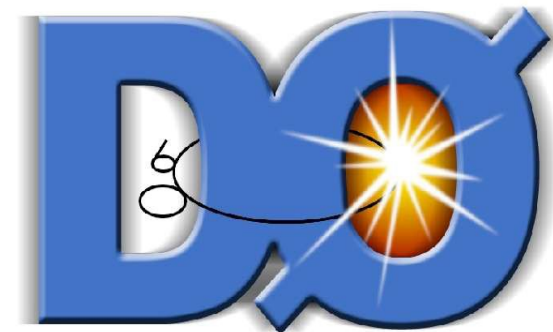
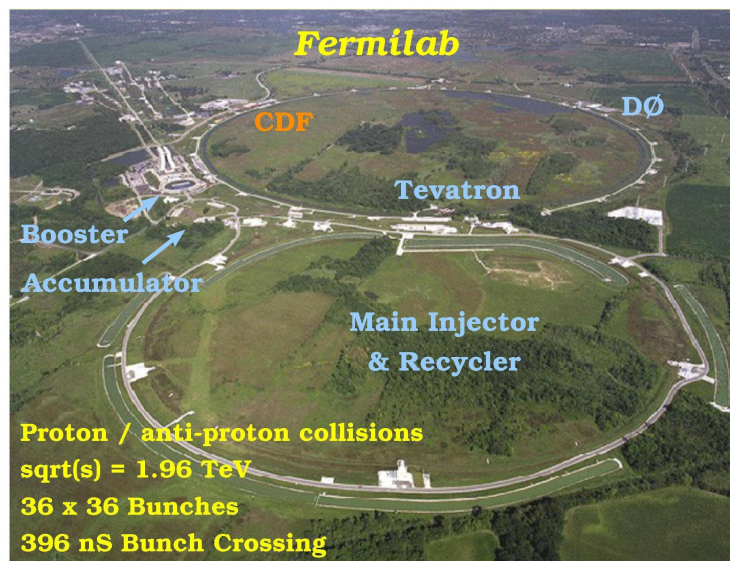


Selected Topics from $t\bar{t}$ bar/single top Production at the Tevatron

Weiming Yao (LBNL)

On behalf of the CDF and D0 Collaborations

LHCP 2015, August 31-September 5, 2015 St. Petersburg, Russian



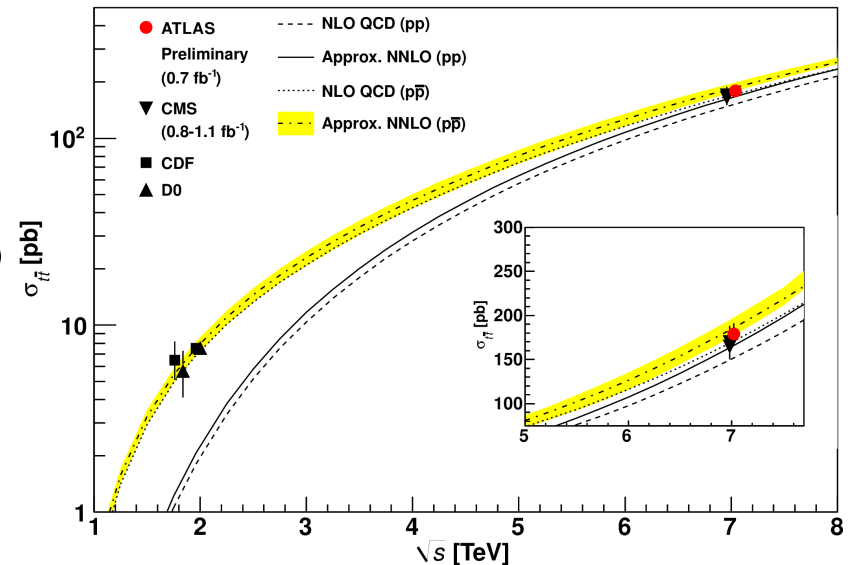
Outline

- Introduction
- Recent ttbar inclusive and differential cross sections
- Recent single top production cross sections
- Legacy measurements are based on full dataset(10fb-1)
- Conclusion

- More Details:
 - <http://www-cdf.fnal.gov/Physics/S15CDFResults.html>
 - <http://www-d0.fnal.gov/Rn2Physics/D0Summer2012.html>

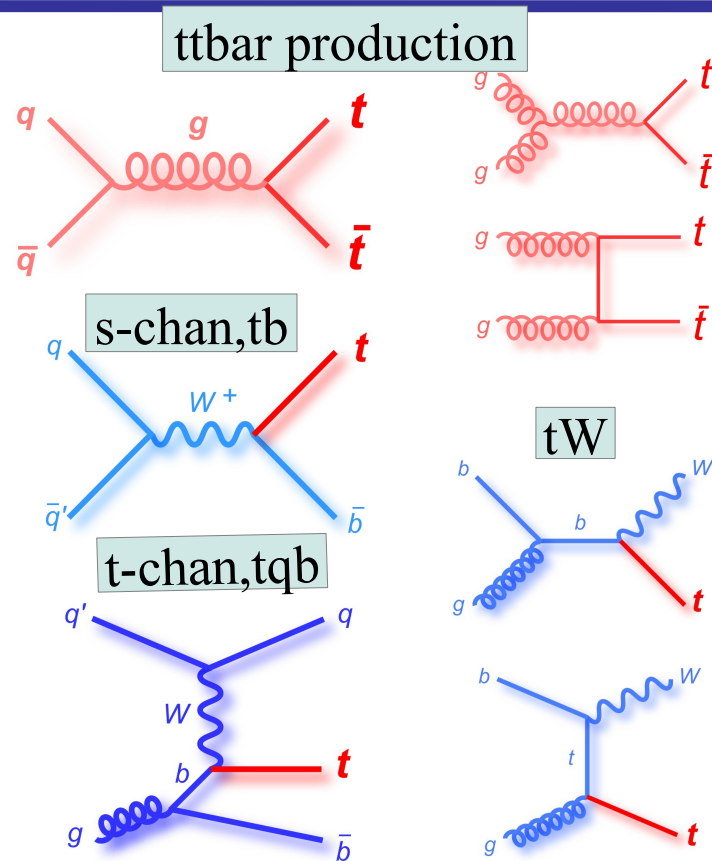
Introduction

- Top quark was discovered at Tevatron by CDF & D0 in 1995, the heaviest quark discovered so far.
- First bared quark ever observed due to a short lifetime of $5 \times 10^{-25} \text{ s} \ll \tau_{\text{QCD}}$
- Large Yukawa coupling ($y_t \sim 1$) to Higgs boson may play special role in ESB.
- Studies of top-quark production cross section provide excellent test of QCD and probe physics beyond the standard model (BSM).



