Prompt Photons in Photoproduction

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

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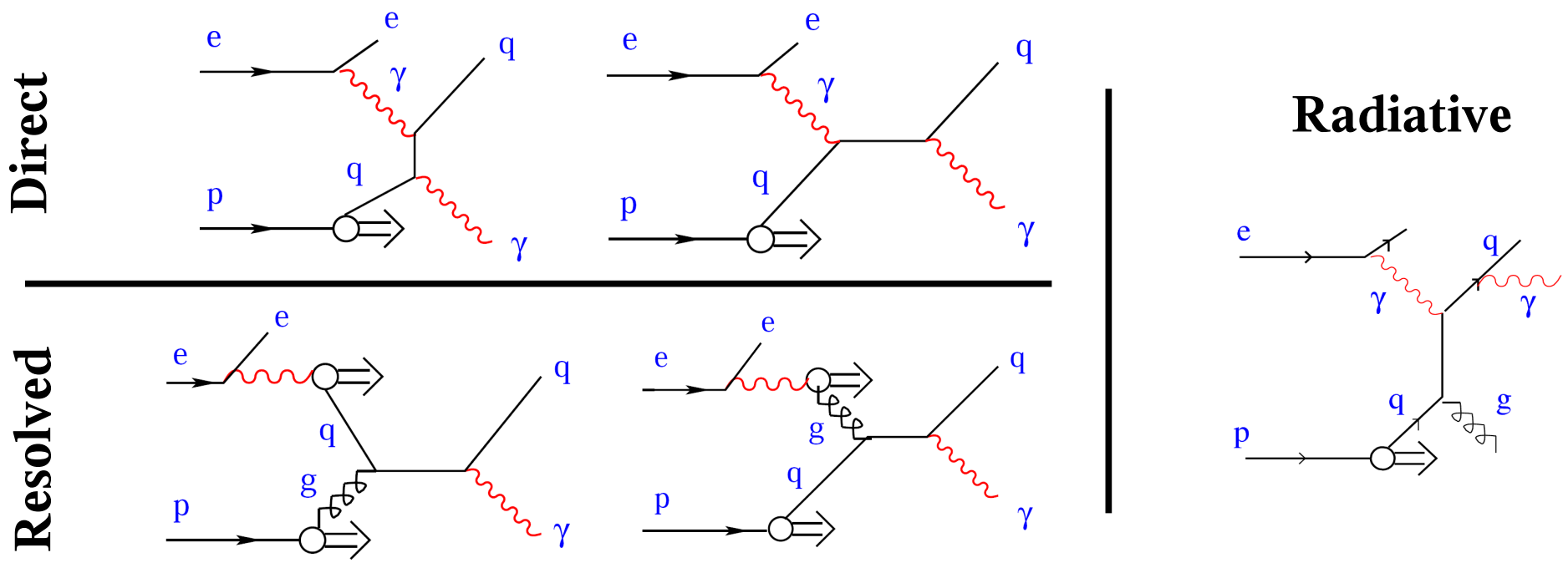
on behalf of the H1 Collaboration

Prompt photons at HERA

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

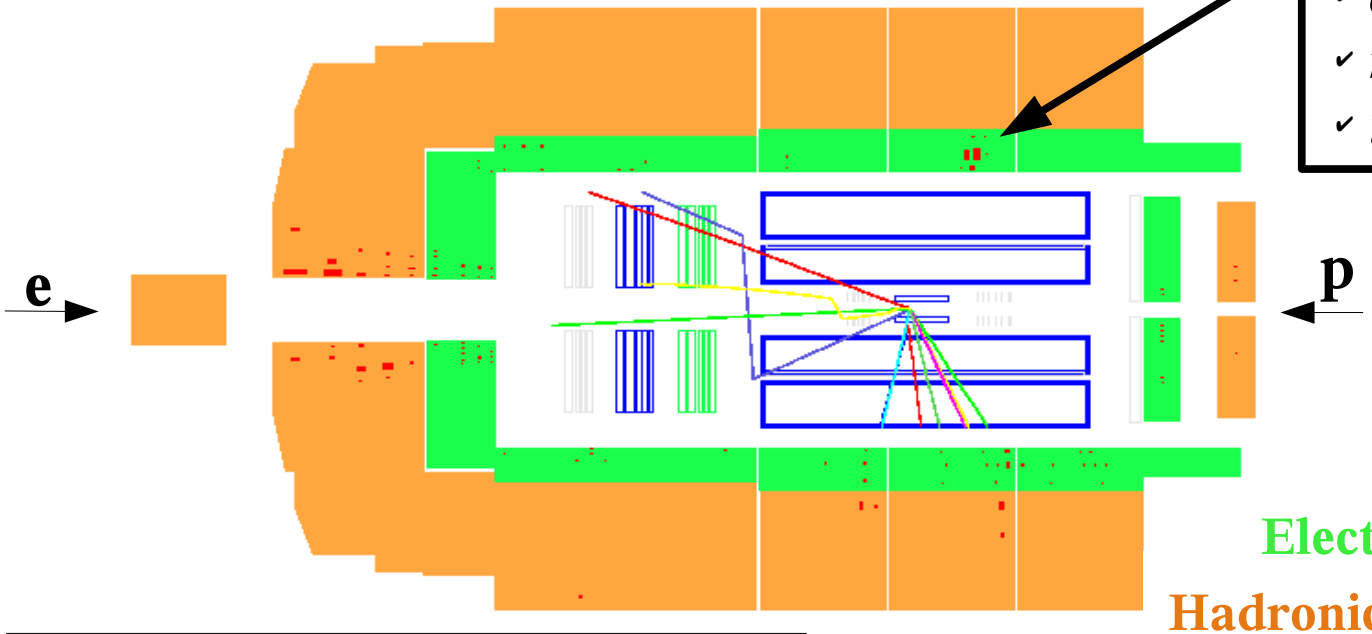
LO Feynman diagrams:



Prompt photon in the H1 detector

- *HERA collider:*

- *H1 detector*



Photon candidate:
- *cluster in em calorimeter*
- *not associated to track*
- *isolated*

