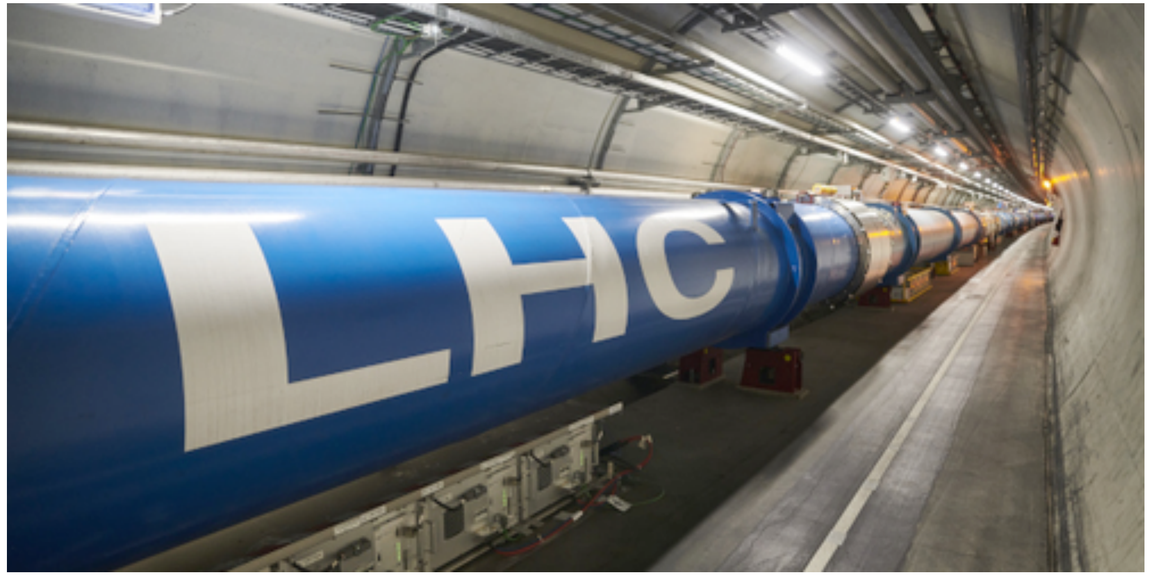
Combined measurement of the top quark mass at 7 and 8 TeV *by ATLAS and CMS*

Phys. Rev. Lett. 132, 261902 (2024)
See also: synopsis

42nd International Conference on High Energy Physics

Prague, 17-24 July 2024

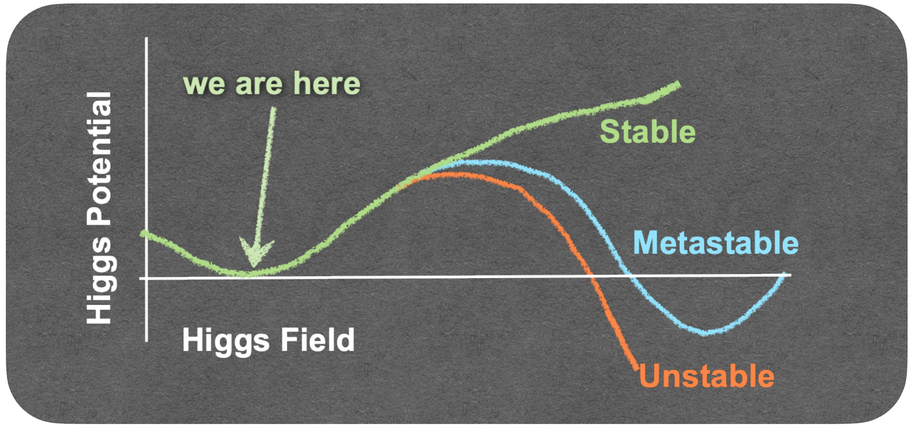


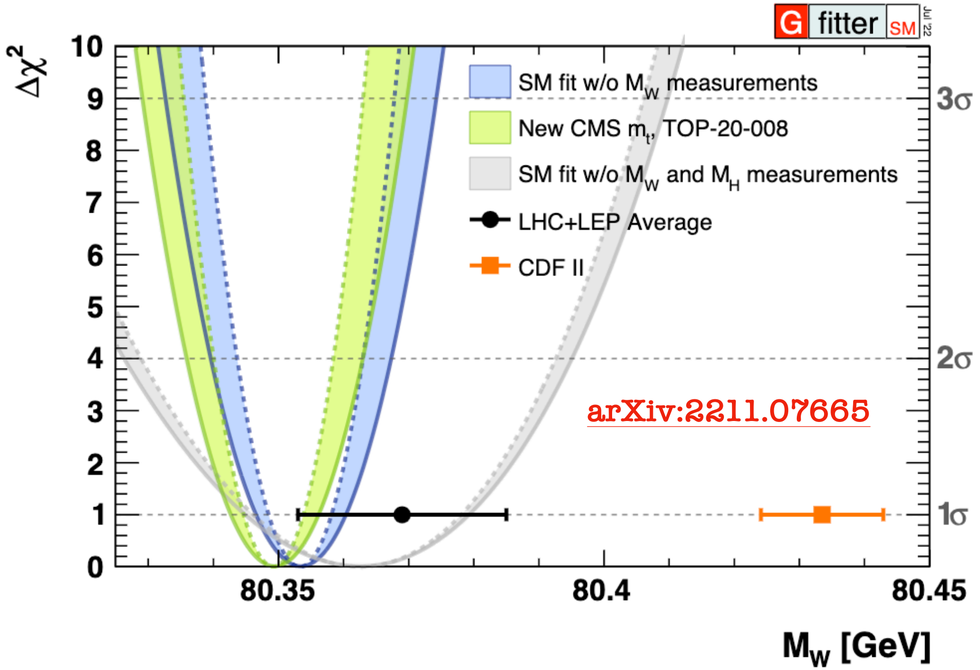
Matteo M. Defranchis (CERN)
on behalf of the CMS and ATLAS Collaborations

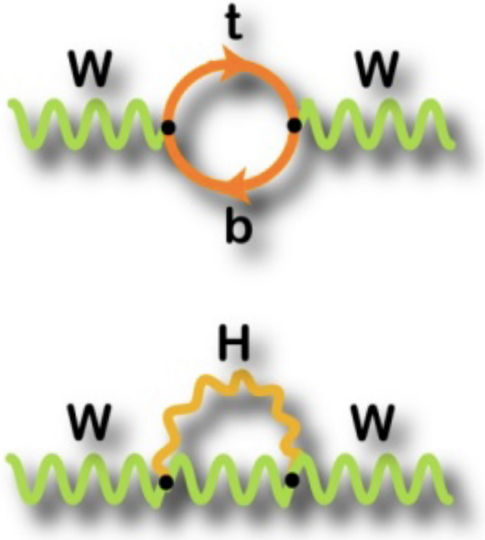
The role of m_t in the SM

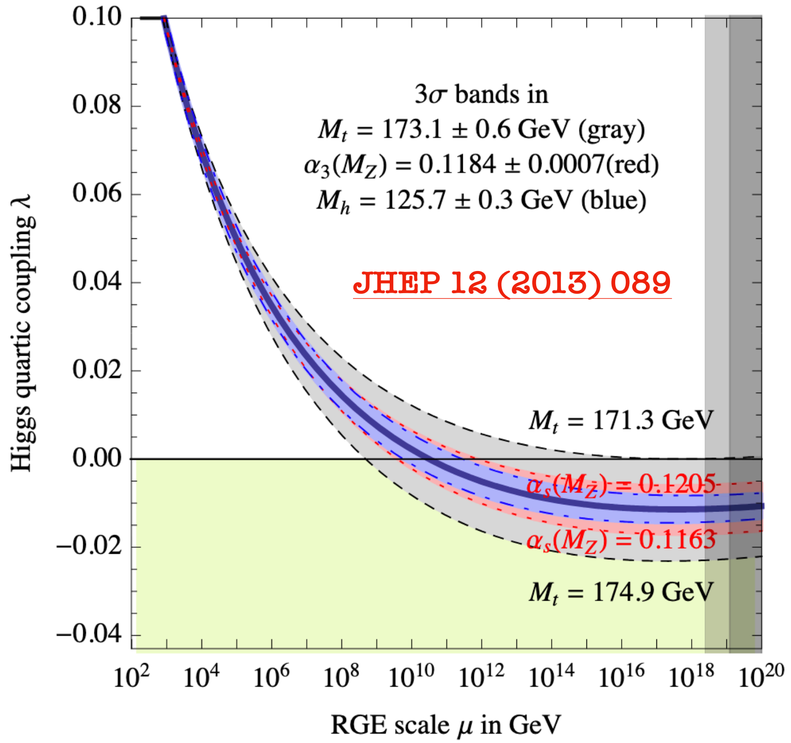
In the SM, m_t can be related to m_W and m_H thanks to loop corrections to precision EW observables
-> **internal consistency of SM**

Stability of Higgs potential at the Planck scale depends on value of m_t
-> $\lambda < 0$ would be indirect evidence of BSM physics









