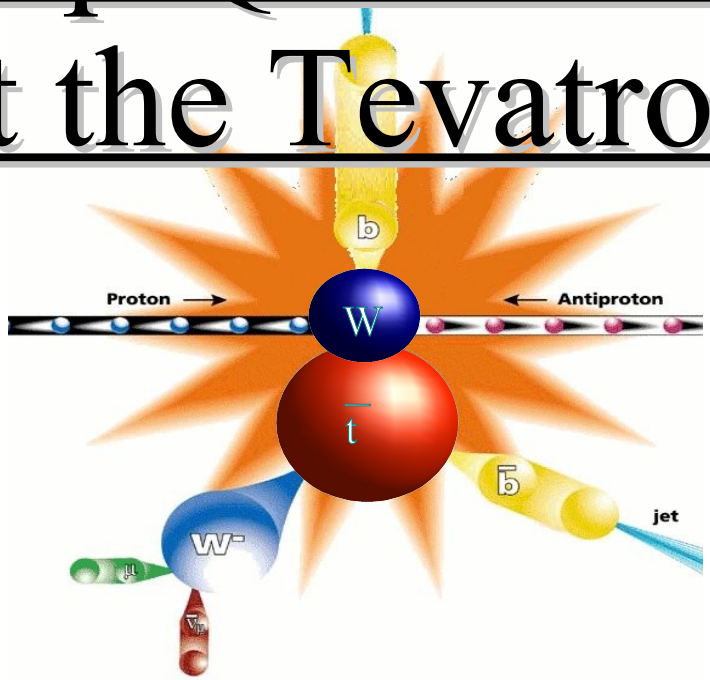
Single Top Quark Production at the Tevatron



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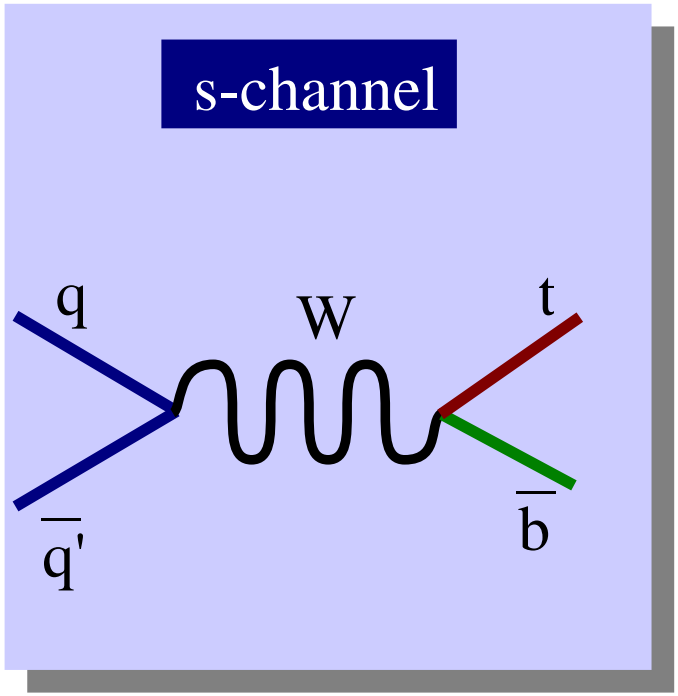
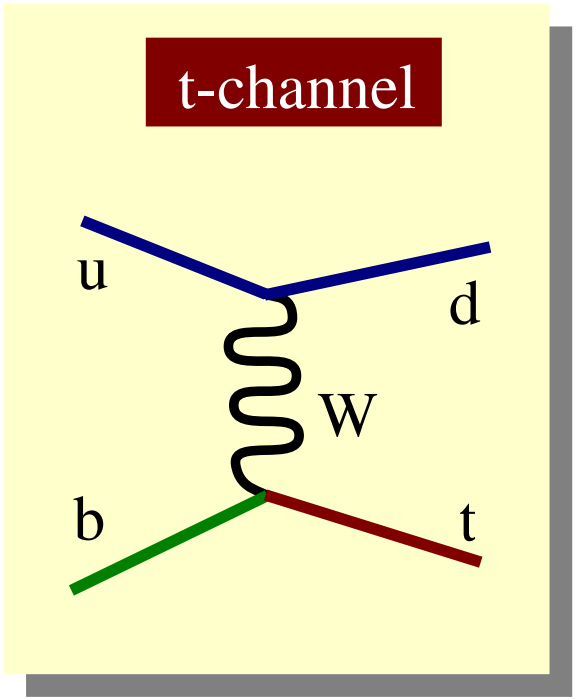
MICHIGAN STATE UNIVERSITY

on behalf of the DØ and CDF collaborations

Rencontres de Moriond EW 2008

SM single top quark production





SM cross section:

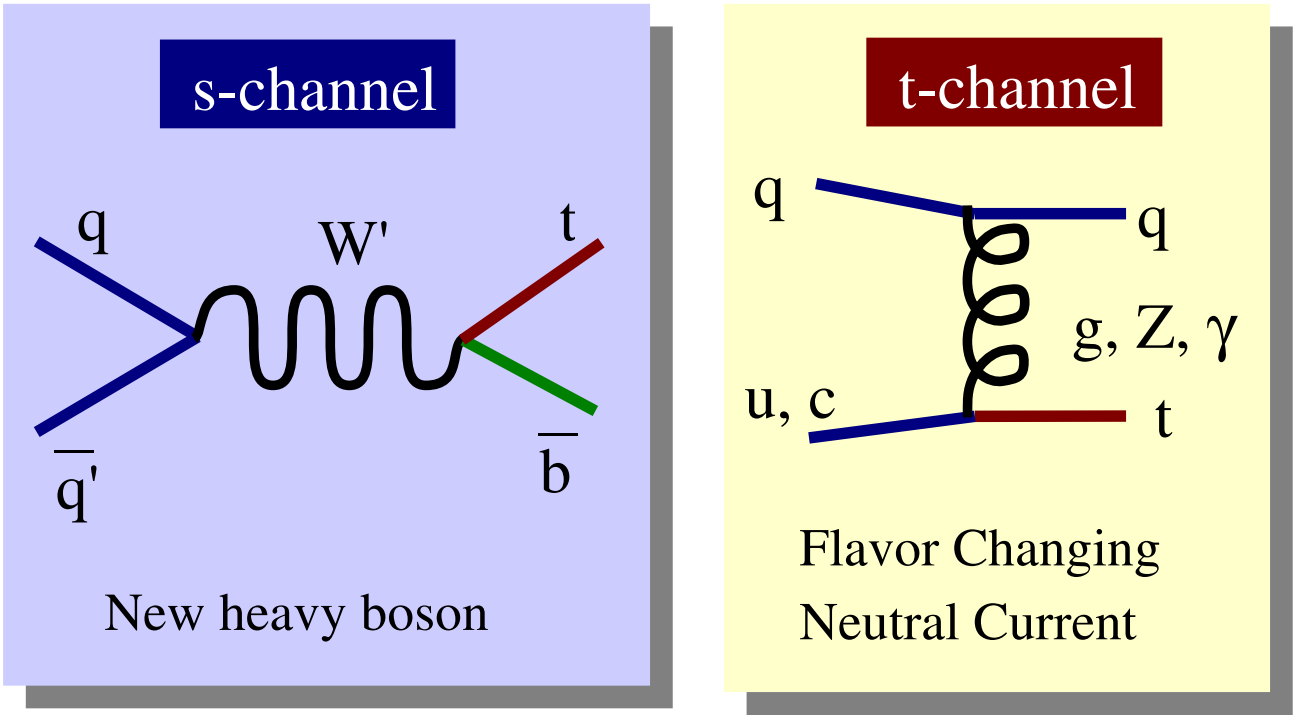
$\sigma_{tot} = 3$ pb

$\sigma_s = .88$ pb $\sigma_t = 1.98$ pb

Tevatron Goals:

- Discover single top quark production
- Measure production cross sections σ_s, σ_t
- First direct measurement CKM matrix element V_{tb}
- Study top quark spin polarization
- Understand as background to many searches
- Establish techniques that will also be used in Higgs searches

