Tevatron Results

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on behalf of the CDF and DØ Collaborations

DIS 2005

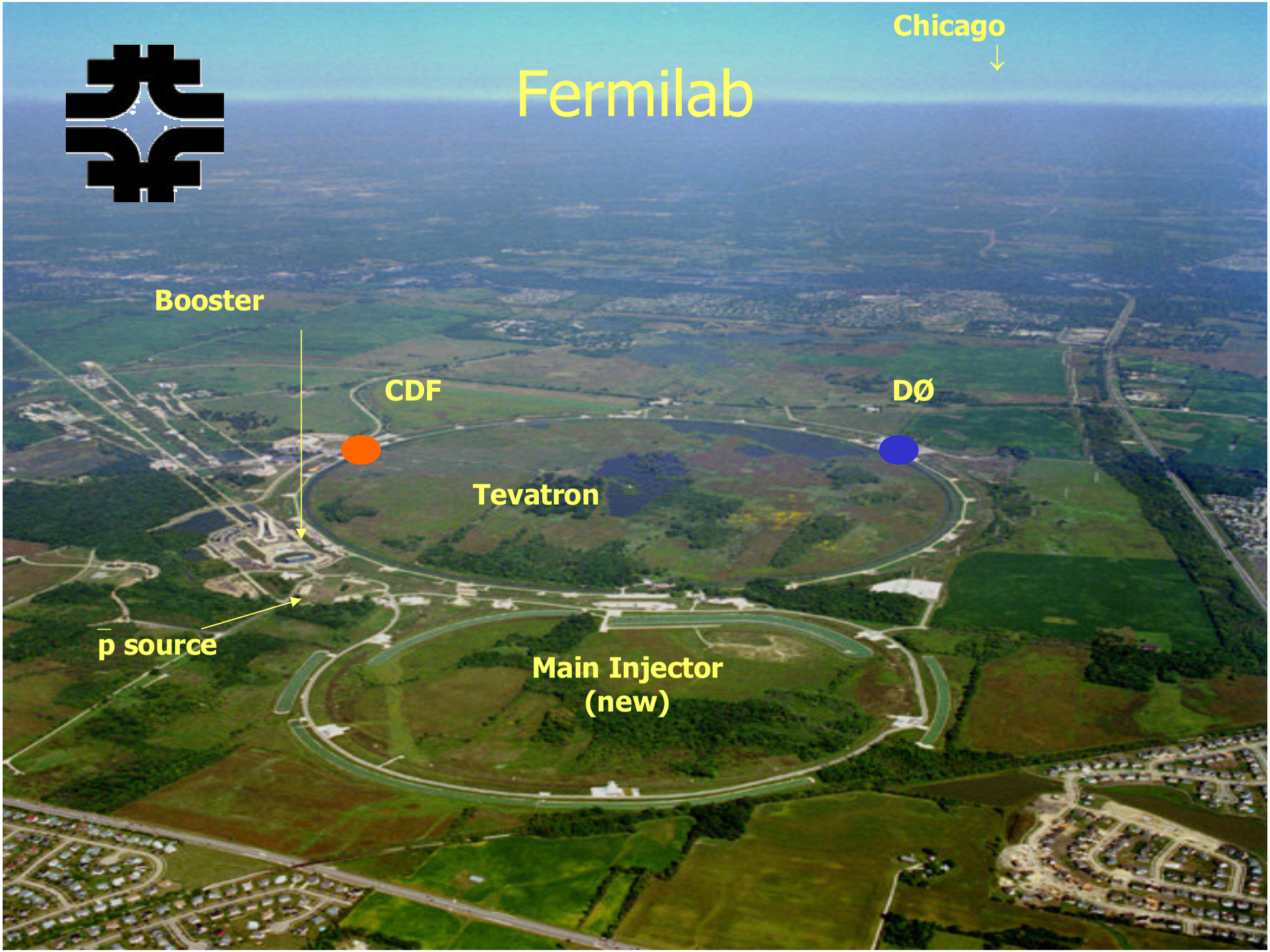
XIII International Workshop on Deep Inelastic Scattering

April 27th – May 1st 2005, Madison, Wisconsin, U.S.A.

Outline

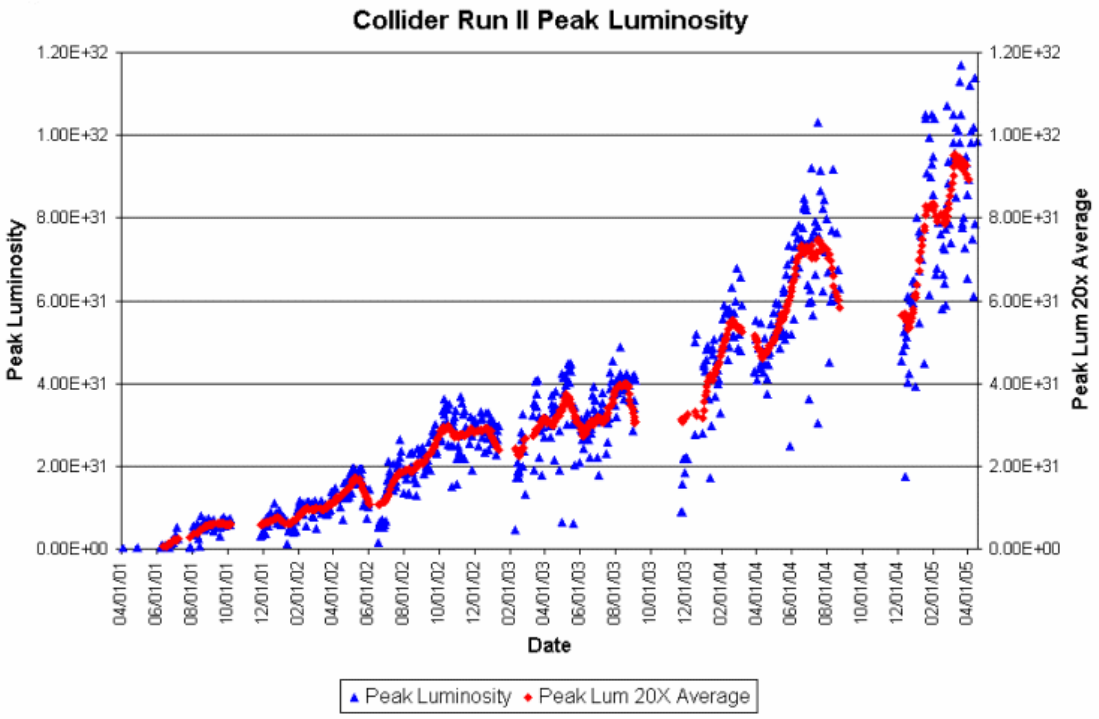
- Introduction
  - Tevatron, CDF & DØ
- Jet Physics
  - Inclusive jet production, dijet $\Delta\phi$ decorrelations, jet shape, b-jet production, Z+jets
- EW Physics
  - W & Z production, W charge asymmetry, Γ_W
- Top Physics
  - Top pair production, top mass
- Examples of searches
  - $b\bar{b}h(\rightarrow b\bar{b})$ in MSSM, gluino$\rightarrow$sbottom
- Conclusion

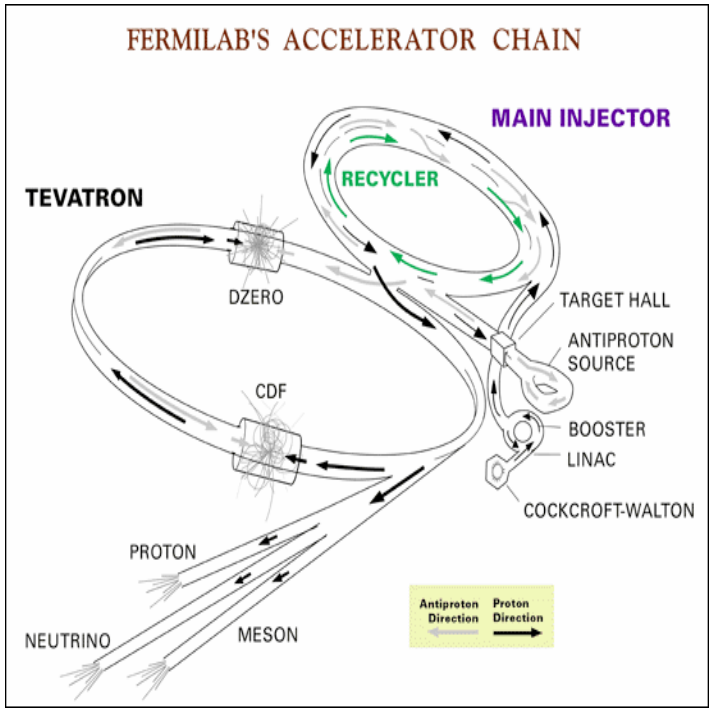
$\rightarrow$ A lot more not presented here!


Chicago
Fermilab
Booster
CDF
DØ
Tevatron
p source
Main Injector
(new)

Tevatron

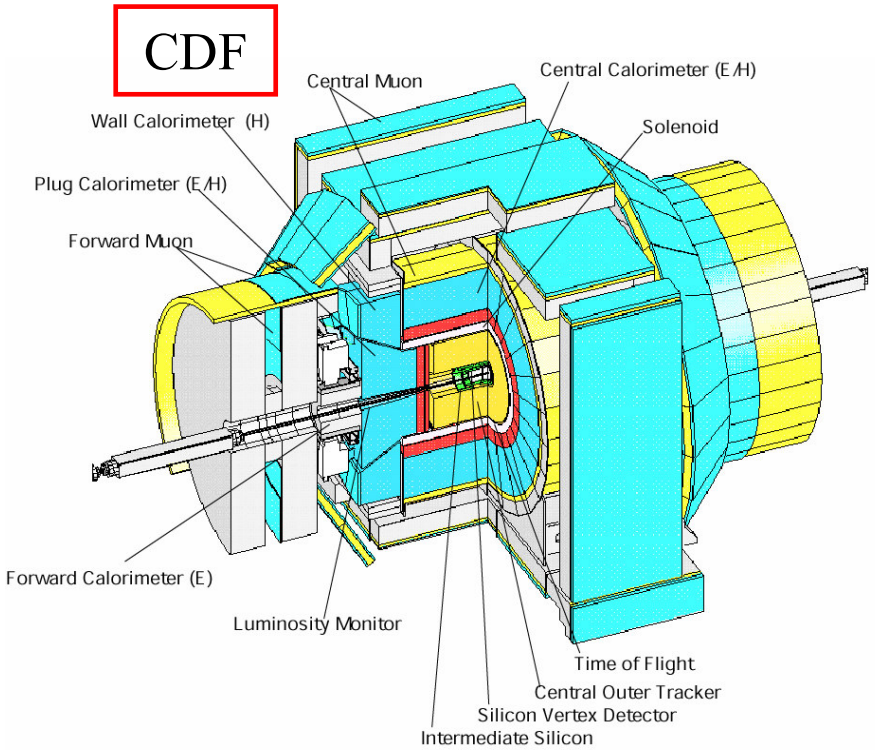
- proton-antiproton collisions
- $\sqrt{s}$ = 1.96 TeV (Run I → 1.8 TeV)
- 36 bunches: 396 ns crossing time
- Peak luminosity is now ~ 10^{32} cm^{-2} s^{-1}





