# Status of Top Mass (world?) average

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***for the TOPLHC WG***

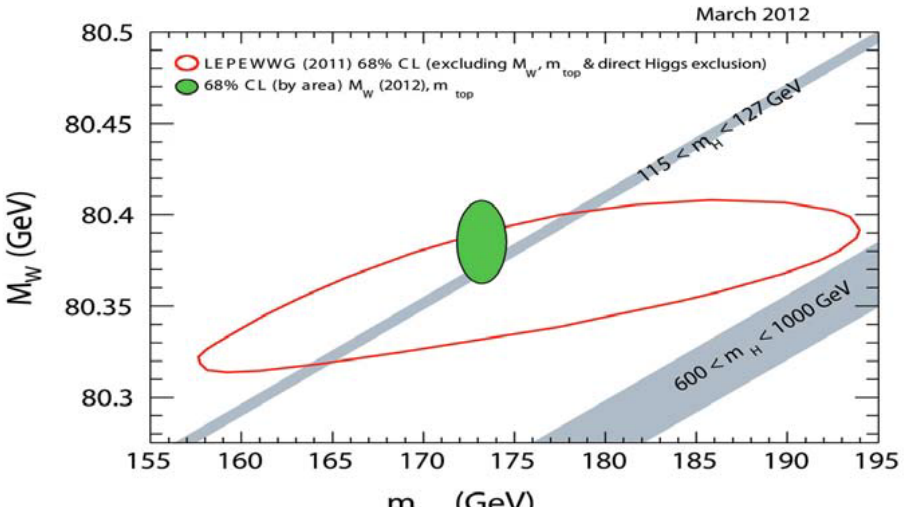

**Open TOPLHC WG Meeting, November 29, 2012**

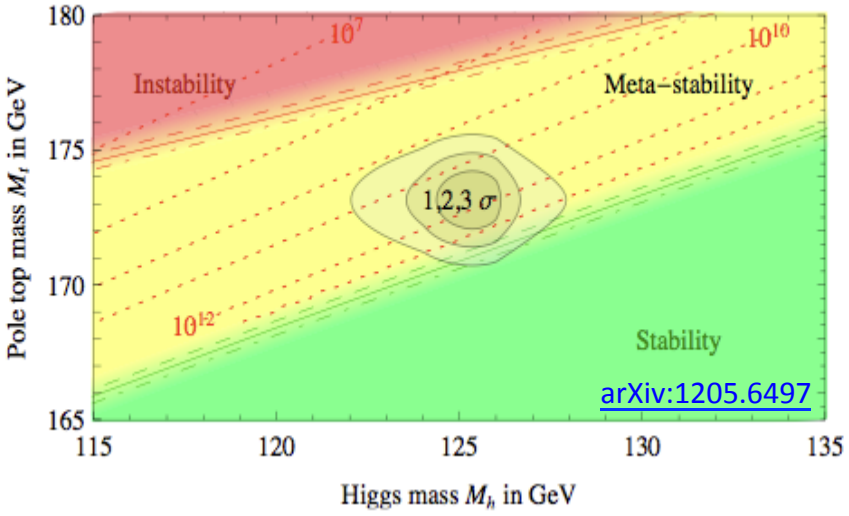
# After July 4th 2012…

- The Top quark is *still* the heaviest known elementary particle!
- Is there a special reason for this?
- The Top mass is *still* an important Standard Model parameter

