JET PHYSICS AT HERA.

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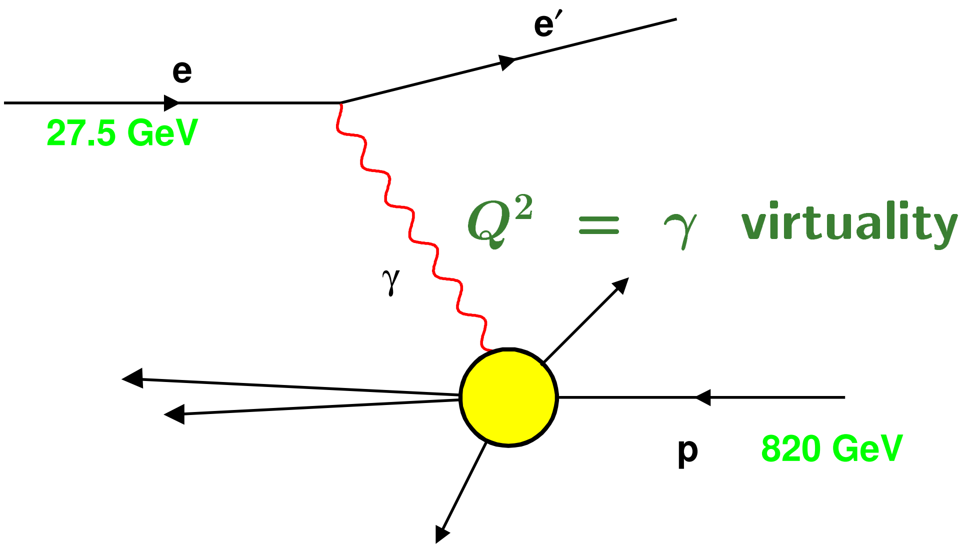
CONTENTS OF TALK

(1) Jets in Photoproduction

(2) Jets in DIS

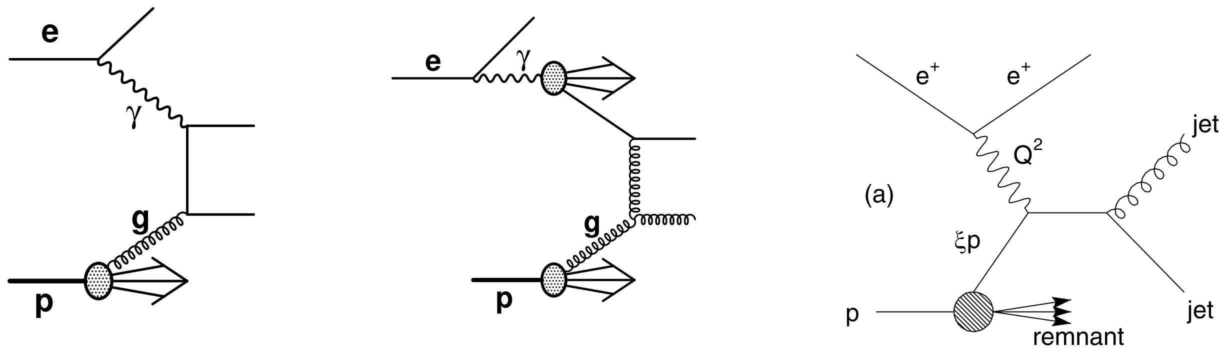
(3) Virtual photon structure

(4) Prompt photons; Multijets



$Q^2 \approx 0$ — photoproduction γp
$Q^2 \gg 0$ — Deep Inelastic Scattering (DIS)
$Q^2 = O(1$ GeV$^2)$ 'Low Q^2' transition region

Typical Diagrams



γp /DIS direct   resolved   DIS (NLO)
$\rightarrow \gamma$ structure

JETS — powerful means of studying partons in the proton and also in the photon. Test our understanding of QCD. (Various jet algorithms are used.)

