More Top Quark Physics and the Trigger Program

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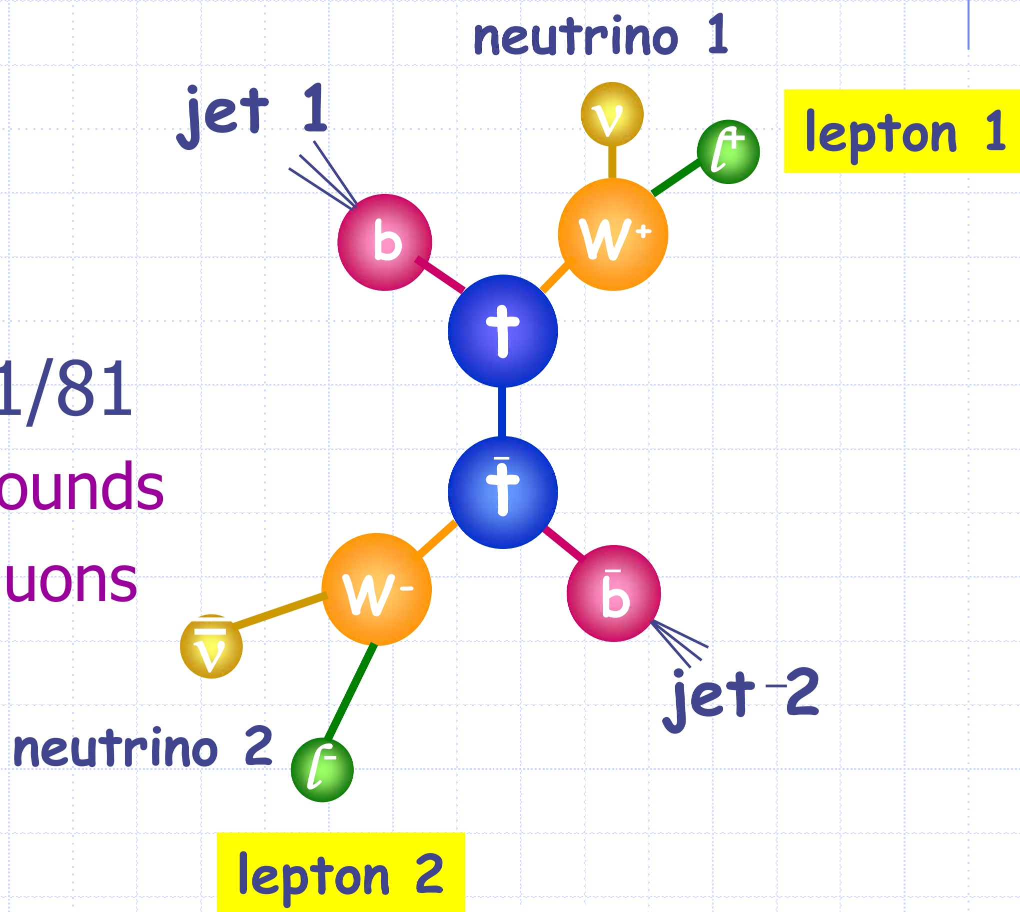
Top Pair Production Cross Section

- Given our expertise in muon detectors and triggering, one of the first Run II top physics measurements we performed was the $t\bar{t}$ production cross section in the $\mu\bar{\mu}$ channel
  - Early studies and machinery development
  - Measurement of $\sigma_{t\bar{t}}$ using 240 pb^{-1} (published)
  - Measurement of $\sigma_{t\bar{t}}$ using 370 pb^{-1} (conference)
  - Measurement of $\sigma_{t\bar{t}}$ using 370 pb^{-1} in all dilepton channels including lepton plus track and with improved muon identification (to be published)
  - Susan Burke Ph.D. defense in 12/06 or 01/07

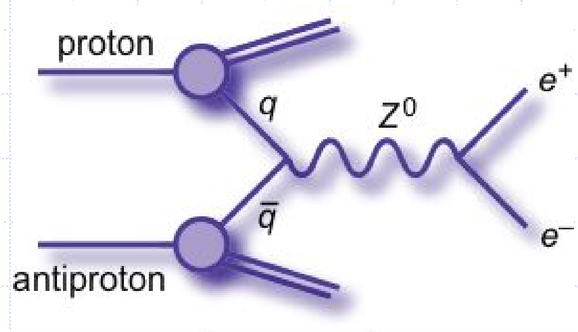
Top Pair Production Cross Section

- Signature for $t\bar{t} \rightarrow \mu\mu$
  - 2 high P_T leptons
    - Isolated
  - 2 high E_T jets
  - Large missing E_T
- Branching ratio = 1/81
  - But smaller backgrounds
  - Low rate of fake muons



Top Pair Production Cross Section

- Physics backgrounds
  - $Z/\gamma^* \to \tau\tau \to \mu\mu$ and WW/WZ
  - With intrinsic missing E_T
  - Estimated from Monte Carlo
- Instrumental backgrounds
  - $Z/\gamma^* \to \mu\mu$
  - Fake missing E_T
  - Estimated from Monte Carlo normalized to data
  - $W + jets$ and $multijet$
  - Fake muon isolation
  - Estimated from data



