Top quark property at Tevatron

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On behalf of the CDF and D0 collaborations

Hadron Collider Physics 2012

What is most interesting about the top quark

W helicity

Ratio of $\frac{t \to Wb}{t \to Wq}$

FCNC

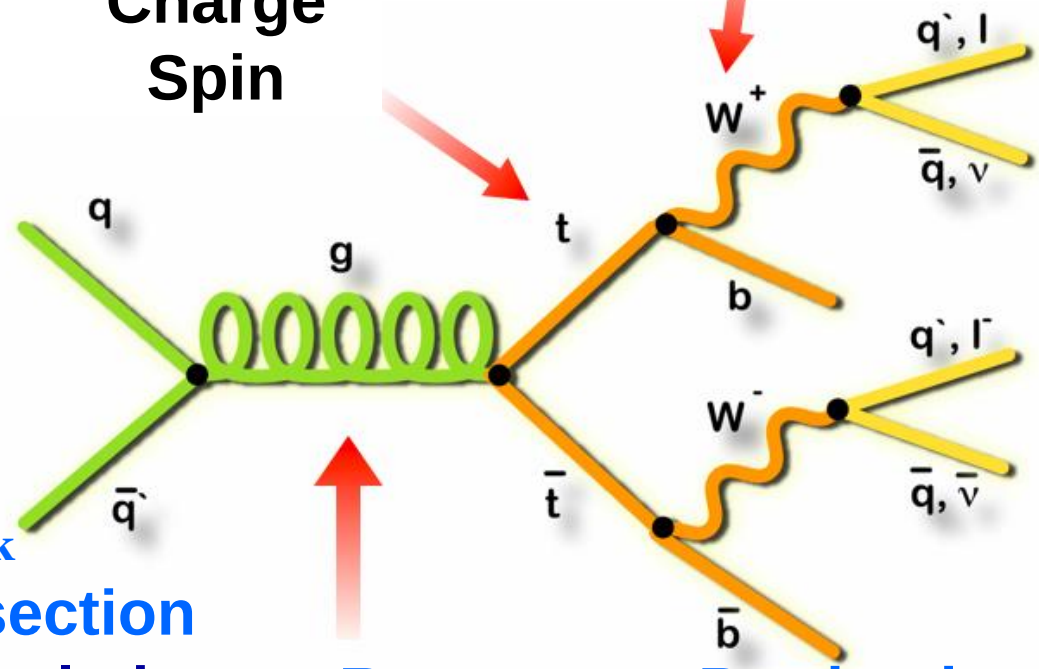
Charged Higgs

Mass

Width

Charge

Spin



See R. Demina's talk

Cross section

Spin correlation

FB asymmetry

New particle production

