ODDERON AND IPOMERON PHYSICS IN MULTI-PHOTON FINAL STATES AT HERA

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on behalf of the H1 Collaboration

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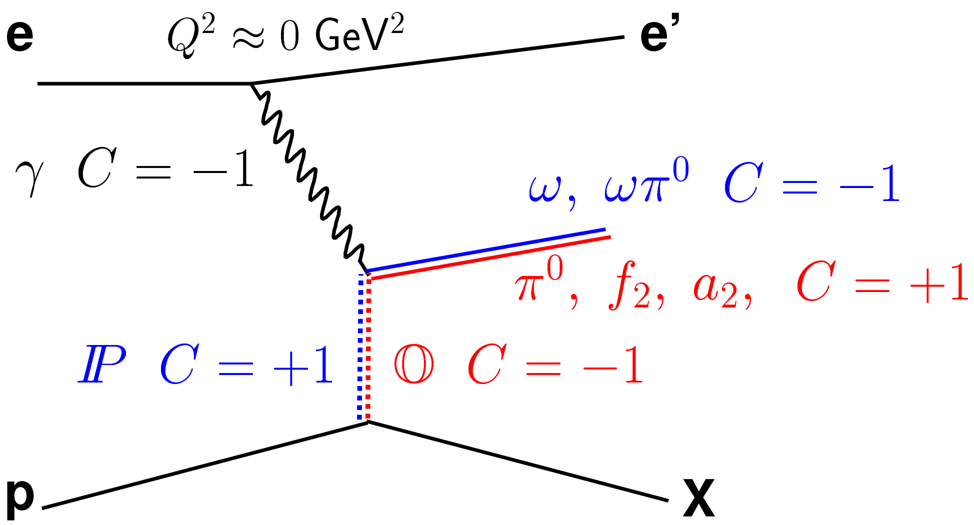
Odderon and $I\!P$omeron Physics in Multi-Photon Final States



	X
$\pi^0 \to \gamma\gamma$	$N^* \to n\pi(\pi)$
$f_2(1270) \to \pi^0\pi^0 \to 4\gamma$	no restriction
$a_2(1320) \to \pi^0\eta \to 4\gamma$	no restriction
$\omega \to \pi^0\gamma \to 3\gamma$	$M_X < 1.6$ GeV
$(b_1 \to)\; \omega\pi^0 \to \pi^0\gamma\;\gamma\gamma \to 5\gamma$	no restriction

What is the Odderon ?

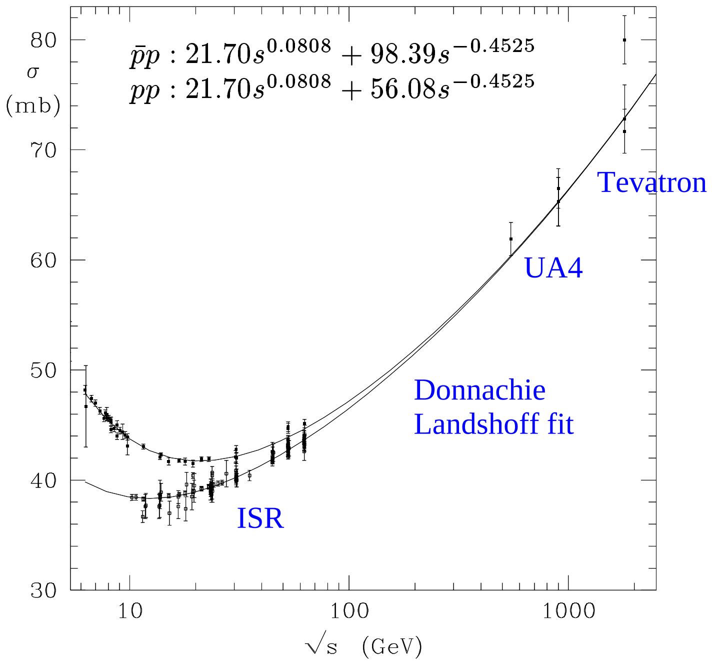
1973: $C = -1$ contribution brought into discussion of hadron-hadron scattering at high energies
L. Łukaszuk and B. Nicolescu, Lett. Nuov. Cim. **8** (1973) 405

1975: Name-giving ***Odd****-under-crossing-Pom****eron***
D.Joynson, E.Leader, B.Nicolescu, C.Lopez, Nuov. Cim. **30 A** (1975) 345

The Odderon is the $C = P = -1$ partner of the Pomeron with $\alpha_{\mathbb{O}}(0) \approx 1$
$\longrightarrow$ It has the same quantum numbers as the photon

If the Odderon exists, then:

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



But:

- No evidence for Odderon
- Fit makes only use of Pomeron and Reggeon terms

THE SIGNATURE

TRIGGER:

Electron Energy $>$ 6 GeV

π^0:

Photon Energy $>$ 5 GeV

Neutron Energy $>$ 200 GeV

$a_2, f_2, \omega, \omega\pi^0$:

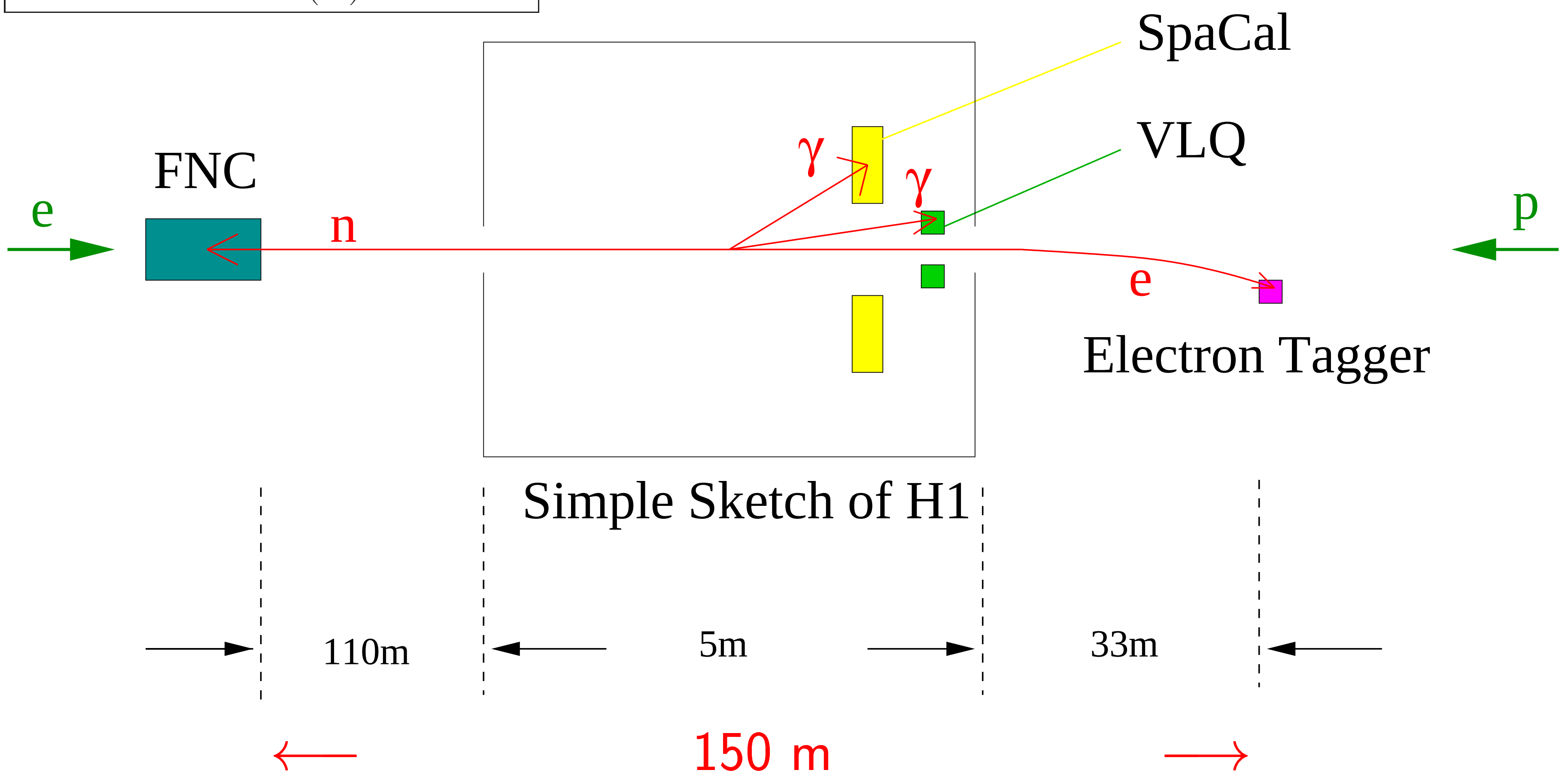
Photon Energy $>$ 2 GeV

$$ep \to e + \text{Meson} + X$$

$$\text{Meson} \to \text{Photons}$$

EXAMPLE: $\pi^0 \to \gamma\gamma$

$X = N^* \to n\pi(\pi)$



Monte Carlo Models used

GENERATOR	channel
$\mathbb{O}\mathbb{P}$IUM	$\pi^0 \to \gamma\gamma$
	$f_2 \to \pi^0\pi^0 \to \gamma\gamma\gamma\gamma$
	$a_2 \to \pi^0\eta \to \gamma\gamma\gamma\gamma$
	$b_1 \to \omega\pi^0 \to \gamma\gamma\gamma\gamma\gamma$
PYTHIA	PYTHIA*
	$\omega\pi^0 \to \gamma\gamma\gamma\gamma\gamma$ non resonant
DIFFVM	$\omega \to \pi^0\gamma \to \gamma\gamma\gamma$

π^0: E. R. Berger et al., Eur.Phys.J. **C9** (1999) 491.

f_2: E. R. Berger et al., Eur.Phys.J. **C14** (2000) 673.

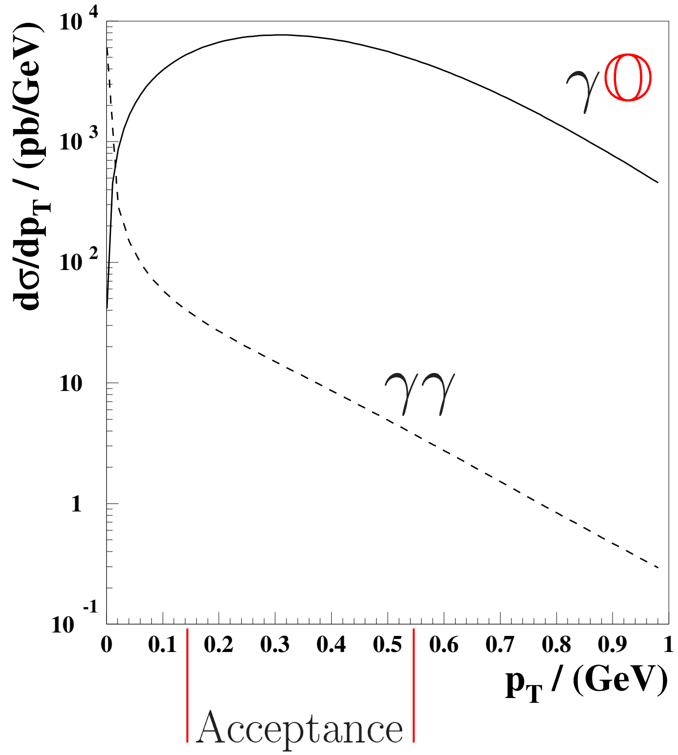
a_2: H. G. Dosch, Private communication (2000)

*PYTHIA was modified, T.Sjöstrand, Priv. comm. (2001)

(e.g. exclude isospin violating decay $\rho^0_{\rm diff} \to \pi^0\pi^0$, but this has a negligible effect on global HERA event properties)

EXAMPLE: $\pi^0 \to \gamma\gamma$

π^0 $p_\perp$ DISTRIBUTION



$0.02 < |t| < 0.3$ GeV^2

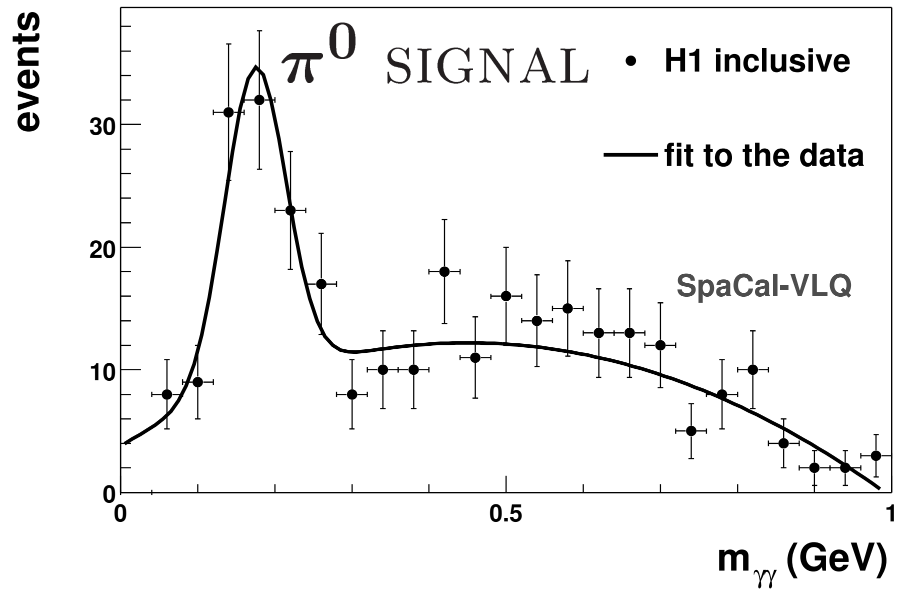
π^0 Background

Inclusive π^0's

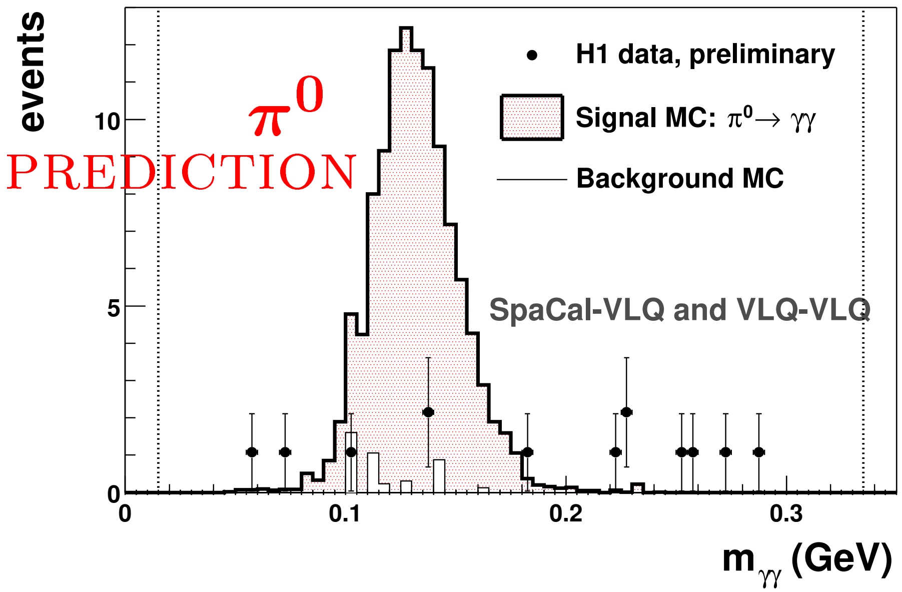
Primakoff effect (negligible)

Regge exchange (negligible)

We Are Able to See π^0's



There is no Odderon



Inclusive (but not yet exclusive!) $\gamma\gamma$ events

Proof of π^0 Detection Sensitivity

Limit at 95% CL

$\sigma_{\gamma p \xrightarrow{\mathbb{O}} \pi^0 N^*} < 39$ nb (H1 preliminary)

$\sigma_{\gamma p \xrightarrow{\mathbb{O}} \pi^0 N^*} = 200$ nb (E.R.Berger et al.)

