Studies of the diffractive photoproduction of isolated photons at HERA

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HERA ep collider 1992 – 2007, DESY, Hamburg

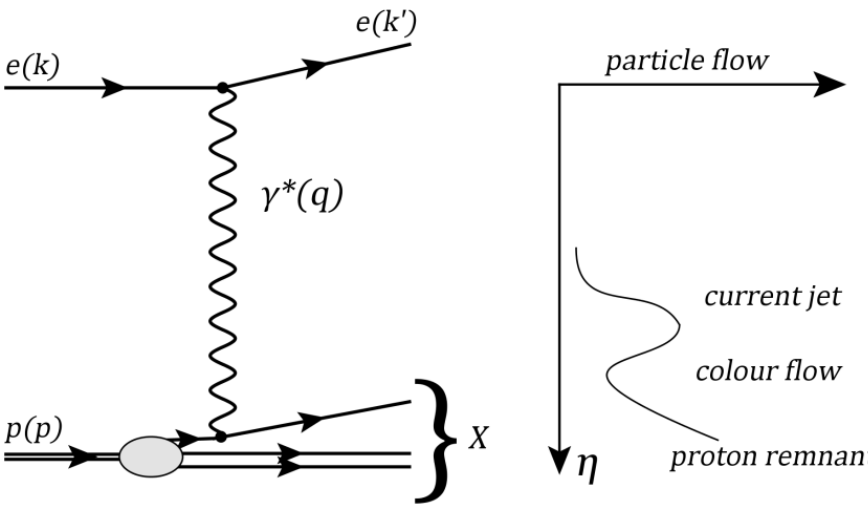
- The world's only electron/positron-proton collider
- $E_e = 27.6$ GeV and $E_p = 820(920)$ GeV (575, 460) HE(LE)
- Total integrated luminosity 0.5 fb^{-1}

This analysis:

- $E_e = 27.6$ GeV and $E_p = 920$ GeV
- HERA-I (1998-2000) with integrated luminosity of 82 pb^{-1}
- HERA-II (2004-2007) with integrated luminosity of 374 pb^{-1}

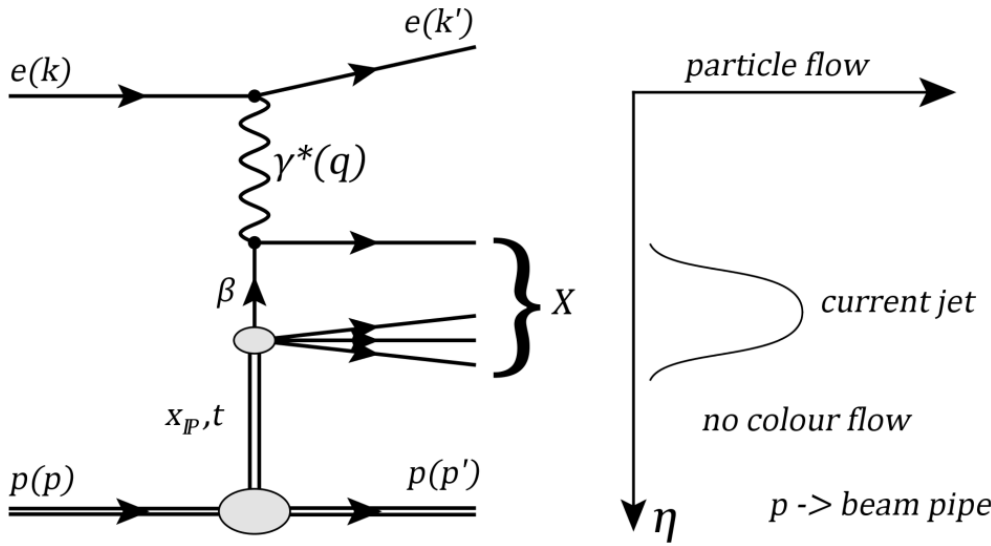
Diffraction in ep collisions

Deep Inelastic Scattering (DIS)



