

# GPDs at HERA & prospects for COMPASS

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Only one fundamental issue is addressed:

Which size of the nucleon is occupied by which partons as  
a function of  $x_{Bj}$  ?

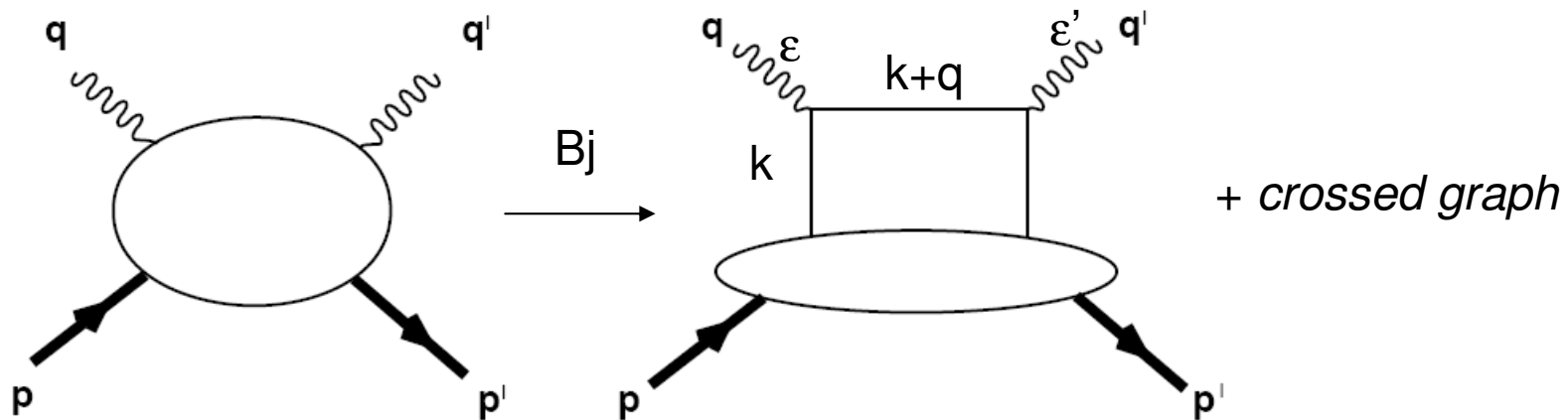
*L.S., arXiv:0706.3488 [hep-ph], PLB. + on behalf of the « GPD » group of COMPASS*

DIS 2008, 7-11 April 2008, University College London

# DVCS process basics

Exclusive production of a real photon

$$e + p \rightarrow e + \gamma + p$$



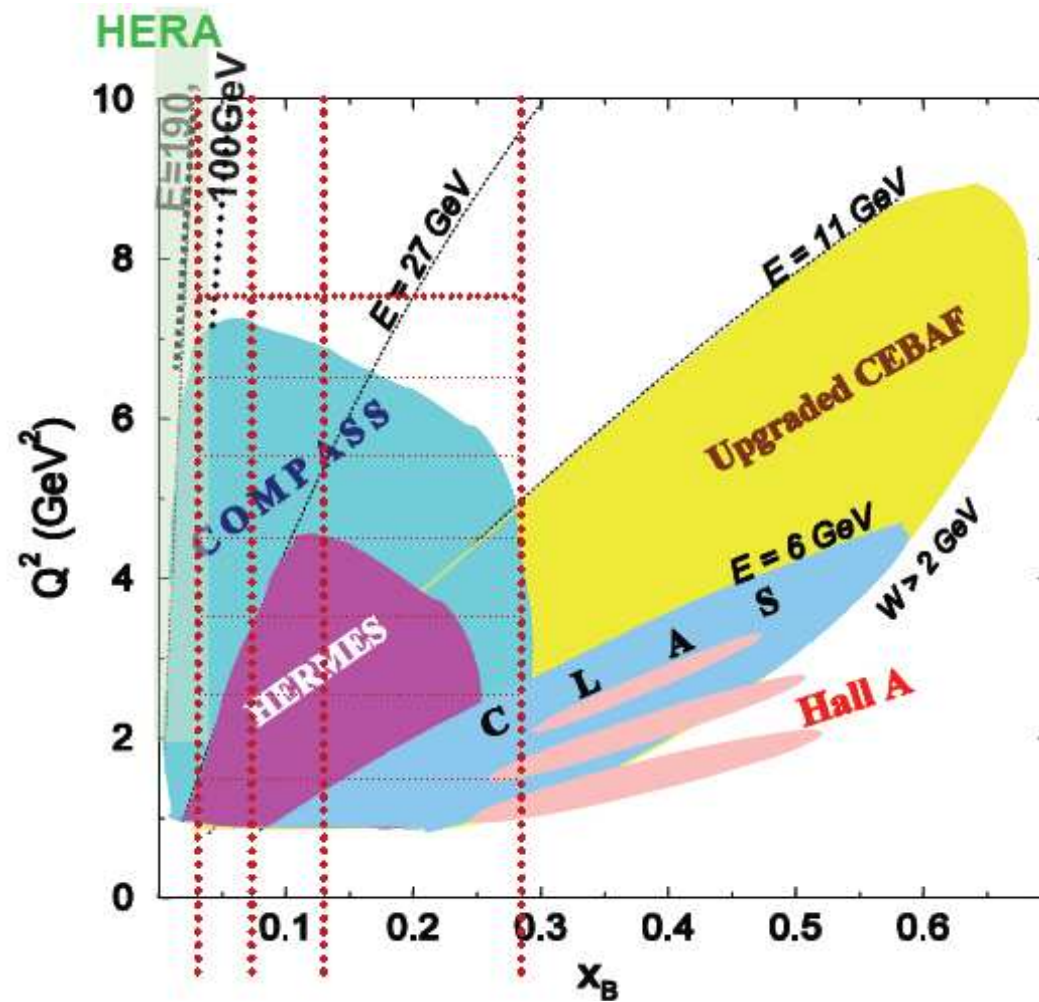
$$\begin{aligned} \text{DVCS} &: \gamma^* p \rightarrow \gamma p \\ \text{DIS} &: \gamma^* p \rightarrow \gamma^* p \end{aligned}$$