Stochastic Vacuum Model
(non-perturbative QCD-model)

at $\langle W_{\gamma p} \rangle = 210$ GeV

visible t range: $0.02\ \text{GeV}^2 < |t| < 0.3\ \text{GeV}^2$

Possible Reasons for the Absence

Small $\gamma\pi^0\mathbb{O}$ coupling

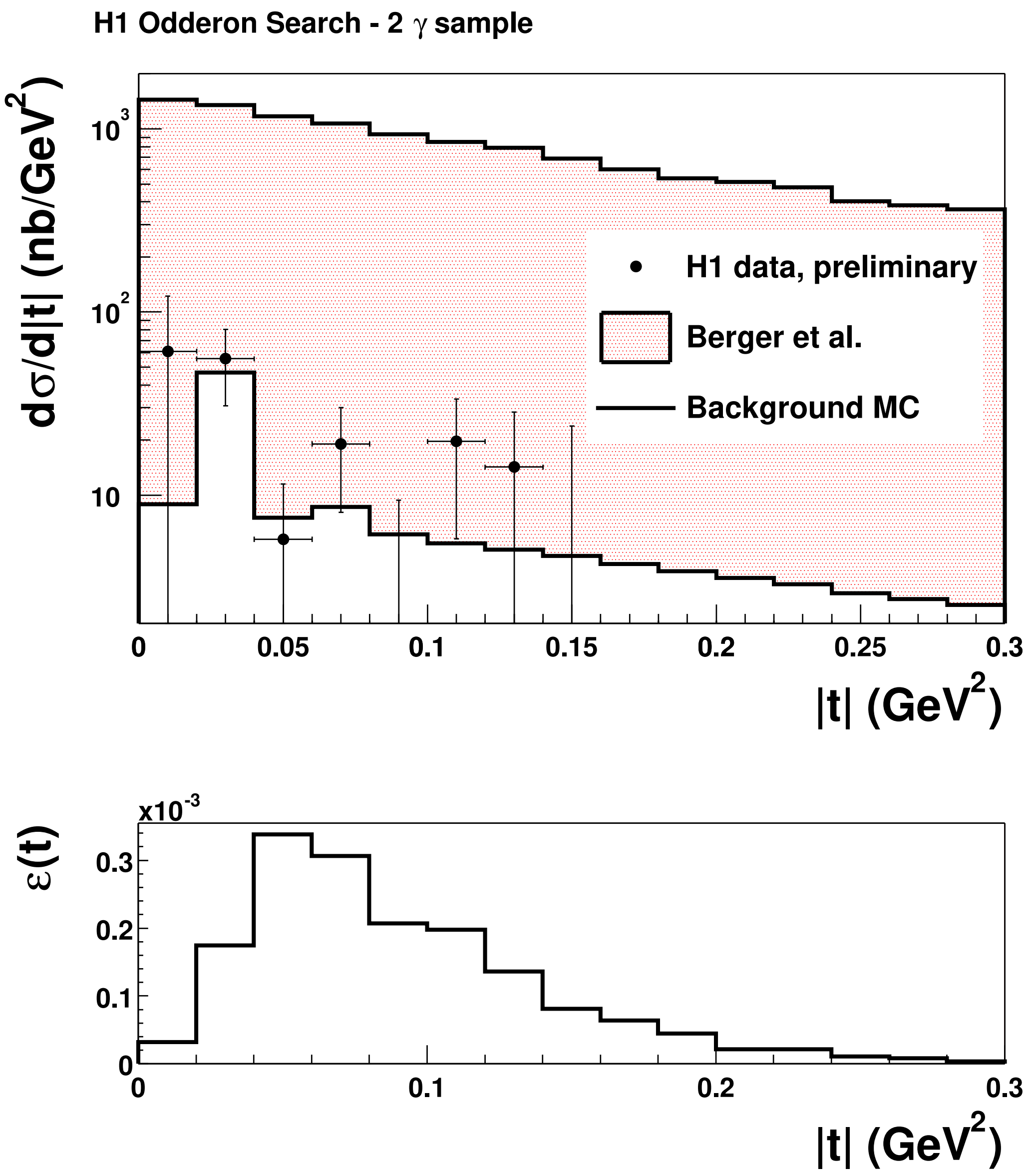
could be due to Goldstone Boson nature of the π^0

$\Longrightarrow$ Look for

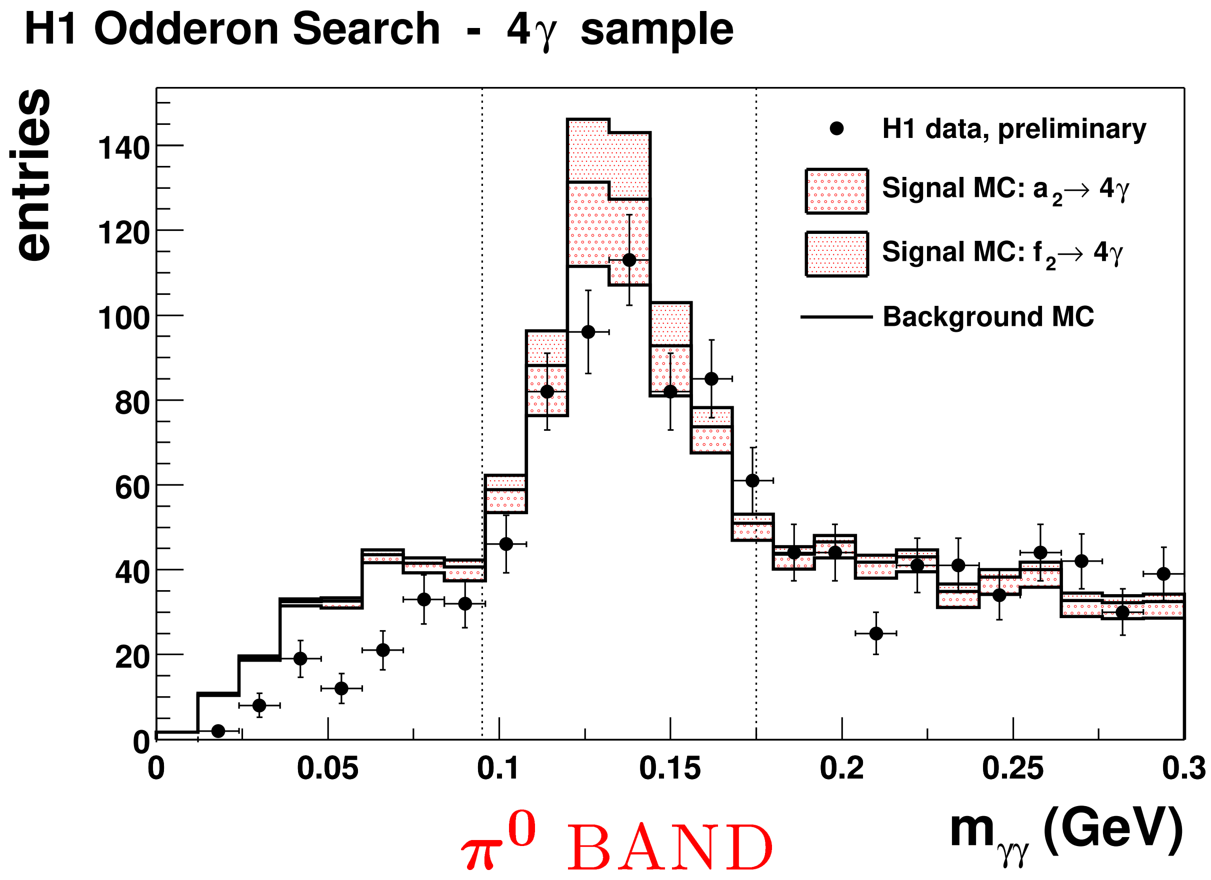
$$\gamma p \to f_2(1270)N^*, \gamma p \to a_2(1320)N^*$$

