Top Cross Section Measurements at the Tevatron

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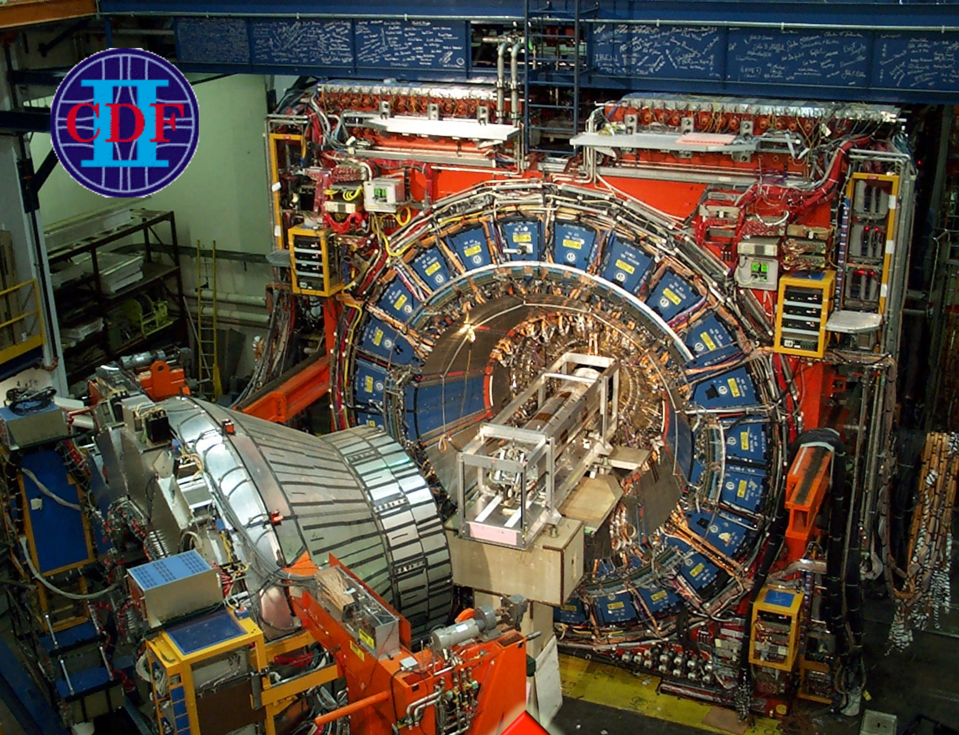
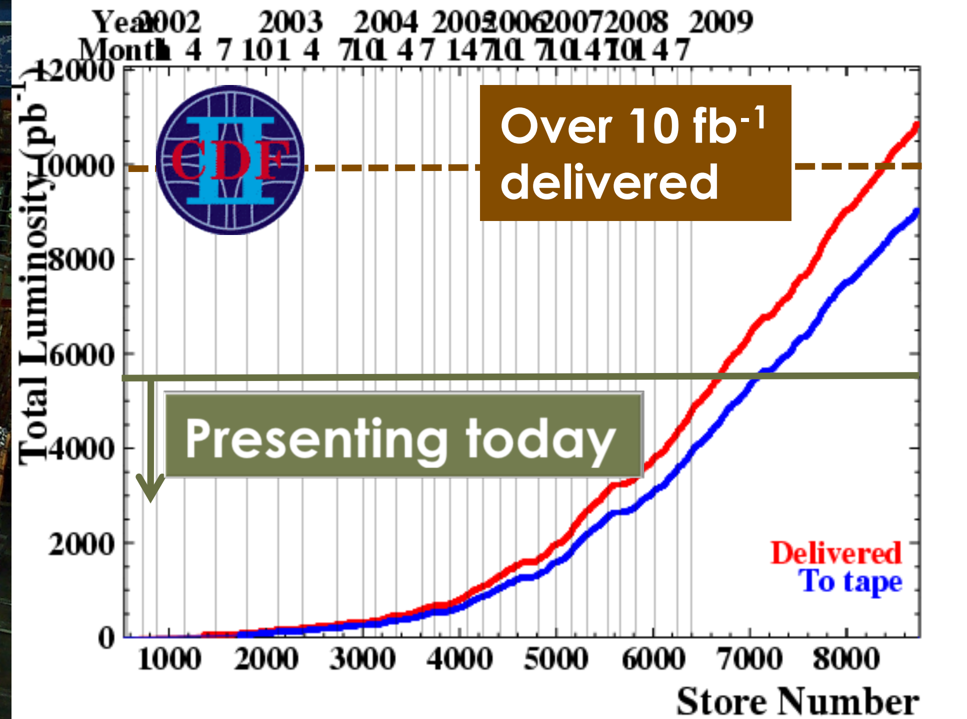
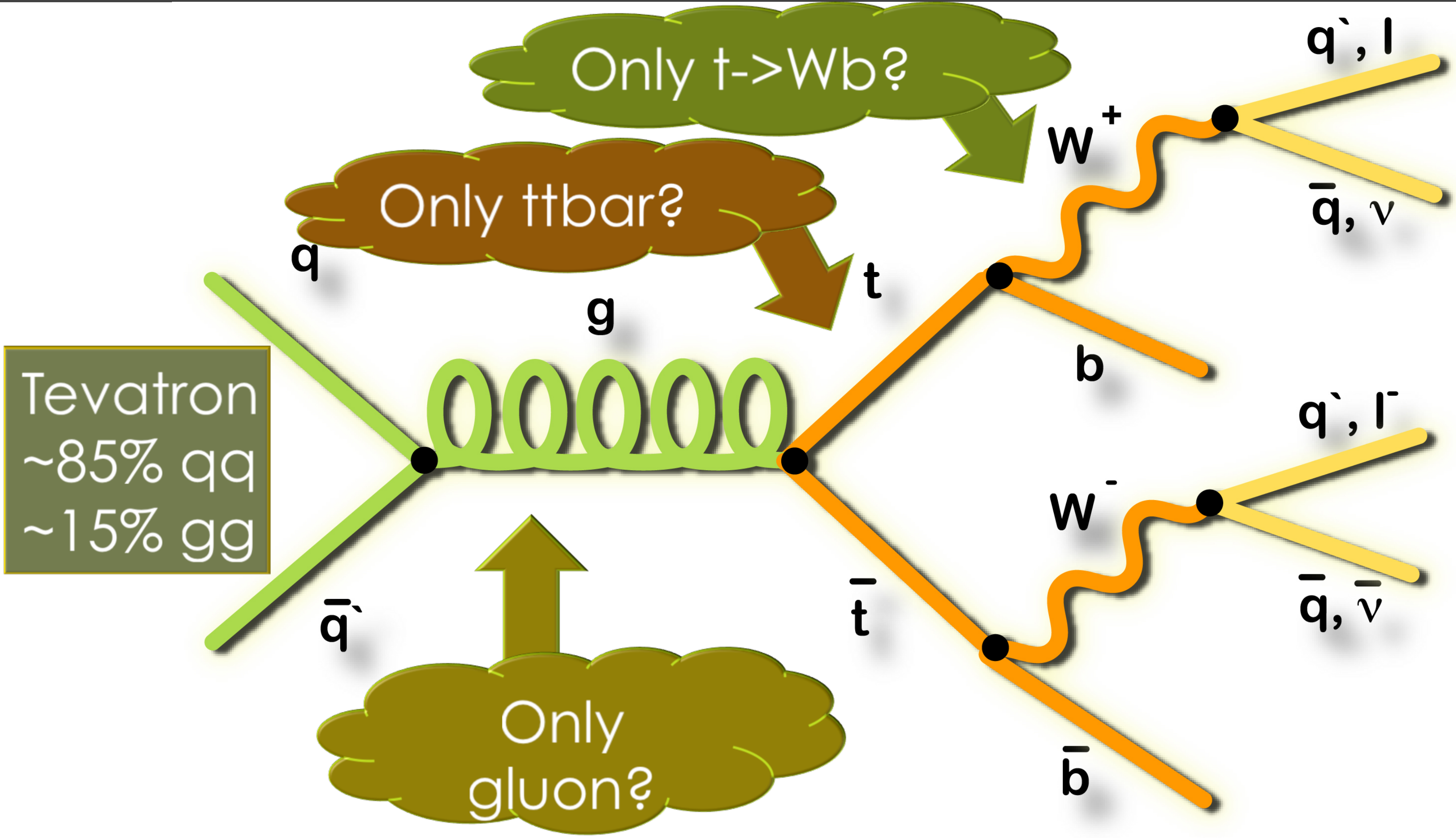



