Observation of Single Top Production at DØ


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U N I V E R S I T Y
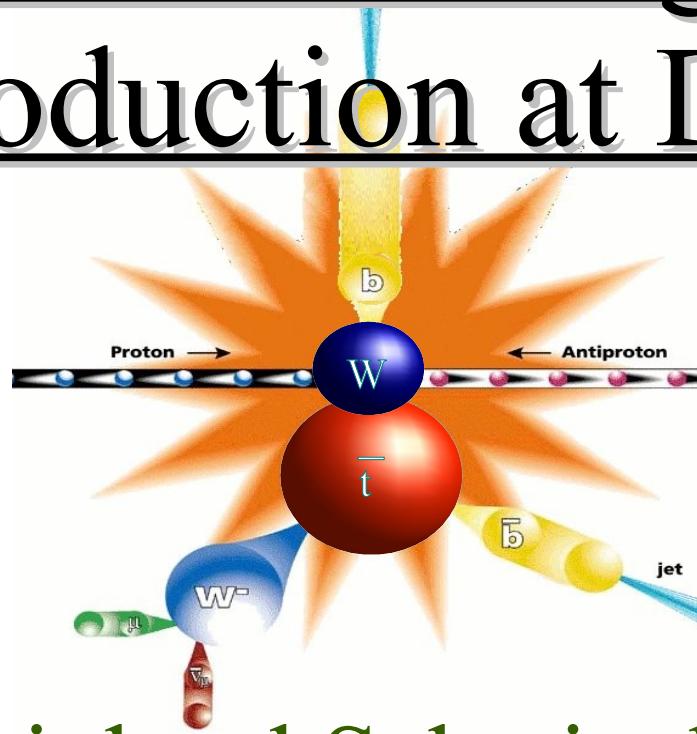
on behalf of the DØ collaboration

EPS – HEP conference 2009

SM single top quark production

s-channel

σ_s = 1.12 pb

t-channel

σ_t = 2.34 pb
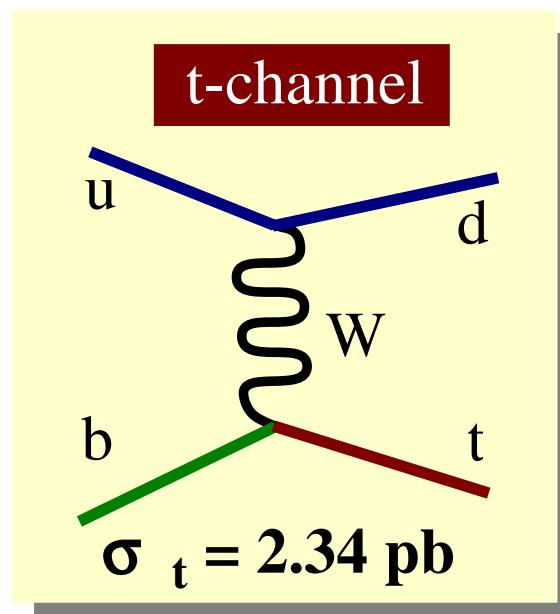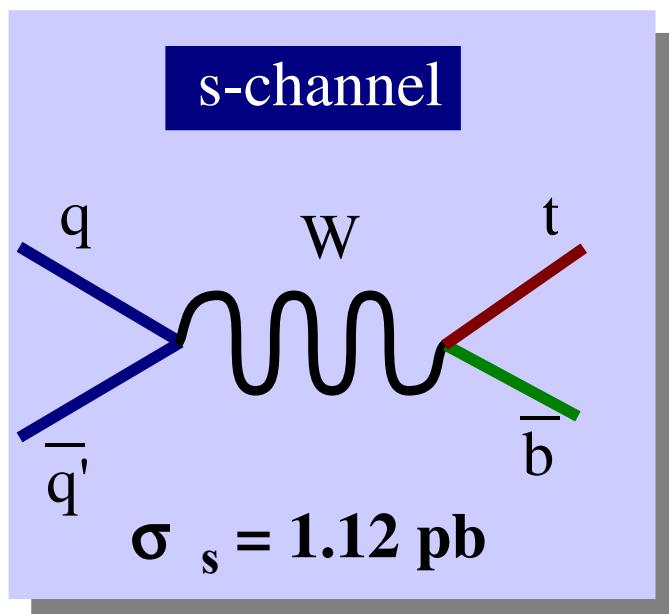
σ_{tot} = 3.46 pb for m_{top} = 170 GeV (Kidonakis et al.)

DØ

|	
· Search:	PRD 63, 031101 (2000)
· Search:	PLB 517, 282 (2001)
· Search:	PLB 622, 265 (2005)
· W':	PLB 641, 423 (2006)
· Search:	PRD 75, 092007 (2007)
· Evidence:	PRL 98, 181802 (2007)
· FCNC:	PRL 99, 191802 (2007)
· W':	PRL 100, 211802 (2007)
· Evidence:	PRD 78, 012005 (2008)
· Wtb:	PRL 101, 221801 (2008)
· Wtb:	PRL 102, 092002 (2009)
· H+:	(PRL) arXiv:0807.0859
· Observation:	(PRL) arXiv:0903.0850

Tevatron Goals:
- – Discover single top quark production
- – Measure production cross sections σ_{s+t}, σ_s, σ_t
- – First direct measurement of CKM matrix element V_{tb}
- – Look for new physics
- – Understand as background to many searches
- – Establish techniques that will also be used in Higgs and other searches
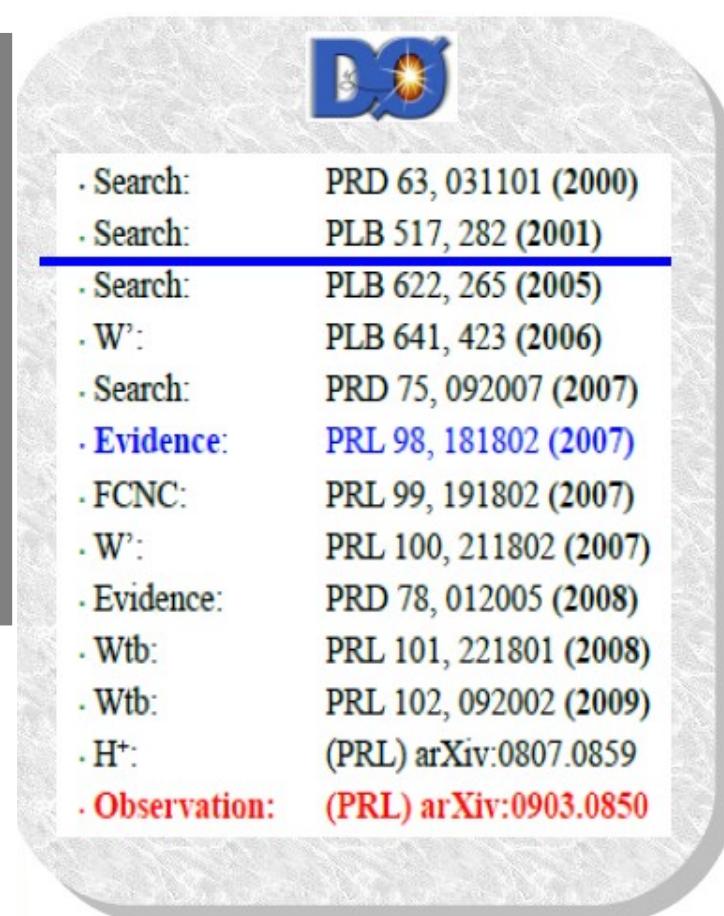
Batavia, Illinois
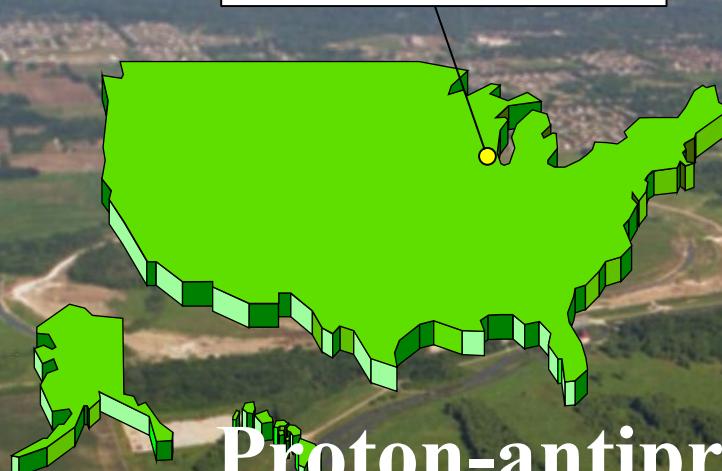
Fermilab Tevatron