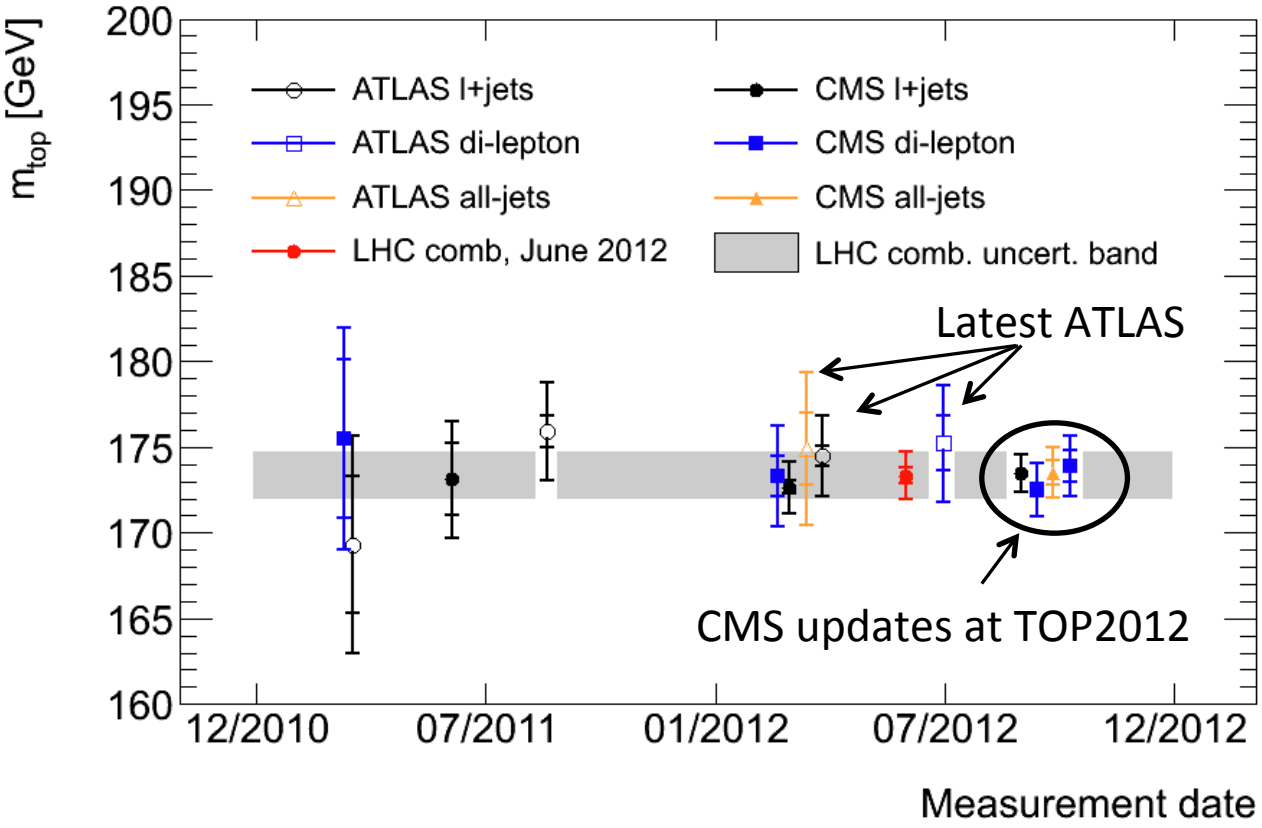
  → worth measuring as precisely as possible

- Interesting (QCD) Puzzle: how secure is the "color confinement prison"? Compare direct measurements from invariant mass decay products to indirect determination from cross-section



# LHC Top Mass: overview




| | LHC | |
|---|---|---|
| [GeV] | ATLAS | CMS |
| Stat. | 0.6 – 4.0 | 0.3 – 4.6 |
| Syst. | 2.3 – 4.6 | 1.0 – 4.6 |
| Tot | 2.4 – 6.3 | 1.1 – 6.5 |

[min,max] across analyses used in LHC comb or presented at TOP2012
red = presented at TOP2012

- Time evolution of LHC Top mass measurements
- The first (and latest) LHC Top mass combination: June 2012

# Latest top mass combinations

LHC Combination (June 2012): $m_{top} = 173.3 \pm 0.5_{stat} \pm 1.3_{syst}$ GeV
CMS-PAS-12-001 & ATLAS-CONF-2012-095

Tevatron Combination (2012): $m_{top} = 173.2 \pm 0.6_{stat} \pm 0.8_{syst}$ GeV
*… does not include the latest measurement(s)*
Phys. Rev. D 86, 092003 (2012)

