Measurement of the Single Top Production Cross Section and |Vtb| at DØ

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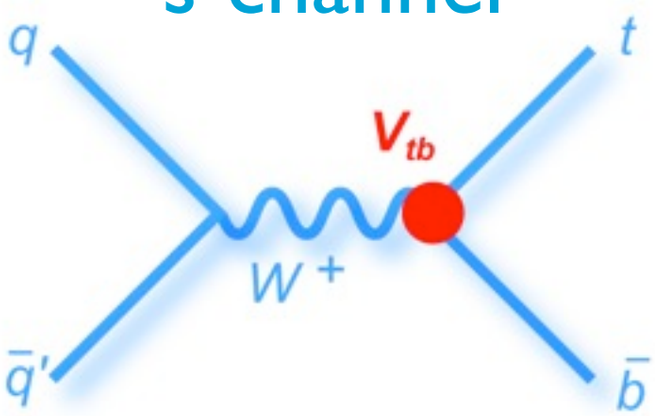
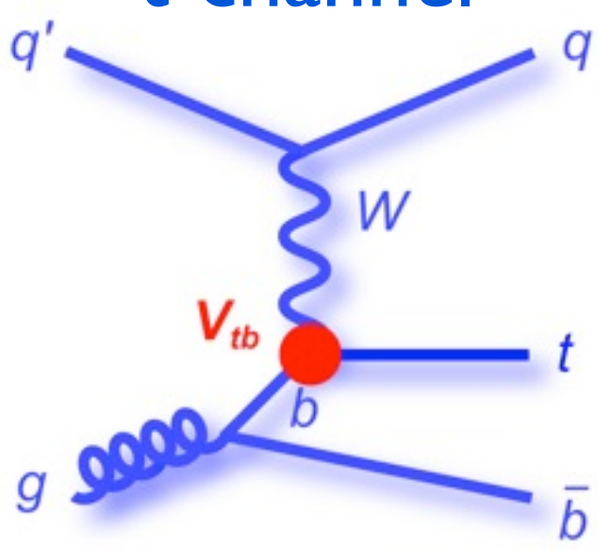
s- & t-channel for EW Production

s-channel



σ_{SM} = 1.04 ± 0.04 pb

t-channel



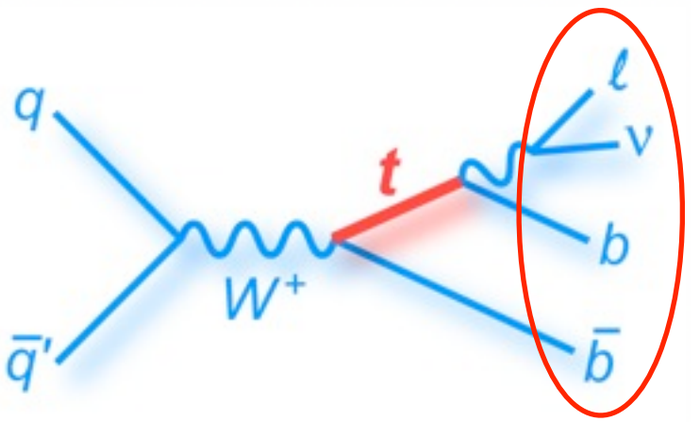
σ_{SM} = 2.26 ± 0.12 pb

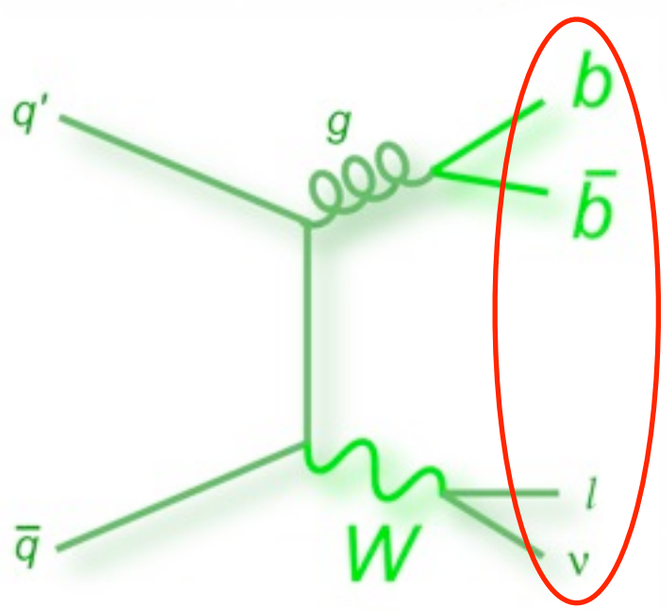
M_{top} = 172.5 GeV

N. Kidonakis, PRD 74.114012 (2006)

- Measure the two important single top production modes at Tevatron: s and t channel
- Directly probe the CKM matrix element |Vtb|
- Measure the top decay width
- New physics can change σ_s and σ_t differently:
  - σ_s: New bosons
  - σ_t: FCNC, anomalous couplings

