Prompt Photons in DIS

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Outline

➜ **Motivation**

➜ **Prompt Photon Production in DIS**

➜ **Signal / Background Separation**

➜ **Inclusive Cross-Sections**

➜ **Summary**

Motivation

➔ First measurement of Prompt Photons in DIS at H1.

➔ We can extend the phasespace of the former measurement at HERA by far - 10x higher total cross section expectation (compared to ZEUS' 04 - hep-ex/0402019).

➔ Brand new LO(α^3) QED calculation is out for the (also inclusive!) prompt photon production in DIS (Gehrmann et al., hep-ph/0601073 and hep-ph/0604030).

➔ For prompt photons in DIS there is no uncertainty of the photon pdf.

➔ Dedicated measurement of the prompt photon production in DIS can give access to the quark-to-photon fragmentation function.

➔ Understanding of prompt photon production is essential for new physics searches at LHC. In H $\rightarrow \gamma\gamma$ channel the QCD induced background with two photons in the final state needs to be well controlled.

Prompt γ-Production in DIS

in Leading Order

DIS: $Q^2 > 0$ GeV²

HERA:

318 GeV

p (920 GeV)   e (27.6 GeV)

e(k)

$Q^2 = -(k - k')^2$

e(k')

γ

q

p

X

4 Graphs contribute!

Electron (FSR and ISR)

e   e

γ

q

p

γ

e   e

q

p

Quark (FSR and ISR)

e   e

γ

q

p

e   e

q

γ

p
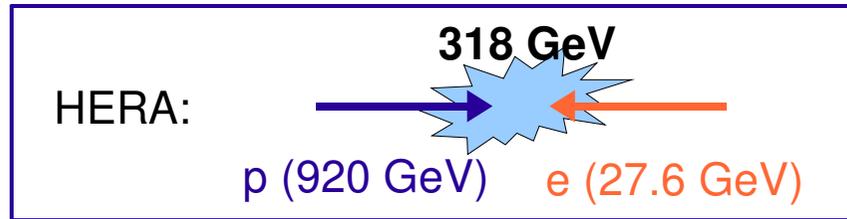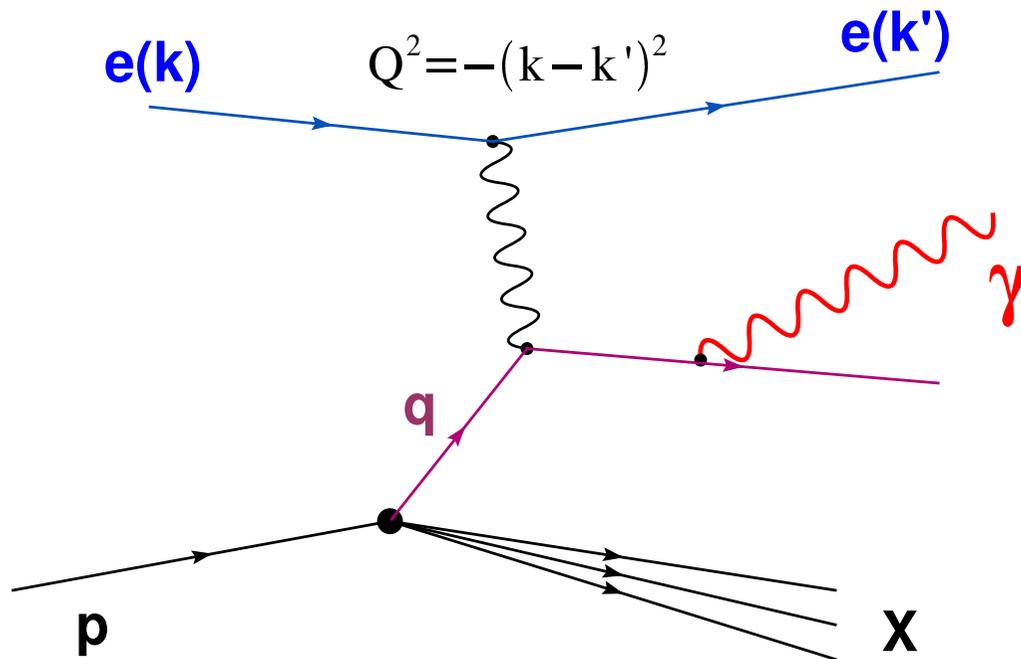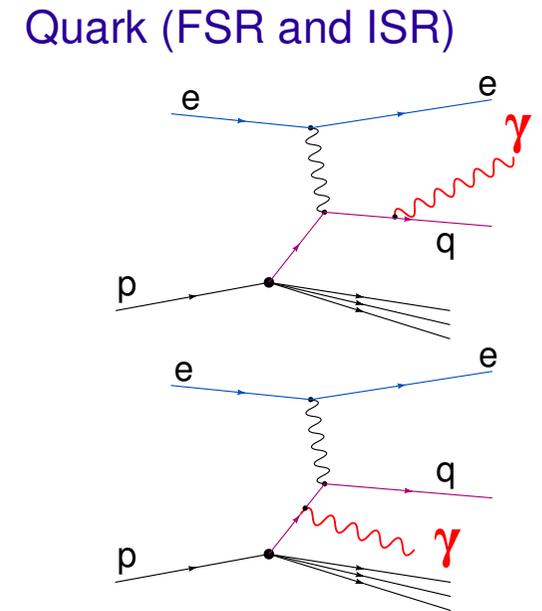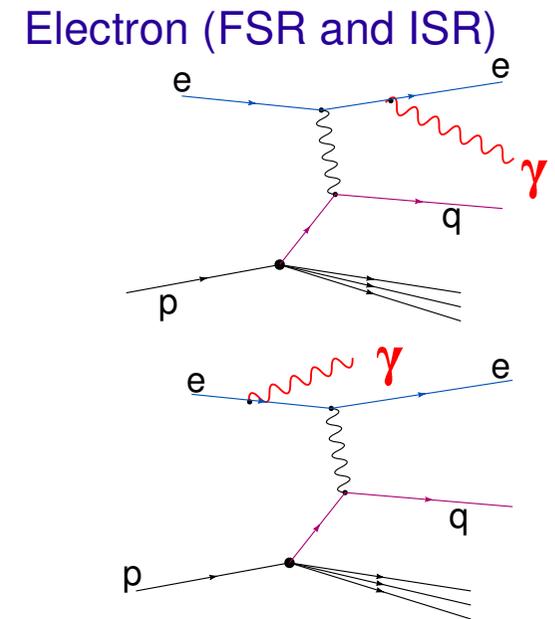
Prompt Photon in the H1-Detector

