9th 'Blois Workshop'

on

Elastic & Diffractive Scattering

Pruhonice, Prague

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Search for Odderon Induced Contributions to Exclusive π° Photoproduction at HERA

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On behalf of the H1 Collaboration

- Introduction
- Experimental Procedure
- Result and Comparison with Theory
- Conclusions and Outlook

The Odderon: What is it?

1973: Discuss possibility of a $C = -1$ contribution in hadron–hadron scattering at high energies

L. Łukaszuk, B. Nicolescu, Lett.Nuov.Cim. 8 (73) 405

1975: Name–giving! Odd–under–crossing–Pomeron

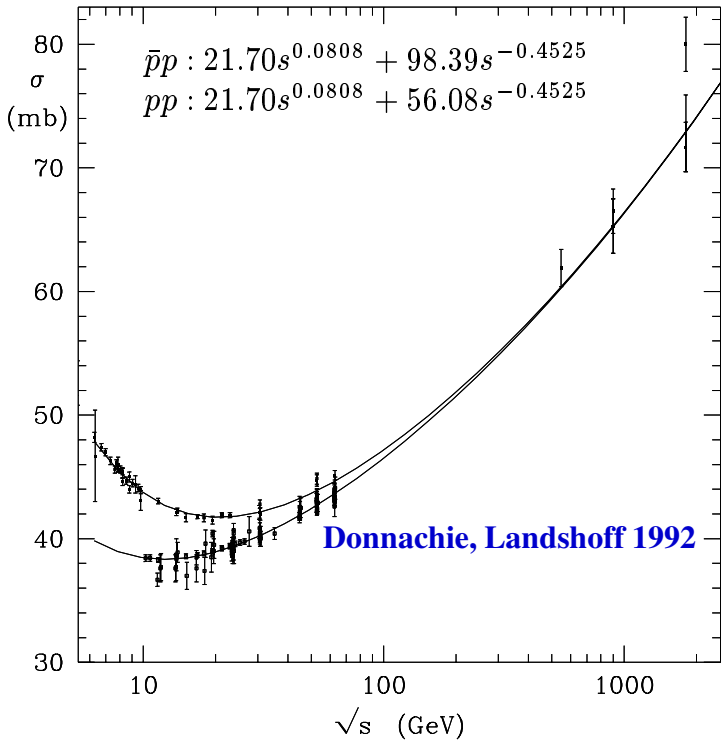
D. Joynson, E. Leader, B. Nicolescu, C. Lopez, Nuov.Cim. 30A (75) 345

Odderon (C=P=-1) and Pomeron (C=P=$+1$) are companions in High Energy Scattering with similar intercepts, i.e. $\alpha_{\mathbb{O}}(0) \approx 1$

Presence of Odderon leads to the prediction that, e.g.

$$\Delta\sigma = \sigma_{\bar{p}p} - \sigma_{pp} \not\longrightarrow 0, \quad s \longrightarrow \infty$$

and similar for other hadron–hadron scattering processes.



- **No evidence for Odderon**
- **All hadron-hadron data excellently fitted, using only Pomeron and Reggeon terms**
- $\alpha_{\mathbb{P}}(0) = 1.0808$
  $\alpha_{\mathrm{R}}(0) = 0.5475$

The perturbative Odderon

QCD developments 1980's, 1990's

- Pomeron interpreted as exchange of 2 gluons
  Odderon interpreted as exchange of 3 gluons
- Meanwhile Odderon is recognized as
  important and basic prediction of QCD
- Odderon solutions have been found

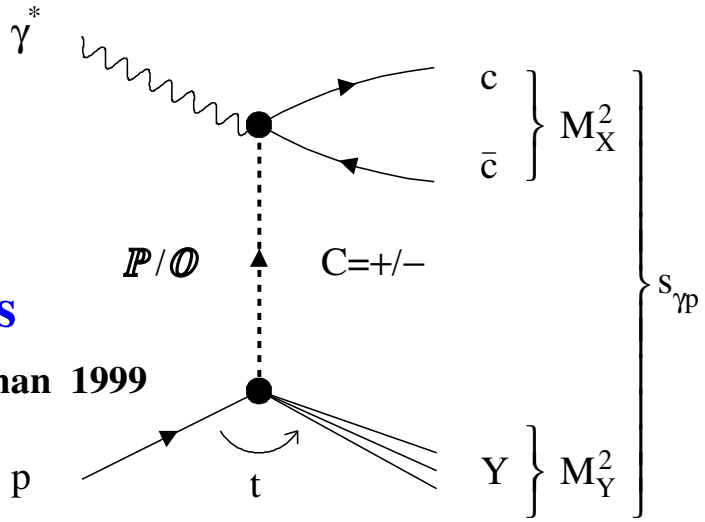
  L.N. Lipatov 1997, R.A. Janik and J. Wosiek, 1999
- Predictions for experimental searches,
  based on perturbative calculations,
  using hard scales Q^2, m_c, etc., e.g.:

  ▷ $\sigma(\gamma p \xrightarrow{\mathbb{O}} \eta_c p) = 50\ \mathrm{pb}$ at $Q^2 = 0$
  $= 1.3\mathrm{pb}$ at $Q^2 = 25\ \mathrm{GeV}^2$

  J. Bartels et al., 2001

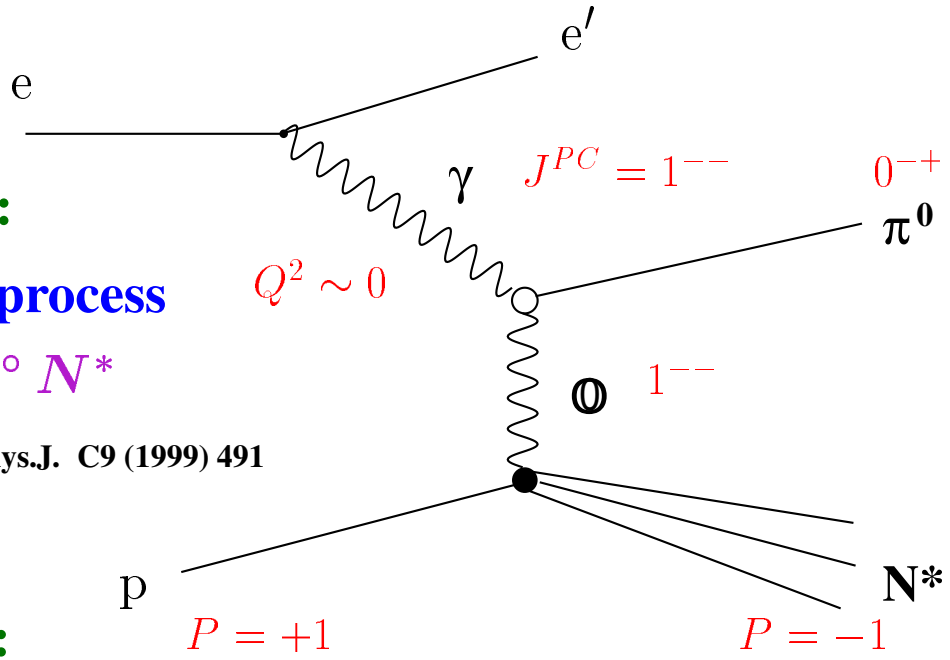
  ▷ Asymmetry in fractional energy in $c - \bar{c}$ jets, due to interference of exchange amplitudes

  S.J.Brodsky, C.Merino, J.Rathsman 1999



Challenge to the HERA experiments !

The non–perturbative Odderon



Heidelberg Group:

Prediction for the process

$$\gamma\, p \xrightarrow{\mathbb{O}} \pi^\circ\, N^*$$

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

Model ingredients:

- Non-perturbative QCD, using Functional Integral techniques
- "Stochastic Vacuum Model", Dosch & Simenov 1987-88, Nachtmann 1991
- Diquark model of the proton Reuter & Dosch, 1996
- Tuned for Pomeron Exchange reactions
- Extended to Odderon Exchange
- Diquark–quark Symmetry arguments:
  - ▷ Explain suppression of Odderon exchange in pp and $\bar{p}p$ data !
  - ▷ Predict suppression of process $\gamma\, p \xrightarrow{\mathbb{O}} \pi^\circ\, p$
  - ▷ But: Large Cross Section if proton excited to N^* with P$= -1$!

