Jet status and workfest goals

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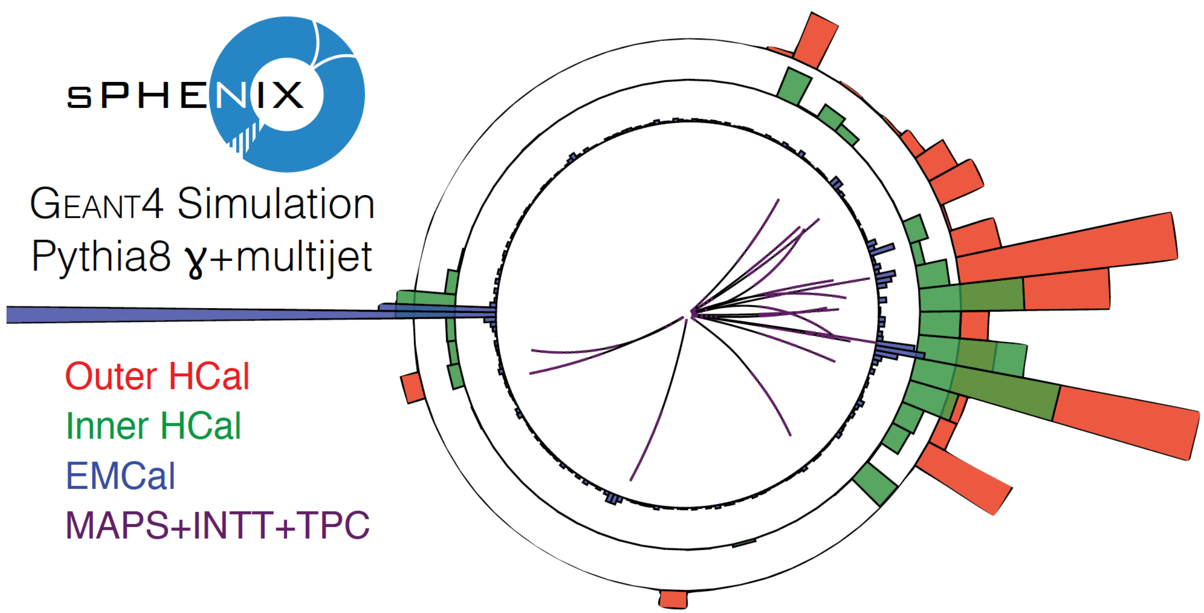
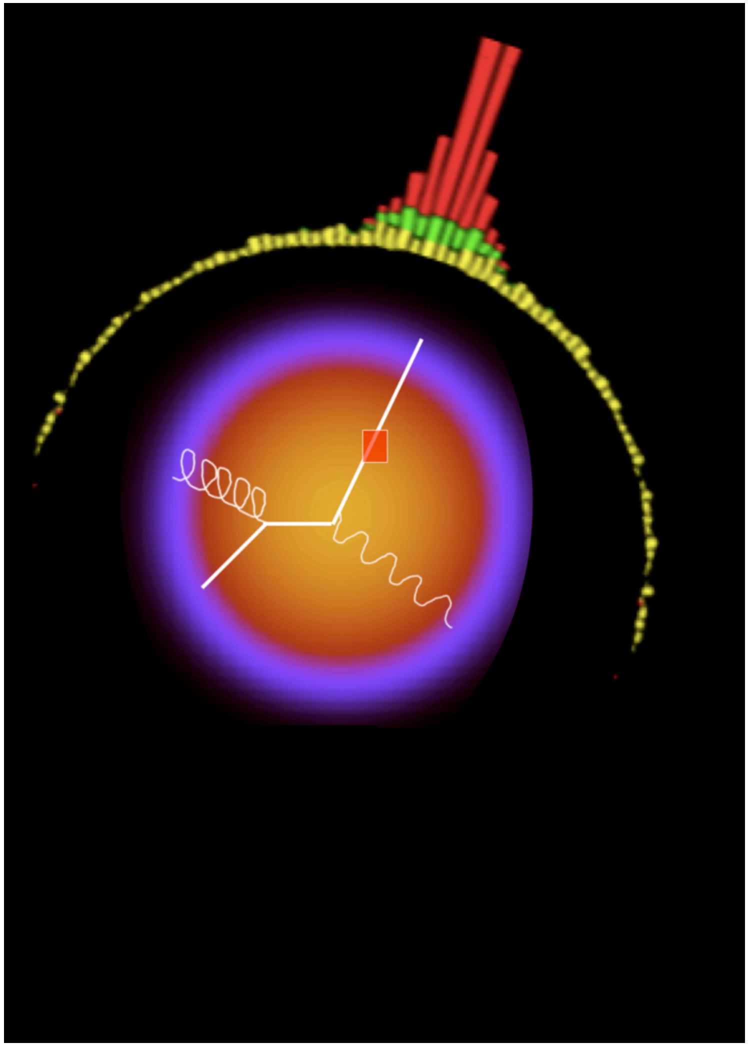


