Proton parton-density-function constraints from Tevatron data on photon and jet production

Photon 2007

9 - 13 July 9, Paris

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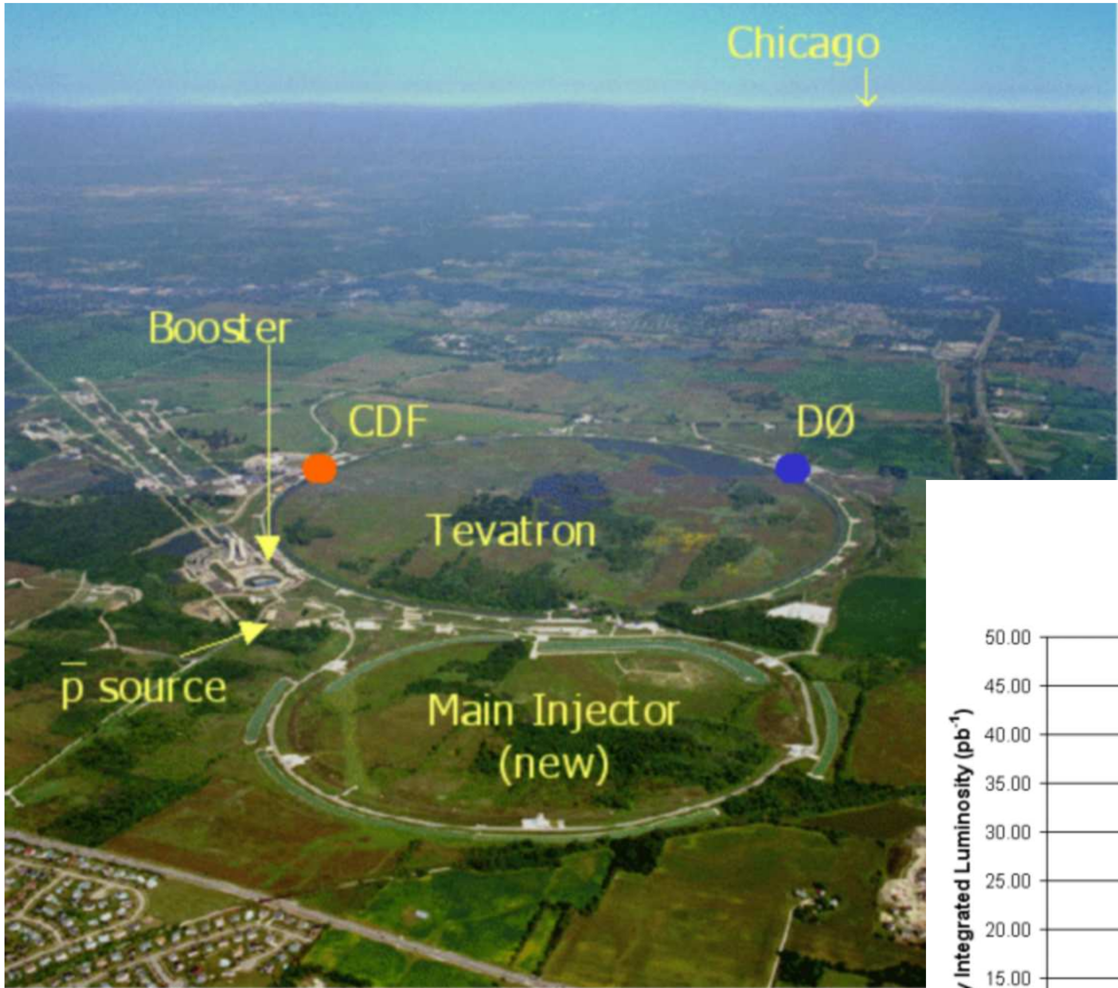
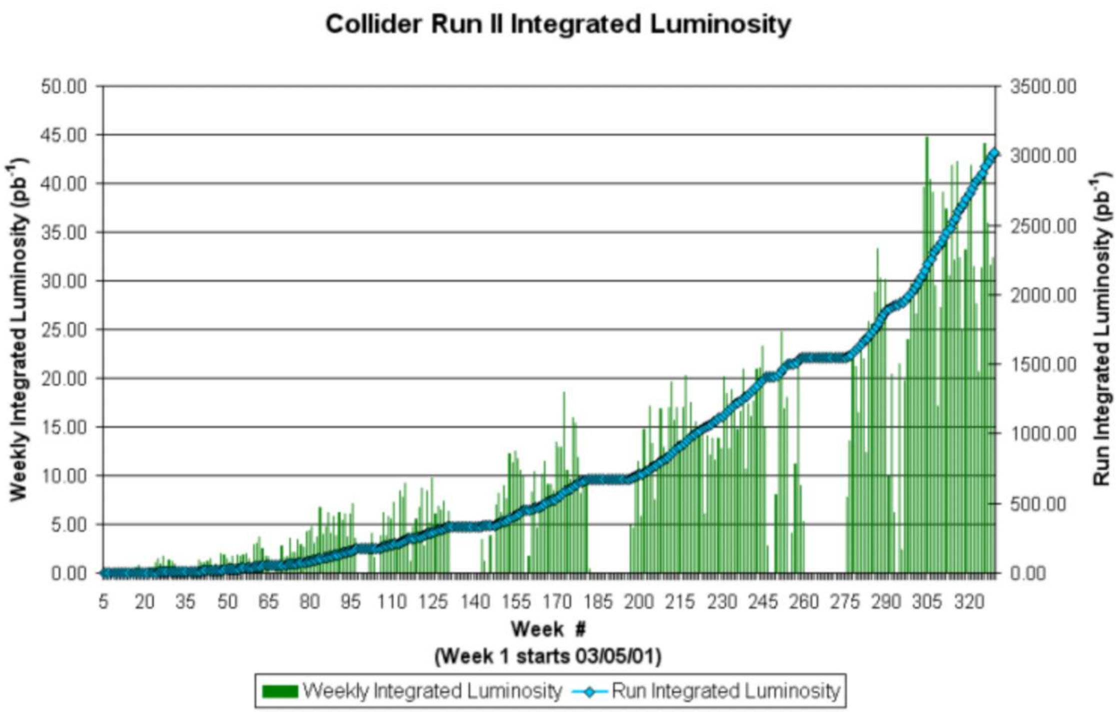
Tevatron



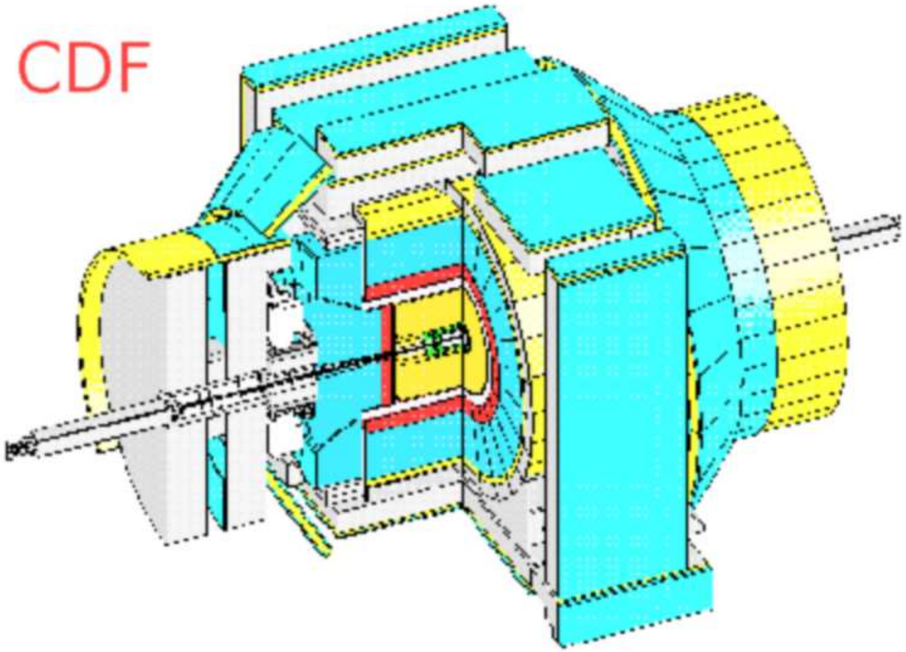
- Run I → Run II
  - 1.8 TeV → 1.96 TeV
  - luminosity upgrade
- delivered more than

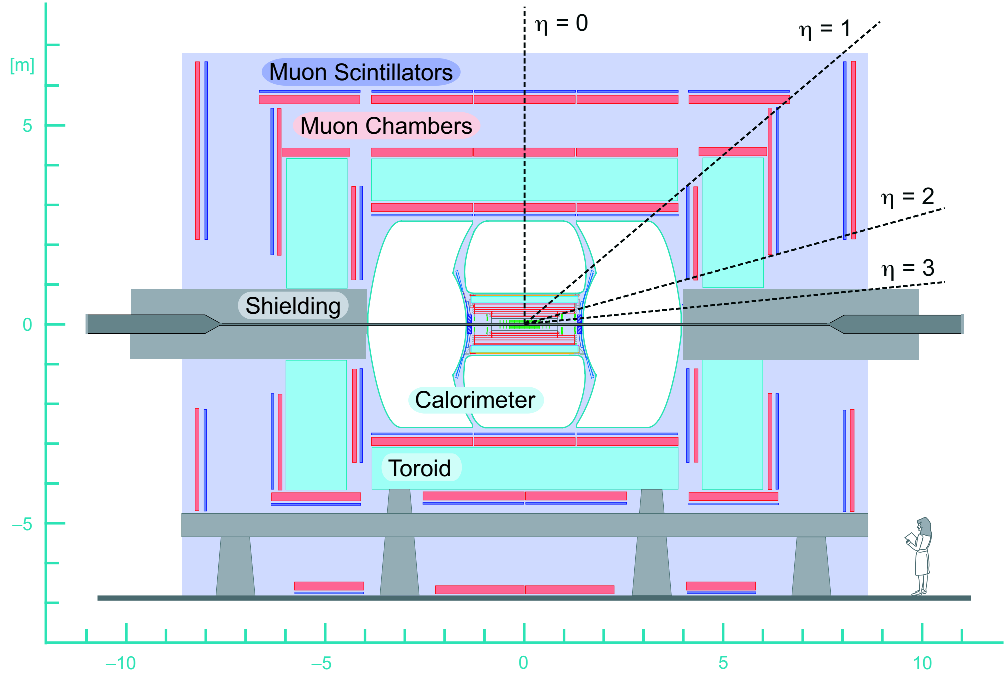
$$\mathcal{L} \sim 3.0\,\text{fb}^{-1}$$