Methods for measuring m_t

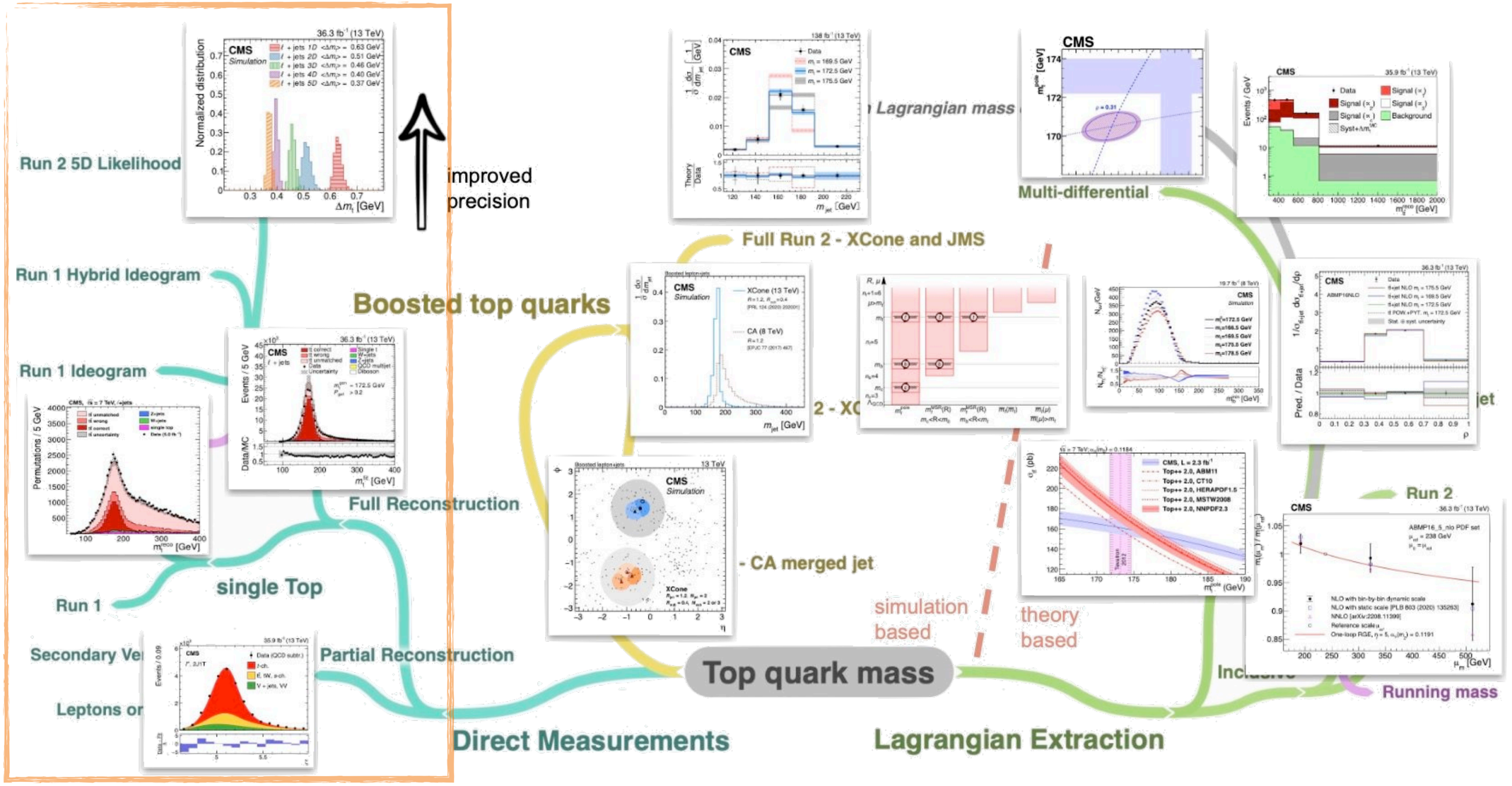
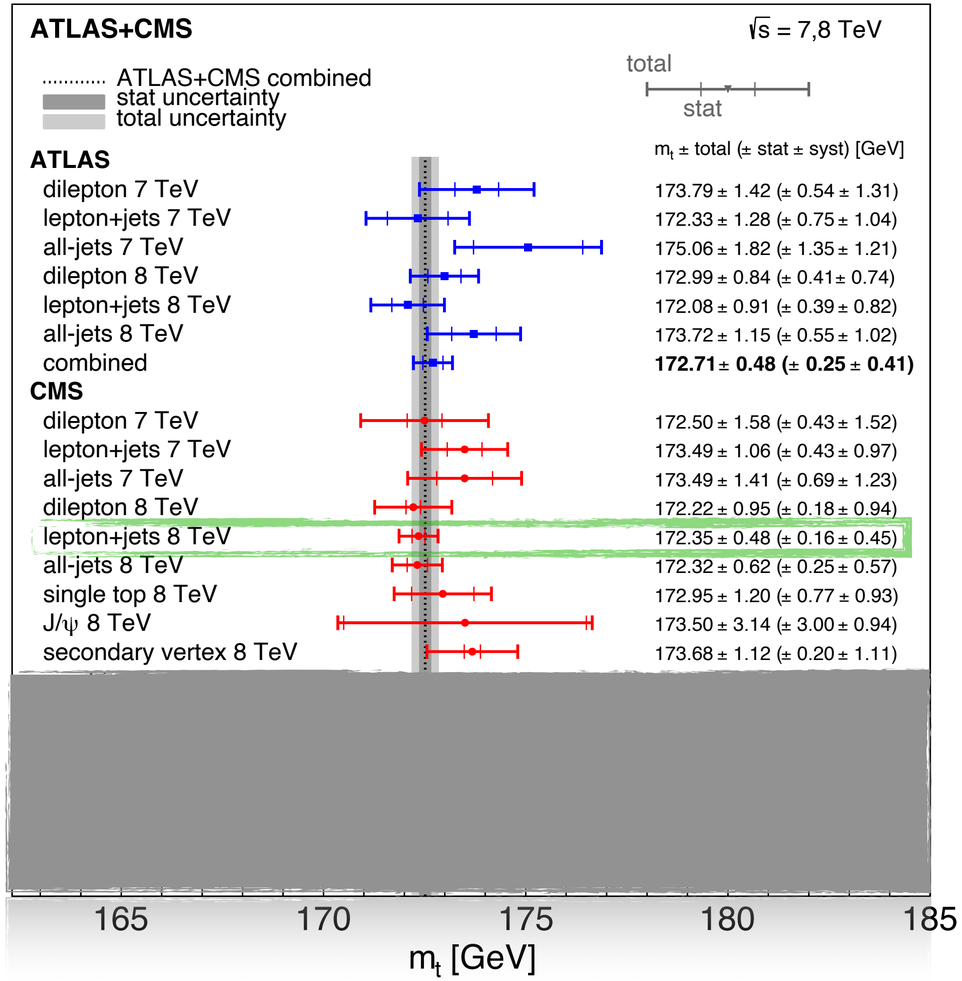


Illustration from CMS Physics Briefing of arXiv:2403.01313 (submitted to Physics Reports)

ATLAS and CMS Run-1 measurements

- 6 ATLAS inputs, already included in previous ATLAS combination
- 9 CMS inputs (6 conventional + 3 alternative)
  - Alternative measurements not included in previous CMS combination
  - Replaced older results with more recent (and precise) ones
  - **Updated CMS combination** as part of LHC combination

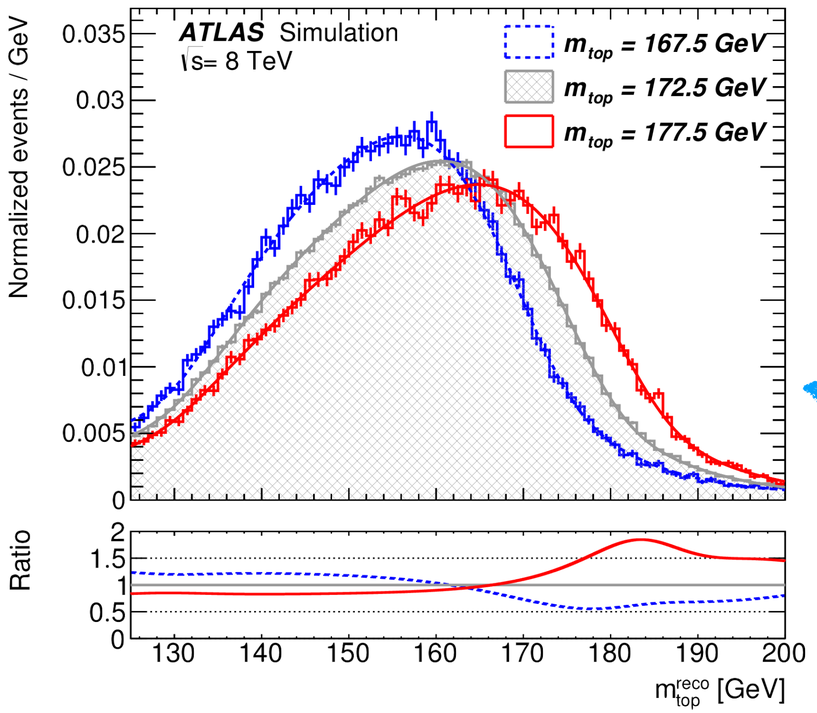
	dilepton	lepton +jets	all -jets	Other final states and topologies
7 TeV	*Eur. Phys. J. C* **72** (2012) 2202 *Eur. Phys. J. C* **75** (2015) 330	*JHEP* **12** (2012) 105	*Eur. Phys. J. C* **74** (2014) 2758 *Eur. Phys. J. C* **75** (2015) 158	Table: courtesy of C. Nellist (slides)
8 TeV	*Phys. Rev. D* **96** (2017) 032002 *Phys. Lett. B* **761** (2016) 350	*Phys. Rev. D* **93** (2016) 092006 *Eur. Phys. J. C* **79** (2019) 290	*JHEP* **09** (2017)118	**Single top:** *Eur. Phys. J. C* **77** (2017) 354 **Secondary vertex:** *Phys. Rev. D* **93** (2016) 092006 **J/psi:** *JHEP* **12** (2016) 123



Most precise single input: 0.48 GeV uncertainty

Direct m_t measurements in LHC Run1

Eur. Phys. J. C 79 (2019) 290

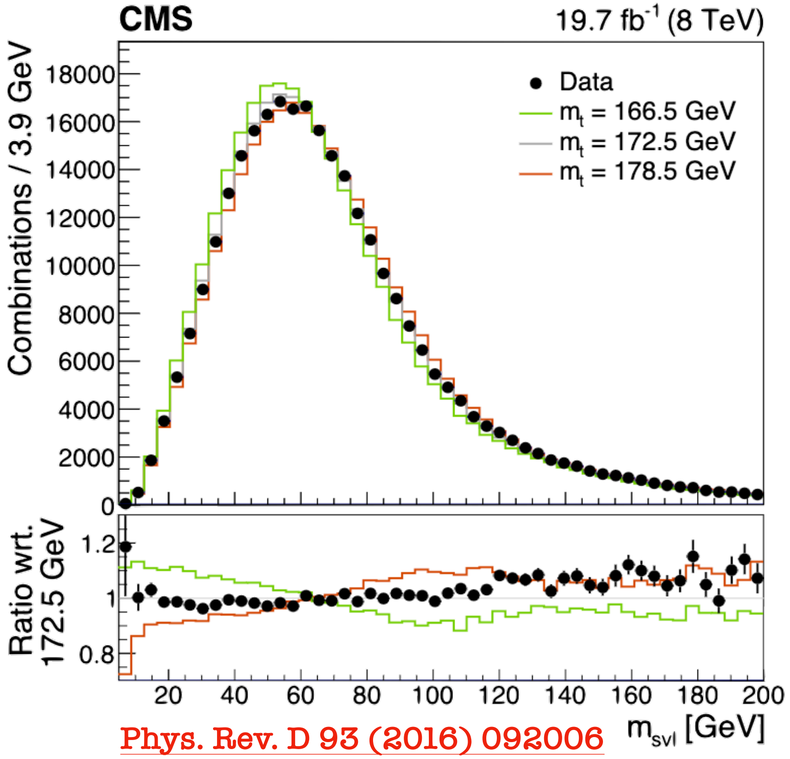


- **Full reconstruction of m_t** (and m_W) using maximum likelihood method
- 3D template fit: m_t, JSF (jet scale factor) and b-JSF
  - Trade larger statistical uncertainty for lower impact of systematics

$$m_{\text{top}} = 172.08 \pm 0.39\,(\text{stat}) \pm 0.82\,(\text{syst})\ \text{GeV}$$

