Future Perspectives for Jet Substructure

ISMD 2014

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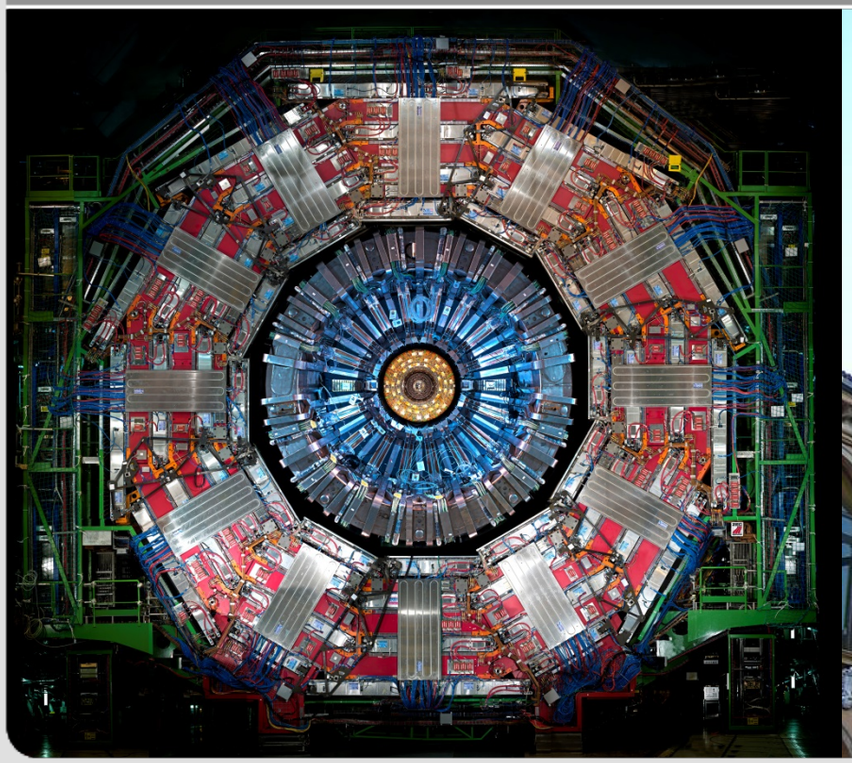
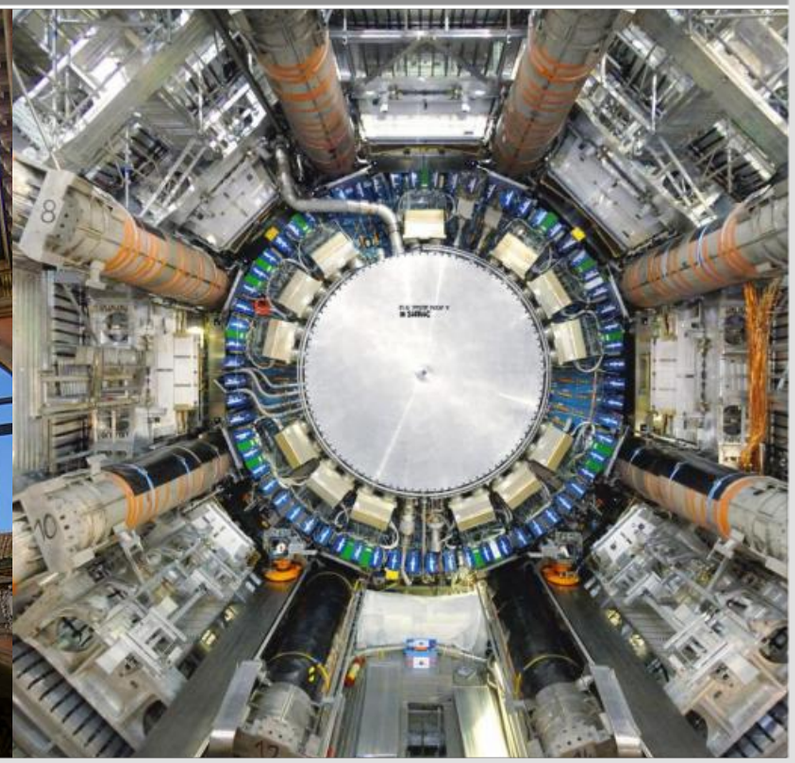




Why Jet Substructure?

- Hadronic decays merging for

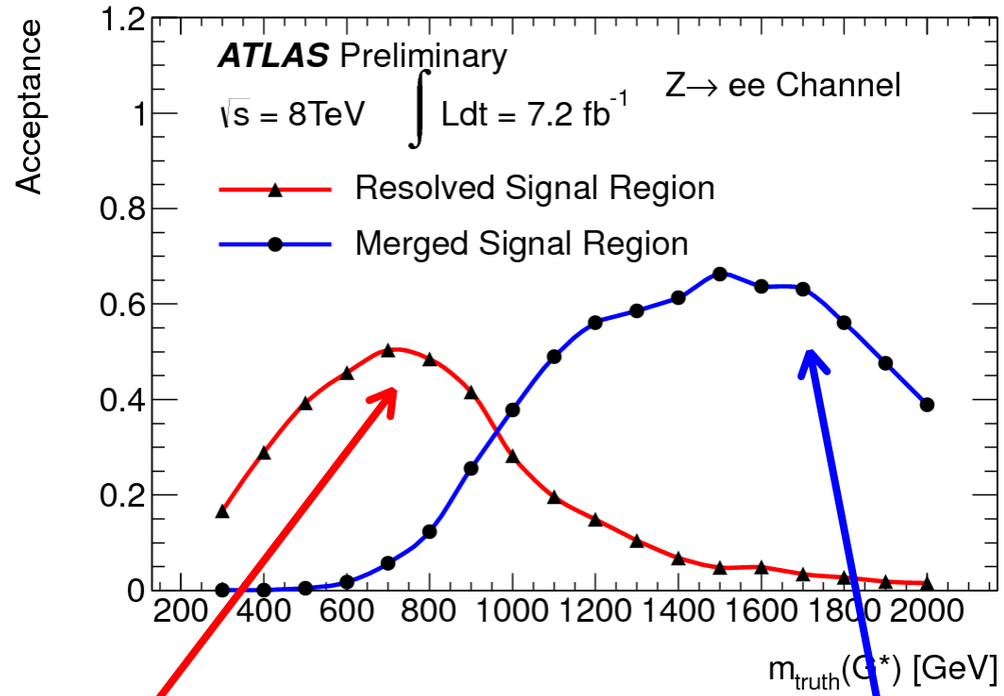
$$\Delta R_{qq} \approx 2\frac{M_X}{p_{t,X}}$$

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

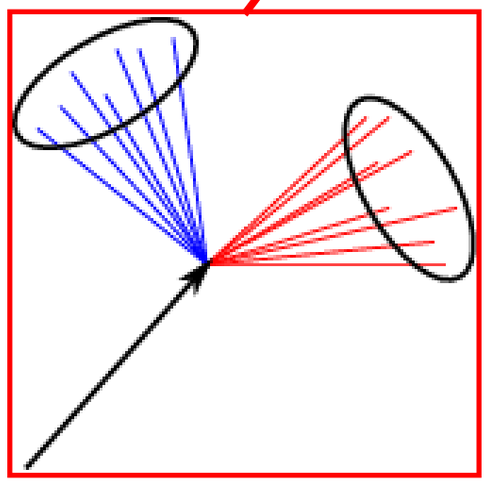
- Limits many searches for high mass resonances

- Study merged jets instead of dijets

- See previous presentations overview of algorithms and results

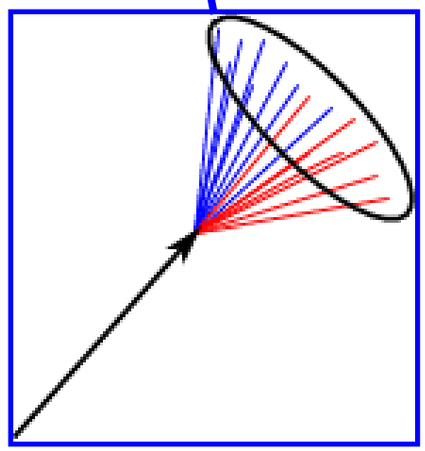


[ATLAS-Conf-2012-150]



ΔR > jet radius

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



ΔR < jet radius

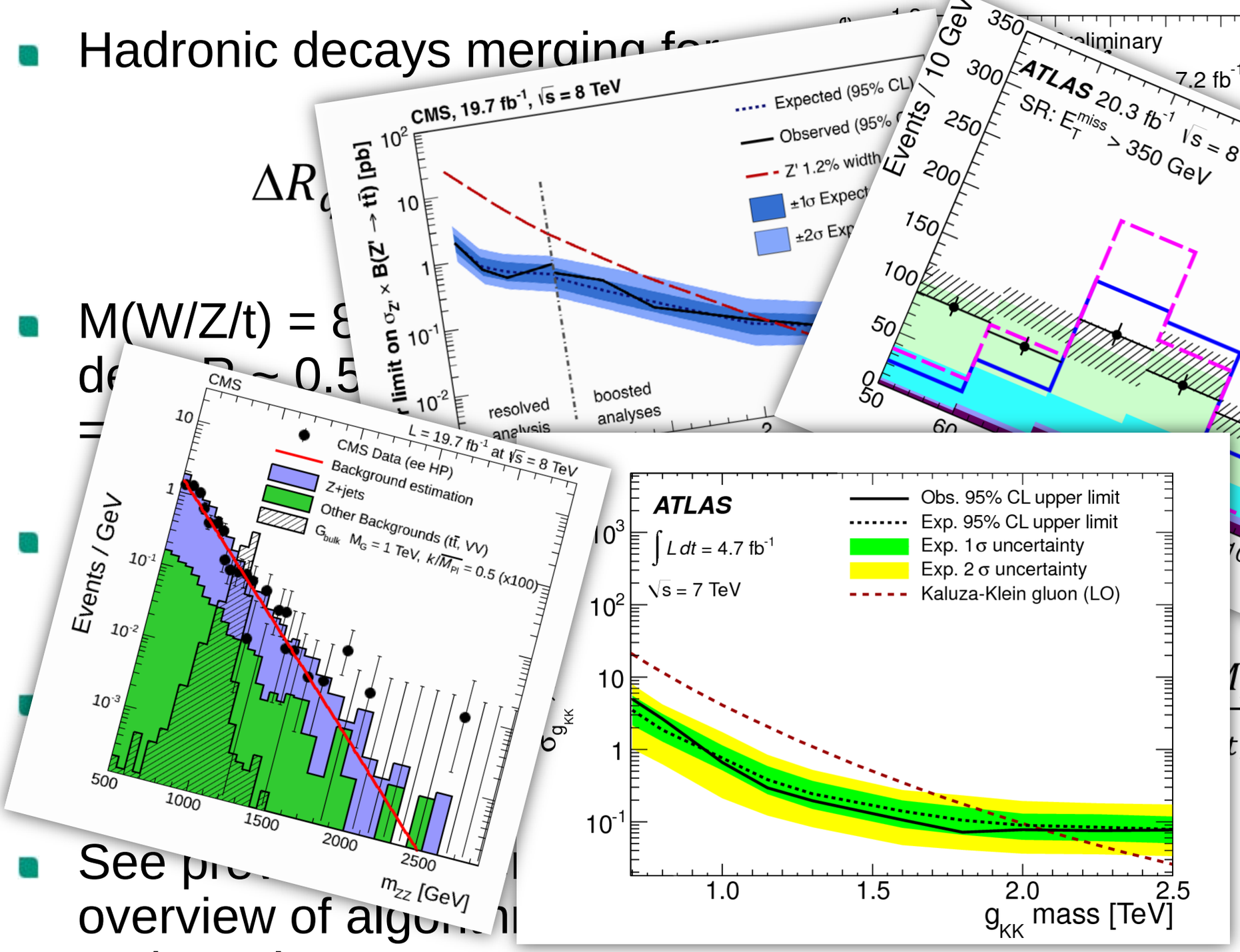
Why Jet Substructure?

