Top quark production at D0

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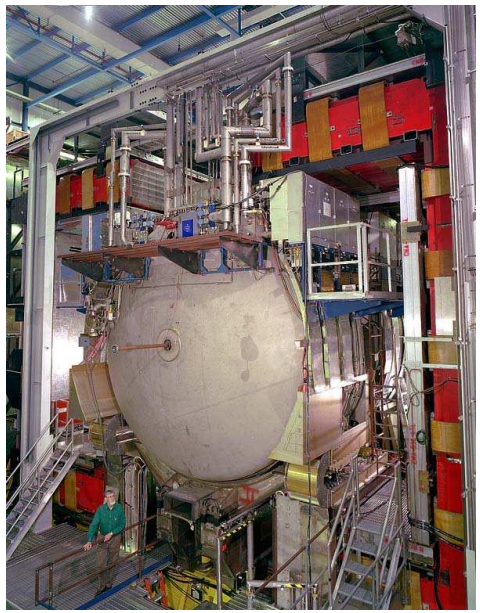
on behalf of D0 Collaboration

Contents

Tevatron and D0

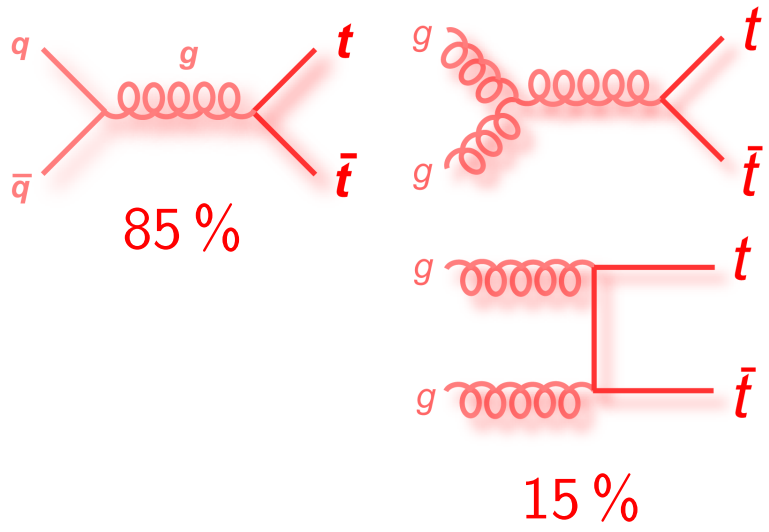
- birthplace of top quark
- $p\bar{p}$ collisions at $\sqrt{s}$=1.96 TeV
- shut down on Sept. 30 2011
- 10.5 fb^{-1} of recorded data per experiment



- high resolution inner detectors for precise tracking and vertex recons.
- electromagnetic and hadronic calorimeters
- outer muon system
- magnetic field

Top quark pair production at the Tevatron

- top pair produced in strong interaction via
  - quark-antiquark annihilation ($\sim 85\,\%$)
  - gluon-gluon fusion ($\sim 15\,\%$)



- theoretical NNLO$_{approx}$ cross section of

  $\sigma_{t\bar{t}} = 7.46\ pb \ \text{at}\ m_t = 172.5\ GeV$

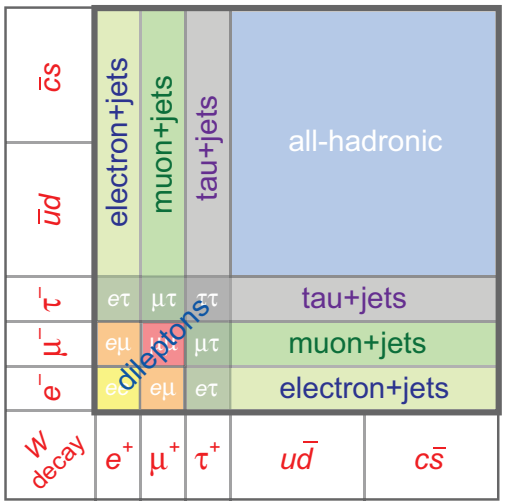
  (PRD78, 034003 (2008))

