

Particle Production at HERA

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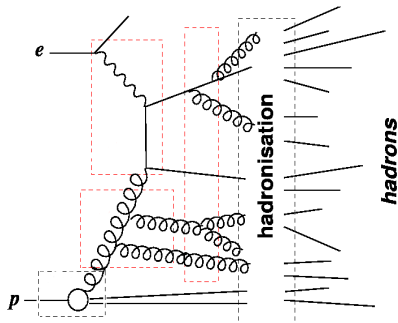
on behalf of the H1 and ZEUS collaborations

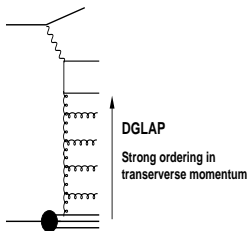
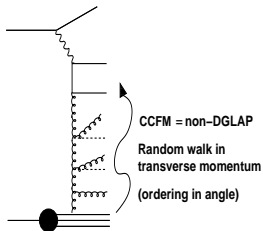
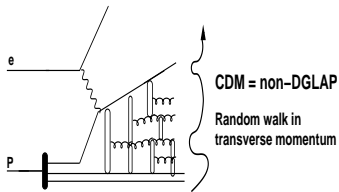
ICHEP 2012, Melbourne
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Outline

- **Parton dynamics**
 - Transverse momentum spectra
- **Hadronisation**
 - Fragmentation function
 - Production of forward photons
- **Summary**

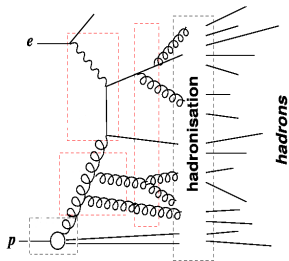


Models for ep scatteringRAPGAP
DGLAPCASCADE
CCFMDJANGO
CDM (Colour Dipole Model)

LO ME		
+		
PS(DGLAP)	PS(CCFM)	Dipole(BFKL-like)
+		
String fragmentation		

Fragmentation parameters tuned to e^+e^- data (ALEPH tune)

Transverse momentum spectra of charged particles



Low p_T region:

hadronisation is expected to play a role.

Small sensitivity to different parton dynamic models.

Hadrons at large p_T :

disfavoured by the strong p_T ordering \rightarrow

difference between different parton dynamics

Observable:

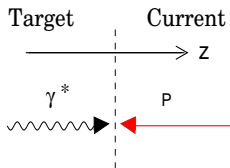
Event normalised charged particle distribution: $\frac{1}{N_{event}} \frac{dn}{dp_T^*}$

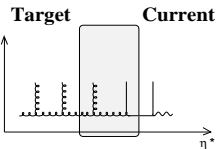
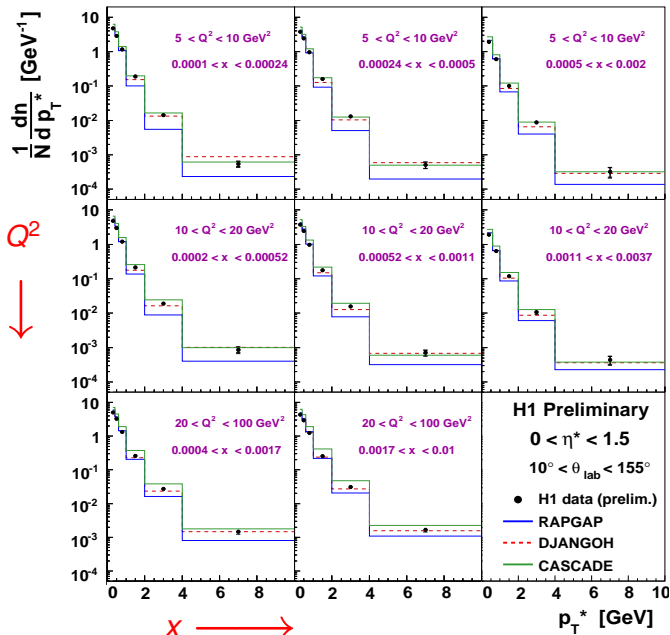
Motivation:

- Low- x dynamic is challenging
- Semi-inclusive measurements
 $ep \rightarrow e' hX$ can potentially discriminate between DGLAP and beyond-DGLAP

H1 preliminary results (H1prelim-11-035):

- $5 < Q^2 < 100 \text{ GeV}^2$, $10^{-4} < x < 10^{-2}$
- Measurements are performed in hadronic centre-of-mass system (p_T^* , η^*)