- $Q^2 = -q^2$ - virtuality of the photon
  $Q^2 \approx 0$ - photoproduction,
  $Q^2 \gg 0$ - DIS
- this analysis:
  scattered lepton undetected
  $Q^2 < 1$ GeV

Diffractive Scattering



- x_{IP} - fraction of proton's momentum carried by exchanged Pomeron
- $z_{IP}(\beta)$ - fraction of Pomeron momentum which takes part in the hard interaction

Hard (isolated) photons in *ep* scattering

High p_T(hard) photons have several origins:

- Produced in a hard partonic interaction often called "prompt" photons
- Radiated from the incoming or outgoing lepton
- Radiated from a quark within a jet
- Decay product of a hadron within a jet

We study photoproduced prompt photons arising from hard diffractive process:

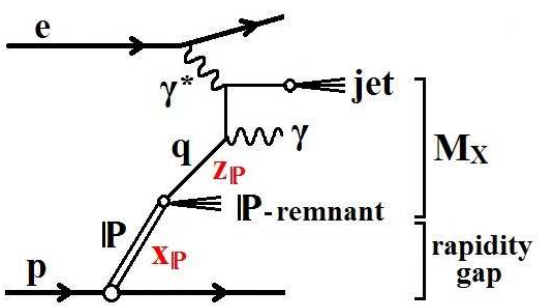
- Prompt photons are relatively well isolated from other final state particles.
- Observation of prompt photons demonstrates the presence either of a quark in the Pomeron or of higher-order processes in which both the Pomeron and the incident photon couple to quarks.
- Above contrasts with diffractive dijet production, which is mainly sensitive to the gluon content of the Pomeron

Direct and resolved processes in photon-Pomeron interaction

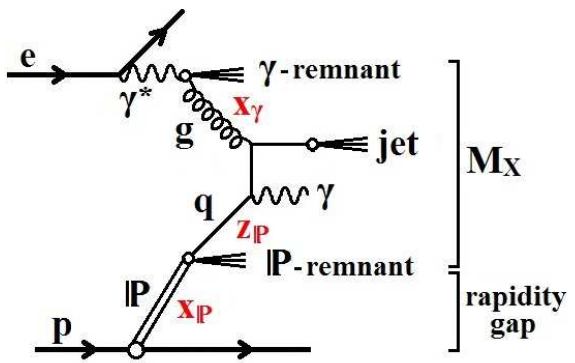
Photon or Pomeron may act as a source of quarks and gluons, which then take part in the QCD scatter (resolved processes) and processes in which the photon or Pomeron interacts as a whole (direct processes)

x_γ - fraction of photon energy which takes part in the hard interaction

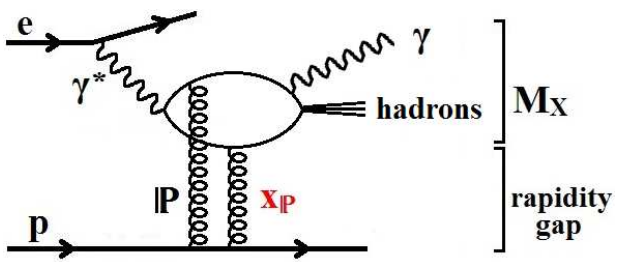
direct-resolved
$x_\gamma \approx 1; z_{IP} < 1$



resolved-resolved
$x_\gamma < 1; z_{IP} < 1$



direct-direct
$x_\gamma \approx 1; z_{IP} \approx 1$



$$x_\gamma^{meas} = \frac{(E-p_z)^\gamma + (E-p_z)^{jet}}{(E-p_z)^{all}} \qquad z_{IP}^{meas} = \frac{(E+p_z)^\gamma + (E+p_z)^{jet}}{(E+p_z)^{all}}$$

MC simulation

Use the RAPGAP generator for correction and comparisons:

- Incoming photon is radiated from the electron using the equivalent-photon approximation.
- Resolved-Pomeron model (G.Ingelman and P.Schlein et al.)
- In direct photon processes, photon scatters elastically off a quark in the resolved Pomeron
- In resolved photon processes, gluon–quark and antiquark–quark scattering produce an outgoing photon and a jet
- Fragmentation uses the Lund string model as implemented in Pythia
- H1 2006 DPDF Fit B set is used to describe parton densities in the diffractivelly scattered proton.

