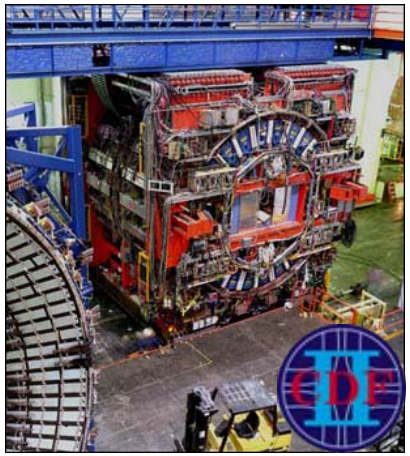
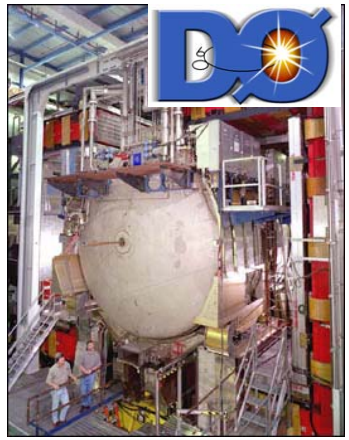




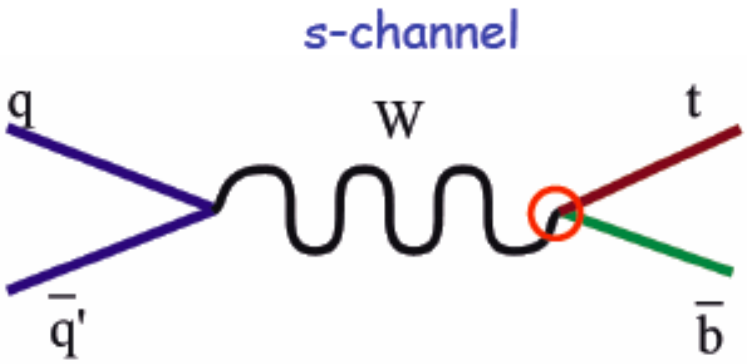
Search for Single Top Quark Production at the Tevatron

Yurii Maravin for
CDF and DØ Collaborations

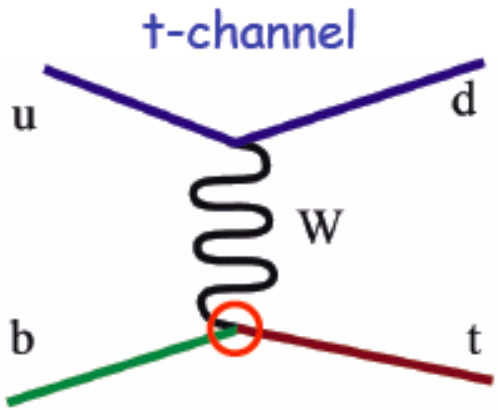
HIGH ENERGY PHYSICS
KANSAS STATE UNIVERSITY
KSU HEP

Single Top Production

- The standard model predicts production of a top quark via the weak current:
  - Dominant processes at the Tevatron are:



σ_{NLO} = 0.88pb ± 8%

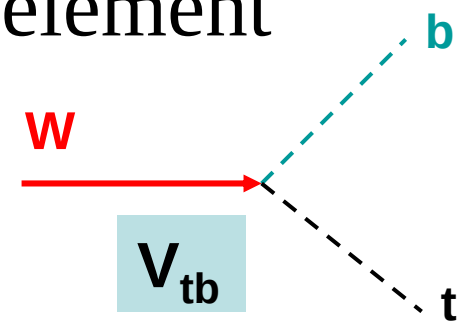


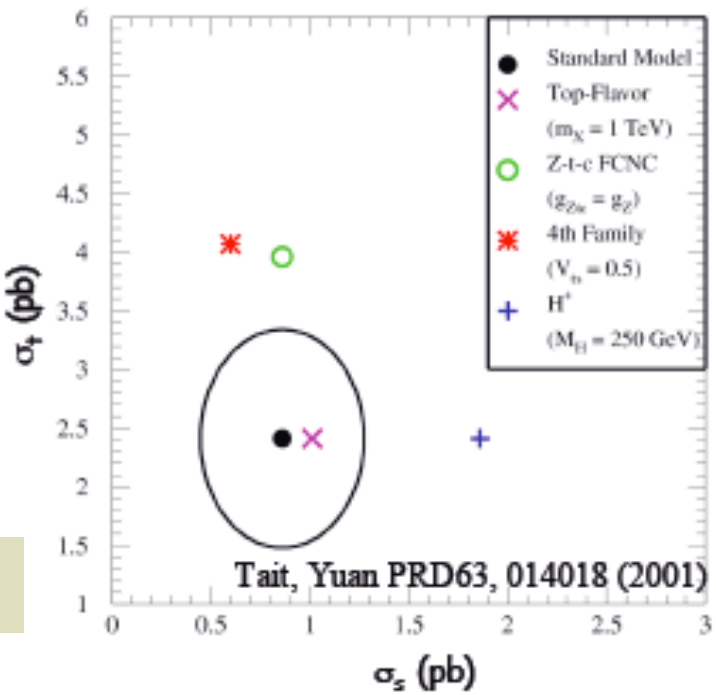
σ_{NLO} = 1.98pb ± 11%

hep-ph/207055 (Harris, Laenen, Phaf, Sullivan, Weinzierl)

Motivation

- Direct measurement of CKM $\mathbf{V_{tb}}$ element
  - Sensitivity towards 4th generation!
- Physics with polarized t-quarks!
- Probe b-quark PDFs
- Search for New Physics
  - H^+ (2 pb)
  - FCNC (1-4 pb)
  - 4th generation

