3rd International Conference on Flavor Physics
October 3-8, 2005

Top Quark Physics at DØ

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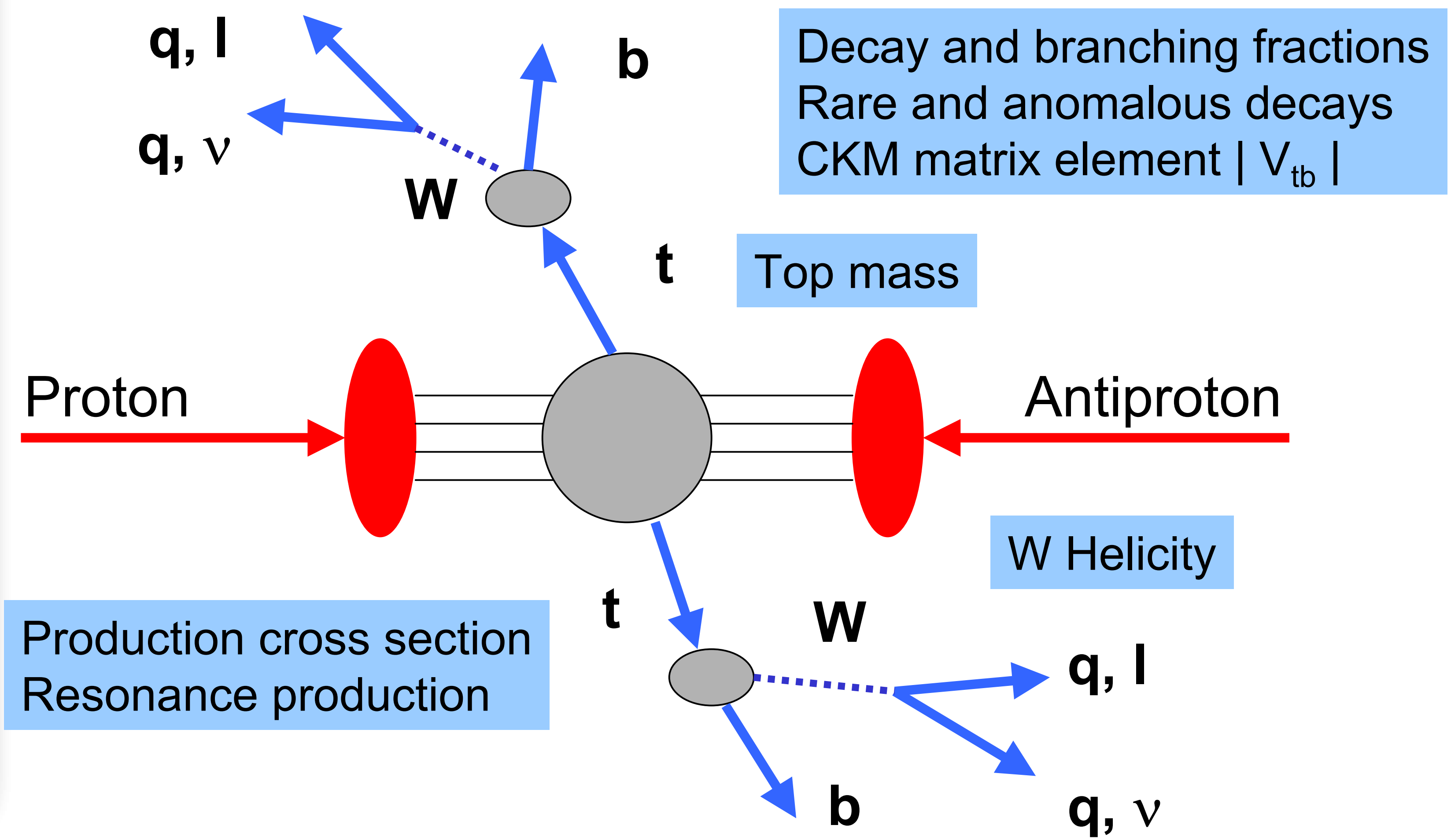
University of Kansas
on behalf of the DØ Collaboration

The DØ Collaboration

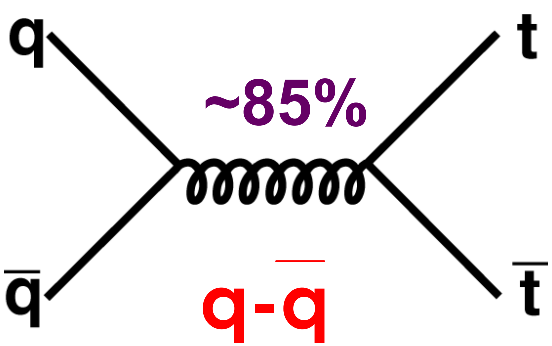
19 countries
86 institutions
~ 676 physicists

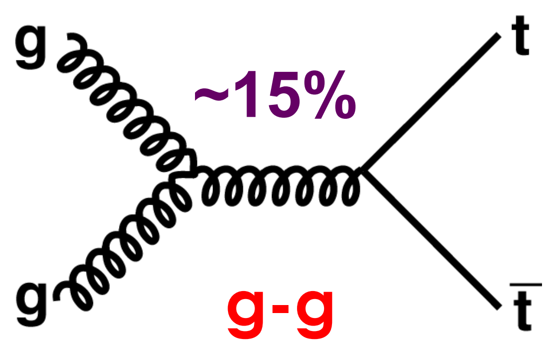
Physics with Top Quarks



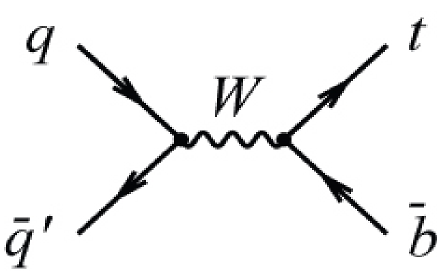
Top Quark Production

At the Tevatron, the strong interaction produces top quarks in pairs:

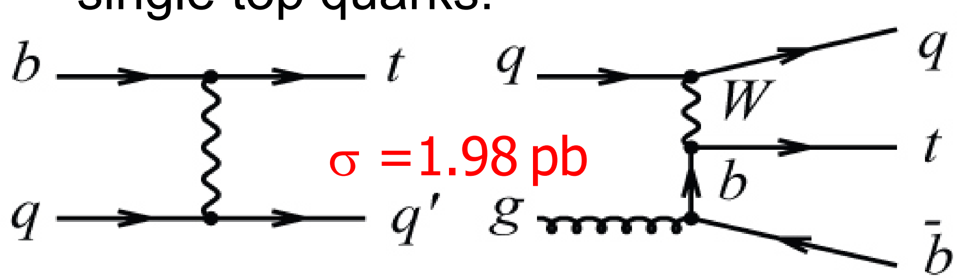




The standard model also predicts electroweak production of single top quarks:



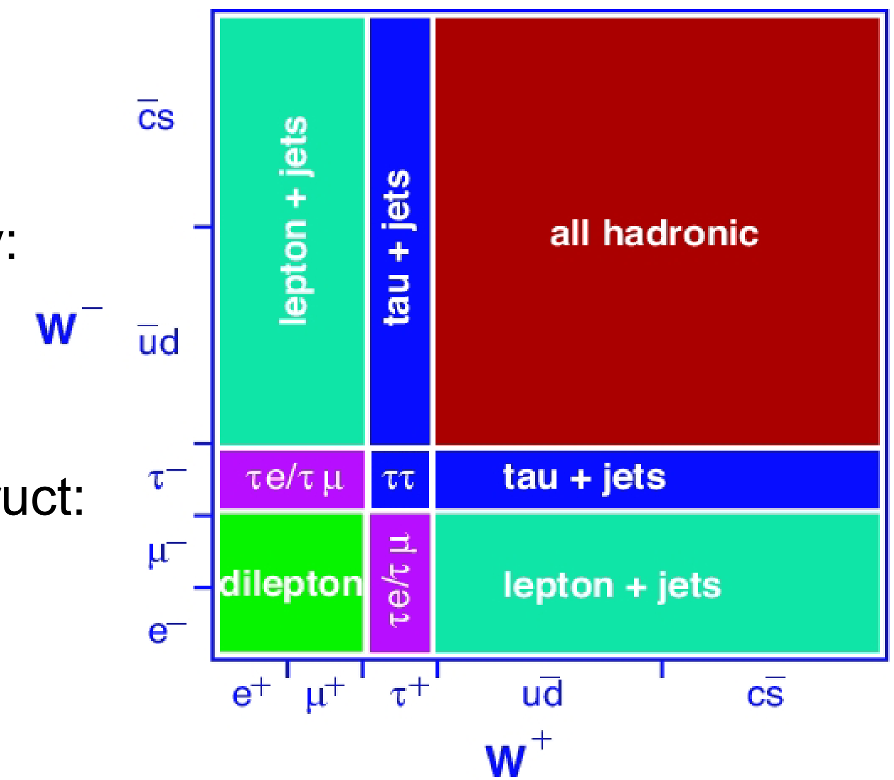
σ = 0.88 pb



W-gluon fusion

Top Quark Decay and Backgrounds

- Electroweak decay
- Br (t → Wb) ~ 99.9%
- Decays before it hadronizes
- Classified by W boson decay:
    - all hadronic B = 46%
    - lepton plus jets B = 34%
    - dileptons B = 6%
- Need to identify and reconstruct: electrons, muons, jets from b-quarks, jets from light quarks, missing transverse energy

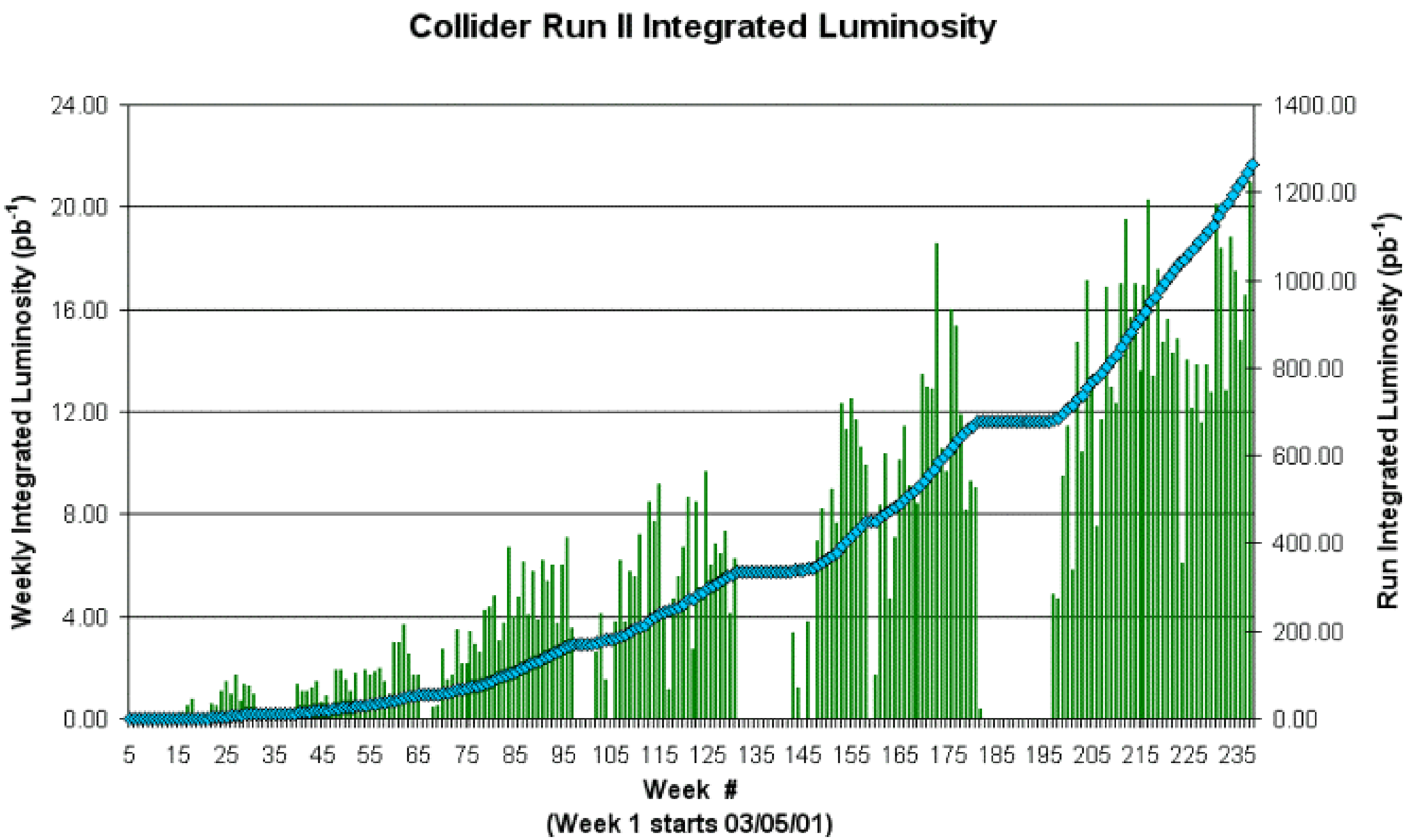


Backgrounds

- Events with real W or Z bosons (I.e. W + jets, Z + jets, WW, WZ, ZZ)
- Events with misidentified isolated leptons or multijet events (i.e. Heavy flavor production with a misidentified electron, or muon from a b decay)

