The Top Mass Combination

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Introduction

- CDF and D0 each determine the top mass in various final states using a variety of methods

- Tevatron Electroweak Working Group (TevEWWG) performs the average of these measurements

- To get it right, need to account for correlations amongst the measurements
  - Δ(stat) == uncorrelated
  - Δ(everything else) == a discussion

Introduction

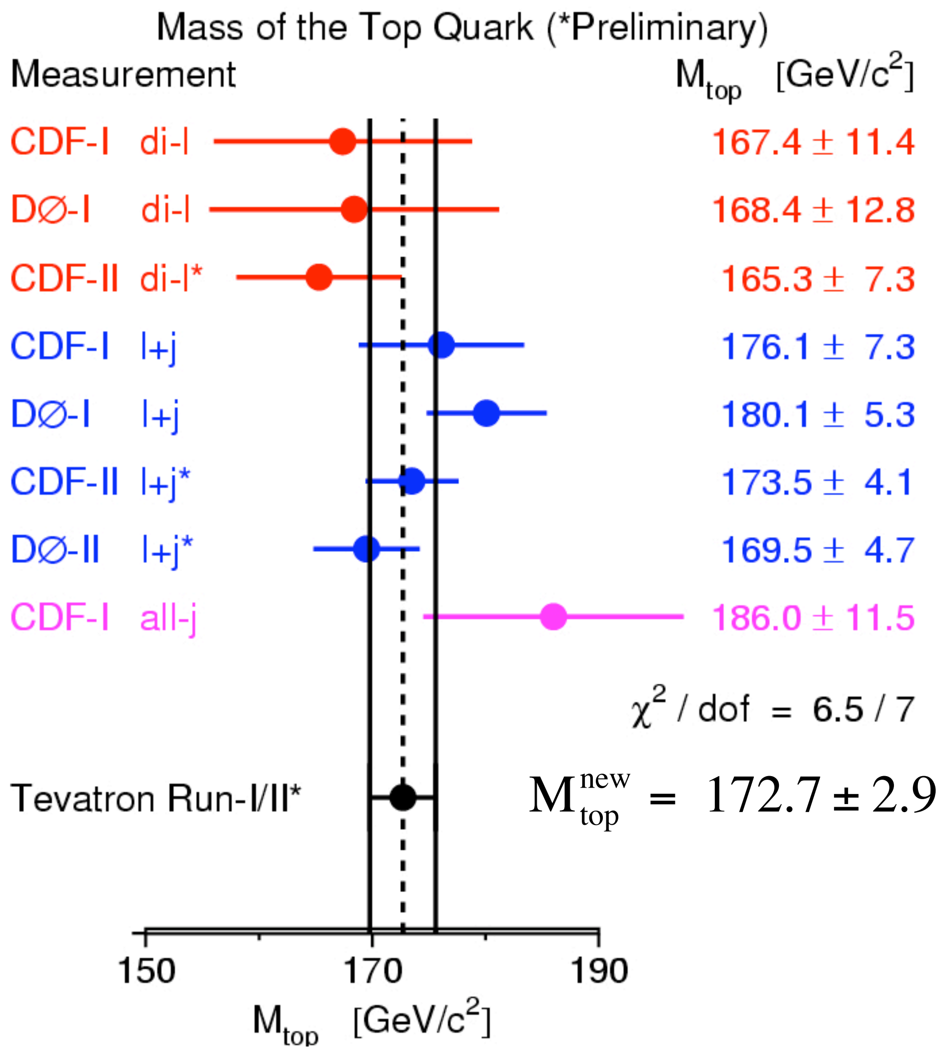
- Best Linear Unbiased Estimator (BLUE)
  - L.Lyons, *et al*., NIM A270 (1988) 110.
  - A.Valassi, *et al*., NIM A500 (2003) 391.
- Returns a weighted average, including breakdown of uncertainties by input category
- Results cross-checked with a MINUIT χ^2 – minimization
- Was used for final Run-I average

$$M_{top}(\text{Run-I}) = 178.0 +/- 4.3 \text{ GeV}$$

Status

- Method unchanged
- Inputs updated to include the following Mtop determinations (all Run-II are preliminary)
  - CDF Run-I (LJT, DIL, HAD)
  - D0 Run-I (LJT, DIL)
  - CDF Run-II (LJT, DIL)
  - D0 Run-II (LJT)
- Additional error class added to account for uncertainties correlated among measurements of same experiment in same run.