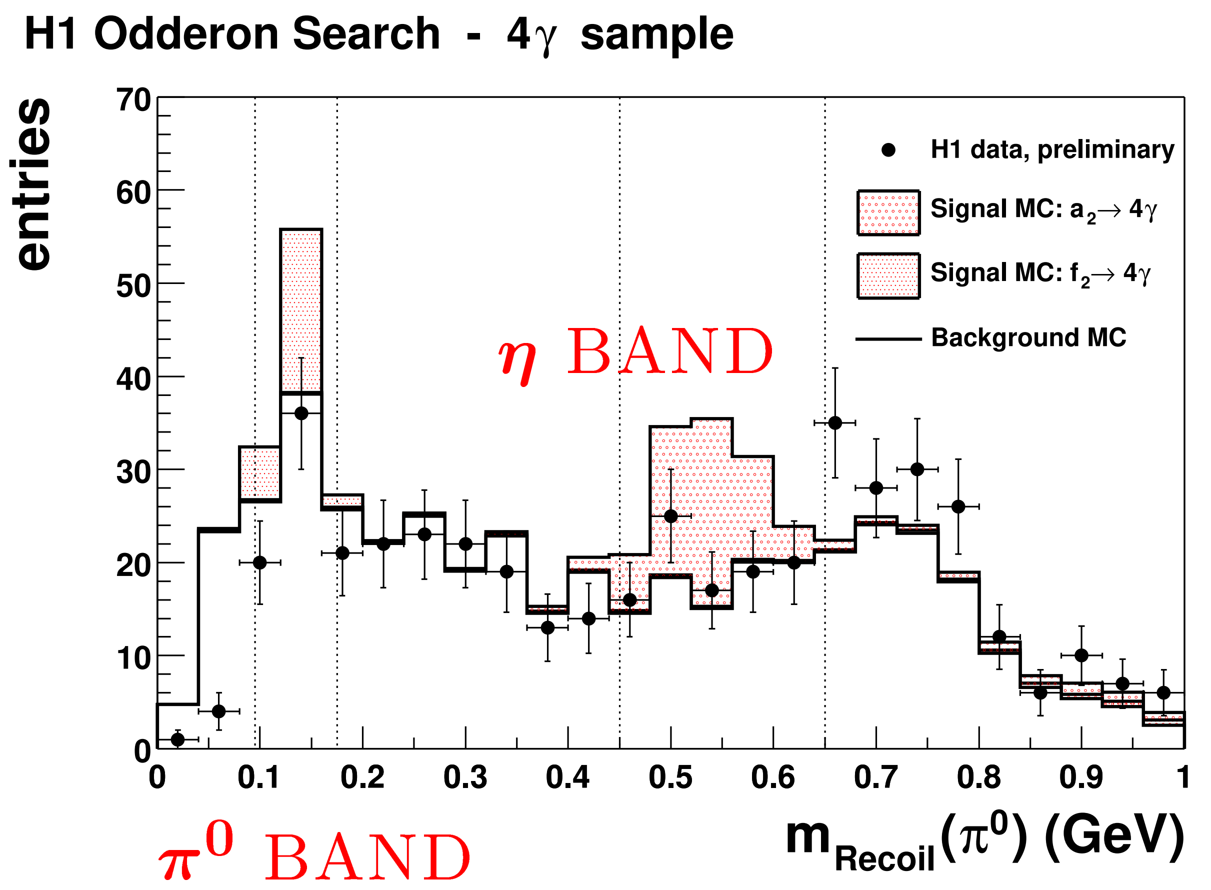
Differential Cross Section

for the reaction
$$\gamma p \rightarrow (\gamma\gamma) N^*$$
with 15 MeV $< m_{\gamma\gamma} <$ 335 MeV

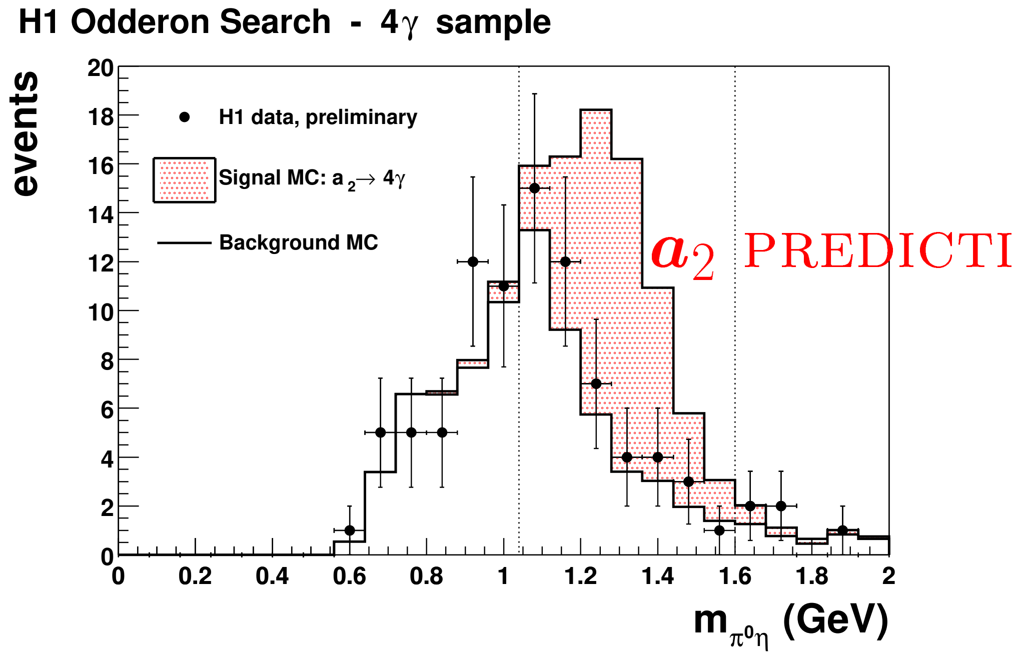


The 4 γ Sample $C = +1$ $\mathbb{O}$ exchange

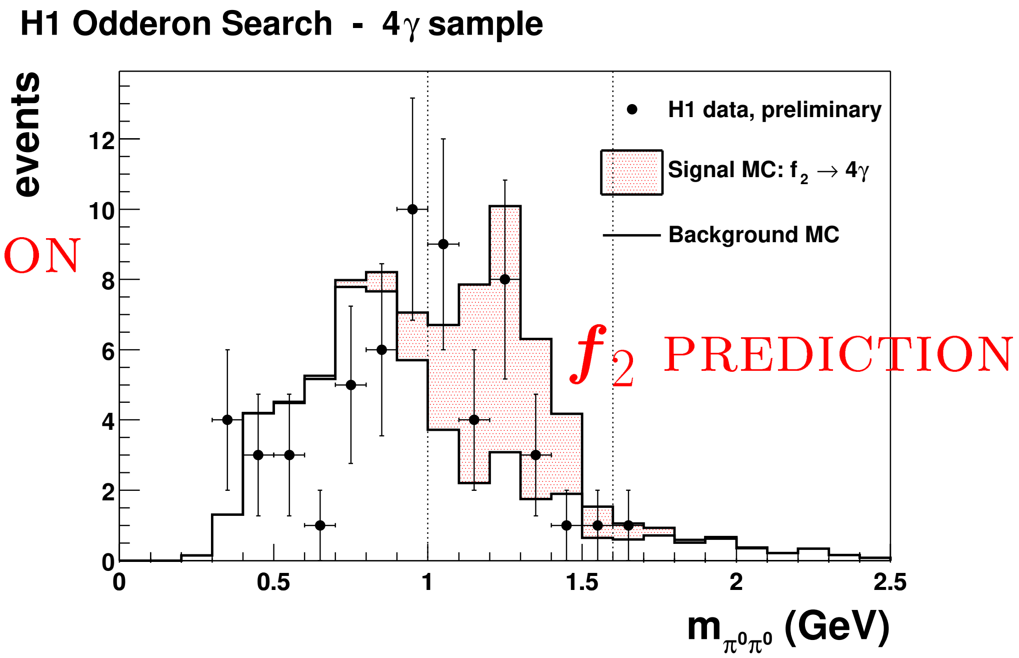




LIMIT ON THE a_2



LIMIT ON THE f_2



$$\sigma^{\mathbb{O}}_{\gamma p \to a_2 X} < 96 \text{ nb}$$
$$\sigma^{\mathbb{O}}_{\gamma p \to a_2 N^*} = 190 \text{ nb}$$