- Hadronic decays merging fo

$$\Delta R_{q}$$

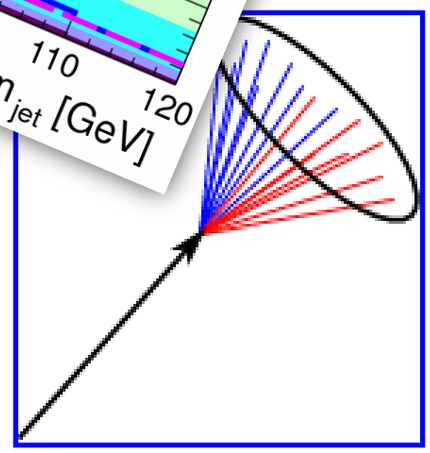
- M(W/Z/t) = 8
  de
  $= 2 \sim 0.5$

- See pre
  overview of algo
  and results



[ATLAS-Conf-2012-150]

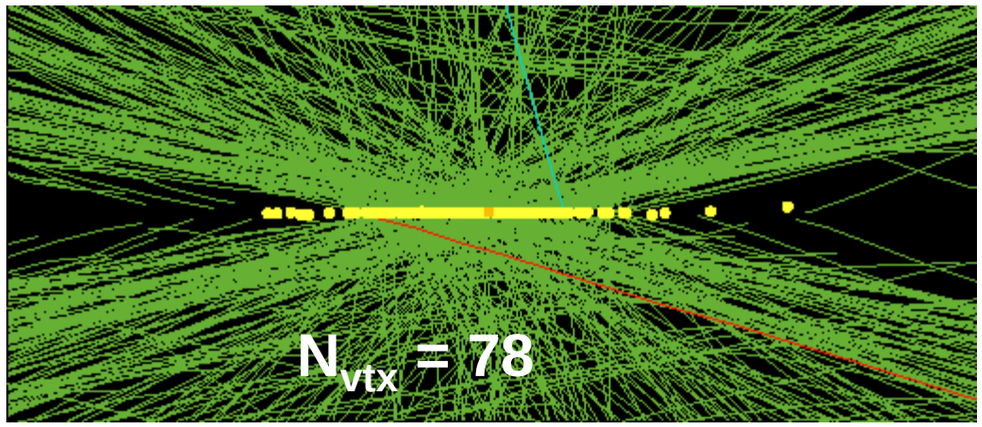
$$\frac{M_Z}{p_{t,z}}$$



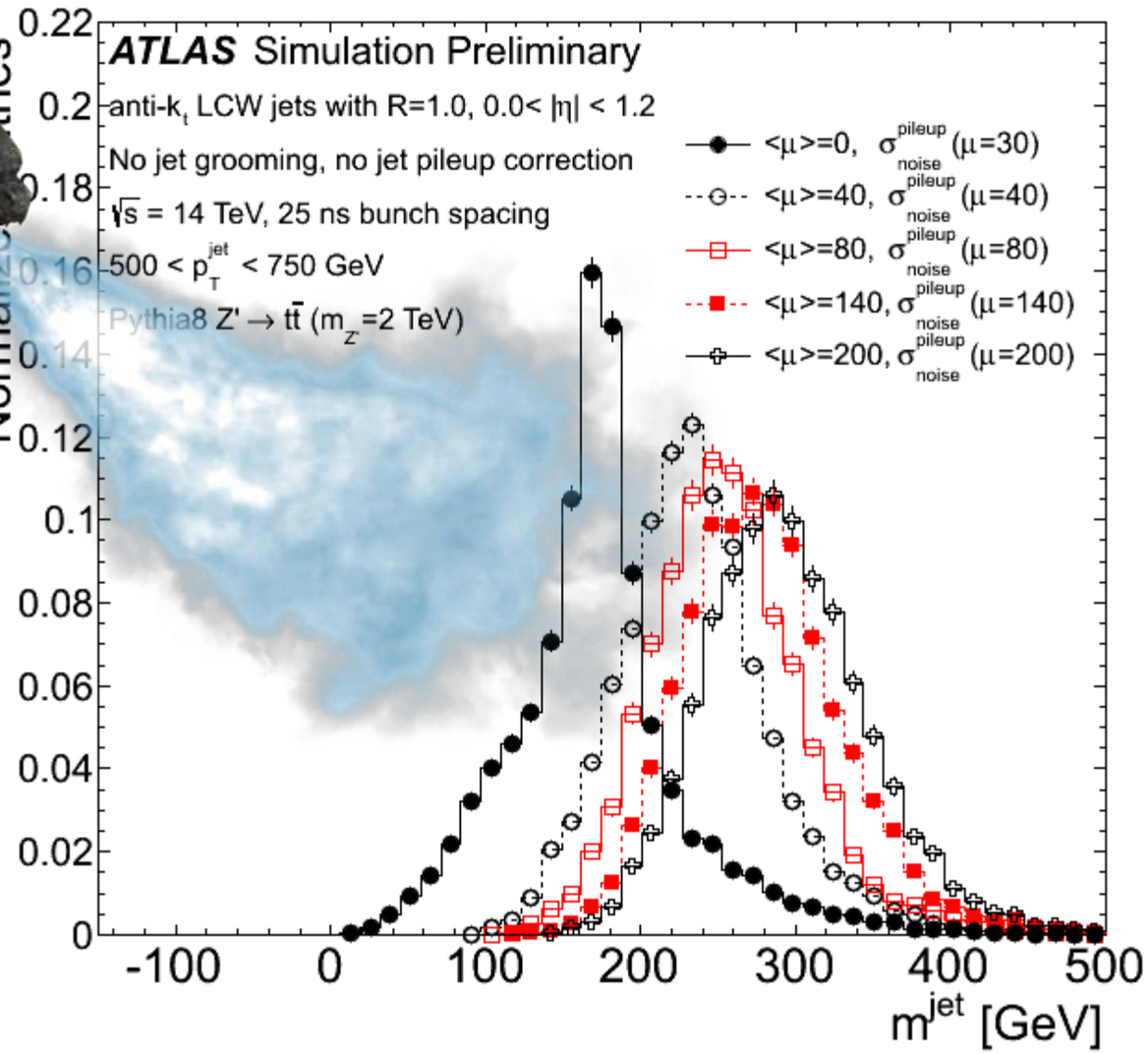
ΔR < jet radius

The Challenge

- Run II (and HL-LHC) will have
  => (much) more PU
  => more energy per collision
  => increased multiplicity
  and occupancy

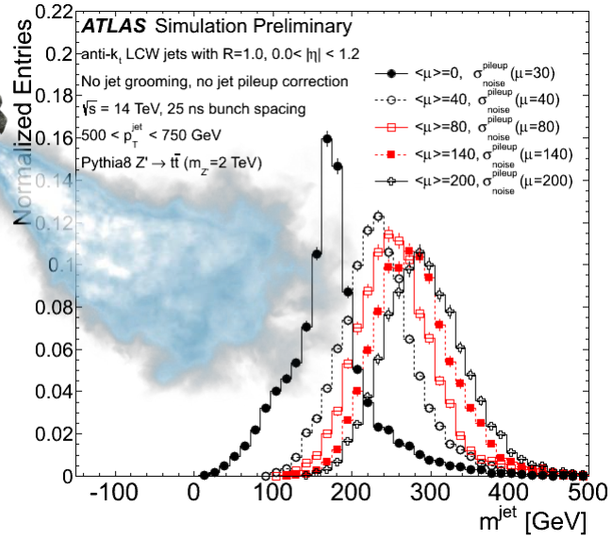


Effects of Pile-Up

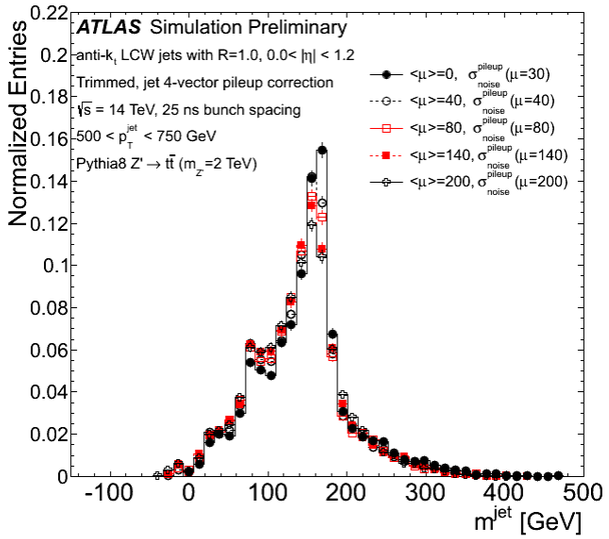


[ATLAS Public Result]

