Jet Reconstruction and Substructure
in ATLAS and CMS at 13 TeV

LHCP 2016

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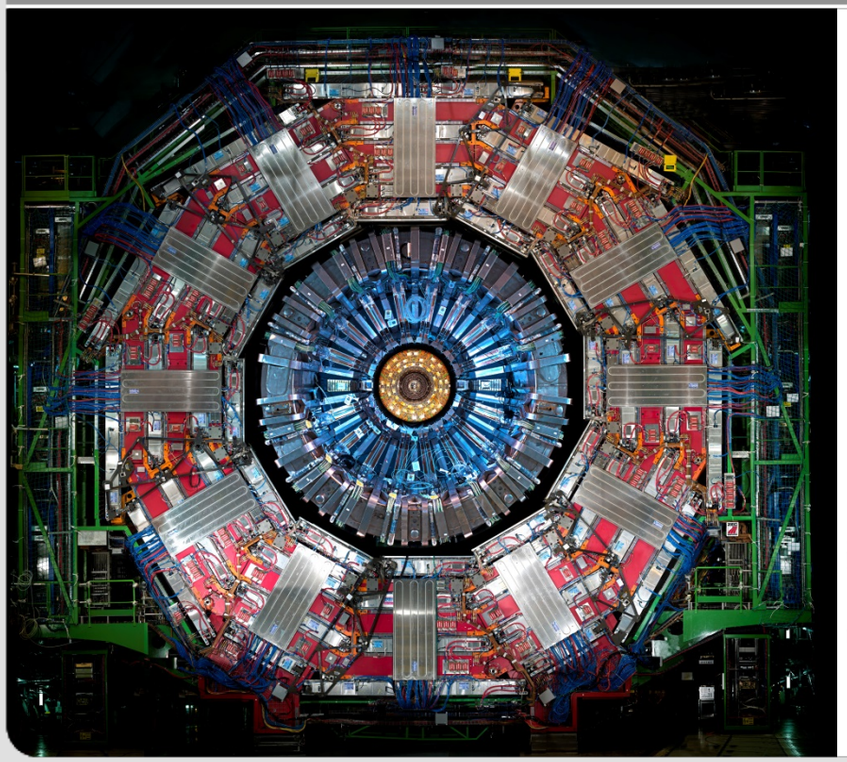
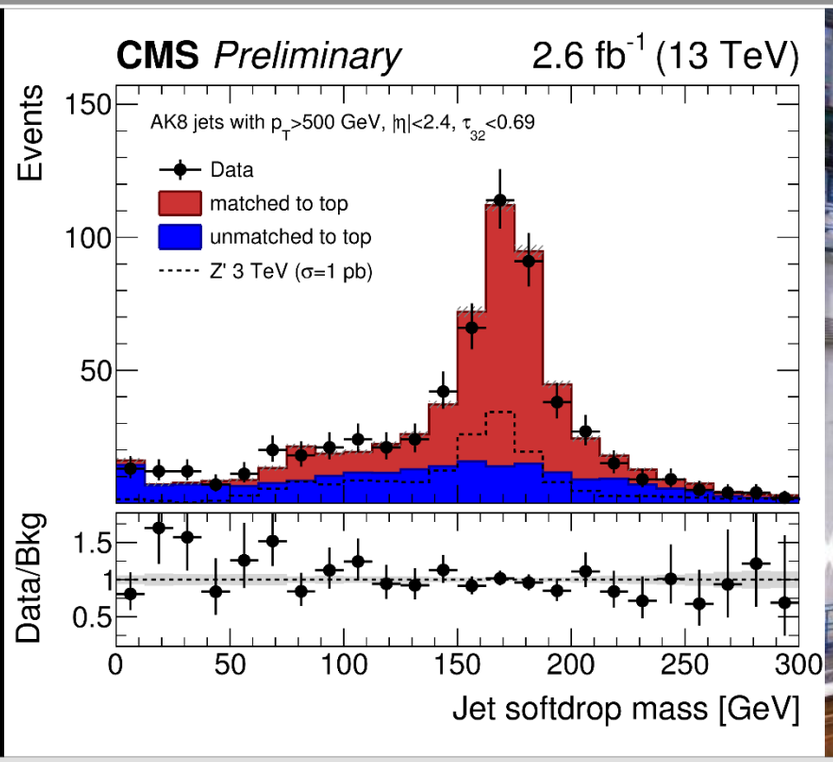
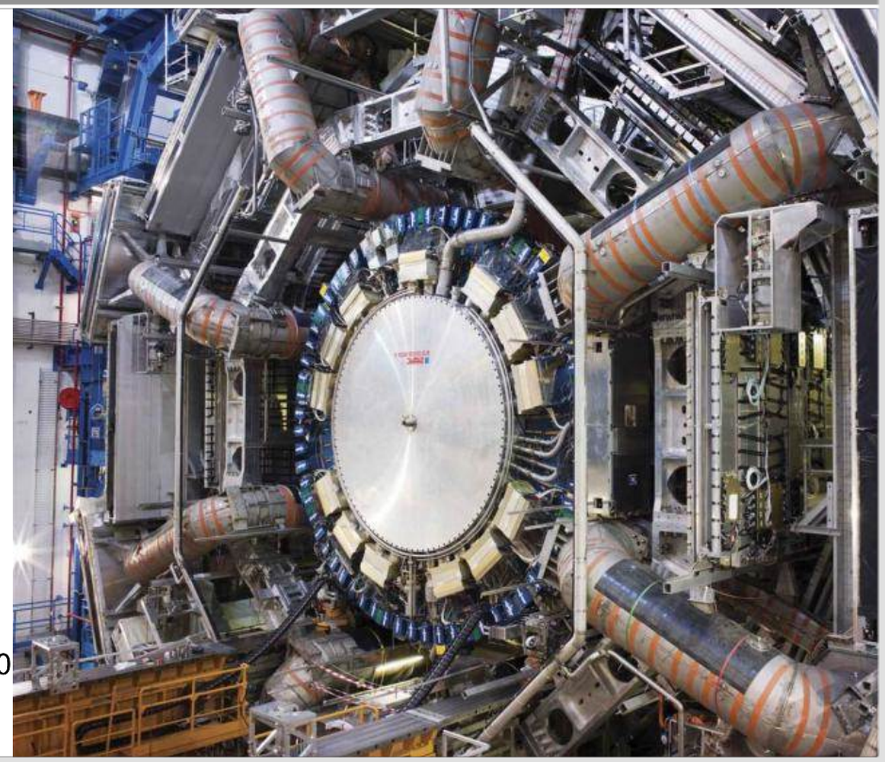
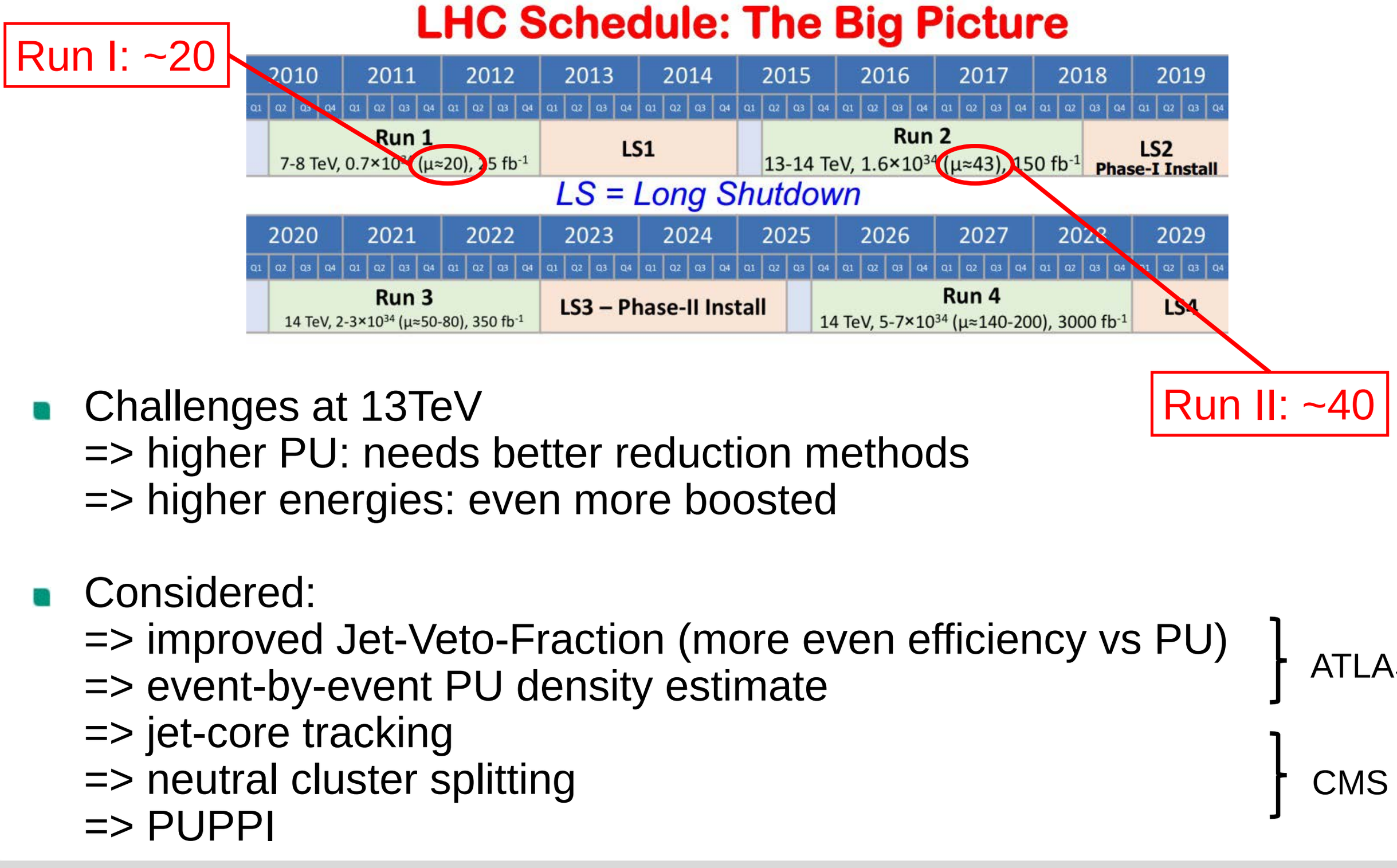