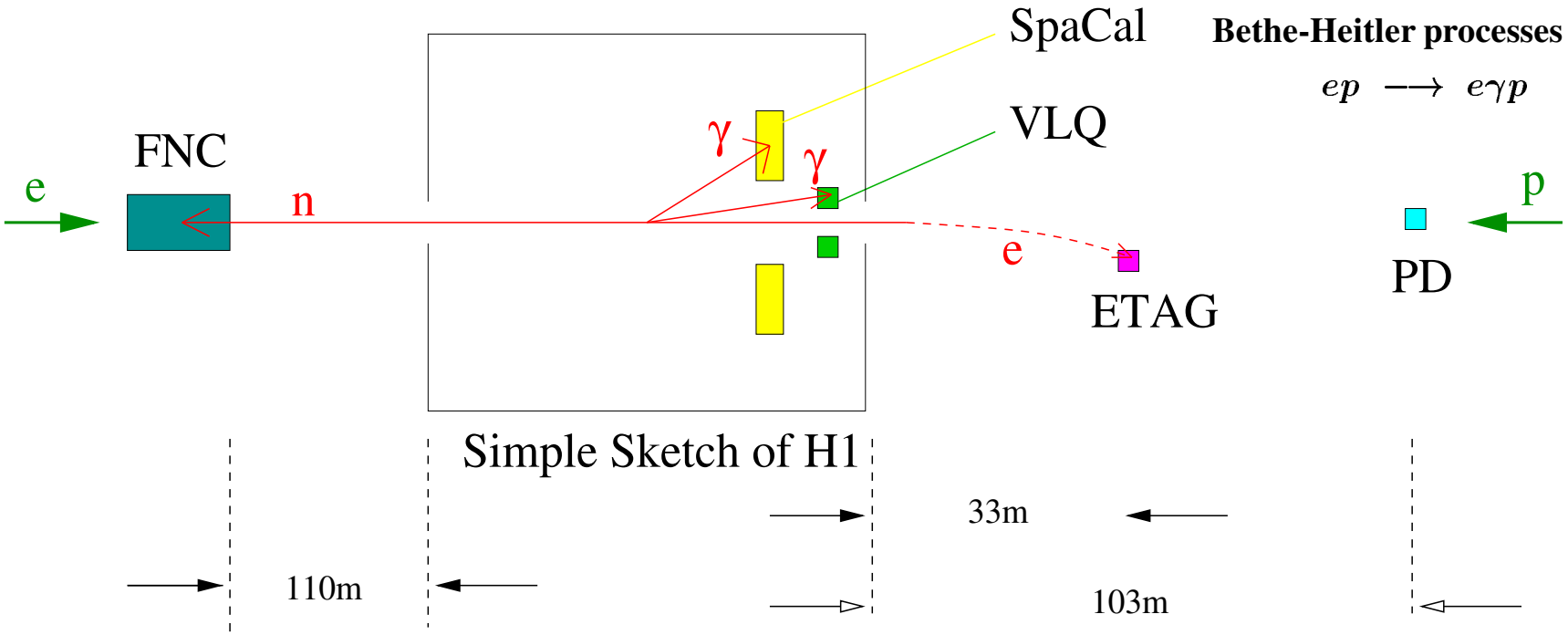
$$\sigma(\gamma p \xrightarrow{\mathbb{O}} \pi^\circ N^*) = 294 \text{ nb} \quad \text{at } W_{\gamma p} = 20 \text{ GeV}$$

Prediction at HERA energies: $\sim$ 600 nb !
1 – 2 events / minute !!

THE SIGNATURE

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

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



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

$$ep \longrightarrow e\gamma p$$

The expected (and trivial) Background:

- **Diffraction, i.e. $\mathbb{P}$omeron exchange**
  - ▷ $\gamma p \longrightarrow \omega N^*, \quad \omega \longrightarrow \gamma\pi^\circ$
  - ▷ $\gamma p \longrightarrow \rho^\circ N^*, \quad \rho^\circ \longrightarrow \gamma\pi^\circ$ **B.R.** $= (6.8 \pm 1.7)10^{-4}$
  - ▷ $\gamma p \longrightarrow \pi^\circ X N^*$ **Inclusive π° production**
- **$\gamma\gamma$ processes, i.e. Primakoff Effect**
  - ▷ **Negligible**
- **Reggeon (ω) exchange, i.e. $\gamma p \xrightarrow{\omega} \pi^\circ N^*$**
  - ▷ **Negligible**

Use PYTHIA for Simulation of Background*

* **PYTHIA-mod:**

With permission of the author, T. Sjöstrand, the Diffractive part of PYTHIA was modified, in order to exclude the isospin violating decay $\rho^\circ \longrightarrow \pi^\circ\pi^\circ$

This decay does not disturb the PYTHIA description of inclusive, high–multiplicty diffractive events, but is an important effect in exclusive, low–multiplicity studies

