EPS HEP

Stockholm, July 2013

Inclusive top pair production and differential cross section

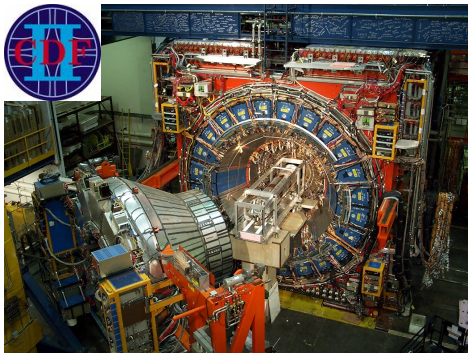
V. Sorin (IFAE-Barcelona)

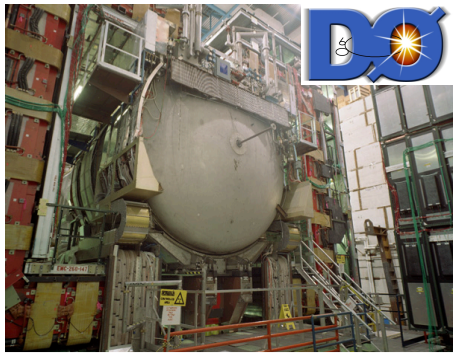
on behalf of the CDF and D0 Collaborations

Tevatron

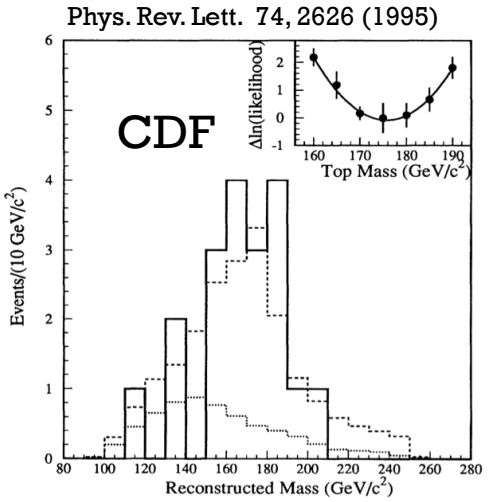
- $p\bar{p}$ collider at Fermilab
- RunI: 1992-1996, $\sqrt{s}$=1.8 TeV , collected 100 pb^{-1}
- RunII: 2001-2011, $\sqrt{s}$=1.96 TeV , collected 10 fb^{-1}

2 multi-purpose detectors

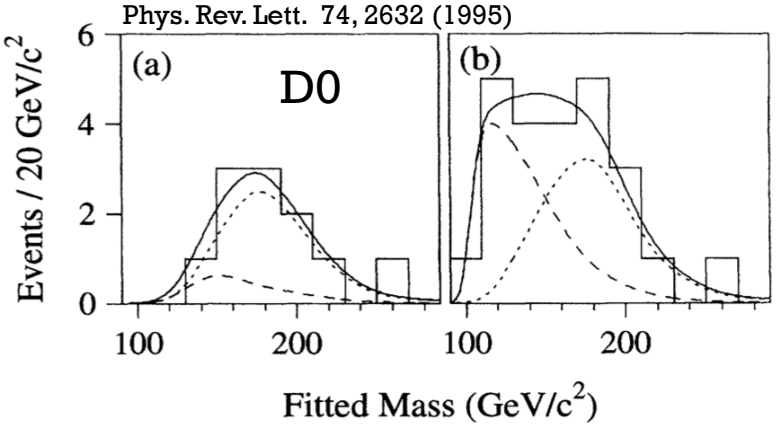




Top quark Discovery



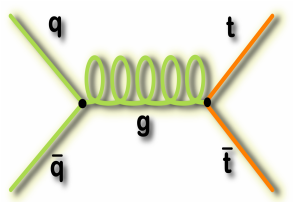
- Discovered in 1995 by the CDF and D0 collaborations
- Large mass: 173.2 ± 0.9 GeV
- Is it the top quark as SM predicted?
- Special role in EWSB?



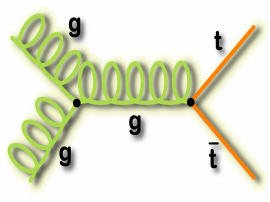
- Events by discovery: 10s
- Run II: 1000s of events
- LHC : 100000s
  - Precise QCD tests
  - New physics searches
  - Calibration sample

Top quark Production and Decay

- At Tevatron , mainly top pair production via strong interactions



~ 85 %

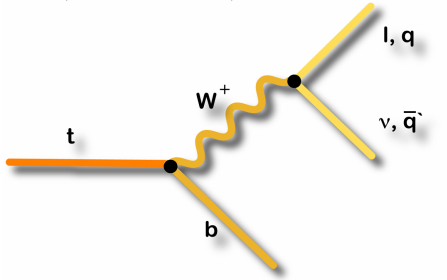


~ 15 %

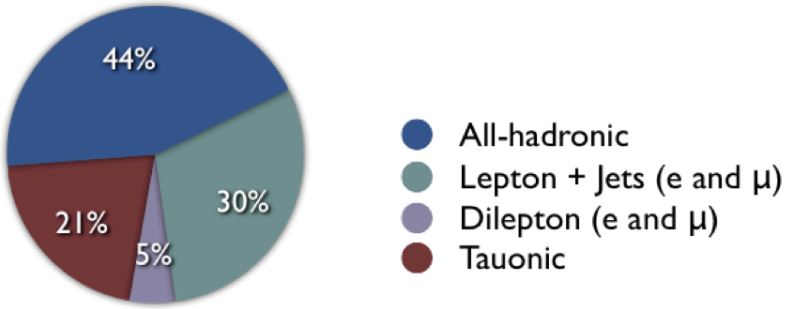
$7.35\ ^{+0.28}_{-0.33}$ pb (at mt=172.5 GeV)

