A Search for Single Top Quark Production with the DØ Detector

On behalf of the DØ Single Top Working Group

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New Perspectives, June 2005

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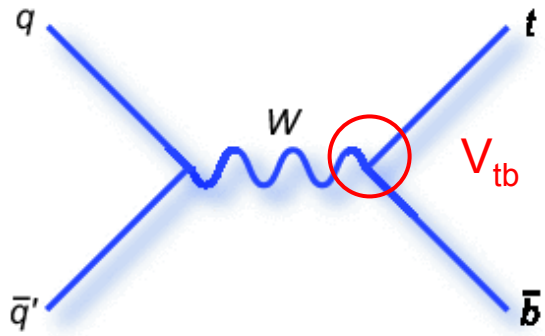
Top Quarks

What We've Seen

- Top quarks DO exist (Fermilab, 1995)
- Pair production (strong interaction)
- Mass and cross section measurements

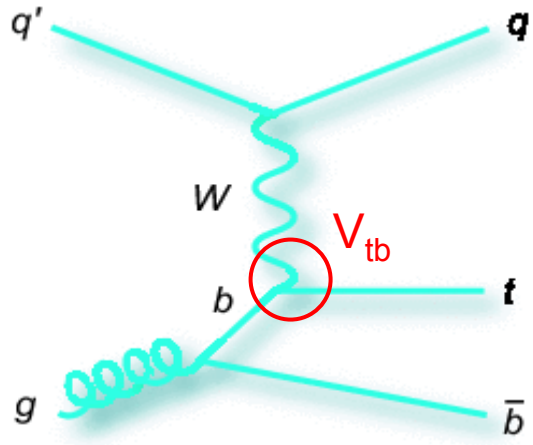


s-channel

A New Window To The Top Quark

Single top production (weak interaction)

- A measurement of $|V_{tb}|$ in the CKM Matrix
- Test of the V–A nature of the top quark
- Top Polarization



t-channel

We probe two channels

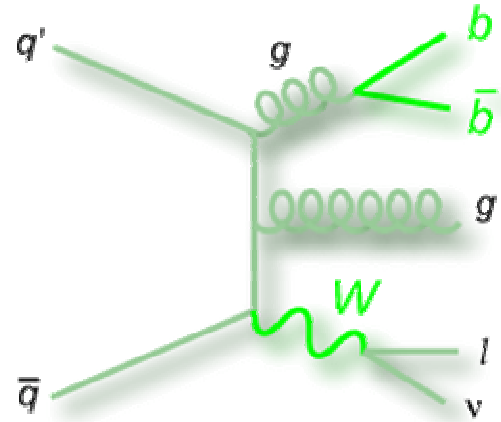
σ(*s*-channel) = 0.88 pb at NLO

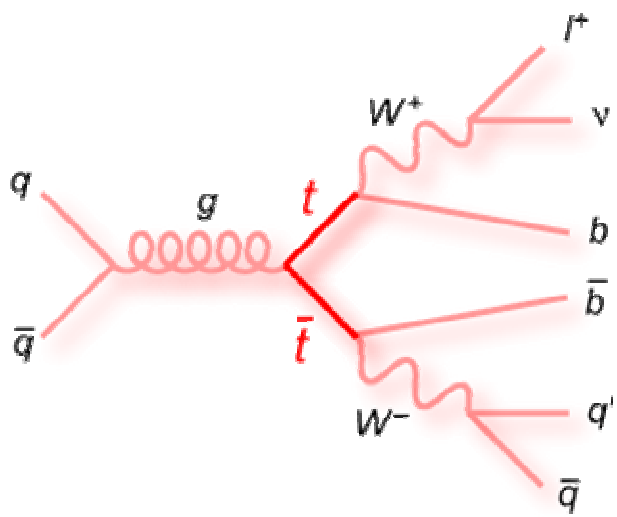
σ(*t*-channel) = 1.98 pb at NLO

Single Top Backgrounds

W+Jets (Wjj, Wbb, WW, WZ)

