Top Quark Measurement at CDF

Lake Louise Winter Institute

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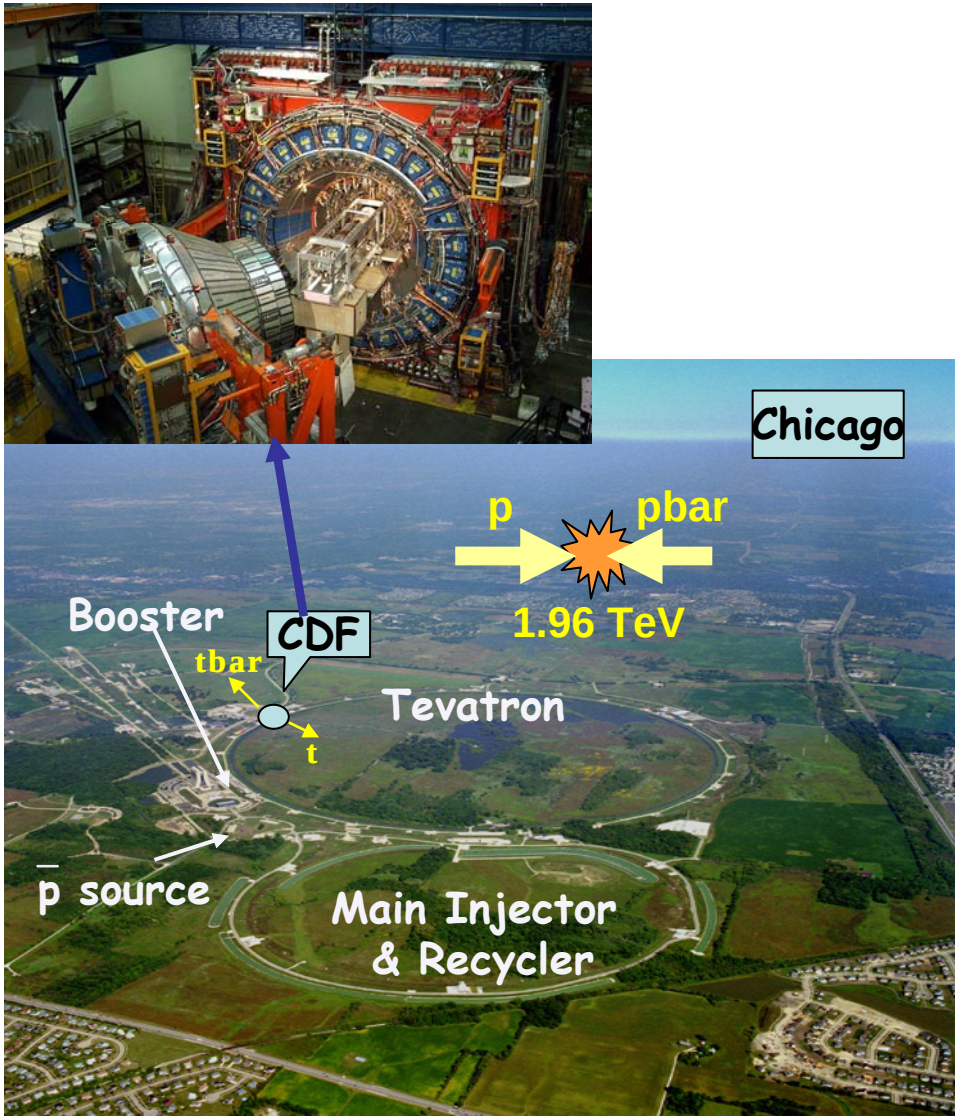
The University of Chicago

