Measurement of DVCS and DVMP at COMPASS

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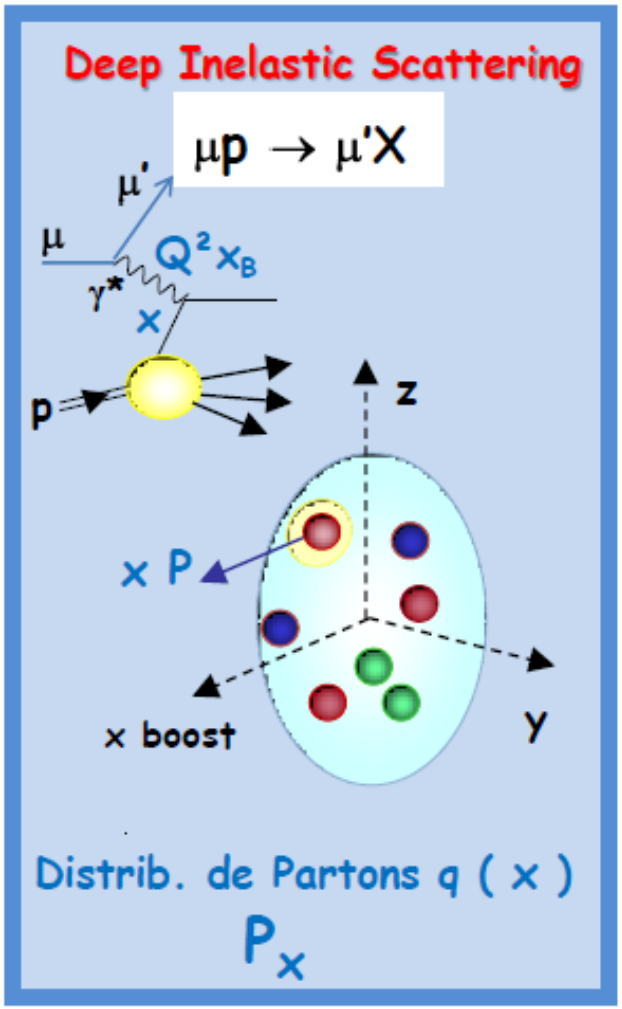
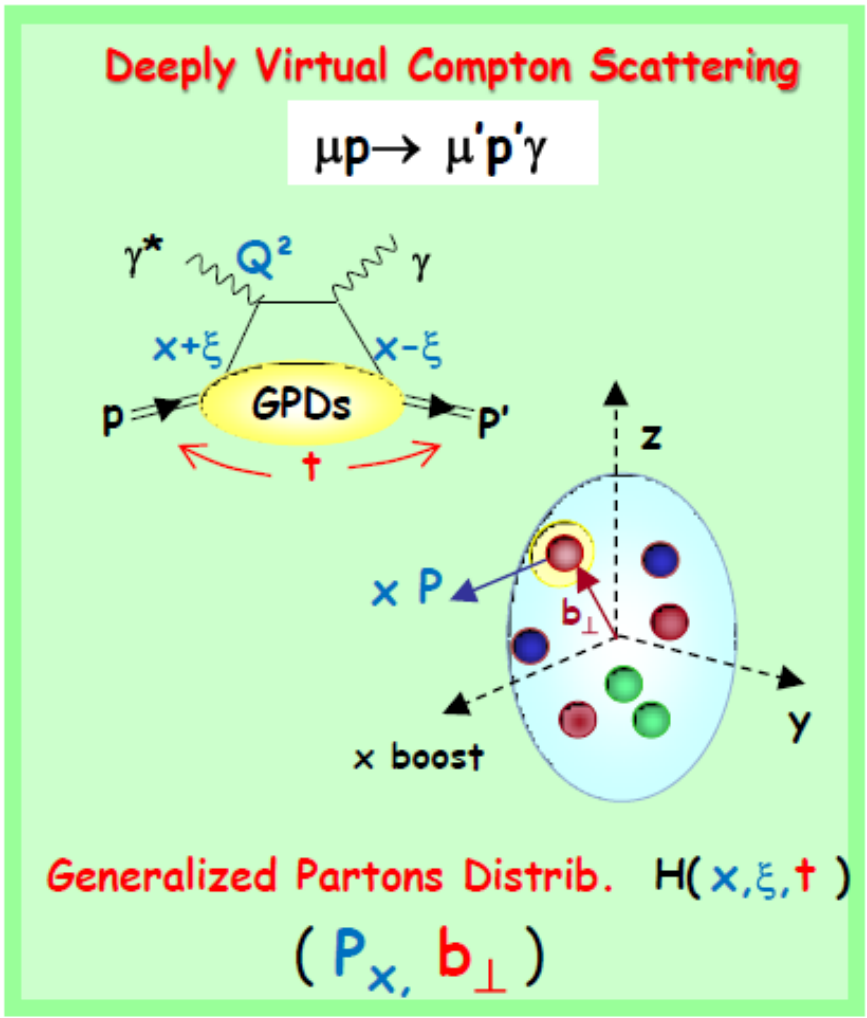
on Behalf of the COMPASS Collaboraton

SPIN2010 Conference

Jülich, September 27 2009

From PDFs to GPDs





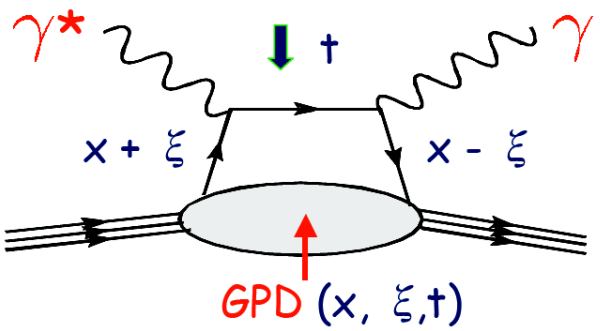
Observation of the Nucleon Structure

in 1 dimension **in 1+2 dimensions**

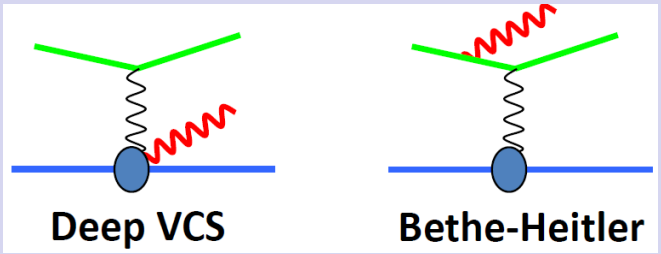
Deeply Virtual Compton Scattering

GPDs appear in the amplitude of hard exclusive processes, like Deeply Virtual Compton Scattering (DVCS)