Tevatron Performance

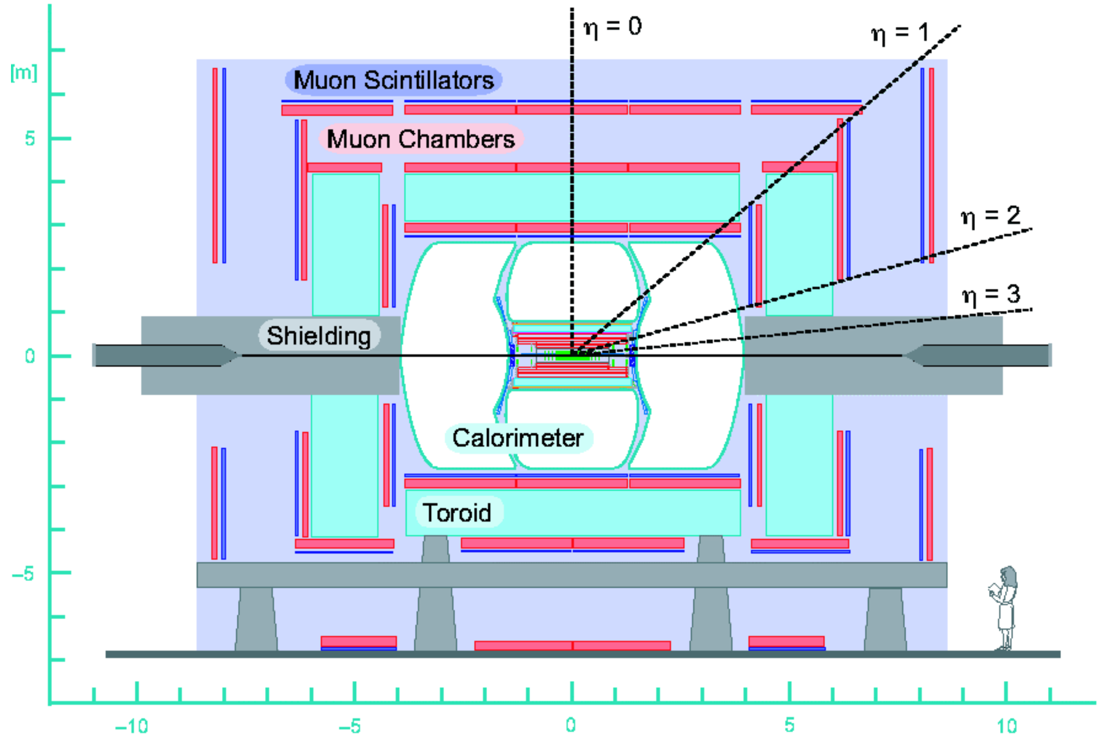
> 1 fb^{-1} recorded to tape



Green – weekly integrated luminosity

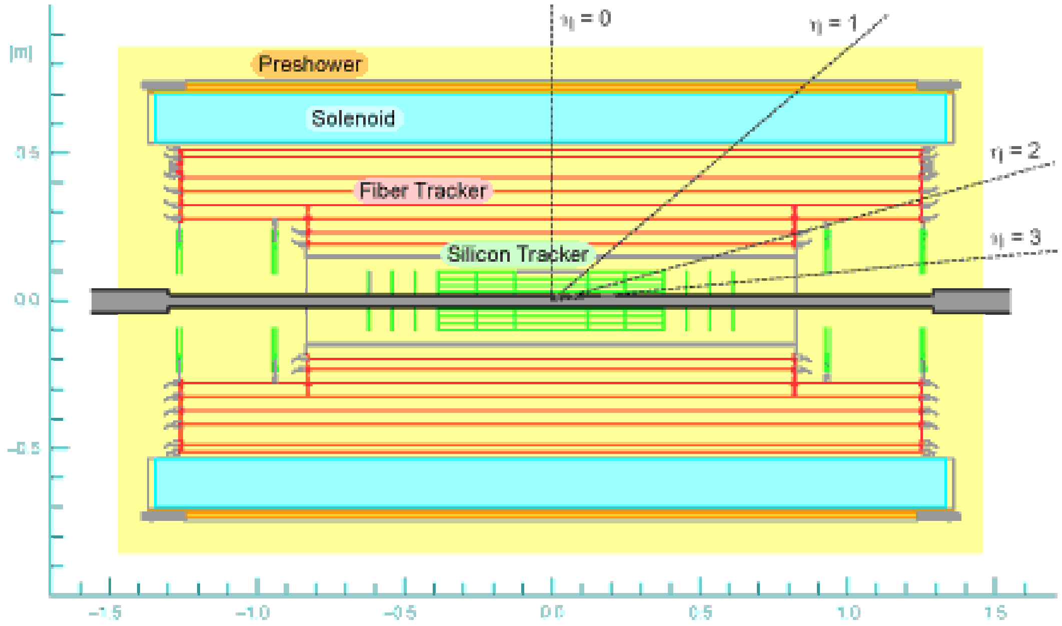
Sky blue – run integrated luminosity

DØ Detector Schematic



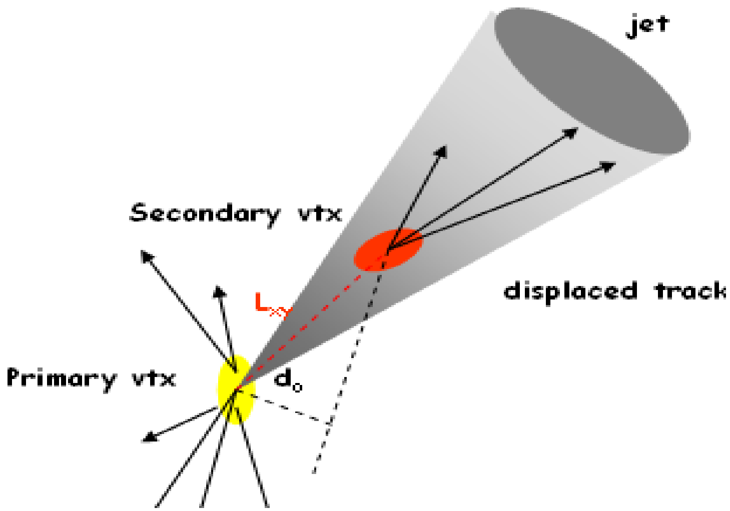
General purpose detector

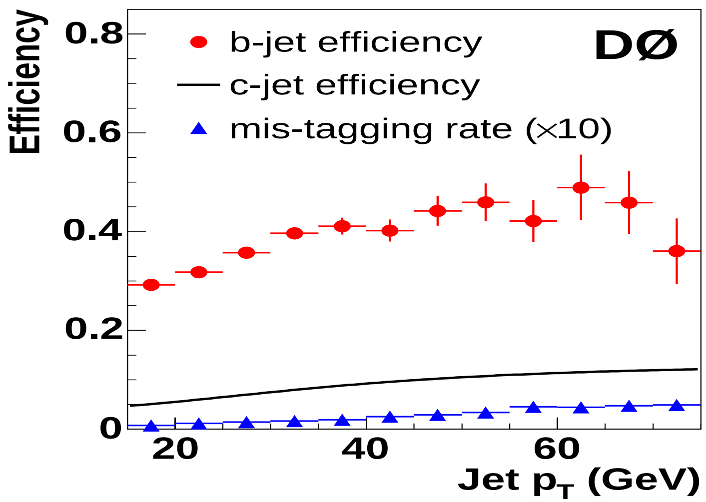
Tracking Detector



High precision Silicon Microstrip Detector
and Scintillating Fiber tracking
in a 2 T magnetic field

B jet Identification and Performance





- B hadrons are long-lived
- Look for vertex of displaced tracks

	W+jets	t-tbar
≥4j, 1 tag	4%	44%
≥4j, 2 tag	0.4%	15%

Lepton Plus Jets Channel "Topological"

- Use a discriminate function to separate t-tbar and W+jets.
- Constructed from kinematic variables (e.g. H_T, centrality, sphericity).
- Form likelihood for channel combination.

"Topological"

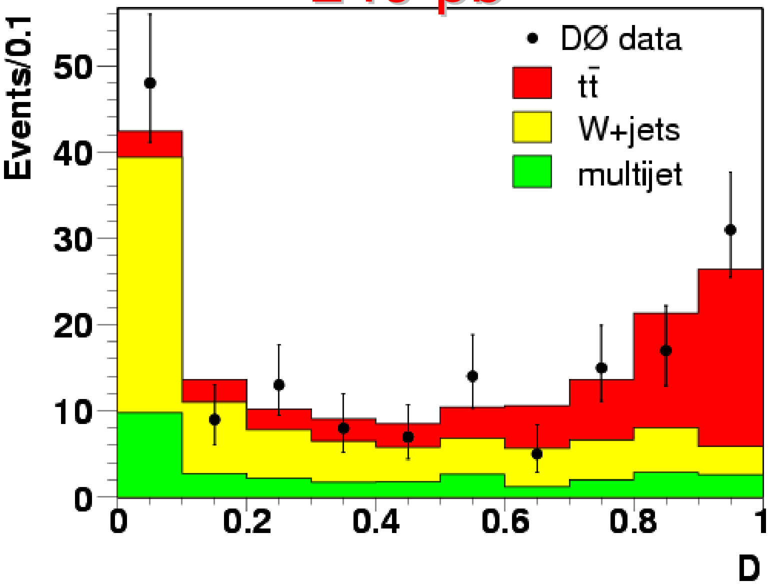
Sample composition:

38% ttbar

44% W+jets

18% multijet

240 pb^{-1}



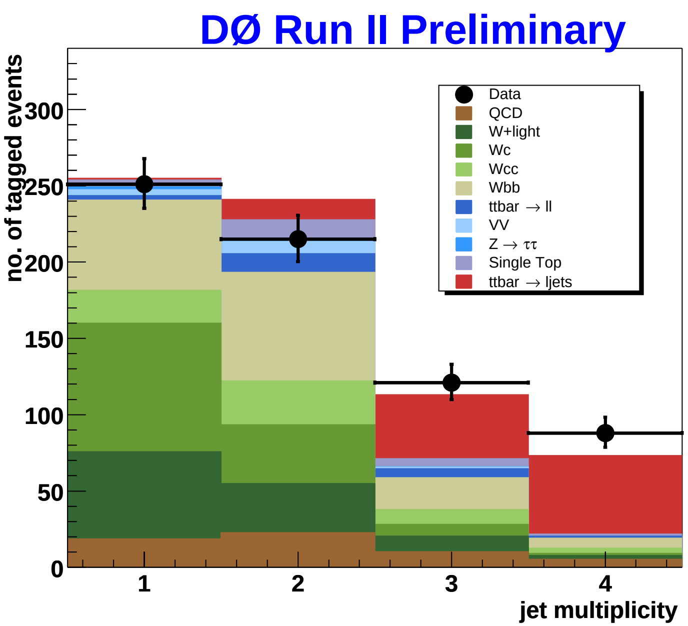
hep-ex/0504043

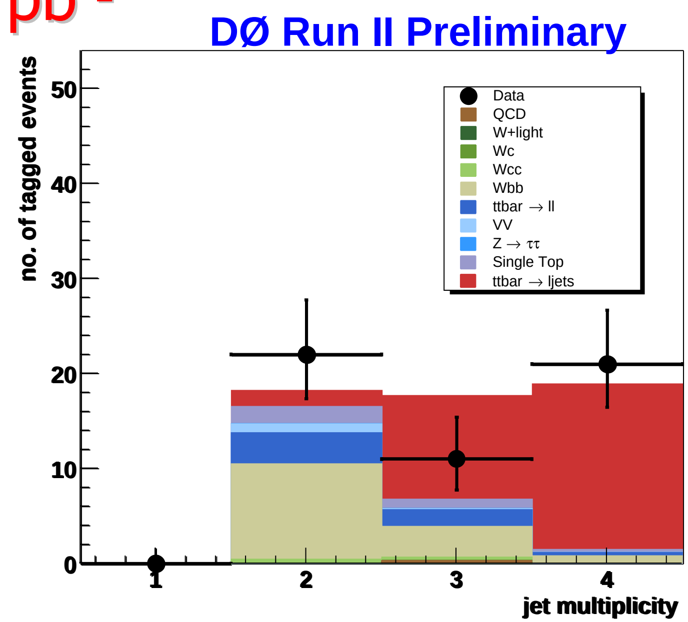
m_t = 175 GeV

$$\sigma_{t\bar{t}} = 6.7^{+1.4}_{-1.3}(stat)^{+1.6}_{-1.1}(syst) \pm 0.4(lumi)\,pb$$

Lepton plus jets channel
"b-tagged"

$L = 363\ pb^{-1}$



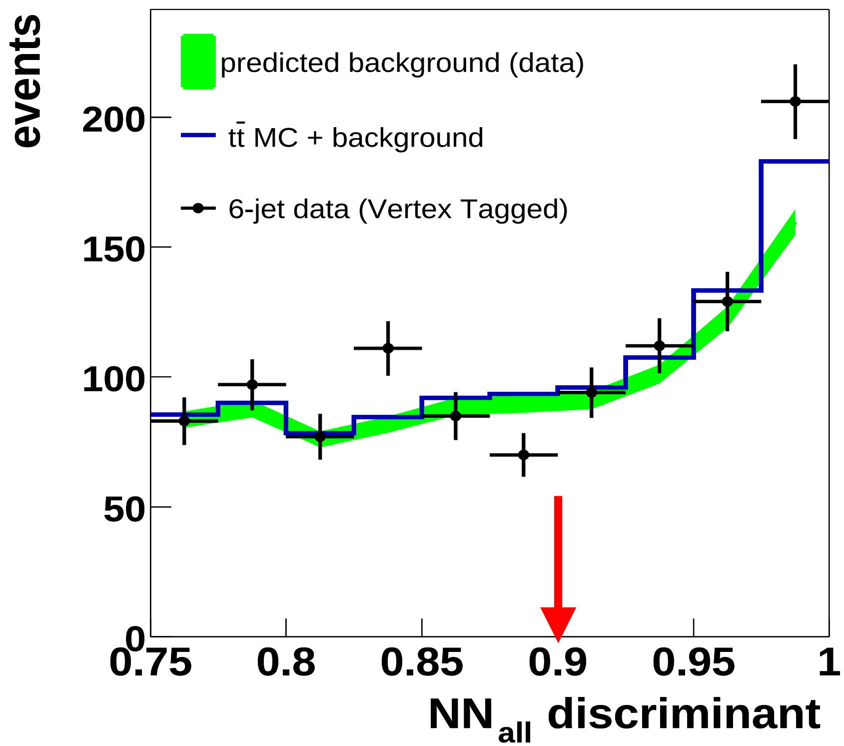


"b-tagged"

single tag double tag

m_t = 175 GeV $\sigma_{t\bar{t}} = 8.1^{+1.3}_{-1.2}(stat + syst) \pm 0.5(lumi)$ pb

All Hadronic

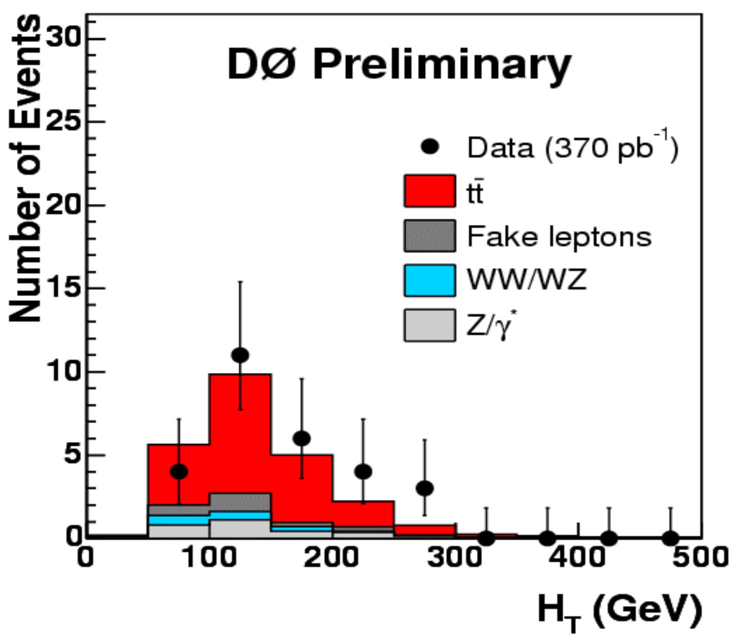


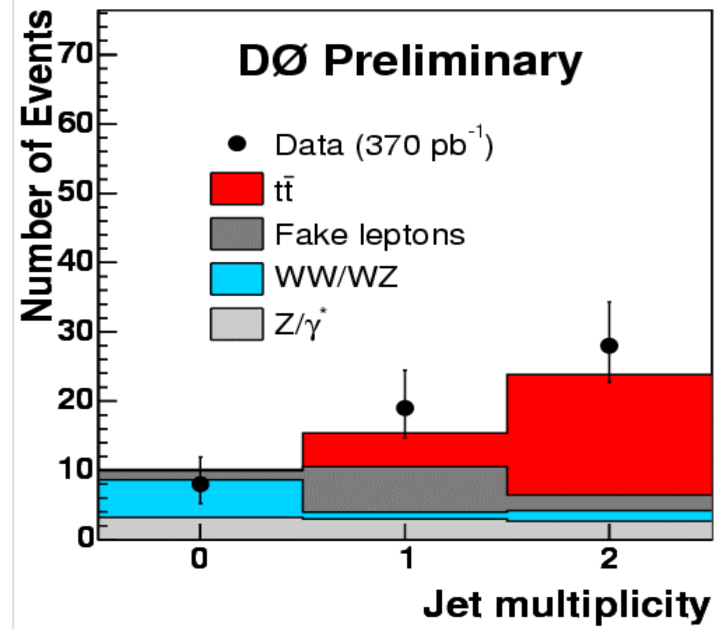
Large multijet background, so neural networks are used to separate the signal

$$\sigma_{t\bar{t}} = 5.2^{+2.6}_{-2.5}(stat)^{+1.5}_{-1.0}(syst) \pm 0.3(lumi)\ \text{pb}$$

