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Soft particle production at HERA

On behalf of H1 and ZEUS collaborations

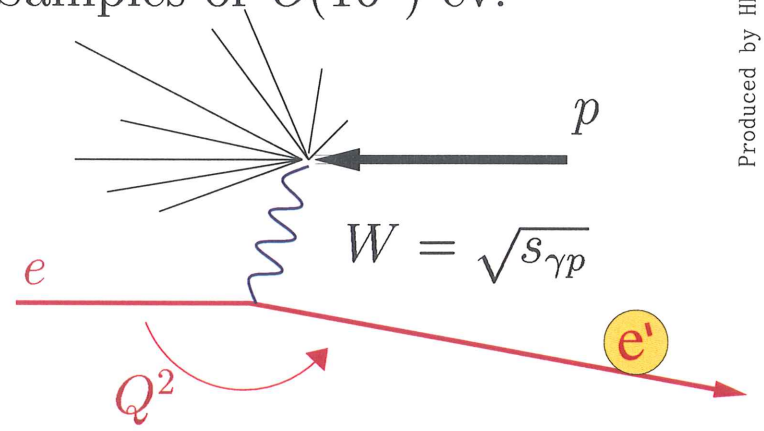
- Inclusive particle photoproduction at HERA
- Exclusive vector meson photoproduction at HERA
- Exclusive multiphoton states
- Search for Odderon induced reactions

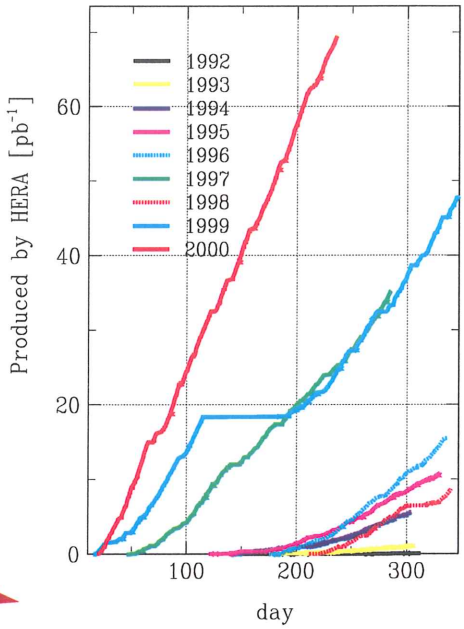
Detectors - Event topologies

HERA - ep collider

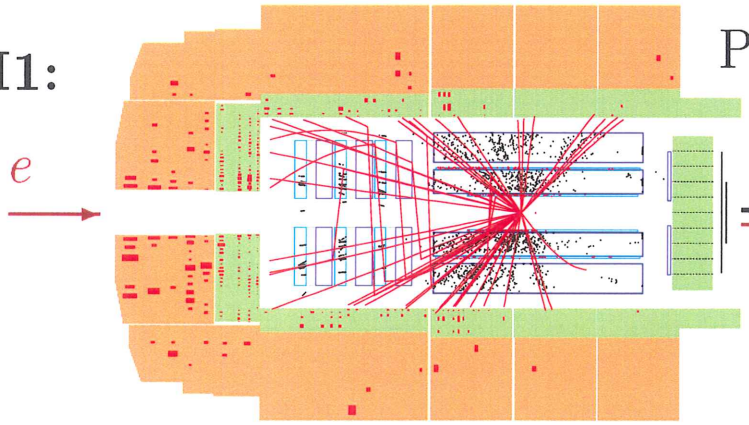
$\sqrt{s} \approx 300\ GeV$

Samples of $O(10^7)$ ev.





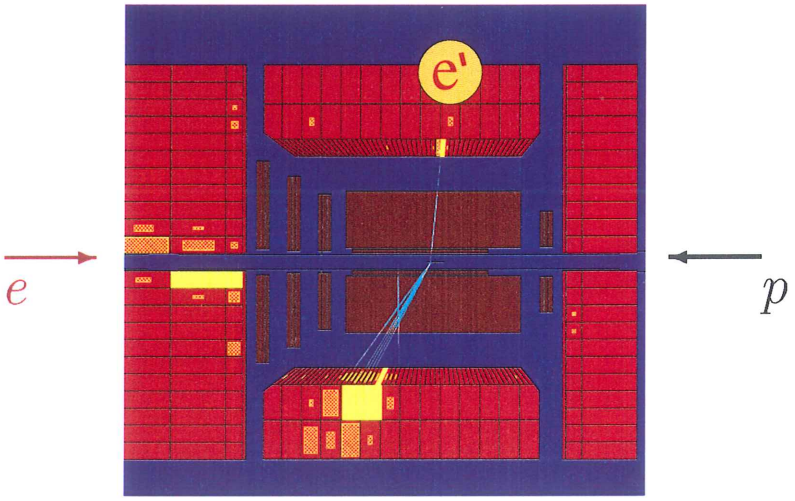
H1:



Photoproduction $Q^2 \approx 0$

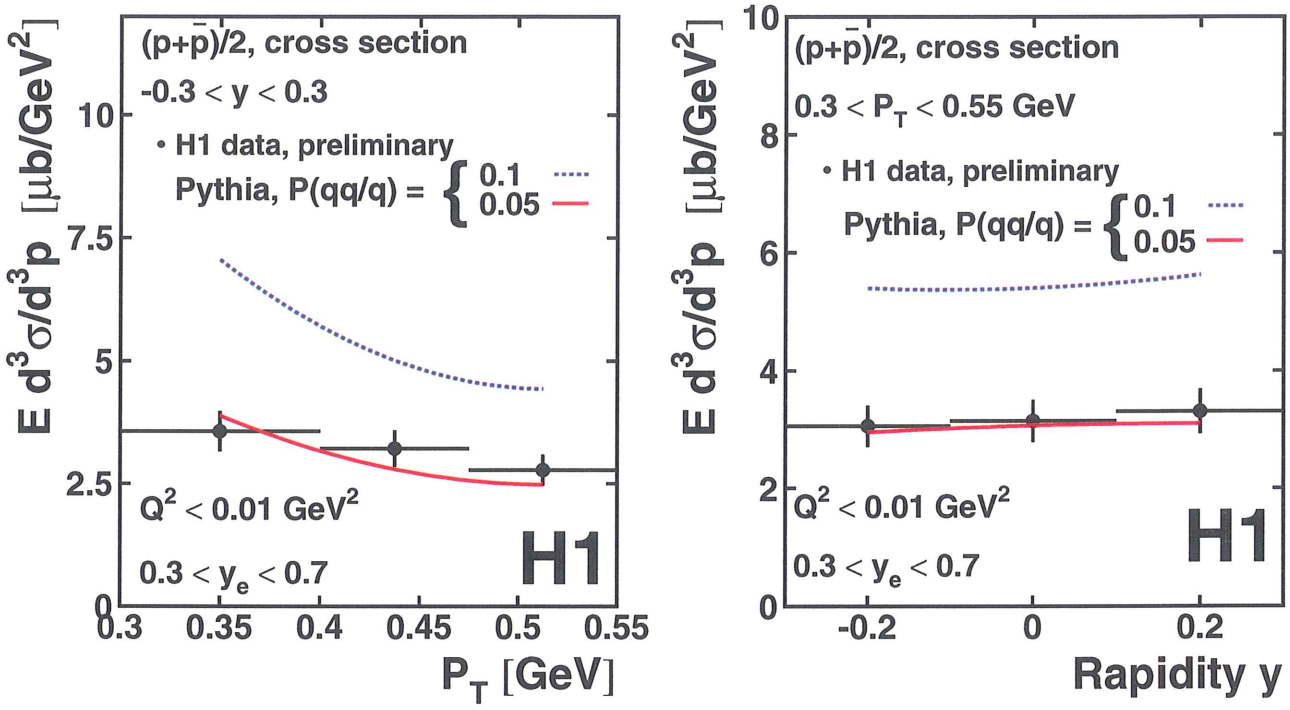
ZEUS:

