Search for Odderon Induced Contributions to Exclusive π^0 Photoproduction at HERA

Tobias Golling
Kirchhoff-Institut für Physik
Universität Heidelberg

on behalf of the H1 collaboration

DIS2001 9th International Workshop on
Deep Inelastic Scattering,
Bologna, April 27 - May 1, 2001

Outline of the Talk

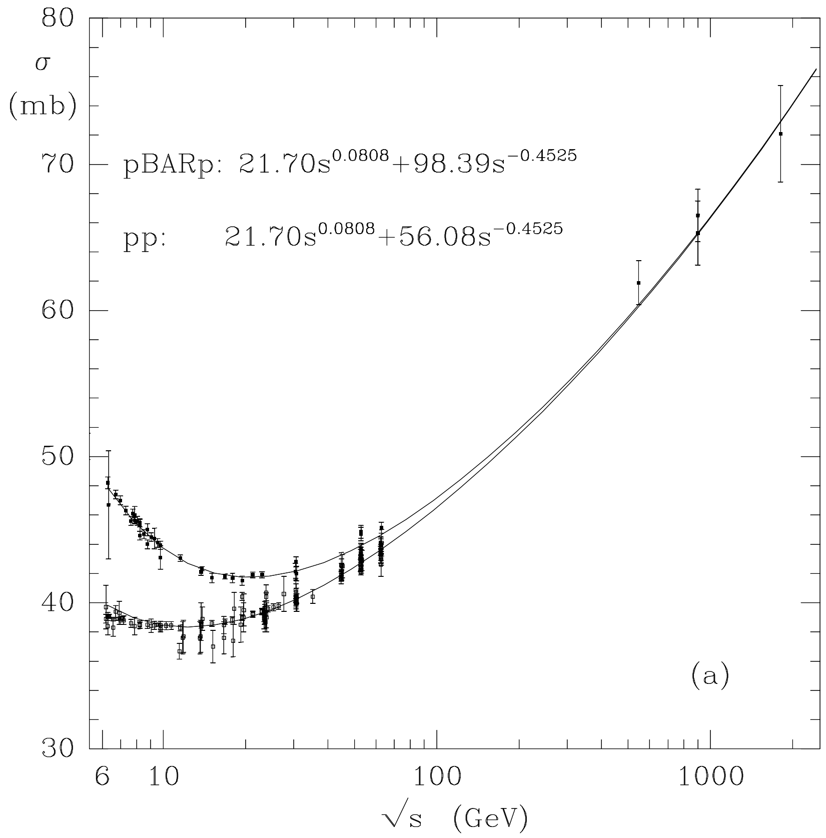
- What is the Odderon and How to Search for it
- Experimental Strategy and Event Selection
- Generators and Simulation
- Results from 1999/2000 Data
- Towards a Cross Section
- Interpretations from the Theoretical Point of View
- Outlook and Summary

What is the Odderon ?

L. Lukaszuk and B. Nicolescu, Lett. Nuov. Cim. **8** (1973) 405

- **Pomeranchuk's conjecture:**

$$\frac{\sigma(p\bar{p})}{\sigma(pp)} \to 1 \quad \text{for} \quad s \to \infty,$$



Odderon denotes ***Odd***-*under-crossing-Pom****eron***:

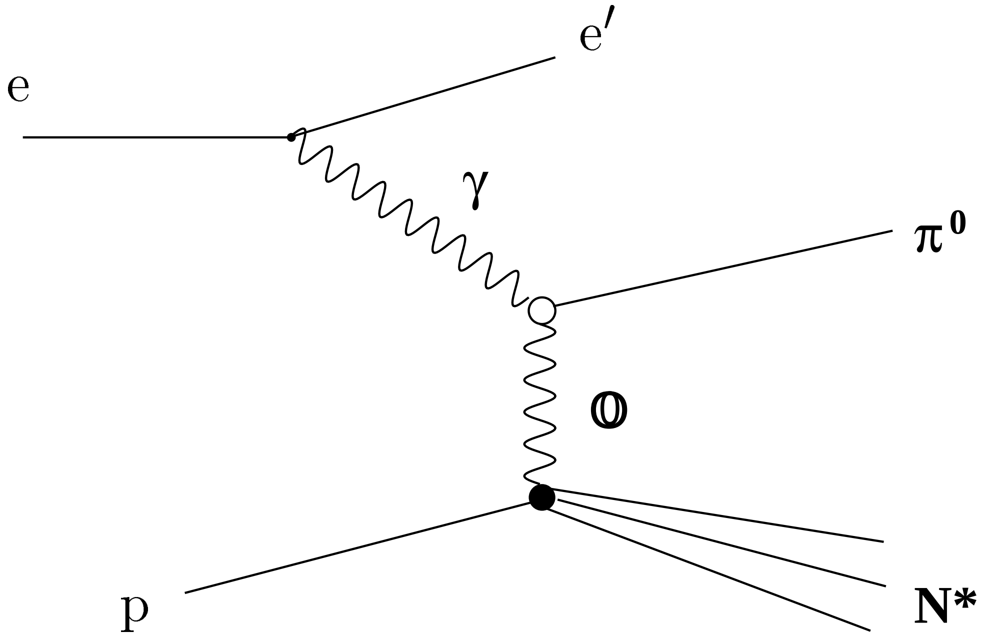
$$\Delta\sigma = \sigma(p\bar{p}) \quad - \quad \sigma(pp) \neq 0 \quad \text{for} \quad s \to \infty$$
$$\Rightarrow \quad \alpha_{\mathbb{O}}(0) \approx 1$$

