Study of Feynman Scaling in Very Forward Neutron and Photon Production in DIS at HERA

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On behalf of the H1 Collaboration

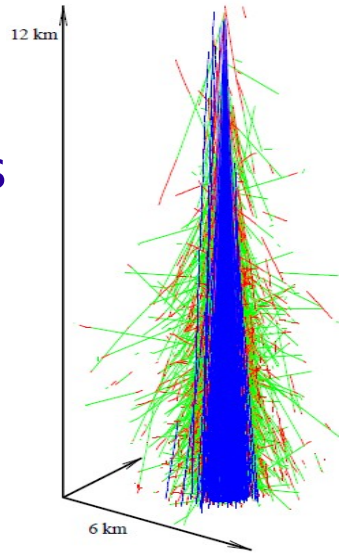
Outline

- **Introduction**
- **Data selection and MC models**
- **Results**
- **Conclusions**

Introduction

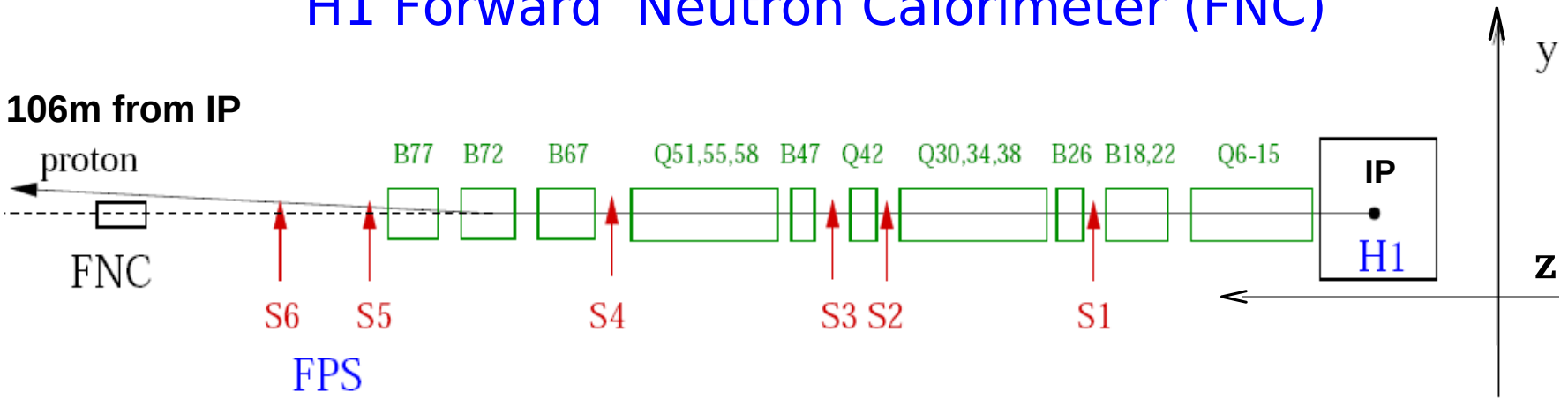
Measurements of Forward Particles (small angles to the proton beam in e-p collisions) are important for:

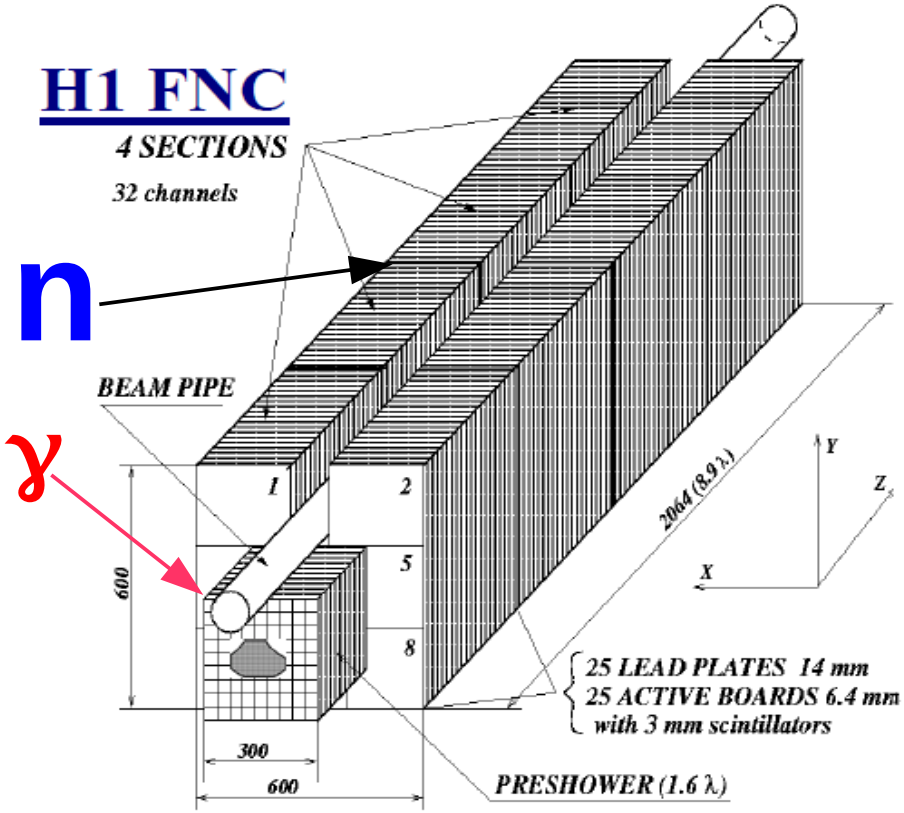
- understanding of proton fragmentation mechanisms
- model tuning, in particular for hadron interaction in Cosmic Ray(CR) models (since the shower in matter is dominated by soft, forward interactions)
- testing the hypothesis of limiting fragmentation: the production of forward particles is independent of the energy of incident particle.
- testing of Feynman Scaling: Cross Section vs. $x_F = p^*_{||}/p^*_{||max}$ integrated over p_t is independent of CM-energy.



- In this analysis the production of forward neutrons and photons in DIS is studied as a function of the CM-energy and Feynman-x variable.
- The normalized cross-sections are compared to the DIS MC models and models of CR interactions.

