Inclusive Jet Production in Z+jets final states at CDF

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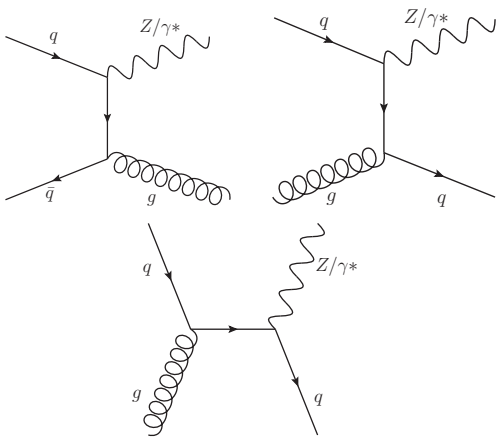
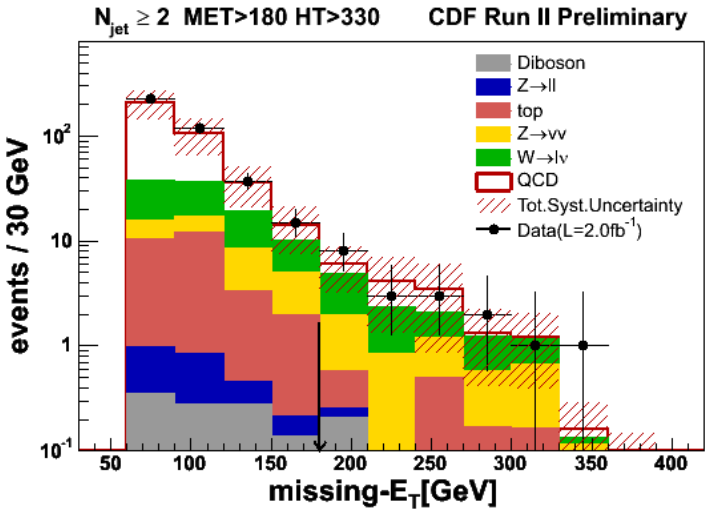
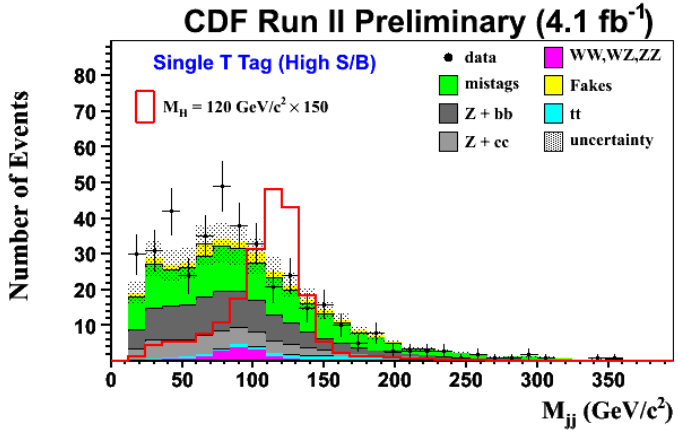
Motivation



