

# Prompt Photon Production in Photoproduction at HERA

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on behalf of the H1 Collaboration*

## OUTLINE

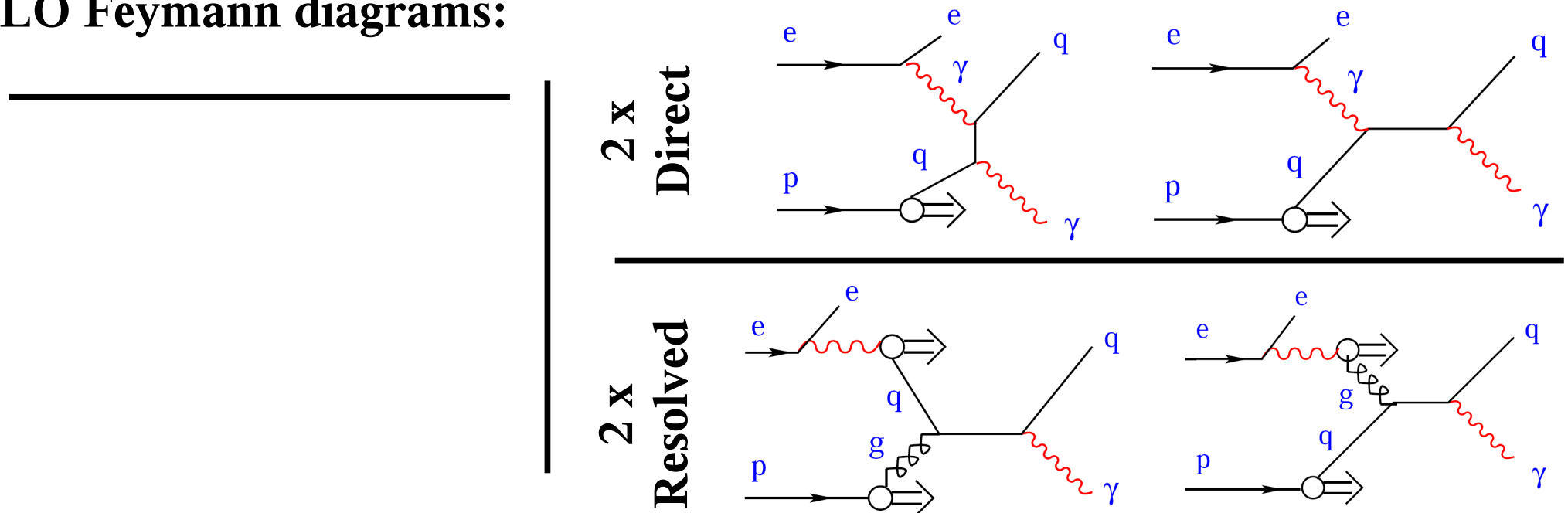
- Prompt Photons at HERA
- Analysis Strategy
- Preliminary Results
- Summary



# Prompt photons at HERA

- Sensitivity to quark and gluon pdfs of photon and proton
- Generally lower hadronization correction than for di-jet events
- Prompt photons as background for Higgs discovery
- Several calculations available (NLO,  $k_T$ -factorization)

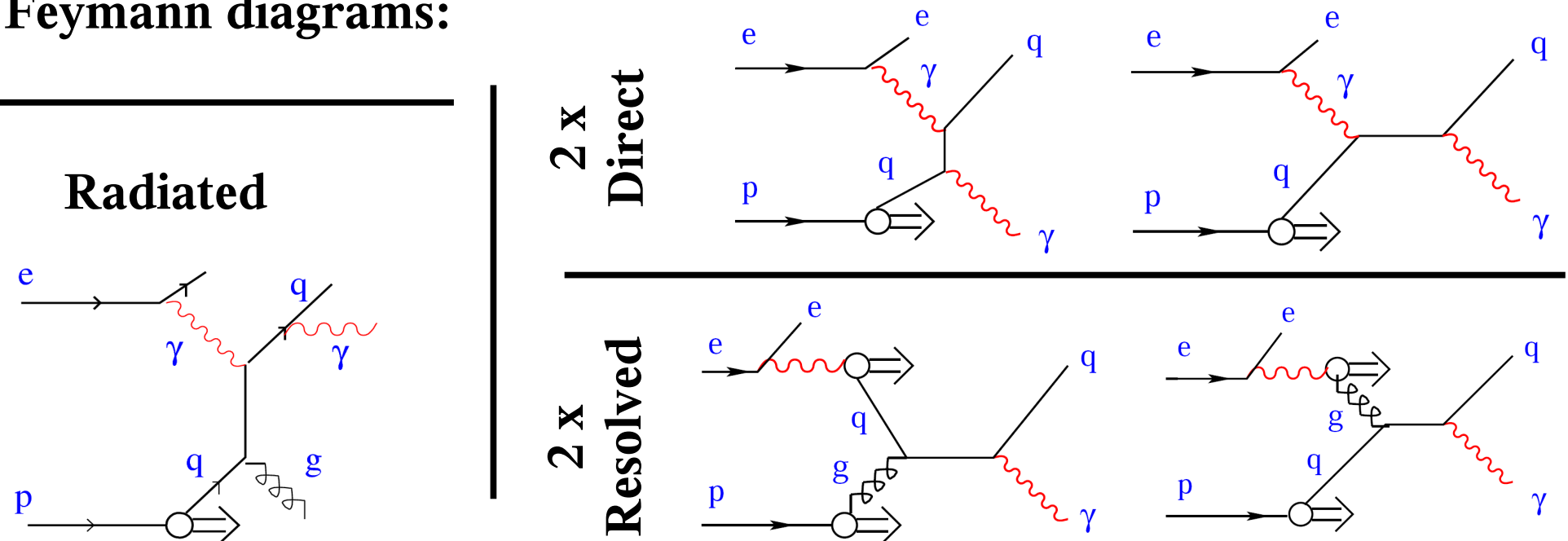
LO Feymann diagrams:



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LO Feymann diagrams:



# Prompt photon in the H1 detector

HERA collider:

electrons (27.6 GeV)

protons (920 GeV)

