Odderon and Pomeron Physics in Multi-Photon Final States at HERA

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on behalf of the H1 Collaboration

31st International Conference on High Energy Physics

Amsterdam
July 24th — 31st 2002

Outline

- Introduction
  - on the Odderon in general
  - and at HERA in particular
- Results
- Summary

What is the Odderon?

- ... the

$$C = P = -1$$

partner of the Pomeron!

- But what is the Pomeron?
  In Regge Theory it is thought to be responsible for the rise of hadronic total cross sections at high energies.

- In pQCD:

$$\mathbb{P} \leftrightarrow 2 \text{ gluons}$$
$$\mathbb{O} \leftrightarrow 3 \text{ gluons}$$

- The Odderon was introduced on amplitude level (for large s) by Łukaszuk and Nicolescu, as an **odd** *under crossing* piece in the scattering amplitude.

$$pp: \quad T = T_+ + T_- \overset{\text{crossing}}{\longleftrightarrow} T = T_+ - T_- \quad : p\bar{p}$$

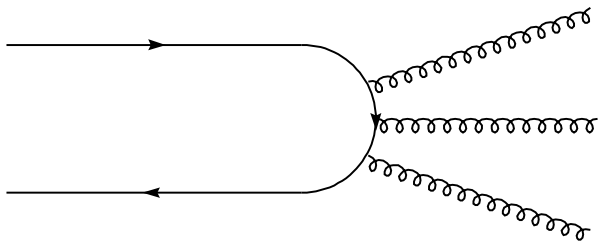
- If $T_- \neq 0 \Rightarrow$

$$\Delta\sigma = \sigma_{\text{tot}}^{pp} - \sigma_{\text{tot}}^{p\bar{p}} \not\to 0 \quad \text{for } s \to \infty$$

- But so far there is no evidence for the presence of the Odderon in hadron hadron scattering! Though it is firmly predicted by QCD.

- On the other hand there are 3 gluon states! at least in the s-channel, namely

$$J/\psi \to 3g \to hadrons$$



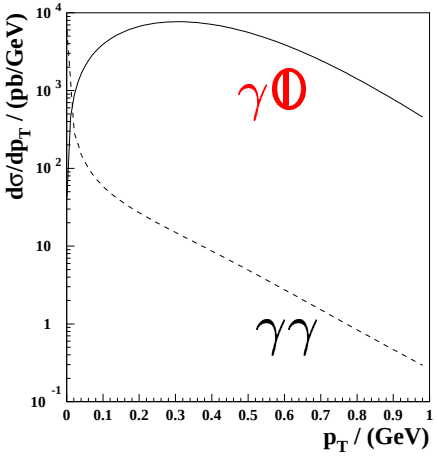
The Odderon at HERA

- HERA is currently the only place to look for Odderon contributions
- There is a non-perturbative QCD model for the Odderon:

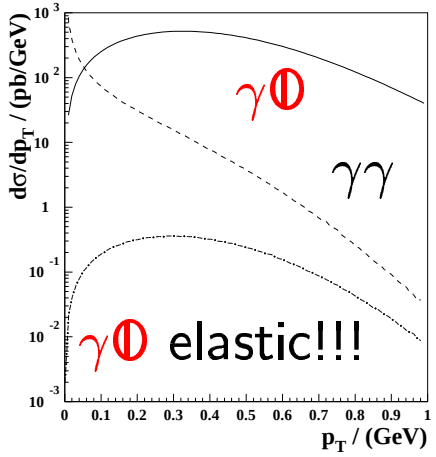
  "Stochastic Vacuum Model" (SVM)

  E. R. Berger et al., Euro. Phys. J **C9**(1999) ibid **C14**(2000) with predictions for HERA of
- *large* cross sections if the proton is excited into N^*s
- The model p_T distributions were implemented into an event generator