- Test perturbative QCD at high Q^2

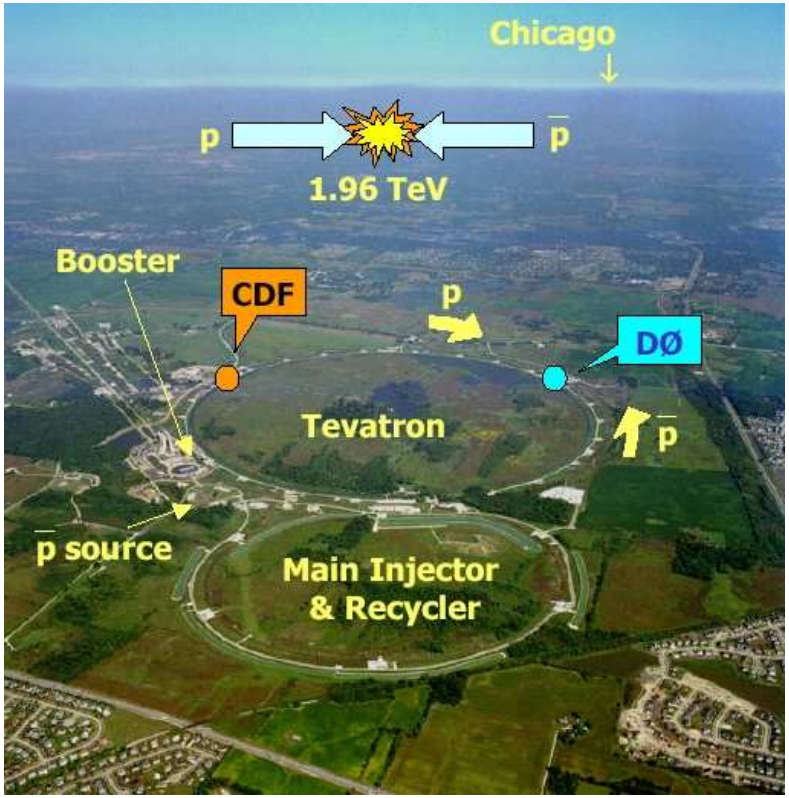


- Important background for Higgs and Susy searches



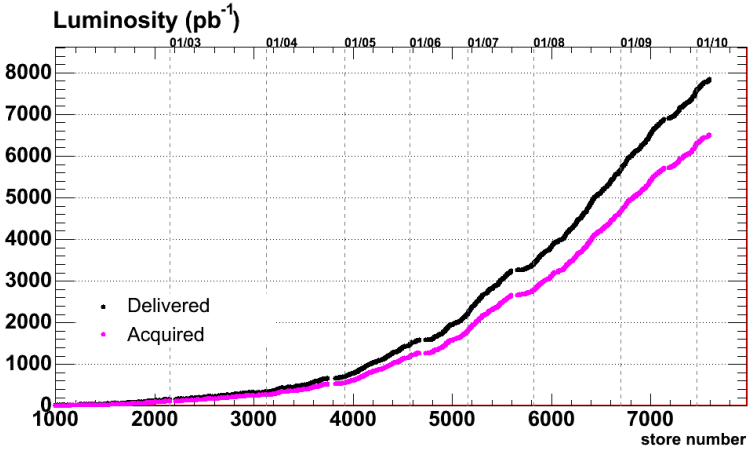
- Main background for $Z + H \rightarrow l^+ l^- b\bar{b}$ process

Tevatron



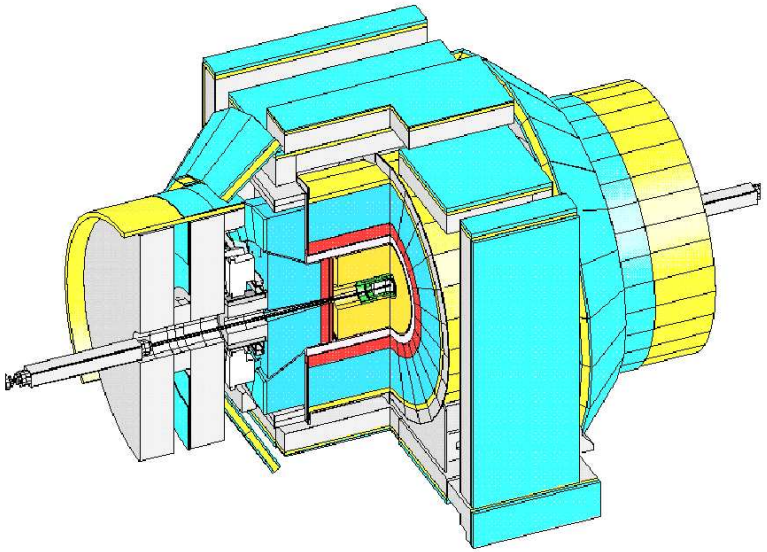
- $p\bar{p}$ collisions at $\sqrt{s} = 1.96\,TeV$
- Peak instantaneous luminosity $> 3 \cdot 10^{32}\ cm^{-2}s^{-1}$

