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

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on behalf of the H1 Collaboration

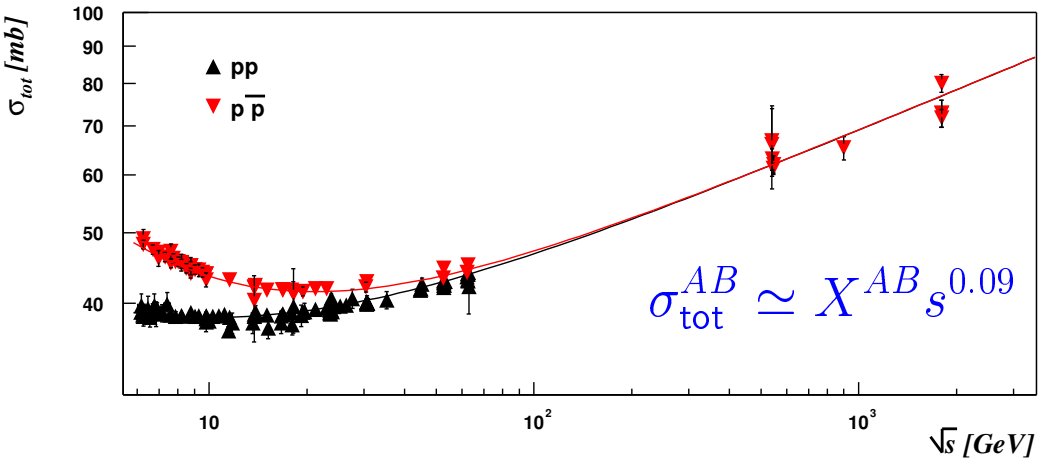
X International Workshop on
Deep Inelastic Scattering

Cracow
30 April — 4 May 2002

# What is the Odderon?

- The
$$C = P = -1$$
partner of the Pomeron!

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



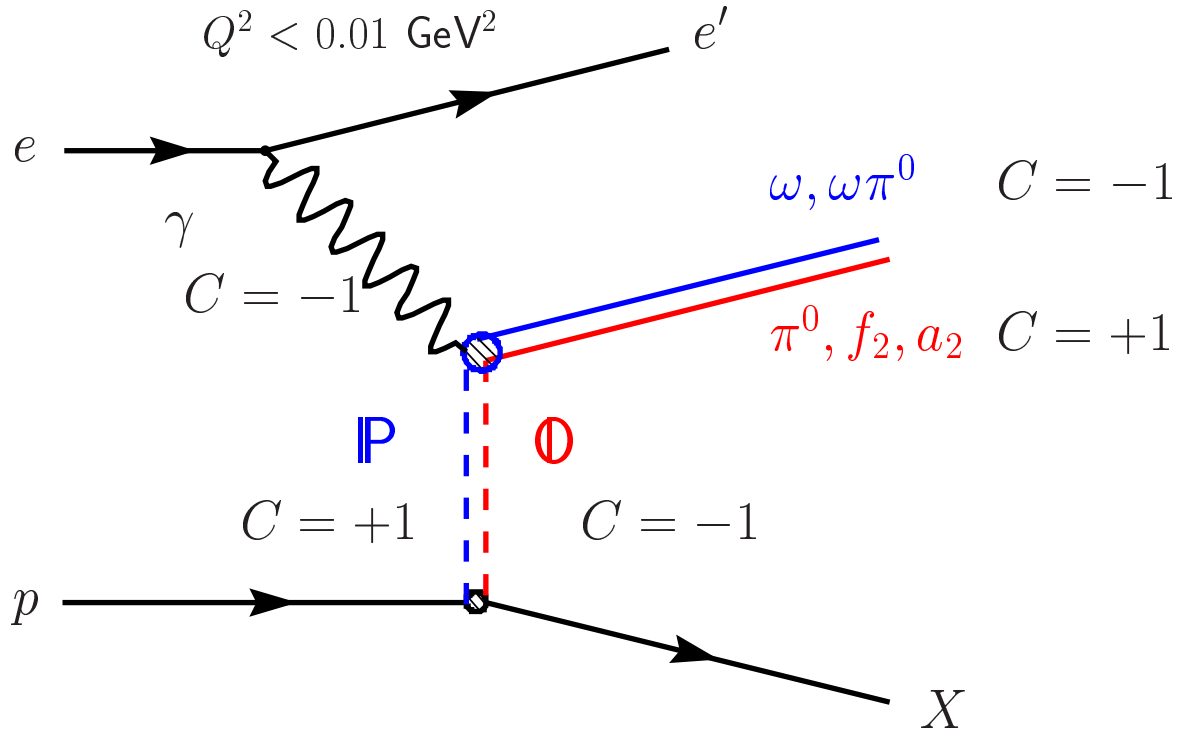

- In pQCD:
$$\mathbb{O} \leftrightarrow 3 \text{ gluons}$$
$$\mathbb{P} \leftrightarrow 2 \text{ gluons}$$

- The Odderon was introduced on amplitude level (for large $s$) by Łukaszuk and Nicolescu,
$$pp: \quad T = T_+ + T_- \overset{\text{crossing}}{\longleftrightarrow} T = T_+ - T_- \quad : p\bar{p}$$
as an **odd** *under crossing* piece in the scattering amplitude.

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

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

# How Do the Pomeron and the Odderon Show up?




| $M$ | | decay | | $n\gamma$ |
|---|---|---|---|---|
| $\pi^0$ | | | $\rightarrow$ | $2\gamma$ |
| $\omega$ | $\rightarrow$ | $\pi^0\gamma$ | $\rightarrow$ | $3\gamma$ |
| $f_2(1270)$ | $\rightarrow$ | $\pi^0\pi^0$ | $\rightarrow$ | $4\gamma$ |
| $a_2(1312)$ | $\rightarrow$ | $\pi^0\eta$ | $\rightarrow$ | $4\gamma$ |
| $\omega\pi^0$ | $\rightarrow$ | $\pi^0\gamma\ \gamma\gamma$ | $\rightarrow$ | $5\gamma$ |
| $\uparrow$ ? | | | | |
| $b_1(1230)$ | | | | |