Bjorken limit:  $Q^2 = -q^2$  et  $W^2 = (p+q)^2 \gg Q_0^2$  &&  $x_{Bj}$  fixed

with:  $t = (p'-p)^2 \ll Q^2$

non-pert scale that we do not know a priori...

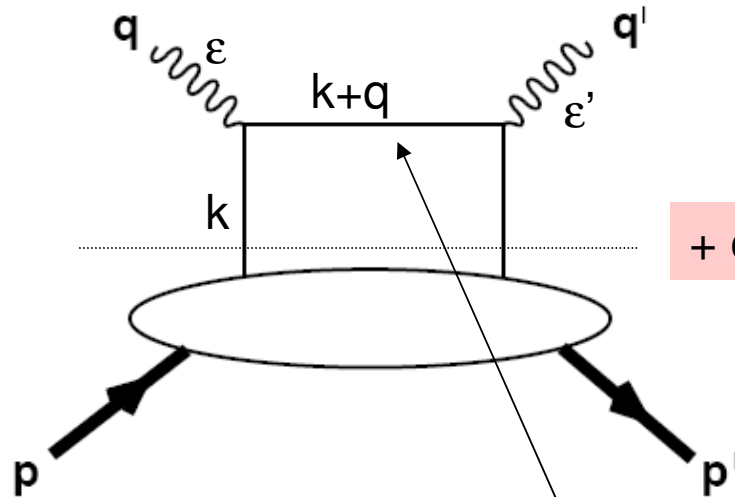
# Around the world: present & future



COMPASS 2010

JLab 12 GeV 2014

# How GPDs enter into the game?



$$M = -i \int d^4z e^{-iqz} \langle p', s' | T \varepsilon' J(0) \varepsilon J(z) | p, s \rangle$$

Bj limit  $\Rightarrow q z \sim q^+ z^-$  (avec  $z^+ \sim 0$ )

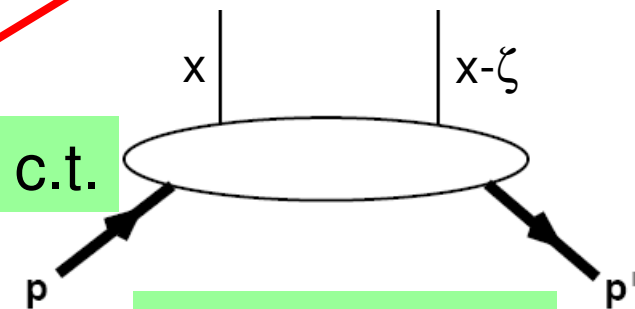
+ c.t.

**Here comes the GPDs**

$$M = \sum_q e_q^2 (\varepsilon_\nu^* g_T^{\mu\nu} \varepsilon_\mu) \int \frac{dk^+}{(k^+ + q^+) + i\varepsilon} \int \frac{dz^-}{4\pi} e^{ik^+ z^-} \langle p', s' | \bar{q}(0) \gamma^+ q(z) | p, s \rangle_{z^+=0, z_\perp=0}$$

$$M \sim -\sum e_q^2 \int dx [1/(x - x_{Bj} + i\varepsilon)] \text{GPD}(x, \zeta, t) + \text{c.t.}$$

$$\Rightarrow \text{P.P. } 1/(x - x_{Bj}) - i\pi \delta(x - x_{Bj})$$



$\zeta \sim x_{Bj}$   
If  $q'$  is a real photon!