Photoproduction:
- *no scattered electron in the detector*

Electromagnetic calorimeter

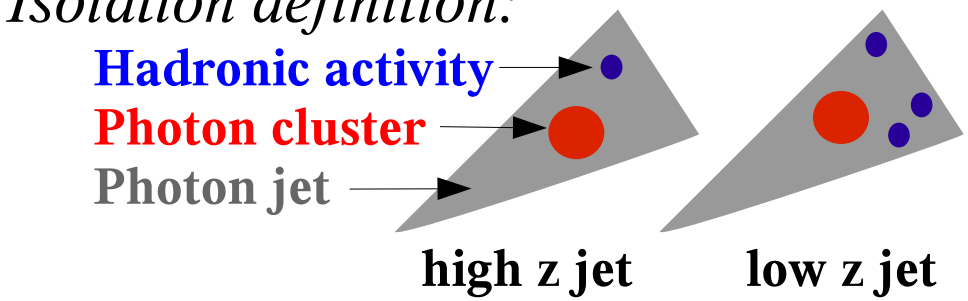
Hadronic calorimeter

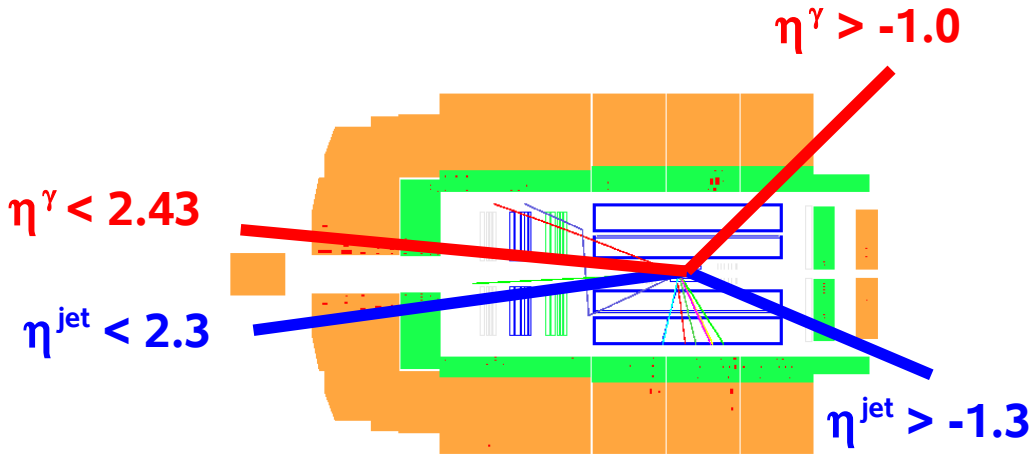
Using full HERA II data:
340 pb^{-1}

Phase space definition

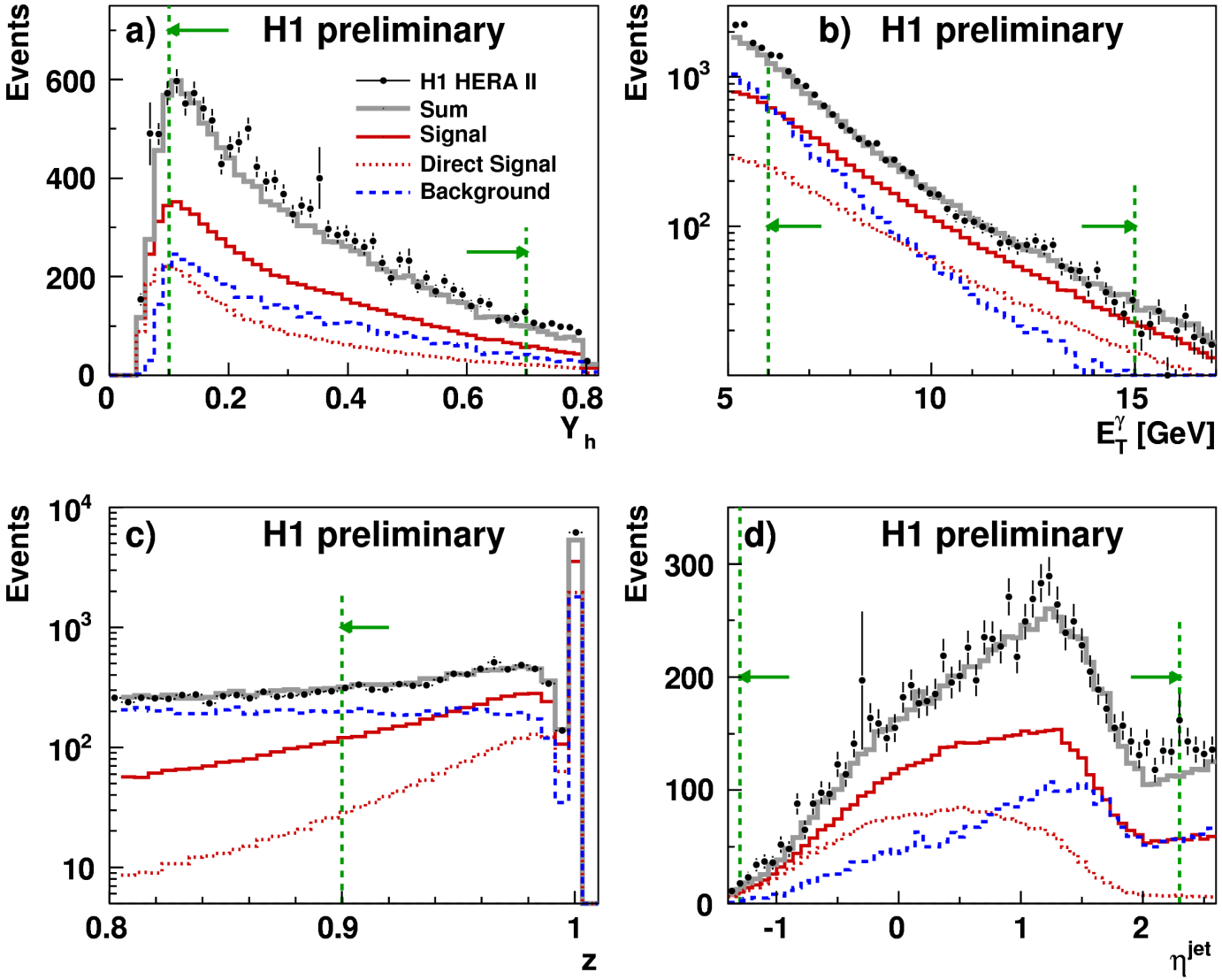
- **Inclusive measurement**
  - $Q^2 < 1\ GeV^2$
  - $0.1 < y < 0.7$
  - $6\ GeV < E_T^{\gamma} < 15\ GeV$
  - $-1.0 < \eta^{\gamma} < 2.43$
  - $z = E_T^{\gamma} / E_T^{\gamma\ jet} > 0.9$
- **Exclusive (photon + jet) measurement**
  - *Inclusive phase space*
  - $p_T^{jet} > 4.5\ GeV$
  - $-1.3 < \eta^{jet} < 2.3$

Isolation definition:





Control plots



- *PYTHIA MC scaled to the measured cross sections*
- *Data described by the sum of MC*
- *Still significant background contamination*