"Conventional": biggest challenges are JES uncertainties and b-JES calibration

"Alternative": limited by modelling of b-quark fragmentation



Phys. Rev. D 93 (2016) 092006

- Invariant mass between lepton and secondary vertex from b-quark jet
  - **Partial reconstruction** of top quark decay products
- Larger overall uncertainty, but less sensitive to jet energy scale uncertainties
  - **Beneficial for combinations**

$$173.68 \pm 0.20\,(\text{stat})^{+1.58}_{-0.97}\,(\text{syst})\ \text{GeV}$$

The BLUE method

BLUE = Best Linear Unbiased Estimator

$$m_t = \sum_i w_i m_t^i \text{, with } \sum_i w_i = 1$$ → Linear combination of inputs

- For a given choice of correlations, set of w_i that provide the Best (i.e. lower variance) estimate of m_t can be calculated
- The result is unbiased, as long as m_t^i are unbiased
- Weights can be negative (e.g. strong negative correlations)

Example for 2 input measurements:

$$x = (1-\beta)\, x_1 + \beta\, x_2$$
$$z \equiv \sigma_2/\sigma_1 \geq 1$$

→

$$\beta = \frac{1-\rho z}{1-2\rho z + z^2}$$

Note: when uncertainties on input measurements are different (z>1), taking rho=1 is not the conservative assumption!

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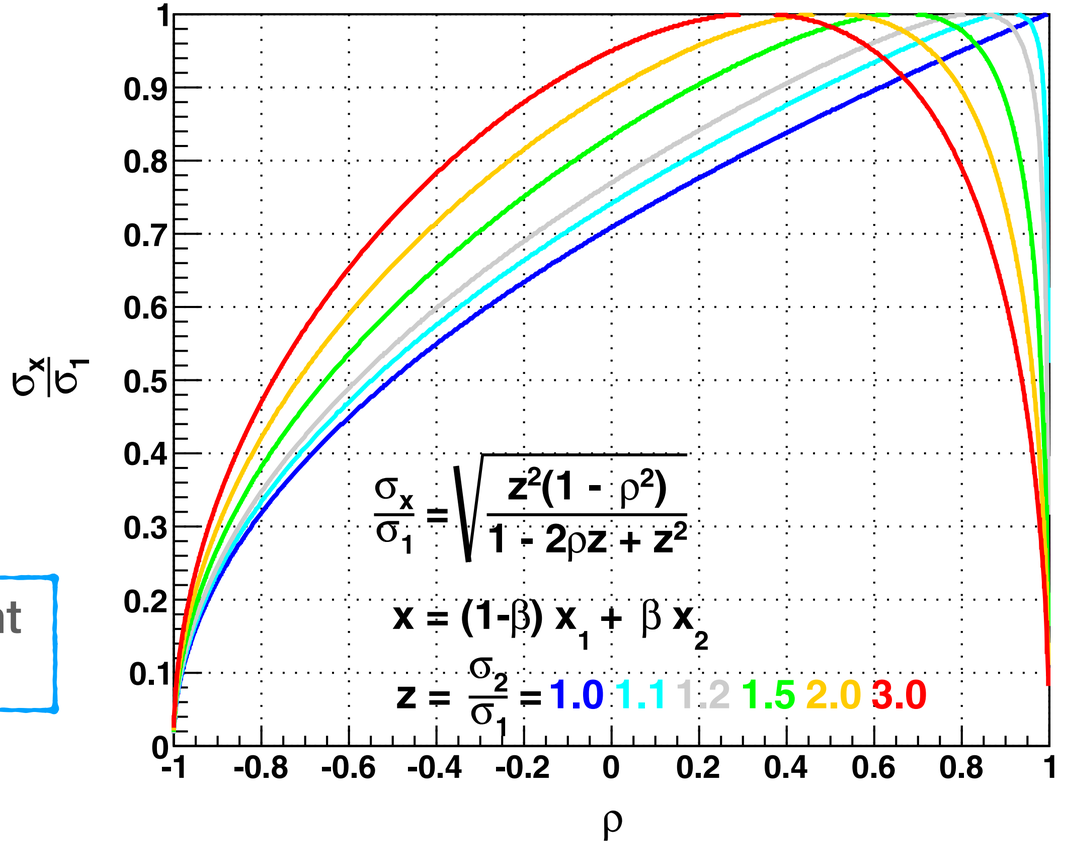

Assessment of correlations

- Within a single experiments, correlations between measurements can be assessed rather rigorously
  - **Same underlying variations** used to assess impact of a given systematic uncertainty
  - Sign of the correlation coefficients can also be accessed

- For the LHC combination, sources of uncertainty are grouped into classes (e.g. b-tagging, PDF)
- For each class, a choice of correlation is made, based on **similarity in the way the uncertainties are estimated** (or underlying physics model)

LHC correlation assumptions

Assessed correlation	Strong	Partial	None
Assigned correlation coefficient	0.85	0.5	0

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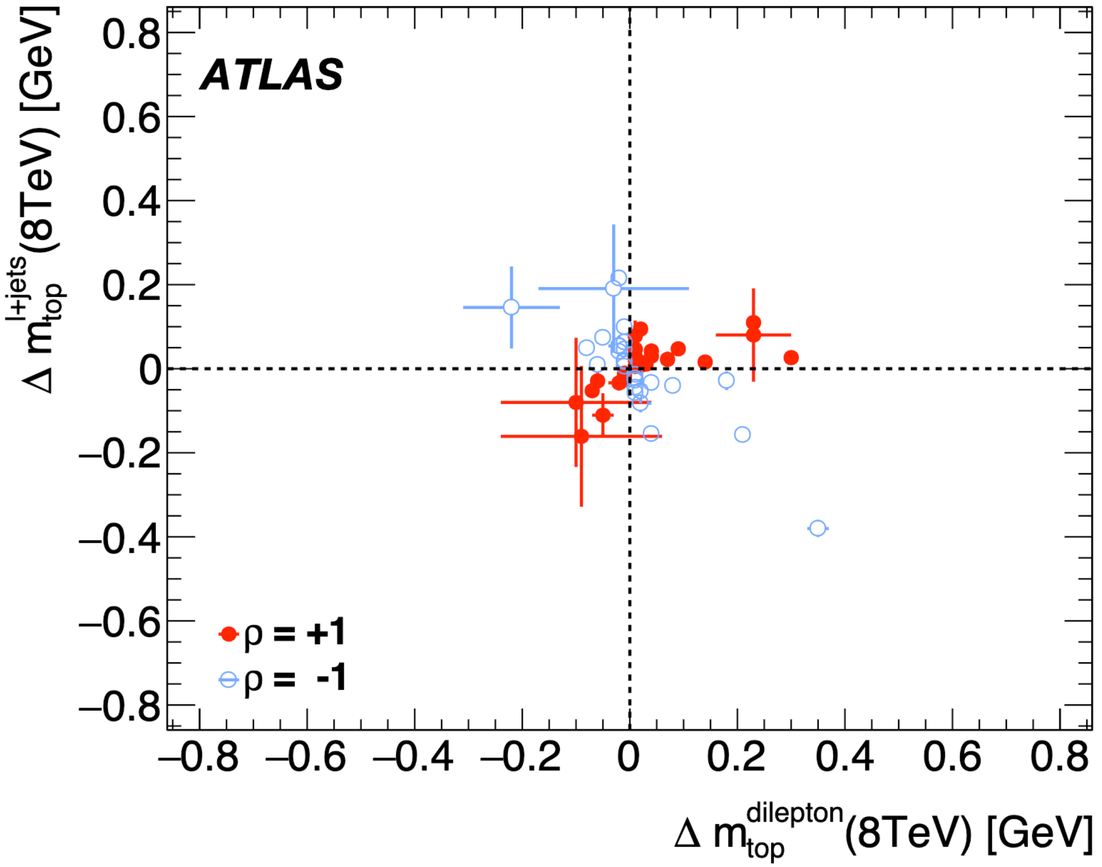
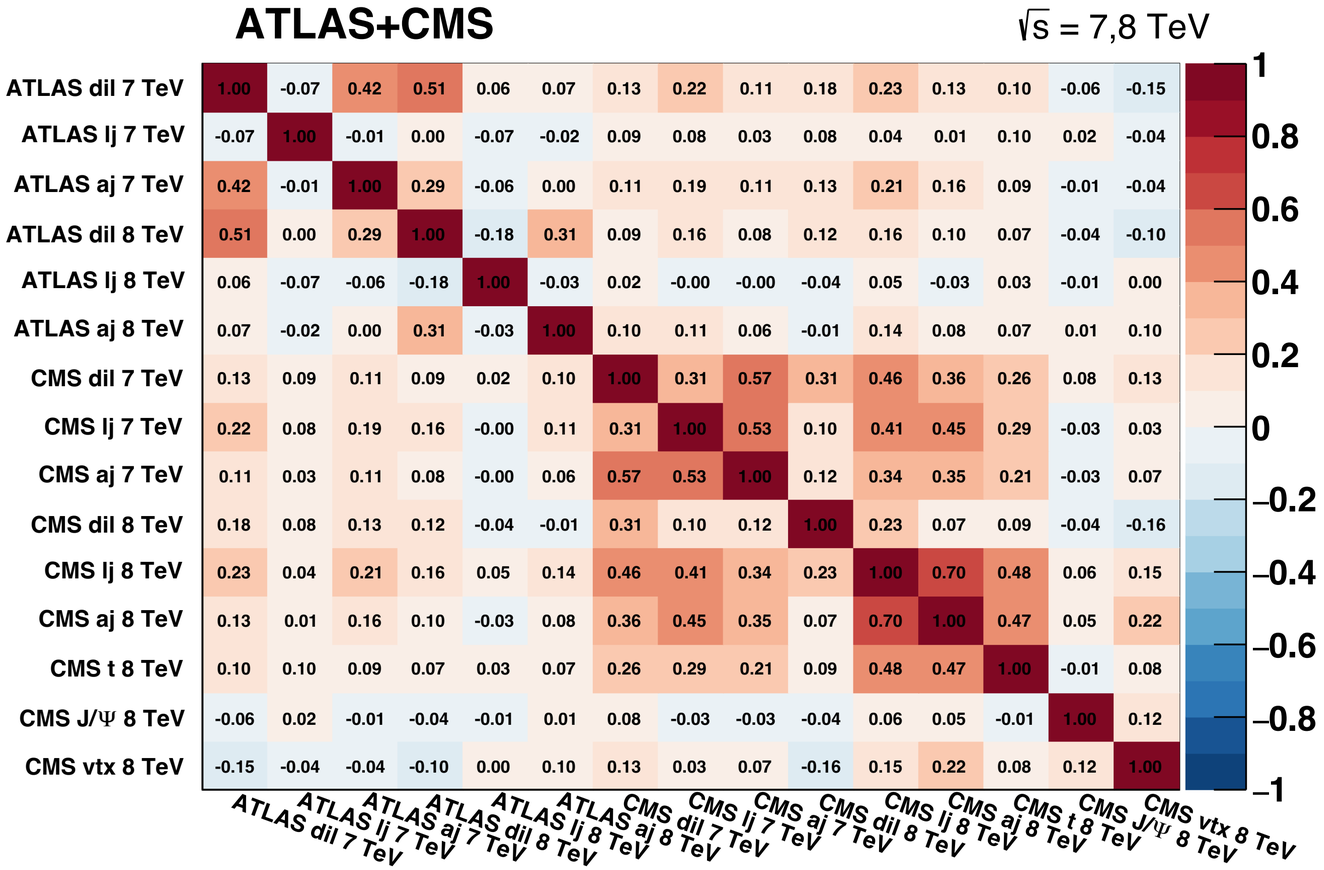