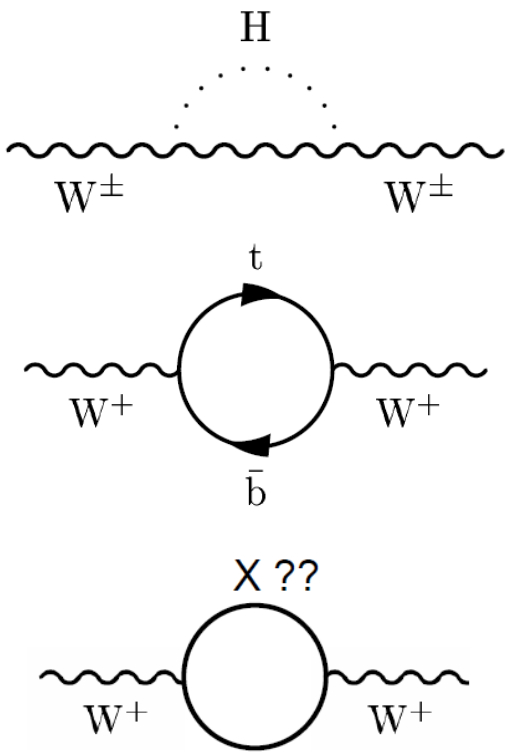
Resonance Production

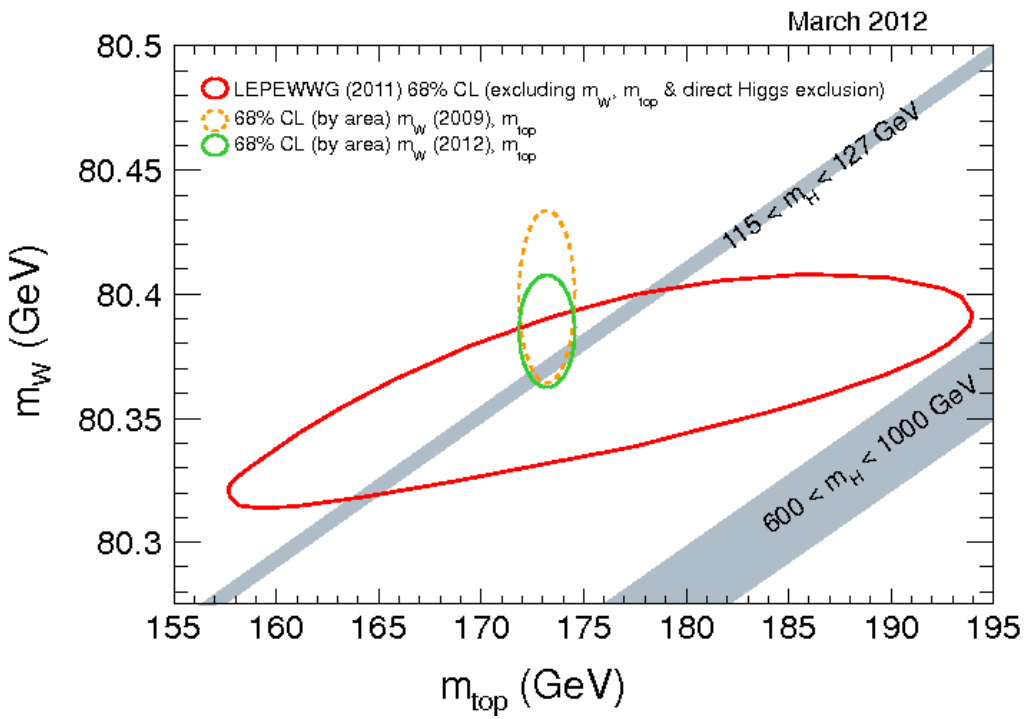
Production mechanism

See Y. Takeuchi's talk

Top quark mass

- Top quark mass is not predicted by SM
- Can constrain SM Higgs boson mass
  - ❖ Important contribution in radiative correction of W
  - ❖ Important test of SM



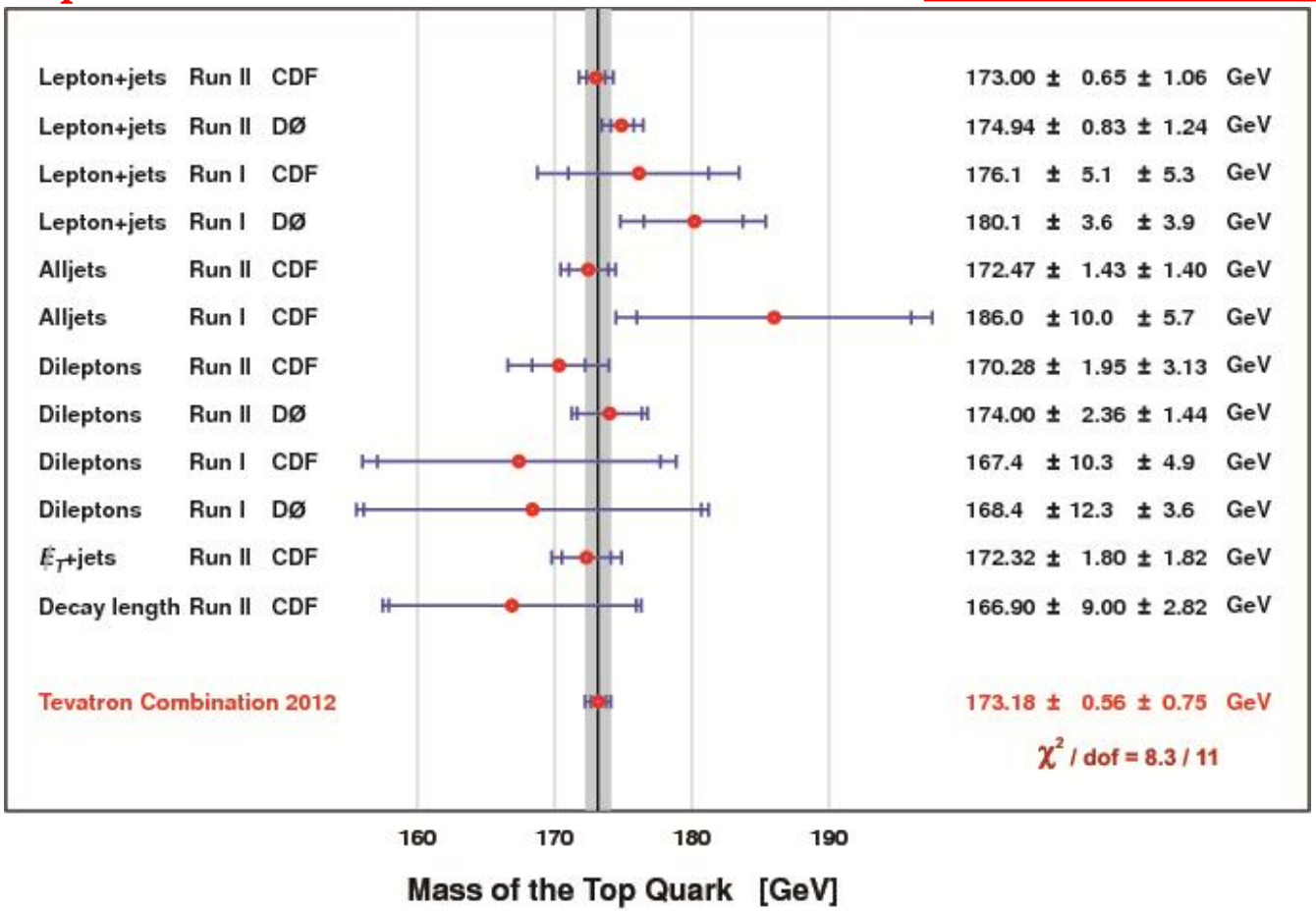


Tevatron Average

Phys. Rev. D 86, 092003 (2012)

