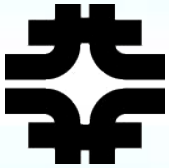


Top Quark Production at the Tevatron

Sandra Leone

(INFN Pisa)

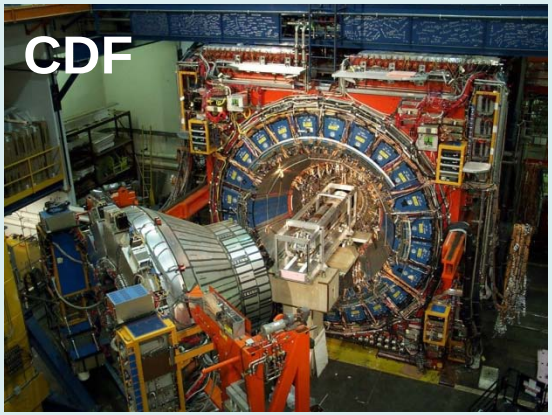
for the CDF and D0 Collaborations

Moriond EWK, March 9, 2012

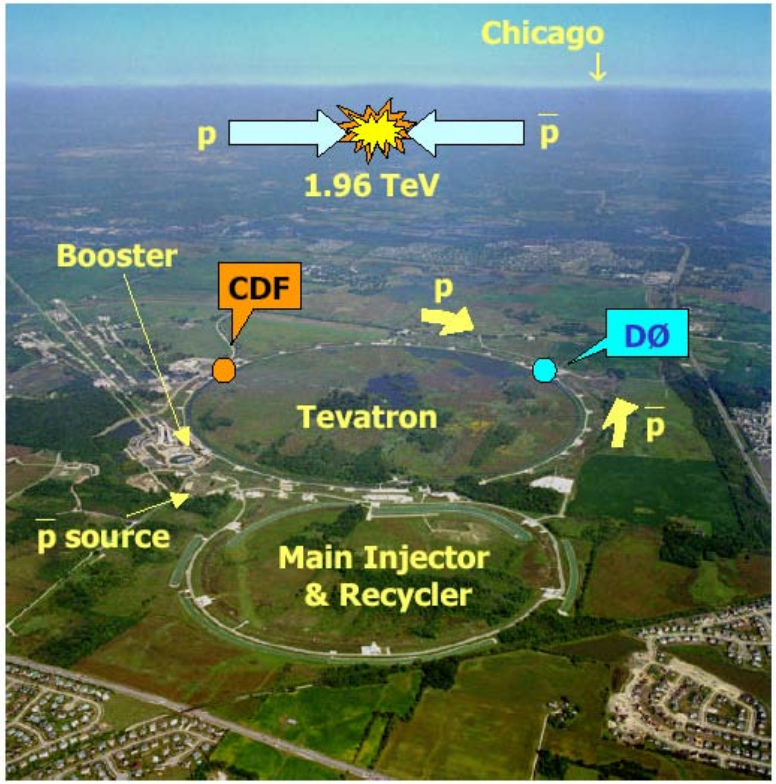
Outline

- The Tevatron & the detectors: CDF & D0

- Exploring top quark production at the Tevatron:
  - ⇒Top Pair production cross section
  - ⇒Single top production
  - ⇒V_{tb} measurement
  - ⇒Forward – backward asymmetry
  - ⇒Search for new physics in top production
- Prospects & Conclusion

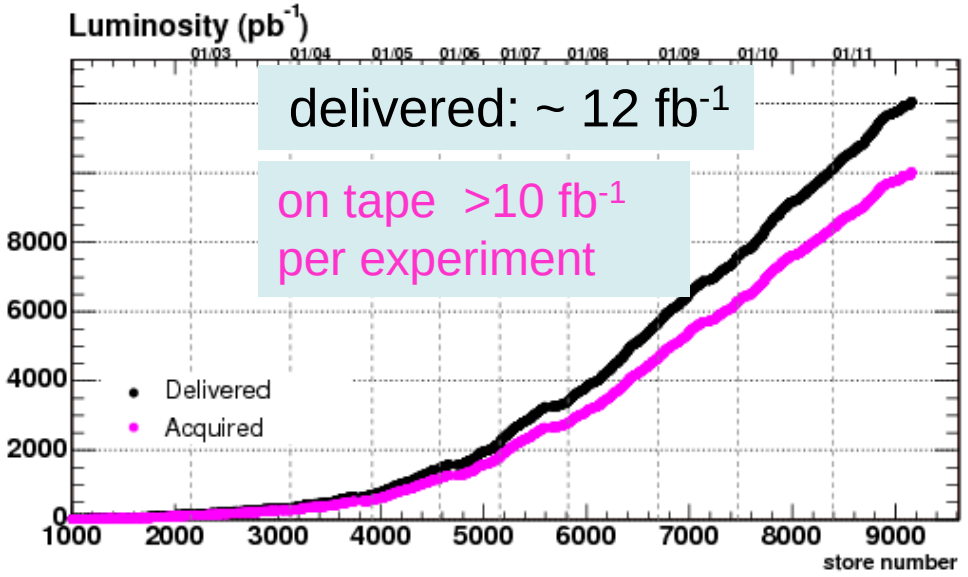


The Fermilab Tevatron



Run II: $\sqrt{s}$ = 1.96 TeV

Tevatron stopped taking data on september 30, 2011



The birthplace of the top quark
The highest ppbar collider in the world ..... until December 2009

Results shown in the following based on datasets up to 8.7 fb^{-1}

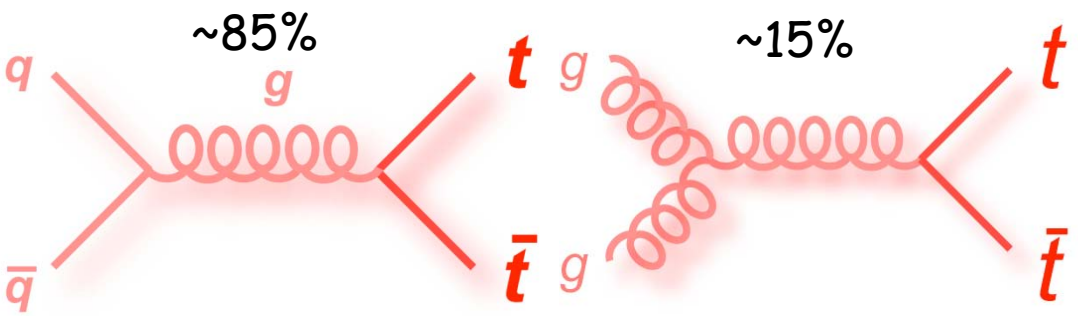
Top Quark Production at Tevatron

- QCD pair production

$\sigma_{SM} = 7.46\ ^{+0.48}_{-0.67}$ pb

(for m_{Top}= 172.5 GeV)

PRD 78, 034003 (2008)



Top Quark Production at Tevatron

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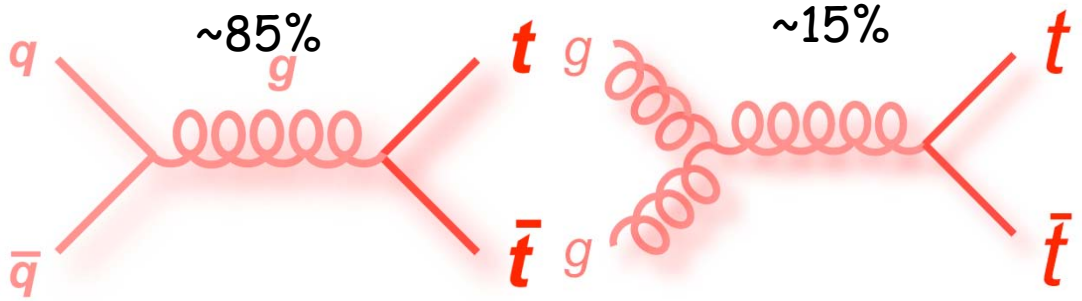
PRD 78, 034003 (2008)

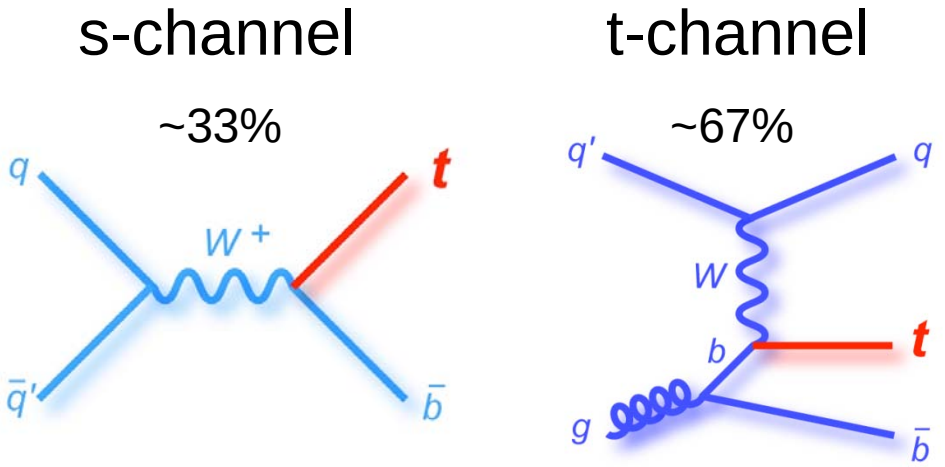


- EWK single-top production
  - s-channel: $\sigma_{SM} = 1.05 \pm 0.07$ pb
  - t-channel: $\sigma_{SM} = 2.10 \pm 0.19$ pb

(Both for m_{Top}= 172.5 GeV)

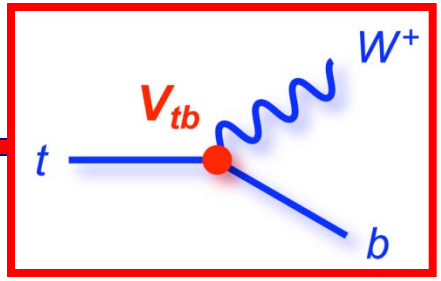
PRD 83, 091503 (2011)

PRD 81, 054028 (2010)

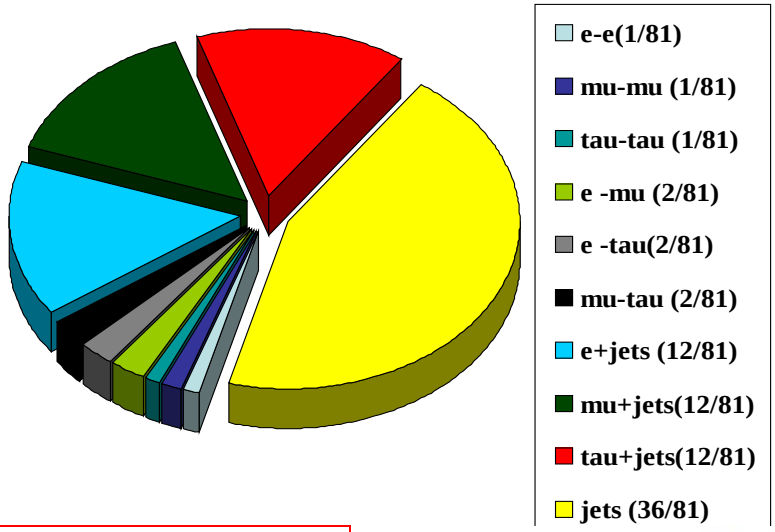


- Single top associated production Wt: $\sigma \sim 0.2$ pb, too small at the Tevatron