Photon Candidate {
→ Cluster in **electromagnetic** Calorimeter
→ No Charge = **No Track**

$\eta_{MAX} = 1.8$

$\eta_{MIN} = -1.2$

5 4 3 2 1

Electromagnetic calorimeter

e

p

Hadronic calorimeter

MC-Event

Quark-Jet

Scattered Electron = DIS
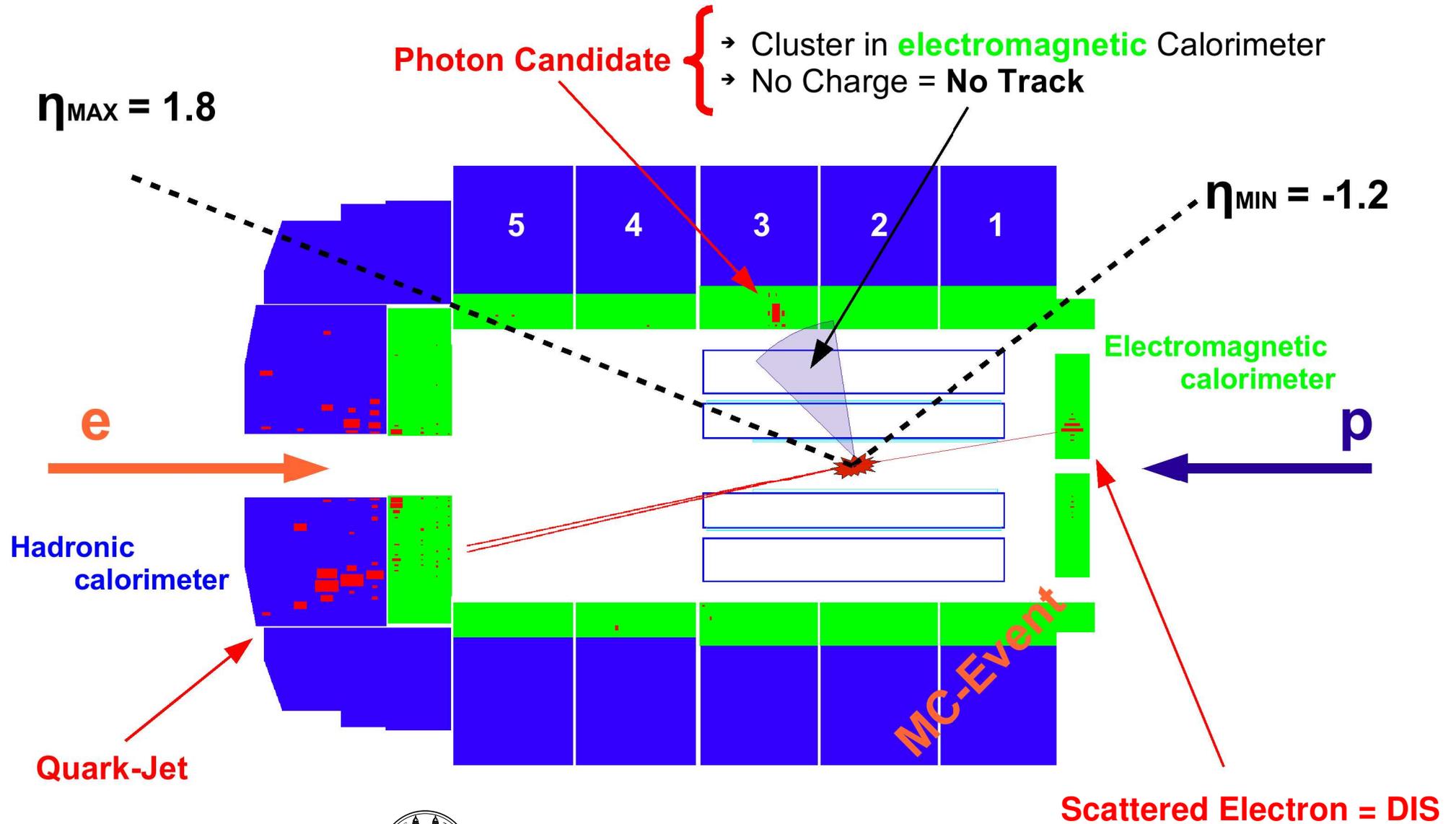
Background: Multi-Photon Clusters

Signal

Photon-Cluster

γ
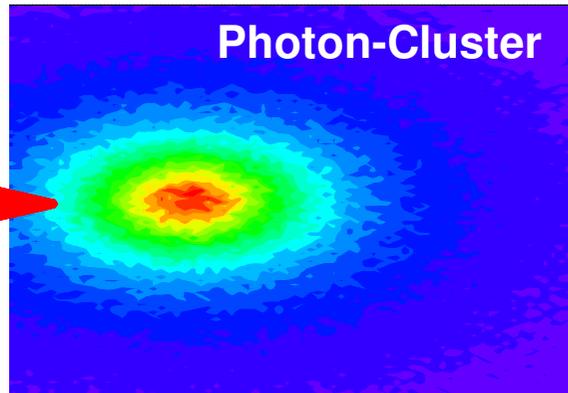
Schematic Cluster representations

Background

Hadrons that decay into **multiple Photons:** $\pi^0, \eta, \eta', \rho, \omega, K^0,$ **etc.** **(neutral mesons)**

Multi-Photon Cluster: Decay photons form a **common cluster** (usual at high energies).

