

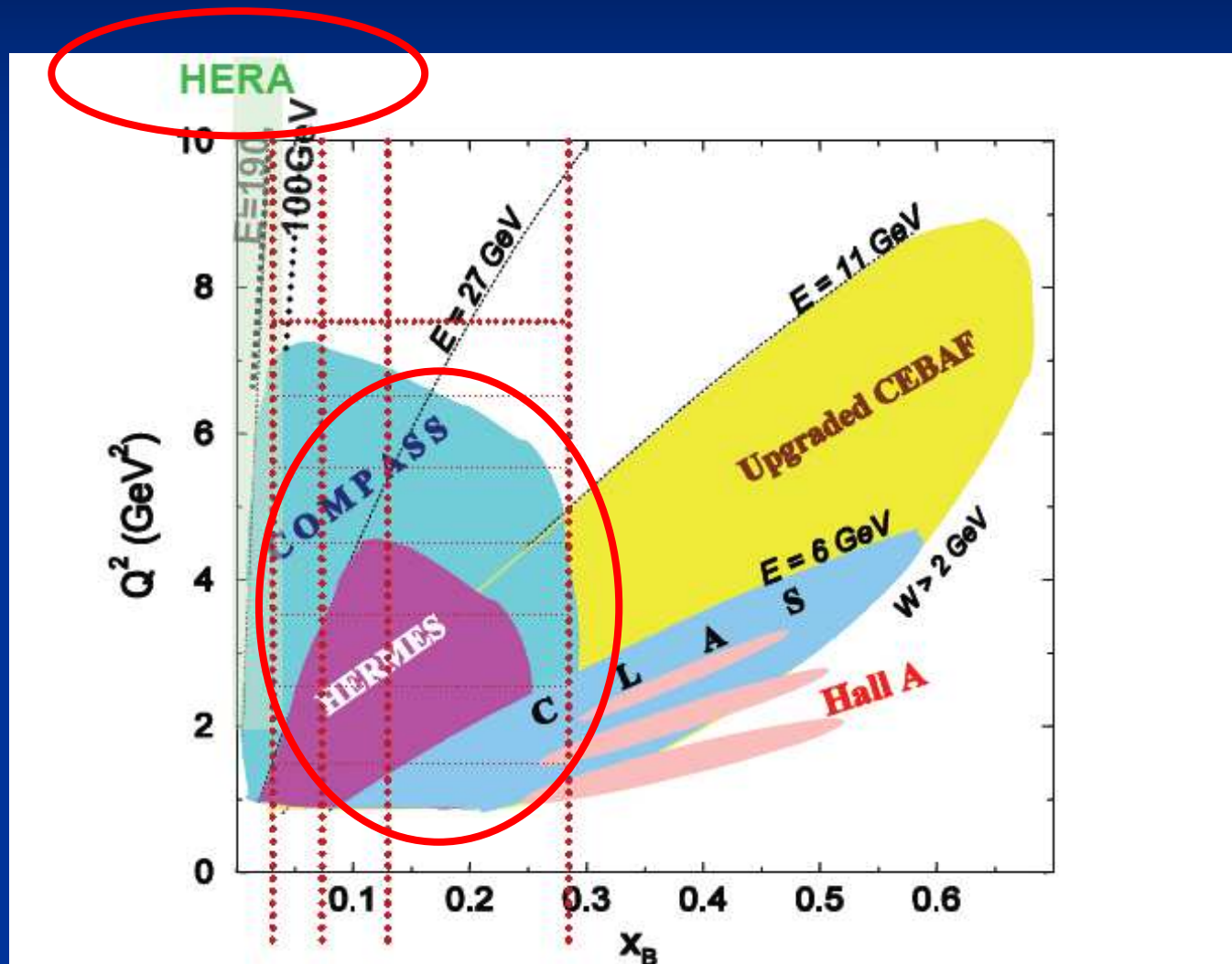
DVCS at HERA

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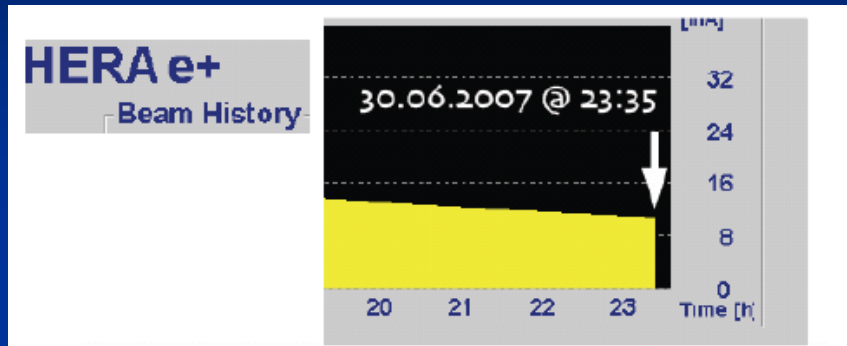
On behalf of **H1 & ZEUS** collaborations

Trento – 10/06/2008

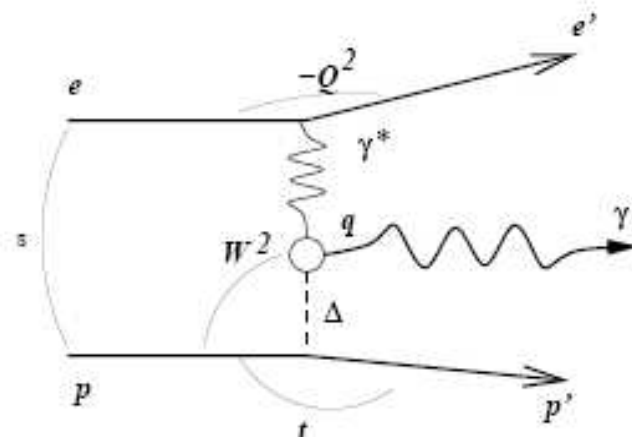
DVCS around the word present & future



DVCS kinematics @ HERA



DVCS: QCD process



$$s = (e + p)^2$$

$$Q^2 = -q^2 = -(e - e')^2$$

$$W^2 = (q + p)^2$$

$$t = \Delta^2 = (p - p')^2 \approx -p_T'^2$$

DVCS at HERA (H1/ZEUS)

