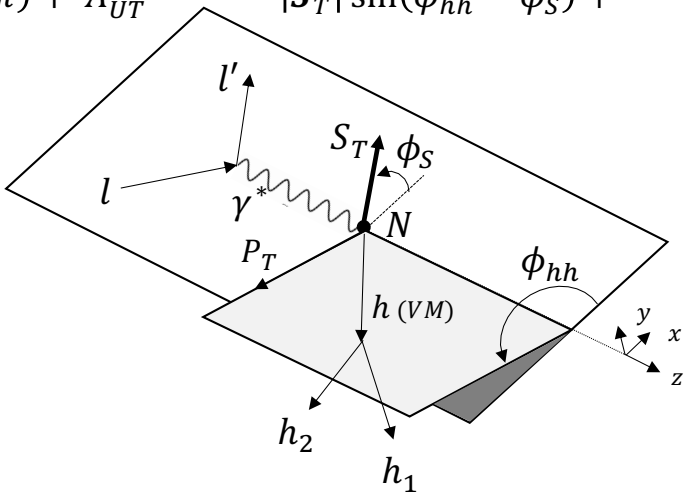
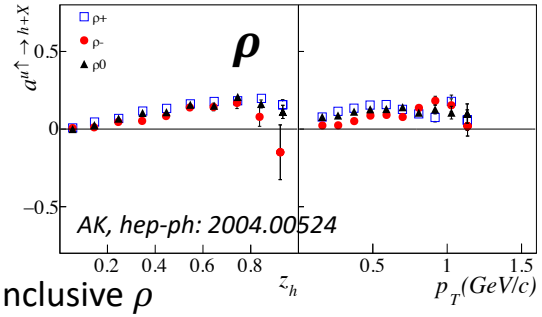


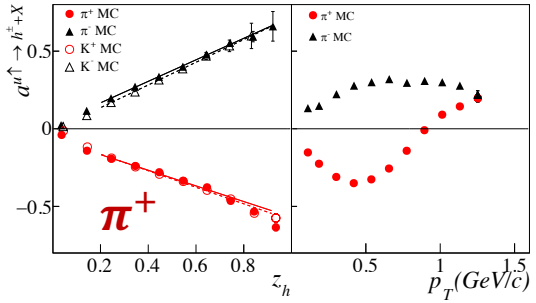
vector mesons are expected to have opposite and smaller Collins asymmetries w.r.t leading PS mesons

Czyzewski '96, Artru '2009, string+3P0 model

stand alone MC implementation of the quantum mechanical string+3P0 model
(fully transversely polarized u quarks)



prediction for inclusive ρ



AK, X. Artru, Z. Belghobsi, F. Bradamante, A. Martin, *PRD* 97 (2018) 7, 074010

COMPASS has measured the Collins and Sivers asymmetries for ρ^0 in SIDIS

preliminary results shown here for the first time

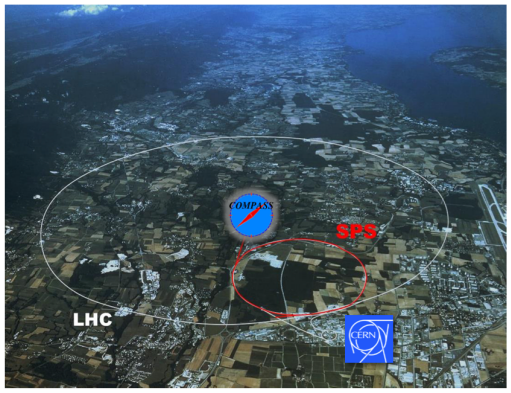
The COMPASS experiment

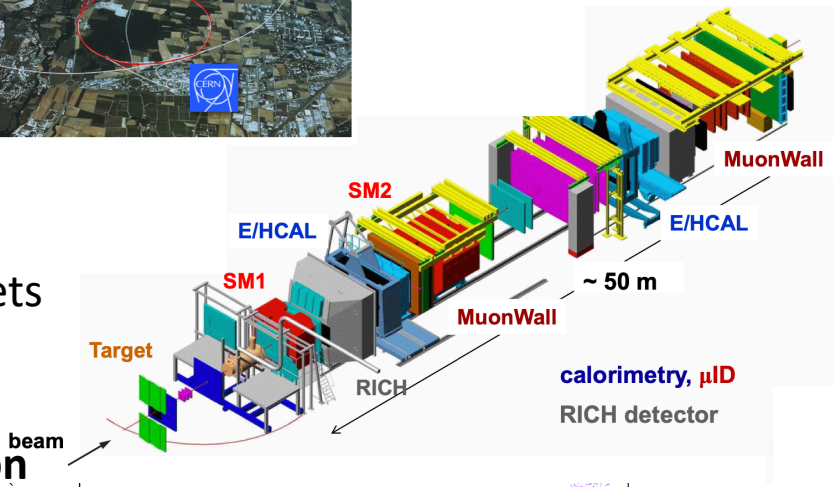
- fixed target experiment
  at the CERN SPS

- approved in 1997

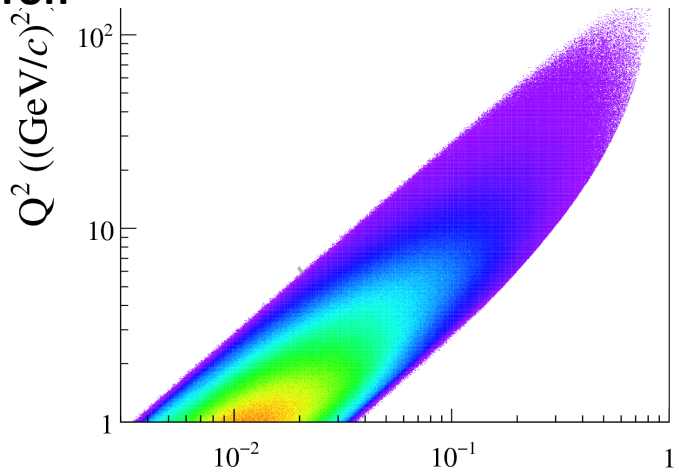
- taking data since 2002
  - muon and hadron beams
    - spectrocopy
    - Primakoff
    - SIDIS with L (d,p) and T (p) polarized targets
    - DVCS
    - polarized Drell-Yann