NNLO+NNLL QCD prediction M. Czakon, P. Fiedler and A. Mitov, arXiv:1303.6254

Br(t → Wb) ~ 100%

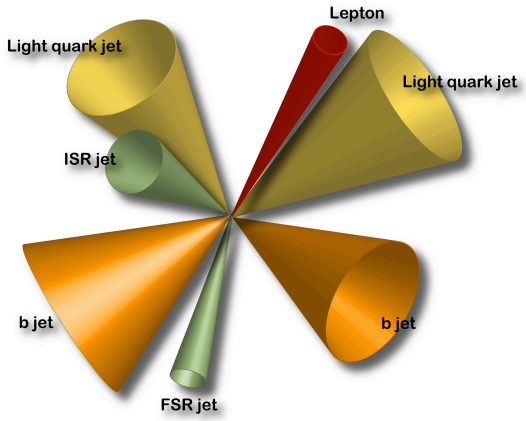


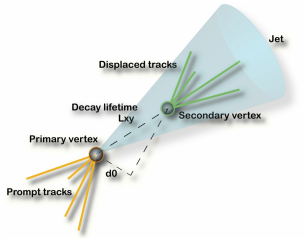
- Channels classified by W decay mode



Top Signatures

- All channels have been explored at Tevatron: different experimental techniques to cope with backgrounds and improve S/B
- Hadronic : large BR , many jets: but large multijet background
- Lepton +jets (L+J):
  - high pt leptons and missing energy
  - jet backgrounds can be largely rejected already at trigger level
- Dileptons: clean signature due to two leptons, but small BR



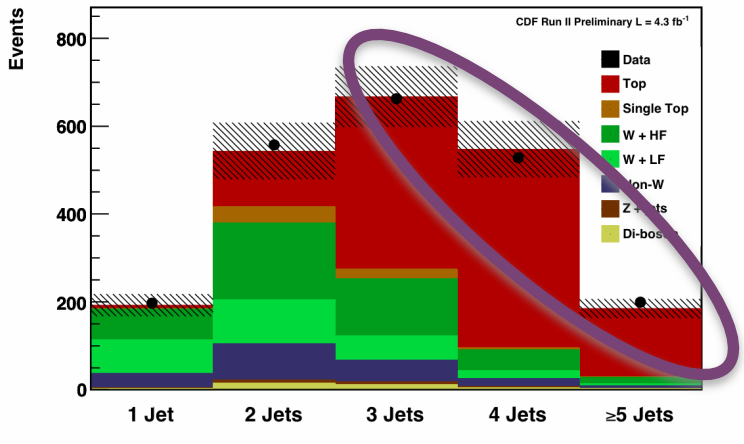


- b-jet identification
  - Secondary vertex
  - NN: track and secondary vertex information
- Backgrounds:
  - Mix of Monte Carlo derived (W/Z+jets, Z/ γ^*,single top, diboson)
  - and data-driven techniques (multijet)

Measurements in the L+J channel

Using b-tagging information for signal enriched sample

Adding cut on sum of transverse energy
HT > 230 GeV (scalar sum lepton+MET+jets)



Signal region ≥ 3 jets

σ = 7.22 ± 0.35 (stat) ± 0.56 (syst) ± 0.44 (lumi) pb

Dominant systematics:

- b-tagging
- background normalization (W+HF)
- Luminosity uncertainty

Normalized to Z inclusive cross section

- Perform measurement in same data sample (consistent trigger and lepton ID)
- Determine ratio and multiply by theoretical prediction 251.3 ± 5.0 pb

