Diffractive vector meson production at COMPASS and plans for GPD's measurements

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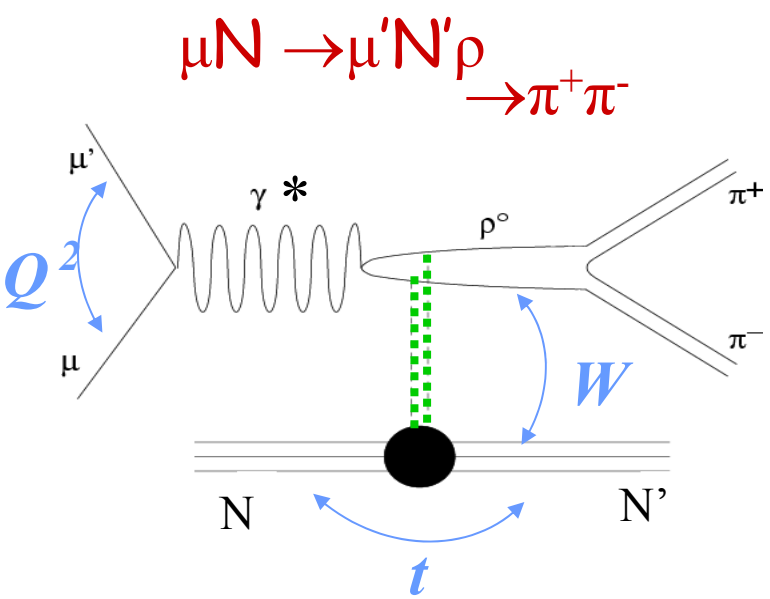
On behalf of the COMPASS *Collaboration*

- Results on spin dependence for exclusive ρ^0 production
  - a) ρ^0 spin density matrix elements and $R = \sigma_L / \sigma_T$
  - b) longitudinal double-spin asymmetry A_1^{ρ} ⟵ new result
- Future measurements of GPDs at COMPASS

PANIC05, Santa Fe, October 24-28, 2005

Physics of exclusive ρ^0 production



pQCD calculations or pQCD-inspired models with exchange of 2 quarks or 2 gluons (at $Q^2 > 1$ GeV^2)

Diffraction

Regge theory:

At low energy ($W < 5$ GeV) exchange of Reggeons ρ, ω, a_2, f_2

At higher energies exchange of Pomeron

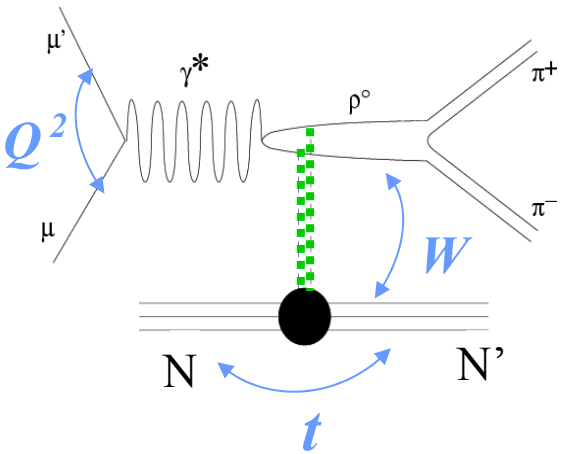
Aim of the present analysis:

spin structure of cross section / helicity amplitudes for $\gamma^*N \rightarrow \rho^0 N$

- is helicity of γ^* retained by ρ^0 (SCHC)
- natural/unnatural parity of exchanged object
- $R = \sigma_L/\sigma_T$ vs. Q^2

→ Better understanding of Pomeron's nature

Incoherent exclusive ρ^0 production



^{6}LiD polarized target

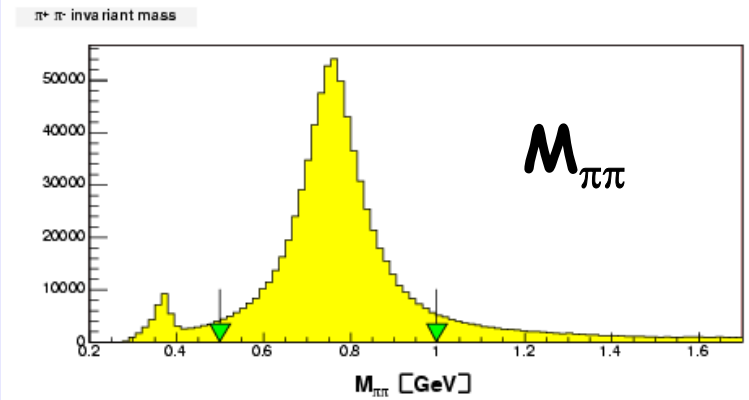
Kinematics:

$\nu > 30$ GeV

$E_{\mu'} > 20$ GeV

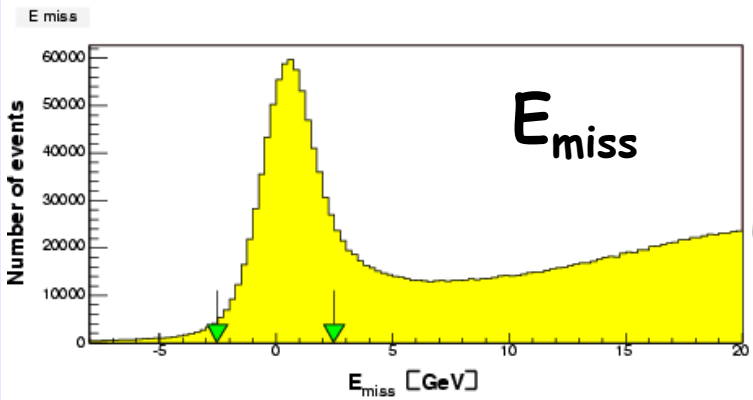
$Q^2 > 0.01$ GeV^2

(Q^2 cut not applied in double-spin asymmetry analysis)