Top Pair Production Cross Section

Efficiencies

Category	Cut	Efficiency	Cum. Efficiency
Muon Identification	Muon ID & Track Match	0.512 ± 0.006	0.512
	$\kappa_{\mu ID}$	1.020	0.522
	$\kappa_{trk-match}$	0.968	0.505
	Muon Track-χ^2	0.995 ± 0.001	0.503
	$\kappa_{trk-\chi^2}$	0.968	0.487
	Opposite Charge	0.888 ± 0.005	0.432
	Muon $p_T > 15$ GeV	0.714 ± 0.008	0.308
Channel Orthogonality	Veto on one EM	0.997 ± 0.001	0.308
Trigger		0.924 ± 0.006	0.284
Jets	≥ 2 Jets	0.811 ± 0.009	0.231
	≥ 2 Jets with $p_T > 20$ GeV	0.927 ± 0.006	0.214
Primary Vertex	$\lvert z \rvert < 60$ cm, $N_{trk} \geq 3$	0.989 ± 0.003	0.212
	κ_{PV}	0.997	0.211
	$\lvert z^{d0root} - z^{reco} \rvert < 5$ cm	0.994 ± 0.002	0.210
	$\kappa_{root-reco}$	1.000	0.210
Muon Promptness	$\lvert z^{\mu} - z^{PV} \rvert < 1$ cm & $\lvert z^{\mu} - z^{PV} \rvert < 1$ cm	0.999 ± 0.001	0.210
	κ_{lv}	0.990	0.208
	Muon DCA Significance	0.866 ± 0.009	0.180
	κ_{DCA}	0.988	0.177
Muon Isolation	$Rat11 < 0.12$ & $Rattrk < 0.12$	0.729 ± 0.012	0.129
	κ_{Iso}	1.001	0.129
Z Fitter	$\chi^2 > 2$	0.788 ± 0.013	0.102
Contour Cut		0.616 ± 0.018	0.063 ± 0.003

Top Pair Production Cross Section

- L1 and L2 trigger efficiencies

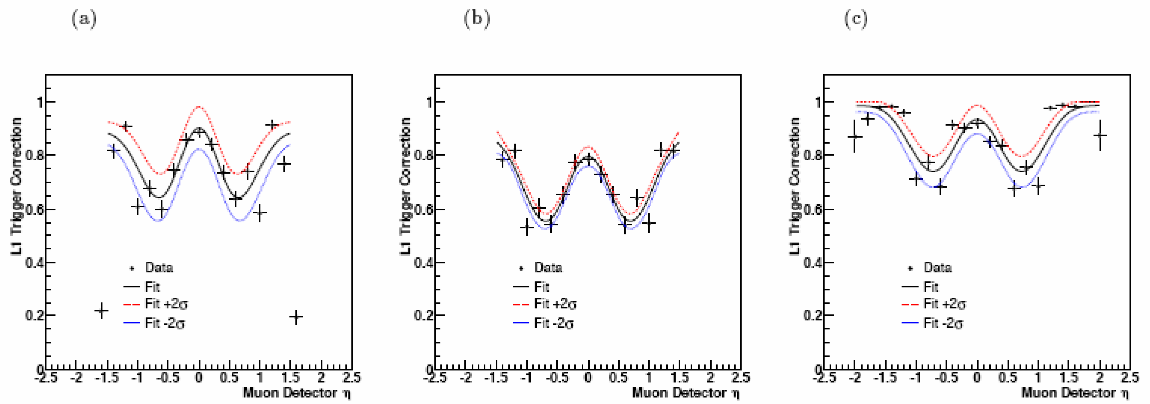


FIG. 4: L1 trigger efficiencies with errors (a), MUW_W_L2M3_TRK10 (b) MUH2_LM15 (c) Dimuon Trigger

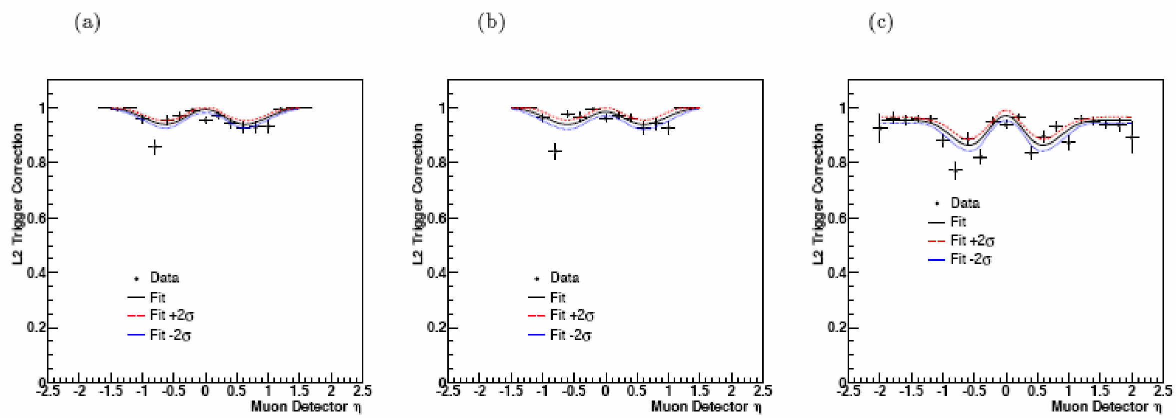
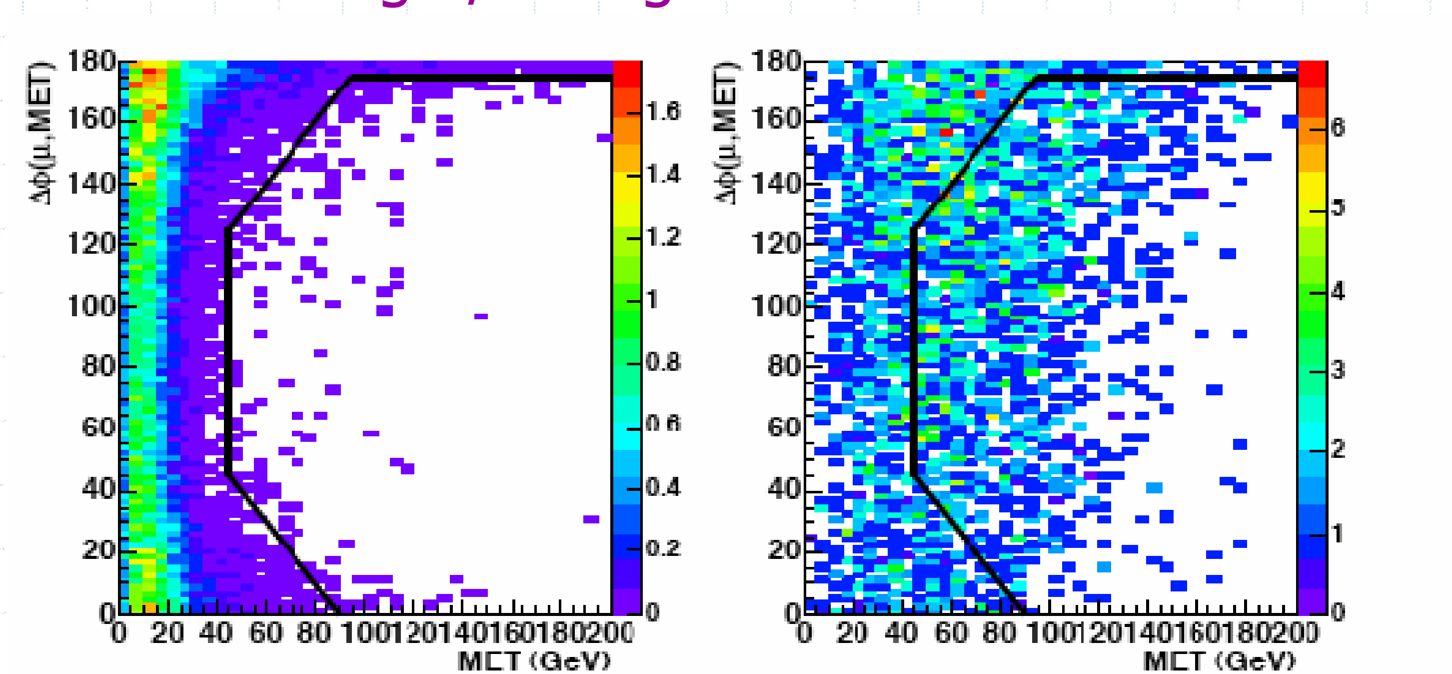