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

Limit at 95% CL
H1 preliminary

E. R. Berger et al.
Stochastic Vacuum Model
non-perturbative
QCD-model

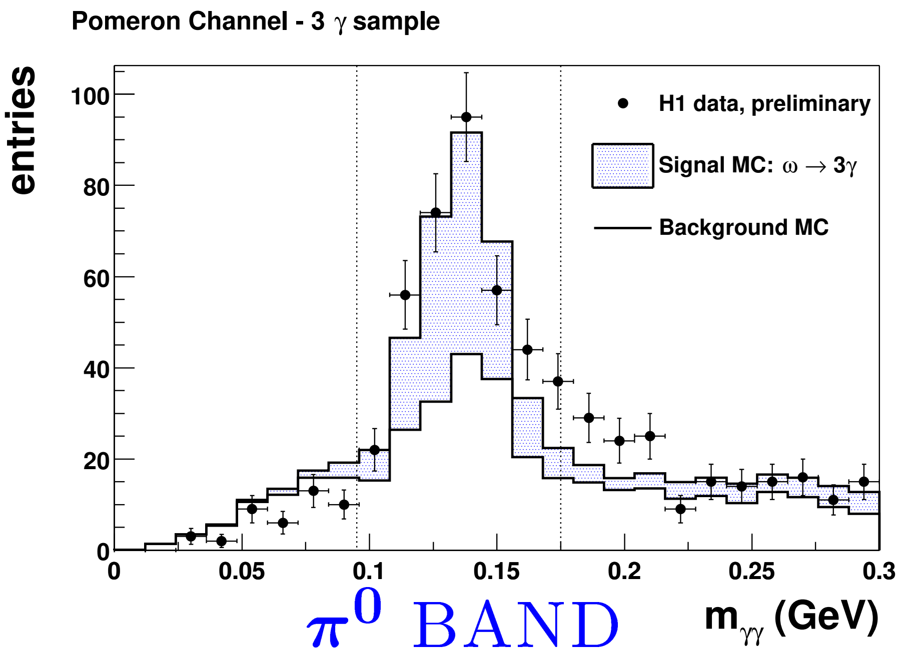
$$\sigma^{\mathbb{O}}_{\gamma p \to f_2 X} < 16 \text{ nb}$$
$$\sigma^{\mathbb{O}}_{\gamma p \to f_2 N^*} = 21 \text{ nb}$$

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

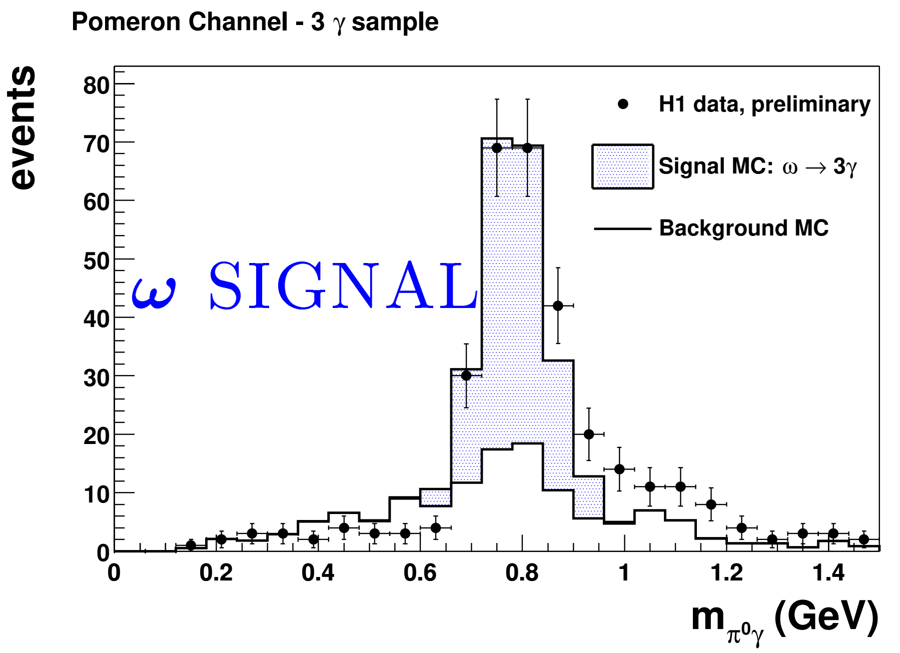
GOLDSTONE BOSON ARGUMENT NOT VALID FOR a_2 AND f_2

WHY NO $\mathbb{O}$DDERON, THEORETICIANS ?

THE 3 γ SAMPLE $C = -1$ $I\!P$ EXCHANGE



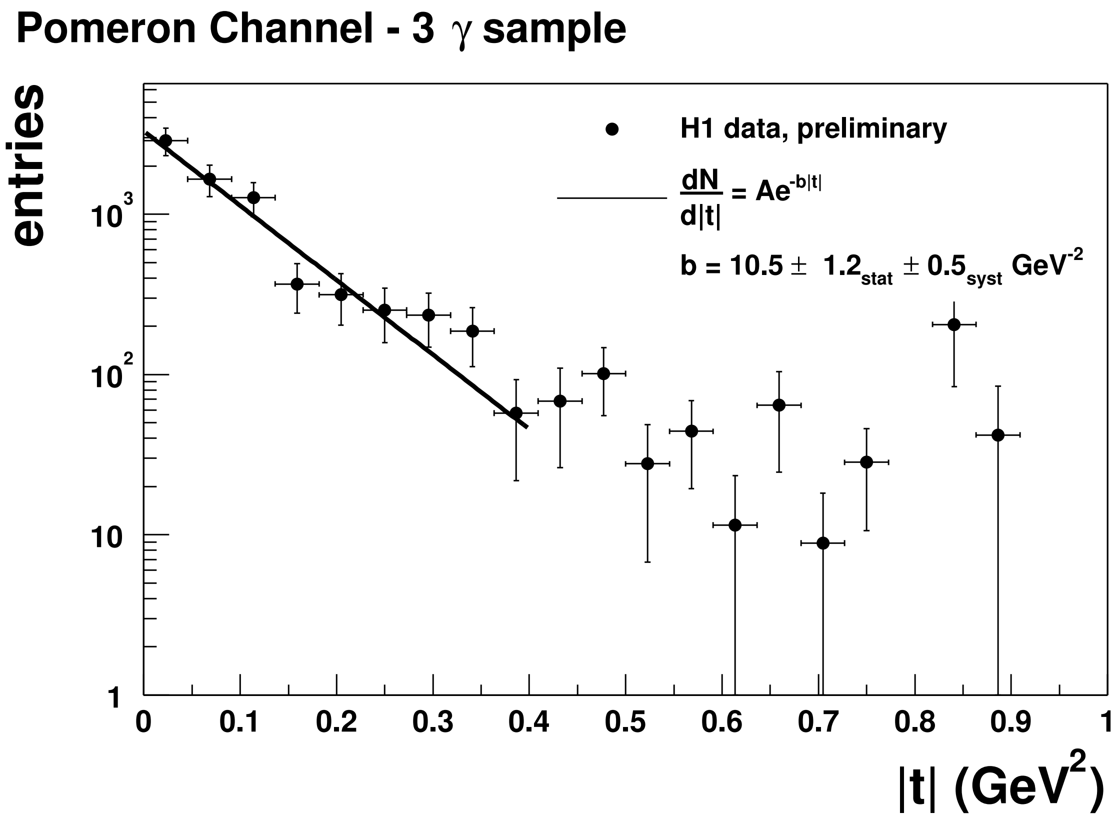
π^0 BAND



$$\boxed{\sigma(\gamma p \to \omega p) = (1.25 \pm 0.17 \pm 0.22)\ \mu\text{b}}$$

