Prompt photon production in diffractive photoproduction at HERA as measured by ZEUS

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First measurement of isolated photons in diffractive photoproduction for ZEUS

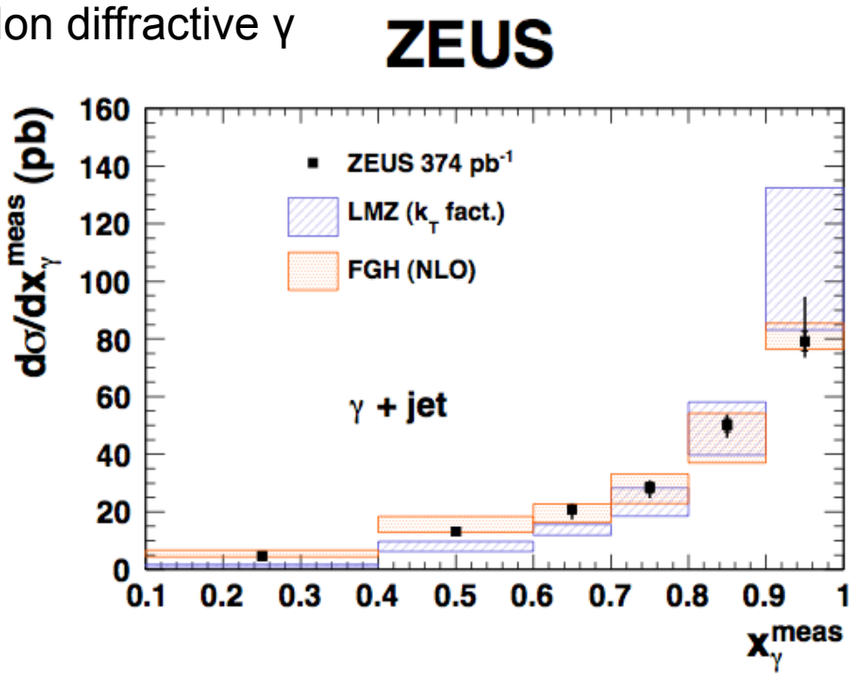
- "clean processes": prompt photon are free from fragmentation and hadronization corrections and sensitive to selected diagrams

  Previous HERA analyses of similar processes:

- H1 inclusive diffractive prompt photons in photoproduction: Phys. Lett. 672 (2009) 219
- Photoproduction of Isolated Photons, inclusively and with a Jet, ZEUS

  Phys. Lett. B 730 (2014) 293-301
- Diffractive photoproduced dijets: H1 Eur. Phys. J. 6 (1999), Eur. Phys. J 421 &0 (2008) 15, ZEUS Eur. Phys. J 55 (2008) 171

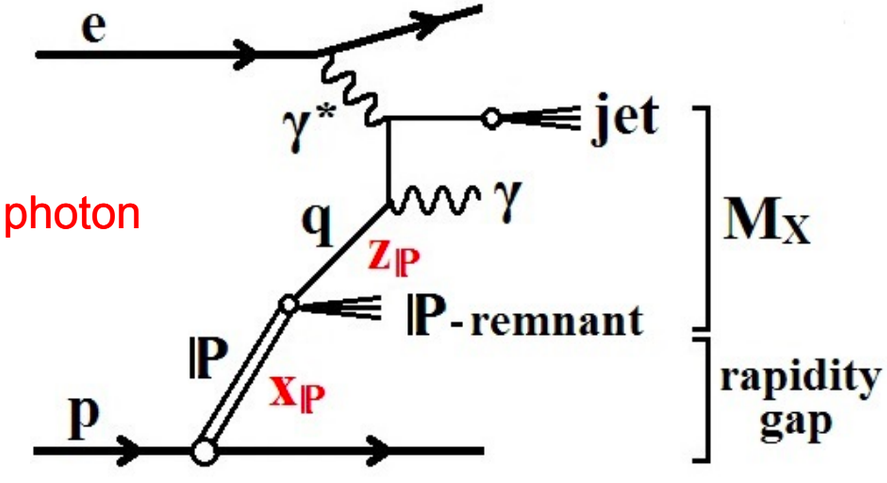
Non diffractive γ



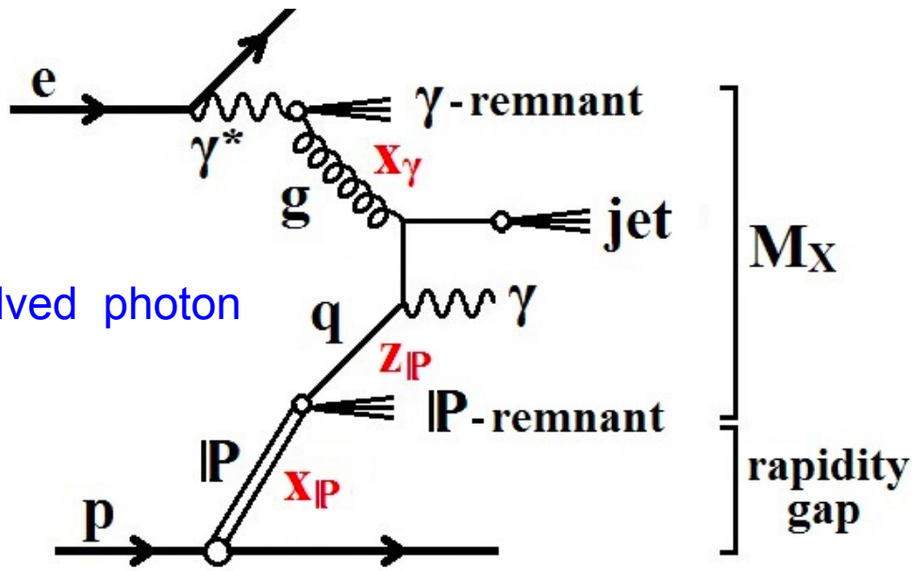
A ZEUS analysis of isolated photons in DIS presented by Volodymyr Myronenko at this workshop

Kinematic – diffractive production of a prompt photon

Direct photon



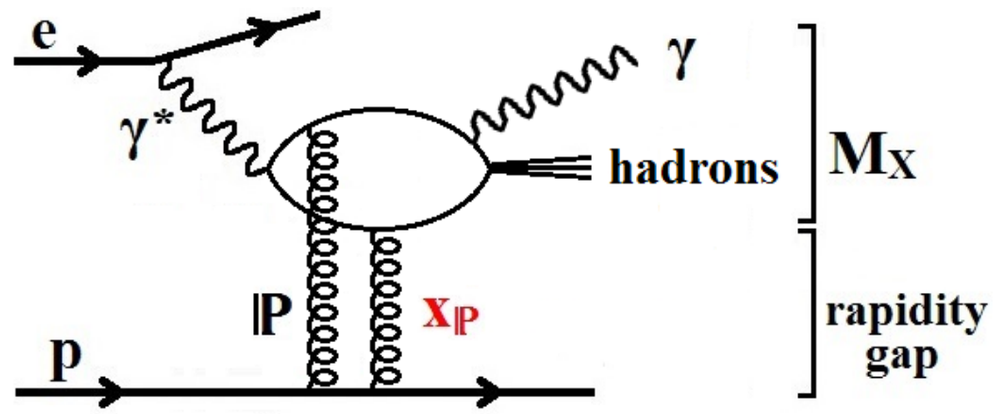
Resolved photon



- Prompt photons must couple to a charged particle line, so the quark content of the exchanged colourless object (the Pomeron IP) is tested
- x_γ = fraction of momentum of the incoming photon participating to the hard process. Direct photon if $x_\gamma = 1$, resolved photon if $x_\gamma < 1$
- x_{Ip} = fraction of the proton energy taken by the colourless exchange <0.03
- z_{IP} = fraction of the Pomeron energy participating to the hard interaction.

diffractive photoproduction of isolated photons - the “direct Pomeron”