H1 Forward Neutron Calorimeter (FNC)





Main Calorimeter:
4 modules 60 x 60 x 51 cm^3,8.9λ

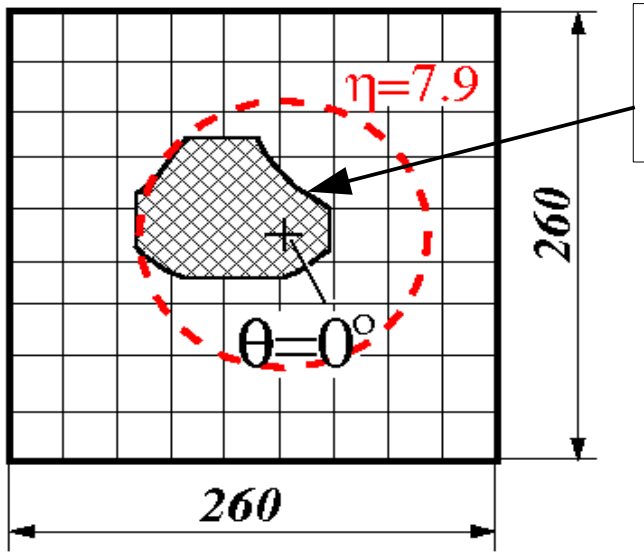
Preshower:
26 x 26 x 40cm^3, 60X_0 , 1.6λ
e/m shower contained in Preshower
⇒ separation photons from neutrons
9x, 9y strips
Position resolution:2mm
$\sigma(E)/E \approx 20\%/\sqrt{E[GeV]} \oplus 2\%$ for e/m shower

Identification of forward Photons and Neutrons

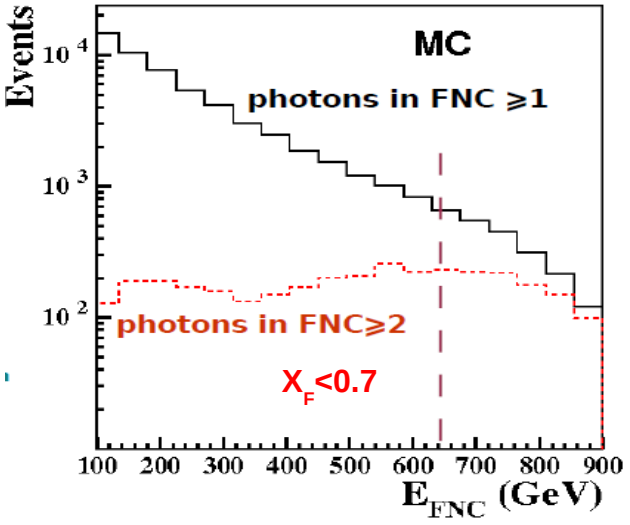
Photons: shower fully contained in the Preshower calorimeter.

Angular Restriction: Θ<0.75 mrad (η>7.9)

0.1<X_F<0.7: due to non negligible ≥2 photons

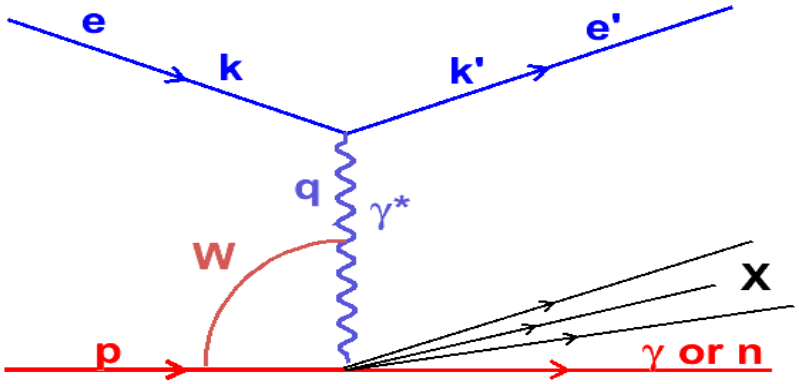


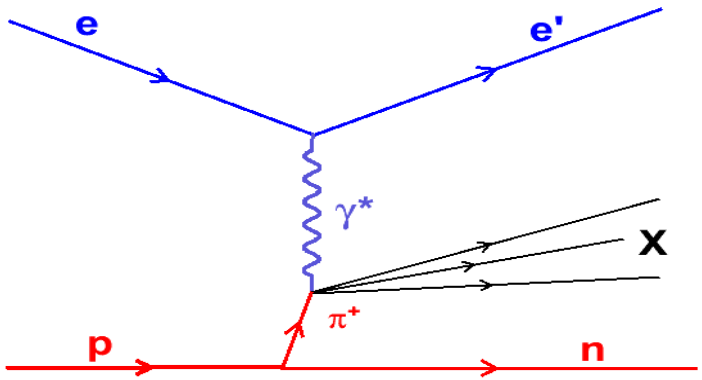
Limitating aperture from beam line elements



Neutrons: Contained in the Main Calorimeter (and Preshower).

Kinematics and selection cuts





γ or n production in proton fragmentation

n production via π^+ - exchange

$q = k-k'$; $Q^2 = -q^2$; $y = (qp)/(kp)$; $W^2=(q+p)^2$

2006-2007 data
Ee=27.5 GeV; Ep=920 GeV; $\sqrt{s}$=319 GeV
Integrated Luminosity = 126pb^{-1}

DIS selection:

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

Photon and Neutrons selection in FNC:

$\eta > 7.9$ (lab frame), $x_F > 0.1$

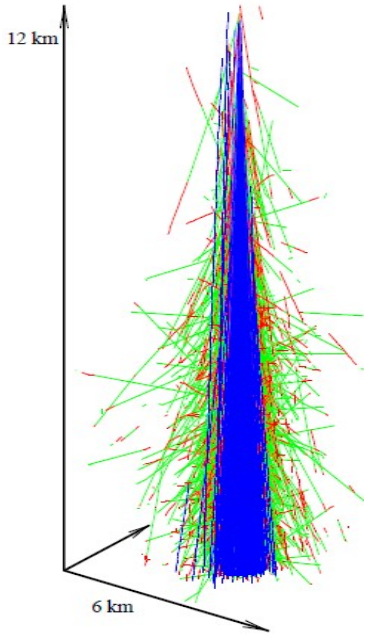
Statistics with DIS electrons:
Photons: ~ 79000
Neutrons: ~231000

Monte Carlo models

Data are compared to Monte Carlo models:

- inclusive DIS MC DJANGOH14 and RAPGAP-π:
  - LEPTO - LO matrix elements+leading log parton shower
  - ARIADNE - LO matrix elements+color dipole model (CDM)
  - RAPGAP-π - Pion exchange model

- Hadronic interaction Cosmic Rays (CR) models:
  - QGSJET 01,QGSJET 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.