- Largest background
- Wbb closely mimics signal



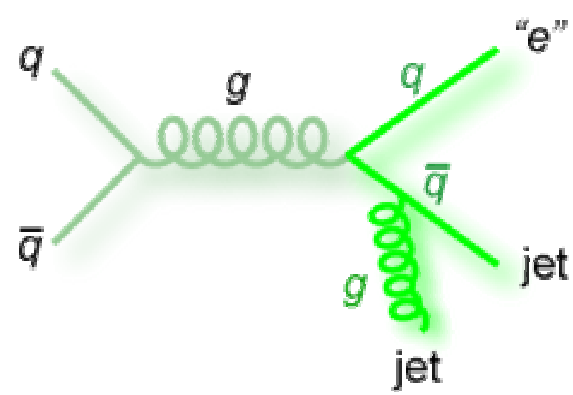


Top Pair Production

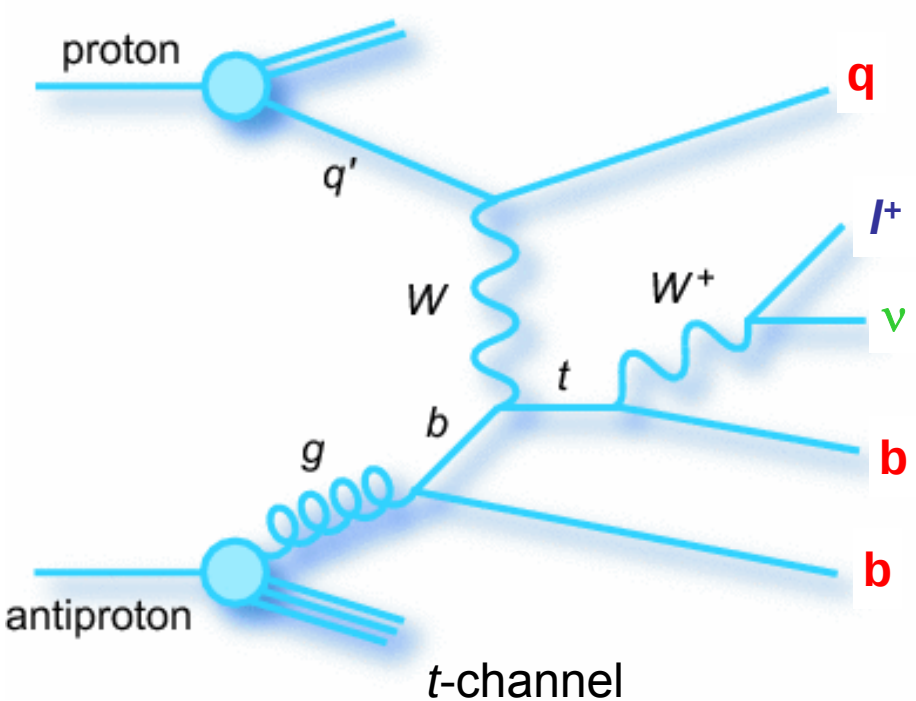
- tt → lepton + jets, tt → dileptons
- Real top quarks, difficult to remove

Mis-Identified Multijet Events (QCD)

- Extremely large cross section
- No real top quarks or W bosons



Single Top Production



q — high P_T light quark jet (in the t-channel)

l^+ — high P_T lepton (e,μ)

ν — high P_T neutrino (Missing Energy)

b — high P_T *b*-quark jet

b — *b*-quark jet

Event Selection

2-4 Jets: P_T > 15 GeV

1 lepton: P_T > 15 GeV

Missing Energy: P_T > 15 GeV

Also apply b-tagging Algorithm:

≥1 b-tagged Jet

Our Selected Samples

Combining Electron and Muon channels after selection cuts

numerous signal events

Source	*s*-channel search	*t*-channel search
tb	5.5 ± 1.2	4.7 ± 1.0
tqb	8.6 ±1.9	8.5 ± 1.9
W+jets	169.1 ± 19.2	163.9 ± 17.8
tt	78.3 ± 17.6	75.9 ± 17.0
Multijet	31.4 ± 3.3	31.3 ± 3.2
Total background	287.4 ± 31.4	275.8 ± 31.5
Observed Events	283	271

decent background / data agreement

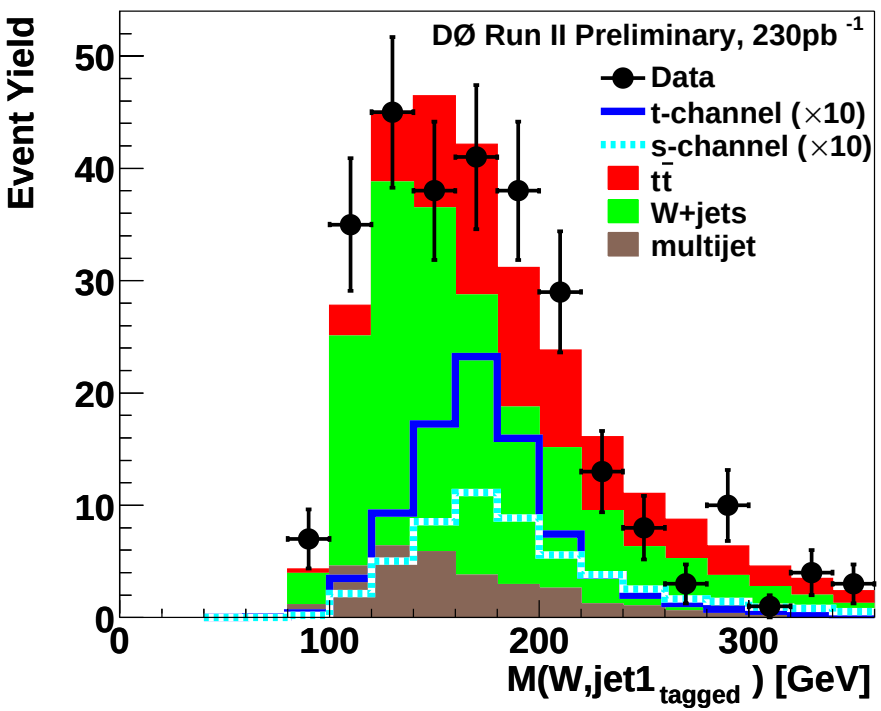
still large levels of background…

Our Selected Samples

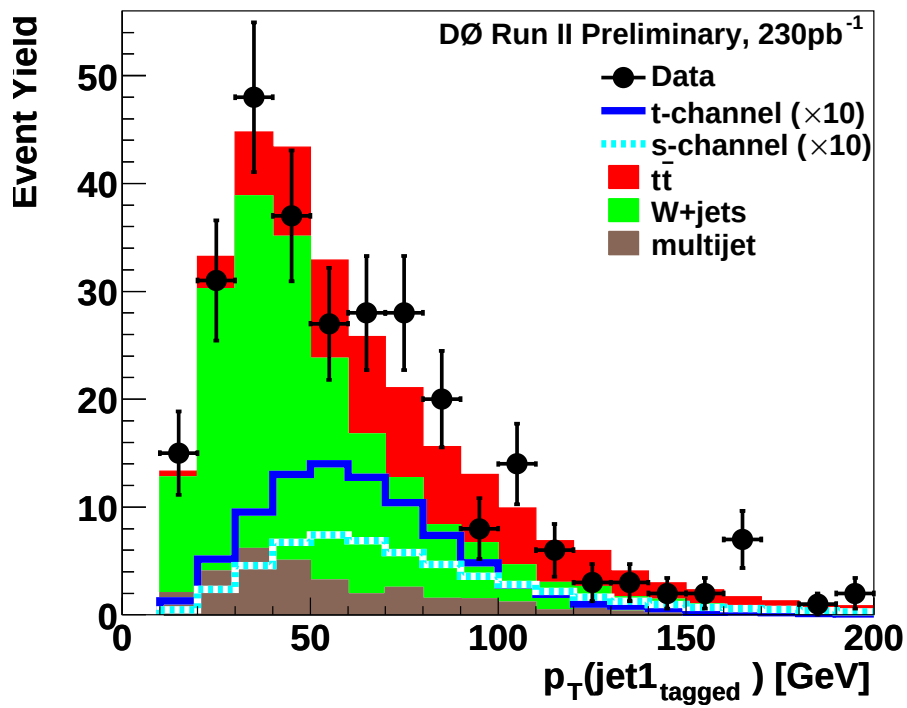
Modeling The Data

