Prompt photon production at HERA

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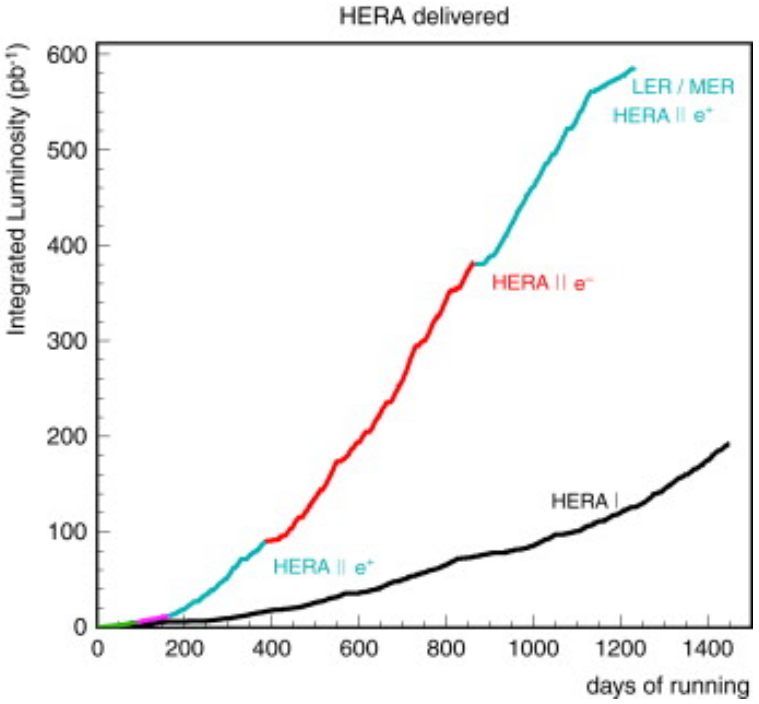
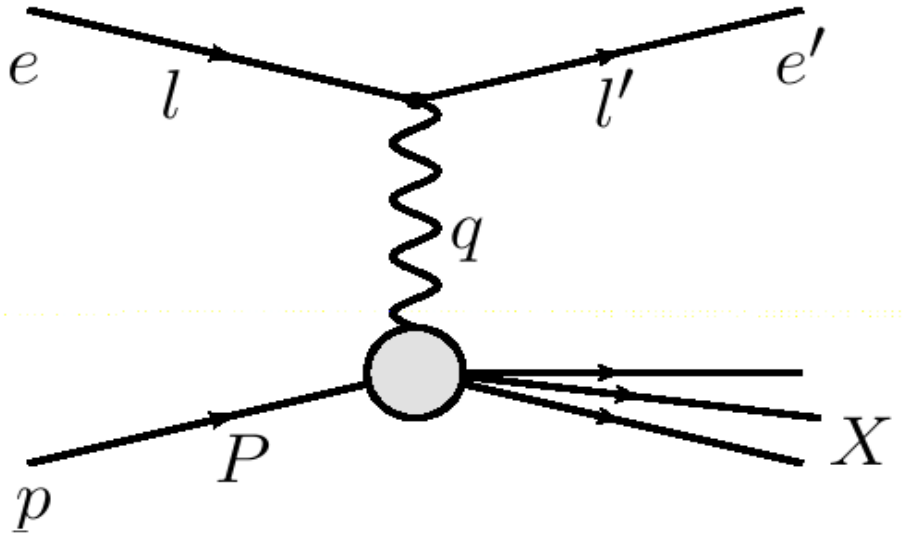
photoproduction of γ and γ + jet: Physics Letters B 730 (2014) 293-301
further studies: DESY-14-086

HERA collider





- **Electrons** / **Positrons** : 27.5 GeV
- **Protons**: 920 GeV

$\sqrt{s} = 318$ GeV

Kinematics:

$Q^2 = -q^2 = -(l - l')^2$

$$y = \frac{P.q}{P.l}$$

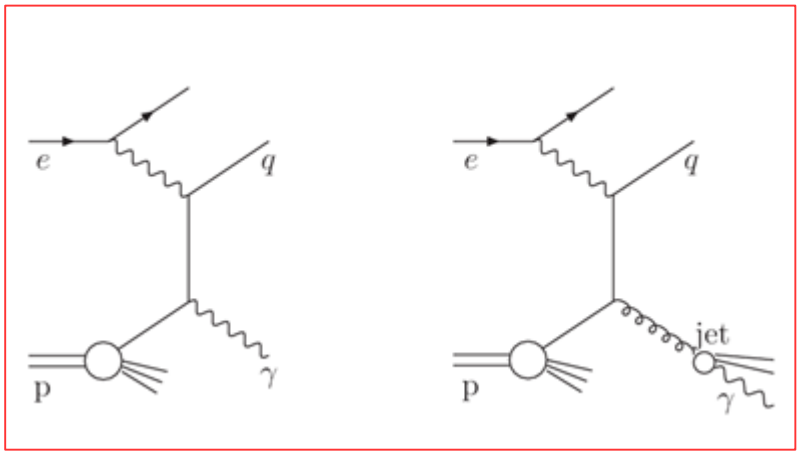
$$x = \frac{Q^2}{2P.q}$$

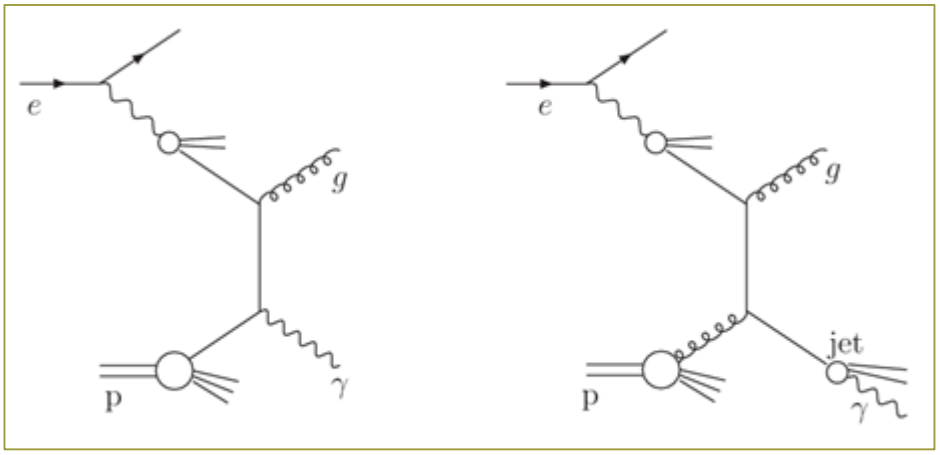
$Q^2 = xys$

$Q^2 \lesssim 1\ GeV^2$: *photoproduction*

$Q^2 \gtrsim 1\ GeV^2$: *deep inelastic scattering*

Isolated photons





Photoproduction:

direct

the entire incoming photon interacts

resolved

a parton from the photon interacts

Prompt photon: one that emerges directly from a pQCD process. It is useful to reduce fragmentation component by isolation requirement.

