Isolated Photons in DIS

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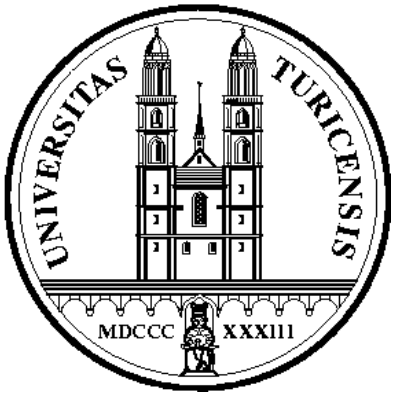
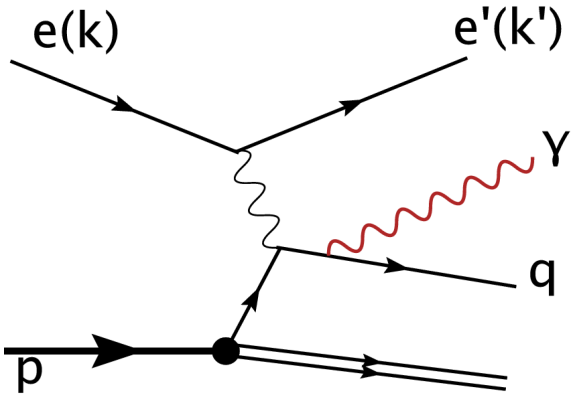
Outline

- Motivation
- Isolated Photon Production in DIS
- Event Selection
- Signal/Background Separation
- Results
- Summary



Motivation

- First measurement of Isolated Photons in DIS at H1
- Extend phasespace of former measurement by ZEUS 04 (hep-ex/0402019)
  in Q^2, transverse energy E_T^{γ} and pseudorapidity η^{γ}
  more than double the luminosity
  10x higher total cross section expectation
- Understanding of isolated photon production essential for searches at LHC.
  Low Higgs masses: $H \rightarrow \gamma\gamma$ best discovery channel
- Recent LO calculation available for inclusive and exclusive measurement

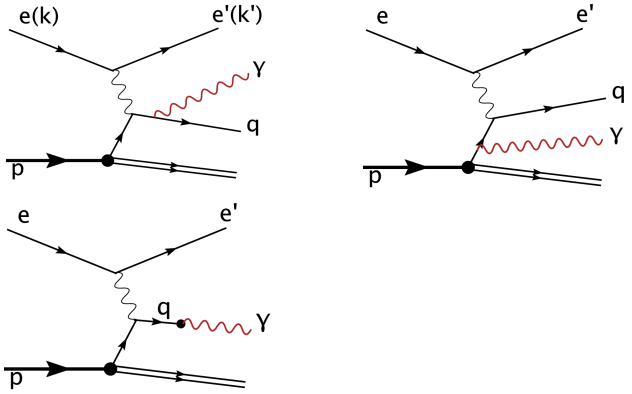


Isolated Photon Production in DIS

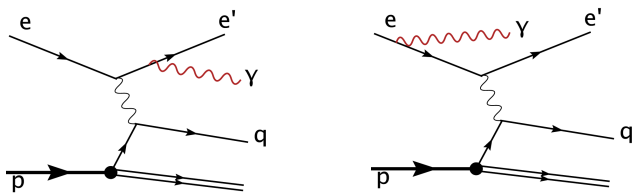
At Leading Order($\alpha^3\alpha_s^0$) at HERA in DIS $Q^2 = -(k-k')^2 > 4\ GeV^2$

- Radiation from the quark (QQ)

  including quark-to-photon fragmentation



- Radiation from the electron (LL)



- Interference (LQ), small (3%)
- LO calculation by Gehrmann et al. (hep-ph/0601073 and hep-ph/0604030) corrected to hadron level (10-20%)
- MC PYTHIA radiation from Quark

  RAPGAP radiation from electron

Signature:

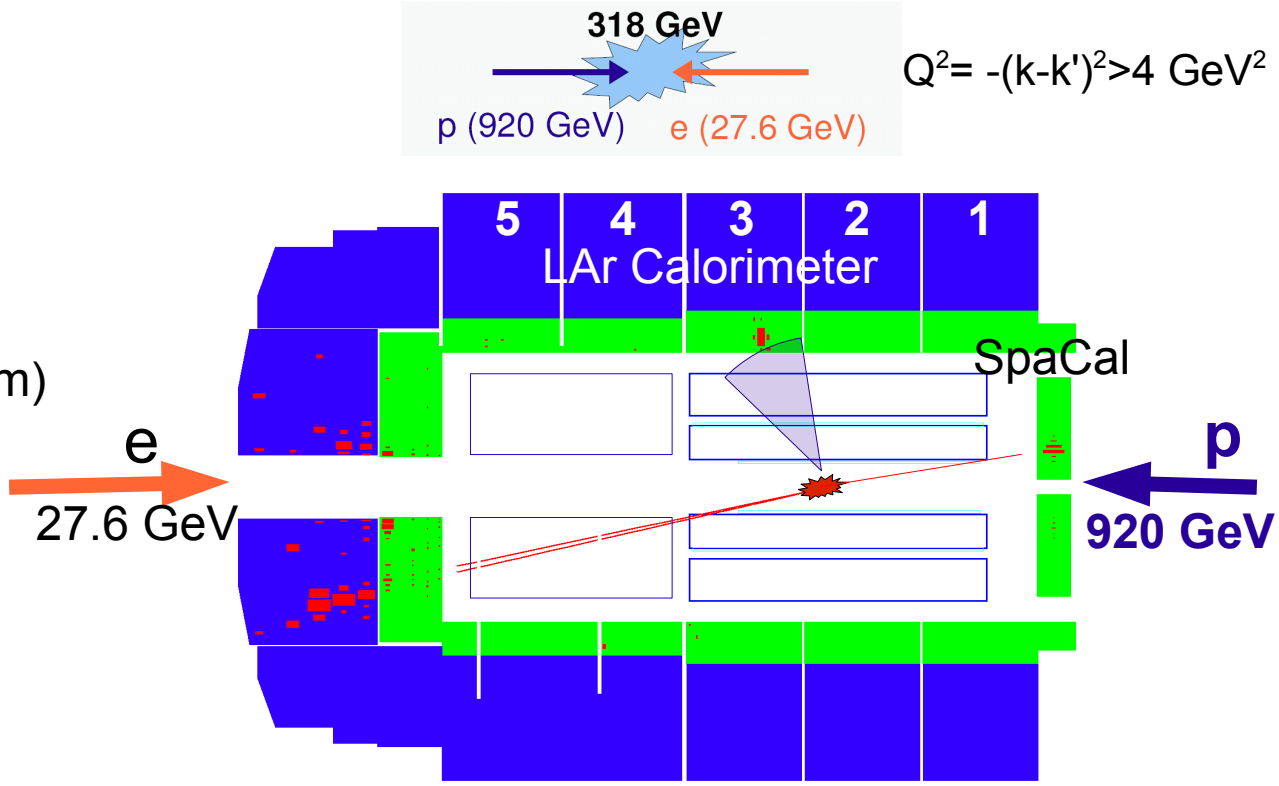
- Scattered Electron
- Isolated photon
- Hadronic activity (Vertex)
- Separation from background (neutral hadrons)

