Further studies of isolated photon production with a jet in deep inelastic scattering at HERA

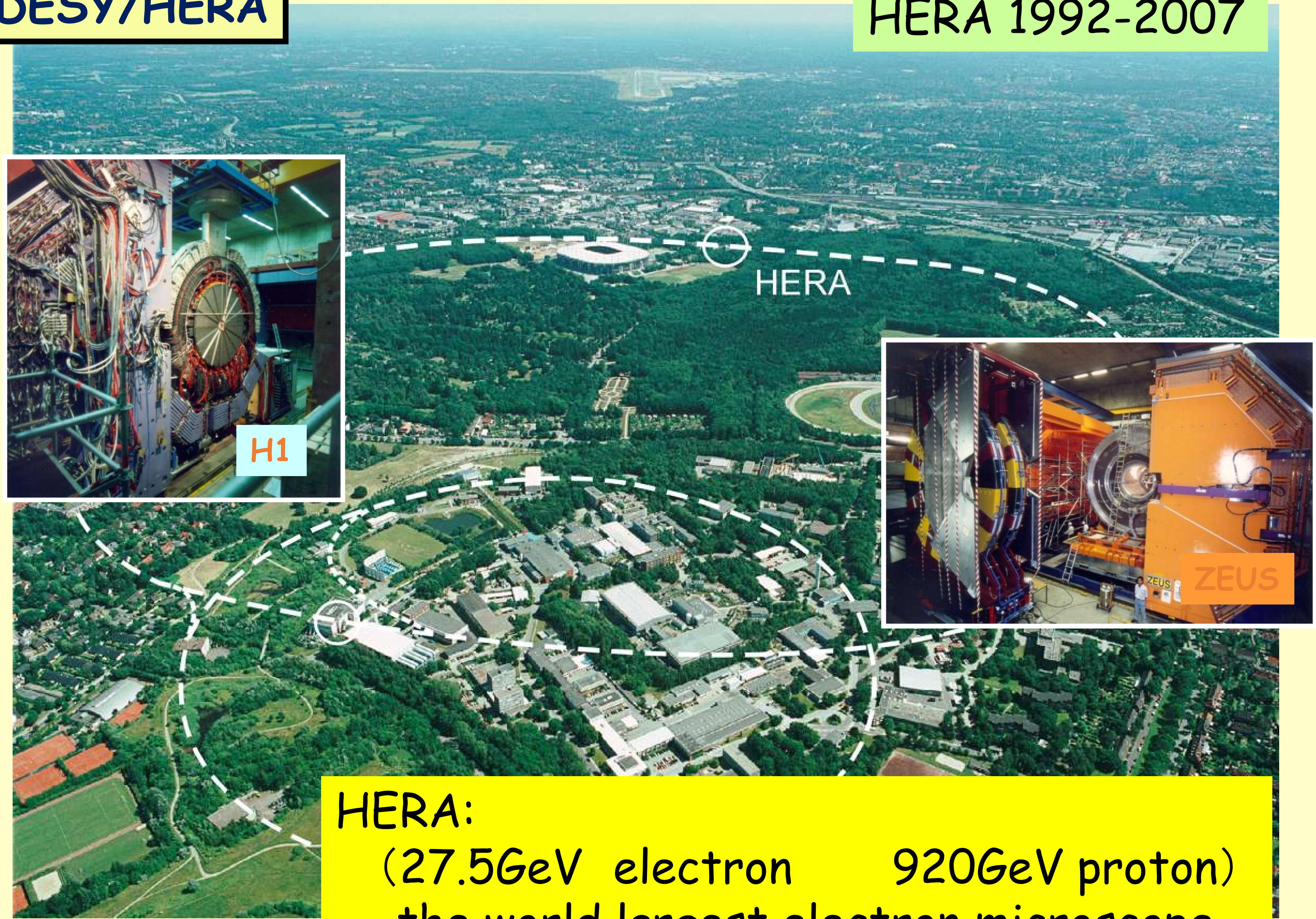
Katsuo Tokushuku

(KEK)

on behalf of the ZEUS Collaboration

DESY/HERA

HERA 1992-2007

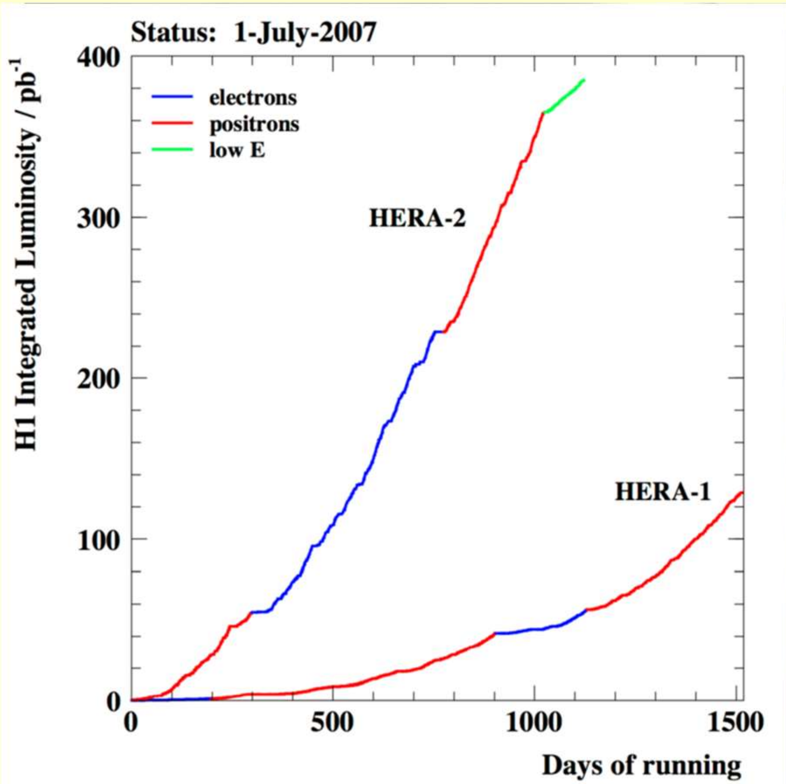


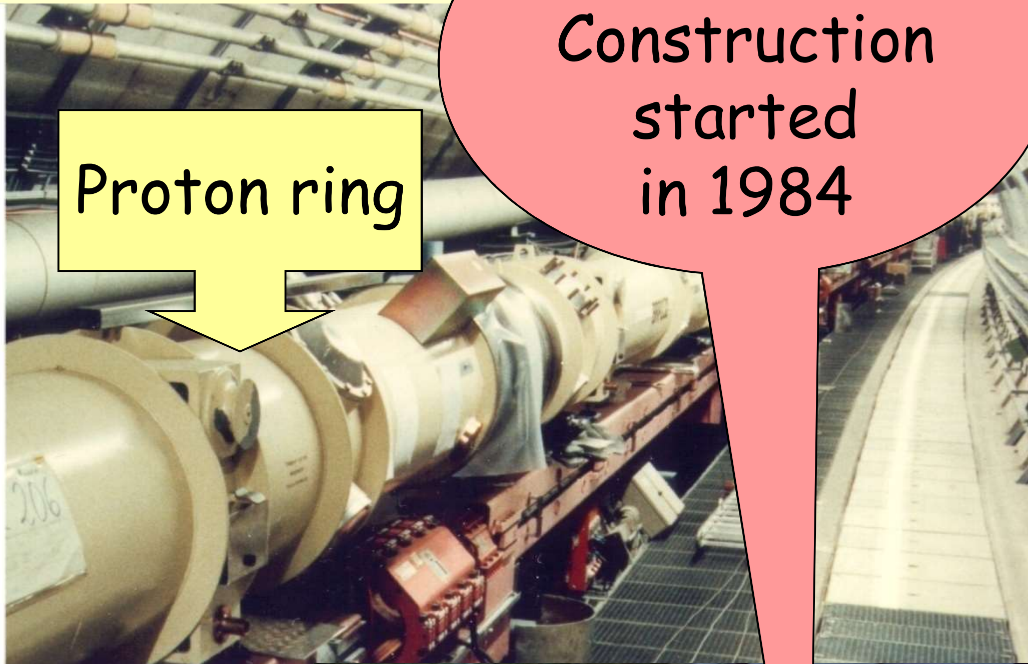
HERA:

