

Isolated hard photons measured in Deep Inelastic Scattering using the ZEUS detector at HERA.

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For the ZEUS Collaboration.



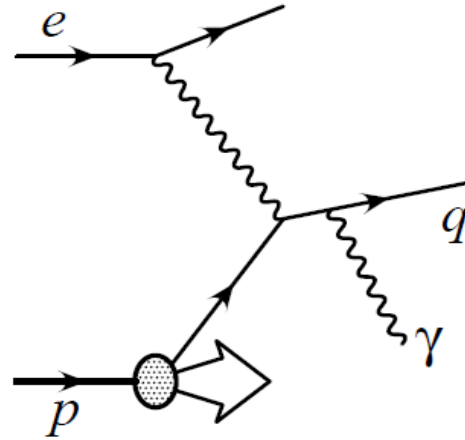
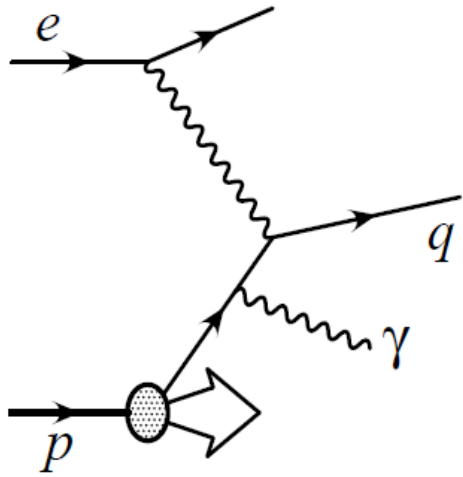
European Physical Society, Grenoble, July 2011

High- p_T photons produced in Deep Inelastic Scattering (DIS) using incident e^+/e^- are of several main types:

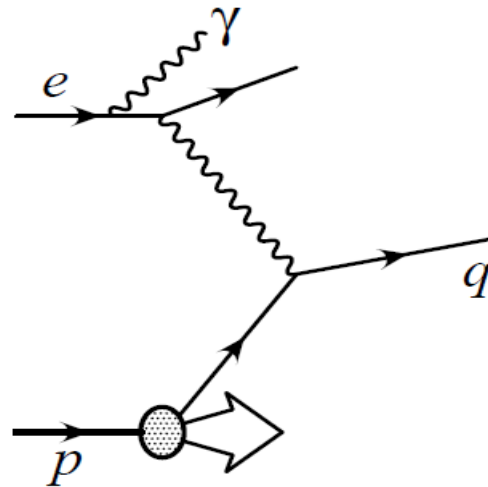
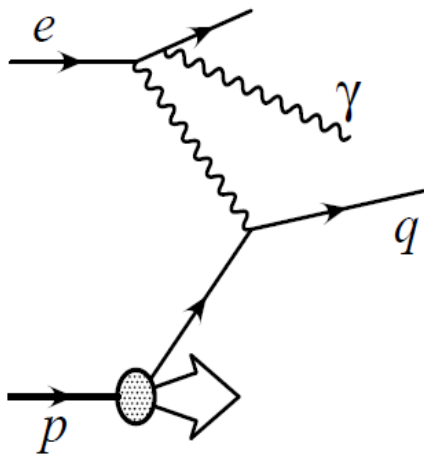
- **Produced in a hard partonic interaction** (“QQ”) (“prompt photons”)
- Radiated from the incoming or outgoing lepton (“LL”)
- Radiated from a quark within a jet
- A decay product of a hadron within a jet

The first two types are photons that are relatively isolated from other outgoing particles, and are the subject of this study.

The main diagrams that contribute:



QQ diagrams



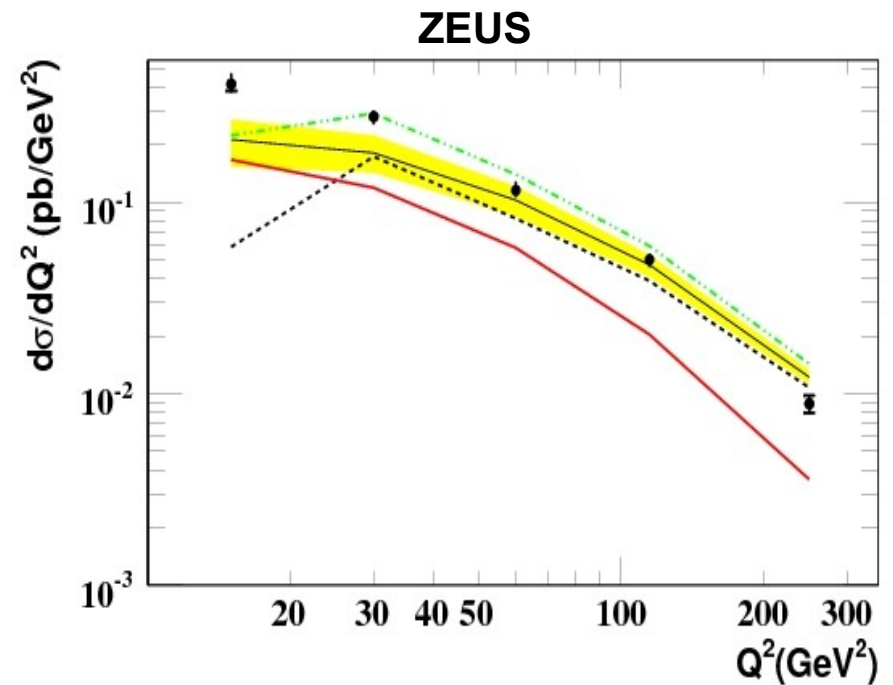
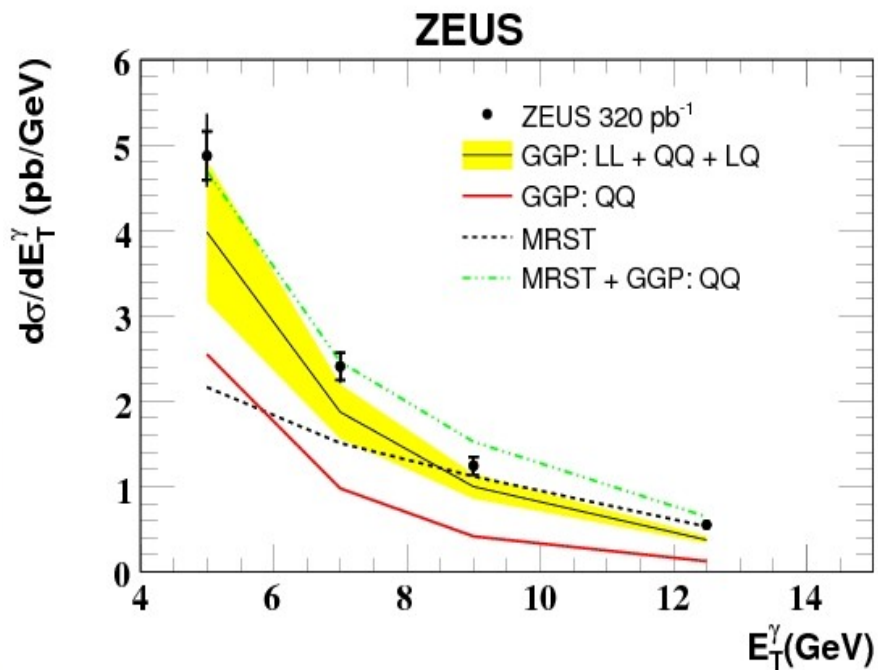
LL diagrams

(LL+QQ interference is small and neglected here)

Some particular motivations for these measurements:

- The prompt photons emerge directly from the hard scattering process and give a particular view of this.
- This allows tests of specific QCD models.
- Prompt photons form a potential background to some interesting “new physics” process (e.g. Higgs $\rightarrow \gamma\gamma$) and this needs to be well understood.