  Shower shape analysis

Isolated Photons in H1

Selection

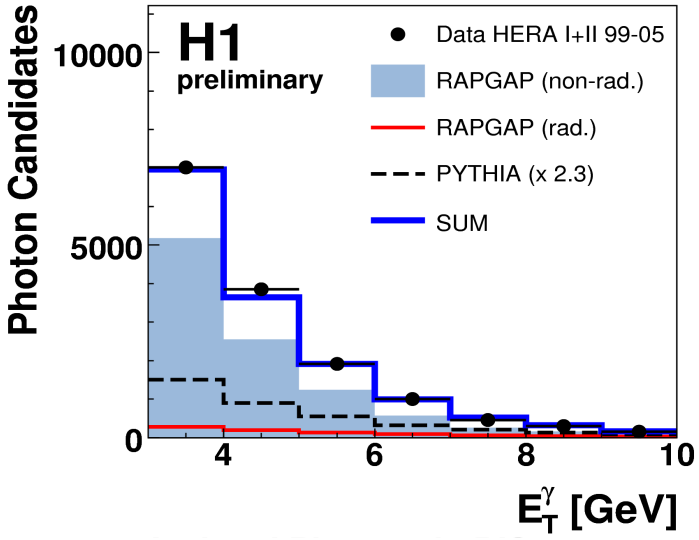
1) Scattered Electron in SpaCal
   - E'>10 GeV
   - θ_e<177°
2) Isolated Photon Candidate in LAr
   - compact elmgn. Cluster
   - 3 < E_T^{γ} < 10 GeV -1.2< η^{γ} <1.8
   - no track pointing to cluster (20cm)
   - Isolation z = E_t^{γ}/E_T^{jet} > 0.9
3) Phasespace:
   - 4< Q^2 < 150 GeV^2
   - y> 0.05
   - $W_X^2 = (p_e + p_p - p_e' - p_\gamma)^2$ >2500 GeV^2
4) Central Track (Vertex)
5) Hadronic Jets
   - k_T algorithm R_0=1
   - P_t^{jet} >2.5 GeV, -1.0 < η^{Jet} < 2.1



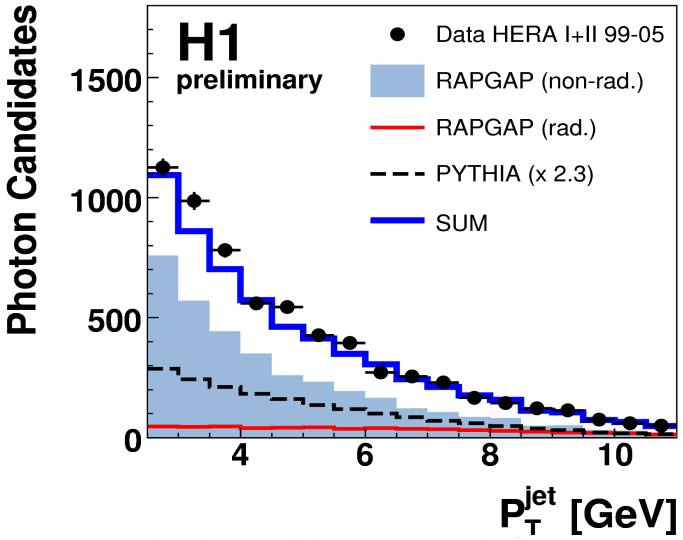
Data 99-05 (HERA I+II) Luminosity 226.2 pb^{-1}
14 670 events, 6 495 with an additional jet,
photon signal extracted with a shower shape analysis

Photon Candidates - Hadronic Jets

Photon



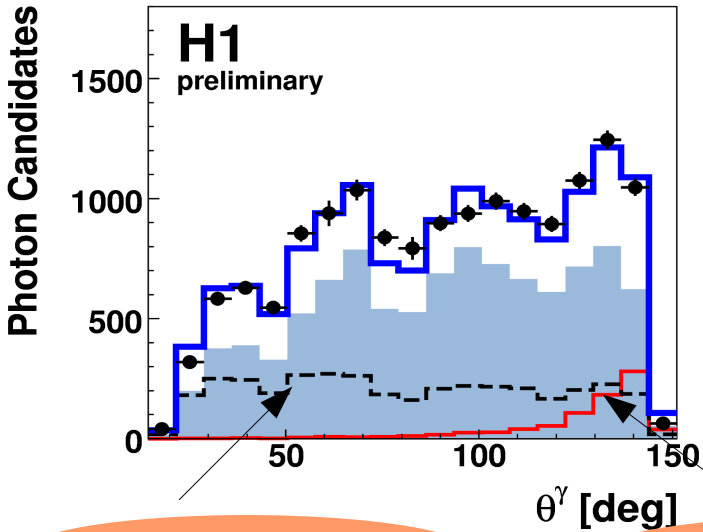
Hadron Jet

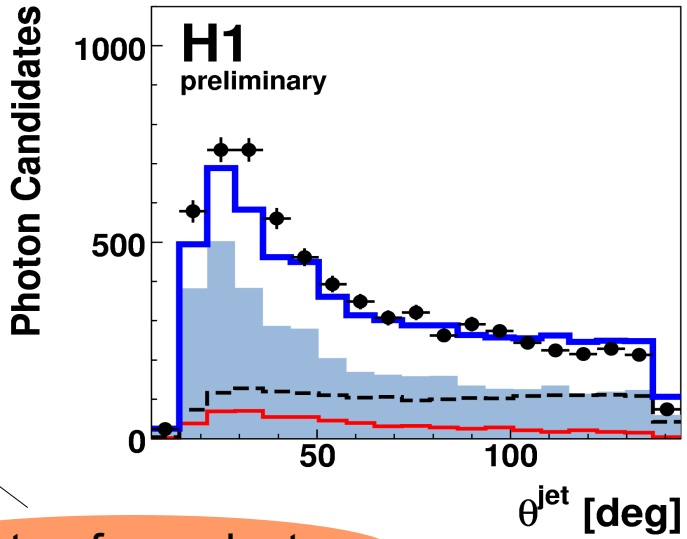


PYTHIA (6.224)
Photons from quark scaled by 2.3

RAPGAP rad. (3.1)
Photons from electron

RAPGAP non-rad. (3.1)
background (mainly neutral hadrons)





