Rob Snihur – McGill University
Lake Louise Winter Institute 2008

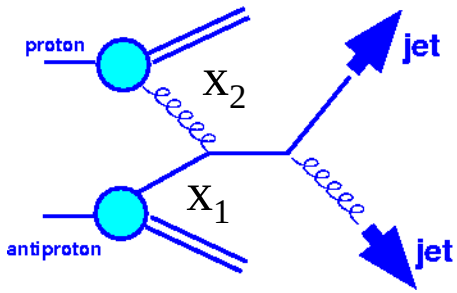
Jet Physics with the Collider Detector at Fermilab

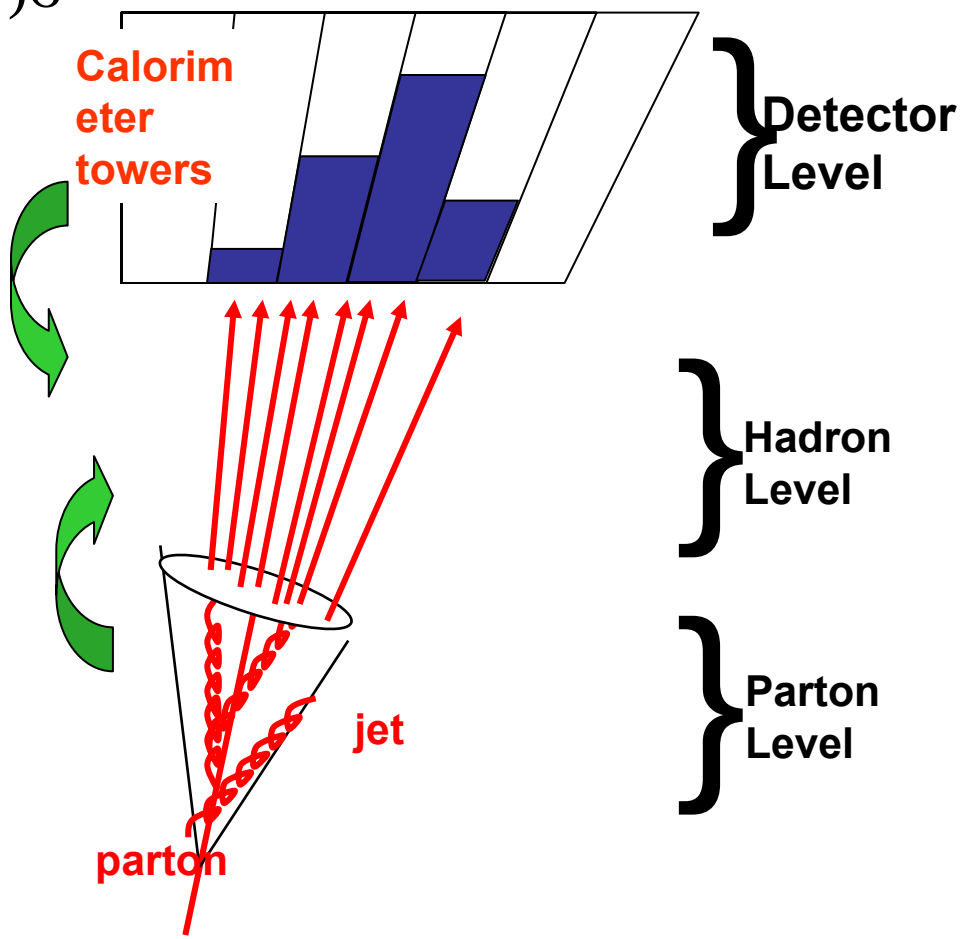
(for the CDF collaboration)

- Jets
- Inclusive jet production
- Bottom jets
- Jets + W/Z
- Summary

Jets

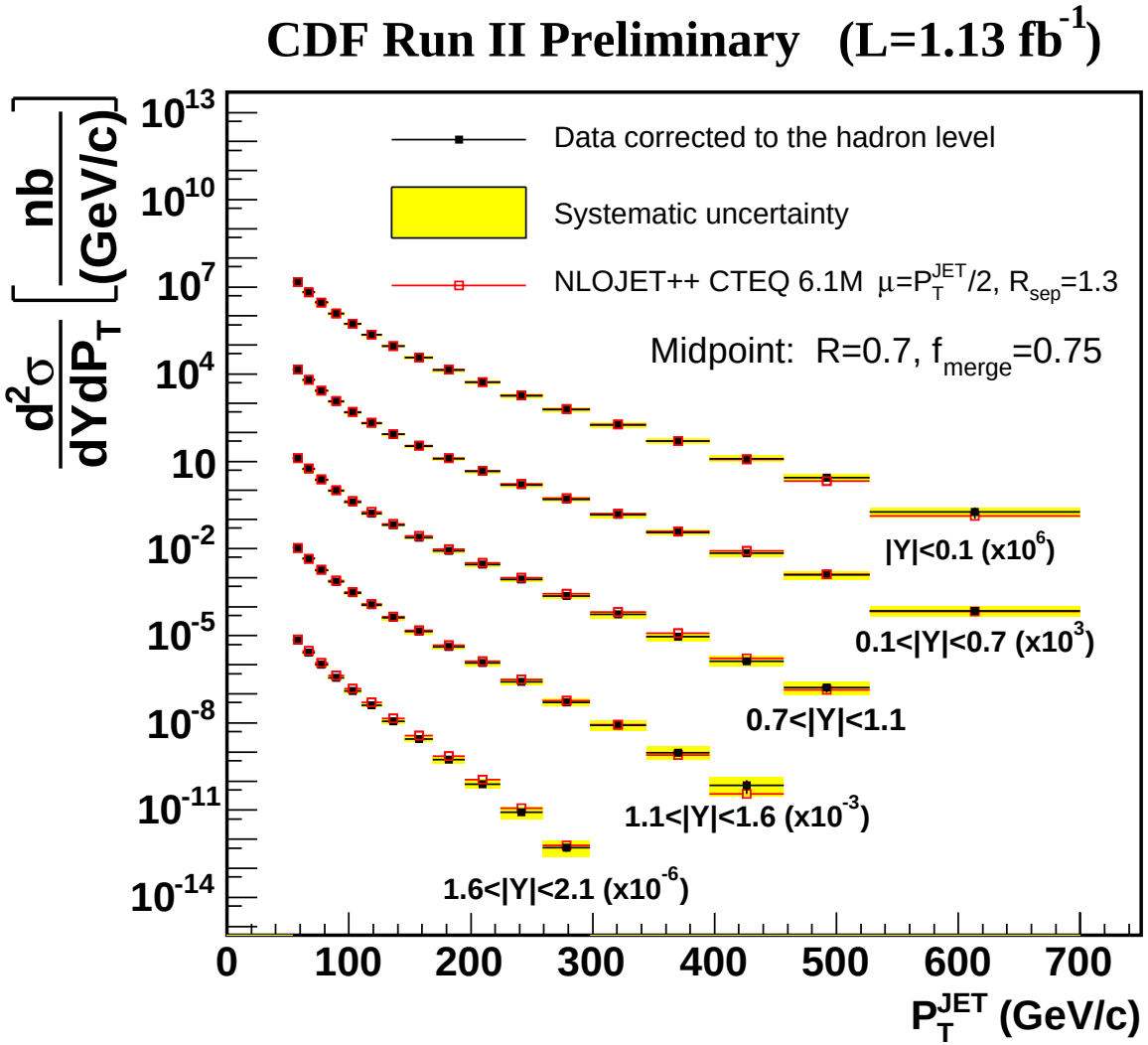
$$\sigma_{GQ}^{total} = \sum \int dx_1 dx_2 f_q(x_1, Q^2) f_g(x_2, Q^2) \hat{\sigma}^{parton}$$