some basic characteristics

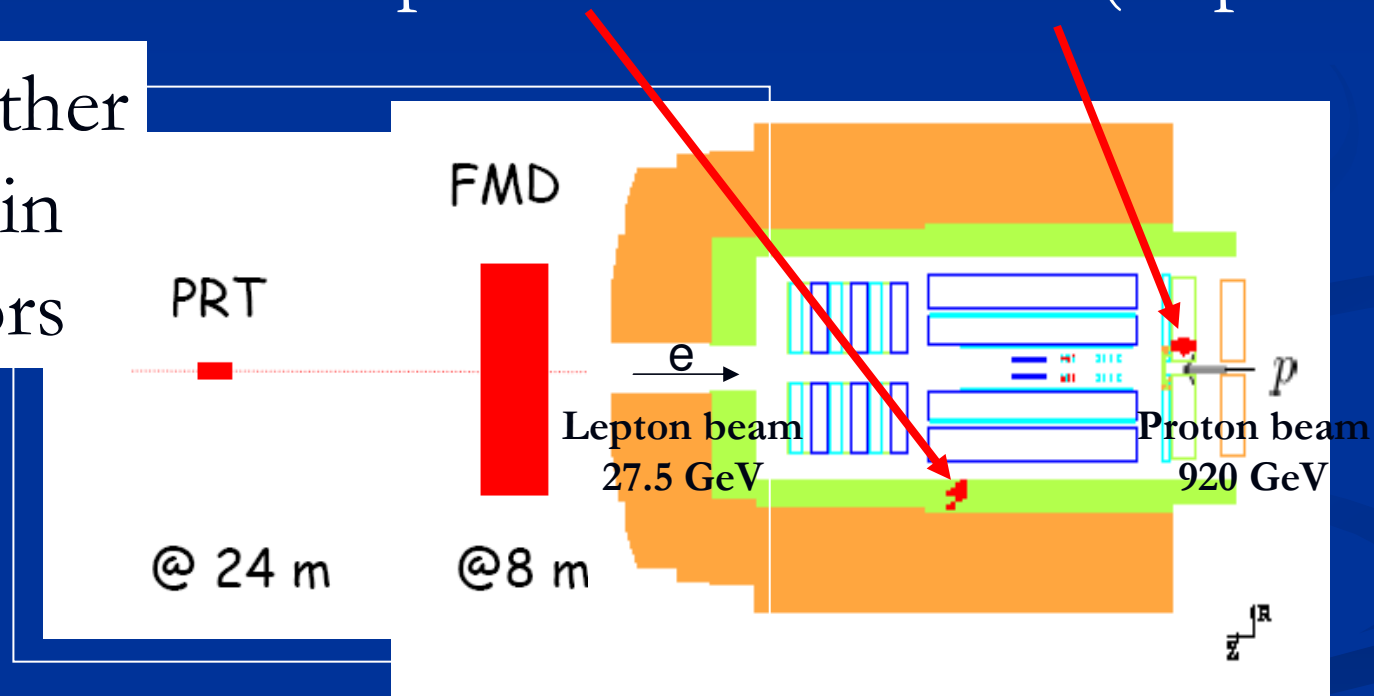
- Low x kinematics ($x < 0.01$) : large gluon density, saturation effects?!
- Large Q^2 range: from 2 GeV^2 till 100 GeV^2 : possibility to test scaling violations in Skewed PDFs (or GPDs) dynamics
- At low x & medium Q^2 , DVCS cross section is larger than BH cross section! Interesting feature which allows direct measurement of DVCS x s

DVCS at HERA

What do we measure?

2 Electro-Magnetic clusters:
1 photon & 1 electron (or positron)

and no other
activity in
detectors

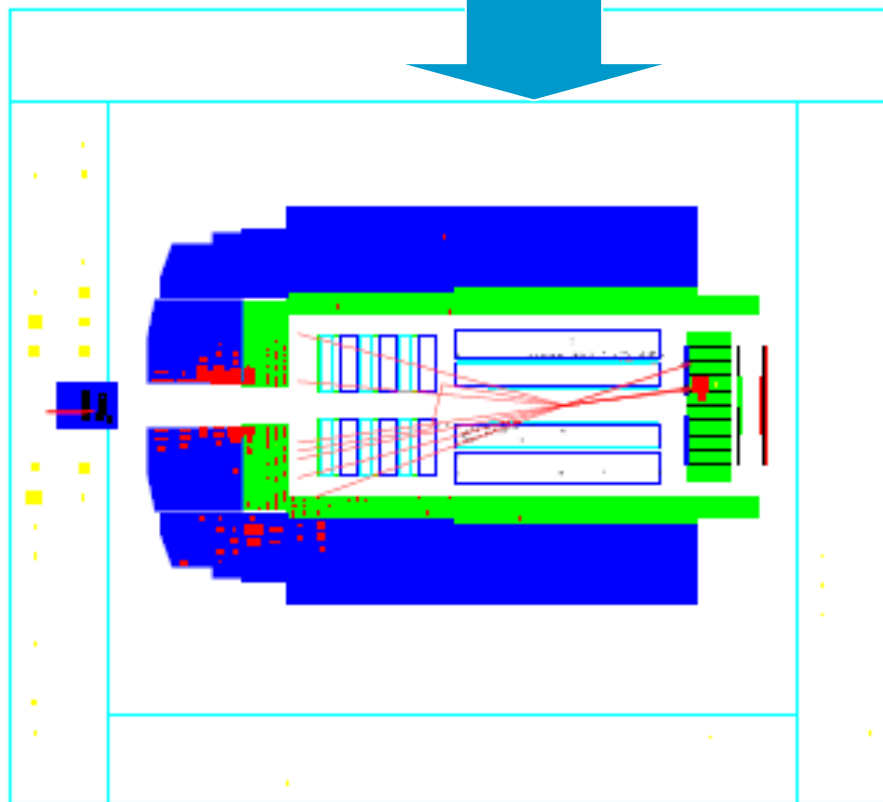
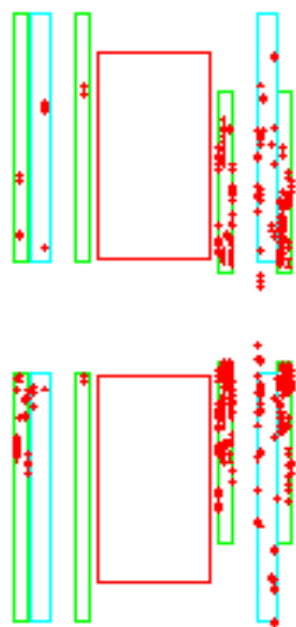


$$e + p \rightarrow e + \gamma + Y \quad Y \sim p'$$

DVCS at HERA

On the visibility of the signal?

Most DIS events @ low x presents some activity due to the proton break up



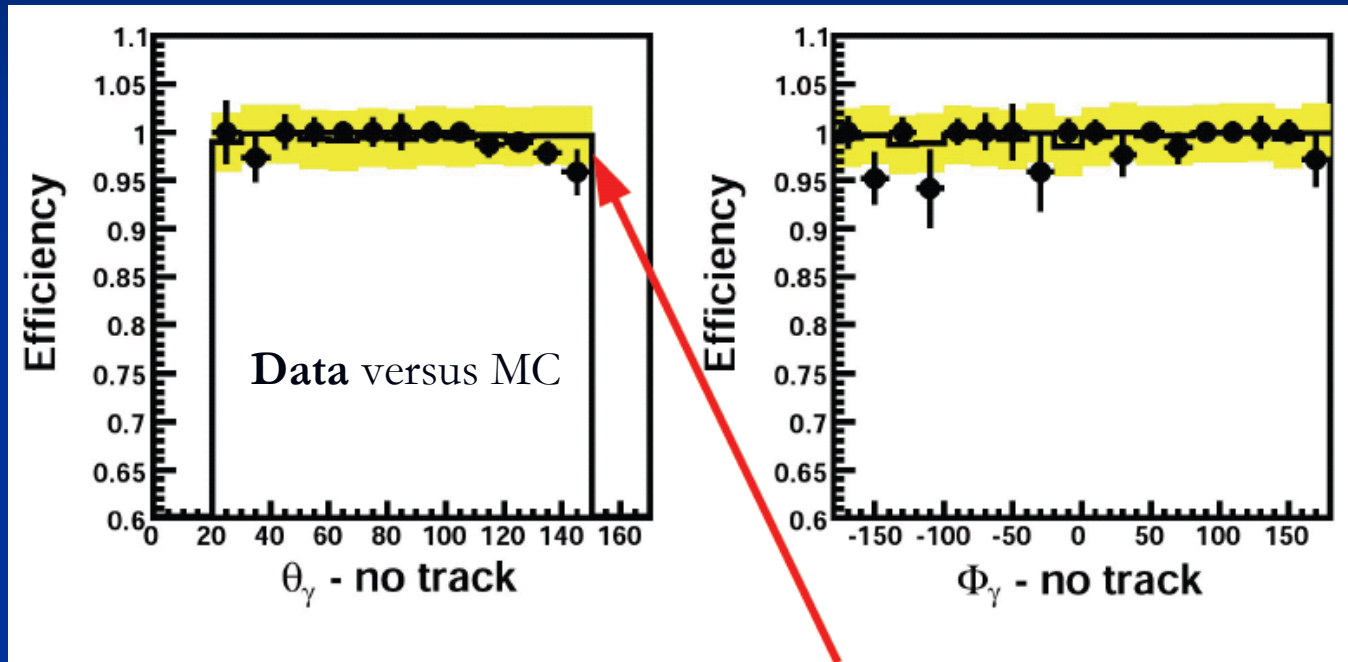
DVCS
represents
 $\sim 1/1000$
of the
DIS recorded
events