Over 10 fb^{-1} delivered
Presenting today
Total Luminosity (pb^{-1})
0
2000
4000
6000
8000
10000
12000
1000
2000
3000
4000
5000
6000
7000
8000
Store Number
Delivered
To tape

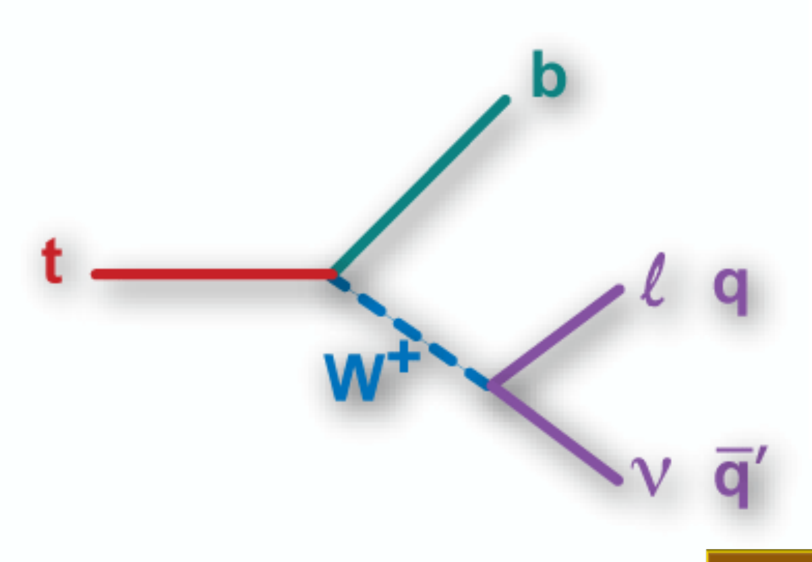
Top Physics

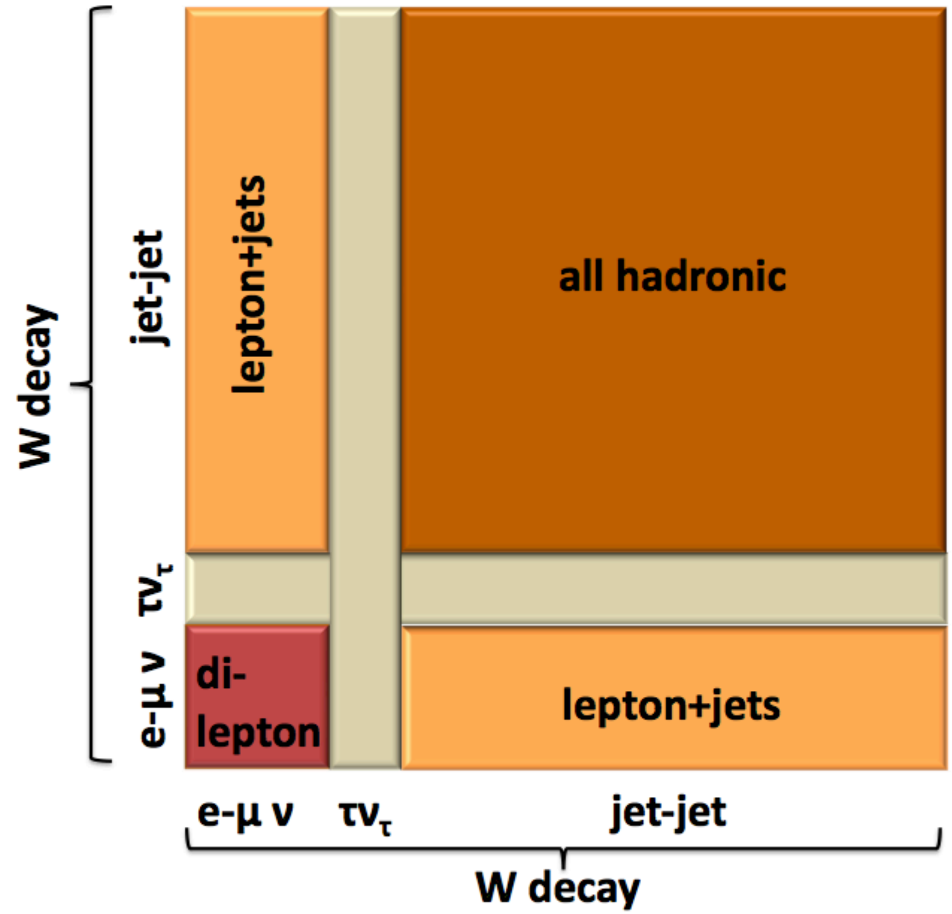


Goal is to measure the top quark as precisely as possible at the Tevatron
Get a complete a picture of the heaviest quark?
Signs of weakness of the SM?

Top Event Decays

- Standard Model
  - BR(t->Wb) ~100%
- Top events are characterised by the decay of the W boson





"Leptons" are only electrons and muons

Top Quark Pair Production Cross Section

$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bck}}{\epsilon \cdot A \cdot L}$$

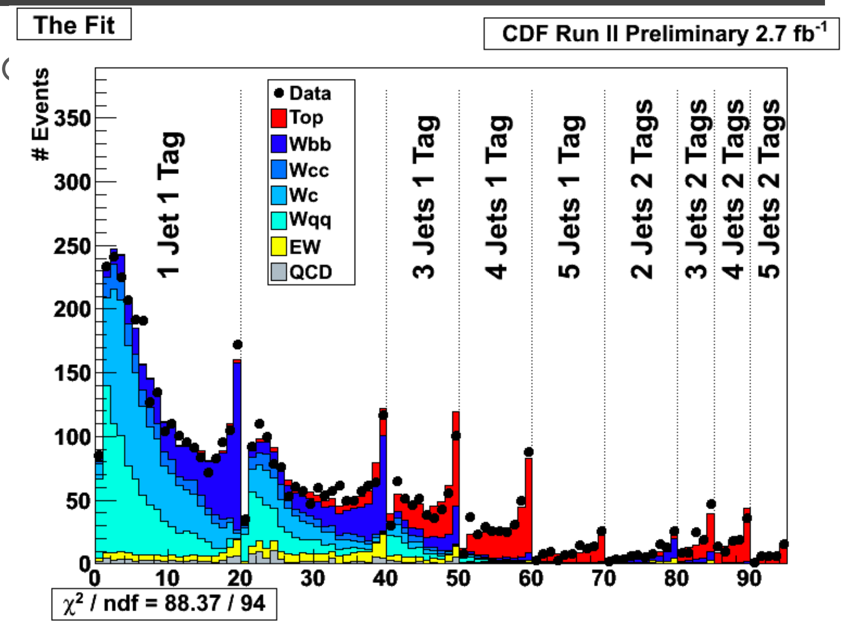
Measurements differ in
- W-decay channel
- Analysis cuts
- Background composition
- Background estimation methods
- Luminosity determination