Outline

- Measuring Jet Quenching with sPHENIX
- Jets in HI physics
- HCal Clustering
- EMCal Clustering
- Workfest Tasks/Goals/Requirements

Jet Quenching at sPHENIX Quick Summary



Measure precisely final state jets (Calorimetry) and jet structure (Tracking)

- Determine response of jet to the medium
- Response of the medium to the jet

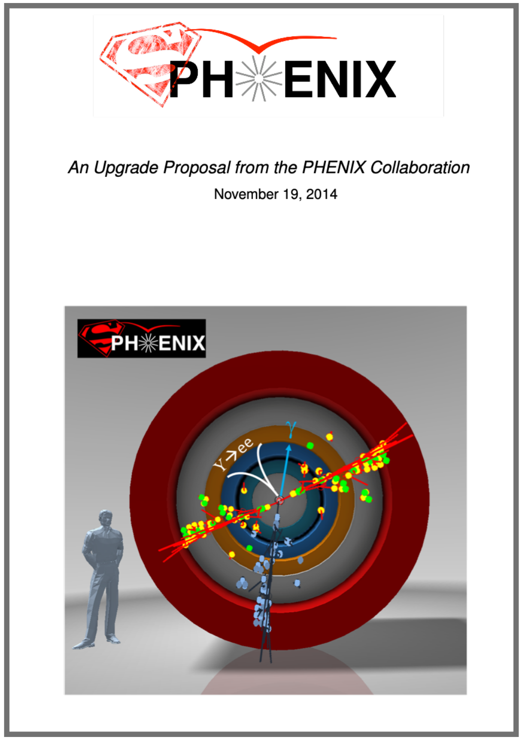
Difficulties

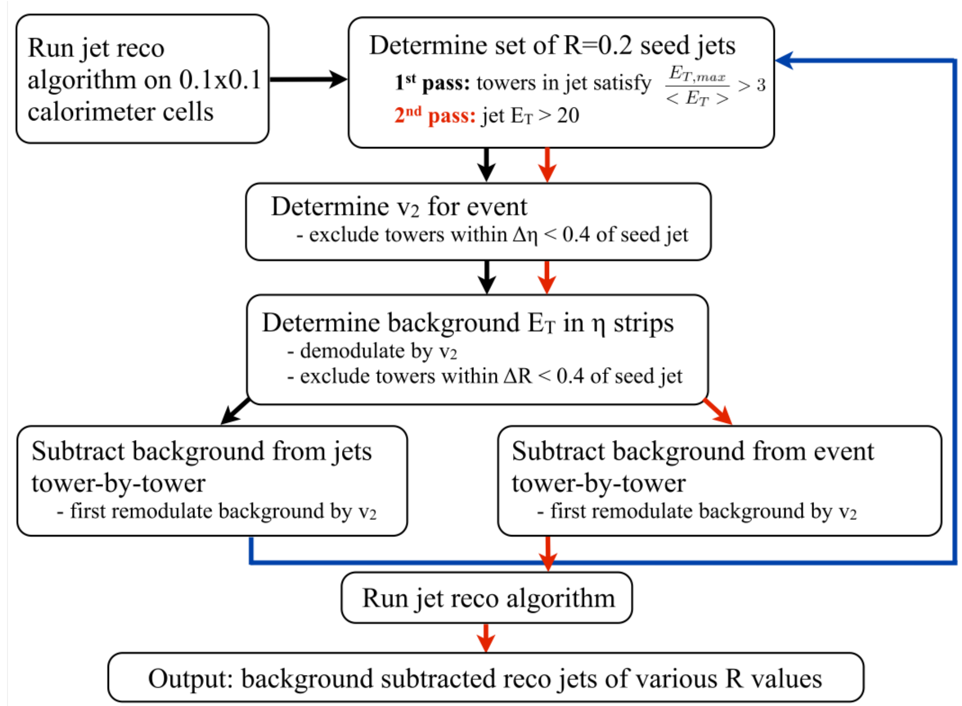
- Underlying Event yields combinatorial jets, smears jet kinematics