Jet Reconstruction at 13TeV

Karlsruher Institut für Technologie

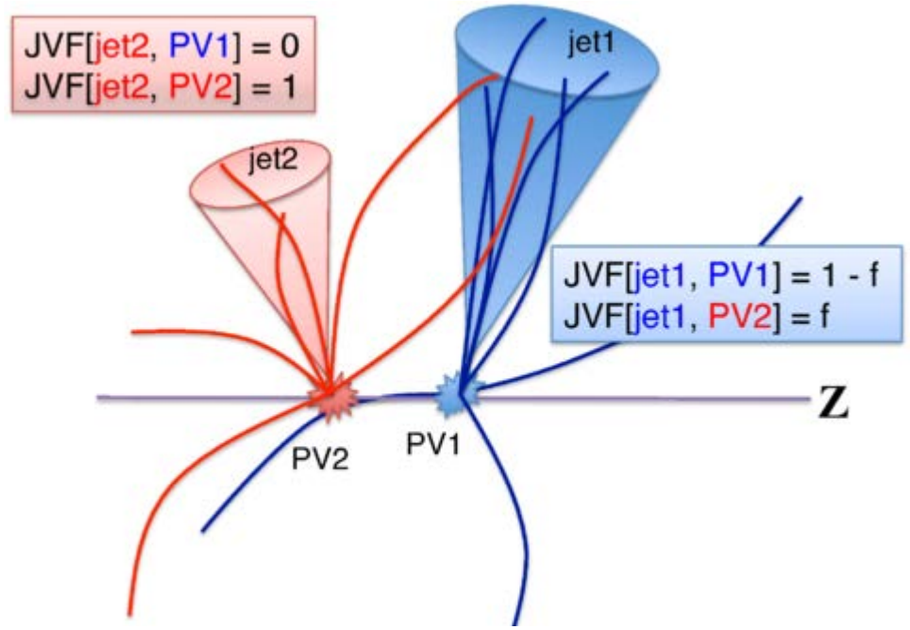


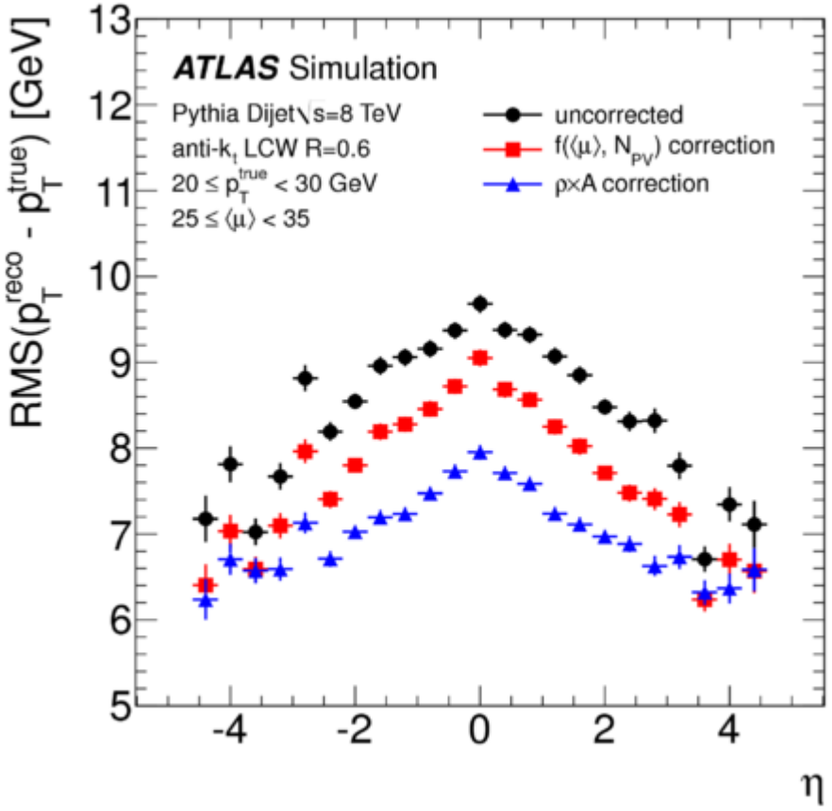
- Challenges at 13TeV
  => higher PU: needs better reduction methods
  => higher energies: even more boosted

- Considered:
  => improved Jet-Veto-Fraction (more even efficiency vs PU) } ATLAS
  => event-by-event PU density estimate
  => jet-core tracking } CMS
  => neutral cluster splitting
  => PUPPI

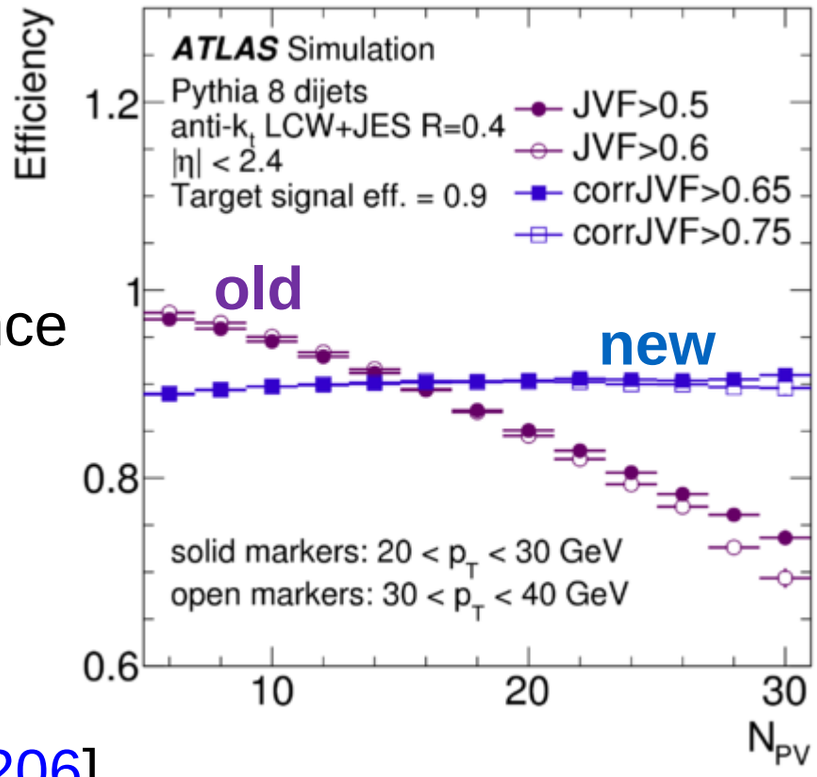
Improved Jet Clustering

- Run I PU correction:
  => Offset function of $<\mu>$, N_{PV}
- Alternative (=CMS Run I)
  => subtract PU-density x jet-area





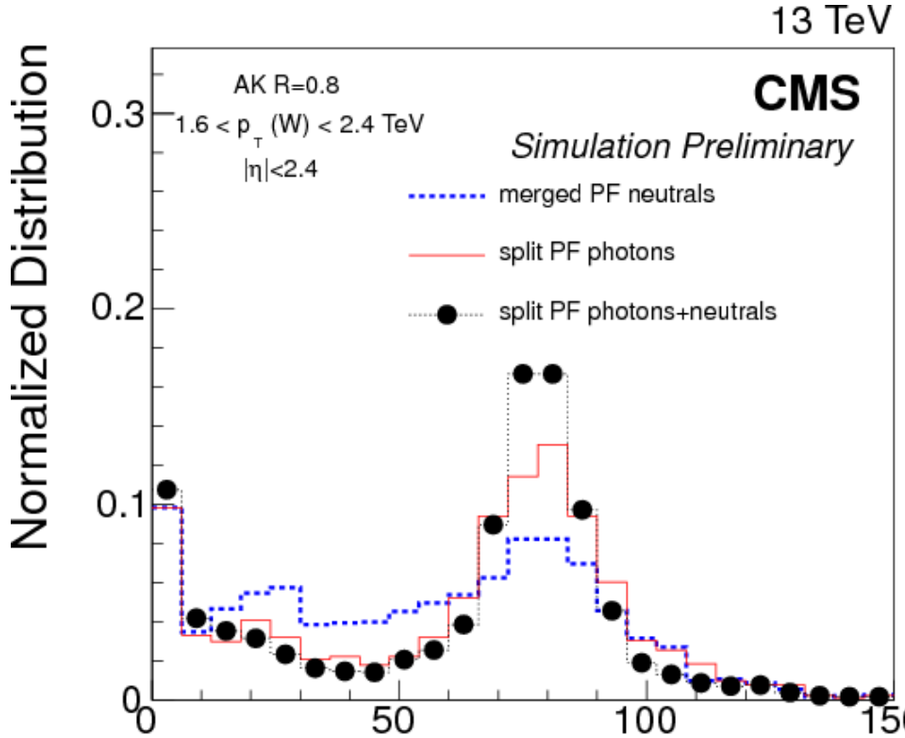
update to JVF:
=> correct for PU density
=> cures dependence on N_{PV}



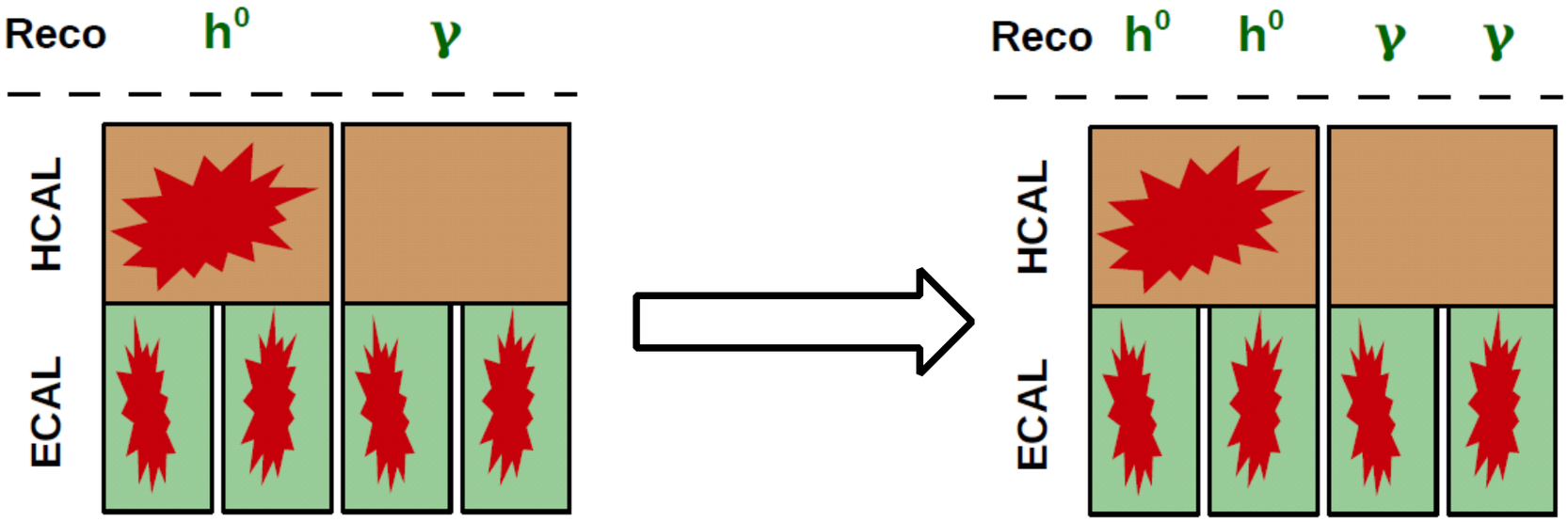
[CERN-PH-EP-2015-206]

Improved Particle Flow

- Jet core tracking:
  additional iterative tracking steps in jets
- Pixel-Cluster splitting:
  reconstruct overlapping tracks
- Split PF photons:
  increased granularity for ECAL deposits
- Split PF neutrals:
  use ECAL granularity to distribute HCAL energy