New physics in single top



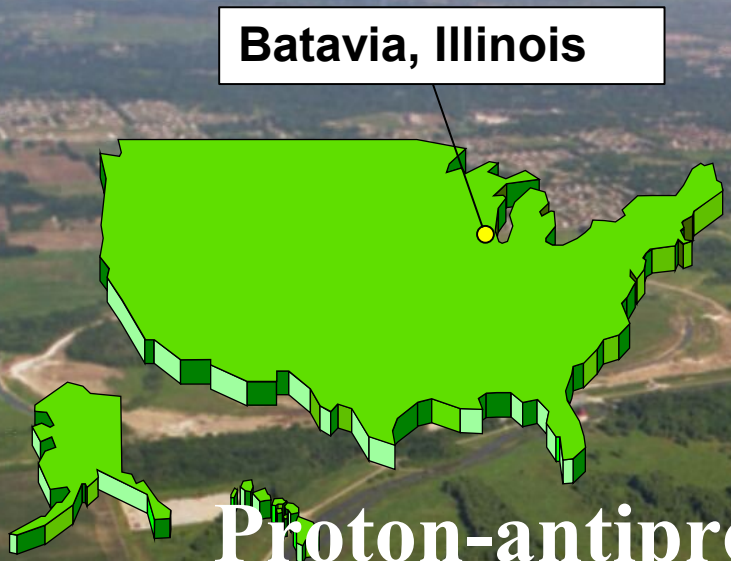
- Recent results:
  - Limits on W' from DØ and CDF:
    - M(W') > 800 GeV to 825 GeV, depending on couplings and decays

DØ: PLB 641:423-431 (2006)

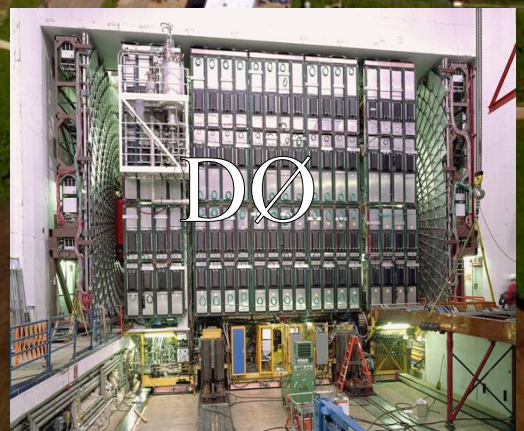
  - FCNC gluon coupling limits from DØ:
    - limit coupling $\kappa^c/\Lambda < 0.15$ TeV^{-1} and $\kappa^u/\Lambda < 0.038$ TeV^{-1}

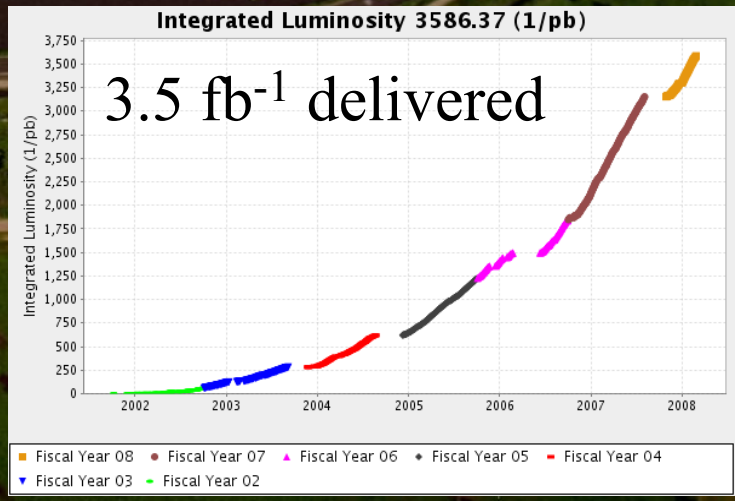
PRL 99:191802 (2007)

Fermilab Tevatron

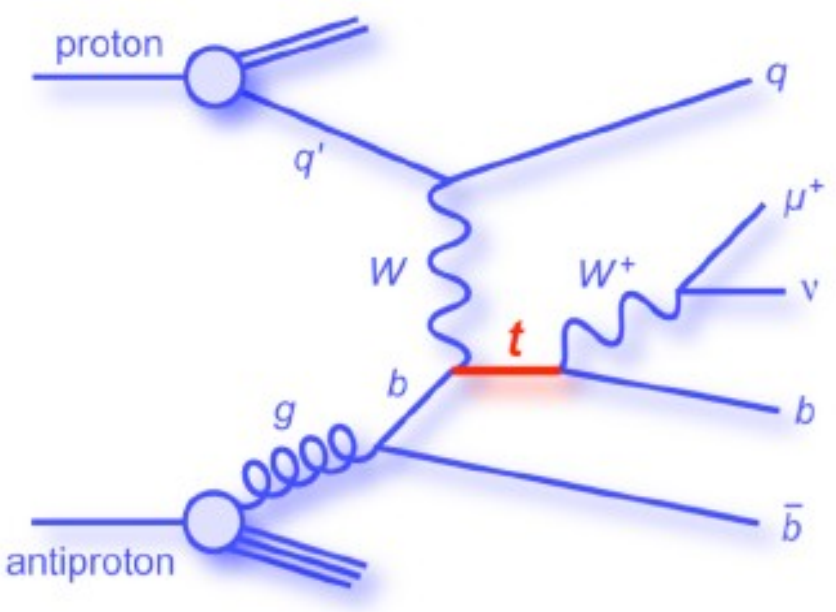


Proton-antiproton collider
CM energy 1.96TeV
→ *Energy frontier*
Instantaneous luminosity reaching 300E30cm^{-2}s^{-1}
→ *Luminosity frontier*



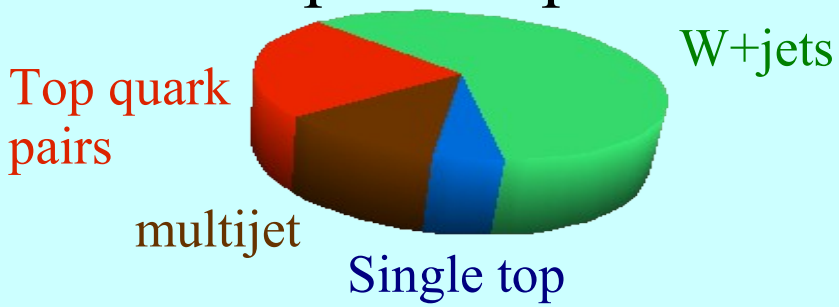


Single top event selection



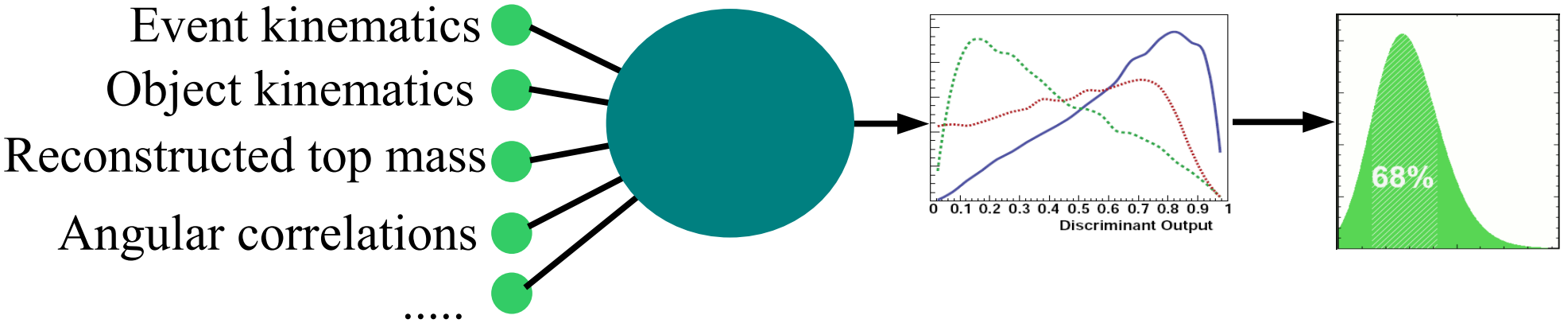
- Basic event signature (e or μ)
  - Single lepton trigger or lepton+jets trigger
  - One high-E_T leptons
    - E_T > 20 GeV or 15 GeV
  - Missing transverse energy
    - Missing E_T > 25 GeV or 15 GeV
  - 2-3 high-E_T jets (2-4 jets)
    - E_T > 15 GeV
  - At least one b-tag
- Expect ~ 50 signal events per fb^{-1}
  - After b-tagging
  - S:B ~ 1:20

