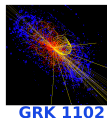# Transverse target spin asymmetries in exclusive ρ^0 muoproduction
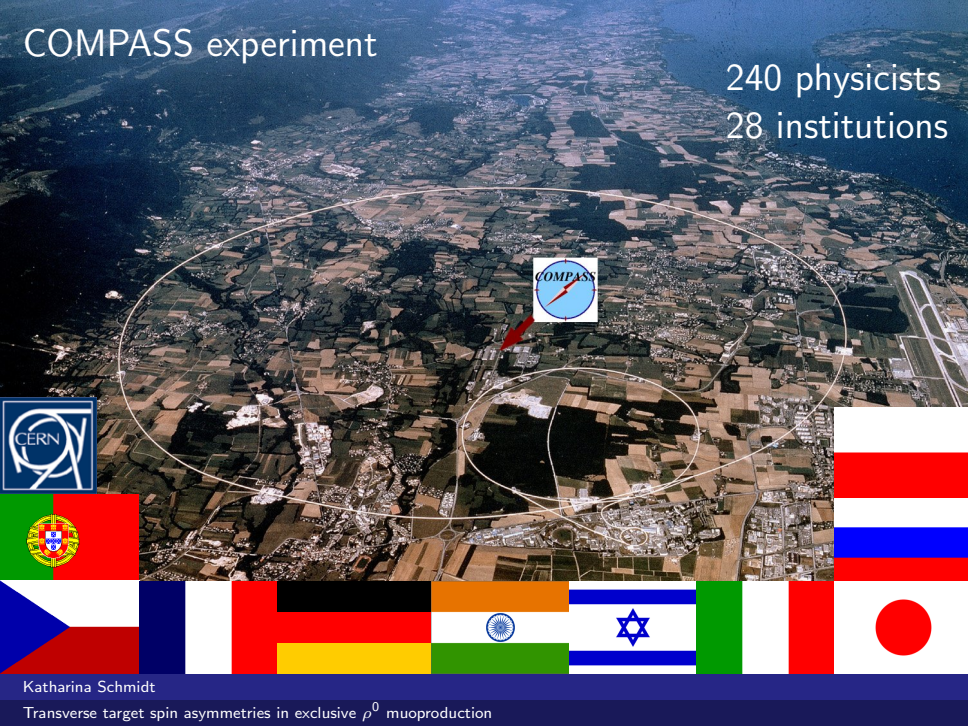
Katharina Schmidt
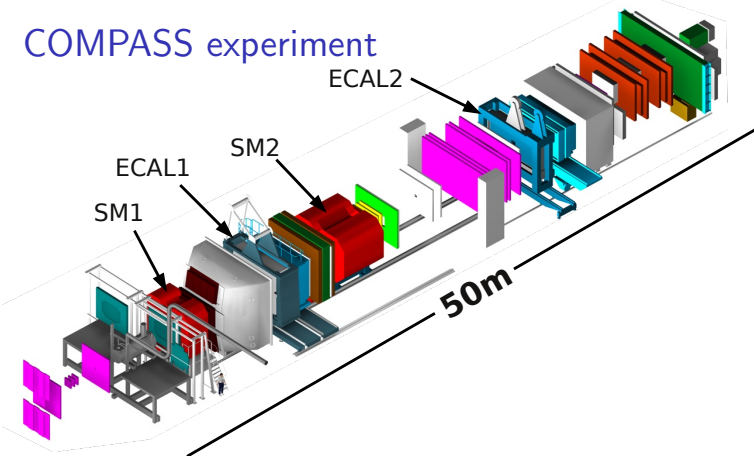
DIS 2013
Marseille

