Dijet Cross Sections from Low to Highest Q^2

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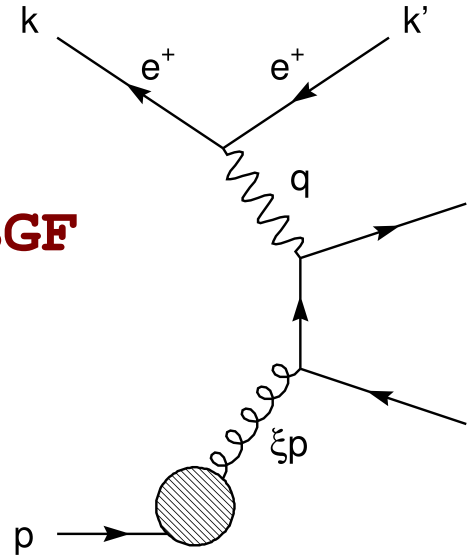
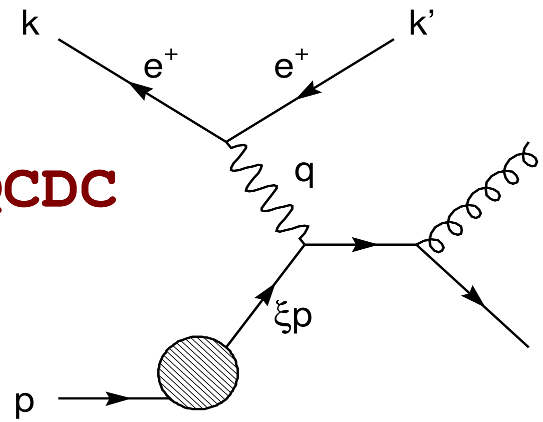
- Intro to Dijets
- Asymmetric jet cut
- Measurement Details
  - Event Selection
  - Detector and Hadronization Corrections
  - Systematics
- NLO pQCD Calculations
  - Comparison with measurement
  - Scale Uncertainty
- Summary

