Top Properties and Single Top at Tevatron

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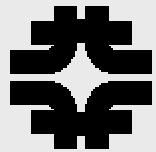


Hadron Collider Physics Symposium 2007
La Biodola, Isola d'Elba (Italy)
May 21, 2007

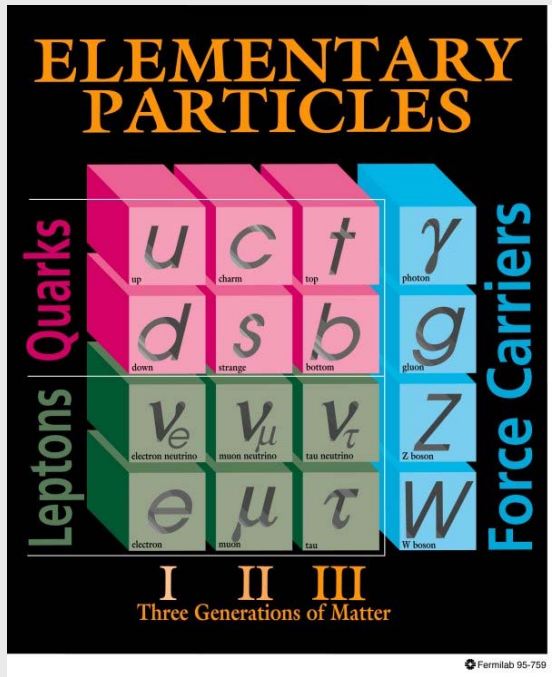
Outline

- Introduction
- Recent top properties results with ttbar sample
  - Cross section
  - Top production mechanism
  - Helicity of W-boson from Top decay
  - Top charge measurement
- Recent electro-weak (EW) single top results
- Search for beyond the Standard Model (SM) physics with top events:
  - Search for ttbar resonance
  - Search for W'
- Summary and prospects

Note: Most of the results in this talk use ~1 fb^{-1} data

Top Quark Physics

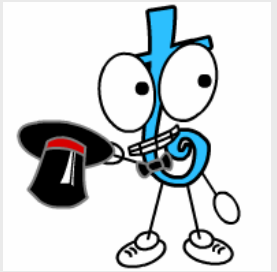
- Existence required by the SM
  - Spin 1/2 fermion, charge +2/3
  - Weak-isospin partner of the bottom quark
- Discovered ~11 years ago at Tevatron
- Mass surprisingly large ⇒ ~40x heavier than the bottom quark
  - Only SM fermion with mass at the EW scale



As Top-quark is heavy:

- **Top decays before hadronization:** $\Gamma \sim 1.4$ GeV $>> \Lambda_{QCD}$
  - **Provide a unique opportunity to study a "bare" quark**
- Currently only produced at Tevatron ⇒ somewhat "rare"

Why Study Top Properties?



Try to address some of the questions:

- Why is top so heavy ? Is top related to the EWSB mechanism?
  (PRD 59, 075003 (1999); PRD 65, 055006 (2002))
- Is it the SM top?
- Search for beyond SM physics:
  - Does top decay into new particles? couple via new interactions?

Pair production
- **Cross section**
- **Production mechanism**
  - **$qq/gg \rightarrow tt$**
- **tt resonance search**
- *Spin-correlations, FCNC,*

DECAY
- **W helicity**
- *Anomalous couplings, Charged Higgs*

Characteristics
- **Mass
- **Charge**
- *Life-time, Spin, ...*

EW-single top
- **Cross section**
- **W' search**
- **…**

Top Quark Pair Production

- **At Tevatron top quark predominantly pair produced via strong interaction**

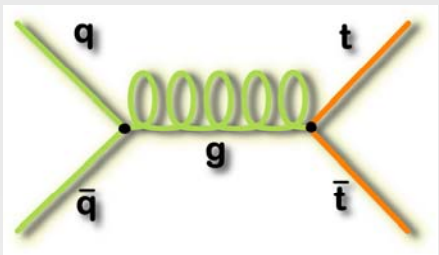
σ_{tt} = 6.8 pb for m_{top}=175 GeV/c^2

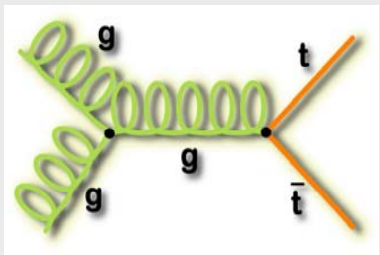
(JHEP 0404:068 (2004), PRD 68, 114014 (2003))

~85% from qq→tt

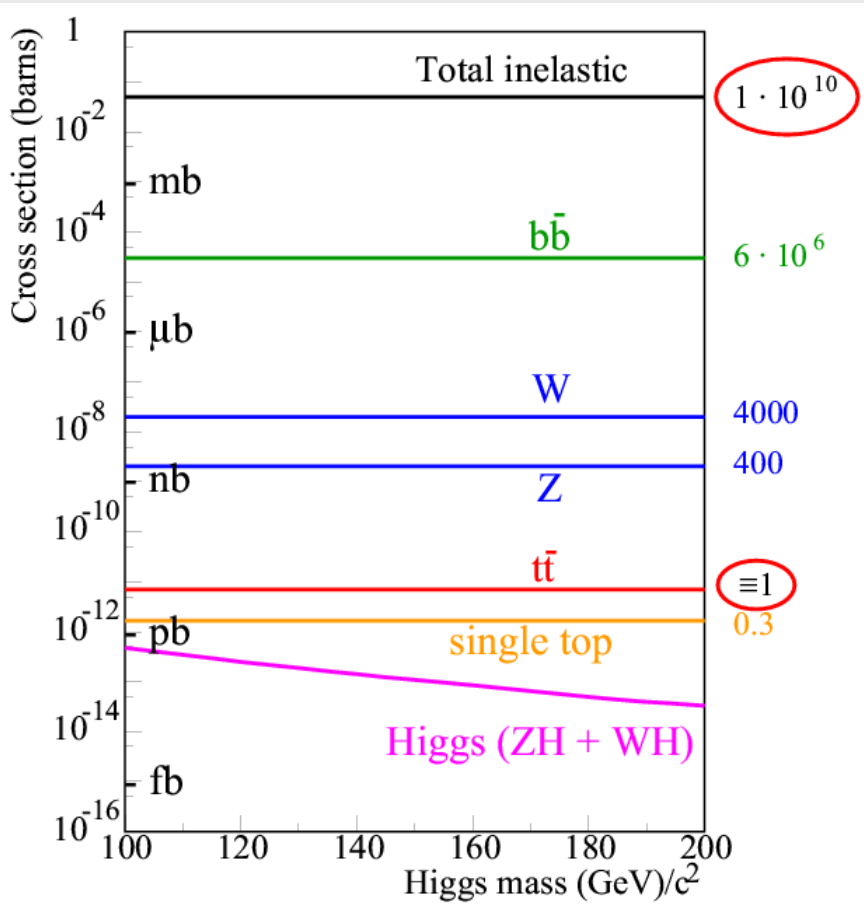
~15% from gg→tt

Pair Production:





Rare at Tevatron: One top pair per 10 billion inelastic collisions

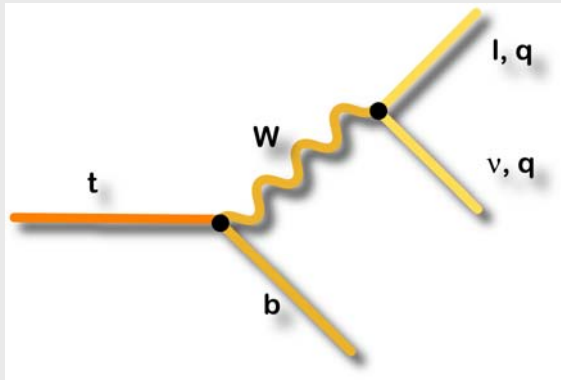


Top Decay

- In the SM: Br(t $\rightarrow$Wb) ~ 100%

Top pair decay channels classified by W decays

- **Dilepton:** *l νl νbb*
  - Experimental signature: 2 high-P_T e's or μ's, 2 high-E_T jets, large missing E_T *(for l = e, μ or τ decaying leptonically)*
  - Low background
- **Lepton+jets:** *l νqqbb*
  - Experimental signature: 1 high-P_T e or μ, 4 jets (2 b's), large missing E_T *(for l = e, μ or τ decaying leptonically)*
  - Medium background
- **All-hadronic:** *qqqqbb*
  - Experimental signature: 6 jets (2 b's)
  - Large background

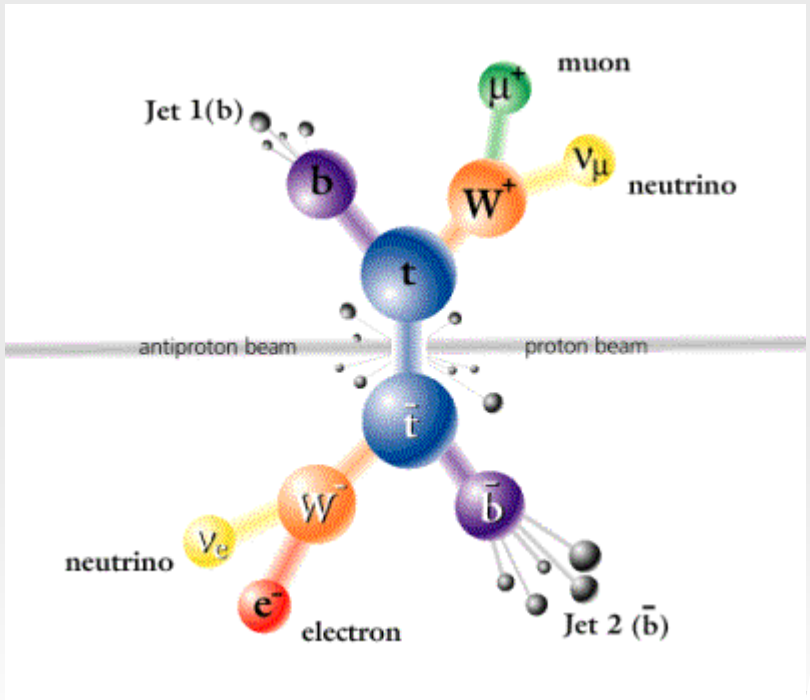


Top Pair Decay Channels

W decay	e^+	μ^+	τ^+	$u\bar{d}$	$c\bar{s}$
e^-	e^-e^+	$e^-\mu^+$	$e^-\tau^+$	electron+jets	
μ^-	μ^-e^+	$\mu^-\mu^+$	$\mu^-\tau^+$	muon+jets	
τ^-	τ^-e^+	$\tau^-\mu^+$	$\tau^-\tau^+$	tau+jets	
$\bar{u}d$	electron+jets	muon+jets	tau+jets	all-hadronic	
$\bar{c}s$					

dileptons

Top Properties Measurements with ttbar Sample



Top Pair Production Cross-Section

- Tests QCD in very high Q^2 regime.
- Compare measured cross sections among various ttbar final states
  - Anomalies in the tt rate would indicate the presence of non-QCD production channels: for example resonant state $X \rightarrow$ tt
- Different methods of extraction with different sensitivity are used
- Provides important sample composition for all other top property measurements.

1.12 fb^{-1}

Cross Section with Lepton+Jets

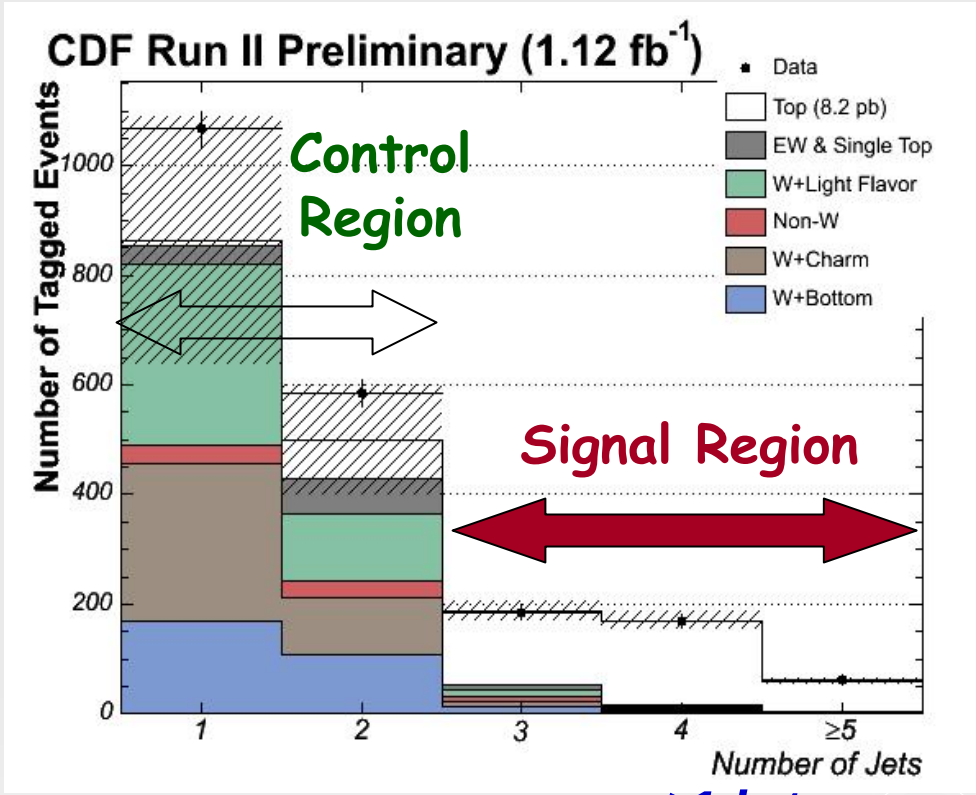
- Counting experiment

$$\sigma_{tt} = \frac{N_{Data} - N_{Background}}{Acc \int Ldt}$$

- Event Samples:
  - ≥1 b-tags

    Signal fraction ~80%
  - ≥2 b-tags

    Signal fraction ~90%
- *Most top properties measurements use ≥4 jets events. Yields: 231 (≥1 b-tag), 101 (≥2 b-tags)*