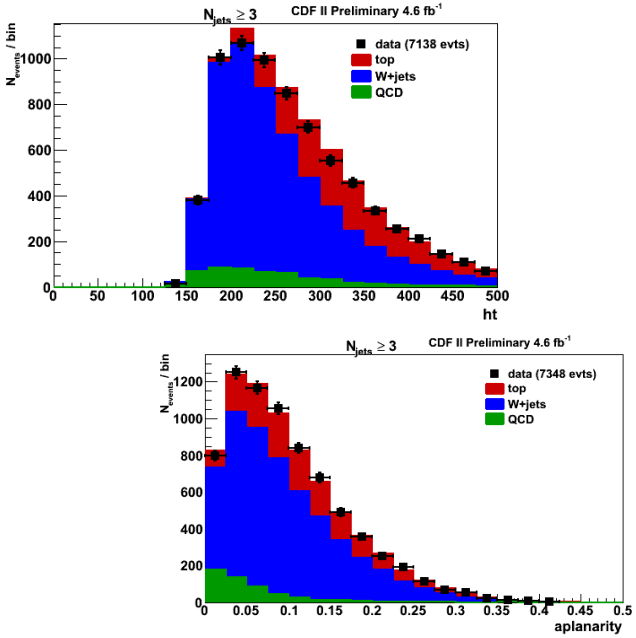
Reduce from 6% to 2% uncertainty

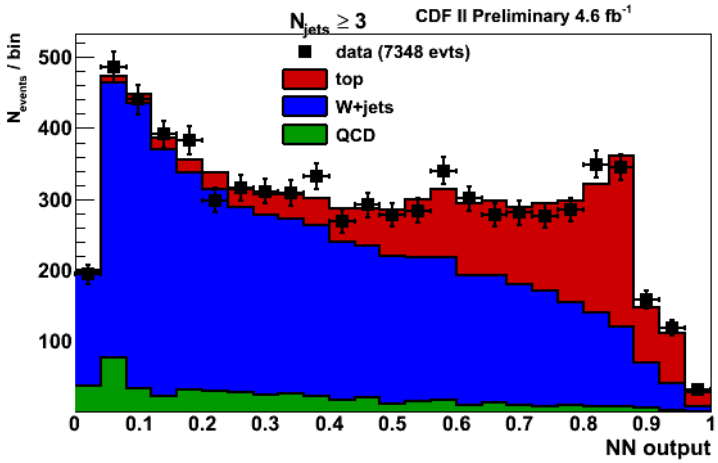
σ = 7.32 ± 0.36 (stat) ± 0.59 (syst) ± 0.14 (theo) pb

CDF PRL 105, 012001 (2010)

Measurements in the L+J channel

Using kinematic properties, build an ANN
and extract the top XS (W+jets allow to float)





Main uncertainties: JES and signal/bckg modeling

Normalized to inclusive Z cross section

$\sigma = 7.82 \pm 0.38\ (stat) \pm 0.37\ (syst) \pm 0.15\ (theo)$ pb

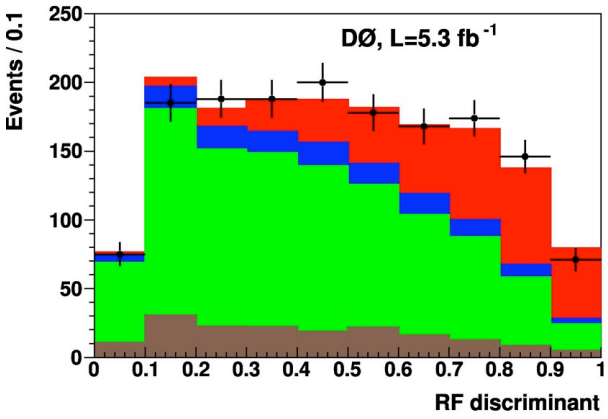
CDF PRL 105, 012001 (2010)

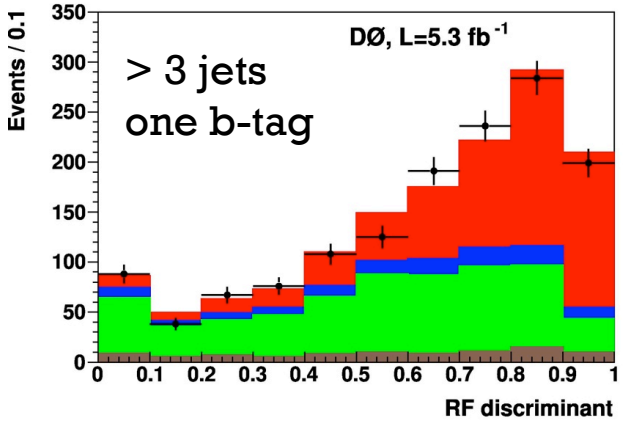
$\Delta\sigma/\sigma$: 7%

Measurements in the L+J channel

Combining counting and kinematic measurements

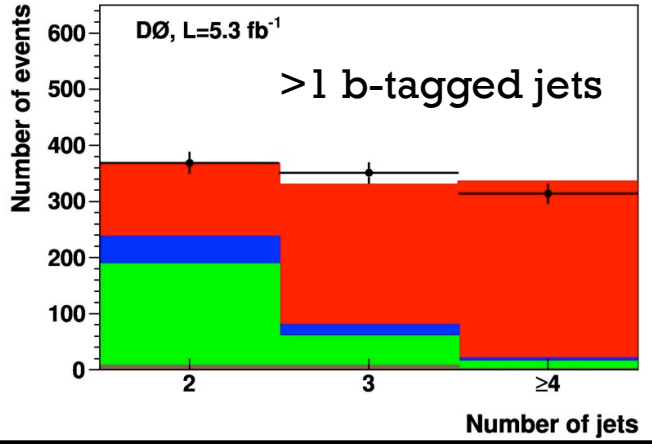
> 3 jets and no b-tags





D0 PRD 84, 012008 (2011)

- Split sample in 0 ,1 and >1 btags
- 2, 3 and > 3 jets
- Use discriminant in regions with at least 3 jets and bckg dominated
- Other channels used to fit for predicted number of events
- Simultaneuosly fit for W+HF (2 jets)



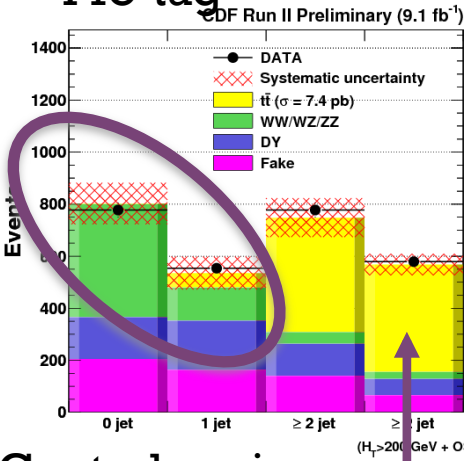
$\sigma = 7.78\ ^{+0.77}_{-0.64}$ (stat +syst) pb

