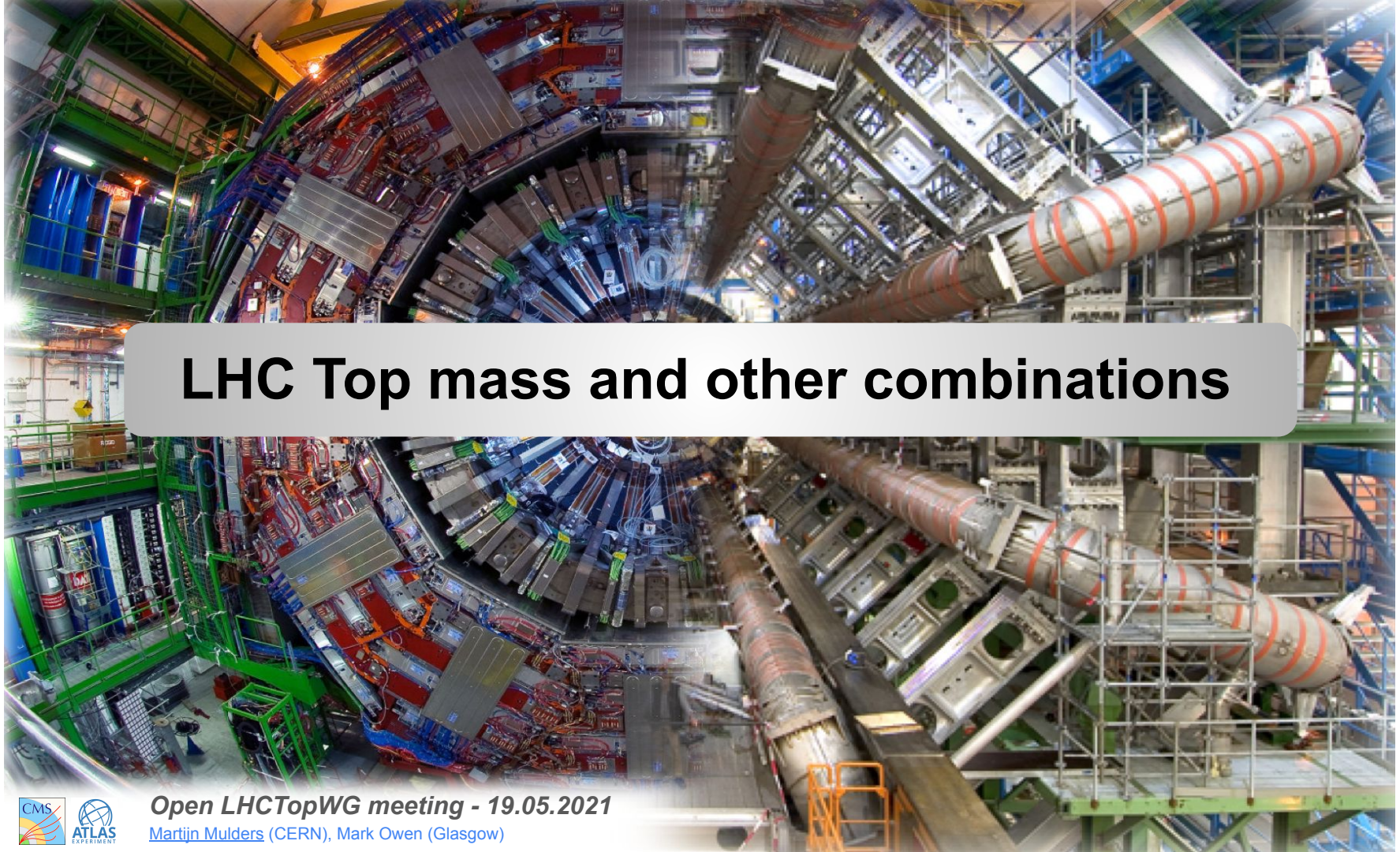


LHC Top mass and other combinations

Open LHCTopWG meeting - 19.05.2021

Martijn Mulders (CERN), Mark Owen (Glasgow)

