Top quark mass and LHC activities

-- update --

MITP workshop on
High precision fundamental constants at TeV scale
March 10-21, 2014

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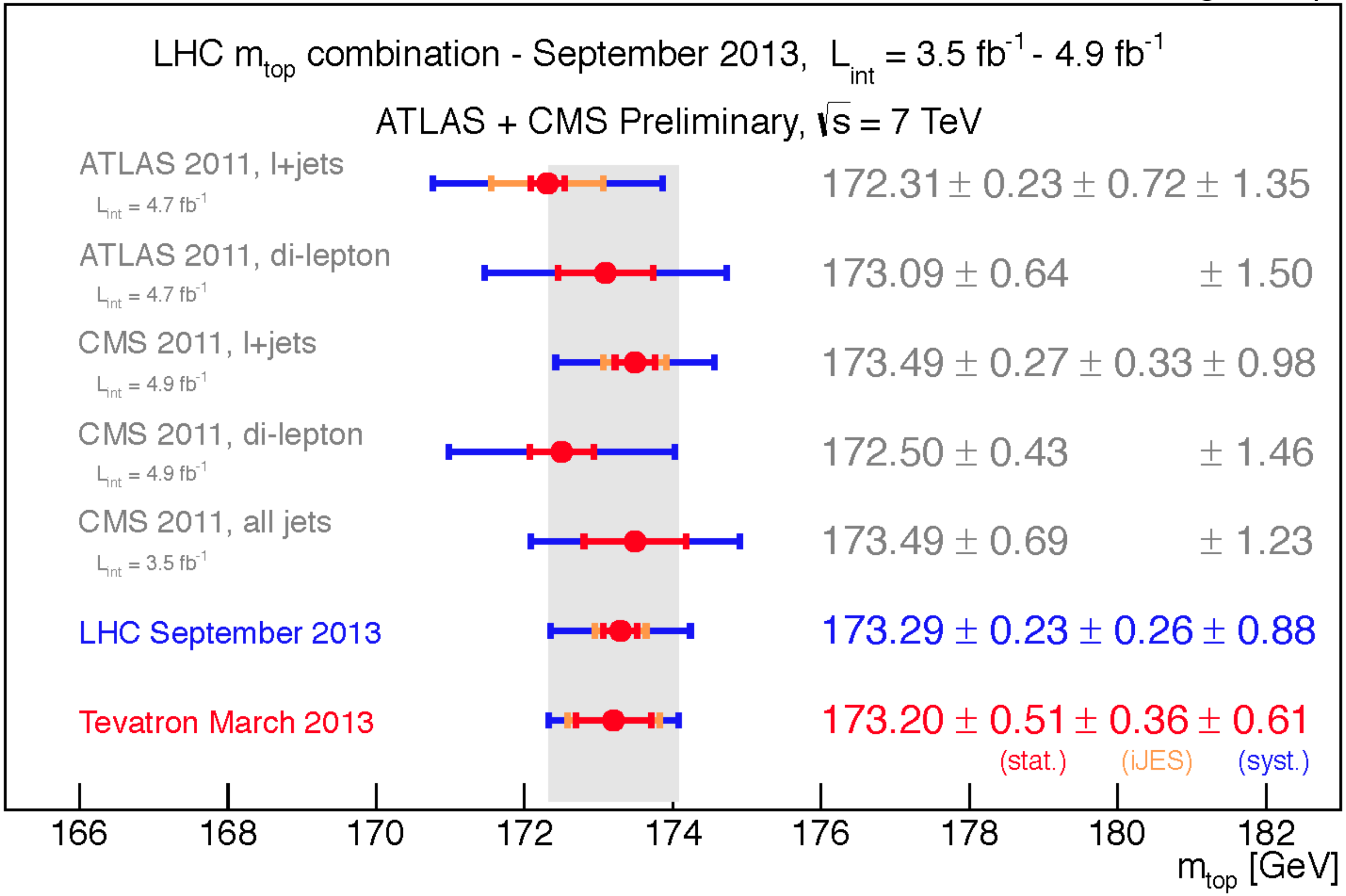
Mainz Institute for Theoretical Physics