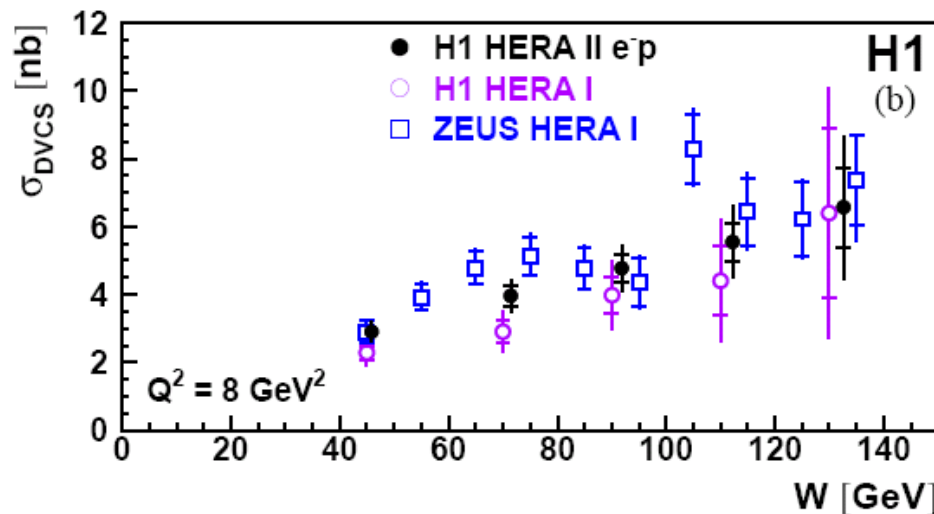
# From GPD to DVCS cross section

**H1/ZEUS kin domain :  $x \sim 10^{-3}$  &  $Q^2 > 4 \text{ GeV}^2$**

$$\text{Im}(M_{+,+,s=s'}) = \pi \sum e_q^2 [\text{GPD}_{\text{Singlet}}(x_{\text{Bj}}, \zeta \sim x_{\text{Bj}}, t)]$$

& **DVCS cross section**  $\sim |\text{Im}M|^2 + |\text{Re}M|^2 = |\text{Im}M|^2 [1 + |\text{Re}M|^2/|\text{Im}M|^2]$

↓  
correction  $\sim$  few %



Hard W dependence ( $\sim W^{0.7}$ )

=>

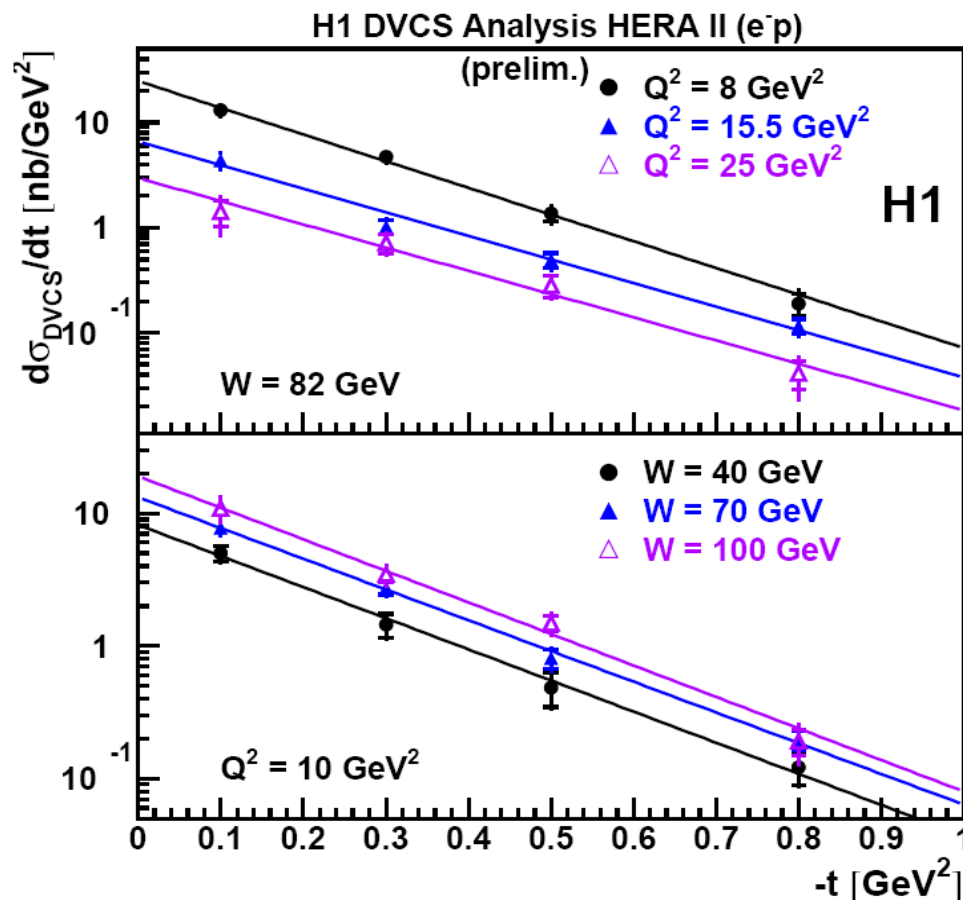
**DVCS is a hard process**

**nano-barn cross section!**

1/1000 versus DIS => not easy to measure...

