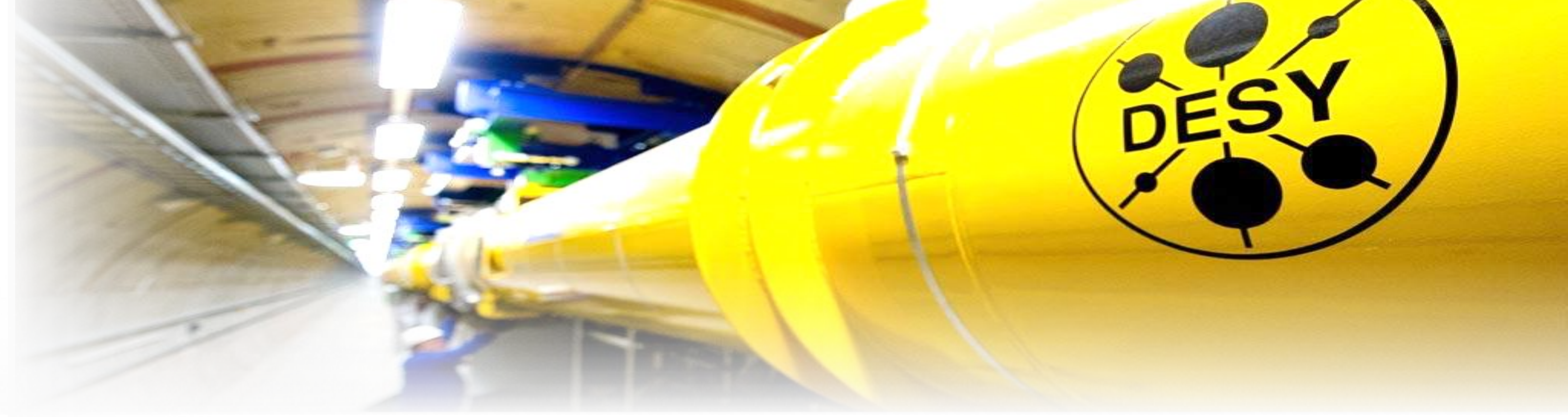
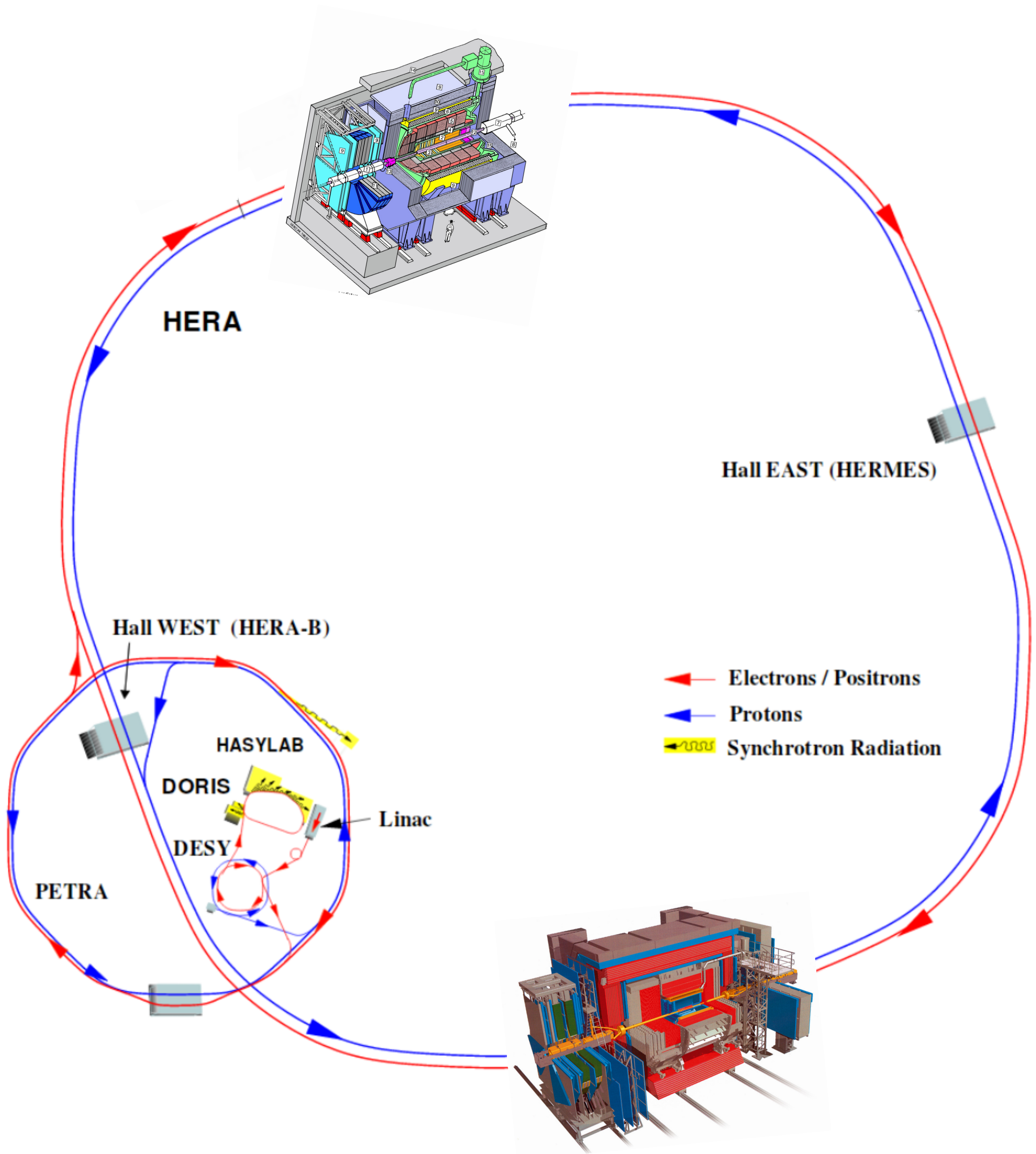