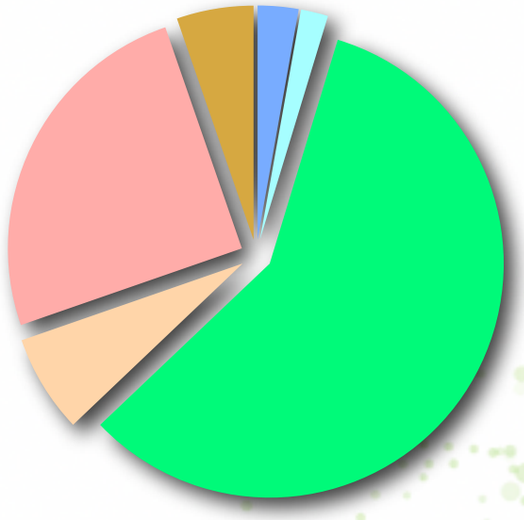
A Challenging Analysis



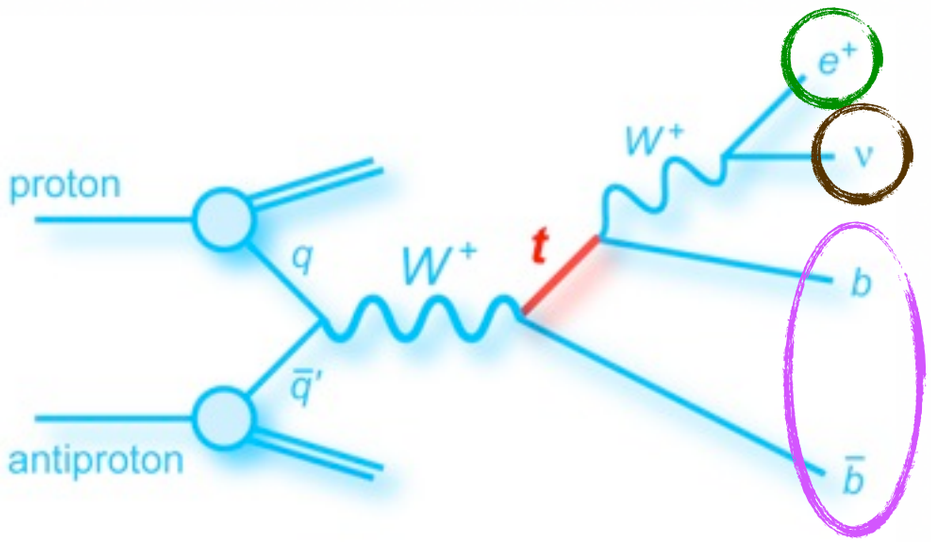


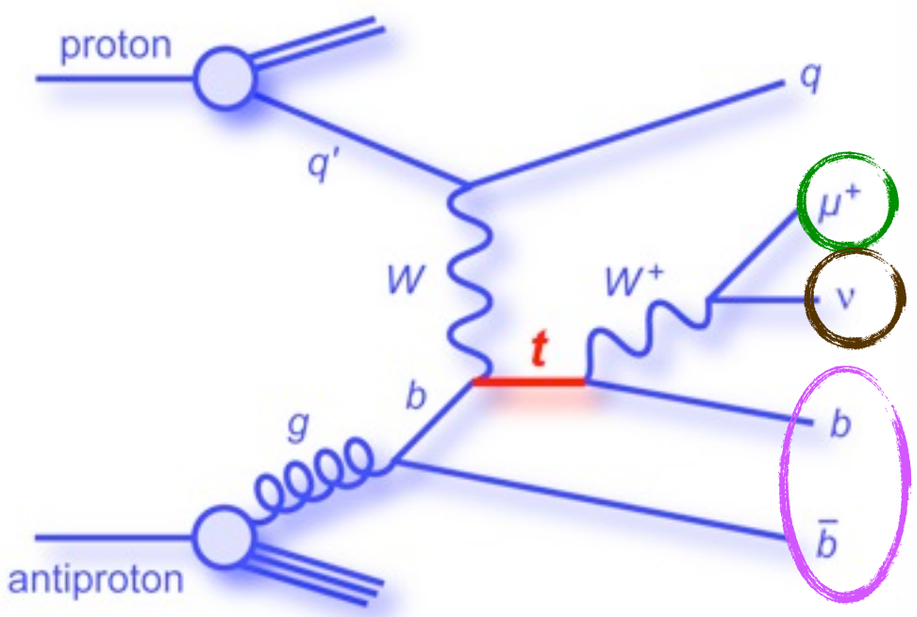
- Small cross section: ~3pb (1/2 of ttbar)
- Same final states as the background (e.g. W+jets)
- Background dominated: after b-jet identification, S:B ~1:20!!
- Observed after 14 years of ttbar observation!