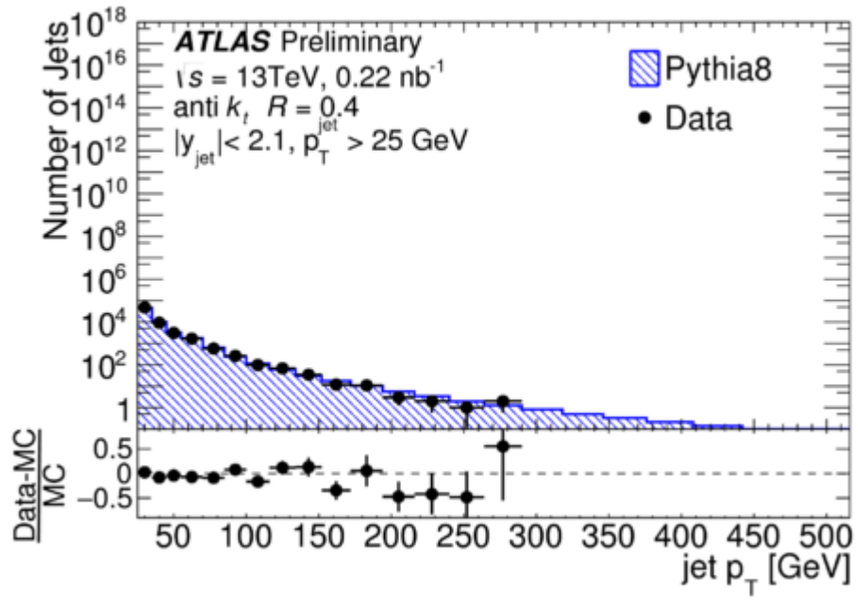


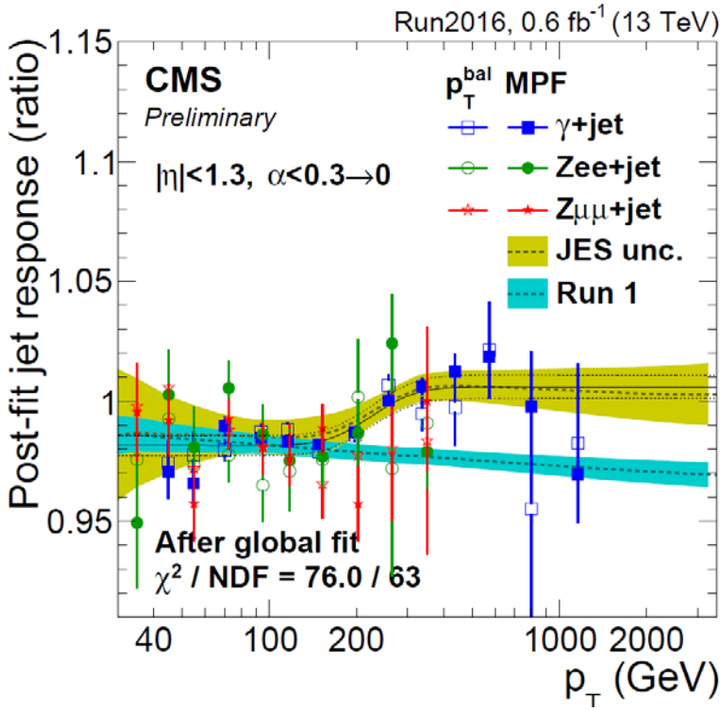
[CMS-JME-14-002]



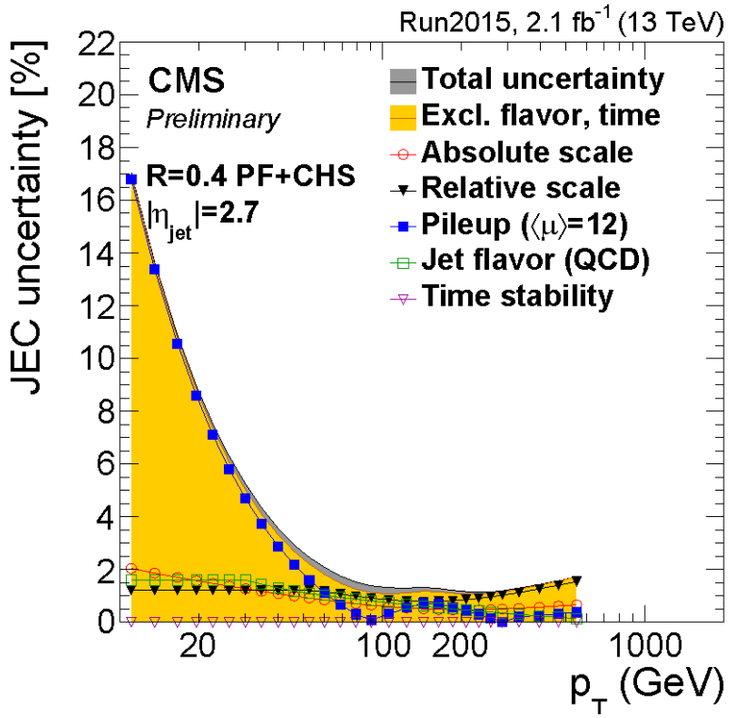
First Look at 13TeV Data

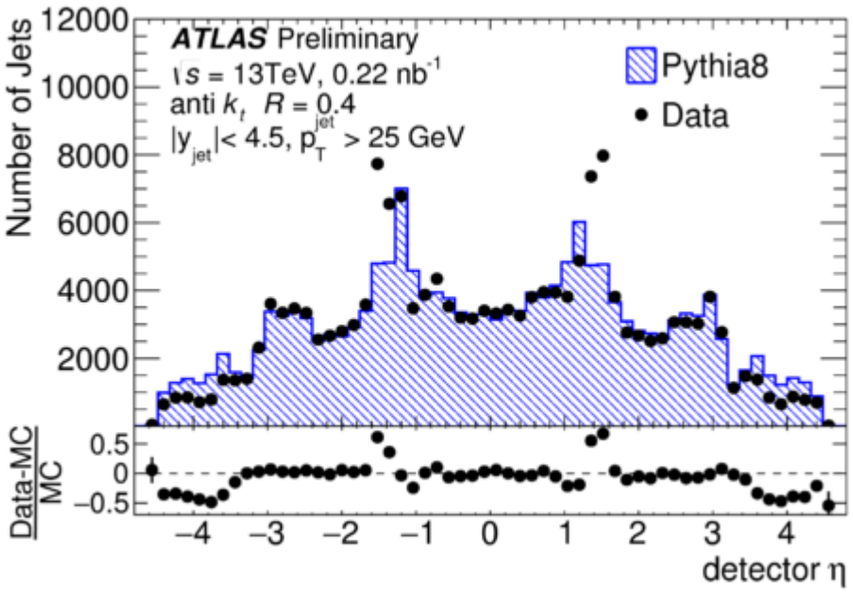
- Overall reasonable description by MC
  => Run I experience showing
- Some deviations seen in more detailed distributions
- First calibrations/corrections available





[CMS-DP-16-020]



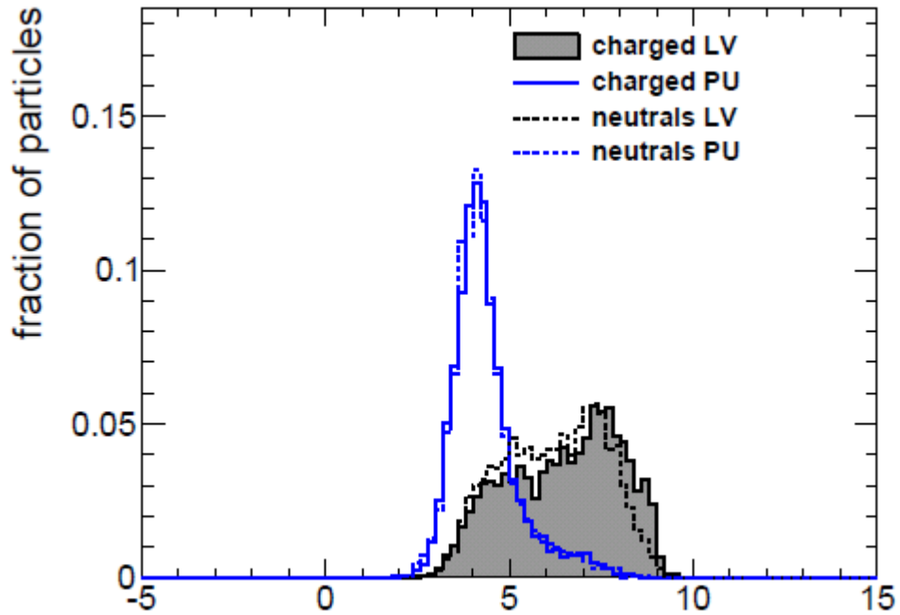


[ATL-PHYS-PUB-2015-036]

PUPPI

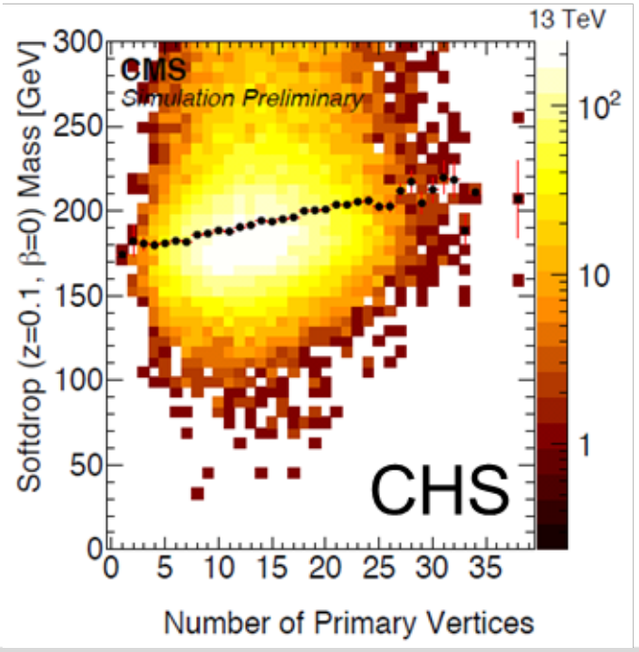
- Pileup per particle identification

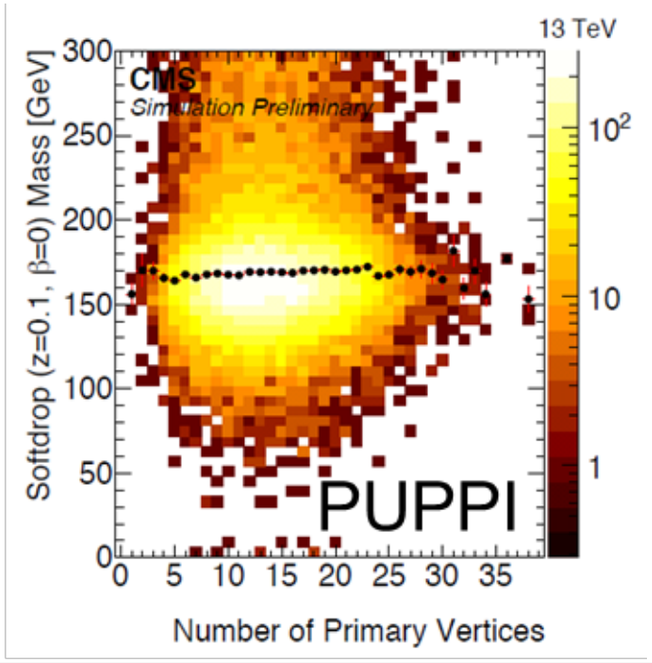
- Avoids issues of other PU reduction tools
  => charged particle subtraction: neutrals remain
  => PU jet id: doesn't correct real jets
  => area subtraction: no correction
  for shapes/substructure



[JHEP 1410 (2014) 59]

- PUPPI-algorithm in a nutshell:
  - classify charge particles by vertex as PU or leading vertex (LU)
  - compute PU-likelihood for charged particles (based on p_T, proximity to other particles)
  - evaluate for neutrals
  - weight neutrals with PU probability





Why Jet Substructure?