≥1 b-tag

≥1 b-tag: $8.2 \pm 0.5(stat) \pm 0.8(syst) \pm 0.5(lum)$ pb

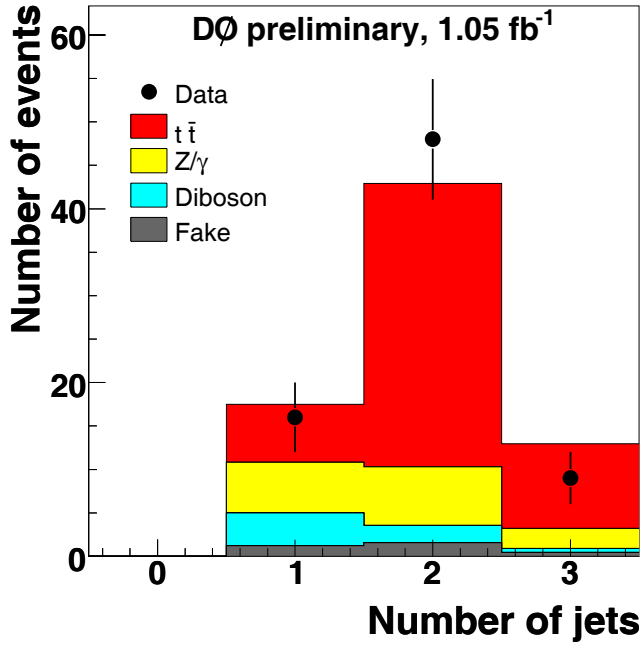
≥2 b-tag: $8.8^{+0.8}_{-0.7}(stat) \pm 1.2(syst) \pm 0.5(lum)$ pb

World's Best

1.05 fb^{-1}

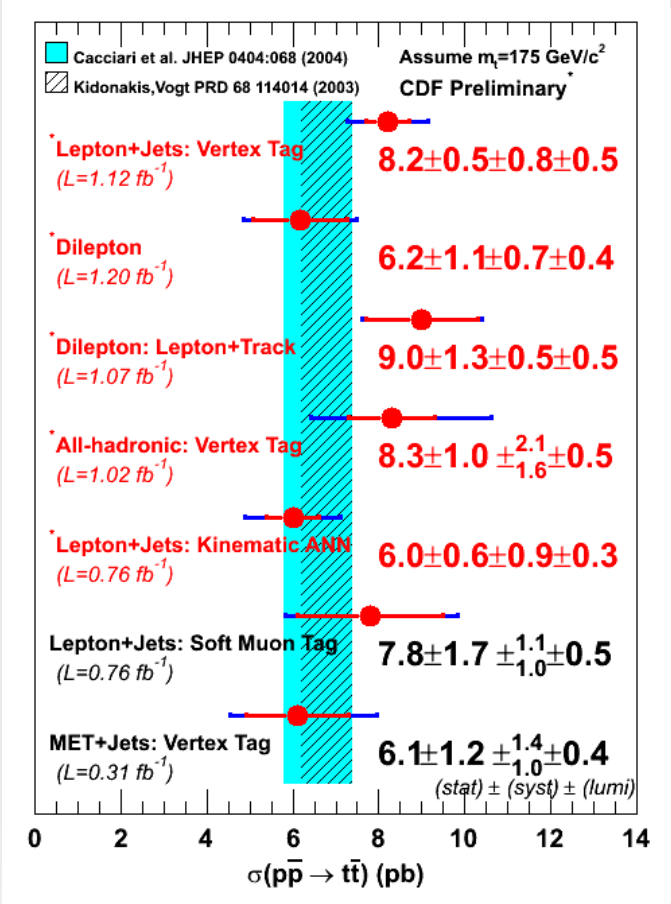
Cross Section with Dilepton

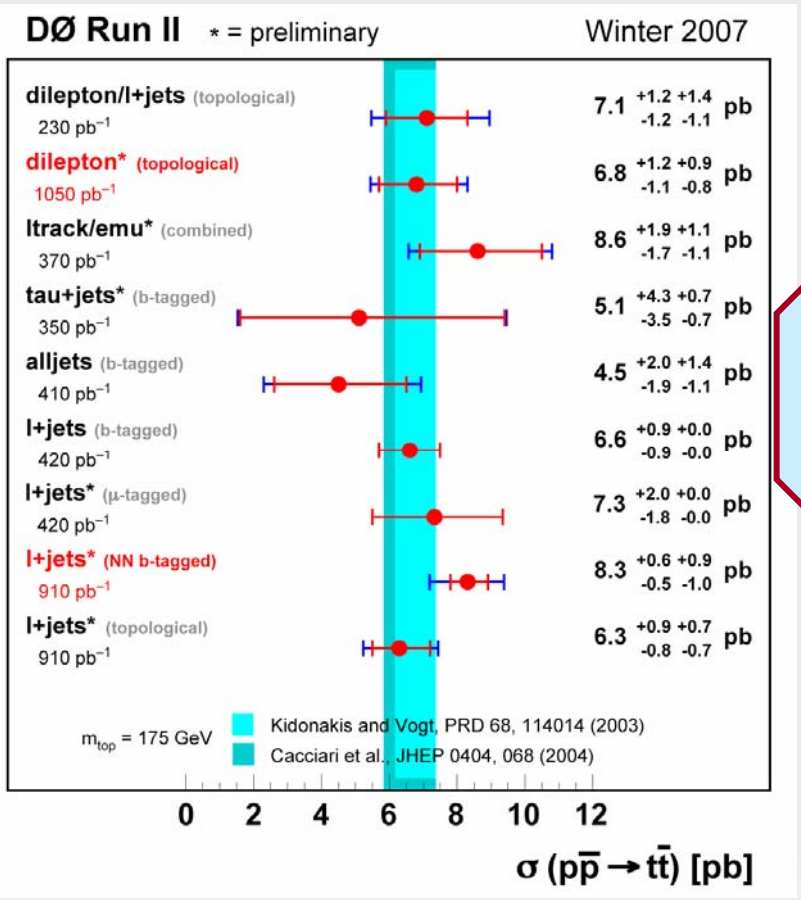
- Counting experiment using events with ee+≥2 jets, μμ+≥2 jets, eμ+≥1 jet
- Observed data events: 73
  - 16 ee, 9 μμ
  - 32 eμ+≥2 jets, 16 eμ+1jet
- Expected background: 23.5
  - No requirement on b-jet identification



$$\begin{aligned}
\text{ee} &: \quad \sigma_{t\bar{t}} = 9.6^{+3.2}_{-2.7}\,(\text{stat})\,^{+1.9}_{-1.6}\,(\text{syst}) \pm 0.6\,(\text{lumi})\,\text{pb} \\
\text{e}\mu &: \quad \sigma_{t\bar{t}} = 6.1^{+1.4}_{-1.2}\,(\text{stat})\,^{+0.8}_{-0.7}\,(\text{syst}) \pm 0.4\,(\text{lumi})\,\text{pb} \\
\mu\mu &: \quad \sigma_{t\bar{t}} = 6.5^{+4.0}_{-3.2}\,(\text{stat})\,^{+1.1}_{-0.9}\,(\text{syst}) \pm 0.4\,(\text{lumi})\,\text{pb} \\
\text{dilepton} &: \quad \sigma_{t\bar{t}} = 6.8^{+1.2}_{-1.1}\,(\text{stat})\,^{+0.9}_{-0.8}\,(\text{syst}) \pm 0.4\,(\text{lumi})\,\text{pb}
\end{aligned}$$

Cross-section Summary



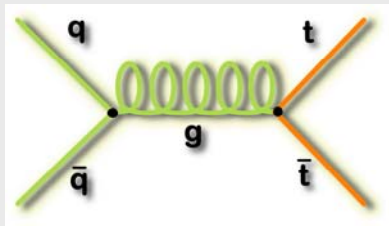


Measurements in all channels using different methods are consistent

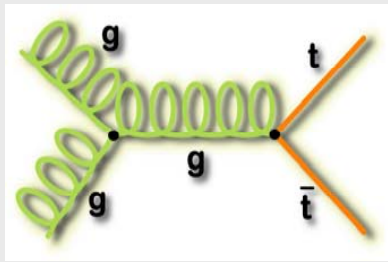
- Uncertainties in Lepton+Jets cross-section measurements becoming comparable to the theoretical uncertainty
- Current best Lepton+Jets cross section measurement is limited by systematic uncertainties ⇒ ***Major sources: luminosity (~6%), b-tagging (~6%), Jet Energy Scale (~4-6%), Parton Density Functions, signal and background modeling***

Top Pair Production Mechanism: Measurement of $\sigma(gg \rightarrow tt)/\sigma(pp \rightarrow tt)$

- Tests pQCD and sensitive to new production mechanisms
- Prediction: At 1.96 TeV
  ~85% from $qq \rightarrow tt$,
  ~15% from $gg \rightarrow tt$



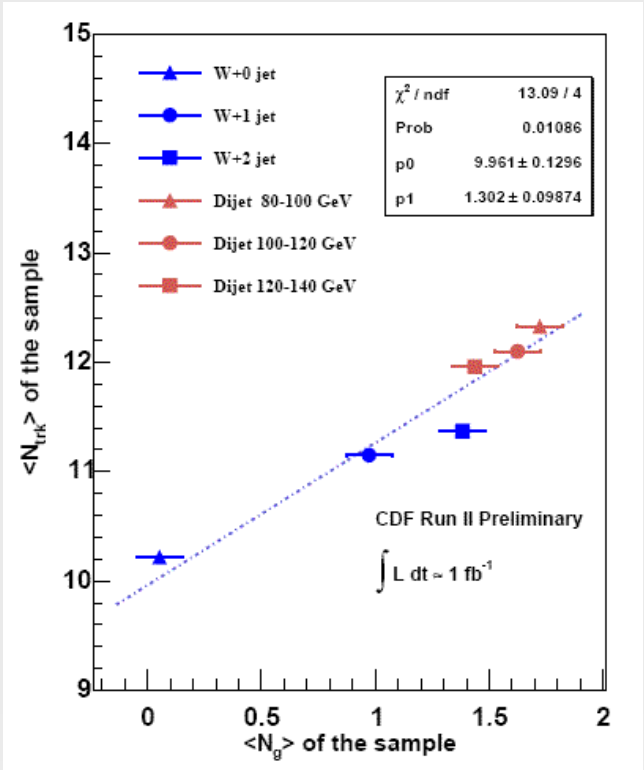
Vs

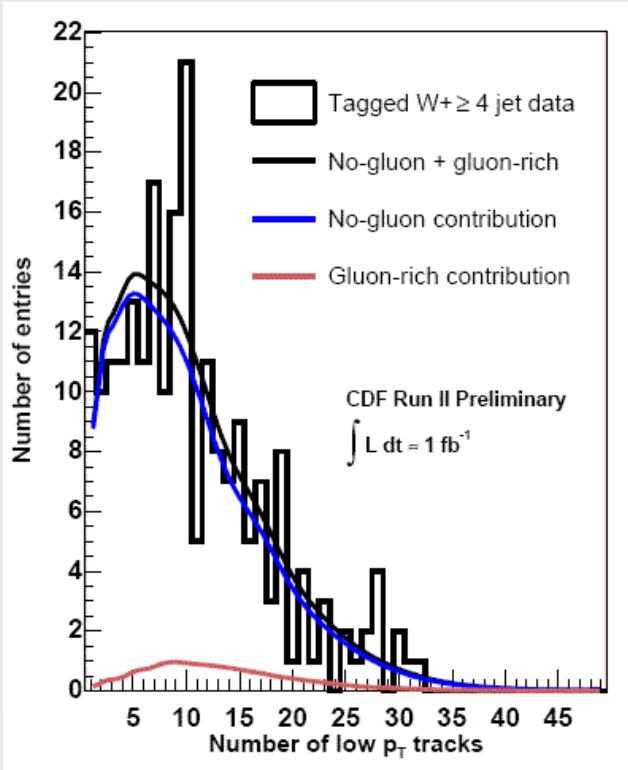


- Two different methods used in CDF
- Method I : Use correlation between the number of low p_T tracks in the event and the number of gluons: $\langle N_{trk} \rangle$ **vs.** $\langle N_g \rangle$
  - gg initial state tends to have greater underlying event activity
- Method II: Use ttbar production and decay kinematics
  - For $gg \rightarrow tt$: tend to produce in forward region with unlike spin
  - For $qq \rightarrow tt$: tend to produce centrally with like spin

Method I : $\langle N_{trk} \rangle$ vs. $\langle N_g \rangle$

1 fb^{-1}





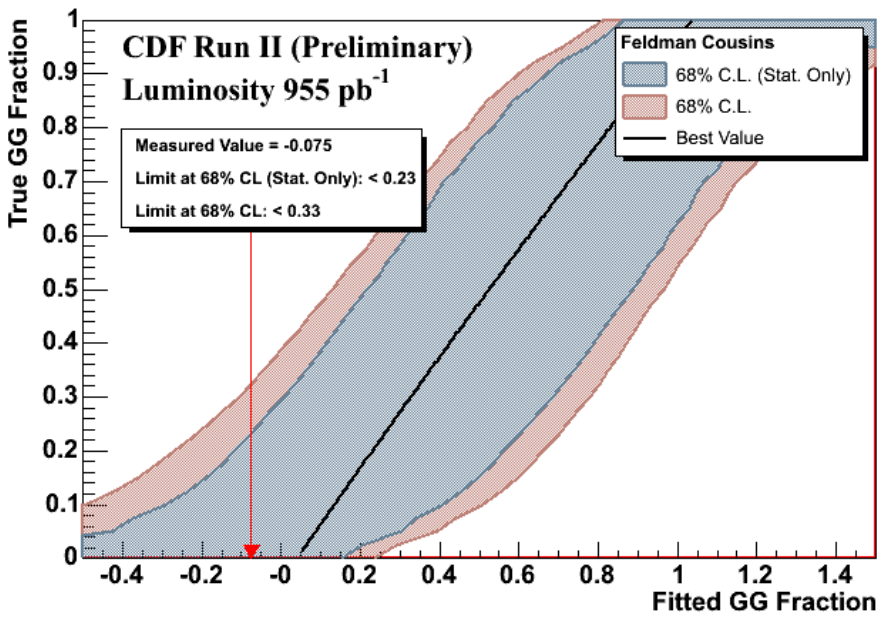
- Calibrate $\langle N_{trk} \rangle$ vs. $\langle N_g \rangle$ correlation using W+jets and dijet data.
- Fit W+jets (b-tagged) data to gluon-rich and **no-gluon $\langle N_{trk} \rangle$ templates**.