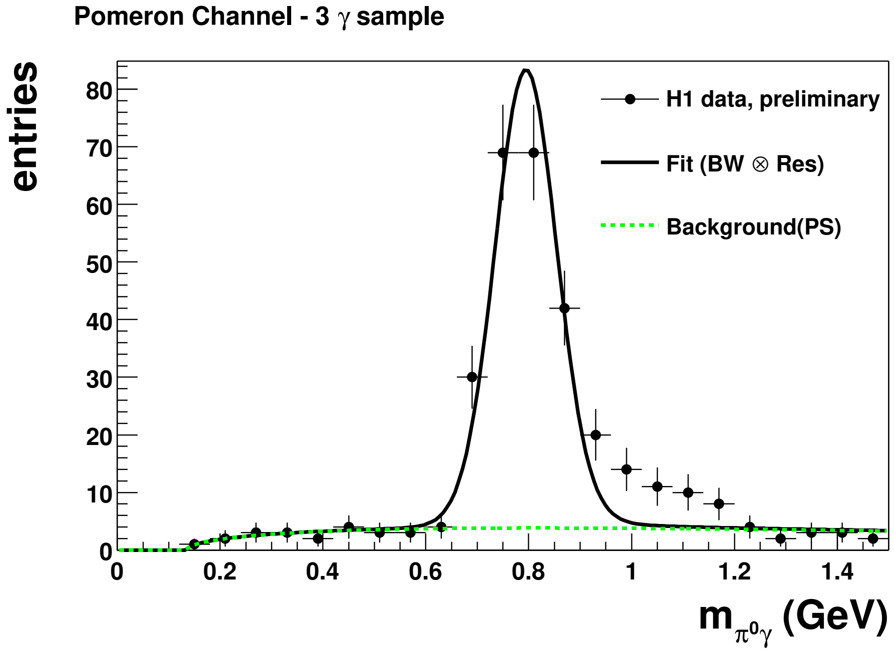
$$\boxed{b = (10.5 \pm 1.2 \pm 0.5)\ \text{GeV}^{-2}}$$

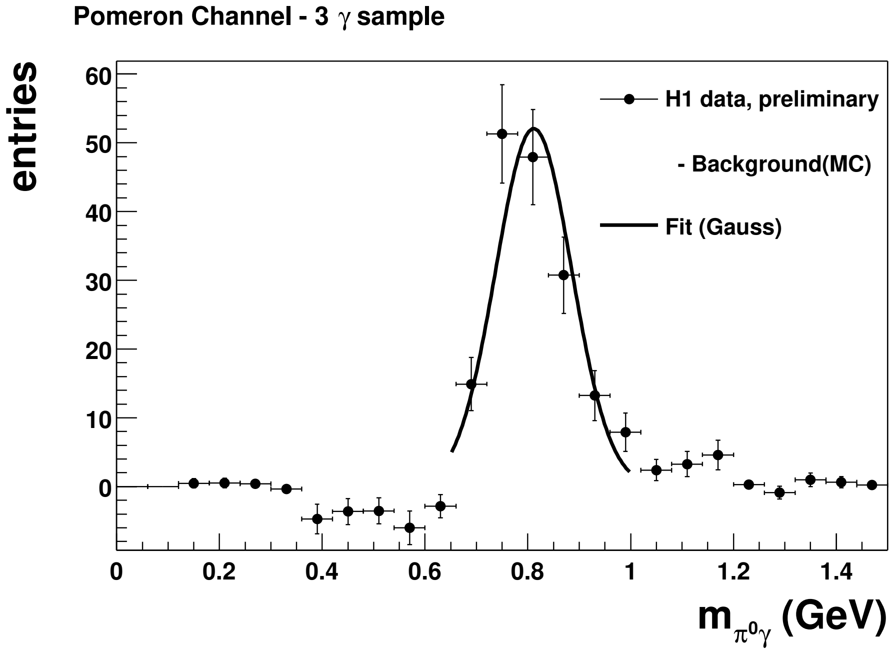
THE 3 γ SAMPLE - $\mathrm{d}N/\mathrm{d}|t|$



$$\boxed{b = (10.5 \pm 1.2\ (\mathsf{stat}) \pm 0.5\ (\mathsf{syst}))\ \mathsf{GeV}^{-2}}$$

