Exclusive meson production with COMPASS and COMPASS II

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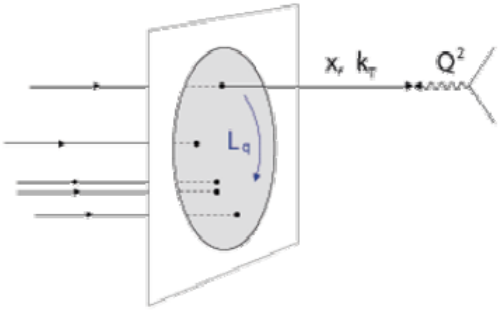
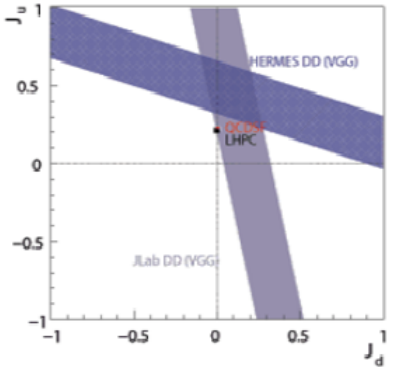
On behalf of the COMPASS Collaboration

INT Workshop INT-12-49W

Orbital Angular Momentum in QCD

February 6 - 17, 2012





GPDs studies @ COMPASS with [redacted], [redacted] 160 GeV

COMPASS-II phase I: test in 2012 and 2 years 2015+16:

with LH_2 target + with Recoil Proton Detection

✓ Vector Meson $\rho^0, \rho^+, \omega, \Phi$ production → GPD H

Using the 2007-10 data: transv. polarized NH_3 target without RPD

✓ The Transverse Target Spin Asymm → GPD E and angular momentum of parton

Projections for Phase 1 in COMPASS-II
(test in autumn 2012 and 2 years 2015-16)