Theoretical Issues

— QCD description: LO, NLO

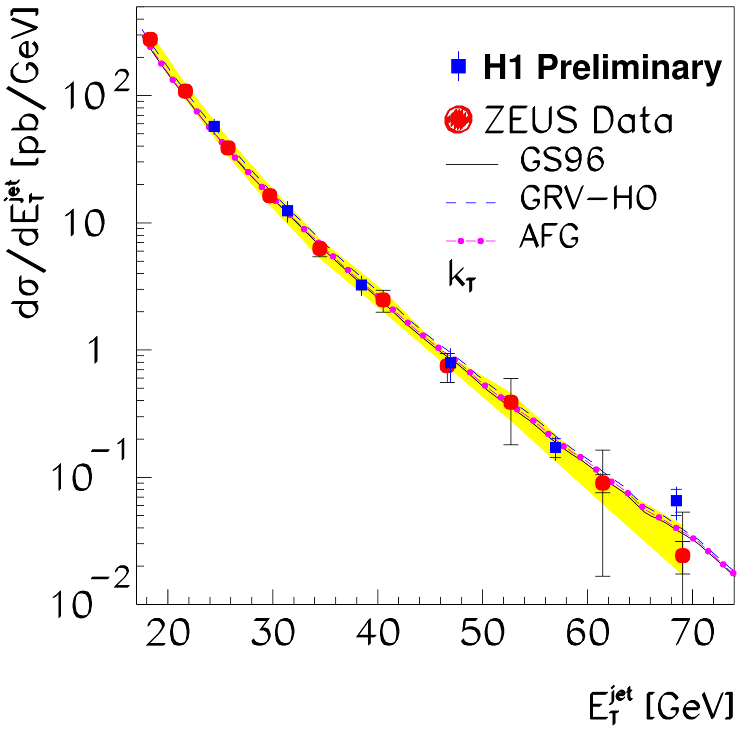
— Hadronisation effects

— Parton densities (PDF) in hadronic structure of incoming photon

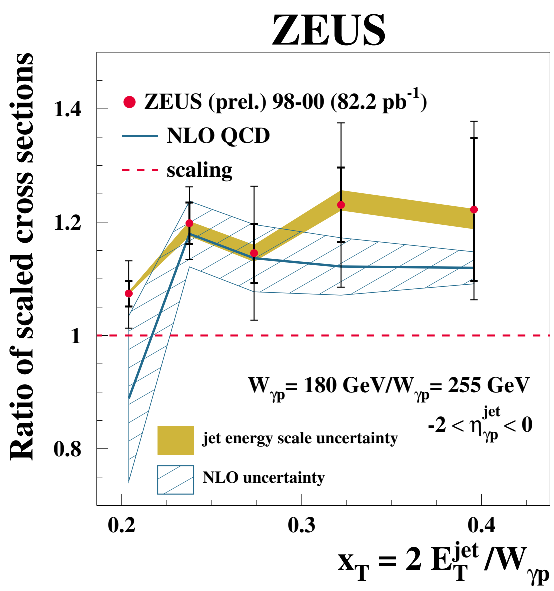
— Relevance of BFKL evolution of amplitudes with x, c.f. normal DGLAP evolution with Q^2, and CASCADE model which attempts to combine these.

INCLUSIVE JETS in PHOTOPRODUCTION

Wide range of transverse energy E_T now measurable

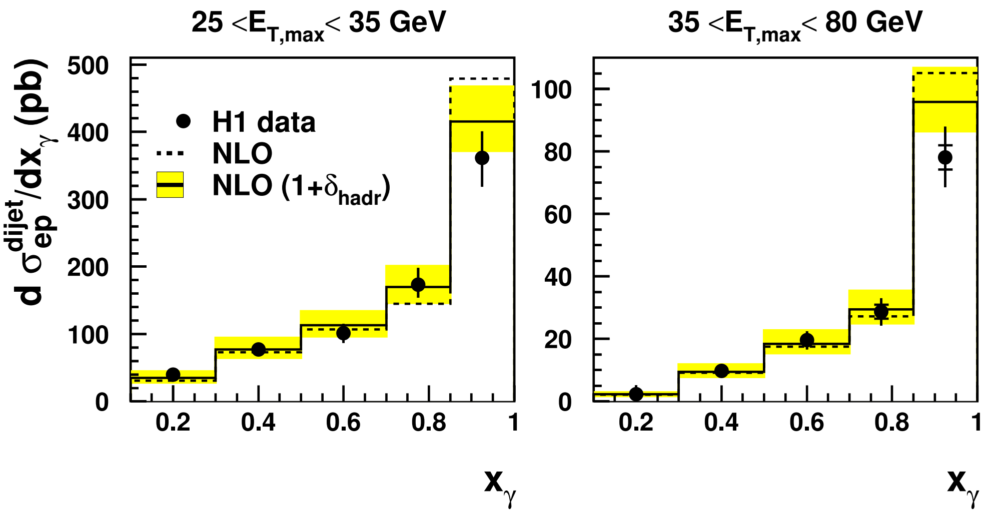


Good agreement with NLO QCD (Frixione & Ridolfi) using standard photon structure PDFs.



Scaling Violations in Jet photoproduction
Xsec varying with $W = \gamma p$ energy.
NLO QCD effect.

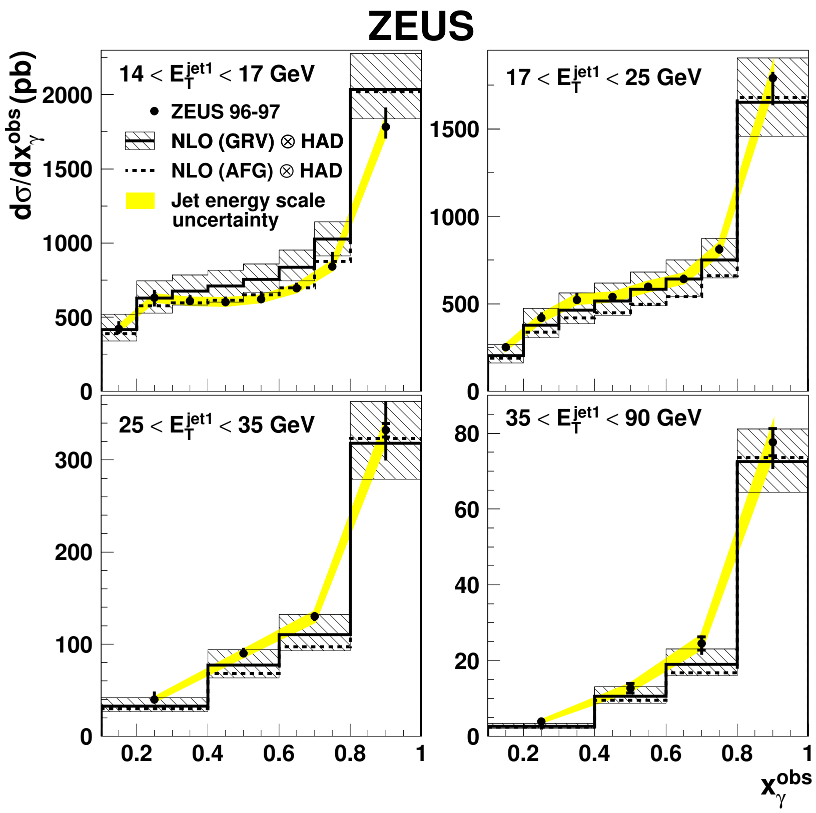
DIJETS IN PHOTOPRODUCTION



$x_\gamma \approx 1$ peak = entire photon couples to $q\bar{q}$ pair
= **direct** process,