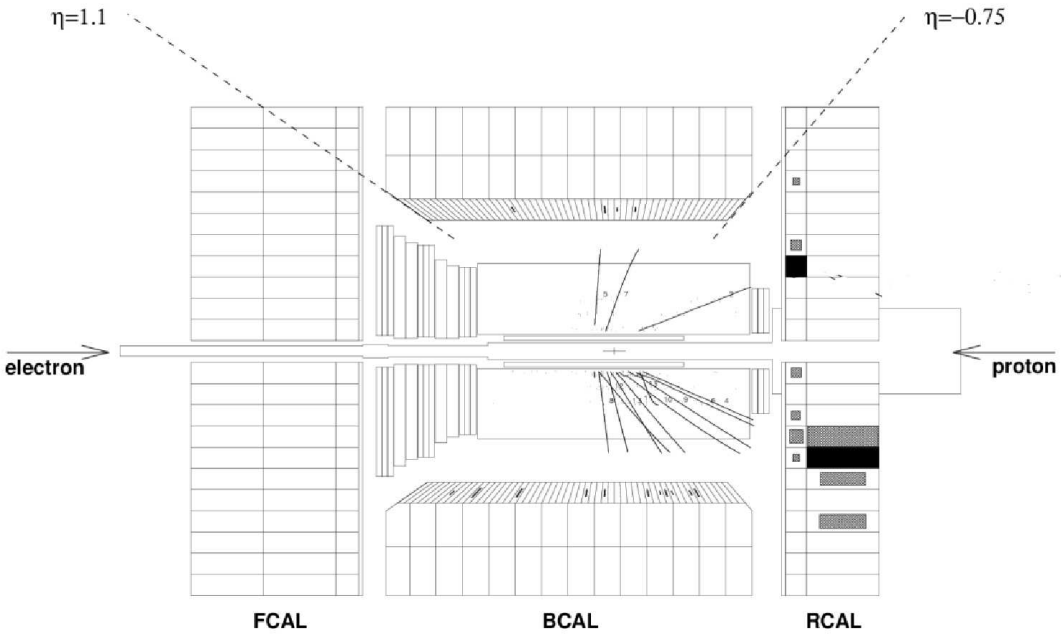
Remarks:

- in H1 2006 QCD fit resolved Pomeron PDFs were obtained for $z_{IP} < 0.8$
- RAPGAP uses extrapolation to cover the entire z_{IP} range.

Event selection

photoproduction:

- no electron with $E > 3.5$ GeV
- inelasticity $0.2 < \frac{(E-p_z)^{all}}{2E_e} < 0.7$



jet definition:

- use k_T-cluster algorithm
- $4 < E_T^{jet} < 35$ GeV
- $-1.5 < \eta^{jet} < 1.8$

prompt photon candidate

- $E_{EMC}/(E_{EMC} + E_{HAC}) > 0.9$
- $5 < E_T^{\gamma} < 15$ GeV
- $-0.7 < \eta^{\gamma} < 0.9$
- in jet: $E_{\gamma}/E_{jet} > 0.9$

