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Related Subjects

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Production of Forward Photons in DIS at HERA

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On behalf of the H1 Collaboration

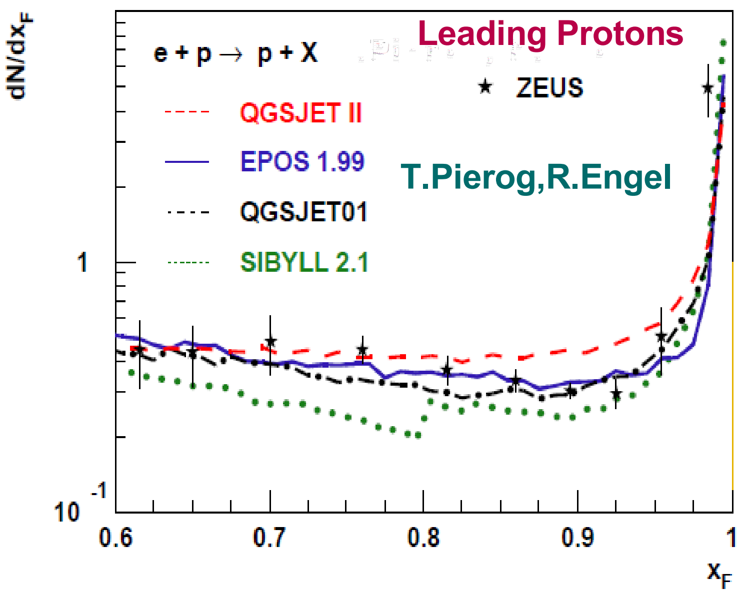
Outline

- Introduction
- Data analysis
- Results
- Conclusions

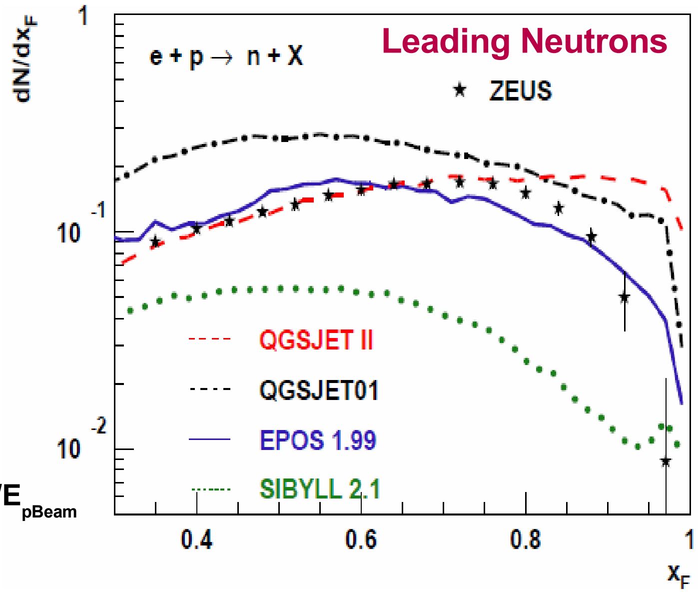
Introduction

Measurements of the forward particles (small angles to the proton beam in ep collisions) are important:

- for understanding the proton fragmentation,
- for models tuning, in particular for hadron interaction Cosmic Ray (CR) models (the shower development in matter is dominated by the soft, forward interactions)
- for testing the hypothesis of limiting fragmentation (production of forward particles is independent from the incident particle energy)