Dijet Production in DIS

BGF



QCDC



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

$x = Q^2/2p \bullet q$

$y = p \bullet q / p \bullet k$

ξ: momentum fraction of incident parton

$\xi = x(1 + M_{jj}^2/Q^2)$

M_{jj} = dijet mass

Measurement Motivation

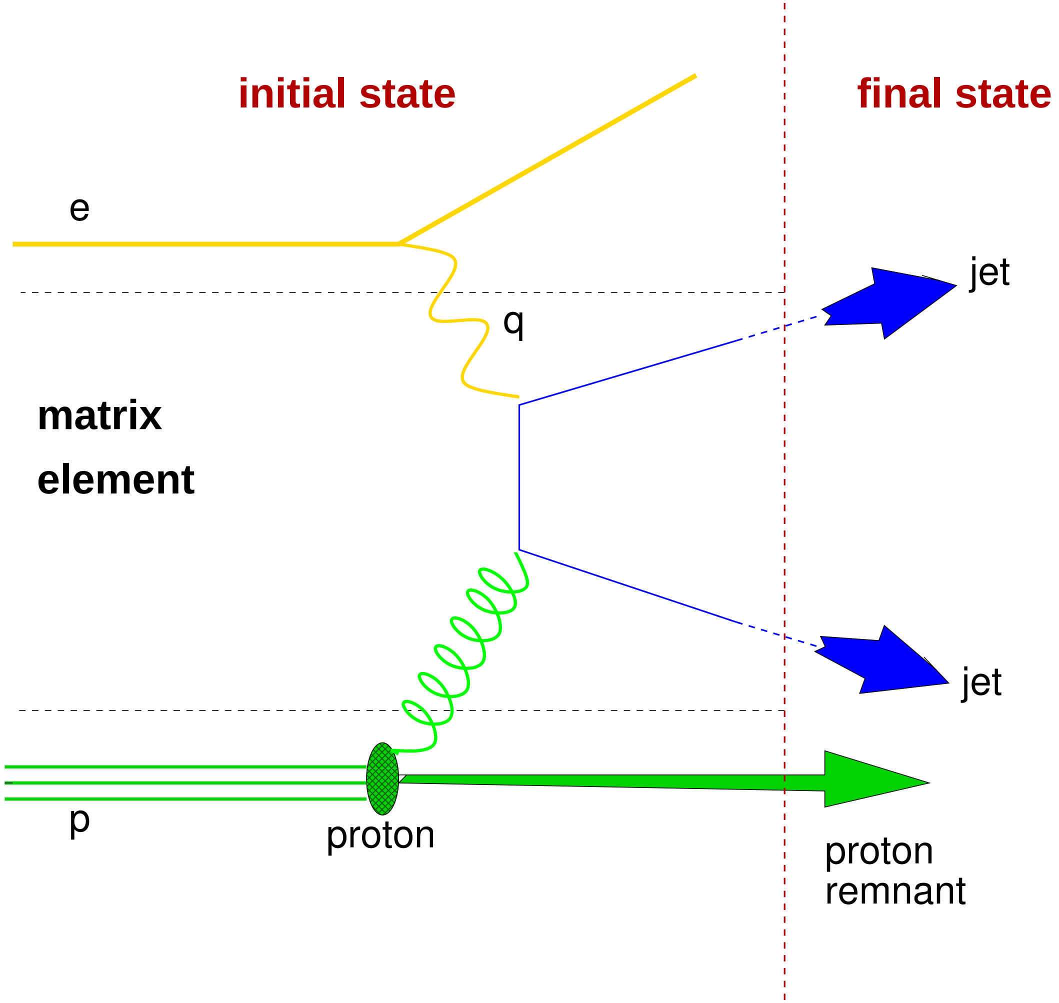


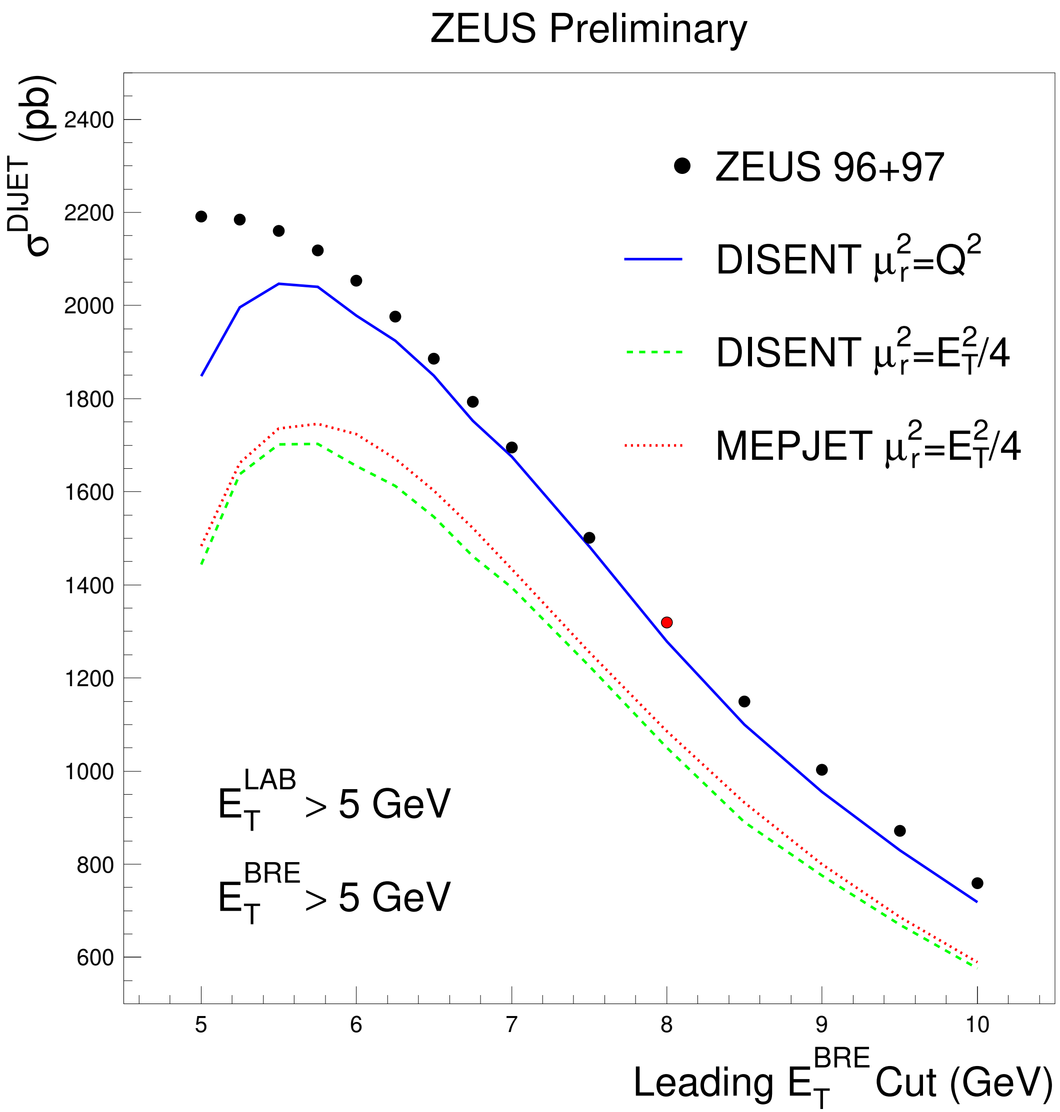
Figure from E.Heaphy

- General Test of pQCD
- Is NLO enough?
- Sensitivity to proton gluon density
- Can we distinguish PDFs within the measurement and theoretical uncertainties?

Analysis History

- "Long, long ago": Analysis of ZEUS 1995 Data
  - $7 < Q^2 < 100$ GeV^2
  - symmetric jet cut: $E_T^{LAB} > 4$ $E_T^{BRE} > 4$ GeV
  - comparison with Mepjet ($\mu^2 = E_T^2$)
  - Goal: measure gluon density
  - But we saw 40% disagreement with NLO
- We have learned more about NLO calculations (next slide)
  - Choice of renormalization scale at low Q^2
  - Symmetric vs Asymmetric jet cuts
- Current analysis
  - More data: 96+97, larger Q^2 range
  - Goal: cross section measurement and general comparison with NLO calculations