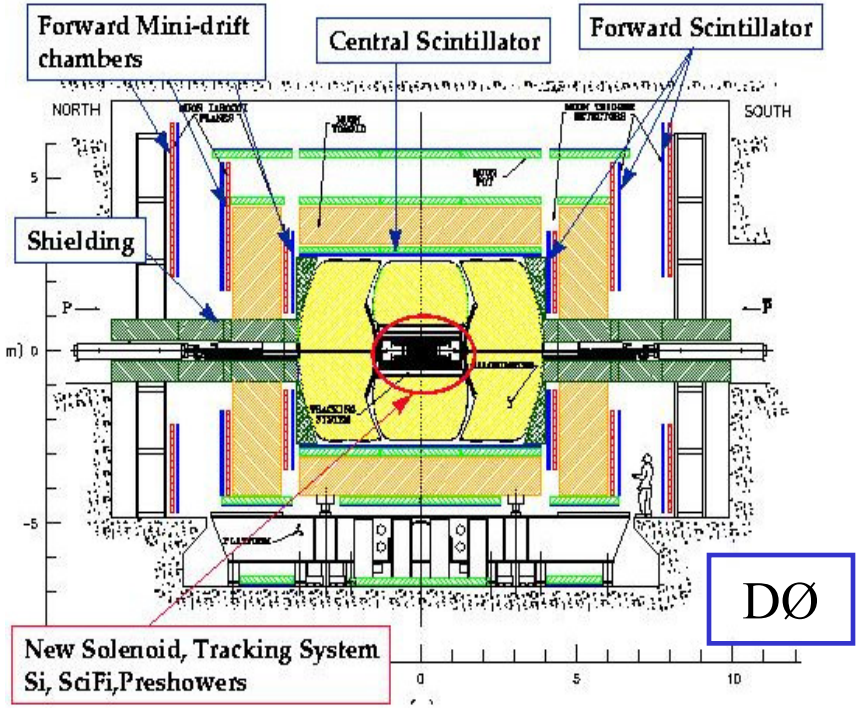
- Long term luminosity goal
  - Base 4.4 fb^{-1}, Design 8.5 fb^{-1} by the end of 2009

CDF and DØ



Both detectors highly upgraded

- New Silicon micro-vertex tracker
- New Tracking System
- Upgraded muon chambers
- CDF: new Plug Calorimeters, new TOF
- DØ: new solenoid, new Pre-showers

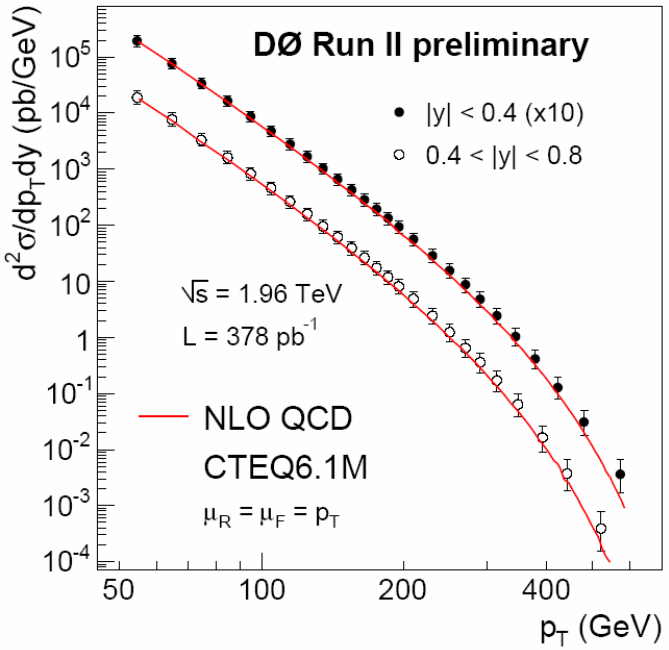


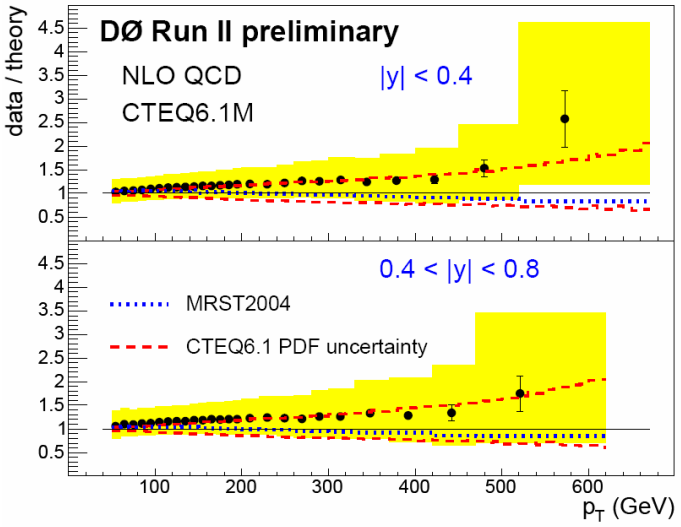
- Both experiments taking data with good efficiency ~ 85 %
- Each experiment has already collected on tape ~ 0.7 fb^{-1}

Jet Physics

Jet Production with Midpoint

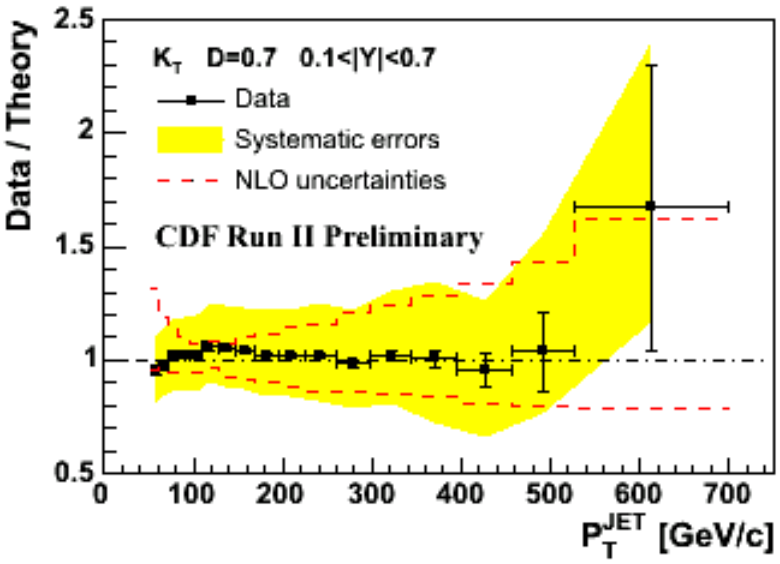
- Inclusive jet cross section @ Tevatron
  - Stringent test of pQCD
  - Tail sensitive to new physics
  - PDFs at high Q^2 & high x
- Midpoint jet algorithm
  - $R_{CONE} = 0.7$ / Merging fraction = 50 %
  - Infrared safe: no R_{SEP} parameter introduced in theory calculation (Merging / Splitting?)
- Direct comparison with NLO
  - QCD Hadronization / Underlying Event corrections small
- Good data-theory agreement
  - Experimental uncertainty dominated by jet energy scale
  - Largest theoretical error from PDFs (gluon at high x)

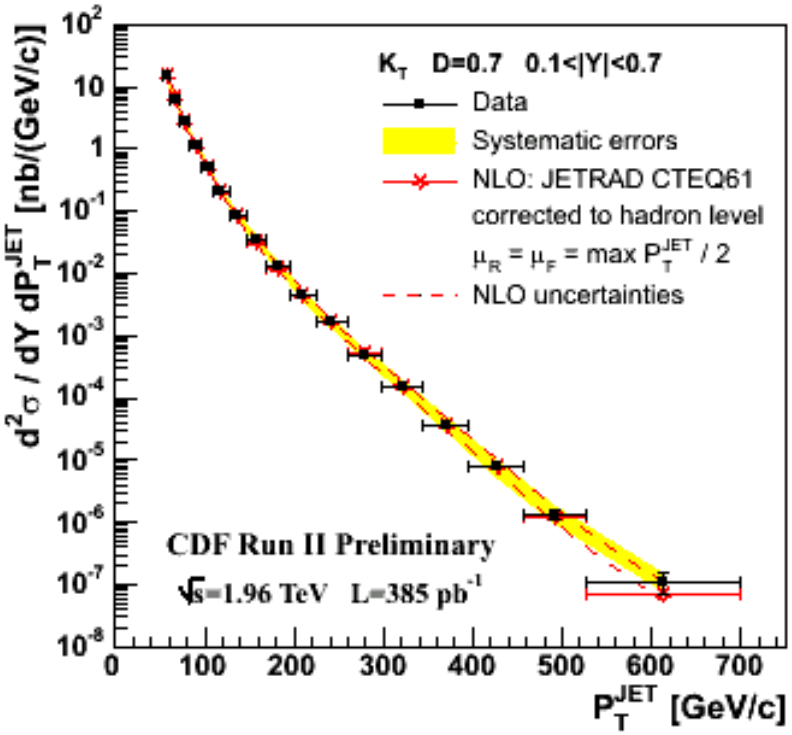


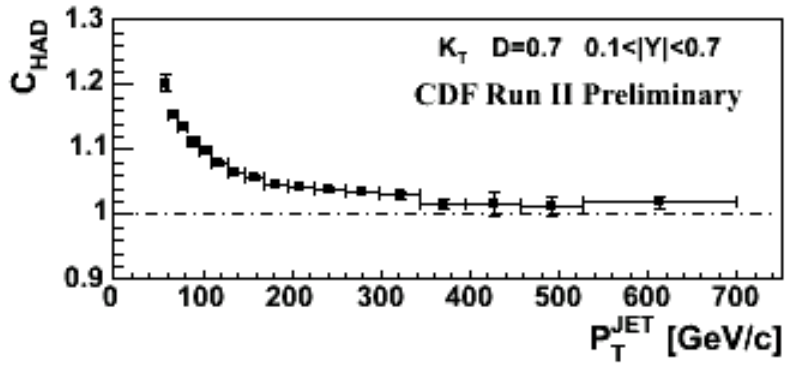


Jet Production with K_T

- Inclusive K_T algorithm
  - Infrared and Collinear safe to all orders in p-QCD
  - No merging / splitting feature
    - No R_{SEP} issue comparing to p-QCD
- NLO corrected to hadron level
- Good data-theory agreement