Following ZEUS publication of inclusive prompt photons in DIS (Phys. Lett. 687 (2010) 16)

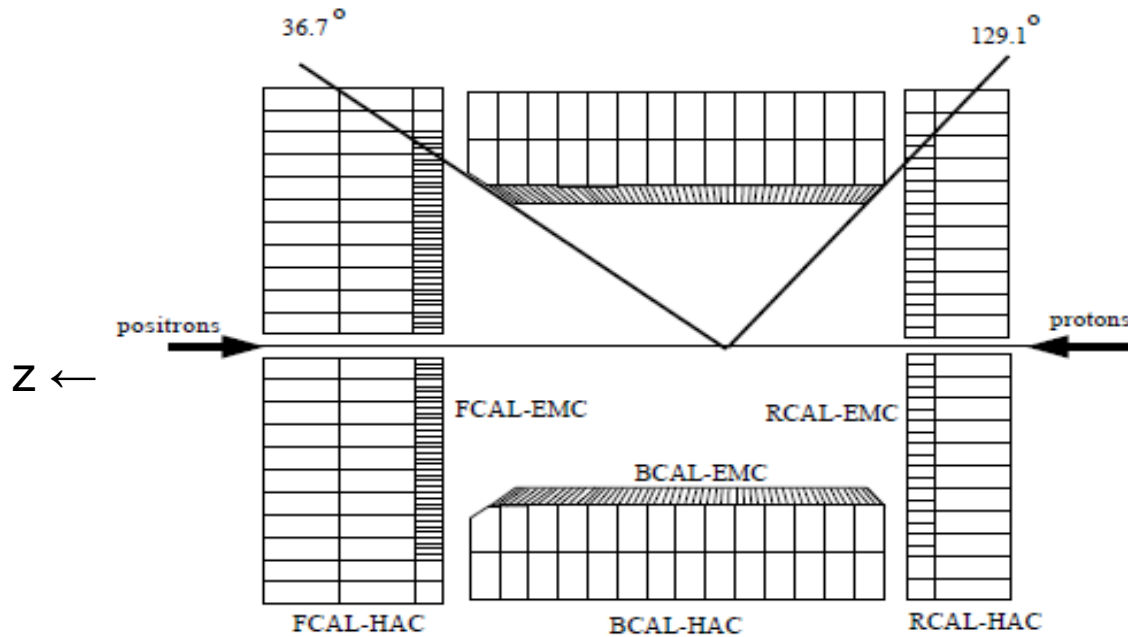


Examples from published results in inclusive prompt photons in DIS.

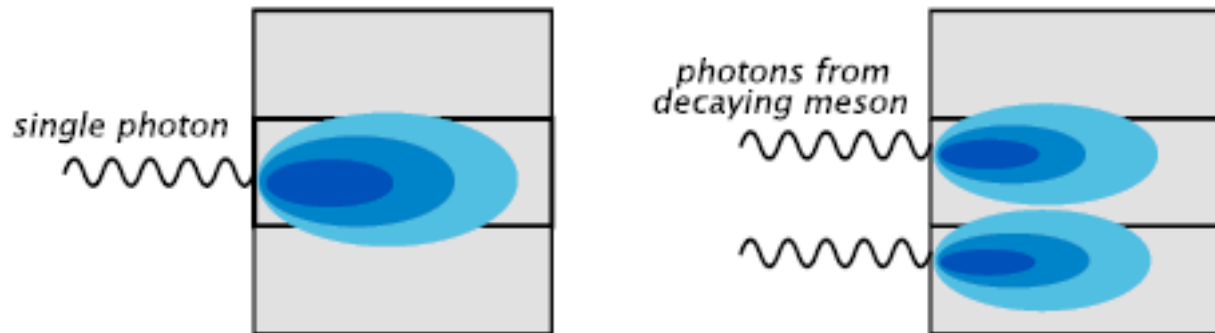
Comparison with NLO theories is not bad, but there is still more work to do.

Next step is to look at prompt photons plus accompanying jets.

