Top Quark Production at 1.96 TeV

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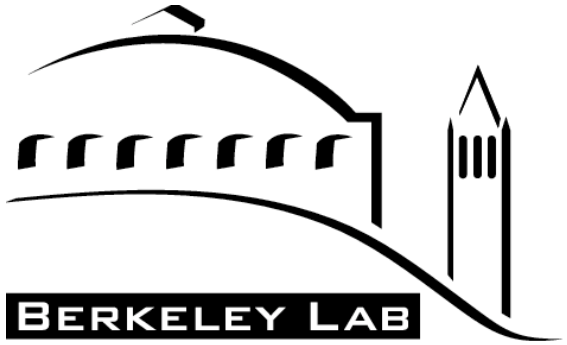
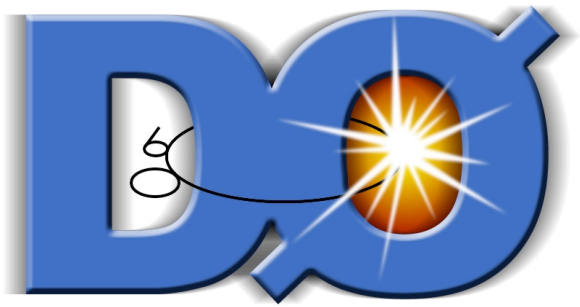




The Lure of Top Quark Physics

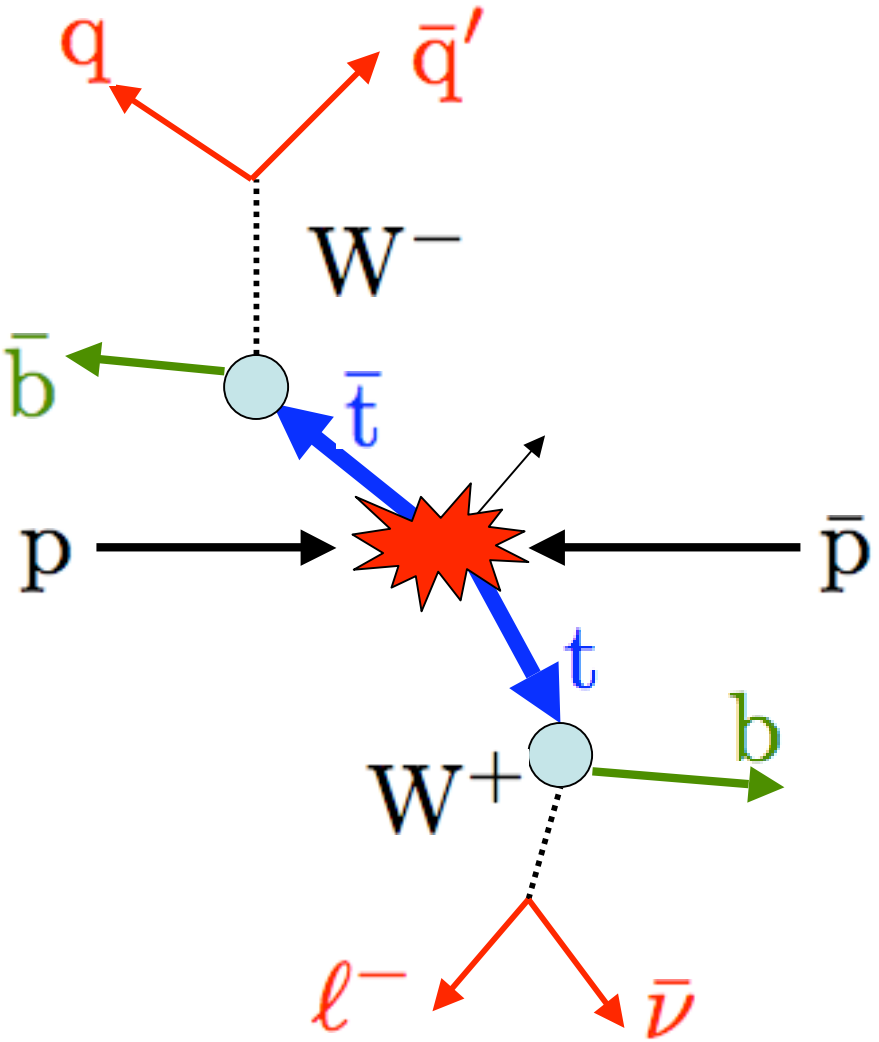
Fits into third generation - CKM

Mass near EWSB scale
- Central role in these theories
- Corrections to $m_W \propto m_t^2, \ln(m_H)$

Top pair production tests QCD
- Explore production kinematics

Possibility of t-tbar resonance

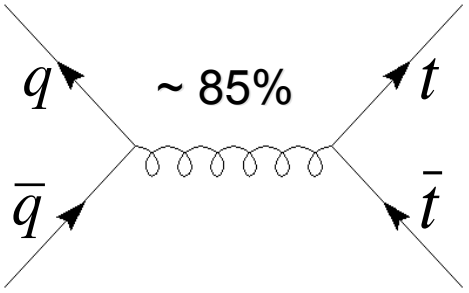
Heavy enough to decay to exotics
- On-shell charged Higgs bosons
- SUSY particles coupling to top

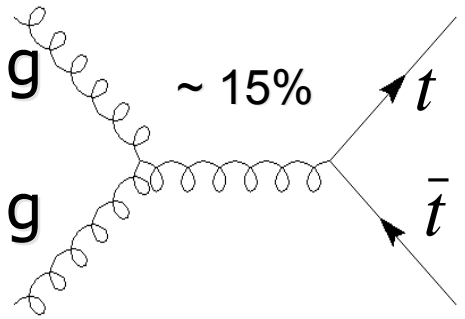


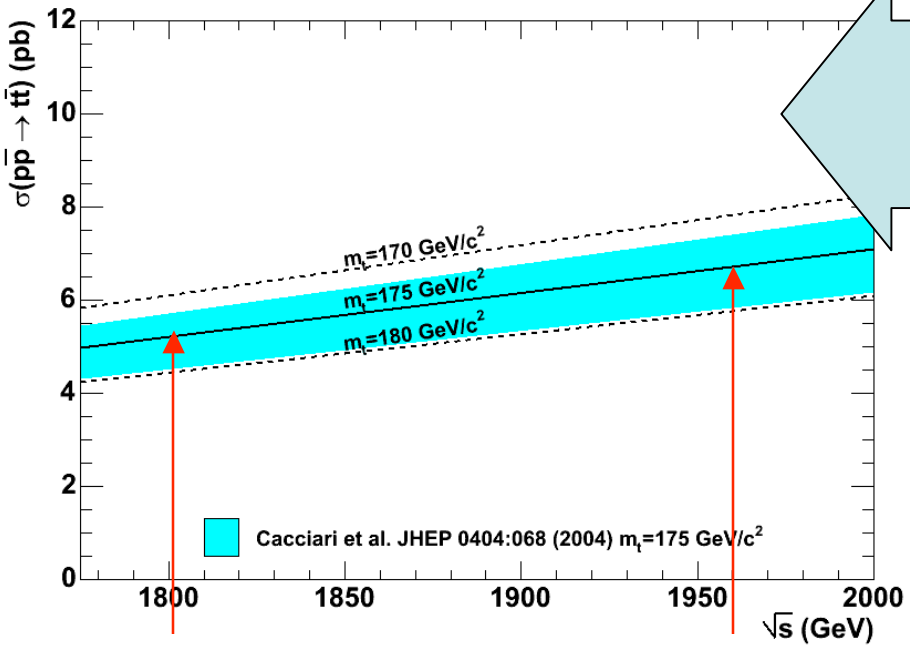
Production cross section is sensitive to new physics in production and decay
- Also an important background to discovery physics at future colliders

Top Quark Pair Production at the Tevatron

What do we expect?
- Central, spherical events
- Large transverse energy





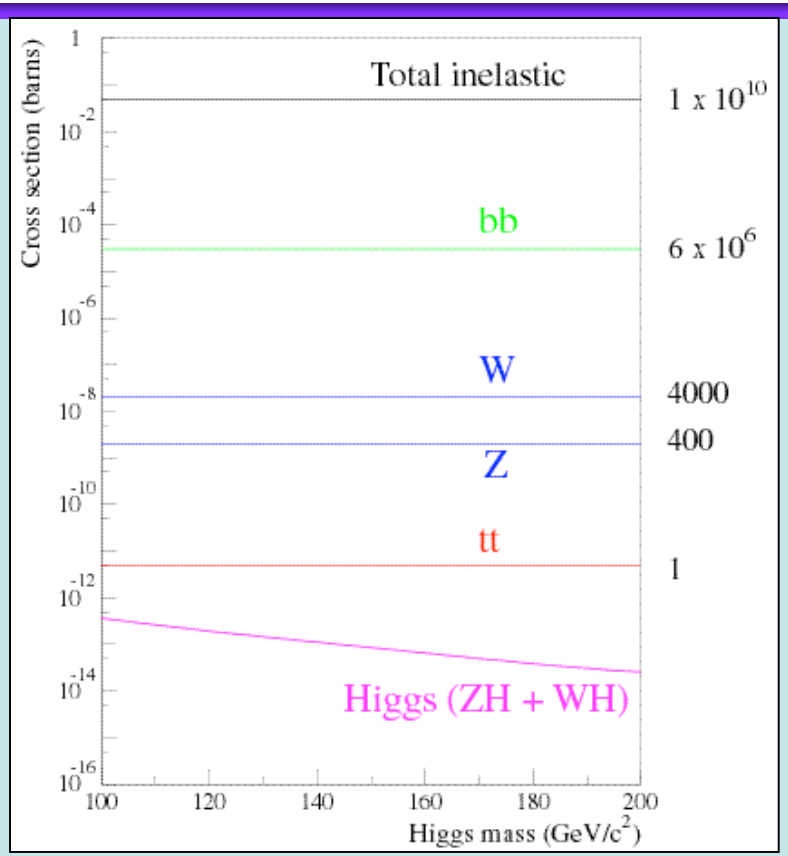


Theoretical predictions at NLL
Results assume m_t=175 GeV/c^2

Dominant uncertainties:
- renormal./factorization scale (5%)
- PDFs (7%)