COMPASS experiment

240 physicists
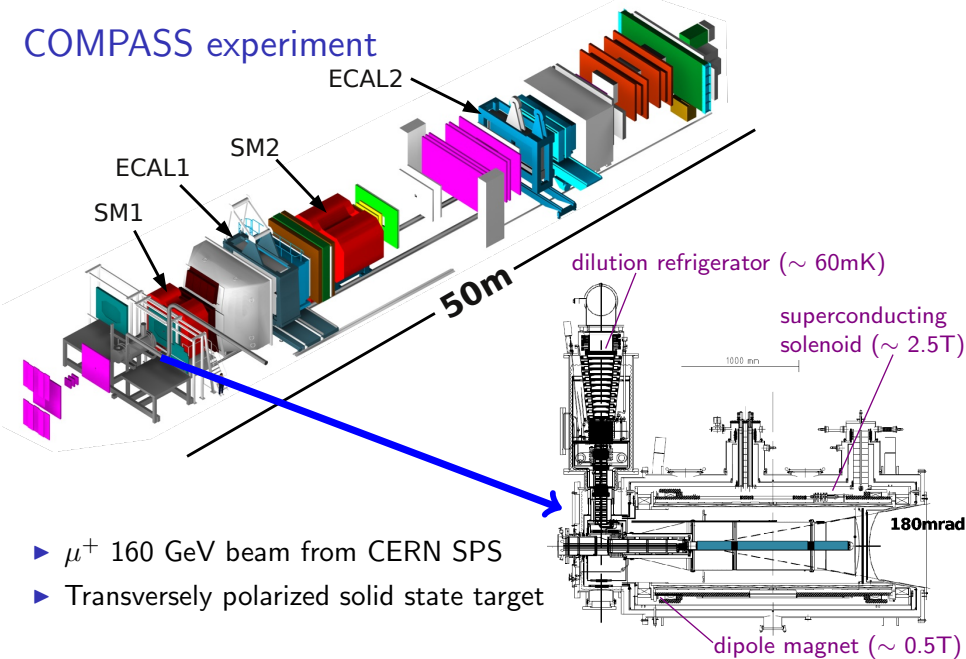28 institutions

Katharina Schmidt
Transverse target spin asymmetries in exclusive ρ^0 muoproduction

COMPASS experiment

- ▶ μ^+ 160 GeV beam from CERN SPS
- ▶ Transversely polarized solid state target

COMPASS experiment

ECAL2

ECAL1

SM2

SM1

50m

dilution refrigerator (~ 60mK)

superconducting solenoid (~ 2.5T)

180mrad

- ▶ μ^+ 160 GeV beam from CERN SPS
- ▶ Transversely polarized solid state target

dipole magnet (~ 0.5T)

Hard exclusive ρ^0 production

$$\left[\frac{\alpha_{\mathrm{em}}}{8\pi^3}\frac{y^2}{1-\varepsilon}\frac{1-x_B}{x_B}\frac{1}{Q^2}\right]^{-1}\frac{d\sigma}{dx_B\,dQ^2\,d\phi\,d\psi}=\frac{1}{2}\left(\sigma_{++}^{++}+\sigma_{++}^{--}\right)+\varepsilon\sigma_{00}^{++}-\varepsilon\cos(2\phi)\mathrm{Re}\,\sigma_{+-}^{++}$$

$$-\sqrt{\varepsilon(1+\varepsilon)}\cos\phi\,\mathrm{Re}\left(\sigma_{+0}^{++}+\sigma_{+0}^{--}\right)\quad-P_\ell\sqrt{\varepsilon(1-\varepsilon)}\sin\phi\,\mathrm{Im}\left(\sigma_{+0}^{++}+\sigma_{+0}^{--}\right)$$

$$-S_L\left[\varepsilon\sin(2\phi)\,\mathrm{Im}\,\sigma_{+-}^{++}+\sqrt{\varepsilon(1+\varepsilon)}\sin\phi\,\mathrm{Im}\left(\sigma_{+0}^{++}-\sigma_{+0}^{--}\right)\right]$$

$$+S_LP_\ell\left[\sqrt{1-\varepsilon^2}\,\frac{1}{2}\left(\sigma_{++}^{++}-\sigma_{++}^{--}\right)-\sqrt{\varepsilon(1-\varepsilon)}\cos\phi\,\mathrm{Re}\left(\sigma_{+0}^{++}-\sigma_{+0}^{--}\right)\right]$$