Top-quark Production at Tevatron

- Top-quark is predominately produced in $q\bar{q}$ annihilation (85%) while at LHC the gluon fusion dominates $>85\%$.
- Top-quark can also be produced singly in electroweak processes, which was first discovered by CDF & D0 in 2009 via s-, t-channels while the wt contribution is small.
- Top production at Tevatron is complementary to LHC and provide unique test of SM & QCD.

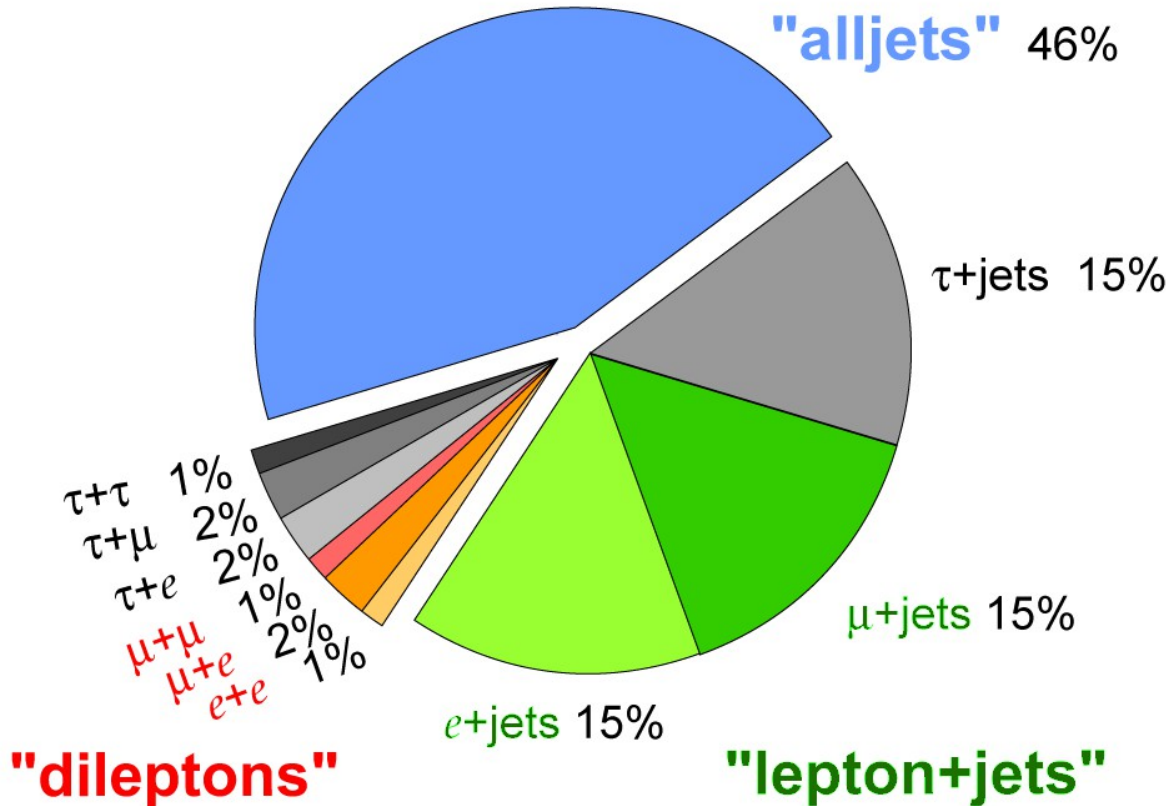


NNLO($m_t=172.5, \text{PRL } 109, 132001$)	ttbar[pb]	tb[pb]	tqb[pb]	tW[pb]
Tevatron(1.96TeV)	7.24	1.04	2.26	0.30
LHC(8 TeV)	248.50	5.50	89.14	19.50
Ratio (LHC/Tevatron)	34	5	39	65

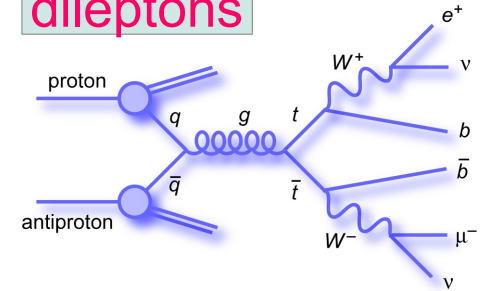
Top-quark Decay in SM

- Top-quark predominately decays into Wb with $B(t \rightarrow wb) = 100\%$, final states determined by W decays.