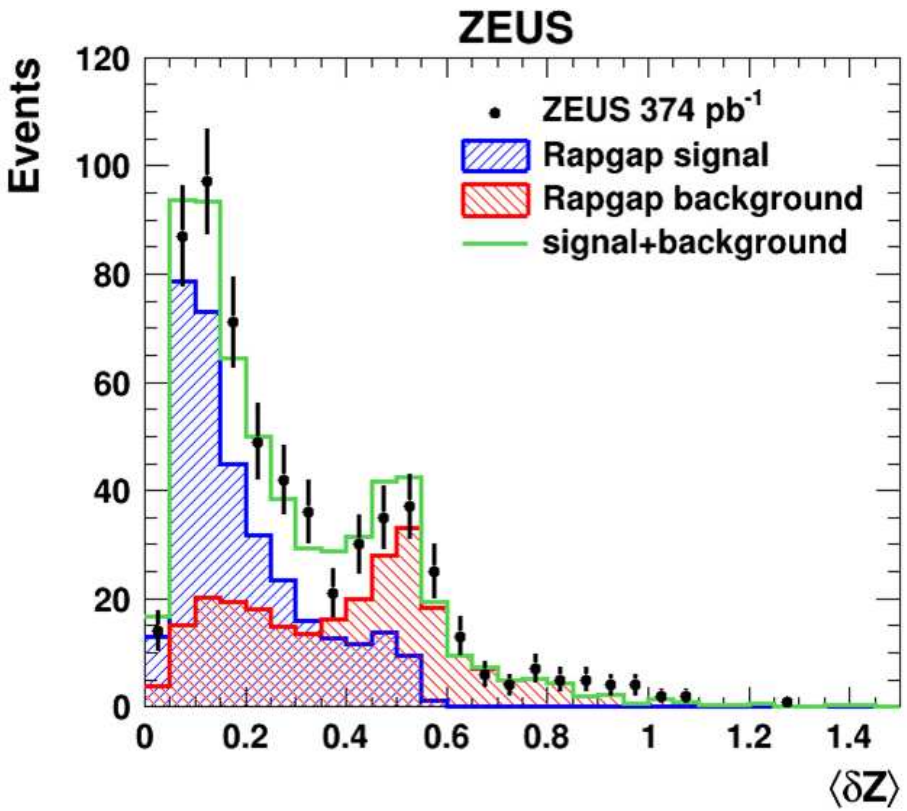
diffraction:

- $\eta_{max} < 2.5$ for ZEUS energy flow objects with energy above 0.4 GeV
- $x_{IP}^{meas} = \frac{(E+p_z)^{all}}{2E_p} < 0.03$

Signal extraction

Prompt photon signal was extracted statistically for each cross-sections interval

- use energy-weighted width $\langle \delta Z \rangle$, measured in the Z direction, of the BEMC energy cluster comprising photon candidate
- isolated-photon events was determined by a binned maximumlikelihood fit to the distribution in the range $0.05 < \langle \delta Z \rangle < 0.8$

