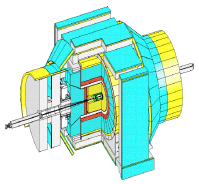
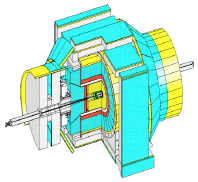


Some jet theory to set up Gene's talk

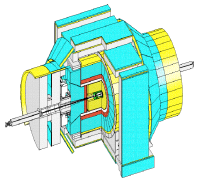
J. Huston

Michigan State University



Global pdf fits

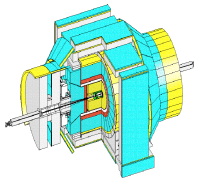
- Calculation of production cross sections at the Tevatron and LHC relies upon knowledge of pdfs in relevant kinematic range
- pdfs are determined by global analyses of data from DIS, DY and jet and direct production
- Two major groups that provide semi-regular updates to parton distributions when new data/theory becomes available
  - MRS->MRST98->MRST99->MRST2001->MRST2002
  - CTEQ->CTEQ5->CTEQ5(1)->CTEQ6->CTEQ6.1(new)
- CTEQ6 is based on series of previous CTEQ distributions, but represents more than an evolutionary advance
  - update to new data sets
  - incorporation of correlated systematic errors for all experiments in the fit
  - new methodology enables full characterization of parton parametrization space in neighborhood of global minimum
    - Hessian method
    - Largrange Multiplier
  - results available both in conventional formalism and in Les Houches accord format (more on this later)



Uncertainties in pdf's

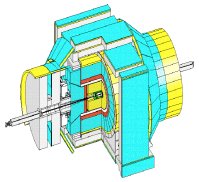
- What's unknown about PDF's
  - the gluon distribution
  - strange and anti-strange quarks
  - details in the {u,d} quark sector; up/down differences and ratios
  - heavy quark distributions

- □ of quark distributions (q + qbar) is well-determined over wide range of x and Q^2
  - Quark distributions primarily determined from DIS and DY data sets which have large statistics and systematic errors in few percent range (±3% for $10^{-4}<x<0.75$)
  - Individual quark flavors, though may have uncertainties larger than that on the sum; important, for example, for W asymmetry
- information on dbar and ubar comes at small x from HERA and at medium x from fixed target DY production on H_2 and D_2 targets
  - Note dbar≠ubar
- strange quark sea determined from dimuon production in □ DIS (CCFR)
- d/u at large x comes from FT DY production on H_2 and D_2 and lepton asymmetry in W production



Uncertainties in pdf fits

- Two sources
  - Experimental errors
    - Hessian/Lagrange multiplier techniques designed to address estimate of these effects
      - question is what $\Delta\chi^2$ change best represents estimate of uncertainty (we use $\Delta\chi^2$ of 100 (out of 2000))
  - Theoretical
    - higher twist/non-perturbative effects
      - choose Q^2 and W cuts to try to avoid
    - higher order effects
      - is NNLO necessary yet?
    - edge of phase space effects

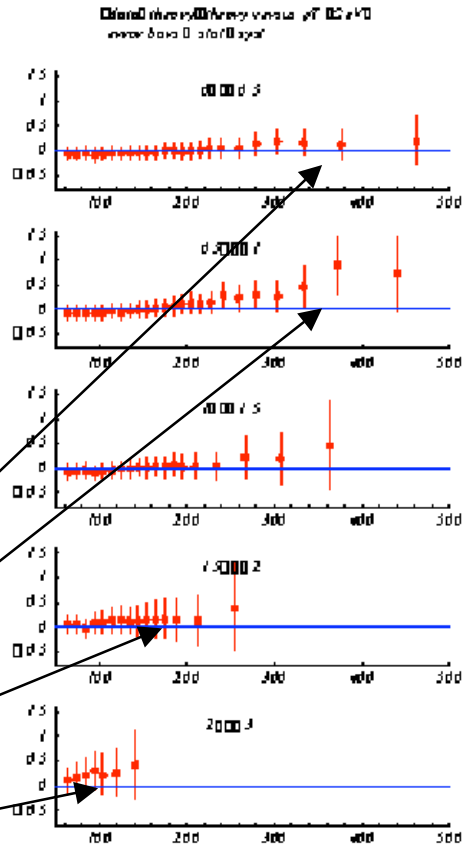


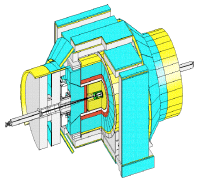
Nuts/bolts of fits

- Functional form used is:
  - $xf(x,Q_o) = A_o\, x^{A1}\, (1-x)^{A2}\, e^{A3x}\, (1 + A_4 x)^{A5}$
    - Q_o = 1 GeV (below any data used in fit)
      - easier to do forward evolution than backward
    - functional form arrived at by adding a 1:1 Pade expansion to quantity d(log xf)/dx
    - more versatile than form used in CTEQ5 or MRST
    - there are 20 free parameters used in the global fit
- Light quarks treated as massless; evolution kernels of PDFs are mass-independent
- Zero mass Wilson coefficients used in DIS structure functions

D0 jet cross section

- CTEQ4 and CTEQ5 had CDF and D0 central jet cross sections in fit
- Statistical power not great enough to strongly influence high x gluon
  - CTEQ4HJ/5HJ required a special emphasis to be given to high E_T data points
- Central fit for CTEQ6 is naturally *HJ-like*
- χ^2 for CDF+D0 jet data is 113 for 123 data points
- Note the power of having *search for new physics* regions and *control* regions
  - pdf explanation should work for all regions
  - new physics should be central