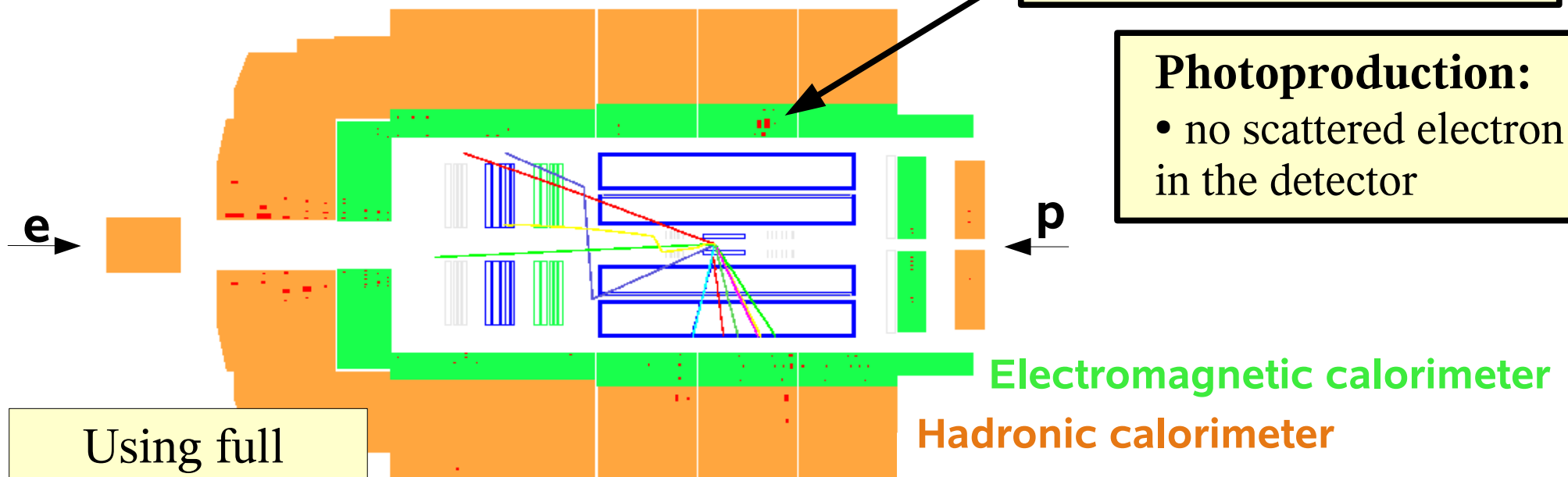
CM: 318 GeV

**Photon candidate:**

- cluster in em calorimeter
- not associated to track
- isolated

**Photoproduction:**

- no scattered electron in the detector



Using full  
HERA II data:  
**340 pb<sup>-1</sup>**

# Phase space definition

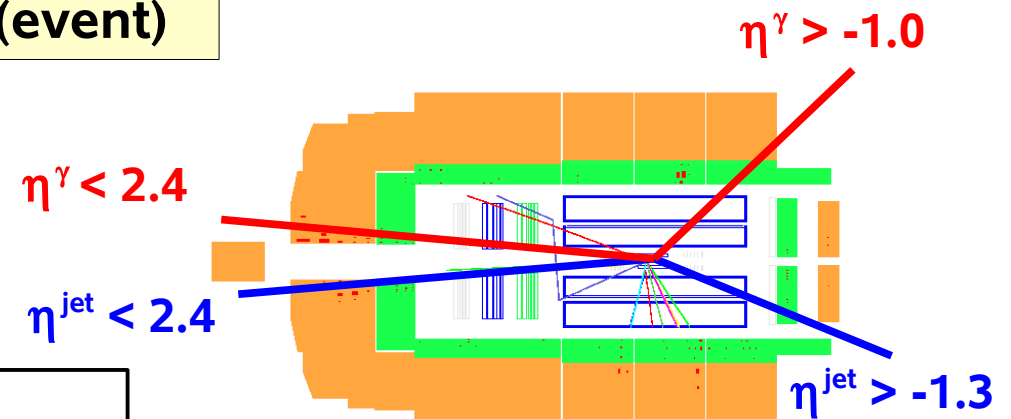
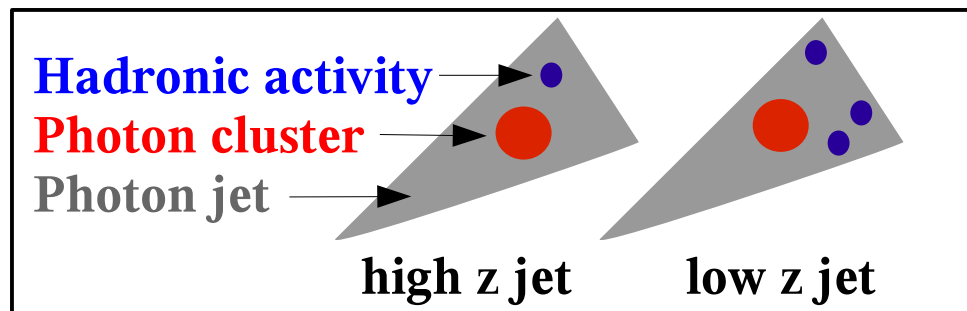
- Inclusive measurement

•  $Q^2 < 1 \text{ GeV}^2$  •  $0.1 < y < 0.7$  (event)

•  $5 \text{ GeV} < E_T^\gamma < 15 \text{ GeV}$  (photon)

•  $-1.0 < \eta^\gamma < 2.4$

•  $z = E_T^\gamma / E_T^{\text{photon-jet}} > 0.9$

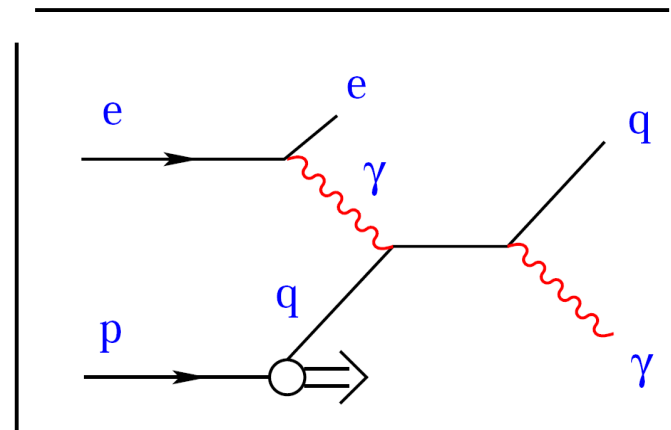


- Exclusive (photon + jet) measurement

•  $p_T^{\text{jet}} > 4.5 \text{ GeV}$  (jet)

•  $-1.3 < \eta^{\text{jet}} < 2.4$

•  $k_T$  jet algorithm used



# Background from multi-photon clusters

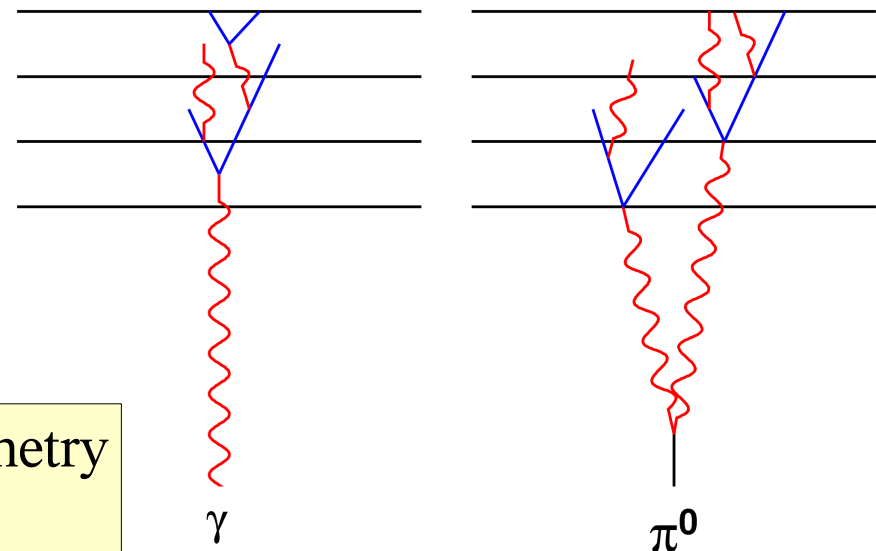
- Hadrons decaying into multi-photon final state

$$\pi^0 \rightarrow \gamma\gamma \quad \eta \rightarrow \gamma\gamma \quad \omega \rightarrow \pi^0\gamma \rightarrow \gamma\gamma\gamma$$

- Cluster shapes used to statistically discriminate between signal and background

- Multi-photon clusters

- less compact
- more asymmetric
- showering earlier

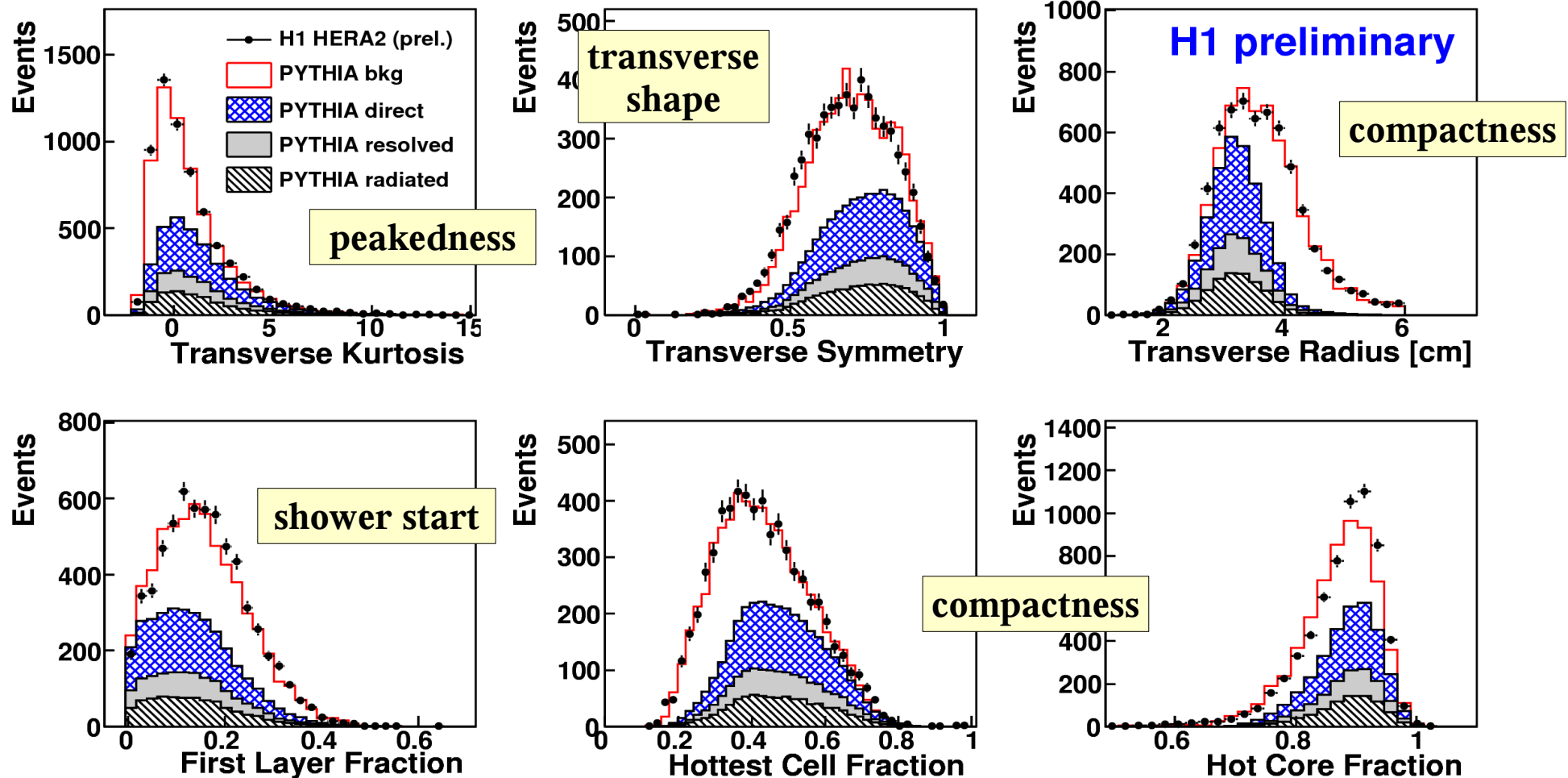


**Remark:** decay kinematics, detector geometry  
- variables highly dependent on  $E_T$ ,  $\eta$

# Variables used in multivariate analysis

Shower shape variables of prompt photon candidates

(full  $E_T$ ,  $\eta$  range)