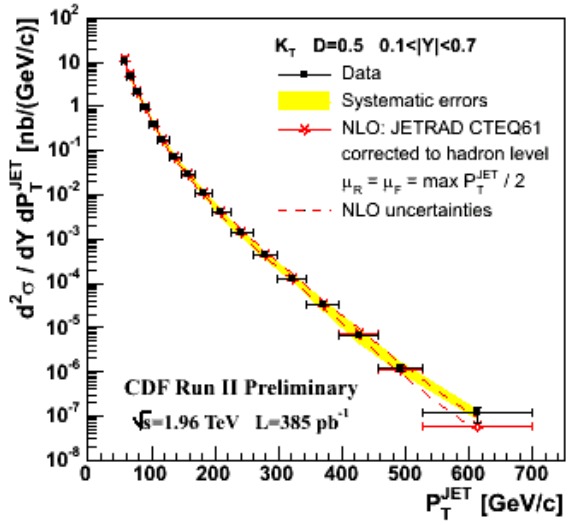


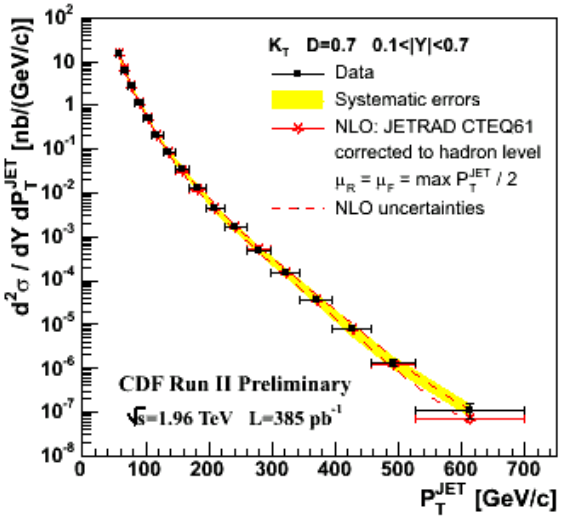


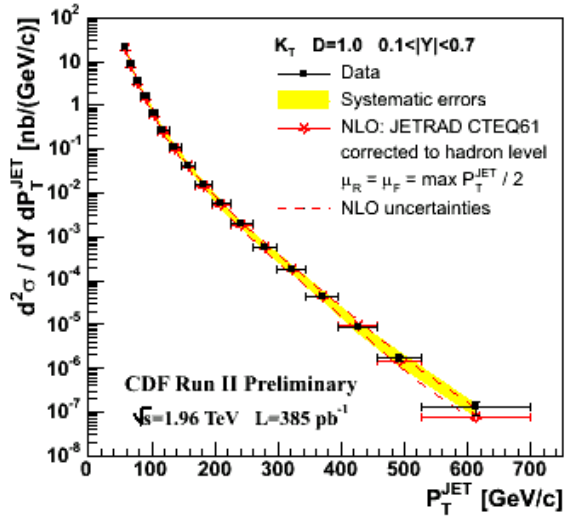
K_T jets vs. D

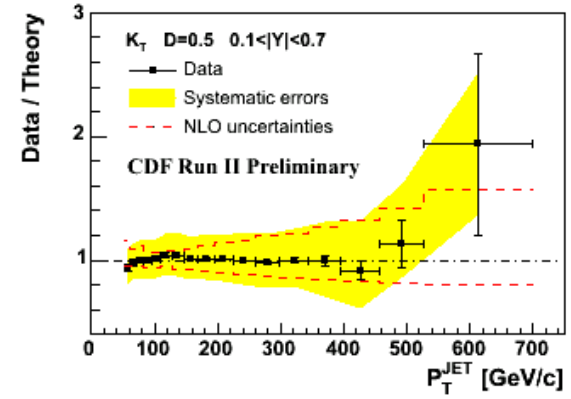
D ↔ size of jets

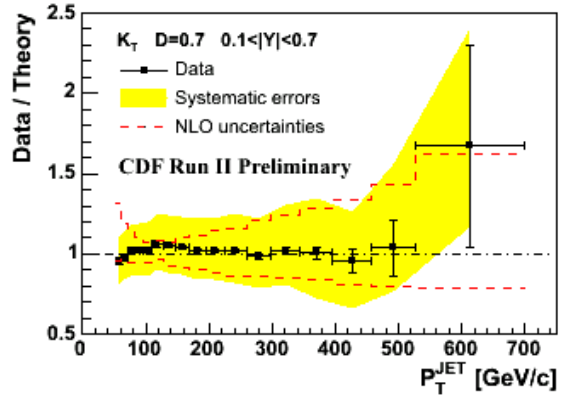
$d_{ij} = \min(P^2_{Ti}, P^2_{Tj}) \cdot \Delta R^2 / D^2$

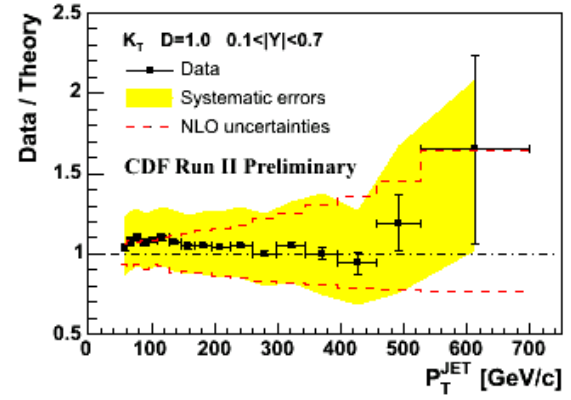


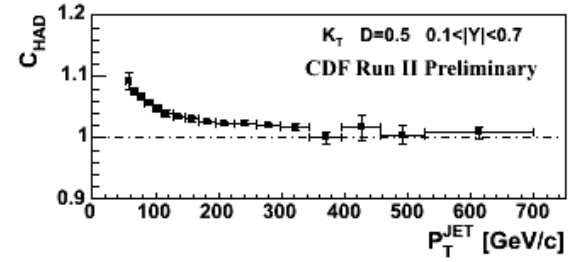


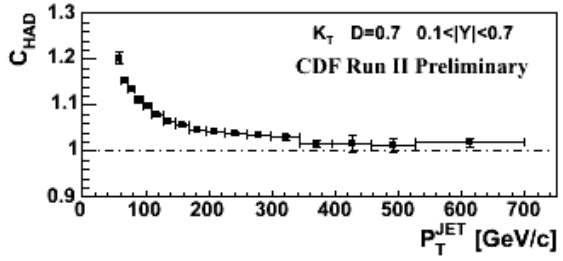


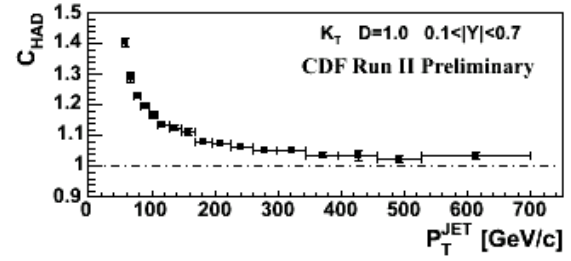






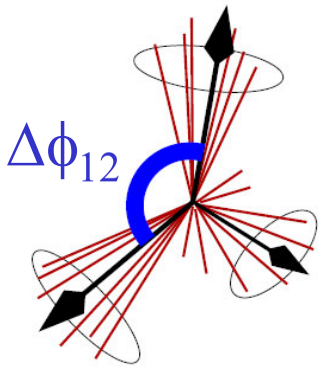




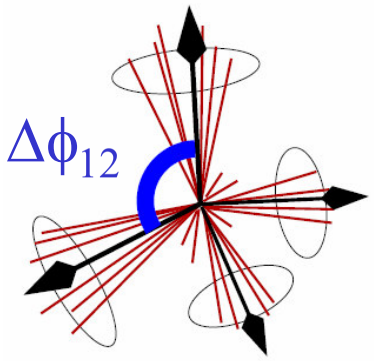


Dijet $\Delta\phi$ decorrelations

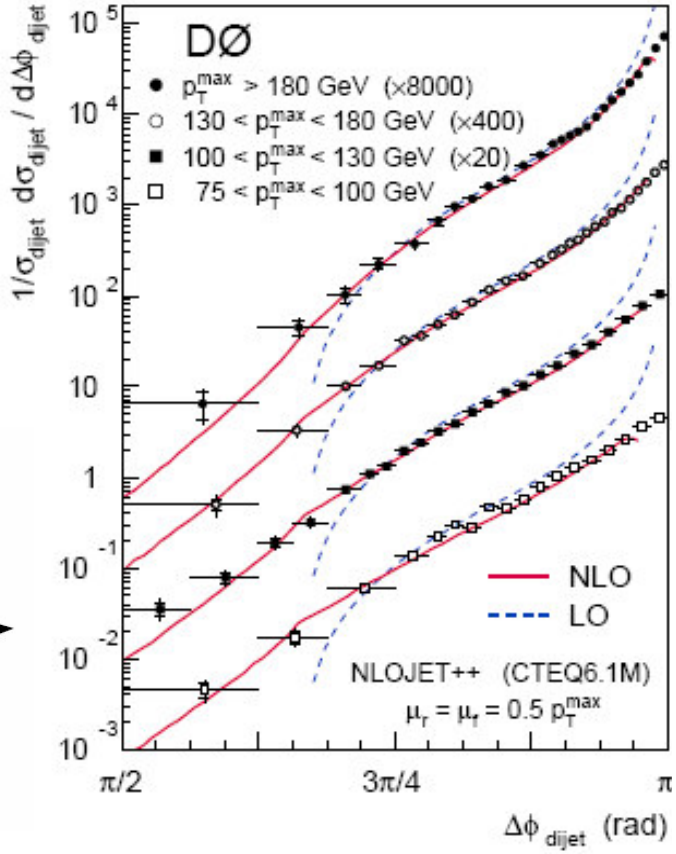
A clean and simple way to study QCD radiative processes

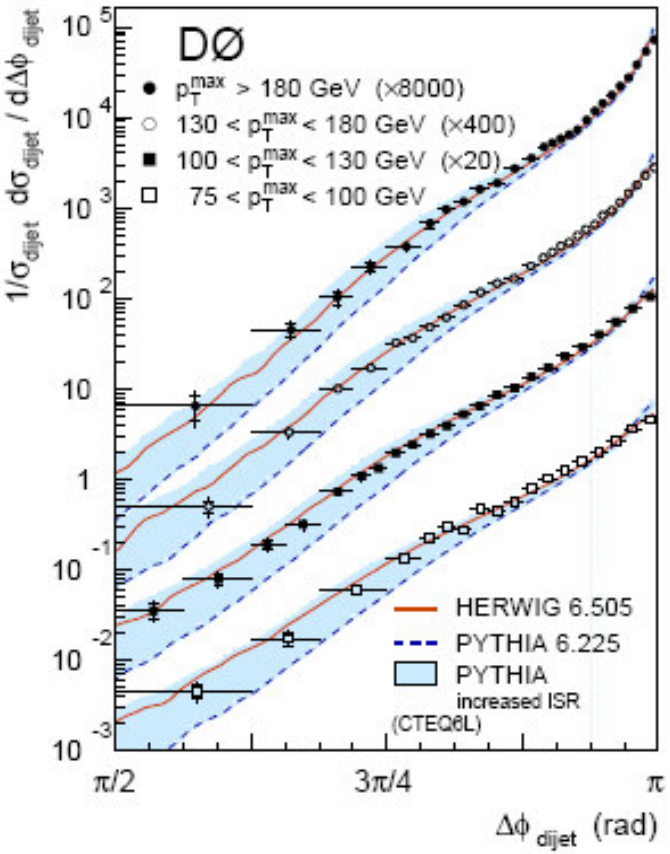


LO in $\Delta\phi$



NLO in $\Delta\phi$





Comparison to NLO pQCD

Good agreement except at $\Delta\phi \rightarrow \pi$ where resummation is needed