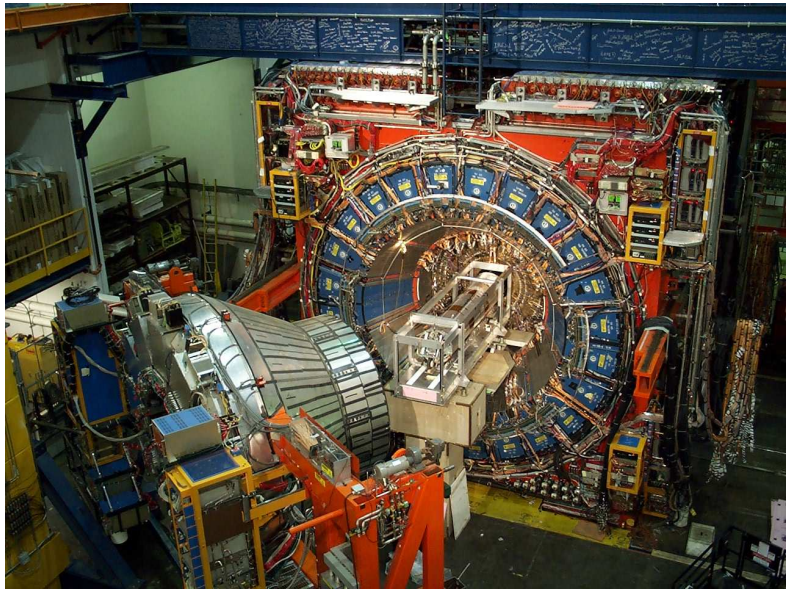
- 6.4 fb^{-1} of integrated luminosity on tape



CDF II Detector

- Tracking System
  - Silicon detector
  - Drift chamber
- 1.4 T Magnetic field
- Calorimeter
  - Electromagnetic Calorimeter
  - Hadronic Calorimeter
- Muon detectors
  - Wire chambers
  - Scintillators
- 3 Level Trigger System
  - Level 3 $\rightarrow \sim 100 Hz$





$Z \rightarrow \mu^+\mu^- +$ jet Production Cross Section

- Measurement definition
- Trigger and data sample
- Muon selection and identification
- Background estimation
- Unfolding to particle level
- NLO theory prediction
- Systematic uncertainties
- Results

Measurement definition

- Muons
  - $p_T^{\mu} \geqslant 25\ GeV/c$
  - $|\eta^{\mu}| \leqslant 1.0$
- Z Boson
  - $66\ \leqslant M_Z \leqslant 116\ GeV/c^2$
  - Two opposite charged tracks
- Jets
  - Midpoint algorithm, $\Delta R_{cone} = 0.7$
  - $p_T^{jet} \geqslant 30\ GeV/c$
  - $|Y^{jet}| \leqslant 2.1$

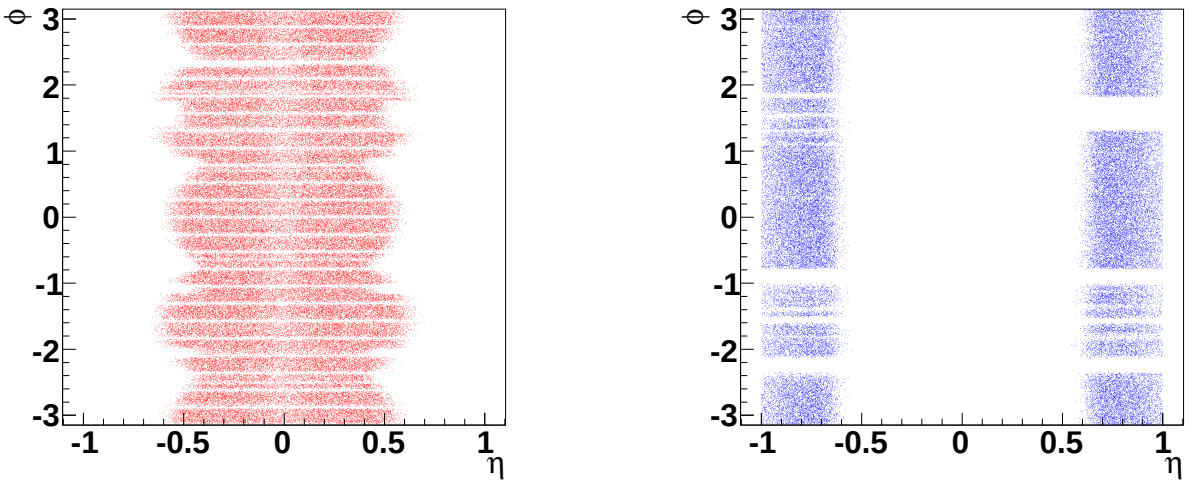
Inclusive jets measurements: All jets in the event are considered

Differential cross sections as a function of p_T^{jet}, $|Y^{jet}|$ in $\mathrm{Z} + \geqslant 1\ \mathrm{jet},\ \ \mathrm{Z} + \geqslant 2\ \mathrm{jets}$ events.
Cross section vs jet multiplicity.