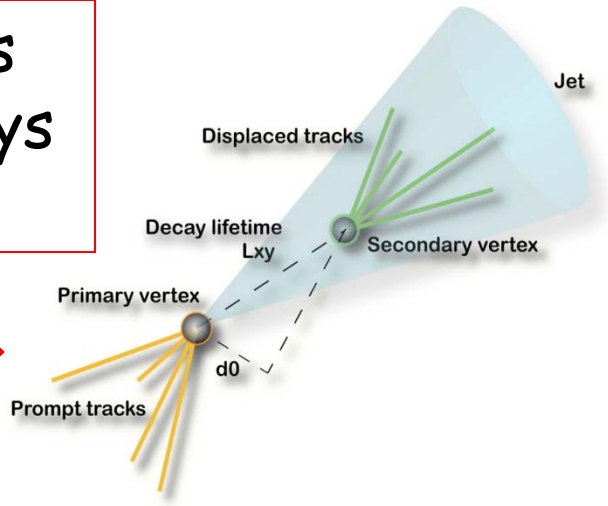
Top Quark Decay



SM predicts BR($t \rightarrow Wb$) ≈ 100%



b quarks are always present



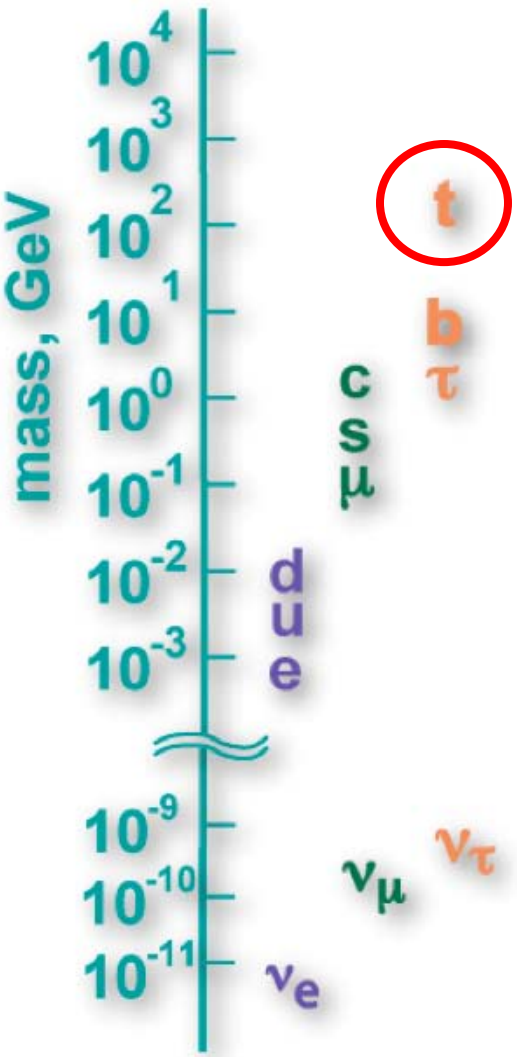
Event topology determined by the W decay modes

For ttbar pairs:

- Dilepton (ee, μμ, eμ)
  ⇒BR = 5%, 2 high-P_T leptons + 2 b-jets + 2 neutrinos
- Lepton (e or μ) + jets
  ⇒BR = 30%, single lepton + 4 jets (2 from b's) + 1 neutrino
- All Hadronic:
  ⇒BR = 45%, six jets, no neutrinos
- τ_{had} +X
  ⇒BR = 21%

Top pairs production

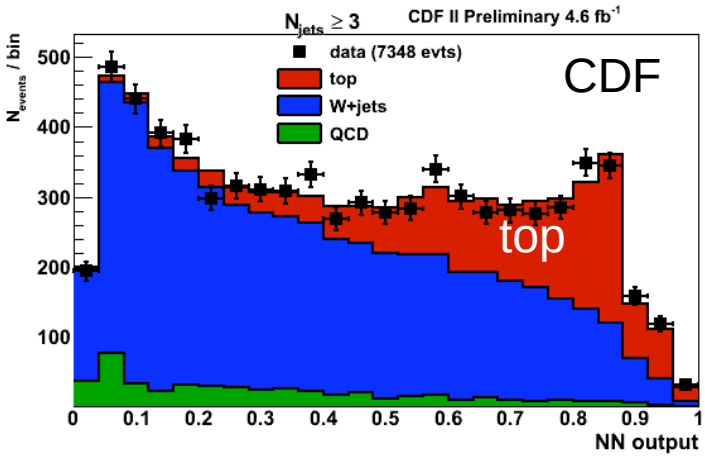
- Top quark is a very special particle:
  - ⇒ Heavier than all known particles
  - ⇒ Decays before hadronizing: Γ_{top}=1.5 GeV > Λ_{QCD}
- Measuring the production cross section is the first step in understanding any selected ttbar sample
- Test of theoretical QCD calculations
- New physics can change:
  - ⇒ overall production rate
  - ⇒ rate in different channels
- Precision measurements of cross section are important in different decay channels



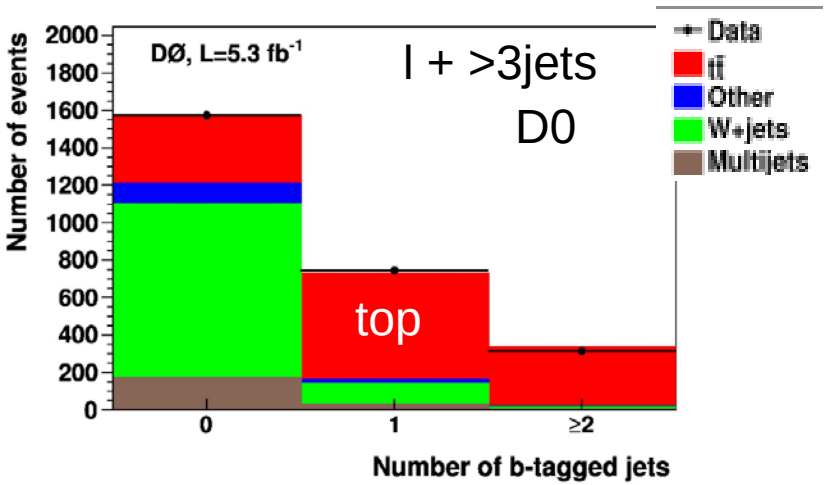
$$\sigma_{tt} = \frac{N_{Data} - N_{Background}}{Acc \int Ldt}$$

Top pair production: Lepton +Jets

- Pre-tagged sample, NN discriminant
- normalizing to the measured *Z cross section:* $\sigma_{tt} = R \bullet \sigma_Z^{theory}$



- When combining kinematic & b-tags determine simultaneously xsection & W+heavyflavor/W+ light flavor ratio



CDF (4.3 fb^{-1},m_t= 172.5 GeV), pre-tagged:
σ_{tt}=7.82±0.38(stat)±0.37(syst)±0.13(theo)pb

D0 (5.3 fb^{-1},m_t= 172.5 GeV), b-tagged:
σ_{tt}=8.13±0.25(stat) $^{+0.99}_{-0.86}$ (syst) pb

Combined kinematical + b-tagging:

CDF (4.3 fb^{-1},m_t= 172.5 GeV):
σ_{tt}=7.70 ±0.52(stat+syst) pb

PRL 105 012008 (2010)

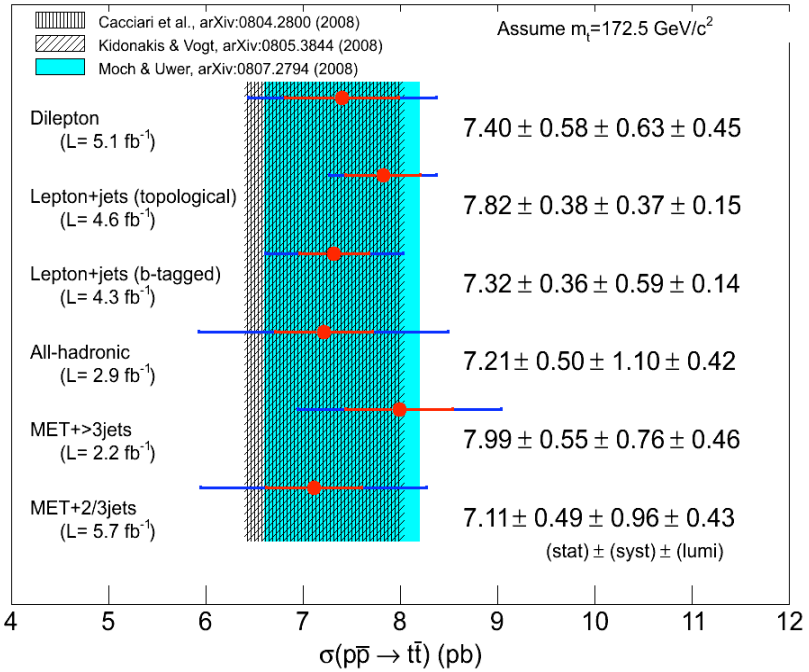
D0 (5.3 fb^{-1},m_t= 172.5 GeV):
σ_{tt}=7.78±0.25(stat) $^{+0.73}_{-0.59}$ (syst) pb

PRD 84, 012008 (2011)

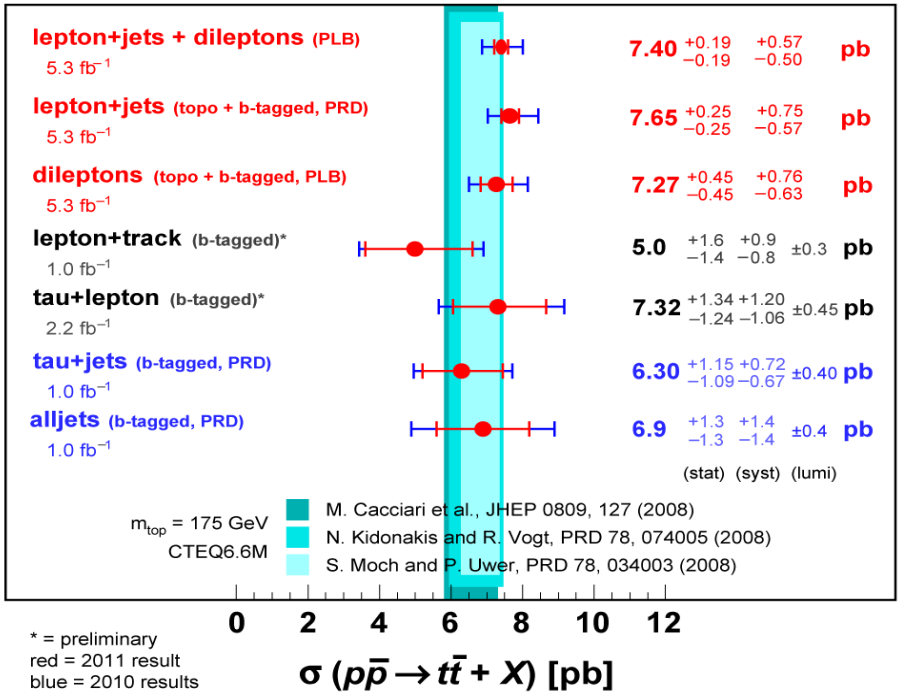
Measurements of σ_{ttbar}

- Dominant exp. uncertainties: JES, b-tag accept., W+bjet background
- Consistent with theory prediction, challenges its precision
- Consistent across channels, methods, experiments

CDF



DØ Run II July 2011



* = preliminary
red = 2011 result
blue = 2010 results

CDF Combination: 7.50 ± 0.48 pb
6.4% precision!

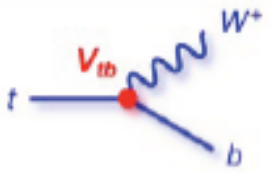
All measurements limited by systematic uncertainty

Electroweak single Top Production

- Give access to the W-t-b vertex:
- Allows direct measurement of CKM matrix element $|V_{tb}|$
- Final state hidden behind large backgrounds with uncertainties larger than signal
- Use of multivariate techniques is mandatory

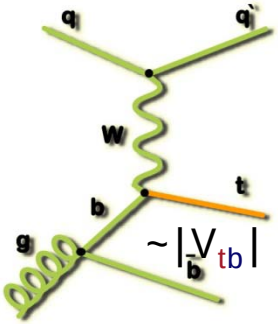
  → No single variable provides enough signal-background separation

$\sigma \sim |V_{tb}|^2$



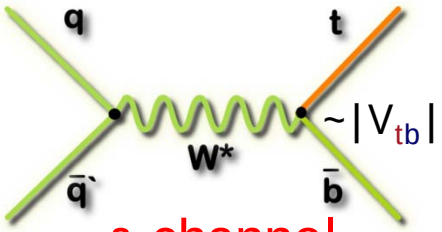
$\sigma_{st} \sim 0.4\ \sigma_{tt}$

Observed by CDF & D0 in March 2009!



