Forward Jet Production in DIS

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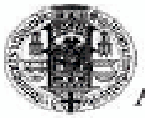
On behalf of the ZEUS Collaboration



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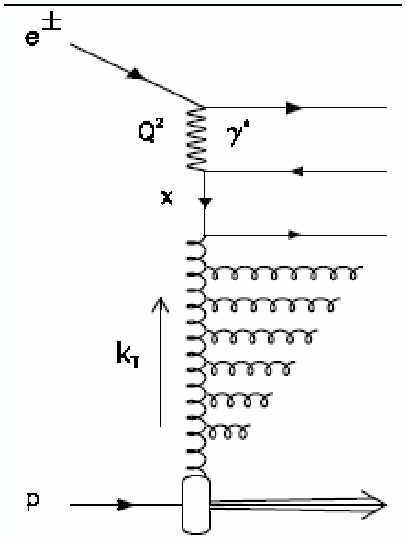
OUTLINE:

- ❑ QCD Dynamics at Low *x*
- ❑ MC Modes and QCD Calculations
- ❑ Inclusive Forward Jet Measurement with ZEUS data 95-97
- ❑ Inclusive Forward Jet Measurement with ZEUS data 98-2000
- ❑ Conclusions

QCD Dynamics at Low *x*

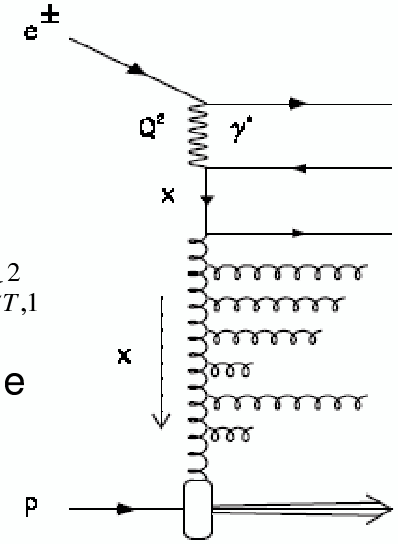


DGLAP

Evolution & resummation in powers of *lnQ2*

$$Q^2 >> k^2_{T,n} >> \ldots >> k^2_{T,2} >> k^2_{T,1}$$

The DGLAP gluon cascade is strongly ordered in k_T and ordered in *x*



BFKL

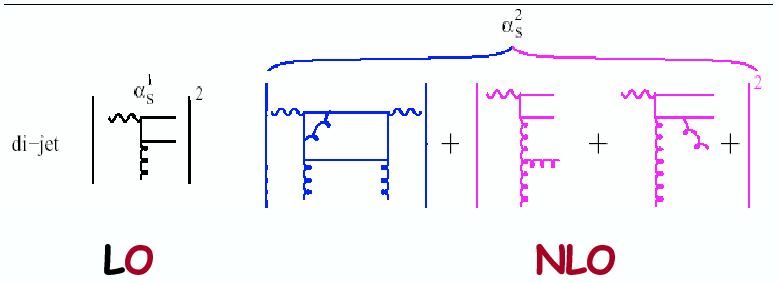
Evolution & resummation in powers of *ln(1/x)*

$$x_1 >> x_2 >> \ldots >> x_n >> x$$

The BFKL is only strongly ordered in *x*

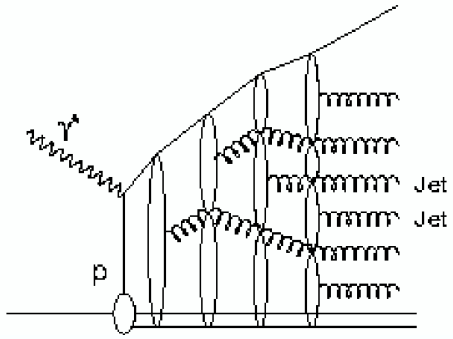
- **DGLAP** (**D**okshitzer-**G**ribov-**L**ipatov-**A**ltarelli-**P**arisi) is expected to break down at low *x* and Q^2 region
- **BFKL** (**B**alitsky-**F**adin-**K**uraev-**L**ipatov) can be applicable at low x
- **CCFM** (**C**iafaloni-**C**atani-**F**iorani-**M**archesini) describes an evolution in both Q^2 and *x* and approches BFKL at low *x* and DGLAP at high Q^2; angular ordering

