Top Mass Combination and Hadronization Uncertainties

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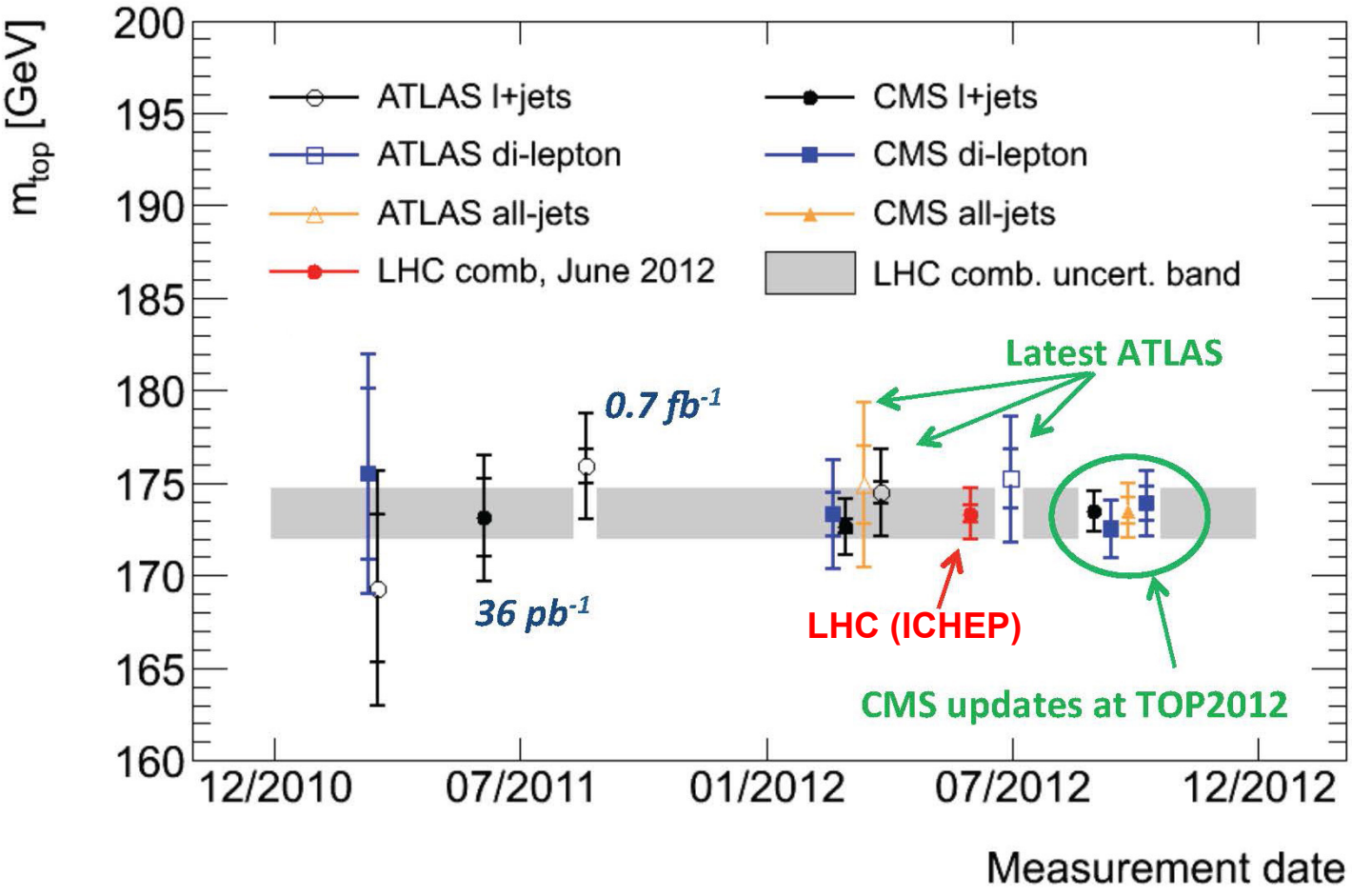
★ Topics Covered

- *Summer 2012 LHC Combination:*
  - *what it does/doesn't contain*
- *Additional Results and Prospects:*
  - *CMS & ATLAS updates*
- *What is needed for the next LHC Combination:*
  - *topics to be addressed*
- *Fragmentation Meeting 25/3/13:*
  - *short and longer-term studies*
  - *preliminary b-quark D(z) study*
  - *search for kinematic biases*