CMS latest (September 2012): $m_{top} = 173.4 \pm 0.4_{stat} \pm 0.9_{syst}$ GeV
*… does not include the latest CMS di-lepton measurement*
CMS-PAS-11-018

- Beautiful agreement in central values
- LHC is starting to reach a precision similar to the Tevatron
- LHC: systematic uncertainties (and correlations) dominant
- None of the combination is fully up-to-date…

# Our Home Work

- A better understanding of systematic uncertainties and correlations between ATLAS and CMS is becoming increasingly important
- Currently we are using BLUE with systematics categories similar to the Tevatron combination (for details see talk by Giorgio in previous TOPLHC WG meeting https://indico.cern.ch/event/189617 )
- An "ultimate combination" of results would require
  - More refined categories for systematic uncertainties in BLUE
  - Better understanding of the values of the systematic uncertainties
  - Better understanding of the correlations to put in
- More harmonisation between ATLAS and CMS is needed (see talks about JetMET and Radiation systematics today)
- Also proposing an improved presentation of BLUE results

  (see talk by Andrea Valassi today)

# ATLAS and CMS signal modeling Systematics

| | ATLAS | CMS |
|---|---|---|
| PDF | CTEQ6.6 | MSTW08/ CTEQ6.6 / NNPDF2.0 |
| Unc. on $m_{top}$ [GeV] | 0.1 – 0.6 | 0.1 – 0.5 |
| MC generator | MC@NLO / PowHeg | Madgraph/PowHeg/Alpgen |
| Unc. on $m_{top}$ [GeV] | 0.3 – 1.3 | <0.1 – 0.4 |
| Hadronization | Powheg Pythia/Herwig | (considered only in the JES syst determination) |
| Unc. on $m_{top}$ [GeV] | 0.2 – 0.9 | |
| UE tune | Varying Pythia tunes | |
| Unc. on $m_{top}$ [GeV] | 0.2 – 0.6 | 0.2 – 1.4 |
| Colour reconnection (CR or noCR) | Pythia Tune A and Perugia variations | Pythia Perugia variations |
| Unc. on $m_{top}$ [GeV] | 0.6 – 1.2 | 0.1 – 0.5 |

0.04 GeV, di-lepton and l+jets (only quoted for di-lepton)

- Some differences in approach – ongoing discussions
- Hadronization: Pythia vs Herwig – quote only as part of JES (CMS), or also applied to whole event (ATLAS)? … Double counting?
- Radiation: → (ultimately) constrain from data
- (b-JES) → (ultimately) constrain from data
- CR: → drop Tune A; (ultimately) constrain from data?

# Scope for significant improvements?

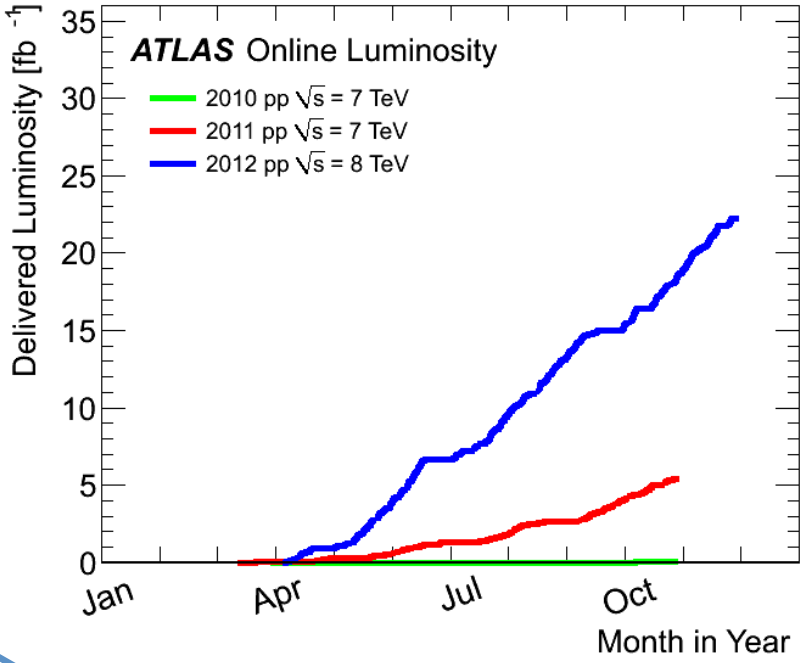
**Yes!**

- 4x more data on tape
- 2 year to analyze them…
- Improved MC tools arriving
- Current systematics tend to be conservative by necessity *