FIG. 5: L2 trigger efficiencies with errors (a), MUW_W_L2M3_TRK10 (b) MUH2_LM15 (c) Dimuon Trigger

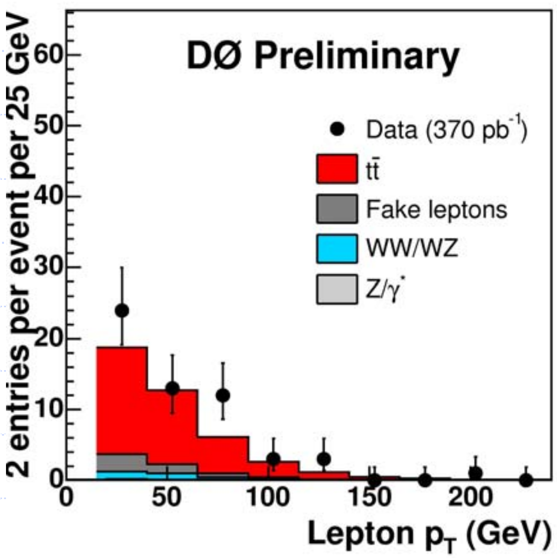
Top Pair Production Cross Section

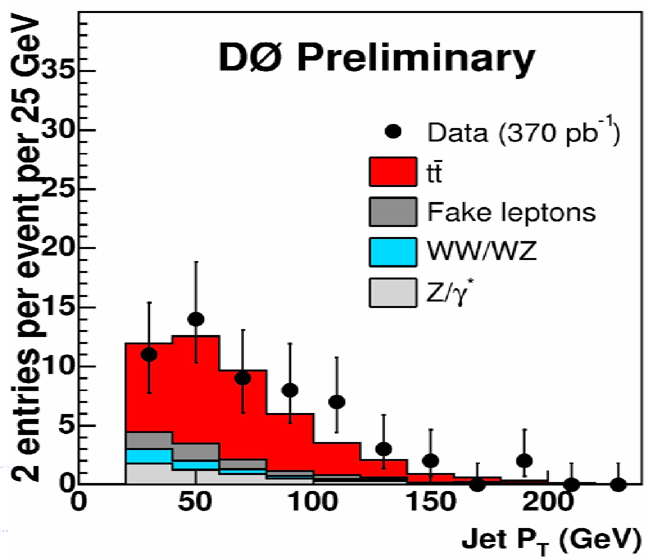
- χ^2_Z and a contour cut (below) are used to reduce the Z/γ^* background
  - Cut values optimized using 2400 combination grid search using $S/\sqrt{B}$ significance

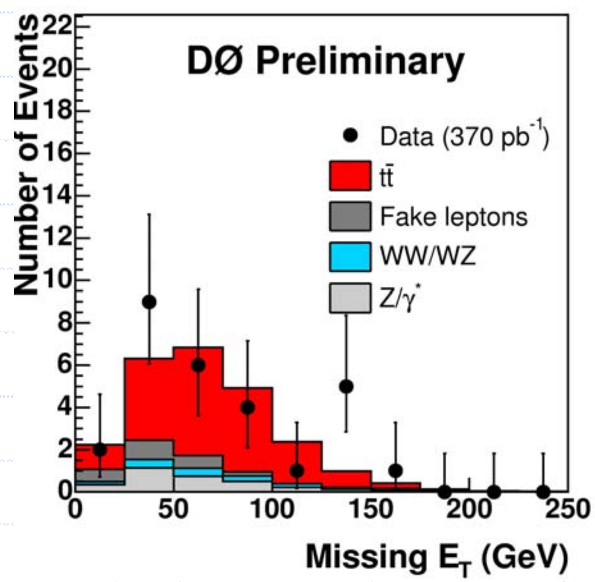


Top Pair Production Cross Section

- Data – Monte Carlo agreement (all dilepton channels combined)







