Measurement of Prompt Photon Cross Sections in Photoproduction at H1

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Jozef Ferencei

Institute of Experimental Physics

Slovak Academy of Sciences

Košice, Slovakia

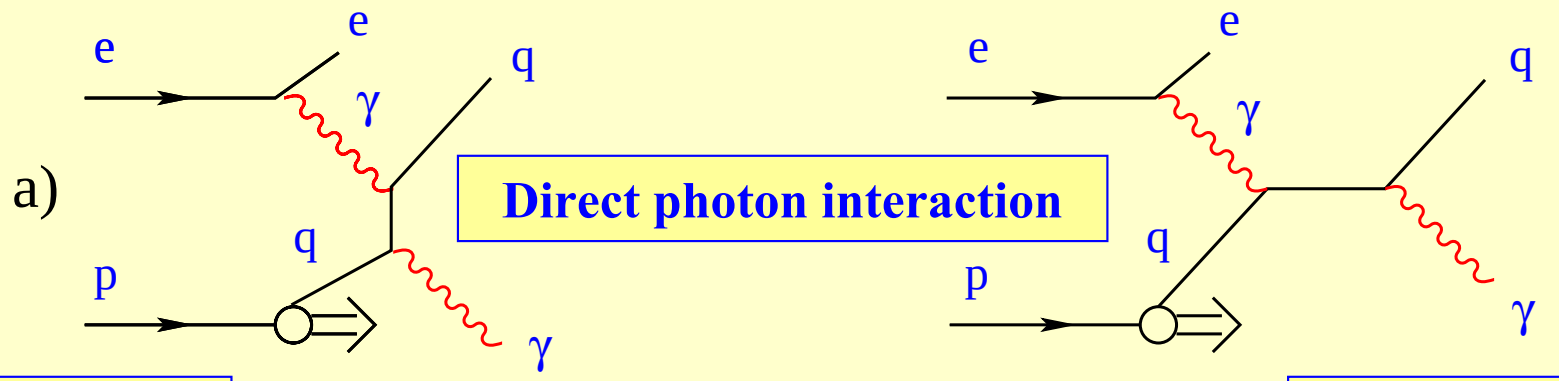
On behalf of the H1 Collaboration

Outline

- Introduction
- Event selection
- Rejecting π^0 / η background using shower shapes
- Results
  - Inclusive prompt photons
  - Prompt photons with associated jet
- Conclusion

Prompt Photons in Photoproduction at HERA

Examples of LO Diagrams

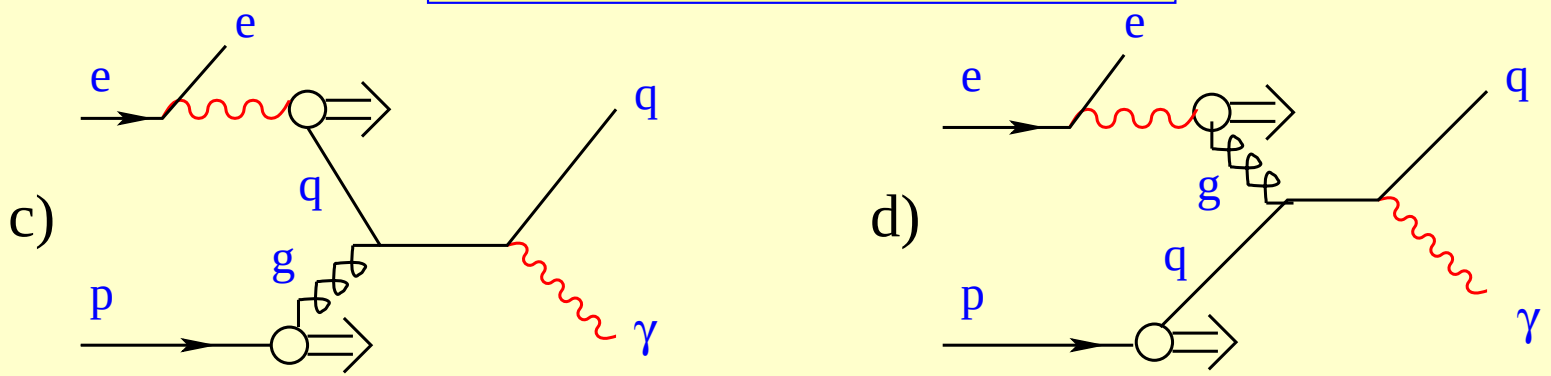


Direct photon interaction

Point like coupling of photon to quark => direct link to parton level of interaction

Expect a jet opposite the photon => search for photon + jet final state

Resolved photon interaction



Prompt Photons in Photoproduction at HERA

- Photoproduction initiated by quasi-real photons ($Q^2 < 1$ GeV^2)
- Photon is generated in hard scatter.
- Photon in the final state with substantial E_T