On behalf of the CDF collaboration

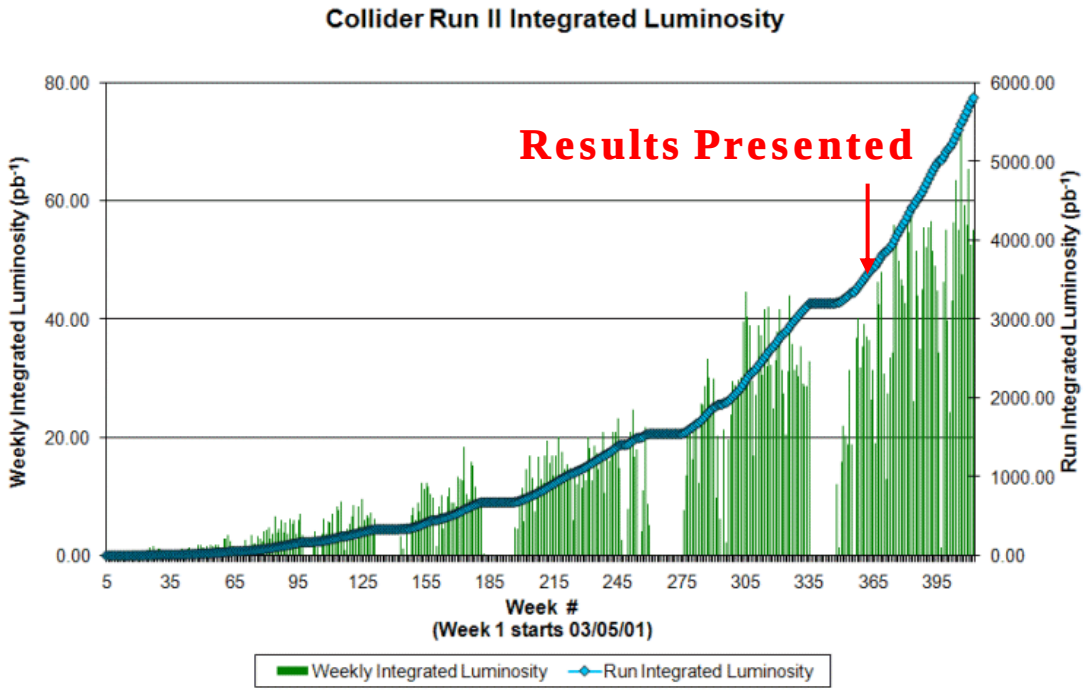
The Tevatron and CDF



The only place has produced top quark

Excellent performance

- 6 fb^{-1} was delivered
- Up to 3 fb^{-1} (Good silicon) data currently used



What we know (believe) about Top quark

Top Quark

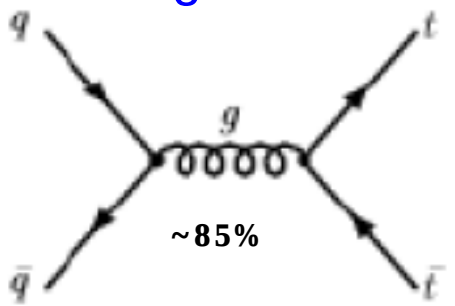
Spin = 1/2 , Charge = 2/3 e

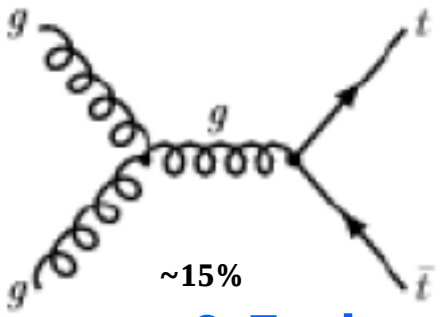
Width = 1.5 GeV,

Mass = 172.4 ± 1.2 GeV/c²
(2008 summer world average)

Production

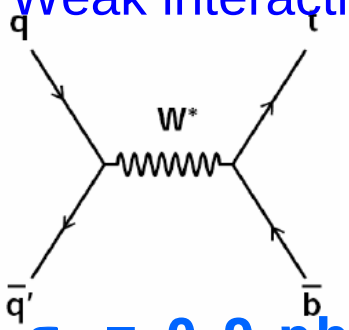
Strong interaction



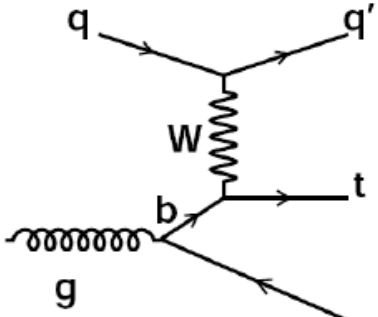


σ = 6.7 pb

Weak interaction

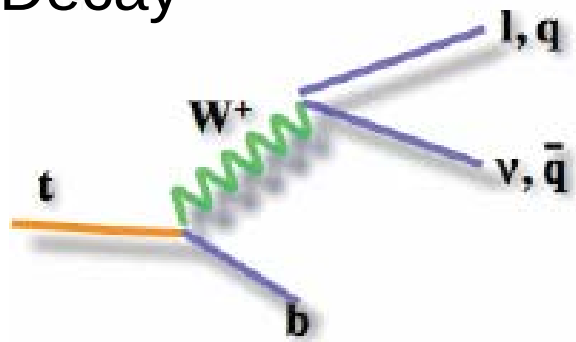


σ_s = 0.9 pb



σ_t = 2.0 pb

Decay



~ 100% decay to W+b
$|V_{tb}|$=1

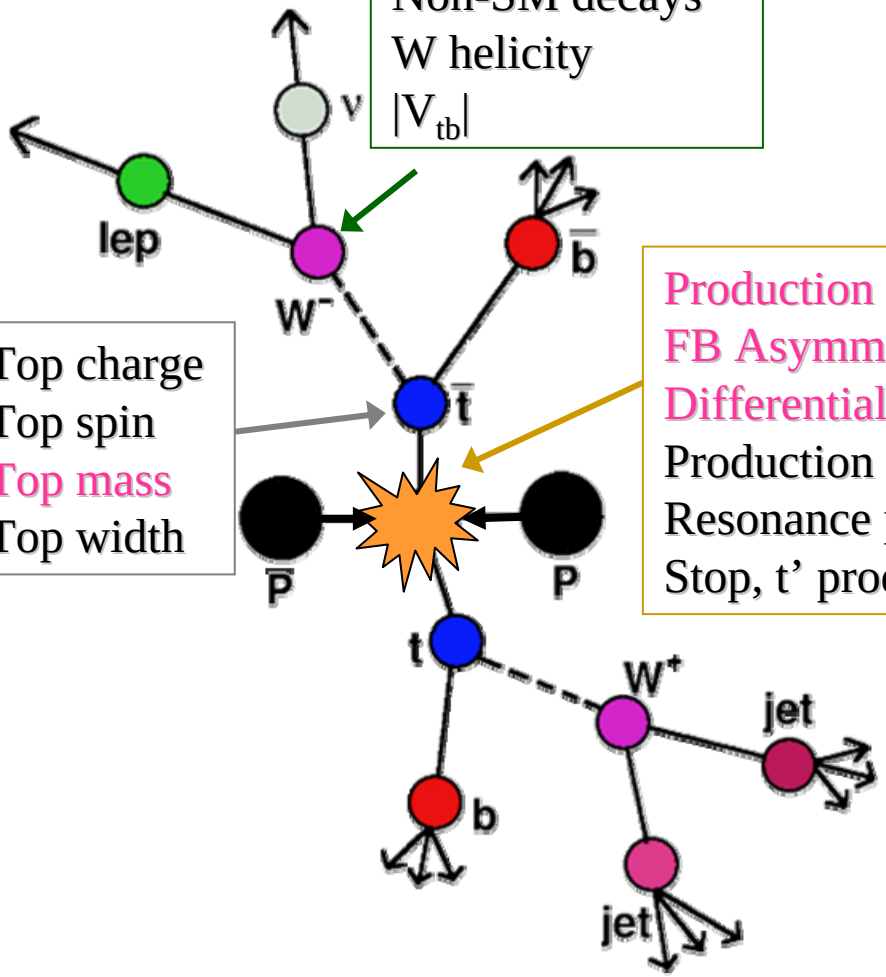
70% longitudinal and
30% left handed W

What we are doing with Top quark at the CDF

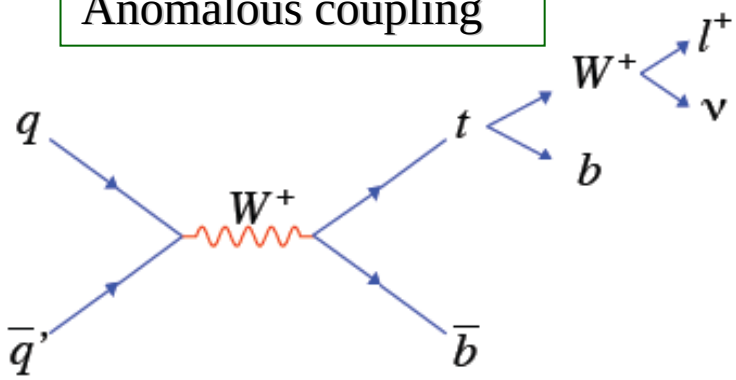
Branching ratios
Rare decays
Non-SM decays
W helicity
$|V_{tb}|$