Taming the Pile-Up



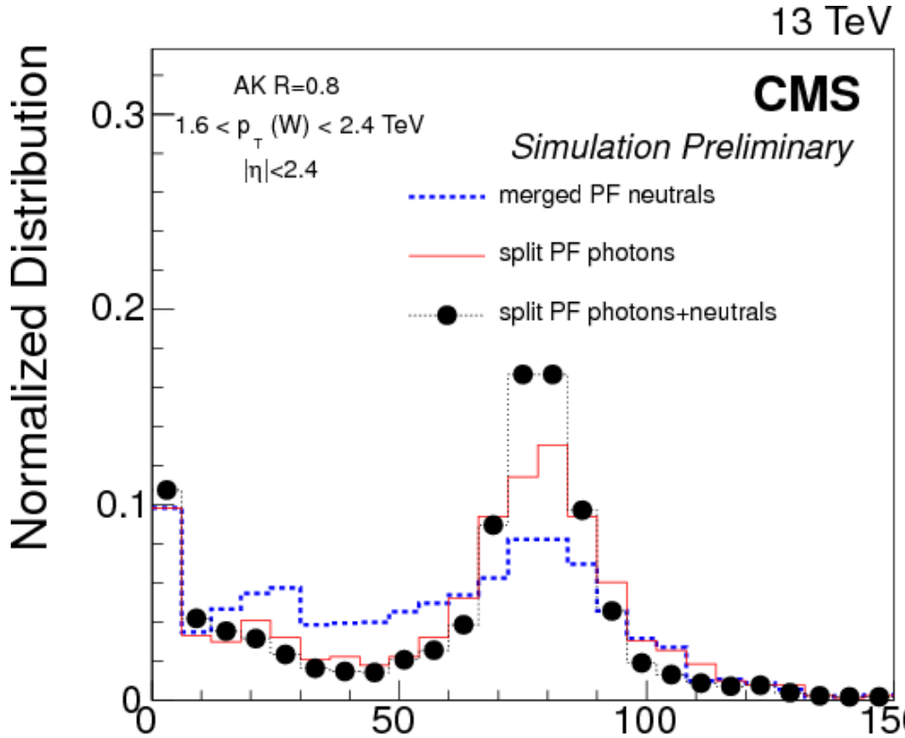
- Improve reconstruction
  => Pflow
  => Clustering
- Remove PU
  => CHS, PUPPI…
  => JVF, JVT…
- Improve Jet Grooming
  => PU dependence
  => re-evaluate algos



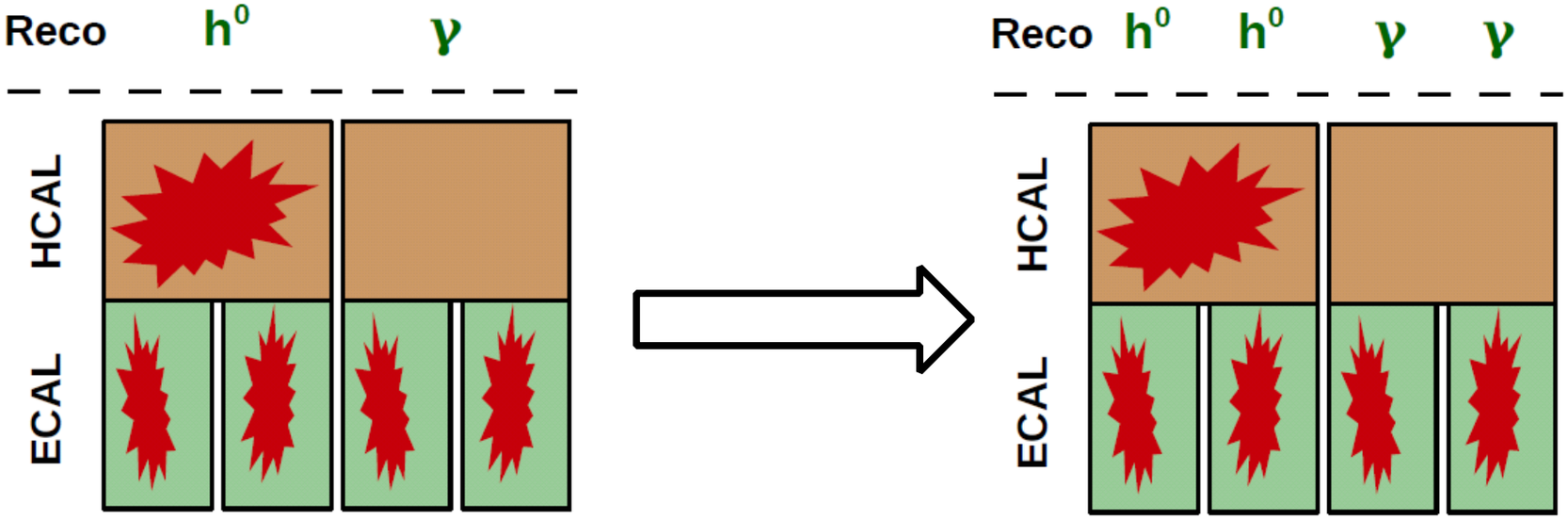
[ATLAS Public Result]

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

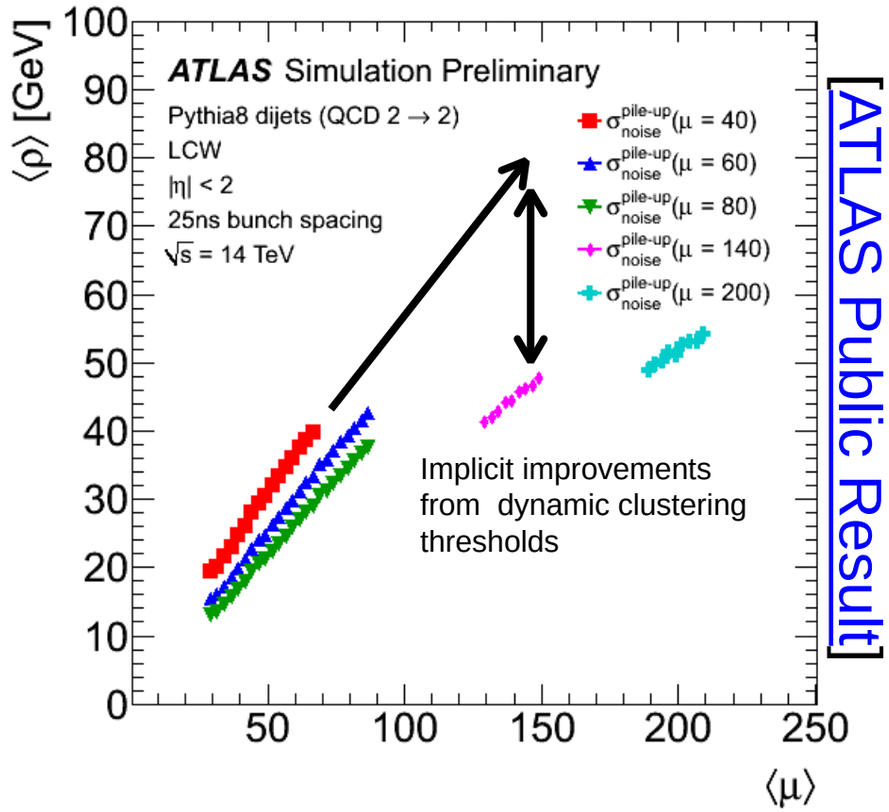


[CMS-JME-14-002]

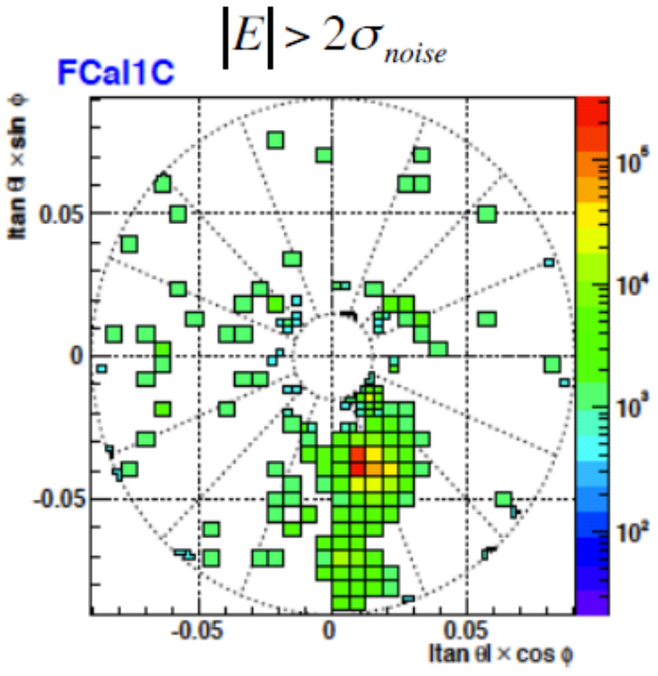


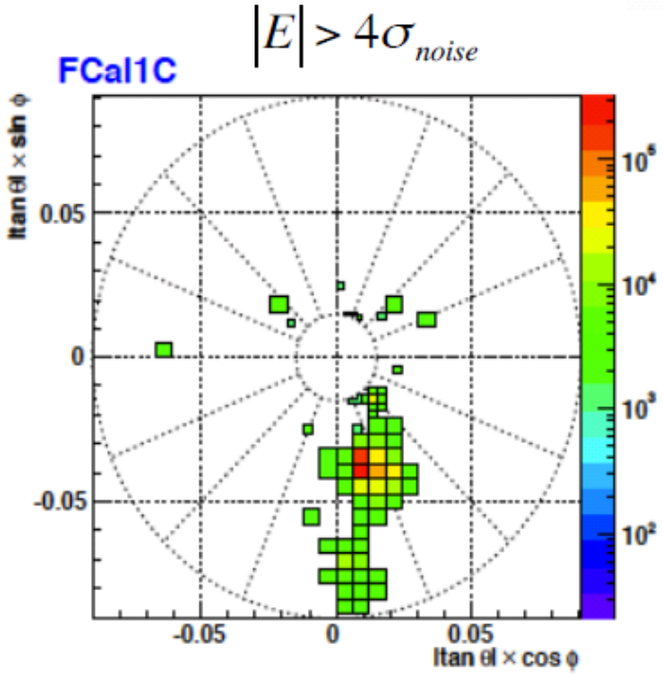
Improved Clustering

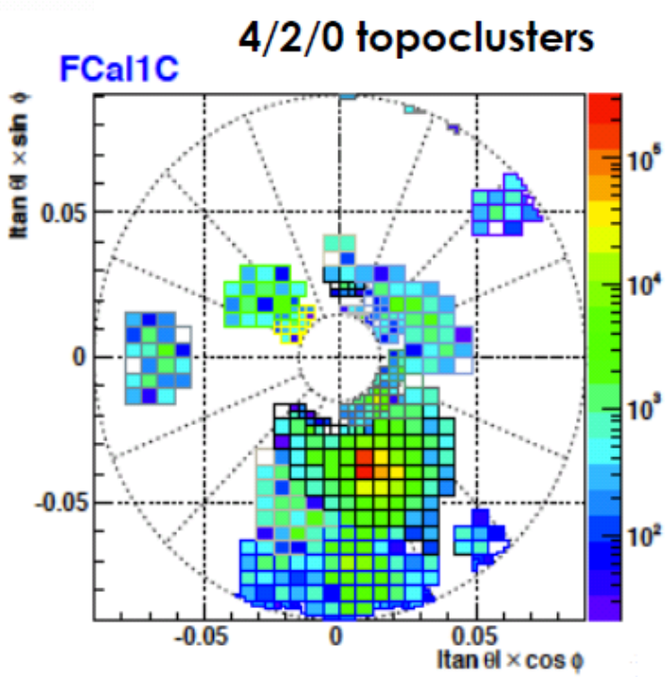
- Clusters reconstructed with hierarchy of energy thresholds E > x*σ
- Dynamically adapt sigma to account for PU density
- Keeps jet scale stable at high lumi