DIS $Q^2 = 16000 GeV^2$



Inclusive Proton Cross Section

H1 has measured inclusive photoproduction of protons using dE/dx identification.



In the Lund fragmentation model a number of suppression parameters are used to describe the particle production rates.

A diquark suppression factor value

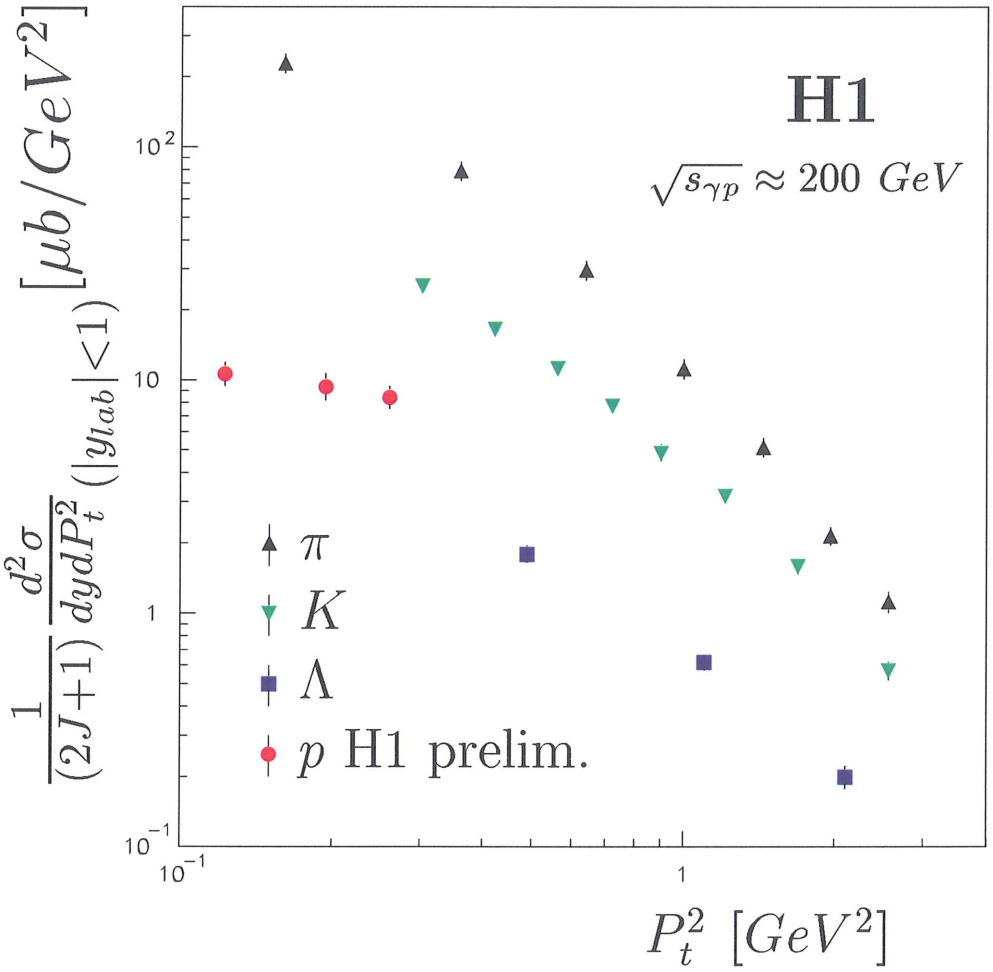
$$R = \frac{(qq, \bar{q}\bar{q})}{(q, \bar{q})} = 0.05$$

is favoured by the HERA data.

At LEP $R = 0.1$ is found.

"Map" of particle photoproduction at HERA

Compilation of all H1 data on inclusive photoproduction cross section for π, K^0, p and Λ. The data are compared for one spin and one isospin projection.



Modified Leading Log Approximation (MLLA) predicts in the soft limit

$$P \longrightarrow 0 \quad \langle n \rangle \sim \frac{1}{M^2} \ ,$$

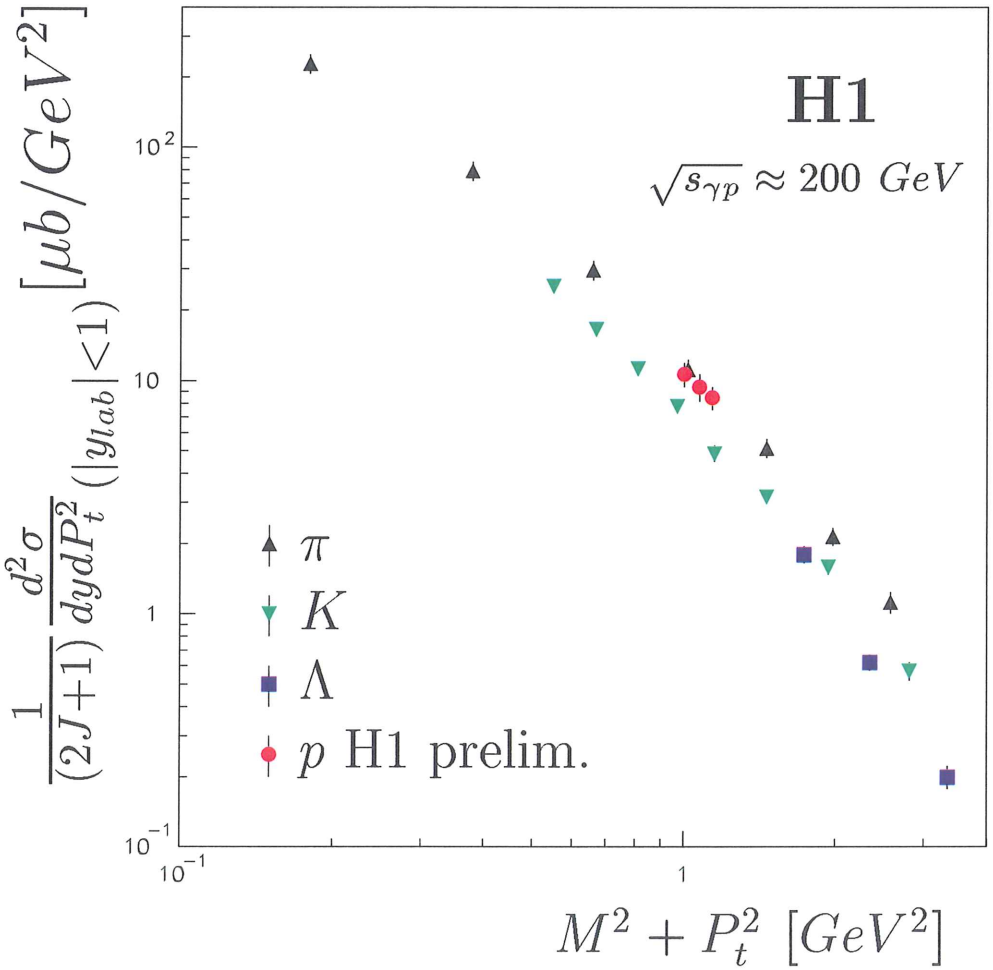
which is broadly in agreement with the data.