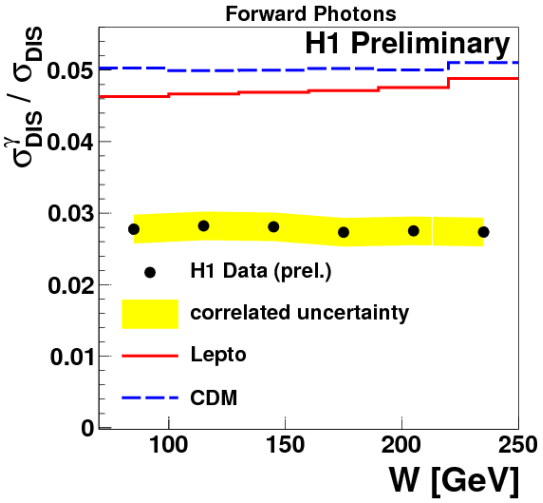
Differences in modeling ==> mini-jet production, formation of color strings and fragmentation, treatment of saturation effects, multiparton interaction, treatment of hadron remnants.

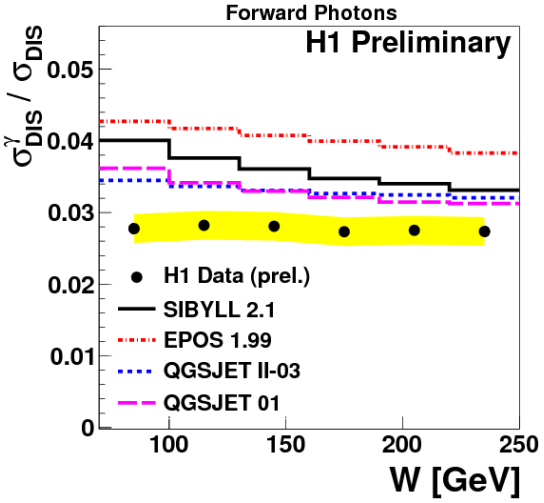
- Forward Photons are produced in π^0 decay from hadronisation of the proton remnant.
- Forward Neutrons are produced in proton fragmentation and by the **π-**exchange mechanisms, **p->n+π^+**

Fraction of DIS events with forward Photons and Neutrons vs γ*p CM energy W

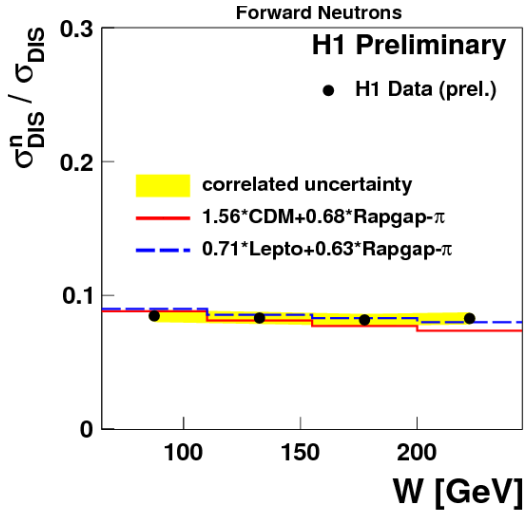
Results

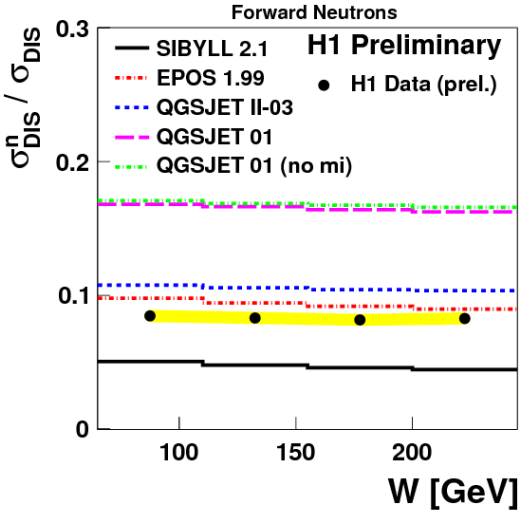
Forward Photons





Forward Neutrons

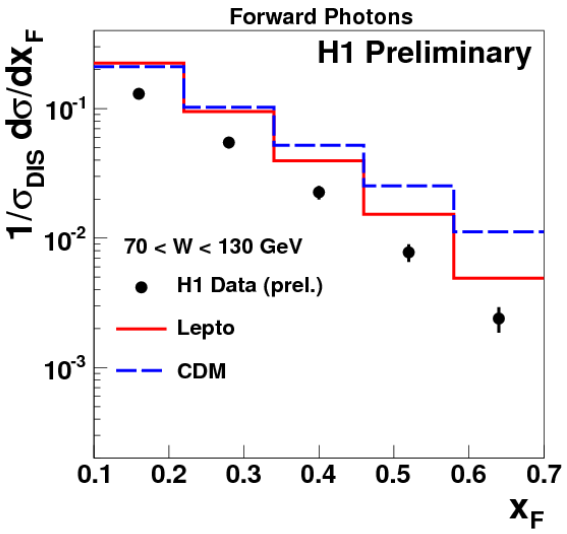


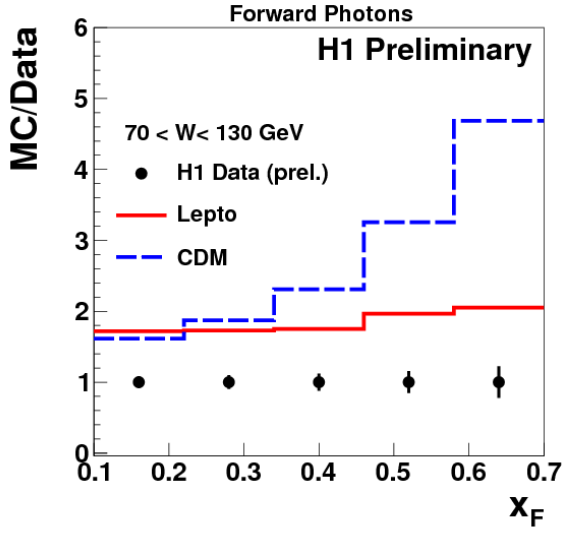


- Fraction of DIS events with forward photons and neutrons independent of CM energy W
  ==>consistent with limiting fragmentation
- All models predict too high rate of forward photons.
- Large spread of CR models prediction.
- Models indicate W dependencies of photons and neutrons yields