# The Odderon at HERA

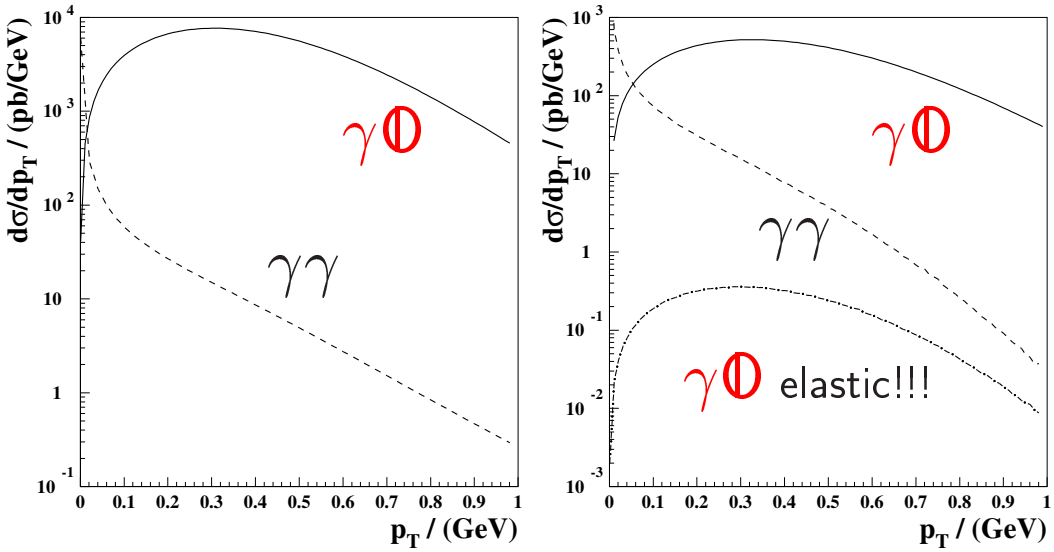
- HERA is currently the only place to look for Odderon contributions
- There is a non-perturbative QCD model for the Odderon:

  "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

$\pi^0$ $\qquad\qquad$ $f_2/a_2$




with

$$t = -p_T^2$$

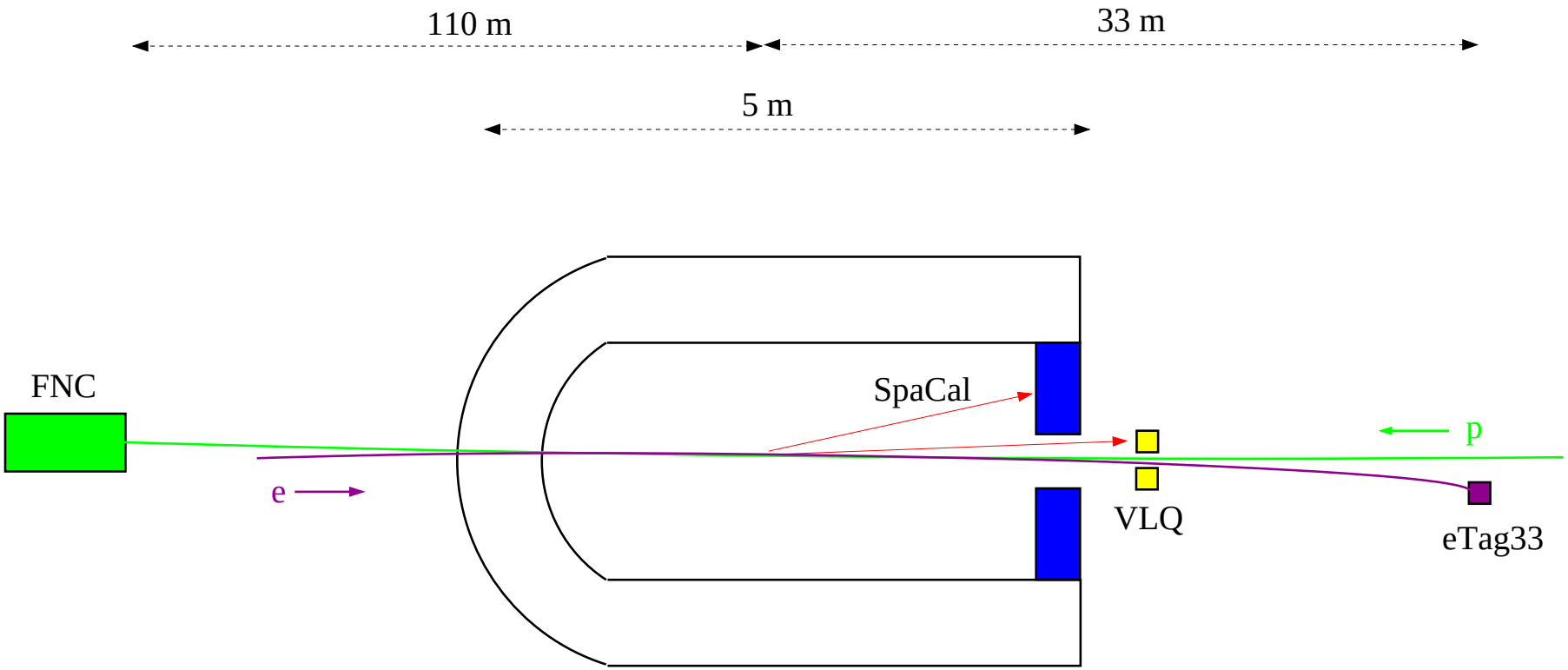
- These distributions were implemented into an event generator

# ... And Experimentally?

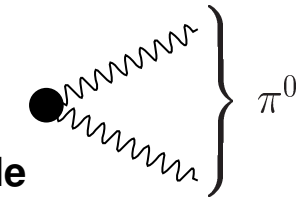
photoproduction ($Q^2 < 0.01$ GeV$^2$) of the processes