- The Odderon is the $C = P = -1$ partner of the Pomeron
  $\longrightarrow$ It has the same quantum numbers as the photon

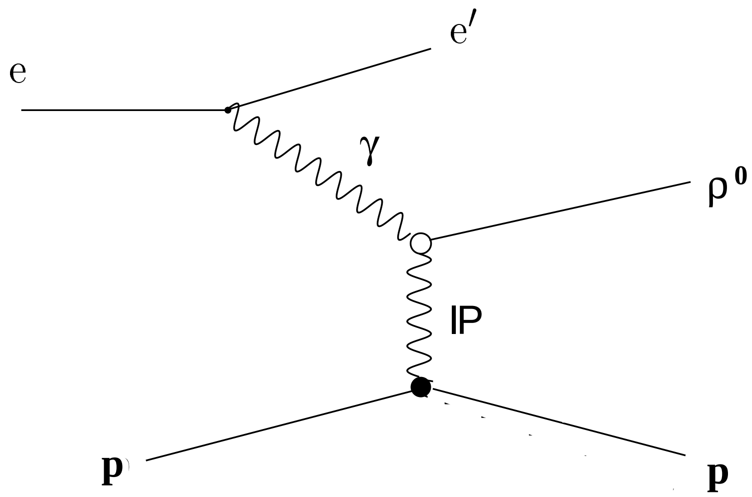
ANOTHER DIRECT PROBE OF THE ODDERON

Pure C = – 1 Channel

No Pomeron Mixing



Compare with Pomeron Exchange



Theoretical Background

Non-Perturbative Treatment of
High Energy Scattering by Functional Methods

O. Nachtmann: Ann.Phys. **209** (1991) 436.

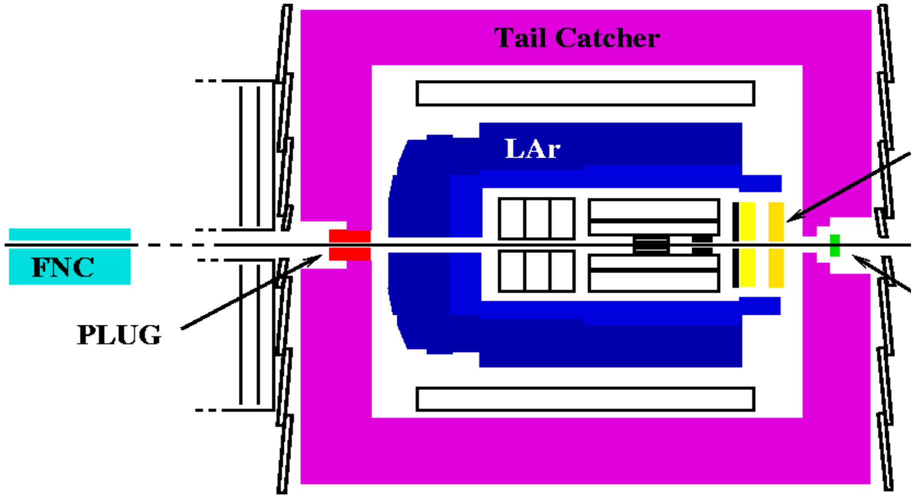
Model for Non-Perturbative QCD:
Model of the Stochastic Vacuum (MSV)

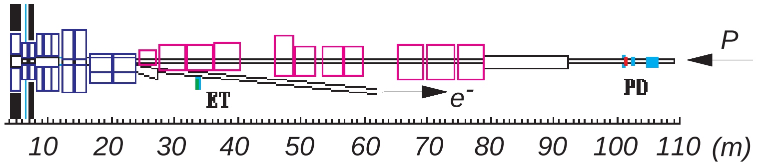
H. G. Dosch, Yu. A. Simonov, Phys Lett. **B205** (1988) 339.

MSV applied to High Energy Scattering,
especially $\gamma p \to \pi^0 N^*$

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

- Proton as a Quark-Diquark System in Transverse Space
- Model tuned for Pomeron Exchange at 20 GeV
- Model extended to Odderon Exchange
- Extrapolated to HERA Energies via $(s_{\gamma p}/400)^{\alpha_{\mathbb{O}}(0)-1}$, $\alpha_{\mathbb{O}}(0) \approx 1$