(27.5GeV electron 920GeV proton)

the world largest electron microscope

A view of the HERA ring tunnel





Proton ring

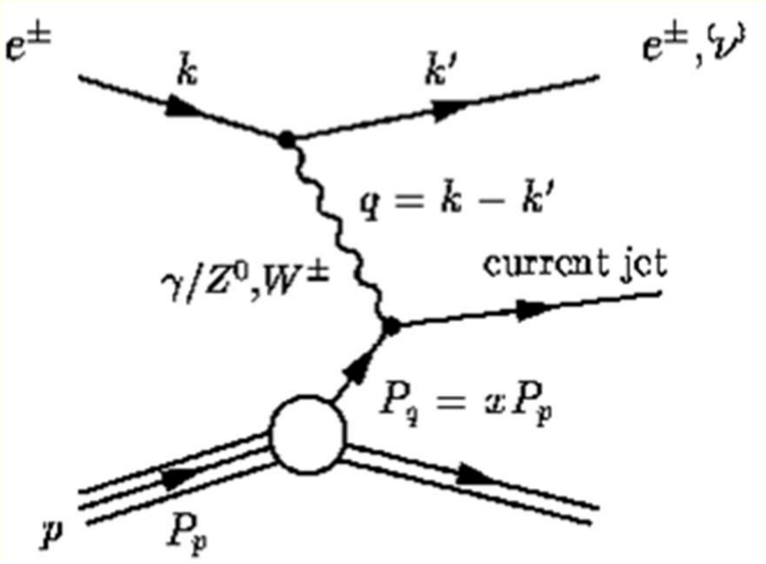
Electron ring

Tunnel Construction started in 1984

DIS scattering

With the DIS, we can analyze structure of the proton.

LO: Naïve Quark-Parton Picture



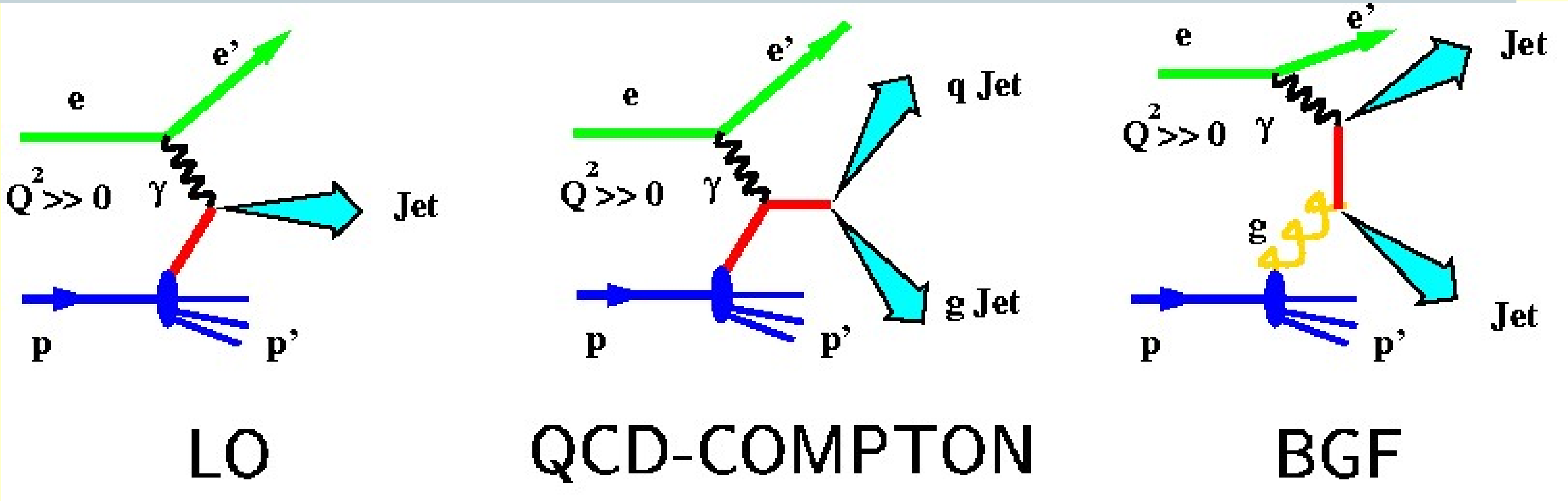
$\sqrt{s}$ = ep cms energy

$Q^2 = -q^2$ = 4-momentum transfer squared (or virtuality of the "photon")

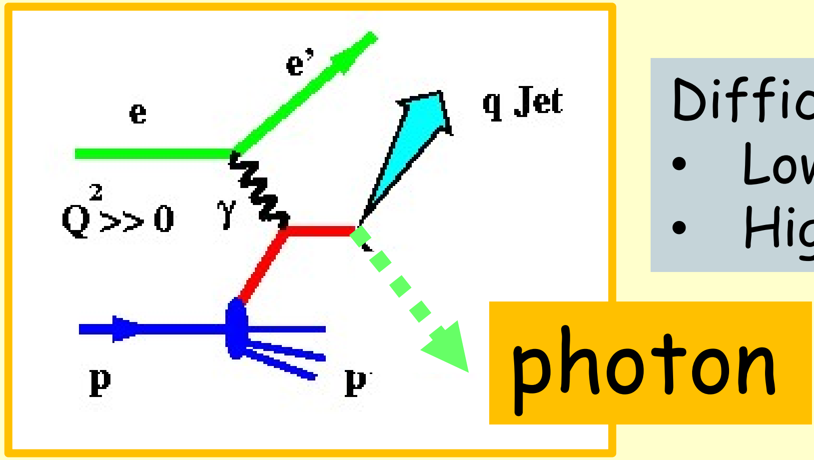
x = fractional longitudinal momentum carried by the struck parton

DIS scattering

… and we can study the QCD evolutions observing the higher order processes.



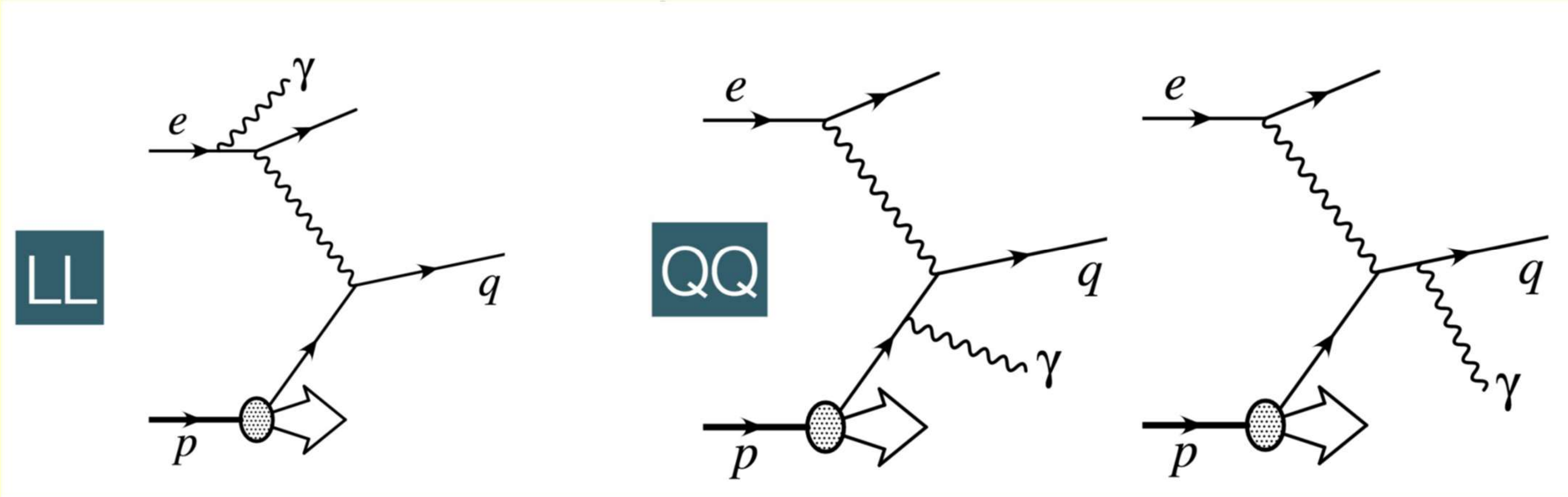
Events with an isolated photon give another type of information.