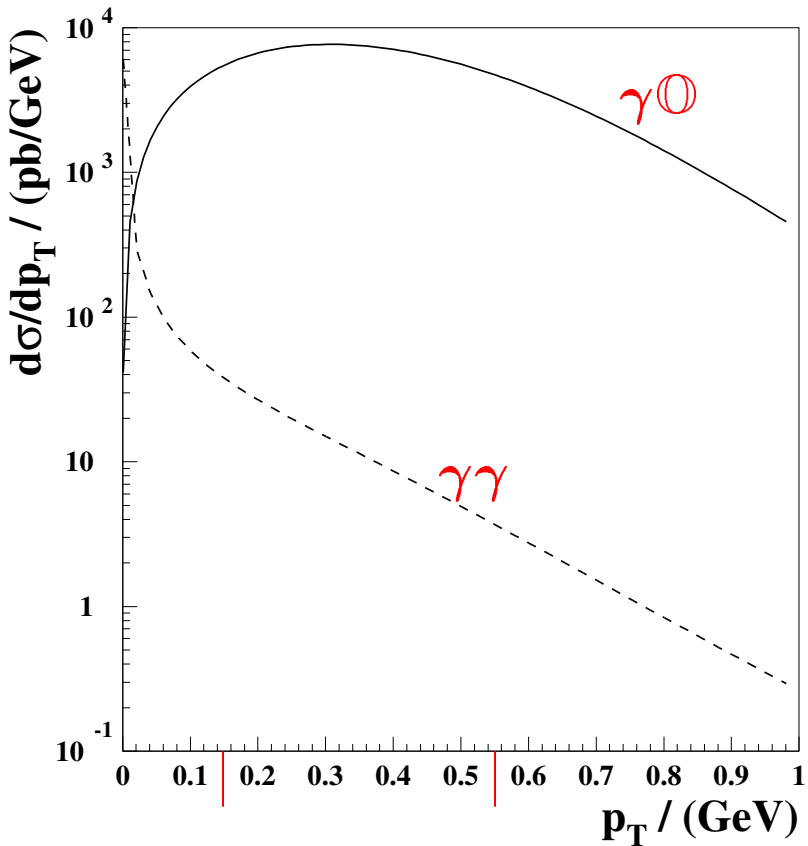
$\mathbb{O}$ $\mathbb{P}$ IUM *

- **Simulates the process** $\gamma\, p \xrightarrow{\mathbb{O}} \pi^\circ\, N^*$
- **is an extension of DIFFVM** **(B. List, A. Mastroberardino)**
- **Considers the baryon states** $(I = \frac{1}{2},\ J^P = \frac{1}{2}^-,\ \frac{3}{2}^-)$

$N^*(1520),\ N^*(1535),\ N^*(1650),\ N^*(1700)$

45% **45%** **5%** **5%**

- **Final State Neutron in 42% of the N^* decays**
- **π° transverse momentum distribution from MSV**



Acceptance

$\gamma\gamma$ exchange important only at very low $p_\perp$

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

$(t \sim -p_\perp^2)$

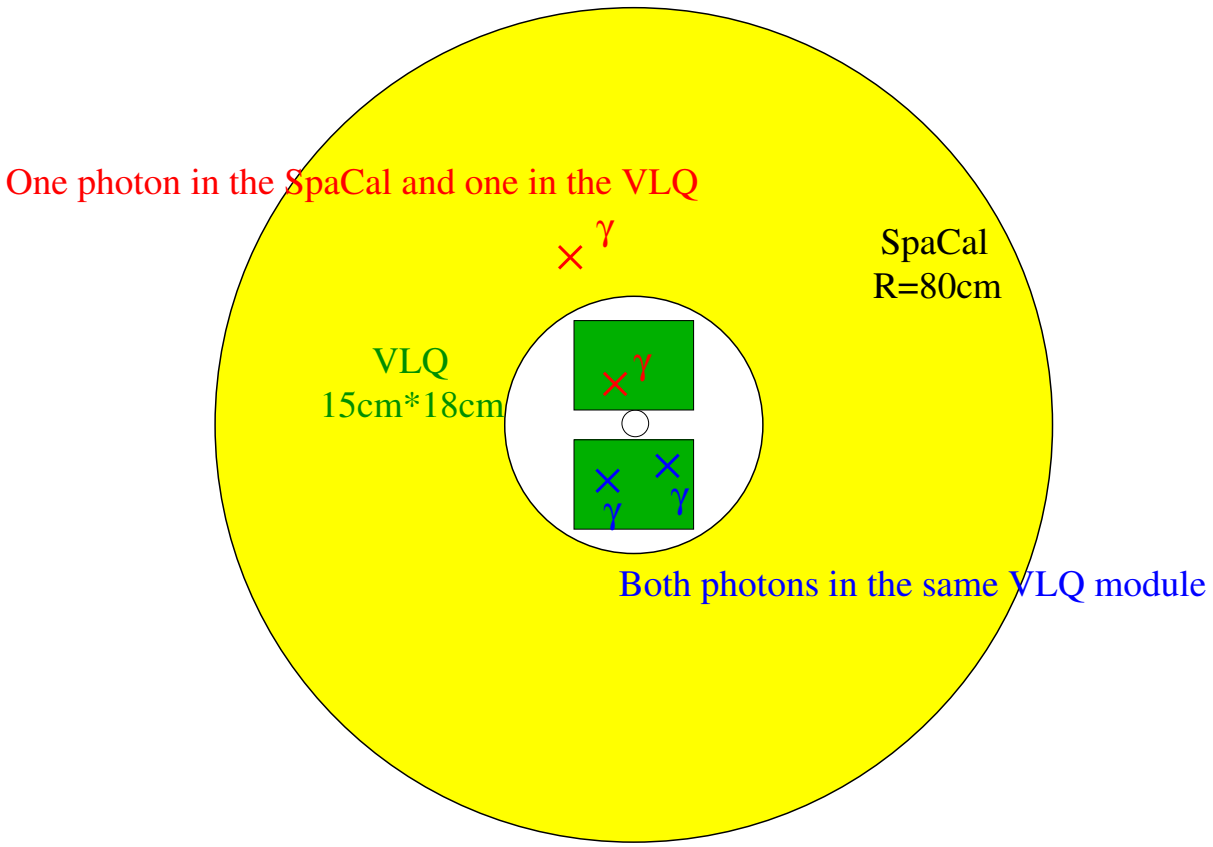
***$\mathbb{O}$dderon and $\mathbb{P}$omeron Induced Unified Meson maker** **(W. Kornelis)**