Multi-Photon Clusters:
→ **less compact**
→ **transversly wider**
→ **more asymmetric**
→ **shower earlier**
→ **...**

γ

π^o

Multi-Photon Cluster

γ
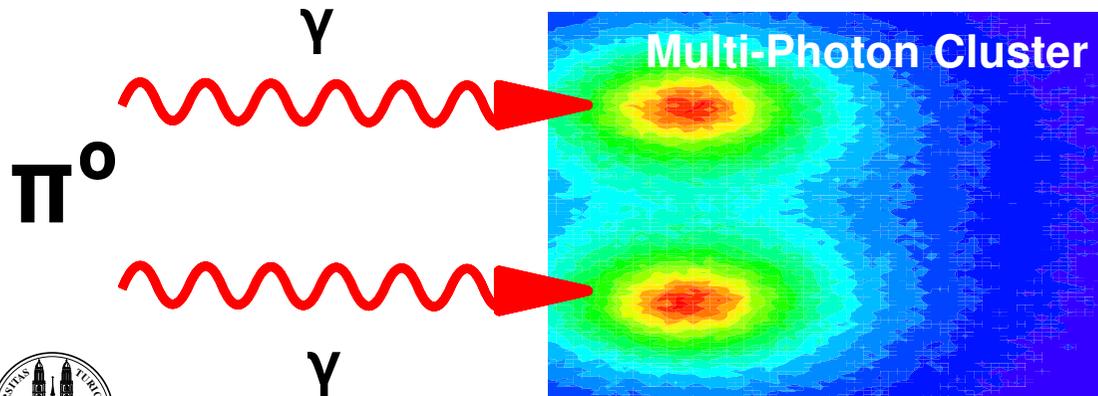
Higher energy
↓
Photonangle smaller
↓
Separation more difficult

Signal / Background Separation

Example: Transverse Radius of Cluster!

Cluster-Variables used for Separation of Photons from Neutral Mesons:

(1) Transverse Radius
(2) Transverse Symmetry
(3) Transverse Kurtosis
(4) Energy Fraction of Hot-Core
(5) Energy Fraction of most energetic cell
(6) Energy Fraction of 1st Layer in calorimeter
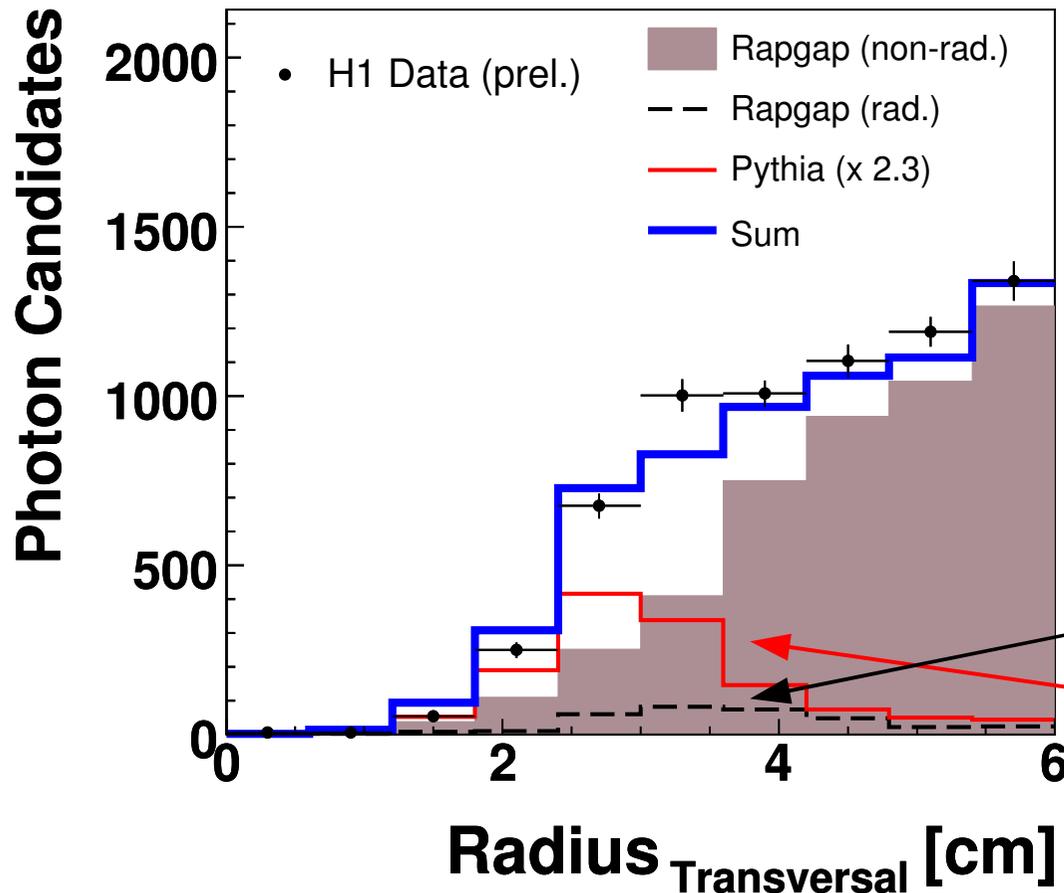
Rapgap (non-rad.)= neutral Mesons

Rapgap (rad.)= Photons from Electron

Scaled to Lumi!