with recoil proton detection and hydrogen target

- **→Transverse Imaging : dσ/dt**
- **→Constrains on the GPD H**

Transverse imaging at COMPASS

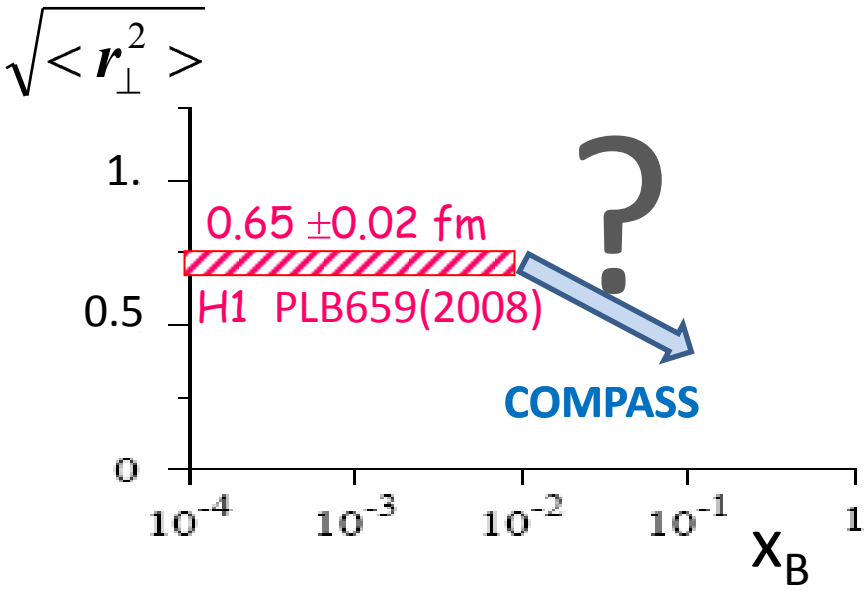
$d\sigma^{VCS}/dt \sim \exp(-B|t|)$

$B(x_B) = \frac{1}{2} < r_\perp^2(x_B) >$

distance between the active quark
and the center of momentum of spectators

Transverse size of the nucleon

mainly dominated by $H(x, \xi=x, t)$

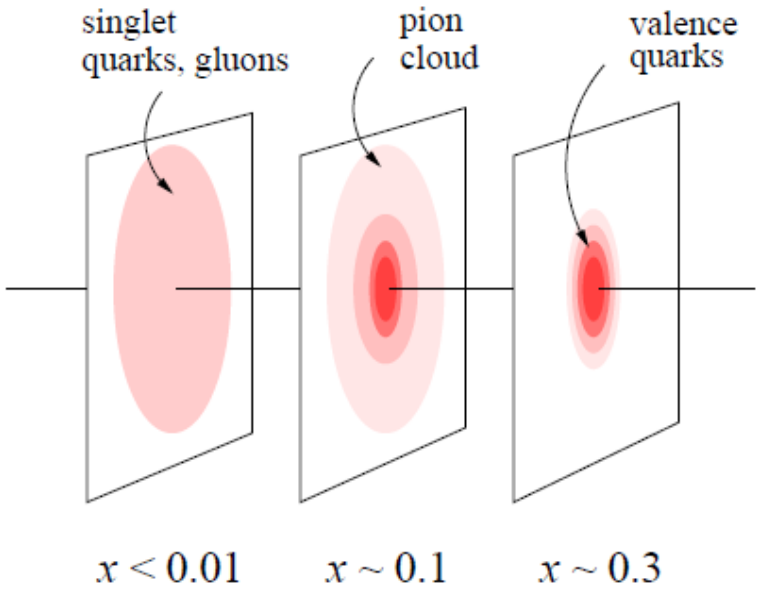


related to $\frac{1}{2} < b_\perp^2(x_B) >$

distance between the active quark
and the center of momentum of the nucleon

Impact Parameter Representation

$q(x, b_\perp) <-> H(x, \xi=0, t)$



Transverse imaging at COMPASS

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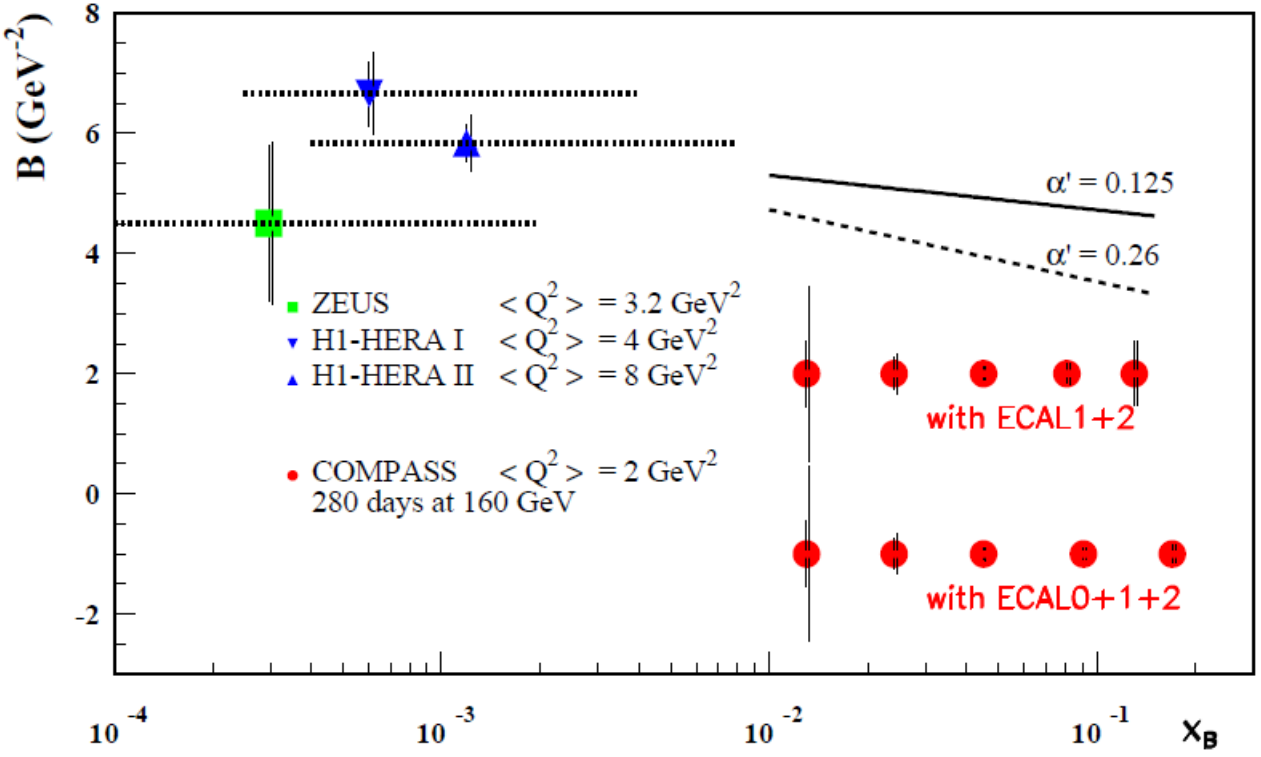


2 years of data
160 GeV muon beam
2.5m LH_2 target
$\varepsilon_{global} = 10\%$

ansatz at small x_B
inspired by
Regge Phenomenology:

$B(x_B) = b_0 + 2\,\alpha' \ln(x_0/x_B)$

α' slope of Regge traject

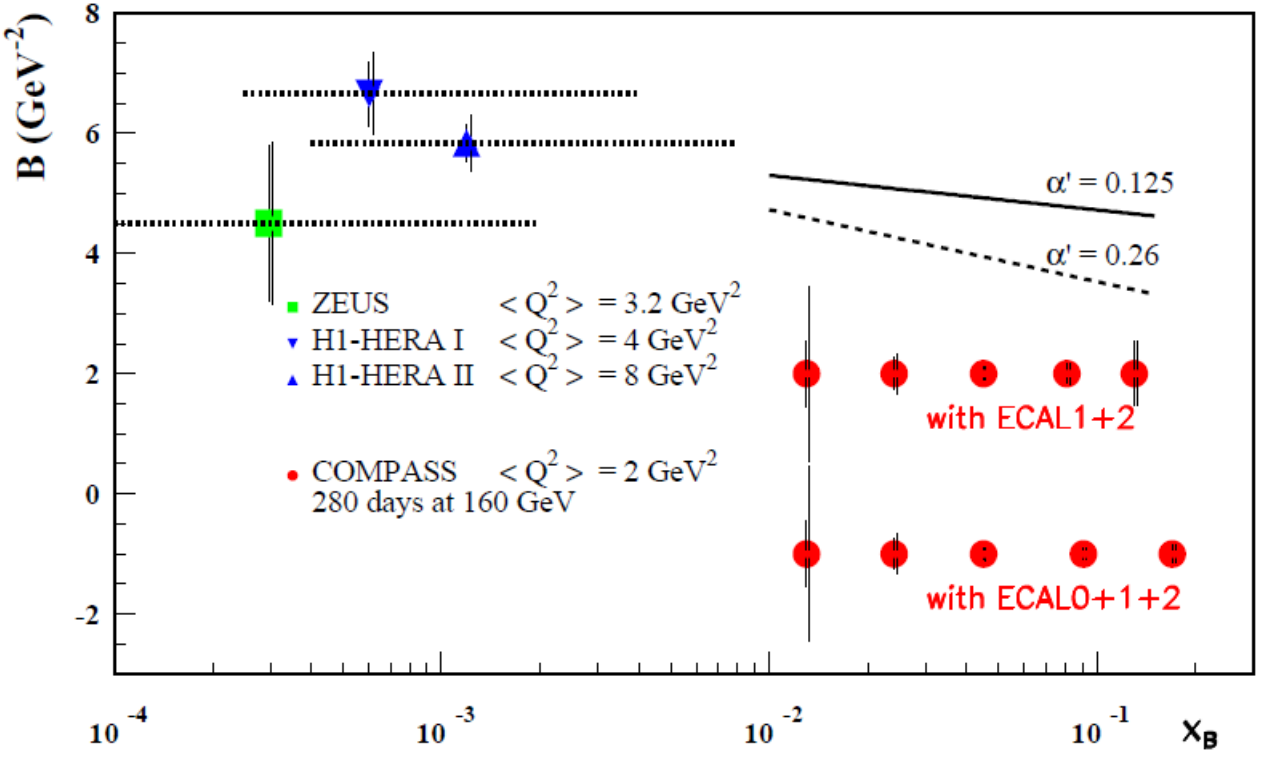
for valence quark $\alpha' \sim 1$ GeV^{-2} to reproduce FF $\cong$ meson Regge traj.

for gluon $\alpha' \sim 0.164$ GeV^{-2} (J/Ψ at $Q^2=0$) $<<$ $\alpha' \sim 0.25$ GeV^{-2} for soft Pomeron

$\alpha' \sim 0.02$ GeV^{-2} (J/Ψ at $Q^2=2$-80 GeV^2)

Transverse imaging at COMPASS

$d\sigma^{VCS}/dt \sim \exp(-B|t|)$



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160 GeV muon beam
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$B(x_B) = b_0 + 2\,\alpha' \ln(x_0/x_B)$

α' slope of Regge traject

without any model we can extract $B(x_B)$

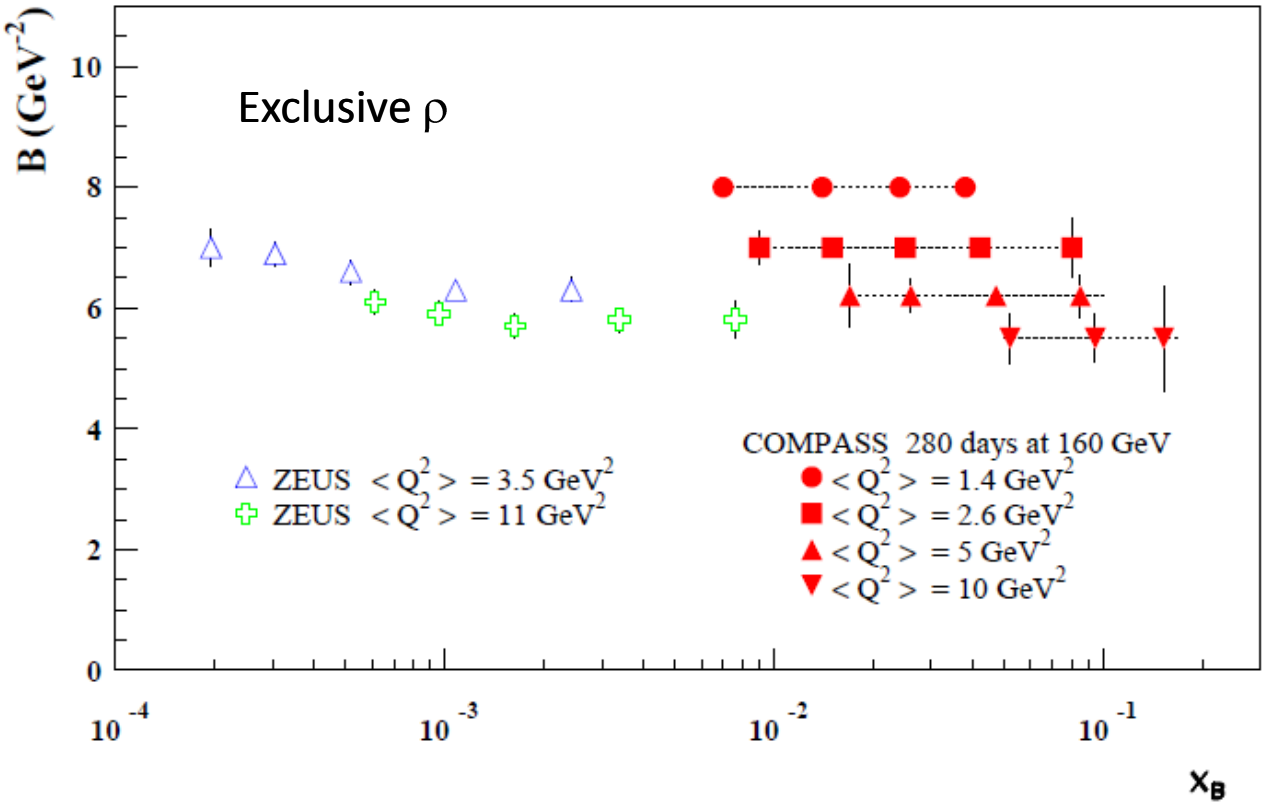
$B(x_B) = \frac{1}{2} < r_\perp^2(x_B) >$