2021/22: SIDIS transversely polarised deuteron





high energy beam
  broad kinematic coverage



ρ^0 selection

full 2010 COMPASS data set collected with transversely polarized protons (NH_3) used

DIS event selection

$0.003 < x < 0.7, \quad Q^2 > 1\ (GeV/c)^2, \quad W > 5 GeV/c^2, \quad 0.1 < y < 0.9$

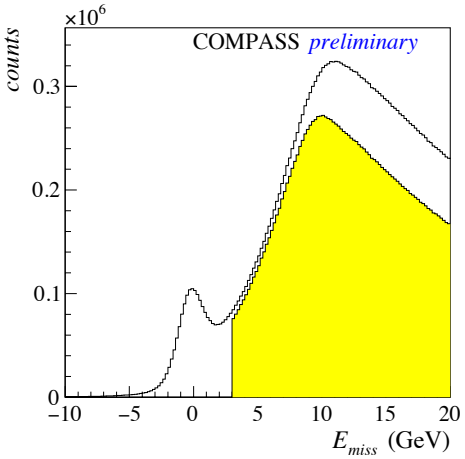
hadrons selection

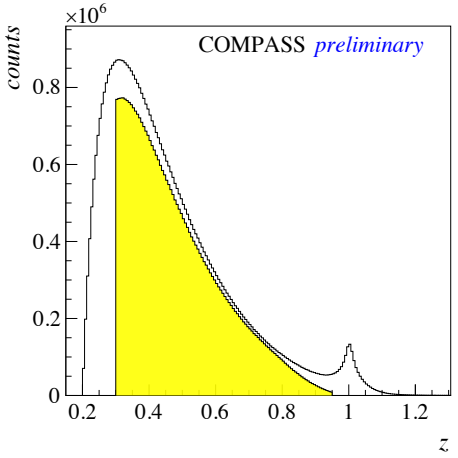
$z_{h_1} > 0.1,\ z_{h_2} > 0.1,\ P_{h_1 T} > 0.1\ GeV/c,\ P_{h_2 T} > 0.1\ GeV/c$

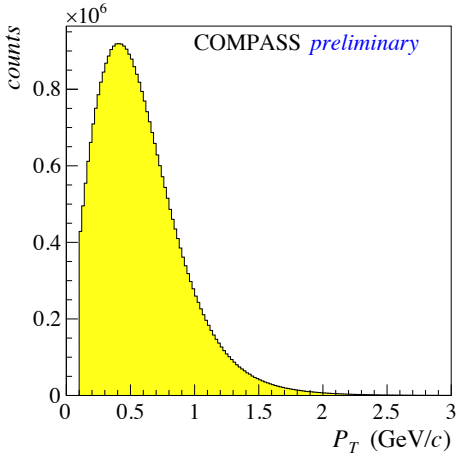
starting from the 1h samples we have built samples for h^+h^-, h^+h^+, h^-h^- pairs

hadron pair selection

$E_{miss} > 3$ GeV	missing energy
$0.3 < z < 0.95$	fractional energy of the pair $z = z_{h_1} + z_{h_2}$
$0.1 < P_T < 4.0$ GeV/c	transverse momentum of the pair $\vec{P}_T = \vec{P}_{1T} + \vec{P}_{2T}$
$0.35 < M_{hh} < 3.0\ GeV/c^2$	invariant mass







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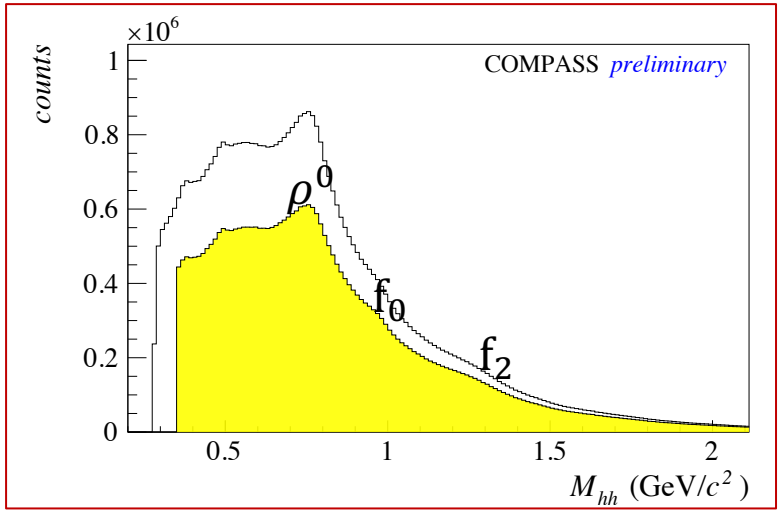

ρ^0, f_0, and f_2 are visibile

large background under the ρ^0 peak
→ a recipe for the measurement of the ρ^0 asymmetries is needed

asymmetry extraction procedure

steps for the extraction TSAs for inclusive ρ^0

i. measure the TSA of the h+h- pairs in the invariant mass region of the ρ^0 $a_{UT}^{sin\,\phi_X}$

ii. evaluate the ρ^0 fraction in the invariant mass region of the ρ^0 f_s

iii. measure the background TSA from the side regions $A_{UT,bg}^{sin\,\phi_X}$

iv. subtract the background TSA to obtain the final ρ^0 TSA

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

$X =$ Collins, Sivers

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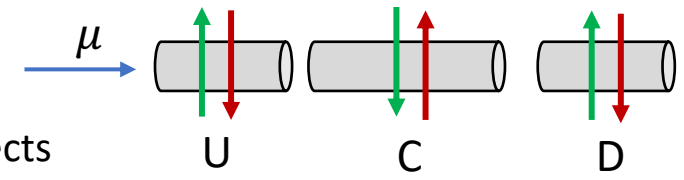
extraction of asymmetries

standard COMPASS methods applied for the extraction of the asymmetries *(NP B765 (2007) 31–70)*

- events with vertices in the three target cells with opposite polarizations combined in order to minimize systematic effects
- asymmetries extracted for each of the 12 periods of data taking and then combined