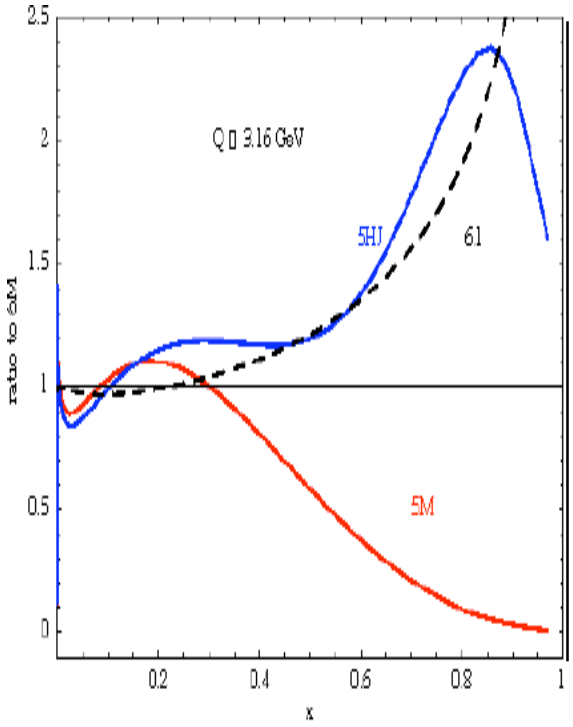
Remaining questions/discussion

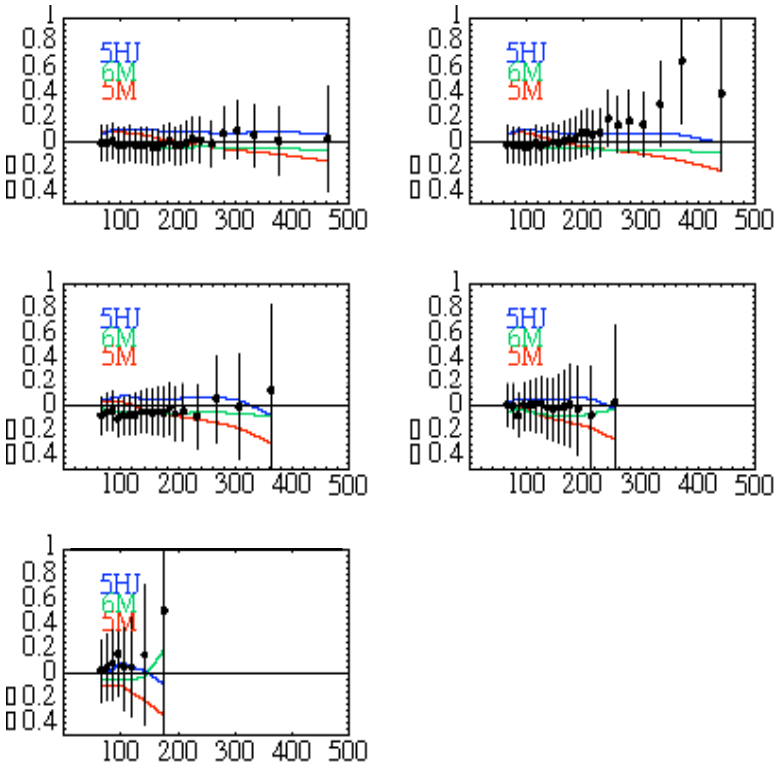
- HJ-like behavior for gluon motivated to describe CDF Run 1 data now seems a natural consequence of global fitting
- …but need to be careful not to hide any possible new physics in the gluon uncertainty
- How much room is left over for new physics in Run 1 data?
- What is uncertainty on Run 2 jet cross sections?
- Is NLO QCD valid for description of jet cross sections in full range of E_T/p_T and rapidity, for both Run 1 and Run 2?
- These and other questions to be answered in CTEQ paper in preparation
- Here are a few excerpts

6.1 gluon compared to 5M/5HJ/6M

- In the course of investigations for this paper, some improvements to the analysis were made that changed the gluon distribution: cteq6m->cteq6.1

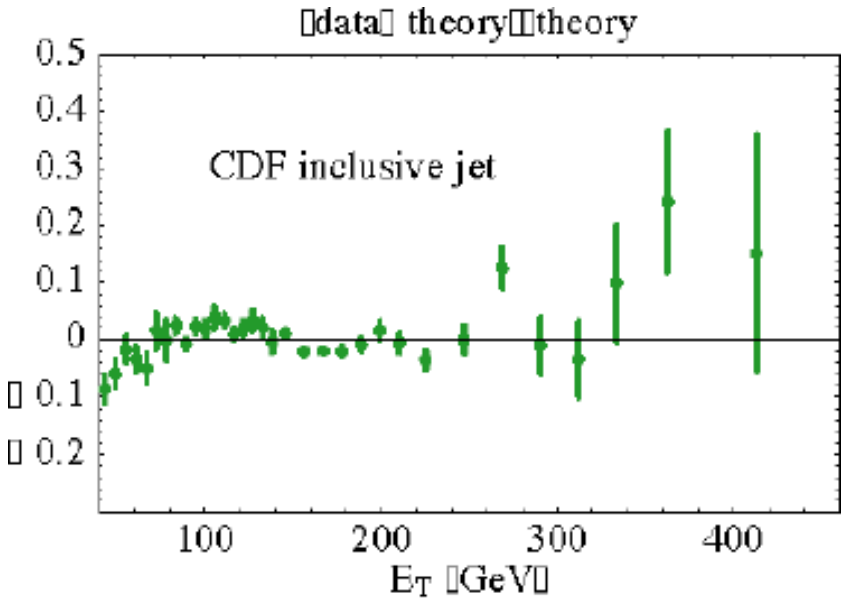
•small changes in jet cross sections, as for example the D0 jet cross section below



