University of Glasgow | Experimental Particle Physics

Prompt photons in DIS

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For the ZEUS Collaboration

PHOTON 2009

We study prompt photon production because:

- **the emergence of a photon directly from a QCD-governed interaction allows particular diagrams to be studied: new perspectives on QCD processes**

- **the photon does not suffer from the process of fragmentation that complicates the study of parton jets**

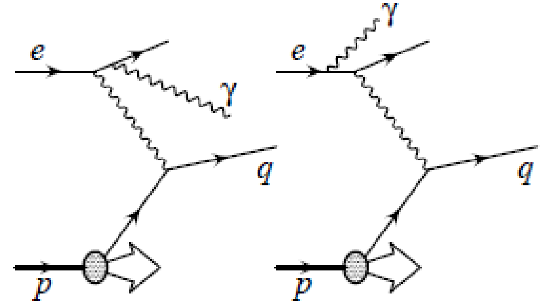
Deep inelastic scattering provides a particular environment to study prompt photons, presents its own challenges and allows theory to be tested from new viewpoints.

Theoretical approach of
A Gehrmann – De Ridder,
T. Gehrmann and E. Poulson.

Phys. Rev. Lett. 96 132002 (2006)

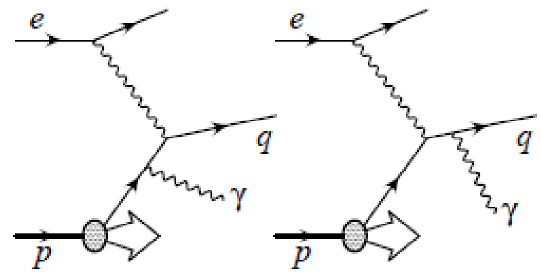
LO(α^3) with three components:

Top - photon radiated from in-coming or outgoing lepton. LL



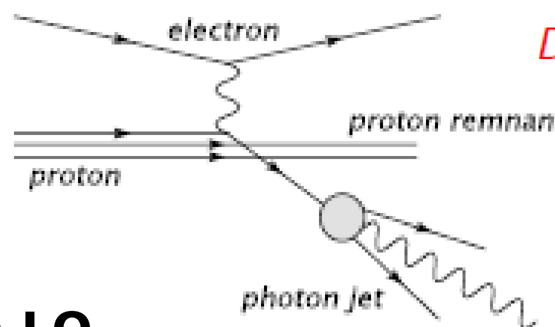
LL

Middle - photon radiated from a quark. QQ



QQ

Bottom: photon from jet frag-mentation $D_{q\to\gamma}(z)$



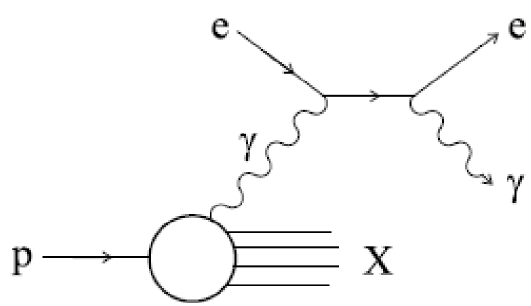
$D_{q\to\gamma}(z)$

Total = LL + QQ + D $_{q\to\gamma}$(z)

Neglect the small interference term LQ.

Another approach from MRST

Eur Phys J C39 (2005) 155



Here the proton is assigned a photon content and the photon scatters off the lepton. There is also an initial-state radiative diagram.

MRST neglect the quark fragmentation component. Also the proton-radiated photon does not have to be hard. In the other model there is a QQ diagram that seems absent from the GdR model.

So we expect MRST to give lower predictions.

The present analysis: inclusive prompt photons in DIS.

We use 320 pb^{-1} of ZEUS data, updating our first analysis.

Definitions:

$Q^2 = (k - k')^2$ where k, k′ = 4-mom. of incoming and outgoing electrons

$x = Q^2/2P.(k - k')$ where P = 4-mom. of incoming proton.