- $\mathrm{Br}(\mathrm{t} \to \mathrm{Wb}) \simeq 100\,\%$

  $\mathrm{t\bar{t}}$ final states categorized according to W decay

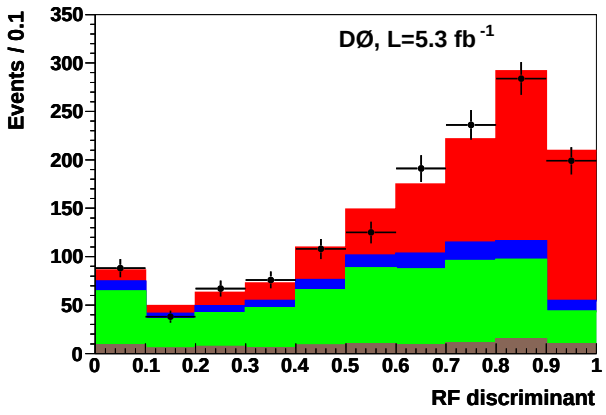
  - dilepton - small BR for signal ($\sim 5\,\%$), small background
  - lepton+jets - best in sensitivity, golden channel
  - all-hadronic - large BR for signal ($\sim 50\,\%$), huge QCD background

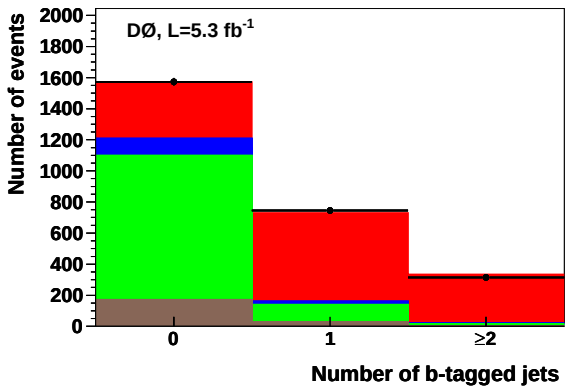
Top Pair Decay Channels



Top quark pair production - lepton+jets

- 5.3 fb^{-1} of data
- required 1 isolated e or μ, ≥ 2 jets, large $\not\!\!E_T$
- main backgrounds: W+jets, QCD multijet production, Z+jets and diboson production
- used 3 methods to extract $\sigma_{t\bar{t}}$
  - kinematic method - multivariate discriminant maximum likelihood fit of distributions in discriminant (templates)
  - counting method using b-tagging - neural network based b-tagging, maximum likelihood fit to data
  - combination of the above
- largest uncertainty from luminosity

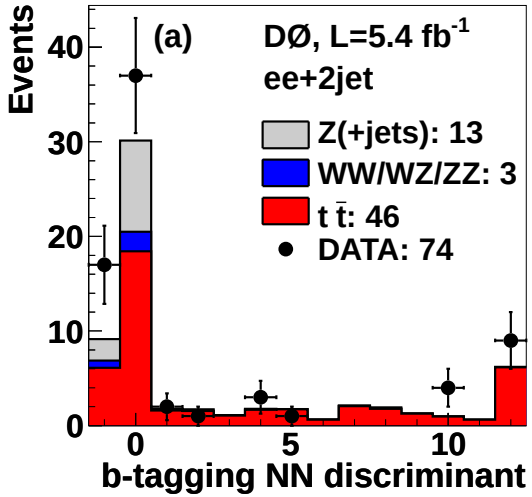


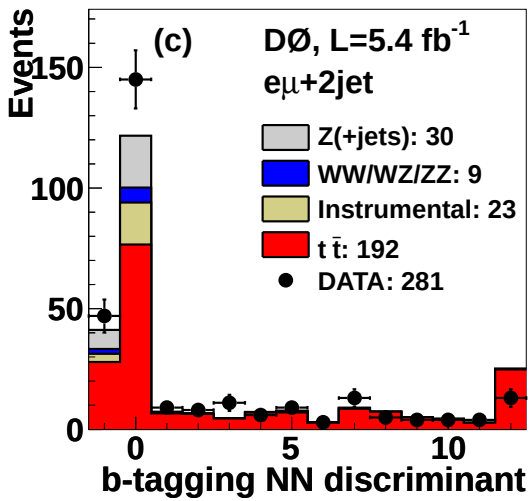


$\sigma_{t\bar{t}} = 7.78^{+0.77}_{-0.64}\,(\text{stat} + \text{syst})\,\text{pb}$ **PRD 84, 012008 (2011)**