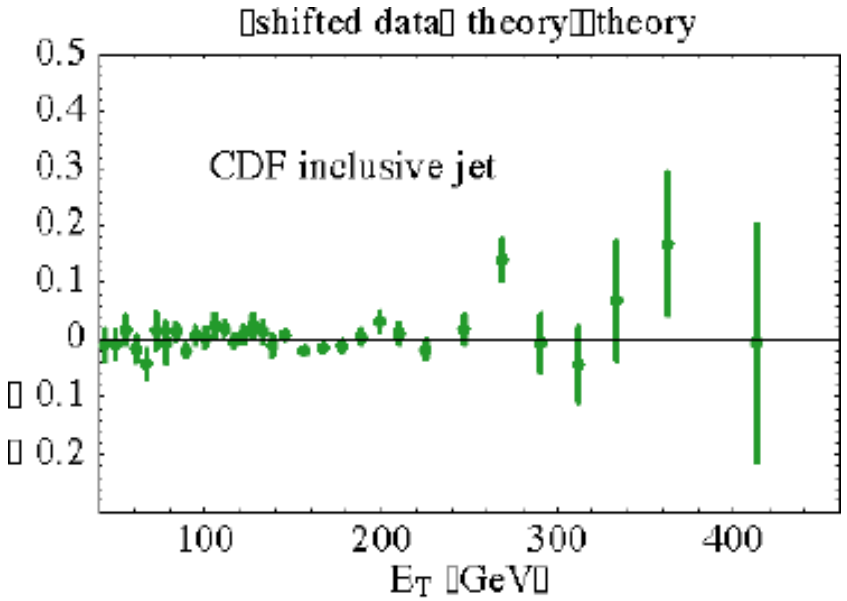


CDF Run 1 data and CTEQ6.1

before systematic error shifts

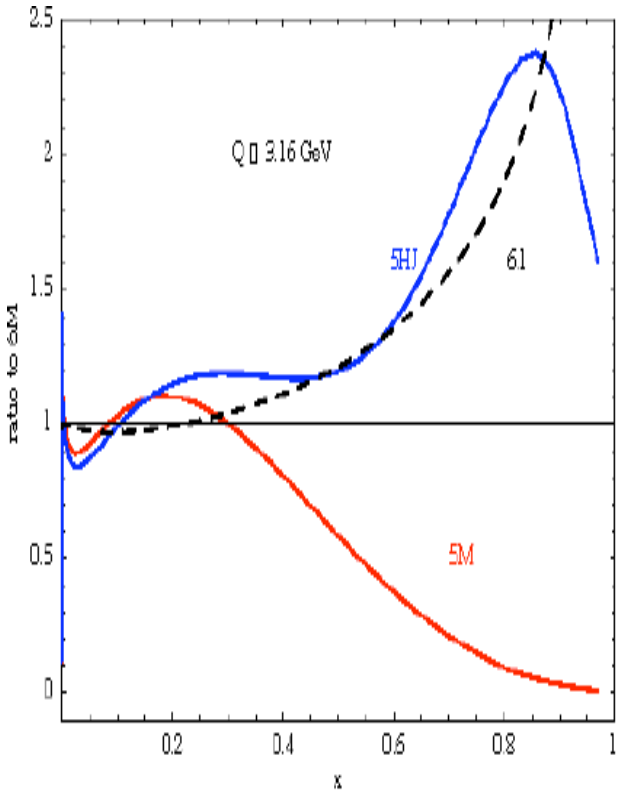


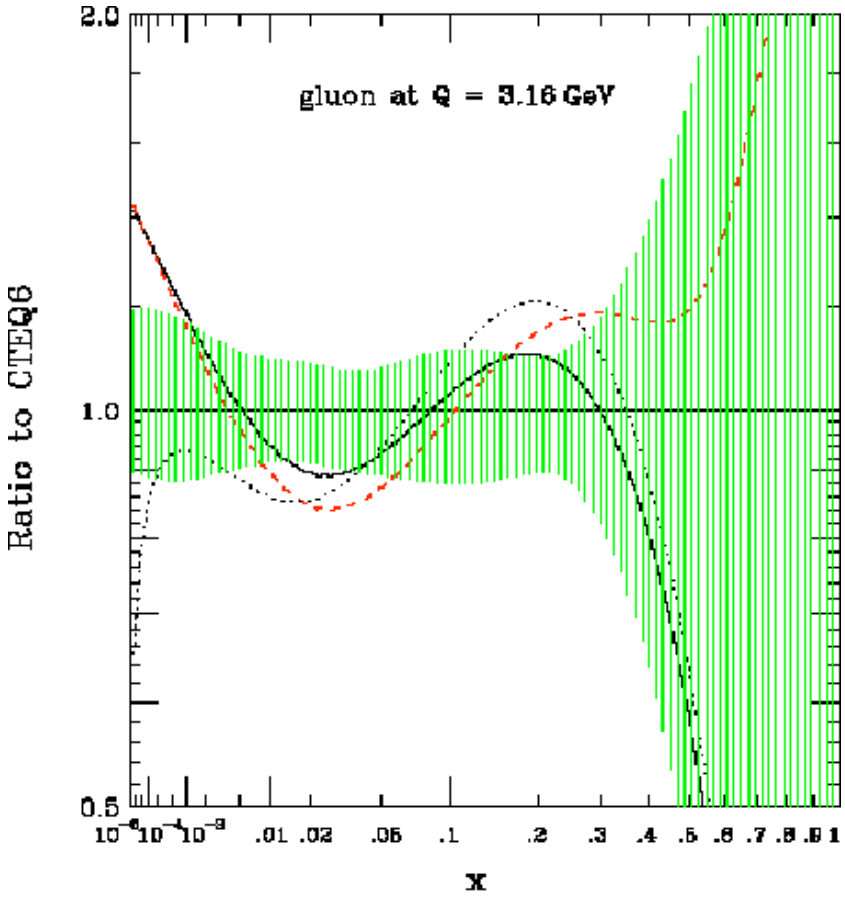
after systematic error shifts



Remaining gluon uncertainties

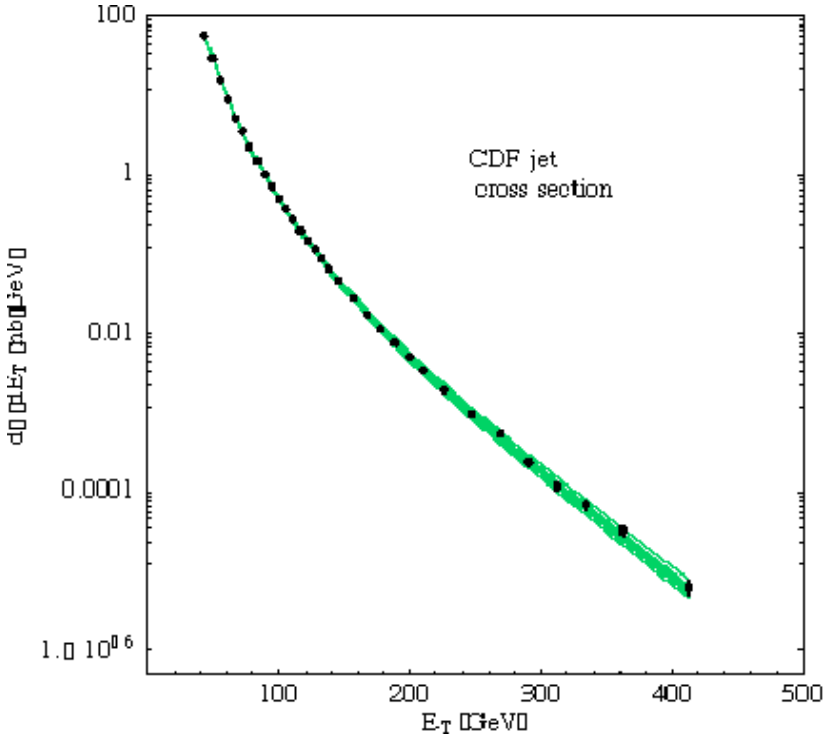
New cteq6.1 well within uncertainty band for gluon distribution





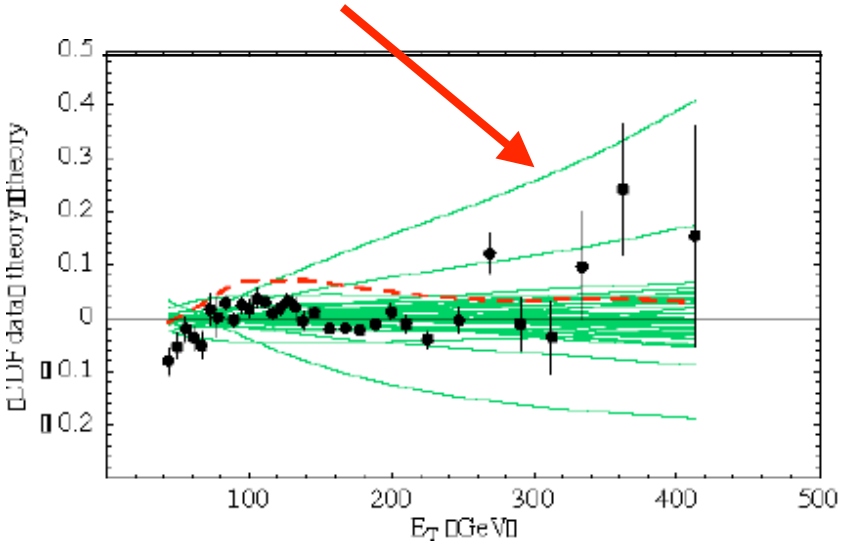
PDF uncertainties for Run 1 cross section

- 20 free parameters in the fit
- In the Hessian method, a 20X20 matrix is diagonalized and 20 orthogonal eigenvector directions in parameter space are determined



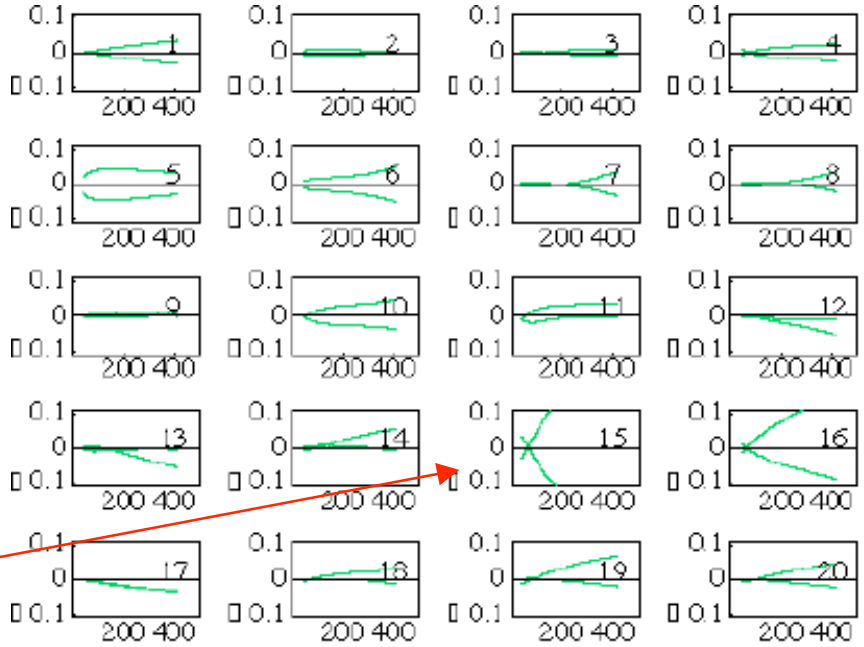
•Each eigenvector direction corresponds to some linear combination of pdf parameters
•Large eigenvalues correspond to highly determined directions (e.g. valence quarks)
•Small eigenvalues correspond to poorly determined directions (high x gluon)
•Result is 40 pdf's (go along + and - direction $\Delta\chi^2$ of 100 for each eigenvalue)

