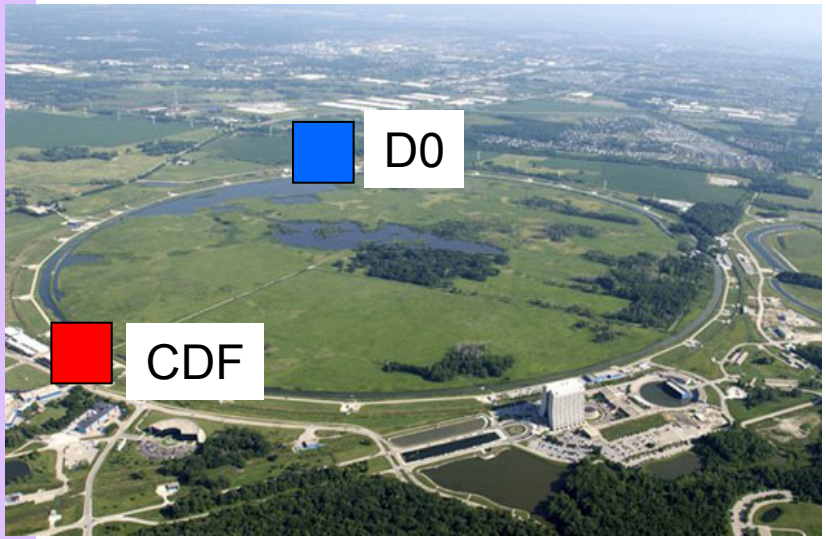
Tevatron results

Heidi Schellman for the D0 and CDF Collaborations

Outline

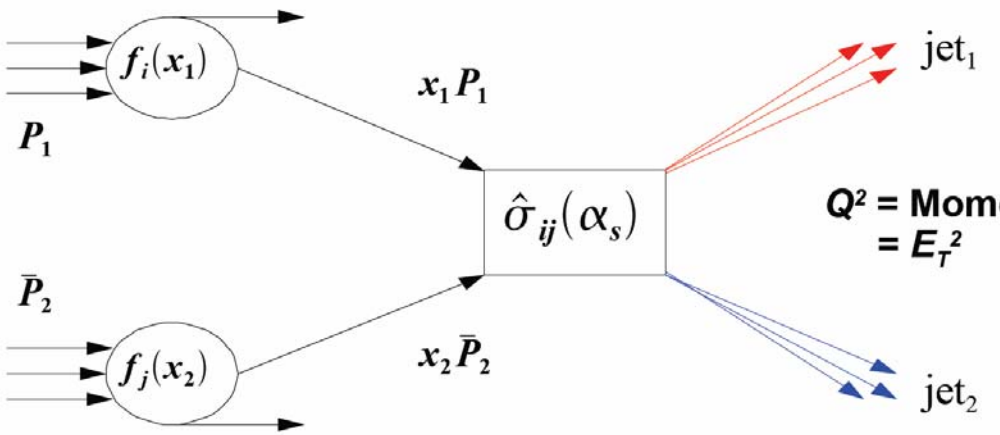
- Explore some of the newest results organized by rate
  - 10 Hz - high PT jets
  - 1 Hz - W and Z properties
  - 0.001 - Hz top production and mass
  - 0.0001 - Hz ZZ production
  - ? Hz – Higgs
- See the parallel sessions for much more….

The TeVatron - ppbar scattering at 1.96 TeV



- New record luminosity is
  - 3.18 10^{32} /cm^2/sec
- 1996 0.1 fb^{-1}/expt.
- 2006 1 fb^{-1}/expt.
- 2008 3.3 fb^{-1}/expt.
- Goal for 2002-2010 is 6-7 fb^{-1}

What's happening



$$y = \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right)$$

Q^2 = Momentum Transfer = E_T^2

$\eta = \log \tan \theta/2 \sim y$

$$\sigma = \sum_{ij} \int dx_1\, dx_2 f_i(x_1, \mu_F^2) f_j(x_2, \mu_F^2)\, \hat{\sigma}_{ij}\left(\alpha_s^m(\mu_R^2), \textit{elementary process}\right)$$

Parton distributions

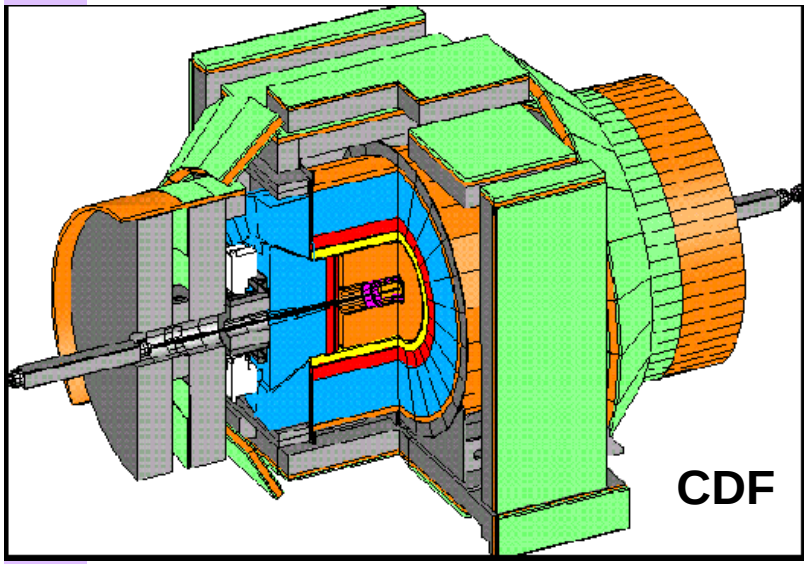
Factorization scale

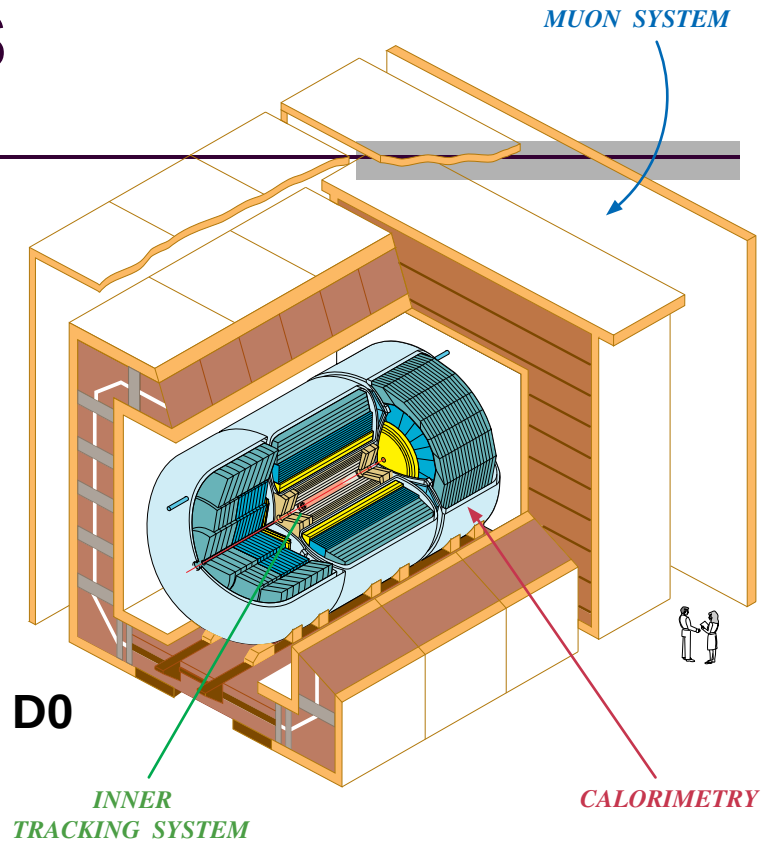
Elementary cross section

Order α_s^m

Renormalization scale

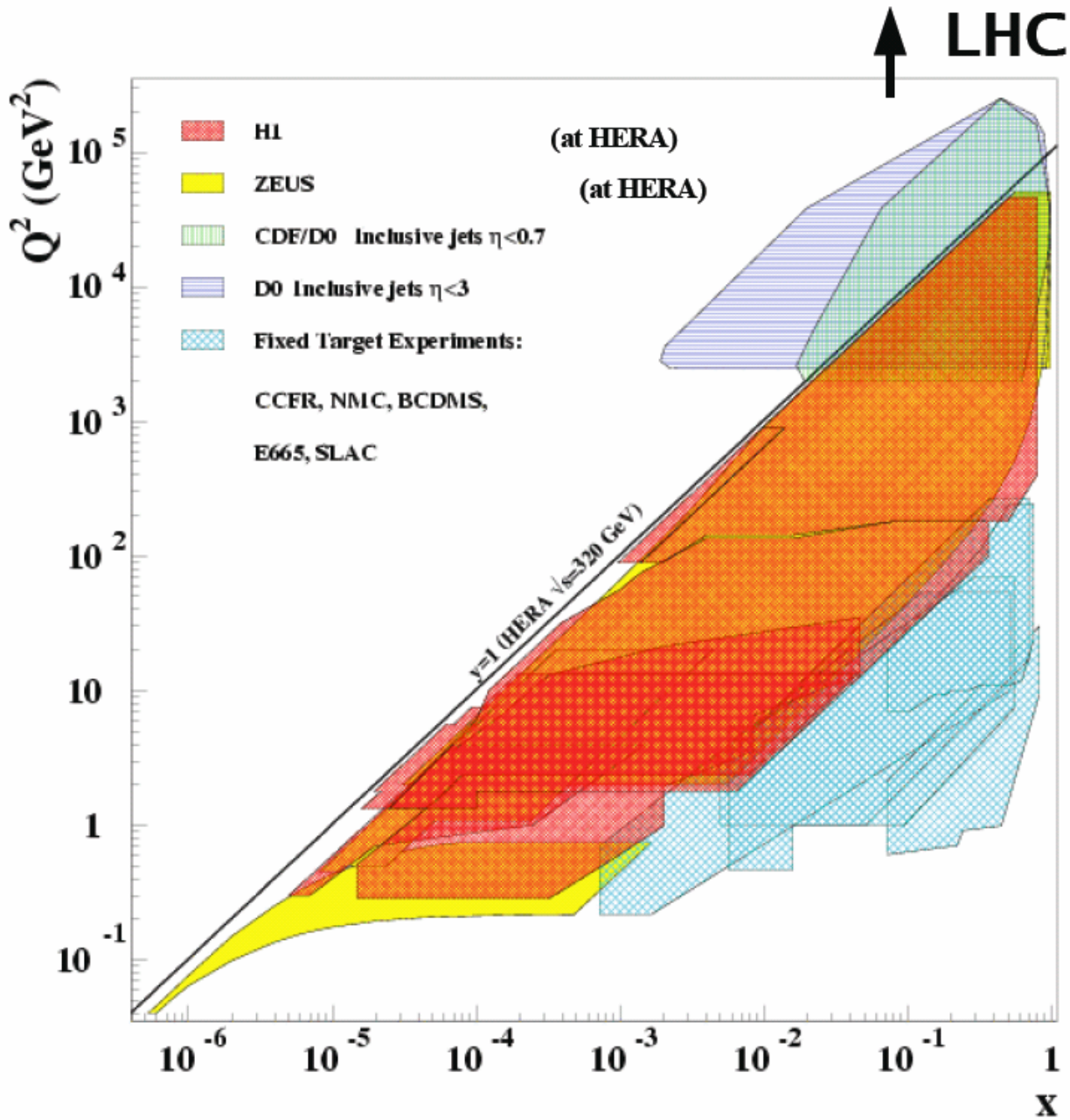
CDF and D0 detectors

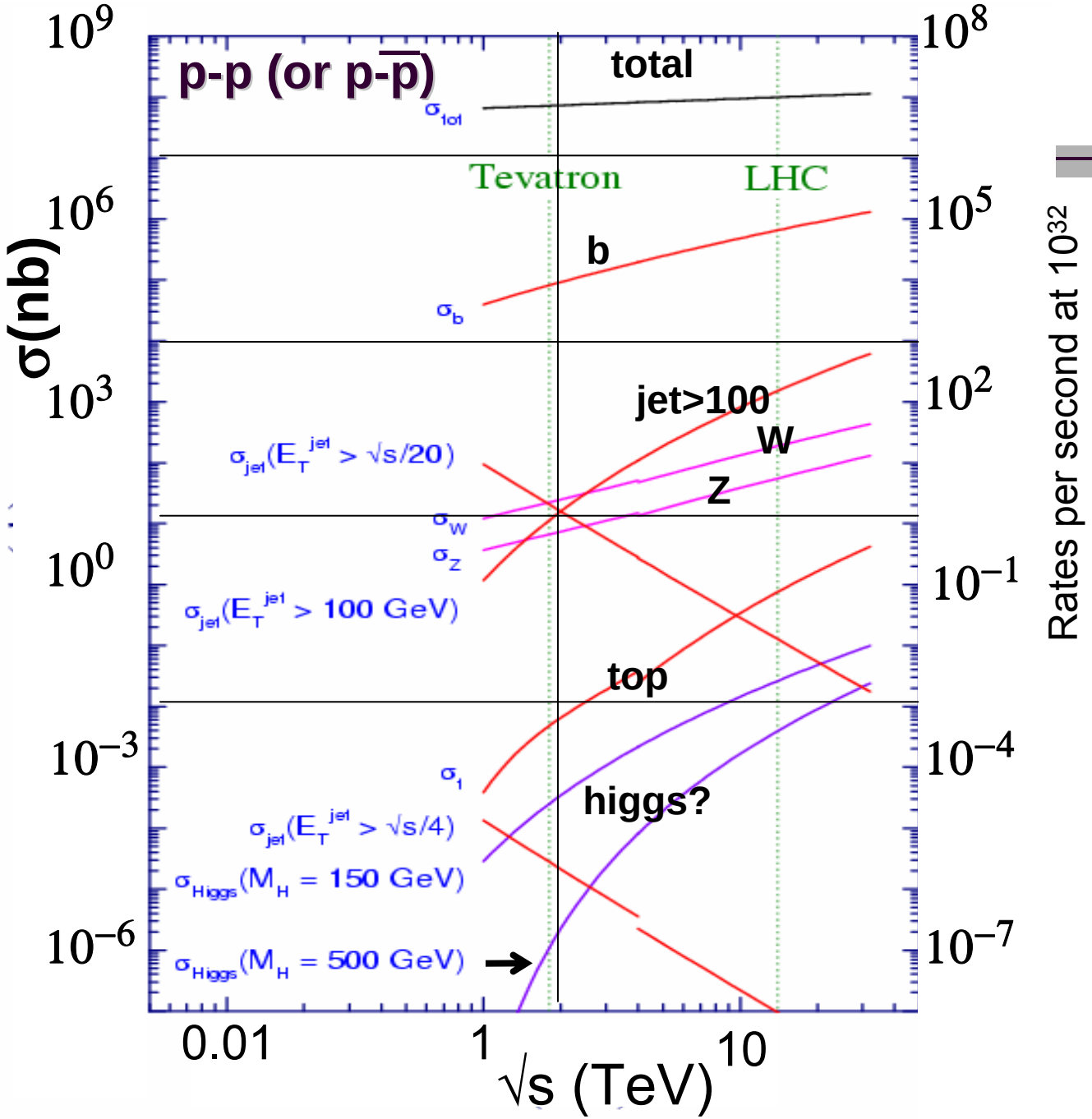




- **Common features**
  - High field magnetic trackers with silicon vertexing
  - electromagnetic and hadronic calorimeters
  - muons systems
- **Competitive Advantages**
  - CDF has much better momentum resolution in the central region and displaced track triggers at Level 1
  - D0 has more calorimeter segmentation, silicon disks, and a far forward muon system.