Top Pair Production Cross Section

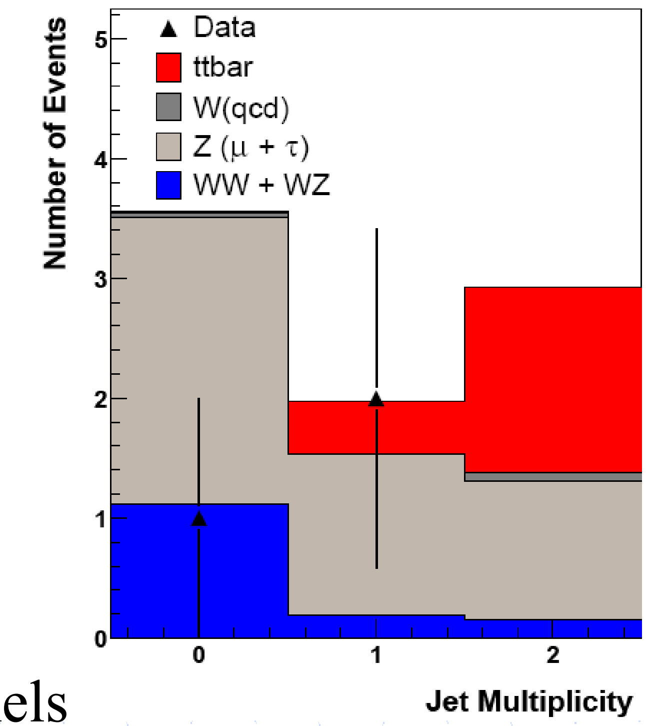
- Systematic uncertainties

Source	$t\bar{t}$
Primary vertex	± 0.4
$\Delta z(d\O reco, d\O root)$	± 0.2
Lepton promptness	± 0.1
μ ID	± 3.0
μ isolation	± 0.8
μ σ_{dca}	± 0.6
μ tracking	± 2.4
χ^2	± 0.2
μ smearing	-0.2 +0.1
L1 μ trigger	+3.9 -4.8
L2 μ trigger	+0.2 -0.4
JES	+5.7 -7.4
Jet ID	+0.4 -4.9
Jet energy resolution	-2.5 -1.4
Uncorrelated	$\pm$ 3.1

Top Pair Production Cross Section

Results for 240 pb^{-1}

Category	Yield	Stat Err	Sys Err
WW/WZ	0.16	0.02	$^{+0.07}_{-0.06}$
Z/γ^* (μ or τ)	1.14	0.16	$^{+0.38}_{-0.30}$
W/QCD (Isolation Fakes)	0.07	0.04	$^{+0.02}_{-0.02}$
Total Bkg	1.37	0.16	$^{+0.47}_{-0.39}$
Expected signal	1.55	0.07	$^{+0.20}_{-0.22}$
Selected Events	0	–	–



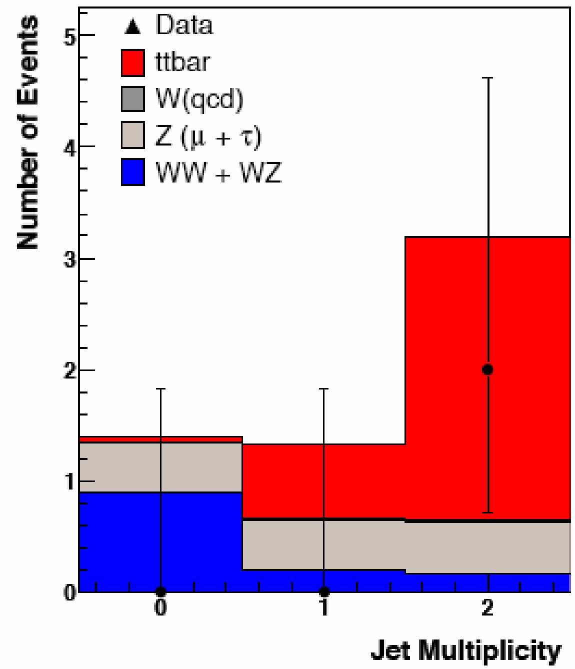
$\sigma_{t\bar{t}}$ for the combined $e\mu(8)$, $ee(5)$, and $\mu\mu(0)$ channels is found by maximizing the likelihood to observe the N_{obs} in the data given N_{bkg} and ε_{sig}