$$\frac{\sigma(gg \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} = 0.01 \pm 0.16(stat.) \pm 0.07(syst.)$$

Method II : Kinematics

955 pb^{-1}

- Fully reconstruct the kinematics of the lepton+jets system
- Use NN with 8 input variables:
  - Two corresponds to ttbar production
  - Six contains spin correlation information from the decay
- Fit data to templates constructed from the NN output shapes

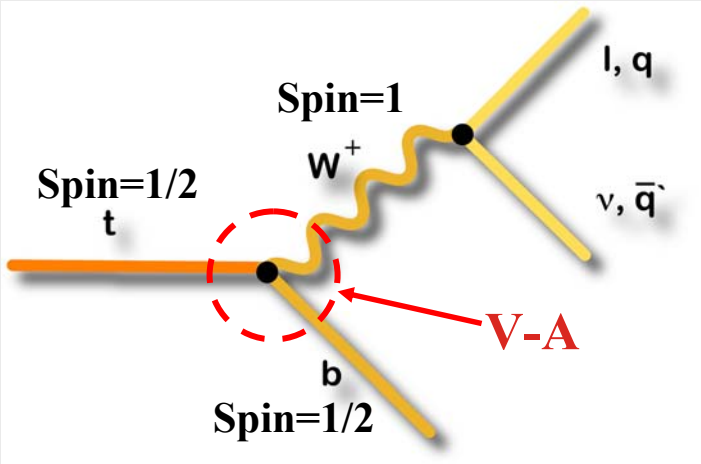


$$\frac{\sigma(gg \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} < 0.61 \quad @ \quad 95\% \quad CL$$

$$\frac{\sigma(gg \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} < 0.33 \quad @ \quad 68\% \quad CL$$

W Helicity: tbW coupling

- The SM top decays via EW interaction: Br(t→bW)~100%
  - Top decays as a bare quark ⇒ spin info transferred to final states
- Possible W helicities:
  - J•P = 0: longitudinal
  - J•P = -1: left-handed
  - J•P = +1: right-handed
- V-A coupling in the SM ⇒
  - longitudinal fraction f_0 ~70%
  - left-handed fraction f_- ~30%
  - right-handed fraction f_+ ~0%



- The SM prediction modified in various new physics models
  - PRD 45, 124 (1992); PRL 38, 1252 (1977); J. Phys. G26, 99 (2000); PRD 62, 011702 (2000); PRD 65, 053002 (2002).

Most recent CDF results with 955 pb^{-1} (next slides)

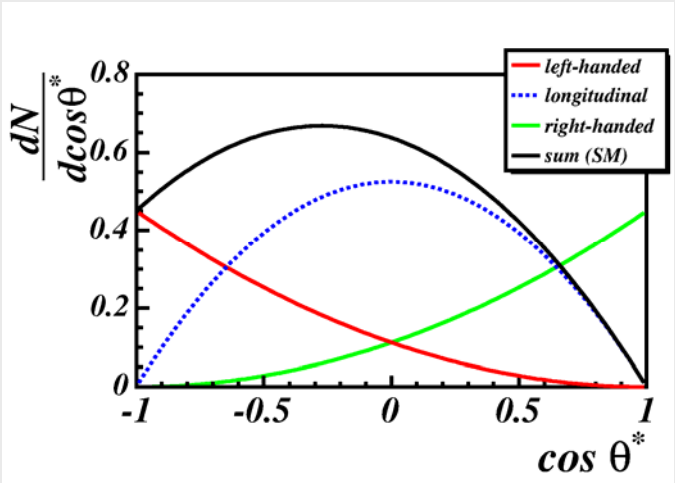
Some of the previous measurements:

CDF : Lepton+jets and Dilepton in 750 pb^{-1} ($f_+ < 0.09$ @ 95% C.L.)

D0: Lepton+jets and Dilepton in 370 pb^{-1} ($f_+ < 0.23$ @ 95% C.L)

W Helicity (Cont')

- Most recent measurements use **cosθ***
  - **cosθ*** : Angle between lepton and b in W rest frame.



cosθ*(lepton,b-quark) in W frame

W+≥4jets with ≥1 b-tags → Fully reconstruct ttbar events. Boost to top and W rest frames to reconstruct cosθ*

Likelihood fit to the reconstructed cosθ* and obtain W helicity fractions

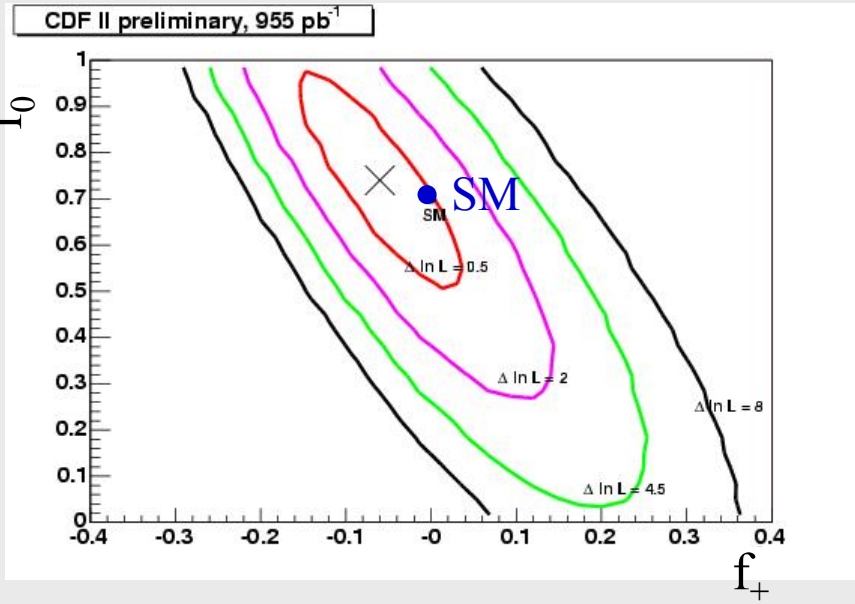
(1) Fix f_+=0.0, fit for f_0

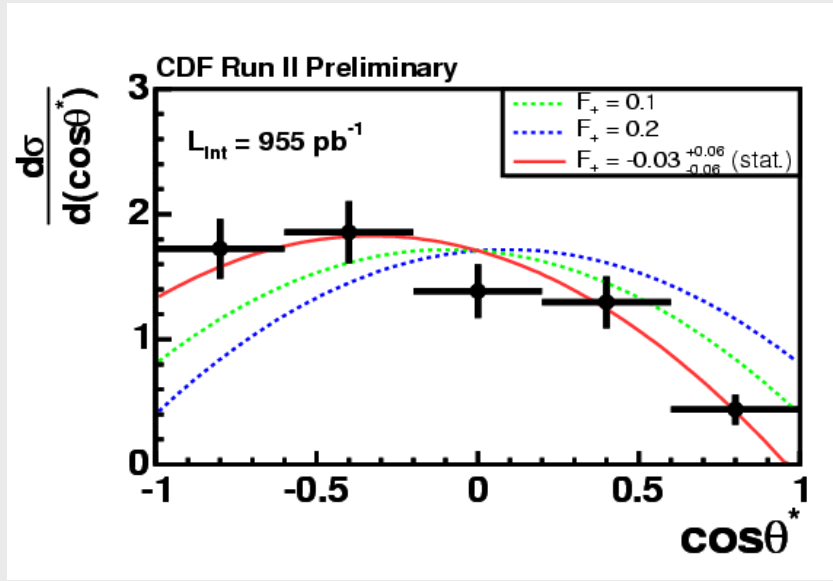
(2) Fix f_0 to the SM expected value, fit for f_+

(3) Simultaneous fit to f_0 and f_+

W Helicity Results

955 pb^{-1}





f_0= 0.61±0.12(stat)±0.06(syst) with f_+ fixed to SM expectation (f_+=0)

f_+< 0.11 @95% CL with f_0 fixed to SM expectation (f_0=0.7)

Simultaneous Fit: **f_0=0.74±0.25(stat)±0.06(syst), f_+ = -0.06±0.10(stat)±0.03(syst)**

f_0=0.59± 0.12 (stat) ± 0.06 (syst) with f_+=0, **f_+< 0.10 @95% CL** with f_0=0.7

- Measured f_0 and f_+ consistent with the SM expectation
- Measurements limited by statistics

Top Charge

- Is the observed particle with mass ~170 GeV really the SM top?
  - The SM does predict top charge of 2e/3
- Other top physics measurements DO NOT check the flavor of the b-jet
  - Ambiguity in pairing of W and b-jet from top decay ⇒ 2e/3 or -4e/3 ?
- There is a beyond SM theory that predicts an exotic particle with charge -4e/3 and the same other properties as "top" (D.Chang et al. PRD 59, 09153(99)):
- CDF and D0: discriminate between **2e/3 (Standard Model-like)** and **-4e/3 (Exotic Model-like)** scenarios

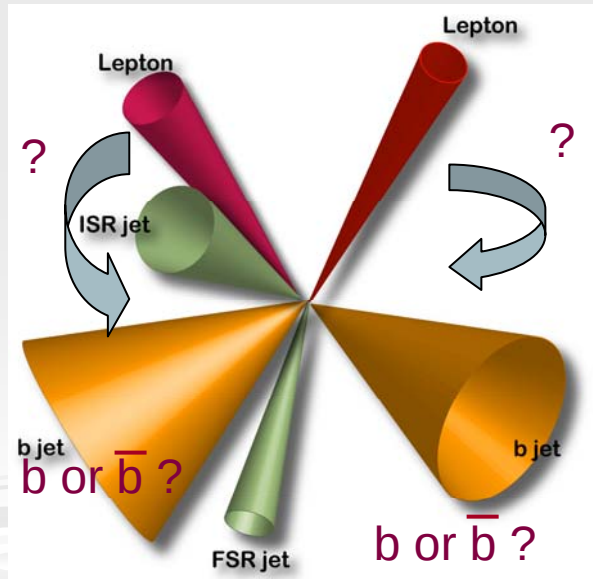
- CDF measurement : 955 pb^{-1} (next slide)
- First measurement by D0 (370 pb^{-1})

Pairing of W and b-jet

W charge : use lepton charge

Flavor of b: jet charge

$$Q_{bjet} = \frac{\sum_i q_i^{track} \left(\vec{p}_i^{\,track} . \hat{a}_{jet}\right)^{0.5}}{\sum_i \left(\vec{p}_i^{\,track} . \hat{a}_{jet}\right)^{0.5}}$$



955 pb^{-1}

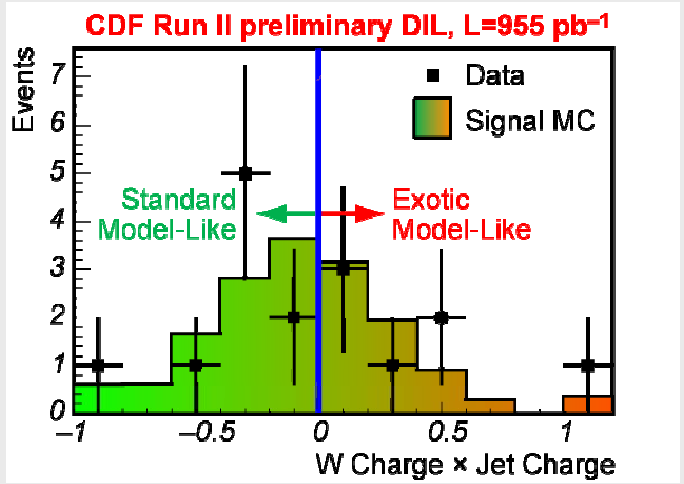
Top Charge (Cont')

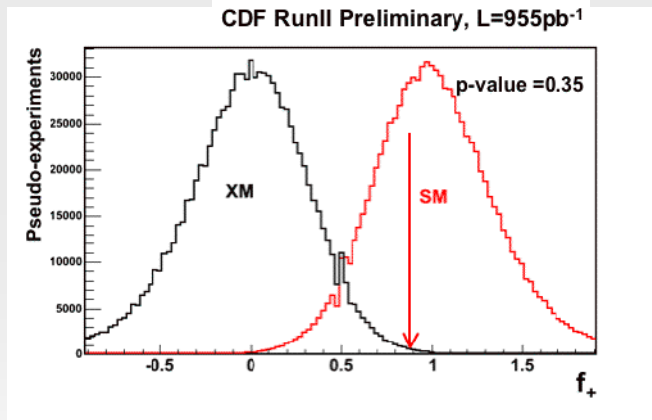
- Use Lepton+Jets and Dilepton events
- Counting experiment
  - **62 Standard Model-like (SM)** and **48 Exotic Model-like (XM)** pairs in data
- Obtain CL on either hypothesis using profile likelihood method (NIM A551, 493 (2005))
  - Incorporate "purity" ⇒ *probability of correctly pairing Wb and getting the correct flavor of b-jet*

Signal purity = 0.586 ± 0.007 (stat) ± 0.015 (syst)

- **Fraction of pairs with charge 2e/3 in data = 0.88**
- Result:
  - **Consistent with charge 2e/3 hypothesis**
  - **Exclude charge -4e/3 hypothesis at 81% confidence**