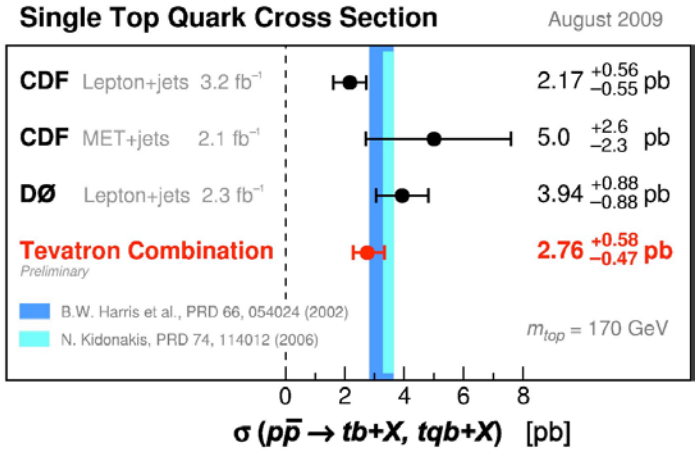
t-channel

$\sigma_{SM} = 2.10 \pm 0.19$pb ($m_t$=172.5 GeV/$c^2$)



s-channel

$\sigma_{SM} = 1.05 \pm 0.07$pb



Tevatron combination (3.2 fb^{-1}):

$\sigma_t = 2.76\ ^{+0.58}_{-0.47}$ (stat+syst) pb

$|V_{tb}| = 0.88 \pm 0.07$ (stat+syst)

$|V_{tb}| > 0.77$ @ 95% CL m_t = 170 GeV/c^2

PRL 103, 092001(2009). PRL 103, 092002(2009)

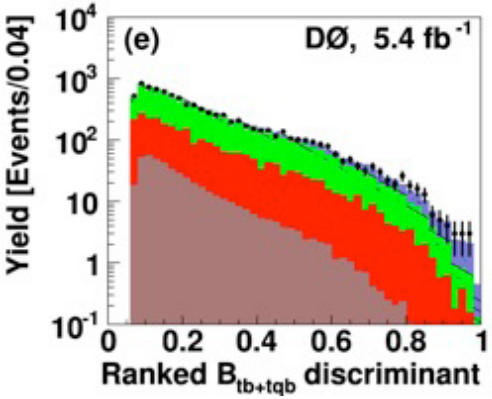
B.W. Harris et al., Phys. Rev. D66, 054024 (2002)
Z. Sullivan, Phys. Rev. D70, 114012 (2004).
Campbell/Ellis/Tramontano, Phys. Rev. D70, 094012 (2004).
N. Kidonakis, Phys. Rev. D83 091503 (2011).
.N. Kidonakis, Phys. Rev. D81 054028 (2010)

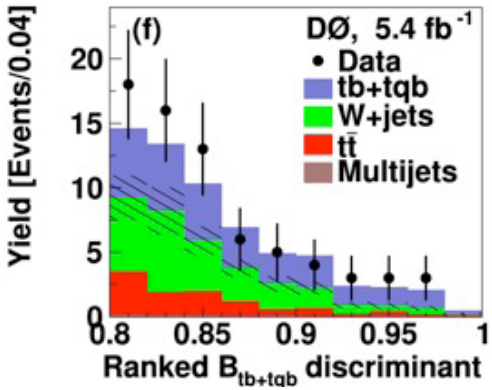
Single top: s+t channel cross section

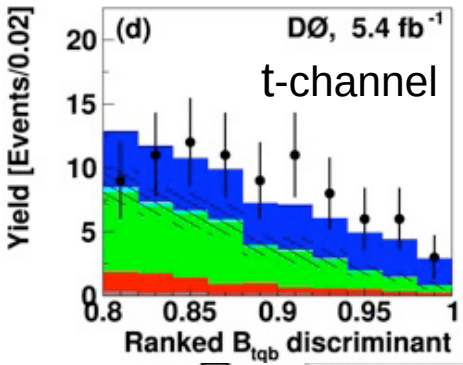
- D0 updated the analysis on 5.4 fb^{-1}
- Discriminating variables are combined into:
  - ⇒ Boosted Decision Tree (BDT)
  - ⇒ Bayesian Neural Network
  - ⇒ Neuroevolution of Augmented Topologies (NEAT)
- Correlation ~ 70%
  - ⇒ a second BNN is used to construct a combined discriminant for each channel

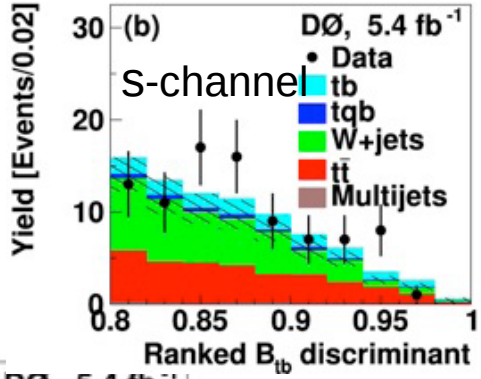
channel	σ(pb)
s+t	$3.43^{+0.73}_{-0.74}$
t	$2.86^{+0.69}_{-0.63}$
s	$0.68^{+0.38}_{-0.35}$

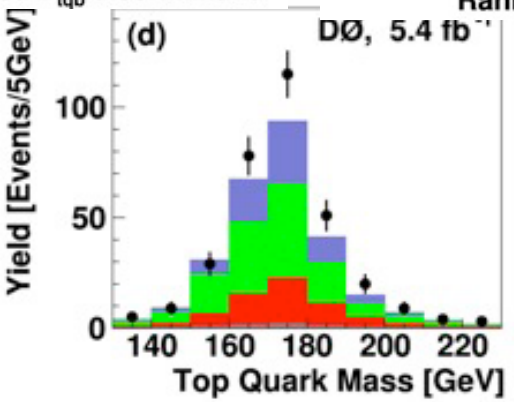
PRD84, 112001 (2011)











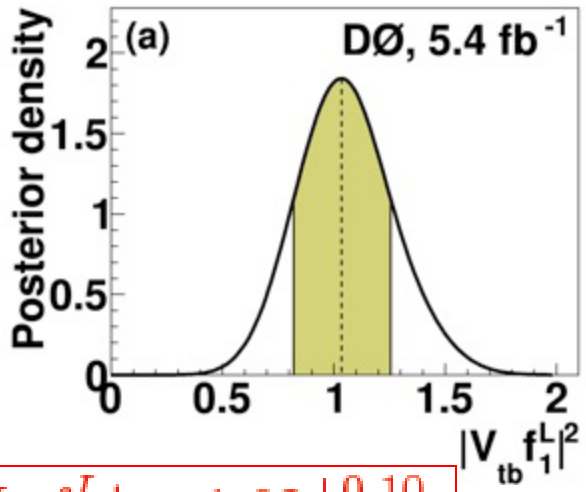
More in YSF4:
J. Joshi talk

Direct $|V_{tb}|$ measurement

- Using cross section result to measure $|V_{tb}|$
- Measurement assumes SM production mechanisms, V-A coupling in decay, does not assume 3 generations or unitarity
- Maintain the possibility for an anomalous strenght of the left-handed Wtb coupling f^L_1

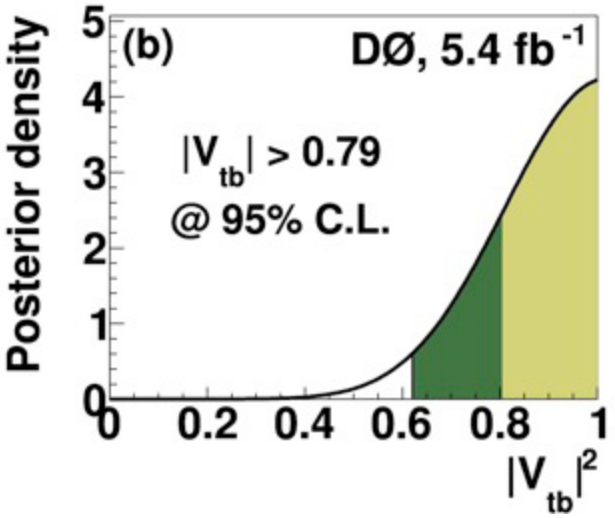
$$|V_{tb,meas}|^2 = \frac{\sigma_{meas}}{\sigma_{SM}} \cdot |V_{tb,SM}|^2$$

Measure strength of V-A coupling $|V_{tb}\, f^L_1|$:



$$|V_{tb} f_1^L| = 1.02^{+0.10}_{-0.11}$$

If restrict to SM region [0.1] and assume $f^L_1 = 1$

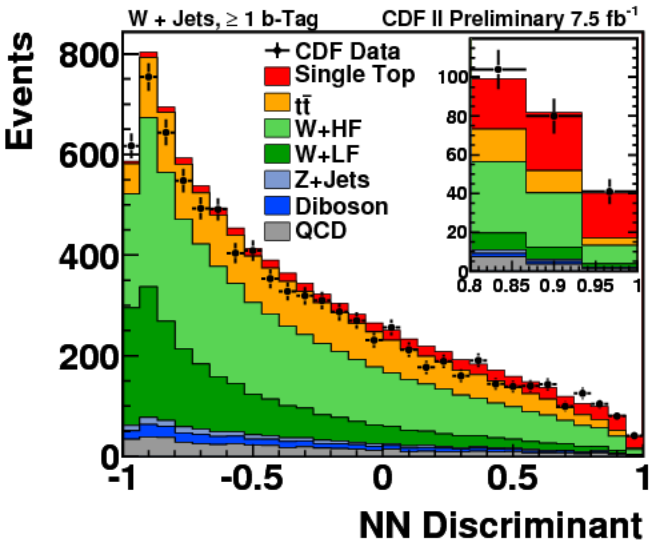


PRD84, 112001 (2011)

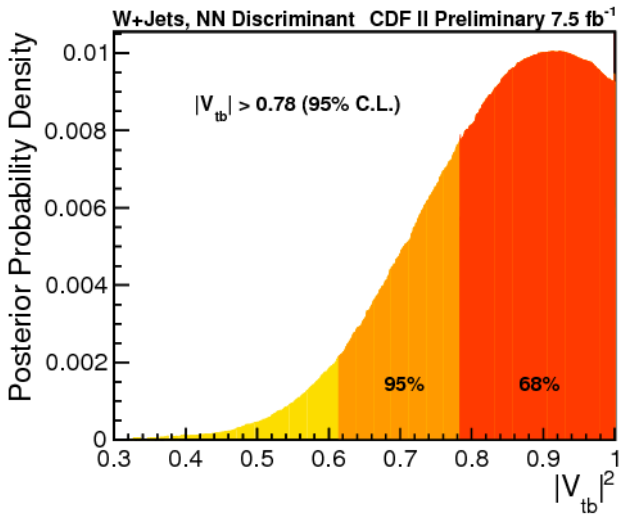
Single top: CDF update

NEW!

- Based on 7.5 fb^{-1} of data
- Use NN with same input variables as the observation analysis
- Signal: s-chan+t-chann+Wt-chan simulated with NLO POWHEG



$$|V_{tb,meas}|^2 = \frac{\sigma_{meas}}{\sigma_{SM}} \cdot |V_{tb,SM}|^2$$



$\sigma_{stop} = 3.04\ ^{+0.57}_{-0.53}$ (stat+syst) pb

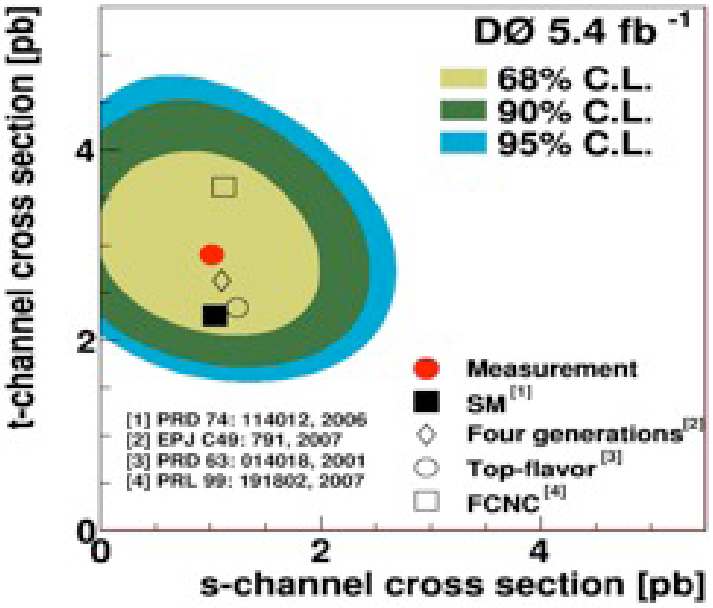
$|V_{tb}| > 0.78$ @ 95% CL

At 'Moriond QCD' dedicated talk given by Z. Wu

$|V_{tb}| = 0.92\ ^{+0.10}_{-0.08}$ (stat+syst) ± 0.05 (theory)

Single top s- and t-channel measurements

- s and t-channel sensitive to different BSM physics
- Construct a 2D posterior probability density for t vs s cross section
  - ⇒ no SM constraint on the relative rate of t vs s production
- Extract t cross section from 1D posterior by integrating over x-axis (s)
  - ⇒ no assumption on s rate



σ(t-ch) = 2.90 ± 0.59 pb

σ(s-ch) = 0.98 ± 0.63 pb

the most precise measurement in t-channel
> 5 σ significance

PLB 705 (2011)313

Ratio of branching fractions R

$$R = \frac{BR(t \to Wb)}{BR(t \to Wq)} = \frac{|V_{tb}|^2}{|V_{td}|^2 + |V_{ts}|^2 + |V_{tb}|^2}$$

- SM: R=1 constrained by CKM unitarity. R<1 could indicate new physics
- Drop assumption R=1 in dilepton (D0) and l+jets (D0 & CDF) cross section measurements
- changes predicted fraction of events with 0,1 and >1 b-tags in l+jets channel (changes the shape of the NN output distribution in dilepton channel, D0)
- Measure R simultaneously with ttbar cross section

NEW!