MC Models and QCD Calculations



- DISENT: Fixed order QCD partonic cross section, on mass shell ME + DGLAP

- LEPTO: LO ME+PS , (DGLAP)
  - Strong ordering in k_T



- ARIADNE: LO, an implementation of Color Dipole Model (CDM)
  - Independently radiating dipoles formed by quarks and emitted gluons
  - Random walk in k_T like in BFKL

- CASCADE: LO off mass shell ME + parton shower based on k_T factorized CCFM evolution model
  - Angular ordering in parton emission
  - Unintegrated gluon densities fits *J2003 set 1* (with new treatment of soft region) and *J2003 set 2* (fit form includes non singular terms)

Inclusive Forward Jet Measurements

DIS kinematical range

95-97 Data, L≅38 pb^{-1}

$Q^2 > 25$ GeV^2

No restriction

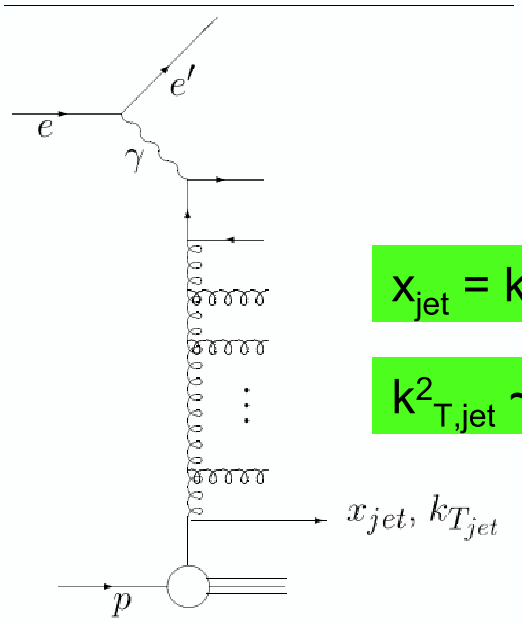
$y > 0.04$

98-00 Data, L≅ 82 pb^{-1}

$20 < Q^2 < 100$ GeV^2

$0.0004 < x_{Bj} < 0.005$

$0.04 < y < 0.7$



$x_{jet} = k_{z,jet}/p >> x_{Bj}$

$k^2_{T,jet} \sim Q^2$

Forward Jet selection

Jet finding with inclusive K_T algorithm in Lab frame

$E_{T,jet} > 6$ GeV

No restriction

$0.5 < E^2_{T,jet}/Q^2 < 2$

$0 < \eta^{jet} < 3$