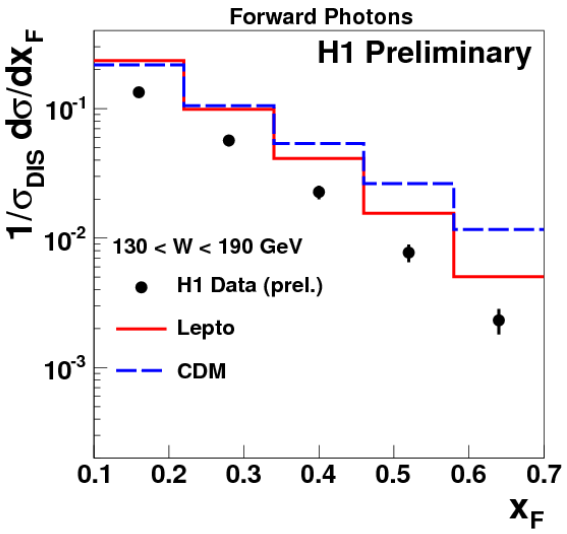
$x_F = p^*_{||}/p^*_{||max}$ Normalized Forward photon cross sections vs x_F

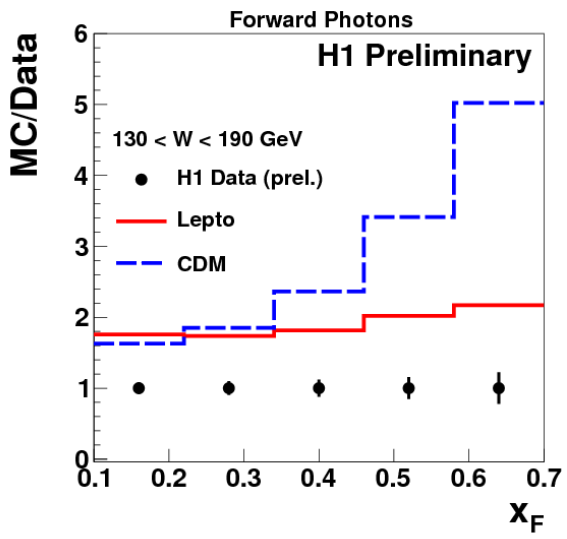
70 < W1 < 130 GeV



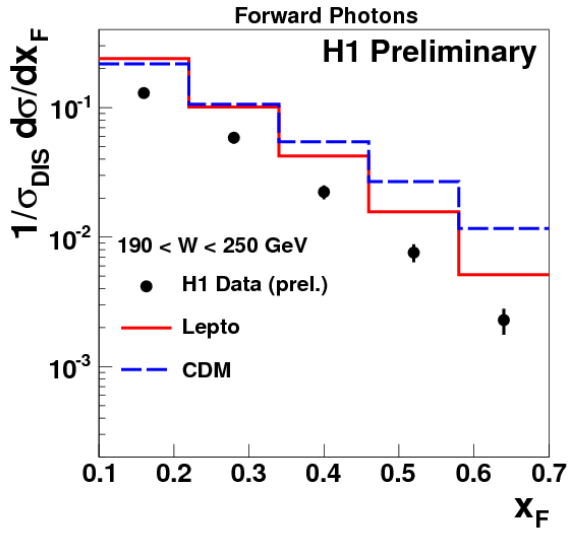


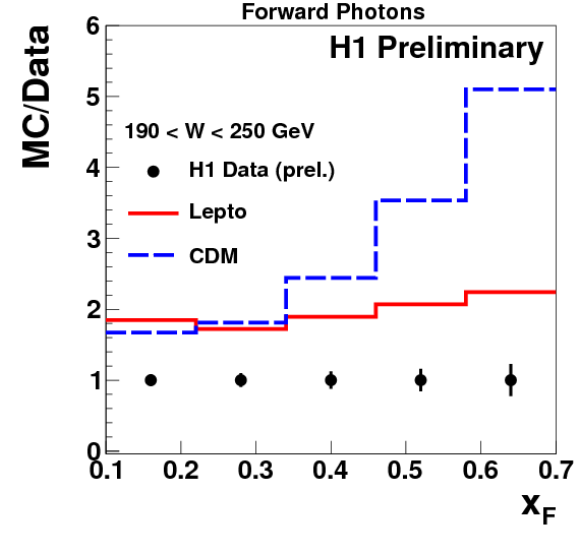
130 < W2 < 190 GeV





190 < W3 < 250 GeV

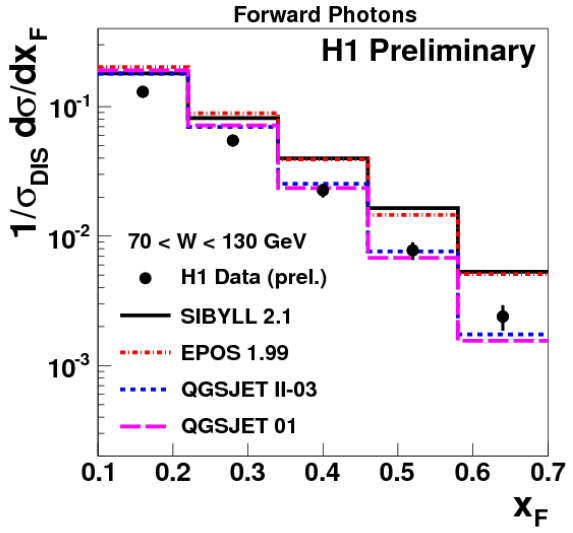


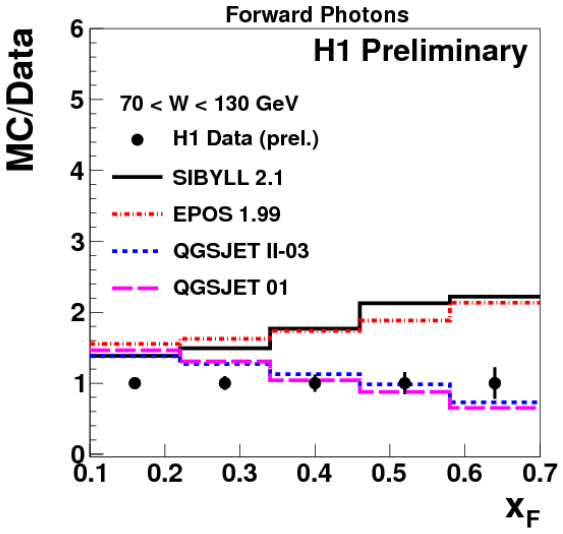


Photon rate in all used MC models is significantly higher than in the data.
LEPTO,CDM higher by 70% . CDM predict much harder x_F spectra,independent of W.