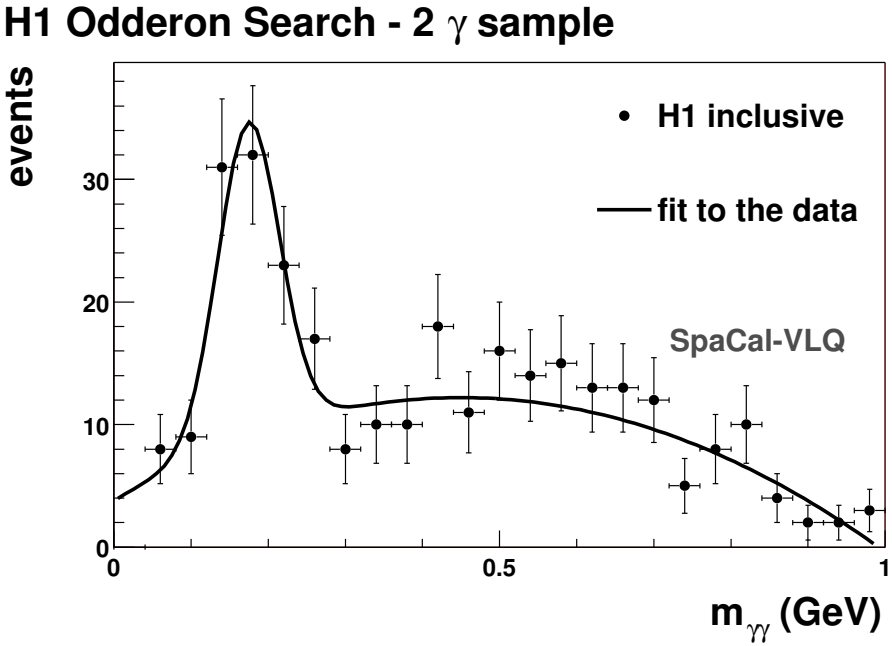
$$ep \to e'MX$$

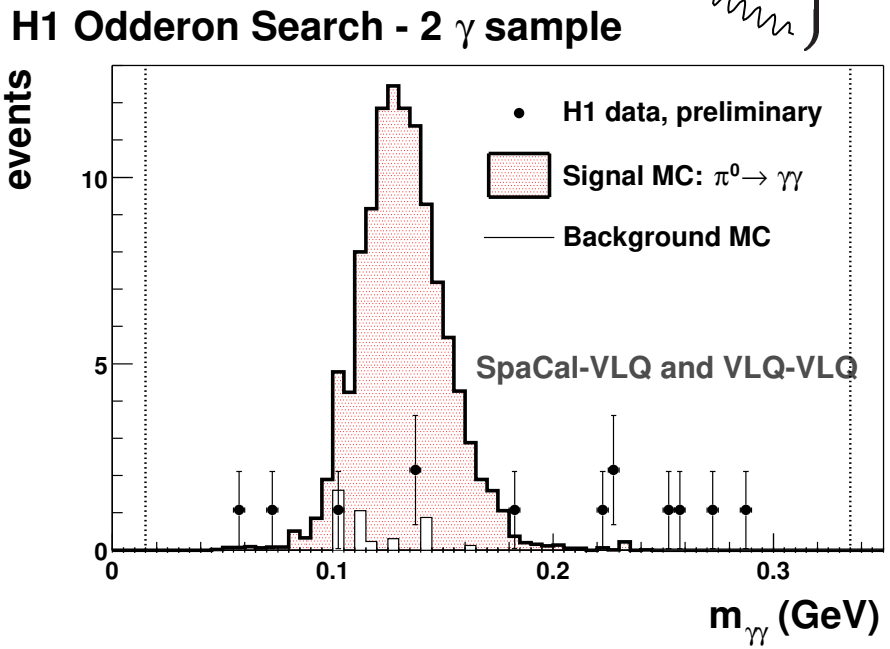
$\hookrightarrow$ photons



# There Are Inclusive Pions But No Exclusive Pions




## H1 Limit (preliminary) @ 95 % CL

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

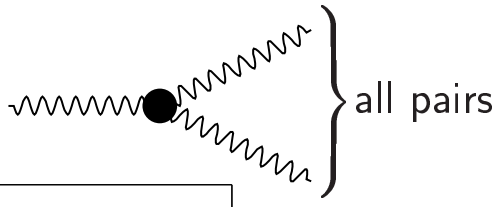
$$\sigma(\gamma p \to \pi^0 N^*) < 39 \text{ nb}$$