$r_\perp$ is the transverse size of the nucleon

Accuracy > 2.5 [illegible] $\alpha' = 0.125$ and full ECALS

Transverse imaging at COMPASS

$d\sigma^{excl.}/dt \sim \exp(-B|t|)$

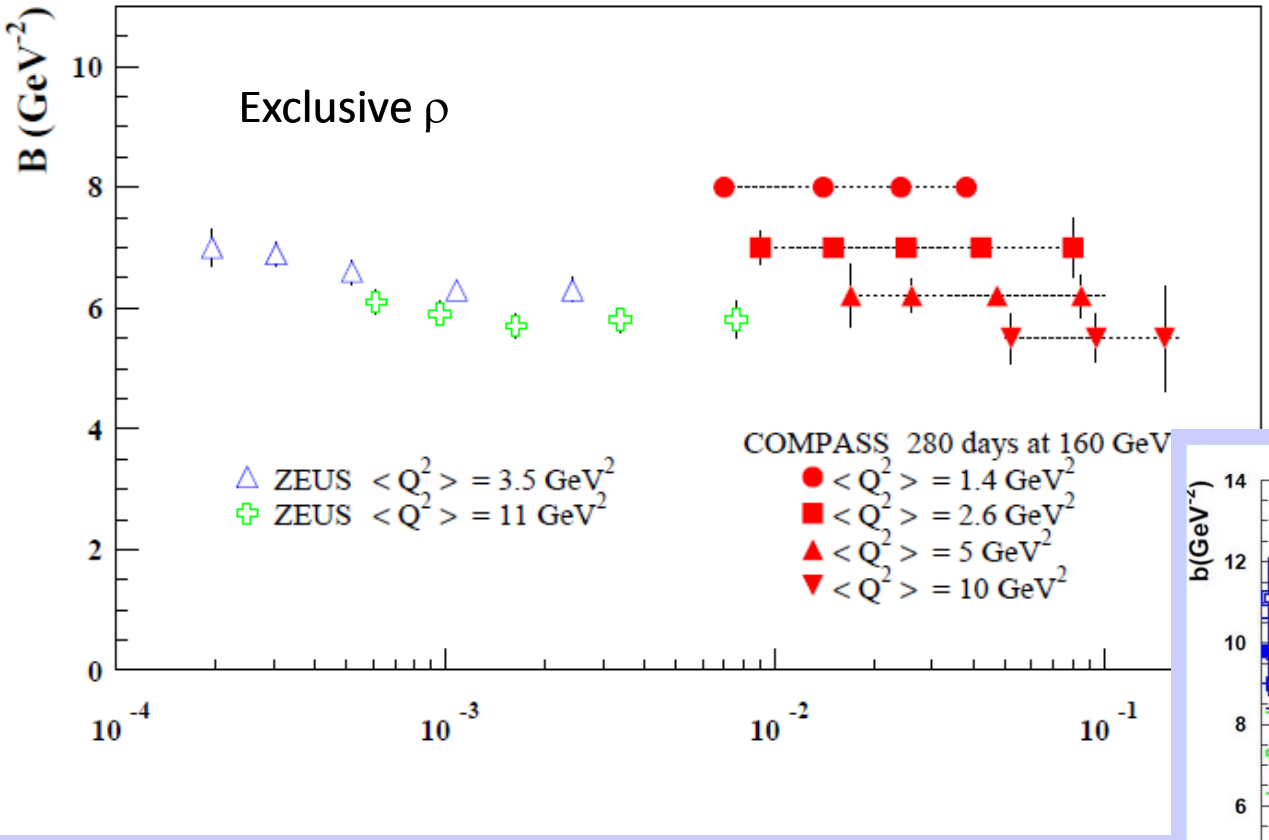


2 years of data
160 GeV muon beam
2.5m LH_2 target
ε_{global} = 10%

model developed by Sandacz
renormalised according
Goloskokov and Kroll prediction