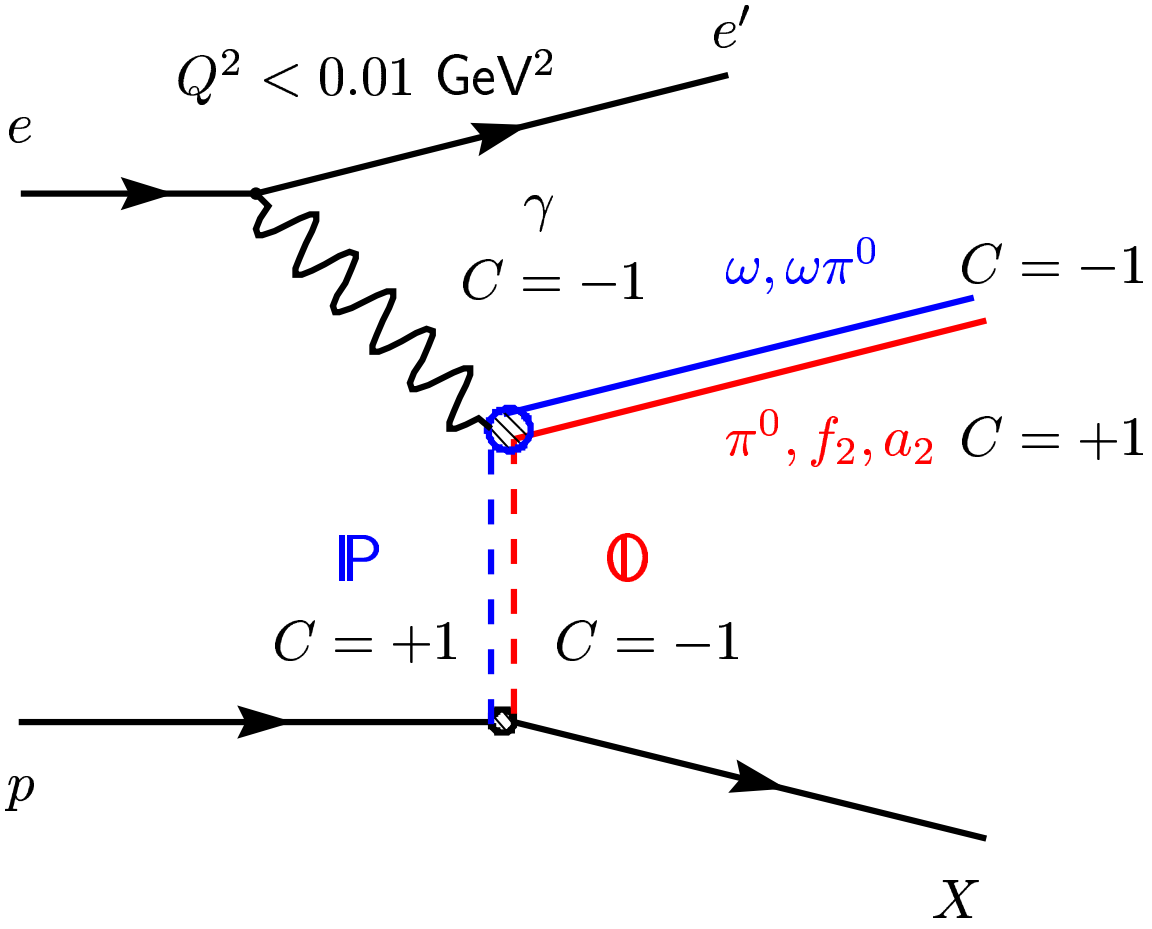
π^0



f_2/a_2



How Do the Pomeron and the Odderon Show up at HERA?



M	$\rightarrow$	decay	$\rightarrow n\gamma$
π^0			$\rightarrow 2\gamma$
$f_2(1270)$	$\rightarrow$	$\pi^0\pi^0$	$\rightarrow 4\gamma$
$a_2(1312)$	$\rightarrow$	$\pi^0\eta$	$\rightarrow 4\gamma$
ω	$\rightarrow$	$\pi^0\gamma$	$\rightarrow 3\gamma$
$\omega\pi^0$	$\rightarrow$	$\pi^0\gamma\ \gamma\gamma$	$\rightarrow 5\gamma$

$\uparrow$?