t-channel	*s*-channel
W+jets	Z+jet, dibosons
tt	Multijets



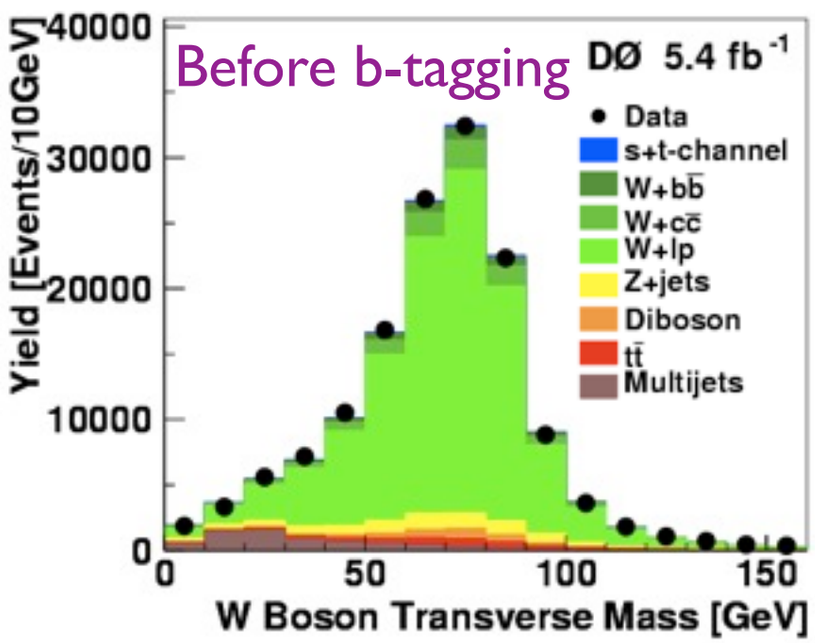
Event Selection

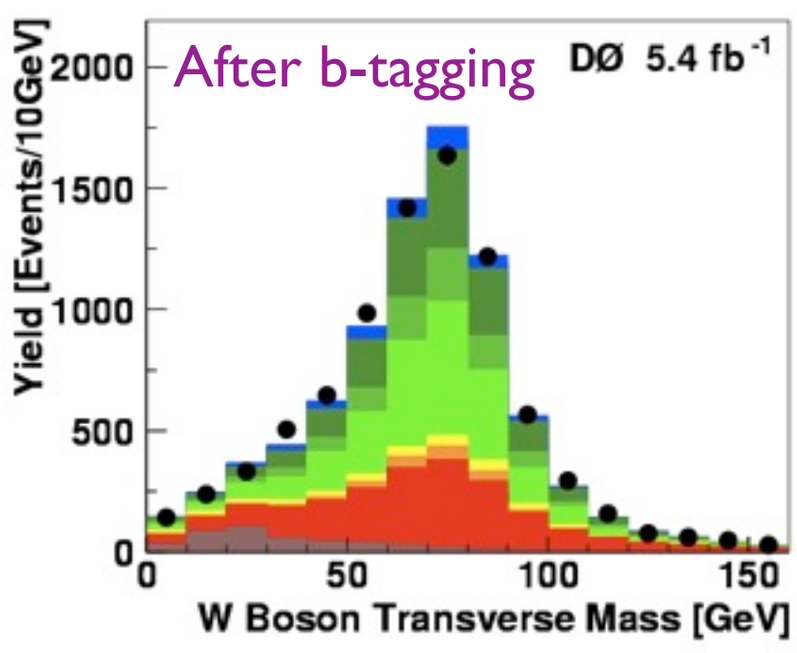




- 5.4 fb^{-1} dataset
- One high p_T isolated electron or muon: $p_T > 15$ GeV
  - electron: $|\eta^{det}| < 1.1$
  - muon: $|\eta^{det}| < 2.0$
- Large missing energy
- Two, three, or four jets
  - $p_T > 15$ GeV, $|\eta^{det}| < 3.5$
  - The leading jet $p_T > 25$ GeV
- Total transverse energy (H_T) cut to reject multijet background
- Require one or two b-tagged jets

Background Determination

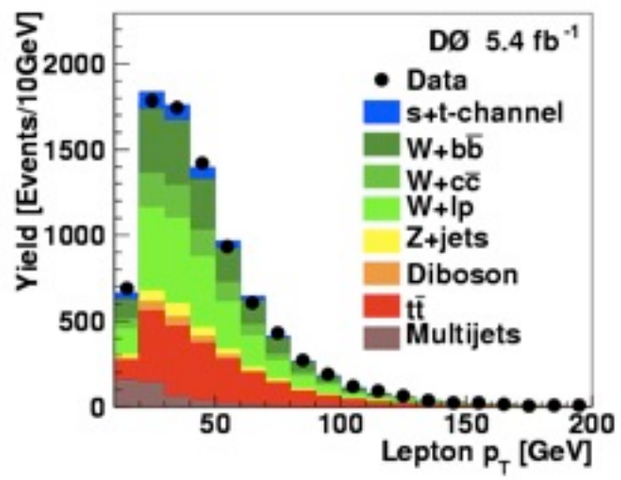




- Signals: CompHEP+Pythia
- W+jets and ttbar: Alpgen+Pythia
- QCD: Data with not isolated lepton
- W+jets NLO/LL factors: 1.836/1.648/1.249 (Wbb+Wcc/Wcj/Wjj)
- Apply angular corrections on jetsη
- Normalize W+jets and QCD to data
- After b-tagging:
  - No extra corrections for W+heavy flavors are needed.
  - Wbb+Wcc :Wcj :Wjj ~ 1/3:1/3:1/3

Multivariate Analyses

Good data-MC agreement in all input variables!



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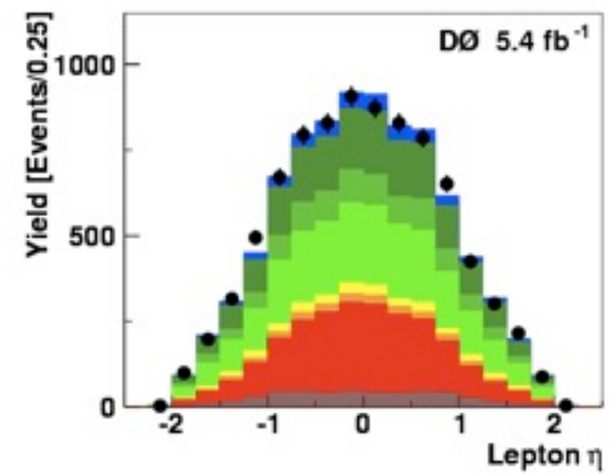

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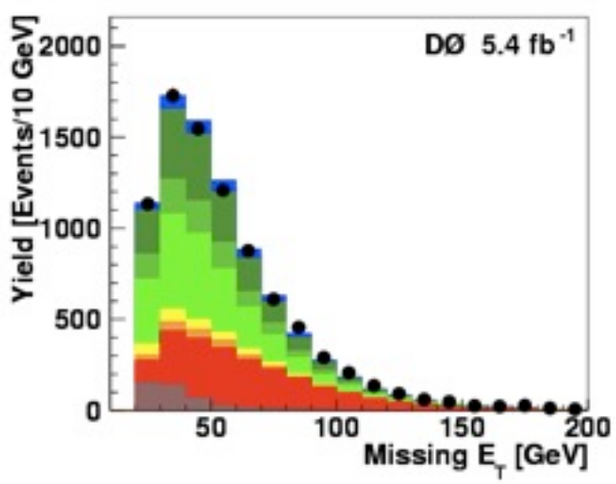