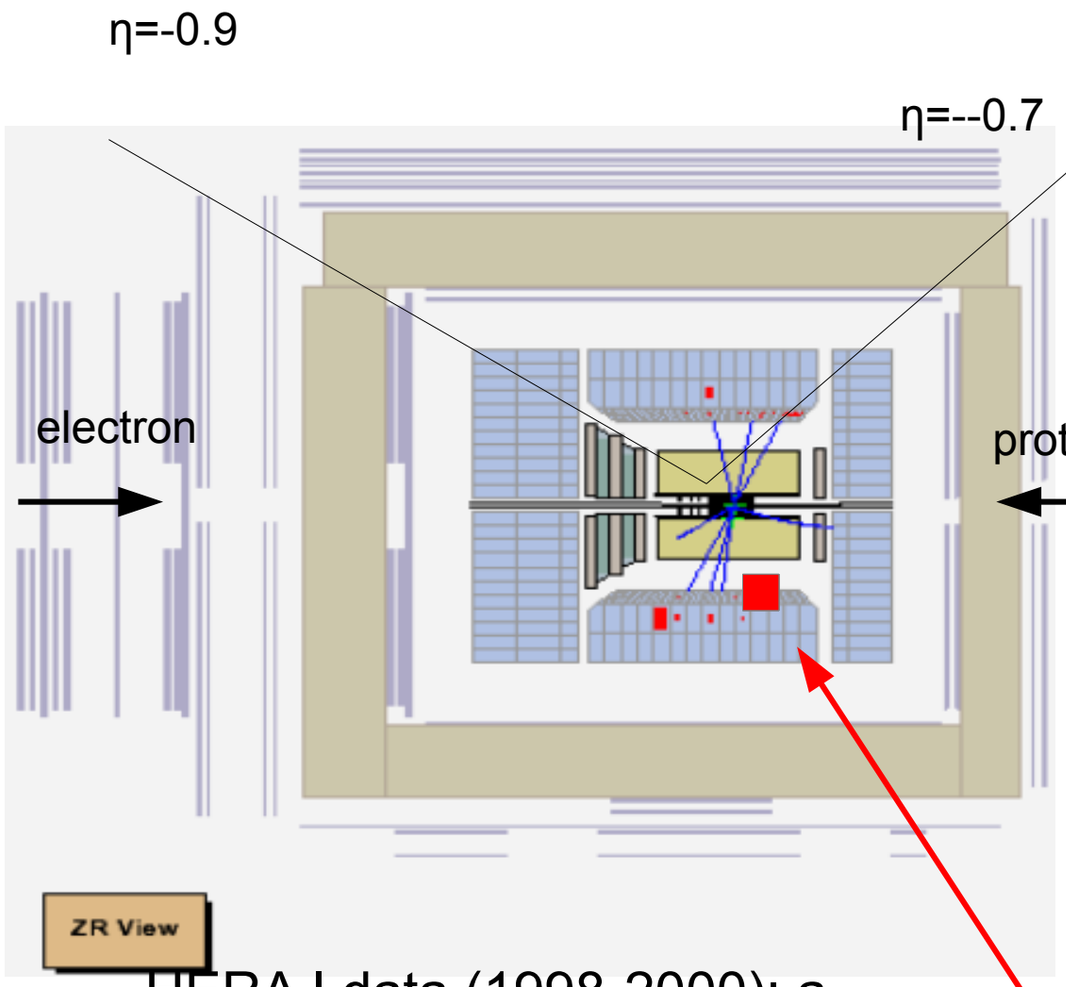
- HERA: collisions of electron at 27.5 GeV against protons of /920 GeV



- A diagram of a hard interaction of a direct photon with a direct colourless object producing a prompt photon and a jet, $z_{IP} \sim 1$

- Testing colourless exchange
- Test of QCD factorization both at photon and Pomeron vertices
- Comparison with perturbative QCD calculations is possibile

Selection: diffractive photoproduction of isolated photons



- Photoproduction: No scattered electron observed $0.2<y_{JB}<0.7$, usual cut
- Events triggered by energy released in calorimeter

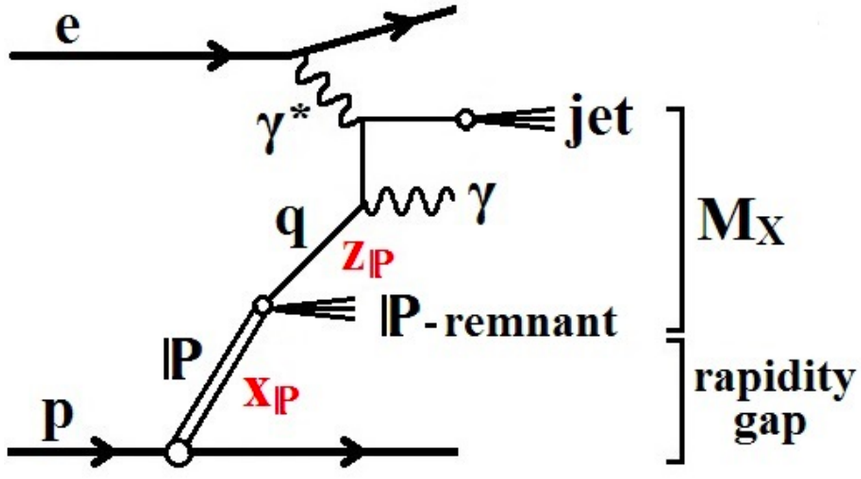
- Diffraction: No energy in the forward region, $\eta_{max}^{EFO}<2.5$
- Jets are reconstructed with k_T algorithm
  $-1.5<\eta^{jet}<1.8$, $E_t^{jet}> 4$ GeV
- Photons identified in Barrel ElectroMagnetic Calorimeter, finely segmented in the Z direction

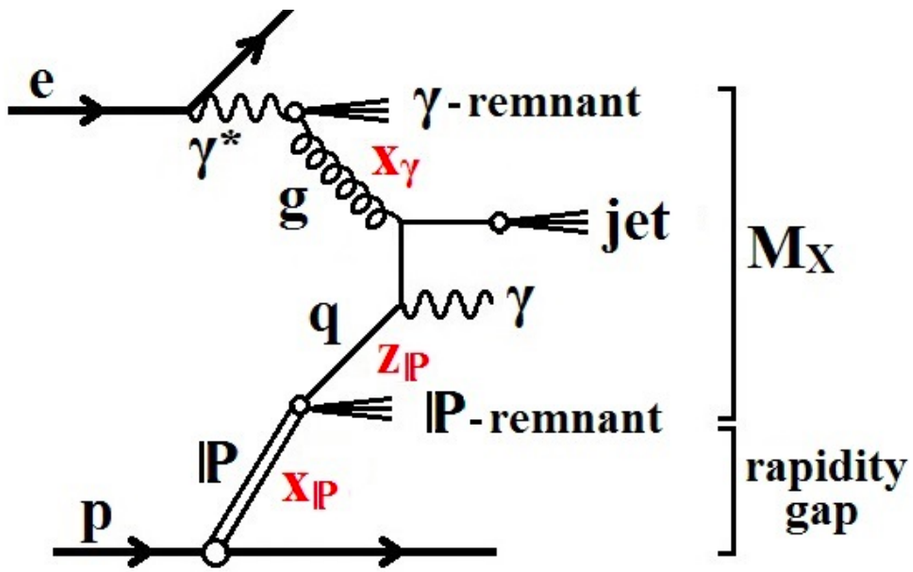
  $E_t^{\gamma}> 5$ GeV, $-0.7<\eta<0.9$, "isolated", $E_T^{\gamma}>0.9\ E_T^{jet}$

HERA I data (1998-2000): a forward plug calorimeter allowed the rejection of proton dissociative processes

HERA II data (2004-2007): forward calorimeter replaced by a magnet, => additional background scattered within the detector, making challenging the measurement of diffractive cross sections

Reconstruction of kinematic variables





- x_γ = fraction of momentum of the incoming photon participating to the hard process. Direct photon if $x_\gamma = 1$

$$x_\gamma^{\text{meas}} = \frac{E^\gamma + E^{\text{jet}} - p_Z^\gamma - p_Z^{\text{jet}}}{E^{\text{all}} - p_Z^{\text{all}}},$$

- $x_{I\!P}$ = fraction of the proton energy taken by the colourless exchange

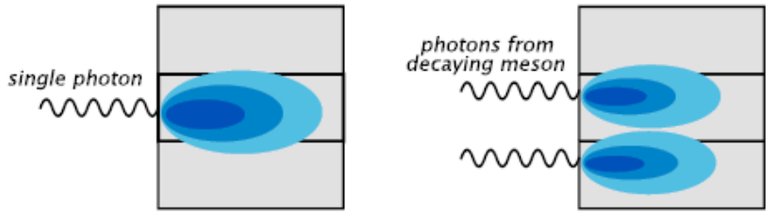
$$x_{I\!P} = \left(E^{\text{all}} + p_Z^{\text{all}}\right)/2E_p$$