Top charge
Top spin
Top mass
Top width

Production cross section
FB Asymmetry
Differential cross section
Production mechanism
Resonance production
Stop, t' production

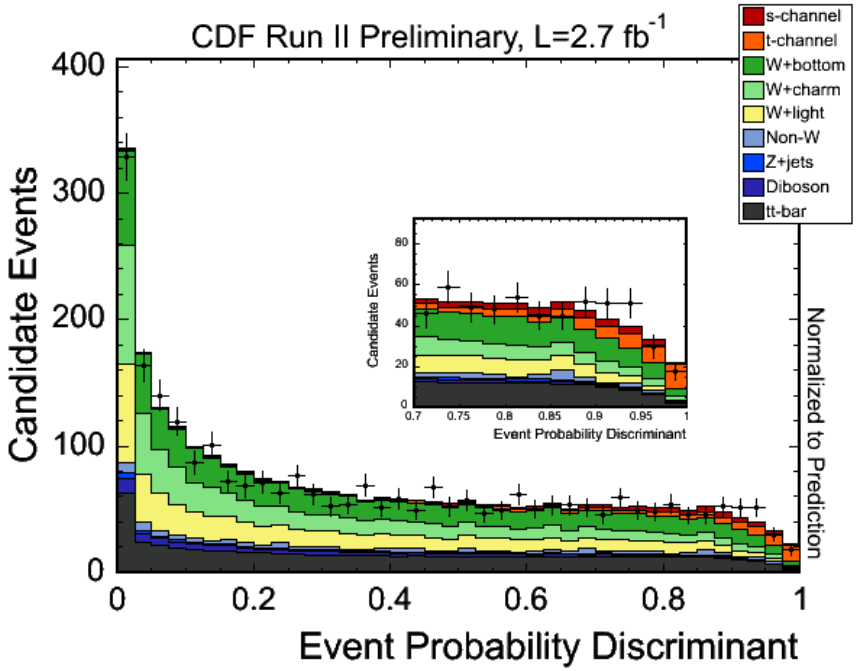


Single top cross section ($|V_{tb}|$)
Anomalous coupling



Single top cross section

- Construct a single variable (discriminat) which is highly sensitive to single top kinematics
- Extract single top cross section with four different way
- Combining different method

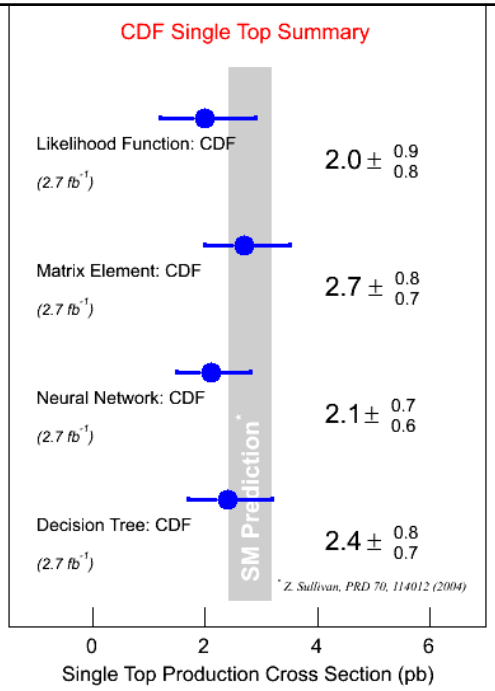


Strong evidence of single top production

Combination(2.2 fb^{-1})

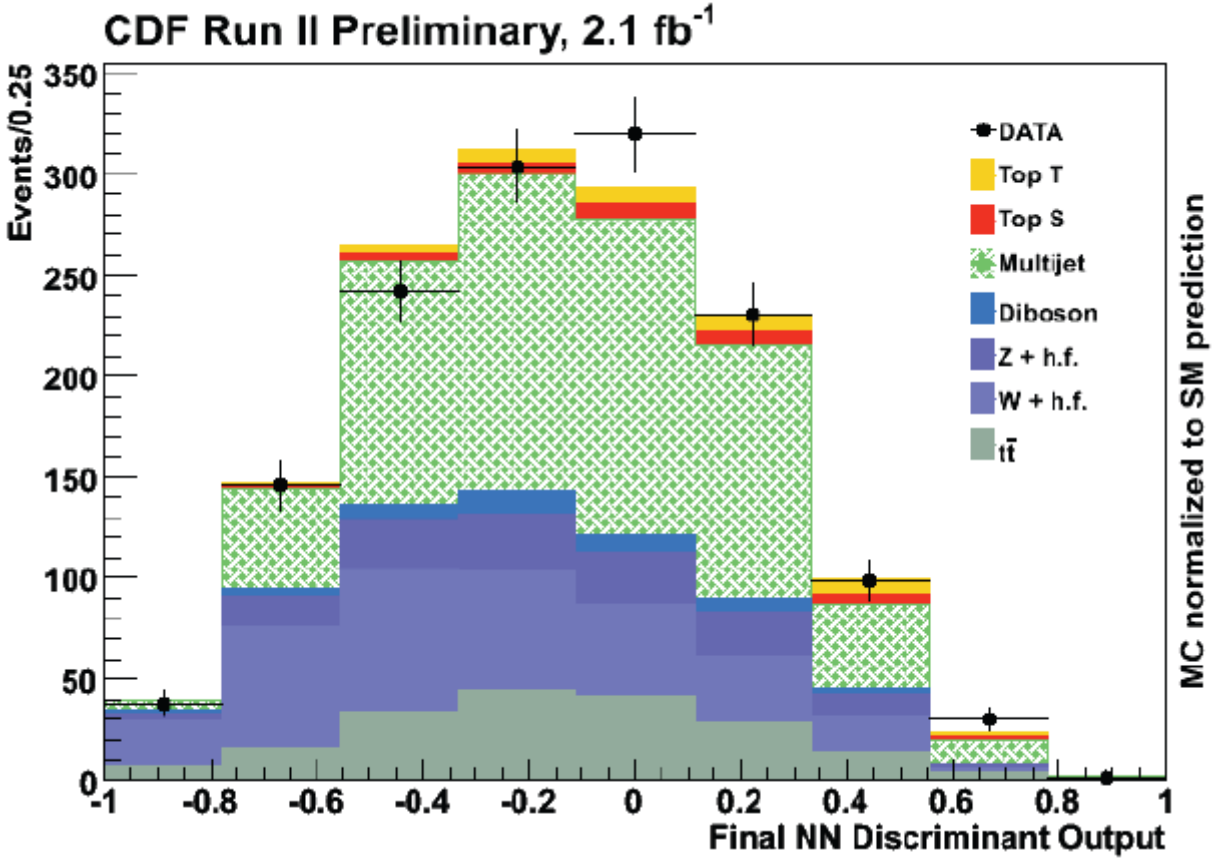
2.2 +0.7/-0.6 pb, 3.7σ

$1 \geq |V_{tb}| > 0.66$ (95% CL)