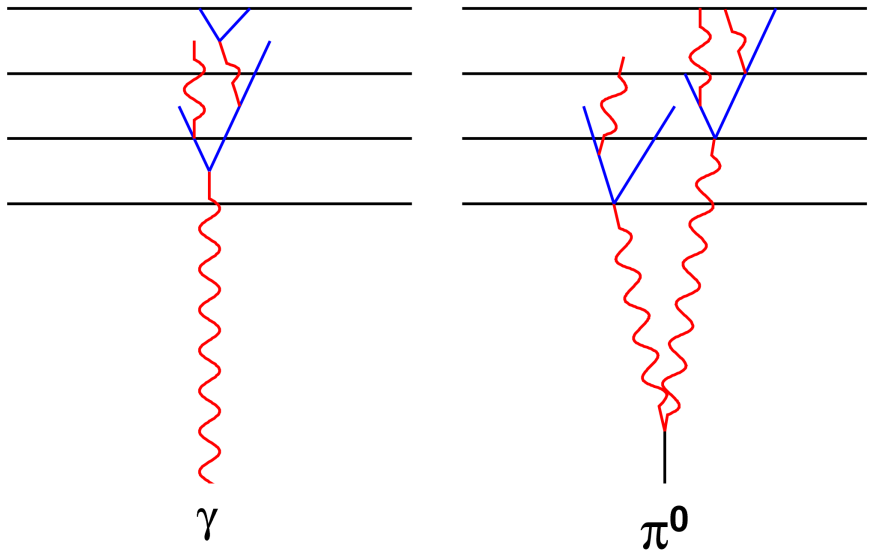
Background from multi-photon clusters

- *Hadrons decaying into multi-photon final states*

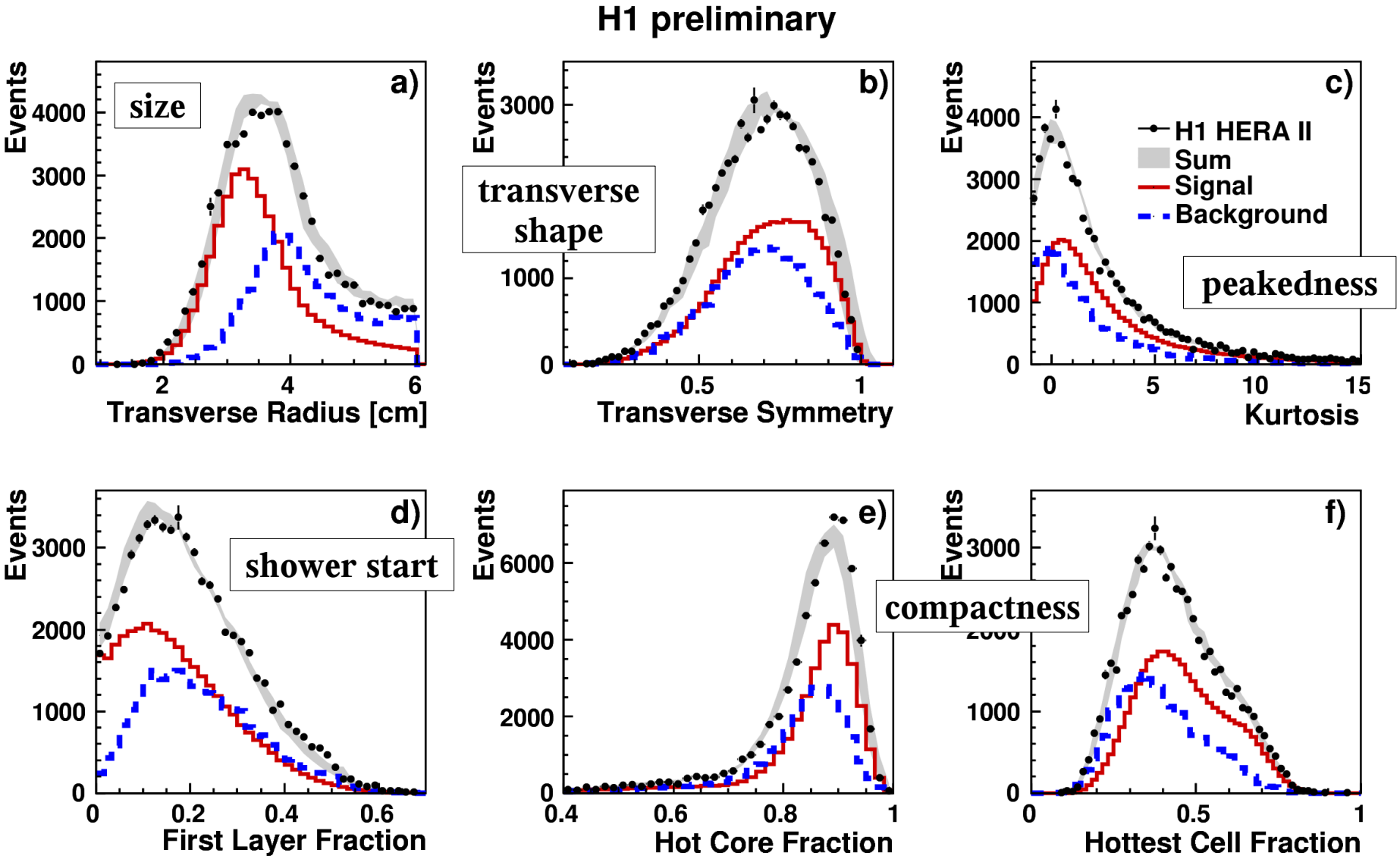
$$\pi^0 \to \gamma\gamma \qquad \eta \to \gamma\gamma \qquad \omega \to \pi^0\gamma \to \gamma\gamma\gamma$$

- *Cluster shapes used to statistically discriminate between signal and background*

- *Multi-photon clusters*
  - *less compact*
  - *more asymmetric*
  - *showering earlier*



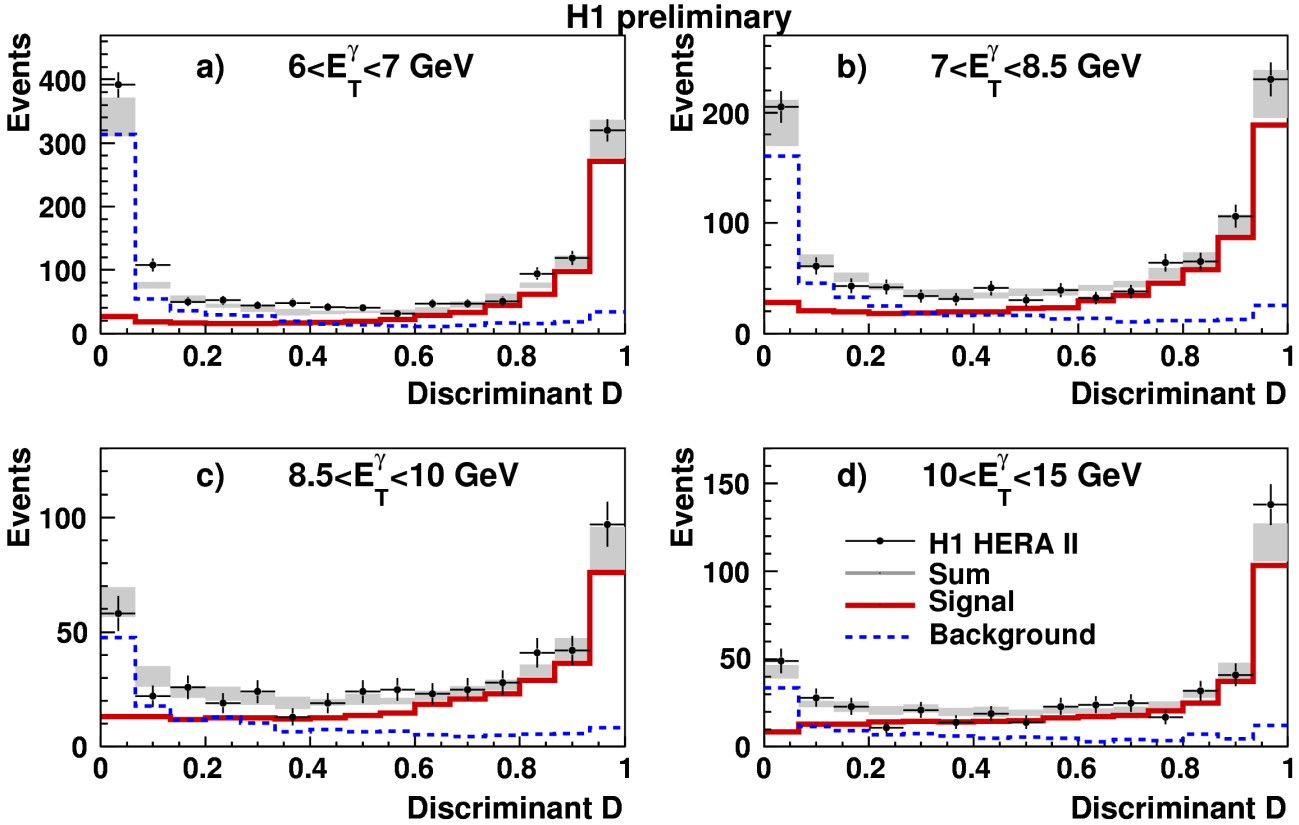
Variables used in multivariate analysis



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

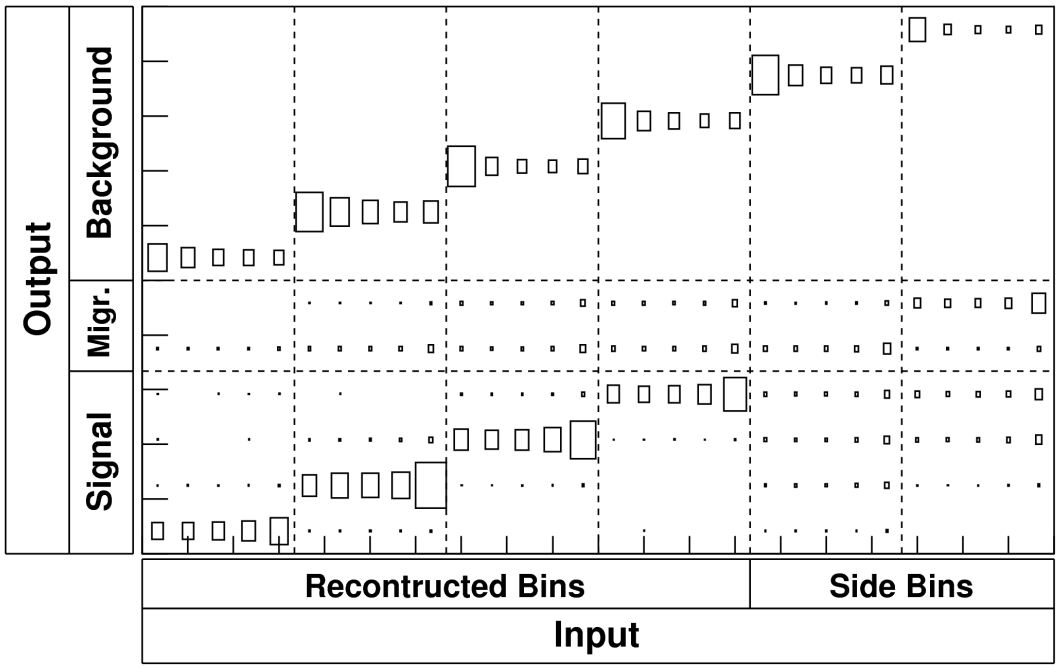
Signal – background discrimination

- *Variables combined into a discriminator with MVA*
- *Example of discriminator for $0.94 < \eta^{\gamma} < 1.42$*
- *Data described within cluster shapes systematic uncertainty*
- *Discrimination power depends on η^{γ} and E_T^{γ}*