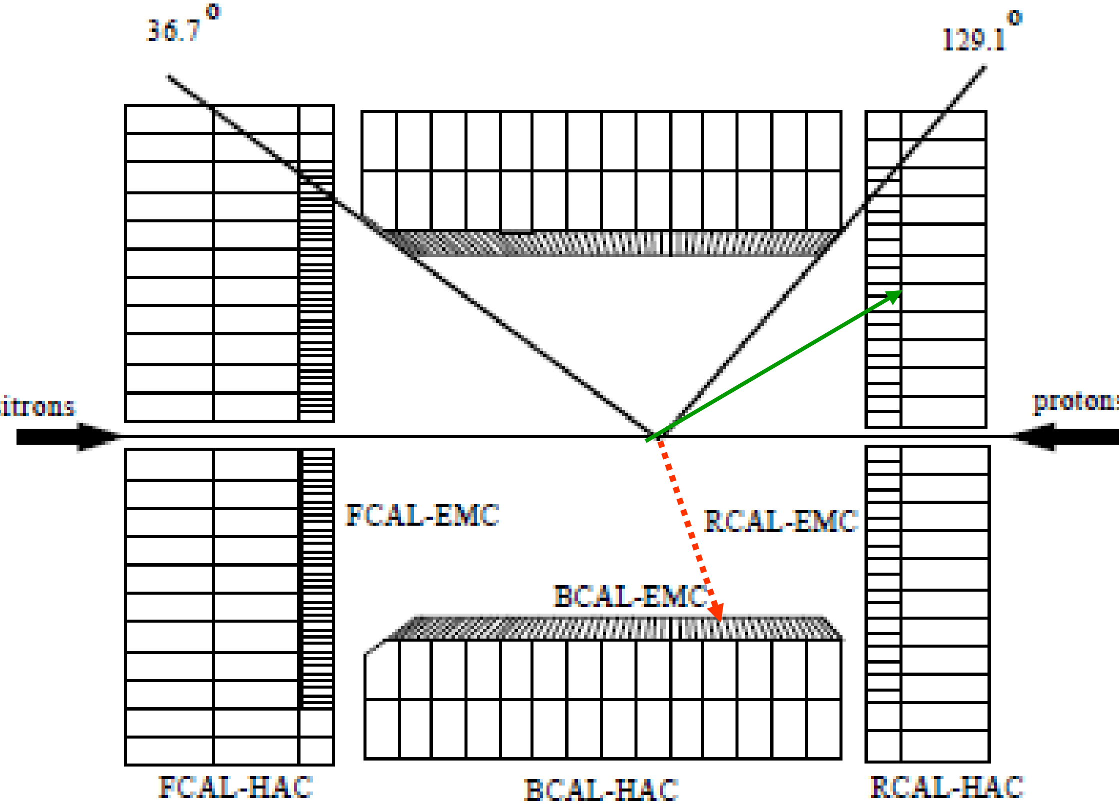
Kinematic selections

Outgoing electron:	$E_e > 10$ GeV
Electron scattering angle:	$140° < \theta_e < 172°$
DIS scatter:	$10 < Q^2 < 350$ GeV^2
Prompt photon:	$4 < E_T < 15$ GeV
Photon rapiditiy:	$-0.7 < \eta < 0.9$
Photon isolation:	0.1

The photon isolation was imposed by requiring that in a k_t cluster "jet" containing the photon, the photon had at least 90% of the E_T of the "jet".

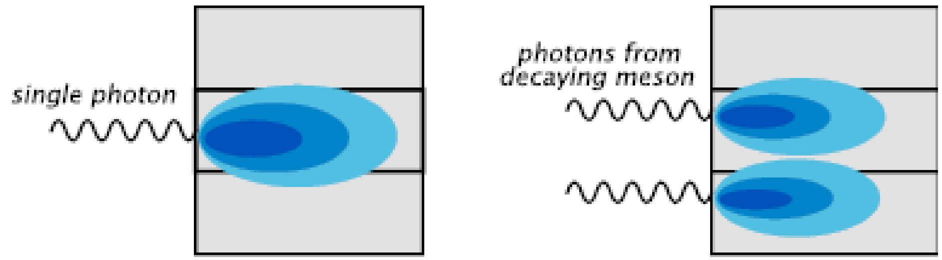
The challenge:

Distinguish a photon signal from a back-ground of neutral mesons (mainly π°, η°) in the ZEUS barrel electromagnetic calorimeter BCAL.