Difficulties:

- Lower cross section
- High Back grounds

Isolated Photon in DIS



Photon from lepton; well described by the model (DJANGOH HERACLES)

More interesting part:

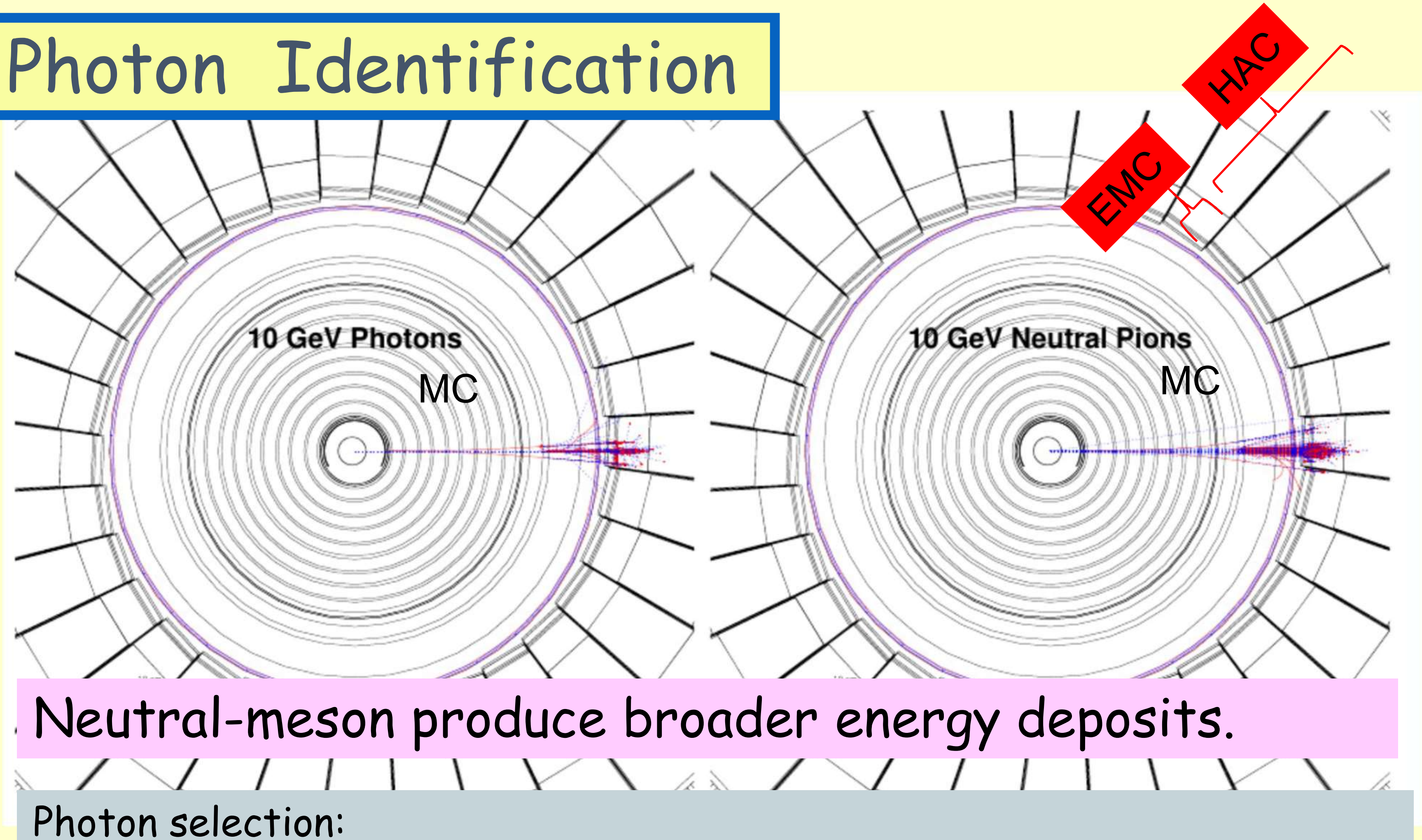
- MC model: PYTHIA
- NLO calculation by Aurenche, Fontannaz and Guillet
- Kt factoriation Model by Baranov, Lipatov, Zotov (including LL component)

In the previous publications, inclusive distributions of photons and jets (PLB 715 (2012) 88) were shown and were compared with theories of NLO and K_T factorization.

Further tests with various jet-photon correlation variables.

-> This talk (and published as JHEP 1801 (2018) 032)

Photon Identification

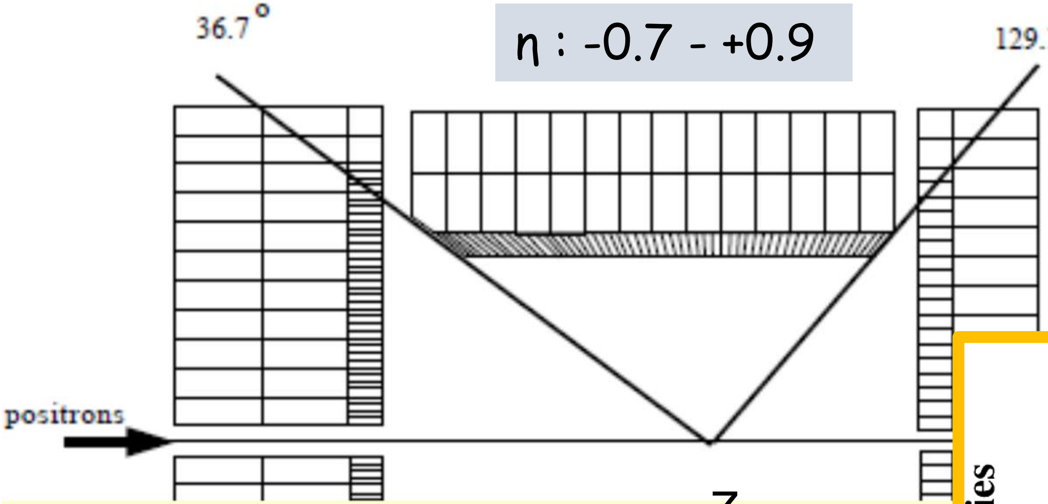


Neutral-meson produce broader energy deposits.

Photon selection:

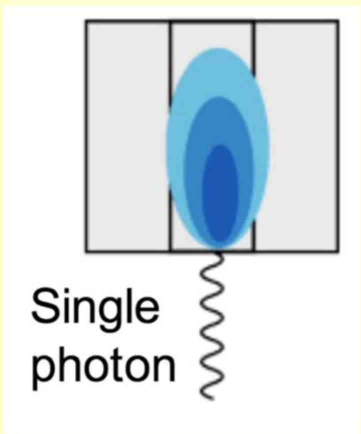
- CAL cluster: Et: 4-15 GeV, η : -0.7 - +0.9
- Isolation Requirement: In the jet containing the photon candidate, the photon contains at least 90% of the jet energy.
- Longitudinal Energy balance in CAL : $E_{EMC}/(E_{EMC}+E_{HAC})>0.9$
- Transverse shape analysis (next page)