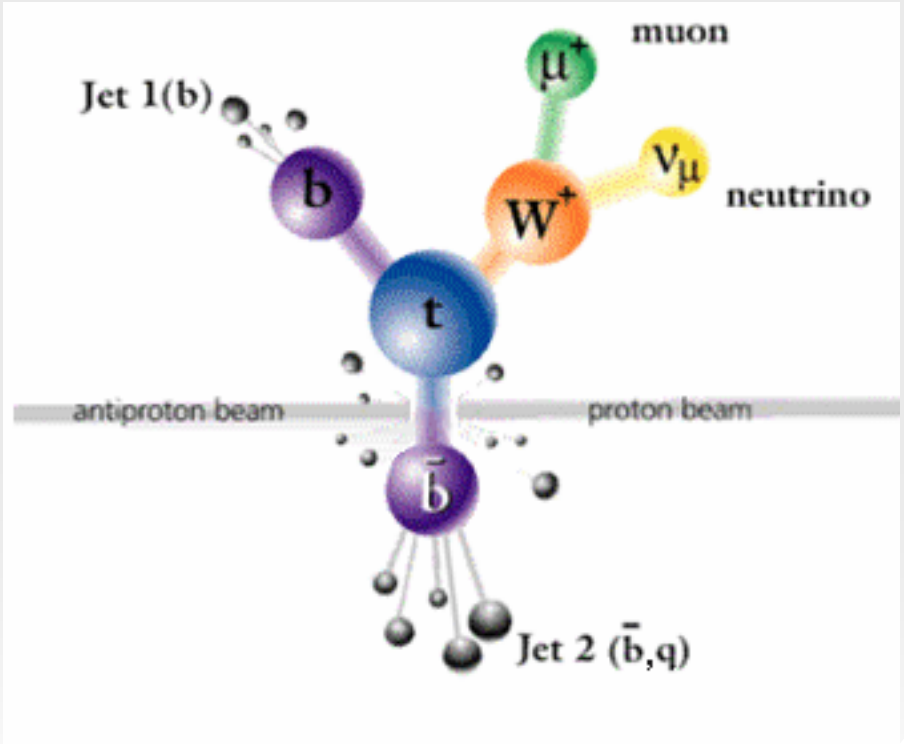
(Statistical treatment: a-priori 1% probability of incorrectly rejecting the SM)





Fraction of SM like pairs (f_+) assuming either the XM or the SM

Single Top

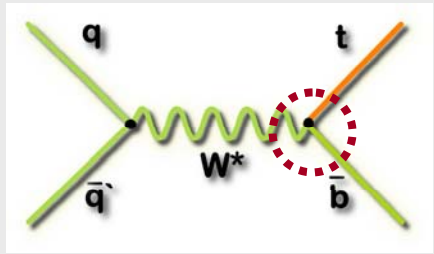

muon
Jet 1(b)
b
μ^+
ν_μ
neutrino
W^+
t
antiproton beam
proton beam
$\bar{b}$
Jet 2 ($\bar{b}$,q)

Physics of EW Single Top Production

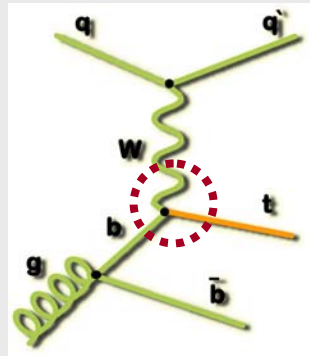
- The SM predictions (PRD70, 114012 (2004))
  - $\sigma_{\text{s-channel}} = 0.88 \pm 0.11$ pb
  - $\sigma_{\text{t-channel}} = 1.98 \pm 0.25$ pb

  (for $m_{top} = 175$ GeV/c^2)
- Direct measurement of V_{tb}: *(S. Willenbrock,* Rev. Mod. Phys. 72, 1141-1148*)*

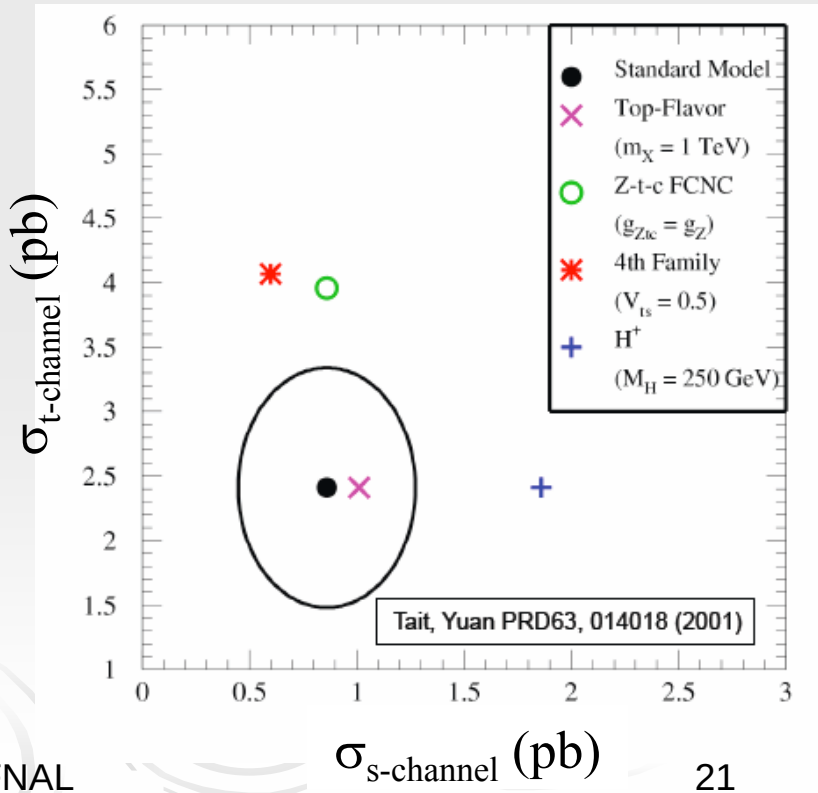
  $\sigma_{\text{single top}} \propto |V_{tb}|^2$
- Produced ~100% polarized top, can be used to test the V-A structure of the top EW interaction. *(G. Mahlon, hep-ph/9811219)*
- Sensitive to beyond SM physics
  - t-channel: 4th family, FCNC
  - s-channel: W', H^+



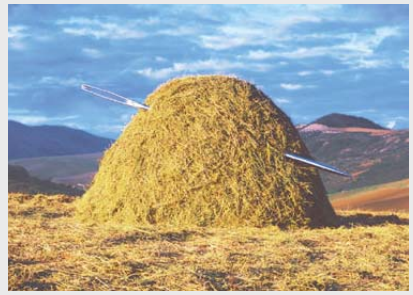
s-channel

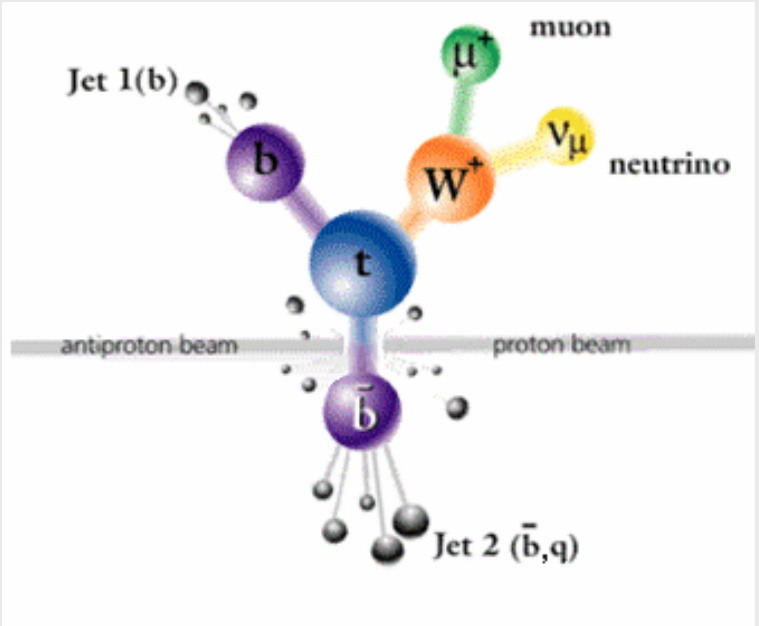


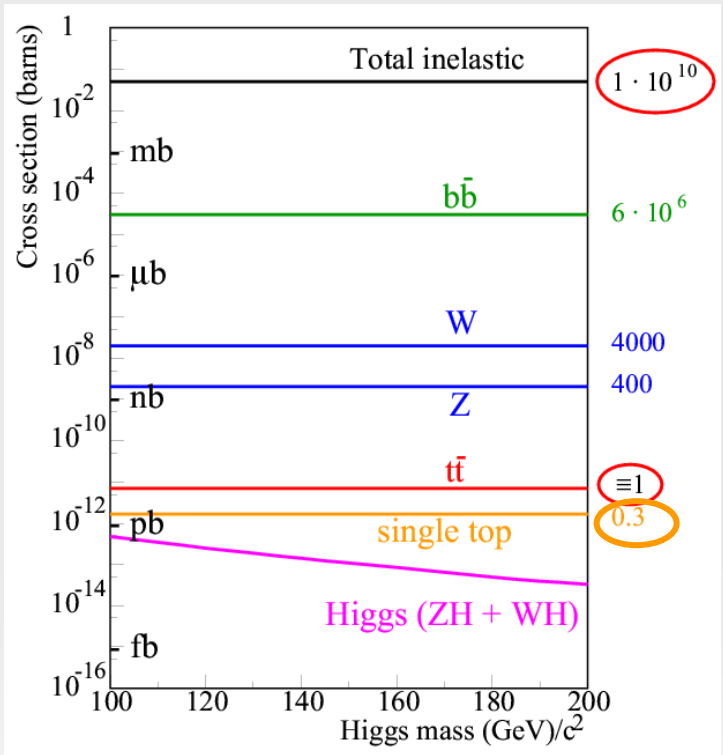
t-channel



Experimental Challenge

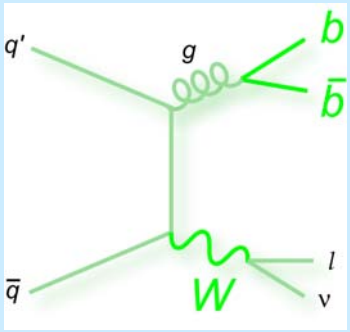


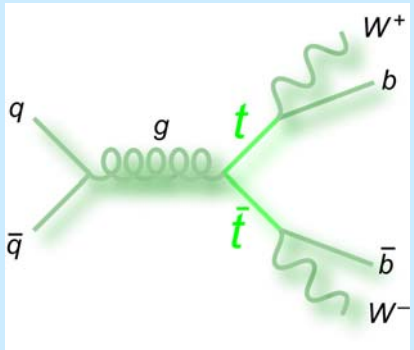


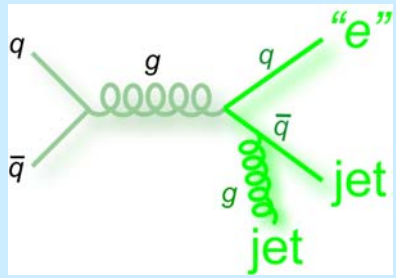


- Experimental signatures:
  - One high P_T isolated e or μ
  - Large missing transverse energy
  - ≥ 2 jets (≥ 1 b-tag)
- Suffers from large amount of W+jets backgrounds

Backgrounds







- Dominant backgrounds
  - W+jets and ttbar
- Non-W (multijets): jet faking e/μ
- Diboson (WW/WZ/ZZ), Z→ττ

- *b*-tagging crucial for improving S/B
- Most sensitive search region:

Lepton+2 Jets, ≥1 b-tag

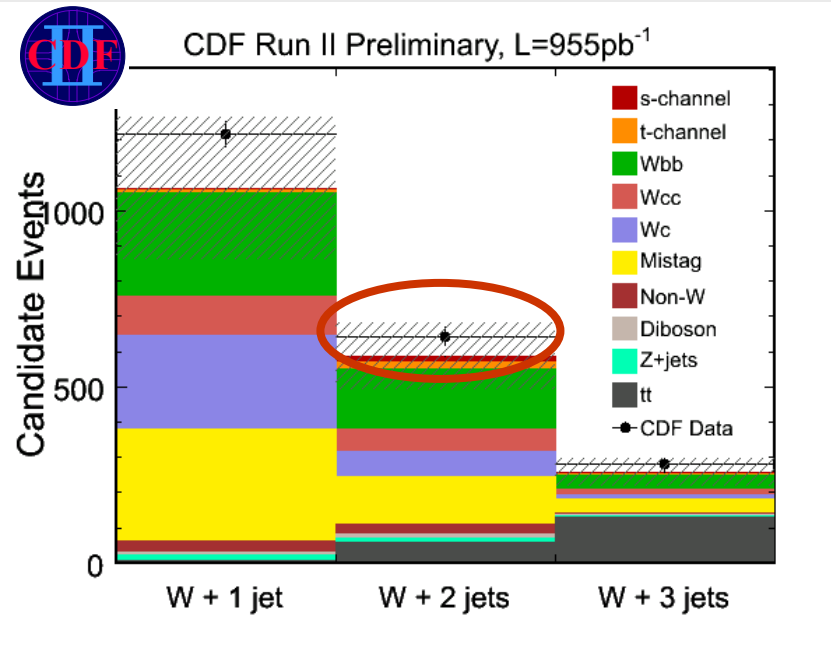
- S/B ~1/15 @ CDF

Percentage of single top *tb+tqb* selected events and S:B ratio (white squares = no plans to analyze)

Electron + Muon	1 jet	2 jets	3 jets	4 jets	≥ 5 jets
0 tags	10% 1 : 3,200	25% 1 : 390	12% 1 : 300	3% 1 : 270	1% 1 : 230
1 tag	6% 1 : 100	21% 1 : 20	11% 1 : 25	3% 1 : 40	1% 1 : 53
2 tags		3% 1 : 11	2% 1 : 15	1% 1 : 38	0% 1 : 43