- Some loss of resolution at low pt



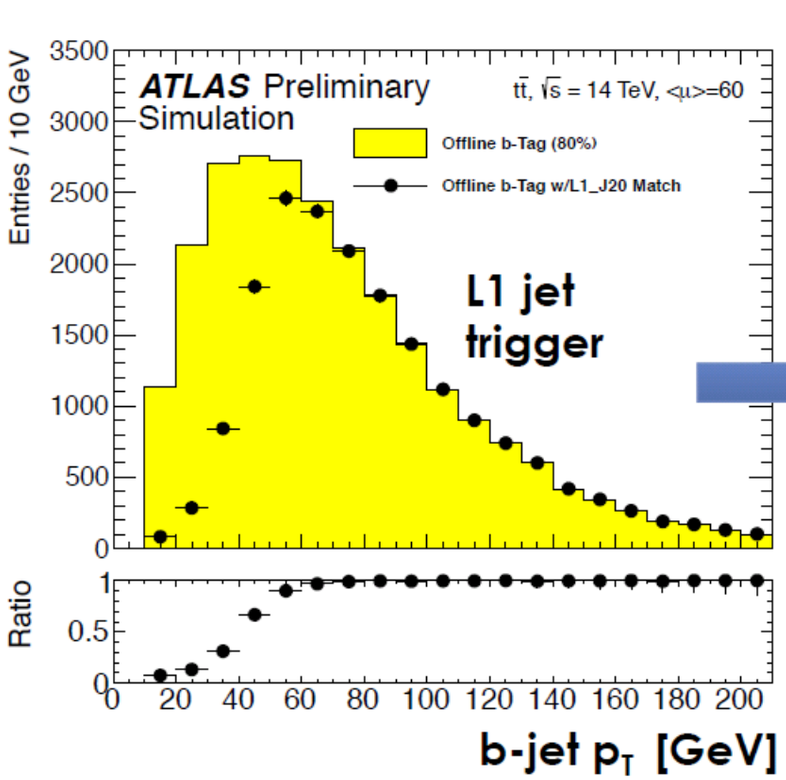


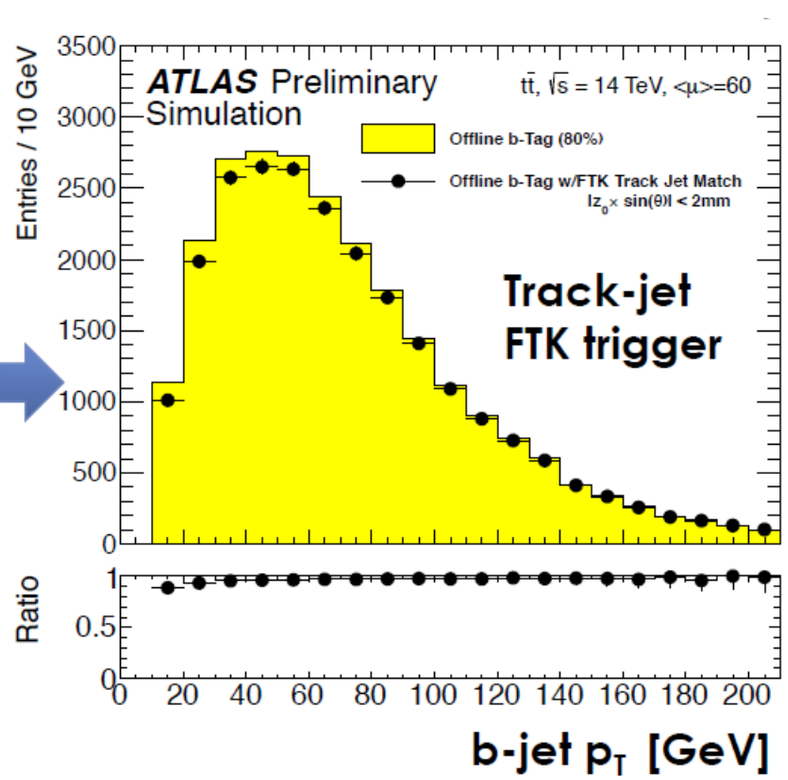


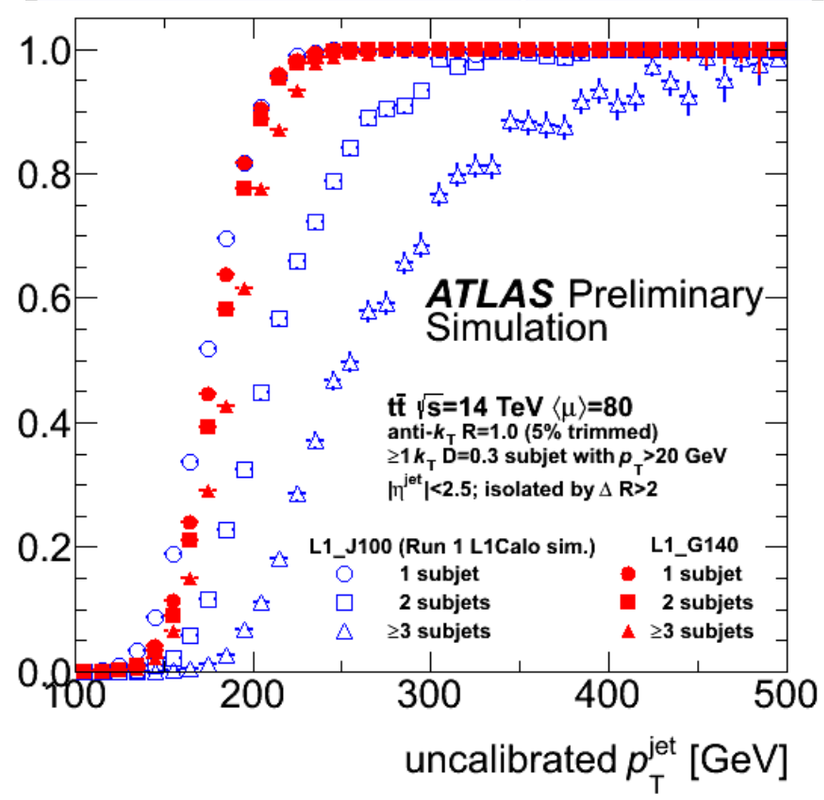
Triggers

- Reco doesn’t help if event aren’t kept
- Adding fat jets at L1 (ATLAS)
- Adding L2 tracking for better btag and PU rejection (ATLAS)
- Running jet substructure in HLT (CMS)

[ATLAS-COM-DAQ-2014-087]