- Long Term Luminosity Plans (2009)
  - base goal: $4.4\,\text{fb}^{-1}$, design: $8.5\,\text{fb}^{-1}$

CDF and DØ calorimeters





- lead/iron + scinitillator
- new plug calorimeter

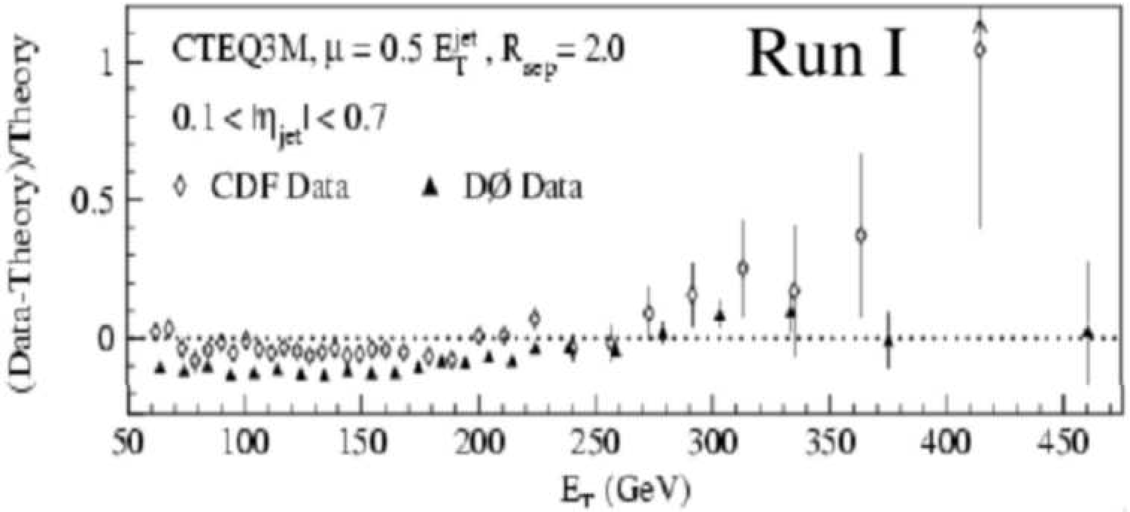
- uranium/iron + liquid argon

- faster readout and trigger electronics
  - 396 ns between $p\bar{p}$ bunches in RunII; $2.4\,\mu$s in RunI
- new tracking detectors ⇒ more material in front of calorimeter
- new calorimeter calibration needed (→ also new jet energy calibration)

High p_T jets

Main results from Run I

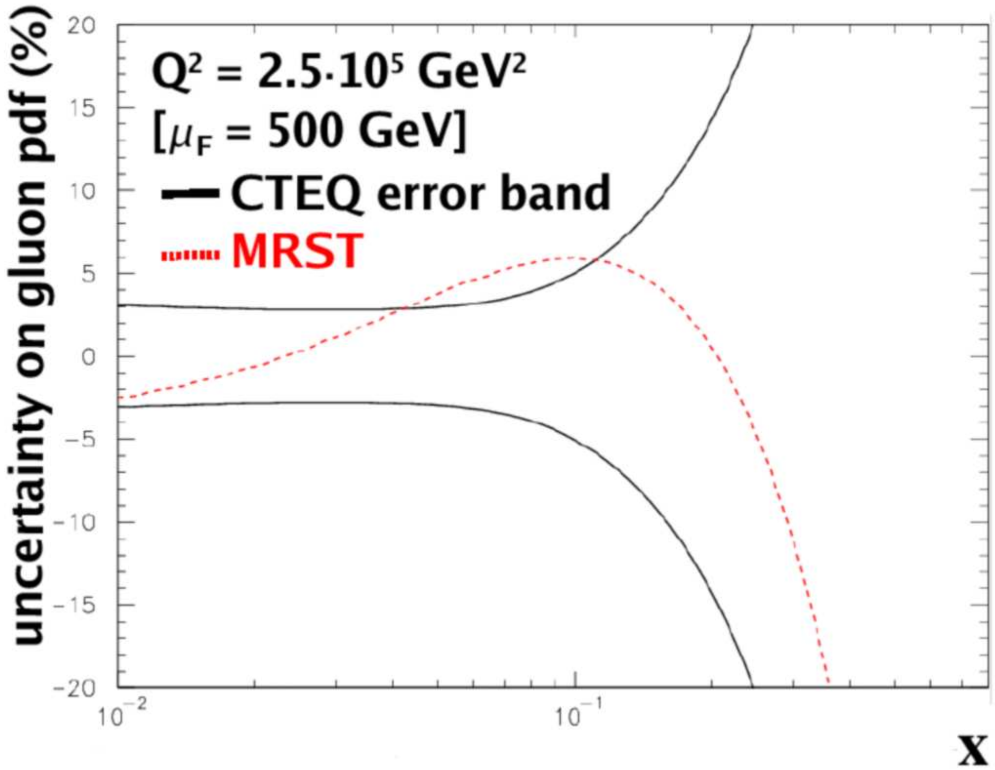
- constraining gluon distribution function at high x
- confirmation of QCD
- no quark substructure observed up to ~ 2 TeV scale

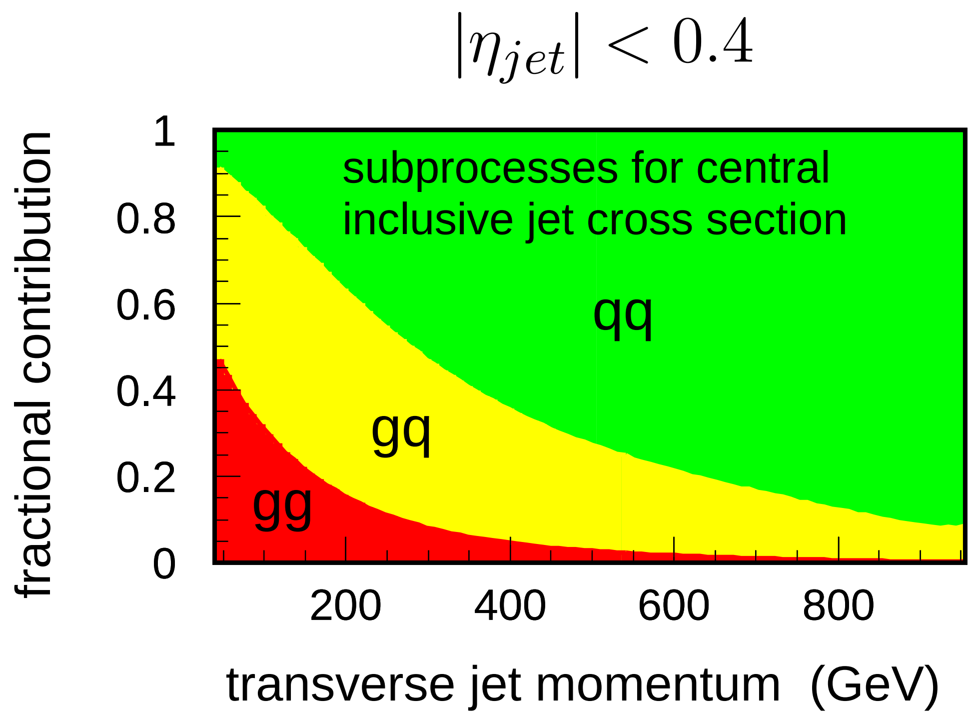


High p_T jets in Run II

- higher luminosity (Run I results based on $0.1\,\text{fb}^{-1}$ of data)
- increase of beam energy (another factor of three in cross section for jets with $p_T \sim 600$ GeV)
- calls for new improved measurements with extended reach at high energies