$Q^2 >> 1\ GeV^2$ $\quad -t < 1\ GeV^2$

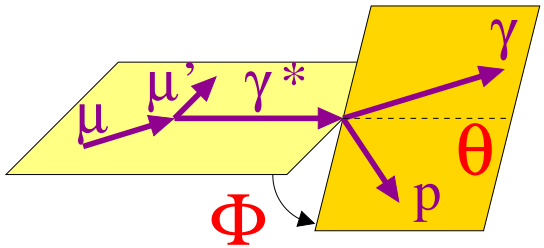


The total cross-section is the coherent sum of DVCS and BH

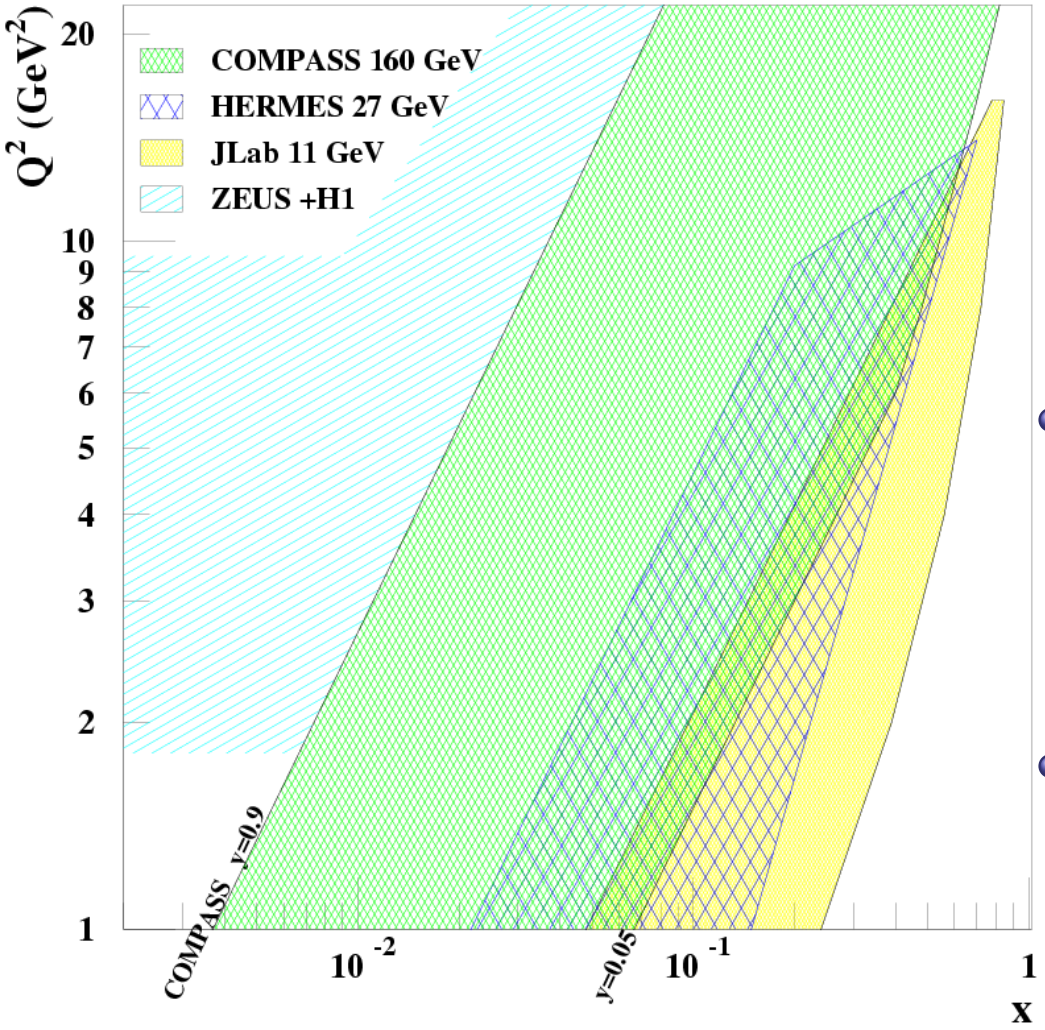


For polarized beam and unpolarized target:

$$\mathrm{d}\sigma_{\mu p\to\mu p\gamma} = \mathrm{d}\sigma^{BH} + \mathrm{d}\sigma^{DVCS}_{unpol} + P_\mu \mathrm{d}\sigma^{DVCS}_{pol} + e_\mu \mathrm{Re}(I) + e_\mu P_\mu \mathrm{Im}(I)$$



What Makes COMPASS Unique?



CERN high energy muon beam

- 100 - 190 GeV
- 80% polarization
- μ^+ and μ^- beams with opposite polarization

- Uncovered region between ZEUS+H1 and HERMES+Jlab before new colliders may be available

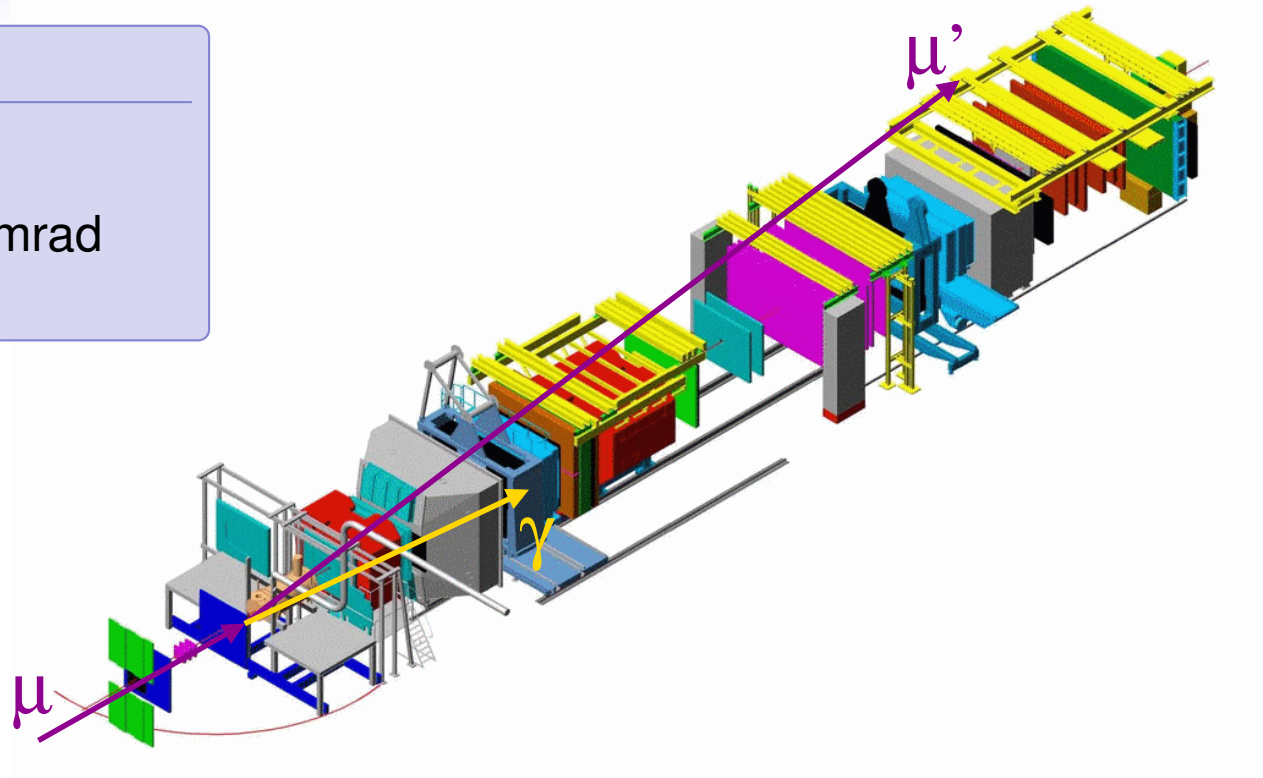
- low x_B: pure BH (useful for normalization)

high x_B: DVCS predominance

The COMPASS Apparatus for DVCS

ECAL2

- 3000 channels
- $\sim$0 mrad to $\sim$40 mrad acceptance



Beam

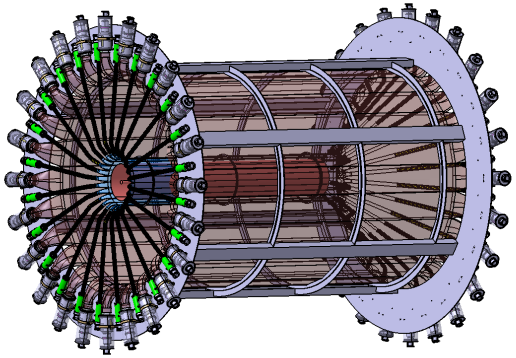
- 100-190 GeV
- 80% polarization
- μ^+ and μ^- with opposite polarization