Effect of Asymmetric Jet Cut



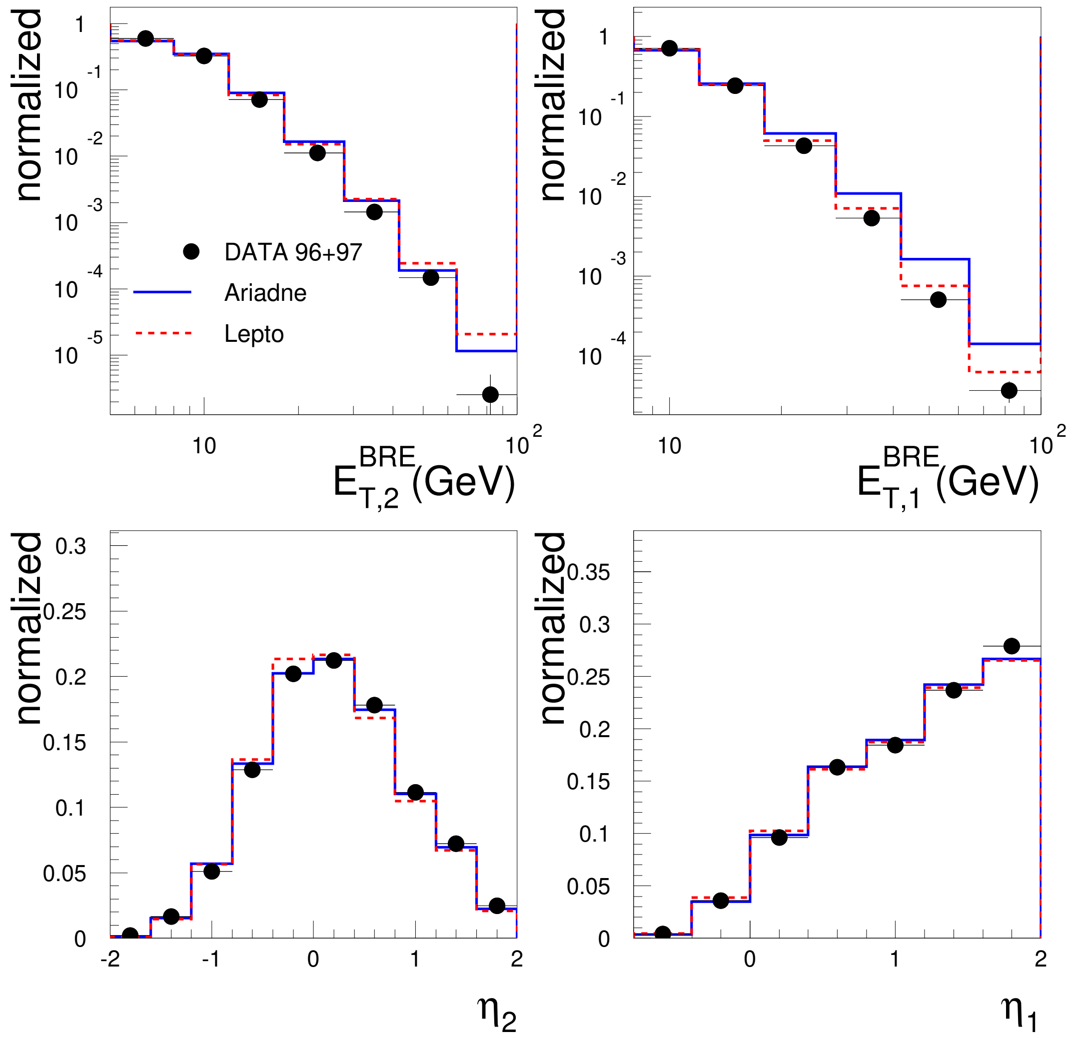
- Total inclusive dijet cross section
- NLO calculations MEPJET and DISENT behave unphysically near the symmetric cut
- Away from the symmetric cut they match the behavior of the data
- "Just Say No" to the symmetric cut

Data Selection

ZEUS

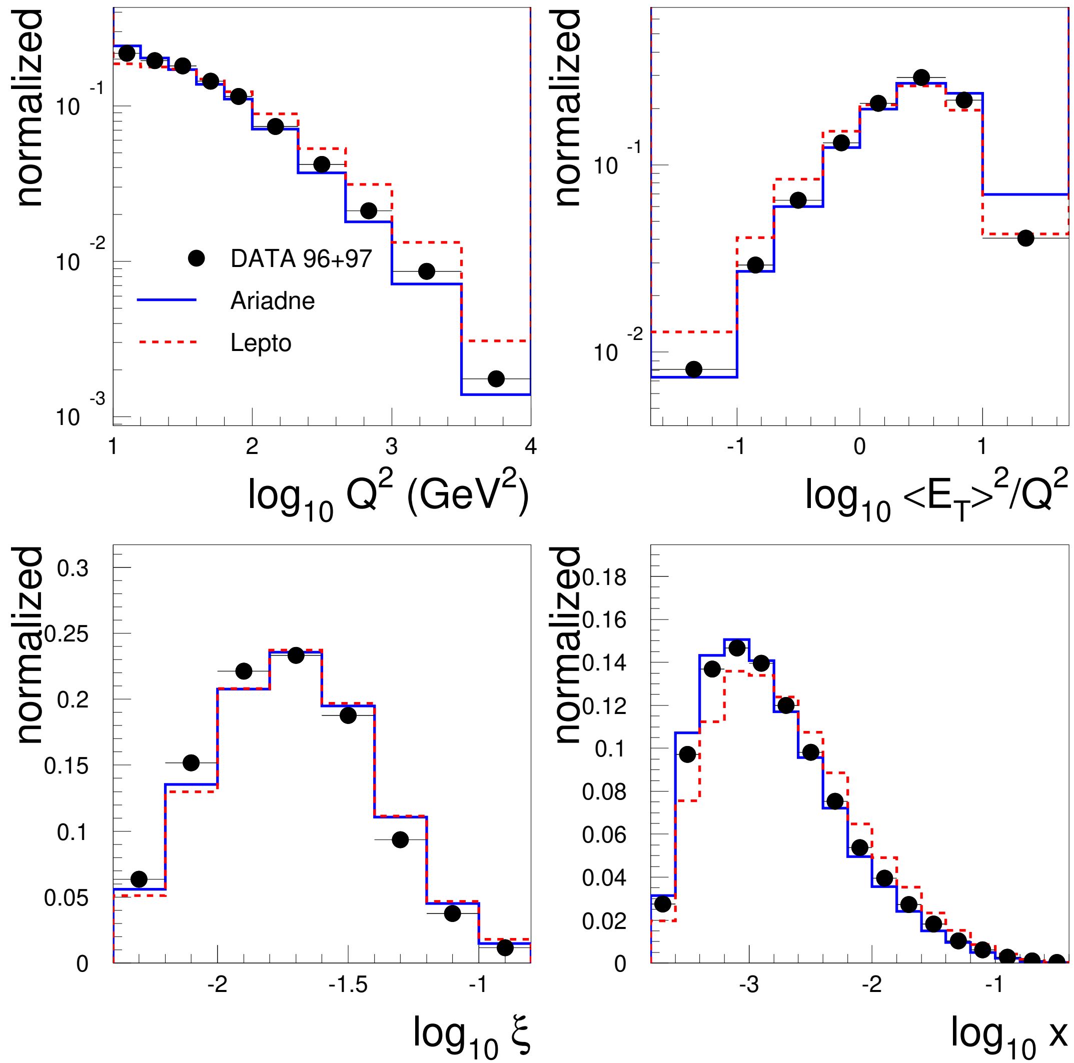
- HERA
  - e^+p collisions in 1996 and 1997
  - E_e=27.5 GeV, E_p=820 GeV, –> $\sqrt{s}$=300 GeV
- Data collected with the ZEUS Detector
  - 96+97 sample, 38.40 pb^{-1}
- Cross Section Definition
  - $10 < Q^2 < 10000$ GeV^2, $y>0.04$, $E_e > 10$ GeV
  - Breit frame: Jet $E_T > 5$ and 8 GeV (asymmetric cut)
  - Lab frame: Jet $E_T > 5$ GeV, $|\eta| < 2.0$
  - Jets defined by the longitudinally invariant k_T algorithm in inclusive mode. Run in the Breit frame