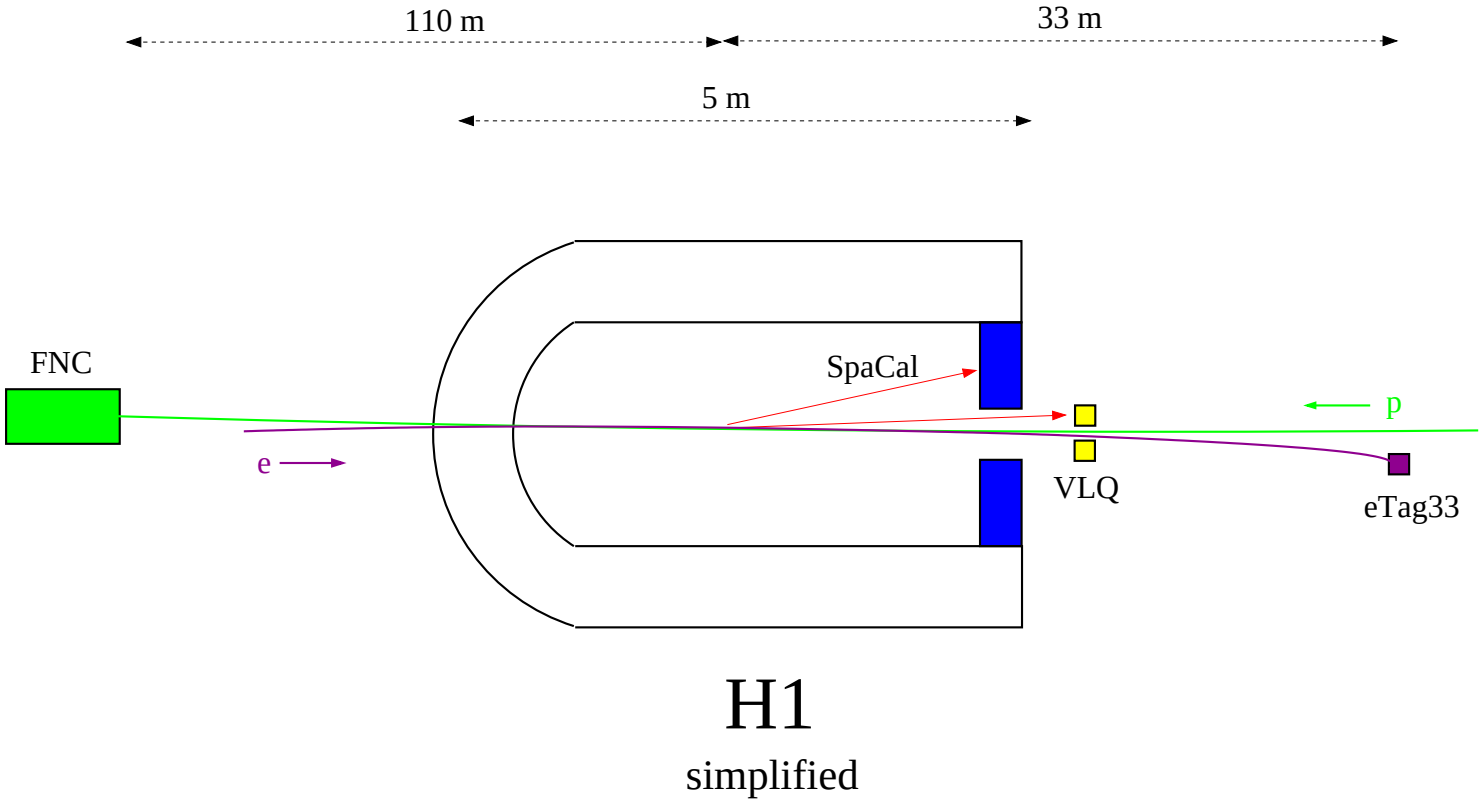
$b_1(1230)$

. . . And Experimentally?

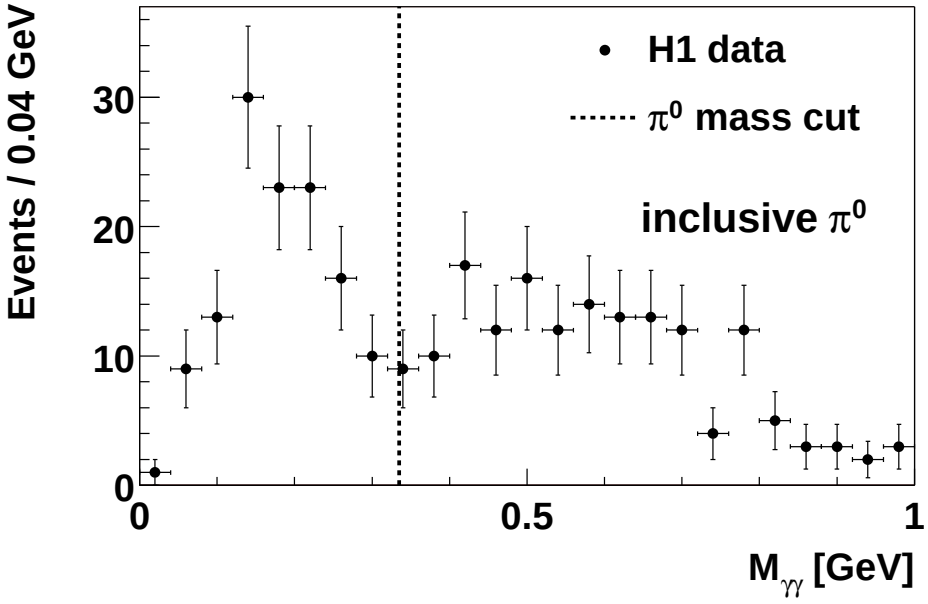
photoproduction ($Q^2 < 0.01$ GeV^2) of the processes