Assuming both hadrons are π

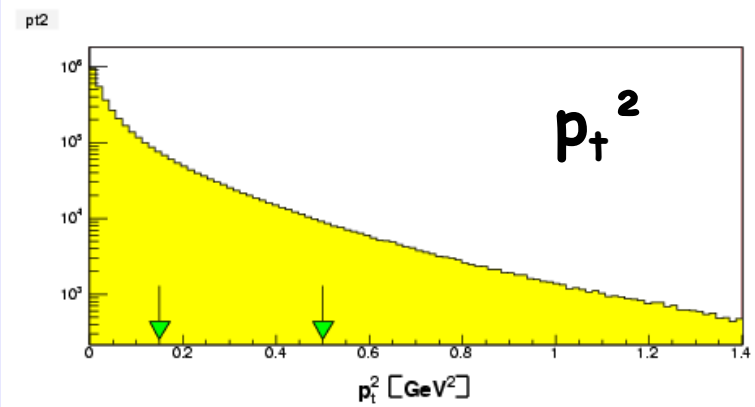
$0.5 < M_{\pi\pi} < 1$ GeV



Exclusivity of the reaction

$E_{miss} = (M^2_X - M^2_N) / 2M_N$

$-2.5 < E_{miss} < 2.5$ GeV



Incoherent production

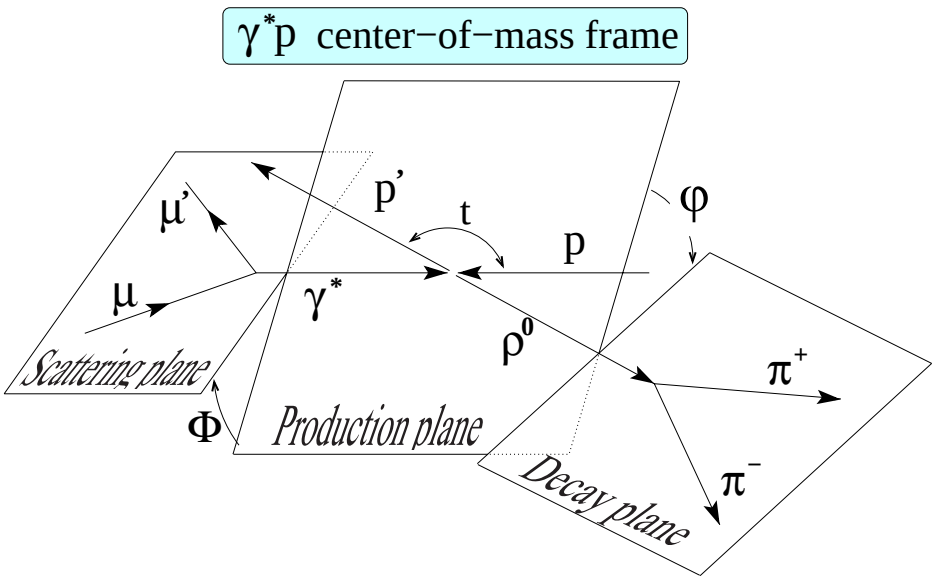
$0.15 < p_t^2 < 0.5$ GeV^2

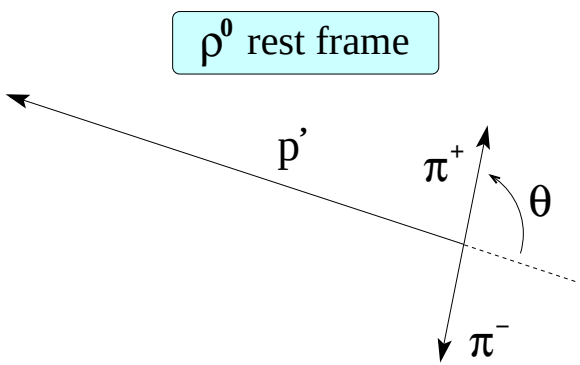
scattering off a quasi-free nucleon

Background ~12%

ρ° angular distributions $W(\cos\theta, \varphi, \Phi)$ depend on the spin density matrix elements (SDME)

⇨ 23 (15) observables with polarized (unpolarized) beam





SDMEs are bilinear combinations of the helicity amplitudes

$$A(\gamma^*(\lambda_\gamma) \rightarrow \rho(\lambda_\rho)) \equiv T_{\lambda\rho,\,\lambda\gamma}$$

$$\lambda_\gamma = \pm 1, 0 \qquad \lambda_\rho = \pm 1, 0$$

This analysis:

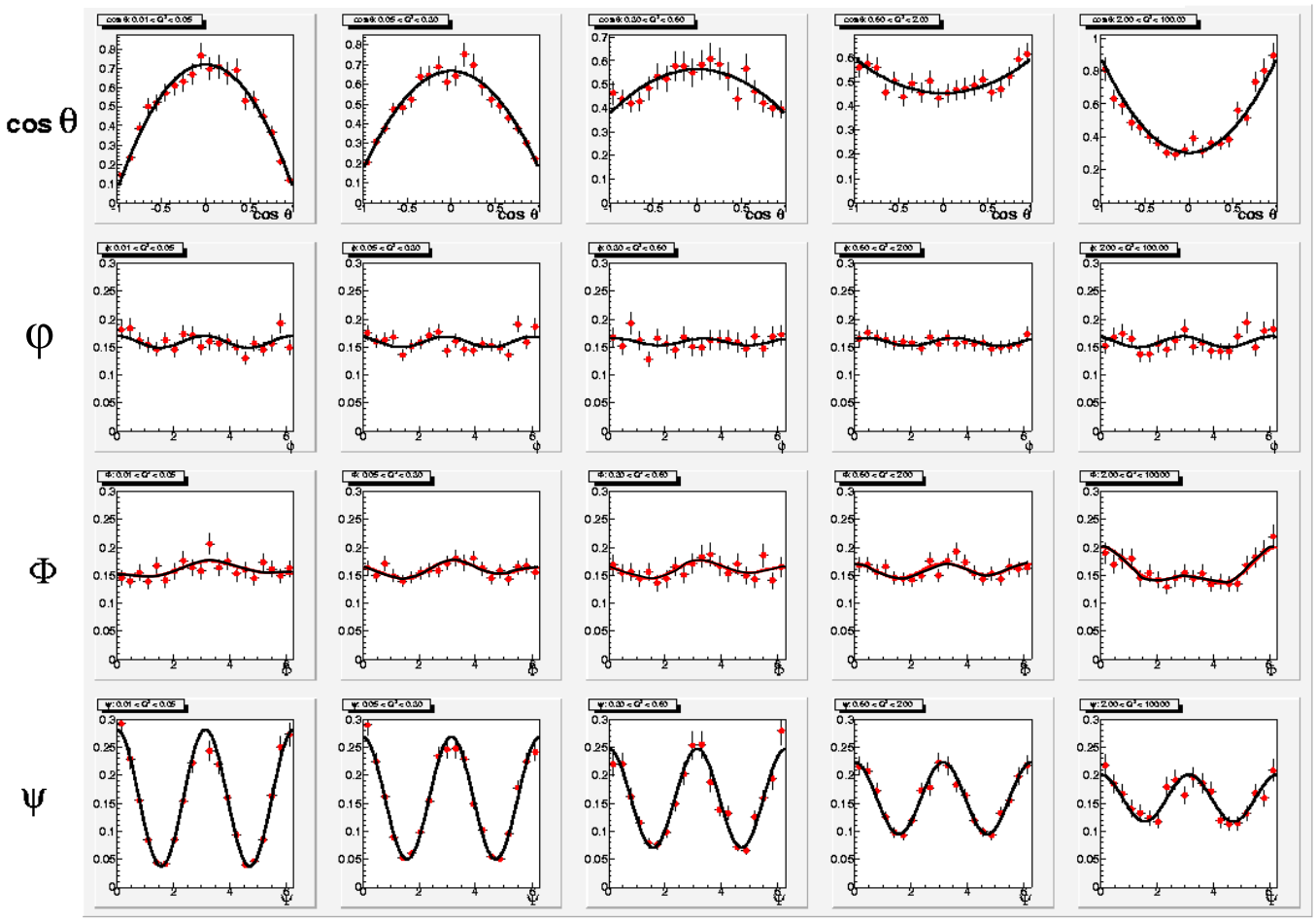
only one-dimensional angular distribution

We also use:

$\psi = \varphi - \Phi$

Angular distributions

$0.01 < Q^2 < 0.05 < Q^2 < 0.3 < Q^2 < 0.6 < Q^2 < 2.0 < Q^2 < 10\ GeV^2$



Preliminary :

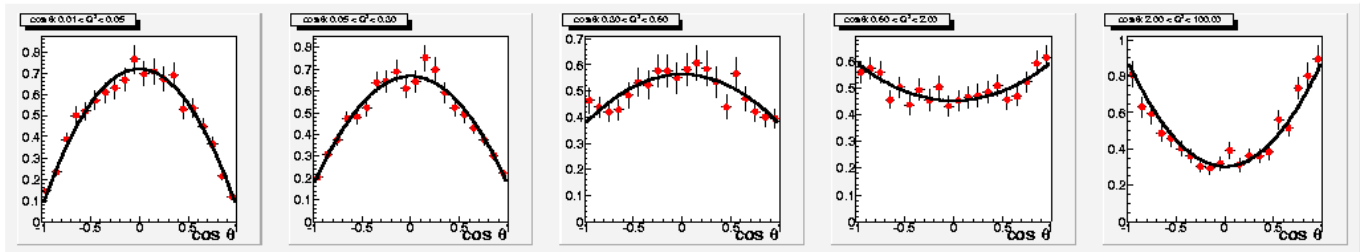
- Corrected for Acceptance, smearing and efficiency (MC:DIPSI gen)

- Background not subtracted

Statistical errors only, limited by MC

Measurement of r_{00}^{04}

$0.01 < Q^2 < 0.05 < Q^2 < 0.3 < Q^2 < 0.6 < Q^2 < 2.0 < Q^2 < 10\ GeV^2$



Distribution :

$$W(\cos\theta) = \frac{3}{4}\left[(1-r_{00}^{04}) + (3r_{00}^{04}-1)\cos^2\theta\right]$$

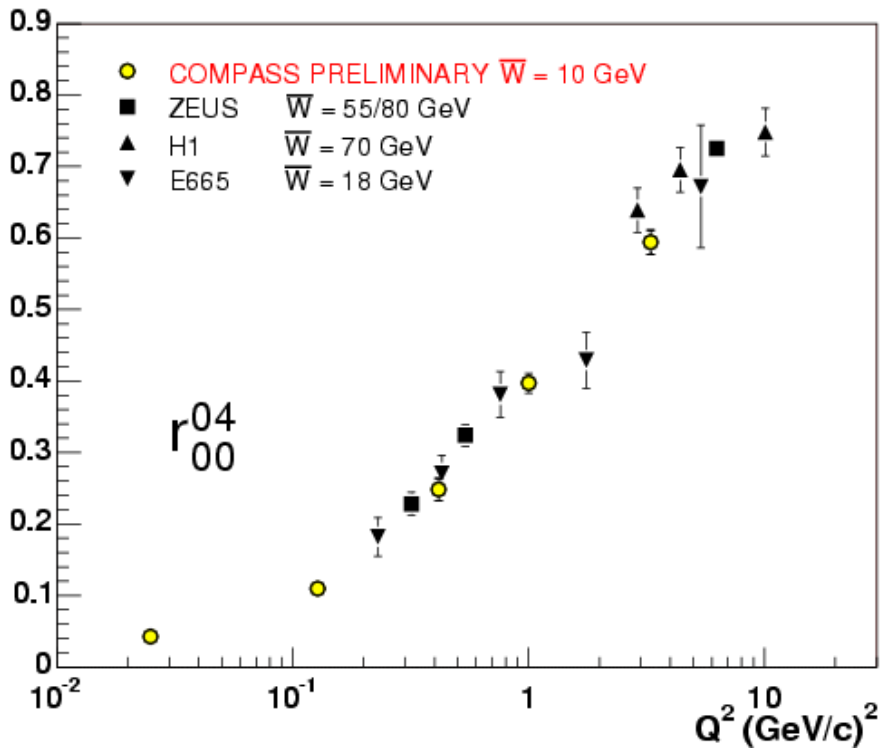
Spin density matrix element:

$$r_{00}^{04} \sim \frac{|T_{01}|^2 + (\varepsilon+\delta)|T_{00}|^2}{\sigma_T + (\varepsilon+\delta)\sigma_L}$$

