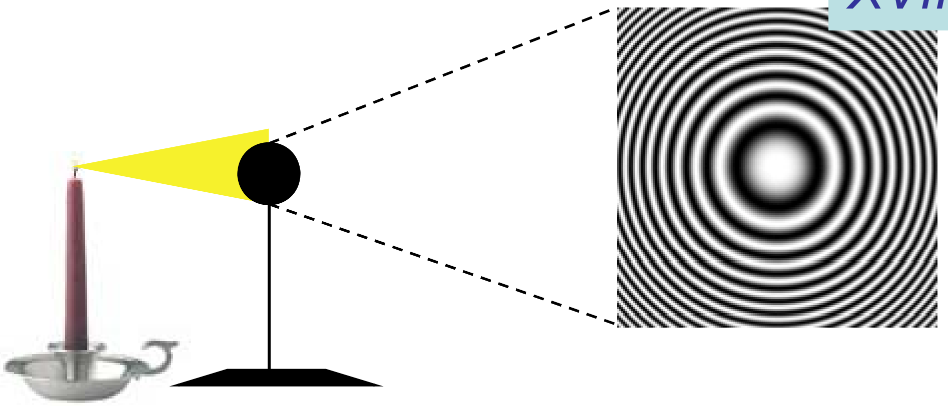
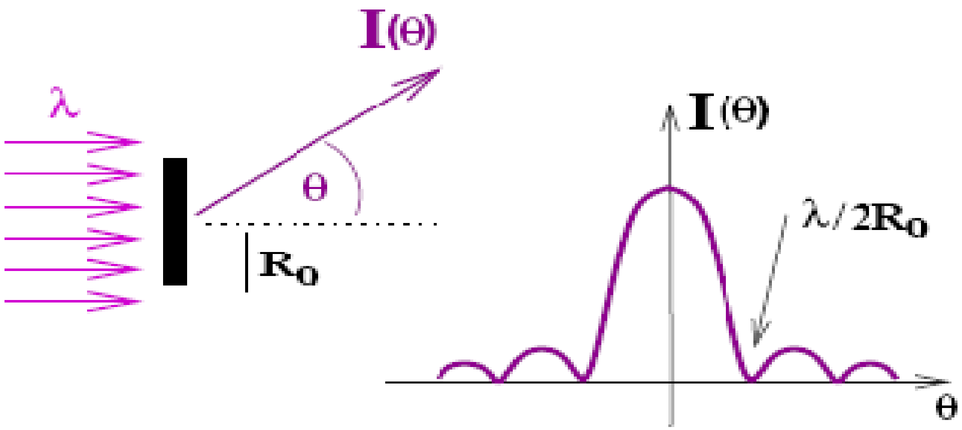
Low-x 2007
August 31

A scale, α' and b in diffractive vector meson production

A.Rostovsev (ITEP, Moscow)

To read the diffractive peak size





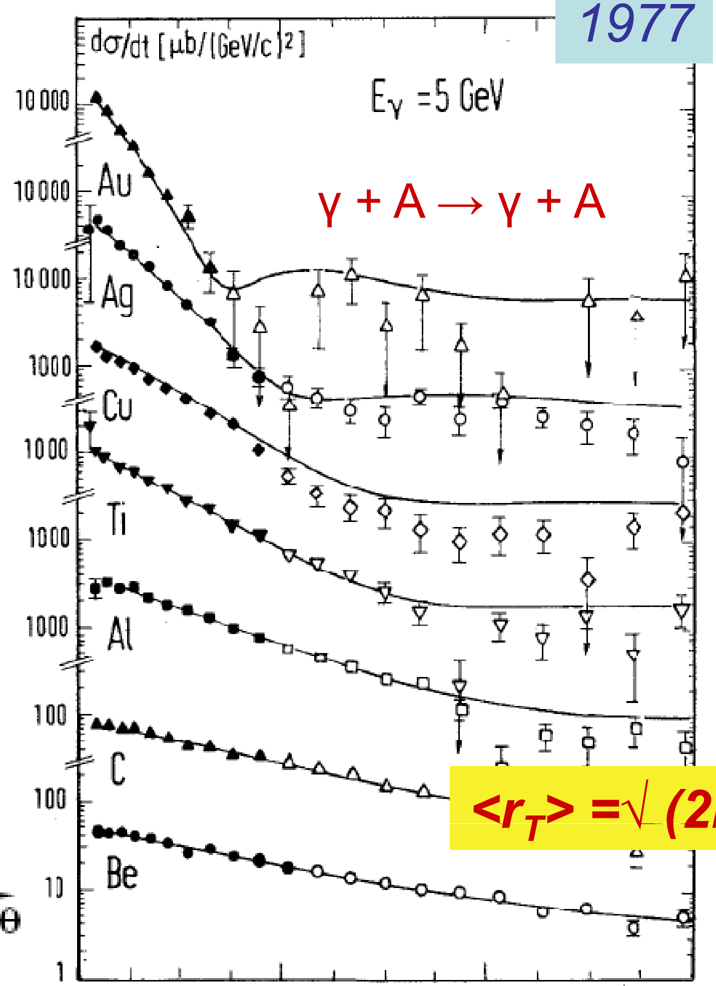


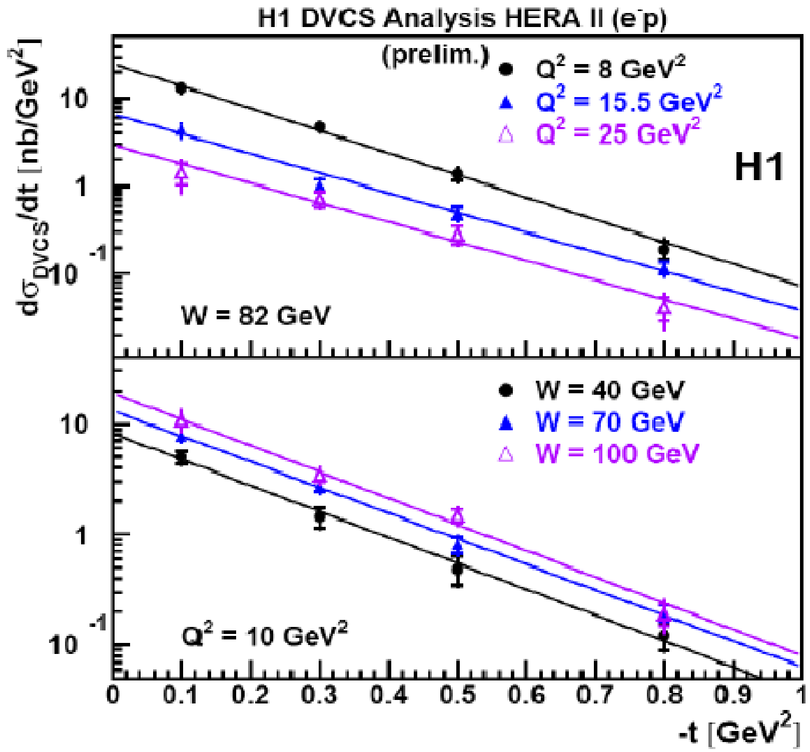
Fig.2a Differential Compton cross section on heavy nuclei at 5 GeV