See experimental talks @ this workshop

# Prior to everything: dependence in $t$ of DVCS xs



Best description with an exponential fit of the form :  
 $d\sigma/dt \sim \exp(bt)$  [A]

**Then:**

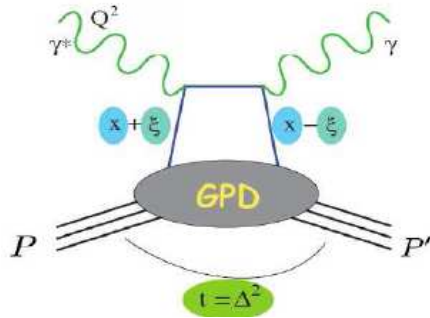
The DVCS xs  $\sim 1/b$  [A]  
**b gives the normalisation...**

Without it, it is useless  
 to go further => we would never  
 be able to say a word on any  
 GPD model... plain && simple.

$$d\sigma/dt = [d\sigma/dt]_{t=0} \exp(-b|t|) \quad : \quad b = 5.45 \pm 0.19 \pm 0.34 \text{ GeV}^{-2}$$

$$@ x=10^{-3} \text{ \& } Q^2=10 \text{ GeV}^2$$

# Nucleon tomography: a new issue



With DVCS, we measure/extract a  $GPD(x_1, x_2, t)$

--  $t$ -dependence is essential in normalisation

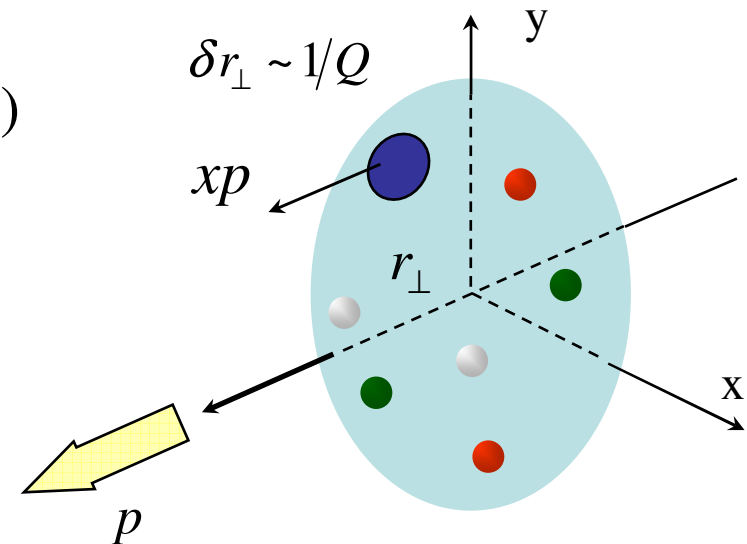
-- **A more fundamental point : it gives access to a completely new issue in nucleon physics : the TRANSVERSE SIZE!**

PDF (transverse plane)  $\equiv$  F.T.  $\{ GPD[\Delta_\perp] \}$

$$q(x, \mathbf{r}_\perp, Q^2) = \int \frac{d^2 \Delta_\perp}{(2\pi)^2} e^{-i\mathbf{r}_\perp \cdot \Delta_\perp} GPD_q(x, Q^2, t = -\Delta_\perp^2)$$

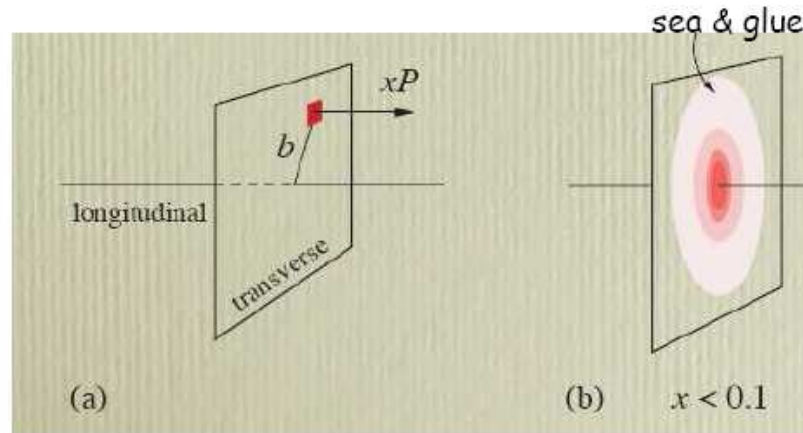
$r_\perp$  &  $\Delta_\perp$  are conjugate variables :

$$\begin{aligned} \langle r_\perp^2 \rangle &= 4 \, d/dt[GPD(x, t)] / GPD(x, 0) \\ &= 2 \, d/dt[\sigma(t)] / \sigma(t=0) \end{aligned}$$