$$\sigma_{t\bar{t}} = 8.6^{+3.2}_{-2.7}(stat) + 1.1(syst) + 0.6(lumi)\ pb$$

Top Pair Production Cross Section

- Results for 370 pb^{-1}

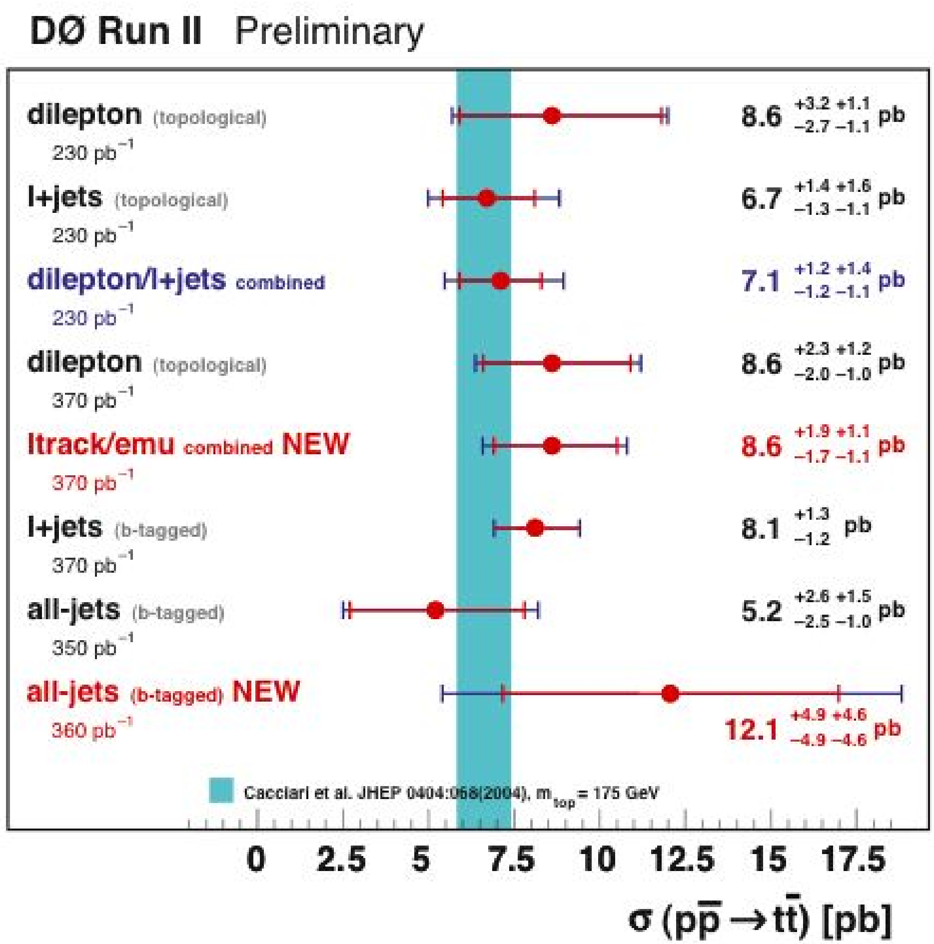
Category	Yield	Stat Err	Sys Err
WW/WZ	0.162	0.026	$^{+0.079}_{-0.054}$
Z/γ^* (μ or τ)	0.471	0.082	$^{+0.144}_{-0.155}$
WQCD (Isolation Fakes)	0.009	0.003	$^{+0.003}_{-0.003}$
Total Bkg	0.642	0.086	$^{+0.212}_{-0.200}$
Expected signal	2.549	0.068	$^{+0.262}_{-0.296}$
Selected Events	2	–	–



$$\sigma_{t\bar{t}} = 3.72^{+4.84}_{-3.02}\,(\text{stat})\ ^{+1.03}_{-0.96}\,(\text{syst})\ \pm 0.24\,(\text{lumi})\ \text{pb};$$

Top Pair Production Cross Section

- Combined results for 370 pb^{-1}
  - eμ (21), ee (5), and μμ (2)
  - Not including improved muon ID analysis



Top Pair Production Cross Section

- Status
  - Stefan Anderson is the lead author of the 370 pb^{-1} cross section PRD
  - This PRD will contain all three dilepton channels plus *e+track* and *μ+track* channels
    - These latter require 1 isolated lepton plus 1 isolated track with at least one jet tagged as a b-jet
    - The five channels are not orthogonal so correlations must be determined
  - EB approval of this paper is in progress

Top Mass in the Dilepton Channel

- Precision measurements of the W boson and top quark masses provide a constraint on the Higgs boson mass
- The measurement of the top mass in the dilepton channel is statistically limited but can be used as a consistency check and compared with other channel
  - Early studies and machinery development
  - Measurement of top mass using neutrino weighting using 370 pb^{-1} (conference)
  - Measurement of top mass using neutrino weighting and matrix element weighting using 370 pb^{-1} (submitted to PRL)
  - Jeff Temple Ph.D. defense in 11/06

Top Mass in the Dilepton Channel

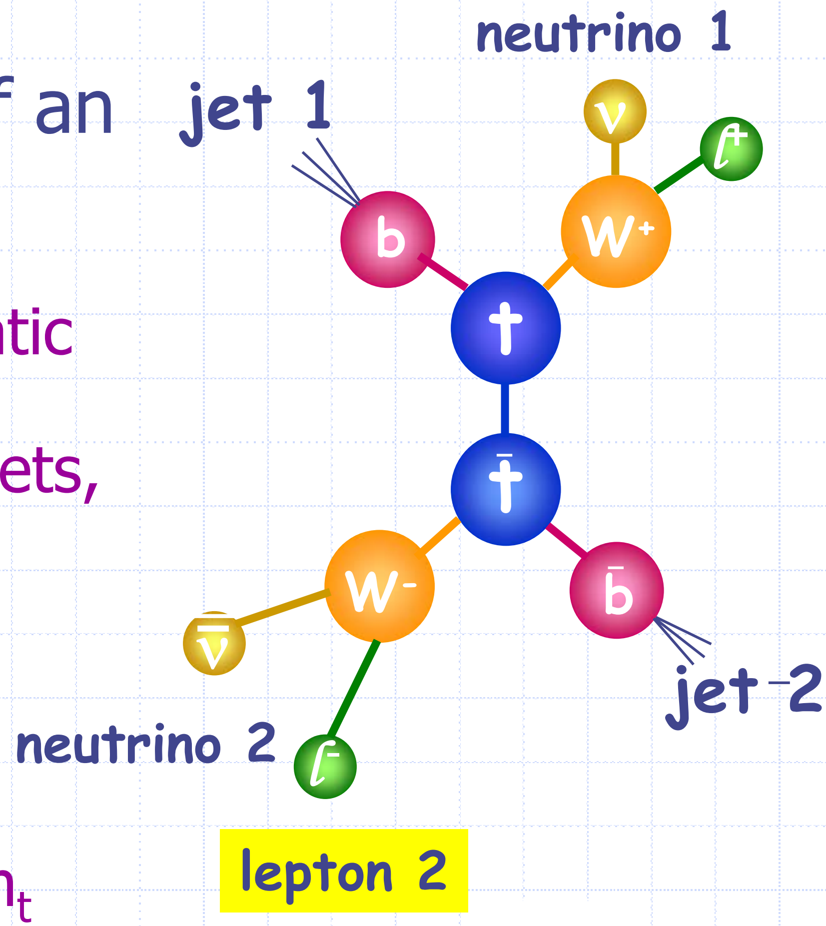
- Start with isolated dileptons
  - Cuts that maximize S/B include
    - H_T > 122 GeV for *eμ*
    - S > 0.15 and E_T^{miss} > 35 GeV for *ee*
    - χ^2_Z and contour cut in *μμ*
    - > 0 b-tagged jets and E_T^{miss} > 35 GeV in *l+track*

TABLE I: Expected and observed dilepton event yields for $t\bar{t}$ production with m_t = 175 GeV and the backgrounds from WW and Z production based on Monte Carlo, and from misidentified leptons (mis-id) based on collider data.