$\langle r_T \rangle = \sqrt{(2b)}$

Size of diffractive peak ⇒ R_0

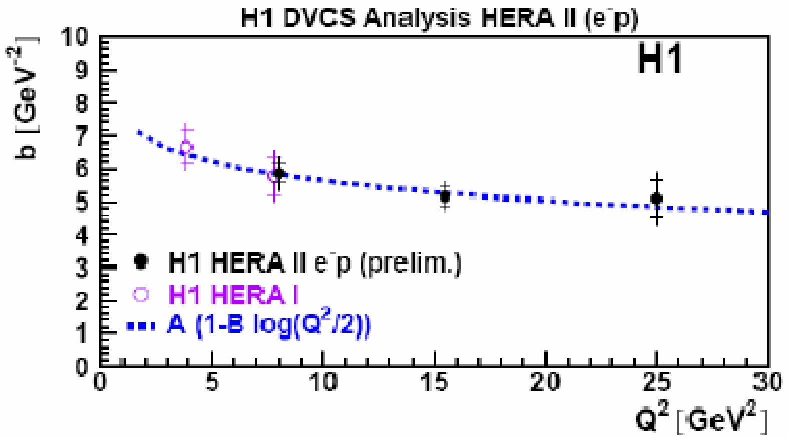
Proton tomography with DVCS at HERA

A measurement of ***t***-dependence of DVCS cross section at different values of **Q^2, W**



Approximated : *dσ/dt ~ exp(bt)*

t-slope parameter **b(Q^2) decreases with increasing Q^2**



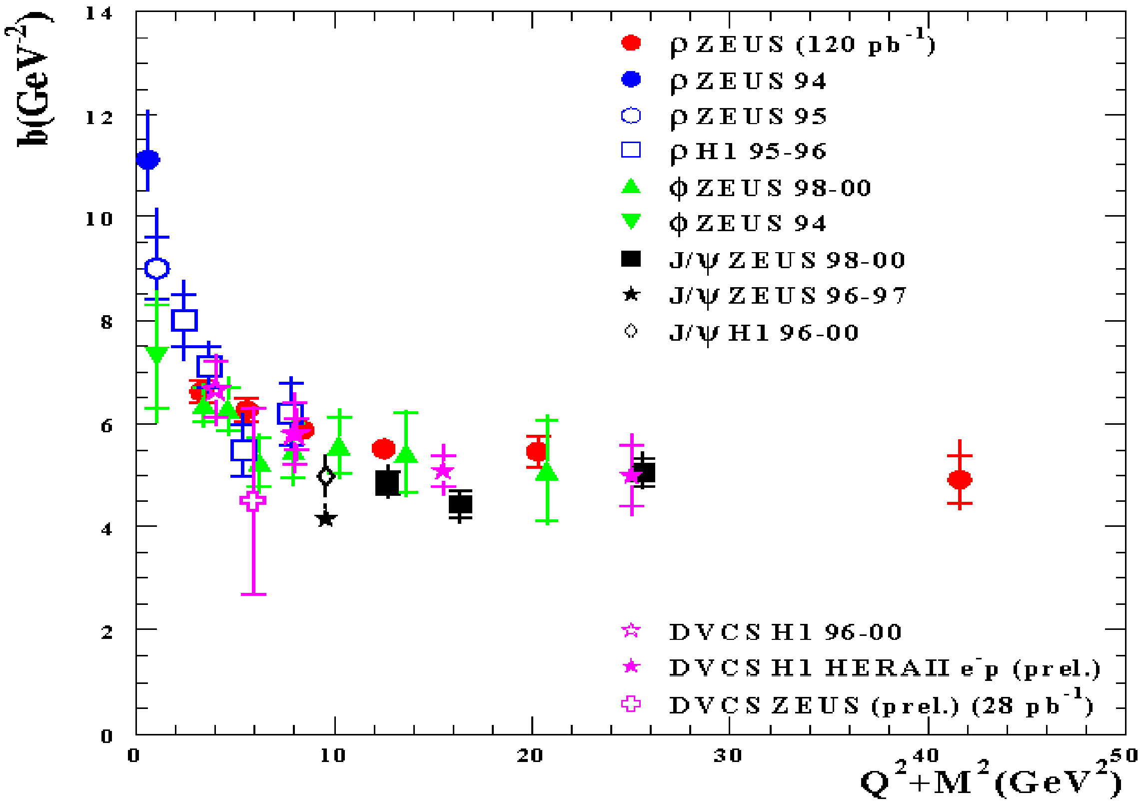
No W-dependence of t-slope observed.

$<r_T>$ =√ (2b) ≈ 0.65 fm dominated by sea and gluons (low-x @ HERA)

$<r_T>$@HERA **<** $<r_T>$ = 0.8 fm in real γ-proton scattering @ low energy

$d\sigma/dt(\gamma^*+p \rightarrow V+p)$. t- dependence.