Pythia (scaled by 2.3)= Photons from Quark

Scaling Factor motivated by cross section measurement

Discriminating Cluster Variables
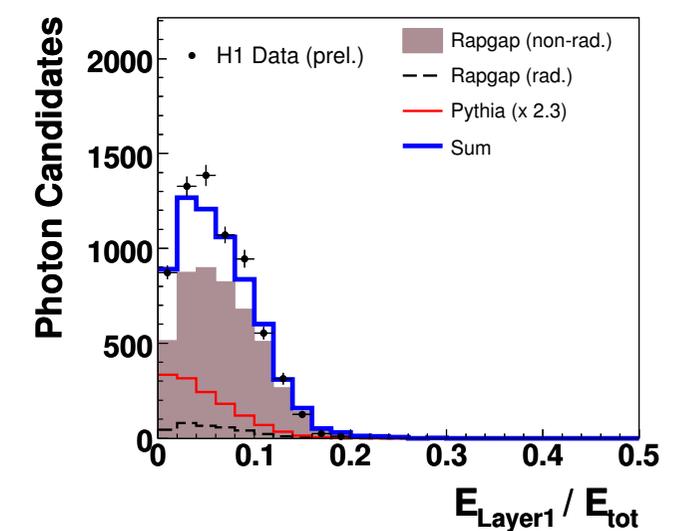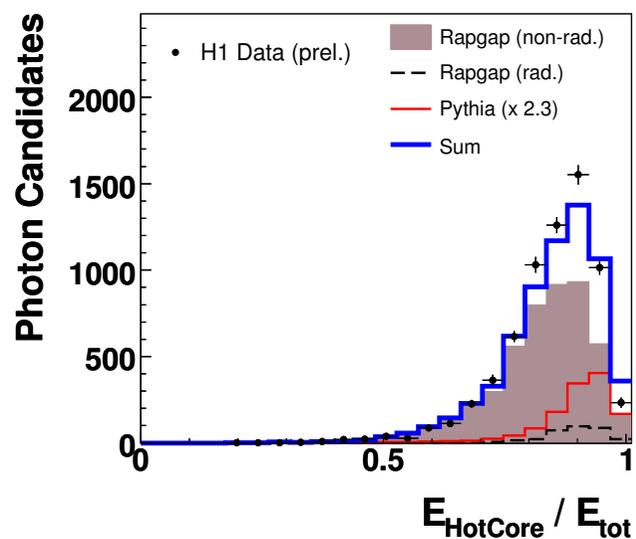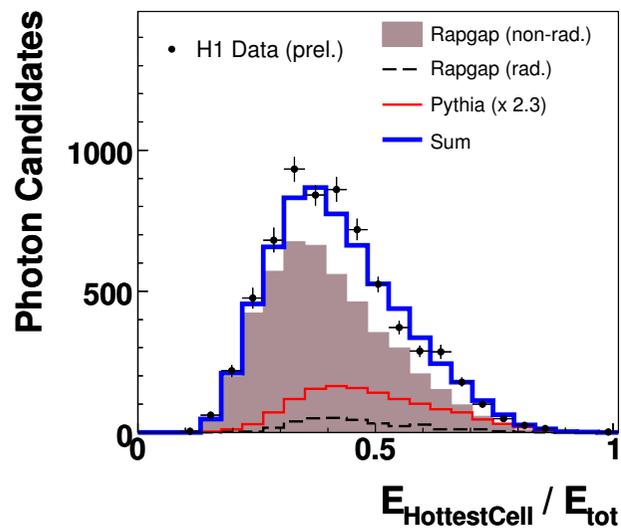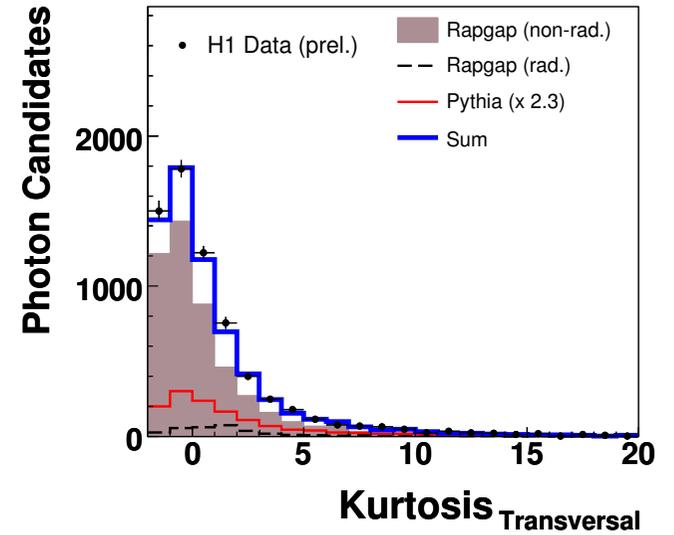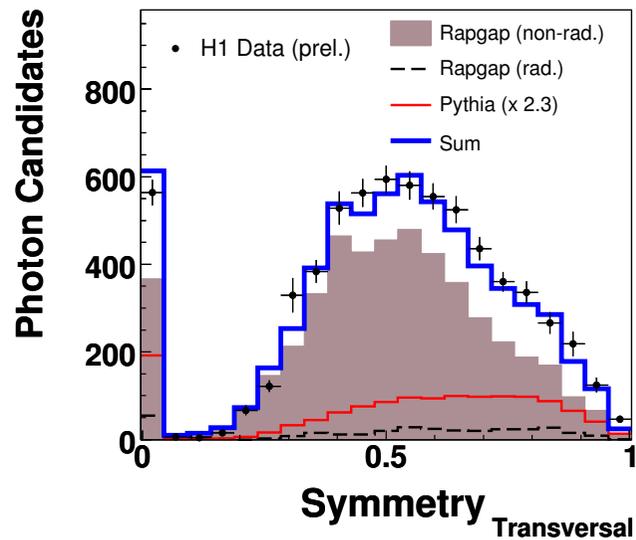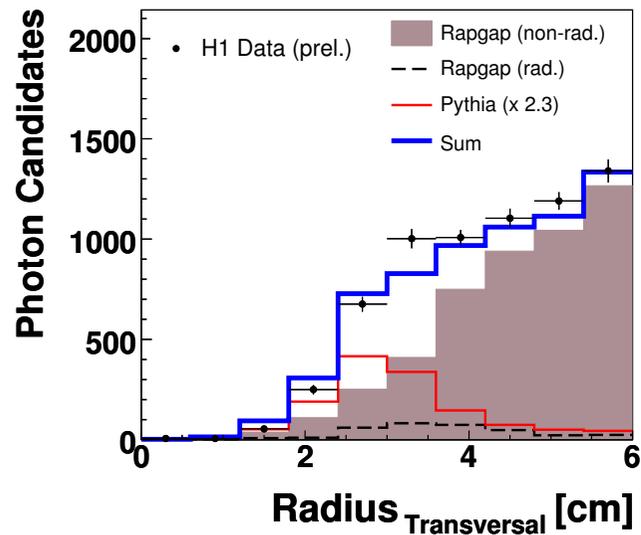
Cluster Shapes well described by MC!

