Generalized Parton Distributions

at COMPASS

- *Prospects*
- *Experimental Setup 2010 - 2015*

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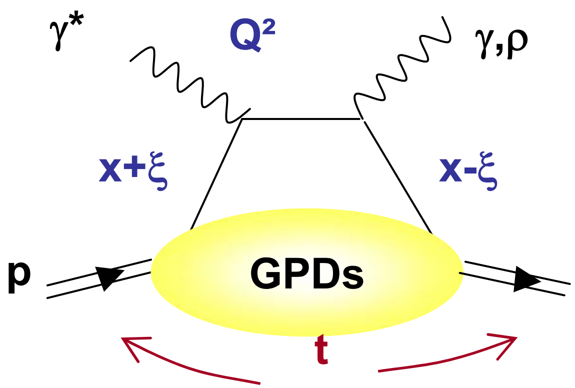
on behalf of the COMPASS collaboration

DIS 2007, München, 18. April 2007

Generalized Parton Distributions: Coherent description of the nucleon

$\mu p \rightarrow \mu p \gamma$ ($\mu p \rho$)



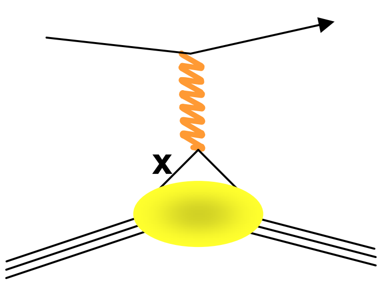
x: longitudinal quark momentum fraction $\neq x_{Bj}$

2ξ: longitudinal momentum transfer: $\xi = x_{Bj}/(2 - x_{Bj})$

t: momentum transfer squared to the target nucleon (Fourier conjugate to the transverse impact parameter r)

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

Elastic Form Factors



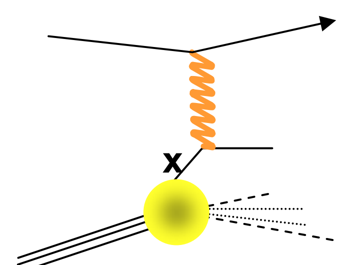
$\int H(x,\xi,t)dx = F(t)$

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



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

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

COMPASS: The QCD Facility to study GPDs

Timeline

- *now:* COMPASS with polarized target
  - Complete analysis of ρ production
  - Other channels: φ, 2π …
  - GPD E/H investigation with the transverse polarized target
  - GPD E from Sivers

- *2010-2015:* Generalized Parton Distributions
  with recoil detector, calorimeter, liquid H_2 and D_2 target

Polarized beam: E_π=110 GeV → E_μ=100 GeV

$P(\mu^+) = -0.8$ $2 \cdot 10^8$/spill
$P(\mu^-) = +0.8$ $2 \cdot 10^8$/spill

Maximize
- muon flux
- interference →

Advantage of $\overleftarrow{\mu}^{+}$ and $\overrightarrow{\mu}^{-}$ for DVCS (+BH)

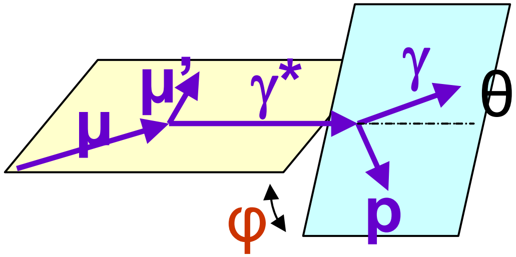
$$A^{DVCS}_{(\mu p\to\mu p\gamma)} = \int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi+i\varepsilon} = \mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi} - i\,\pi\, H(x=\xi,\xi,t)$$

t, $\xi \sim x_{Bj}/2$ fixed

$$d\sigma_{(\mu p\to\mu p\gamma)} =$$

$$(d\sigma^{BH} + d\sigma^{DVCS}_{unpol}) + e_\mu\, a^{BH}\, \mathcal{Re}\, \mathbf{A}^{DVCS} \qquad \times \cos n\varphi$$

$$+ \; P_\mu\, d\sigma^{DVCS}_{pol} + e_\mu\, P_\mu\, a^{BH}\, \mathcal{Im}\, \mathbf{A}^{DVCS} \qquad \times \sin n\varphi$$



$P_{\mu+}$=-0.8 $P_{\mu-}$=+0.8

Diehl

Advantage of $\overleftarrow{\mu}^+$ and $\overrightarrow{\mu}^-$ for DVCS (+BH)

$$\mathcal{A}^{DVCS}_{(\mu p \to \mu p \gamma)} = \int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi+i\varepsilon} = \mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi} - i\pi H(x=\xi,\xi,t)$$