Status



$$M_{top}^{new} = 172.7 \pm 2.9 \text{ GeV}/c^2$$

- 30% reduction in ΔM_{top}
- Already systematics limited
  - Δ(stat) = 1.7 GeV/c^2
  - Δ(syst) = 2.4 GeV/c^2
- described in detail in hep-ex/0507091

Details: Error Classes

- JES
  - aJES: D0 Run-II e/h calibration
  - bJES: JES issues specific to b-jets
  - cJES: fragmentation and OOC showering
  - dJES: correlated w/i experiment but *not* RunI&II
  - iJES: in-situ calibration from W→jj
  - rJES: remaining JES (e.g. relative response, MI, UE, etc.)
- Signal : signal modeling (ISR,FSR,PDF,NLO)
- Bgd: QCD fraction, Q^2 scale
- UN/MI: D0 Run-I Uranium noise and MI
- Fit: fit method, finite MC stats
- MC: Pythia vs Herwig (vs ISAJET)
- Statistical: limited data statistics

Error Classes: Jet Energy Scale Uncertainties

- Intricate because
  - CDF and D0 employ different philosophies for determining their JES
  - Within each there is a mix of modeling uncertainties (ie. theory) and simulation uncertainties (ie. detector description)
  - Run 1 and Run 2 not exactly the same
- Tricky to precisely determine because
  - The modeling and simulation uncertainties not always easy to untangle
  - We lack an ideal control sample (ie. high statistics, high purity, well measured, well modeled)
  - There is some overlap with "Signal" category (e.g. Out-of-Cone ~ FSR)

Error Classes: Signal Modeling Uncertainties

- Includes ISR, FSR, PDF, and NLO related uncertainties
- Important because
  - Correlated among all measurements
  - Will also be correlated with LHC measurements
  - Expected to be among dominant in future
- Tricky to precisely determine because
  - The above categories don't cleanly separate
  - Difficult to specify "reasonable" modeling variations in order to quantify related systematic
  - Few good control samples in which to use data to limit modeling variations
- CDF and D0 employ different philosophies/methods

Error Classes: Other Uncertainties

- Background Related
  - Dominated by modeling uncertainties which affect shape of fitted mass distribution (e.g. Q^2 scale)
  - Many of the “Signal” comments apply here as well
  - Could become a dominant contribution
- Fit Related
  - Presently treated as uncorrelated… can this last?
- Statistics Related
  - soon to be small (yeah Tevatron!)
  - LJT : Δ(stat) ~ Δ(syst) already
  - DIL : Δ(stat) ~ Δ(syst) at 2 fb^{-1}
  - HAD : anticipate similar to DIL

Correlations

- Uncorrelated: Stat, Fit, iJES
- Correlated across all measures
  - in same experiment and run: aJES, dJES
  - in same experiment: rJES, UN/MI
  - in same channel: Bgd
  - everywhere: Signal, bJES, cJES, MC
- Correlation taken to be 0 or 100%
  - Requires more work to determine more precisely
  - This workshop a good way to initiate dialogue
  - Real work of ironing out details will happen in Tevatron EWWG

The Measurements

	Published Run-I					Preliminary Run-2			
	C1(HAD)	C1(LJT)	C1(DIL)	D1(LJT)	D1(DIL)	C2(LJT)	C2(LJT)	C2(DIL)	D2(LJT)
Mtop	186.0	176.1	167.4	180.1	168.4	173.5		165.5	169.5
Stat	10.0	5.1	10.3	3.6	12.3	2.7		6.3	3.0
iJES	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	3.3
aJES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
bJES	0.6	0.6	0.8	0.7	0.7	0.6	0.6	0.8	0.7
cJES	3.0	2.7	2.6	2.0	2.0	0.0	2.0	2.2	0.0
dJES	0.3	0.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0
rJES	4.0	3.4	2.7	2.5	1.1	0.0	2.3	1.4	0.0
Signal	1.8	2.6	2.8	1.1	1.8	1.1		1.5	0.3
MC	0.8	0.1	0.6	0.0	0.0	0.2		0.8	0.0
UN/MI	0.0	0.0	0.0	1.3	1.3	0.0		0.0	0.0
Bgd	1.7	1.3	0.3	1.0	1.1	1.2		1.6	0.7
Fit	0.6	0.0	0.7	0.6	1.1	0.6		0.6	0.6
Syst	5.7	5.3	4.9	3.9	3.6	4.6	3.5	3.6	3.6
Total	11.5	7.3	11.4	5.3	12.8	5.3	4.4	7.3	4.7

Split by JES determination

(all quantities in GeV/c^2)
(original authors consulted in every case)