Gluons at large x



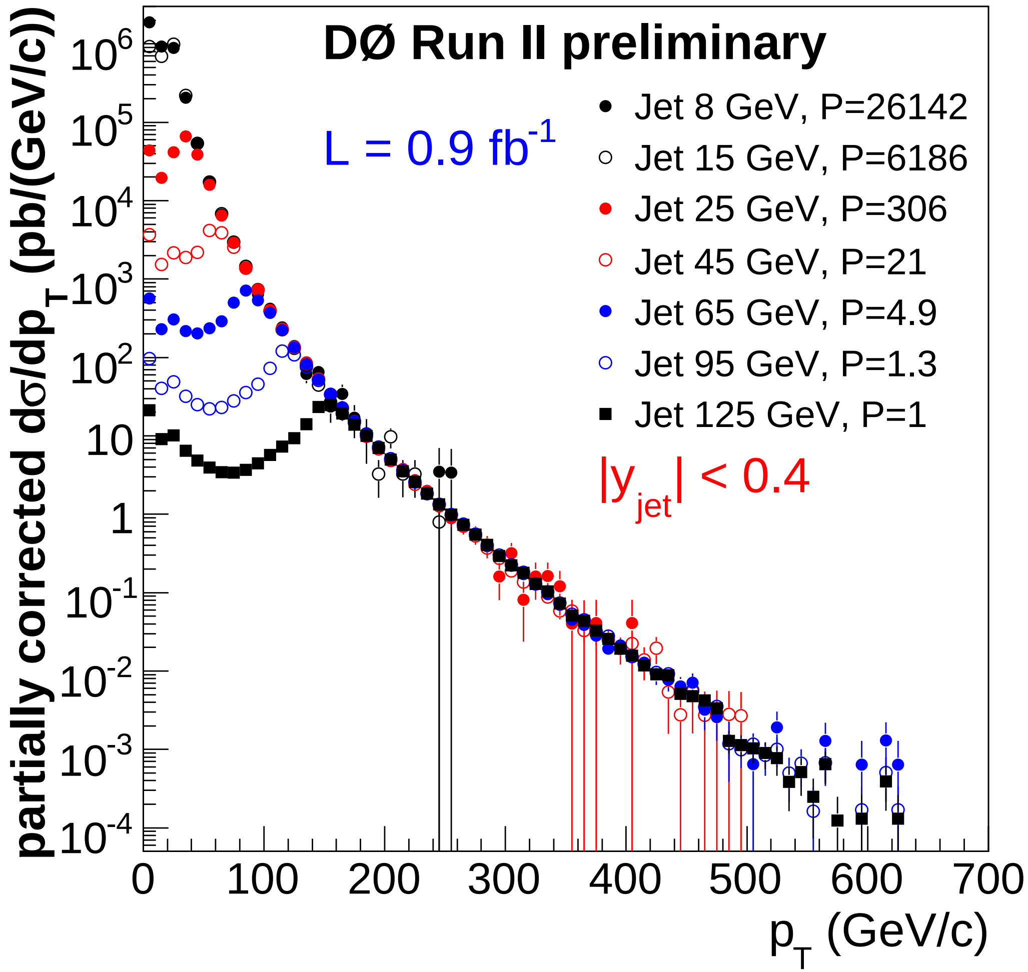


(from DURHAM on-line calculator)

- quark distribution functions quite well constrained even at large values of fractional momenta x
- not too much known about gluons at large x

Jet Triggers

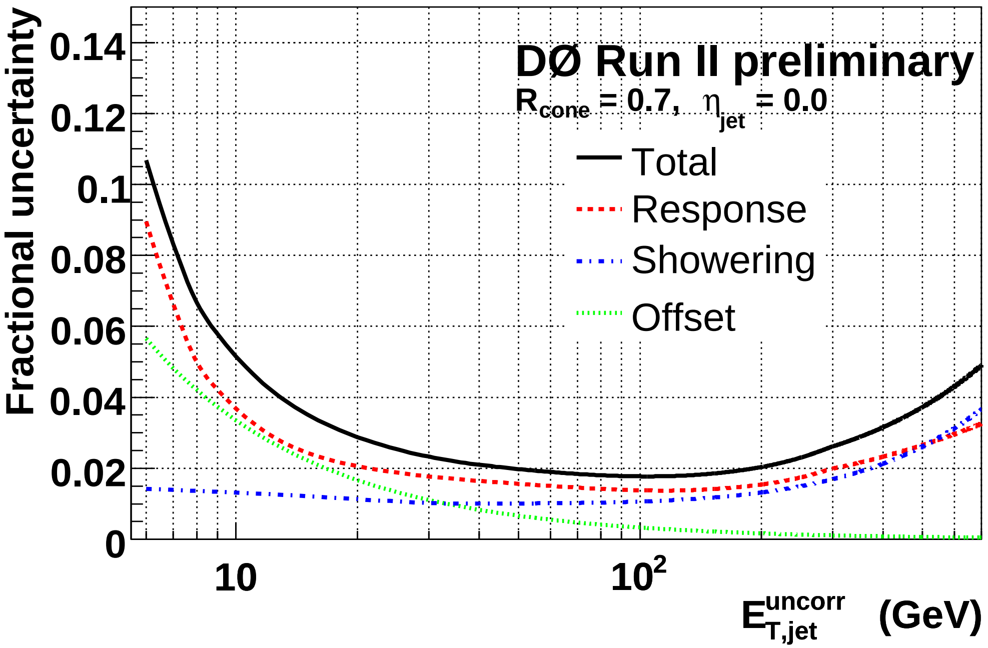
- inclusive jet spectrum falls down by 10 orders of magnitude
- set of jet triggers with increasing jet p_T thresholds
- triggers with lower p_T threshold are more and more prescaled
- the highest p_T trigger collects the full luminosity
- final spectrum is pieced together from all triggers; trigger is used once it is fully efficient



- due to steeply falling spectrum, the measurement of jet production is extremely sensitive to the precision of jet energy calibration

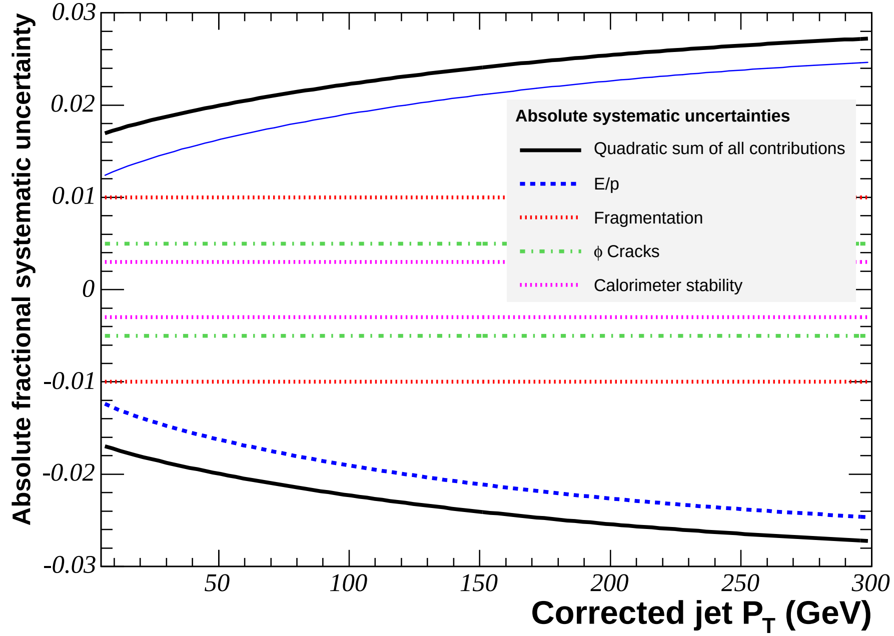
Jet energy calibration

- **DØ:** in-situ calibration
  - from p_T imbalance in γ+jet events



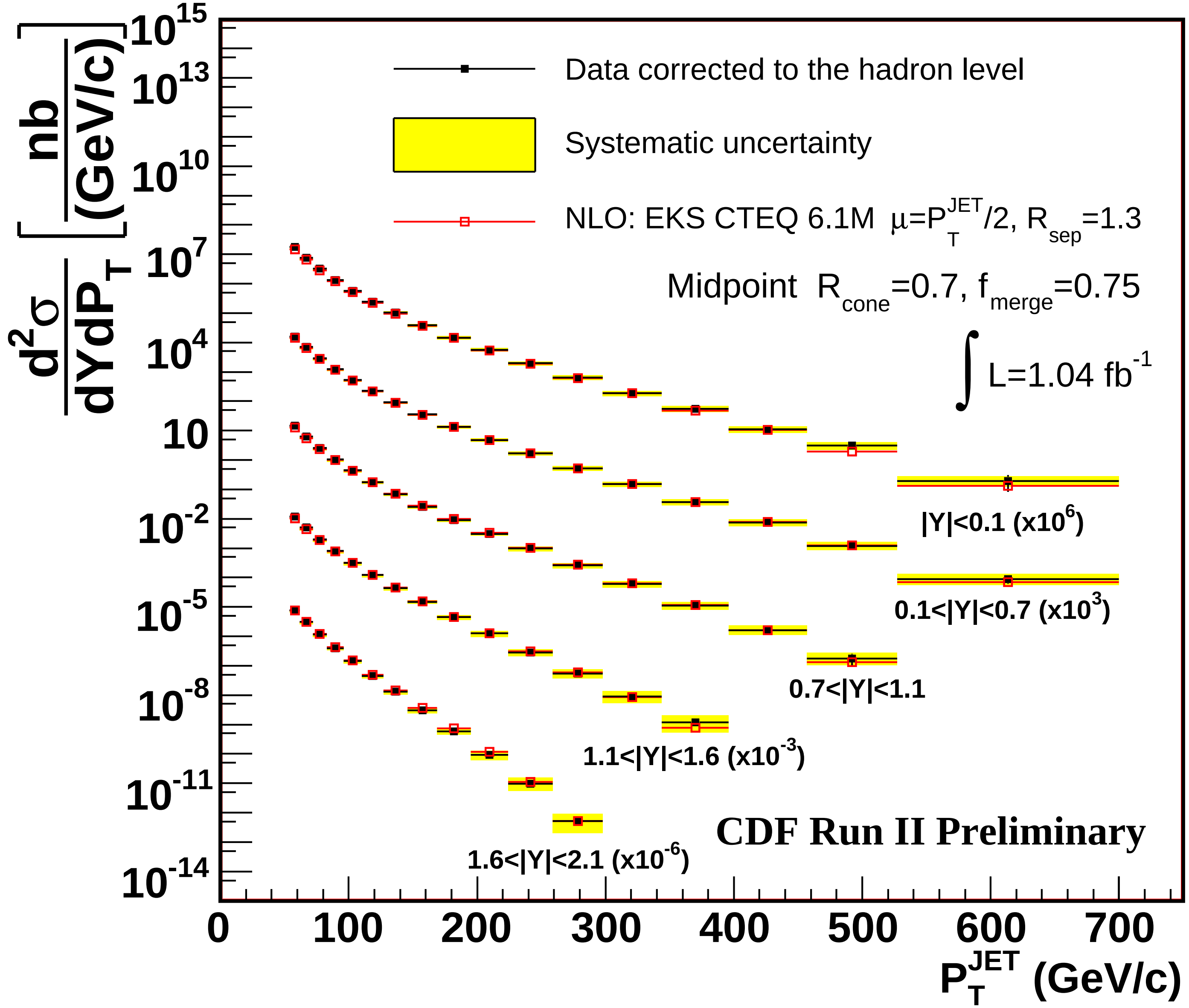
- Run I precision reached for energies below 200 GeV
  - preliminary version based on $\sim 10\%$ of available $\gamma+$jet statstics