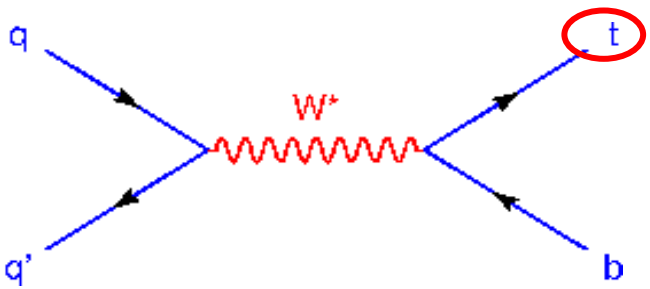




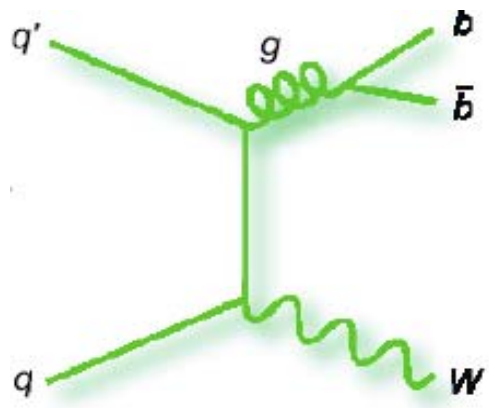
We need to observe the signal first!

Single Top Production

- These processes have never been seen before
  - Cross-sections are half of that for the top-pair production, but much more significant background…



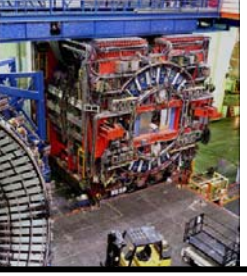
s-channel production (W)*



Backgrounds

Anything with lepton + jets + missing E_T:

Wbb, tt-bar etc.



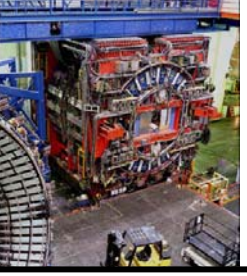
Signal and Background Modeling

- Precise simulation of signal and background is crucial for the discovery
- Signal
  - Benchmark: **ZTOP** NLO single top generator

    http://www.fnal.gov/~zack/ZTOP/ZTOP.html
  - CDF and DØ use LO generators fixed to reproduce NLO simulation
    - CDF:**MADEVENT**;
    - DØ: **SingleTop** based on **CompHep**
- Background
  - **W+jets** (data/ALPGEN)
  - Top-pair production
  - Multi-jet events (data)
  - WW, WZ, ZZ etc.

CDF: Pythia

DØ: ALPGEN



Searching for Single Top

Data selection

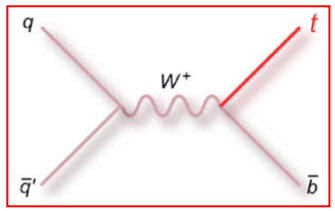
Final criteria

Data analysis

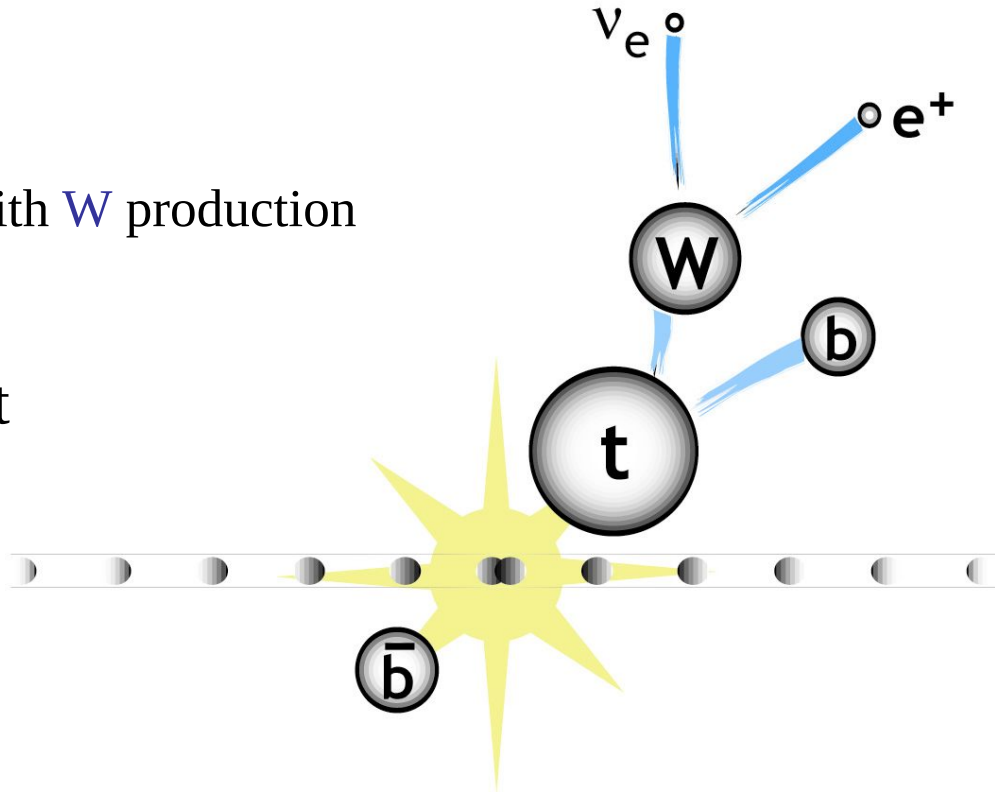
- Clean up data, remove detector backgrounds
  - CDF: restrictive selection
  - DØ: a rather loose selection
- Apply **b-tagging**, understand shape variables, optimize S/B ratio
  - CDF: optimize separation in one variable ($Q_\ell \cdot \eta$), counting experiment
  - DØ: use likelihood discriminants
- Perform binned Bayesian fit of the signal and background expectation compared to data