Extraction of Photons: Method

➜ Variables are combined in a **Likelihood-Method (naïve Bayes).**
➜ The probability density functions are defined using **high statistics Single Particle Samples** only!

Signal: Single Particle Photons
Background: combined Single Particle Mesons (10 types).

Number of Photons is determined by χ^2 **Fit** on Likelihood-Distribution in every analysis bin.

(Using high statistics Single Particle Signal and Background Samples)

Remark:
Monte Carlo can very well describe the fraction of neutral mesons!
(Remember: Rapgap scaled to Lumi)

- H1 Data (prel.)
- Rapgap (non-rad.)
- Rapgap (rad.)
- Pythia (x 2.3)
- Sum

Photon Candidates

Likelihood
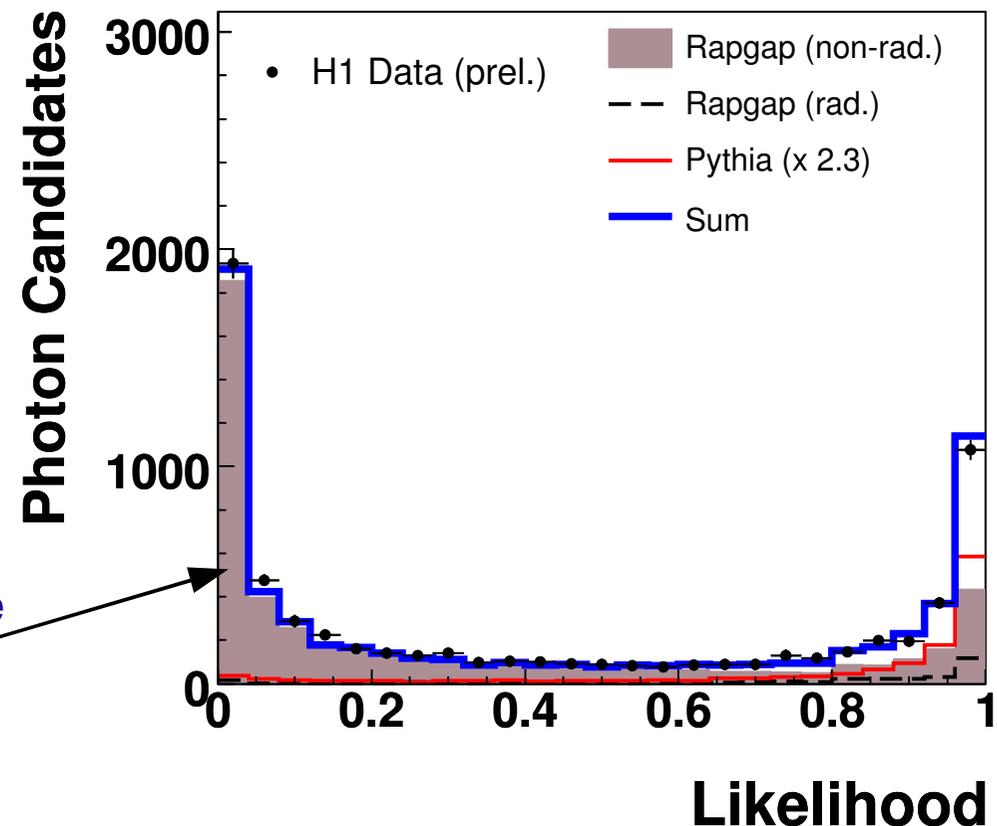
Phasespace

Integrated Luminosity = 70.6 pb^{-1} (HERA I)

Kinematics

$$
\begin{aligned}
Q^2 &> 4\,\mathrm{GeV}^2 \\
y &> 0.05 \\
E^{\mathrm{Elec}} &> 10\,\mathrm{GeV} \\
151° < \theta^{\mathrm{Elec}} &< 177°
\end{aligned}
$$

At least one track in: $30° < \theta < 150°$

Track requirement needed to suppress QED-Compton.

Matched in Calculation by η_{MAX} - Cut of Quark!

democratic clustering approach (photon treated as any other HFS object)

Lower z gives access to fragmentation function

Photon

$$
\begin{aligned}
3\,\mathrm{GeV} < E_T^{\gamma} &< 10\,\mathrm{GeV} \\
-1.2 < \eta^{\gamma} &< 1.8
\end{aligned}
$$

Isolation: $z = E^{\gamma}/E^{\mathrm{PhotonJet}} > 0.9$

Predictions

Prompt Photon Generators

Pythia and **Herwig**

Matrixelement: $\gamma + q \longrightarrow \gamma + q$

➔ Flux of incoming photons is approximated in the DIS-mode.

➔ Radiation off the electron is not included (only radiative corrections = 2nd photon)

Rapgap

Inclusive and radiative NC DIS-MC

➔ Electron-Radiation in these events is taken as an approximation of the prompt photon contribution off the electron line.

Calculation

Matrixelement: $e + q \longrightarrow e + q + \gamma$

Full Matrix Element (LO)

Brand new calculation in $LO(\alpha^3)$ by **Gehrmann et al.** for the prompt photon cross section at HERA.

➔ **hep-ph/0601073**

➔ **hep-ph/0604030**

2006

➔ Includes quark-to-photon fragmentation.