Data Sample: 30.6 pb^{-1}, collected 1999-2000

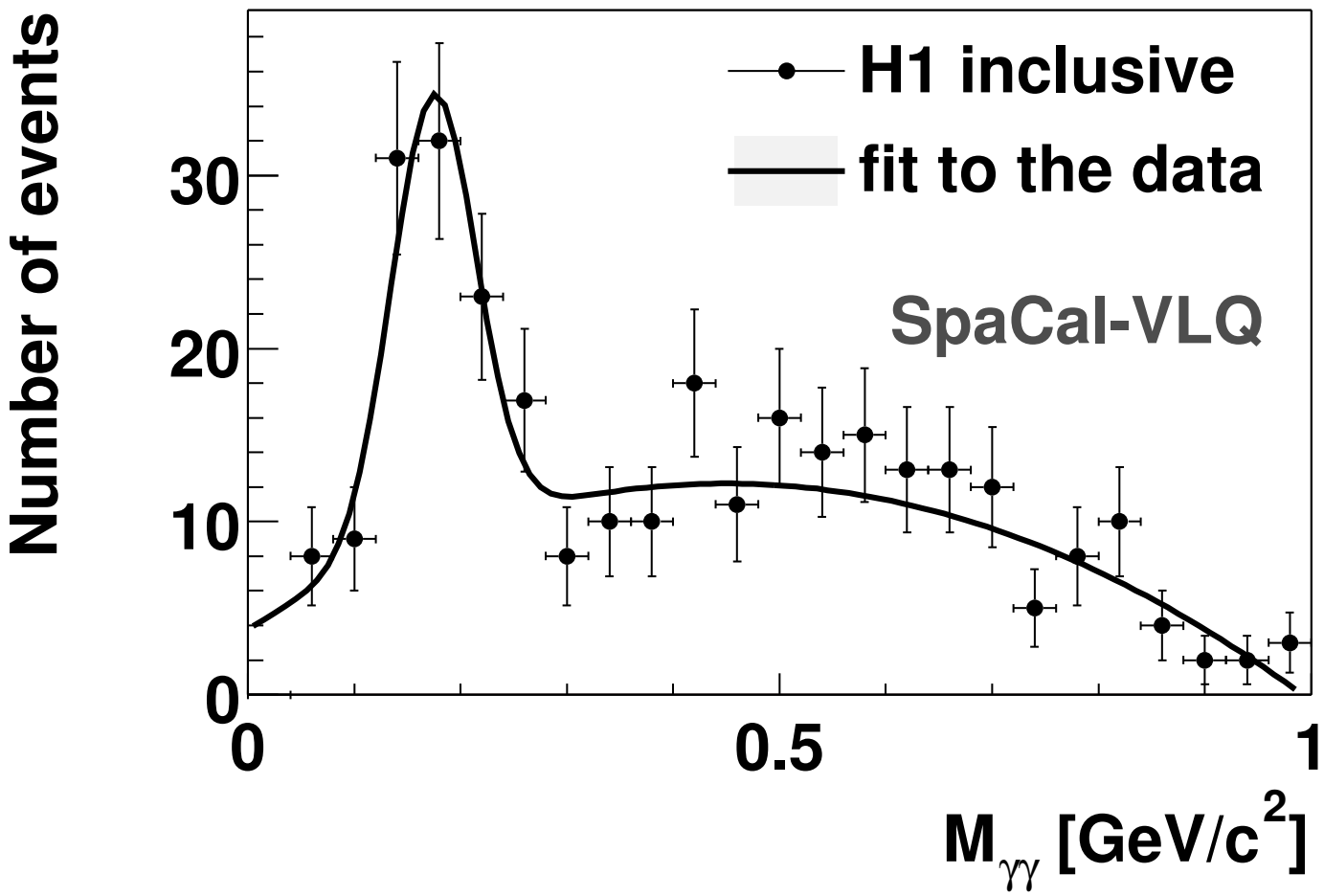
Trigger: Electron Tag, Neutron tag, VLQ energy

Event Selection:

- **Exactly 2 "Good" Photons**
  - ▷ **"SpaCal–VLQ" or "VLQ–VLQ" Topology**
  - ▷ $E_\gamma > 2$ GeV (VLQ)
    $E_\gamma > 60$ MeV (SpaCal)
  - ▷ **Cluster Shapes compatible with Photons**
  - ▷ **Locations well within Fiducial Volumes (no shower leakage)**