Evolution of Mass Measurements at 7 TeV



Summer 2012 Preliminary LHC Combination ICHEP 2012

$m_t = 173.3 \pm 0.5$ (stat.) ± 1.3 (syst.) GeV (0.8 % Precision)

This is based on preliminary and published results from ATLAS and CMS

It does not include/use:

- the ATLAS dilepton measurement from the 2011 data
- the CMS all-hadronic measurement from 2011
- the CMS full luminosity lepton+jets & dilepton measurements from the 2011 data

- results from any additional analyses from CMS or ATLAS (e.g. CMS end-point analysis)

New Results since last LHC combination

Preliminary CMS Combination (TOP2012) CMS-PAS-TOP-11-018

$m_t = 173.36 \pm 0.38\ (\text{stat.}) \pm 0.91\ (\text{syst.})$ GeV (0.6 % Precision)

CMS Kinematic Endpoint Analysis CMS-PAS-TOP-11-027

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

Systematic uncertainties partially uncorrelated with standard analyses (not included in CMS combination)

New Results since last LHC combination

ATLAS preliminary dilepton measurement using m_{T2}
ATLAS-CONF-082

$$m_t = 175.2 \pm 1.6\ (\text{stat.})\ ^{+3.1}_{-2.8}\ (\text{syst.})\ \text{GeV}$$

Systematic uncertainties partially uncorrelated with standard analyses

Also updates to full 2011 luminosity coming (timescale TBC)

➔ time to consider an updated LHC combination

Issues to be addressed

1.) Treatment of Hadronization Uncertainties:

- need a coherent treatment for both ATLAS and CMS

- investigation of the uncertainties due to b-quark D(z) modeling and its coverage in the current b-JES uncertainty

- study of the uncertainties due to the fragmentation modeling (cluster vs string….) and its coverage in the current b-JES/JES uncertainties

2.) Study of the uncertainties due to the modeling of the finite top and W-decay widths
(e.g. when using models with different implementations: Madgraph/Alpgen vs MC@NLO/Powheg)

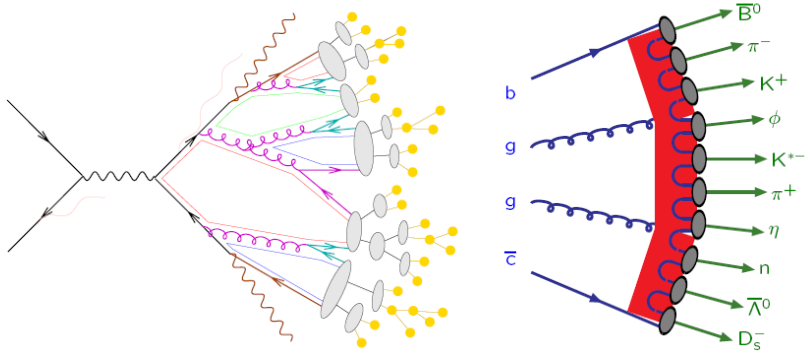
➔ *these need to be addressed for both the next ATLAS/CMS combination and any LHC/Tevatron combination*

➔ *Tentative Plan:*

- *Perform an new preliminary LHC combination as soon as the fragmentation uncertainties are resolved*
- *Proceed with an LHC + Tevatron combination soon afterwards (inputs to be agreed by all four collaborations)*

Hadronization systematics: were do we stand

- Hadronization models describe the transition from final state partons to colorless hadrons
- Cluster and string hadronization models are implemented in Herwig and Pythia, respectively



- Hadronization systematics are considered in the determination of both the JES (Jet Energy Scale) and the MC modelling uncertainties:
  - the component in the JES refers mainly to single isolated jets
  - the hadronization unc. from top-pair MC accounts also for the multi-jet environment

there could be a sizeable double counting

	Tevatron		LHC	
	CDF	D0	ATLAS	CMS
Hadronization	***Pythia/Herwig incl. UE syst***	***Alpgen Pythia/Herwig incl. UE syst***	***Powheg Pythia/Herwig***	***(considered in the JES syst determination)***
Unc. on m_{top} [GeV]	***0.2 – 0.3***	***0.6***	***0.2 – 0.9***	***n/e***

Fragmentation Meeting – CERN, March 25th

- Much discussion of both CMS and ATLAS current implementations and JES terminology (not identical in some cases)

- Also on the role of non-perturbative corrections: UE modeling, OOC corrections vs parton flavor, CR effects and limitations of current modeling

Short-term Proposals (Priority Items):

- both experiments will evaluate the difference between string (Pythia) and cluster fragmentation (Herwig) for a common ME generator

Question: Should this be done using an NLO generator, rather than a matched generator?