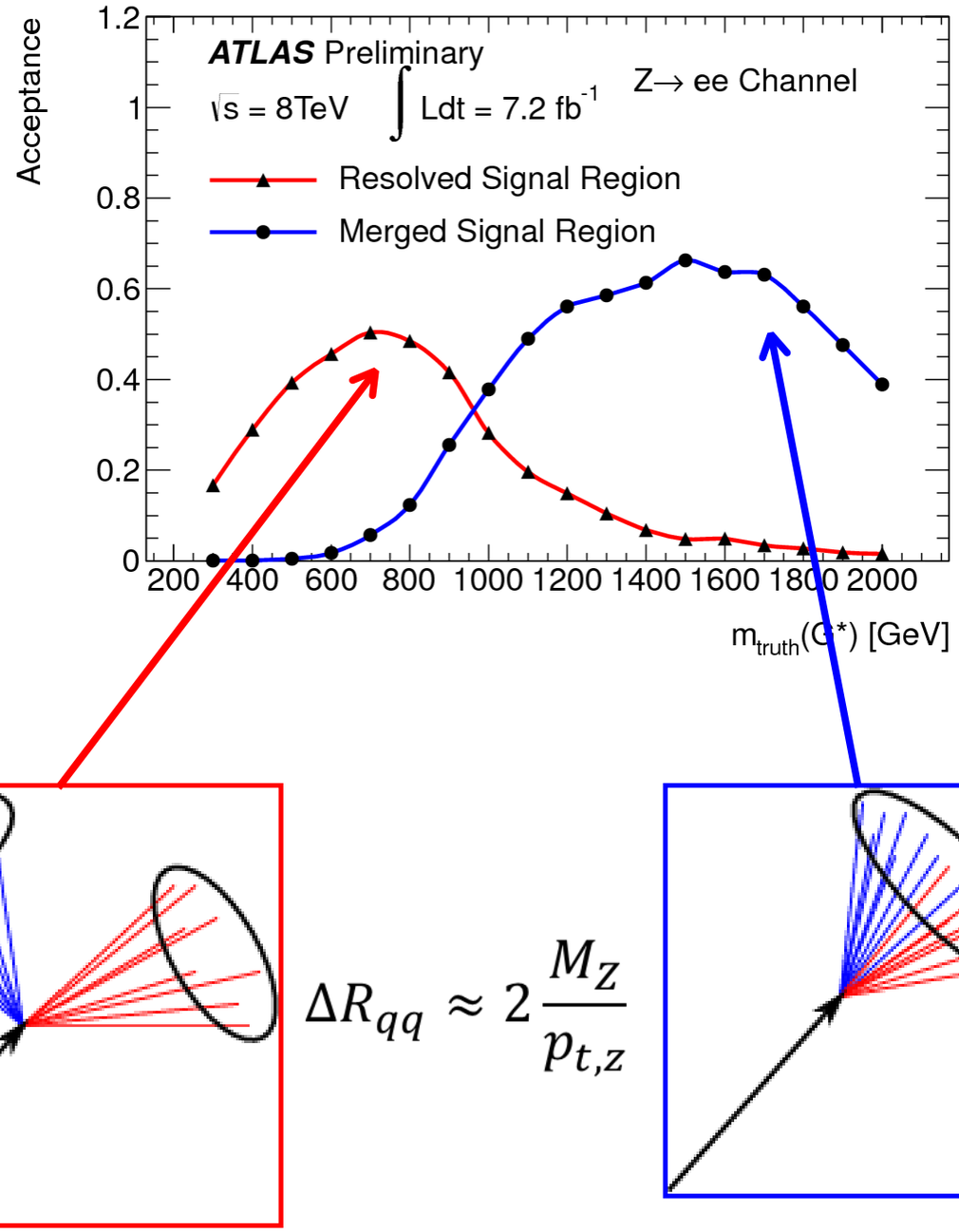
- Hadronic decays merging for

$$\Delta R_{qq} \approx 2\frac{M_X}{p_{t,X}}$$

- M(W/Z/t) = 80/91/175 GeV
  ΔR ~ 0.5
  => $p_{t,crit}$ ~ 320/360/700 GeV

- Limits many searches for high mass resonances

- Study merged jets instead of dijets



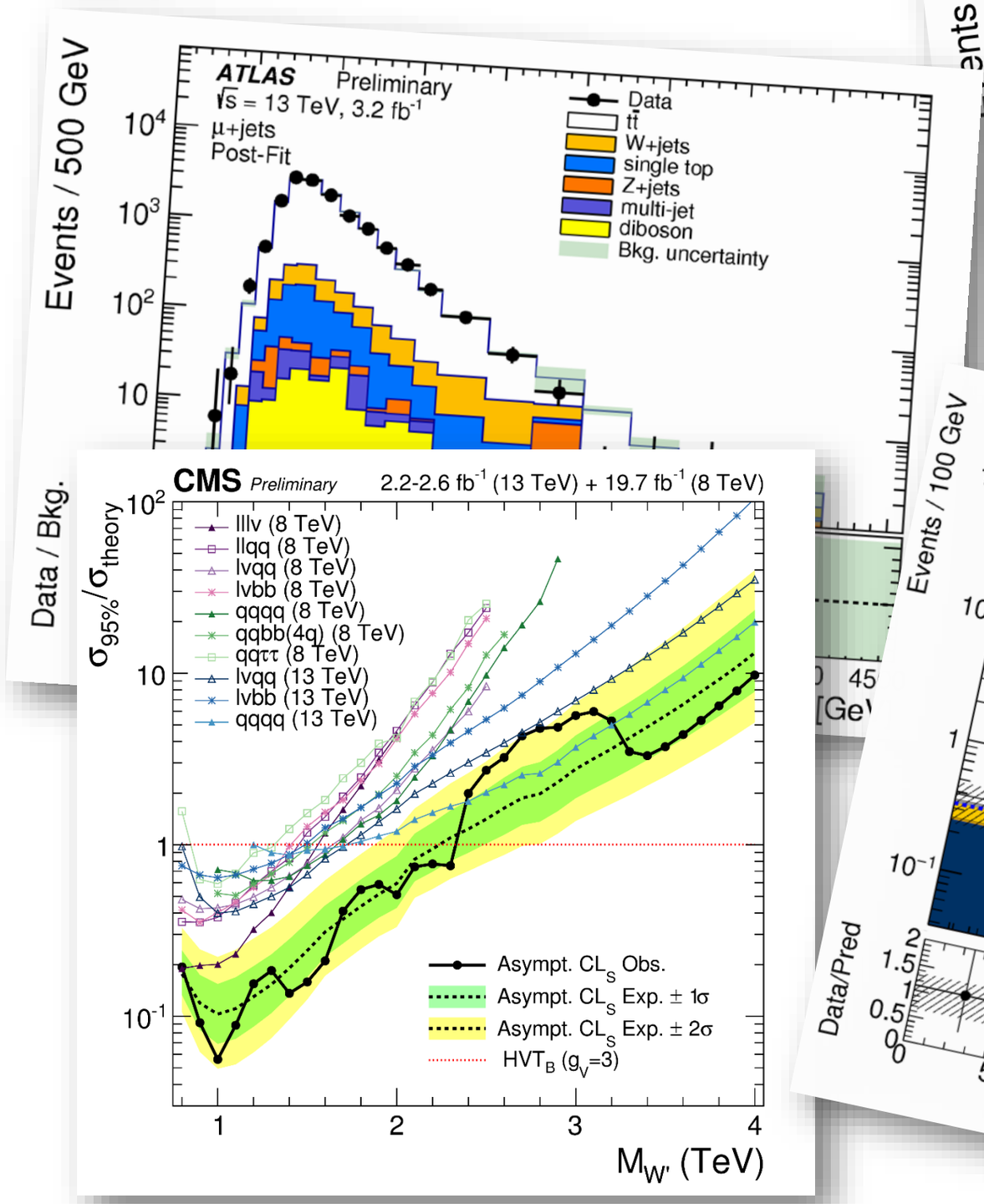
[ATLAS-Conf-2012-150]

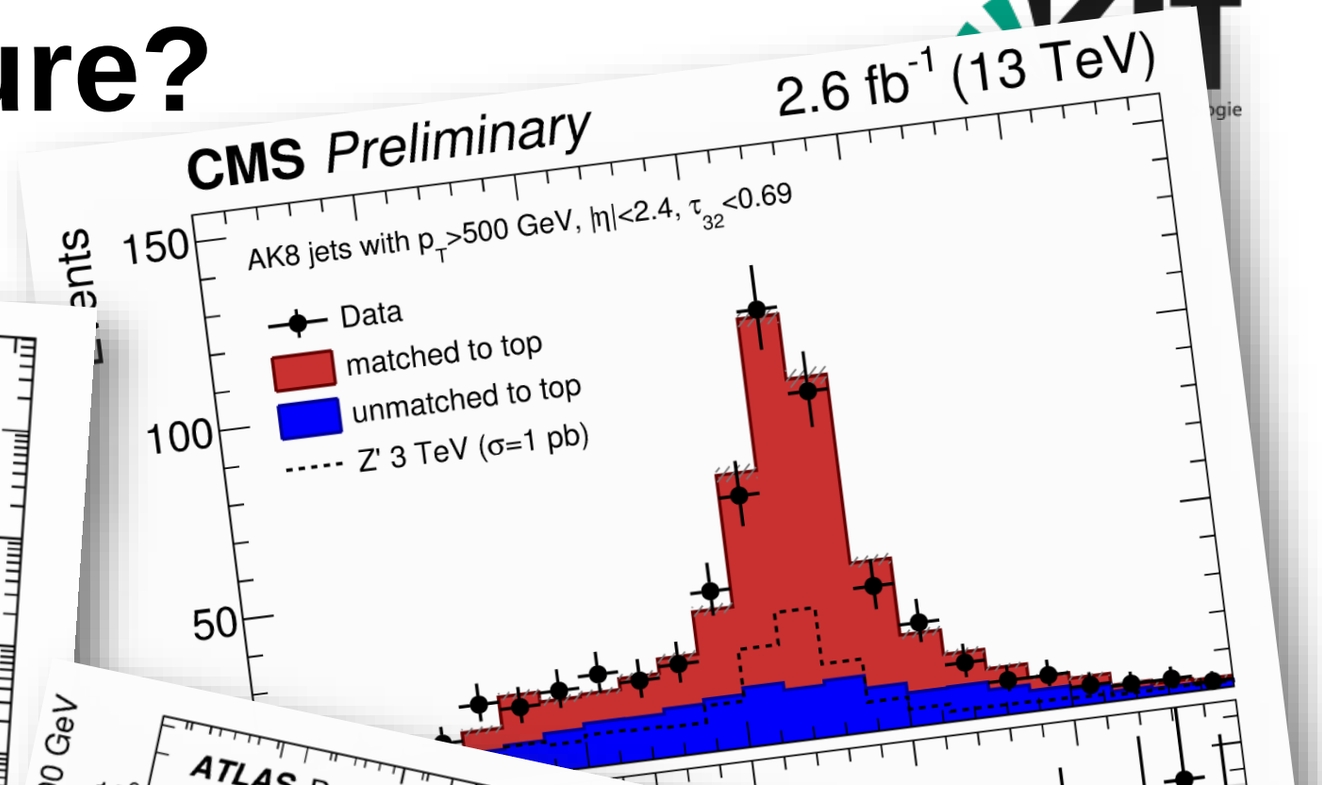
ΔR > jet radius

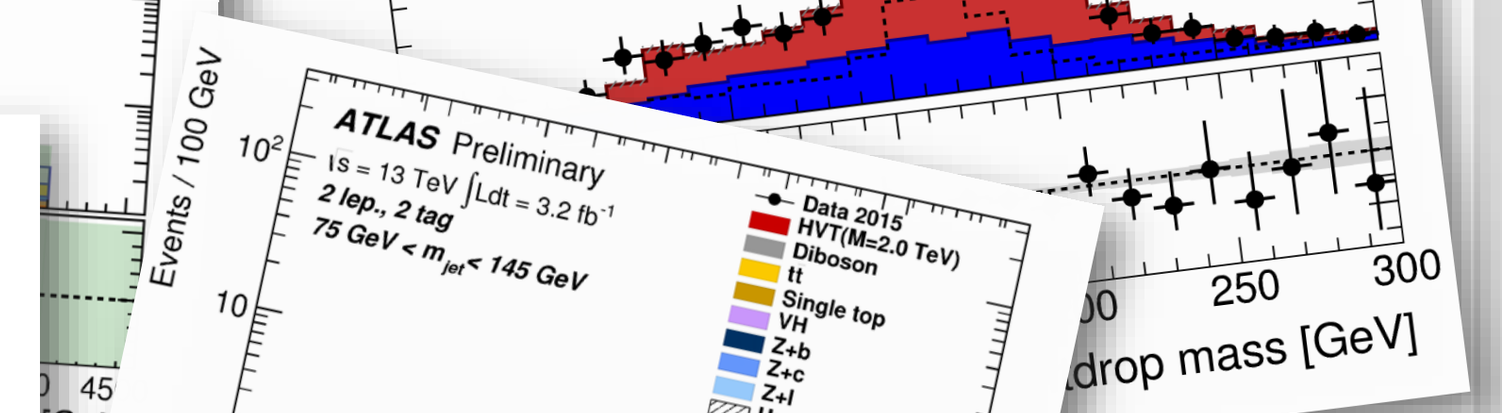
$$\Delta R_{qq} \approx 2\frac{M_Z}{p_{t,z}}$$

ΔR < jet radius

Why Jet Substructure?