transversely polarized target
$$-S_T\left[\sin(\phi-\phi_S)\,\mathrm{Im}\left(\sigma_{++}^{+-}+\varepsilon\sigma_{00}^{+-}\right)+\frac{\varepsilon}{2}\sin(\phi+\phi_S)\,\mathrm{Im}\,\sigma_{+-}^{+-}+\frac{\varepsilon}{2}\sin(3\phi-\phi_S)\,\mathrm{Im}\,\sigma_{+-}^{-+}\right.$$

transversely polarized target +
$$\left.+\sqrt{\varepsilon(1+\varepsilon)}\sin\phi_S\,\mathrm{Im}\,\sigma_{+0}^{+-}+\sqrt{\varepsilon(1+\varepsilon)}\sin(2\phi-\phi_S)\,\mathrm{Im}\,\sigma_{+0}^{-+}\right]$$

longitudinaly polarized beam
$$+S_TP_\ell\left[\sqrt{1-\varepsilon^2}\cos(\phi-\phi_S)\,\mathrm{Re}\,\sigma_{++}^{+-}-\sqrt{\varepsilon(1-\varepsilon)}\cos\phi_S\,\mathrm{Re}\,\sigma_{+0}^{+-}\right.$$

$$\left.-\sqrt{\varepsilon(1-\varepsilon)}\cos(2\phi-\phi_S)\,\mathrm{Re}\,\sigma_{+0}^{-+}\right]$$

ϵ = virtual photon polarization parameter
σ_{mn}^{ij} = spin dependent photoabsorption cross sections, interference terms
m,n = virtual-photon helicity
i,j = target nucleon helicity

Diehl & Sapeta
Eur.Phys.J.C 41 (2005)

Hard exclusive ρ^0 production

- Factorisation valid for σ_L
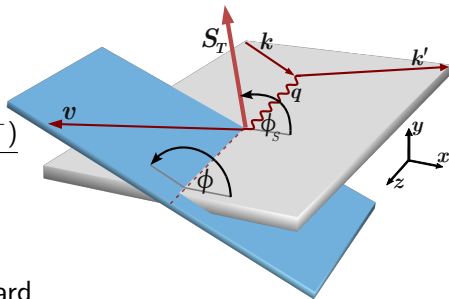- Leading twist term σ_{00}^{+-} sensitive to

$$A_{UT}^{\sin(\phi-\phi_s)} = -\frac{\text{Im}\,(\sigma_{++}^{+-} + \varepsilon\,\sigma_{00}^{+-})}{\sigma_0}$$

$$\text{Im}\,\frac{d\sigma_{00}^{+-}}{dt} \sim \text{Im}\,(\mathcal{E}^\star\mathcal{H})$$

- $\mathcal{E}$ & $\mathcal{H}$ are convolution integrals of hard scattering kernels and the ρ^0 distribution amplitude with GPDs E & H where:

$$E_{\rho^0} = \frac{1}{\sqrt{2}}(\frac{2}{3}E^u + \frac{1}{3}E^d + \frac{3}{4}E^g)$$

$\rightarrow$ Constrain GPD E

- Additional asymmetries contain higher twist terms

Exclusive ρ^0 production at COMPASS

All measurements done with μ^+ 160 GeV beam with polarization $\langle P_B \rangle \sim 80\%$ and a transversely polarized target
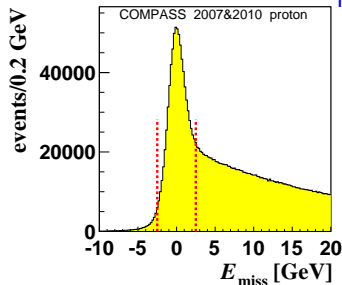
^{6}LiD target (polarized deuterons) 2003&2004