The energy is deposited in cells of the BCAL-EMC

Cells are 5cm in z-direction and ~20 cm in azimuth. A single photon is often quite well contained in one cell.



An algorithm is applied to identify photon candidate as a cluster of calorimeter cells.
The energy must be nearly all contained in the BCAL-EMC.

Two shower shape parameters are used:

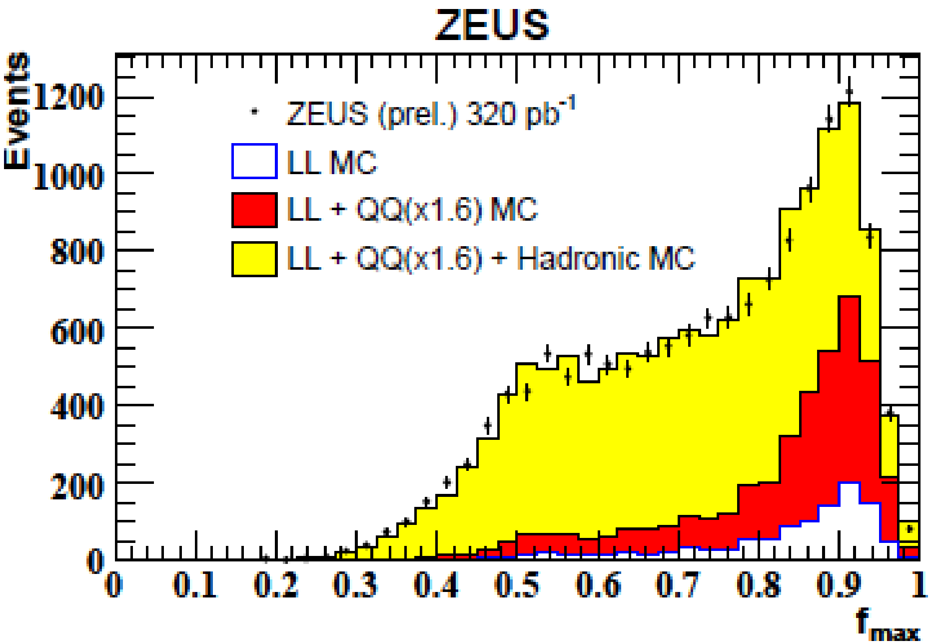
1) f_{max} = fraction of cluster energy in EMC cell with highest energy

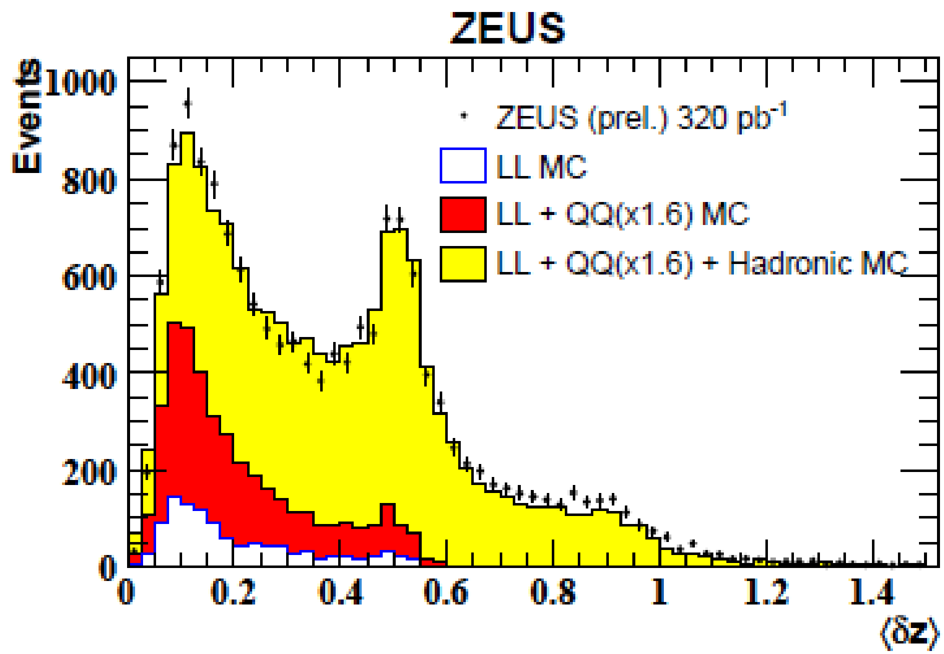
2) $\langle \delta z \rangle$ = mean z width of cluster averaged over cells.
$$= \Sigma_i \; E_i \, (z_i - z_0) \; / \; w \, E_{TOT}$$

where z_0 = energy centroid of cluster
w = width of a cell in z

We fit the distributions using PYTHIA for the QQ part of the cross section and ARIADNE for the LL part, and for the neutral hadron background.