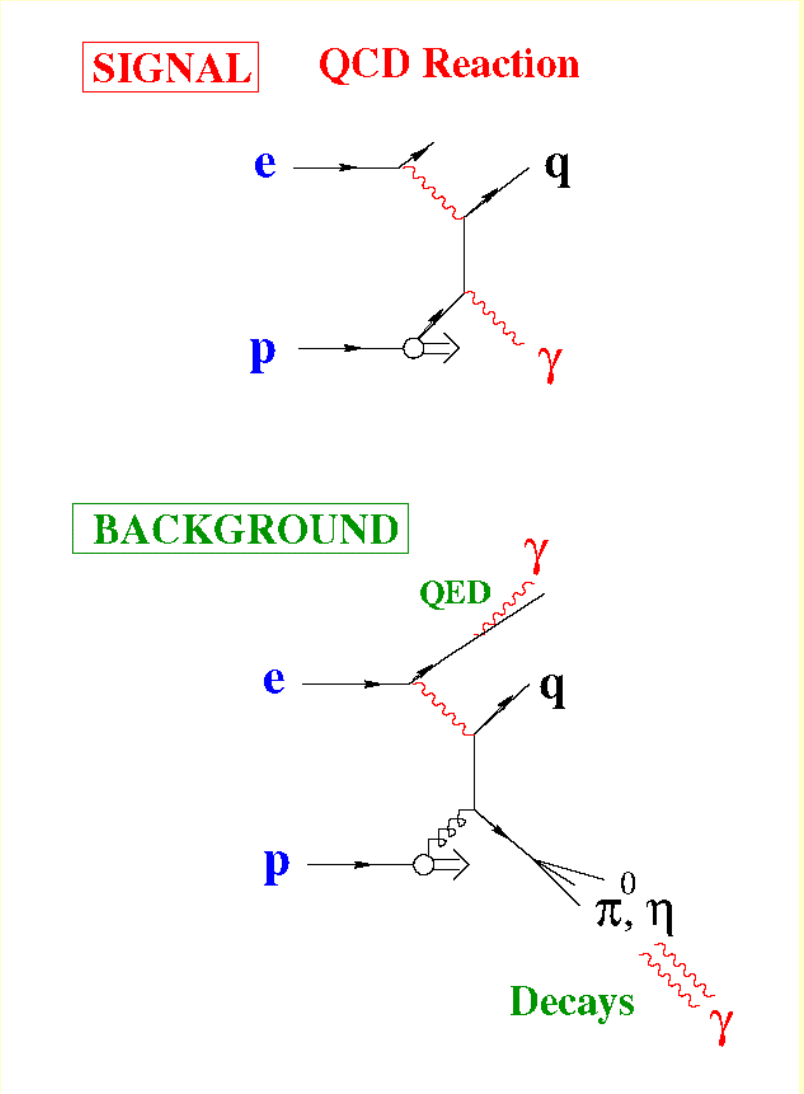
In comparison to jet production:

Pro: no effect of hadronization for photon , good energy measurement

Cons: small cross section relative to jets , difficult to suppress π^0, η

Two signatures are investigated:

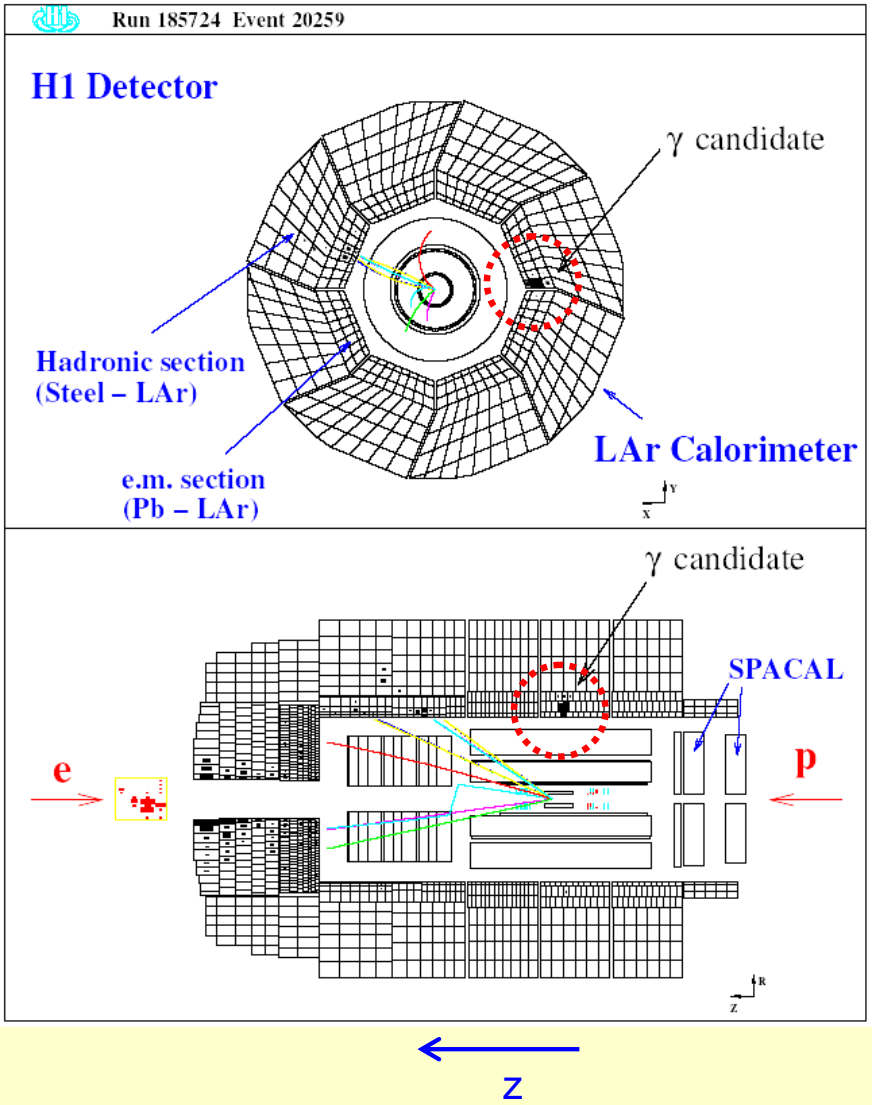
- Isolated photon (inclusive)
- Isolated photon + one jet (E_T > 4.5 GeV)



Event Selection

- 1996-2000 data: 105 pb^{-1}
- Isolation cut: transverse energy in cone with $R = \sqrt{\Delta\Phi^2 + \Delta\eta^2} = 1$ around γ candidate $E_T^{cone} < 0.1\ E_T^{\gamma}$
- No track within 25 cm distance in plane transverse to track at calorimeter surface
- Events with electron candidate rejected => virtuality of the exchanged γ: $Q^2 < 1\ GeV^2$
- $-1 < \eta^{\gamma} < 0.9$ (central region) and $E_T^{\gamma} > 5$ GeV
- Inelasticity $y = W^2/s$: $0.2 < y < 0.7 \Leftrightarrow \gamma p$ center of mass energy: $142 < W < 266$ GeV
- Prompt photon + jet:
  - Jets reconstructed using inclusive k_T algorithm (if more jets, select highest E_T)
  - $E_T^{jet} > 4.5$ GeV to avoid symmetric cuts (discussed by Fontannaz et al. [hep-ph/0107262])
  - $-1 < \eta^{jet} < 2.3$