→ Dilution factor $\langle f \rangle \sim 0.45$

→ Polarization $\langle P_T \rangle \sim 50\%$

NH$_3$ target (polarized protons) 2007&2010

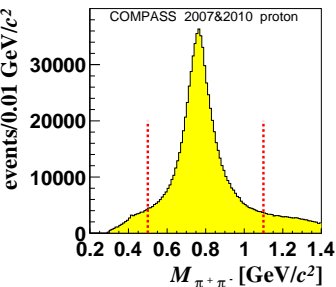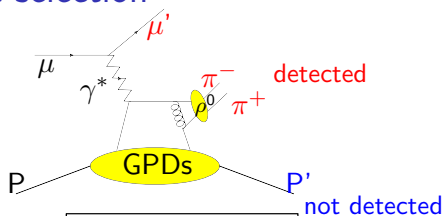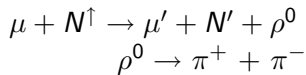→ Dilution factor $\langle f \rangle \sim 0.25$

→ Polarization $\langle P_T \rangle \sim 80\%$
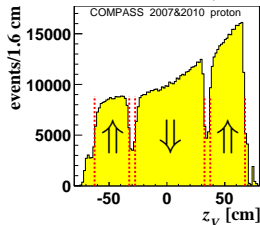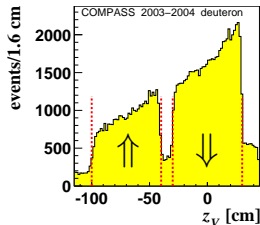
change of polarization $\sim$ weekly

Exclusive ρ^0 production - event selection

$$\mu + N^{\uparrow} \rightarrow \mu' + N' + \rho^0$$
$$\rho^0 \rightarrow \pi^+ + \pi^-$$

► Peak at ρ^0 mass ~ 0.775 GeV/c^2

► Signature for exclusivity $E_{miss} \sim 0$

$$E_{miss} = \frac{(p + q - \rho)^2 - p^2}{2 \cdot M_p} = \frac{M_X^2 - M_p^2}{2 \cdot M_p}$$
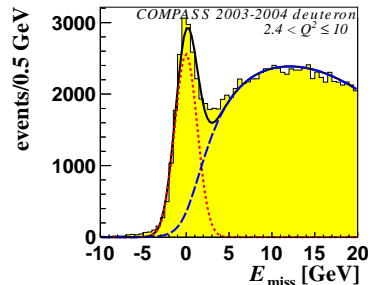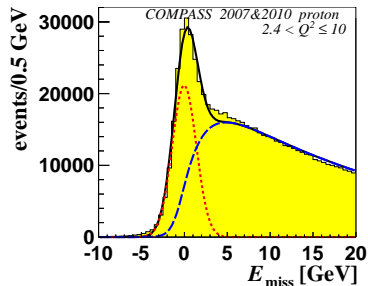
Semi-inclusive background estimation

- LEPTO MC (COMPASS tuning)

1.) Parameterization of MC:

  - MC weighted with the like sign sample

  $$w = \frac{N_{\text{data}}^{h^+h^+}(E_{\text{miss}}) + N_{\text{data}}^{h^-h^-}(E_{\text{miss}})}{N_{\text{MC}}^{h^+h^+}(E_{\text{miss}}) + N_{\text{MC}}^{h^-h^-}(E_{\text{miss}})}$$

  - Parameterize the E_{miss} shape of weighted MC
 - Binning appropriate for asymmetry extraction (x_{Bj}, Q^2 or p_T^2, target cell)

Semi-inclusive background estimation

- LEPTO MC (COMPASS tuning)

2.) Fit to data:

- Normalize MC E_{miss} shape to data by performing a two component signal (gauss) + background fit

- ϕ, ϕ_S distribution for $7 < E_{miss} < 20$ GeV scaled with the number of background events and subtracted from ϕ, ϕ_S distribution in signal range $-2.5 < E_{miss} < 2.5$ GeV