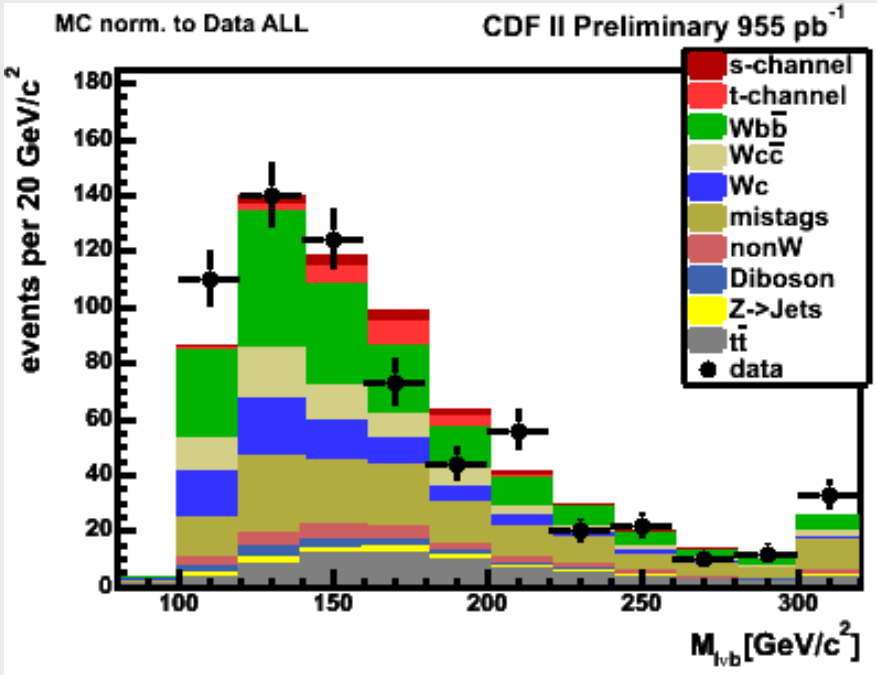
Event Yields

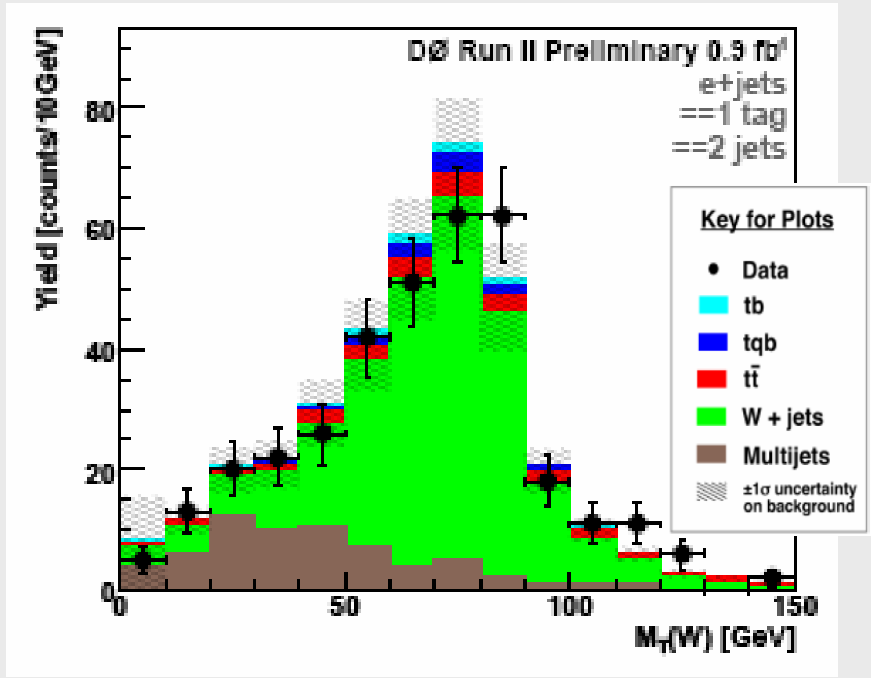
Electron + Muon ≥1 b-tag	CDF (1 fb^{-1}) W($l\nu$)+2 Jets	D0 (0.9 fb^{-1})		
		W($l\nu$)+2 Jets	W($l\nu$)+3 Jets	W($l\nu$)+4 Jets
Single top: s-channel	15±2	16±3	8±2	2±1
Single top: t-channel	22±4	20±4	12±3	4±1
Total background	549±95	686±41	460±39	253±38
Observed	644	697	455	246



Counting experiment not sensitive enough

Extracting Single Top Signal

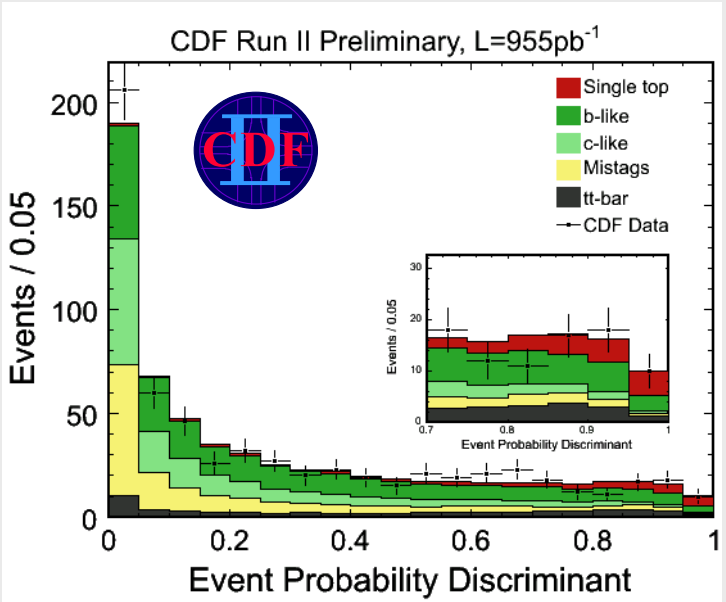


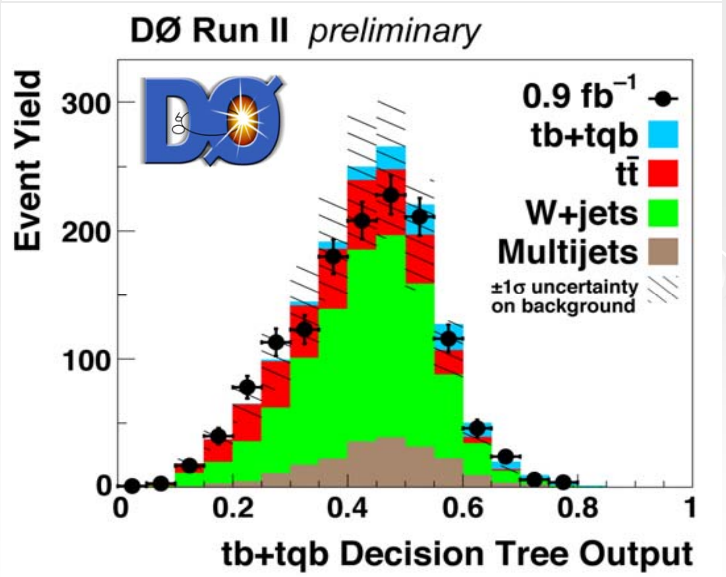


- No single variable provide significant signal-background separation
- Perform multivariate analysis ⇒ take advantage of small signal background separation in many variables:
  - Reconstructed top and W mass, angles between decay products…….

Multivariate Analyses

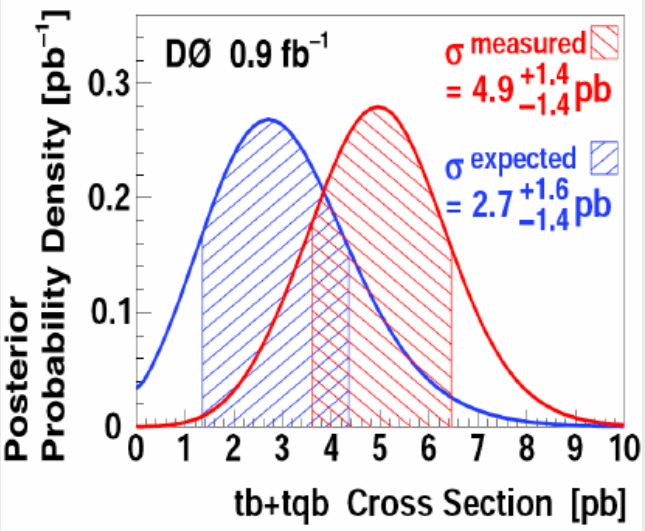
	Multivariate Methods	Expected Significance Assuming SM Rates (Combined s+t channels)
CDF	Likelihood Discriminant	2.0σ
CDF	Neural Network (NN)	2.6σ
CDF	Matrix Element (ME)	2.5σ
DØ	Matrix Element (ME)	1.8σ
DØ	Bayesian NN	1.3σ
DØ	Boosted Decision Trees (DT)	2.1σ





Decision Tree Results

0.9 fb^{-1}



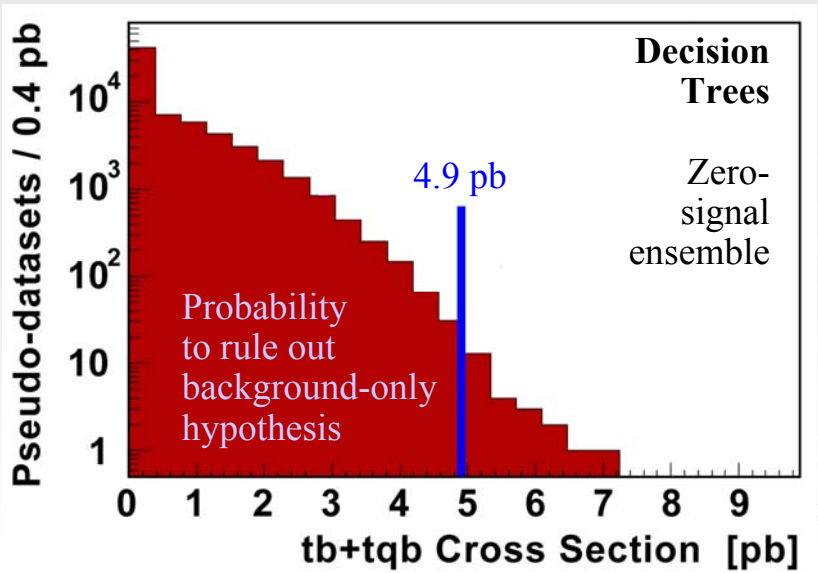
First evidence for single top quark production!

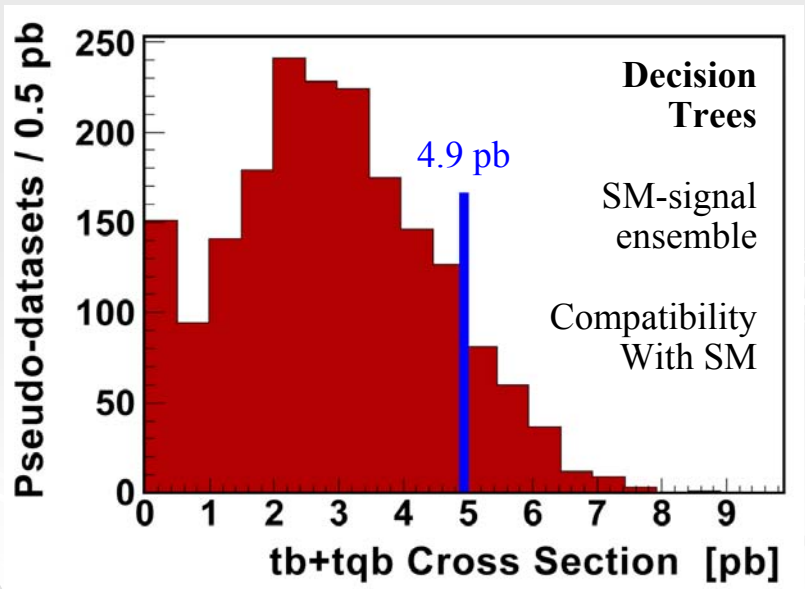
$\sigma_{s+t} = 4.9 \pm 1.4$ pb

Measured significance = 3.4 σ

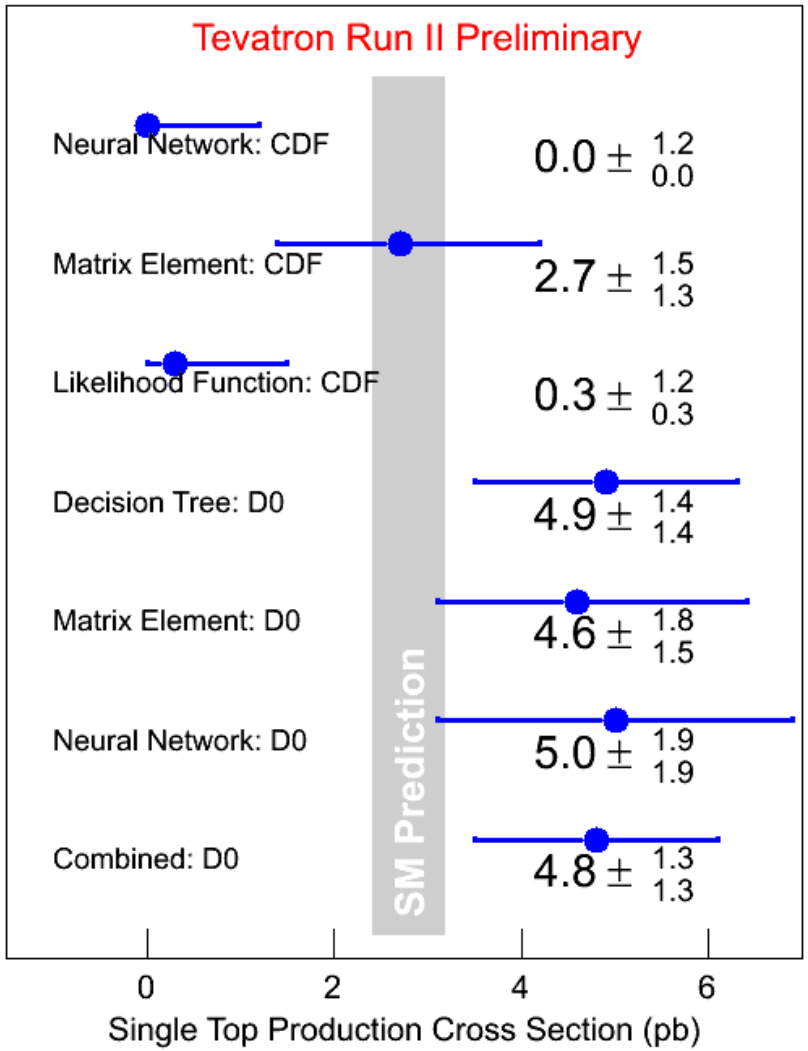
Compatibility with SM = 11%

Prob that background fluctuates up to produce $\sigma_{s+t} \geq 4.9$ pb is 0.035%





Single Top Results



	Multivariate Methods	Observed Significance (s+t)
CDF	Likelihood	-
CDF	NN	-
CDF	ME	2.3σ
D0	ME	2.9σ
D0	Bayesian NN	2.4σ
D0	DT	3.4σ
D0	Combined	3.5σ

From DT result:

$0.68 < |V_{tb}| < 1$ at 95% CL

Assuming pure V-A CP conserving tWb interaction, $|V_{td}|^2 + |V_{ts}|^2 << |V_{tb}|^2$, $f_1^L = 1$

Both experiments analyzing full >2 fb^{-1} data set… Stay Tuned !