Transformation $P_t^2 \longrightarrow M^2 + P_t^2$

Within MLLA universality of soft particle production is found when non-perturbative effects are accounted for by

$$P_t^2 \longrightarrow Q_0^2 + P_t^2 \,,$$

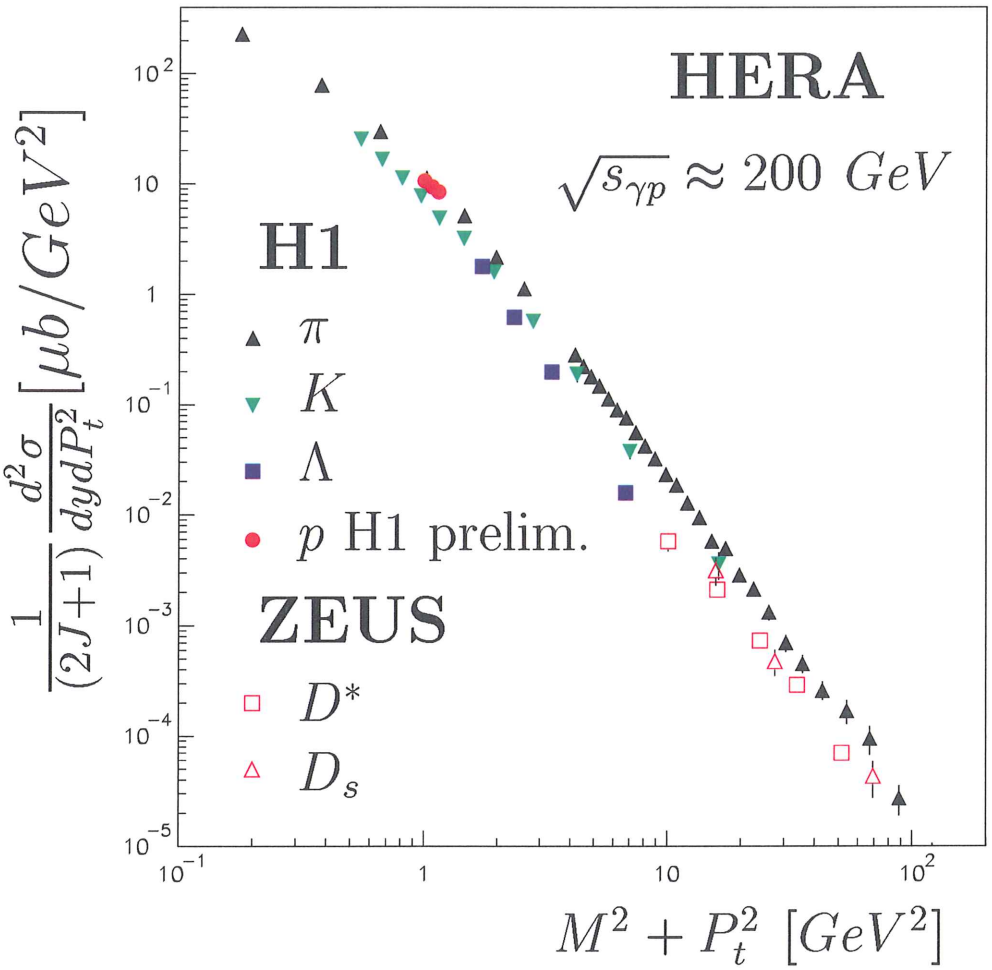
where Q_0 is an effective mass related to the mass of physical particles (V.Khoze *et al.*).



For HERA energies $Q_0^2 = M^2$ works quite well!

Extension to Charm

Adding $D^*(2010)$ and D_s data on the "Map" doesn't destroy the picture:

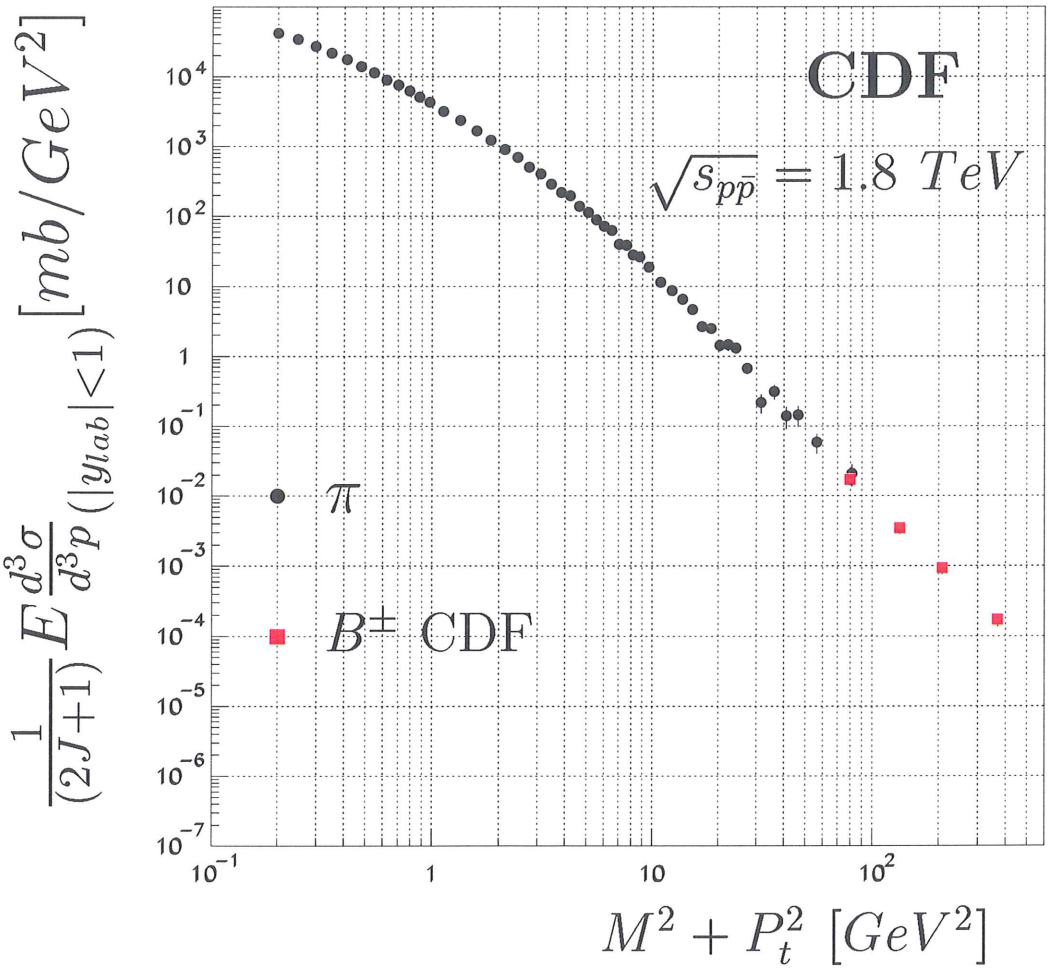


What about B-mesoms?

There is a significant underestimate of the $b\bar{b}$ rate in QCD calculations as compared with the data (factor 2-3 at HERA, Tevatron and LEP($\gamma\gamma$)).

What about B-mesons?

HERA has so far no measurement of inclusive B mesons.
The "M_T-scaling" can be tested at the Tevatron



Surprisingly, M_t-scaling is observed in the data.
Very different assumptions and models are used to describe the meson yield from π to B.
M_t-scaling means also M-scaling.
Check with exclusive meson production. $\Rightarrow$

Exclusive Vector Meson production. Models

Different theoretical approaches to describe the process

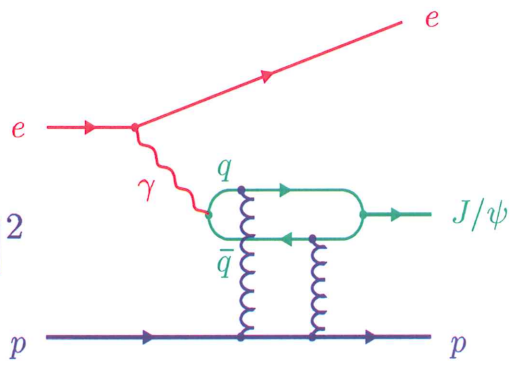
$$\gamma + p \longrightarrow V + p \quad (V = \rho^0, \omega, ... \Upsilon)$$

GVDM for low the mass ρ, ω, and ϕ mesons

$$\frac{d\sigma}{dt}|_{t=0} \sim \frac{M_V^4}{(M_V^2 + Q^2)^2}(1 + \frac{Q^2}{M_V^2})$$

'LO pQCD' for the heavy mesons $J/\Psi, \Psi'$ and Υ

$$\frac{d\sigma}{dt}|_{t=0} \sim \frac{\alpha_s^2 \Gamma_{ee}^V}{2\alpha M_V^5} 16\pi^3 [xg(x, Q^2)]^2$$



The Υ needs additional corrections on top of *LO pQCD*

- for real part of the amplitude $\sim \times 1.5$
- for off-diagonal partons $\sim \times 2$
- NLO correction $\sim \times 1.2$

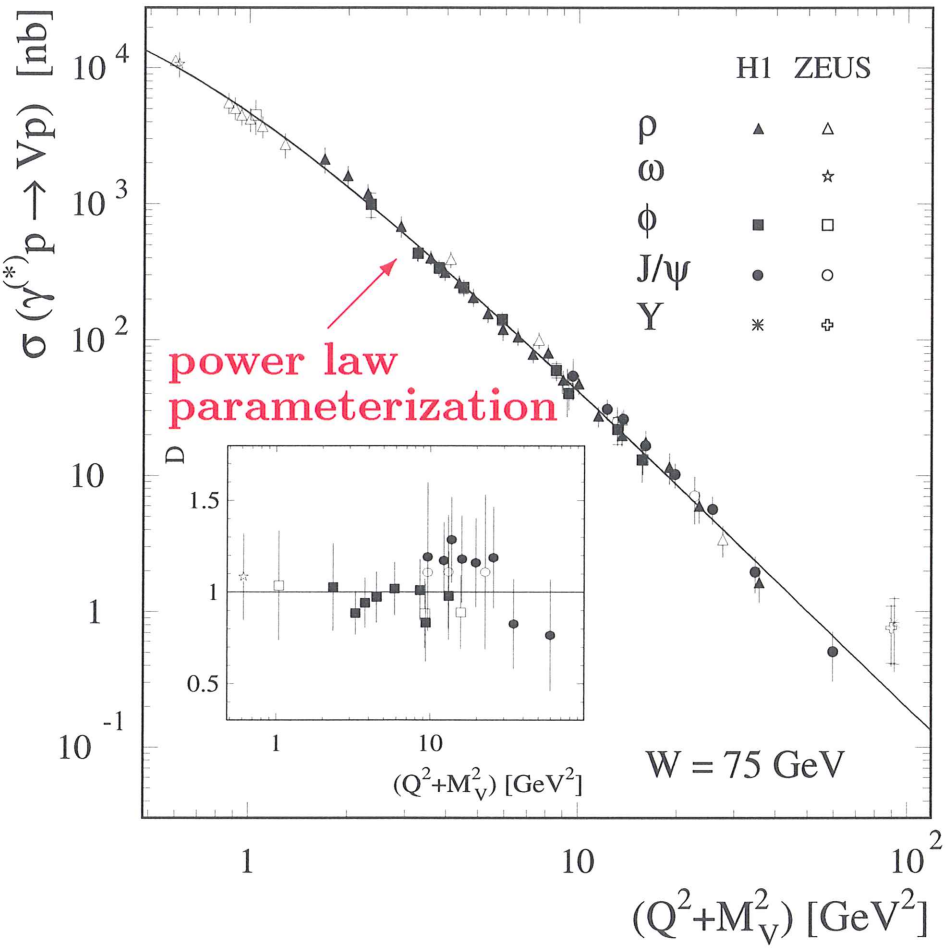
+ Differences in W and t behaviour for different VM's

Diversity of model prescriptions!