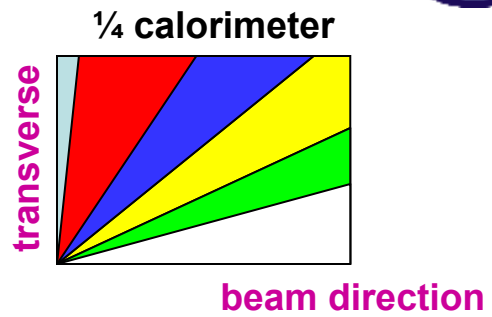




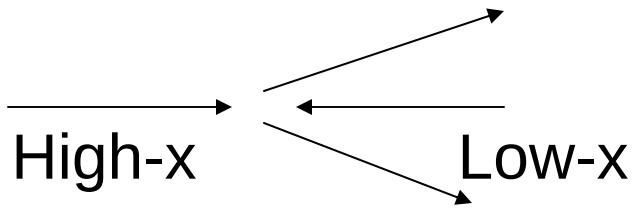
- **Tevatron is a jet factory!**
- **Learn about**
  - **Structure of proton (PDFs)**
  - **Perturbative QCD (LO, NLO, etc.)**
  - **New physics**
- **Experimental measurement of jet energy is usually the largest source of systematic error**

Inclusive jet production

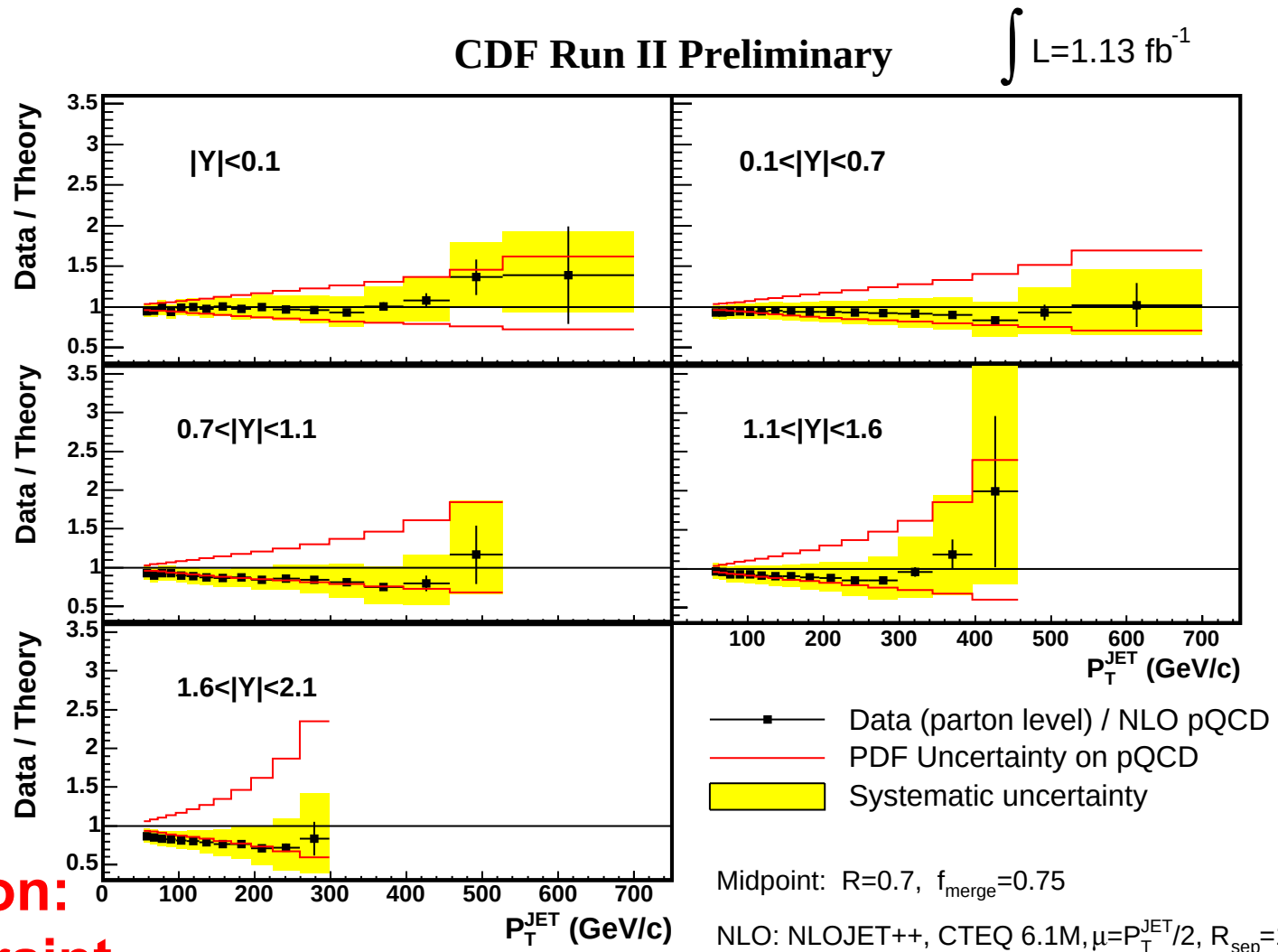




- **Central jets (low y)**
  - **High Q^2**
  - **Look for new physics**
- **Forward jets (high y) ➔ low x**