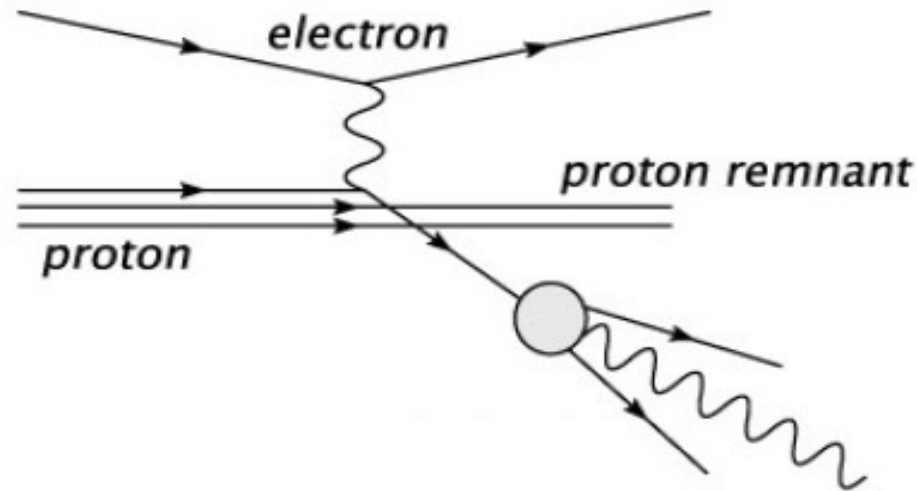
The ZEUS detector



Hard scattered photons are measured in the BCAL, which is finely segmented in the z direction



Why we select isolated photons:



Photons in or near jets come from radiation from quarks and their description is complicated by the presence of the jet.

Also, the background from neutral mesons is large.

The ZEUS analysis

332 pb⁻¹ of HERA 2 data

Photon candidates: found with an energy-clustering algorithm in the barrel calorimeter of ZEUS. $E_{\text{EMC}} / (E_{\text{EMC}} + E_{\text{HAD}}) > 0.9$

Jets: use k_{T} -clus algorithm (include photon candidates)

Main selections are:

DIS electron (or positron):

- Measured energy at least 10 GeV
- Emerges at 140-180° from proton beam direction
- $10 < Q^2 < 350 \text{ GeV}^2$ where $Q^2 =$ squared momentum transferred from lepton

Hard photon candidate:

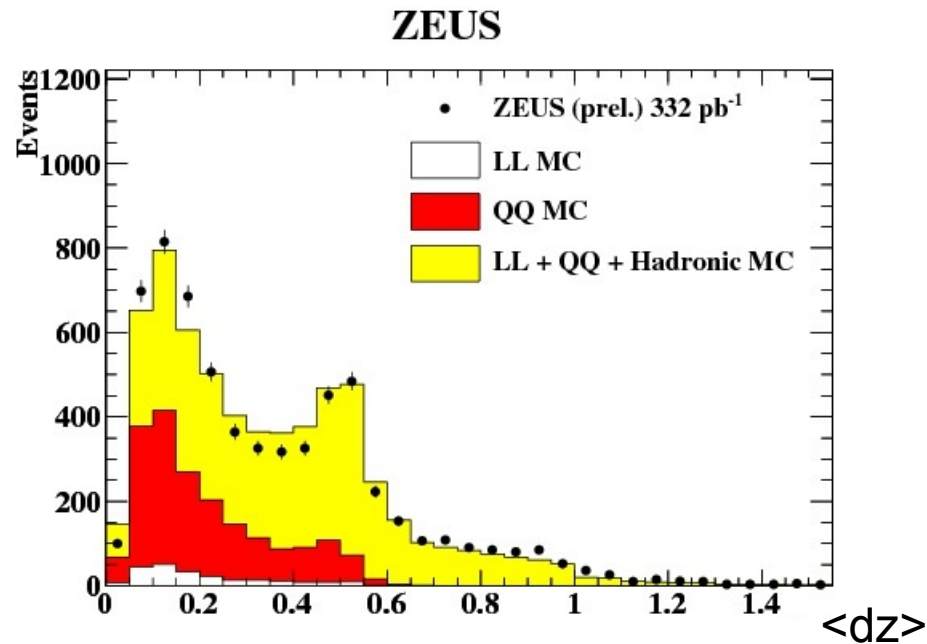
- $E_{\text{T}} > 4 \text{ GeV}$
- $-0.7 < \eta^{\gamma} < 0.9$ where $\eta \equiv$ pseudorapidity. (i.e. within ZEUS barrel calorimeter)
- **Isolated.** In any “jet” containing the photon candidate, the photon must contain at least 0.9 of the “jet” E_{T}

Jet:

- $-1.5 < \eta^{\text{jet}} < 1.8$
- $E_{\text{T}}^{\text{jet}} > 2.5 \text{ GeV}$. (This rather low value is to compare with H1 analysis.)

Photon candidates are groups of signals in cells in the electromagnetic section of the BCAL. Each has a z-position, z_{CELL} . E_T -weighted mean of z_{CELL} is z_{Mean} .