Note 1 eigenvector(15+) leads to noticeably larger prediction than the others



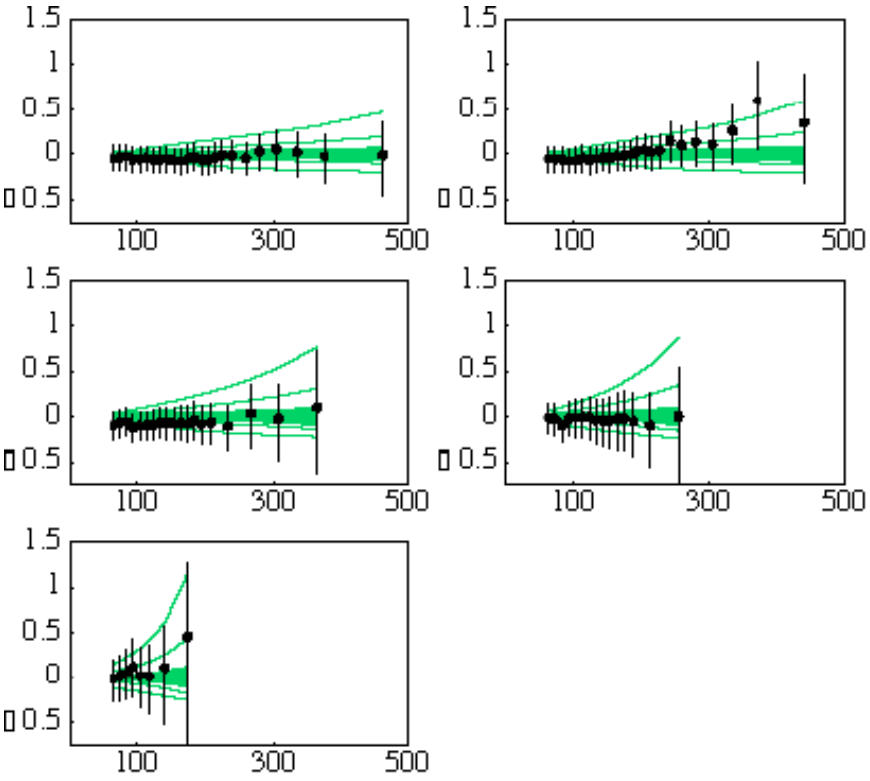
CDF jet cross section uncertainties

- On the right are shown the uncertainties for the CDF jet cross section along each eigenvector ($\Delta\chi^2$ = 100)
  - jet cross section most sensitive to eigenvector 15
    - which mainly contains parameters relating to behavior of high x gluon