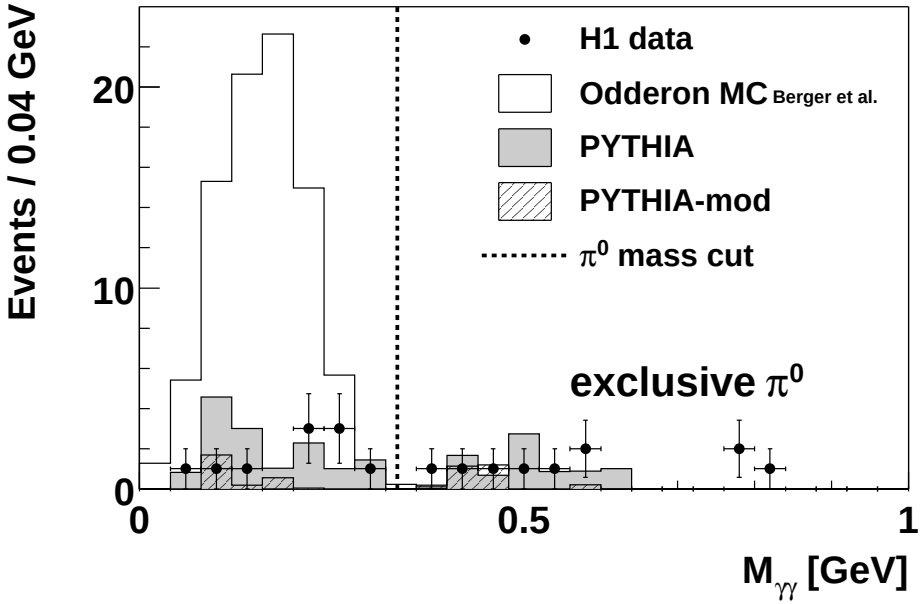
$$ep \rightarrow e'MX$$

$\hookrightarrow$ photons



2γ Sample — π^0





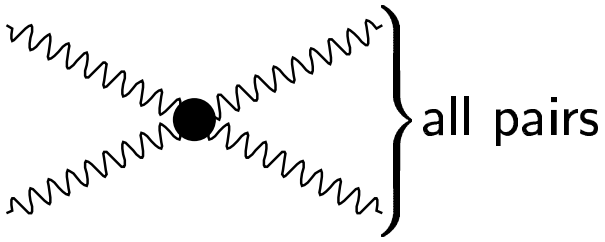
H1 Limit @ 95 % CL; $\langle W \rangle = 215$ GeV

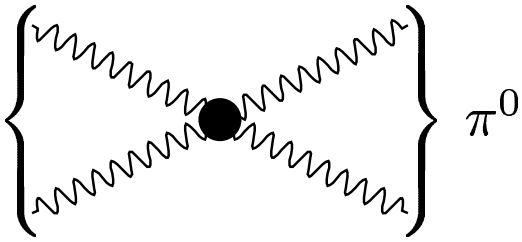
in the visible t-range $0.02 < |t| < 0.3$ GeV^2

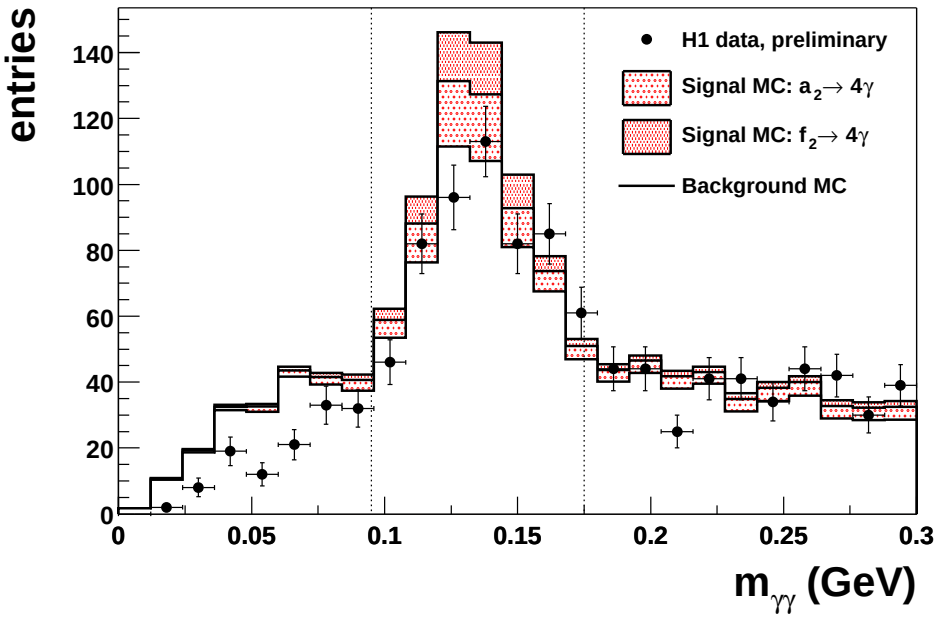
$\sigma(\gamma p \to \pi^0 N^*) < 49$ nb