Single top (Met +jets) (2.1 fb^{-1})

- Leptonic decays with hadronic τ and e/μ not fiducial
- Performing orthogonal channel gives extra information
- It will contribute to combine single top cross section



Observed Cross-section

4.4 +2.5/-2.1 pb

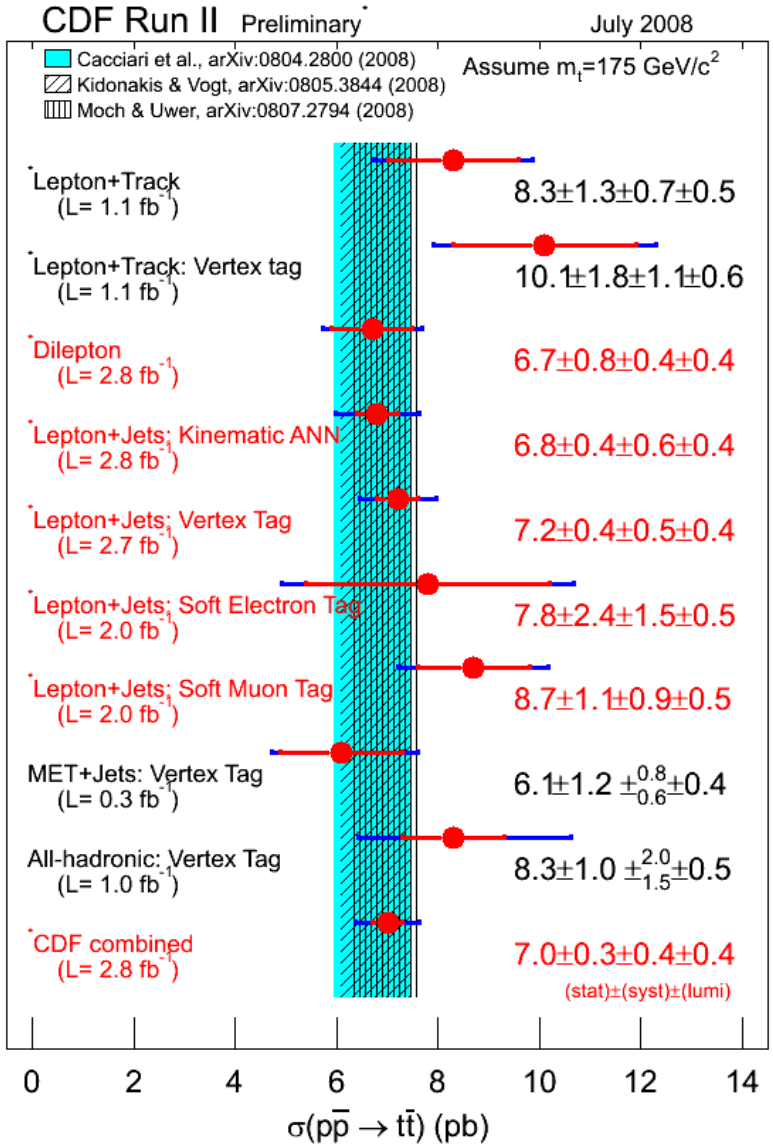
Expected Cross-section

2.7 +2.3/-2.1pb

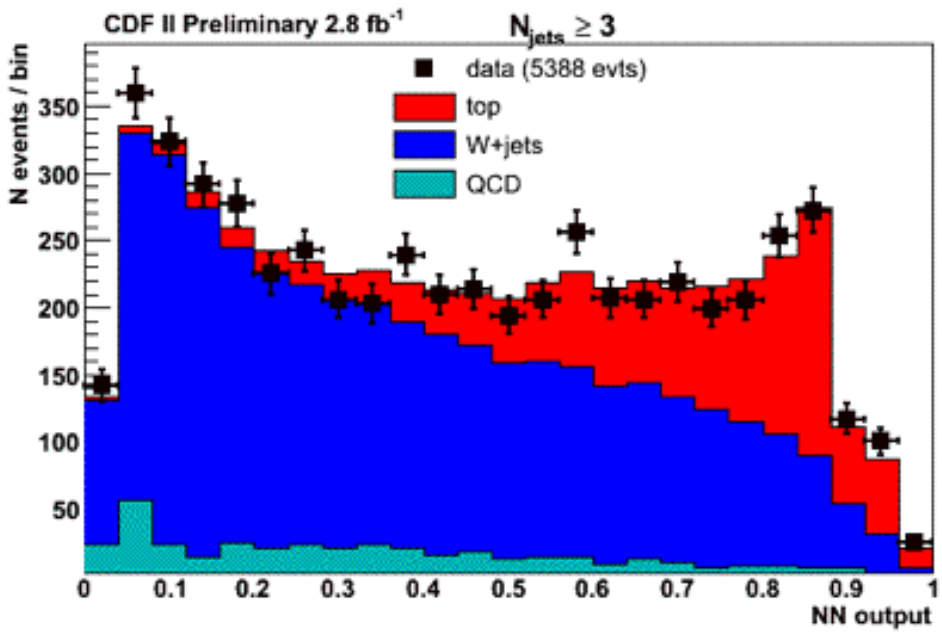
New CDF combination coming

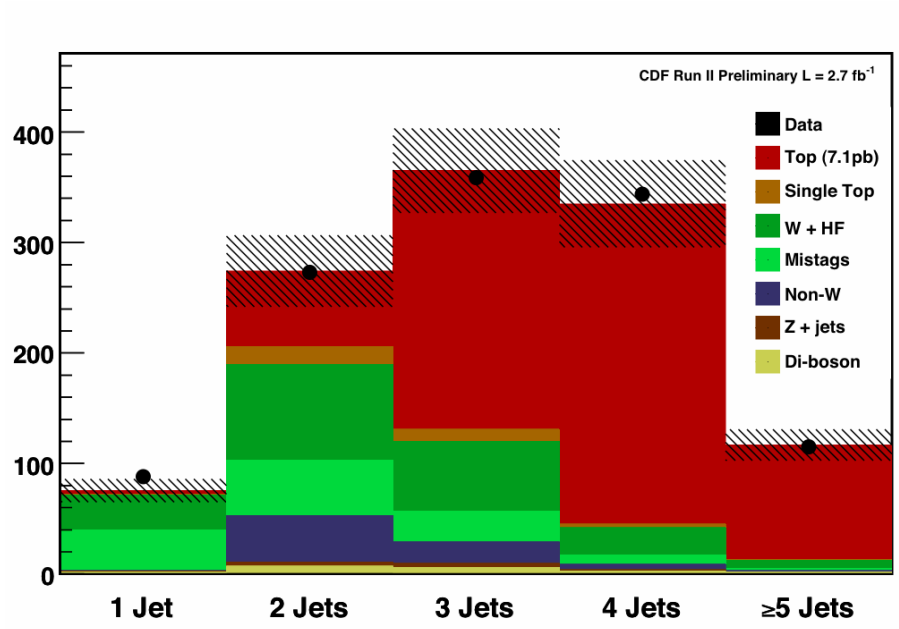
ttbar cross section

- Different channel, different kinematics show good agreement