Longer-term Study Ideas:

- MC studies:

  ΔR(reco-truth jet) vs ΔR_{min}(closest jet) to look for any additional hadronization uncertainty not covered by the standard JES terms

- Data/MC studies:

  compare sensitive variables to exclude extreme models (i.e. derive data-driven constraints of systematics)

Work in Progress

- *Generation of MC files needed for Herwig/Pythia fragmentation comparison*

- *Studies of the effect of using finite top width in simulation*

- *Studies of the uncertainties due to the D(z) modeling for b-quarks*

Hope to get results from these soon

Prelim. b-quark D(z) Study

Markus Seidel

Soft QCD uncertainties: CMS Lepton+Jet Analysis (TOP-11-015)

- *Measurement based on reconstruction of invariant masses from jets*
- *Kinematic fit:*

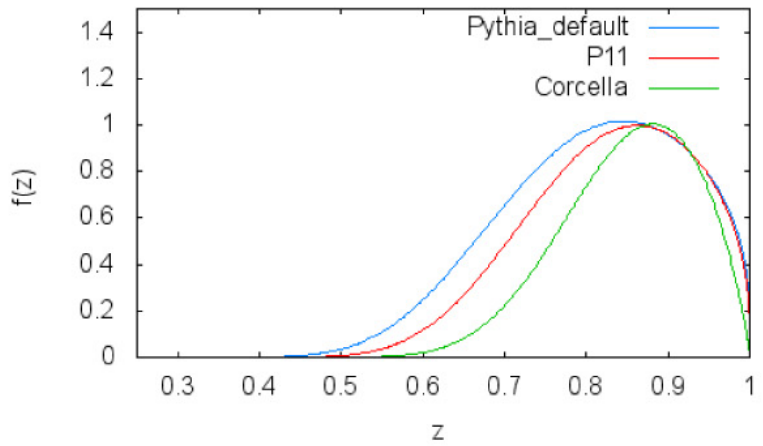
$$m_t^{fit} \rightarrow (m_t, \mathrm{JES}) \qquad m_W^{reco} \rightarrow \mathrm{JES}$$

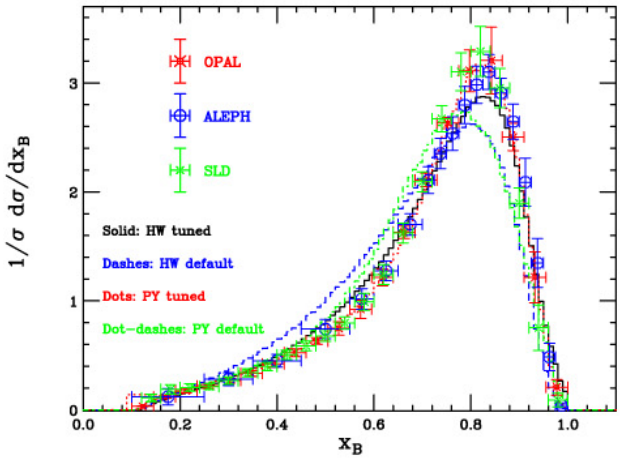
Source	Description	$\delta^{\ell}_{m_t}$	$\delta^{\ell}_{\mathrm{JES}}$
b-JES	Scale b-jet energies $\pm\sigma_{\mathrm{flavour}}$	0.61	0.000
– aka hadronization	factorized approach of "Pythia vs. Herwig"		
Colour reconnection	Pythia P11 vs. P11noCR	0.54	0.004
Underlying event	Pythia P11 vs. P11mpHi & P11TeV	0.15	0.002
Soft QCD total		0.83	0.004
TOP-11-015 total	incl. all uncertainties	**0.98**	**0.008**

➔ Dominant uncertainties for this mass measurement

b fragmentation

- Vary Bowler-Lund parameters for quark fragmentation
  (Caveat: cannot be done independently for light and b quarks in Pythia6)
- Corcella (arXiv:0907.5158v3) tuned to b-hadron data (figure right)
- Compare default/Z2, P11 and Corcella (figure left, table)