The Fit

Published Run-I ⟷ Preliminary Run-2

Correlation coefficients

	C1(HAD)	C1(LJT)	C1(DIL)	D1(LJT)	D1(DIL)	C2(LJT)	C2(LJT)	C2(DIL)	D2(LJT)
C1(HAD)	1								
C1(LJT)	0.32	1							
C1(DIL)	0.19	0.29	1						
D1(LJT)	0.14	0.26	0.15	1					
D1(DIL)	0.07	0.11	0.08	0.16	1				
C2(LJT)	0.04	0.12	0.06	0.10	0.03	1			
C2(LJT)	0.35	0.54	0.29	0.29	0.11	0.45	1		
C2(DIL)	0.19	0.28	0.18	0.17	0.10	0.06	0.30	1	
D2(LJT)	0.02	0.07	0.23	0.07	0.02	0.07	0.08	0.03	1

Split by JES determination

Mt = 172.7 +/- 2.9 GeV/c^2

χ^2/dof = 6.5 / 7 (49%)

	C1(HAD)	C1(LJT)	C1(DIL)	D1(LJT)	D1(DIL)	C2(LJT)	C2(LJT)	C2(DIL)	D2(LJT)
Pull:	+1.19	+0.51	-0.48	+1.67	-0.34	+0.18	+0.24	-1.11	-0.86
Weight:	+1%	-0.2%	+1%	+19%	+2%	+36%		+8%	+33%

The Fit (all quantities in GeV/c^2)

- JES: 2.0
  - aJES: 0.3
  - bJES: 0.7
  - cJES: 1.0
  - dJES: 0.01
  - iJES: 1.4
  - rJES: 0.8
- Signal : 0.9
- Bgd: 0.9
- UN/MI: 0.3
- Fit: 0.3
- MC: 0.2
- Statistical: 1.7

Total Systematic: 2.4

More Fit Results

- Repeat fit to determine M(LJT), M(DIL), M(HAD) separately:

	Fit Value (GeV/c^2)	Correlations M(H)	M(L)	M(D)
M(HAD)	185.0 +/- 10.9	1		
M(LJT)	173.5 +/- 3.0	0.22	1	
M(DIL)	165.0 +/- 5.8	0.15	0.31	1

χ^2/dof = 2.6 / 5 (76%)

Extrapolations: What can we expect?

- Considered three scenarios
  - "Lazy" == only improvement is from additional stats
  - "Proactive" == additionally assume some progress on systematics related to JES (3→2), and modeling (e.g. for LJT non-JES syst 1.5→1.0 GeV/c^2)
  - "Proactive++" == same as Proactive + D0(R2-DIL) + D0(R2-HAD) + CDF(R2-HAD) (assumed these look like CDF(R2-DIL))
- Take as inputs present analyses in world average and project to larger datasets (1, 2, 5, & 8 fb^{-1})
  - use *expected* stat uncertainty in projections

Extrapolations: What can we expect?

- Make projections for ΔM_{top} and M_{top} vs Channel
- Meant to help identify sources of uncertainty which will limit the precision of the world average combination
  - better determine their related correlations
  - begin working to reduce these

Extrapolations: Projections for ΔM_{top} in GeV/c^2

	Lazy	ProAct	ProAct++	
1 fb^{-1}	1.15			JES
	0.76			Signal
	0.84			Bkgnd
	0.42			Other
	1.9			Syst
	1.2			Stat
	2.2			Total
2 fb^{-1}	1.9	1.6	1.6	Total
5 fb^{-1}	1.6	1.4	1.3	Total
8 fb^{-1}	0.98	0.85		JES
	0.63	0.40		Signal
	0.79	0.53		Bkgnd
	0.46	0.48		Other
	1.5	1.2	1.2	Syst
	0.5	0.5	0.4	Stat
	1.6	1.3	1.2	Total

Extrapolations: Projections of M_{top} vs Channel

		Lazy	ProAct++	
2 fb^{-1}		3.1	2.4	
5 fb^{-1}	ΔM_{top}(LJT-DIL)	2.1	1.6	GeV/c^2
8 fb^{-1}		1.8	1.3	

		Lazy	ProAct++	
2 fb^{-1}		10	2.4	
5 fb^{-1}	ΔM_{top}(LJT-HAD)	10	1.6	GeV/c^2
8 fb^{-1}		10	1.3	

Statistical uncertainties only

➔ Addition of R2 DIL and HAD important for comparisons across channels; >=25% improvements possible

Conclusions

- New World Average including new Run-II measurements from CDF and D0 already significantly improves uncertainty

$$M_{top} = 172.7 +/- 2.9 \text{ GeV}/c^2$$

- Seems to me that a total uncertainty of 2 GeV/c^2 with 2 fb^{-1} is very feasible – with work can likely do better.

- Future improvements to M_{top} will require working more closely amongst ourselves to better determine systematic correlations
  (JES, Signal & Background Modeling)