Event sample composition

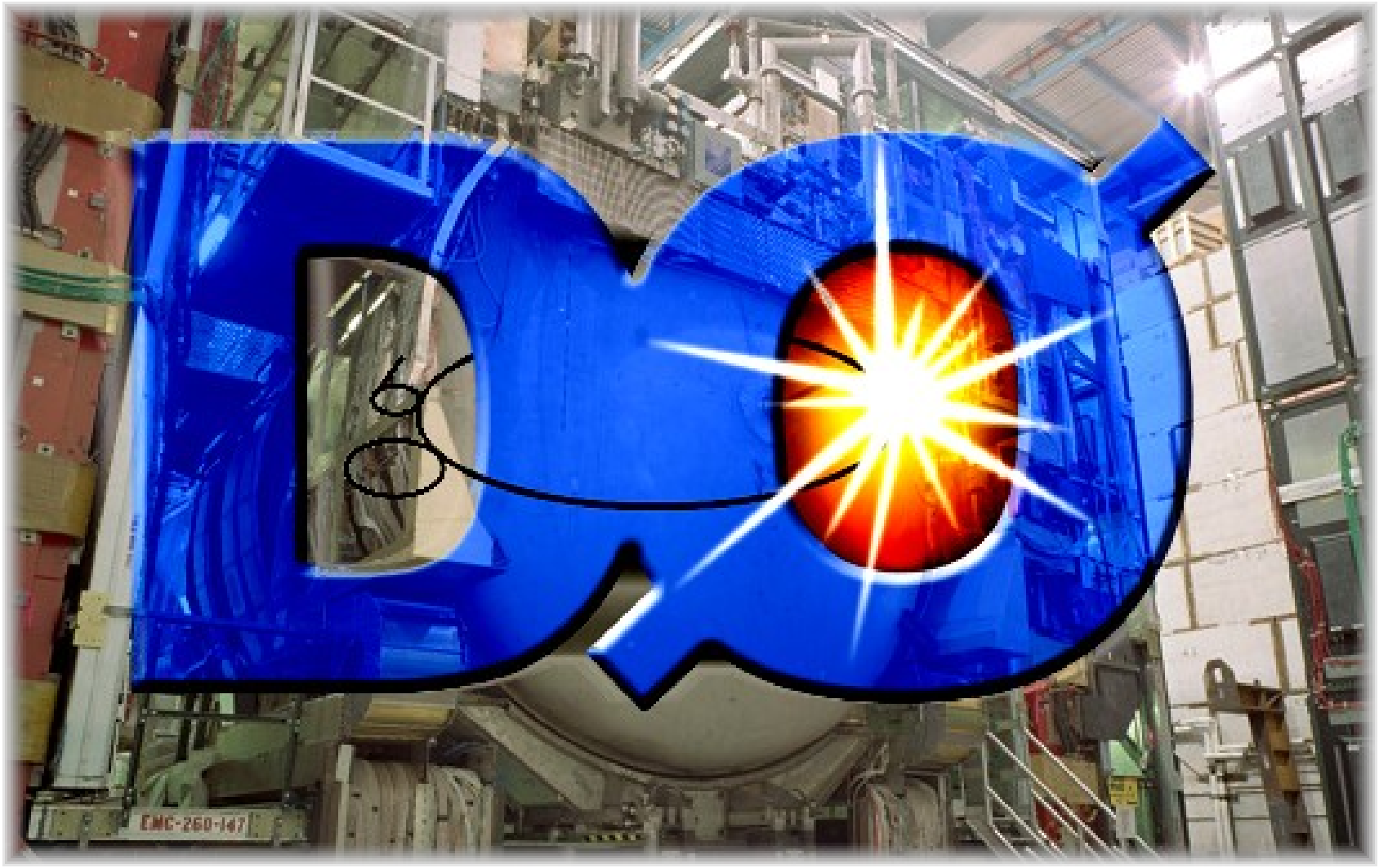


Single top analysis

discriminating variables | multivariate classifier | signal likelihood | statistical analysis



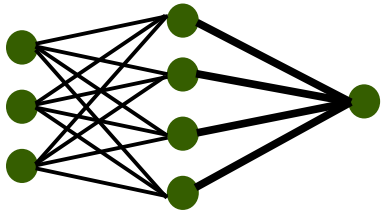
- Classifiers:
  - Likelihood function
  - Neural network
  - Bayesian neural networks
  - Boosted decision trees
  - Matrix Element
- Systematic uncertainties:
  - Normalization uncertainties, for example background composition (10-30%)
  - Shape uncertainty, for example jet energy scale, b-tagging
  - Implement as nuisance parameters



- Update to 0.9 fb^{-1} analysis (3.4 σ, PRL 98, 181802 (2007))
  - Improved Bayesian Neural Network analysis
  - Improved Matrix Element analysis