Forward photon cross sections vs X_F (CR)

70 < W1 < 130 GeV





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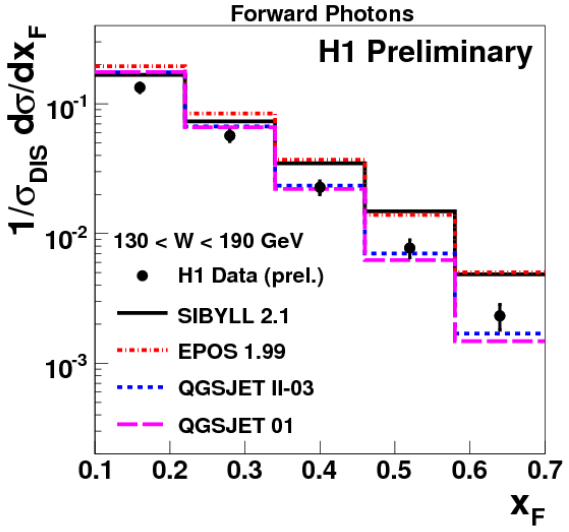

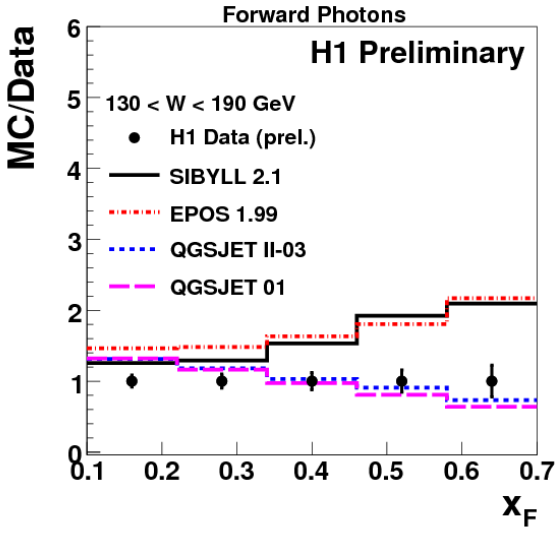

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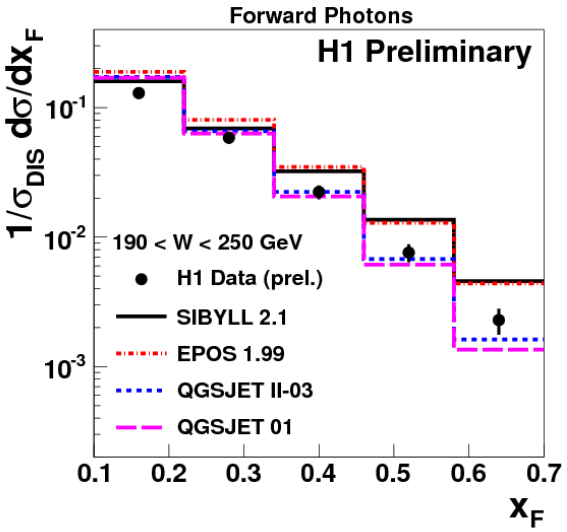
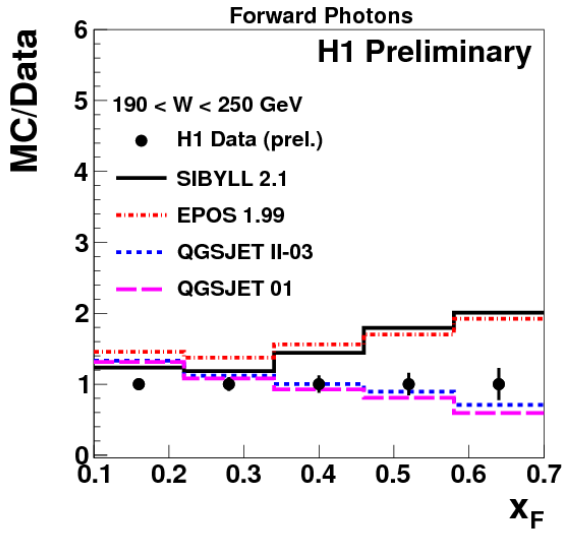
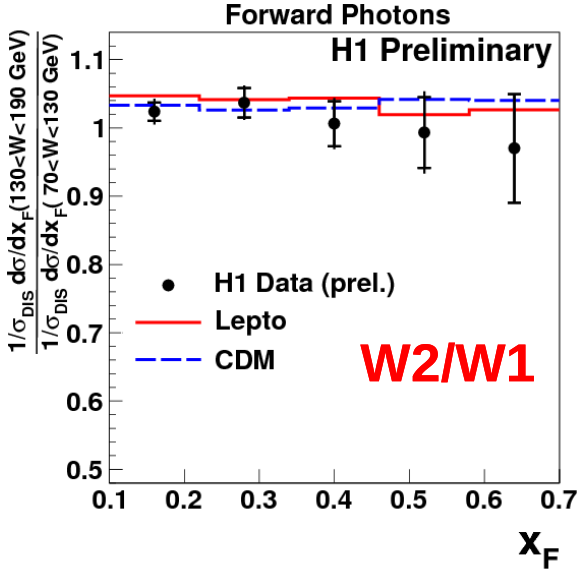
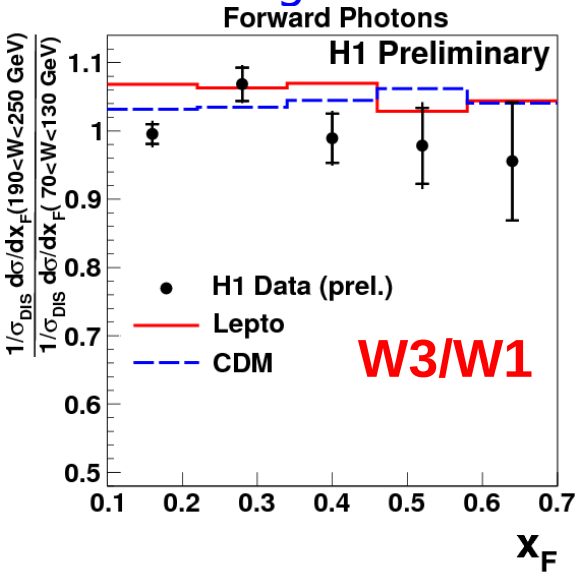




Large difference between models independent of W.
Best description by QGSJET models.