Published so far:

ATLAS+CMS legacy Run 1 combinations already published:

- W polarization measurements in top decays 8 TeV — JHEP 08 (2020) 51
- Single top measurements and extraction of Vtb — JHEP 05 (2019) 088
- Inclusive and differential *ttbar* charge asymmetry — JHEP 04 (2018) 033

Preliminary results listed at https://lpcc.web.cern.ch/content/top-wg-documents

Ongoing combination efforts:

Run 1

- Top pair inclusive production cross-section at 7 and 8 TeV
- Top quark mass from direct measurements

Run 2 (and beyond)

- Top pair $\Delta\varphi\ell\ell$ differential distribution and spin correlations
- Differential distributions
- (EFT combinations) → will be covered in Peter Berta's talk tomorrow

Ongoing combinations: *different challenges*

Run 1

- Top pair inclusive production cross-section at 7 and 8 TeV
  - cannot use ‘standard’ BLUE
- Top quark mass from direct measurements
  - 18 possible inputs, non-trivial correlations, very different methods and precision

Run 2

- Top pair $\Delta\varphi\ell\ell$ differential distribution and spin correlations
  - first combination in Run 2
- Differential distributions
  - many results, with different analysis methods and definitions and MC setups

Top pair production cross-section at 7 and 8 TeV

Contacts:
Veronique Boisvert (ATLAS) and Jan Kieseler (CMS)

ATLAS (EPJC 76 (2016) 642)

7TeV: 182.9±3.1(stat)±4.2(syst)±3.6(lumi) pb (3.5%)
8TeV: 242.9±1.7(stat)±5.5(syst)±5.1(lumi) pb (3.2%)

Dominant uncertainties:
Luminosity, Statistics (7 TeV only),
Signal modeling, PDF, tW background

CMS (JHEP 08 (2016) 029)

7TeV: 173.6 ± 2.1 (stat) ± 4.5 (syst) ± 3.8 (lumi) pb (3.6%)
8TeV: 244.9 ± 1.4 (stat) ± 6.3 (syst) ± 6.4 (lumi) pb (3.7%)

Dominant uncertainties:
Luminosity, Lepton ID/isolation, Z+jets
background, Trigger, Statistics (7 TeV only)

- Aim: combination of inclusive cross-sections at 7 and 8 TeV
- Dominant uncertainties different or partly correlated → expect gain in precision
- Use combined result for extraction of α_s and top pole mass with recent PDF sets

Combination method & current status

- ATLAS: sources of systematic uncertainties uncorrelated between each other; grouped and mapped to correspond to CMS categories as closely as possible