Proton-antiproton collider
CM energy 1.96TeV
→ *Energy frontier*
Instantaneous luminosity
exceeding 3E32cm⁻²s⁻¹
→ *Luminosity frontier*

DØ

2.3 fb⁻¹ Observation Analysis

0.9 fb⁻¹ Evidence Analysis
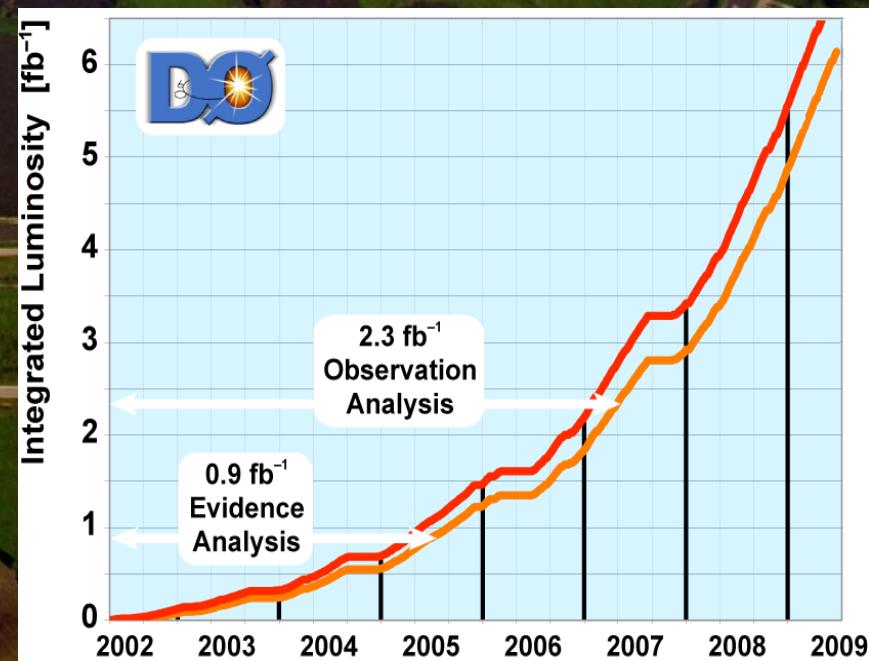
Single top event selection
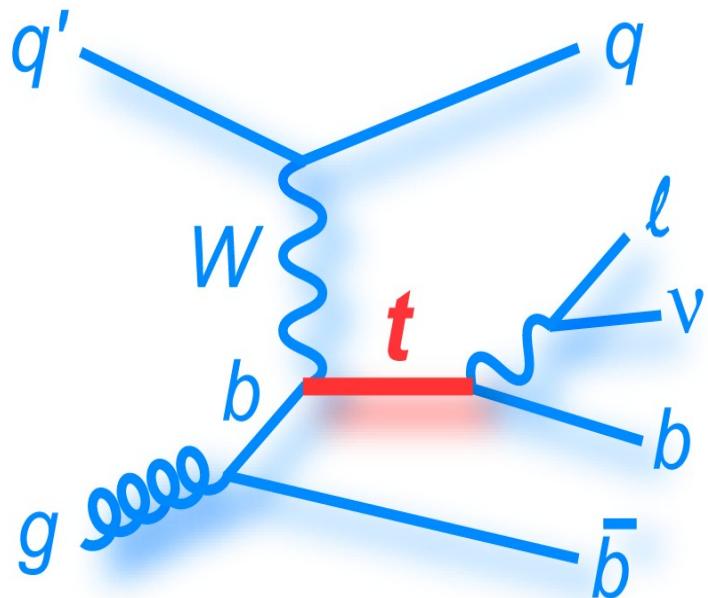
- Basic event signature (e or μ)
  - Include many triggers
  - One high-E_T leptons (>15GeV)
  - Missing transverse energy (>15GeV)
  - 2-4 jets (E_T>15GeV)
  - At least one b-tag

Backgrounds
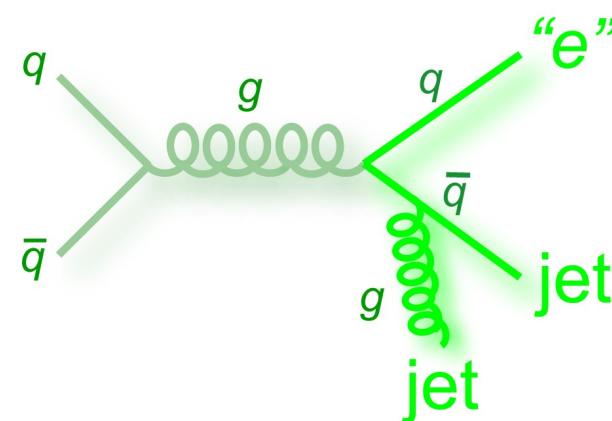
QCD multijets   W+jets: Wjj, Wcj, Wcc, Wbb   Top quark pairs
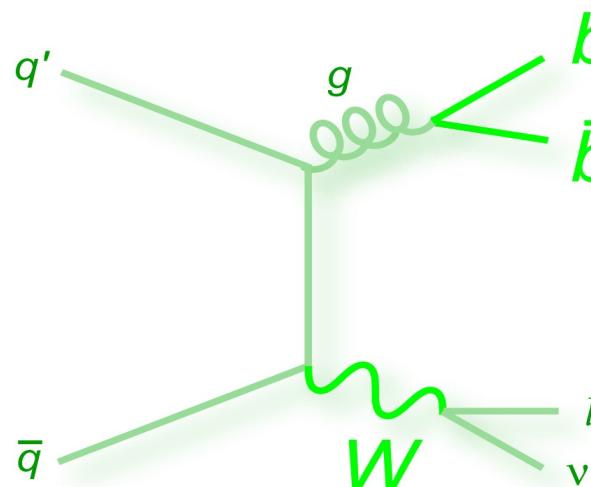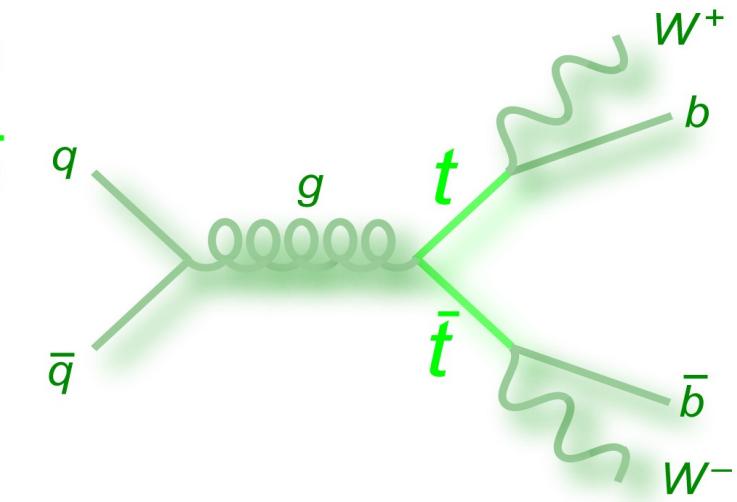
Analysis outline