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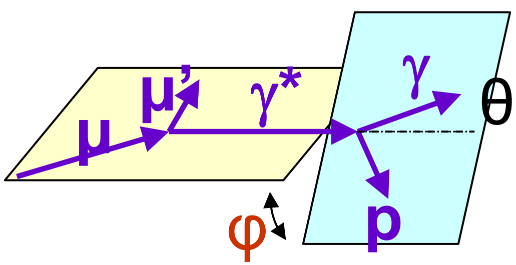
$+ P_\mu d\sigma^{DVCS}_{pol} + e_\mu P_\mu a^{BH} \mathcal{Im}\, \mathbf{A}^{DVCS}$ $\times \sin n\varphi$



$P_{\mu+}$=-0.8 $P_{\mu-}$=+0.8

$$\sigma^{\overleftarrow{\mu}+} + \sigma^{\overrightarrow{\mu}-} \sim H(x=\xi,\xi,t)$$

Diehl

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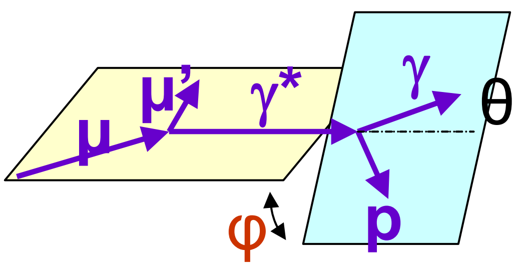
t, $\xi \sim x_{Bj}/2$ fixed

$d\sigma_{(\mu p \to \mu p \gamma)}$ =

$(d\sigma^{BH} + d\sigma^{DVCS}_{unpol}) + e_\mu \, a^{BH} \, \mathcal{R}e \, \mathbf{A}^{DVCS}$ × cos nφ

$+ \; P_\mu \, d\sigma^{DVCS}_{pol} \; + e_\mu \, P_\mu \, a^{BH} \, \mathcal{I}m \, \mathbf{A}^{DVCS}$ × sin nφ



$P_{\mu+}$=-0.8 $P_{\mu-}$=+0.8

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

Diehl

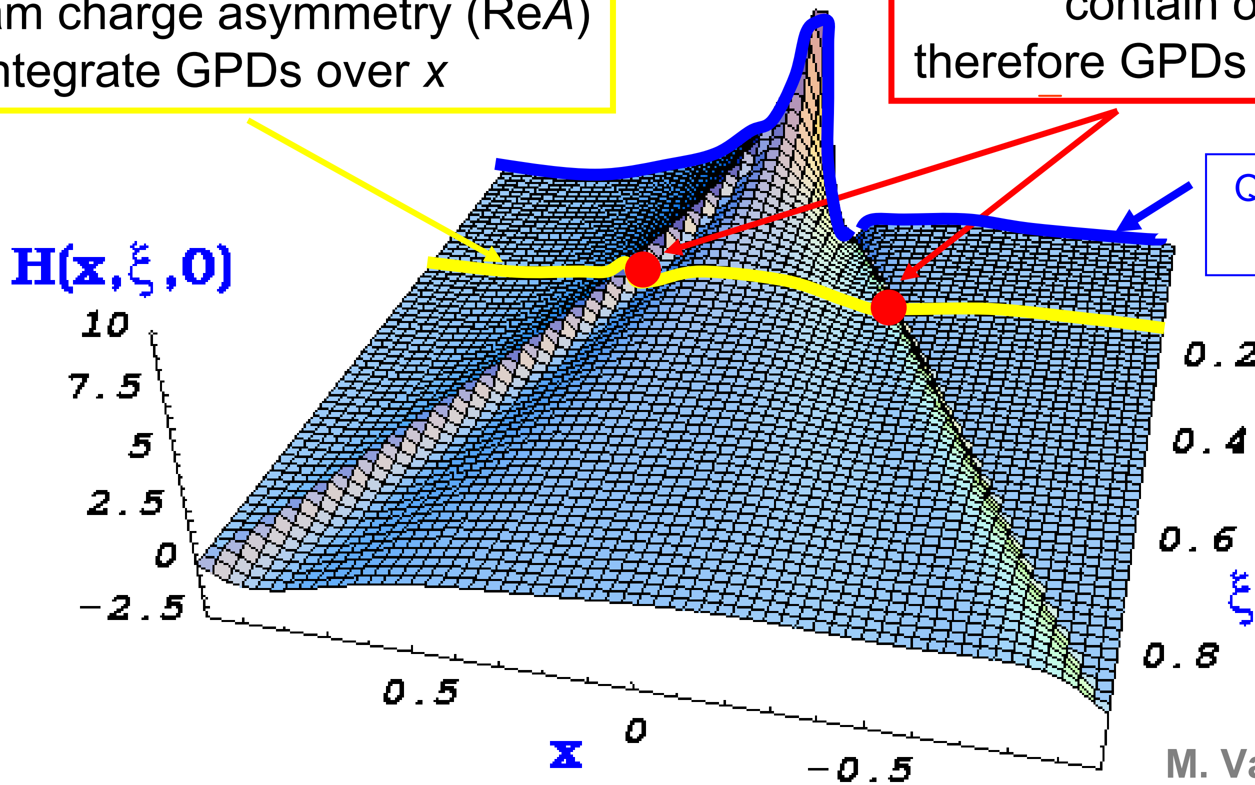
DVCS and Models of GPDs

$$A^{DVCS}_{(\mu p \to \mu p \gamma)} = \int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi+i\varepsilon} = \mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi} - i\pi H(x=\xi,\xi,t)$$