- It's consistent with prediction of standard model
- Relative uncertainty is <10%
  - ❖ Uncertainty of lumi. is significant



ttbar cross section by ttbar/Z cross section (2.7 fb^{-1})





NN (2.7fb^{-1}) :

6.9±0.4(stat) ±0.4(syst) ±0.1(theory) pb

b-tagging (2.7fb^{-1}) :

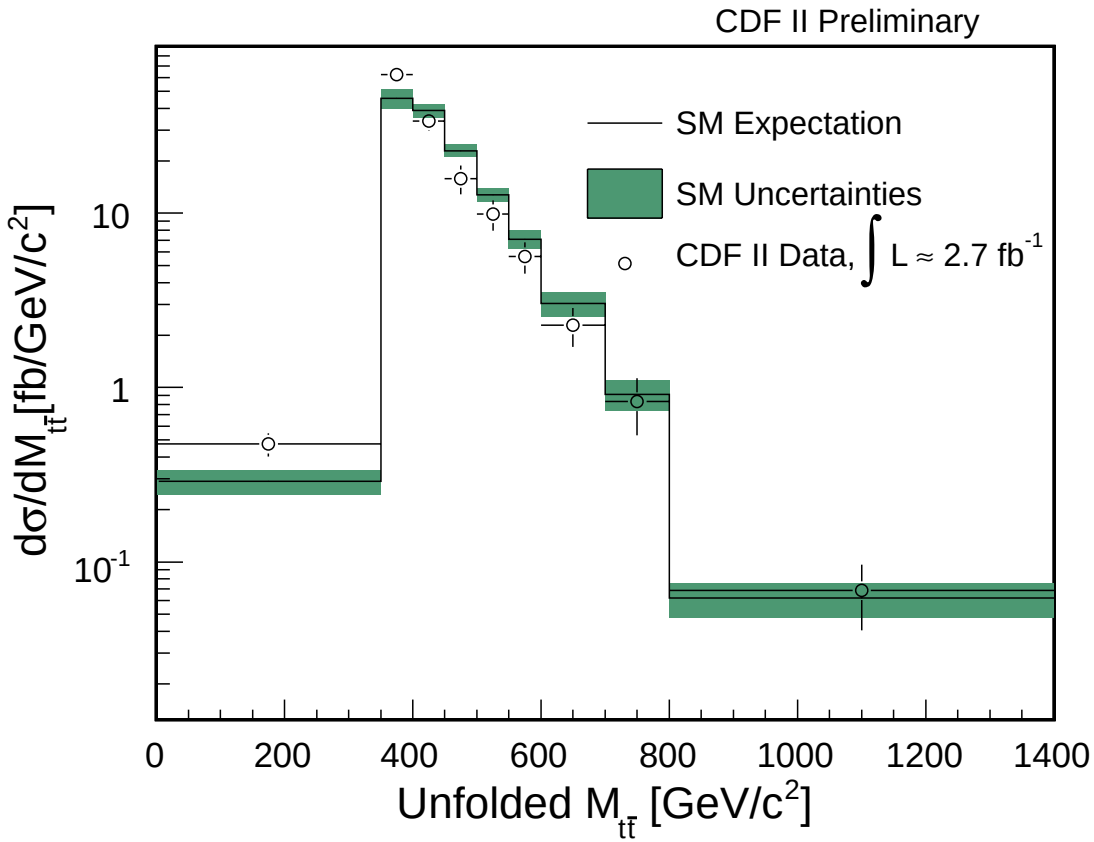
7.0±0.4(stat) ±0.6(syst) ±0.1(theory) pb

- We measured ttbar/Z cross section ratio to remove lumi uncertainty. Then, we can have ttbar cross section by scale up using well known Z cross section.
- Relative uncertainty
  - NN is ~8% b-tagging is ~10%