6 bins in x, z and P_T and

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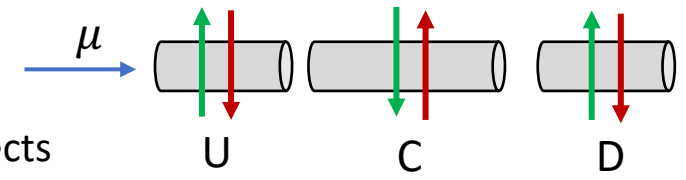
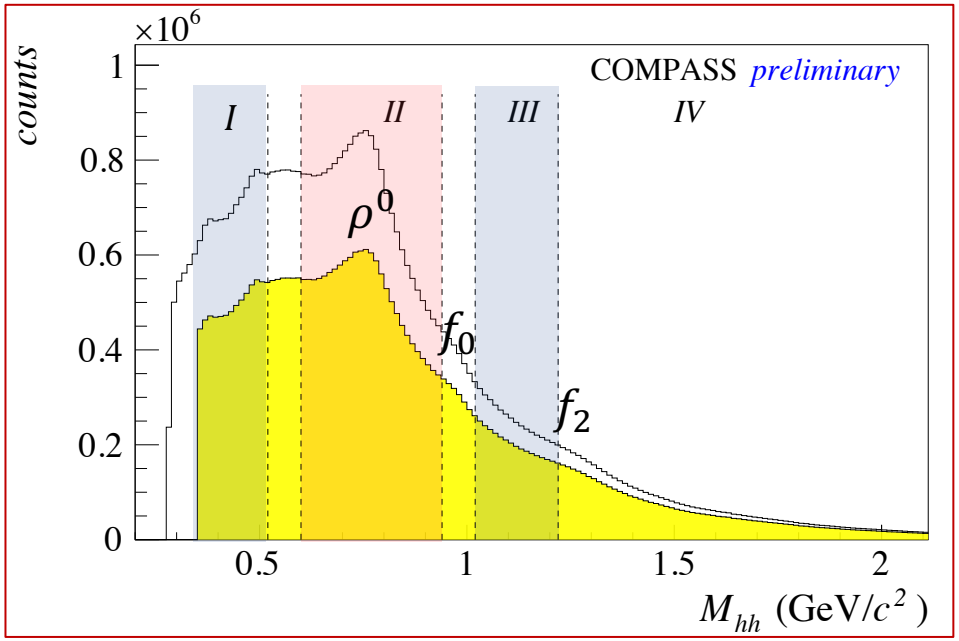


6 bins in x, z and P_T and **4 regions in invariant mass**



invariant mass regions

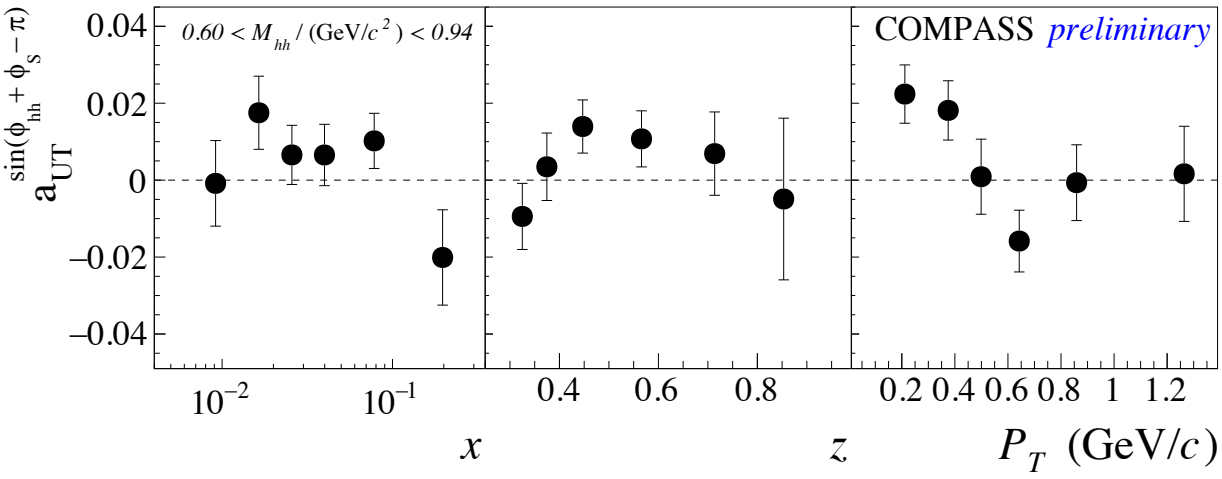
$I \quad 0.35 < M_{hh}/(GeV/c^2) < 0.52$