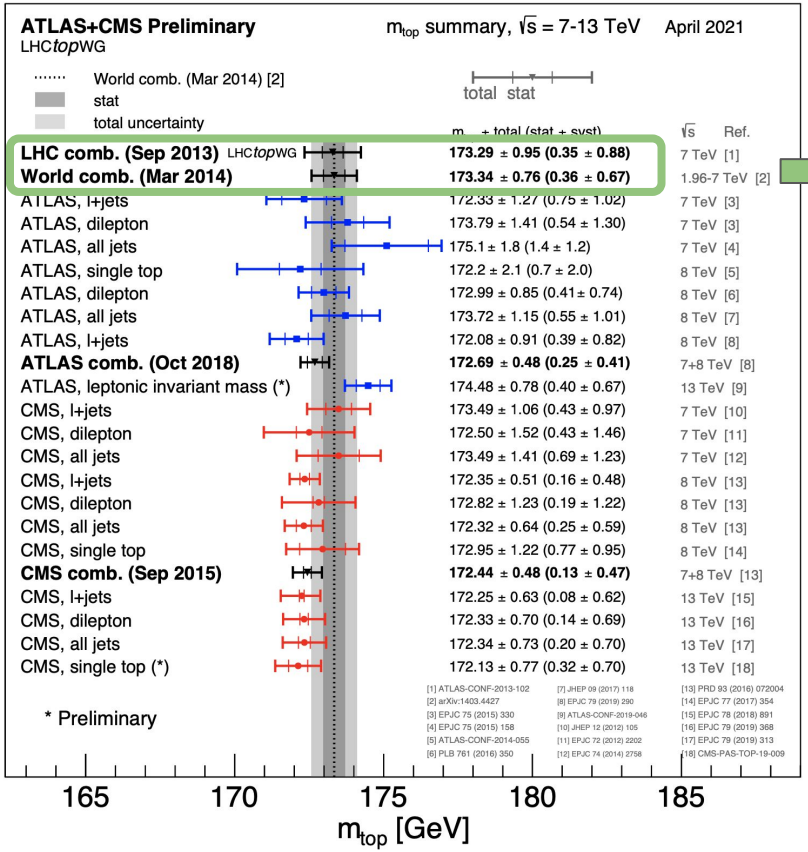
- CMS: simultaneous likelihood fit 7 & 8 TeV caused uncertainty sources to be correlated → ‘standard’ BLUE implementations not equipped to handle this

- Jan developed the CONVINO method+tool [1] (models measurement likelihood with penalty terms for correlations, input central values and covariances, fit χ^2)

- **Status:** results and paper draft ready and **in review** by both collaborations
- Soon starting CMS Collaboration Wide Review // ATLAS 1st circulation

[1] EPJC 77 (2017) 792, approved by ATLAS & CMS statistics committees

LHC top mass combination… time for an update



First combination of Tevatron and LHC measurements of the top-quark mass

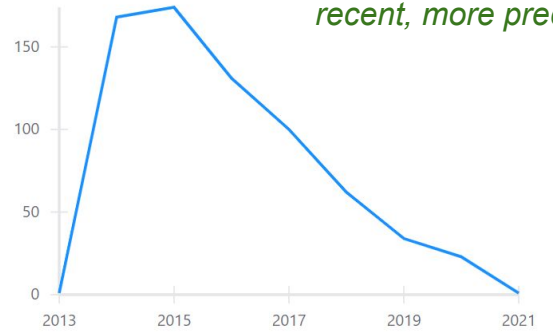
ATLAS and CDF and CMS and D0 Collaborations
Mar 18, 2014

https://arxiv.org/abs/1403.4427

34 pages
e-Print: 1403.4427 [hep-ex]
Report number: ATLAS-CONF-2014-008, CDF-NOTE-11071, CMS-PAS-TOP-13-014, D0-NOTE-6416, FERMILAB-TM-2582-E
Experiments: CERN-LHC-ATLAS, FNAL-E-0823, CERN-LHC-CMS, FNAL-E-0830
View in: OSTI Information Bridge Server, CERN Document Server, ADS Abstract Service

pdf links cite 694 citations

Citations per year



Existing LHC and world average have lost relevance, due to more recent, more precise results

Top Mass combination of ‘direct’ measurements

Contacts:

Mark Owen (ATLAS)

Steve Wimpenny & Matteo Defranchis & Martijn Mulders (CMS)

- Combination of ATLAS+CMS Run 1 measurements ‘from top quark decay’
- Include only published results

  ATLAS: 6 inputs available

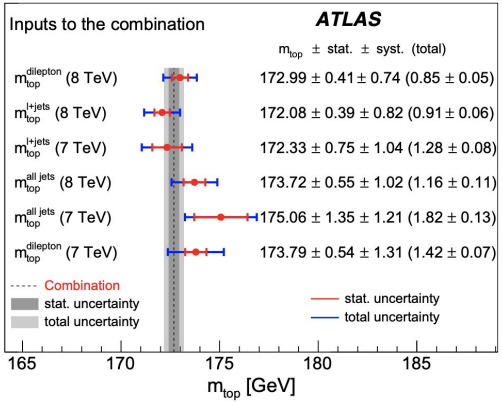
  CMS: 12 inputs available → make a selection