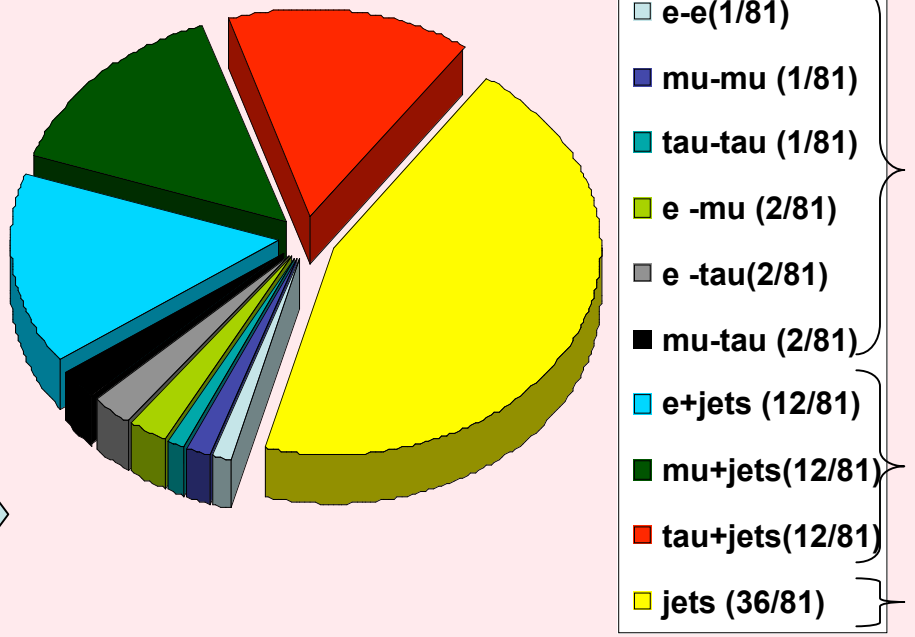
Cross section increases ≈30% with Tevatron √s increase to 1.96 TeV

Top Quark Decay and Event Signatures



Need special techniques to flag top signal since cross section is relatively small

Looking for decays with rate 1 in 10 billion



Assume top decays to Wb before hadronization

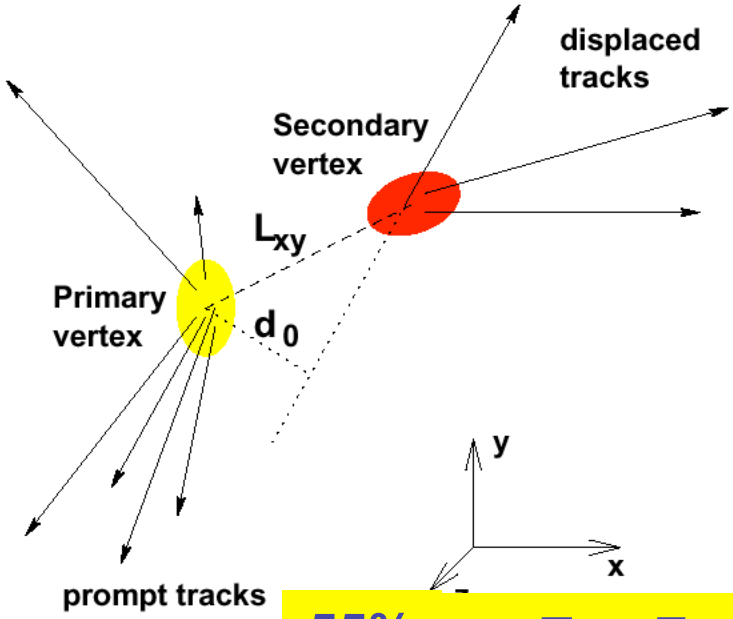
Top event signatures (from W bosons)
All include 2 b jets from top pair

Tagging Tools: Vertexing and Soft Muons

B hadrons in top signal events

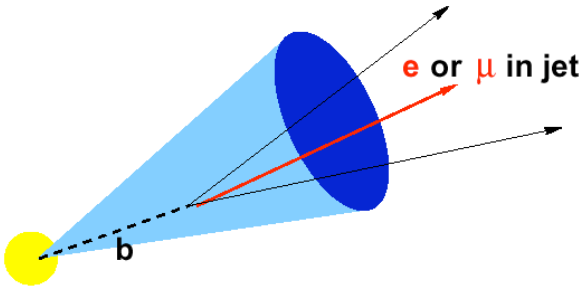
are long-lived and massive

- Counting displaced tracks
- Vertex of displaced tracks
- Impact parameter probability



may decay semileptonically

Identify low-pt muon from decay



- $b \to \ell\nu c$ (BR $\sim$ 20%)
- $b \to c \to \ell\nu s$ (BR $\sim$ 20%)

55%	Top Event Tag Efficiency	15%
0.5%	False Tag Rate (per jet)	3.6%

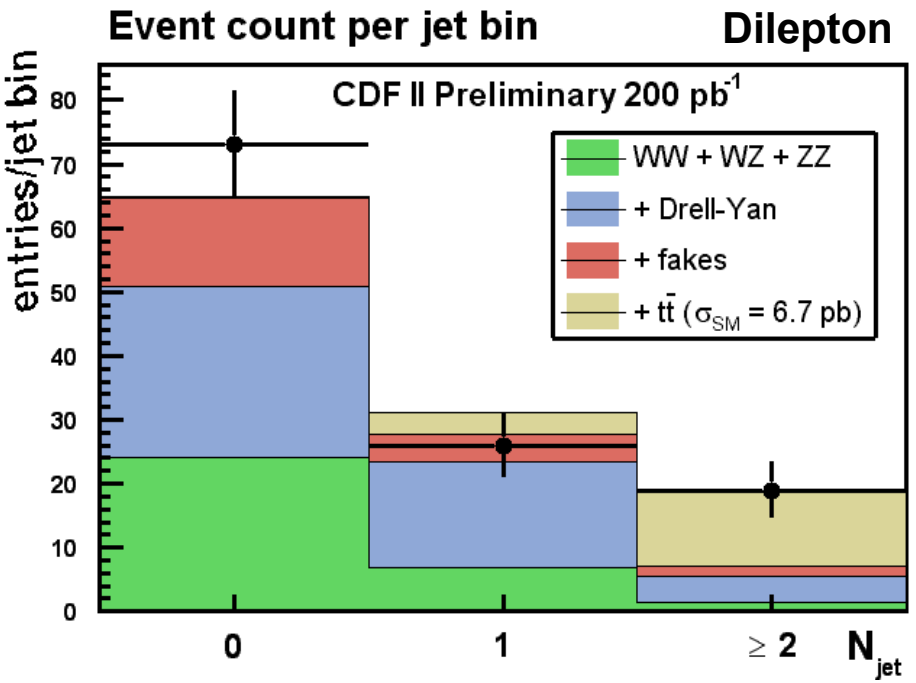
Top Pair Production Data Samples

Define samples counting leptons and/or jets with energies above 20 GeV
Establish component contributions to samples

Optimized event selections for top physics and new physics

In both cases, the sample composition is important

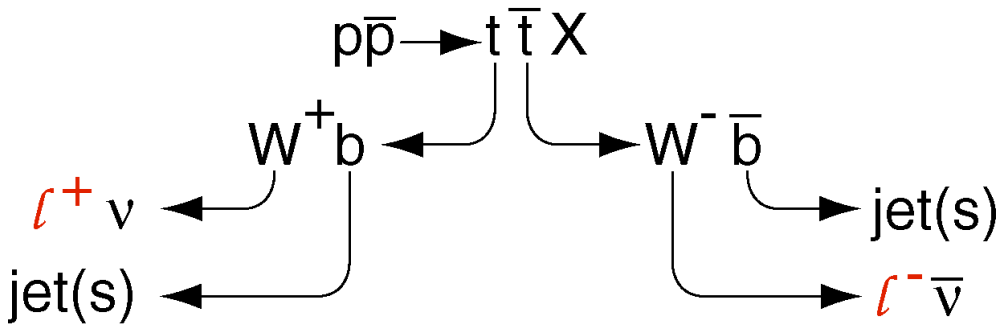
- Check background prediction in regions with no top events
- Also testing for non-SM effects
- Retain high efficiency for top in expected signal regions



Demonstrate good understanding of control regions and see clear excess from top in signal region.