- Asymmetry extraction with corrected ϕ, ϕ_S distribution

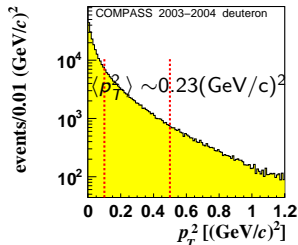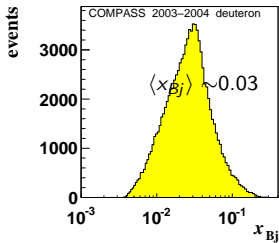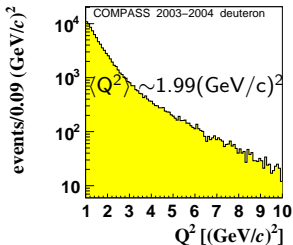$\rightarrow$ Total amout of SIDIS background: 18% (^{6}LiD), 22% (NH$_3$)
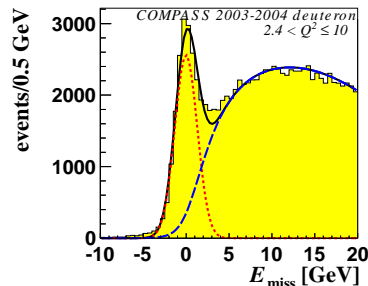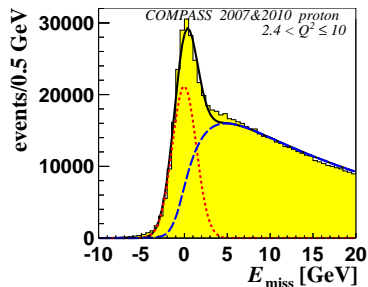
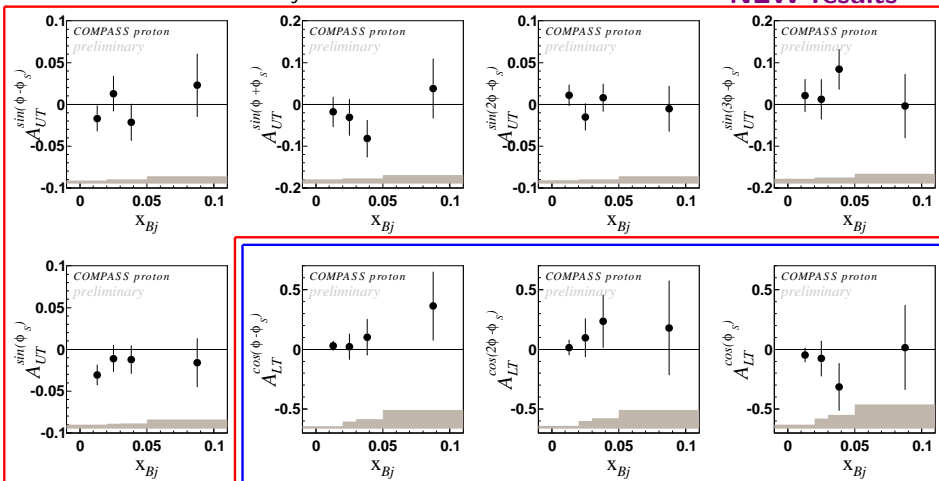# Exclusive ρ^0 production - kinematical distributions

protons
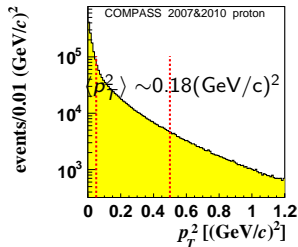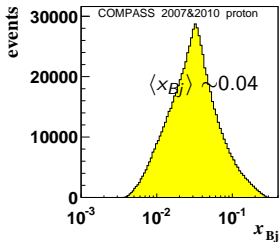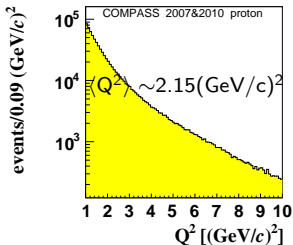
deuterons