Jet Reconstruction Methodology

- Calibrate calorimeter towers
- Cluster calorimeter based objects
  - EMCal vs HCal
  - Outlook to Particle Flow
- Use jet finding algorithm on clustered objects
- Remove background contribution (iterative w/ previous state
- Unfold correct for issues of JES/JER
- Correlate Calo based jets with tracking
  - Reduces autocorrelations between measurement of the jet/jet structure

HI Jet reconstruction (1/4)

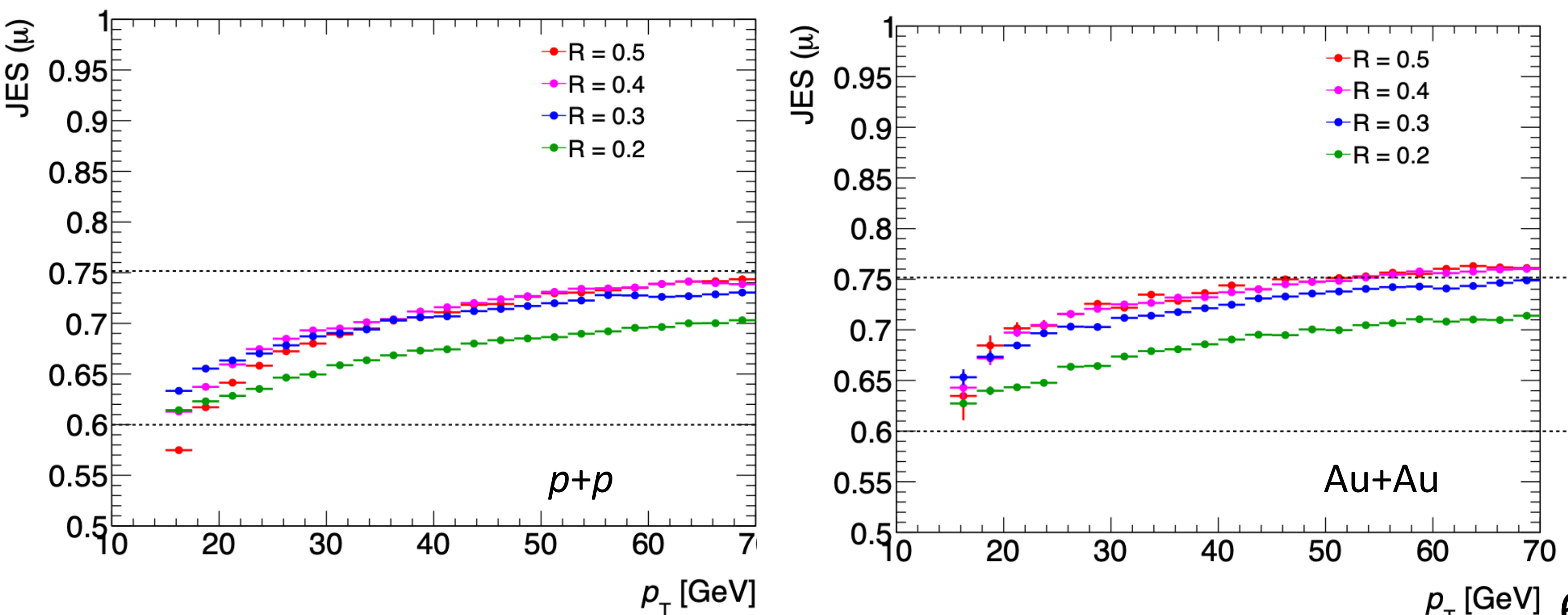




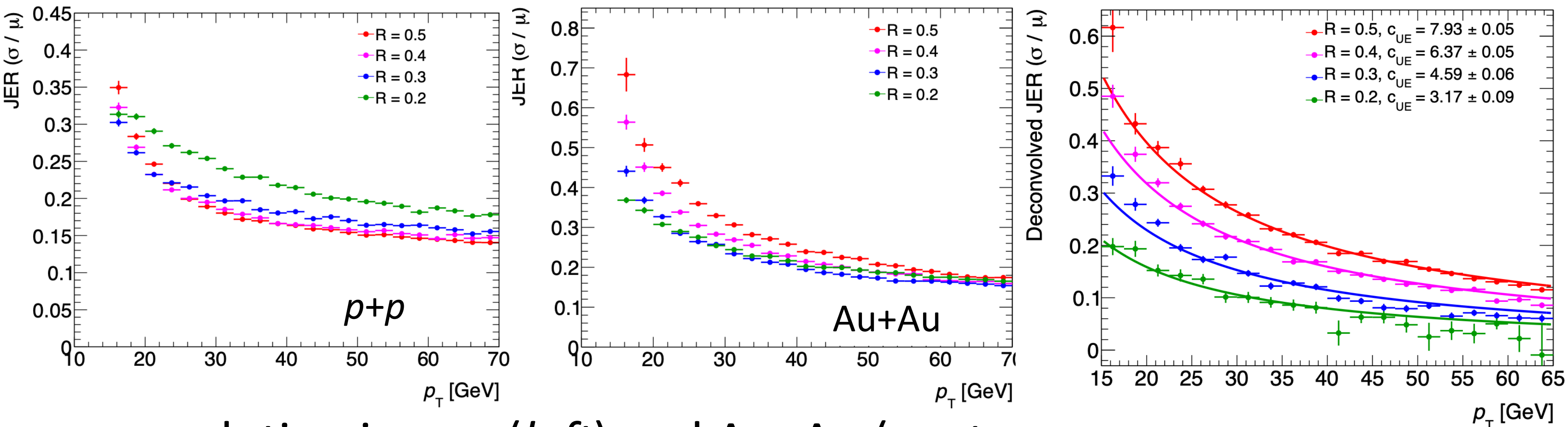
- **Iterative algorithm** to determine & **subtract UE background** based on ATLAS, described by sPHENIX collaborators in nucl-ex/1203.1353
  - Historical proof of principle for jet measurements at sPHENIX & "default" approach
  - Makes initial guess about jets to exclude them from background determination, then iteratively updates these guesses (& the resulting background estimate)
  - Separate UE estimate in each of 3 calo layers & η strip + global Ψ_2 & v_2^{calo} estimate

HI Jet reconstruction (2/4)

- For visual example of algorithm behavior step-by-step for a jet event in HI, see March '19 sPHENIX Asia Mtg slides
- Implementation in *coresoftware/offline/packages/jetbackground*
  - Set with "*do_HIjetreco*" and parameters configured in "*G4_HIJetReco.C*"
- Below: "EM"-scale p_T response for jets in *p*+*p* events (*left*) and embedded into 0-20% sHijing Au+Au events (*right*), different jet *R* values in different colors
  - Subtraction algorithm **estimates approximately correct UE level on average**



HI Jet reconstruction (3/4)