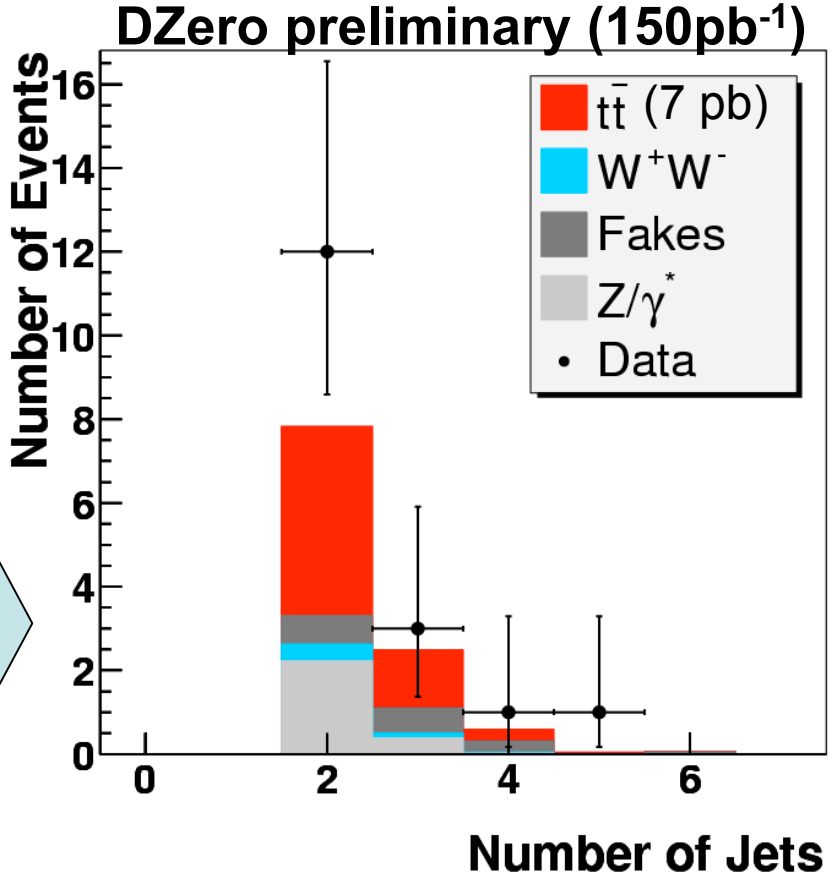
Measurements in Dilepton (e,μ) Sample

2 lepton + ≥2 jets + missing E_T sample is small but very clean for top signal



Physics backgrounds:
- $Z_{\tau\tau}$, WW

Instrumental backgrounds:
- Fake isolated leptons
- Fake missing E_T

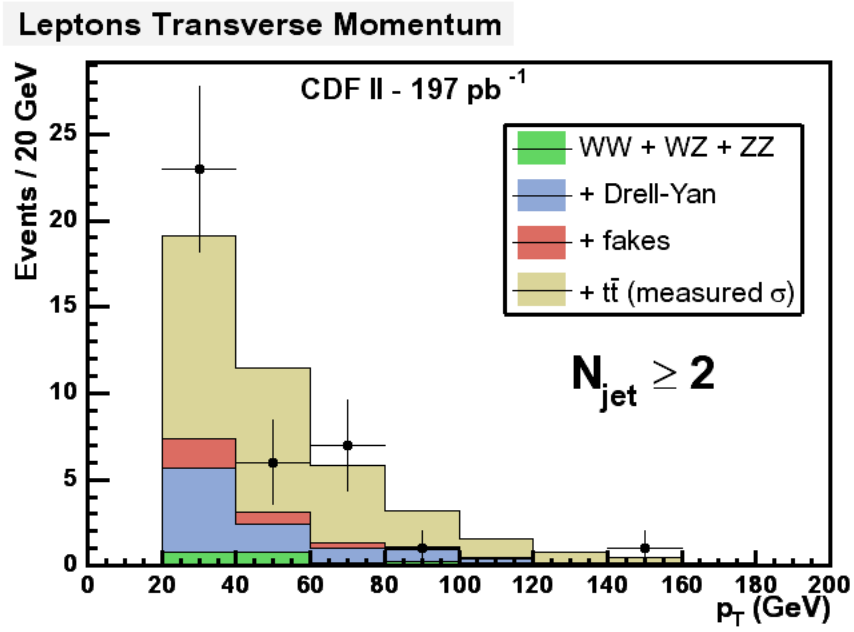


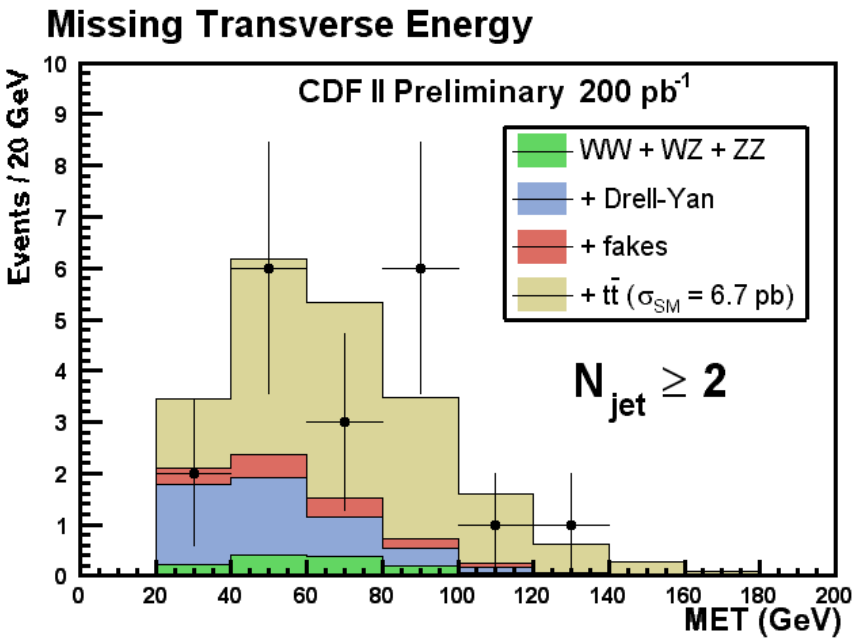
$$\sigma_{t\bar{t}} = 14.3^{+5.1}_{-4.3}\ (\text{stat})\ ^{+2.6}_{-1.9}\ (\text{syst}) \pm 0.9\ (\text{lumi})\ \text{pb}$$

Consistent cross sections for all lepton types (large stat. uncertainties)

Top Dilepton Sample Composition

Cross section requires careful study of background contributions
- Ready for comparison of kinematic distributions in the sample
- This larger sample includes events with lepton + isolated track





$$\sigma_{t\bar{t}} = 7.0^{+2.4}_{-2.1}\ (\text{stat})\ ^{+1.7}_{-1.2}\ (\text{syst})\ \text{pb}$$

Enhanced Analyses in Dilepton Channels

Reduce background in eμ channel with b-

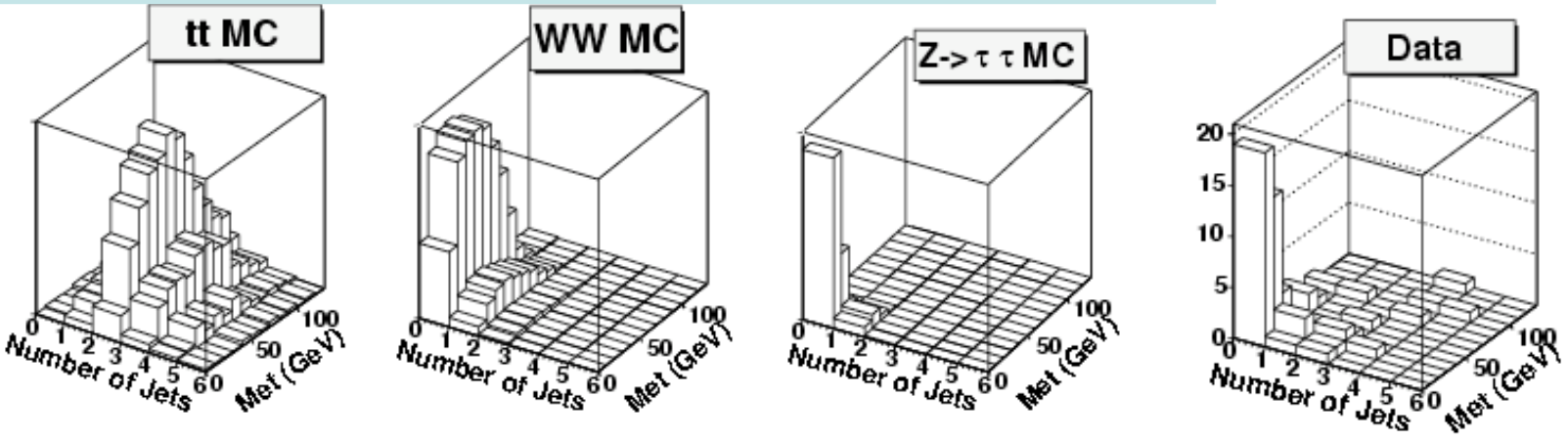
Expected Sample	N_{jets}≥2	After tagging
Top	4.58±0.09	2.70±0.09
WW	0.46±0.03	0.008±0.002
Z_ττ	0.6±0.1	0.017±0.007
Z _μμ	0.10±0.04	<0.005
QCD, W+j	0.33±0.04	0.011±0.002
Total	6.1±0.2	2.74±0.09

DZero Preliminary (158 pb^{-1})

5 observed events with 0.04 bkgd.

$$\sigma = 11.1^{+5.8}_{-4.3} \pm 1.4 \pm 1.7(\text{lumi})\ \text{pb}$$

Or loosen cuts to increase number of signal events



CDF
Preliminary
200 pb^{-1}

Fit distributions for physics backgrounds and find 10 top dilepton events in ee,eμ,μμ

$$\sigma = 8.6^{+2.5}_{-2.4} \pm 1.1\ \text{pb}$$

Measurements in Lepton + Jets Channel

High-p_T isolated electron, muon with missing E_T and ≥4(3) jets (2 are b-jets)