Cross-section measurement
and beam charge asymmetry (Re*A*)
integrate GPDs over *x*

Beam or target spin asymmetry
contain only Im*A*,
therefore GPDs at *x* = ξ and –ξ

Quark distribution
q(x), -q(-x)



M. Vanderhaeghen

Simulations with 2 Model Variations

Double Distribution Parametrizations of GPDs
(Vanderhaeghen, Guichon, Guidal)

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

Vanderhaeghen *et al.*, PRD60 (1999) 094017

Model 2: **includes correlation between x and t**

considers fast partons in the small valence core
and slow partons at larger distance (wider meson cloud)

$H(x,0,t) = q(x)\, e^{t \langle b_\perp^2 \rangle} = q(x) / x^{\alpha' t}$ (**α'slope of Regge traject.**)

$\langle b^2_\perp \rangle = \alpha' \ln 1/x$ **transverse extension of partons in hadronic collisions**

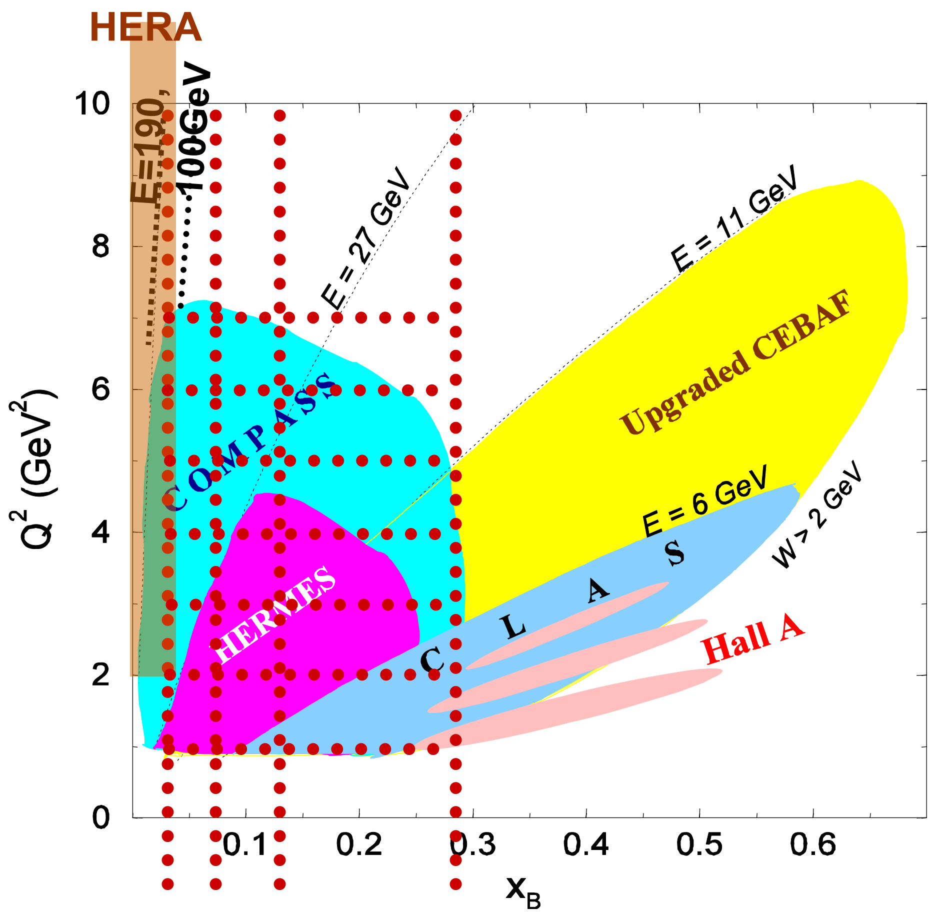
This ansatz reproduces the
Chiral quark-soliton model: Goeke *et al.*, NP47 (2001) 401

DVCS Simulations for COMPASS at 100 GeV

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

Beam Charge Asymmetry

- 6 bins in Q^2 from 1.5 to 7.5 GeV^2
- 3 bins in x_{Bj}=0.05,0.1,0.2
- Assumptions
  - L=1.3 10^{32} $cm^{-2}s^{-1}$
  - 150 days
  - efficiency=25%