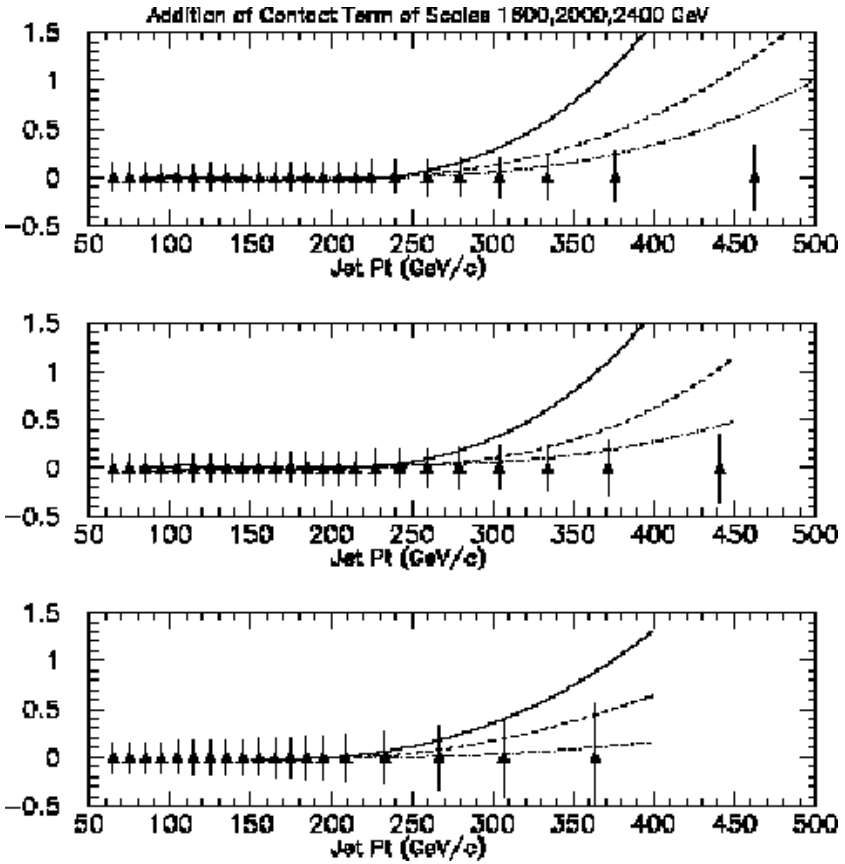


Room for new physics

- Uncertainties for D0 Run 1 jet cross section as a function of rapidity

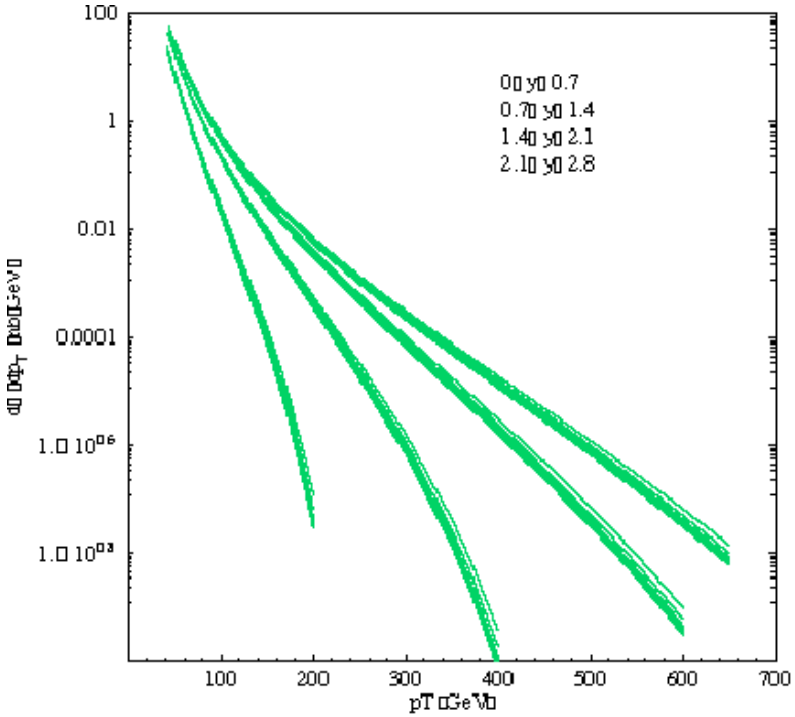


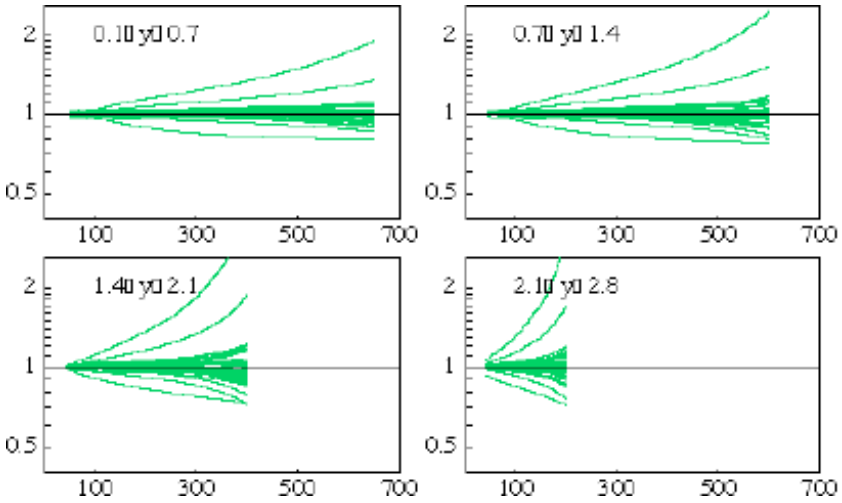
Effect of new physics (compositeness) for the first 3 rapidity bins (effects on last bins are negligible)



Uncertainties on Run 2 predictions for CDF

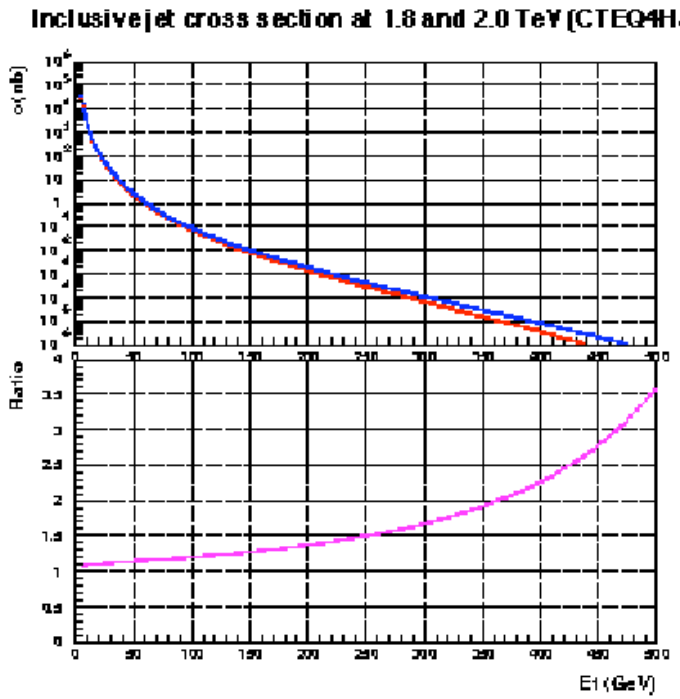
- CDF will measure the inclusive jet cross section in the forward regions as well



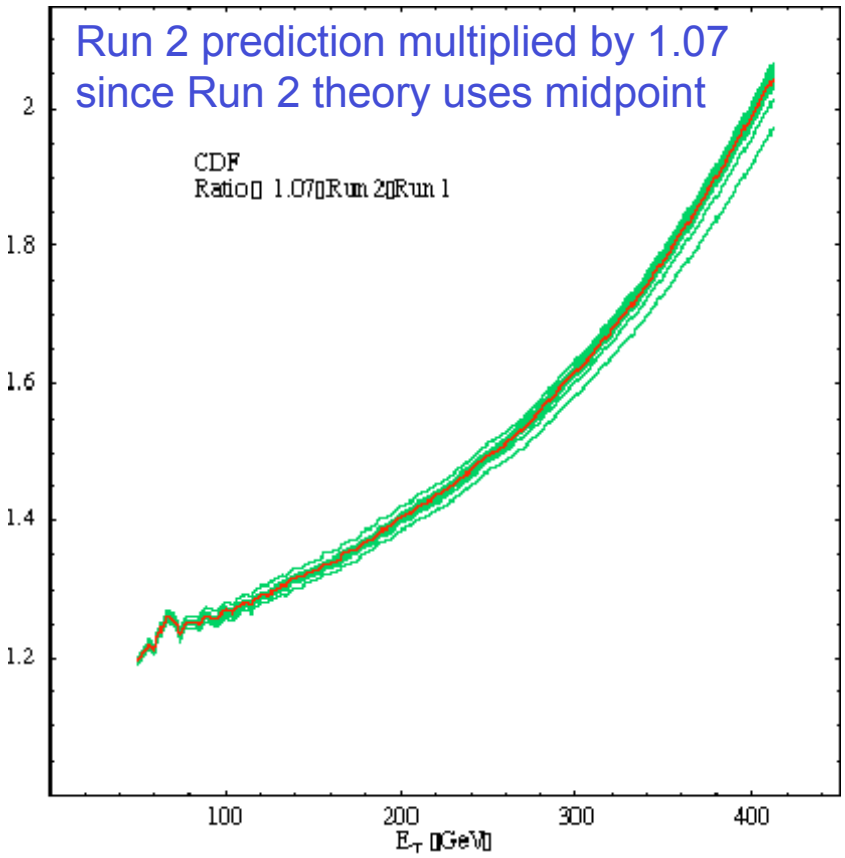


Ratio of Run 2/Run 1

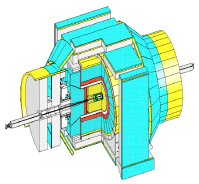
The increase in the center-of-mass energy from 1.8 to 1.96 TeV has a large effect on the high E_T jet rate.



For the full Run IIa sample the number of jets above 400 GeV will increase from 11 to ~ 500.



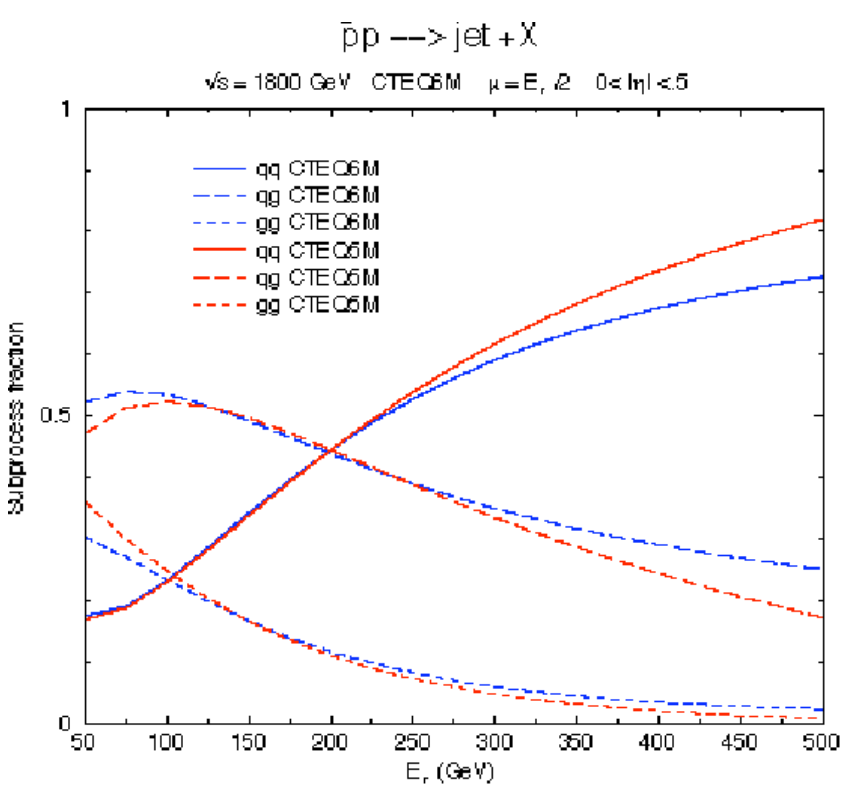
Small theoretical uncertainties on the ratio; experimental uncertainties should partially cancel as well