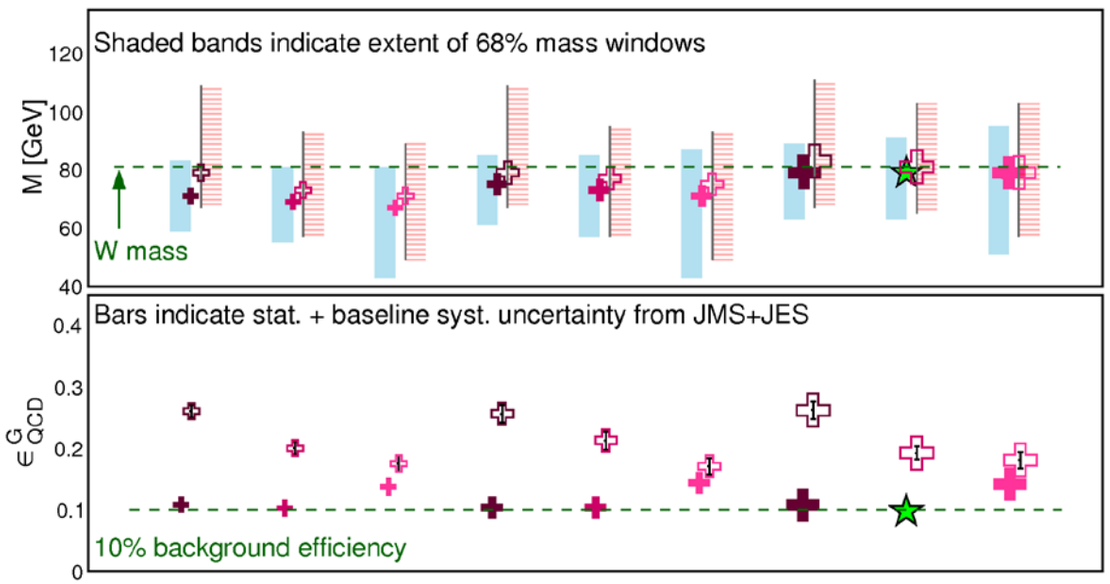


Preparatory Studies

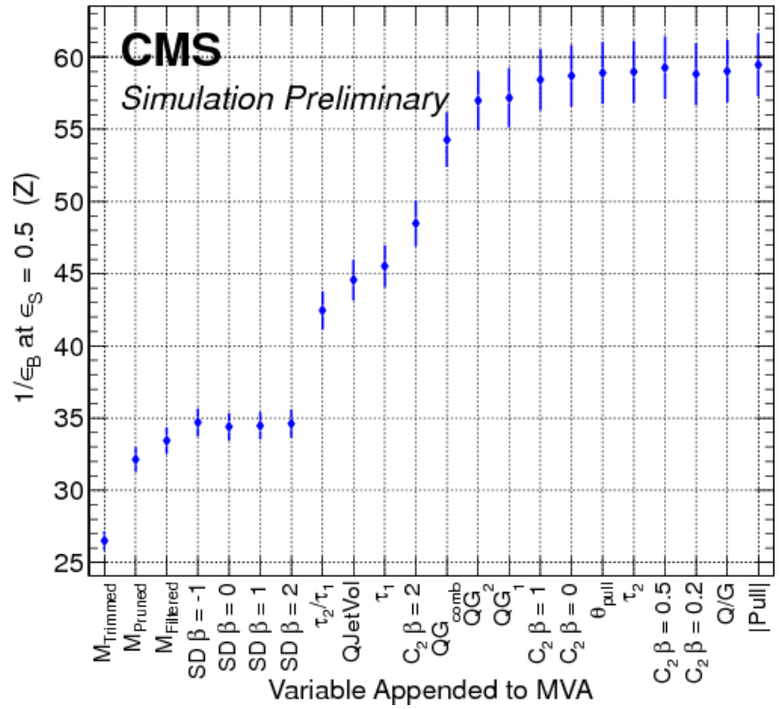
- Run I V-tag techniques organically grown

- Shutdown used for systematic review:
  => collect many possible substructure vars.
  => compare single and combined performance

- Good results with one substructure var + one groomed mass var
  => but significant gains from larger multivariate combinations



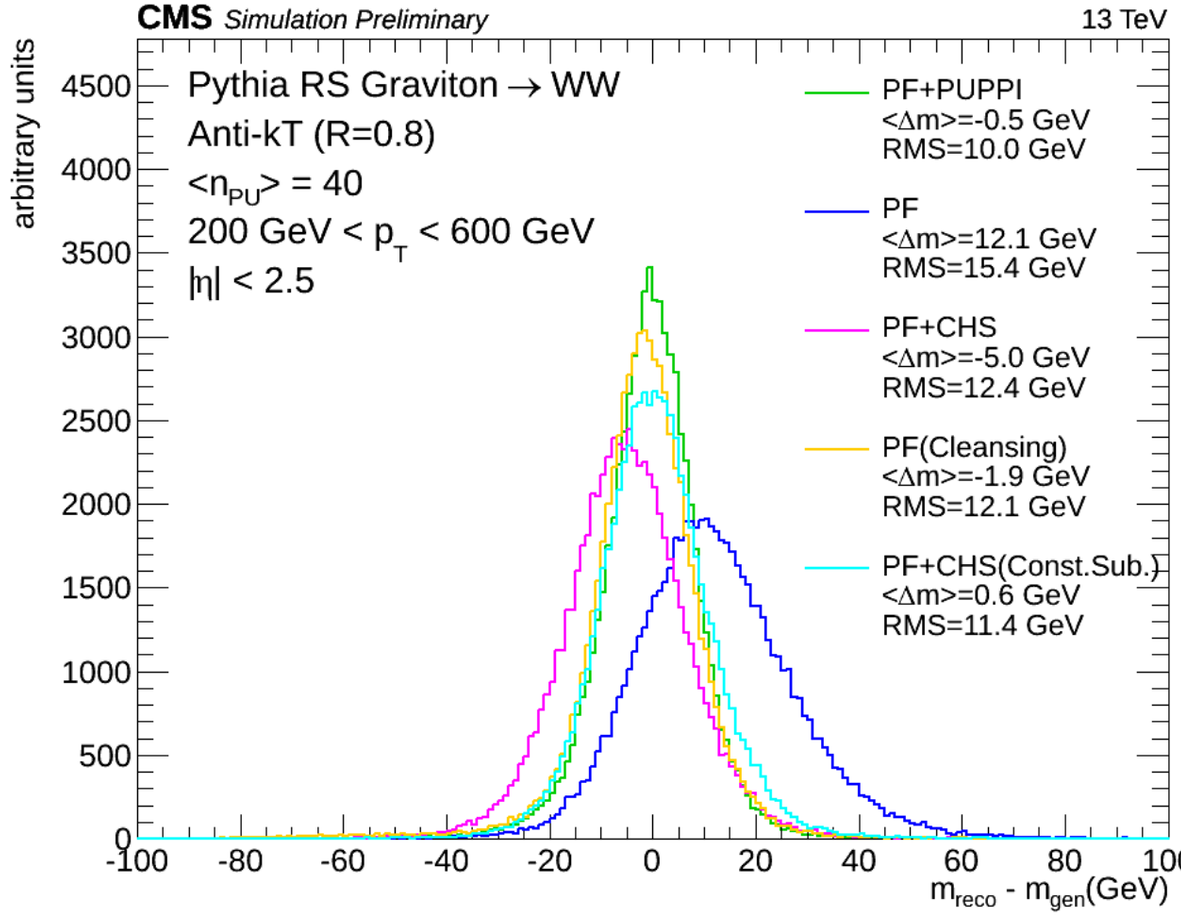
[Eur. Phys. J. C 76(3) (2016) 1-47]



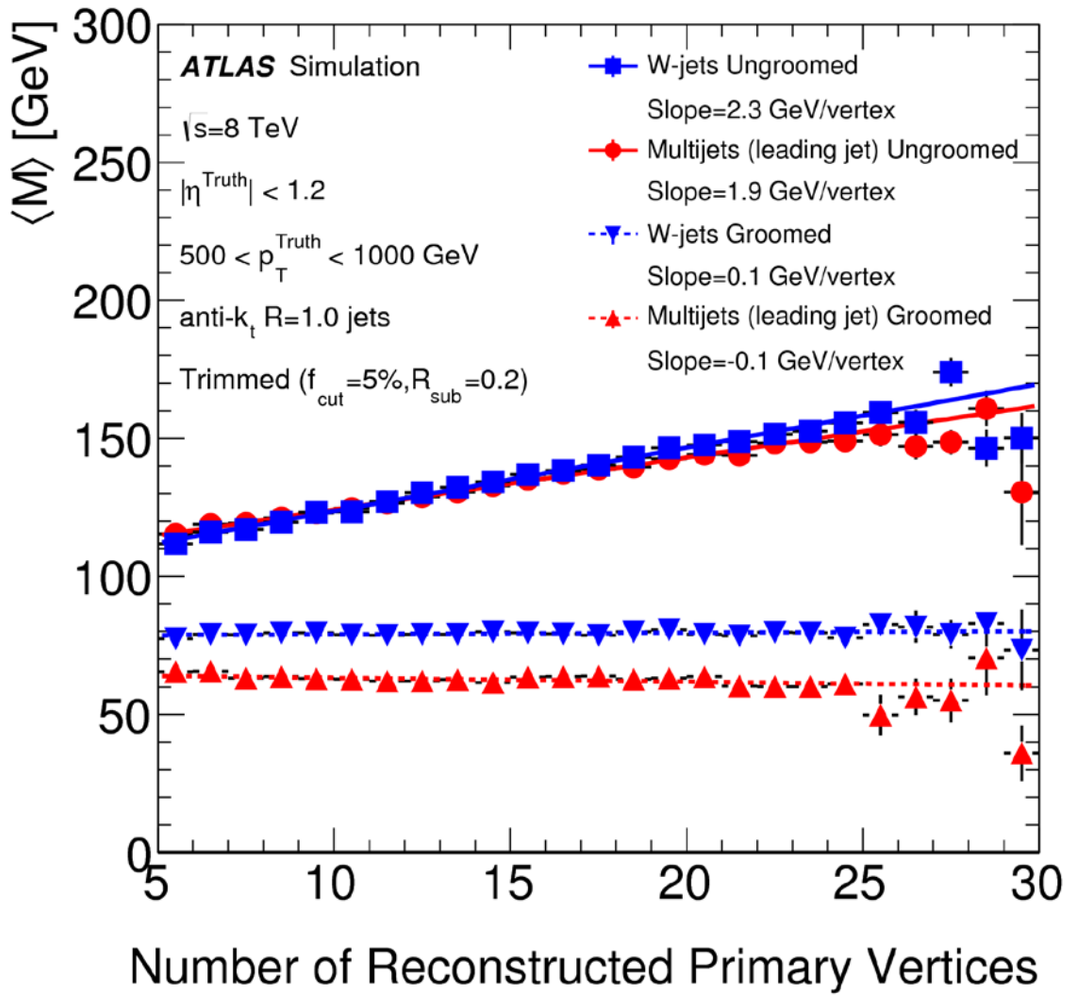
[CMS-PAS-JME-14-002]