Selecting Single Top

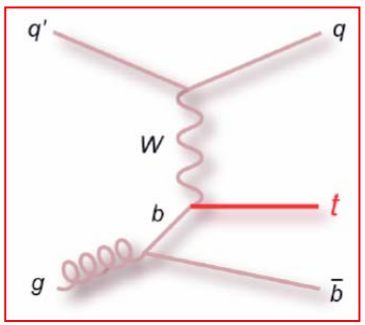
- s-channel



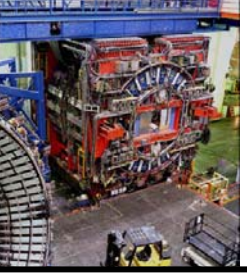
  - W
    - High-p_T lepton (e or μ)
      - Missing E_T consistent with W production
  - 2 b-jets
    - At least one b-tagged jet



- t-channel



  - Same as above + extra jet

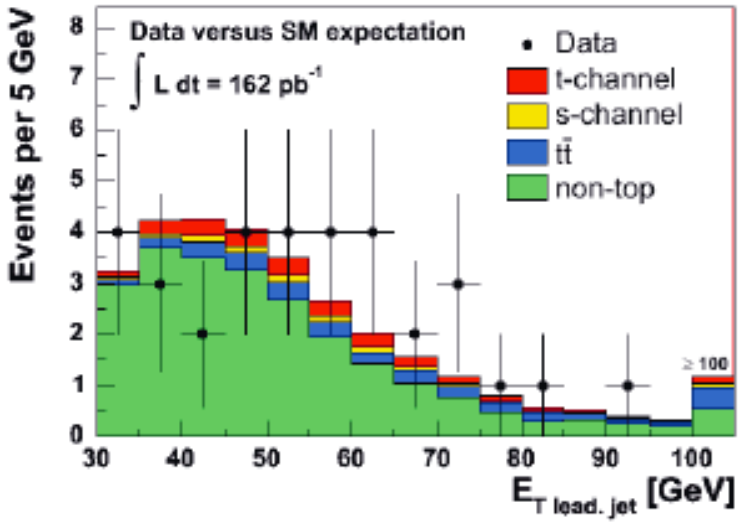


CDF Single Top Analysis

Published: PRD 71 012005

- W selection:
  - $p_T(\ell) > 20$ GeV/c, $|\eta| < 1.0$
  - Missing $E_T > 20$ GeV
- Jets selection:
  - Exactly two jets, at least one is b-tagged
  - Jet $E_T > 15$ GeV, $|\eta| < 2.8$
    - If only one jet is b-tagged, leading jet's $E_T > 30$ GeV

Use 162 pb^{-1}



Event detection efficiency

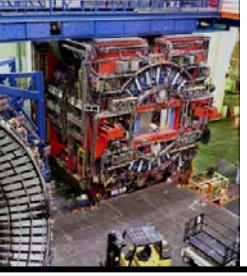
s-channel	1.06 ± 0.08%
t-channel	0.89 ± 0.07%

Main systematics

b-tag efficiency	7%
Luminosity	6%
JES	4%

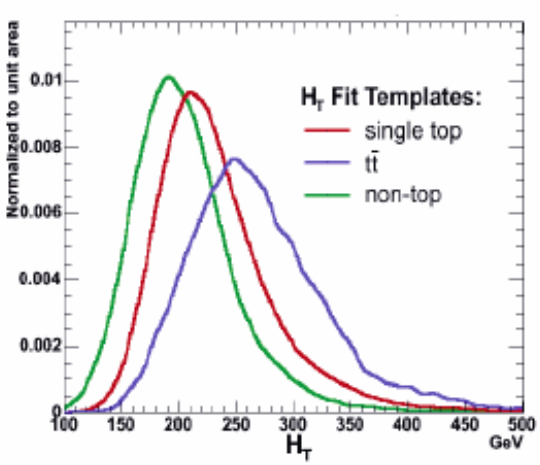
Combined (s- and t-channels)

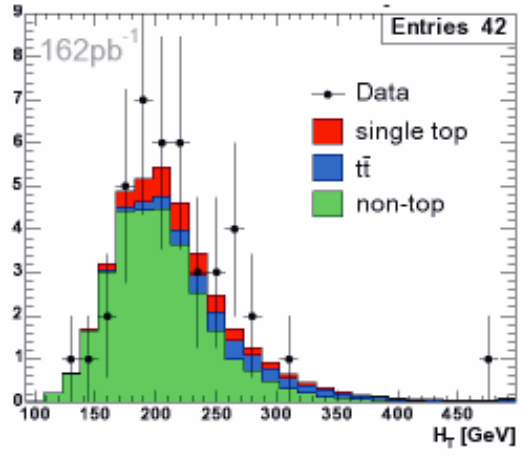
Expected signal	4.3 ± 0.5 events
Expected background	33.8 ± 5.9 events
Observed	42 events

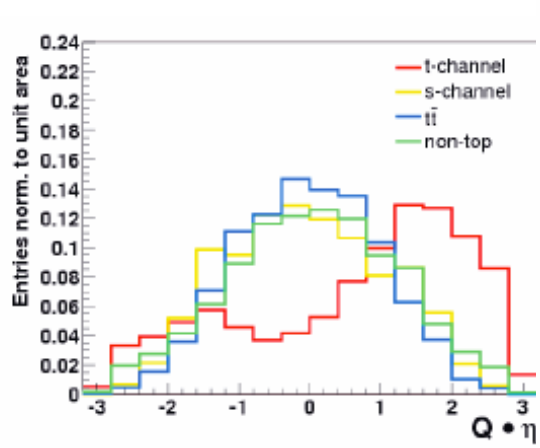


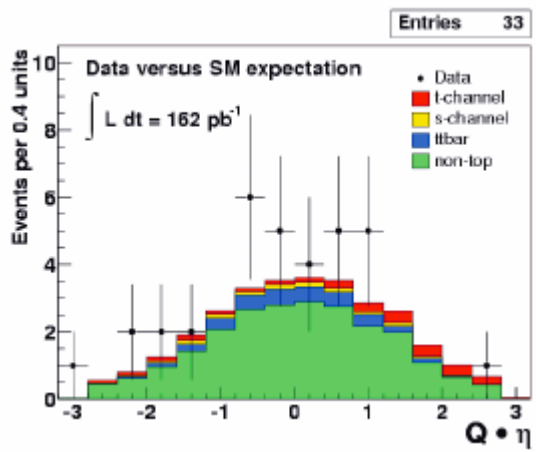
CDF Analysis Strategy

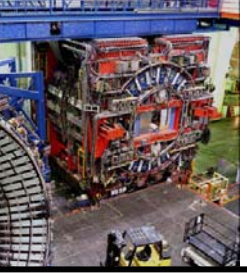
- Use combined channels to search for single top quark production using H_T distribution
- Separating channels:
  - **s-channel**: counting experiment
    - **2 b-tagged jets**
  - **t-channel**: $(Q_\ell \cdot \eta)$ distribution