Ratios of 2-nd and 3-rd W ranges to 1-st W range





70 < W1 < 130 GeV
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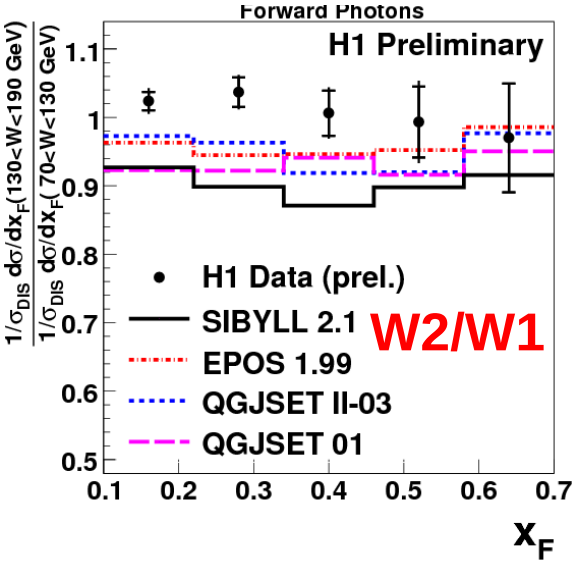
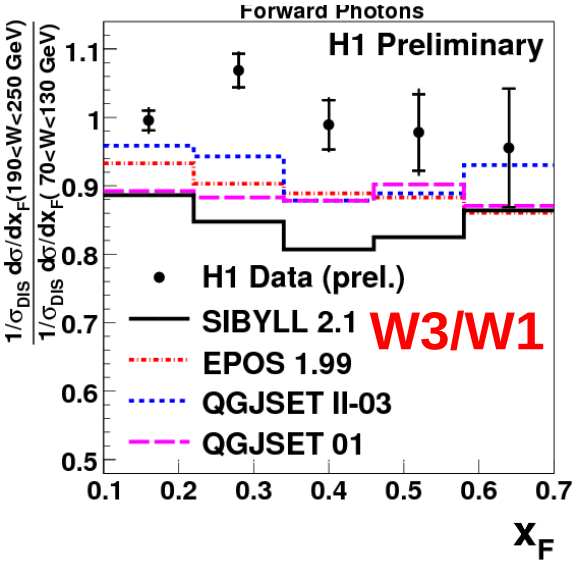
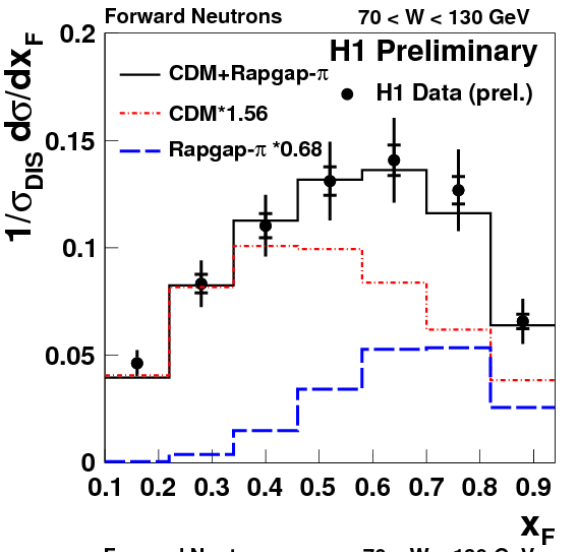


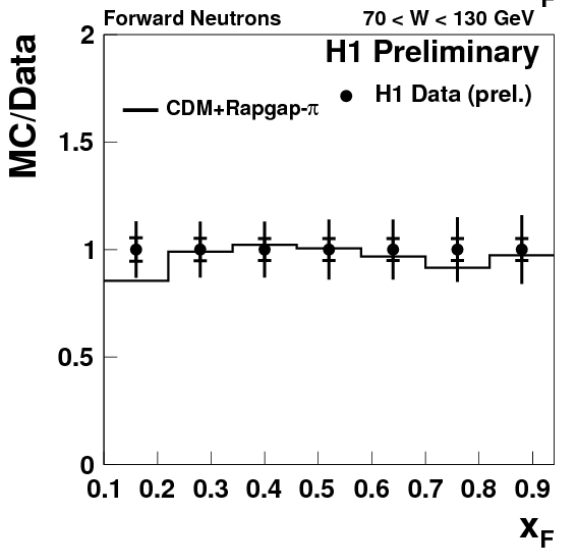


Data consistent with unity within error ==>support Feynman scaling.
CR models show clear deviation from scaling.