Top quark pair production - dilepton

- 4 channels (ee+2j, $\mu\mu$+2j, $e\mu$+1, 2j)
- 5.4 fb^{-1} of data
- required 2 isolated leptons, $\geq$ 1,2 jets, large $\not\!\!E_T$
- main backgrounds: Drell-Yan, Z boson production, diboson production, instrumental background
- used neural network based b-tagging to construct event discriminant
- $t\bar{t}$ cross section extracted from the fit to b-tagging NN discriminant
- largest uncertainty from luminosity





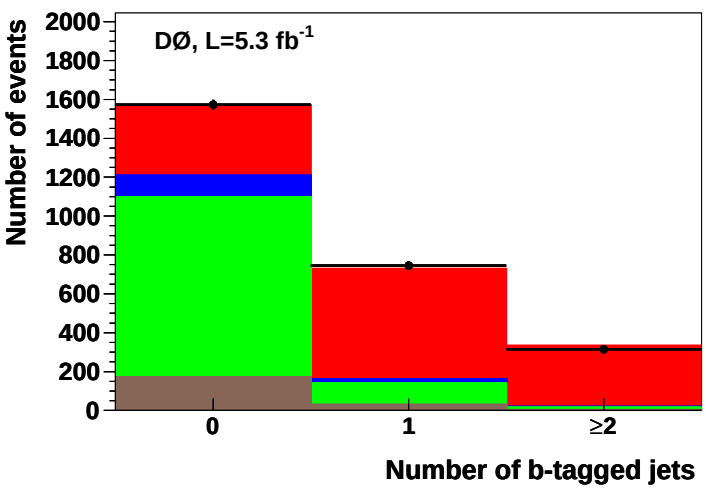
$\sigma_{t\bar{t}} = 7.36^{+0.90}_{-0.79}\,(\text{stat} + \text{syst})\,\text{pb}$

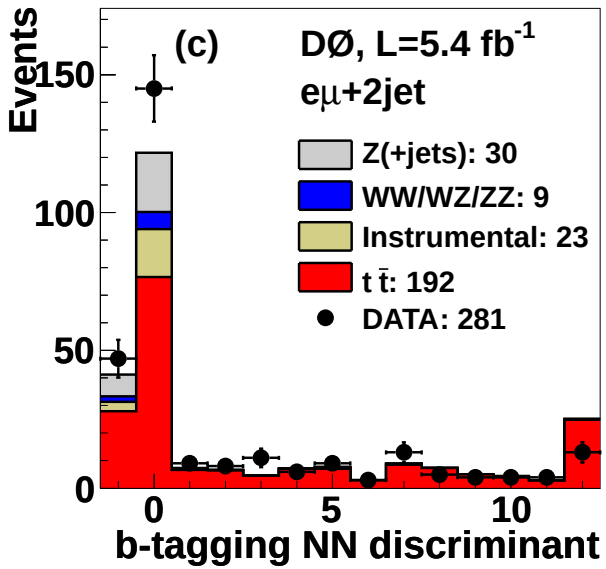
PLB 704, 403 (2011)

Top quark pair production - lepton+jets and dilepton

- combined measurements in lepton+jets and dilepton channel
- 5.4 fb^{-1} of data
- lepton+jets events with only 2 jets not used in the combination
- relative precision of 8 %

$$\sigma_{t\bar{t}} = 7.56^{+0.63}_{-0.56}\,(\text{stat} + \text{syst})\,\text{pb}$$ PLB 704, 403 (2011)