Sample	$t\bar{t}$	WW	Z	Mis-id	Total	Data
$\ell\ell$ no-tag	7.2	1.1	2.6	2.2	$13.2^{+2.8}_{-2.1}$	12
$\ell\ell$ b-tag	9.9	0.05	0.12	0.09	10.1 ± 0.9	14
$\ell\ell$ tight	15.8	1.1	2.4	0.5	19.8 ± 0.6	21
ℓ+track	11.3	0.02	4.4	0.4	16.2 ± 1.1	15

Top Mass in the Dilepton Channel

- This channel is challenging because of an underconstrained kinematic fit
  - 18 independent kinematic variables
  - 12 measured directly (jets, charged leptons)
  - 2 measurements from MET_x, MET_y
  - 2 constraints from m_{W+} and m_{W-}
  - 1 constraint from $m_t = m_{\bar{t}}$



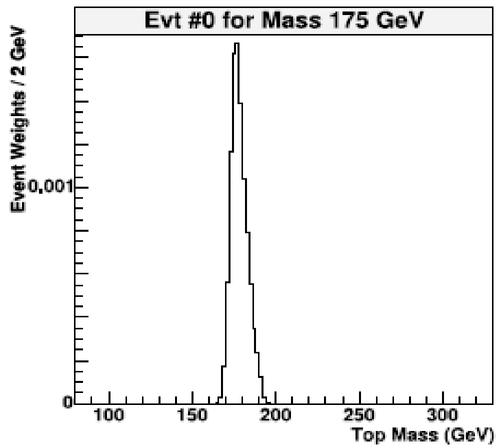
Top Mass in the Dilepton Channel

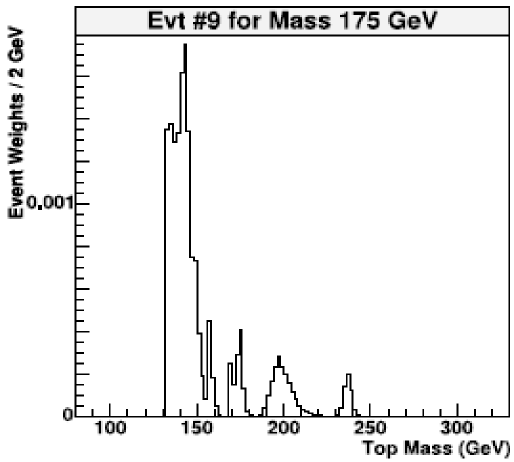
- The general method for both techniques is similar
  - Assume a top mass
  - Calculate an event weight $W(m_t)$ based on agreement with observables
    - Neutrino weighting uses missing E_T
    - Matrix element weighting uses lepton E
  - Produce weight templates using Monte Carlo at each trial top mass
  - Perform a maximum likelihood fit to the data to determine the best estimate top mass

Top Mass in the Dilepton Channel

- Neutrino weighting
  - Actually in this case the MET_x and MET_y information is ignored and instead neutrino rapidities are judiciously chosen in addition to m_t

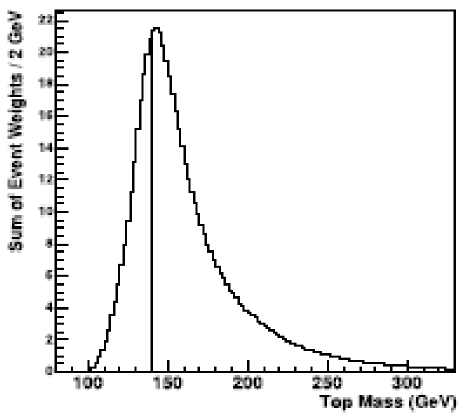
$$W(m_t) = \sum_{\eta_\nu, \eta_{\bar{\nu}}} \sum_{i=x,y} \exp(-(MET_i - p_{\nu_i} - p_{\bar{\nu}_i})^2 / 2\sigma_i^2)$$



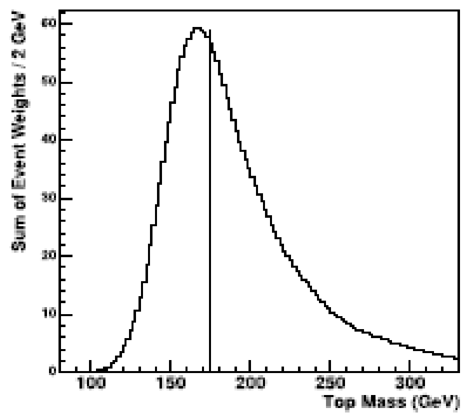


Top Mass in the Dilepton Channel

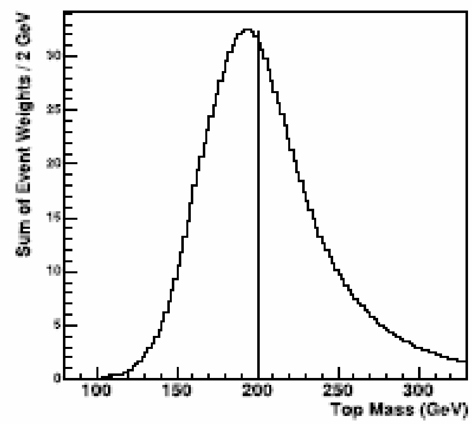
- Templates for a range of top masses are formed by summing over events and smearing of jet and lepton momenta



(a) m_{top} = 140 GeV (333 events)