Inclusive jet production

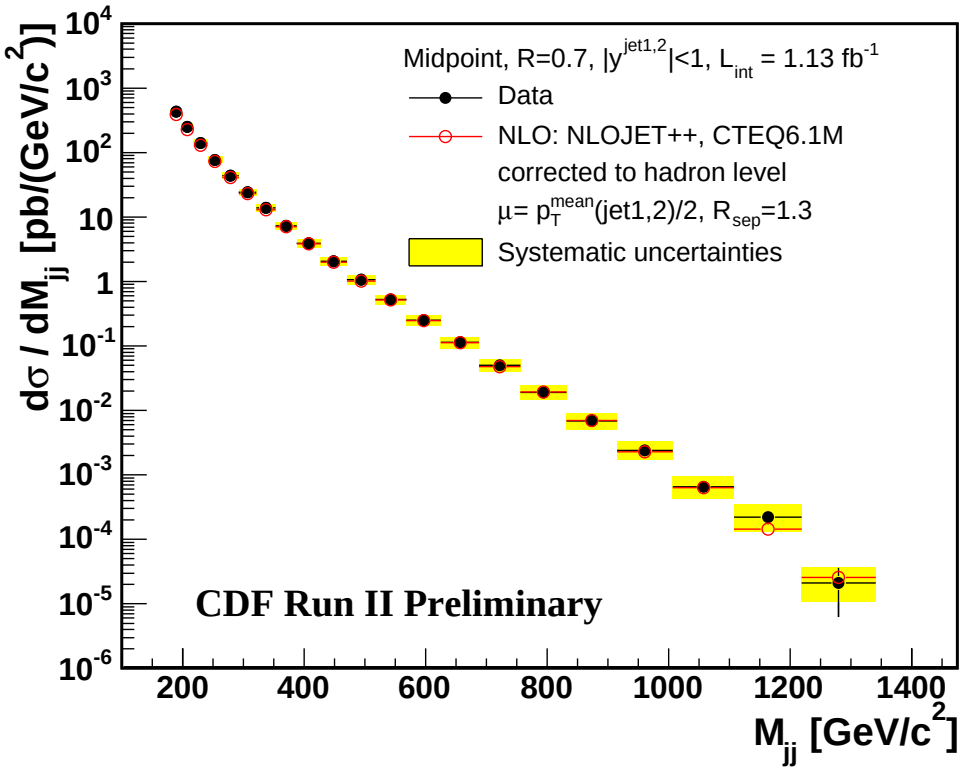


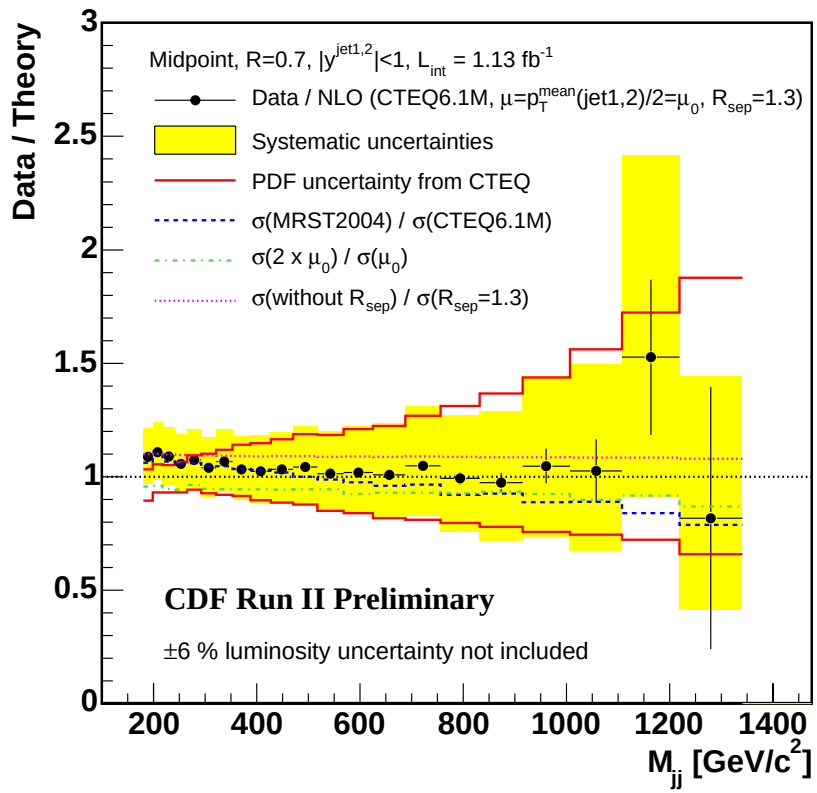
Midpoint: R=0.7, f_{merge}=0.75

NLO: NLOJET++, CTEQ 6.1M, $\mu=P_T^{JET}/2$, R_{sep}=1.3

Forward region: useful constraint on global PDF fits

Dijet production

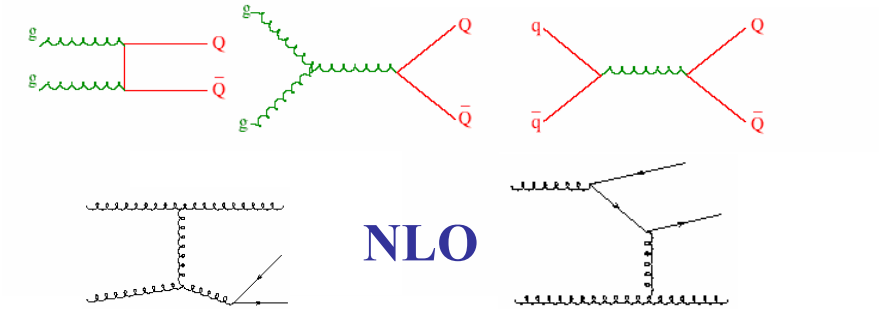




- **Experimental uncertainties comparable to those on PDFs**
- **Heavy resonances / compositeness limits extracted**

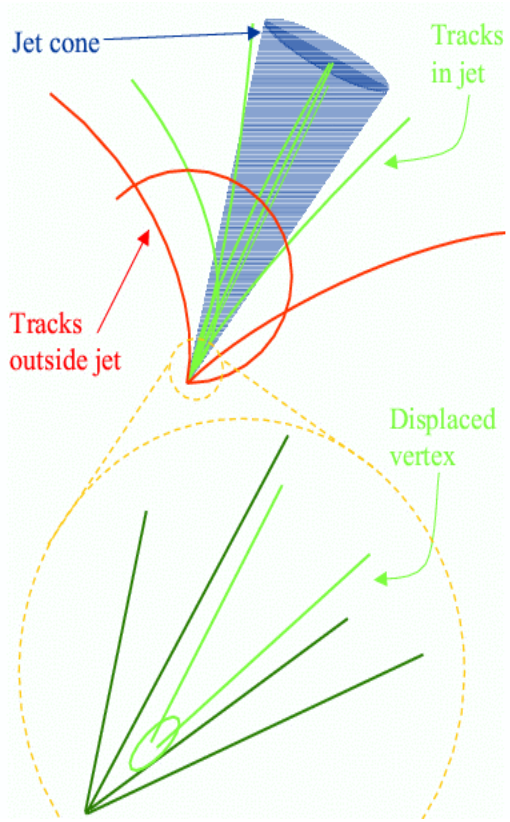
Jets from bottom quarks

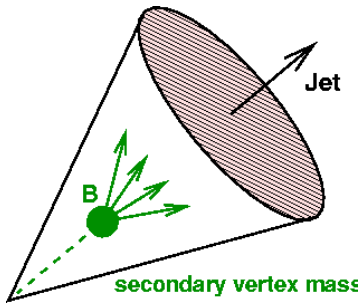
LO: Flavor creation

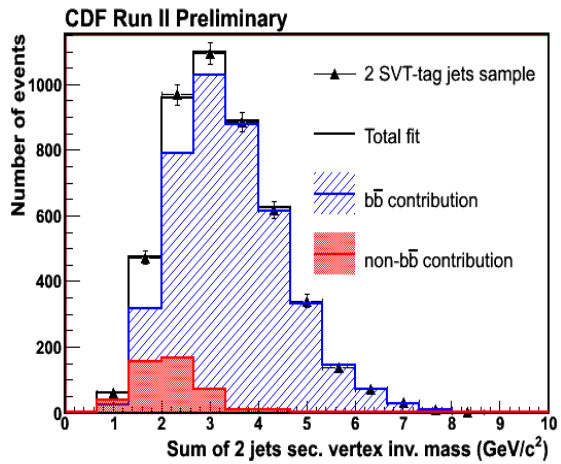


NLO

Gluon splitting **Flavor excitation**







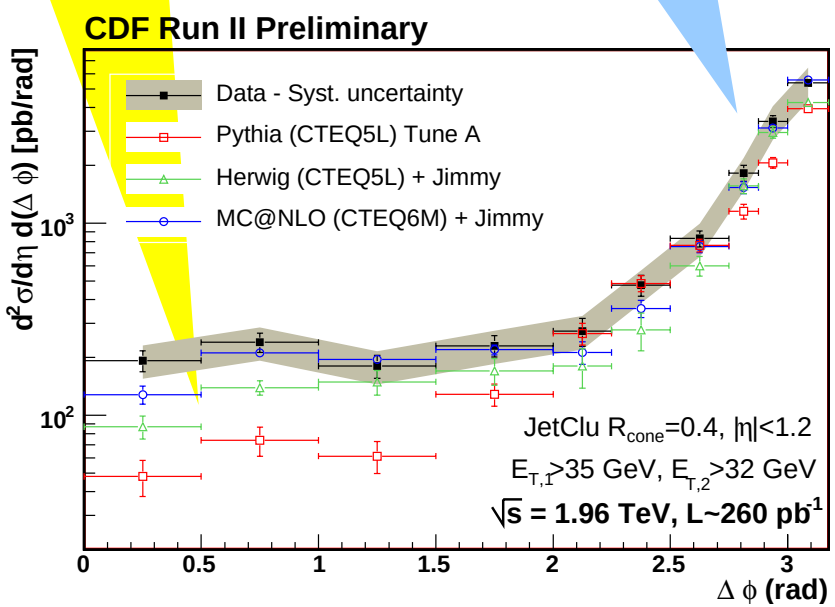
Purity ~ 85 % : extracted from data using shape of secondary vertex mass

