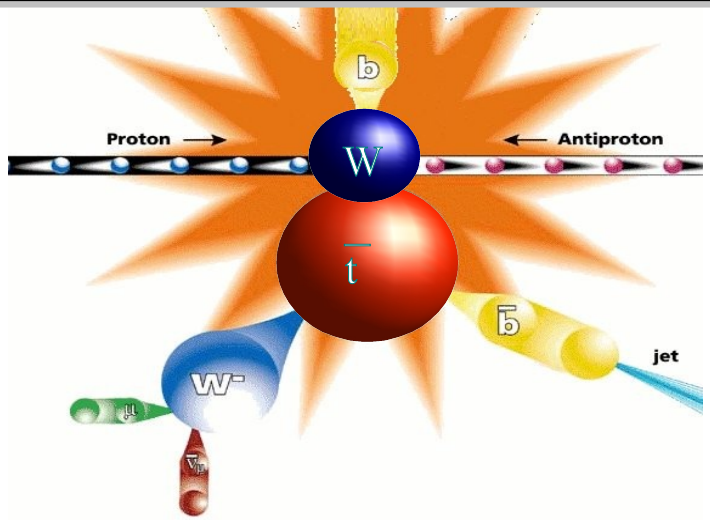
Single Top Quark Production at the Tevatron



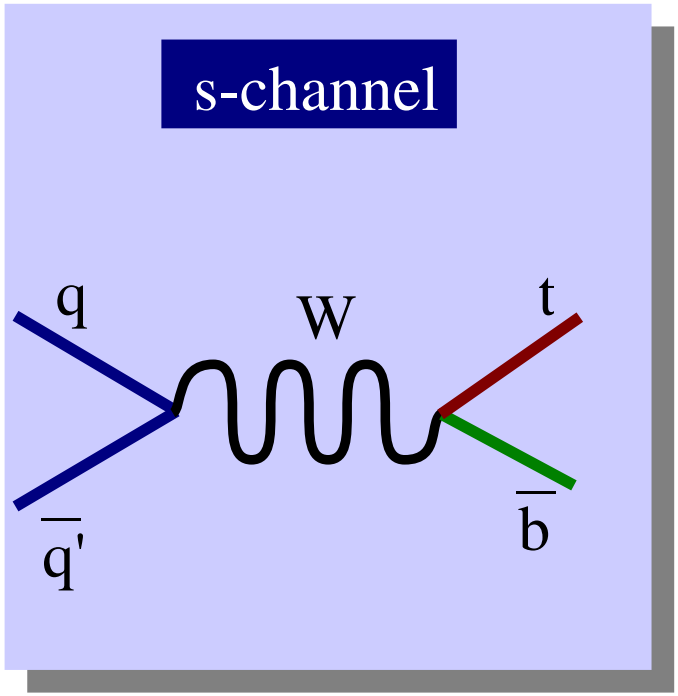
Reinhard Schwienhorst

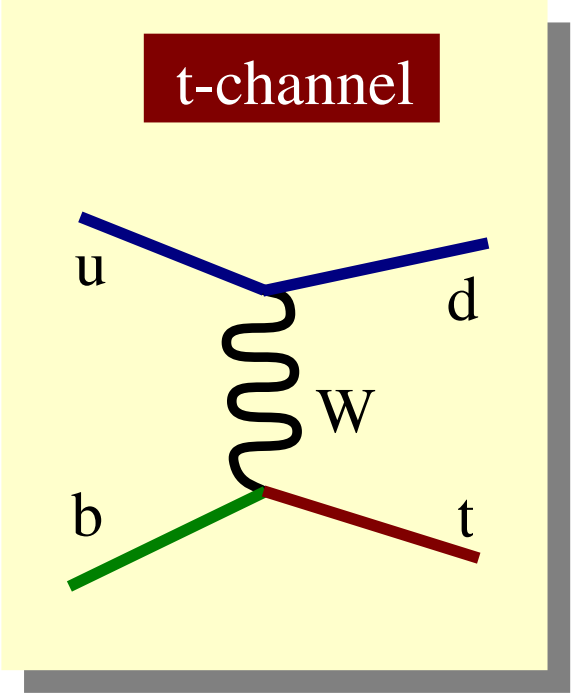
MICHIGAN STATE UNIVERSITY

on behalf of the DØ and CDF collaborations

Rencontres de Moriond EW 2008

SM single top quark production





SM cross section:

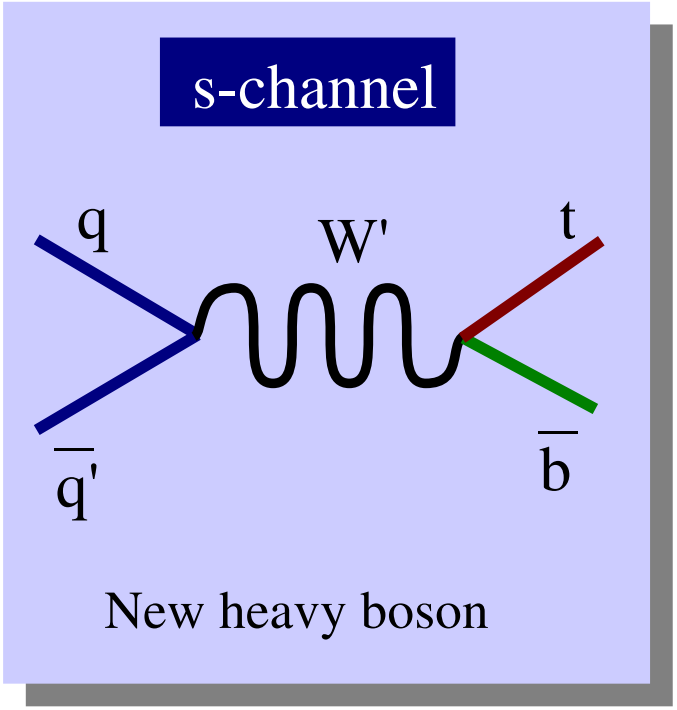
σ_{tot} = 3 pb

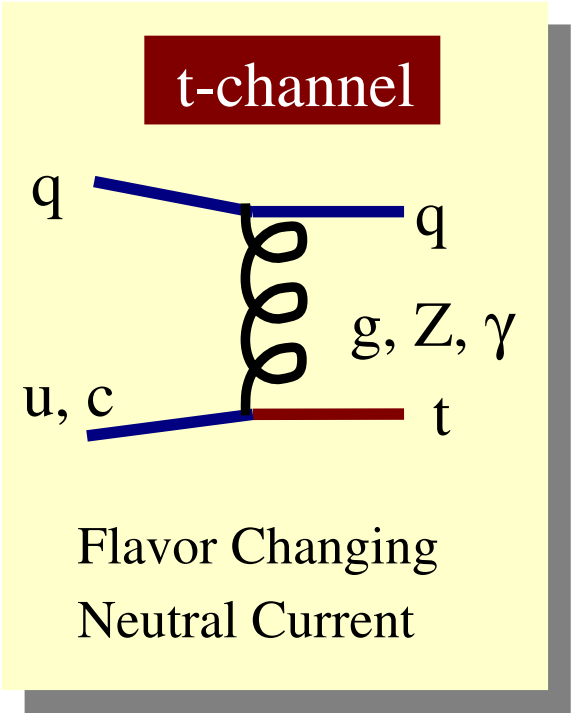
σ_s = .88 pb **σ_t = 1.98 pb**

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





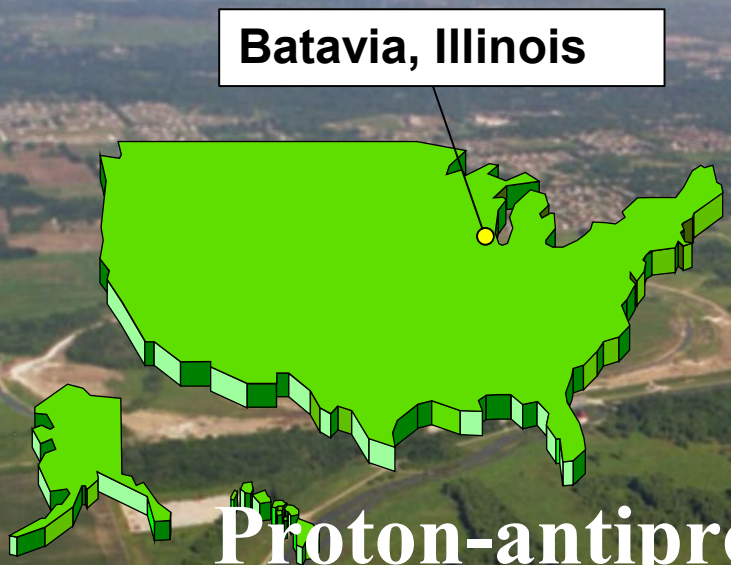
- Recent results:
  - Limits on W' from DØ and CDF:
    - M(W') > 800 GeV to 825 GeV, depending on couplings and decays