$\cos\gamma_{had} < 0$ suppresses QPM

Jet finding with inclusive K_T algorithm in Breit frame

$E_{T,jet} > 5$ GeV

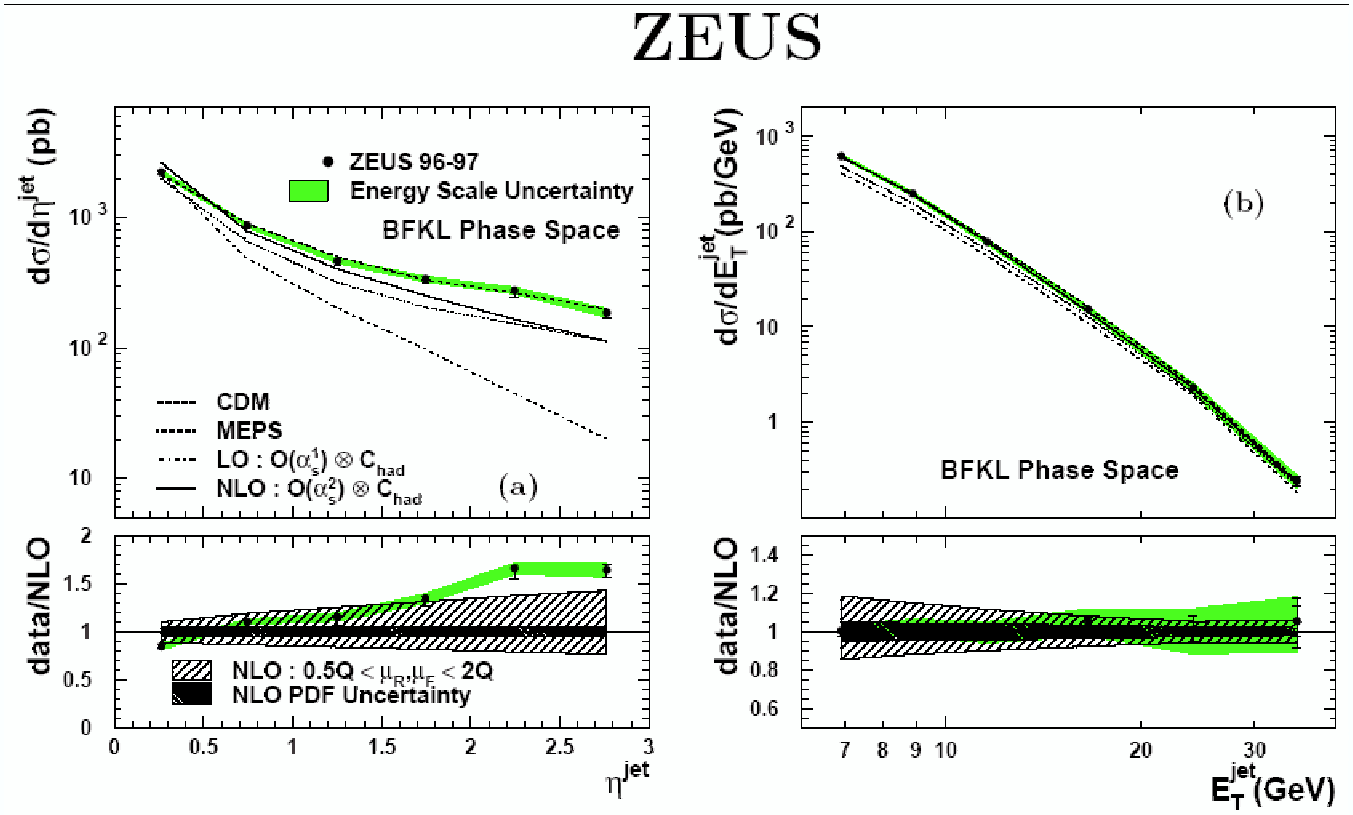
$x_{jet} > 0.036$

$0.5 < E^2_{T,jet}/Q^2 < 2$

$2 < \eta^{jet} < 3.5$

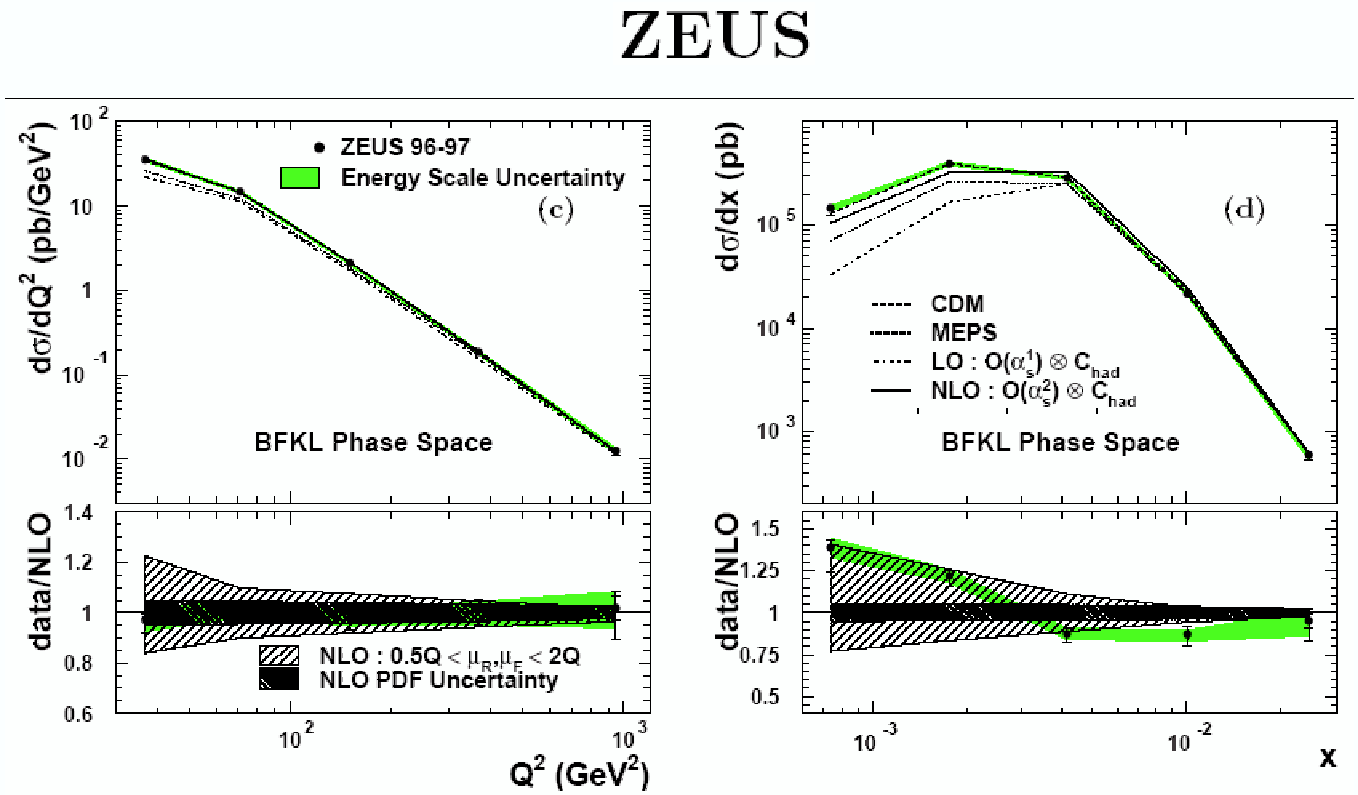
- Jet carries a large fraction of longitudinal momentum of proton in order to maximise phase space for BFKL evolution
- DGLAP type of evolution is suppressed, leaving no room for strong ordering in transverse momenta

Inclusive Forward Jet Measurement (DESY-05-017)