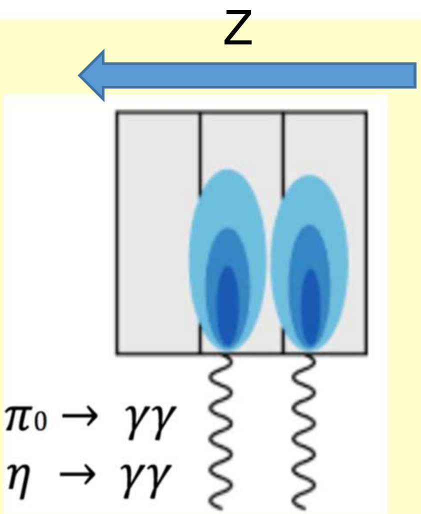
Photon Identification

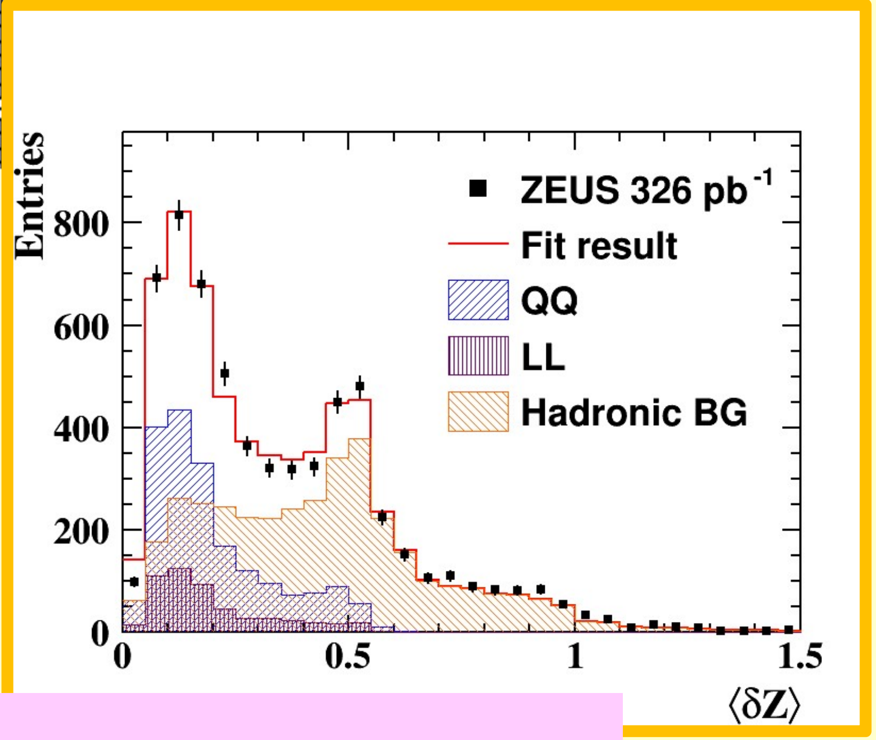


The ZEUS Barrel EM calorimeter (BEMC) has a projective geometry.
-> Good for gamma/pi0 discrimination.

Template fit to energy-weighted mean width of calorimeter EM cluster (<delta Z>).



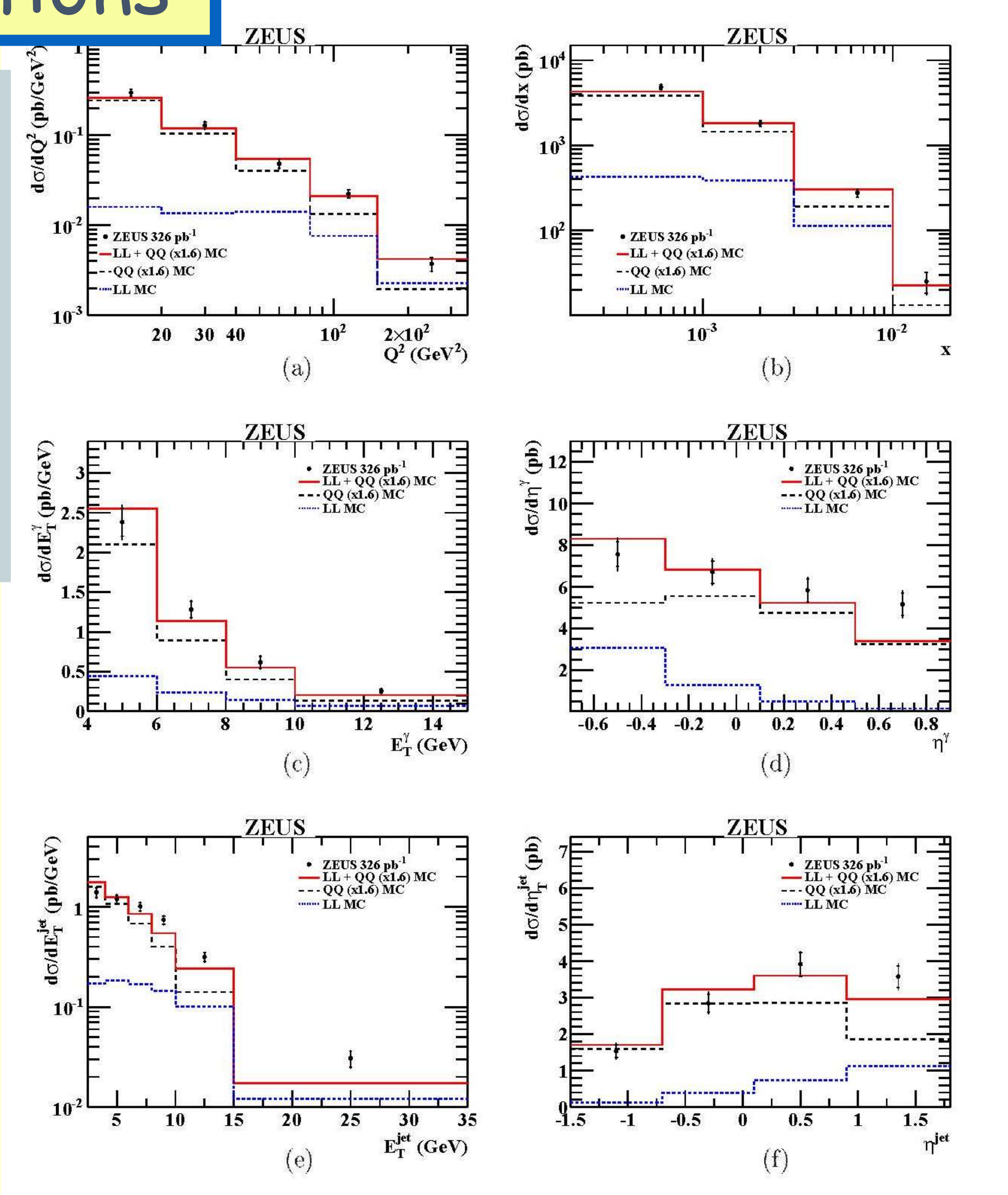




6167 Events including backgrounds
-> 2440 +- 20 events for photon candidates (326 pb^{-1})

Inclusive Cross sections

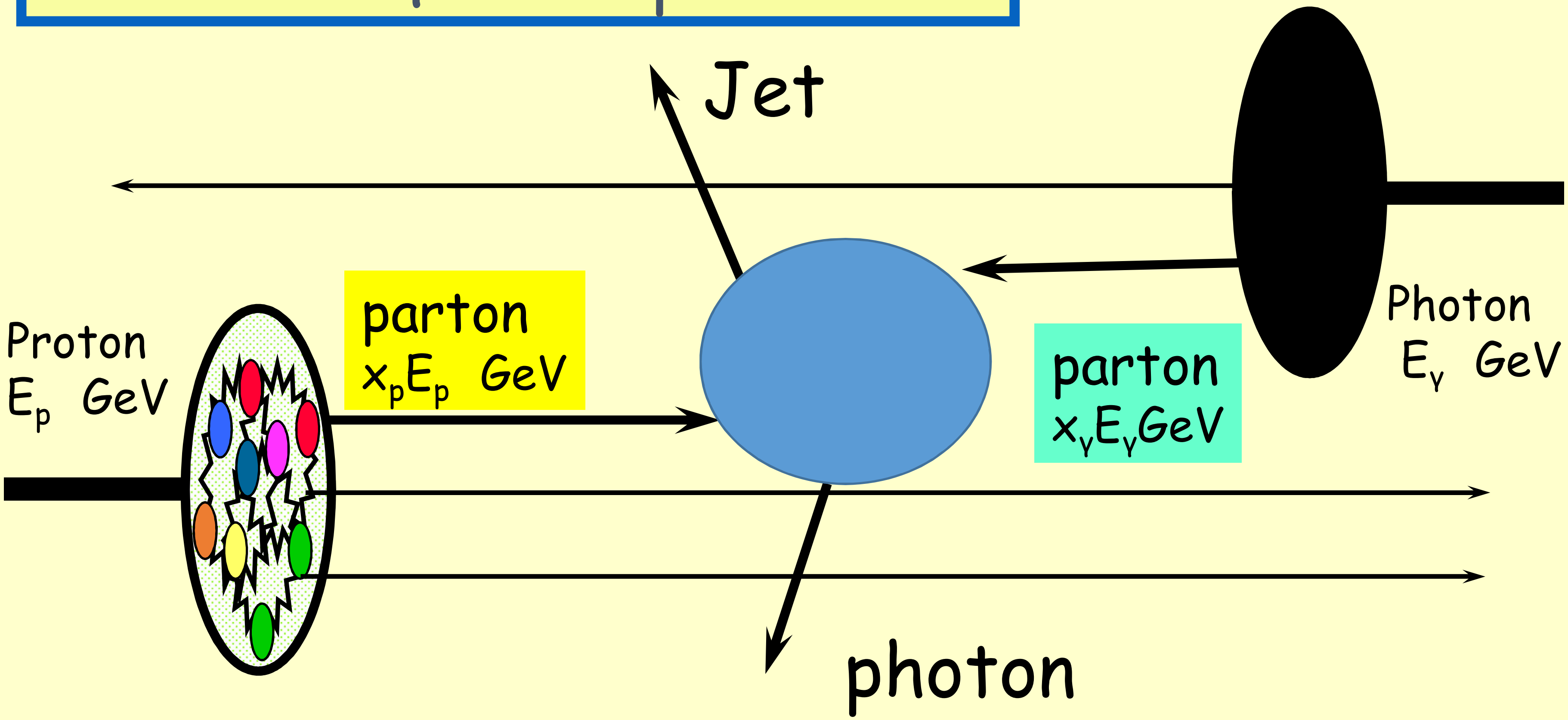
Published as PLB 715 (2012) 88.
Q^2 : 10 – 350 GeV^2
Jet: Et>2.5 GeV, (kT algorithm)
η_{jet} : -1.5 – +1.8
Photon: Et: 4-15 GeV,
η : -0.7 - +0.9
(with isolation cuts)