CDF preliminary 7.5 fb^{-1}
L+jets channel

$\sigma_{p\bar{p}\to t\bar{t}}(pb)$	7.4 ± 1.1
R	0.91 ± 0.09
$\lvert V_{tb}\rvert$	0.95 ± 0.05

(stat+syst uncertainties)

D0 on 5.4 fb^{-1}
L+jets & dilepton

$\sigma_{t\bar{t}} = 7.74^{+0.67}_{-0.57}$ pb

R=0.90±0.04 (stat+syst)

$|V_{tb}|$=0.95±0.02 (stat+syst)

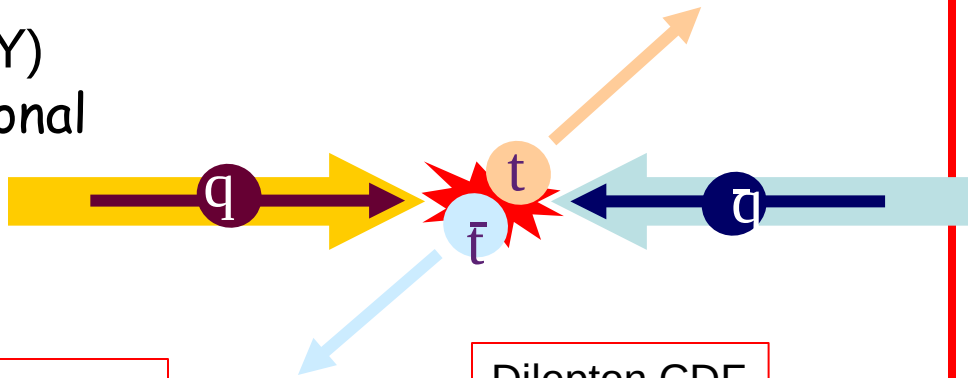
$|V_{tb}|$>0.88 @99.7% C.L.

PRL 107, 121802 (2011)

Forward backward asymmetry (A_{FB})

- NLO QCD predicts small (~7%) asymmetry from qqbar➜ttbar
- New physics could give rise to an asymmetry (Z´,axigluons,..)
- Reconstruct the top direction and the rapidity of top and anti-top quarks
- We use the rapidity difference (ΔY) of t➜lvb and t➜jjb, which is proportional to Y_t in ttbar rest frame:

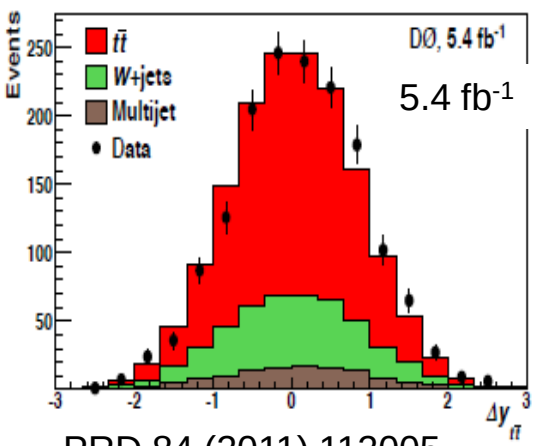
$$Y_t \propto q_{lepton} \cdot \Delta Y$$



In terms of frame-independent rapidity difference:

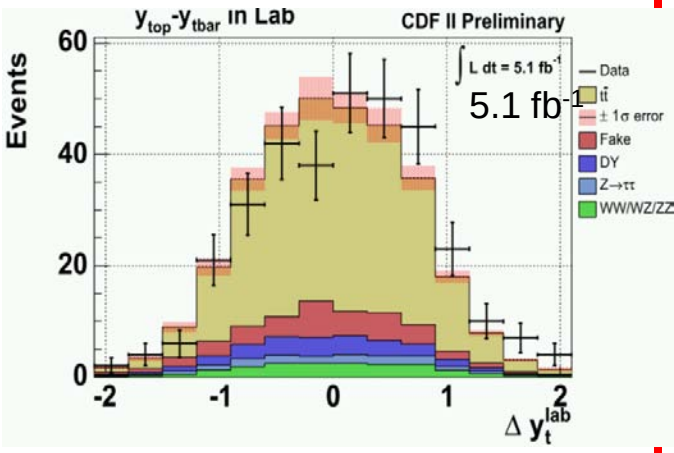
$$A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

Lepton + jets, D0



PRD 84 (2011) 112005

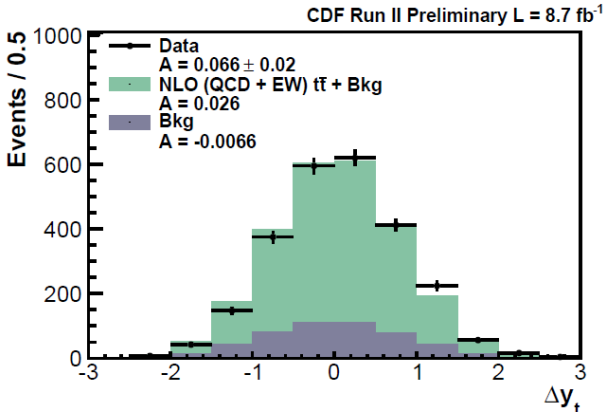
Dilepton CDF



Forward backward asymmetry (A_{FB})

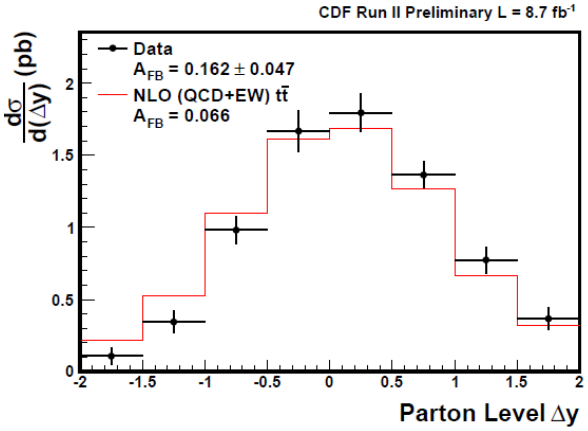
NEW!

- CDF updated the lepton +jets analysis on 8.7 fb^{-1}
- Use Powheg +EW correction for SM prediction
  - At reconstruction level: →



$A_{FB} = 0.066 \pm 0.020$

- To better compare to theory predictions ➜ correct data for background and acceptance and resolution effects
  - Inclusive parton level: →



$A^{\Delta y}_{FB} = 0.162 \pm 0.041(stat) \pm 0.022\ (syst)$

Main syst uncertainty: from background size & shape

At "Moriond QCD" there will be a talk given by D. Mietlicki

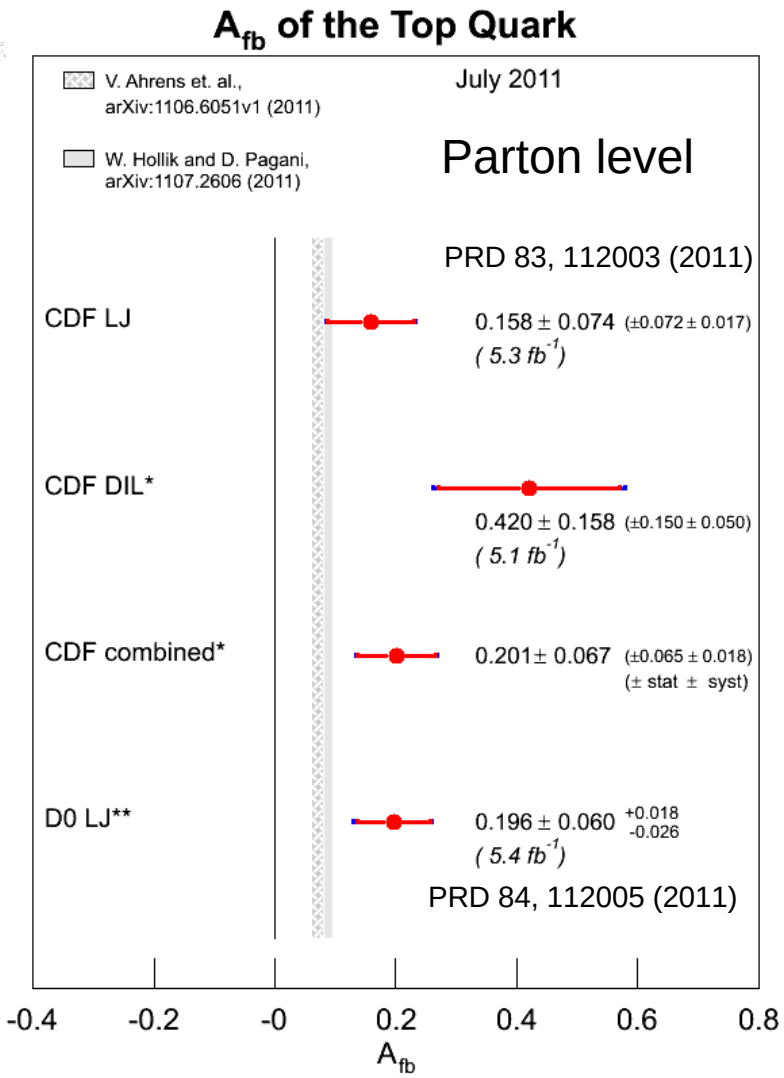
Forward backward asymmetry (A_{FB})

- Inclusive parton level asymmetry:

$A^{\Delta y}_{FB} = 0.162 \pm 0.041(stat) \pm 0.022\ (syst)$

- can be compared with previous CDF results and D0 result

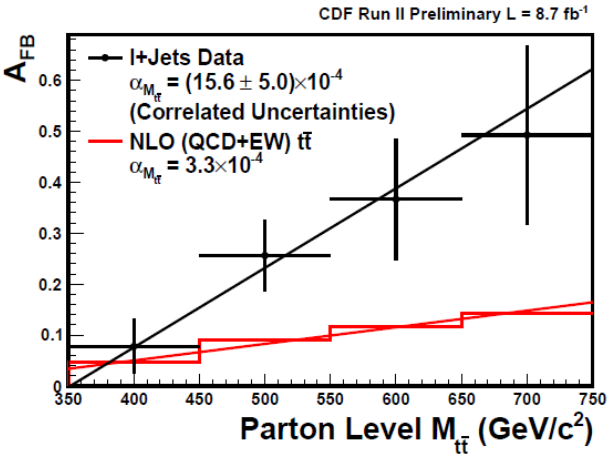
  - ➢ in agreement



A_{FB} dependence on M_{ttbar}

- Study the asymmetry vs. the mass of the ttbar system
- A_{FB} could increase at higher energy due to new production mechanisms
- In the SM A_{FB} increases linearly with M_{ttbar}
- Unfold M_{ttbar} dependence back to parton level
- Compare with old CDF and D0 results

NEW!