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



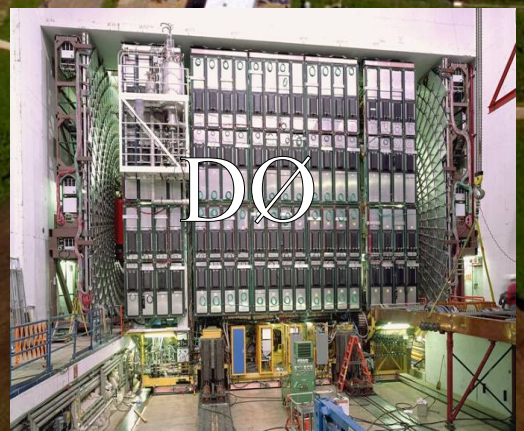
Proton-antiproton collider

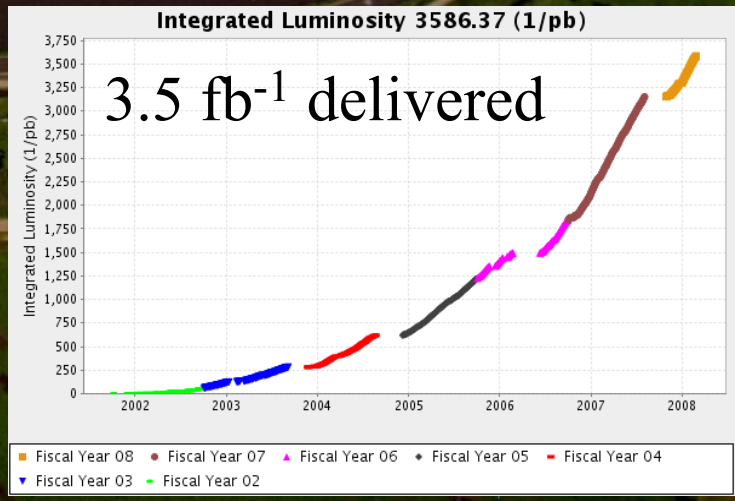
CM energy 1.96TeV

→ ***Energy frontier***

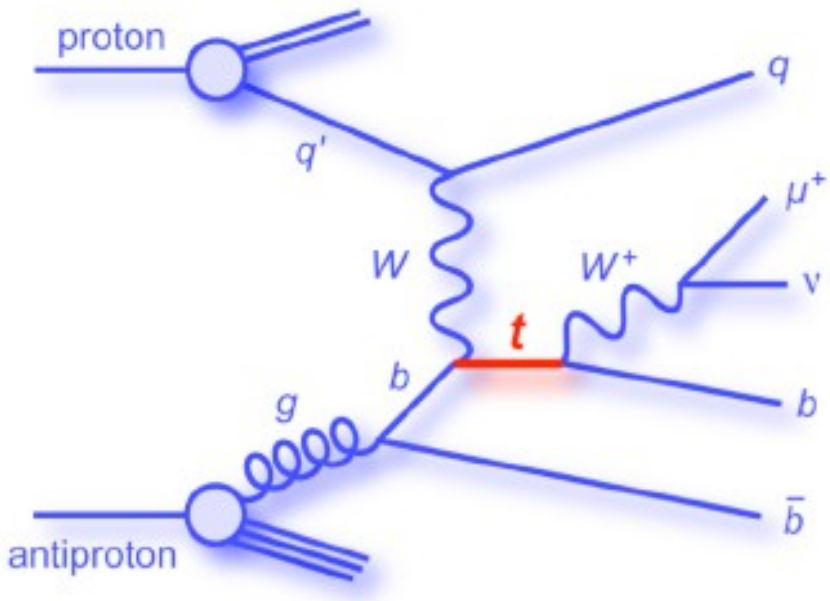
Instantaneous luminosity reaching 300E30cm^{-2}s^{-1}

→ ***Luminosity frontier***



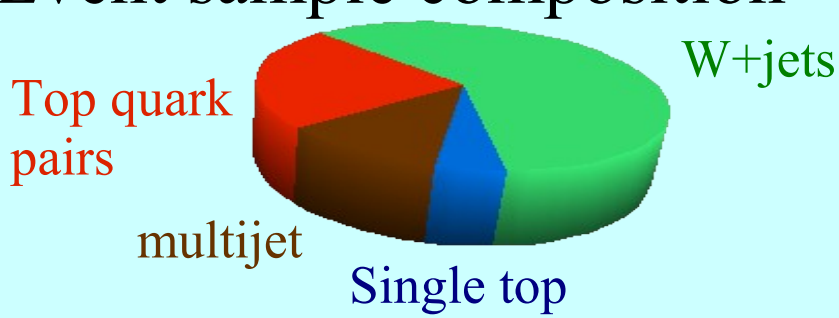


Single top event selection



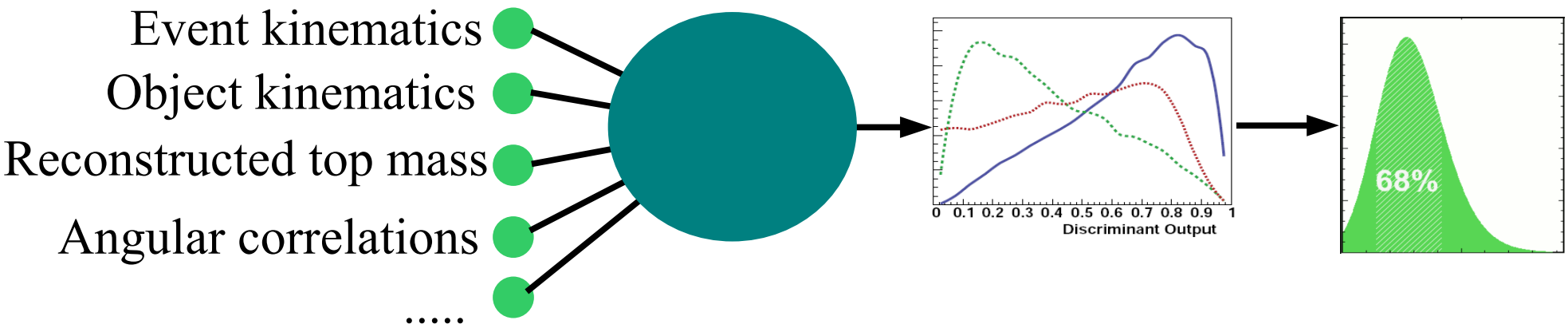
- Basic event signature (e or μ)
  - Single lepton trigger or lepton+jets trigger
  - One high-E_T leptons
    - E_T > 20 GeV or 15 GeV
  - Missing transverse energy
    - Missing E_T > 25 GeV or 15 GeV
  - 2-3 high-E_T jets (2-4 jets)
    - E_T > 15 GeV
  - At least one b-tag
- Expect ~ 50 signal events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