Detector Level
MC-Data Comparison



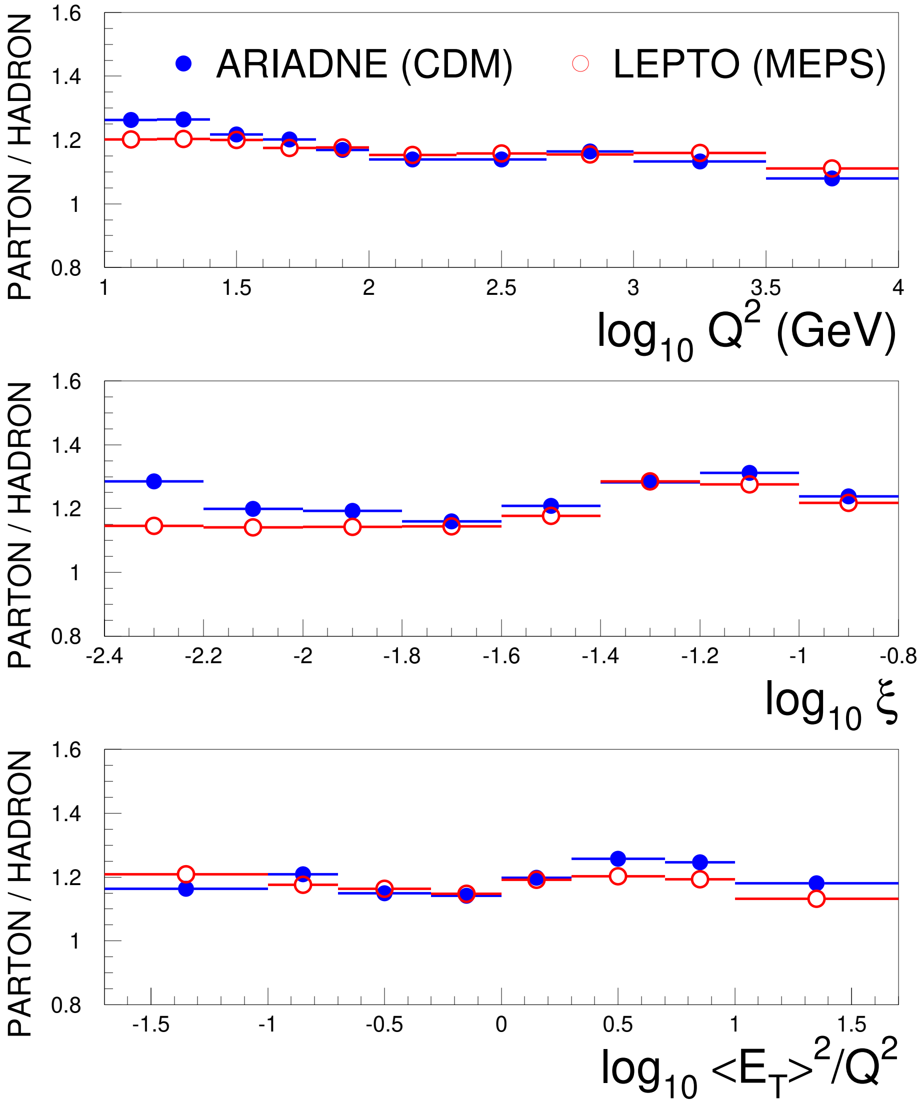
- Ariadne 4.08 with High Q^2 patch
  - CDM + Lund
- Lepto 6.5
  - MEPS + Lund
- LO MCs have significant normalization difference w/r data
  - Shape comparison only
- Reasonable agreement
  - Ariadne overestimates jet E_T at high E_T

