The transverse size of the nucleon

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Plan

- description of models describing the transverse size of the nucleon (others than GPD models)

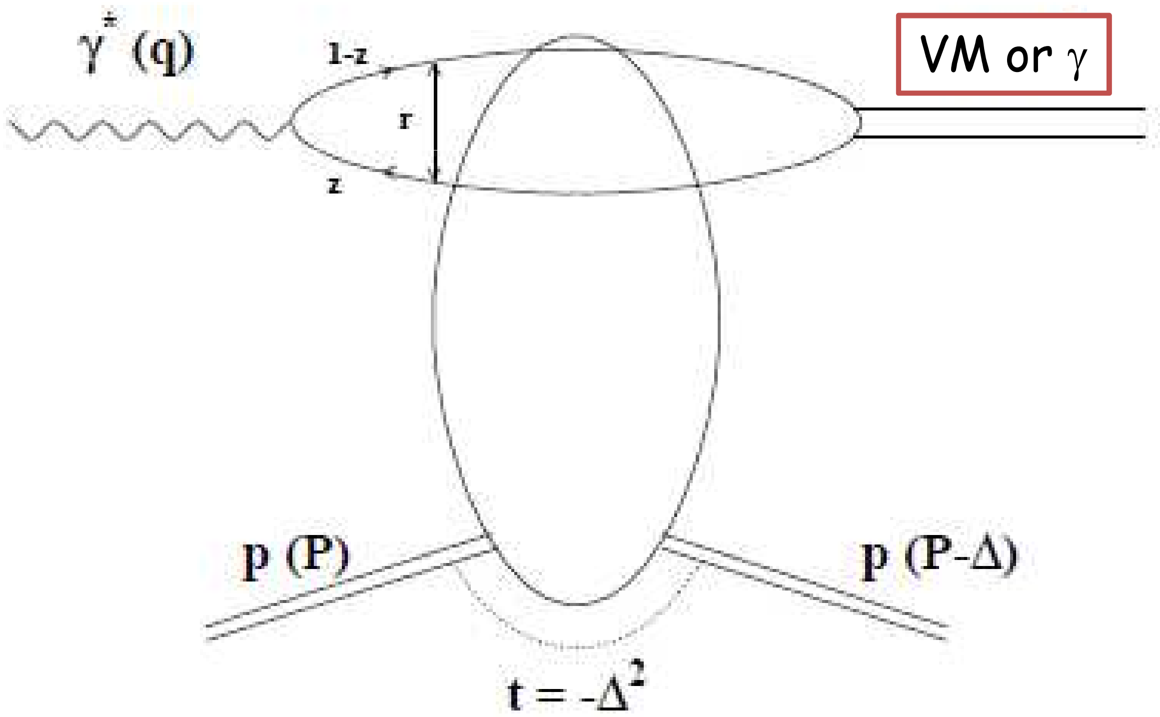
- status of experimental knowledge of today on transverse nucleon size

- expected impact of planned COMPASS measurements in this field (show projections for t-slope measurements)

Processes under study

Exclusive production of Vector Mesons or real photon (DVCS)
First part: at small x values x<0.01

Second part: dedicated measurement for DVCS at COMPASS (x~0.1)
with large statistics

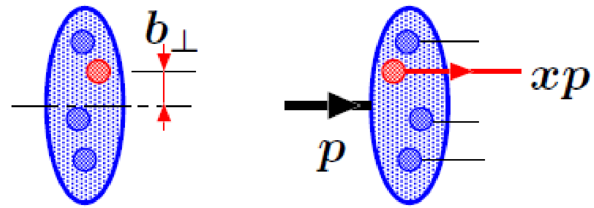


t is the momentum exchange (squared) at the proton vertex

Nucleon structure from the Basic principe

The Fourier transform of the square root of the cross section (VM) is directly related to the S matrix

$$S(x, r_Q, b) = 1 - \frac{1}{2\pi^{3/2} N(Q)} \int d^2\Delta e^{-i\Delta b} \sqrt{\frac{d\sigma}{dt}}$$



b (:=$b_\perp$) is the impact parameter in the proton
N(Q) is a flux factor (coming from the overlap of γ^* and VM wave function)

S tells us how how dense the nucleon looks like!
S=0 means blackness (unitarity limit)
and 1-S^2 is the interaction probability of the γ^* (or dipole) that hits the nucleon at impact parameter b

Program: Measure $d\sigma/dt$, extract S and then conclude on the proton structure