COMPASS: valence and sea quarks, gluons

DVCS Simulations for COMPASS at 100 GeV

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

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

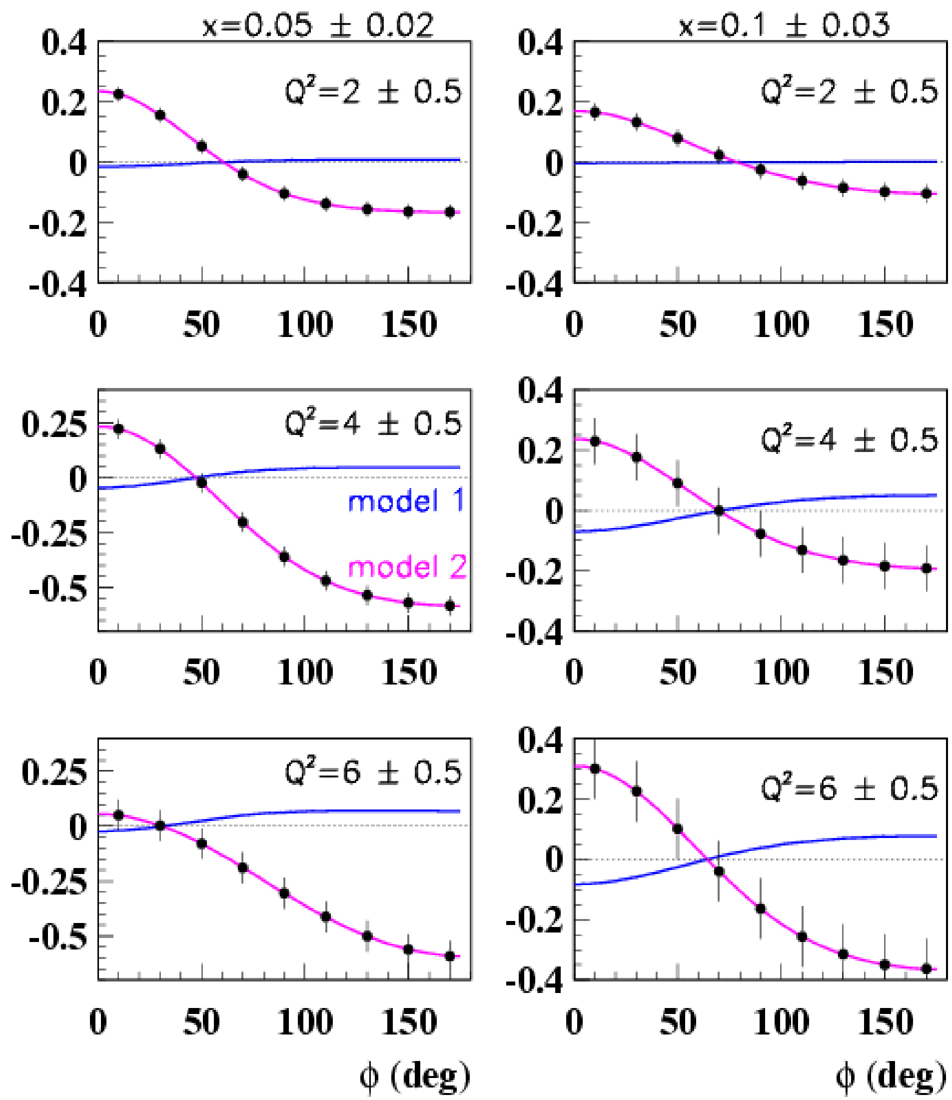
Model 2: $H(x,0,t) = q(x)\, e^{t \langle b_\perp^2 \rangle}$

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

- 6 bins in Q^2 from 1.5 to 7.5 GeV^2 (3 shown)
- 3 bins in x_{Bj}=0.05,0.1,0.2 (2 shown)

- Assumptions
  - L=1.3 10^{32} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$
  - 150 days
  - efficiency=25%