Global fits of data to signal + background:





(The fitted histograms are cumulative.)

f_{max} (left) - photon signal (total = red) peaks at high end.

<δz> (right) – photon gives a narrow peaks at 0.1, and a π° signal is clearly seen at <δz> = 0.5

Overall the fits are good.

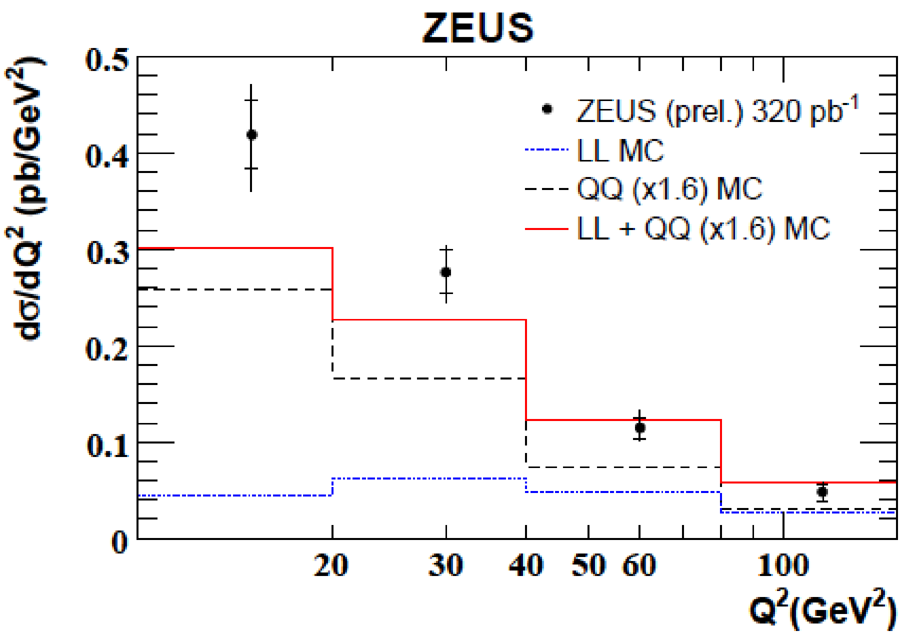
Systematic uncertainties:

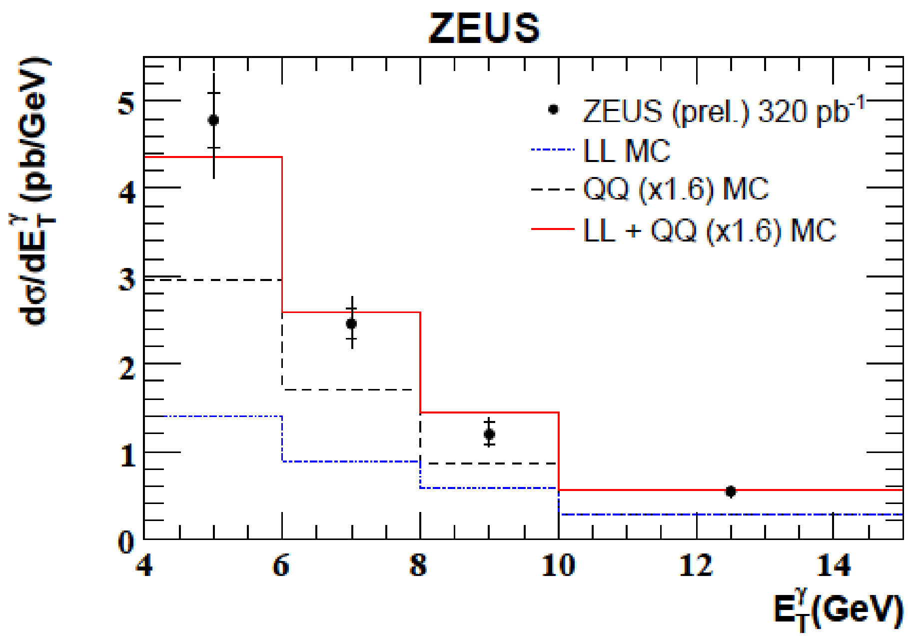
The main systematic uncertainties were

- **Uncertainty on shape of background in <δz> plot (±5 %, by varying fitting range)**
- **Use f_{max} instead of <δz> (up to 5%)**
- **Energy scale of EMC (up to 2%)**
- **EMC energy fraction cut (< 2%)**

Varying the other selections and apparatus cuts produced effects typically up to 1%.

Results: prompt photon cross sections vs Q^2 and photon E_T



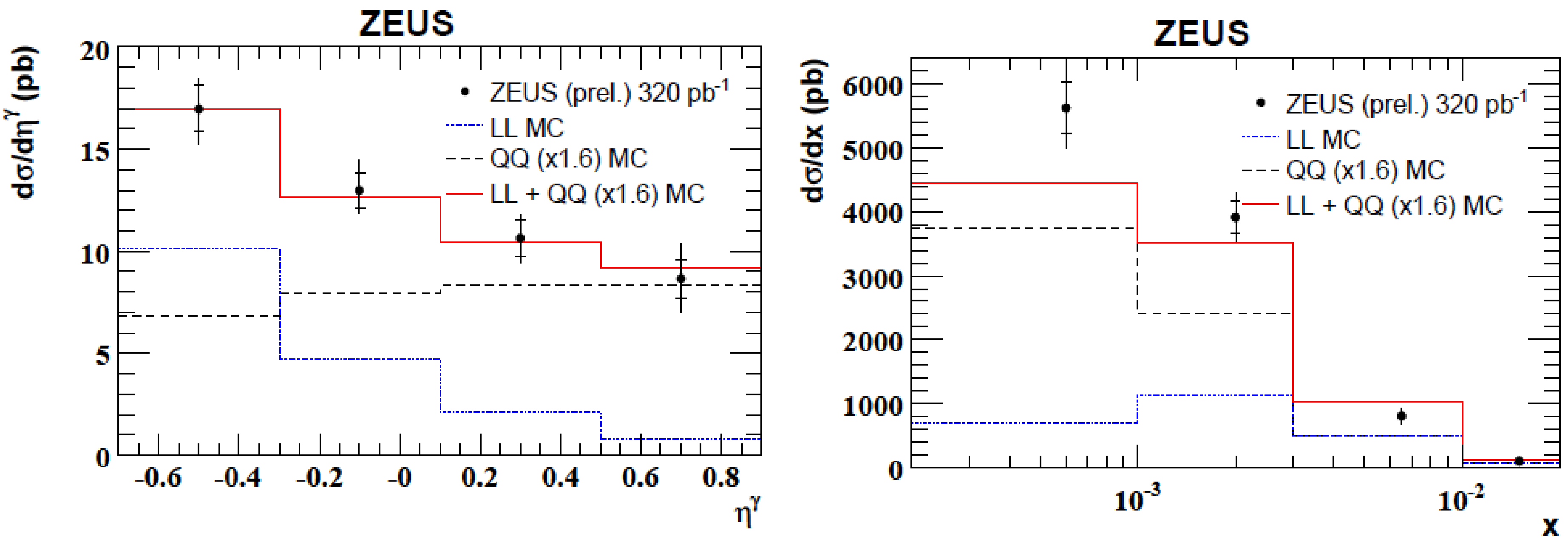


Q^2 is plotted only up to 150 GeV^2 but in the other plots the full range up to 350 GeV^2 is used.

The LL component of the theory is plotted unscaled.
The QQ component is plotted scaled by 1.6 to give a good representation of the data.

Not good for low Q^2 but shape of the E_T distribution is good.