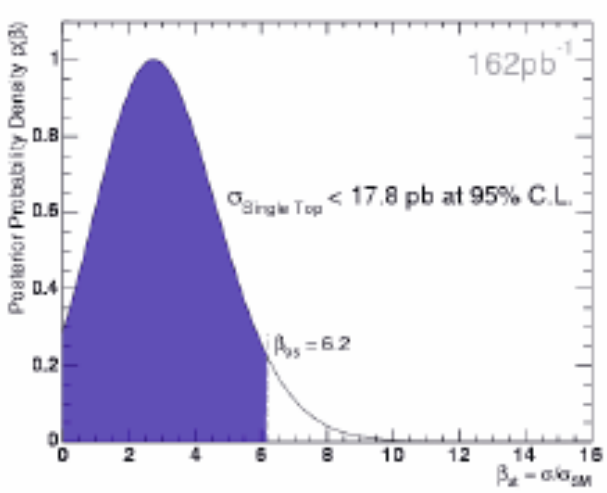


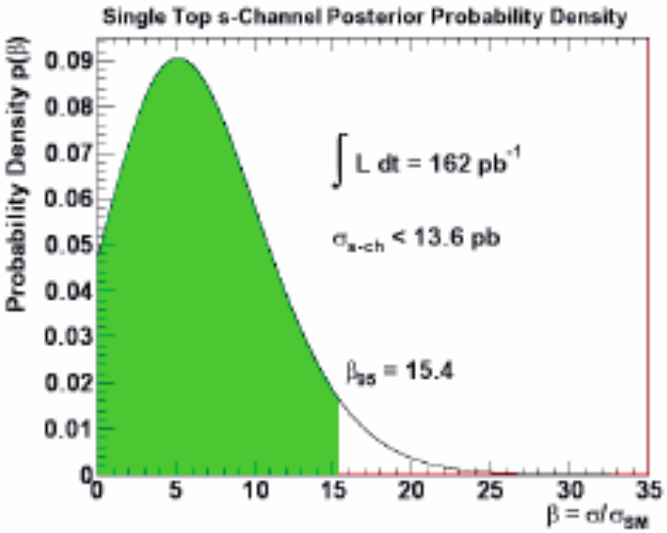


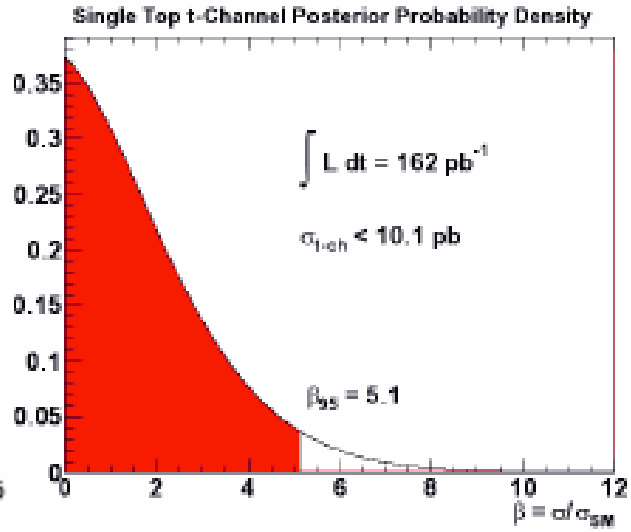




CDF Likelihood Results







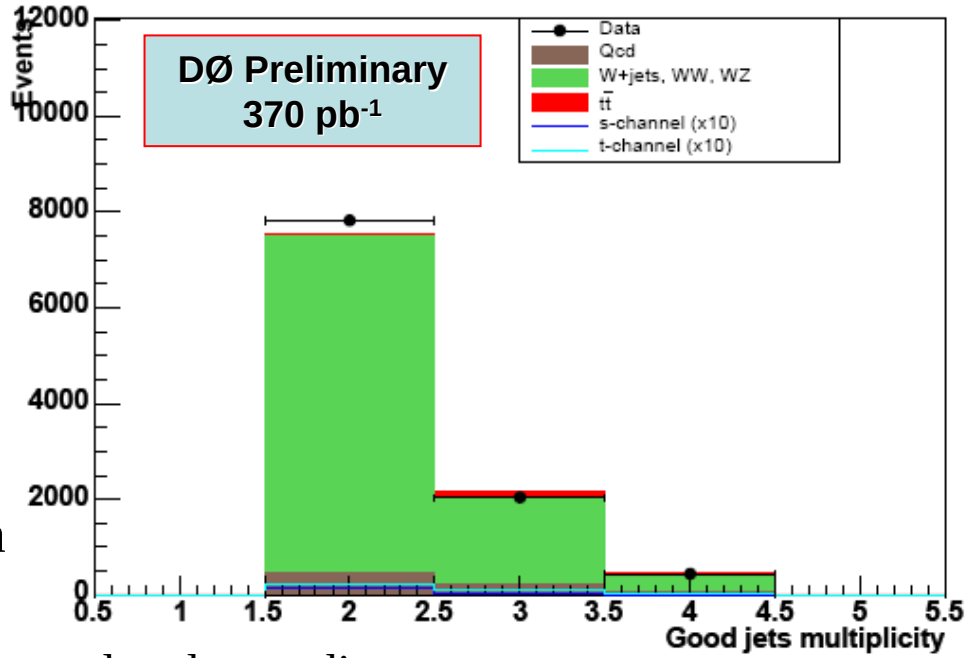
95% C.L. on the single top cross-section

Combined		t-channel		s-channel	
Observed	**Expected**	**Observed**	**Expected**	**Observed**	**Expected**
17.8 pb	**13.6 pb**	**10.1 pb**	**11.2 pb**	**13.6 pb**	**12.1 pb**

DØ Single Top Analysis

Preliminary!