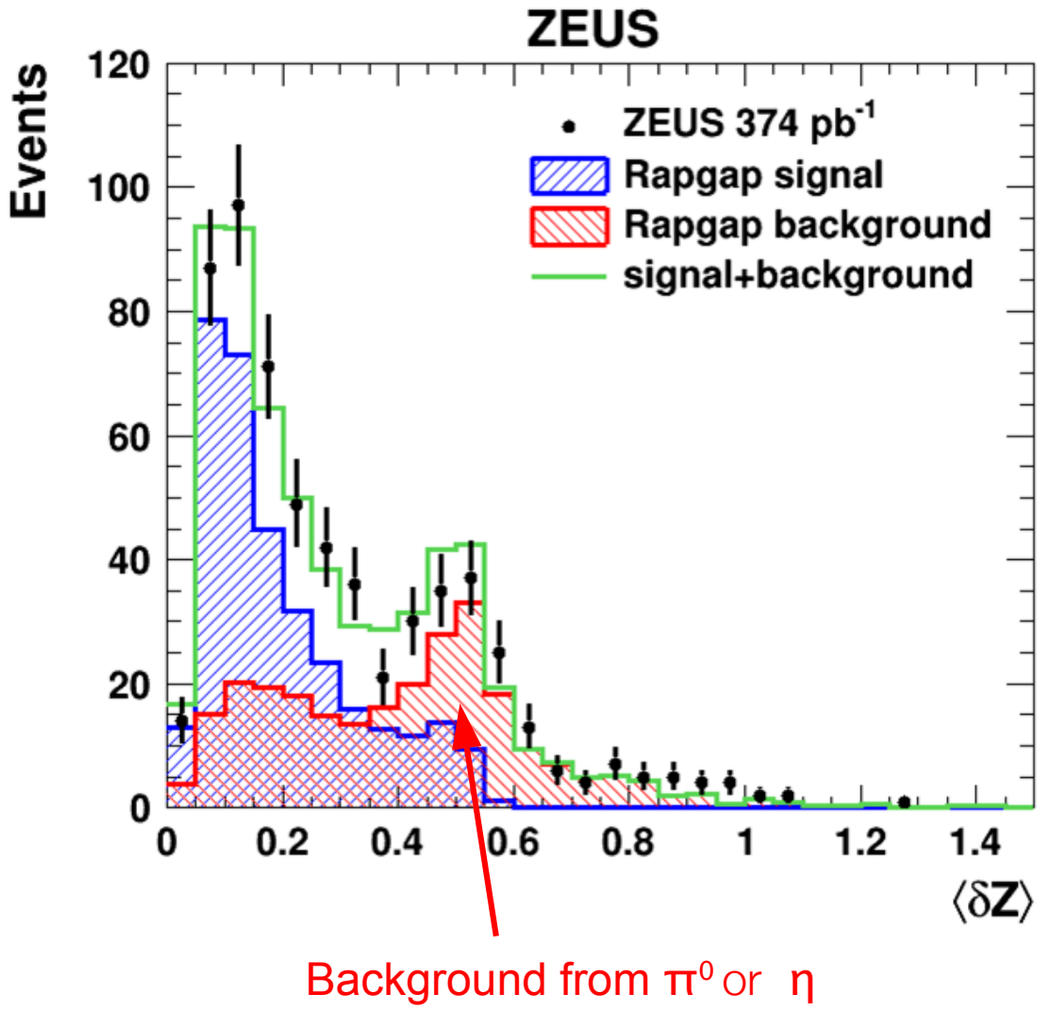
- $z_{I\!P}$ = fraction of the Pomeron energy participating to the hard interaction. Direct Pomeron if $z_{I\!P} \sim 1$

$$z_{I\!P}^{\text{meas}} = \frac{E^\gamma + E^{\text{jet}} + p_Z^\gamma + p_Z^{\text{jet}}}{E^{\text{all}} + p_Z^{\text{all}}}$$

Background: photons from decays of neutral mesons are subtracted

- Large background from photons from π^0 or η + multi π^0
- The δZ distribution of the EM calorimeter cells in the barrel detector allows to separate photons from π^0





- For each measured quantities, for each bin, the background from photons from π^0 or η + multi π^0 is fitted and subtracted statistically

- Large background from neutral mesons reduced

Cross section definition

- Integrated luminosity 456 pb^{-1} (82 in HERA I + 374 in HERA II)
- Photoproduction: $Q^2<1$ GeV^2; $0.2<y<0.7$, no electron
- Diffraction: $\eta_{max}<2.5$ of Energy Flow Objects and $x_{IP}<0.03$
- Photons: $5<E^{\gamma}_{T}<15$ GeV, $-0.7<\eta^{\gamma}<0.9$, "isolated", $E_{\gamma}>0.9\ E_{jet}$
- Cross sections measured with or without asking for an additional jet with $4<E^{jet}_{T}<35$ GeV, $-1.5<\eta^{jet}<1.8$

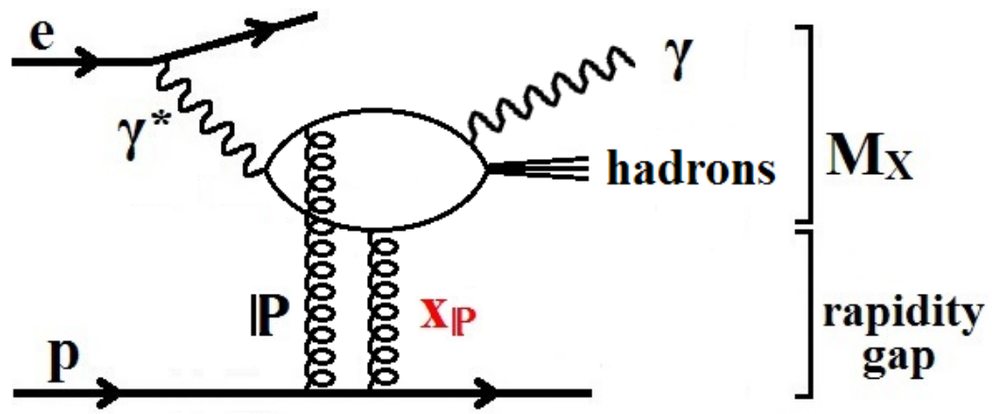
- Additional background from Bethe-Heitler process and Deeply Virtual Compton Scattering removed asking at least 5 energy-flow objects
- Cross section evaluated using normalisation from the HERA I sample, where p-dissociation contribution reasonably known

Monte Carlo simulation

- RAPGAP generators used: H.Jung Comp. Phys. Comm. 86 (1995) 147
- Based on leading order parton-level QCD matrix elements
- Some higher order modeled by initial and final state leading-log parton showers
- Fragmentation from PYTHIA Lund model

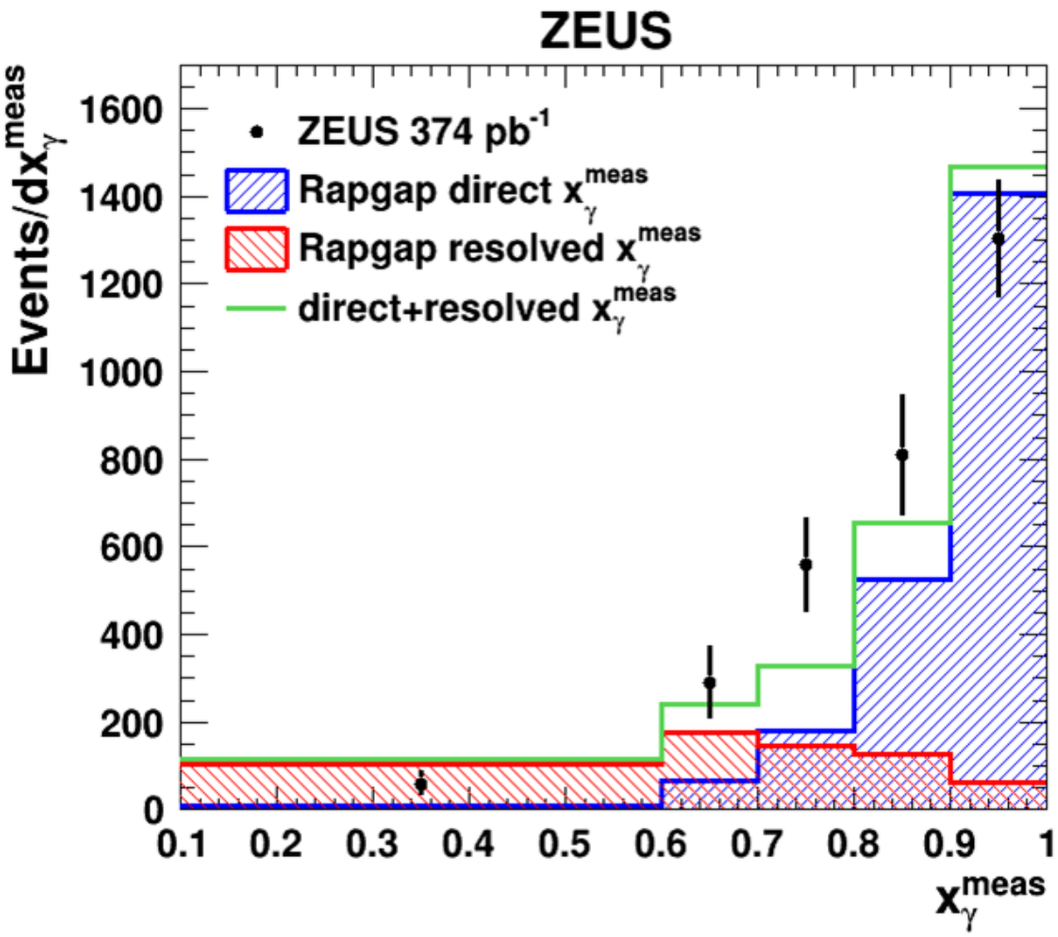
- Resolved pomeron model: diffractive parton densities used are the H1 2006 DPDF fit B, extracted in DIS diffractive scattering, for $z_{IP}<0.9$!!
- Resolved photons: pdf SASGAM-2D used