Does the background model agree with data? – yes, within uncertainties

Top Quark Mass



P_T Leading Tagged Jet



Disentangling Signal and Background

Several Multivariate Approaches

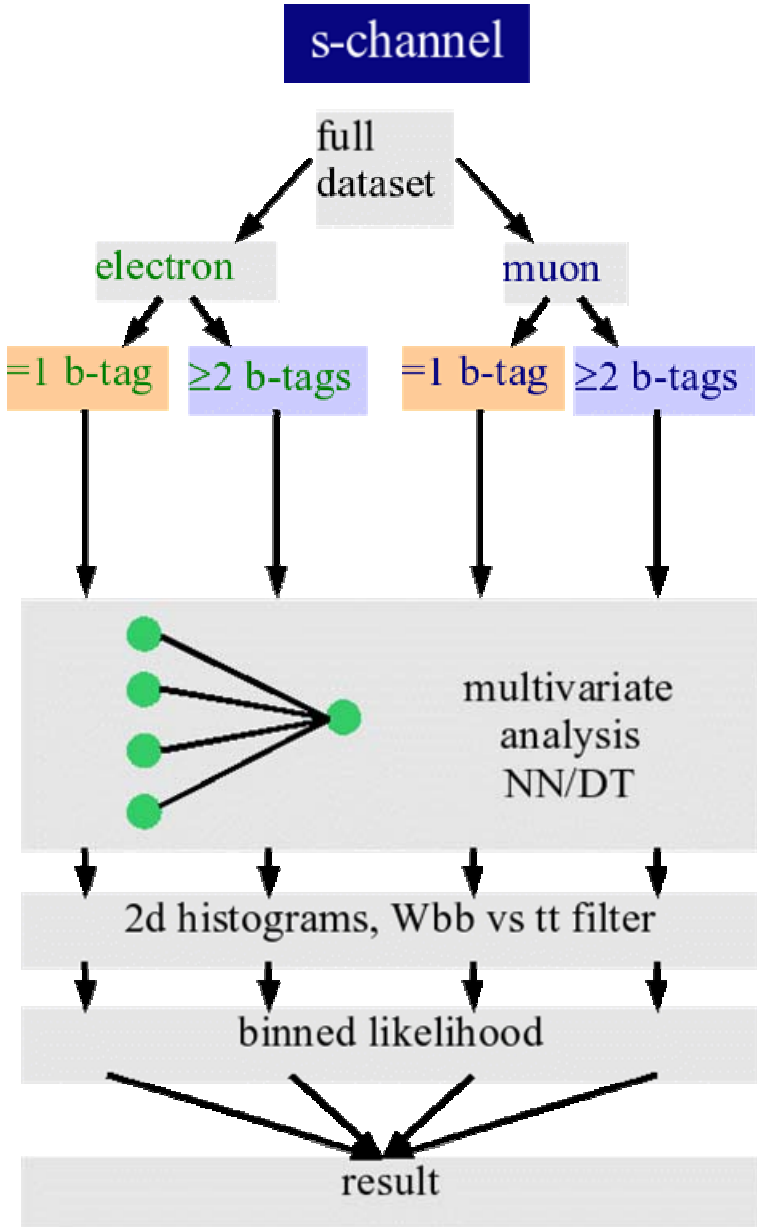
- Neural Networks
- Decision Trees
- Random Grid Search

Final Analysis Overview

- Split into 8 orthogonal channels

  (s,t) x (e,μ) x (1 tag, 2 tag)
- Multivariate approach applied to

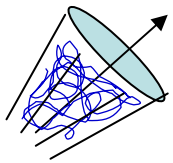
  Wbb & $t\bar{t}$(lepton+jets) backgrounds
- Limits are calculated
- Limits are combined