Starting point: Run 1 legacy combinations

ATLAS: EPJC 79 (2019) 290

- 6 input measurements
- Includes treatment of negative correlations
- Statistical uncertainties on systematic effects propagated to final combined result with toys

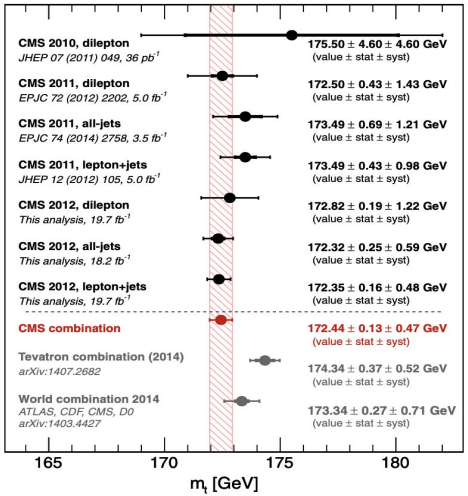
m_t = 172.69 ± 0.48 [± 0.25 (stat) ± 0.41 (syst)] GeV



CMS: PRD 93 (2016) 072004

- 7 input measurements
- Signs of correlations not included, correlations reduced for measurements of different precision, using max (syst, MC stat) -- meant to be "conservative"

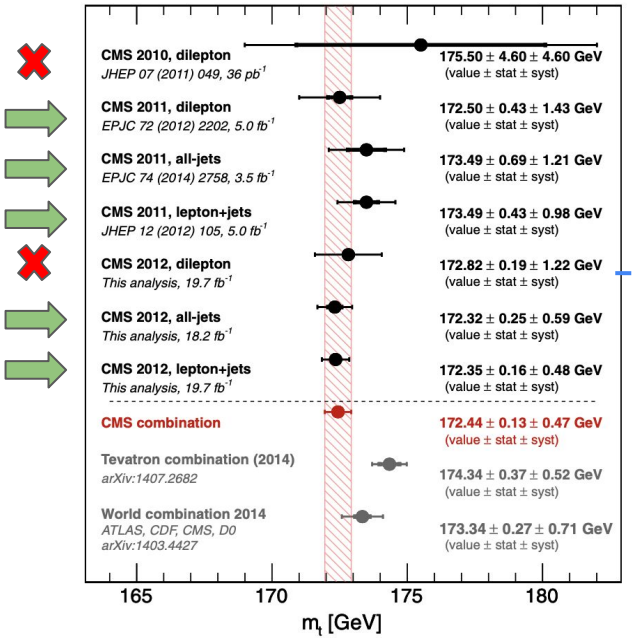
m_t = 172.44 ± 0.48 [± 0.13 (stat) ± 0.47 (syst)] GeV