Dilepton channel

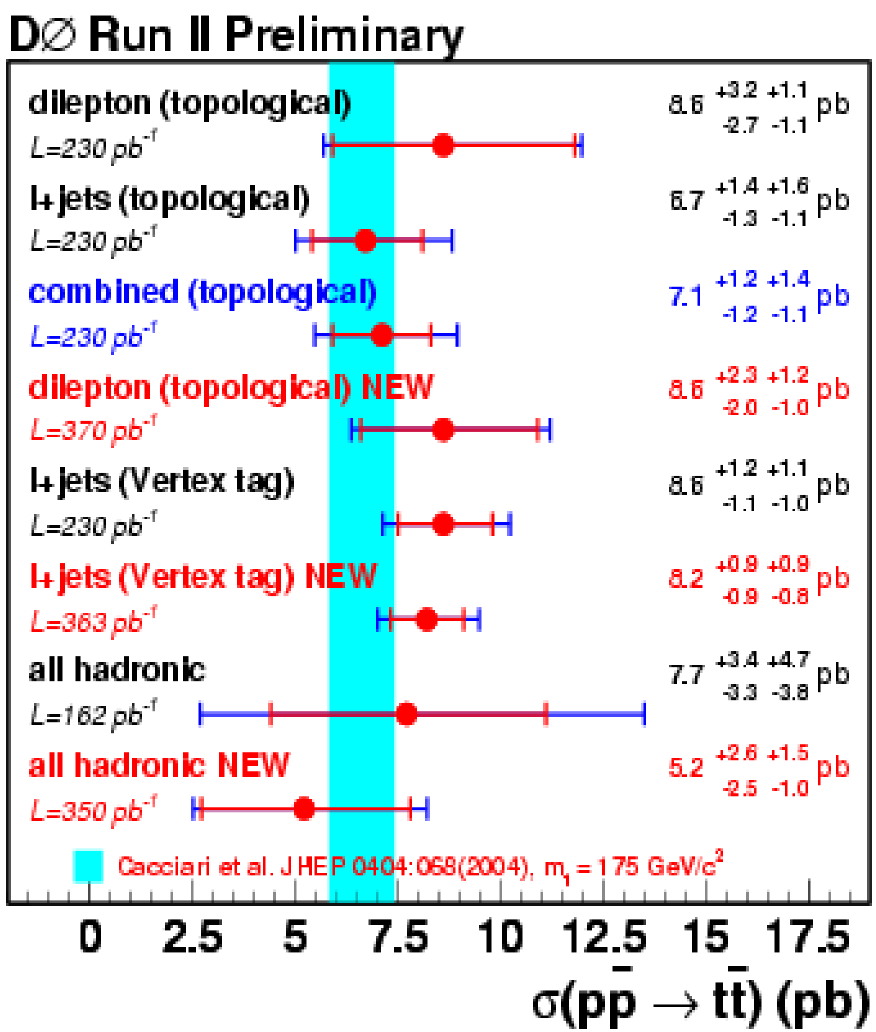
L= 370 pb^{-1}





$$\sigma_{t\bar{t}} = 8.6^{+2.3}_{-2.0}(stat)^{+1.2}_{-1.0}(syst) \pm 0.6(lumi)\,pb$$

Top Quark Pair Production Cross Section



Summary:

work in progress to combine results up to $370\ pb^{-1}$

How about the top quark mass?

Matrix Element Method

- Method which uses the matrix elements for t-tbar and W+jet production
- Extended to allow a simultaneous fit to the jet energy scale (or calibration) which is the dominant source of systematic uncertainty

$$P_{evt}(x, m_t) = f_{top} \cdot P_{\mathrm{sgn}}(x, m_t) + (1 - f_{top}) \cdot P_{bkg}(x)$$

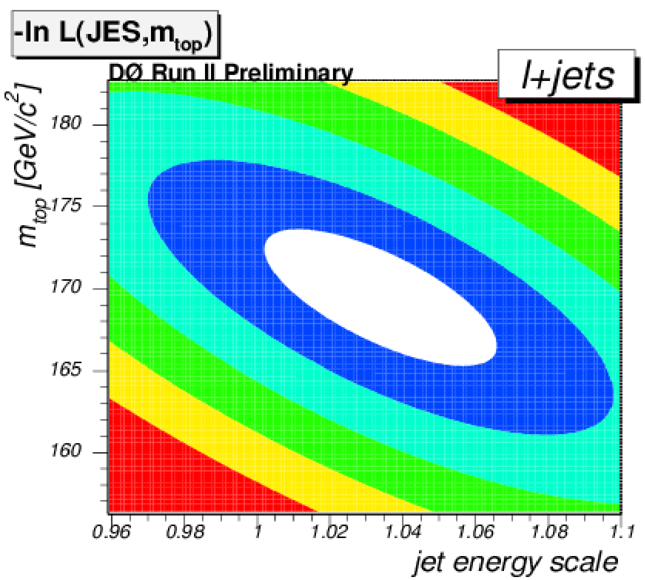
$$P_{\mathrm{sgn}}(x; m_t) = \frac{1}{\sigma(m_t)} \int d^n\sigma(y; m_t)\, dq_1\, dq_2\, f(q_1)\, f(q_2)\, W(x, y)$$

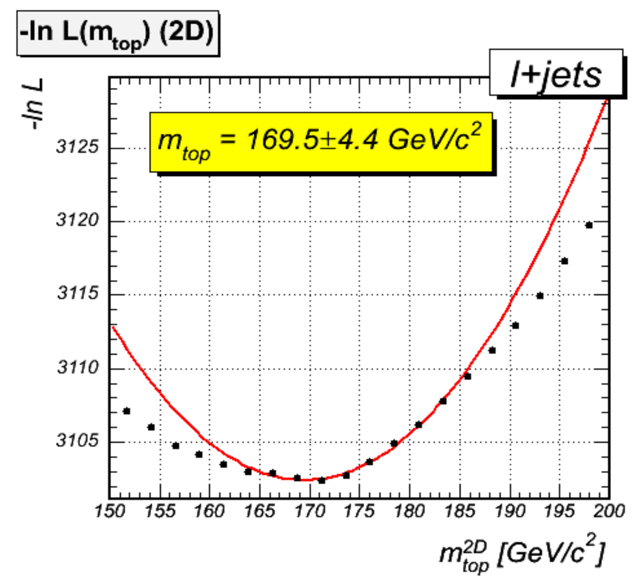
Probability to observe a set of kinematic variables x for a given top mass

Differential cross section of produced partons and incoming quark momenta

Structure functions and detector resolution functions

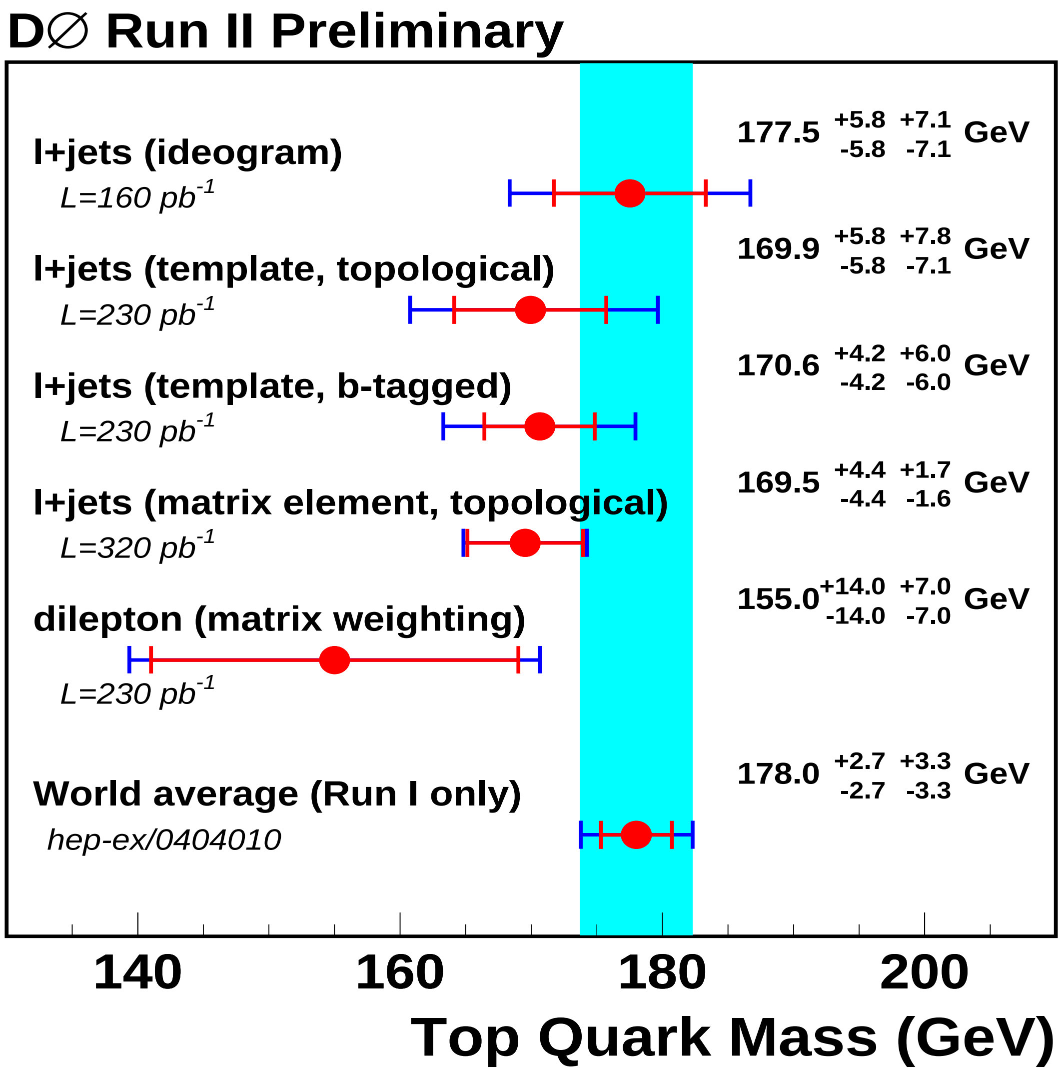
Matrix Element Method (cont'd)