SCHC $\rightarrow \frac{\sigma_L}{\sigma_T}$

$T_{\lambda\rho\,\lambda\gamma}$ are helicity amplitudes

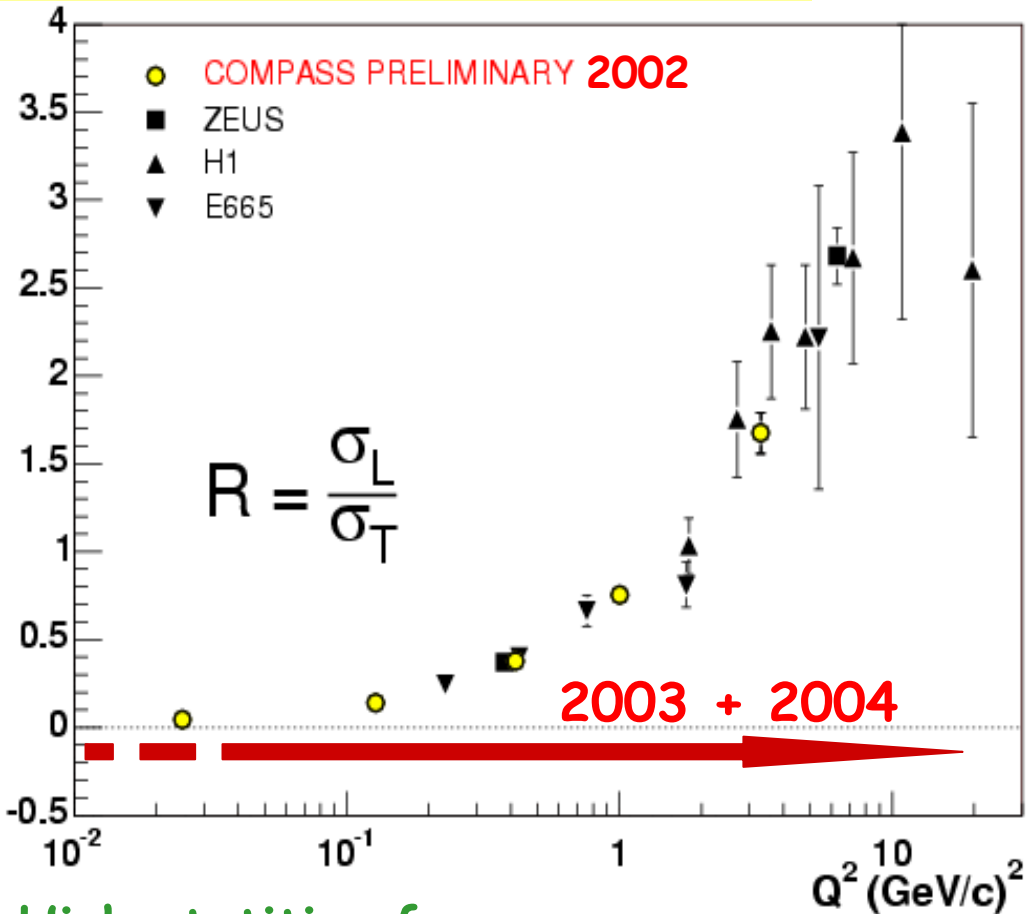
meson photon



Determination of $R_{\rho^0}=\sigma_L/\sigma_T$

If SCHC holds :
only $T_{00}\neq 0$
$T_{11}\neq 0$
Then :

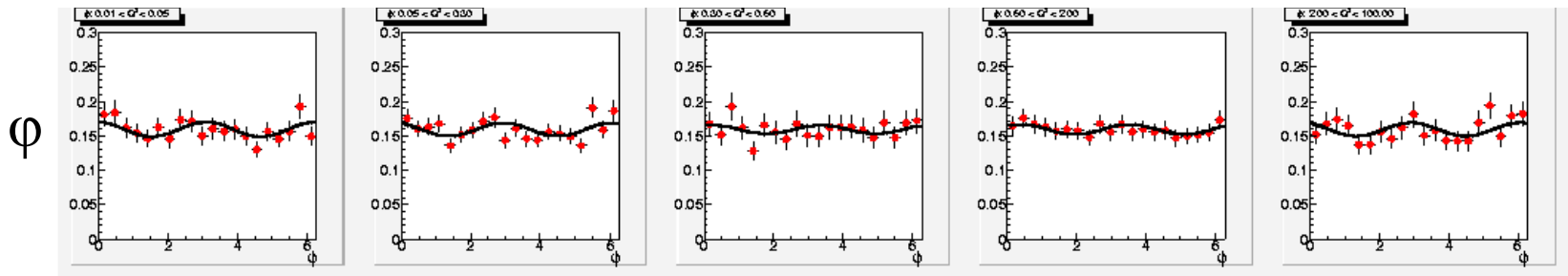
$$R=\frac{\sigma_L}{\sigma_T}=\frac{1}{(\varepsilon+\delta)}\frac{r_{00}^{04}}{1-r_{00}^{04}}$$



Impact on GPD study:
easy determination of σ_L
factorisation only valid for σ_L
σ_L is dominant at $Q^2>2$ GeV^2

- High statitics from quasi-photoproduction to hard production
- Better coverage at high Q^2 with 2003 and 2004 data

Measurement of r^{04}_{1-1} and Im r^{3}_{1-1}



Distribution :

$$W(\varphi) = \frac{1}{2\pi}[1 - 2r^{04}_{1-1}\cos 2\varphi + 2\,\mathrm{Im}\; r^{3}_{1-1} P_\mu \sqrt{1-\varepsilon^2}\sin 2\varphi]$$