Tail Catcher
LAr
FNC
PLUG

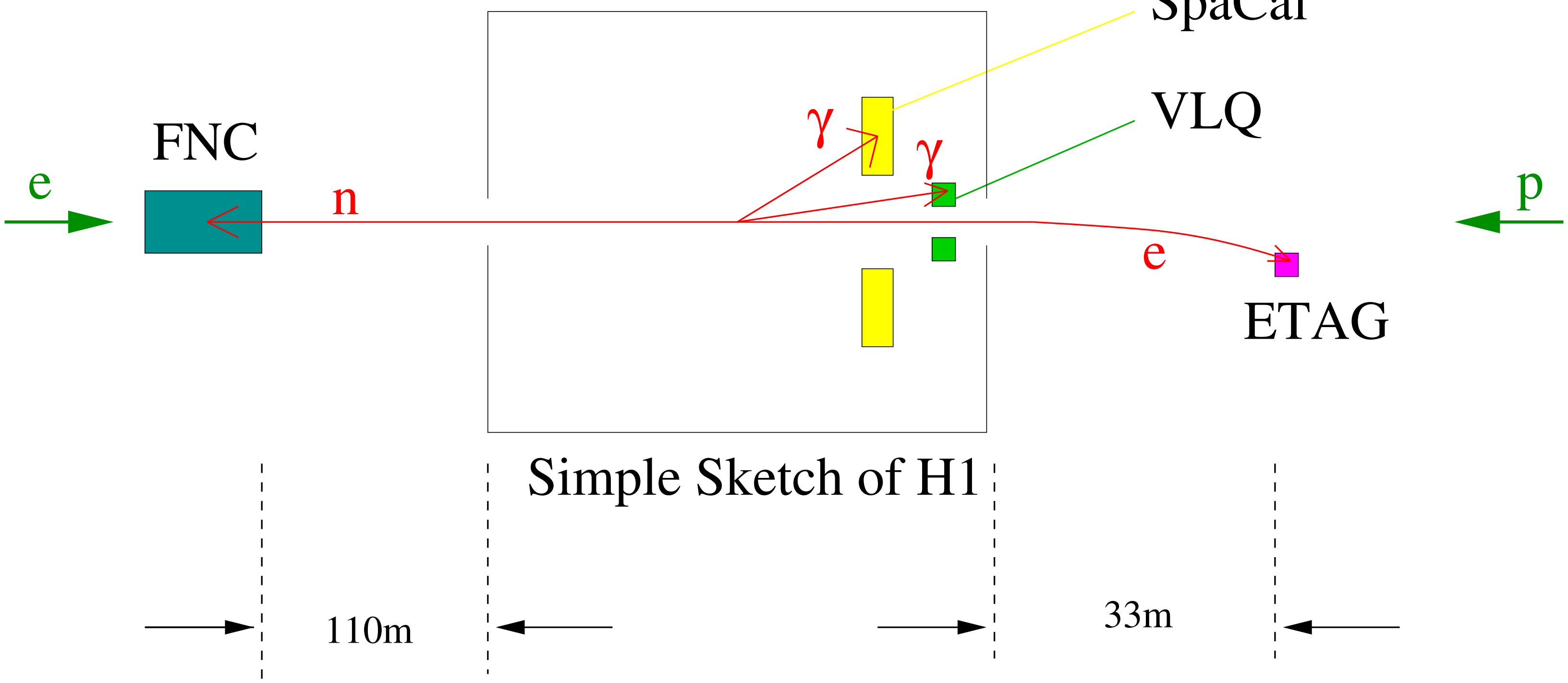

P
ET
PD
e-
10 20 30 40 50 60 70 80 90 100 110 (m)

THE SIGNATURE

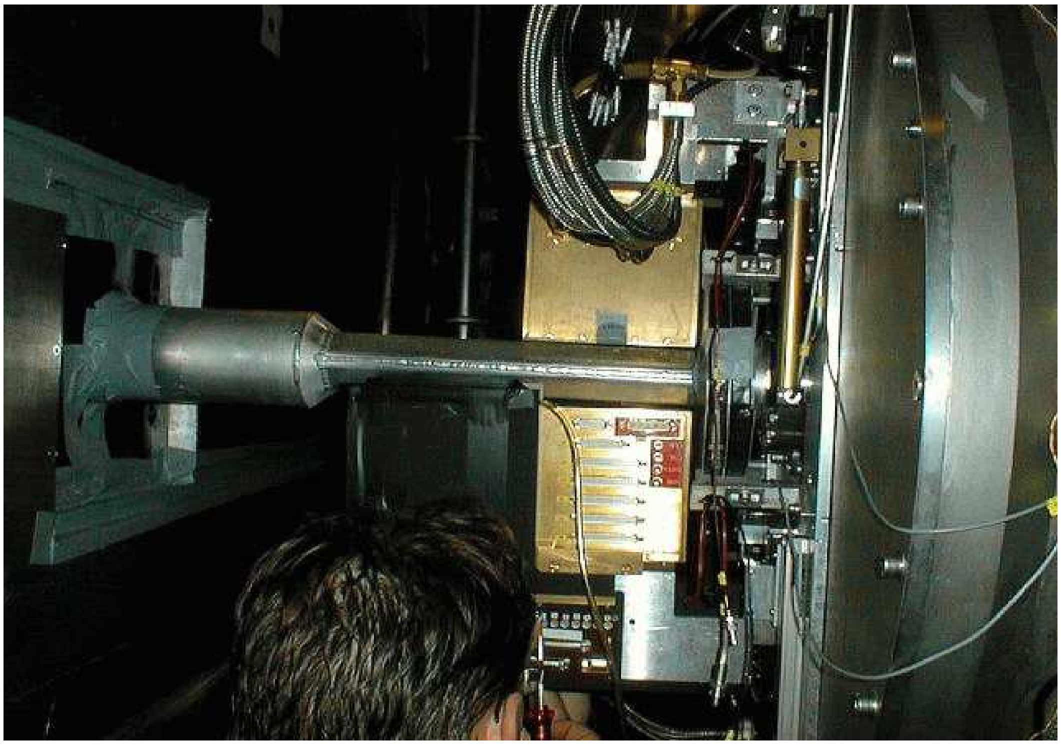
$$ep \longrightarrow e\,\pi^{o}\,N^{*}$$