LHC combination

ATLAS-CONF-2013-102
CMS-PAS-TOP-13-005

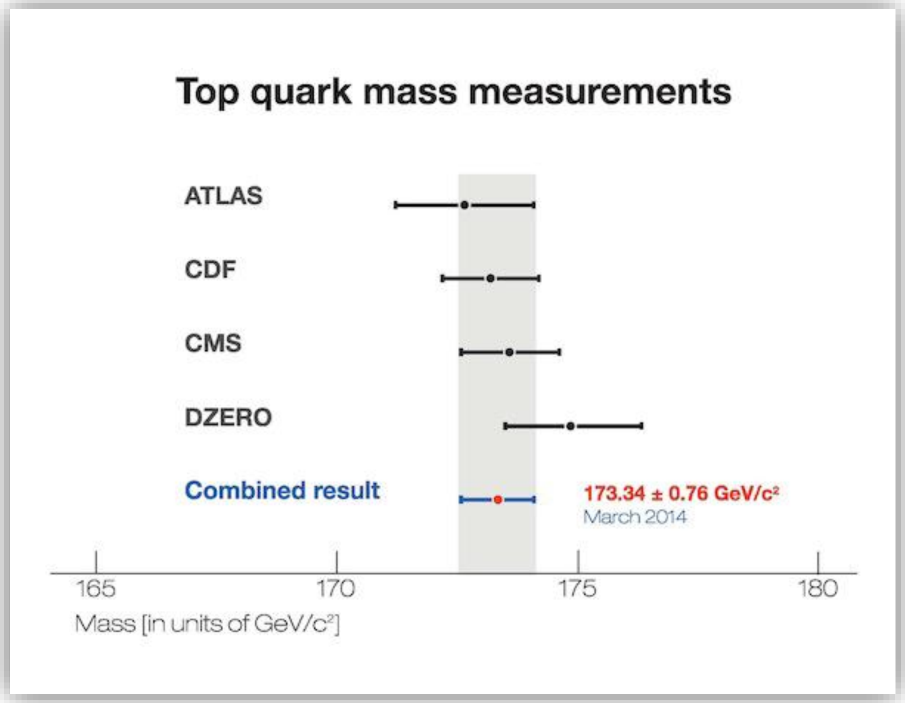
TOP LHC Working Group



Wednesday March 19

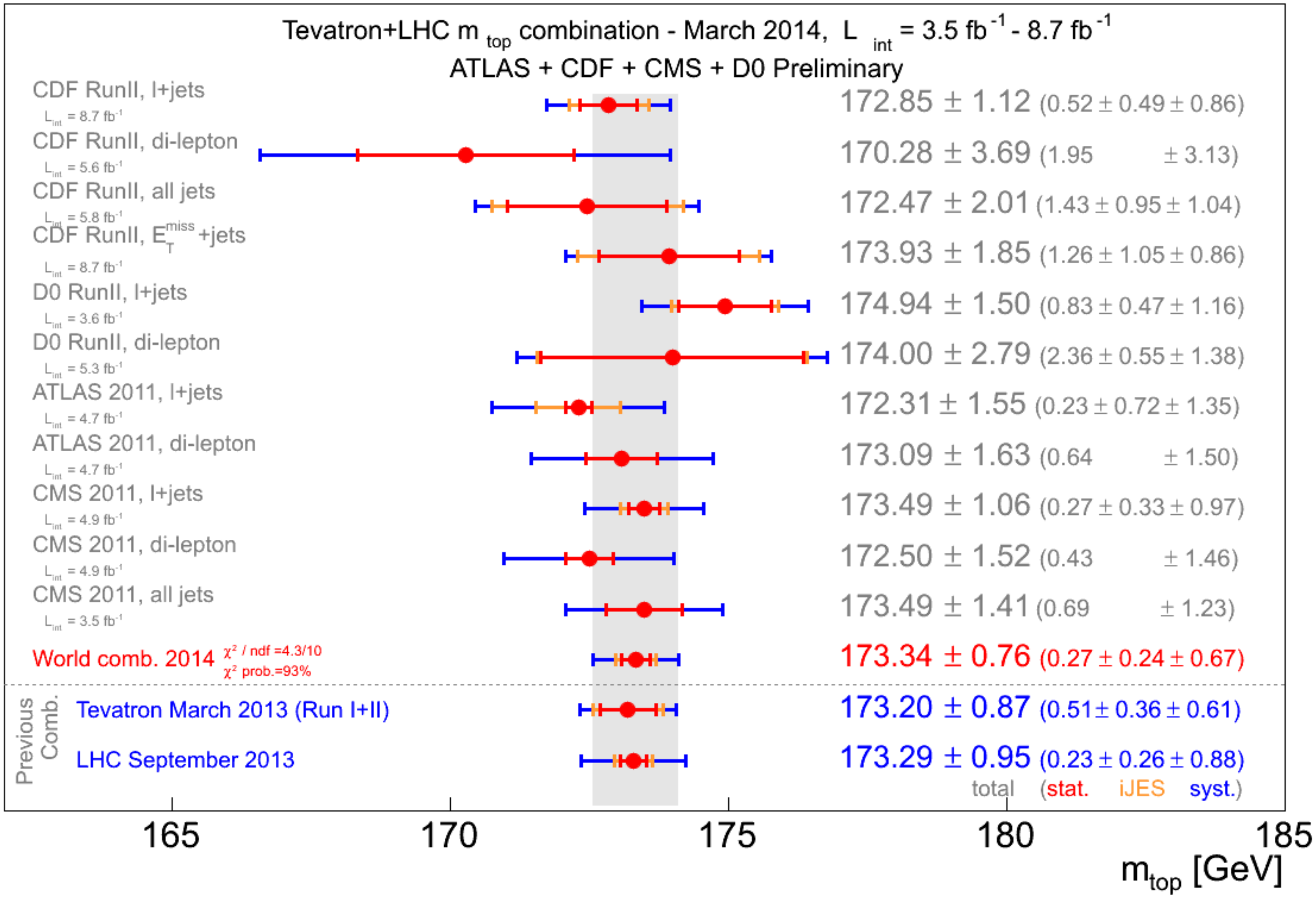
Joint CERN-Tevatron press release:

International team of LHC and Tevatron scientists announces first joint result

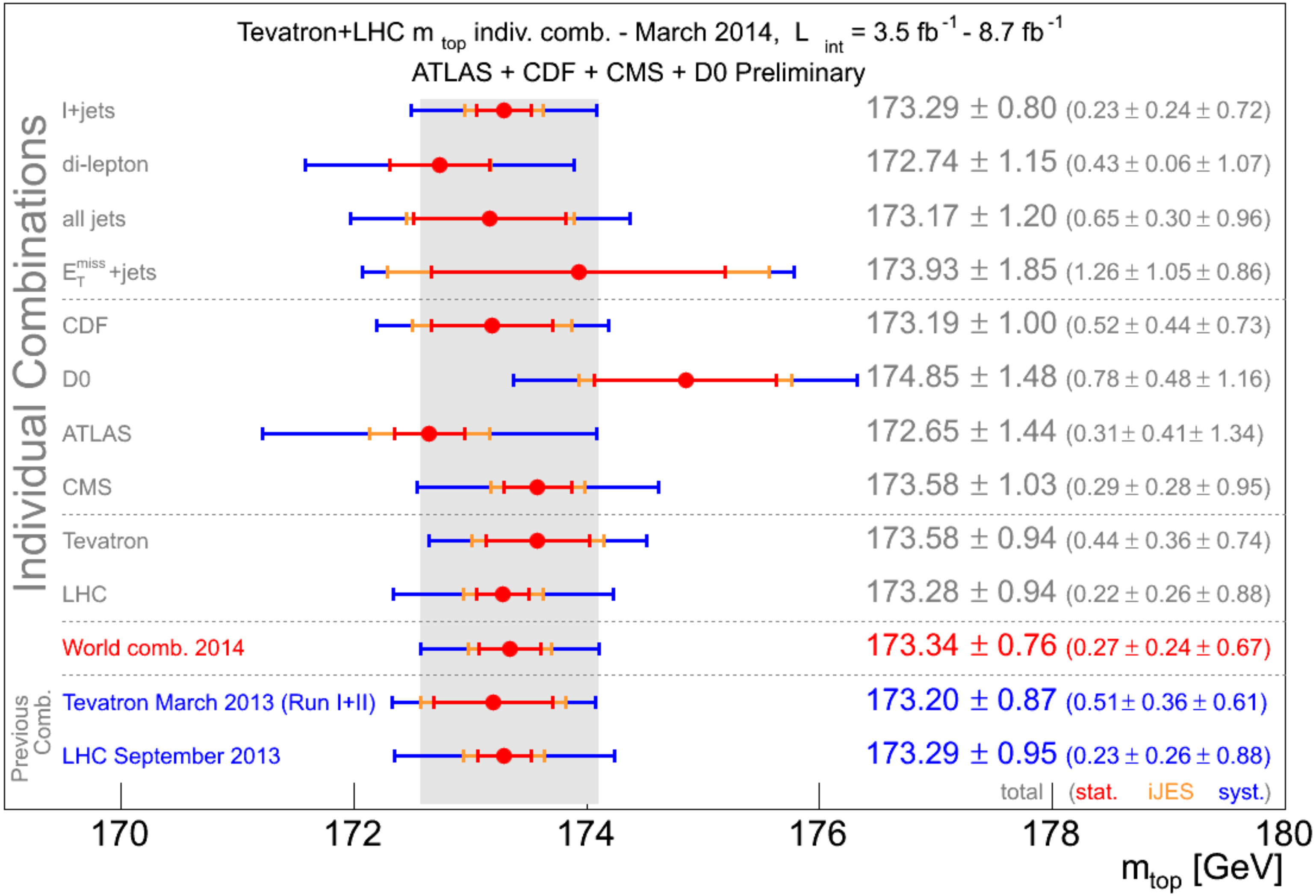


ATLAS-CONF-2014-008
CDF Note 11071
CMS PAS TOP-13-014
D0 Note 6416
http://arxiv.org/abs/1403.4427

First top mass World Average



Breakdown in channels / experiments



Mass definition

$\mathcal{L}_{\rm int}$ = 4.9 fb^{-1} of data, refer to the $t\bar{t} \rightarrow$ lepton+jets, $t\bar{t} \rightarrow$ dilepton and $t\bar{t} \rightarrow$ all jets channels [16–18]. In all measurements considered in the present combination, the analyses are calibrated to the Monte Carlo (MC) top-quark mass definition. It is expected that the difference between the MC mass definition and the formal pole mass of the top quark is up to the order of 1 GeV (see Refs. [19, 20] and references therein).