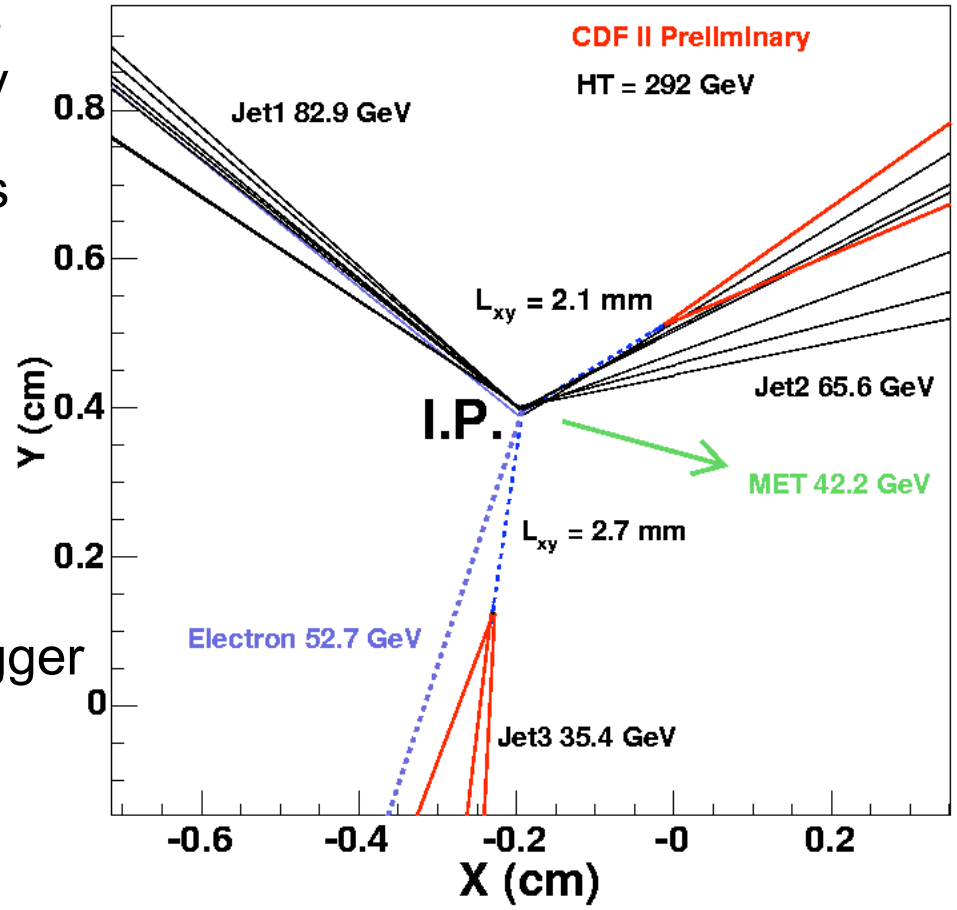
Large sample for other measurements
• mass, other top properties, W helicity

W+jets physics background dominates

Typically 500 events in 160 pb^{-1}
(includes 3-jet events, too)

↓

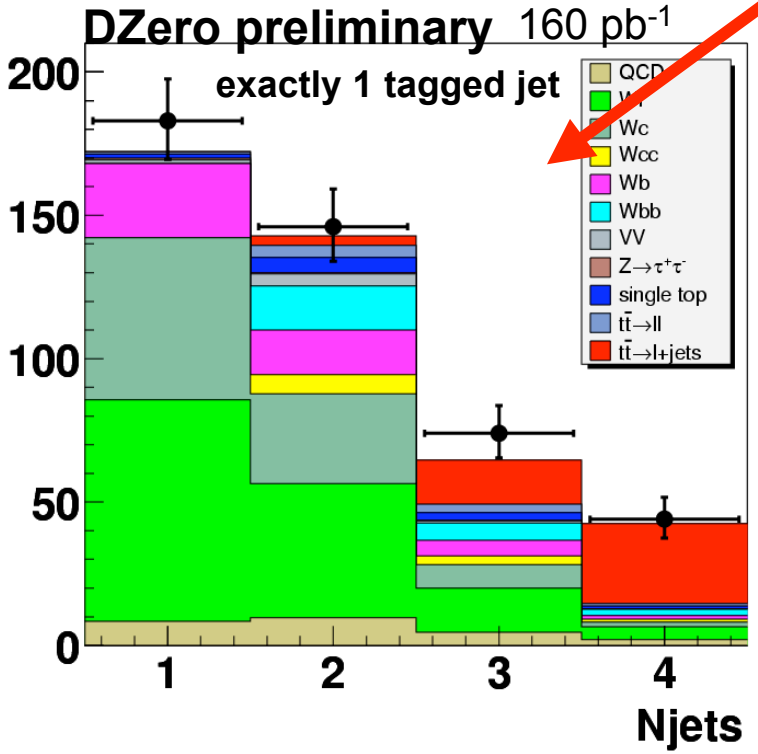
B-tagged sample of 50 -120 events,
depending on tight/loose tuning of tagger

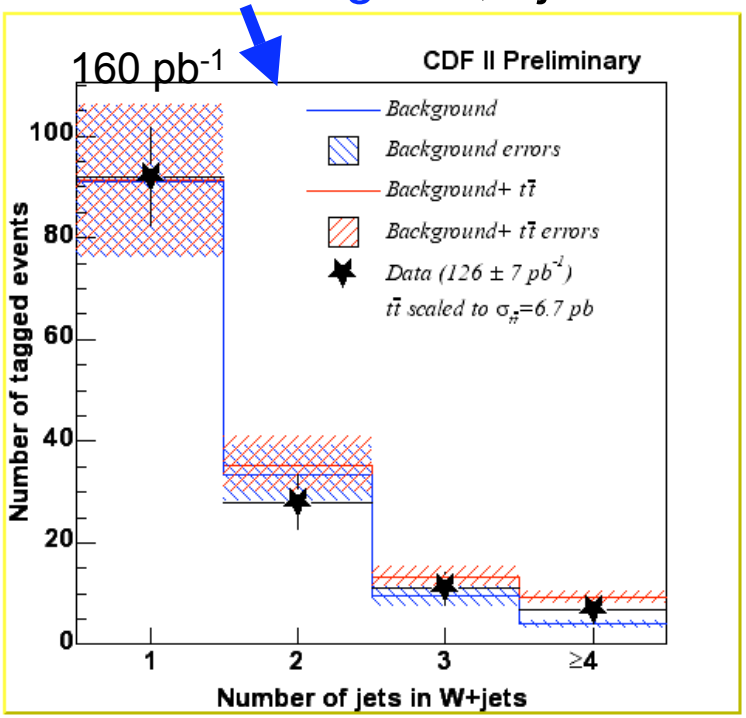


Double-tagging can improve S/B
• tight tagging (8 events): S/B=8
• loose tagging (19 events): S/B=4
Largest systematic uncertainty from b-tagging efficiency measurement

Cross Section Results using B-Tagging

Counting experiments with lifetime tag and soft muon tag in 3,4-jet bins





Estimate backgrounds in the lepton + jets sample from first principles:

- Using data as much as possible (fake W bosons, fake b-tags)

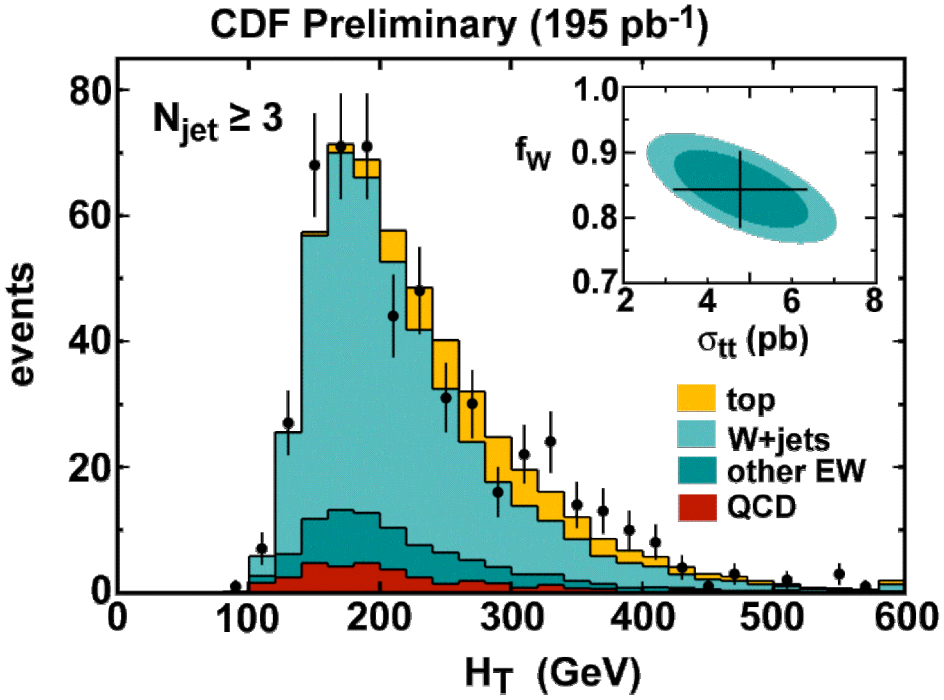
Most precise measurement at Run 2 is in b-tagged lepton+jets sample