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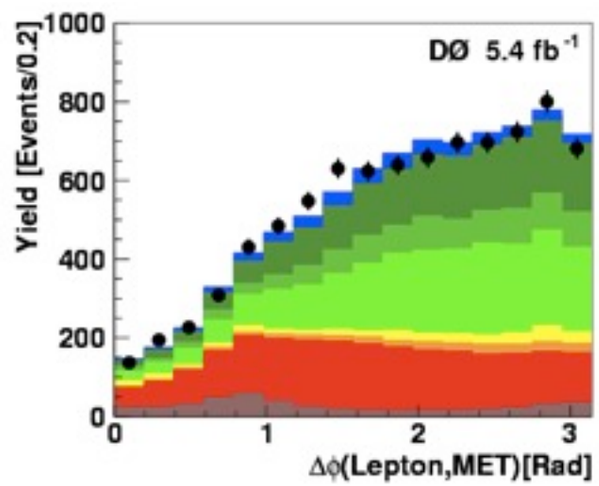

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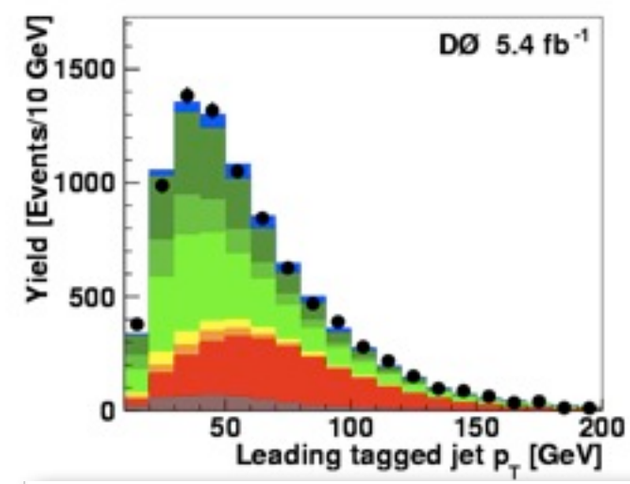

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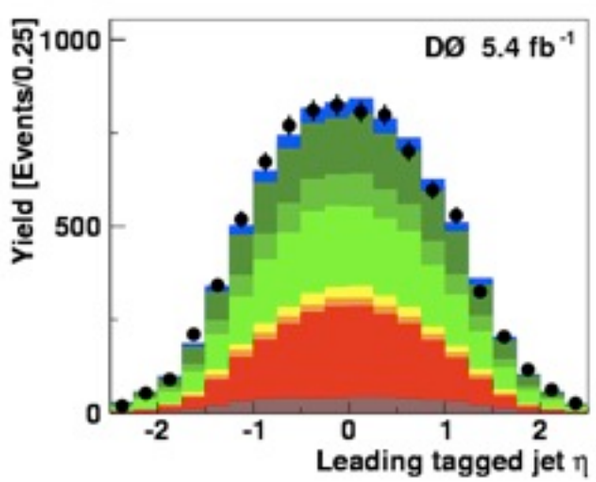

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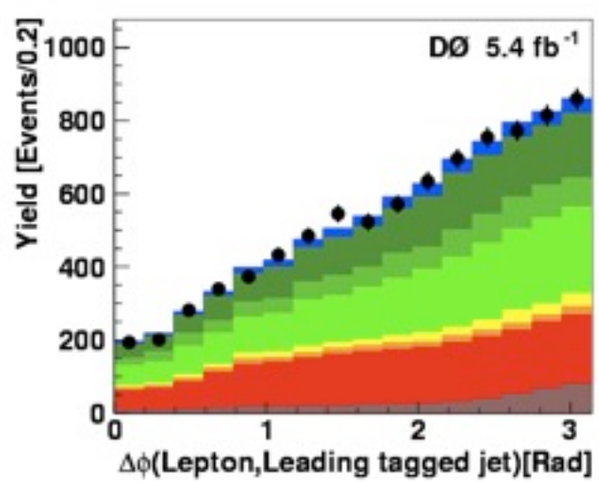