Detector Level
MC-Data Comparison



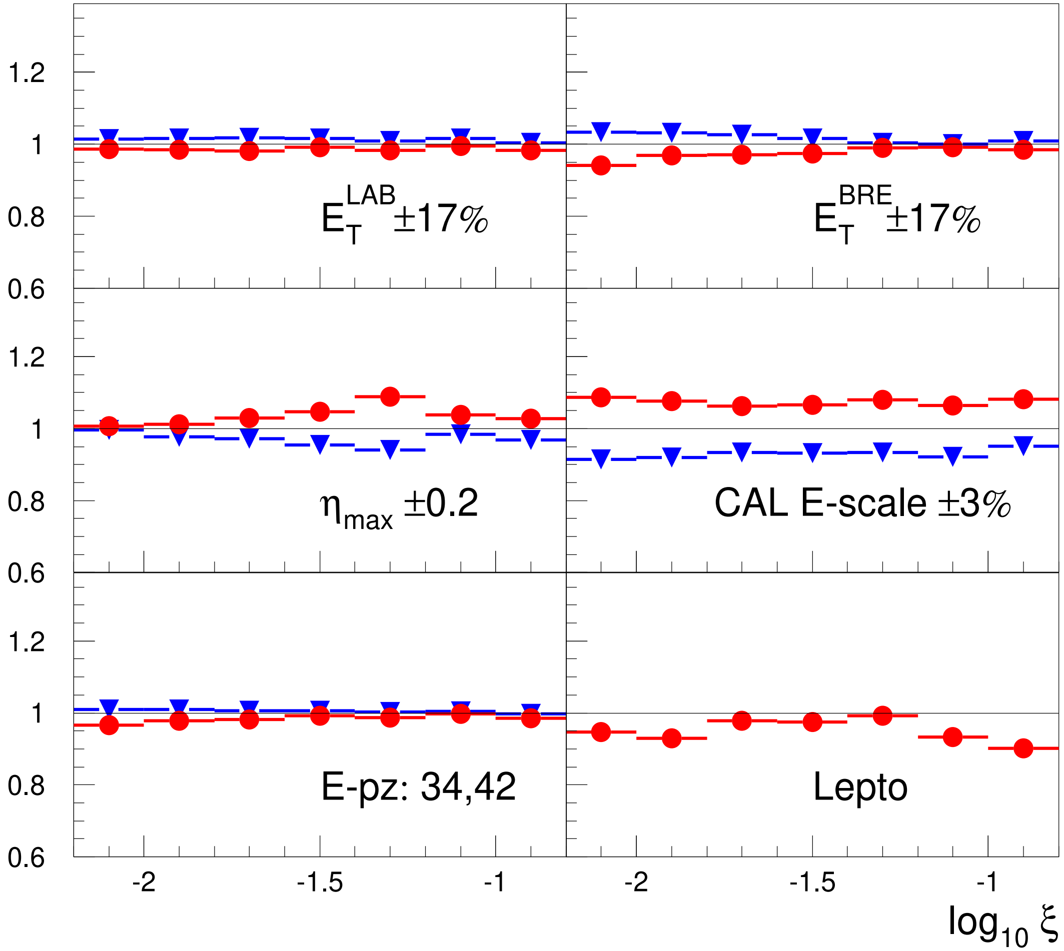
- Neither LO MC describes entire Q^2 range or $\langle E_T\rangle^2/Q^2$
- But good for detector corrections and hadronization estimates
- Overall Ariadne has better shape agreement with data
  - Ariadne used as default
  - Include Lepto as a systematic

Hadrons -> Partons



- Estimated hadronization corrections from Ariadne (CDM) and Lepto (MEPS)
  - both use Lund fragmentation
- 25% at low Q^2 to 10% at high Q^2
- Difference between Ariadne and Lepto account for significant part of the overall systematic error

Systematic Error Estimate

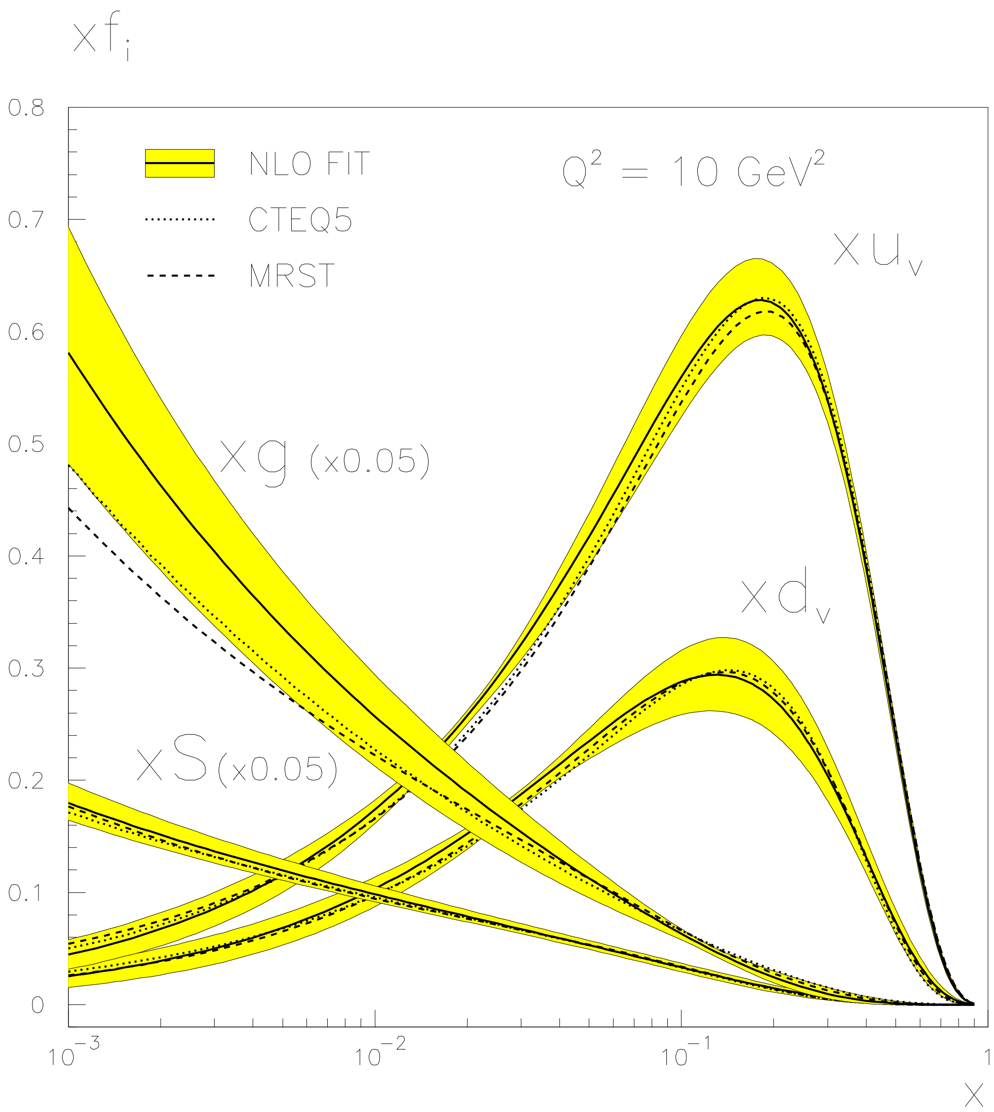


- Vary detector level cuts by +1 and –1 sigma in resolution
- Calorimeter Energy Scale Uncertainty determined separately
- Use of Lepto and CAL Energy Scale Uncertainty give largest contributions to the systematic error