ATLAS-CMS correlations

Correlation	LHC categories
Strong	• Flavour component of JES* • Pileup modelling • Parton distribution functions (PDFs) • MC-based background estimates
Partial	• b tagging (similar method) • MC modelling (different systematic variations to assess similar effects)
None	• Experimental uncertainties (calibrations using independent datasets) • Analysis-specific calibrations

Example correlation matrices per systematic uncertainty can be found in the backup



*correlations between jet energy scale (JES) uncertainties studied in detail in dedicated LHCTopWG note

Results, impact, correlation scans

$m_t = 172.52 \pm 0.33$ GeV

Most precise m_t result to date!

Improvement of 31% with respect to most precise single input measurement

- Uncertainty dominated by b-JES
- **Negligible impact** on final result by varying correlation assumptions within ranges that reflect the understanding of the correlation

Uncertainty category	Uncertainty impact [GeV] LHC	ATLAS	CMS
b-JES	0.18	0.17	0.25
b tagging	0.09	0.16	0.03
ME generator	0.08	0.13	0.14
JES 1	0.08	0.18	0.06
JES 2	0.08	0.11	0.10
Method	0.07	0.06	0.09
CMS b hadron $\mathcal{B}$	0.07	—	0.12
QCD radiation	0.06	0.07	0.10
Leptons	0.05	0.08	0.07
JER	0.05	0.09	0.02
CMS top quark p_T	0.05	—	0.07
Background (data)	0.05	0.04	0.06
Color reconnection	0.04	0.08	0.03
Underlying event	0.04	0.03	0.05
g-JES	0.03	0.02	0.04
Background (MC)	0.03	0.07	0.01
Other	0.03	0.06	0.01
l-JES	0.03	0.01	0.05
CMS JES 1	0.03	—	0.04
Pileup	0.03	0.07	0.03
JES 3	0.02	0.07	0.01
Hadronization	0.02	0.01	0.01
p_T^{miss}	0.02	0.04	0.01
PDF	0.02	0.06	<0.01
Trigger	0.01	0.01	0.01
Total systematic	0.30	0.41	0.39
Statistical	0.14	0.25	0.14
Total	0.33	0.48	0.42

Uncertainty category	ρ	Scan range	$\Delta m_t/2$ [MeV]	$\Delta\sigma_{m_t}/2$ [MeV]
JES 1	0	—	—	—
JES 2	0	$[-0.25, +0.25]$	8	7
JES 3	0.5	$[+0.25, +0.75]$	1	<1
b-JES	0.85	$[+0.5, +1]$	26	5
g-JES	0.85	$[+0.5, +1]$	2	<1
l-JES	0	$[-0.25, +0.25]$	1	<1
CMS JES 1	—	—	—	—
JER	0	$[-0.25, +0.25]$	5	1
Leptons	0	$[-0.25, +0.25]$	2	2
b tagging	0.5	$[+0.25, +0.75]$	1	1
p_T^{miss}	0	$[-0.25, +0.25]$	<1	<1
Pileup	0.85	$[+0.5, +1]$	2	<1
Trigger	0	$[-0.25, +0.25]$	<1	<1
ME generator	0.5	$[+0.25, +0.75]$	<1	4
QCD radiation	0.5	$[+0.25, +0.75]$	7	1
Hadronization	0.5	$[+0.25, +0.75]$	1	<1
CMS b hadron $\mathcal{B}$	—	—	—	—
Color reconnection	0.5	$[+0.25, +0.75]$	3	1
Underlying event	0.5	$[+0.25, +0.75]$	1	<1
PDF	0.85	$[+0.5, +1]$	1	<1
CMS top quark p_T	—	—	—	—
Background (data)	0	$[-0.25, +0.25]$	8	2
Background (MC)	0.85	$[+0.5, +1]$	2	<1
Method	0	—	—	—
Other	0	—	—	—

Consistency check: 2D combination

Overall correlation and consistency between ATLAS and CMS can be assessed via **simultaneous ATLAS-CMS combination**:

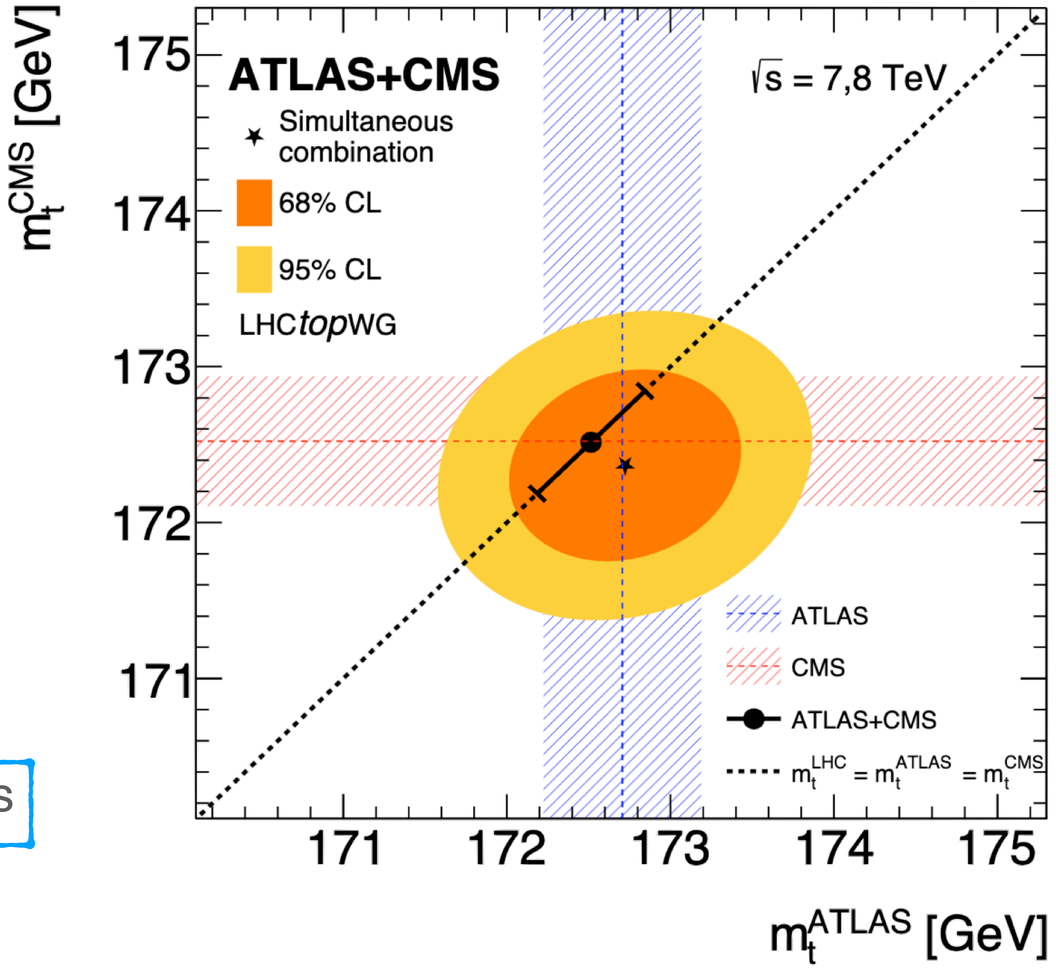
- One top mass parameter per experiment
- Different from single-experiment combination due to effect of systematic correlations

For example, for ATLAS (vice-versa for CMS):

$$m_{\mathrm{t}}^{\mathrm{ATLAS}} = \sum_i w_i^{\mathrm{ATLAS}}\, m_{\mathrm{t}}^{\mathrm{i,ATLAS}} + \sum_j w_j^{\mathrm{CMS}}\, m_{\mathrm{t}}^{\mathrm{j,CMS}}$$

$$\text{with} \sum_i w_i^{\mathrm{ATLAS}} = 1 \text{ and } \sum_j w_j^{\mathrm{CMS}} = 0$$