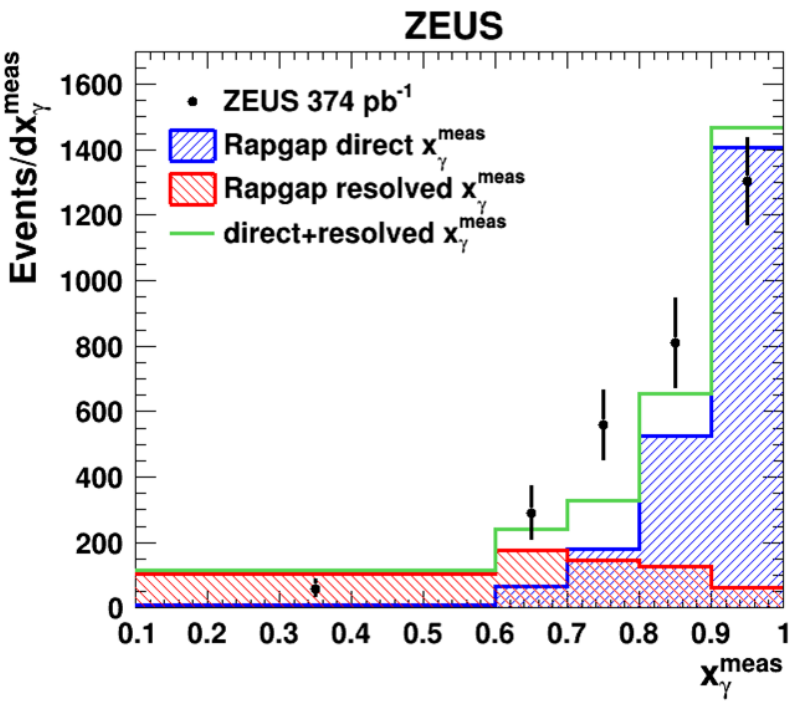


- HERA I: 91 (76 with jet(s)) prompt photons
- HERA I: 336 (311 with jet(s)) prompt photons

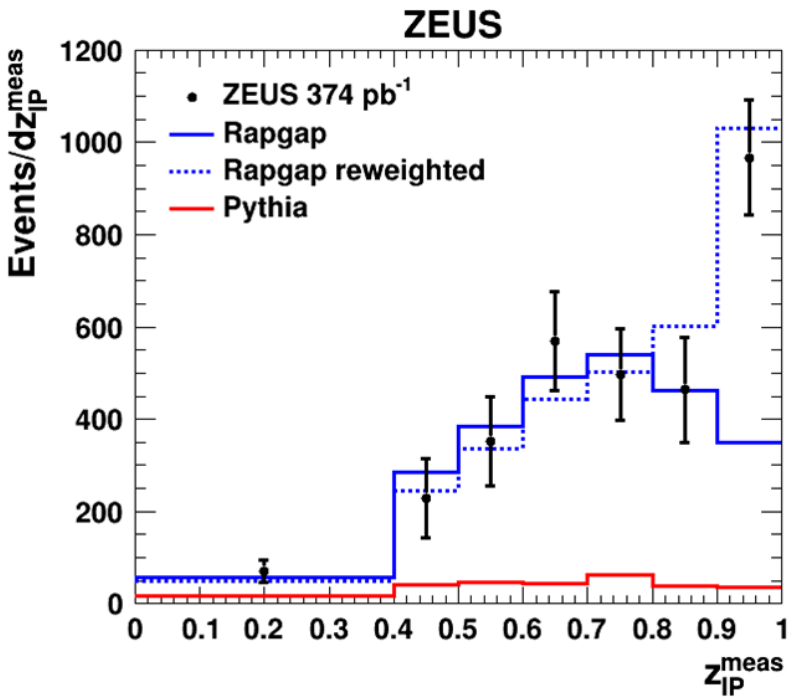
Most photons are accompanied by a jet.