Beam Charge Asymmetry

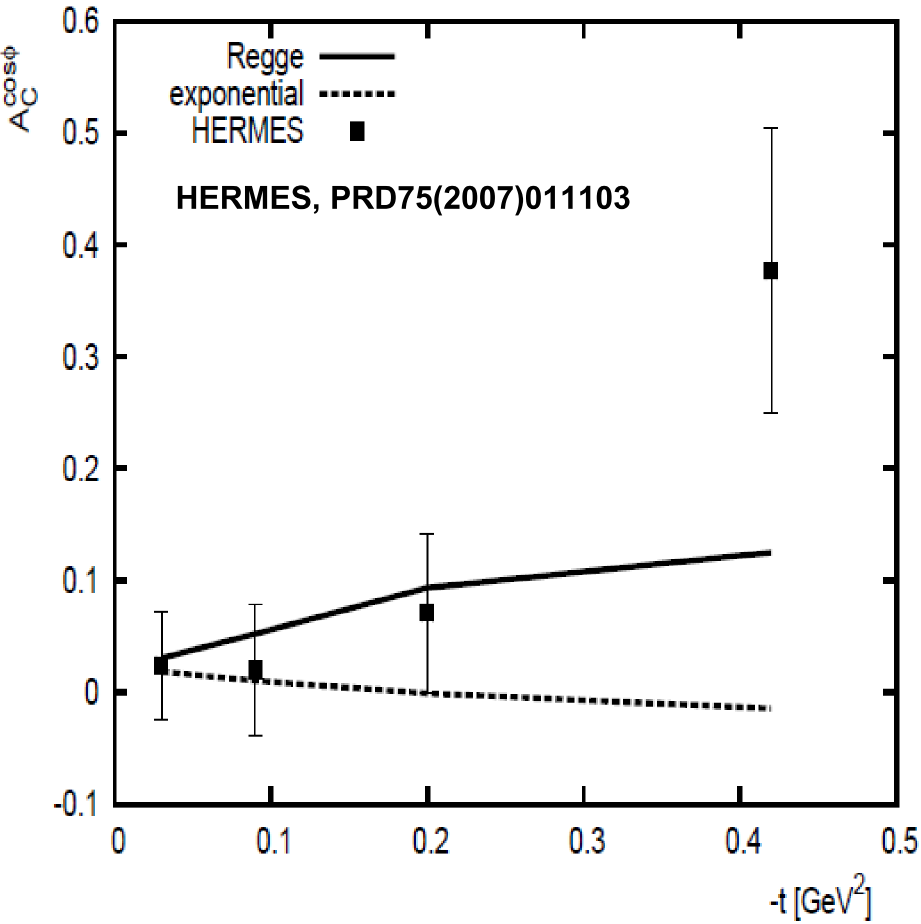


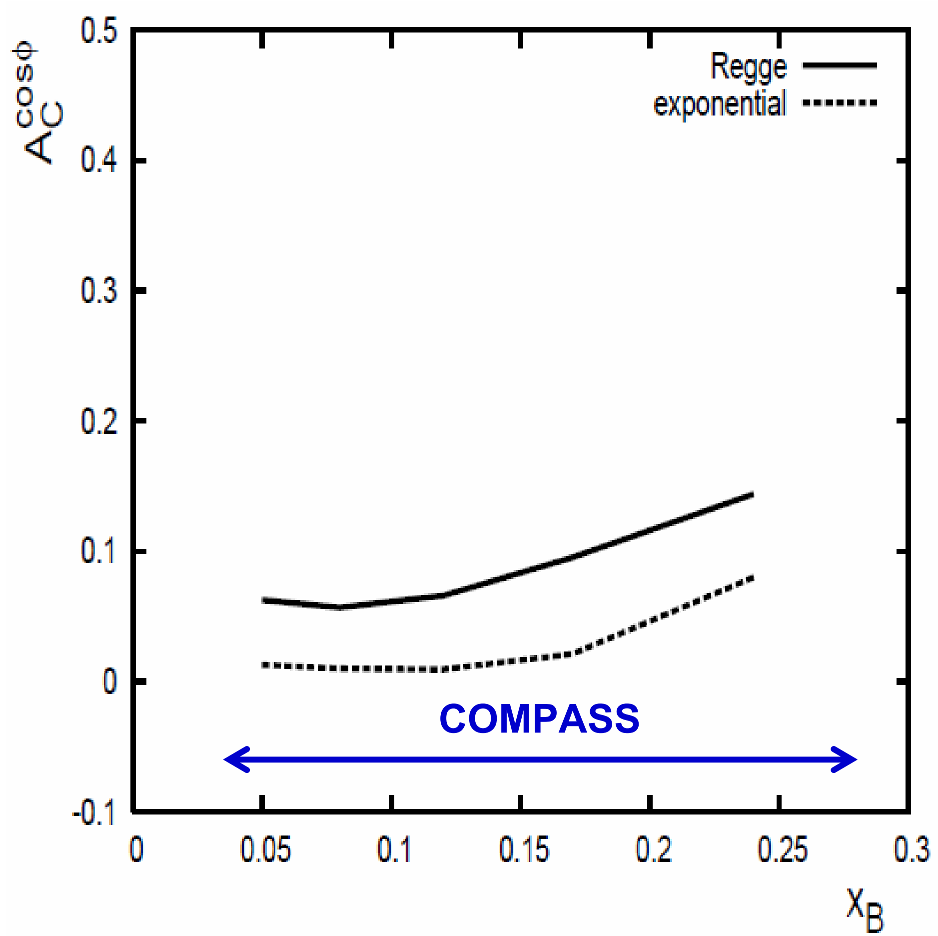
Beam Charge Asymmetry: Other Model and HERMES