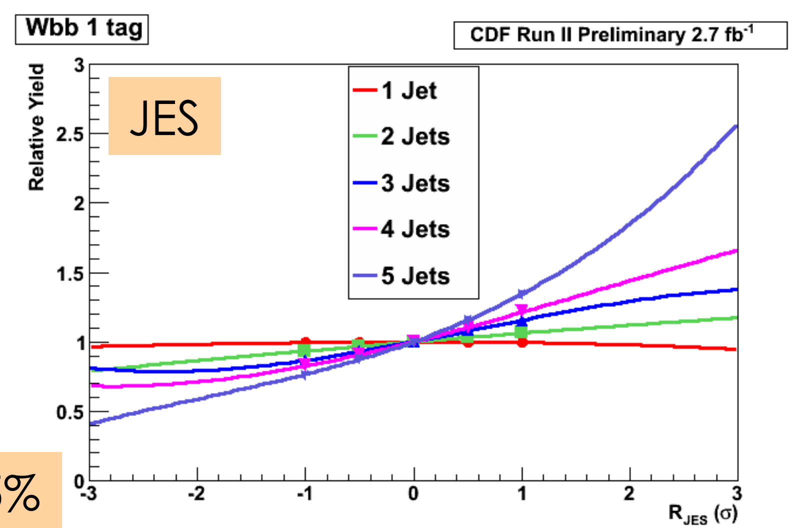
A : acceptance
ε : efficiency
L : luminosity

Lepton+Jets Channel

M_t =175 GeV, L=2.7 fb^{-1}

- Fit the Neural Network based flavor separat and nJet spectrum
  - Binned Poisson Likelihood fitter
- Selection (standard CDF l+j)
  - 1 lepton pt > 20 GeV
  - MET > 20 GeV
  - ≥1 jet ET > 20 GeV
  - ≥1 identified b-jet
  - QCD veto cuts
- Systematics
  - For each source
    - Make additional templates
    - Compare event yields relative to nominal
    - Interpolated to a function
    - Included in fit as multiplicative factors to template normalisation



