Photons and Jets at the Tevatron

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On hehalf of the D0 and CDF collaborations

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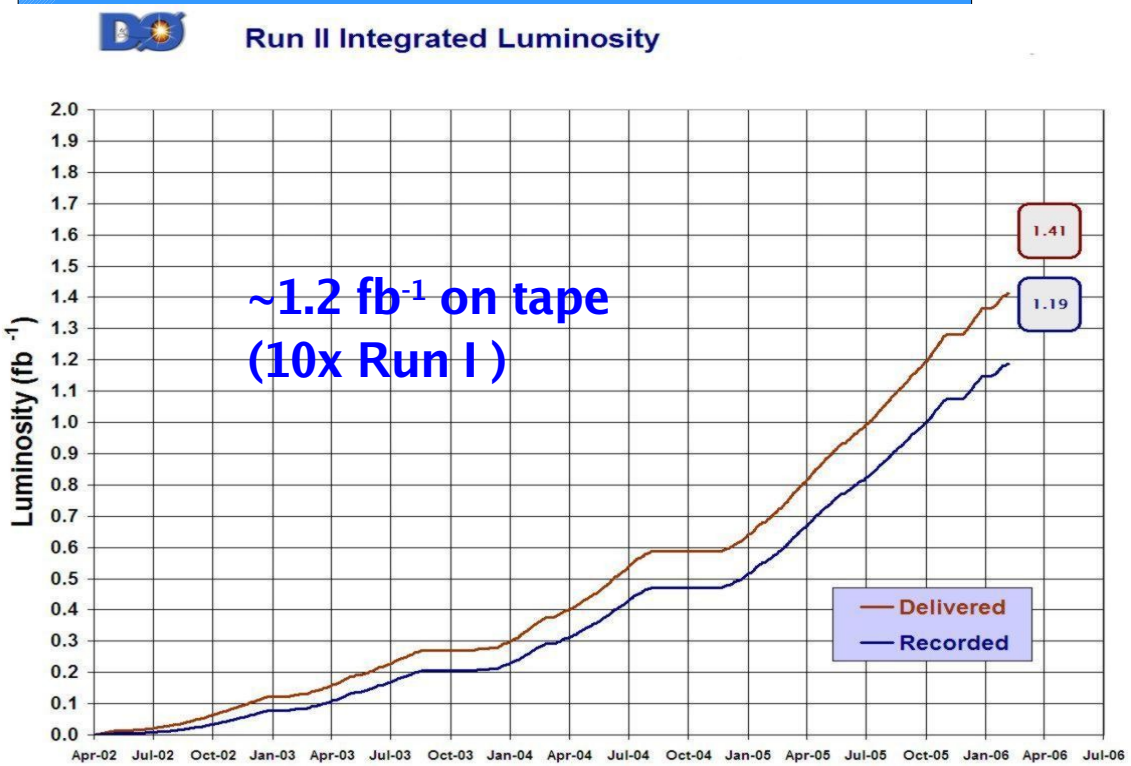
Overview

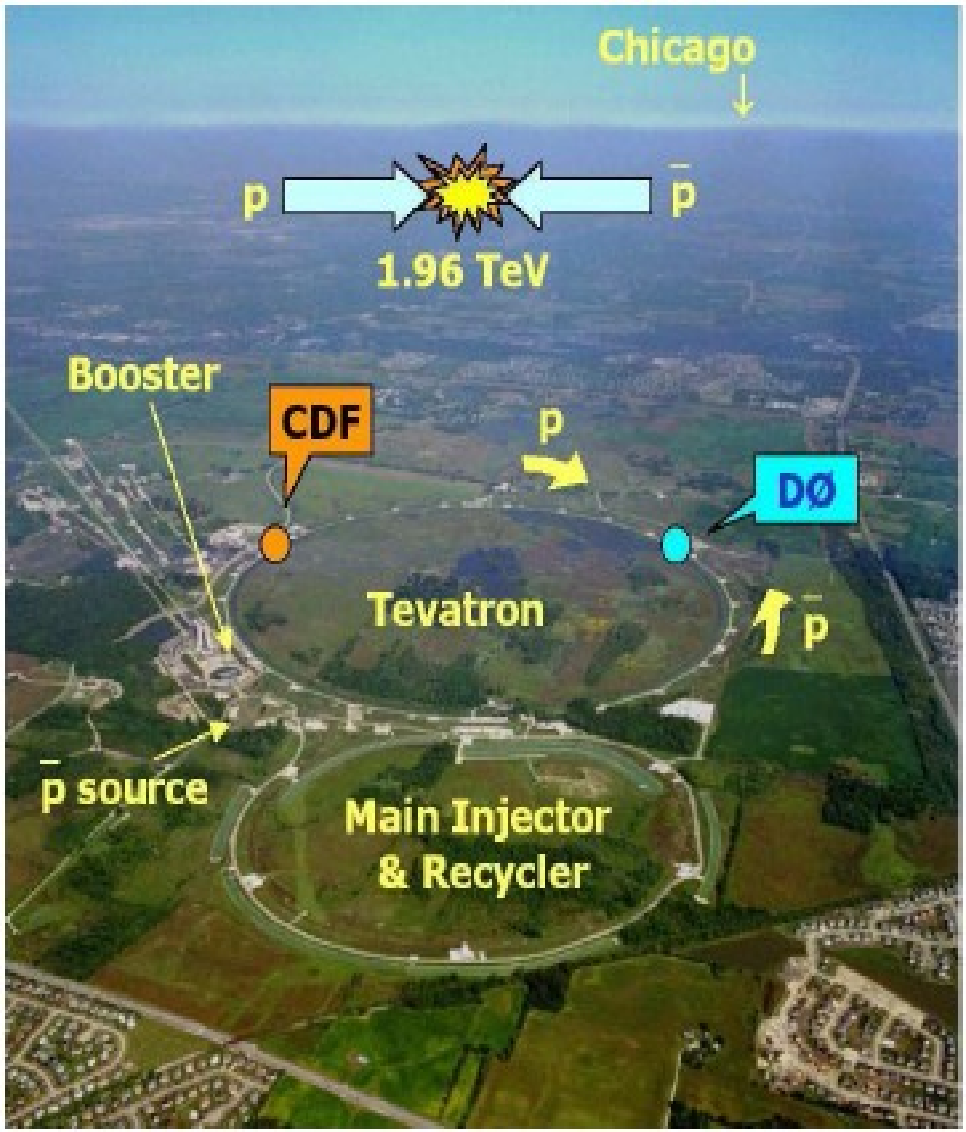
- Tevatron collider
- D0/CDF jet results:
  - inclusive jets
  - W/Z + jet events
  - b-jet events
- D0/CDF photon results:
  - inclusive photons
  - di-photon

Tevatron p-pbar collider

Run II (March 2001→) √s = 1.96 TeV
36x36 bunches colliding per 396 ns
2-3 interactions/crossing

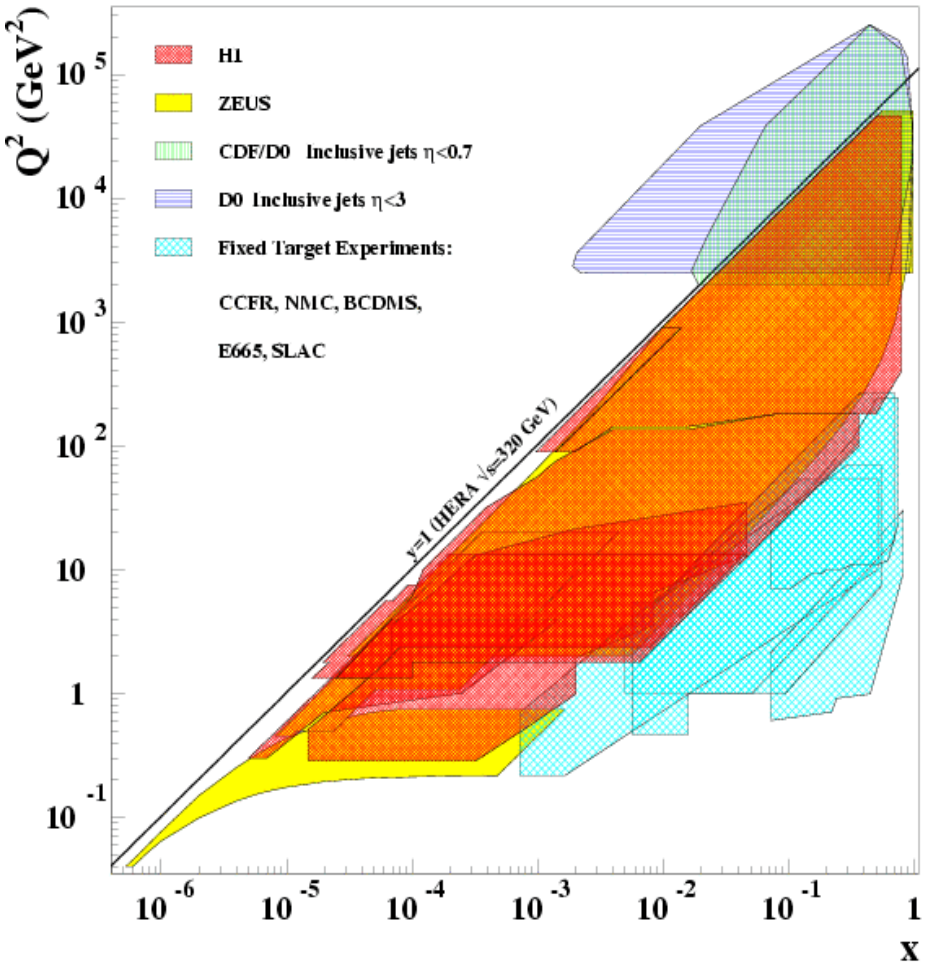
Excellent Tevatron performance!
Peak **L** : 1.72E32 $cm^{-2}s^{-1}$
$\int L\,dt$: 27 pb^{-1} /week
Delivered >1.4 fb^{-1}
Goal : 8 fb^{-1} by 2009