Good agreement with MC, once LL (DJANGOH HERACLES) and QQ (PYTHIA) contribution is normalized.

-> More comparisons with correlation variables among e, γ and jet

Xγ and Xp



$$x_p^{\mathrm{obs}} = \frac{E^\gamma + p_Z^\gamma + E^{\mathrm{jet}} + p_Z^{\mathrm{jet}}}{2E_p}$$

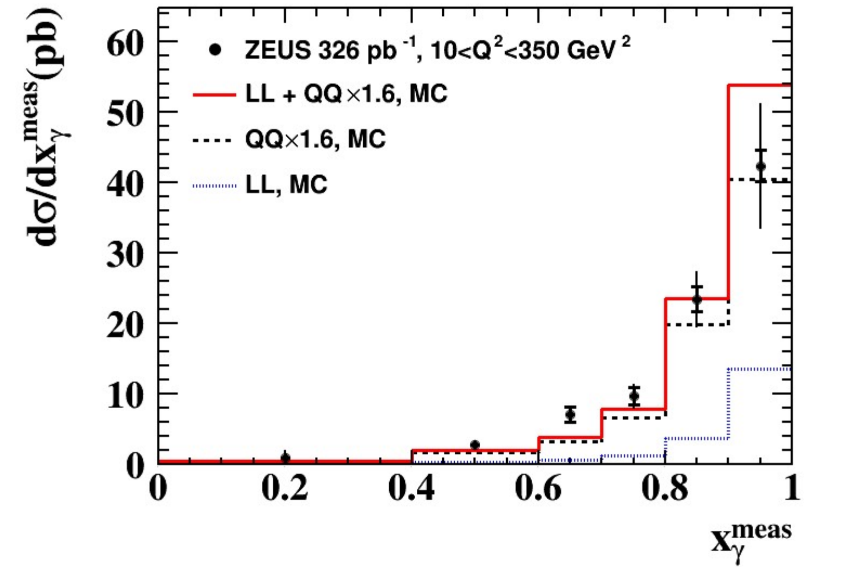
$$x_\gamma^{\mathrm{meas}} = \frac{E^\gamma - p_Z^\gamma + E^{\mathrm{jet}} - p_Z^{\mathrm{jet}}}{2E_e y_{\mathrm{JB}}}$$

$X\gamma^{meas}$ and Xp^{obs} are the measures of the momenta of partons involved in the hard scattering.

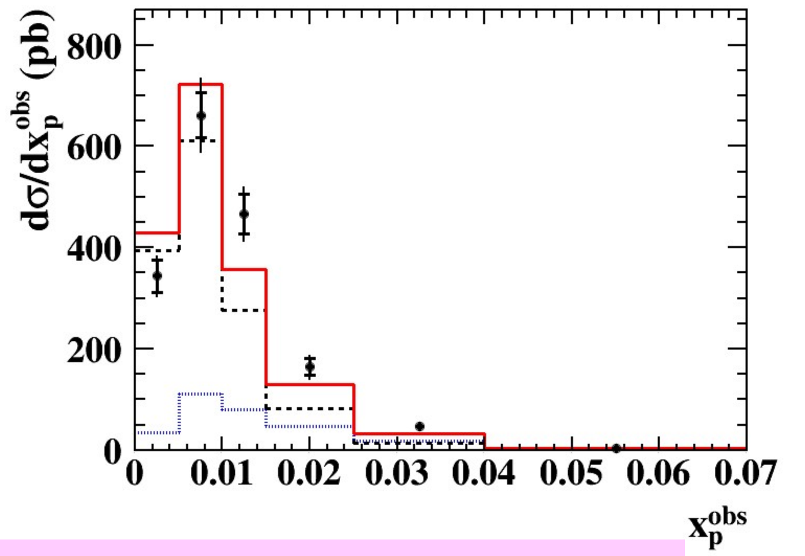
Comparison with MC 1

Q^2 : 10 – 350 GeV^2
Jet: Et>2.5 GeV,
η_{jet} : -1.5 – +1.8
Photon: Et: 4-15 GeV,
η : -0.7 - +0.9
(with isolation cuts)

$$x_\gamma^{\rm meas} = \frac{E^\gamma - p_Z^\gamma + E^{\rm jet} - p_Z^{\rm jet}}{2E_e y_{\rm JB}}$$



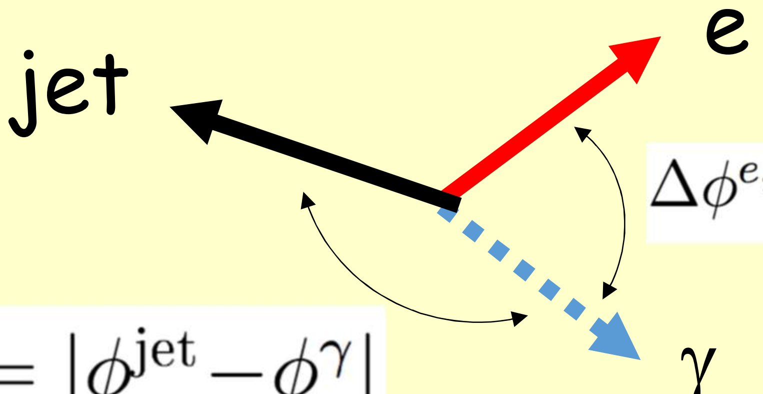
$$x_p^{\rm obs} = \frac{E^\gamma + p_Z^\gamma + E^{\rm jet} + p_Z^{\rm jet}}{2E_p}$$



Comparison with MC : Good agreement after the QQ contribution (PYTHIA) is normalized.

