ATLAS/CMS jet uncertainties and correlations

ATLAS: Bogdan Malaescu, Steven Schramm, Dimitris Varouchas
CMS: Henning Kirschenmann, Mikko Voutilainen

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Disclaimer

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- These slides are a nearly direct copy from a past talk I gave
  - November 22, 2016 LHC top WG meeting
- Since then, there have been no official updates
  - As we near the end of run 2, interest is again growing
  - We have been trying to meet again for months
  - Waiting for final confirmation, hopefully will start soon
- The following is therefore the run 1 recommendations
  - There will be a few comments on run 2, but not the focus
  - We hope to cross-check/update these recommendations "soon"

Introduction

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- ATLAS and CMS place strong constraints on top-related observables
  - Combining results further improves these precision measurements
  - Requires knowledge of the inter-experimental uncertainty correlations
- The Jet Energy Scale/Correction (JES/JEC) uncertainties are often the dominant experimental systematic in top combinations
  - Depending on the analysis, I imagine they can be for EW too
- Correlation procedures have been defined for $7\,\mathrm{TeV}$ and $8\,\mathrm{TeV}$
  - The $8\,\mathrm{TeV}$ document is an incremental update, same general idea
- Can the same procedures be extended to $13\,\mathrm{TeV}$?
  - Need to understand what has changed since $8\,\mathrm{TeV}$

Jet calibration, MC

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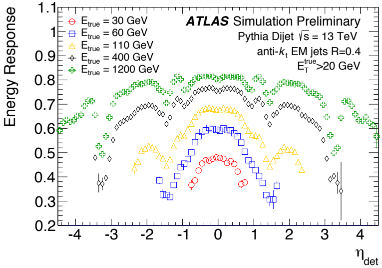

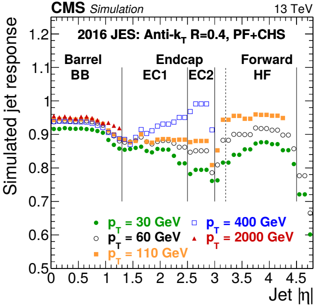

- The MC-based calibration accounts for the detector response profile
  - Calibrates jets to the truth hadron scale, applied to data and MC
- Different detector features are can be seen
  - However, similar general trends are visible

Jet calibration, *in situ*

(ATLAS,CMS)

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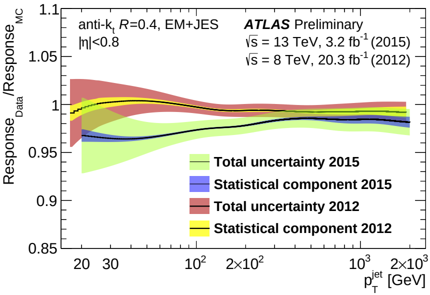
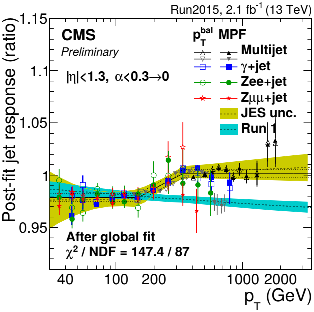
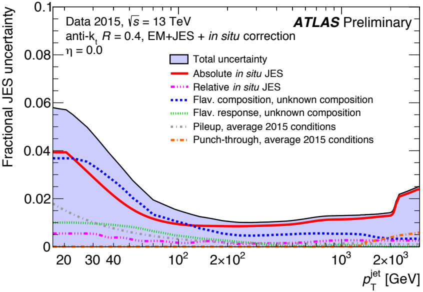
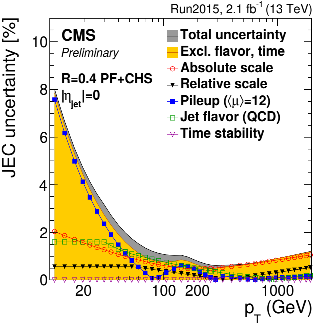




- Applying MC-based calibration to data needs to be studied *in situ*
- Experiments use same three primary approaches to cover p_{T} range
  - Z+jet, γ+jet, multi-jet balance (increasing p_{T} order)
- Some clear differences in data/MC ratio between Run I and Run II
  - ATLAS: largest impact from Geant4 simulation change (since reduced)
  - CMS: observed differences becoming smaller in re-reconstructed data
- Central value is corrected for both, not a problem for combination

JES/JEC uncertainties (ATLAS,CMS)





- Final systematics combination of *in situ* and other sources
  - *Absolute* label represents Z+jet, γ+jet, and multi-jet balance terms
  - *Relative* label represents di-jet balance calibration of forward vs central
    - Larger and more relevant in forward regions
- Vertical scales are aligned for ease of comparison, but this is 2015

Correlations between ATLAS and CMS (approved note)