Trigger and data sample

- 2.4 fb^{-1} of integrated luminosity are used for this measurement
- Data are collected with a high p_T muon trigger ($p_T \geqslant 18 GeV/c$)

Coverage of the Muon Detectors in η and ϕ



Muon Selection and Identification

- Minimum ionizing particles $\rightarrow$ tracks associated to low energy release in the calorimeter
- Impact parameter consistent with tracks originating from interaction primary vertex
- High quality reconstructed tracks

μ Efficiencies

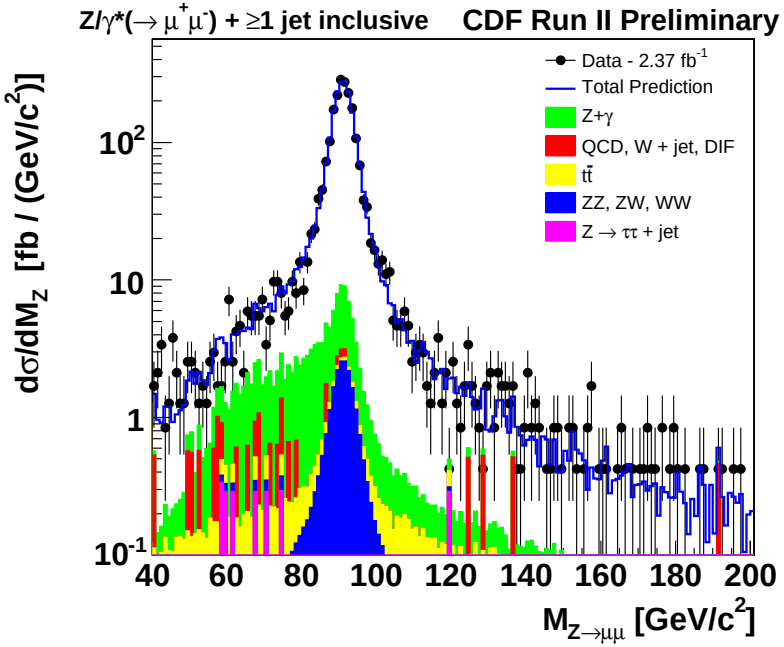
- Muon trigger and ID efficiencies are evaluated on data
- Tag leg - probe leg method is applied to $Z \rightarrow \mu^+\mu^-$ events
- Evaluated muon efficiencies give a $Z \rightarrow \mu^+\mu^-$ cross section consistent with NLO prediction and published result

Background estimation

Monte Carlo backgrounds

Pythia simulation

- $Z \rightarrow \mu^+\mu^- + \gamma$
- $t\bar{t}$
- diboson ZZ, ZW, WW
- $Z \rightarrow \tau^+\tau^-$