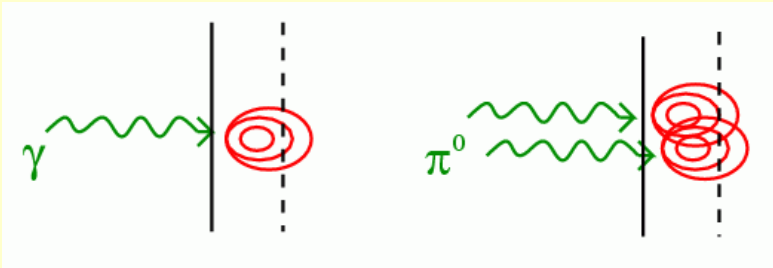
Prompt Photons in the H1 Detector



Signature: well isolated compact shower in Liquid Argon Calorimeter + track veto.

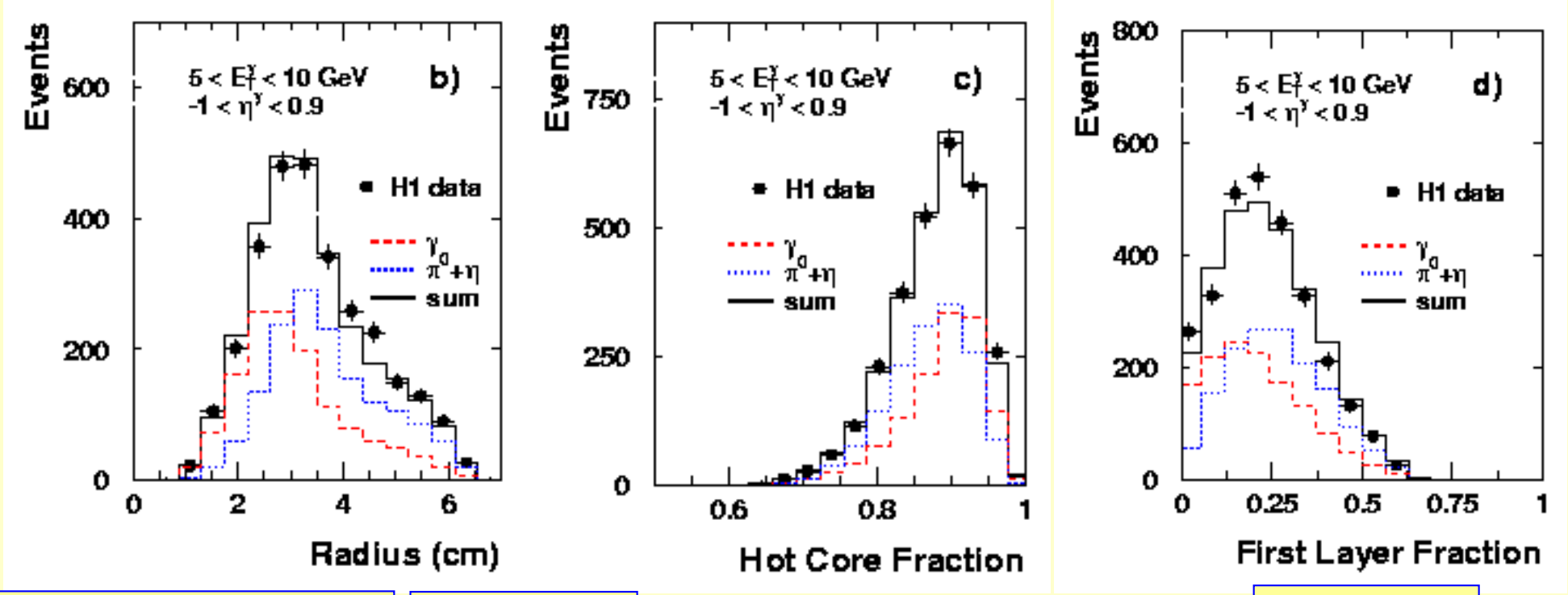
Main experimental difficulty: separation of prompt photons from hadronic background, in particular π^0 decays.

Good calorimeter granularity to separate γ's from π^o's and η's up $E_T \sim 10$ GeV