Results compatible with the hypothesis $m_t^{ATLAS} = m_t^{CMS}$

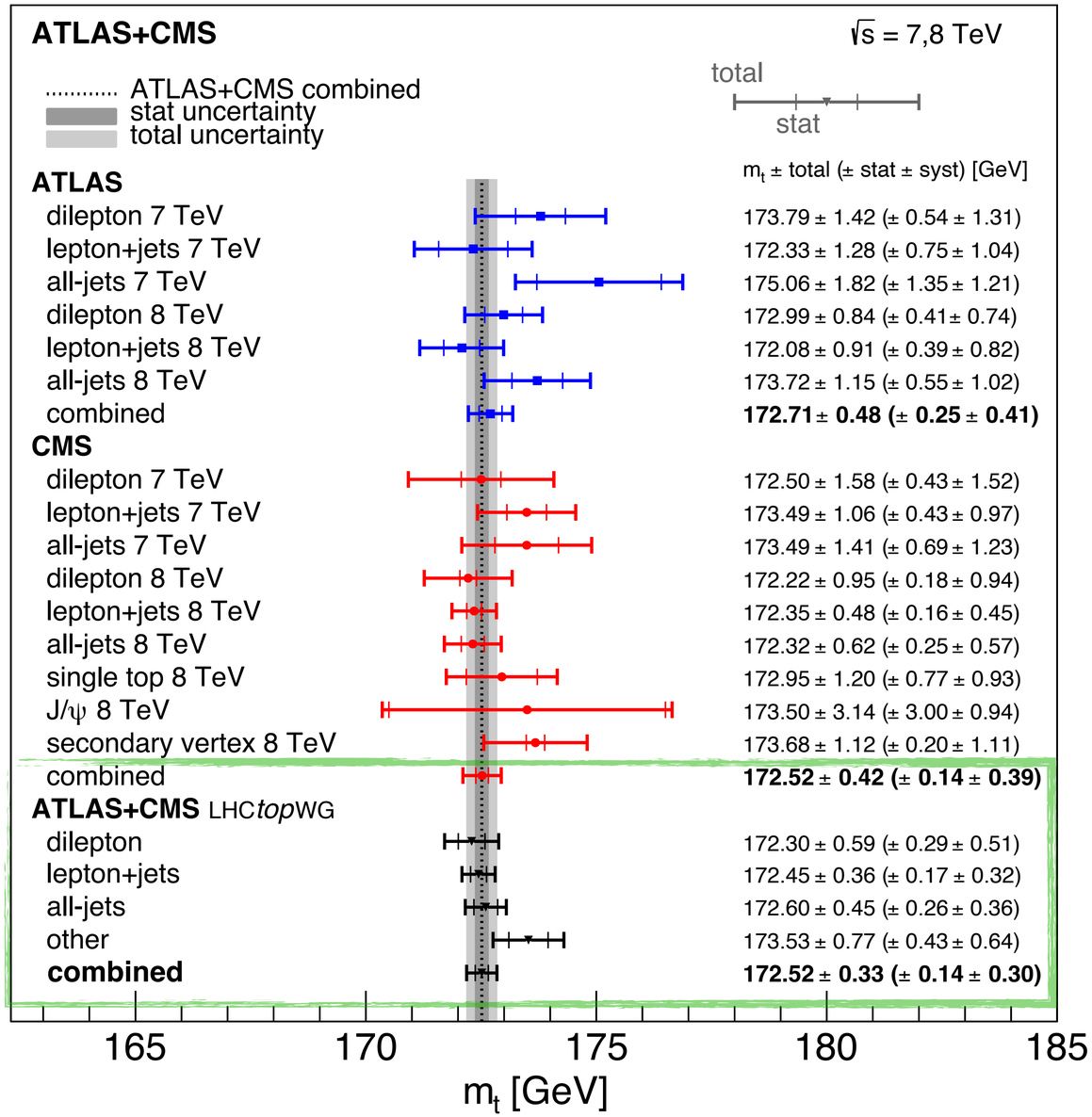


Consistency check: channels

The same can be done to check the **compatibility between different "channels"**:

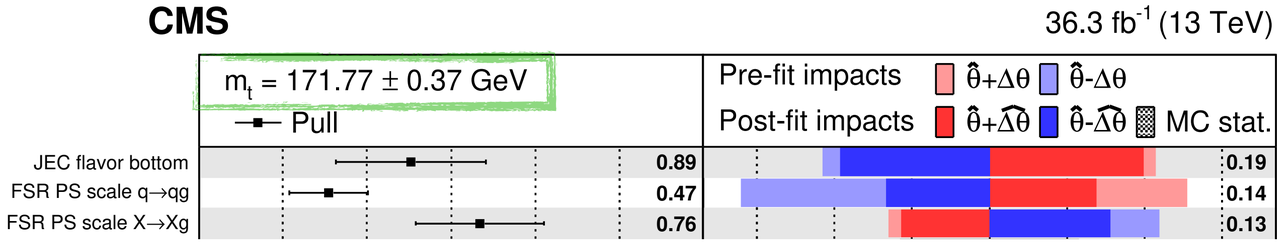
	χ^2 (ndf)	χ^2/ndf
Full combination	7.5 (14)	0.54
2-dimensional	7.2 (13)	0.55
Per channel	5.4 (11)	0.49

No significant differences in χ^2/ndf demonstrates compatibility between channels and experiments



Comparison with CMS 13 TeV

Eur. Phys. J. C 83 (2023) 963



- 5-dimensional **profile-likelihood fit** in l+jets final state
- Central value is 0.75 GeV below Run1 combination
- Various differences between Run1 and Run2 in terms of MC simulation and systematic variations

New: parton shower (PS) splitting kernel considered as independent systematic variation in the fit

Central value depends on choice of correlation between PS splitting kernels

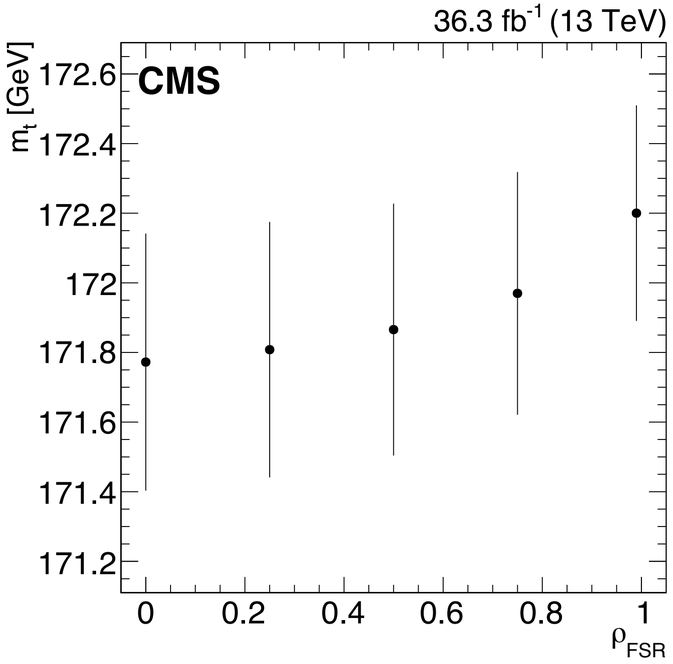


Table adapted from CMS review paper [arXiv:2403.01313, sub. to Physics Reports]

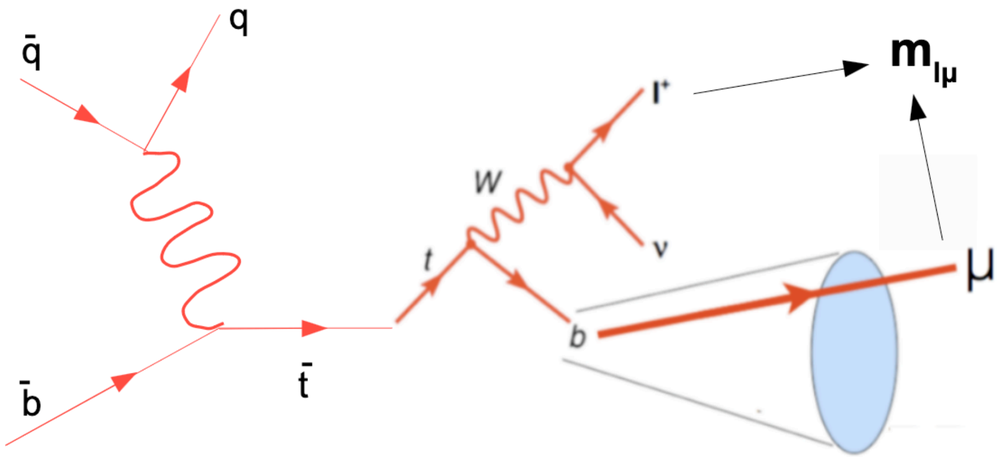
	Run 1	Run 2 legacy
Default setup		
ME generator	MADGRAPH5 $t\bar{t}$ + ≤3 jets @ LO	POWHEG v2 $t\bar{t}$ @ NLO
PDF	CT10 NLO	NNPDF3.1 NNLO
PS/UE generator	PYTHIA6.4	PYTHIA8.2
PS/UE tune	Z2(*)	CP5
Uncertainties		
PDF	CT10 eigenvectors, MSTW08, NNPDF2.3 †	NNPDF eigenvectors, CT14, MMHT14 †
ME scales	$\mu_r \oplus \mu_f$ up/down	$\mu_r \oplus \mu_f$ 7-point †
ME-PS matching	threshold up/down	h_{damp} up/down
Alternative ME	POWHEG v1	MADGRAPH5_aMC@NLO
Top quark p_T	ratio to 7/8 TeV data	ratio to 13 TeV data
ISR	μ_r^{ISR} up/down (correlated with ME)	μ_r^{ISR} up/down †
FSR	—	μ_r^{FSR} up/down †
UE	P11, P11 mpiHi/TeV	CP5 up/down
CR	P11, P11noCR	ERD on/off, CR1, CR2 (both ERD off)
b fragmentation	r_b up/down †	r_b up/down, un/tuned, Peterson †