ECAL1

- 1500 channels
- $\sim$40 mrad to $\sim$150 mrad acceptance

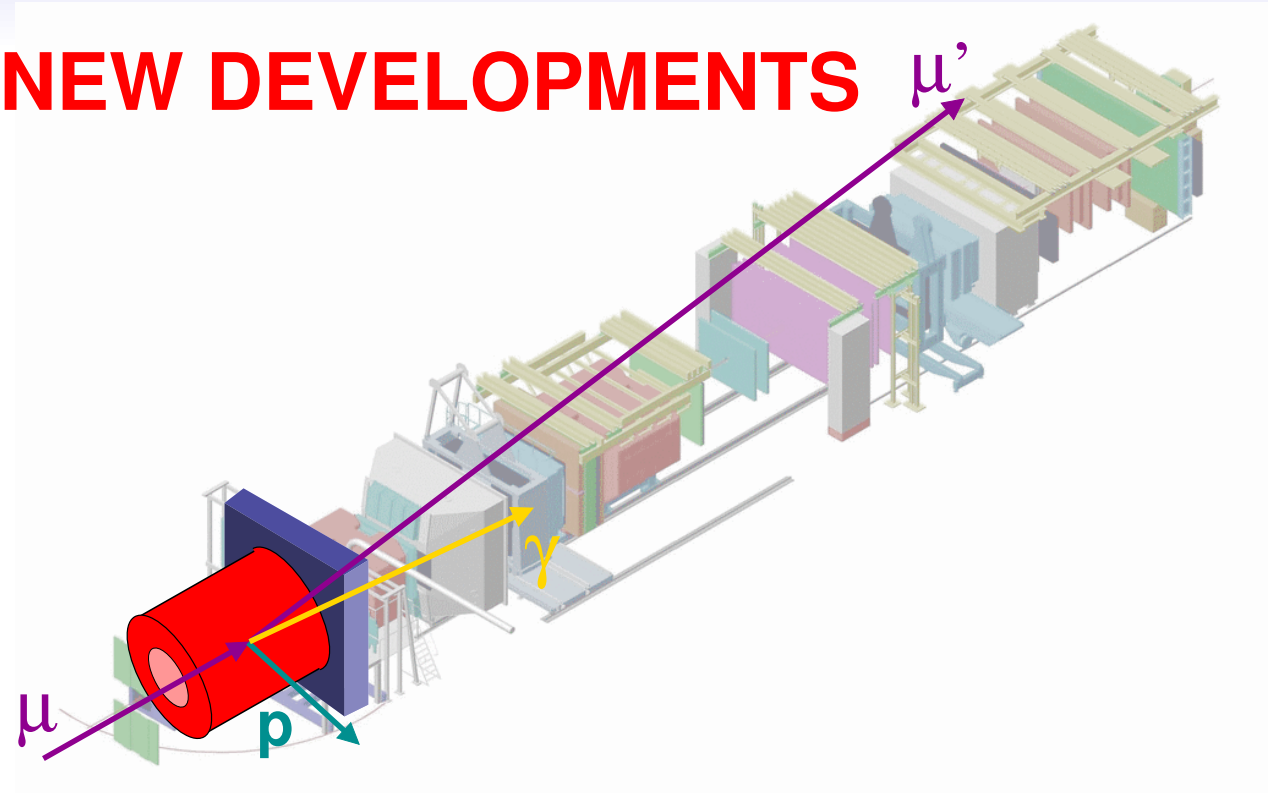
The COMPASS Apparatus for DVCS

Future Target & RPD



- **2.5m** long **LH2** target
- **4m** long TOF barrel
- recoil proton ID by **TOF** and **dE/dx**
- GANDALF boards:
  1 GHz digitization
  ENOB: **12bit**

NEW DEVELOPMENTS



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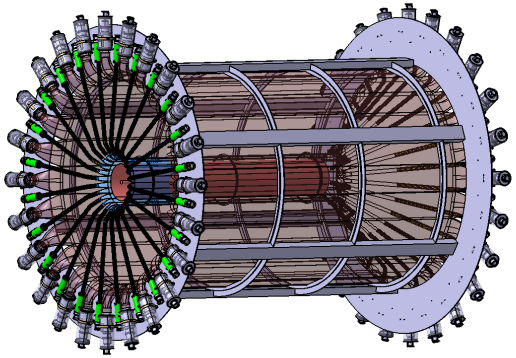

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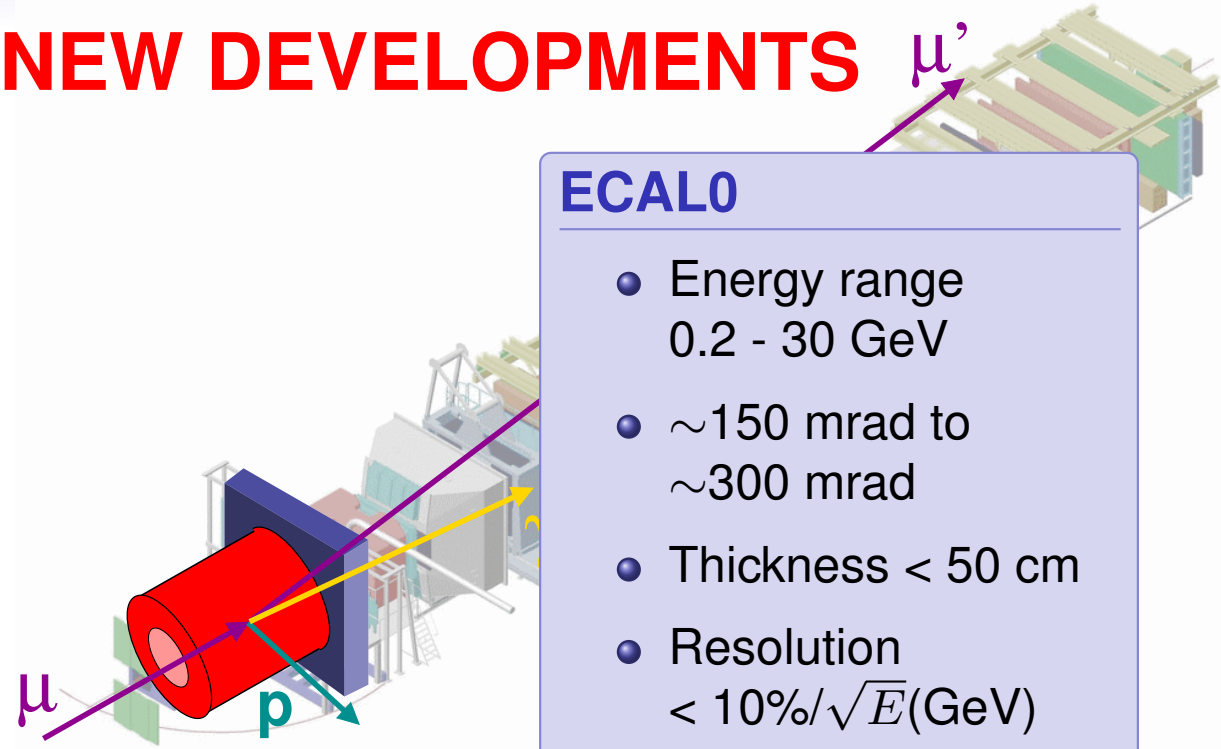
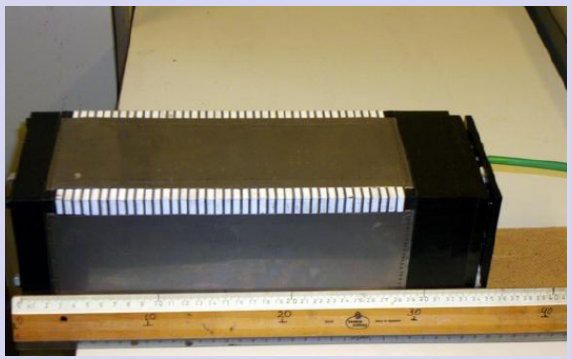
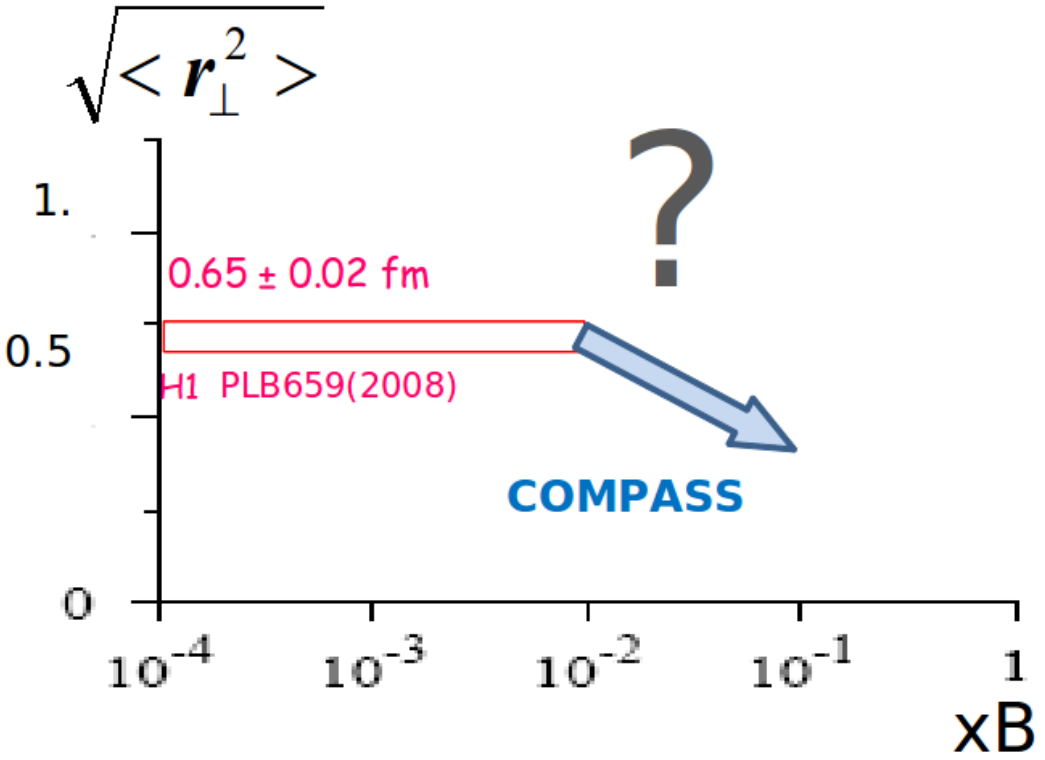