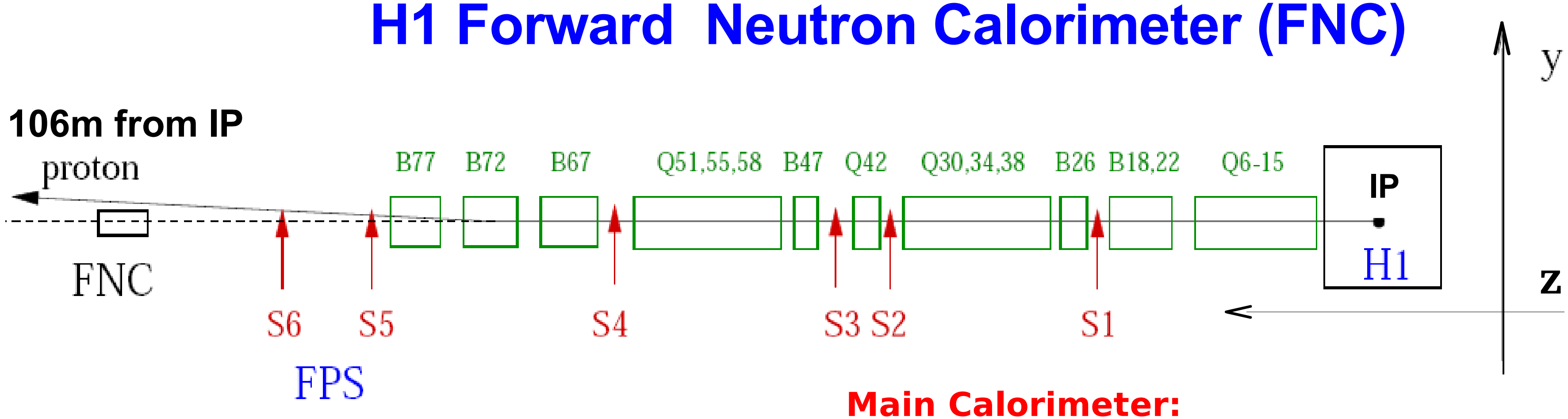


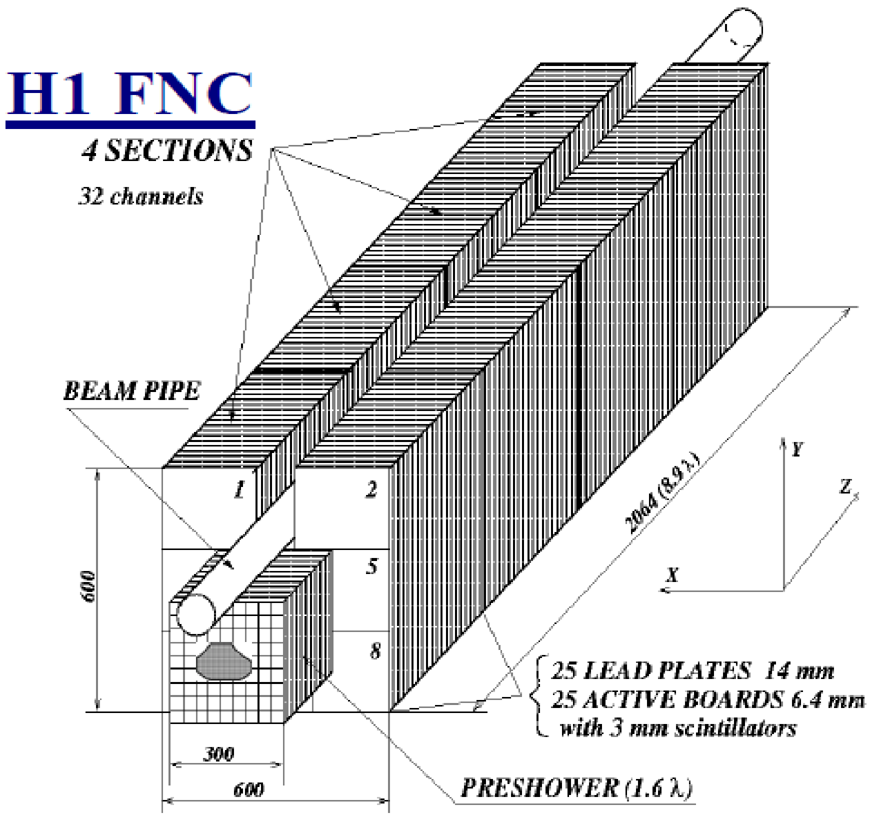
$x_F = x_L = E_{Lp}/E_{pBeam}$



- Reasonable prediction for leading proton data (after model tuning)
- None of models describe leading neutron data well
- Goal:Measure photon production in DIS and compare to the models
- Similar measurement reported by LHCf in pp collisions

H1 Forward Neutron Calorimeter (FNC)





Main Calorimeter:

4 modules 60 x 60 x 51 cm^3, 8.9λ

Preshower:

26 x 26 x 40cm^3, 60X_0, 1.6λ

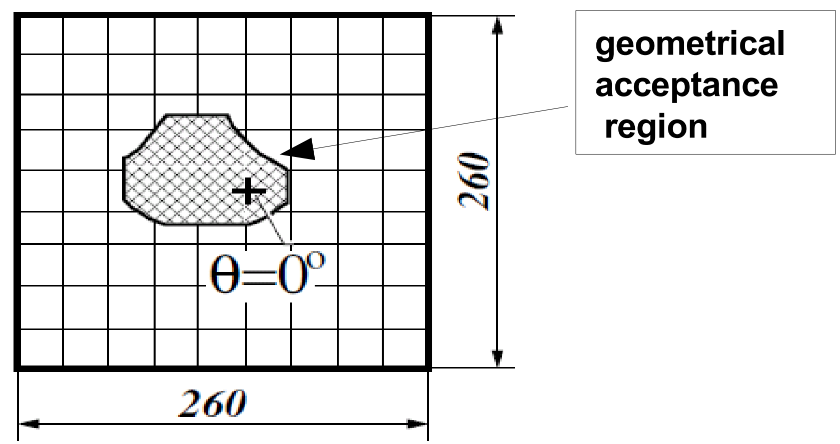
e/m shower contained in Preshower

⇒ separation photons from neutrons

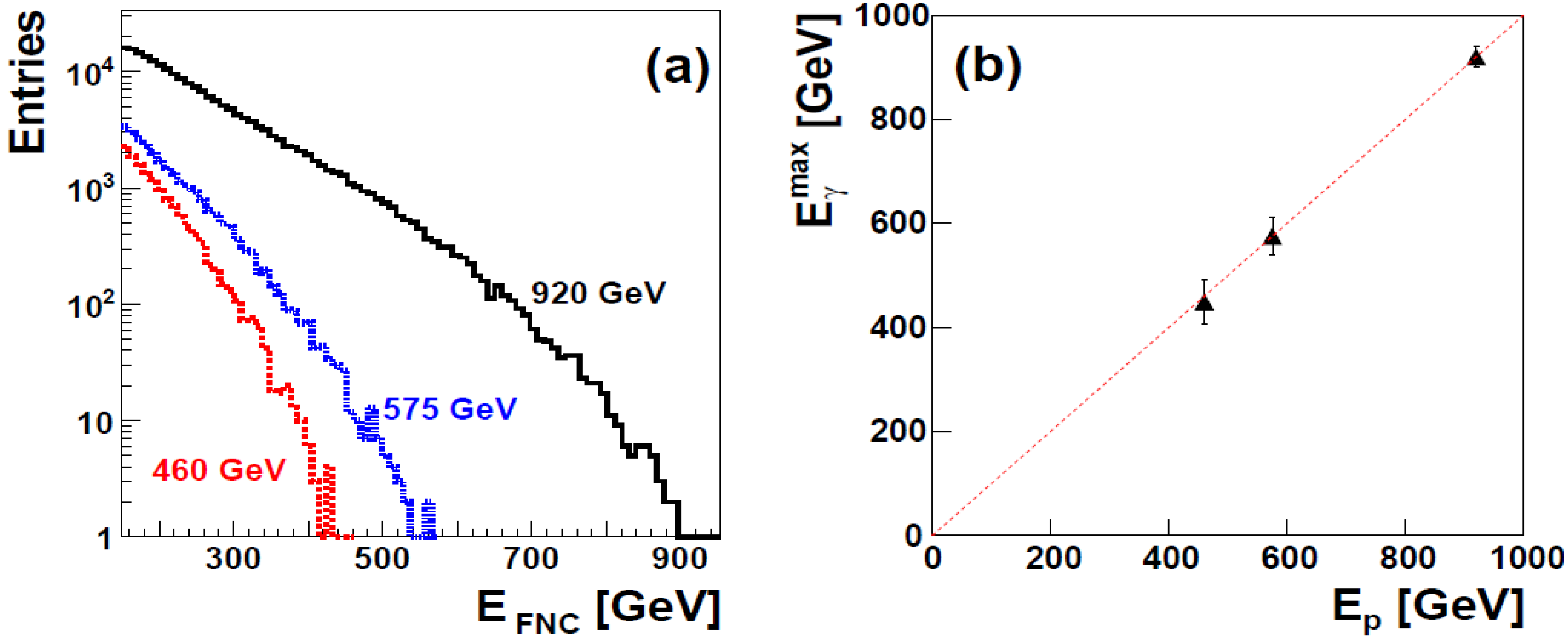
9x, 9y strips

Position resolution: 2mm

$\sigma(E)/E \approx 20\%/\sqrt{E[GeV]} \oplus 2\%$ for e/m shower



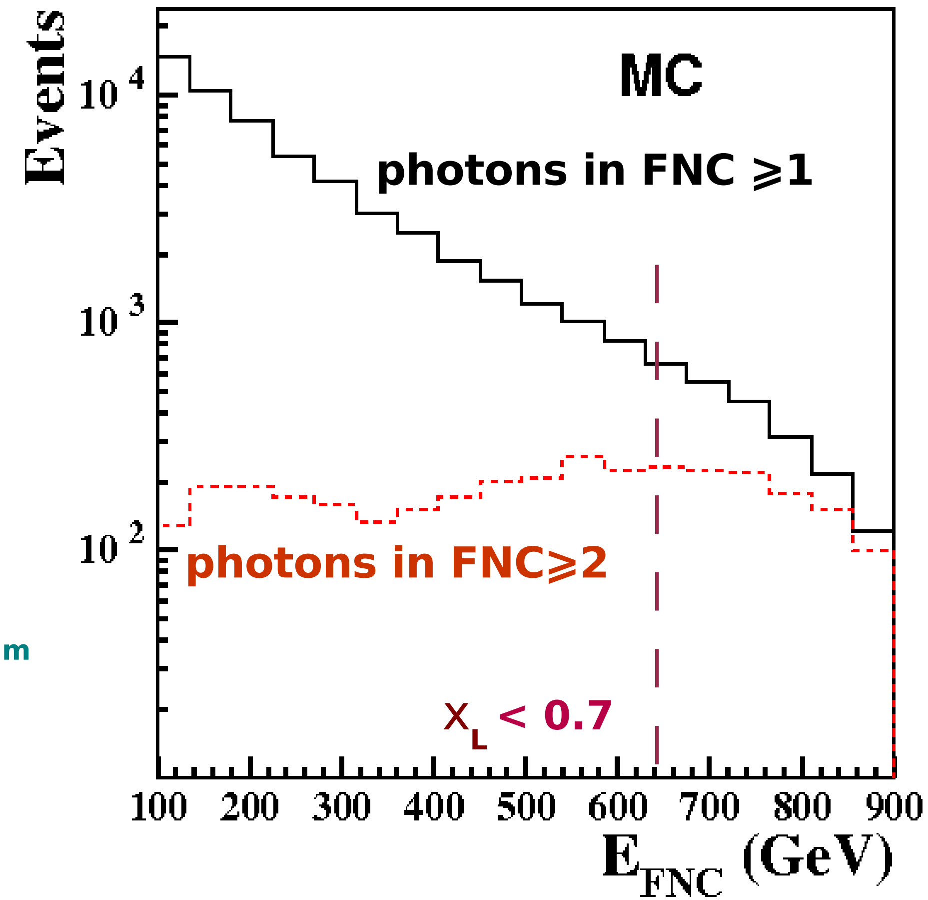
Preshower Calibration

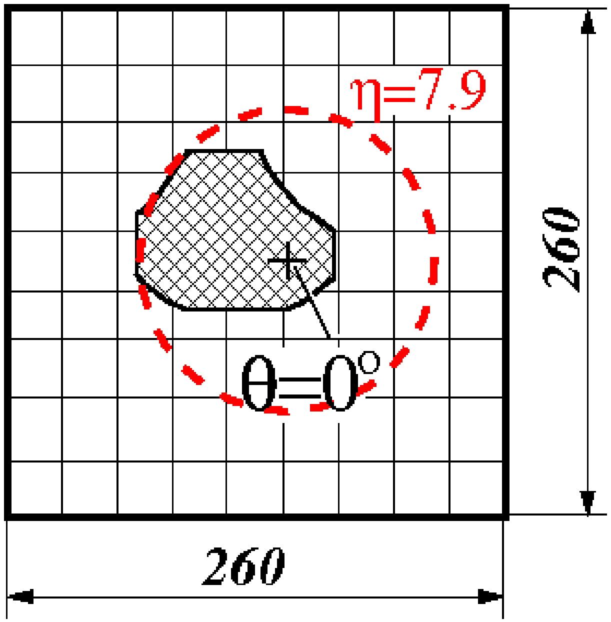


- Refined calibration constants are determined using an iterative procedure assuming that the $E_{\gamma}^{max} \approx E_{pBeam}$ in case of unlimited statistics.
- a) The measured photon energy spectra for three proton beam energies.
- b) The correlation between the proton beam energy and E_{γ}^{max}

Photon candidates

At high x_L, many FNC clusters are from more than one photon! So measurement represents the sum of photons inside the angular range defined by the geometrical acceptance $\eta>7.9$. But at lower x_L we can assume that to a good approximation we measure one photon.



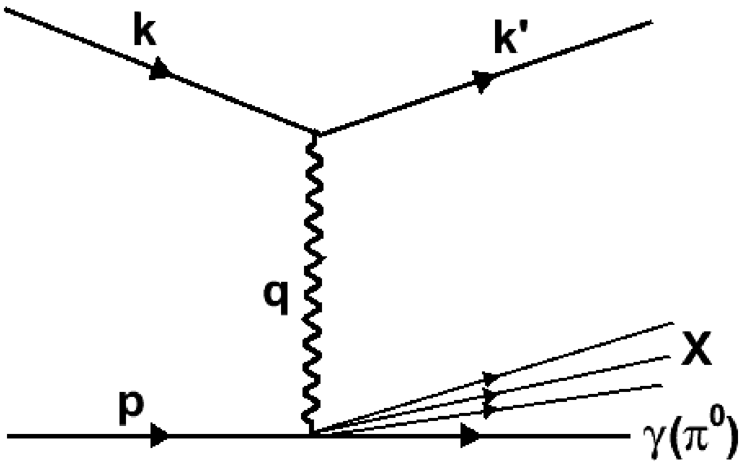


$x_L = E_{FNC}/E_{PBeam}$

provide cross sections:

- x_L and p_T of leading photon in a range $\eta>7.9$ for $x_L < 0.7$
- x_L of sum of photons in a range $\eta>7.9$ for $x_L < 0.95$

Kinematics and selection cuts



$q = k - k'$ $\quad$ $Q^2 = -(k-k')^2$

$y = (qp)/(kp)$ $\quad$ $x_{Bj} = Q^2/(2pq)$

2006-2007 data

$E_e = 27.5$ GeV $\quad E_p = 920$ GeV $\quad \sqrt{s} = 319$ GeV

Lumi = $126\,pb^{-1}$

DIS selection:

$E'_e > 11$GeV $\quad \Theta'_e = (156^\circ\text{-}175^\circ)$ in SpaCal

$|Zvtx| < 35$ cm $\quad \Sigma(E-p_z) = (35\text{-}70)$ GeV

$6 < Q^2 < 100\ GeV^2 \quad 0.05 < y < 0.6$

Photon selection:

Photon candidate in FNC with

$\eta_\gamma > 7.9$ (lab frame)

$x_L = E_\gamma/E_P > 0.1$

Statistics:

78740 DIS events with forward photons

Monte Carlo models

Data compared to Monte Carlo models:

- inclusive DIS MC DJANGOH14 (H1PDF2009 parametrization):
  - LEPTO - leading log parton shower
  - ARIADNE - color dipole model (CDM)

- Hadronic interaction Cosmic Rays (CR) models:
  - QGSJET 01 and II-03: (Kalmykov, Ostapchenko)
  - EPOS 1.9: (Pierog, Werner)
  - SIBYLL 2.1: (Engel, Fletcher, Gaisser, Lipari, Stanev)

Based on: Regge theory, Gribov-Regge approximation, perturbative QCD, unitarisation.