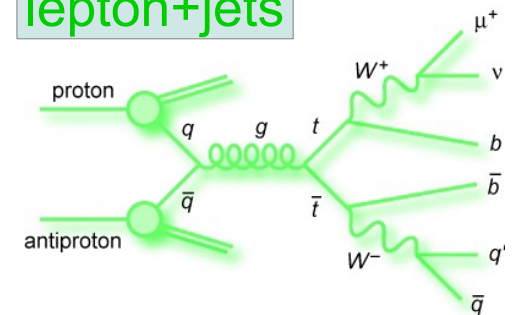
Top Pair Branching Fractions



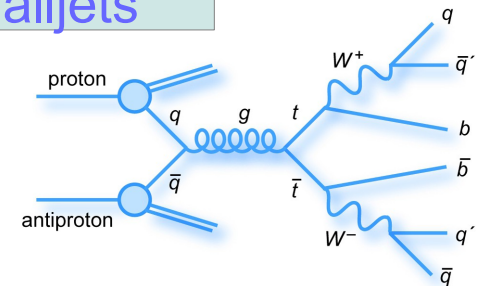
dileptons



lepton+jets

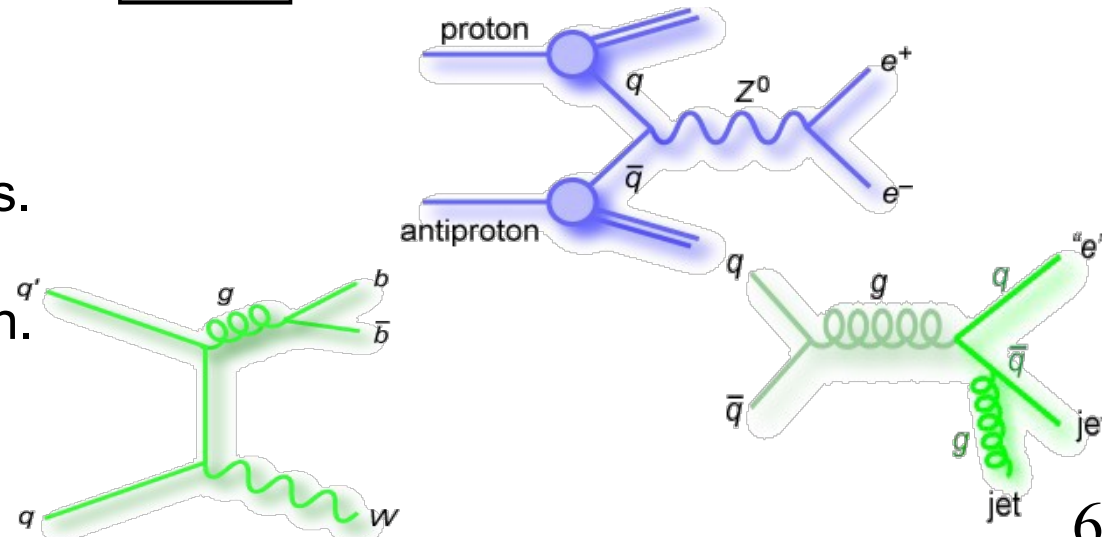
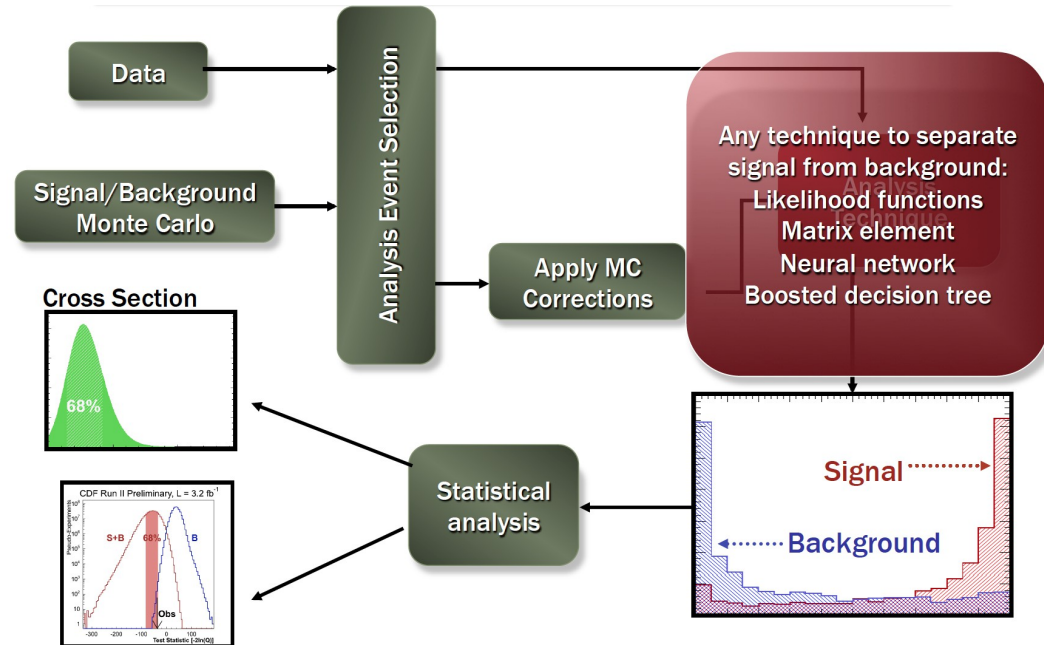


alljets



Events Selection and Analysis Strategies

- Select isolated lepton(s), high missing E_t from neutrinos, one or more btagged jets:
- **The $t\bar{t}$ final states:**
 - Dilepton: 2 isolated leptons
 - Lepton+jets: one isolated lepton+jets
 - Alljets: 0 isolated leptons.
- **Single top production:**
 - S-chan: one isolated lep+ 2bs
 - T-chan: one isolated lep+1b+q
- **Backgrounds:**
 - W+jets is dominated in l+jets.
 - Z+jets is dominated in dileptons.
 - Multijet is dominated in allhad.
 - Small background from diboson.
 - **NLO MC are calibrated using control samples from data.**
- **Using MVA to separate S from B**



ttbar Cross Section using Full dataset

- D0 recently updated their ttbar xsec using improved analysis technique and full dataset:
 - l+jets: divided six subsamples based on lepton type and each trained its own BDT with 20 variables plus b-tag MVA.
 - Dilepton: divided four subsamples and use b-tag MVA of leading jet as discriminant

• Simultaneous fits across all samples (pb):

→ Ljets: $\sigma_{tt} = 7.63 \pm 0.14 \pm 0.59$

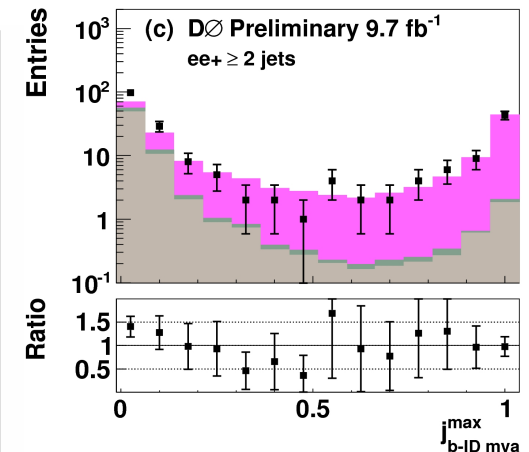
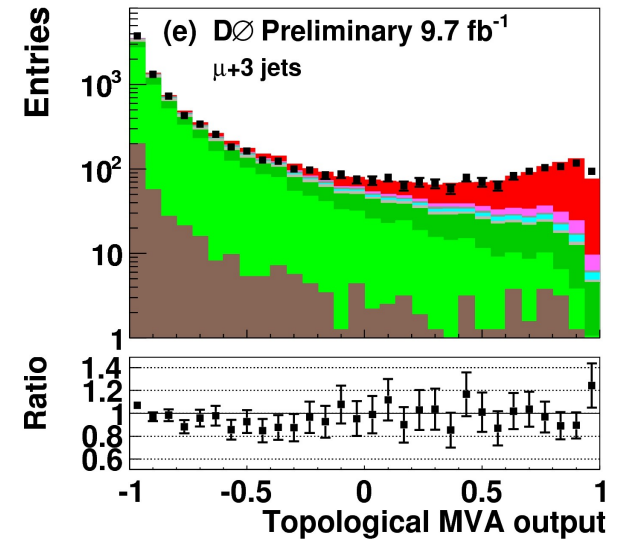
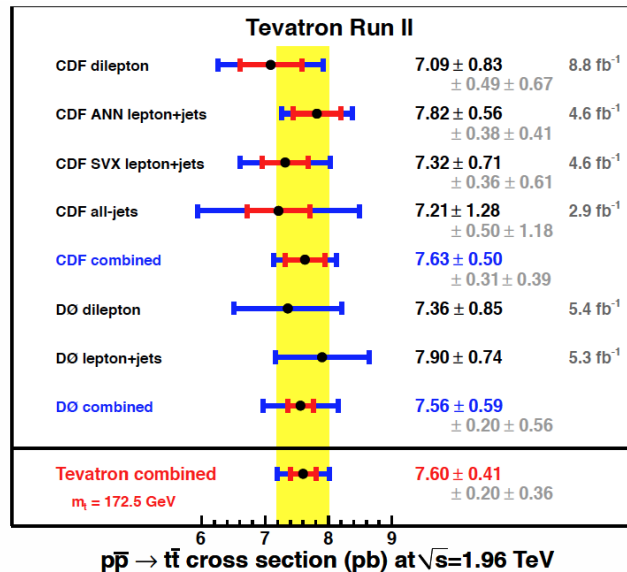
→ Dilep: $\sigma_{tt} = 7.60 \pm 0.34 \pm 0.60$