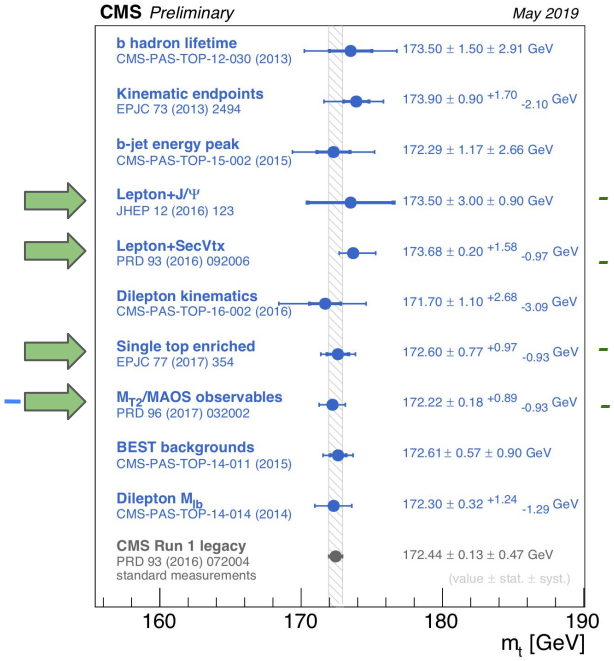


+ CMS has 5 additional inputs available

Updating CMS inputs: proposal

From PRD 93 (2016) 072004





- *very clean: three leptons only*
- *more precise; still tracking only*
- *'orthogonal' single top channel*
- *replaces older 8 TeV dilepton result*

(more details in backup)

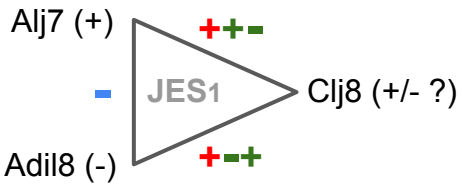
⇒ Agreed to use these 9 inputs (➡) as baseline to set up the combination, and afterwards re-evaluate the gain from including the additional measurements

ATLAS: correlation signs and statistical uncertainties

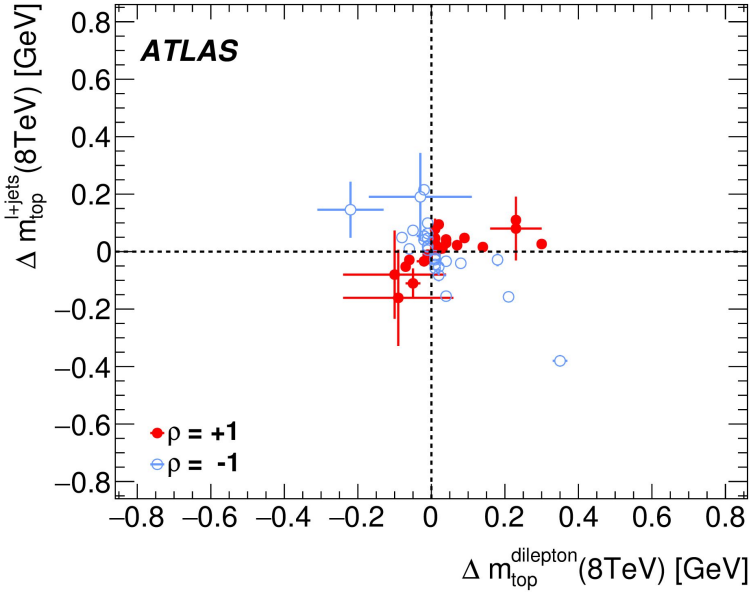
m_{top} = 172.69 ± 0.25 ± 0.41 (0.48 ± 0.03) GeV

(stat) (syst) (tot)

- In the ATLAS combination, several (important) systematic uncertainties are anti-correlated
- This motivates also investigating signs for CMS uncertainties (to avoid “unphysical” correlations)



- Statistical uncertainties on systematic effects propagated to final combination result with toys → consider using the same approach for CMS



Base plan for the top mass combination

- Use ATLAS inputs and (signed) correlations as they are: “ready to plug in”

- CMS: adopt ‘ATLAS’ combination approach where possible:
  - include negative signs of correlations
  - instead of max(syst, MC stat), propagate stat uncertainty to final results
  - instead of “reduced correlations” for measurements with different precision (see backup), use accurate fine-grained correlation estimates if available

- Fully implement the combination both in BLUE and CONVINO programs, for independent cross-checks
  - Consider using CONVINO’s alternative built-in approach to including (statistical) uncertainties on (systematic) uncertainties