- Dual parameterization
- Mellin moments decomposition, QCD evolution
- separation of x, ξ and ξ, t

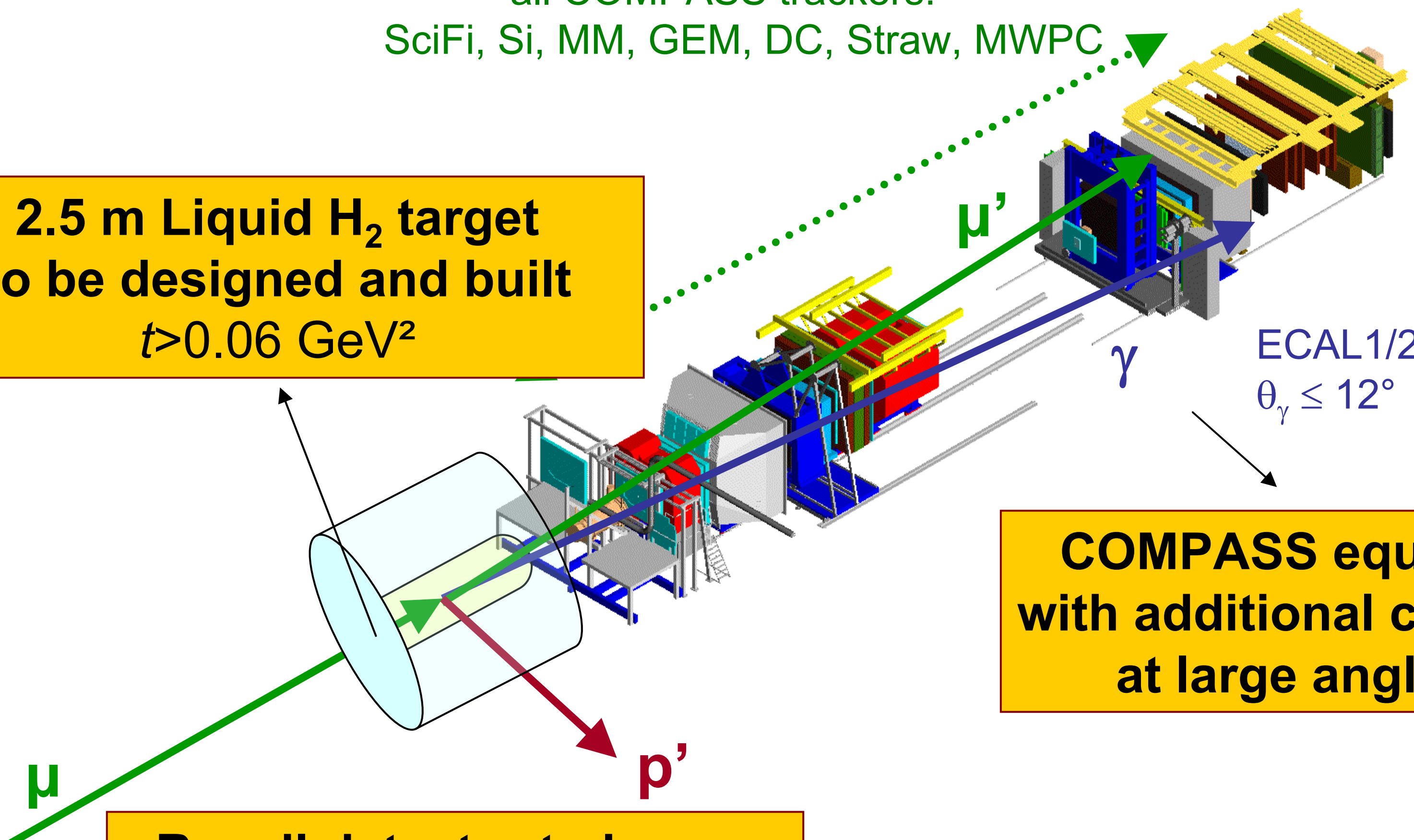
Guzey,Teckentrup PRD74(2006)054027

Only $A^{\cos\phi}$
Dominant contribution at twist-2





Experimental Setup: Target & Detektor



2.5 m Liquid H_2 target
to be designed and built
t>0.06 GeV²

COMPASS equipment
with additional calorimetry
at large angle (π^0 bkg)