$M_{top} = 173.18 \pm 0.94\ GeV/c^2$

Up to 5.6 fb^{-1}

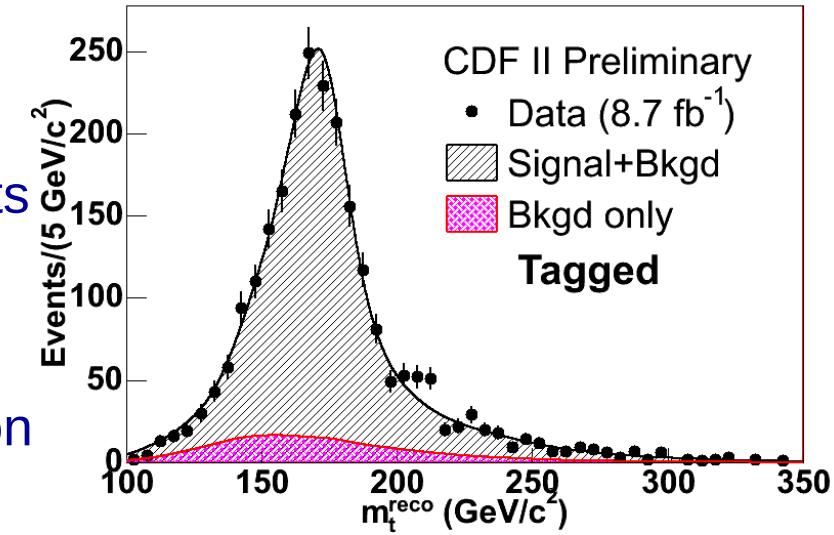


Both collaborations had approximately 10 fb^{-1}

CDF lepton+jets with full data set

Lepton+Jets

8.7 fb^{-1}



- 8.7 fb^{-1} data – 3989 candidate events
  - Five categories based on b-tagging and jets requirement
- Improvement
  - Employ neural network jet energy correction
  - Include 0-tag and loose 1-tag sample
  - Obtain approximately 25% additional gain in statistical precision
- Template method
  - Three variables : two of mass terms and one hadronic W mass (*in situ* JES calibration) from kinematic fitter

M_{top}=172.85 ±0.71(stat.) ±0.85(syst.)=172.85 ±1.11 GeV/c^2

Phys. Rev. Lett. 109, 152003 (2012)

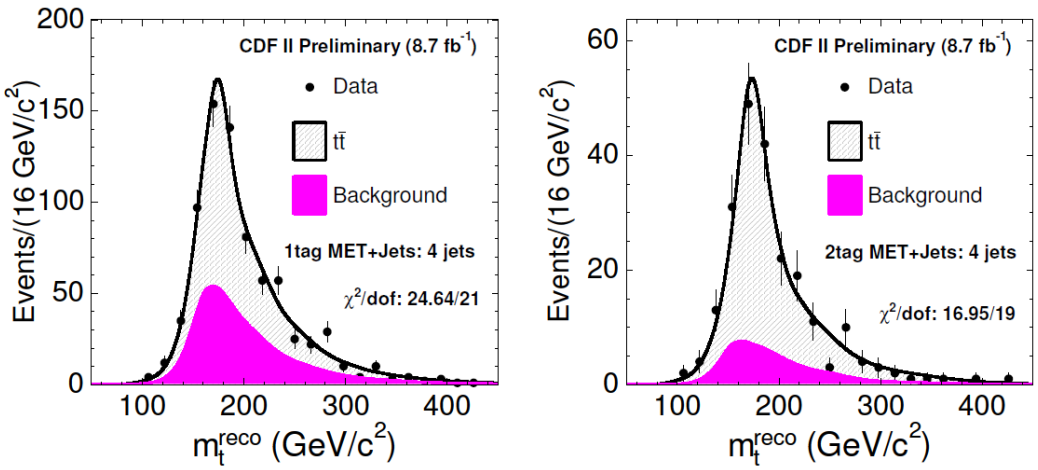
No lepton, MET, jets with full data set

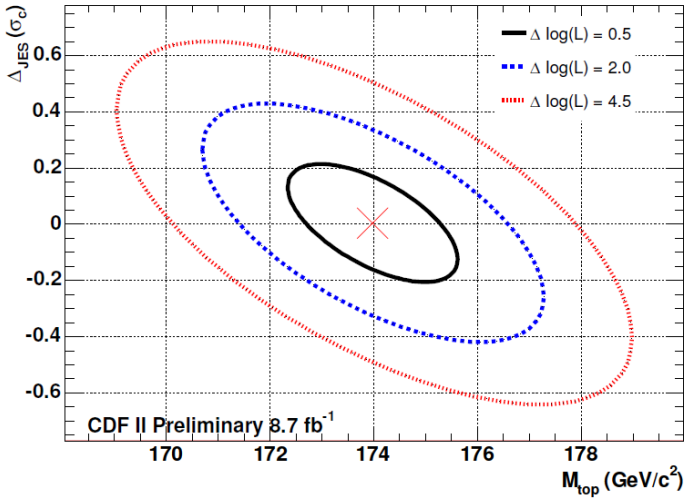
MET+Jets

8.7 fb^{-1}

- Full Event Reconstruction
  - Use kinematic fitter
  - Reconstruct leptonic W (not decaying product)
    - Overconstrained system
- Template method
  - Two reconstructed top masses and dijet (W) mass
  - *In situ* JES calibration