- **CDF:** MC simulations
  - MC single particle response and fragmentation tuned on data



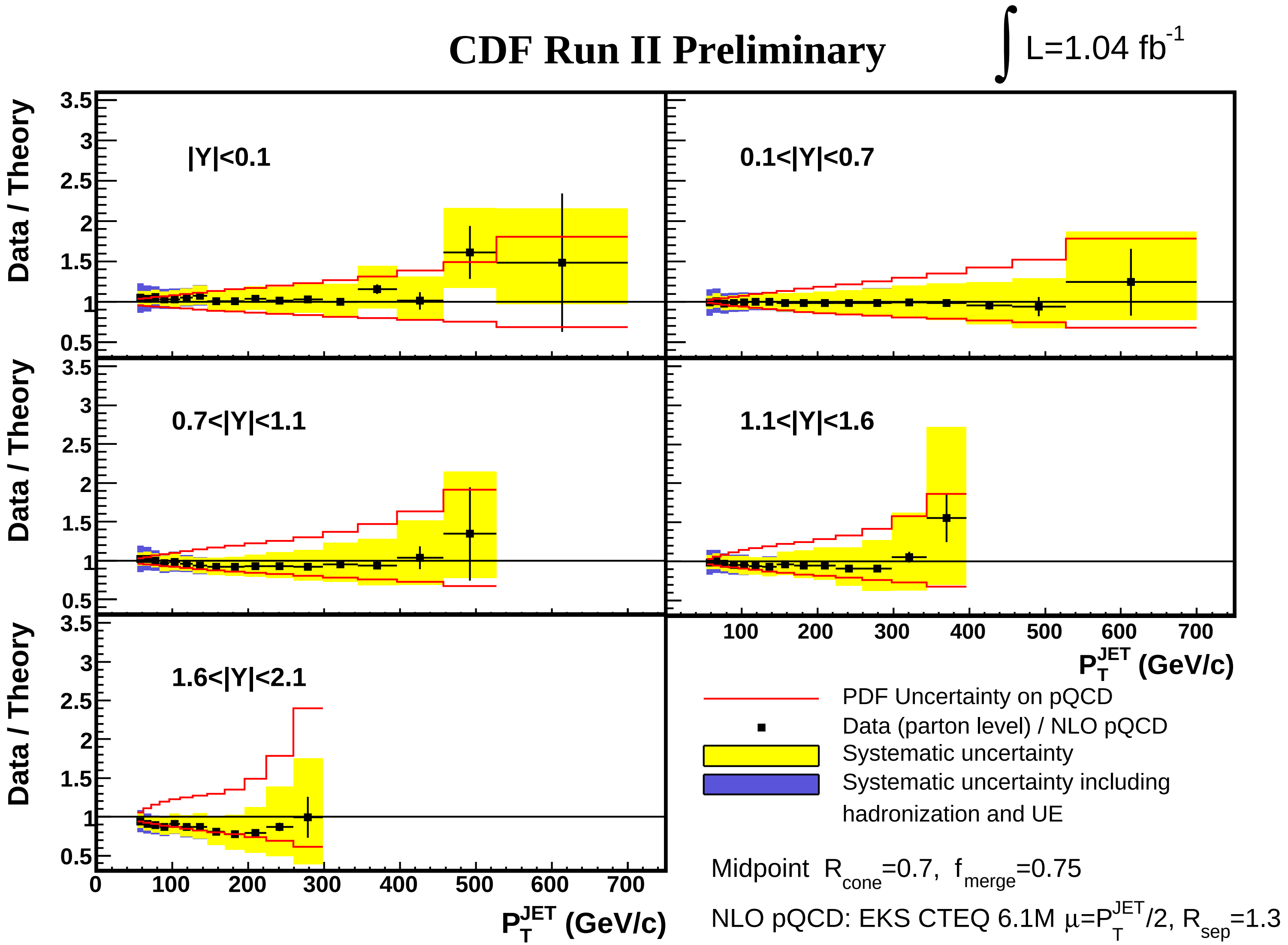
- better than in Run I, especially in the forward calorimeter region

Jet production from CDF



- changes from Run I:
  - 10 times more luminosity
  - modified Run II midpoint cone algorithm with search cone (infrared unsafe)
- good agreement with NLO QCD over entire p_T range in all five rapidity bins

Data/Theory plots (CDF)

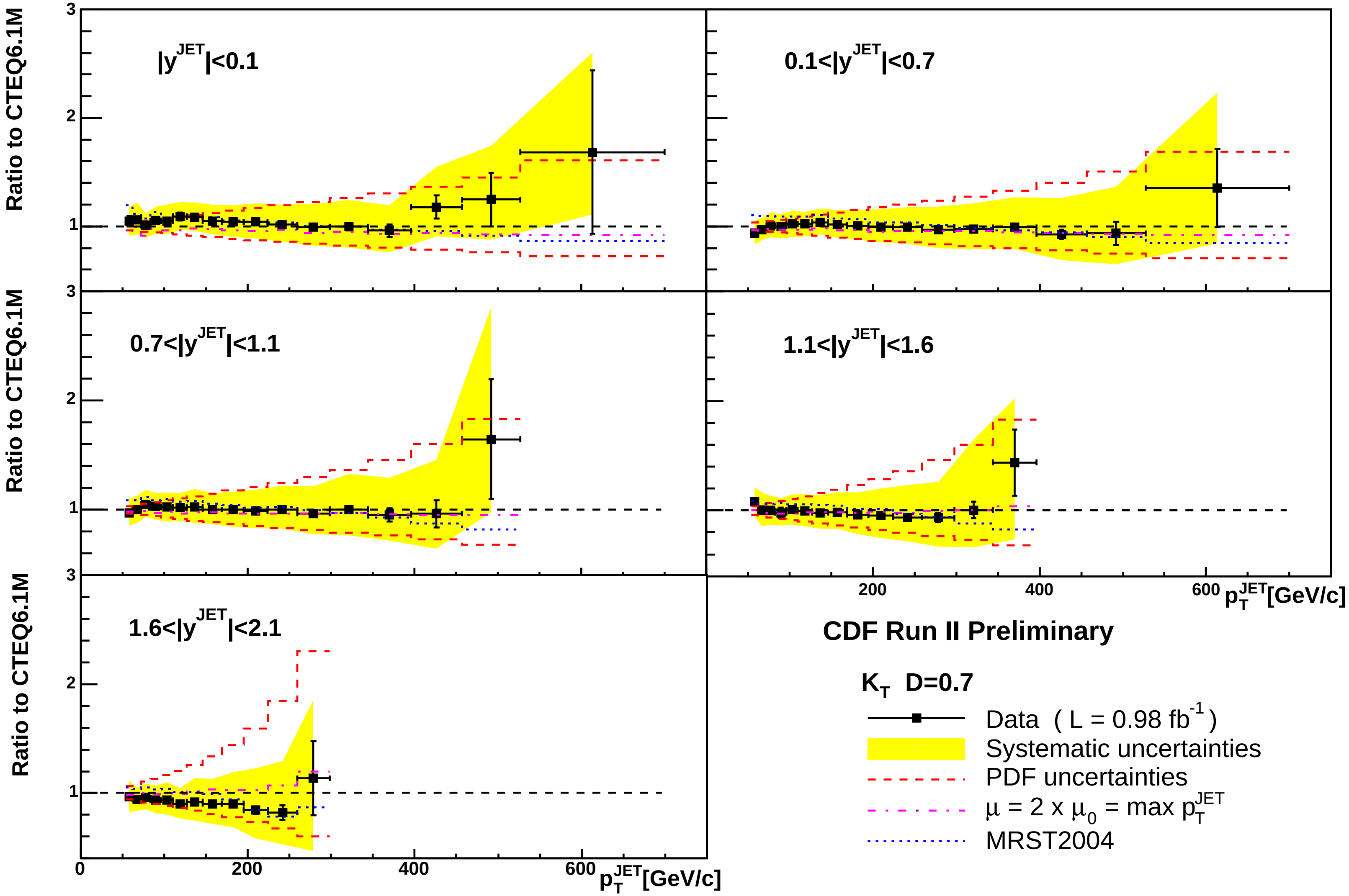


- data corrected to parton level
  - dominant uncertainty at low p_T
- uncertainty on jet energy calibration dominates the systematics at high p_T
- going forward is important for PDF constrains
  - more gluons involved in the initial state
  - new physics should manifest itself mostly in the central region