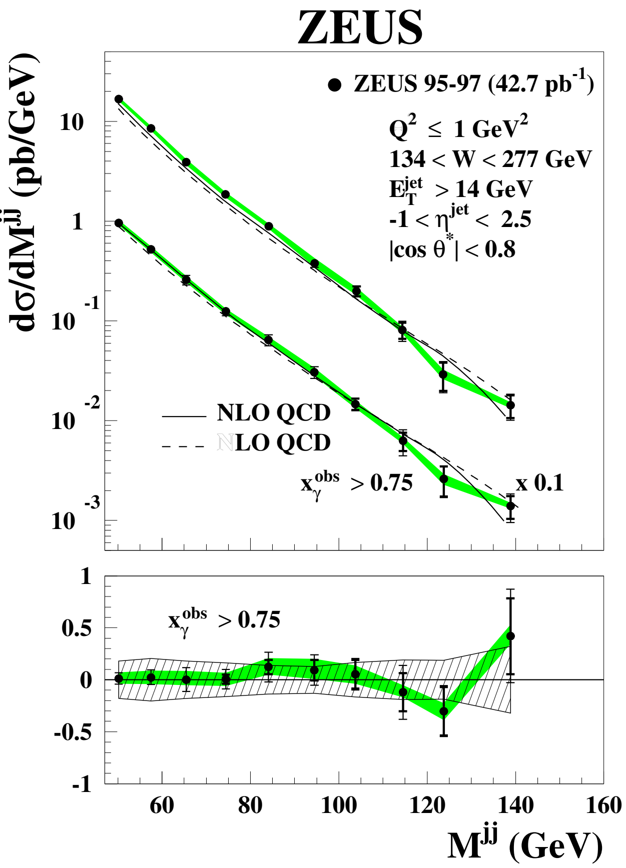
Lower distribution = **resolved** process (partons in photon)

Good description at NLO. GRV-HO photon PDF is OK.

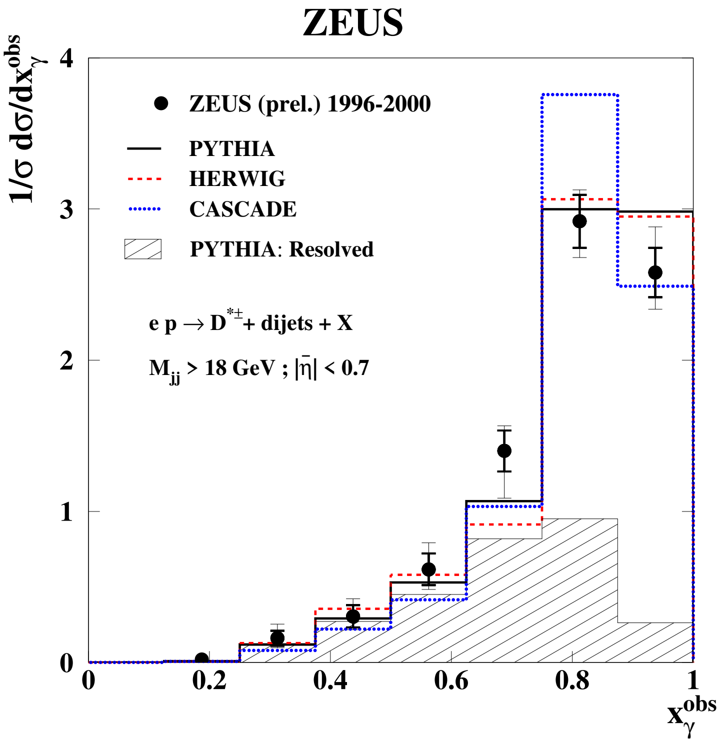


Similar - but NLO theory + GRV tends to be high at low E_T and low at high E_T. AFG better in this plot.

DIJETS IN PHOTOPRODUCTION

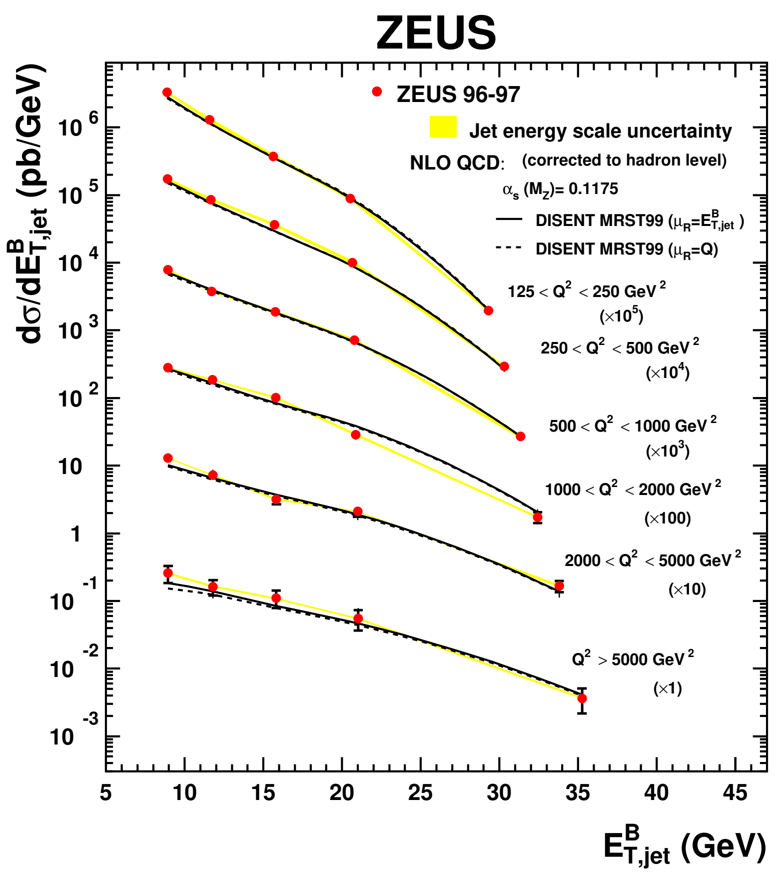


Dijet Masses
NLO QCD good
Can place limits on high-mass photoproduced objects decaying to two jets.