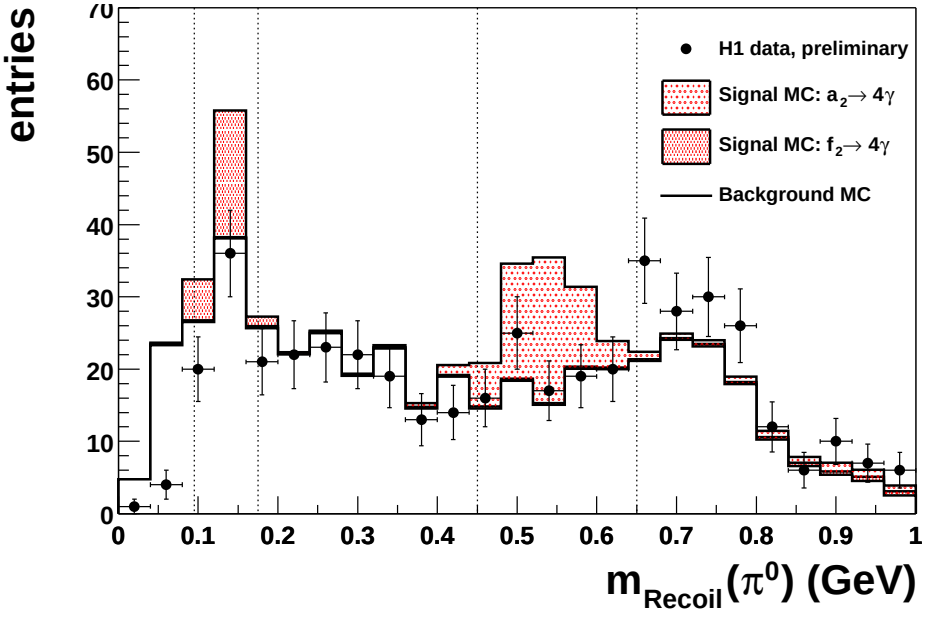
with the SVM prediction of > 200 nb

4 γ-Sample

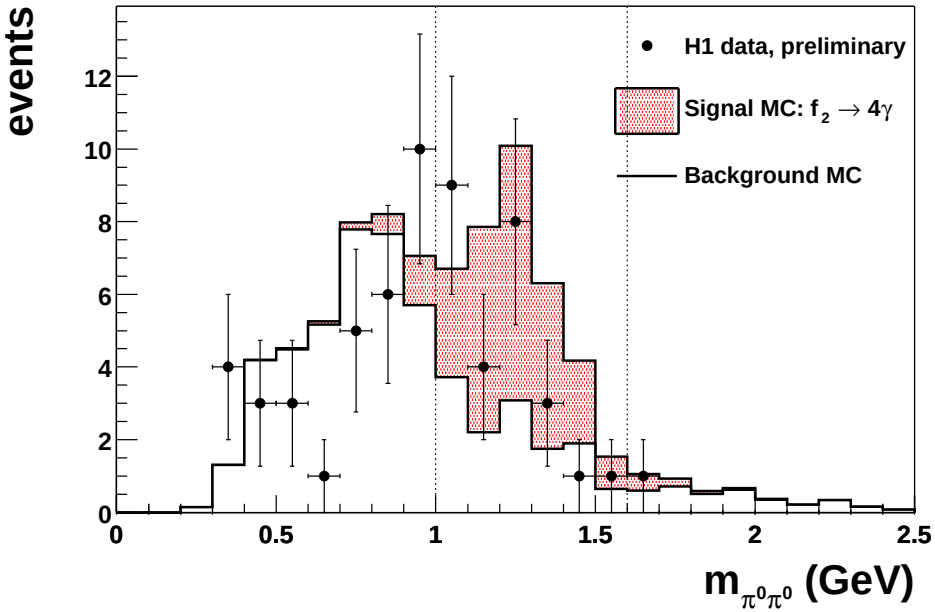




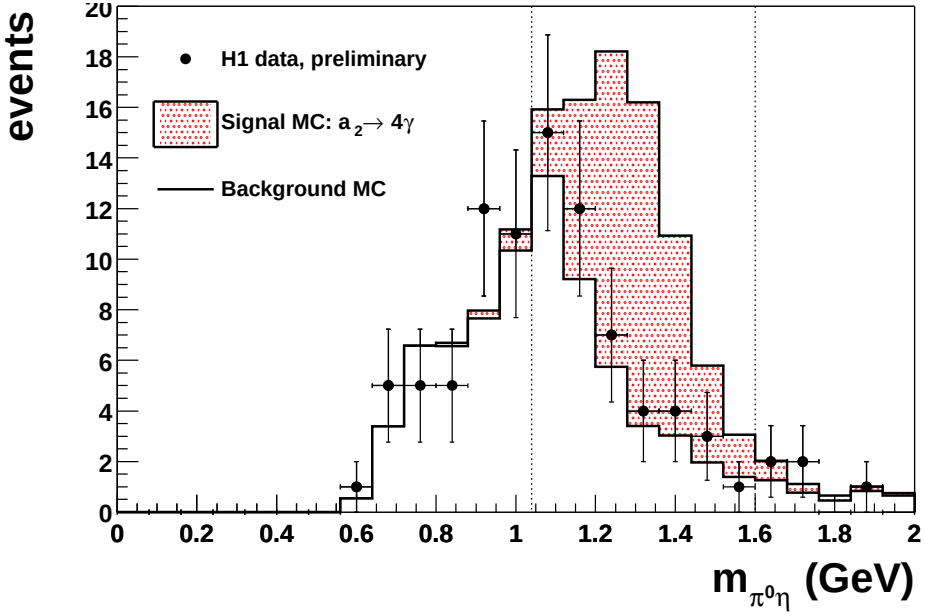




Limit on the f_2



Limit on the a_2