$II \quad 0.60 < M_{hh}/(GeV/c^2) < 0.94$

$III \quad 1.02 < M_{hh}/(GeV/c^2) < 1.22$

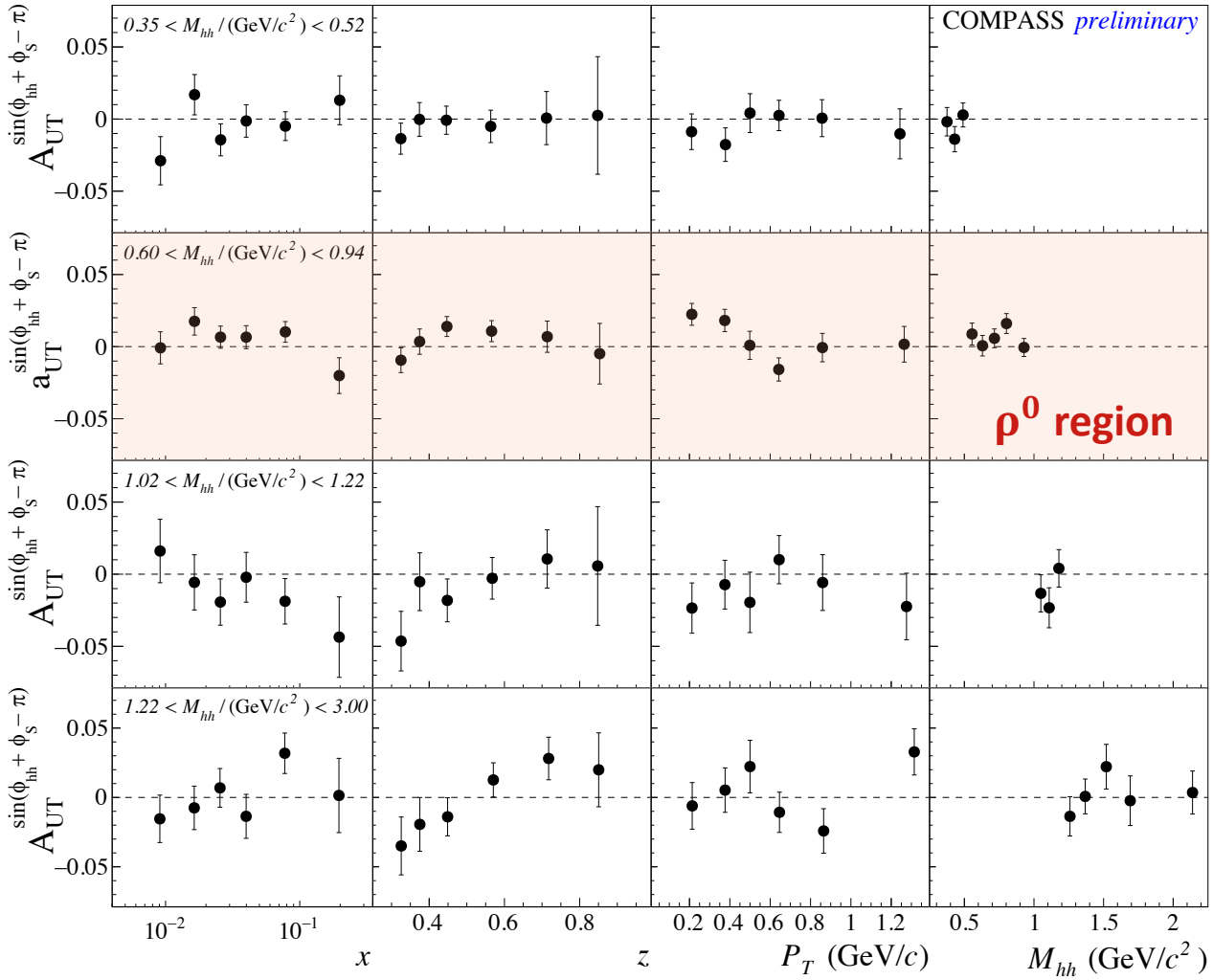
$IV \quad 1.22 < M_{hh}/(GeV/c^2) < 3.0$

Collins asymmetry for h^+h^- pairs as function of x, z and P_T in the ρ^0 region



indication for a positive Collins asymmetry at intermediate z and small P_T in the ρ^0 region

Collins asymmetry for h^+h^- pairs as function of x, z and P_T in the four mass regions



ρ^0 region: indication for a positive Collins asymmetry at intermediate z and small P_T

regions I and III (background): similar and compatible with zero

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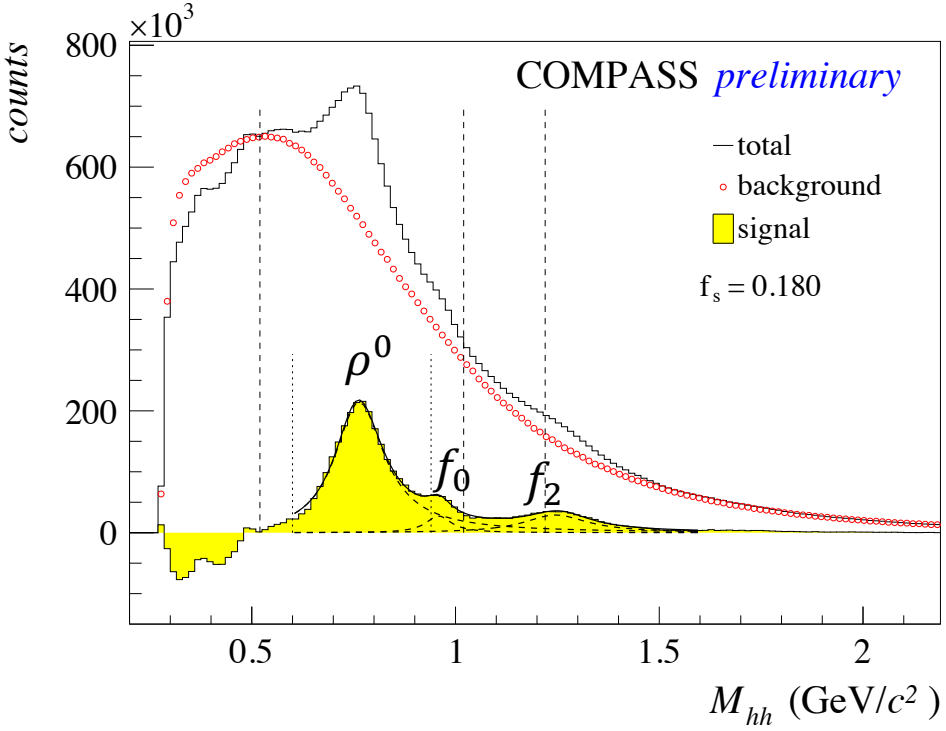
X = Collins, Sivers

calculation of the signal fraction

result of many tests



caveat: empirical method
same procedure for all x/z/PT bins

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

i. $h^+h^+ + h^-h^-$ the distribution is normalized in $M_{hh} \sim 0.5\ \mathrm{GeV/c^2}$