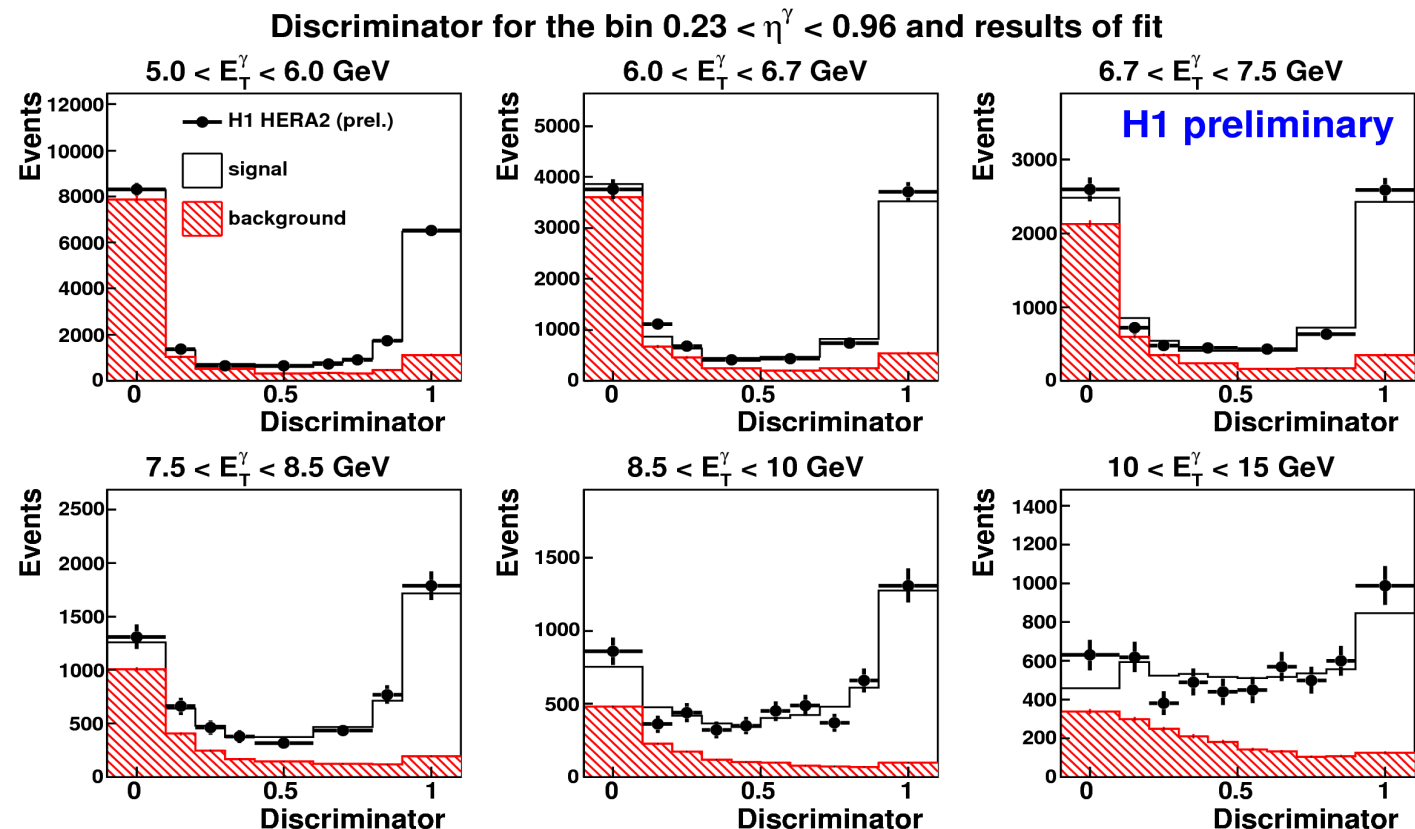


- Cluster shapes described well in MC (scaled to meas. cross sections)

# Signal extraction

- Number of photons determined in each analysis bin by discriminator fit (likelihood method used)

- Single particles ( $\gamma$ ,  $\pi^0$ ,  $\eta$ , ...) MC used for training and evaluation
- Decrease of discriminating power with rise of cluster's energy





# Calculations

- Fontannaz-Guillet-Heinrich (FGH)

- collinear approach (NLO)
- includes quark-to-photon fragmentation
- box diagram  $\gamma g \rightarrow \gamma g$

- Zotov-Lipatov (ZL)

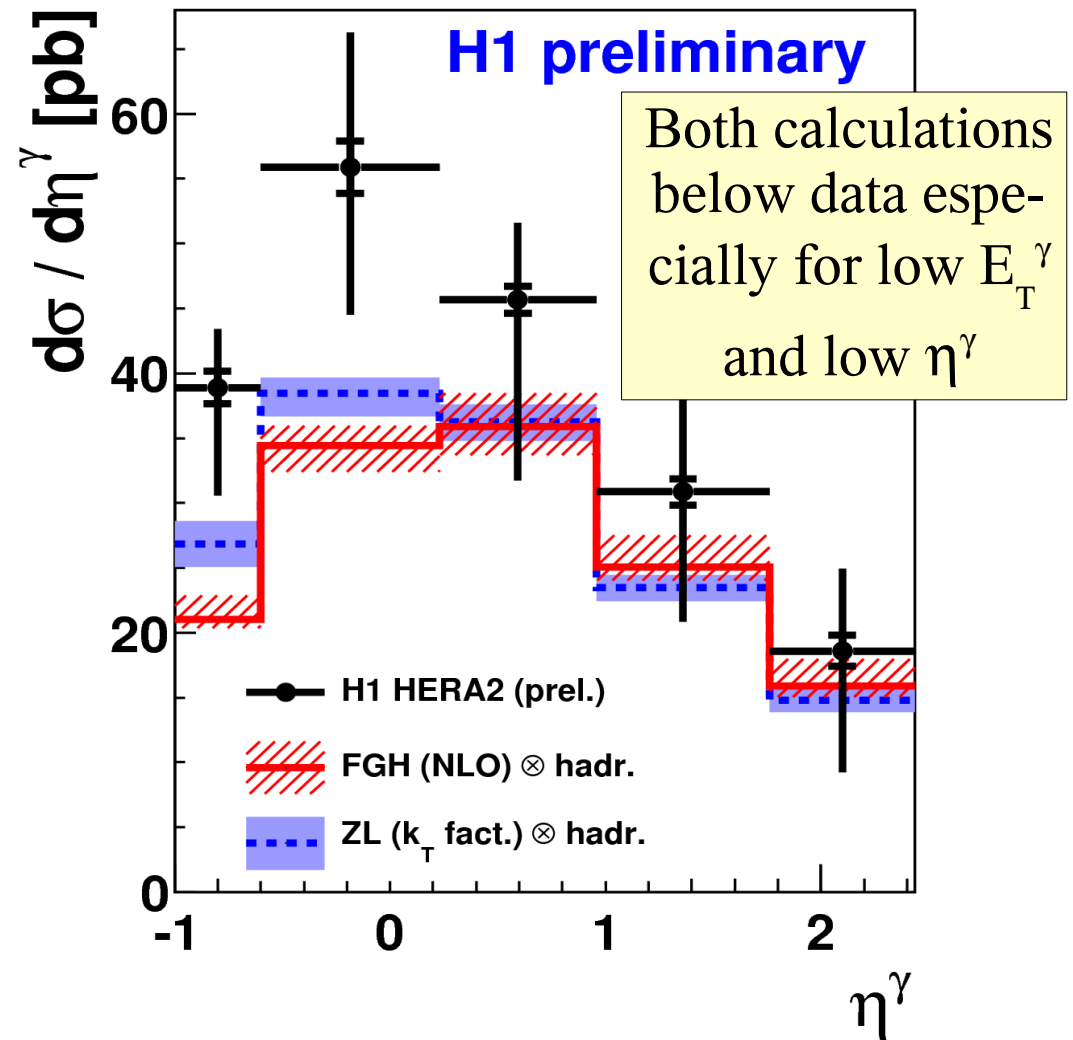
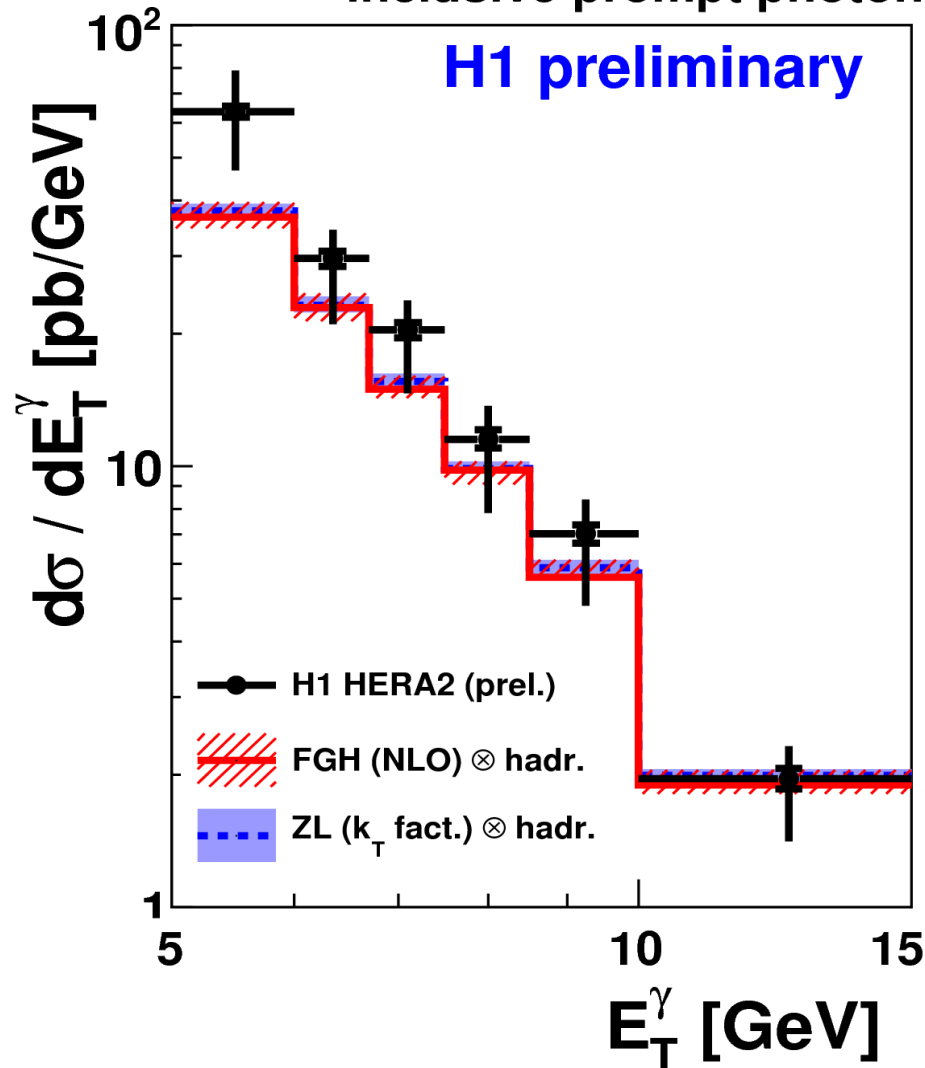
- $k_T$ -factorization approach (unintegrated pdfs used)
- using Kimber-Martin-Ryskin prescription for updf