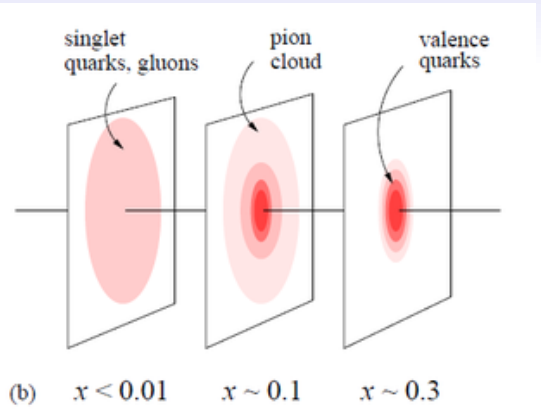
ECAL0

- Energy range
  0.2 - 30 GeV
- ∼150 mrad to
  ∼300 mrad
- Thickness < 50 cm
- Resolution
  $< 10\%/\sqrt{E}(\text{GeV})$



Transverse Size of the Nucleon (I)





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

$$B(x_B) = 1/2 < r_\perp^2(x_B) >$$

$r_\perp \rightarrow$ Tranverse size of the Nucleon

The trasverse size $r_\perp$ as function of x_B can be extracted in a model-independent way from the **t-slope** of the measured DVCS cross-section $\rightarrow$ **"Nucleon Tomography"**

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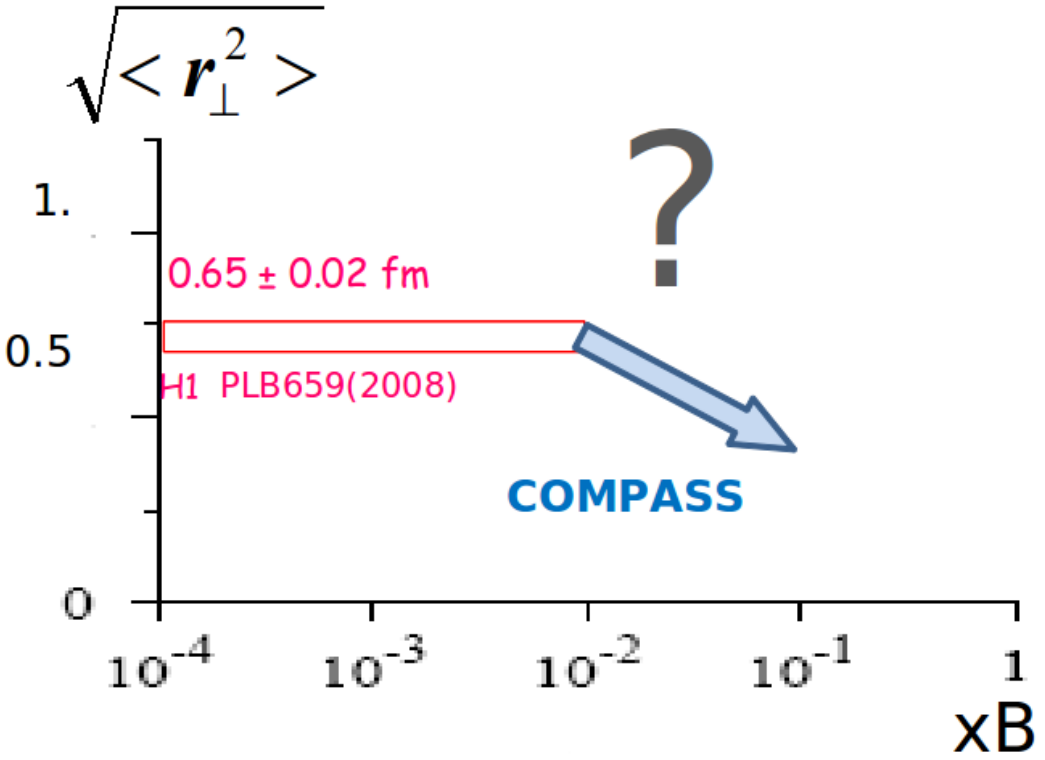

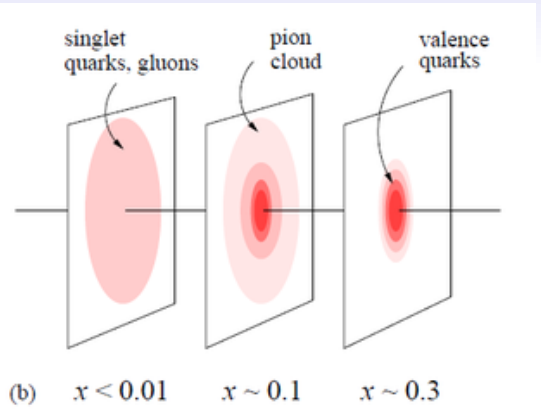

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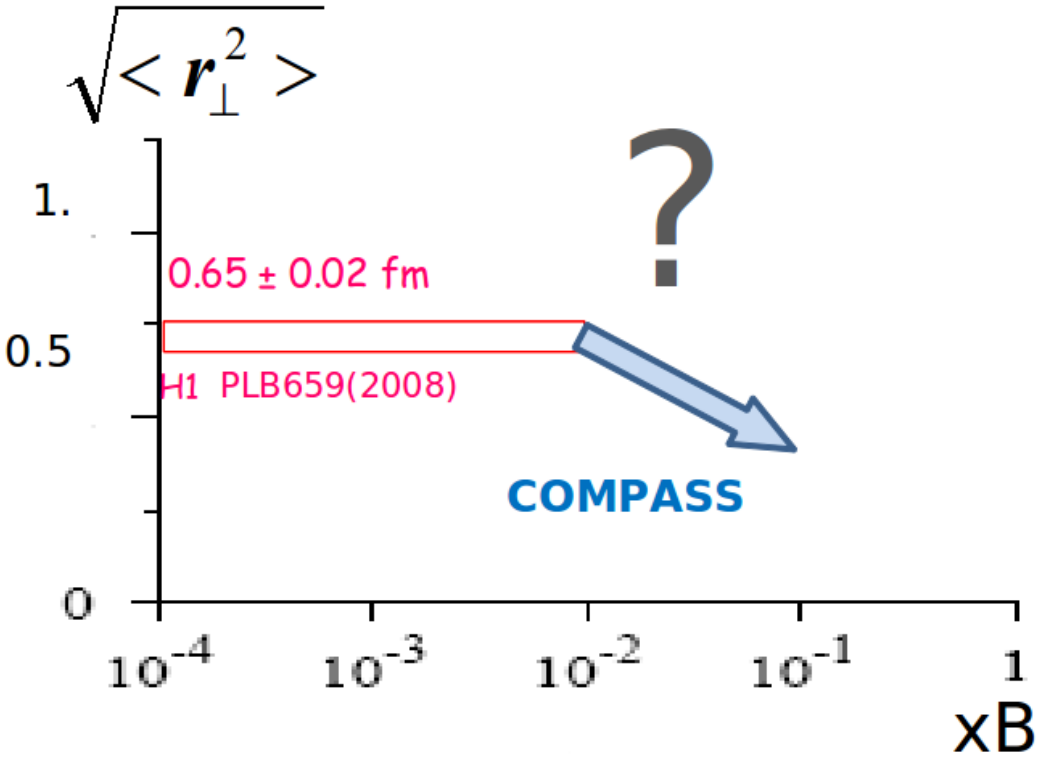