Dileptons

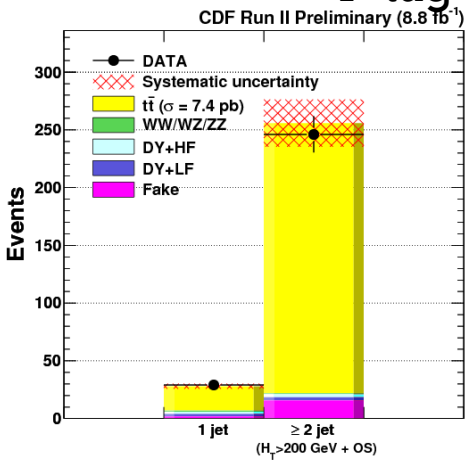
- Counting experiment on pre-tag and at least 1 btagged jets

9.1 fb^{-1}

Pre-tag

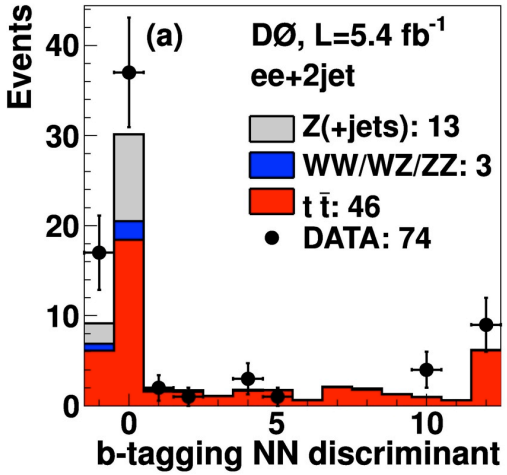


1 tag



Control regions

Signal region: HT and OS cuts



Use b-tagging NN as discriminant in different lepton channels (ee, $\mu\ \mu$,e μ)

$\sigma = 7.36\ ^{+0.90}_{-0.79}$ (stat +syst) pb

More than 400 (200) events for pretag (1tag)

Systematic dominated

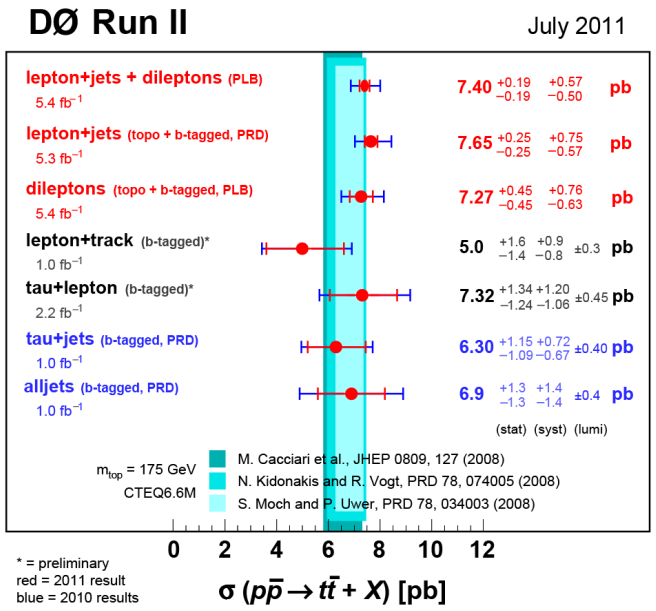
pre-tagged $\sigma = 7.60 \pm 0.44$ (stat) ± 0.65 (syst) ± 0.47 (lumi) pb