→ Comb: $\sigma_{tt} = 7.73 \pm 0.13 \pm 0.55$

→ NNLO: $\sigma_{tt} = 7.35^{+0.23}_{-0.27}$ (mt=172.5)

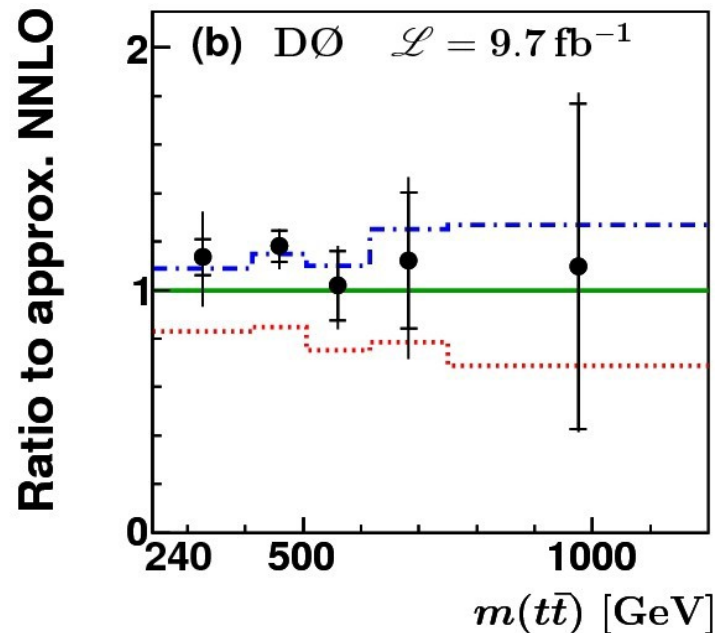
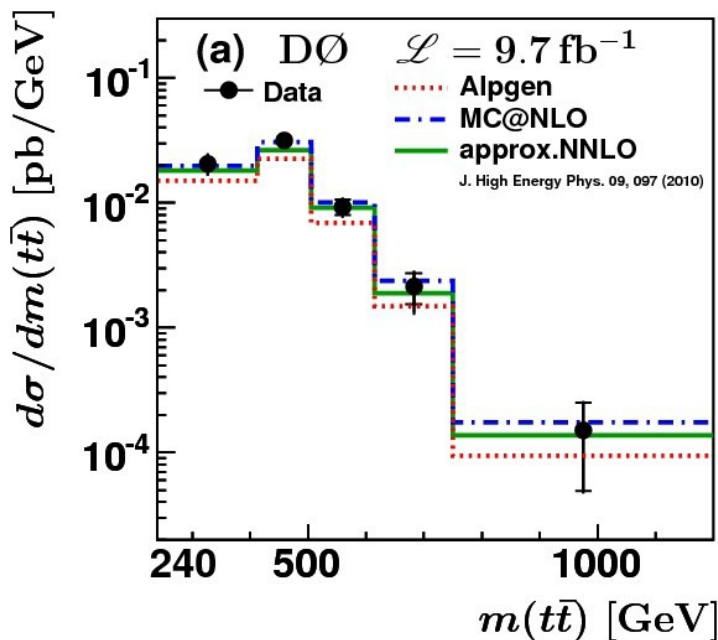
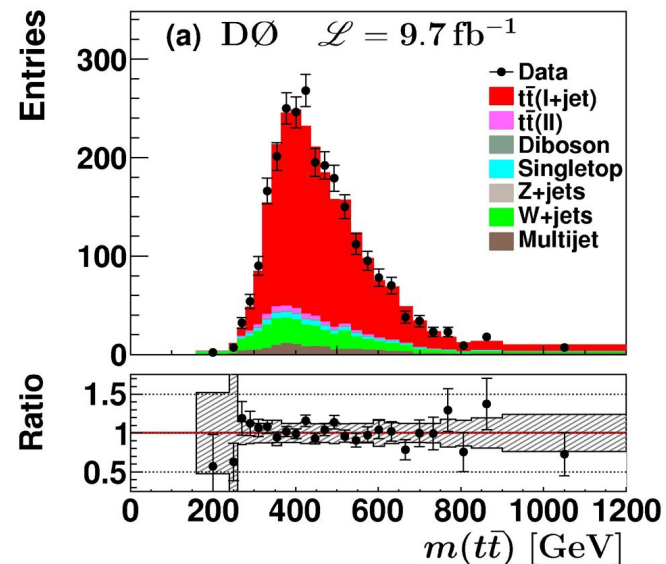
→ Consistent with Tevatron averages.