Scaling factor from cross section measurement

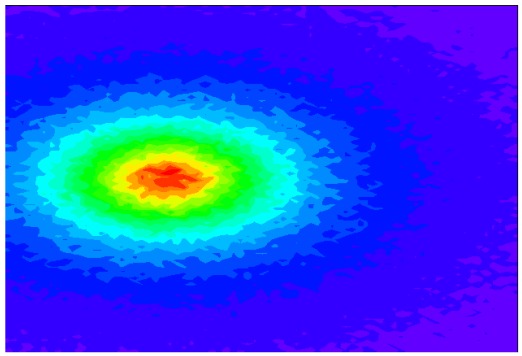
Acceptance corrections:
PYTHIA (scaled by 2.3) plus RAPGAP

Photon from quark

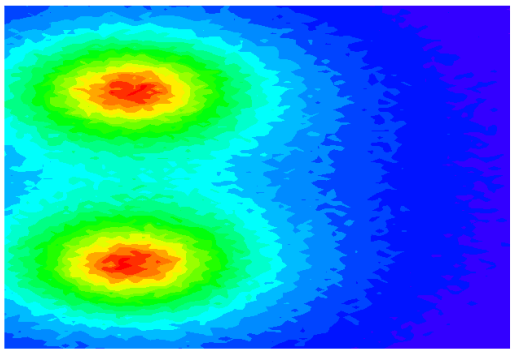
Photon from electron

Background: multi-photon clusters

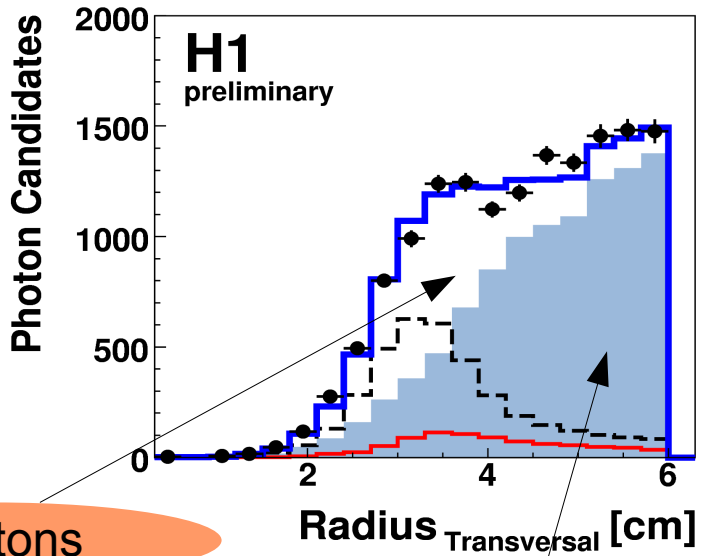
Signal: single photons



Background: multi-photon clusters
from hadronic decays: π^0, η, η', ρ, K^*, K_S, K_L, Ω, (anti)neutrons