Prompt proton production in DIS at HERA

V. Myronenko,
For the ZEUS Collaboration

Low x Meeting
Brisceglie, Italy 2017

The HERA collider and the experiments



Location: Hamburg, Germany

Research operation: 1992 - 2007

Length: 6336 m

Proton and electron (positron) beams

4 experimental halls

2 experiments on colliding beams

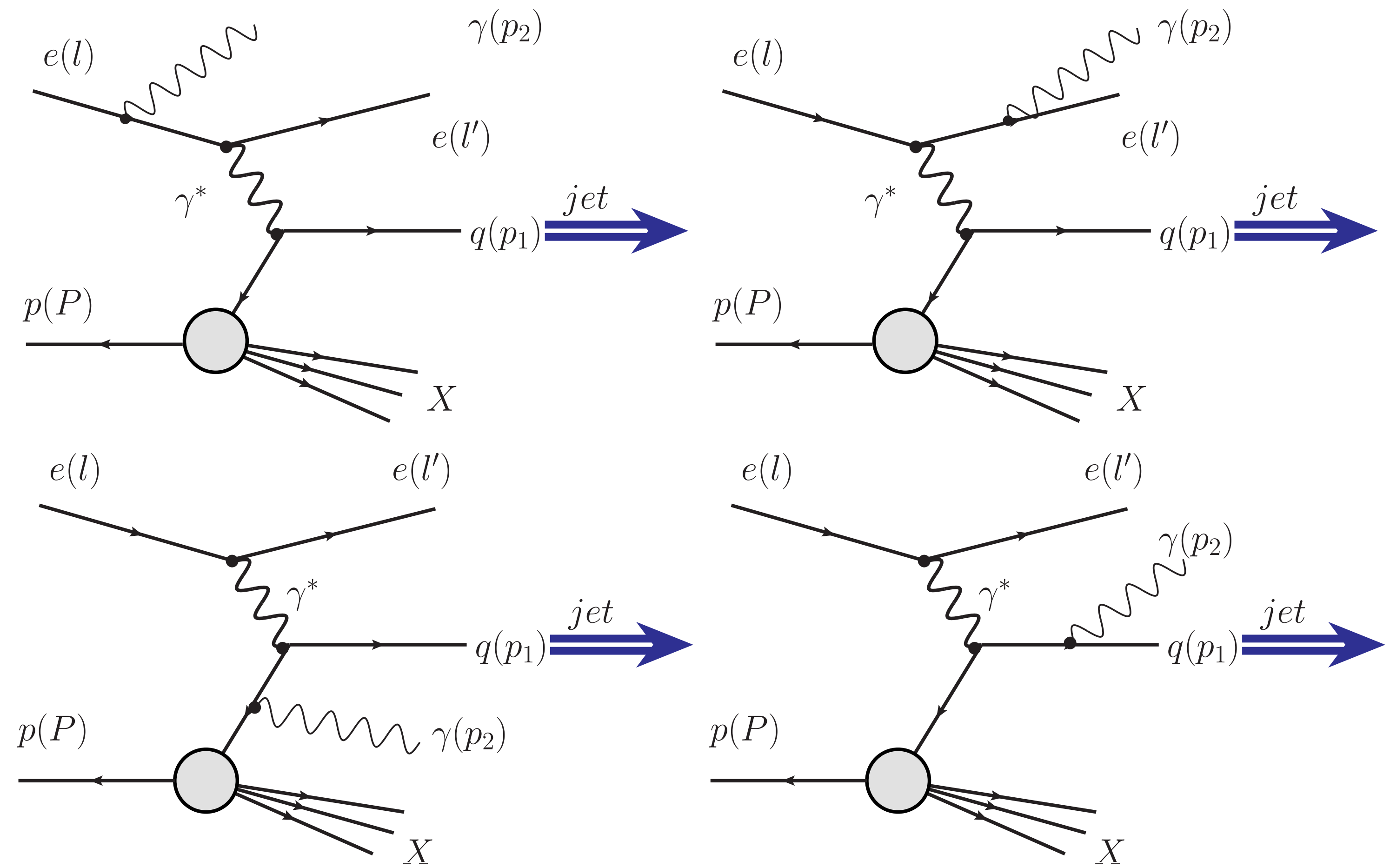
$$E_P = 920(820, 575, 460)GeV$$
$$E_e = 27.5GeV$$
$$\sqrt{s} = 318(300, 252, 225)GeV$$