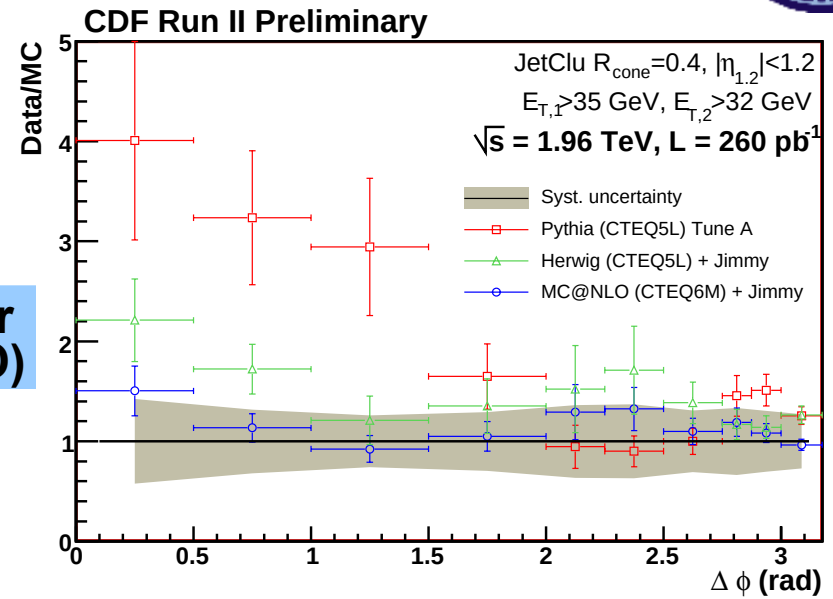
$b\bar{b}$ dijet production

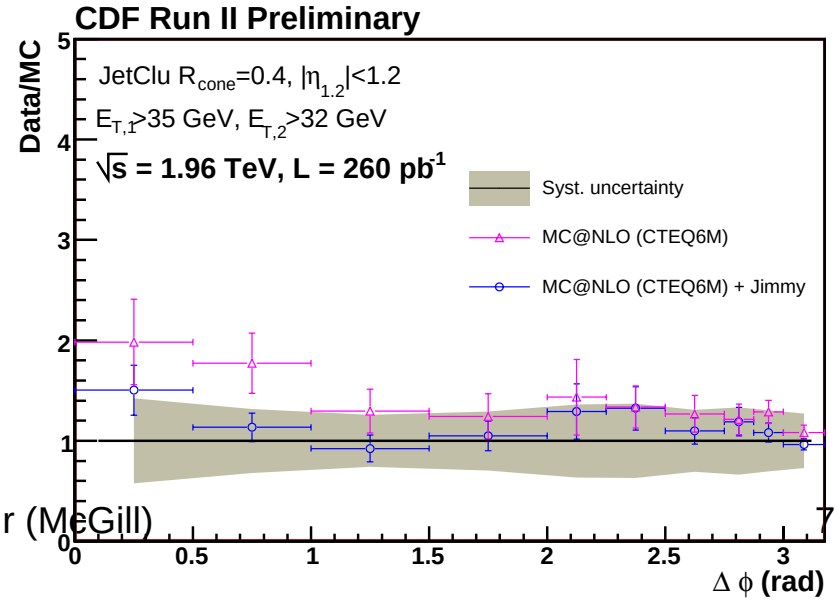
$\Delta\phi$ is sensitive to the different production mechanisms

Small $\Delta\phi$: flavor excitation & gluon splitting (NLO)

Large $\Delta\phi$: flavor creation (LO)