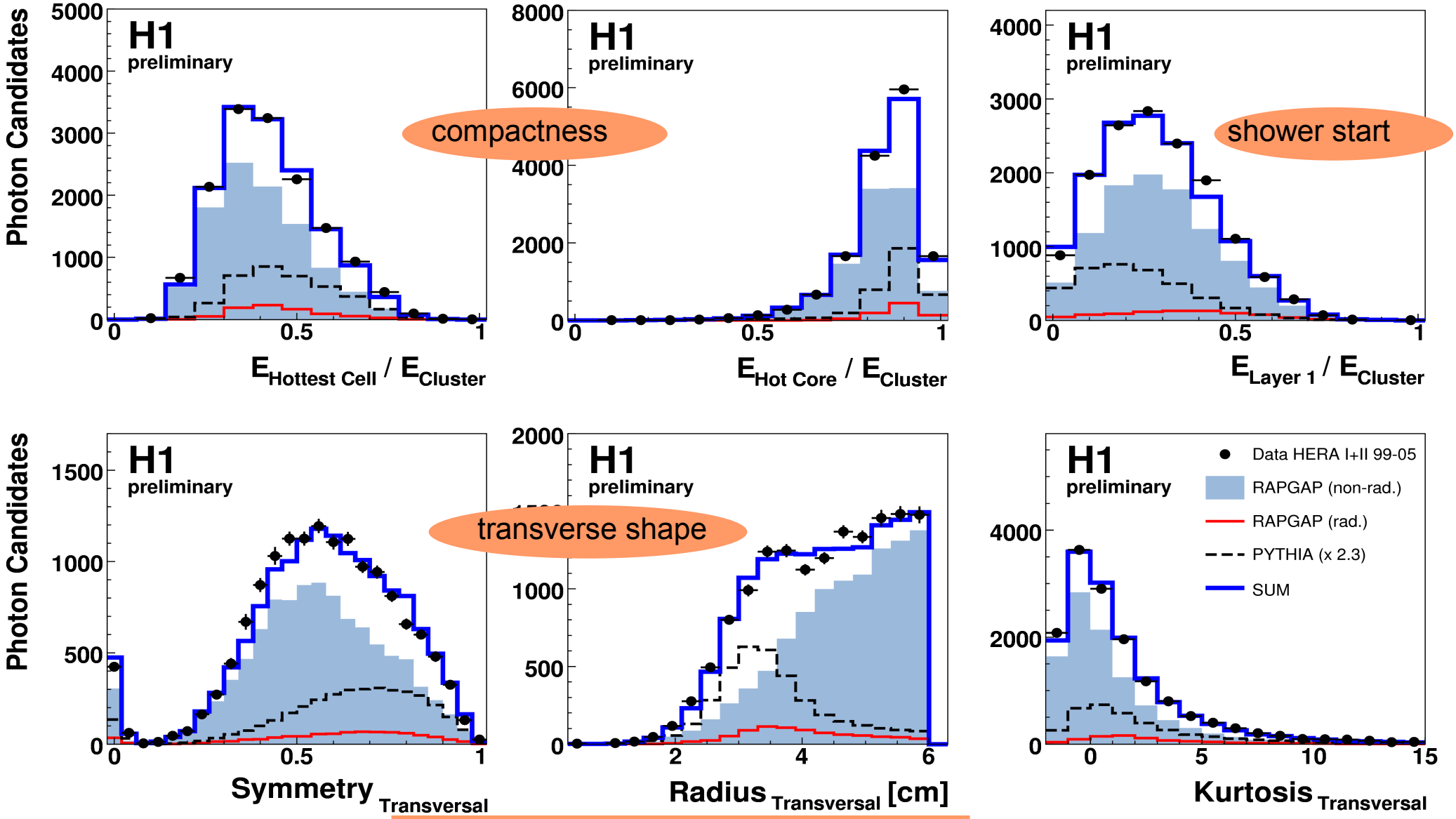


- less compact
- transversly wider
- more asymmetric
- shower starts earlier



Signal – Background Separation with shower shape analysis

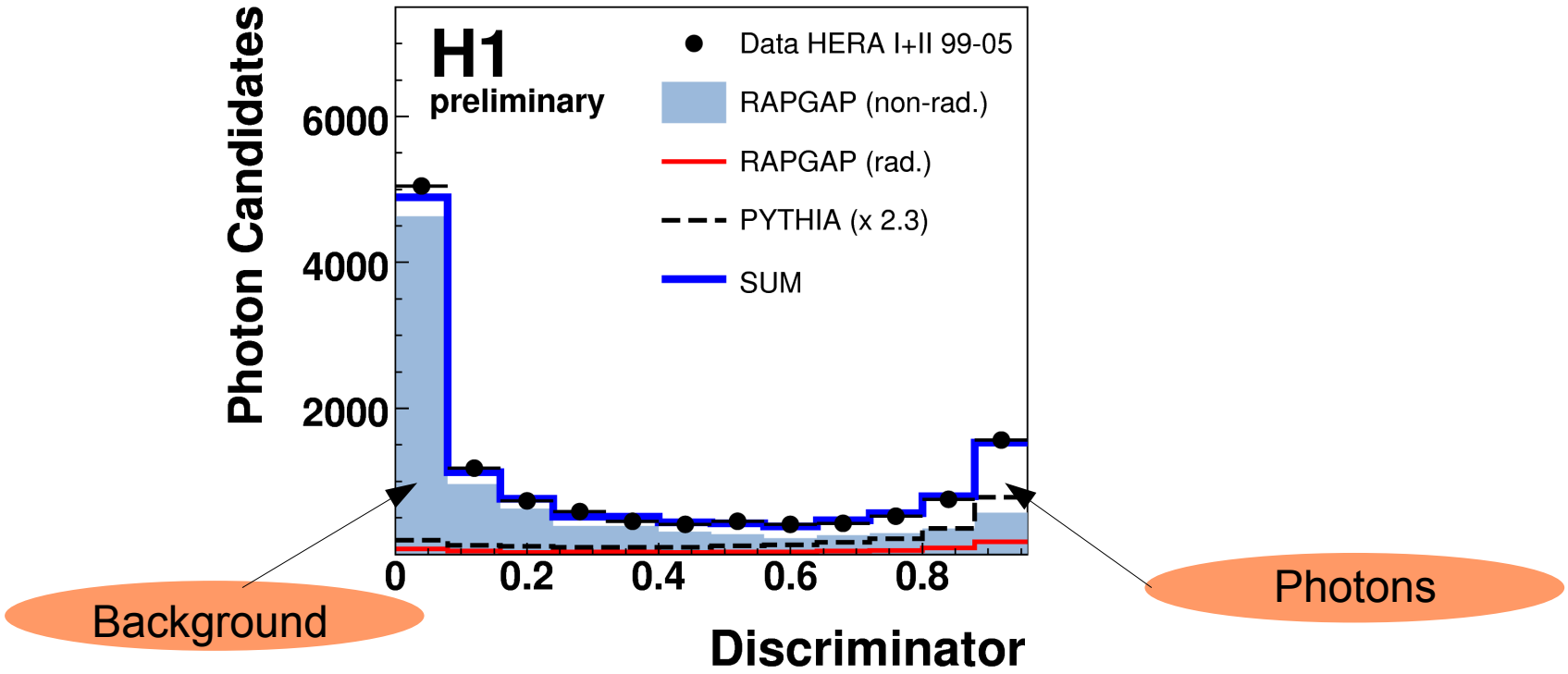
Shower Shape Variables



Cluster shapes well described by MC

Photon Signal Extraction

- Shower Shape Analysis in bins of E_T^γ, η^γ and Q^2
- Discriminator formed (likelihood approach) with 6 shower shape variables
- Probability densities functions defined by MC events with Single Particles (high statistics)
  Signal: photons, Background: mix of neutral hadrons π^0, η, η', ρ, K^*, K_S, K_L, Ω, (anti)neutrons

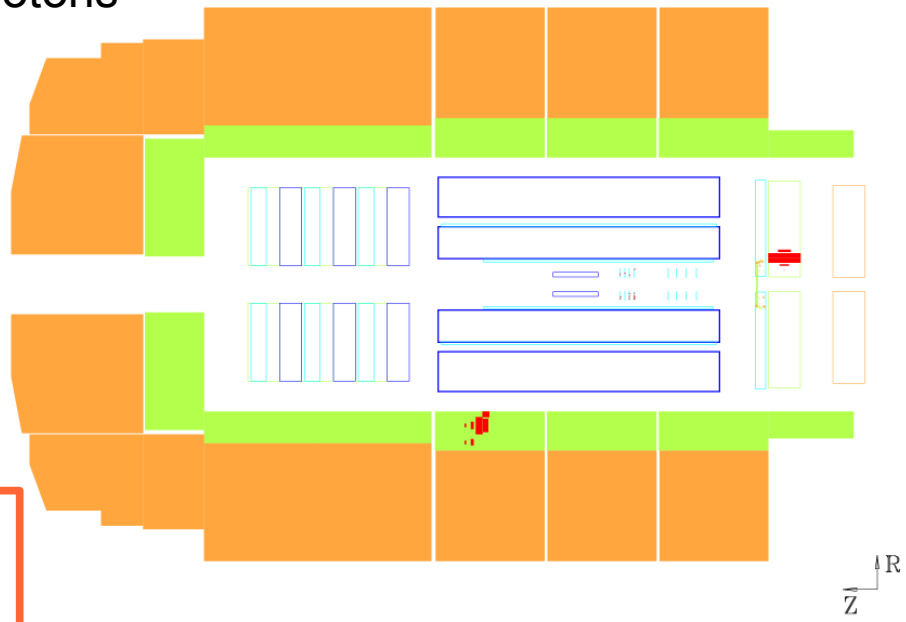


- Extract photon content in bins of E_T^γ, η^γ and Q^2 by χ^2 fit to discriminator