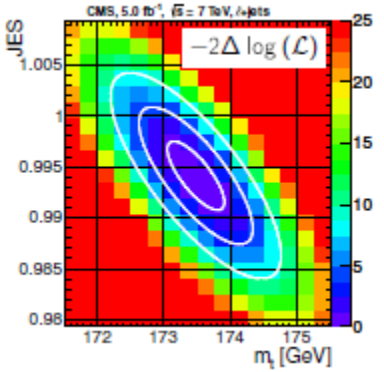
**For example in CMS:**

- Using pre-calibrated JES scale or in-situ, **not both**
- B-JES covers perhaps **2x** b- vs light-jet difference
- **Double**-counting UE tune and pile-up (JES and full event)
- Always using **max** of syst. shift or stat. unc. on it

**Similar room for future improvements in ATLAS**




| channel | Official JES | In-situ JES |
|---|---|---|
| Di-lepton | 1.5-2% | **Not used** |
| Lepton+jets | **Not used** | 0.994 ± 0.009 |
| All-jets | 1.5-2% | **Not used** |



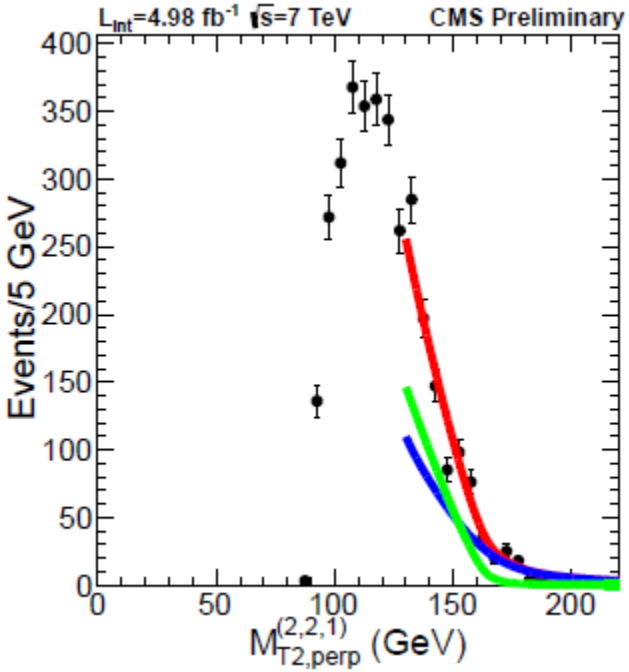