PRD 89, 072001, 2014

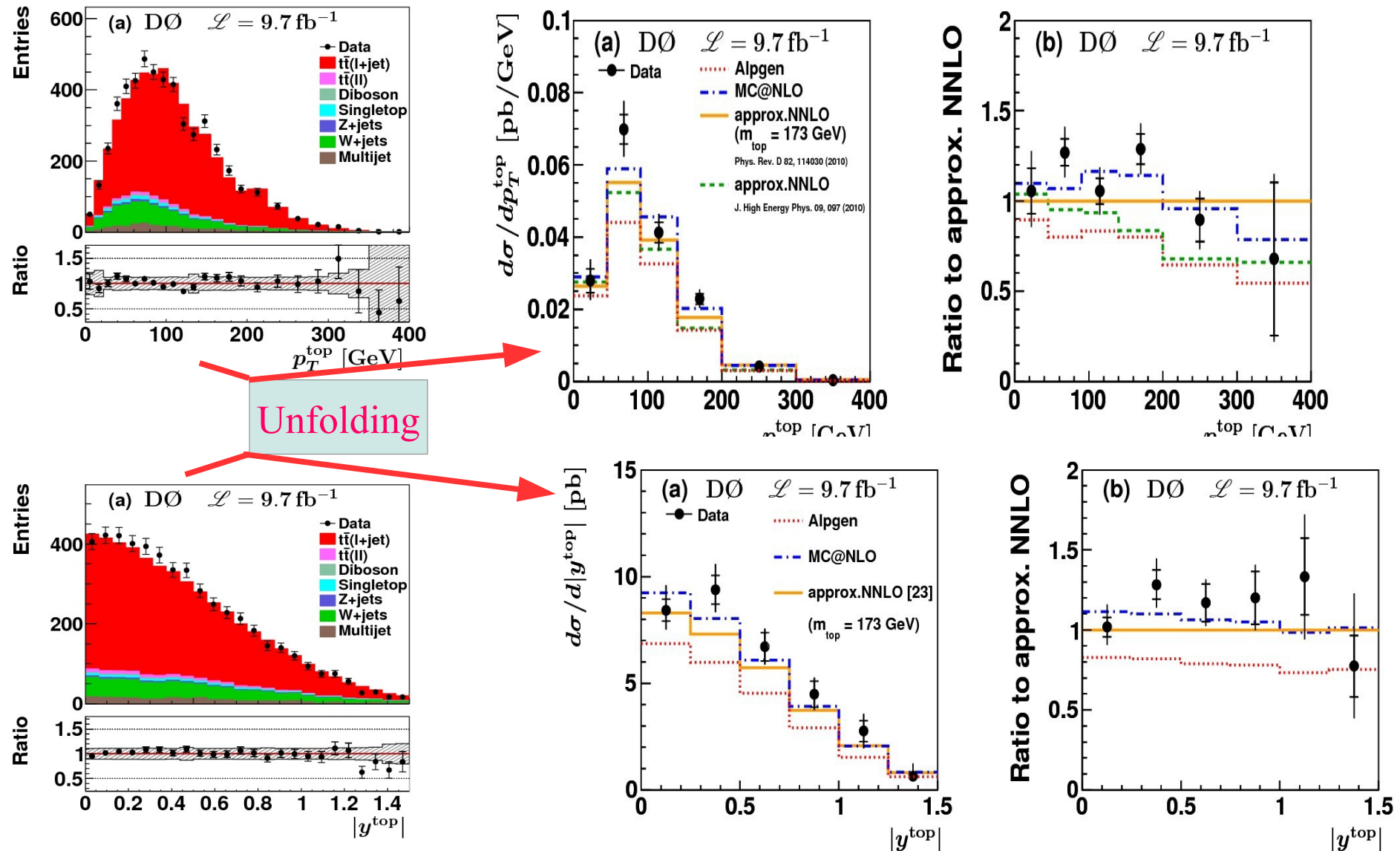


Differential Cross Section

- Differential cross section as function of $m_{t\bar{t}}$, $p_{t, \bar{t}}$, y_t is sensitive to various $t\bar{t}$ production mechanism and can be measured using full reconstructed the b-tagged lepton + 4 jets.
- Consistent with MC after unfolding up to the parton-level by correcting detector effects.



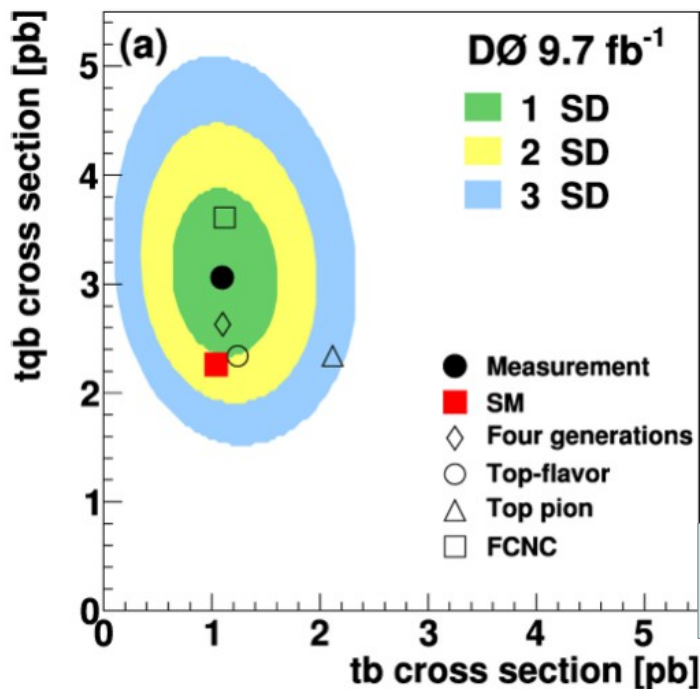
More Differential Cross Sections



Data are in excellent agreement with NNLO.

D0 Single Top Analysis

- Measuring each single top cross section simultaneously in lepton+2 or 3jets with 9.7fb^{-1} .
- Used 3 MVAs that select different event kinematics to separate tqb and tb signals from backgrounds.
- Combination of the 3 MVAs in a BayesianNN:



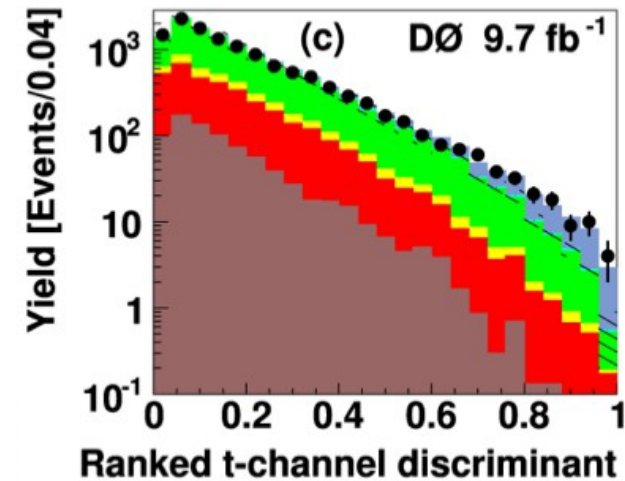
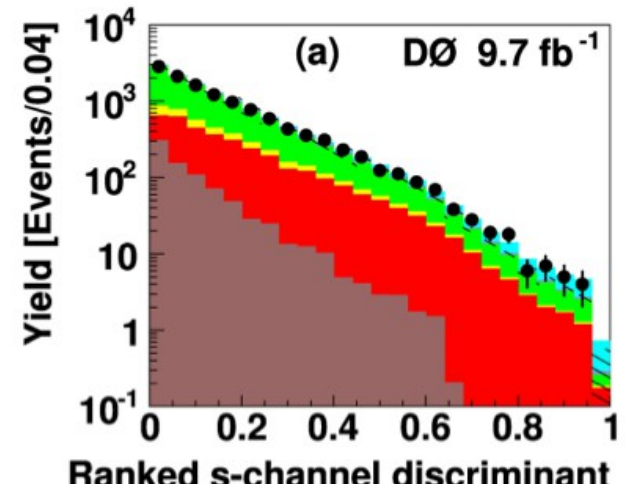
$$\sigma_{s+t} = 4.11^{+0.60}_{-0.55} \text{ pb}$$

$|V_{tb}| > 0.92$ at 95%CL

$$\sigma_s = 1.10^{+0.33}_{-0.31} \text{ pb}$$

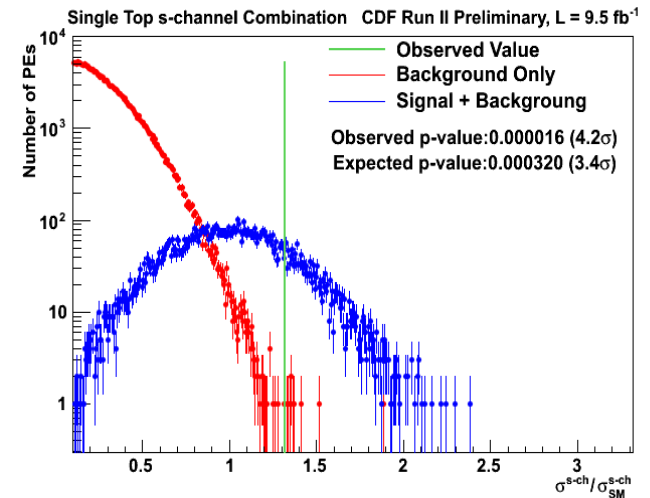
$$\sigma_t = 3.07^{+0.54}_{-0.49} \text{ pb}$$

First s-chan evidence at 3.7σ !

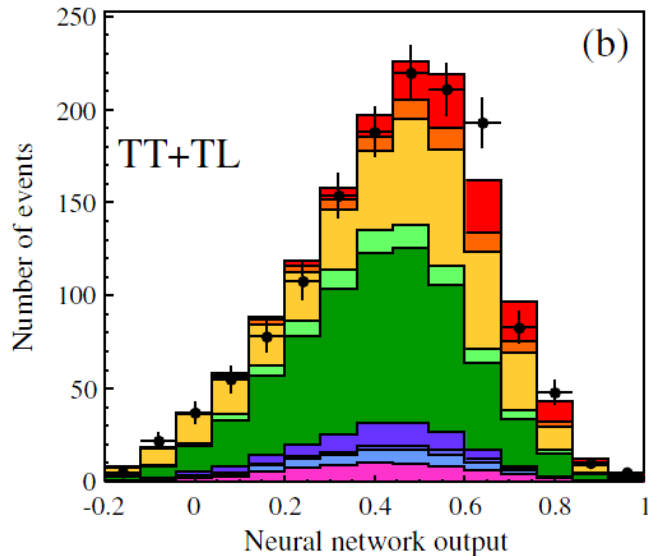


CDF s-channel Single Top Analyses

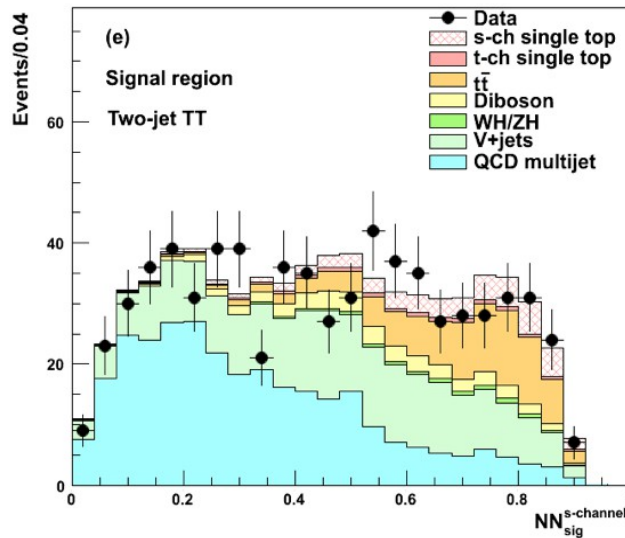
- CDF updated s-chan tb search using full dataset based on Higgs search techniques and selections.
 - L+jets: Lepton + 2 or 3 jets with 1 or 2 btags
 - Met+jets: orthogonal to L+jets selection
- Both used MVA discriminant sensitive to s-chan.