Control of cluster shapes

Dominant systematic error from description of cluster shapes
studied using Bethe Heitler and Deeply Virtual Compton Scattering events ep → epγ

- Bethe Heitler: Electron in LAr, photon in SpaCal
- DVCS: Electron in SpaCal, photon in LAr
- Energy range:comparable
- Compare cluster shapes with MC electrons and photons

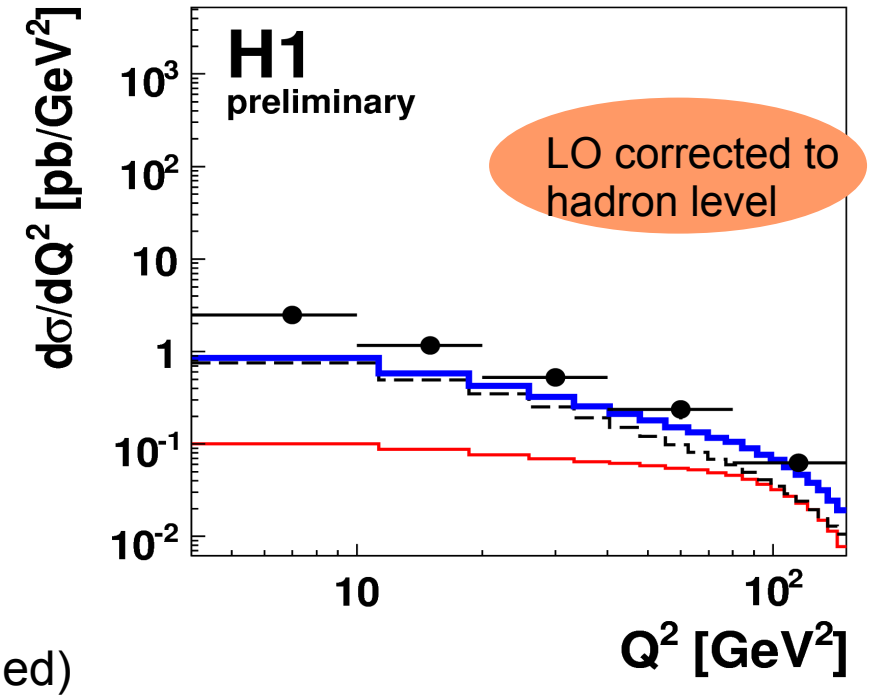


➔ uncertainty increasing with E_T and η

➔ 11%-25% effect on cross section measurement

Cross sections

Phase Space
- $3 < E_T^{\gamma} < 10$ GeV $-1.2 < \eta^{\gamma} < 1.8$
- $z = E_t^{\gamma}/E_T^{jet} > 0.9$
- $4 < Q^2 < 150$ GeV^2
- $y > 0.05$
-
- $W_X^2 > 2500$ GeV^2
- Electron $E' > 10$ GeV, $\theta_e < 177^o$



Total inclusive cross section:

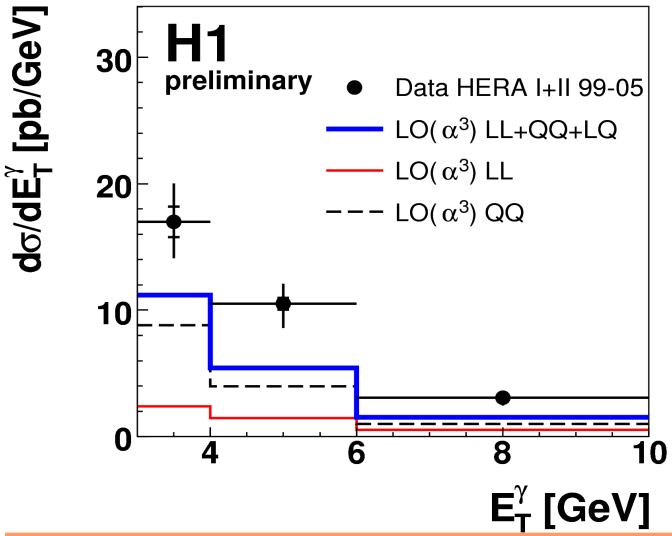
$50.3 \pm 1.7\ (\text{stat})\ ^{+6.8}_{-7.8}\ (\text{syst})$ pb

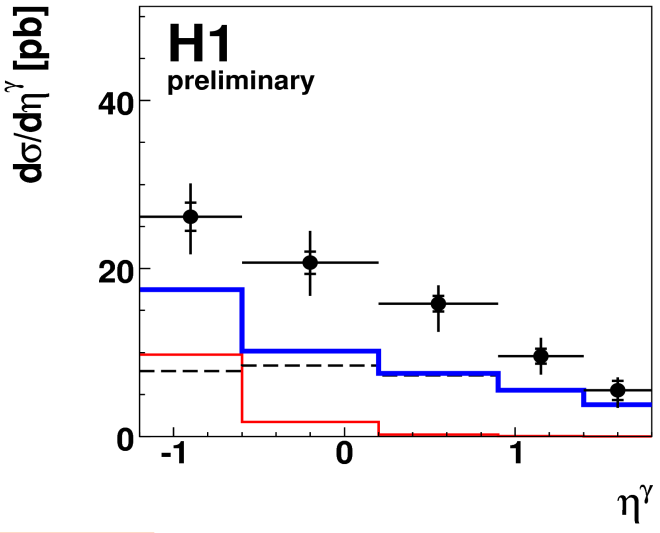
LO 28.6 pb MC 26.4 pb (note PYTHIA not scaled)