Error estimation: simultaneous variation of fragmentation and renormalization scale ( $E_T^\gamma$ ) by factor 2.0 and 0.5

Corrected for hadronisation and multi-parton interaction effects and compared to measured cross sections

# Inclusive prompt photons

Inclusive prompt photons in photoproduction at H1



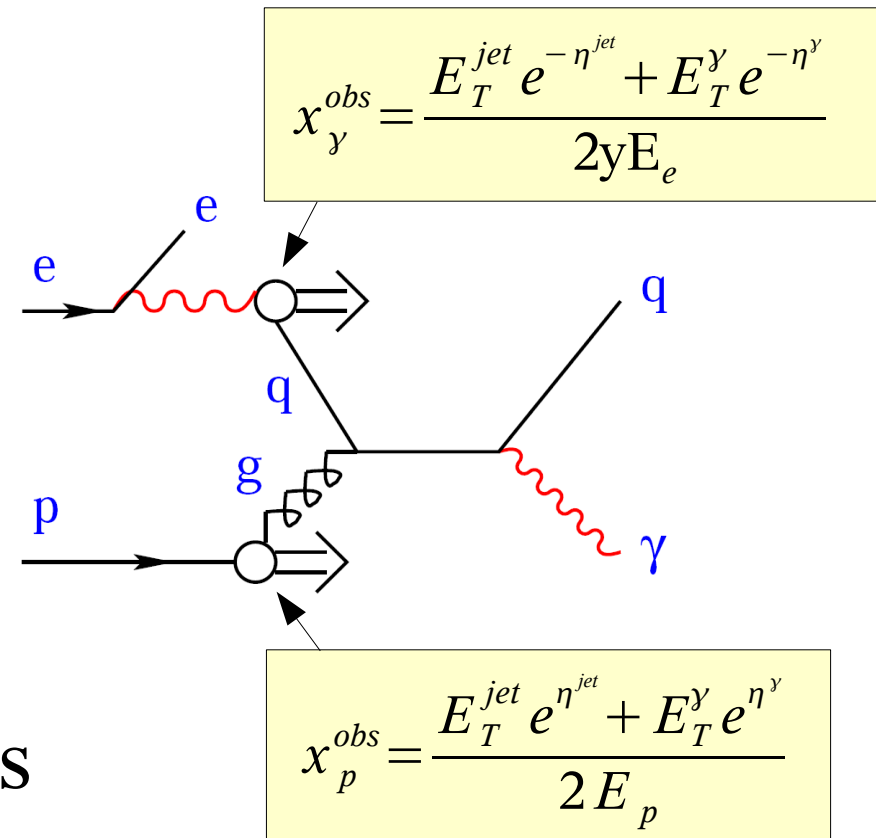
# Exclusive prompt photons + jet

- Phase space

as inclusive photon + jet

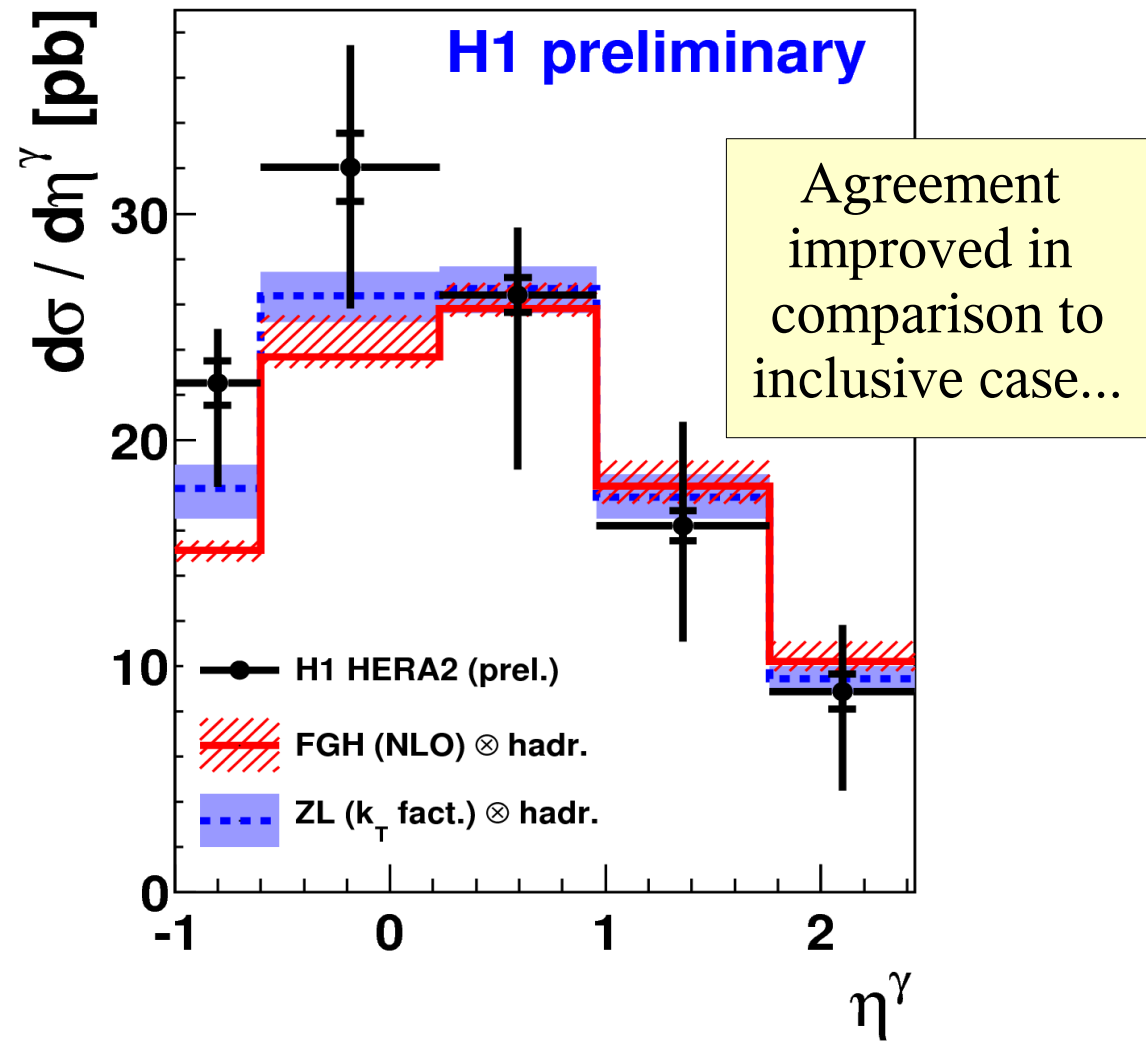
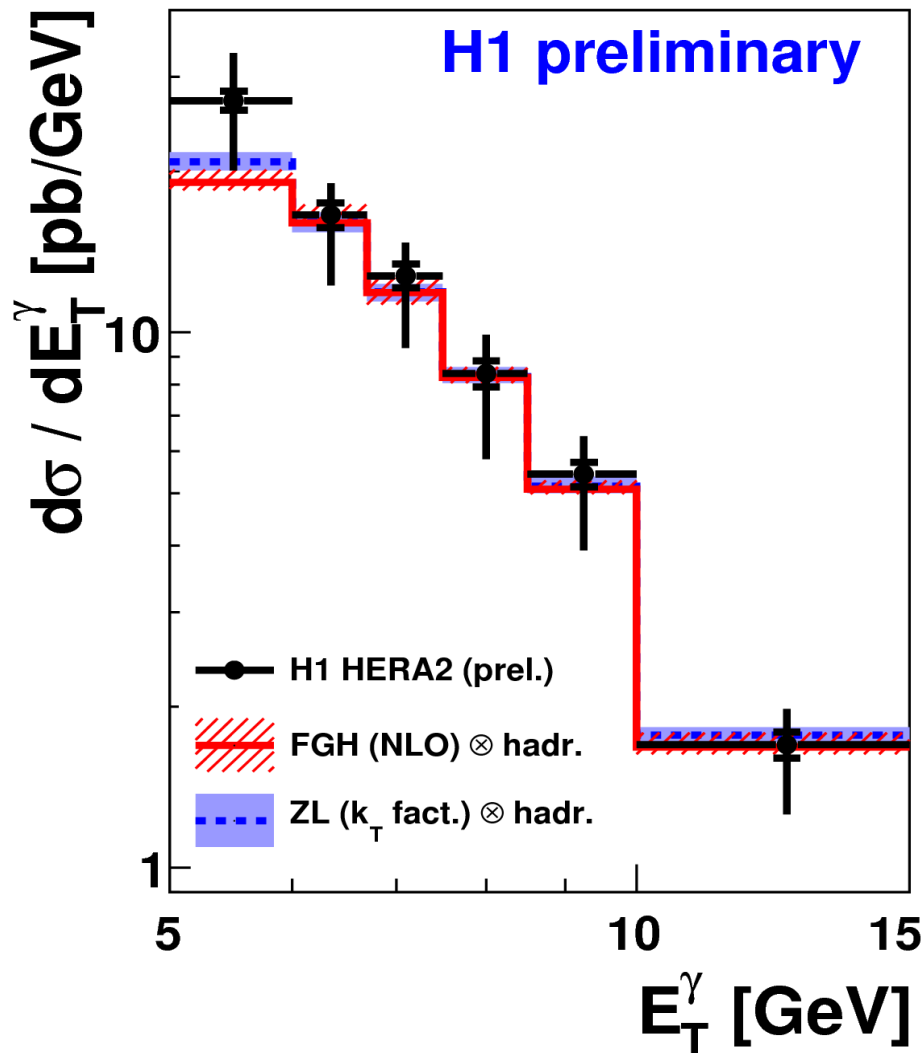
$$\begin{cases}