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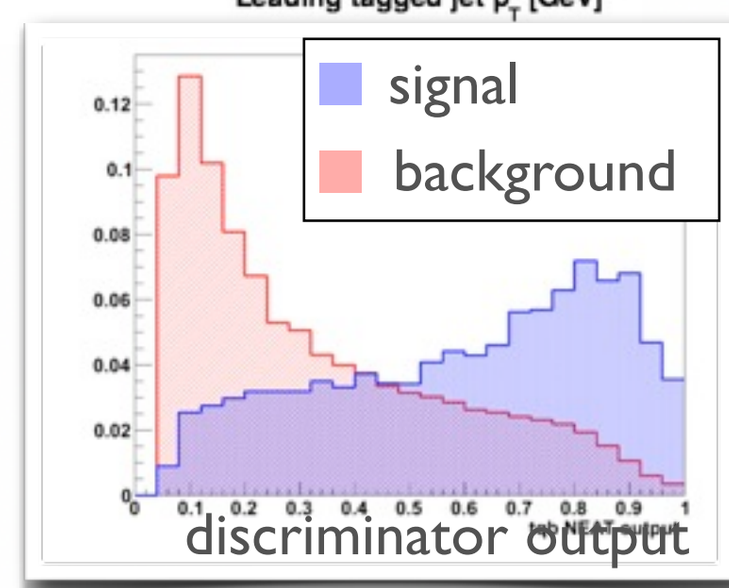
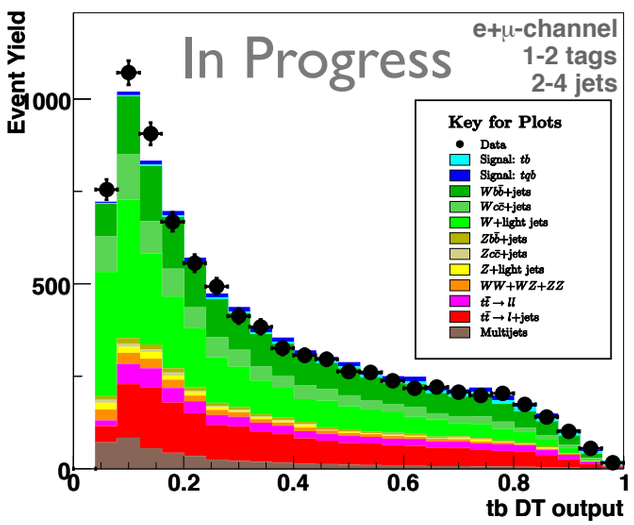
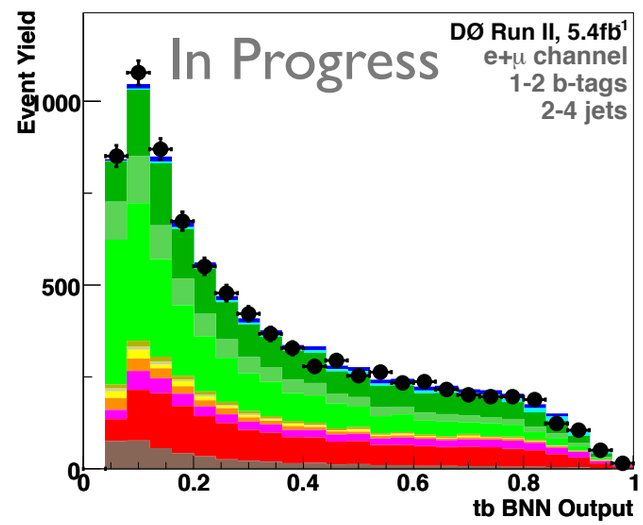


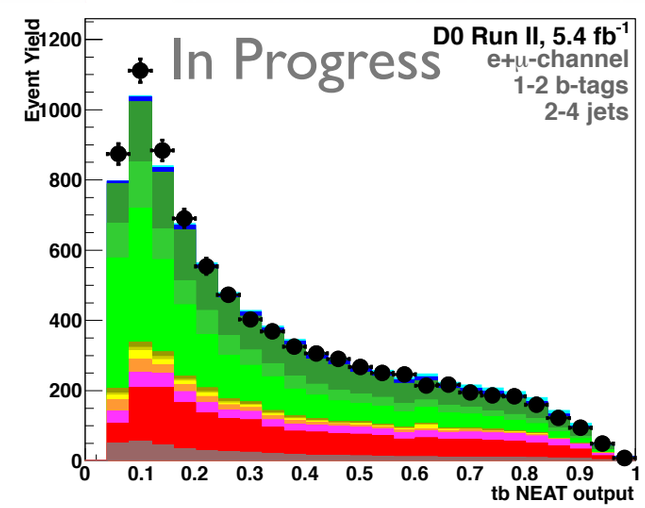
Multivariate Analyses

- The same 3 MVAs are used as the t-ch search (previous talk)