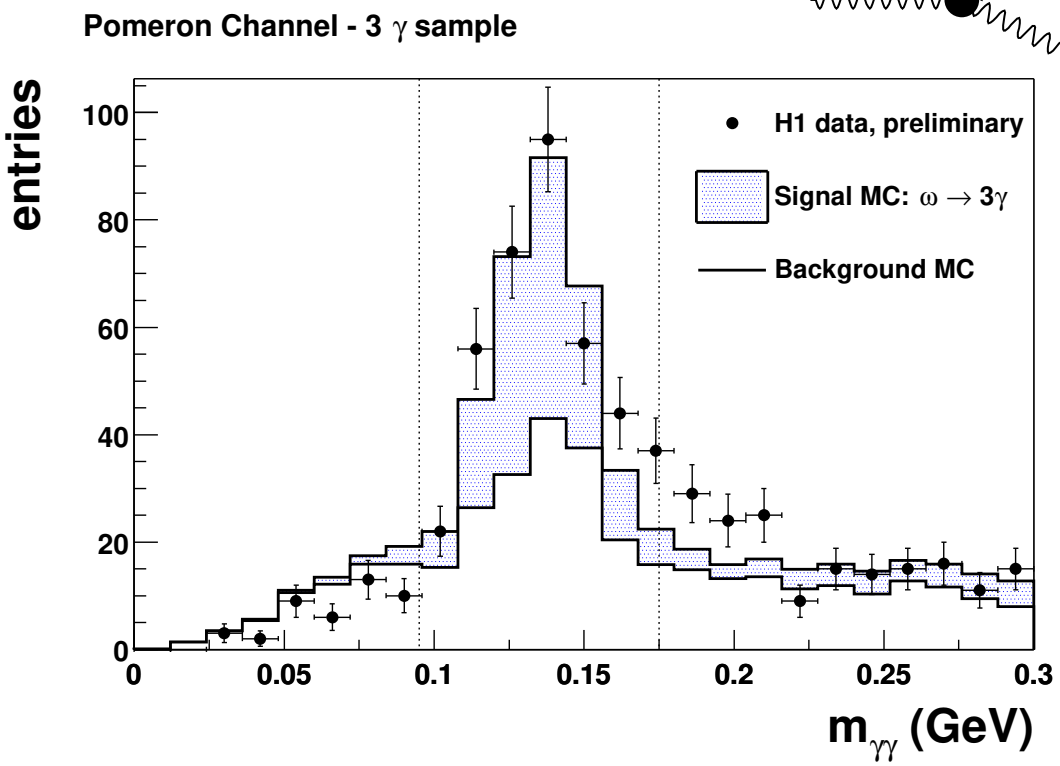
at $\langle W \rangle = 210$ GeV

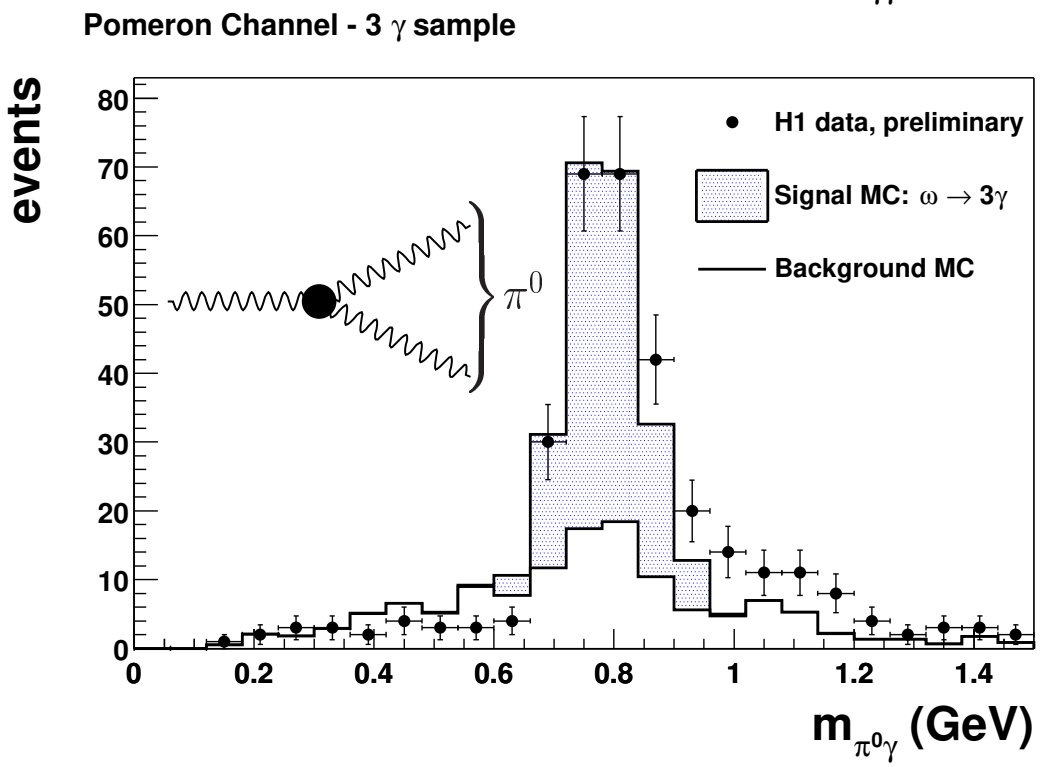
compared to the SVM prediction of E. R. Berger et al.