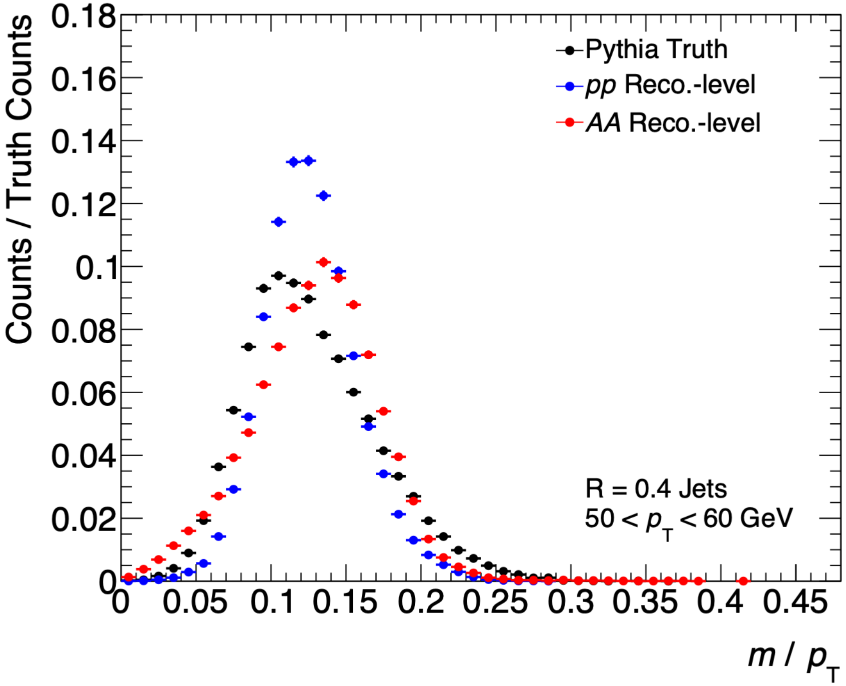


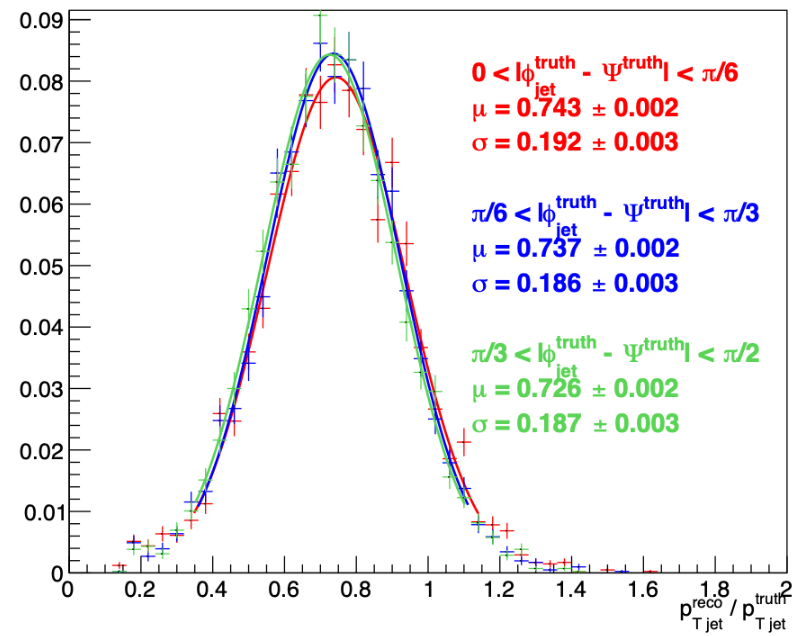
- p_T resolution in *p+p* (*left*) and Au+Au (*center*)
- Deconvolution of *p+p*-like component from Au+Au res. (*right*)
  - Test of factorization of *p+p* jet response ⊗ UE in our reco.
  - Identical, i.e. sensitivity of to fragmentation, in —> implications calibration strategies (see later slides)

$$\frac{\sigma_{p_T}}{p_T} = \frac{n}{p_T} \oplus \frac{s}{\sqrt{p_T}} \oplus c$$

Noise Stochastic Constant

HI Jet reconstruction (4/4)

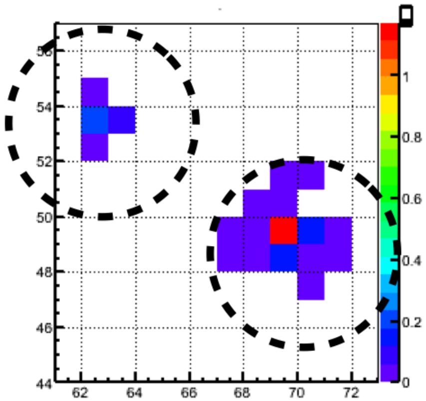




- *Left:* can optionally configure "Constituent Subtraction" in *G4_HIJetReco.C* (UE estimate identical, just accounted for differently), to enable, e.g. ungroomed jet mass reconstruction
- *Right:* if flow-aware UE determination/subtraction is set in *G4_HIJetReco.C*, can test jet response vs. angle to true reaction plane
  - In active development & testing, see later slides on EP reco plans

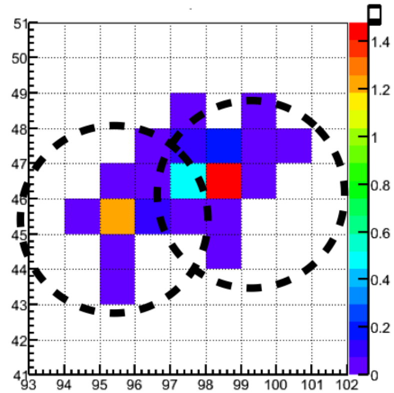
Cluster reconstruction in EMCal (1/2)