CDF publicnote 10810





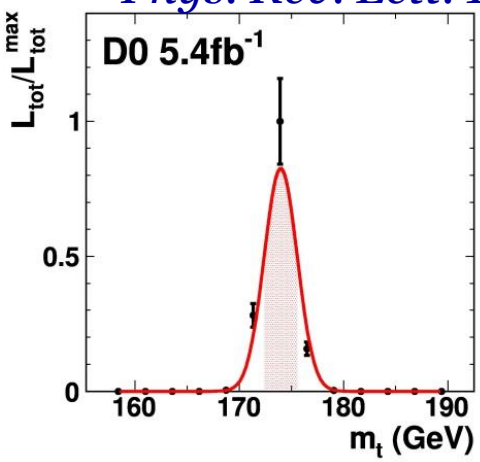
M_{top} = 173.9 ±1.6 (stat.+JES)±0.9 (syst.) GeV/c^2
=173.9 ± 1.9 GeV/c^2

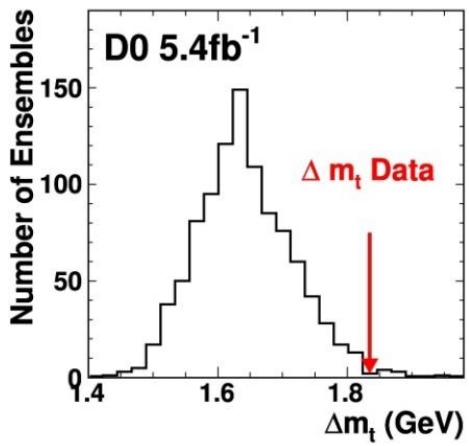
D0 dilepton channel

- Matrix element method

Phys. Rev. Lett. 107, 082004 (2011)

5.4 fb^{-1}





174.0 ± 1.8 (stat.) ± 2.4 (syst.) GeV/c^2

Source	Uncertainty (GeV)
Jet energy calibration	
Overall scale	0.9
Flavor dependence	0.5
Residual scale	0.3
Signal modeling	
ISR/FSR	0.4
Color reconnection	0.5
Higher order effects	0.6
b quark fragmentation	0.1
PDF uncertainty	0.5
Object reconstruction	
Muon p_T resolution	0.2
Electron energy scale	0.2
Muon p_T scale	0.2
Jet resolution	0.3
Jet identification	0.3
Method	
Calibration	0.1
Template statistics	0.5
Signal fraction	0.2
Total systematic uncertainty	1.5

Dilepton

- Template method + JES calibration derived from lepton+jets

174.0 ± 2.4 (stat.) ± 1.4(syst.) GeV/c^2

Phys. Rev. D 86, 051103 (2012)

- Combine two results

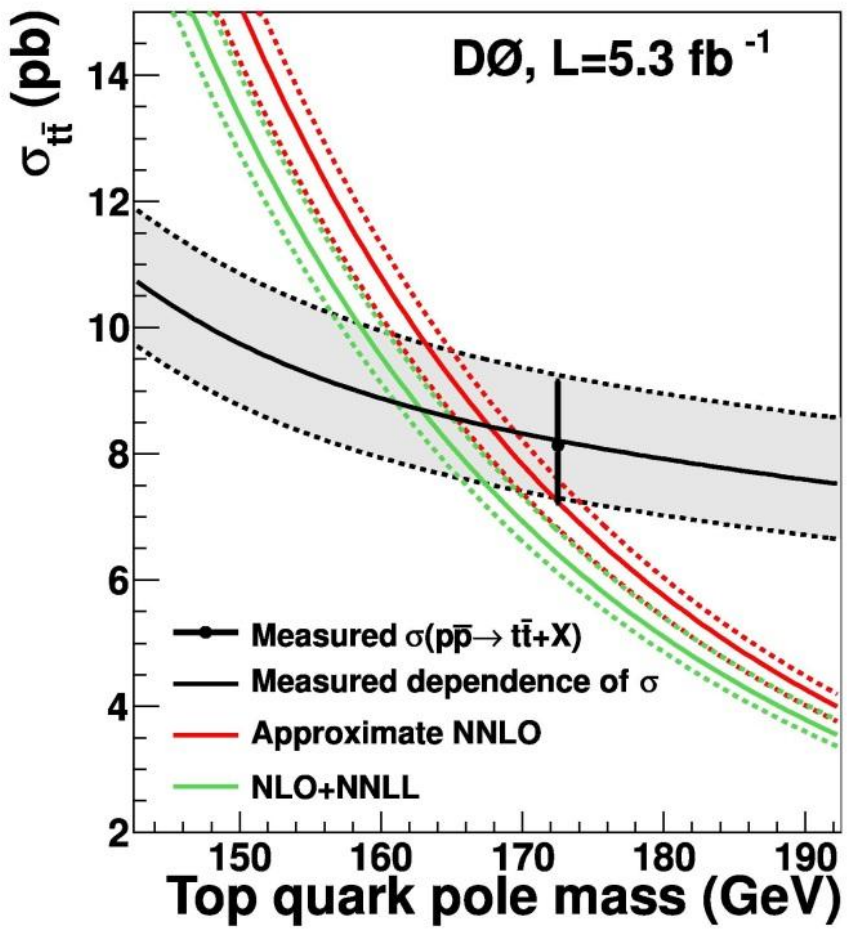
M_{top} =173.9 ± 1.9 (stat.) ±1.6 (syst) GeV/c^2