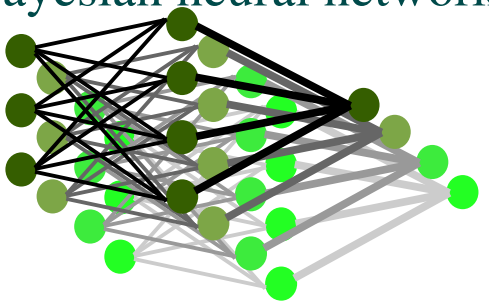
Bayesian neural networks

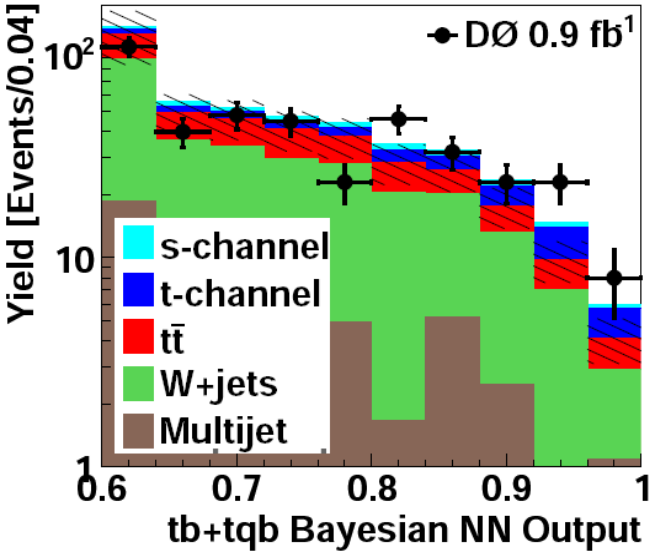
Single network

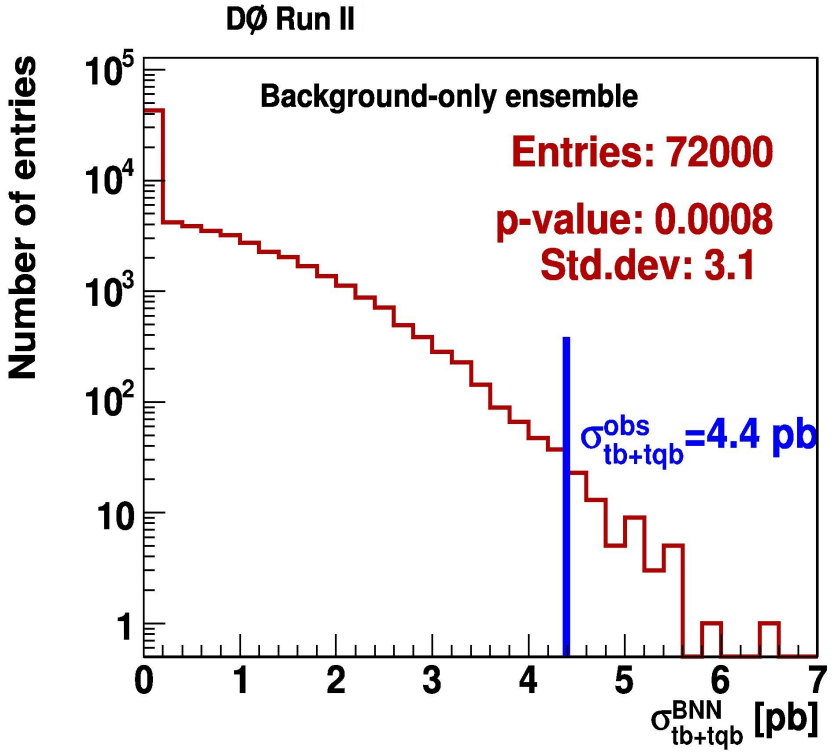


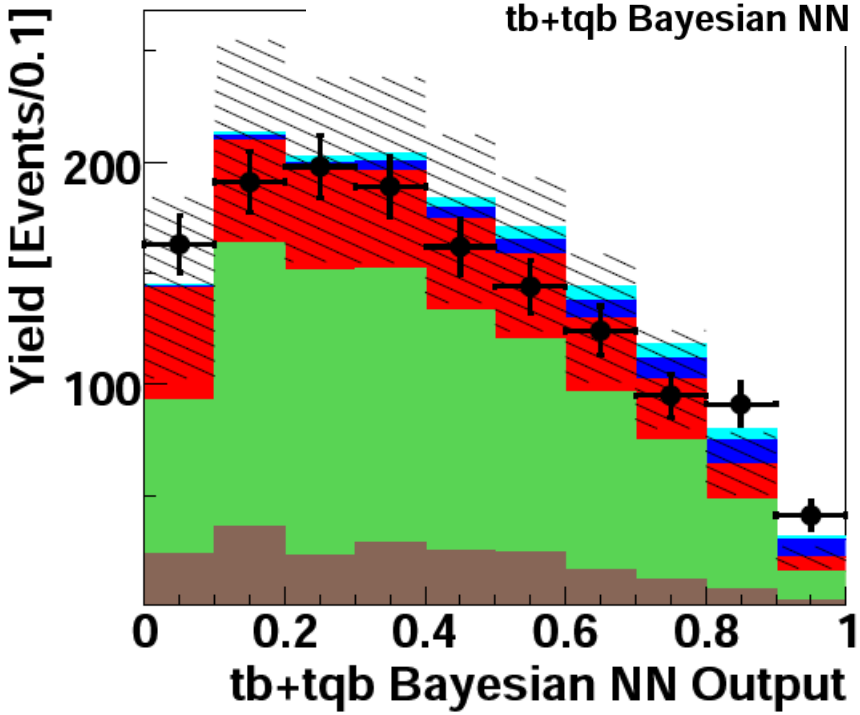
integrate over possible network parameters

Bayesian neural networks



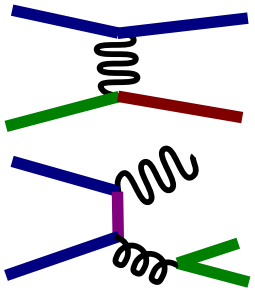






Matrix element

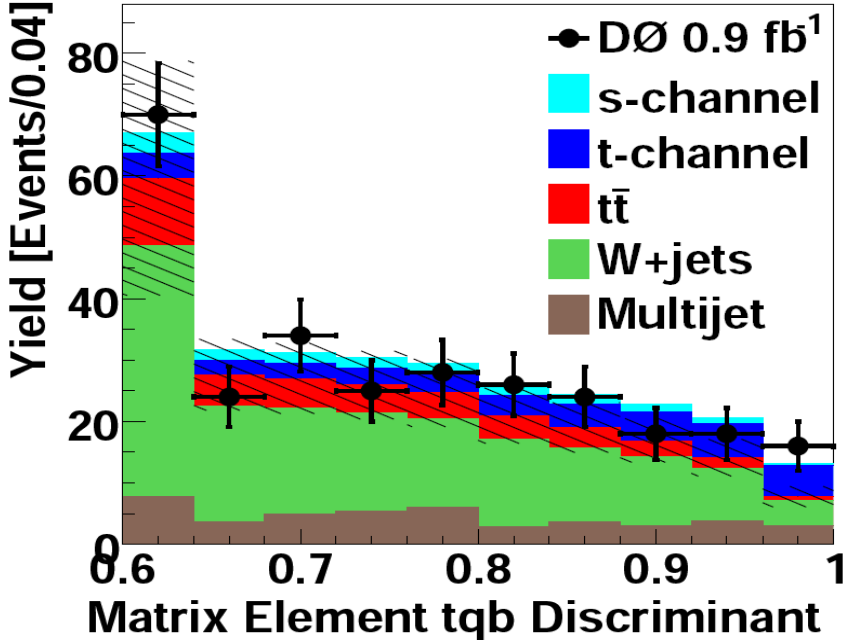
Parton level matrix elements



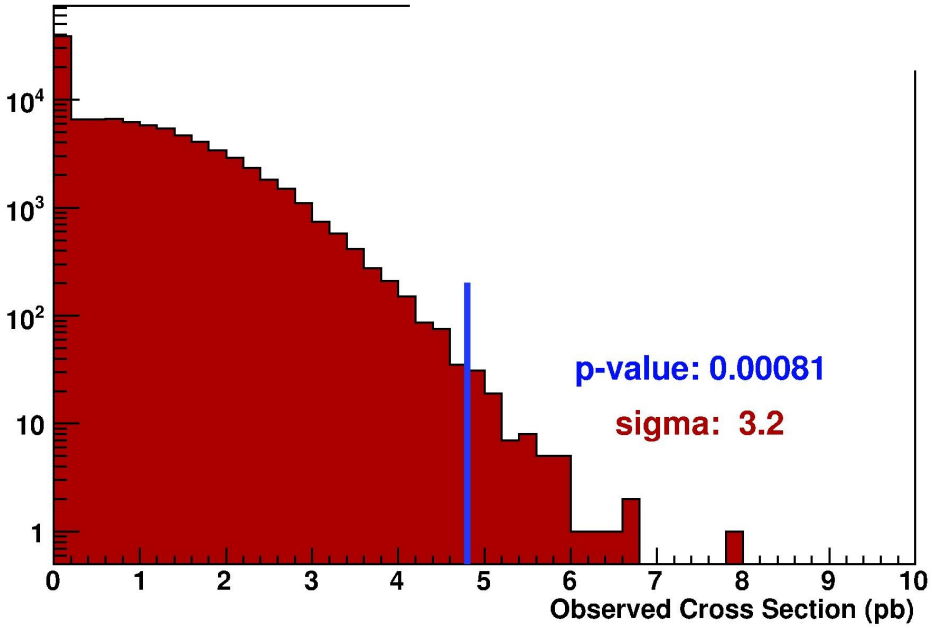
integrate over measurement uncertainties