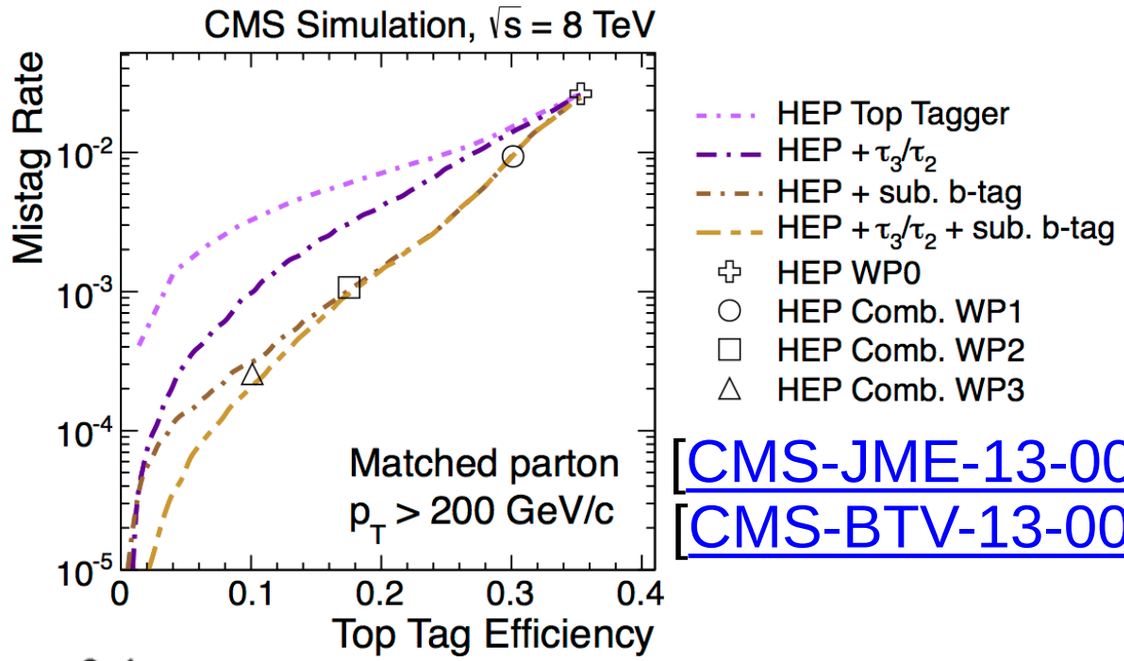




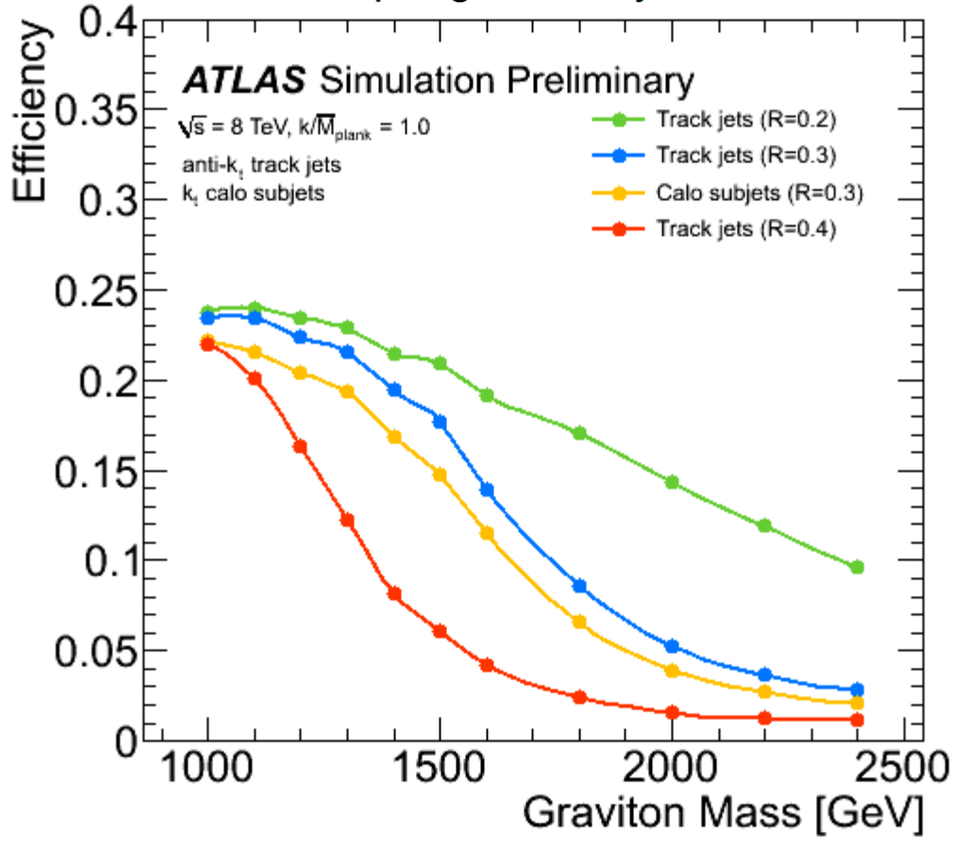


Subjet B-tags

- Very useful for Top-tagging, H→bb tagging
- CMS using standard b-tag also for fat-jets/subjets
  - somewhat increased uncertainty
  - tricky for large overlaps
  - successfully in use at 8TeV
- ATLAS completely reoptimizing b-tagging for merged jets
  - using small R track-jets
  - independent of other subjet studies



[CMS-JME-13-007]
[CMS-BTV-13-001]



[ATLAS-PHYS-PUB-2014-013] [ATLAS-PHYS-PUB-2014-014]

PU reduction

- Trying to remove PU once particles are reconstructed
- Independent of jet substructure
- Already in use now
- ATLAS JVF / CMS PU Jet Id => remove jets from predominantly PU
- CMS Charge Hadron Subtraction => throw away charged hadrons not from primary vertex
- Works well at 8TeV / 20 PU
  => improve for 13 TeV / 40 PU and more

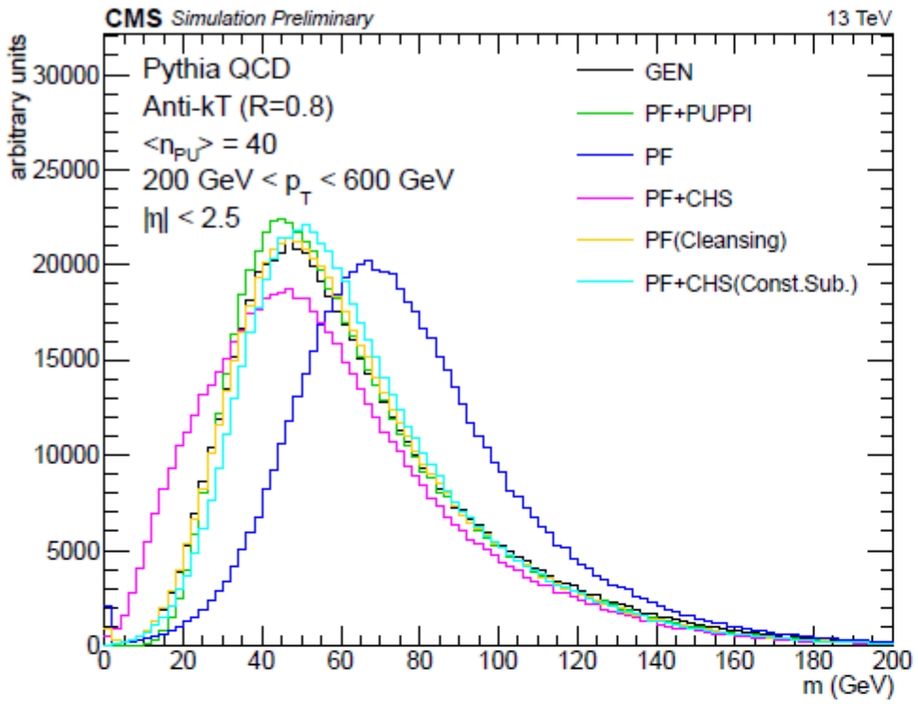
Particle-Level Reduction

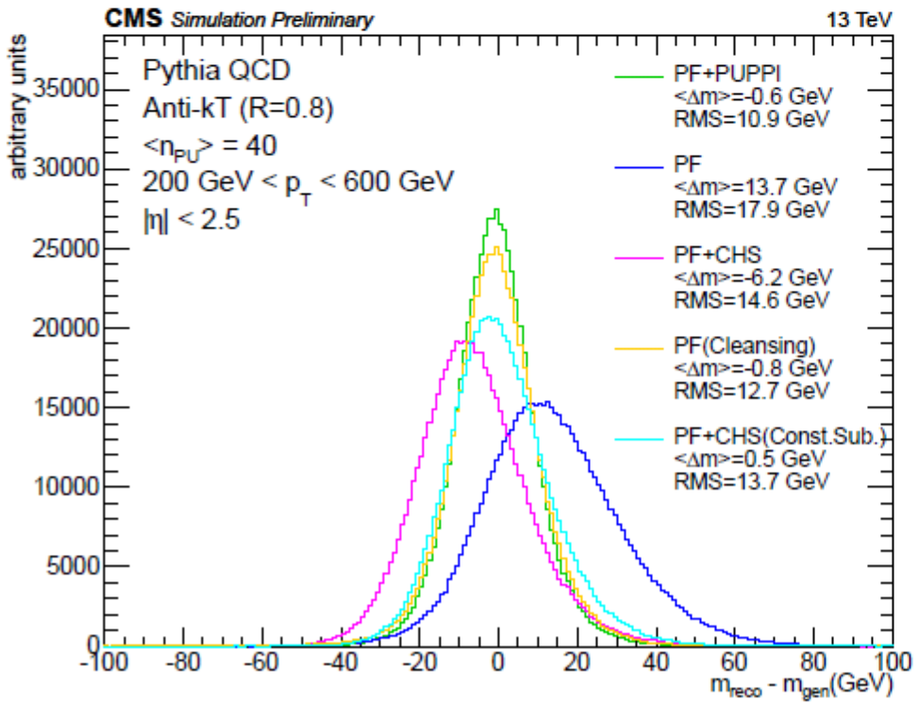
- Try to remove PU particles without relying on substructure
- CHS: remove all PF particles that don’t come from PV
  => exact subtraction, not statistical
  => leaves neutrals
- Constituent subtraction: define per-particle area similar to jet area, correct each particle accordingly
  => corrects neutrals as well
  => statistical subtraction, can’t correct for fluctuations
- PUPPI: Use local correlation to define PU affinity of single particles weight particles accordingly, with event-by event probability
  => exact charged subtraction
  => neutral subtraction not exact, but still better than statistical

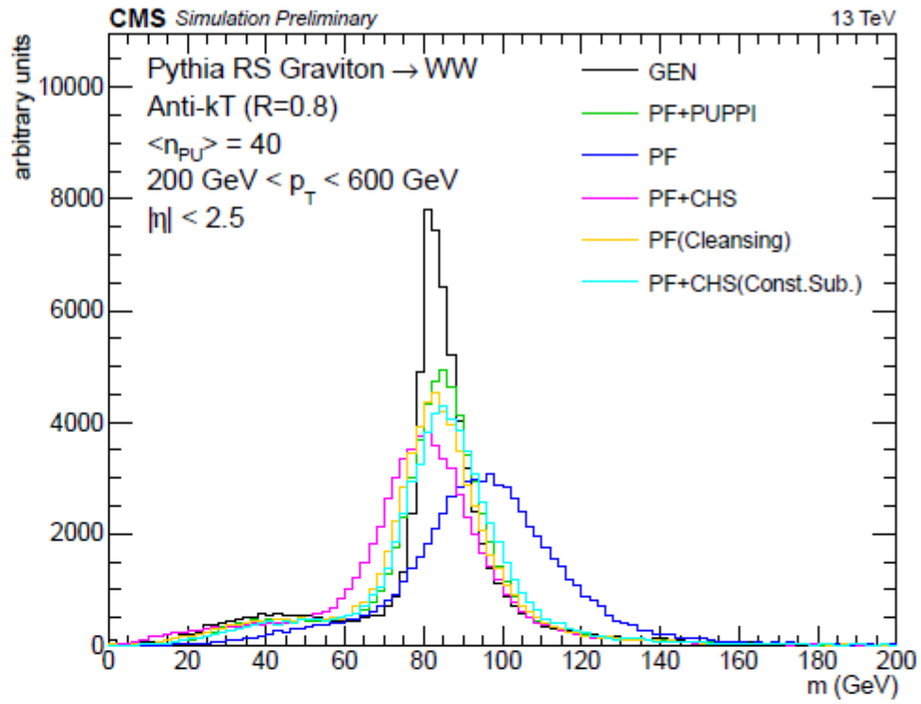
Performance Comparison [CMS-JME-14-001]