DIS regime: $Q^2 > 1$ GeV^2

Prompt photons at DIS

High-p_T photons produced in the *ep* scattering before hadron formation:

- Radiated from the incoming or outgoing lepton (l- , FSR, **LL**)
- Produced in a hard partonic interaction (**QQ**)



Only isolated photons are of interest!

Prompt photons at DIS

- Direct photons emerge promptly from the hard scattering process;
- Prompt photons may give an insight on proton's PDFs;
- Form background to many processes studied at the colliders;
- Combined variables (photon, electron, jet) give more detailed view on the reaction + detailed theory tests.

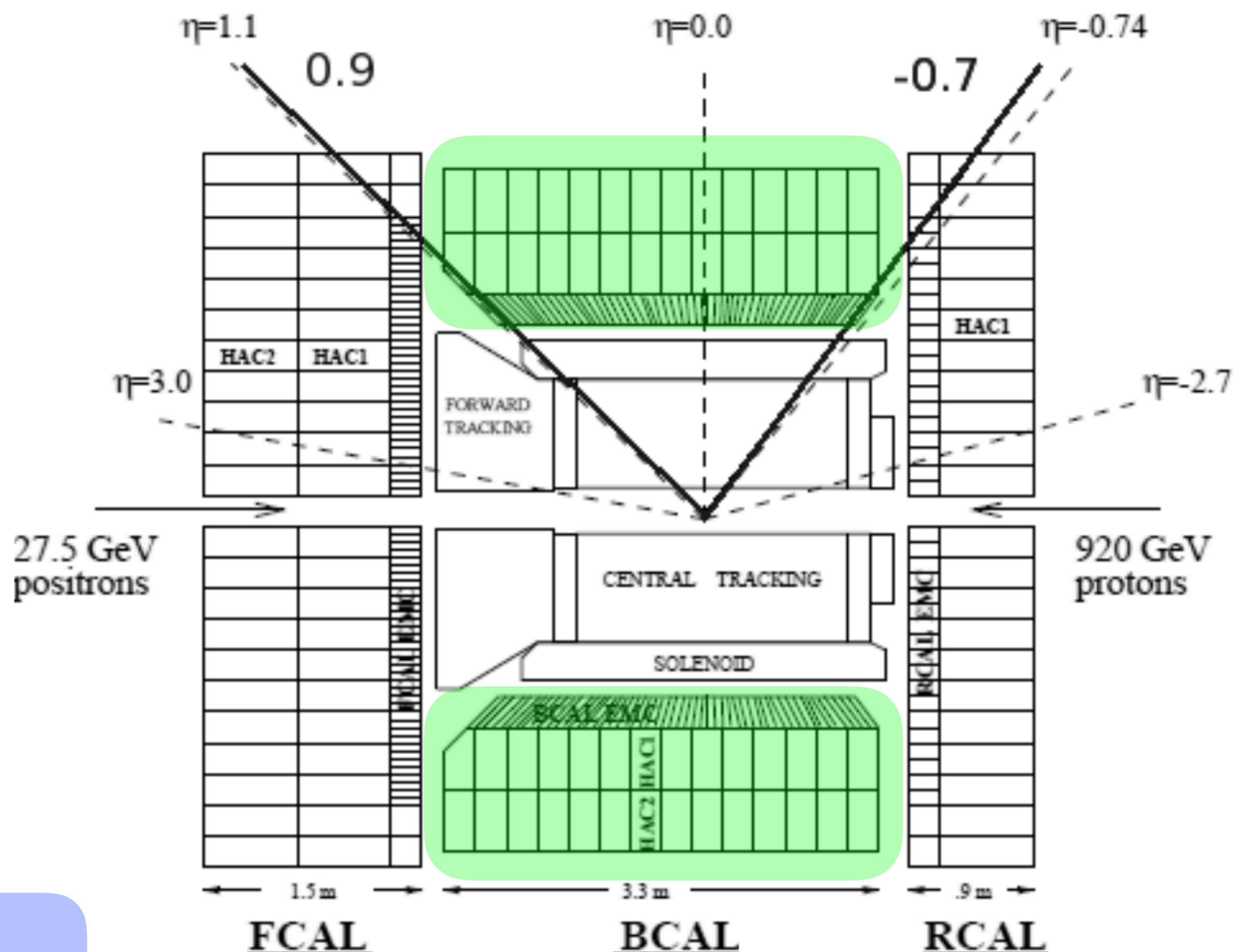
Phys.Lett. B715 (2012) 88-97, [arXiv:1206.2270]