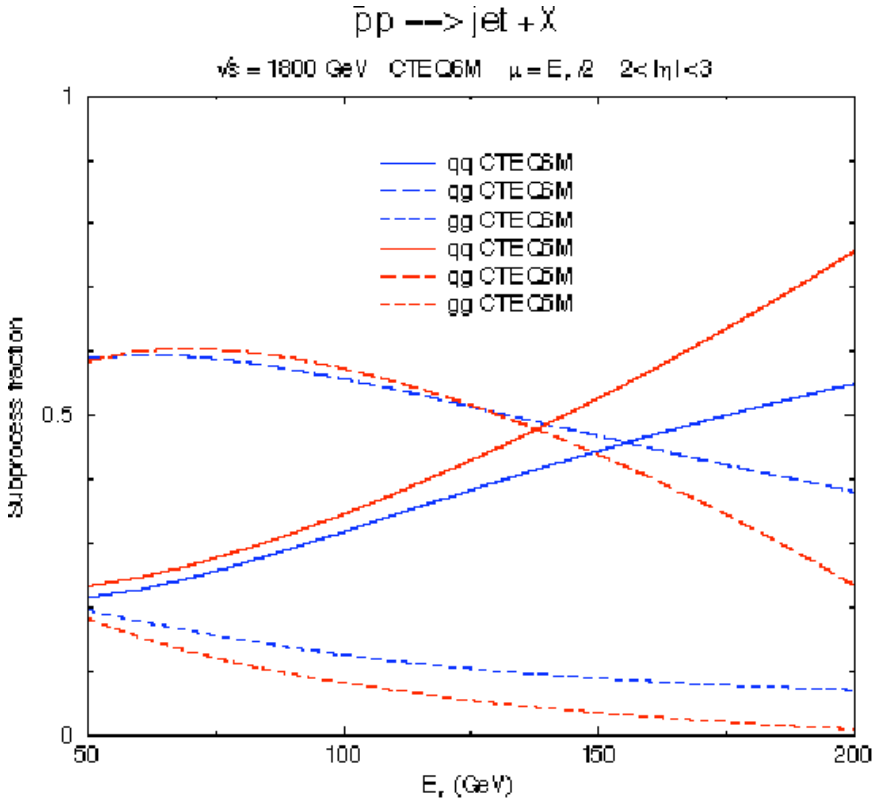


Subprocess plots

- Enhanced gluon-quark scattering in CTEQ6

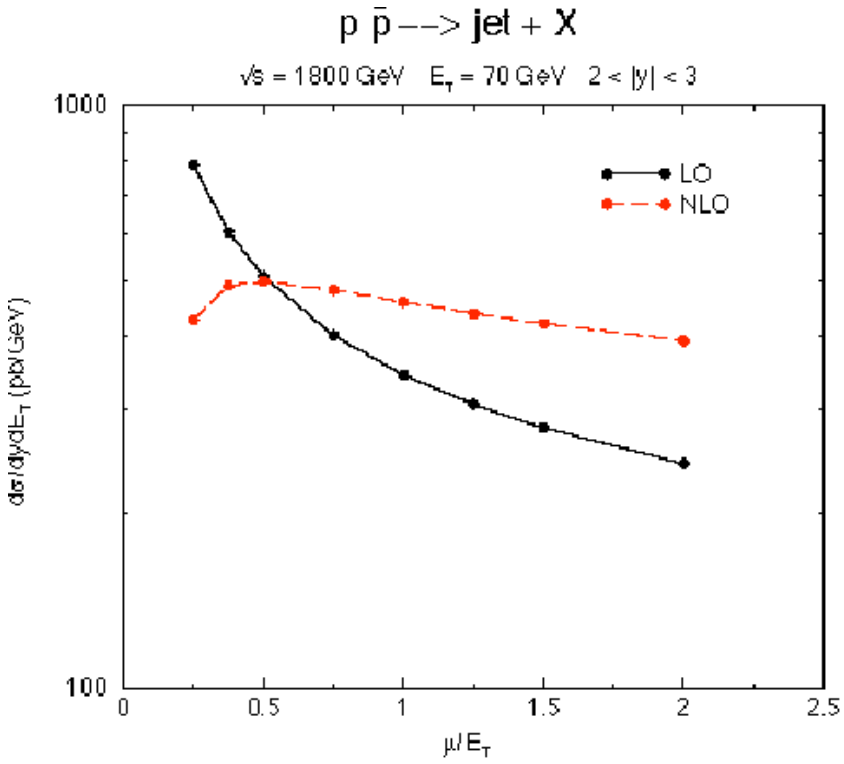
Larger contribution for forward rapidities





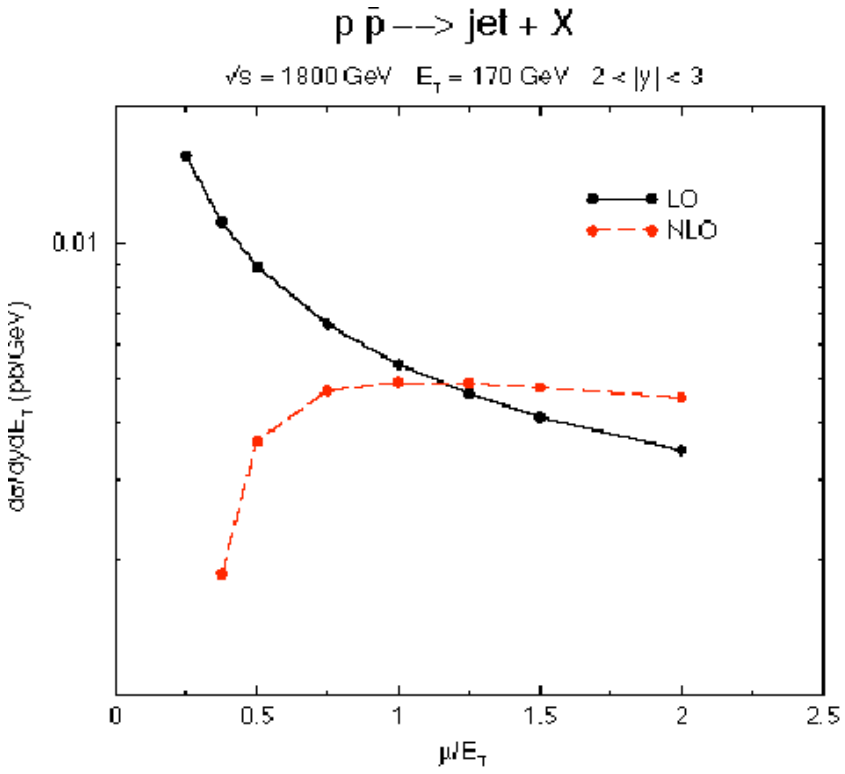
Reliability of NLO QCD

- One way of looking for possible effects of higher order terms is to examine the scale dependence of the jet cross section
- Also, look at the K-factor (NLO/LO) at scale cross section evaluated at
- For □/E_T=0.5, K-factor is of the order of 1 for most of Tevatron jet data
- Is NLO QCD reliable for all data taken in Run 1?