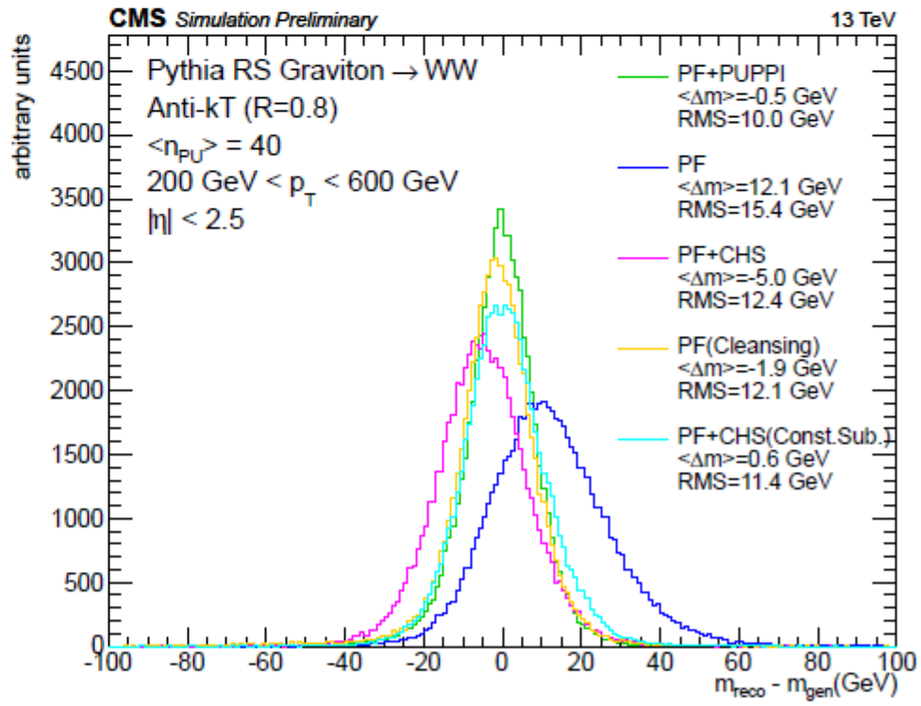
Karlsruher Institut für Technologie

QCD Jets









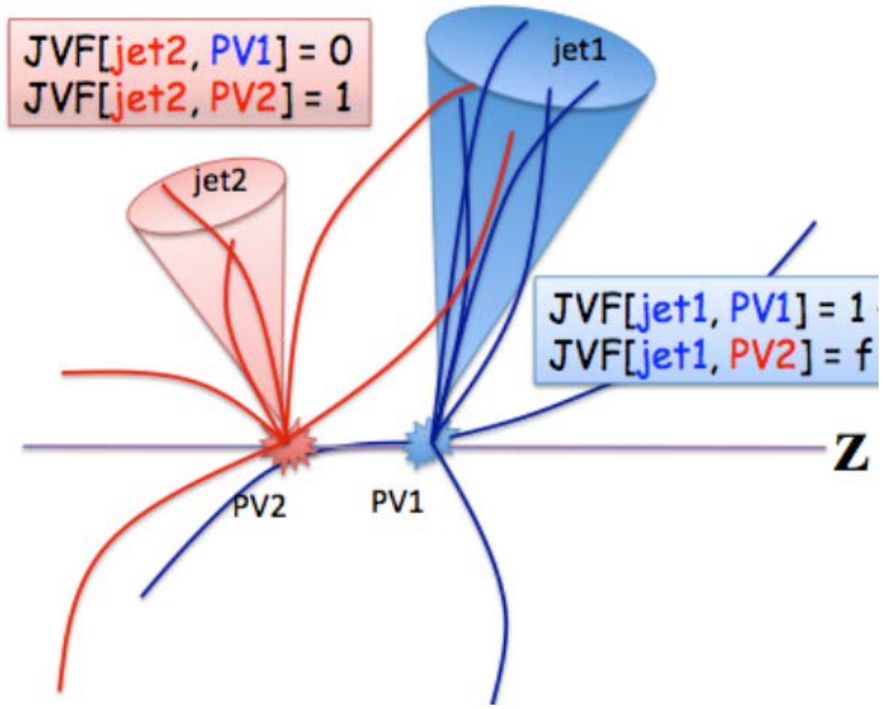
Boosted W Jets

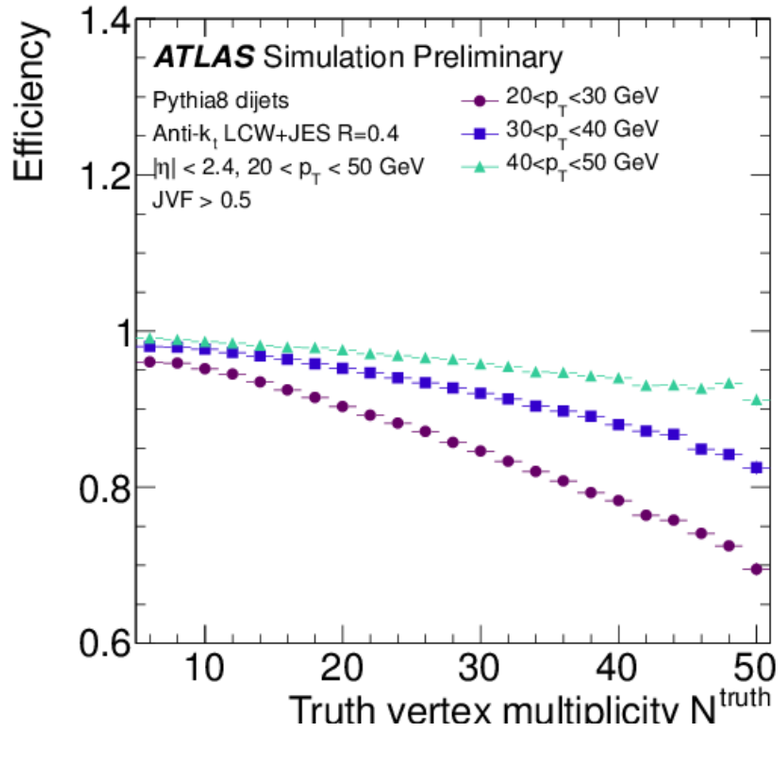
JVF Improvements

- JVF:

$$JVF = \frac{\sum_{PV} p_{T,trk}}{\sum p_{T,trk}}$$

- Problem: depends on number of PU vertices
  => PU dependent efficiency

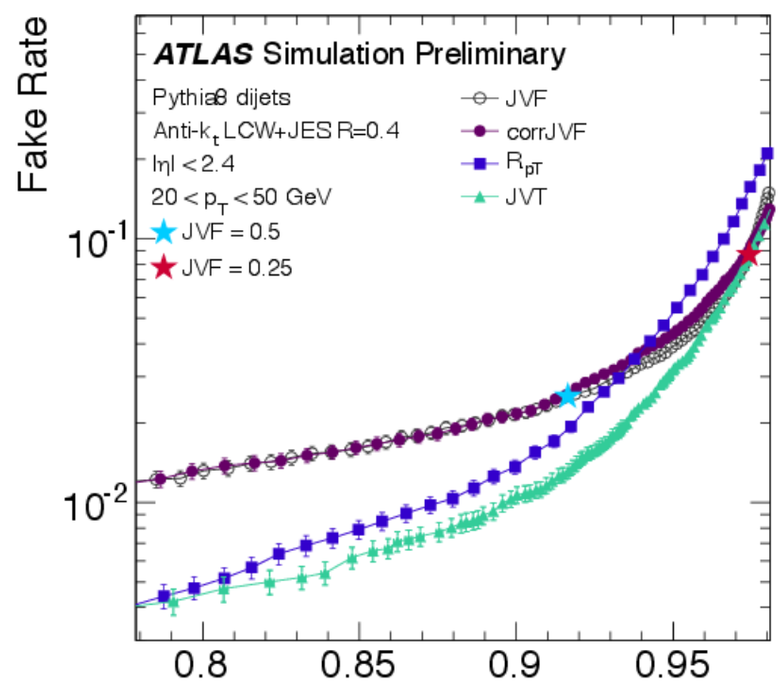




- Correct for PU: $JVF(corr) = \frac{\sum_{PV} p_{T,trk}}{\sum_{PV} p_{T,trk} + \frac{\sum_{PU} p_{T,trk}}{k n_{PU,trk}}}$

- Combined with R_{pT}
  (related to charge fraction)

- Result: better performance, stable vs PU

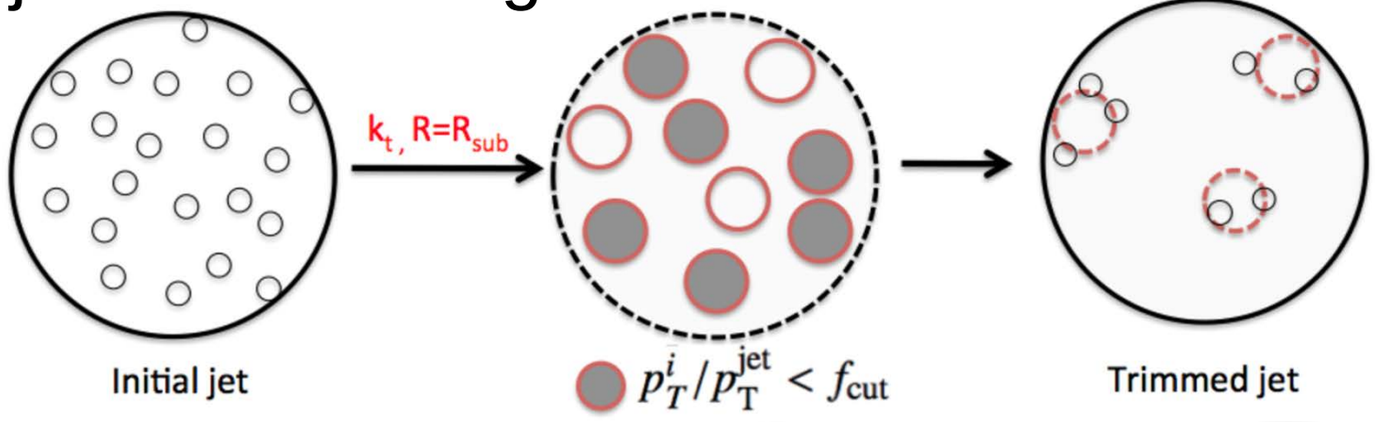


[ATLAS-CONF-2014-018]