Charm-containing dijet events.
Event must have a D^*.
PYTHIA + GRV OK.
CASCADE less good.

INCLUSIVE JETS in DIS



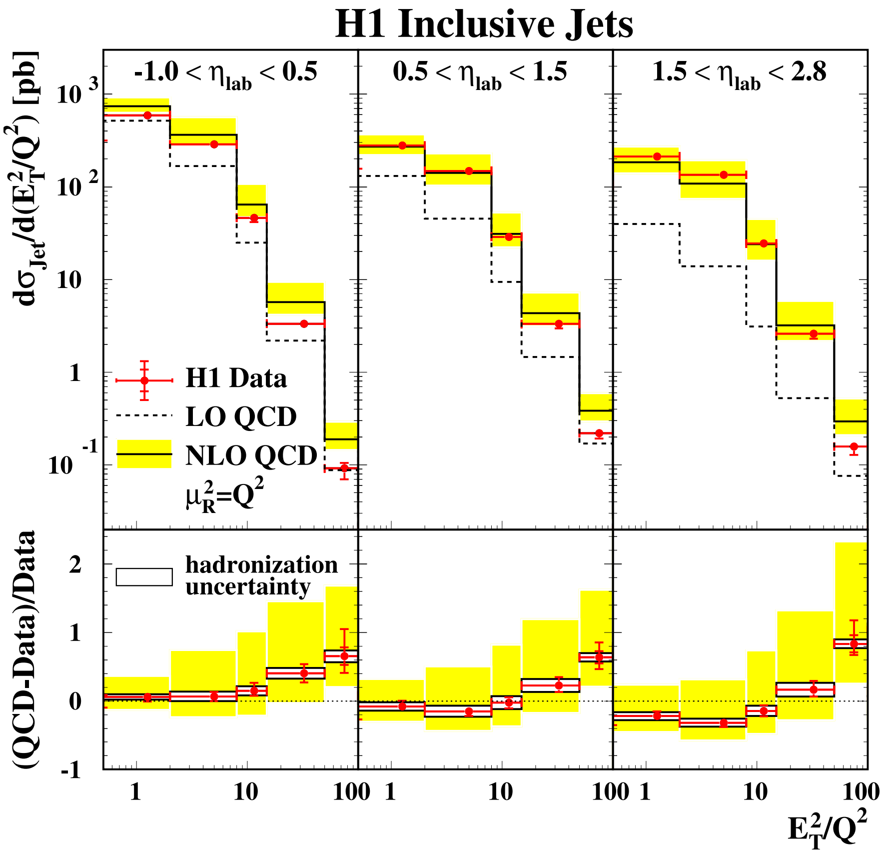
Breit frame Xsecs can exclude proton remnant effects

Well described at NLO QCD

Scaling violation evident.

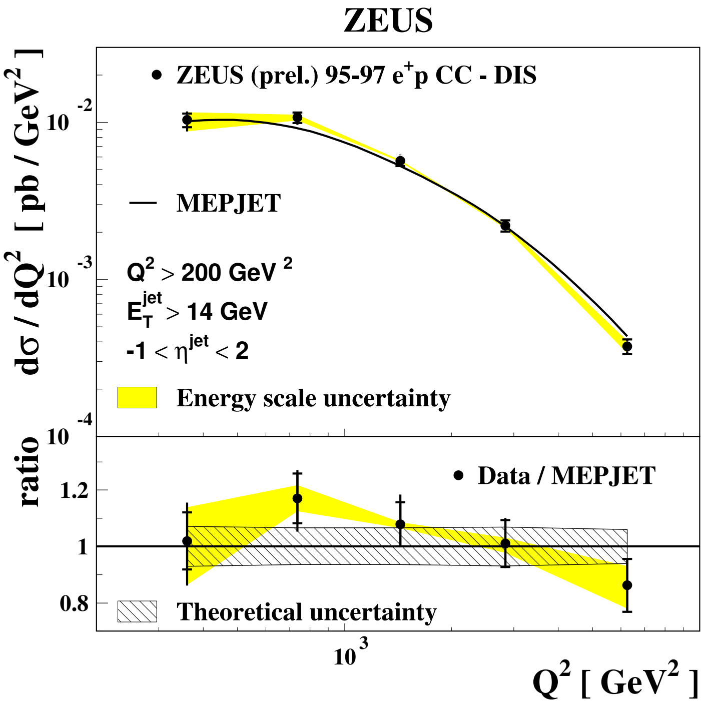
Plot against dimensionless quantity E_T^2/Q^2 .