2 GeV π0



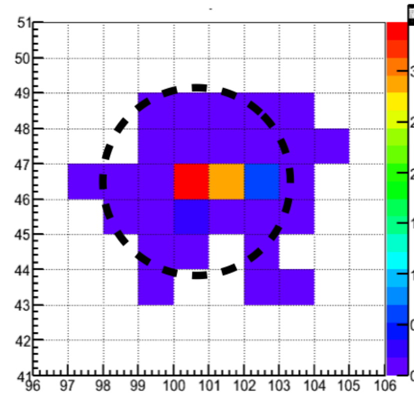
Two fully separated clusters

4 GeV π0



Two sub-clusters sharing energy of middle towers

8 GeV π0

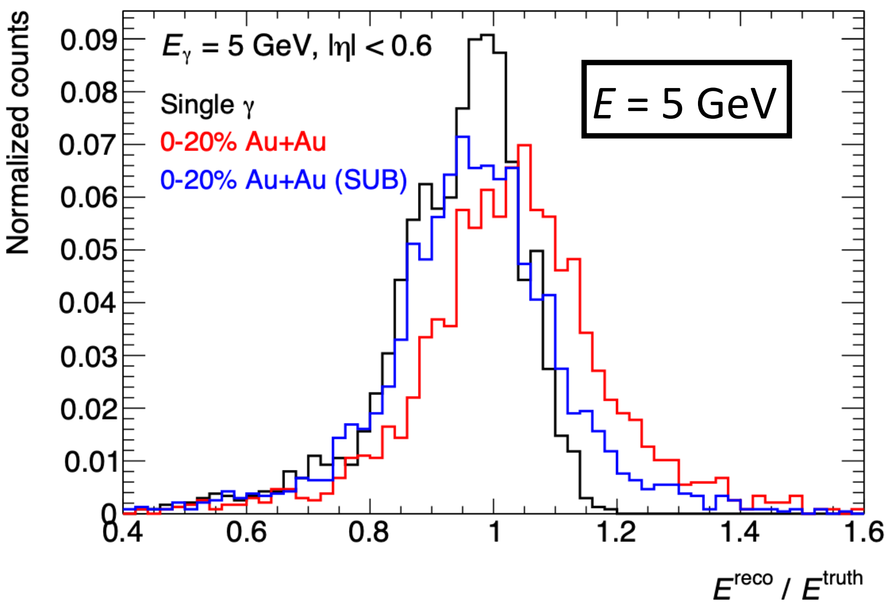


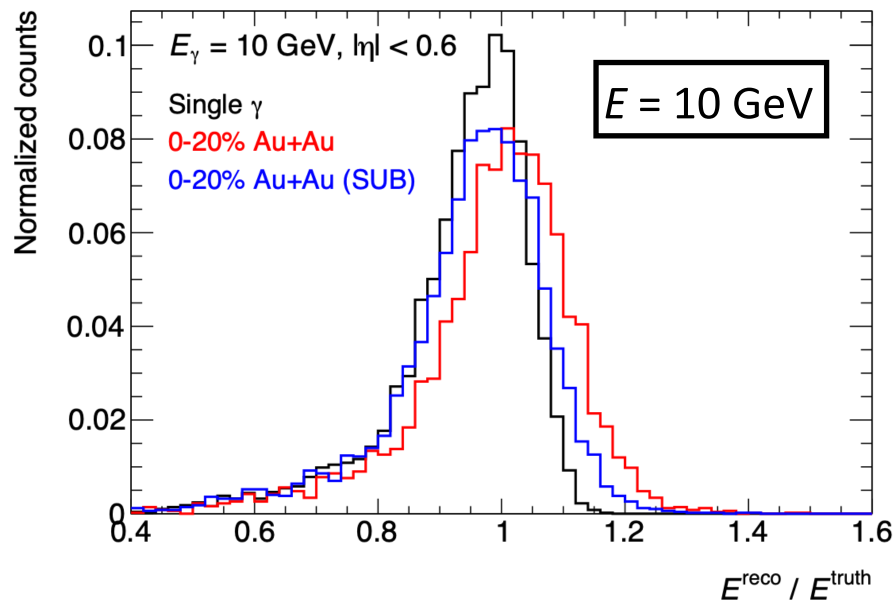
One (in this case inseparable) cluster

- EMCal cluster reconstruction taken from PHENIX, imported by A. Bazilevsky
  - Heavy lifting happens in *coresoftware/offline/packages/CaloReco/BEmcRec.cc*
  - Set with "*do_cemc_cluster*" & configured in *G4_CEmc_Spacal.C*
  - Not the unique approach, but historically "default" one with most activity
- Grouping of contiguous energy deposits into initial clusters
  - Splitting of clusters according to # of local maxima in energy profile
  - Energy sharing — multiple clusters partially "own" a given EMCal tower, with fractions following expectations from γ shower shape (determined from MC)

Cluster reconstruction in EMCal (2/2)

- Recent functionality in HI events: CEMC w/ original segmentation, corrected for CEMC-layer UE determined during HI jet reco stage
  - Needed since impact of HI UE larger in sPHENIX given larger EMCal towers