ii. the scaled $h^+h^+ + h^-h^-$ distribution is subtracted from the h^+h^-

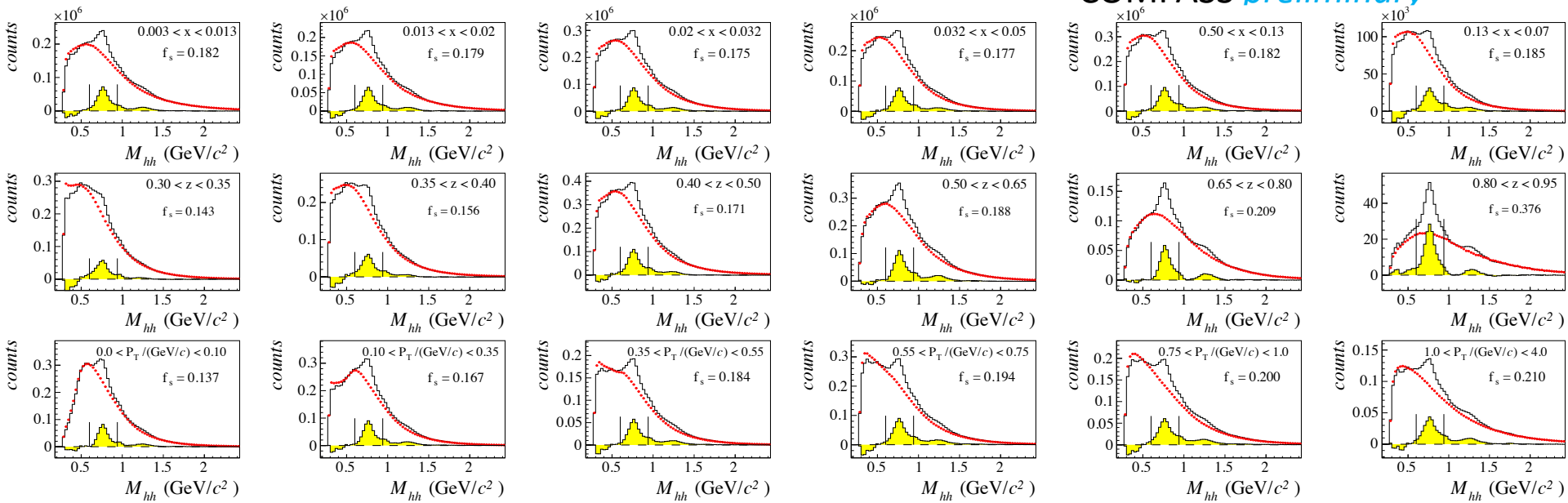
the signal distribution can be a fitted with the sum of three relativistic Breit-Wigner functions for ρ^0, f_0, f_2

iii. the signal fraction is calculated by couting the signal yields in region II as

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

Estimation of the signal fraction f_s as function of x, z, P_T

COMPASS *preliminary*



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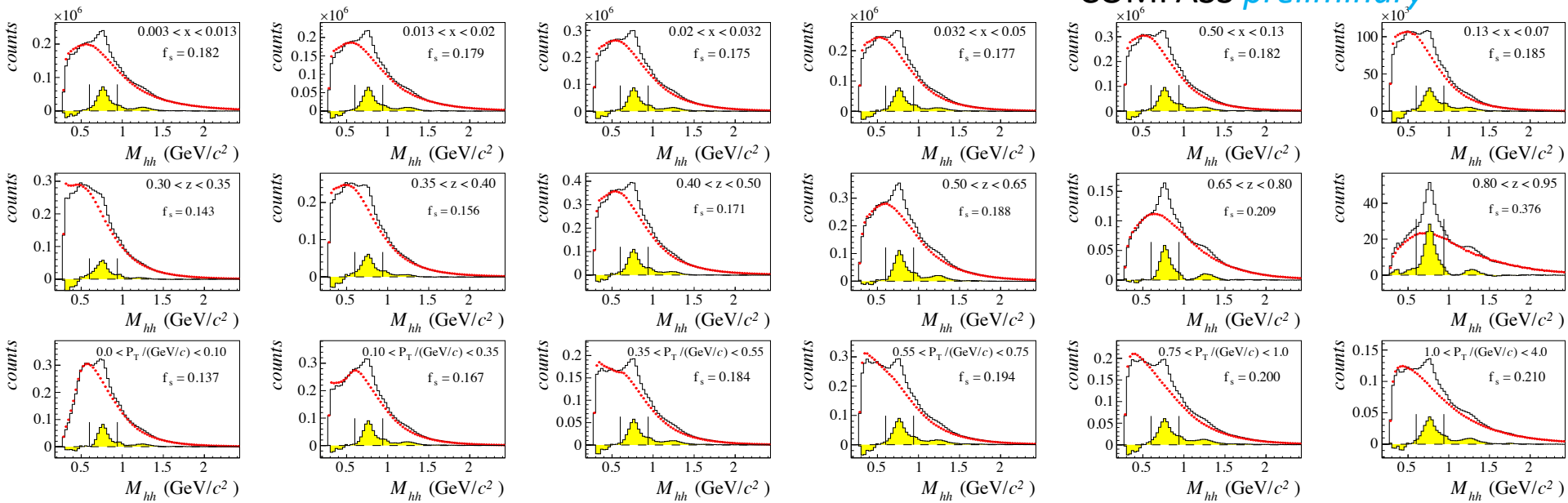
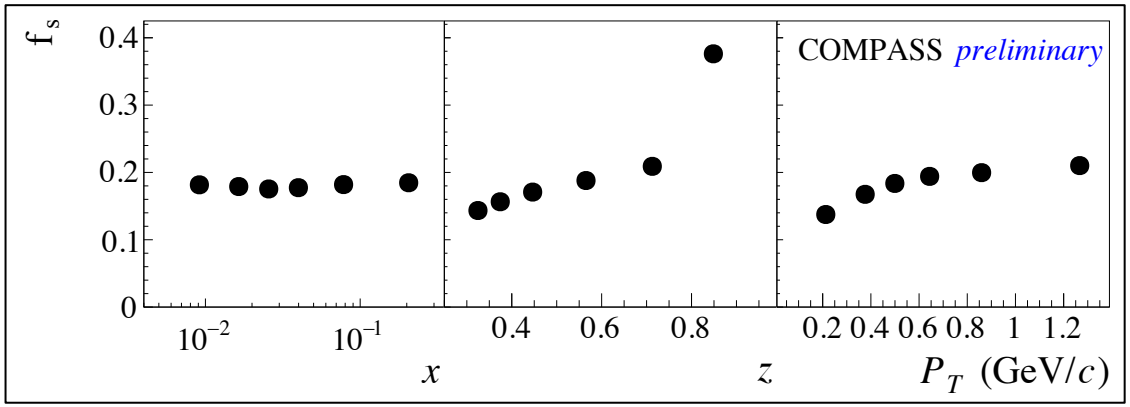


signal fraction in bins of x/z/PT



signal fraction f_s
- about 18%
- rises with z, up to 38%
- (as expected, e.g. in the string fragmentation model)