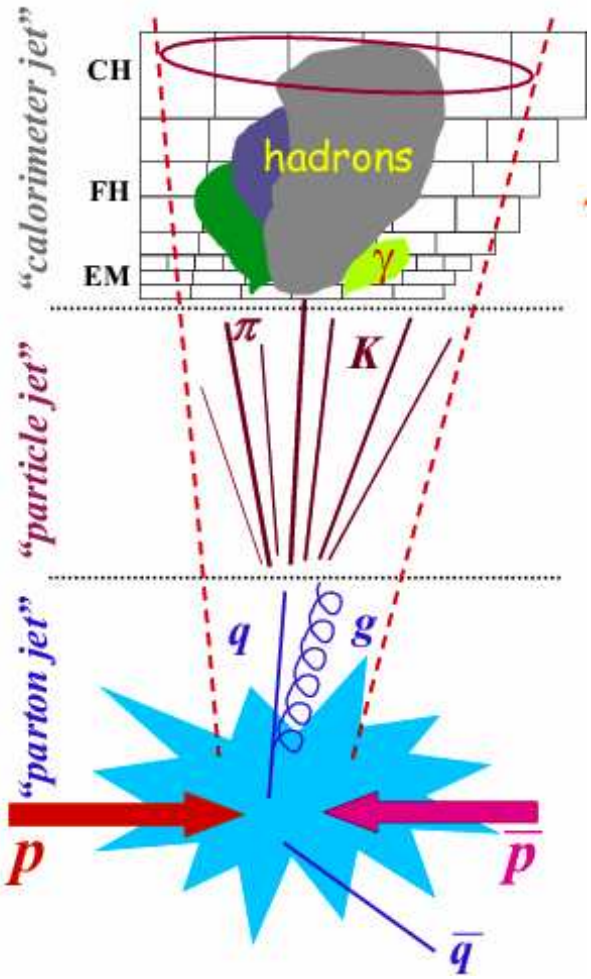
Data driven backgrounds

Same Charge tracks required instead of **Opposite charge**

- QCD dijet
- W + jet
- μ fakes

Unfolding

- Calorimeter jets are unfolded back to particle level jets using detector simulation
- Account for resolution effects: bin to bin migration
- Account for detector acceptance of $Z \rightarrow \mu^+\mu^-$ reconstruction
- Bin by bin unfolding for every variable

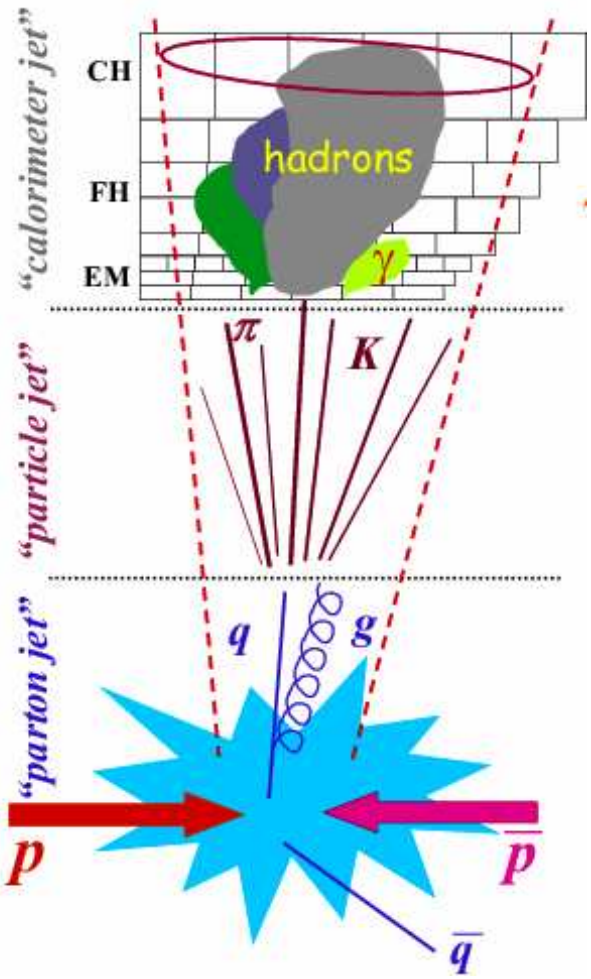


$$U = \frac{(Particle\ level\ jets - Kinematic\ Z \rightarrow \mu^+\mu^-)}{(Calorimeter\ jets - Reconstructed\ Z \rightarrow \mu^+\mu^-)}$$

NLO prediction

- NLO perturbative QCD prediction
- MCFM simulation

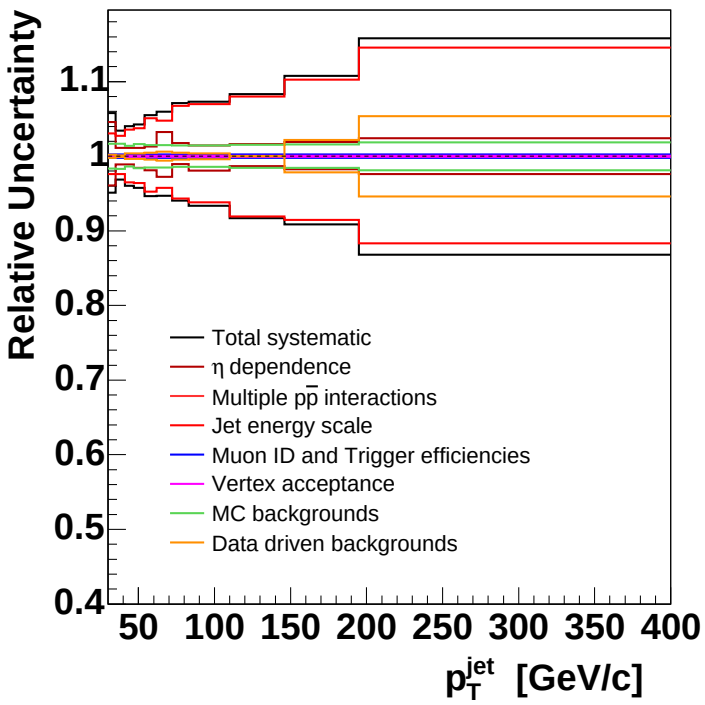
  J.Campbell, R.K.Ellis: Phys.Rev.D 65:113007(2002)
- PDF set: CTEQ6.1M
- Renormalization and factorization scale $\mu_0 = \sqrt{M_Z^2 + P_T^2(Z)}$
- Parton level cross sections are corrected to particle level for non-perturbative contributions $\rightarrow$ Underlying Event and hadron fragmentation