Input Variables

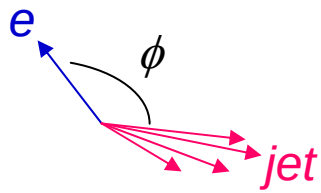
Must be chosen carefully – the heart of our discrimination power

Single Object Kinematics



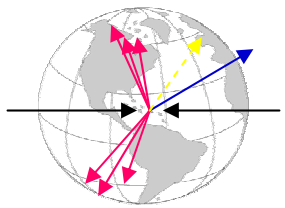
- Leading jet P_T
- Tagged jet P_T

Angular Variables



- Q(lepton) x η(Untagged Jet)
- cos(lepton,Untagged Jet)$_{\text{tagged top}}$

Global Event Variables



- Center of mass energy ($\hat{s}$)
- H_T - Sum of object transverse energies

25 total variables

All channels are optimized independently to probe different physics

Signal – Background Pairs

tqb – Wbb tqb – $t\bar{t}$(lepton+jets)

tb – Wbb tb – $t\bar{t}$(lepton+jets)

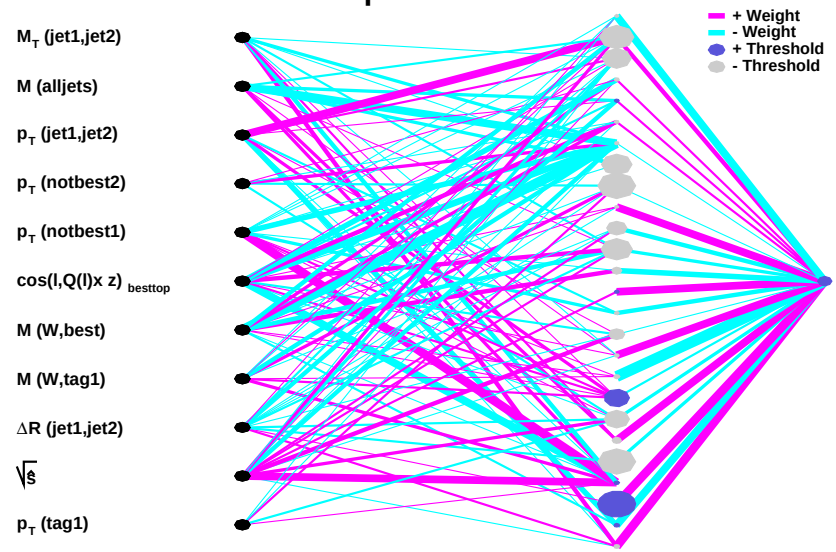
Neural Networks

Neural Networks find an intricate yet effective function of weighted variables.