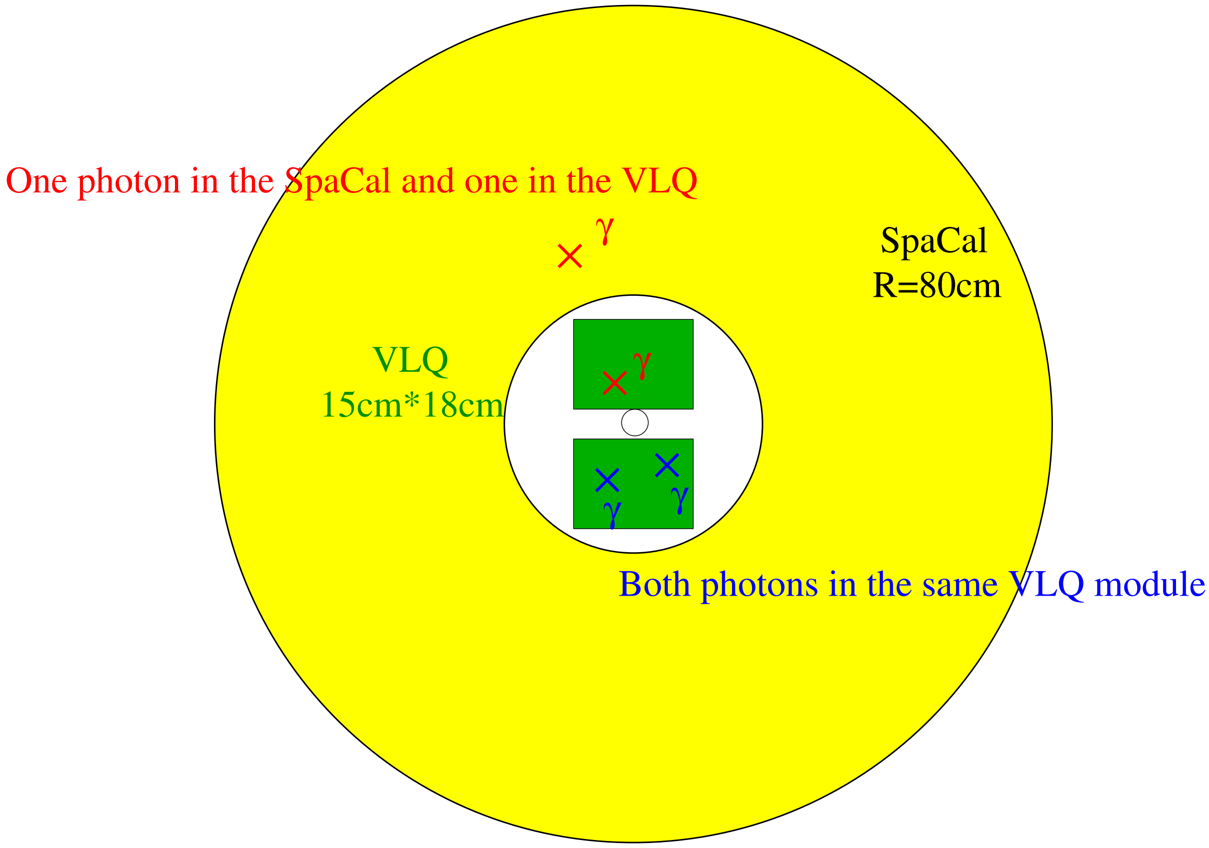
$$N^{*} \longrightarrow n\;X \qquad \pi^{o} \longrightarrow \gamma\gamma$$

Background Reduction
- No Bethe–Heitler
- No Tracks
- Energy–Momentum Conservation



Signature of the π^0 decay

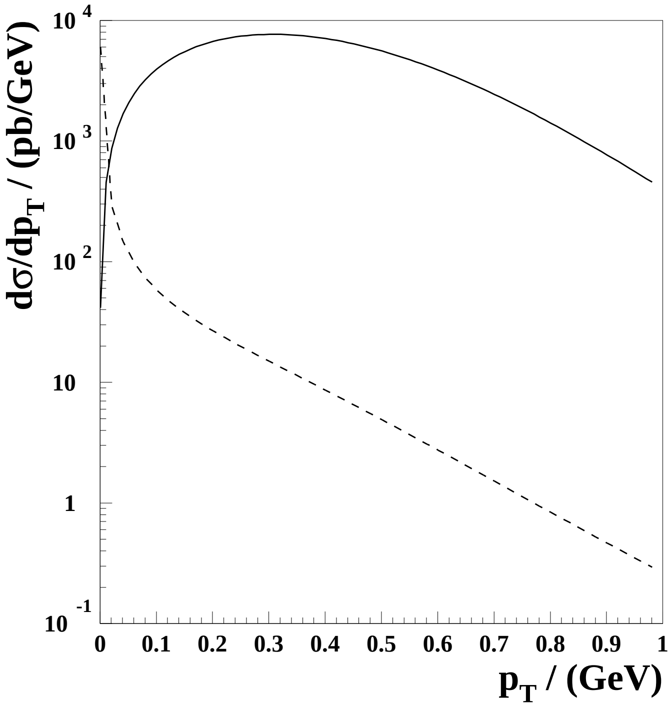




$$10 \text{ GeV} \lesssim E_{\pi^0} \lesssim 20 \text{ GeV}$$

Dedicated Signal Generator

MSV Signal Monte Carlo (called OPIUM)
p_T-distribution from the MSV.



- Excitation to N^*: $I(J^P) = \frac{1}{2}(\frac{3}{2}^-), \frac{1}{2}(\frac{1}{2}^-)$

$N^*(1520$ MeV$)$	–	45%
$N^*(1535$ MeV$)$	–	45%
$N^*(1650$ MeV$)$	–	5%
$N^*(1700$ MeV$)$	–	5%

- N^* decay: $N^* \rightarrow n\pi(\pi)$
$\longrightarrow$ 42 % have a neutron in the final state

What are the Backgrounds ?