Kinematics

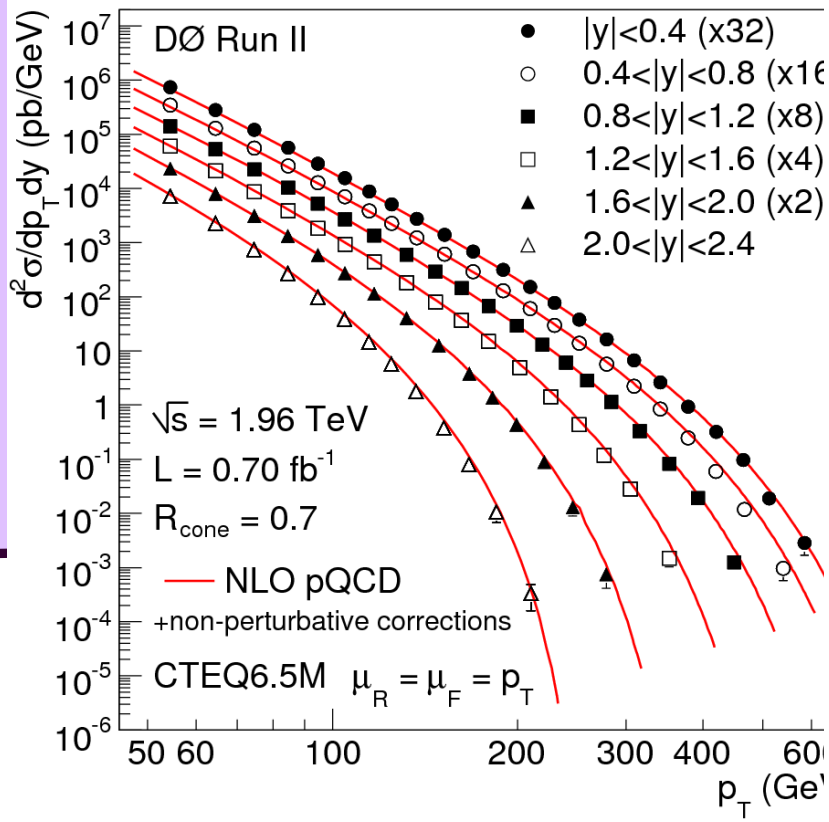

LHC
H1
(at HERA)
ZEUS
(at HERA)
CDF/D0 Inclusive jets η<0.7
D0 Inclusive jets η<3
Fixed Target Experiments:
CCFR, NMC, BCDMS,
E665, SLAC
y=1 (HERA √s=320 GeV)
Q² (GeV²)
10 5
10 4
10 3
10 2
10
1
10 -1
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
1
x

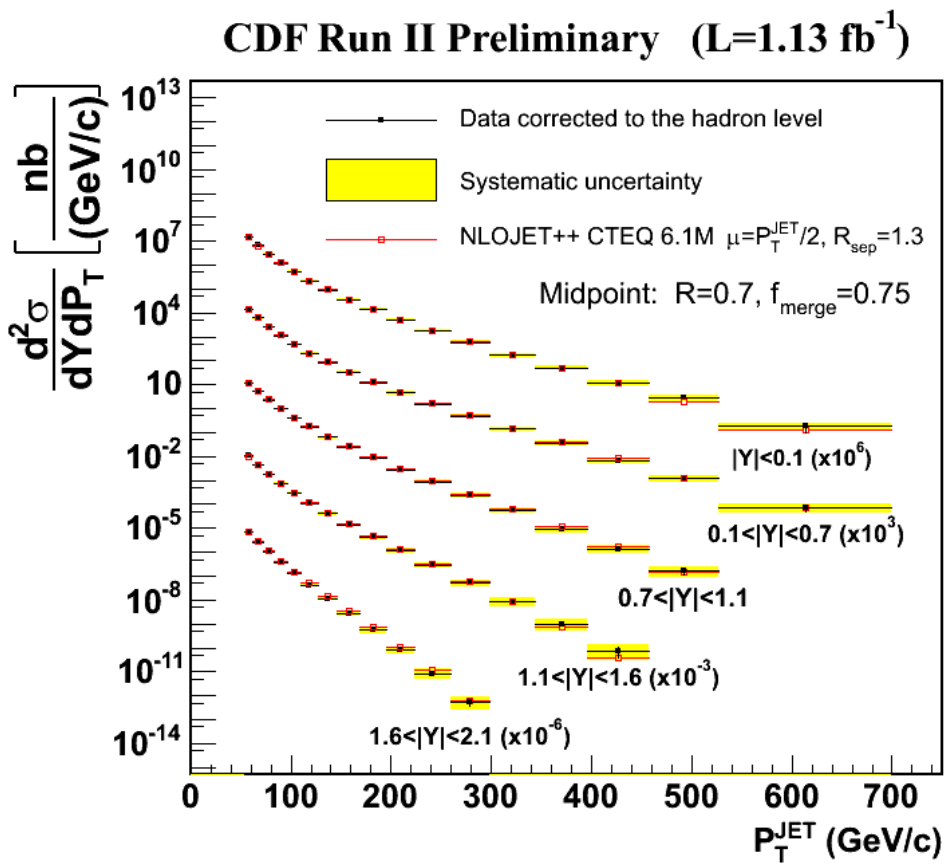

p-p (or p-$\overline{p}$)
total
σ_{tot}
Tevatron
LHC
b
σ_b
jet>100
W
Z
$\sigma_{jet}(E_T^{jet} > \sqrt{s}/20)$
σ_W
σ_Z
$\sigma_{jet}(E_T^{jet} > 100$ GeV)
top
σ_t
higgs?
$\sigma_{jet}(E_T^{jet} > \sqrt{s}/4)$
$\sigma_{Higgs}(M_H = 150$ GeV)
$\sigma_{Higgs}(M_H = 500$ GeV)
σ(nb)
10^9
10^6
10^3
10^0
10^{-3}
10^{-6}
10^8
10^5
10^2
10^{-1}
10^{-4}
10^{-7}
Rates per second at 10^{32}
0.01
1
10
$\sqrt{s}$ (TeV)