Event sample composition

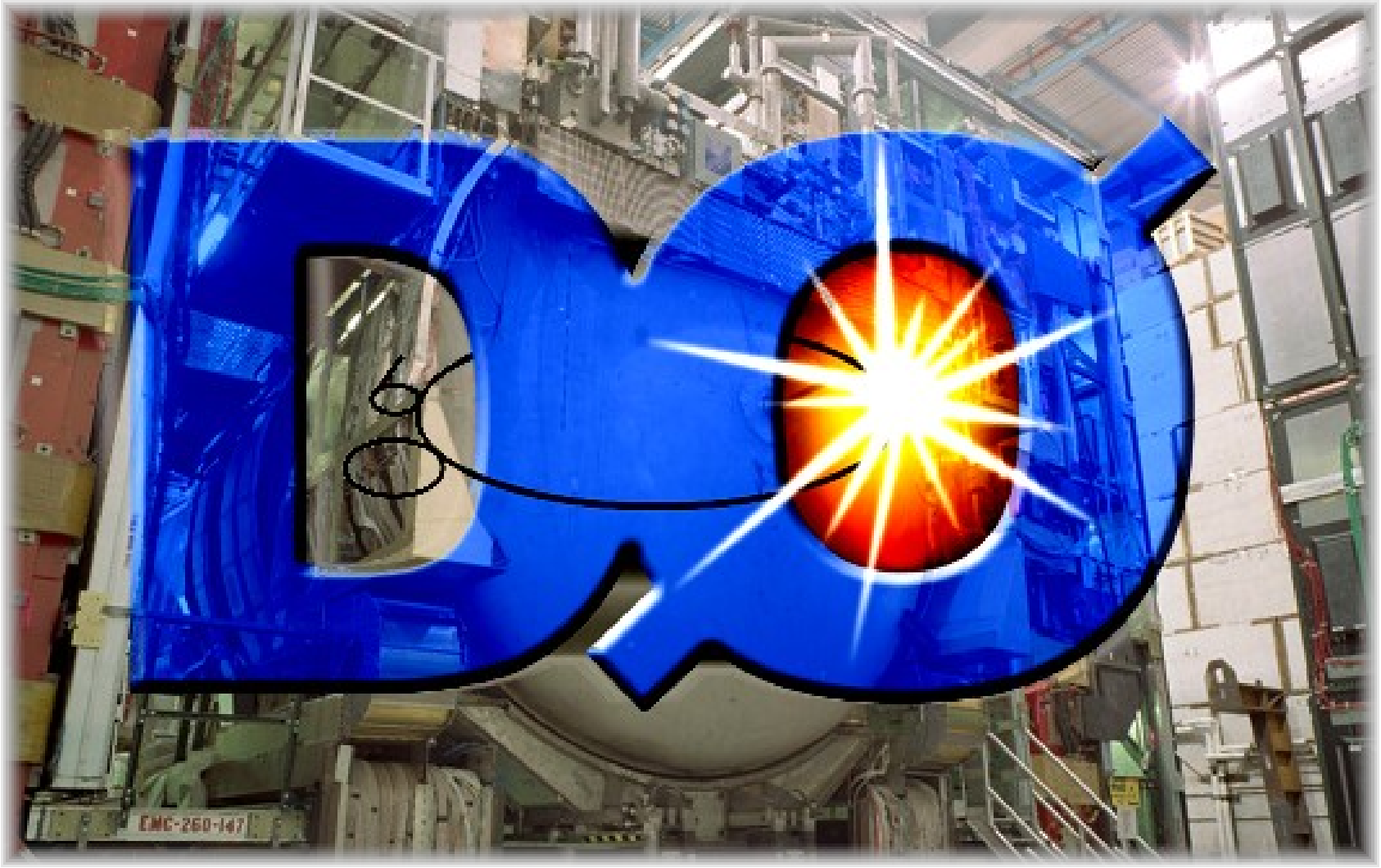


Single top analysis

discriminating variables | multivariate classifier | signal likelihood | statistical analysis



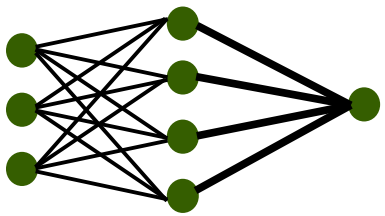
- Classifiers:
  - Likelihood function
  - Neural network
  - Bayesian neural networks
  - Boosted decision trees
  - Matrix Element
- Systematic uncertainties:
  - Normalization uncertainties, for example background composition (10-30%)
  - Shape uncertainty, for example jet energy scale, b-tagging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