Differences in modeling the mini-jet production, formation of colour strings and fragmentation, treatment of saturation effects, treatment of hadron remnants.

In all these models the main source of forward photons is the decay of π^0 mesons produced from the hadronisation of the proton remnant.

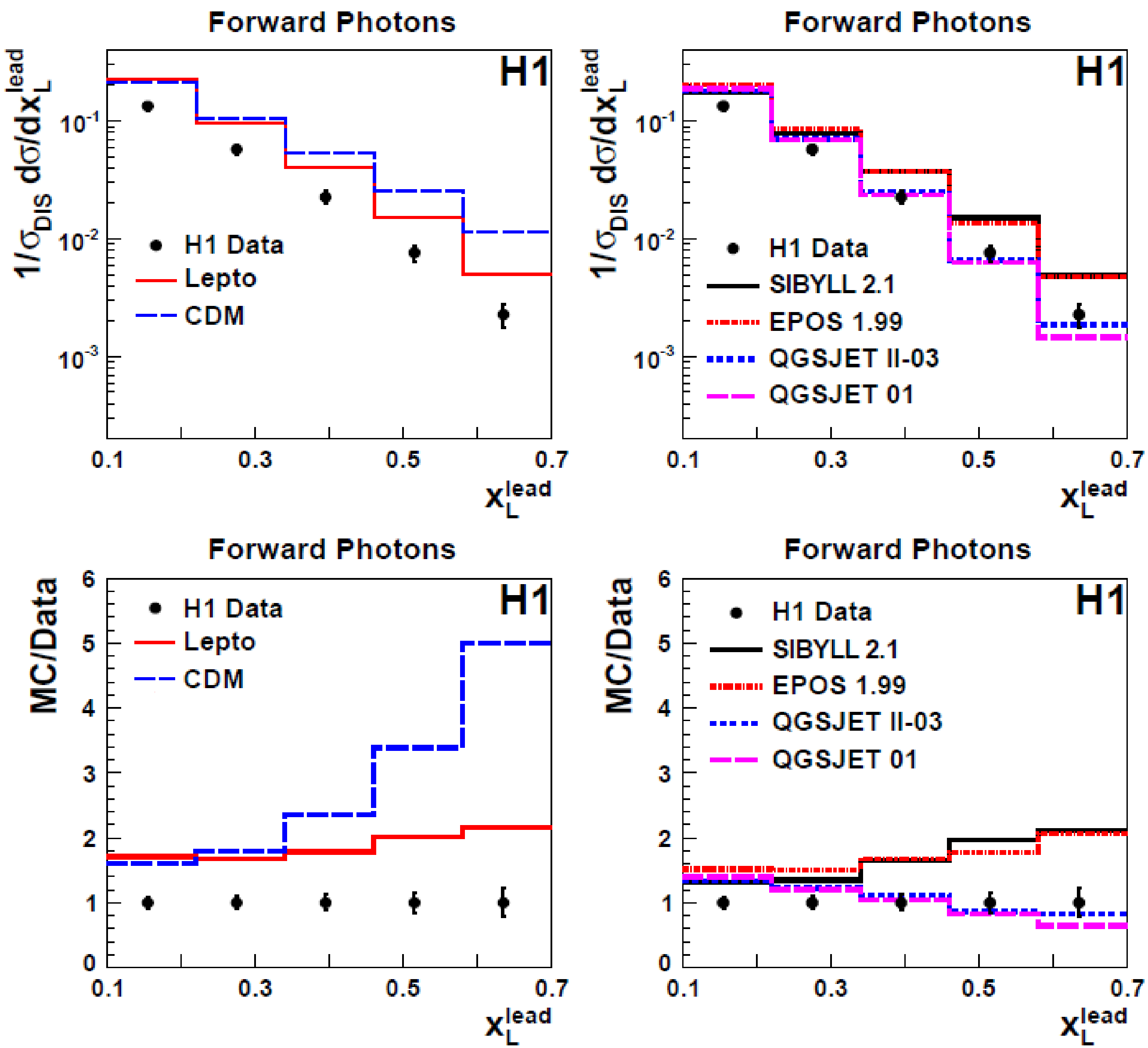
Forward photon cross sections vs x_L^{lead}

Photon rate in all used MC models is significantly higher than in the data. LEPTO,CDM higher by 70% CR models higher by 30-50%.

LEPTO model describe the shape reasonably well.

CDM to data discrepancy larger at higher x_L.

QGSJET models have steeper behavior than the data, close to data in absolute values except at low x_L



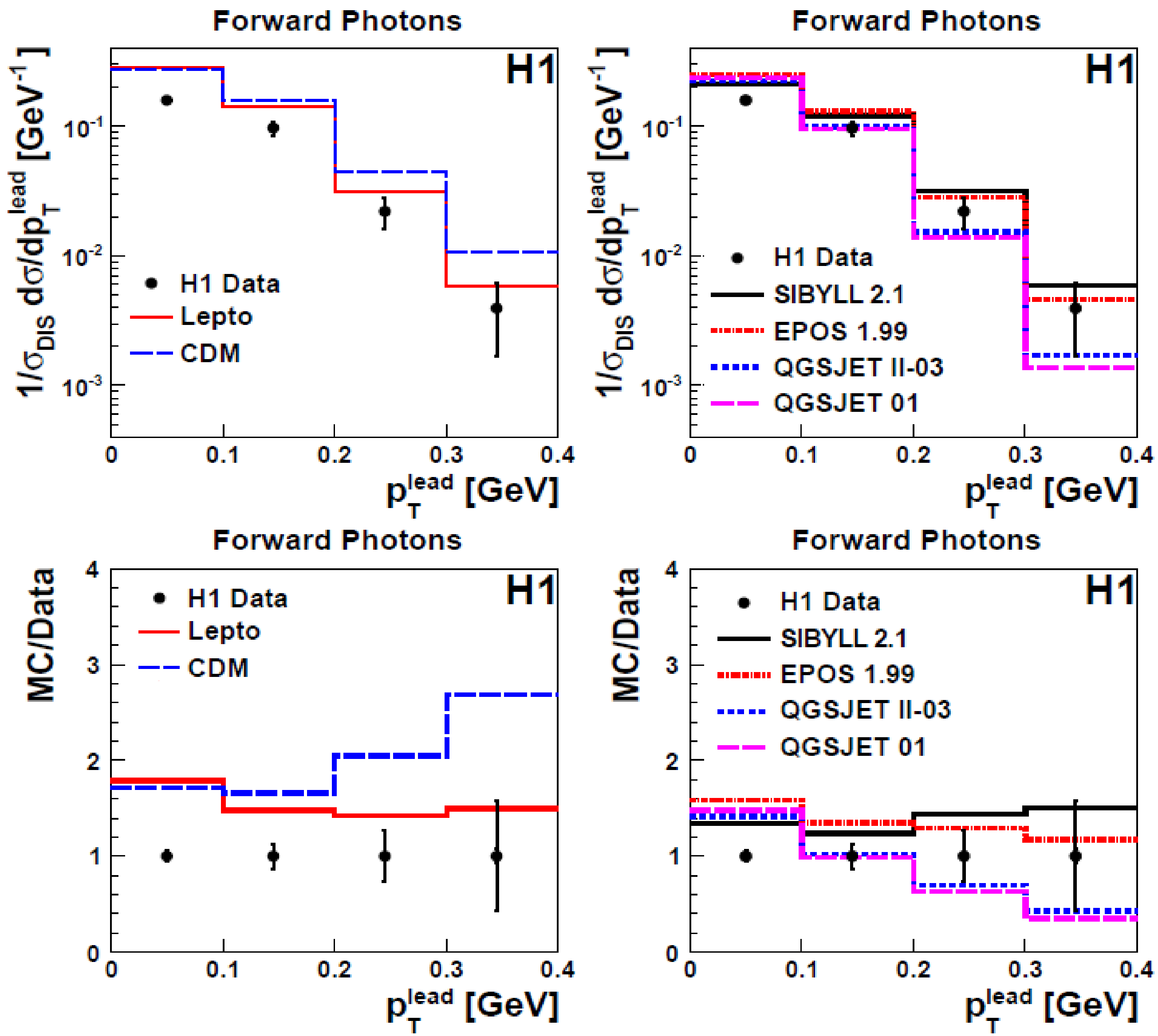
Forward photon cross sections vs p_T^{lead}