What mass? Pole, $\overline{\mathrm{MS}}$, or … ?

- Extract mass from cross section measurements

Lepton+Jets

5.3 fb^{-1}



Pole Mass

Theoretical prediction	m_t^{pole} (GeV)	$\Delta m_t^{\mathrm{pole}}$ (GeV)
MC mass assumption	$m_t^{\mathrm{MC}} = m_t^{\mathrm{pole}}$	$m_t^{\mathrm{MC}} = m_t^{\overline{\mathrm{MS}}}$
NLO [12]	$164.8^{+5.7}_{-5.4}$	-3.0
NLO+NLL [13]	$166.5^{+5.5}_{-4.8}$	-2.7
NLO+NNLL [14]	$163.0^{+5.1}_{-4.6}$	-3.3
Approximate NNLO [15]	$167.5^{+5.2}_{-4.7}$	-2.7
Approximate NNLO [16]	$166.7^{+5.2}_{-4.5}$	-2.8

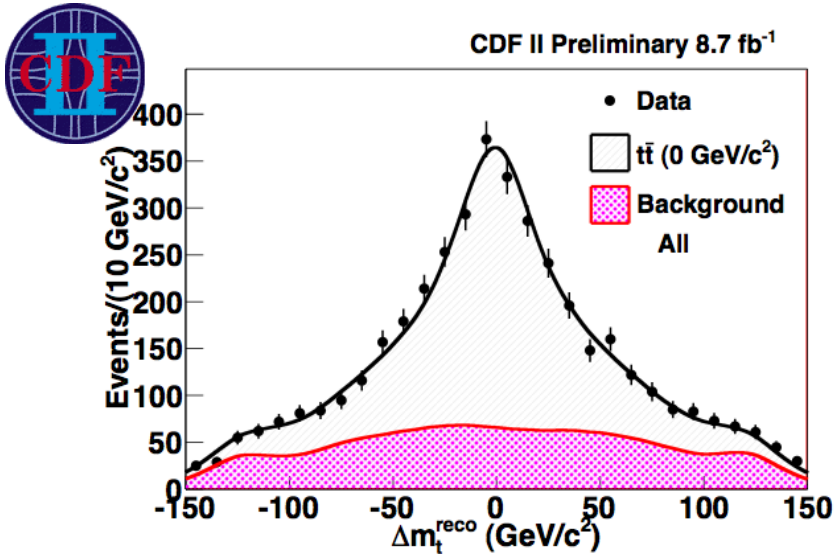
$\overline{\mathrm{MS}}$ Mass

Theoretical prediction	$m_t^{\overline{\mathrm{MS}}}$ (GeV)	$\Delta m_t^{\overline{\mathrm{MS}}}$ (GeV)
MC mass assumption	$m_t^{\mathrm{MC}} = m_t^{\mathrm{pole}}$	$m_t^{\mathrm{MC}} = m_t^{\overline{\mathrm{MS}}}$
NLO+NNLL [14]	$154.5^{+5.0}_{-4.3}$	-2.9
Approximate NNLO [15]	$160.0^{+4.8}_{-4.3}$	-2.6

Phys. Lett. B 703, 422 (2011)

t and $\bar{t}$ mass difference

- If CPT is conserved, ΔM_{top} should be zero (SM)
- We test this assumption by measuring ΔM_{top}
- We use similar technique with mass measurements



ME technique but allow different mass of top and anti-top

3.6 fb^{-1} | Lepton+Jets

$\Delta M_{top} = +0.8 \pm 1.9$ GeV/c^2

Phys. Rev. D 84, 052005 (2011)