$$\frac{d\sigma}{dt} \propto \exp(b \cdot t)$$

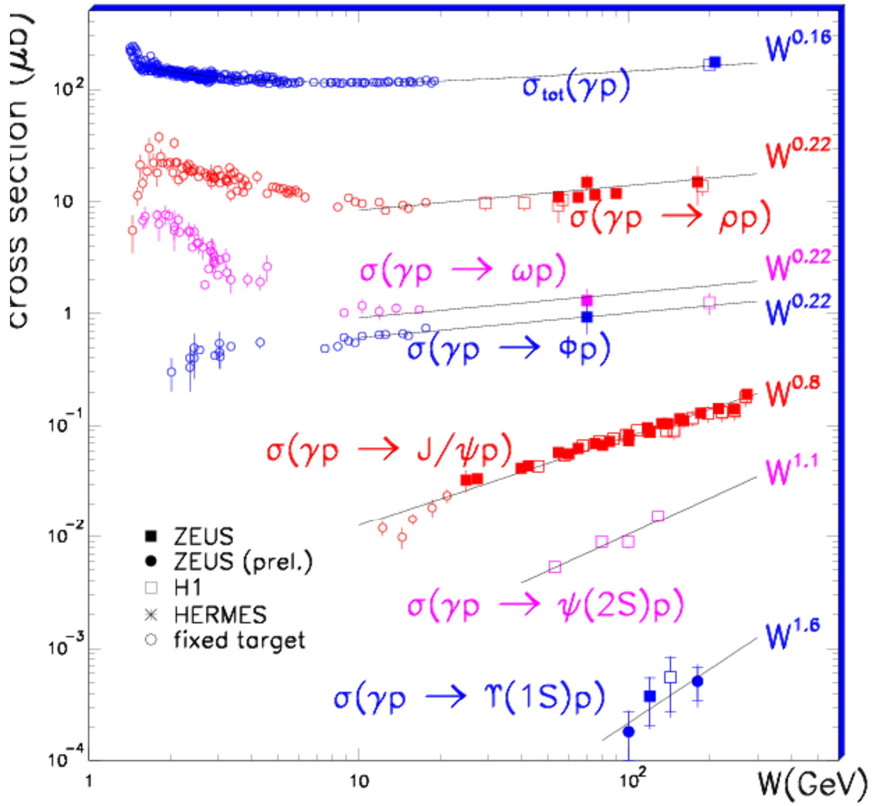


The slope of the t distribution decreases with Q2 and levels off at b ~ 5-6 GeV^{-2}.

Universality of the b-data on the Q^2+M^2 scale

$\sigma(\gamma^* + p \rightarrow V + p)$. Energy dependence.

Photoproduction ($Q^2 \approx 0$)



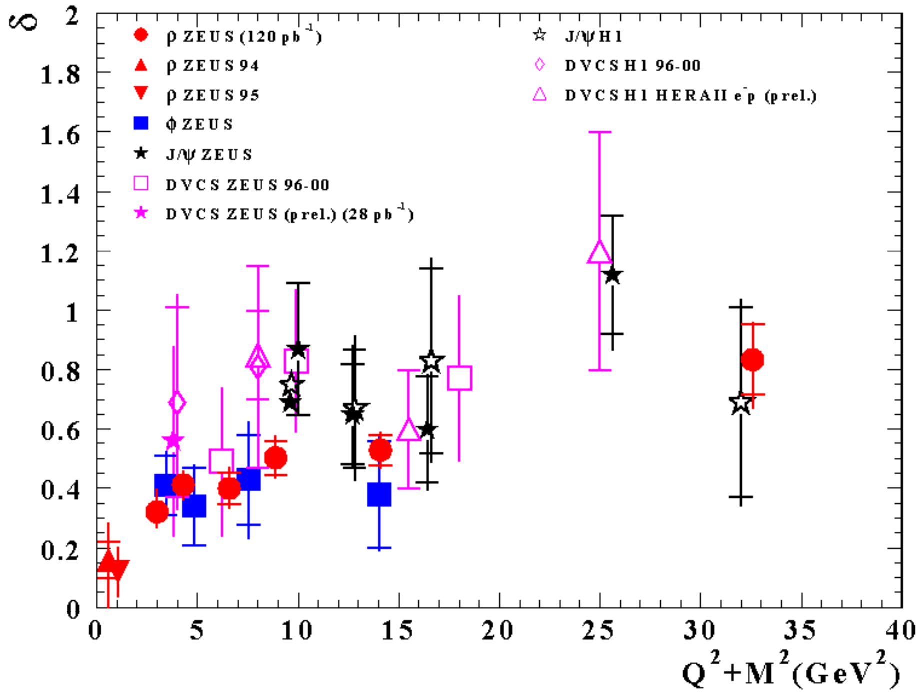
process becomes hard as Q^2+M^2 -scale becomes larger.

Cross section rises with energy.

$$\sigma(W) \sim W^{\delta}$$

the exponent is Q^2+M^2 scale dependent

$$\delta = \delta_0 + 0.25 \ln(Q^2+M^2)$$



Total γ^* + $p \rightarrow$ V + p cross section as function of Q^2

The cross sections were scaled by factors, according to the quark charge content of the vector meson

$$\rho : \omega : \varphi : J/\Psi = 1 : 9 : 9/2 : 9/8$$

Gross feature:

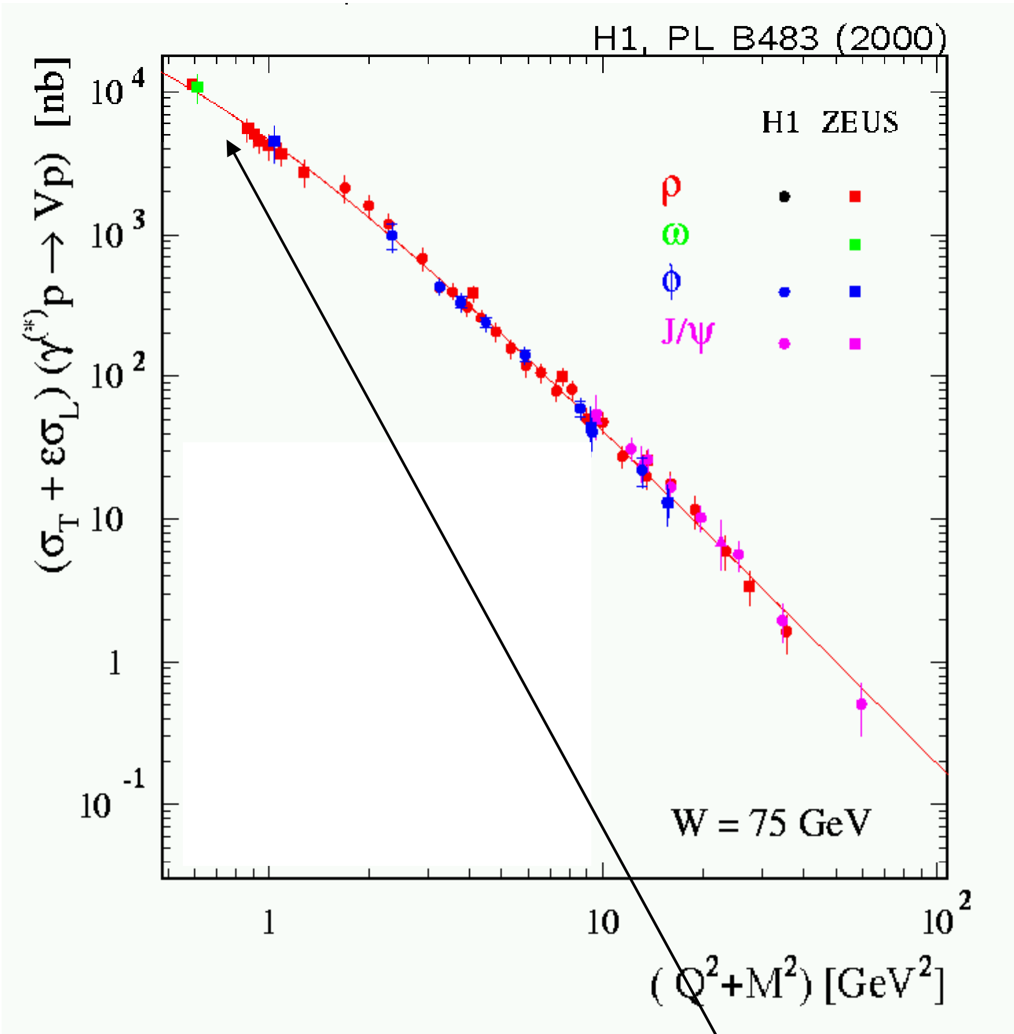
Approximated with

$$\sigma(Q^2) \propto 1/(Q^2 + M^2)^n$$

Vector Mesons : n $\approx$ 2.5

Details:

Fit to whole Q^2 range gives bad χ^2/dof



- striking universality in vector meson production as scaled with Q^2+M^2.
- The Q2 dependence of $\sigma(\gamma^* p \rightarrow \rho p)$ cannot be described by a simple propagator term.

$d\sigma/dt(\gamma^* + p \to V + p)$. Interplay of t, Q^2

Take as a scale $Q^2 + M^2 - t$

$$\frac{d\sigma}{dt} \propto \frac{\exp(b_0 t)}{(Q^2 + M_V^2 - t)^n} \Rightarrow \frac{\exp\left(b_0 t + \dfrac{n}{Q^2 + M_V^2} \cdot t\right)}{(Q^2 + M_V^2)^n}$$

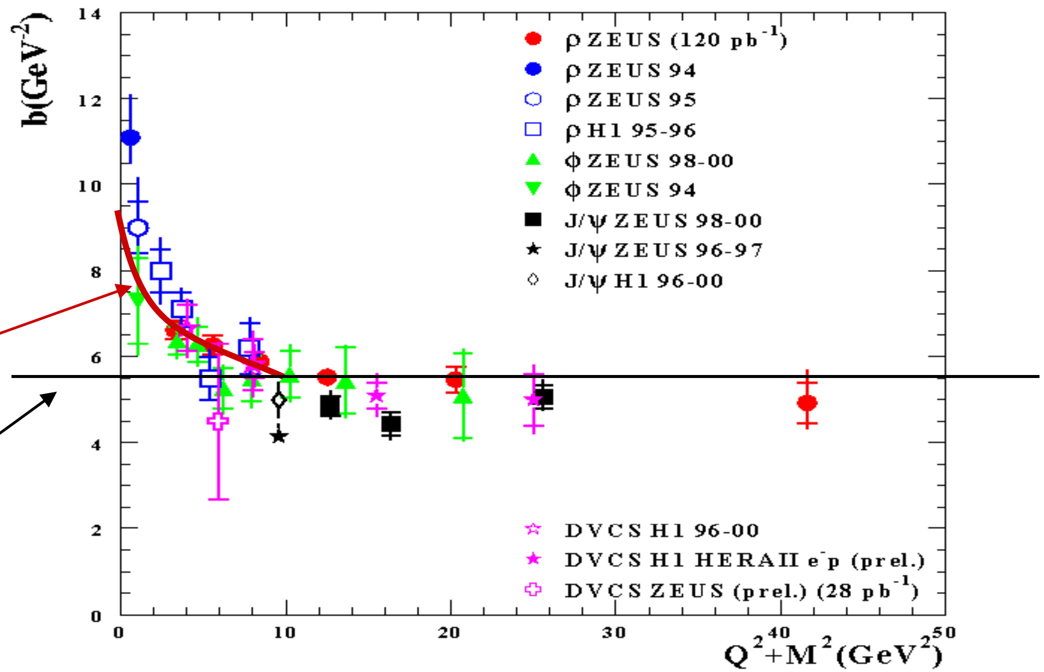
- at low t- values

For $n = 2.5$

$b_0 = 5.5\ \mathrm{GeV}^{-2}$

effective slope b :

$$b = 5.5 + \frac{2.5}{Q^2 + M_V^2} \quad GeV^{-2}$$



If so,

The slope $b \approx 5.5\ \mathrm{GeV}^{-2}$

$b_{\gamma p} \approx \frac{1}{2}\, b_{pp}$ – one proton in γp and two protons in pp

Now the exponential slope of the t distribution does not change with Q^2 and M^2

$d\sigma/dt(\gamma^* + p \rightarrow V + p)$. t- dependence.

$$\frac{d\sigma}{dt} \propto F_V^2 F_p^2 \propto (1 + a_V t)^{-n_V} (1 + a_p t)^{-4} \Rightarrow \begin{cases} \exp(b \cdot t) & \text{- at low t, } b = n_V a_V + 4a_p \equiv b_V + b_p \\ 1/|t|^n & \text{- at large t, } (4 < n < n_V + 4) \end{cases}$$