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- The JES/JEC uncertainty is built from many uncertainty sources
  - First step: merge components of similar types into groups
- Experiments have uncertainties to cover roughly the same effects
  - Absolute scale, relative scale, pileup, flavour, ...
  - Second step: identify corresponding groups of uncertainty components
- The methods used to derive the uncertainties may vary
  - Different MC generators for differences, different parametrizations, ...
  - Third step: determine the degree of similarity in the derivation method
- The next slide quickly covers the 8 TeV recommendation
  - The recommendation is divided into nine groups of components

8 TeV combination procedure (approved note)

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Description	Components, CMS	Components, ATLAS	Corr. range
1a. Statistical *in situ* terms	AbsoluteStat, SinglePionHCAL, RelativeStat[FSR][EC2][HF]	[11] **Z**-jet balance `stat./meth.` terms (p_T), [13] γ-jet balance `stat./meth.` terms (p_T), [10] multi-jet balance `stat./meth.` terms (p_T), η-intercalibration statistical term (p_T,η)	0%
1b. Detector *in situ* terms	AbsoluteScale, SinglePionECAL, RelativeJER[EC1][EC2][HF], RelativePt[BB][EC1][EC2][HF]	**Z**-jet balance `det.` term, γ-jet balance `det.` term, [2] correlated **Z**/γ-jet balance `det.` terms (p_T)	0%
2. Absolute balance modeling	AbsoluteMPFBias	[7] **Z**-jet balance `model` + `mixed` terms (p_T), [4] γ-jet balance `model` + `mixed` terms (p_T), [2] correlated **Z**/γ-jet balance terms (p_T), [5] multi-jet balance `model` + `mixed` terms (p_T)	0-50%
3. Relative balance modeling	RelativeFSR	η-intercalibration modeling (p_T,η)	50-100%
4. *g*-jet fragmentation	FlavorPureGluon	Flavor response (p_T,η)	100%
5. *b*-jet fragmentation	FlavorPureBottom	*b*-jet response (p_T)	50-100%
6. Other fragmentation types	FlavorPureQuark, FlavorPureCharm	Flavor composition (p_T,η)	0%
7. Pileup	PileupDataMC, PileupPt[Ref][BB][EC1][EC2][HF]	N_{PV} offset (p_T,η,N_{PV}), $\langle\mu\rangle$ offset (p_T,η,$\langle\mu\rangle$), p_T term (p_T,η,N_{PV},$\langle\mu\rangle$), ρ topology (p_T,η)	0%
8. High-p_T	Fragmentation	High-p_T (p_T)	0%
9. Single-experiment terms	TimeEta, TimePt	Fast simulation closure (p_T,η), punch-through (p_T,η,$N_{segments}$)	0%

- There are nine uncertainty groups to correlate between experiments
  - Uncertainties should be merged within each experiment for each group
  - The nine resulting per-experiment components should be combined (pairwise across experiments) following the specified correlation range
  - These nine terms *should not be merged* before the combination

Limitations of the procedure

(approved note)

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- The procedure described is useful, but not perfect
- Combinations must pay attention to the following limitations
  1. The correlation ranges are motivated, but the endpoints are arbitrary
     - If large differences are observed near endpoints when scanning over the range, extend the endpoint and perform more detailed studies
  2. Merging the components within a given group throws away shape info
     - Procedure is primarily aimed at single-observable results (top mass)
     - Limited uses when applied to multi-observable results (differential xsec)
- The procedure is expected to work well for most combinations
  - For run 2, it would be useful to revisit shapes for combinations

Changes to JES/JEC uncertainties

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- ATLAS and CMS have made minor changes in early Run II
  - Run II JES/JEC uncertainty approaches very similar to 2012
  - Note: this may have changed since Nov 2016, needs to be re-confirmed
- Most differences involve changing the number of *in situ* cut variations
  - Does not impact correlation procedure
- One larger change by ATLAS to the multi-jet balance
  - All recoil system jet uncertainties should be propagated to probe jet
  - Before, only *in situ* Z+jet and γ+jet terms were propagated
  - Flavour, pileup, etc are now propagated through multi-jet balance
  - More details on next slide

Multi-jet balance propagation change (ATLAS,CMS)

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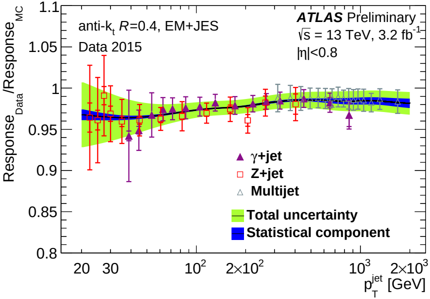
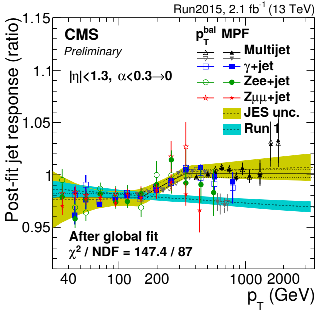
- Propagation will change correlations if CMS does not also do so
  - CMS had agreed to look into the possibility of doing this for run 2
  - Otherwise correlation level will decrease, needs to be re-evaluated
- Multi-jet balance only relevant for $p_{\mathrm{T}} \gtrsim 600\,\mathrm{GeV}$
  - Unlikely to be a concern for most combinations, but some will care