Result from ρ meson from HERA[Q^2]

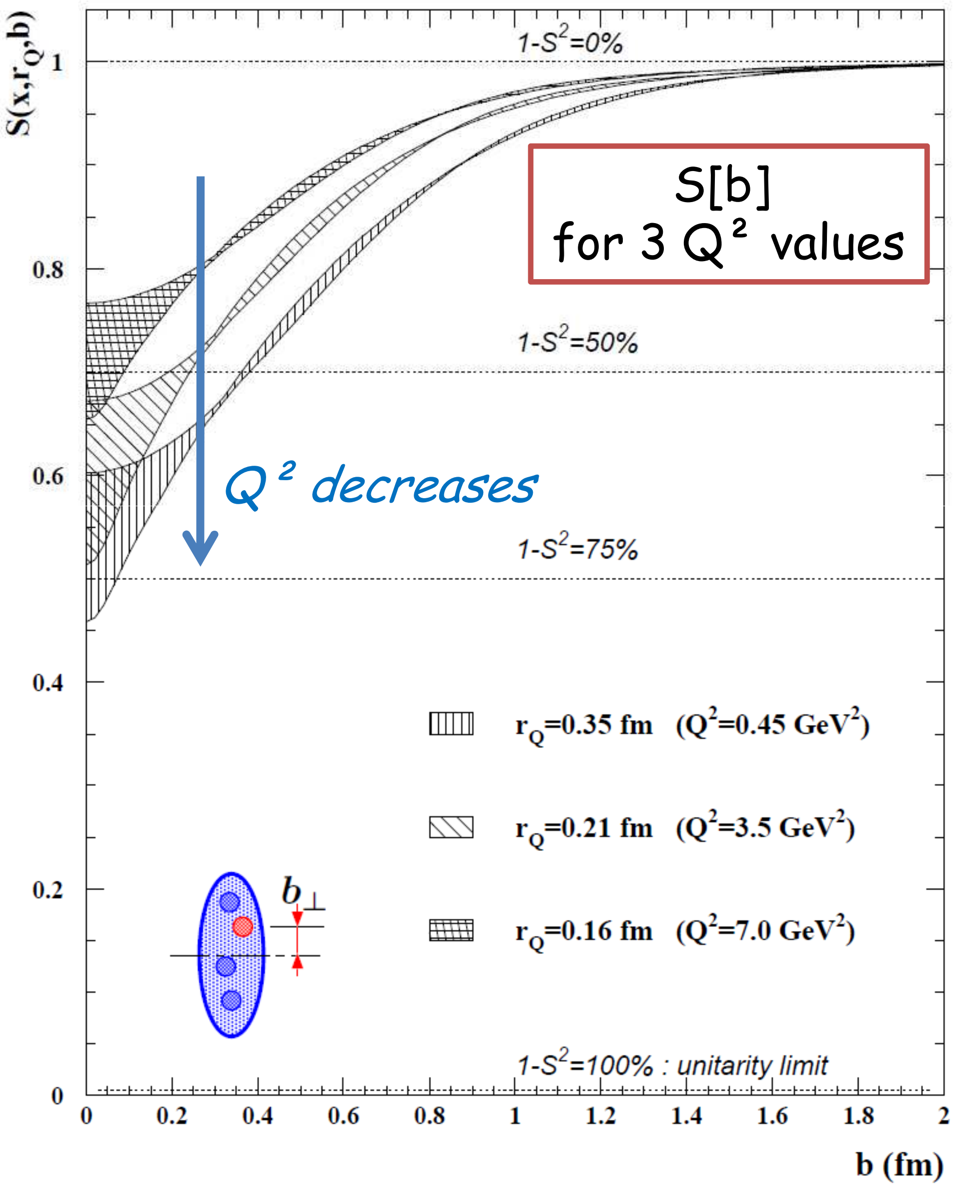
From Munier et al. + H1 exp.
note: analysis done for $x<10^{-2}$ with HERA data on ρ exclusive production

Large error at small b due to the lack of data for $|t|>0.6$ GeV^2

Interaction probability>50%(75%) in the center of the proton b<0.3 fm (« black disk »)

And then, proton is more transparent when b is increasing ('grey area')
(more transparent also at larger Q^2
-smaller dipole (probe) size-
similar to optics)