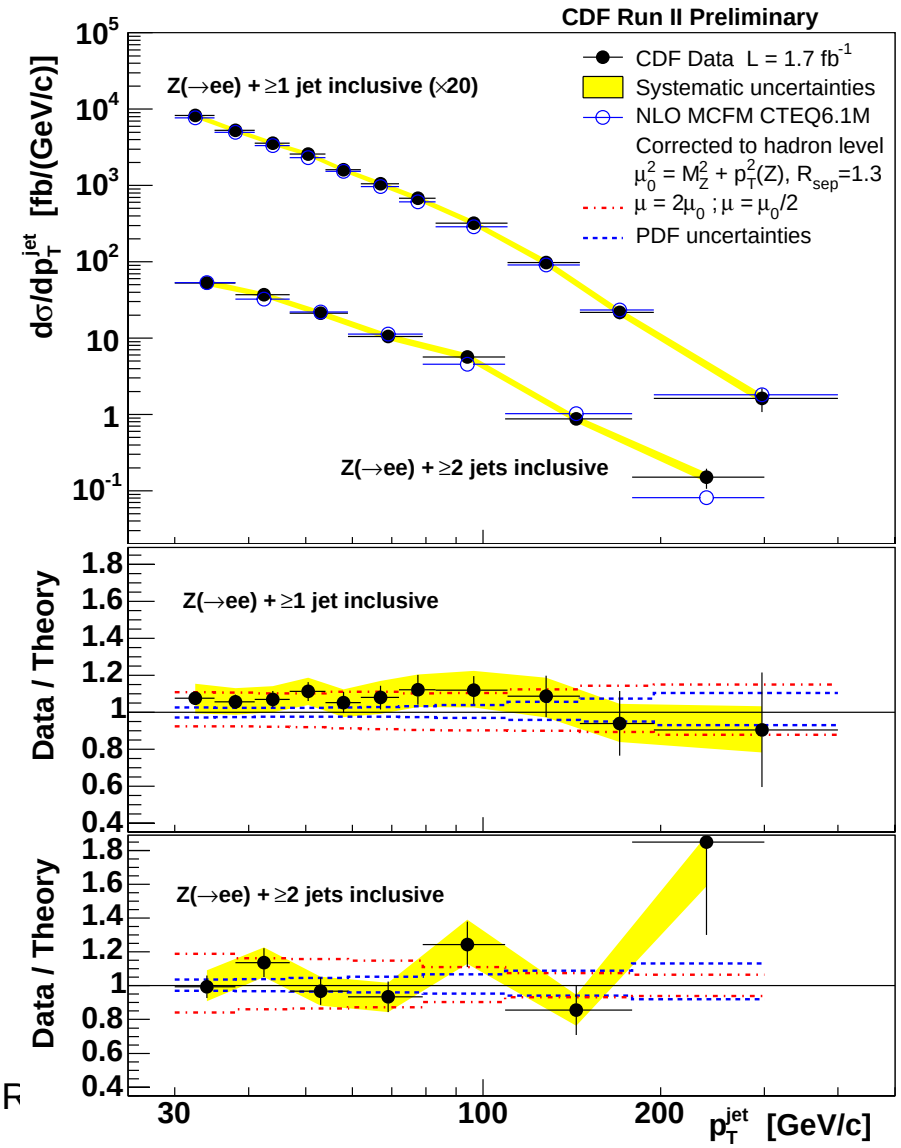




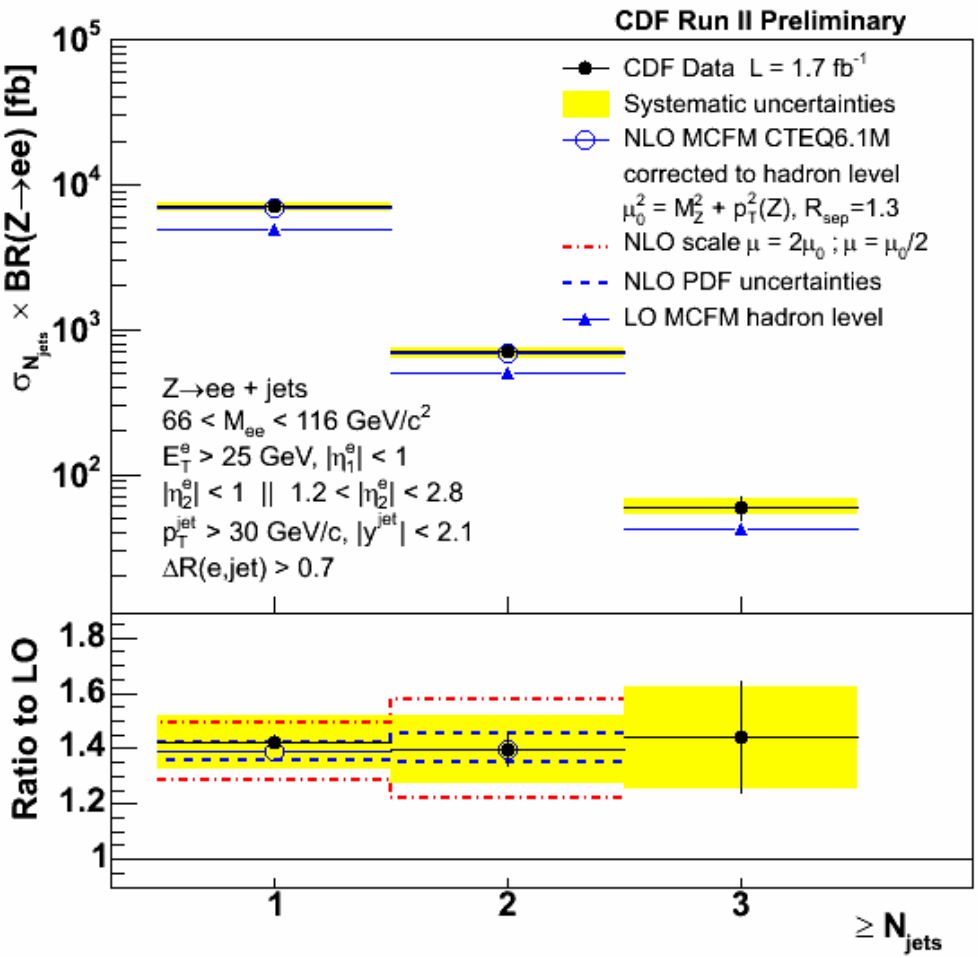
Best description: NLO + UE

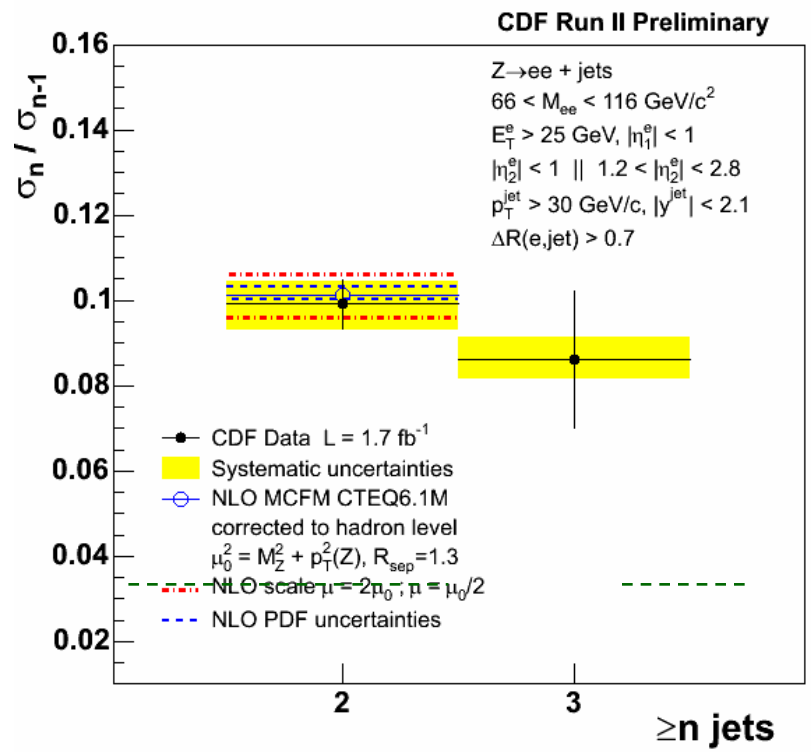
Z + jets production

- Small backgrounds
- Can be used to test QCD at high Q^2
- Important background for Higgs and squark/gluino searches
- Z ➔ ee
- 1, 2, or 3 jets
- NLO shows good agreement



Z + jets: Integrated cross section





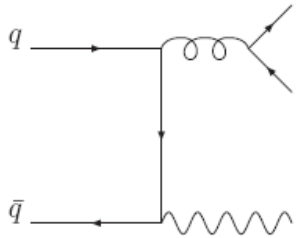
- **Excellent agreement**
- **Constant NLO/LO ratio**
- **$\sigma(N)/\sigma(N-1) \approx \alpha_s(M_Z)$**

W + b-jet production

Many interesting processes have W & b

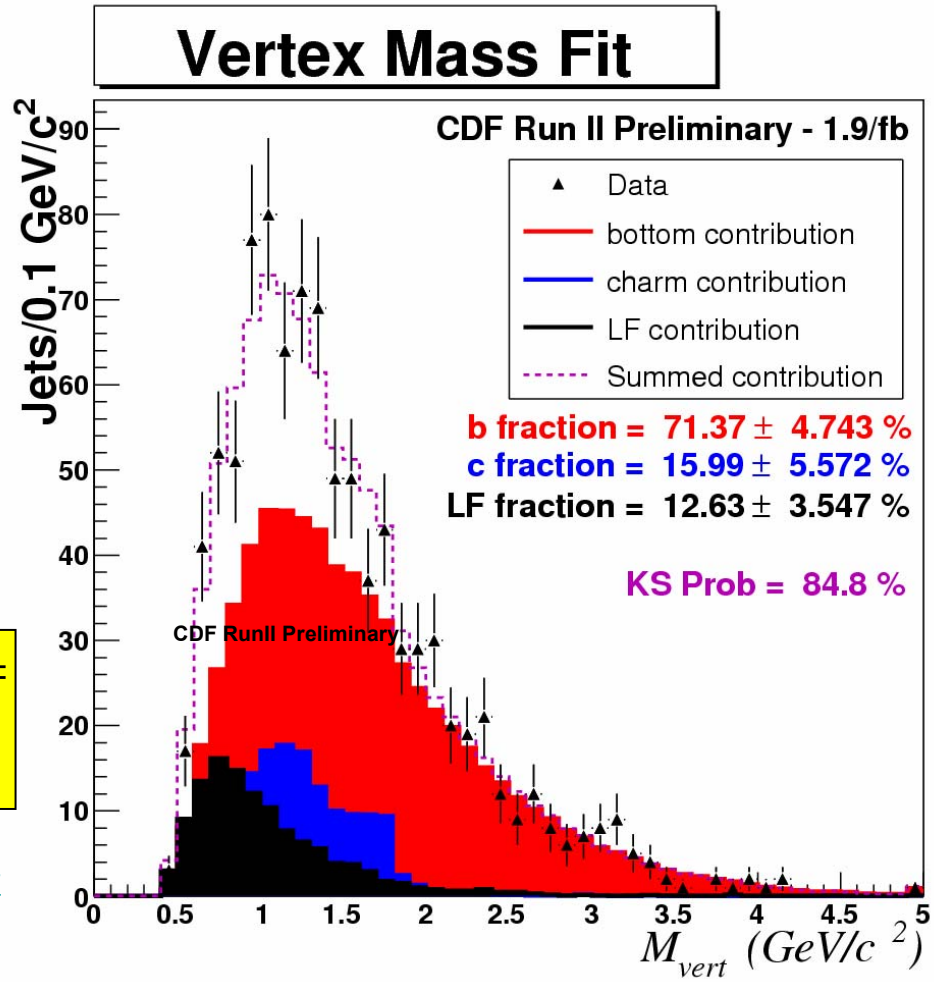
- **ttbar → *WbWb***
- **Single top → *Wbb***
- ***WH* → *Wbb***

QCD production dominates all



$$\sigma_{\text{b-jets}}(W+b-\text{jets})\times \text{BR}(W\to \ell\nu) = 2.74\pm 0.27(\text{stat})\pm 0.42(\text{syst})\ \text{pb}$$

This cross section is for *b* jets from *W*+*b*-jet production in events with a high p_T central lepton, high p_T neutrino and 1 or 2 total jets.