Also availbale for ZEUS'04-phasespace. Will be compared to

Zeus Results 2004   **H1 Preliminary Results 2006**

Cross Sections and Calculation

LL   =   **Photon from Electron**
QQ   =   **Photon from Quark**

Entire η-Range
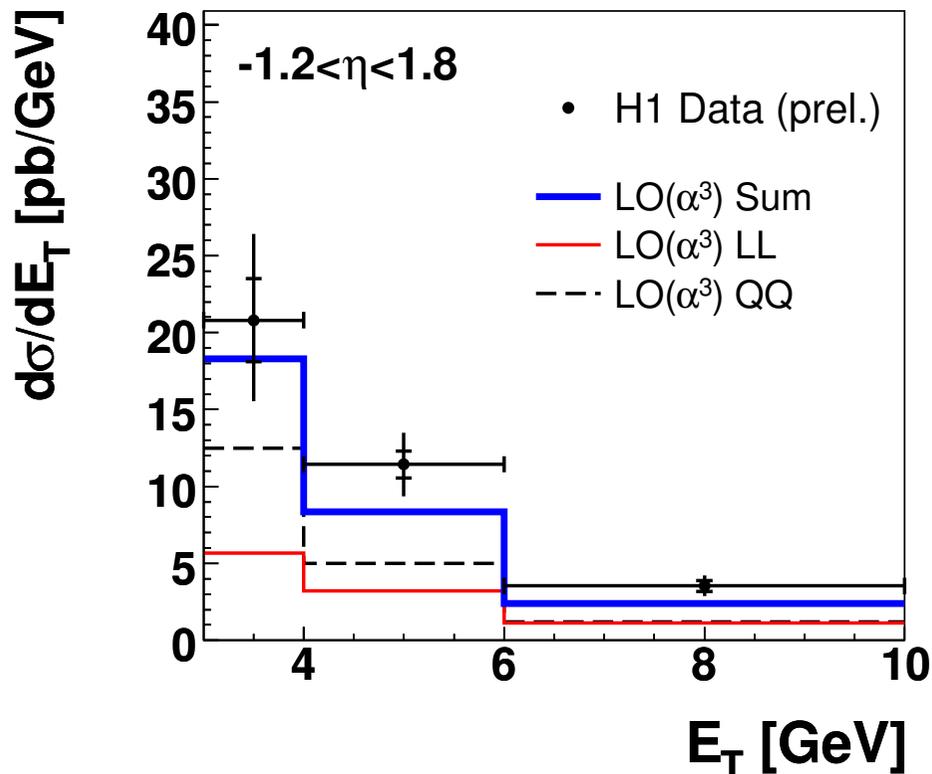
Entire E_T-Range
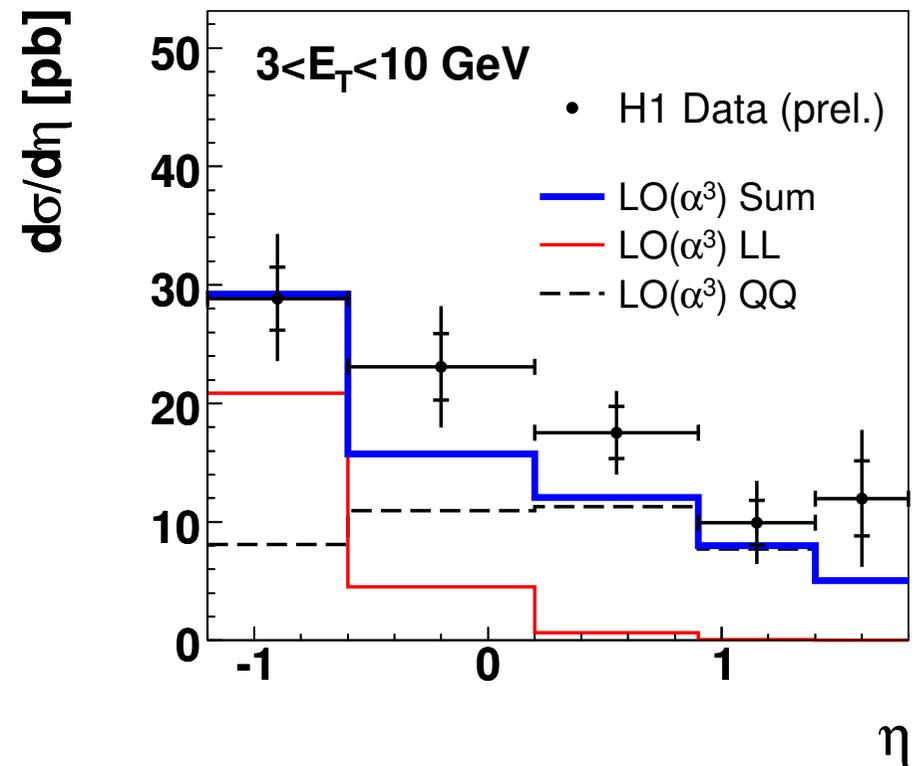
Calculation by Gehrmann et al.
(hep-ph/0601073, hep-ph/0604030)