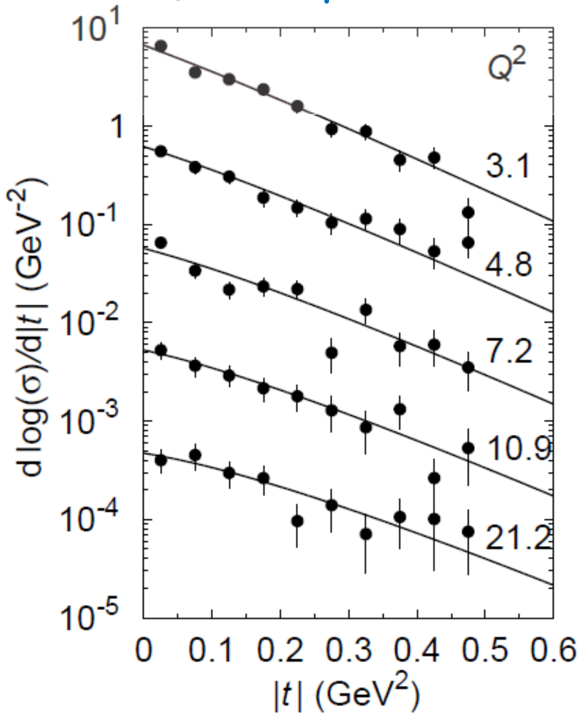
Similar results for J/ψ



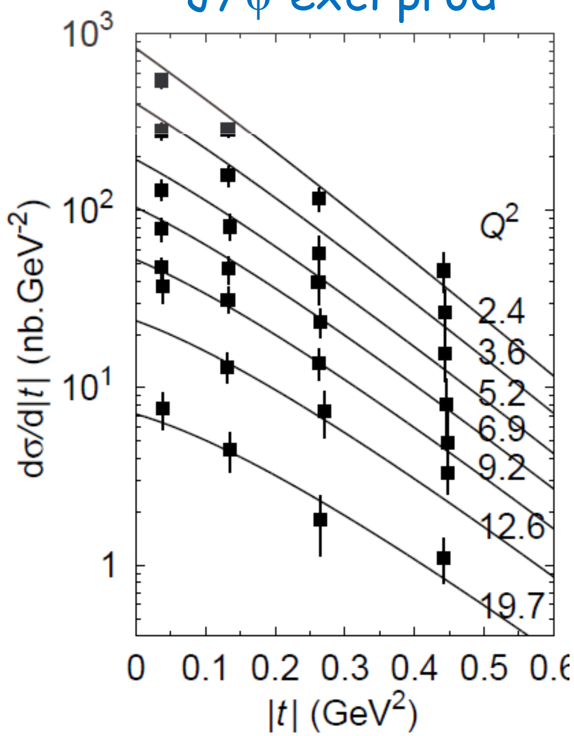
t-dependence measurements at HERA

Measurements done for all processes and various Q^2
The x range for these measurements is between 10^{-4} and 10^{-2}
We note also the good agreement with theory (dipole model)