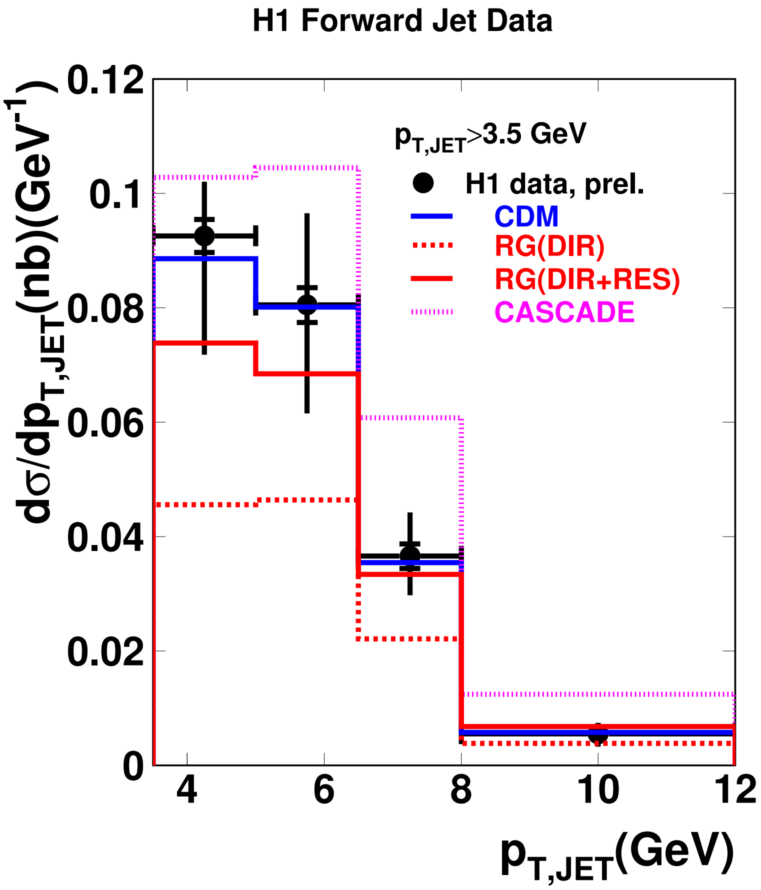
Need for NLO calculation (DISENT)



INCLUSIVE JETS in DIS

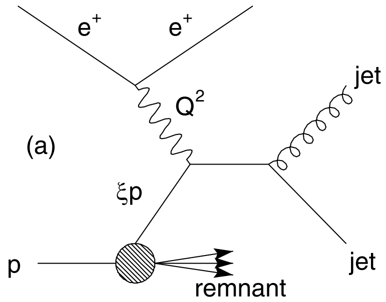
Charged current process $Q^2 > 200 \text{ GeV}^2$)
NLO (MEPJET) description 'reasonable'
H1 results similar

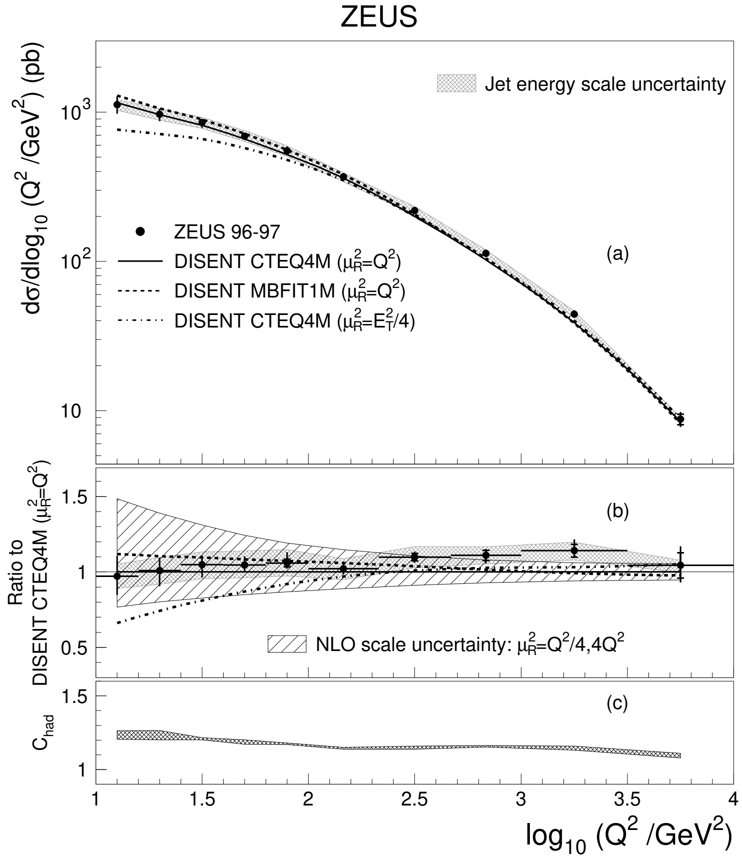




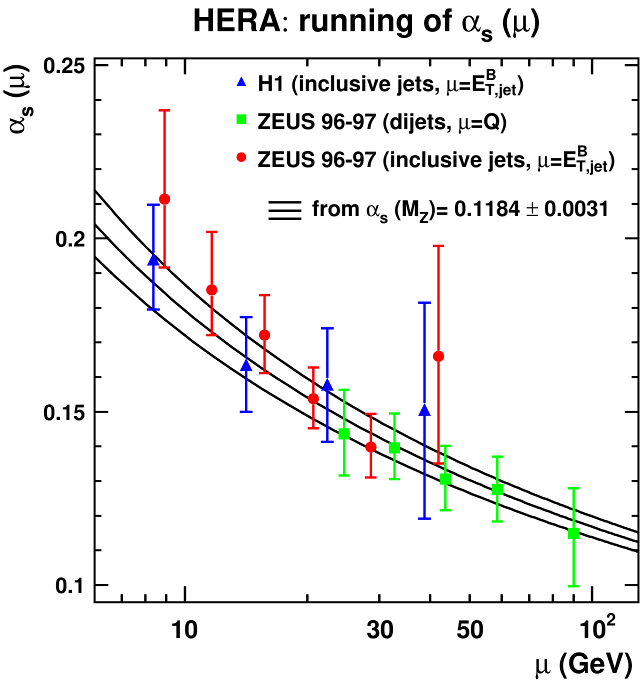
Forward jets measured in region sensitive to BFKL evolution (CASCADE) rather than DGLAP.
RAPGAP reasonable.
Colour Dipole Model best.