Predictions 44% and 48 % too low, most significant at low Q^2

Inclusive Isolated Photons

Comparison to LO calculation: LO 44% too low

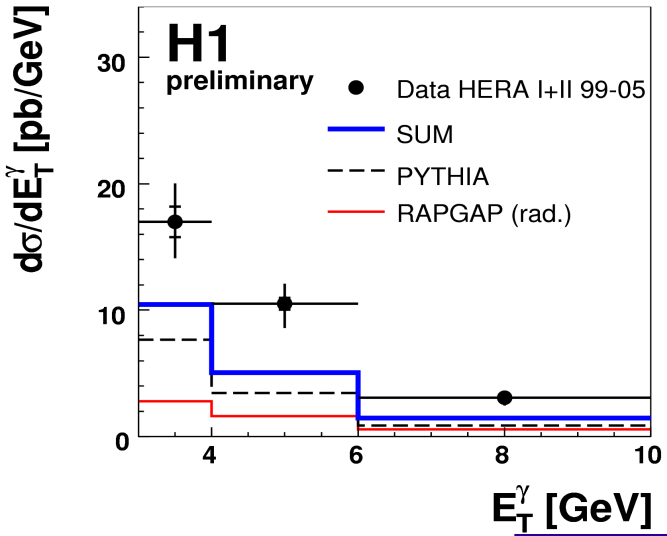


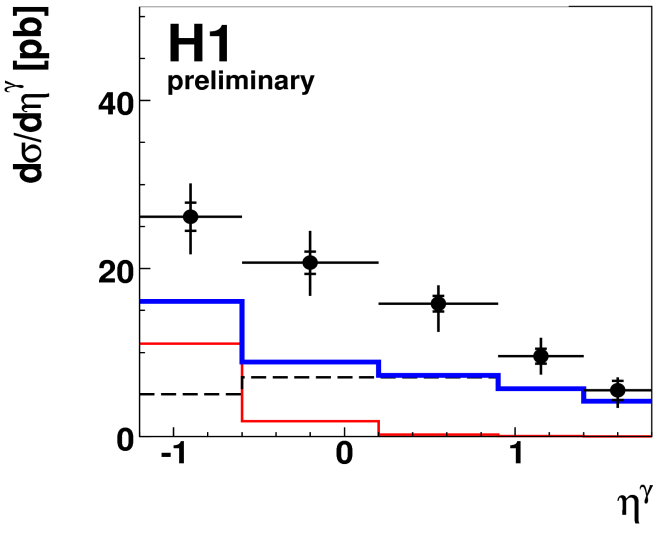


Radiation from electron contributes only in first bin in η^γ

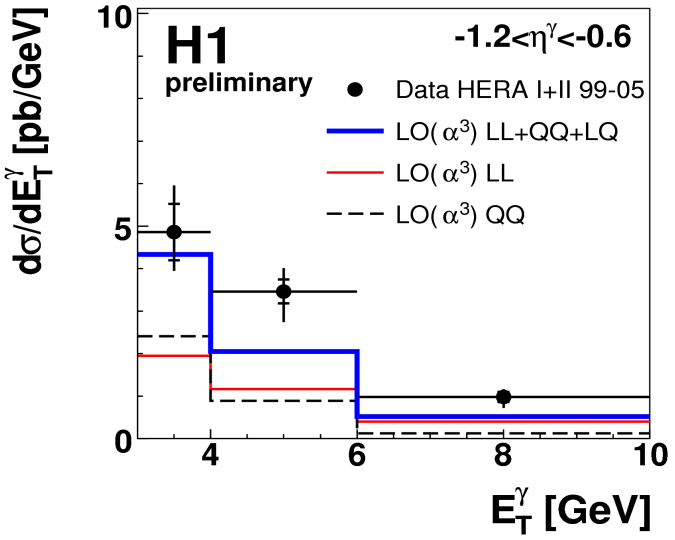
MC prediction very similar to LO calculation