Unfolding

- *Regularised unfolding procedure based on matrix inversion applied for the cross section determination*



- *Migration matrix developed such as to contain*
  - *Signal – Background discrimination*
  - *Migration within and from outside of the phase space*
  - *Acceptance correction*
- *Matrix of order 600 x 1700*

Calculations

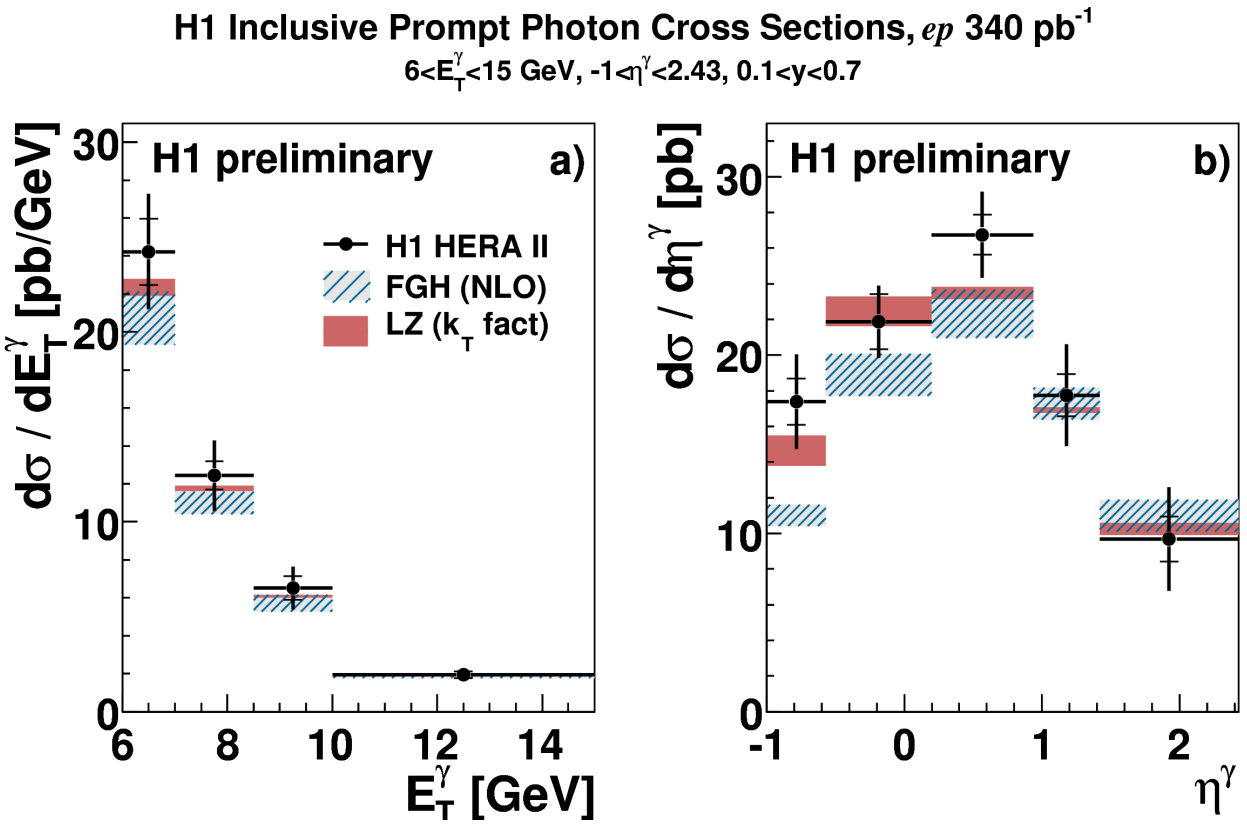
- *Fontannaz-Guillet-Heinrich (**FGH**)*
  - *collinear approach (NLO)*
  - *includes quark-to-photon fragmentation*
  - *box diagram $\gamma g \rightarrow \gamma g$*
- *Lipatov-Zotov (**LZ**)*
  - *k_T-factorisation approach (unintegrated pdfs used)*
  - *using Kimber-Martin-Ryskin prescription for updf*

- *Error estimation: simultaneous variation of fragmentation and renormalisation scale (E_T^{γ}) by factor 2.0 and 0.5*
- *Corrected for hadronisation and multi-parton interaction effects and compared to measured cross sections*