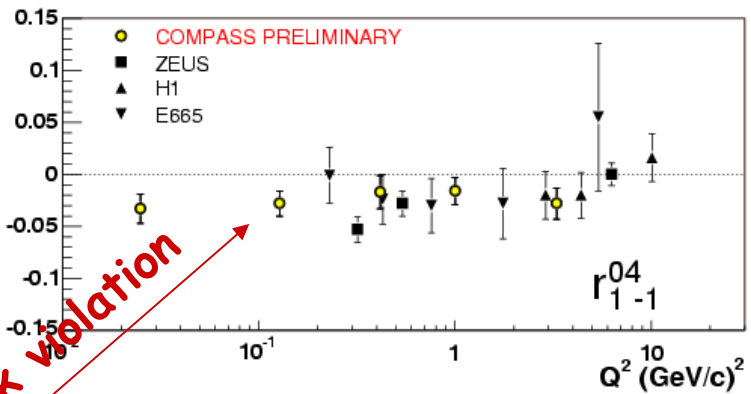
beam polarisation

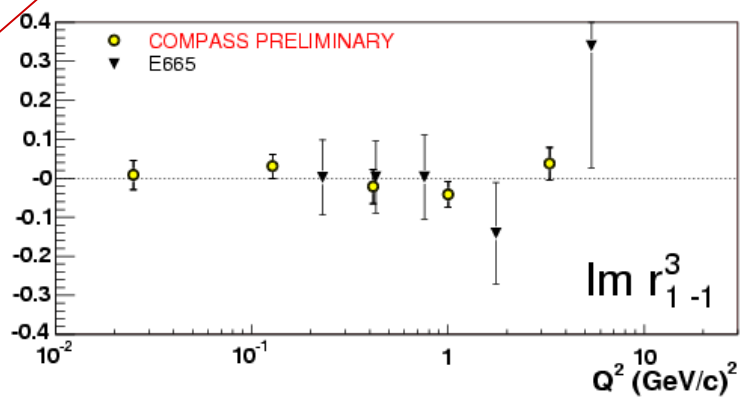
Spin density matrix elements:

$$r^{04}_{1-1} \sim \frac{\mathrm{Re}(T_{11}T^{*}_{-11}) - (\varepsilon+\delta)|T_{10}|^2}{\sigma_T + (\varepsilon+\delta)\,\sigma_L} = 0$$

$$\mathrm{Im}\; r^{3}_{1-1} = \ldots = 0 \longleftarrow \text{If SCHC holds}$$

weak violation





Longitudinal double-spin asymmetry for exclusive ρ^0 production

Both muon beam and target have to be polarized along the beam direction

for COMPASS polarized d from ^{6}LiD

Ultimately one determines $A_1^\rho = \dfrac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$

$\sigma_{1/2}$ ($\sigma_{3/2}$) cross section for $\gamma^* N \to \rho^0 N$ for antiparallel (parallel) spin orientation of γ^* and target ***N***

- can arise from exchange of ***a_1(1260)*** trajectory in t-channel (small at 160 GeV)
- from interference of amplitudes for exchange in t-channel of Reggeons

  with natural parity: ***ρ, ω, f, a_2(1320), P***(pomeron) and unnatural parity: ***π, a_1(1260)***

  (sensitivity even to small contributions of the latter ones)

- if only non-perturbative ***P*** $A_1^\rho \approx 0$
- in pQCD-inspired models possible $A_1^\rho \neq 0$ => access to spin dependent GPDs

Ryskin Goloskokov and Kroll

Evaluation of depolarization factor (D) and dilution factor (f) for incoherent exclusive ρ^0 production

$$A_{LL}(\mu N \to \mu N \rho^0) = \frac{\sigma(\mu N)_{\uparrow\downarrow} - \sigma(\mu N)_{\uparrow\Uparrow}}{\sigma(\mu N)_{\uparrow\downarrow} + \sigma(\mu N)_{\uparrow\Uparrow}} = \frac{1}{f} \cdot \frac{1}{P_b} \cdot \frac{1}{P_t} \cdot A_{LL}^{raw}$$

$$A_1^{\rho}(\gamma^* N \to \rho^0 N) \approx \frac{1}{D} A_{LL}(\mu N \to \mu N \rho^0)$$

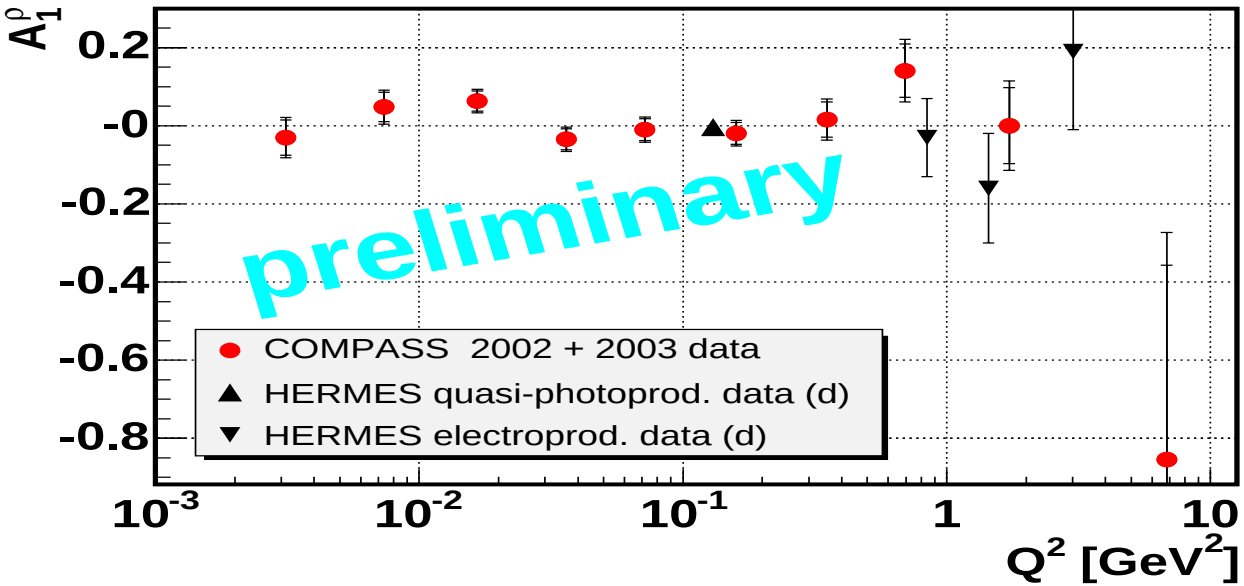
used values of A-dependent cross sections (for f) and ratio R (for D)