$$C_{Had} = \frac{(\textbf{Particle}\ \textit{level jets}\ \textbf{with}\ \textit{Underlying Event})}{(\textbf{Parton}\ \textit{level jets}\ \textbf{without}\ \textit{Underlying Event})}$$

Systematic uncertainties

- Jet Energy Scale $3 - 15\%$
- Data driven backgrounds $1 - 5\%$
- Monte Carlo backgrounds $1 - 3\%$
- Calorimeter Uniform response in η $2 - 5\%$
- Trigger and Muon ID efficiencies 0.2%
- Multiple interaction Jet Energy correction $< 0.1\%$
- Vertex acceptance $< 0.1\%$



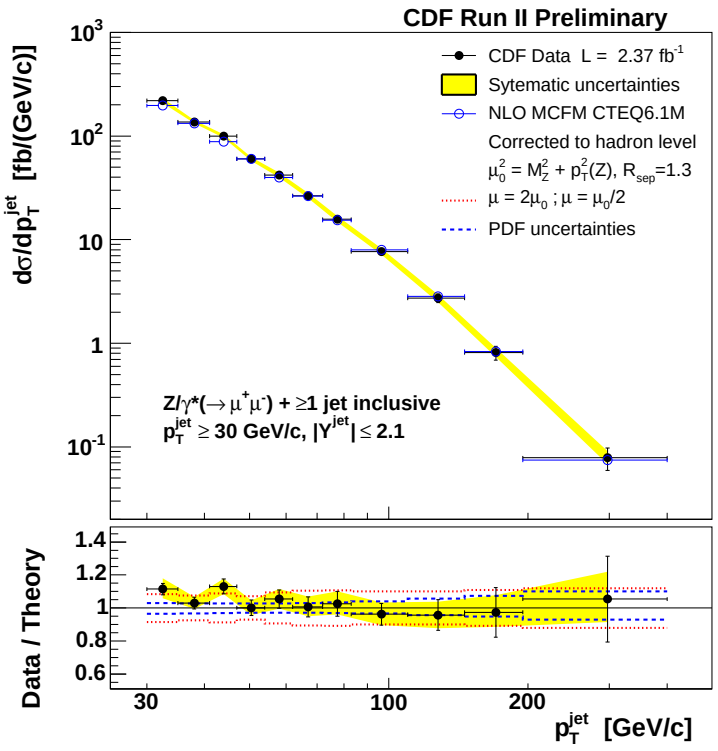
Uncertainties on the theoretical prediction