 \bullet Q^2 < 1 \text{ GeV}^2 \\
 \bullet 0.1 < y < 0.7 \\
 \bullet 5 \text{ GeV} < E_T^\gamma < 15 \text{ GeV} \\
 \bullet -1.0 < \eta^\gamma < 2.4 \\
 \bullet z = E_T^\gamma / E_T^{\text{photon-jet}} > 0.9 \\
 \bullet p_T^{\text{jet}} > 4.5 \text{ GeV} \\
 \bullet -1.3 < \eta^{\text{jet}} < 2.4
 \end{cases}$$

- $x_{\gamma(p)}^{\text{obs}}$  variables interpreted as momentum fraction of photon (proton) entering the hard interaction



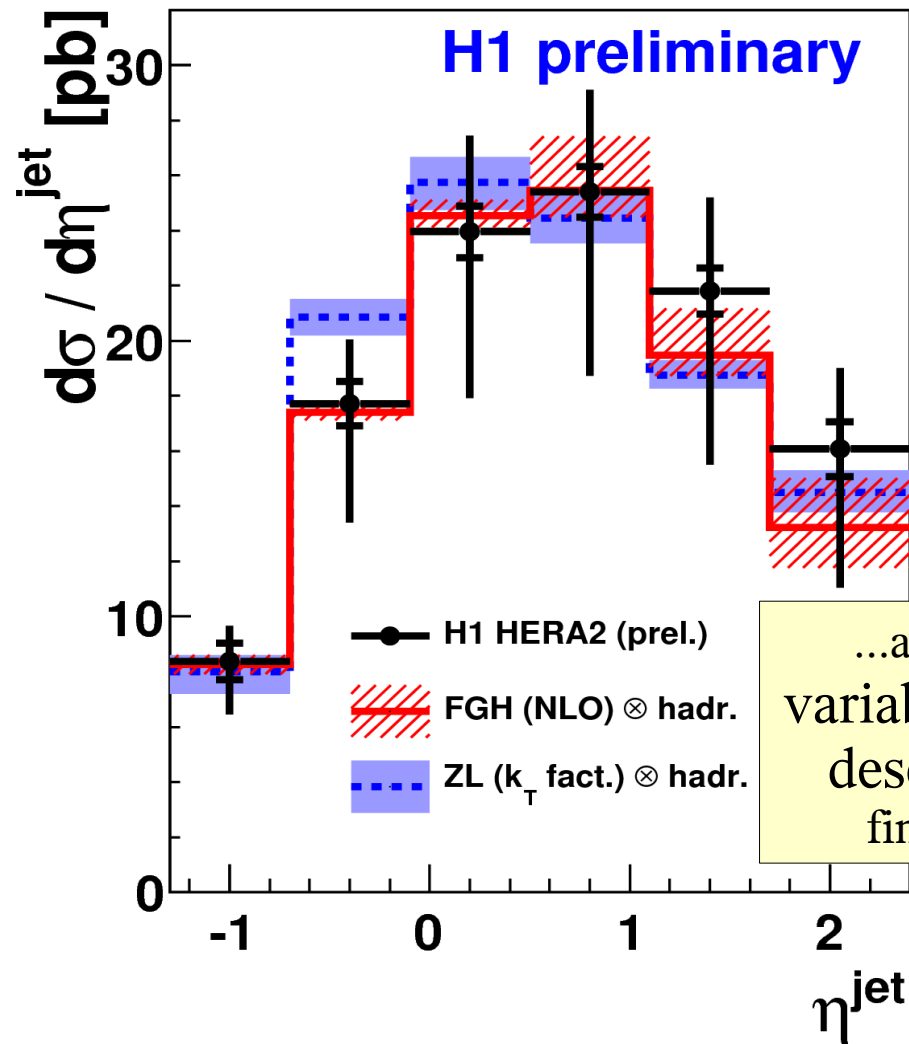
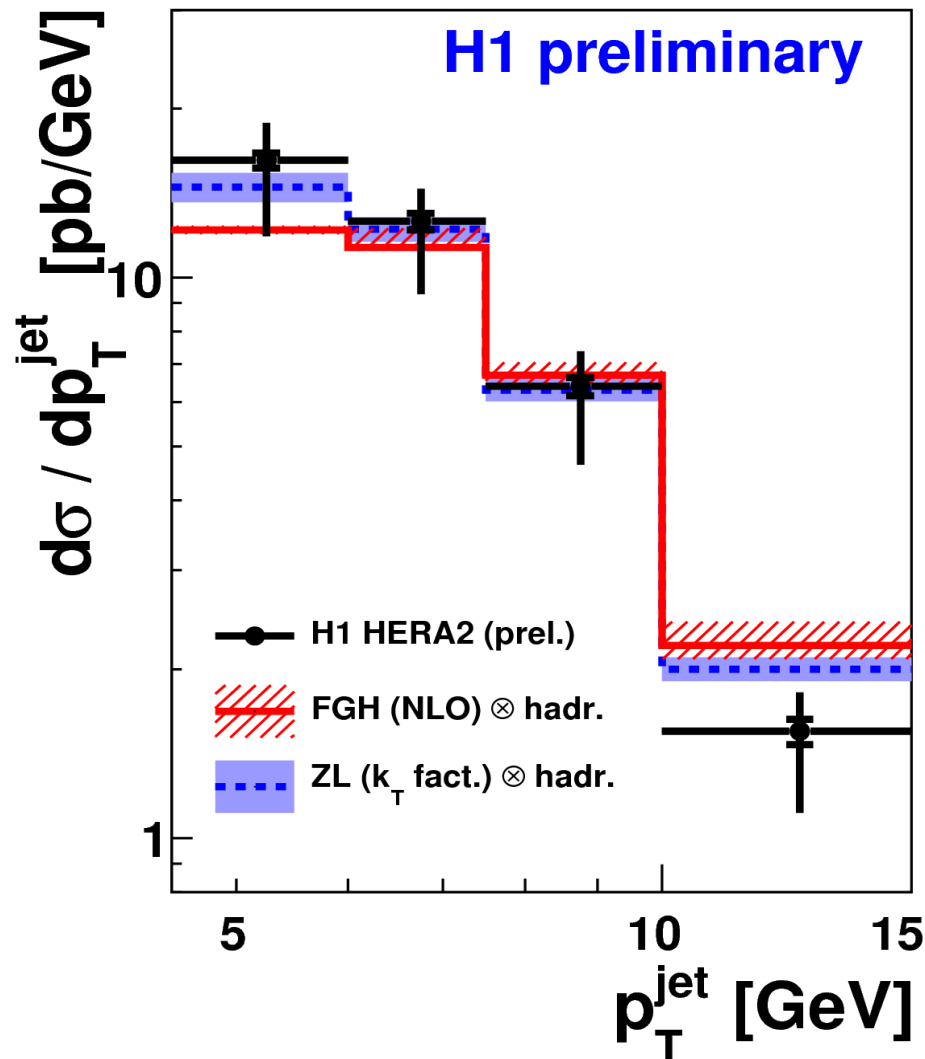
# Exclusive prompt photons + jet