10 Hz – high PT jets

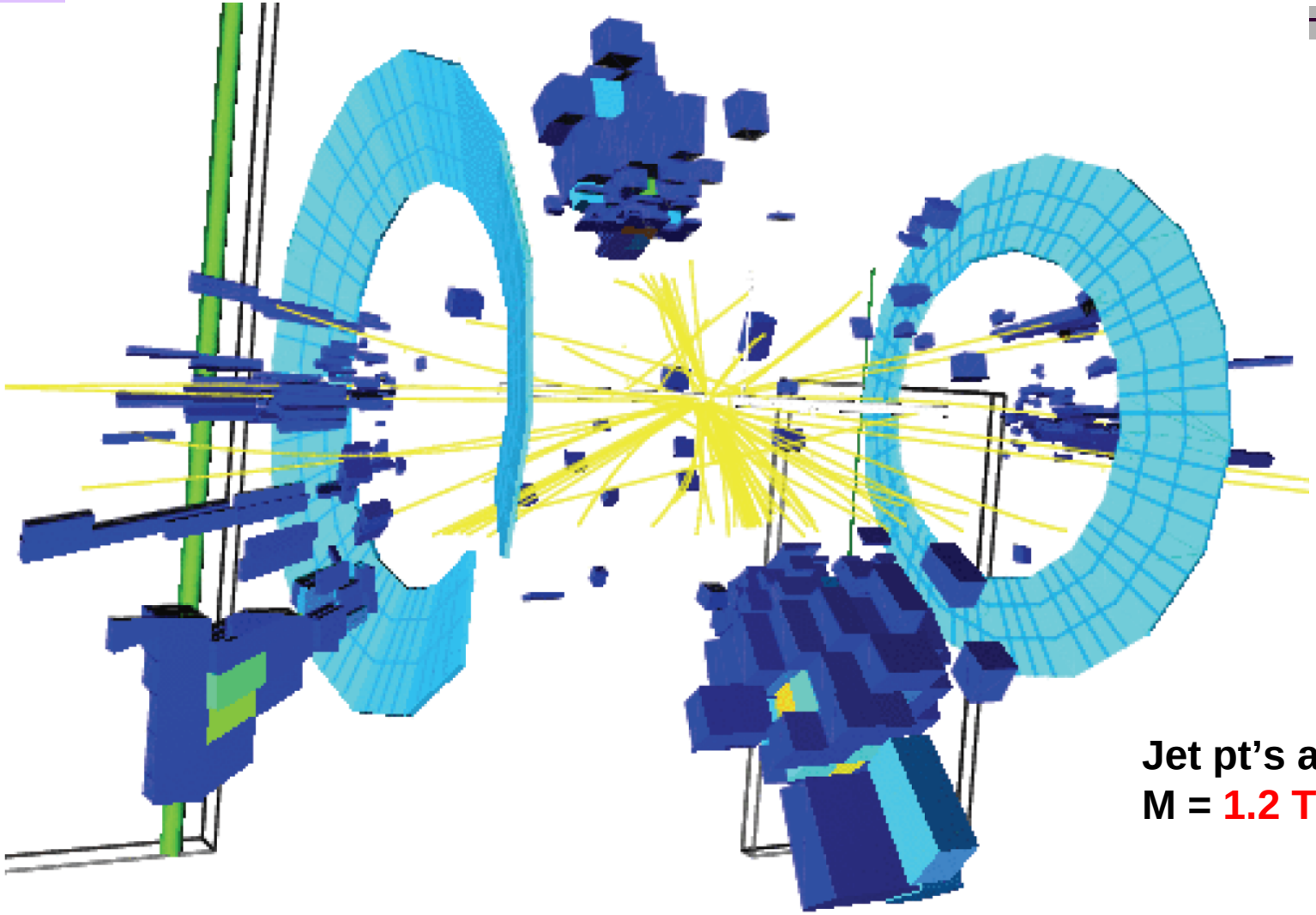
Mehta HFS
Voutilainen HFS

- Inclusive jets with E > 50 GeV





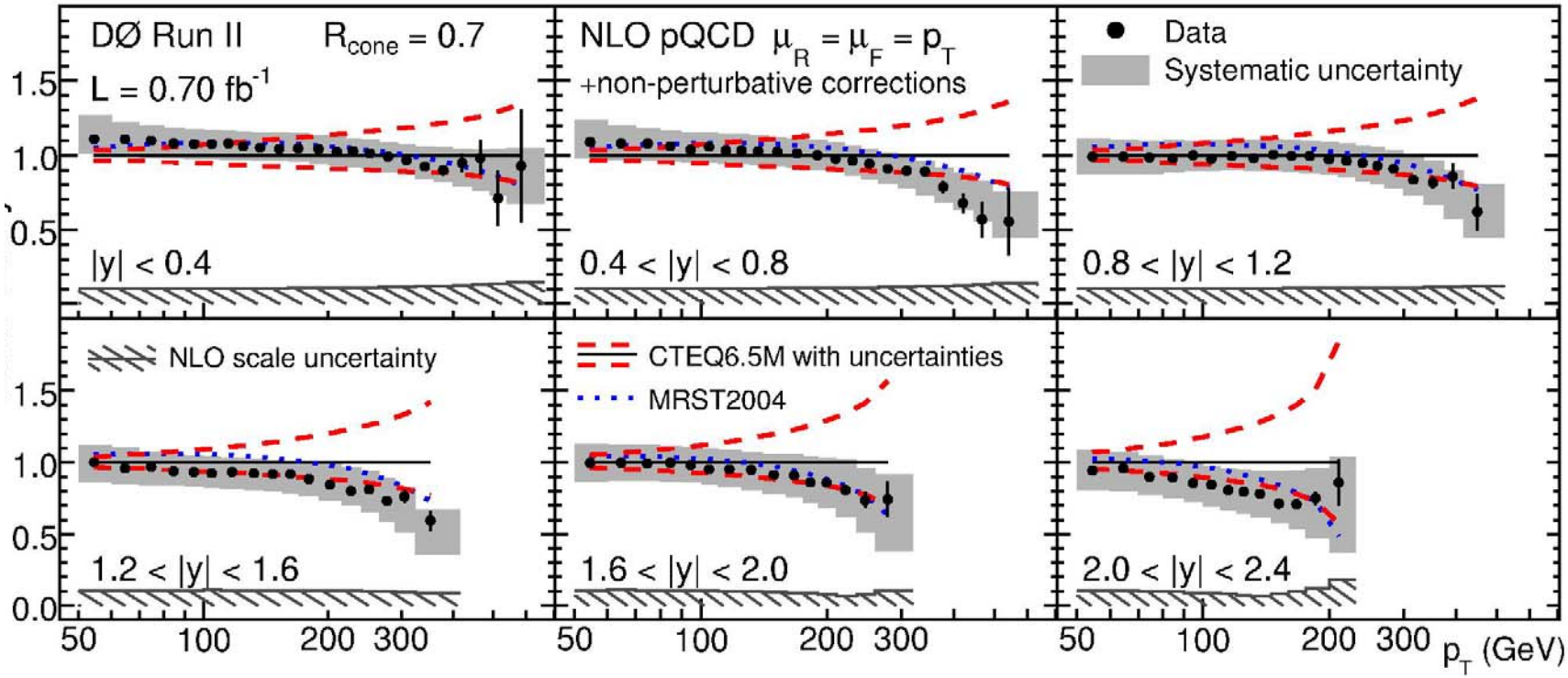
“Typical” event at D0



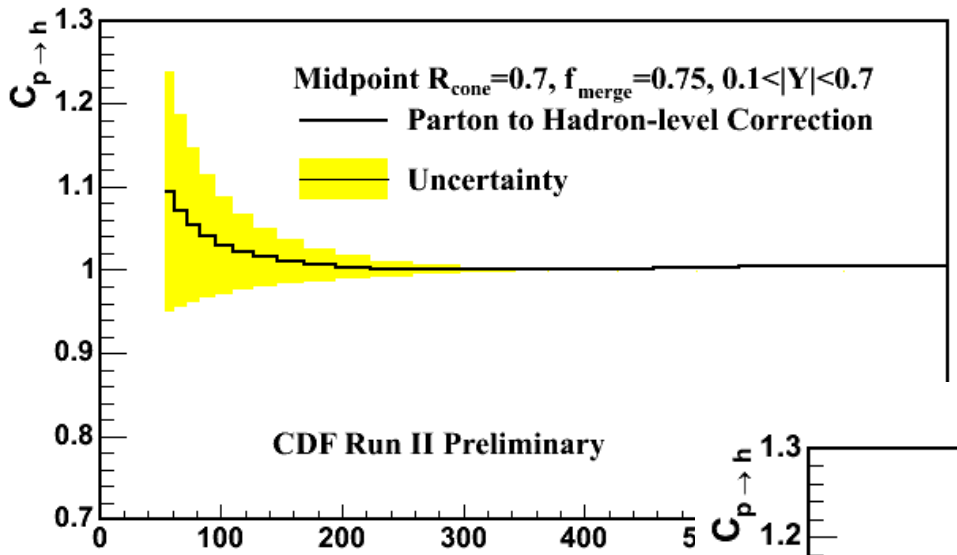
Jet pt’s are ~ 600 GeV
M = 1.2 TeV

Comparison to theoretical predictions

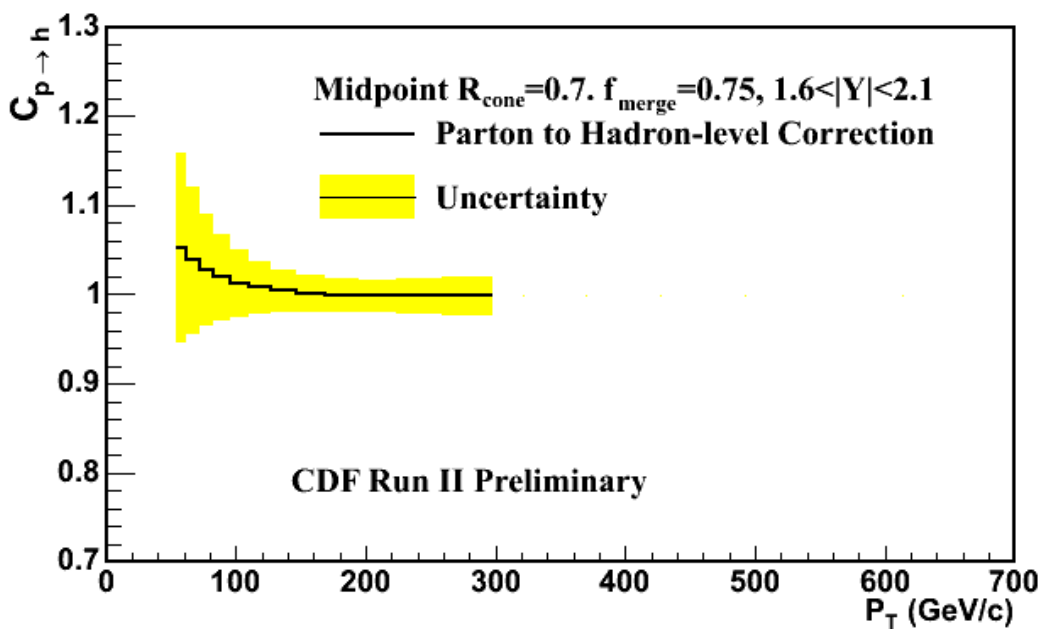
- D0 results – submitted to PRL **arXiv:/0802.2400 [hep-ex]**
- Compare to NLOJET++ with CTEQ6.5M PDF's
- Hadronization and underlying event corrections of 20→2 % needed for comparison with theory
- μ= pt



Parton to Hadron level correction

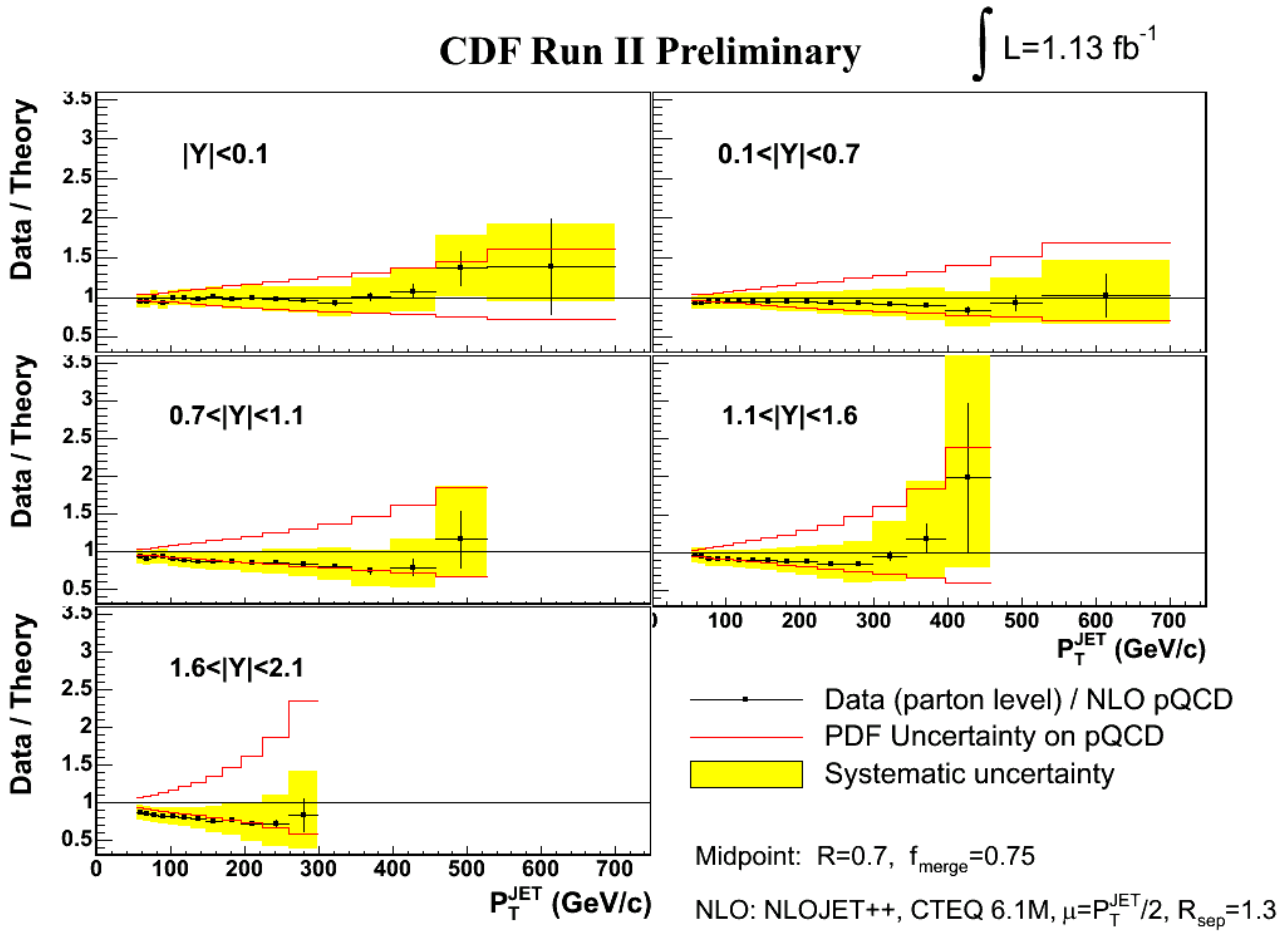


CDF estimate



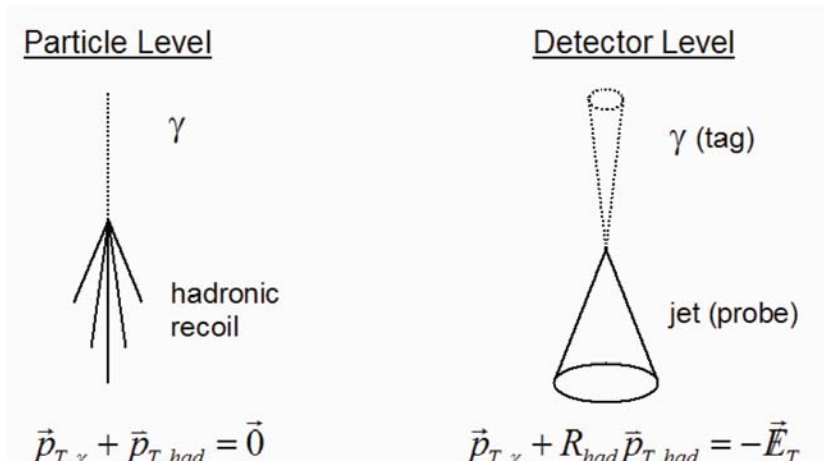
CDF comparison to theory

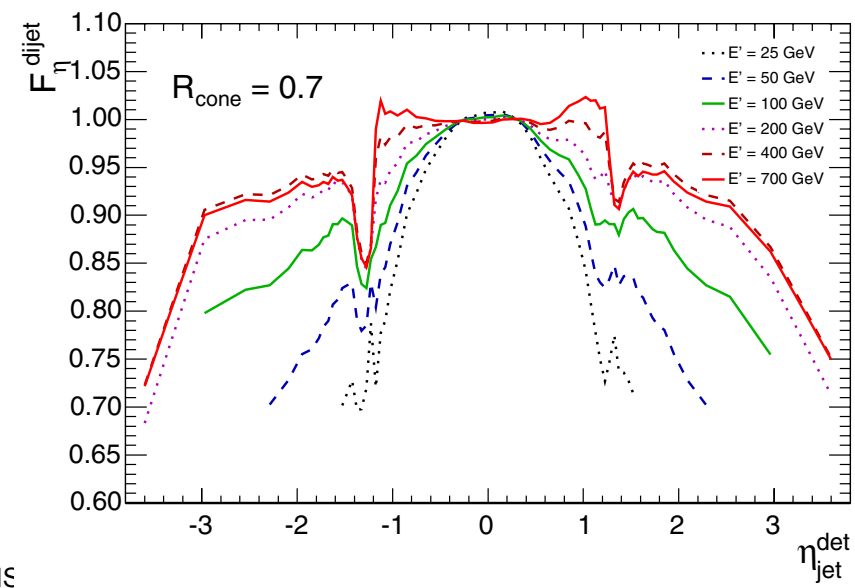
- Comparison to NLOJET++ with CTEQ6.1M
- Includes the parton to hadron corrections illustrated
- μ = pt/2



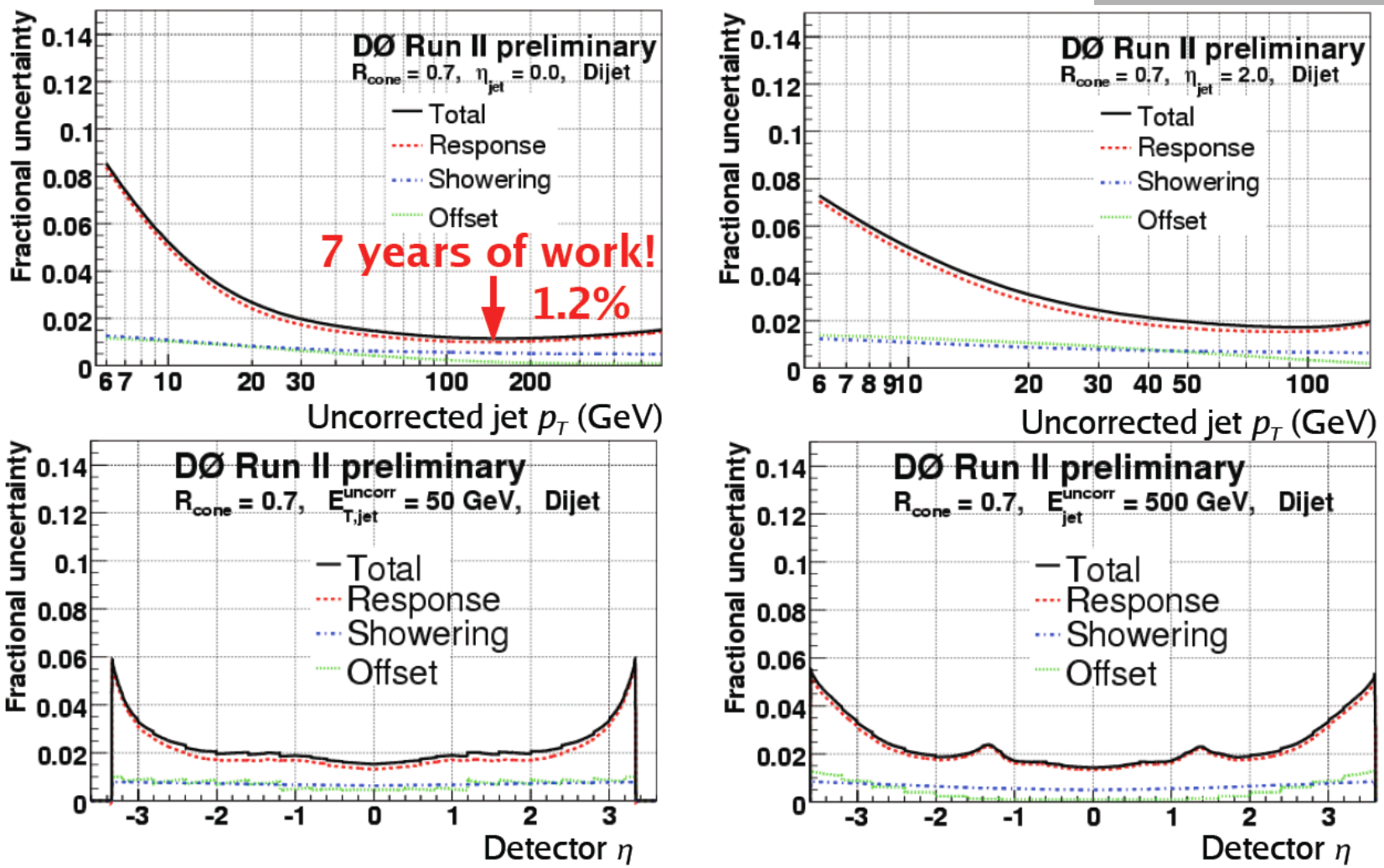
How did we do this?