EM Calorimeter Shower Shape Variables

Result of the fits summed over all (E_T,η) bins

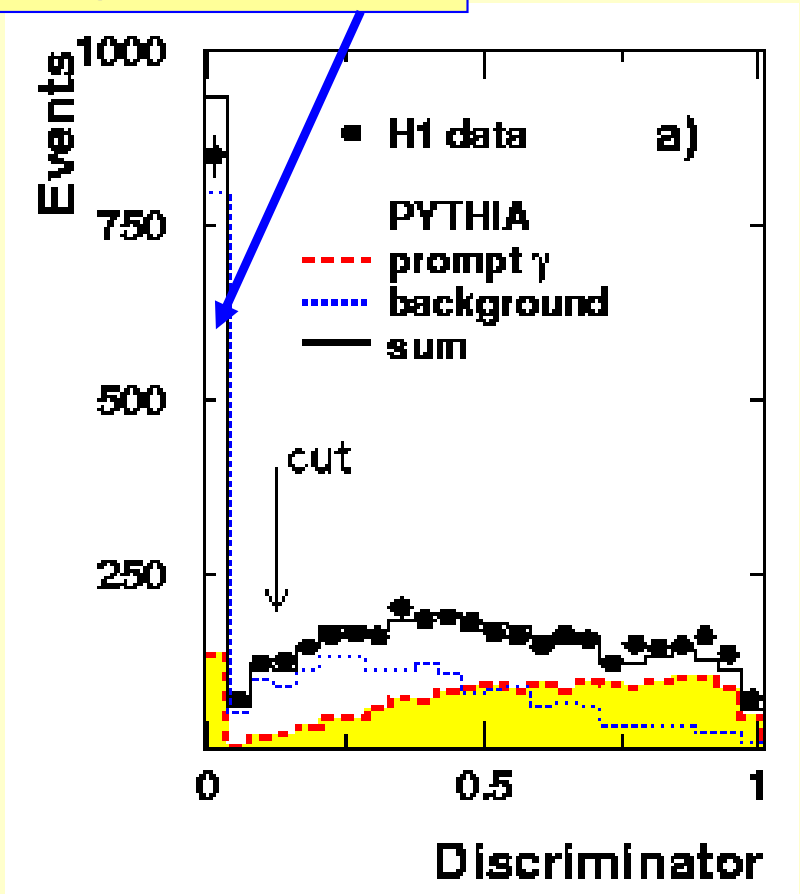


The background showers: **less narrow** **less compact** **start earlier**

=> Data well described by signal and background components

Discriminator Cut

Mostly (~90%) background: 65% π^0, 30% η and 5% others



η/π^0 fraction fixed from PYTHIA

Likelihood discriminator in (E_T,η) bins

with P^i = probability distribution

for variable i = 1, 2, 3 :

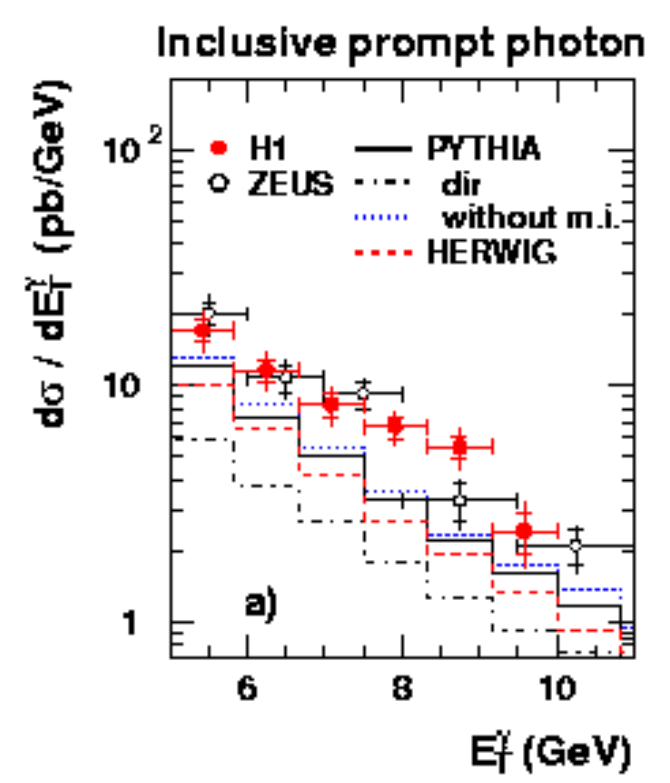
$$D = \frac{\Pi_i P^i_\gamma(x_i)}{\Pi_i P^i_\gamma(x_i) + \Pi_i P^i_{\pi^0}(x_i)}$$

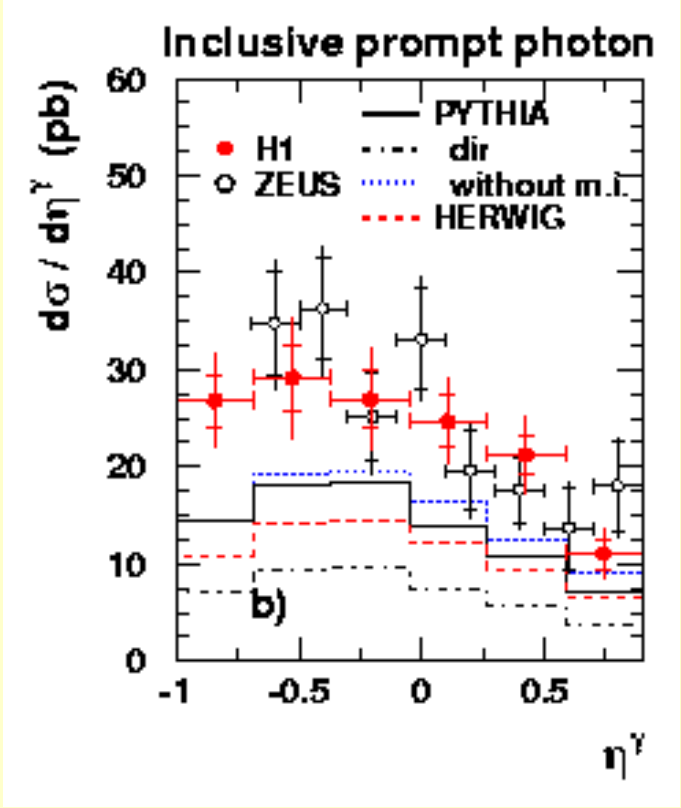
After cut **D > 0.125** remaining ~50% background composition (PYTHIA):

- 94 % of the background are π^0's
- 5 % of the background are η's
- other sources below 2 % (e.g. 0.4 % $\bar{n}$)

Using simulated discriminator distributions for γ's, π^o's, η's => fit data composition in each bin of (E_T,η) grid independently => extract the contribution of prompt photons