Preparatory Studies

- Run I V-tag techniques not all robust against PU
  => reevaluate for Run II for improved PU residtance



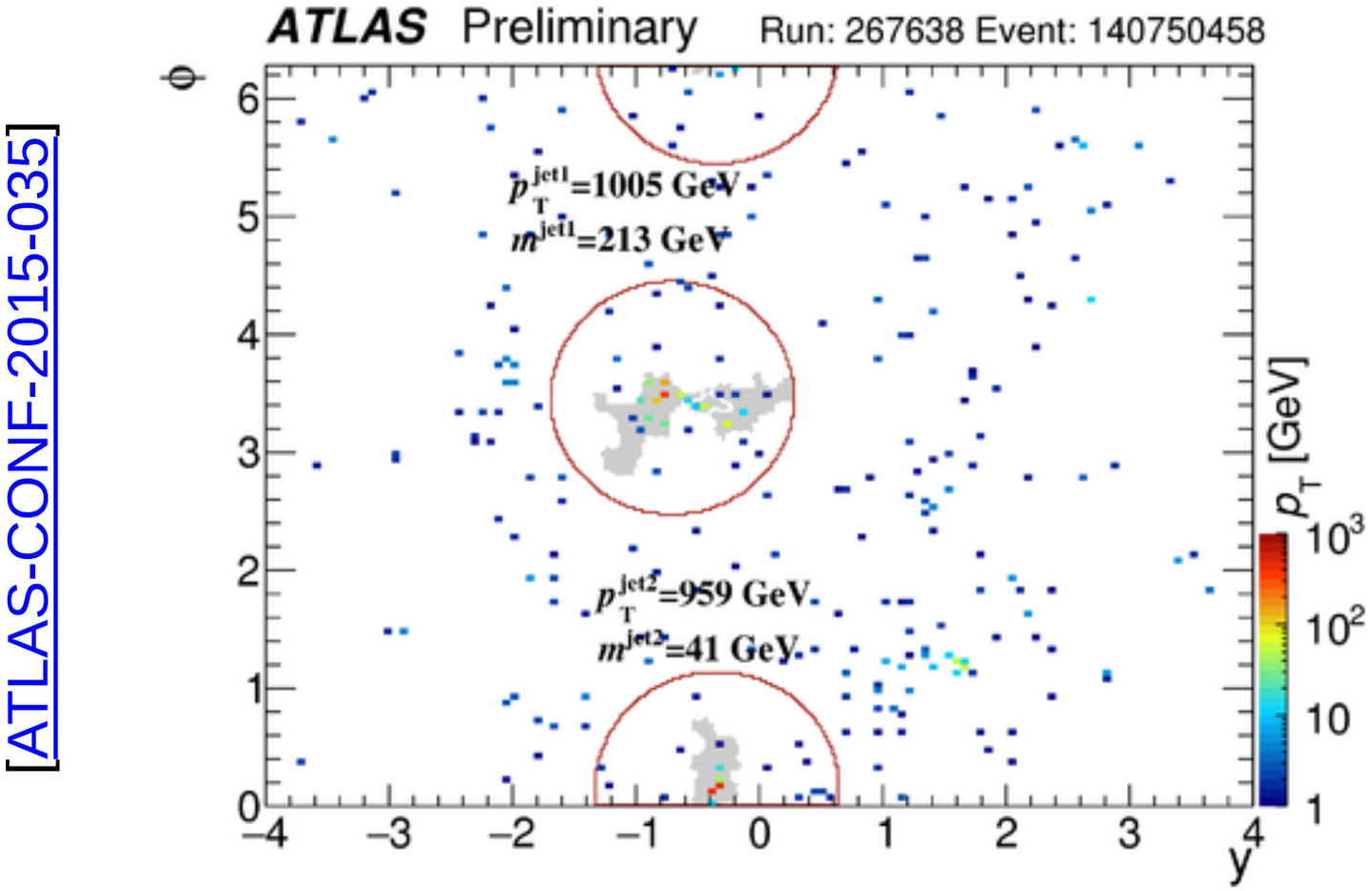
[CMS-PAS-JME-14-001]



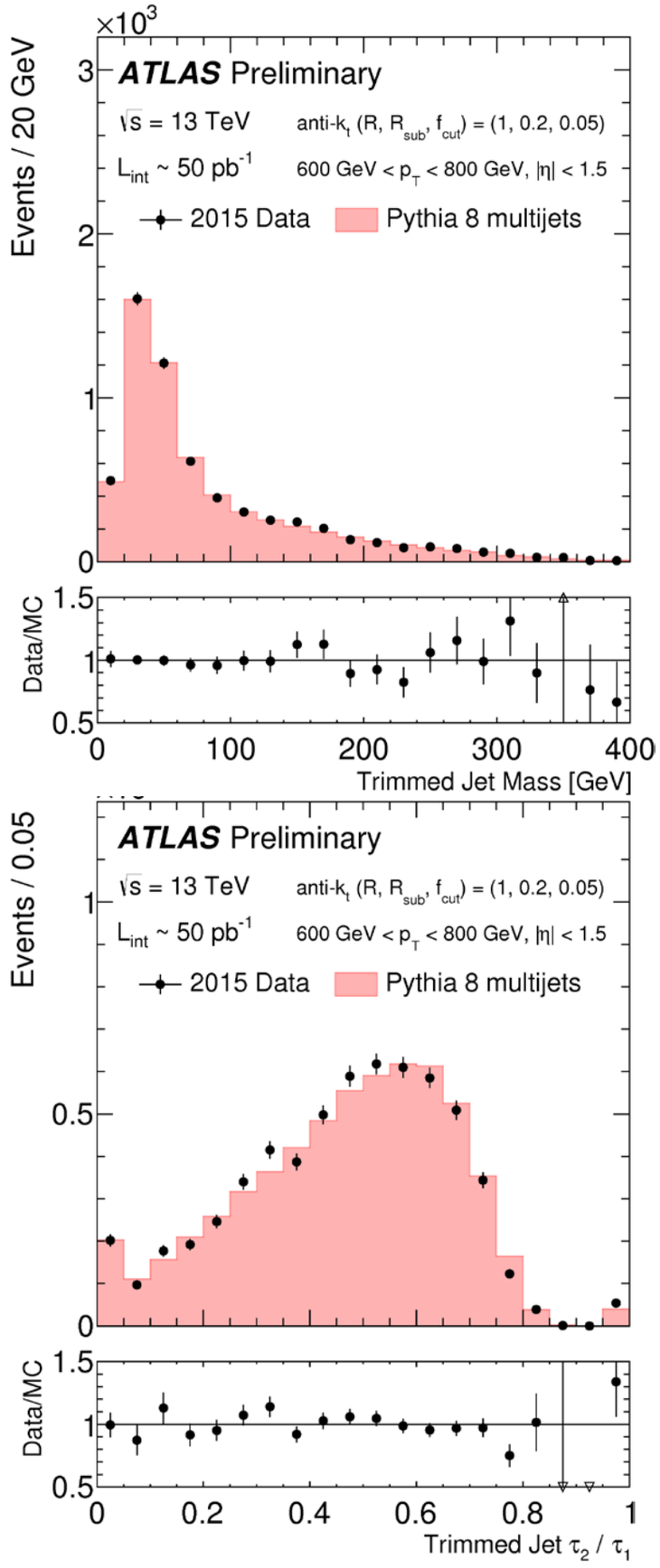
[Eur. Phys. J. C 76(3) (2016) 1-47]

Results ATLAS

- Check in Data?
- Easy for background:
  => lots of QCD jets even with little data
- Good agreement with simulation

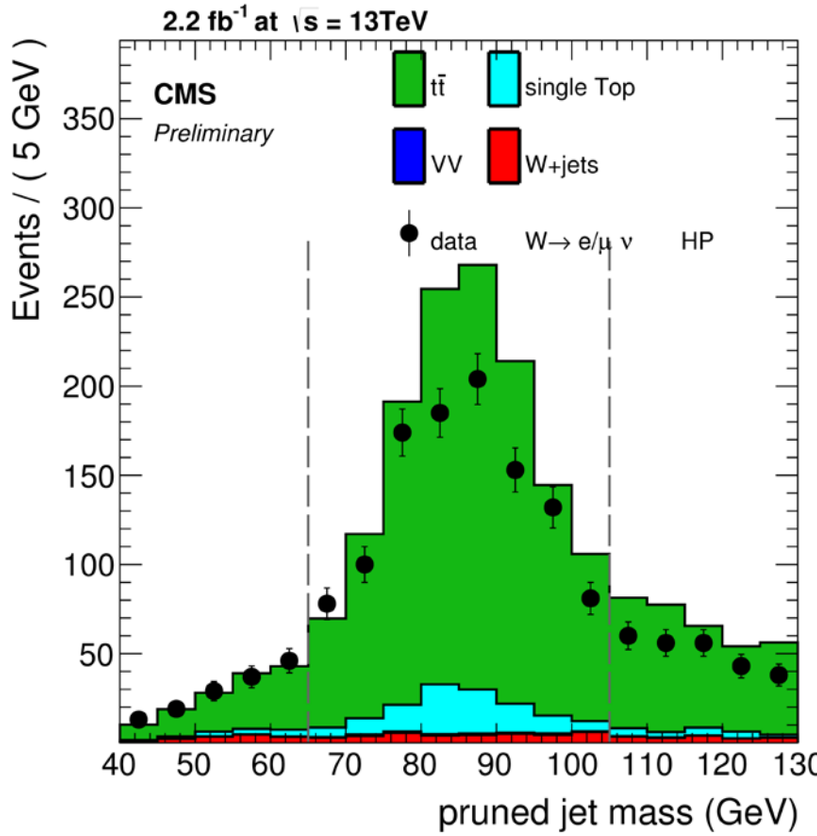


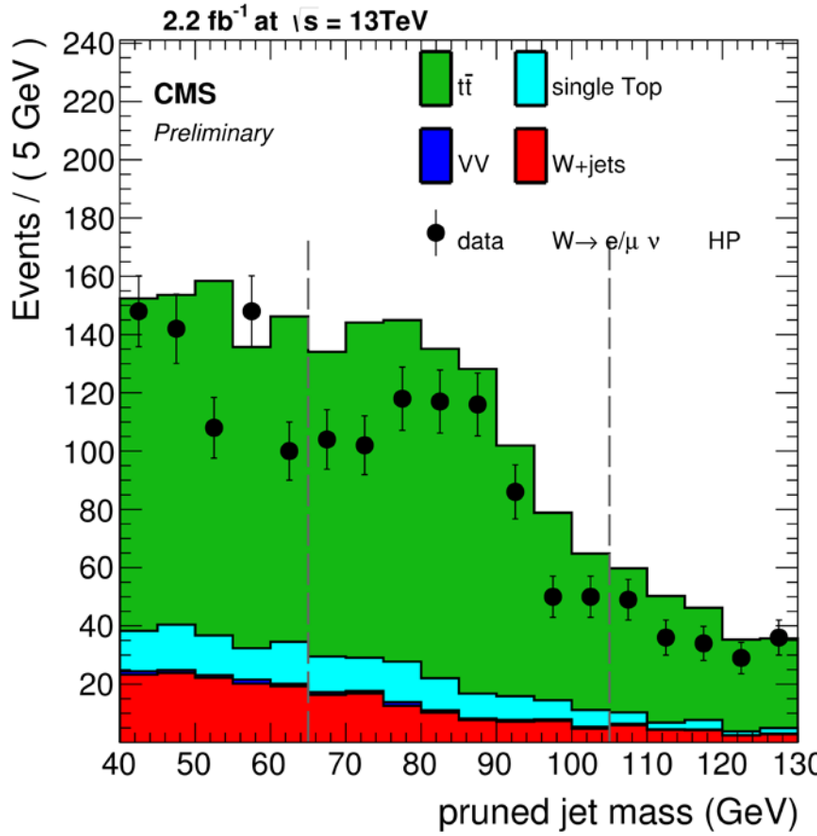
[ATLAS-CONF-2015-035]