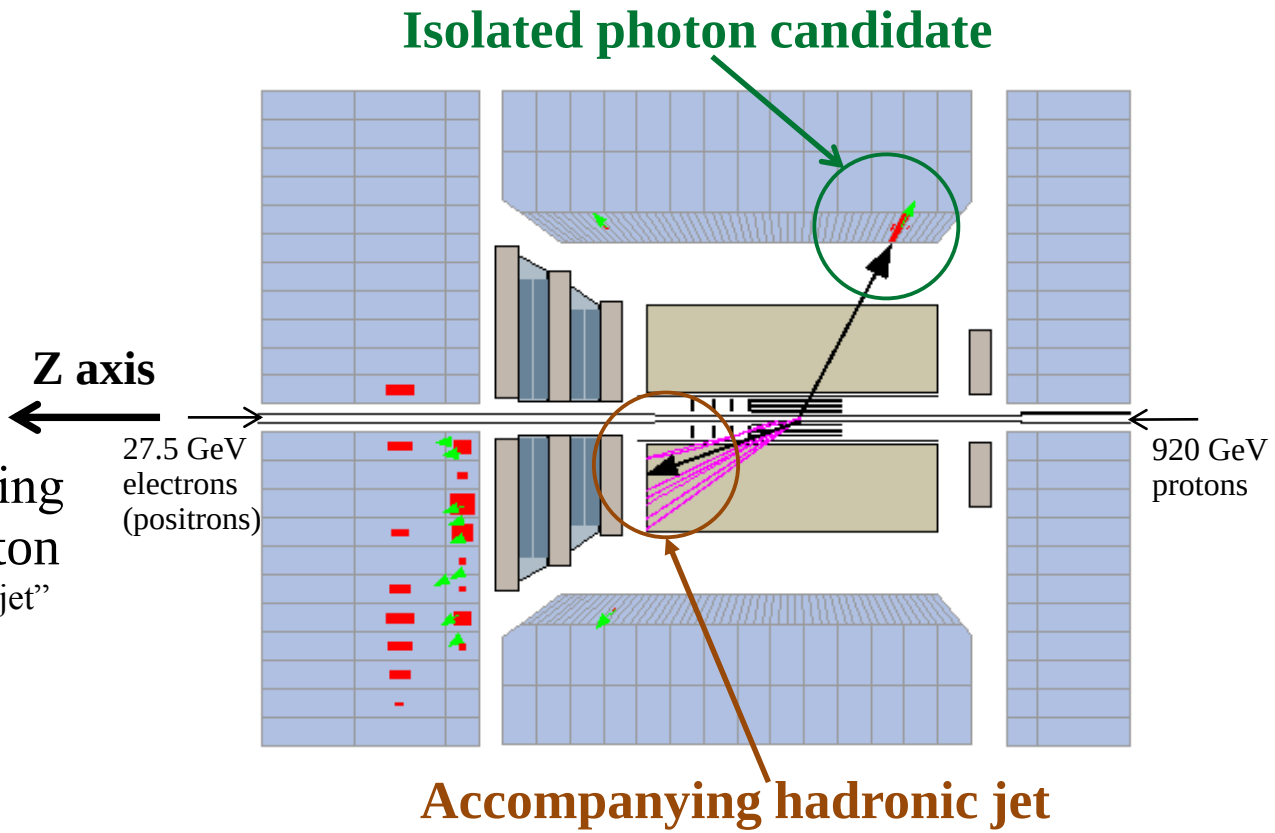
- A good tool to test QCD model to order α^3
- Can be used to measure and constrain the parton densities of proton and photon

Data samples. Event selection

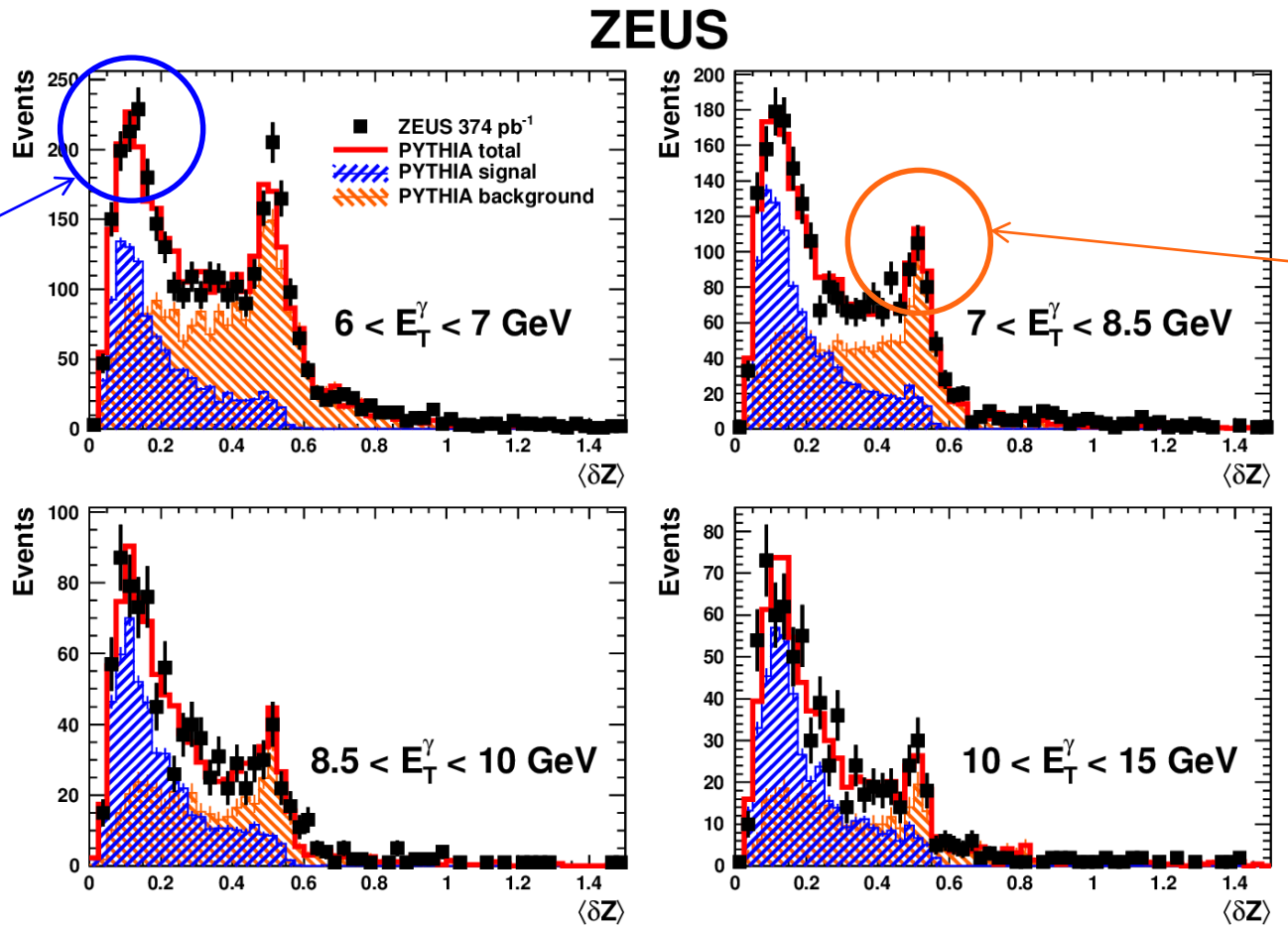
- ZEUS HERA II 2004-2007: 374 pb^{-1} positron and electron data
- Monte Carlo Signal: PYTHIA
- Monte Carlo Background: PYTHIA (photons from: $\pi^0 \rightarrow \gamma\gamma$, $\eta \rightarrow \gamma\gamma$, $\eta \rightarrow \pi^0\pi^0\pi^0$)

- **Photon:**
- $Q^2 < 1\ GeV^2$
- $6 < E_T^{\gamma} < 15$ GeV
- $-0.7 < \eta^{\gamma} < 0.9$
- Isolation: In any "jet" containing the photon candidate, the photon must contain at least 0.9 of $E^{\text{"jet"}}$
- No tracks in cone 0.2 about γ