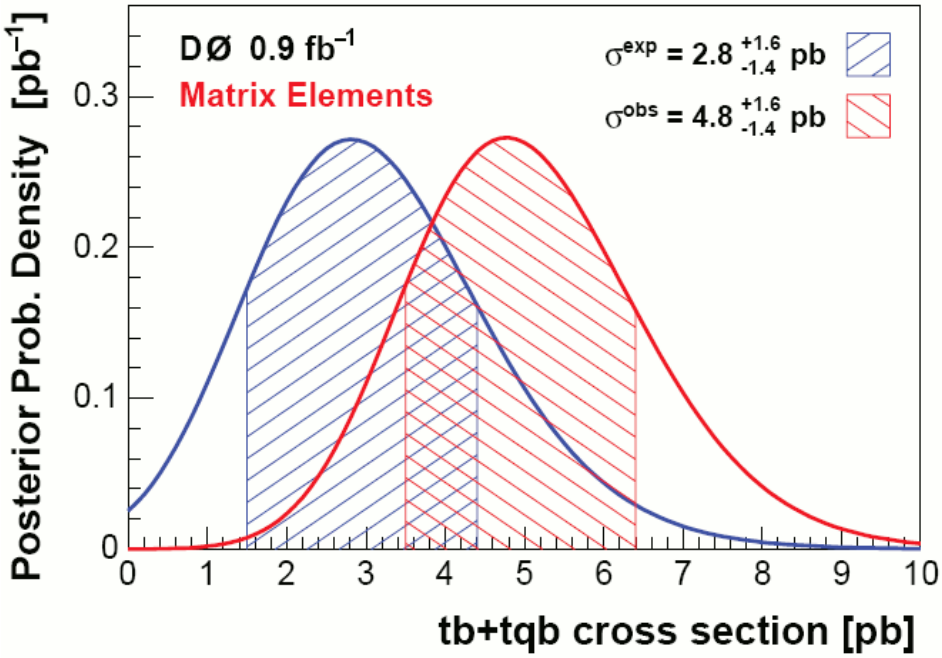
Signal discriminant

$$L = \frac{P(sig)}{P(sig)+P(bkg)}$$



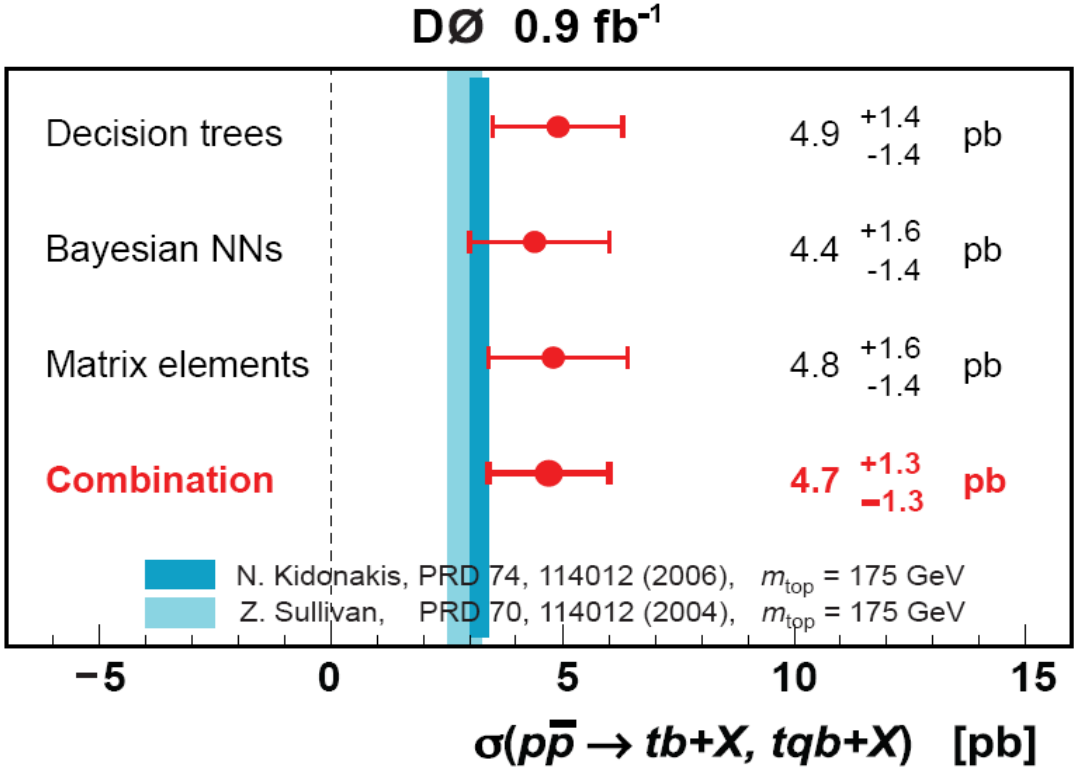
- Include ME for s, t, Wbb, Wcg, Wgg
- In 3-jet bin also $tt \rightarrow l$+jets



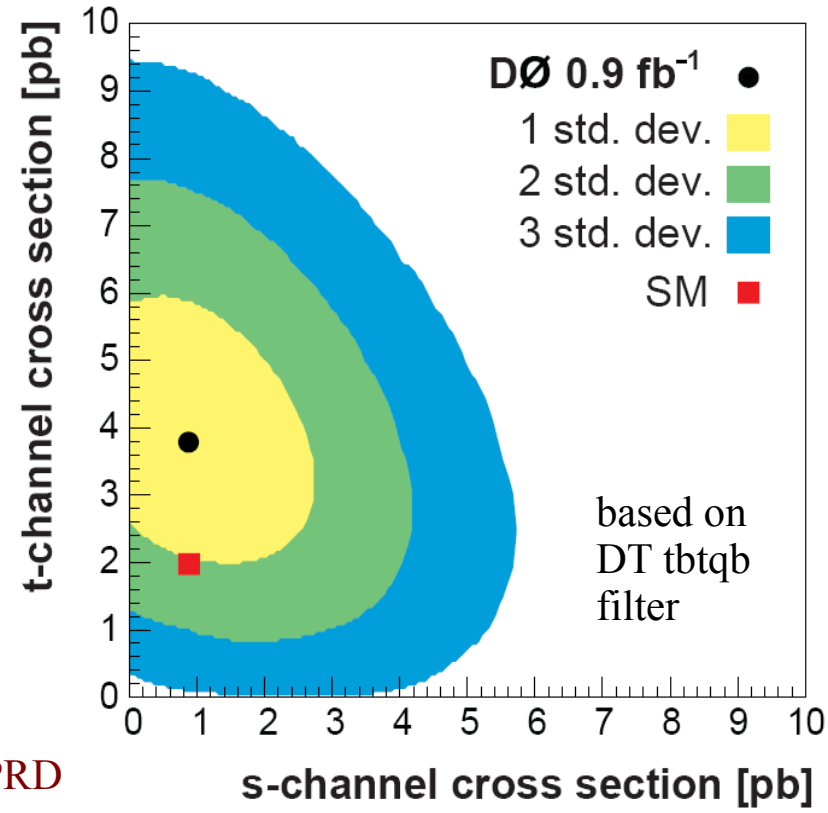


Summary

- Combination using BLUE method
  - Using large sets of ensembles for weights and correlations



3.6 σ evidence for single top (2.3 σ expected)