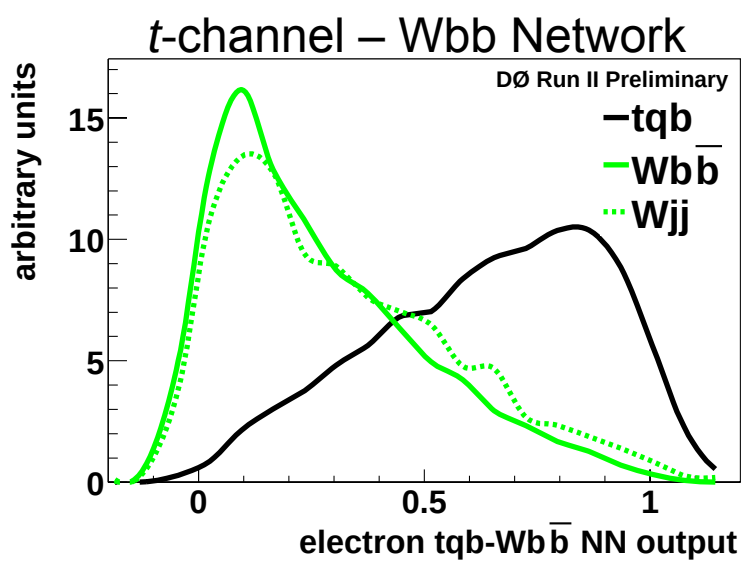
Output Function guides…

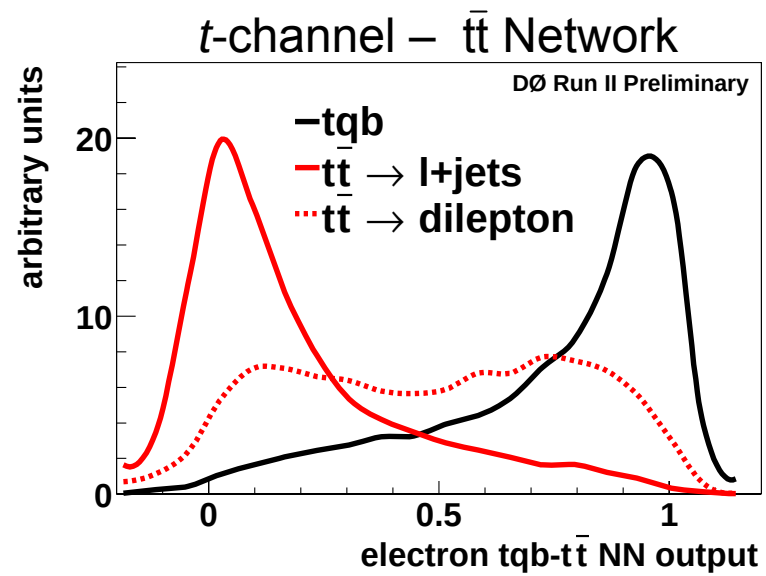
background → 0
signal → 1

A Sample Architecture



Electron Channel Neural Network Output



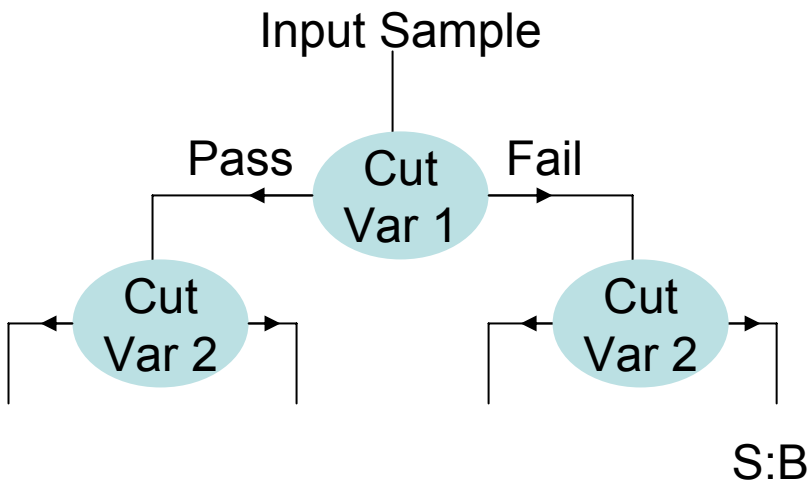


Decision Trees

Decision trees apply successive cuts on variables

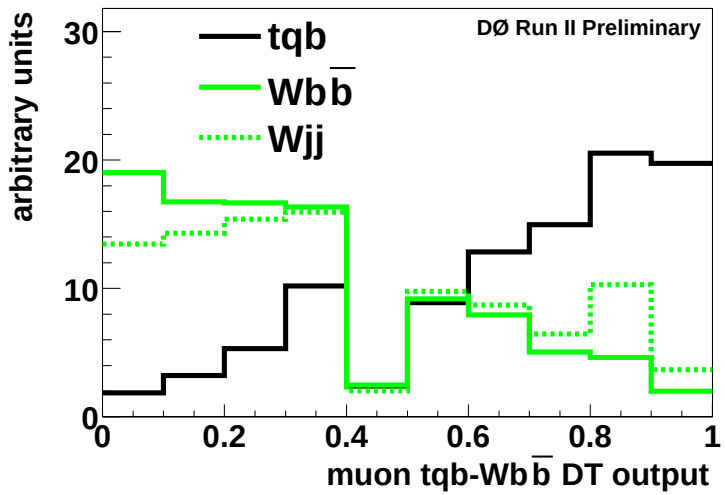
Measure the final signal:background ratio in each of the leaves