- RAPGAp has no direct Pomeron contribution



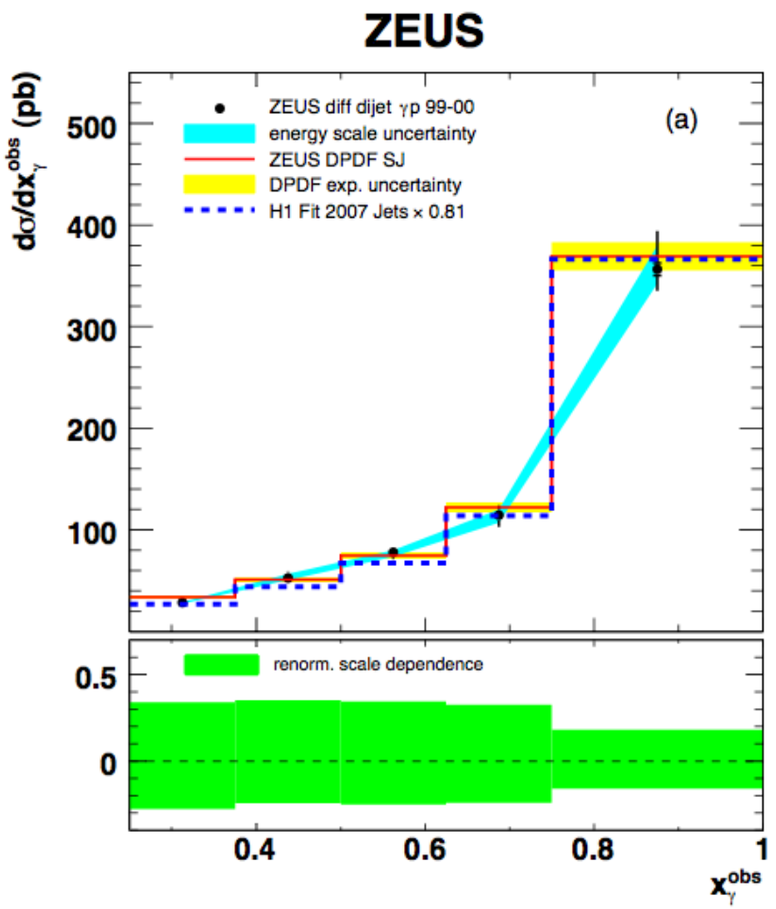
Photon vertex: direct and resolved contribution

- MC generates separately direct and resolved photon processes, and need to be re-weighted to the x_γ distribution of the data
- x_γ distribution is compatible with a mixture 70% direct photon process + 30% resolved photon



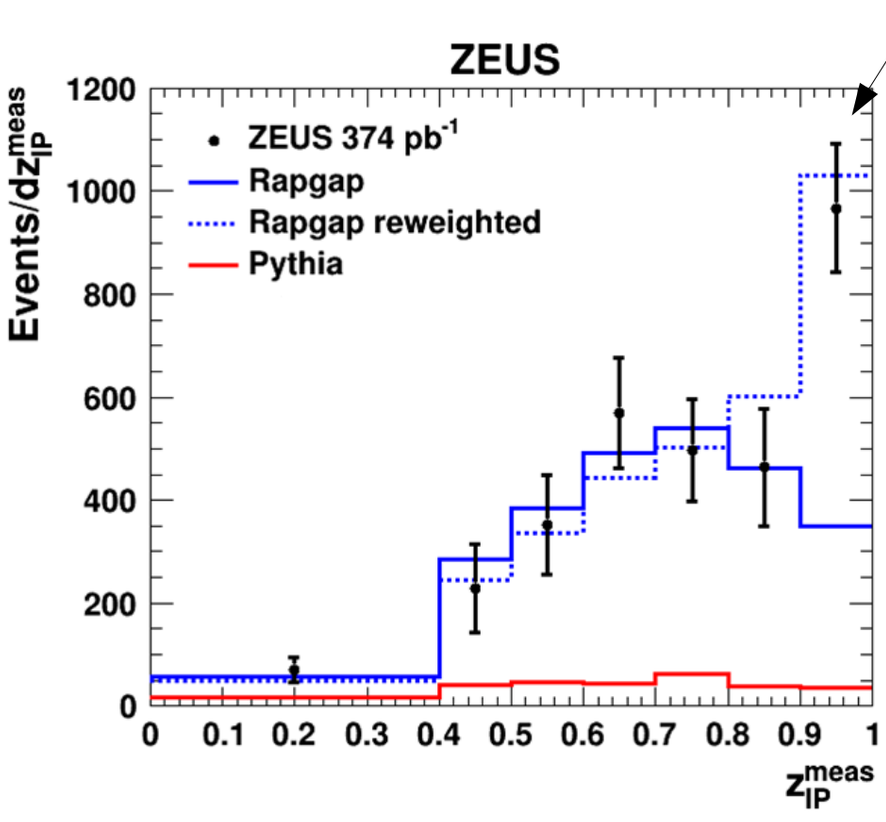
x_γ for diffractive photoproduction of 2-jets