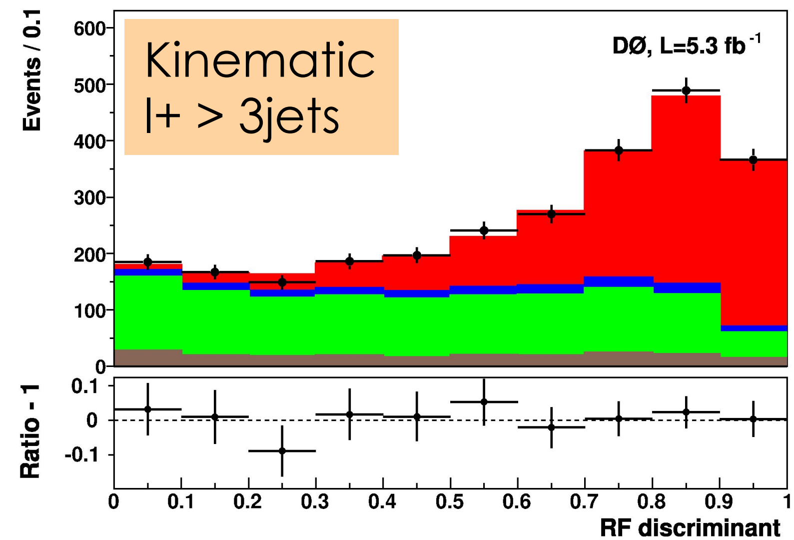


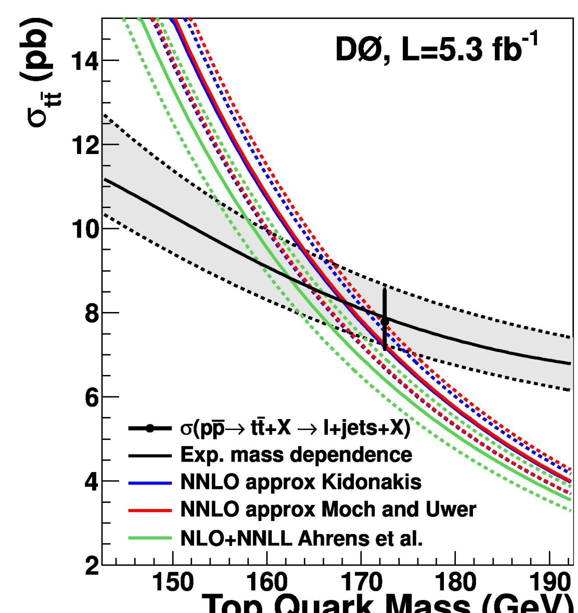
$\sigma_{t\bar{t}} = 7.64 \pm 0.57_{(stat+syst)} \pm 0.45_{(lumi)}$ pb ~9.5%

Lepton+Jets Channel

M_t =172.5 GeV, L=5.3 fb^{-1}

- 3 methods
  - Counting method using b-tagging
    - 24 independent measurements combined
    - W+jets constrained from data
  - Kinematic method
    - 'Random Forest' of 200 decision trees
    - 6 input variables
    - Binned Max Likelihood fit to output
  - Combined method
    - Use b-tagging and kinematic information
    - Constrain from data W+ heavy flavour relative to W+light flavour
  - Systematics as 'nuisance parameters' (normalisation only)



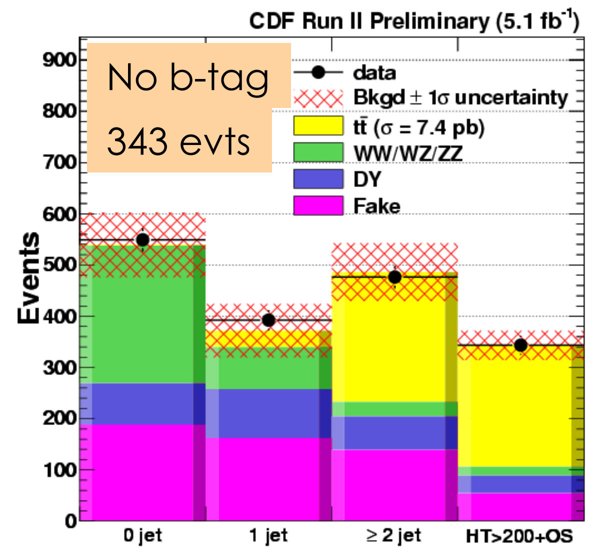


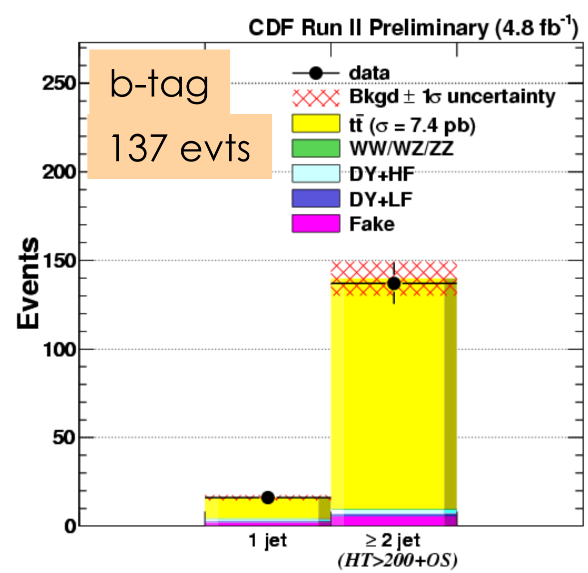
$\sigma_{ttbar} = 7.78 \pm 0.25_{(stat)}\ {}^{+0.73}_{-0.59\ (syst+lumi)}$ pb ~9%

Dilepton Channel

M_t =172.5 GeV, L=5.1 fb^{-1}

- Selection
  - 2 opposite charge leptons
    - 1 isolated 'tight' lepton $p_T > 20$ GeV
    - 1 'looser' lepton $p_T > 20$ GeV
  - ≥2 jets
    - $E_T > 15$ GeV, $|\eta| < 2.5$
  - Missing transverse energy (MET) > 25 GeV
  - Z-veto and J/Ψ-veto
  - Summed transverse energy: $H_T > 200$ GeV
  - For b-tagged version: ≥1 identified b-jet
- Dominant systematics
  - Jet corrections (~3.3%)
  - Lepton ID (~2.2%)
  - B-tagging (~4.1%)