DIJETS in DIS





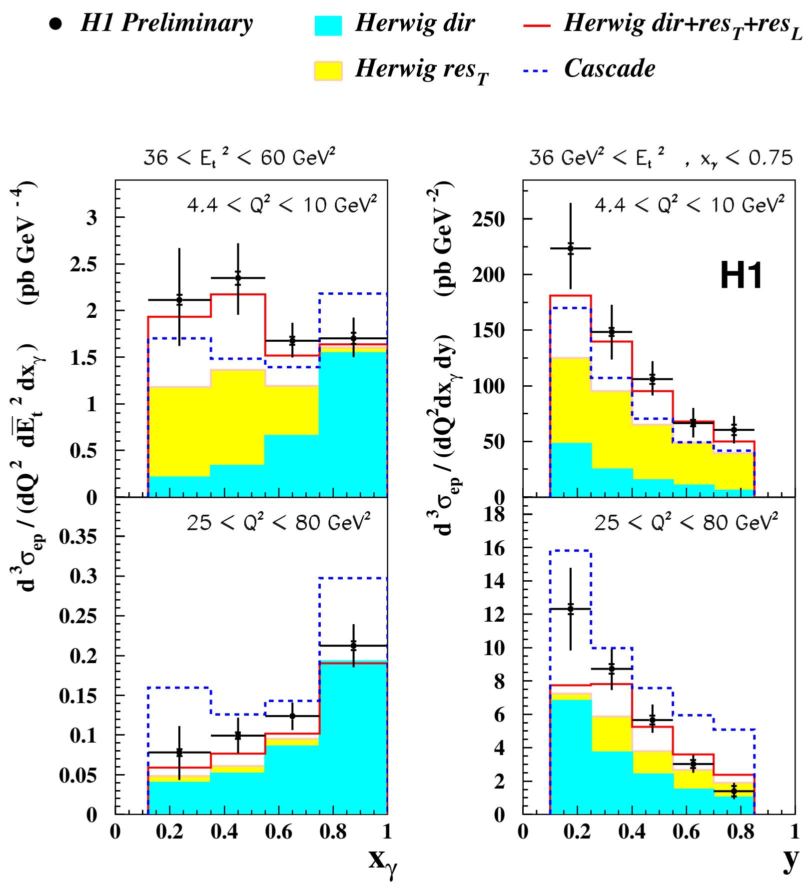
Xsecs in reasonable agreement with NLO (DISENT).
Note QCD scale uncertainties.



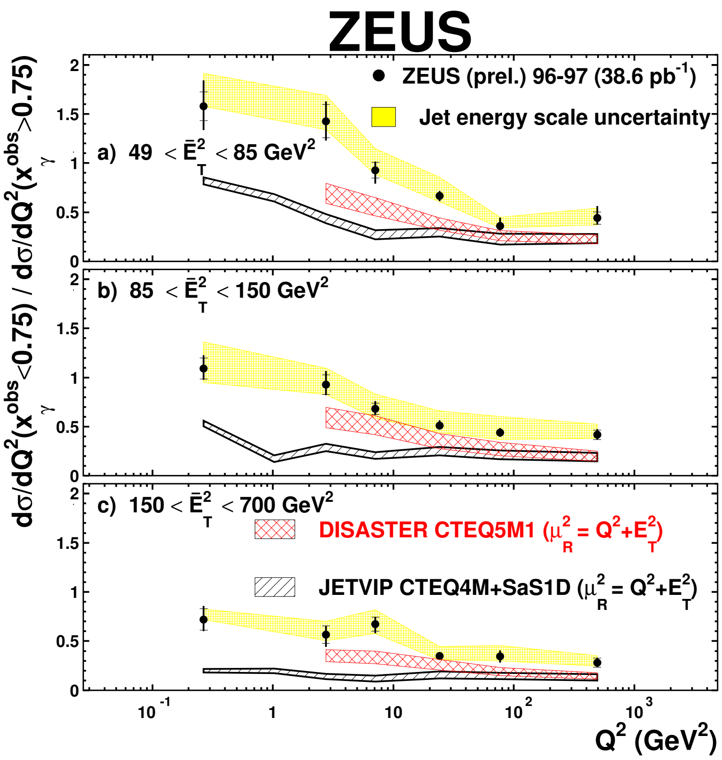
Various HERA DIS measurements sensitive to NLO and hence α_s
Plot vs scale of measurement (e.g. jet E_T): α_s runs!