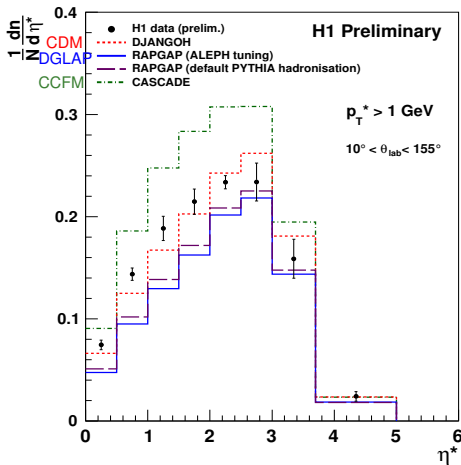


p_T^* distribution

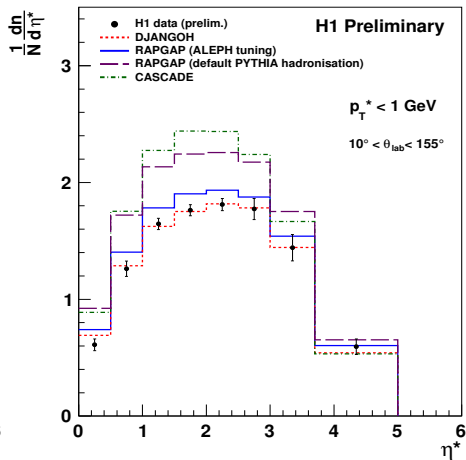
DJANGO(CDM)
describes the data for
whole p_T^* spectra

strong deviation from
RAGAP(DGLAP) at
low x and Q^2

CASCADE(CCFM)
describes the data at
high p_T^*

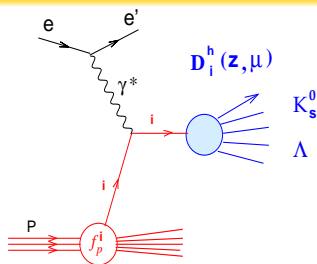
η^* - distributionsCharged particles with $p_T^* > 1$ GeV:

Strong sensitivity to parton dynamics

Charged particles with $p_T^* < 1$ GeV:

Strong sensitivity to hadronisation

Hadron production

Fragmentation function (FF) for K_s^0 and Λ 

$$\frac{d\sigma}{dx_p} = f(x, Q^2) \otimes \hat{\sigma}(Q^2) \otimes D(z, Q^2)$$

Observable:

$$x_p \equiv \frac{|\vec{p}_h|}{p_{max}} = \frac{p_h}{Q/2} \text{ (Breit frame)}$$

$$\frac{1}{N_{event}} \frac{dn}{dx_p}$$

NLO QCD calculations \otimes FF:

AKK+CYCLOPS: FFs from fits to e^+e^- data

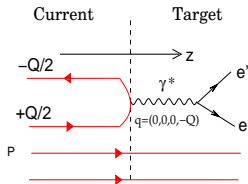
DSS: FFs from fits to e^+e^- , ep and pp data

Motivation:

- Scaling violations in fragmentation functions
- Universality of fragmentation function
- Test NLO QCD calculations and universality of factorisation theorem

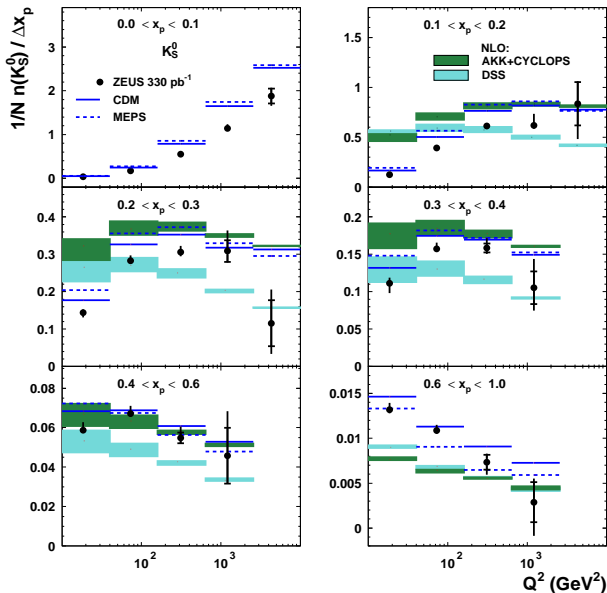
ZEUS JHEP 03 (2012) 020

- $10 < Q^2 < 40000 \text{ GeV}^2$, $0.001 < x < 0.75$
- Measurements are performed in current region of Breit frame (similarity with e^+e^-)