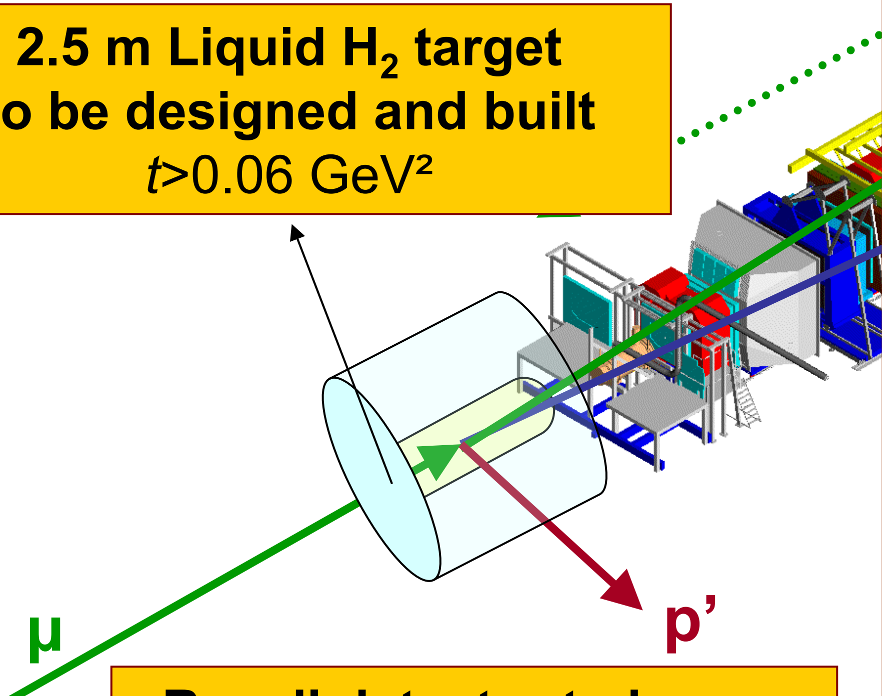
Recoil detector to insure
exclusivity
to be designed and built

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

Experimental Setup: T

all COMPASS trac
SciFi, Si, MM, GEM, DC,

2.5 m Liquid H_2 target
to be designed and built
t>0.06 GeV²



Recoil detector to insure exclusivity
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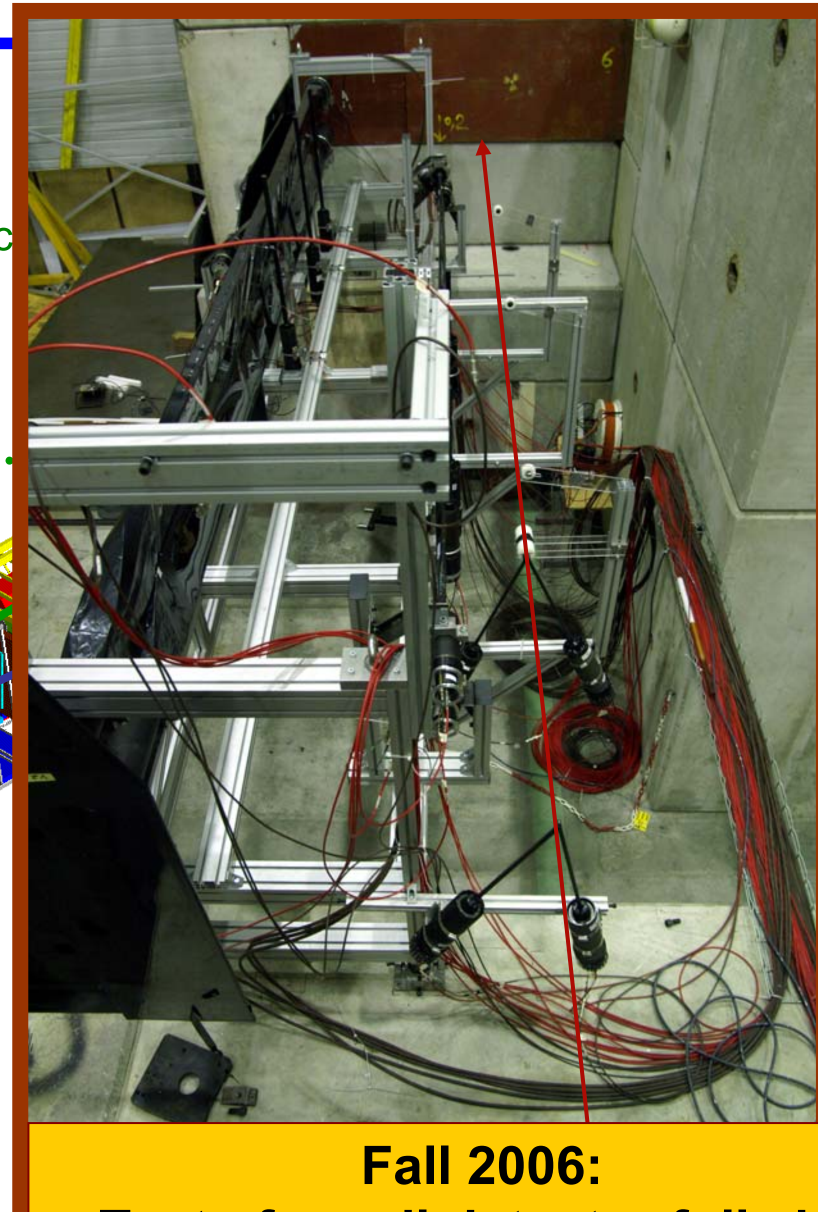