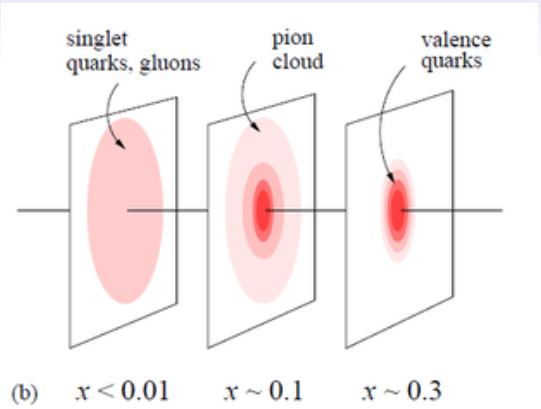

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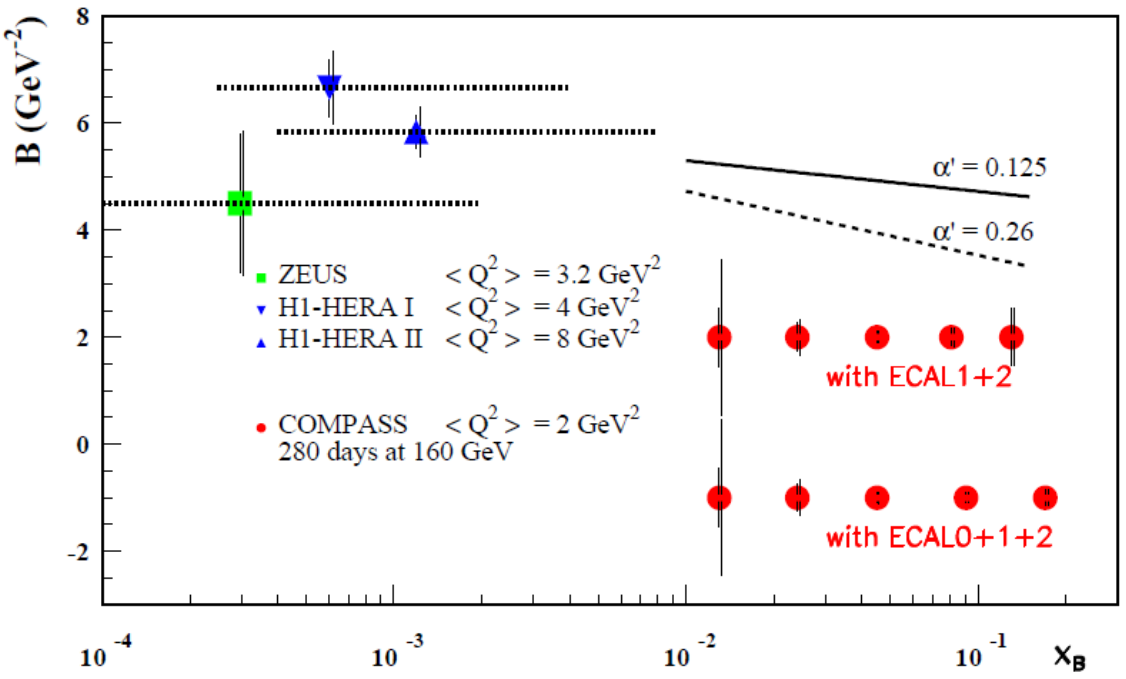
Transverse Size of the Nucleon (II)

$$S_{CS,U} \equiv d\sigma(\mu^{+\leftarrow}) + d\sigma(\mu^{-\rightarrow}) \propto d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + e_\mu P_\mu Im(I)$$

Integrating $S_{CS,U}$ over ϕ and after subtraction of the BH contribution one obtains $d\sigma^{DVCS}/dt \sim \exp(-B|t|)$



COMPASS Projected:

- 2 years of data
- eff = 10%
- lumi = $1222 pb^{-1}$

Ansatz at small x_B:

$B(x_B) = B_0 + 2\alpha' \ln(x_0/x_B)$

α' slope of Regge traject

Accuracy $\geq 2.5\sigma$ if $\alpha' > 0.125$ and full ECALs

Systematic errors dominated by **BH subtraction** at low x_B

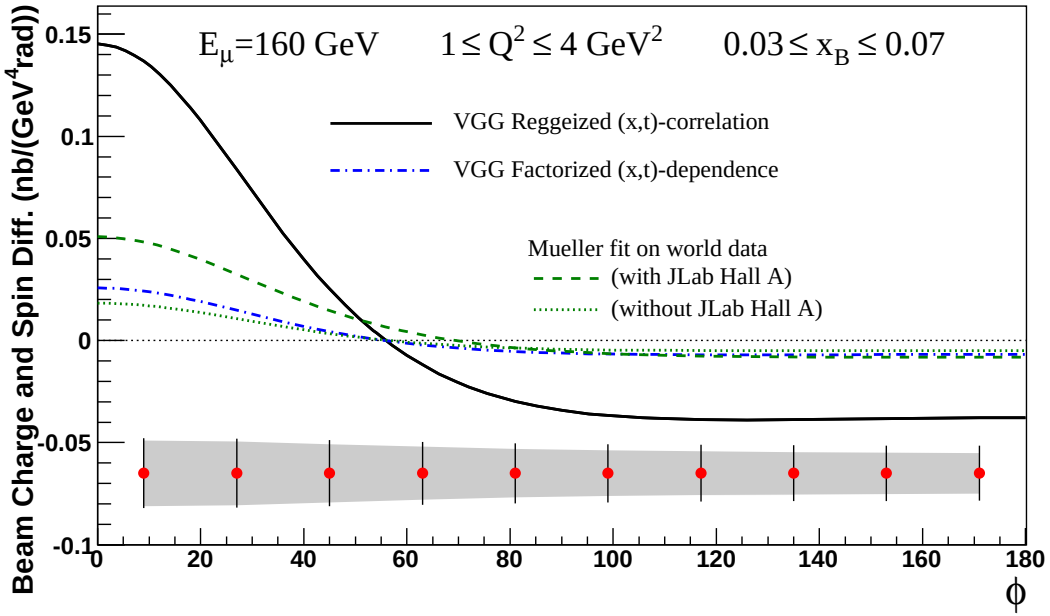
Angular Dependence of $\mathrm{d}\sigma$

$$\mathbf{d\sigma_{\mu p\to\mu p\gamma} = d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + P_\mu d\sigma^{DVCS}_{pol} + e_\mu Re(I) + e_\mu P_\mu Im(I)}$$

Angular Dependence of $d\sigma$

$$d\sigma_{\mu p\to\mu p\gamma} = d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + P_\mu d\sigma^{DVCS}_{pol} + e_\mu Re(I) + e_\mu P_\mu Im(I)$$

Combine μ^+ and μ^- data with opposite beam polarizations



$$D_{CS,U} \equiv d\sigma\mu^{+\downarrow} - d\sigma\mu^{-\uparrow} \propto c_0^{Int} + c_1^{Int}\cos(\phi)$$