Exclusive (photon + jet) prompt photons in photoproduction at H1



# Exclusive prompt photons + jet

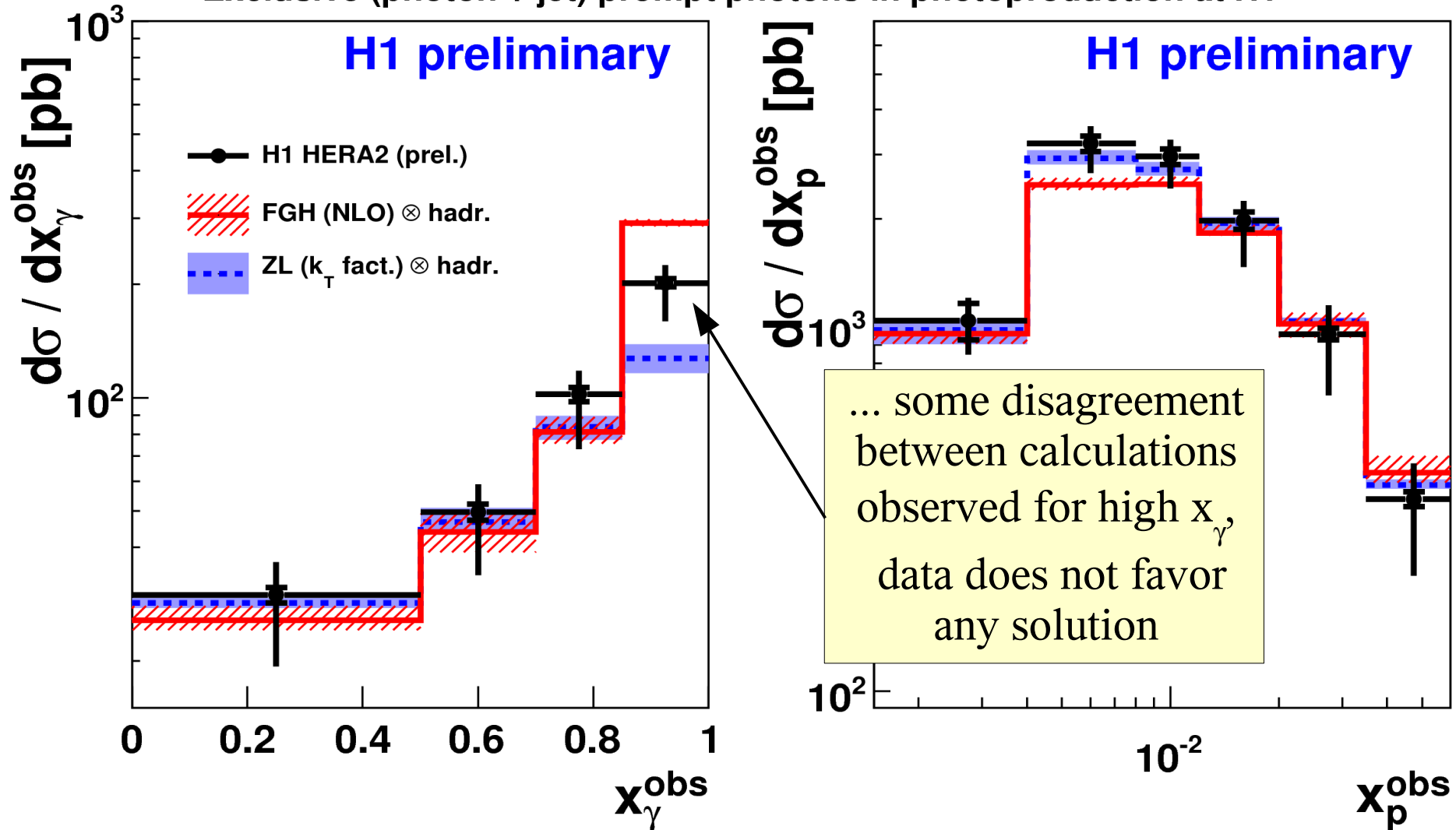
Exclusive (photon + jet) prompt photons in photoproduction at H1



...also jet variables well described, finally...

# Exclusive prompt photons + jet

Exclusive (photon + jet) prompt photons in photoproduction at H1



# Isolated photons in DIS at HERA

- Parallel measurement in DIS recently published by H1  
(0711.4578 [hep-ex])