NLO and LO scale dependence

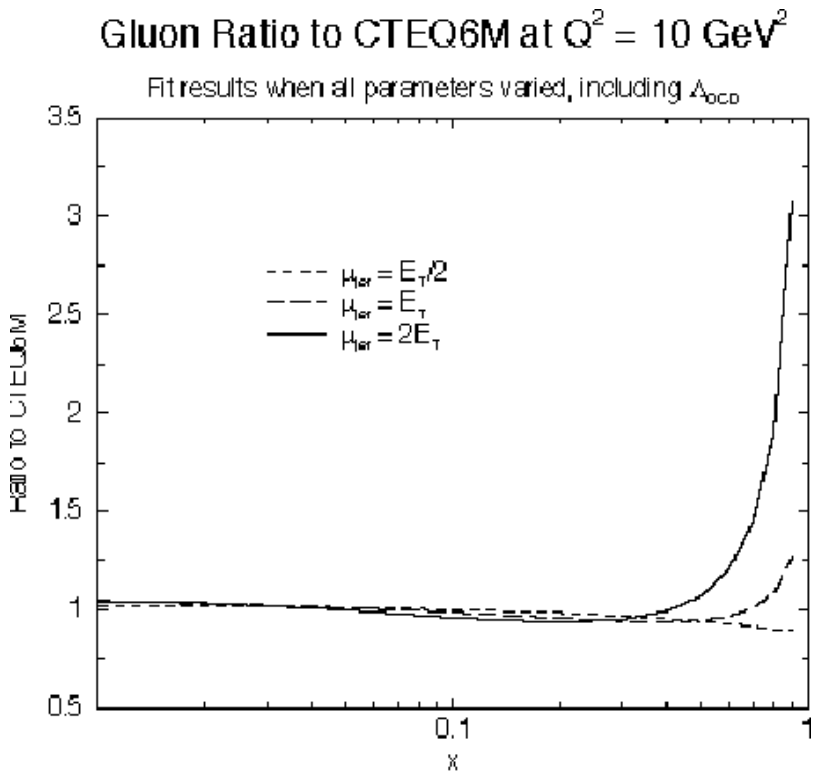
- Leading log calculations of the jet cross section at high E_T generally decrease as renorm/factorization scales are increased
- At NLO, scale dependence is reduced and cross section typically has parabolic shape as function of scale
- For large y, high E_T, point where NLO curve crosses LO curve moves out in □/E_T, due to kinematic reasons
- So, K-factor at □/E_T can be significantly less than 1
- Not a cause for alarm per se, but scale dependence of cross section does become steep at scales lower than 0.5 E_T

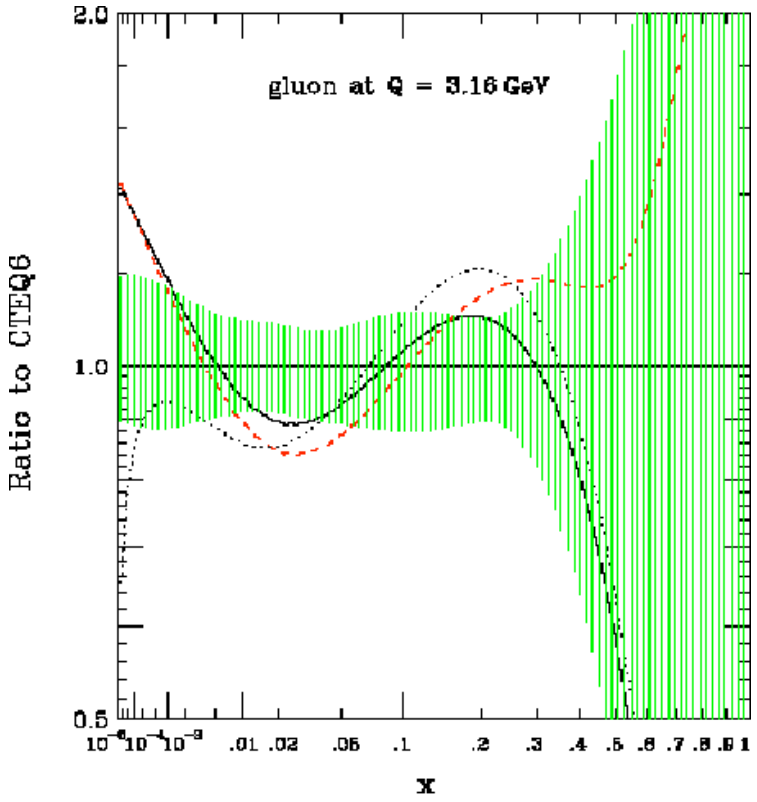


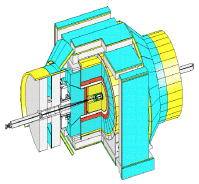
Scale dependent fits

- Repeat CTEQ6 fit using scales of E_T, $2E_T$ for jet cross section
- Compare gluon distribution to CTEQ6M ($\mu = E_T/2$)