Top mass combination: status and next steps

- Reproduced CMS published combination in ATLAS BLUE code and setup
- First tests with CONVINO show identical results to BLUE in partial combinations
  - Some issues with non-convergence in specific fits under investigation (CONVINO)
- Steve and Mark have prepared the signs of the correlations for CMS inputs
- Steve and Mark had already prepared a tentative ATLAS-CMS mapping of systematic uncertainties and correlations →
- Started a paper draft

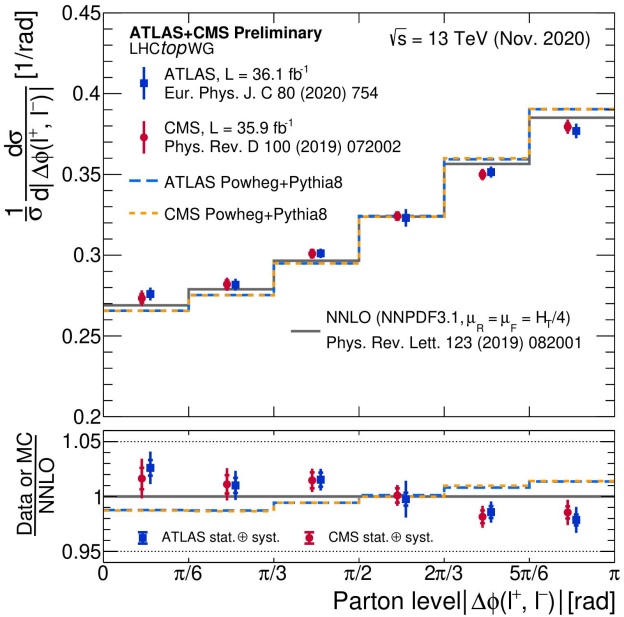
Ultimately all choices and results to be reviewed and approved by both collaborations

Category	Correlation	Category	Correlation
JES1	0	MC background	1
JES2	0	Data background	0
JES3	0.5	Hadronisation	0
JES4	1	PDF	1
JES5	0.5	Radiation	0.5
JES6	0	MC Generator	0.5
JES8	0	UE	1
Leptons	0	PU	1
MET	0	CR	1
JER	0	BTAG	0.5
Trigger	0	Method	0

Run 2: Δφℓℓ differential distribution and spin correlation

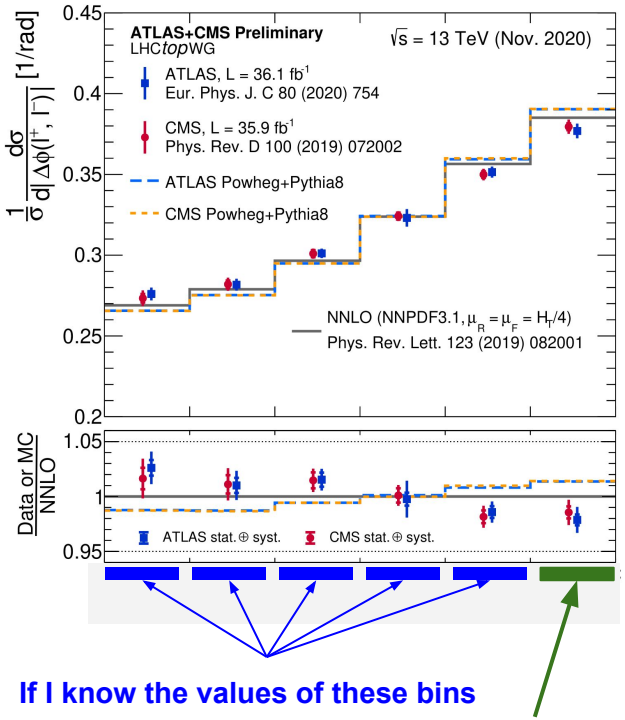
Contacts:
Miriam Watson and James Howarth (ATLAS),
Giulia Negro and Afiq Anuar (CMS)