Cross Sections and Calculation

in Eta-Bins
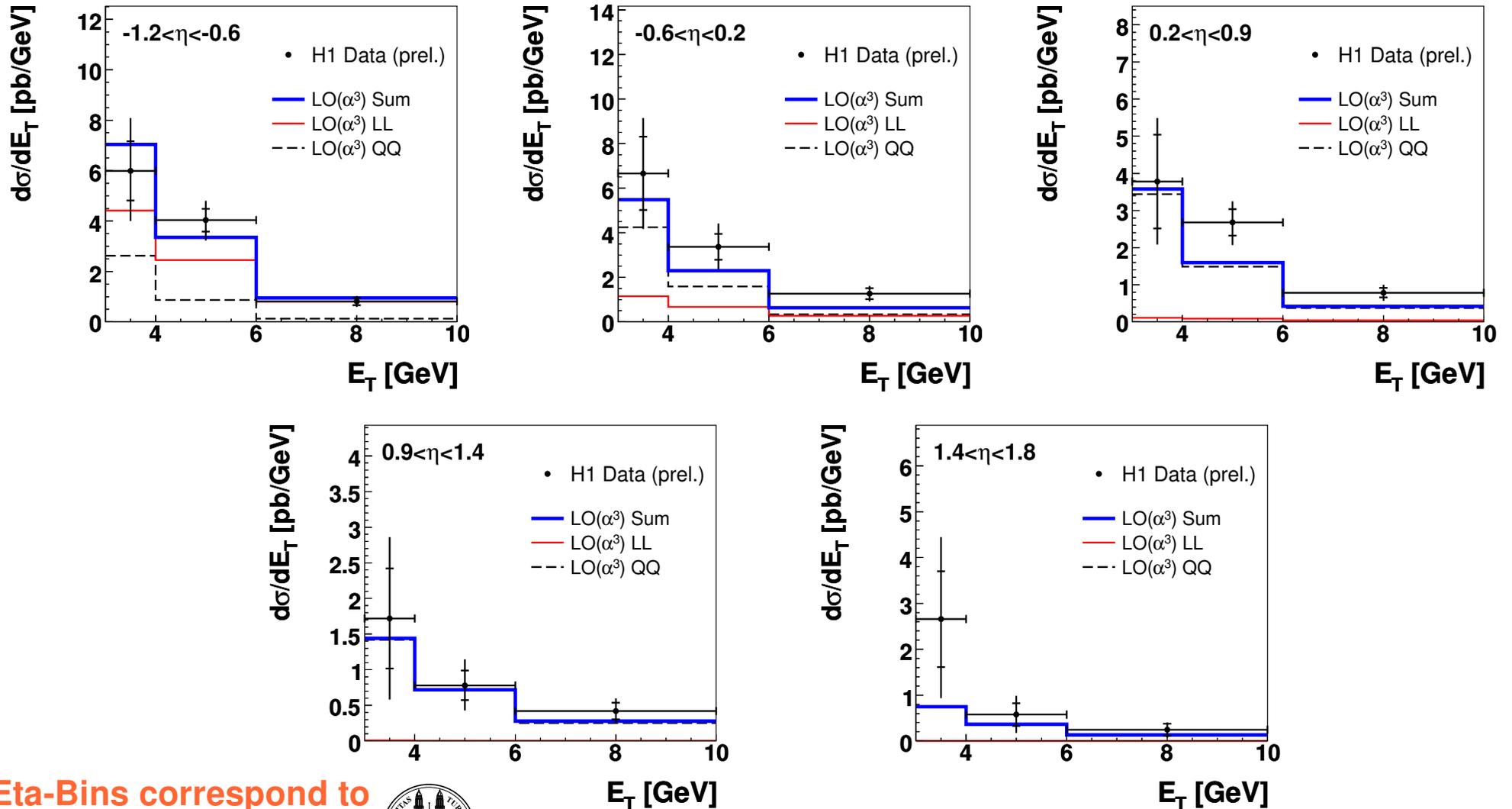
Eta-Bins correspond to Wheels in Calorimeter

Cross Sections and Generators

Pythia/Herwig scaled in order to match total cross section:
- **Pythia scaled by 2.3**
- **Herwig scaled by 2.6**

Rapgap (rad.) =
Photons from Electron
Pythia/Herwig =
Photons from Quark
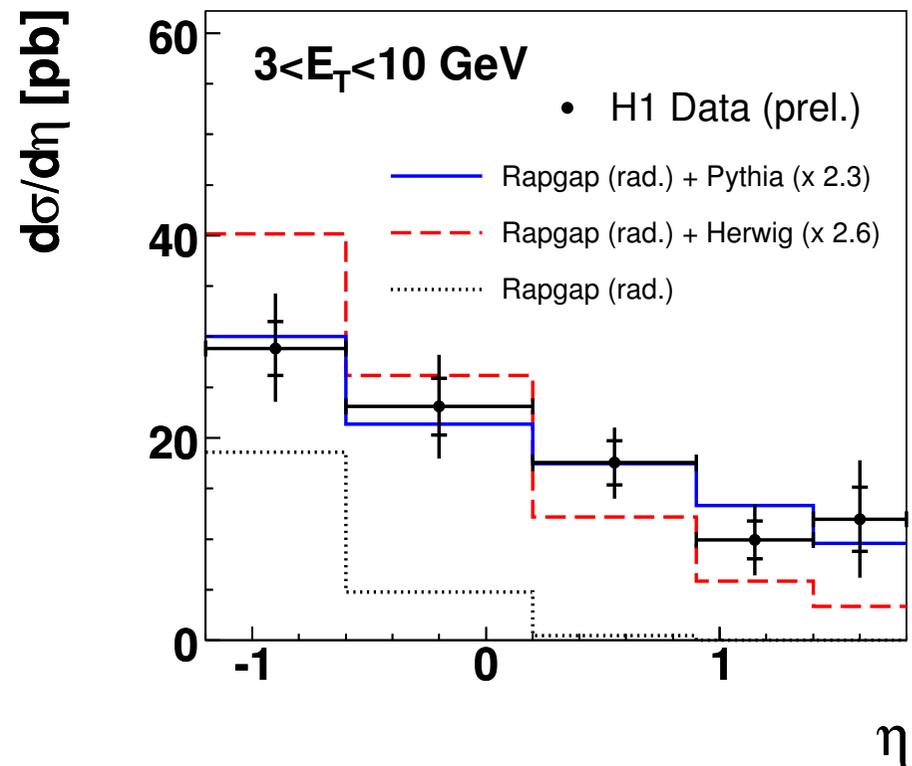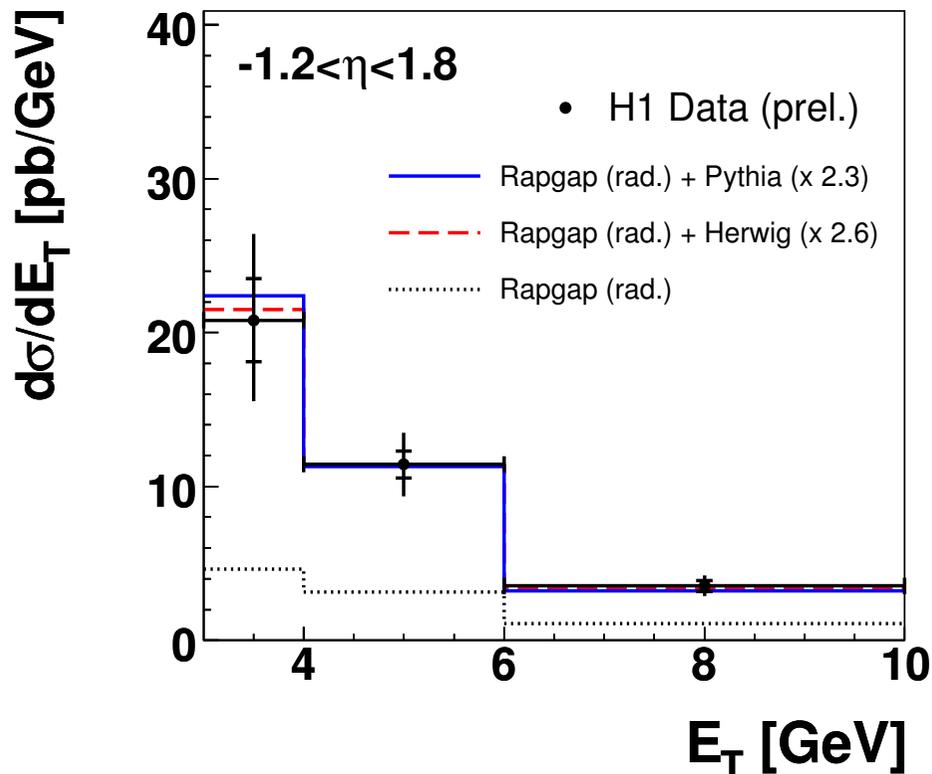
Comparison to ZEUS