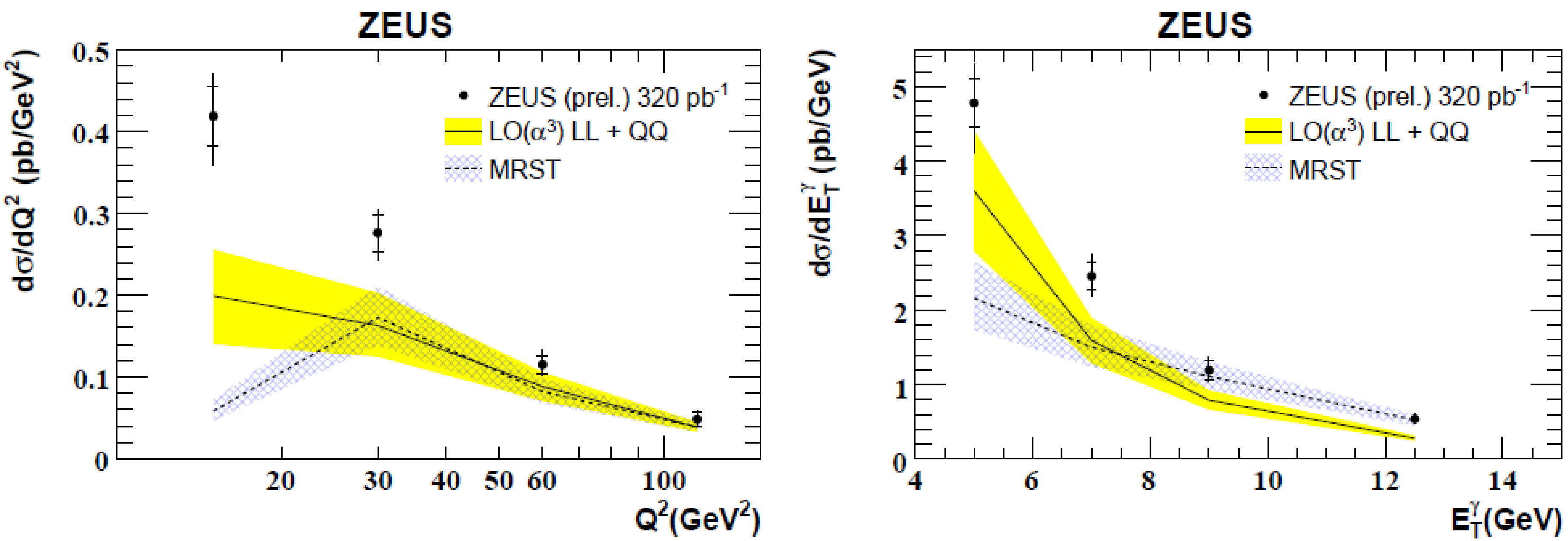
Results: prompt photon cross sections vs γ and x.



Standard kinematic selections.
The η distribution is good, but the x distribution falls more steeply in the data than in the model.

First HERA x distribution for this channel.

Results: cross sections compared to theories



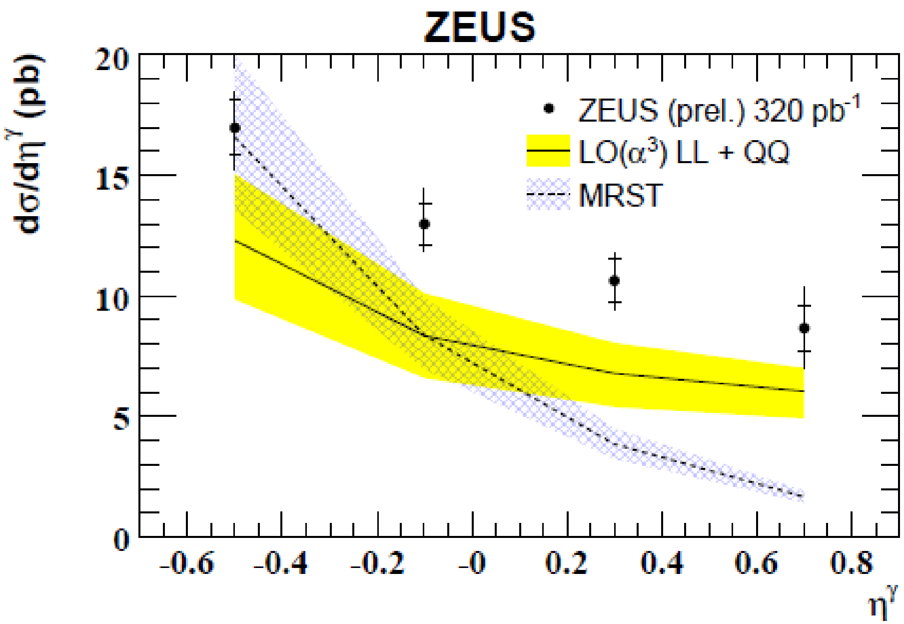
Yellow: GdRDP Yellow band = multiply factorisation scale by 0.5, 2.