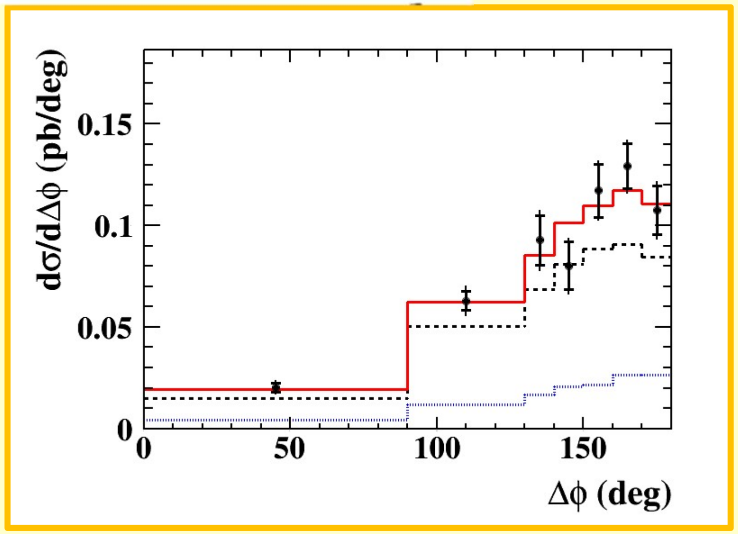
Comparison with MC
Phi correlation

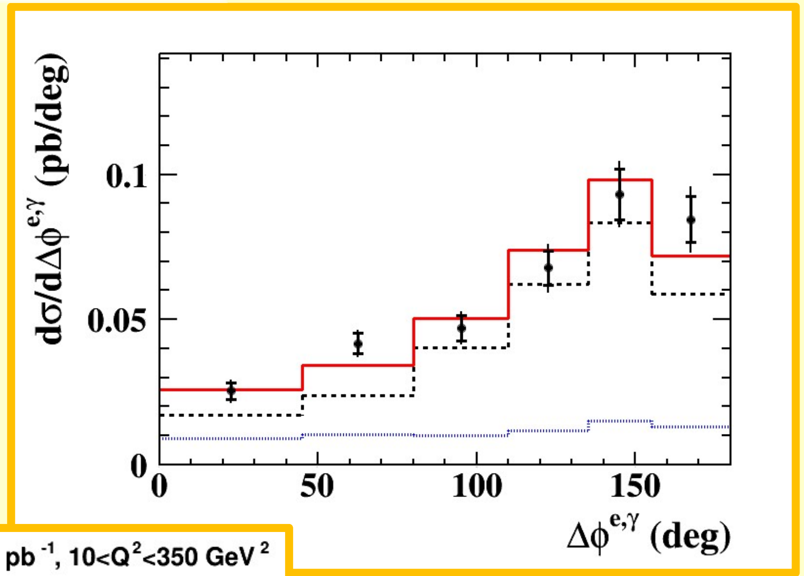
Q^2 : 10 – 350 GeV^2
Jet: Et>2.5 GeV,
η_{jet} : -1.5 – +1.8
Photon: Et: 4-15 GeV,
η : -0.7 - +0.9
(with isolation cuts)

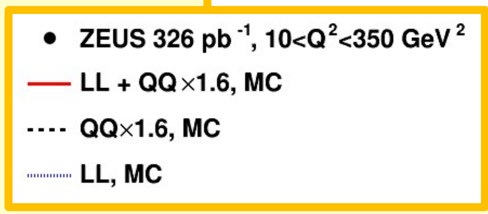


$$\Delta\phi^{e,\gamma} = |\phi^e - \phi^\gamma|$$

$$\Delta\phi = |\phi^{\rm jet} - \phi^\gamma|$$



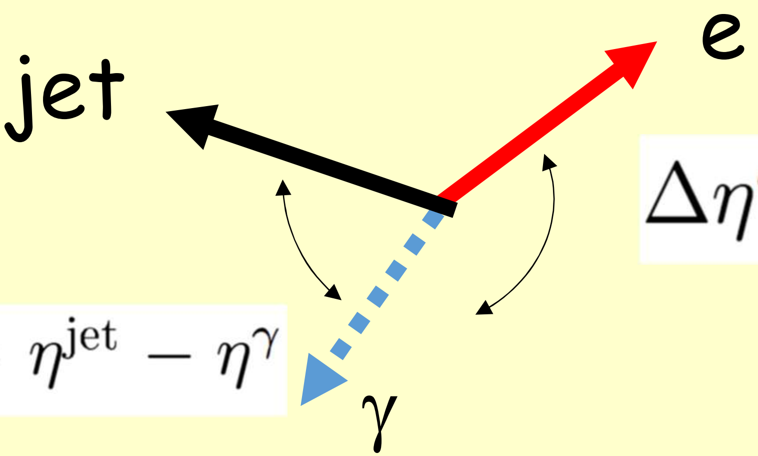




Comparison with MC: Good agreement

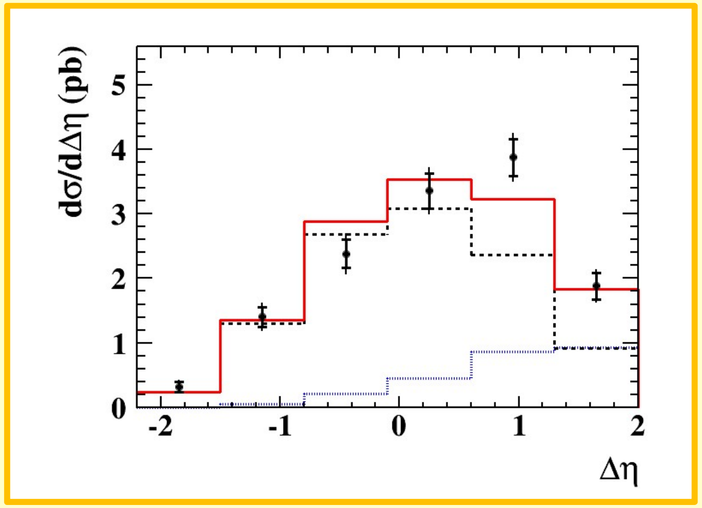
Comparison with MC
Eta correlation

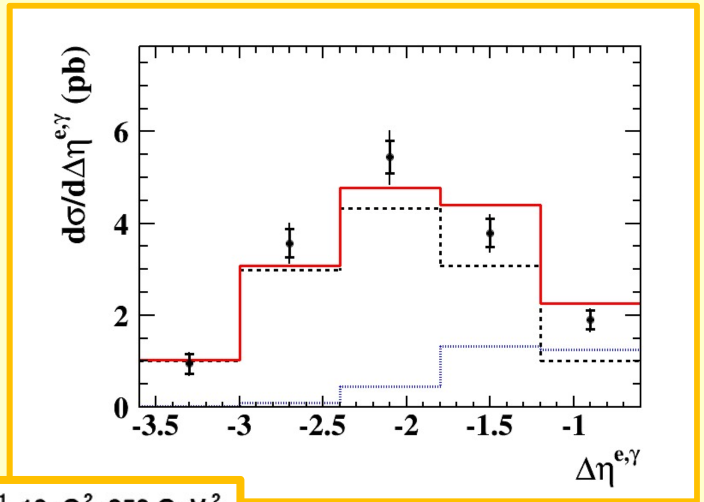
Q^2 : 10 – 350 GeV^2
Jet: Et>2.5 GeV,
η_{jet} : -1.5 – +1.8
Photon: Et: 4-15 GeV,
η : -0.7 - +0.9
(with isolation cuts)