Event selection

$10 < Q^2_{el} < 350$ GeV^2
$E_{el} > 10$ GeV
$140° < \theta_{el} < 180°$
$35 < E - p_z < 65$ GeV

Hadronic jet:
Jet with $E_{max\ T}^{jet}$
$E_T^{jet} < 2.5$ GeV
$-1.5 < \eta_{jet} < 1.8$

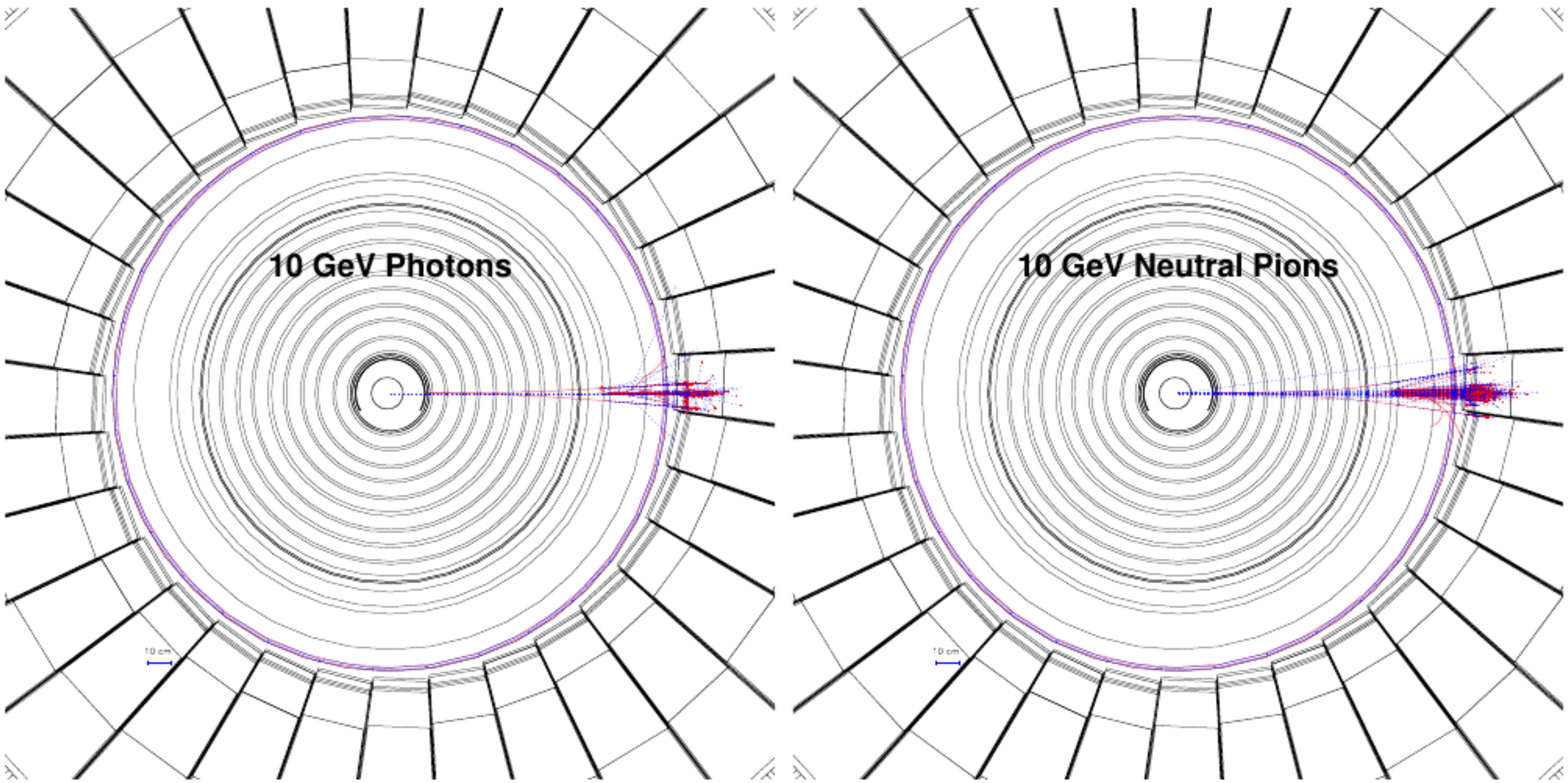
Prompt photon:
$4 < E_T^{\gamma} < 15$ GeV
$-0.7 < \eta_{\gamma} < 0.9$
$\Delta R(\eta,\phi) < 0.2$
$E^{\gamma} / E_{jet} > 0.9$
$E_{EMC} / (E_{EMC} + E_{HAD}) > 0.9$



Irreducible background

Contribution from neutral-meson decays - irreducible!