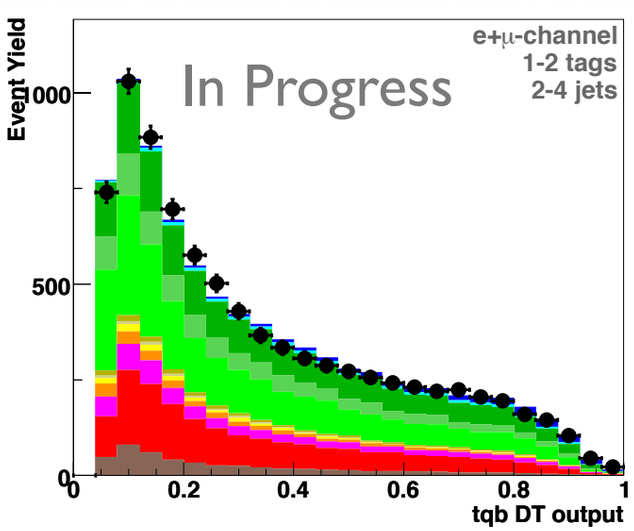
s-ch discriminants

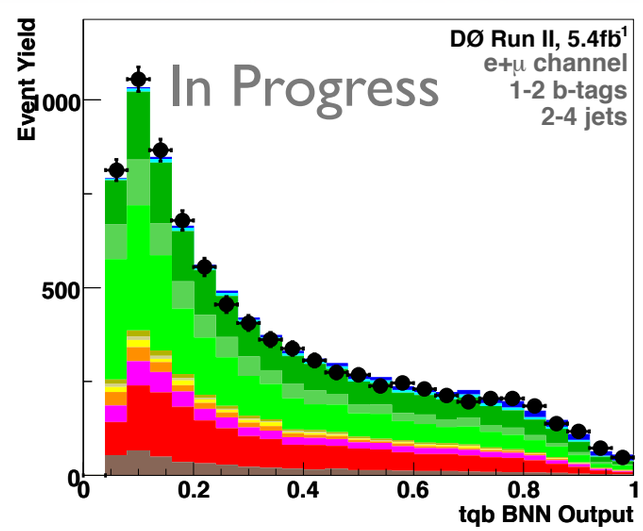


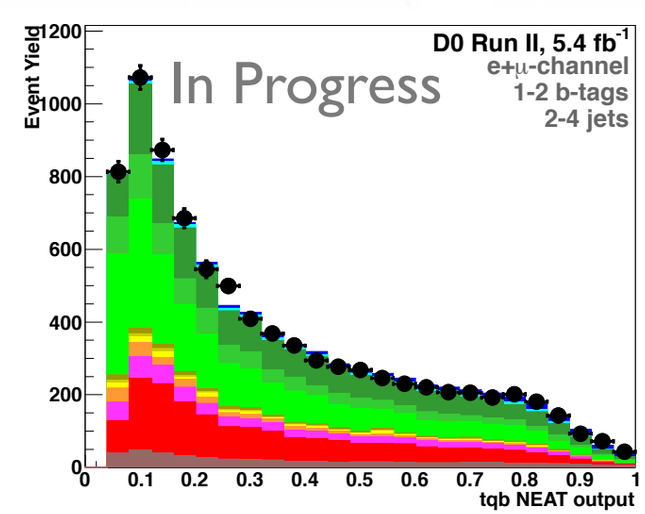




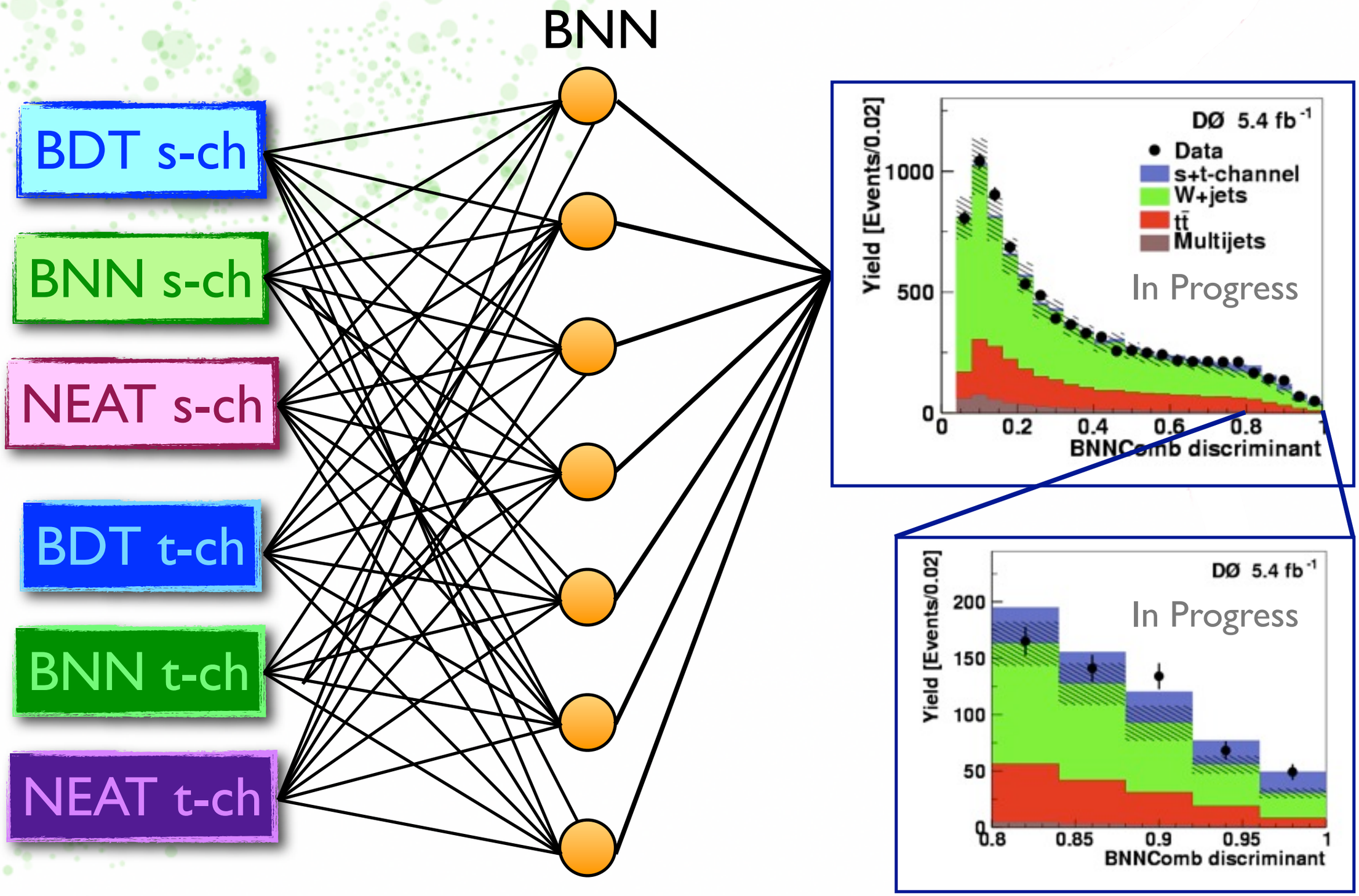
t-ch discriminants





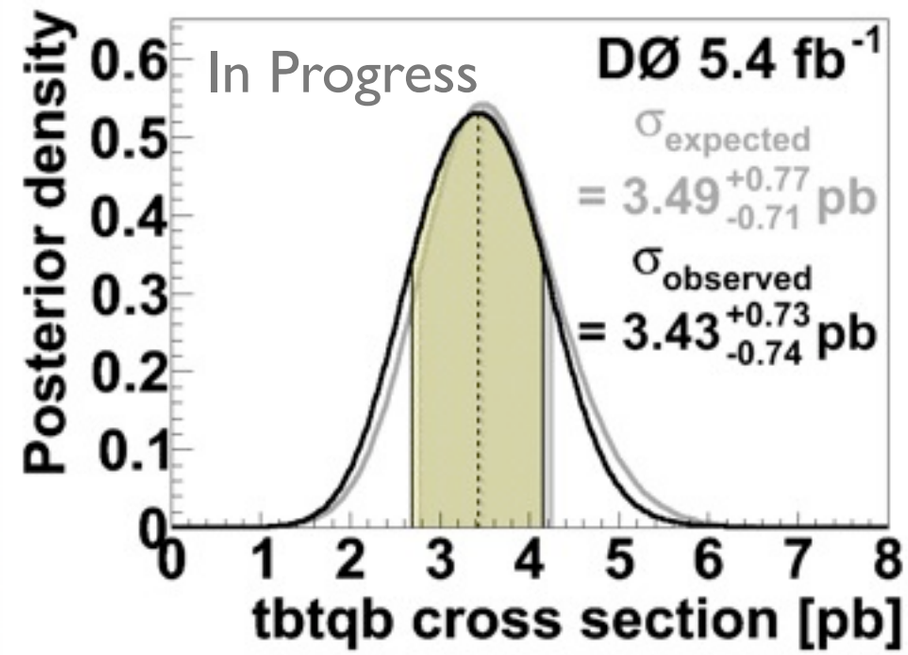


Combined Discriminants



Cross Sections

- Bayesian posterior probability density
  - Binned likelihood
  - No cut on the discriminants
- Poisson distribution for the observed data
- Flat, non-negative prior for signal cross section
- Uncertainties and their correlations taken into account
- Measured cross section: Peak
- Uncertainty: Width (68% area)