200 nb

# 3 $\gamma$-Sample — $\omega$



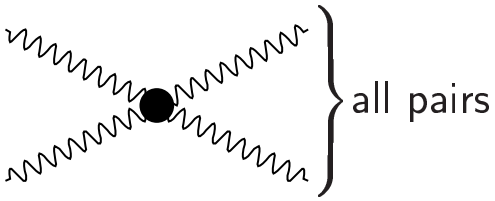



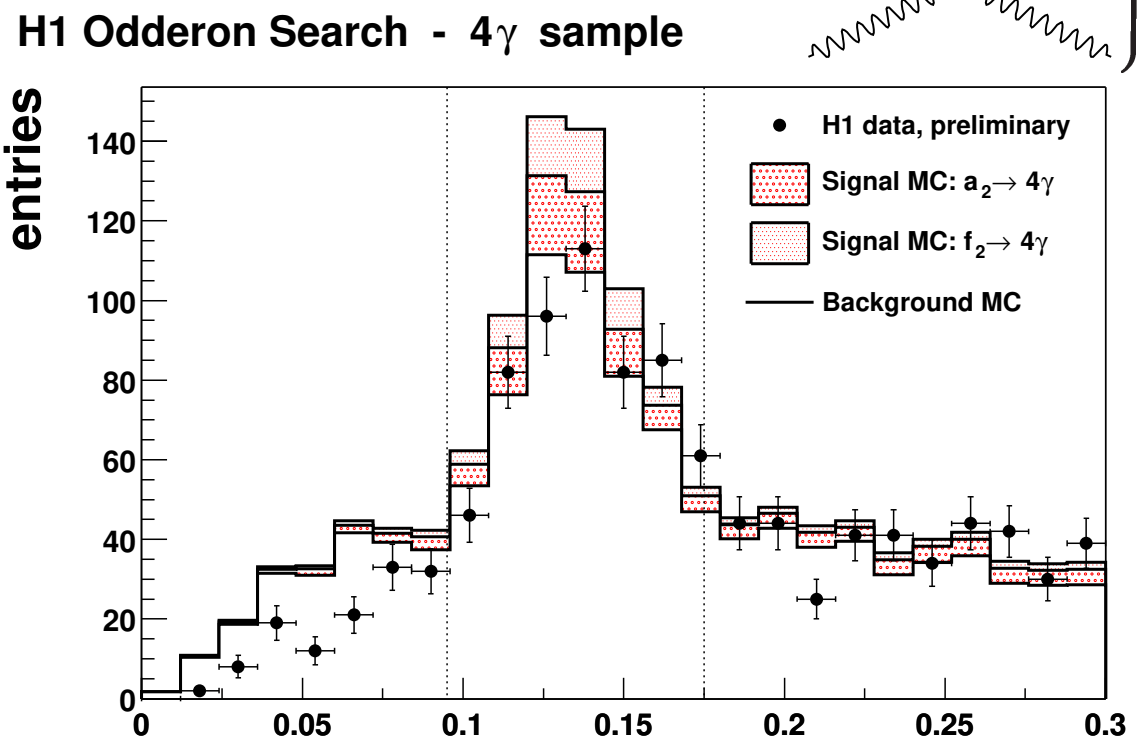

$$\sigma(\gamma p \to \omega p) = (1.3 \pm 0.2 \pm 0.2)\,\mu\text{b}$$

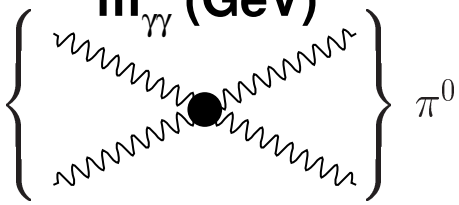
at $\langle W \rangle = 200$ GeV

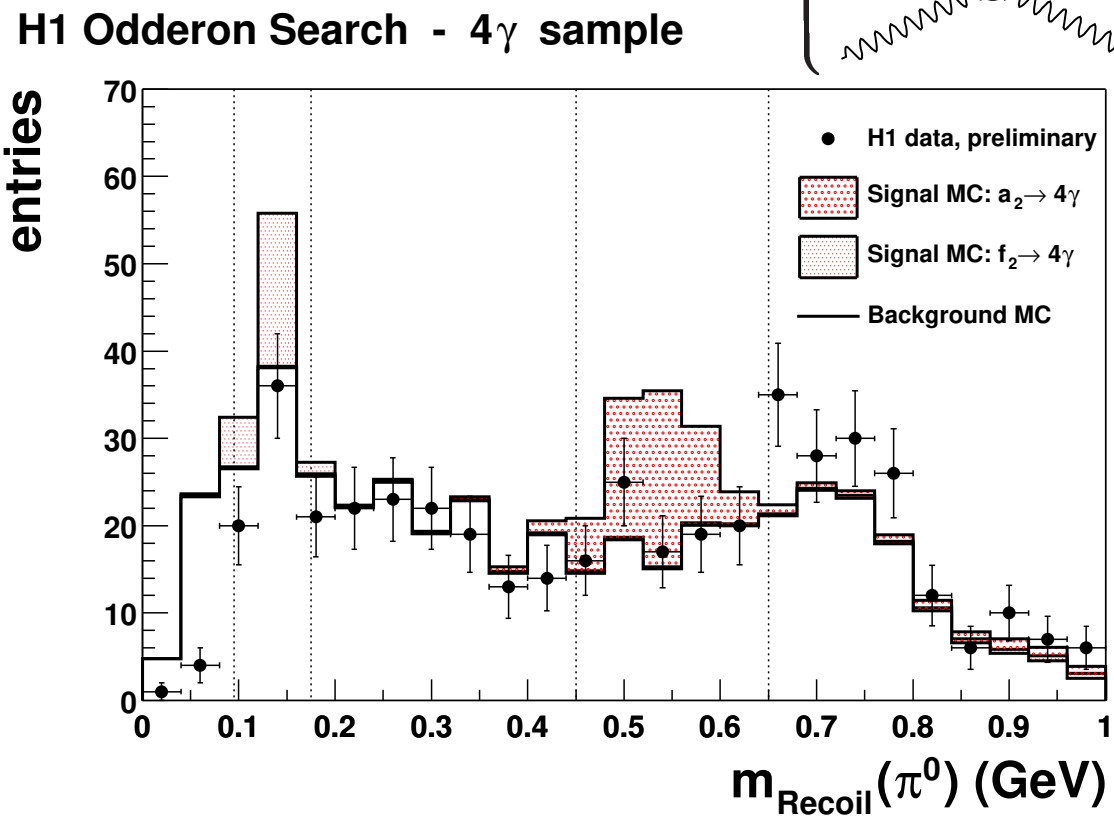
as expected!