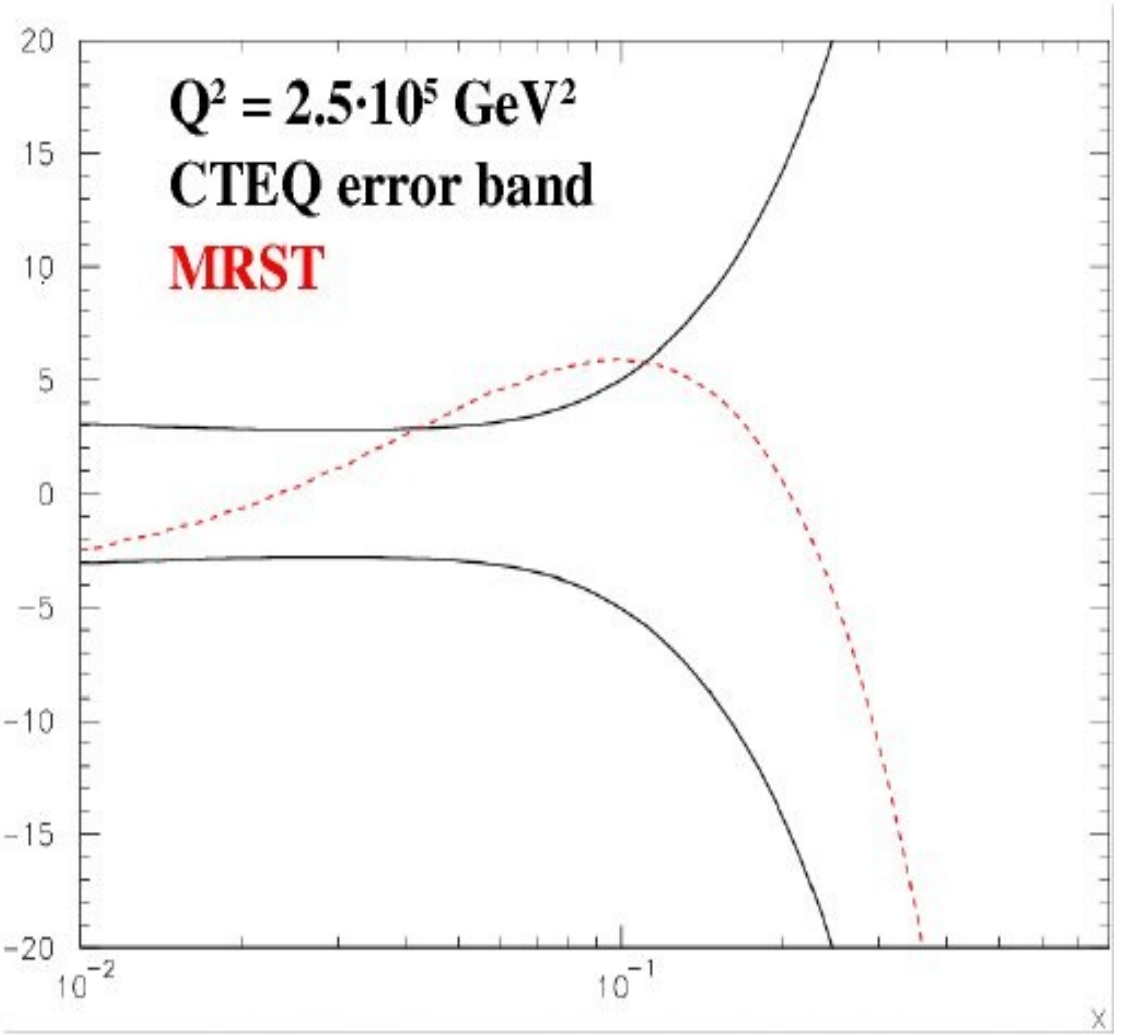


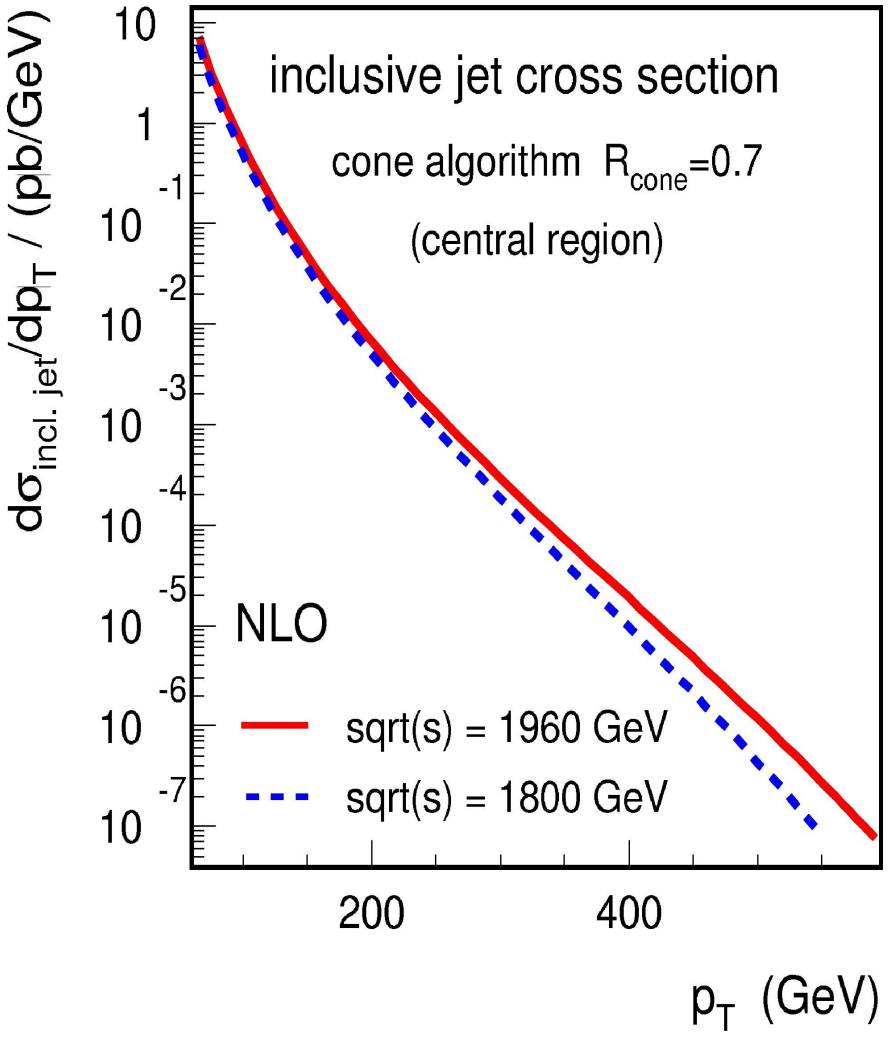


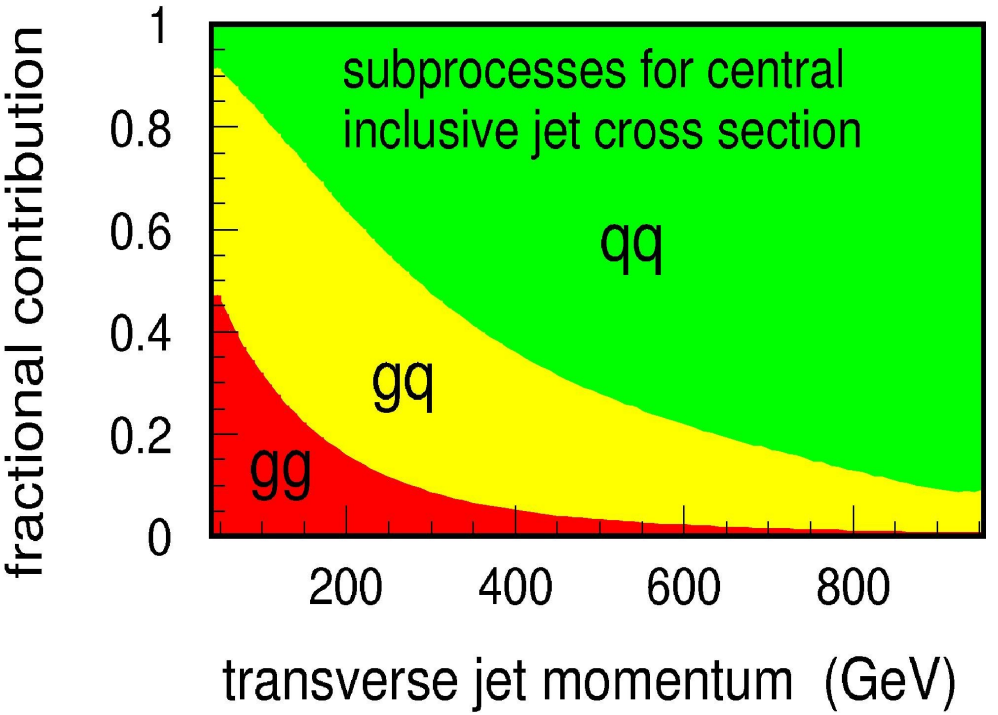
Jet inclusive pT cross section: Motivation

- left: (x,Q2) kinematic plane for HERA, fixed target and Tevatron experimens
- right: uncertainty on gluon PDF from 40 CTEQ6.1 sets and difference with MRST









- RunI and Run II cross sections noticeably differ: *about 300% at pT=500 GeV.*
- In the region of pT = 500 GeV about 30% events are still caused by qg scattering:

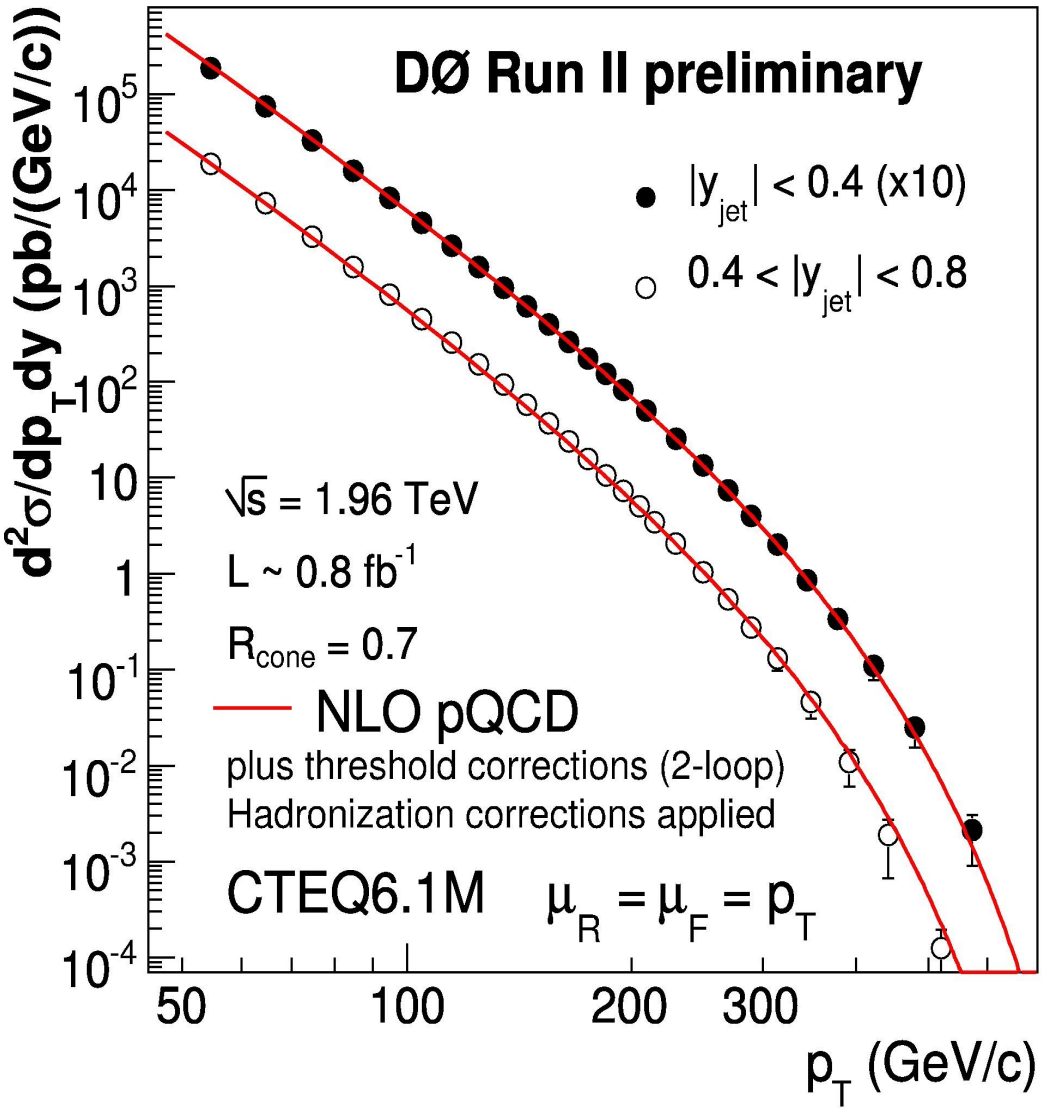
sensetivity to gluon PDF in this Q2 region at $x \approx 0.5$.

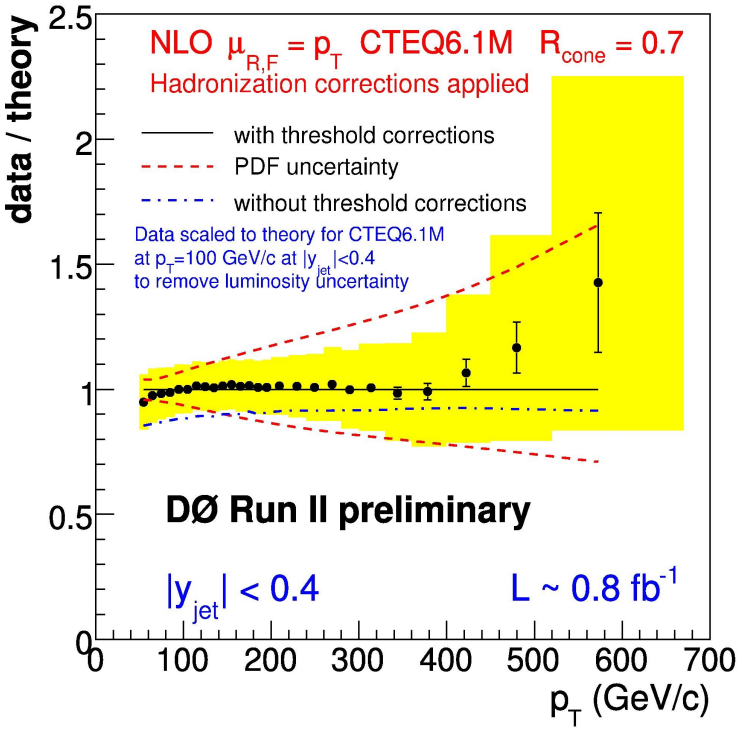
Jet inclusive pT cross section (D0)

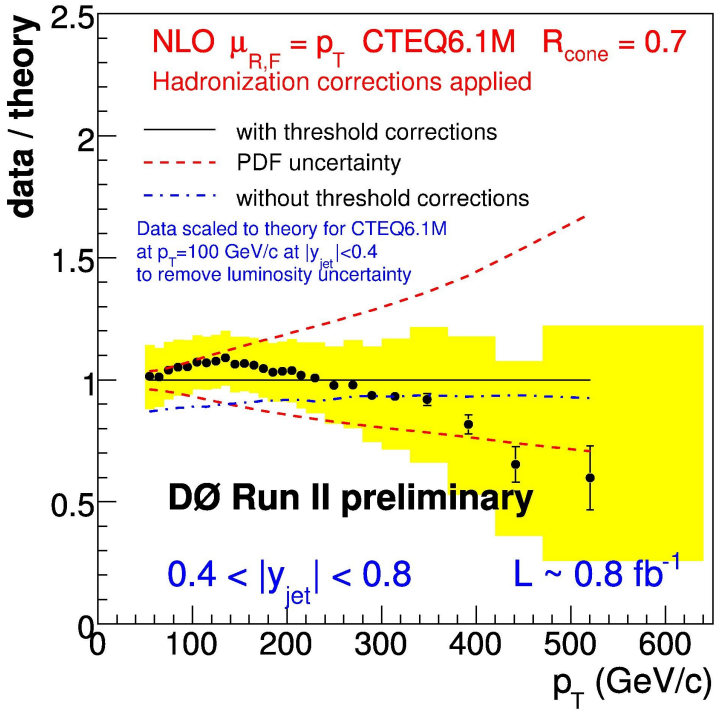
Measurement of the inclusive jet pT cross section at 0.8 inv. fb in 2 rapidity bins

- Data compared to NLO QCD calculations: NLOJET++ with CTEQ6.1M, and corrections using threshold resummation techniques (Kidonakis *et al.*)

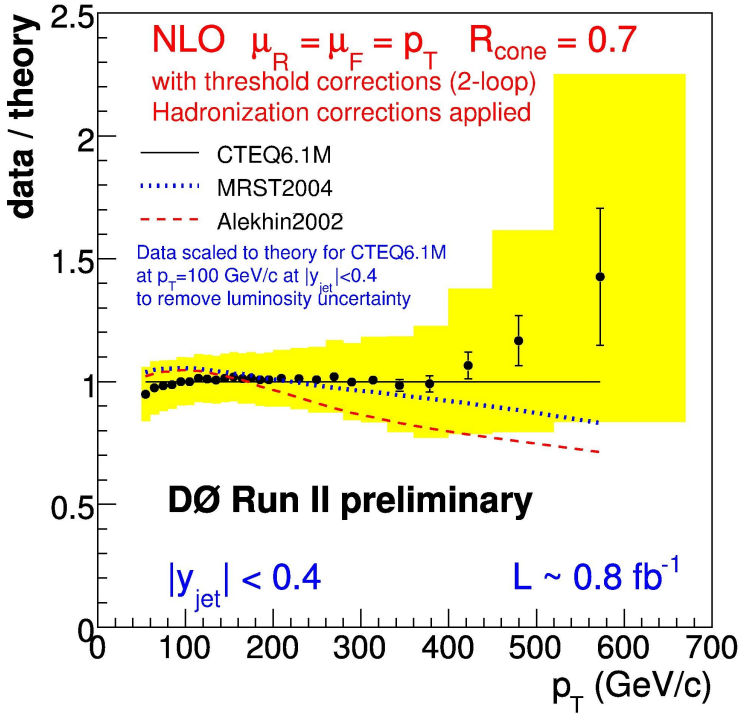
- Data have been scaled to NLO QCD predictions at pT =100 GeV and |y|<0.4 to remove luminosity uncertainty.

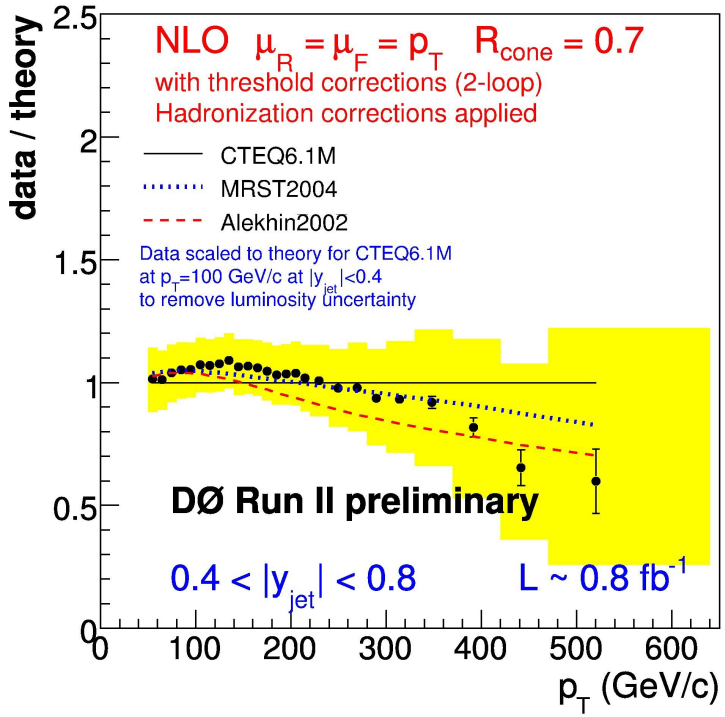






- Uncertainties on data of the same order as uncertainties on PDF from CTEQ, will allow to further constrain PDF.