Scaled momentum distributions: K_S^0

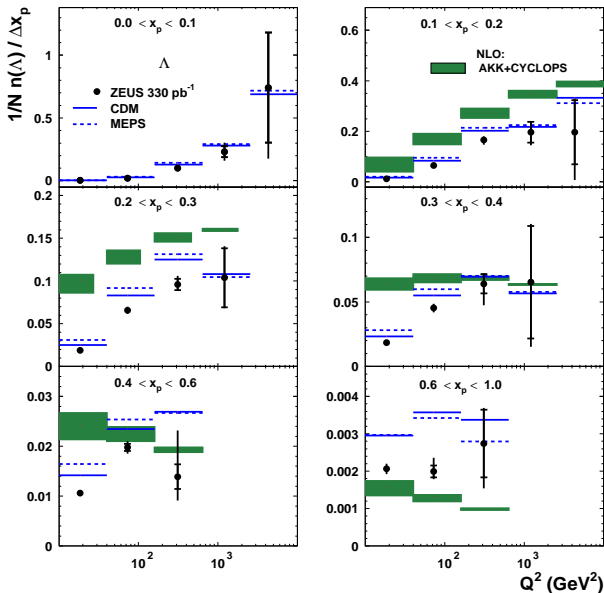
ZEUS



- **Scaling violations:** Q increases \rightarrow more soft gluon radiation \rightarrow more particles with low x_p
- ARIADNE (CDM) and LEPTO (MEPS) describe the data in most parts of phase space
- QCD NLO predictions fail to describe the data
- Data can be used for further FF fit

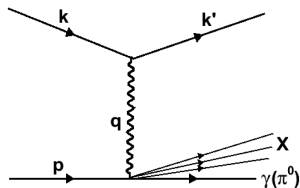
Scaled momentum distributions: Λ

ZEUS



- Scaling violations are observed
- ARIADNE (CDM) and LEPTO (MEPS) describe the data in most parts of phase space.
- QCD NLO predictions does not describe the data
- Data can be used for further FF fit

Production of very forward photon in DIS



Main source: $\pi^0 \rightarrow \gamma\gamma$

Observable:

Normalised differential cross sections
for leading forward photon :

$$\frac{1}{\sigma_{\text{DIS}}} \frac{d\sigma}{dx_L^{\text{lead}}}$$

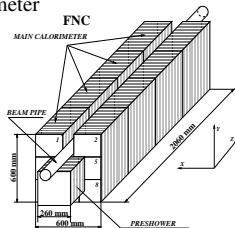
Motivation:

- Understanding the proton fragmentation
- Testing the hypothesis of limiting fragmentation
- Models tuning, in particular for hadron interaction
Cosmic Ray models

H1 Eur. Phys. J.C71 (2011) 1771

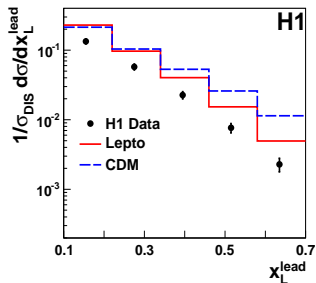
- $6 < Q^2 < 100 \text{ GeV}^2$, $0.05 < y < 0.6$
- $\eta_\gamma > 7.9$, $x_L = E_\gamma / E_p > 0.1$
- γ is detected in e/m part of Forward Neutron