- **Accompanying jet:**
- $4 < E_T^{jet} < 35$ GeV
- $-1.5 < \eta^{jet} < 1.8$



Photon identification



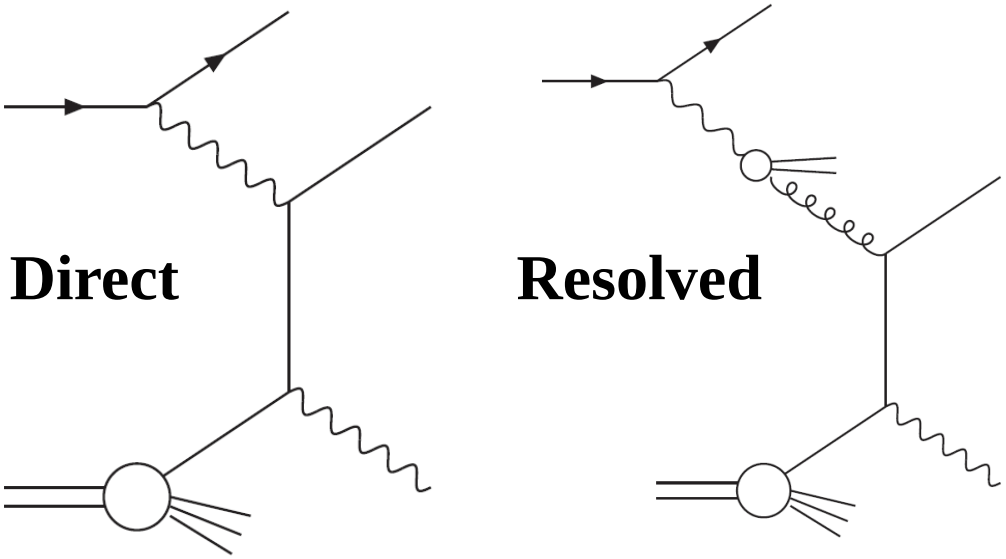
Photon peak

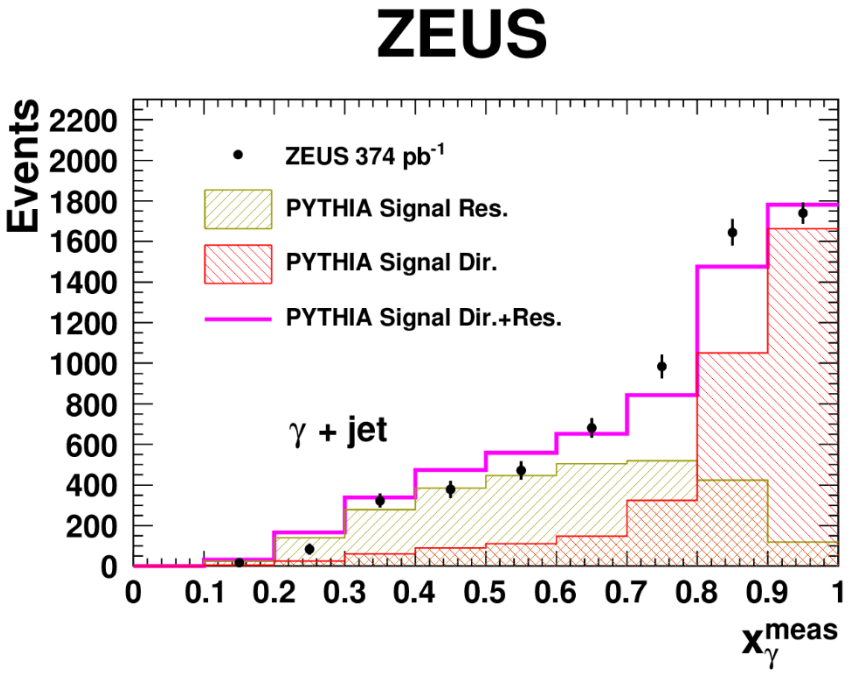
π^0 peak

The photon signal is distinguished from the background using the <δZ> = the energy weighted mean width of the electromagnetic cluster in the Z direction

$$< \delta Z > = \frac{\sum_i E_i |Z_i - Z_{cluster}|}{w_{cell} \sum_i E_i}$$

Definition of direct/resolved mix





x_γ^{meas} = fraction of the incoming photon energy given to the final state photon and jet to lowest-order approximation

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

Each measured cross-section point has a <dZ> fit.

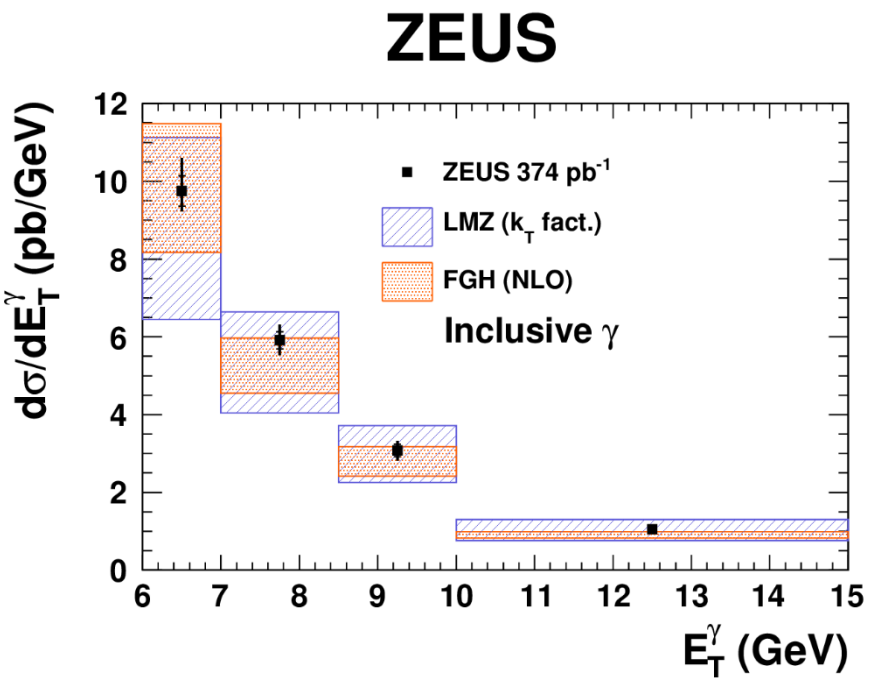
Theoretical predictions

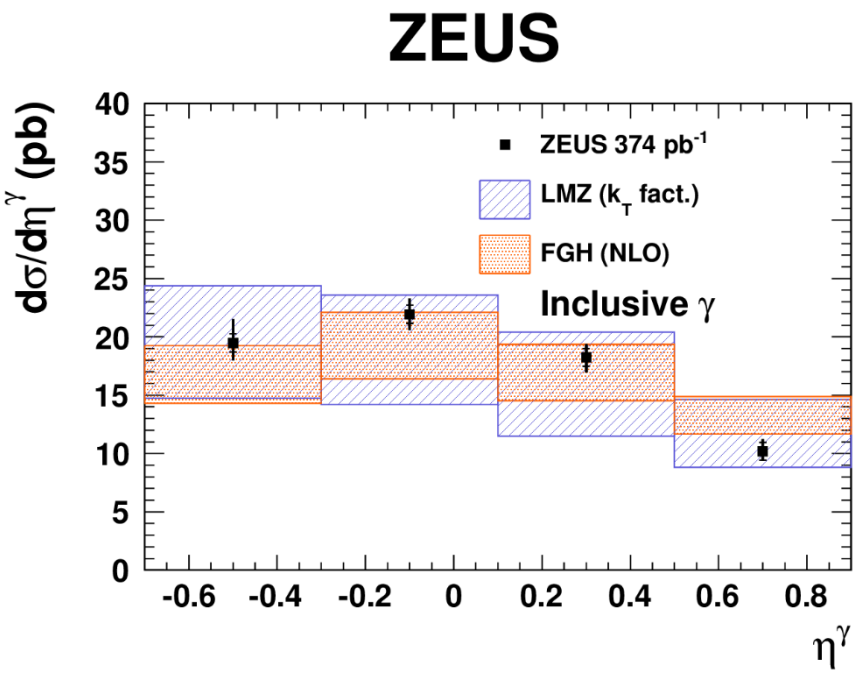
Comparison is made to predictions by

- **M. Fontannaz, J.-P. Guillet, G. Heinrich (FGH) [Eur. Phys. J. C 21 (2001) 303, Eur. Phys. J. C 34 (2004) 191]**
- LO and NLO and the box diagram term calculated explicitly.
- Fragmentation processes calculated in terms of a fragmentation function.

- **A.V. Lipatov, M.A. Malyshev, N.P. Zotov (LMZ) [Phys. Rev. D 81 (2010) 094027, Phys. Rev. D 88 (2013) 074001]**
- the k_T factorisation method.
- use of unintegrated parton densities at LO.

