515: Top Quark Results from DØ

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Abstract. This is a brief summary of DØ's top quark measurements, including $\sigma_{t\bar{t}}$ and m_t in the ℓ+jets and dilepton channels, $\sigma_{t\bar{t}}$ in the all jets channel, and the search for top disappearance via $t\to bH^+$, $H^+\to\tau\nu$ or $c\bar{s}$.

1 $\sigma(p\bar{p}\to t\bar{t}+X)$; m_t in the ℓ+jets channel

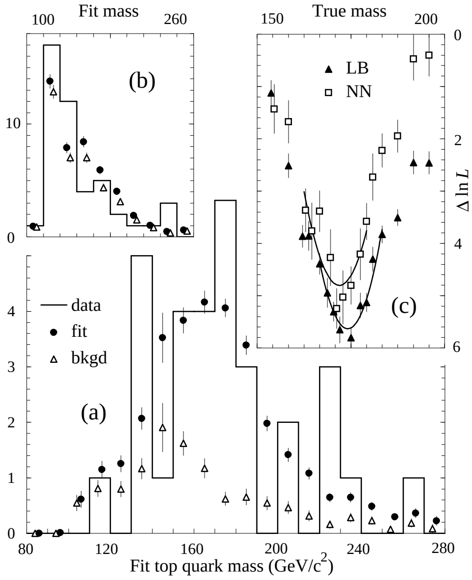
DØ recently published[1] its measurement of the top pair production cross section, $\sigma_{t\bar{t}}$=5.5±1.8 pb. It is dominated by the ℓ+jets channel, in which one of the W's from the decay $t\to bW$ decays to an isolated e or μ and the other W decays to a $q\bar{q}$ pair. Distinctive aspects of the analysis in this channel are the use of a logarithmic extrapolation in minimum jet multiplicity to estimate the main (W + $\geq$4 jets) background, and the use of stringent cuts on aplanarity ($\mathcal{A}$>0.65) and scalar transverse energy (H_T>180 GeV) to suppress it. Fig. 1 tabulates the main selection criteria and the signal and background for each channel. It includes a plot showing the excellent agreement of this result with theory.

Published[2] in the same journal issue is DØ's measurement in the ℓ+jets channel of the top quark mass, m_t=173.3±5.6±6.2 GeV/c^2. This analysis uses a multivariate discriminant $\mathcal{D}$ to separate top signal from background, based on input kinematic variables especially chosen to be only weakly correlated with the 2C fitted top mass $m_{\rm fit}$. The true top mass m_t is extracted from a likelihood (L) fit to events binned in both $m_{\rm fit}$ and $\mathcal{D}$. Fig. 1 shows the distribution of $m_{\rm fit}$ for both a top-enriched and a top-depleted sample, as well as L *vs.* m_t. Tabulated there are the fit parameters for two different definitions of $\mathcal{D}$, the systematic errors, and the result.

2 m_t in the dilepton channel

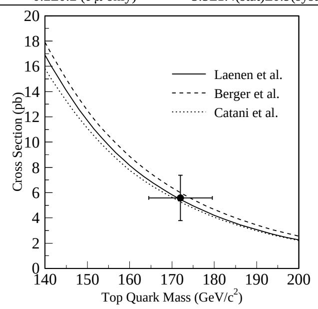
DØ's measurement of m_t in the dilepton channel has been submitted for publication[3]. Here, with both ν momenta unmeasured, the fit is $-$1C rather than +2C for ℓ+jets. If m_t is *assumed*, the system can be reconstructed via a quartic equation with 0, 2, or 4 real solutions, which usually exist for a wide range of m_t. More resolving power is gained by asking "if m_t had a certain value, how likely is it that the top decay products would appear in the detector as they did?" The factors[4] in this likelihood $\mathcal{L}(m_t)$ are: (A) $(1/\sigma_{t\bar{t}})(d\,\sigma_{t\bar{t}}/d\,\textsc{lips})$, (B) the lepton energy density $d\,N/d\,E_\ell$ in the top quark