$$c_{0,1}^{Int} \propto Re(F_1\mathcal{H})$$

Red points: COMPASS Projected

- 2 years of data
- eff = 10%
- lumi = 1222pb^{-1}

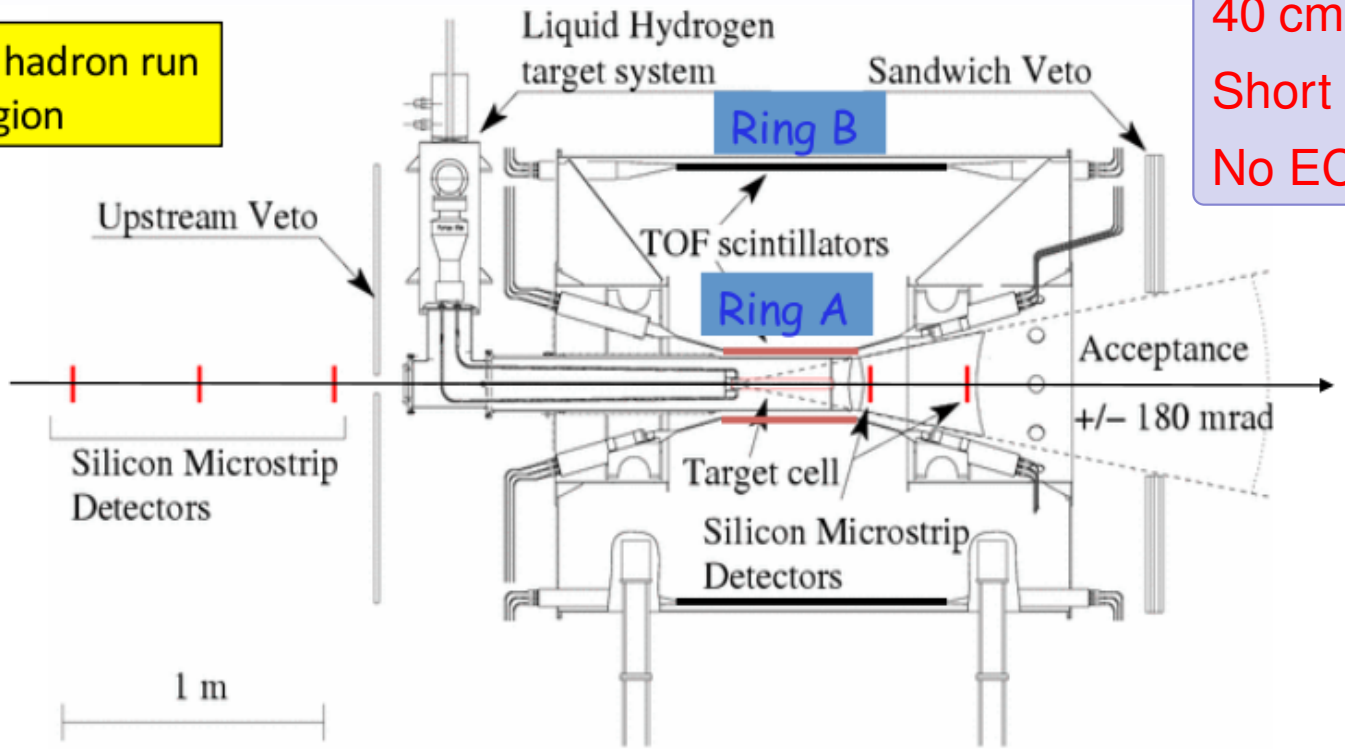
$$Re\mathcal{H}(\xi,t) = P\int dx\, H(x,\xi,t)/(x-\xi) \rightarrow$$ **Exp. constrain to GPD H!**

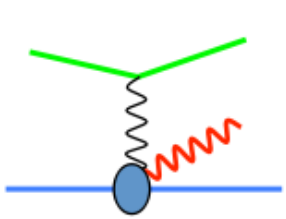
Syst. error: 3% charge-dependent effect between μ^+ and μ^-

2008-2009 DVCS Test

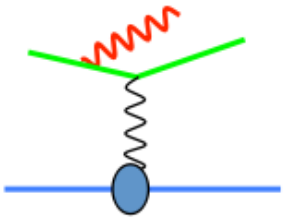
Compass hadron run
Target region

40 cm LH2 target
Short RPD
No ECAL0





DVCS

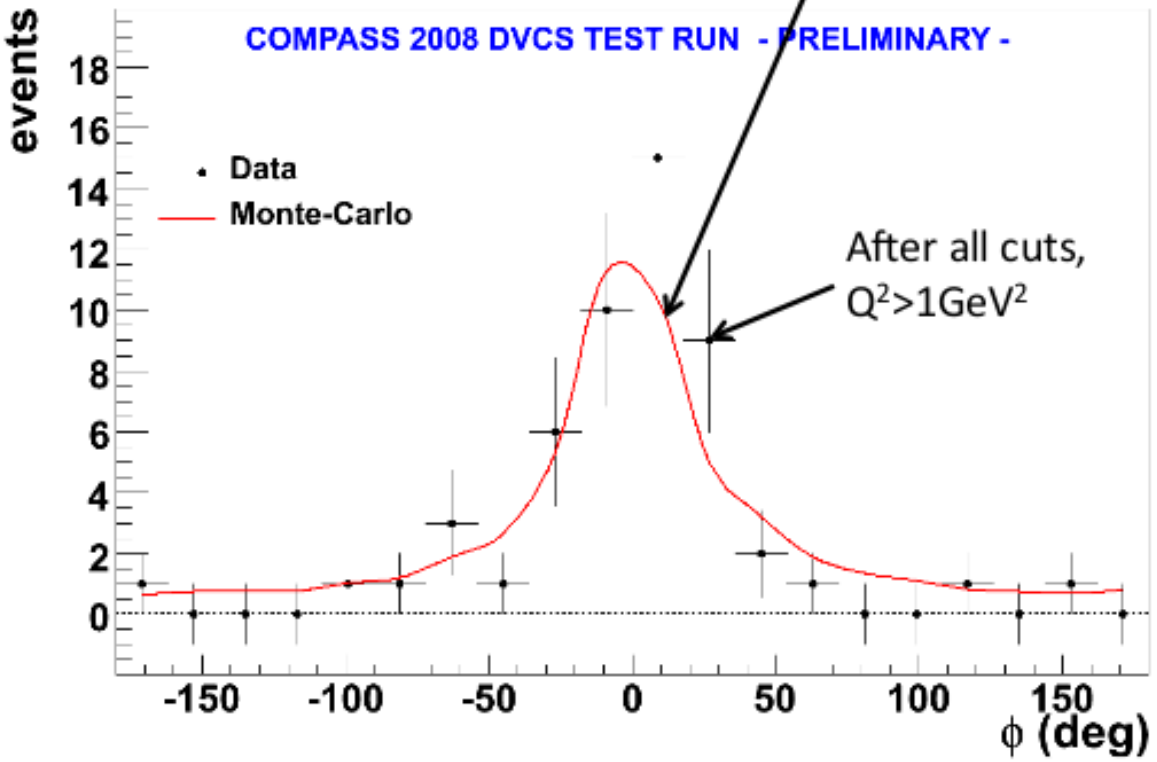


Bethe-Heitler

Selection of events :

- one vertex with μ and μ'
- no other charged tracks
- only 1 high energy photon ($\Delta t < 5$ns)
- 1 proton in RPD with $p < 1.$ GeV/c

Results - 2008 Test Run



Estimated global eff. from BH yield:

$\varepsilon = 0.13 \pm 0.05$

- Detection efficiency:

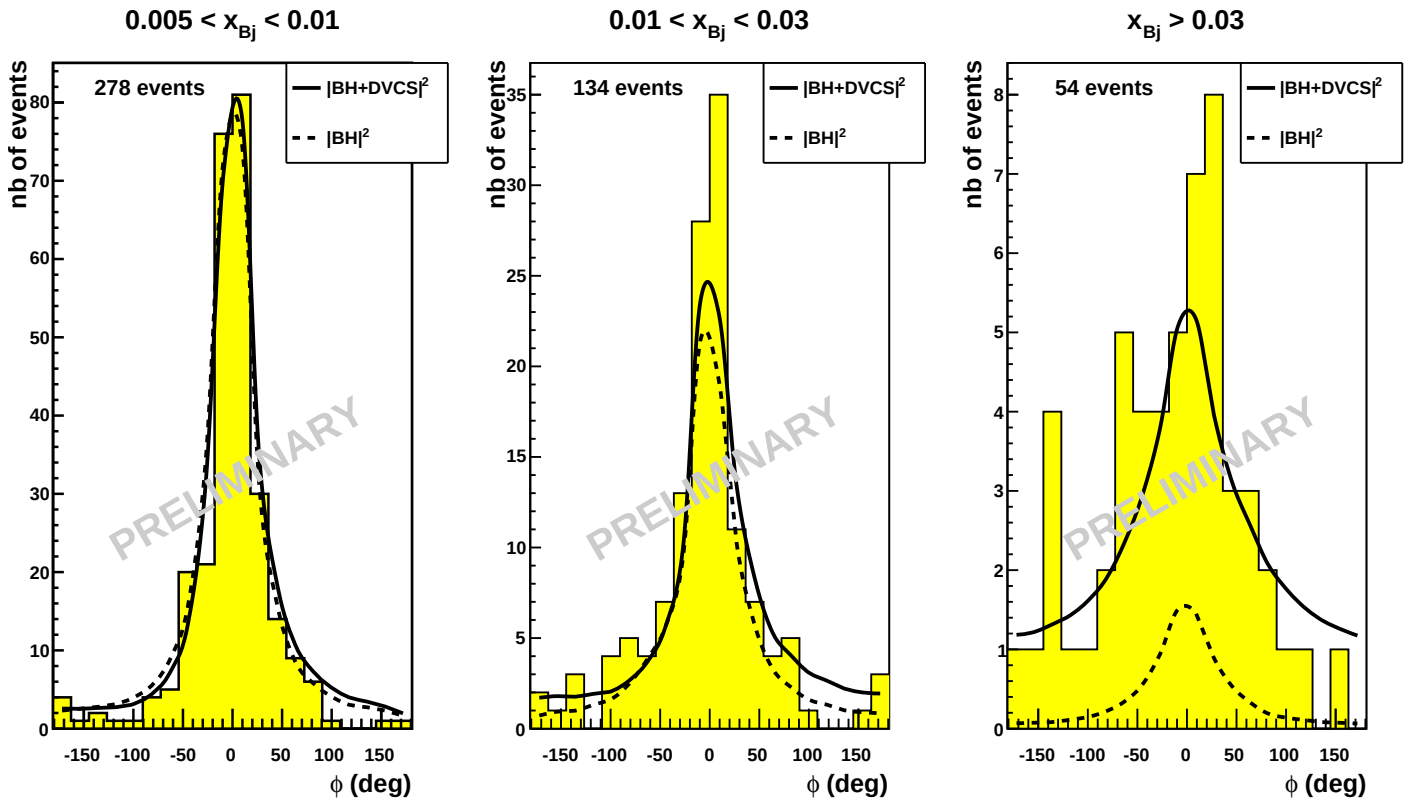
  0.32 ± 0.13
- SPS+COMPASS availability
- dead time
- trigger