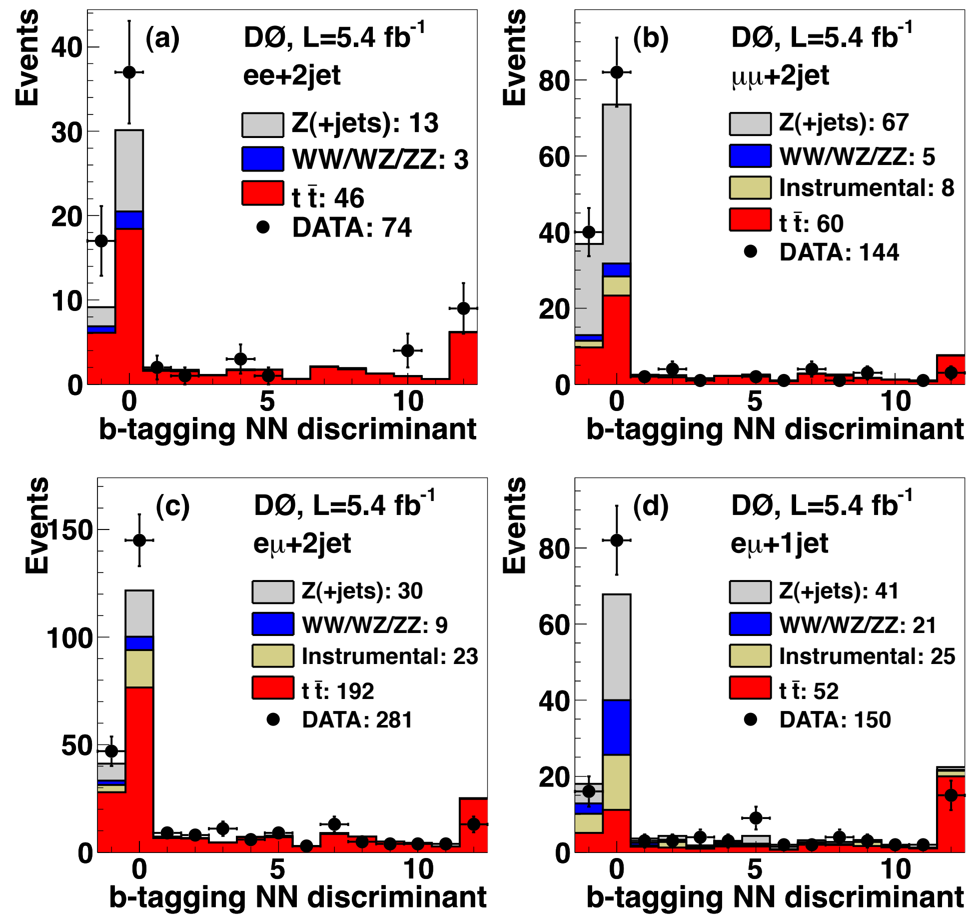


$$\sigma_{pretag} = 7.40 \pm 0.58_{(stat)} \pm 0.63_{(syst)} \pm 0.45_{(lumi)}\ \text{pb}$$
$$\sigma_{btag} = 7.25 \pm 0.66_{(stat)} \pm 0.47_{(syst)} \pm 0.44_{(lumi)}\ \text{pb}$$

Dilepton Channel

M_t =172.5 GeV, L=5.4 fb^{-1}

- Similar event selection
  - Small changes but same principles
  - 2 'tight' leptons
- Final discriminant
  - B-tagging Neural Network (NN) discriminant
    - Use the smallest value from the leading 2 jets
- Simultaneous fit in 4 regions
  - (ee, $\mu\mu$, eμ) + 2 jets
  - e μ + 1 jet
- Systematics as Gaussian constrained nuisance parameters



Combination with l+j (but with const. syst.)

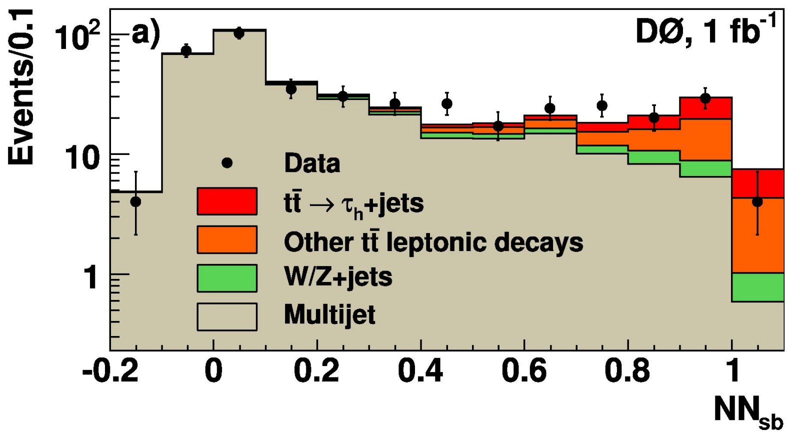
$\sigma_{ll} = 7.36^{+0.90}_{-0.79}$ (stat + syst) pb	~11%