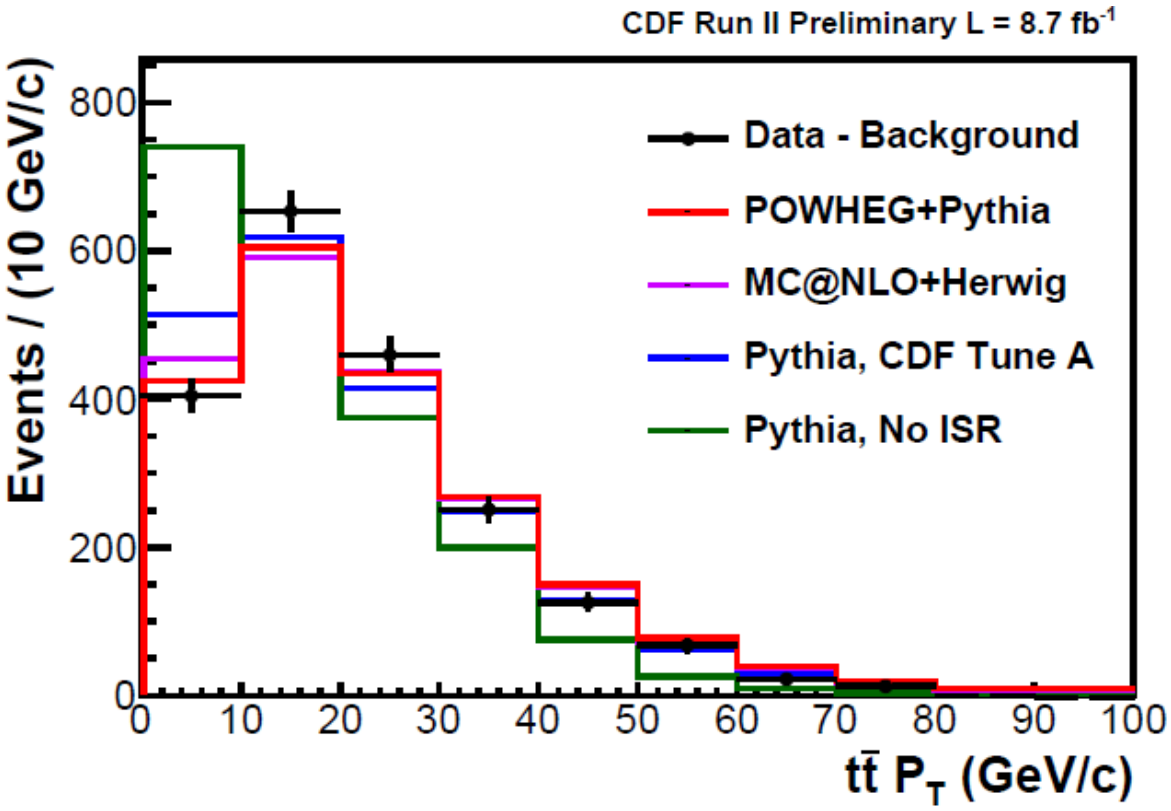


M_{tt} (GeV)	NLO (QCD+EW) ttbar	CDF 5.3 fb^{-1}	CDF 8.7 fb^{-1} Run II Preliminary	D0 5.4 fb^{-1}
Inclusive	0.066	0.158 ± 0.074	0.155 ± 0.048	0.196 ± 0.065
< 450	0.047	−0.116 ± 0.153	0.078 ± 0.054	0.078 ± 0.048 Recon. Level
> 450	0.100	0.475 ± 0.112	0.296 ± 0.067	0.115 ± 0.060 Recon. Level

Forward backward asymmetry (A_{FB})

NEW!

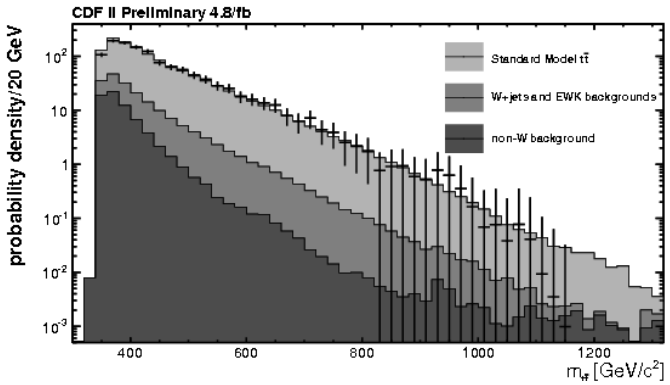
- Top pair P_T is a sensitive test of reconstruction and modeling (expecially at low values, due to soft jets)
- Background-subtracted data in good agreement with NLO Powheg and MC@NLO

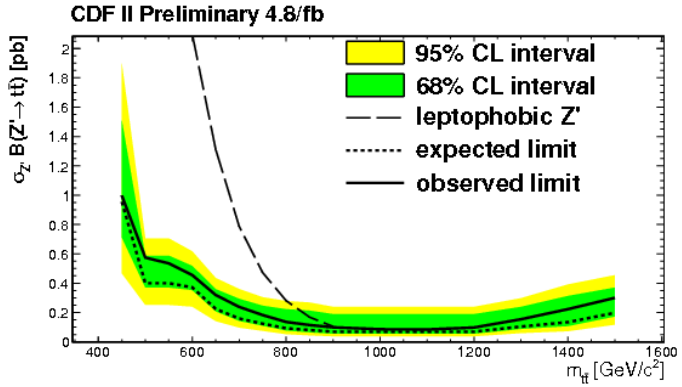


Search for resonant ttbar production

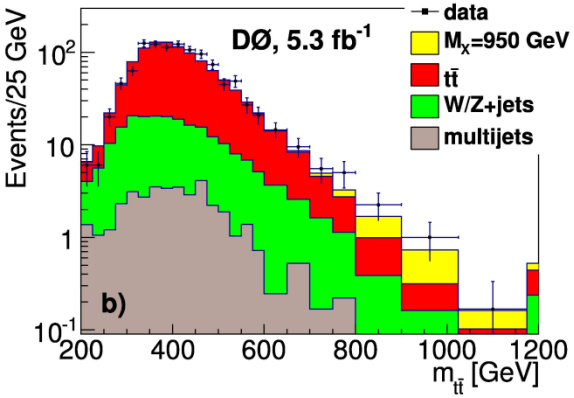
- Look at the M_{ttbar} spectrum in the lepton +jets final state, to see any deviation over the SM prediction

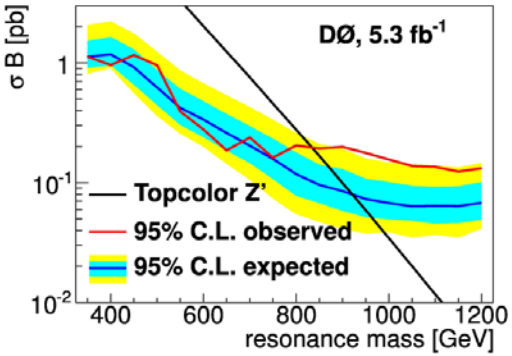
CDF L = 4.8 fb^{-1}





D0 L = 5.3 fb^{-1}





A topcolor leptophobic* Z' → ttbar is excluded at 95%CL with:

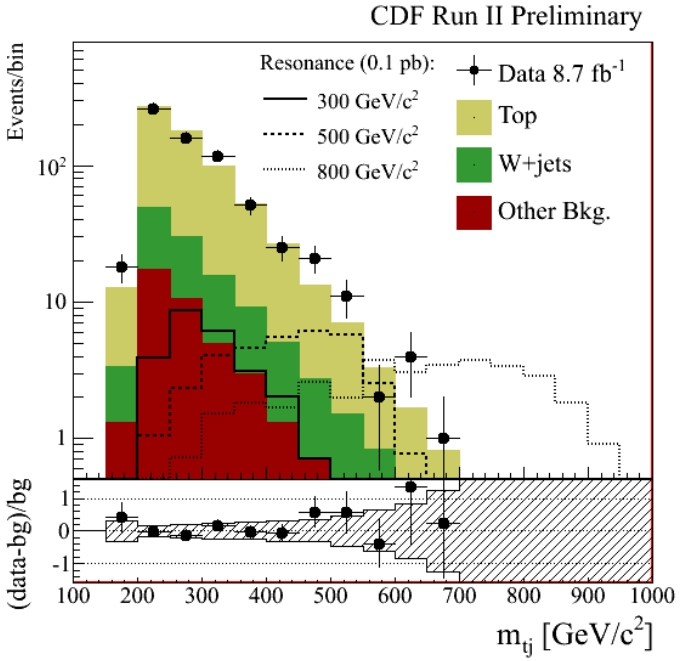
$M_{Z'} < 900$ GeV/c^2 PRD 84, 072004 (2011)

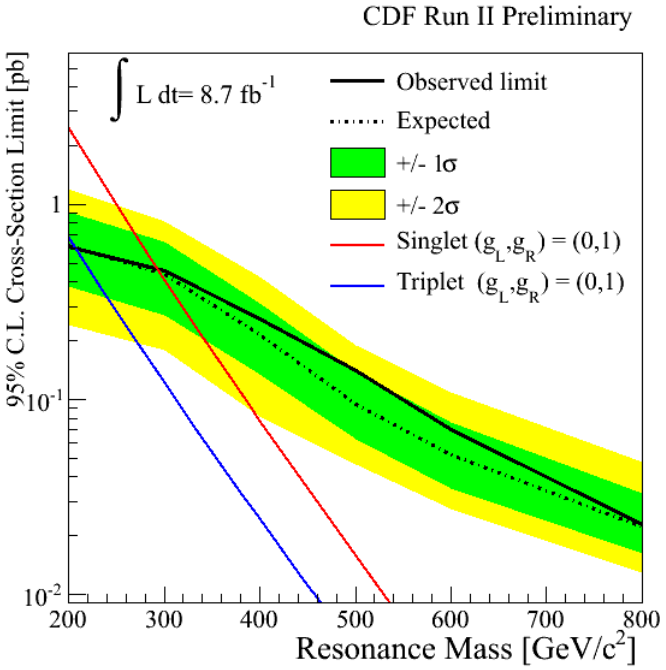
$M_{Z'} < 835$ GeV/c^2 arXiv:1111.1271 Accepted by PRD

* Harris, Hill, Parker '99

Search for top+jet resonances in ttbar +jet

- Search for a heavy new particle M produced in association with a top quark $p\bar{p} \to Mt \to \bar{t}qt$ leading to a resonance in the $t + jet$ system of $t\bar{t} + jet$ events.*
- Select events in lepton +jets channel with at least 5 jets and 1 b-tag, use 8.7 fb^{-1} of data.





NEW!

* Zurek et al, 2011

Conclusions

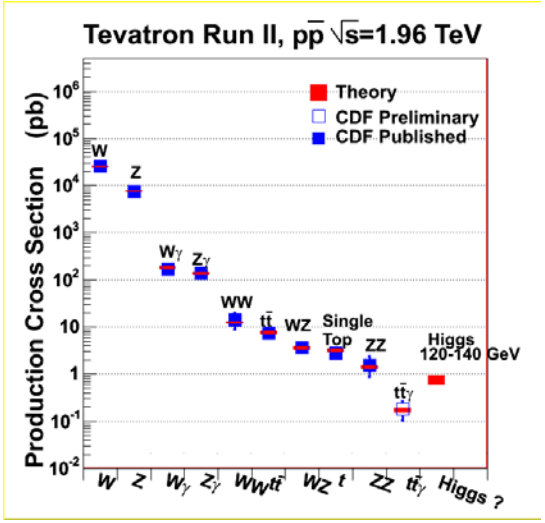
- The Tevatron keeps providing precise measurements of the top pair production cross sections in different channels challenging the precision of the theoretical calculations
- Electroweak single top has been observed.
  - ⇒ New cross section measurements have precision < 20%
  - ⇒ Observation of t-channel production
  - ⇒ Measurements and limits on V_{tb}
- No evidence for resonant production
- Legacy measurements from the Tevatron with the full data set will include:
  - ⇒ top pair production cross section
  - ⇒ single top cross sections and $|V_{tb}|$
- Study of forward-backward asymmetry of top events keeps indicating a discrepancy with current NLO QCD prediction.