- Combine Δφℓℓ differential measurements from
  - ATLAS : EPJC 80 (2020) 754
  - CMS : PRD 100 (2019) 0720002
- Measurement with identical binning available, unfolded to parton level
- ATLAS only eμ, CMS: eμ, ee, $\mu\mu$
- Compare the combined measurement to various theory and MC predictions (including the Common Sample). Further interpretation being considered as well.
- One ‘issue’: CMS only published a normalized distribution



Run 2: Δφℓℓ differential distribution and spin correlation

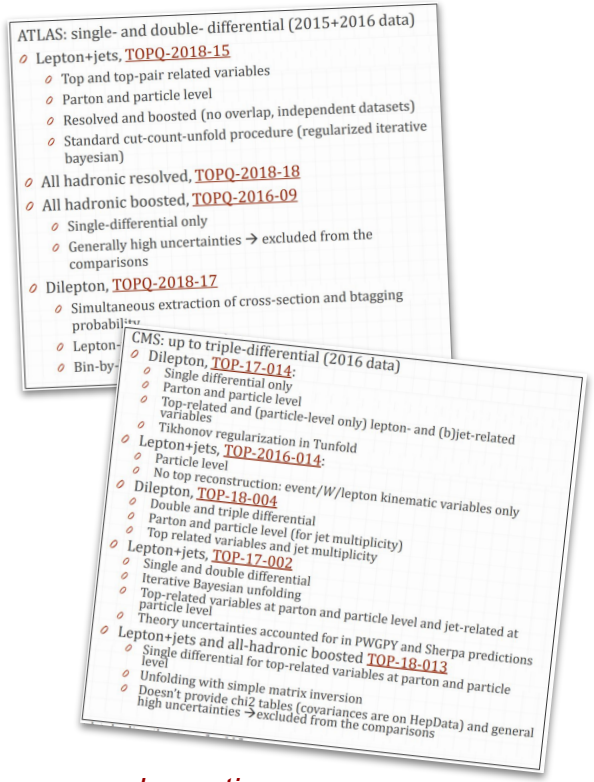
- Method: combine n-1 bins and calculate last bin from the overall normalization (tested and it works well)
- First combination of Run 2 measurements
  - Tentative ATLAS-to-CMS mapping of 136 systematic uncertainties done
  - Main effects are from 9 “Modelling” uncertainties; studying effect of correlation assumptions (0 -- 1)
- Try EFTFitter and CONVINO fit implementations
- Status: checking effects of correlations, smoothing systematics, EFTFitter vs CONVINO
- *Targeting a public document* (paper?)



Run 2: differential distributions

Contacts:
Olaf Behnke (CMS) and Marino Romano (ATLAS)

- Follow-up from presentation and discussion in the last open LHCTopWG meeting : exploration of 1D, 2D, 3D differential measurements in Run 2
- Is it possible to compare ATLAS vs CMS vs theory and identify trends, similarities, differences ?
- *Huge challenge:* many differences in MC setups, object definitions, fiducial and phase space choices, analysis methods used, in different channels, at particle and at parton level…

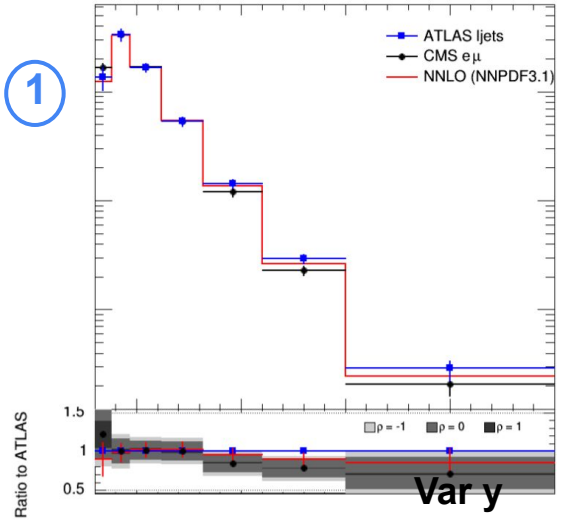


… and counting

Run 2: differential distributions

- Considering various approaches:
  - **1** Compare ATLAS vs CMS data directly
    (*IF* same objects, phase space, binning …)
  - **2** Compare the ratio (data / prediction) in both experiments
    ⇒ *the Common Sample* might help here !?
- Qualitative vs quantitative comparisons (χ^2)?
  correlations; how to treat theory uncertainties ?
- *Target to be defined:* a note, paper, combination ?