- Photon-photon-fusion (Primakoff Effect):
  $\gamma\gamma \to \pi^0$ (negligible)

- Regge ($= \omega$-trajectory) exchange (negligible)

- Pomeron exchange (Diffraction):
  Exclusive ω and ρ^0 Photoproduction:

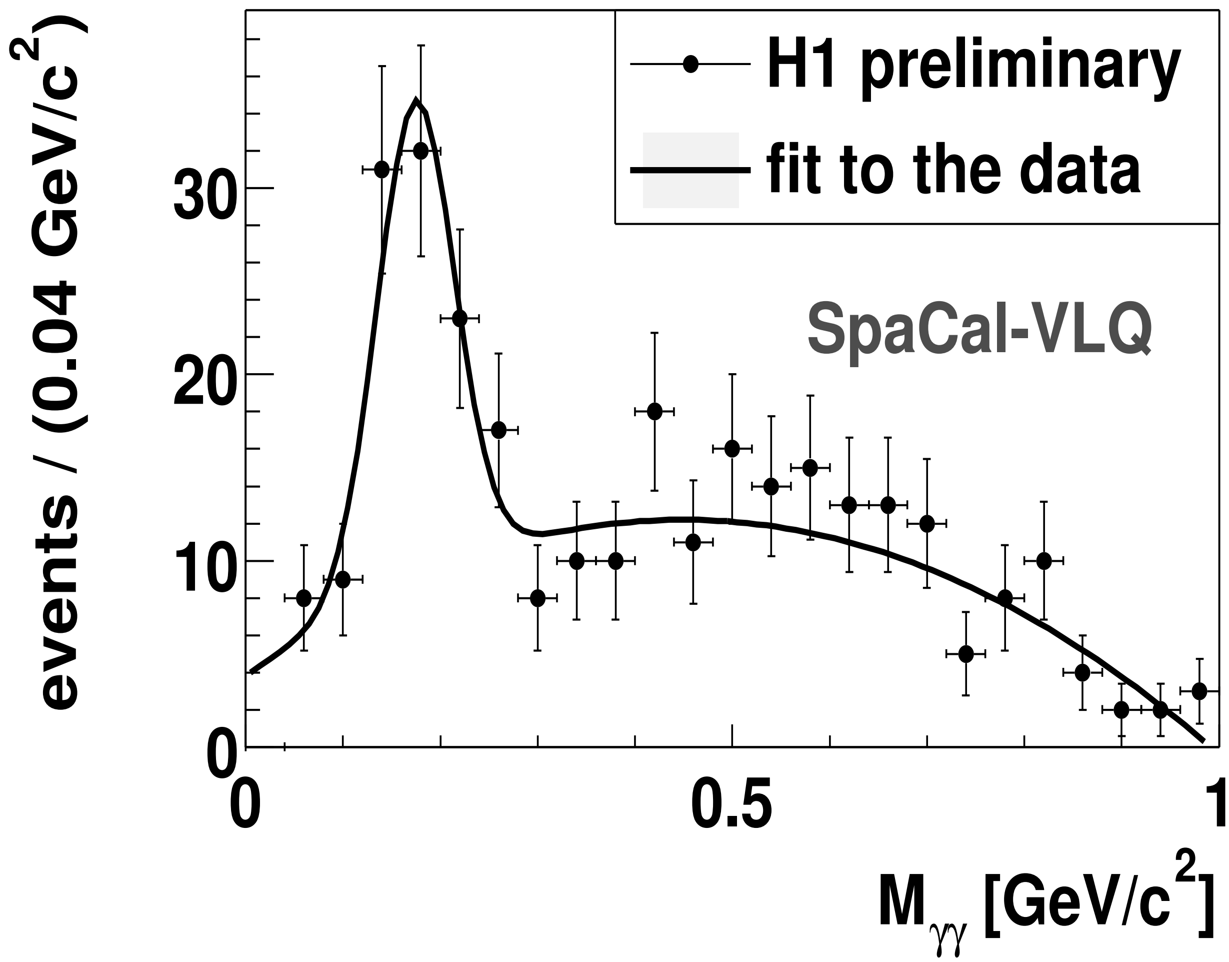
$$
\begin{array}{lll}
\gamma p \to & \omega \;\; (\rho^0) N^* & \\
 & \downarrow & \\
 & \omega \;\; (\rho^0) \to \pi^0\gamma &
\end{array}
$$