- errors are comparable with PDF uncertainty

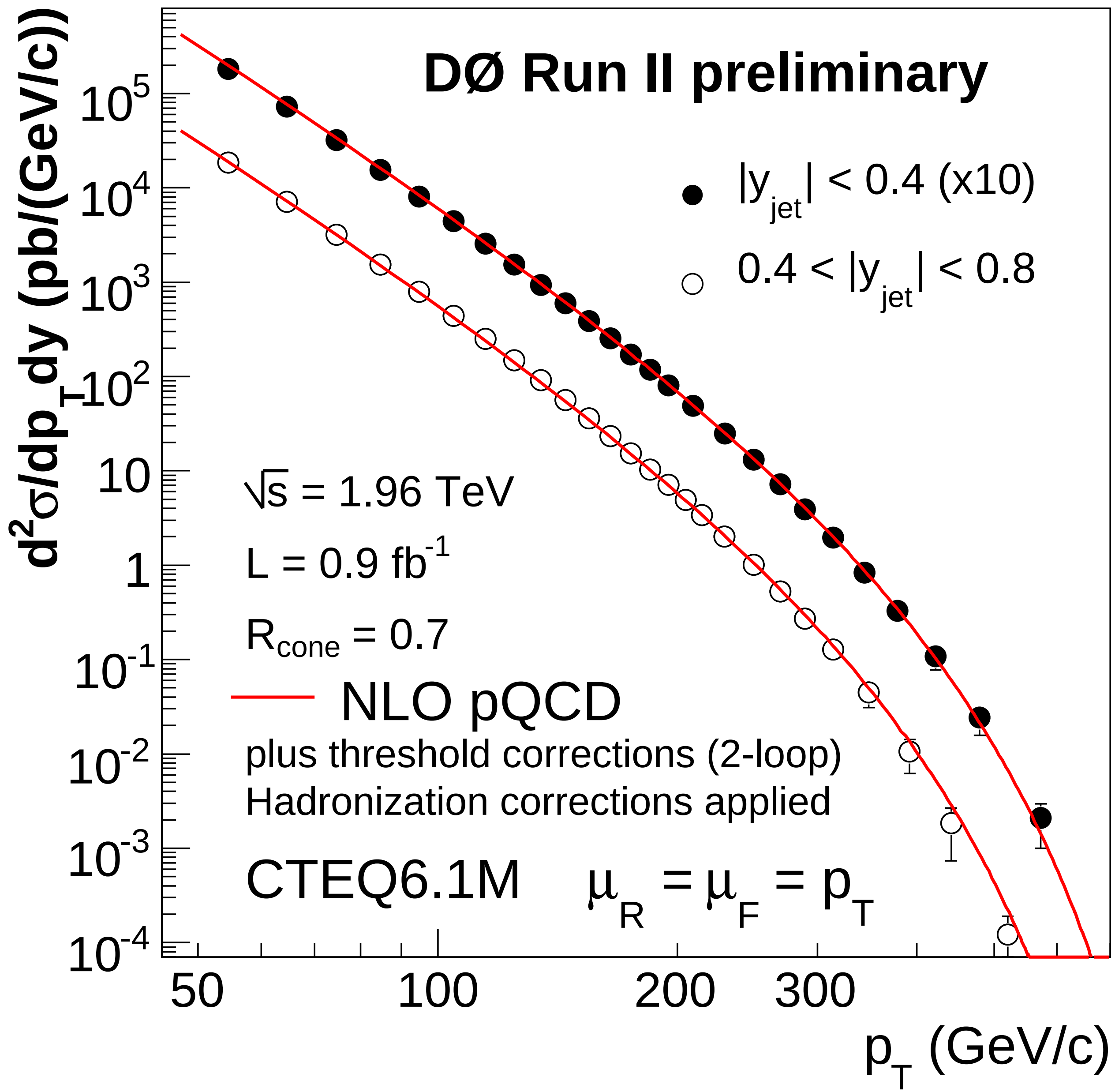
Data/Theory plots for k_T jets (CDF)

Phys. Rev. D75, 092006 (2007)



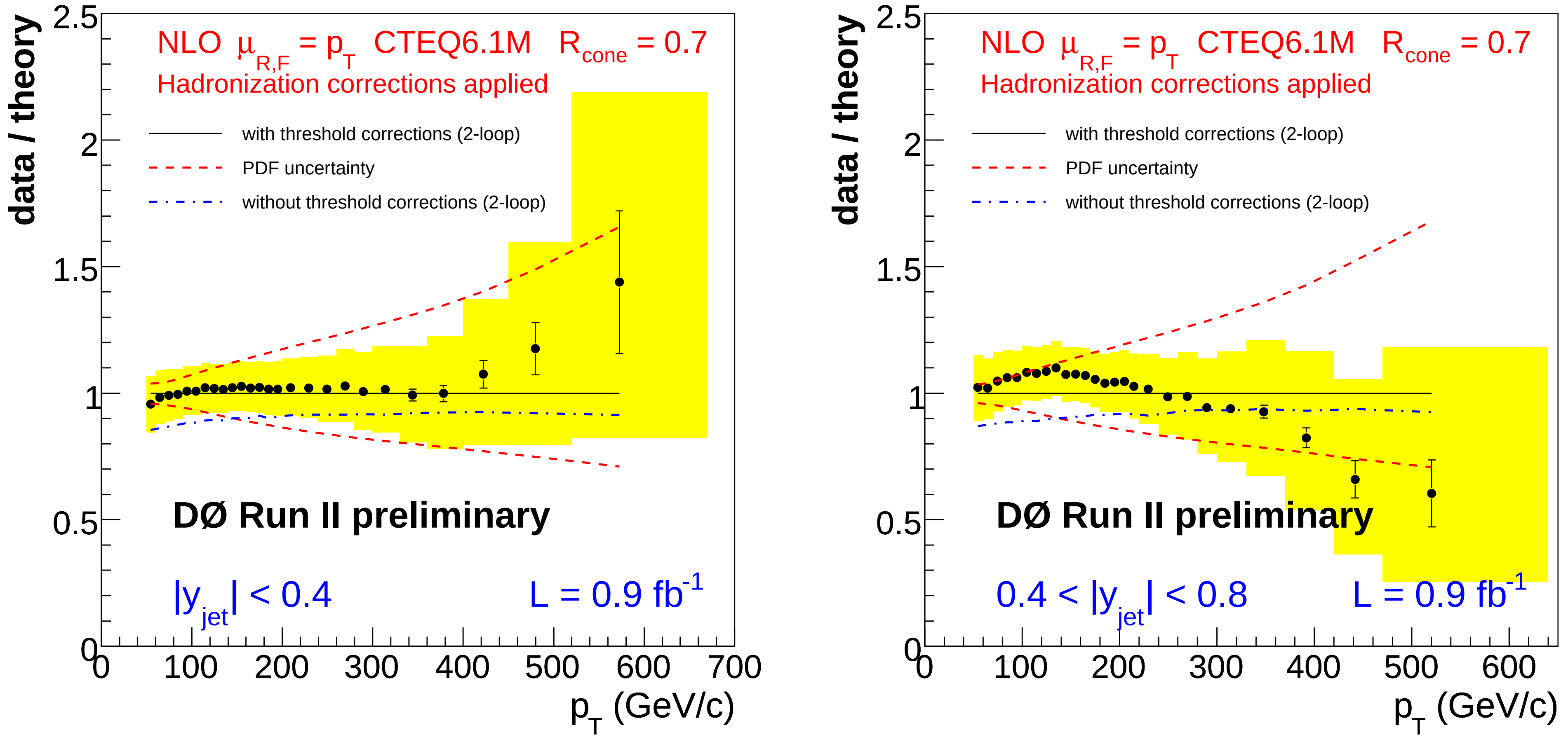
- in very good agreement with measurement based on cone algorithm

Jet production from DØ



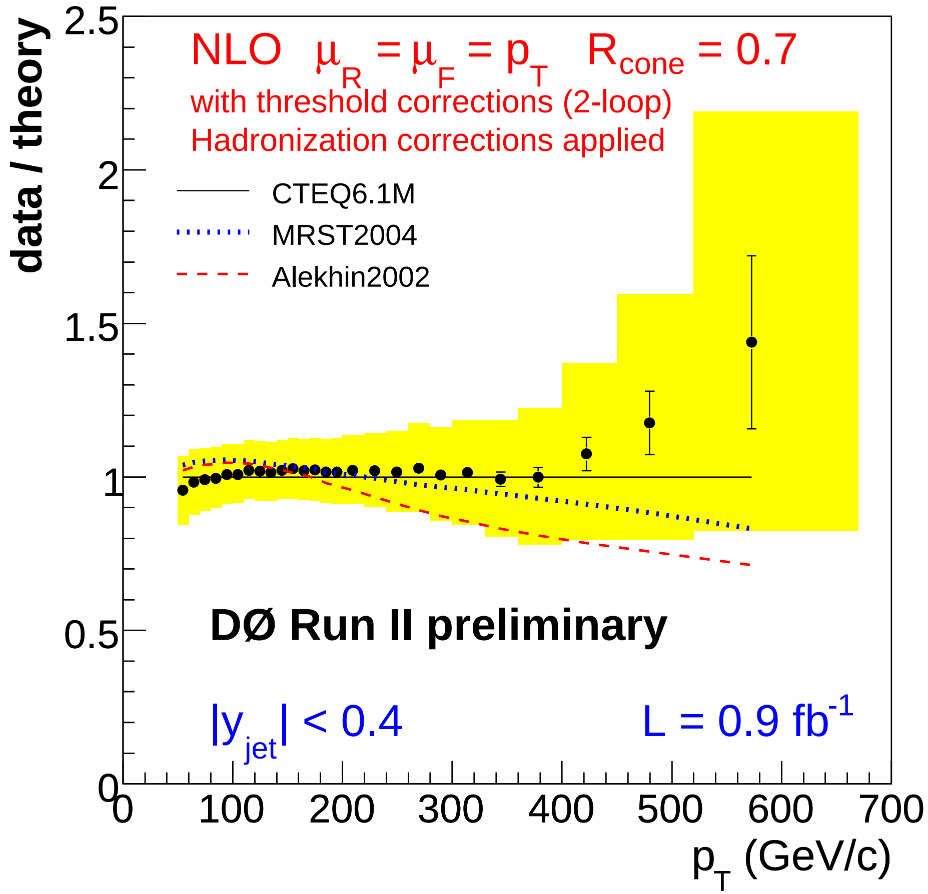
- Run II midpoint cone algorithm (infrared safe)
- new theory calculated with fastNLO and NLOJET++
  - NLO QCD plus threshold 2-loop corrections (Kidonakis and Owens)
- good agreement with pQCD