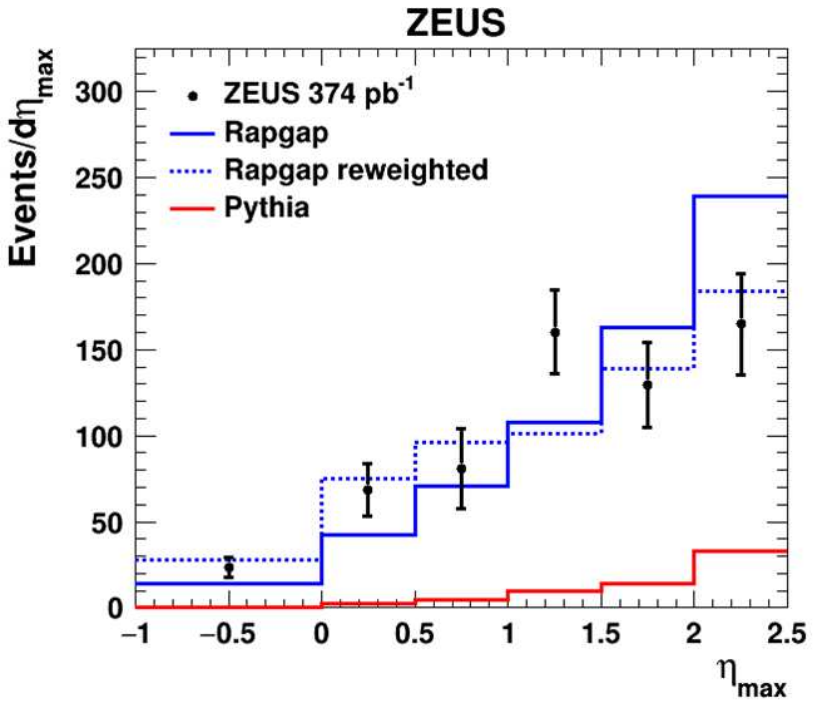
Event distribution

A 70:30 mixture of direct:resolved photon events generated with Rapgap gives a reasonable description of the data and was employed in the following distributions.



Event distribution





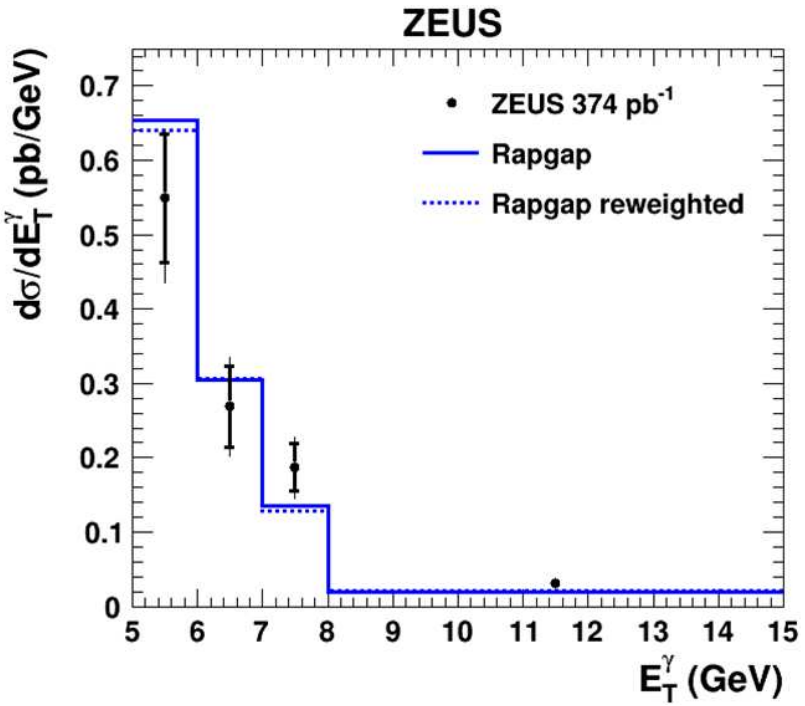
- Shape of z_{IP}^{meas} does not agree
- An excess seen at $z_{IP}^{meas} > 0.9$
- Reweight RAPGAP to describe the shape

- η_{max} distribution better described by reweigthed RAPGAP
- no significant effect of reweigting on other distributions