- Inclusive pions

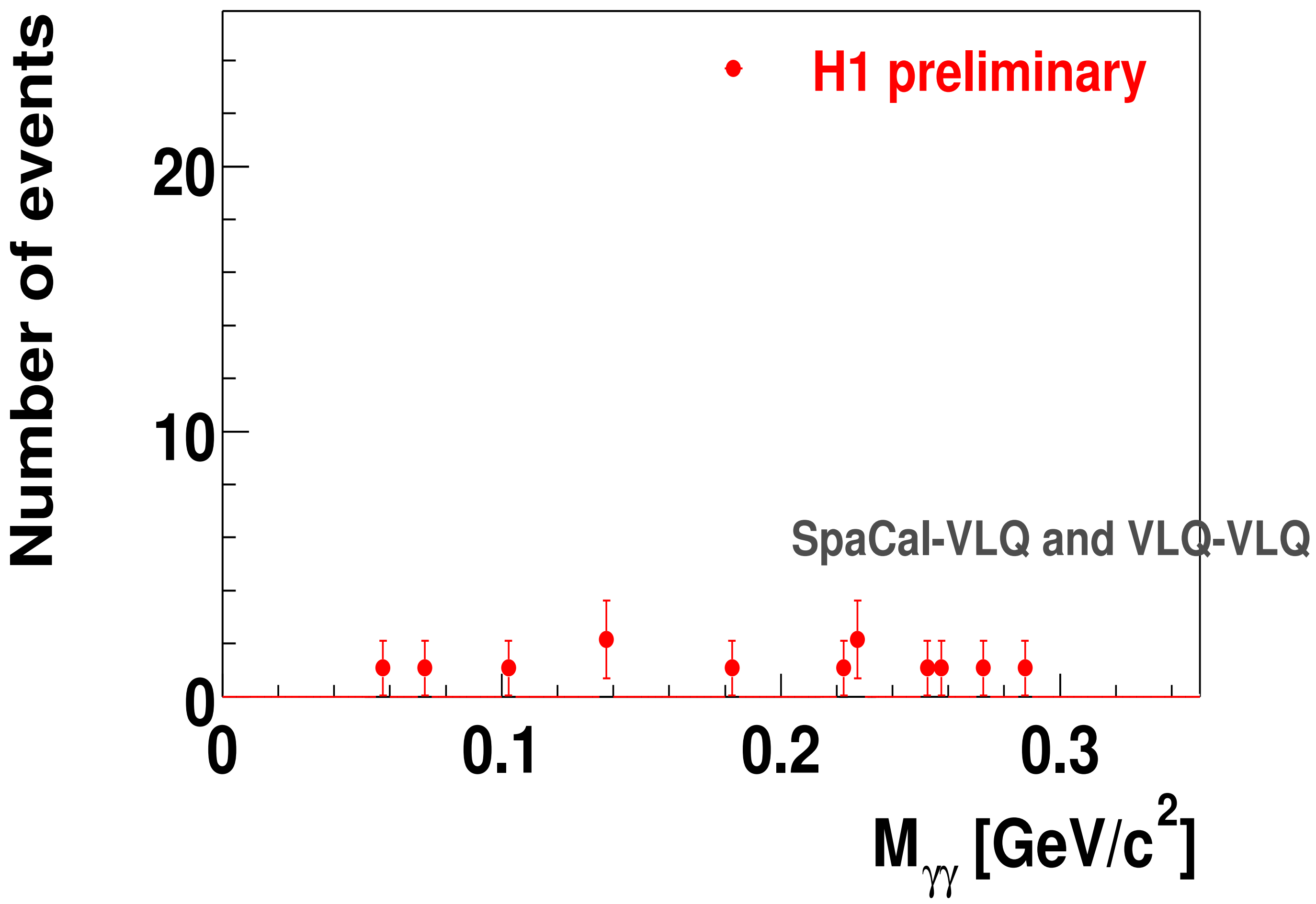
PYTHIA (T.Sjöstrand)

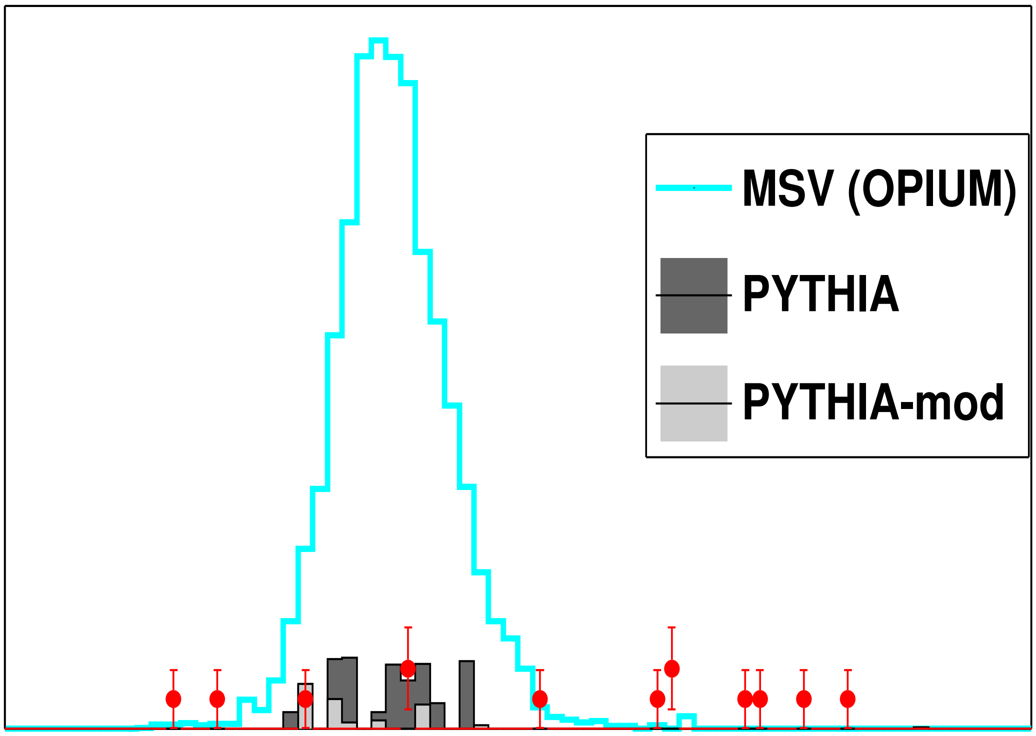
is our Background Monte Carlo

Are We Able to See Pions ? - YES !



Do We See the Odderon ? - NO !