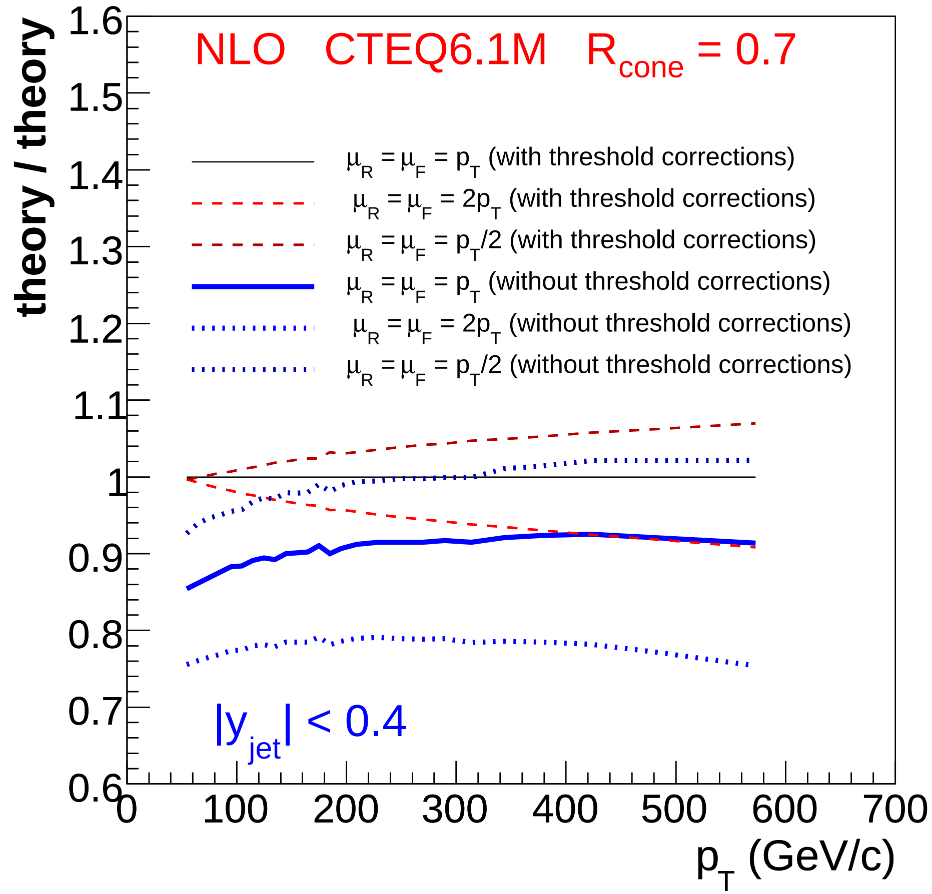
Data/Theory plots (DØ)



- based on preliminary $100\ \text{pb}^{-1}$ JES
- different shapes in the two rapidity bins are due to highly uncorrelated errors in energy calibration
- experimental errors comparable with theoretical PDF uncertainties

Other PDFs and scale sensitivity (DØ)

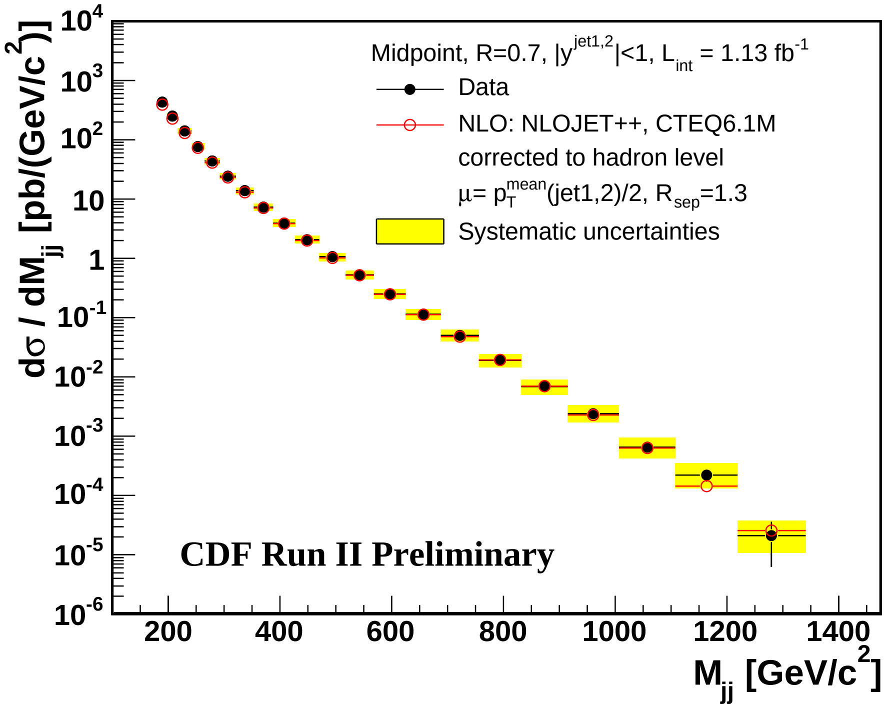


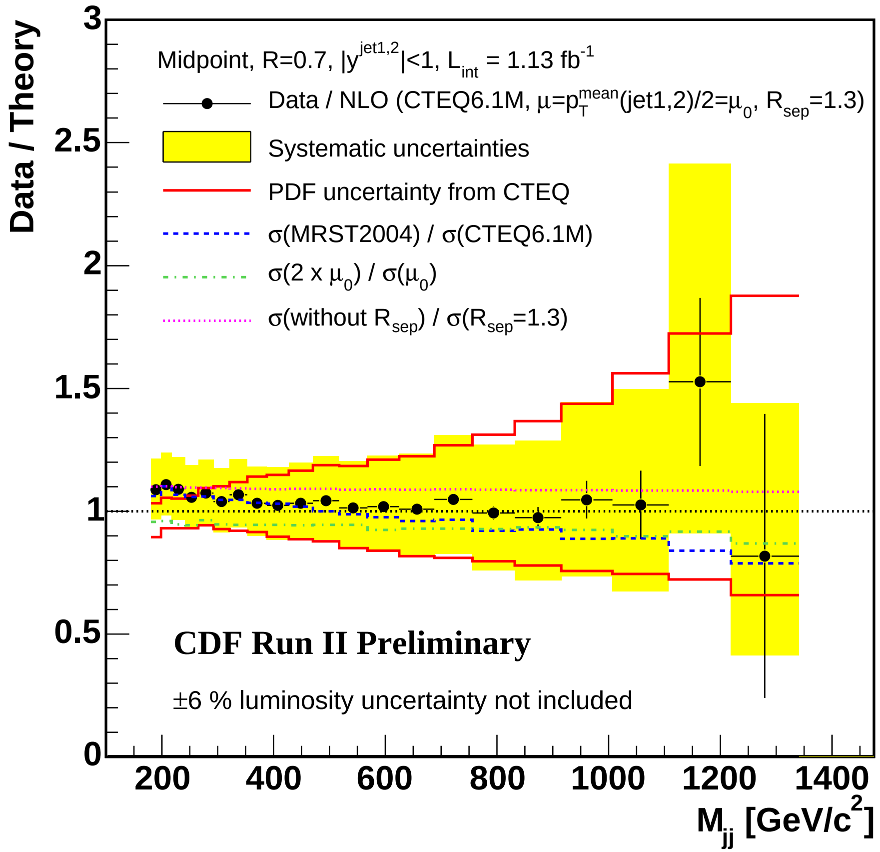


- other sets of proton PDF within the CTEQ6.1 errors
- 2-loop threshold corrections reduced the scale sensitivity

theoretically well behaved jet algorithms are crutial for the calculations beyond NLO

Dijet mass distribution (CDF)