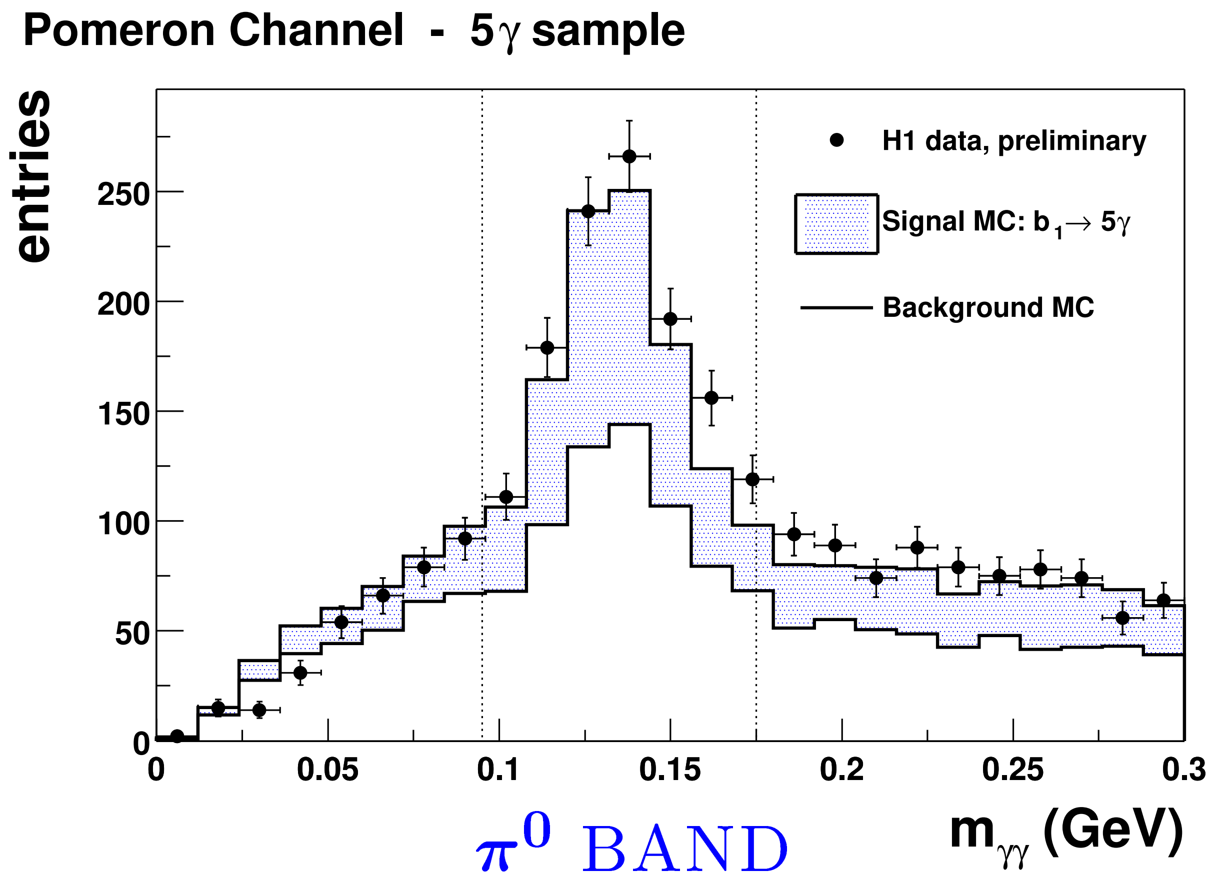
ω Cross Section



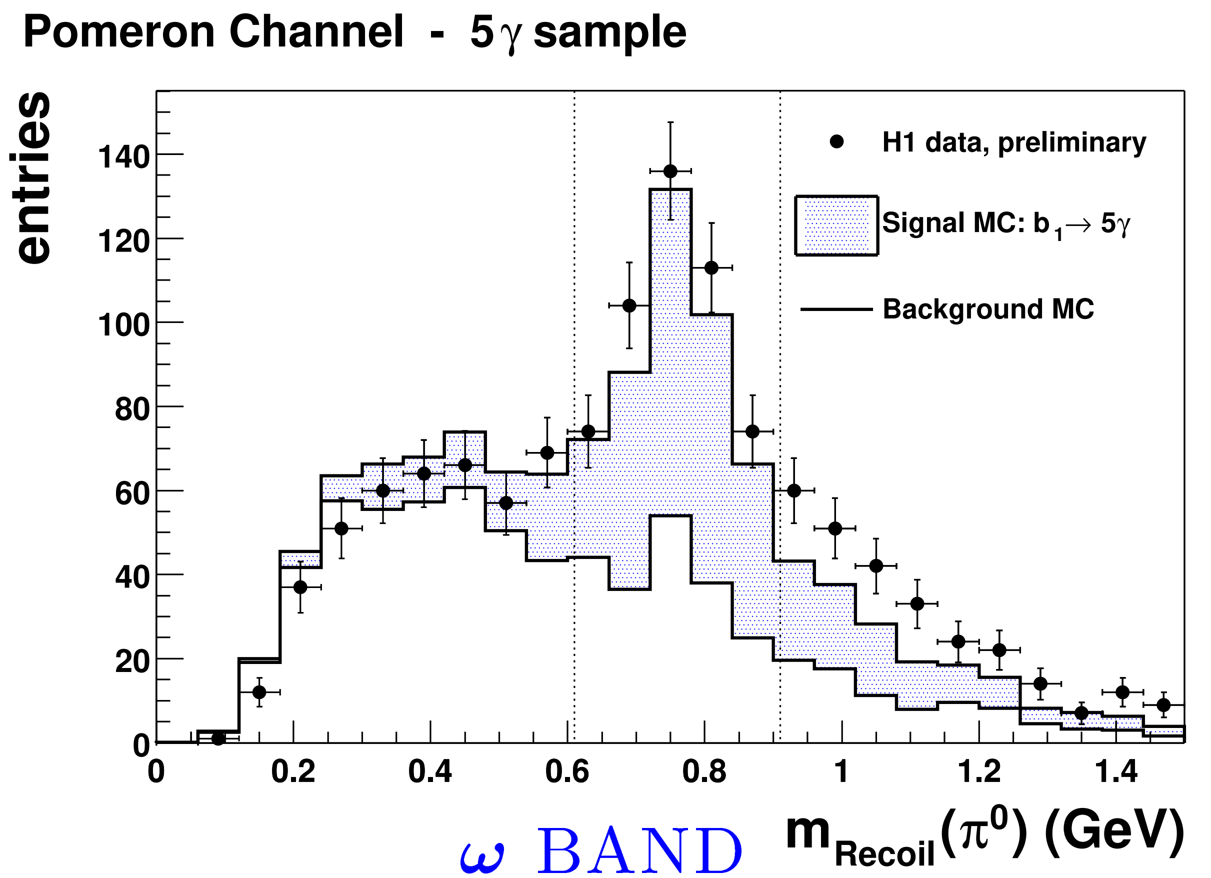


$$\boxed{\sigma(\gamma p \to \omega p) = (1.25 \pm 0.17\ (\mathrm{stat}) \pm 0.22\ (\mathrm{syst}))\ \mu\mathrm{b}}$$

The 5 γ Sample $C = -1$ $I\!\!P$ exchange

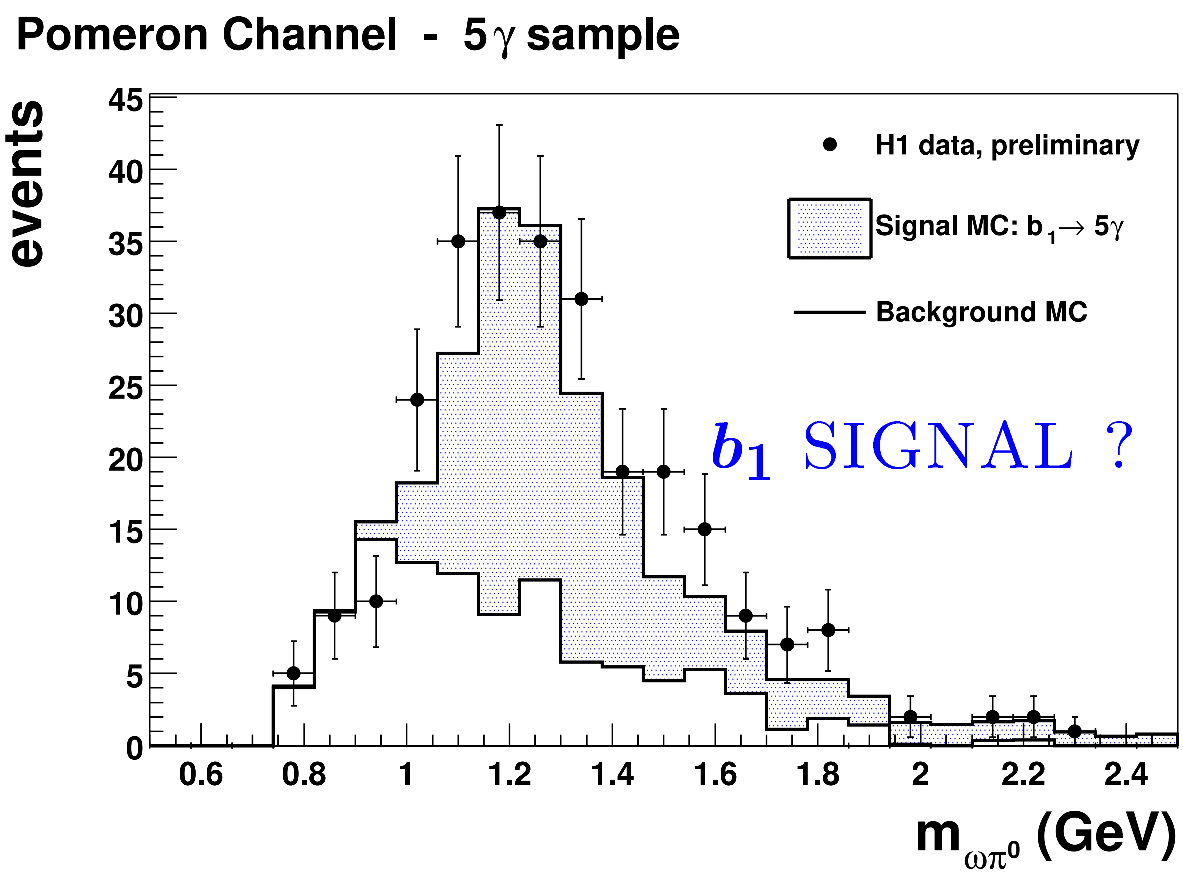


π^0 BAND



ω BAND

$\omega\pi^0$ Cross Section $C = -1$ $I\!P$ exchange



$$\sigma(\gamma p \to \omega\pi^0 X) = (980 \pm 200\ \textsf{(stat)} \pm 200\ \textsf{(syst)})\ \textsf{nb}$$

to be compared with

$$\sigma_{\textsf{PYTHIA}}(\gamma p \to \omega\pi^0 X) = 190\ \textsf{nb}$$

$$\sigma_{\textsf{extrapolated}} * (\gamma p \to b_1(1235)X) = 660\ \textsf{nb}$$

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

* $b_1(1235)(J^{PC} = 1^{+-})$ measurement by the Omega Photon collaboration and extrapolated to HERA energies: Nucl. Phys. **B243** (1984) 1.