DVCS at HERA

experimental considerations

- Simple signal with 2 EM clusters: but simple is not easy!
- Not easy to trigger with a high efficiency 1 event out of 1000 standard DIS events recorded on tape
- Not easy to cope with low multiplicity DIS backgrounds: need to manage photon conversion, track reconstruction efficiency etc.

1 example: efficiency of γ identification in the central part of the detector



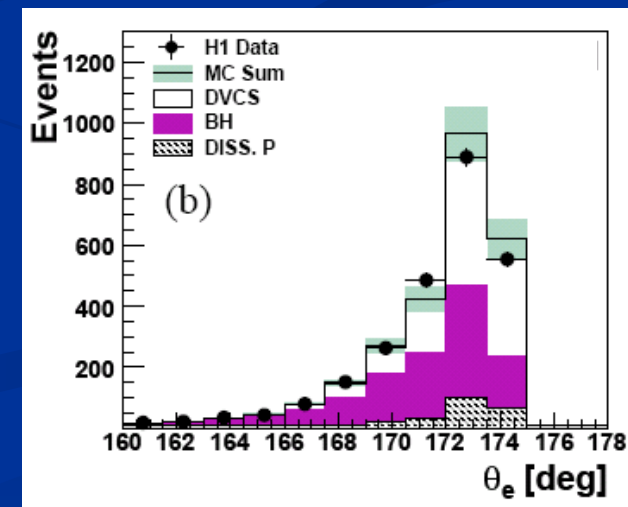
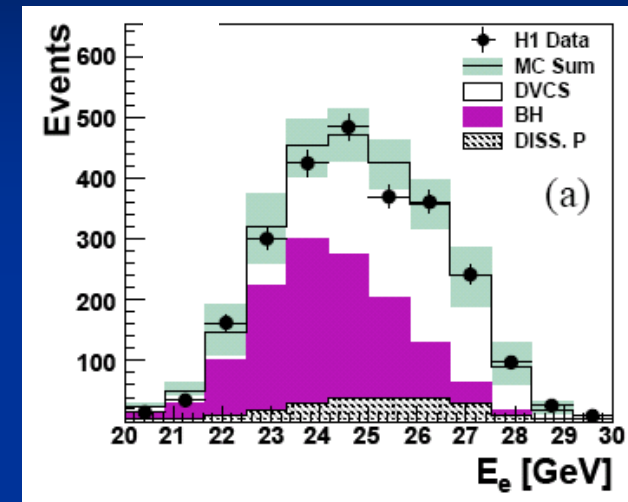
↘ Small correction applied to MC if $\theta_\gamma > 120^\circ$, to match efficiency observed in the data

↘ 3% of systematic error applied

DVCS at HERA

Results on control distributions

- Lepton variables
 - Good description by Monte-Carlo (MC) with 2 dominant contributions:
 - DVCS signal (ok)
 - BH background (irreducible)
- Note: interference contribution $< 1\%$ as we integrate over ϕ (lepton-proton azimuthal angle)

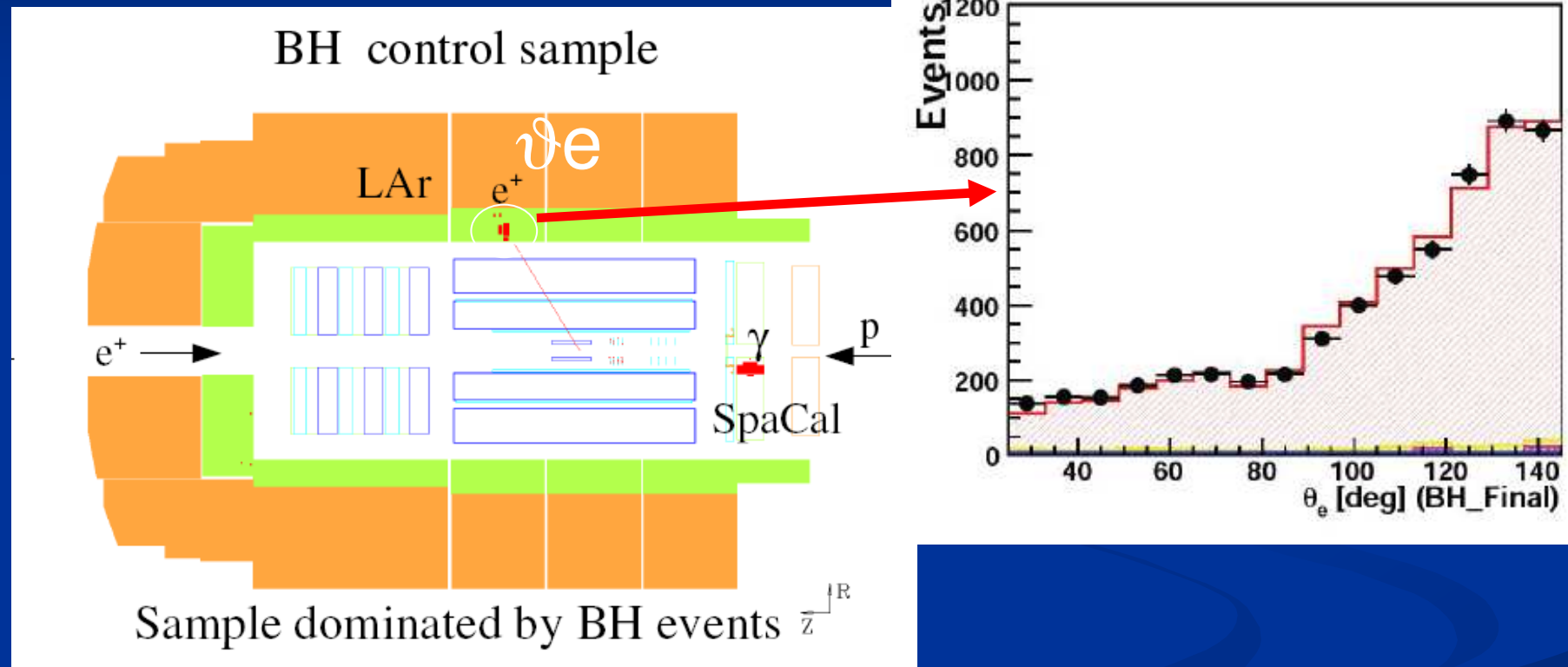


From data events to cross sections

- We measure N_{data} in a kinematic bin
- We need to **CORRECT** this number:
 - Ndata **corrected in** $N_{\text{data}} * N_{\text{gen}}/N_{\text{rec}}$
 - Then, we get the cross section!
 - The correction factor $N_{\text{gen}}/N_{\text{rec}}$ is calculated with the MC: it can be large ~ 1.5 or 2.
- Therefore, it is an obligation to start with Data/MC comparisons at the best level! No other way to do... **This is not for aesthetical purposes...**