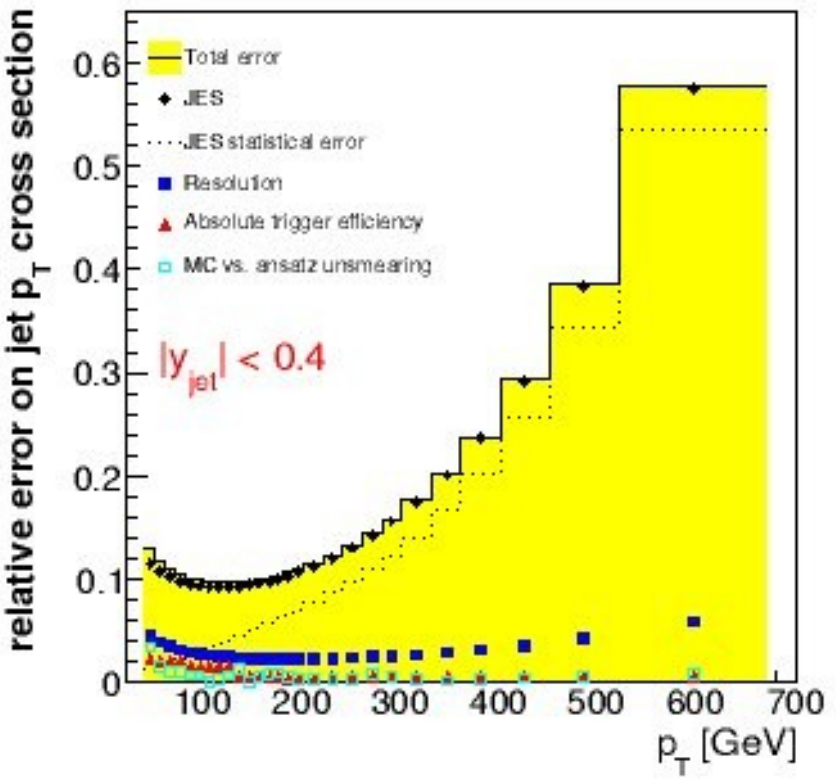


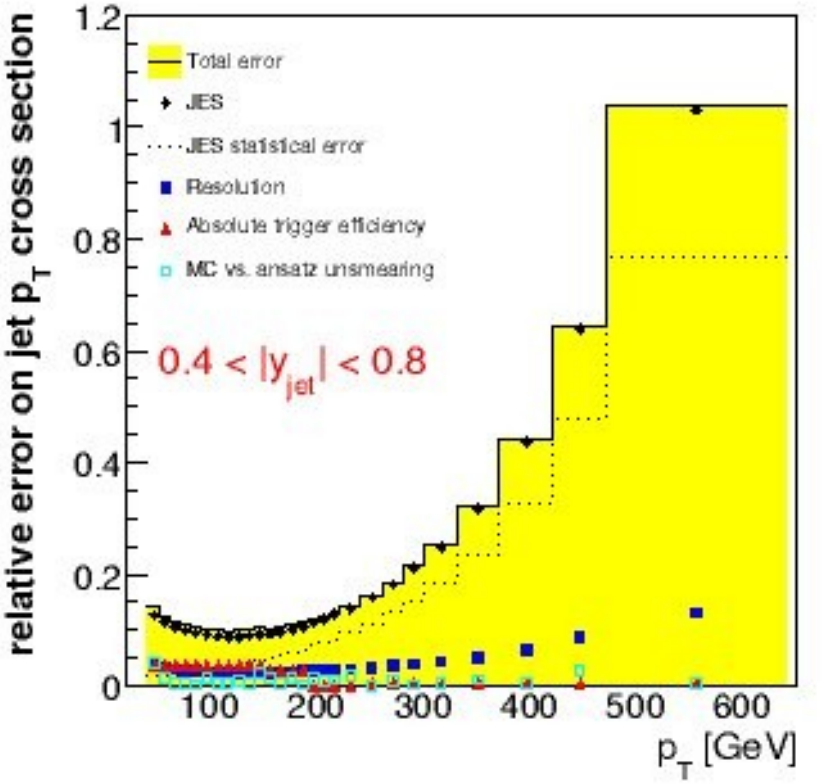


- Data show potential sensitivity w. r. t. MRST and Alekhin parametrisations.

Uncertainties on jet inclusive pT cross section (D0)

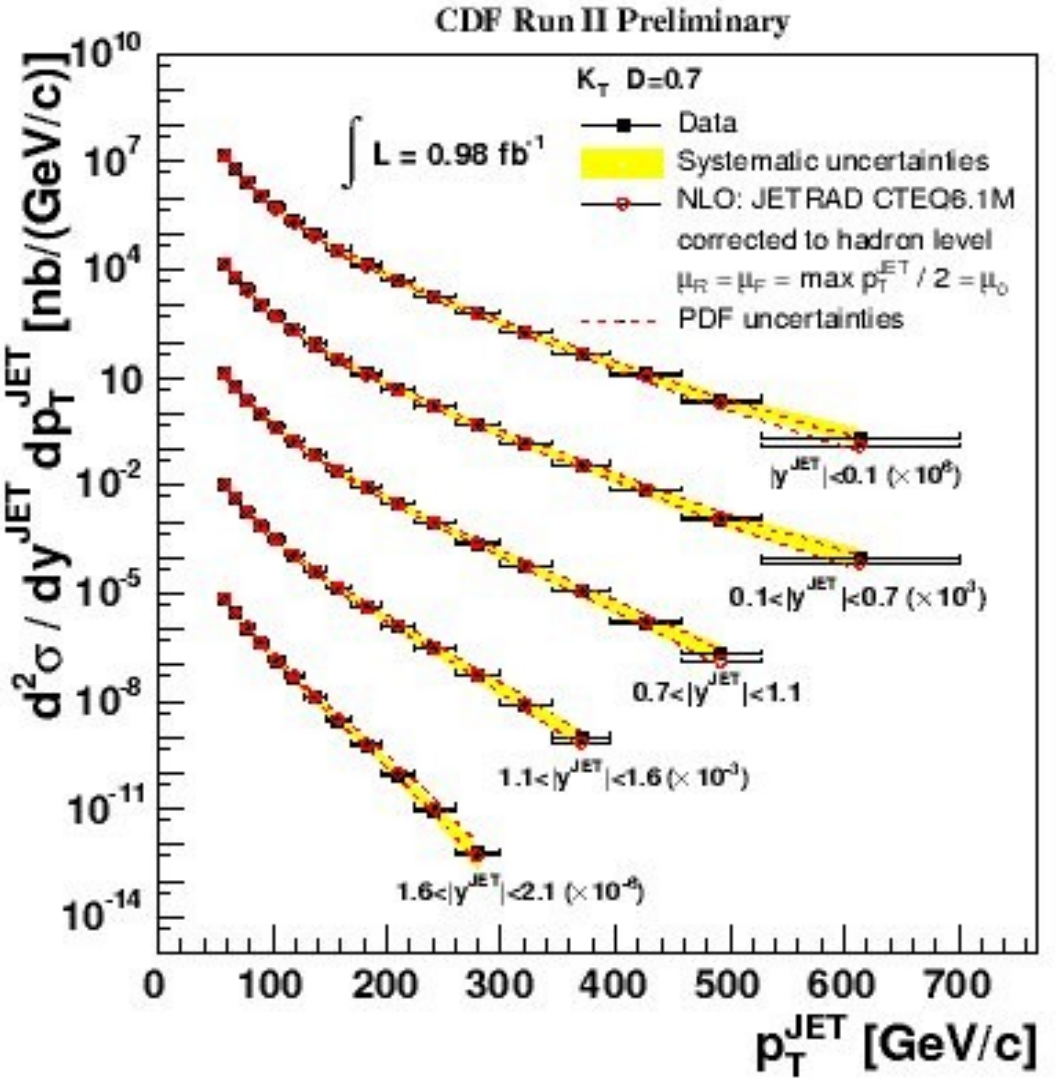
- Dominated by JES uncertainties
- Large stat. error at hight pT due to JES determination
  (just 15% of the data set is used). Will be updated this summer.
- Substantial reduction of systematics by factor of 2 as compared with prev. results of 2005





Jet inclusive pT cross section using kT algorithm (CDF)

- Measurement done in 5 rapidity bins for |y| < 2.1
- NLO QCD calculations (JETRAD) corrected for hadronization and underlying events