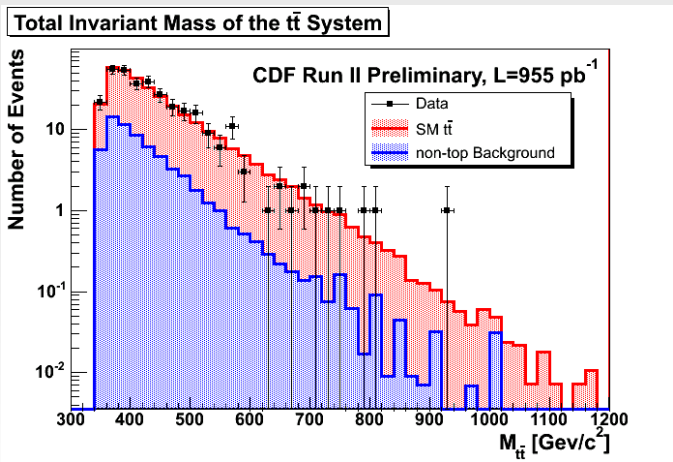
Search for Beyond the SM Physics

955 pb^{-1}

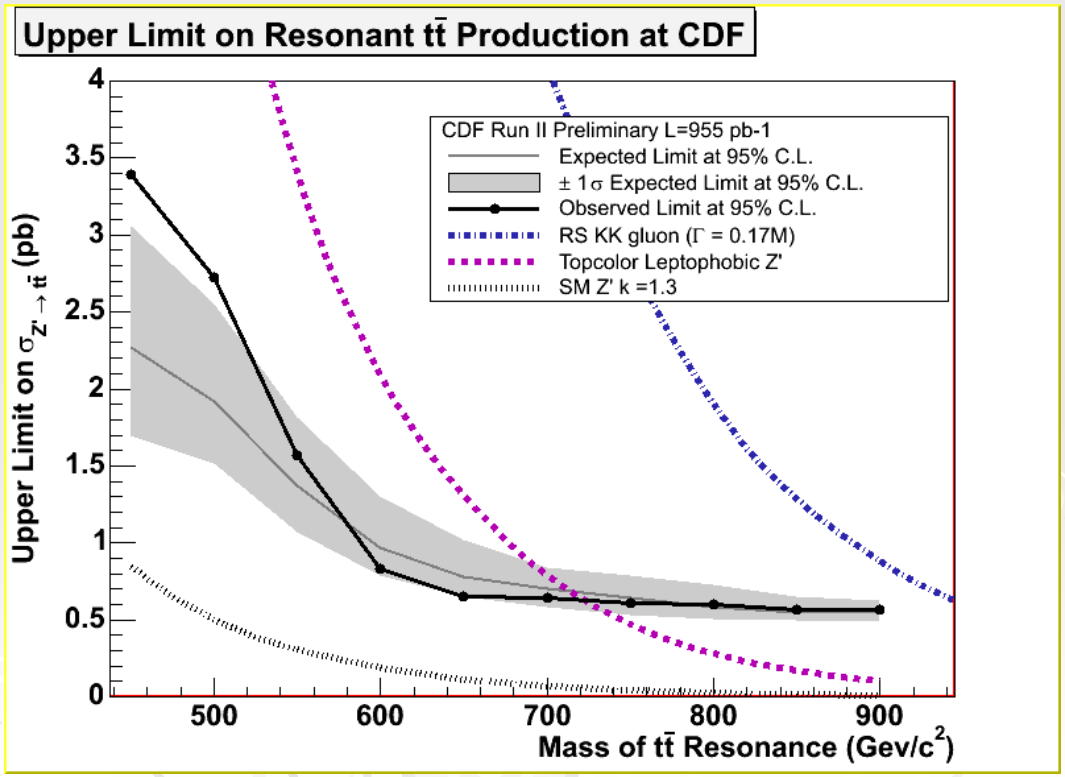
Resonant ttbar Production

- Various beyond the SM theories predict resonant top pair production from the decays of massive Z-like bosons:
  - Topcolor (C. Hill, S. Park, PRD49, 4454, 1994), KK gluon excitation in the RS model (hep-ph/0701166) etc.

➢ Search for narrow width Z' with same coupling as $Z^0 \Rightarrow$ no resonant interference with the s channel gluon production

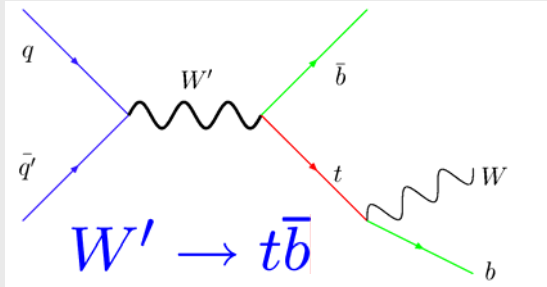


M_{tt} (GeV): Lepton+Jets

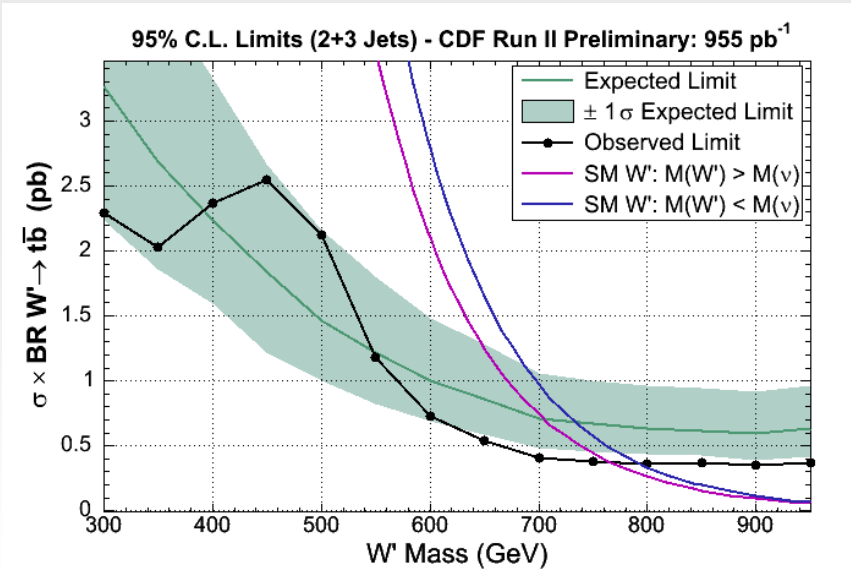


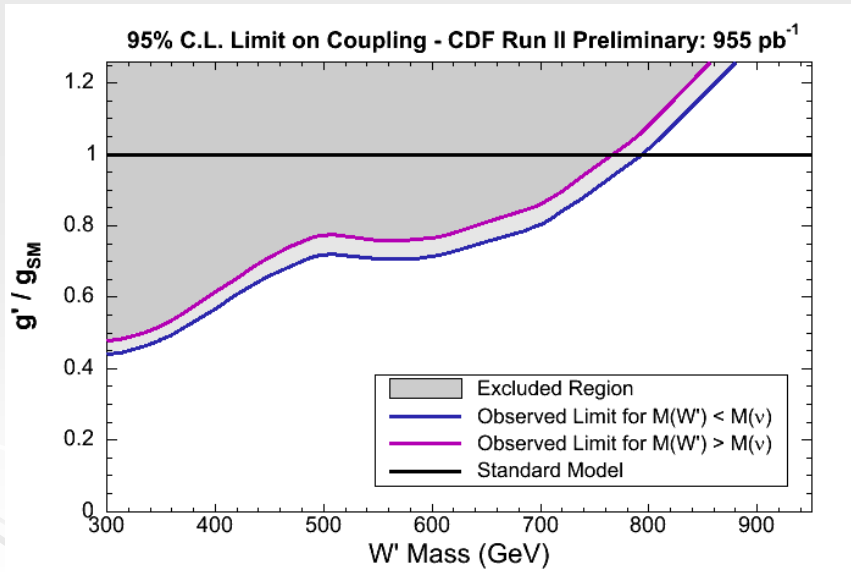
W'-like Resonances

- Many theories predicts W' : massive W-like boson
  - PRD 10, 275 (1974); PRD 11, 566 (1975); PLB 385, 304 (1996) etc.



- Search for resonant tb production: W'→tb
- Resonant *tb* production modeled as W' with SM-like couplings to fermions.
- Set limits on W' production and it's coupling to fermion.



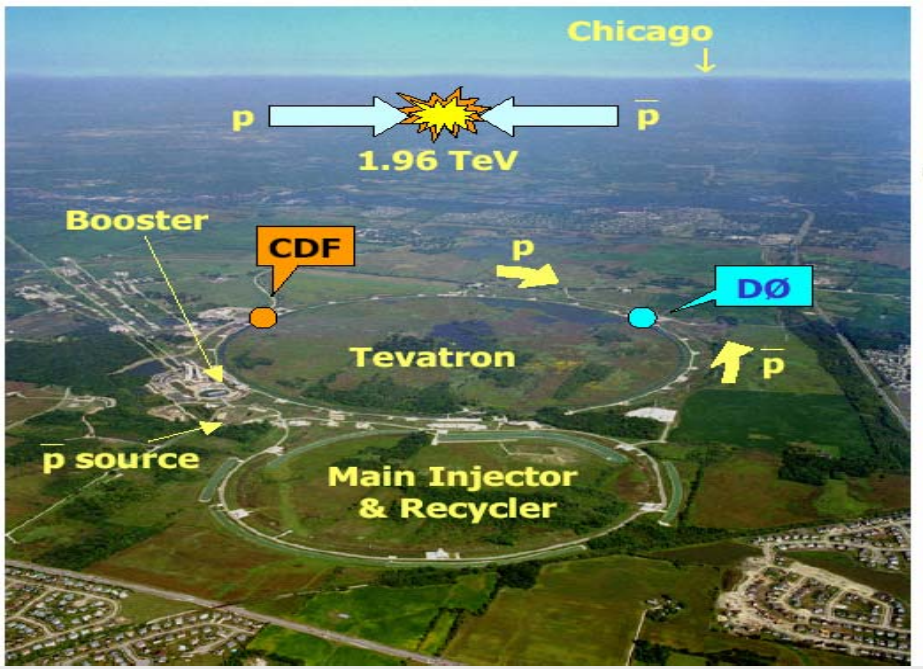


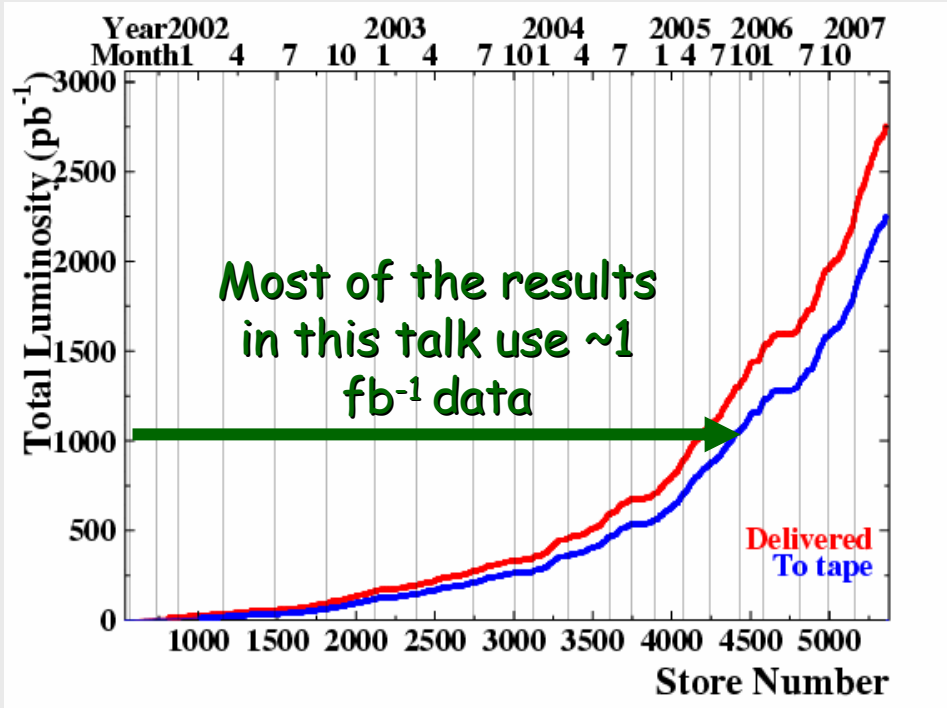
Summary and Outlook

- Recent top properties results from CDF and D0 are shown
  - All the measurements are consistent with the SM prediction so far
- Searches for EW single top production are presented
  - **The first evidence of single top production**
- Searches for ttbar and tb resonances using top sample are shown
- Besides ttbar cross-section all the top properties measurement are currently statistics limited
  - **Few hundred reconstructed ttbar events in ~1 fb^{-1} of dataset**
- **Results with 2 fb^{-1} data coming soon.**
- Increasing data from Tevatron will further help reveal the true nature of top quark
  - **Expect 6-8 fb^{-1} by the end of Run II**