- Dominant error is the energy scale
- D0 as an example
- Use the data
  - Start with Z→ee
  - then use γ+jet in the best parts to get calibration
  - then use j+j to carry the calibration everywhere

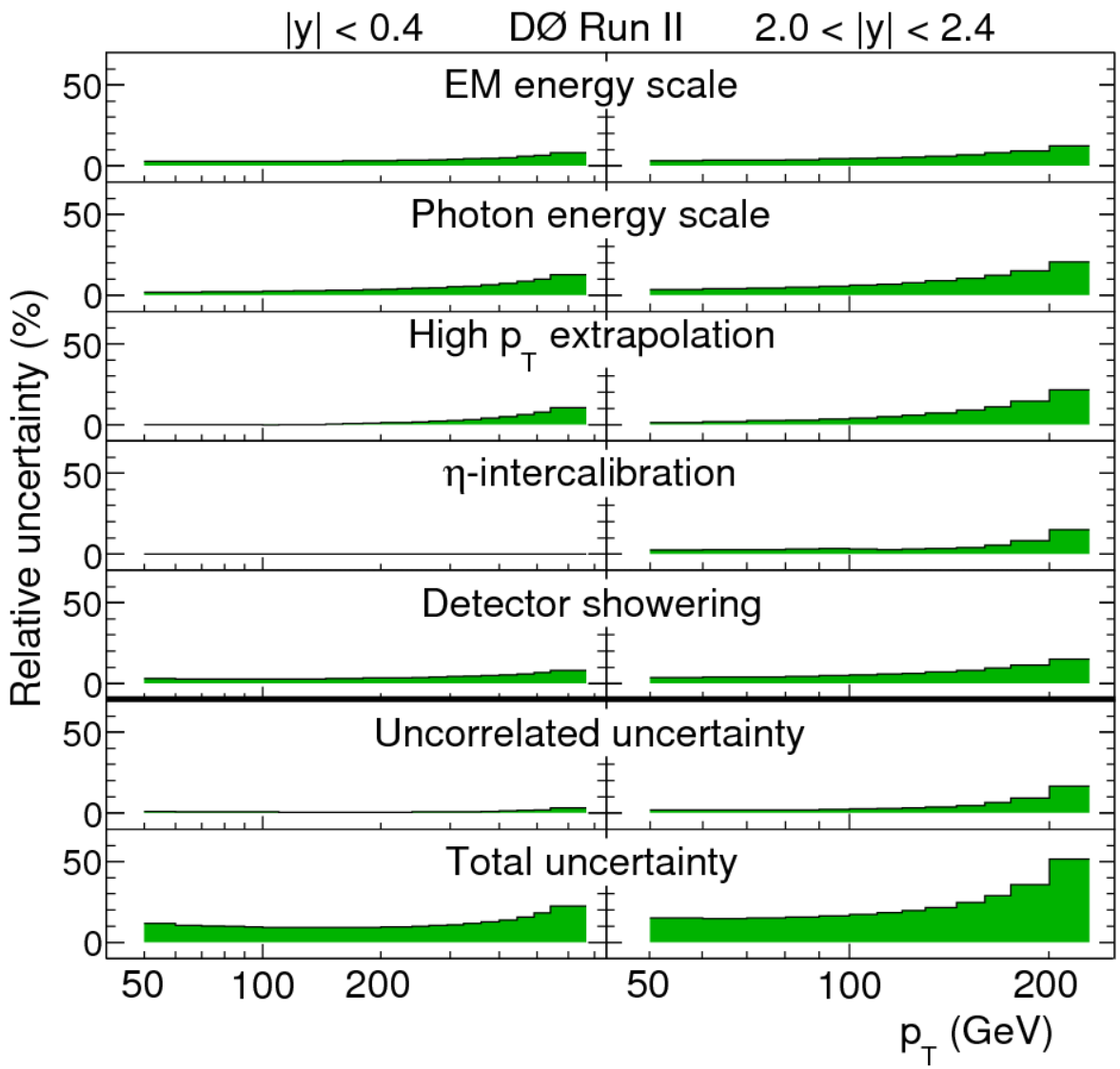




Jet energy scale errors



Major systematic errors



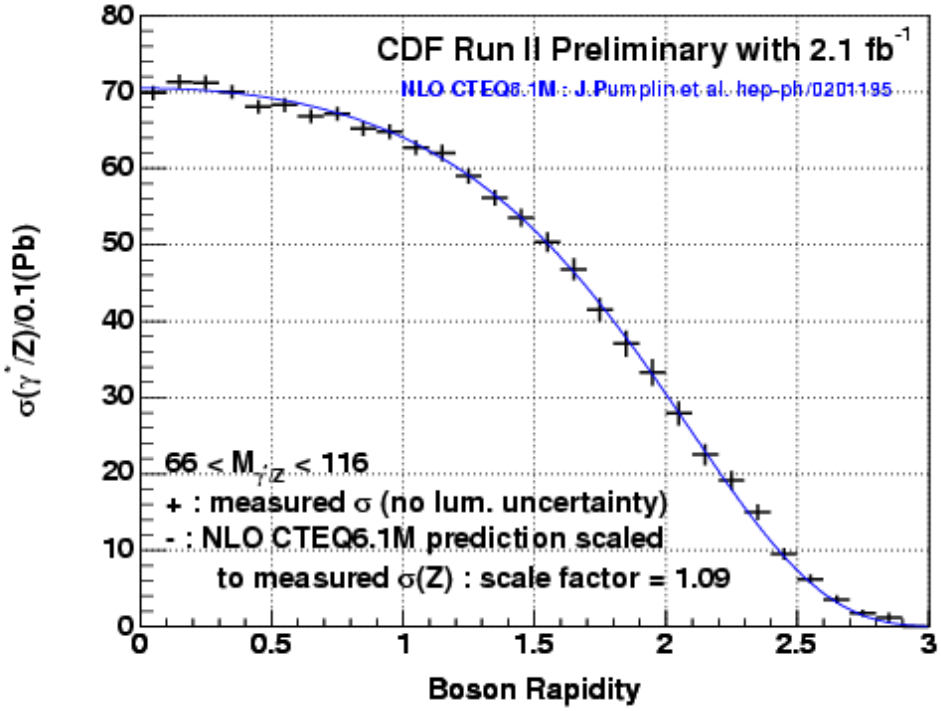
Jets conclusions

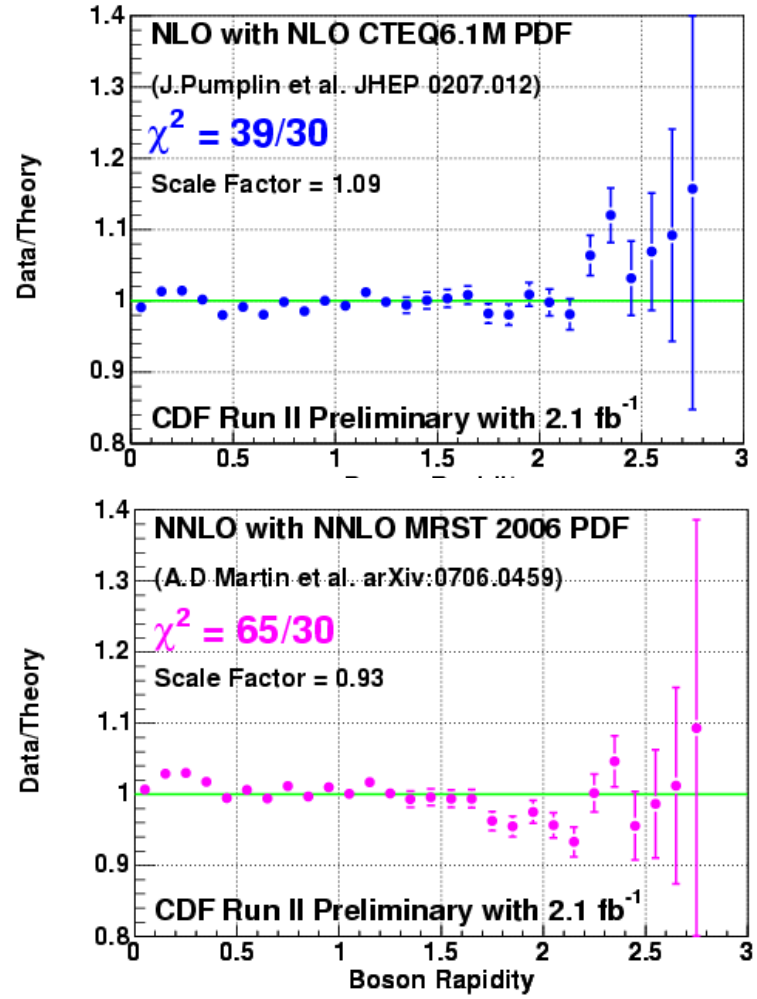
- Inclusive jet measurements are now “precision” measurements with errors small enough to constrain PDF’s
- Entering the regime where we are “theory” limited by nonperturbative effects.

1 Hz Z and W production

Galea EWK/SF

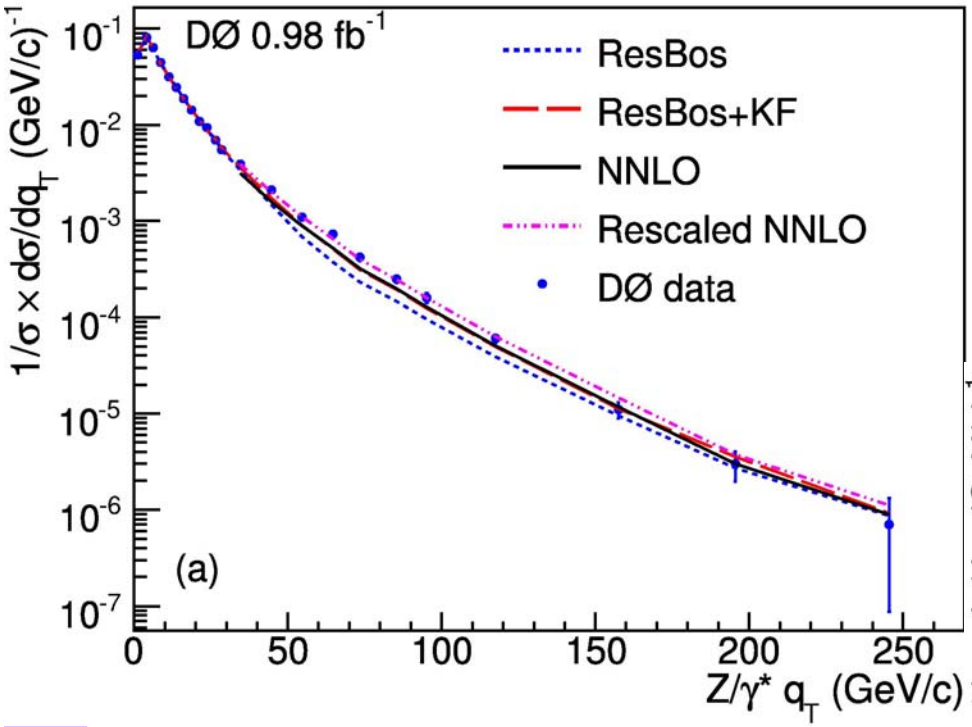
New high statistics Z rapidity from CDF

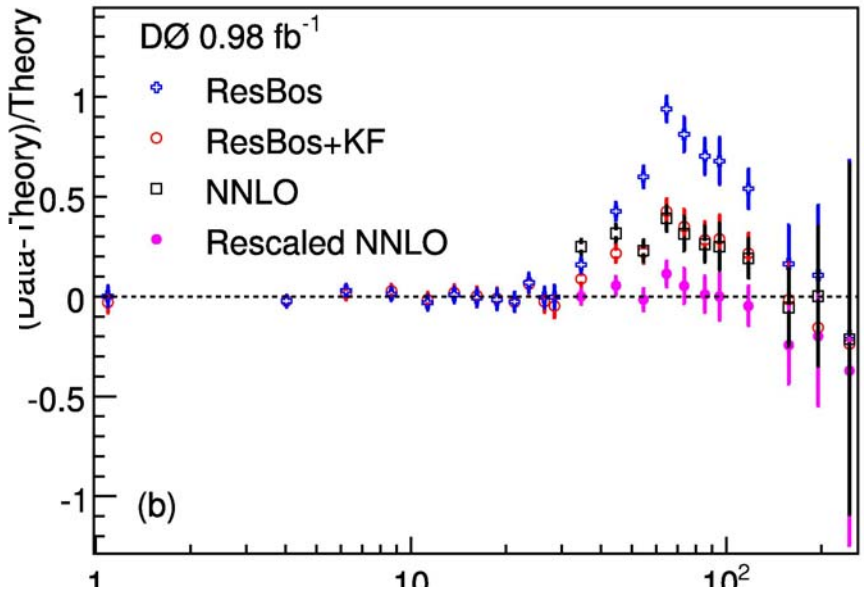


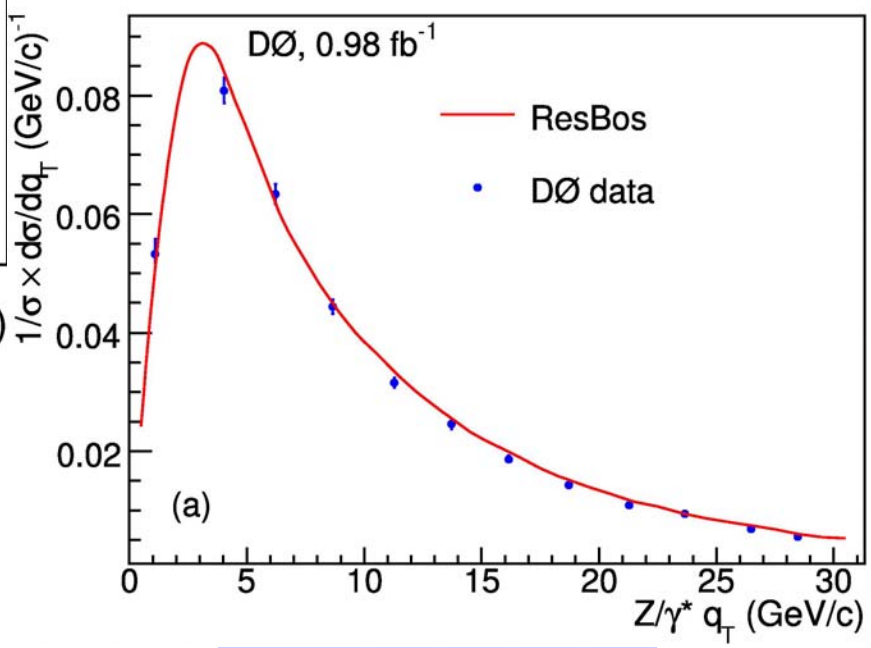


Z pt from D0

Phys. Rev. Lett. 100 , 102002 (2008)







Good agreement with RESBOS at low P_T
Shape above 30 GeV agrees with NLO and NNLO QCD but not the normalization