Proposal 1a (to be refined by A. Hoang) -- replace this disclaimer by: “The uncertainty on the translation from the MC mass definition to a theoretically well defined short-distance mass definition is currently estimated to be of the order of 1 GeV []”

Proposal 1b : provide a Table (or code) to translate the MC mass (?) to the Msbar mass definition?

Proposal 2 : quantify the systematic uncertainty of experimental observables related to the mass interpretation, by comparing the prediction of the MC Tool “of choice” to a well-defined NLO calculation *as a function of kinematic variables*, similar to what was done in CMS-TOP-12-029 (see next slide)

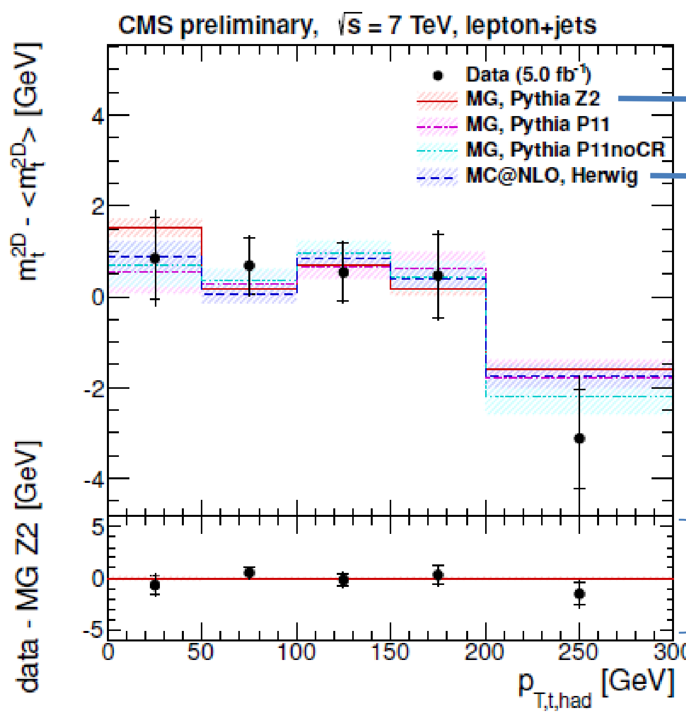
How invariant is the “invariant mass”?