Exclusive VM production. Experiment

Compilation of exclusive vector meson cross sections at HERA scaled according to the quark charge content of the VM:

1 (ρ), 9 (ω), 9/2 (ϕ and Υ), 9/8 (J/Ψ)



♠ surprisingly good scaling of $\sigma(Q^2 = 0)$ with VM-mass.

$$\sigma(\gamma + p \to V + p) \sim \frac{F_{SU(5)}}{M^n} \quad (n = 4.7 \pm 0.1)$$

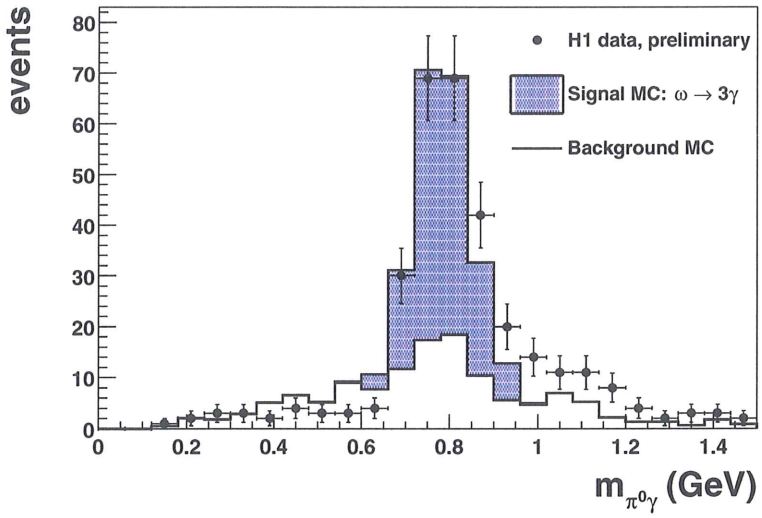
See more detailes in A.Savin talk.

♠ The "charge" factors are proportional to Γ_{ee} of the mesons

Vector meson photoproduction at high W

Two recent measurements:

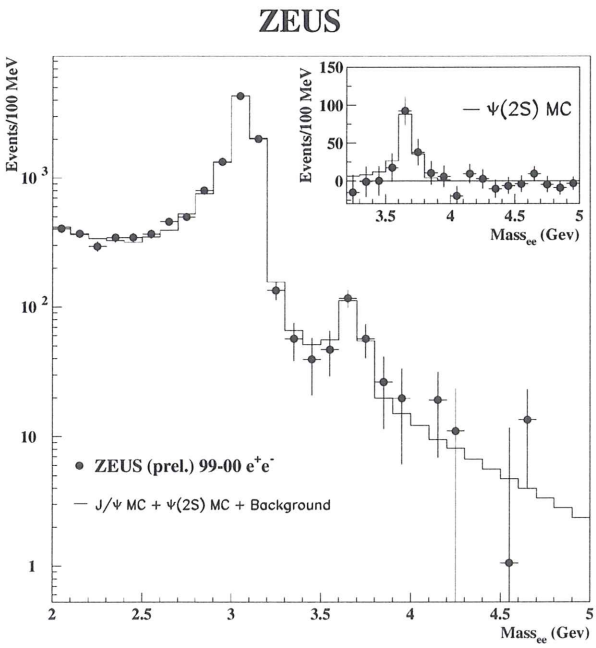
ω



H1 prelim.

$$\sigma(\gamma + p \to \omega + p) = (1.25 \pm 0.17 \pm 0.22)\mu b \quad (\langle W \rangle = 200\ GeV)\,.$$

$\Psi(2S)$

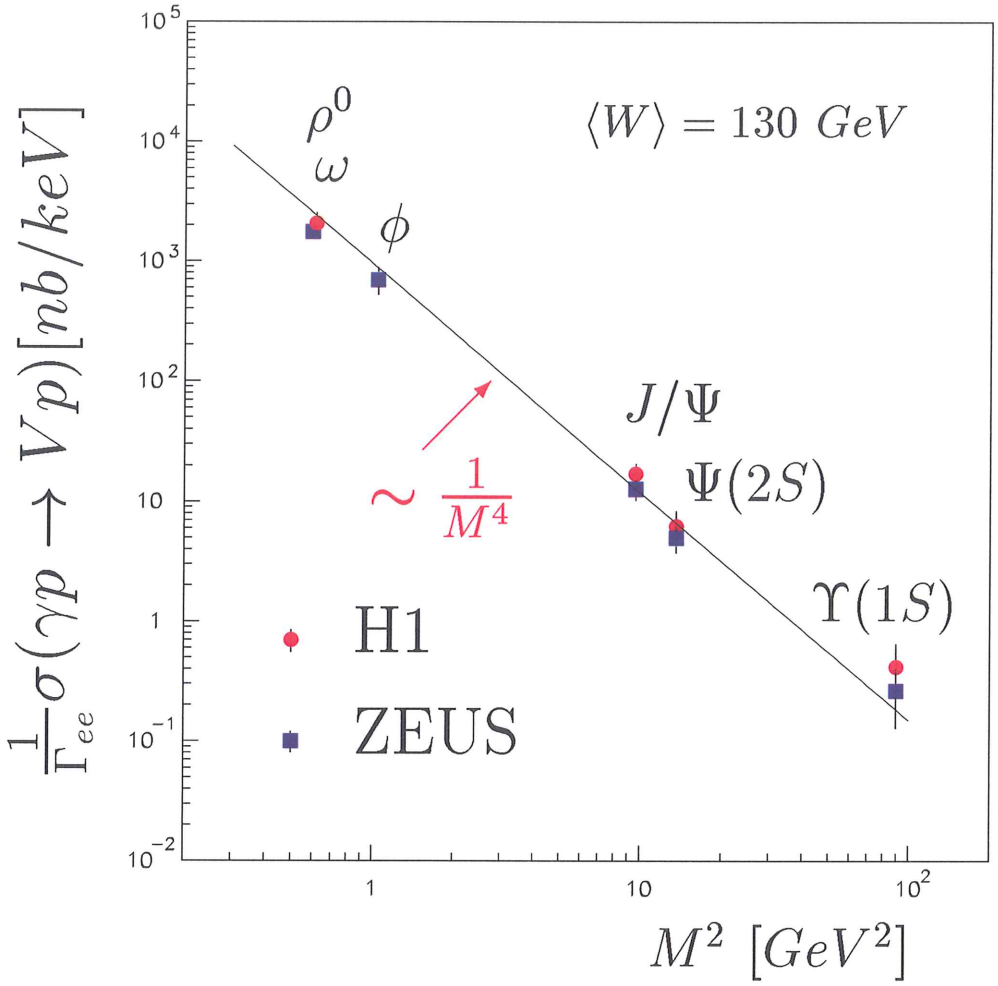


ZEUS prelim.

$$R = \frac{\sigma(\gamma + p \to \Psi(2S) + p)}{\sigma(\gamma + p \to J/\Psi + p)} = (0.16 \pm 0.02) \quad (\langle W \rangle \approx 100\ GeV)\,.$$