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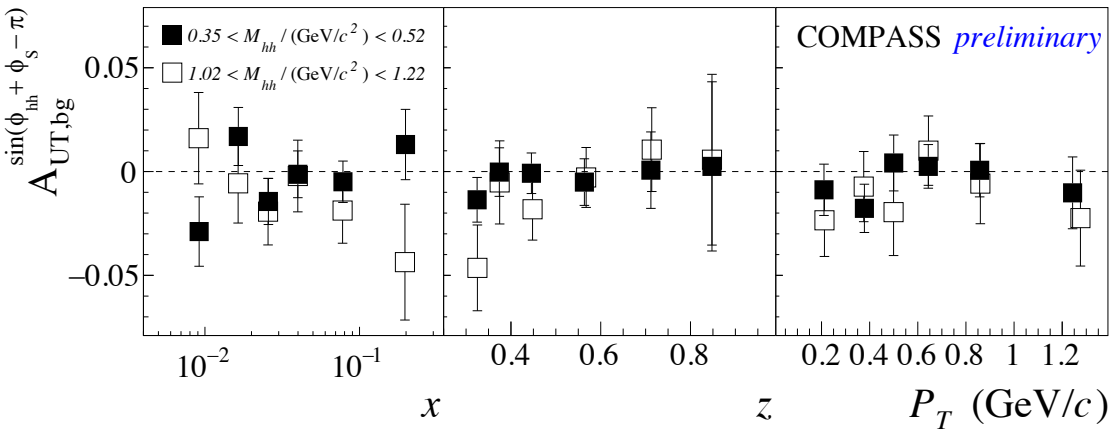
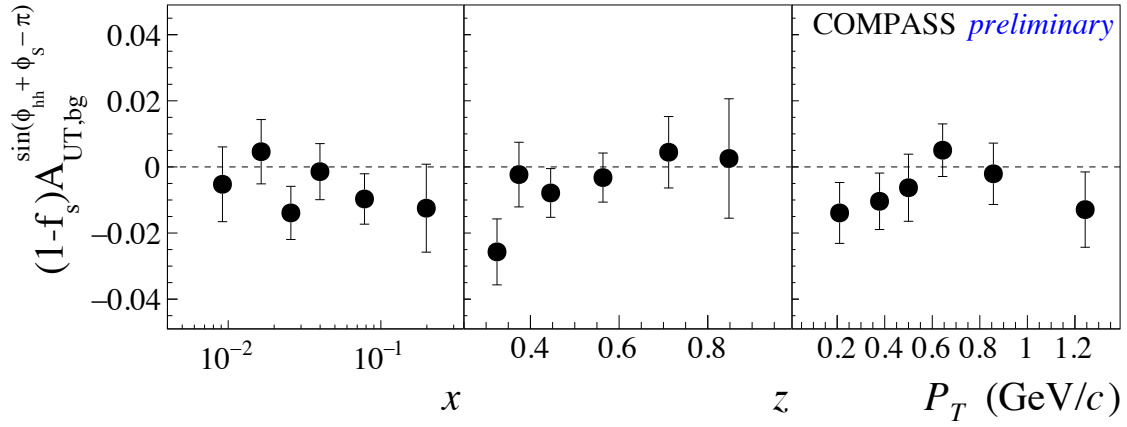
background Collins asymmetry



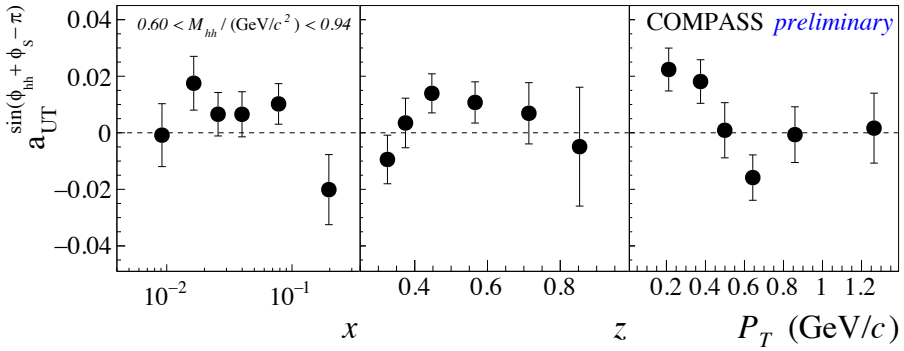
background asymmetry $A_{UT,bg}^{sin\,\phi_{hh}+\phi_S-\pi}$ arithmetic mean of asymmetries in regions I and III



background contribution to the asymmetry in the ρ^0 region

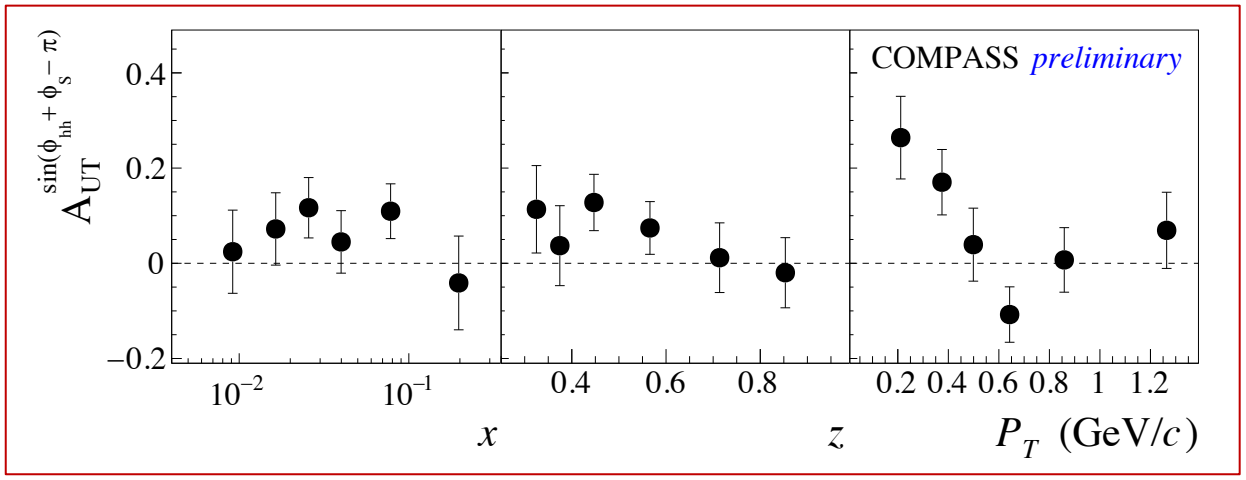
$$A_{UT}^{sin\,\phi_X} = \frac{1}{f_s}[a_{UT}^{sin\,\phi_X} - (1-f_s)A_{UT,bg}^{sin\,\phi_X}]$$