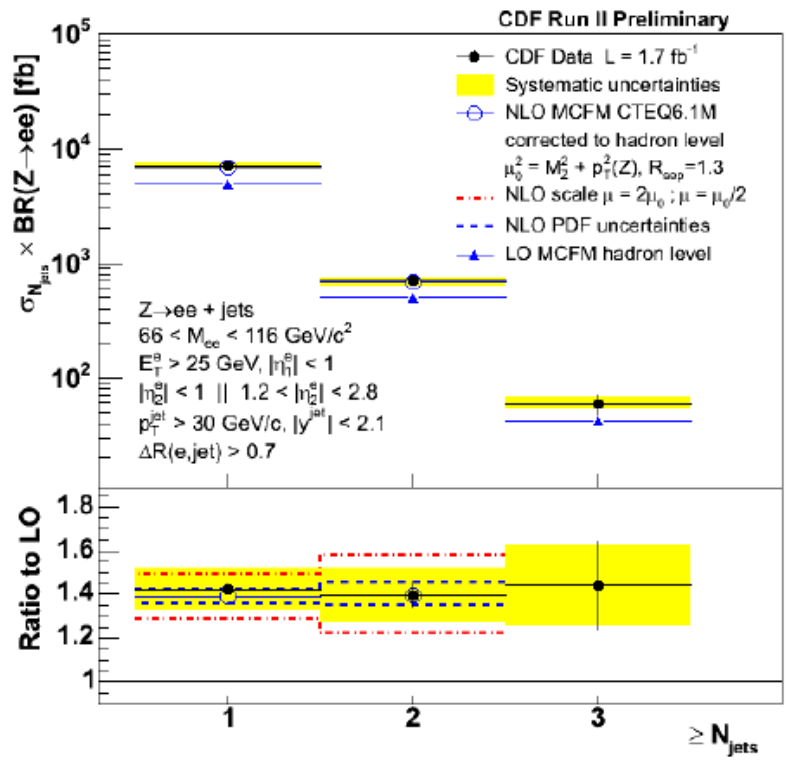
Galea EWK/SF

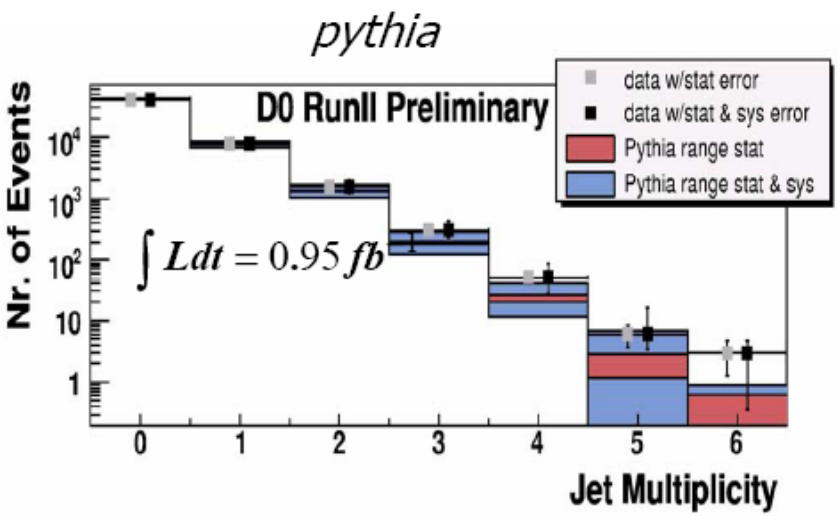
W/Z+jets

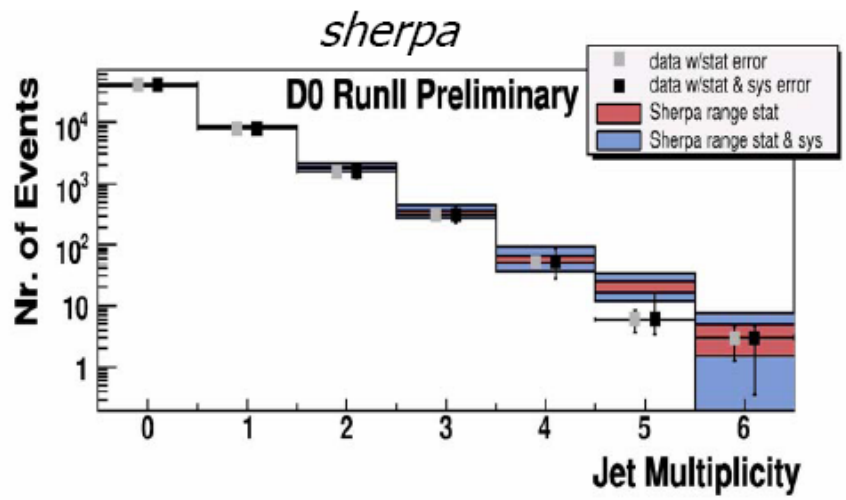
Cooper EWK/HFS

- Very important for new physics searches at hadron colliders

Cross Section w.r.t. the number of jets





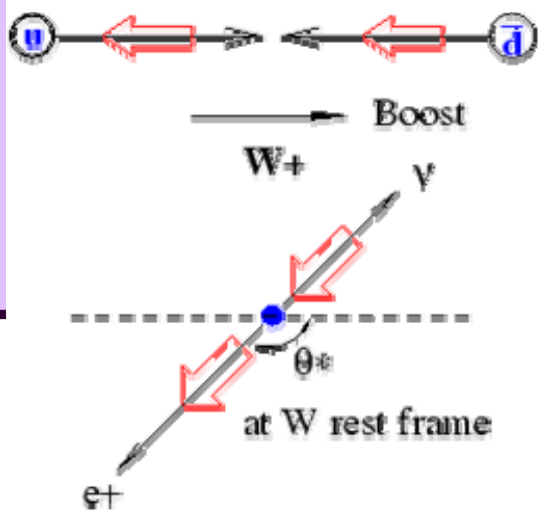


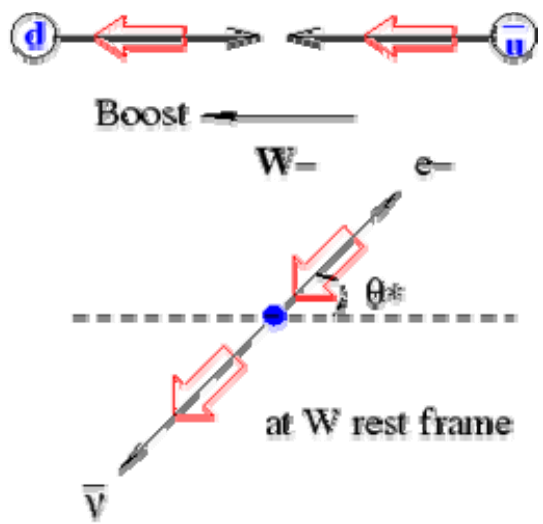
W asymmetry

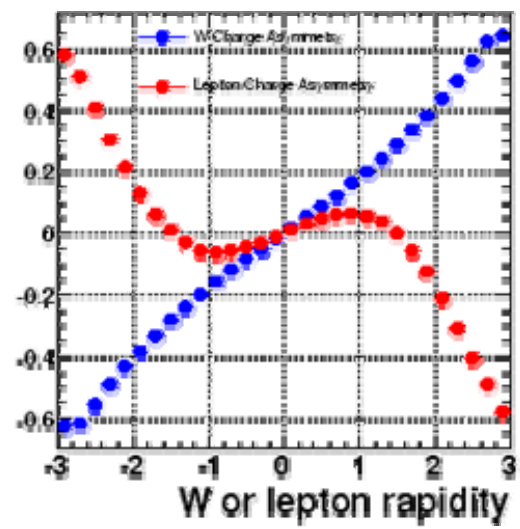
McFarland EWK/SF

- CDF now have a direct measurement of the W asymmetry

$$A(y_W) = \frac{d\sigma_+ / dy_W - d\sigma_- / dy_W}{d\sigma_+ / dy_W + d\sigma_- / dy_W} \approx \frac{u(x1)d(x2) - d(x1)u(x2)}{u(x1)d(x2) + d(x1)u(x2)}$$





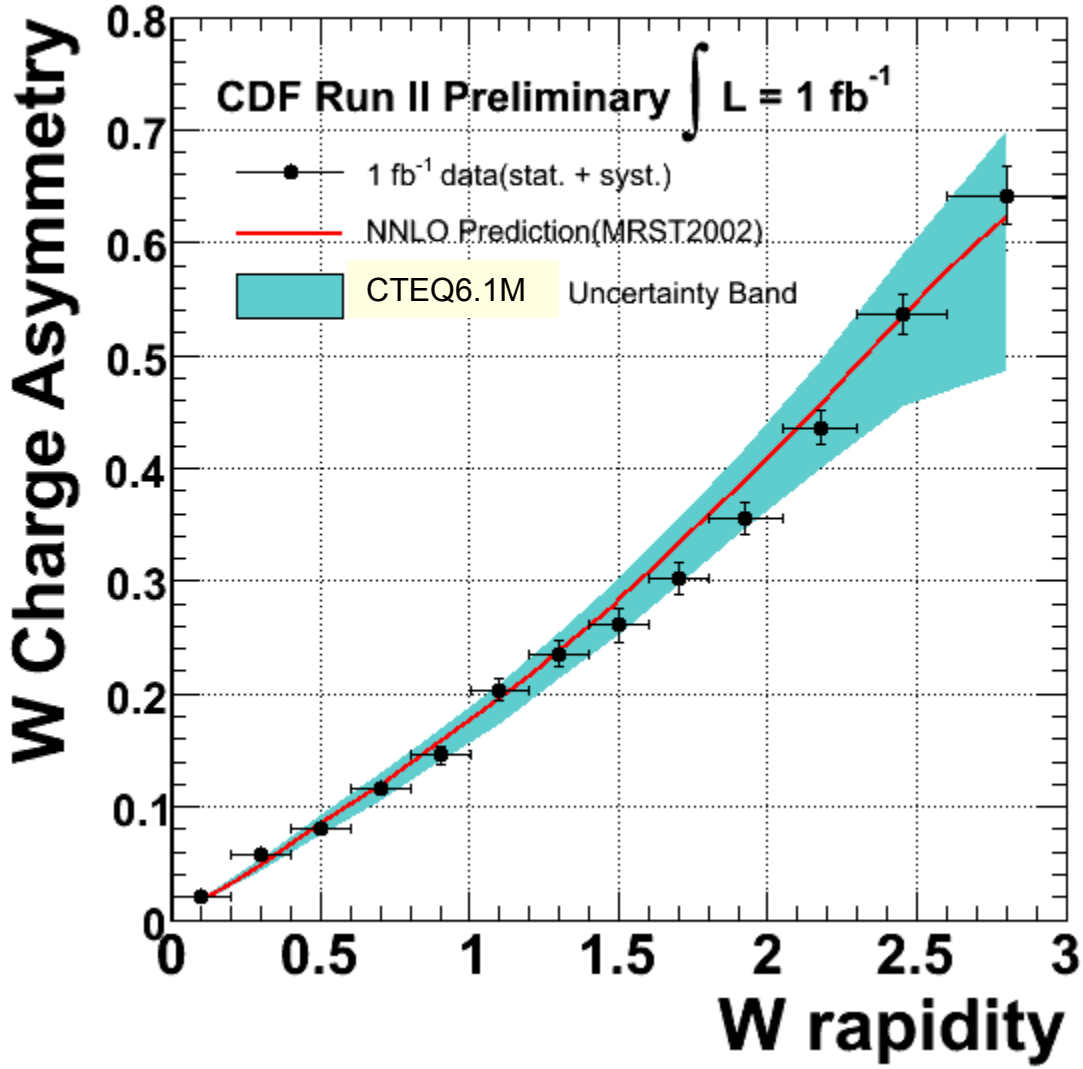


How?

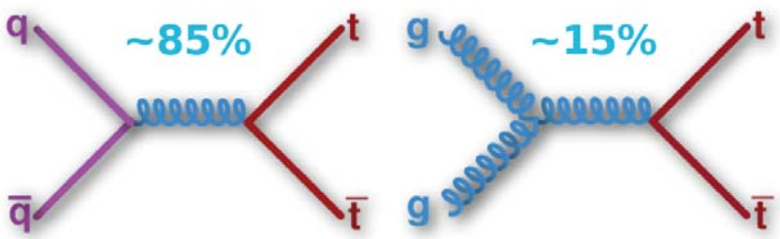
- We know $p_T(e)$, $p_z(e)$ and $p_T(\nu)$.
  - Don't know $p_z(\nu)$.
- A W mass constraint gives two solutions for $p_z(\nu)$.
- Use QCD to calculate the relative probabilities for the two solutions and then use the weighted events to measure the asymmetry as a function of the W rapidity.
- Need to iterate as the weights include assumptions about u(x) and d(x)!

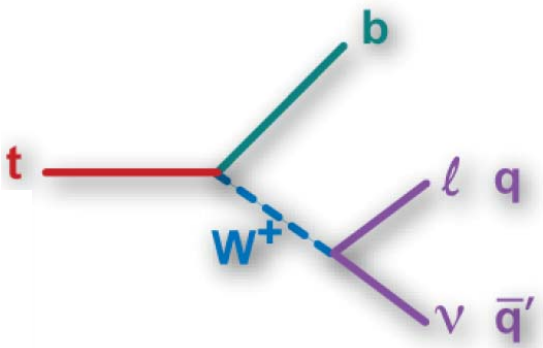
W asymmetry

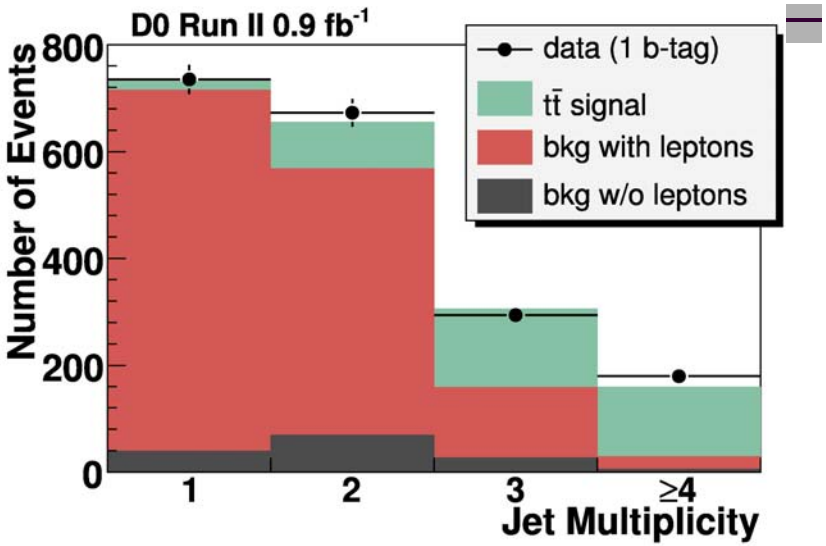
- Looks as if it significantly constrain pdfs!