- Use 370 pb^{-1} of data
- W selection:
  - $p_T(\ell) > 15$ GeV/c
  - $|\eta_{\mu(e)}| < 2.0$ (1.1)
  - Missing $E_T > 15$ GeV
- Jets selection:
  - Require 2-4 jets in the event with $E_T > 15$ GeV, and $|\eta| < 3.4$
    - Important cross-check for background understanding
  - Leading jet's $E_T > 25$ GeV, $|\eta| < 2.5$
  - At least one jet is b-tagged

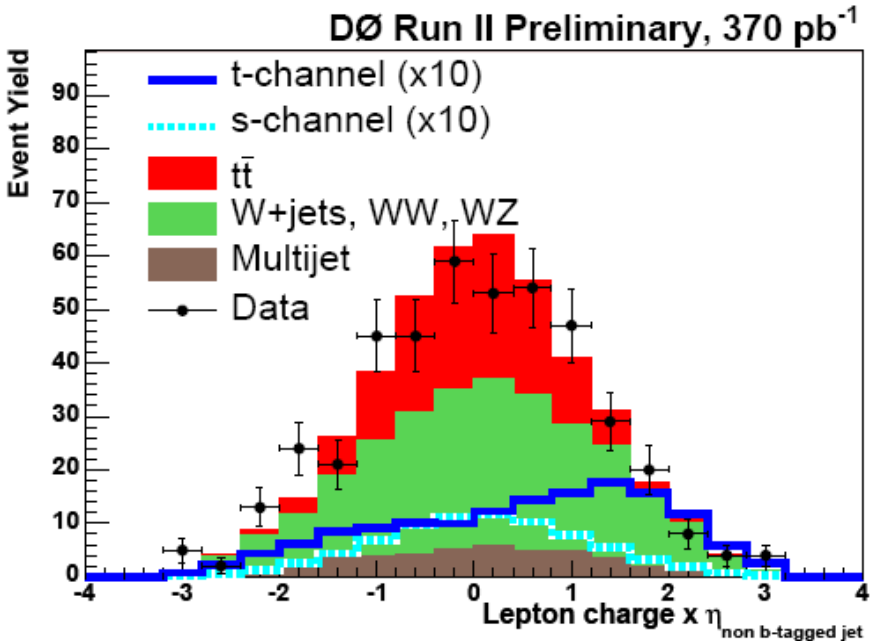


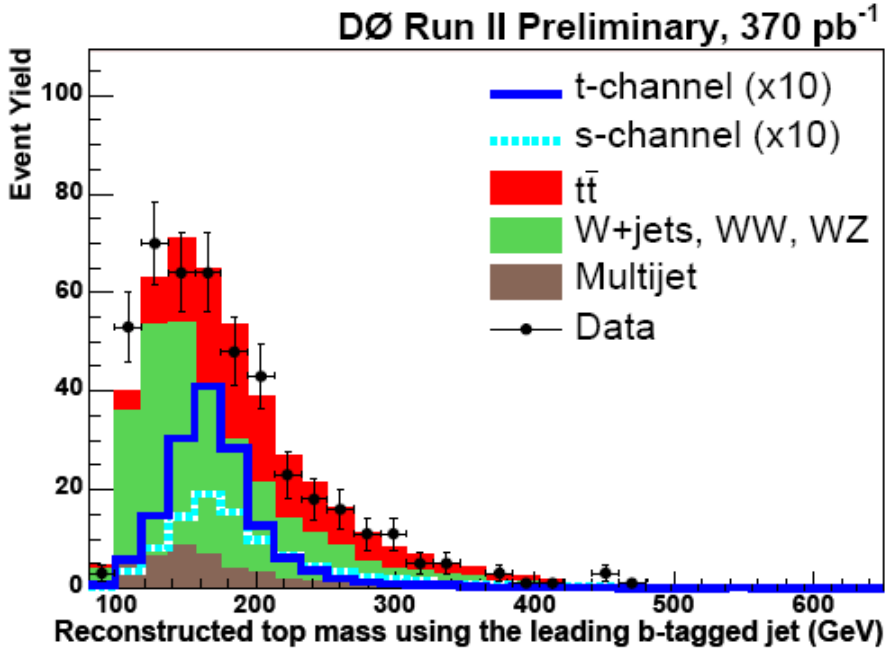
Combined (s- and t-channels, 1 tag)

Expected signal	19.4 ± 2.0 events
Expected background	372.9 ± 27.2 events
Observed	367 events

DØ Analysis Strategy

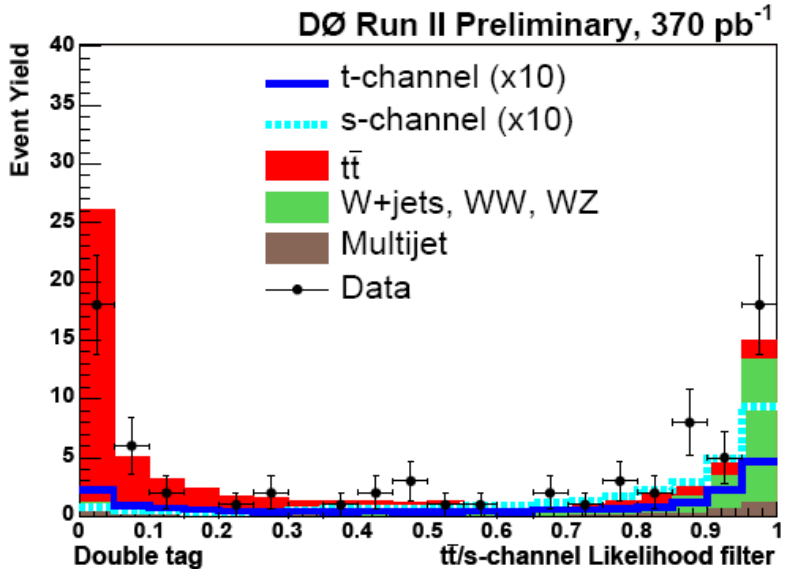
- Study various kinematic observables that have a discriminating power against W+jj and tt-bar processes
  - Example: ($Q_\ell \cdot \eta$) and top mass