No W dependence or R is found

"Map" of VM photoproduction



♠ Mass and Γ_{ee} define exclusive VM yield:

$$\sigma \sim \frac{\Gamma_{ee}}{M^n}\,;\ (n \approx 4, \langle W \rangle = 130\ GeV)\,.$$

♠ Striking similarity to the scaling law found by F.Halzen *et al.* 1977 for narrow vector mesons $(\phi, J/\Psi, \Upsilon)$ inclusive production in $h - h$ interactions:

$$\sigma \sim \frac{\Gamma_{ggg}}{M^n}\,;\ (n \approx 4)\,.$$

Exclusive $N\gamma$ photoproduction

Diffractively produced VM's $C = C_\gamma \times C_{I\!P} = -1$
What about exclusive production of $C = +1$ states?

$$\gamma + p \longrightarrow Y(C = +1) + p \ ,$$

$$(Y = \pi^0, f_2(1270), a_2(1320), ...)$$

The $C = +1$ final states decaying into $N\gamma$ $(N = 2, 4, ..)$.

The exclusive diffractive π^0 photoproduction has been studied before at lower $(W < 6\ GeV)$.
Strongly falling with W cross section is observed.

An evidence of f_2 production at $W = 20\ GeV$ (E687 exp.)

Candidates for exchange particle with $C = -1$:

A. Photon. Primakoff process of $\gamma - \gamma$ fusion

$$\sigma^{em}_{p+\gamma \longrightarrow \pi^0 + X} < 0.1\ nb$$

B. Reggeon with a typical intercept $\alpha(0) \approx 0.5$:

$$\sigma = O(0.1\ nb)$$

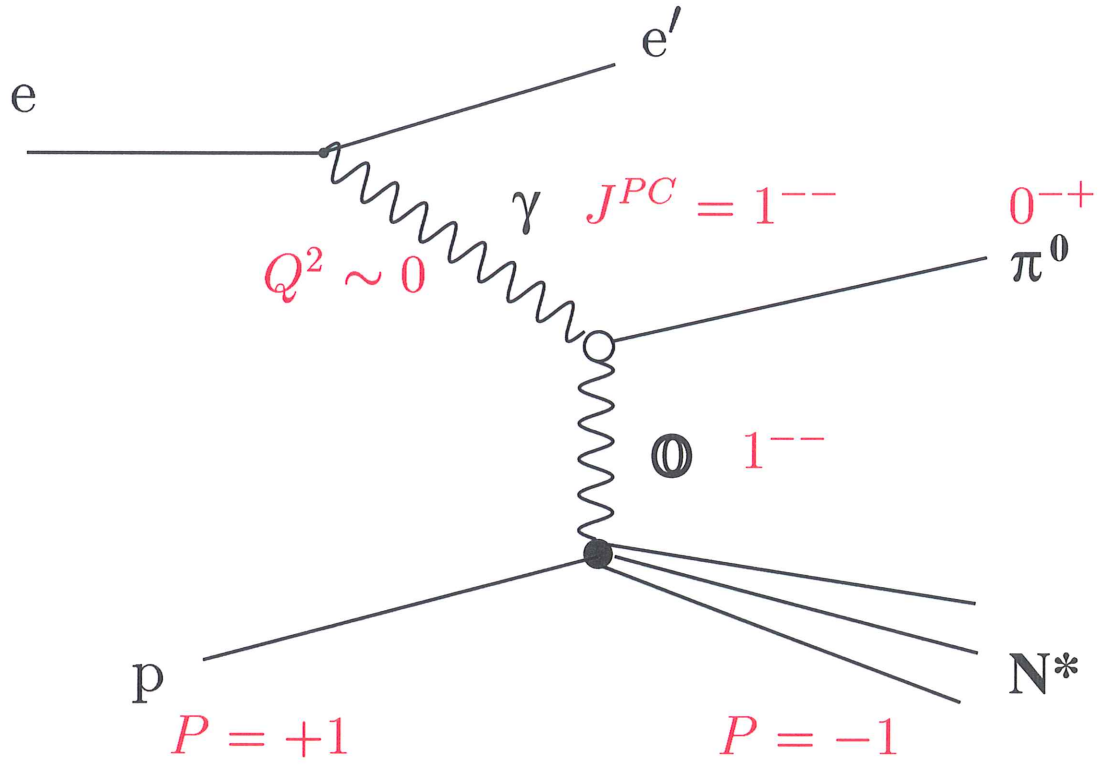
C. Odderon with a typical intercept $\alpha(0) \approx 1.0$

$\Rightarrow$

Odderon induced π^0 photoproduction

$$\gamma + p \longrightarrow \pi^0 + p$$

Odderon (C=P=-1) exchange could define asymptotic behaviour of diffractive π^0 photoproduction



E.R.Berger *et al.* (1999) predict large cross section for

$$\sigma(\gamma + p \longrightarrow \pi^0 + X) \approx 600nb \ ,$$

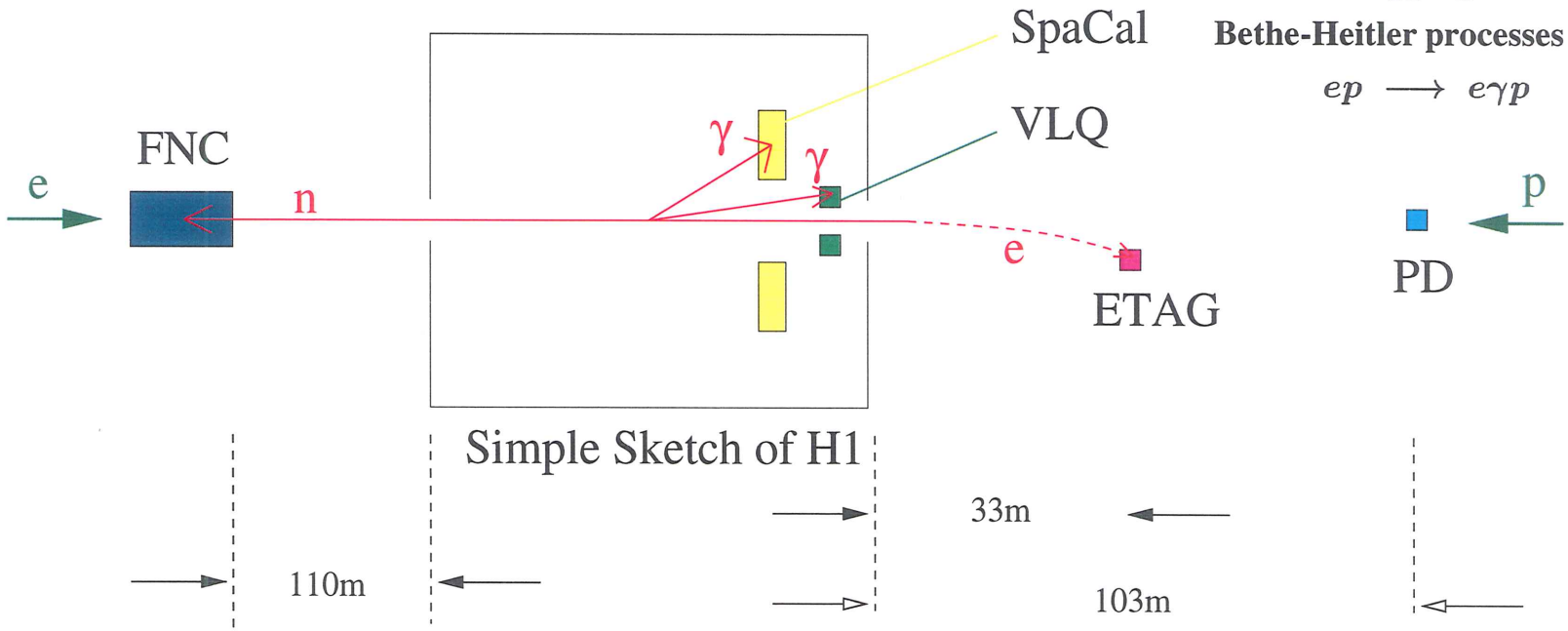
X- diffractively excited proton ($M_X < 2GeV$) with about 70% $X \equiv N^*$ baryonic resonances.