General top pair analysis:	l+jets	l+jets/μ	dilepton	$e\nu$	all jets
# of jets	≥ 4	≥ 3	≥ 2	≥ 2	≥ 6
jet E_T (GeV)	≥ 15	≥ 20	≥ 20	≥ 30	≥ 10
H_T=sum of jet $\lvert E_T \rvert$ (GeV)	—	—	$\geq \sim 100$	—	—
# of isolated leptons (l)	1	1	2	1 (e)	0
# of tag muons (in jet cone)	0	≥ 1	—	—	≥ 1
lepton E_T (GeV)	≥ 20	≥ 20	≥ 15 or 20	≥ 20	—
missing E_T (GeV)	≥ 20 or 25	≥ 20	≥ 20 or 25	≥ 50	—
$e\nu$ M_T (GeV/c^2)	—	—	—	≥ 115	—
$l+\nu$ E_T (GeV)	≥ 60	—	—	—	—
$\lvert\eta\rvert$ of W	< 2	—	—	—	—
major background	W+jets	W+jets	Z decay	W+jets	QCD
Mass analysis: # of jets	—	≥ 4	—		
Cross section analysis:					
H_T (GeV)	≥ 180	≥ 110	$\geq \sim 100$	—	*NN*
A = aplanarity (jets+W)	≥ 0.065	≥ 0.04	—	—	*NN*



Channel	--- Expected (Laenen *et al.*) --- background	top 170	sum	Observed	σ(pb) (m_t=173.3)
Dilepton	1.4±0.4*	4.1±0.7	5.5	5 (3 $e\mu$, 1 ee, 1 $\mu\mu$)	
$e\nu$	1.2±0.4	1.7±0.5	2.9	4	
Sum (dilepton + $e\nu$)					6.3±3.3
l+jets	8.7±1.7	14.1±3.1	22.8	19	4.1±2.0
l+jets/μ	2.4±0.5	5.8±1.0	8.2	11	8.2±3.5
Total	**13.7±2.2**	**25.7±4.6**	**39.4**	**39**	**5.5±1.8**†

*0.2±0.2 ($e\mu$ only)   5.5±1.4(stat)±0.9(syst)±0.6(gen)†



Fits to data	---LB fit---		---NN fit---	
Quantity fit	value	σ(stat)	value	σ(stat)
m_t (GeV/c^2)	174.0	± 5.6	171.3	± 6.0
n_s	23.8	$^{+8.3}_{-7.8}$	28.8	$^{+8.4}_{-9.1}$
n_b	53.2	$^{+10.7}_{-9.3}$	48.2	$^{+11.4}_{-8.7}$
m_t correlation of LB and NN fits	(88 ± 2)%			
Systematic error on m_t	energy scale ± 4.0			
	generator ± 4.1			
	other ± 2.2			
Resulting m_t (GeV/c^2)	**173.3 ± 5.6 (stat) ± 6.2 (syst)**			

Combined top quark mass from lepton+jets analysis (above) and dilepton analysis (below):
$m(t)$ = 172.0 ± 5.1(stat) ± 5.5(syst) GeV/c^2

Analysis method	Result of fit to m_t (GeV/c^2)
Matrix element weighting	168.1 ± 12.4(stat)
Neutrino weighting	169.9 ± 14.8(stat)
Combined (77% correlated)	168.4 ± 12.3(stat)
Source of systematic error	σ(m_t) (syst) (GeV/c^2)
jet energy scale	2.4
signal model	1.8
multiple interactions	1.3
background model	1.2
likelihood fit	1.3
Total systematic error	3.7
m_t (GeV/c^2) from dileptons	**168.4 ± 12.3(stat) ± 3.7(syst)**