Collins asymmetry for ρ^0



Collins asymmetry in the ρ^0 region

$a_{UT}^{sin\,\phi_{hh}+\phi_S-\pi}$



final Collins asymmetry for ρ^0

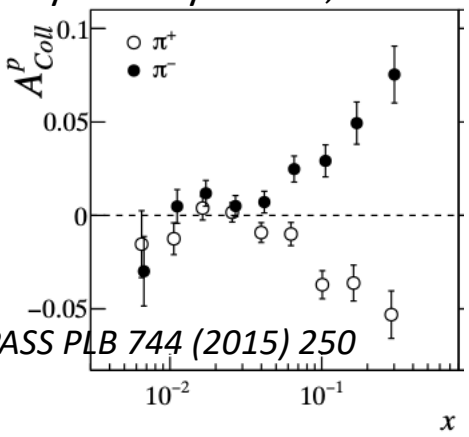
indication for a positive asymmetry

large at small P_T

(only statatistical uncertaintes, $\sigma_{sys} = 0.3\sigma_{stat}$)

Collins asymmetry for ρ^0

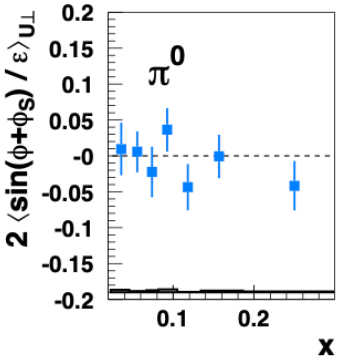
Collins asymmetry for π^+, π^-



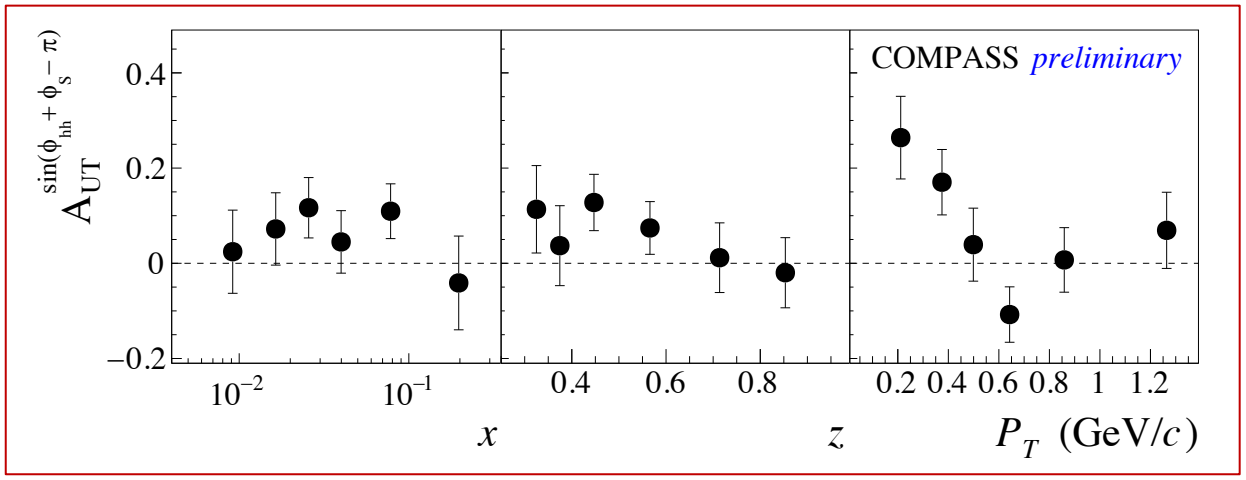
COMPASS PLB 744 (2015) 250

indication for opposite Collins asymmetries for ρ^0

Collins asymmetry for π^0



HERMES JHEP 12 (2020) 010



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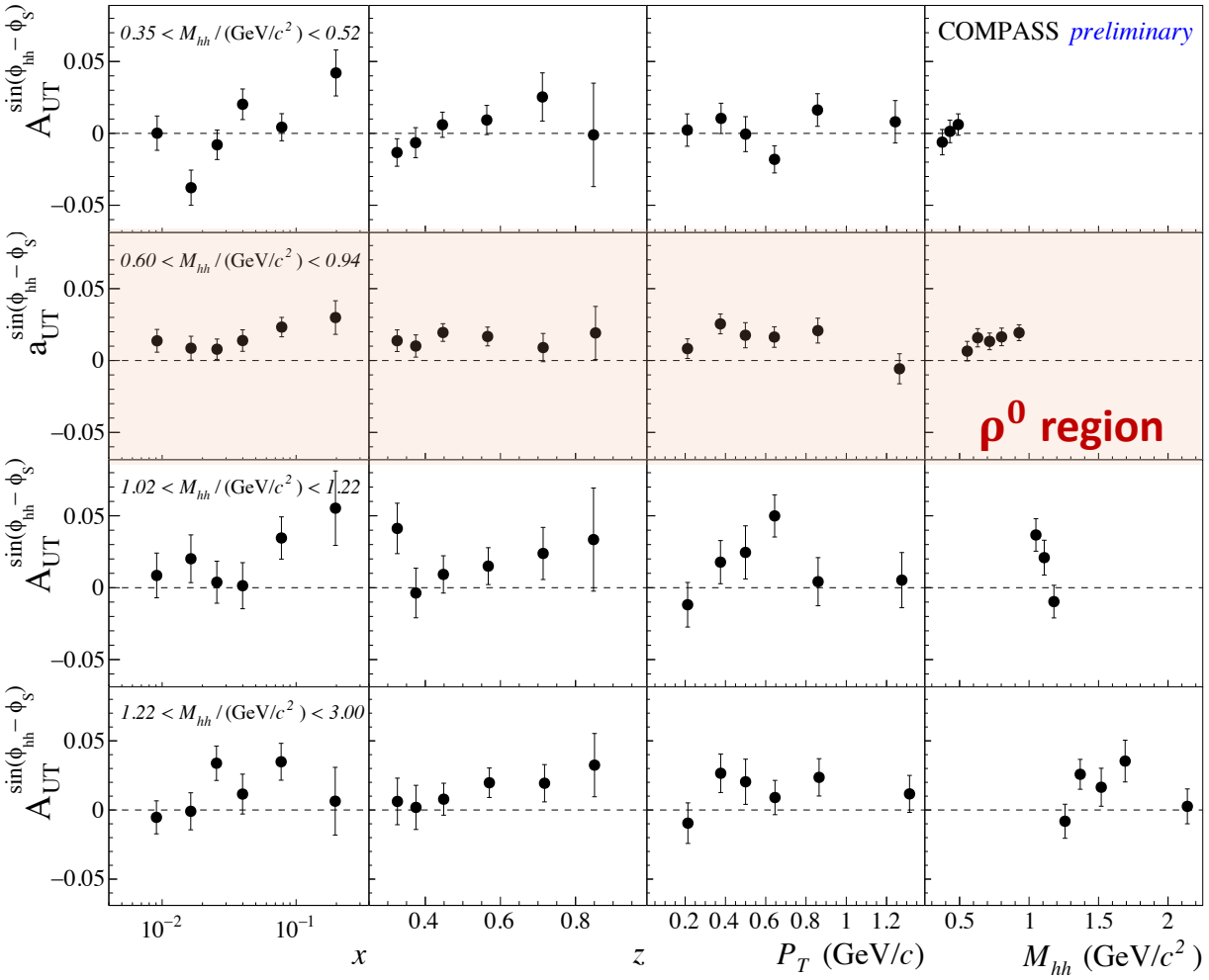
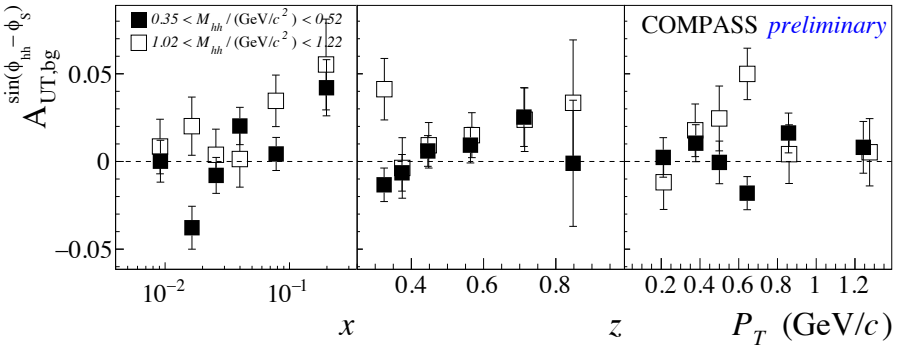
Sivers asymmetry for h^+h^- pairs as function of x, z and P_T in the four mass regions