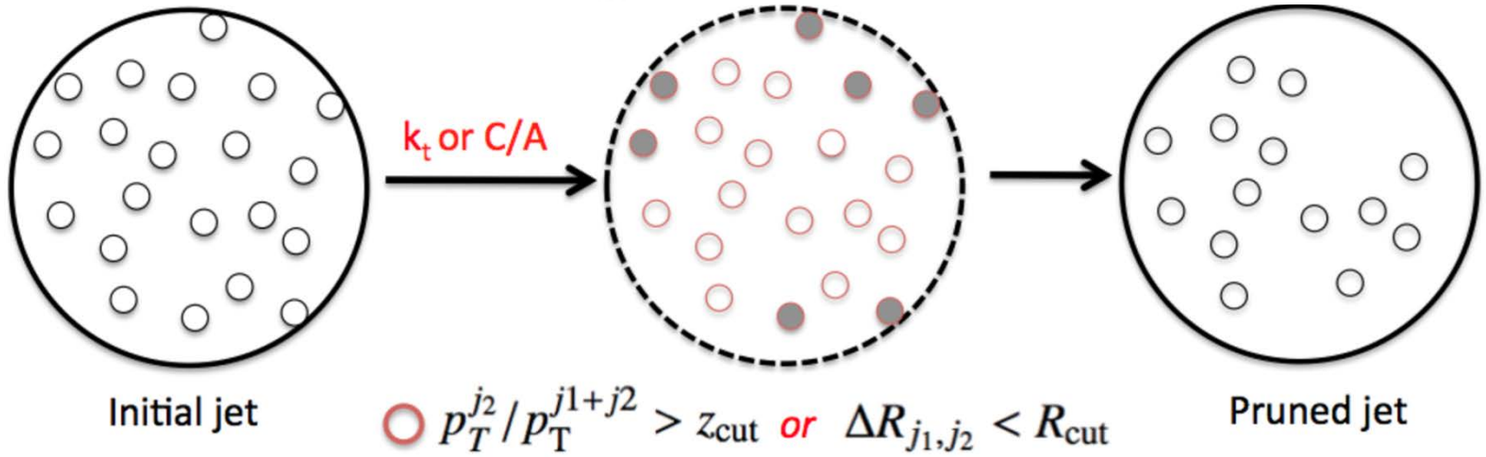
Grooming Techniques

- Use knowledge of QCD shower dynamics to improve separation between massive decays and shower/PU induced jet mass
  => make light jets lighter
  => make heavy jets have the right mass

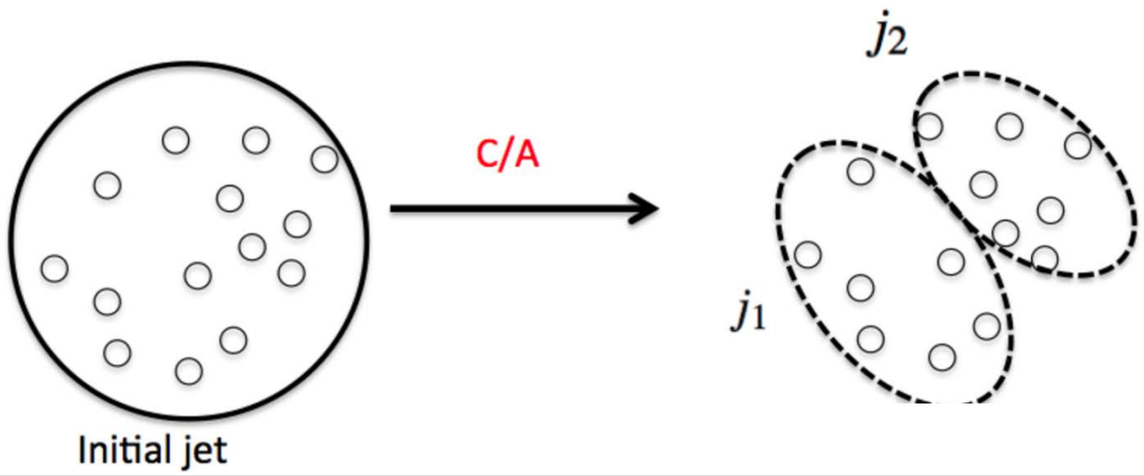
- Trimming



- Pruning



- Softdrop



$$\frac{\min(p_{Tj1}, p_{Tj2})}{p_{Tj1} + p_{Tj2}} > z_{cut} \times \left(\frac{\Delta R_{12}}{R_0}\right)^{\beta}$$

Where do we stand?

- Many options investigated, but could improve coordination

- Reasons to choose a particular algorithm:

  - best performance on a given MC dataset
  => may hide PU dependence, p_t dependence

  - practical considerations (existing code/datasets, approved methods…)
  => may not get best performance

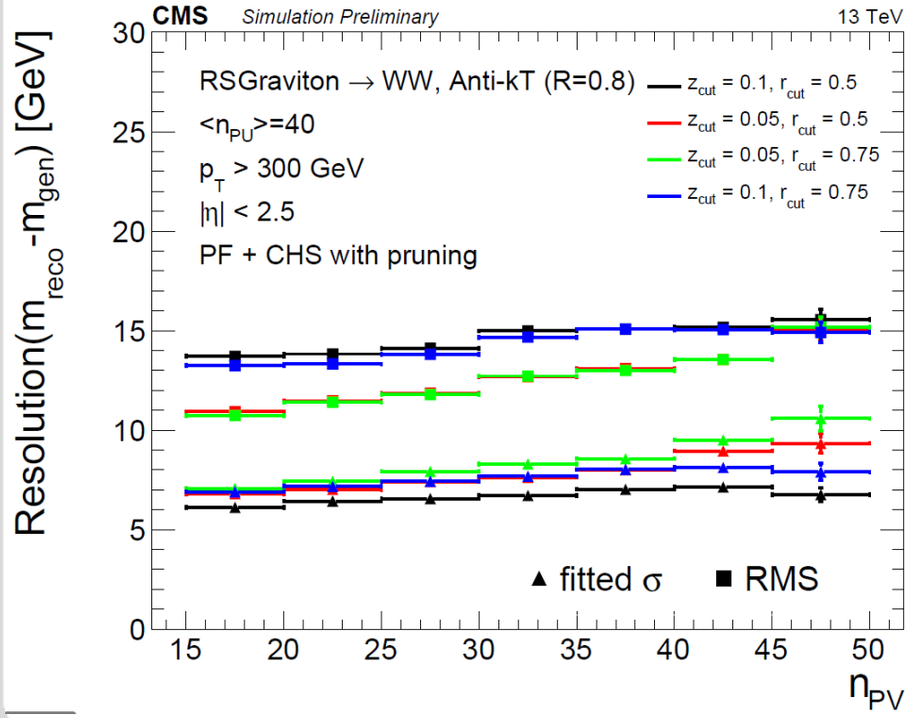
- Trying to re-assess methods more systematically for higher lumi, higher energies and higher PU
  => CMS focused on Run II
  => ATLAS focused on HL-LHC

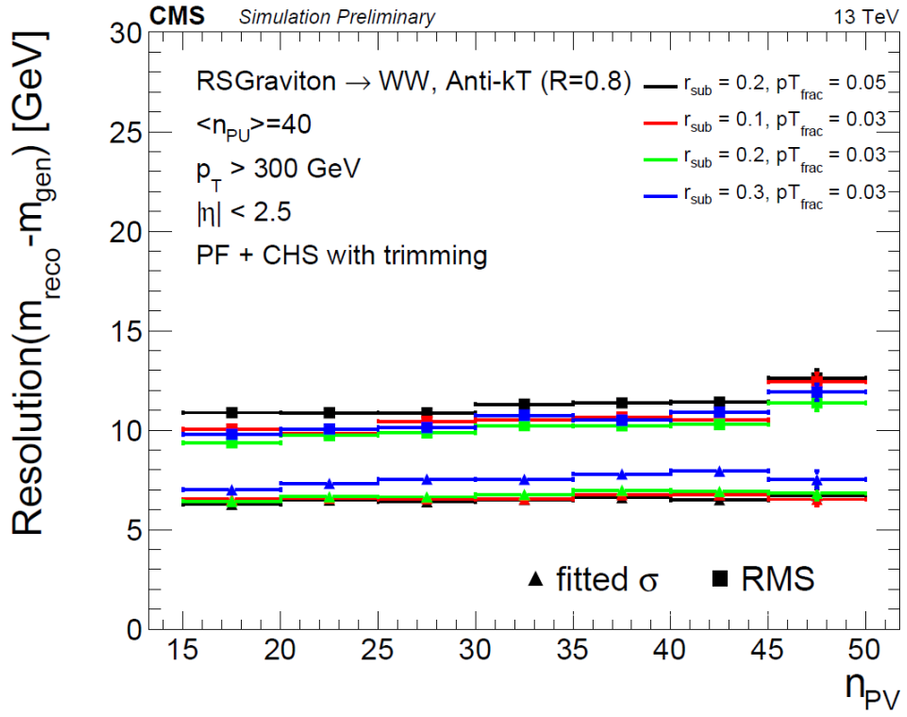
- Cooperation ongoing between experiments, also involving theorists (i.e. May workshop)

Re-Assessing Algorithms

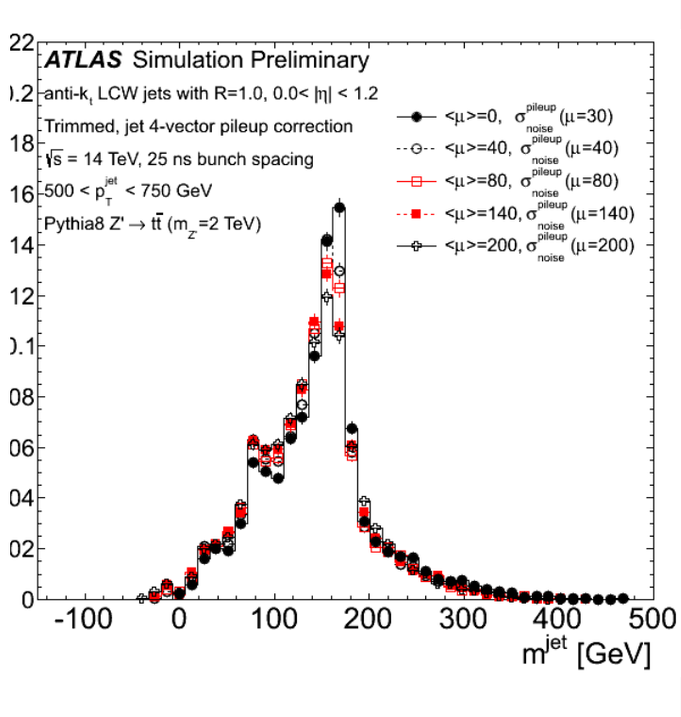
- Pruning PU stability is problematic (somewhat less with CHS)
- Trimming seems most stable (good stability also seen by ATLAS)
- All algorithms have long tails in resolution (some more than others)
- Combine with PU particle reduction tools for best performance