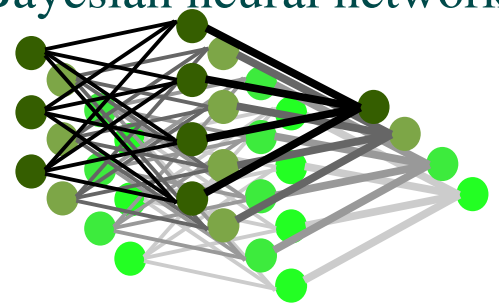
Bayesian neural networks

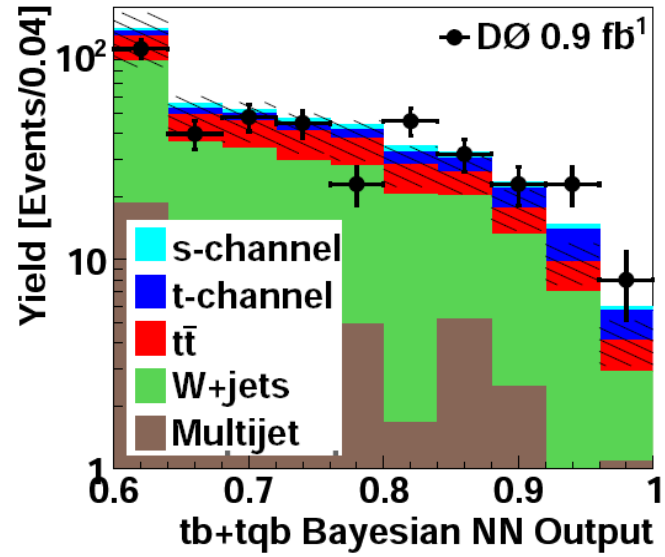
Single network

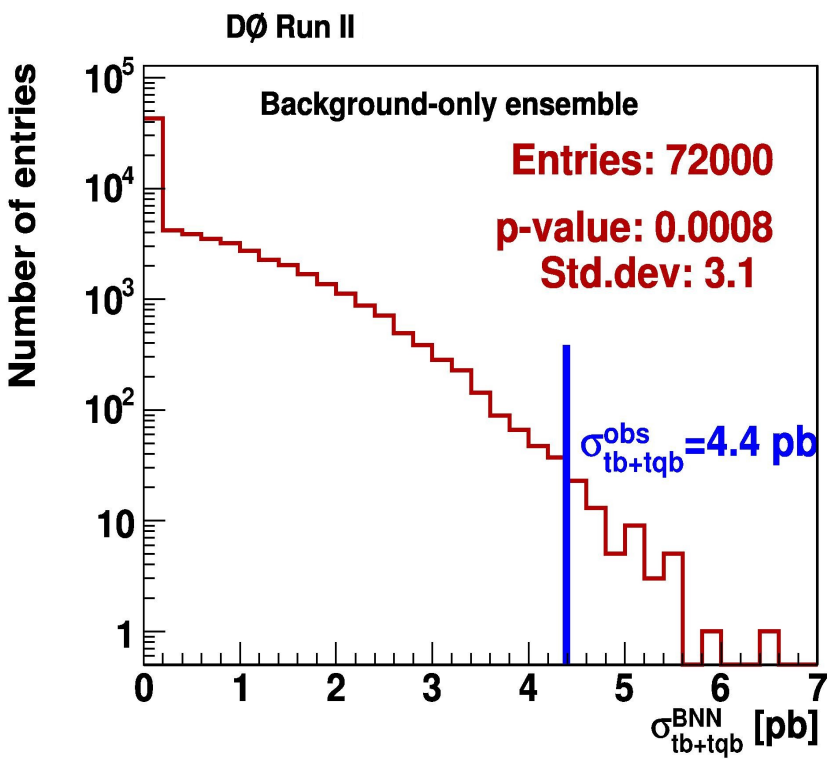


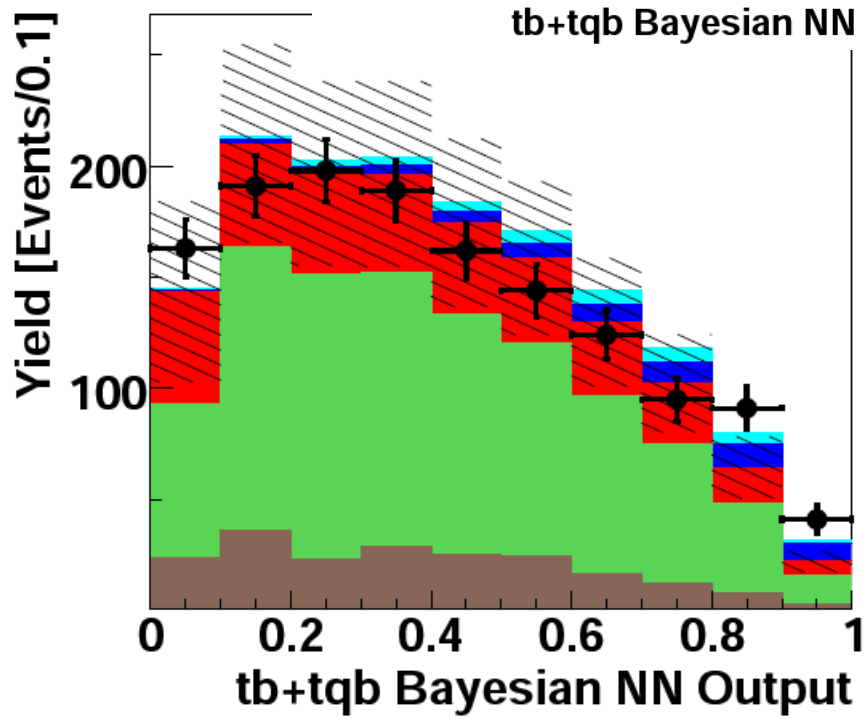
integrate over possible network parameters

Bayesian neural networks



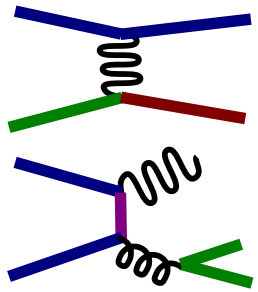






Matrix element

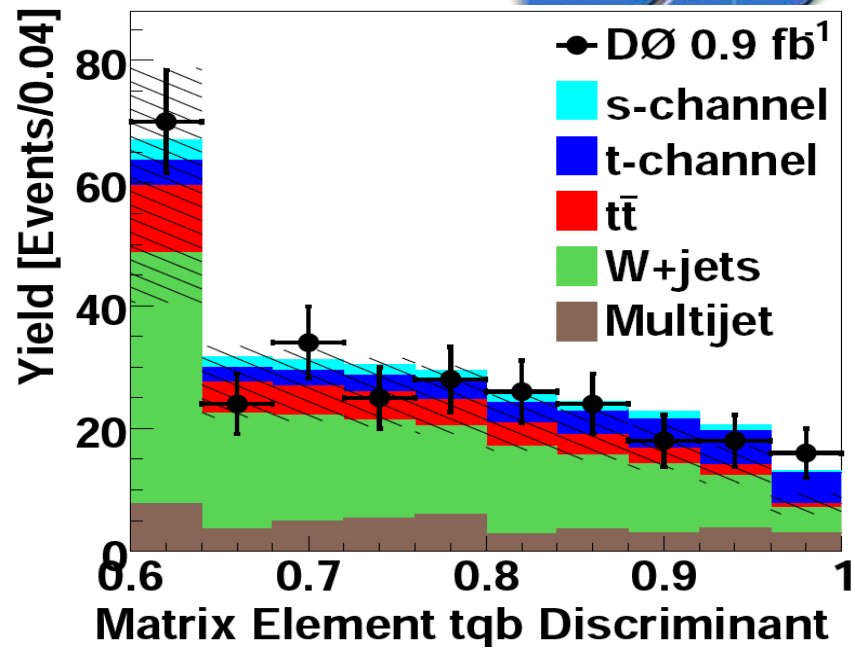
Parton level matrix elements



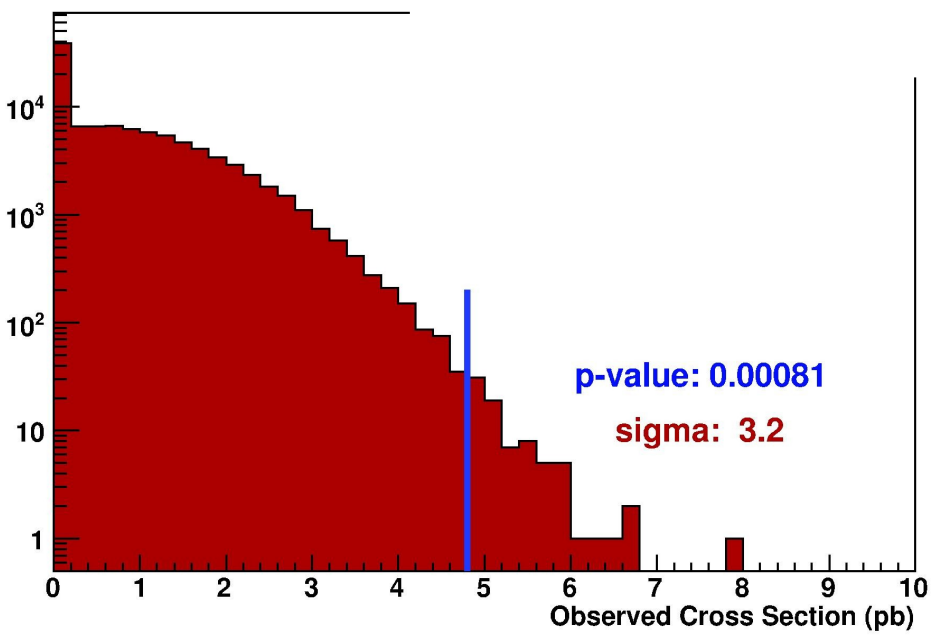
integrate over measurement uncertainties