# 4 $\gamma$-Sample

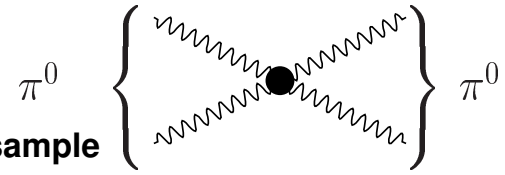


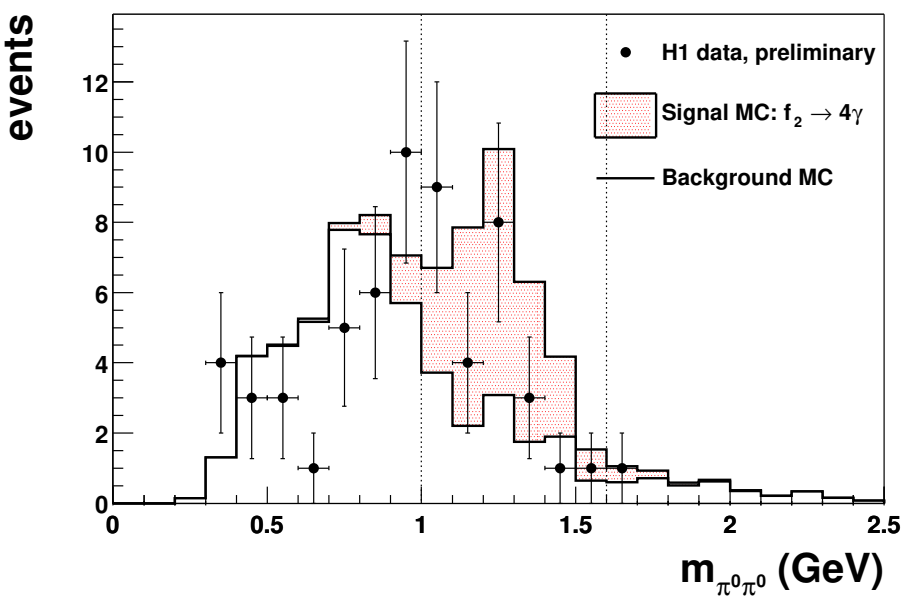



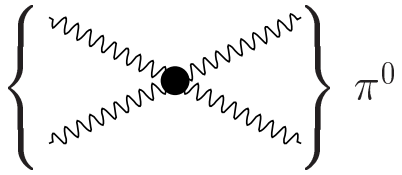



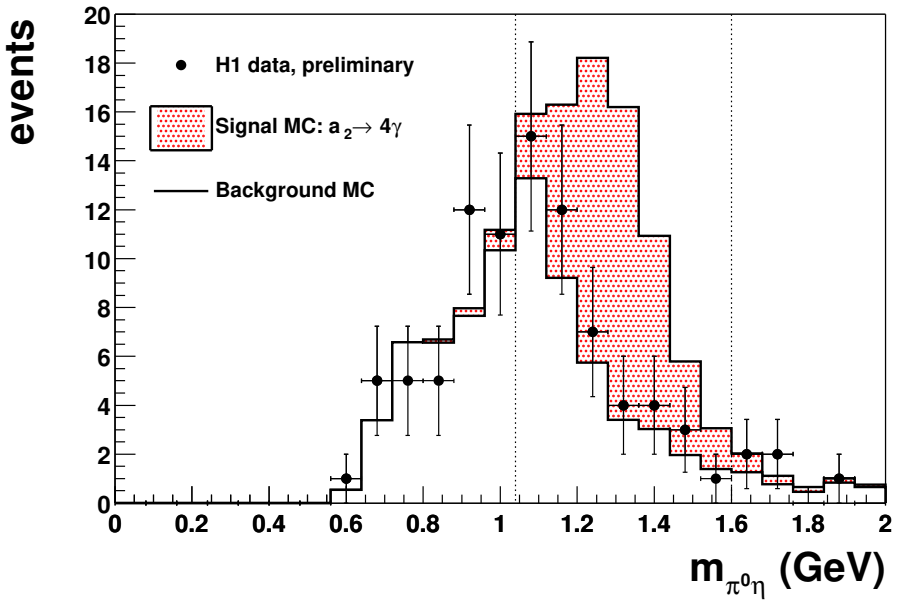
## Limit on the $f_2$




## Limit on the $a_2$




H1 Limit (preliminary) @ 95 % CL

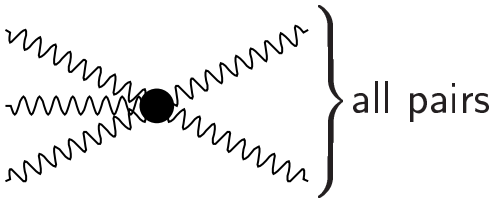
$\sigma(\gamma p \to f_2 X) < 16$ nb $\qquad$ $\sigma(\gamma p \to a_2 X) < 96$ nb

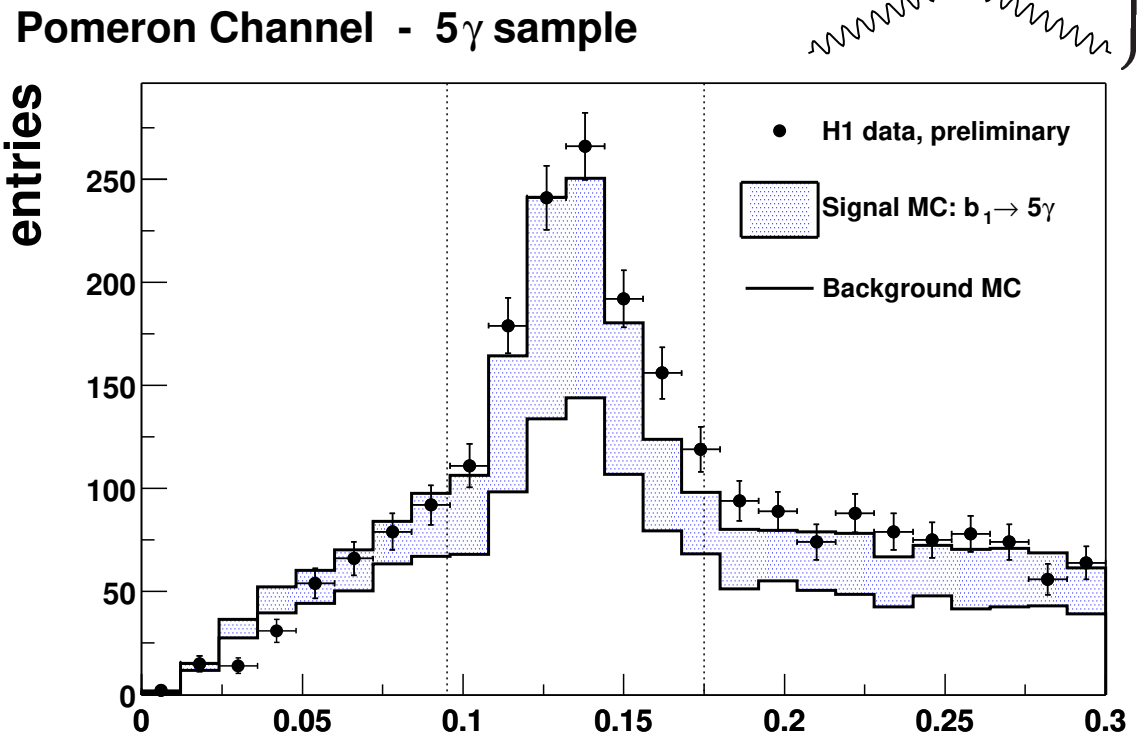
at $\langle W \rangle = 200$ GeV

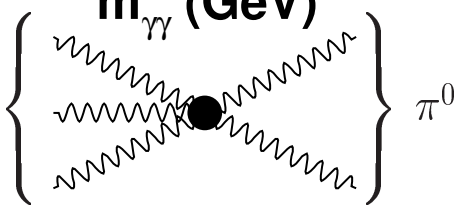
compared to the SVM prediction of E. R. Berger et al.