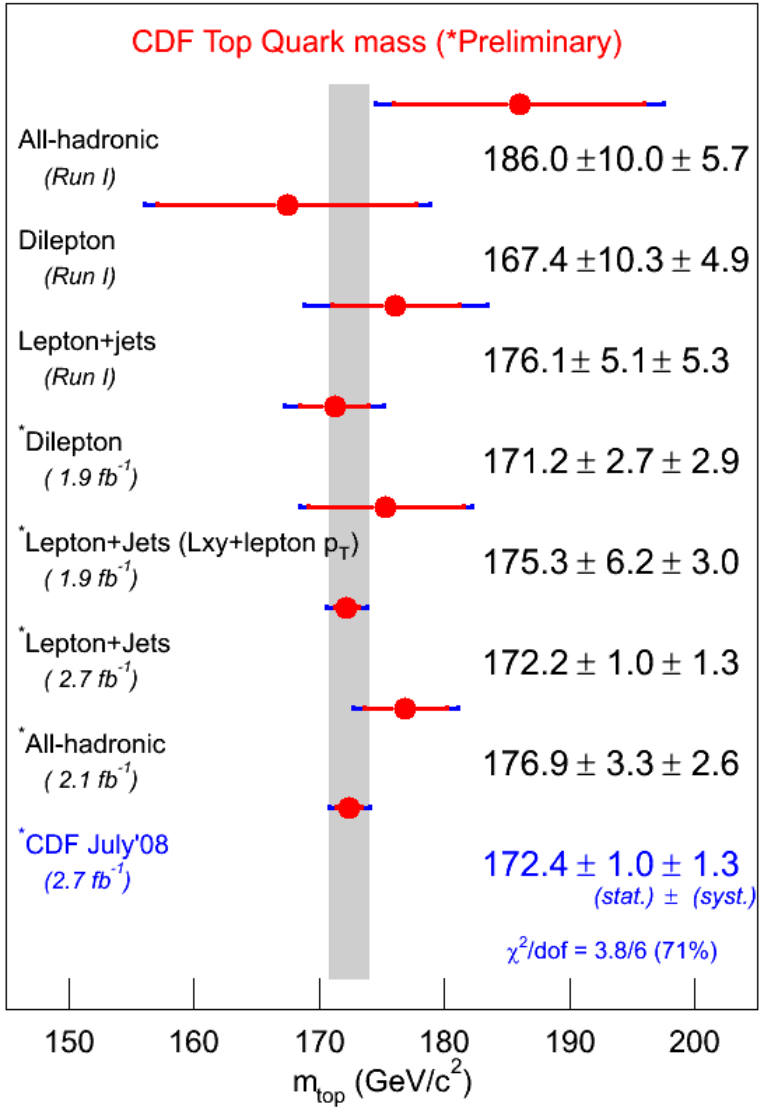
$d\sigma/dm_{ttbar}$ (2.7 fb^{-1})

- ttbar differential cross section in situ jet energy scale calibration
  - Significantly reduce the systematics
- $d\sigma/dm_{ttbar}$ is sensitive to a broad class of models

No evidence of inconsistency with SM



Top quark mass measurement



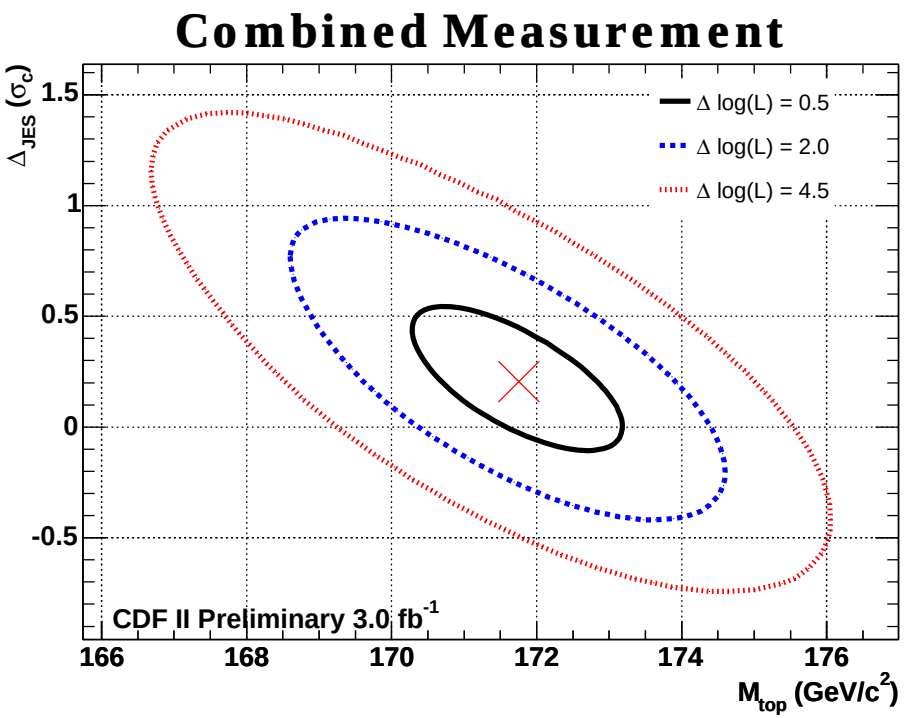
- Precision measurement
  - ❖ Best single measurement in the l+jets channels is already <1%
  - ❖ Systematic is key of precision
- We are revisiting the systematic jointly with D0

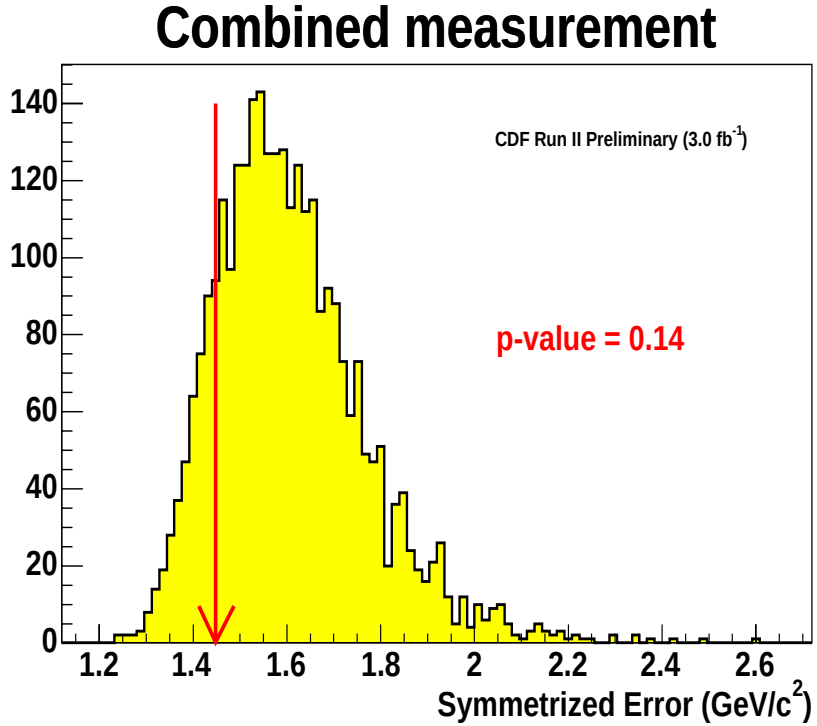
Systematic uncertainty of top quark mass (3.0 fb^{-1})