- PDF (Hessian method)
- Dependence on μ_0 scale

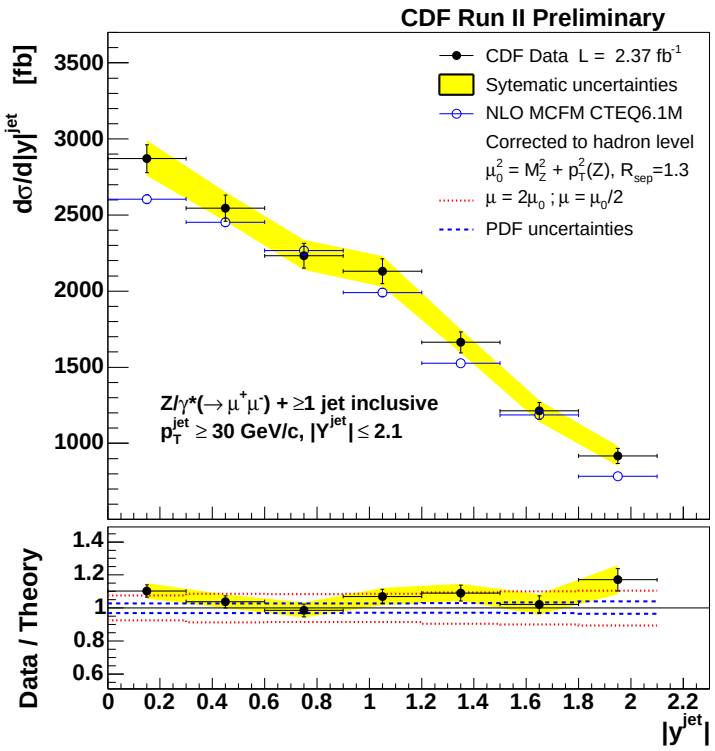
Vary renormalization and factorization scale up and down by a factor of 2

$Z + \geqslant 1$ jets results

Differential cross sections



Inclusive jet p_T

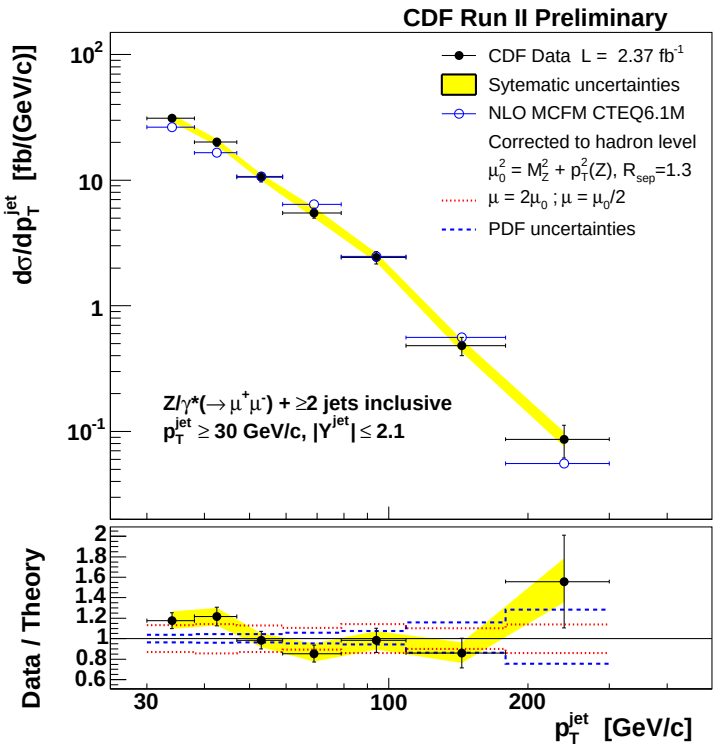


Inclusive jet rapidity

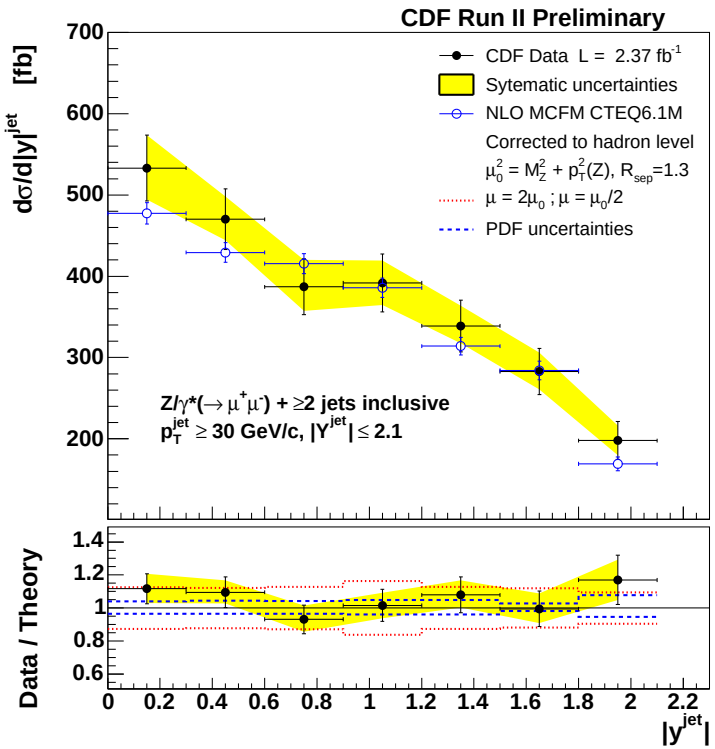
Good agreement between data and NLO prediction