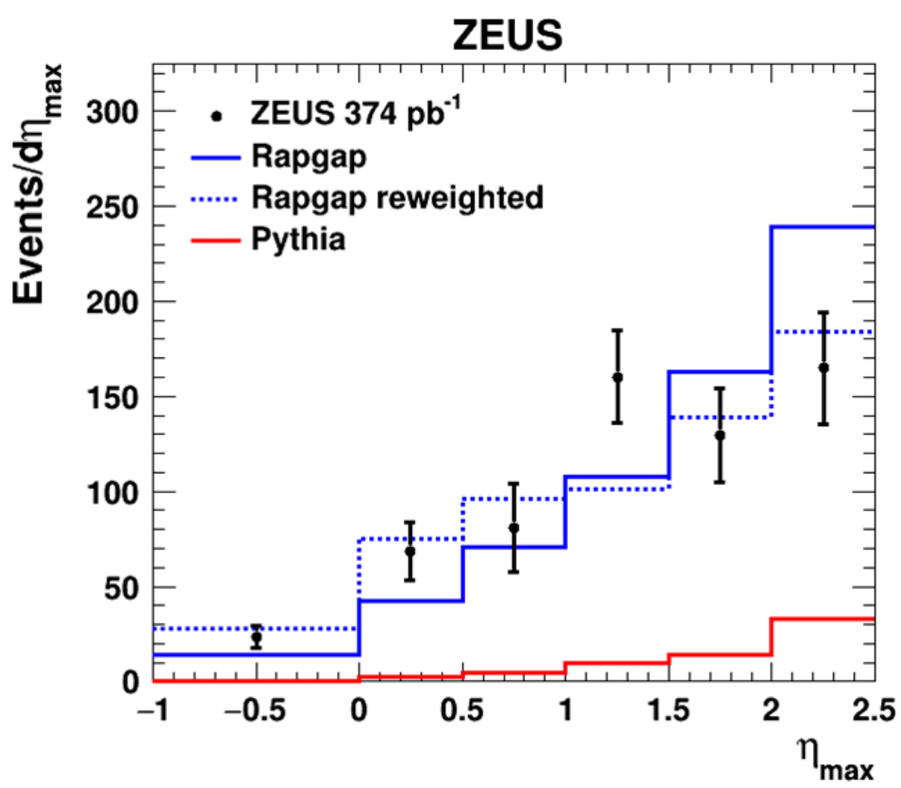
Nucl. Phys. B 831 (2010) 1-25



Evidence for direct Pomeron interaction

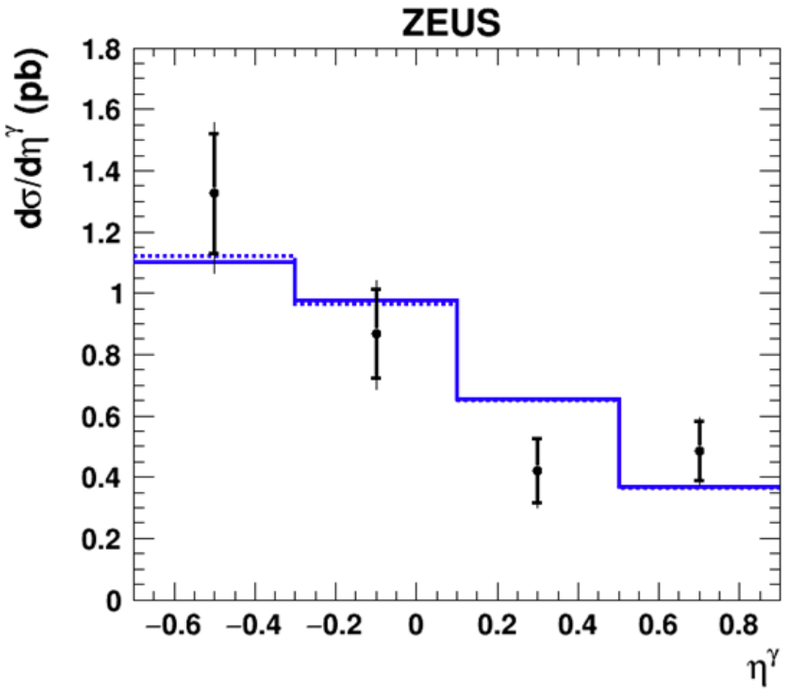
- Measured z_{IP} not described by RAPGAP MC
- Data show excess of “direct Pomeron” processes
- Non-diffractive contribution (red histogram) is flat in z_{IP}
- RAPGAP reweighted for z_{IP} >0.9, re-weighting improves description of η_{max} distribution

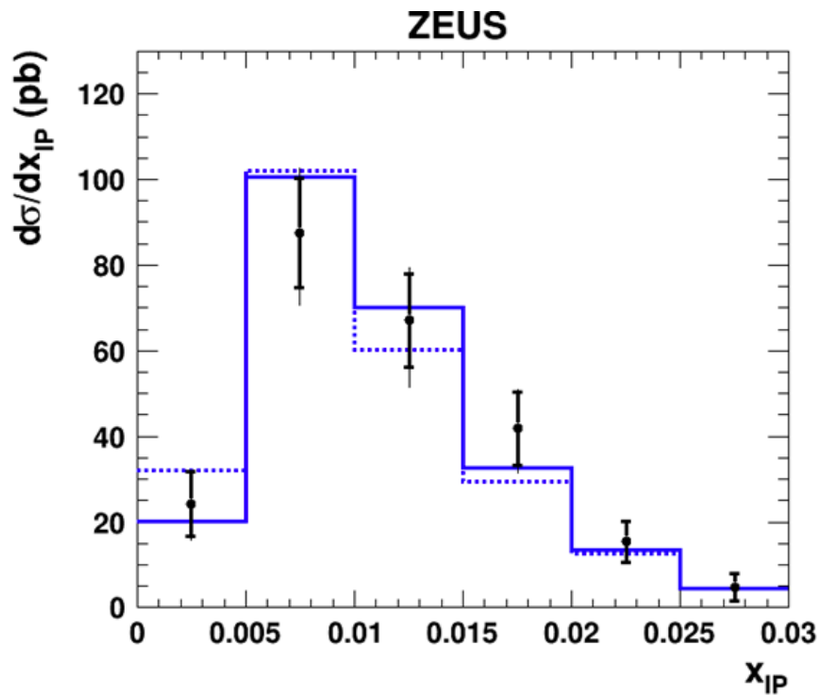


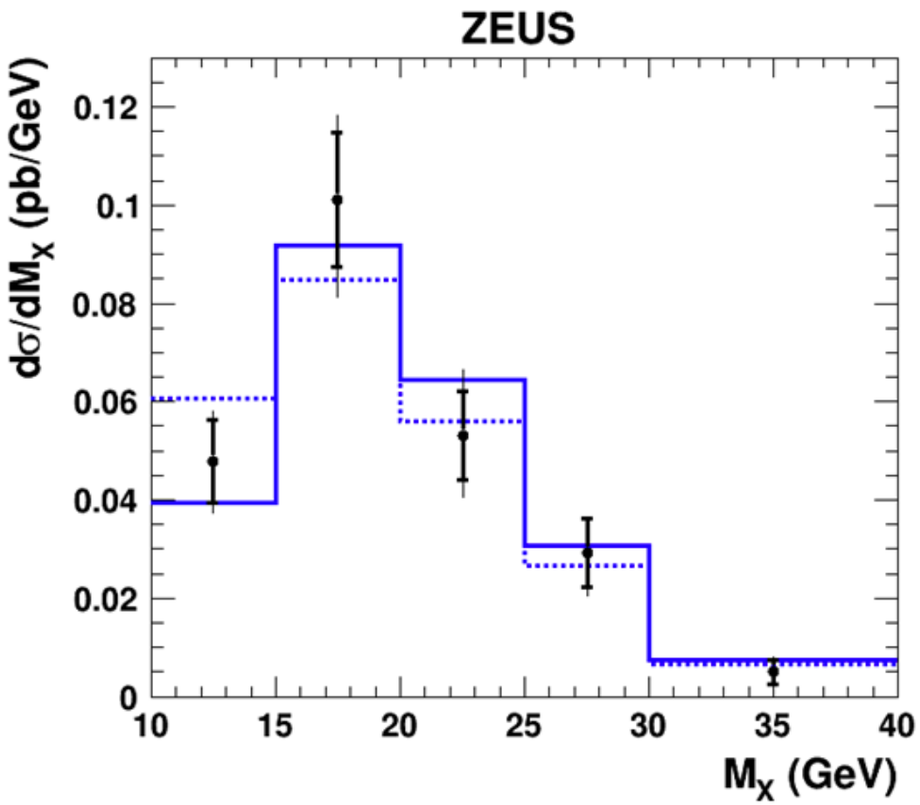


Diffractive isolated photoproduction: η_γ, x_{IP}, M_x

- Data distribution well described in general by RAPGAP MC, not sensitive to z_{IP} reweighting