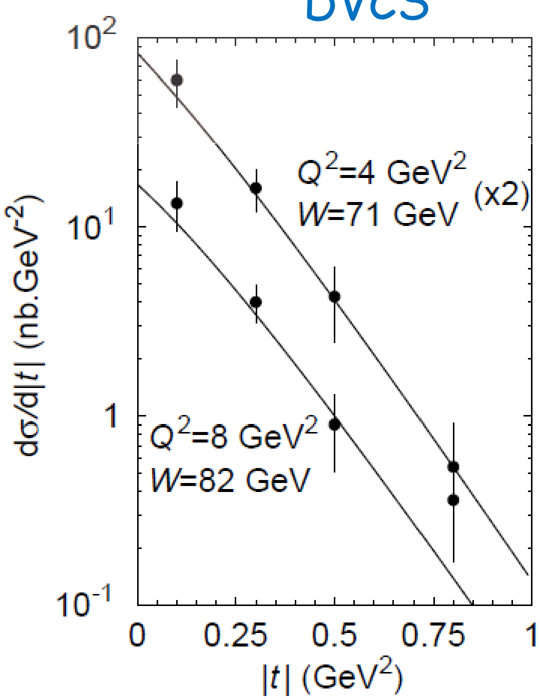
ρ excl prod



J/ψ excl prod

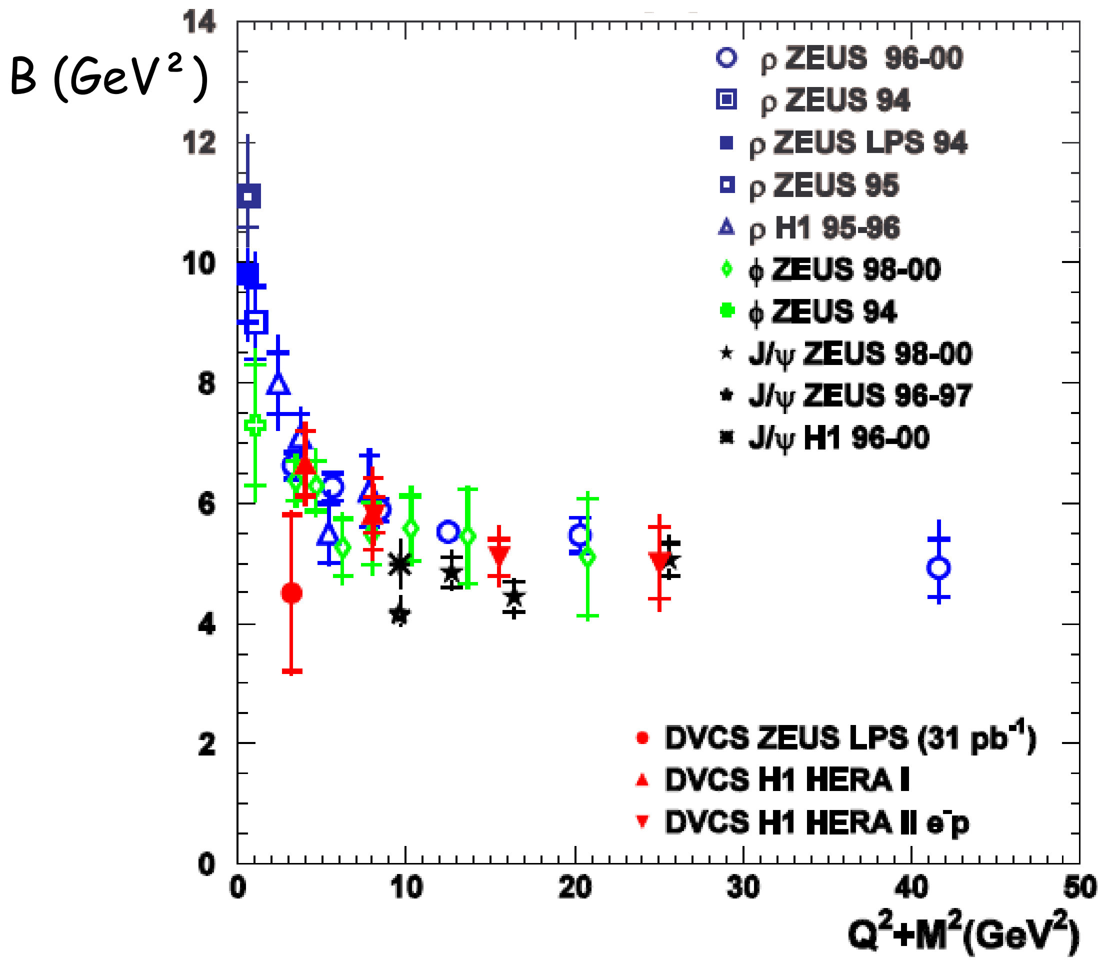


DVCS

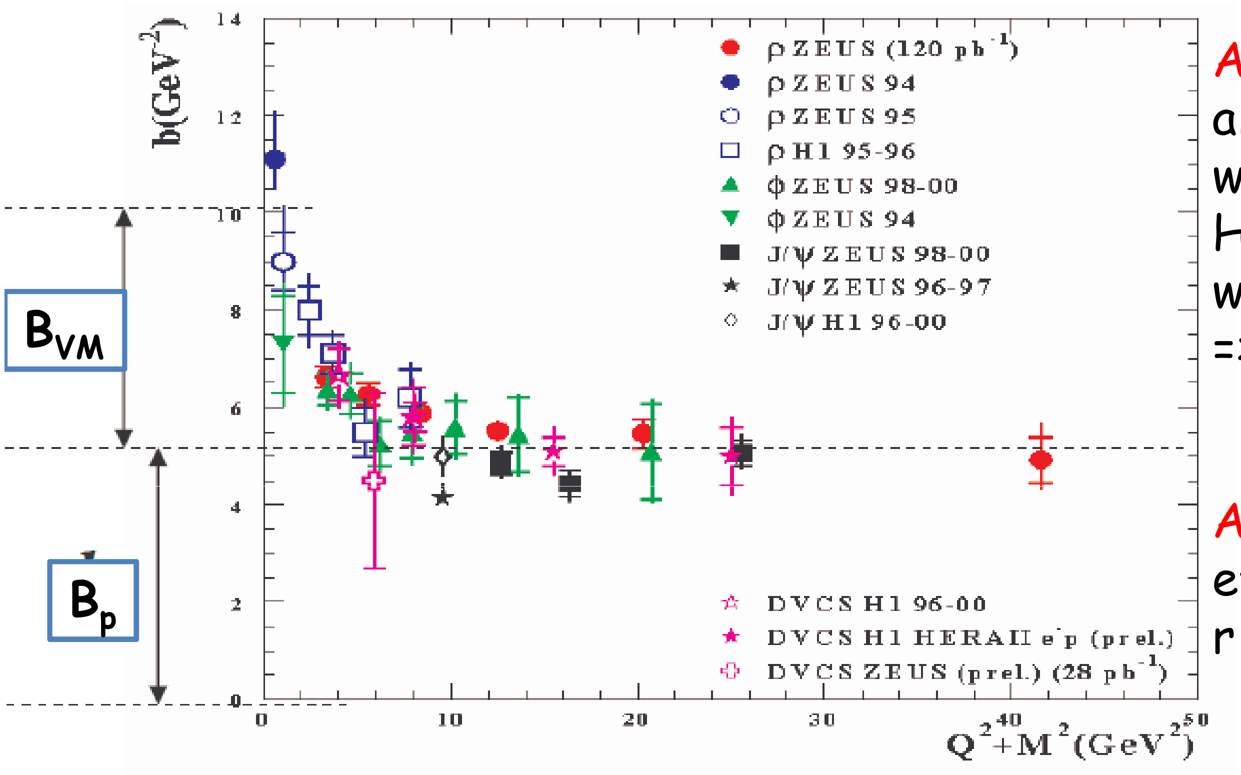


Compilation of t-slopes measurements from H1/ZEUS

From previous measurements we can parameterise the cross section as **$d\sigma/dt$ ~exp(Bt)** and then extract B values (t-slopes)



Interpretation of the t-slopes



At large Q^2>8 GeV^2
all measurements scale with Q^2 (B~5 GeV^{-2})
Here the proton is probed with a point-like configuration
=> It corresponds to the proton size