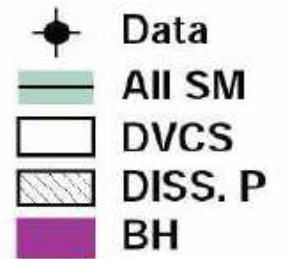


How do we control the BH component ?



Data	MC	DVCS ela.	DVCS pdis.	BH	e-e Grape	ρ	Satellites
5717	5714 ± 404	5.9 ± 0.7	1.0 ± 0.3	5430 ± 391	204 ± 12	67 ± 13	6.6 ± 2.2

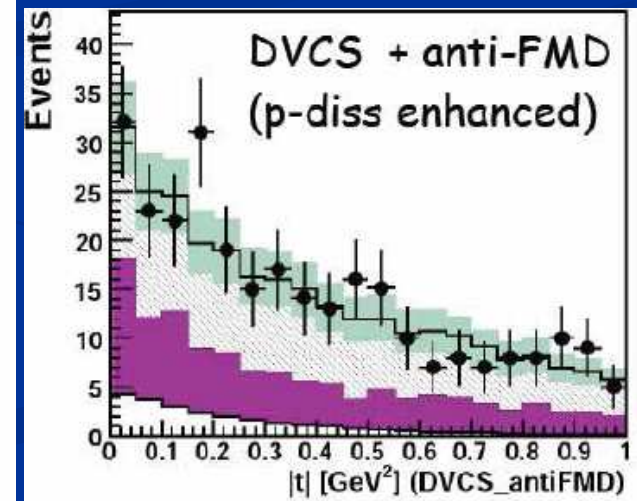
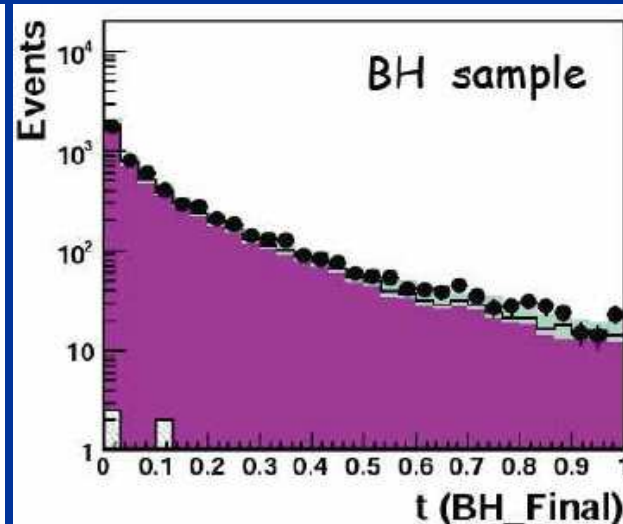
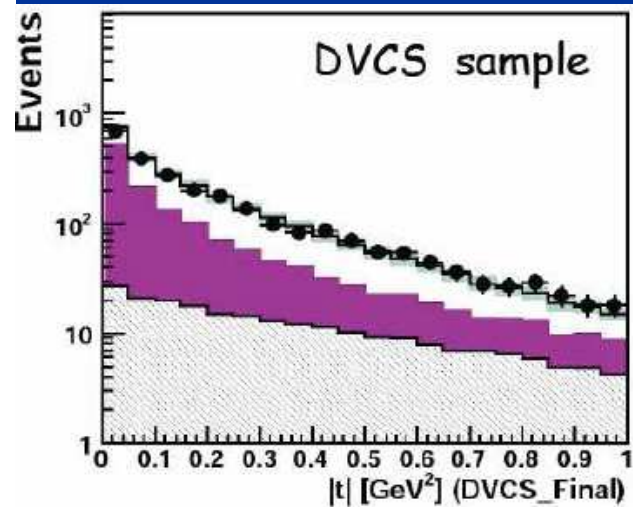
Backgrounds & MCs within the t -spectrum



DVCS signal sample

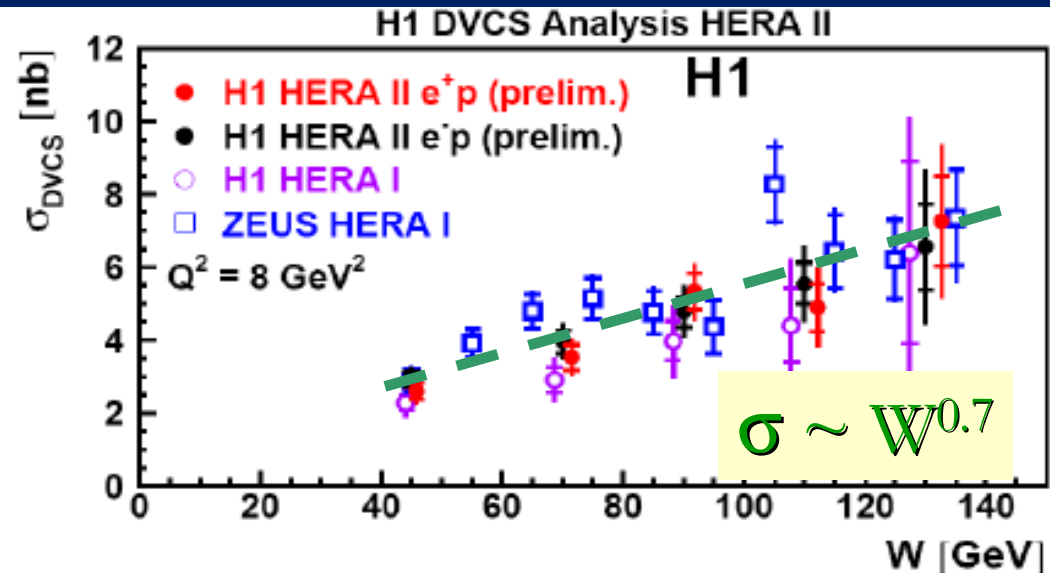
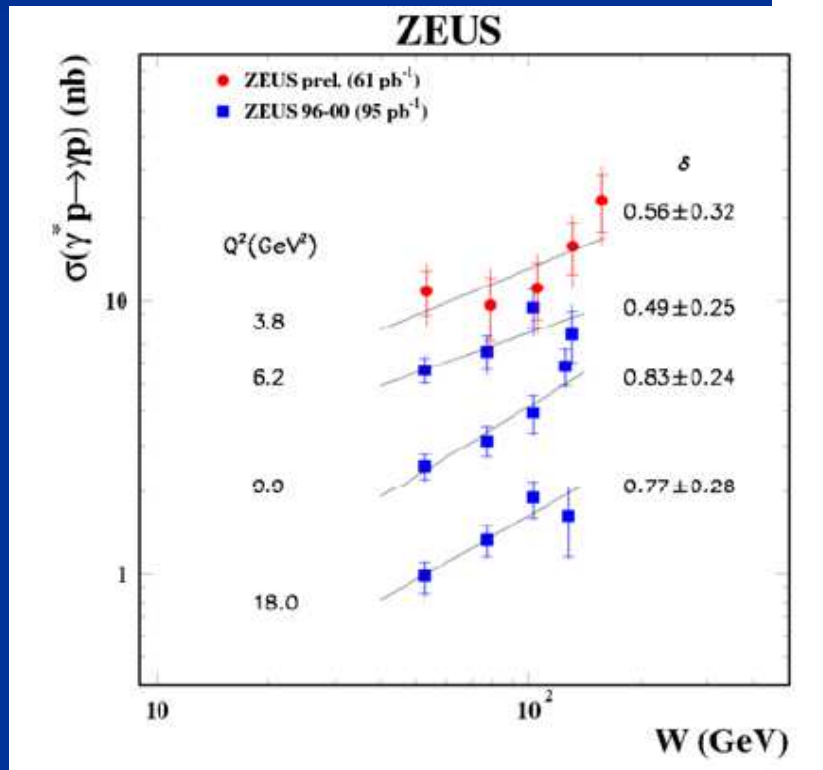
BH control sample