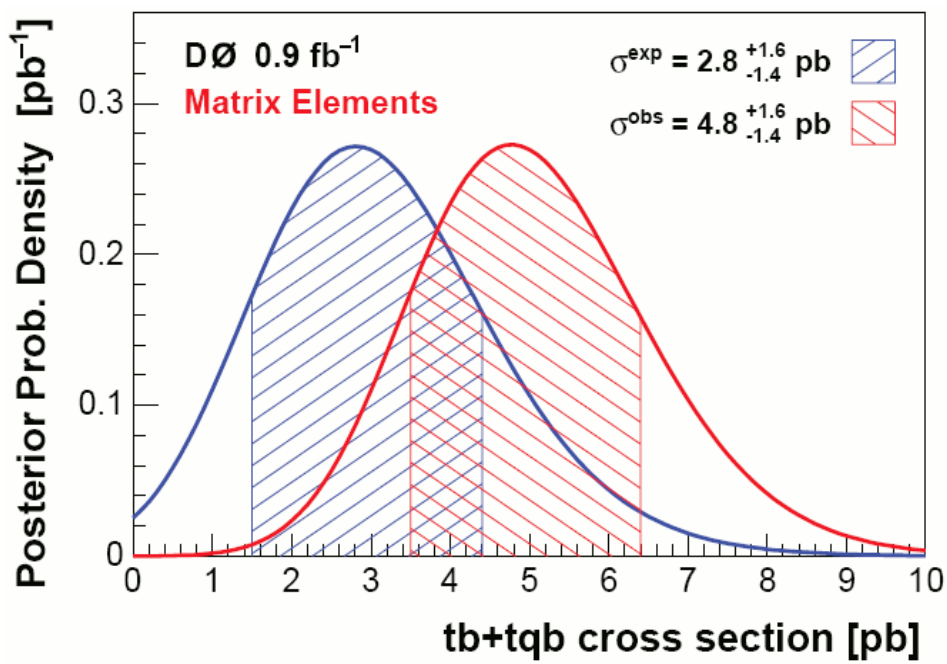
Signal discriminant

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



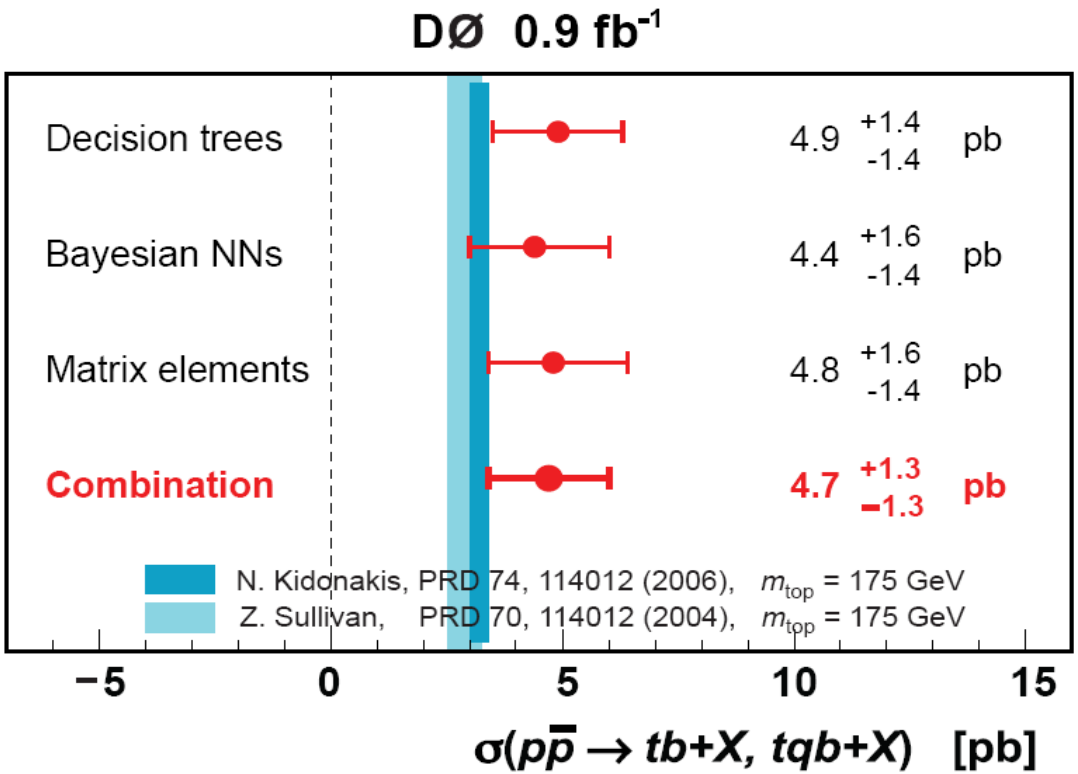
- Include ME for s, t, Wbb, Wcg, Wgg
- In 3-jet bin also tt→*l*+jets



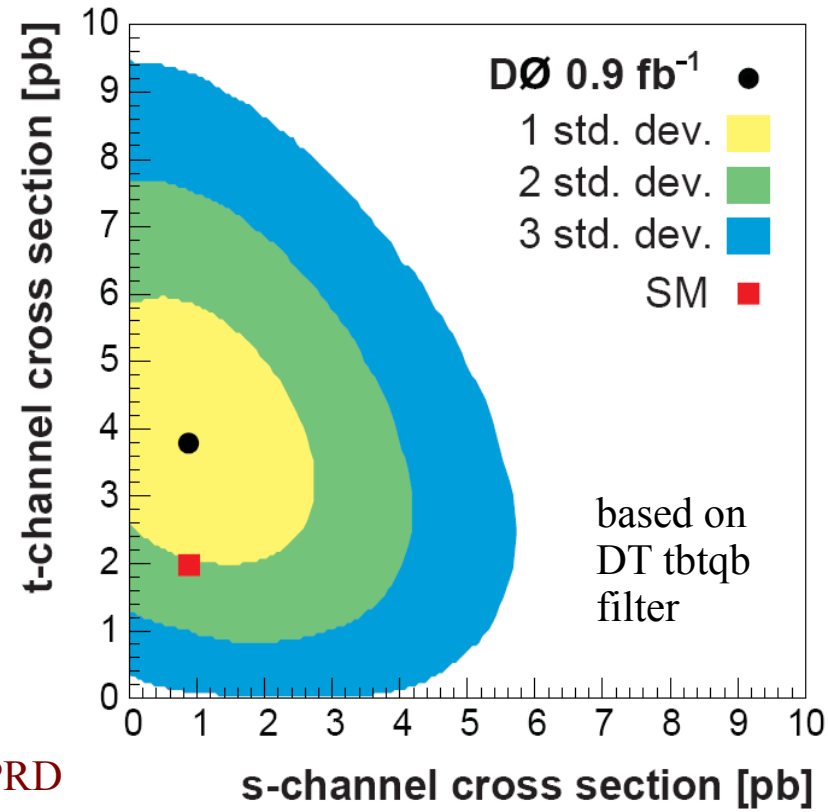


Summary

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



3.6 σ evidence for single top (2.3 σ expected)