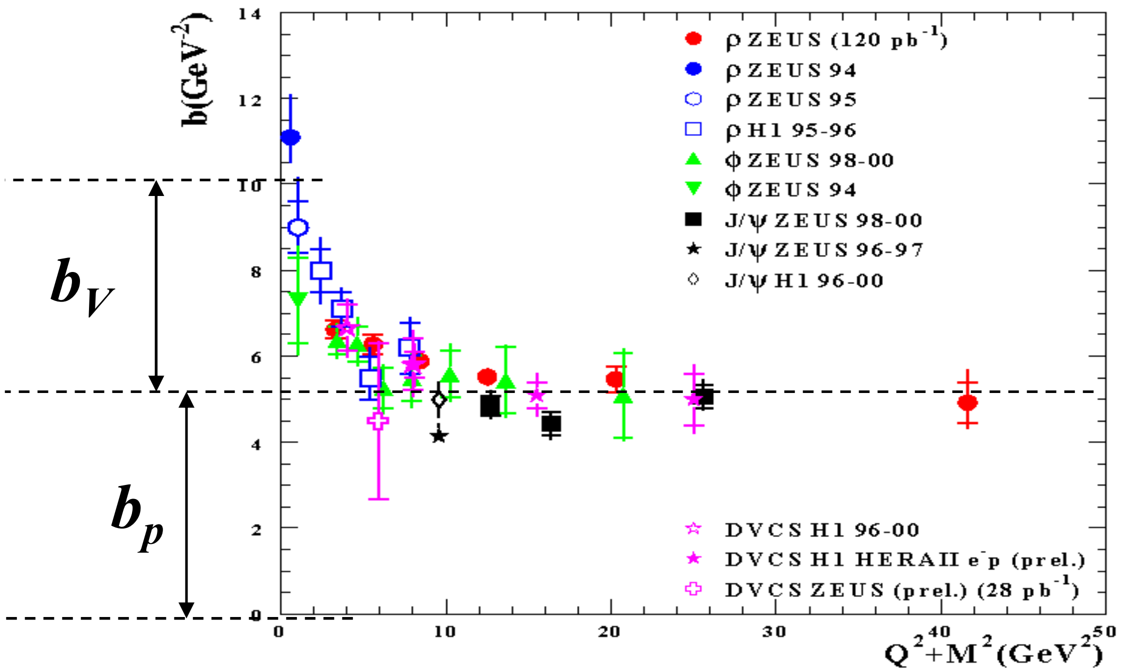
t- dependence is defined by Form Factors ($F_V F_p$)

Geometric picture:

$$\boldsymbol{b = b_p + b_V}$$

Size of the scattered vector meson is getting smaller with $Q^2 + M^2$ scale

$$b_V \propto \frac{1}{Q_2 + M_V^2}$$

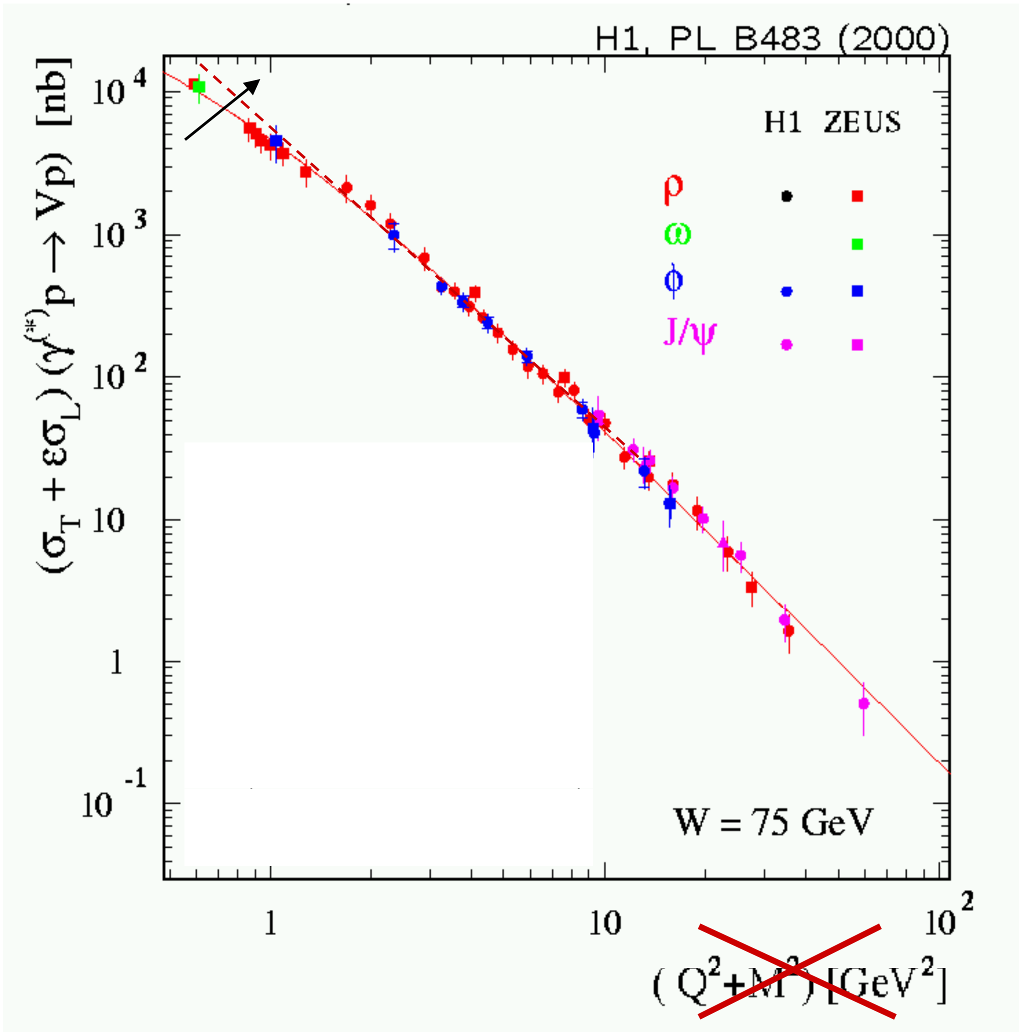


$$t < -m_p^2 \frac{(Q^2 + M^2)^2}{W^4}$$

Average t-value:

$$\langle t \rangle < -\frac{1}{b}$$

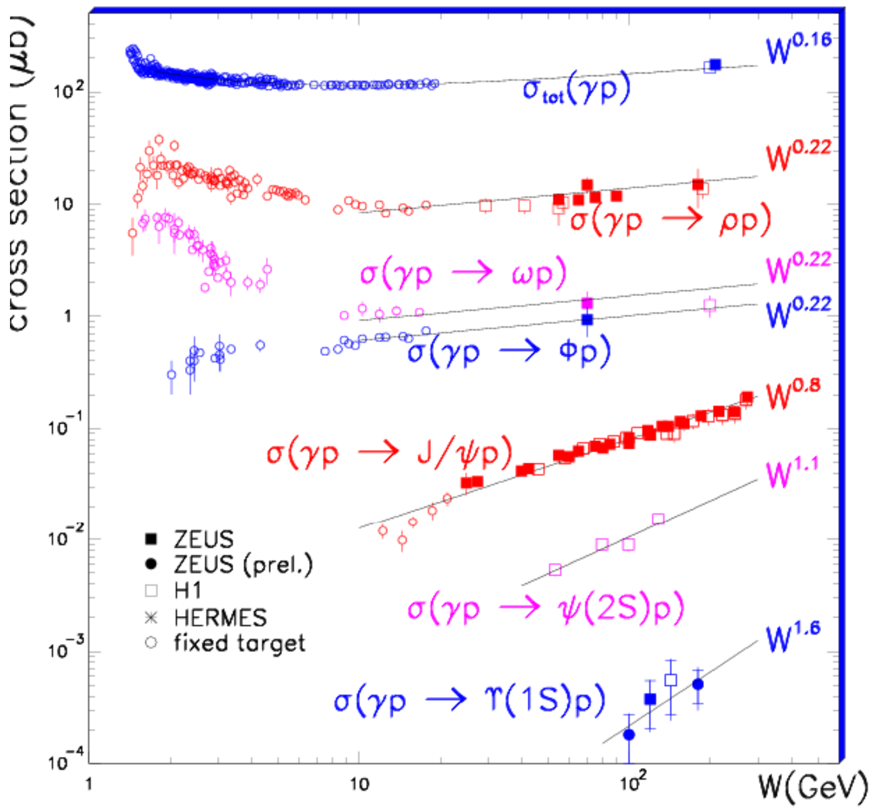
The scale change works in the right direction correcting the power-law Q^2+M^2 dependence.



$$Q^2 + M^2 - \langle t \rangle \left[GeV^2\right]$$

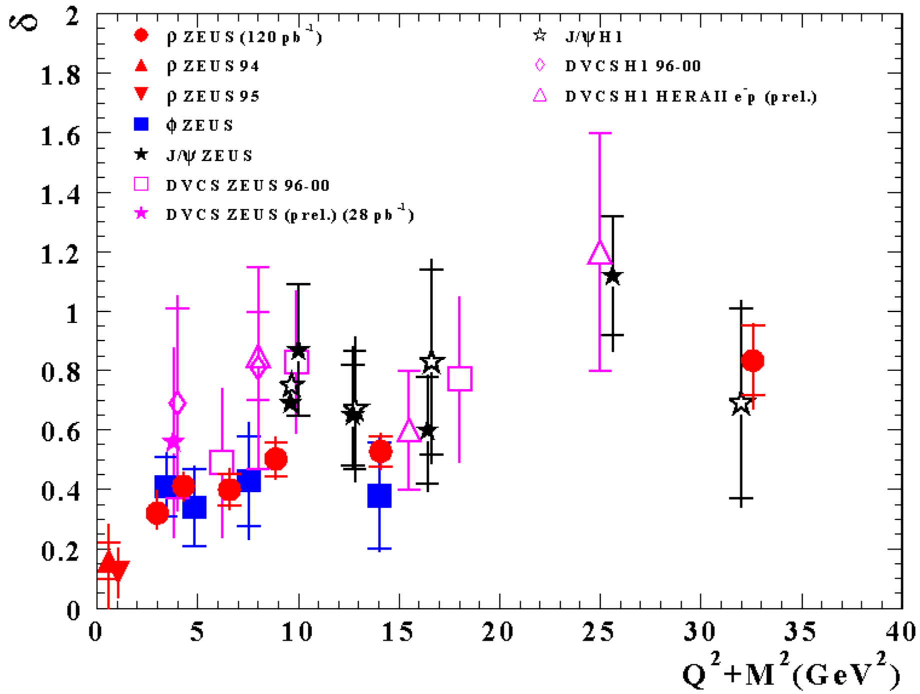
What is a scale for the energy dependence?

Photoproduction ($Q^2 \approx 0$)



process becomes hard as scale becomes larger.

$\sigma(W) \sim W^{\delta}$



ρ^0 photoproduction at high t – hard process?

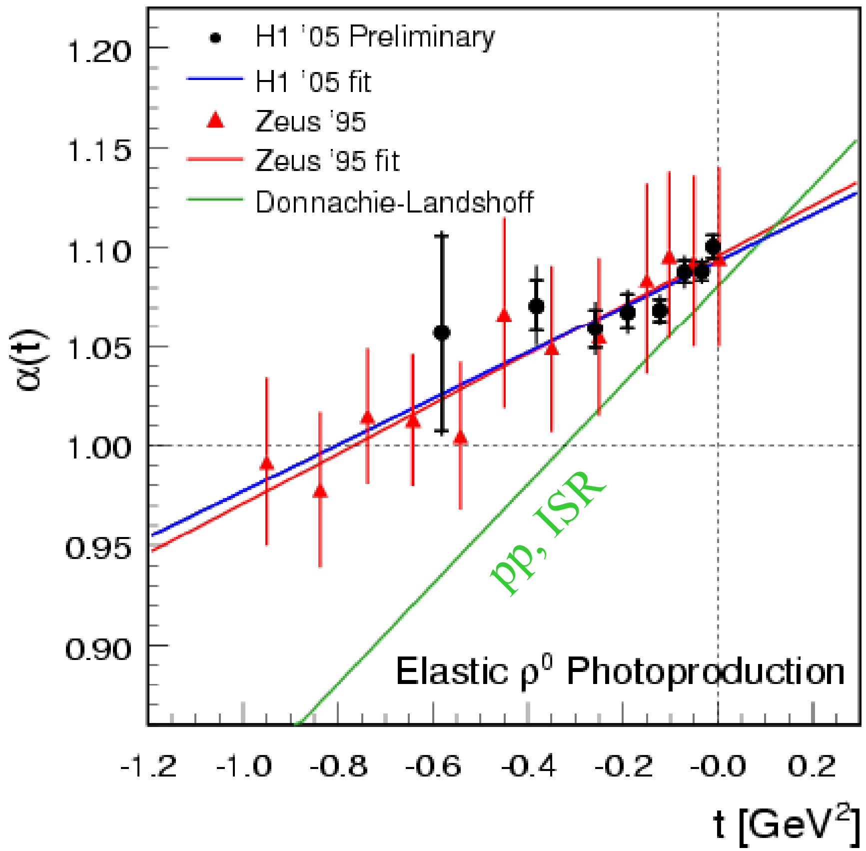
$$Q^2 + M^2 \to Q^2 + M^2 - t \ ?$$

Effective Pomeron Trajectory $\gamma p \to Vp$

$$\frac{d\sigma}{dt} \propto \exp(b_0 t) \cdot W^{4\alpha(t)-4} \qquad \alpha(t) = \alpha(0) + \alpha' \cdot t$$

ρ^0

$$\alpha(0) = 1.093 \pm 0.008$$
$$\alpha' \quad = 0.116 \pm 0.05$$



Elastic ρ^0 photoproduction $(Q^2+M^2) = 0.6\ \mathrm{GeV}^2$

$\alpha(0)(\gamma p) \approx \alpha(0)(pp)$

$\alpha'(\gamma p) \approx \frac{1}{2}\, \alpha'(pp)$

Two different soft Pomeron trajectories?