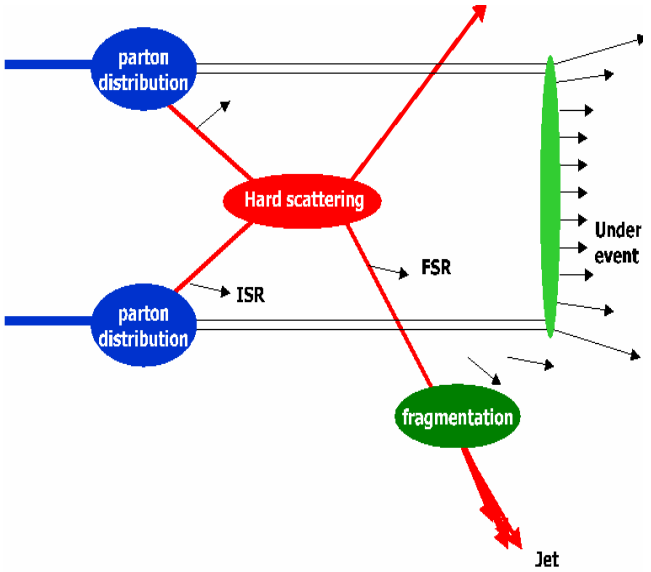
Comparison with MC

Impact of tuning MC generators

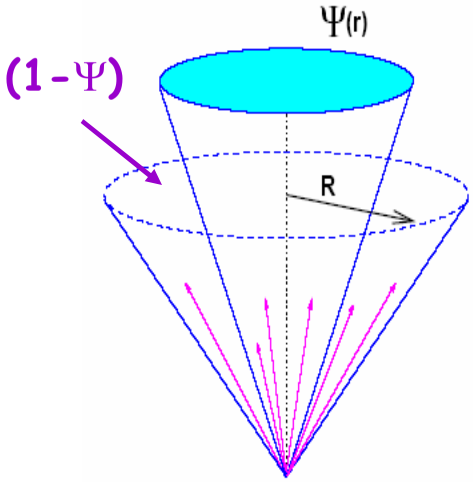
Energy Flow Inside Jets

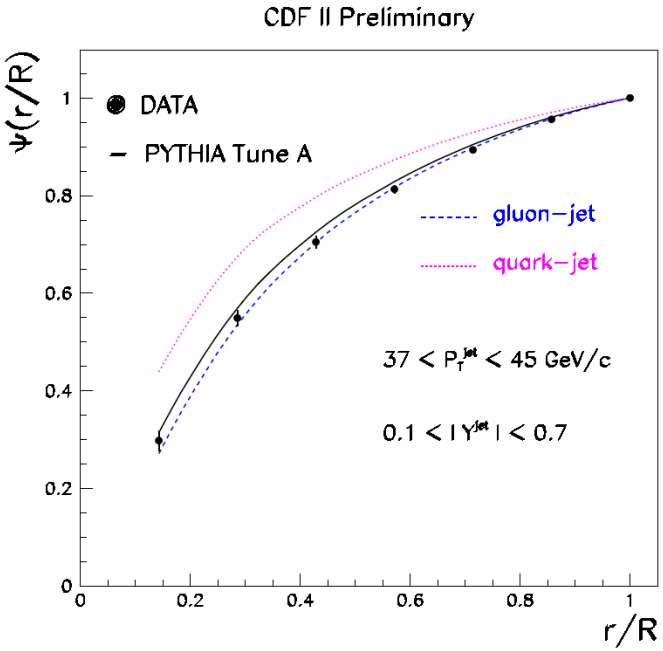
Jet shapes governed by multi-gluon emission from primary parton

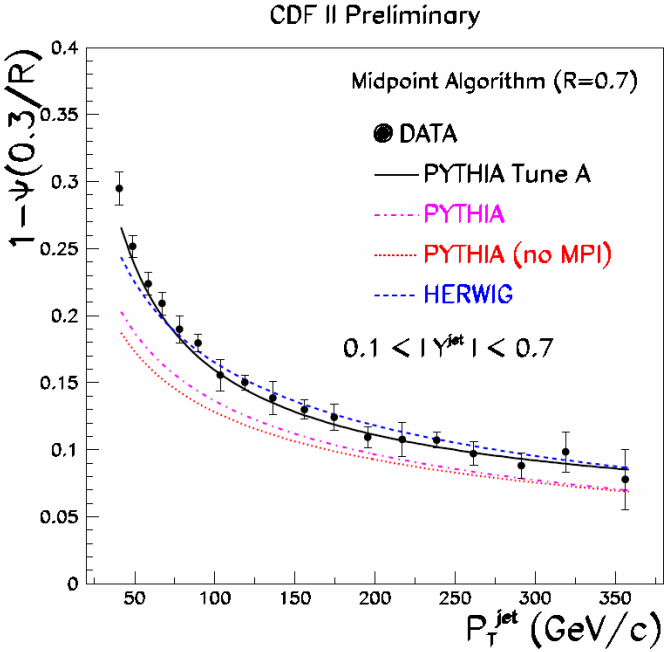
- Test of parton shower models
- Sensitive to underlying event structure
- Sensitive to quark and gluon mixture in the final state



$$\Psi(r) = \frac{1}{N_{jets}} \sum_{jets} \frac{P_T(0,r)}{P_T(0,R)}$$





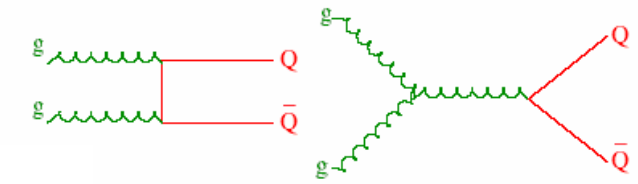


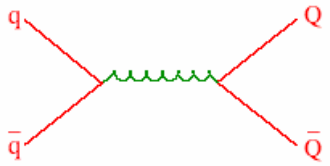
Inclusive b-jet production

Important test of pQCD

- Full calculations up to NLO and beyond

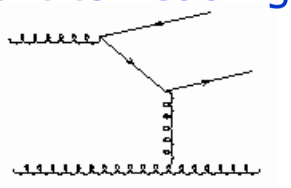
Leading Order



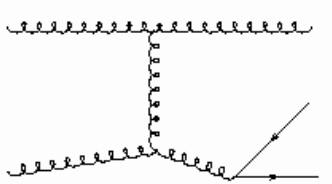


Flavor creation

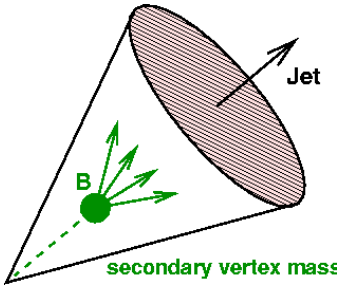
Next to Leading Order

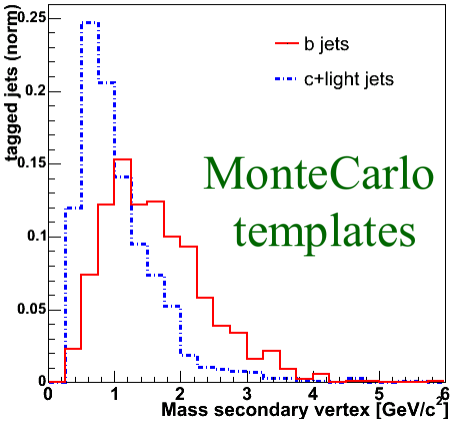


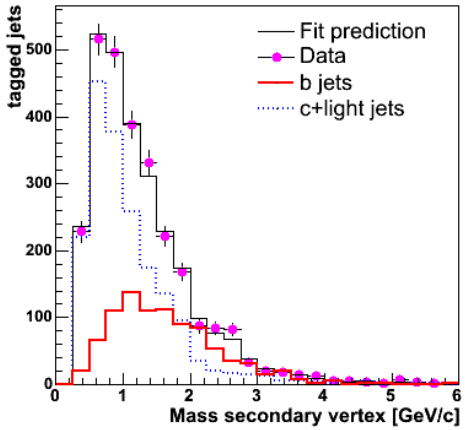
Flavor excitation

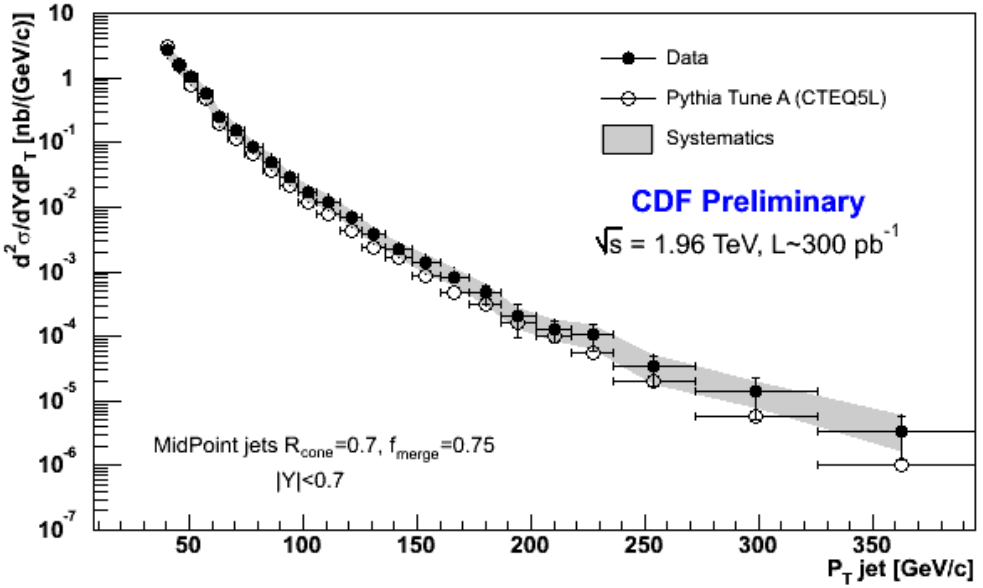


Gluon splitting



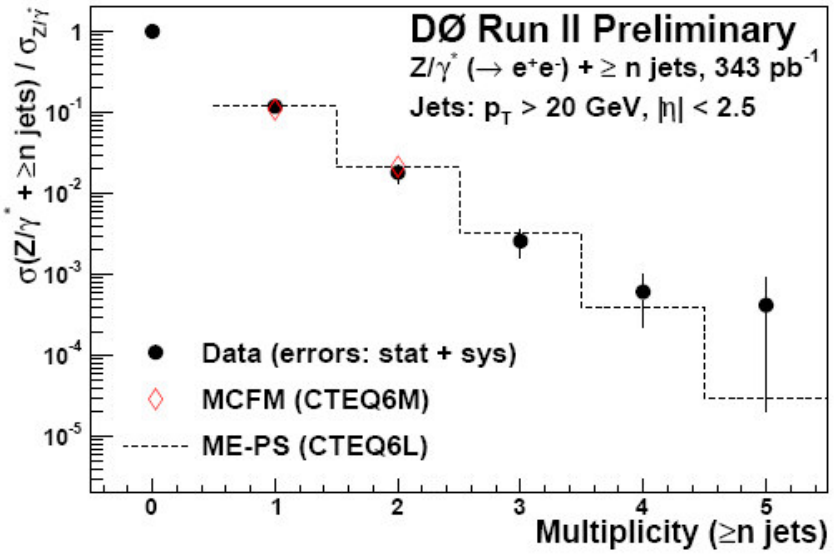


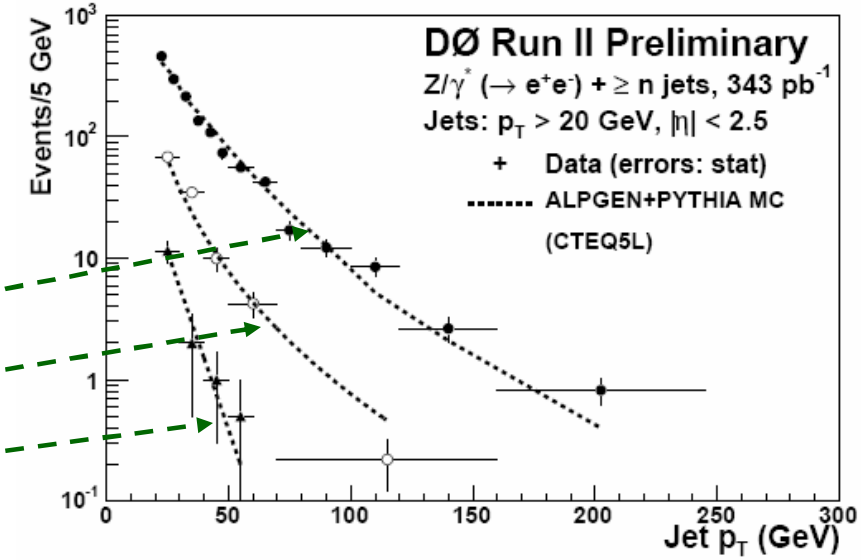




Z+jets

- Test of pQCD at high Q^2 ($\geq M_Z$)
- Fundamental channel for SM and new physics processes
  - ZH
- MCFM
  - NLO up to Z + 2 partons
- ME-PS
  - Leading Order Matrix Element (Madgraph) + Parton Shower (Pythia)