- Phase space

•  $4 < Q^2 < 150$  [GeV<sup>2</sup>] **Event**

•  $y > 0.05$

•  $W_x > 50$  GeV

•  $E_e > 10$  GeV **Scattered electron**

•  $153^\circ < \theta_e < 177^\circ$

•  $3 < E_T^\gamma < 10$  [GeV] **Photon**

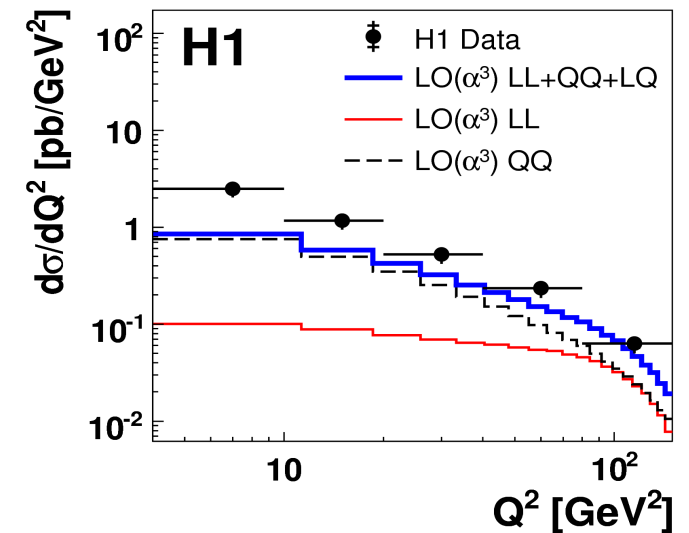
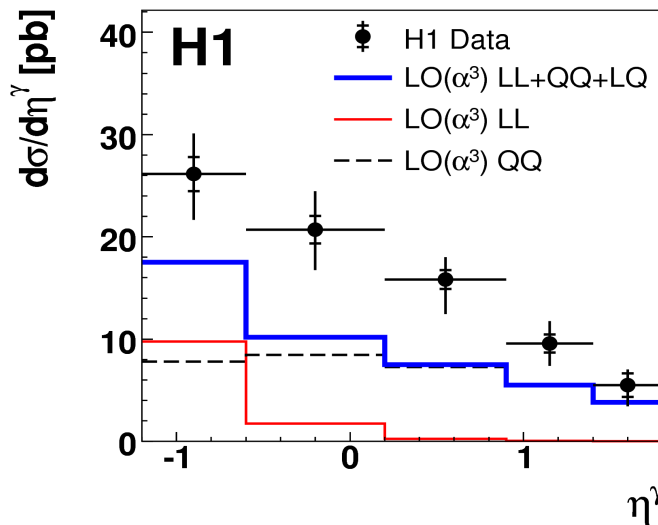
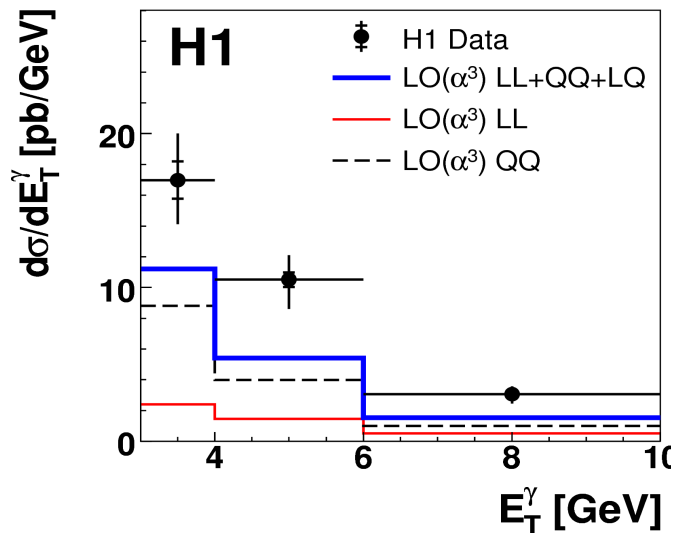
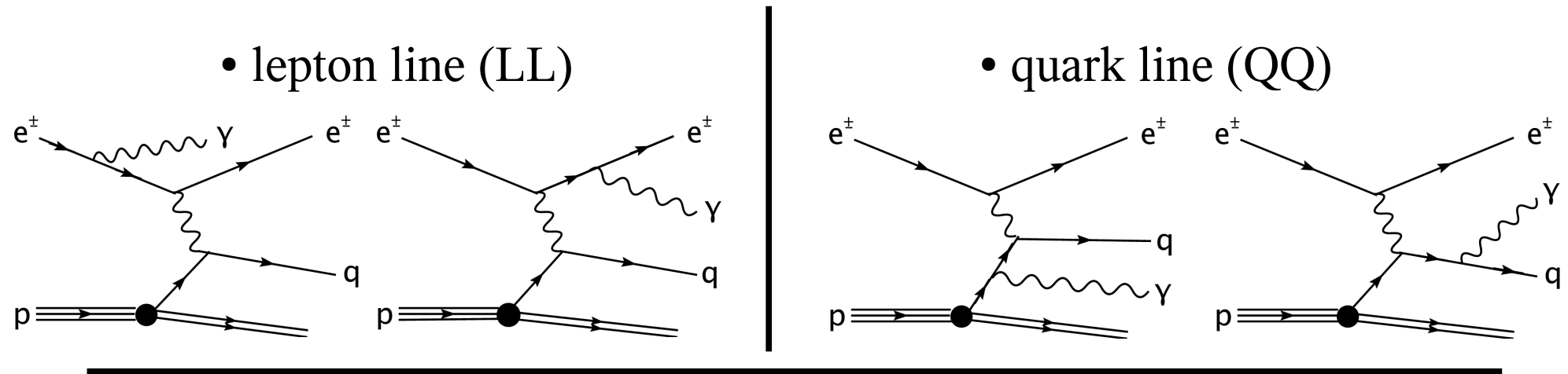
•  $-1.2 < \eta^\gamma < 1.8$

•  $z = E_T^\gamma / E_T^{\text{photon-jet}} > 0.9$

- LO collinear calculation available for photon and photon plus jet production, NLO only for exclusive photon plus jet

# Inclusive isolated photons in DIS at HERA

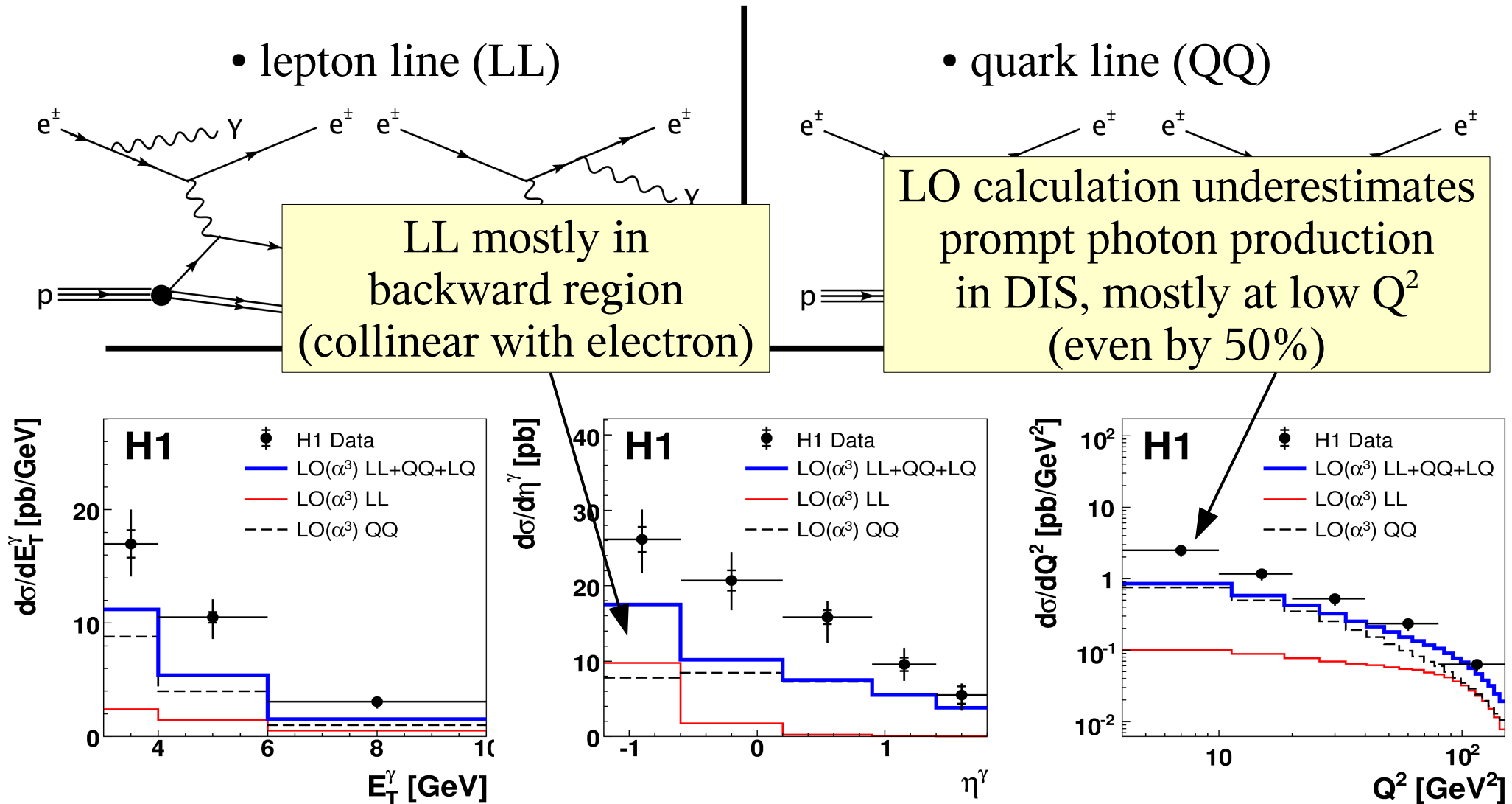
- Contribution from photons radiated from





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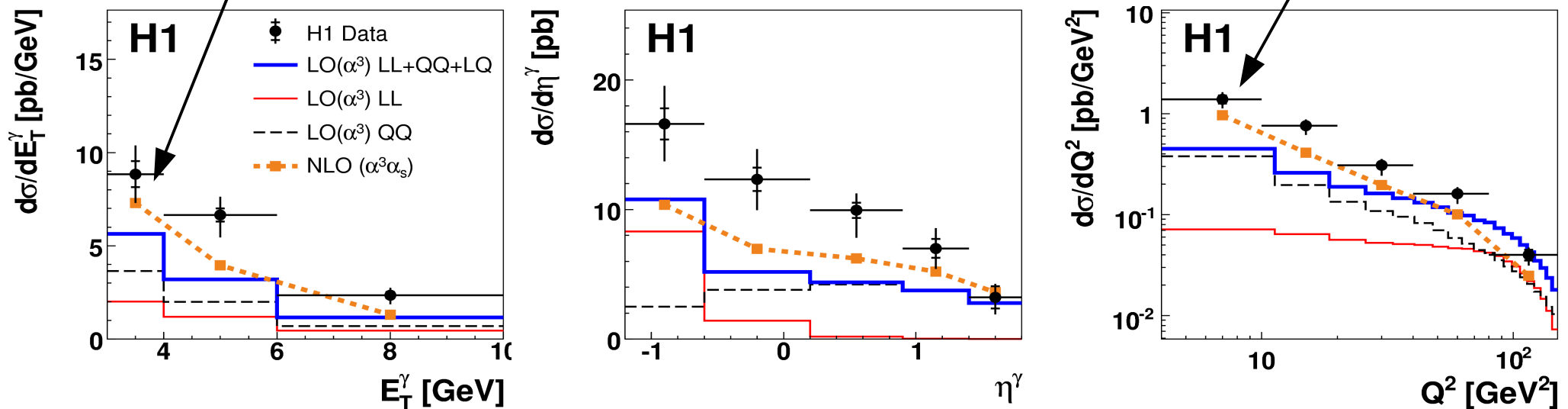
- Contribution from photons radiated from