1



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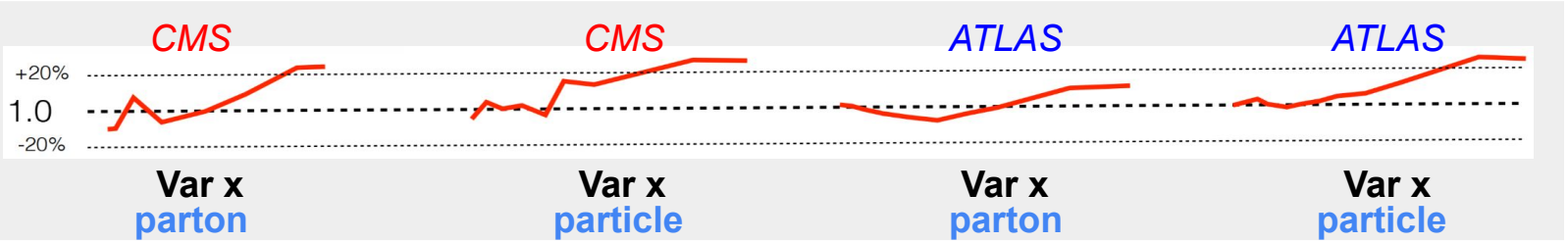

To Summarize:

Run 1

- Top pair inclusive cross-section at 7 and 8 TeV → in final review stages
- Top quark mass from direct measurements → in progress

  inputs defined; preparing BLUE and CONVINO setups; started paper draft

Run 2 (and beyond)

- Top pair $\Delta\varphi\ell\ell$ differential distribution and spin correlations → in progress
- Differential distributions → exploring options
- EFT combinations*: more in Peter Berta's talk tomorrow*


BACKUP

Why perform combinations?

“The purpose of the TOPLHCWG is to define guidelines for the combination of results on top physics measurements from ATLAS and CMS […] ”

mandate v8, Nov.2012

- To achieve ultimate precision, beyond that of the input measurements
- To learn from comparisons between experiments, improving overall understanding, both of methods and results

CMS top mass inputs proposal

Include the following additional measurements as baseline:

- M_{T2}/MAOS to *replace* the original (2012) 8 TeV dilepton measurement; it is more advanced and precise, including in-situ mitigation of b-jet uncertainties
- Lepton + Sec Vtx based on tracking only → low correlation with other inputs
- Lepton + J/psi uses leptons only → experimentally very clean, low correlation, larger stat. uncertainty
- Single top enriched → selection orthogonal to other channels, different production process and kinematics

→ Afterwards re-evaluate the gain from including these additional measurements

Reduced correlations [from CMS legacy paper: PRD 93 (2016) 072004]

The nominal values are set to either zero for uncorrelated or unity for fully correlated. Because the measurements from the 2012 analyses are significantly more precise, both statistically and systematically, than those from the 2010 and 2011 analyses, the use of unity coefficients for ρchan and ρyear is problematic. To mitigate this, we have chosen to perform combinations in which the correlation coefficients are limited to value of less than unity. This has been done by setting the correlation coefficients for each pair of measurements in the fully correlated cases to ρ = σi/σj, where σi and σj are the uncorrelated components of the uncertainties in measurements i and j, respectively, and σi < σj . For all of the measurements, the statistical uncertainties are assumed to be uncorrelated.