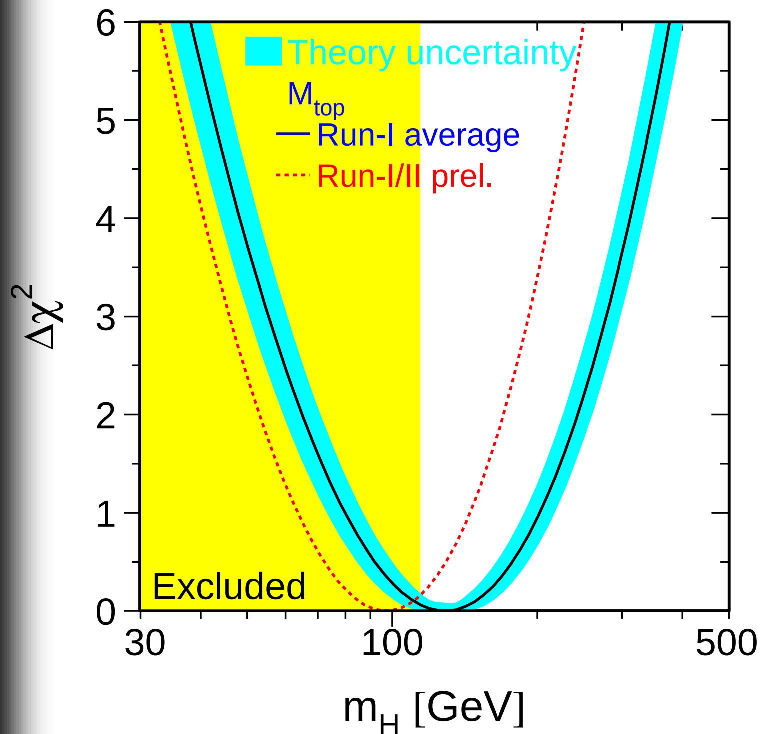


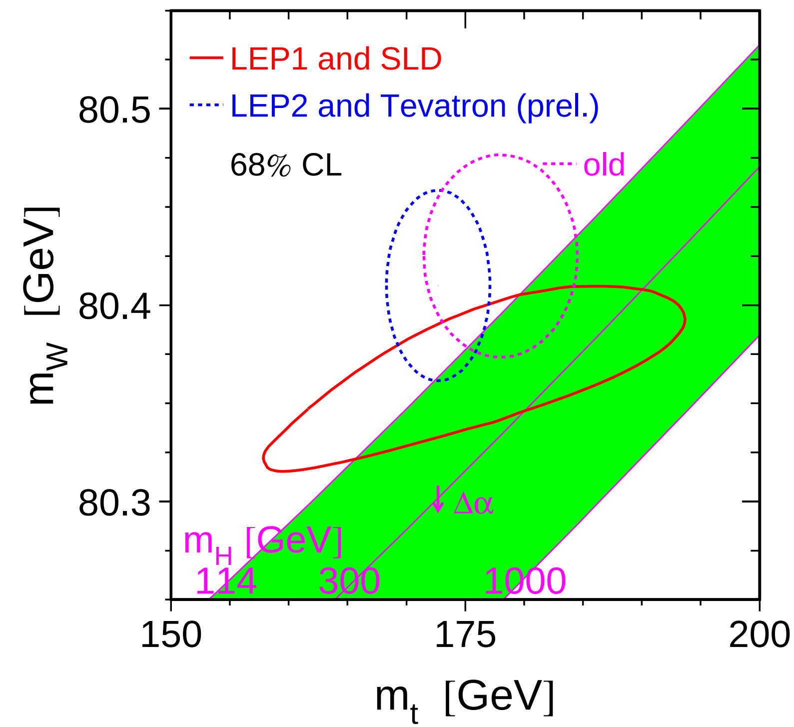
$M_t = 169.5 \pm 4.4$ (stat + JES) $^{+1.7}_{-1.6}$ (syst) GeV

Top Quark Mass



The Higgs Mass

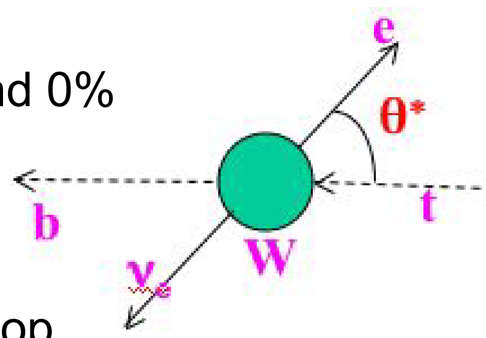


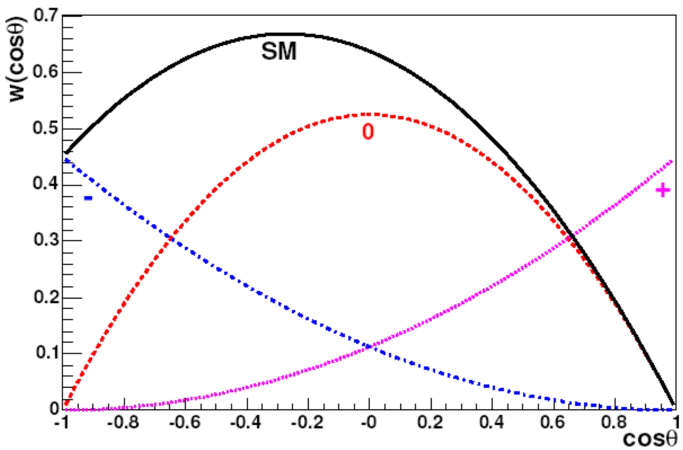


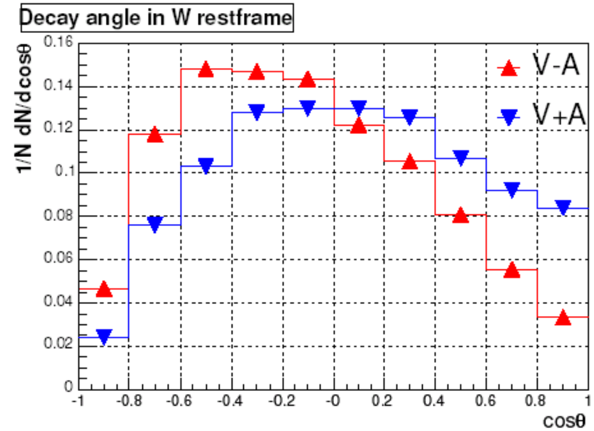
- $M_H = 91^{+45}_{-32} GeV/c^2$
- $M_H < 186\ GeV/c^2$ @ 95%CL

W Boson Helicity from Top Quark Decays

- In SM, W boson helicity depends on the top quark and W boson masses:
  - Predicted 70% longitudinal, 30% left-handed, and 0% right-handed.
  - We measure right-handed fraction f_+ or V+A component.
  - Angle ($\cos\theta^*$) between the charge lepton and top quark direction in the W boson rest frame.