⇒ .... <u>many more top properties in S. Sharyy talk!!</u>

Backup

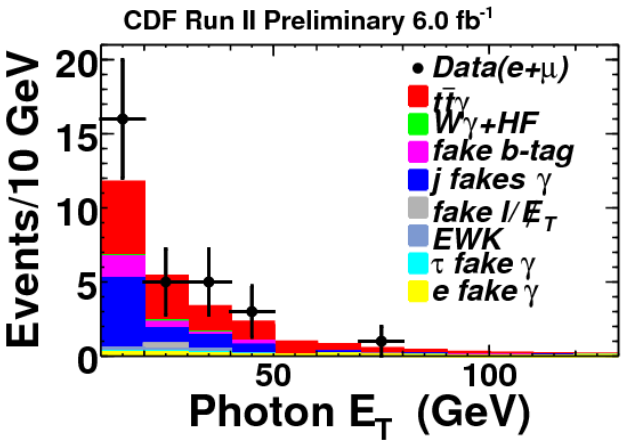
Evidence for ttbar + photon

- First measurement of ttbar + one additional radiated photon in 6 fb^{-1}
- Expected ~order of magnitude smaller than top pair production rate



- $\sigma_{ttbar\gamma}$ = 0.18 ± 0.08 pb
- $\sigma_{ttbar\gamma}$ / σ_{ttbar} = 0.024 ± 0.009

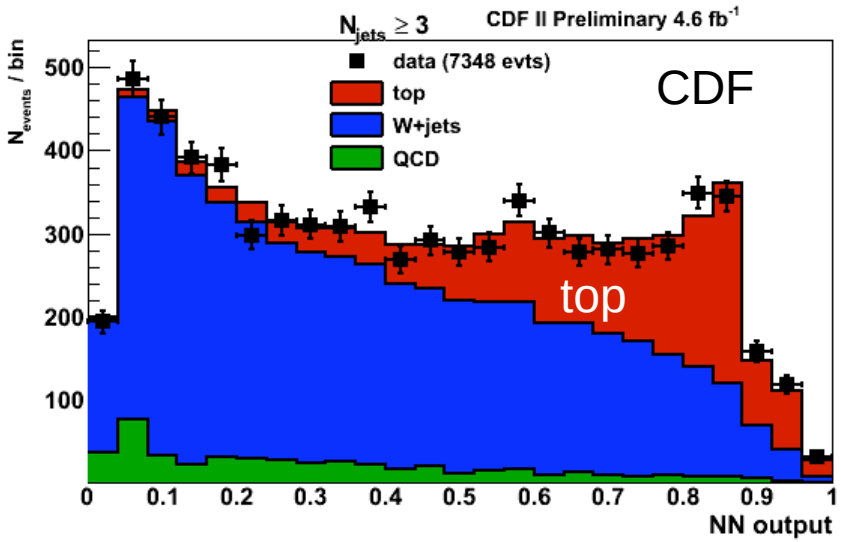
- result well consistent with prediction arXiv:0907.1324



PRD 84, 031104 (2011)

Top pair production: Lepton +Jets

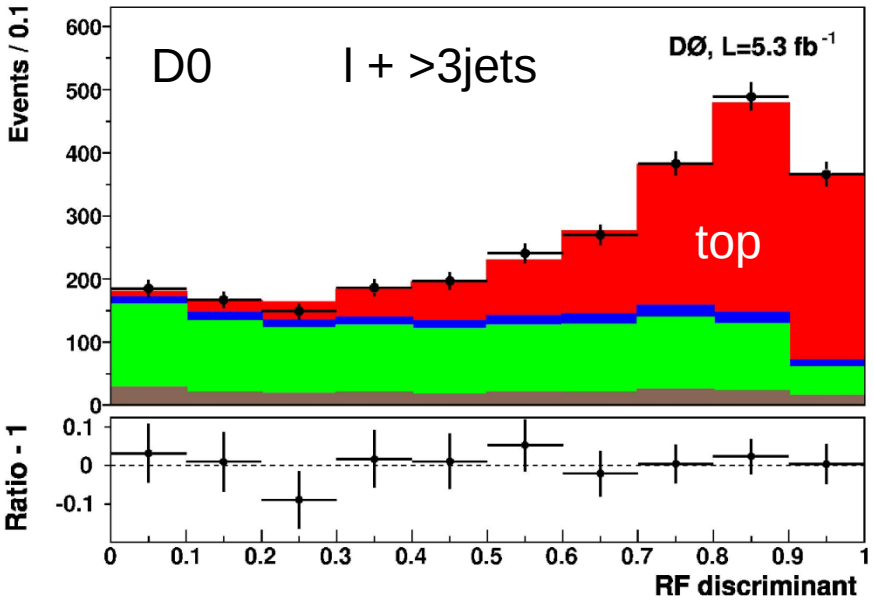
- Pre-tagged sample, NN discriminant



Systematic	tt_{tag}	tt_{ANN}	$Z/\gamma^* \to ll$
Luminosity	6.1	5.8	5.9
b-tag modeling	4.7	-	-
W+HF correction	4.0	-	-
Jet energy scale	4.1	2.9	-
Monte Carlo generator	2.7	2.6	-
Initial/final state radiation	0.6	0.4	-
PDF	0.6	0.9	1.4
Background shape model	0.2	1.9	0.3
Lepton ID/trigger	1.3	1.3	1.1
Total	10.0	7.5	6.2
Total $\sigma_{tt}/\sigma_{Z/\gamma^* \to ll}$	8.2	4.7	

PRL 105 012008 (2010)

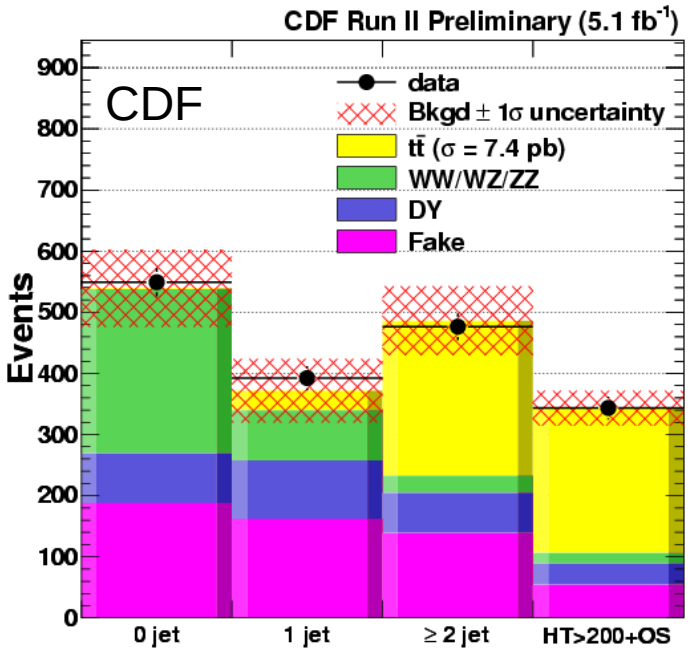
Kinematic method. RF discriminant

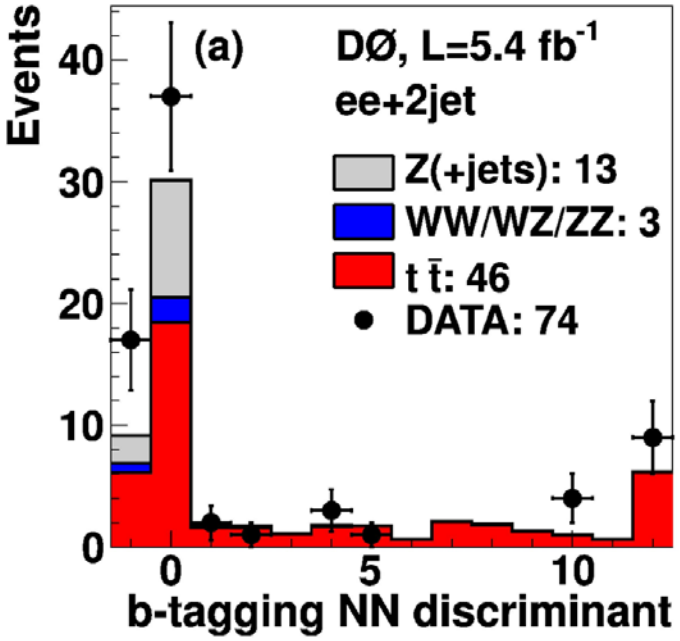


D0 (5.3 fb^{-1},m_t= 172.5 GeV), pre-tagged
σ_{tt} =7.68±0.31(stat) $^{+0.64}_{-0.56}$ (syst)pb

PRD 84, 012008 (2001)

Dileptons





240 dilepton events
cut and count with and w/o b-tagging

Fit to b-tag NN discriminant distribution
systematics included via nuisance param.
largest uncertainty from luminosity

CDF (5.1 fb^{-1}, m_t= 172.5 GeV), pre-tagged,
σ_{tt} (dil)=7.4±0.6(stat)±0.6(syst)±0.5(lum) pb

CDF (4.8 fb^{-1}, m_t= 172.5 GeV), b-tagged,
σ_{tt}(dil)=7.25±0.7(stat)±0.5(syst)±0.4(lum)pb

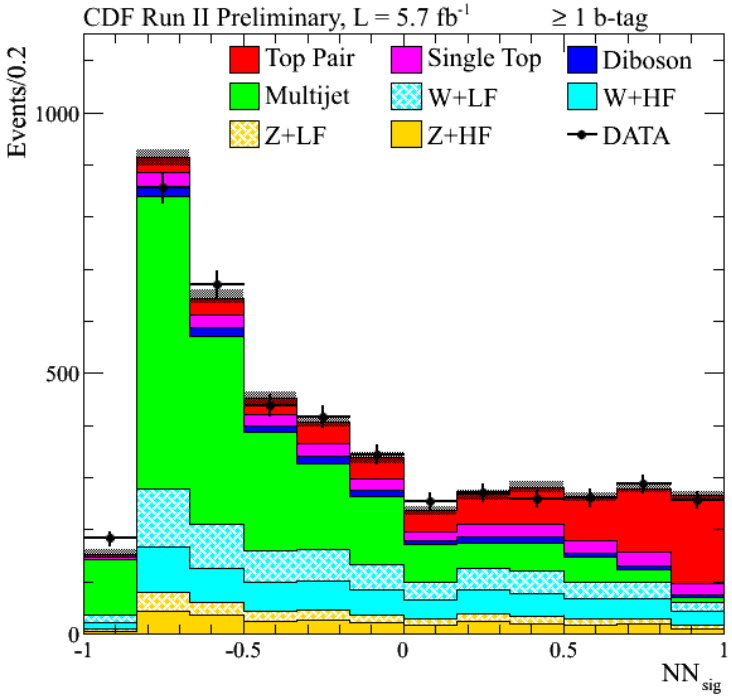
D0 (5.4 fb^{-1}, m_t= 172.5 GeV), b-tagged,
σ_{tt} (dil)=7.36$^{+0.90}_{-0.79}$(stat+syst+lum) pb

Combined with L+jets:

D0 (5.4 fb^{-1}, m_t= 172.5 GeV), b-tagged,
σ_{tt} (dil)=7.56$^{+0.63}_{-0.56}$(stat+syst+lum) pb

Missing energy plus b jets

- MET + jets:
  - ⇒ Independent from "lepton+jets" channel
  - ⇒ Interesting channel to searches for new physics (i.e. low mass Higgs)
- 2 or 3 identified jets, at least one b-tagged jet
- NN trained against QCD background
- Another NN to isolate top pair from remaining background



CDF (5.7 fb^{-1}, m_t= 172.5 GeV):

σ_{tt} = 7.12 $^{+1.20}_{-1.12}$ (stat+syst+lumi) pb

Conf, Note 10237

Updated single top

NEW!