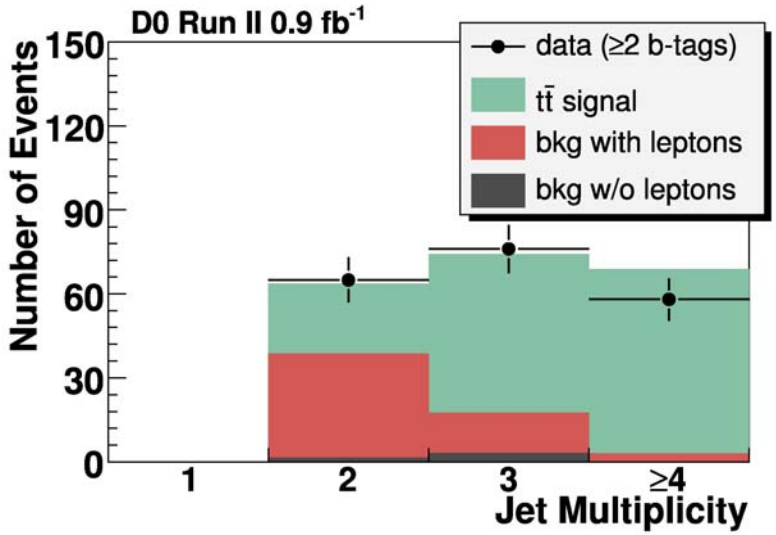


0.001 Hz - Top



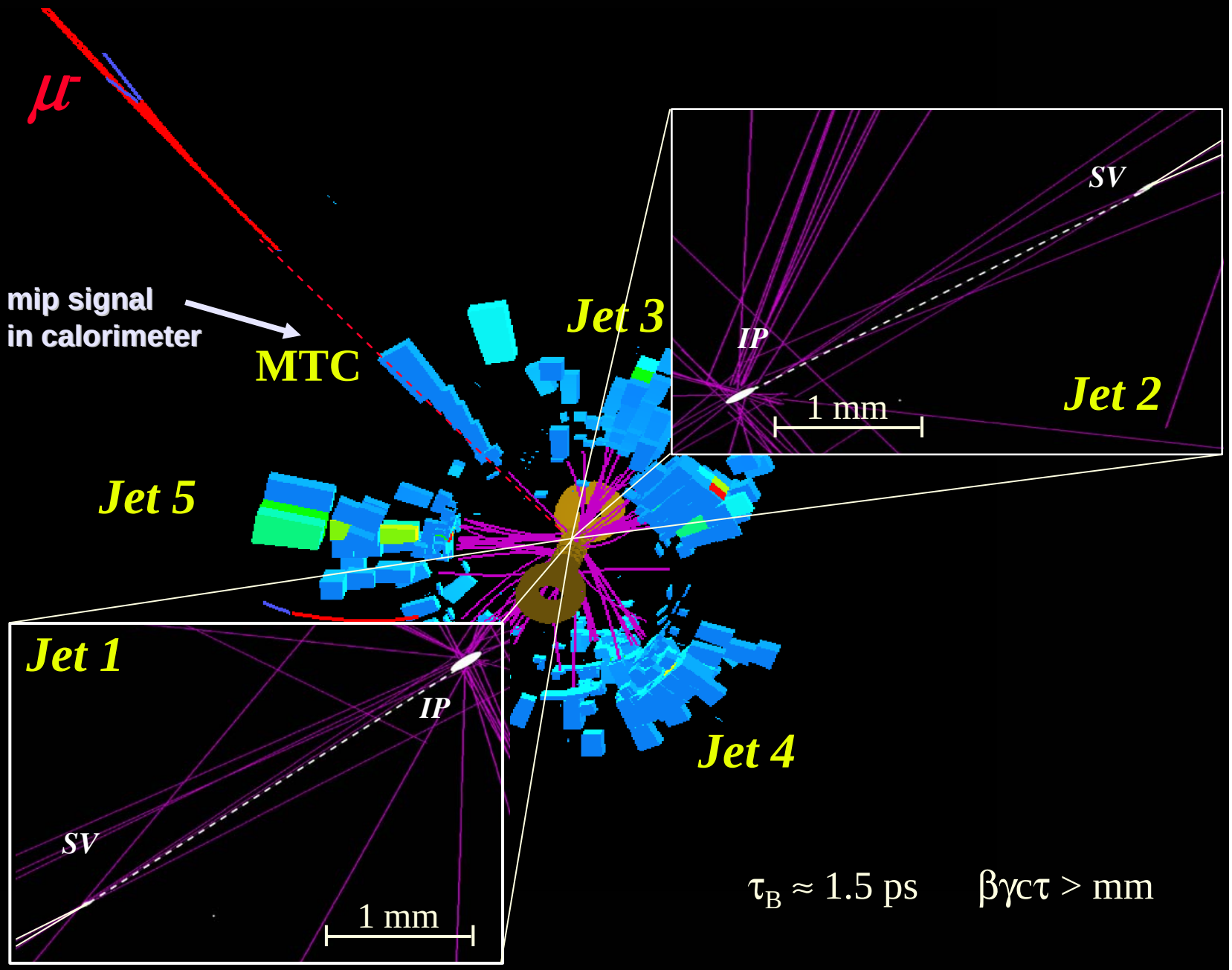






Requiring a b-tagged jet makes a very pure top signal

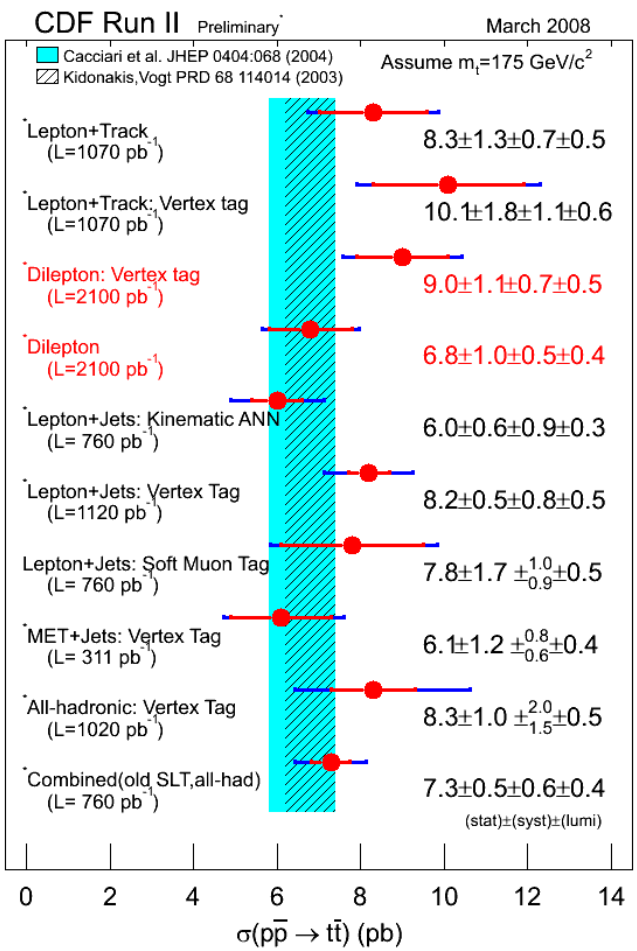
$t\bar{t} \rightarrow bW \rightarrow 2j,\ bW \rightarrow \mu\nu$

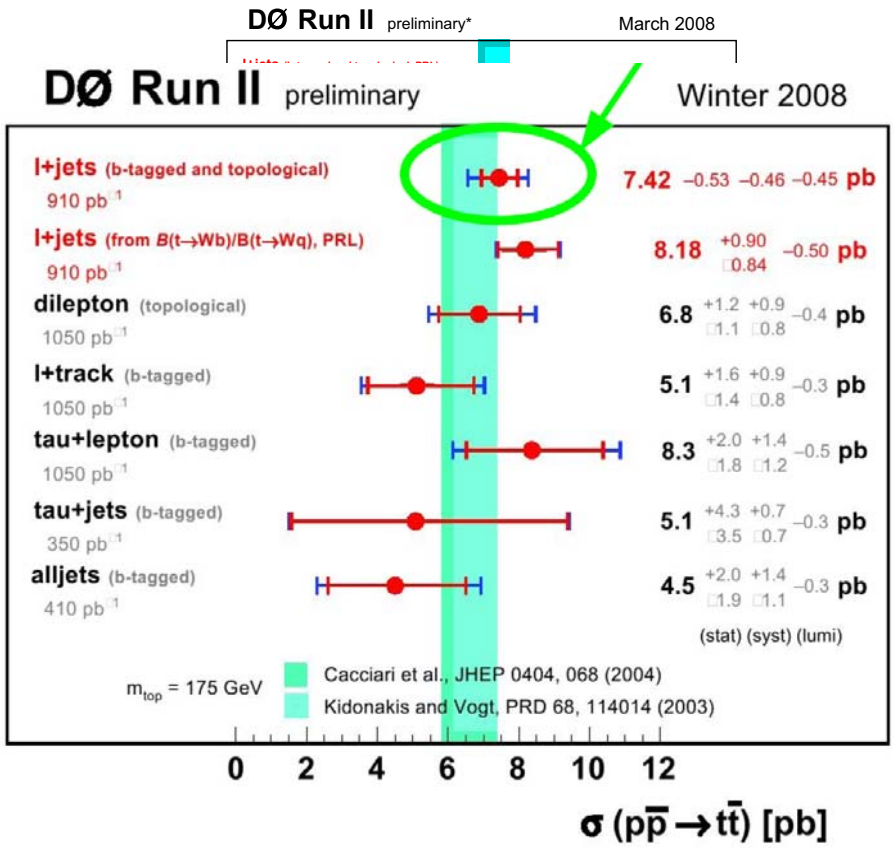


$\tau_B \approx 1.5$ ps $\quad \beta\gamma c\tau >$ mm

Current status

CDF Run II





Top Mass – matrix method

Matrix method description

Note – all of this depends on QCD/PDF

Partonic differential Cross Section, based on LO Matrix Element

Normalisation

$$P_{t\bar{t}}(x, m_t, JES) = Acc(x)\frac{1}{\sigma_{t\bar{t}}(m_t)}\int dq_1 dq_2\, f(q_1) f(q_2)\, d\sigma(y, m_t)\, T(x, y, JES)$$

use hadronic W decay

Acceptance

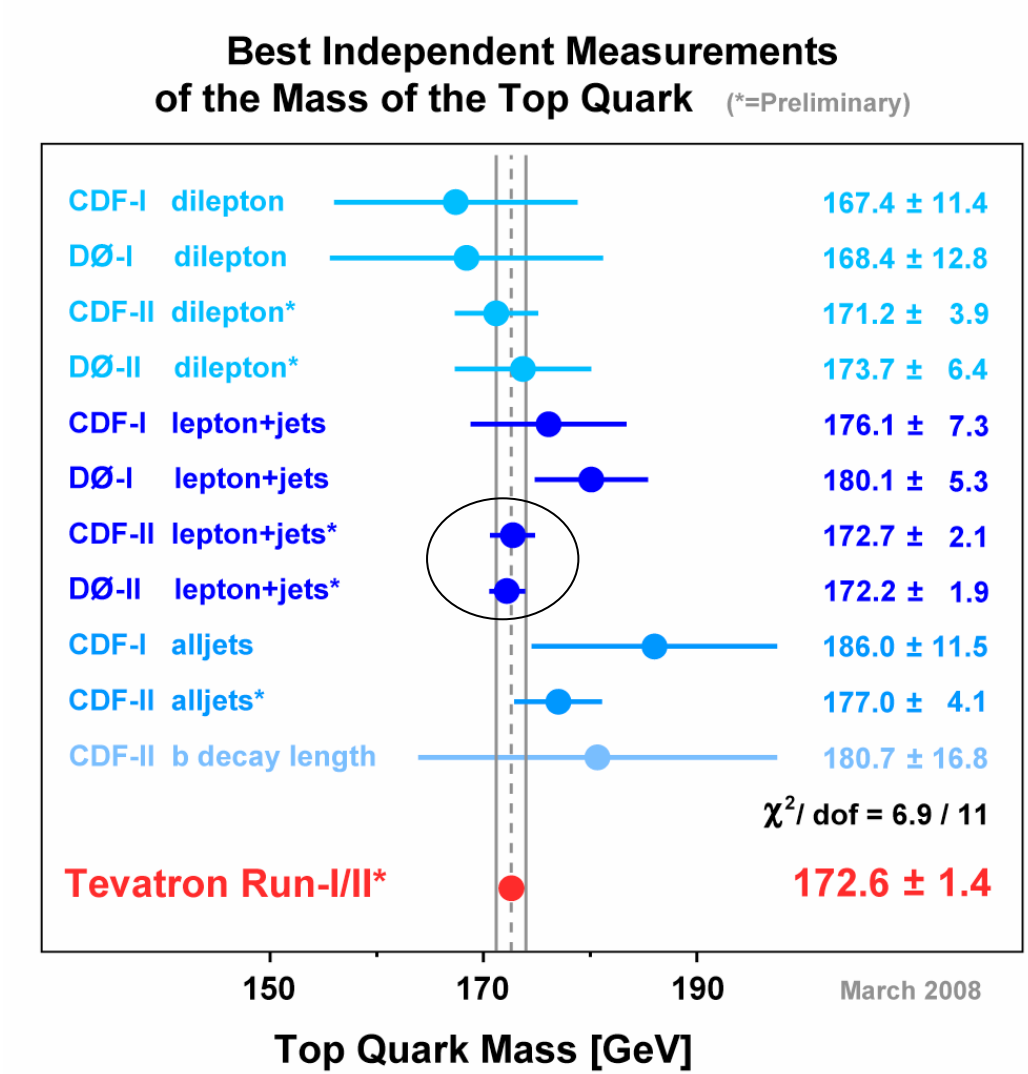
initial state

Transfer Function: Prob. to measure x from parton-level y

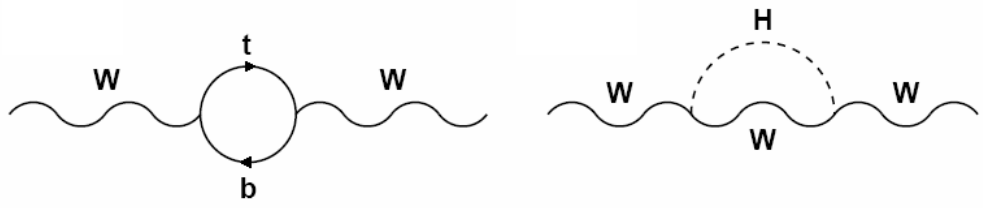
- Calculate a probability that each event is signal or background as a function of m_t
- The product of all event probabilities yields the most likely mass.
- Can improve the energy scale by using a mass constraint on W→jj

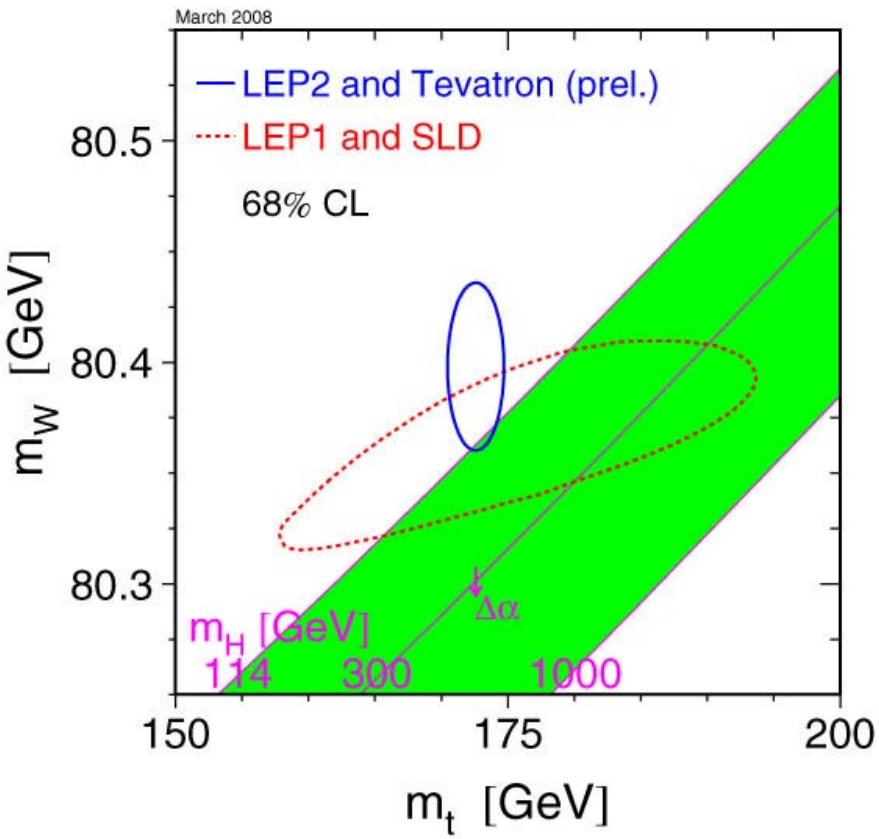
- Statistical errors are ~ 1 GeV, systematic at 1.5 GeV!