MSV (OPIUM)
PYTHIA
PYTHIA-mod

Towards an Upper Limit

$$\sigma_{\gamma p} = \frac{\sigma_{ep}}{c_{EPA}}$$

$$\begin{aligned}
\sigma(\gamma p \to \pi^0 N^*) &= \frac{1}{\epsilon \cdot BR_{\pi^0 \to \gamma\gamma} \cdot BR_{N^* \to nX} \cdot c_{EPA}} \cdot \frac{N_{observed}}{\int \mathcal{L}\, \mathsf{d}t} \\
&= \mathcal{F} \cdot N_{observed}
\end{aligned}$$

$N_{observed}$	13	
$N_{background}$	4	
$BR_{\pi^0 \to \gamma\gamma}$	0.99	
$BR_{N^* \to nX}$	0.42	
$\epsilon = \frac{N_{rec}}{N_{gen}}$	$1.51 \cdot 10^{-3}$	$\mathcal{F}$=1.76 nb
c_{EPA}	0.0136	
$\int \mathcal{L}\, \mathrm{d}t$	30.6 pb^{-1}	
$\Delta\sigma_{sys}$	0.25	

$$\sigma(\gamma p \overset{\mathbb{O}}{\to} \pi^0 N^*) \;=\; \mathcal{F} \cdot \{N_{observed} - N_{background}\}$$

$$\Downarrow$$

$$N_{limit}$$

Determination of an Upper Limit

Cousins et al. (Phys.Rev.**D57** (1998) 3873) and

(Nucl. Instr. Meth. **A320** (1992) 331)

$$\begin{aligned} N_{observed} &= 13 \\ N_{background} &= 4 \\ \text{Systematic Uncertainty} &= 25\% \end{aligned}$$

$$\Downarrow$$

$$N_{limit} = 22 \qquad \text{(95\% CL)}$$

Result: **Upper limit on σ at 95% CL:**

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

$$\sigma_{\gamma p \overset{\mathbb{O}}{\rightarrow} \pi^0 N*} = 400 \text{ nb} \qquad \text{(Berger et. al)}$$

Model of the Stochastic Vacuum

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

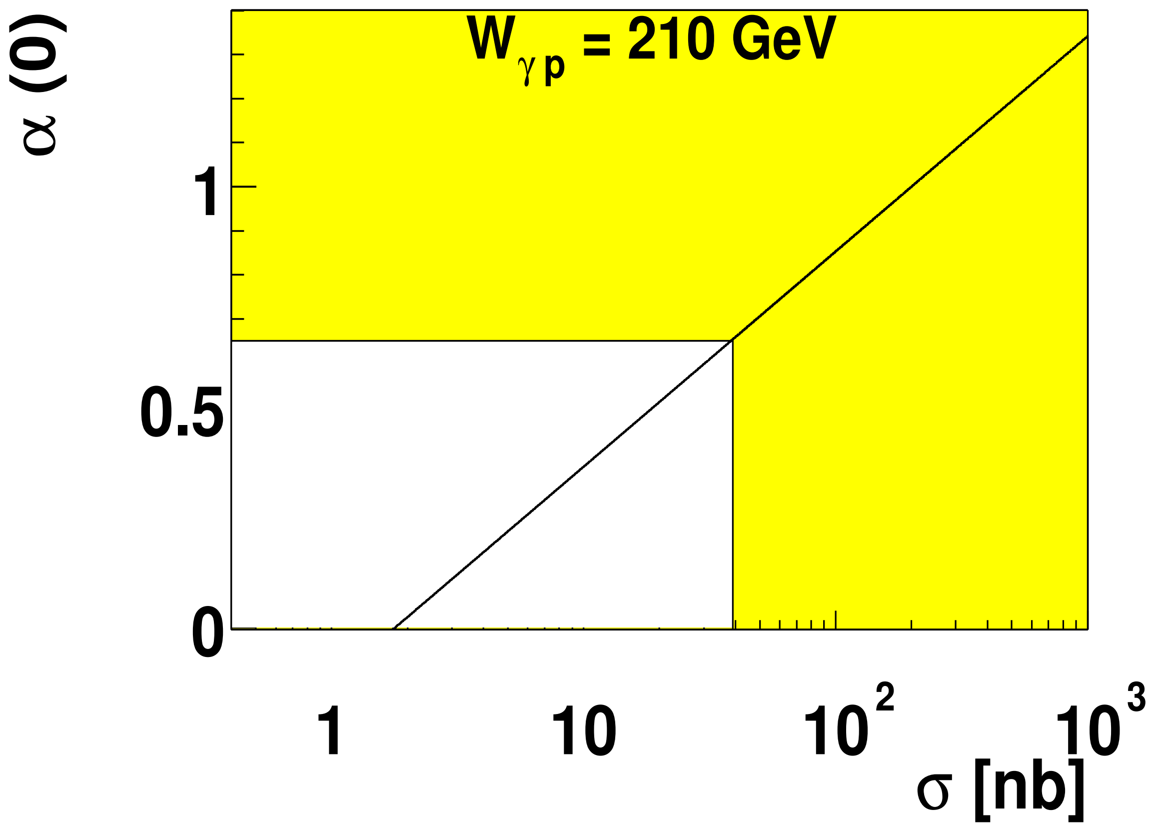
restricted to the visible t range: 0.02 GeV$^2 < t <$ 0.3 GeV^2

Can we understand the Non-Observation

1. **Energy Dependence:** Cross Section scales like

$$(s_{\gamma p}/400)^{\alpha_{\mathbb{O}}(0)-1}$$

$$\textbf{Berger et. al} \longrightarrow \alpha_{\mathbb{O}}(0) = 1.15$$
$$\textbf{B. Nicolescu} \longrightarrow 0.94 \lesssim \alpha_{\mathbb{O}}(0) \lesssim 0.96$$