$$\sigma(\gamma + p \longrightarrow \pi^0 + N^*) \approx 400nb \ .$$

THE SIGNATURE

$$ep \longrightarrow e\,\pi^{\circ}\,N^{*}$$

$$N^{*} \longrightarrow n\,X \qquad \pi^{\circ} \longrightarrow \gamma\gamma$$



TRIGGER:

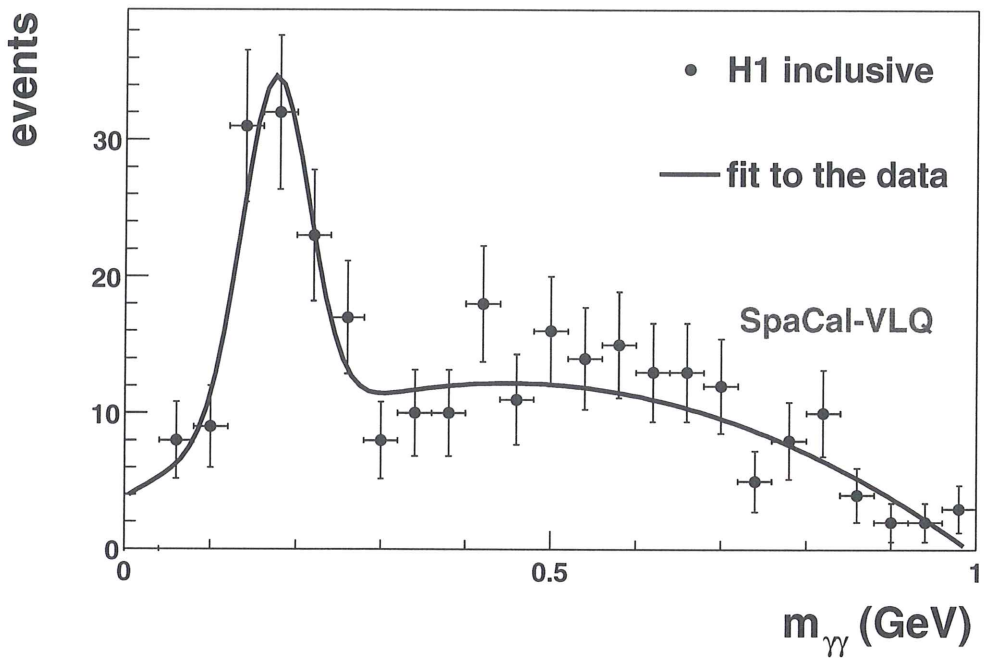
Neutron Energy $>$ 200 GeV
VLQ Energy $>$ 6 GeV
Electron Energy $>$ 6 GeV
PD Energy $<$ 2 GeV

Rejection of background from overlapping Bethe-Heitler processes

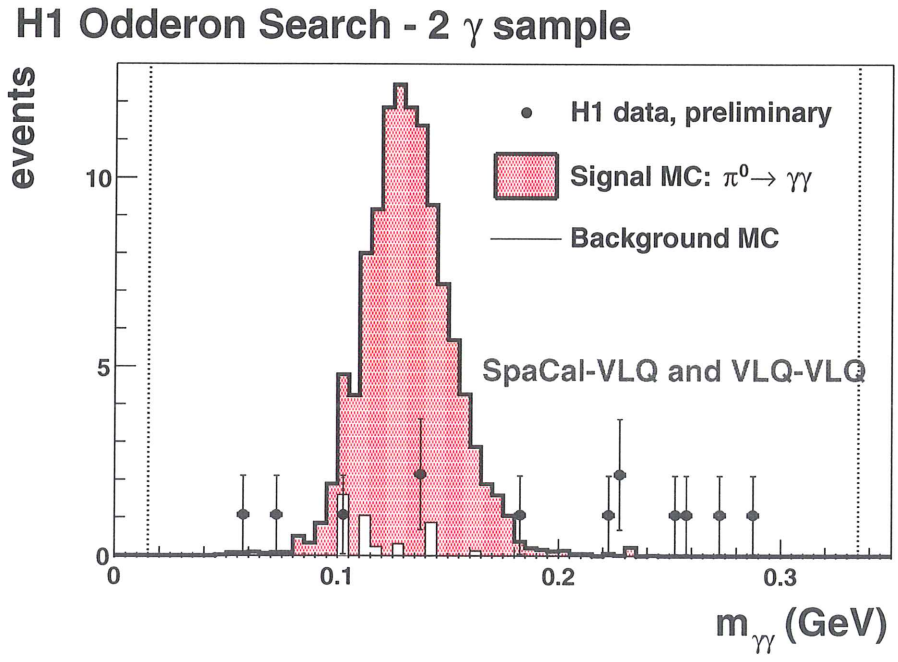
$$ep \longrightarrow e\gamma p$$

Exclusive π^0 photoproduction

π^0s are detectable at small ($\theta_\gamma \approx 178°$!) angle



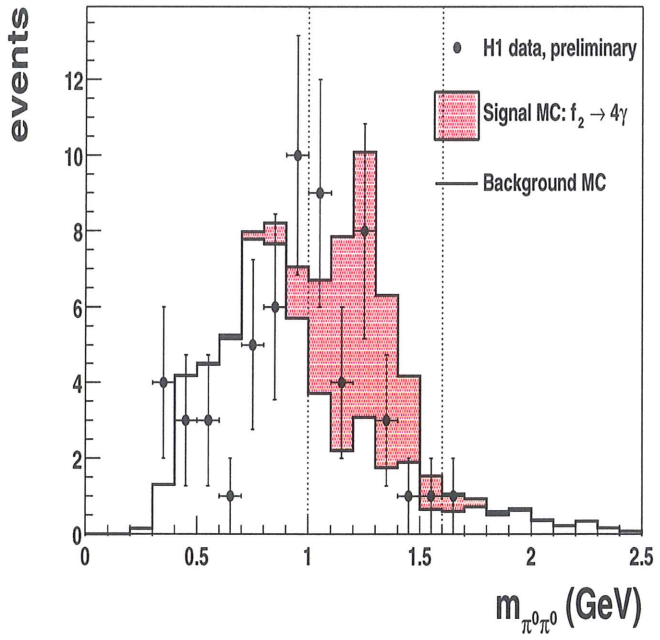
...but no signal is seen for exclusive π^0s