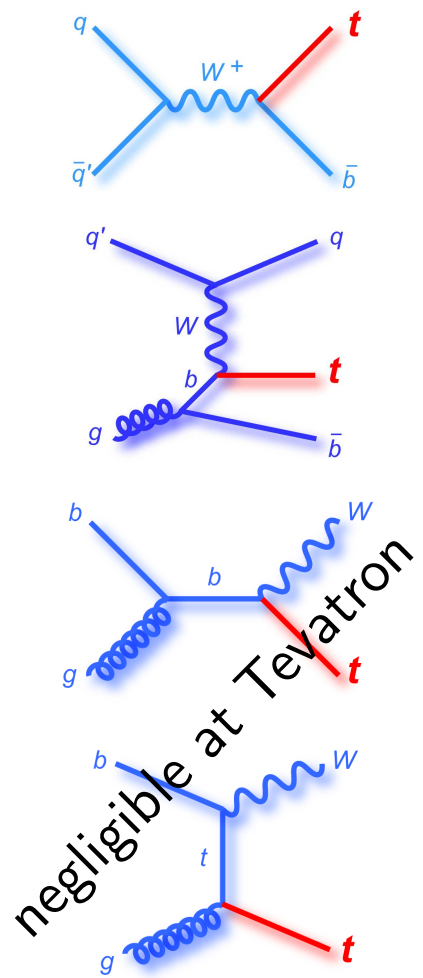
Single top quark production at the Tevatron

- single top quark produced via electroweak interaction
  - s-channel $\sigma_{s-ch} = 1.04\ pb$ at $m_t = 172.5\ GeV$
  - t-channel $\sigma_{t-ch} = 2.26\ pb$ at $m_t = 172.5\ GeV$
  - tW channel $\sigma_{tW} = 0.28\ pb$ at $m_t = 172.5\ GeV$

  PRD 74, 114012 (2006)

- observed by CDF and D0 collaborations in 2009

  PRL 103, 092001 (2009)



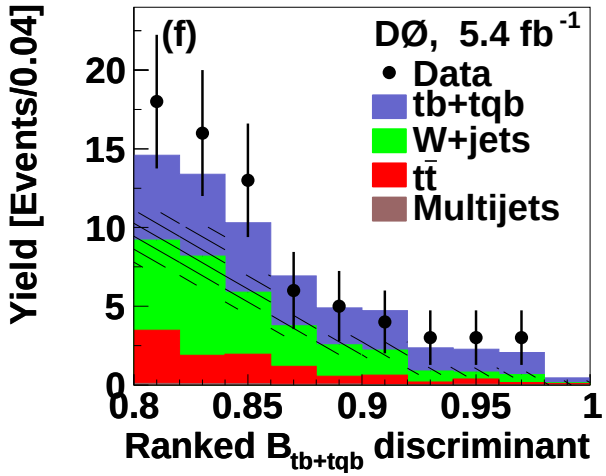
Single top quark production - s+t channel cross section

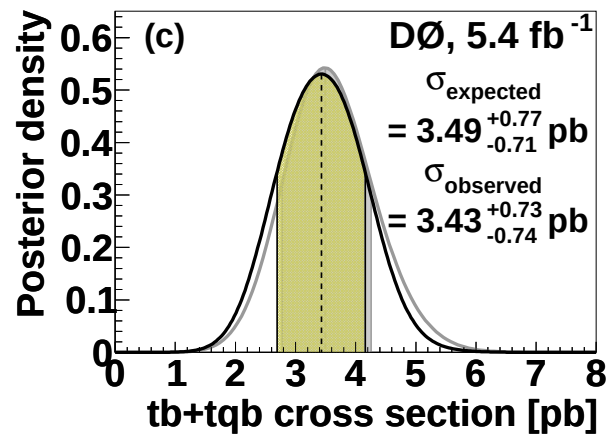
- 5.4 fb^{-1} of data, lepton+jets channel
- required 1 isolated e or μ, large $\not\!\!E_T$
  2-4 jets, 1 or 2 b-tagged jet
- main backgrounds: W+jets, $t\bar{t}$ and multijet production
- used 3 methods to extract the signal from multivariate discriminant
- used Bayesian approach to extract s- and t-channel cross sections together and separately

$$\sigma_{s+t} = 3.43^{+0.73}_{-0.74}\ \text{pb}$$

$$\sigma_{s-ch} = 0.68^{+0.38}_{-0.35}\ \text{pb}$$

$$\sigma_{t-ch} = 2.86^{+0.69}_{-0.63}\ \text{pb}$$





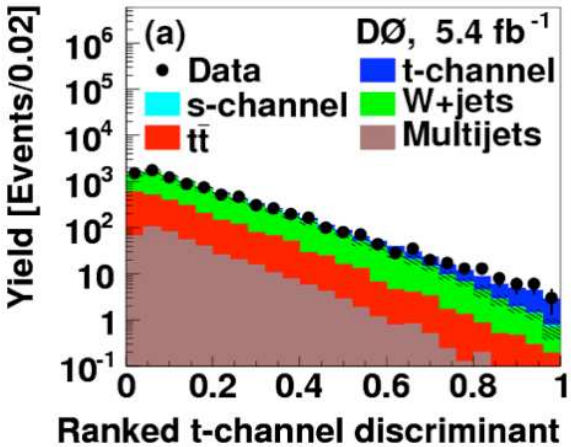
PRD 84, 112001 (2011)