$\pi^0 \to \gamma\gamma$ $\eta \to \pi^0\pi^0\pi^0(\gamma\gamma)$



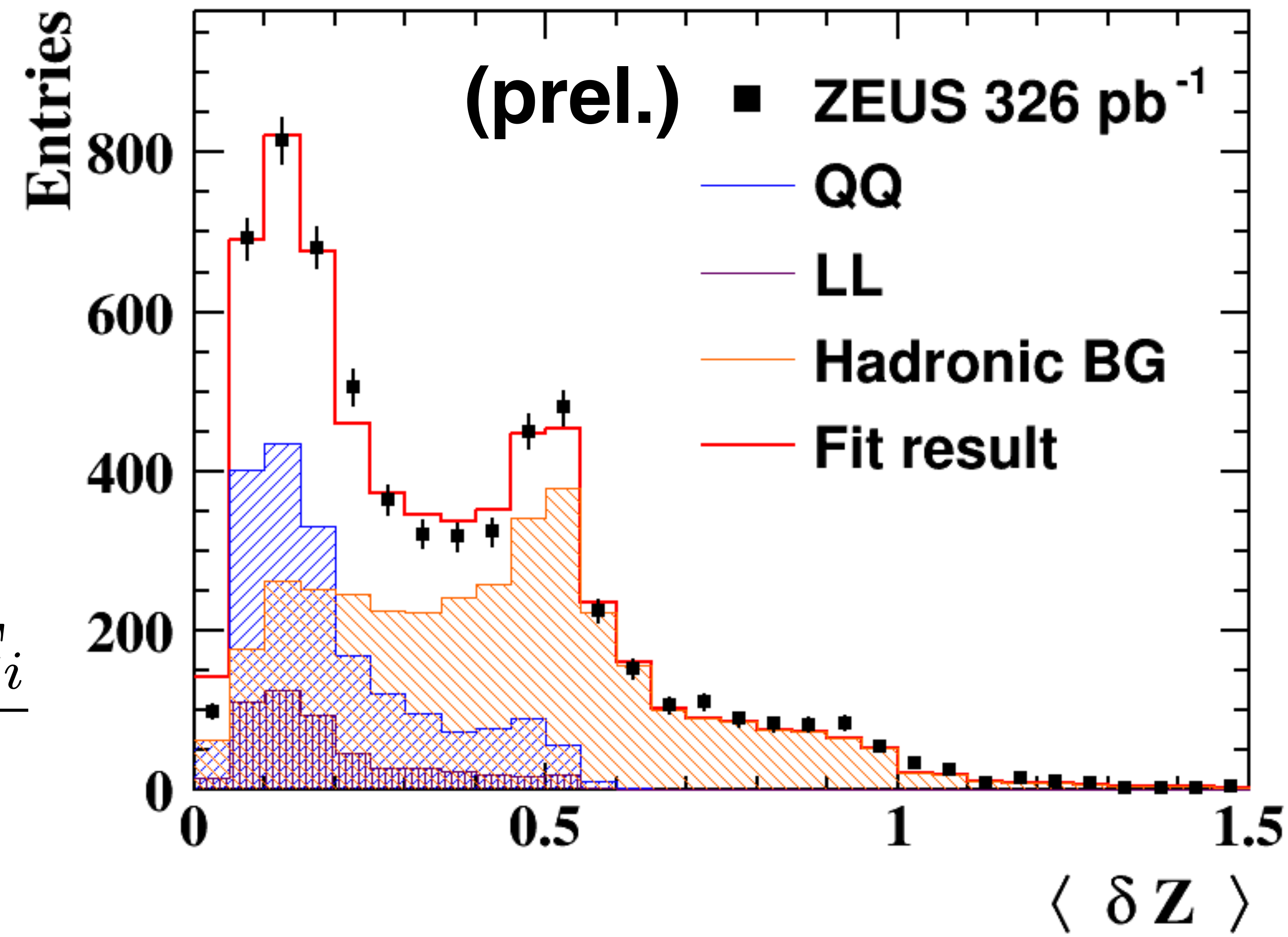
Neutral-meson produce **broader energy deposits**

Irreducible background

Template fit to

energy-weighted mean width of an EM cluster

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



QQ: Pythia 6.4, LL: Djangoh 6 (resolved component - neglected)

Fit produced in each analysed bin!