1st jet in Z + ≥ 1 j

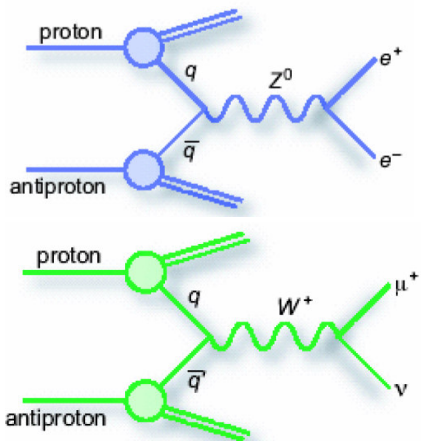
2nd jet in Z + ≥ 2 j

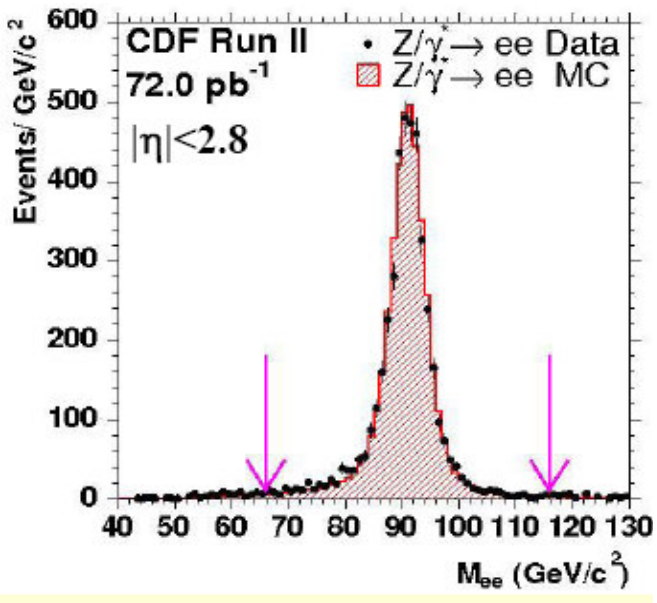
3rd jet in Z + ≥ 3 j

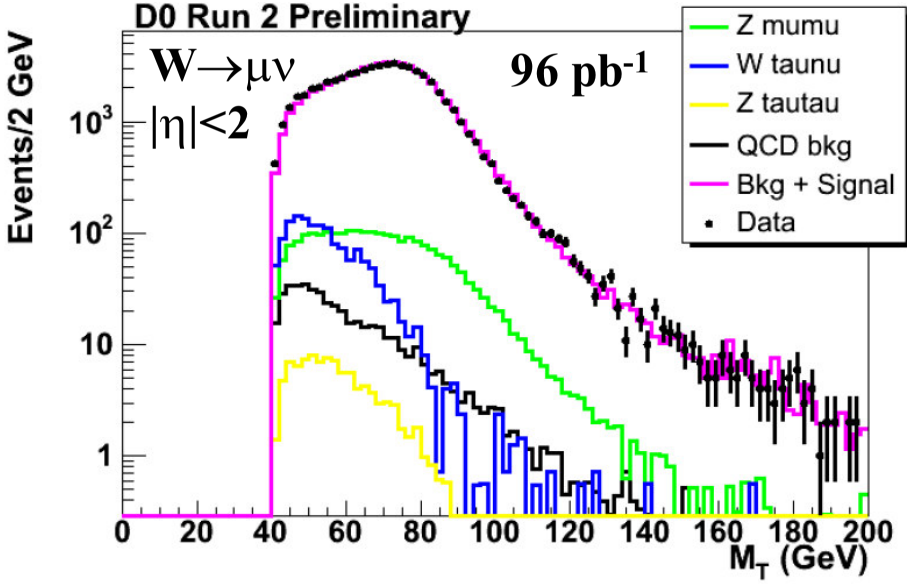
EW Physics

W, Z production

- Test of standard Model
- Require high level of understanding of the detectors
  - e, μ and τ identifications
  - Backgrounds







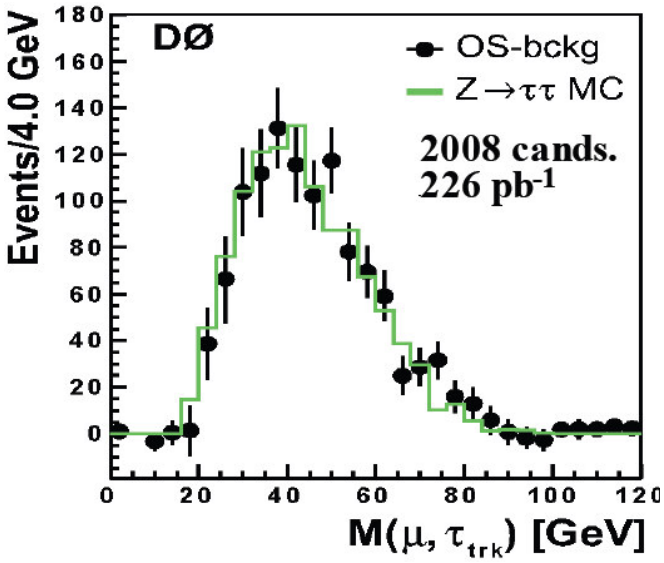
→ Efficiencies computed on data

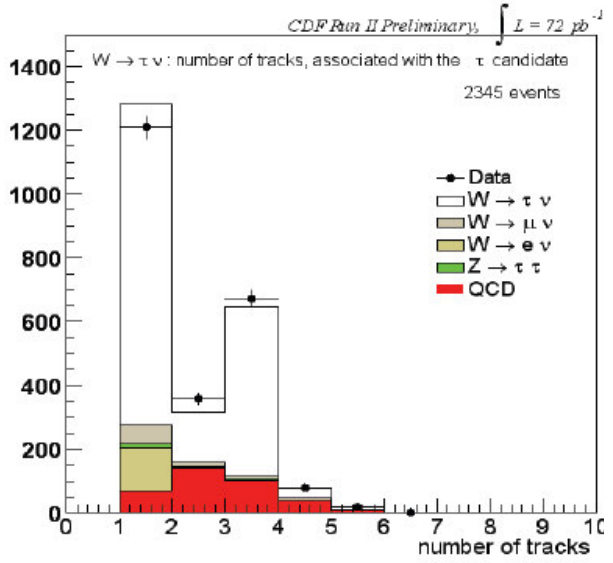
→ QCD background evaluated on data

W, Z cross sections

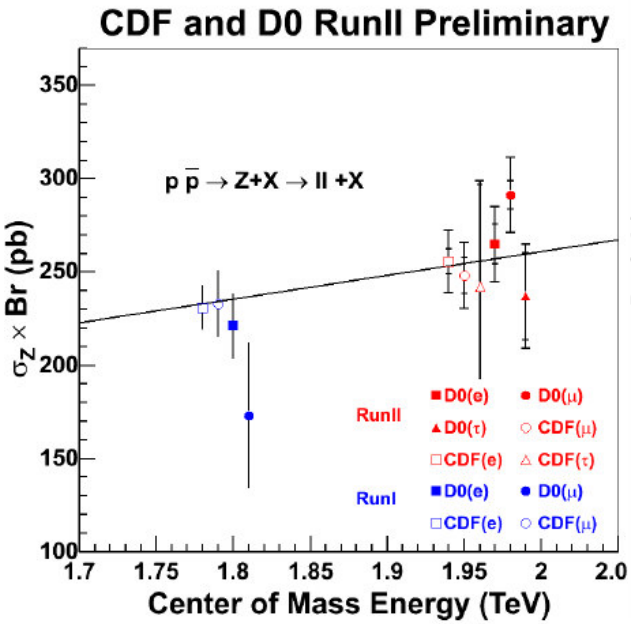
W/Z→τ cross sections

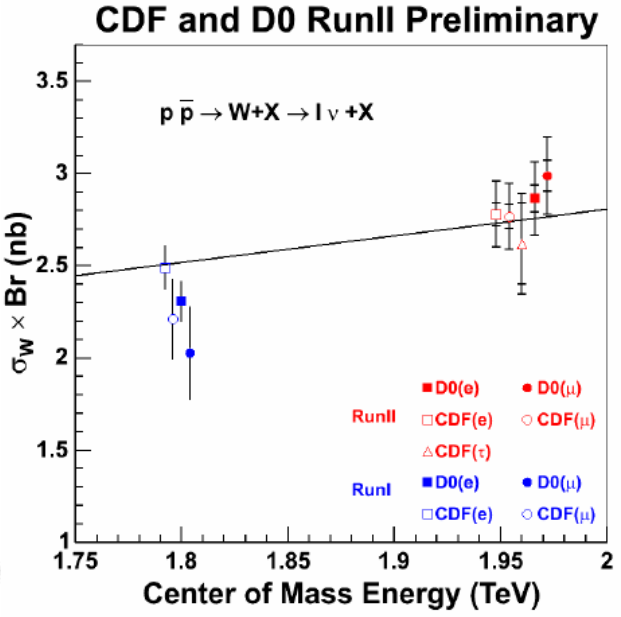
- Test the SM
  - τ often enters in non SM final states
- Ability to identify τ





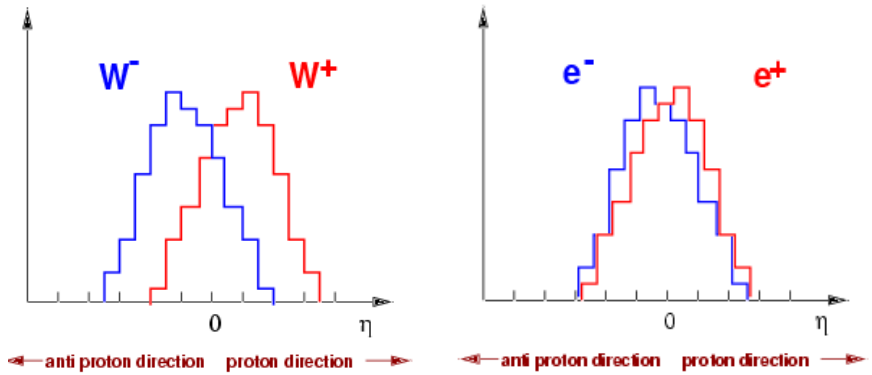
Good agreement with NLO (van Neerven)