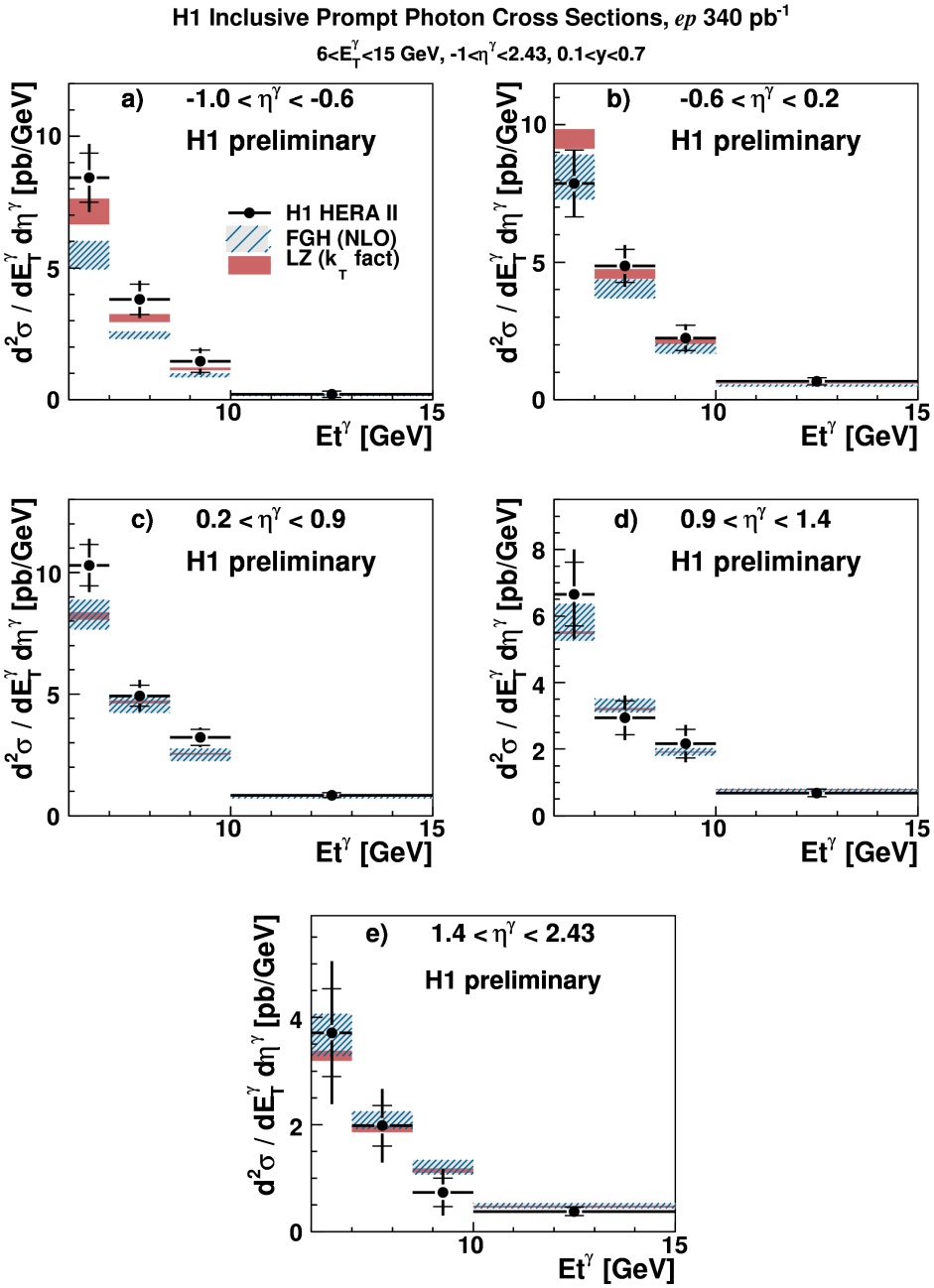
Inclusive prompt photon cross sections

- *Results presented with the correlated and uncorrelated error bars*
- *Systematic error dominates, mainly uncertainty of cluster shapes description in MC (10% - 25%)*

- ***Observation 1**: FGH significantly below the measurement for low η^{γ}*
- ***Observation 2**: LZ predicts the shape of η^{γ} more accurately*

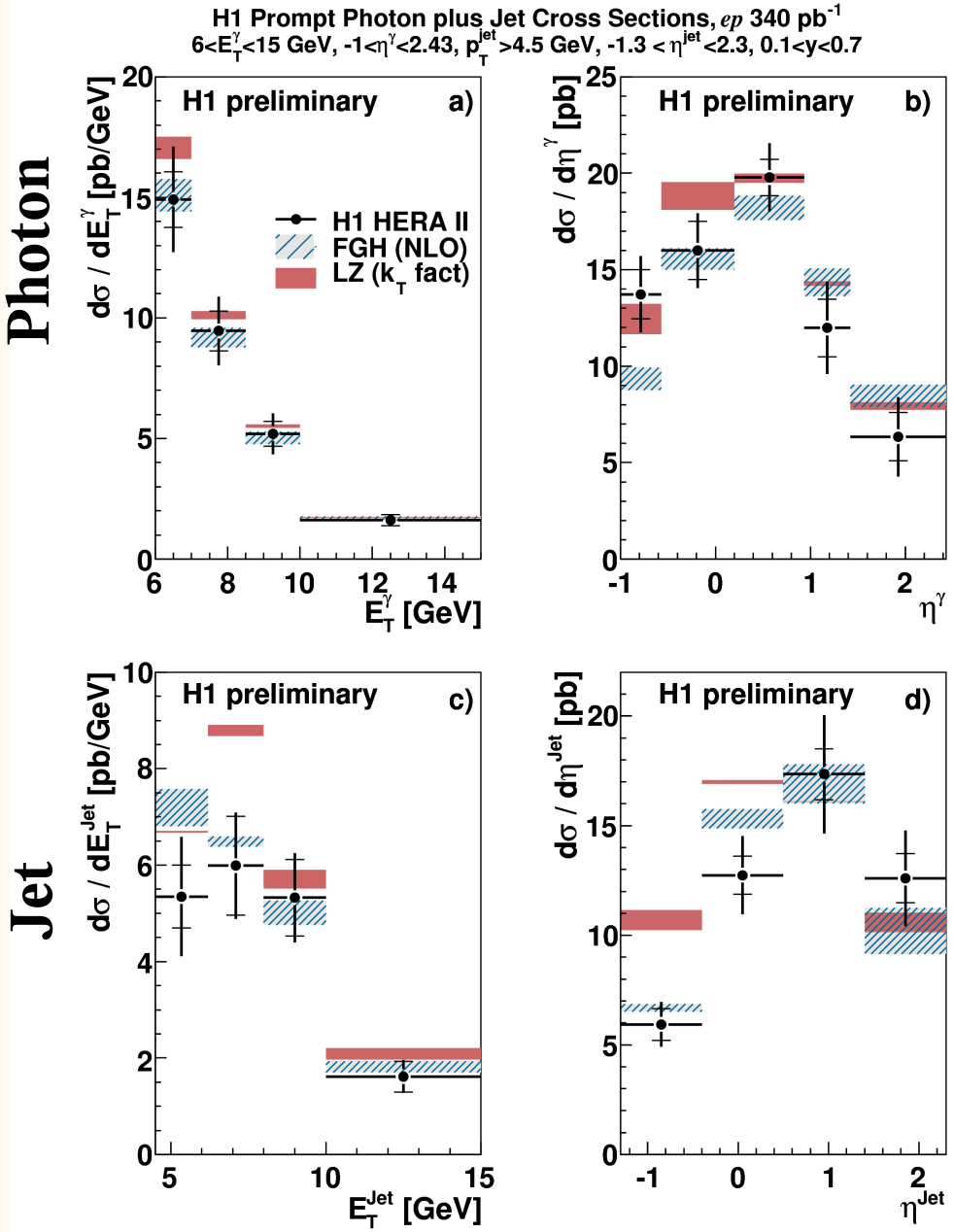


Inclusive 2d prompt photon cross sections



- *Double differential cross sections*
  - *high statistics of HERA II*
  - *multidimensional unfolding*
- *More insight into the discrepancy*
- *May be used for pdf fit*

Prompt photon + jet cross sections



PHASESPACE FOR JET

- *Photons $\eta^{\gamma} > 1.0$ not studied before at HERA*
- ***Observation 1**: Cross sections in bins of photon variables better described by LZ*
- ***Observation 2**:On contrary, jet properties better described by FGH*

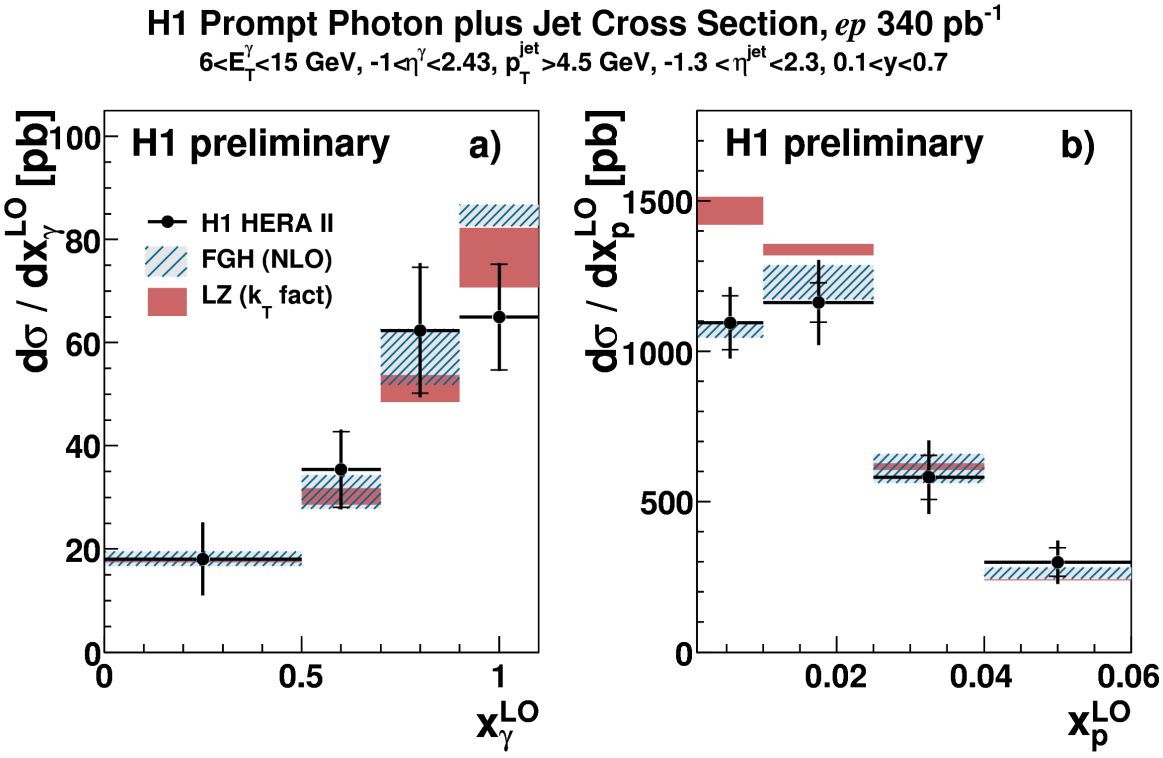
Prompt photon + jet cross sections

- *Exclusive phase space gives insight into the photon and proton content*
- *Longitudinal momentum fractions of partons in x_γ and x_p*