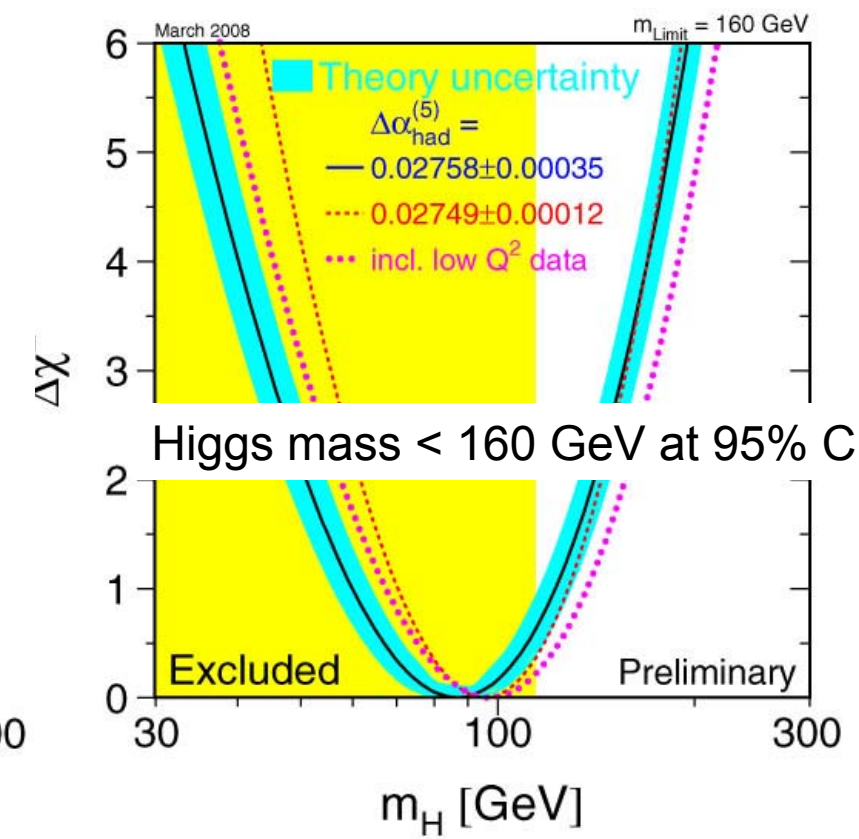
Top mass summary



LEP / TEVEWWG



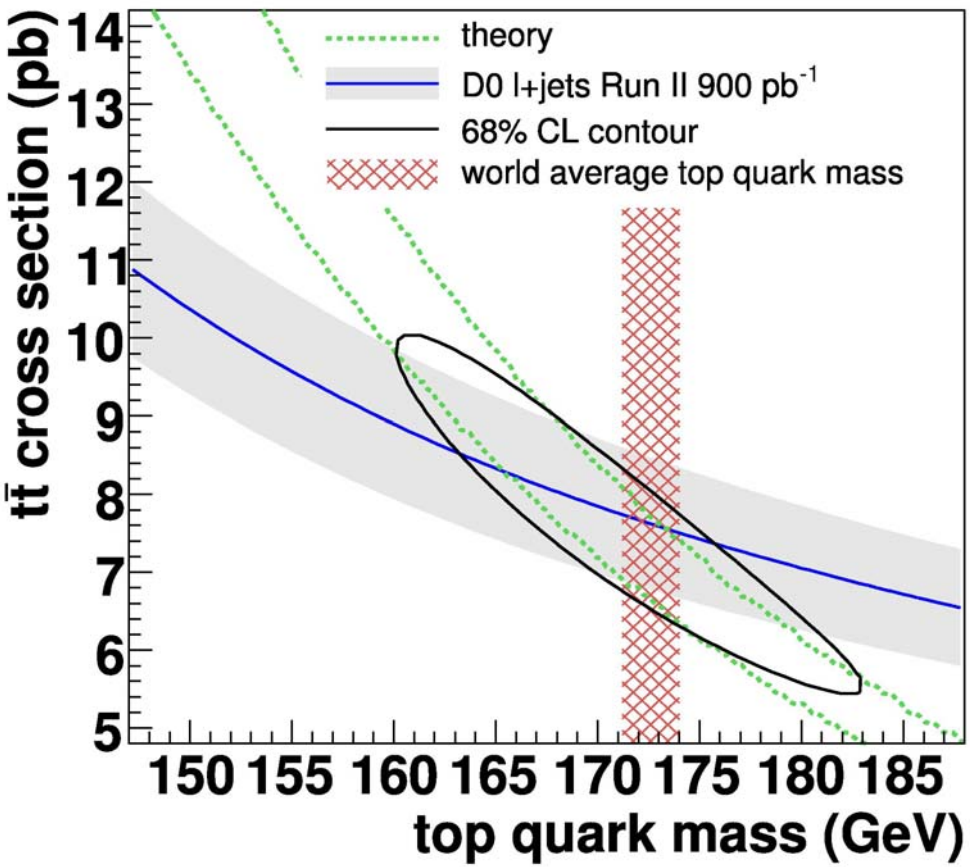




Higgs mass < 160 GeV at 95% CL

One caveat

- The current template or matrix element methods measure the “Pythia” mass. What is the real “mass” of the top in the presence of QCD effects.
- Current status is ???
- Something closer to the real mass can be measured by comparing the cross sections between theory and data.

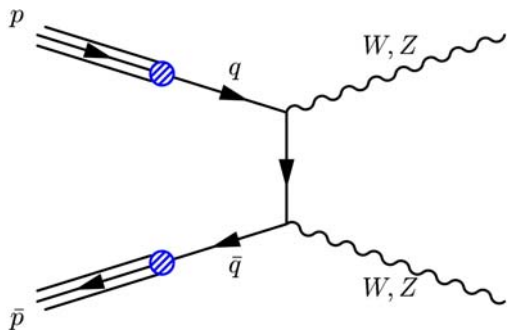


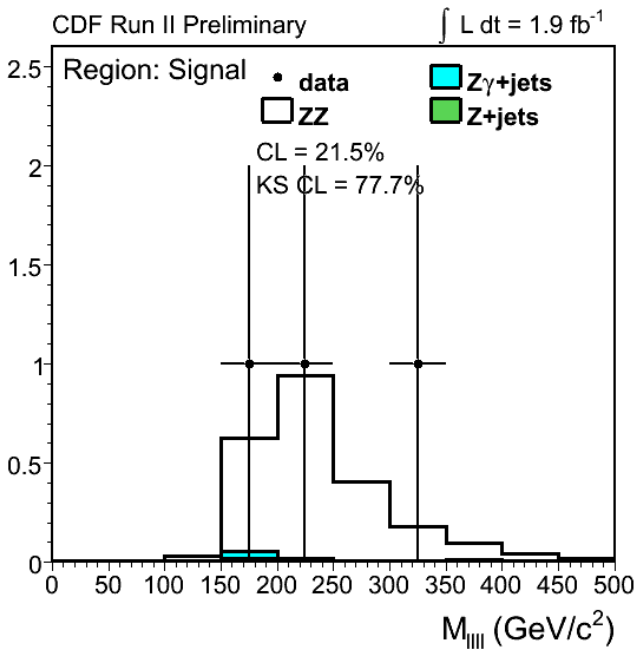
Precision top?

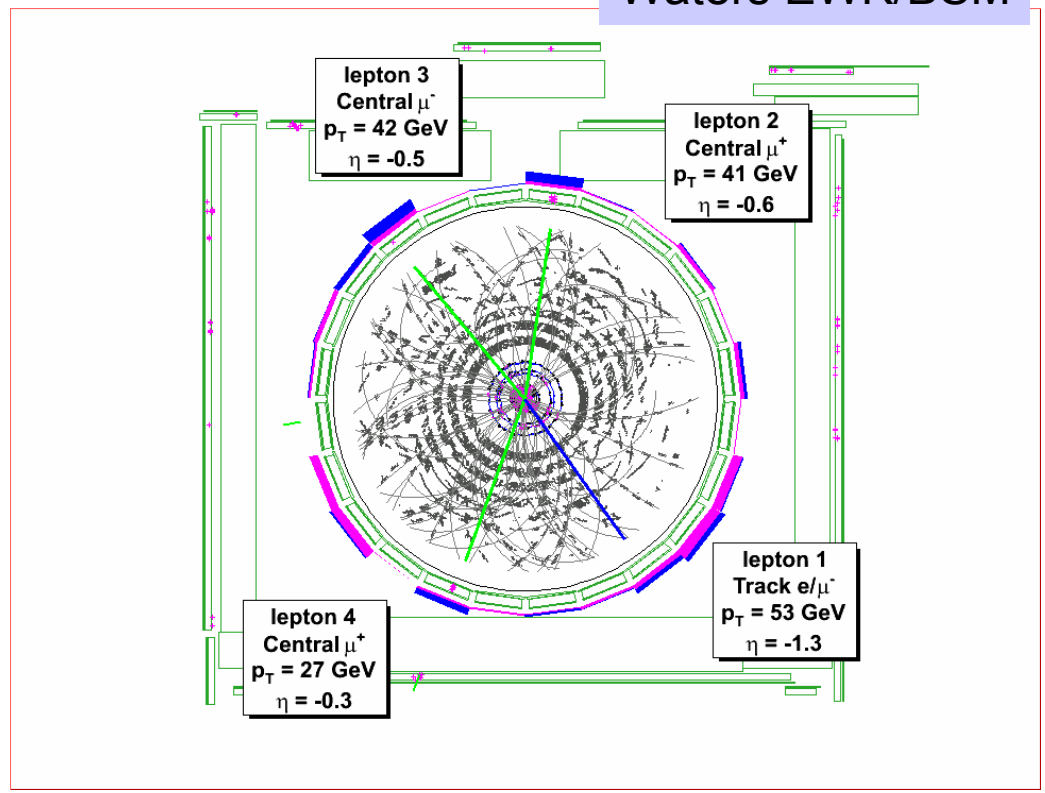
- Top signals are very clean and the cross section errors are ~ 10%, with PDF and luminosity errors becoming dominant.
- Z/W cross section errors are also dominated by luminosity and PDF uncertainties.
- Luminosity error is probably irreducible but we can learn something about PDF's from Z/W/top comparions.

The littlest cross section (so far)

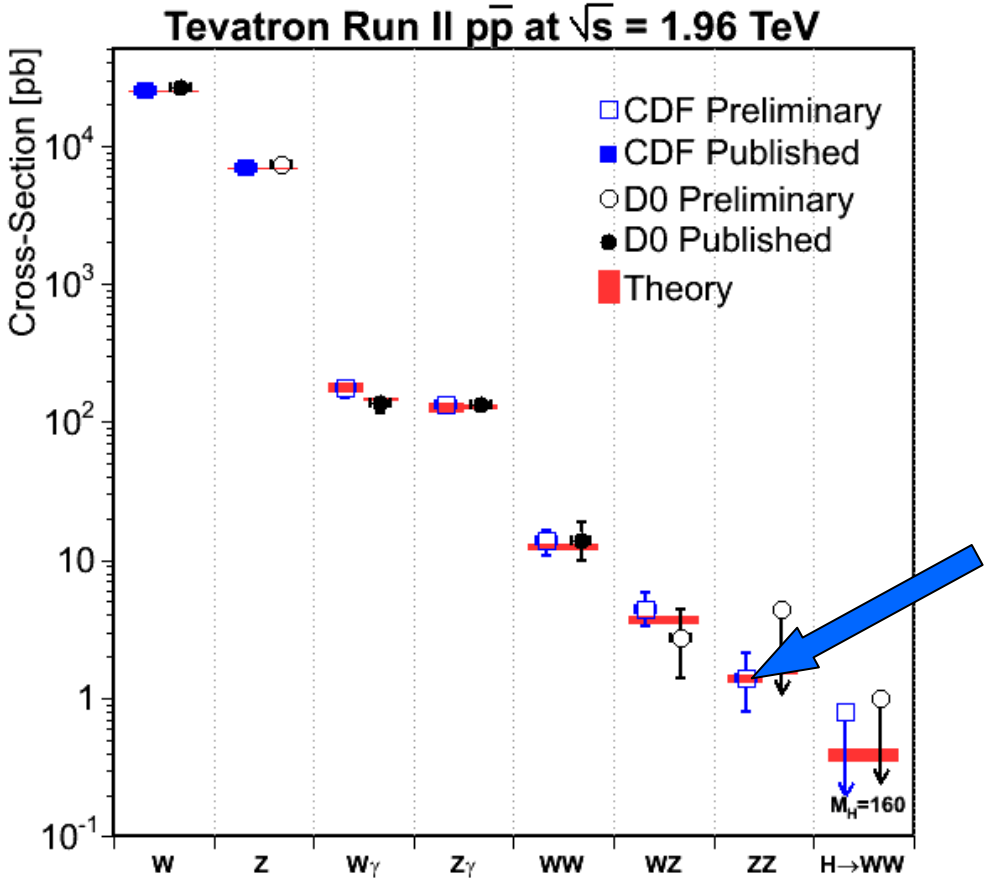
Waters EWK/BSM





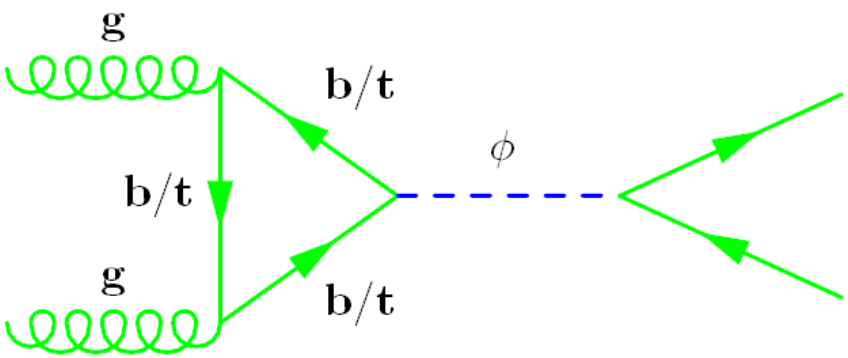


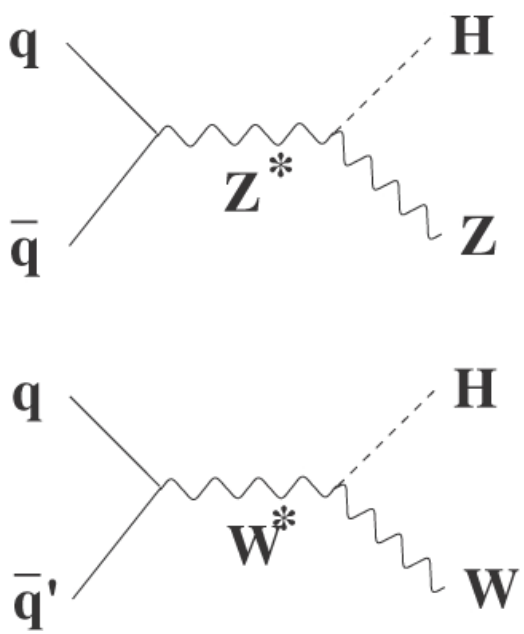
σ(ppbar -> ZZ) = 1.4 + 0.7 - 0.6 pb
from 3 llll and 5 llνν candidates
http://arxiv.org/abs/0801.4806v1