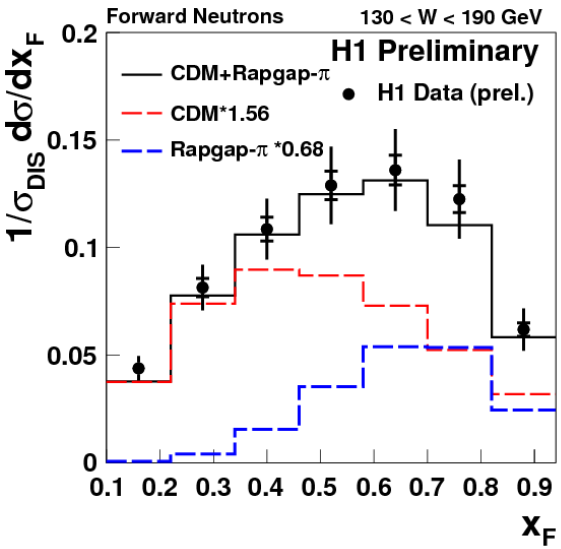
Forward neutrons cross sections vs x_F

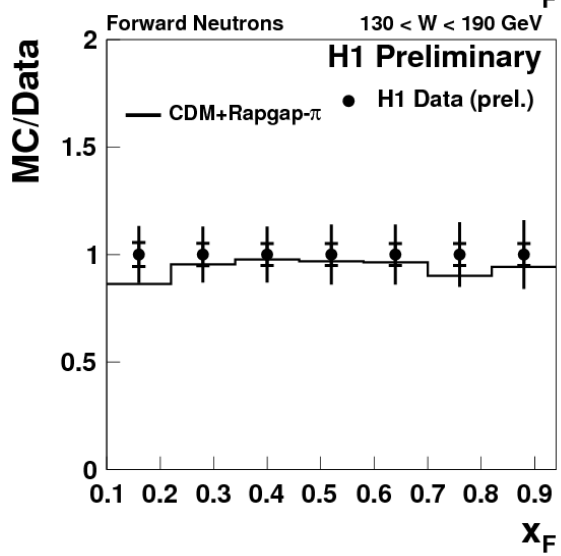
70 < W1 < 130 GeV



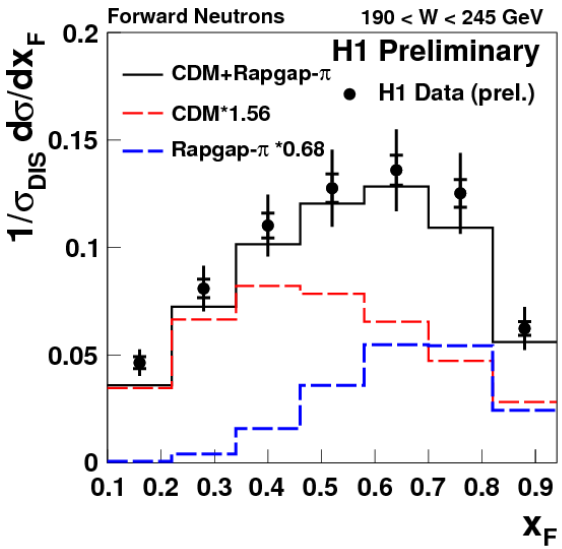


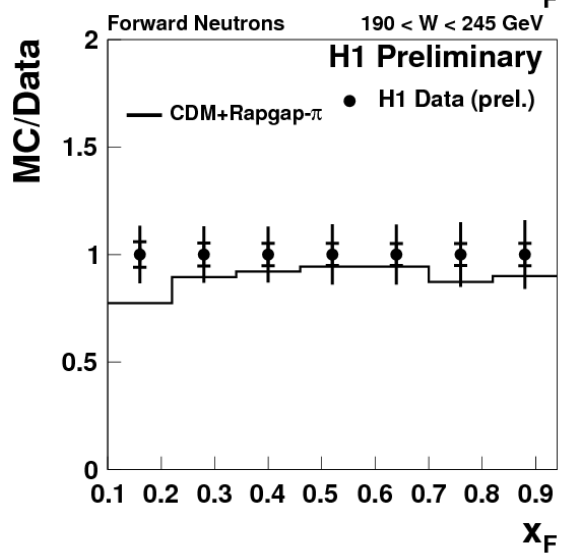
130 < W2 < 190 GeV





190 < W3 < 245 GeV

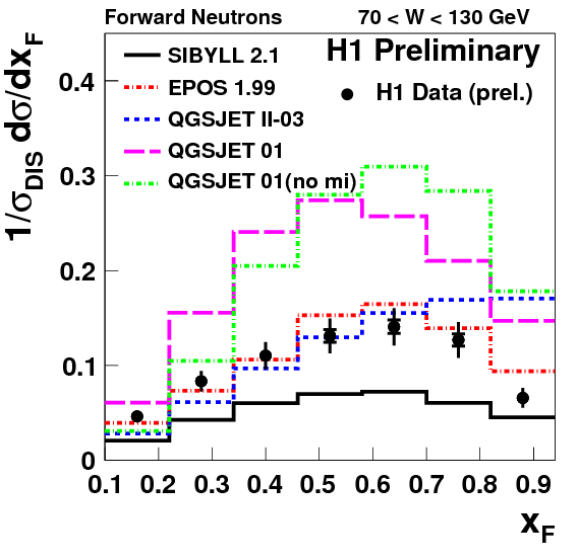


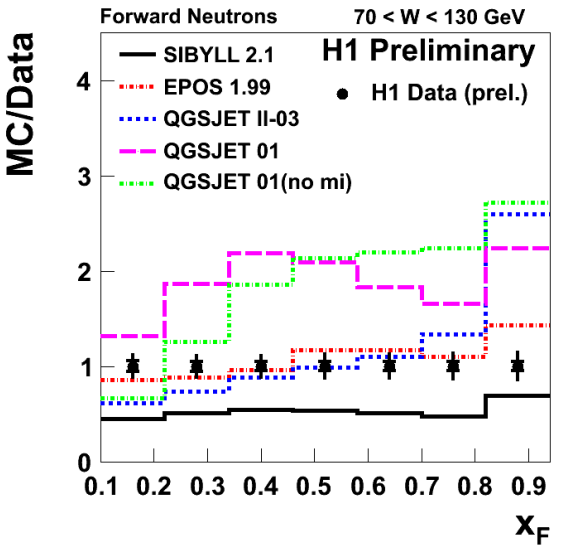


Combination of π-exchange(Rapgap) and 'standard' (CDM) fragmentation models (1.56*CDM+0.68*RAPGAP) describe the data well.

Forward neutrons cross sections vs x_F (CR)

70 < W1 < 130 GeV





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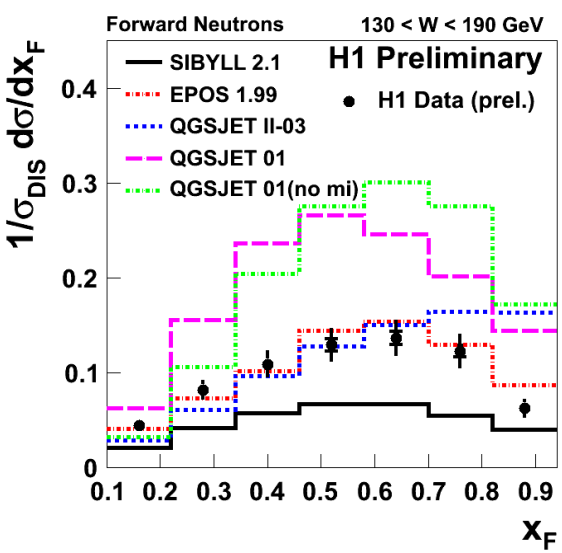