Transverse imaging at COMPASS

$d\sigma^{excl.}/dt \sim \exp(-B|t|)$



2 years of data
160 GeV muon beam
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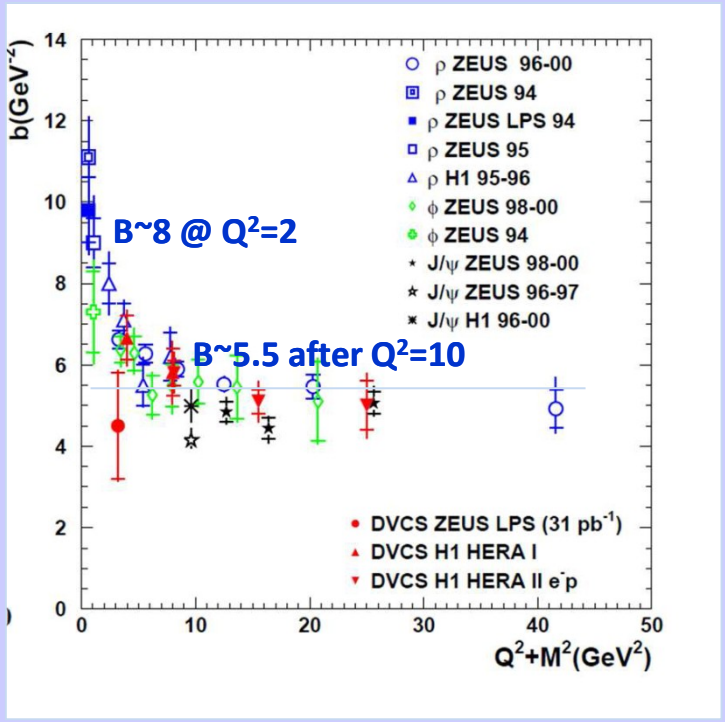


We are sensitive
to the nucleon transverse size
+ to the meson transverse size

Constrains on the GPD E

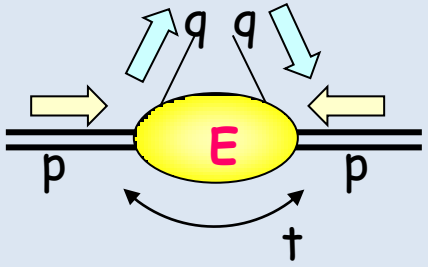
on transversely polarized protons (NH3 target)

1) **without** recoil detection (2007 & 2010)

the GPD **E** allows nucleon helicity flip

so it is related to the angular momentum

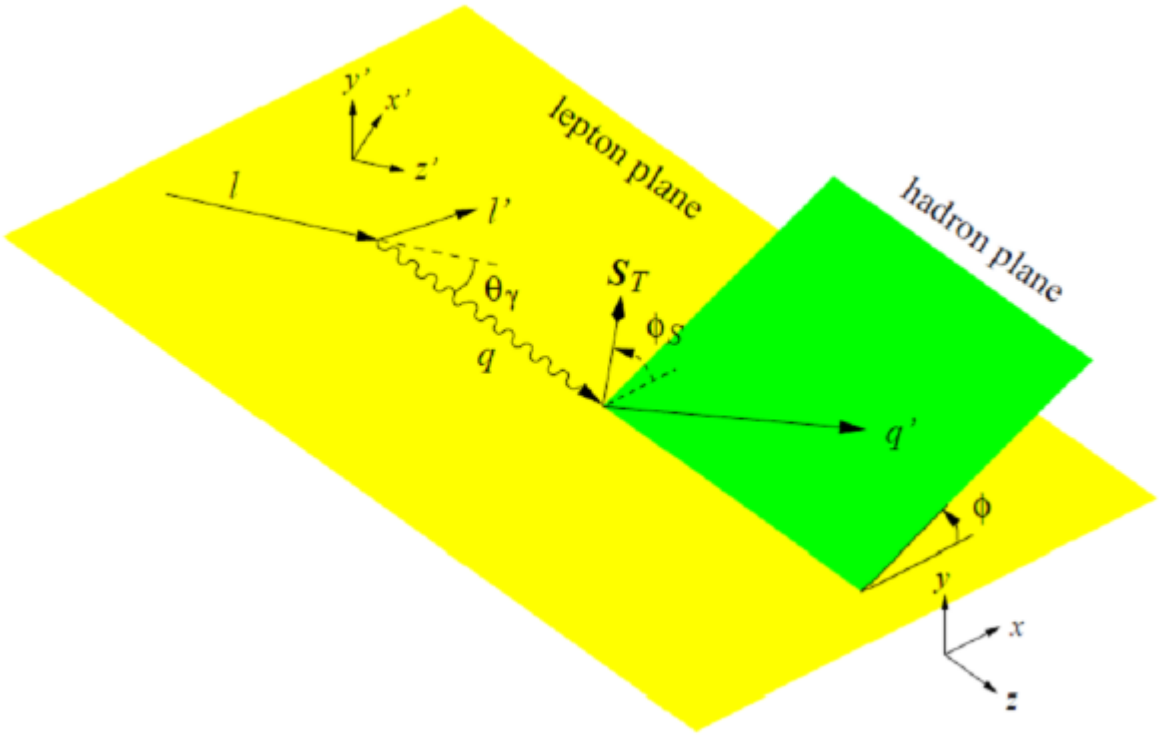
Ji sum rule: $2J_z^q = \int x\,(H^q(x,\xi,0) + E^q(x,\xi,0))\,dx$