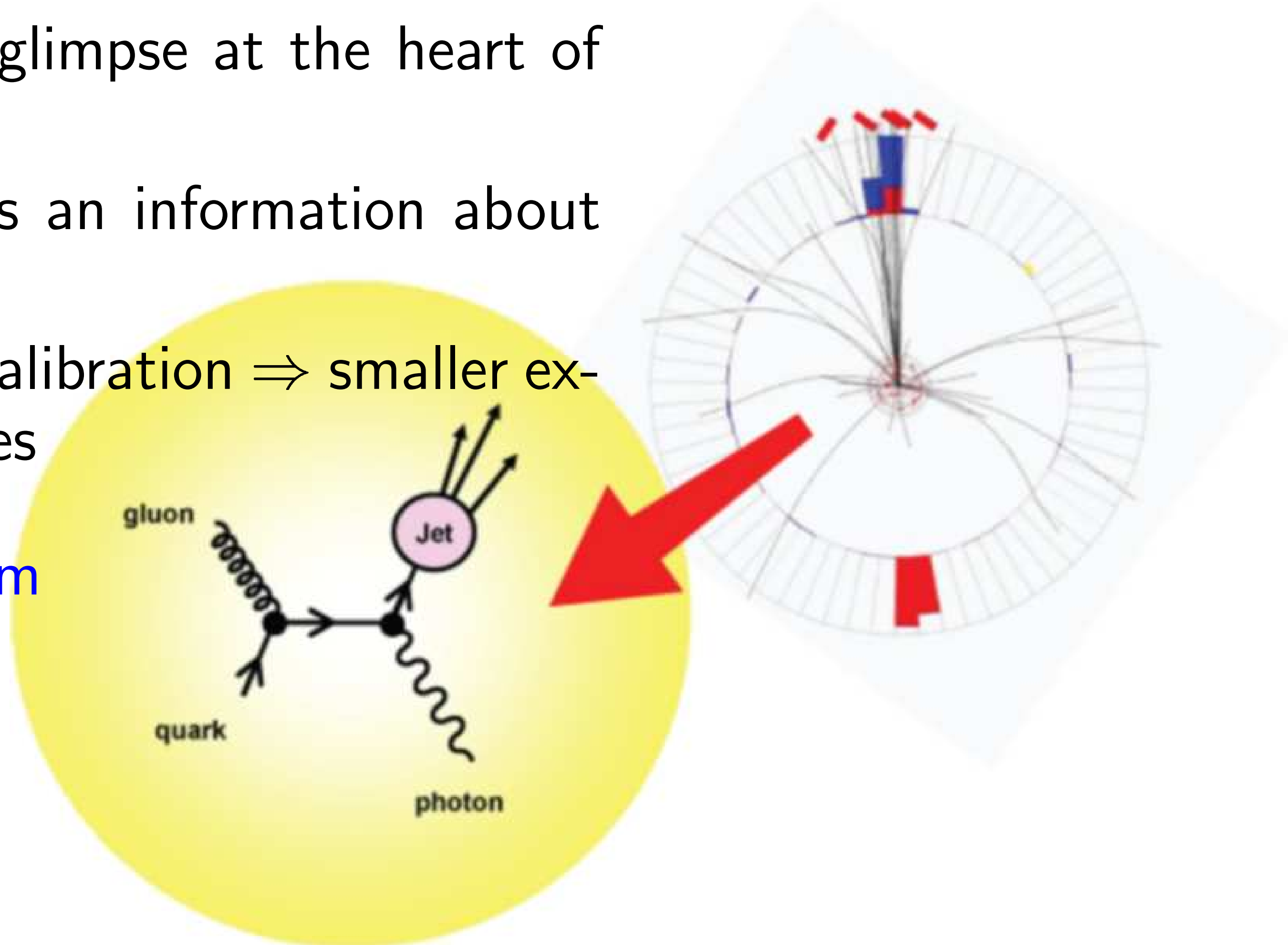


- similar information on proton structure as from inclusive jets
- helps to identify whether possibly observed difference from theory prediction is due to PDF uncertainties or due to some new physics

  (best limits from Run I on quark compositeness were coming from ratio of two dijet mass distributions in pseudorapidity bins: $|\eta| < 0.5$ and $0.5 < |\eta| < 1$)

Isolated photon cross section

- Motivation
  - unlike jets, photons are not affected by multi-parton radiation and subsequent hadronization
  - photons give a direct glimpse at the heart of the collision
  - measurement brings us an information about the proton structure
  - better photon energy calibration ⇒ smaller experimental uncertainties



- Inclusive photon spectrum

  PLB 639, 151, 2006

- Triple differencial xsec

  see Nikolay's talk

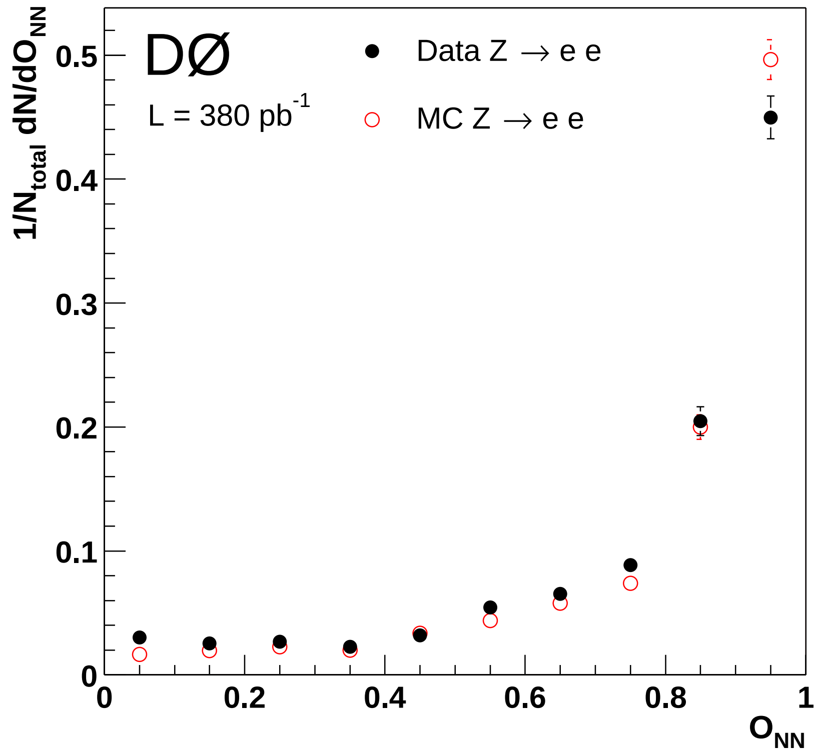
Extracting the direct photon signal

- large background due to meson production in jets (like π^0 and η)

- photon isolation

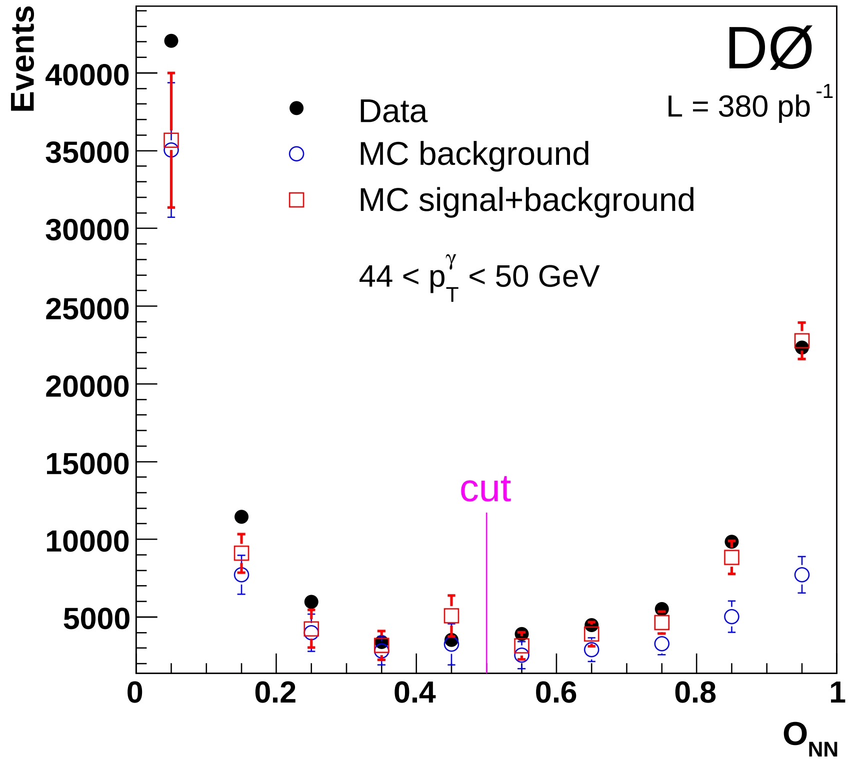
$$\frac{E_{\Delta R<0.4} - E_{\Delta R<0.2}}{E_{\Delta R<0.2}} < 0.10$$

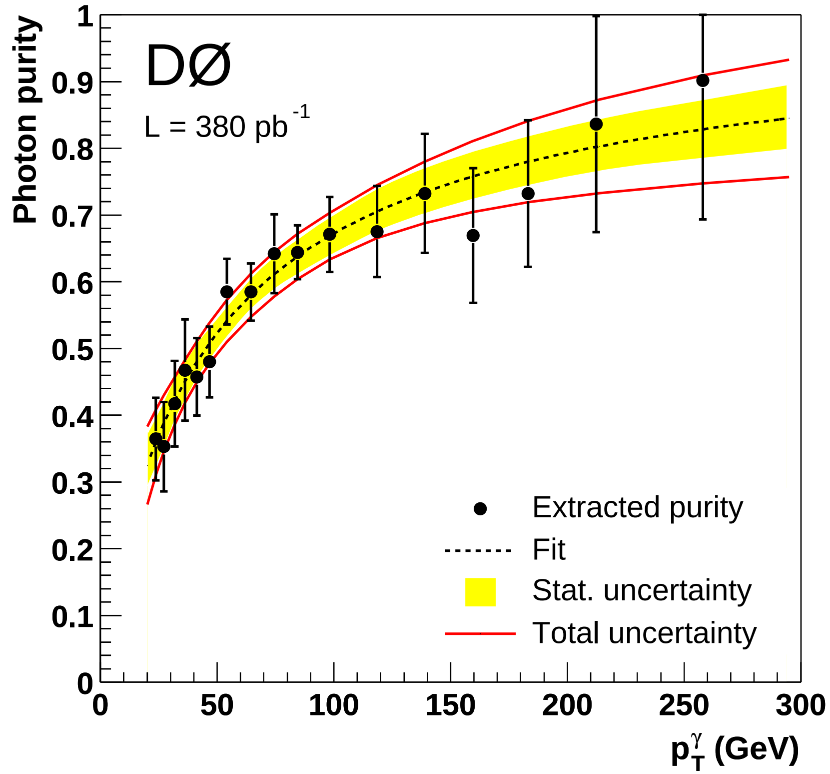
- no matching track, most of energy deposited in the electromagnetic part of calorimeter, ...
- neural network
  - number of EM cells in the 1st layer of calorimeter with $E > 0.4$ GeV in $R < 0.2$ and $0.2 < R < 0.4$ rings
  - sum of tracks p_T within $0.05 < R < 0.4$
  - width of EM cluster in the 3rd calorimeter layer