Principal challenge is to separate out photons from the background of candidates from photon decays of neutral mesons.



$\langle dz \rangle = E_T$ -weighted mean of $|z_{\text{CELL}} - z_{\text{Mean}}|$.

Peaks correspond to photon and π^0 signals, on a background from η + multi- π^0 .

In each bin of each measured quantity, **fit to QQ photon signal + hadronic bgd. including a fixed calculated LL photon contribution.**

LL contribution

Evaluated with ARIADNE 4.12 Monte Carlo

QQ contribution

Evaluated with PYTHIA 6.416

Neutral meson background

Evaluated using ARIADNE 4.12

Systematic uncertainties

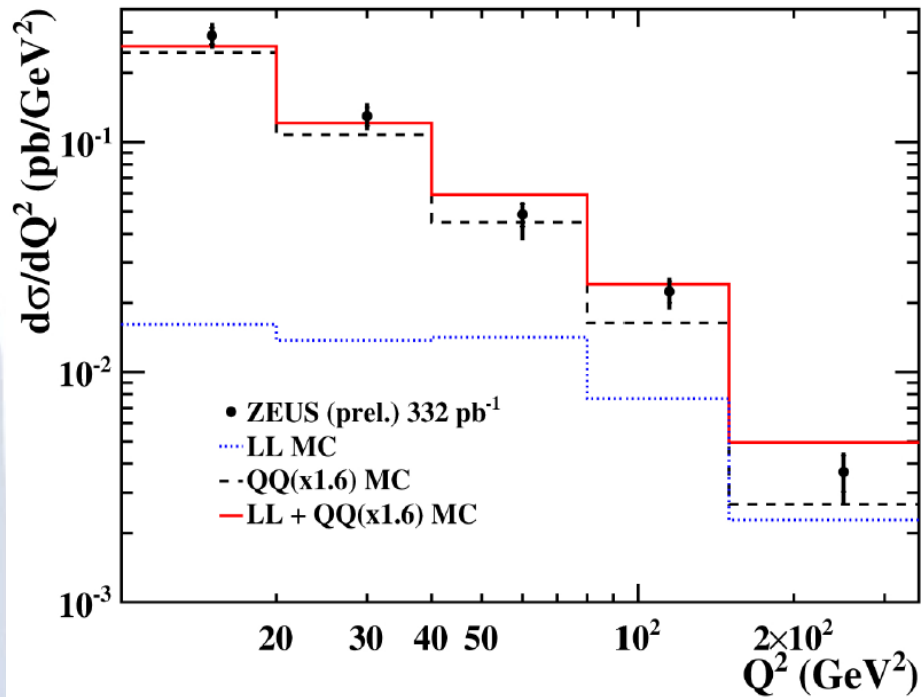
These are dominated by:

- jet energy scale
- photon energy scale
- modelling of background with ARIADNE Monte Carlo

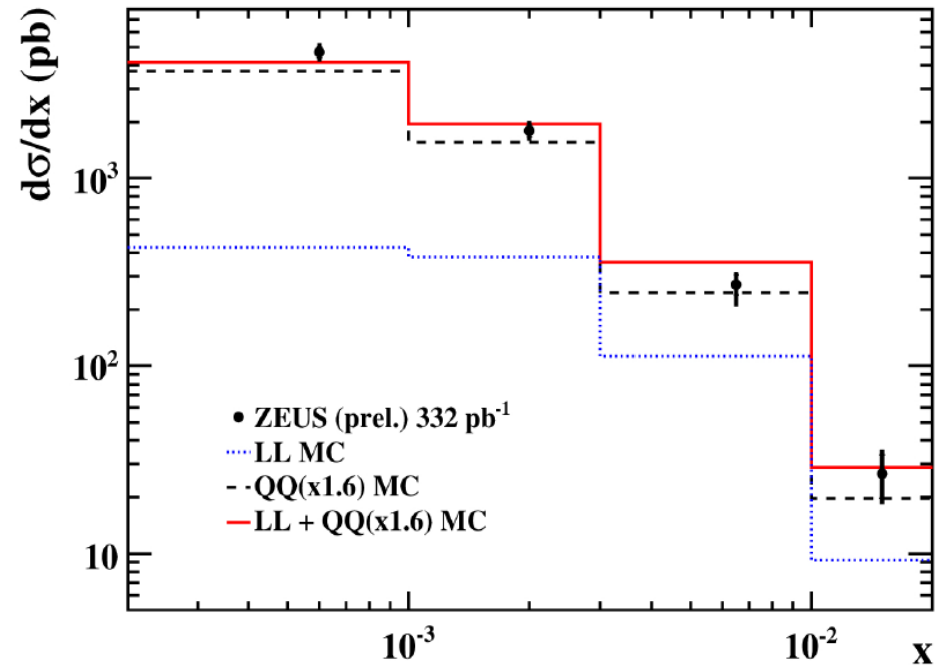
Fitting procedure: scale the QQ and background contributions applying a linear reweighting in Q^2 to the signal.