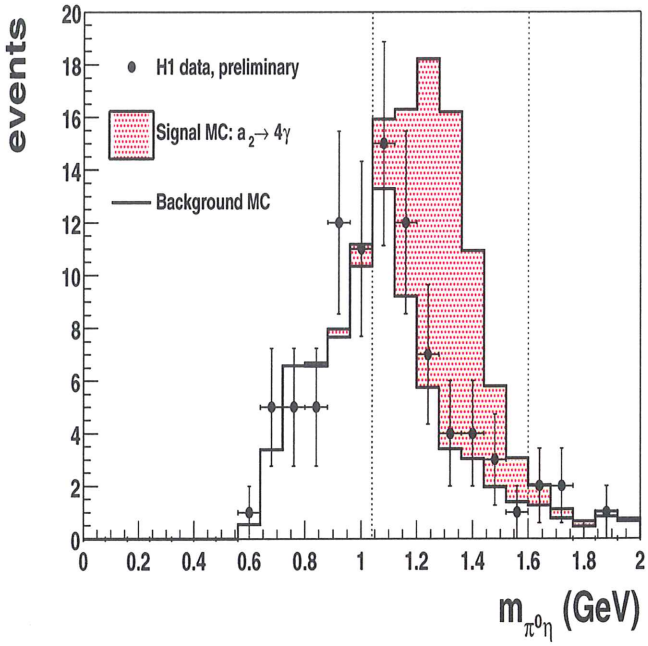
Exclusive $N\gamma$ photoproduction

4γ sample

$f_2 \longrightarrow \pi^0 + \pi^0$

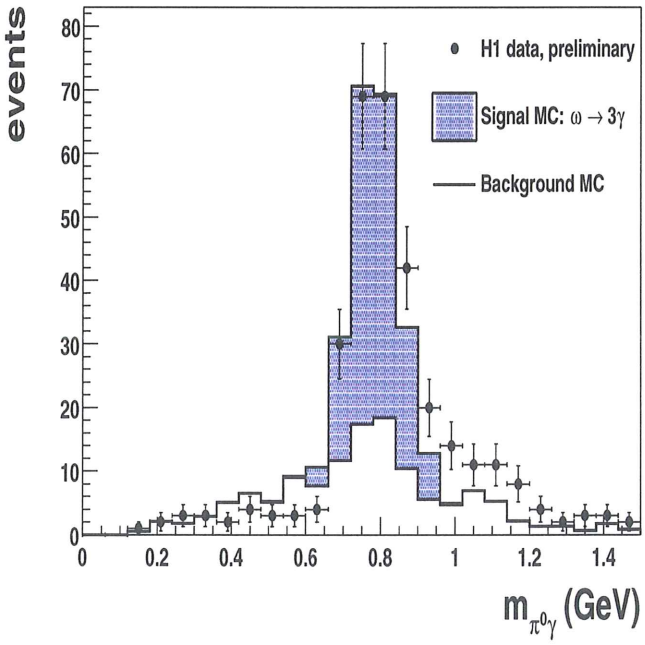


$a_2 \longrightarrow \pi^0 + \eta$

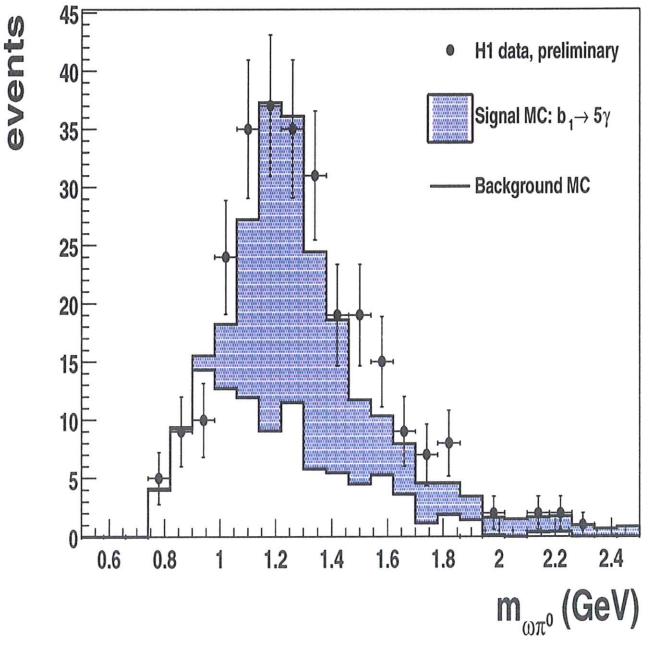


...but in 3γ and 5γ

$\omega \longrightarrow \pi^0 + \gamma$



$b_1(1235) \longrightarrow \pi^0 + \omega$



Experimental limits

H1 gives limits on the cross sections:

$$\sigma(p+\gamma \xrightarrow{\mathbb{O}} \pi^0 + N^*) < 39nb \qquad (\sigma^{theor} = 200nb)$$

$$\sigma(p+\gamma \xrightarrow{\mathbb{O}} f_2(1270) + N^*) < 16nb \quad (\sigma^{theor} = 21nb)$$

$$\sigma(p+\gamma \xrightarrow{\mathbb{O}} a_2(1320) + N^*) < 96nb \quad (\sigma^{theor} = 190nb)$$

All limits are for $< W_{\gamma p} >= 210GeV$ and visible range $0.02 < |P_t^2| < 0.3GeV^2$

The limits are preliminary.

No signal for the Odderon induced reaction is found.

Summary

HERA is a rich and unique source of the data on soft particle production.

While very different assumptions and models prescriptions are used to describe the meson yield from π to Υ the data show an approximate scaling with the meson mass.

- Exclusive photoproduction of Vector mesons at HERA could be parameterized by a simple function of mass and Γ_{ee} of the meson.
- In inclusive photoproduction of pseudoscalar mesons of different flavours at HERA the meson mass to a good approximation defines the yield of the mesons.

Is there a good reason for the approximate mass scaling at high energies, or it is coincidental?

No evidence for Odderon induced reactions is found in the data.