8.7 fb^{-1} | Lepton+Jets

Kinematic reconstruction and template fit

$\Delta M_{top} = -1.95 \pm 1.26$ GeV/c^2

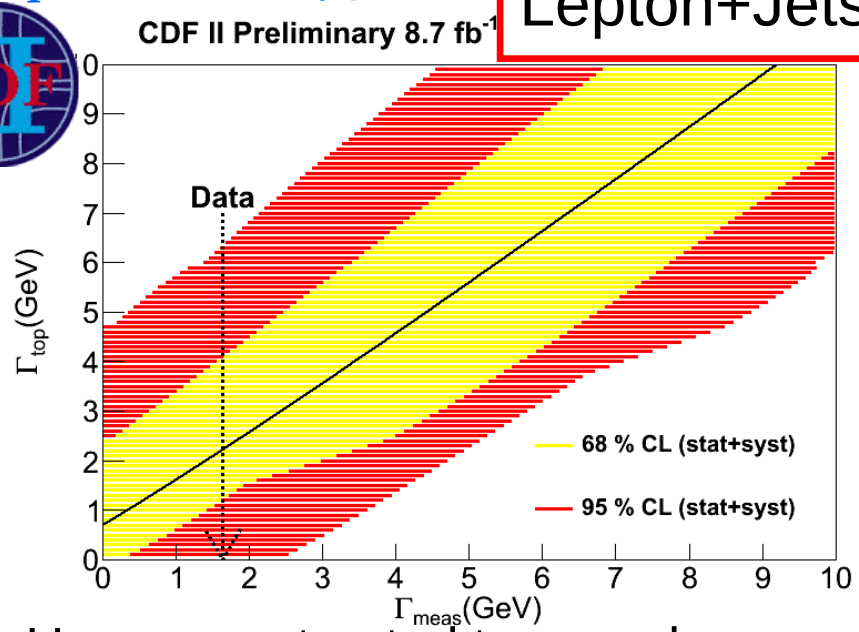
arXiv:1210.6131

Top quark width (Decay before hadronization?)

Direct measurement

CDF publicnote 10936

Lepton+Jets



- Use reconstructed top quark mass (RMS distribution)
- No assumption of SM

8.7 fb^{-1}

$\Gamma_{top} = 2.21\ ^{+1.84}_{-1.11}$ GeV

$\Gamma_{top} < 6.38$ GeV @ 95 CL

Indirect measurement

- Assume SM
- the single top t-channel cross section
- Ratio of t→Wb/t →Wq

5.4 fb^{-1}

$$\Gamma_t = \frac{\sigma(t-ch)}{Br(t \to bW)} \cdot \frac{\Gamma(t \to bW)_{SM}}{\sigma(t-ch)_{SM}}$$

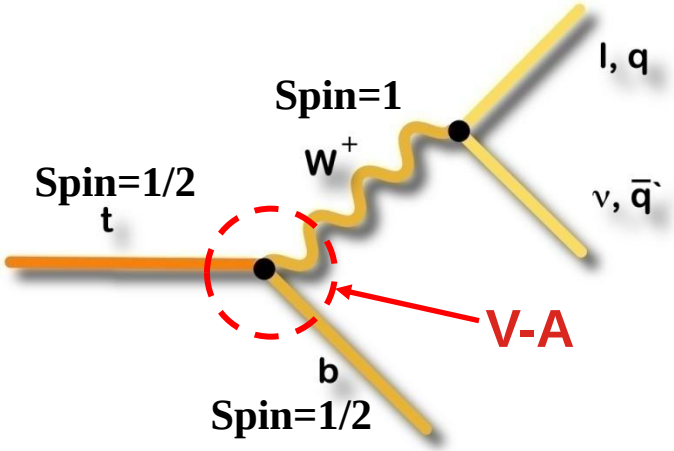
$\Gamma_{top} = 2.00\ ^{+0.47}_{-0.43}$ GeV

$\tau_{top} = 3.29\ ^{+0.90}_{-0.63}\ 10^{-25}$ s $< \tau^{had.}$

Phys. Rev. D 85, 091104 (2012)

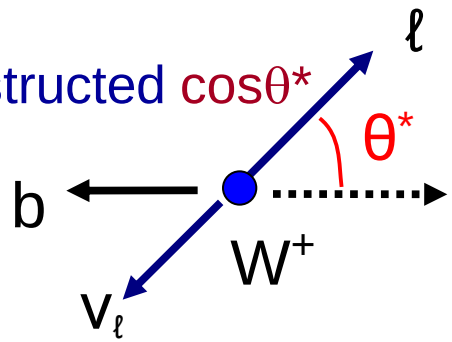
W Helicity

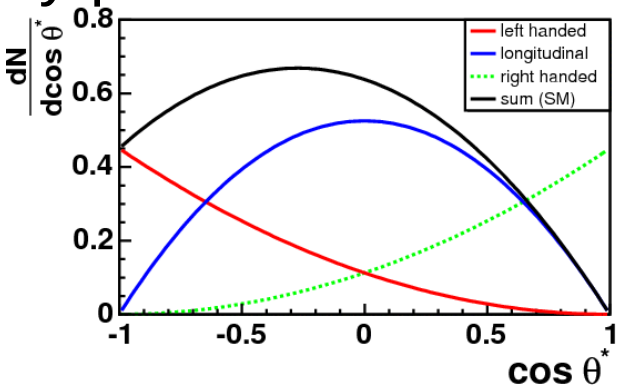
- The SM top decays via EW interaction
  - Top decays as a bare quark ⇒ spin information transferred to final state particles



- V-A coupling predict
  - f_0 = 0.7 (longitudinal polarization)
  - f_+ ~ 0 (right handed polarization)
  - f_- = 0.3 (left handed polarization)

- Measuring the fraction of longitudinally polarized W bosons
  - Reconstructed cosθ*