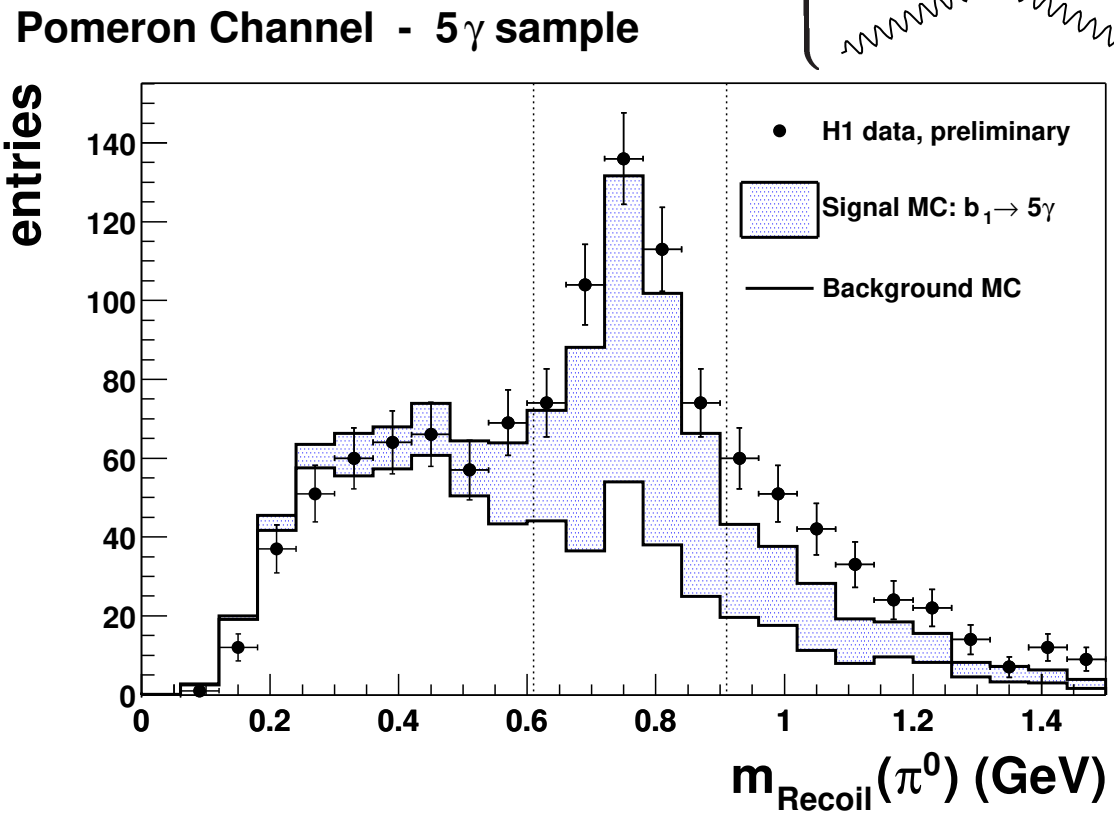
21 nb $\qquad$ 190 nb

# 5 $\gamma$-Sample — $\omega\pi^0$

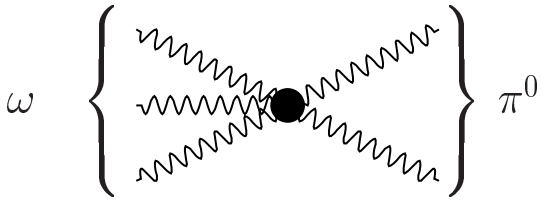


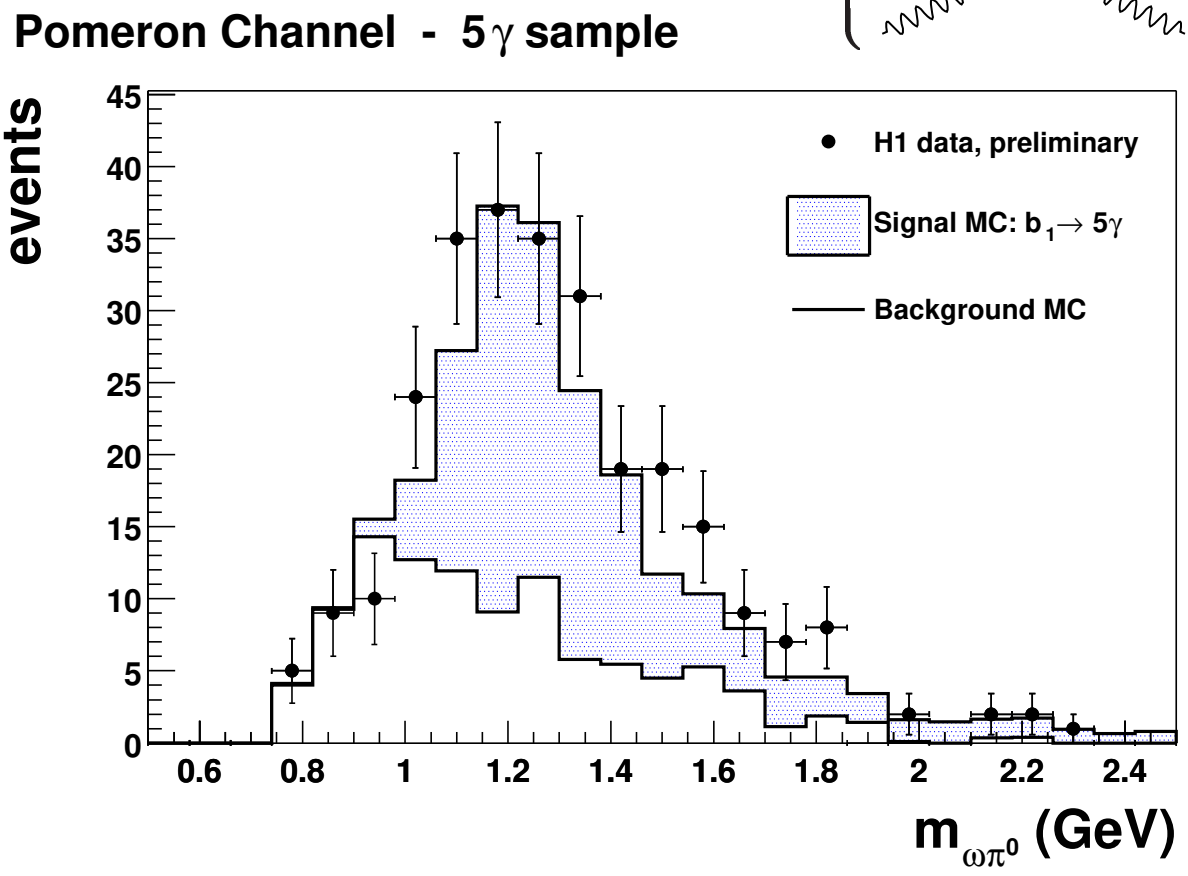



# $\omega\pi^0$ — Cross Section




First measurement at HERA!!!