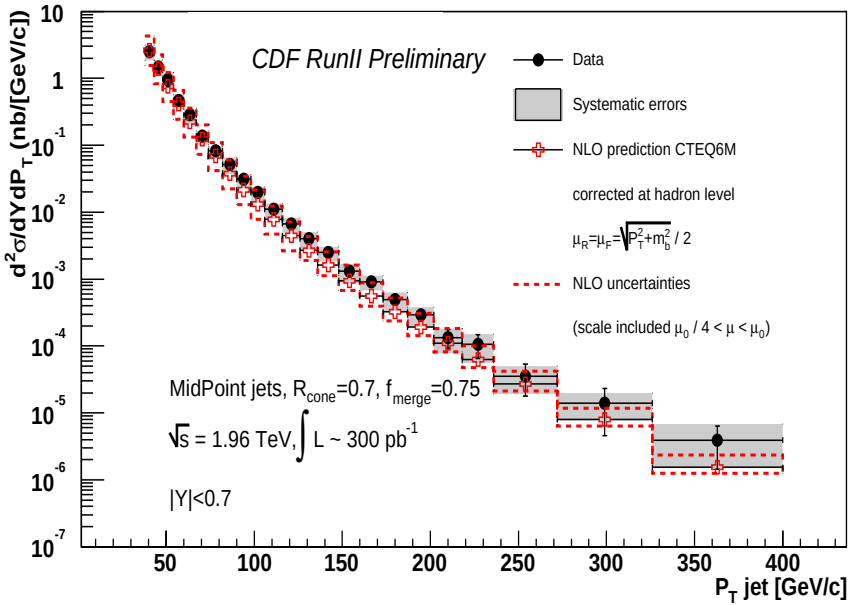


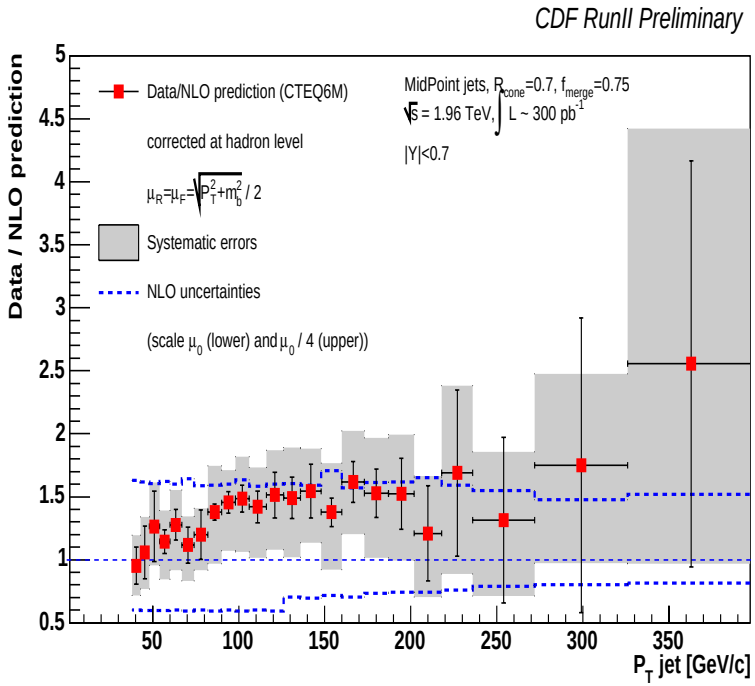
Summary

- **Jets studied in detail at CDF**
  - **Inclusive jet production**
    - **Experimental errors now small enough to probe PDFs @ low x (➔ high y)**
  - **b jet production**
    - **Test production mechanisms of heavy quarks**
  - **Jets produced with W & Z bosons**
    - **Test the predictions of the ME+PS MCs**
    - **Validate background estimates in searches for new physics**
- **QCD in good agreement with data ☺**
  - **8 orders of magnitude in p_T**
  - **Will help to better constrain the gluon PDF**
- **Tevatron will deliver a lot more data until 2009**

Backups

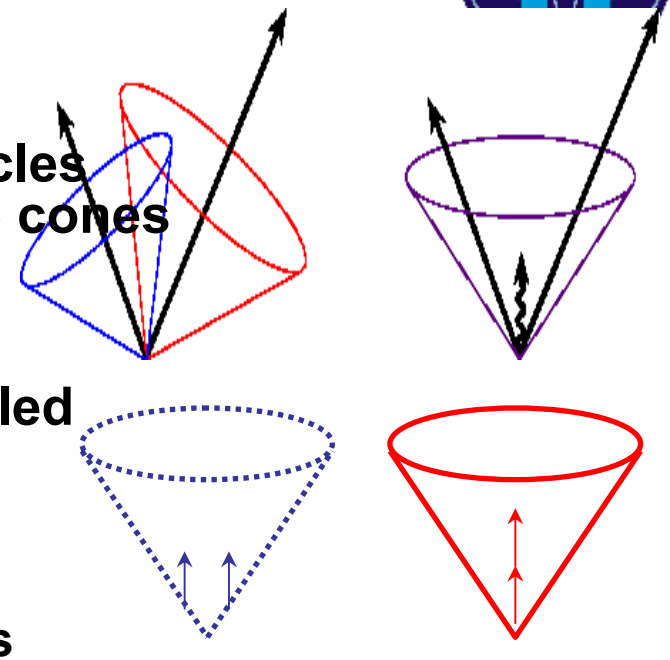
Inclusive b-jet production





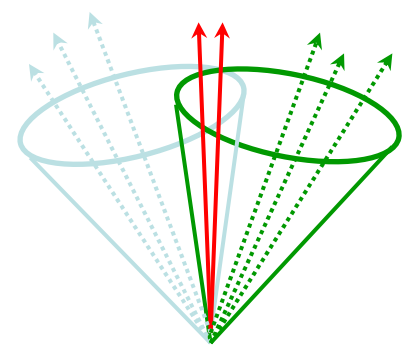
Cone Jet Algorithms and pQCD

- **Iterative cone algorithms**
  - **Staring from seeds, iteratively cluster particles in cones of radius R_{CONE} and look for stable cones (geometrical center = p_T-weighted centroid)**
- **Infrared and Collinear Safety**
  - **Fixed order pQCD contains not fully cancelled infrared divergences**
    - **Inclusive jet cross section affected at NNLO**
  - **Tevatron Run II Cone Algorithm: Midpoint**
    - **Uses midpoints between pairs of proto-jets as additional seeds → Infrared and collinear safety restored**
- **Merging/Splitting**
  - **Emulated in NLO pQCD calculation by merging 2 partons only if they are within $R' = R_{CONE} \times R_{SEP}$ of each other**
    - **Arbitrary parameter R_{SEP}: prescription $R_{SEP} = 1.3$ (based on parton level approximate arguments)**