**H1 : measurement of  $d\sigma/dt$  [DVCS]  
=> spatial distribution of sea (and glue)**

## Result: quark imaging @ $x_{Bj}=10^{-3}$



$$[\langle r_T^2 \rangle]^{1/2} = 0.65 \pm 0.02 \text{ fm}$$

@  $x=10^{-3}$  &  $Q^2=10 \text{ GeV}^2$

Physics content =>

It gives the

transverse area (average) occupied by the sea quarks [& gluons]

& probed during the DVCS reaction...

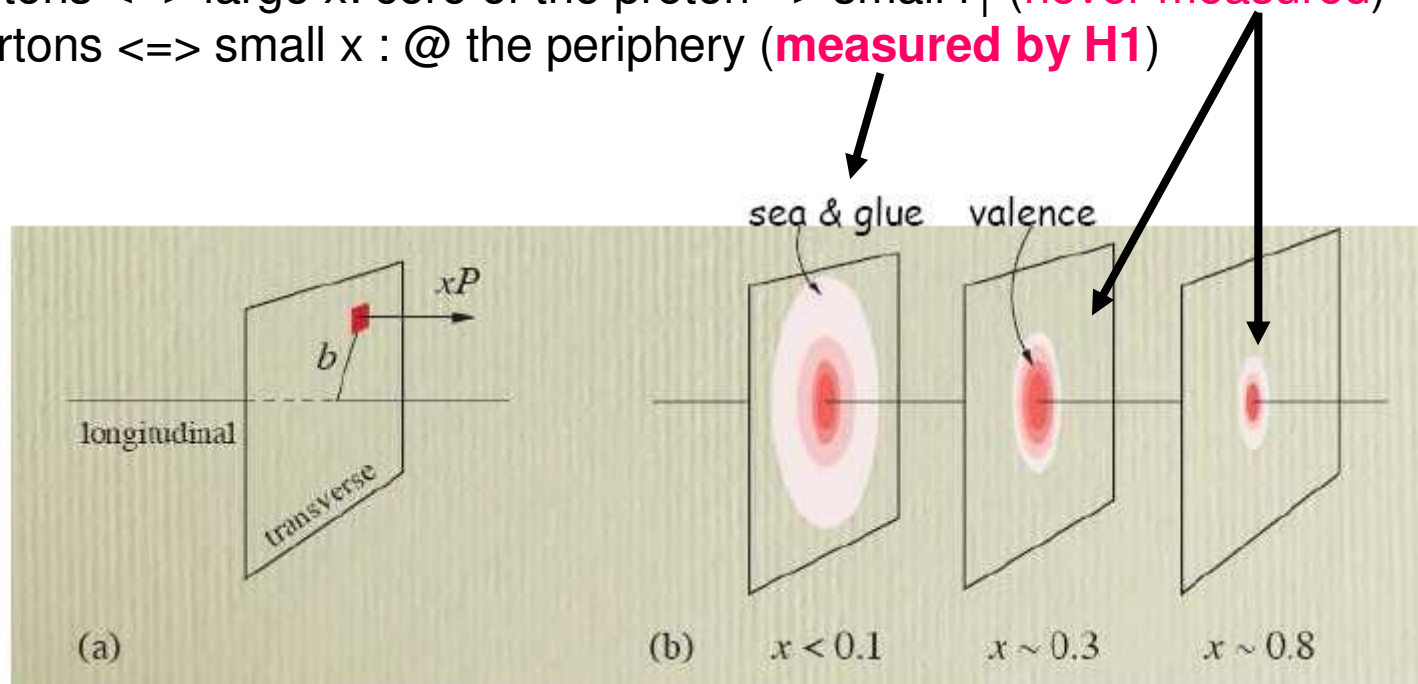


# A non trivial prejudice

We expect a dependence in  $x$  of the the transverse size filled up by partons( $x$ ):

Fast partons  $\Leftrightarrow$  large  $x$ : core of the proton  $\Rightarrow$  small  $r_T$  (never measured)

Slow partons  $\Leftrightarrow$  small  $x$  : @ the periphery (measured by H1)