L+Jets



Met+Jets



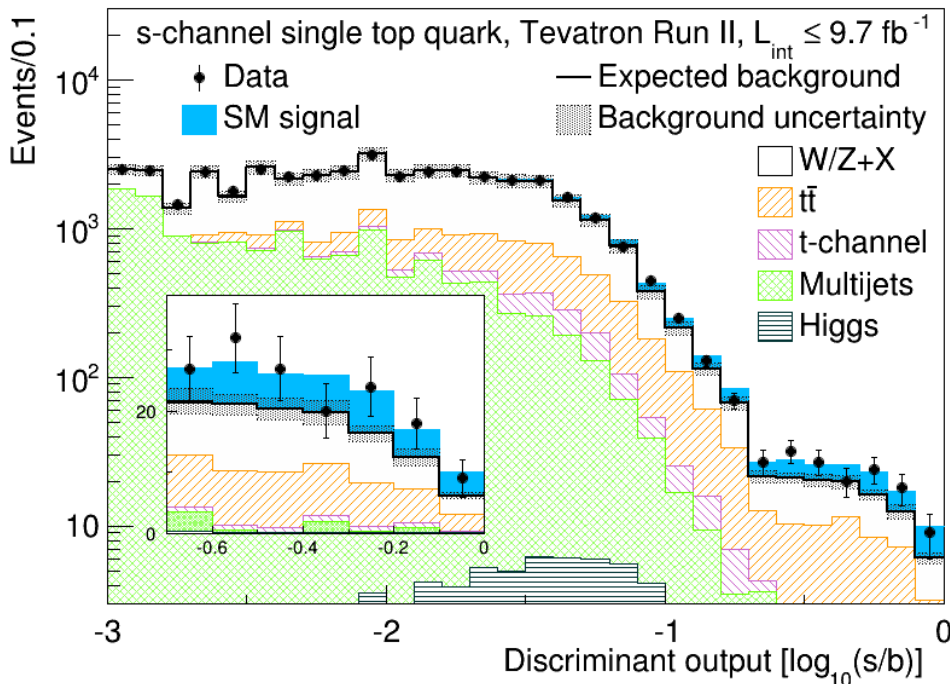
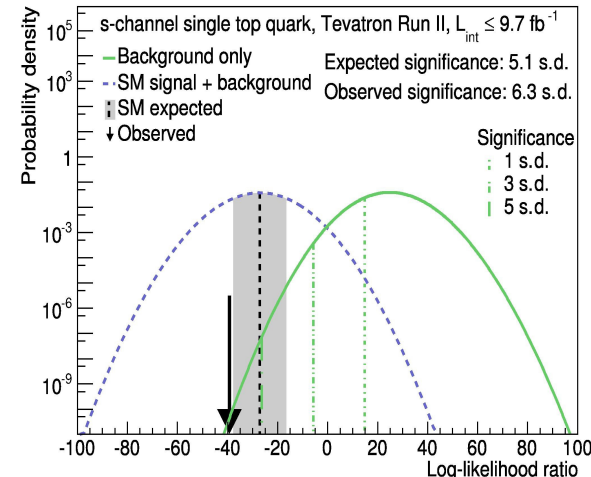
CDF combination:
 $\sigma_s = 1.36^{+0.37}_{-0.32} \text{ pb}$

Observed s-chan
evidence at 4.2σ

PRL 112,231805 (2014)

Observation of s-chan Single Top Production

- Combine CDF(l +jets and MET+Jets) and D0(l +jets) MVA discriminants
- Combined s-chan cross section using Bayesian statistical analysis with all systematic & correlations.
- Observed first s-chan single top at 6.3σ (PRL 112 231803)



s-channel single top quark, Tevatron Run II, $L_{\text{int}} \leq 9.7 \text{ fb}^{-1}$

Measurement

CDF l +jets

CDF \cancel{E}_T +jets

CDF combined

D0 l +jets

Tevatron combined

Theory (NLO+NNLL)

$1.05 \pm 0.06 \text{ pb}$ [PRD 81, 054028, 2010]

$m_{\text{top}} = 172.5 \text{ GeV}$

Cross section [pb]

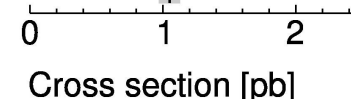
$1.41^{+0.44}_{-0.42}$

$1.12^{+0.61}_{-0.57}$

$1.36^{+0.37}_{-0.32}$

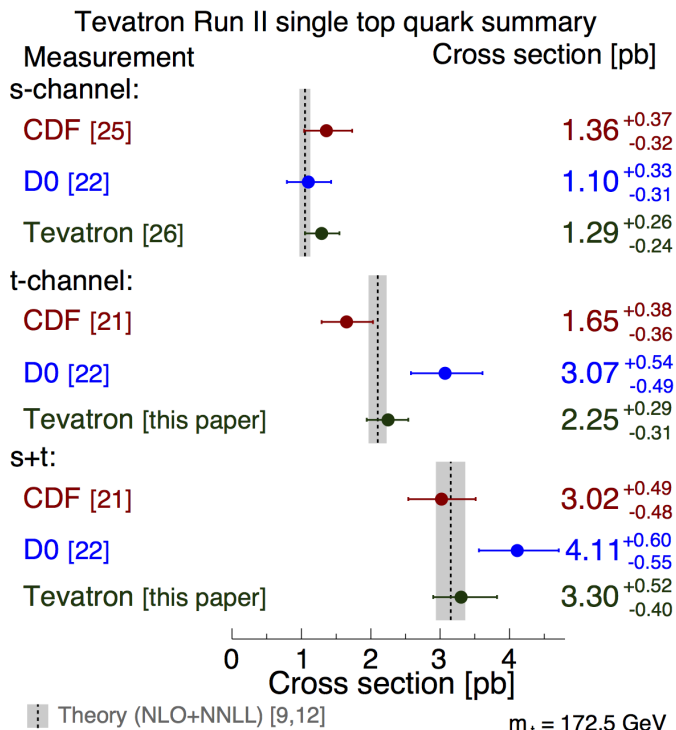
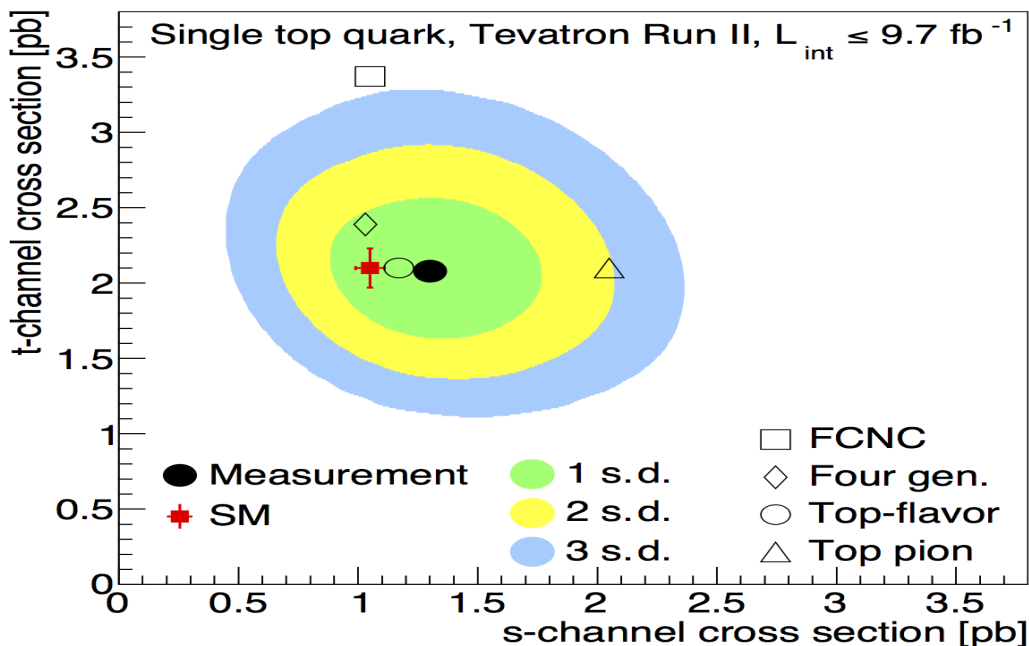
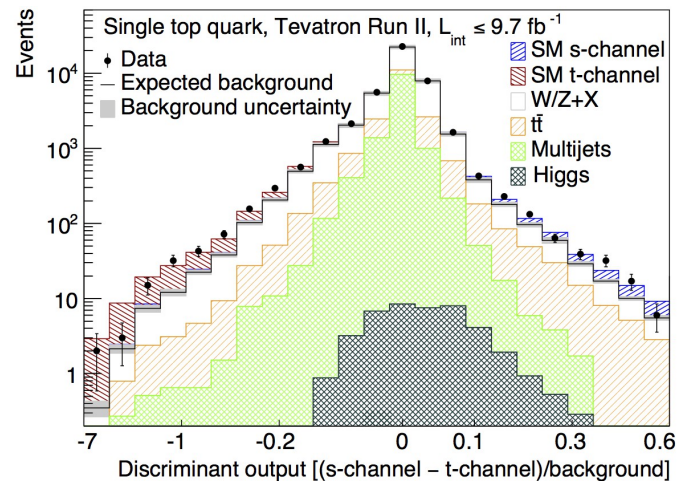
$1.10^{+0.33}_{-0.31}$