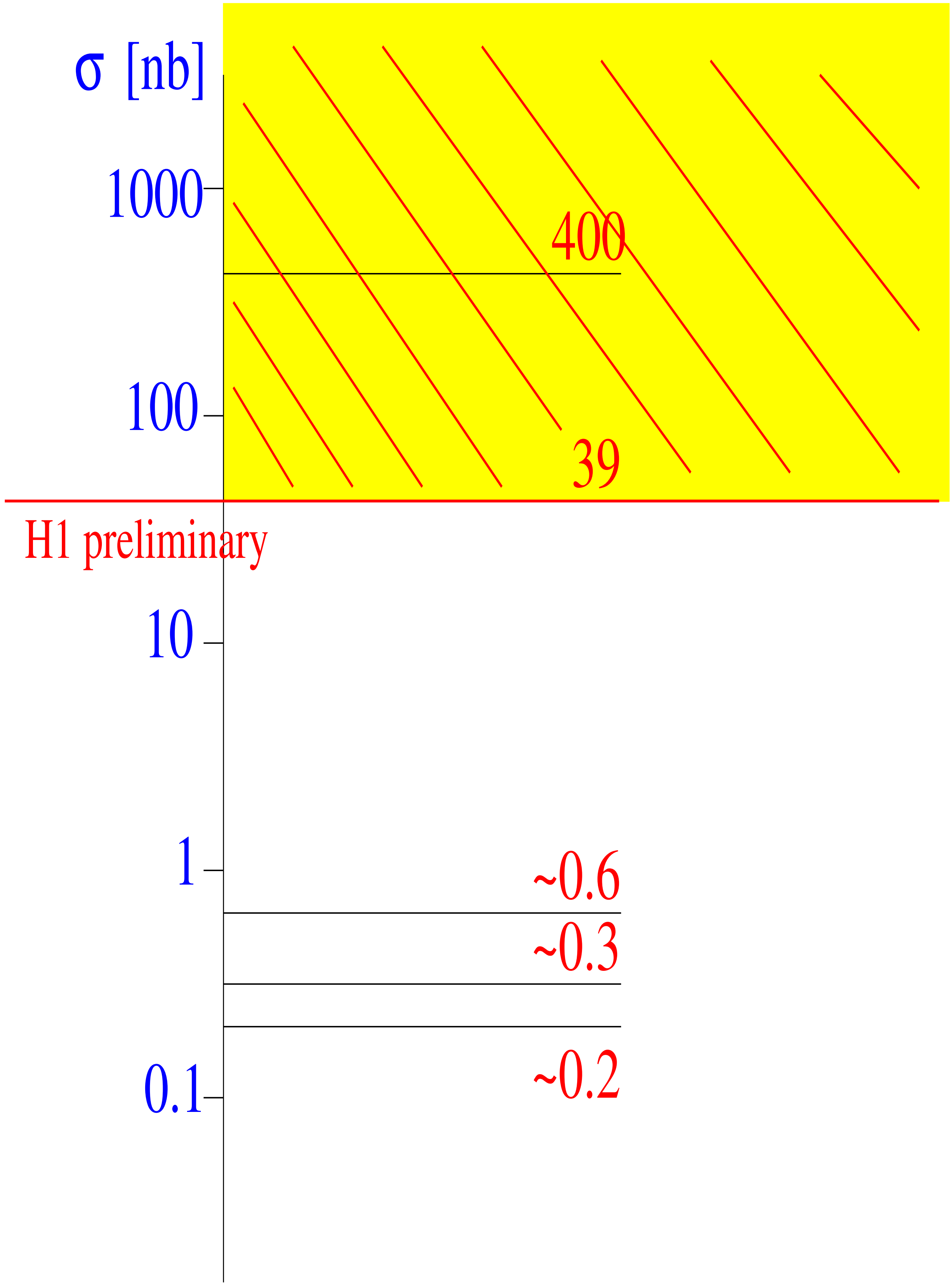


$\alpha_{\mathbb{O}}(0) < 0.65 \Longrightarrow$

Odderon is not an "Odderon" anymore

2. **Small $\gamma\pi\mathbb{O}$ Coupling** due to Goldstone Boson Nature of the Pion (Coupling $\sim m_q \approx 0.005$ GeV)

SUMMARY



Do we see the Odderon ?

NO !

Summary and Outlook

$$pp \leftrightarrow \bar{p}p$$

No Odderon $\longrightarrow$ Proton = Quark-Diquark

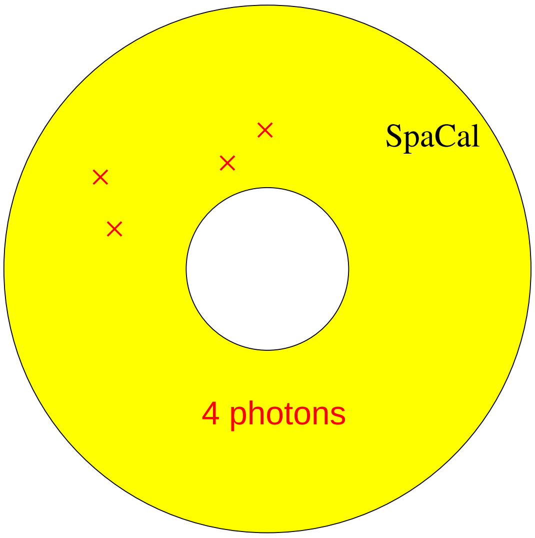
$$\gamma p \to \pi^0 N^*$$

We have excluded the prediction from Berger et. al
on a 95% Confidence Level:
No Odderon $\longrightarrow$ Current Quark Mass

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

We have the experiment and the theory
$f_2 \to \pi^0\pi^0 \to 4\gamma$ and $a_2 \to \eta\pi^0 \to 4\gamma$

Odderon ?



$\longrightarrow$ **HERA II**