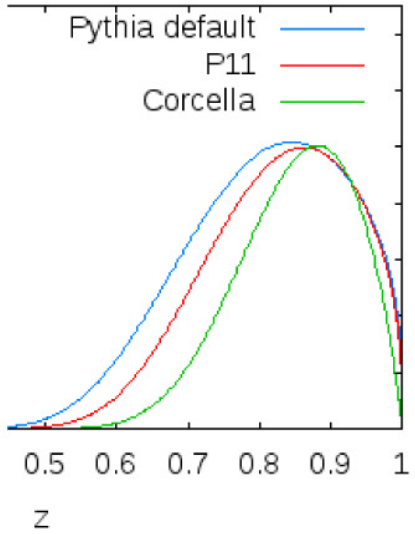


	P11 - Z2	Corcella - Z2	Effect
m_t^{2D} [GeV]	+0.01±0.20	+0.03±0.20	Coherent change compensated
JES	+0.0019	+0.0008	Sensitive to light fragmentation
m_t^{1D} [GeV]	+0.19±0.11	+0.11±0.11	Sensitive to b fragmentation

- Harder fragmentation = more energy in jet cone
- 2D fit absorbs parameter change
- Estimate impact on b-jets by fixing JES=1

$\rightarrow$ Small effect of b fragmentation

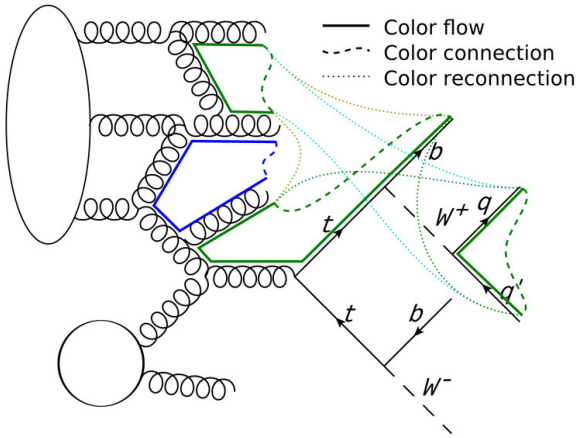
- $0.1 - 0.2$ GeV on m_t
- Should hold for other "standard" measurements