**Trigger selection**

S/B = $1/10^9$
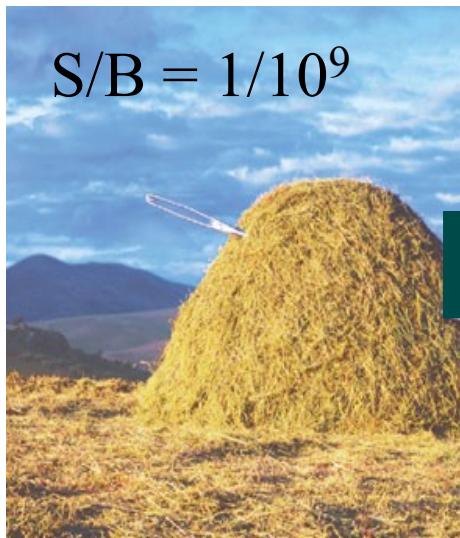
Single top event kinematics

S/B = 1/250, 115,000 events

b-quark tagging

S/B = 1/20, 4500 events in 24 channels

Legend:
- tb
- tqb
- $t\bar{t} \to ll$
- $t\bar{t} \to l$+jets
- $Wb\bar{b}$
- $Wc\bar{c}$
- Wcj
- Wjj
- Z+jets
- Dibosons
- Multijets

Statistical analysis

68%
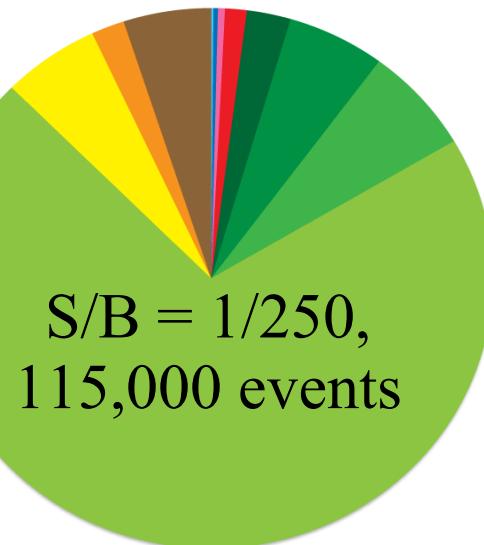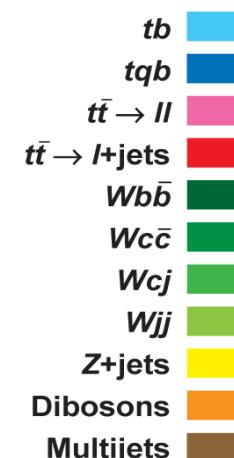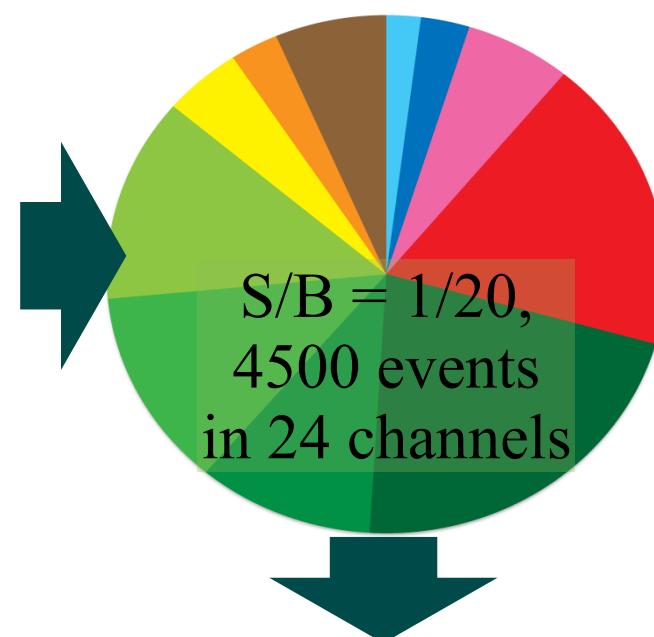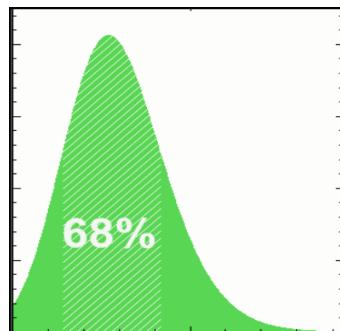
Combination
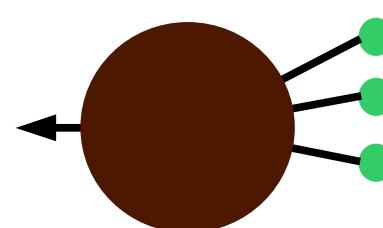
Multivariate techniques
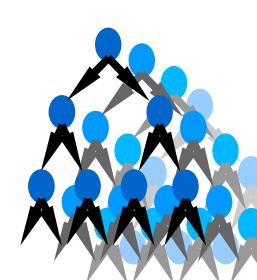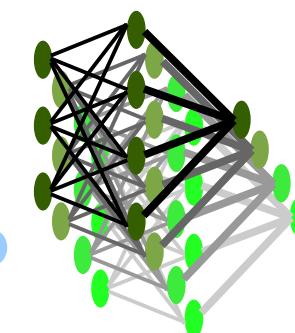
BDT   BNN   ME
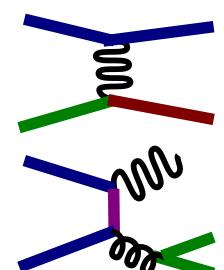
Discriminating variables