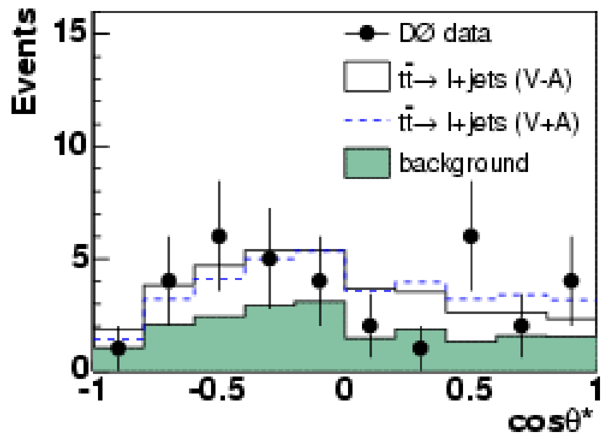




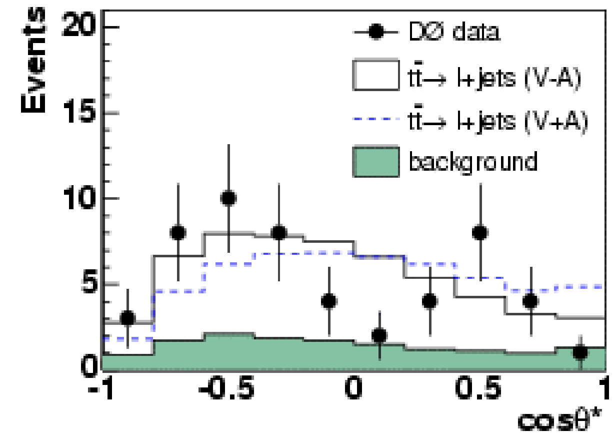


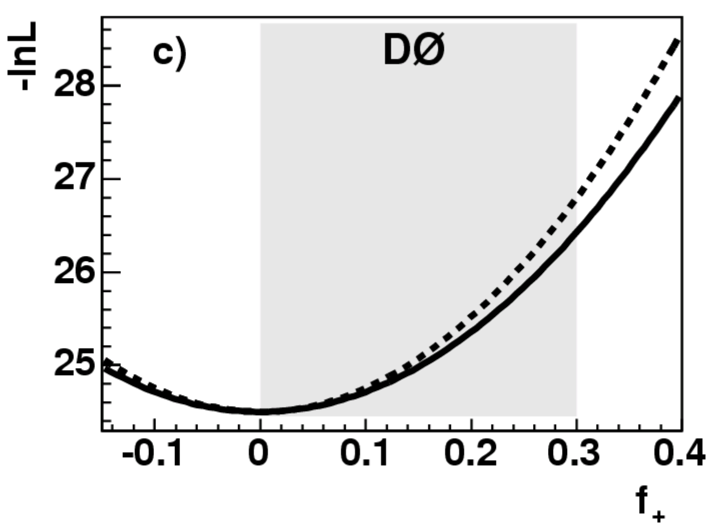
W Boson Helicity from Top Quark Decays

Topological



b-tag



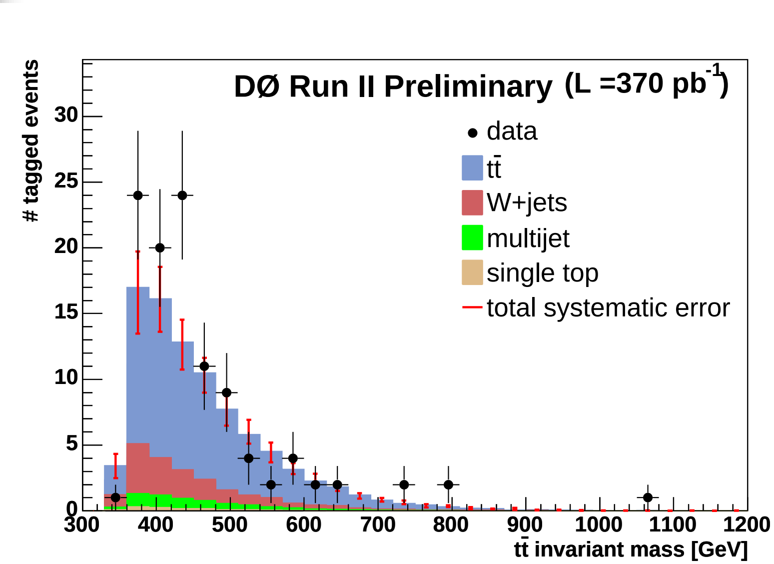


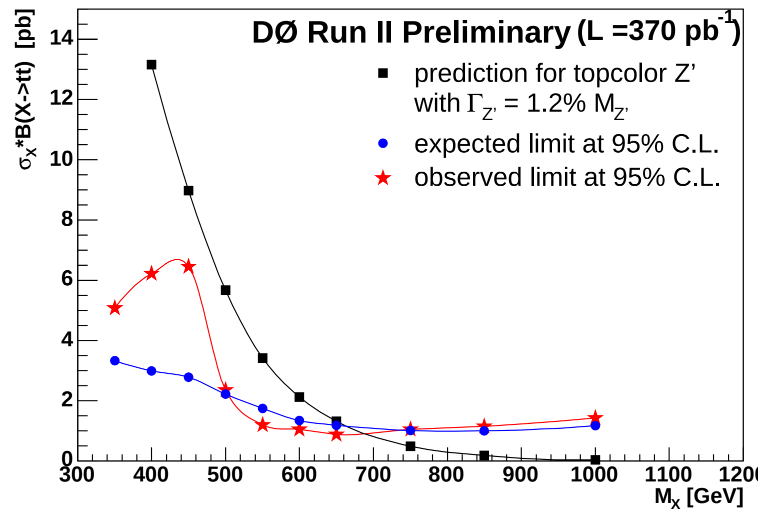
Combined result:

$f_+ = 0.00 \pm 0.13$ (stat) ± 0.07 (syst)

$f_+ < 0.25$ @ 95% Bayesian C.L.