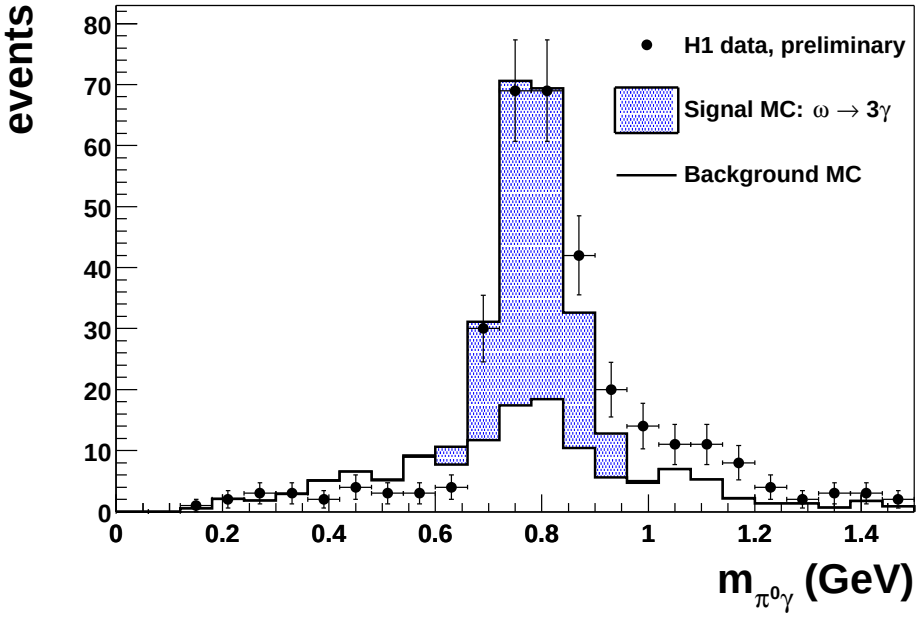
H1 Limit (preliminary) @ 95 % CL ($\langle W \rangle = 200$ GeV)

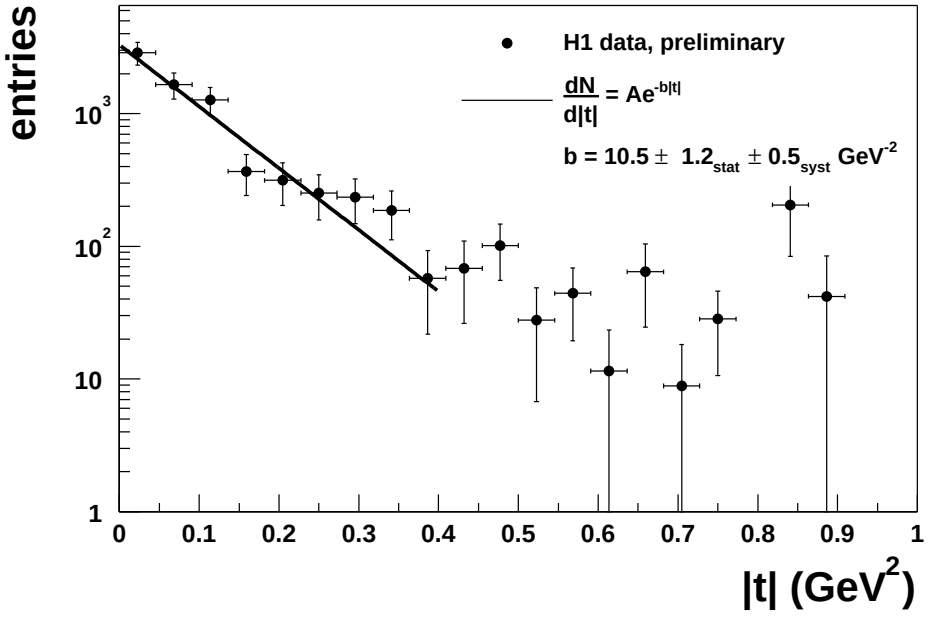
$\sigma(\gamma p \to f_2 X) < 16$ nb $\qquad$ $\sigma(\gamma p \to a_2 X) < 96$ nb