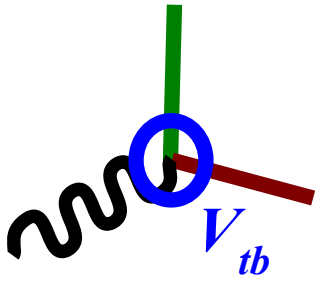
$\sigma(s+t) = 4.7 \pm \mathbf{1.3}$ pb

$\sigma(s) = 1.0 \pm \mathbf{0.9}$ pb

$\sigma(t) = 4.2\ ^{+\mathbf{1.8}}_{\mathbf{-1.4}}$ pb

submitted to PRD

CKM matrix element $|V_{tb}|$



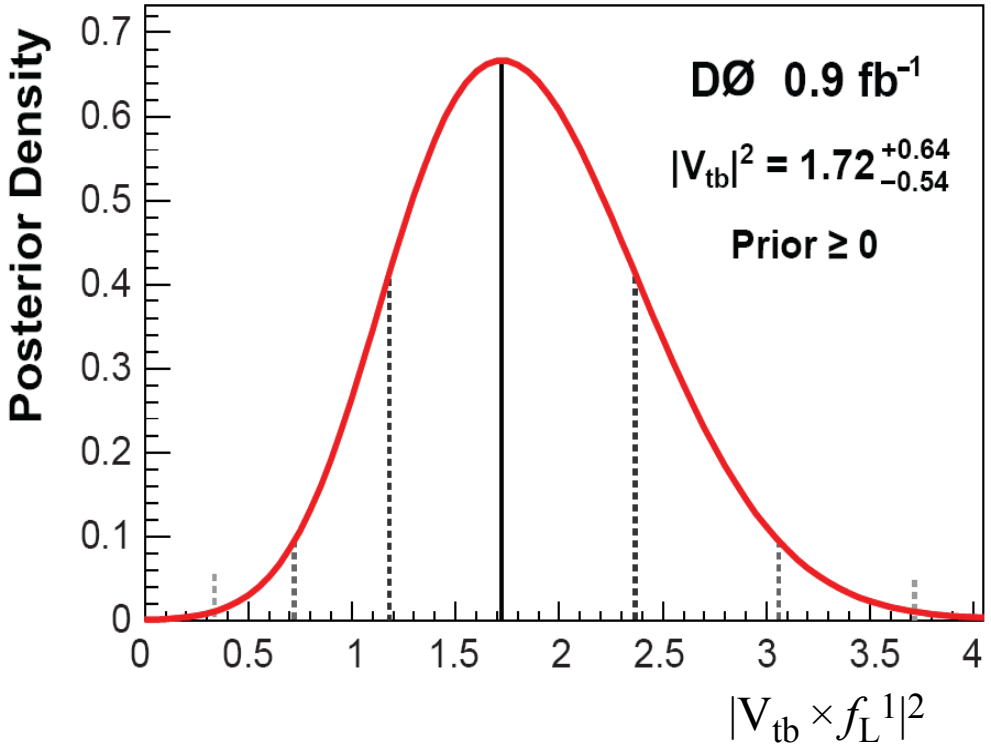
CKM Matrix

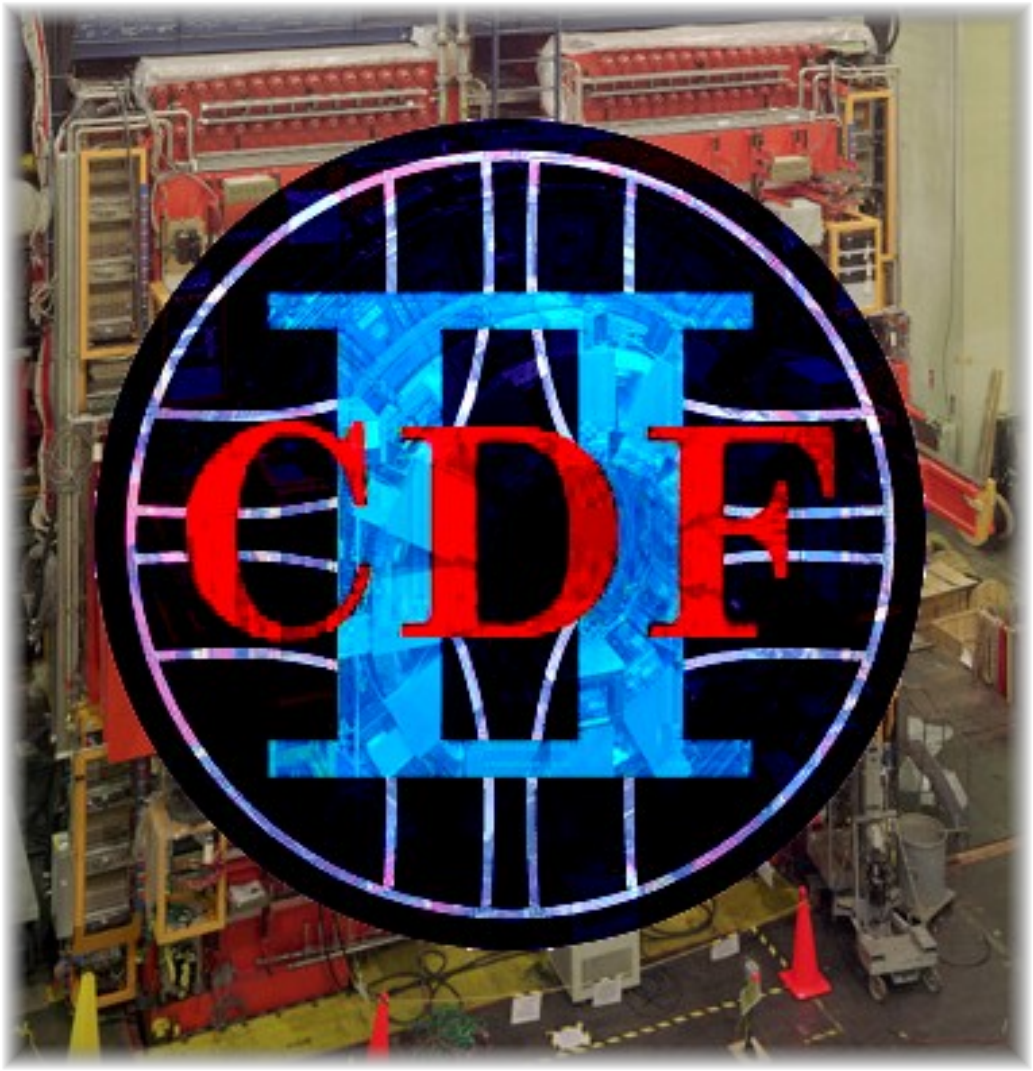
$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

- Measurement: $|V_{tb} \times f_L{}^1|$
  - Based on DT result
  - Assume top decays to b ($V_{tb} \gg V_{ts}, V_{td}$)
- No constraint on # of generations
- Assume $f_L{}^1 = 1$

  $\rightarrow$ lower limit on V_{tb}
  - At the 95% C.L.:

|Vtb| > 0.68

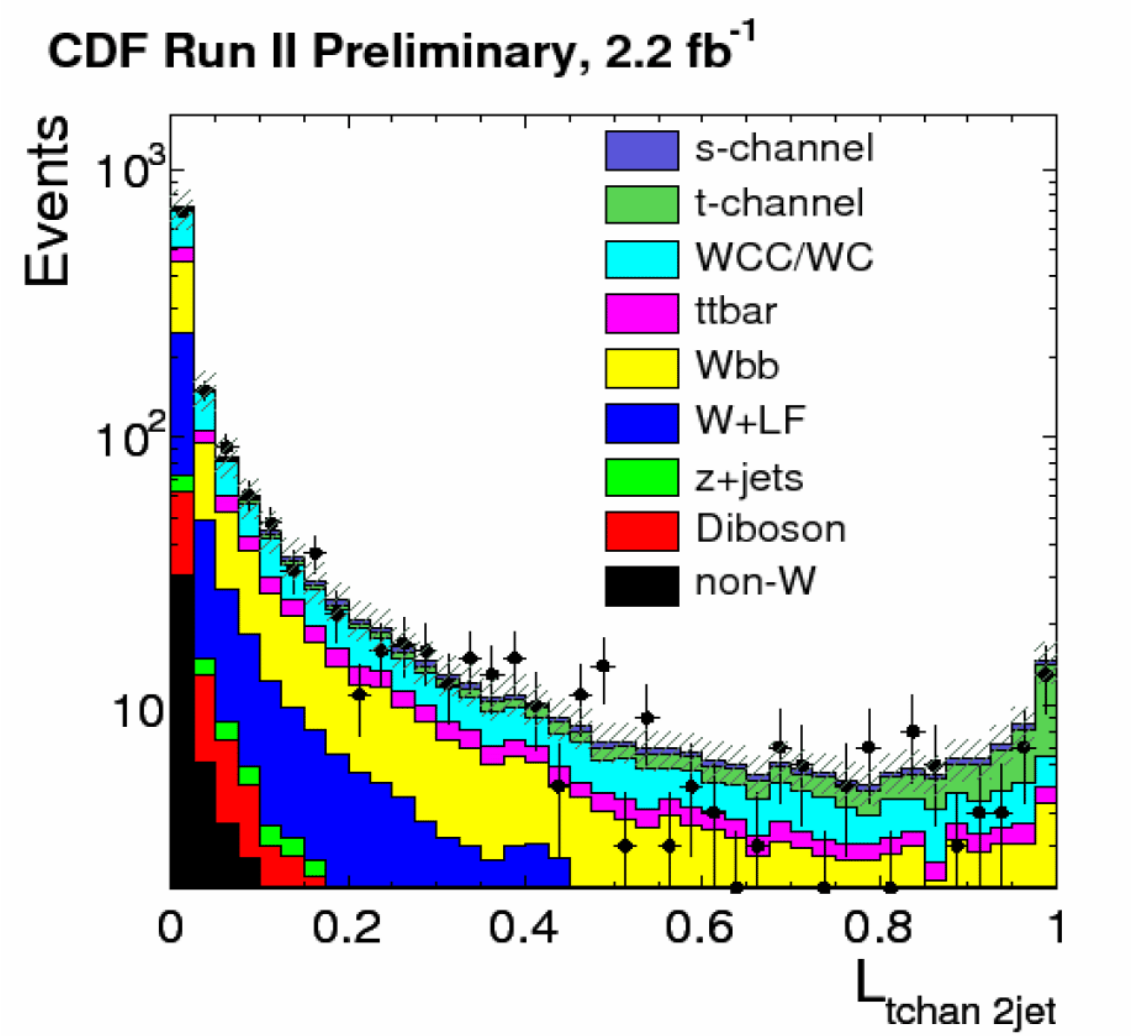




- Analyses based on 2.2 fb^{-1}
- Increased acceptance
  - MET trigger
  - more muons
- Now including 3-jet channel
- Improved background model