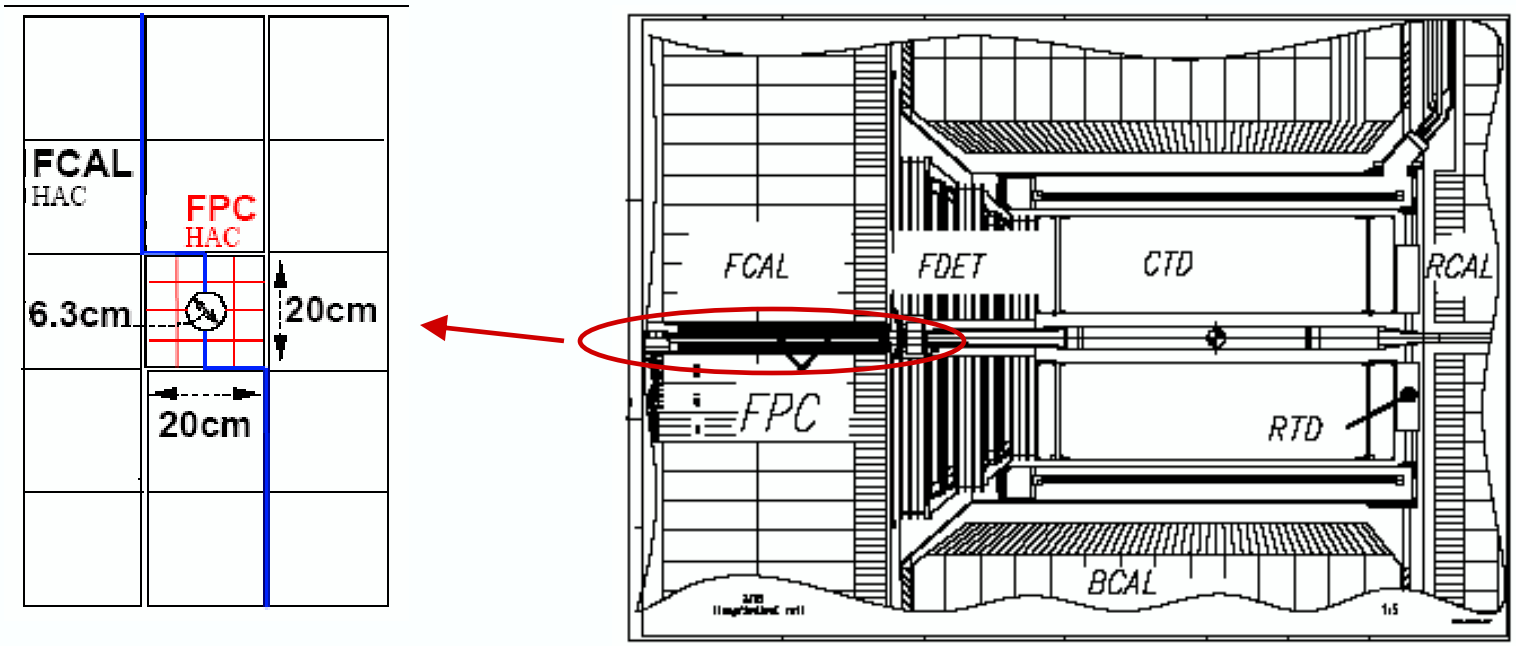
- NLO predictions lower than data at low x_{Bj} but still within theoretical uncertainties. Gives a good description of Q^2 and E_T^{jet} dependences
- Discrepancy between data and NLO in the forward region $1.5 < \eta^{jet} < 3$; this region is more sensitive to higher order radiations (estimation of uncertainty from higher orders is large)

Inclusive Forward Jet Measurement (DESY-05-017)