- Expected events in 7.5 fb^{-1}:

Process	W+2jets, 1 tag	W+3jets, 1 tag	W+2jets, 2 tag	W+3jets, 2 tag
$t\bar{t}$	473.9 ± 49.1	1067.2 ± 108.6	98.3 ± 14.5	284.2 ± 41.8
WW	147.7 ± 20.6	48.3 ± 6.6	1.1 ± 0.3	1.2 ± 0.3
WZ	52.9 ± 5.8	14.4 ± 1.6	8.8 ± 1.3	2.4 ± 0.4
ZZ	1.7 ± 0.2	0.7 ± 0.1	0.3 ± 0.0	0.1 ± 0.0
Zjets	118.3 ± 15.5	45.6 ± 5.9	4.8 ± 0.7	2.7 ± 0.4
Wbb	1452.1 ± 436.9	434.1 ± 131.1	182.9 ± 56.1	64.7 ± 19.8
Wcc	766.1 ± 233.0	254.5 ± 77.4	10.2 ± 3.2	7.0 ± 2.2
Wcj	583.2 ± 177.4	127.7 ± 38.8	7.8 ± 2.4	3.5 ± 1.1
W+Mistags	1459.3 ± 148.5	432.6 ± 47.0	7.4 ± 1.5	5.4 ± 1.1
Non-W	315.7 ± 126.3	141.5 ± 56.6	6.8 ± 3.5	3.4 ± 3.2
t-channel	192.8 ± 25.3	84.0 ± 10.6	5.9 ± 1.0	14.7 ± 2.4
s-channel	127.6 ± 11.3	42.8 ± 3.8	32.3 ± 4.4	11.6 ± 1.6
Wt-channel	16.2 ± 4.3	25.7 ± 6.8	0.7 ± 0.2	2.3 ± 0.6
Total Prediction	5707.4 ± 876.6	2719.1 ± 292.9	367.3 ± 65.7	403.1 ± 52.6
Observed	5533.0	2432.0	335.0 ± 0.0	355.0 ± 0.0

- Sources of systematic uncertainties:

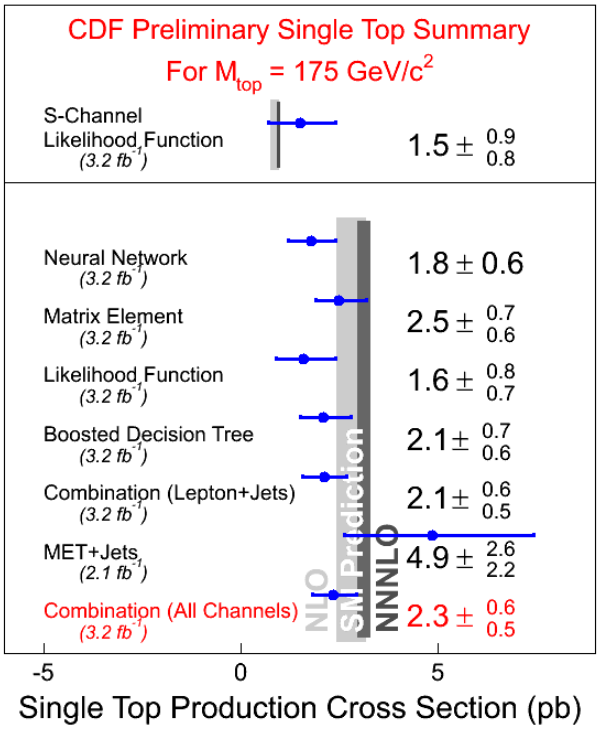
Source of Uncertainty	Rate	Shape	Processes affected
Jet energy scale	0–16%	X	all
Initial state radiation	0–11%	X	single top, $t\bar{t}$
Final state radiation	0–15%	X	single top, $t\bar{t}$
Parton distribution functions	2–3%	X	single top, $t\bar{t}$
Acceptance and efficiency scale factors	0–9%		single top, $t\bar{t}$, diboson, Z/γ^*+jets
Luminosity	6%		single top, $t\bar{t}$, diboson, Z/γ^*+jets
Jet flavor separator		X	all
Mistag model		X	W+light
Non-W model		X	Non-W
Factorization and renormalization scale		X	$Wb\bar{b}$
Jet η distribution		X	all
Jet ΔR distribution		X	all
Non-W normalization	40%		Non-W
$Wb\bar{b}$ and $Wc\bar{c}$ normalization	30%		$Wb\bar{b}$, $Wc\bar{c}$
Wc normalization	30%		Wc
Mistag normalization	17–29%		W+light
$t\bar{t}$ normalization	12%		$t\bar{t}$
Monte Carlo generator	1–5%		single top

Single top Combination: results

PRL 103, 092002 (2009)

	CDF (3.2 fb^{-1})	
	Exp.	Obs.
ME	4.9	4.3
BDT	5.2	3.5
NN	5.2	3.5
LF	4.0	2.4
$\not\!\!E_T$+jets	1.4	2.1
Comb	**5.9**	**5.0**

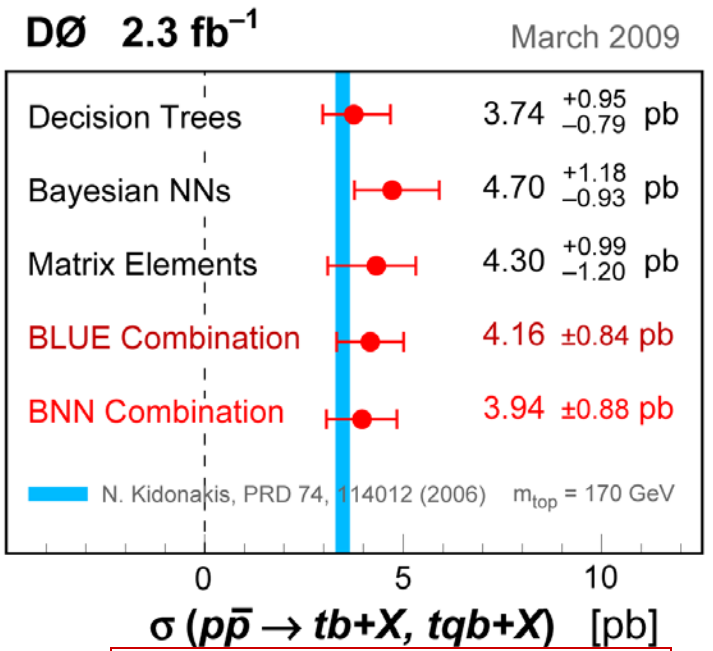
The various MV methods give consistent results



$\sigma_{s+t} = 2.3\ ^{+0.6}_{-0.5}$ pb

PRL 103, 092001 (2009)

	D0 (2.3 fb^{-1})	
	Exp.	Obs.
BDT	4.3	4.6
BNN	4.1	5.2
ME	4.1	4.9
BNN Comb	4.5	5.0

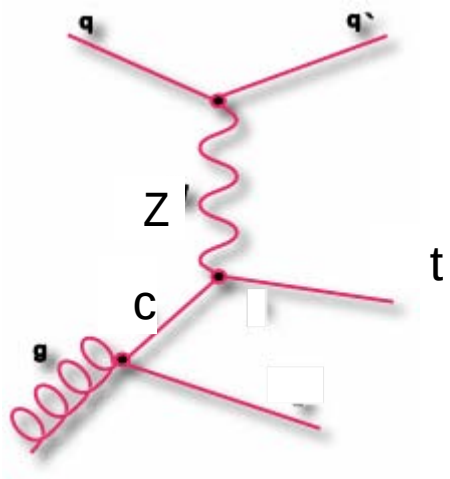


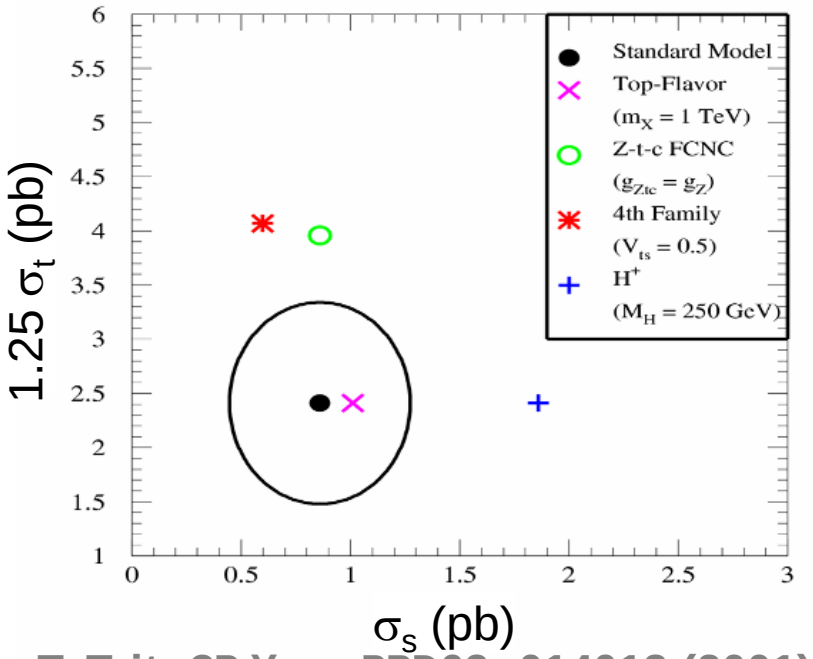
$\sigma_{s+t} = 3.94 \pm 0.88$ pb

Sensitivity to New Physics

- s- and t-channel sensitive to different BSM physics

t-channel

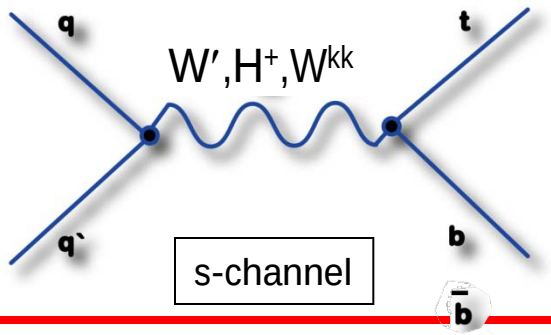




T. Tait, CP Yuan PRD63, 014018 (2001)

- Flavor changing neutral currents (t-Z-c, t-γ-c, t-g-c)

- heavy W' boson
- charged Higgs H^+
- Kaluza Klein excited W^{kk}

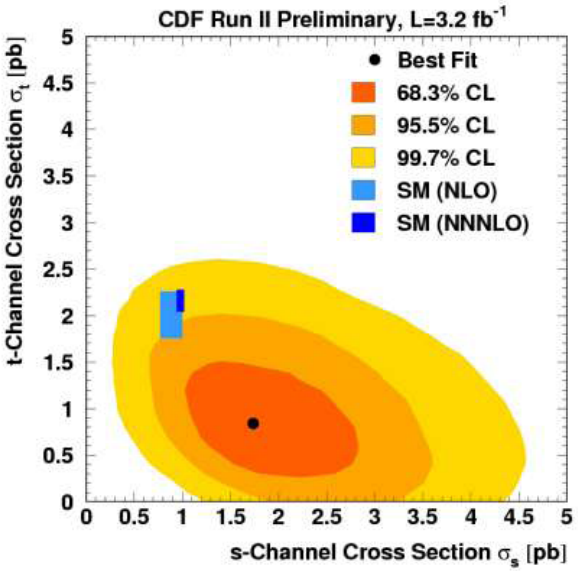


Separate t and s channel search

- Measure σ_s and σ_t separately, relax assumed SM s/t ratio

The results of the eleven separate channels ℓ + jets and MET + jets interpreted in the (σ_s,σ_t) plane

arXiv:1004.1181

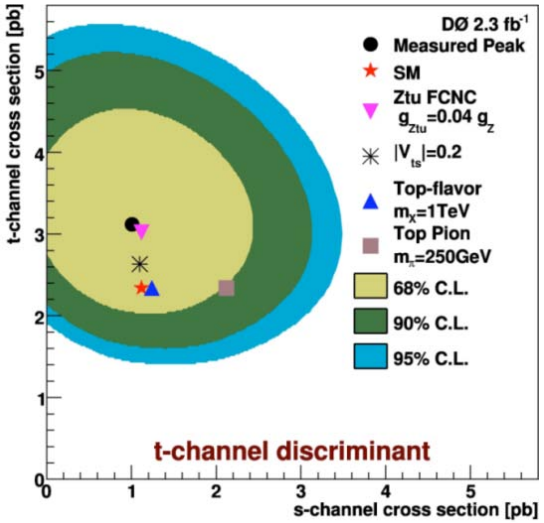


$\sigma_s = 1.8^{+0.7}_{-0.5}$ pb

$\sigma_t = 0.8 \pm 0.4$ pb

Train NN, BDT and ME for t-channel, Measure t-channel and s-channel simultaneously

DØ PLB 682, 363 (2010)