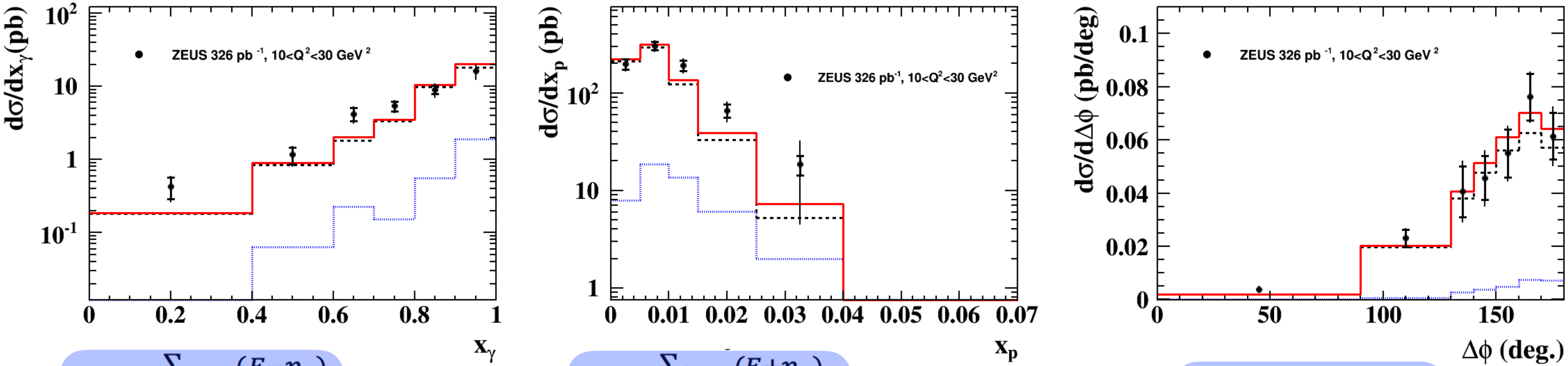
Uncertainties summary

- Typical statistical uncertainty is **13%**
  - ΔAcc – acceptance uncertainty, **~3-4%** effect
- Typical systematic uncertainty is **10%**
  - Dominated by the energy scale
- Fit of fraction of QQ in data
  - Δa – uncertainty of fit parameter, **~1%** effect
- $\Delta\mathcal{L}$ – 2%, but not included in the following plots

Two kinematic regions

- Cross sections for two separate kinematic regions: $10 < Q^2 < 30$ GeV^2 and $30 < Q^2 < 350$ GeV^2 were also calculated
- $Q^2 = 30$ GeV^2 was chosen to divide available data sample into 2 with similar numbers of events

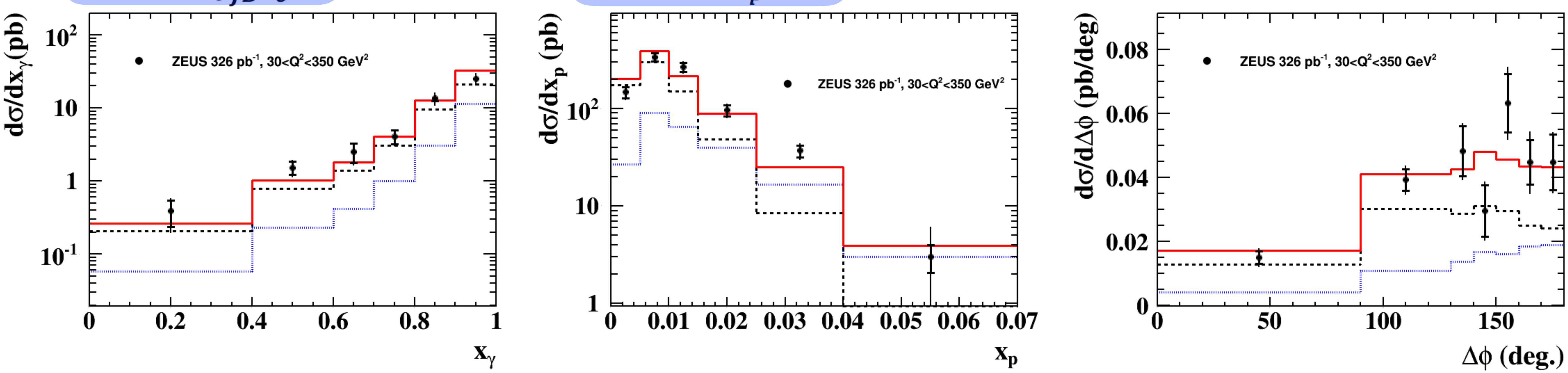
Differential cross sections (prel.)