**(*) inevitable to err on the side of caution, until more refined treatments are available**

# Further Food for Thought (& Optimism)

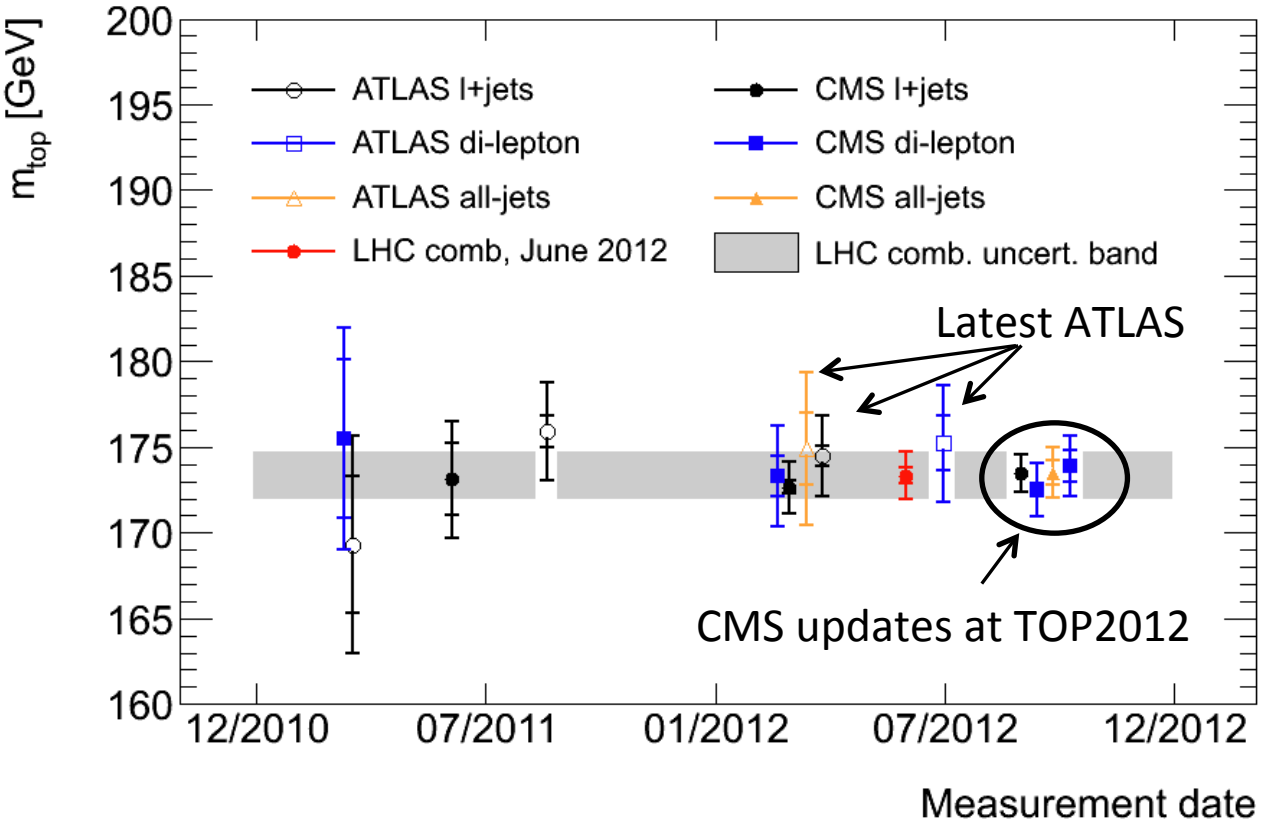
- Another way to reduce the overall uncertainty would be to aim for reduced correlations
- Useful to include less-correlated alternative methods, eg CDF Lxy method, or the ATLAS and CMS $M_{T2}$ di-lepton endpoint methods:

- CMS $M_{T2}$: no use of MC for calibration and using endpoint. Less precise than standard dilepton analysis, but would give bigger improvement combination
- Should analyses no longer be optimized 'stand-alone', but with the combination in mind?