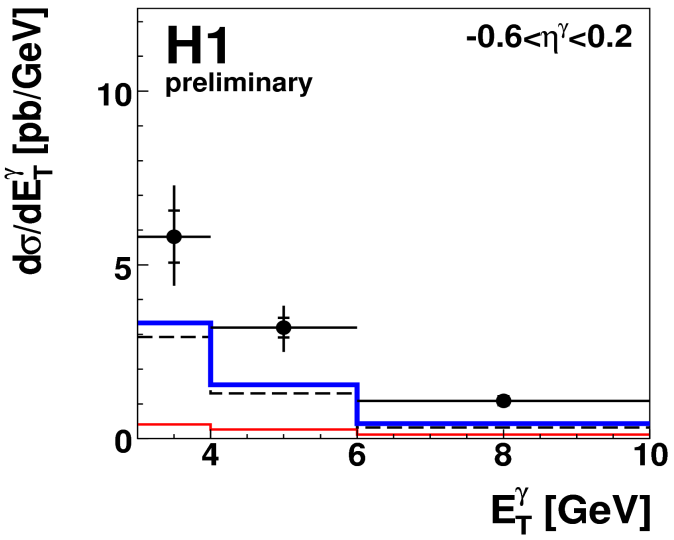
Comparison to MC: MC 48% too low

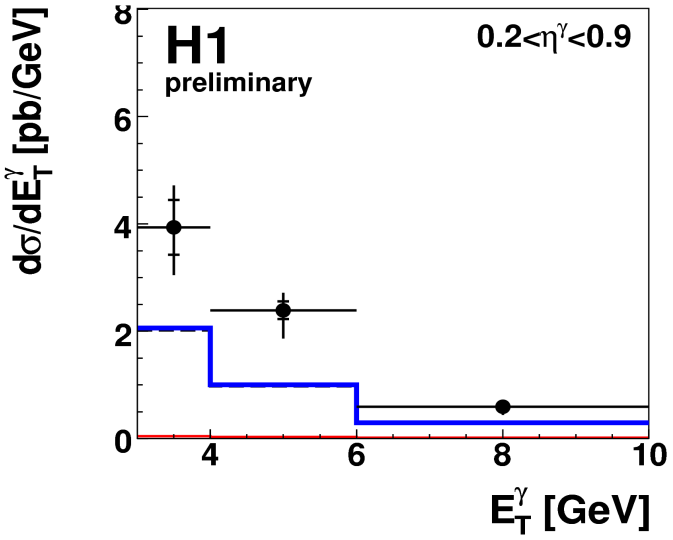


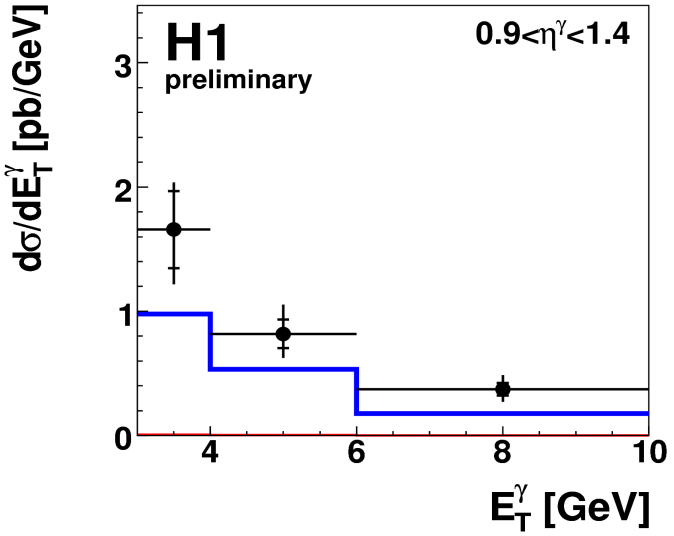


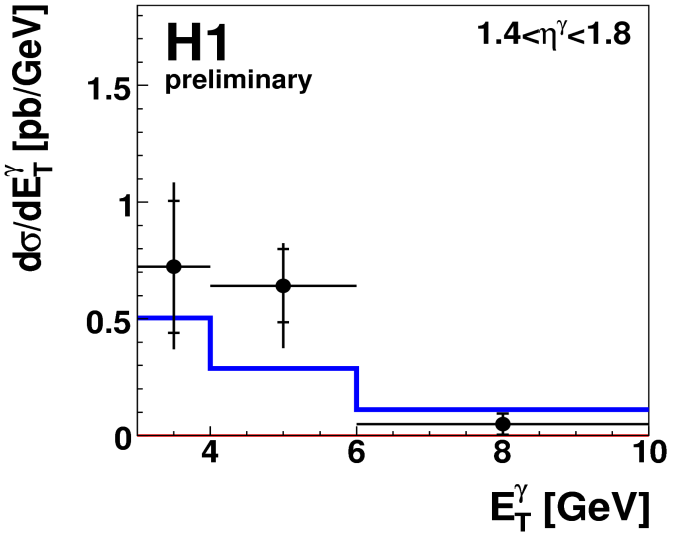
Inclusive Isolated Photons





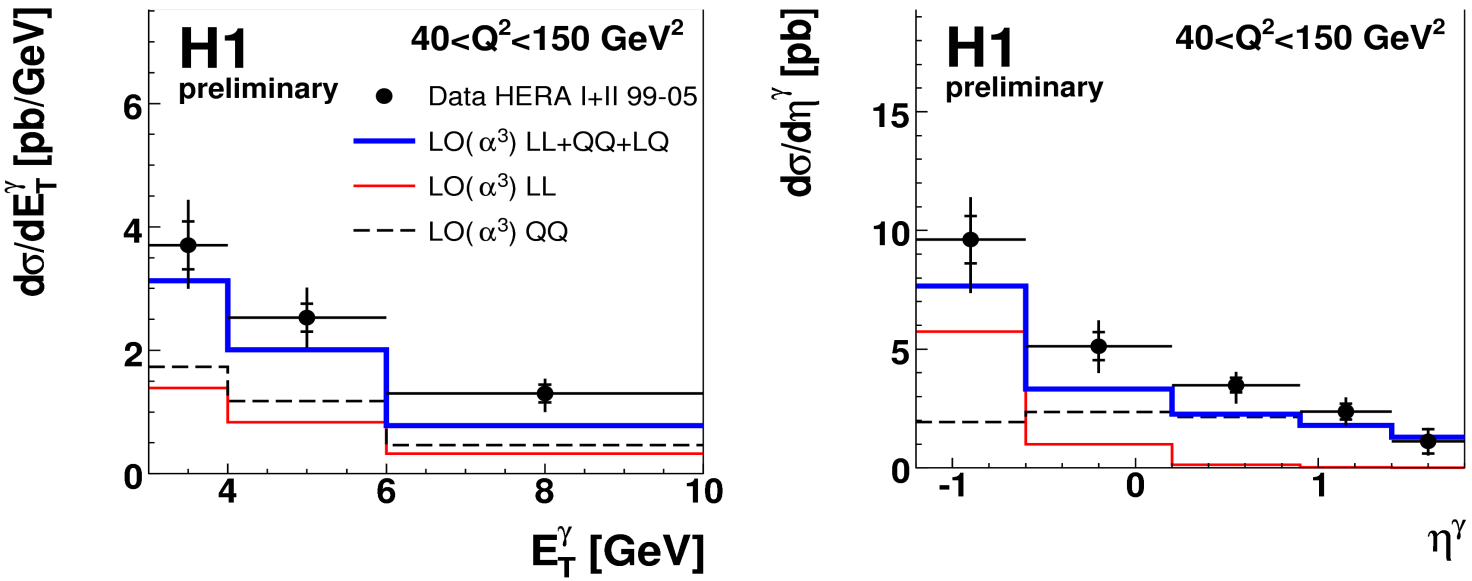






- $\eta^\gamma < -0.6$ has largest contribution of LL (rad from electron)
- LL negligible for $\eta^\gamma > -0.6$
- Shapes well described for $-0.6 < \eta^\gamma < 1.8$
- QQ seems to be too low by a factor of 2

Q^2>40 GeV^2



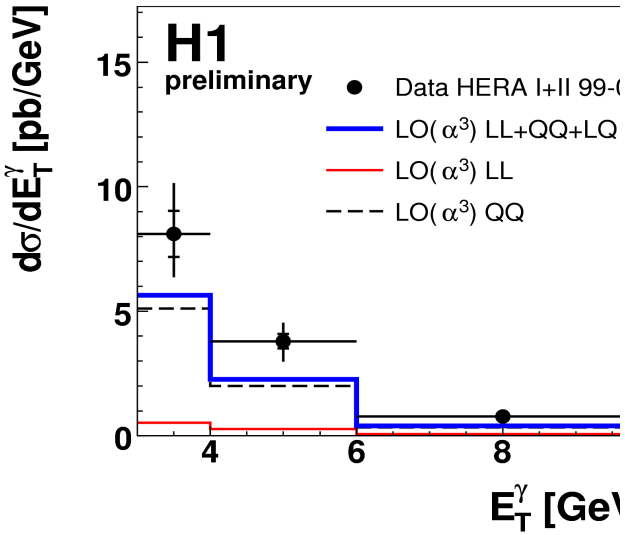
Total inclusive cross section Q^2>40 GeV^2:

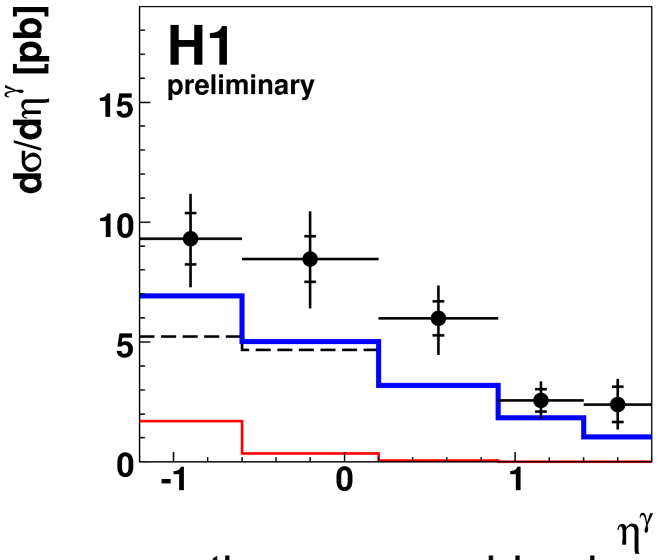
14.0 ± 0.8 (stat) $^{+2.1}_{-2.1}$ (syst) pb (LO 10.3 pb MC 8.8 pb)