At small Q^2: we observe the effect of the VM size in $r^2 \sim 1/(Q^2+M^2)$

Then we can write the measured t-slope B as the sum of both contributions

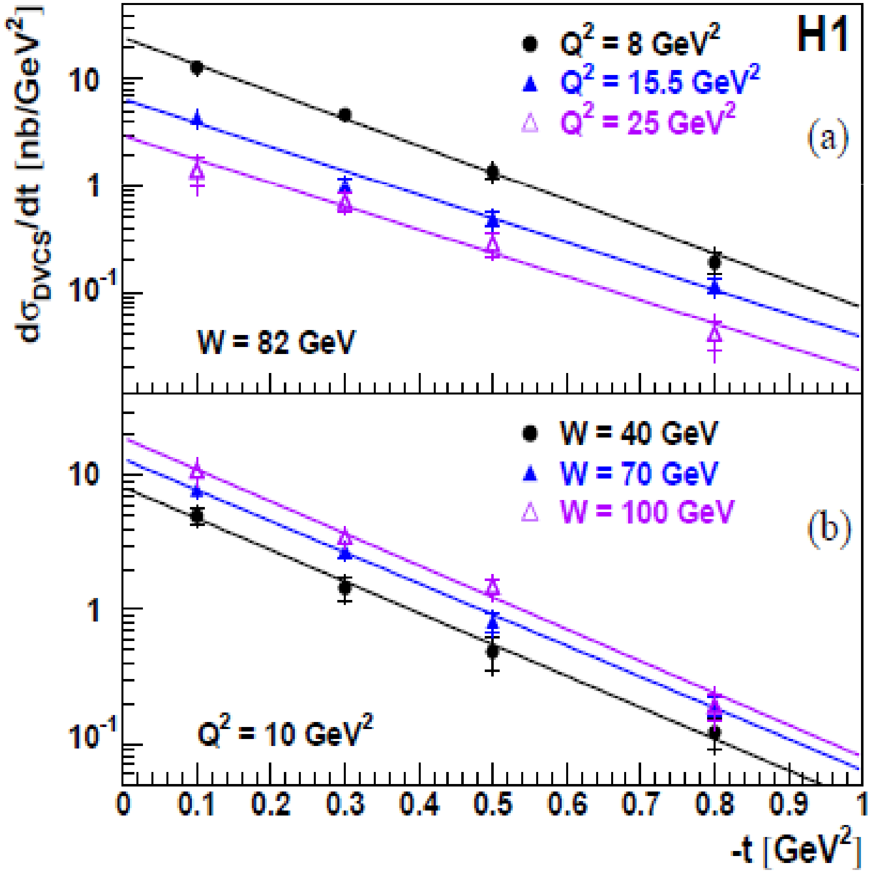
$$B = B_p + B_{VM}$$

Bp corresponds to an average transverse proton-size (in 2D) of 0.6fm

Let's focus on DVCS measurements

Interesting process as we do not have the complexity of VM wave function in the interpretation