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



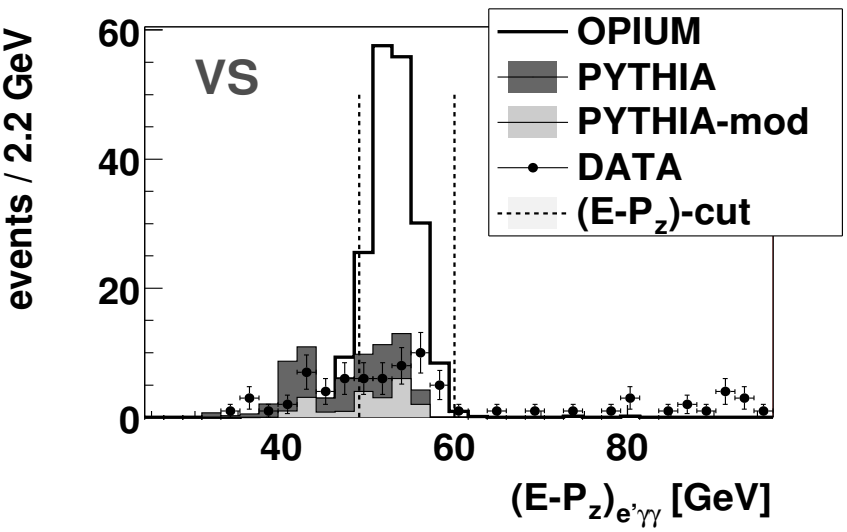
Proof of π° Detection Sensitivity

Is there an Odderon signal ?

Event Selection, continued:

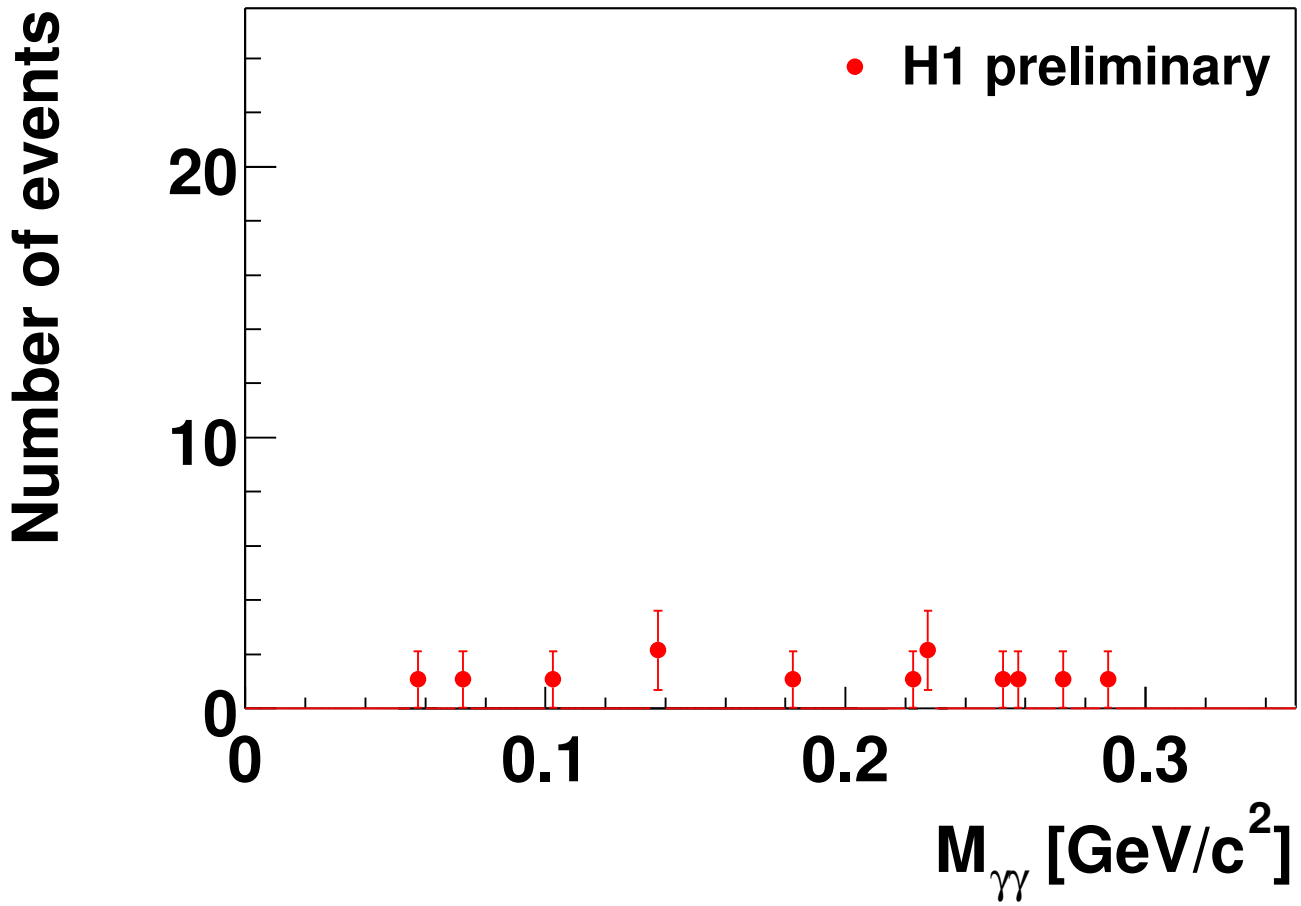
- **Electron**
  - ▷ **Well measured,**
    $\Longrightarrow$ **electron energy cluster well within fiducial volume**
  - ▷ **Inelasticity** $0.3 < y = 1 - E'_e/E_e < 0.7$
    $\Longrightarrow$ $8 \leq E_{\pi^\circ} \leq 19$ GeV
  - ▷ $E_{PD} < 2$ GeV
    $\Longrightarrow$ **Reduce background from Bethe–Heitler processes.**
- **Neutron**
  - ▷ **Well measured,**
    $\Longrightarrow$ **neutron energy cluster well within fiducial volume**
  - ▷ $E_n > 200$ GeV **(nominal trigger threshold)**
- **Exclusive events**
  - ▷ **No track vertex reconstructed (No charged particles)**
  - ▷ **Energy – Momentum Balance**