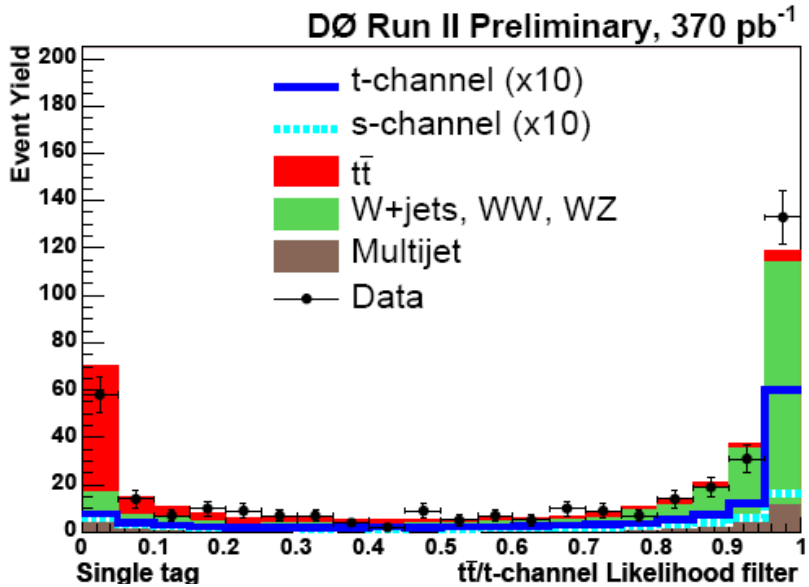


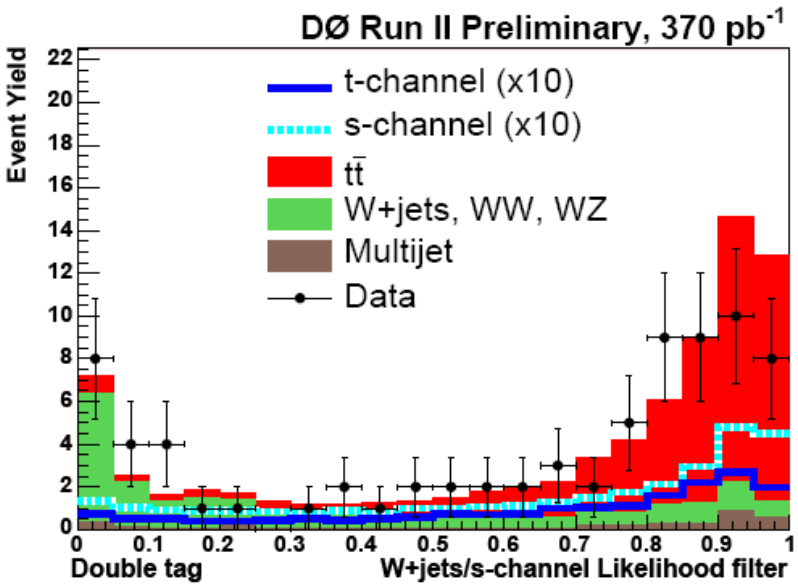


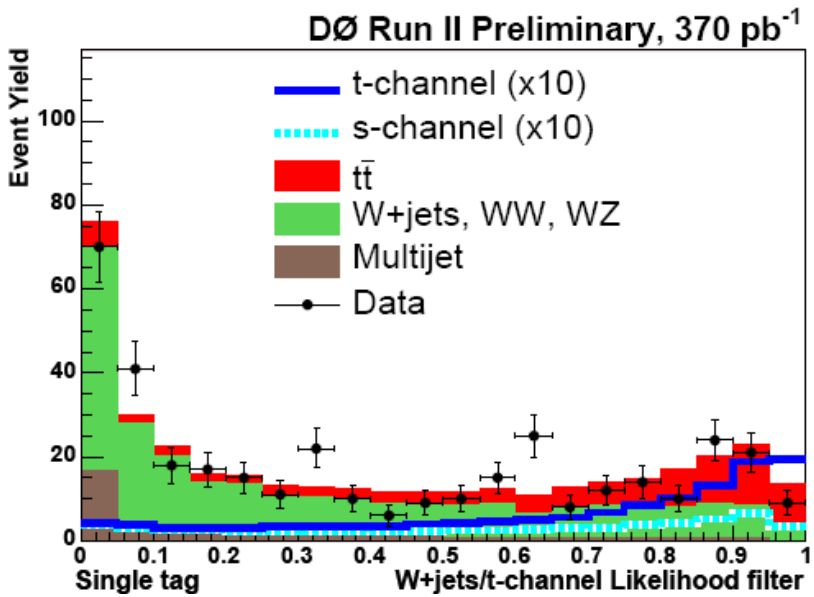
- Design16 likelihood discriminants for S/B separation:
  - 4 signal/background pairs: s-channel and t-channel / W+jj and tt-bar
  - 2 b-tagging schemes: 1-tag and 2-tags
  - 2 lepton flavors: electron and muon