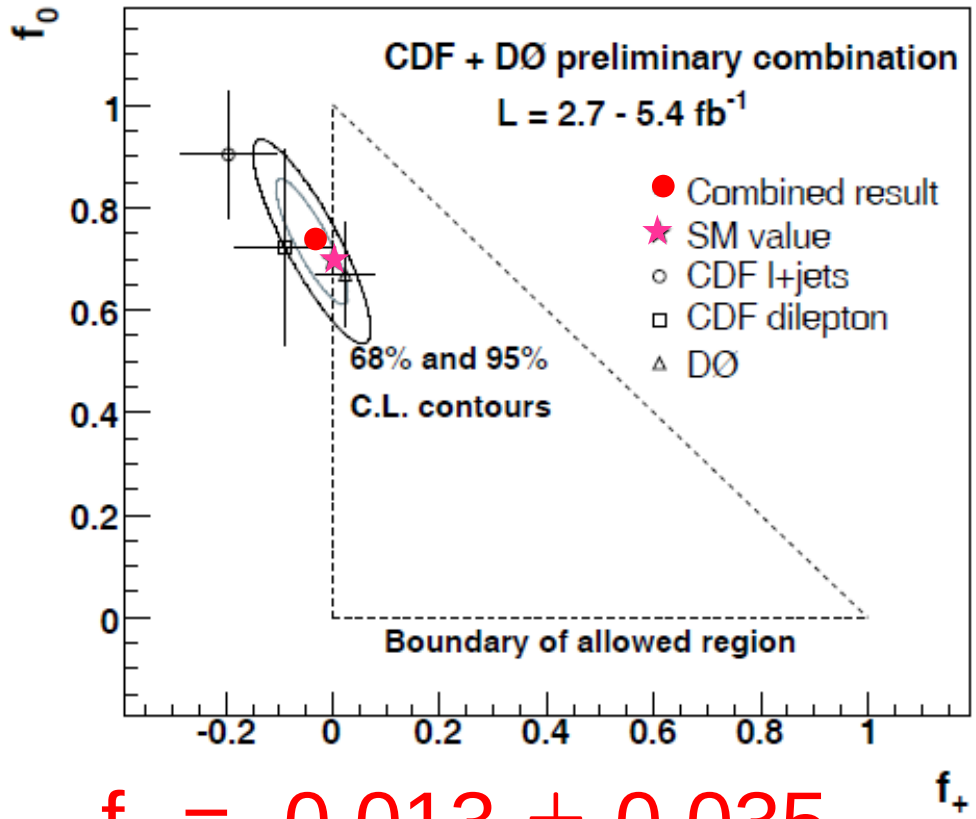




Tevatron combination

Phys. Rev. D 85, 071106 (2012)