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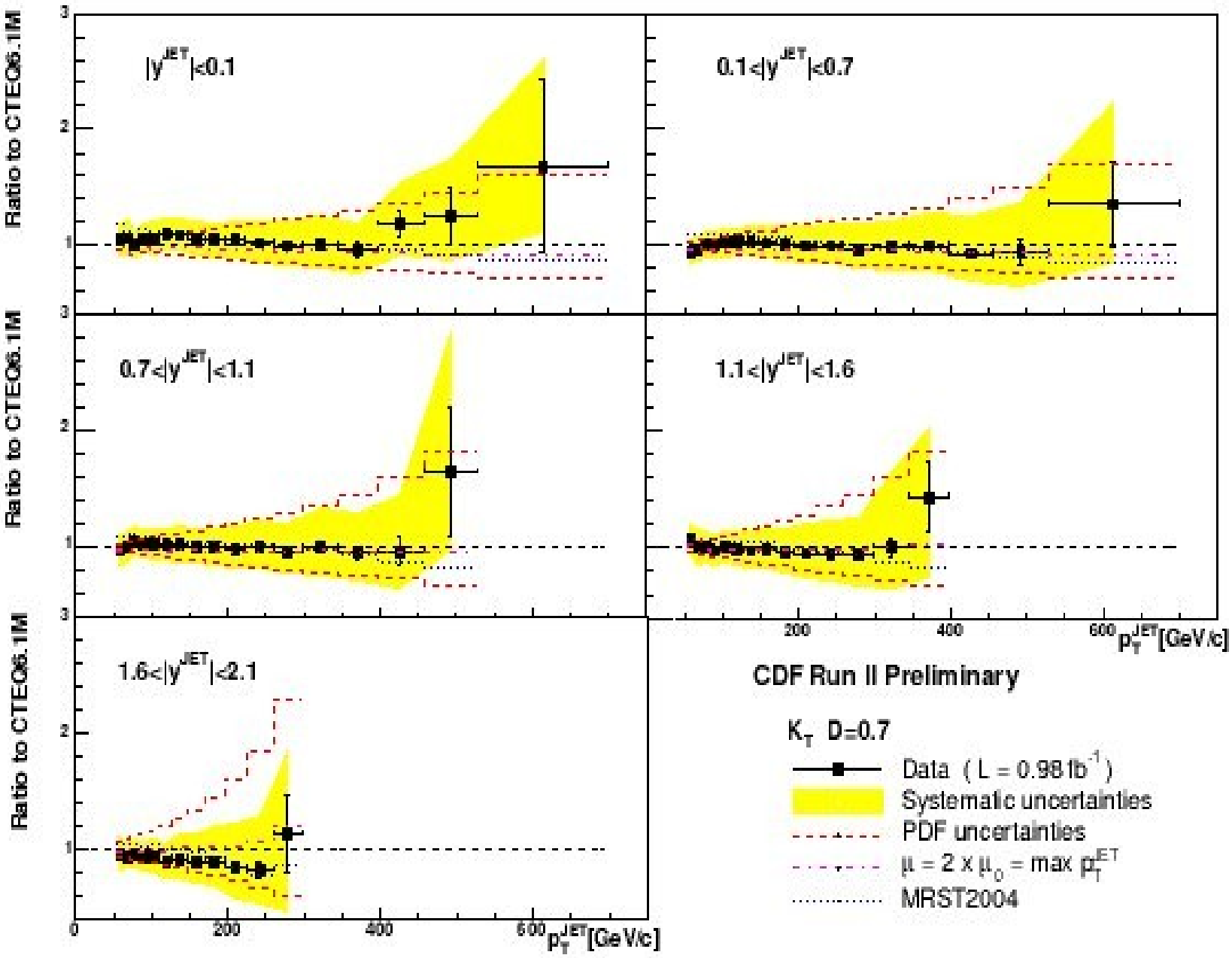
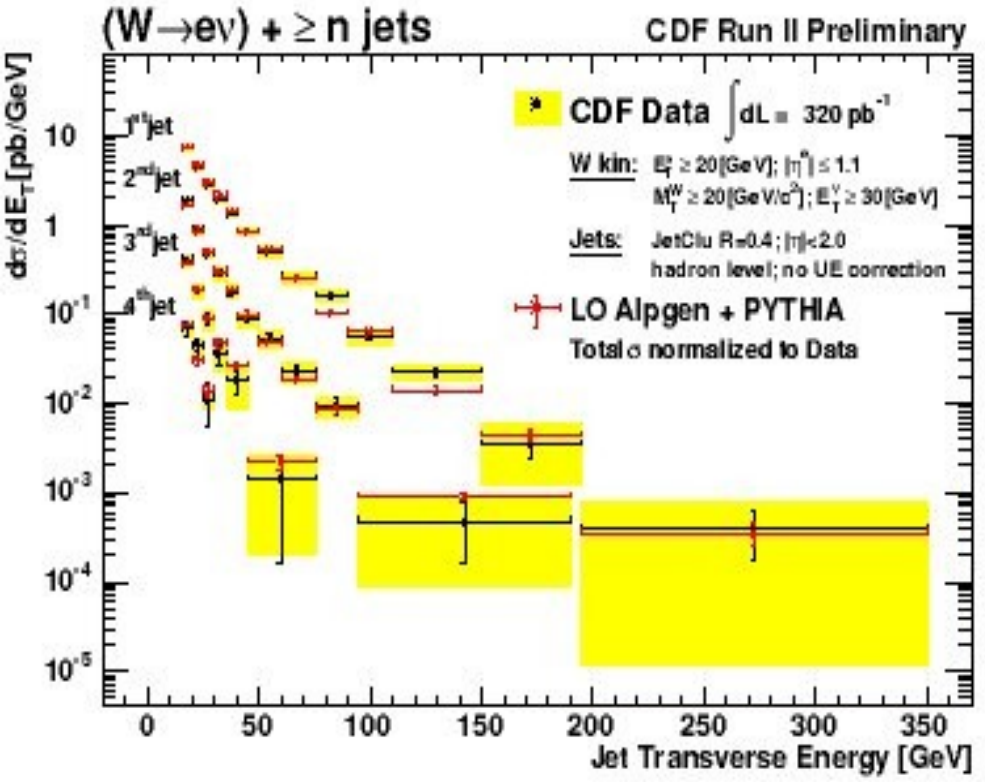
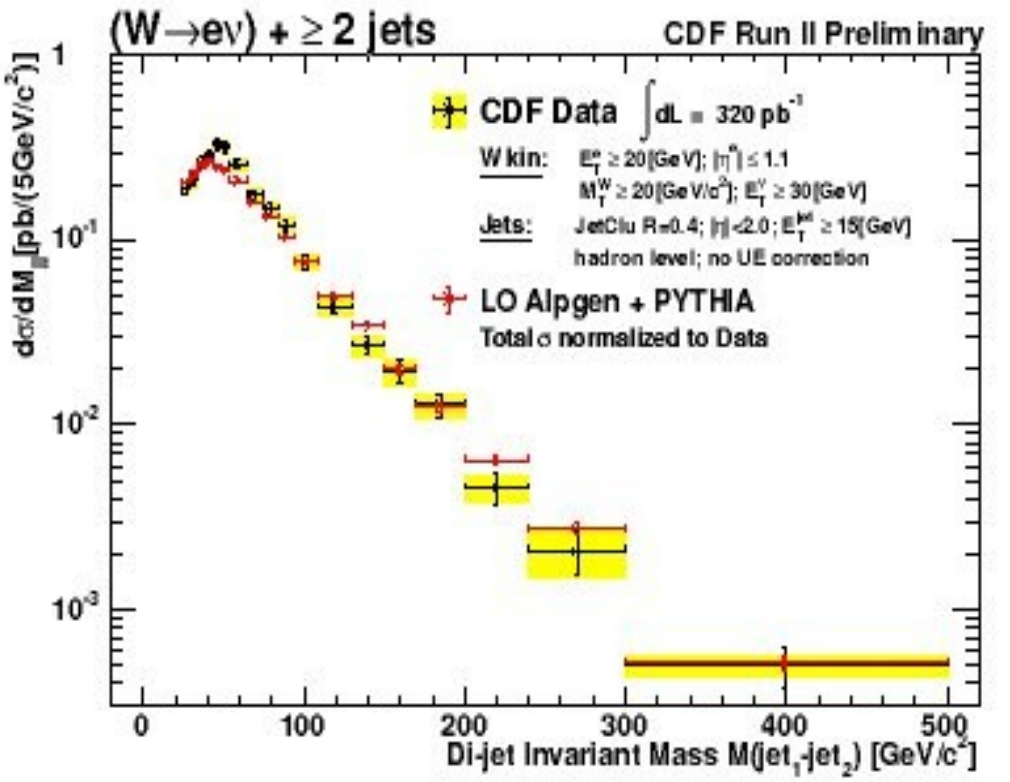


Data will allow to constrain further PDF especially using high rapidity bins

W+jets differential cross sections (CDF)

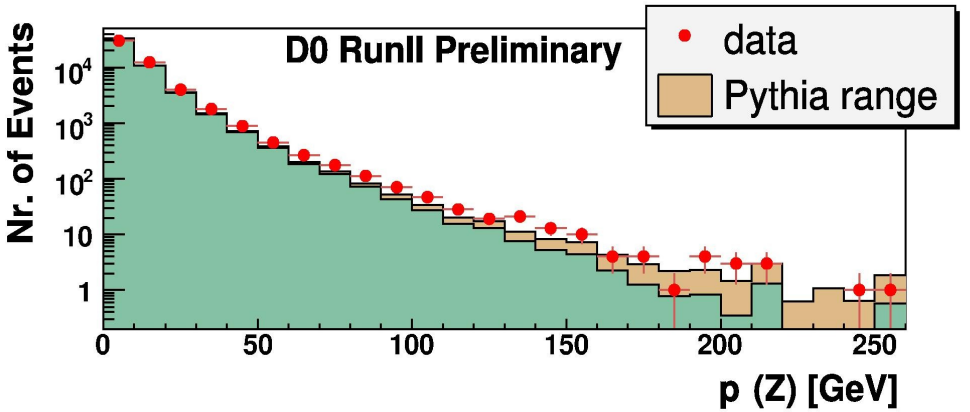
- Measurement of the W +n jets as a function of jet pT, R between jets, and jet-jet invariant mass.
- Comparison with LO theory (ALPGEN+PYTHIA, normalized to total data cross section)
- Cross section measured for a restricted phase space for W to obtain a flat W acceptance as a function of jet pT and not alter the shape of the cross section
- In general: data points withing uncertainties agree with theory, but there are tendencies to differ at leading jet high pT and in the shapes of inv. mass and di-jet dR distributions.