DØ Likelihood Distributions



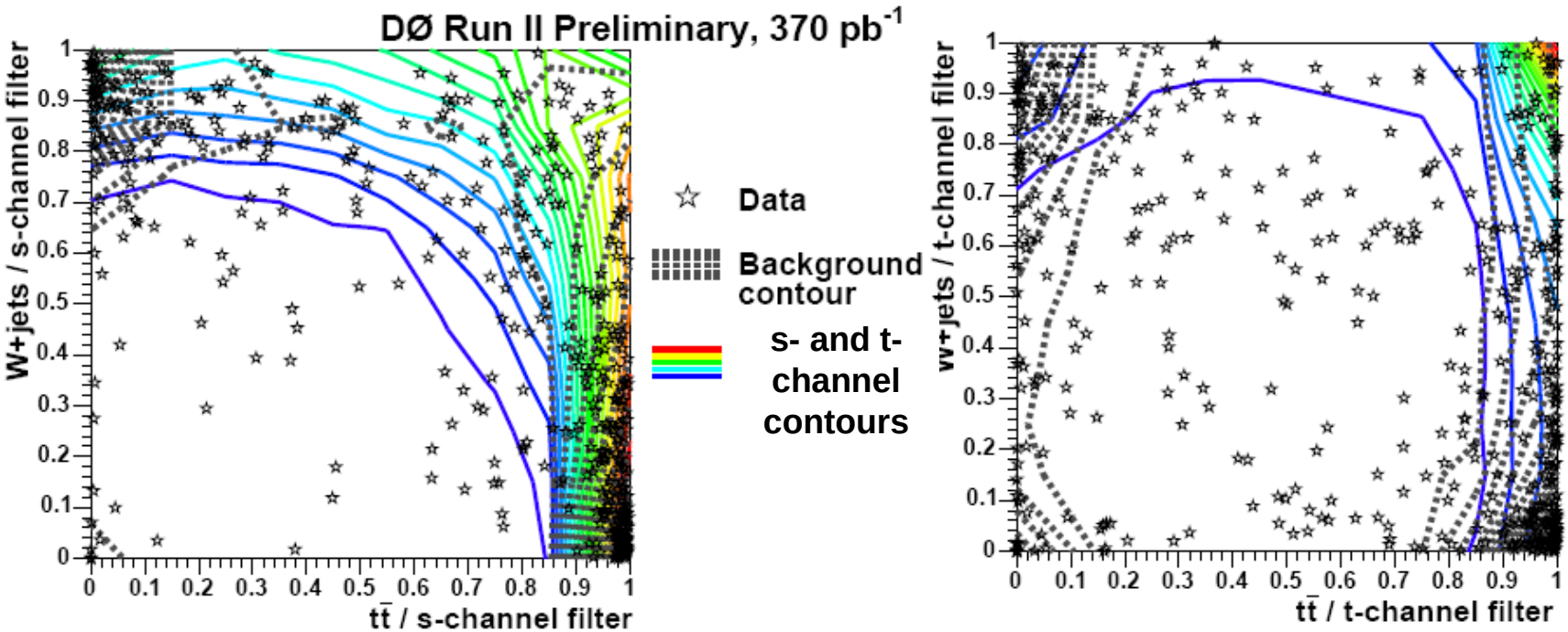






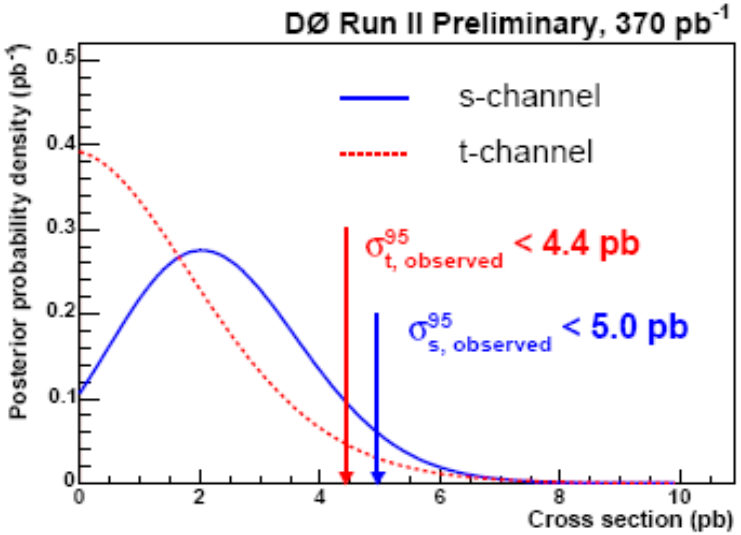
DØ Results

Combine results of likelihood discriminants in 2D histograms



No evidence for a signal, extract limits on cross-section!

DØ Results

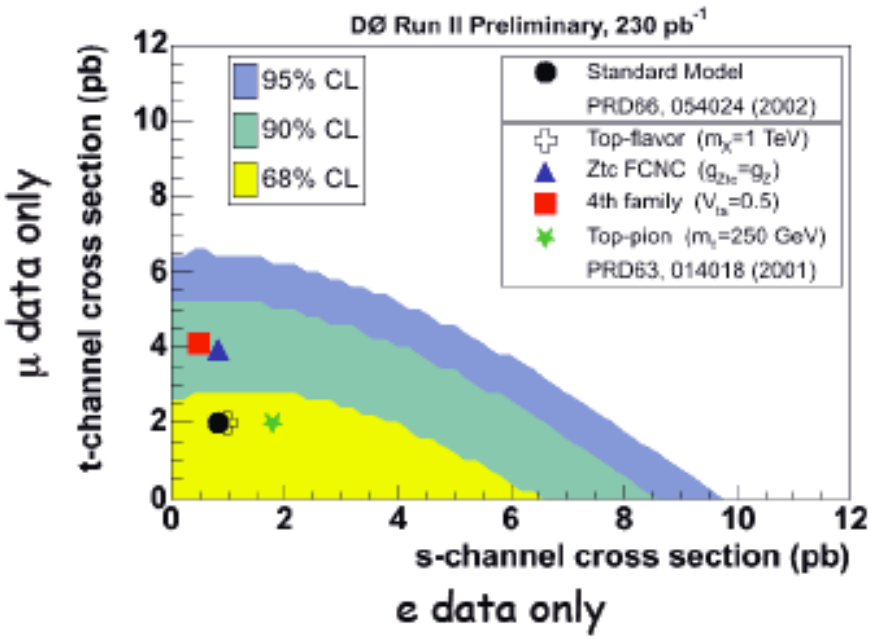


t-channel		s-channel	
Observed	**Expected**	**Observed**	**Expected**
4.4 pb	**4.3 pb**	**5.0 pb**	**3.3 pb**

Analysis is statistics limited!