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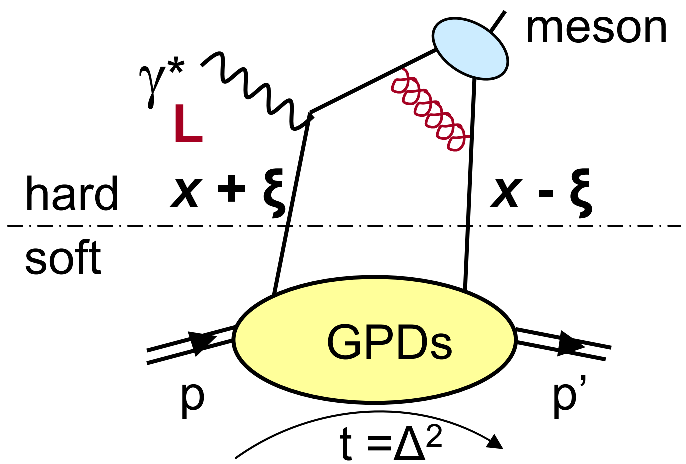
Fall 2006:
Test of recoil detector full size prototype at COMPASS: σ_t=310ps.
Goal: 300 ps for 10 bins in *t*

Hard Exclusive Meson Production (ρ,ω,ϕ…,π,η…)

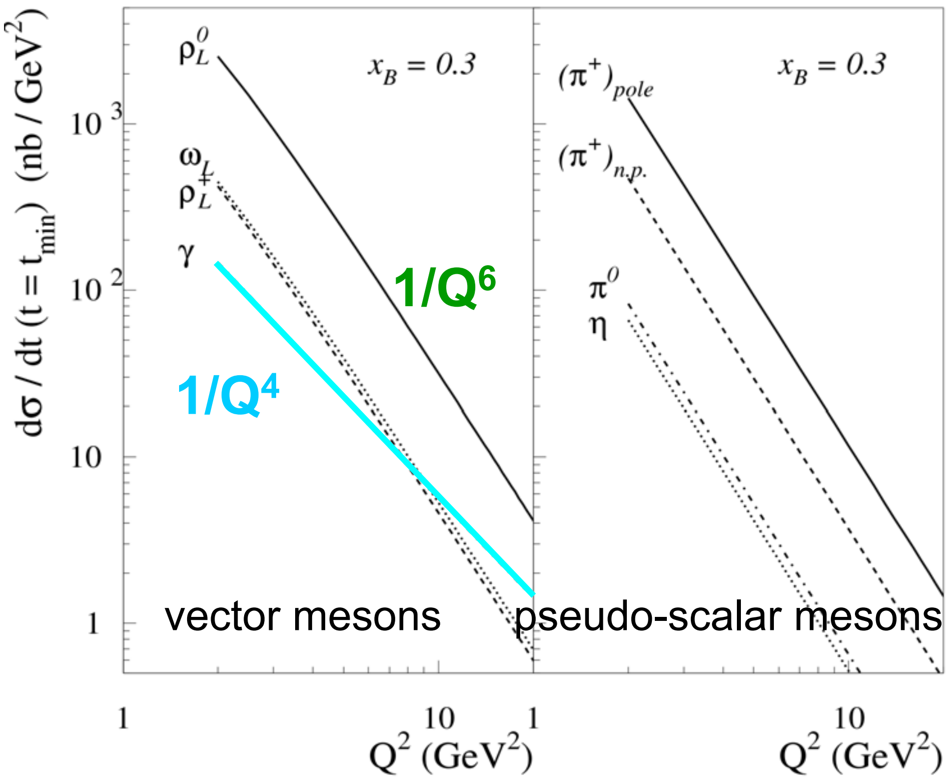


Collins et al. (PRD56 1997):

1. factorization applies only for γ^*_L

2. $\sigma_T \ll \sigma_L$

Scaling predictions:



ρ^0 largest production, presently studied with COMPASS

Outlook for GPDs at COMPASS

- Currently: Simulations and preparation of proposal
- 2007-2009: Construction of
  - recoil detector (prototype tested)
  - LH_2 target
  - ECAL0
- 2010-2015: Study of GPDs at COMPASS
- >2014: JLab12, FAIR, EIC

COMPASS advantage:

sensitivity in the valence quark – sea quark region of x_{Bj}

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