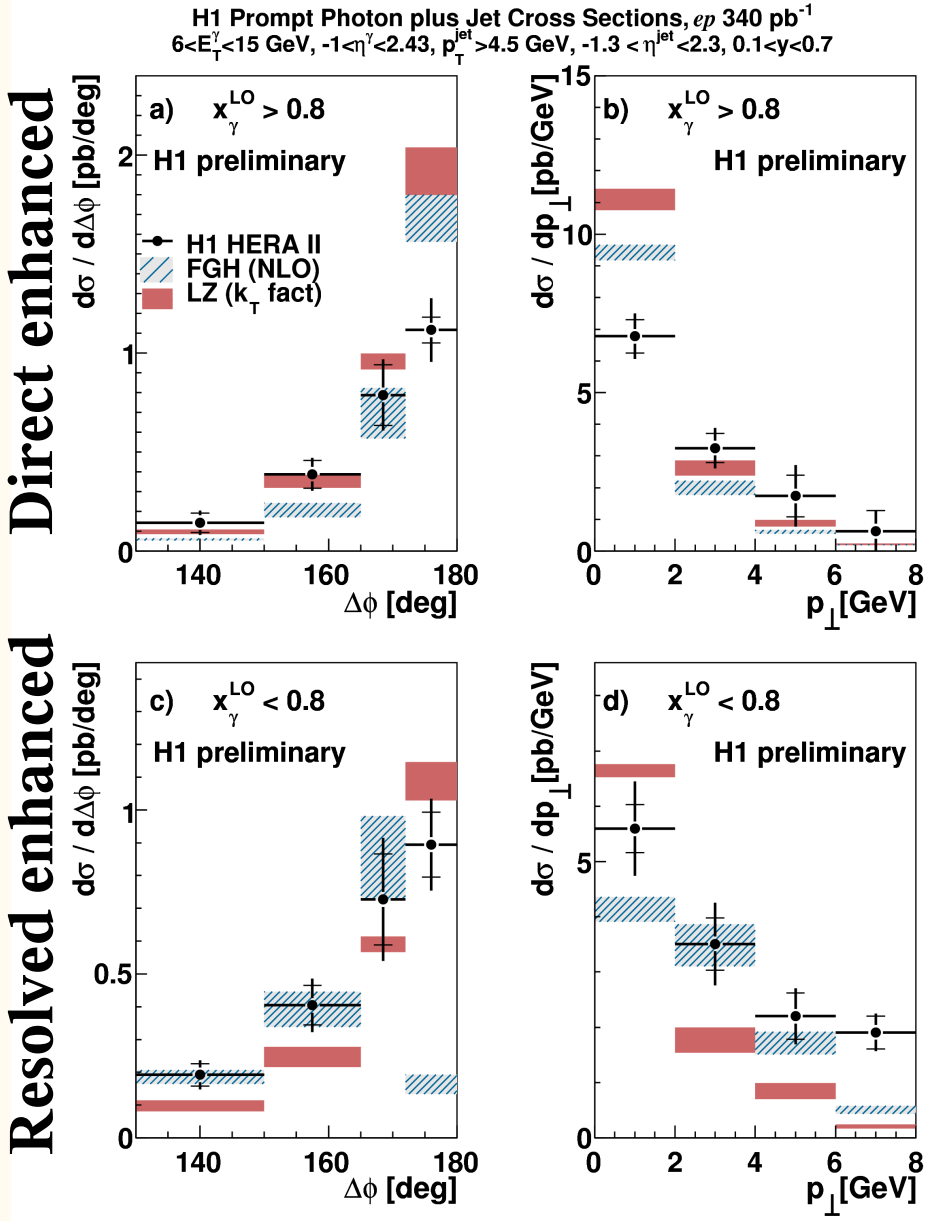
$$x_\gamma^{LO} = E_T^\gamma \frac{e^{-\eta^{jet}} + e^{-\eta^\gamma}}{2yE_e}$$

$$x_p^{LO} = E_T^\gamma \frac{e^{\eta^{jet}} + e^{\eta^\gamma}}{2E_p}$$

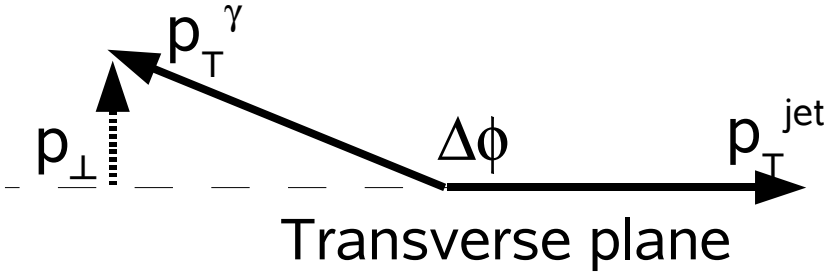
- *LO definitions do not use energy of the jet*



Exclusive prompt photon cross sections



- *Photon – jet correlations in direct (resolved) enhanced phase space*



- *Direct process more back-to-back*
- *Sensitivity to soft gluon emission in the highest Δφ bin in the resolved case*
  - *fixed order FGH calculation not reliable*
  - *k_T factorisation includes all orders in the pdf*
- *LZ missing diagrams visible in the tails of resolved cross sections*

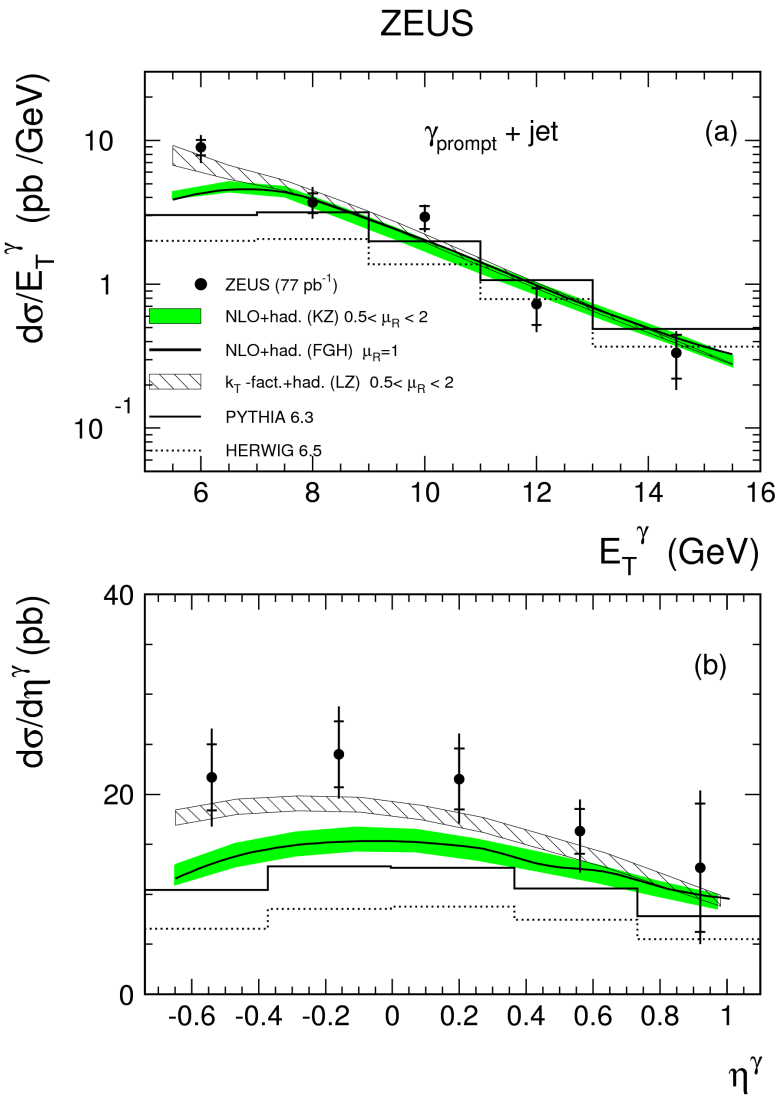
Summary

- ***New H1 results on prompt photon production in photoproduction presented***
  - *Phase space of the measurement extended into forward region*
  - *High luminosity of HERA II improves results*
- ***Results compared to calculations***
  - *Inclusive production underestimated in NLO calculation in the low η^{γ} region*
  - *For exclusive measurement deficits found in both calculations*
  - *Most strongly visible in γ-jet correlation studies*