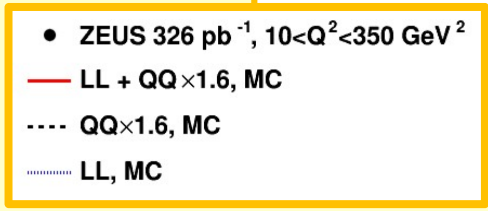


$$\Delta\eta^{e,\gamma} = \eta^e - \eta^\gamma$$

$$\Delta\eta = \eta^{\rm jet} - \eta^\gamma$$



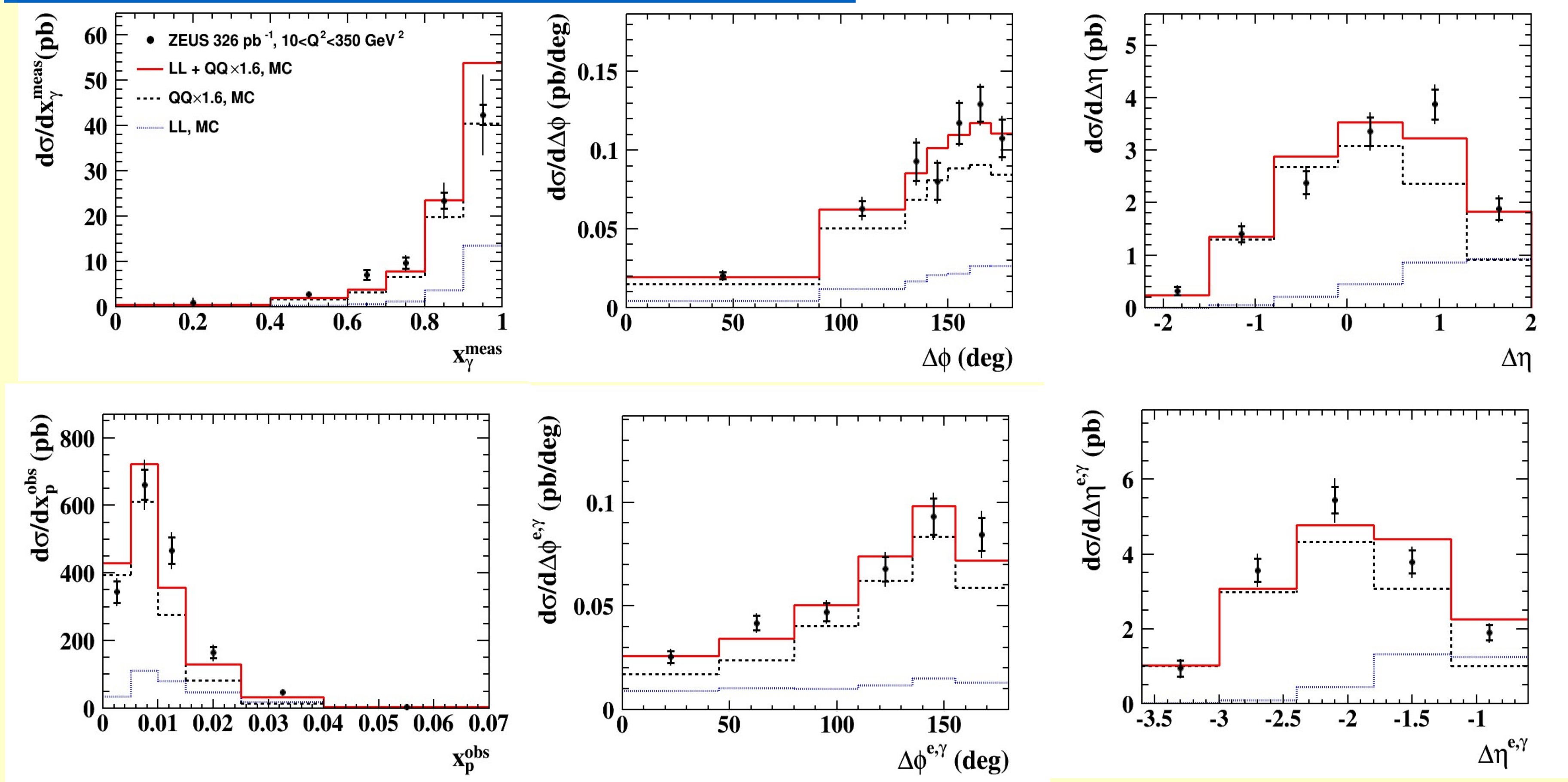




Comparison with MC: Good agreement

Comparison with MC Summary

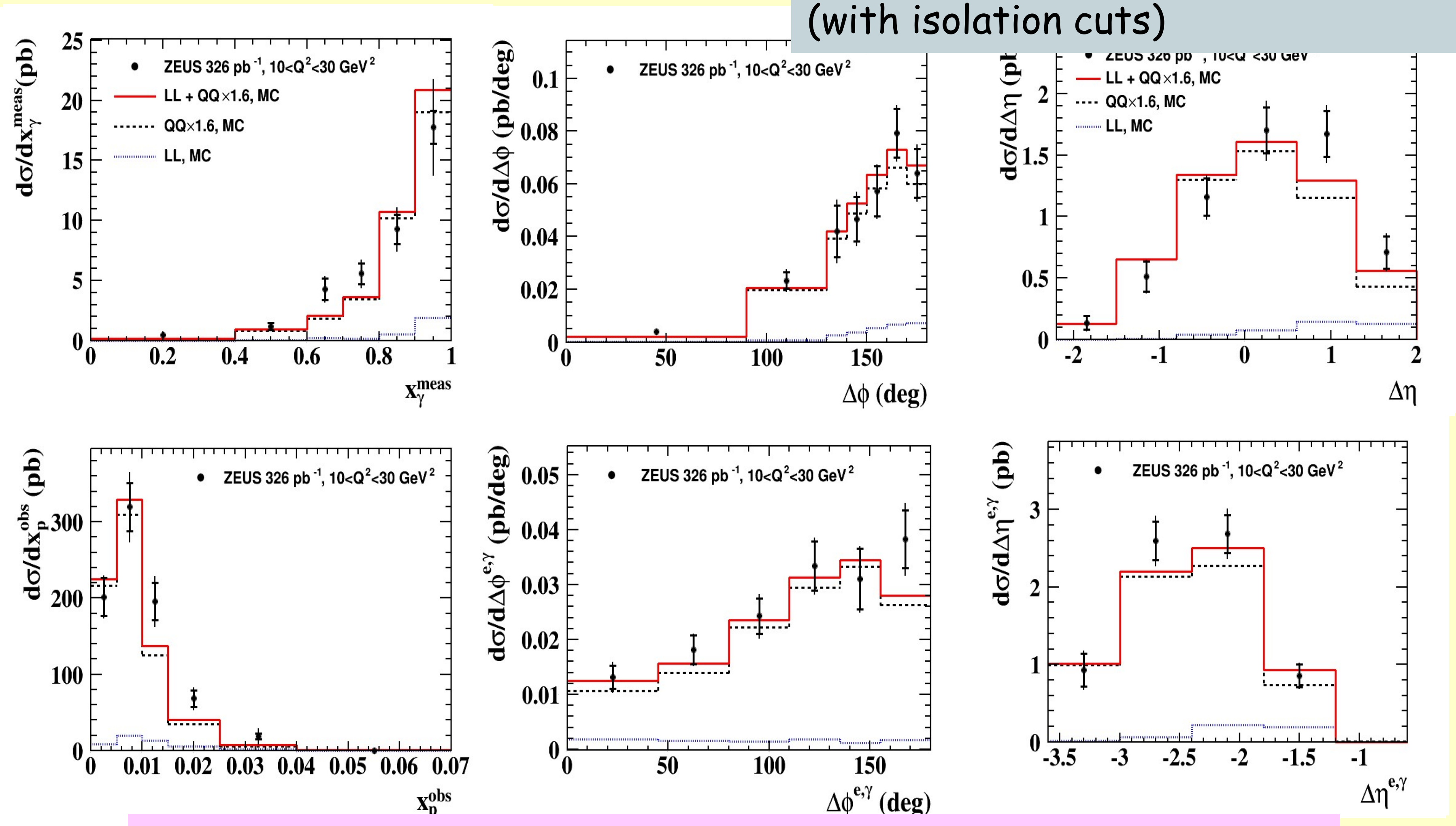
Q^2 : 10 – 350 GeV^2
Jet: Et>2.5 GeV, η_{jet} : -1.5 – +1.8
Photon: Et: 4-15 GeV, η : -0.7 - +0.9
(with isolation cuts)



Comparison with MC : Good agreement after the QQ contribution (PYTHIA) is normalized.