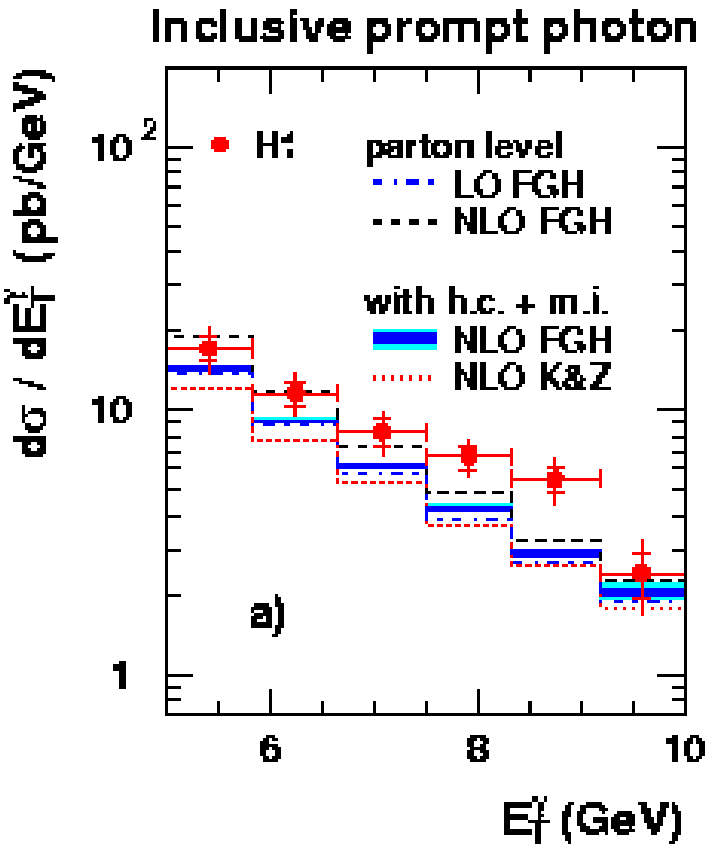
Inclusive γ, Comparison to PYTHIA and HERWIG

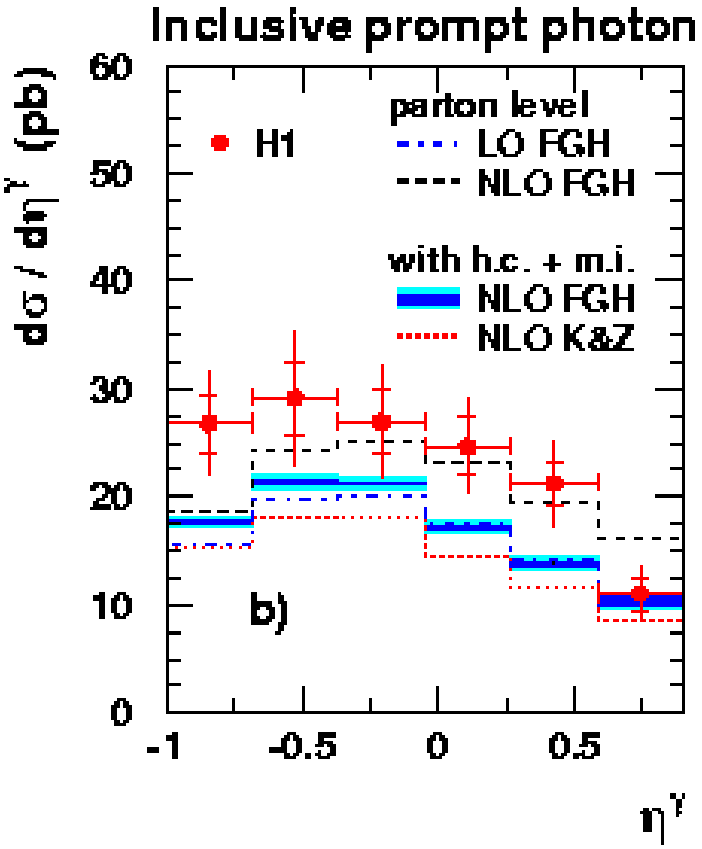




- H1 and ZEUS data consistent within errors
- > 50 % of prompt photons produced in direct exchanged γ interactions
- Reasonable description of shape by PYTHIA (HERWIG) with default multiple interactions included, but low by about 40 % (50 %)
- Multiple interactions tend to reduce the cross section (isolation cone requirement)

Comparison to NLO pQCD Calculations for γ





FGH: Fontannaz, Guillet and Heinrich [hep-ph/0105121]

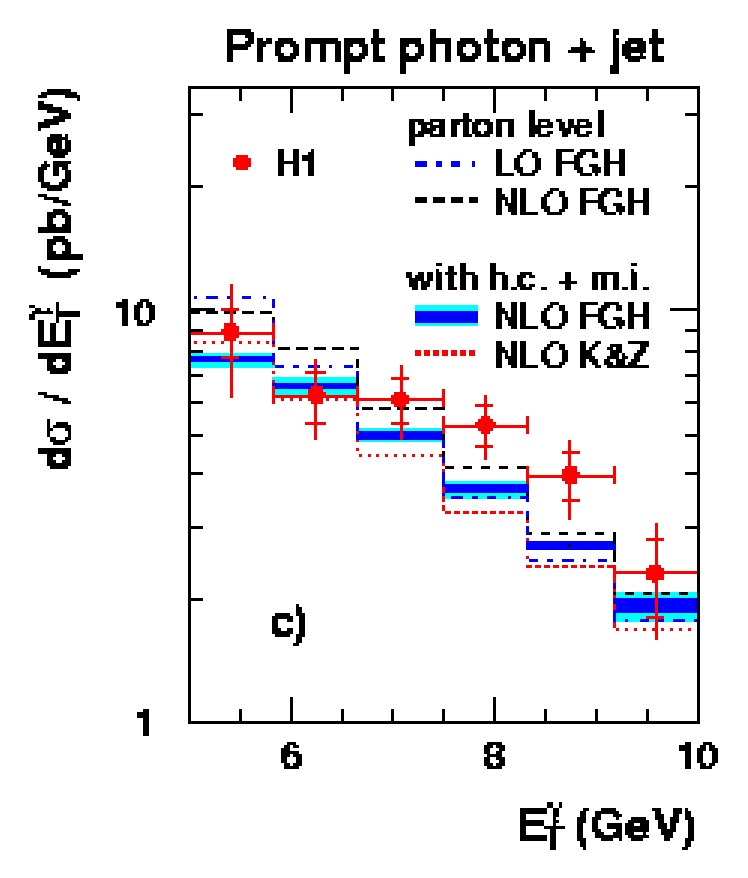
K&Z: Krawczyk, Zembruski [hep-ph/0309308]