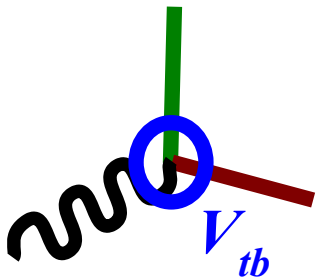
$\sigma(s+t) = 4.7 \pm \mathbf{1.3}$ pb

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

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

submitted to PRD

CKM matrix element $|V_{tb}|$



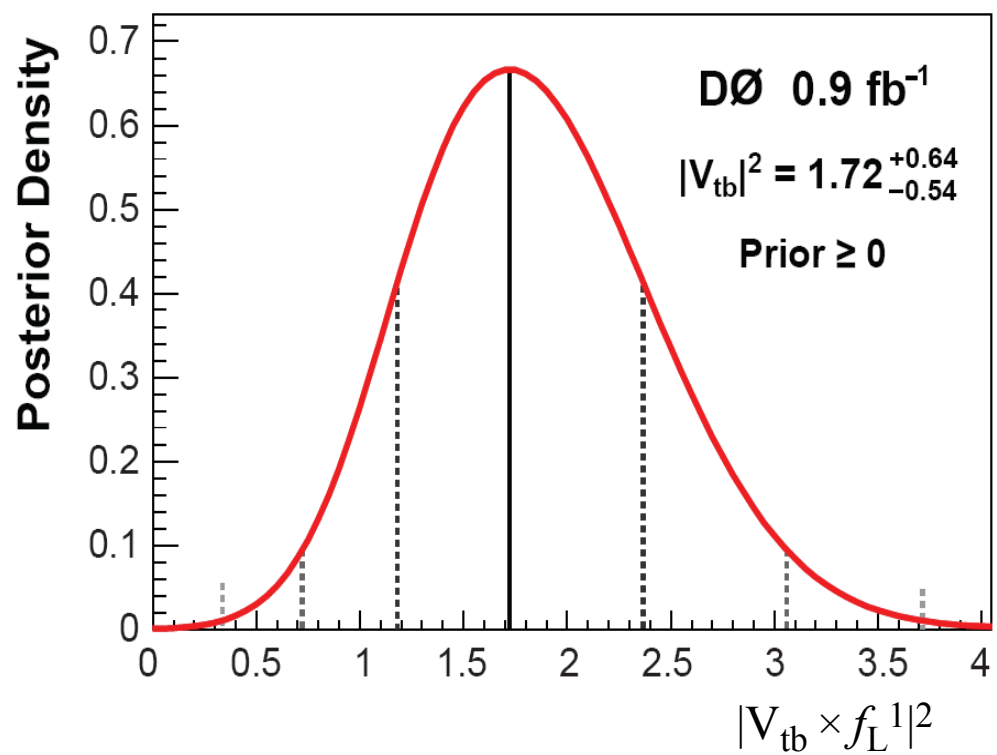
CKM Matrix

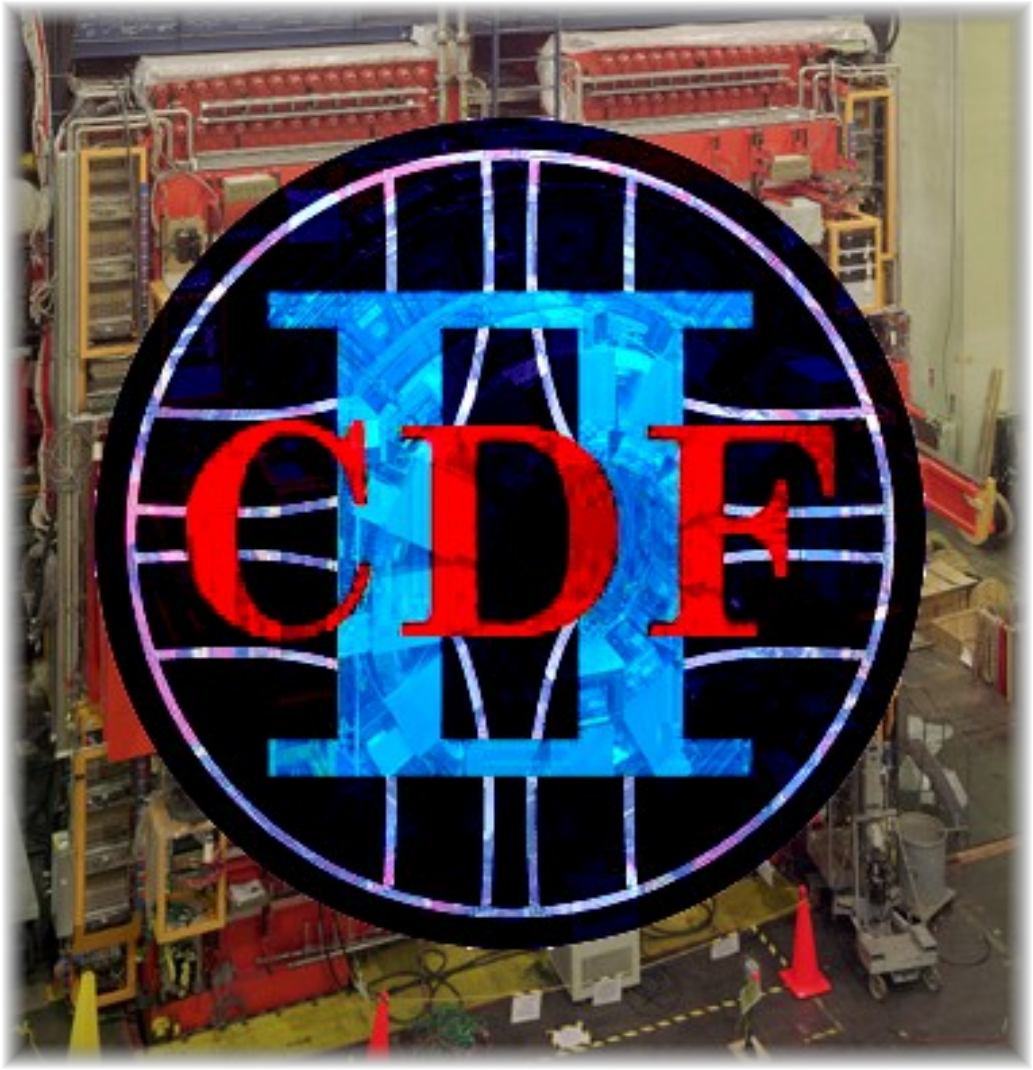
$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

- 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

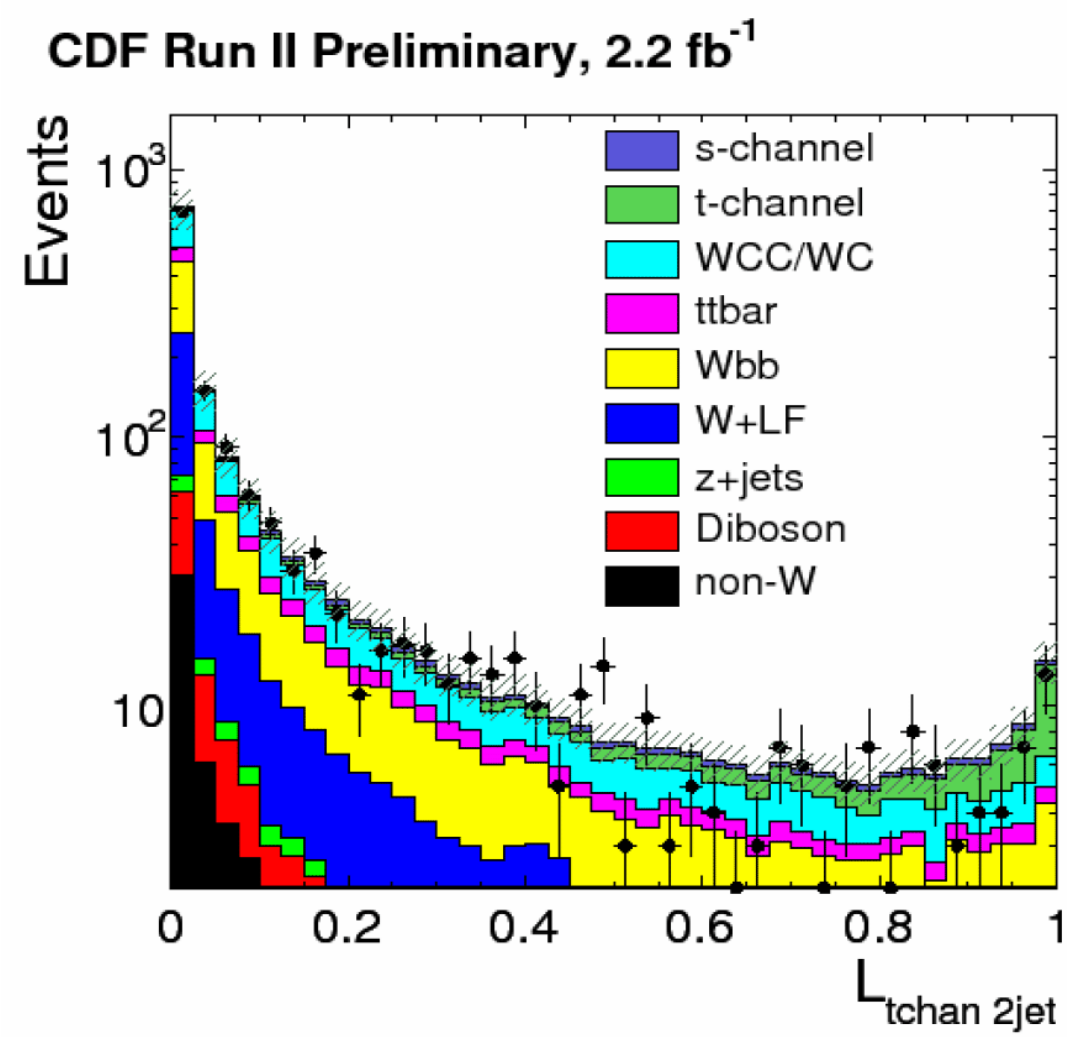




- Analyses based on 2.2 fb^{-1}
- Increased acceptance
  - MET trigger
  - more muons
- Now including 3-jet channel
- Improved background model