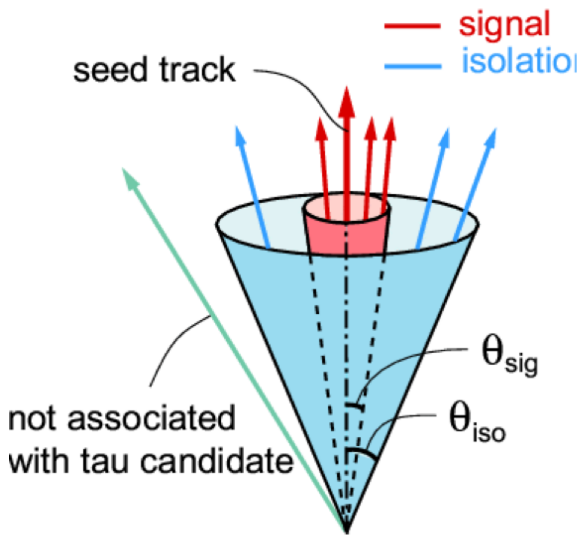
$\sigma_{ttbar} = 7.56^{+0.63}_{-0.56}$ (stat + syst) pb	~8%

Tau+Jets Channel

M_t =172.5 GeV, L=1.0 fb^{-1}

- World first
  - Previous measurements: tau+lepton +jets
- Investigate properties of only third generation fermions in single process
  - Looking for anomalous branching ratios to taus
- Semi-hadronic tau decays
  - Taus to leptons hard to distinguish from direct leptons
  - Reconstructed using a neural network
- Using multijet trigger: ≥4 jets
- Expect ~15% signal





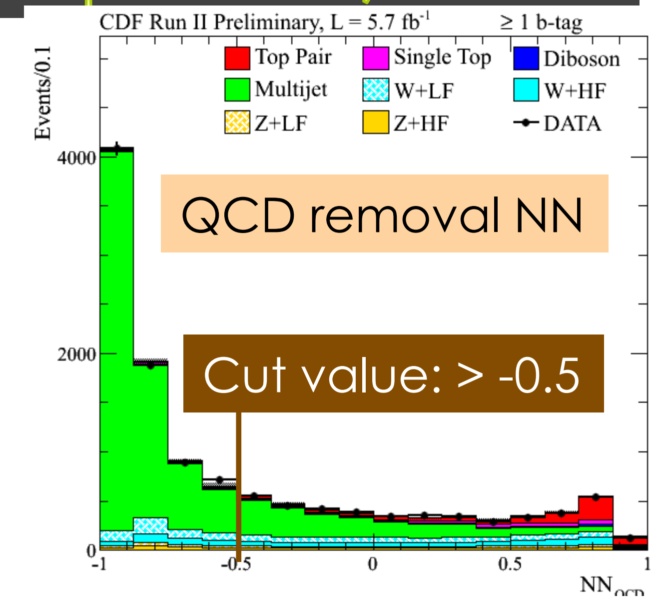
$\sigma_{ttbar} = 6.9 \pm 1.2_{(stat)} {}^{+0.8}_{-0.7\,(syst)} \pm 0.4_{(lumi)}$ pb ~9%

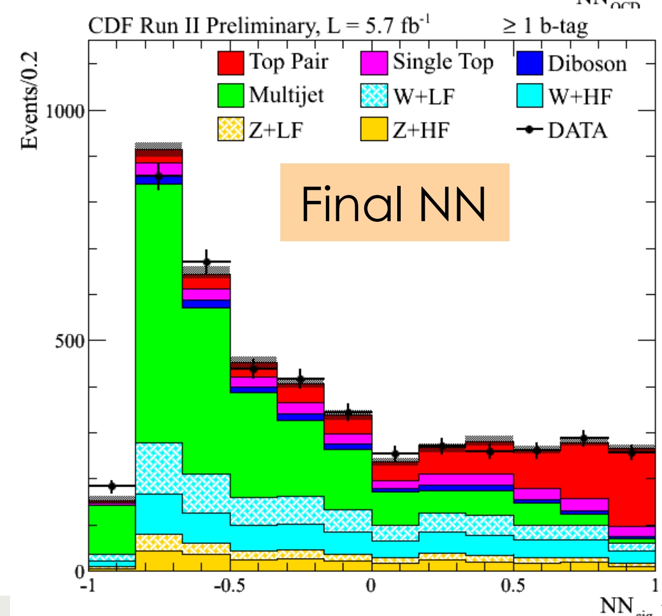
MET + b-jets Channel

- Measuring the Top Pair background to Higgs search in MET+b-jet
- No lepton ID (veto on leptons)
- Require ≥1 identified b-jet
- Dominant background QCD
  - S:B is 1:15
  - From mis-measured jets leading to MET
  - From semi-leptonic b-quark decays
  - Reduced through a cut on a Neural Network (NN)
    - 15 input variables
    - S:B is 1:6
- Another NN isolates ttbar from other backgrounds
  - 5 input variables (incl. QCD NN)