Photon rate in all MC the models is significantly higher than in the data.

LEPTO model describe the shape reasonably well.

p_T spectrum shape is well described by SIBYLL and EPOS models.

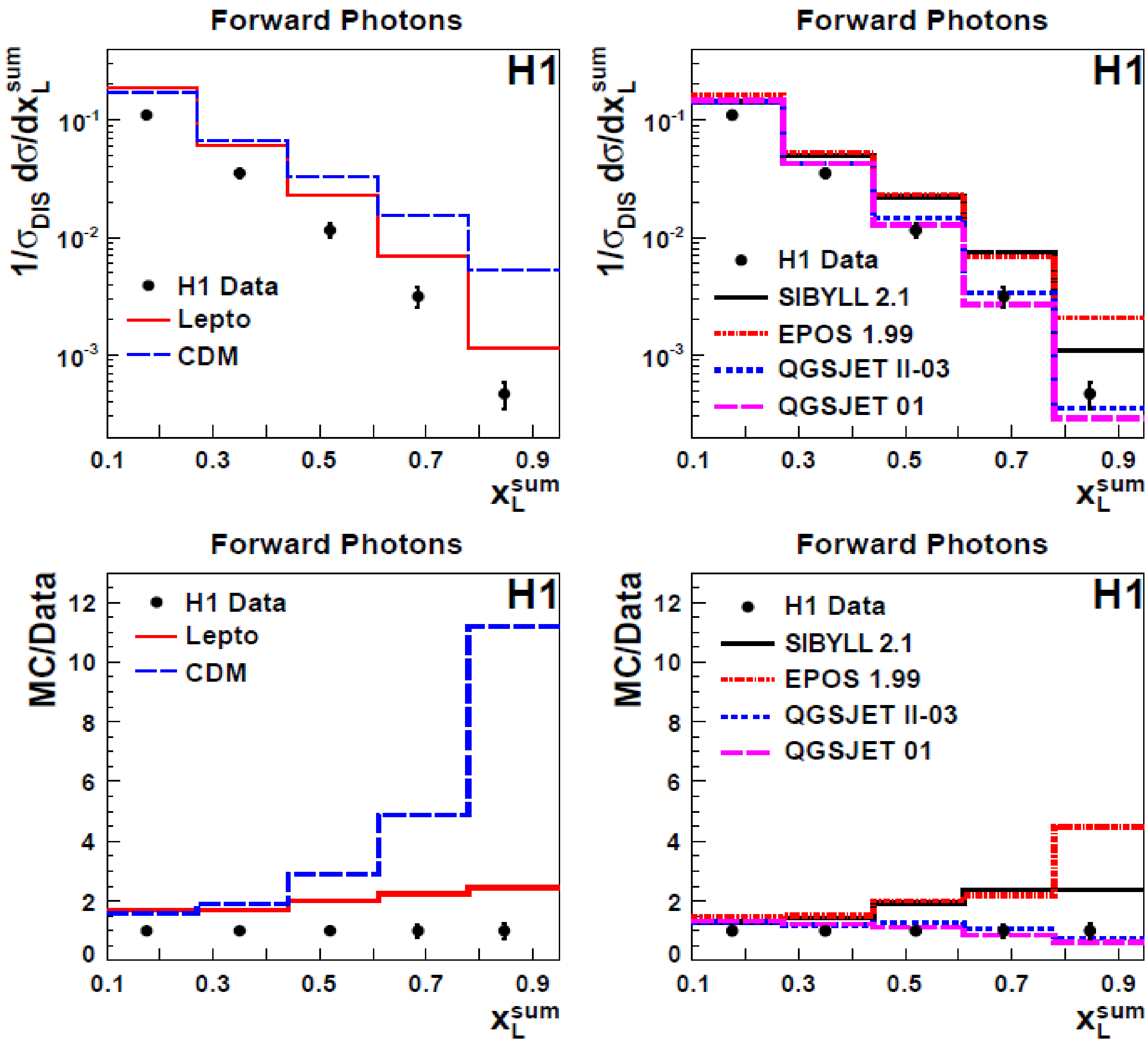
QGSJET also agree with data within uncertainties (except lowest p_T)



Forward photon cross sections vs x_L^{sum}

$x_L^{sum} = \Sigma E_i / E_{Pbeam}$

for photons in η>7.9



Photon rate in all MC models is significantly higher than in the data.

LEPTO model describe the shape reasonably well.