- Check data-background agreement for 600 variables
- Choose 20-64 variables for different MVAs in different channels
 - Object and event kinematics, angular correlations, top reconstruction, jet reconstruction
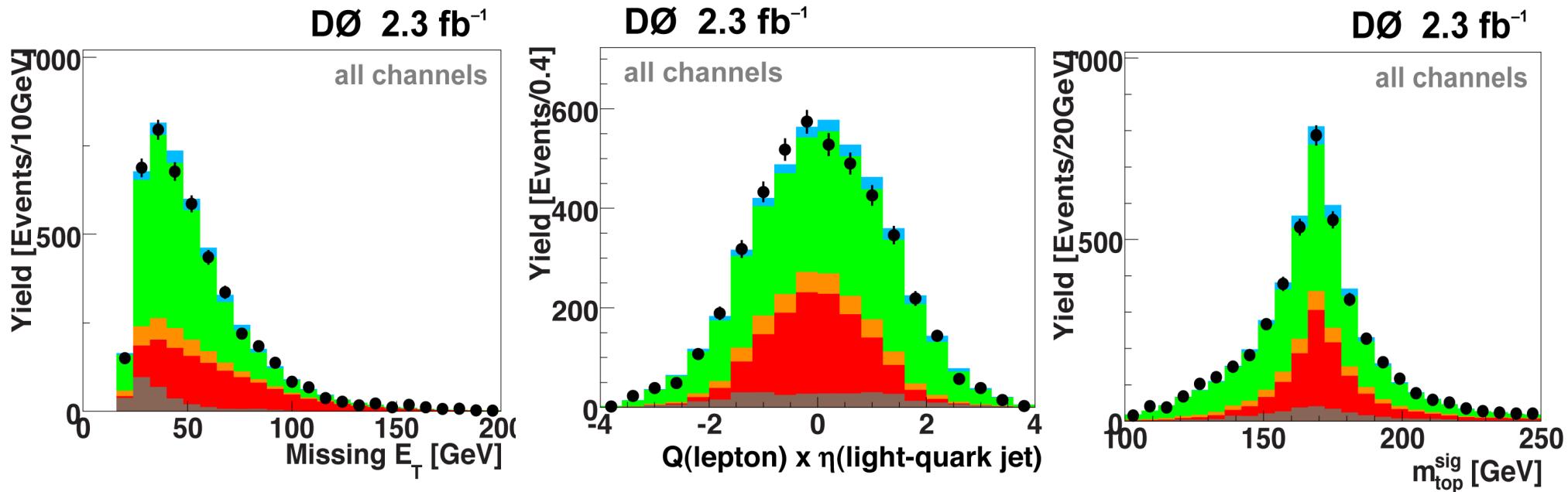
- Systematic uncertainties
  - Shape and normalization uncertainties
 - Background uncertainty 10% to 20%, larger in the signal region