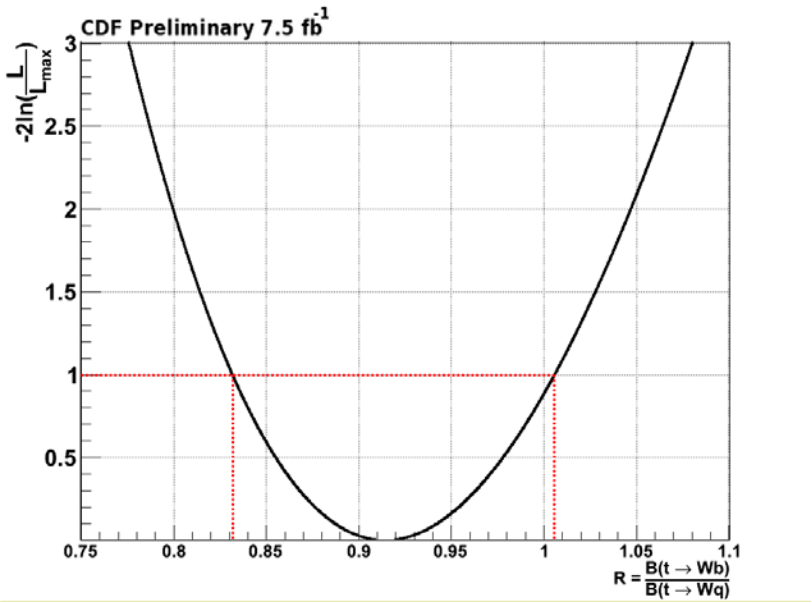


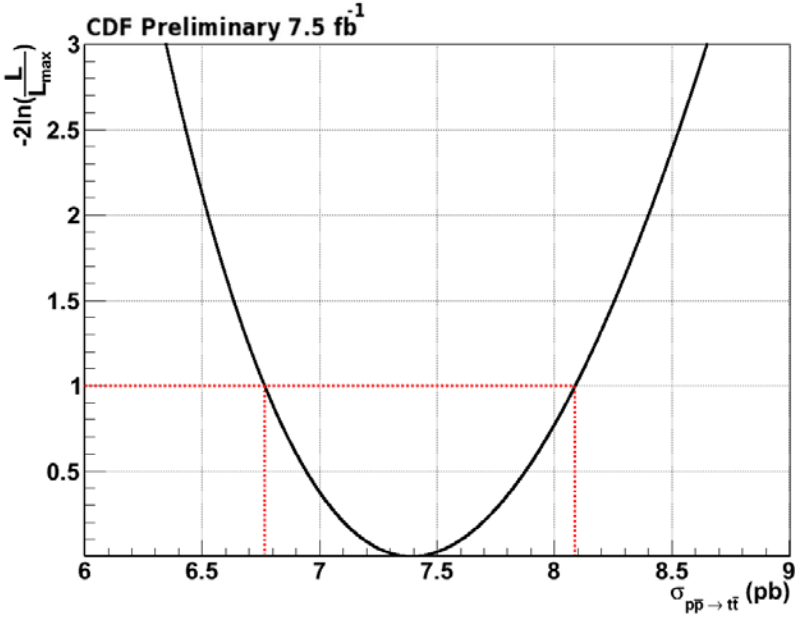
$\sigma_s = 1.05 \pm 0.81$ pb

$\sigma_t = 3.14^{+0.94}_{-0.80}$ pb

New CDF "R" Measurement

NEW!





Systematic	δR	$\delta\sigma_{p\bar{p}\to t\bar{t}}$ (pb)
Jet Energy Scale	± 0.03	± 0.5
Generator	± 0.006	± 0.4
ISR/FSR	± 0.03	± 0.2
Top Mass(m_t)	± 0.007	± 0.4

Table: Systematics not inserted in the fit

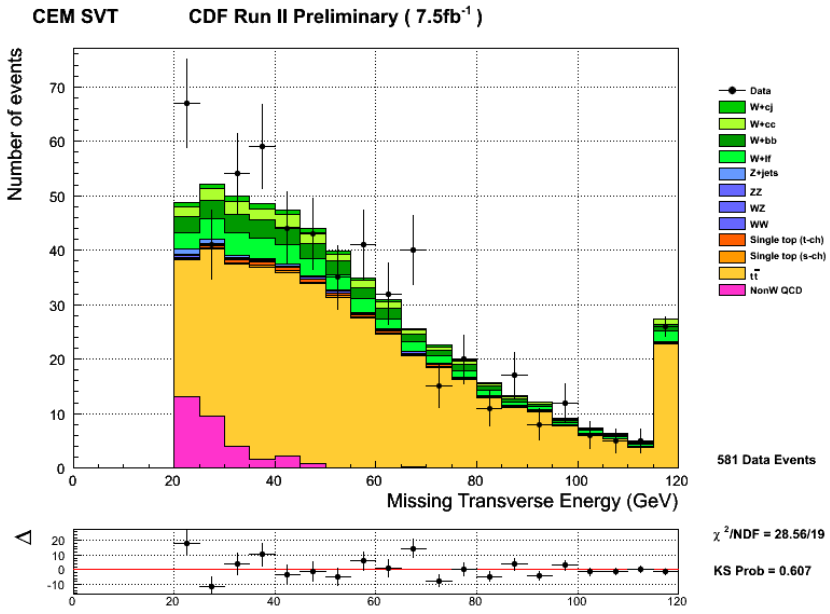
Systematics included in the fit:

- Tag efficiency
- Selection efficiency
- Background normalisation
- Luminosity

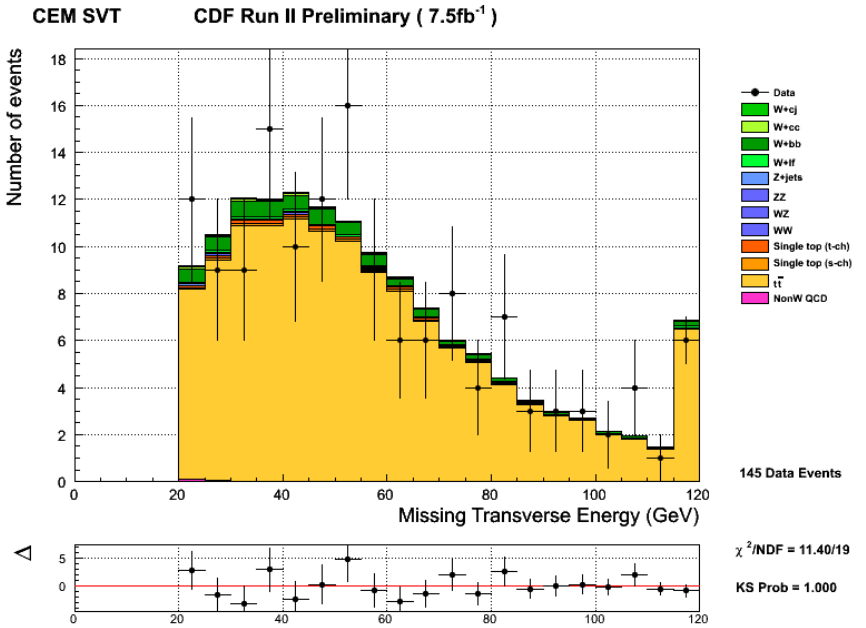
New CDF "R" Measurement

NEW!

Missing transverse energy for central electron candidates, 4 jets



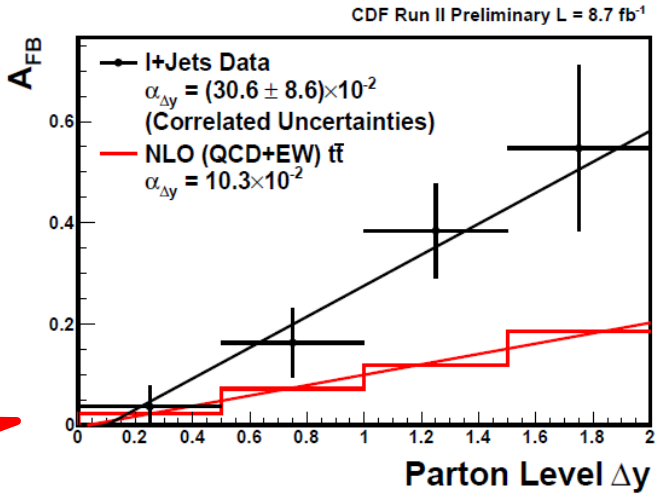
Events with 1 b-tag



Events with 2 b-tags

A_{FB} dependence on Δy

- Study the Δy dependence of the asymmetry
- In the SM A_{FB} increases linearly with Δy
- Unfold dependence back to parton level
- Compare with old CDF and D0 results

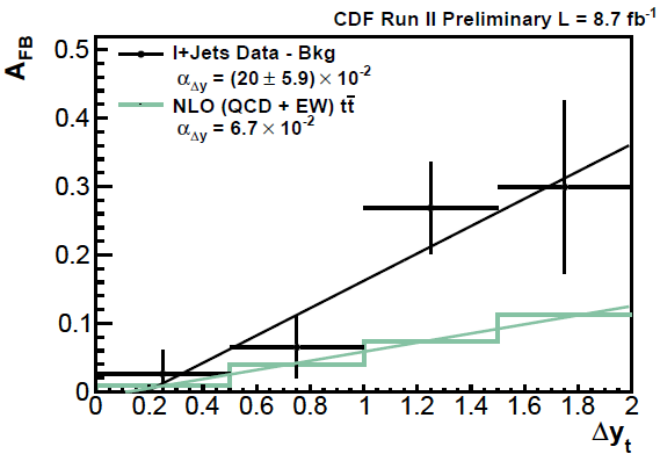


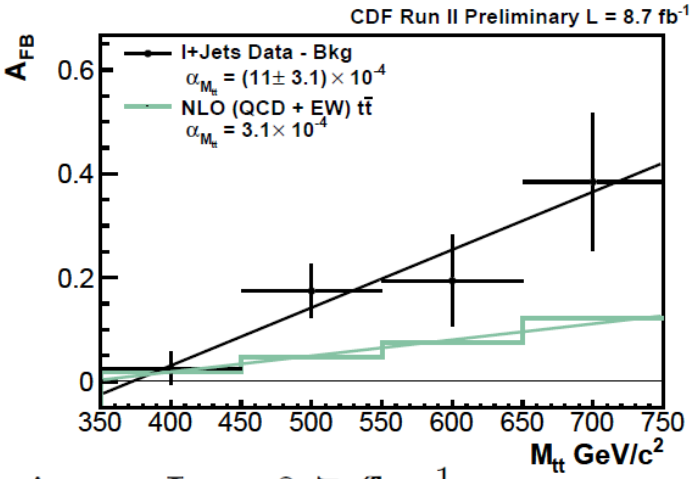
NEW!

|Δy|	NLO (QCD+EW) ttbar	CDF 5.3 fb^{-1}	CDF Run II Preliminary 8.7 fb^{-1}	D0 5.4 fb^{-1}
Inclusive	0.066	0.158 ± 0.07)	0.162 ± 0.047	0.196 ± 0.065
< 1.0	0.043	0.026 ± 0.118	0.088 ± 0.047	0.061 ± 0.041 (recon. Level)
> 1.0	0.139	0.611 ± 0.256	0.433 ± 0.109	0.213 ± 0.097 (recon. Level)

A_{FB} Asymmetry: Background-subtraction level significance

- We compare the observed slopes to the POWHEG predictions
- Starting with the POWHEG predictions, we perform simulated experiments by fluctuating the contribution from ttbar and each background source
- For each simulated exp. the nominal background-subtracted differential asymmetry is measured.
- The p-value is the fraction of simulated exp.in which the slope exceeds that which we observe in our data.





CDF Run II Preliminary L = 8.7 fb^{-1}

Slope Parameter	Data p-value
$\alpha_{\Delta y}$ ($A_{\rm FB}$ vs. $\lvert\Delta y\rvert$)	0.00892
$\alpha_{M_{t\bar{t}}}$ ($A_{\rm FB}$ vs. $M_{t\bar{t}}$)	0.00646

Forward backward asymmetry (A_{FB})

NEW!

- Systematic uncertainties on the parton level Δy measurement:

CDF Run II Preliminary L = 8.7 fb^{-1}

Source	Systematic Uncertainty
Background Shape	0.014
Background Normalization	0.011
Parton Showering	0.010
Jet Energy Scale	0.005
Initial and Final State Radiation	0.005
Color Reconnection	0.001
Parton Distribution Functions	0.001
Correction Procedure	0.003
Total Systematic Uncertainty	0.022
Statistical Uncertainty	0.041
Total Uncertainty	0.047