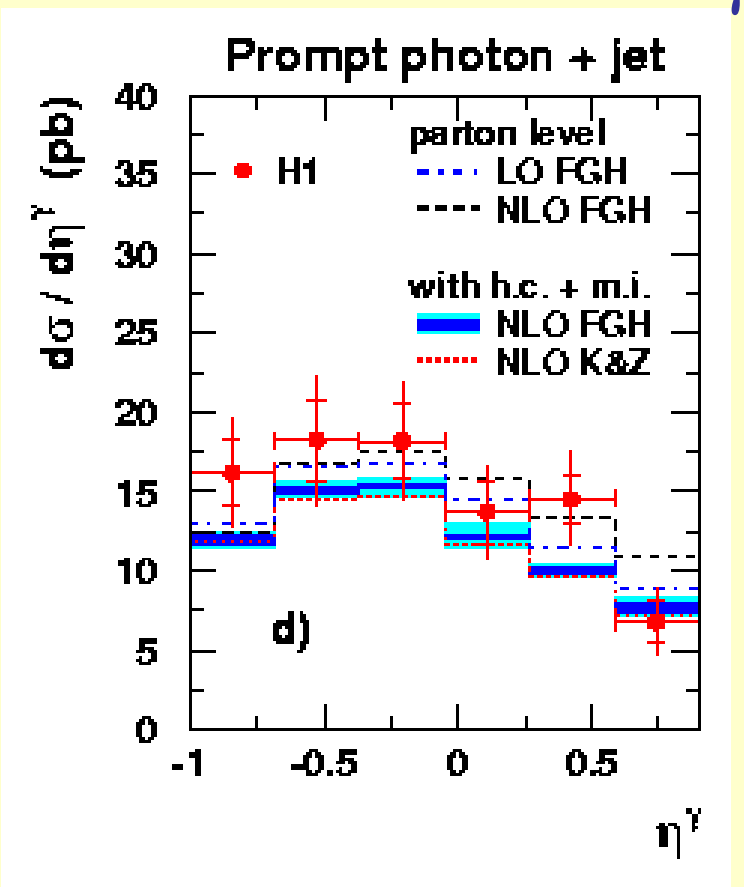
Both calculations use PDFs: AFG for photon, MRST2 for proton and BFG fragmentation functions

- Reasonable description by NLO calculations on parton level
- After corrections for hadronization and multiple interactions

normalization 30% (40%) below the data for FGH (K&Z) calculations

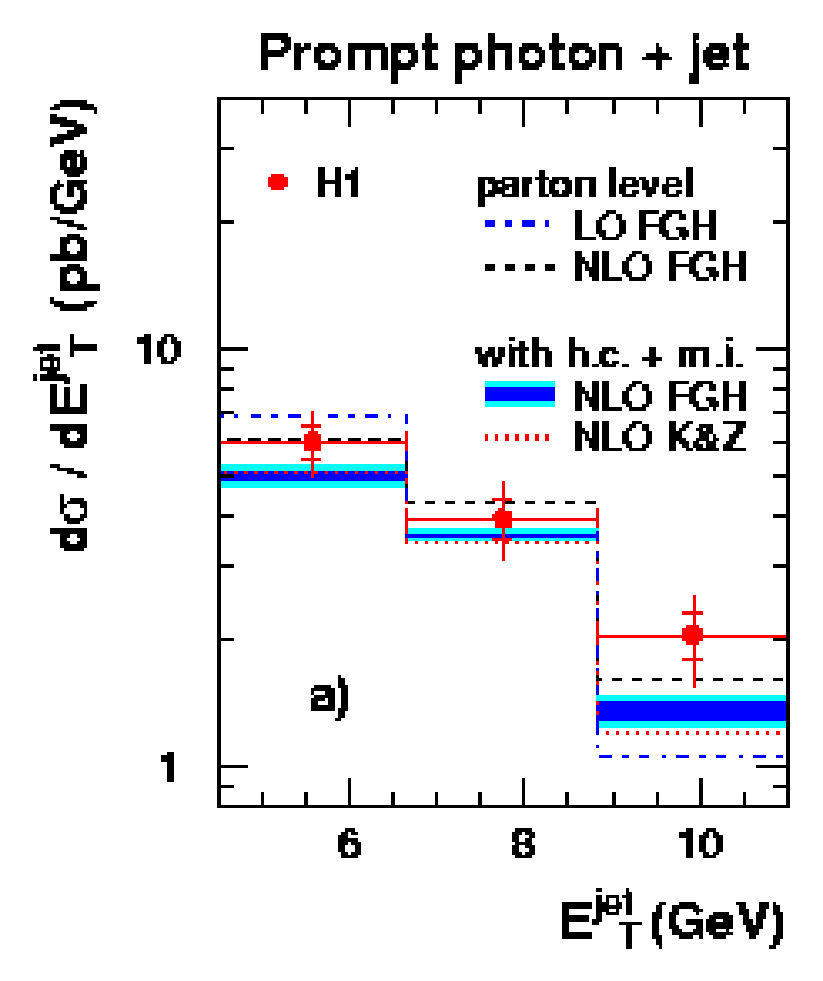
Comparison to NLO pQCD Calculations for γ+jet