$$\alpha_s(M_z) = 0.1184 \pm 0.0031$$

DIJETS AT LOW Q^2 – VIRTUAL γ STRUCTURE

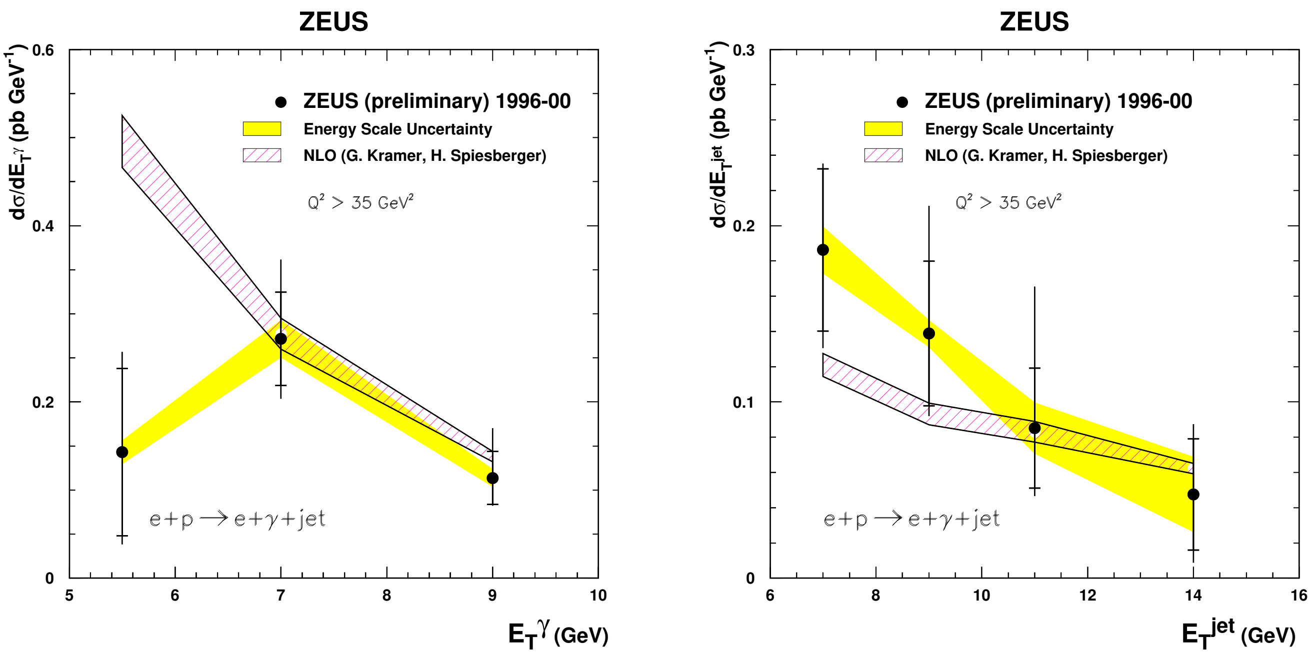


Resolved Xsec falls with Q^2
HERWIG based model ≈ OK.
CASCADE poorer.
y measures γ energy.
Q^2 = 4–10, 25–80 GeV^2. High Q^2 less well described.



$Q^2 > 1$ GeV^2
Resolved/Direct ratio vs Q^2, for different jet E_T DISASTER and JETVIP both poor.

PROMPT PHOTON + JET IN DIS

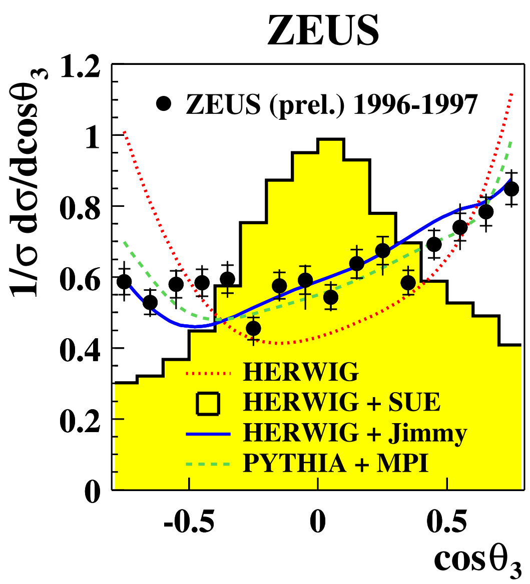


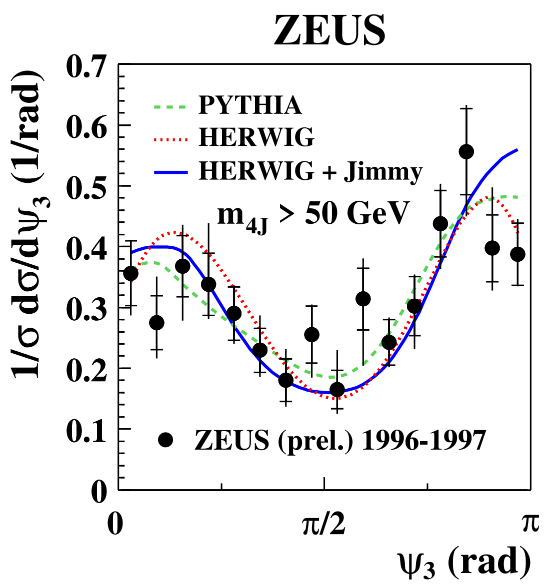
$$Q^2 > \ \textbf{35 GeV}^2; \quad E_T^{\rm jet} > 6 \ \ \textbf{GeV}, \quad E_T^{\gamma} > 5 \ \ \textbf{GeV}$$
$$-1.5 < \eta^{\rm jet} < 1.8, \quad -0.7 < \eta^{\gamma} < 0.9$$

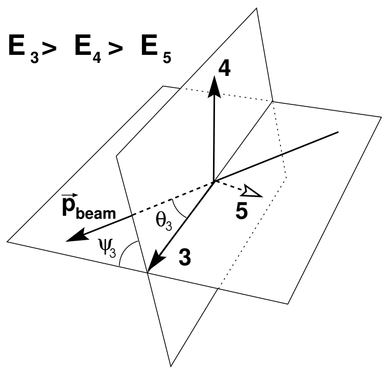
compare to NLO QCD theory of Kramer & Spiesberger.

Fair agreement within large errors.