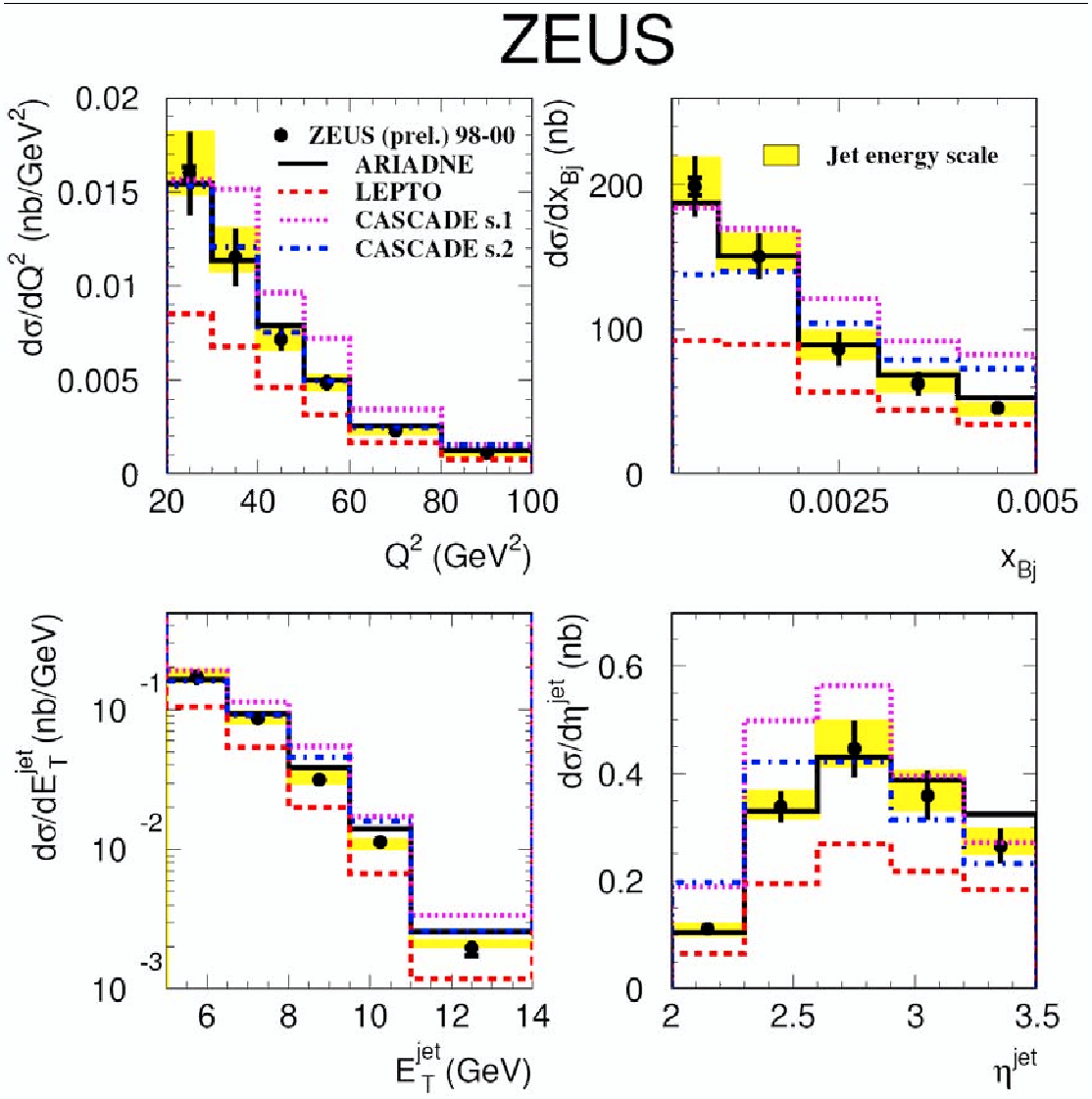
- CDM describes all measured cross sections
- ME+PS:LEPTO (DGLAP) fails for η^{jet} and for low x_{Bj} and Q^2

Forward Jet Measurement with Forward Plug Calorimeter (FPC)



- Forward Plug Calorimeter in the *20 x 20 cm²* beam hole of FCAL for 98-2000
- Lead-scintillator sandwich with 60 EMC and 16 HAC cells
- Extend calorimeter acceptance by about 1 unit in pseudorapidity to $\eta \leq 5$