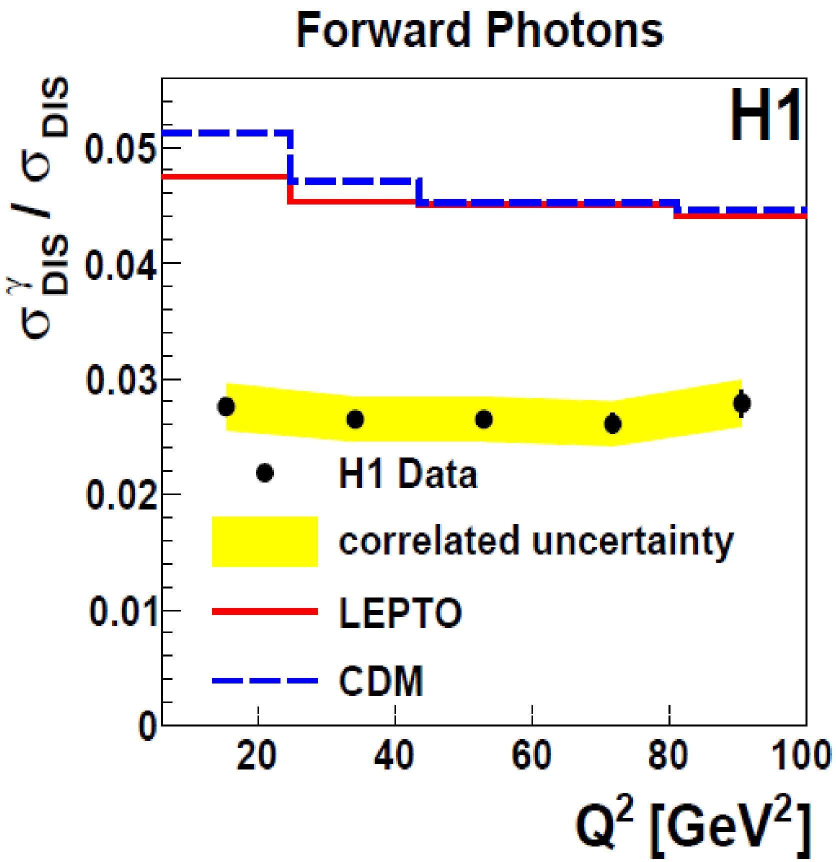
CDM:large discrepancy at higher x_L.

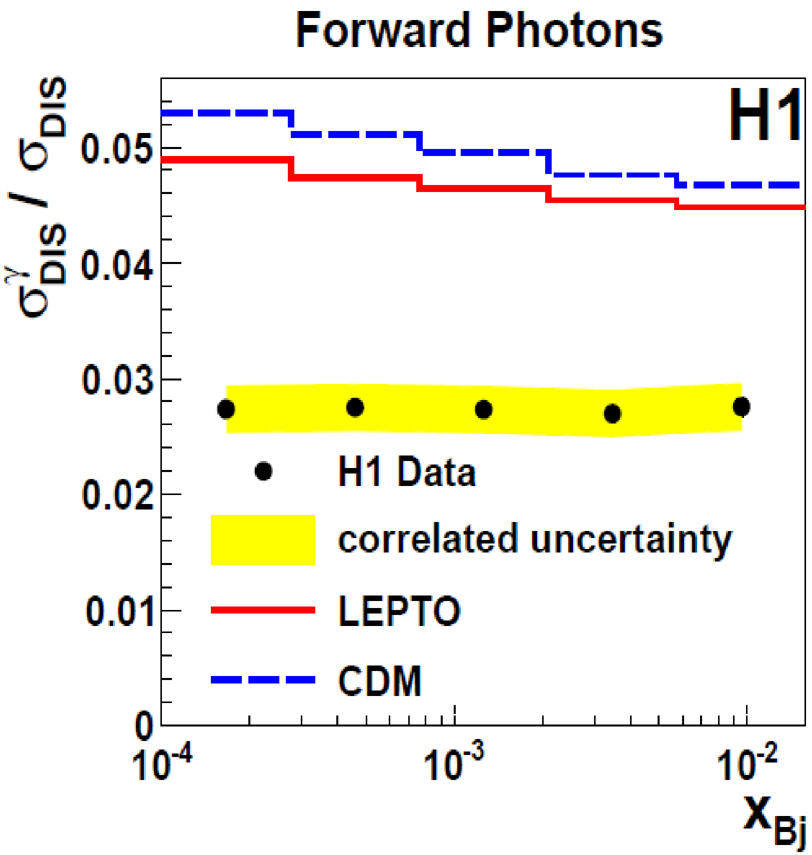
QGSJET models describe data shape better than SIBYLL and EPOS. Difference is more pronounced for EPOS in highest x_L^{sum} bin.

Fraction of DIS events with forward photons

Test of limiting fragmentation hypothesis
(Forward particle production insensitive to Q^2, x_{BJ}).

DIS events with forward photons $6 < Q^2 < 100$ GeV^2, $0.05 < y < 0.6$, $\eta_\gamma > 7.9$, $0.1 < x_L^{sum} < 0.95$





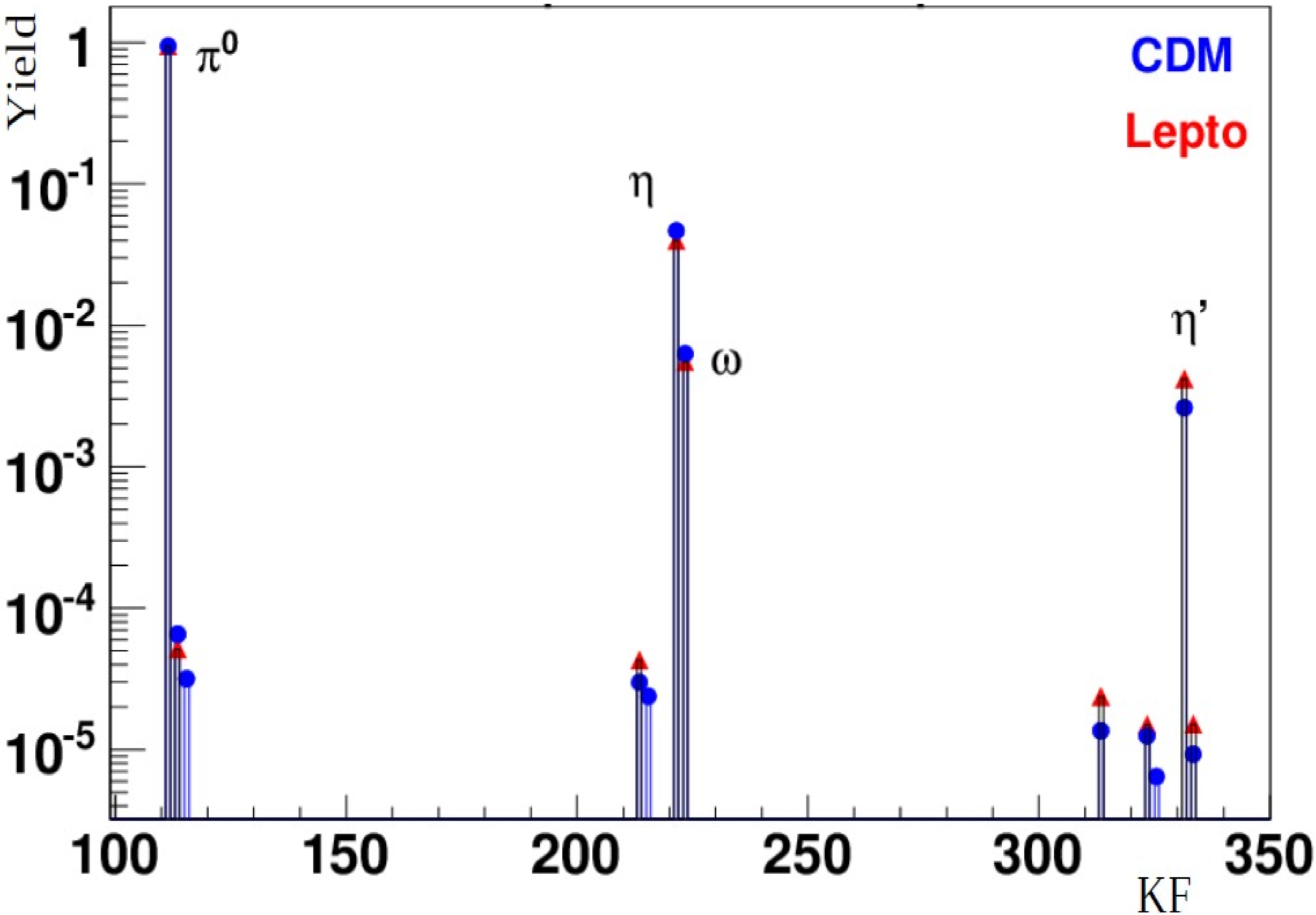
LEPTO and CDM models predict much higher rate of forward photons and show slight Q^2 and x_{BJ} dependance.