NLO Calculations

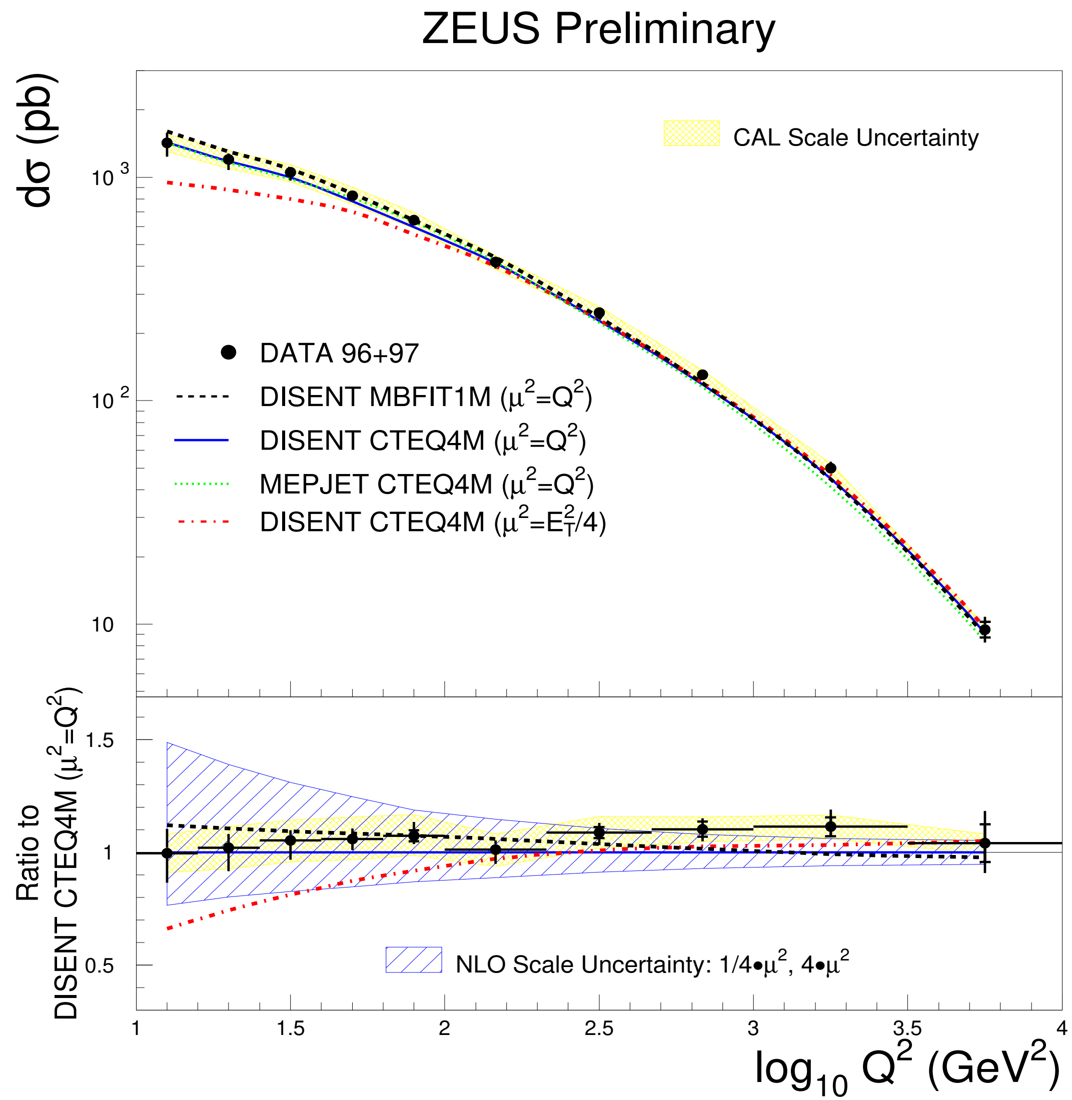
- MEPJET v2.2 – phase space slicing method
  - factorization scale: Q or ½E_T
  - includes Z exchange and running α_{em}
- DISENT v0.1 – subtraction method
  - factorization scale: Q
  - no Z exchange and fixed α_{em}
  - No correction for z–exchange
    - ~5–10% effect for Q^2>3000 GeV^2 (<0.3% of data sample)
- Renormalization scale: We choose Q ($\mu_r^2=Q^2$) and ½ sum of the jet E_T in the breit frame ($\mu_r^2=E_T^2/4$)
- PDFs used: CTEQ4M and MBFIT