Up to 5.4 fb^{-1}



$f_{+\,SM} \sim 0$

$f_{0\,SM} = 0.7$

$f_+ = -0.013 \pm 0.035$

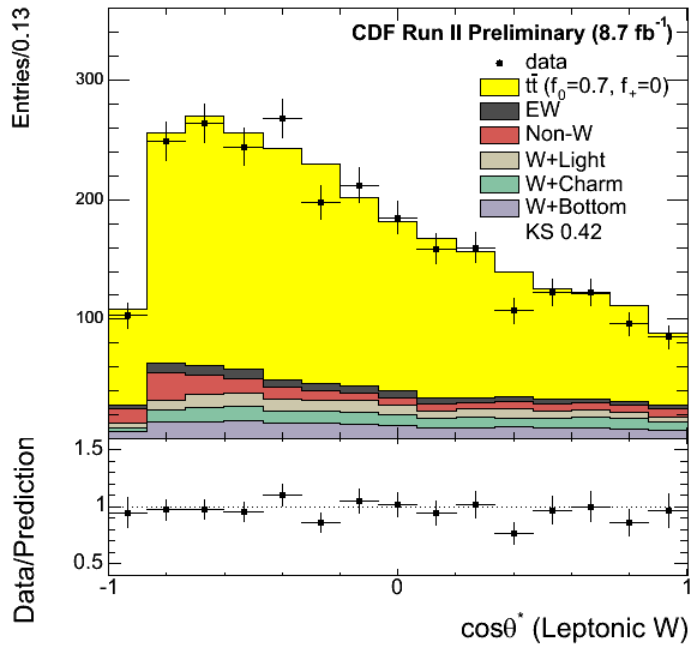
$f_0 = 0.685 \pm 0.057$

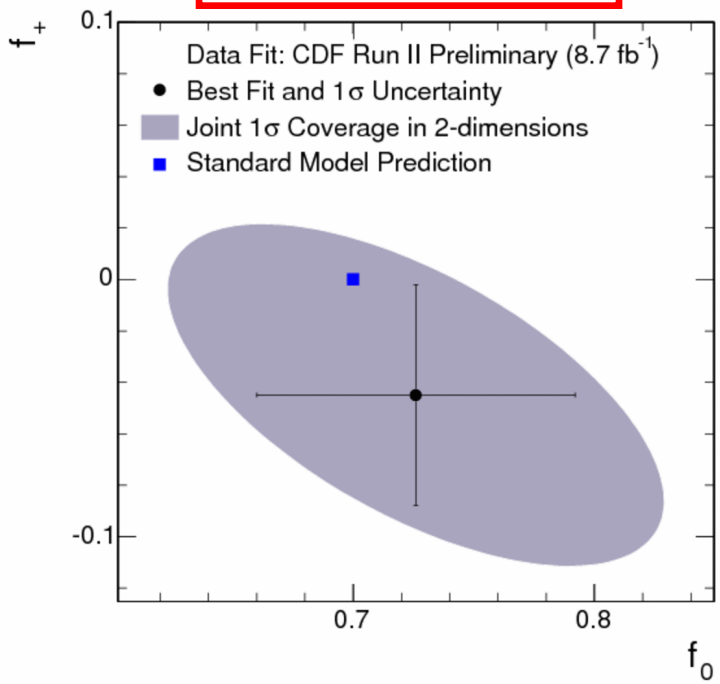
Consistent with SM

CDF lepton+jets with full data set

8.7 fb^{-1}

Lepton+Jets





$f_{+\,SM} \sim 0$

$f_{0\,SM} = 0.7$

CDF Publicnote 10855

Matrix element technique

$f_+ = -0.045 \pm 0.043$

Consistent with SM

$f_0 = 0.726 \pm 0.067$

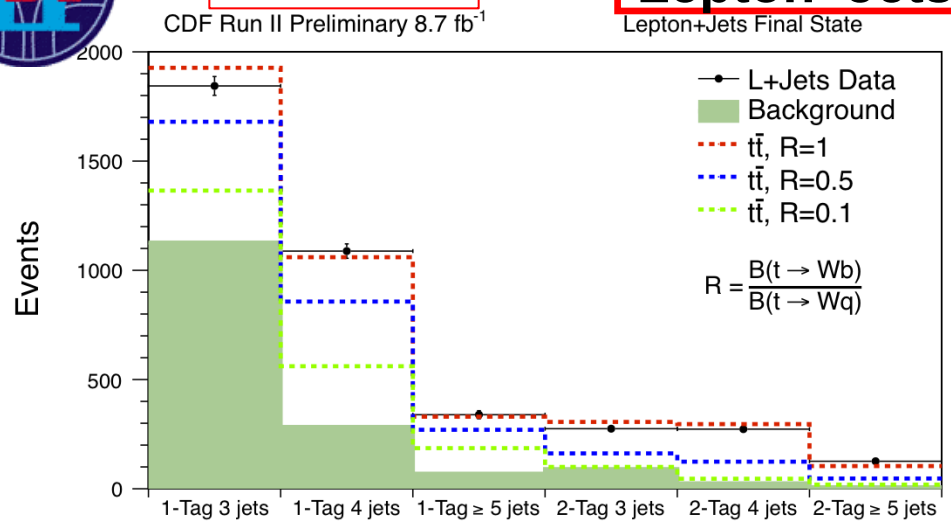
Ratio $R = B(t \to Wb)/B(t \to Wq)$

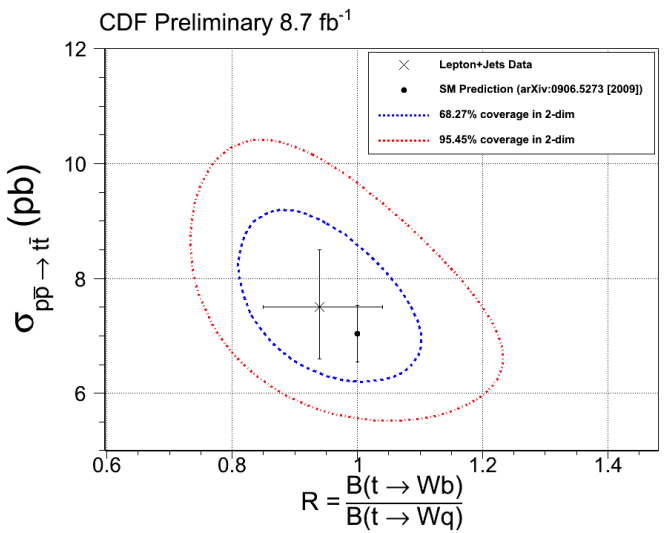
- SM prediction is $R = 0.998$
- Using b-tag and jet multiplicity to extract both $\sigma_{p\bar{p}\to t\bar{t}}$ and R

8.7 fb^{-1}

Lepton+Jets

CDF Publicnote 10887





$R = 0.94 \pm 0.04\ (\text{stat}) \pm 0.09\ (\text{syst})$

5.4 fb^{-1}

Lepton+Jets and dilepton

$R_{SM} = 0.998$

$R = 0.90 \pm 0.04$

Phys. Rev. Lett. 107, 121802 (2011)

Conclusion

- Top quarks properties are well being studied at Tevatron
  - We are performing rigorous study for top quark
  - Unique/Complementary measurements to test SM and new physics

- Tevatron's legacy on top physics is ongoing
  - A couple of measurements were updated with full data sample but, still many of measurements are ongoing
  - It is not only update with full data set but also improving the machinery

http://www-cdf.fnal.gov/physics/new/top/top.html

http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html