$$49 < (E - p_z)_{e\gamma\gamma} < 60 \text{ GeV}$$



Reject non-exclusive events

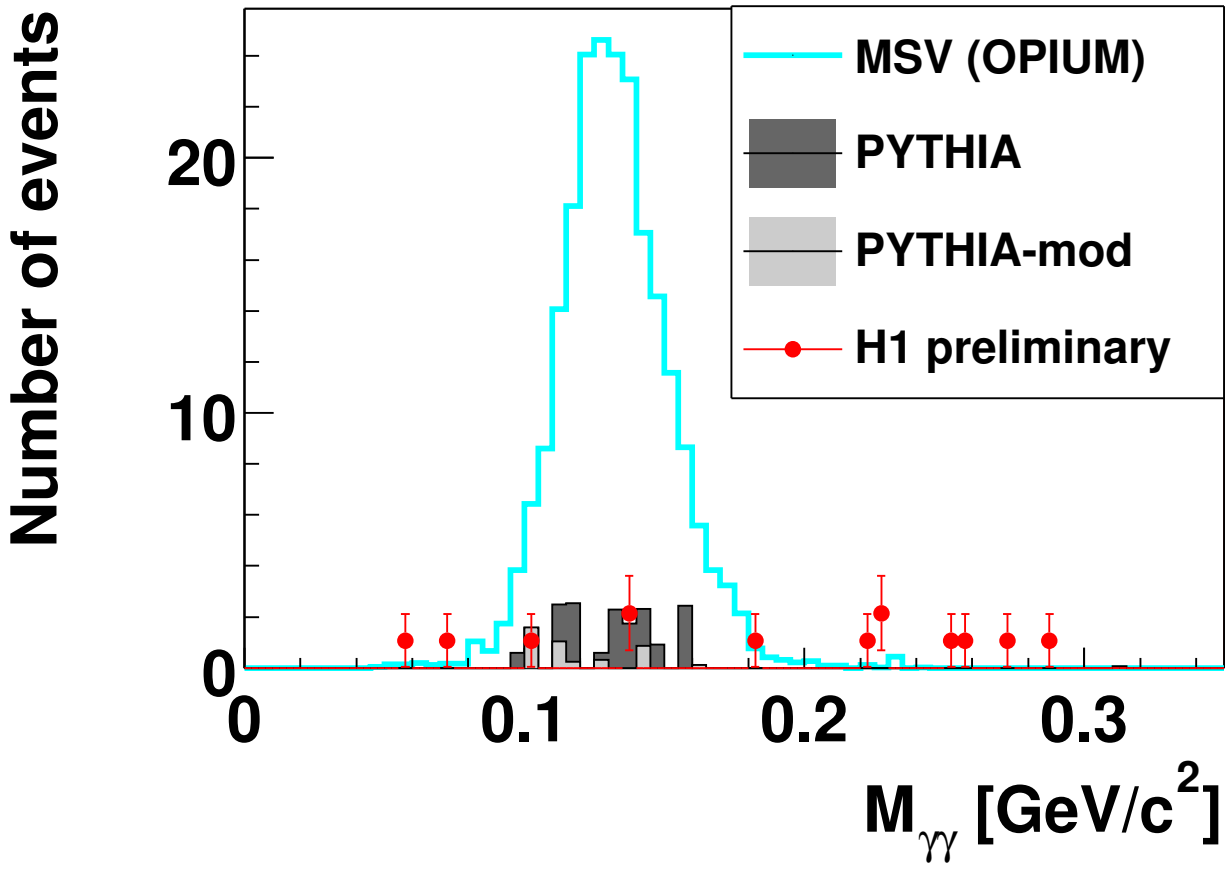
After all Selection Cuts:



No Signal !