DVCS sample focused
On the large M_Y values
From it, we understand
this inelastic background



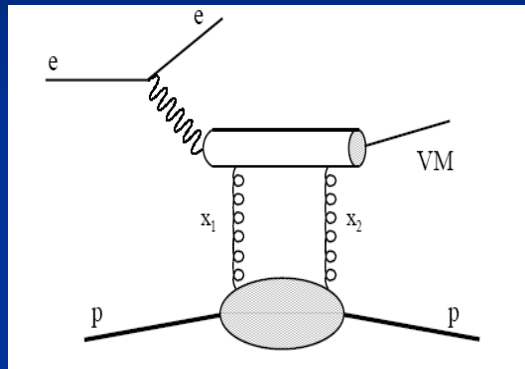
DVCS cross sections in W...

a first fundamental result

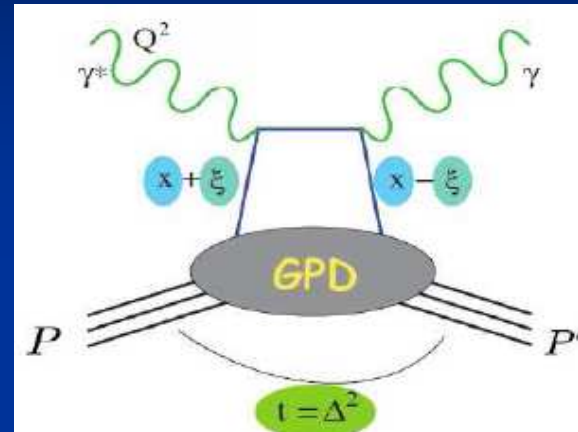


Hard W dependence
 => DVCS at HERA (low x)
 is a hard process...
 can be described (a priori)
 by pQCD...

DVCS versus Skewing: the prospects



VM \Rightarrow photon

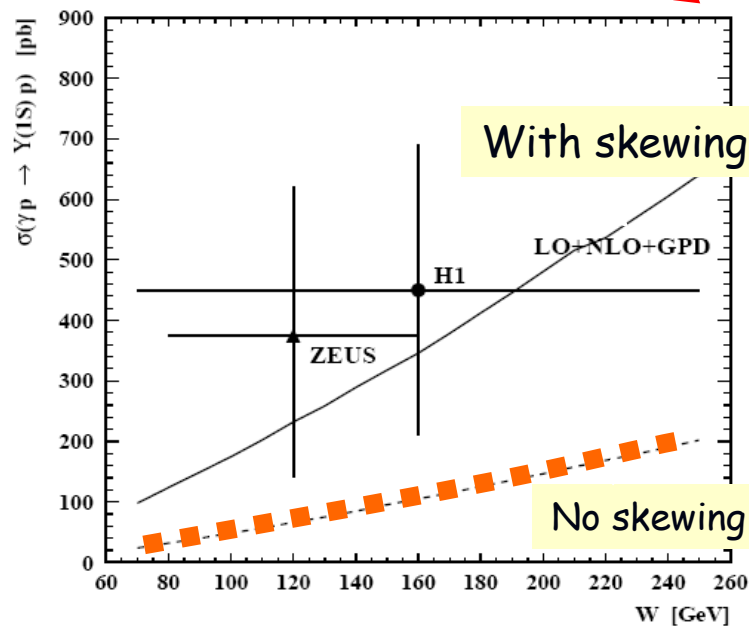


$$x_1 - x_2 \sim [Q^2 + M^2] / W^2 \Rightarrow \xi \sim x_{bj}/2$$

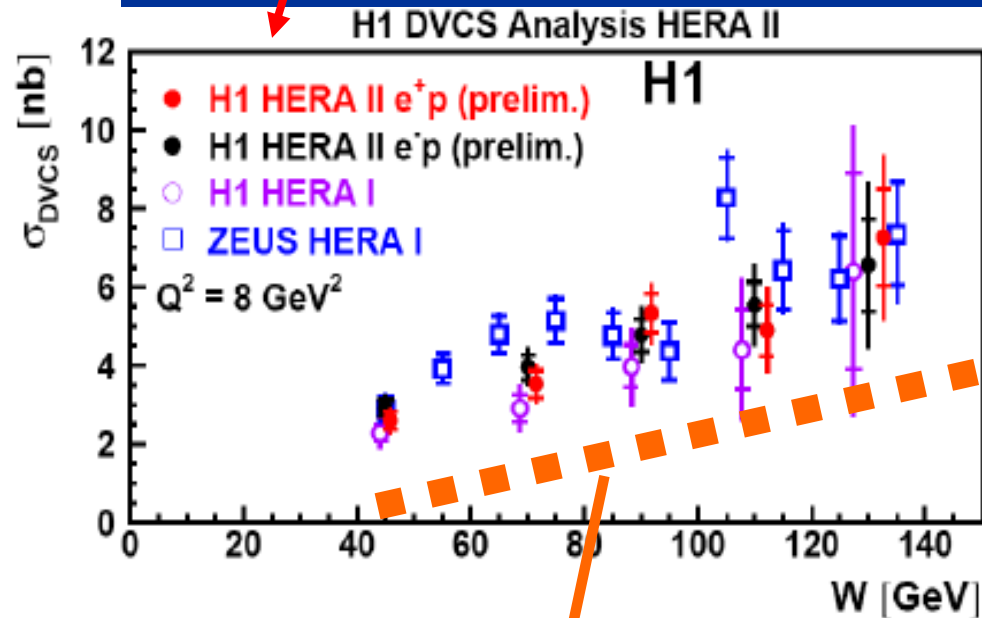
We expect skewing effects to be important
in VM & DVCS processes @ HERA
 \Rightarrow Replacement of PDFs by GPDs ?!