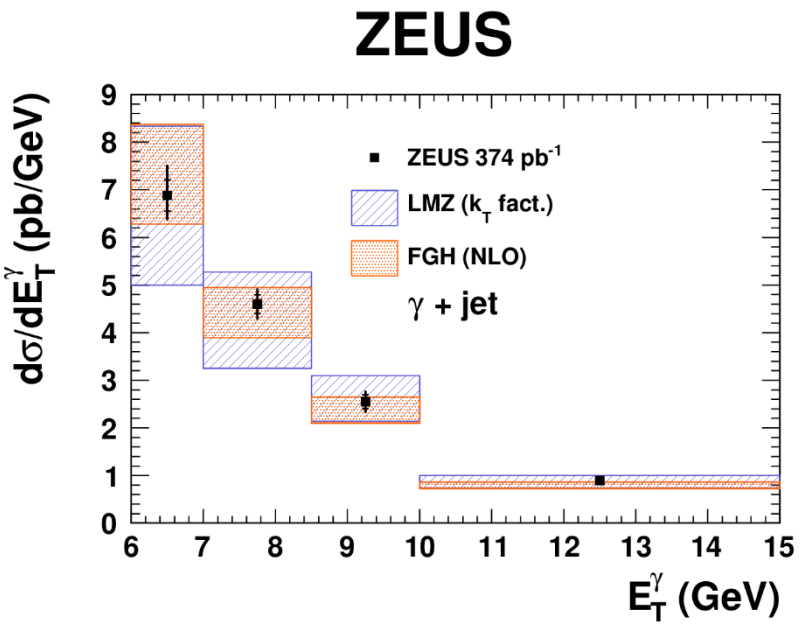
Inclusive photon cross sections

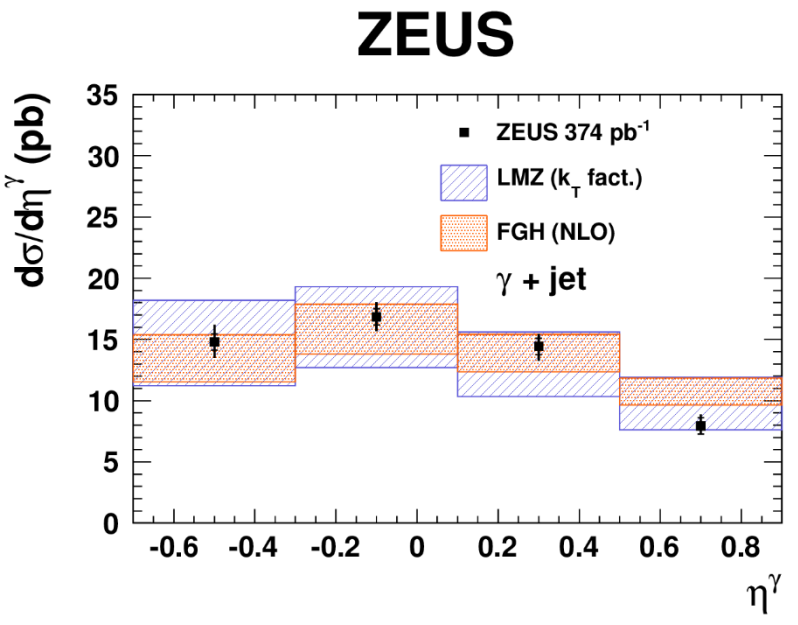


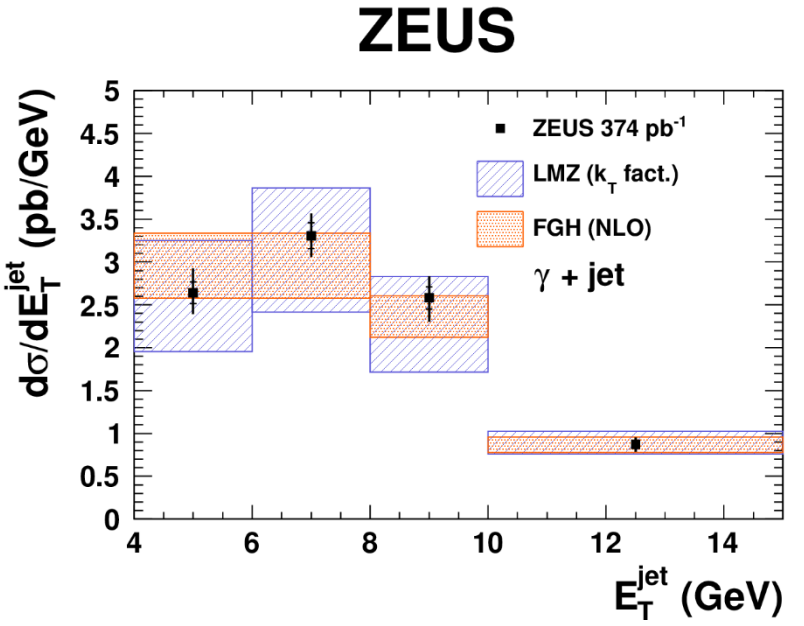


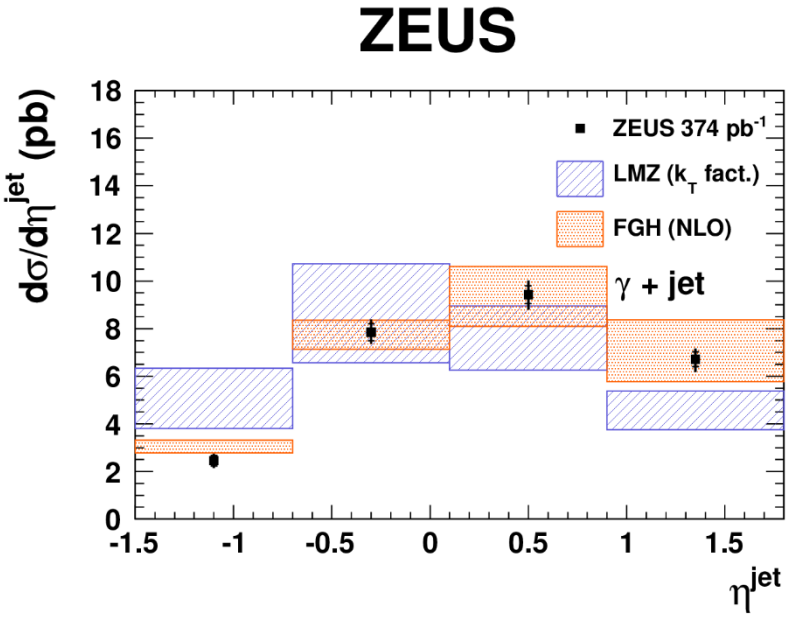
- Main source of data systematics is due to photon and jet energy scale uncertainties.
- FGH theoretical uncertainty due to renormalisation scale variation by factor 2 up and down.
- LMZ uncertainties come from renormalisation and factorisation scales varied by factors 0.5 and 2 simultaneously.
- Within errors there is an agreement between data and theory.