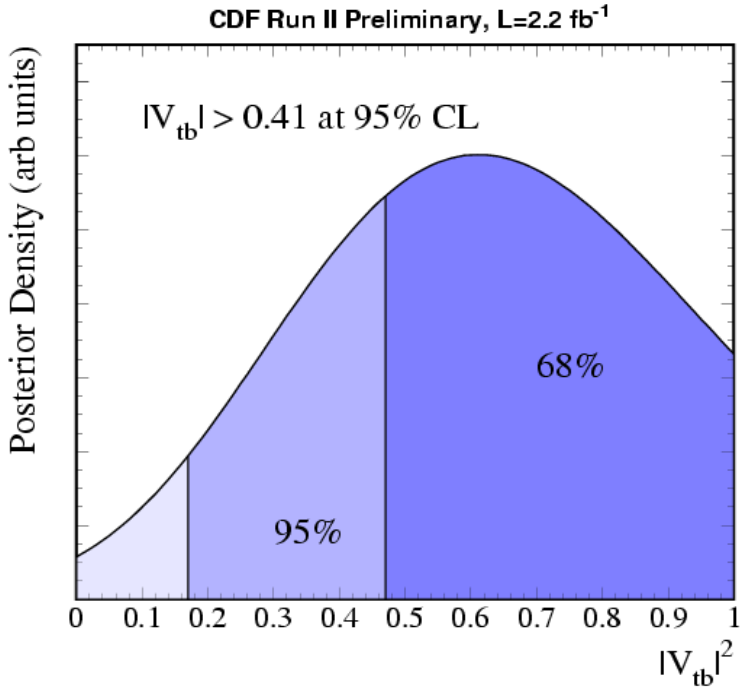
Multivariate likelihood function

- Likelihood functions built from 7 variables (10 for 2-tags)
  - Kinematic variables, b-tag NN, t-channel ME, kinematic solver



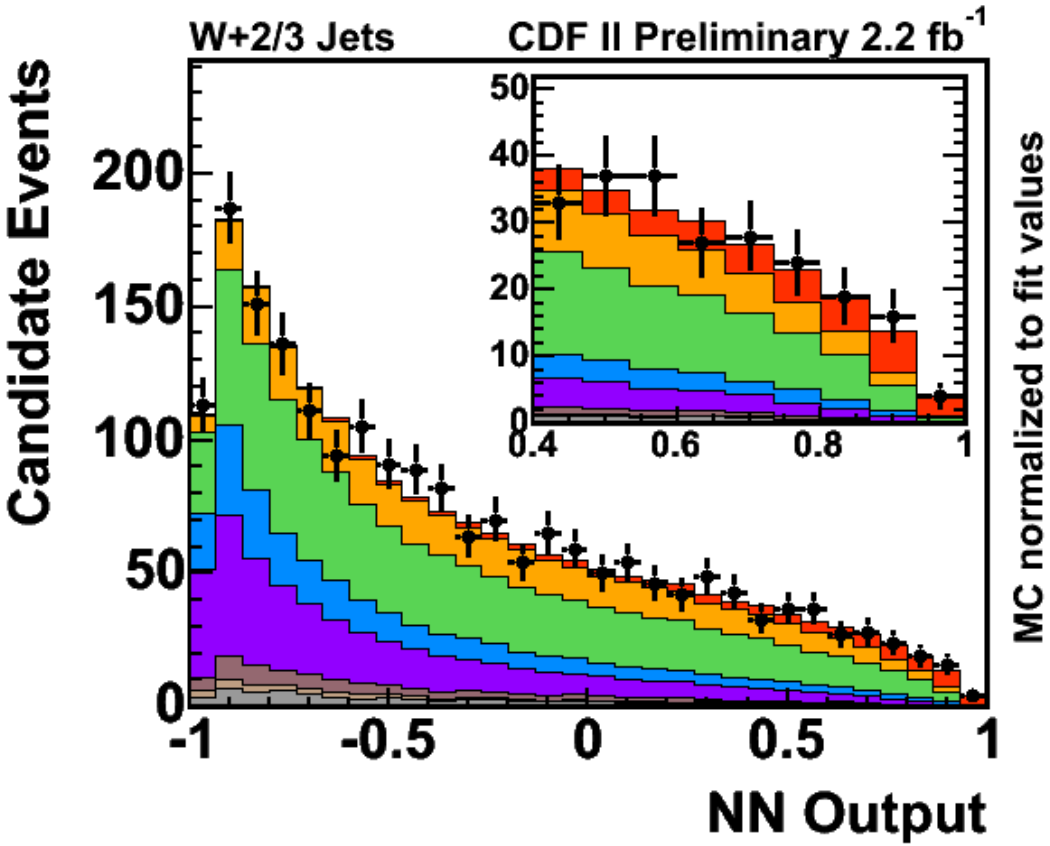
Measured cross section:

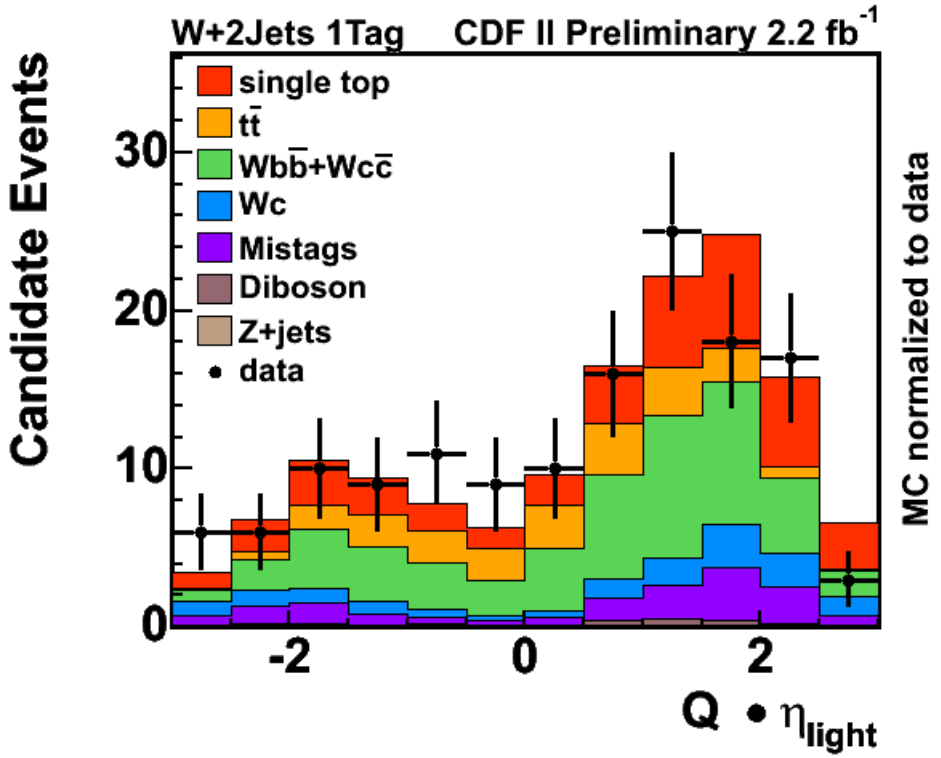
$$\sigma(s+t) = 1.8^{+0.9}_{-0.8}\ \text{pb}$$



Neural Networks

- 4 separate s+t networks built from 10-14 variables each
  - Including b-tag NN, kinematic variables, angular correlations