Data support the hypothesis of limiting fragmentation.

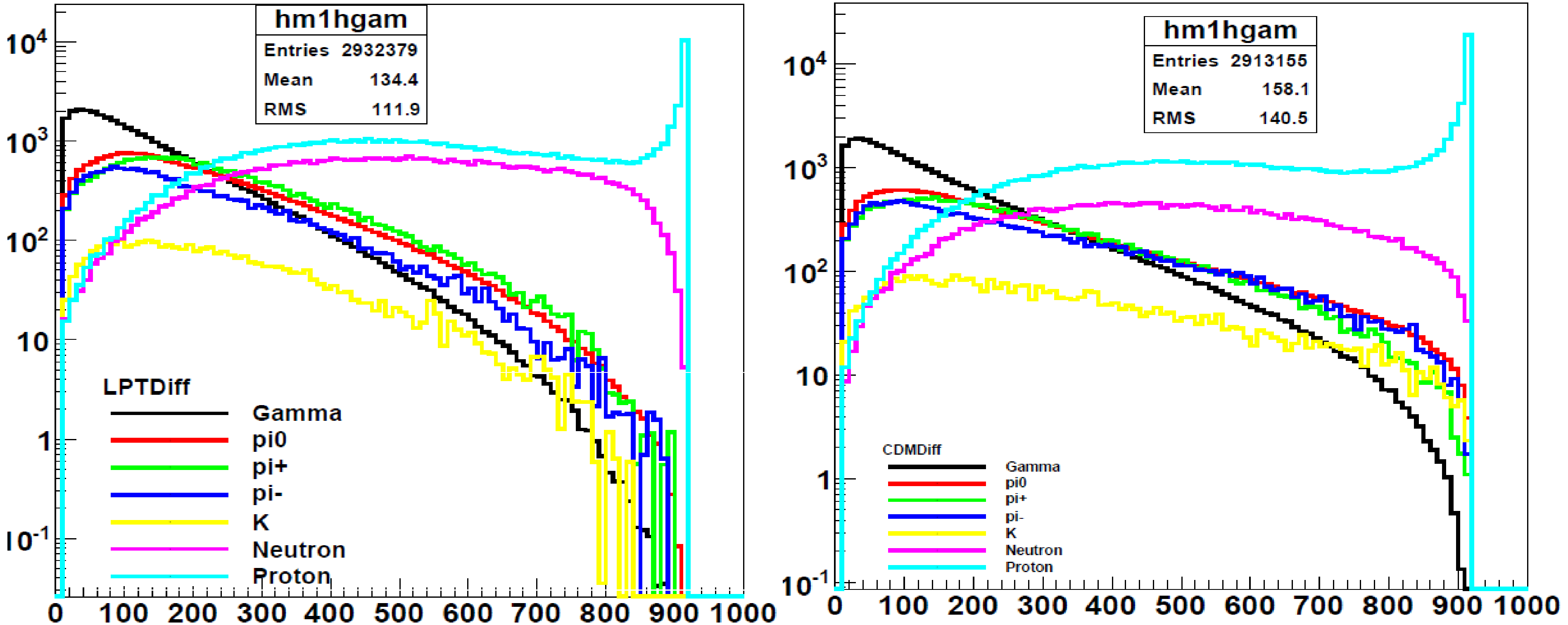
Conclusions

- First measurement of very forward photon production in DIS
- Measurements show sensitivity to proton fragmentation models. Useful input for MC models tuning
- All models predict significantly higher yield of photons than data
- LEPTO describes the shape well
- CDM predicts harder x_L and p_T spectra
- Hadronic interaction CR models overestimate the measurements by 30-50% and predict different x_L and p_T spectra
- Fraction of DIS events with forward photons is independent of Q^2,x_{Bj} ,supporting limiting fragmentation hypothesis