In the following $W^2 \sim Q^2/x$

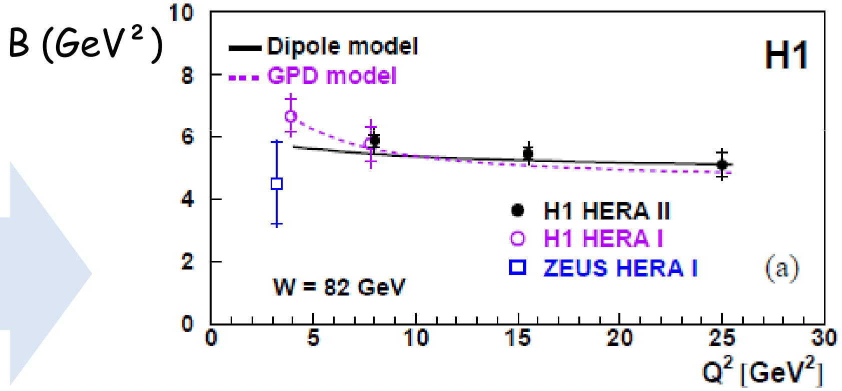


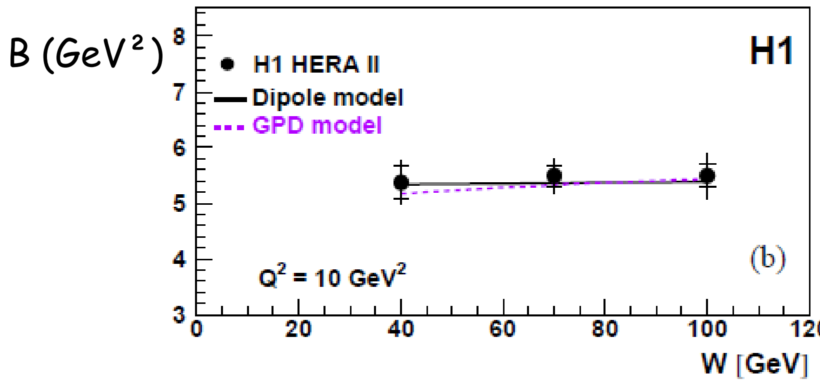
In average $Q^2 > 5$ GeV^2

$b=5.41 \pm 0.14 \pm 0.31$ GeV^{-2}

which gives =>

$[\langle r_T^2 \rangle]^{1/2} = 0.64 \pm 0.02$ fm



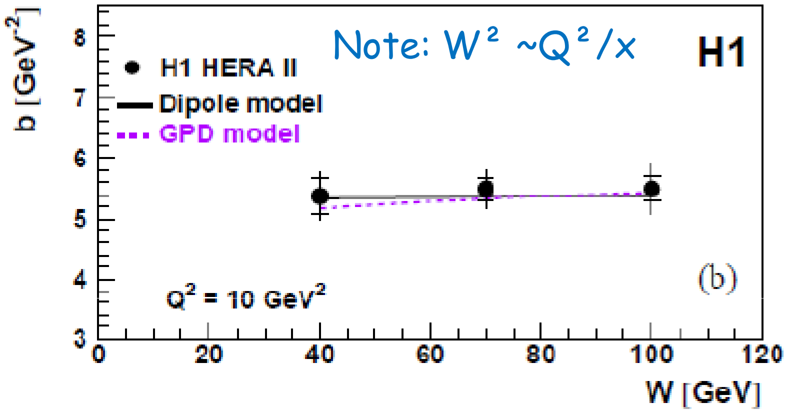


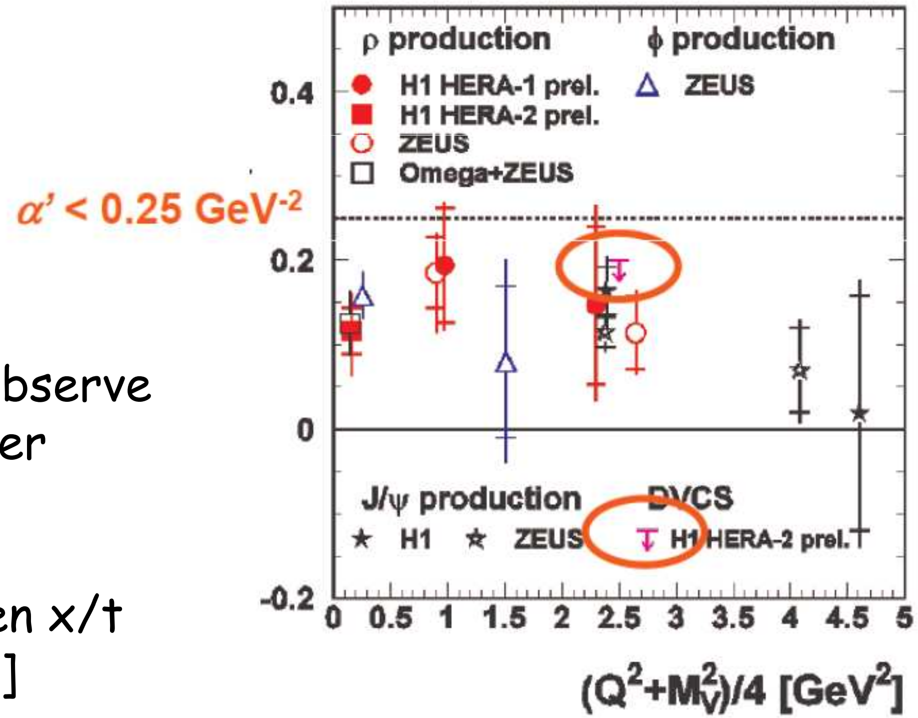
The interplay between x and t

We can examine the dependence of B(x)

Let's write $B(x) = B_0 + \alpha' \, Log(1/x)$

From previous slide, we know that α' is small





For all VM + DVCS at HERA we observe a small value of α' and even smaller values when Q^2 is increased

Then, *negligible* interplay between x/t at small x (x<0.01) [within errors]

Discussion

As $B(x) = B_0 + \alpha' \, Log(1/x)$ Then $[\langle r_T^2 \rangle]^{1/2} \sim \alpha' \, Log(1/x)$

α' reflects the spread of partons in the transverse dimension as a function of the rapidity (log(1/x)). It makes the link between the x-dynamics and the transverse structure of the nucleon