[CMS-JME-14-001]

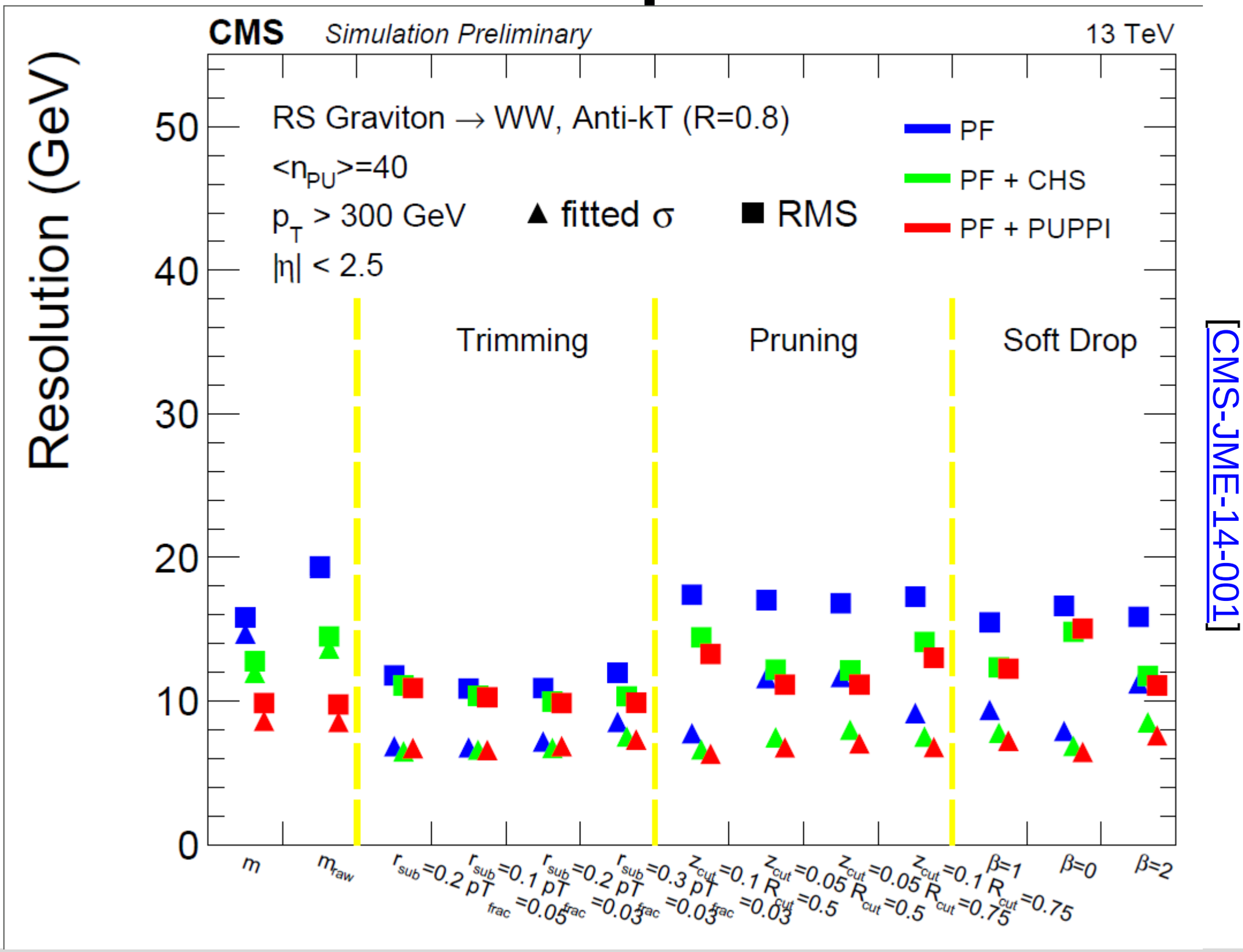




[ATLAS Public Result]



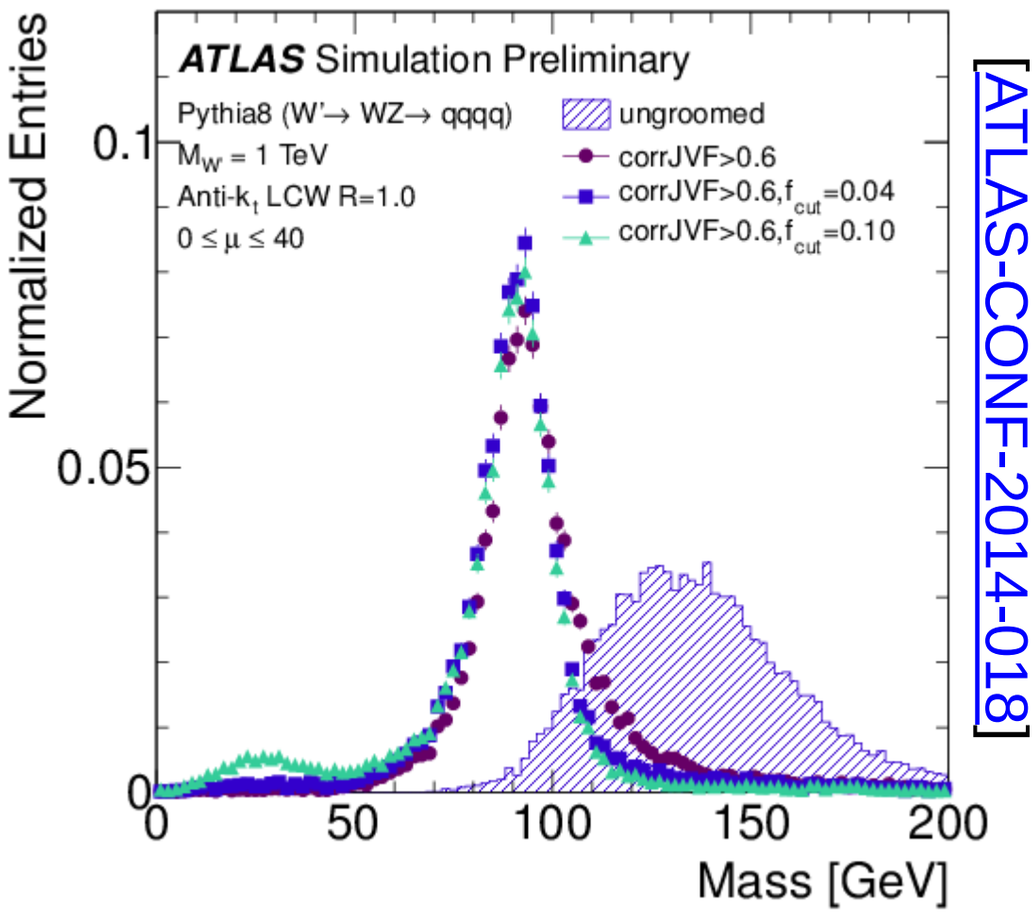
Performance Comparison

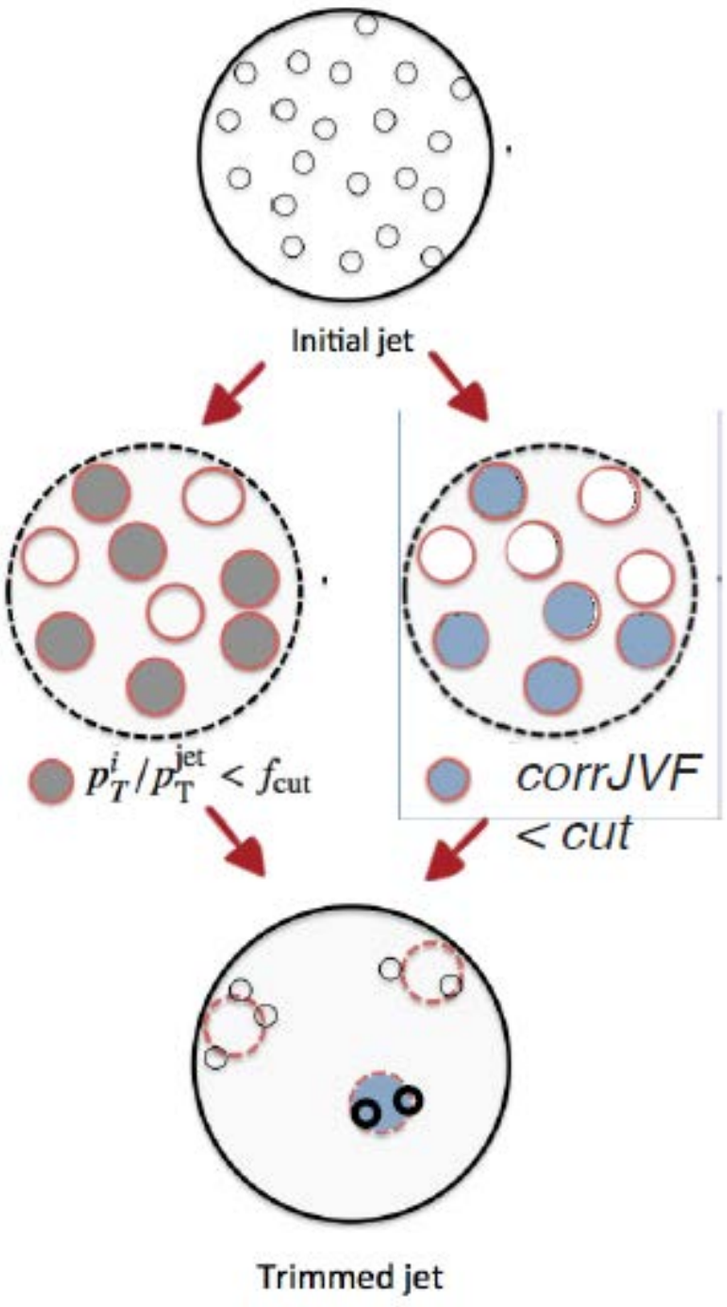


[CMS-JME-14-001]

Combined Grooming and Cleaning

- Combining jet trimming with JVF
- Retune JVF and trimming parameters simultaneously for best performance





ATLAS-CONF-2014-018

Conclusion

- 13 TeV beam energy means that merged final states will be even more important in Run II and beyond
- Increased pileup poses the greatest challenge to the performance of analysis with merged final states
- Experiments are addressing the issue on three fronts:
  - Making global reconstruction more resilient to PU, high energies
  - PU reduction at the particle level
  - Optimizing jet-substructure for PU resistance

Promising results in Simulation
but the real test will be in 2015