Cross sections for photon plus jet



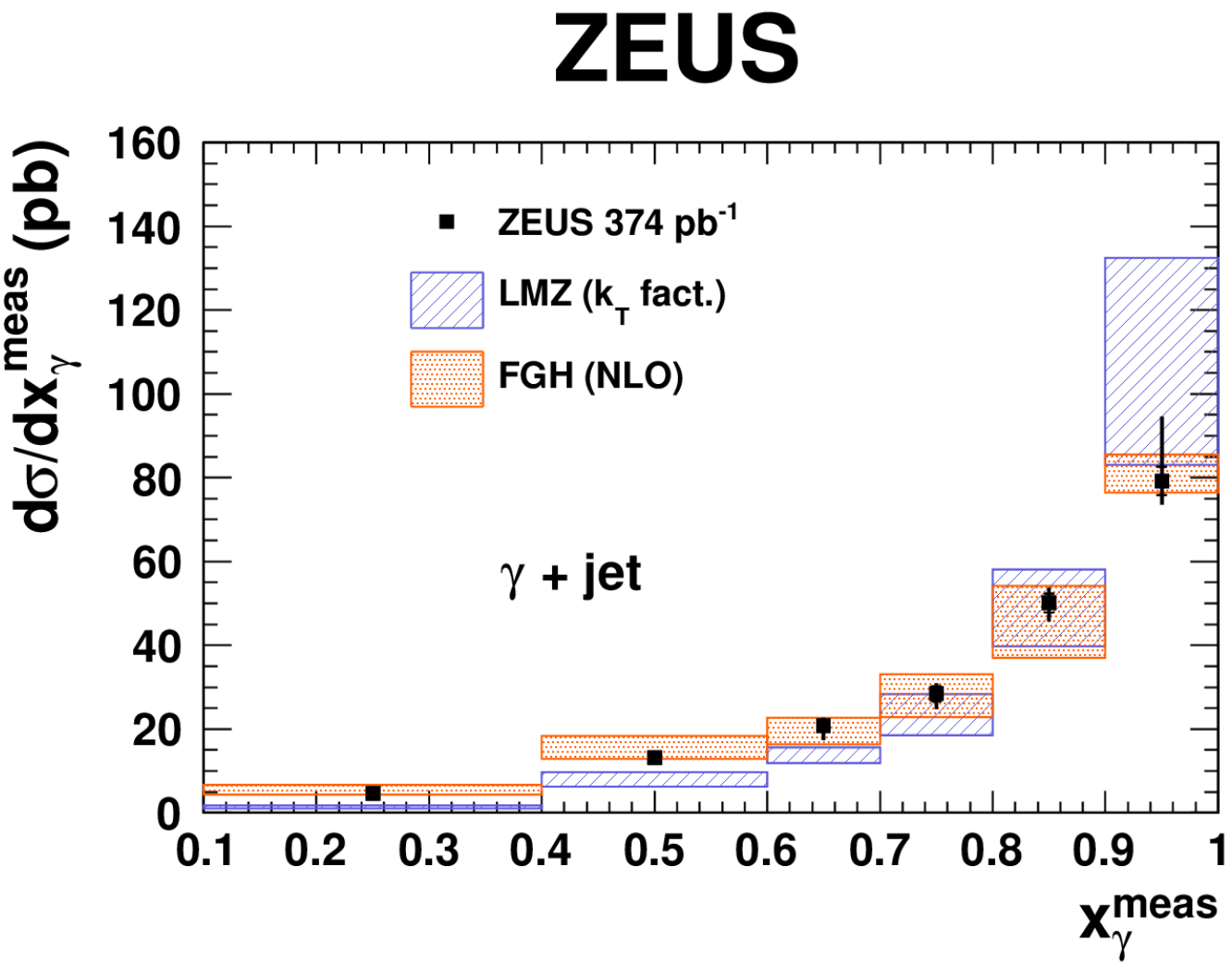






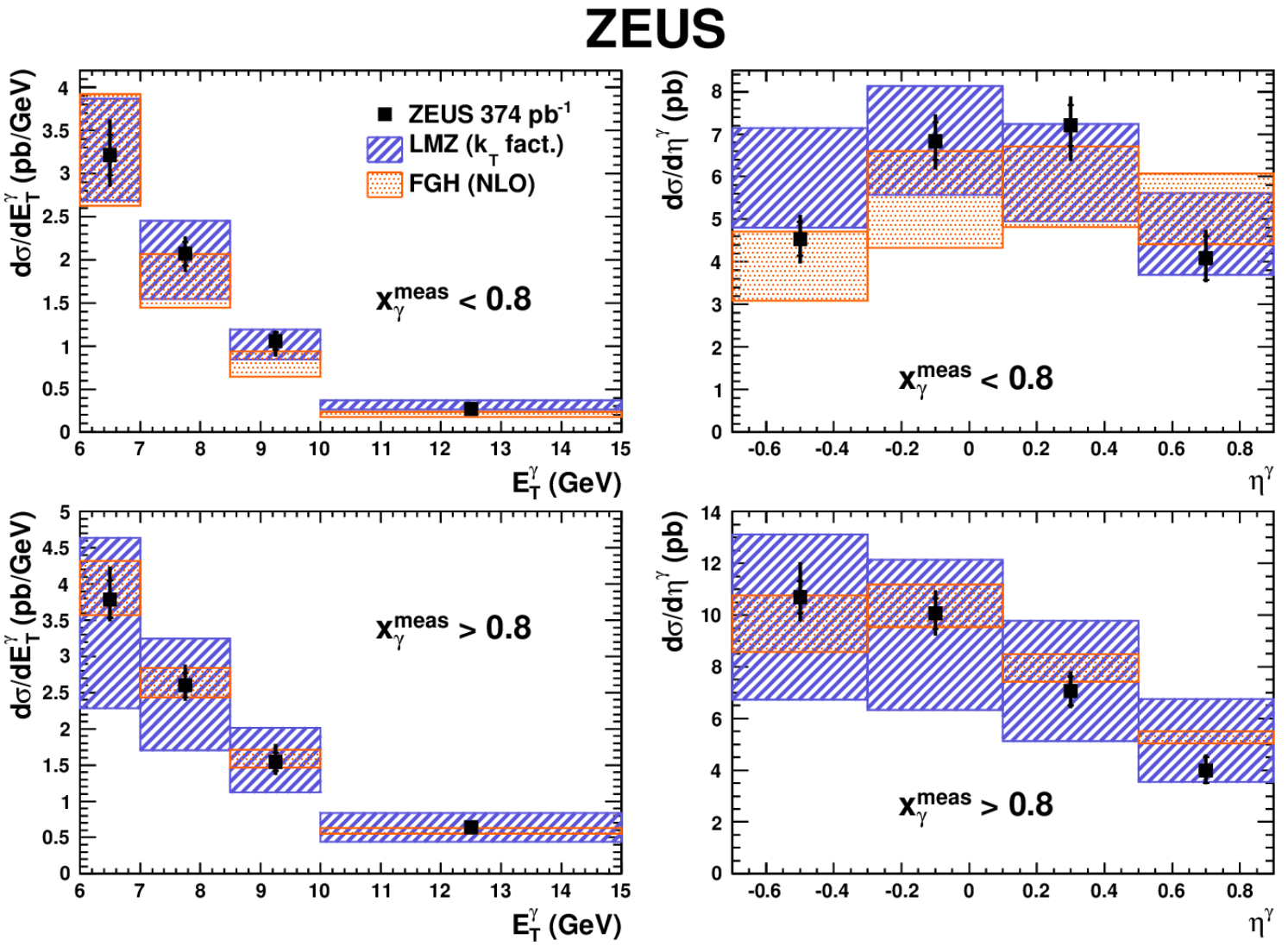
- Within uncertainties both theories provide a reasonable description of data.

Cross sections for photon plus jet



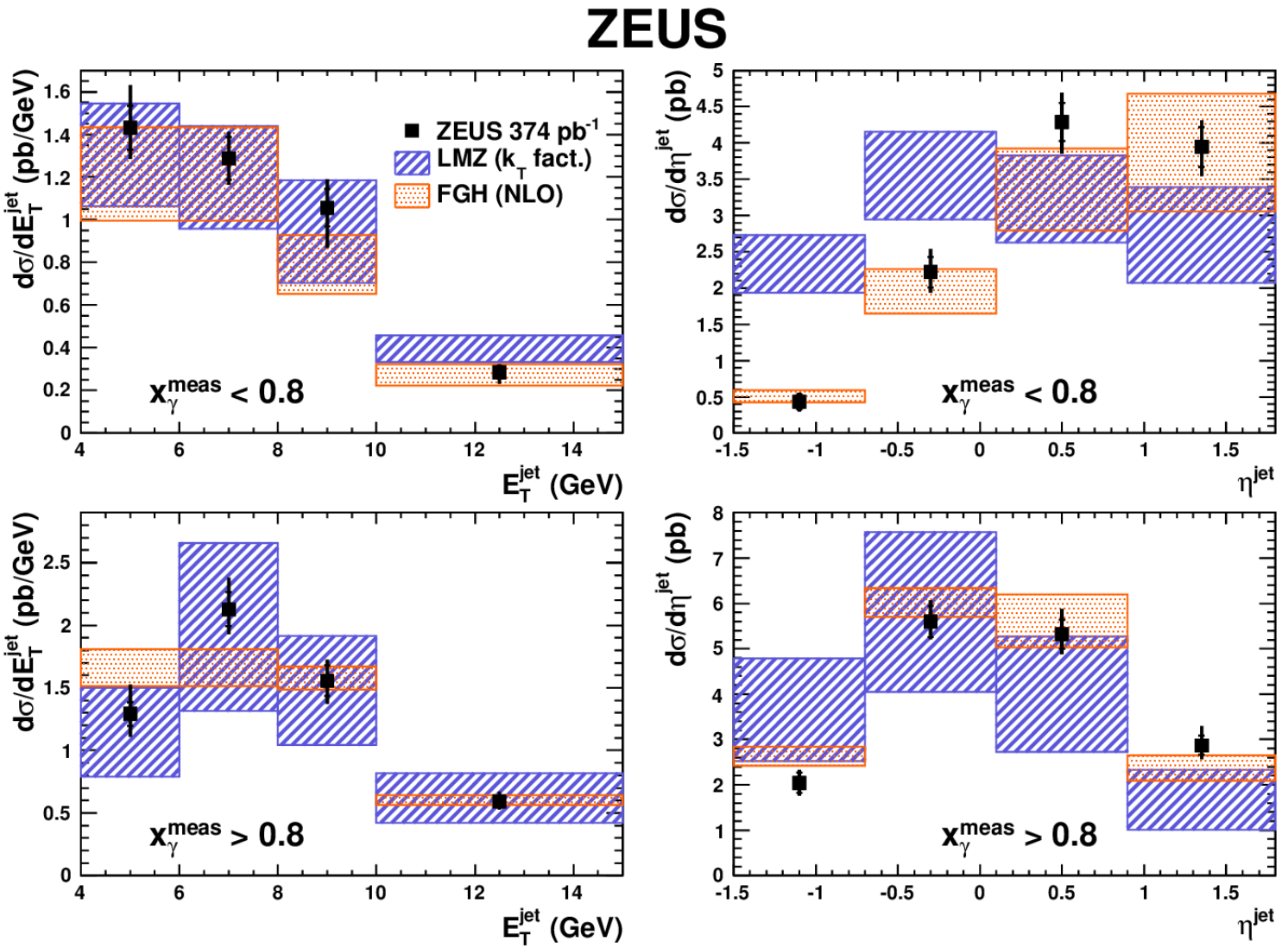
- Good description of full distribution by FGH.
- LMZ tends to underestimate low x_γ^{meas} region.