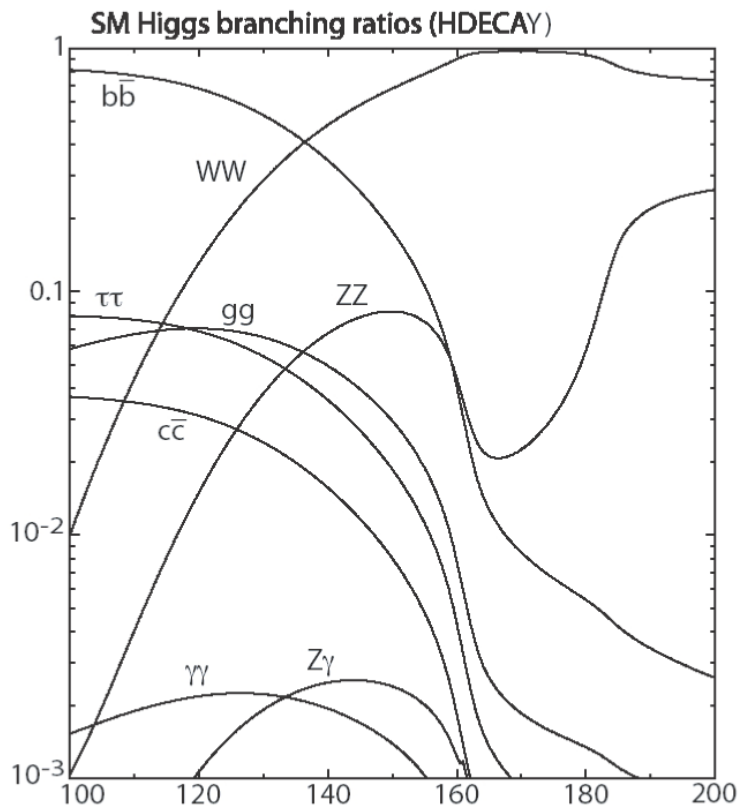

Tevatron Run II pp̄ at √s = 1.96 TeV
Cross-Section [pb]
CDF Preliminary
CDF Published
D0 Preliminary
D0 Published
Theory
M_H=160
W
Z
Wγ
Zγ
WW
WZ
ZZ
H→WW

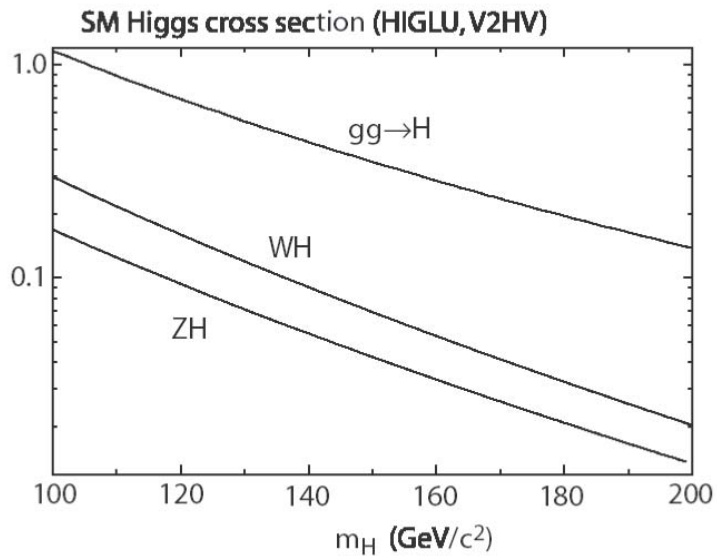
We are here

On to the Higgs…

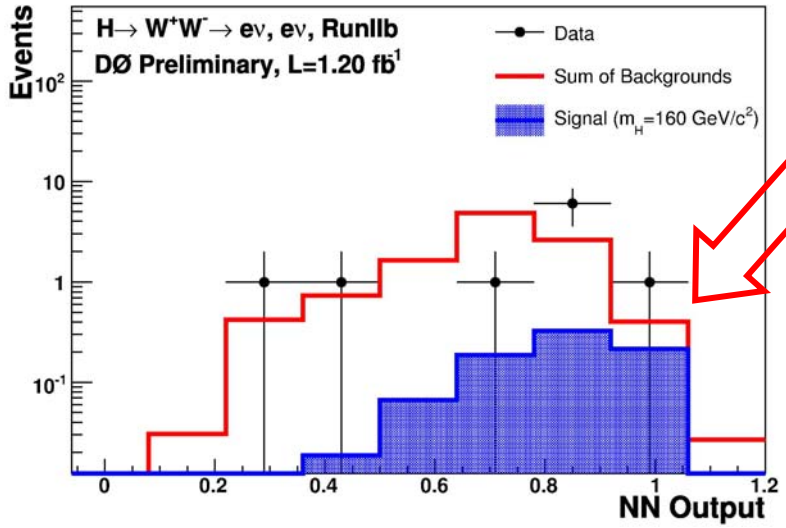


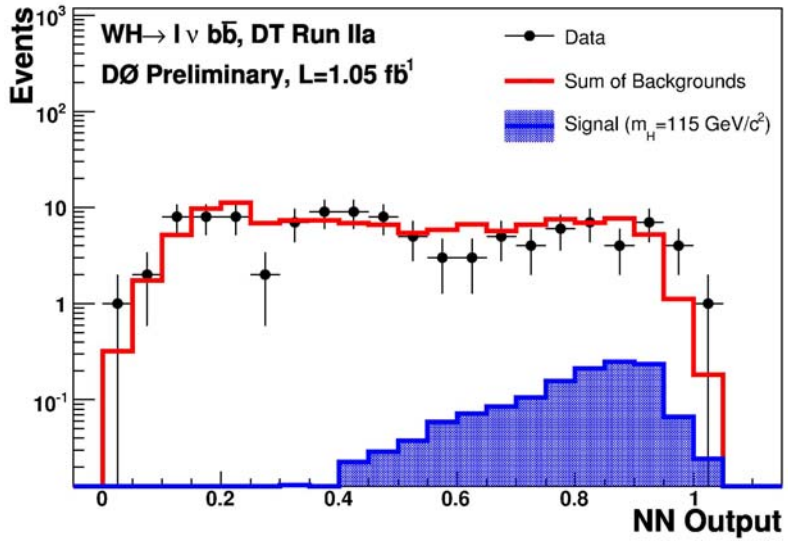




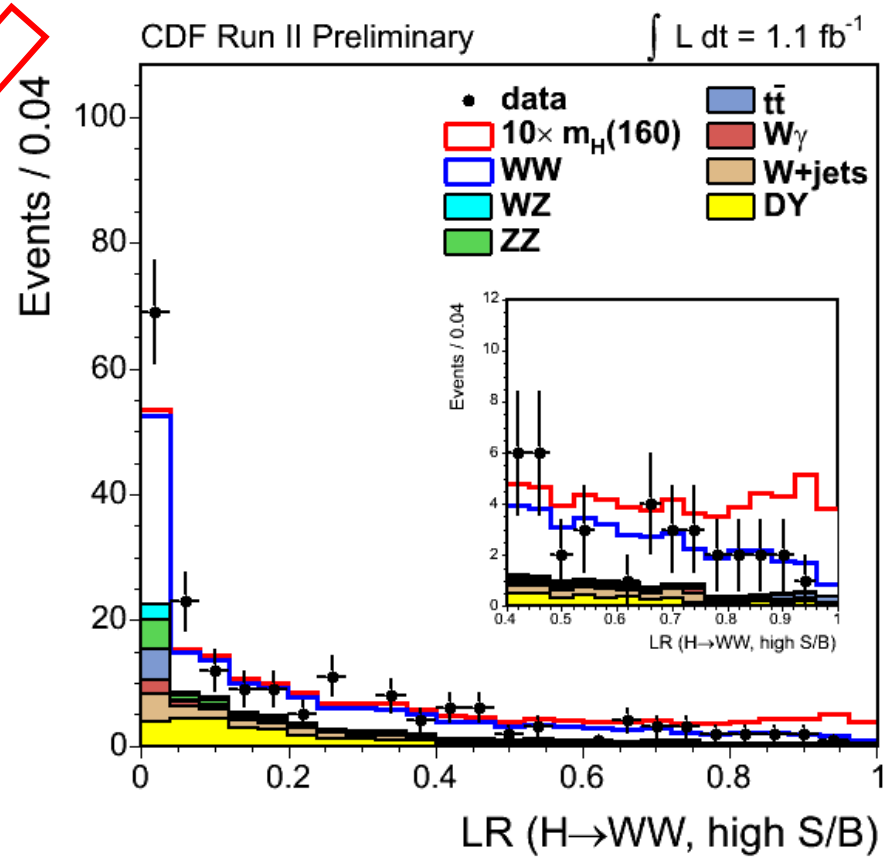


Limits are made up of combinations of many different channels

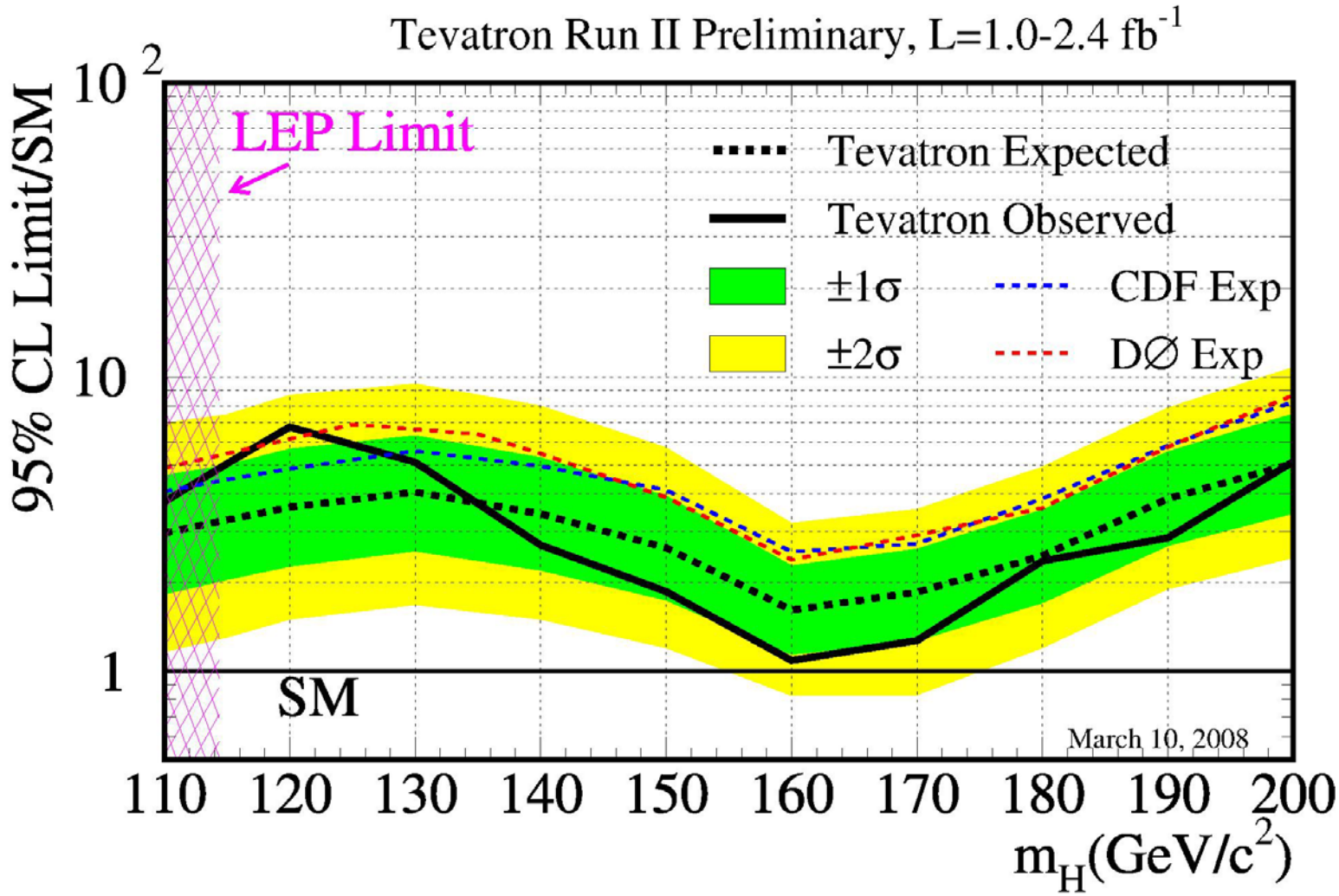




This all depends on QCD expt/theory



Limits as of March 2008



Conclusions

- Tevatron is doing precision QCD measurements of jet and W/Z production.
- New rarest process ZZ has been seen in 2 channels
- Top quark mass known to < 2 GeV, tt cross section is known to ~ 10%.
- The SM Higgs is going to have to start taking evasive maneuvers soon.