∼10 times more data collected in 2009

Results - 2009 Test Run

Comparison of MC simulation (solid & dashed lines) with data

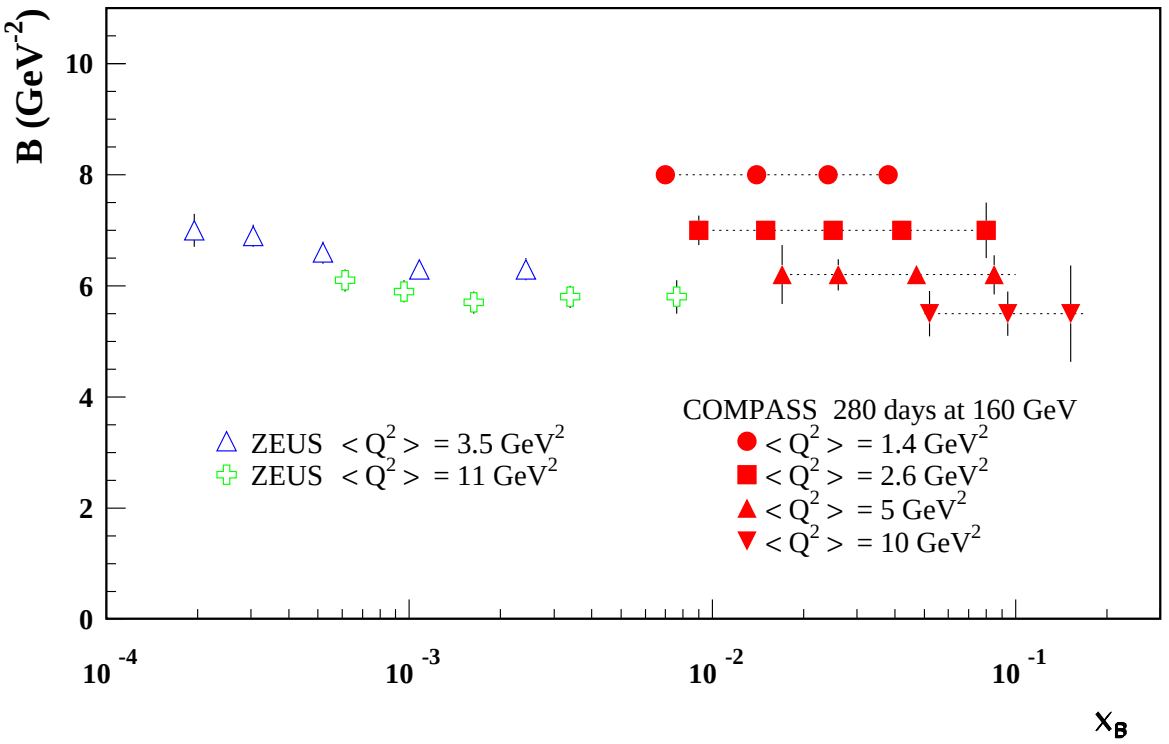
MC yield normalized to low-x_B bin (where BH dominates)

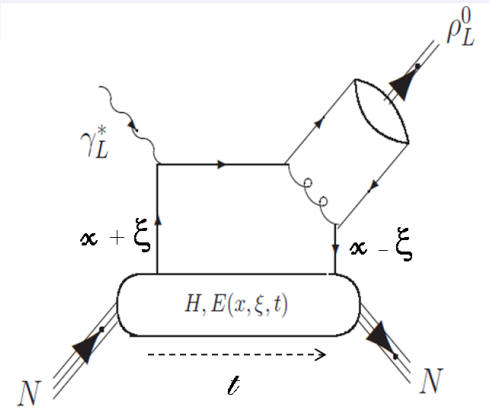


Excess of data at $x_B > 0.03$ is a sign for DVCS

Tranverse Imaging with Vector Mesons

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





Red points:

COMPASS Projected

- 2 years of data
- eff = 10%
- lumi = 1222$\mathbf{pb}^{-1}$

We are sensitive to the Nucleon size + the transv. meson size

$\mathbf{Q^2 = 1\ GeV^2}$ $\quad \mathbf{B \sim 8\ GeV^{-2}}$

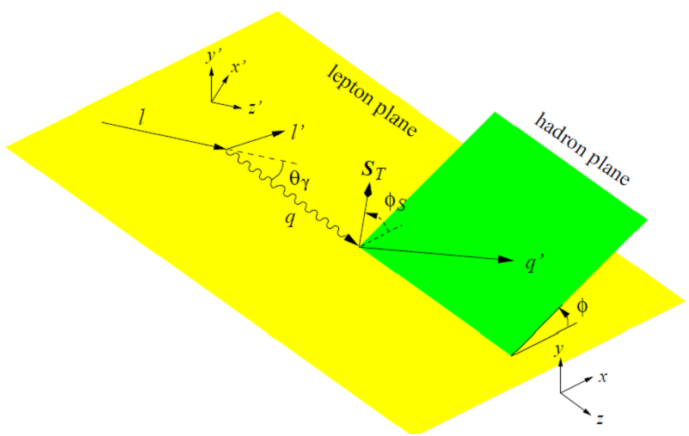
$\mathbf{Q^2 = 10\ GeV^2}$ $\quad \mathbf{B \sim 5.5\ GeV^{-2}}$

DVMP with Transversely Pol. Target

- **Cross-section measurement:**

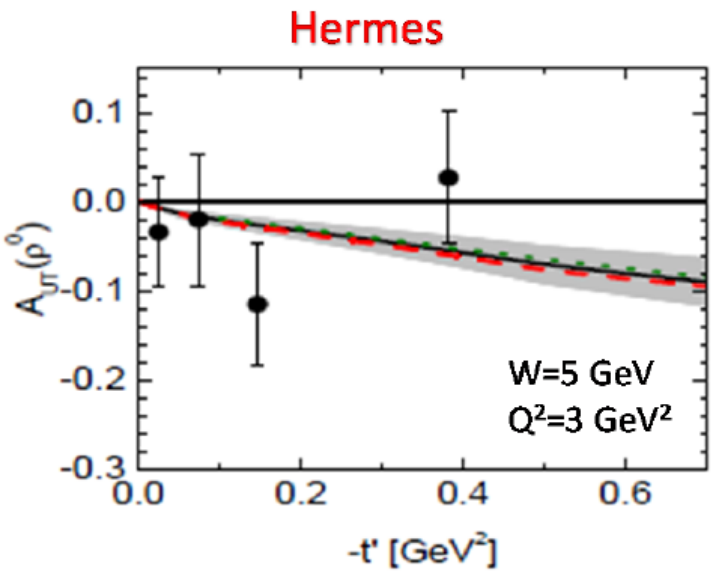
  Vector meson production ($\rho,\ \omega,\ \phi$) $\longrightarrow \mathbf{H},\ \mathbf{E}$