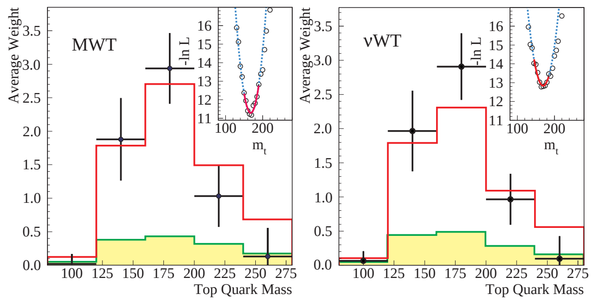


Fig. 1. Collage of DØ top quark results. Top left: main selection criteria by channel. Beneath: event statistics and $\sigma_{t\bar{t}}$, total and by channel; plot comparing measured $\sigma_{t\bar{t}}$ to theory. Top right: distributions in $m_{\rm fit}$ for (a) top enriched and (b) top depleted ℓ+jets samples; (c) likelihood *vs.* m_t. Beneath: fit parameters for two different discriminants; errors and resulting m_t. Bottom left: results and errors for m_t from dileptons. Bottom right: average weight in 5 m_t regions for both dilepton weights, with likelihood *vs.* m_t inset. Box: combined m_t.

rest frame, and (C) the Jacobian $|\partial\,\text{LIPS}/\partial\,\{o\}|$, where $\{o\}$ (LIPS) is the set of observed (Lorentz-Invariant Phase Space) variables.

We make two independent approximations to $\mathcal{L}(m_t)$. The *matrix element weight* (MWT) method ignores (C), includes (B), and approximates (A) using a product of proton pdf's with an empirical m_t dependent factor. The *neutrino phase space weight* (νWT) method ignores (A) and (B). It approximates (C) by predicting $\not{E}_T$ after fixing both ν rapidities to many different values. This is compared to the measured $\not{E}_T$ and a likelihood sum is incremented. To obtain the final weight, we sum over quartic solutions, jet assignments (including ISR and FSR), and many resolution-smeared versions of each event.

For both methods, a vector consisting of the fractional weight integrated over each of five m_t regions is stored for each event. To estimate the probability densities for signal and background in this vector space, we accumulate a Gaussian kernel for each event in the modeled sample. Plotted in Fig. 1 for each of the five m_t regions and both methods are the average weight for 6 data events, the best fit mixture, and the background. Inset is the likelihood *vs.* m_t. Tabulated also in Fig. 1 are the fit parameters for both methods, the systematic errors, and the result m_t=168.4±12.3±3.7 GeV/c^2. Combining this with DØ's ℓ+jets result, we obtain m_t=172.0±5.1±5.5 GeV/c^2.

3 $\sigma(p\bar{p}\rightarrow t\bar{t}+X)$ in the all jets channel

When both of the daughter W's decay into $q\bar{q}$, at least six jets are produced (we rank them with jet 1 highest in E_T). Compared to the huge background from QCD multijets, top events in this channel are harder, less planar, and more central, with stiffer nonleading jets. As inputs to the first of two neural networks (NN$_1$ and NN$_2$ with outputs $\mathcal{O}_1$ and $\mathcal{O}_2$), we use 2-3 kinematic variables for each property. These are H_T, $\sqrt{\hat{s}}$, $E_T(\text{jet } 1)/H_T$, $\mathcal{A}$, sphericity, centrality ($=H_T/\sum E(\text{jets})$), rms η weighted by E_T, geometric mean η^2 and E_T of jets 5 and 6, H_T excluding jets 1 and 2, and E_T weighted no. of jets.

Events are required to have ≥1 non-isolated μ (tagging ≥1 jet as a b candidate). The inputs to NN$_2$ are $\mathcal{O}_1$; $p_T(\mu)$; a variable sensitive to the quality of a constrained fit to any top mass; and a Fisher discriminant sensitive to the jet width (considering signal to be quarks, background to be gluons). Both NN's are trained on HERWIG $t\bar{t}$ events as signal. The background model is non μ-tagged data to which a μ-tag-rate function $f(p_T(\mu), \text{jet } E_T, \text{detector } \eta)$ is applied. For all 14 NN inputs, observed (μ-tagged data) distributions agree with those of the model.

Fig. 2 exhibits the best fit for μ-tagged data of $\mathcal{O}_2$ to a sum of signal and background, with the background normalization and top cross section as free parameters. The preliminary result is $\sigma_{t\bar{t}}$=7.9±3.1±1.7 pb. The largest systematic uncertainties are in the background model (11%), $p_T(\mu)$ spectrum (7%), μ efficiency (7%), and μ-tag parametrization (7%), with nine smaller sources. Requiring $\mathcal{O}_2$>0.78, we obtain 44 events with an expected background of 25.3±7.3 and an expected top signal of 11.6±4.5. The observed excess corresponds to a Gaussian equivalent background fluctuation of ≈3σ.