b-tagged $\sigma = 7.09 \pm 0.49$ (stat) ± 0.52 (syst) ± 0.43 (lumi) pb

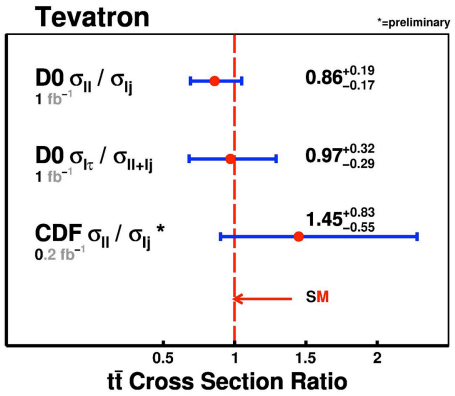
Exploring different decay modes

Top pair XS measured in different decay channels

- Test of SM and sensitive to BSM



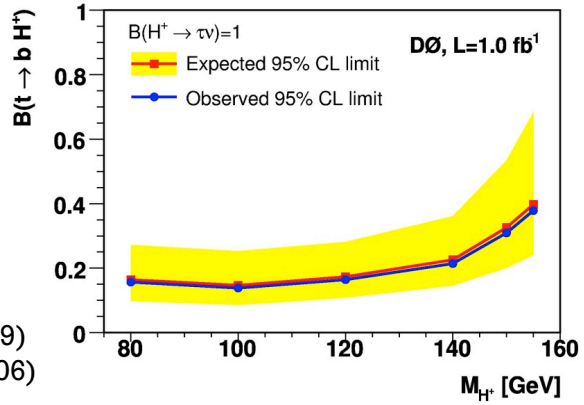
Ratios of XS



$R_{ll/lj} = 0.86^{+0.19}_{-0.17}$

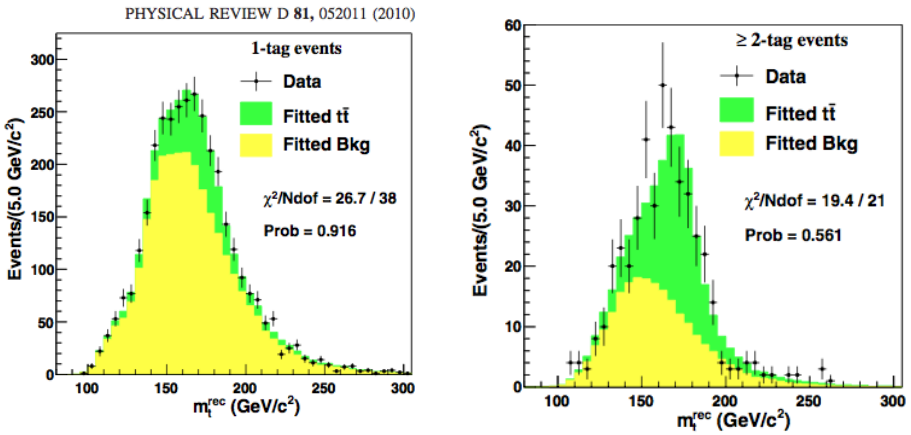
$R_{\tau\, l/ll+lj} = 0.97^{+0.32}_{-0.29}$

Establish limits, Br(t → H^+b), H^+ → τ ν



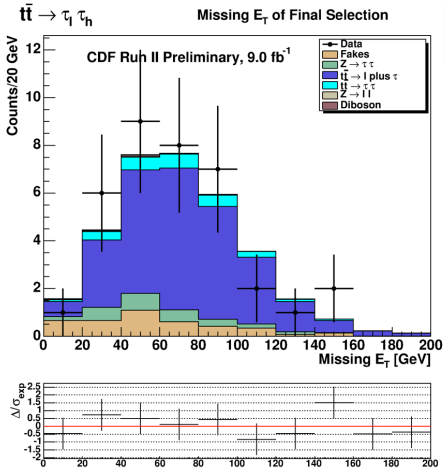
D0 PRD 80, 071102 (2009)
CDF PRL 96 042003 (2006)

More challenging channels



- Large multijet background (6-8 jets in signal region)
  - NN to differentiate
- Derived cross section from the fits for the top mass

σ = 7.2 ± 0.5 (stat) ± 1.0 (syst) ± 0.4 (lumi) pb



9.0 fb^{-1}

- Lepton + τ channel (decaying hadronically)
- Around 30 expected events after tagging requirement

σ = 8.2 ± 2.3 (stat) ± 1.2 (syst) ± 0.5 (lumi) pb

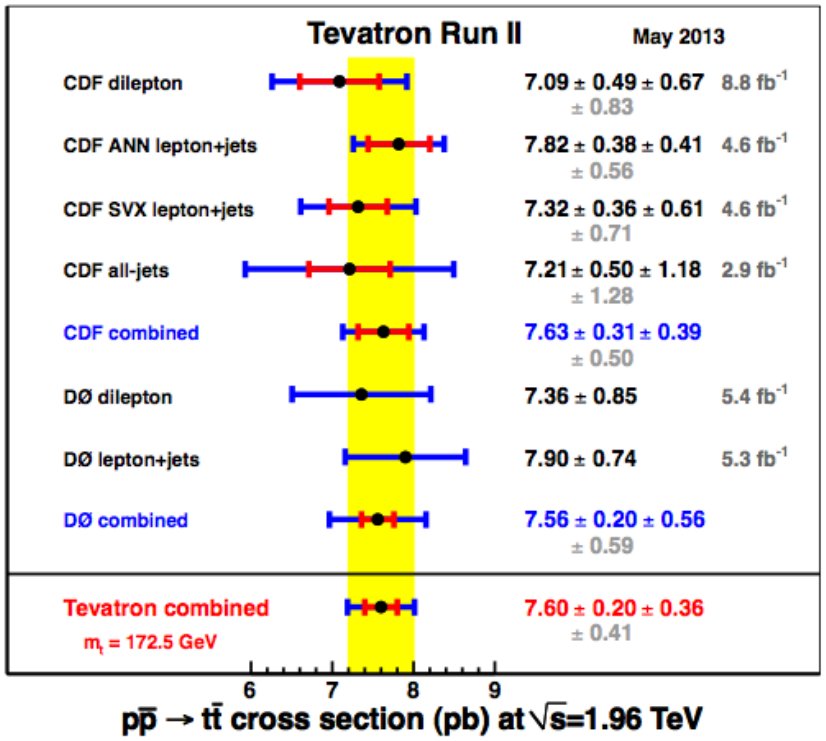
Tevatron combination

- Precise measurements from each experiment are combined for a detector and a Tevatron combination
- Combination is performed taking into account statistical and systematic correlations (much of the exercise done for top mass)

	CDF	D0	
Central value of $\sigma_{\bar{t}t}$	7.63	7.56	
Sources of uncertainty			Corr.
Statistics	0.31	0.20	no
Modeling of the detector	0.17	0.22	no
Modeling of signal	0.21	0.13	yes
Modeling of jets	0.21	0.11	no
Method of extracting $\sigma_{t\bar{t}}$	0.01	0.07	no
Background modeled from theory	0.10	0.08	yes
Background based on data	0.08	0.06	no
Normalization of Z/γ^* prediction	0.13	–	no
Inelastic $p\bar{p}$ cross section	0.05	0.30	yes
Detector luminosity	0.06	0.35	no
Total systematic uncertainty	0.39	0.56	