- Result:

$$\sigma(p\bar{p} \to tb + X, tqb + X) = 3.43^{+0.73}_{-0.74}\ pb$$

Uncertainty: 21%

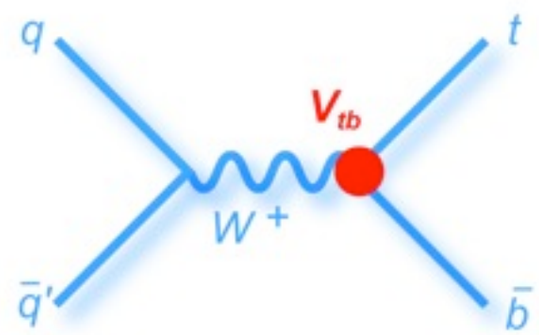
- Remark: ttbar→lepton+jets

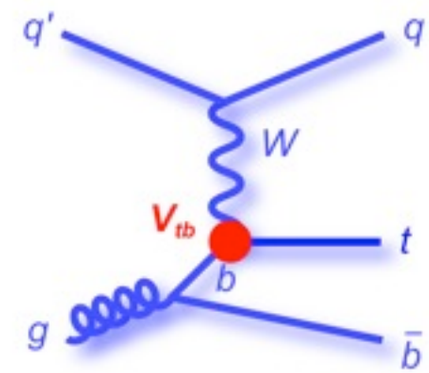
$\sigma_{t\bar{t}} = 7.78^{+0.77}_{-0.64}\ pb$

Uncertainty: 9%, ref. link

CKM Matrix Element |Vtb|

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$





- Most general Wtb vertex:

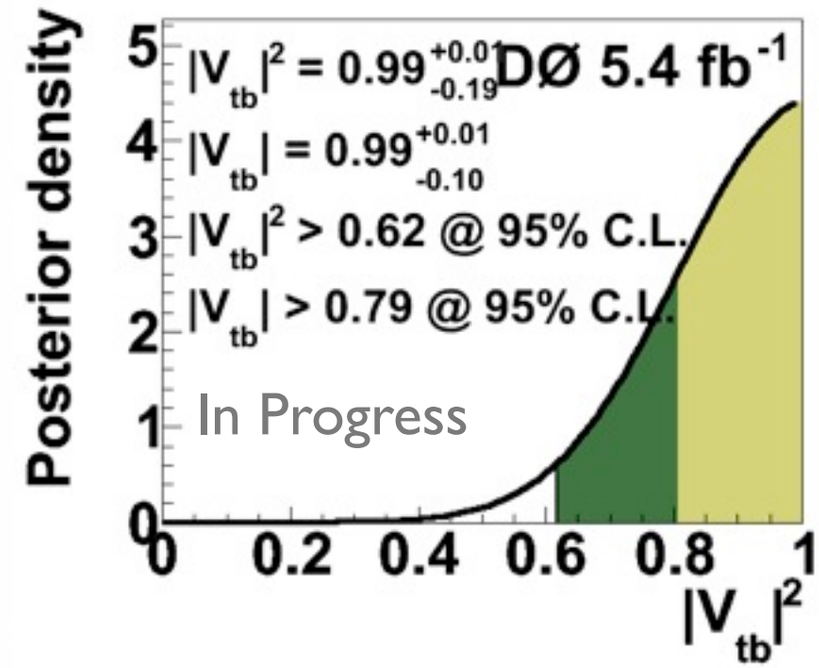
$$\Gamma^{\mu}_{Wtb} = -\frac{g}{\sqrt{2}} V_{tb} \{\gamma^{\mu}[f_1^L P_L + f_1^R P_R] - \frac{i\sigma^{\mu\nu}}{M_W}(p_t - p_b)_{\nu}[f_2^L P_L + f_2^R P_R]\}$$