Looking to the future: JER

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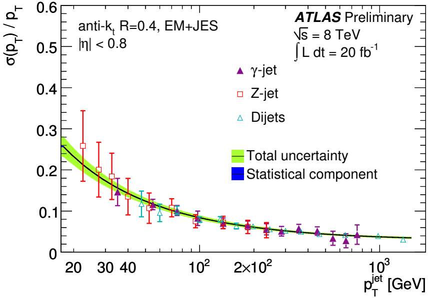

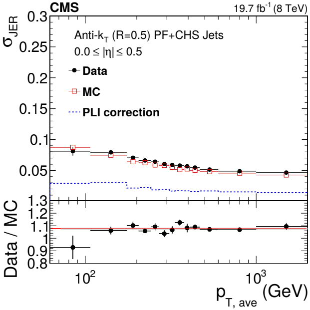

- JER is also an important systematic for many measurements
- Traditionally a single uncertainty component from dijet asymmetry
  - ATLAS has performed a full Z+jet, γ+jet, and dijet JER combination
  - Resulting JER uncertainty has several components, not widely used
- With several components, becomes possible to evaluate correlations
  - Interesting possibility for both experiments to pursue in the future

Looking to the future: JER

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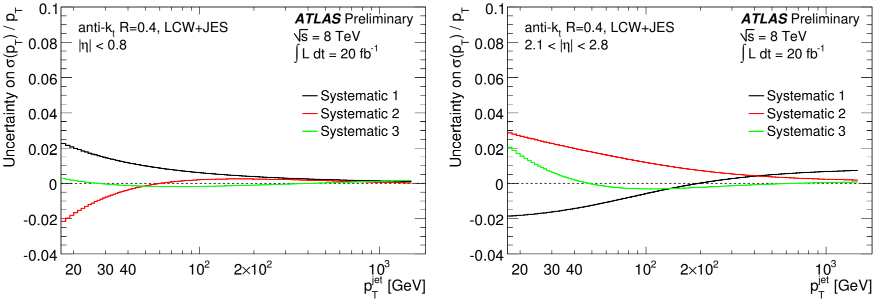

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Summary

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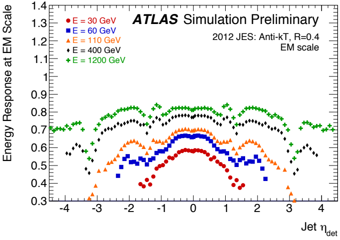
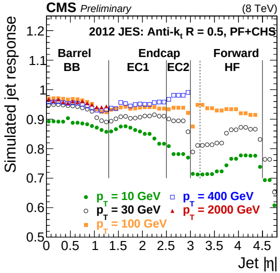
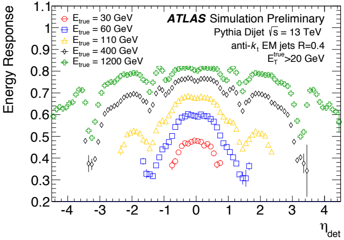
- Correlation procedures previously defined for $7\,\mathrm{TeV}$ and $8\,\mathrm{TeV}$
  - Supports combinations of single-observable measurements
  - Has limitations for multi-observable results (such as differential xsec)
- Methods used by ATLAS/CMS to derive $13\,\mathrm{TeV}$ JES/JEC uncertainties are mostly similar to the $8\,\mathrm{TeV}$ approach
  - Main difference is ATLAS propagation through multi-jet balance
  - Correlation ranges to be re-evaluated if CMS does not do the same
  - Minimal impact on most measurements, relevant for $p_{\mathrm{T}} \gtrsim 600\,\mathrm{GeV}$
- Given similarities of 8 and $13\,\mathrm{TeV}$ JES /JEC uncertainty derivations, $8\,\mathrm{TeV}$ combination procedure is a good starting point for $13\,\mathrm{TeV}$
  - Need to check if this is still true for full run 2
- Looking to the future, a similar approach for the JER would be useful

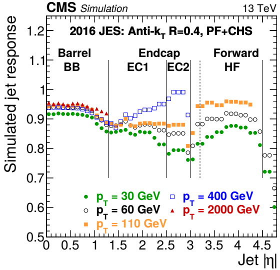
Backup Material

JES/JEC factors, 2012 vs 2015









JES/JEC uncertainties, 2012 vs 2015

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