Skewing effects: the PROOF

The DVCS xs calculations include terms in $|GPD(x_1, x_2)|^2$ (skewing)
If we forget these effects, we replace GPD by PDF in calculations but it fails!



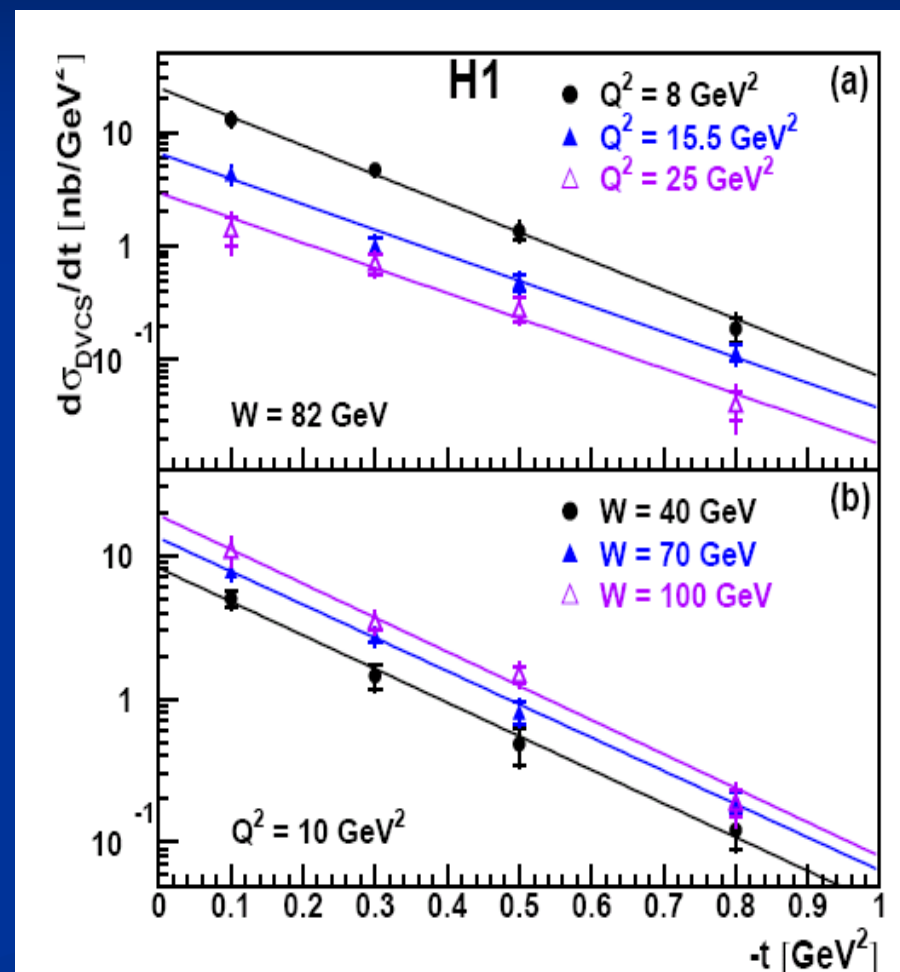
The first observation of
skewing (GPDs) impact



Prediction without skewing
a factor ~4 below the data

Measurement of the t dependence

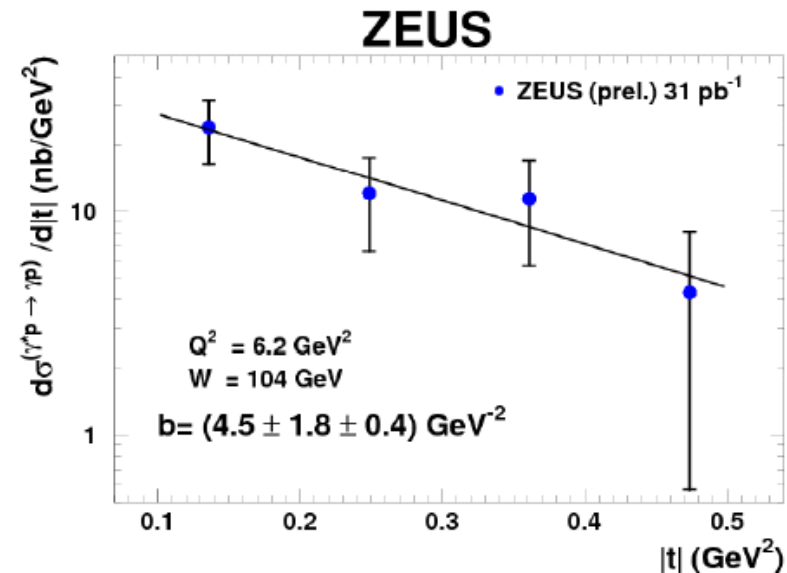
- As we observe, $d\sigma/dt \sim \exp(bt)$ where b is the effective t -slope in a given kinematic domain
- Then, $\sigma \sim 1/b$ (something) where « something » is proportional to GPD^2 ...
- Therefore, b measurement is essential to allow any data/theory comparison!



Measurement of the t dependence

Last result from ZEUS

Central value a bit lower
than the H1 result
but compatible within
the errors...

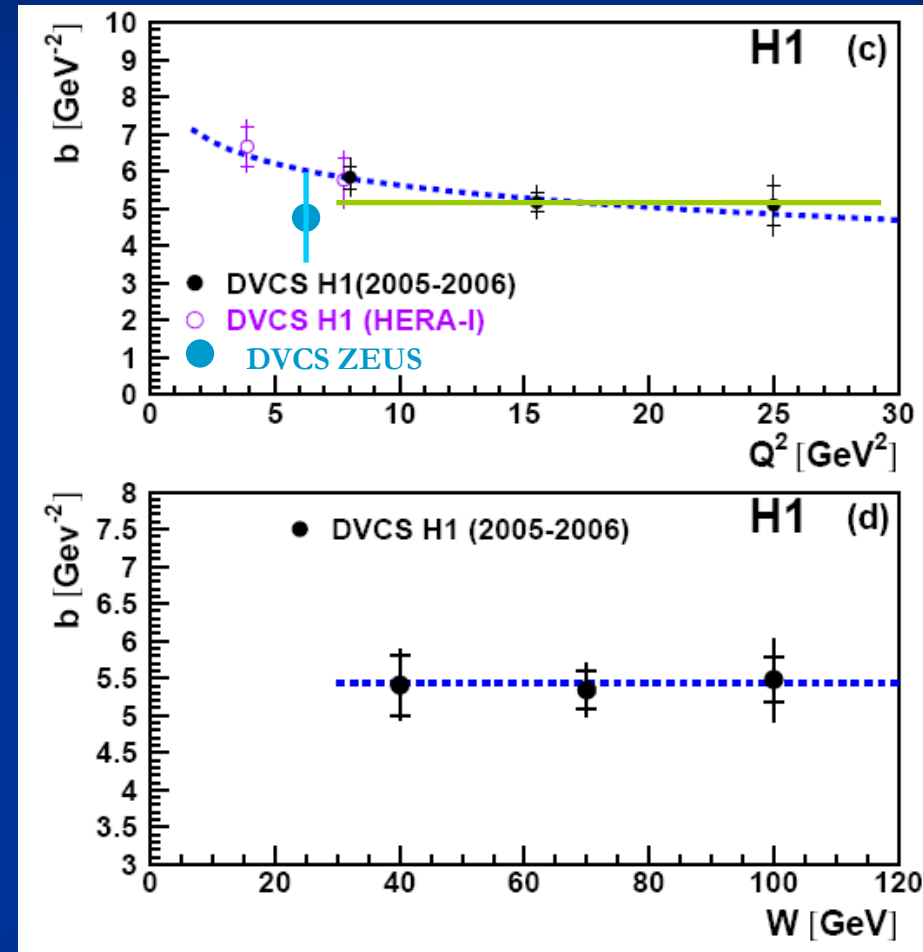


*First **direct measurement** of differential cross section as a function of t using LPS*

Measurement of the t dependence

What do we learn?