Tevatron combination

New



- Per experiment combination

CDF

σ = 7.63 ± 0.50 (stat+syst) pb

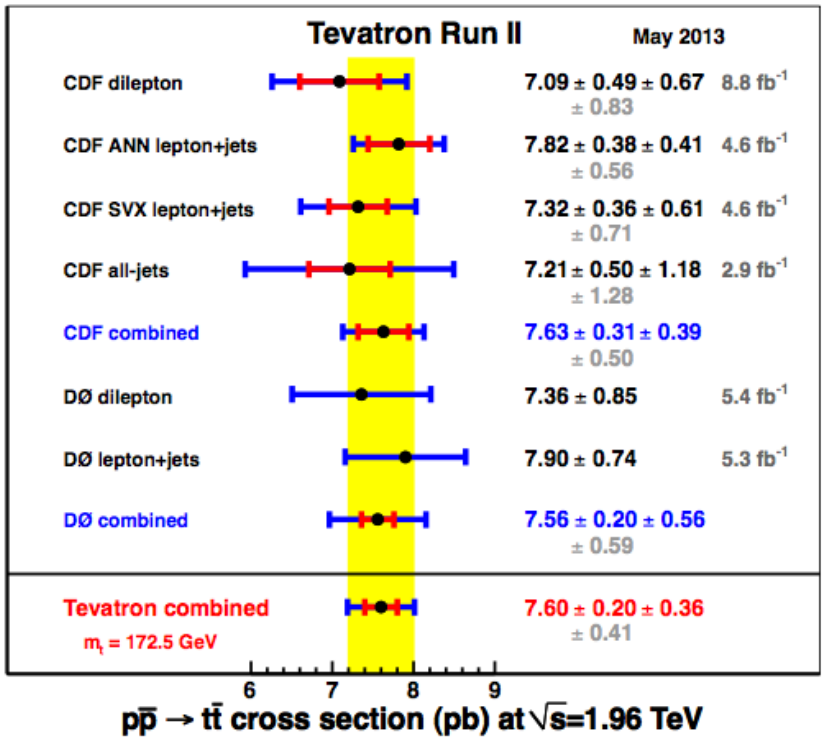
D0

σ = 7.56 ± 0.59 (stat+syst) pb

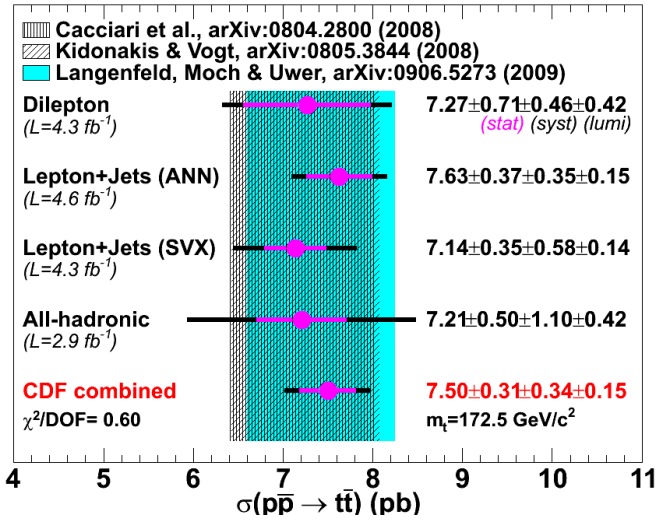
Consistent results from the different channels and detectors

Tevatron combination

New



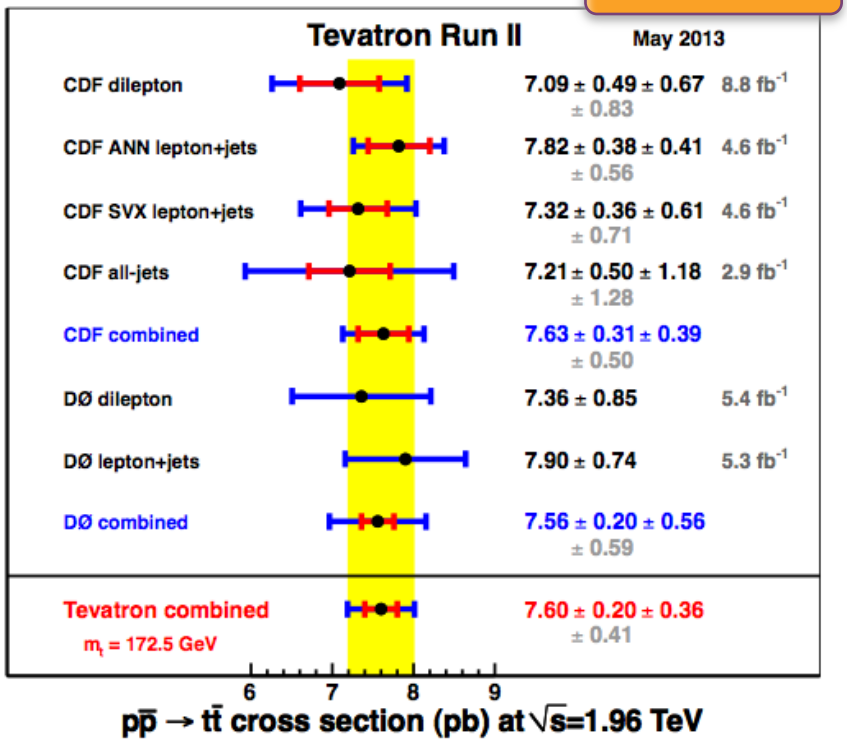
Previous results for illustration of comparison with theory