The GPD E is the 'Holy-Grail' of the GPD quest

Hard Exclusive Vector Meson Production

$$A_{UT}(\rho^0_L) \propto \sqrt{|-t'|}\, Im(\mathcal{E}^{*}\mathcal{H}) \,/\, |\mathcal{H}|^2 \times \sin(\phi - \phi_S)$$



S_T target spin vector / γ^* direction

P_T target transverse polarization / the μ beam direction

$\theta\gamma^*$ mainly smaller than 60mrad at COMPASS

Diehl, Sapeta, EPJC41 (2005)

Diehl, JHEP09 (2007)

Hard Exclusive Vector Meson Production

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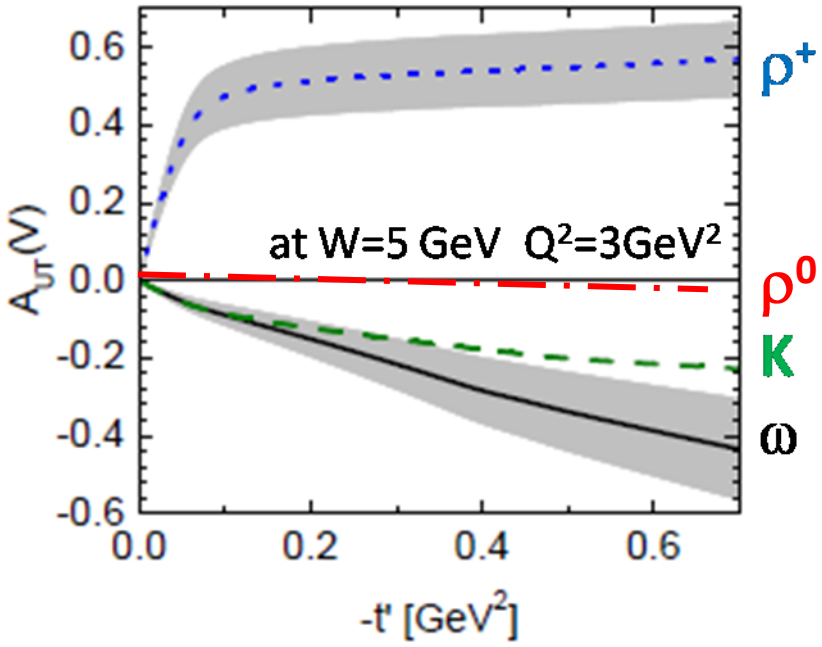


$E\rho^0 \propto 2/3\, E^u + 1/3\, E^d + 3/8\, E^g$

$E\omega \propto 2/3\, E^u - 1/3\, E^d + 1/8\, E^g$

$E\rho^+ \propto E^u - E^d - 3/8\, H^g$

$\kappa^q = \int e^q(x)\, dx$

➔ $E^u \sim -E^d$

Goloskokov-Kroll: the most complete model (Q^2>3GeV² x<0.2)

with H and E for quarks and gluons

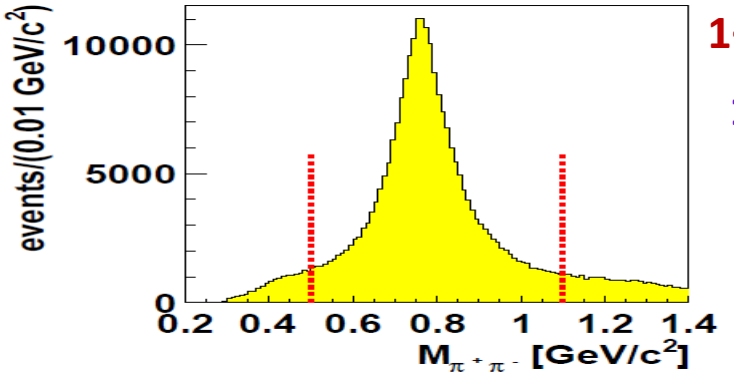
and with quark transverse degrees of freedom