CMS-PAS-TOP-12-029

- Huge top event samples at LHC allow to probe top mass observable as a function of event variables (here: using l+jets, standard 2D fit)

mass Observable,

“projected on MC Mass definition”



Default MC tool

Well-defined NLO tool / Calculation

+ Test effect of renorm. and fact. Scales, pdfs, Alpha_s

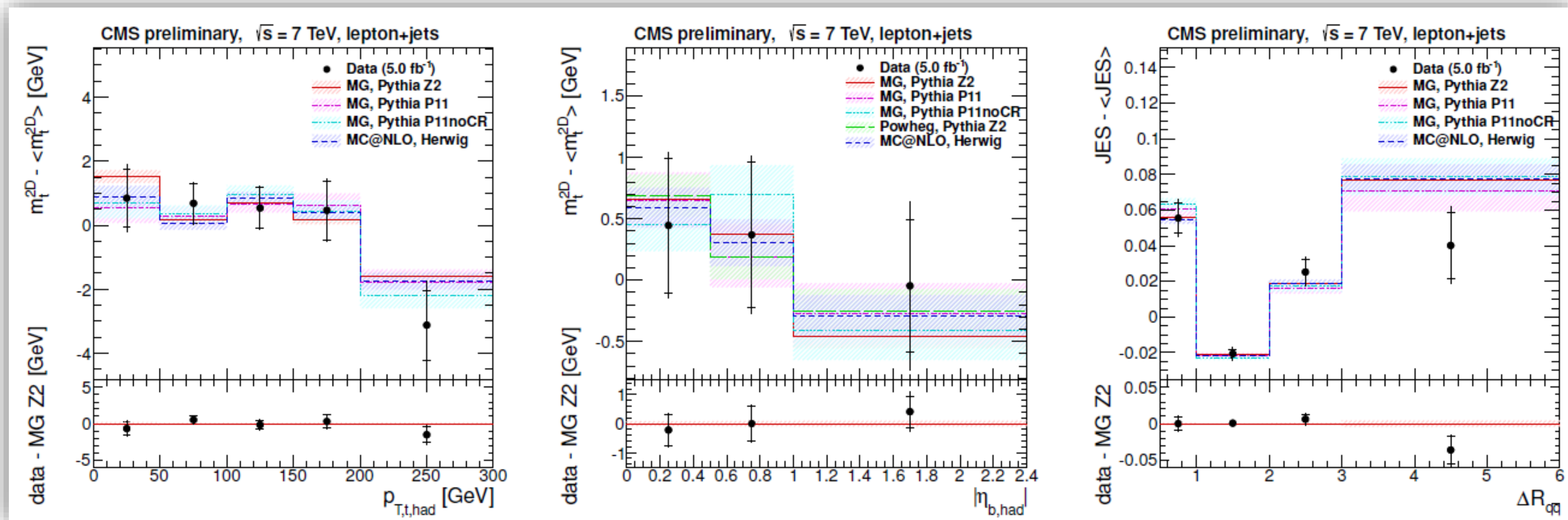
Take the difference → Need a prescription to derive estimated uncertainty from this…

Kinematic variable

How invariant is the "invariant mass"?