Results CMS

- Signal? => ttbar tag & probe
- Somewhat more ttbar in MC than data
- Ratio of pass/fail well described
- Better MC description than in Run I (Thanks, Pythia8!)
- Still based on pruned mass + τ_{21}
- Improvements planned for 2016:
  => Softdrop mass
  => PUPPI

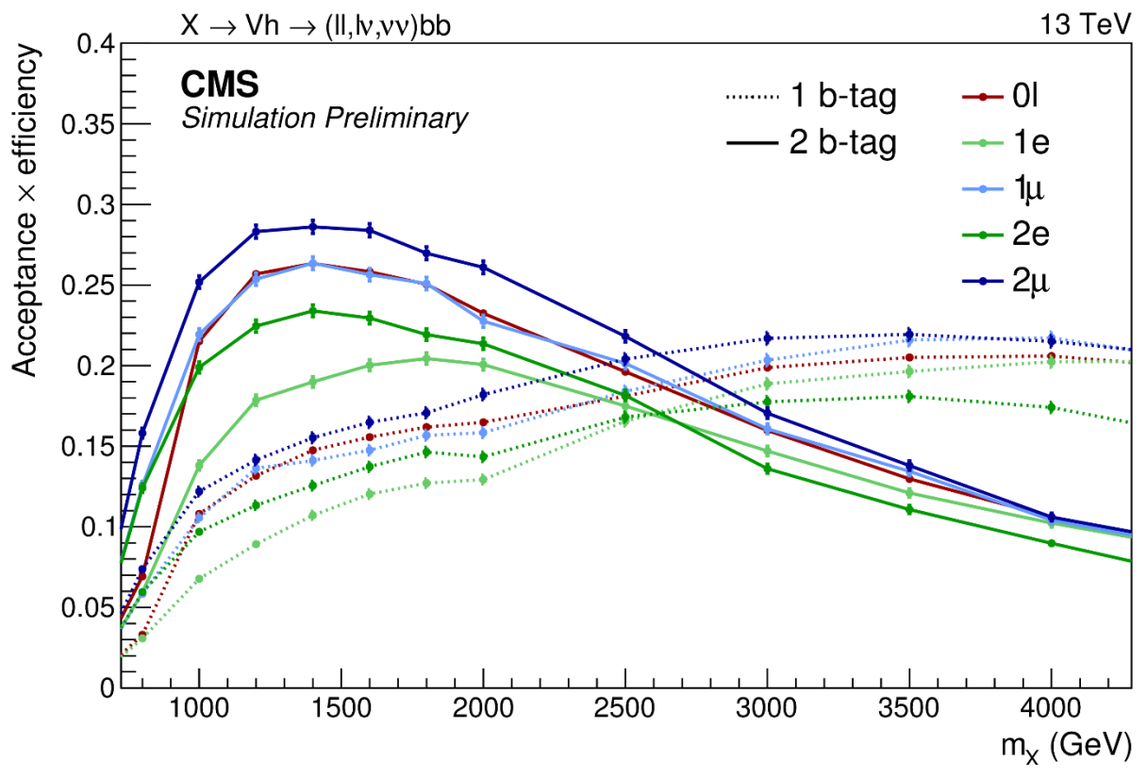




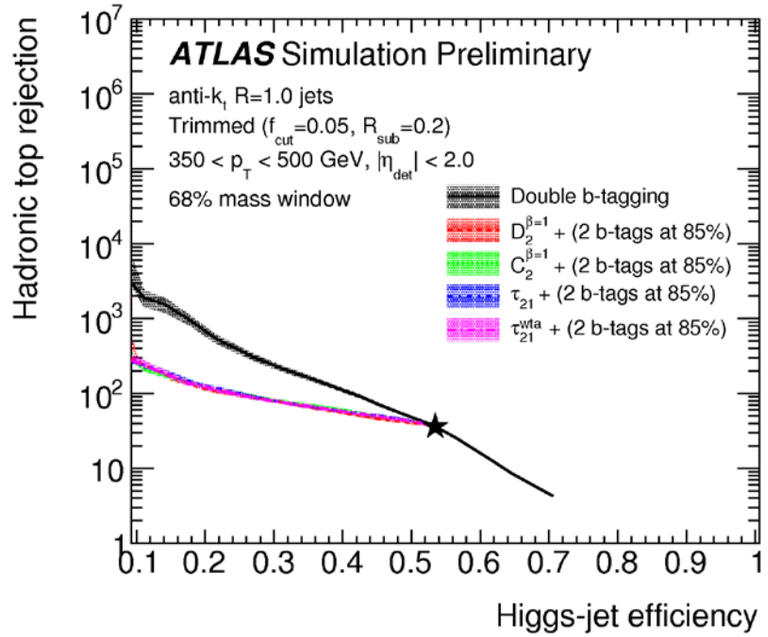
[CMS-EXO-15-002]

Higgs Tagging

- Similar strategy to V tag:
  => jet mass ~ M_H
  => two-prong structure
- Additional discriminant
  find b-tags in the boosted H
- Tricky optimization:
  subjets overlap for high pt
  difficult to disentangle two
  separate b-quarks
- Early analysis typically splitting
  in number-of-tag categories
- Active work on specialized algorithms
  taking p_T evolution into account



[CMS-B2G-16-003]

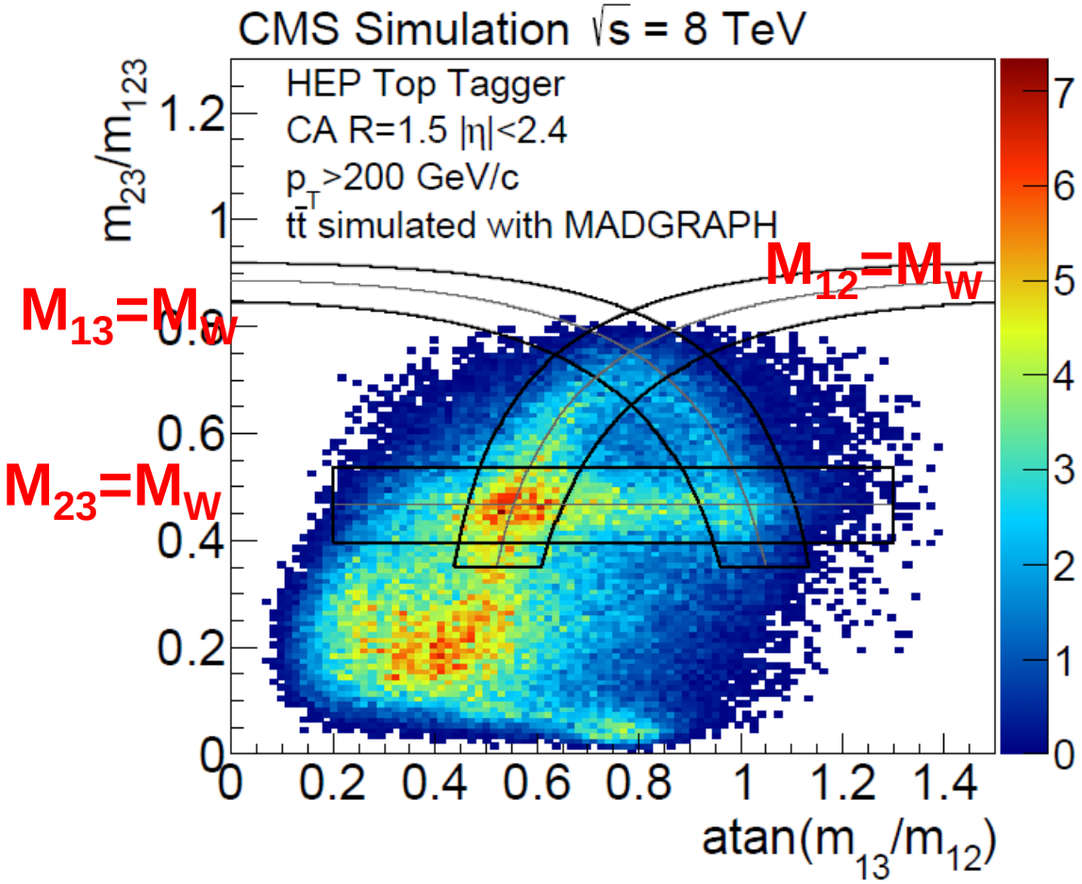


[ATL-PHYS-PUB-2015-035]

Top Tagging

- Rich phenomenology:
  => three prongs
  => two of which combine to a W
  => one b-tag