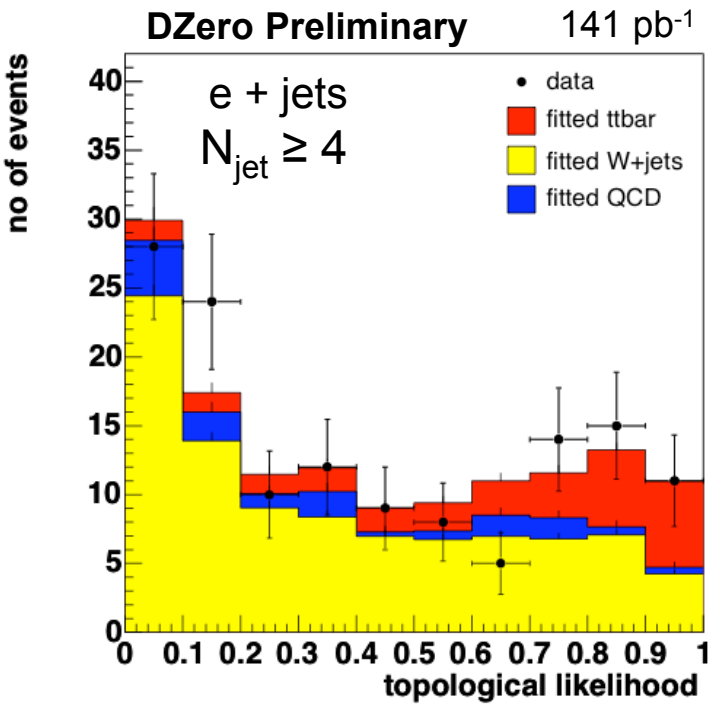
$$\sigma_{t\bar{t}} = 5.6^{+1.2}_{-1.1}\ (\text{stat})\ ^{+0.9}_{-0.6}\ (\text{syst})\,\text{pb}$$ (CDF sec. vtx.)

Kinematic Analyses using Lepton + Jets

Use jet energy and event shape info to discriminate top pairs from W + jets

(Trade off S/B for increased number of top signal events)





Best result w/o b-tag (CDF ANN): $\sigma_{t\bar{t}} = 6.7 \pm 1.1 \pm 1.6$ pb

Fit to data distribution to extract top pair signal fraction (15-20%)

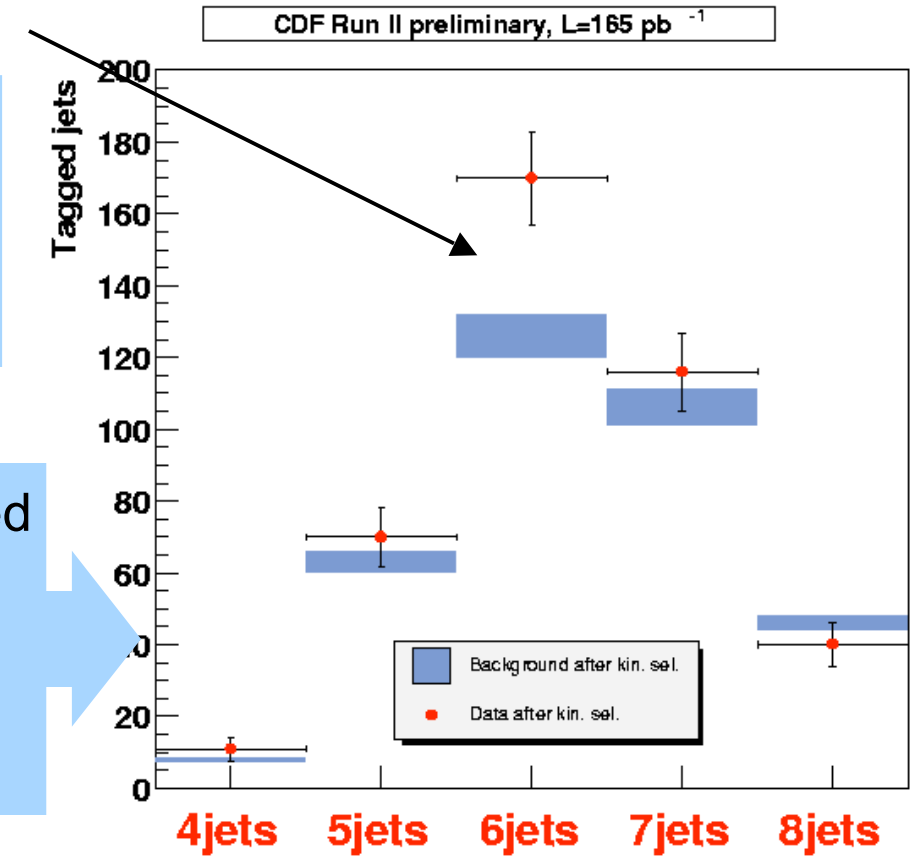
- Large uncertainty for energy scale when fitting jet energies
- In future, can apply b-tagging before performing fit

Results from All-Hadronic Jet Channels

Expect ≥6 jets when W decay hadronically

Special multijet trigger:
- 4 high E_T jets (≥15 GeV)
- large total E_T (>125 GeV)
- optimized for hadronic top events

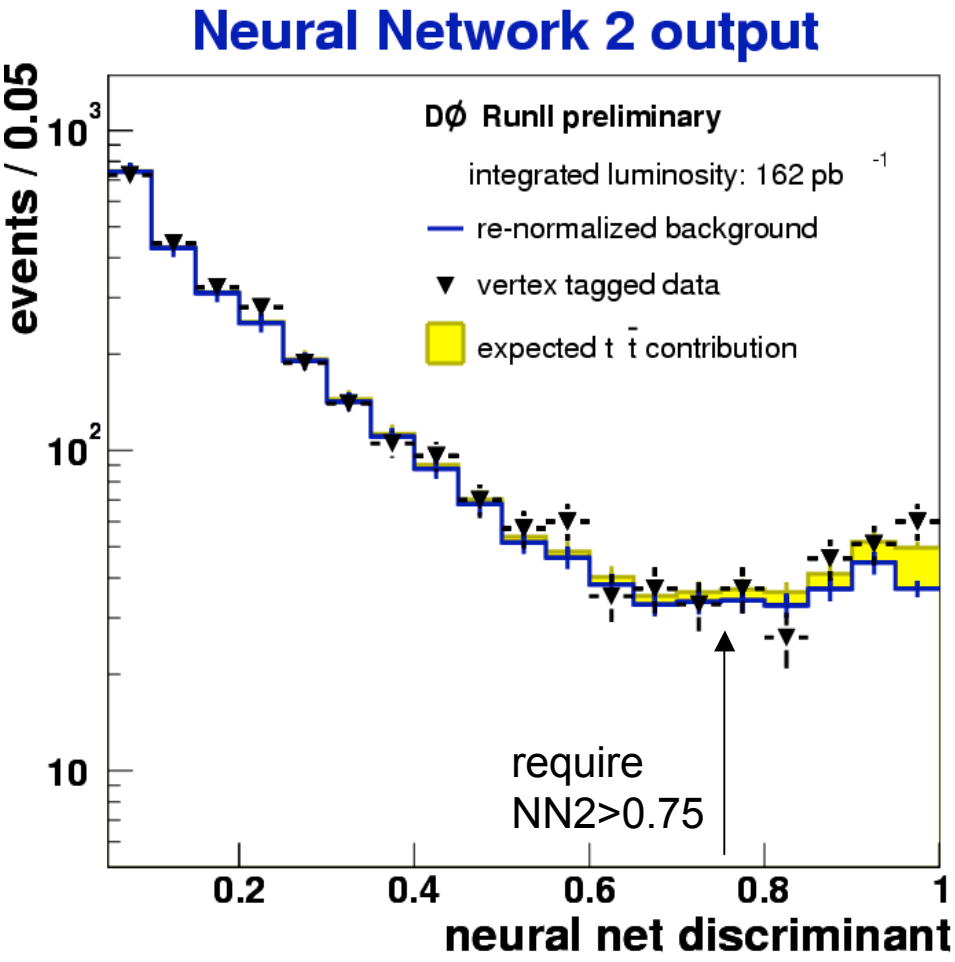
1. Estimate background tags expected from data with no top contribution
2. Require high E_T spherical events: S/B = 0.03 _0.3
3. Cross section from event counting



$$\sigma = 7.8 \pm 2.5\,(\text{stat.})\ ^{+4.7}_{-2.3}\ (\text{syst.})\,\text{pb}$$