$1.29^{+0.26}_{-0.24}$



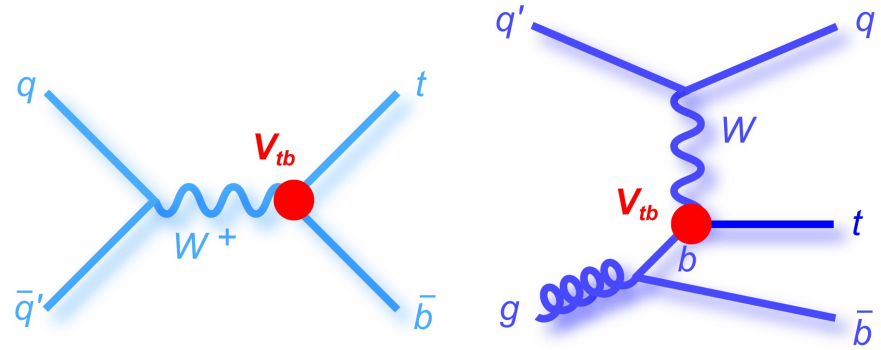
Tevatron Final Single Top Measurements

- Combines CDF and D0 analysis: same method as s-ch.
- Employ s-, t-chan discriminants from CDF and D0; both fitted simultaneously.
- Results are in good agreement with SM.



Measurement of V_{tb}

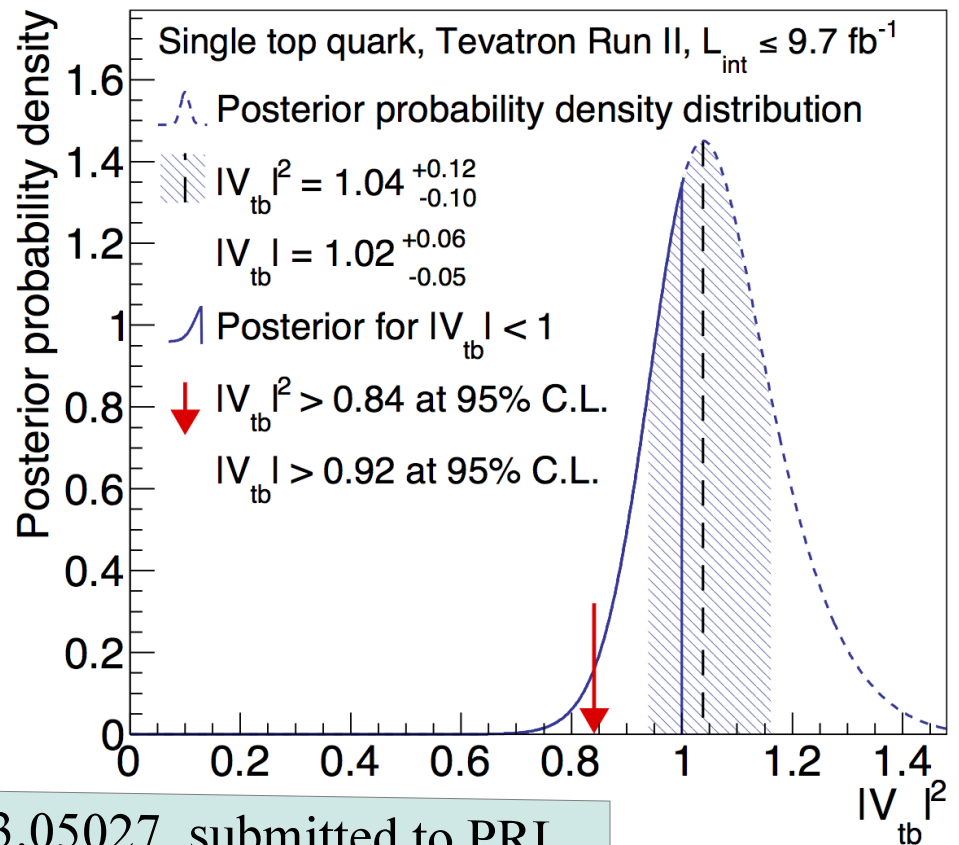
- Assuming SM top decay, the single top cross section is proportional to CKM matrix element V_{tb} . Consequently, V_{tb} can be measured directly without any assumptions on SM σ_s/σ_t ratios, 3 generations, or unitarity.



- Form a Bayesian posterior probability density for $|V_{tb}|$ by assuming a flat prior.

Tevatron Results:

- $|V_{tb}| = 1.02^{+0.06}_{-0.05}$
- $|V_{tb}| \geq 0.92$ at 95% C.L.



Conclusion

- Selected $t\bar{t}b\bar{a}$ and single top results at Tevatron are presented based on full Run II dataset.
- Complementarity of initial state provides unique opportunity to study top quark.
- Tevatron experiments are finishing their legacy measurements and the results are in excellent agreement with the SM predictions.