CMS-PAS-TOP-12-029

- Huge top event samples at LHC allow to probe top mass observable as a function of event variables (here: using l+jets, standard 2D fit)



- Any sign of color connections between b jets and beam, spoiling inv. mass?
- Tested 12 observables, global chi2/ndf = 69/78→prob=77% (data vs MG Z2)
- Various dependencies well modeled, by all MC models/tunes tested
- Mass measurement is stable; tests will be *more precise* with *more statistics*

BACKUP

LHC top mass combination

TOP LHC Working Group

	ATLAS comb.	CMS comb.	LHC comb.
Measured M_T	172.65	173.59	173.29
iJES	0.41	0.27	0.26
uncorrelated JES comp.	0.66	0.32	0.29
in-situ JES comp.	0.30	0.08	0.10
intercalib. JES comp.	0.28	0.02	0.07
flavour JES comp.	0.21	0.19	0.16
b-jet energy scale	0.35	0.56	0.43
Monte Carlo simulation	0.40	0.06	0.14
Radiation modelling	0.42	0.28	0.32
Colour reconnection	0.31	0.48	0.43
Underlying event	0.25	0.17	0.17
Proton PDF	0.15	0.07	0.09
Detector modelling	0.22	0.25	0.20
b-tagging	0.66	0.11	0.25
Lepton reconstruction	0.07	0.00	0.01
Background from MC	0.06	0.10	0.08
Background from Data	0.06	0.03	0.04
Method	0.08	0.07	0.06
Multiple Hadronic Interactions	0.02	0.06	0.05
Statistics	0.31	0.29	0.23
Systematics	1.40	0.99	0.92
Total Uncertainty	1.43	1.03	0.95

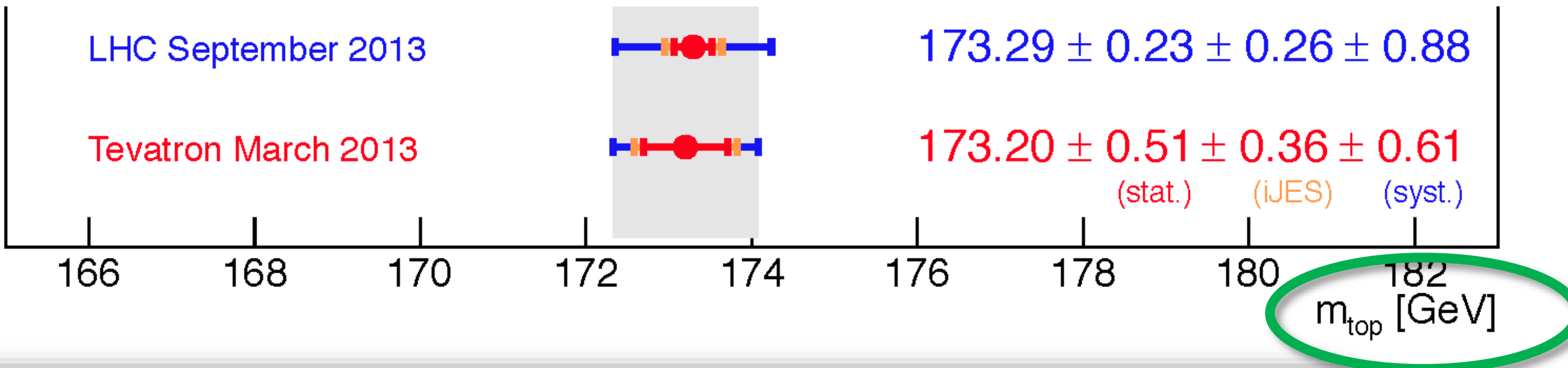
JES*: good progress, 5 common correlation groups defined*

MC/Radiation*: different MCs and treatment*

CR/UE*: somewhat ad-hoc, testing available simplified models/tunes; to be improved*

b-tagging*: working on similar understanding of correlations as for JES*

LHC combination



3.3 Measurements calibration

In all measurements considered in the present combination, the fitting procedures are calibrated to the Monte Carlo (MC) top-quark mass definition. The baseline MC program for the simulation and calibration of the top-quark mass analyses in ATLAS is PowHeg interfaced with Pythia for the parton shower and underlying event modelling [13–15]; MadGraph interfaced with Pythia is used within CMS [14, 16]. The parton configurations generated by MadGraph are matched with the parton showers using the MLM prescriptions [17]. It is expected that the difference between the MC mass definition and the top-quark pole mass is of order 1 GeV [18]. A systematic uncertainty, ranging from 0.02 GeV to 0.20 GeV, depending on the analysis, is assigned to the input measurements, covering differences between MC models.