# Multivariate analysis methods

Boosted Decision Trees
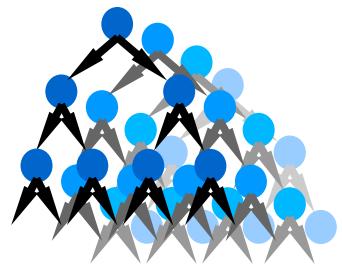
Bayesian Neural Networks
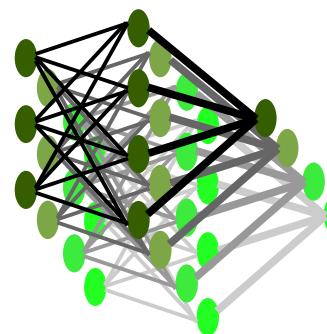
Matrix Elements
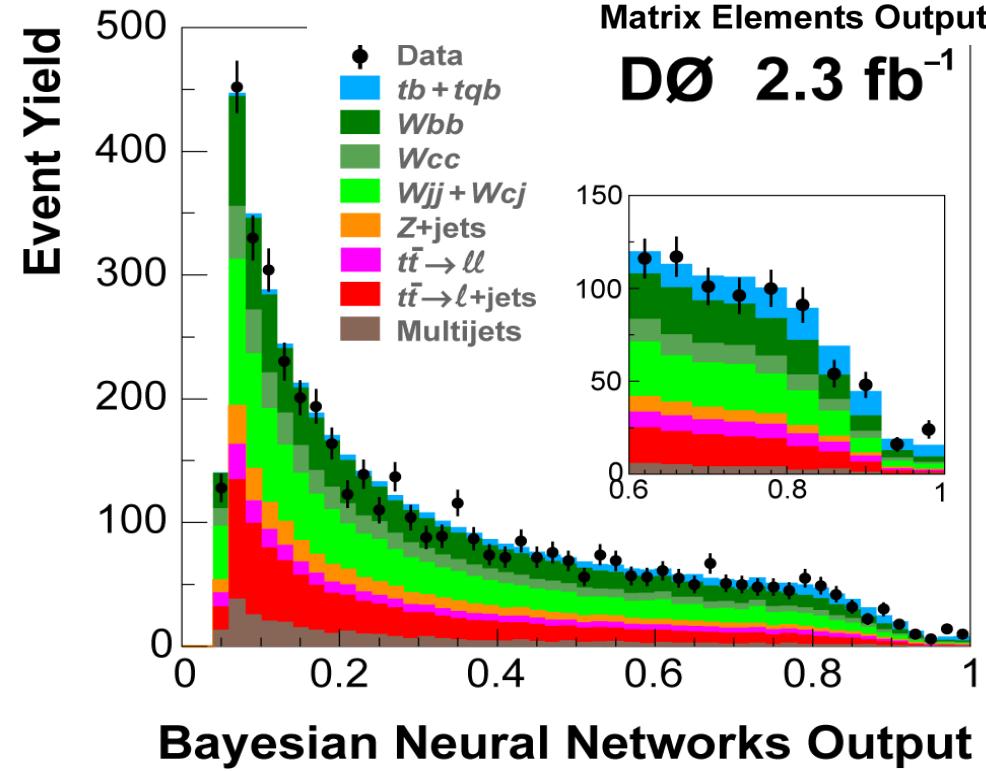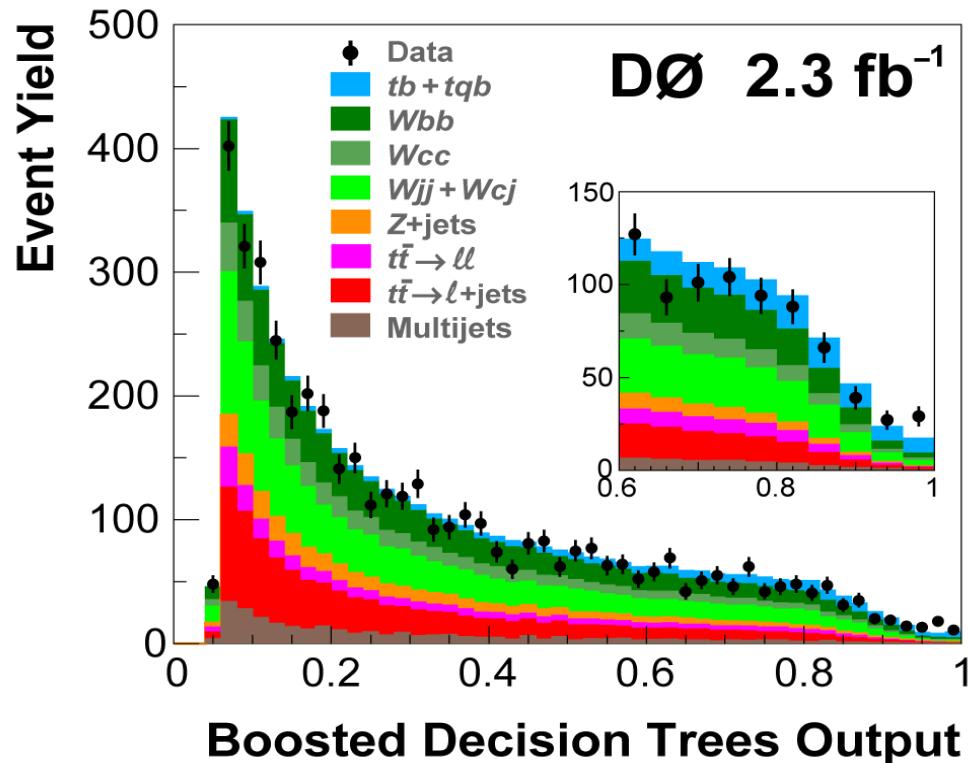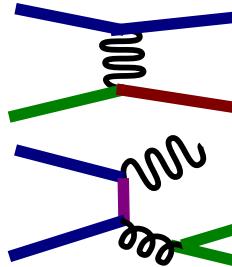
Combination: Another BNN
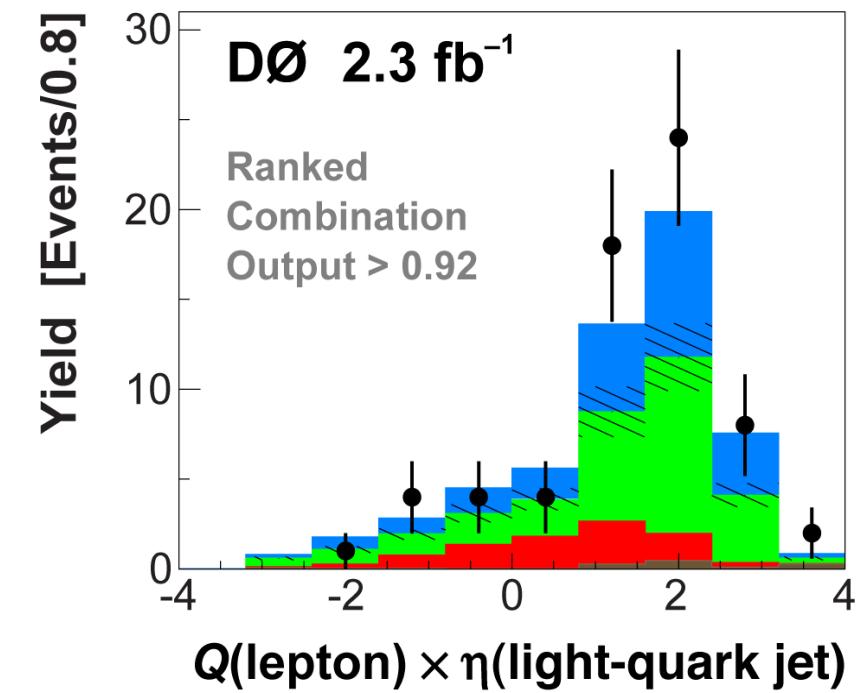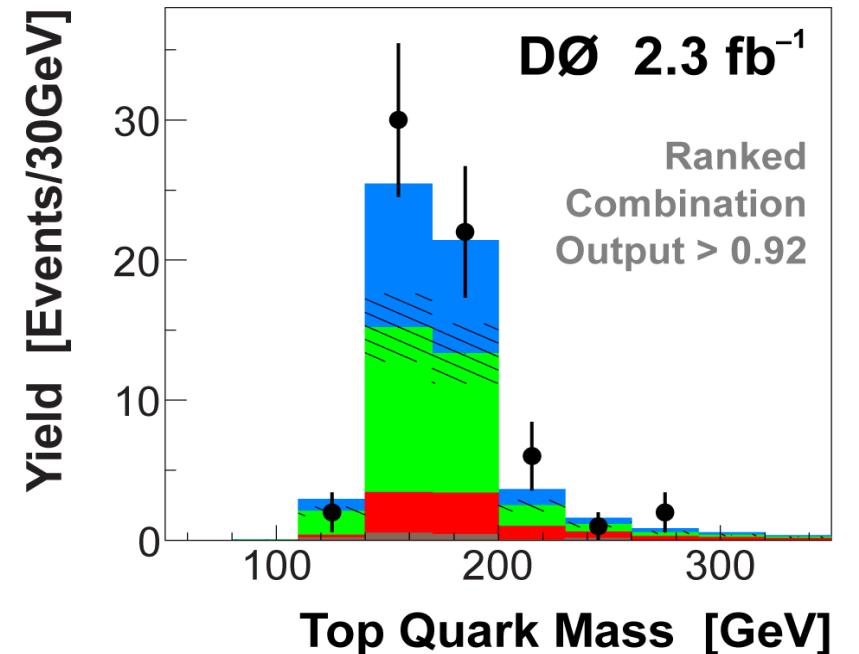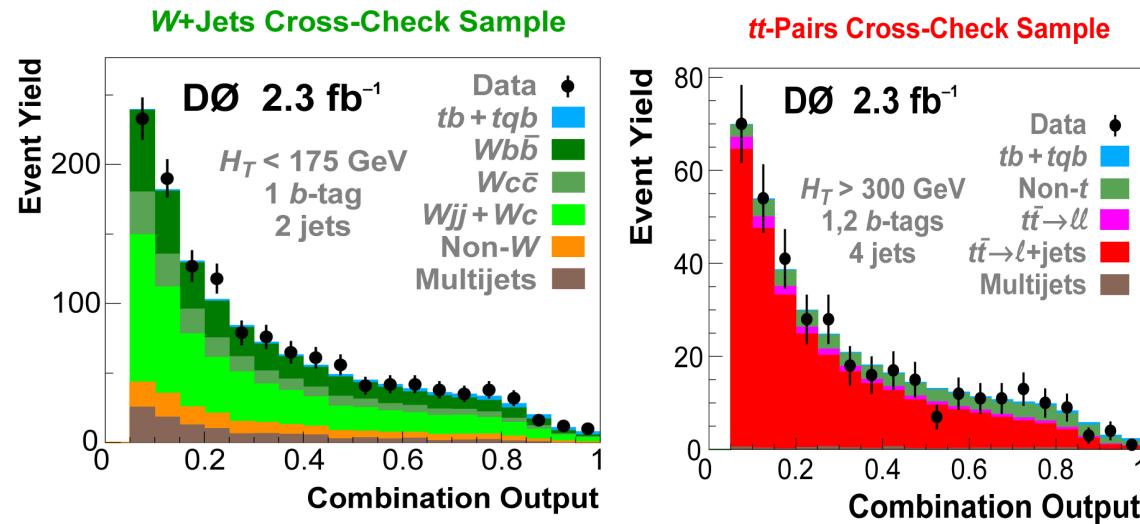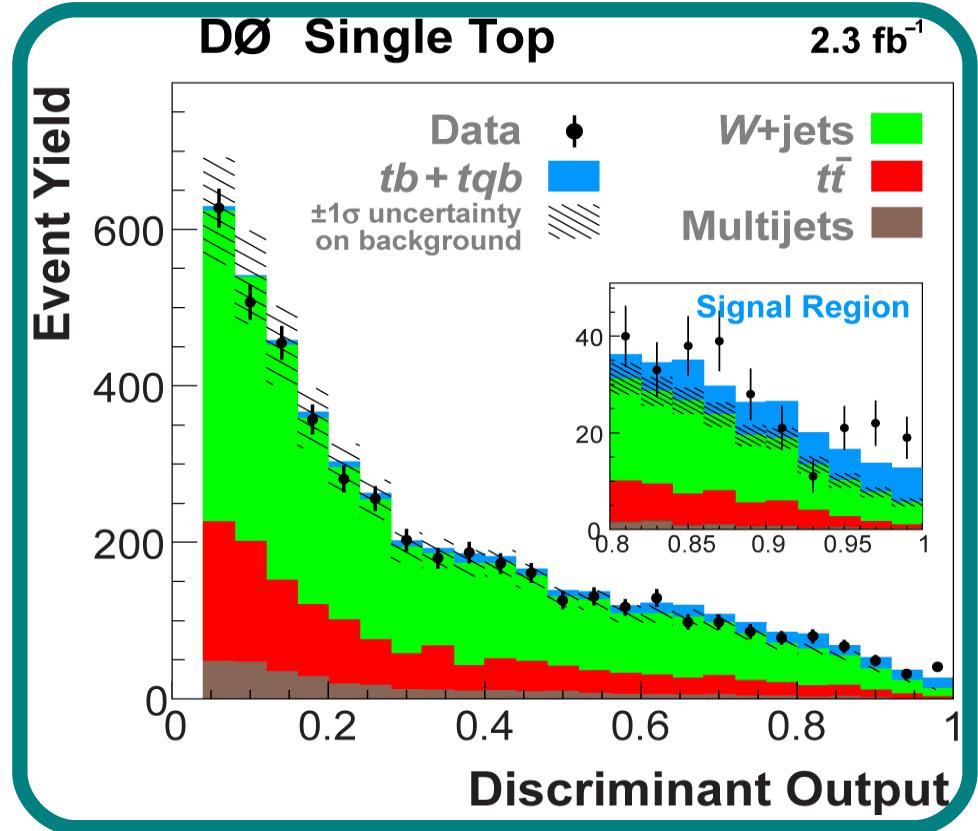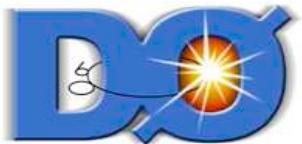
Cross section and significance