Asymmetry $A_{UT,LT}$ - NH$_3$ target (2007&2010)

as a function of x_{Bj}

NEW results
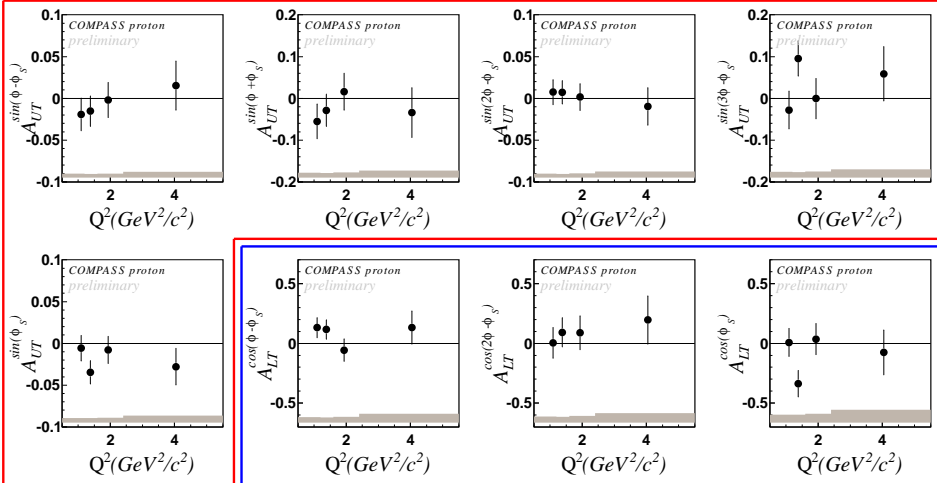

▶ Asymmetry extraction using a 2D binned maximum likelihood fit after subtracting the SIDIS background

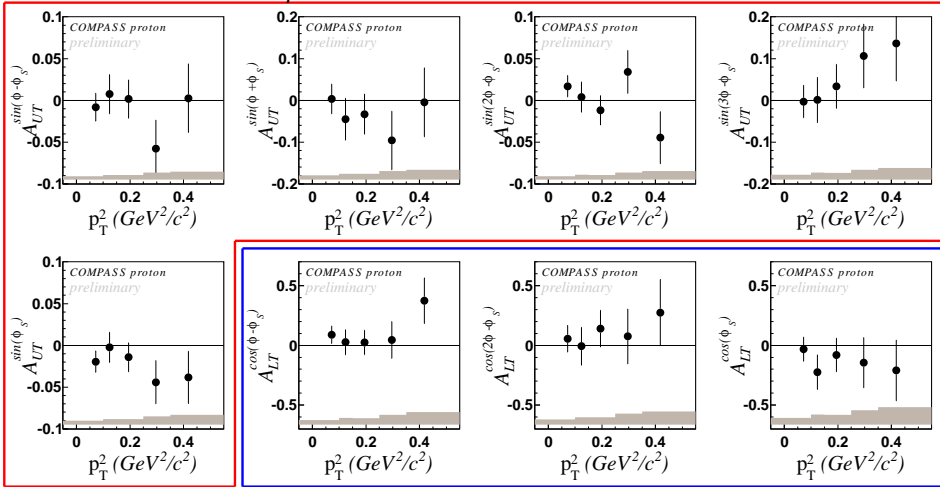# Asymmetry $A_{UT,LT}$ - NH_3 target (2007&2010)

as a function of Q^2

NEW results
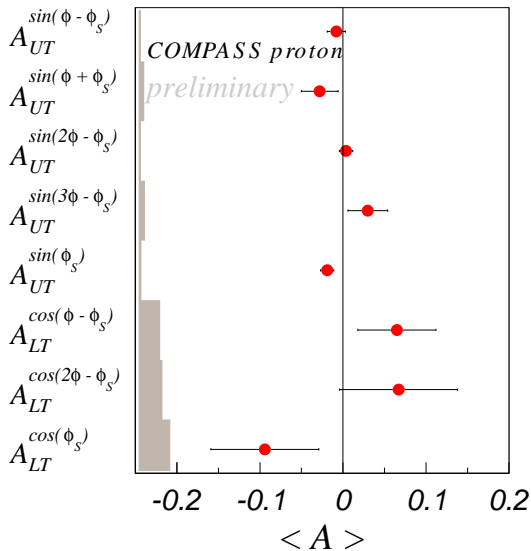
Asymmetry $A_{UT,LT}$ - NH_3 target (2007&2010)
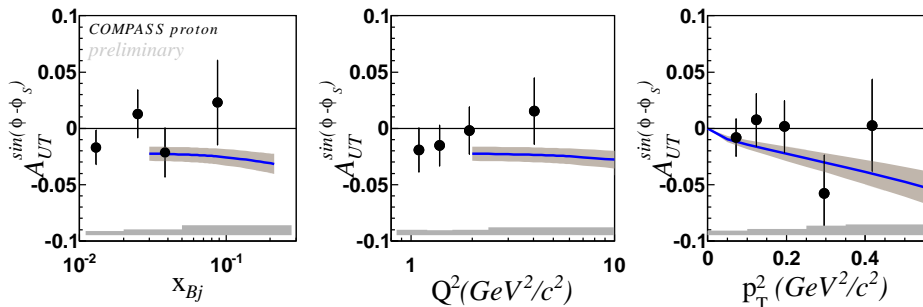
as a function of p_T^2