Z + ⩾ 2 jets results

Differential cross sections



Inclusive jet p_T

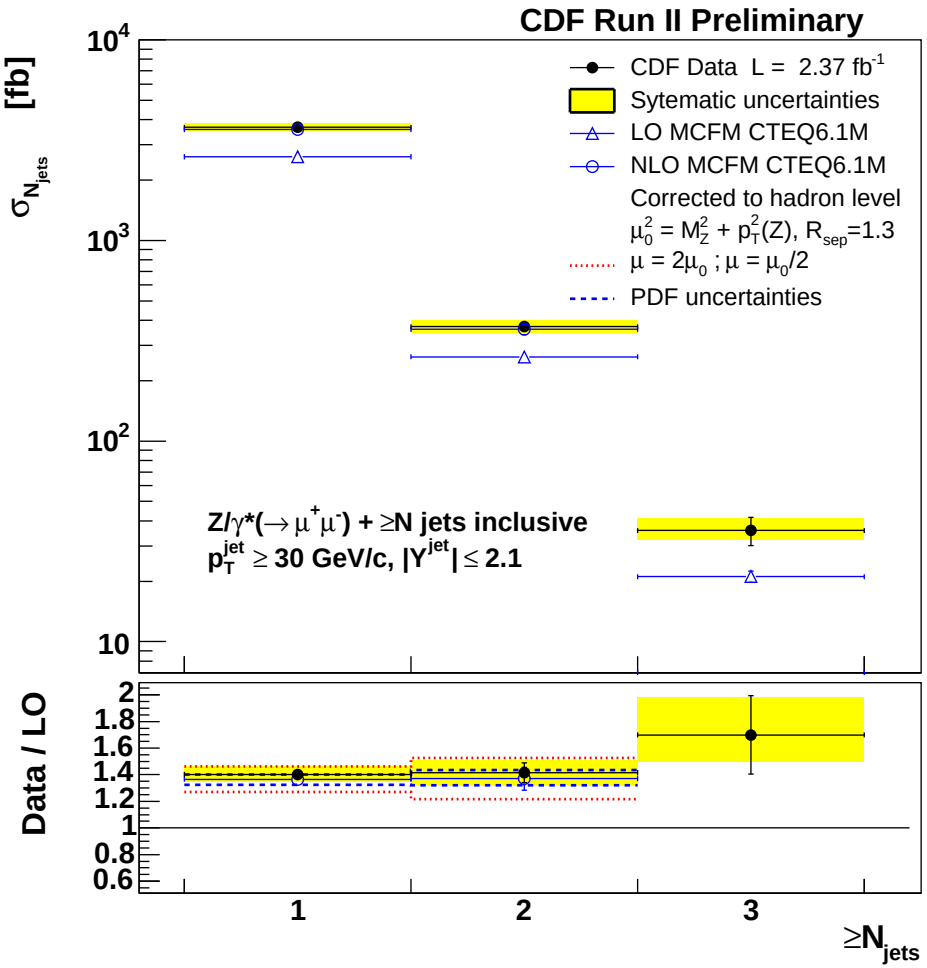


Inclusive jet rapidity

Good agreement between data and NLO prediction

Z + ⩾ N jets results

Cross section vs jet multiplicity



Good agreement between data and NLO prediction in ⩾ 1 jet and ⩾ 2 jets bins
Data suggest a ratio to LO of ∼ 1.4

Conclusions

Z + jets cross sections in the $Z \rightarrow \mu^+\mu^-$ decay channel have been measured with 2.4 fb^{-1} of data collected with the CDF detector.

- Differential cross sections for events with $\geqslant$ 1 jet and $\geqslant$ 2 jets.
- Inclusive jets cross section vs jet multiplicity up to $\geqslant$ 3 jets.

Good agreement is found between data and NLO prediction.

Plans:

- Extend the measurement with more data.
- Combine with the $Z \rightarrow e^+e^-$ decay channel.

Measurement published in Phys. Rev. Lett. 100, 102001 (2008)