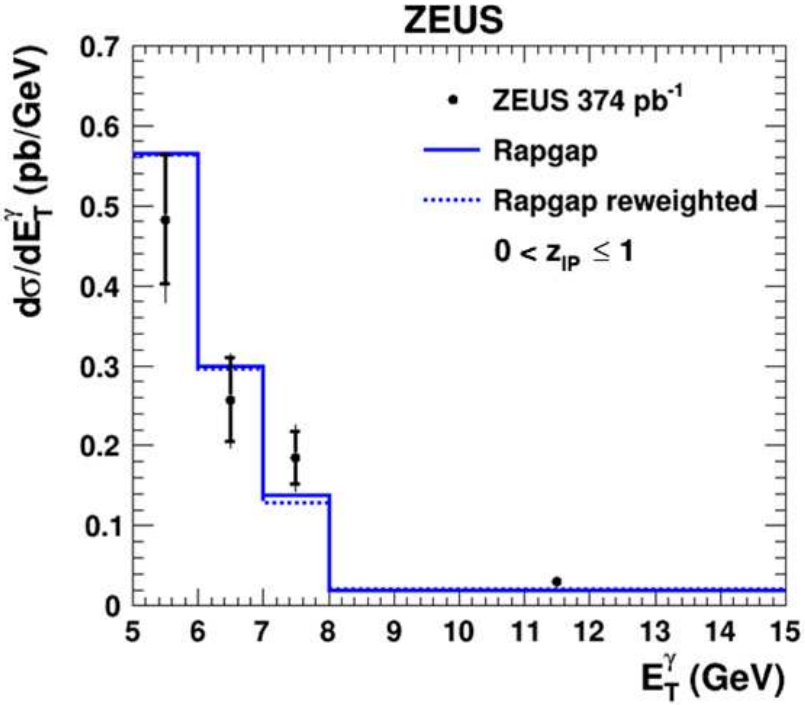
Results

Visible cross sections compared to RAPGAP normalized do observed cross section.