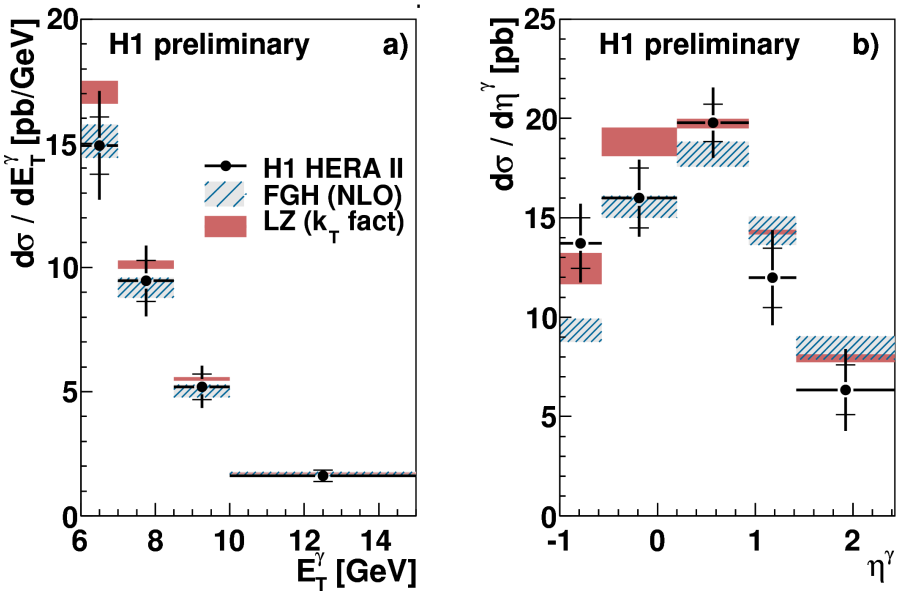
Backup

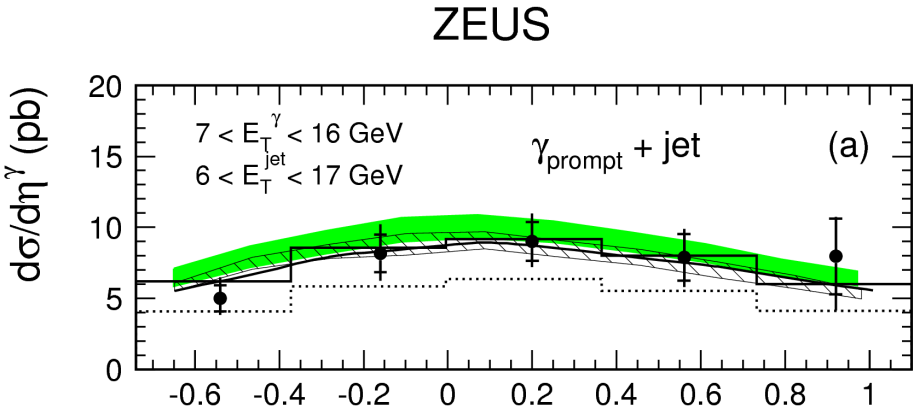
Zeus measurement - γ

$E_T^{\gamma} > 5$ GeV, $E_T^{jet} > 6$ GeV



$E_T^{\gamma} > 6$ GeV, $E_T^{jet} > 4.5$ GeV

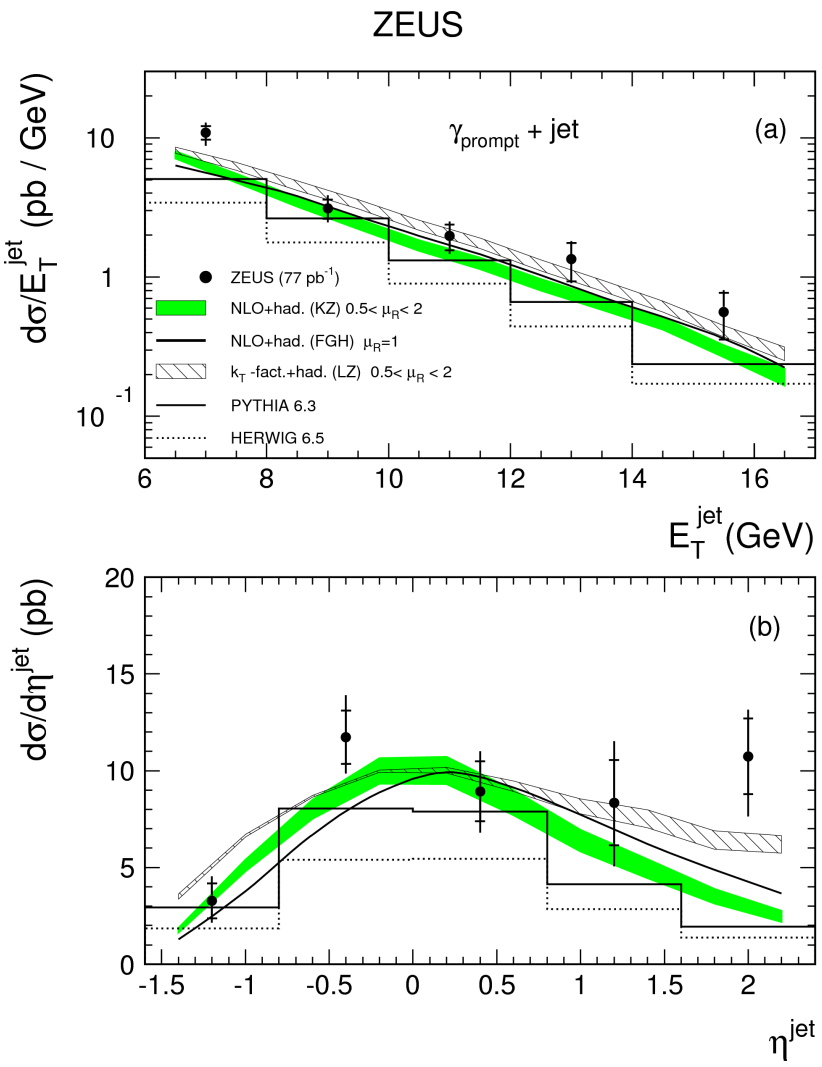




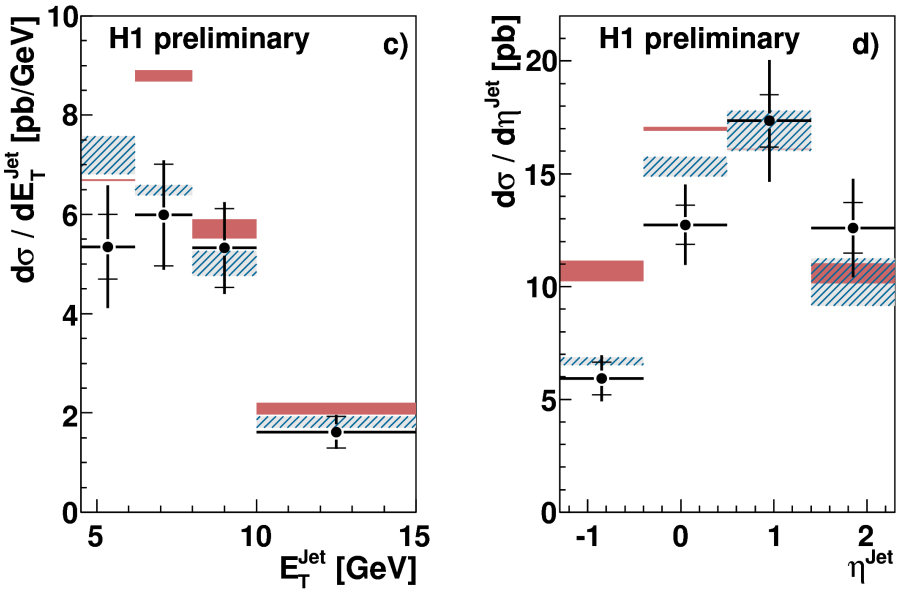
$E_T^{\gamma} > 7$ GeV, $E_T^{jet} > 6$ GeV

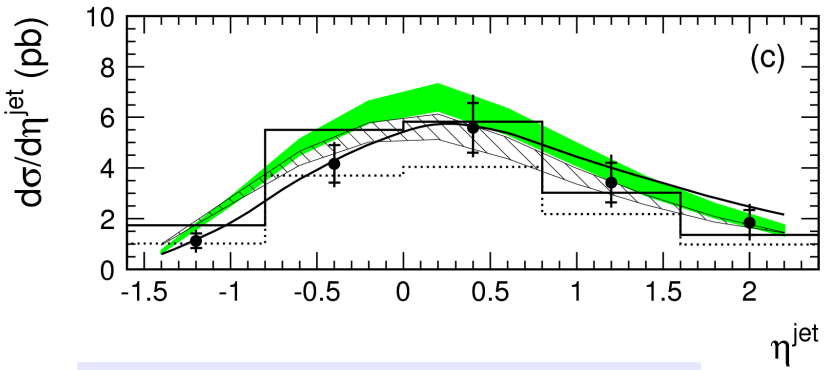
Zeus measurement - jet

$E_T^{\gamma} > 5$ GeV, $E_T^{jet} > 6$ GeV



$E_T^{\gamma} > 6$ GeV, $E_T^{jet} > 4.5$ GeV

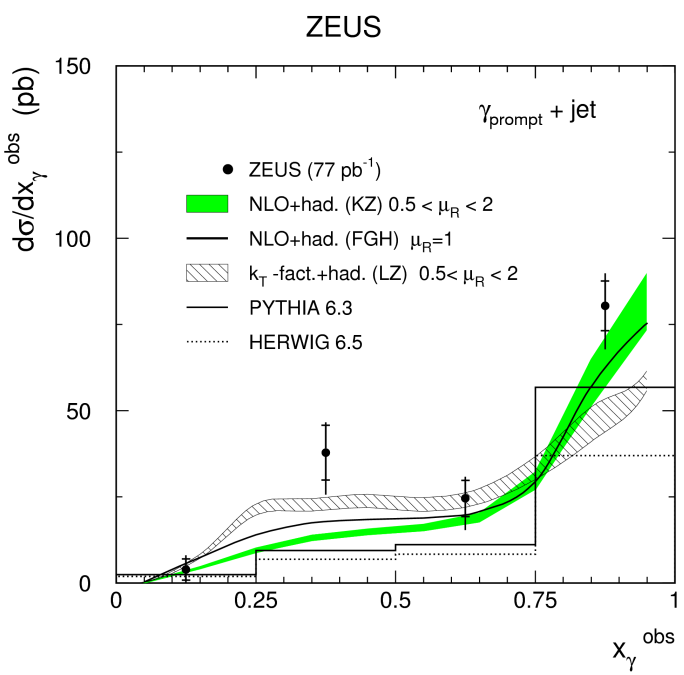




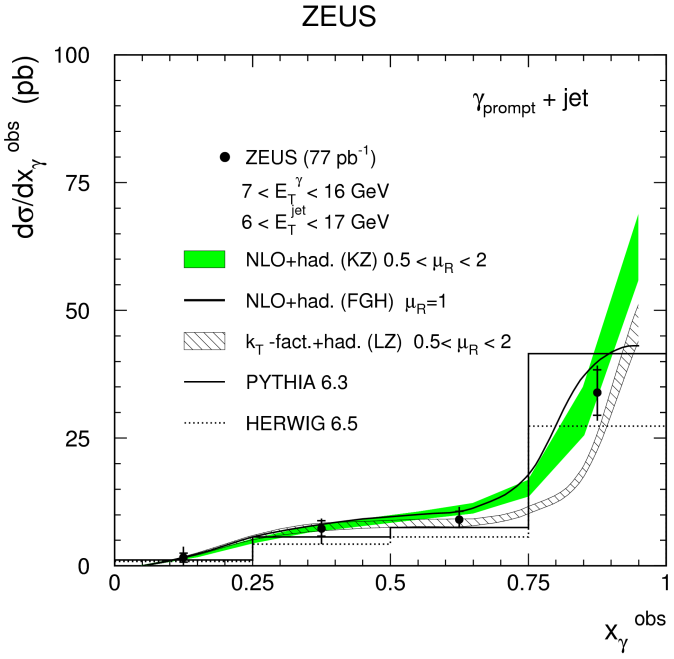
$E_T^{\gamma} > 7$ GeV, $E_T^{jet} > 6$ GeV

ZEUS measurement x_γ