Cross sections in bins of x_γ^{meas}



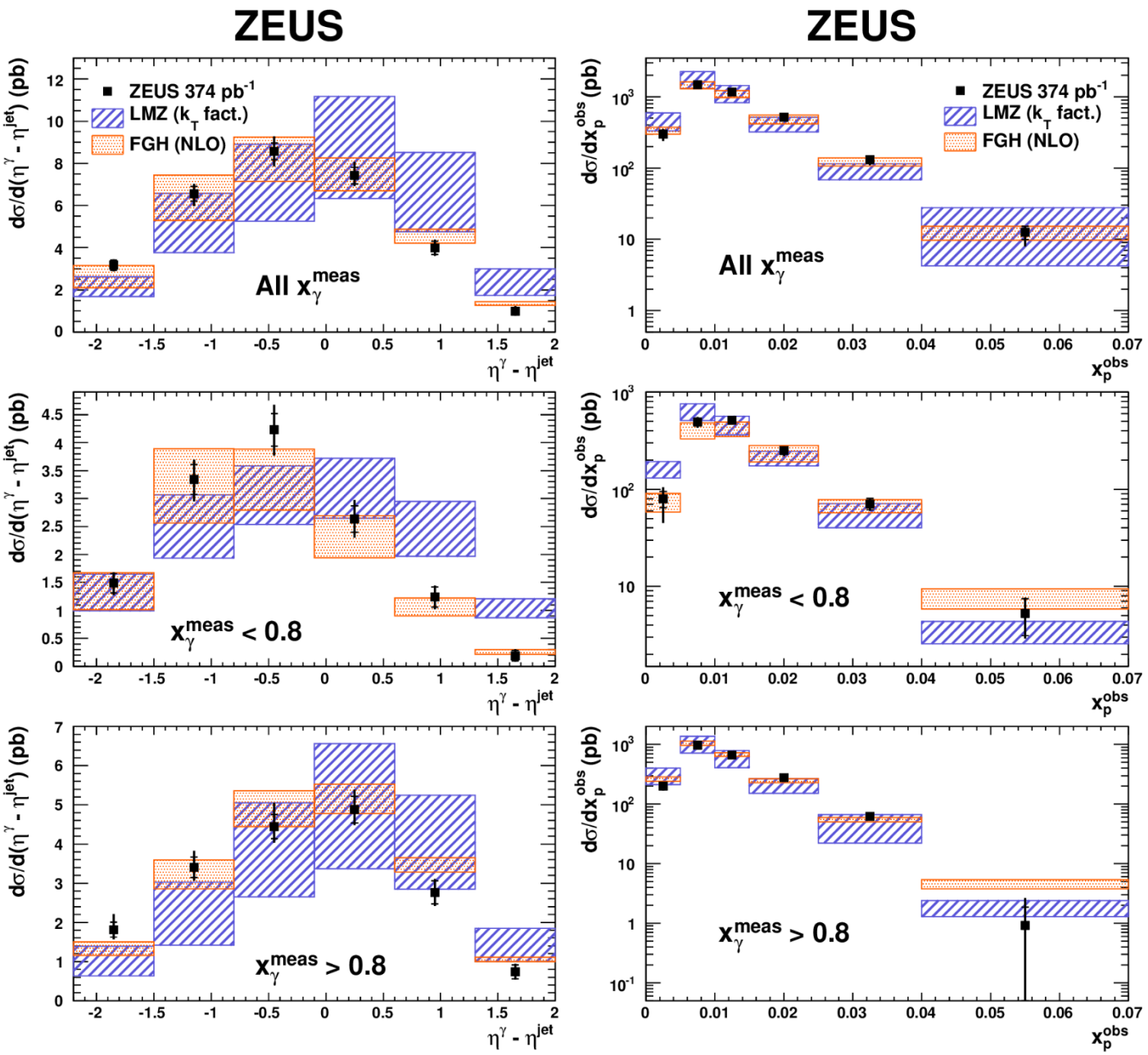
- Within large uncertainties both theories describe the data well.

Cross sections in bins of x_γ^{meas}



- Within large uncertainties both theories describe the data well, except LMZ in negative η^{jet} region.

Cross sections in bins of x_γ^{meas}

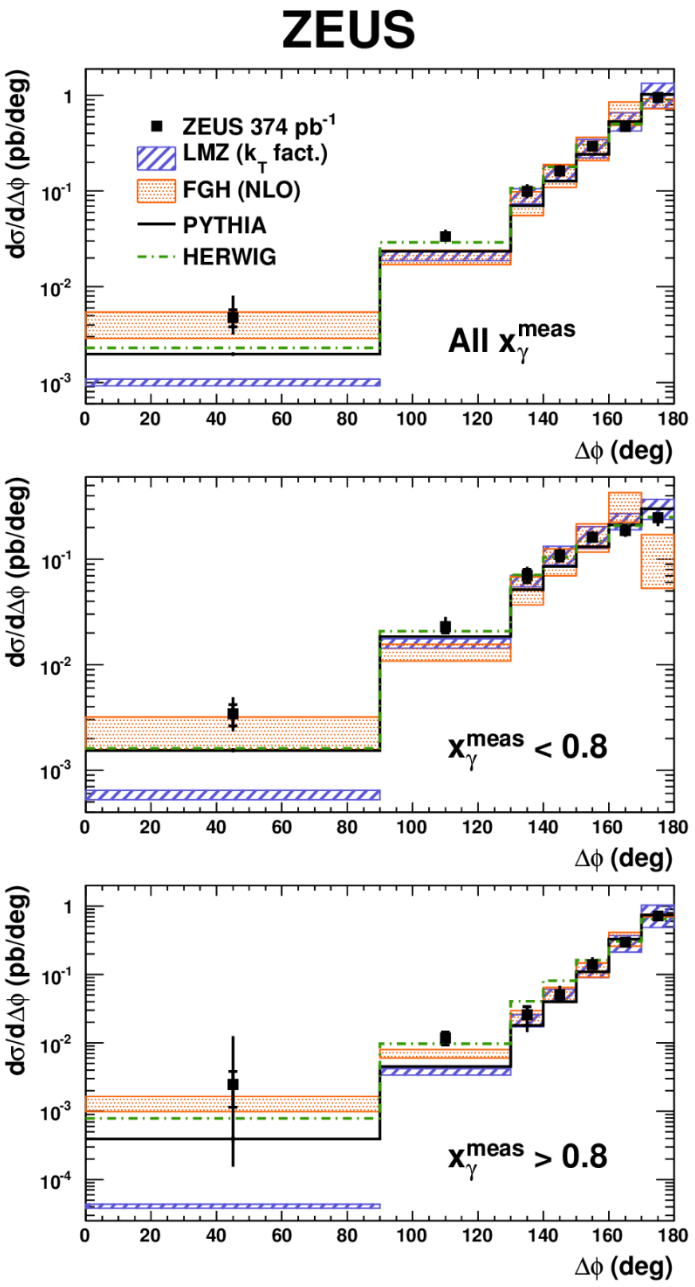


$$x_p^{obs} = \frac{E_T^\gamma \exp\eta^\gamma + E_T^{jet} \exp\eta^{jet}}{2E_p}$$

– the fraction of proton energy taken by the parton that interacts with the photon.