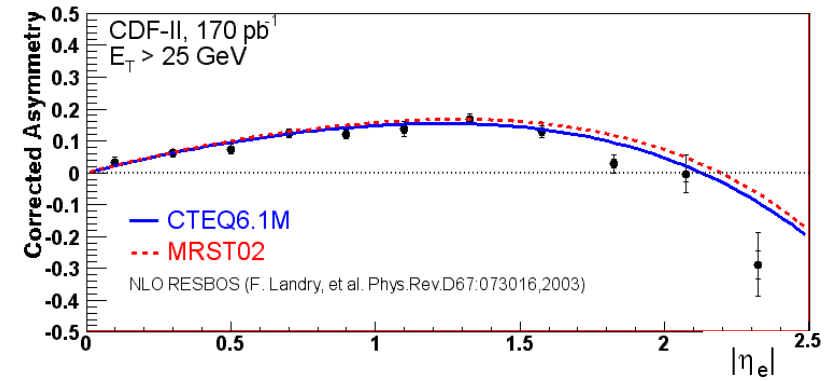
W charge asymmetry

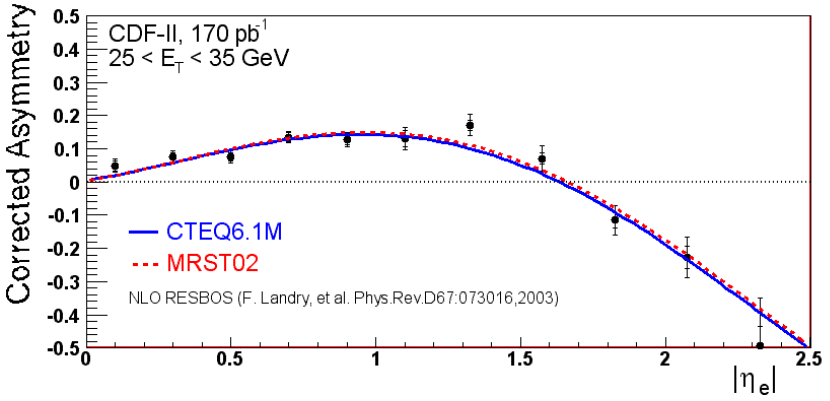
- CDF: W→ eν (170 pb^{-1})
  - u quarks carry higher fraction of the proton momentum
    - W$^+$ boosted in the proton direction

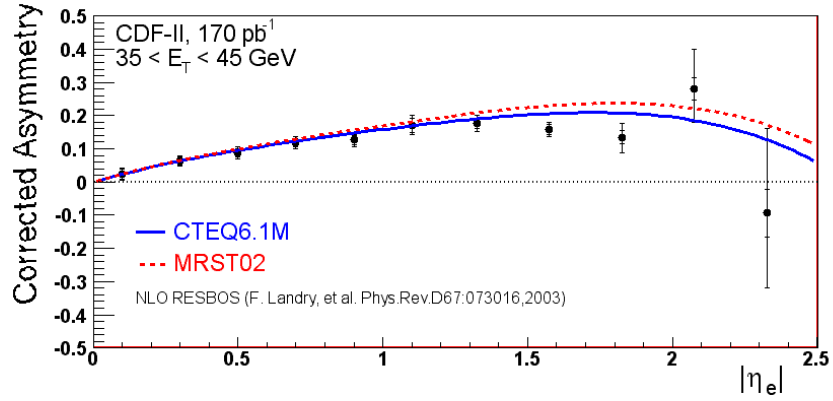


$$A_l(\eta) = \frac{d\sigma(e^+)/d\eta - d\sigma(e^-)/d\eta}{d\sigma(e^+)/d\eta + d\sigma(e^-)/d\eta} \simeq \frac{\mathrm{d(x)}}{\mathrm{u(x)}}$$

- Measure Y_e instead of Y_W
  - Assume SM W→eν coupling
- New constraints to PDF's



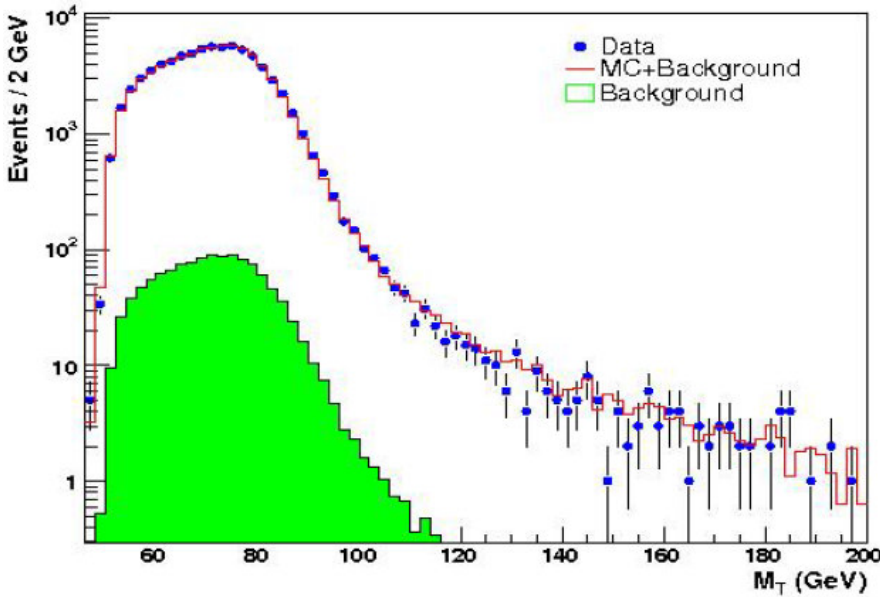


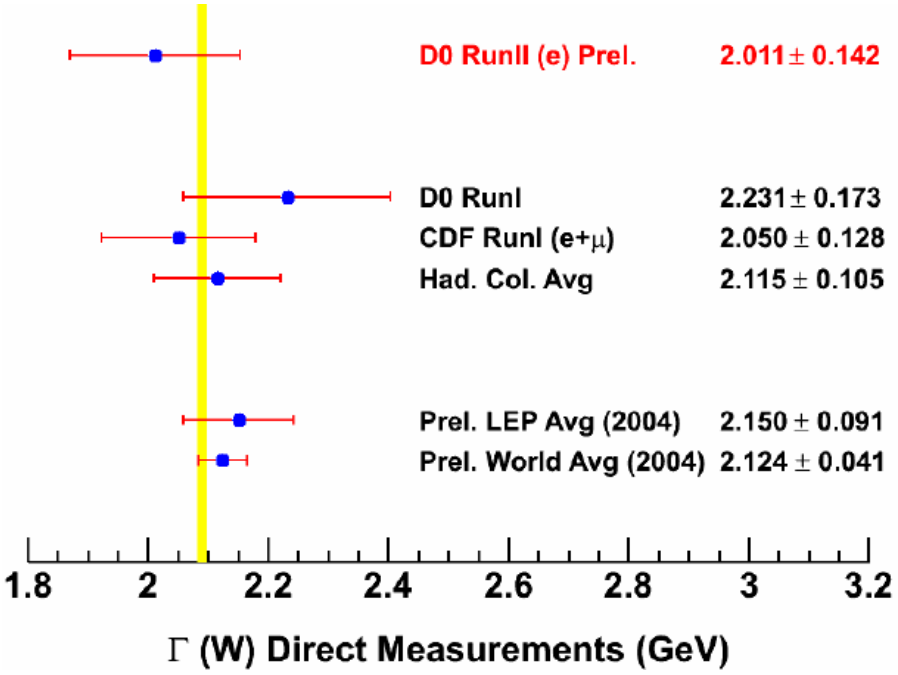


Direct measurement of Γ_W

DØ: $W \rightarrow e\nu$ (177 pb^{-1})

- Fit the transverse mass distribution in the region $100 < M_T(W) < 200$ GeV
  - 625 candidates in this range





Main systematic uncertainties

- Hadronic response and resolution ~ 64 MeV
- Underlying event ~ 47 MeV
- EM resolution ~30 MeV

Top Physics

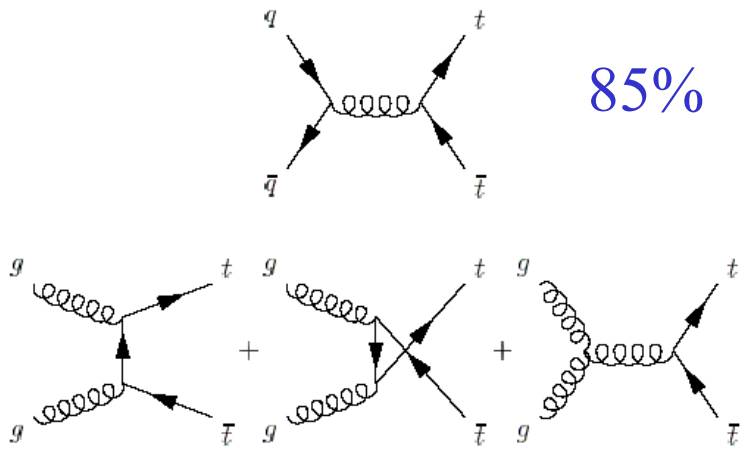
Top production and decay

$\Lambda_{QCD}^{-1} \approx (100\ \text{MeV})^{-1} \approx 10^{-23}\ \text{s}$ ← Hadronization time

$M_t > 120\ \text{GeV} \rightarrow \Gamma_t > 1\ \text{GeV} \Rightarrow \tau_t < 10^{-23}\ \text{s}$

No top hadrons

top-antitop pairs



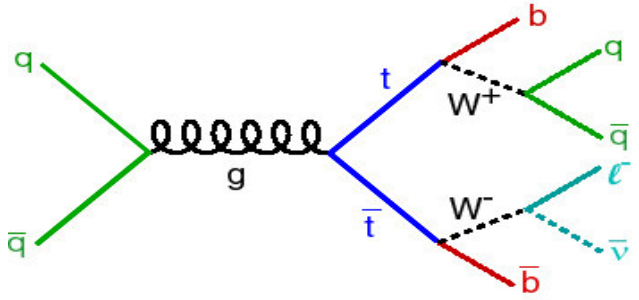
85%

15%

$\sigma(\bar{p}p \rightarrow t\bar{t}) \approx 6.1\ \text{pb}$

$Br(t \rightarrow Wb) \approx 100\%$

Final state given by W^+ W^- decays



Event Classification

tt→lνlνbb	dilepton	5%
tt→lνqqbb	lepton+jets	30%
tt→qqqqbb	hadronic	45%

$\sigma_{\text{inel}}(p\bar{p} \rightarrow X) \approx 60\ \text{mb}$

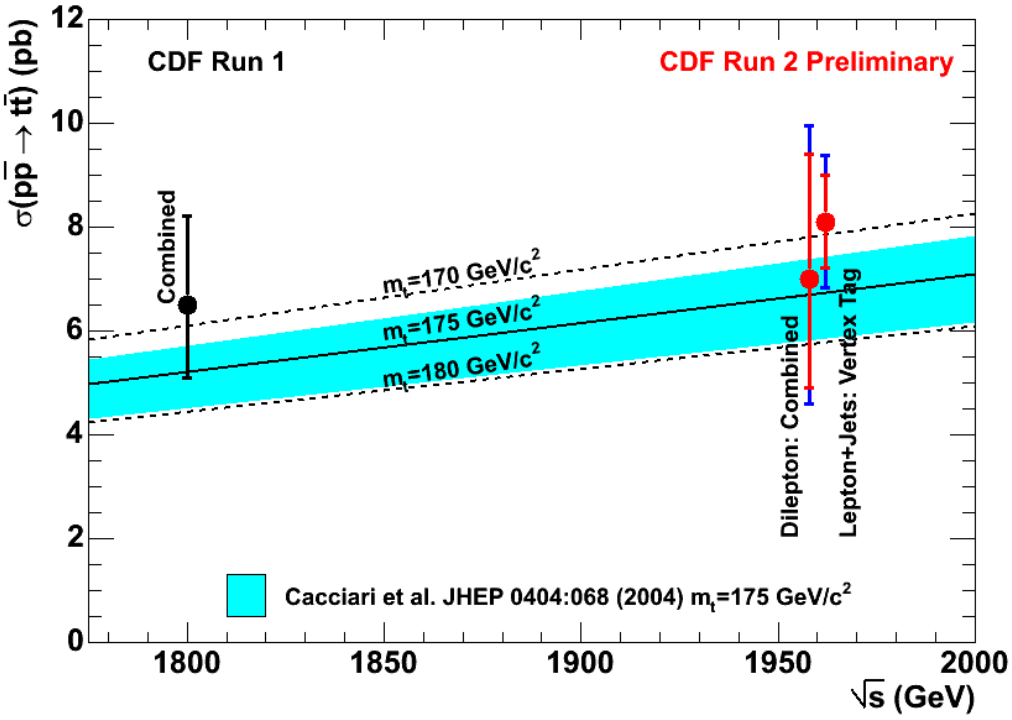
~ one top event / 10 billion inelastic collisions