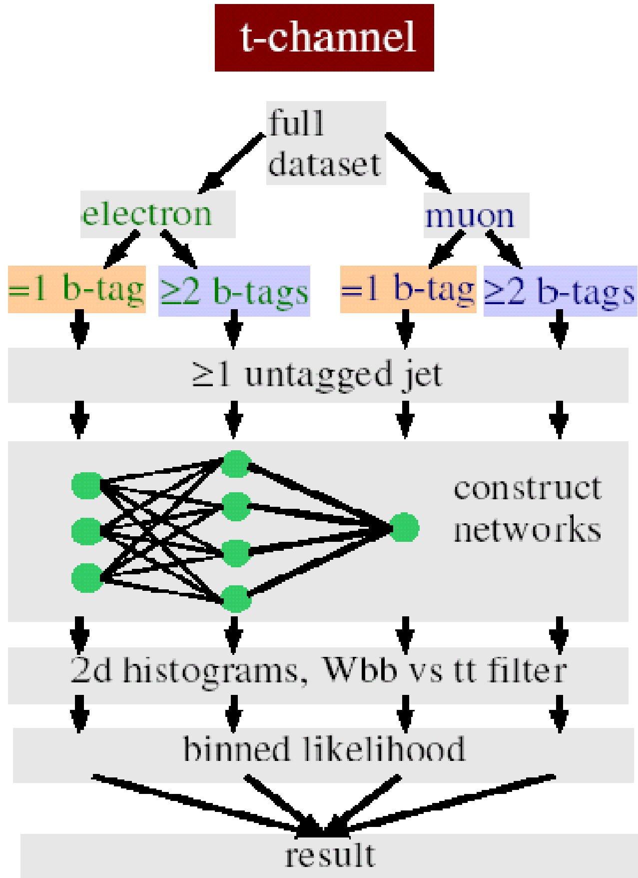
Top Resonances



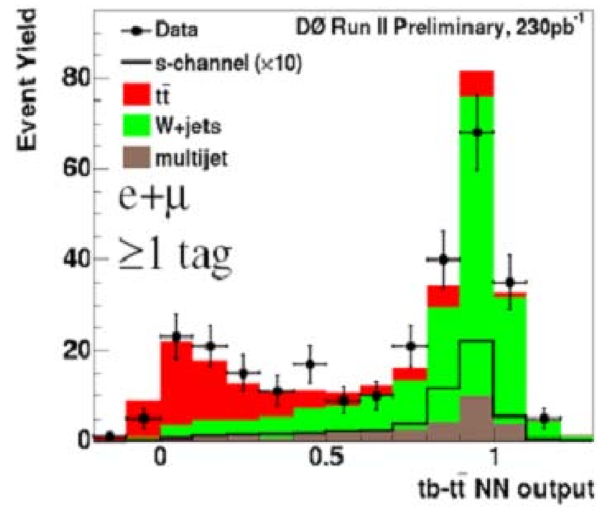


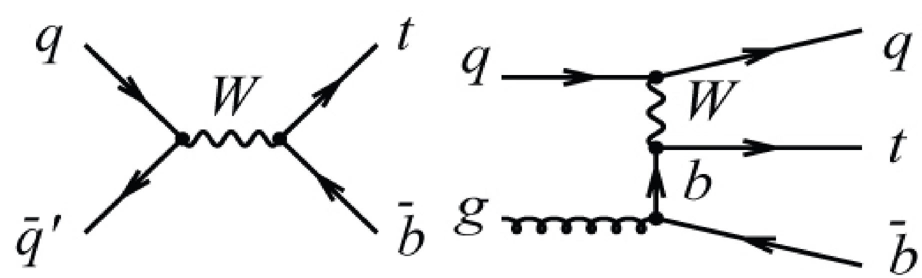
- Check the t-tbar invariant mass for possible resonance production
- Limit M(Z')>680 GeV/c^2 with $\Gamma_{Z'}$=1.2% $M_{Z'}$ at 95% C.L.
- Model independent limits

Single Top Quark Production

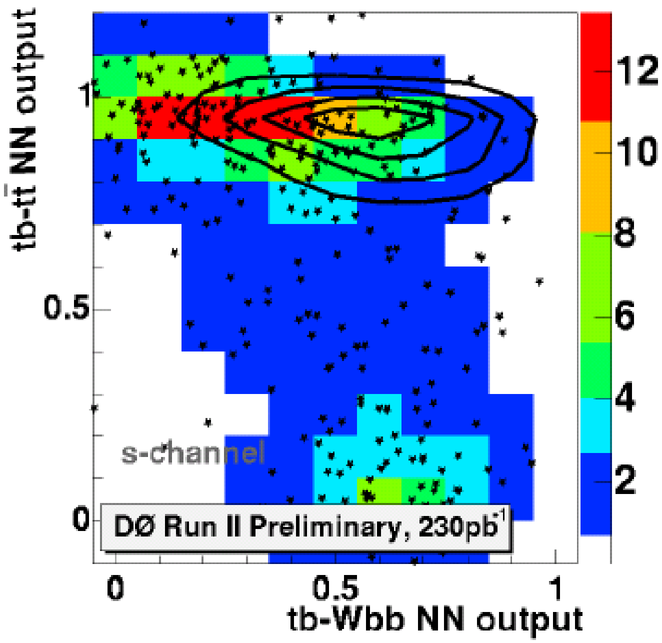


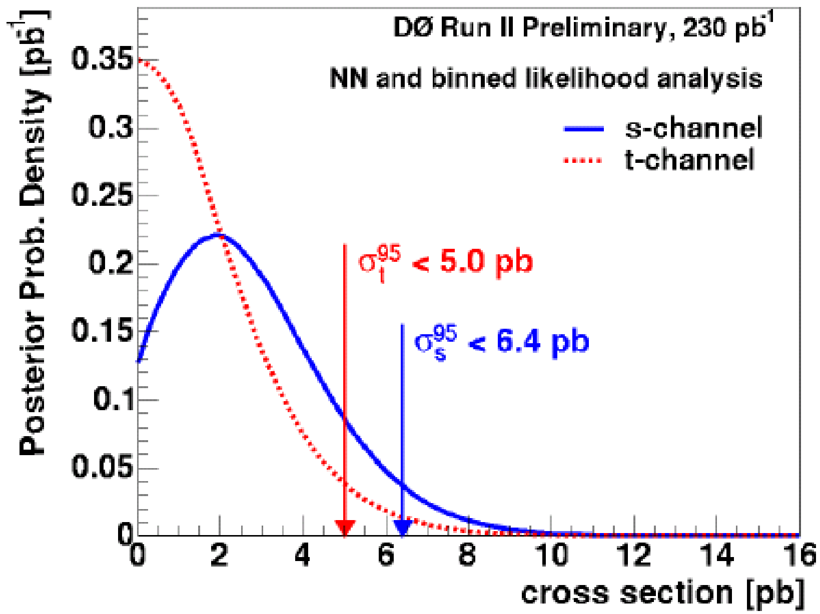
Use neural networks to improve sensitivity





Single Top Quark Production





- No evidence for electroweak single top quark production
- Set Bayesian 95% C.L. upper cross section limits:

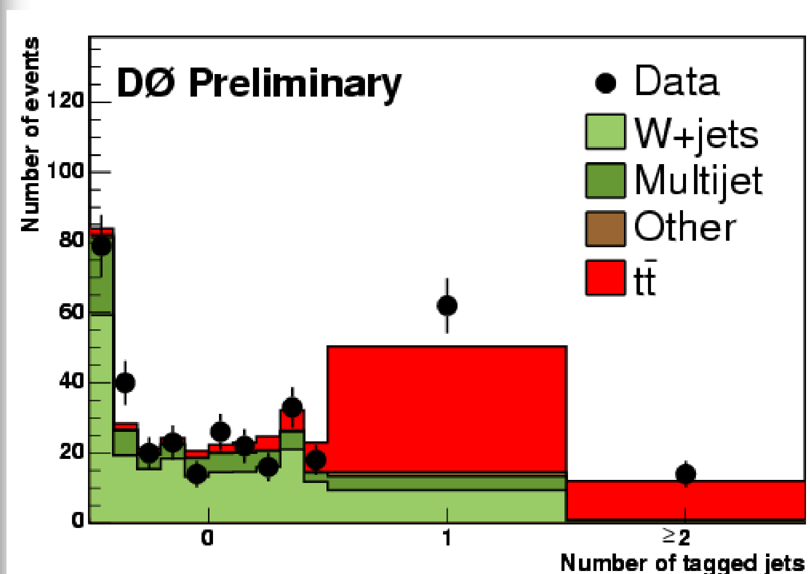
  $\sigma_s < 6.4$ pb $\qquad \sigma_t < 5.0$ pb
- Presently, most sensitive limit in the world

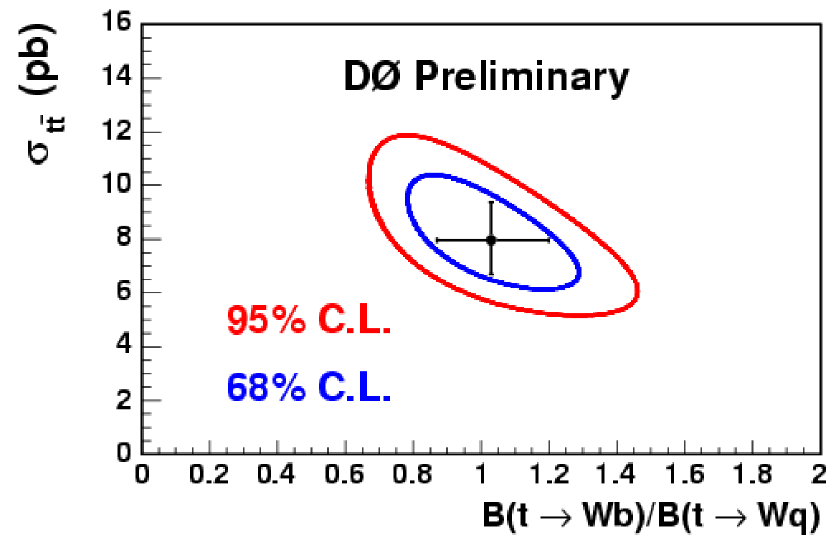
Summary

- The fun is just beginning !
  - Many other top quark analyses in progress:
    - Top charge, top decay to charged Higgs, anomalous kinematics (P_T of top quark), top mass in all jets channel, etc…
- We now have 10 times more data from previous run.
- For more details on results available:
  - http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html

Decay modes

$$R=\frac{Br(t\to Wb)}{Br(t\to Wq)}=\frac{|V_{tb}|^2}{|V_{tb}|^2+|V_{ts}|^2+|V_{td}|^2}=|V_{tb}|^2$$





$$\frac{Br(t\to Wb)}{Br(t\to Wq)}=1.03^{+0.19}_{-0.17}(stat+syst)$$