Comparison with ATLAS 13 TeV

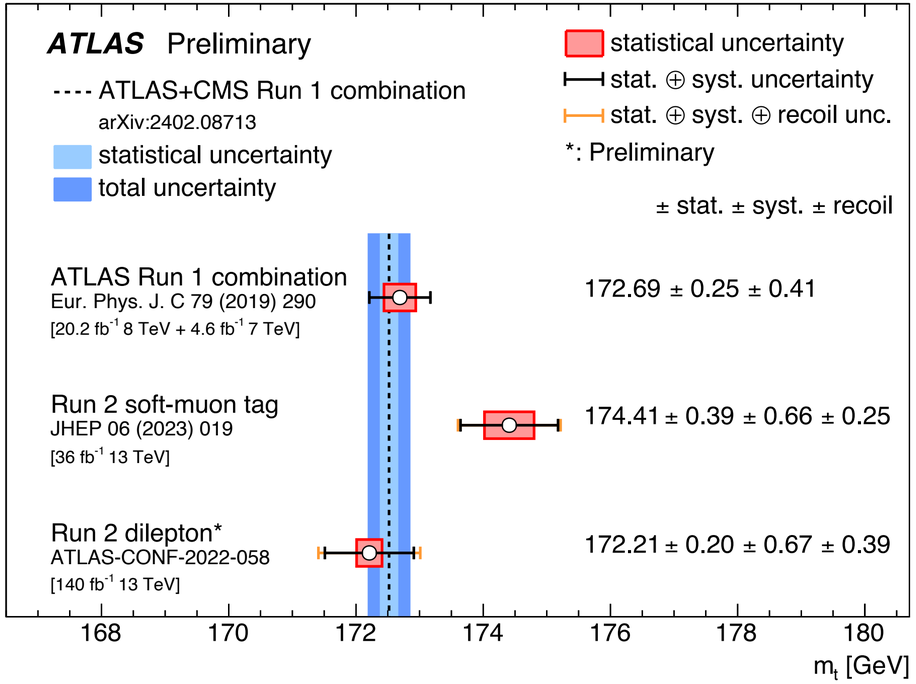
JHEP 06 (2023) 019

- Invariant mass between lepton from top quark decay and **soft muon from b-quark decay** ("alternative" method)
- Less sensitive to JES, but dependent on b quark fragmentation
- In agreement with ATLAS combination within 2 standard deviations

$$m_t = 174.41 \pm 0.39\,(\text{stat.}) \pm 0.66\,(\text{syst.}) \pm 0.25\,(\text{recoil})\,\text{GeV}$$



From ATLAS Top physics review [arXiv:2404.10674, sub. to Physics Reports]

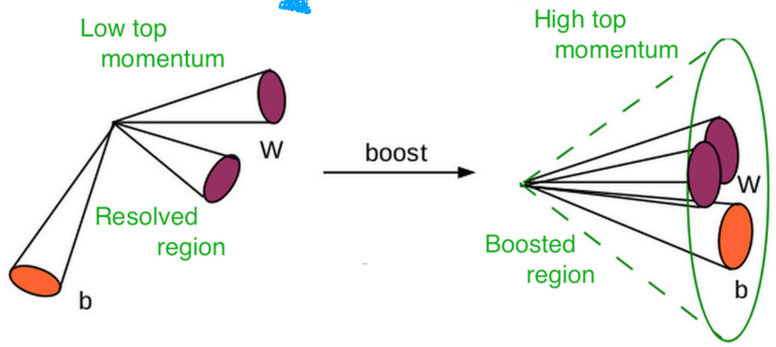


- Ambiguity in Pythia on choice of recoiler particle from second gluon emissions in top quark decays
- Effect on the LHC combination estimated to be at most 35 MeV, well below the total uncertainty

Prospects for m_t at the (HL-)LHC

See talk by A. Paasch

- **Enormous progress** in m_t measurements using boosted top quark decays
  - Big margin of improvement with large datasets (Run3, HL-LHC)
- Possibility to perform both direct measurement and indirect extraction of m_t using first-principles theoretical predictions (SCET, HQET)
  - Unambiguously interpret result in well-defined theoretical framework



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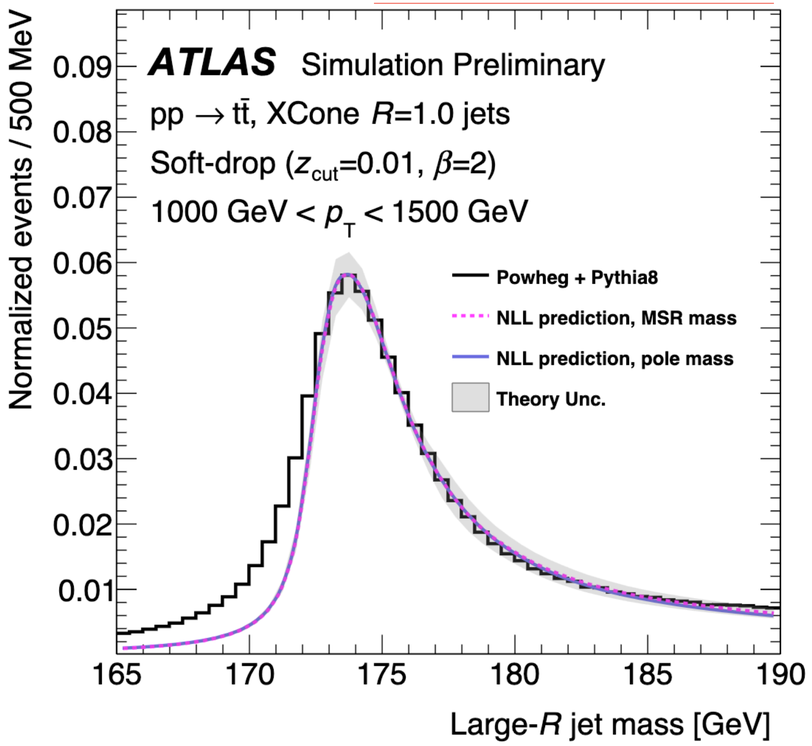
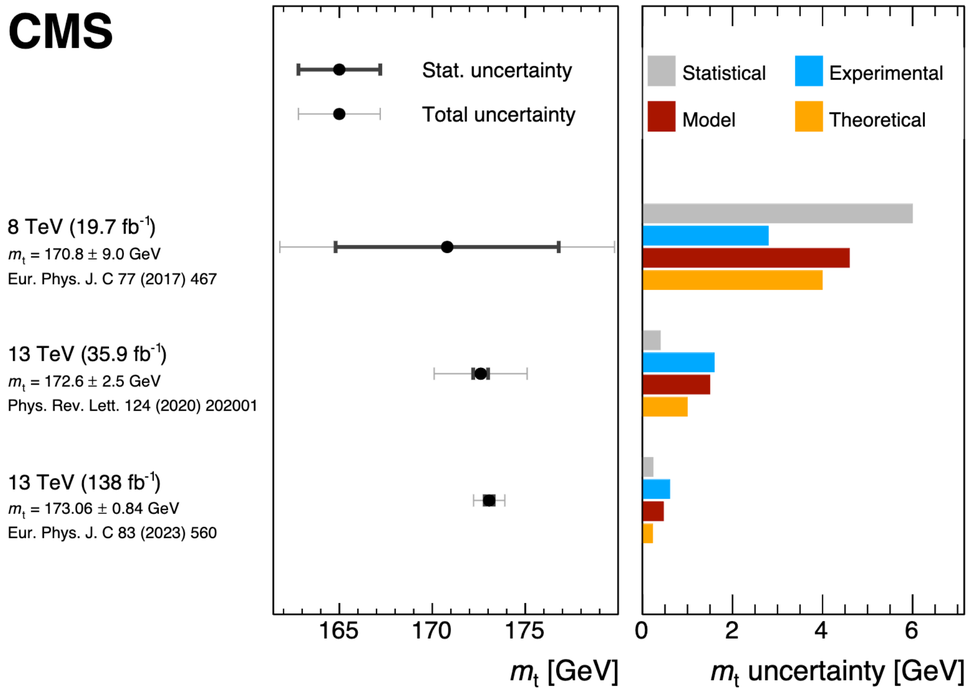


arXiv:2403.01313 (sub. to Physics Reports)



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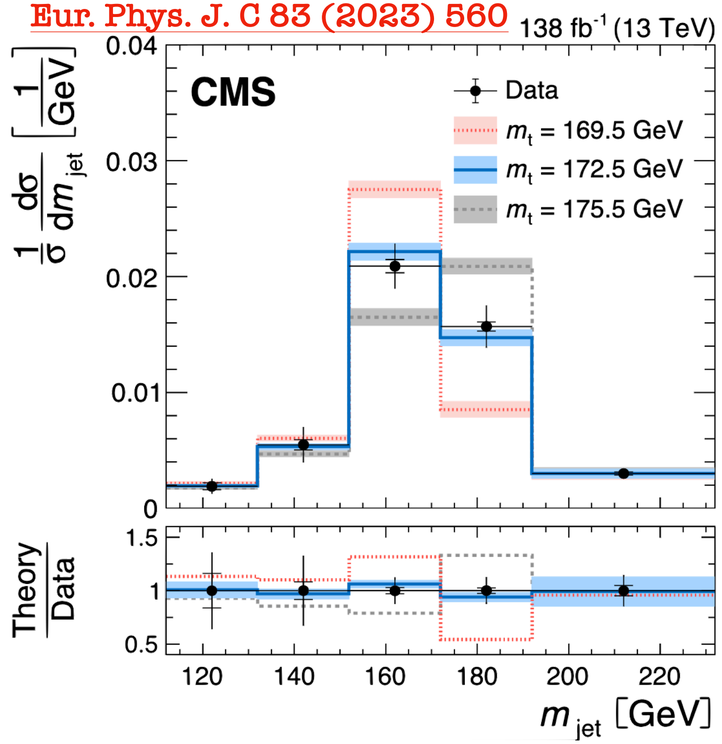