- Reasonable description of data by both theories within large uncertainties.

Cross sections in bins of x_γ^{meas}



– the absolute difference between the azimuths of the photon and the accompanying jet.

- Reasonable description of data by both theories and by LO MC programs.

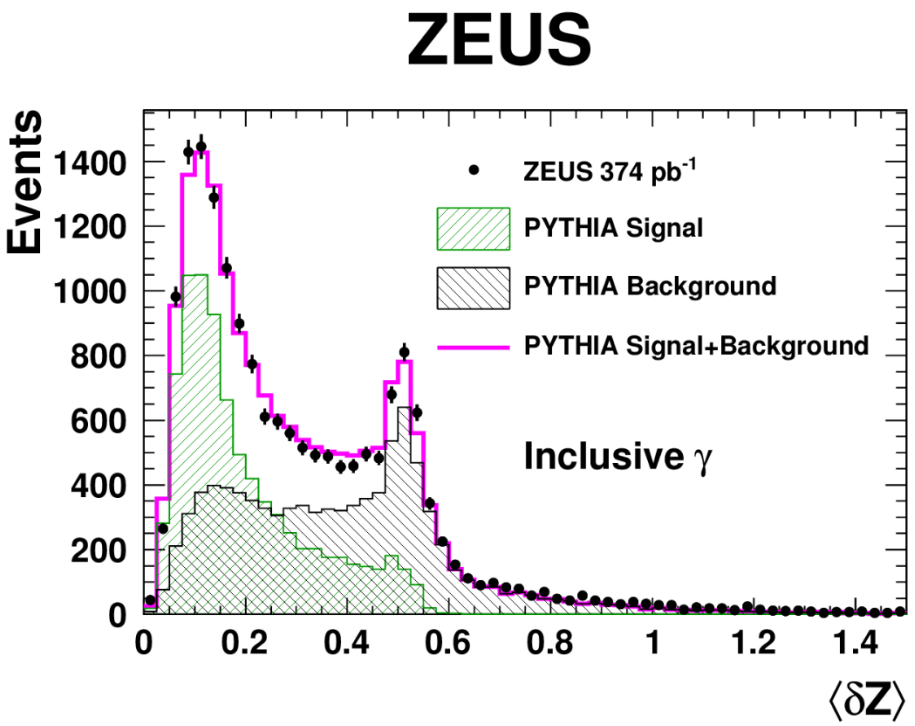
Summary

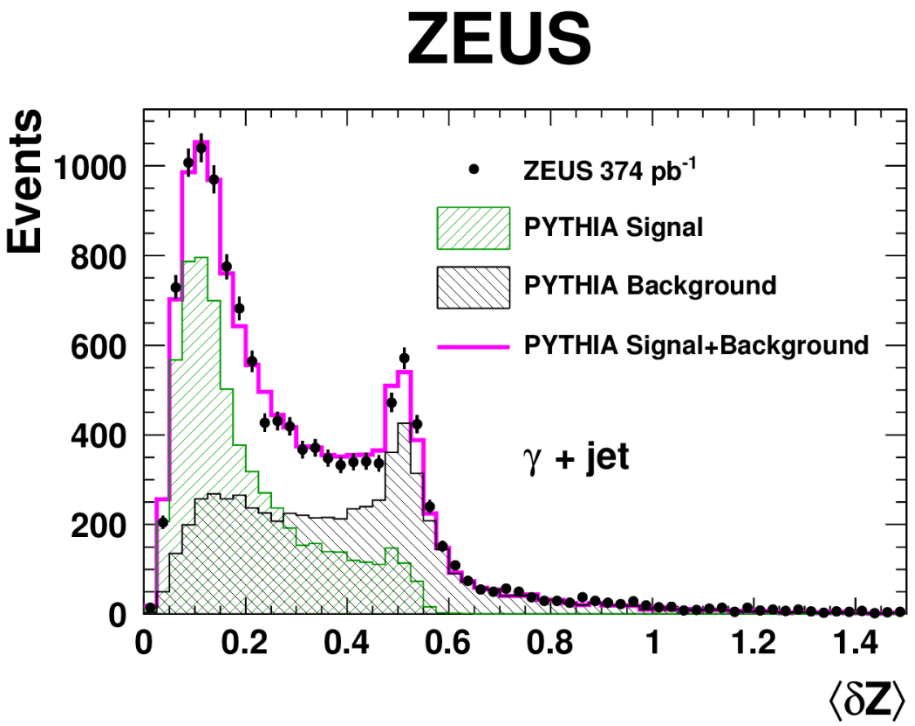
- Isolated photons in photoproduction have been measured by ZEUS at HERA, with and without a jet requirement.

- Uncertainties on data are much smaller than on both theories.
- Within errors, the NLO predictions of FGH describe well the experimental data.
- A reasonable description is also provided by the k_T factorisation model of LMZ with the exception of the jet pseudorapidity at low x_γ^{meas}.
- Obtained results are a potentially significant input to the future PDF fits.

Backup slides

Photon identification





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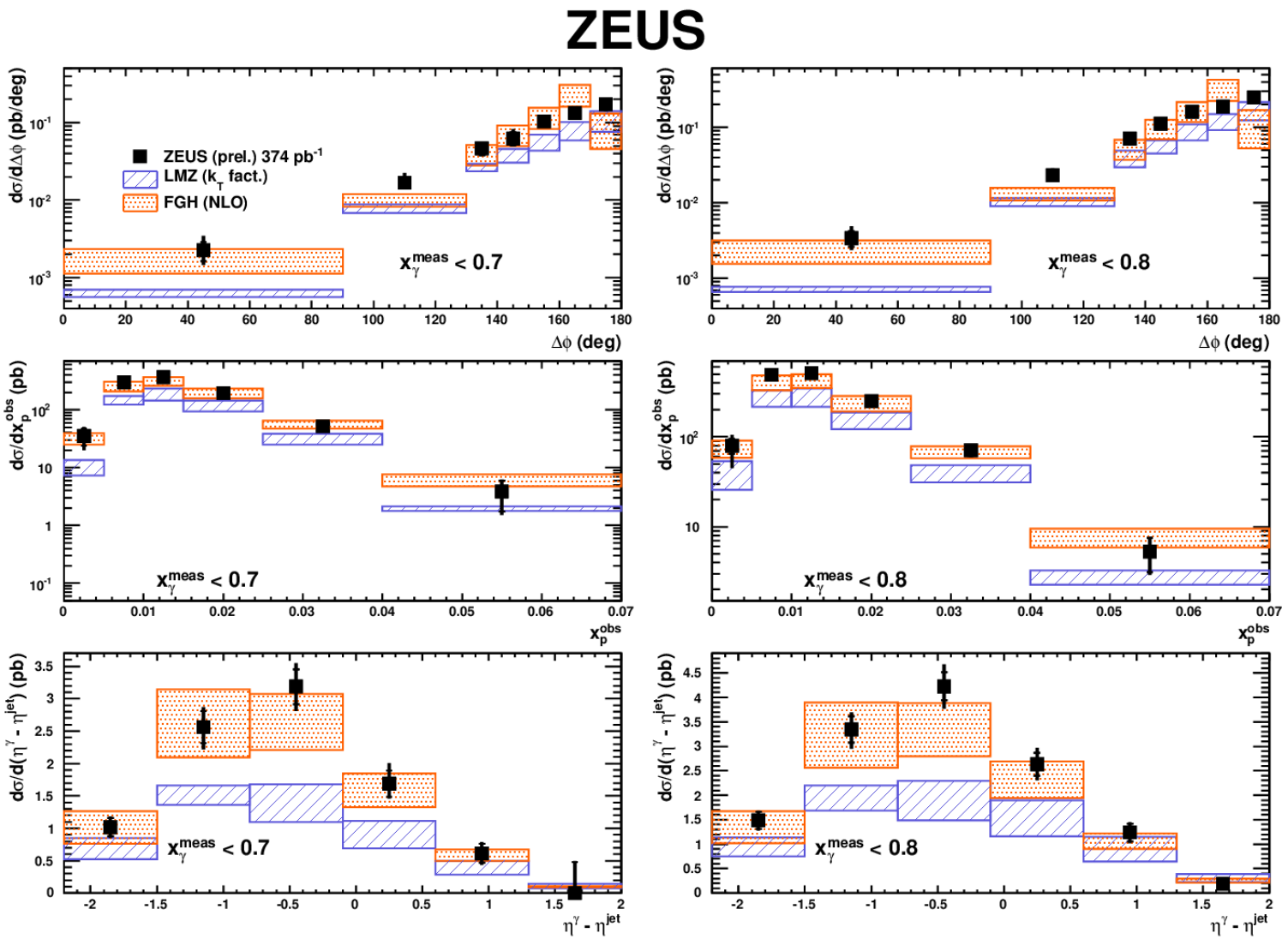