$$M_t = 173.9 \pm 0.9(\text{stat}) \, ^{+1.2}_{-1.8}(\text{syst}) \text{ GeV}$$



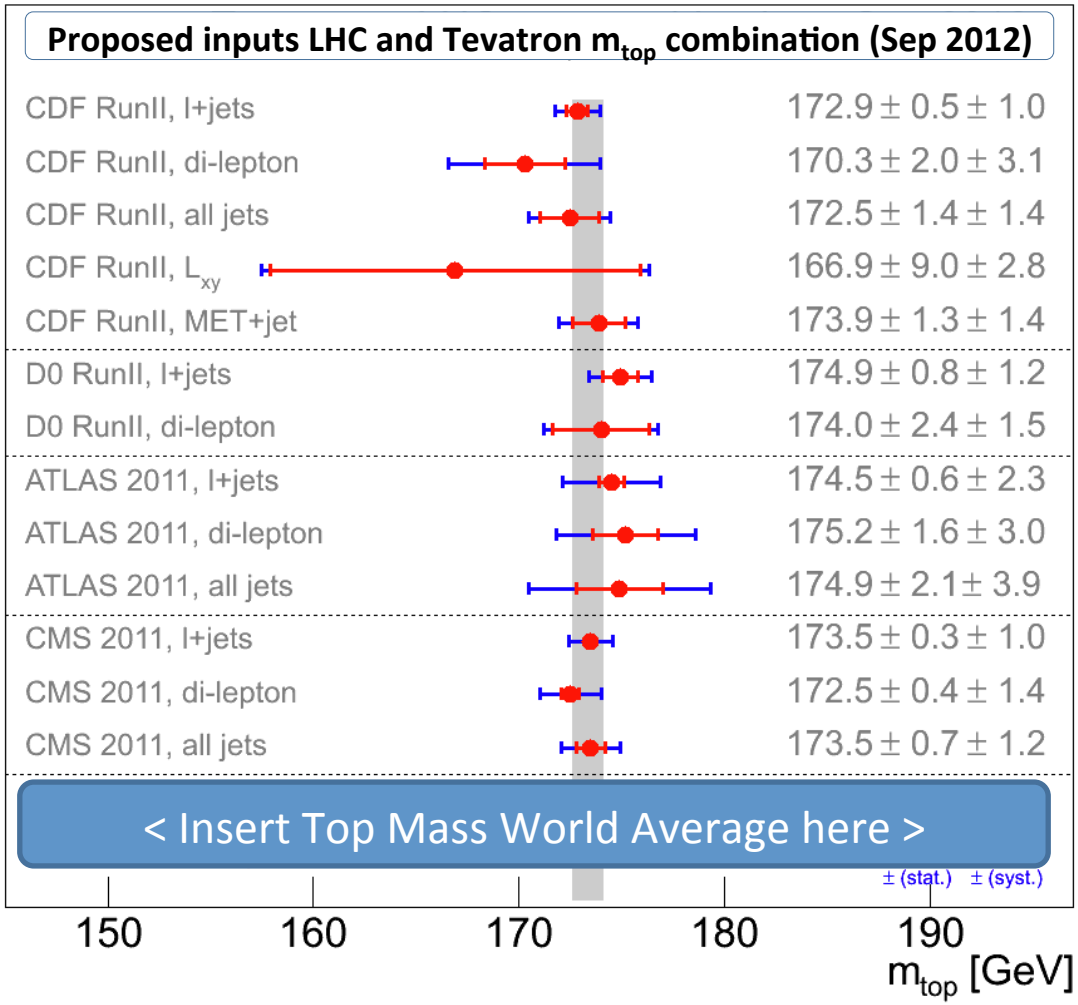
# Recap: LHC Top Mass overview




- Time for an updated LHC top mass combination…
- Also working towards a Tevatron + LHC world combination!

# Towards a World Combination

- Informal discussion has started between Tevatron and LHC communities
- Proposal for inputs for 1st combination: best measurement per channel / method per experiment (Sep'12)
- Technically straightforward to perform combination
- But first: need formal agreement between the 4 experiments on exact procedure to be followed



# Time Line

- The goal is/was to have the first preliminary LHC + Tevatron combination approved as soon as possible by the 4 collaborations
  - Combinations will be performed using the BLUE method
  - Systematic uncertainties will be reviewed and mapped to each other from the different inputs, ensuring a homogeneous treatment
  - Single document approved in 4 collaborations, containing:
    - Individual (updated) combinations for Tevatron and LHC
    - The First preliminary World Average top-quark mass combination
    - Comparisons of the World Average combination per channel

- Moriond 2013 : a natural target for the first world combination, including preliminary and published results
- Also prepare combination (only published results) as input for Particle Data Group, summer 2013 edition (deadline: Spring 2013) → *My opinion: very important to provide this, to the best of our current knowledge*

# Top Mass Combination Summary & Outlook

- The LHC experiments are quickly improving the precision of their top-quark mass measurements.
- Results from ATLAS and CMS show beautiful agreement with existing Tevatron results.
- A good moment for the LHC and Tevatron working groups to combine forces and prepare a top mass world average
- *Scope for significant further improvements in LHC top mass measurements. Improved understanding of systematic uncertainties (experimental and theoretical) and correlations will be key*
- We are just getting started! Exciting Top Physics years ahead!