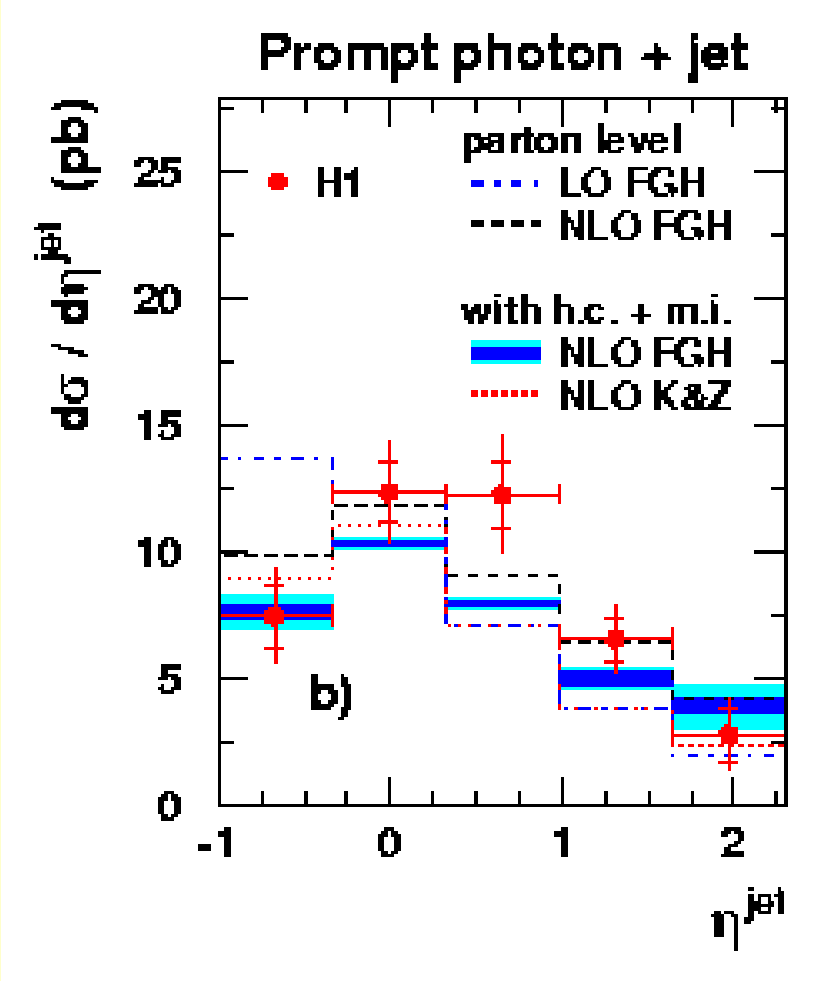




- Reasonable description of the data by both NLO calculations on parton level
- If a jet is required: slightly better description, NLO/LO correction more moderate
- Corrections for hadronization and multiple interactions, taken from PYTHIA, in general do not improve the description

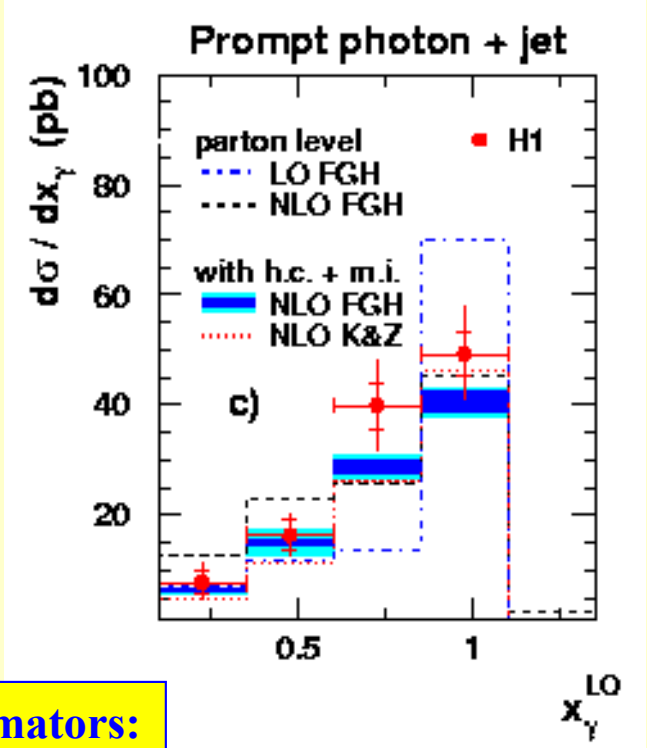
Prompt Photon + Jet Cross Section vs. E_T^{jet}, η^{jet}





- Both NLO calculations consistent with data in most bins

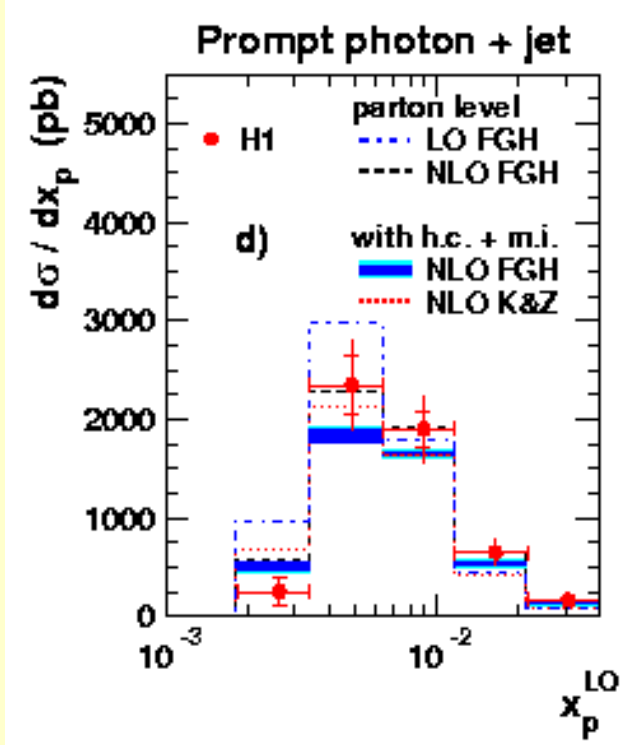
Prompt Photon + Jet Cross Section vs. x_γ^{LO}, x_p^{LO}