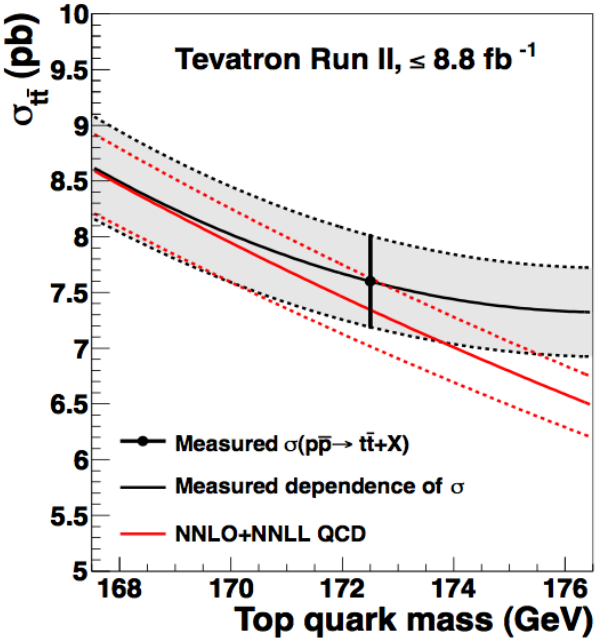


Comparison with theoretical predictions
6.5% experimental uncertainty
Theory: 10-11%

Tevatron combination

New



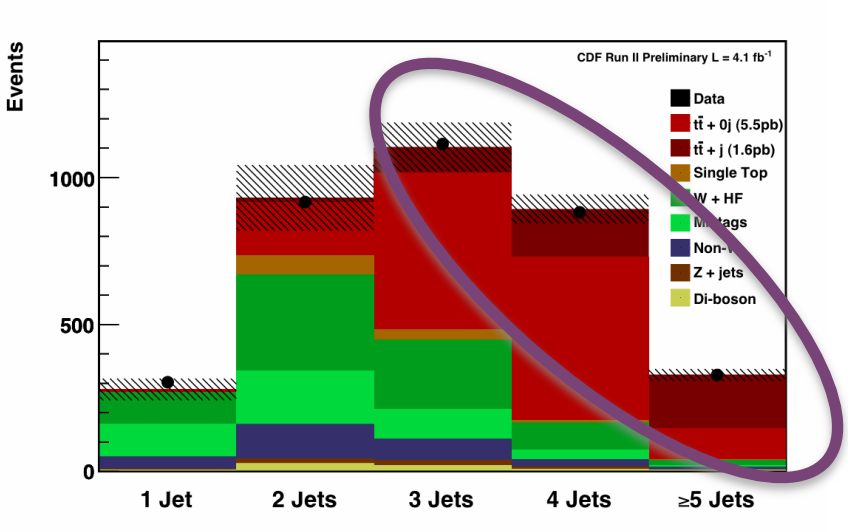


$\sigma = 7.60 \pm 0.41$ pb

5.4% experimental uncertainty
Theory prediction: ≈4%

$t\bar{t}$ +j

Looking into 3 or more jets:
2D likelihood for $t\bar{t}$+jet and $t\bar{t}$+0jet



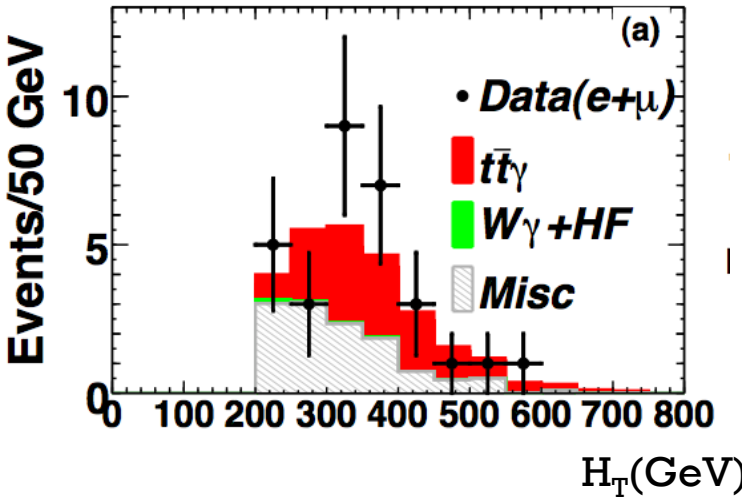
$\sigma_{tt+j} = 1.6 \pm 0.2\ (stat) \pm 0.5\ (syst)$ pb

$\sigma_{NLO} = 1.79\ ^{+0.16}_{-0.31}$ pb

Uwer et al. arXiv:0810.0452

$t\bar{t} + \gamma$

CDF PRD 84 031104 (2011)



Search in the semileptonic channel

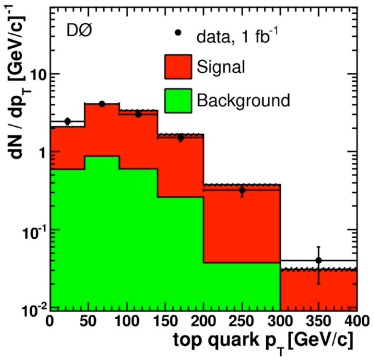
Observed 30 candidates

3 σ probability for background only assumption

$\sigma = 0.18 \pm 0.07\ (stat) \pm 0.04\ (syst) \pm 0.01\ (lumi)$ pb

Differential cross sections

- Looking into detail to the production mechanism:
  - Testing pQCD predictions and potential indicators of new physics
  - Very important for accurate modeling