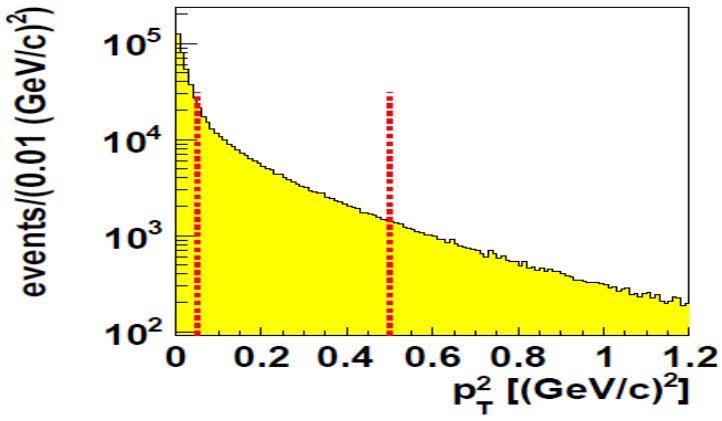
the asymptotically dominant (longitudinal) amplitude for $\gamma_L^*\, p \rightarrow \rho_L\, p$

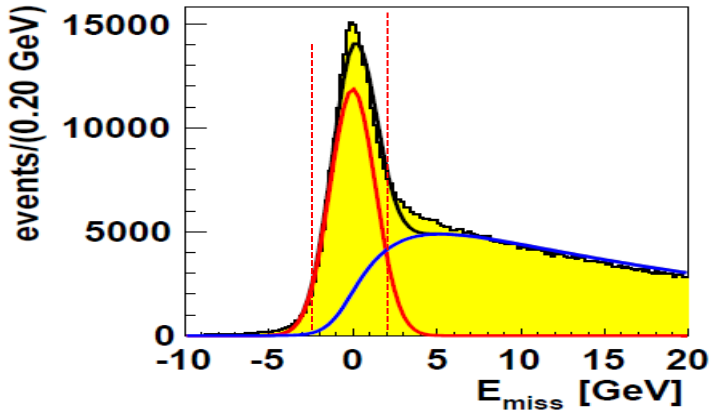
but also the one for transversely polarized photons and vector mesons $\gamma_T^*\, p \rightarrow \rho_T p$

Selection of Exclusive ρ^0 Production: $\mu\ p \rightarrow \mu'\ \rho^0\ p$

without RPD







$1 < Q^2 < 10\ GeV^2$ $0.1 < y < 0.9$ $W > 4$ GeV $E_\rho > 15$ GeV

1- Assuming both hadrons are π

$0.5 < M_{\pi\pi} < 1.1$ GeV

To maximize the purity of the sample of ρ^0 / non resonant $\pi^+\pi^-$

2- Incoherent production on quasi-free protons in NH_3 polarized target

$0.05 < p_t^2 < 0.5\ GeV^2$

Contamination of about a 5% coherent production

3- Exclusivity of the reaction

$$E_{miss} = \frac{M_X^2 - M_P^2}{2 \cdot M_P} = E_{\gamma^*} - E_{\rho^0} + t/(2 \cdot M_P)$$

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

Diffractive dissociation ~12%

Does not change the asymmetry (confirmed by HERA)

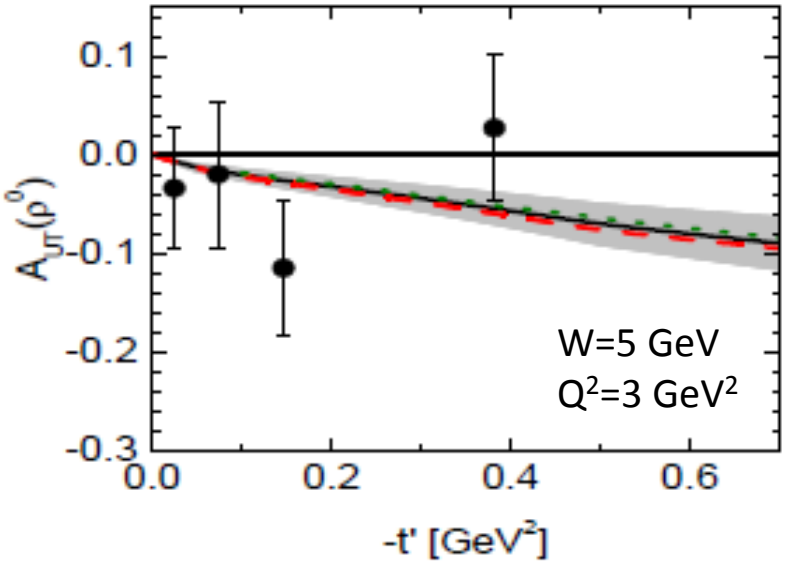
➔ **Background correction in every bin in:**