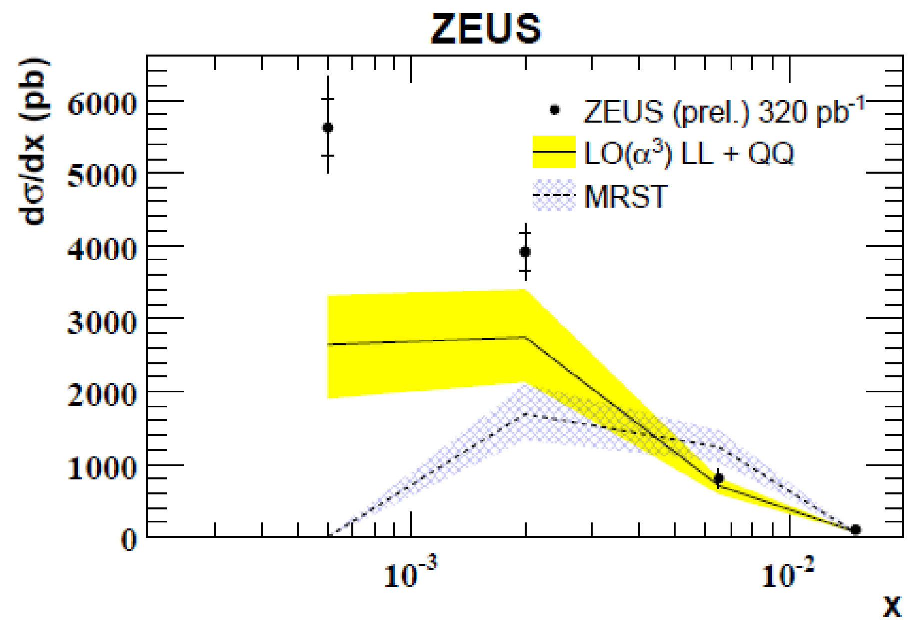
Grey: MRST. Band is theory uncertainty on same basis.

No hadronisation corrections have been applied.

Both theories low at low Q^2. GdRDP E_T shape OK, MRST good at high E_T.