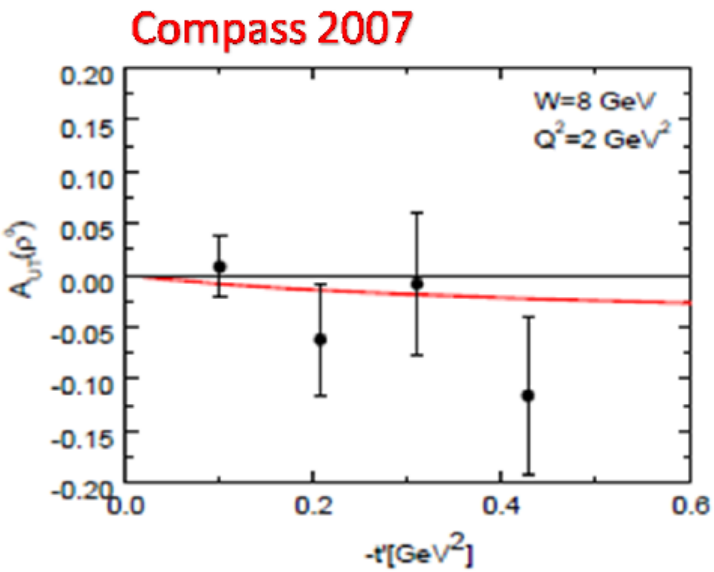
  Pseudo-scalar production ($\pi,\ \eta,\ \ldots$) $\longrightarrow \tilde{\mathbf{H}},\ \tilde{\mathbf{E}}$



- **Tranverse target spin asymmetry** $\mathbf{A_{UT}^{\sin(\phi-\phi_S)}}$

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





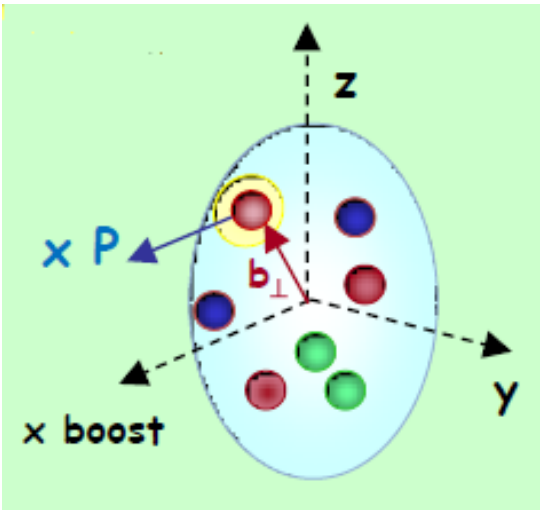
COMPASS data: **transversely polarized proton target**

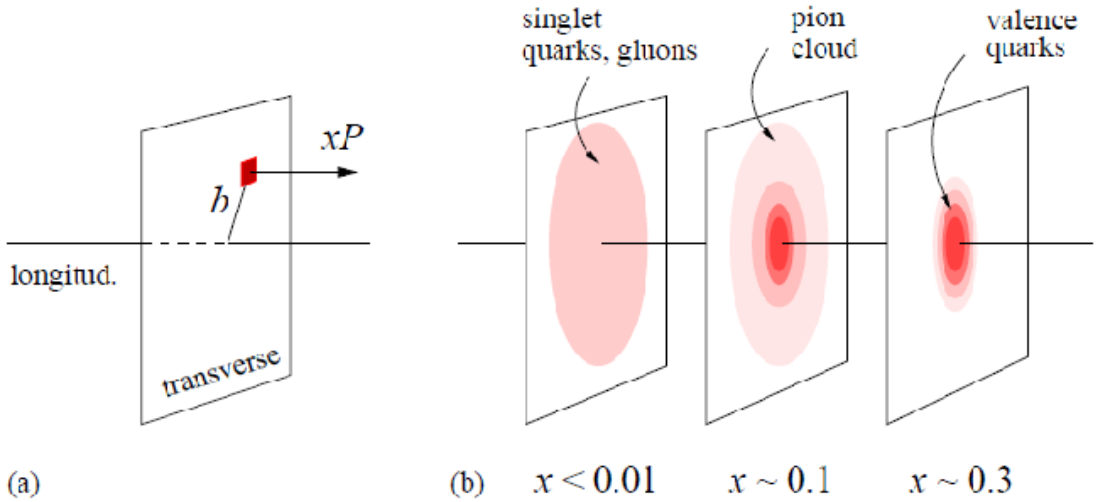
Conclusions and Outlook

- COMPASS will investigate quark GPDs through DVCS
  - **Intermediate x_B regime** not accessible to present or planned facilities in the near future
  - Two beam charges available with opposite polarizations - **UNIQUE**
  - Nucleon **transversal dimension** as function of x_B ("Nucleon Tomography")
  - Constrain **GPD H** through ϕ dependence of $D_{CS,U}$
- Complementary information from exclusive meson production
- In a second phase, constrain of **GPD E** by using a transversely polarized target

Backup Slides

Generalised Parton Distributions

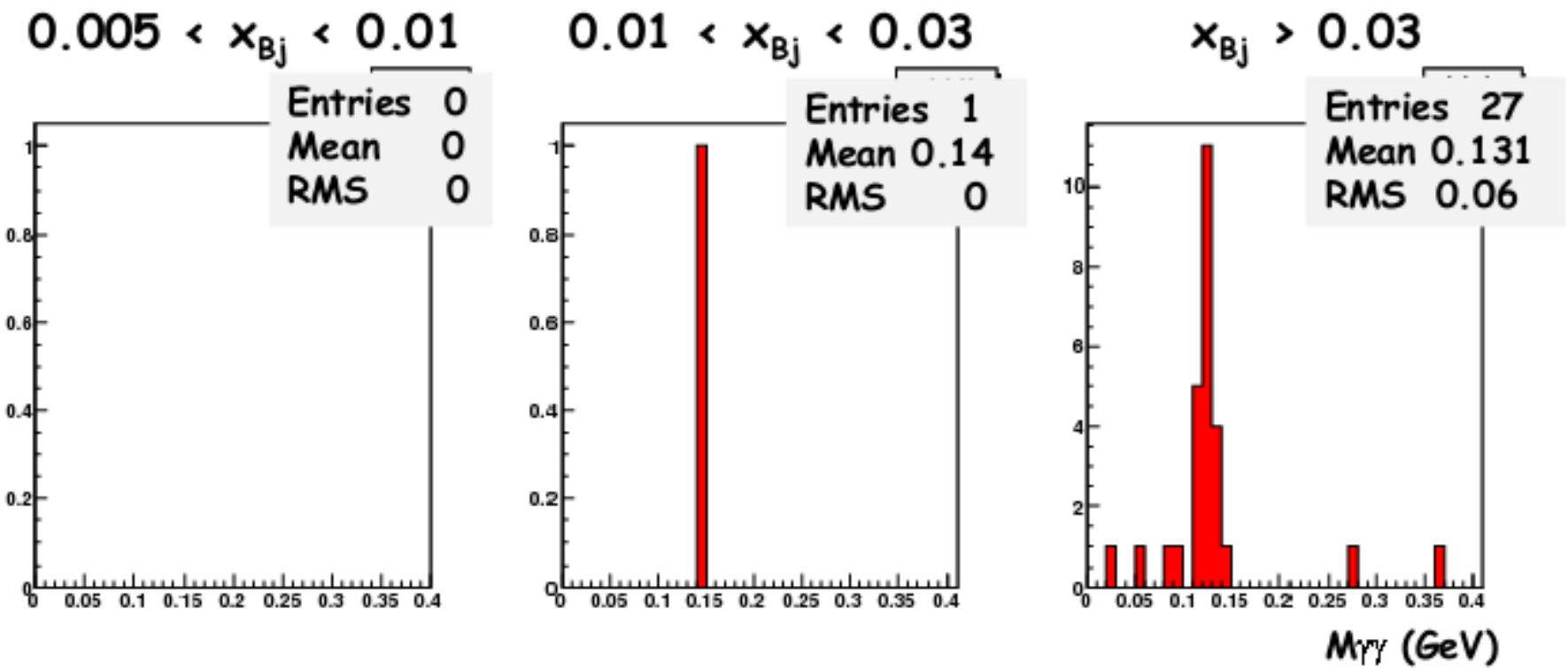




GPDs: Correlation between transverse position and longitudinal momentum of partons

- “3D picture” of nucleon structure
- FFs and PDFs derived from GPDs as limiting cases
- Related to the total angular momentum of partons

π^0 Signal in 2009 DVCS Test Data



A signal around the π^0 mass is observed in the 2009 data after applying all exclusivity cuts. The analysis work is in progress...