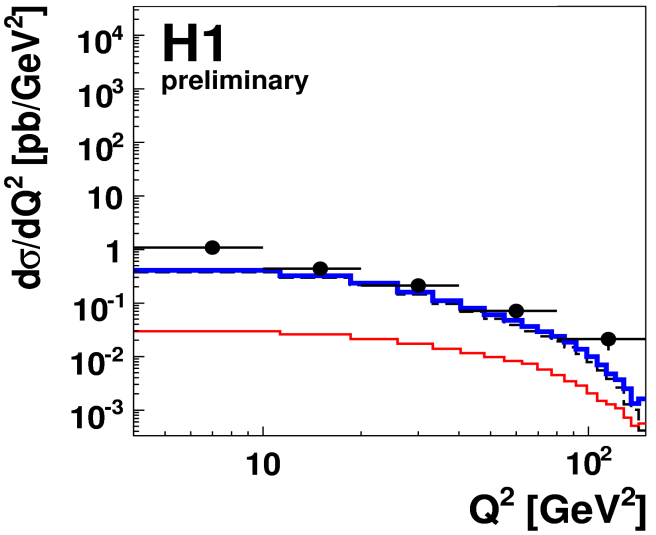
- LO and MC predictions agree better - undershoot 23% (35%)
- Shapes well described
- Relative contribution of radiation from quark smaller than at small Q^2
- Radiation from electron negligible in forward region ($\eta^\gamma > 0$)

Photon plus (no-)Jets

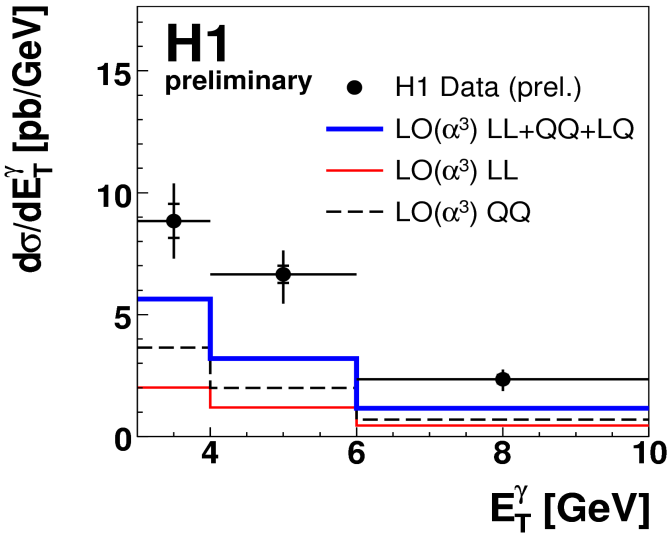
Photon plus no-jets (no hadronic jet E_T^{Jet}>2.5 GeV -1.0 <η^{Jet} <2.1): LL suppressed

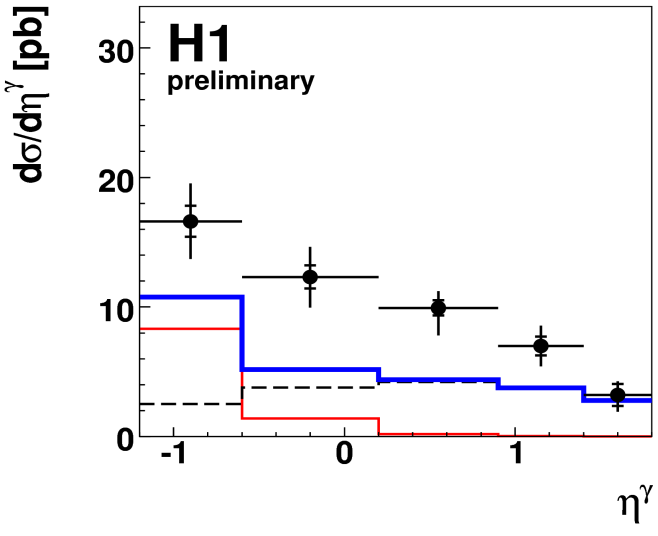


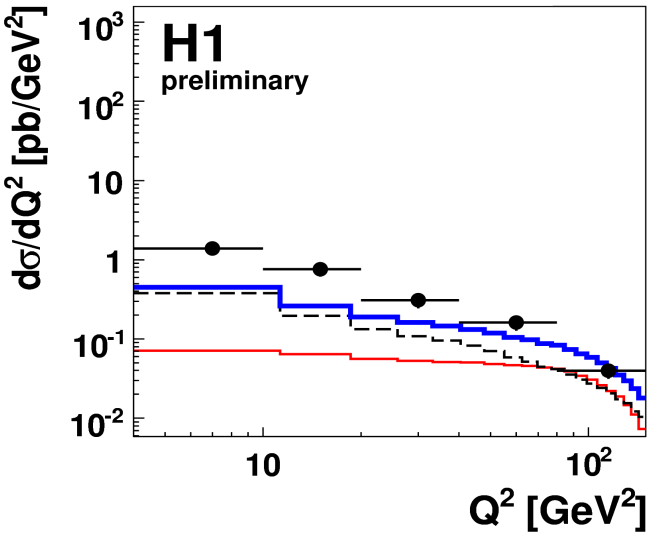




Photon plus jets cross section comparable size to photon plus no-jets







Conclusions

- First measurement of isolated photons in DIS by H1 (HERA I+II), luminosity 226 pb^{-1}
- Two contributions: radiation from quark and from electron
  - Different η^{γ}-dependence
  - Radiation from electron small for $\eta^{\gamma} > -0.6$
- LO and MC significantly lower than the data (roughly 50%)
  - Most prominent at low Q^2
  - High Q^2: LO and MC lower, but only by 30%, shapes described
- Exclusive measurement: photon plus no-jets, photon plus jets
  - Underestimated by LO calculation and MC
  - Photon plus jets cross section roughly twice the photon plus no-jets cross section
  - Photon plus no-jets: radiation from electron suppressed (W cut)
- Need for NLO calculation