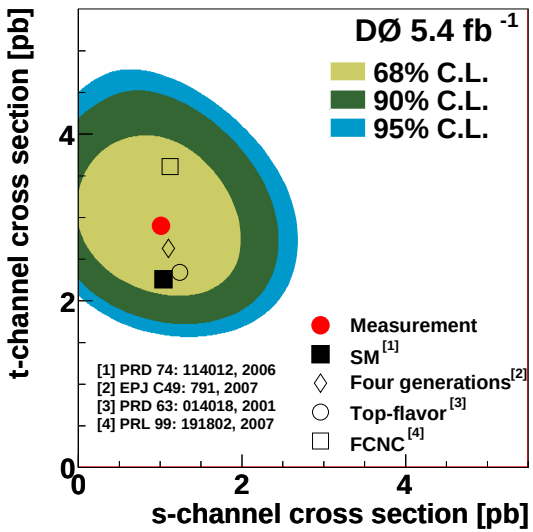
Single top quark production - t-channel

- combined discriminant used to separate signal from background
- contructed Bayesian 2D posterior probability density for t-ch and s-ch cross sections

  no constraint on relative rates of s-ch and t-ch production
- t-ch cross section extracted from 1D posterior probability by integrating over s-ch cross section values (no assumption on s-ch cross section)

  s-ch cross section obtained in the same way





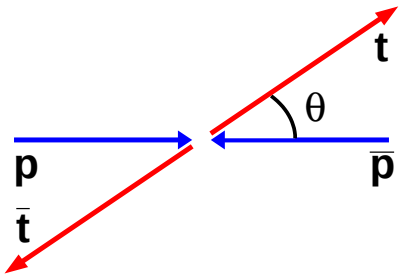
$\sigma_{t-ch} = 2.90 \pm 0.59$ pb

$\sigma_{s-ch} = 0.98 \pm 0.63$ pb

PLB 705, 313 (2011)

Forward-backward asymmetry - A_{fb}

- QCD predicts no asymmetry at LO, small asymmetry at NLO ($\sim$5 - 9 %)



- forward-backward asymmetry

$$A_{fb} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}, \quad \Delta y = y_t - y_{\bar{t}}, \quad y = \frac{1}{2} \ln \left(\frac{E + p_z}{E - p_z} \right)$$

reconstructed $\Delta y = q_l \cdot (y_{t,lep} - y_{t,had})$

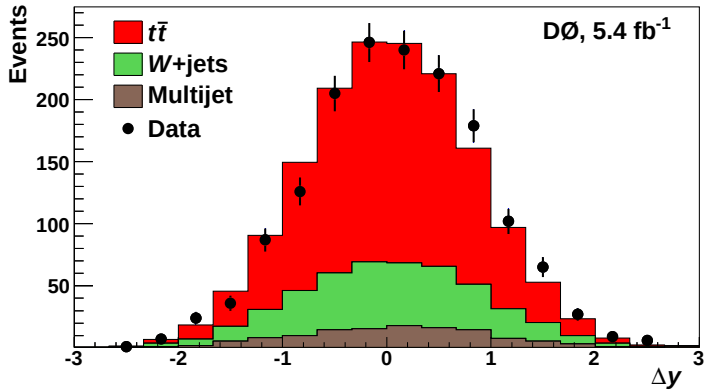
- asymmetry based on charge, rapidity (q_l, y_l) of lepton from top decay

$$A_{fb}^{l} = \frac{N(q_l y_l > 0) - N(q_l y_l < 0)}{N(q_l y_l > 0) + N(q_l y_l < 0)}$$