Inclusive photons

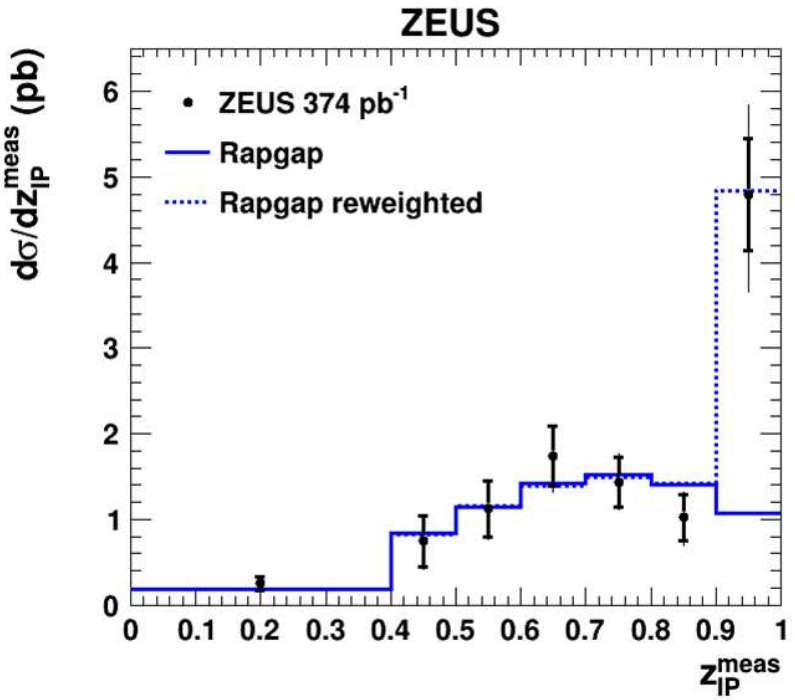


Photon + jet



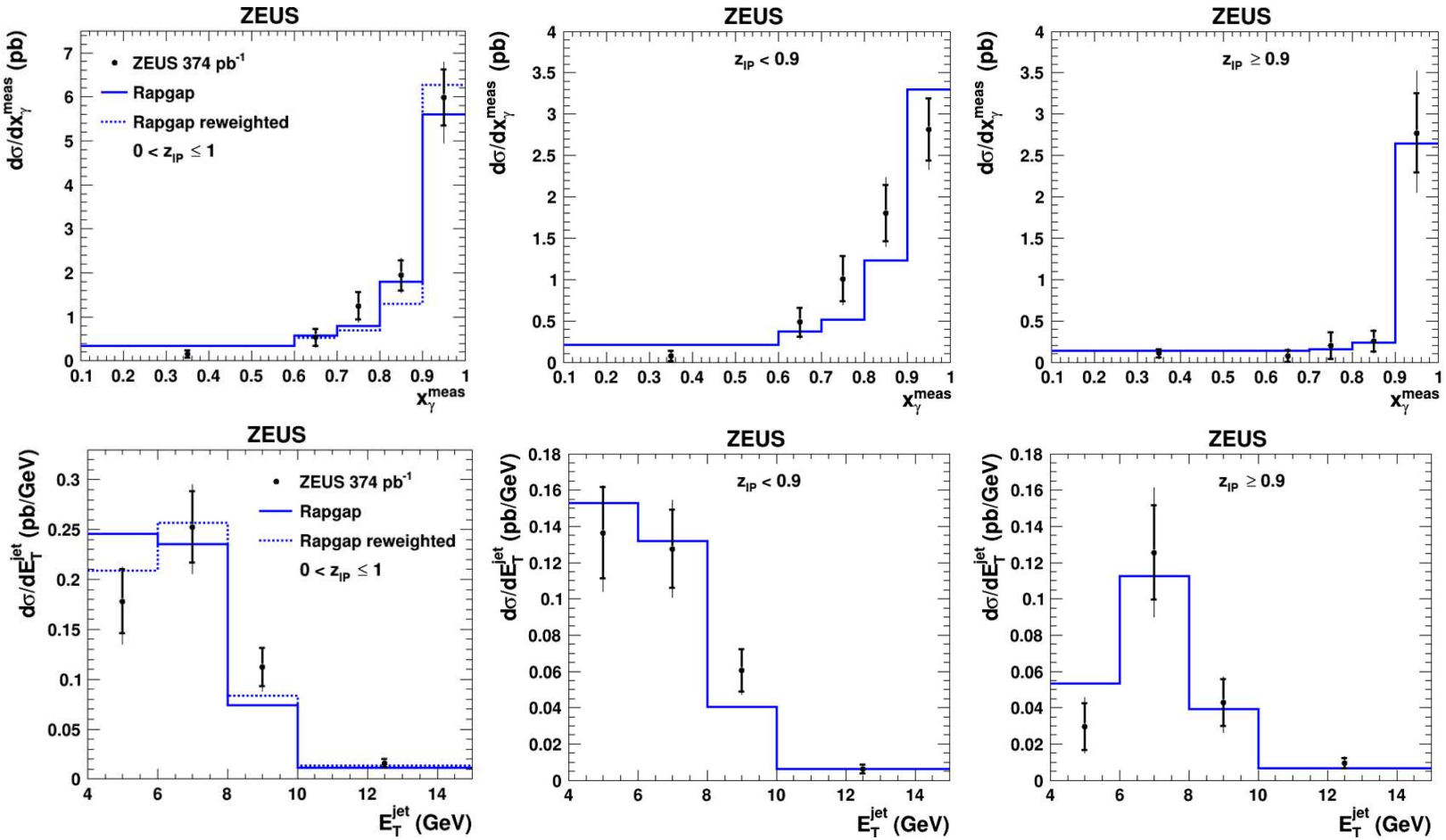
- Distributions well reproduced by the RAPGAP MC
- Most photons are accompanied by a jet

Results



- RAPGAP missing some processes at high z_{IP}
- Evidence for direct Pomeron interactions

Results



- Direct Pomeron interactions dominantly for direct photons
- Good agreement in shape with all variables, also for $z_{IP} < 0.9$ and $z_{IP} > 0.9$

Summary

- The first measurement of diffractively photoproduced prompt photons was presented
- Visible cross sections were calculated in $\eta_{max} < 2.5$ and $x_{IP} < 0.03$
- Most of the detected photons are accompanied by a jet
- The variable z_{IP} shows a peak at high values that implies the presence of processes not modeled in RAPGAP
  - Evidence for direct Pomeron interactions
  - Dominantly in the direct-photon channel
- Kinematic variables are well described in shape by RAPGAP, confirming universality of PDF in diffractive DIS and diffractive prompt photon photoproduction.