Optimize a discriminant based on the S:B

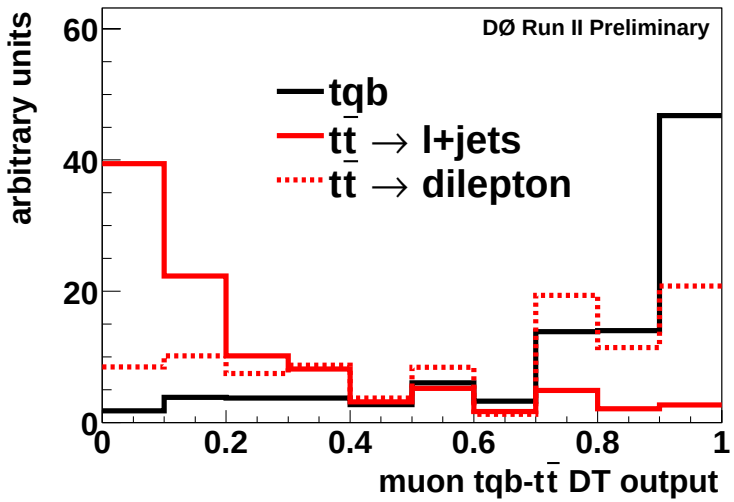


Muon Channel Decision Tree Output

t-channel – Wbb Network



t-channel – $t\bar{t}$ Network



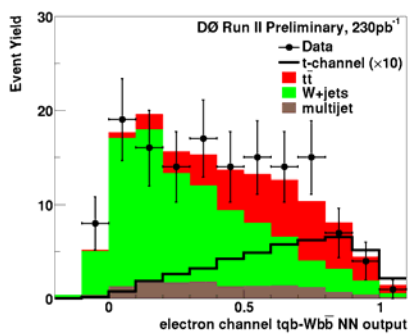
Deriving Limits

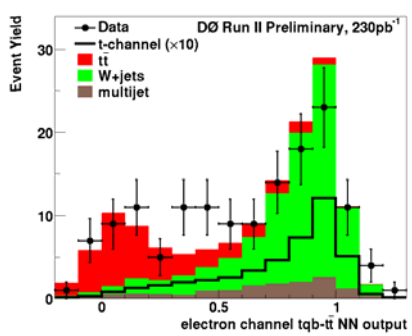
Several Approaches

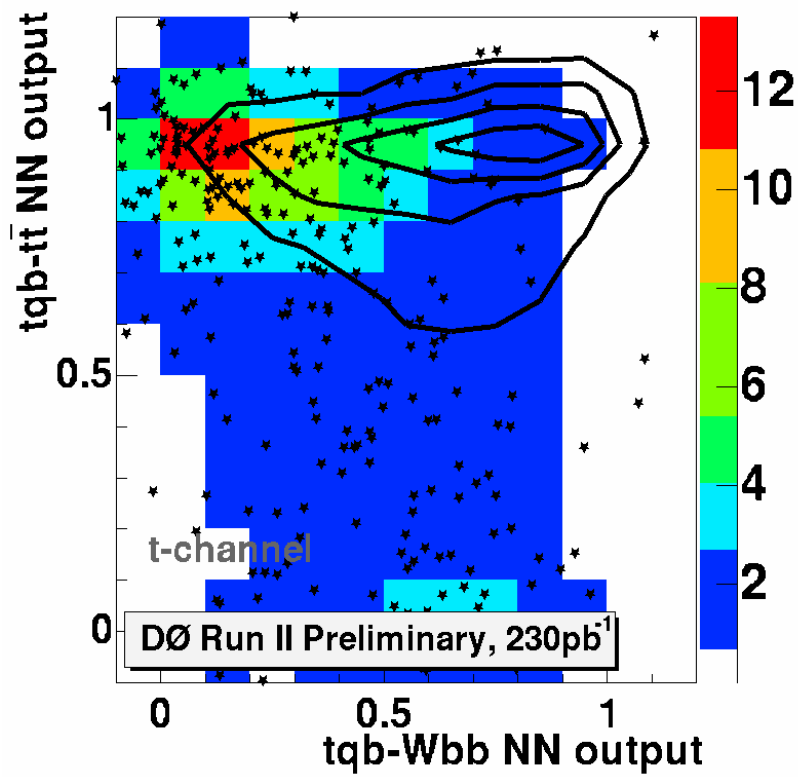
- Make a hard cut on the multivariate analysis output