Summary - Clear Experimental Picture

First study of $\mathbb{O}$-induced *ep*-reactions

QCD-test with purely electromagnetic final state

Experimentally easily accessible

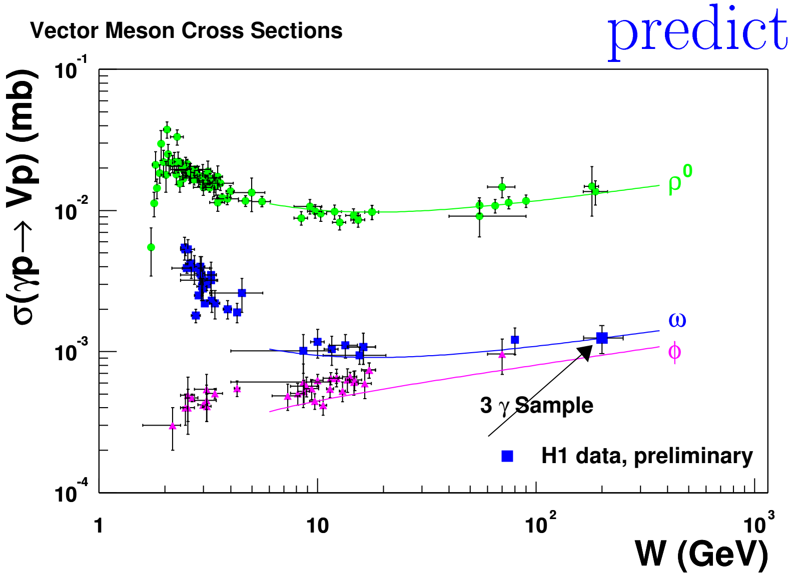
Number of photons fixes C-parity

has revealed no evidence in the magnitude as predicted by non-perturbative QCD-models (SVM)

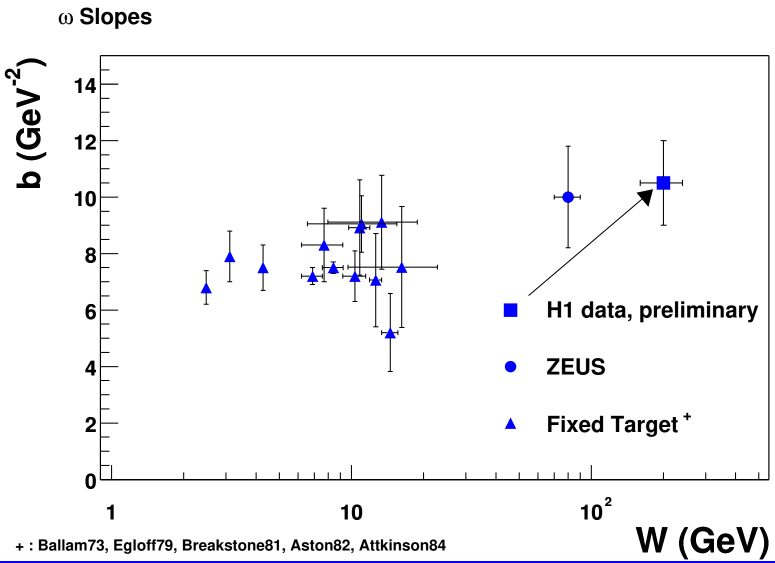
H1 Preliminary	**E.R.Berger et al.**
$\sigma^{\mathbb{O}}_{\gamma p\to\pi^0 N^*} < 39$ nb	200 nb
$\sigma^{\mathbb{O}}_{\gamma p\to a_2 X} < 96$ nb	190 nb
$\sigma^{\mathbb{O}}_{\gamma p\to f_2 X} < 16$ nb	21 nb

So far no explanation in the framework of non-perturbative QCD

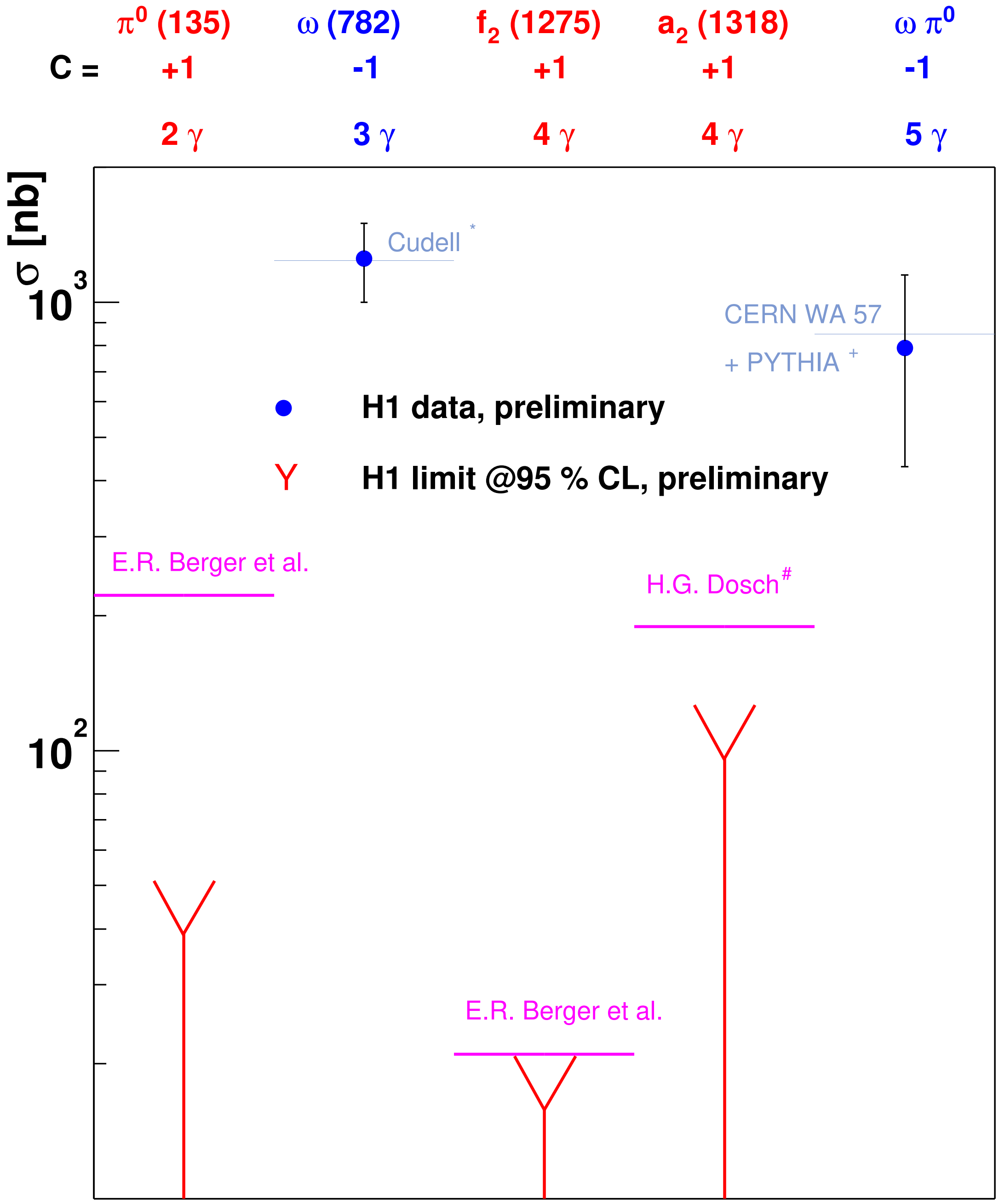
All $I\!P$-induced reactions are seen as predicted



$$\sigma(\gamma p \to \omega \pi^0 X) = (980 \pm 200 \pm 200)\ \text{nb}$$



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

- a_2, f_2 : **Limit $\rightarrow$ Measurement ?**
- π^0 : **sensitive to Primakoff effect & Regge exchange**
- b_1 : **sensitive to line shape**

$\Longrightarrow$ **Lumi increase @ HERA II !**