- two different types of measurements
  - reconstruction level : after event selection, reconstruction and background subtraction
  - production level : after correction for detector effects ("unfolding")

Forward-backward asymmetry - A_{fb}

- 5.4 fb^{-1}, lepton+jets channel
- 1 isolated e/μ, $\not\!\!E_T$, ≥ 4 jets, ≥ 1 b-jet kinematic fitter to reconstruct events
- backgrounds : W+jets, multijet production
- constructed likelihood discriminant to separate signal/background



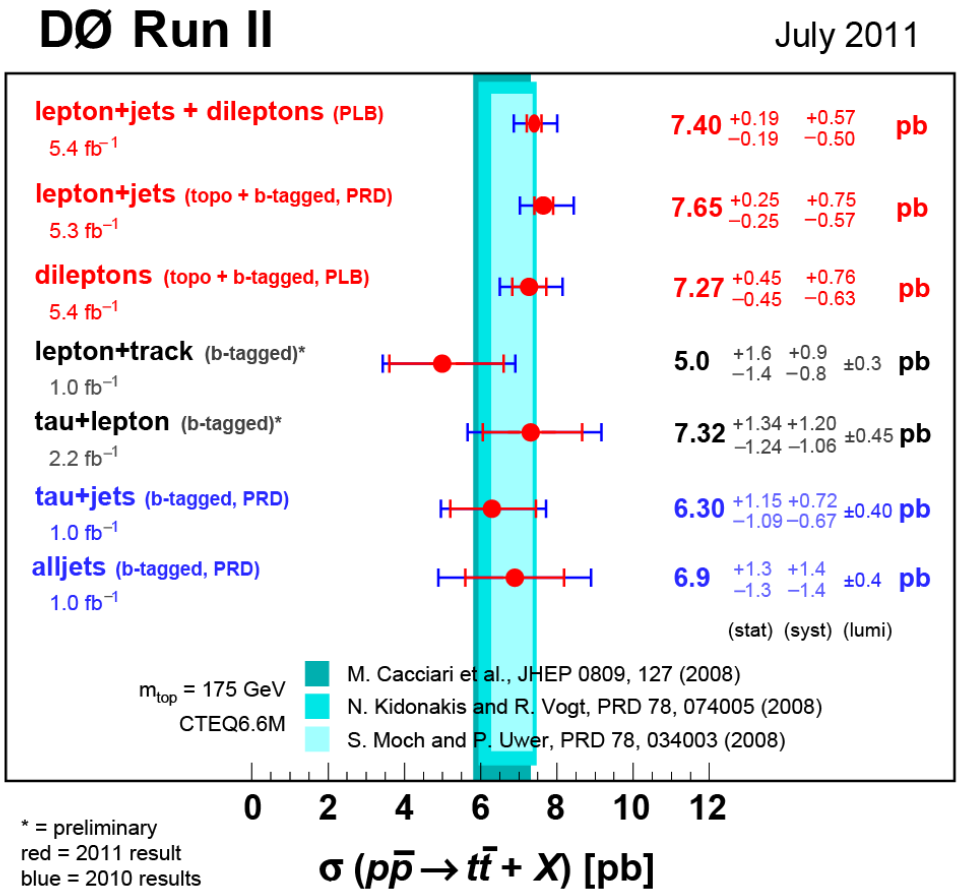
- maximum likelihood fit to measure reconstructed asymmetry
- regularized unfolding to correct for detector effects