specific for incoherent exclusive ρ^0 production

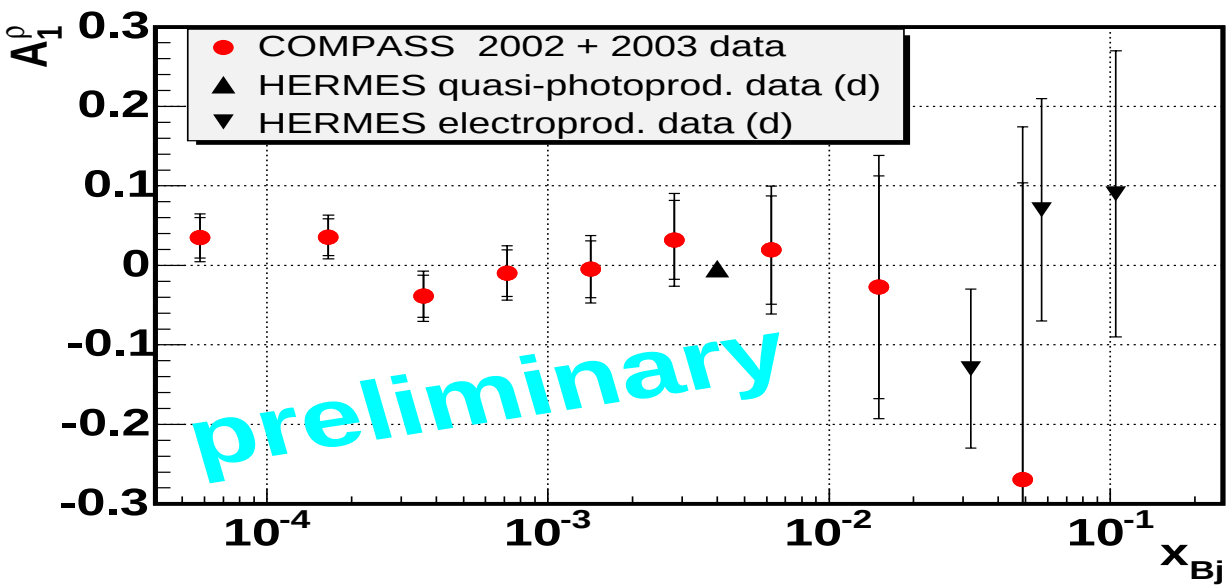
for more details on extraction of A_1^{ρ} see talk of Oleg Grajek at Dubna-Spin05

at http://thsun1/jinr.ru/meeting/2005/spin2005

COMPASS preliminary and HERMES results on A_1^p (d)



COMPASS results on A_1^p on polarized deuteron target consistent with 0

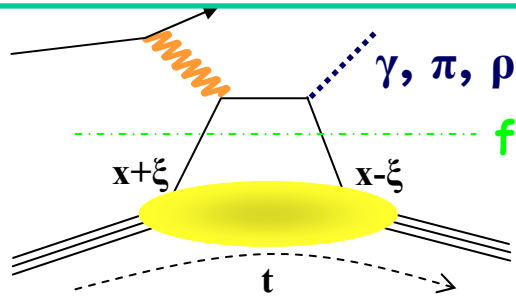


Extended kinematical range of COMPASS by almost 2 decades down both in Q^2 and x

COMPASS : inner bars –stat. outer – total errors

HERMES: total errors

GPDs and relations to the physical observables



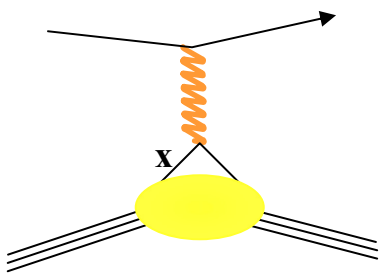
The observables are some integrals of GPDs over x