Backup Slides

The Tevatron Accelerator

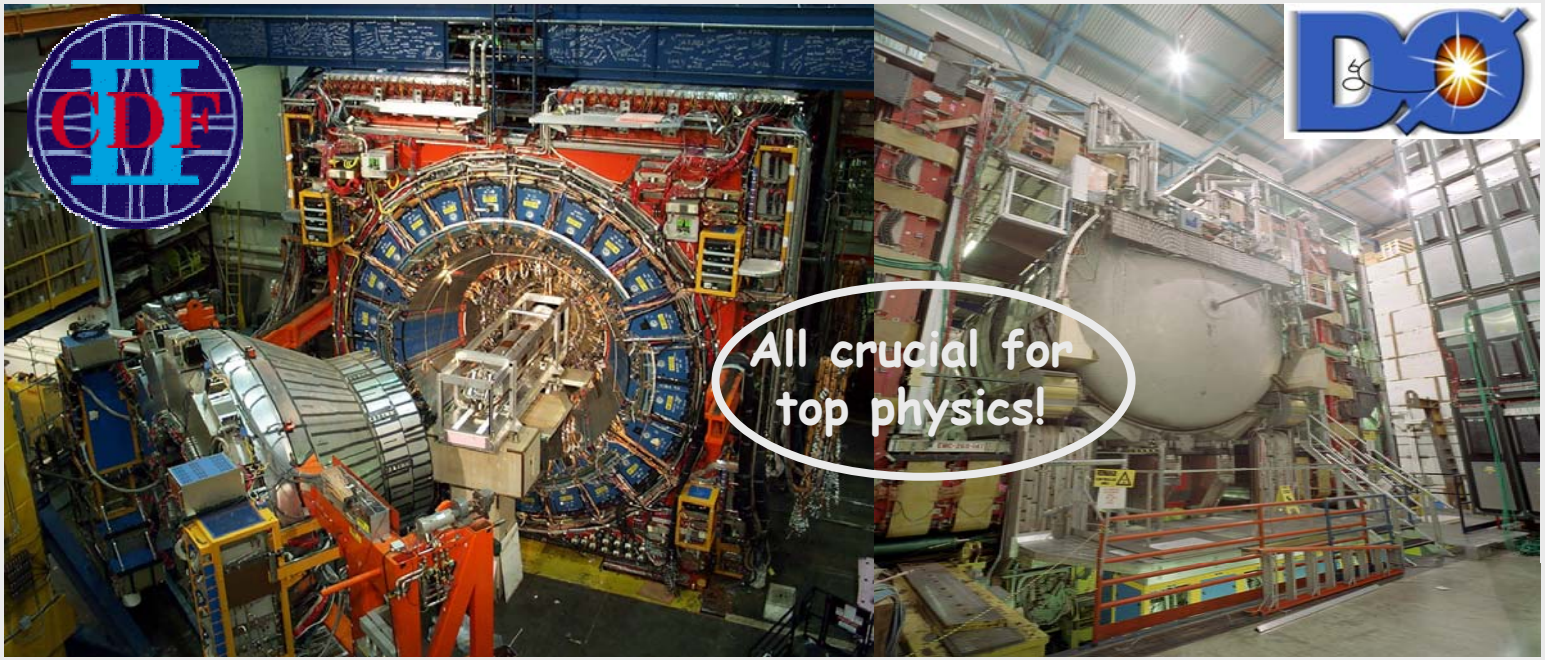




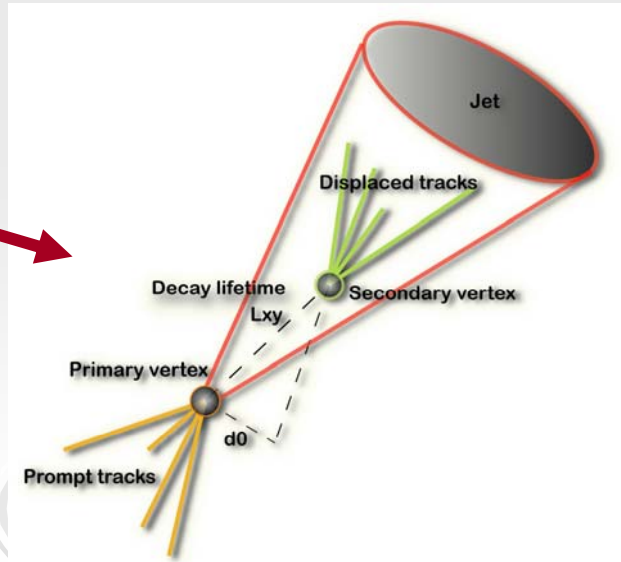
- World's highest energy collider (until LHC starts)
  - Proton-antiproton Synchrotron
- Run II :
  - $\sqrt{s}$ = 1.96 TeV
  - Both experiments have now > 2 fb^{-1} on tape.
  - Aim for 6-8 fb^{-1} by 2009

Currently only place in the world to produce top quarks.

CDF and D0 Detectors



- Inner Silicon Precision Vertexing
  - Essential for b-tagging based on secondary vertex information
- Tracking Systems
- Solenoid
- EM and HAD calorimeters
- Muon Detectors



More Top Properties Results

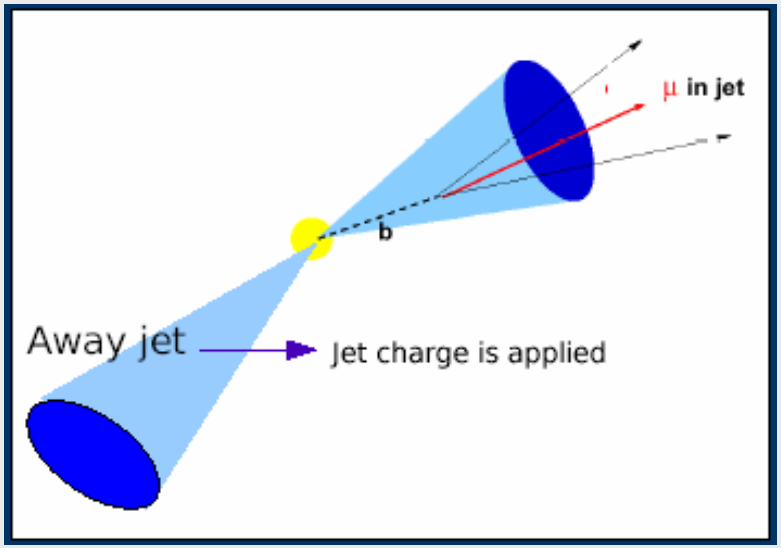
CDF

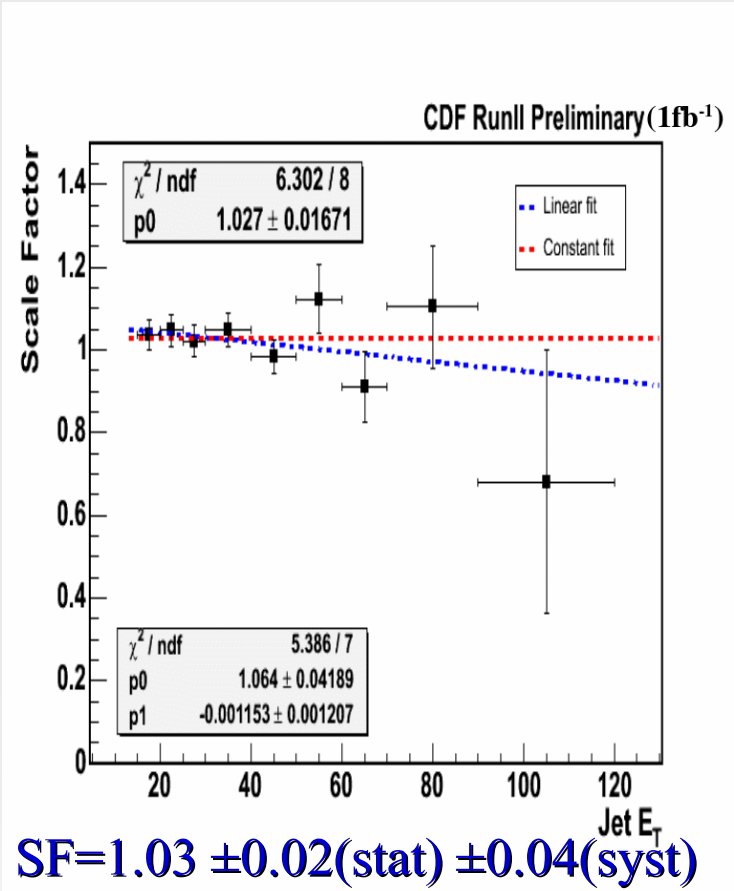
- Search for resonances in ttbar mass spectrum, matrix element + template , 680 pb^{-1}, Preliminary Conf. Note 8087
- Search for a Massive t' Quark, 760 pb^{-1}, Preliminary Conf. Note 8495
- Top Quark Lifetime , 318 pb^{-1}, Preliminary Conf. Note 8104
- Search for Anomalous Kinematics, 194 pb^{-1}, PRL 95, 022001
- t->tau nu q , 350 pb^{-1}, Preliminary Conf. Note 8376
- BR(t->Wb)/BR(t->Wq), pb^{-1}, PRL 95, 102002
- Search for Charged Higgs in top decays, 162 pb^{-1}, PRL 96, 042003

D0

- Search for a ttbar Resonance in Lepton+jets, 370 pb^{-1}
- Search for single production of top quarks via FCNC , 230 pb^{-1}
  hep-ex/0702005, FERMILAB-PUB-07/031-E, *Submitted to PRL*
- Measurement of B(t→Wb)/B(t→Wq) , 230 pb^{-1}
  hep-ex/0503002, FERMILAB-PUB-06/037-E, *PLB 639, 616 (2006)*
- Search for W' Boson Decay in the Top Quark Channel , 230 pb^{-1}
  hep-ex/0507102, FERMILAB-PUB-06/257-E, *PLB 641, 423 (2006)*

Top Charge: Calibration of Jet Charge Algorithm in Data





SF=1.03 ±0.02(stat) ±0.04(syst)

Scale Factor between the corrected purity and the Jet Charge algorithm purity in b-jets in a HF enriched MC (Pythia).

- Performance of the Jet Charge (JQ) algorithm is calibrated using dijet data.
- Select b-bbar events where one of b's decay semileptonically to a muon.
- Correct for b→c→μ and mixing
- Obtain non-b fraction: using μ PTrel fit, for Away Jet (AJ) M_{vtx}

Top Charge : Statistical Treatment

- Use Profile Likelihood method
- f_+ = fraction of true +2/3 events (signal MC:1)

$$N_+ = p_s N_s f_+ + (1-p_s) N_s (1-f_+) + p_b N_b$$
$$N_- = (1-p_s) N_s f_+ + N_s (1-f_+) + (1-p_b) N_b$$

- Nuisance parameters: $N_s \pm s_{Ns}$ (total signal), $N_b \pm s_{Nb}$ (total background), $p_s \pm s_{ps}$ (signal purity), $p_b \pm s_{pb}$ (background purity)
- L made of 5 parts: L_s: Poisson*Binomial L_q: Gauss(q,s)

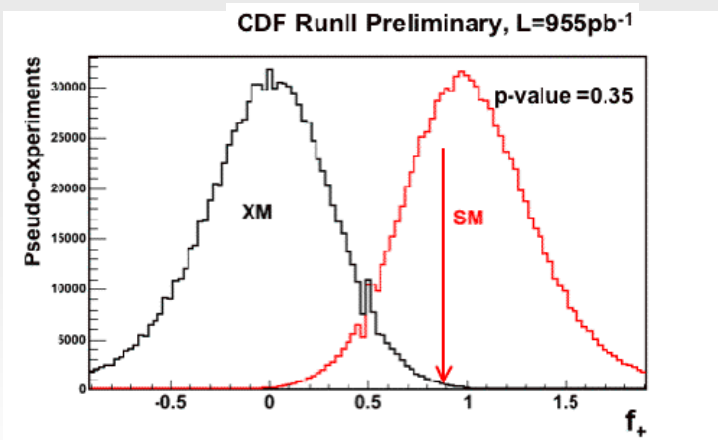
$$L_s = \frac{(N_+)^{x^+} e^{-N_+}}{x^+!} \frac{(N_-)^{x^-} e^{-N_-}}{x^-!} \qquad L_b = \frac{1}{\sigma_{N_b}\sqrt{2\pi}} e^{-\frac{(y_b - N_b)^2}{2\sigma_{N_b}^2}}$$

- Fit: scan in f+ and at each point fit for the nuisance parameters, get -2LnL curve

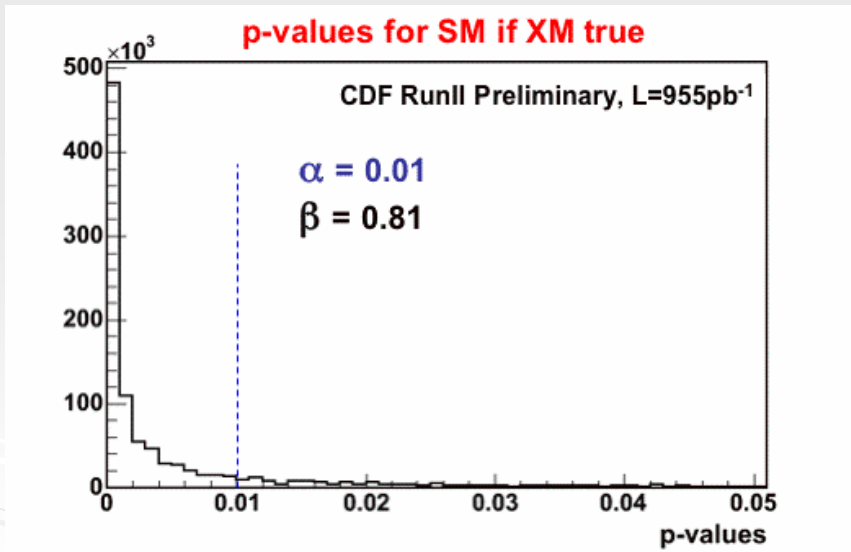
Top Charge: Statistical Treatment

- Generate Pseudo-Experiments based on expectations
- Get p-value according to SM:
  - Prob of measuring f_+ <= value
- Decide before looking at the data a value of α=1%
  - α=Prob of incorrectly rejecting the SM
  - β=sensitivity= prob of rejecting the SM if XM is true
  - β=81%

N_s	$91.30 \pm 1.14(stat) \pm 16.18(sys)$
N_b	2.80 ± 1.92
p_s	$0.586 \pm 0.007(stat) \pm 0.015(sys)$
p_b	0.518 ± 0.012



Fraction of SM like pairs (f_+) assuming either the XM or the SM



Top Charge: Statistical Treatment

- Since comparing 2 hypothesis (SM vs XM) compute a Bayes Factor:
  - Likelihood ratio: L(SM)/L(XM)
  - Integrate over the nuisance parameters independently for the numerator and denominator
  - Typically: 2*Ln(BF) since ~χ2
    - 0-2: Not worth more than a bare mention
    - 2-6: Positive
    - 6-10: Strong
    - >10: Very strong
- **Observed 2*Ln(BF) = 8.54.**
  Based on Bayes Scale, **8.54 means "data favors strongly SM over XM"**.