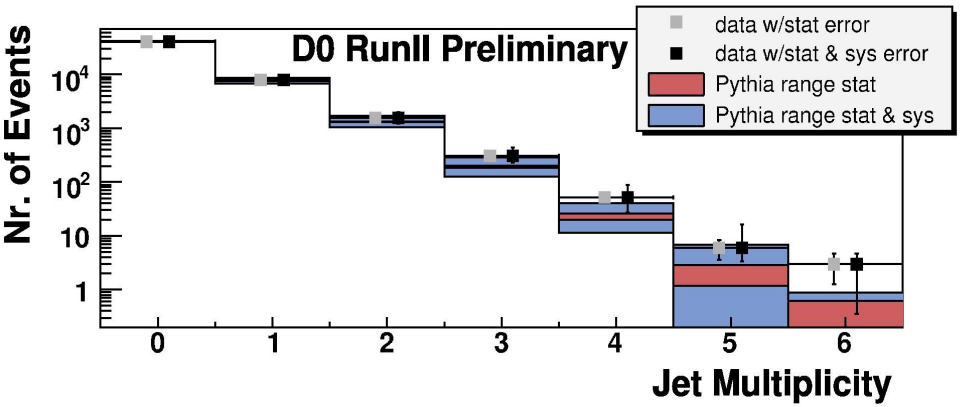


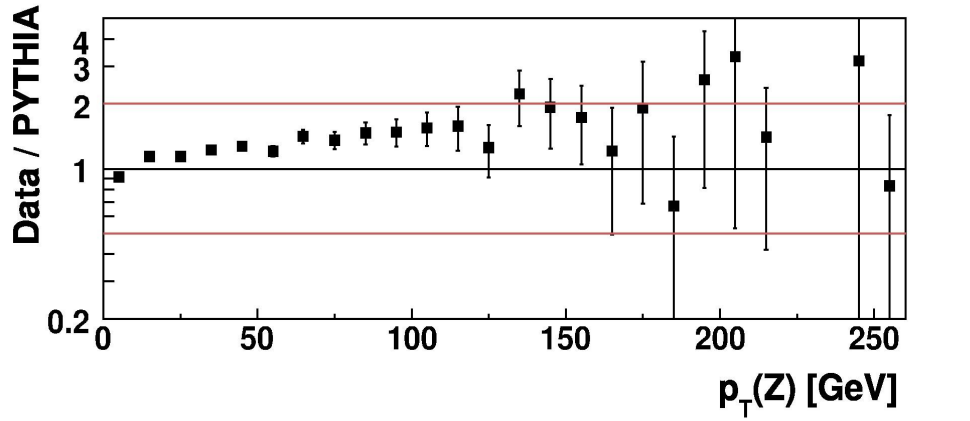


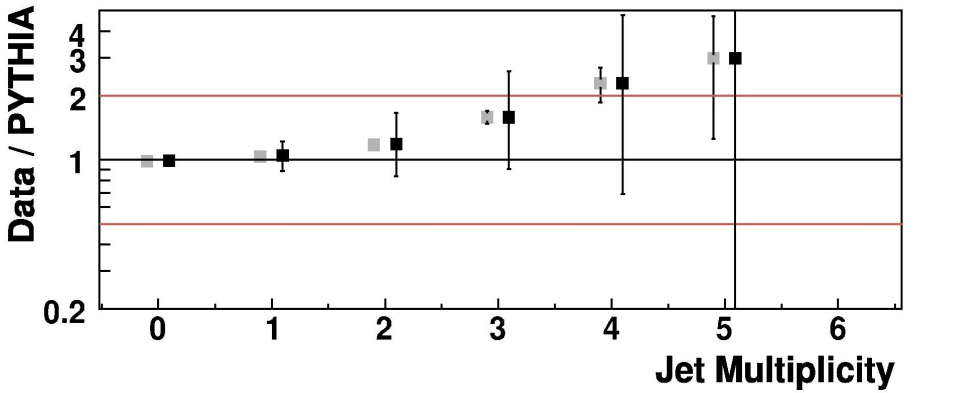
Z+jet event properties (D0)

- Compare jet and Z distributions between MC (Pythia and Sherpa) predictions and data: very useful to tune and check MC for the LHC
- In general, good agreement, but central prediction from Pythia contains fewer hard jets than seen in data and discrepancy increases with jet multiplicity; $\Delta\phi$(jet,jet) distribution shows significant peak at π in Pythia sampe but not in data.



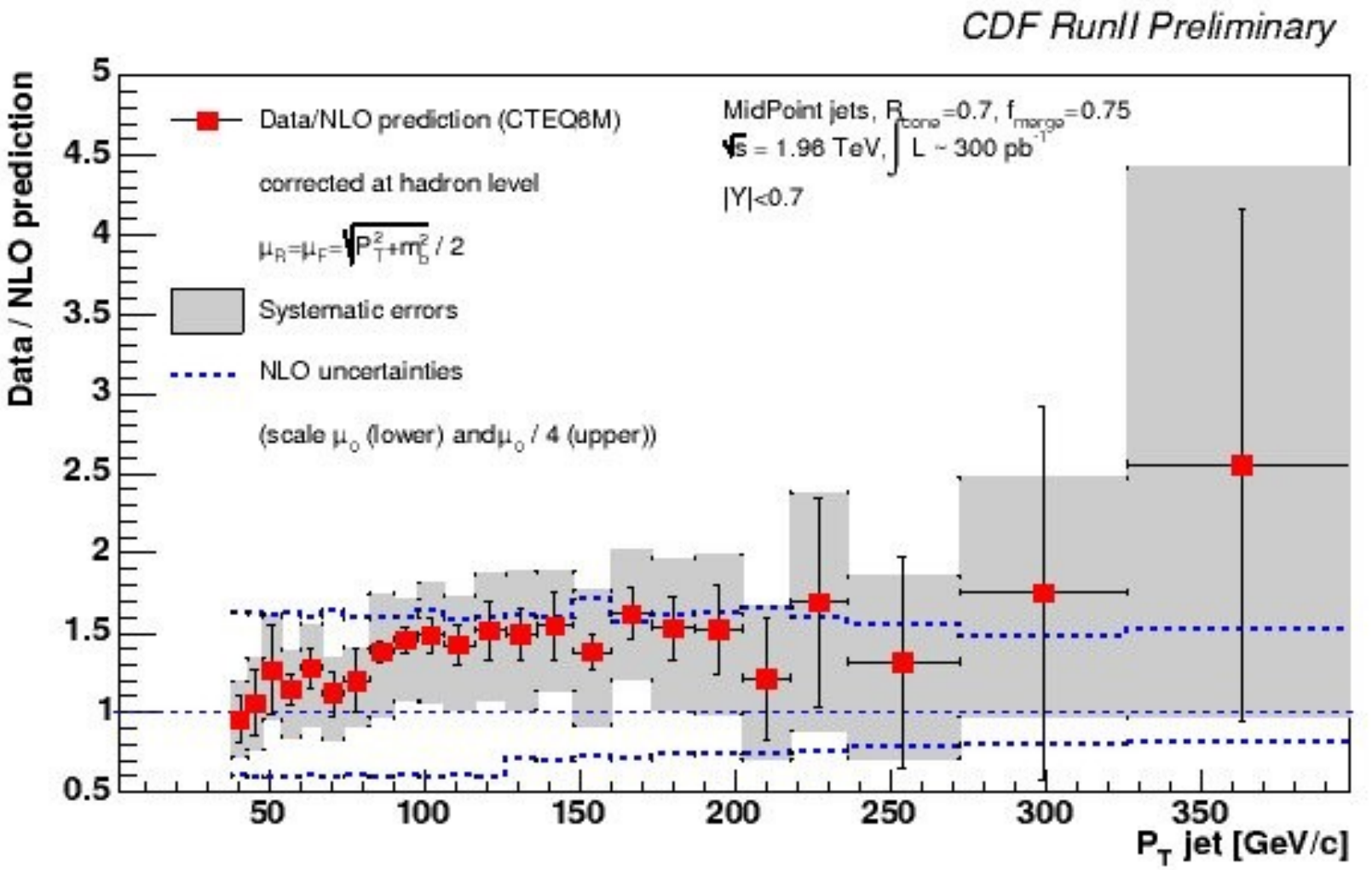






Inclusive b-jet cross section (CDF)

- Measurement of the b jet cross section in central region with |Y| < 0.7 vs. jet pT covering range up to 350 GeV. Theory is pQCD NLO from Mangano &Frixione.
- Main theor. uncertainties are related to renormalization and factorization scales (40-50% at pT < 150 GeV) -> not-included higher order contributions might play a major role in b-jet production calculations.

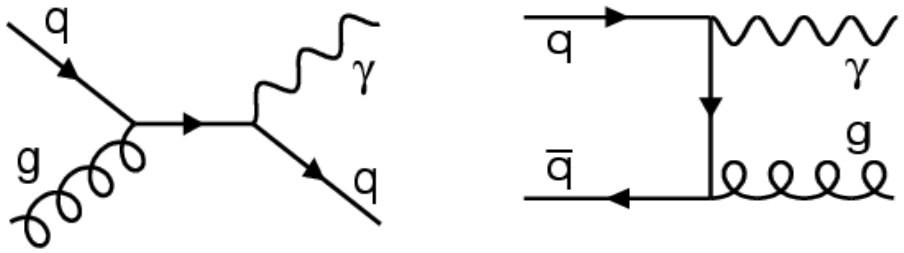


Inclusive photon cross section (D0): Motivation

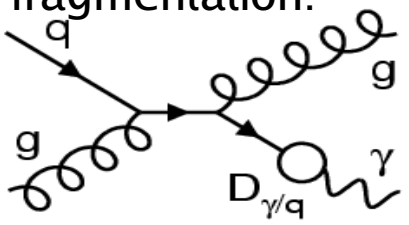
Direct photons emerge unaltered from the hard interaction

⇒**direct probe** of the hard scattering dynamics

clean probe without complication from fragmentation & systematics associated with jet identification and measurement



also fragmentation:



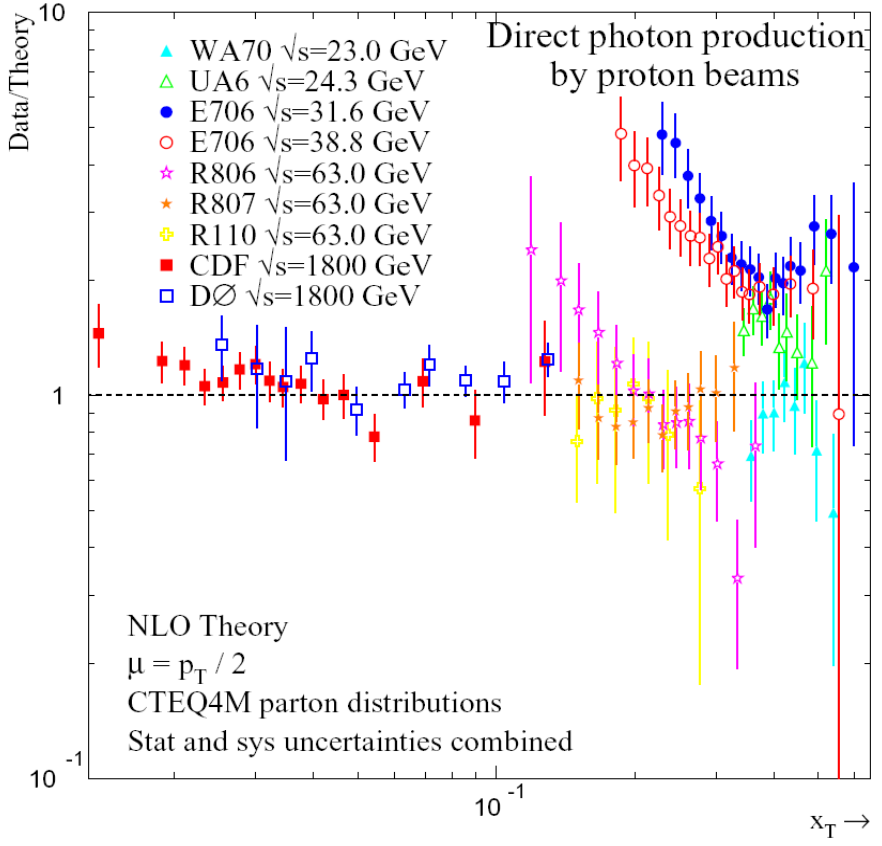
Precision test of pQCD

Direct information on gluon density

in the proton : gluon involved at LO in contrast to DIS & DY processes

Test of soft gluon resummation, models of gluon radiation,..