All-Jets Channel Neural Network Analysis

Challenge to separate top from QCD multijet production



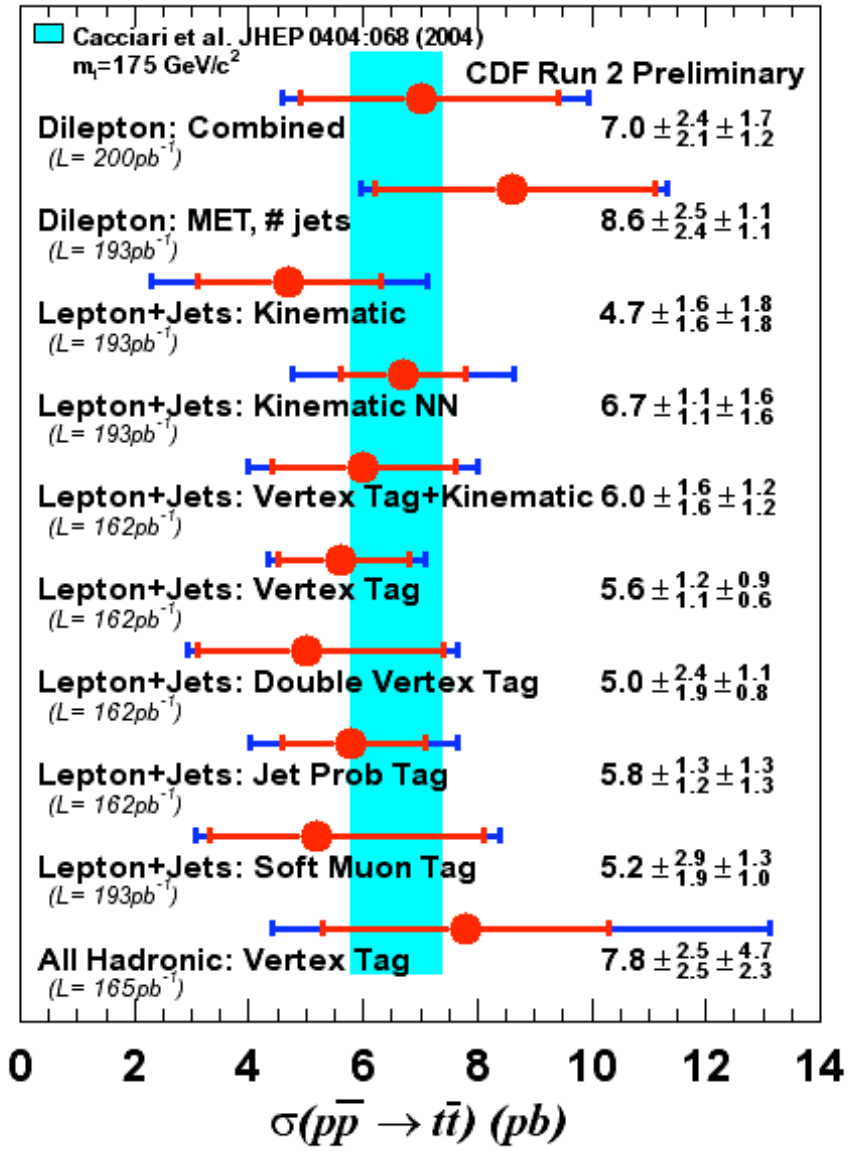
Kinematic ANN
- total transverse energy H_T
- aplanarity, sphericity

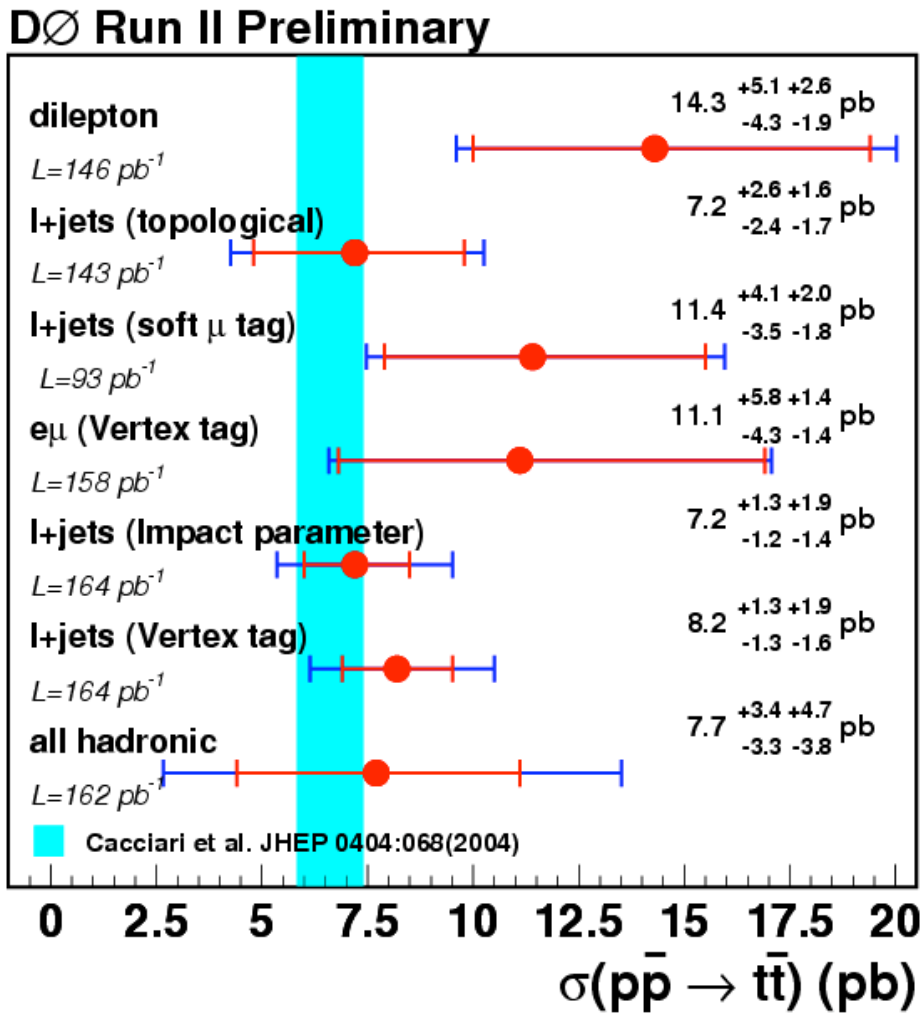
Variables in final selection ANN are sensitive to high mass objects:
- output from first neural network
- dijet masses, top pair mass

Fit for 220 evts, estimate 186 are bkgd (large error from jet energy scale)

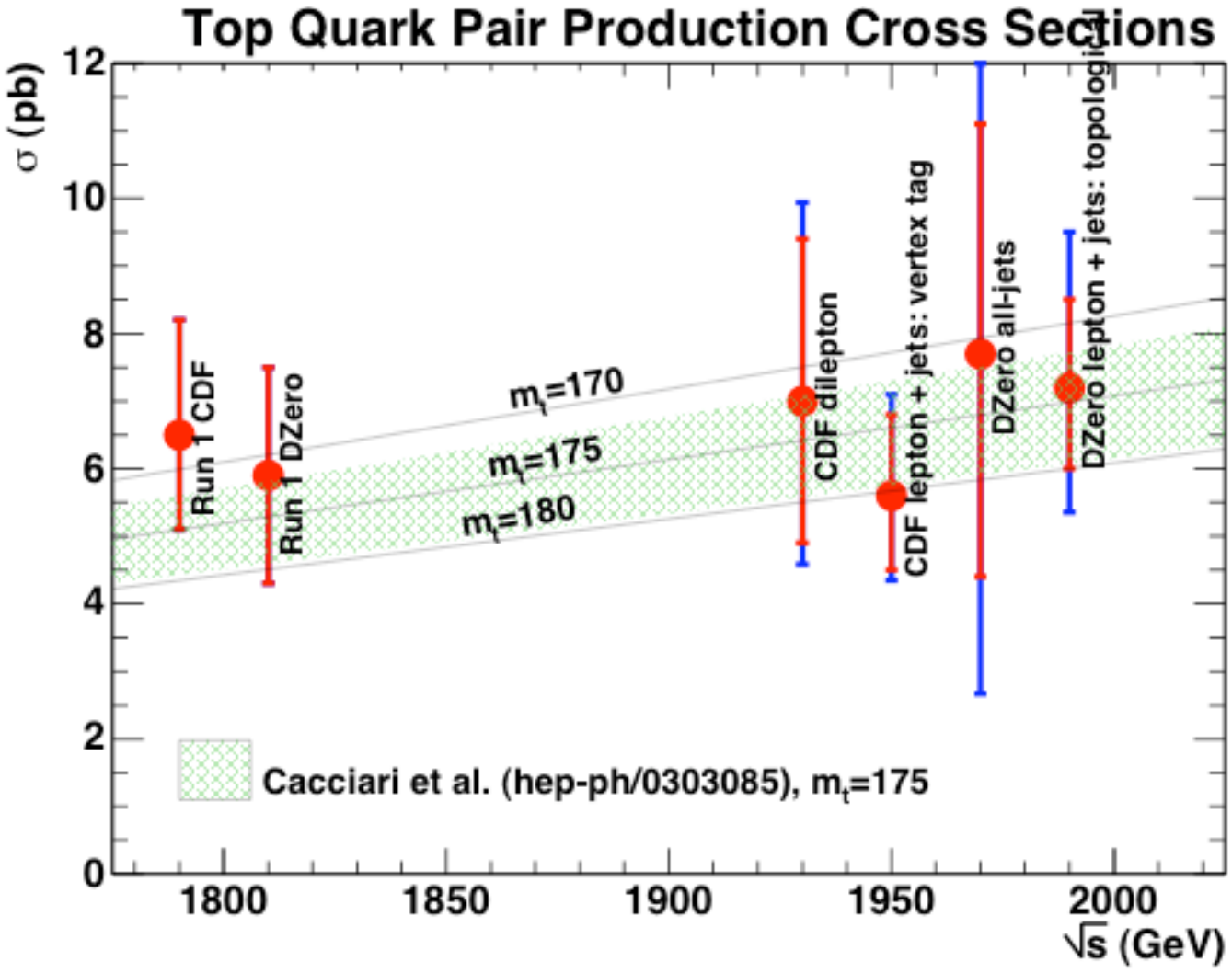
$$\sigma = 7.7^{+3.4}_{-3.3}(\text{stat})^{+4.7}_{-3.8}(\text{syst}) \pm 0.5(\text{lumi})\ \text{pb}$$