$x_\gamma = \frac{\sum_{jet,\gamma}(E-p_z)}{2y_{JB}E_e}$

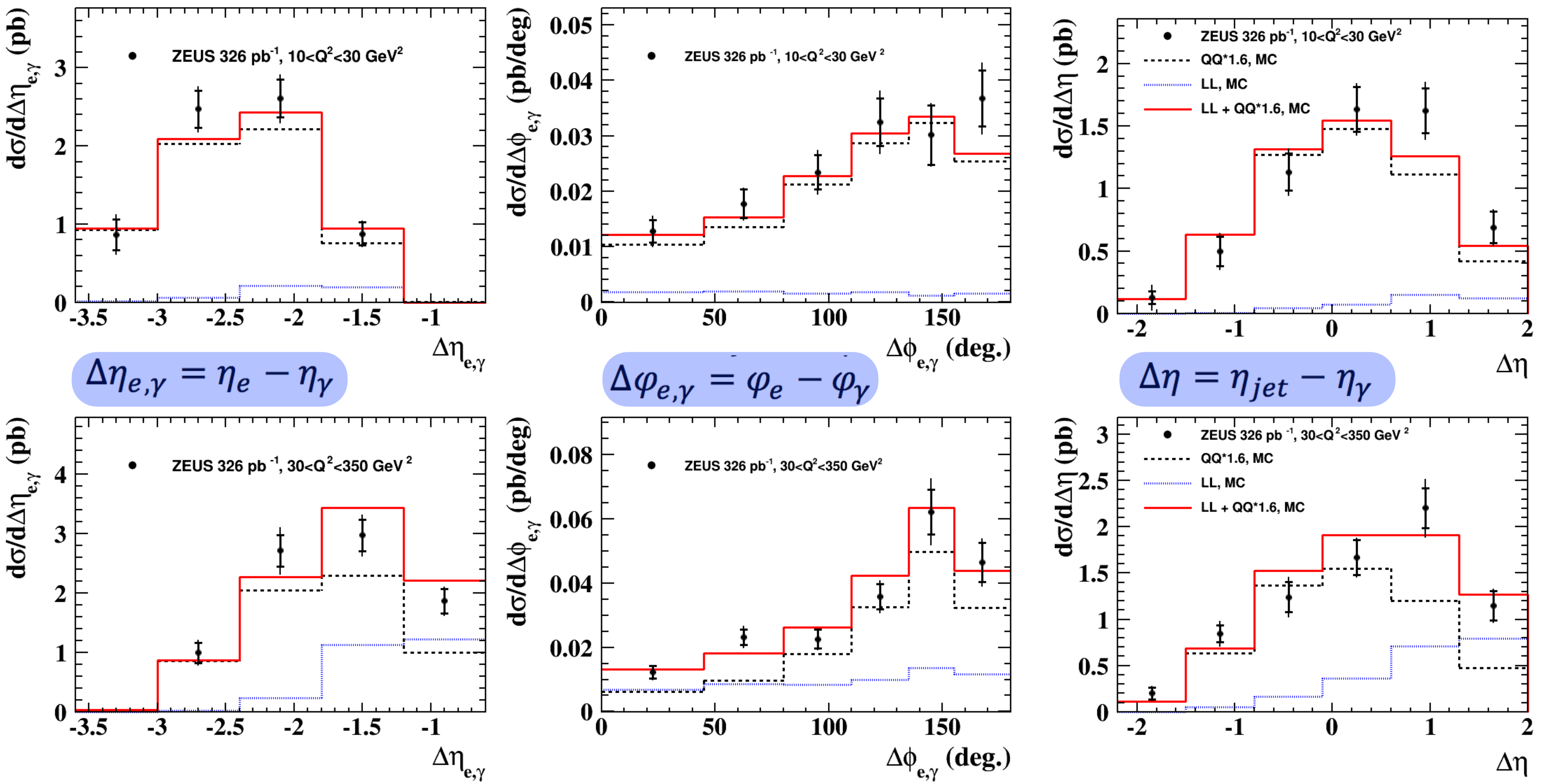
$x_p = \frac{\sum_{jet,\gamma}(E+p_z)}{2E_p}$

$\Delta\varphi = \varphi_{jet} - \varphi_\gamma$



The LL contribution gets enhanced at higher Q^2

Differential cross sections (prel.)