# Exclusive isolated photons in DIS at HERA

- LO exclusive (photon+ jet) calculation underestimates the cross section by the same factor as in inclusive case
- NLO correction helps to describe the shape

NLO most significant improvement at low  $E_T^\gamma$  and low  $Q^2$



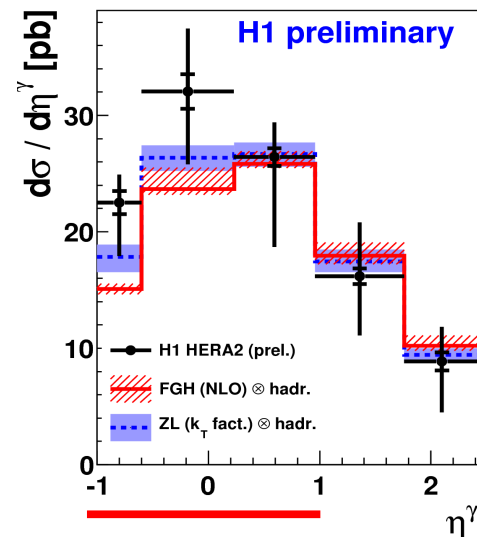
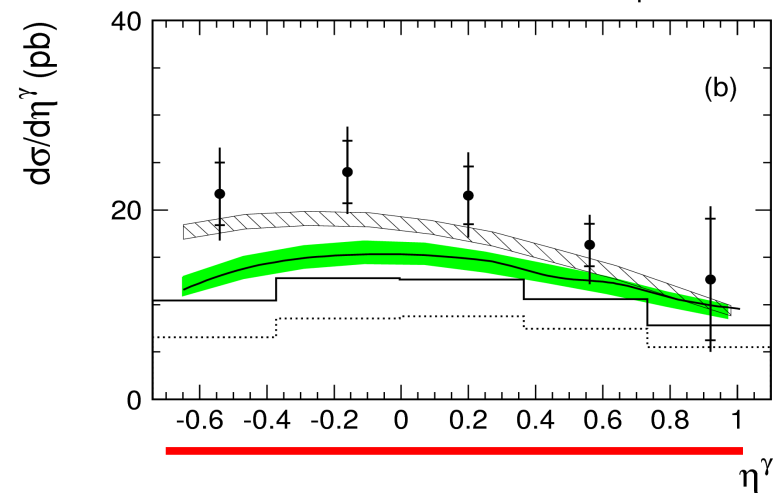
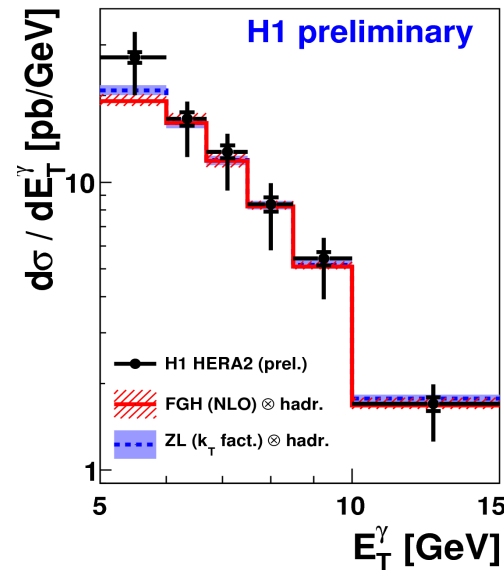
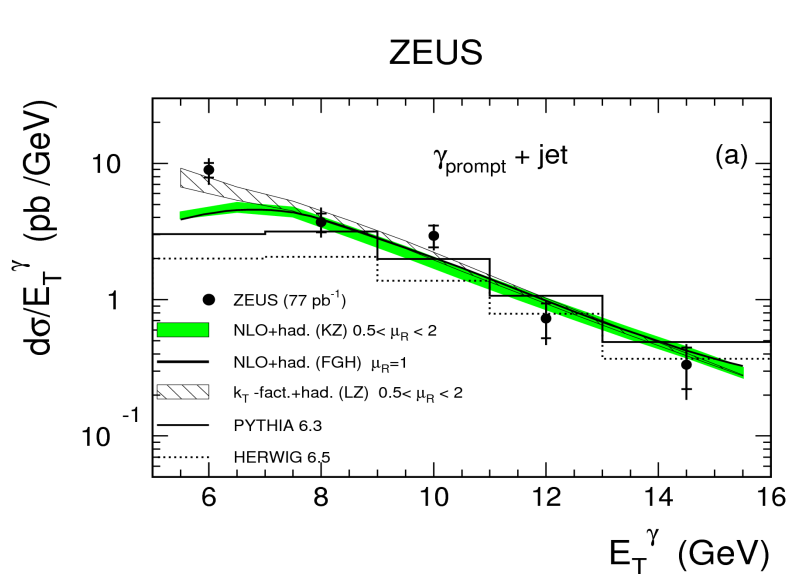
# Summary

- New H1 results on prompt photon production presented
- With HERA II data statistical error eliminated, systematic error dominant
- Measurement compared to calculation predictions
  - Inclusive prompt photon production underestimated by calculations (especially at low  $E_T^\gamma$ )
  - Exclusive prompt photon production found to be nicely described by calculations (except high  $x_\gamma$  region)
- Similar observation derived from H1 measurement in DIS
  - LO significantly underestimates data at low  $Q^2$  and low  $E_T^\gamma$
  - For photon plus jet NLO 30% below data, shape described

# Systematic error summary

- Cluster shower shapes description in MC – high dependence of final results on small changes - up to 30%
- Trigger correction + Energy uncertainty - 5% (20% at low  $E_T^\gamma$ )
- Description of conversion rate in the detector - 15% in the most forward  $\eta^\gamma$  bin
- Single particle usage impact – 15% in the most forward  $\eta^\gamma$  bin
- HERWIG-PYTHIA acceptance correction difference – 10% in the most forward  $\eta^\gamma$  bin

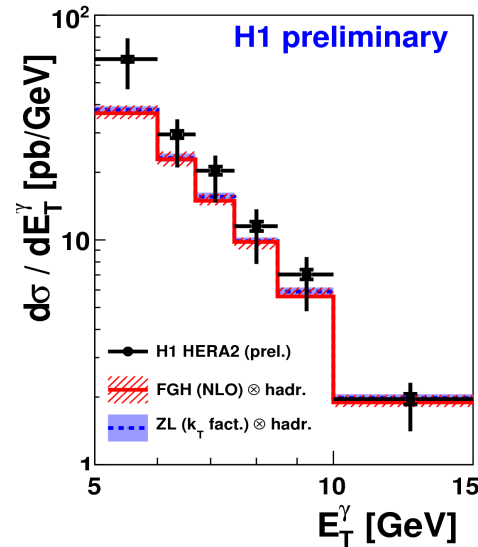
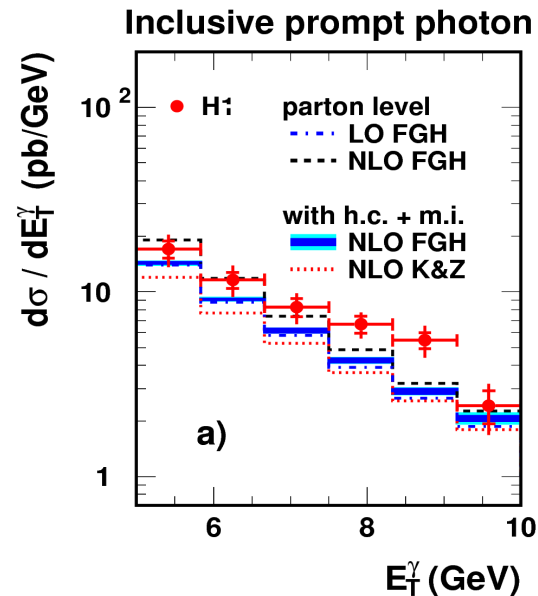
# Other measurements – Exclusive ZEUS



- ZEUS HERA I data (hep-ex/0608028)
- Phase space differences:

	ZEUS	H1
$y$	(0.2, 0.8)	(0.1, 0.7)
$\eta^\gamma$	(-0.74, 1.1)	(-1.0, 2.4)
$\eta^{\text{jet}}$	(-1.6, 2.4)	(-1.3, 2.4)
$p_T^{\text{jet}}$	$> 6$ GeV	$> 4.5$ GeV

# Other measurements – Inclusive H1



- H1 HERA I data (hep-ex/0407018)
- Phase space definition differences:

	H1 HERA I	H1 HERA II
$y$	(0.2, 0.7)	(0.1, 0.7)
$E_T^\gamma$	(5, 10) [GeV]	(5, 15) [GeV]