Summary and outlook

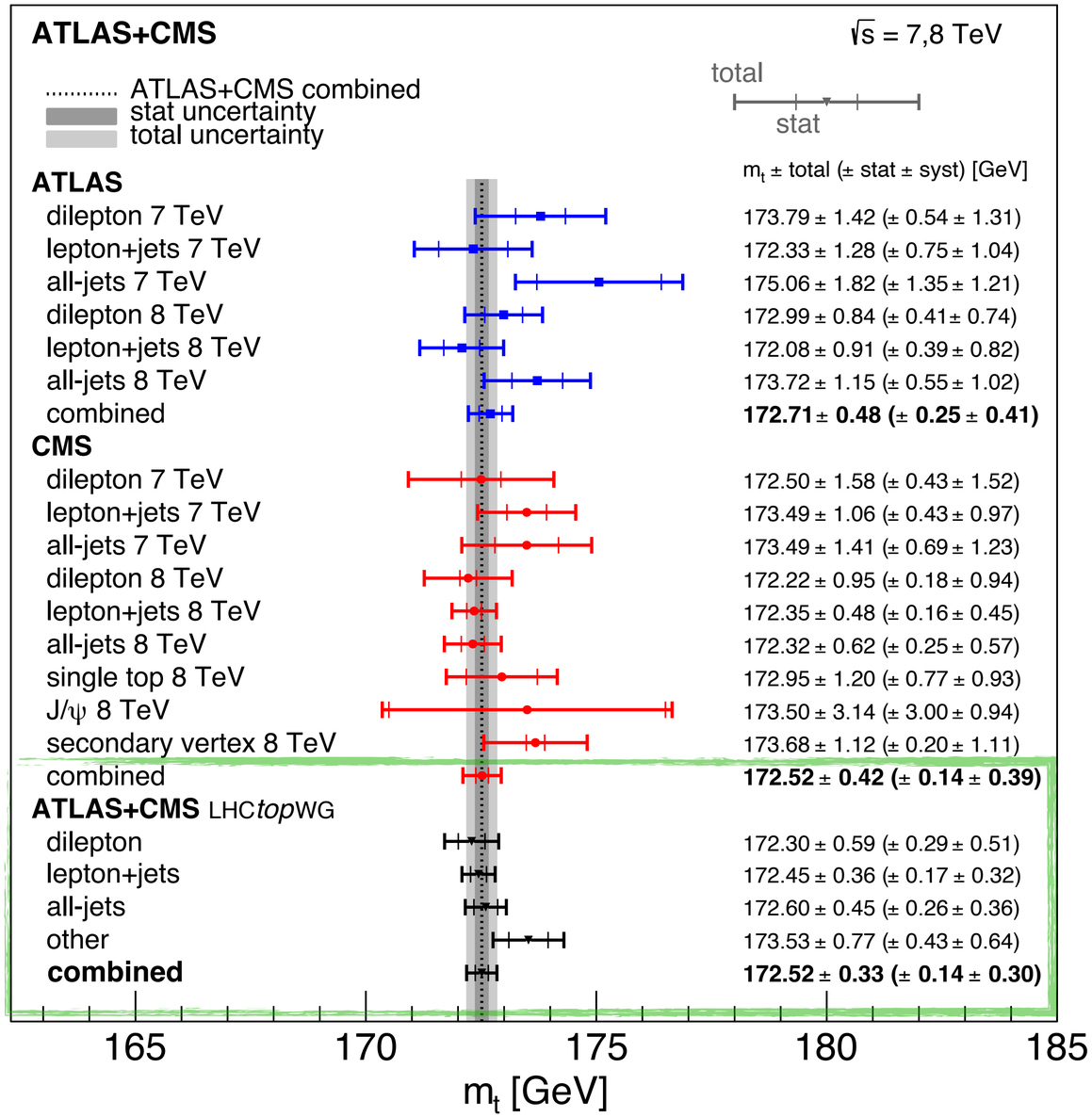
- BLUE combination of 15 Run-1 measurements from ATLAS and CMS yields **most precise m_t result to date**
  - Better than 2 per mill precision!
- 31% improvement over most precise single input

m_t = 172.52 ± 0.33 GeV

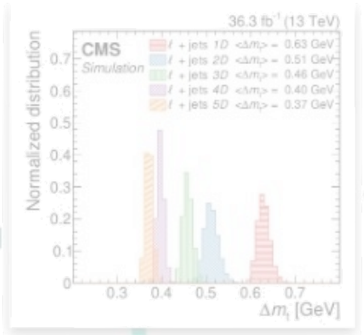
- Careful assessment of inter-experiment correlations
- Result is robust against the choice of correlations
- High level of compatibility between ATLAS and CMS, and between different channels

E. Canonero, G. Cowan [arXiv:2407.05322]

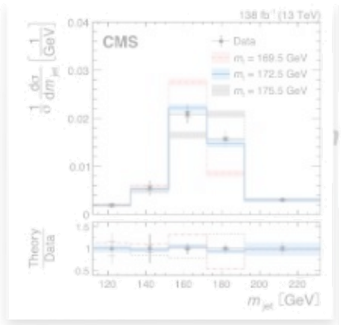
Combination was found to be very stable across a wide range of assumptions on possible errors-on-errors

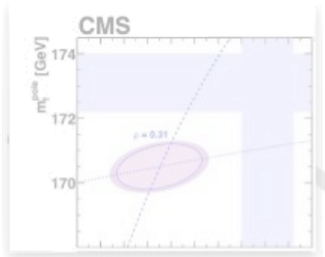


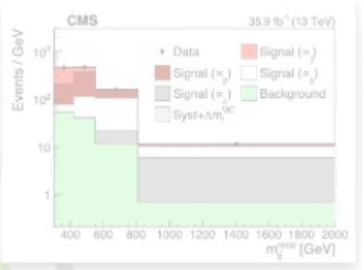
Backup slides

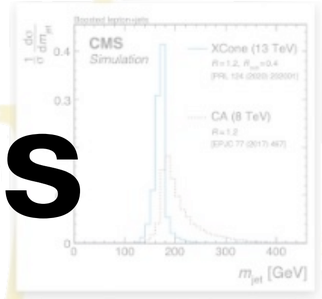


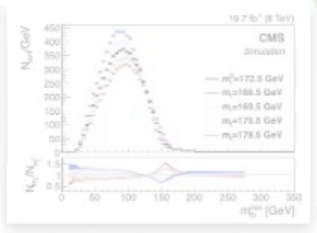
improved precision

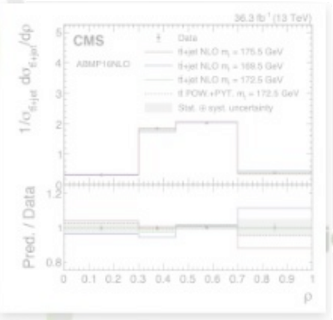


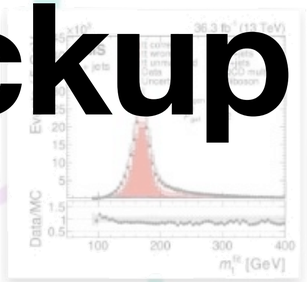


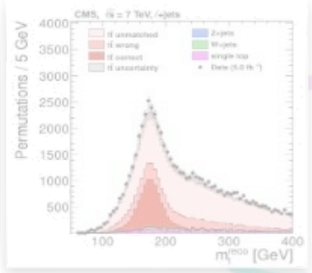


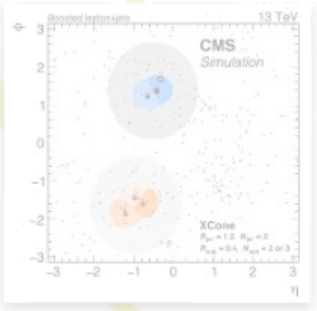


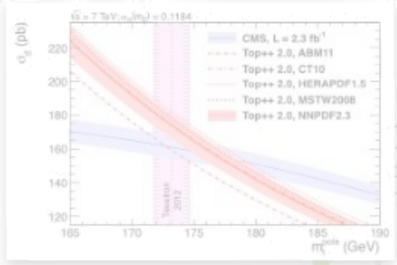


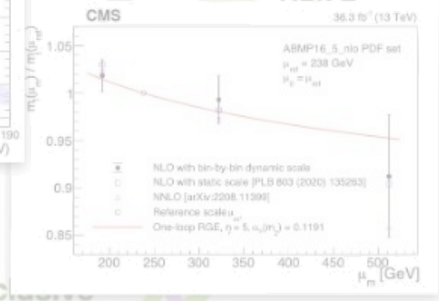


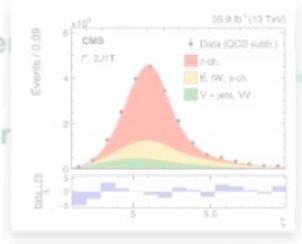












Full Run 2 - XCone and JMS

Boosted top quarks

Full Reconstruction

- CA merged jet

single Top

Partial Reconstruction

Top quark mass

simulation based

theory based

Direct Measurements

Lagrangian Extraction

Run 2

Running mass

Multi-differential

Run 2 5D Likelihood

Run 1 Hybrid Ideogram

Run 1

Secondary Ve

Leptons or

Combination weights and channel correlations

Full combination

	ATLAS						CMS								
	2011 (7 TeV)			2012 (8 TeV)			2011 (7 TeV)			2012 (8 TeV)					
	dil	lj	aj	dil	lj	aj	dil	lj	aj	dil	lj	aj	t	J/ψ	vtx
Pull	+0.93	−0.15	+1.43	+0.61	−0.51	+1.09	−0.01	+0.96	+0.71	−0.33	−0.47	−0.37	+0.38	+0.31	+1.08
Weight	−0.02	+0.07	+0.00	+0.16	+0.17	+0.03	−0.08	−0.01	+0.03	+0.12	+0.34	+0.12	−0.03	+0.01	+0.08

2D combination

	ATLAS						CMS								
	2011 (7 TeV)			2012 (8 TeV)			2011 (7 TeV)			2012 (8 TeV)					
	dil	lj	aj	dil	lj	aj	dil	lj	aj	dil	lj	aj	t	J/ψ	vtx
ll	+0.02	+0.03	−0.07	+0.55	+0.18	−0.08	+0.10	−0.02	−0.07	+0.33	−0.19	+0.22	−0.08	<0.01	+0.08
lj	−0.04	+0.09	+0.01	+0.09	+0.18	+0.03	−0.10	+0.03	+0.03	+0.05	+0.71	−0.06	−0.06	+0.01	+0.06
aj	−0.03	+0.08	+0.05	+0.04	+0.17	+0.15	−0.13	−0.13	+0.13	+0.12	−0.12	+0.67	−0.05	+0.01	+0.04
Other	+0.02	+0.05	+0.03	+0.02	+0.12	+0.04	−0.18	−0.04	+0.10	+0.14	−0.12	−0.18	+0.46	+0.05	+0.49