MULTIJETS in PHOTOPRODUCTION & DIS



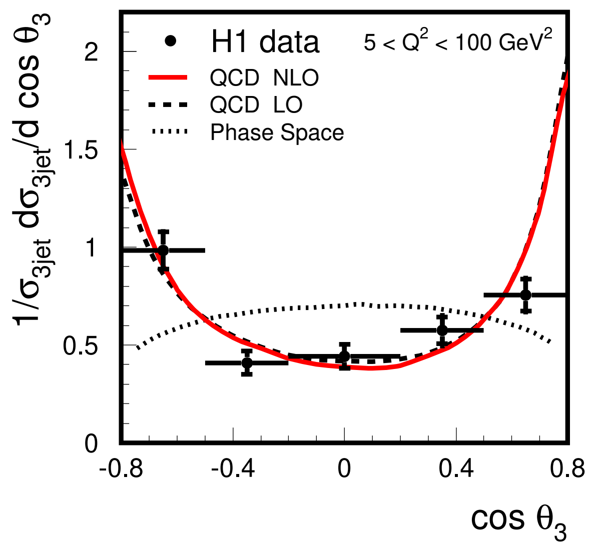


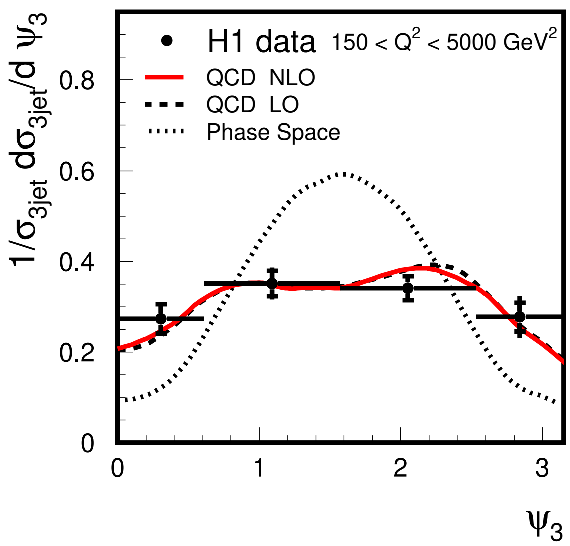


ZEUS study 4-jets in γp but merge 2 lowest- M jets to use 3-jet kinematics.

PYTHIA + MPI good at low M_{jets} .

At high M_{jets} MPI unimportant.

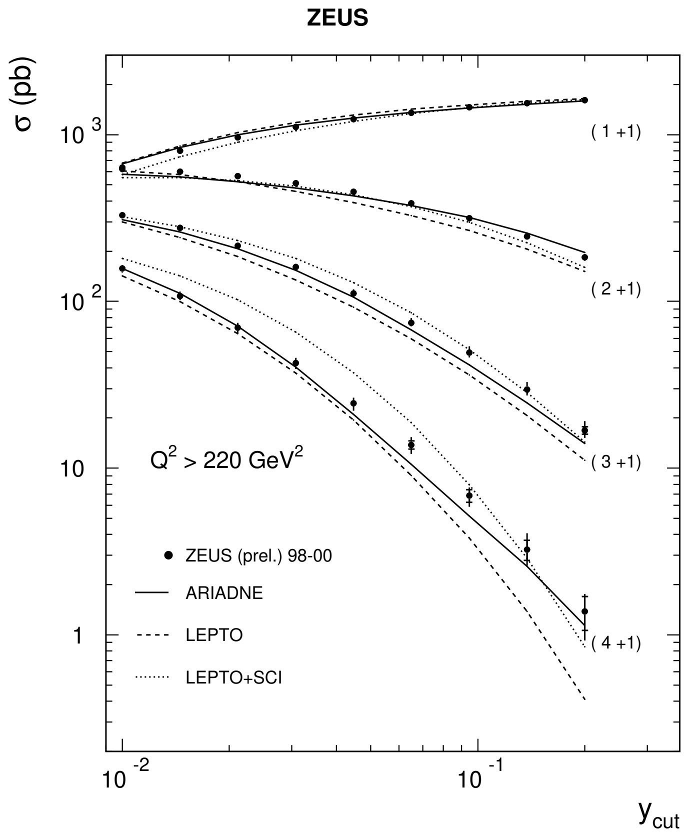




3-jet DIS results from H1 (typical plots).

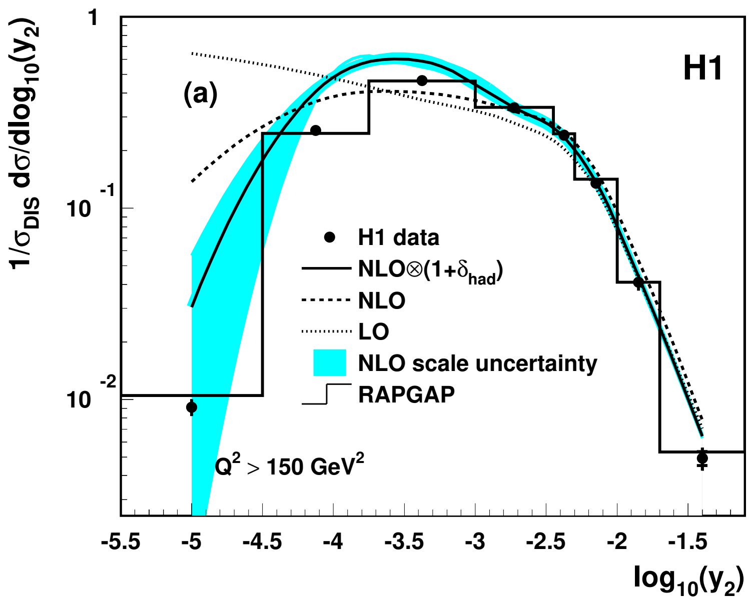
Shapes well described by LO and NLO.

MULTIJETS/DIJETS IN DIS



ZEUS plot 3-jet cross section vs y jet separation parameter

ARIADNE (Colour Dipole Model + hadronisation) OK (less good at parton level)
MEPJET:
NLO OK if corrected to hadron level.



H1 measure dijets at small separation y
RAPGAP (LO + parton showers) better than NLO.

CONCLUSIONS

HERA provides an environment in which a wide range of jet physics can be investigated.
Many results are unique to HERA.
QCD is studied from various angles.

— Jets at high E_T using suitable algorithms and cuts show no problems.

— NLO QCD usually OK $\rightarrow \alpha_s$ measurable.
In most areas QCD well modelled and verified.

— In possible BFKL region CASCADE needs improvement.

— Multiparton Interactions at low E_T only.

— Virtual γ 'structure' not well modelled yet.

— Testing more processes with a hard and a softer scale – greater challenge to theorists.