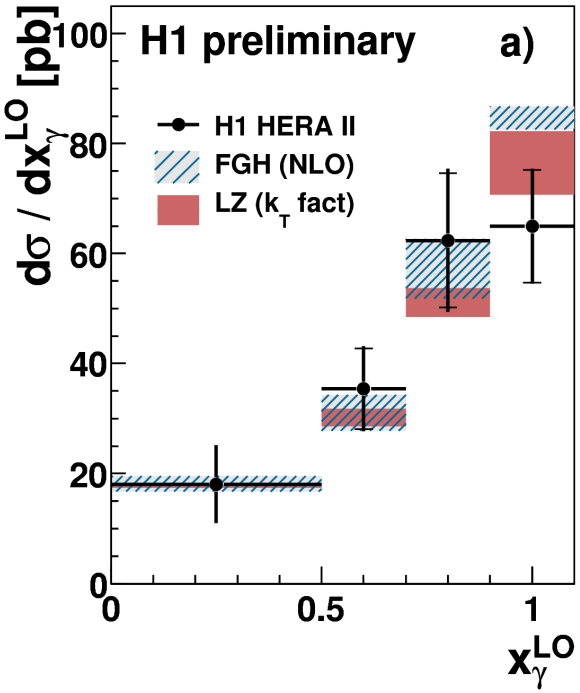
$E_T^\gamma > 5$ GeV, $E_T^{jet} > 6$ GeV



$E_T^\gamma > 6$ GeV, $E_T^{jet} > 4.5$ GeV



$E_T^\gamma > 7$ GeV, $E_T^{jet} > 6$ GeV



Systematic error summary

Source	Variation	Error on cross section
θ^{γ}	3-4 mrad	< 1 %
E^{γ}	1-4 %	~ 1.5%
HFS	2 %	~ 1 %
Symmetry	2-8 %	~ 1 % (4% forw.)
Kurtosis	4-10 %	~ 1 % (2% forw.)
First Layer Fr.	2-10 %	~ 1%
Width	1-4% HCF, 1-8% R	~ 10% (25% forw.)
Direct / Resolved	7 %	< 1%
Radiation scale	20 %	< 1 %
Trigger corr.	monitored with Etag	~ 1%
Conversion	10% (30% forw.)	1% (3% forw.)
Veto	2% CJC, 1% CIP	2.5%
Lumi	3.4%	3.4%
DIS substraction	1-2%	1-2%