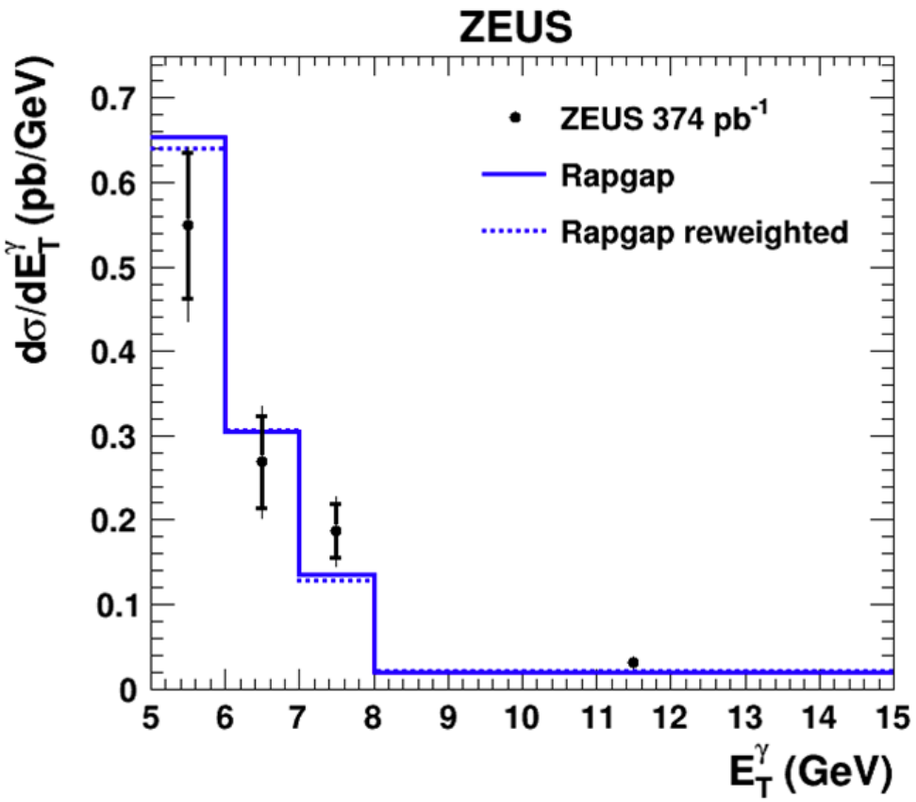




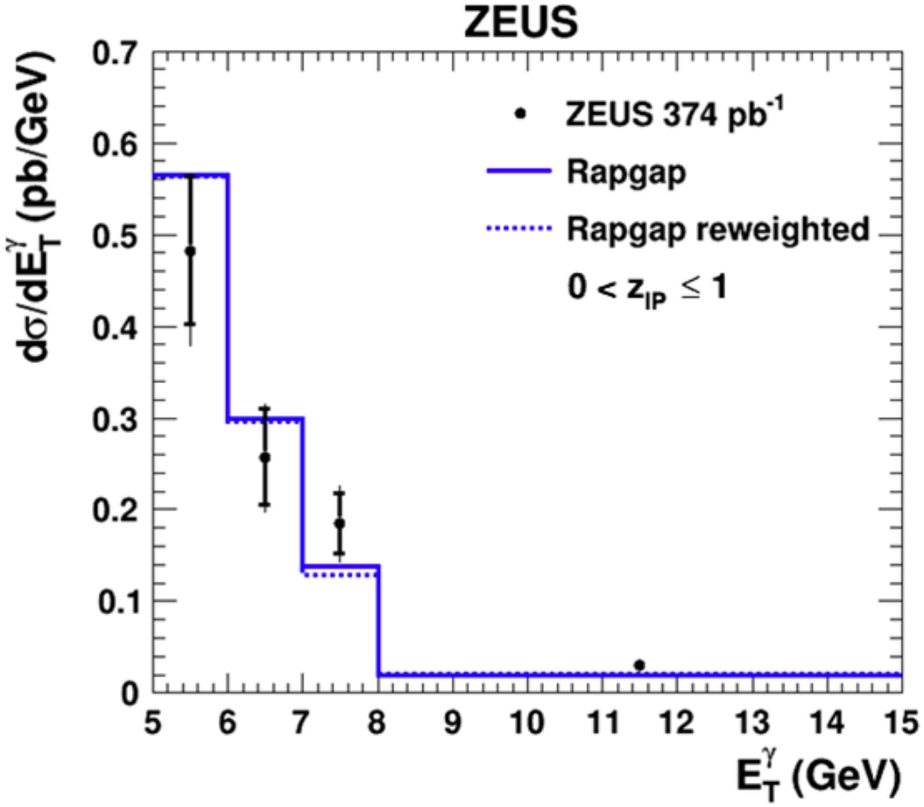


Inclusive photon and photon + jet; E^{γ}_{T}

- Most of the events have isolated photon + jet
- Cross section measured both for inclusive prompt photon and photon + jet
- In both samples, distributions are well described by RAPGAP

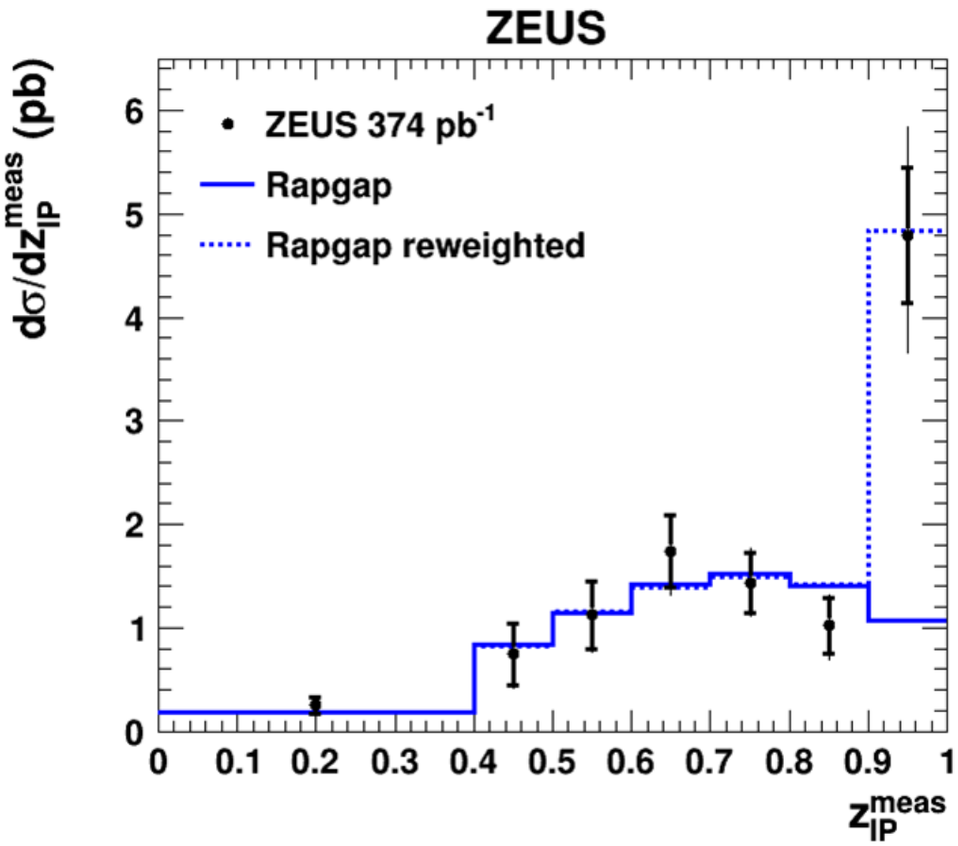


Inclusive photon



photon + jet

Cross sections



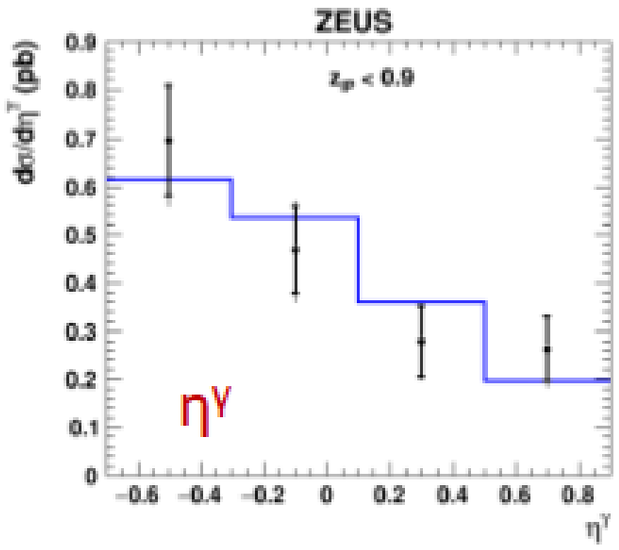
photon + jet

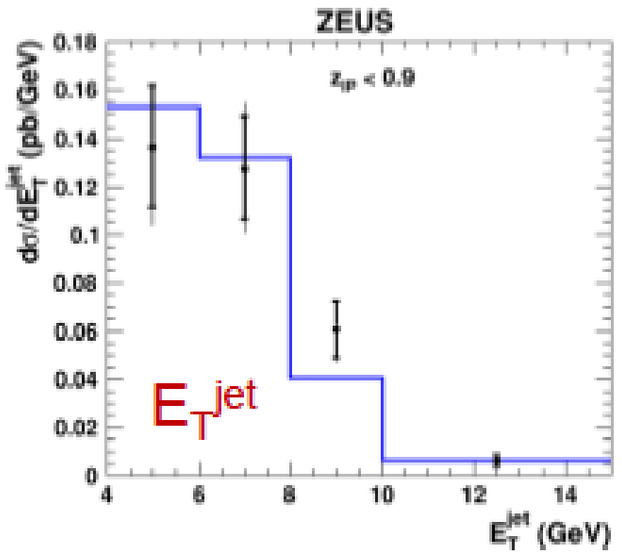
Cross section evaluated for inclusive
Photon and photon + jet samples
As a function of many kinematic variables

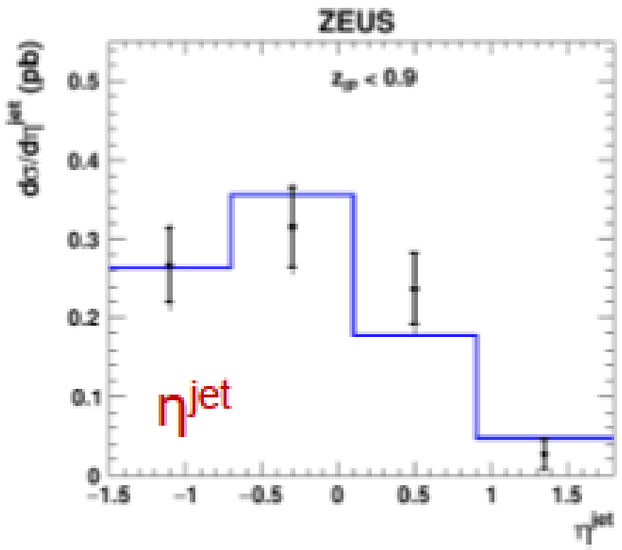
- Cross section is $1.21 \mp 0.19^{+0.14}_{-0.14}$ pb for inclusive photon and $1.10 \mp 0.19^{+0.09}_{-0.13}$ pb for photon + jet