What do we expect to see?

MC Calculations: ⟹



Few events in Signal Region

Consistent with PYTHIA estimate of trivial background

Theory expects 230 events !

(”Uncertainty at least a factor 2”)
E.R. Berger et al.

No Odderon Signal

$\Longrightarrow$ **Upper Limit on Cross Section**

- **Observe 13 Events in π° window 30–350 MeV**
- **PYTHIA predicts 4 Events background**
- **Systematic Uncertainty 25 %**

$\Longrightarrow$ **22 events** **(for Limit at 95% C.L.)***

H1 Preliminary

$$\sigma(\gamma p \xrightarrow{\mathbb{O}} \pi^\circ N^*) < 39 \text{ nb}$$

For $\langle W_{\gamma p} \rangle = 210$ GeV
and $0.02 < |t| < 0.3$ GeV^2
(visible t range)

Prediction from E.R. Berger et al.:

$$\sigma(\gamma p \xrightarrow{\mathbb{O}} \pi^\circ N^*) = 400 \text{ nb}$$

* **R.D. Cousins and G.J. Feldman, Phys.Rev. D57 (1998) 3873**
R.D. Cousins and V.L. Highland, Nucl.Instr.Meth. A320 (1992) 331

No Odderon seen! What can be the Reason ?

- **Cross Section correctly estimated ?**

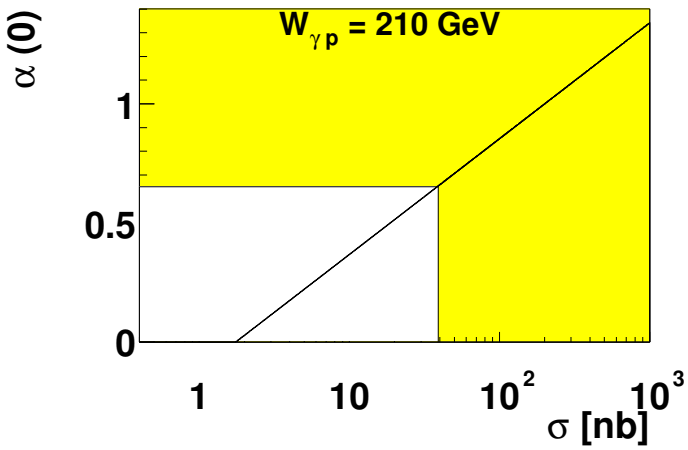
  Model prediction at $W_{\gamma p} = 20$ GeV
  Extrapolation to HERA energies, assuming

  $$\sigma = \sigma_\circ \, (W^2_{\gamma p}/400)^{\,\alpha_{\mathbb{O}}(0)-1}$$

  E.R. Berger et al. estimate $\alpha_{\mathbb{O}}(0) = 1.15$
  Other authors estimate $\alpha_{\mathbb{O}}(0)$ **close to 1**

  The H1 non-observation can be interpreted as upper limit on the intercept:

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



- **Small $\gamma\pi^\circ\mathbb{O}$ coupling ?**

  Coupling could be small,
  due to Goldstone Boson nature of π
  (coupling $\propto m_q \approx 0.005$ GeV)

  $\Longrightarrow$

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

S U M M A R Y

- **A Search for the Odderon was performed, using the Exclusive Single π° Photoproduction reaction:**

$$ep \longrightarrow e\pi^\circ N^*, \quad N^* \longrightarrow n\pi(\pi)$$

- **No Signal was found above trivial Background**

H1 Preliminary

$$\sigma(\gamma p \xrightarrow{\mathbb{O}} \pi^\circ N^*) < 39 \text{ nb}$$

For $\langle W_{\gamma p} \rangle = 210$ GeV
and $0.02 < |t| < 0.3$ GeV^2
(visible t range)

- **This Upper Limit is one Order of Magnitude below the Prediction from E.R. Berger et al.**

Eur.Phys.J.C9 (1999) 491

- **Good example of fruitful interaction between Theory and Experiment!**

O U T L O O K

- **Interest in the Odderon is an Order of Magnitude below interest in the Pomeron.**
  A Search in WWW reveals:
  Odderon: $\sim$ 150 hits Pomeron: $\sim$ 1500 hits
  This may change in the future

- **Odderon physics**
  now becoming an interesting field of research also for the HERA experiments

- **In particular,**
  Diffractive, Exclusive Production of Pseudoscalars and Tensors should in future attract much more interest, similar to the interest Diffractive Vector Meson Production enjoys today.

- **Will there be a Signal ??**

"The real problem with the Odderon is the paradoxical scarcity of the high–energy data in hadron–hadron scattering, leading to an excessive focus on the pp and $\bar{p}p$ data ... The recent shift in attention from pp and $\bar{p}p$ scattering towards ep scattering is, in this context, very positive."

B. Nicolescu, EDS 1999, Protvino

Wait for the HERA II data !