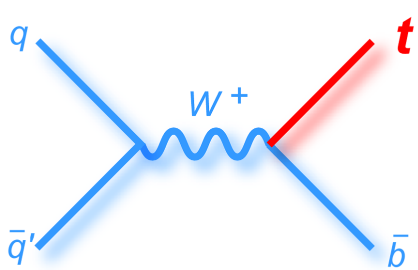
$\sigma_{ttbar} = 7.12^{+1.20}_{-1.12\,(stat+syst)}$ pb ~16%

M_t =175 GeV, L=5.7 fb^{-1}

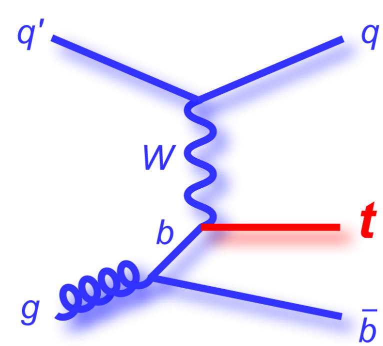




Single Top Quark Production Cross Section



s-channel
σ_{SM} ~1 pb



t-channel
σ_{SM} ~2.2 pb

Associated production
(t and W)
Negligible at the Tevatron

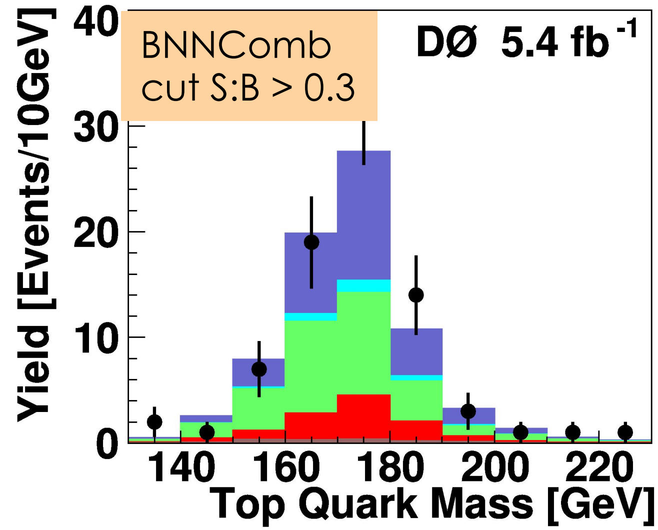
Single Top

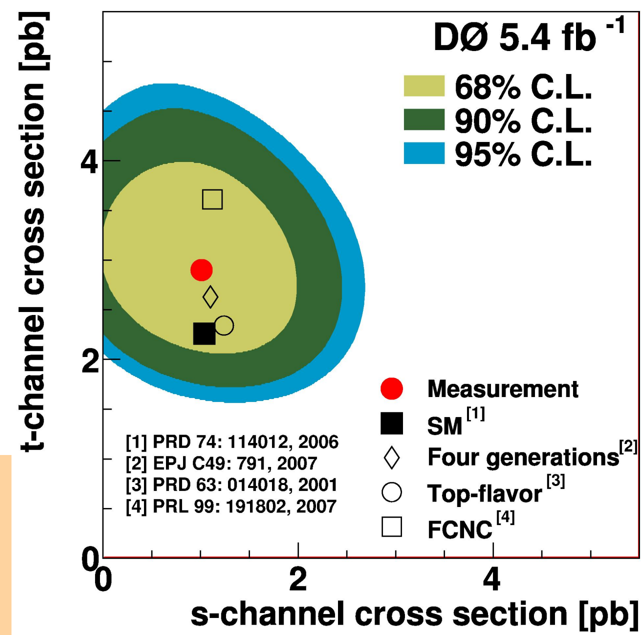
$M_t = 172.5$ GeV, $L = 5.4\ fb^{-1}$

- Measure s-channel and t-channel separately
  - Independent of relative rate
- Many different triggers combined
  - Maximise the acceptance
- ≥1 b-tagged jet
  - S:B 1:33 for 1 b-tag
  - S:B 1:50 for 2 b-tags
- Use 3 MVA techniques
  - Boosted Decision Trees
  - Bayesian Neural Network (BNN)
  - Neuroevolution of Augmented Topologies (NEAT)
  - Combined into an additional BNN (BNNComb)
    - Only ~70% correlated with each other
  - All treat s-channel as background for training
- Fit simultaneously s- and t-channel cross sections

$$\sigma_{pp\to tqb+X} = 2.90 \pm 0.59_{(stat+syst+lumi)}\ \text{pb}$$
$$\sigma_{pp\to tb+X} = 0.98 \pm 0.64_{(stat+syst+lumi)}\ \text{pb}$$

t-channel:
~5.5 sigma
(4.6 exp)





Conclusions And Outlook

- Many precision top quark measurements being carried out at the Tevatron
- Precision of cross section measurements now similar to theoretical uncertainties
  - Single best measurement has total uncertainty of ~7%
  - Legacy measurements!!!
- All measurements are consistent with the Standard Model … unfortunately ☺