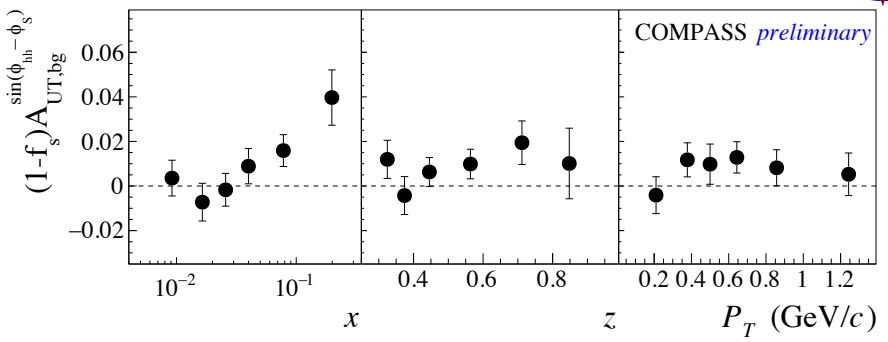


larger effects in ρ^0 region

background asymmetry large, compatible in regions I and III

Sivers asymmetry for ρ^0



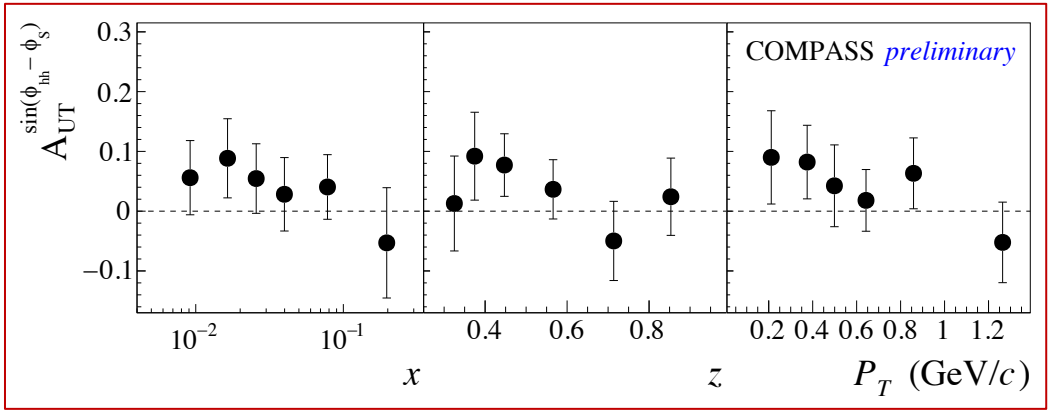


non-negligible background asymmetry, compatible with the asymmetry in the signal region

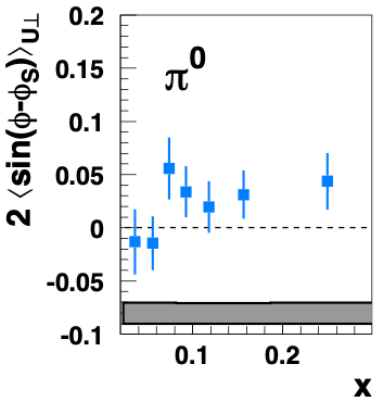
arithmetic average of the asymmetries in regions I and III

the final Sivers asymmetry for ρ^0 production is

$$A_{UT}^{\sin\phi_h-\phi_S} = \frac{1}{f_s} \times \left(a_{UT}^{\sin\phi_h-\phi_S} - (1-f_s) A_{UT,bg}^{\sin\phi_h-\phi_S} \right)$$



Sivers asymmetry for π^0



HERMES JHEP 12 (2020) 010

indication for a positive asymmetry

(only statistical uncertainties, $\sigma_{sys} = 0.3\sigma_{stat}$)

conclusions

- COMPASS has measured the Collins and Sivers asymmetries for inclusively produced ρ^0
- indication for a positive Collins asymmetry for ρ^0, opposite to the asymmetry for π^+, as expected from models
- indication for a positive Sivers asymmetry, as expected