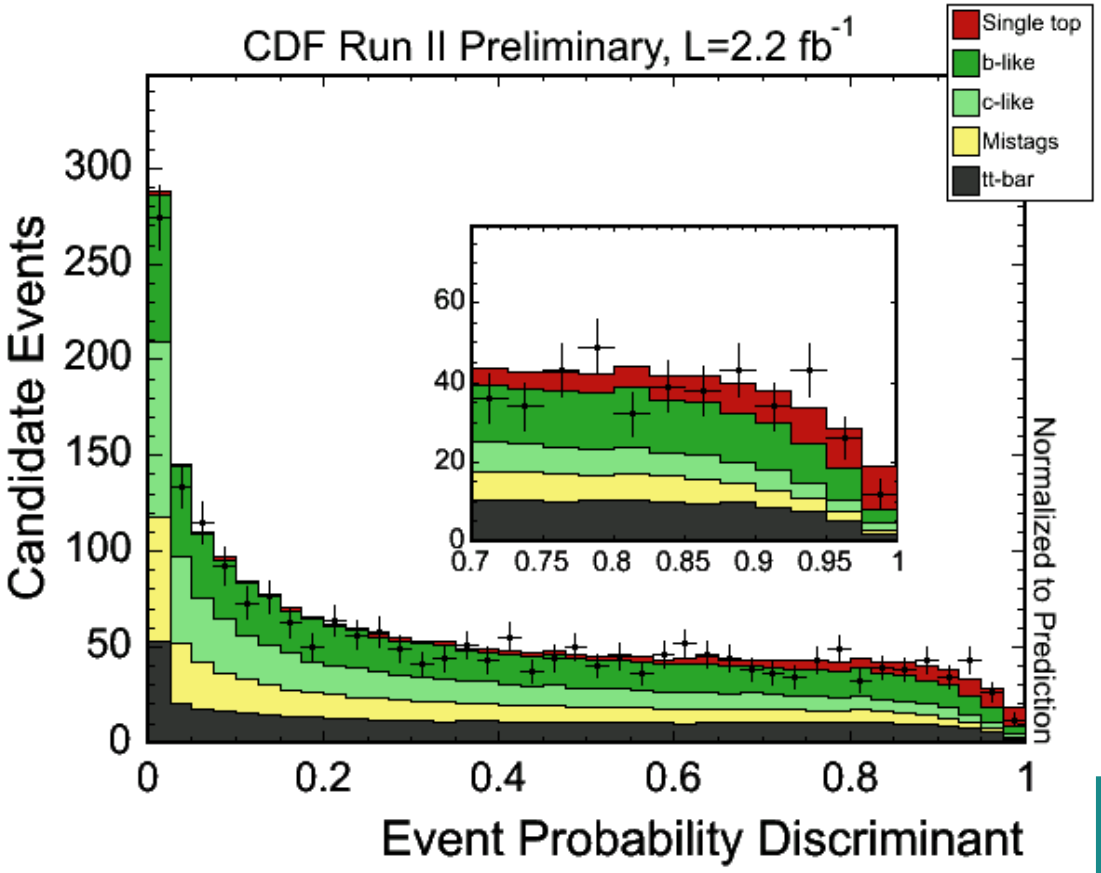


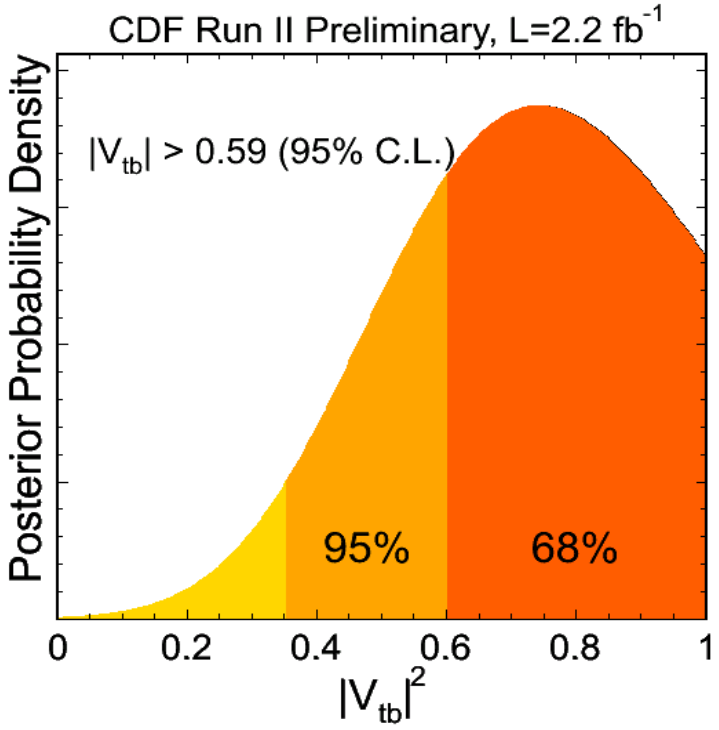
Measured cross section:

$\sigma(s+t) = 2.0^{+0.9}_{-0.8}$ pb

Matrix element

- Analyze 2-jet and 3-jet events
  - Include ttbar matrix element for both 2-jet and 3-jet events
  - Include b-tag NN as weight in likelihood ratio

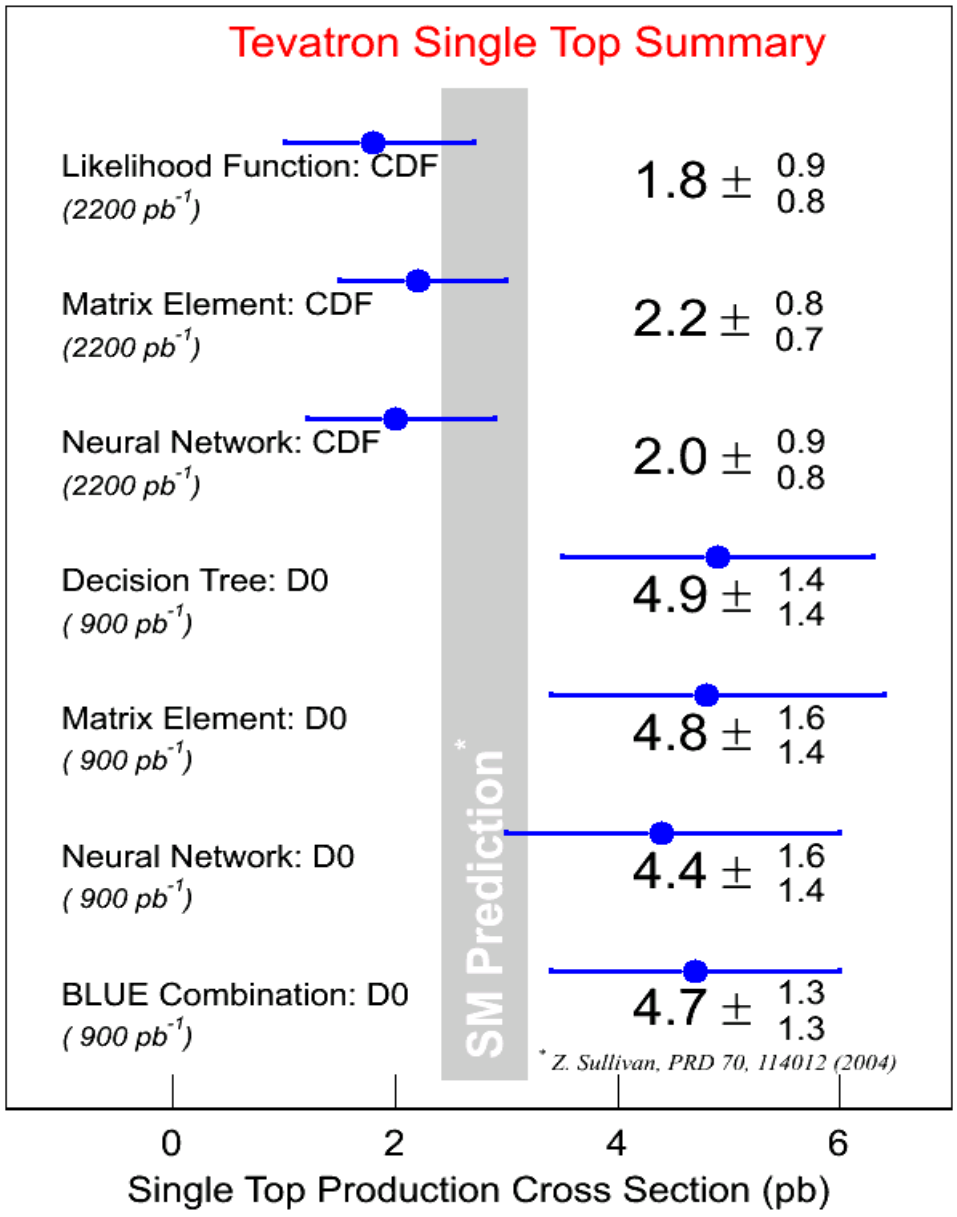




Measured cross section:

$\sigma(s+t) = 2.2^{+0.8}_{-0.7}$ pb

Summary for s+t



Conclusions/Outlook

- The search for single top quark production is turning into measurements in the single top final state
  - Both experiments have seen 3 σ evidence
  - $|V_{tb}|$ measurement to better than 15%
- Further improvements in progress
  - CDF combination
  - DØ update with larger dataset