M.Botje Parton Distribution Set



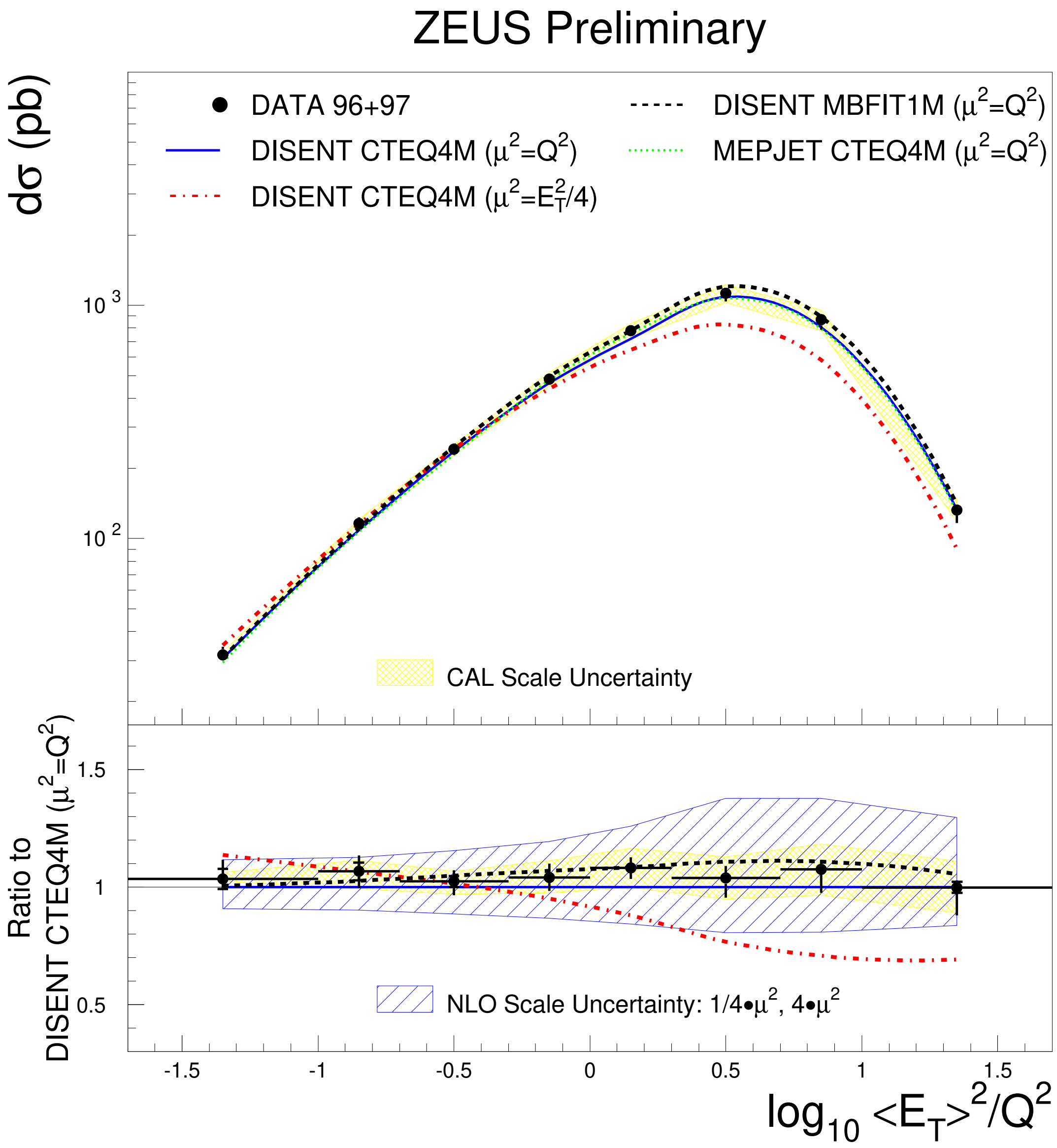
- hep–ph/9912439
- Global fit to ZEUS, H1, and fixed target structure function data
  - does not include ZEUS 96–97 data (this analysis)
- Larger gluon and slightly larger sea than CTEQ and MRST

Inclusive Dijet $d\sigma/dQ^2$ vs NLO



- Shape described if $\mu^2=Q^2$ used
  - Data reproduced within 10%
- Large scale uncertainty at lower Q^2
  - Are choices of scale reasonable?
- Cannot distinguish MBFIT and CTEQ4

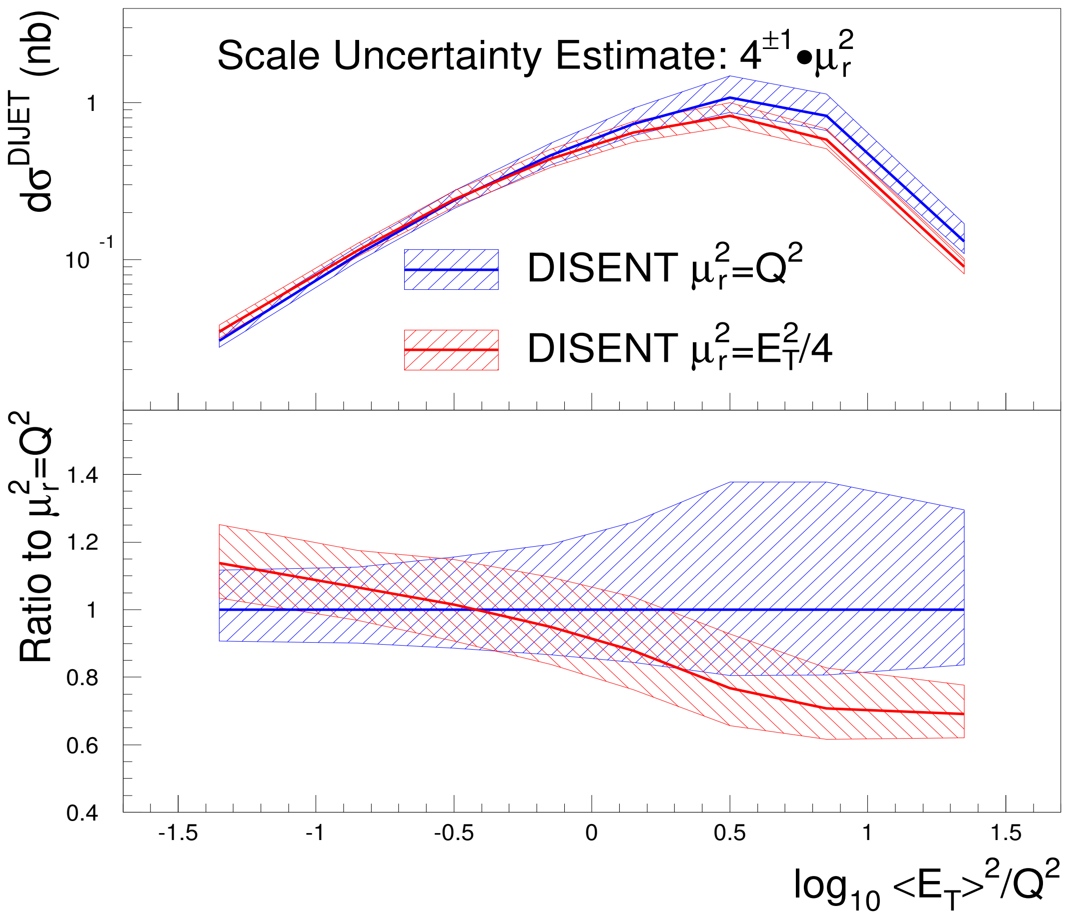
Inclusive Dijet $d\sigma/d\langle E_T\rangle^2/Q^2$ vs NLO