α' reflects the diffusion of partons in impact parameter, b_t, plane during the evolution in rapidity ~ln(s)

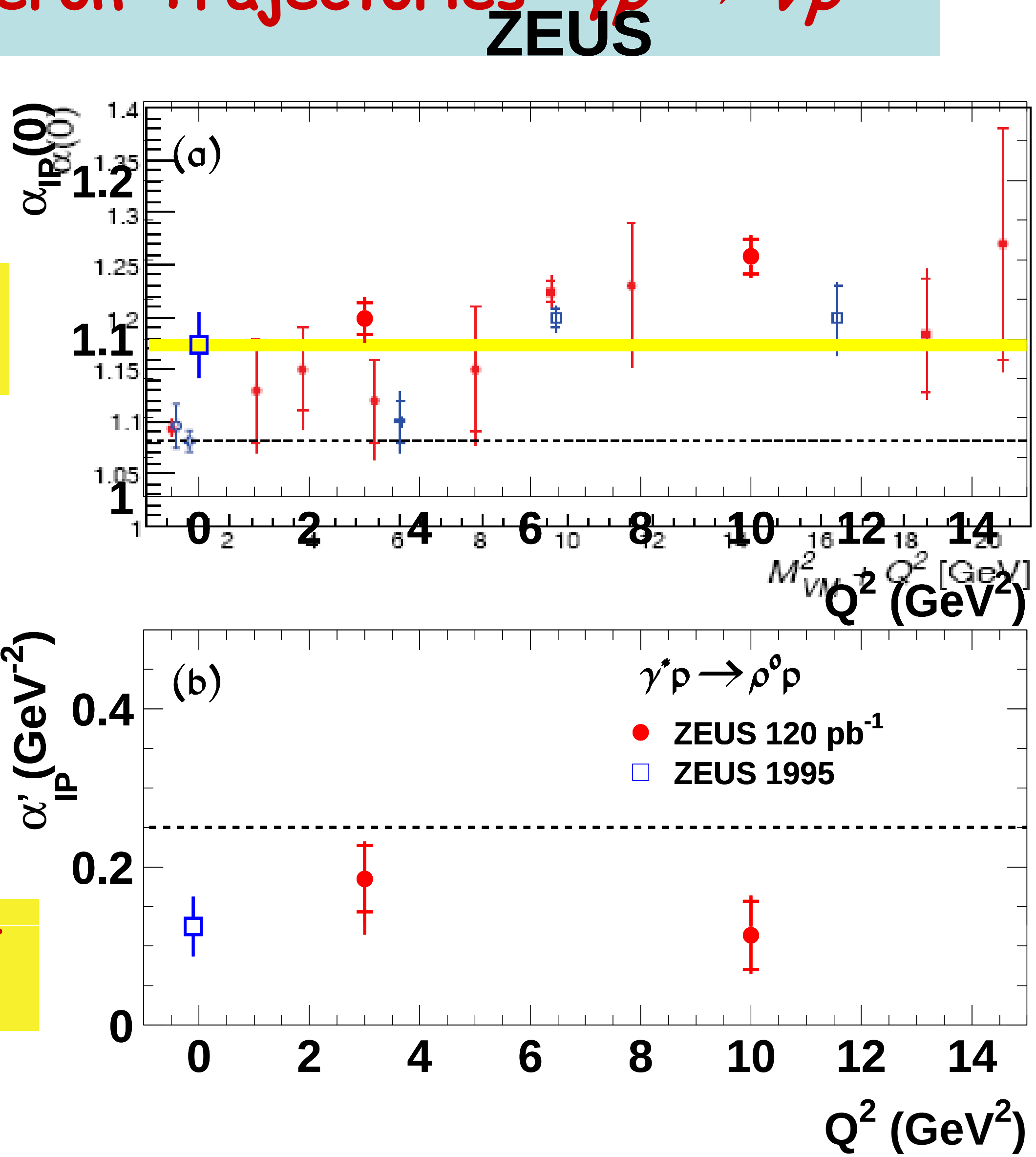
$$\frac{d\sigma}{dt} \propto \exp\{(b_0 + 4\alpha' \ln(W/W_0)) \cdot t\}$$

Size of 2 proton system in pp scattering grows twice faster with s than a size of a single proton in γp-scattering?

Effective Pomeron Trajectories $\gamma p \rightarrow Vp$

As the scale gets harder the intercept grows

The most precise measurements of α' at HERA:



The available data consistent with α'(γp) = ½ α'(pp)

$\sigma(\gamma^* + p \to V + p)$. Energy dependence.