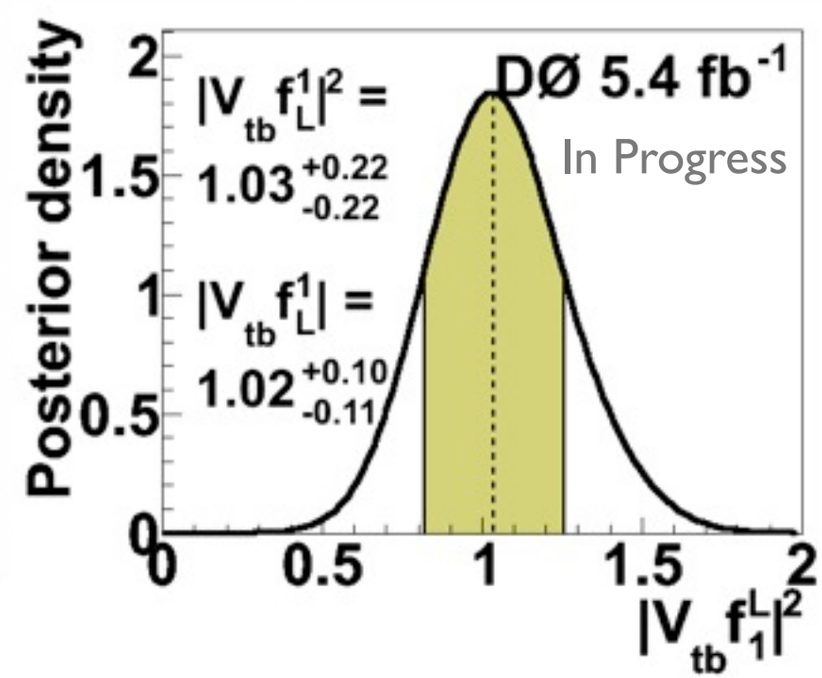
- Assume:
  - SM top decay: $|V_{td}|^2 + |V_{ts}|^2 << |V_{tb}|^2$
  - Pure V-A interaction: $f_1^R = 0$
  - CP conservation: $f_2^R = f_2^R = 0$
- Neither assumption on 3 generations nor unitarity of the CKM matrix

  ⇒Effectively measuring $|V_{tb} f_1^L|^2$, which can be >1

CKM Matrix Element |Vtb|

- Assume $0 \leq |V_{tb}|^2 \leq 1$
  - $|V_{tb}| > 0.79$ @ 95% C.L.
- Allow $|V_{tb} f_1^L|^2 > 1$
  - $|V_{tb} f_1^L| = 1.02^{+0.10}_{-0.11}$
- Additional systematic uncertainties
  - theoretical uncertainty on single top cross section
  - applied to s- and t-ch samples separately
- Complementary to $R_{Wb/Wq}$ measurement in tt decays
  - PRL 100, 192003 (2008)





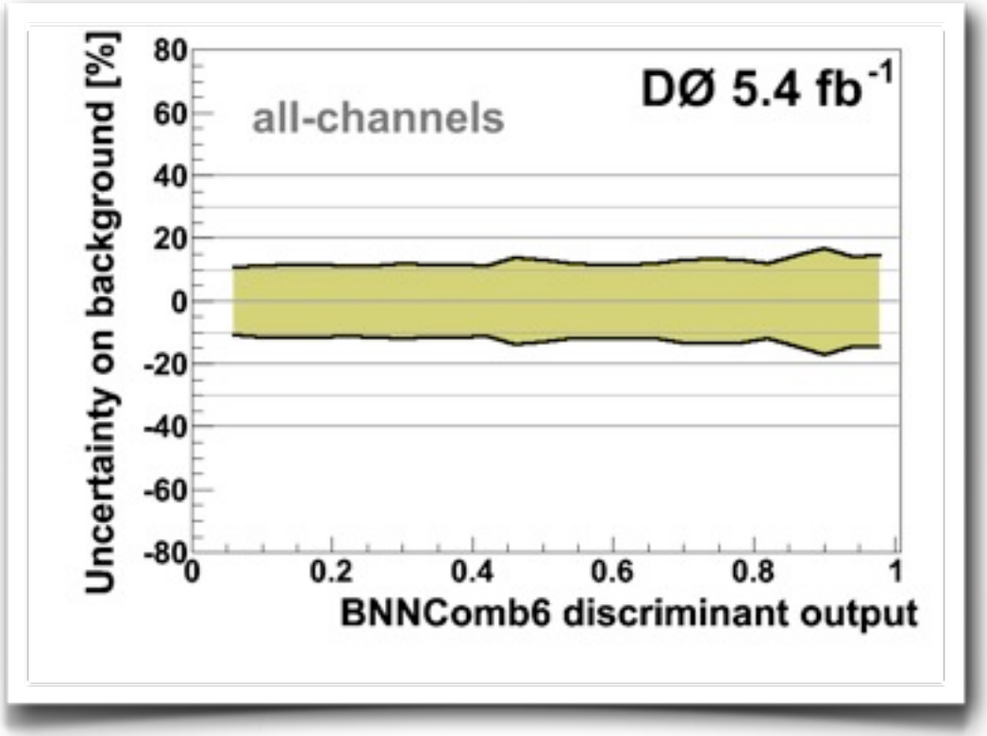
Conclusions

- Measure the single top production cross sections using 5.4 fb^{-1} dataset collected at DØ
- Combine 3 MVAs: BDT, BNN, and NEAT, using 6 variables
- $\sigma(p\bar{p} \to tb + X, tqb + X) = 3.43^{+0.73}_{-0.74}\ pb$
  21% total uncertainty, 13% stats, 17% systs
- $|V_{tb} f_1^L| = 1.02^{+0.10}_{-0.11}$
- Still to come with 5.4 fb^{-1} dataset:
  - top width measurement
  - anomalous Wtb couplings
  - CP violation
  - Charged Higgs search

Backup Slides

Systematic Uncertainties

- Most important ones:
  - W+jets heavy flavor scale factor (12%)
  - Jet energy scale (<15%)
  - Jet energy resolution (<12%)
  - b-jet Taggability (22%)
  - b-tagging (<14%)
  - Integrated luminosity (6%)



- New ones:
  - Color reconnection (1%)
  - Relative b / light-jet calorimeter response (<1%)
  - Higher-order jet fragmentation effects (few %)