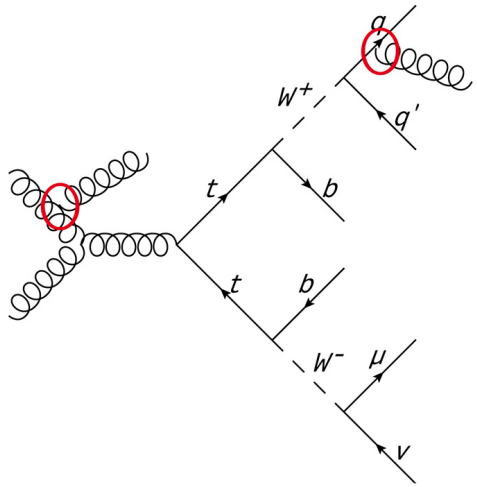
Kinematic Study CMS-PAS-TOP-12-029

Search for possible bias due to systematic uncertainties - lepton + jets channel

Color Reconnection



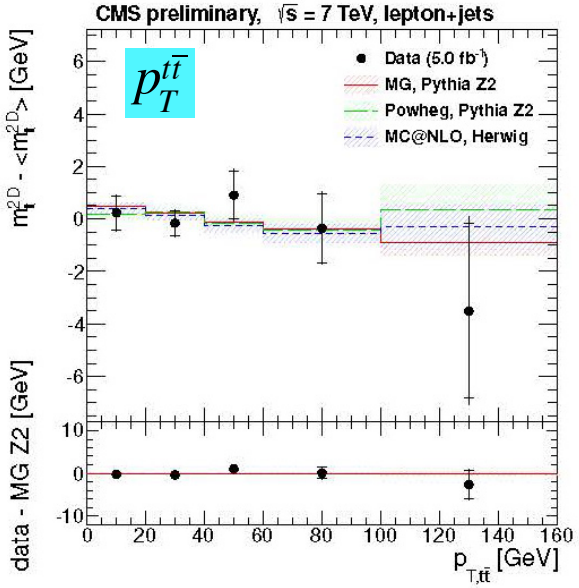
ISR and FSR

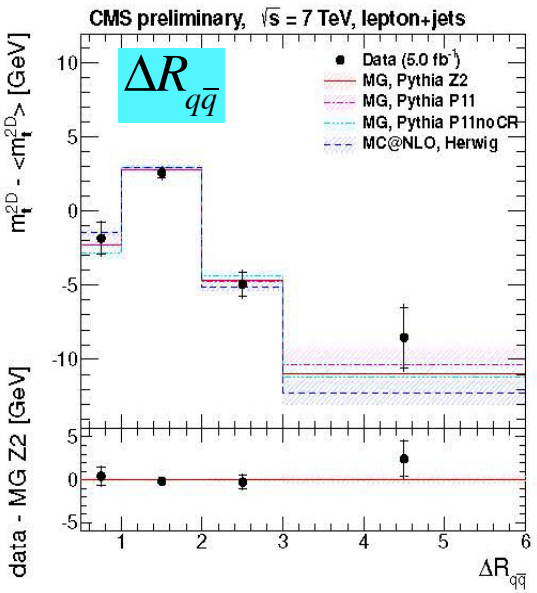


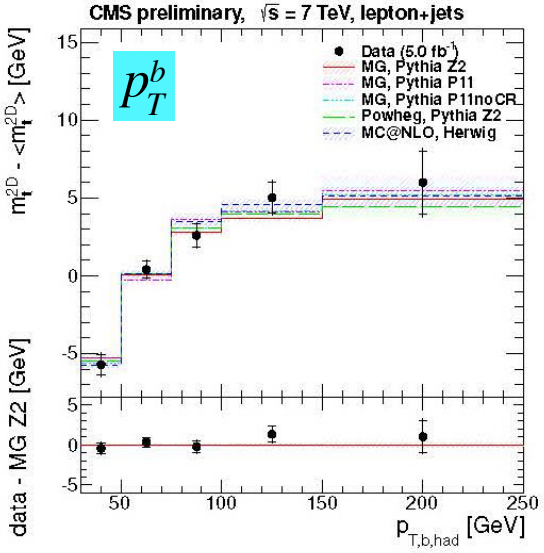
Measure top quark mass as a function of kinematics (12 variables) using the analysis method taken from TOP-11-015

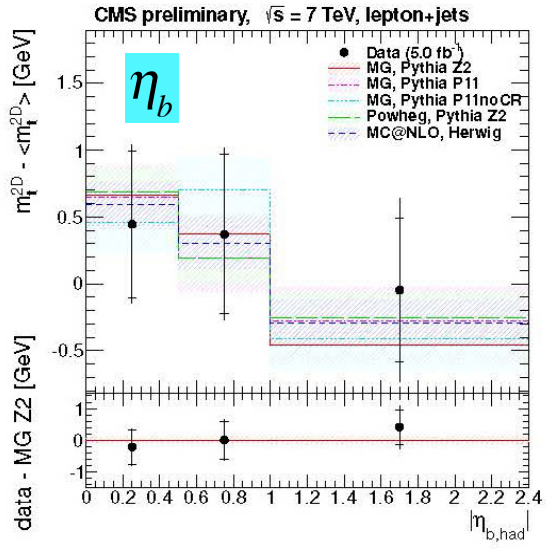
Compare results to:

Madgraph+Pythia Z2 tune (CMS default)
Madgraph+Pythia P11 and P11noCR
MC@NLO+Herwig6
POWHEG+Pythia Z2 tune









➔ no evidence for kinematic bias and dramatic effects are excluded

12 kinematic variables studied using both JES =1 and simultaneous JES and m_t fits:

$$\Delta R_{q\bar{q}}, \quad \Delta\phi_{q\bar{q}}, \quad p_T^t, \quad |\eta_t|$$
$$H_T, \quad m_{t\bar{t}}, \quad p_T^{t\bar{t}}, \quad N_{jet}$$
$$p_T^b, \quad |\eta_b|, \quad \Delta R_{b\bar{b}}, \quad \Delta\phi_{b\bar{b}}$$

Observations:

no evidence for large bias from CR, ISR/FSR, or b-quark kinematics

no evidence for large bias due to difference between m_t (MC) and m_t?

Summary

- There have been significant improvements to the precision of the individual ATLAS and CMS analyses since the last LHC combination was made.

- New results are available/coming in the near future. Some of these have systematics which are partially uncorrelated with the standard analyses.

- We have started working towards a new combination.

- Studies are needed to improve the characterization of the systematics for the fragmentation and width uncertainties. These are in progress.

- On completion of the studies and certification of the results, we will proceed with the new preliminary LHC result, followed by a first pass at an LHC + Tevatron combination.