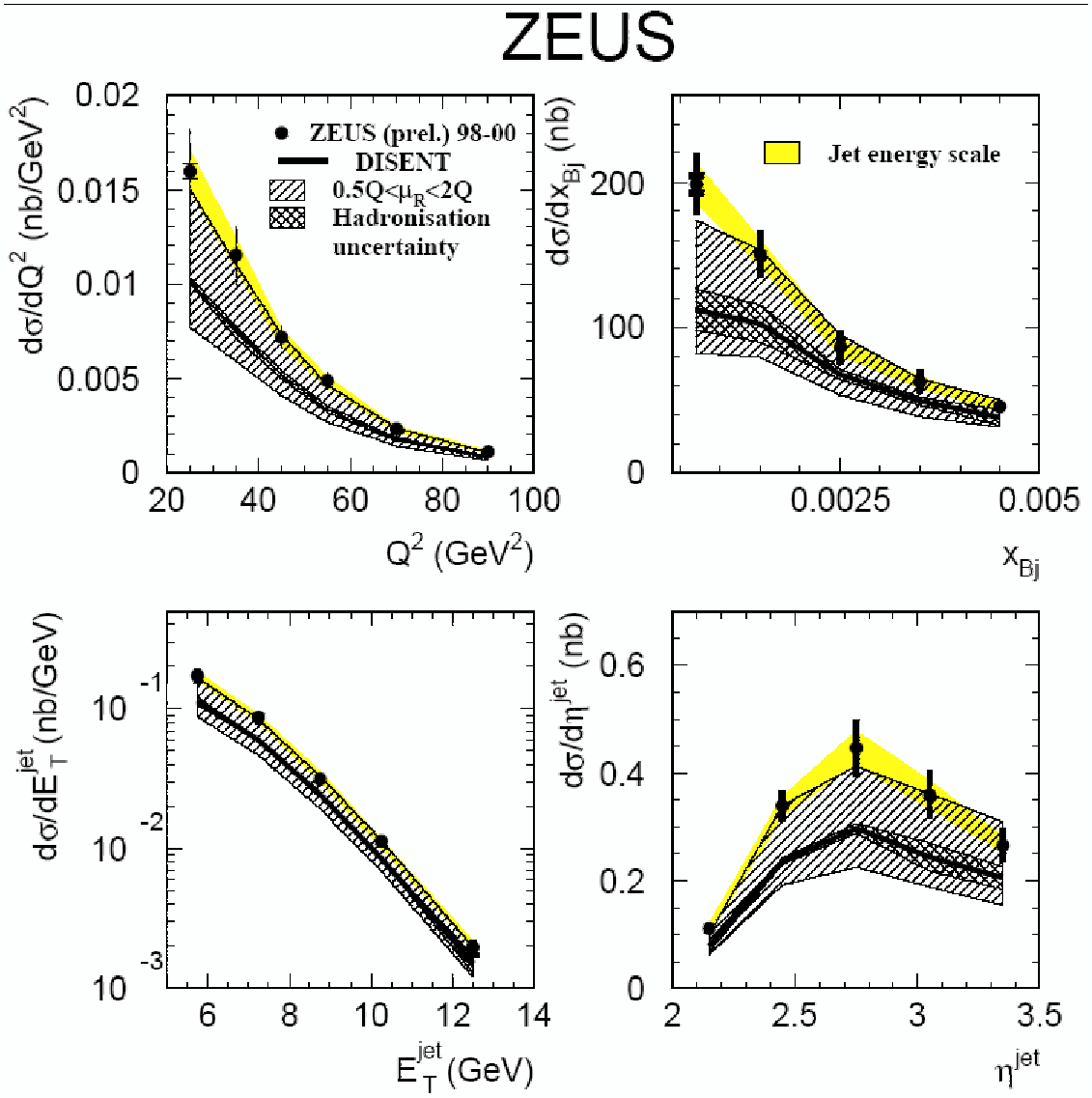
Inclusive Forward Jet Measurement



Measurement extended to $2<\eta^{jet}<3.5$

- CASCADE *set1* disagrees with all cross sections
- CASCADE *set2* is in a good agreement with data in Q^2 and E_T^{jet} but fails to reproduce the shapes of x_{Bj} and η^{jet}
- CDM (ARIADNE) gives a good description of data in all measured cross sections
- LEPTO underestimates data by a factor of 2

Inclusive Forward Jet Measurement



- Average hadronisation correction obtained with LEPTO and ARIADNE
- Proton PDF CTEQ5D
- NLO predictions lower than data but within theoretical uncertainties (except very low x_{Bj})
- Theory has too large uncertainty
- No disagreement with NLO DGLAP has been observed for forward jets

Conclusions

- Parton dynamics at low-x has been studied in forward jet production in DIS by ZEUS
- CDM (ARIADNE) gives a good description of data in all measured cross sections
- Lowest-order DGLAP calculations fail to describe forward jet cross sections
- LO CCFM-based CASCADE does not describe shapes of forward jet cross sections
- NLO calculations fail to describe data at low Bjorken-x but the agreement is good for very forward jets within theoretical uncertainties
- Large renormalisation uncertainty does not permit more detailed comparison