Calorimeter

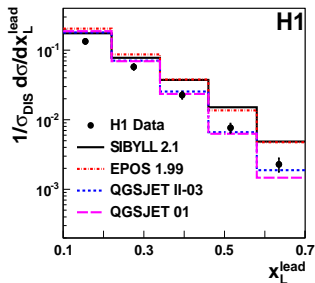


Production of very forward photon in DIS

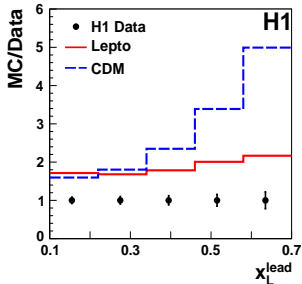
Forward Photons



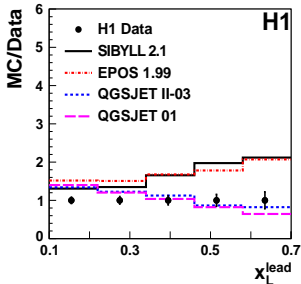
Forward Photons



Forward Photons



Forward Photons

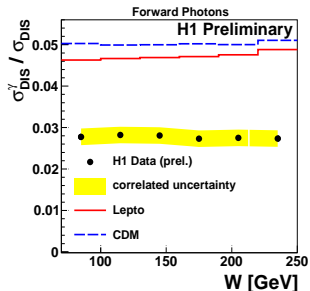
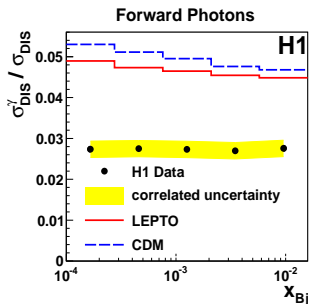
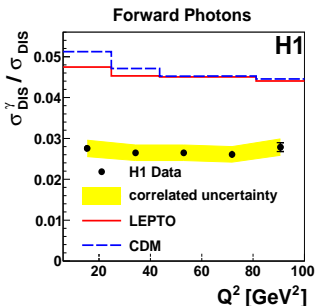


- Both CDM and LEPTO models are significantly higher than data
- QGSJET models have steeper behavior than the data, close to data in absolute values except at low x_L
- Similar behavior observed for p_T^{lead}

Fraction of DIS events with forward photons

Test of limiting fragmentation hypothesis (forward particle production insensitive to Q^2 , x_{Bj} and W)

H1prelim-12-111



→ proton remnant does not "feel" the hard interaction

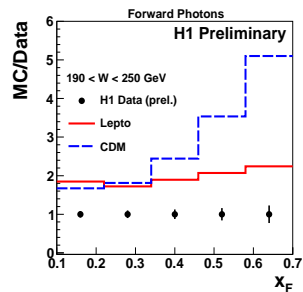
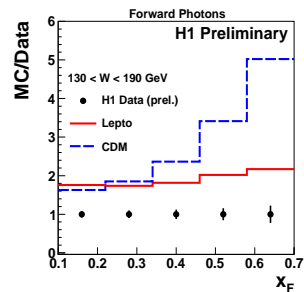
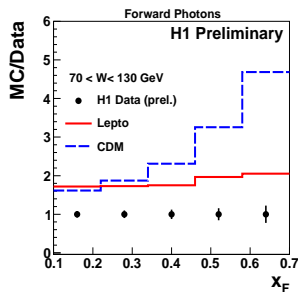
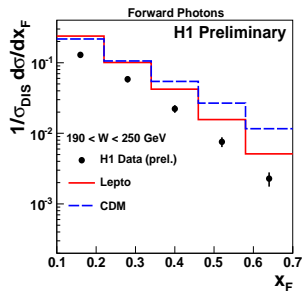
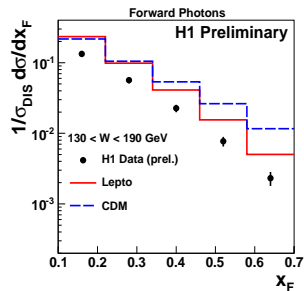
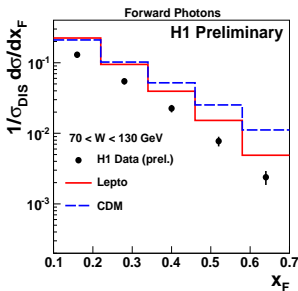
Data support the hypothesis of limiting fragmentation.

Summary

- Parton dynamic
 - CDM is the best in description of charged particle spectra
 - DGLAP is below the data for low x and large p_T of charged particles
- Hadronisation
 - Fragmentation function for K_S^0 and Λ :
 - Scaled momentum distributions show the scaling violation
 - NLO QCD calculations fail to describe the data
 - Measurements can be used for further FF fit
 - Forward photon:
 - Models predict higher yield of photons than data
 - Data support the hypothesis of limiting fragmentation

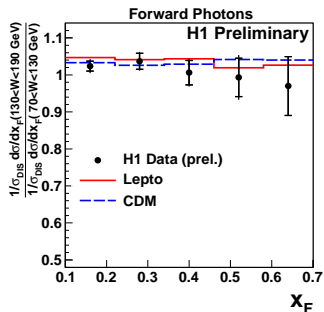
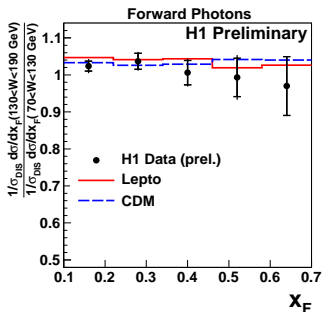
Back up slides

Forward photons production in DIS (H1prelim-12-11)



Forward photons production in DIS (H1prelim-12-111)

Ratios of normalised cross sections of forward photons production in DIS corresponding to two different W intervals:



→ Data support Feynman scaling