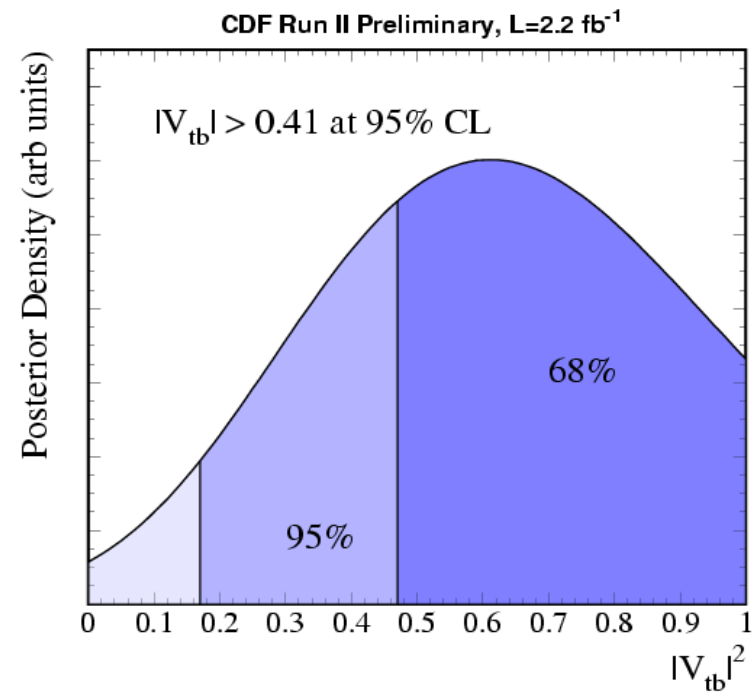
Multivariate likelihood function

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



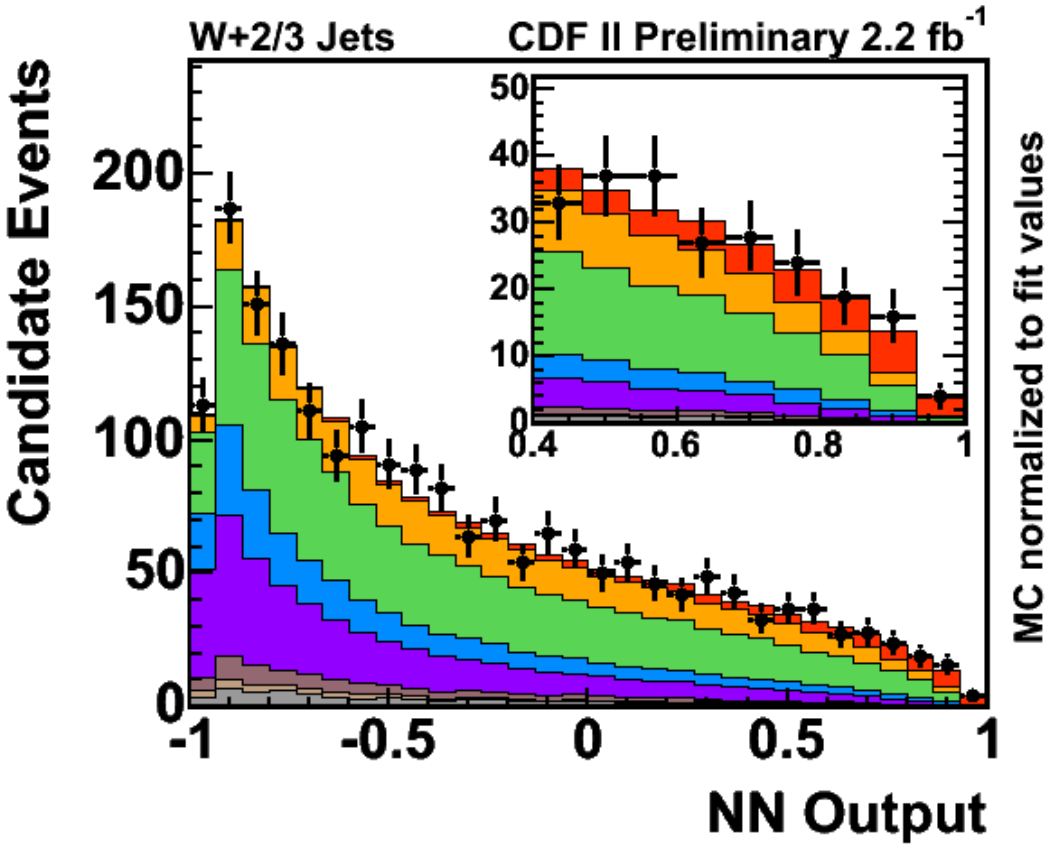
Measured cross section:

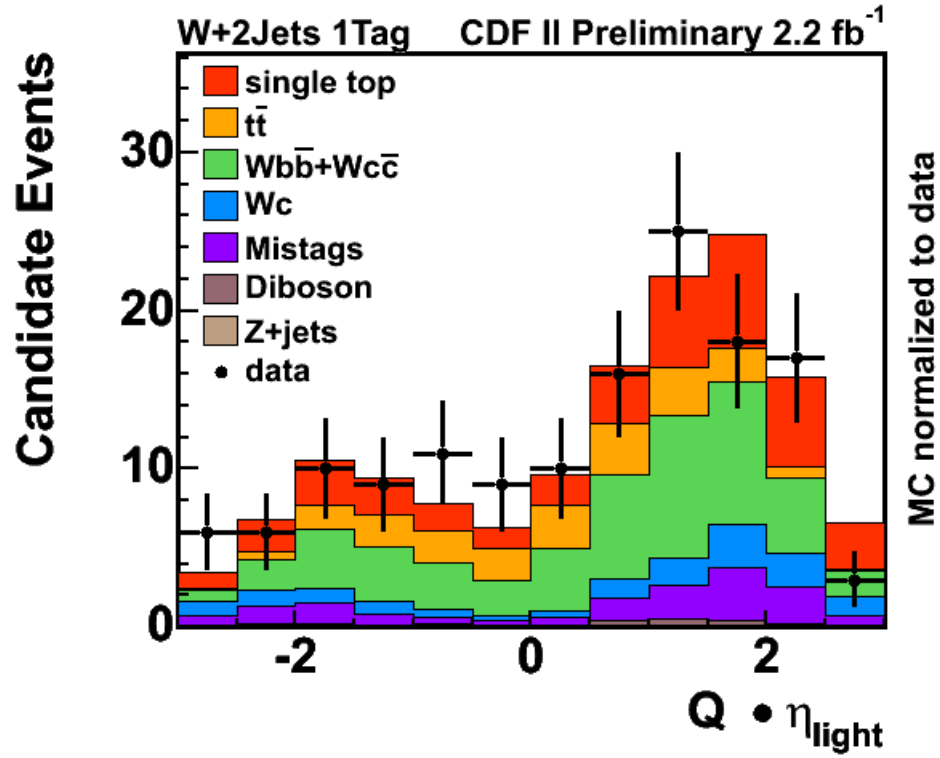
$$\sigma(s+t) = 1.8^{+0.9}_{-0.8}\ \text{pb}$$