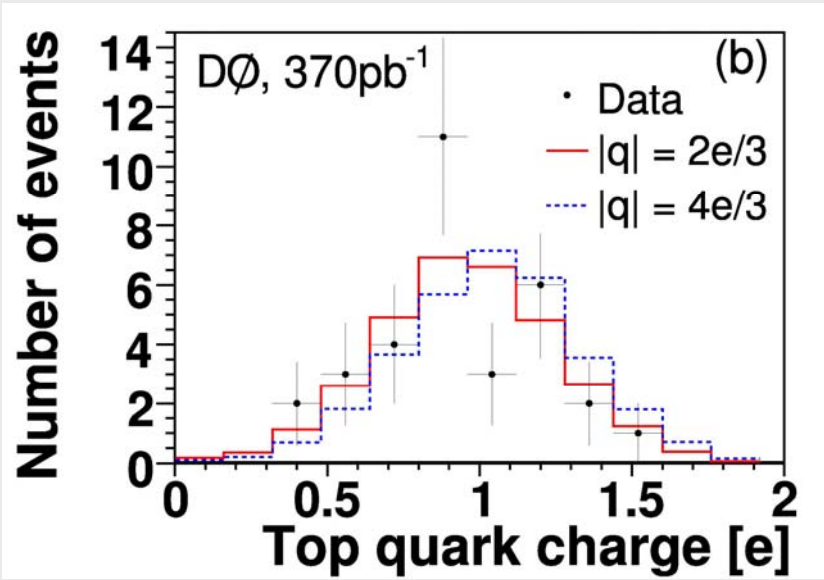
Top Charge

D0 Result

- Use 370 pb^{-1} Lepton+Jets double tag
- 32 pairs (use shape of JetQ)
- P-value according to XM is 0.078
  - 92.2%CL exclusion of XM
- Sensitivity: 91.2%
- Measure ρ=-0.13±0.66±0.11

($\rho \equiv$ fraction of exotic quark pairs)

  - $0 \leq \rho < 0.52$ at 68%CL and <0.8 at 90%CL using Bayesian flat prior



Comparison with CDF Result

D0 P-value according to XM = 0.078

CDF P-value according to XM = 0.002

Using D0 limit setting method: CDF P-value (XM) $\Rightarrow$ 99.8% CL exclusion of XM

Since CDF and D0 do not calculate the confidence limits in the same way a direct comparison of their results is not possible. What can be compared is their p-values.

b-Tagging

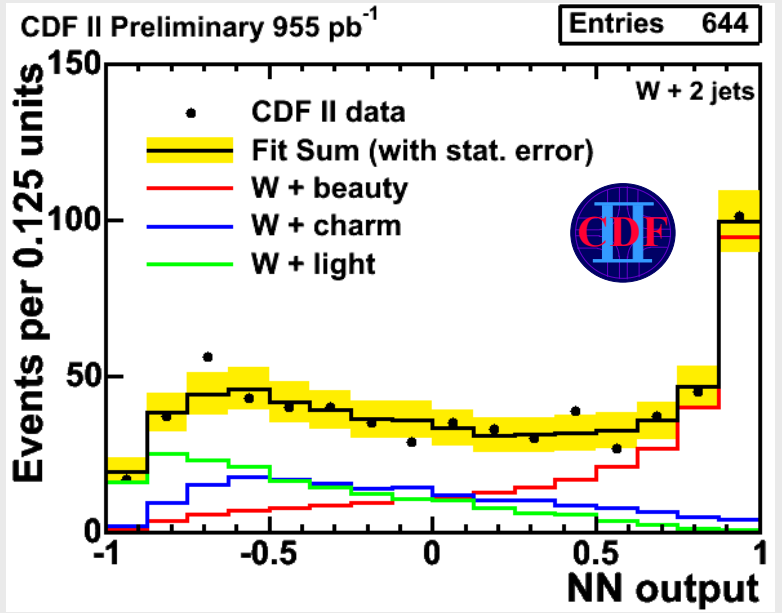
Crucial for improving S/B

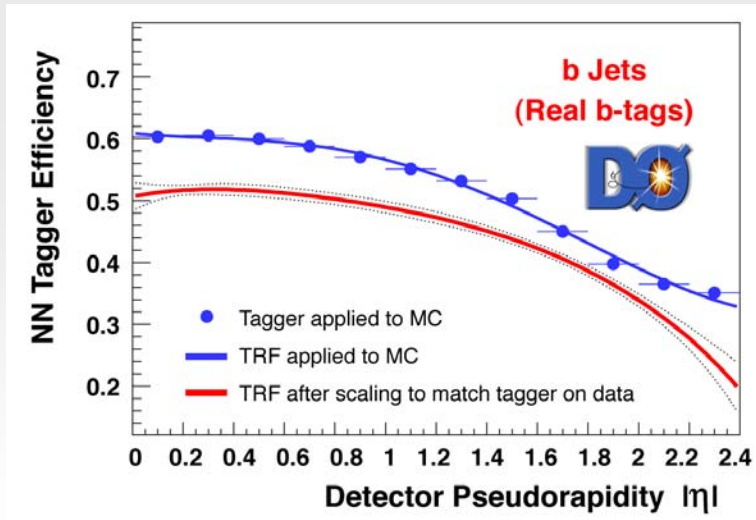
- CDF:
  - Secondary vertex tag used for event selection
    - ε: b-jet ~40%, light-jet ~0.8%

	S/B	√S/B
W+2jets	~1/210	~0.6
W+2jets+ ≥ 1 b-tag	~1/15	~1.6

  - NN algorithm: NN shapes provide further discrimination between b, c and light jets
- D0
  - NN algorithm:

    ε: b-jet ≈ 50%, c-jet ≈ 10%, light-jet ≈ 0.5%





Event Yields

CDF Run II Preliminary, L=955 pb^{-1}
Event yield in W + 2 jets bin

***s*-channel**	**15.4 ± 2.2**
***t*-channel**	**22.4 ± 3.6**
tt	**58.4 ±13.5**
Diboson	**13.7 ± 1.9**
***Z* + jets**	**11.9 ± 4.4**
Wbb	**170.9 ± 50.7**
Wcc	**63.5 ± 19.9**
Wc	**68.6 ± 19.0**
Non-*W*	**26.2 ± 15.9**
Mistags	**136.1 ± 19.7**
Single top	**37.8 ± 5.9**
Total background	**549.3 ± 95.2**
Total prediction	**587.1 ± 96.6**
Observed	**644**

Event Yields in 0.9 fb^{-1} Data
Electron+muon, 1tag+2tags combined

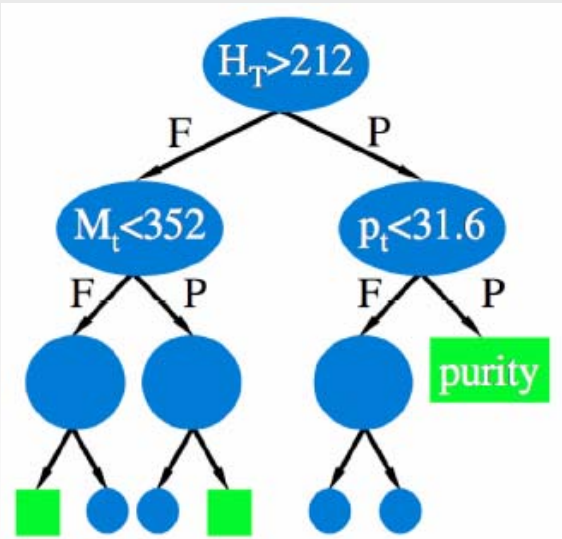
Source	2 jets	3 jets	4 jets
tb	16 ± 3	8 ± 2	2 ± 1
tqb	20 ± 4	12 ± 3	4 ± 1
$t\bar{t} \rightarrow ll$	39 ± 9	32 ± 7	11 ± 3
$t\bar{t} \rightarrow l$+jets	20 ± 5	103 ± 25	143 ± 33
$W+b\bar{b}$	261 ± 55	120 ± 24	35 ± 7
$W+c\bar{c}$	151 ± 31	85 ± 17	23 ± 5
$W+jj$	119 ± 25	43 ± 9	12 ± 2
Multijets	95 ± 19	77 ± 15	29 ± 6
Total background	686 ± 41	460 ± 39	253 ± 38
Data	697	455	246

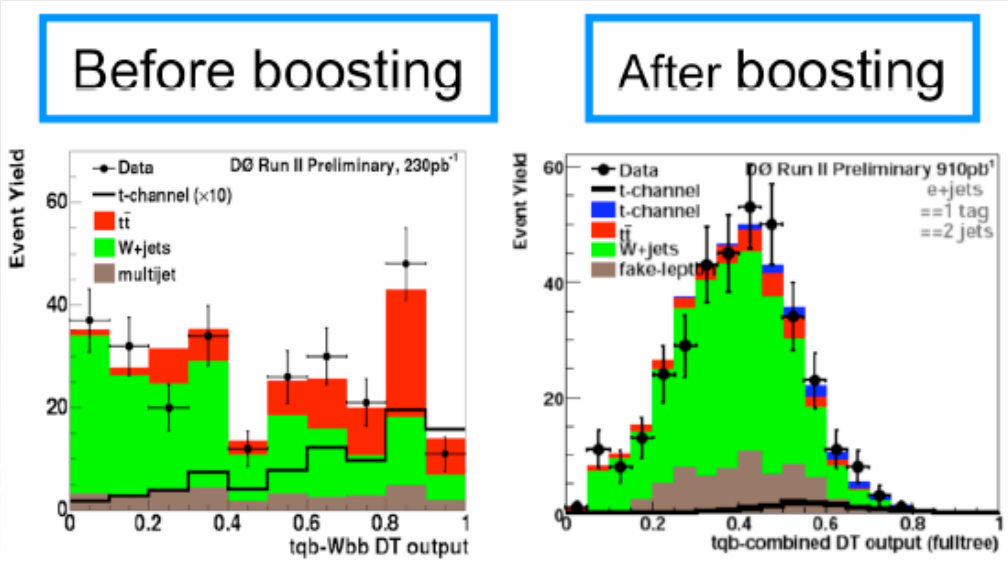
Signal Acceptance (including BR)

	tb (%)	tbq(%)
CDF (W+2jets)	**~1.9**	**~1.3**
D0 (W+2,3,4 jets)	**~3.2**	**~2.1**

Boosted Decision Trees

- Goal: recover events that fail a simple cut-based analysis
- Use 49 variables for training: most discriminating variables **M(alljets), M(W,b-tag1), cos(b-tag1,lepton), Q(lepton)*η(untagged1)**
- Decision tree output for each event = leaf purity: $N_S/(N_S+N_B)$
- Train network on signal and background simulated events:
  - Signal tends to one and background tends towards zero
- Boosting: retrain 20 times to improve "weak classifier"

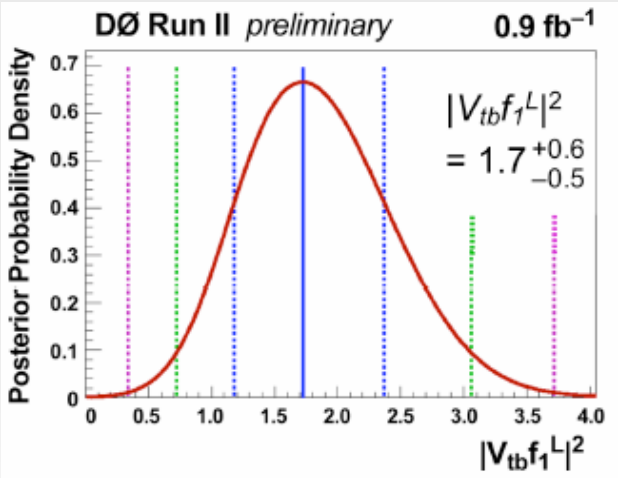


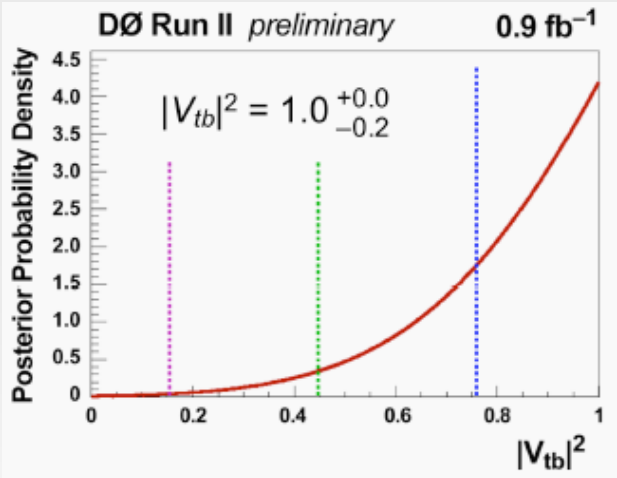


Extracting $|V_{tb}|$: Using DT Result

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

- Assuming SM:
  - Pure V-A and CP conserving interaction: $f_1^R = f_2^L = f_2^R = 0$.
  - $|V_{td}|^2 + |V_{ts}|^2 << |V_{tb}|^2$ or $B(t \rightarrow Wb) \sim 100\%$.





$|V_{tb} f_1^L| = 1.3 \pm 0.2$

$0.68 < |V_{tb}| < 1$ at 95% CL ($f_1^L = 1$)

Combination of D0 Single Top Results

0.9 fb^{-1}

Correlation matrix

Highly correlated.

$$\rho = \begin{pmatrix} DT & ME & BNN & \\ 1 & 0.57 & 0.51 & DT \\ 0.57 & 1 & 0.45 & ME \\ 0.51 & 0.45 & 1 & BNN \end{pmatrix}$$

$\sigma = 4.8 \pm 1.3$ pb

Significance = $3.5\ \sigma$