- Bayesian statistical analysis
  - Including all systematics and their correlations

$\sigma(s+t) = 3.94 \pm 0.88$ pb

- Significance and linearity from ensembles of pseudo-datasets

DØ 2.3 fb^{-1}

$\sigma^{measured} = 3.94 \pm 0.88$ pb

$\sigma^{expected} = 3.50 {}^{+0.99}_{-0.77}$ pb

$tb + tqb$ Cross Section [pb]

DØ Combination

67.8M pseudo-datasets (background-only)
17 above measured cross section

p-value = 2.5×10^{-7}

Observed significance = 5.03 σ

σ^{meas} = 3.94 pb

$tb + tqb$ Cross Section [pb]

BNN Combination

DØ

Slope = 1.017 ± 0.006
Intercept = −0.009 ± 0.032

Input $tb+tqb$ Cross Section [pb]

Measured $tb+tqb$ Cross Section [pb]
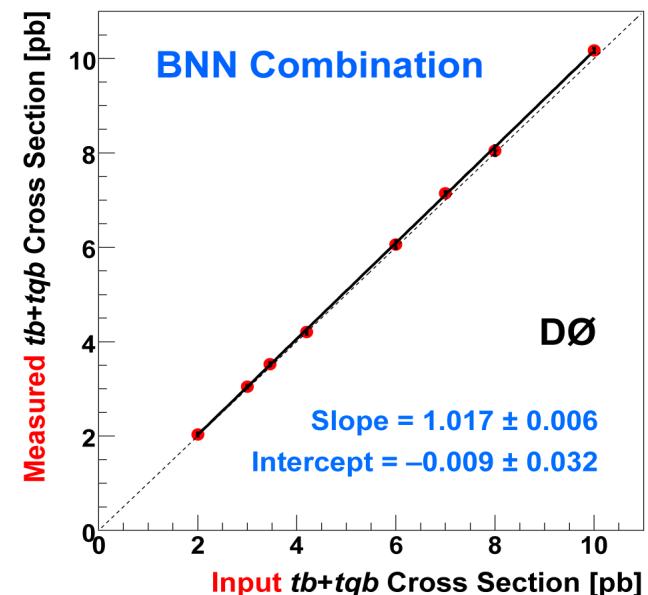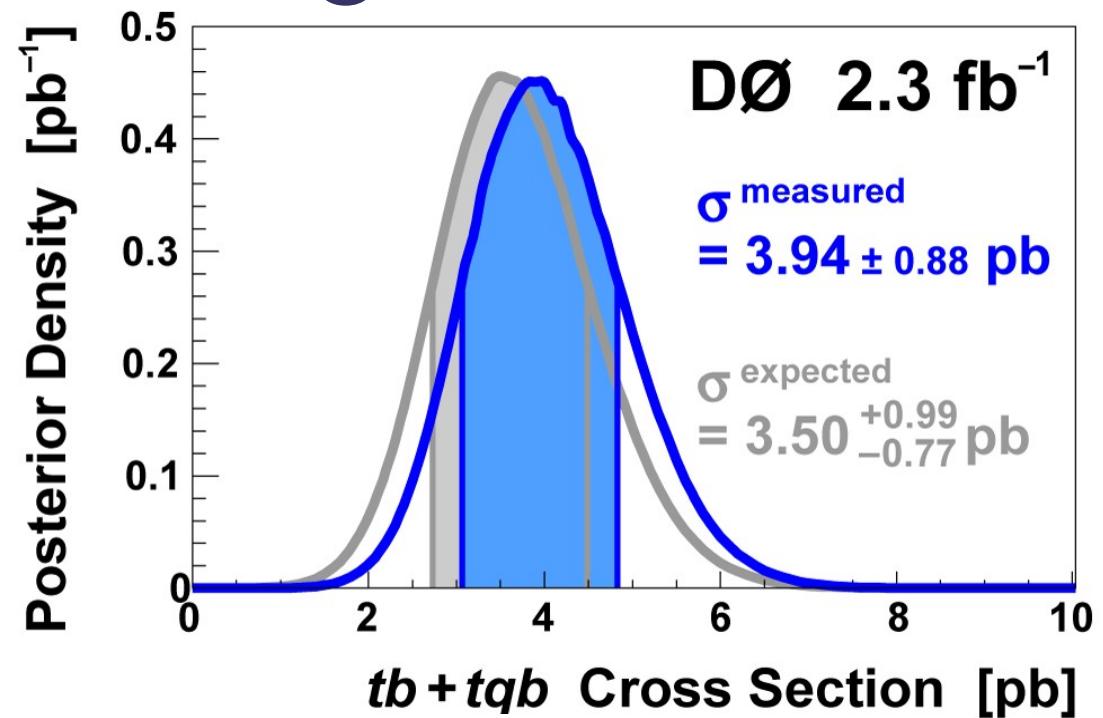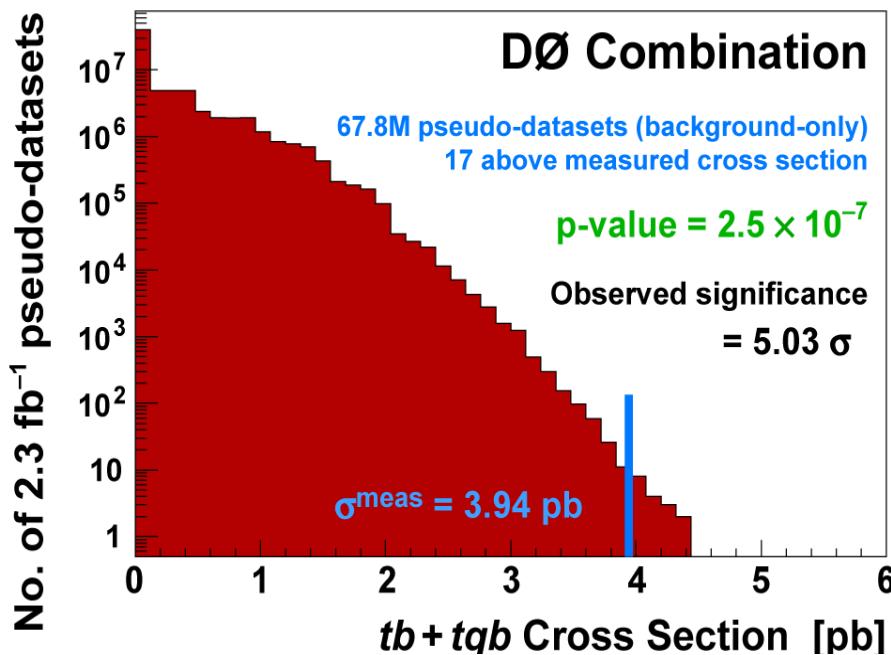
Summary and Vtb
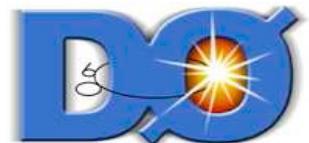
DØ 2.3 fb^{-1} Single Top Results			
Analysis Method	Single Top Cross Section	Significance	
		Expected	Measured
Boosted Decision Trees	$3.74^{+0.95}_{-0.79}$ pb	4.3 σ	4.6 σ
Bayesian Neural Networks	$4.70^{+1.18}_{-0.93}$ pb	4.1 σ	5.4 σ
Matrix Elements	$4.30^{+0.99}_{-1.20}$ pb	4.1 σ	4.9 σ
Combination	3.94 ± 0.88 pb	4.5 σ	5.0 σ