Comparison with MC

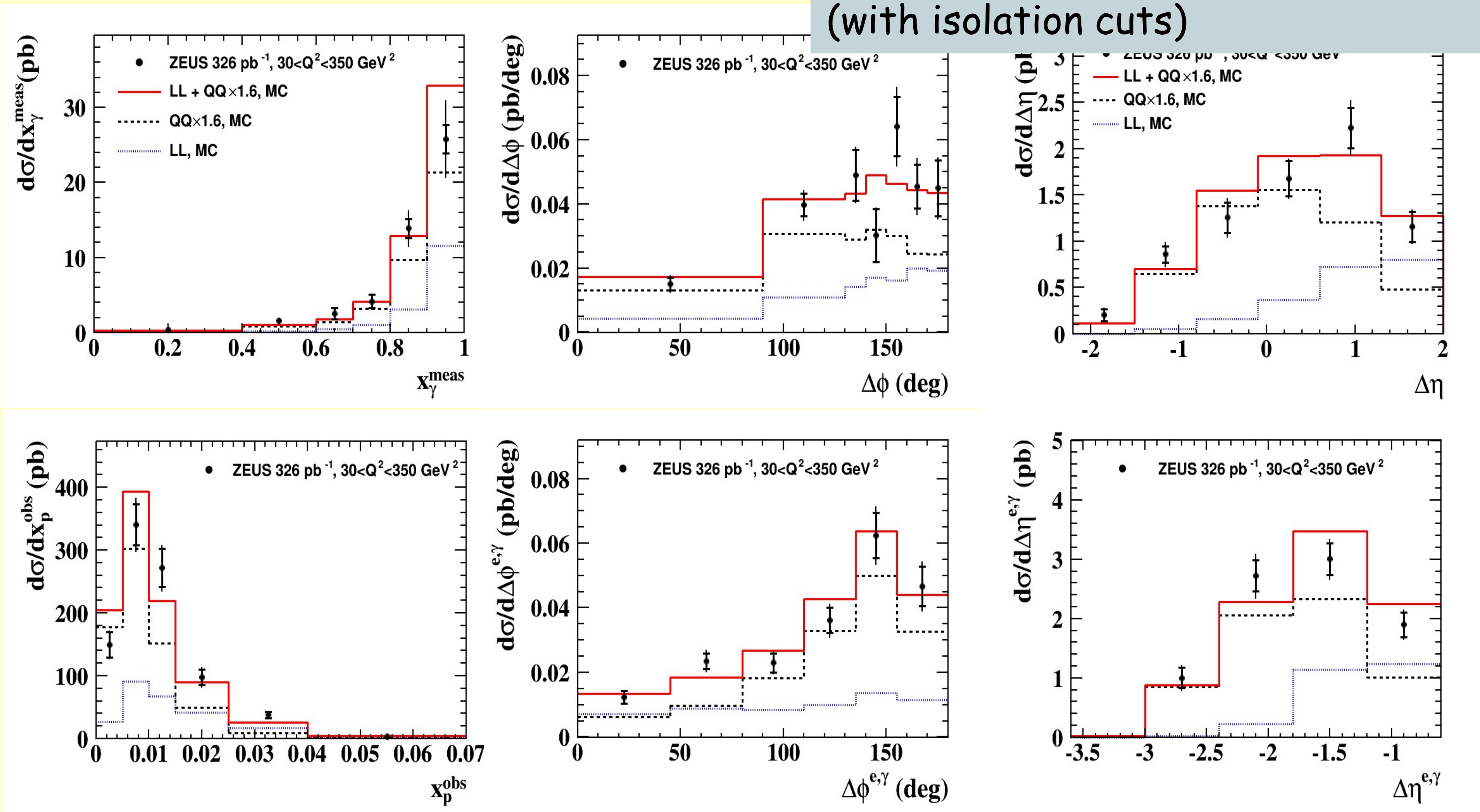
Q^2 : 10 – 30 GeV^2
Jet: Et>2.5 GeV, η_{jet} : -1.5 – +1.8
Photon: Et: 4-15 GeV, η : -0.7 - +0.9
(with isolation cuts)



Comparison with MC for low Q^2 area

Comparison with MC

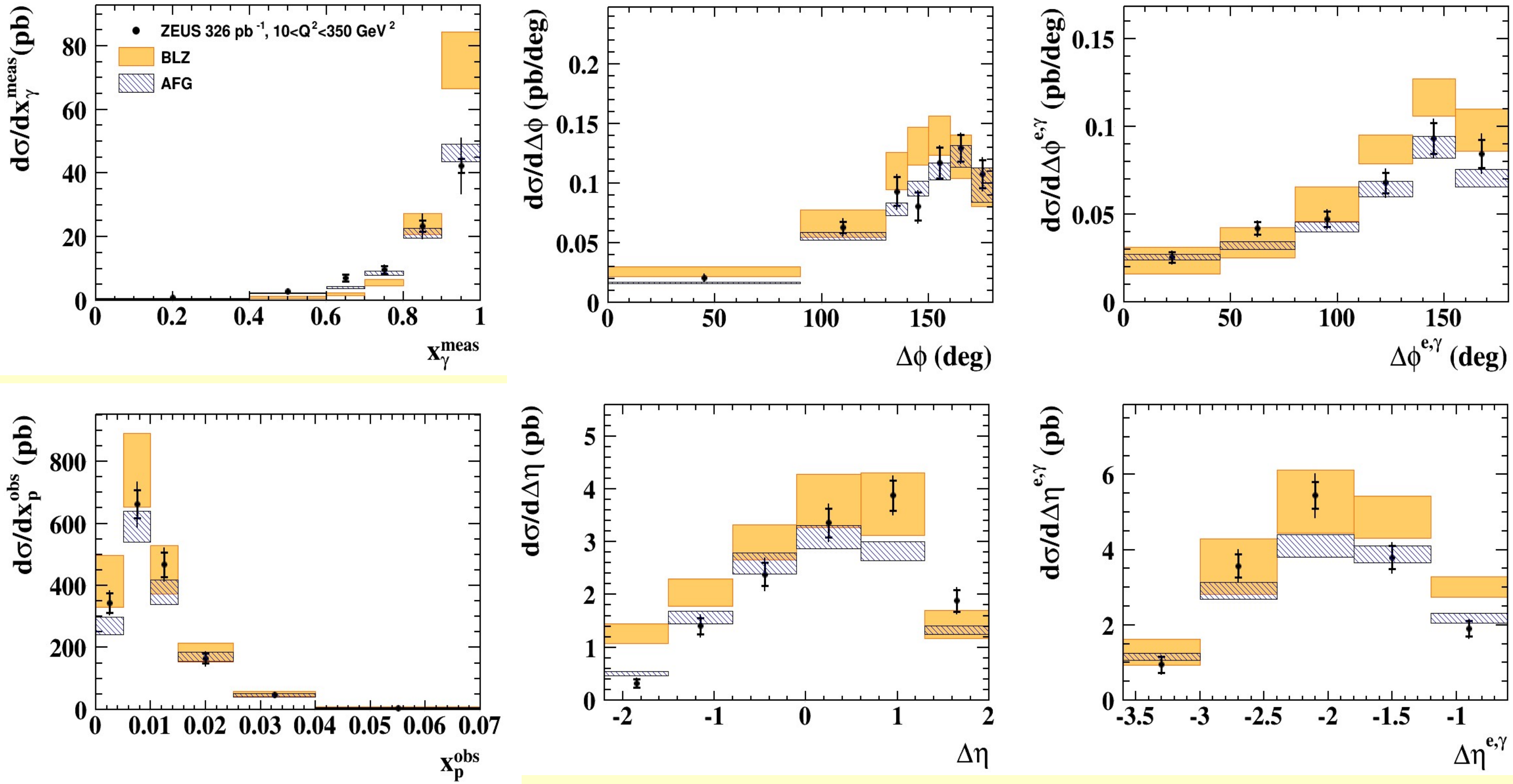
Q^2 : 30 – 350 GeV^2
Jet: Et>2.5 GeV, η_{jet} : -1.5 – +1.8
Photon: Et: 4-15 GeV, η : -0.7 - +0.9
(with isolation cuts)



Comparison with MC for high Q^2 area.
Higher contribution from the LL component.

Comparison with Theory

Q^2 : 10 – 350 GeV^2



- NLO (AFG) calculations give excellent data description.
- Kt-factrization (BLZ) gives fair data description, however normalization slightly high (~20%) and has extremely peaked predications for the x_γ^{meas}.

Summary

- ZEUS at HERA has measured isolated photons in Deep Inelastic Scattering, measuring new combinations of kinematic variables. $X\gamma^{meas}$, Xp^{obs}, $\Delta\eta$, $\Delta\phi$, ,$\Delta\eta_{e\gamma}$, $\Delta\phi_{e\gamma}$, with two Q^2 ranges.
- The distributions are well described by the MC, once a normalization factor is introduced (x 1.6 PYTHIA)
- NLO (AFG) calculations give excellent data description.
- Kt-factrization (BLZ) gives fair data description, however normalization slightly high and some distributions not describe in shape.