- $\langle E_T\rangle^2 > 40\ GeV^2$
- Large scale uncertainty for $E_T^2 > Q^2$
  - Unreasonable scale chosen, large HO effects, or both?
- If $\mu^2 = Q^2$, better agreement
- Unable to differentiate PDFs even within measurement uncertainty

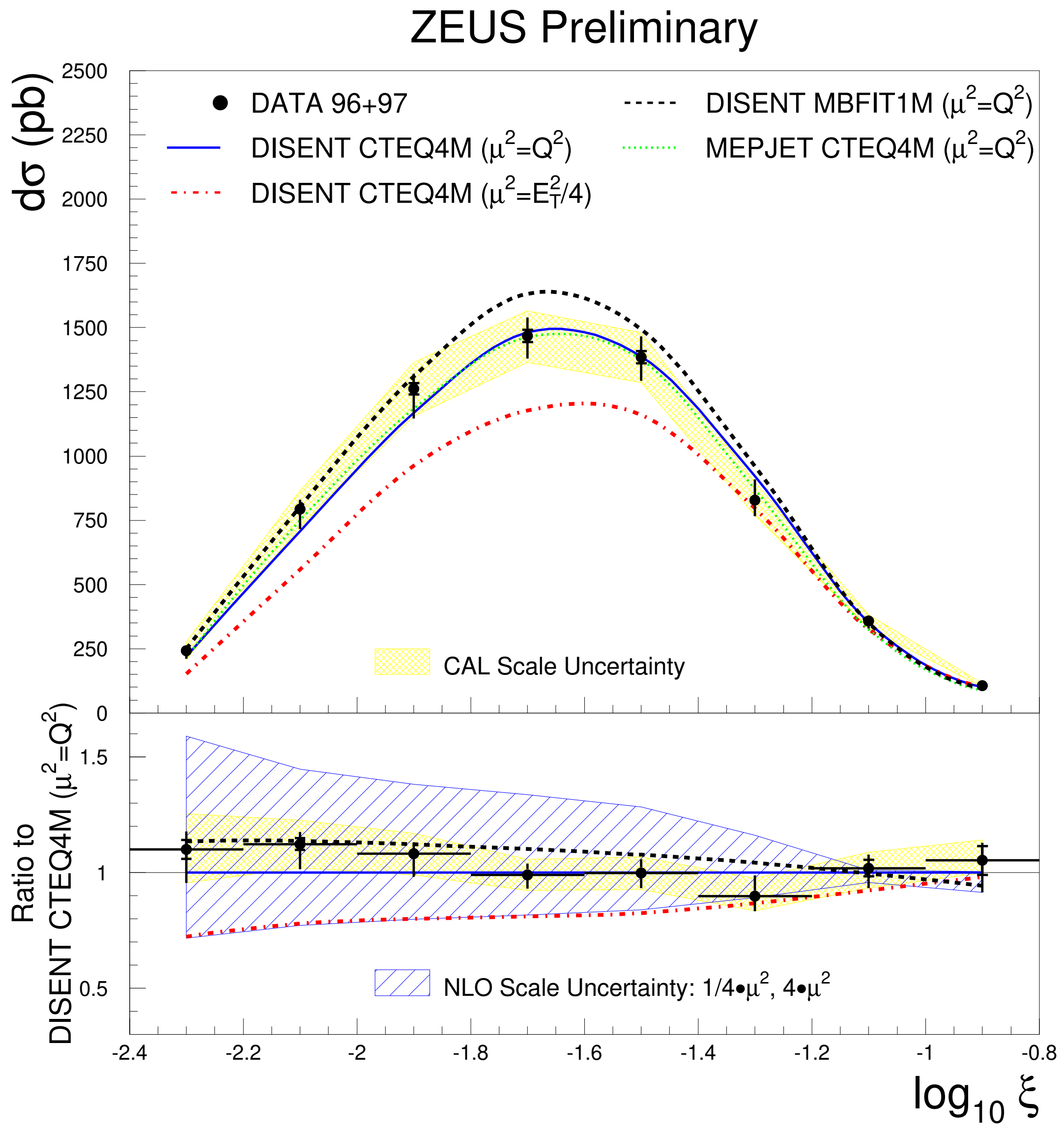
Renormalization Scale

Q^2 vs $E_T^2/4$



- No surprise in the shapes
  - larger $\mu \rightarrow$ smaller α_s
- But for $E_T^2 >> Q^2$, estimated uncertainty is much larger if $\mu^2=Q^2$
- Data prefers $\mu^2=Q^2$, but intuitively E_T is the more "natural" scale

Inclusive Dijet
$d\sigma/d\xi$ vs NLO



$\xi = x_{BJ}\,(1+M_{jj}^2/Q^2)$

- sensitive to PDFs
- Better agreement if $\mu^2 = Q^2$
- Scale uncertainty larger than measurement uncertainty at low ξ

Summary

- Inclusive Dijet cross section measured for $10<Q^2<10000$ GeV^2, jet $E_T^{BRE}>8$ (and 5) GeV
- NLO pQCD calculations reproduce the data within 10% over 3 orders of magnitude in Q^2
- At low Q^2, where $E_T^2>>Q^2$, the choice of renormalization scale has significant effect on NLO calculation
  - Using $E_T^2/4$ severely underestimates the data
  - Questions about appropriate scale open
- Theoretical uncertainty larger than measurement uncertainty in most of the kinematic range
  - Unable to distinguish PDFs