x_{Bj}, Q^2, p_T^2, $\Phi - \Phi_S$ and cell state and polar. state

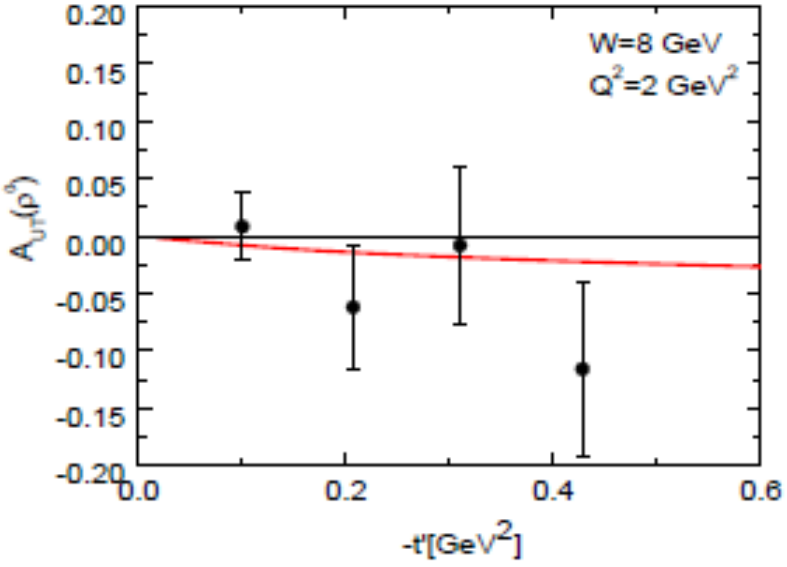
2007 results for the Transverse Target Asymmetry

$$A_{UT}(\rho^0_L) \propto \sqrt{|-t'|}\, Im(\mathcal{E}^* \mathcal{H}) / |\mathcal{H}|^2$$

Hermes



Compass 2007 preliminary



$A_{UT}(\omega)$ and $A_{UT}(\rho^+)$ should be more promising
To be completed with the analysis of 2010 data

What could come in the future?

IF SUFFICIENT MANPOWER

Study of other vector mesons: ρ^0,ρ^+,ω, Φ, (J/Ψ)

Study of all the asymmetries, cross-section, L / T , SDME, slope in t

For transversely polarized proton (NH_3 target:2007-10)
For unpolarized proton (LH_2 2012 + …)

For transversely polarized deuteron (^{6}LiD target: 2002-3-4-6)

Hard Exclusive Vector Meson Production

$$\left[\frac{\alpha_{em}}{8\pi^3}\frac{y^2}{1-\epsilon}\frac{1-x_B}{x_B}\frac{1}{Q^2}\right]^{-1}\frac{d\sigma}{dx_B dQ^2 d\phi d\phi_s} \simeq \frac{1}{2}\left(\sigma_{++}^{++}+\sigma_{++}^{--}\right)+\epsilon\sigma_{00}^{++}-S_T\sin\left(\phi-\phi_s\right)\mathrm{Im}\left(\sigma_{++}^{+-}+\epsilon\sigma_{00}^{+-}\right)+\ \ldots$$

$$A_{UT}(\phi,\phi_S)=\frac{1}{S_T}\cdot\frac{d\sigma(\phi,\phi_S)-d\sigma(\phi,\phi_S+\pi)}{d\sigma(\phi,\phi_S)+d\sigma(\phi,\phi_S+\pi)}$$

$$A_{UT}^{\sin(\phi-\phi_s)}(\phi,\phi_S)\ \propto\ \frac{\mathrm{Im}(\sigma_{++}^{+-}+\epsilon\,\sigma_{00}^{+-})}{\frac{1}{2}(\sigma_{++}^{++}+\sigma_{++}^{--})+\epsilon\,\sigma_{00}^{++}}$$

$$\sigma_{mn}^{ij}(x_B,Q^2,t)\propto\Sigma_{spins}(\mathcal{A}_m^i)^*\mathcal{A}_n^j$$

$$\sigma_L = \sigma_{00}^{++}$$

$$\sigma_T = \tfrac{1}{2}(\sigma_{++}^{++}+\sigma_{++}^{--})$$

$$\frac{1}{\Gamma'}\frac{d\sigma_{00}^{++}}{dt} = (1-\xi^2)|\mathcal{H}_M|^2-(\xi^2+\frac{t}{4M_p^2})|\mathcal{E}_M|^2-2\xi^2\mathrm{Re}(\mathcal{E}_\mathrm{M}^*\mathcal{H}_\mathrm{M}),$$

$$\frac{1}{\Gamma'}\frac{d\sigma_{00}^{+-}}{dt} = -\sqrt{1-\xi^2}\frac{\sqrt{t_0-t}}{M_p}\mathrm{Im}(\mathcal{E}_\mathrm{M}^*\mathcal{H}_\mathrm{M})\ ,$$

$\mu\ p \rightarrow \mu'\ p\ \rho$

quasi-free protons in NH_3 polarized target

$P_T = 0.5 \pm 2\%$

$f = 0.25 \pm 2\%$ (from 0.27 at $Q^2=1$ to 0.18 at $Q^2 = 10$) calculated for the material composition and the nuclear dependence of the cross section of this exclusive reaction

$-2.5 < E_{miss} < 0$ GeV and $1 < Q^2 < 1.4$