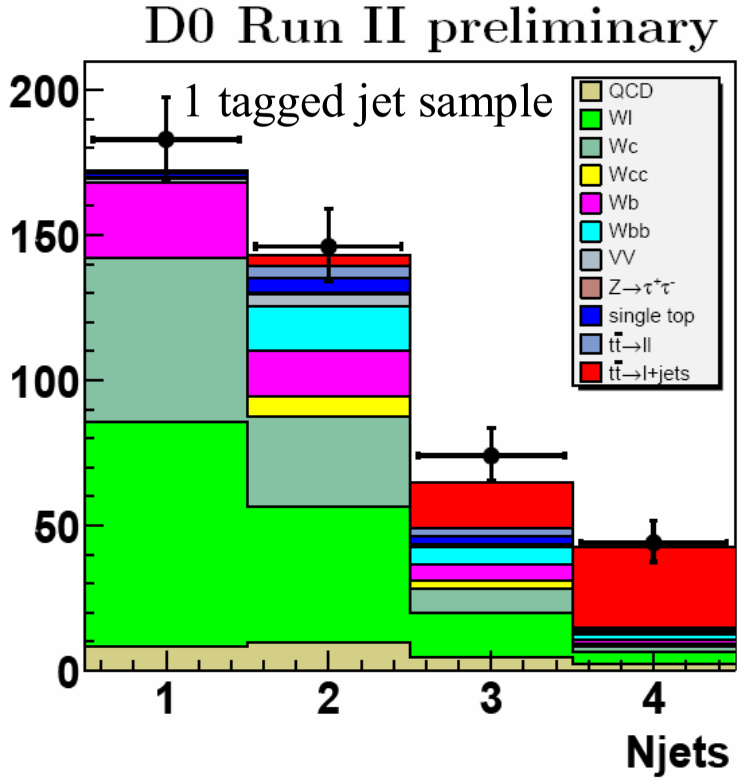
Here lepton = e or μ

Top quark production

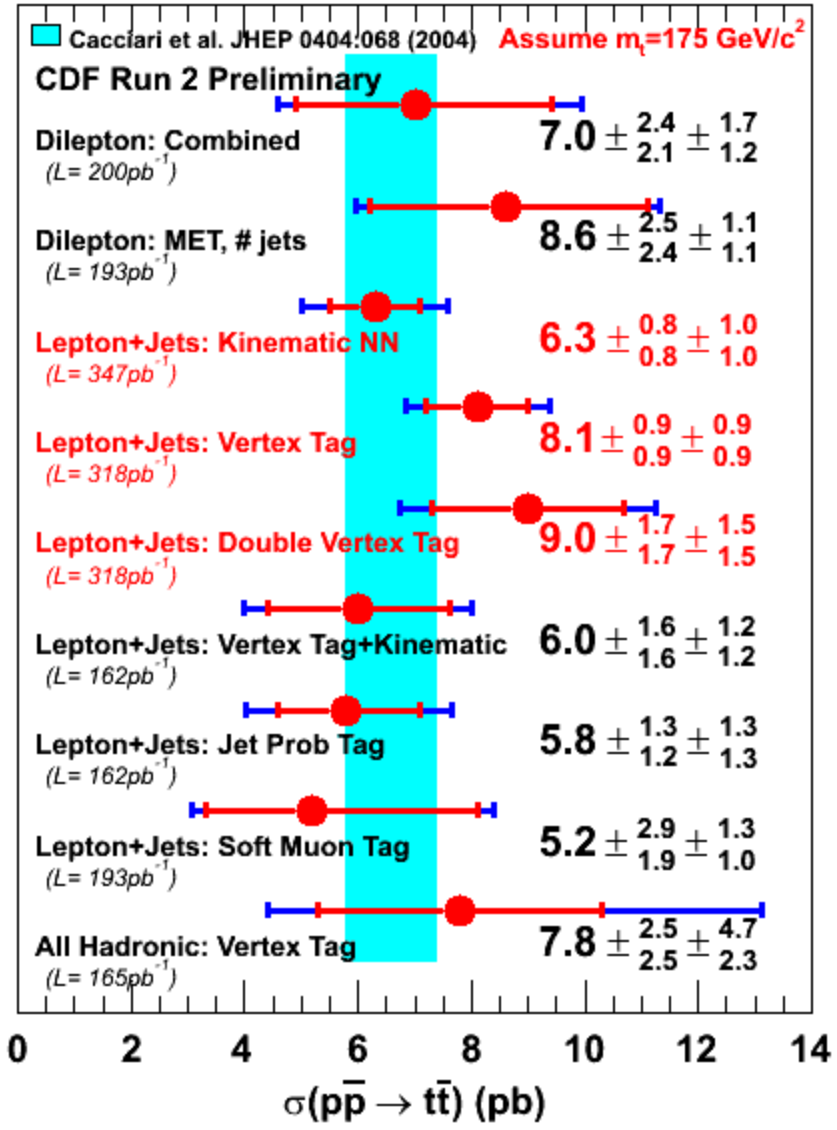
- Sensitive to New Physics in production and decay
- Increases by ~ 30 % with Run II √s enhancement

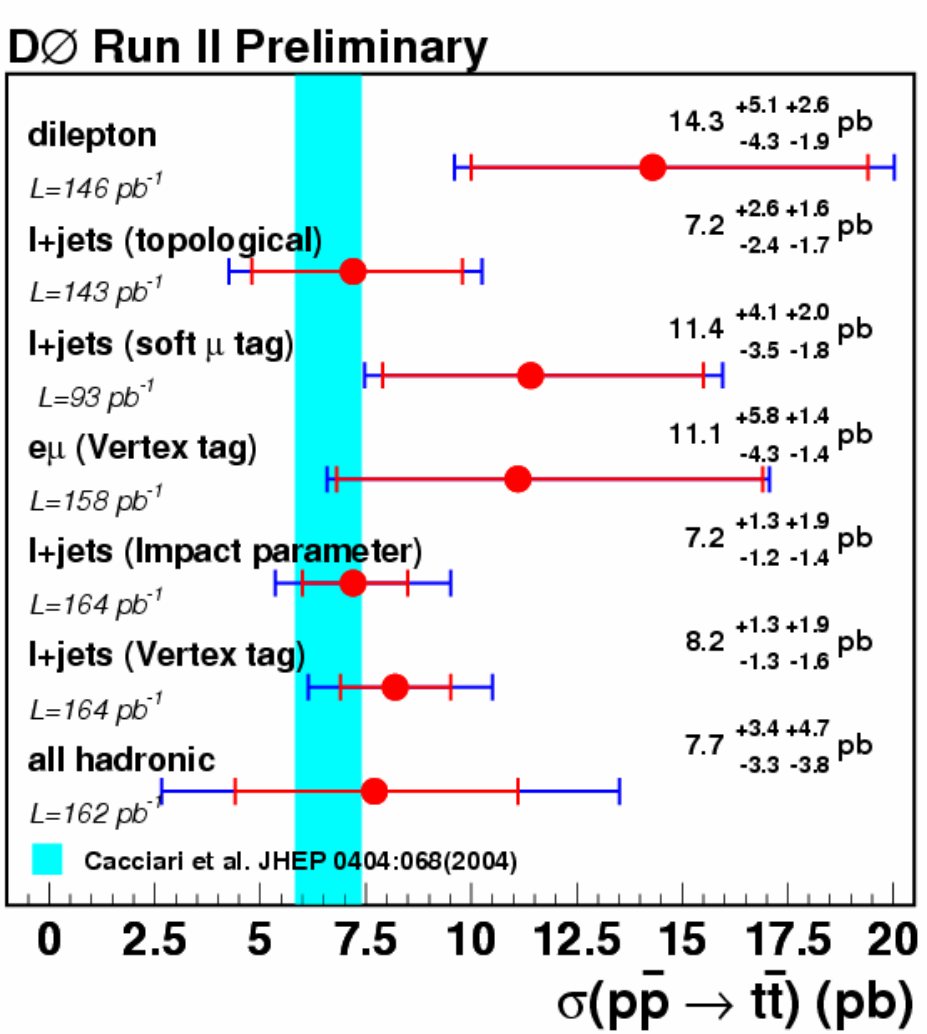
DØ Lepton+Jets (164 pb^{-1})
- Impact parameter tag
- Fit 3-4 jet bins in 1 and 2 tagged jet samples