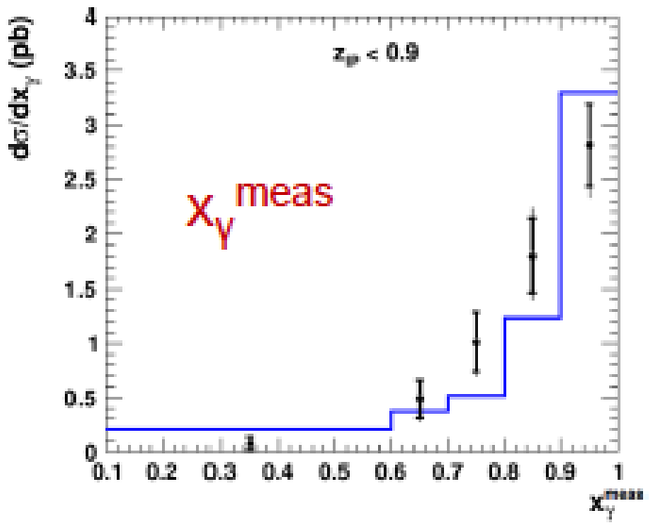
- Cross section for $z_{IP}<0.9$ is $0.68 \mp 14^{+0.06}_{-0.07}$ pb, including proton dissociation (~16%)
- Cross section estimated by RAPGAP is 0.68 pb, but without proton dissociation contribution

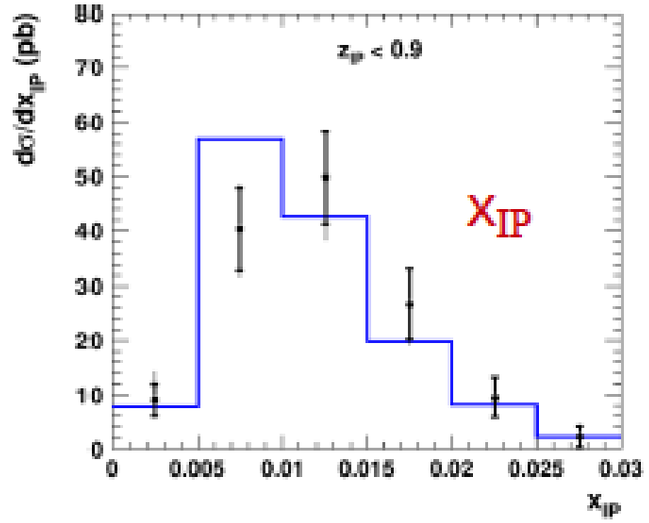
Cross sections for z_{IP}<0.9, “resolved Pomeron region”