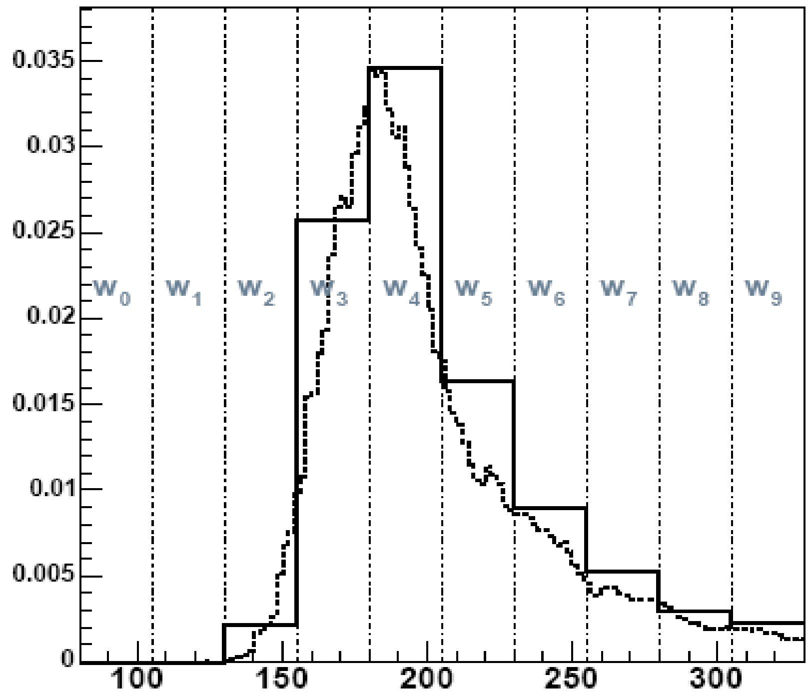
(b) m_{top} = 175 GeV (1323 events)



(c) m_{top} = 200 GeV (673 events)

Top Mass in the Dilepton Channel

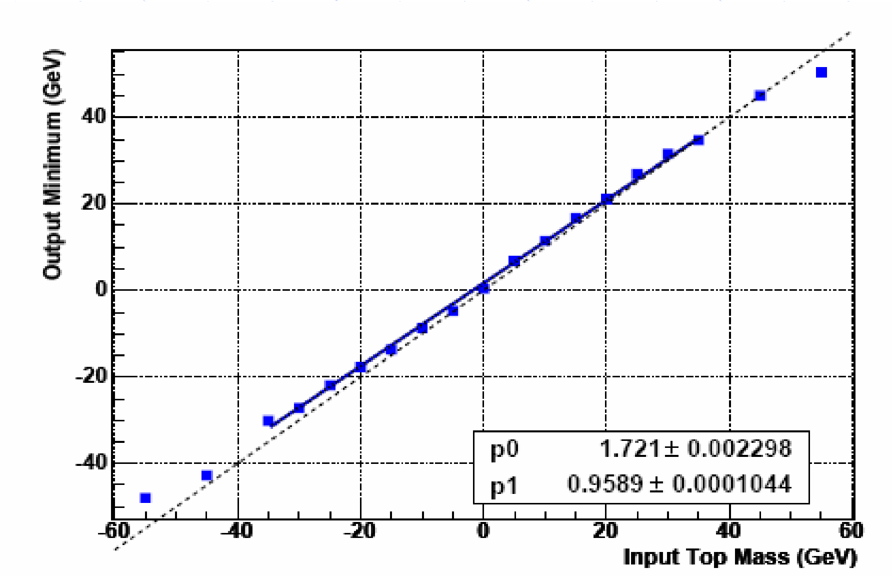
- The templates can be characterized by an event weight vector $\vec{w}$ found by rebinning the weight templates into 25 GeV bins

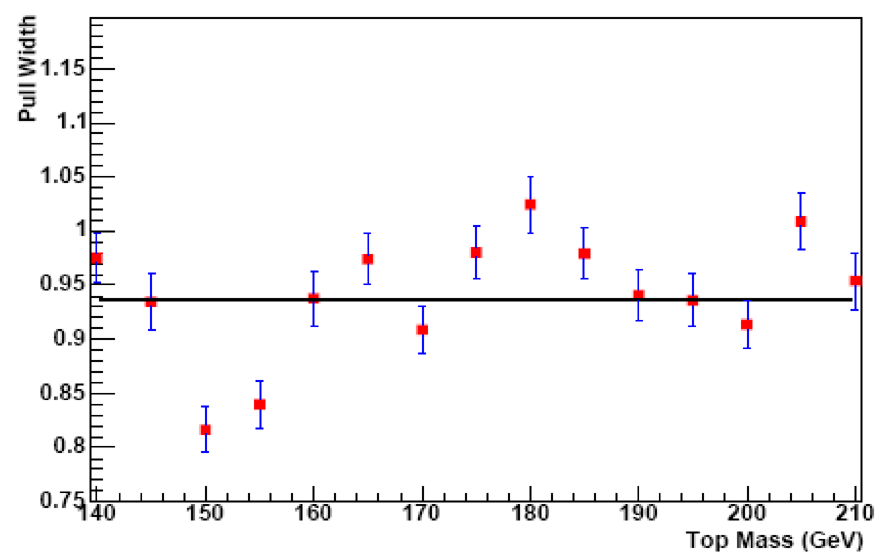


Top Mass in the Dilepton Channel

- The event weight vectors from data events are compared to those from the signal and background Monte Carlo templates by forming and maximizing a likelihood

$$L(w, \bar{n}_b, N \mid m_t, n_s, n_b) = L_{template}(m_t) \times G_{n_b, \bar{n}_b} \times P_{n_s + n_b, N}$$