Warning: different phasespace!
(ZEUS04: $Q^2 > 35$ GeV^2/H106: $Q^2 > 4$ GeV^2)

H1 06

3 – 10 GeV   -1.2 – 1.8

5 – 10 GeV   -0.7 – 0.9

ZEUS 04

E_T η
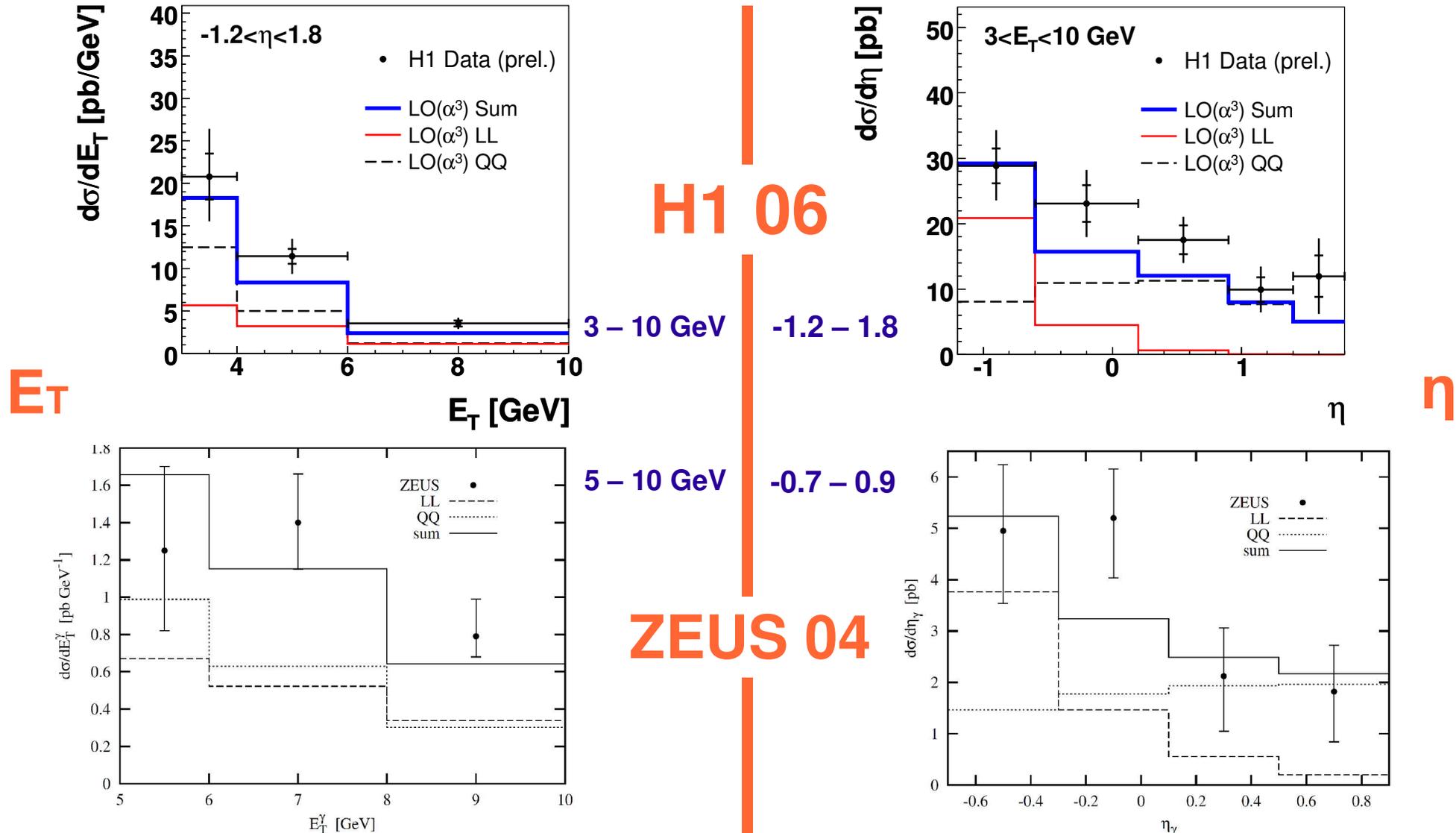
Same new Calculation for ZEUS'04
(Gehrmann et al.): hep-ph/0601073

ZEUS'04: hep-ex/0402019

Summary

New H1-Results on inclusive prompt photon production in DIS have been presented!

➔ The measured cross sections are well described by a new LO(α^3) QED calculation (Gehrmann et al., hep-ph/0601073 and hep-ph/0604030) – It is the first calculation for the **inclusive** prompt photon production in DIS!

➔ The data is also nicely described in shape by the PYTHIA Event generator plus radiation off the electron line as modelled by RAPGAP, though the absolute scale is too low.

➔ Compared to the previous measurement (ZEUS '04, hep-ex/0402019) the phasespace is significantly extended (about 10x higher total cross section expectation).

Much better understanding of the inclusive prompt photon production in DIS now.

Outlook:
➔ Statistics will be increased by including HERA II Data
➔ Quark-to-photon fragmentation function