With SVM predictions of

21 nb $\qquad$ 190 nb

3 γ-Sample — ω

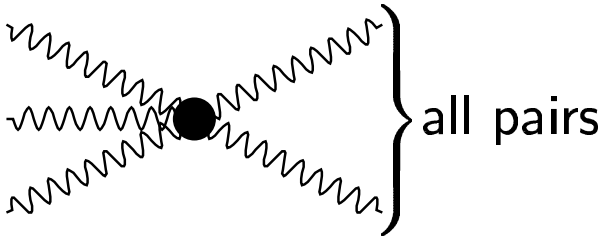


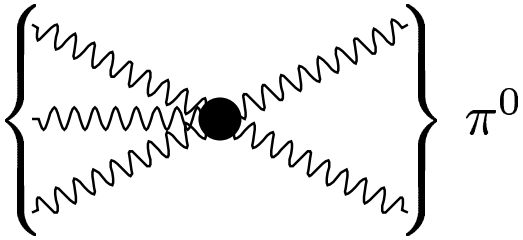


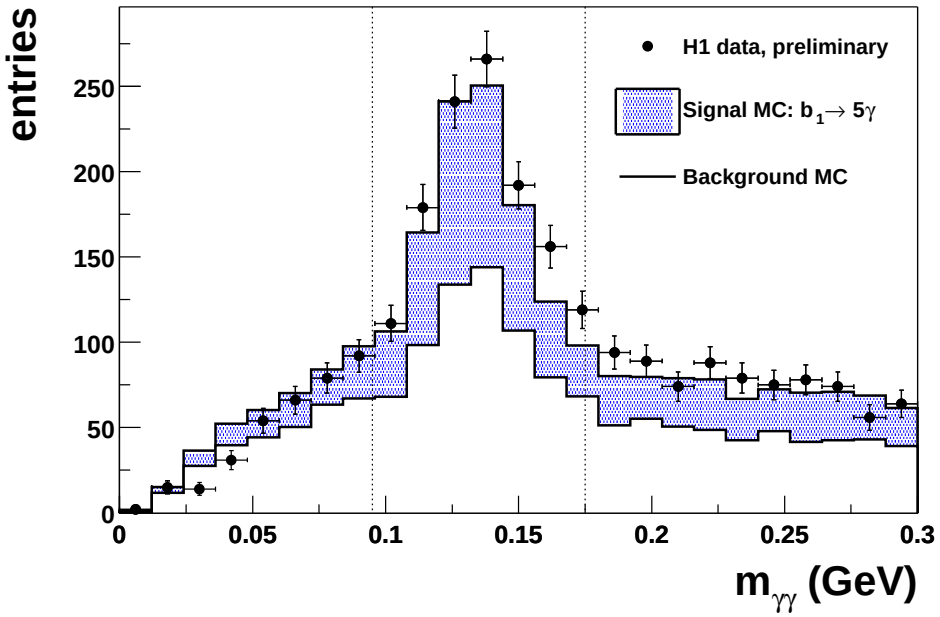
$$\sigma(\gamma p \to \omega p) = (1.3 \pm 0.2 \pm 0.2)\,\mu\text{b}$$
$$b = (10.5 \pm 1.2 \pm 0.5)\ \text{GeV}^{-2}$$

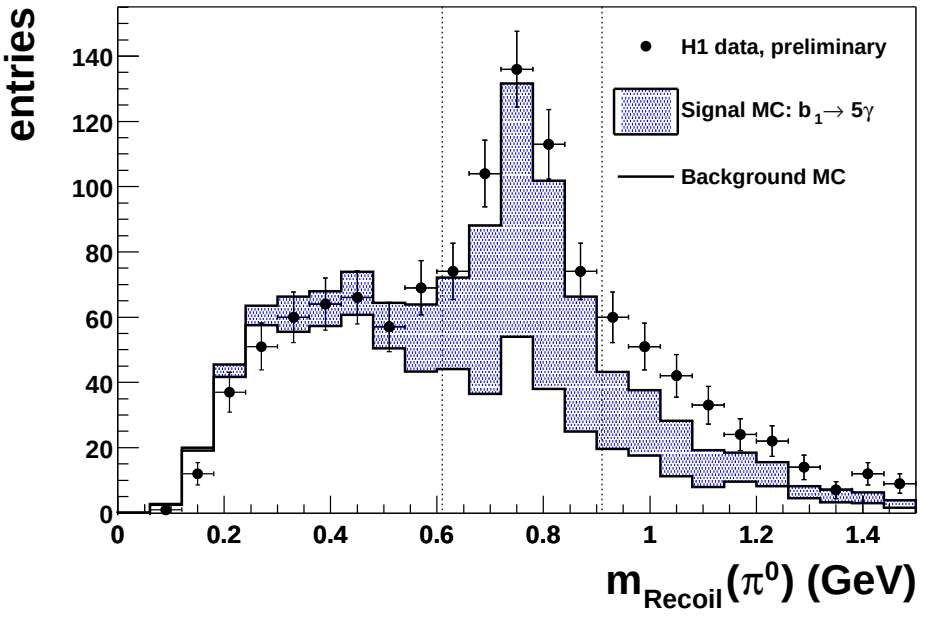
at $\langle W \rangle = 200$ GeV as expected!