Results - mean asymmetries

NEW results

Asymmetry $A_{UT,p}^{sin(\phi-\phi_S)}$ - NH$_3$ target (2007&2010)

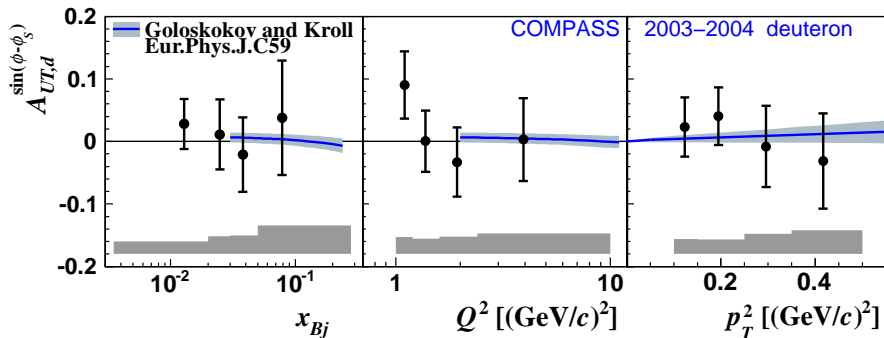- ▶ Blue line: Model from Goloskokov and Kroll
- ▶ Predictions for COMPASS kinematic
  $W = 8.1$ GeV/c^2, $p_T^2 = 0.2$ (GeV/c)^2, $Q^2 = 2.2$ (GeV/c)^2
- ▶ Model includes contributions from γ_L^* and γ_T^*

Asymmetry $A_{UT,d}^{sin(\phi-\phi_S)}$ - ^{6}LiD target (2003&2004)

- Averaged over COMPASS kinematical region:
 $A_{UT,p}^{sin(\phi-\phi_S)}$ = -0.008 ± 0.011 ± 0.003
  $A_{UT,d}^{sin(\phi-\phi_S)}$ = 0.02 ± 0.03 ± 0.02
- GPDs E^u and E^d approx. cancel

Nucl.Phys. B865 (2012) 1-20

Summary

- Exclusive ρ^0 production in high energy muon scattering off transversely polarized protons and deuterons were studied

- $A_{UT,d}^{sin(\phi-\phi_S)}$ was found to be compatible with 0 and consistent with theoretical predictions

- Results for 5 transverse target single-spin asymmetries $A_{UT,p}$ and 3 transverse target double-spin asymmetries $A_{LT,p}$ for transversely polarized protons were presented

- Most of the modulations are small, compatible with 0

- $A_{UT,p}^{sin(\phi_S)} = -0.019 \pm 0.008 \pm 0.003$
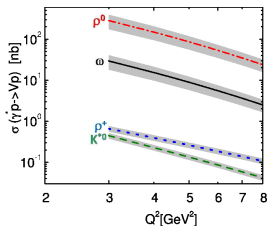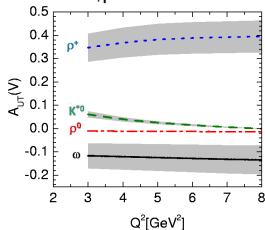
Goloskokov & Kroll
Eur.Phys.J.C 59 (2009)