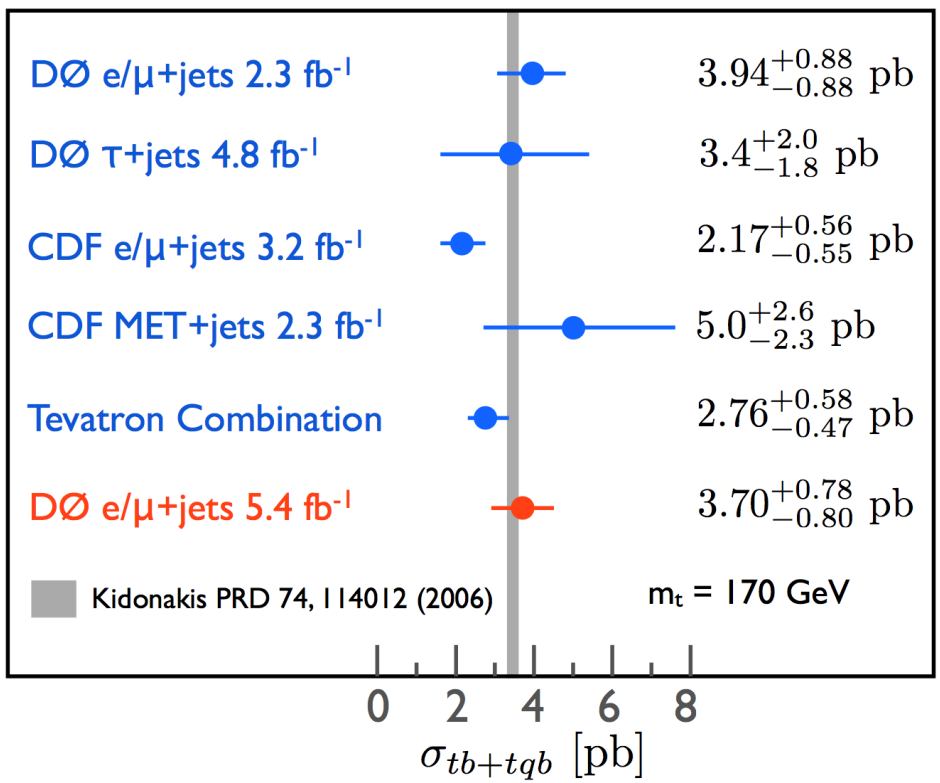
reconstructed	unfolded
$\mathbf{A_{fb} = (9.2 \pm 3.7)\,\%}$	$\mathbf{A_{fb} = (19.6 \pm 6.5)\,\%}$
$\mathbf{A^l_{fb} = (14.2 \pm 3.8)\,\%}$	$\mathbf{A^l_{fb} = (15.2 \pm 4.0)\,\%}$

PRD 84, 112005 (2011)

Summary

- top pair production cross section measured with 8 % relative precision
- both top pair and singletop cross sections consistent with SM prediction
- forward-backward asymmetry in $t\bar{t}$ events above prediction