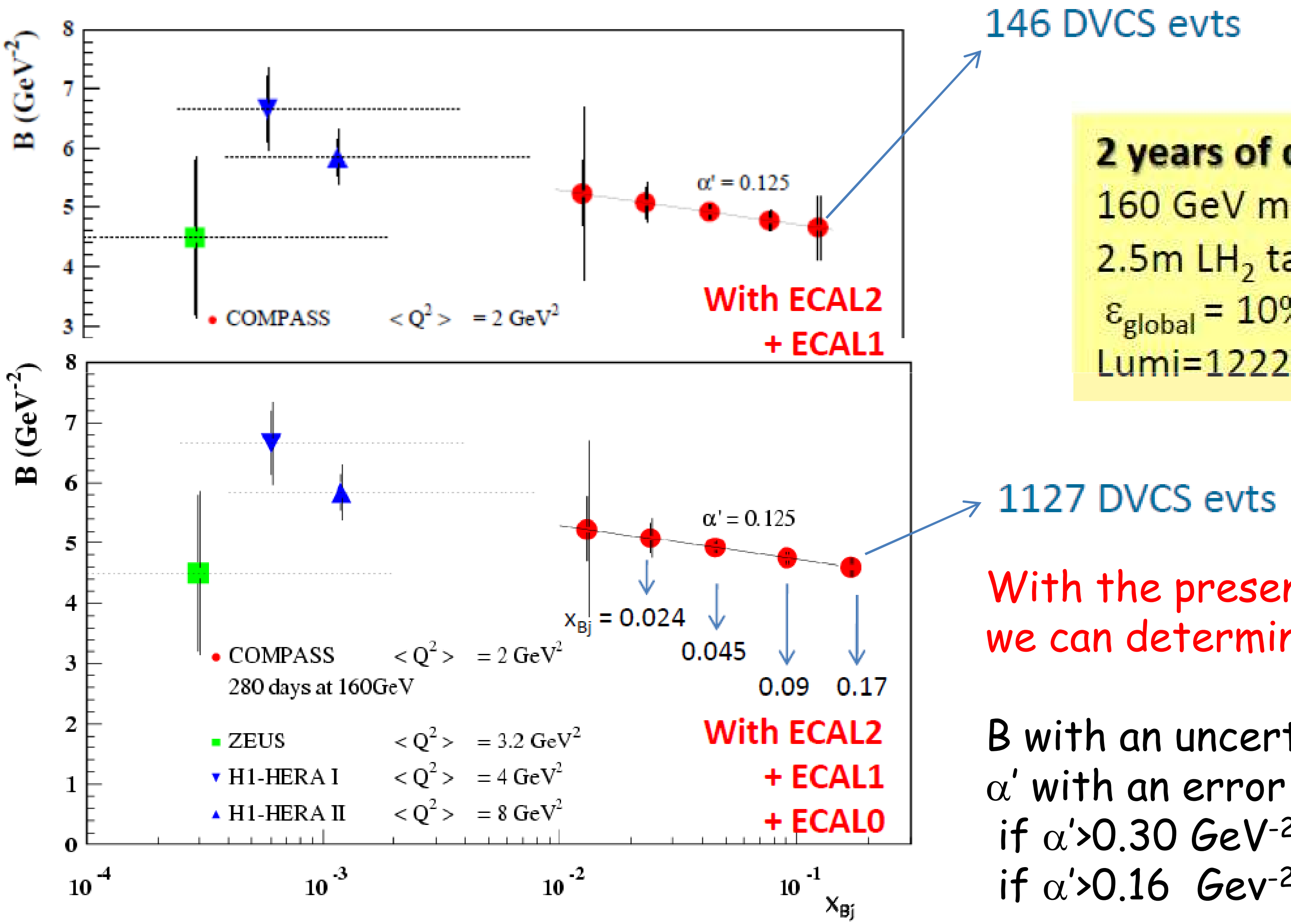
α' is found small at small x (compatible with a hard process)

We do not know the value at larger x (x~0.1) in the domain
Where COMPASS can provide measurements with high precision

This is a fundamental issue encoded in GPDs whose evolution in Q^2 *and rapidity must be predicted!*

t-slopes projections for COMPASS

With 3% error on the BH subtraction



2 years of data
160 GeV muon beam
2.5m LH_2 target
ε_{global} = 10%,
Lumi=1222pb^{-1}

With the present projection we can determine:

B with an uncertainty<0.1 GeV^{-2}
α' with an error better than 3σ
if α'>0.30 GeV^{-2} with ECAL1+2
if α'>0.16 Gev^{-2} with ECAL0+1+2

Discussion

(1)
the correlation between x/t variables is also encoded in the BC(S)A prediction

a. From t-slope measurements, determine B(x) => B_0 and α'
b. To be included into the BC(S)A calculations
c. Check what comes out w.r.t. direct BC(S)A data (see other talks)

(2)
Orbital angular momentum: comes with GPD Eq
We know the upper limit: $|Eq|<q(x)m||r_T||[x]$
Where $||r_T||[x]$ can be determined directly from t-slopes B(x)

Then, most probably main contribution to Lq comes from not too large x
and with direct determinations of b(x) or $||r_T||[x]$ at various x,
we can derive the upper limit on Lq

Summary

With HERA data on VM and DVCS at small x ($x<0.01$) we have a clear view of the transverse nulceon size in this kinematic domain
Also with the conclusion that we observe a *negligible* interplay between x and t
Example: $\alpha'<0.2$ GeV^{-2} with 90% confidence level for DVCS

As we have seen, DVCS is the best process for these studies as it does not suffer from the lack of knowledge of the VM wave function in the interpretation

COMPASS experiment is dedicated to produce high statistics DVCS cross section measurements and then extract t-slopes with high precision as well as the interplay between x and t

It can give a definite answer on the transverse size of the nuleon for $0.01<x<0.1$ and moderate Q^2