Summary of All Tevatron Results





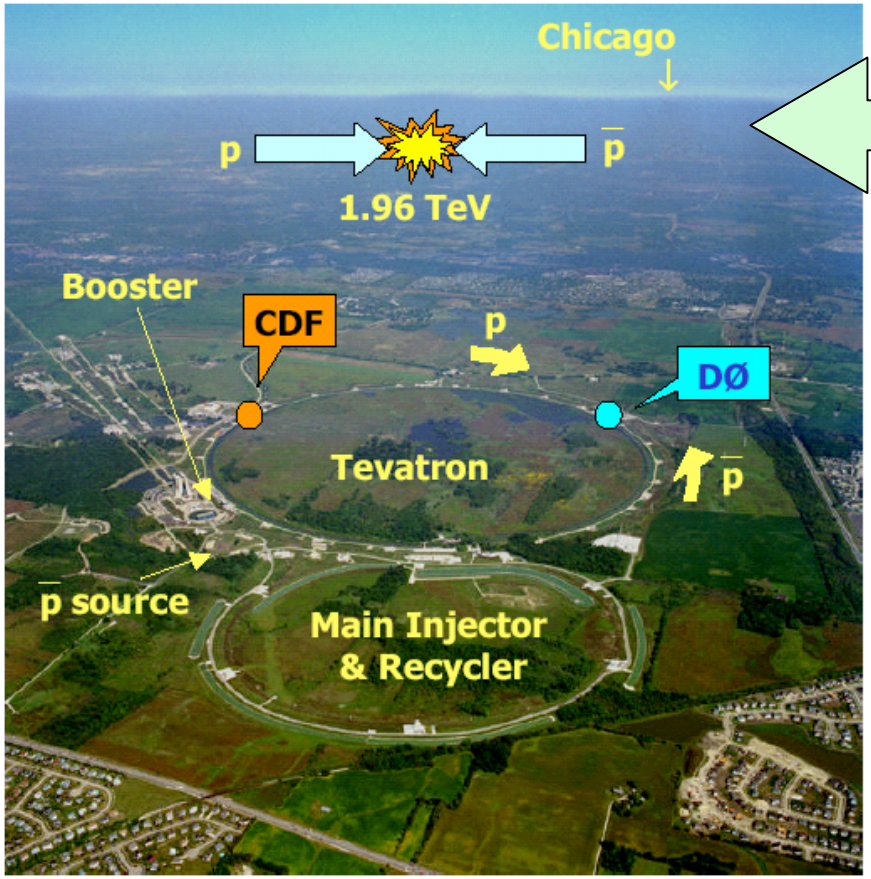
Comparison: Theory vs. Experiment



Summary

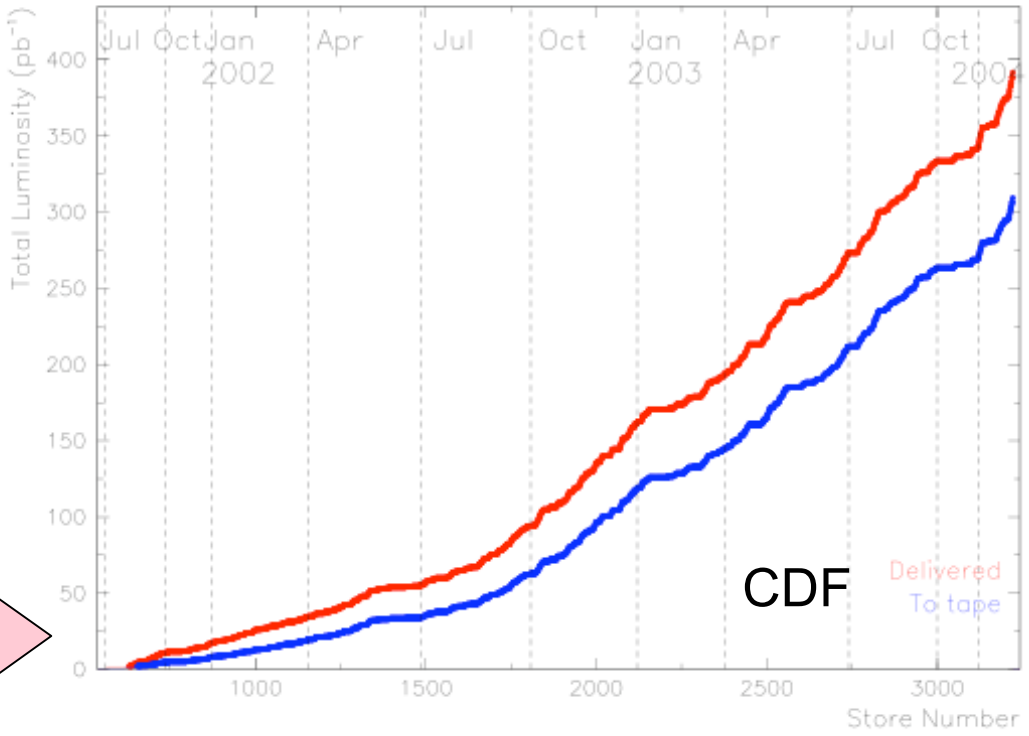
- Top pair production has many experimental signatures
  - We test as many as possible with different measurements
  - All seem consistent with QCD calculations at NLL
- Tevatron delivering high luminosity
- Working on reducing systematic experimental uncertainties (goal is 10% with 10x more data)
  - B-tagging efficiency measurement
  - Jet energy measurements (in kinematic analyses)
  - Improved modeling of W+jets processes
- Eagerly anticipating 4x statistics later this year
  - Test QCD prediction more precisely
  - Look for signs of physics beyond SM in the top sample

Tevatron Run 2 at Fermilab



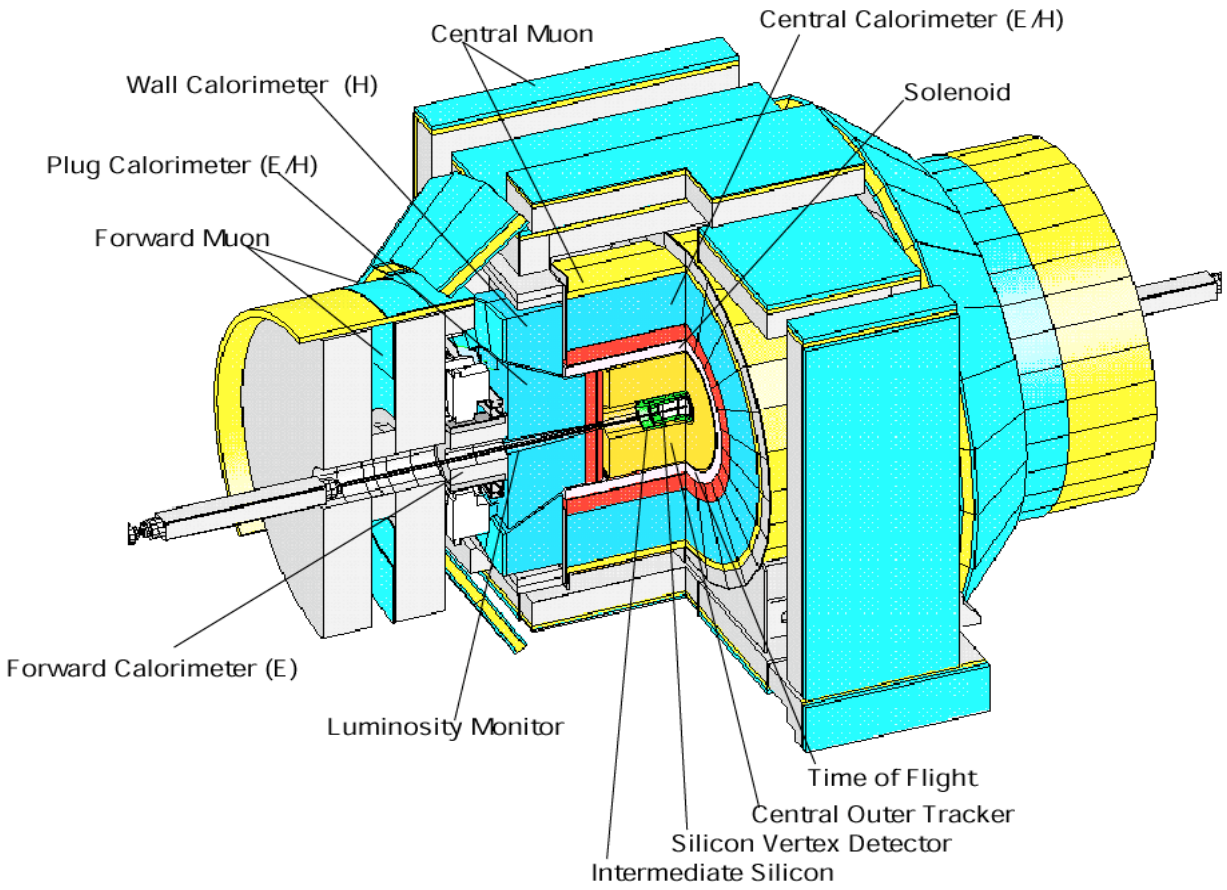
Tevatron success in early 2005:

- Record luminosity 1.1E32



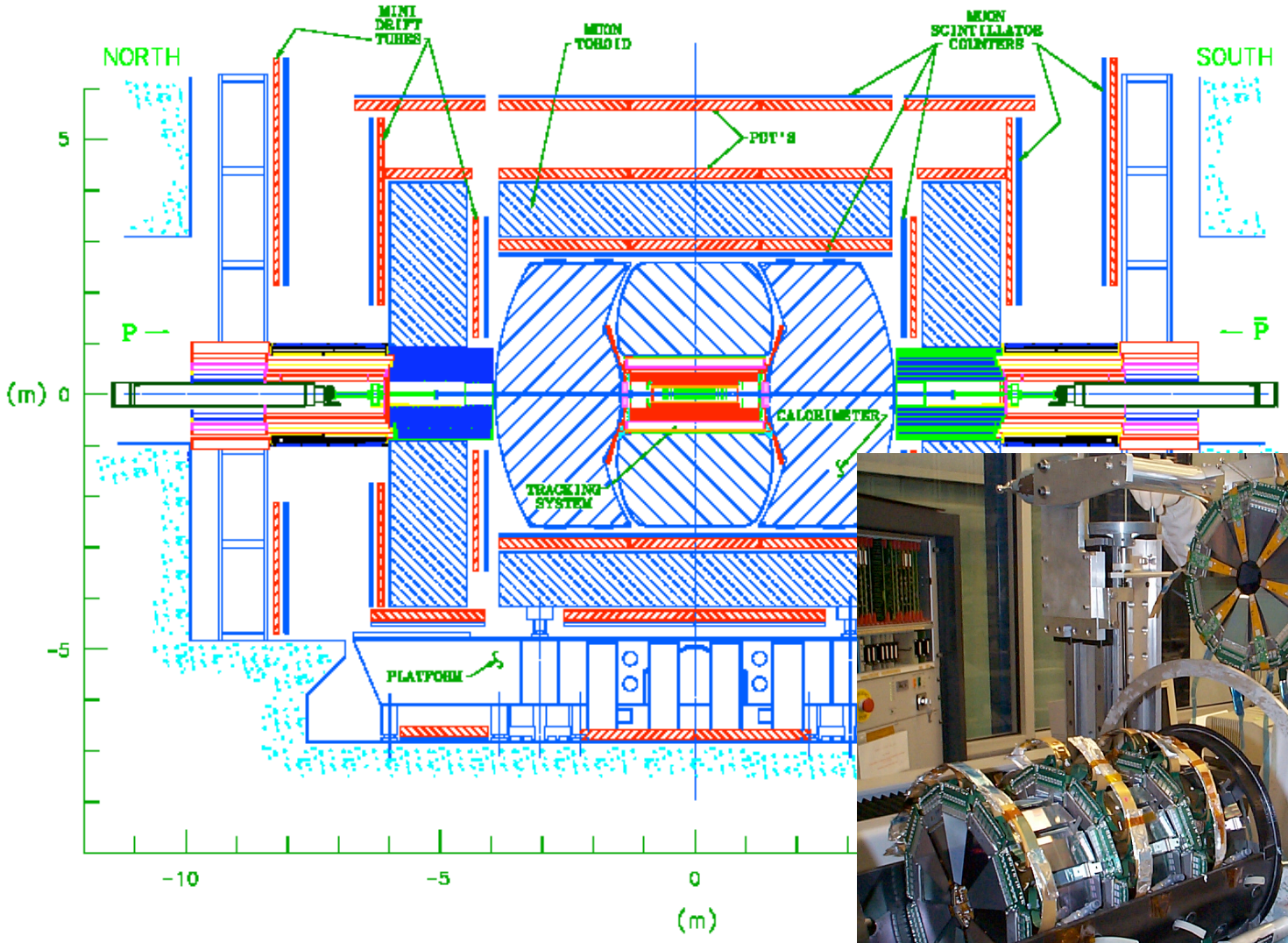
These results use 200pb-1 collected through Oct. 2003 (cf. 110 pb^{-1} from Run 1)

CDF II Detector at the Tevatron



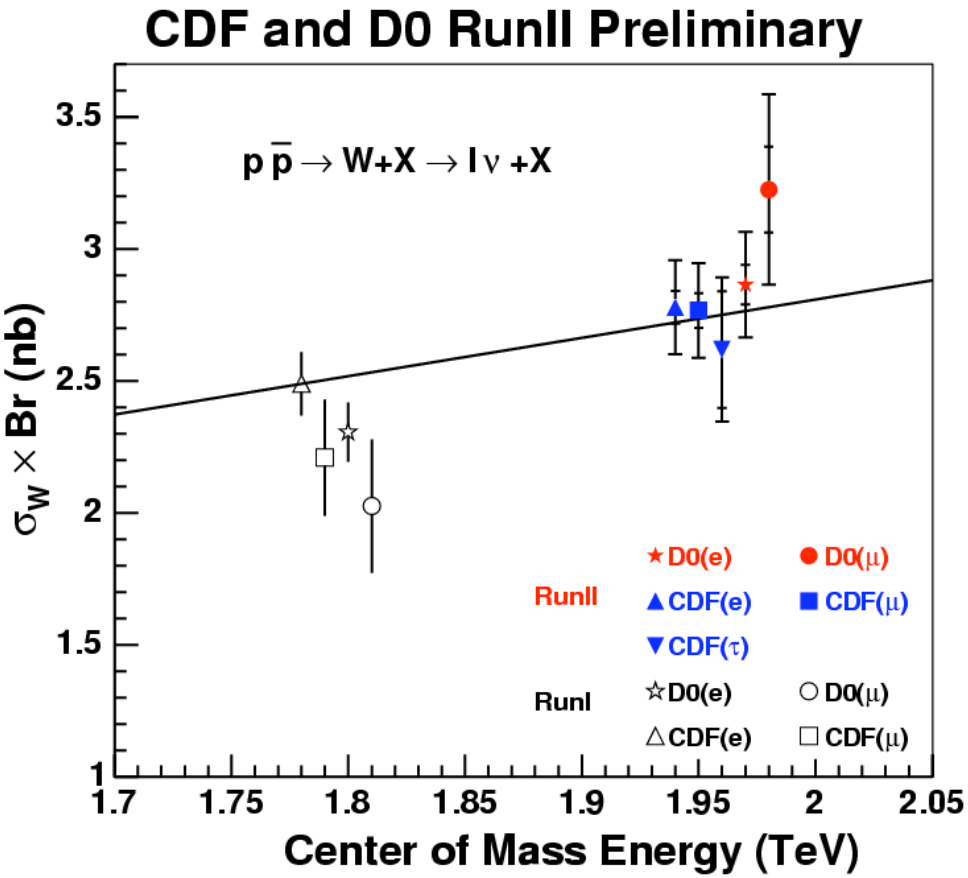
- Continuing work to incorporate upgraded detectors in data analysis
- Accurate detector simulation vital to precision physics measurements

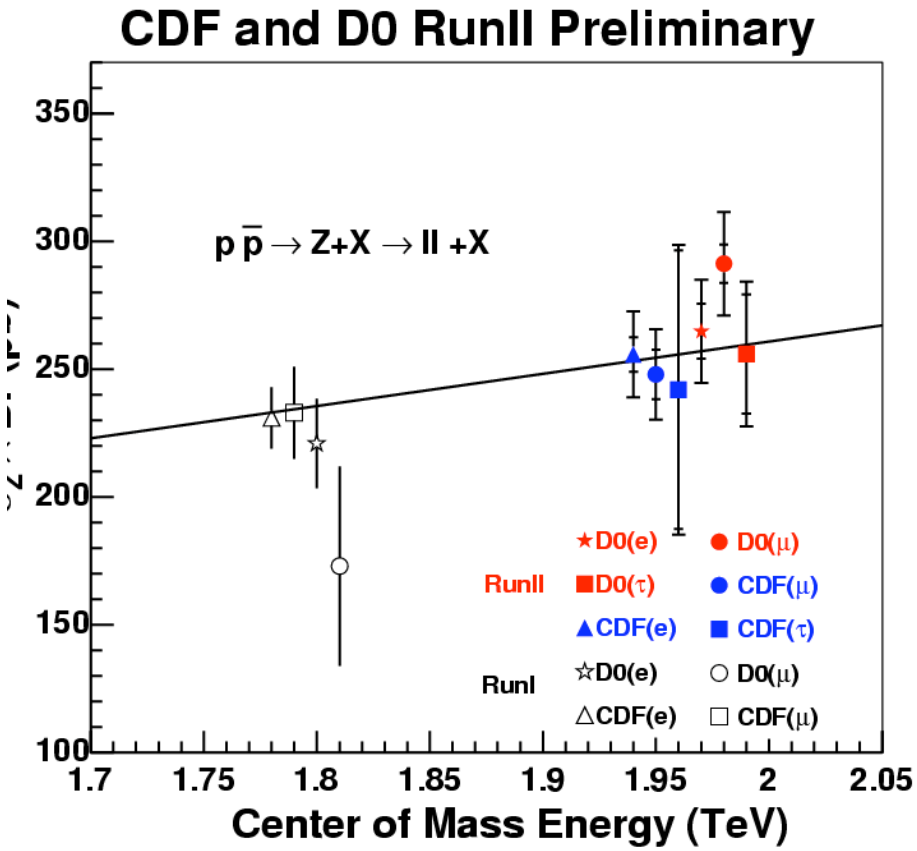
DZero Detector at the Tevatron



W/Z Cross Section Cross-Checks

Validate luminosity measurement, lepton identification and measurements





Also provides a link back to connect with Run 1 cross section results