Results of the fit

ZEUS



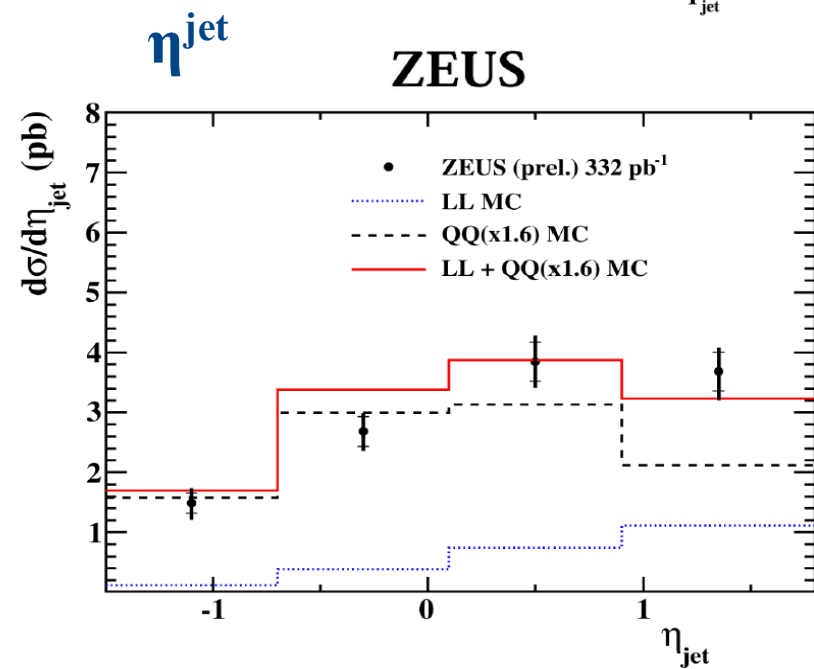
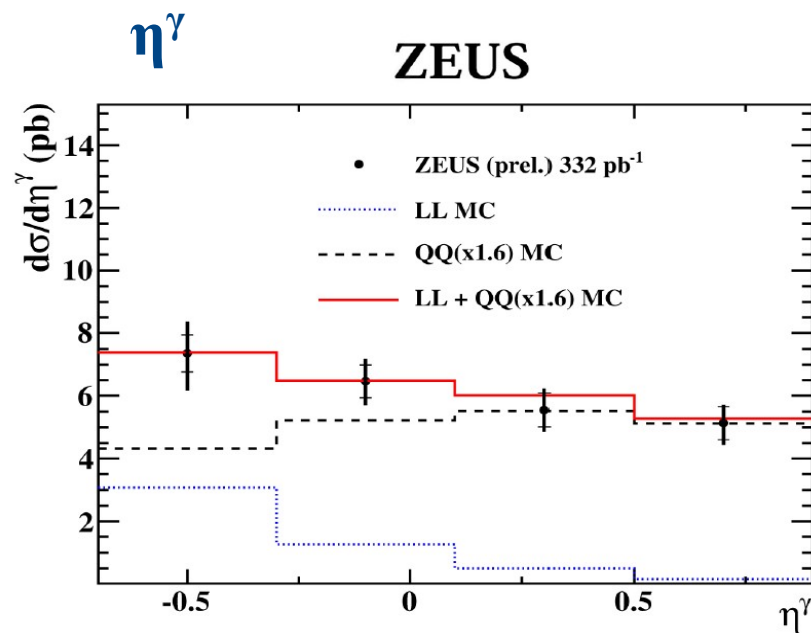
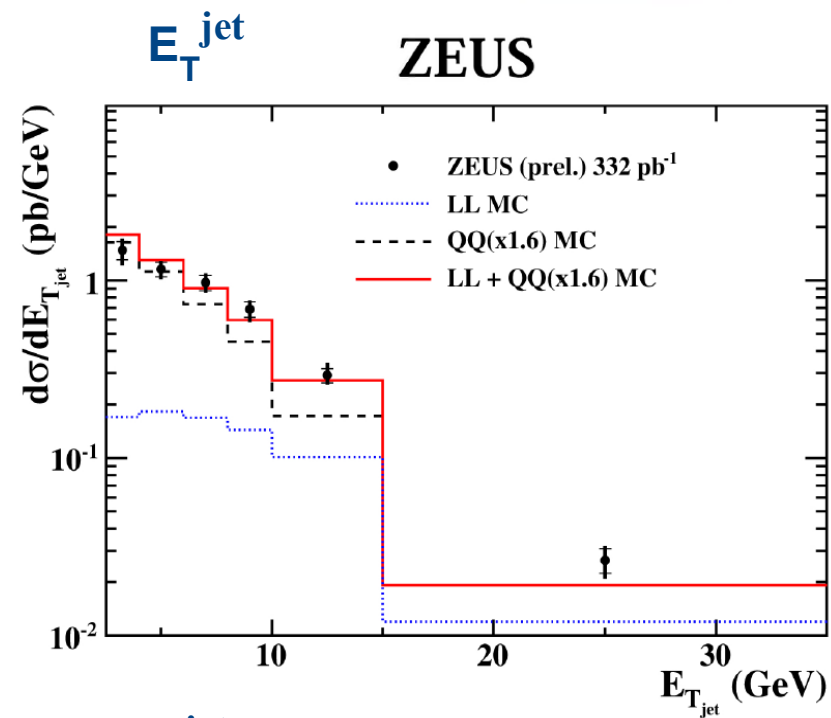
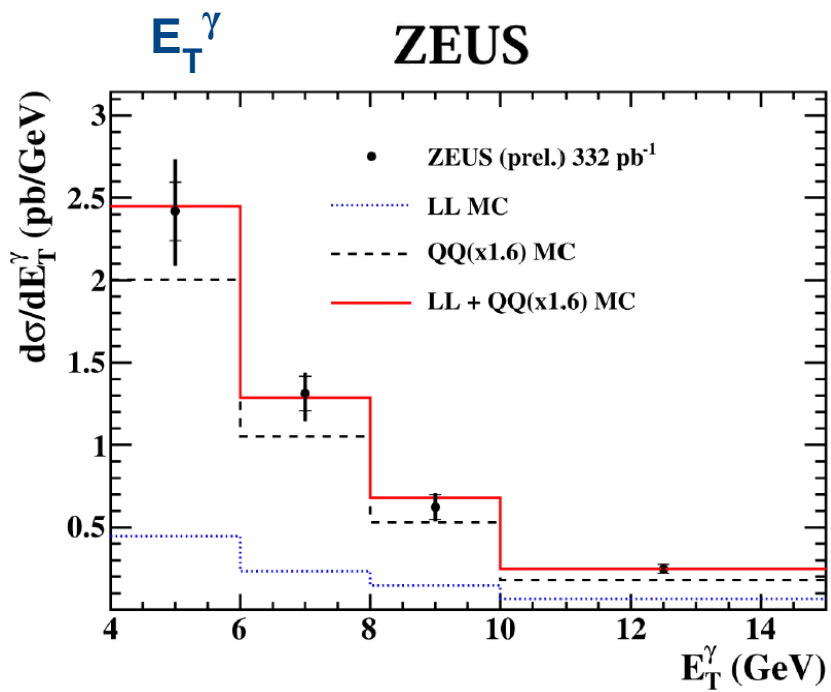
ZEUS



Q^2 = squared momentum transferred from initial to outgoing lepton
 x = Bjorken variable

The reweighted Q^2 fit is good, as it should be.
Resulting x distribution is well described by the model.

.So look at the photon and jet variables:



Summary:

- Measurements of prompt photons with jets in DIS have been made by ZEUS using the full HERA II data sample.
- Results are well described by PYTHIA model.
- Preparing to compare to NLO theories next.