Variations within CTEQ6 pdf uncertainty band

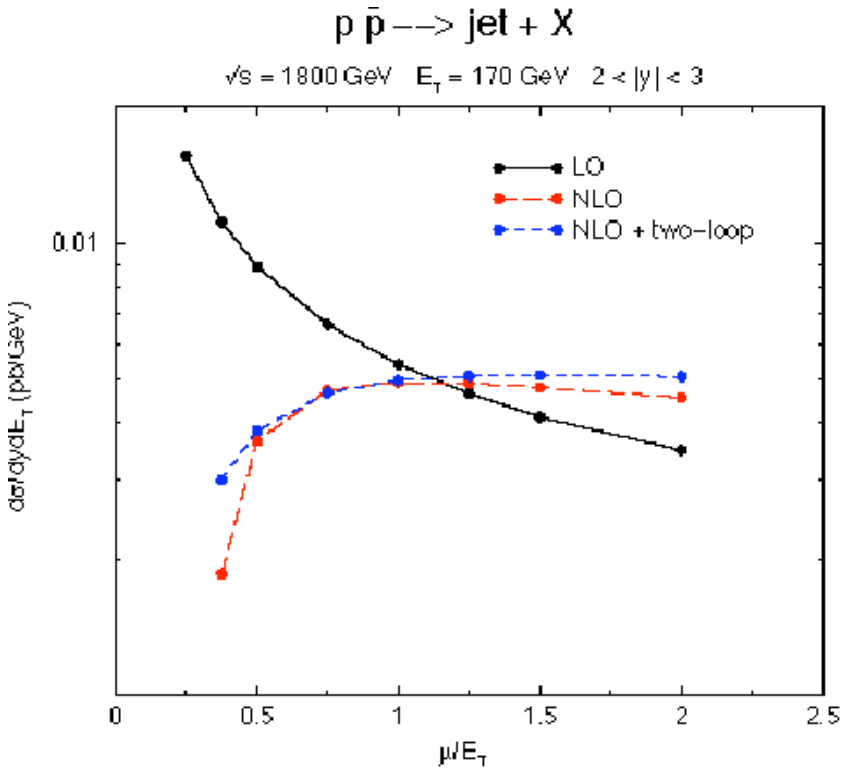


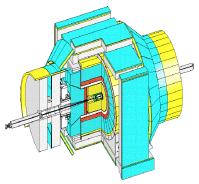




Edge of phase space

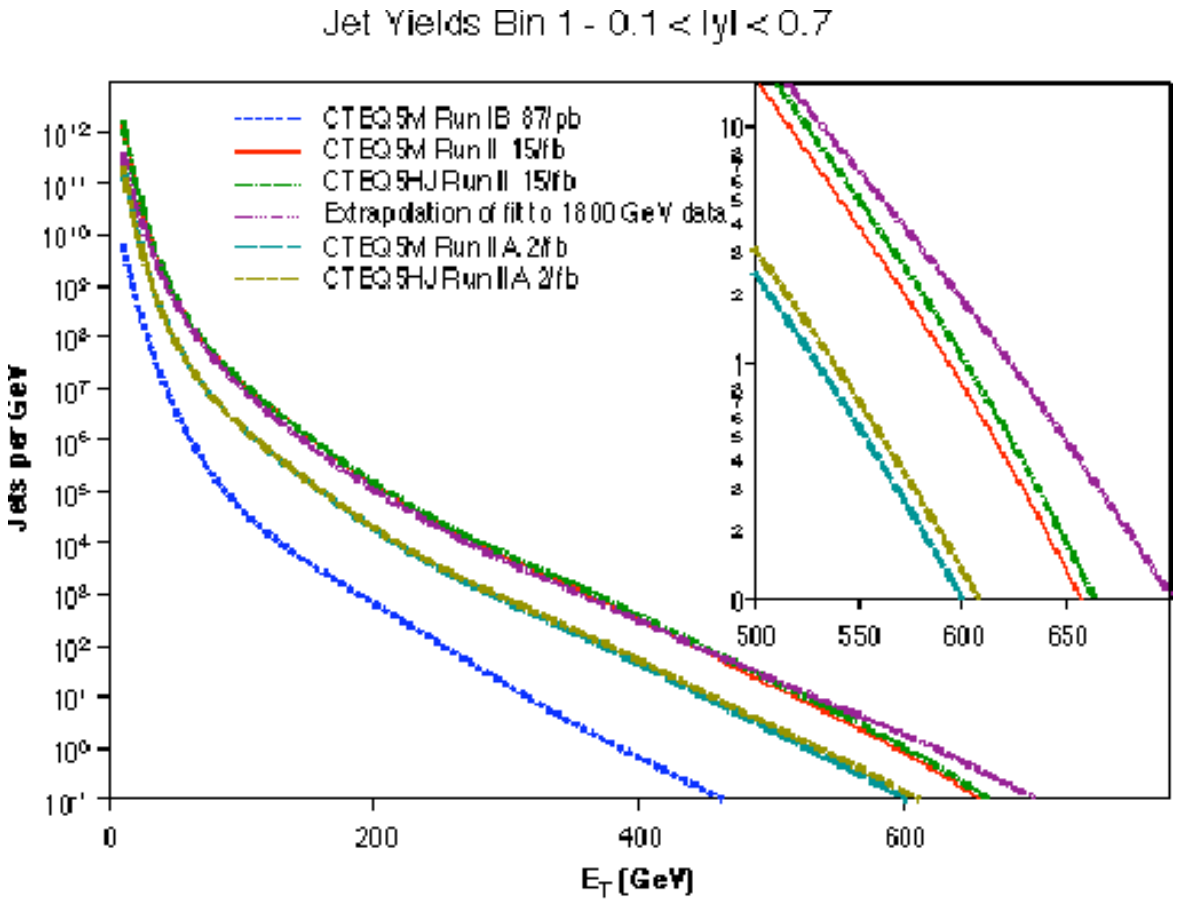
- Potentially significant problems from phase space limitations at large E_T and rapidity
- Such corrections can be treated by threshold resummation techniques
- Estimated at two loop level and found to be small for central rapidity region
- Repeated for forward rapidity region and again are not significant at scale used in fit

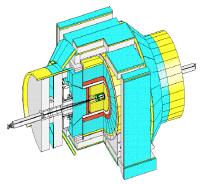




Jet Yields in Run II(from Steve Ellis)

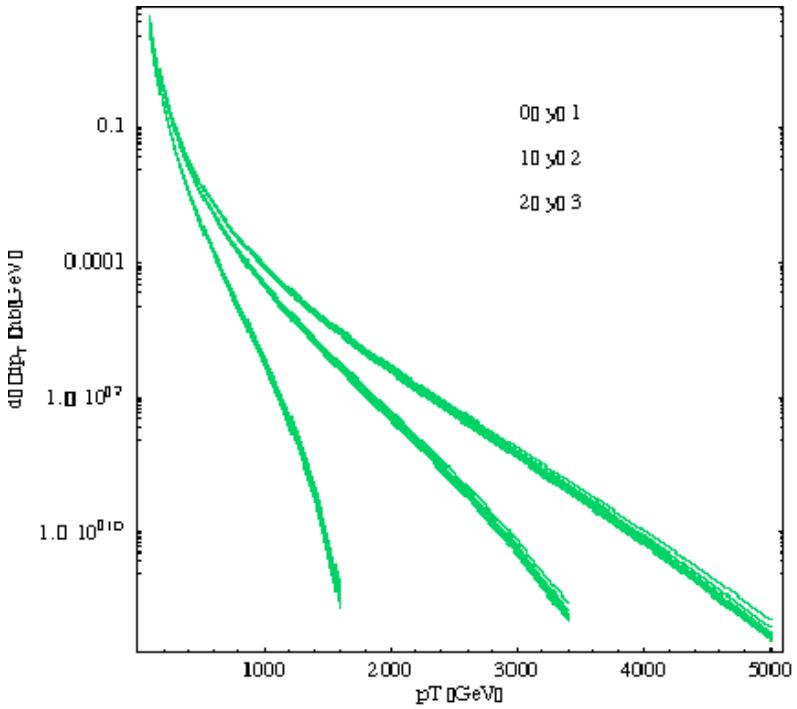
See http://www.pa.msu.edu/~huston/run2btdr_qcd/tdr.ps .

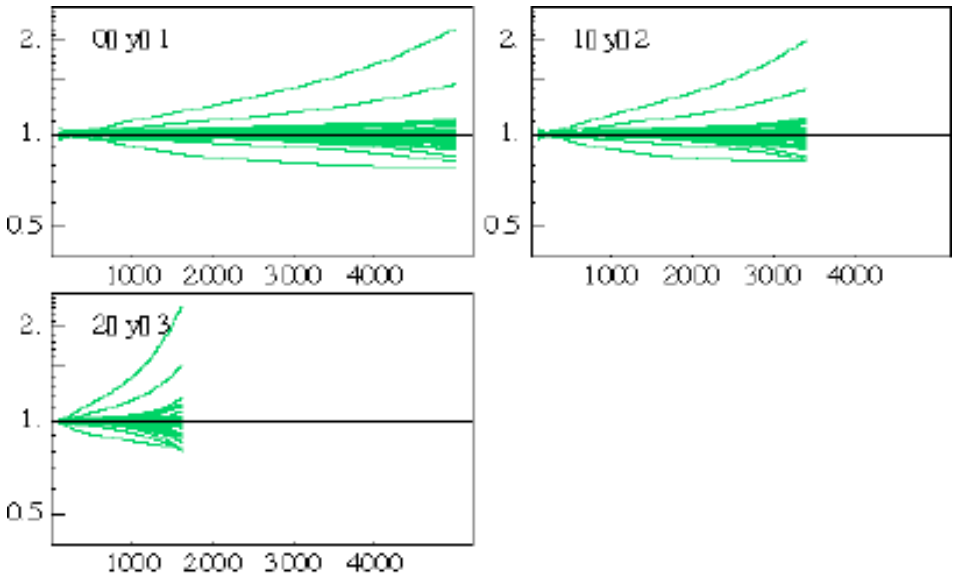


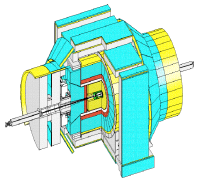


Jet cross sections at the LHC

- Apply the same exercise to the LHC







Conclusions regarding jet uncertainties

- Paper should be finished in <1 month
  - uncertainties on jet cross sections in both Run 1 and Run 2
  - room for new physics in both