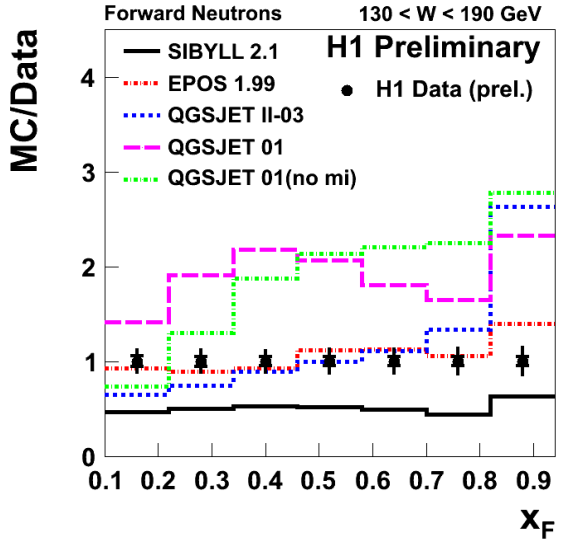

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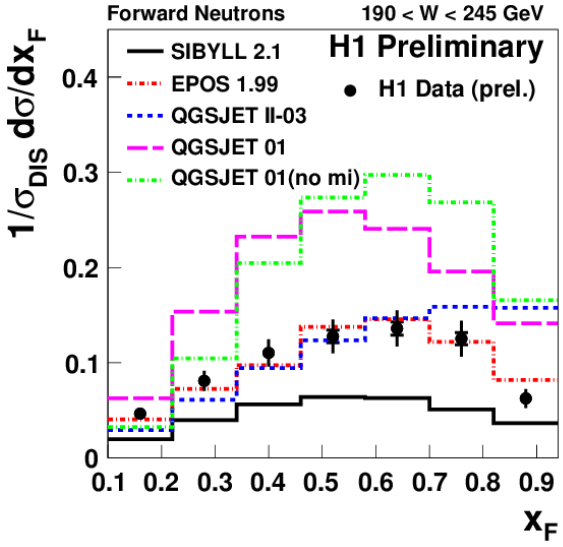
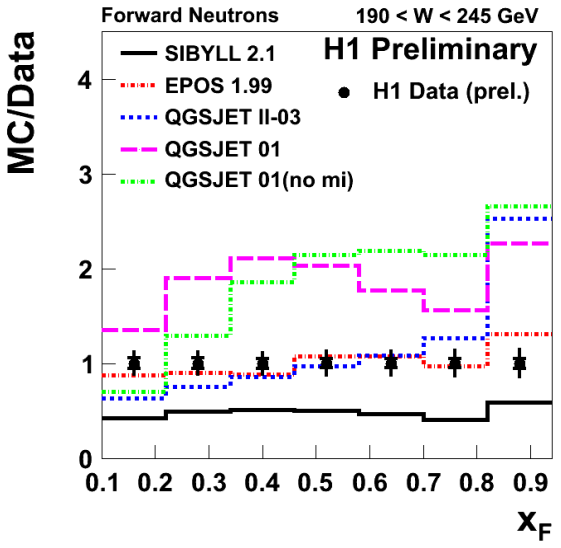
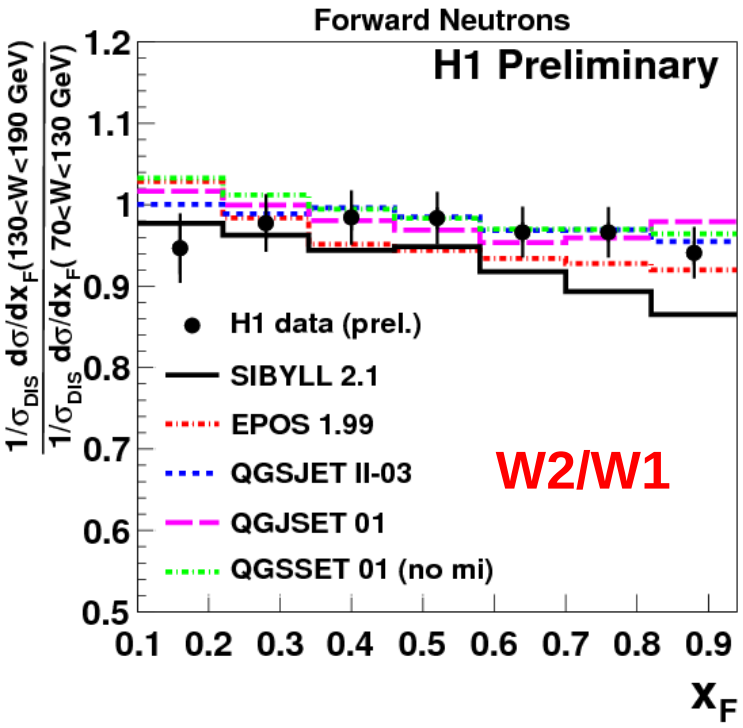


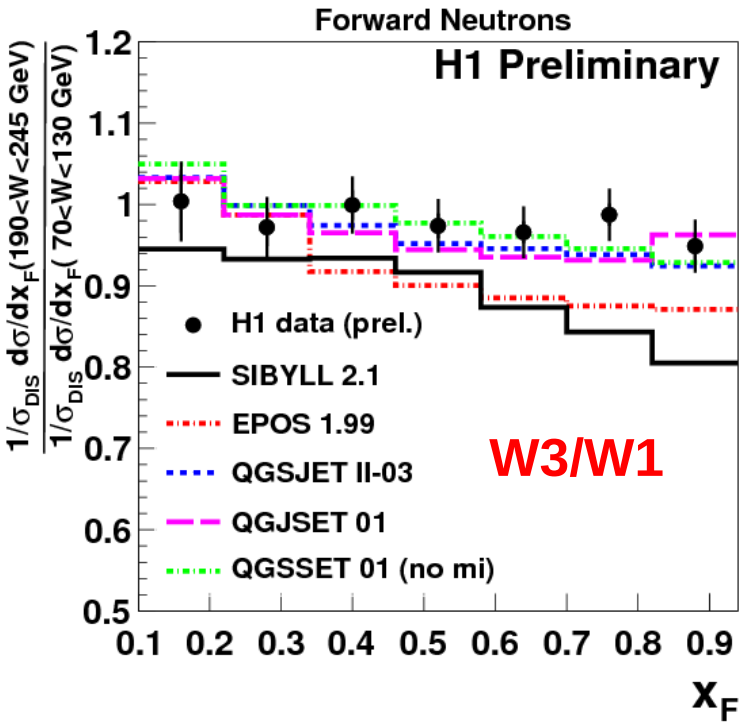


Large spread of models, EPOS gives best description of the data.

Ratios of 2-nd and 3-rd W ranges to 1-st W range

70 < W1 < 130 GeV
130 < W2 < 190 GeV
190 < W3 < 245 GeV





Data ratios are independent of x_F and consistent with unity within errors

Some of CR models show clear deviation from unity

Conclusions

- Presented measurements of very forward photon and neutrons production in DIS.
- Measurements show sensitivity to proton fragmentation models.
  ==> Useful input for MC model tuning.

Forward Photons:

- All models predict significantly higher yield of photons compared to the data
- LEPTO describe the shape of the data.
- CDM predicts harder x_F spectra
- CR models are closer to the data in normalisation.

Forward Neutrons:

- No model describes the data well
- Combination of standard fragmentation and π-exchange models describes x_F spectra well.

These measurements:

- Support the Limiting Fragmentation Hypothesis.
- Consistent with Feynman Scaling.