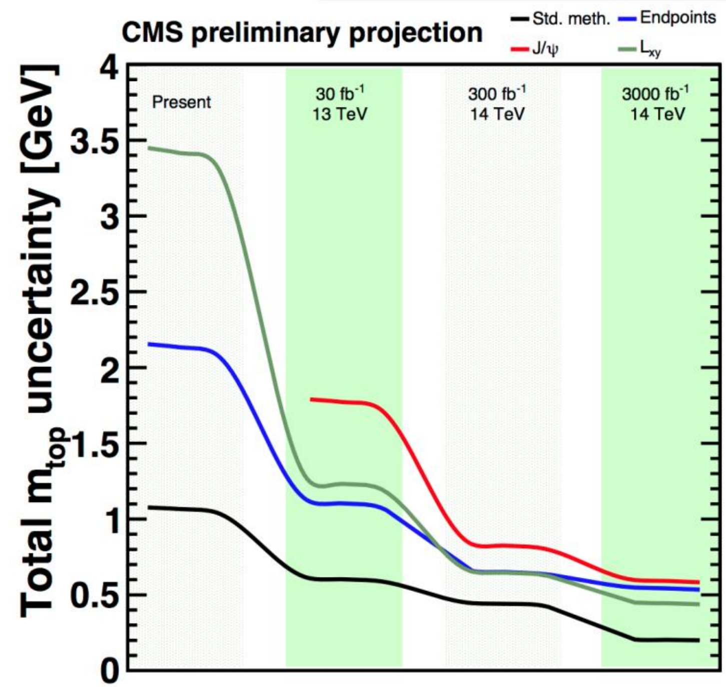
?

[18] A. Buckley et al., "General-purpose event generators for LHC physics", *Phys. Rept.* **504** (2011) 145, doi:10.1016/j.physrep.2011.03.005, arXiv:1101.2599.

Prospects for m_{top} at the LHC

CMS-PAS-FTR-13-017

- Top mass projections (CMS, ECFA)
  - Cautiously optimistic estimates of possible experimental precision at LHC
  - Assumes reduction in experimental and theoretical modeling, using the ATLAS 3D fit and differential studies with high statistics
- Some alternative methods can reach sub-GeV precision with 300 fb^{-1}
- Standard method may reach 0.2 GeV experimental precision, provided
  - Fundamental improvements in knowledge on key uncertainties:
  - Radiation, (b-)jet fragmentation, non-perturbative QCD effects, tuning of event generators
- Worthwhile to understand precise relation between m_{top}^{MC} and m_{top}^{pole} !



	Ref.[13]	Projections				
CM Energy	7 TeV	14 TeV				
Luminosity	$5 fb^{-1}$	$100 fb^{-1}$		$300 fb^{-1}$		$3000 fb^{-1}$
Pileup	9.3	19	30	19	30	95
Syst. (GeV)	0.95	0.7	0.7	0.6	0.6	0.6
Stat. (GeV)	0.43	0.04	0.04	0.03	0.03	0.01
Total, GeV	**1.04**	**0.7**	**0.7**	**0.6**	**0.6**	**0.6**

See also Snowmass Top working group report http://arxiv.org/pdf/1311.2028v1.pdf

Snowmass: less optimistic for standard approach

Questions for Discussion

- m_{top}^{MC} vs m_{top}^{pole} : for a given MC generator, would it be possible to pin down the difference between the MC mass and a well-defined mass by comparing the predicted distribution of an observable (like lepton p_T) between a well-defined calculation and the MC generator? Which observables would be most useful?
- Will NLO+PS Monte Carlo solve this issue? What about NNLO?
- What other observables can we use to measure the top mass?
- Non-perturbative QCD: is it sufficient to explore cluster- and string-based fragmentation models with all possible different tunes (UE, CR) that describe LHC data? Or could we be missing some important QCD effects?
- Any data-driven methods, observables, other than m_{top} that can be used to probe / discover / constrain unexpected, badly modeled QCD effects ?
- What can we learn from the “differential” studies, using the m_{top} observable as a probe of anomalous effects? What variables should we look at?