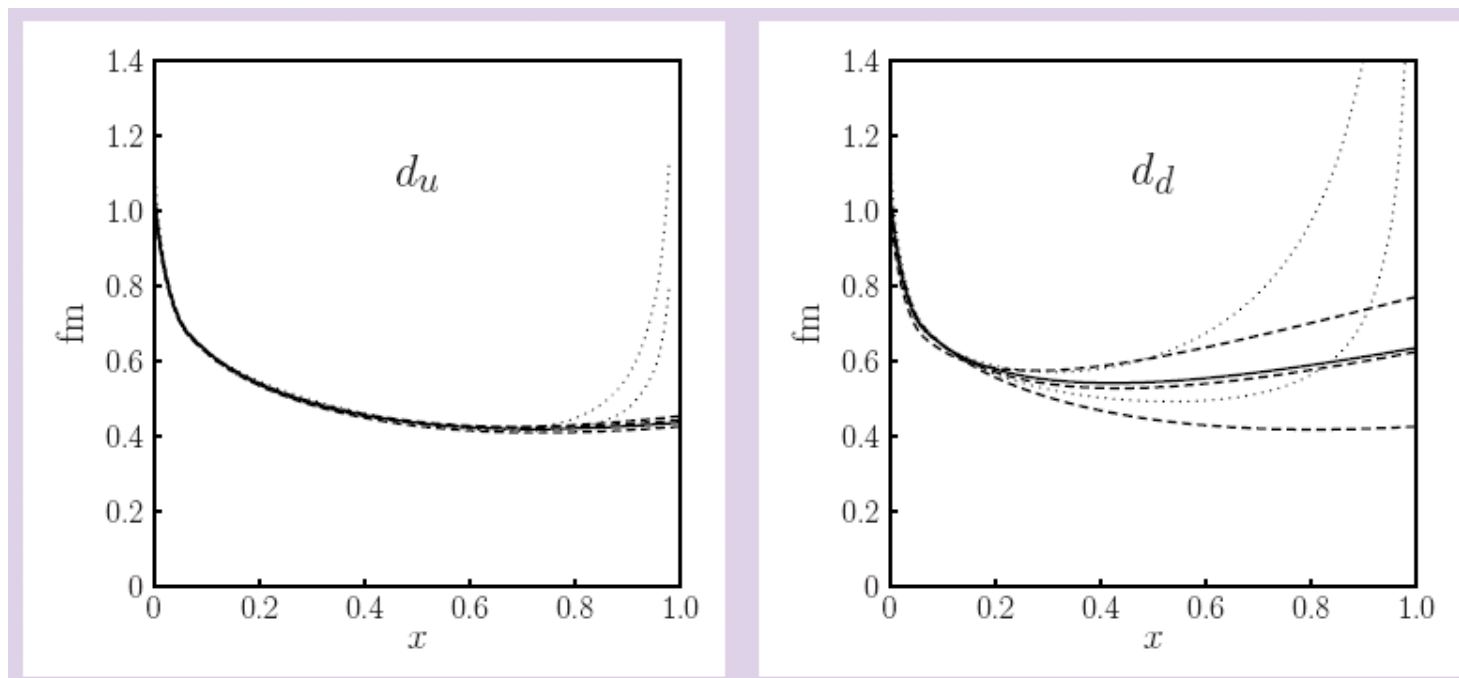


We need to see this  $x/r_T$  correlation within a single observable!  
Very rich physics content & insight for nucleon structure:  
**HOW IT IS BUILT UP BY PARTONS?**

# Indirect quark imaging (some comments)

Diehl & al. (// *Guidal & al.*) have fitted the **Form Factors  $F_1$  &  $F_2$**   
& assuming general  $t$  dependences with  
 **$b(x) == a (1-x)^3 \ln x + b (1-x)^3 + c x(1-x)^2$**

notation  $d_q :=$  transverse size by  $q = [2b(x_{Bj})/(1-x_{Bj})^2]^{1/2}$



This indirect analysis confirms that  $\langle r_T^2 \rangle$  is a function of  $x$  for valence quarks => **sensitivity of the analysis essentially @ medium/large  $x$ .**  
(it would be nice to have a direct measurement)

# A solution to the prejudice

Measure the real part of the DVCS amplitude:

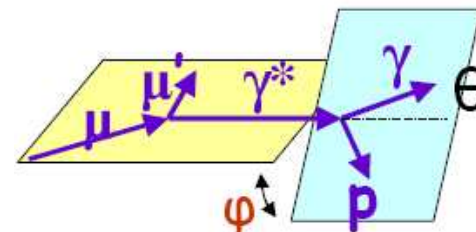
$$\text{Re}(M) \sim \text{P.P.} \int dx [1/(x-x_{Bj}+i\epsilon)] \text{GPD}(x,\dots,t) + \text{c.t.}$$

~ Beam Charge Asymmetry (BCA)

Let's admit this fundamental relation for this talk...