- test on $Z \to e^+e^-$ data

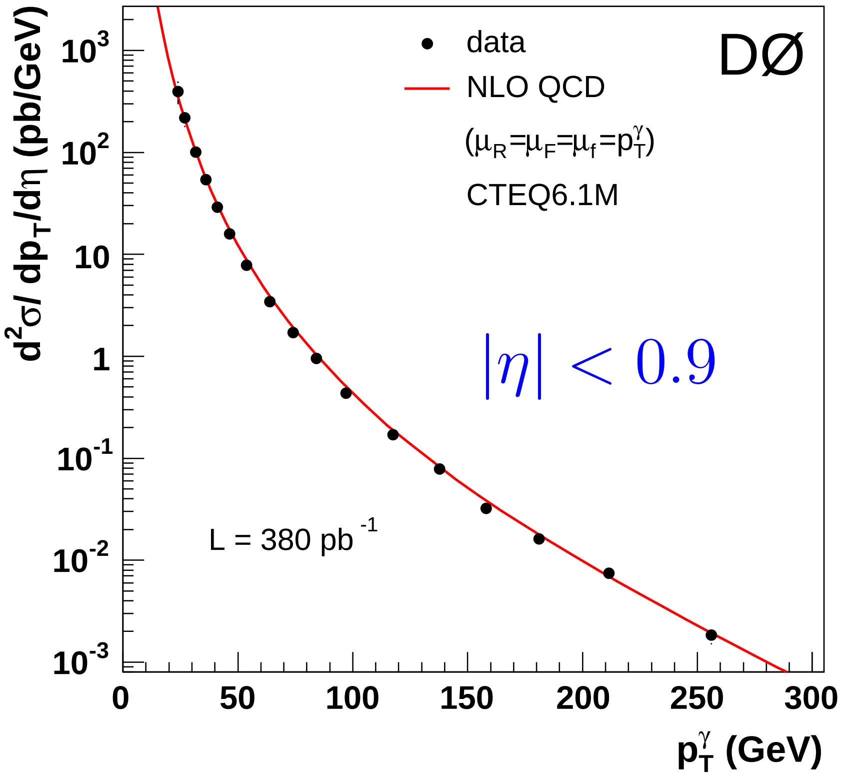
Estimation of photon purity

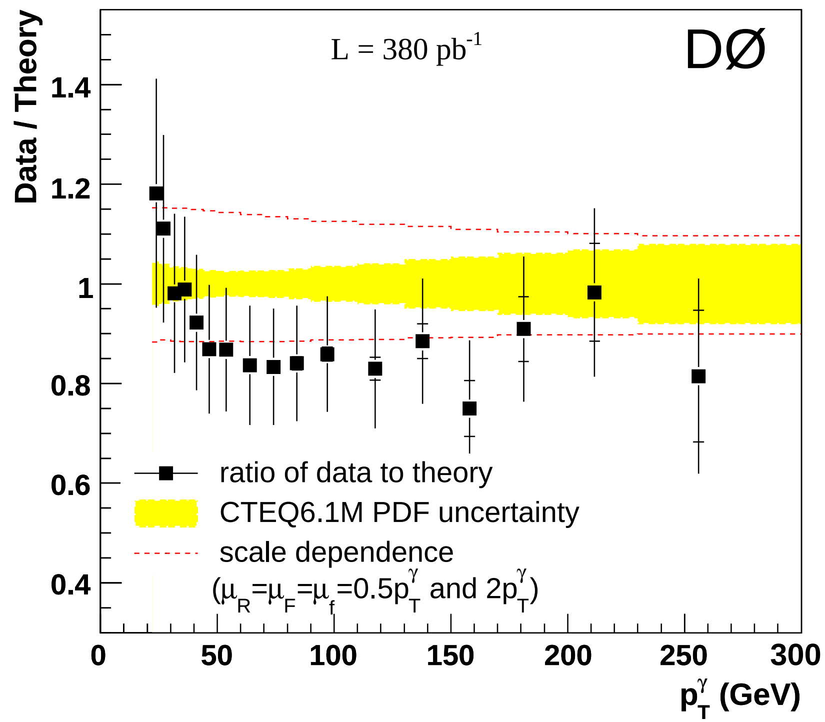




- background simulated with PYTHIA
  - preselected QCD and electroweak processes
- used to determine the photon purity of the final sample

Photon cross section - final result





- central photon production measured over wide range of p_T: $23-300$ GeV
  - significant extension to Run I, where $p_{Tmax} \sim 110$ GeV
- good agreement with NLO QCD over 5 orders of magnitude
- experimental and theoretical errors have about the same size

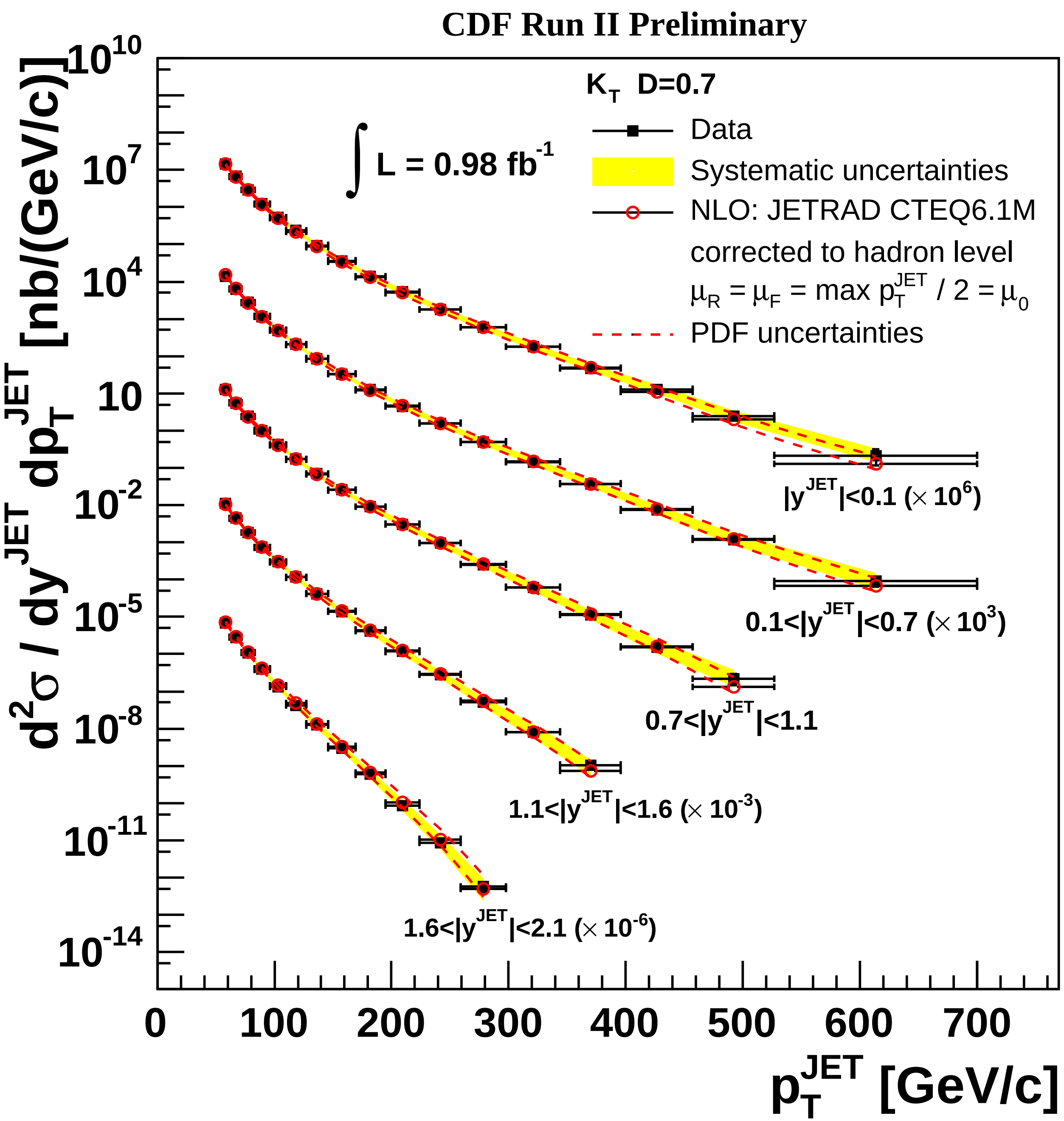
Summary

- new Run II measurements of jet production based on $\sim 1\,\mathrm{fb}^{-1}$ samples significantly extended the Run I results towards high energies
  - testing pQCD at distancies never explored before
  - consistent with QCD over 8 orders of magnitude
  - experimental errors comparable with PDF uncertainties from CTEQ6 $\Rightarrow$ the data brings new information about gluons at large x
- Run II measurement of photon production is also in agreement with QCD predictions
  - measurement more precise than for jets however less sensitive to PDF uncertainties
  - scale dependence of NLO QCD prediction larger than PDF uncertainties

$\Rightarrow$ makes the interpretation of results in terms of proton structure harder

Backup

Jet production for k_T jets (CDF)



- update from:

Phys. Rev. Lett. 96, 122001 (2006)

- k_T algorithm:
  - iterative procedure
  - closest pair are recombined into one until the mutual distance is lower then some cut
  - no fixed geometrical shape
  - no split/merge procedure
  - infrared/collinear safe