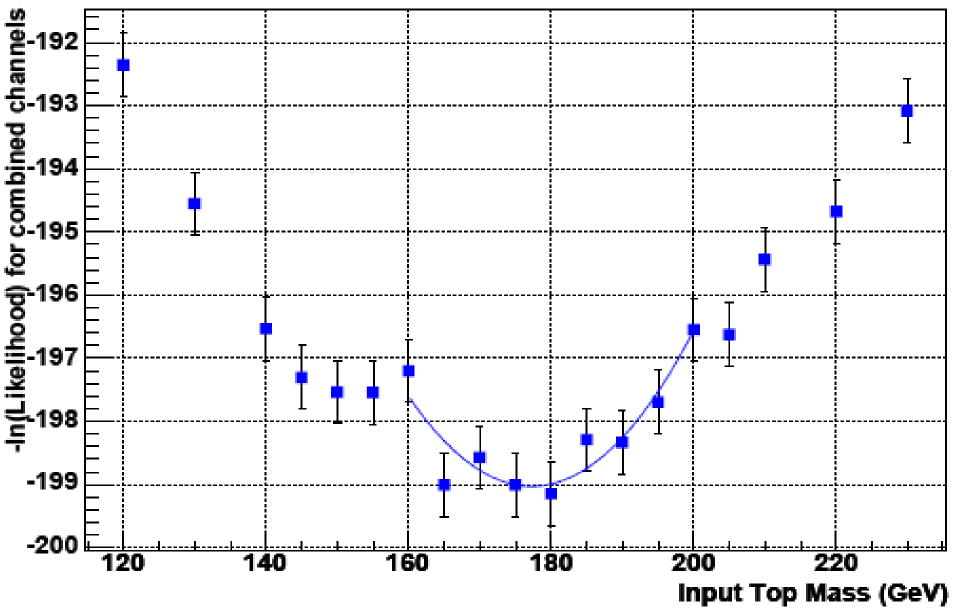


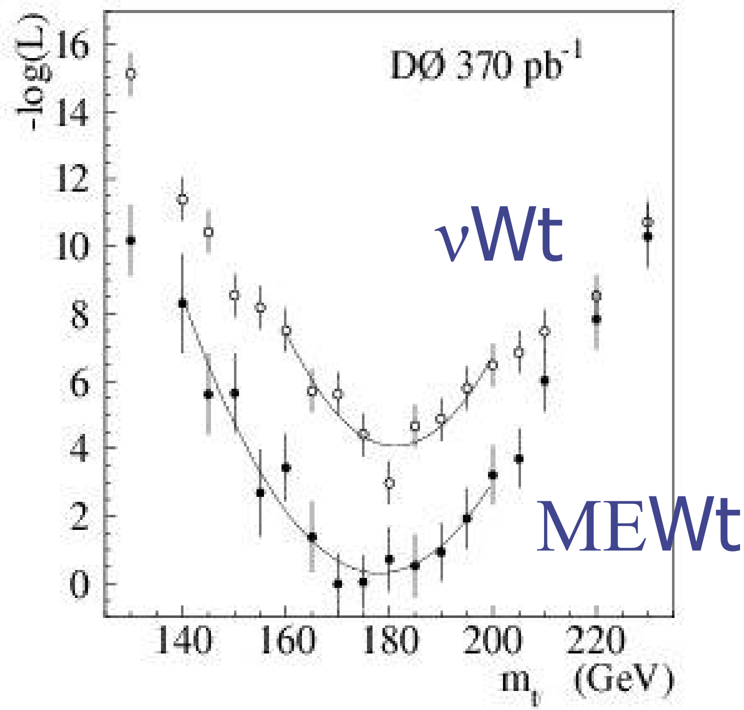


Top Mass in the Dilepton Channel

- Results
  - Dilepton νWt

Combined



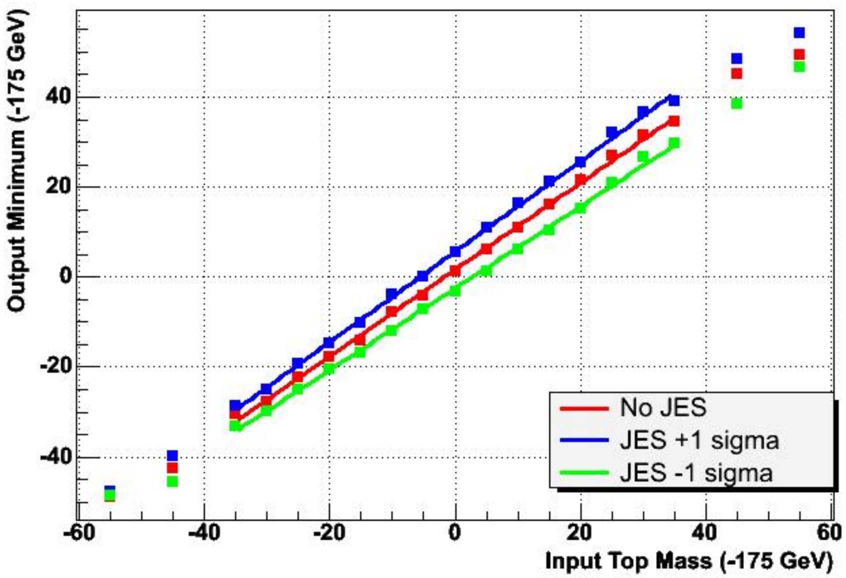


$$m_t = 175.6 \pm 10.7(stat)\,\text{GeV}$$

$$m_t = 178.1 \pm 6.7(stat)\,\text{GeV}$$

Top Mass in the Dilepton Channel

- Systematic errors are estimated by generating ensembles of fake data from parent distributions with error sources varied by their uncertainties and then comparing these ensembles to the original templates



Source	Uncertainty (GeV)
Jet Energy Scale	4.3
Gluon Radiation	1.5
Background Statistics	0.9
Signal MC Statistics	0.9
PDFs	0.8
Jet Resolution	0.3
Heavy Flavor	0.3
Muon Resolution	0.2
Total	**4.8**

Top Mass in the Dilepton Channel

- Final combined (neutrino weighting and matrix element weighting) result submitted to PRL