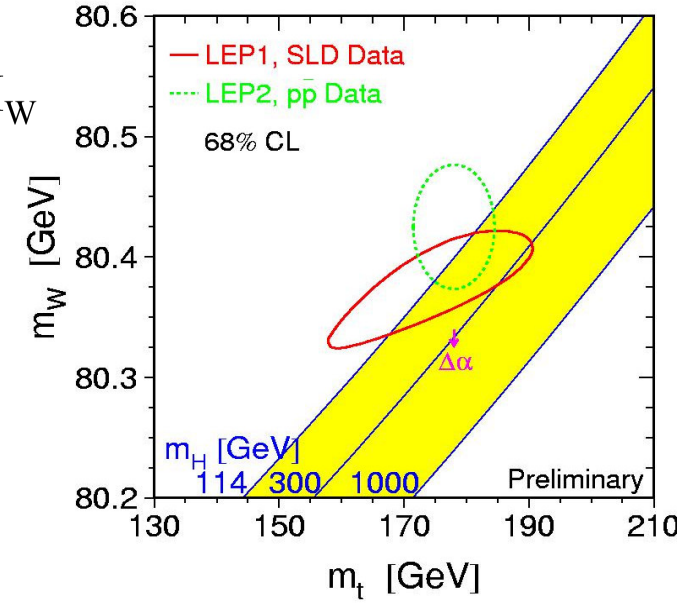
Top quark cross section

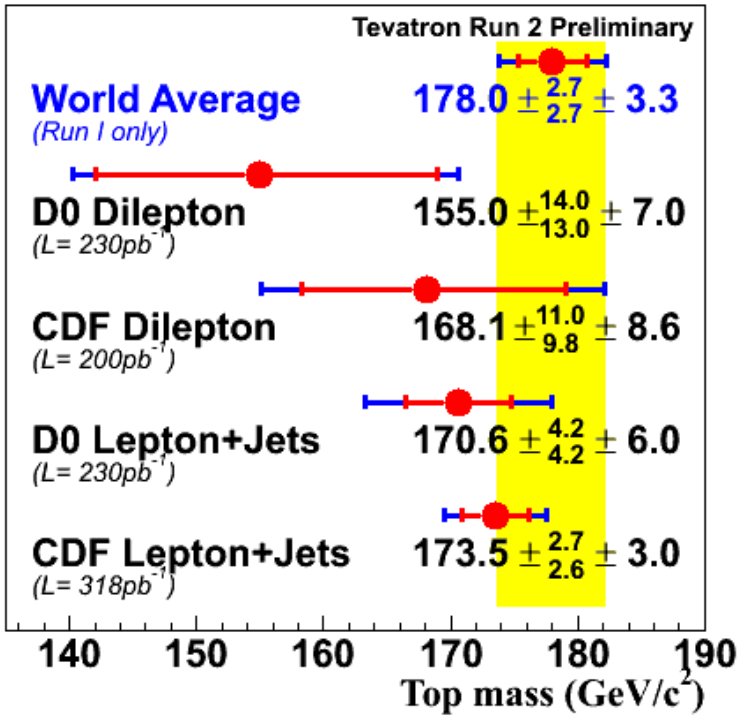


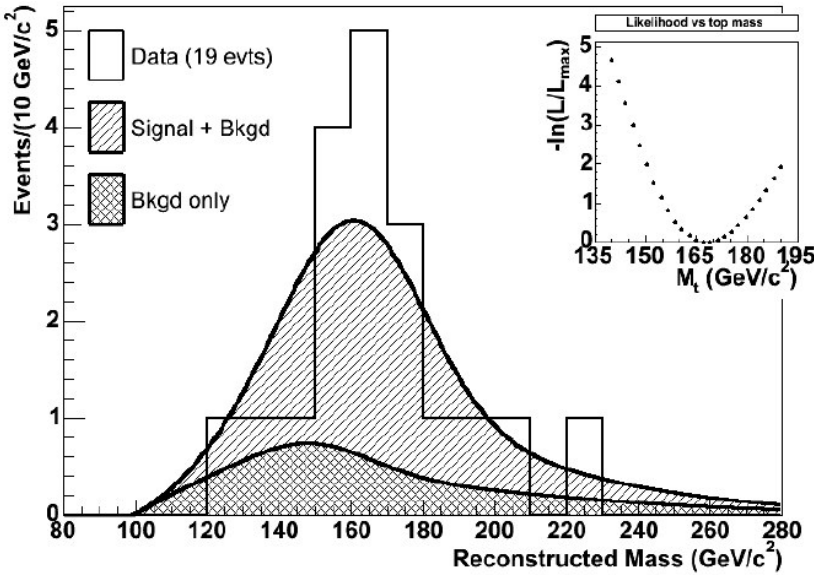


Top quark mass

Corrections to M_W ~ m_t^2, ln(m_H)







CDF Dilepton (200 pb^{-1})

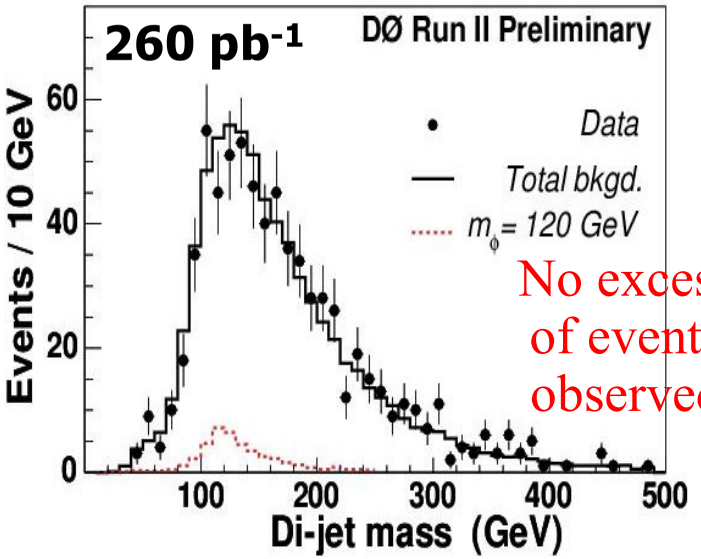
- ν weighting: assume rapidities of both ν's and calculate likelihood of observed missing E_T
- Plot m_t which maximizes $W_X \cdot W_Y$ and compare to MC templates

Examples of searches

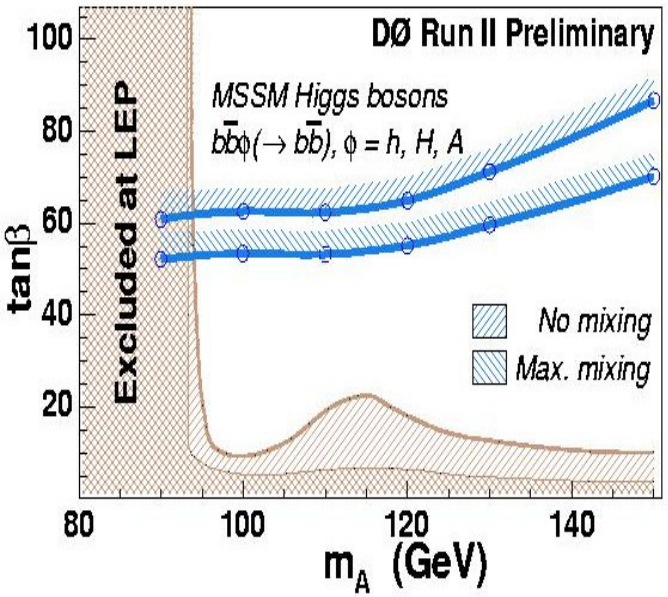
MSSM Higgs: $b\bar{b}h(\rightarrow b\bar{b})$ search

- Sample Selection
  - Trigger > 3 jets with E_T>15 GeV
  - Offline cut on E_T of leading jets optimised for each Higgs mass
  - 3 b-tagged jets or more
- Backgrounds
  - "QCD heavy flavor" : bbjj, ccjj, cccc, bbcc, bbbb
  - "QCD fakes" : jjjj
  - "Other" : Z(bb,cc), tt
- Exclude significant portion of tan β down to 50
  - Depending on m_A and MSSM scenario

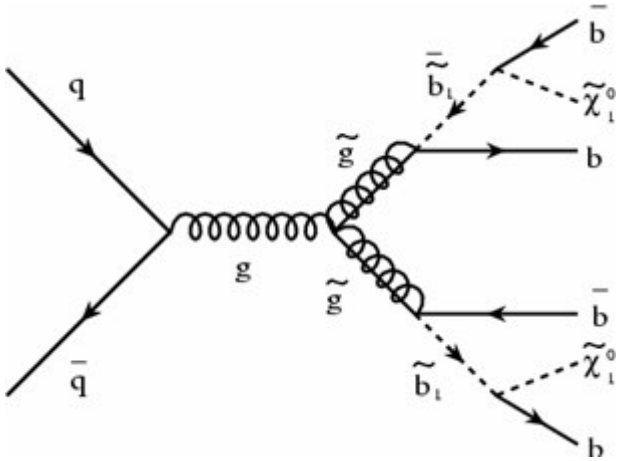
Di-jet mass in ≥ 3b-tagged events



No excess of events observed

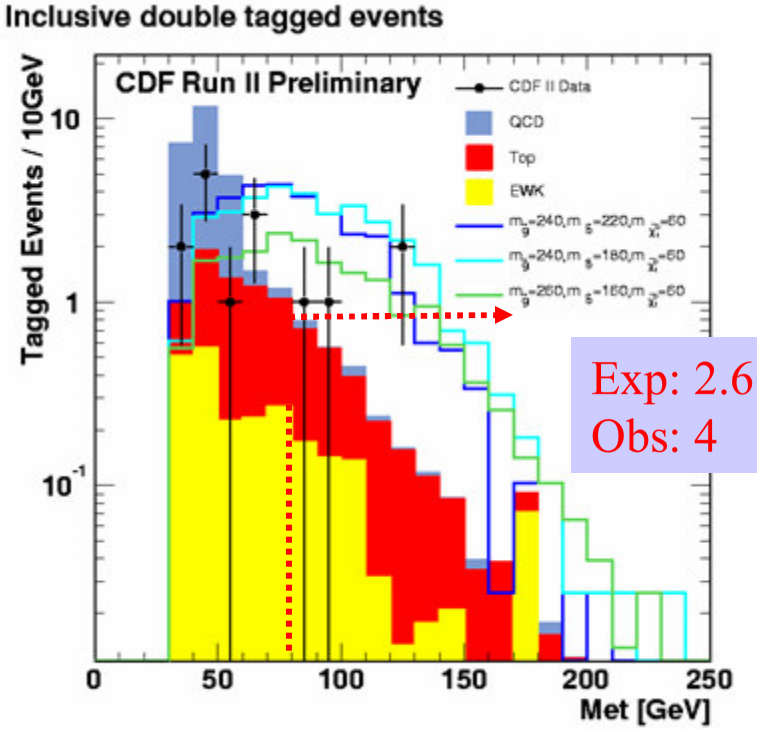


Search for gluino → sbottom

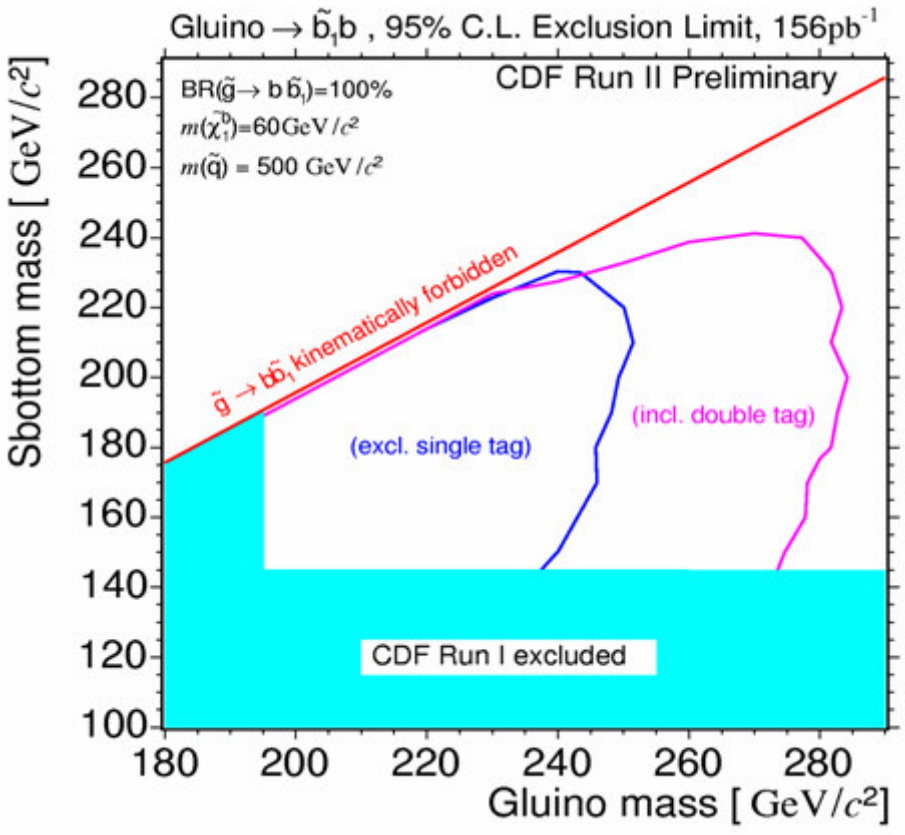


- $\tilde{b}_1$ can be very light for large tanβ
- Expect large branching fraction of gluino to sbottom

→ Signature: 4 b-jets and missing E_T



Exp: 2.6 +- 0.7
Obs: 4



Conclusion

- Tevatron on is way to increase luminosity
  - Already ~ 10^{32} cm^{-2} s^{-1}
- CDF & D0 efficiently taking very good data
  - Already ~ 0.7 fb^{-1}
- Very large and very exiting Physics program
  - A lot more not presented here!
  - Preparation of the LHC
- Stringent tests of pQCD and SM
- Implication on PDFs
- Better and better precision on m_{top}
- Most stringent limits for some searches