Systematic (GeV/c^2)	Combined fit	L+J	DIL	DIL(mT2 only)
Residual JES	**0.68**	**0.66**	**3.04**	**2.58**
Generator	**0.74**	**0.72**	**0.46**	**0.22**
PDF	**0.19**	**0.17**	**0.48**	**0.47**
b jet energy scale	**0.17**	**0.18**	**0.21**	**0.21**
Background shape	**0.24**	**0.27**	**0.12**	**0.36**
gg-fusion fraction	**0.04**	**0.00**	**0.01**	**0.32**
ISR and FSR	**0.13**	**0.14**	**0.34**	**0.57**
MC statistics	**0.10**	**0.08**	**0.32**	**0.33**
Lepton energy scale	**0.03**	**0.06**	**0.28**	**0.56**
Pileup	**0.19**	**0.24**	**0.34**	**0.18**
Color reconnection	**0.34**	**0.38**	**0.55**	**0.68**
Total	**1.14**	**1.14**	**3.24**	**2.91**

Systematics from template method for L+J and DIL channel

Top mass : 3.0 fb^{-1} template method





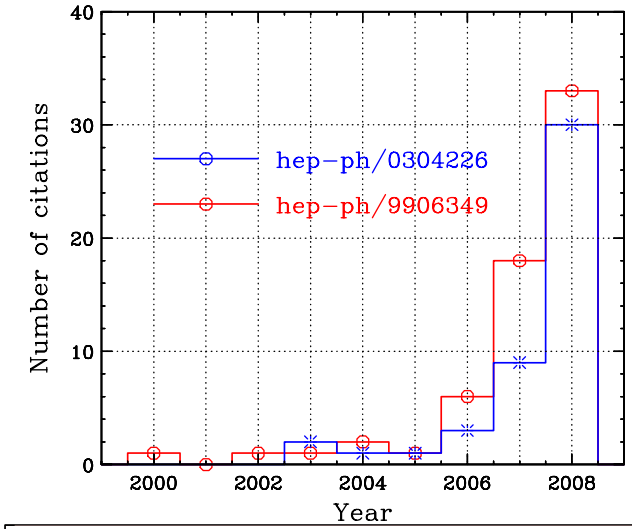
$$171.8 \pm 1.5\ (\text{stat+JES}) \pm 1.1\ \text{GeV}/c^2(\text{syst})$$

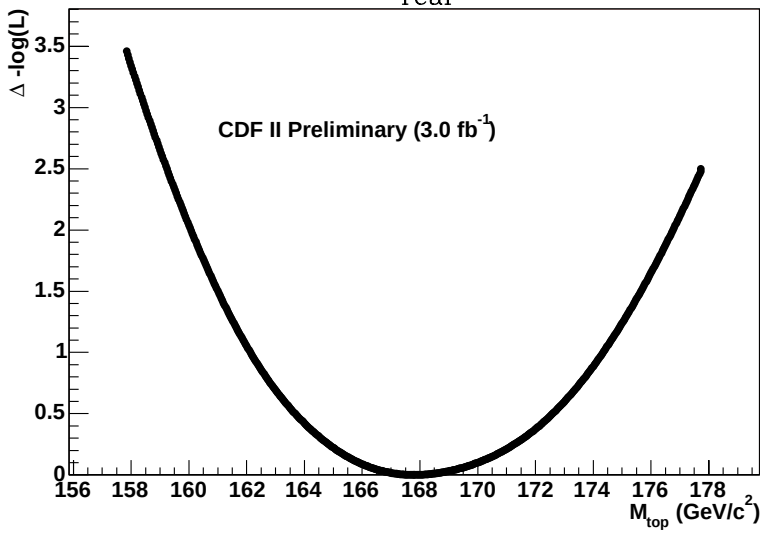
L+J	$172.5 \pm 1.6\ (\text{stat+JES}) \pm 1.1\ \text{GeV}/c^2(\text{syst})$
DIL	$169.0\ ^{+2.6}_{-2.7}\ (\text{stat}) \pm 3.2\ \text{GeV}/c^2(\text{syst})$

Top mass in the Dilepton channel with m_{T2} (3.0 fb^{-1})

- m_{T2} is the transverse mass in the two missing particle system
- This is golden observable to measure the mass of exotic particle in pair production

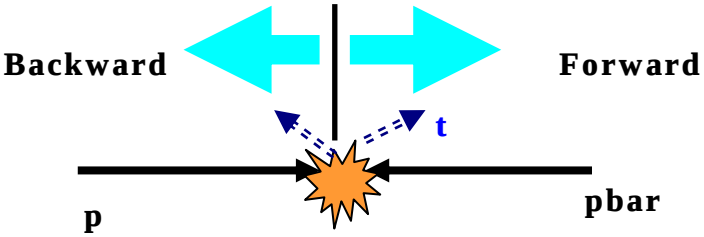
- Top dilepton channel is good example (standard candle)
- First application in the real data





$$167.9\,^{+4.8}_{-4.1}\ (\text{stat}) \pm 2.9\ \text{GeV}/c^2(\text{syst})$$

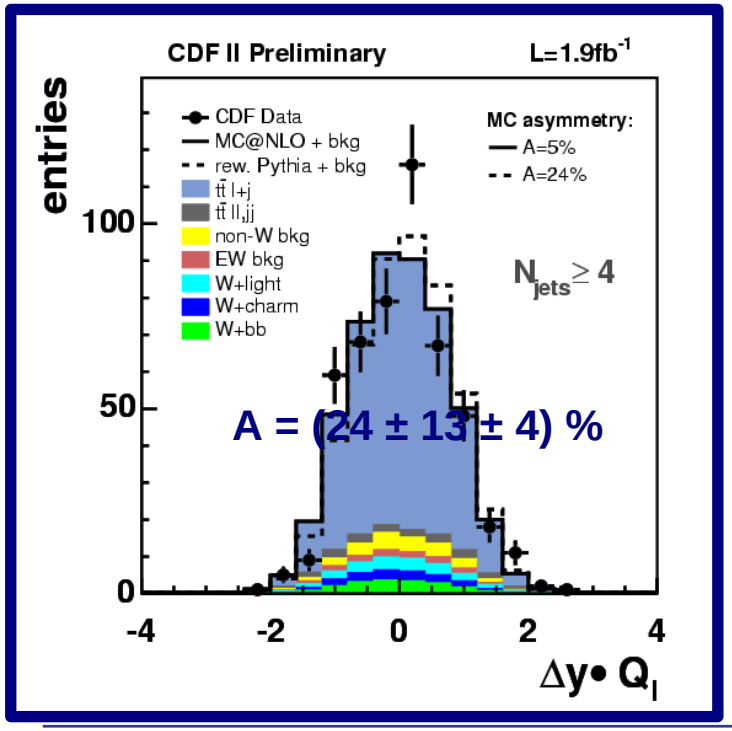
Forward backward asymmetry (1.9 fb^{-1})