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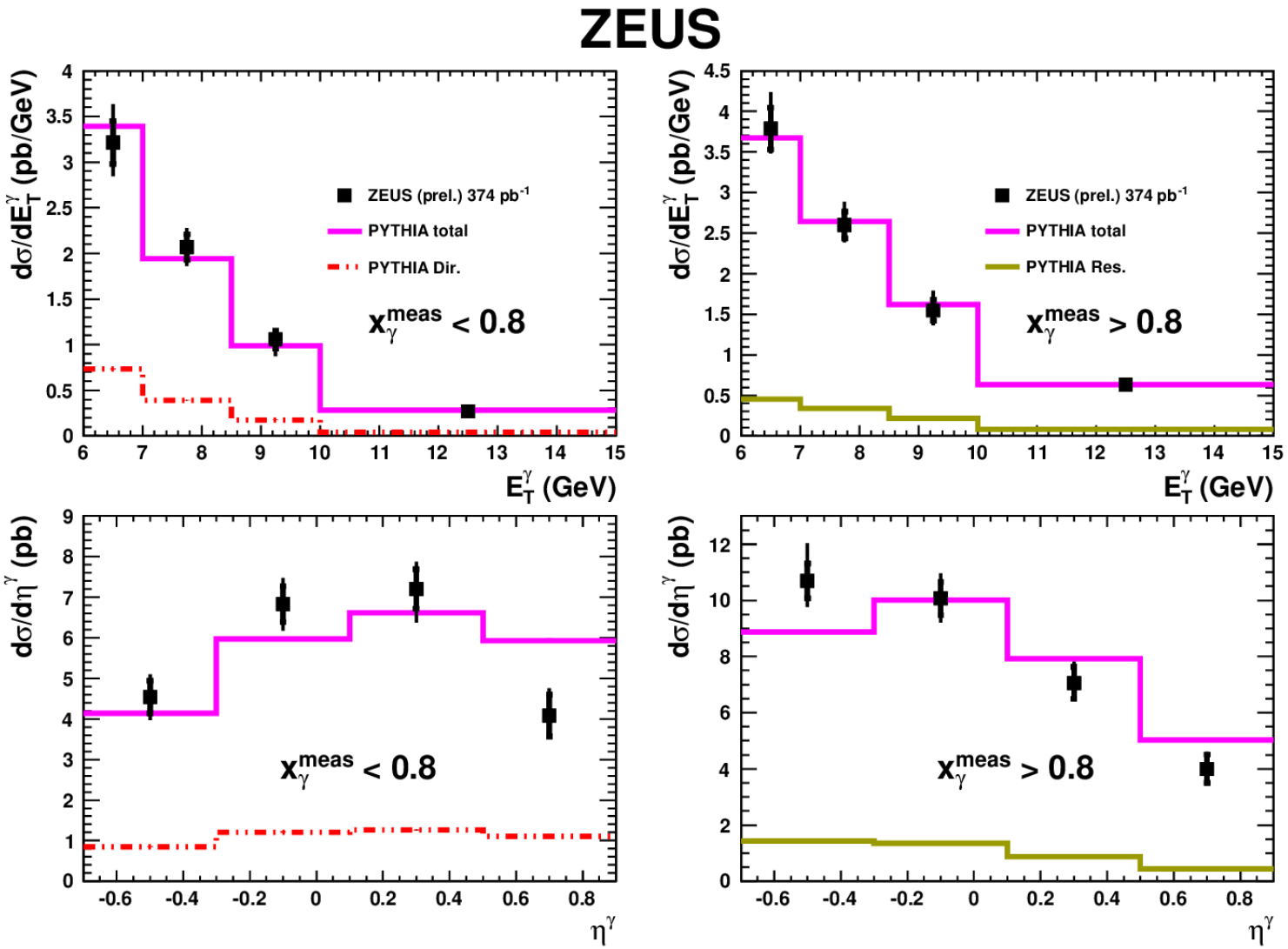

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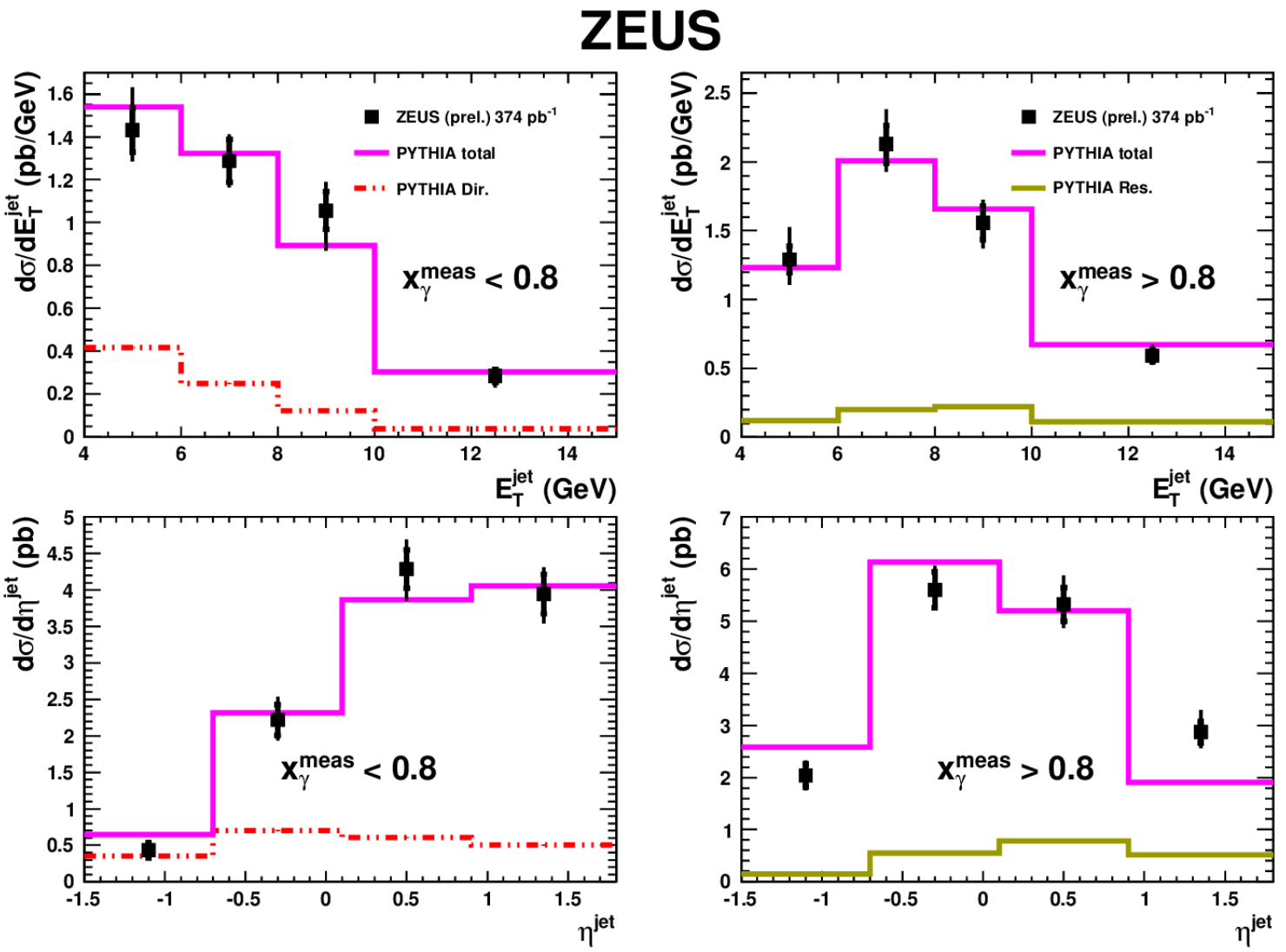

Cross sections in bins of x_γ^{meas}