Understanding the QCD production mechanisms of photons is prerequisite to searches for new physics.

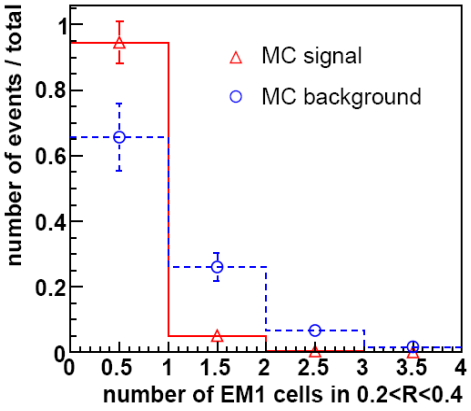


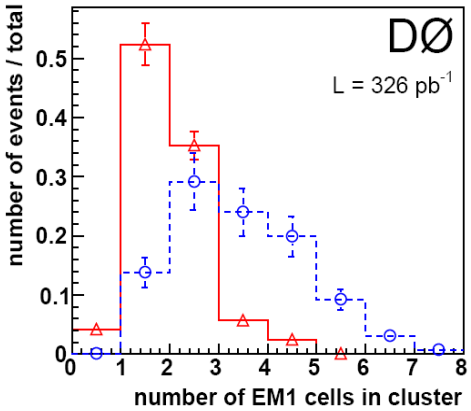
Inclusive photon cross section (D0)

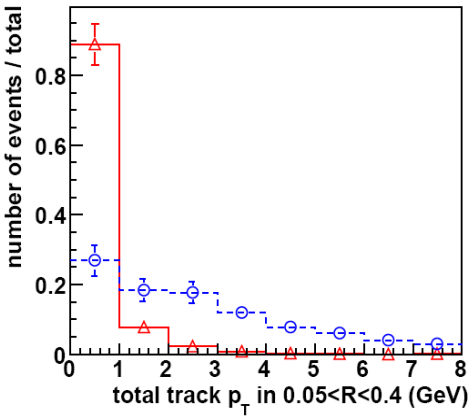
Extremely challenging!

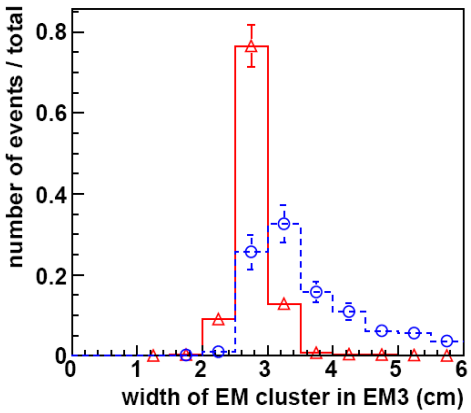
$\sigma(\text{jets})/\sigma(\gamma) \approx 10^3 \Rightarrow$ **severe background** from jet fragmenting into a leading π^0 (or η), particularly at small p_T^γ

Design a neural network (NN)

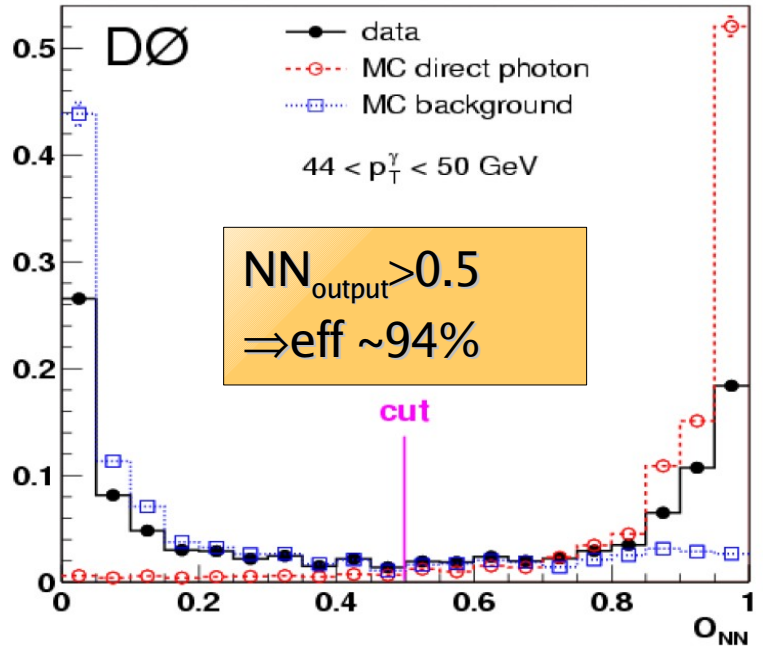


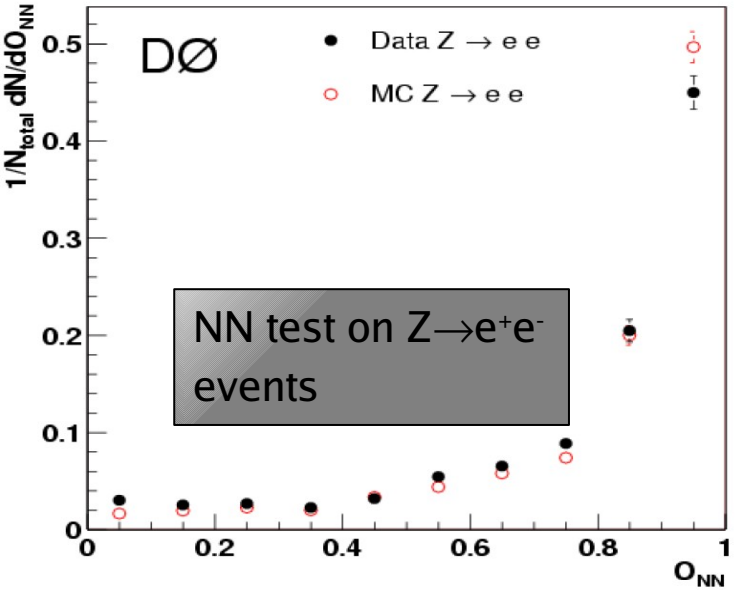




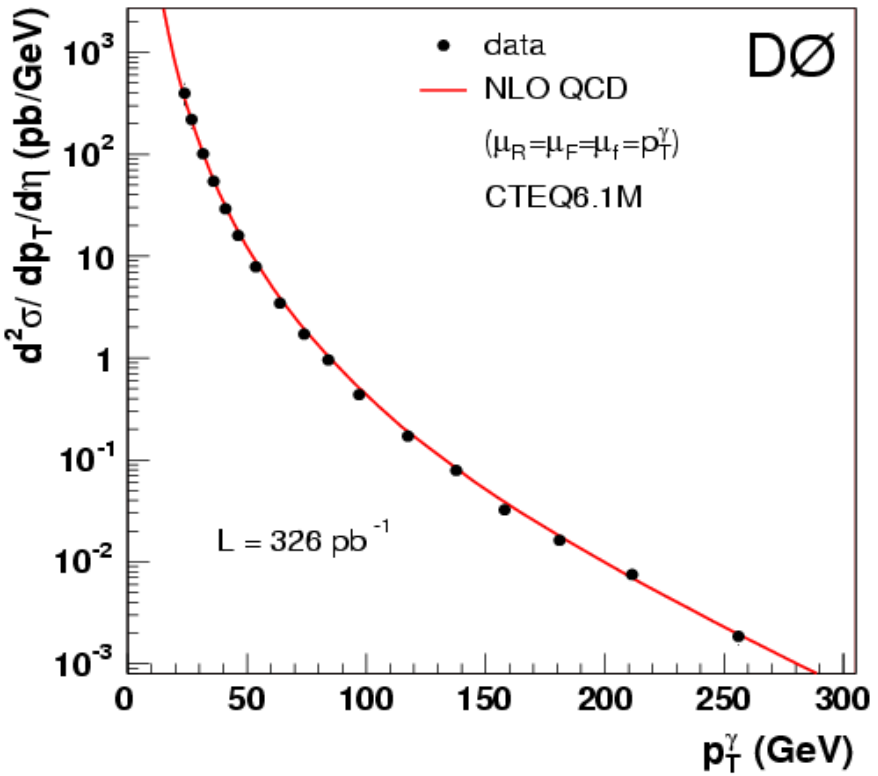


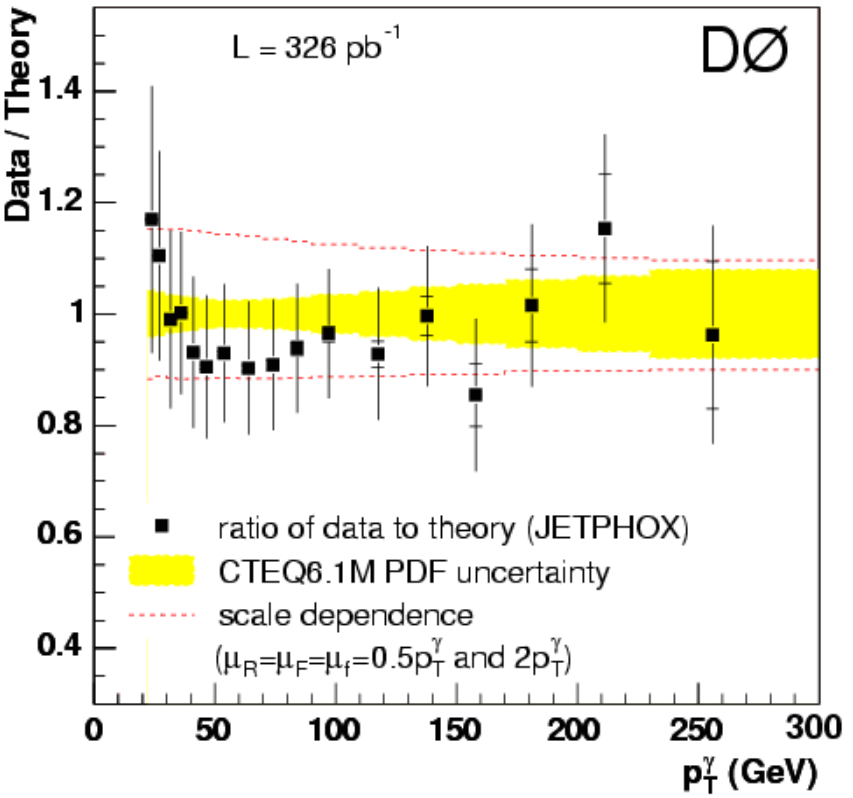
NN trained to discriminate between direct photons and em-jets.