5 γ-Sample — $\omega\pi^0$

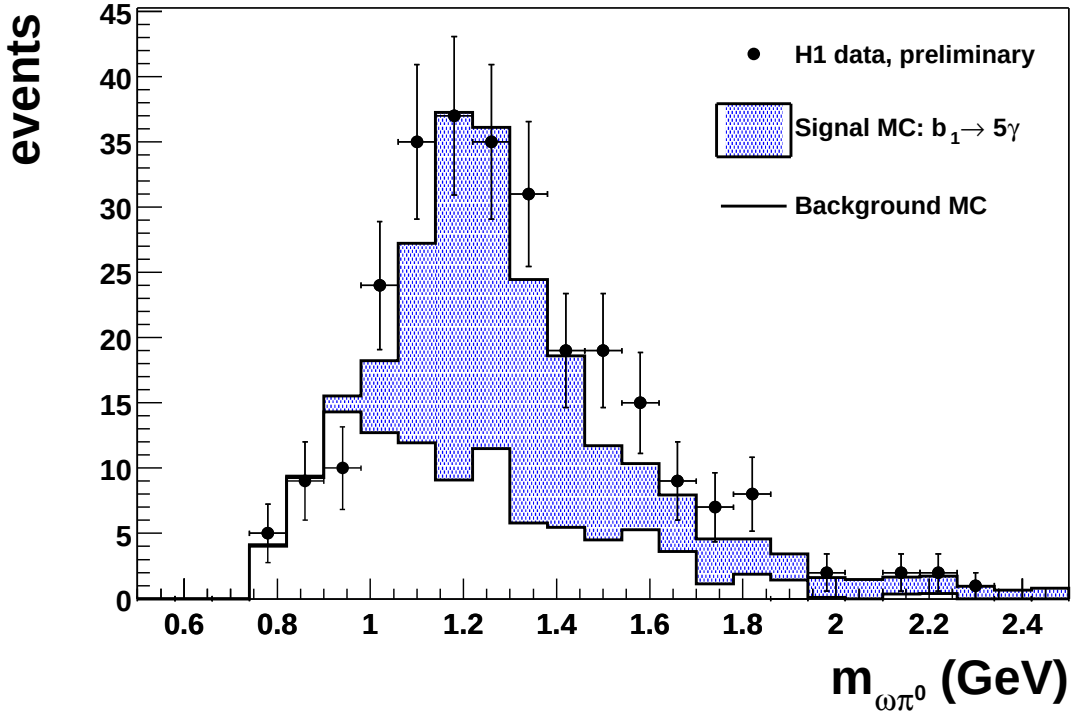








$\omega\pi^0$ — Cross Section



First measurement at HERA!!!

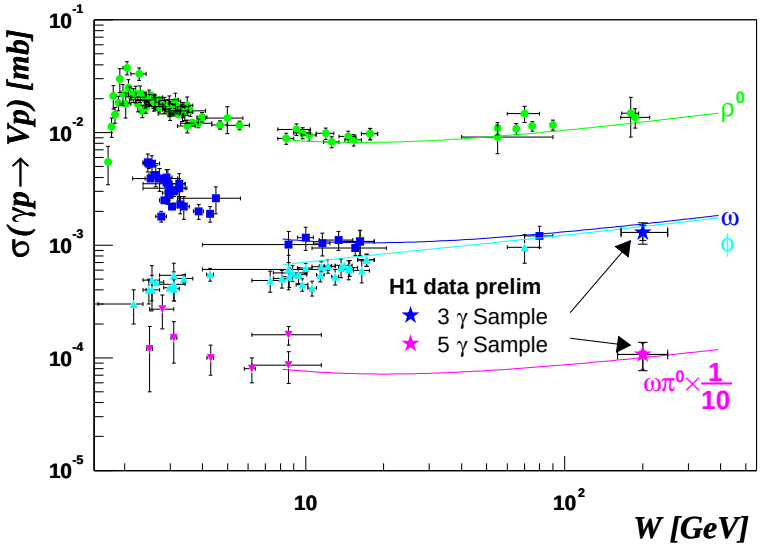
$\sigma(\gamma p \to \omega\pi^0 X) = (1.0 \pm 0.2 \pm 0.2)\ \mu$b

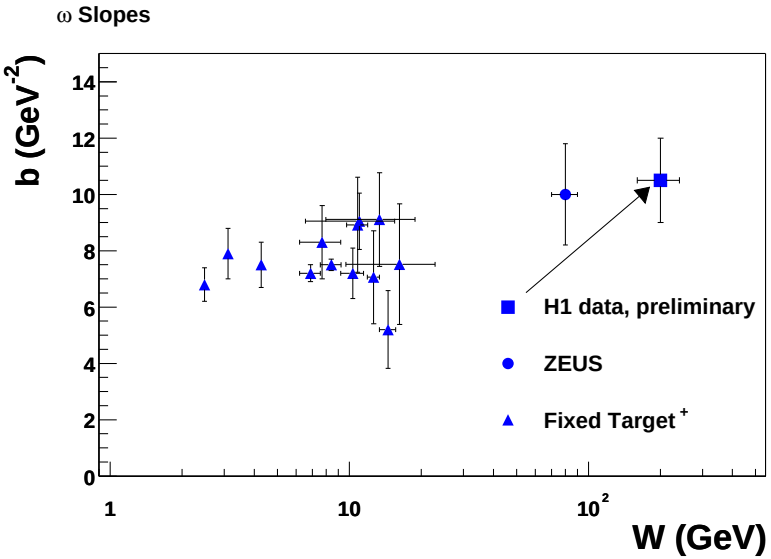
at $\langle W_{\gamma p} \rangle = 200$ GeV

to be compared with a $0.2\ \mu$b NR-contrib from Pythia and $0.7\ \mu$b exclusive b_1 as extrapolated from low E

Summary

The Pomeron is there as expected





No Odderon-contribution seen!!!

In a first search for $\mathbb{O}$-contribution in an $e(\gamma)p$ environment.

$$\sigma(\gamma p \to MX)$$

	H1 @95% CL	E. R. Berger
$\pi^0 N^*$	$<$ 49 nb	$>$ 200 nb
$a_2 X$	$<$ 96 nb (prel)	190 nb
$f_2 X$	$<$ 16 nb (prel)	21 nb

So far, no explanation in npQCD