V_{tb}

t

W

$\bar{b}$

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & \boxed{V_{tb}} \end{pmatrix}$$

Decision Trees $3.74^{+0.95}_{-0.79}$ pb

Bayesian NNs $4.70^{+1.18}_{-0.93}$ pb

Matrix Elements $4.30^{+0.99}_{-1.20}$ pb

BLUE Combination   4.16 ±0.84 pb

BNN Combination   3.94 ±0.88 pb

N. Kidonakis, PRD 74, 114012 (2006) m_{top} = 170 GeV

$\sigma(p\bar{p} \to tb+X, tqb+X)$ [pb]

DØ 2.3 fb^{-1}

$|V_{tb}| > 0.78$

at 95% CL
$0 \leq$ flat prior ≤ 1

Posterior Density

95%

68%

$|V_{tb}|^2$
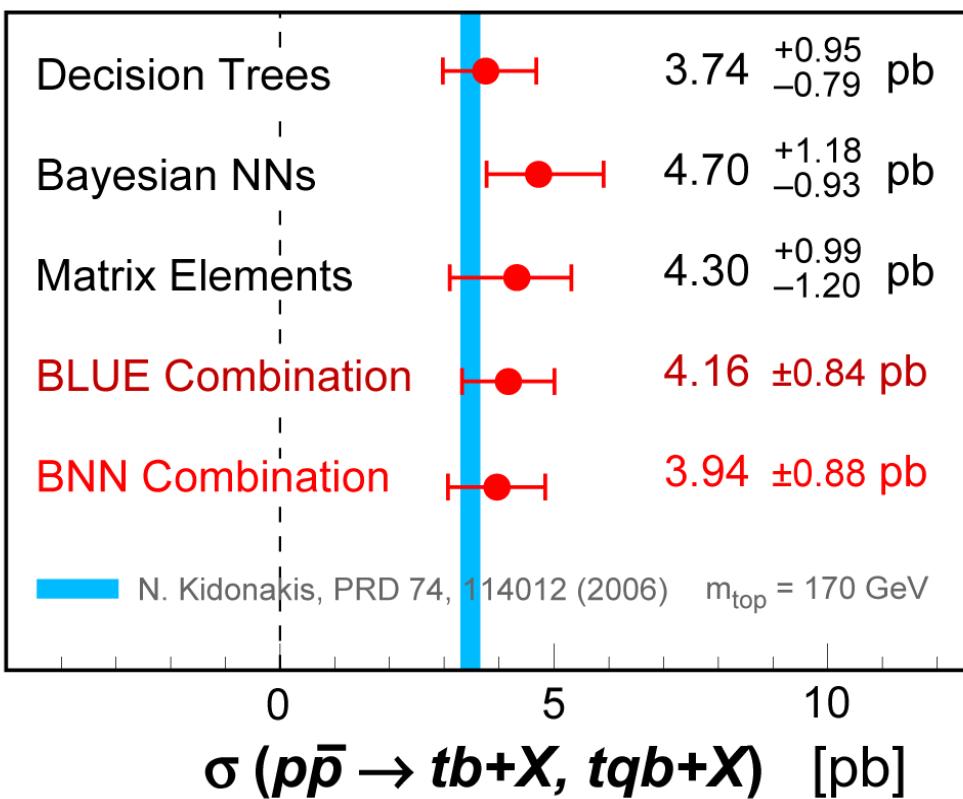
Submitted to PRL, arXiv:0903.0850

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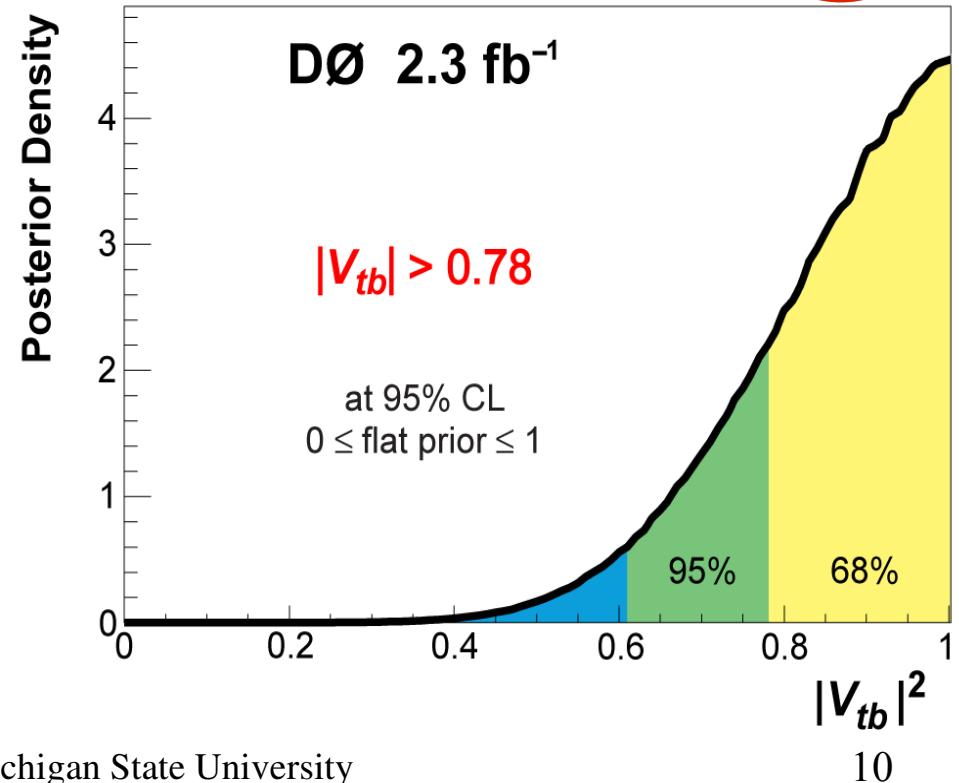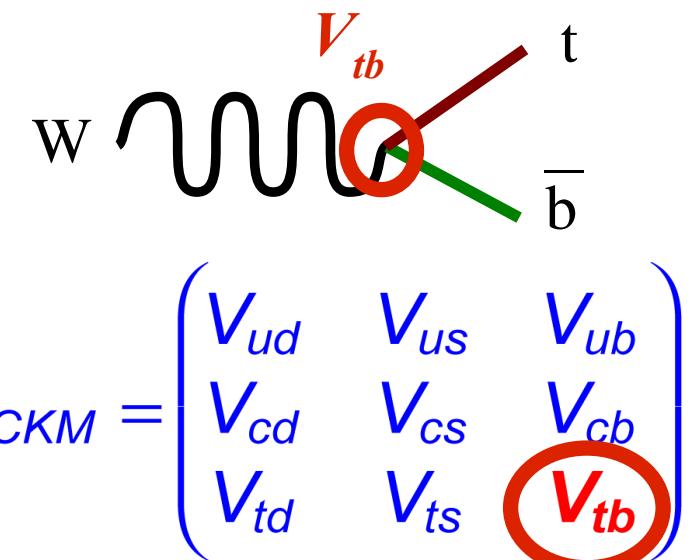
First evidence for t-channel production
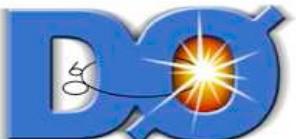
- Train MVA filters for t-channel