- Outgoing b-quark color-connected to other particles in the events

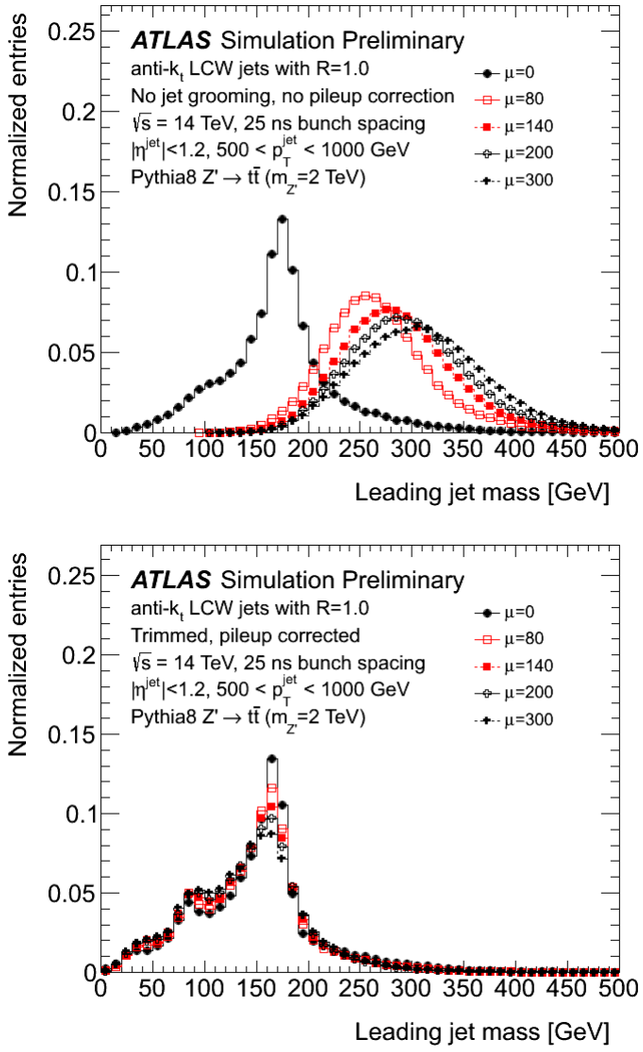


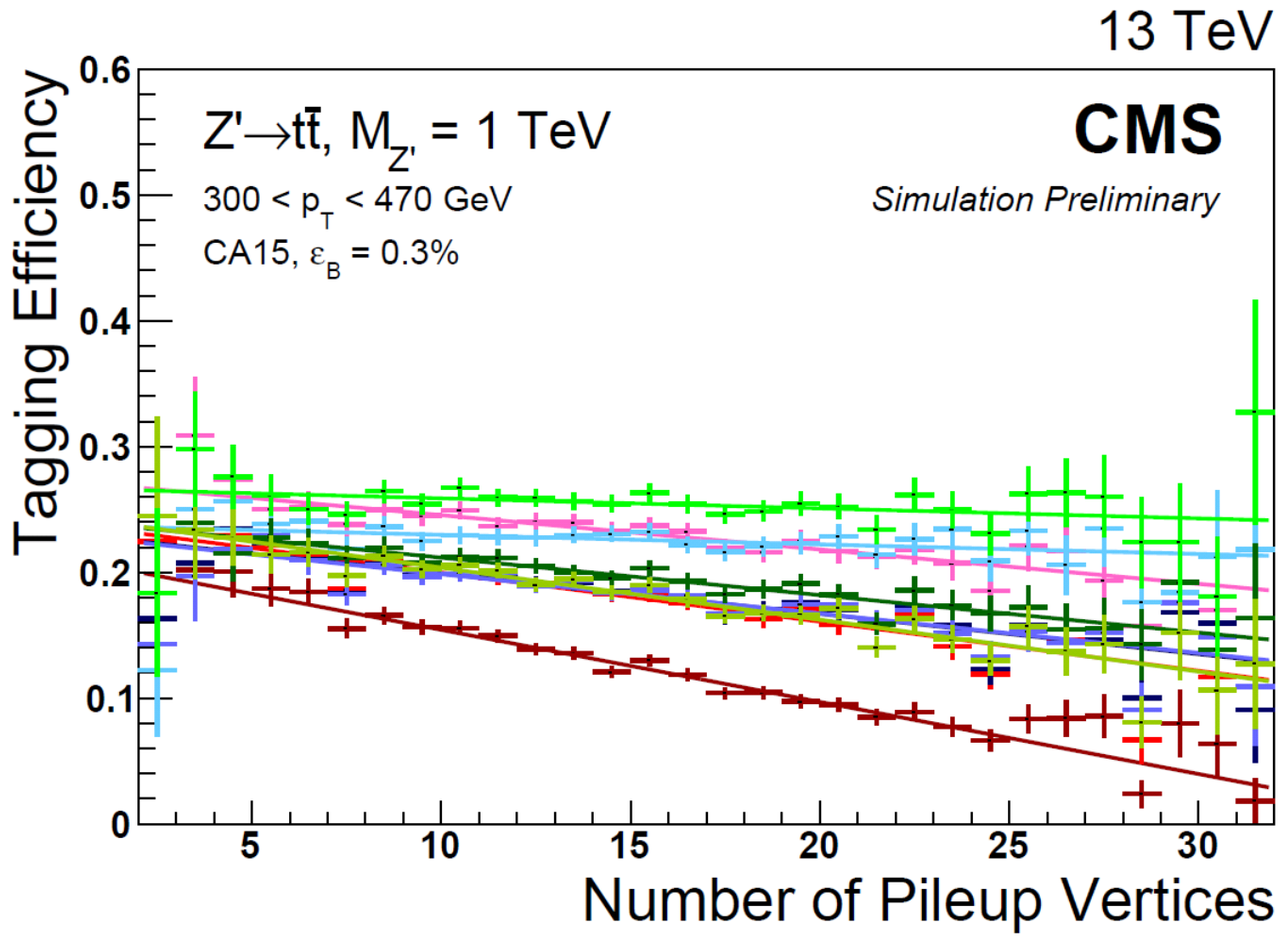
- Many different approaches:
  => basic groomed mass + 3-prong structure
  => additionally reconstruct W (HEPTop-Tagger JHEP 1010:078,2010)
  => shower decompostion
  (Likelihood discriminant derived from simplified parton shower)
  Phys.Rev. D87 (2013) 054012
  => additionally subjet b-tag

Improvements for 13TeV

- Improved HEP-Top-Tagger (JHEP 1506 (2015) 203) variable radius to improve high p_T behaviour
- PU-resistance important going forward

[https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetSubstructureECFA2014]

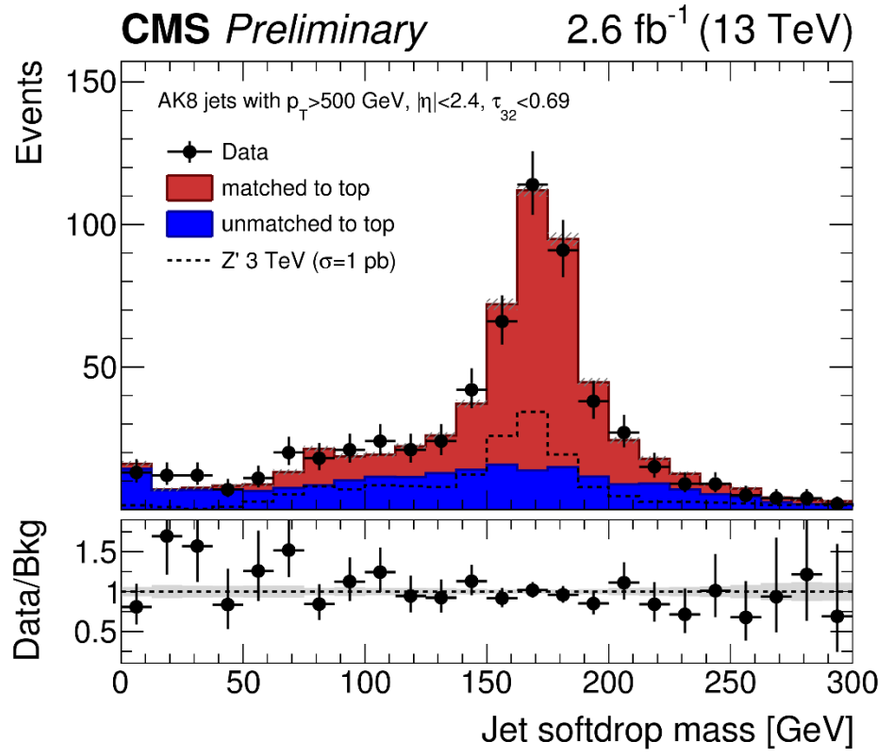


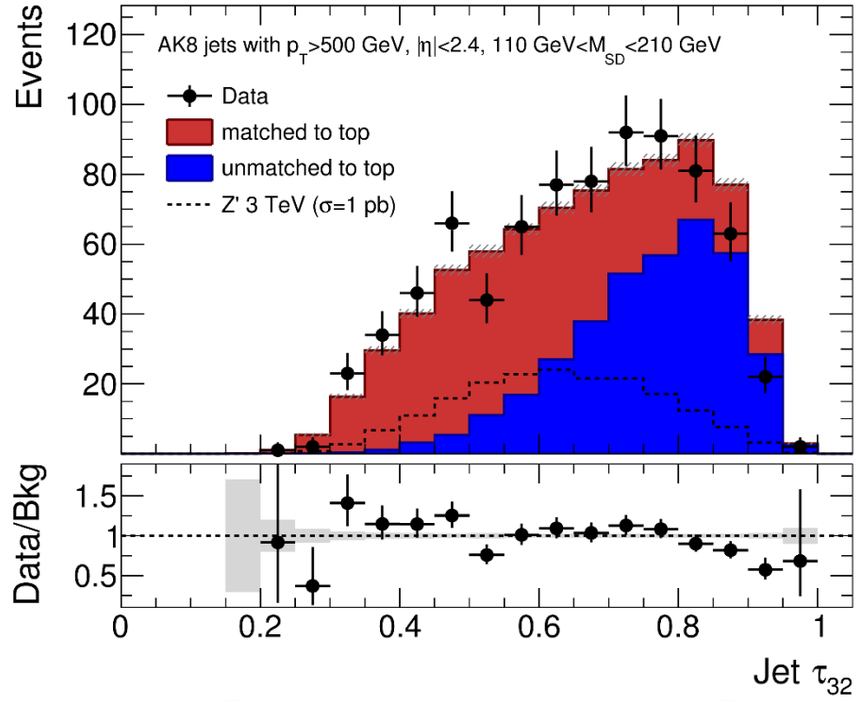


[CMS-PAS-JME-15-002]

Results at 13 TeV

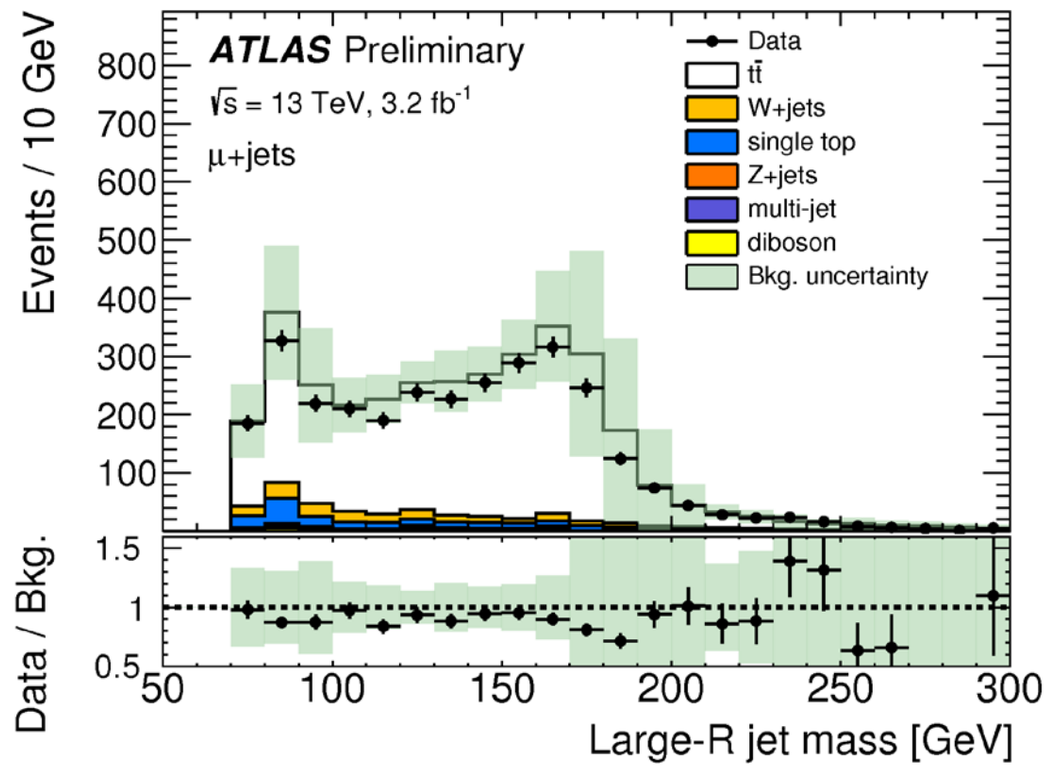
- First results using simple taggers:
  => M(softdrop) + τ_{32} (CMS)
  => M(trimmed) + τ_{32} (ATLAS)
- Comparisons to simulation promising
- Try more advanced tagging with more data





[CMS-B2G-15-002]

[ATLAS-CONF-2016-014]



Summary

- Boosted decays promising for high acceptance at good purity

- Serious work during 2013/2014 long shutdown
  => from ad-hoc solutions to real V/H/t tags
  => methods are maturing

- Large set of 13TeV results from ATLAS + CMS available
  => excited by di-boson excesses

- First 13TeV analysis still commonly using simple methods
  => harsh time-pressure for first results

- Commissioning of more sophisticated methods on 13TeV data ongoing

- Look forward to BOOST2016