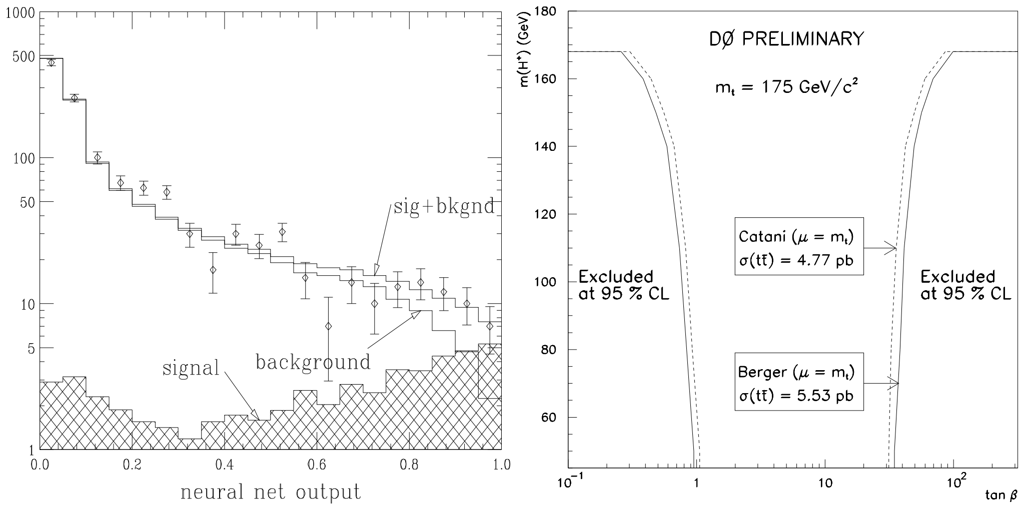


Fig. 2. Preliminary DØ results. Left: best fit for output of NN$_2$ to a mixture of all jets top signal and background. Right: regions in the M_{H^+} *vs.* $\tan\beta$ plane excluded, each at 95% CL, by top disappearance search with the MSSM parameters shown.

4 Top disappearance via $t\to bH^+$, $H^+\to\tau\nu$ or $c\bar{s}$?

If one or both of the produced $t\bar{t}$ were to decay to $H^{\pm}b$ rather than $W^{\pm}b$, the ℓ+jets analysis used for DØ's top cross section measurement would be less efficient, causing a shortfall in the measured cross section relative to the SM calculation. Within the MSSM, $t\to H^+b$ occurs primarily at low and high $\tan\beta$. The shortfall occurs both at low $\tan\beta$, where $H^+\to c\bar{s}$, and at high $\tan\beta$, where $H^+\to\tau\nu$, due mainly to a lack of energetic isolated leptons. It leads to exclusion regions at the $\tan\beta$ extremities of the M_{H^+} *vs.* $\tan\beta$ plane, based on the relative likelihood *vs.* $\log\tan\beta$ of obtaining the observed number (30) of ℓ+jets events, for a given M_{H^+}.

Fig. 2 shows this exclusion region for two values of calculated $\sigma_{t\bar{t}}$. Within the MSSM, taking m_t=175 GeV/c^2 and $\sigma_{t\bar{t}}$=5.53 pb, at 95% confidence the data require 0.96(0.26)< $\tan\beta$ for M_{H^+}=50(168) GeV/c^2, or $\tan\beta$ <35(96) for M_{H^+}=50(168) GeV/c^2. The dependence on m_t and on renormalization scale μ is modest over most of the M_{H^+} *vs.* $\tan\beta$ plane.

References

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[2] DØ Collaboration, S. Abachi *et al.*, Phys. Rev. Lett. **79** (1997), 1197.
[3] DØ Collaboration, B. Abbott *et al.*, submitted to Phys. Rev. Lett., hep-ex/970614 (1997).
[4] M. Strovink for the DØ Collaboration, HEP 93 (Proc. Europhysics Conf. on HEP, Marseille, J. Carr and M. Perrottet, eds.) (1994) 292.