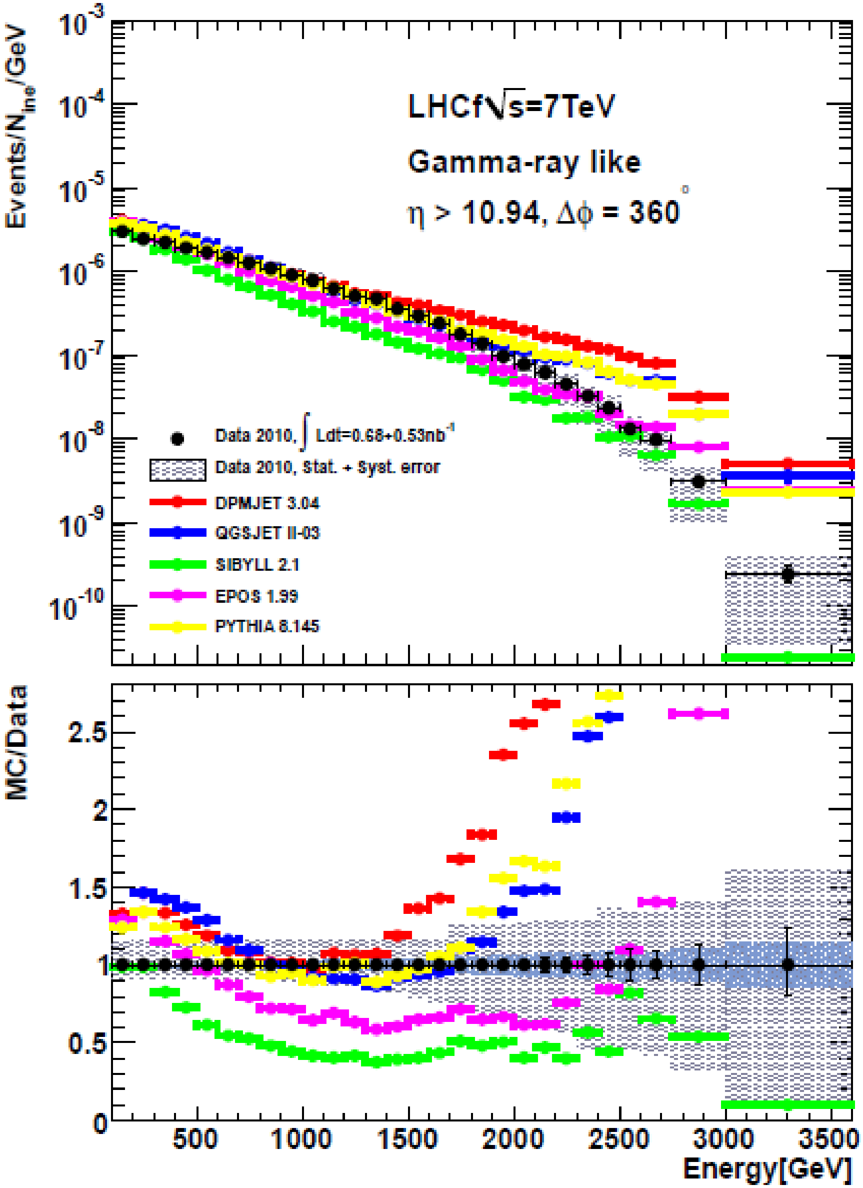
PID of forward photons mother particles

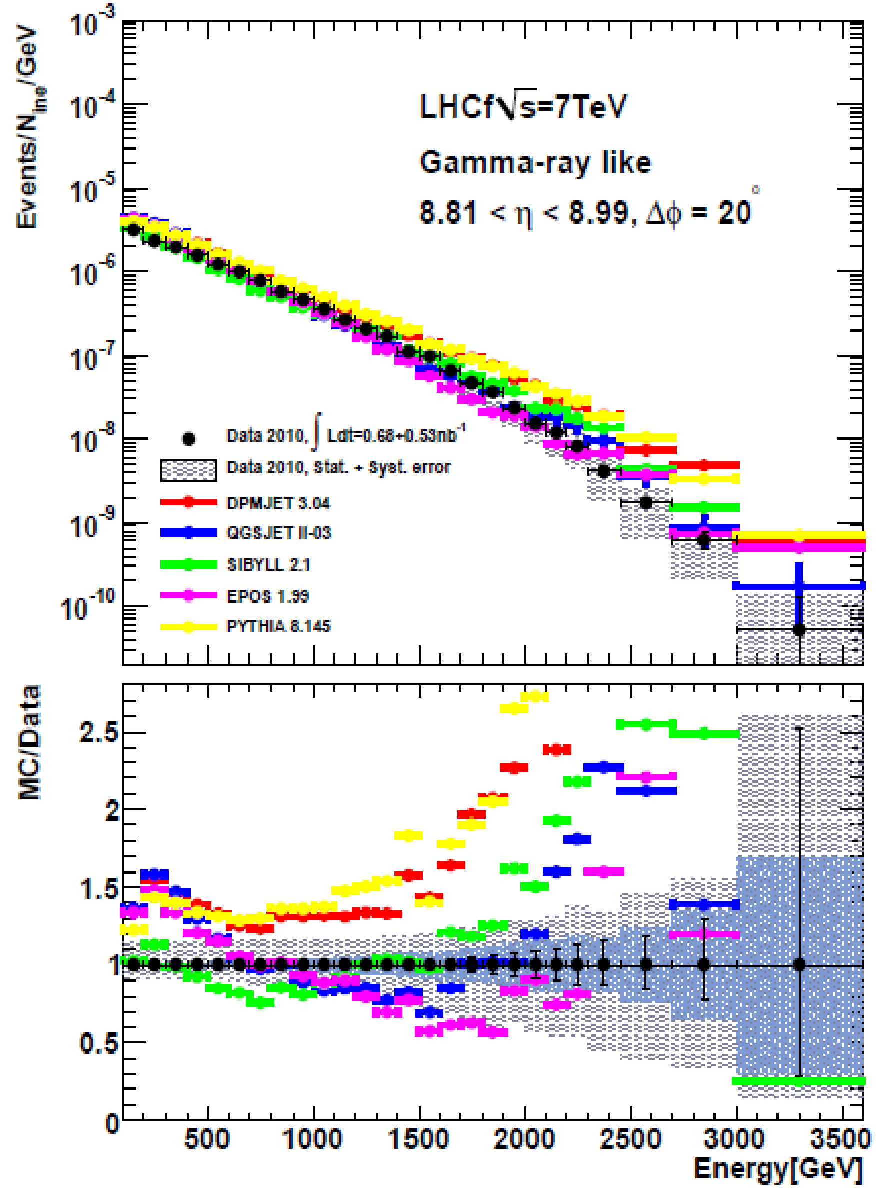


Forward particles from MC



LHCf forward photon measurements and models





Example of event with high energy photon from Lepto

0	e+	beam	-1	-1	-1	-1	-0.0000	-0.0000	-27.6000	27.6000	0.0000
1	proton	beam	-1	-1	-1	-1	-0.0000	-0.0000	919.9995	920.0000	0.9479
2	Z0	doc	0	-1	-1	-1	-1.5038	2.2638	-2.1872	2.0421	-2.8285
3	e+	stable	0	-1	-1	-1	1.5032	-2.2625	-25.3478	25.4929	0.0043
4	gamma	rad gam	0	-1	-1	-1	0.0006	-0.0013	-0.0650	0.0650	-0.0000
5	u	decayed	-1	-1	7	9	-1.8420	2.6292	-0.8964	3.3331	0.0136
6	ud_0	decayed	1	-1	7	9	0.3383	-0.3653	918.7076	918.7079	0.5593
7	u	decayed	5	-1	10	10	-0.9880	2.0348	-0.9832	2.4664	0.0114
8	ud_0	decayed	5	-1	10	10	-0.4697	-0.3783	0.0584	0.8383	0.5793
9	pi0	decayed	5	-1	13	14	-0.0461	0.6073	918.7360	918.7362	-0.1858
10	string	decayed	7	8	11	12	-1.4577	1.6565	-0.9248	3.3047	2.2797
11	Delta0	decayed	10	-1	15	16	-0.9938	1.5687	-0.7063	2.3378	1.2320
12	rho+	decayed	10	-1	17	18	-0.4638	0.0878	-0.2185	0.9670	0.8151
13	gamma	stable	9	-1	0	0	-0.0014	-0.0034	0.8916	0.8916	-0.0003
14	gamma	stable	9	-1	0	0	-0.0447	0.6107	917.8445	917.8446	-0.3884
15	neutron	stable	11	-1	0	0	-0.5484	1.2748	-0.4870	1.7452	0.9396
....											
20	gamma	stable	16	-1	0	0	-0.0921	0.0370	0.0089	0.0997	0.0000