Dynamics of partons in the Nucleon Models: Parametrization

Fit of Parameters to the data

$H, \tilde{H}, E, \tilde{E}\ (x,\xi,t)$

Elastic Form Factors

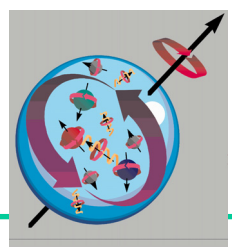


$\int H(x,\xi,t)dx = F(t)$

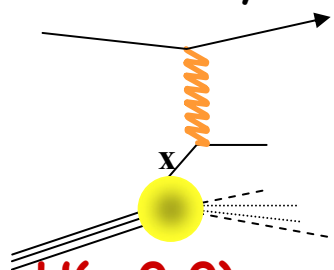
Ji's sum rule

$2J_q = \int x(H^q+E^q)(x,\xi,0)dx$

$1/2 = 1/2\ \Delta\Sigma + L_q + \Delta G + L_g$



"ordinary" parton density

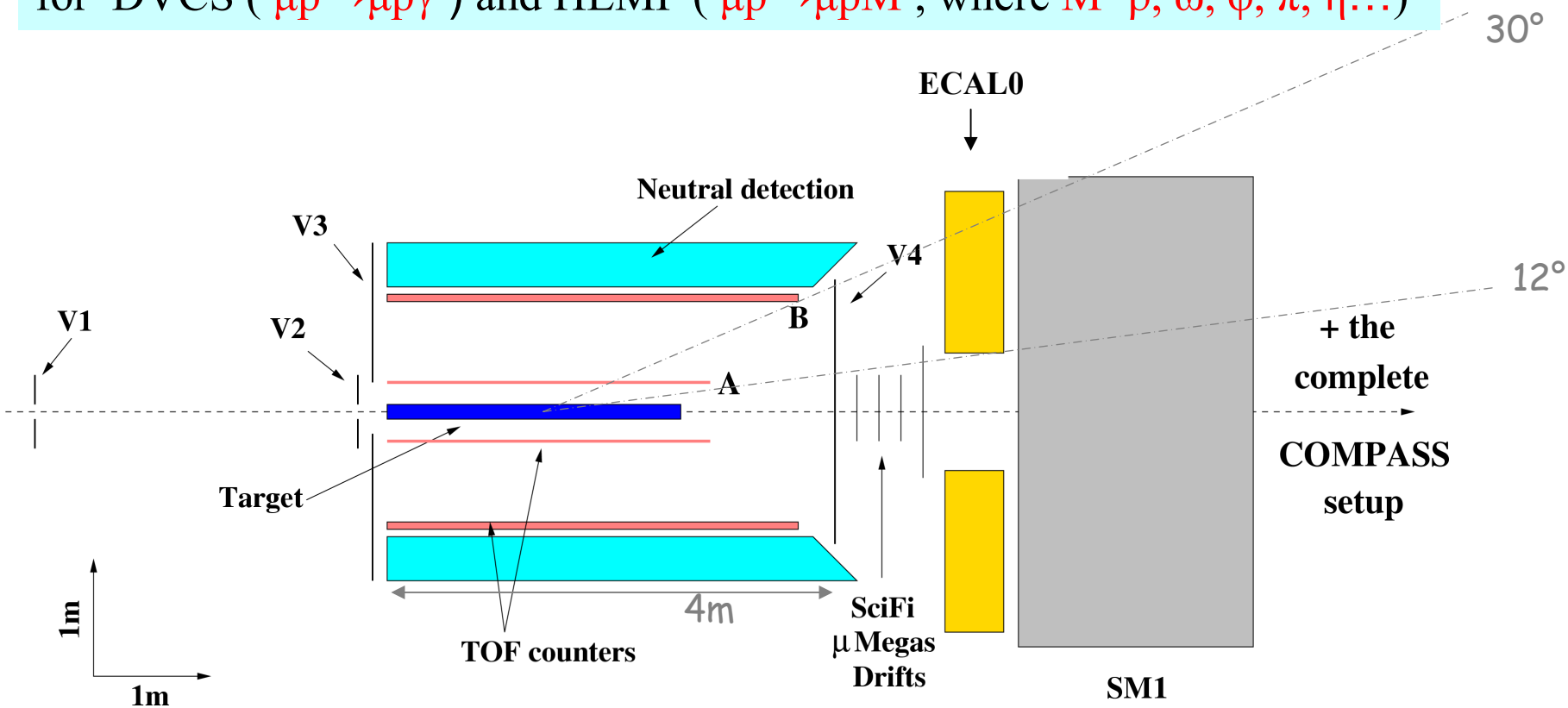


$H(x,0,0) = q(x)$

$\tilde{H}(x,0,0) = \Delta q(x)$

possible solution to complete the COMPASS setup

for DVCS ($\mu p \rightarrow \mu p \gamma$) and HEMP ($\mu p \rightarrow \mu p M$, where $M=\rho, \omega, \varphi, \pi, \eta \ldots$)



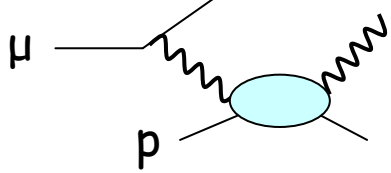
New: liquid H2 target + recoil detector + extended calorimetry (ECAL0)

2004-2007:

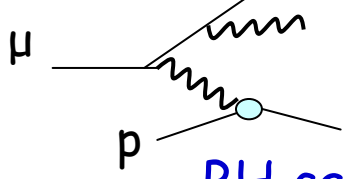
Goal: full test of feasibility of a 45° (in φ) sector recoil detector

2010:

To be ready with the full detector



DVCS+ Bethe Heitler



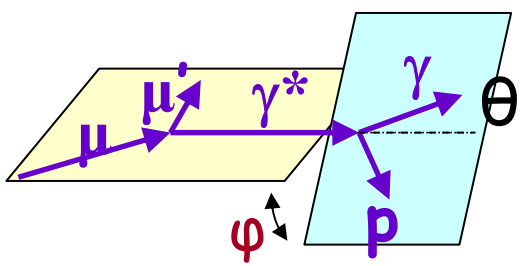
BH calculable

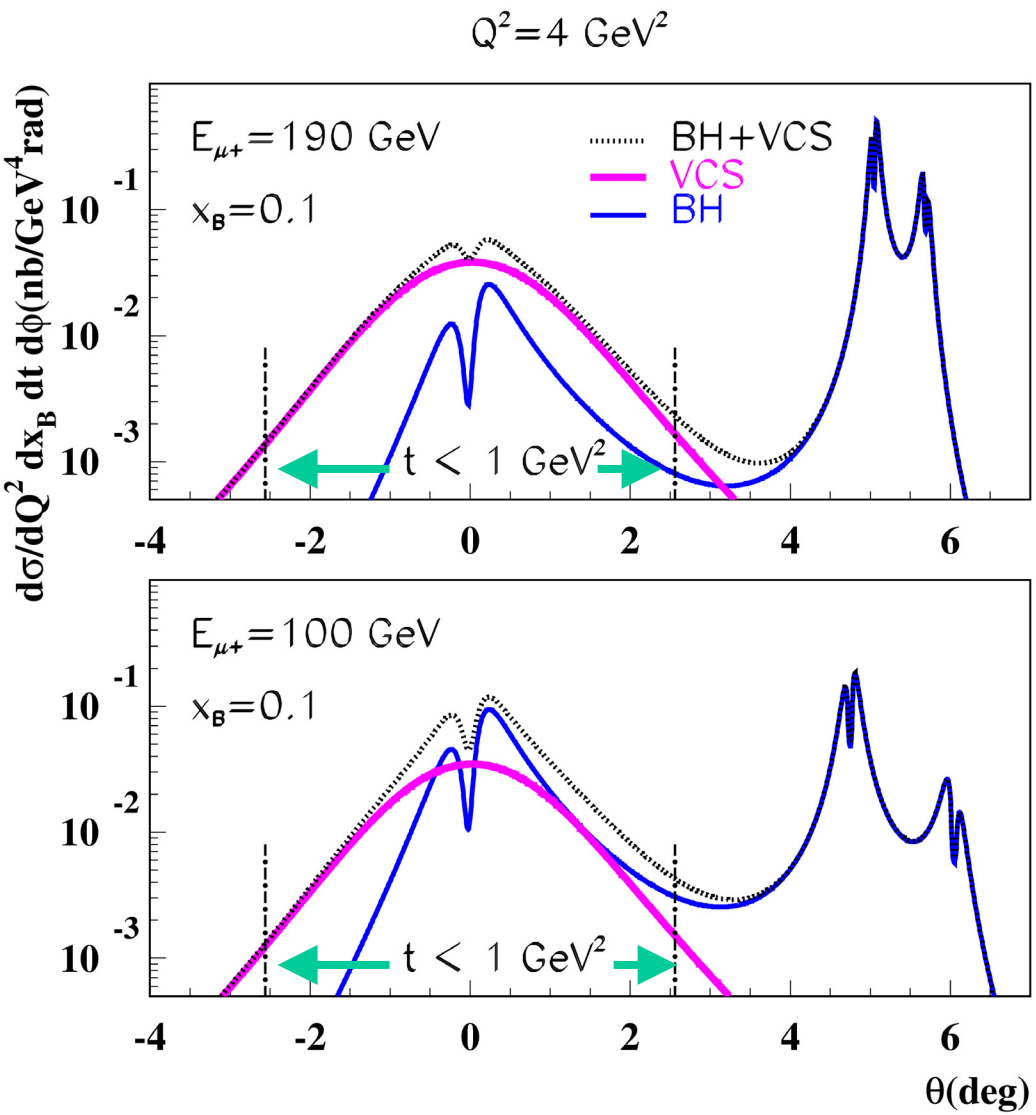
The high energy muon beam at COMPASS allows to play with the relative contribution DVCS-BH which depends on

$$1/y = 2\, m_p\, E_\ell\, x_{Bj}\, /Q^2$$

Higher energy: DVCS>>BH
⇒ DVCS cross section

Smaller energy: DVCS~BH
⇒Interference term will provide DVCS amplitude





Example of estimates for DVCS at COMPASS

DVCS Beam Charge Asymmetry (BCA) measured with the 100 GeV muon beam at COMPASS

$$\sigma^{\vec{\mu}+} - \sigma^{\vec{\mu}-} \sim \mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi}$$

Model 1: $H(x,\xi,t) \sim q(x)\, F(t)$

Model 2: $H(x,0,t) = q(x)\, e^{t \langle b_\perp^2 \rangle}$

$= q(x) / x^{\alpha' t}$

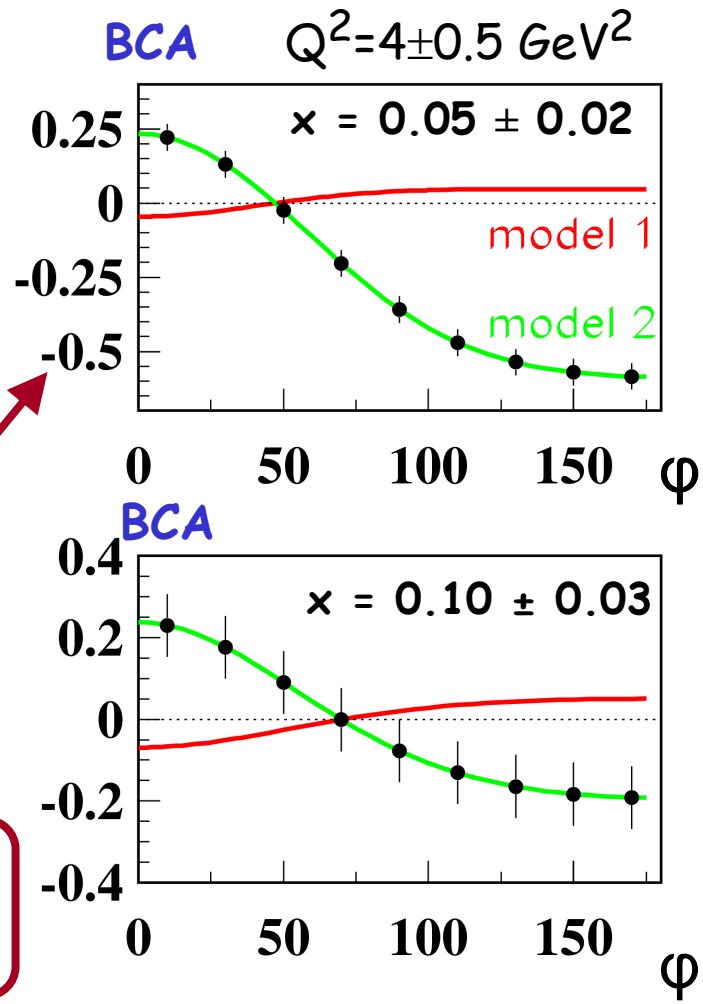
In 2010

$\mathcal{L} = 1.3\ 10^{32}\ cm^{-2}\ s^{-1}$

efficiency=25%

150 days data taking

Only 2/18 data sets



In total 3 bins in x_{Bj} = 0.05, 0.1, 0.2

6 bins in Q^2 from 2 to 7 GeV²

Summary

- High-statistics data on SDM elements and R for incoherent exlusive ρ^0 production in a wide Q^2 range (including small Q^2 not covered previously)

- Asymmetry A_1^{ρ} (d) consistent with zero over wide range of Q^2 and x
  first measurement at small Q^2 and small x

- Preparations for GPDs measurements at COMPASS in progress
  high-statistics results on DVCS and HEMP possibly since 2010