Unfolding

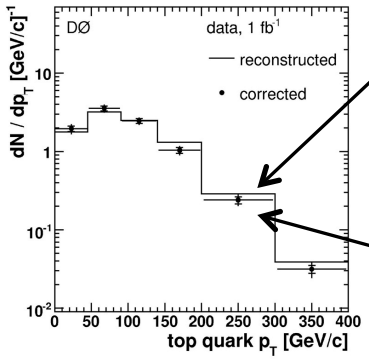
From reconstructed top quark p_T spectrum

⇓

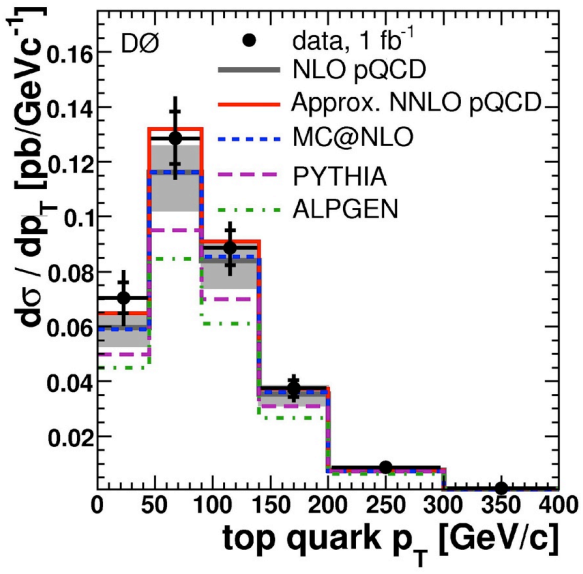
to background-substracted

⇓

to spectrum corrected by finite resolution effects



D0 PLB 693, 515 (2010)



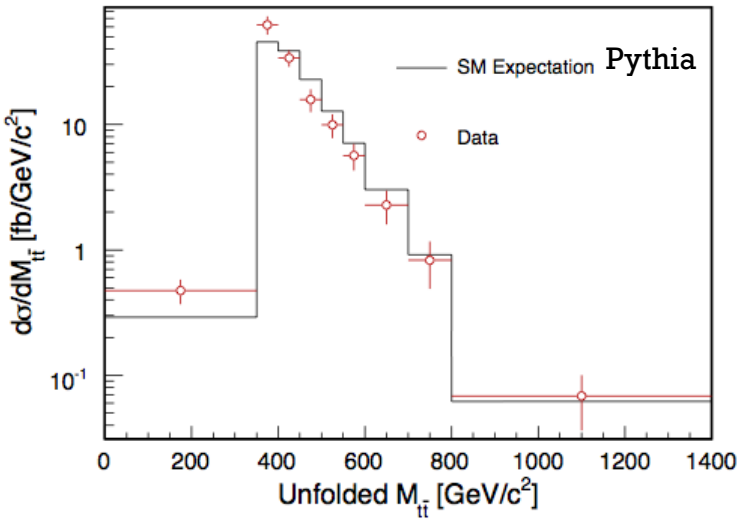
Good agreement with NLO and approx NNLO pQCD

Soon to be released a full Run II dataset measurement from D0

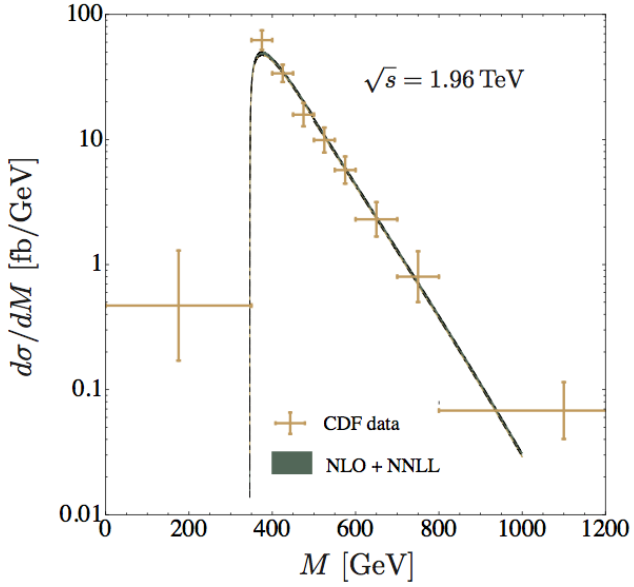
Differential cross sections II

- Many BSM mechanisms could distort the Mtt spectrum

CDF PRL 102 222003 (2009)



Ferroglia et al. Nucl.Phys.Proc.Suppl.205-206:48-53,2010



More recently compared with NLO+NNLL with improved agreement

CDF Full RunII data result on distributions of ttbar production angle on Afb talk.

More results from Tevatron

- "Measurement of the top quark mass at the Tevatron", Y.Peters
- "Single top quark production cross section at the Tevatron", A. Garcia-Bellido
- "Top quark properties studies at the Tevatron", S. Leone
- "Measurement of the charge asymmetry in top quark pair production at the Tevatron", R. Demina

CDF results:
http://www-cdf.fnal.gov/physics/new/top/top.html
D0 results:
http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html

Summary

- Presented measurements of inclusive top pair cross section from D0 and CDF collaborations
- Consistent results from different decay channels
- First Tevatron combination, uncertainty of 5.5% , in agreement with latest theoretical prediction

$$\sigma_{TEVATRON} = 7.60 \pm 0.41 \text{ pb}$$

- New results of differential cross sections are expected using the full Run II dataset