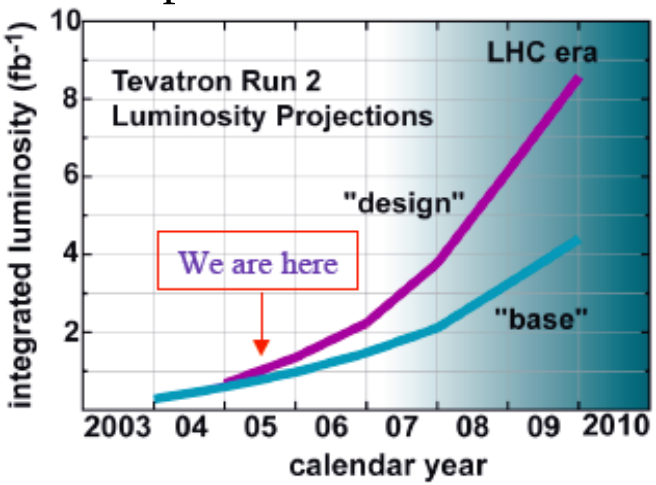
Monte Carlo Systematic Uncertainties	
Components affecting normalization	
$\sigma_{t\bar{t}}$ theory and mass	18 %
$\sigma_{s(t)}$ theory	15 %(16 %)
Jet Fragmentation	5 %
e (μ) ID	4 %(5 %)
Components affecting shape and normalization	
Single (double) b-tagging modeling	6 %(17 %)
Jet Energy Scale	1-5 %
Trigger Modeling	2-7 %
Jet ID	1-4 %

Reaching sensitivity for new physics (FCNC and 4th generation)

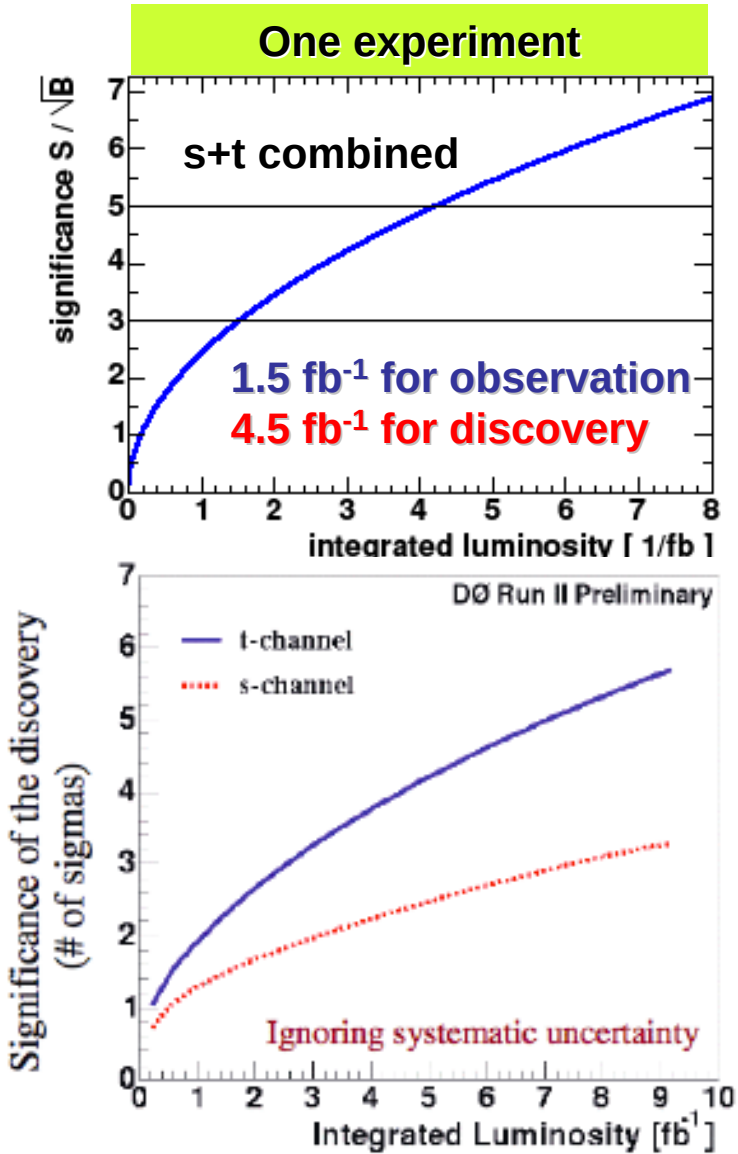


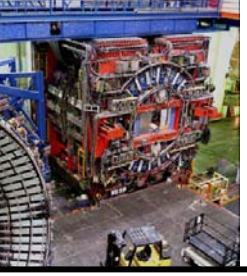
Outlook

- Assume no improvement in analysis technique, methods, and resolution:
  - It will take **1.5 fb^{-1}** of data to have an evidence for a single top production for one experiment!
- Both experiments have more than 1 fb^{-1} on tape!



- Lots of work to improve resolution and increase acceptances/efficiencies





Summary

- Current analyses not only provide drastically improved limits on the single top cross-section, but set all necessary tools and methods toward discovery with larger data sample.

95% C.L. limits on single top cross-section

Channel	CDF(162 pb^{-1})	DØ (370 pb^{-1})
Combined	17.8 pb	
s-channel	13.6 pb	5.0 pb
t-channel	10.1 pb	4.4 pb

Channel	Theory (NLO)
s-channel	0.88 pb
t-channel	1.98 pb

- Both collaborations aggressively work on improving the results:
  - Improving ID algorithms (lepton ID, b-tagging algorithms etc.), acceptance
  - Developing data analysis tools (Neural Nets, Boosted Decision trees, Maxtrix Element analysis etc.)
  - Reducing systematic errors (JES, background modeling, etc.)

Single Top Discovery is feasible in Run II, stay tuned!!!