- @ low Q^2 : higher twists effects in $1/Q^2$: finite size of the $q\bar{q}$ pair probe?!
- @ large Q^2 : scaling in Q^2 ... we are really probing the proton structure with a « pointlike » $q\bar{q}$ pair configuration
- No dependence in W for the singlet part & the low x kin. domain...
More on this in 3 slides!



H1/ZEUS data & Lattice estimations

$$b = 5.45 \pm 0.19 \pm 0.34 \text{ GeV}^{-2}$$

$$\Rightarrow \sqrt{\langle r_T^2 \rangle} = 0.65 \text{ fm}$$

>> valence quarks value

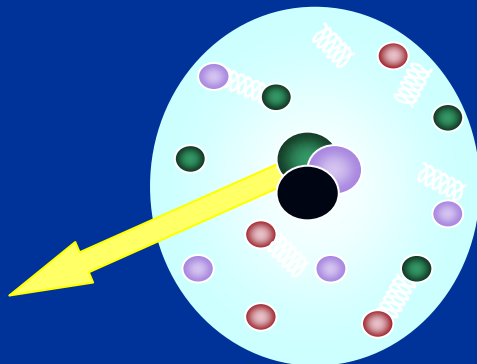
Smaller central value found by ZEUS but compatible within the uncertainty...

Lattice calculation (unquenched QCD):

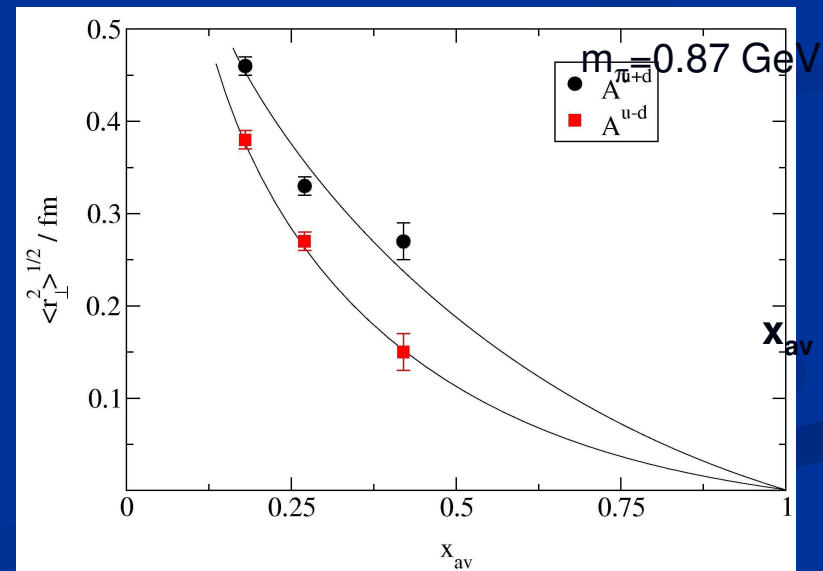
Negele *et al.*, NP B128 (2004) 170

Göckeler *et al.*, NP B140 (2005) 399

- fast parton close to the N center
≡ small valence quark core
- slow parton far from the N center
≡ widely spread sea q and gluons

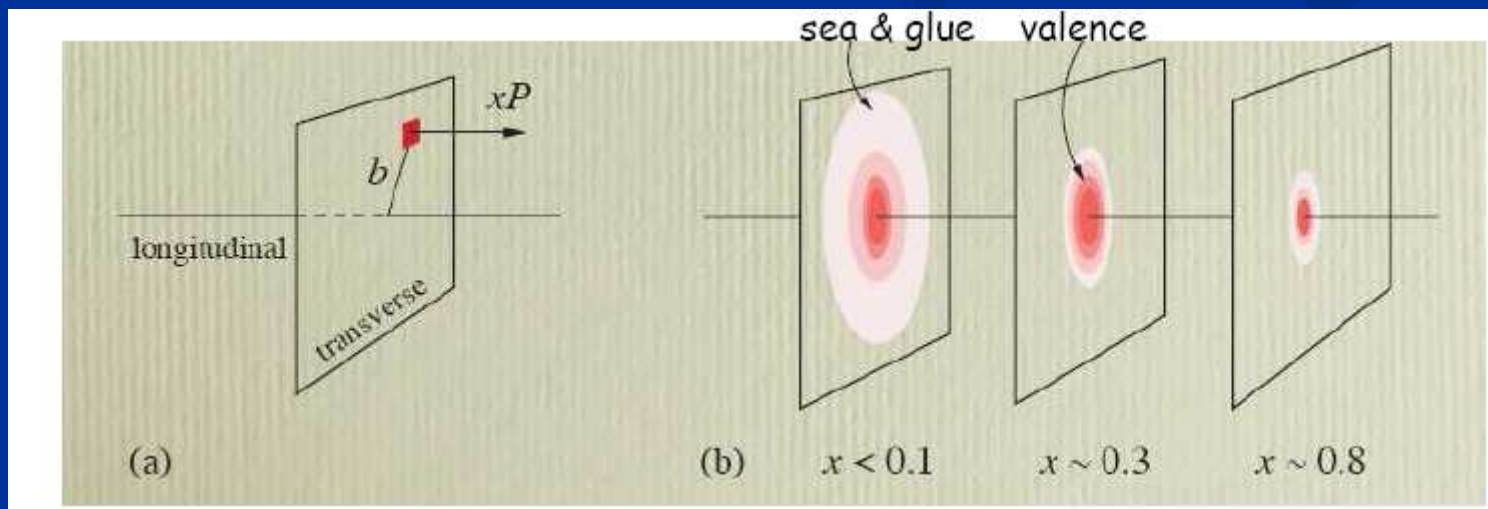


In agreement with « ideas » coming from Lattice QCD...



Some more picks from the t dependence...