Per-channel combination

	ATLAS						CMS								
	2011 (7 TeV)			2012 (8 TeV)			2011 (7 TeV)			2012 (8 TeV)					
	dil	lj	aj	dil	lj	aj	dil	lj	aj	dil	lj	aj	t	J/ψ	vtx
m_t^{ATLAS}	<0.01	+0.16	+0.04	+0.33	+0.36	+0.11	−0.05	−0.07	+0.03	+0.03	−0.11	+0.14	−0.03	+0.01	+0.05
m_t^{CMS}	−0.04	+0.01	−0.03	+0.04	+0.04	−0.02	−0.10	+0.02	+0.04	+0.18	+0.67	+0.10	−0.04	+0.01	+0.11

Per-channel: correlations

	dil	lj	aj	Other
dil	1.00	0.29	0.24	<0.01
lj	0.29	1.00	0.59	0.31
aj	0.24	0.59	1.00	0.34
Other	<0.01	0.31	0.34	1.00

$$m_t^k = \sum_{i \in k} w_i m_t^i + \sum_{j \notin k} \lambda_j m_t^j$$

$$\text{with } \sum_i w_i = 1 \text{ and } \sum_j \lambda_j = 0$$

Inputs

ATLAS

	2011 (7 TeV)			2012 (8 TeV)			comb.
	dil	lj	aj	dil	lj	aj	
m_t	173.79	172.33	175.06	172.99	172.08	173.72	172.71
JES 1	0.54	0.33	0.38	0.35	0.28	0.40	0.18
JES 2	0.30	0.30	0.20	0.41	0.39	0.42	0.11
JES 3	0.43	0.07	0.24	0.08	0.05	0.12	0.07
b-JES	0.68	0.06	0.62	0.30	0.03	0.34	0.17
g-JES	0.03	0.28	0.10	0.02	0.21	0.05	0.02
l-JES	0.02	0.24	0.02	0.01	0.10	0.06	0.01
JER	0.19	0.22	0.01	0.09	0.20	0.10	0.09
Leptons	0.13	0.04	—	0.14	0.16	0.01	0.08
b tagging	0.07	0.50	0.16	0.04	0.38	0.10	0.16
p_T^{miss}	0.04	0.15	0.02	0.01	0.05	0.01	0.04
Pileup	0.01	0.02	0.02	0.05	0.15	0.01	0.07
Trigger	0.01	—	0.01	—	0.01	0.08	0.01
ME generator	0.26	0.22	0.30	0.09	0.16	0.18	0.13
QCD radiation	0.47	0.32	0.22	0.23	0.08	0.10	0.07
Hadronization	0.53	0.18	0.50	0.22	0.15	0.64	0.01
Color reconnection	0.14	0.11	0.22	0.03	0.19	0.12	0.08
Underlying event	0.05	0.15	0.08	0.10	0.08	0.12	0.03
PDF	0.10	0.25	0.09	0.05	0.09	0.09	0.06
Background (data)	0.04	0.11	0.35	0.07	0.05	0.17	0.04
Background (MC)	0.01	0.29	—	0.03	0.13	—	0.07
Method	0.09	0.11	0.42	0.05	0.13	0.11	0.06
Other	0.07	0.12	0.24	0.02	0.10	0.03	0.06
Total systematic	1.31	1.04	1.21	0.74	0.82	1.02	0.41
Statistical	0.54	0.75	1.35	0.41	0.39	0.55	0.25
Total	1.42	1.28	1.82	0.84	0.91	1.15	0.48

CMS

	2011 (7 TeV)			2012 (8 TeV)						comb.
	dil	lj	aj	dil	lj	aj	t	J/ψ	vtx	
m_t	172.50	173.49	173.49	172.22	172.35	172.32	172.95	173.50	173.68	172.52
JES 1	0.77	0.24	0.69	0.31	0.10	0.16	0.40	<0.01	0.11	0.06
JES 2	0.54	0.02	0.35	0.17	0.12	0.19	0.21	<0.01	0.13	0.10
JES 3	0.06	0.01	0.08	0.03	0.01	0.02	0.05	<0.01	0.01	0.01
b-JES	0.70	0.61	0.49	0.37	0.32	0.29	0.38	—	—	0.25
g-JES	—	—	—	0.07	0.08	0.02	—	—	—	0.04
l-JES	—	—	—	0.04	0.06	0.01	0.07	—	—	0.05
CMS JES 1	0.58	0.11	0.58	—	—	—	—	—	—	0.04
JER	0.14	0.23	0.15	—	0.03	0.02	0.05	<0.01	0.05	0.02
Leptons	0.14	0.02	—	0.25	0.01	—	0.05	0.10	0.24	0.07
b tagging	0.09	0.12	0.06	0.01	0.06	0.02	0.10	—	0.02	0.03
p_T^{miss}	0.12	0.06	—	0.01	0.04	—	0.15	—	—	0.01
Pileup	0.11	0.07	0.06	0.05	0.06	0.06	0.14	0.07	0.05	0.03
Trigger	—	—	0.24	—	—	0.01	—	0.02	—	0.01
ME generator	0.04	0.02	0.19	0.07	0.12	0.16	—	0.37	0.42	0.14
QCD radiation	0.58	0.30	0.33	0.24	0.09	0.18	0.35	0.74	0.20	0.10
Hadronization	—	—	—	0.38	0.01	0.04	—	0.30	0.54	0.01
CMS b hadron $\mathcal{B}$	—	—	—	0.12	0.16	0.13	0.15	—	0.16	0.12
Color reconnection	0.13	0.54	0.15	0.13	0.01	0.16	0.05	0.12	0.08	0.03
Underlying event	0.05	0.15	0.20	0.11	0.08	0.14	0.20	0.13	—	0.05
PDF	0.09	0.07	0.06	0.17	0.04	0.03	0.11	0.11	0.04	<0.01
CMS top quark p_T	—	—	—	0.51	0.02	0.06	—	—	—	0.07
Background (data)	—	—	0.13	—	—	0.20	—	—	0.44	0.06
Background (MC)	0.05	0.13	—	—	0.03	—	0.17	0.01	—	0.01
Method	0.40	0.06	0.13	—	0.04	0.06	0.39	0.22	0.62	0.09
Other	—	—	—	0.03	—	—	0.25	0.09	0.09	0.01
Total systematic	1.52	0.97	1.23	0.94	0.45	0.57	0.93	0.94	1.11	0.39
Statistical	0.43	0.43	0.69	0.18	0.16	0.25	0.77	3.00	0.20	0.14
Total	1.58	1.06	1.41	0.95	0.48	0.62	1.20	3.14	1.12	0.42

Example correlation matrix: b-JES

All correlation matrices can be found on the public webpage and will soon be available in the HepData record

	ATLAS						CMS								
	2011 (7 TeV)			2012 (8 TeV)			2011 (7 TeV)			2012 (8 TeV)					
	dil	lj	aj	dil	lj	aj	dil	lj	aj	dil	lj	aj	t	J/ψ	vtx
dil	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
lj	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
aj	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
dil	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
lj	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
aj	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
dil	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
lj	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
aj	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
dil	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
lj	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
aj	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
t	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
J/ψ	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
vtx	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Example correlation matrix: ME scale

All correlation matrices can be found on the public webpage and will soon be available in the HepData record

	ATLAS						CMS								
	2011 (7 TeV)			2012 (8 TeV)			2011 (7 TeV)			2012 (8 TeV)					
	dil	lj	aj	dil	lj	aj	dil	lj	aj	dil	lj	aj	t	J/ψ	vtx
dil	1.00	1.00	−1.00	1.00	1.00	1.00	−0.50	−0.50	−0.50	0.50	−0.50	−0.50	0.50	−0.50	−0.50
lj	1.00	1.00	−1.00	1.00	1.00	1.00	−0.50	−0.50	−0.50	0.50	−0.50	−0.50	0.50	−0.50	−0.50
aj	−1.00	−1.00	1.00	−1.00	−1.00	−1.00	0.50	0.50	0.50	−0.50	0.50	0.50	−0.50	0.50	0.50
dil	1.00	1.00	−1.00	1.00	1.00	1.00	−0.50	−0.50	−0.50	0.50	−0.50	−0.50	0.50	−0.50	−0.50
lj	1.00	1.00	−1.00	1.00	1.00	1.00	−0.50	−0.50	−0.50	0.50	−0.50	−0.50	0.50	−0.50	−0.50
aj	1.00	1.00	−1.00	1.00	1.00	1.00	−0.50	−0.50	−0.50	0.50	−0.50	−0.50	0.50	−0.50	−0.50
dil	−0.50	−0.50	0.50	−0.50	−0.50	−0.50	1.00	1.00	1.00	−1.00	1.00	1.00	−1.00	1.00	1.00
lj	−0.50	−0.50	0.50	−0.50	−0.50	−0.50	1.00	1.00	1.00	−1.00	1.00	1.00	−1.00	1.00	1.00
aj	−0.50	−0.50	0.50	−0.50	−0.50	−0.50	1.00	1.00	1.00	−1.00	1.00	1.00	−1.00	1.00	1.00
dil	0.50	0.50	−0.50	0.50	0.50	0.50	−1.00	−1.00	−1.00	1.00	−1.00	−1.00	1.00	−1.00	−1.00
lj	−0.50	−0.50	0.50	−0.50	−0.50	−0.50	1.00	1.00	1.00	−1.00	1.00	1.00	−1.00	1.00	1.00
aj	−0.50	−0.50	0.50	−0.50	−0.50	−0.50	1.00	1.00	1.00	−1.00	1.00	1.00	−1.00	1.00	1.00
t	0.50	0.50	−0.50	0.50	0.50	0.50	−1.00	−1.00	−1.00	1.00	−1.00	−1.00	1.00	−1.00	−1.00
J/ψ	−0.50	−0.50	0.50	−0.50	−0.50	−0.50	1.00	1.00	1.00	−1.00	1.00	1.00	−1.00	1.00	1.00
vtx	−0.50	−0.50	0.50	−0.50	−0.50	−0.50	1.00	1.00	1.00	−1.00	1.00	1.00	−1.00	1.00	1.00