Results: cross sections compared to theories

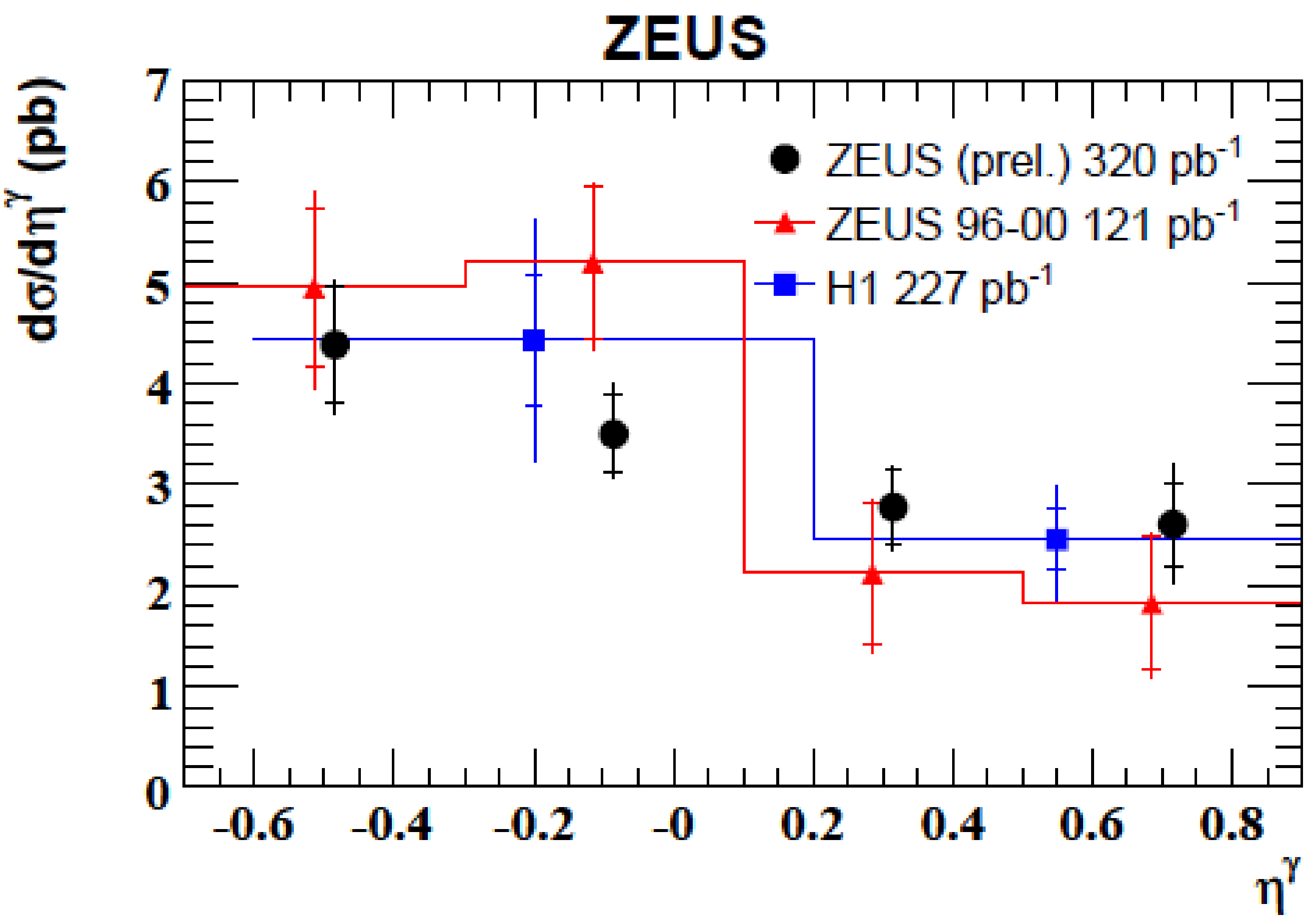




GdRDP et al has good shape in η but low overall.
MRST falls off with η as perhaps expected for process dominated by lepton radiation model.

Both theories are low at low x.

Results: cross sections compared to previous measurments



For compatibility we now restrict Q^2 to 35- 350 GeV^2 and E_T to 5-20 GeV.

Good agreement with earlier ZEUS and H1 results.

Conclusions

- **We have measured inclusive prompt photon cross sections in DIS using the ZEUS detector at HERA**

- **Broader kinematic range than before and higher integrated luminosity now available.**

- **Various differential cross sections presented. Agreement with previous results.**

- **MC model gives reasonable description if the QQ component is scaled, but discrepancies at low Q^2 suggest need for higher order calculation.**

- **Comparisons to LO theory of GdRDP and with photonic proton model of MRST. Rough agreement observed.**

Detailed candidate selection (M. Forrest)

DIS electron selection

- $E'_e > 10$ GeV
- Electron is in RCAL
- Box Cut :
  $|x| < 14.8$ cm,
  $-14.6 \text{ cm} < y < 12.5$ cm

DIS event selection

- $35 \text{ GeV} < E - P_z < 65$ GeV
- $|Z_{vertex}| < 40$ cm
- # vertex tracks NOT in RCAL ≥ 1
- $10 \text{ GeV}^2 < Q^2_{electron} < 350 \text{ GeV}^2$

Photon candidate selection

- $4 < E_T^\gamma < 15$ GeV
- $-0.7 < \eta^\gamma < 0.9$
- No track within 0.2 in (η, ϕ)
- $\frac{\text{candidate EMC Energy}}{\text{Total candiate Energy}} > 0.9$
- $\frac{\text{candidate energy}}{\text{energy of jet containing cand.}} > 0.9$

Using k_T clustering, R=1, mode 3211, E recombination scheme.