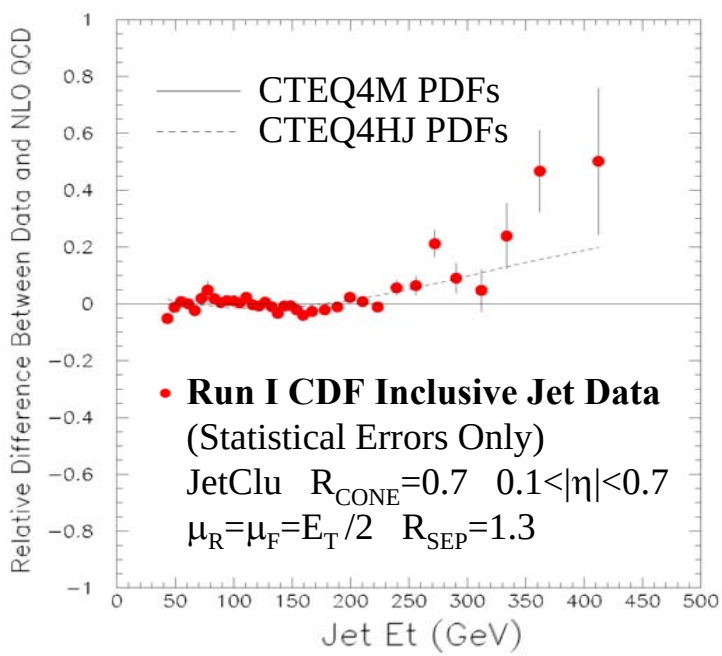
below threshold (no jets)

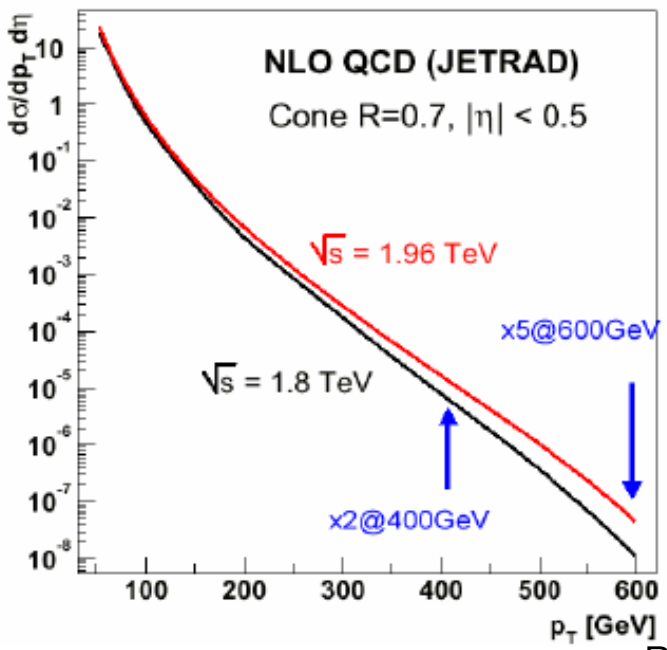
above threshold (1 jet)



Inclusive Jets @ the Tevatron

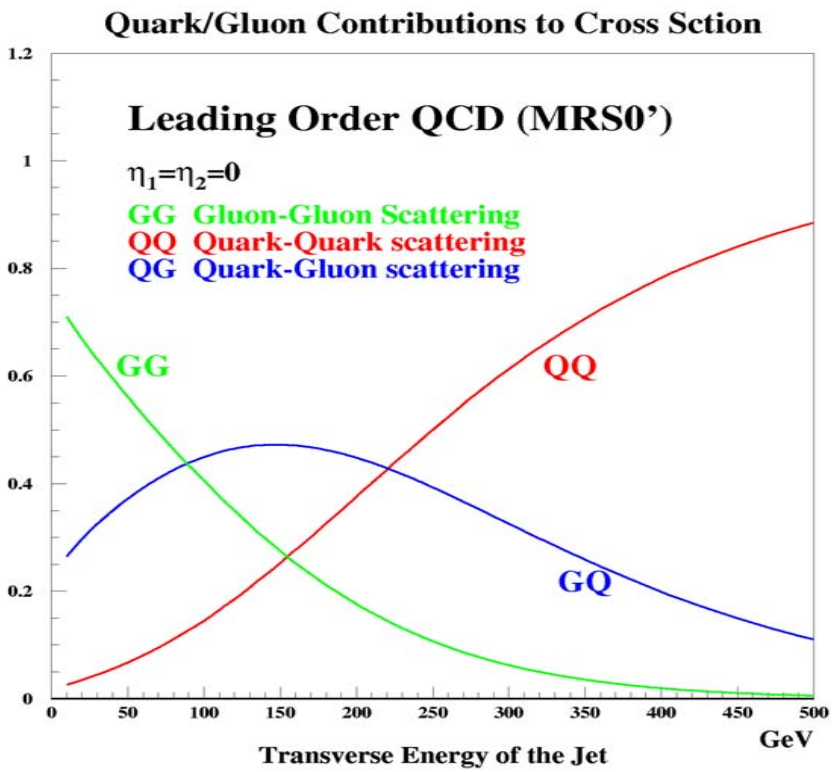
- **Legacy from Run I**
  - **Great interest on apparent excess at high E_T**
  - **SM explanation**
    - **Gluon PDF increased at high x**
    - **Recent PDFs from global fit include CDF and D0 jet data from Run I (CTEQ6, MRST2001)**

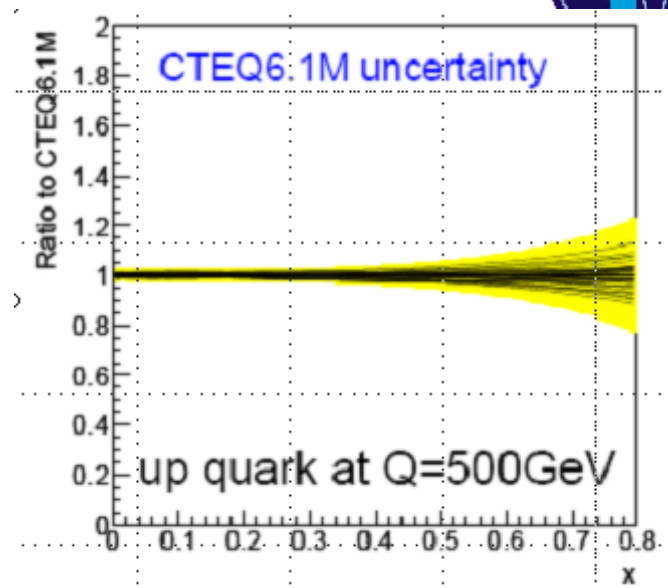


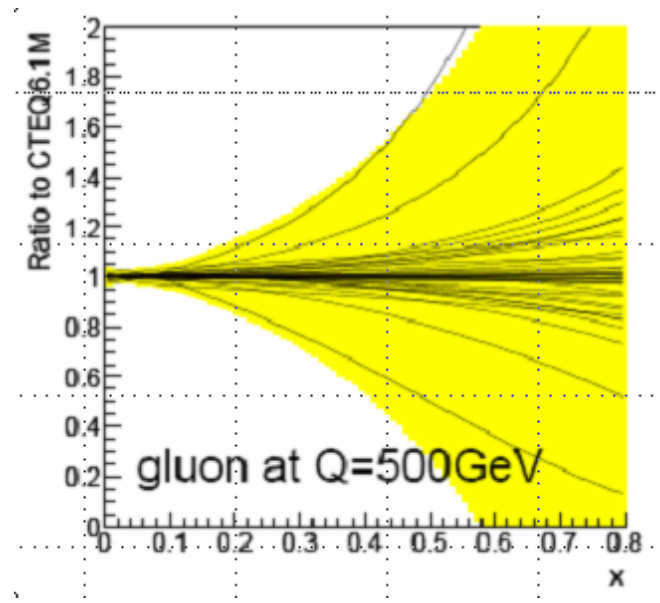


- Stringent test of pQCD
  - Over ~ 8 orders of magnitude
- Tail sensitive to New Physics
  - Probing distances ~ 10^{-19} m
  - Production enhanced at high p_T thanks to new $\sqrt{s}$
- PDFs at high Q^2 & high x