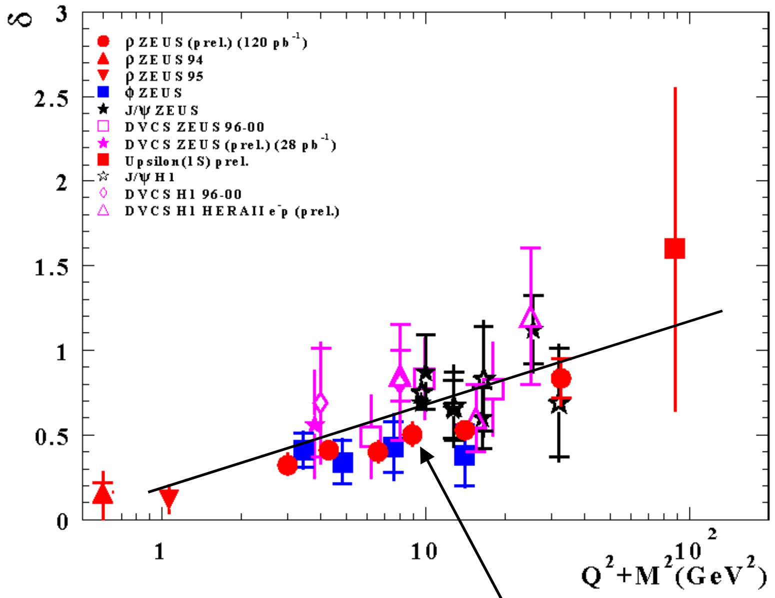
Elastic Vm production c.s. rises fast

$$\sigma(\gamma^* + p \to V + p) \sim (F_2)^2 \sim W^{\delta}$$

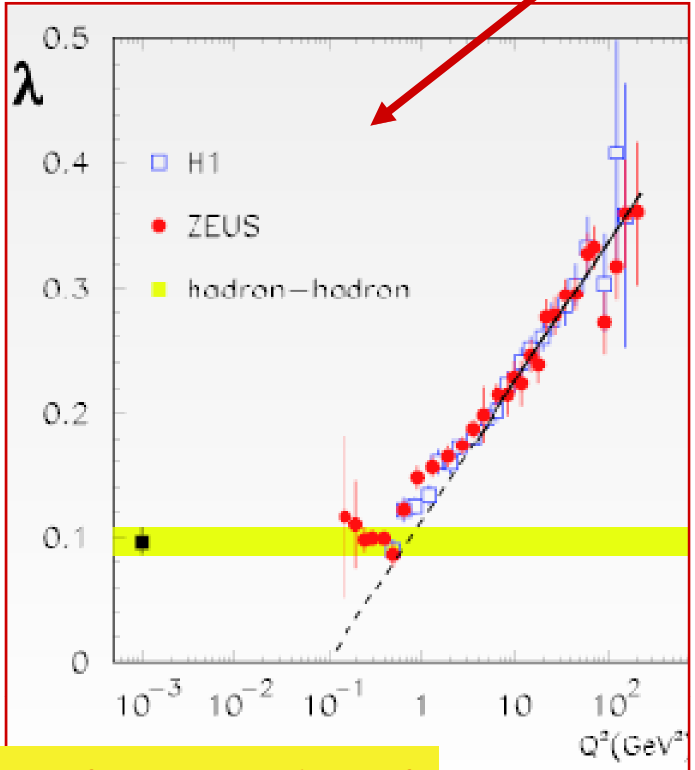
Inclusive c.s. is defined by Structure Function

$$\sigma(\gamma^* + p \to X) \sim (F_2) \sim W^{2\lambda}$$

$$F_2(x, Q^2) \sim (1/x)^{\lambda}$$



$= 4 \cdot$



$\delta \to \delta + 4\alpha'\langle|t|\rangle$

$\delta \to \delta + 0.1$

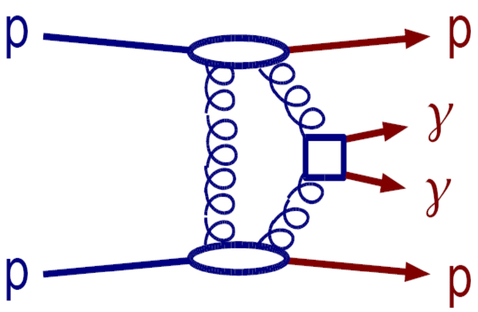
$\delta(Q^2+M^2) = 4$ □ $\lambda(Q^2)$

Summary

• Attempting a more illustrative way to represent the measurements it is an advantage to consider the VM production and DVCS on a Q^2+M^2-t scale.

+ 2 comments on CEP at Tevatron

Central exclusive $\gamma\gamma$ production at CDF



Lumi = 532 pb^{-1}

Search for exclusive $\gamma\gamma$

$E_T(\gamma) > 5$ *GeV and* $|\eta|<1$

✓ 3 candidate events found

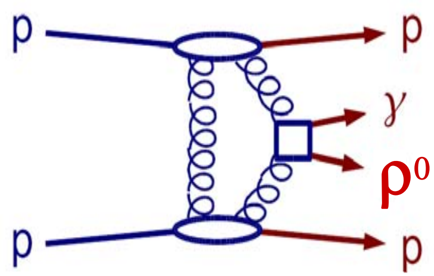
✓ 1 (+2/-1) predicted from ExHuME MC

➢ estimated ~1 bgd event from $\pi^0\,\pi^0$,$\eta\,\eta$

If assume 3 events are DPE $\gamma\gamma$

Upper limit $\sigma < 410$ *fb*

How to increase rates?



$pp \rightarrow pp+\gamma+\rho^0$

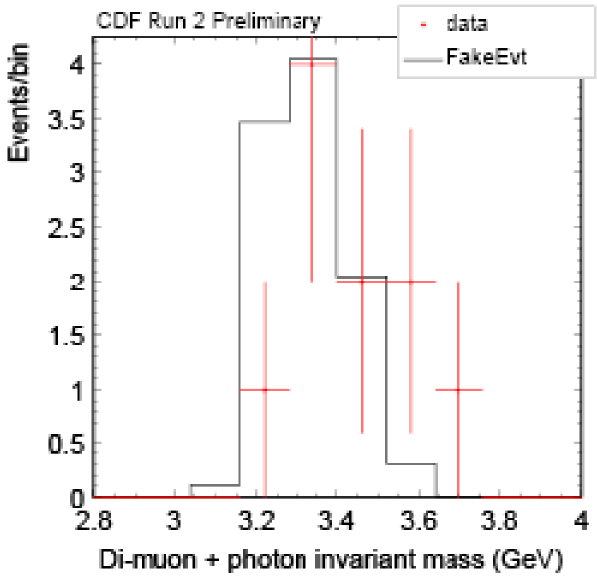
Similar to VM / DVCS-production at HERA

$$\sigma(\gamma\rho^0) \approx 10 \cdot \sigma(\gamma\gamma)$$

Central Exclusive χ_c production at CDF

Use the decays $\chi_c \rightarrow J/\Psi(\mu\mu)\gamma$ within |y|<0.6 central detector

10 events J/Ψ+γ found in the CDF detector and nothing else OBSERVABLE



If assume all 10 events are $\chi_c(0^{++})$

Upper limit of 49 ± 18(stat) ± 39(syst) pb

to be compared with prediction of 70 pb for |y|<0.6 (Khoze, Martin, Ryskin, 2001; uncertainty factor 2÷5)

- small fraction of CDF statistics used in analysis
- needs for account of the $\chi_c(2^{++})$ state

Since $\sigma \sim \Gamma_{gg}$,$\Gamma(2^{++})/\Gamma(0^{++}) \approx 0.13$

But $BR(\chi \rightarrow J/\Psi\gamma)$: $BR(2^{++})/BR(0^{++}) \approx 20$

One expects about equal contributions from 0++ and 2++ states