=> Obviously directly sensitive to  $x/t$  ( $\Rightarrow x/r_T$ ) correlations!

=> Essential dedicated experiment  
@ COMPASS with  $\mu^+$  &  $\mu^-$  beams:



**Proposal** on going for a presentation @ **SPSC** (CERN) this year?!

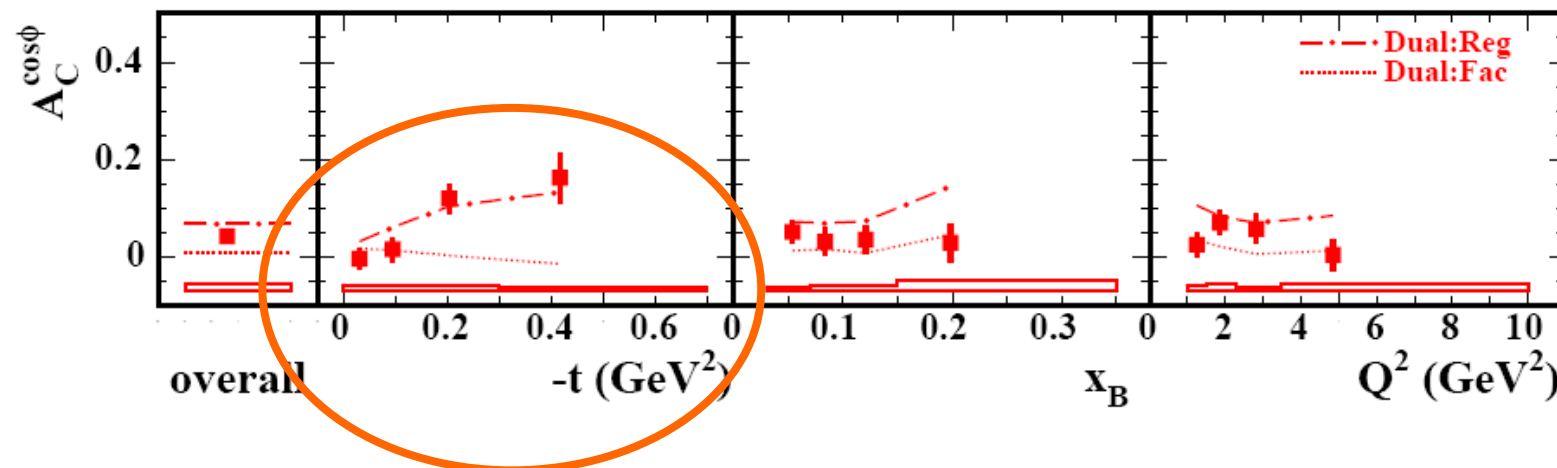
*Concerning BCA @ present experiments:*

First measurements done @ HERMES (large  $x$ ) & H1 (low  $x$ )  
are encouraging [see talks @ this workshop]



# BCA @ present experiments: short comments

**BCA @ HERMES** last result: favors a non-fact approach



**BCA @ H1** has been discussed in the previous talk. Another view =>

From BCA & DVCS cross section, we can determine a key observable:  $\eta = \text{Re}(a_{\text{DVCS}}) / \text{Im}(a_{\text{DVCS}})$

**BCA converted @  $t=0 \text{ GeV}^2$  & DVCS xs =>  $\eta \sim 0.23 \pm 0.10$**   
(a large value favors a non-fact. approach)

**&& to get a confirmation of this value:**

We have another way to extract this ratio from dispersion relations:

$\rho = \text{Re}(a_{\text{DVCS}}) / \text{Im}(a_{\text{DVCS}}) == \tan(\pi/2 \delta/4)$  @ low x with  $\sigma_{\text{DVCS}} \sim W^\delta$

**=>  $\eta \sim \tan(\pi/2 \cdot 0.7/4) = 0.28 \pm 0.07$**

# COMPASS prospects

## Beam Charge Asymmetry for various $Q^2$ & $x$ @ COMPASS

Simulation done for:  
100 GeV muon(+/-) beams  
 $L = 1.3 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$   
 $\Leftrightarrow$  6 month data taking  
with 25 % global efficiency

& 2 models:

Blue line:

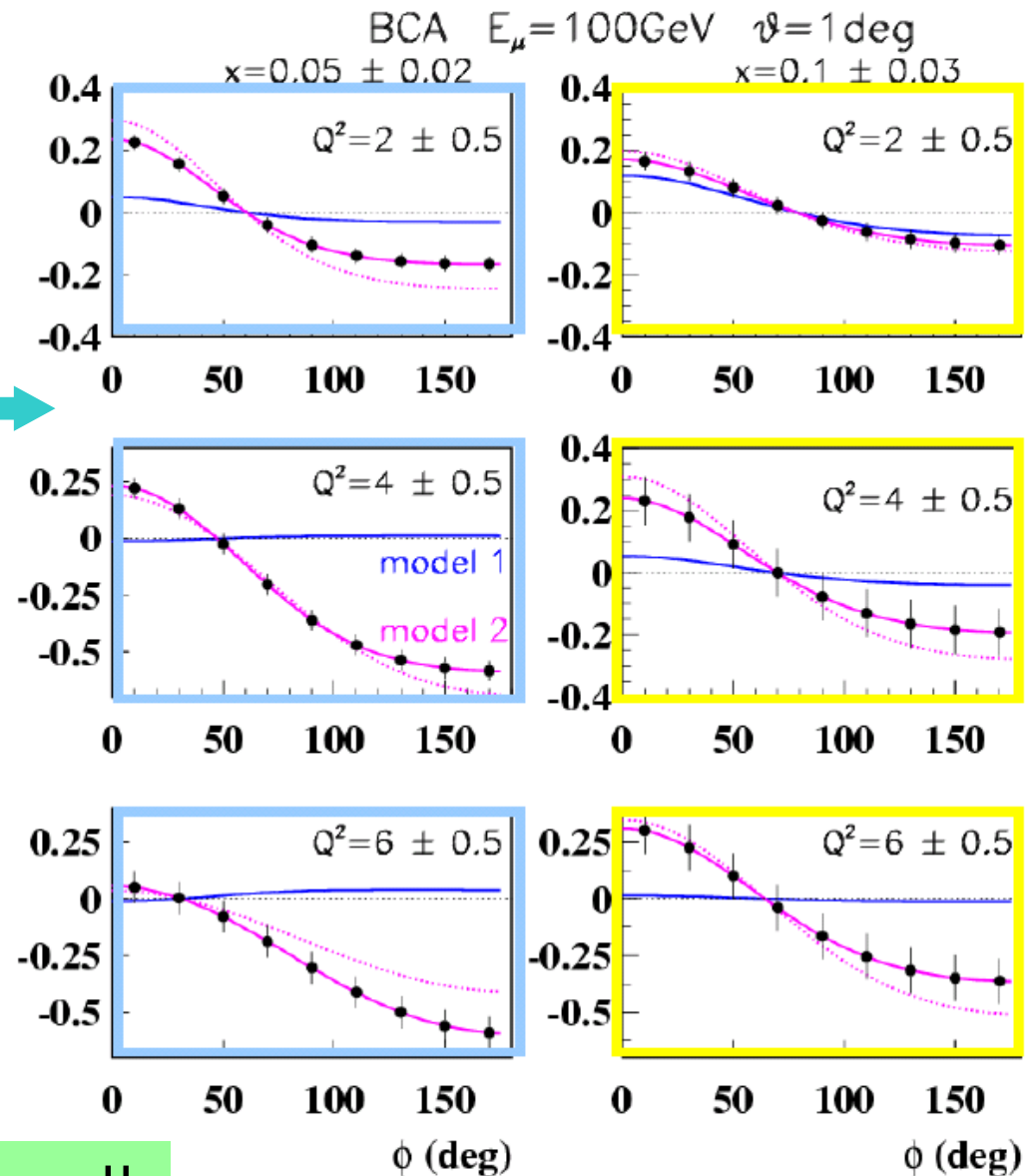
Factorised t-dependence

$\Rightarrow$  no correlation in  $x/t$

Pink line:

Non-factorised model

$\Rightarrow$  Correlation in  $x/t$



The answer can not be missed!

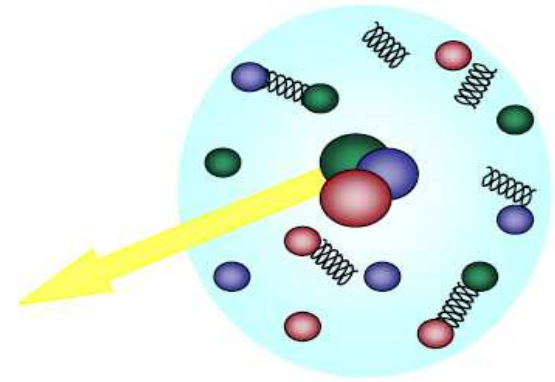
# Conclusions & Outlook

With DVCS we get an access to the fundamental structure of the nucleon:

=>

**How it is built up by partons(x)?**

beyond the standard momentum spectrum ( $F_2$ )



It is possible only when we can measure  $t$  &  $x_{Bj}$  with a good precision & we need to access an observable sensitive to the  $x/t$  correlations!

Beam Charge asymmetry @ COMPASS is then the promising dedicated experiment to address this fundamental physics issue!

*after the first results obtained @ HERA...*