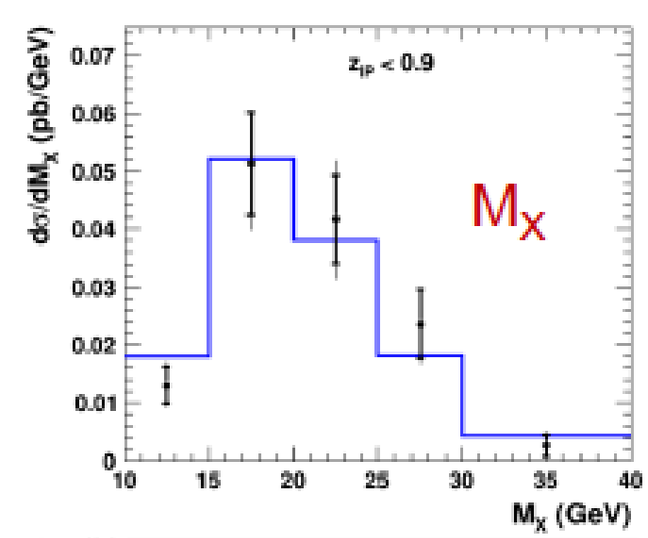


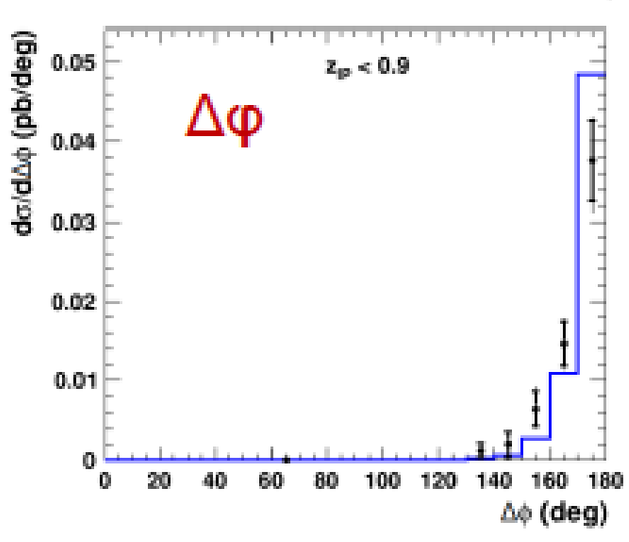


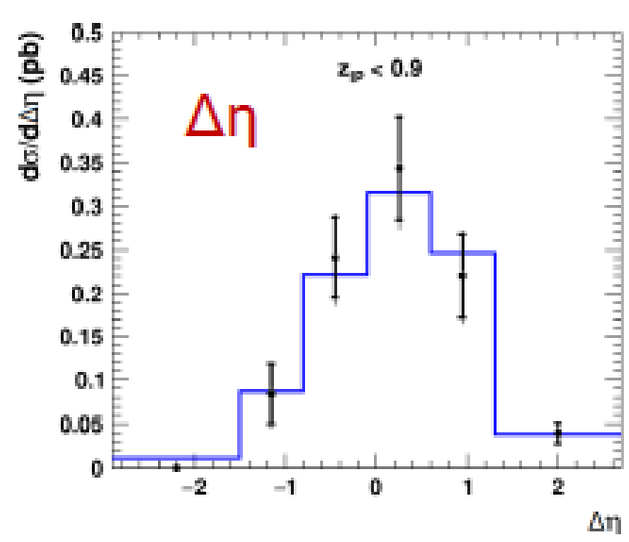


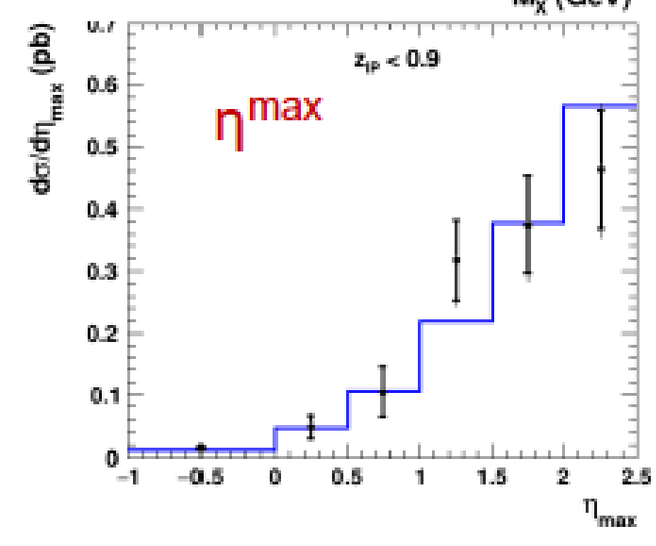




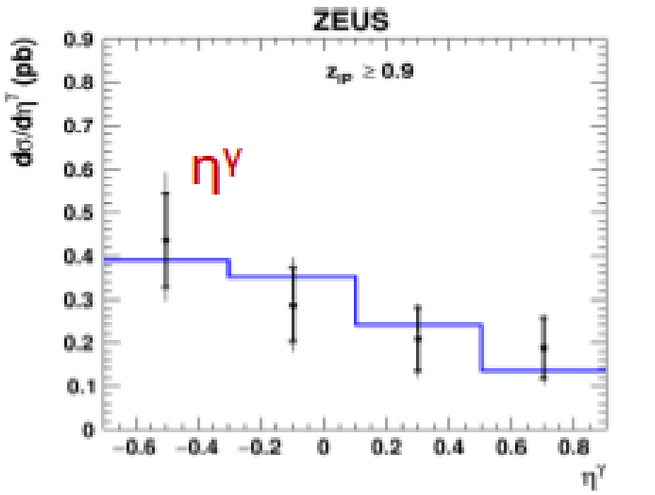


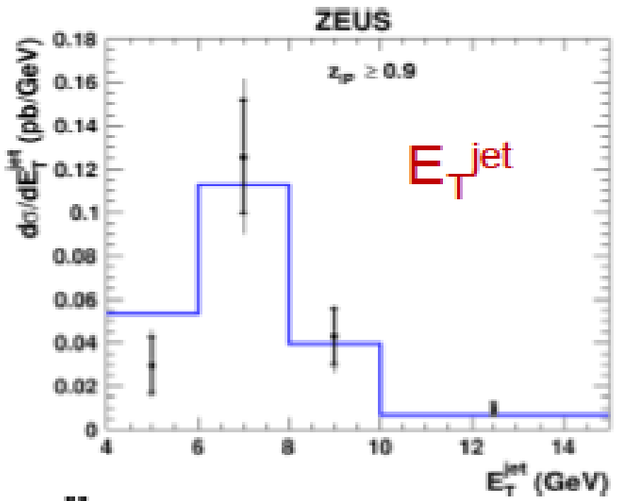


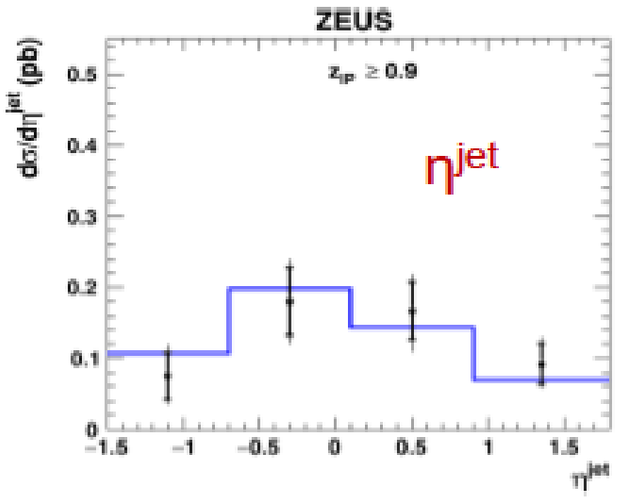


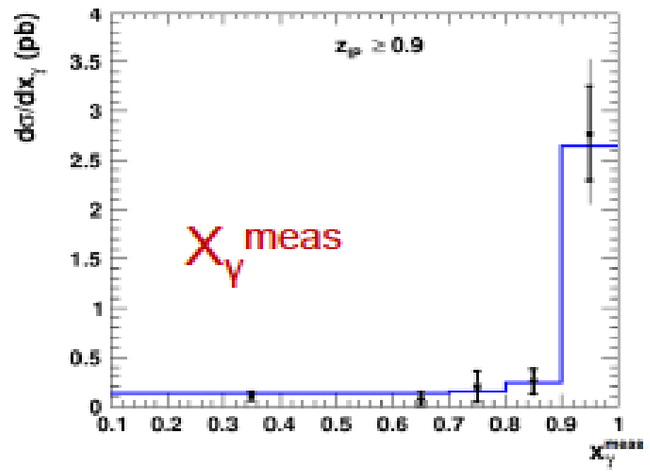


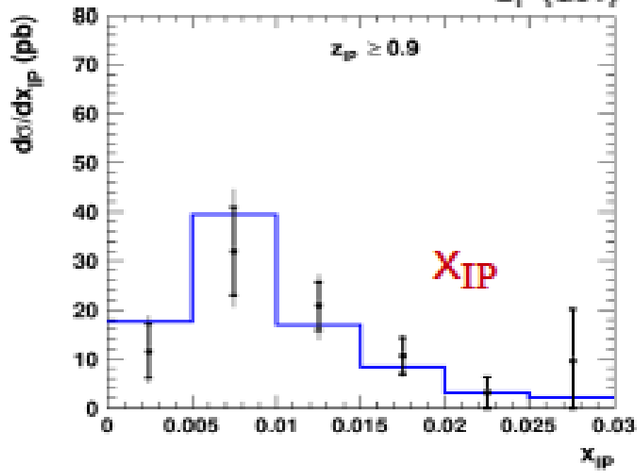
Cross sections for z_{IP}>0.9, “direct Pomeron” region

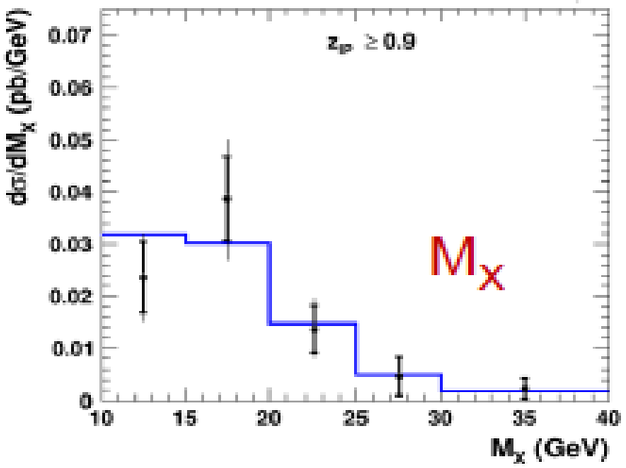


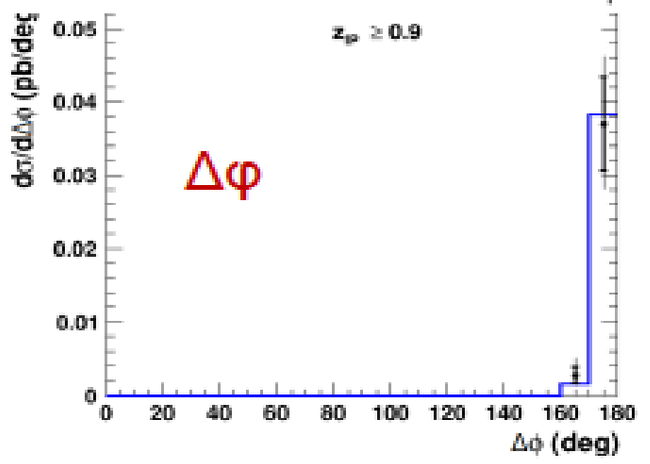


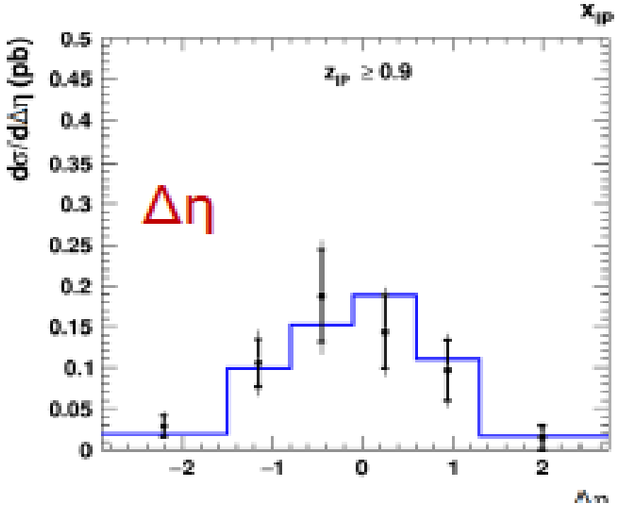


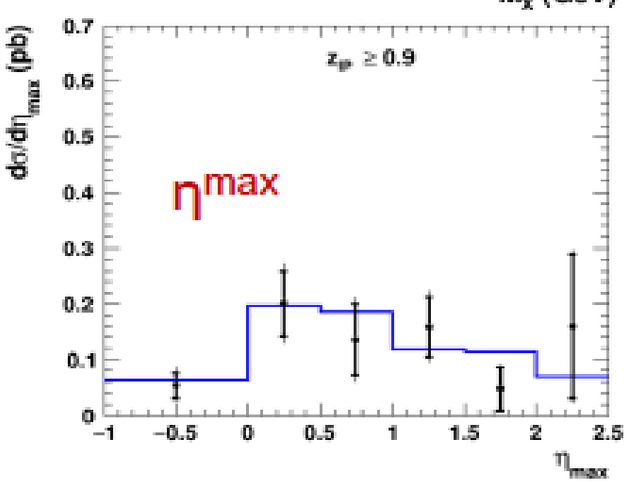












Summary

- ZEUS measured isolated ("prompt") photons in diffractive photoproduction, for the first time
- Most of the detected photons are with an accompanying jet
- Cross sections measured in a diffractive region defined for η_{max} and $x_{\mathbb{P}}$
- The variable $z_{\mathbb{P}}^{meas}$ shows a peak at high values that implies:

i. evidence for a direct-Pomeron process dominantly in the direct photon channel

ii. the presence of processes not currently implemented in the MC RAPGAP

- The cross sections of the different kinematic variables in photoproduction are well described in shape by MC RAPGAP, which implement a common set of diffractive PDFs (measured in diffractive DIS events)