Estimators:

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

Fractional part of incoming photon energy, taking part in interaction



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

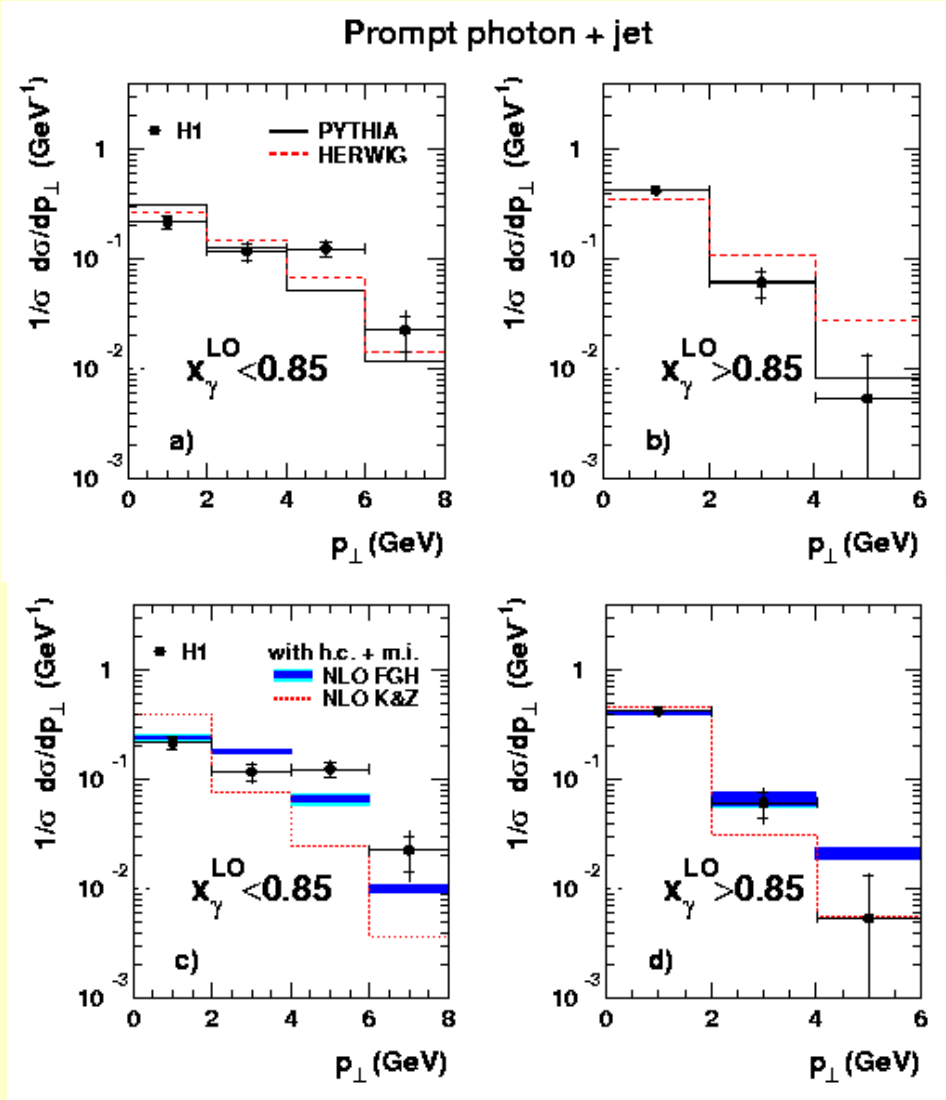
Fraction of proton's momentum involved in hard scatter

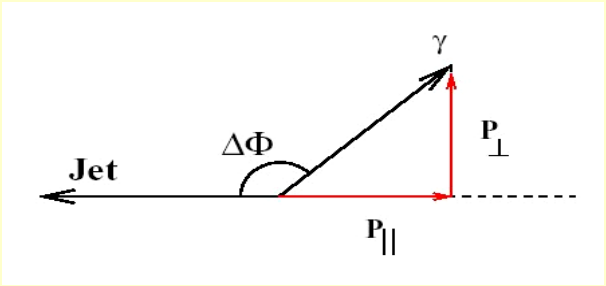
Photon structure enters at lower $x_\gamma < 0.85$ (resolved contribution)

Estimators: explicit use of photon energy only (better measured than jet energy)

❖ NLO + multiple interactions describe the data. Multiple interactions matter at $x_\gamma < 0.5$ (resolved γ region)

Normalized Prompt Photon + Jet Cross Section vs $p_\perp$





$p_\perp$ = P_T^γ component transverse to P_T^{jet}

$$p_\perp = |\ \vec{p_T^\gamma} \times \vec{p_T^{jet}}\ | / |\ \vec{p_T^{jet}}\ | = E_T^\gamma\ sin(\Delta\Phi)$$

$p_\perp$ is zero at LO, prompt photon and jet back-to-back in transversal plane

- Distribution for $x_\gamma^{LO} > 0.85$ well described by PYTHIA. HERWIG prediction harder.
- For $x_\gamma^{LO} < 0.85$ good description by both MC's with exception of $p_\perp \sim 5$ GeV
- FGH NLO describes data better than K&Z

Dominated by resolved γ **Dominated by direct γ**

Conclusions

- Prompt photon cross sections both inclusive and with jets have been extracted.
- Inclusive E_T^{γ},η^{γ} distributions:
  - reasonably well described by NLO pQCD calculations
  - MC generators PYTHIA, HERWIG undershoot the data, shape is in general well described
- Prompt gamma + jet cross sections:
  - well described by NLO calculations including hadronization and multiple interaction corrections
  - normalized $p_{\perp}$ distributions: described by PYTHIA, HERWIG too hard at large x_{γ}^{LO}
  - the present differences of NLO and LO MC's preclude the conclusion on k_T of initial state partons in the proton