Neural Networks

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



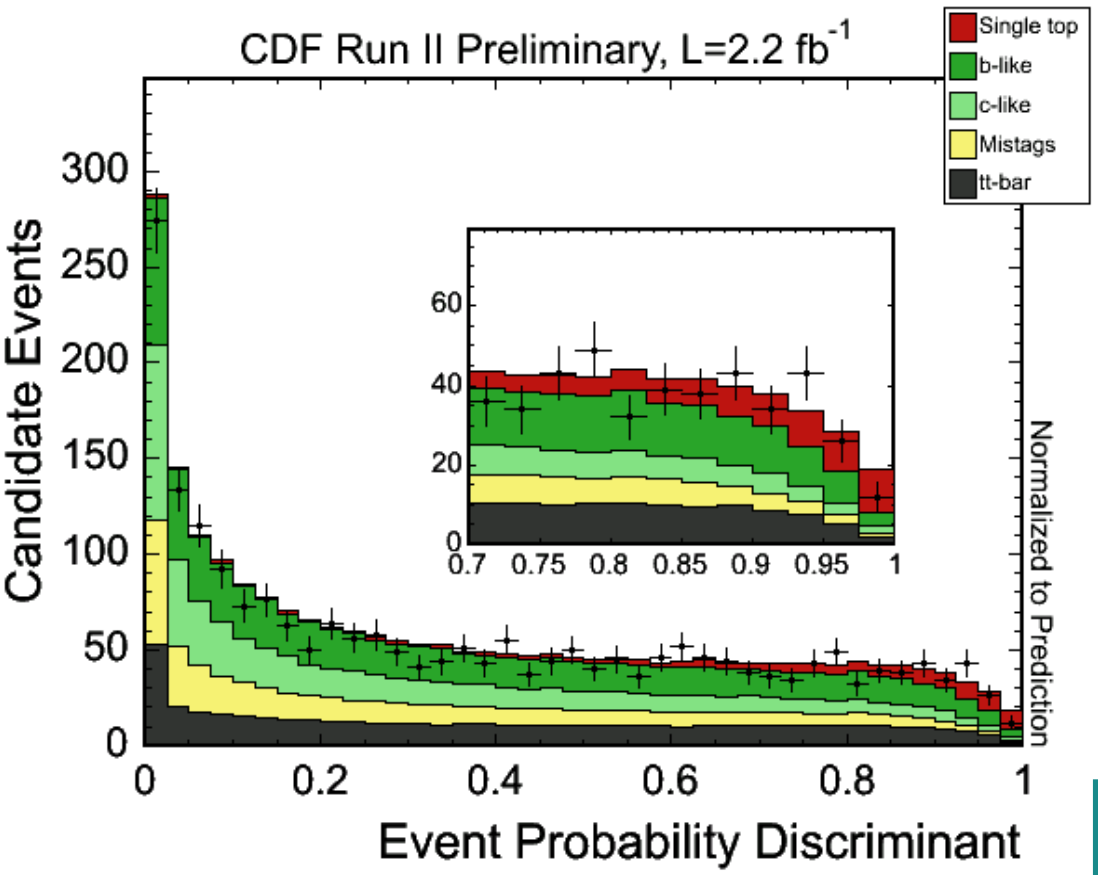


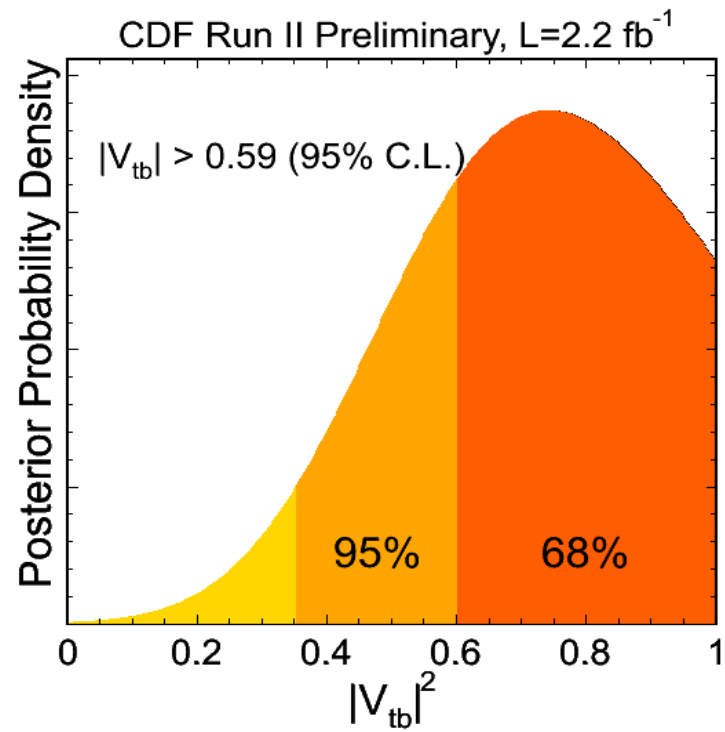
Measured cross section:

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

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

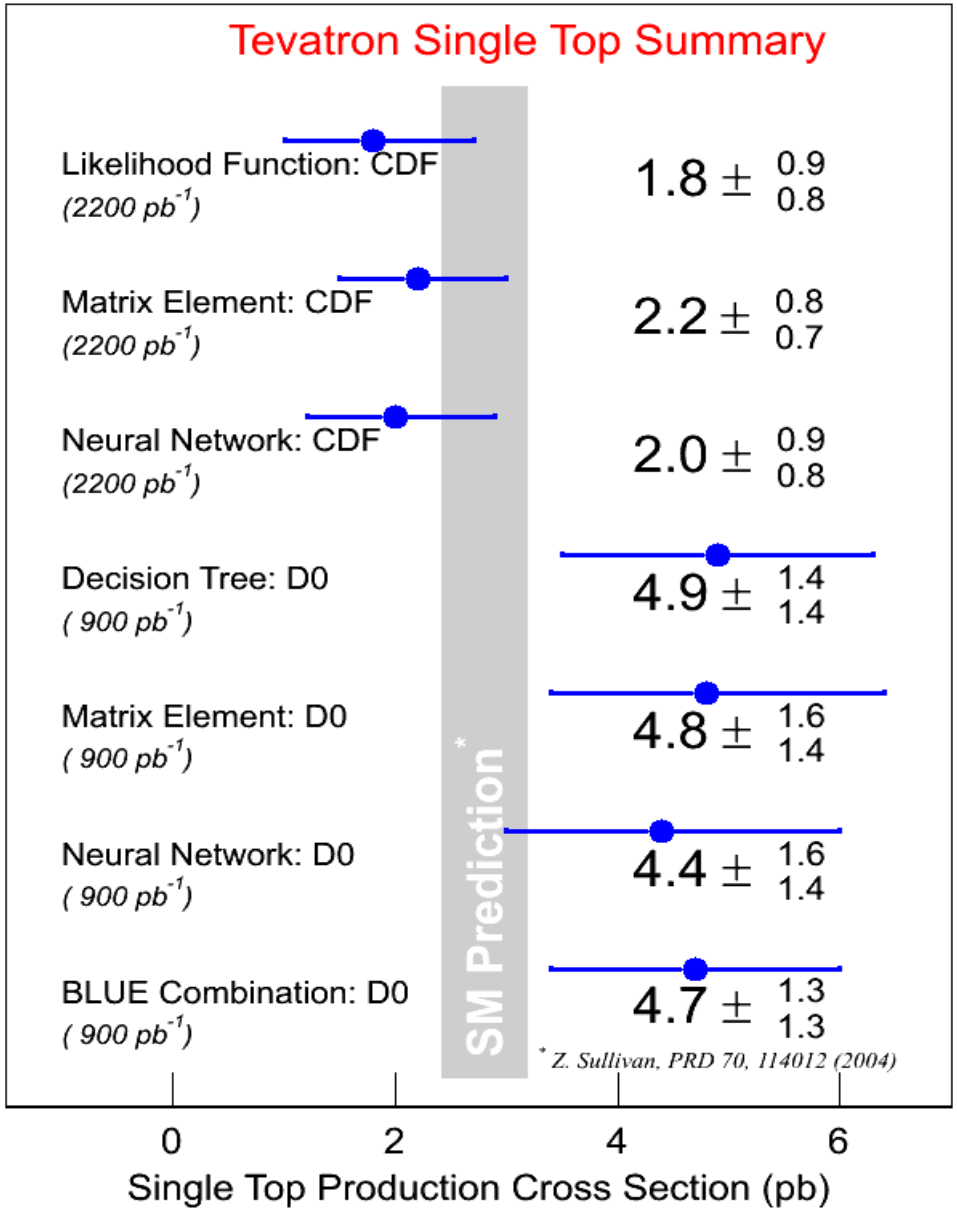


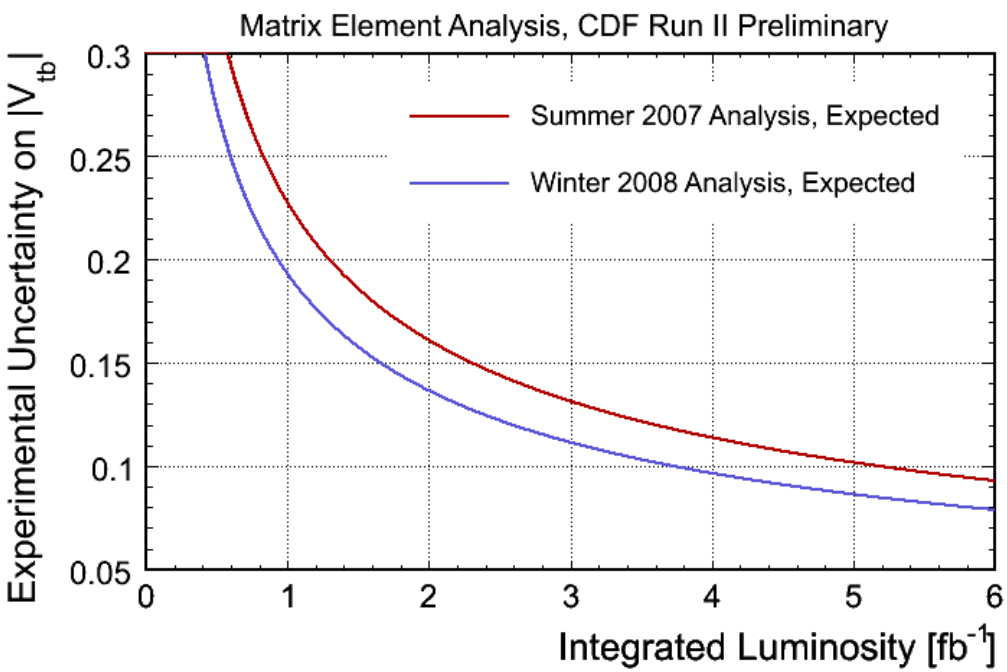


Measured cross section:

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