Gluon PDF at high x





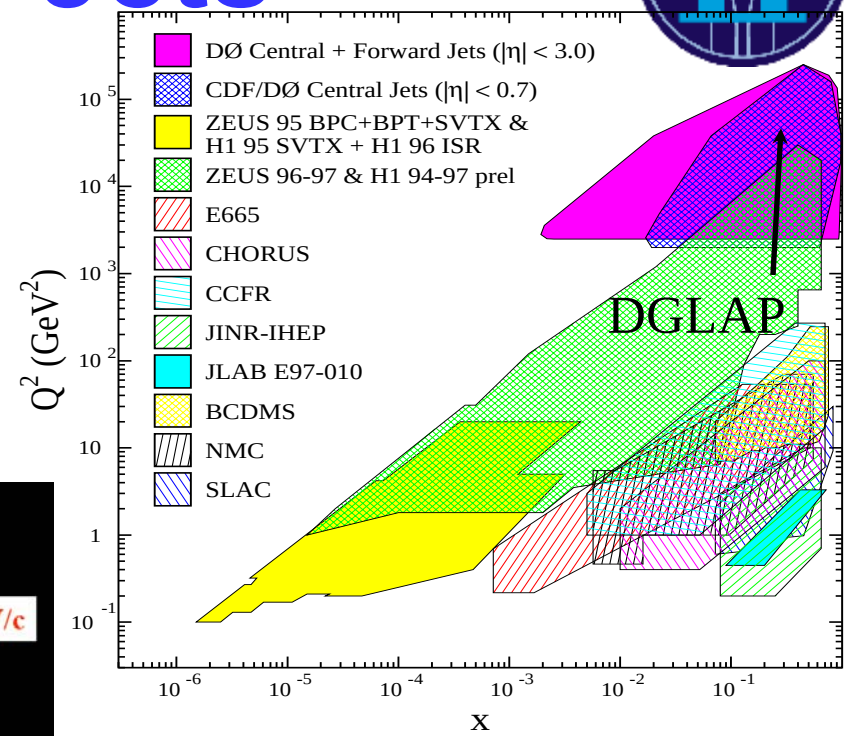


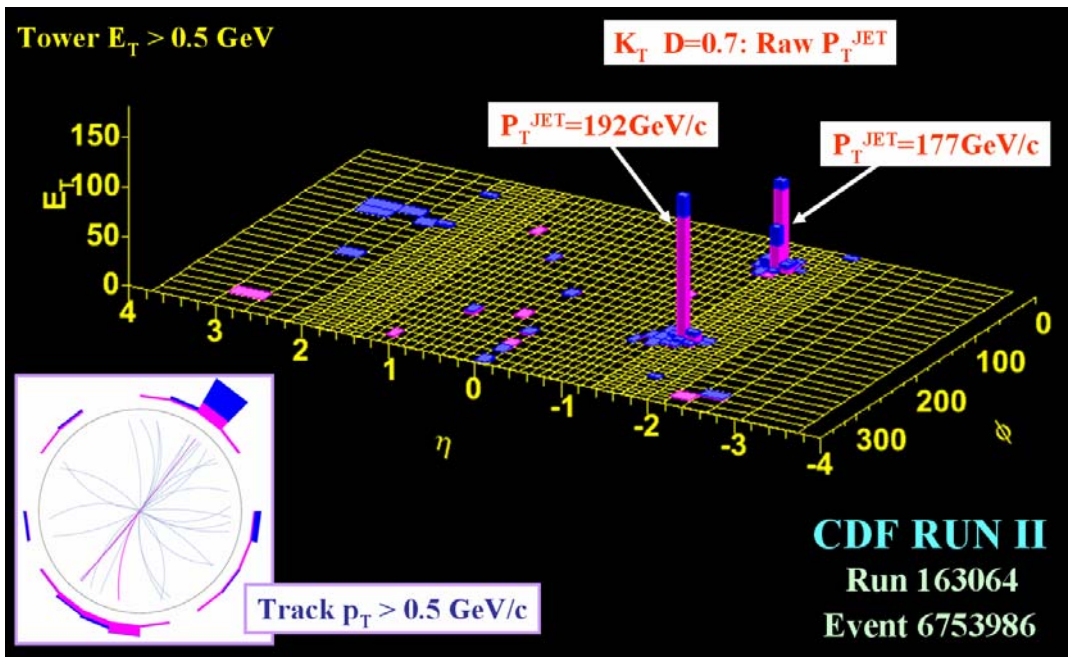
Important GG and GQ contributions

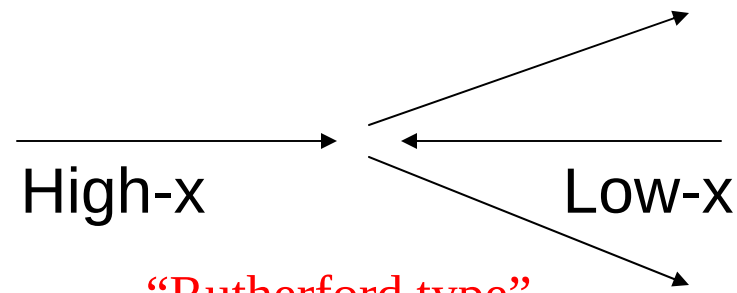
Rob Snihur (McGill)

Forward Jets

- **Essentials to pin down PDFs vs. eventual New Physics at higher Q^2 in central region**
  - **DGLAP gives Q^2 evolution**
- **Expend x range toward low x**



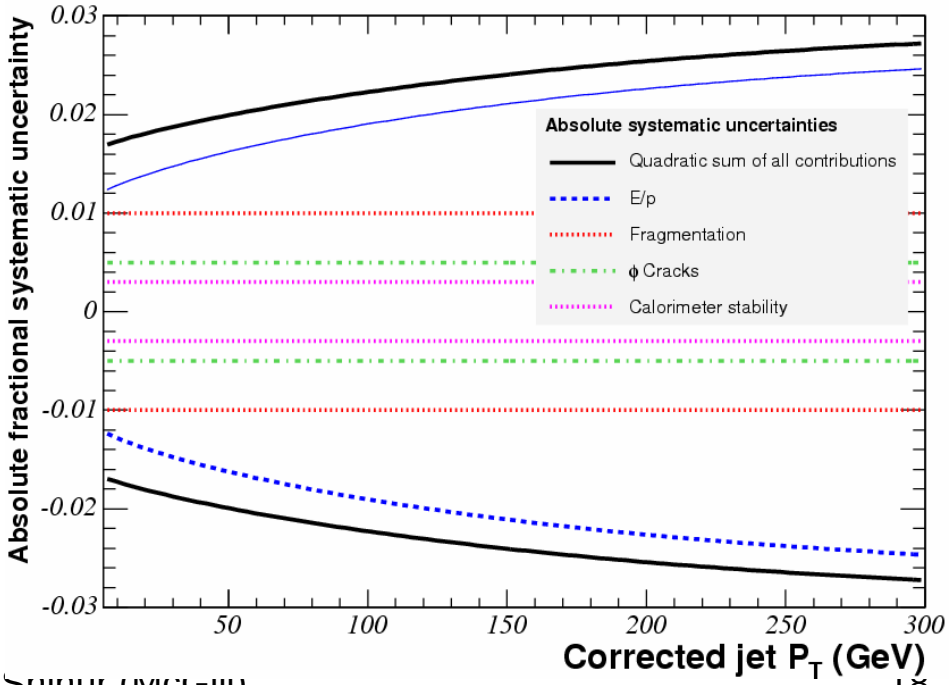




"Rutherford type" parton backscattering

Jet Energy Scale

- **Absolute Calibration: central calorimeter response very well reproduced by the simulation**
  - **E/p of isolated tracks used to tune the showering simulation (G-Flash)**
    - ⇨ **Residual discrepancies taken as systematic uncertainties**
  - **Reasonable simulation of the p_T spectrum of the particles within a jet by PYTHIA and HERWIG fragmentation models**
    - ⇨ **Induced difference on Jet Energy Scale < 1%**
  - **Photon-jet balance**
    - ⇨ **Data and Simulation agree at 1% to 2% level**



- **Non uniformity versus η**
  - **Dijet balance**
- **Resolution**
  - **Bisector method**