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

to be compared with

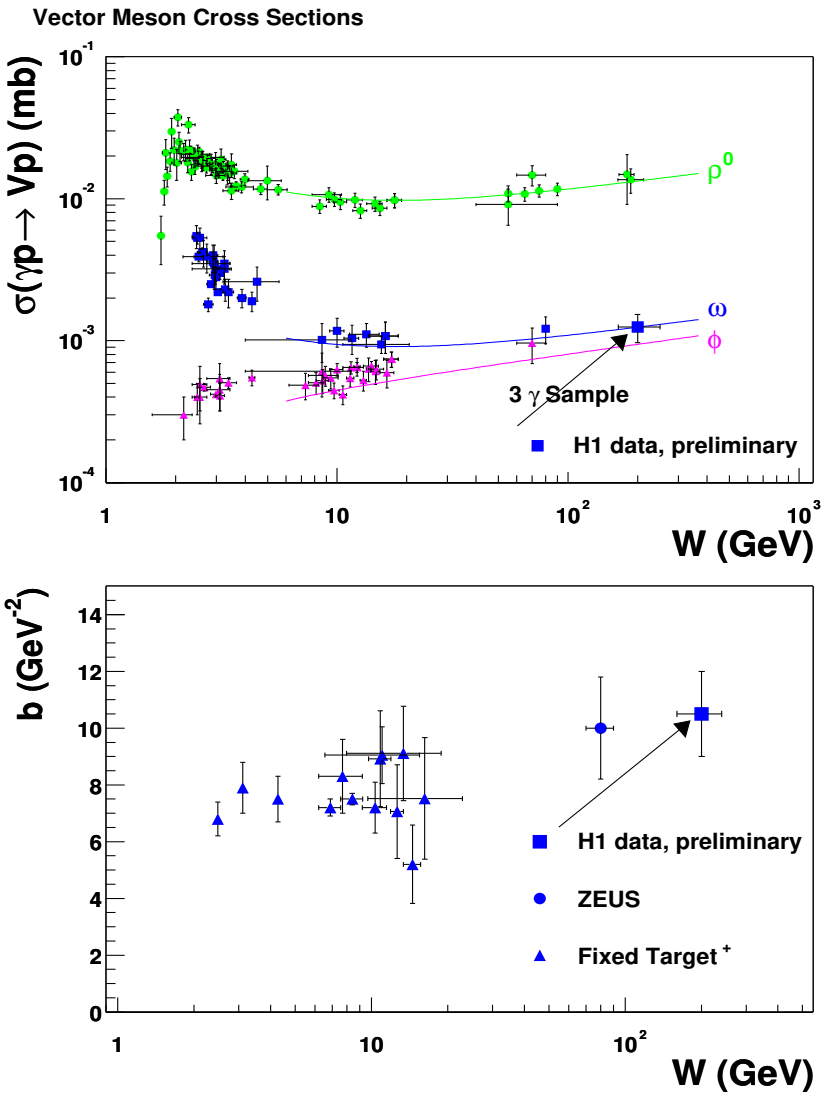
$$\sigma(\gamma p \to \omega\pi^0(NR)X) = 0.2\ \mu\text{b}$$ (from Pythia)

$$\sigma(\gamma p \to b_1 X) = 0.7\ \mu\text{b}$$ (extrapolated from low $E$)

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

# Summary

## The Pomeron is there as expected




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

First search of $\mathbb{O}$-contribution in an $e(\gamma)p$ environment. And

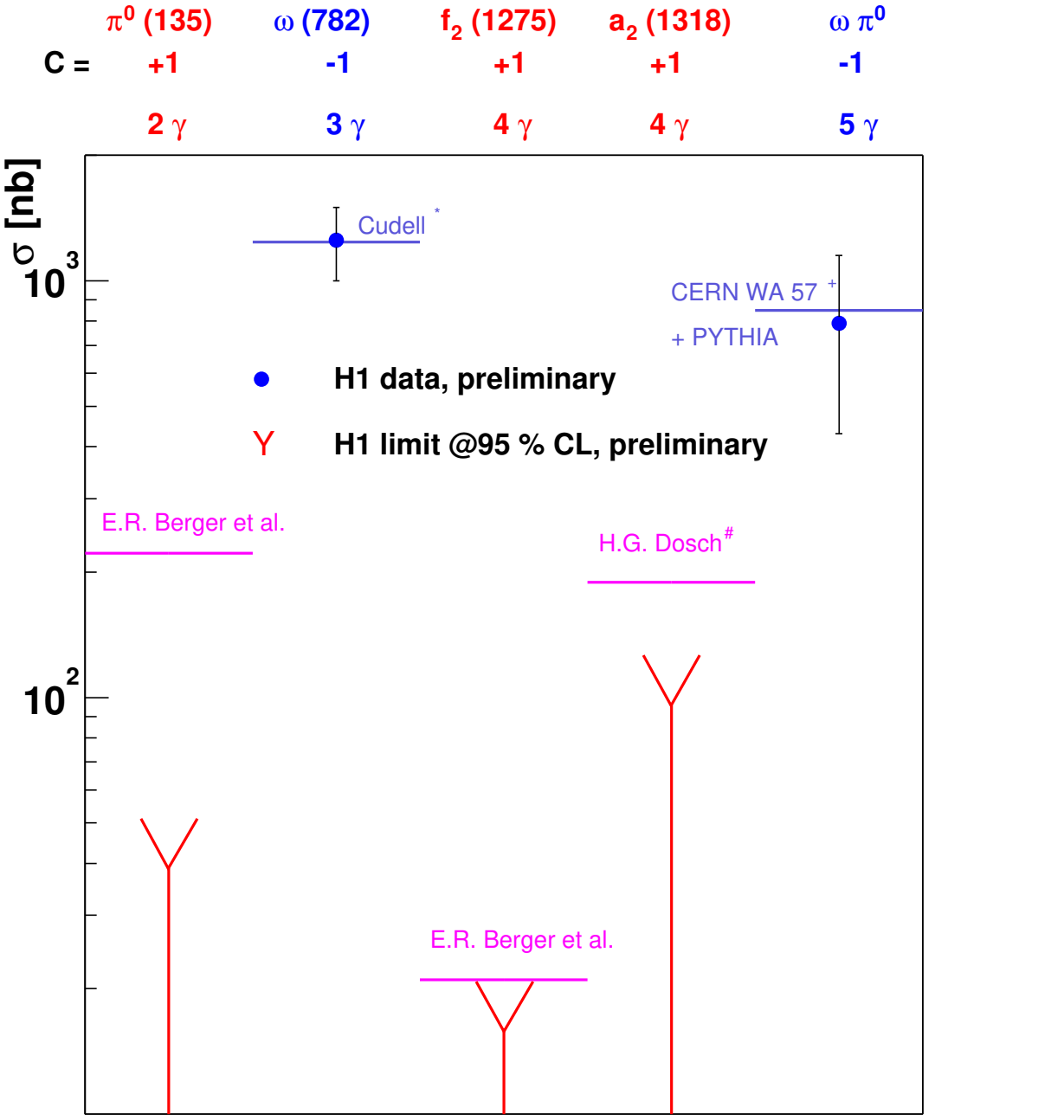
No Odderon-contribution seen!!!

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

| H1 Preliminary @95% CL | | E. R. Berger (SVM) |
|---|---|---|
| $\pi^0 N^*$ | $<$ 39 nb | 200 nb |
| $a_2 X$ | $<$ 96 nb | 190 nb |
| $f_2 X$ | $<$ 16 nb | 21 nb |

N.B.: This is a QCD-test with purely electromagnetic final states

# Summary




* Cudell et al.: Phys.Rev. D61 (00), 034019; Schuler, Sjoestrand: Nucl.Phys. B407 (93), 539

+ CERN WA 57: Nucl.Phys. B243 (84), 1; extrapolated to HERA energies

# private communication

# Outlook

- Increase luminosity to reduce the statistical uncertainties: possible with HERA II