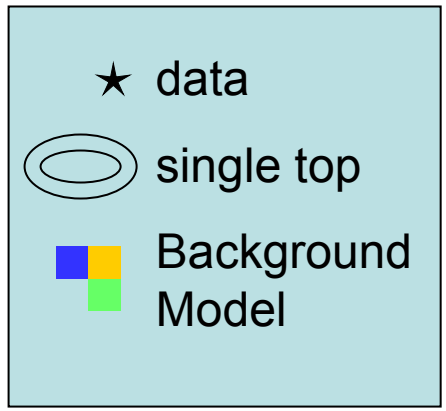
  (Derive limits as a counting experiment)

- Perform a binned likelihood calculation for each output histogram
- Even better – calculate a 2D binned likelihood calculation









Final Results

After combining results from lepton and tagged channels:

95% CL Measured Upper Limits in pb

	t-channel	*s*-channel
DØ Run I, 90 pb^{-1}	17	22
CDF Run II, 162 pb^{-1}	13.6	10.1
DØ Run II , 230 pb^{-1} cuts	**10.6**	**11.3**
DTs & binned likelihood	**8.3**	**8.1**
NNs & binned likelihood	**6.4**	**5.0**
NLO theory	=0.88	=1.98

- New limits are a factor of 2 better than previous best
- Multivariate approach and binned likelihood have improved the limits

Conclusions

- We have completed a sophisticated final analysis and significantly improved the limits

World's Best Single Top Limits

***s*-channel 6.4 pb** ***t*-channel 5.0 pb**

- We have submitted a paper to *Physics Letters B* (can be found at hep-ex/0505063)

Fermilab-Pub-05/207-E

Search for single top quark production in $p\bar{p}$ collisions at $\sqrt{s}$ =1.96 TeV

V.M. Abazov,[35] B. Abbott,[72] M. Abolins,[62] B.S. Acharya,[29] M. Adams,[50] T. Adams,[46] M. Agelou,[18] J.-L. Agram,[19] S.H. Ahn,[31] M. Ahsan,[57] G.D. Alexeev,[38] G. Alkhazov,[39] A. Alton,[62] G. Alverson,[61] G.A. Alves,[2] M. Anastasoaie,[34] T. Andeen,[52] S. Anderson,[44] B. Andrieu,[17] Y. Arnoud,[14] A. Askew,[48] B. Åsman,[40] A.C.S. Assis Jesus,[3] O. Atramentov,[58] C. Autermann,[21] C. Avila,[8] F. Badaud,[13] A. Baden,[59] B. Baldin,[49] P.W. Balm,[33] S. Banerjee,[29] E. Barberis,[61] P. Bargassa,[76] P. Baringer,[56] C. Barnes,[42] J. Barreto,[2] J.F. Bartlett,[49] U. Bassler,[17] D. Bauer,[53] A. Bean,[56] S. Beauceron,[17] M. Begalli,[3] M. Begel,[68] A. Bellavance,[68] S.B. Beri,[27] G. Bernardi,[17] R. Bernhard,[49,*] I. Bertram,[41] M. Besançon,[18] R. Beuselinck,[42] V.A. Bezzubov,[38] P.C. Bhat,[49] V. Bhatnagar,[27] M. Binder,[28] C. Biscarat,[41] K.M. Black,[60] I. Blackler,[42] G. Blazey,[51] F. Blekman,[42] S. Blessing,[48] D. Bloch,[19] U. 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Oguri,[3] N. Oliveira,[3]

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- Expanding the analysis to prepare for observation
  - Include events with forward electrons
  - Perform an untagged analysis
  - Improve the neural network architecture (more signal-background pairs)

- Measured limits are quickly approaching the theoretical cross sections

A single top measurement is just around the corner! (or new physics!!)