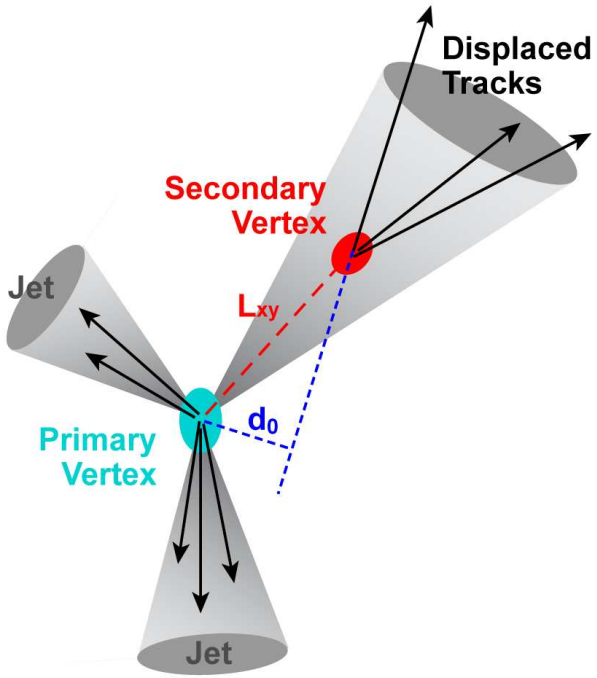




Backup slides

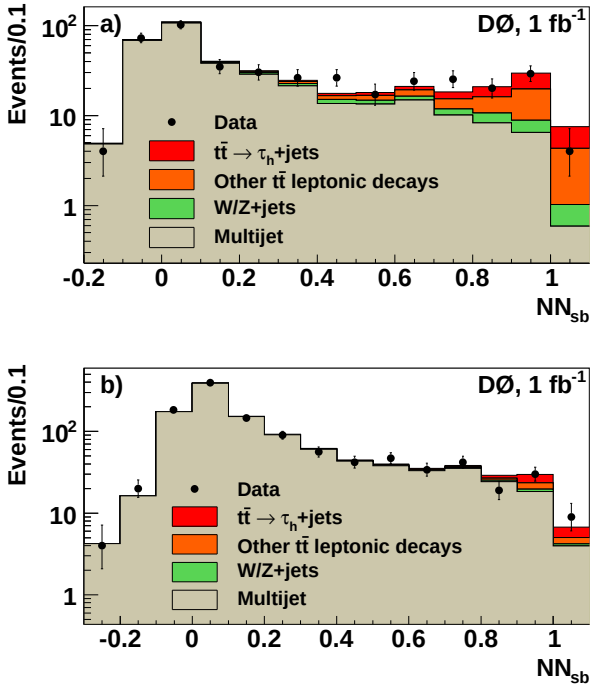
B-tagging

- procedure of linking a jet to b-quark
- b-hadrons usually live long enough to travel measurable distances and can produce muons in semileptonic decays
- b-hadron decays often produce displaced (secondary) verteces with tracks not pointing to primary vertex and muons which is used to recognize them from jets initiated by other partons
- some analyzed final states contain jets coming from hadronization of b quarks (top decays)
  their identification help to reduce combinatorial background and improve signal/background separation



Top quark pair production - tau+jets

- semihadronic decays of τ, hard to distinguish leptons from τ and W decays
- 1 fb^{-1} of data
- required $\geq$ 4 jets, $\geq$ 1 τ_h candidate, large $\not\!\!E_T$ and $\not\!\!E_T$ significance, no isolated leptons three τ candidate categories
- neural network to further discriminate τ/jets $\geq$ 1 b-jet using b-tag neural network
- main backgrounds: multijet production, $t\bar{t}$ decays to leptons, W+jets, Z+jets
- fit to neural network discriminant to estimate signal

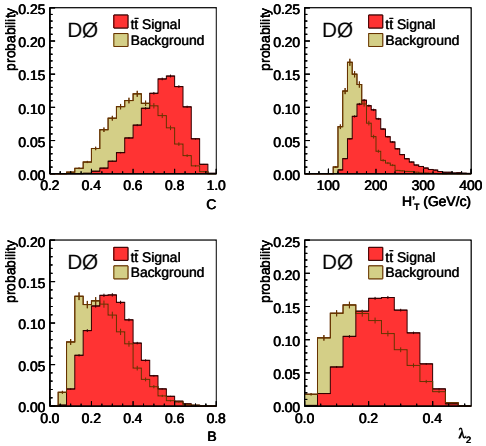


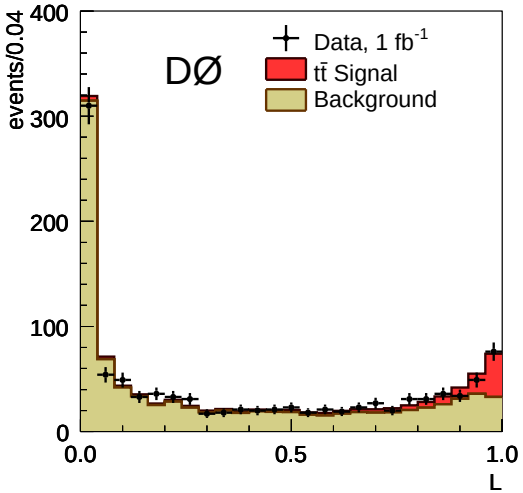
PRD 82, 071102 (2010)

$$\sigma_{t\bar{t}} = 6.9^{+1.5}_{-1.4}\,(\text{stat} + \text{syst})\,\text{pb}$$

Top quark pair production - all-hadronic

- 1 fb^{-1} of data, multijet trigger
- required $\geq$ 6 jets, $\geq$ 4 jets with p_T > 40 GeV
  $\geq$ 2 b-tagged jets (NN), no isolated leptons
- main backgrounds: QCD multijet production
  data driven background model using events with 4 or 5 jets with 2 b-tags
- likelihood discriminant constructed from topological observables to separate S/B
- fit signal and background templates to likelihood output to extract signal fraction





$$\sigma_{t\bar{t}} = 6.9 \pm 2.0\,(\text{stat} + \text{syst})\,\text{pb}$$

PRD 82, 032002 (2010)