$$A_{fb} = \{N(F)-N(B)\}/\{N(F)+N(B)\}$$

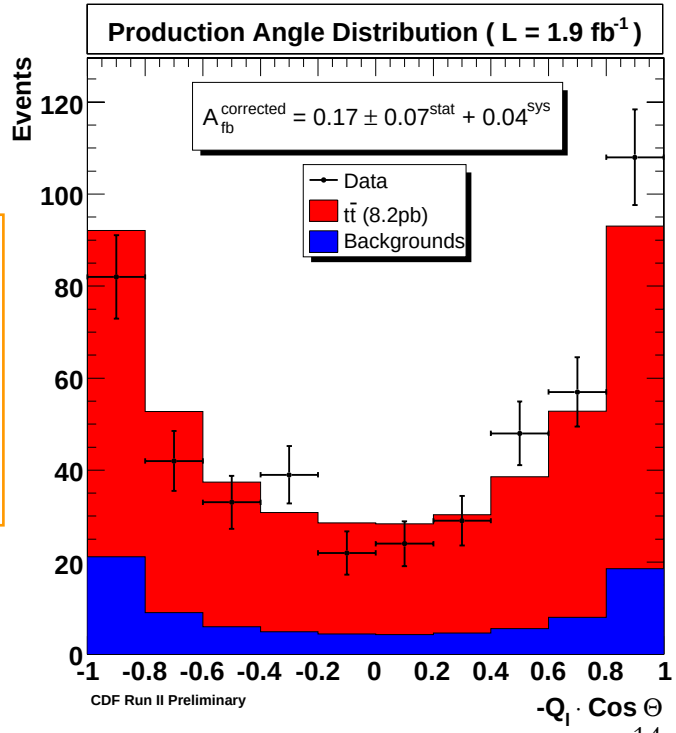
Standard Model NLO prediction = 0.04+-/0.01

ttbar rest frame



Asymmetry is a bit larger than SM prediction but, still consistent

ppbar rest frame

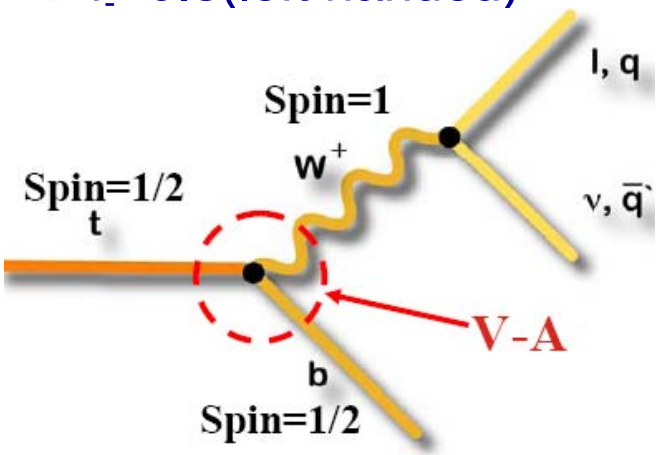
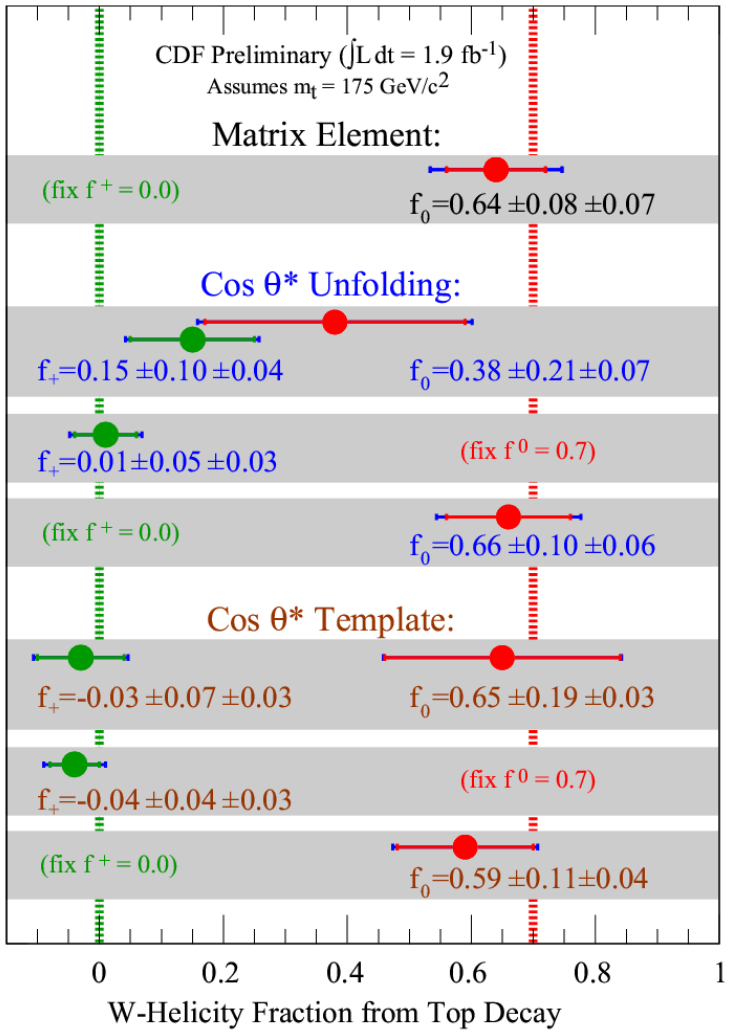


Conclusion

- Top quarks are well being studied at CDF
  - We are performing rigorous study of top quark
- So far, all of results are consistent with SM
  - Statistically limited
  - We already had ~2x data

- Visit the CDF public page for more results
- http://www-cdf.fnal.gov/physics/new/top/top.html

W-Helicity (1.9 fb^{-1})

- Measuring the fraction of logitudinally polarized W bosons from top quark decay(f_0) in the lepton jets channel
- V-A coupling predict
  - f_0=0.7(logitudinal)
  - f_+=0(right handed)
  - f_-=0.3(left handed)

Consistent with SM prediction