- Measure t-channel and s-channel simultaneously

  – Remove s/t constraint

  – $\sigma(t) = 3.14\,^{+0.94}_{-0.81}$ pb

    - Expected/observed significance: 3.7/4.8 SD

  – $\sigma(s) = 1.05 \pm 0.81$ pb
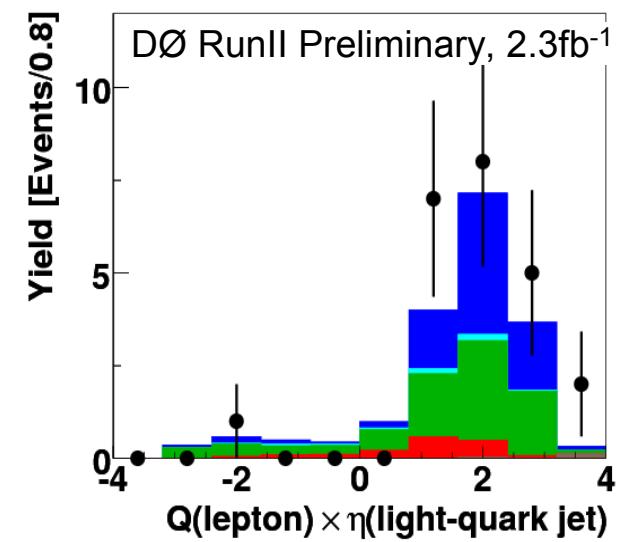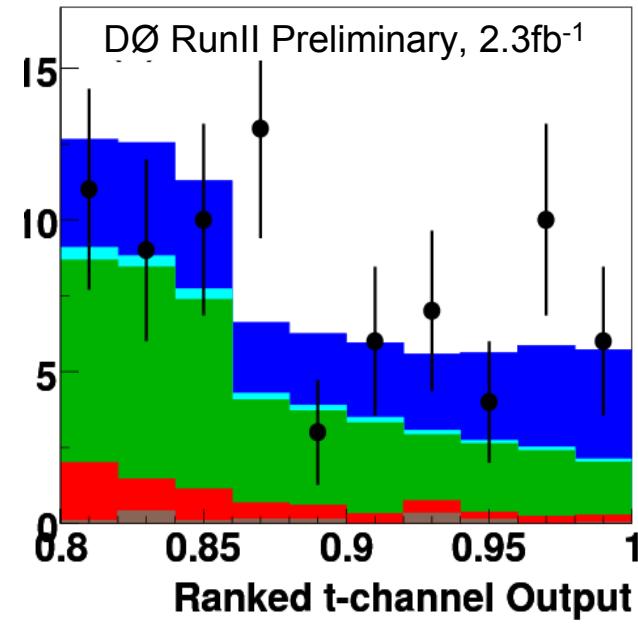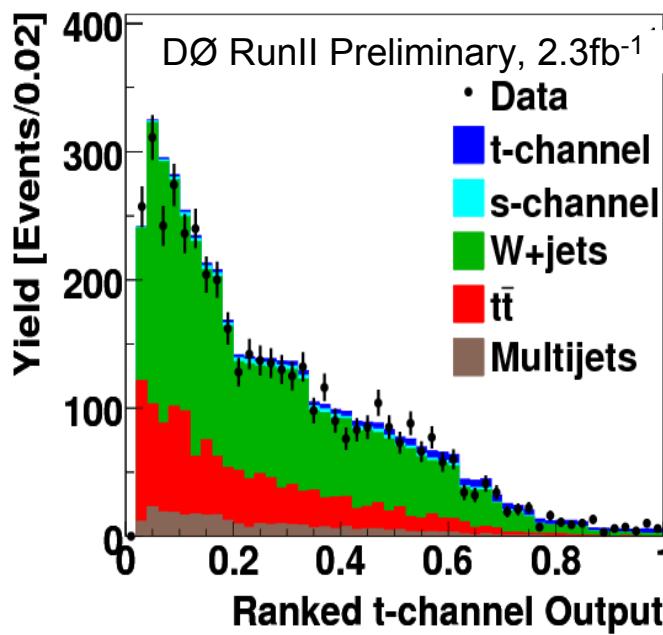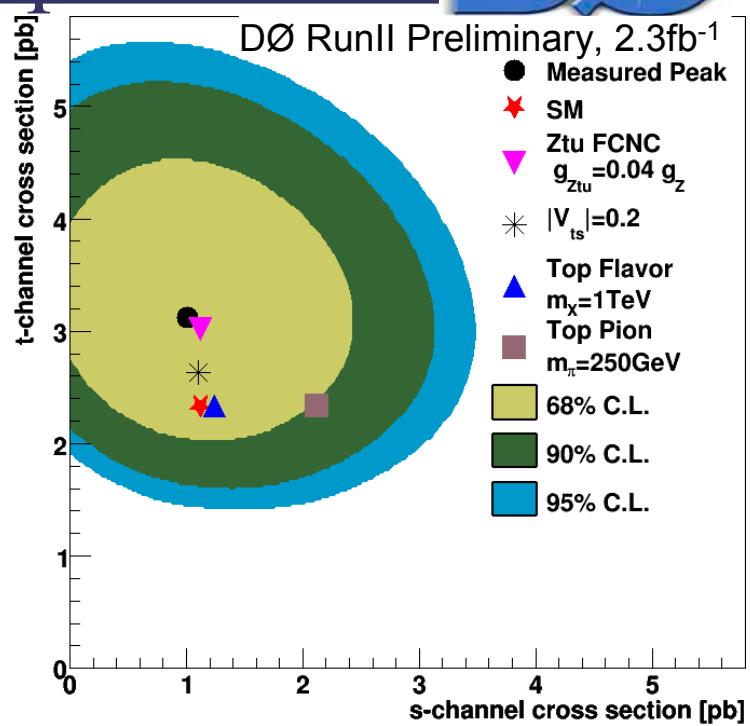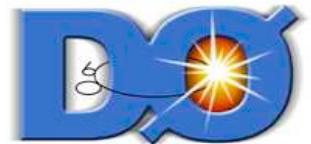
Conclusions

- We are learning a lot about the top quark at the Tevatron
- DØ has observed single top quark production at the 5.03 SD level with 2.3fb^{-1}
  - $\sigma(s+t) = 3.94 \pm 0.88$ pb
  - $|V_{tb}| > 0.78$ at 95% C.L.
- DØ has isolated the t-channel mode
  - Without assumptions about the s-channel cross section
  - $\sigma(t) = 3.14\,_{-0.81}^{+0.94}$ pb
  - Significance 4.8 SD
- Updates with larger dataset and dedicated searches for new physics are in progress