$\Delta\eta_{e,\gamma} = \eta_e - \eta_\gamma$

$\Delta\varphi_{e,\gamma} = \varphi_e - \varphi_\gamma$

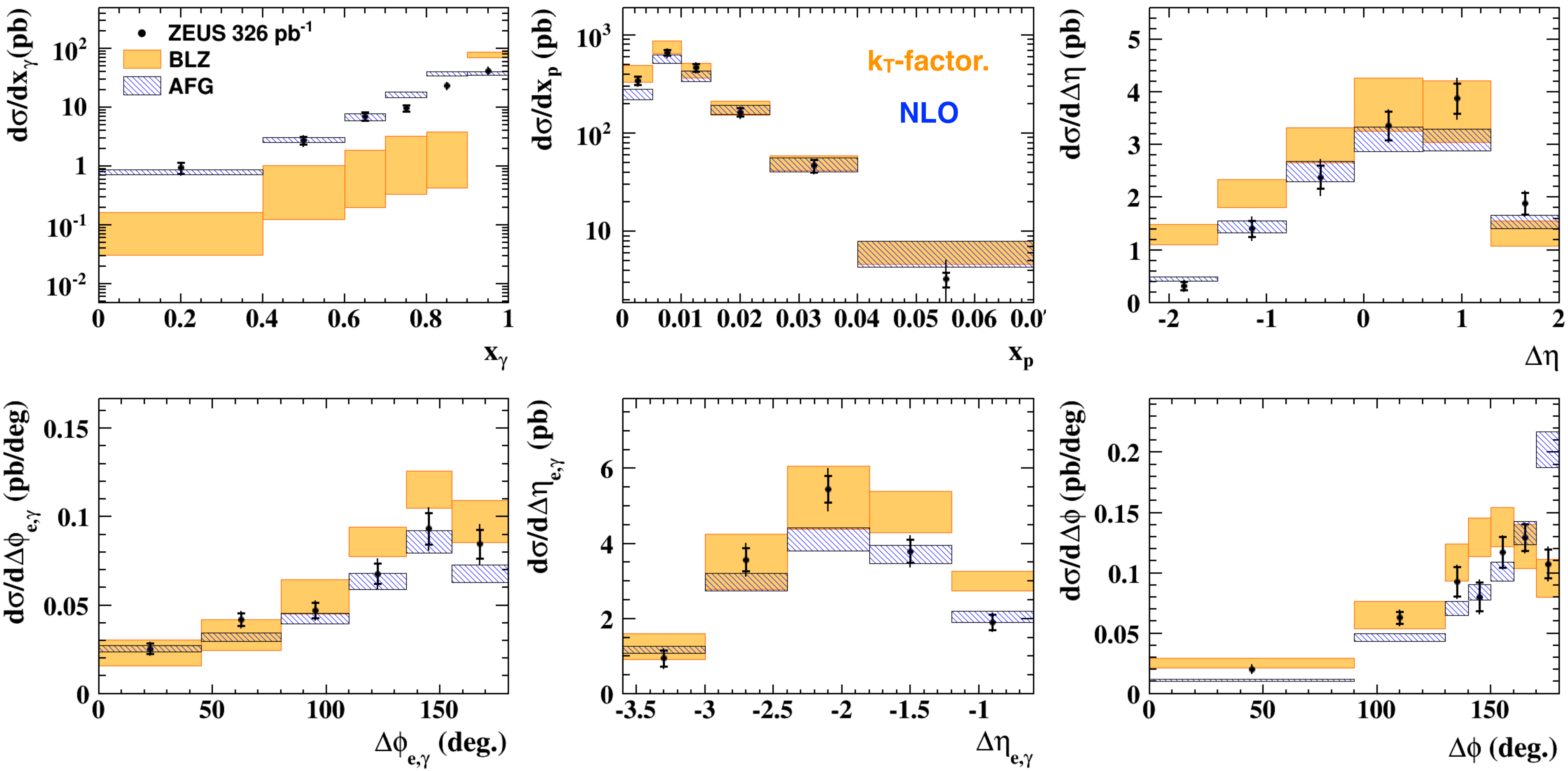
$\Delta\eta = \eta_{jet} - \eta_\gamma$

Reasonable agreement with the measurements.

Theoretical predictions

- Baranov, Lipatov and Zotov (BLZ) : Rev. D 81 (2010) 094034
  - → approach is based on the calculation of the CS using the convolution of the off-shell matrix element and unintegrated quark-distribution (therefore the kt-factorisation).
  - → In the kt-factorization theory some part of final state jets can originate not only from hard subprocess, but also from the parton evolution cascade in initial state.
  - → To determine the 4-momenta of these jets (in particular, their rapidities) model approximation was used
  - → Lambda_QCD = 200 MeV, number of flavours Nf = 4, scale muR^2 = muF^2 = Q^2; MSTW'2008 pdfs as an input for the KMR partons
- Aurenche, Fontannaz and Guillet (AFG) : Rev. D 81 (2010) 094034 – **NLO theory with conventional PDFs**
  - → Predictions are available as CS with pt cut betwen pT_cut in center-of-mass frame 2.5 GeV/c and .5 GeV/c

Cross sections vs theory (prel.)



k_T-factorisation approach follows measurements in selected cases

NLO calculation mostly describes measurements well.

Summary

- Experimental differential cross sections have been obtained for x_γ, x_p, $\Delta\eta$, $\Delta\varphi$, $\Delta\eta_{e,\gamma}$, $\Delta\varphi_{e,\gamma}$ correlated observables
- Pythia describes the shape of the data reasonably well in both Q^2 ranges separately when rescaled by a factor 1.6, as in the previous ZEUS DIS publication
- AFG (NLO) calculations show an overall good agreement to the data
- k_t-factorisation (BLZ) predictions show a fair agreement with the data with the exception of x_γ and $\Delta\eta$

  → However x_γ and $\Delta\eta$ - variables sensitive to the gluon radiation - are reasonably well described by Pythia

Backup
…not necessarily useful