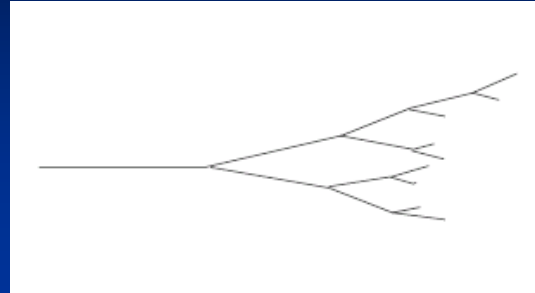
- Most probable scenario: t & x dependence are correlated and $d\sigma/dt \sim \exp\{(b_0 + \alpha' \ln(1/x))t\}$
- **With H1 DVCS results we access directly to b_0 & α' in a specific kin. domain ($x_B < 0.01$) => it has a direct consequence on the quark imaging in the proton (see plot below)...**



A brief status on α'

Gribov diffusion: parton branching as random walk in b space

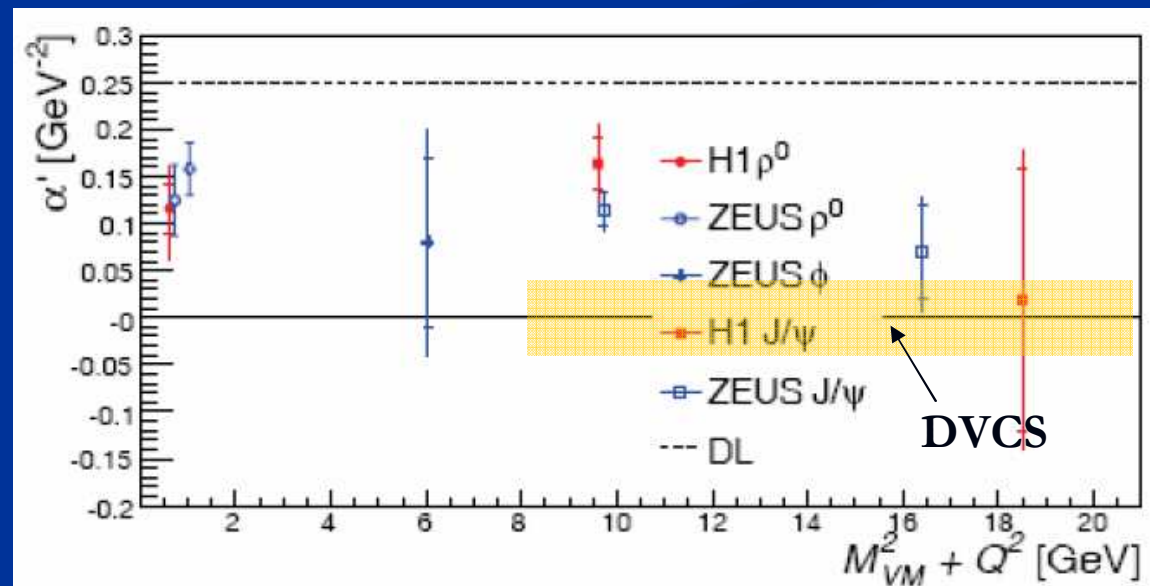
$$\rightarrow \langle b^2 \rangle \propto \alpha' \log(1/x)$$



We expect a non zero value of α' due to « basic » (Gribov) diffusion:
Emission of more & more partons... But @ large Q^2 , low x : results are different!

The 2D-size of a p-p system
grows 2 times faster
than the size of γ -p system
with $\ln(W)$
& the size of a $\gamma^*(Q^2 \text{ large})$ -p
system does not grow...

Not trivial Fact!



A way to measure x/t correlations with a single observable...

With 2 beam charges (e+ & e- @ HERA) we can measure the difference of DVCS cross section for these 2 beams (or the asymmetry)

$$\Rightarrow \text{Beam Charge Asymetry} == (\sigma(+)-\sigma(-))/(\sigma(+) + \sigma(-))$$

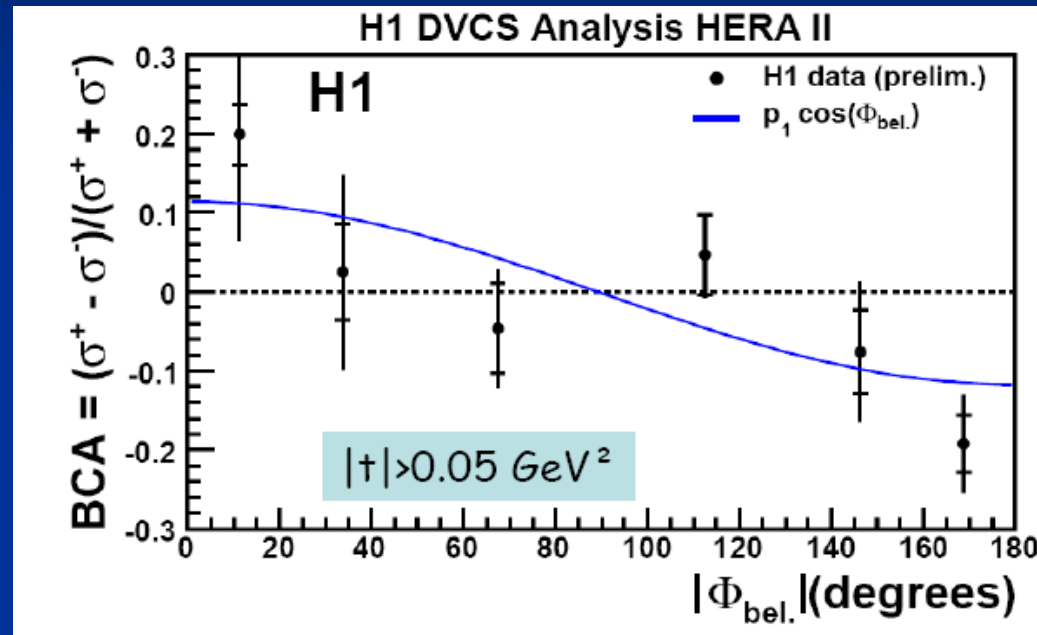
THEN

$$\text{BCA} \sim \text{Re}(M) \sim -\sum e_q^2 \text{P.P.} \int dx [1/(x-x_{Bj}+i\epsilon) - 1/(x+x_{Bj}+i\epsilon)] \text{GPD}(x,\dots,t)$$

Let admit this relation for this talk... (see theory talks for proofs)

\Rightarrow it gives directly a correlation between x & t
as for each t values, the integral covers the “all” x range (P.P.)

BCA in H1



Low $x_{Bj} \sim 0.005$

We extract a fit in
 $0.17 (+/-0.06) \cos(\phi)$

@ $Q^2 = 10 \text{ GeV}^2$

A non zero asymmetry has been extracted
 \Rightarrow It favors non-factorised x/t approaches! (under study)

Another look at this measurement

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

$$\Rightarrow \eta = 0.23 \pm 0.10 \quad (1)$$

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

$$\eta = \text{Re}(a_{\text{DVCS}}) / \text{Im}(a_{\text{DVCS}}) = \tan(\pi/2 \delta/4)$$

@ low x with $\sigma_{\text{DVCS}} \sim W^\delta$ with $\delta \sim 0.75$ (similar value for H1 & ZEUS)

$$\Rightarrow \eta = 0.28 \pm 0.07 \quad (2)$$

- Both values (1) & (2) are in good agreement \Rightarrow
Good confidence in the difficult BCA measurement...

Conclusions & Outlook

DVCS cross sections have been studied since almost 8 years @ HERA

It was a great experimental contest... where H1 & ZEUS contributed with success... **Data H1/ZEUS are based on very solid analysis grounds**

Still the complete set of data to be published in final papers...

The essential role of Skewedness (& thus GPDs) have been shown

A challenging measurement of BCA is under process

=>First evidence in the data that a non factorised approach is favored ?!

Thanks for your attention