Inclusive photon cross section (D0)





Differential cross section is measured in 23<pT<300 GeV and within |y|<0.9

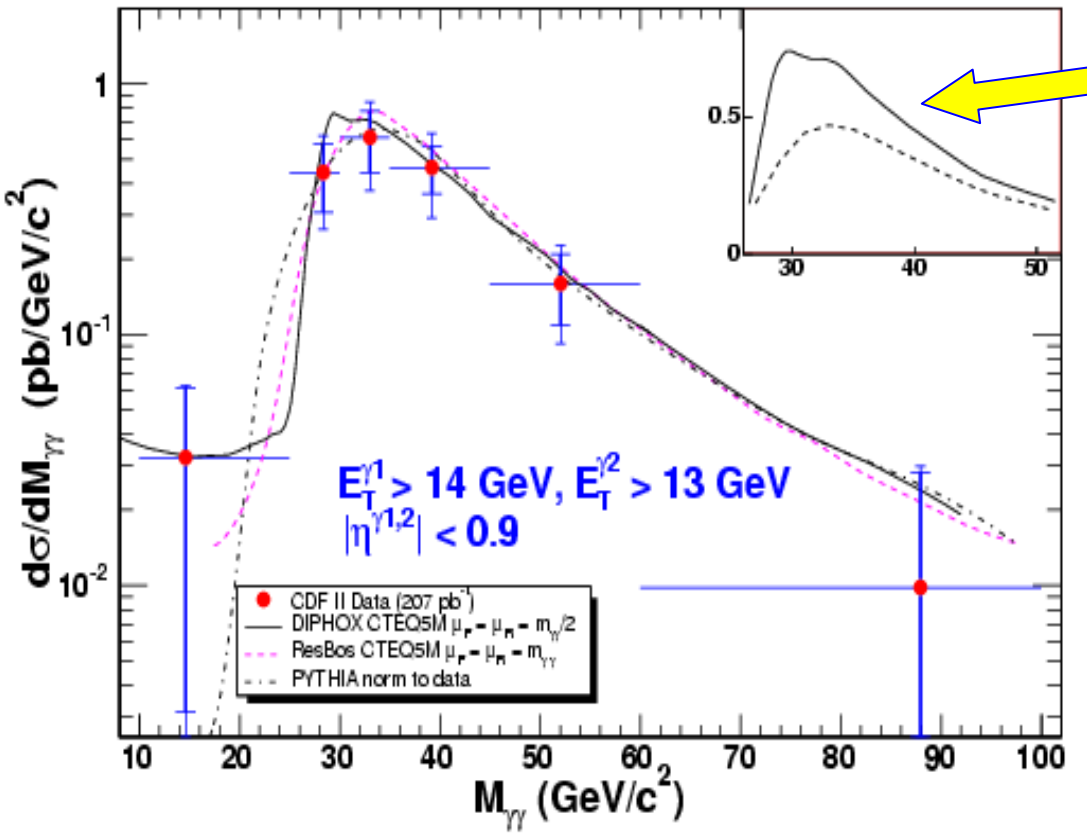
- NLO pQCD calculations from JETPHOX/Vogelsang using CTEQ6.1M and MRST PDFs.
- Good agreement withing uncertainties in the whole pT range. Data/Theory shape diff. at low/medium pT is difficult to interpret due to large theor. scale uncertainty and exper. syst. uncertainty (both are of comparable size).
- PDF sensitivity requires: reduced exp. uncertainty (dominated by purity) and improved theory (resummation/NNLO).

Di-photon cross section (CDF)

- One of main Higgs boson discovery channel at LHC, signature of new physics like extra dimensions.
- sensetive to ISR and gluon PDF.
- direct production: q qbar, qg, gg; fragmentation: one or two hard photons are from partons.

|y|<0.9; Photon pT> 13 & 14 GeV

889 Di-photon candidate events (207 inv. pb)- tot. eff: 15.2% - purity about 50%



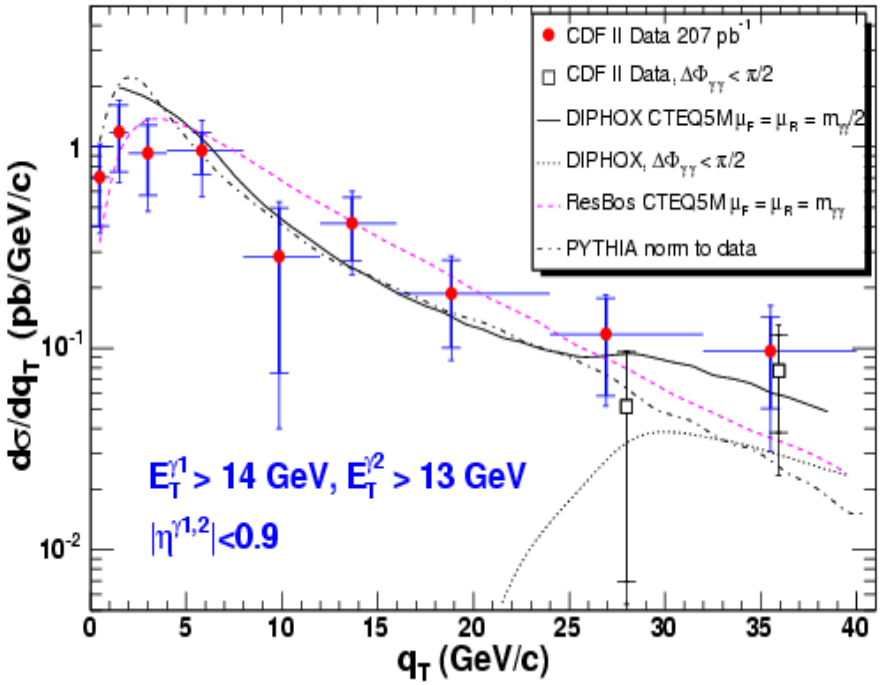
DIPHOX: with and w/o NNLO gg-diagram

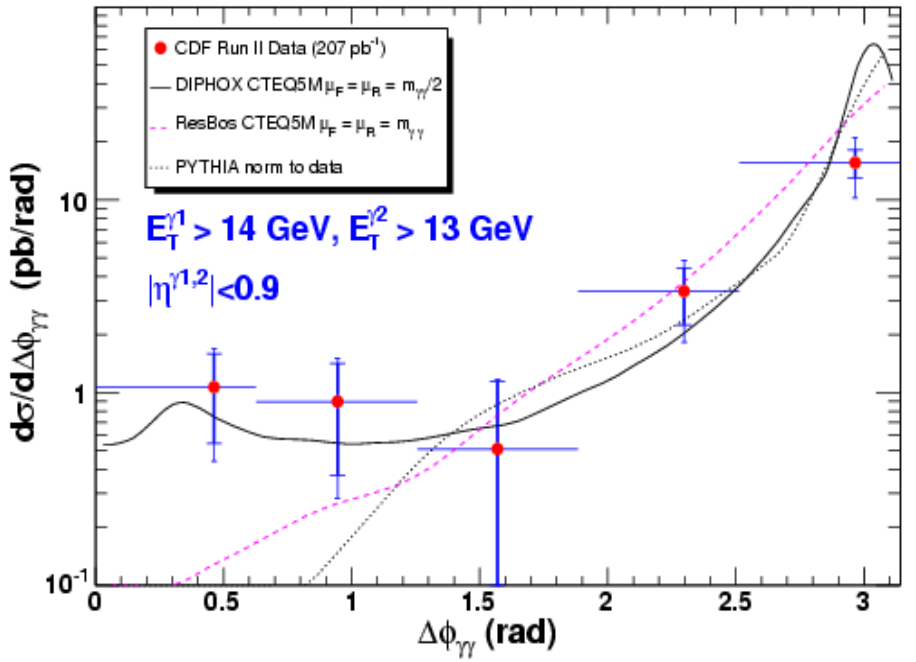
DIPHOX:
- NLO prompt di-photons
- NLO fragmentation (1 or 2 γ)
- NNLO gg→γγ diagram

ResBos:
- NLO prompt di-photons
- LO fragmentation contribution
- Resummed initial state gluon radiation (important for qT)

PYTHIA (increased by factor 2)

Di-photon cross section (CDF)





🡐 Total transverse momentum of pair

- NLO fragmentation contribution
  - only in DIPHOX
  → high pT, low Δϕ, low mass
- Resummed gluon ISR
  - only in ResBos → low qT, high Δϕ

🡐 $\Delta\phi(\gamma,\gamma)$

At large Δϕ gluon resummation contributes more while small Δϕ are accesible only in NLO.

- Systematic uncertainties:
  - selection efficiency (11%)
  - background subtraction (20-30%)
  - luminosity (6.5%)

Summary and Outlook

- Inclusive jet cross section measurements with two jet algorithms with higher precision and in more rapidity bins have been done. They are very useful to constrain better quark and gluon densities in proton, especially at high Q2.

- Other presented jet measurements sensitive to parton distributions: Z,W+jets and b-jet production.

- Photon production is very good tool for testing QCD dynamics and is additional source for constraining PDF. It is also very important channel for searches of new phenomena.

- Exciting work is in progress now with photon+jet, photon+heavy flavour and di-photon events. Along with jet measurements they should provide new limits on QCD and PDF parameters.

BACKUP SLIDES