  - Similar to current ATLAS approach (integrate UE sub for jets & e/γ)
- Run cluster reco on subtracted-CEMC tower input
  - This reco still in private development/testing **— ask Dennis & Francesco for a copy**!





- Examples of response (w/o position-dep. calibration) using clusters in **unsubtracted EMCal in HI events**, **subtracted EMCal in HI**, **single photon**
  - more discussion in Jul '19 Collaboration Meeting

Cluster reconstruction in HCal (1/3)

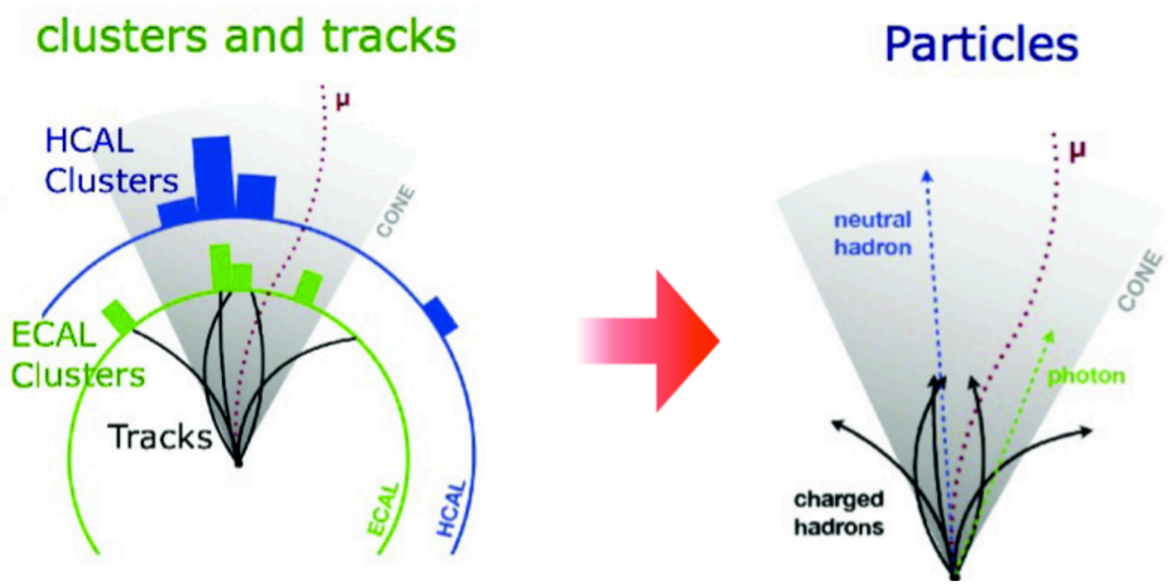
- Newly implemented "3-D topological" cluster reconstruction
  - *coresoftware/offline/packages/CaloReco/*RawClusterBuilderTopo.cc
  - Set with "*do_topoCluster*" & configured in *G4_TopoClusterReco.C*
- Follows topoCluster algorithm as used in ATLAS (hep-ph/1603.02934)
  - ATLAS also has longitudinally segmented 0.1x0.1 HCal where sampling fraction varies with depth!
  - Build cluster outward in all three dimensions, with configurable significance thresholds (w.r.t. expected noise in each layer) for:
    - Seeding a clustering
    - Iterative Growing
    - Fixing the Perimeter

Cluster reconstruction in HCal (2/3)

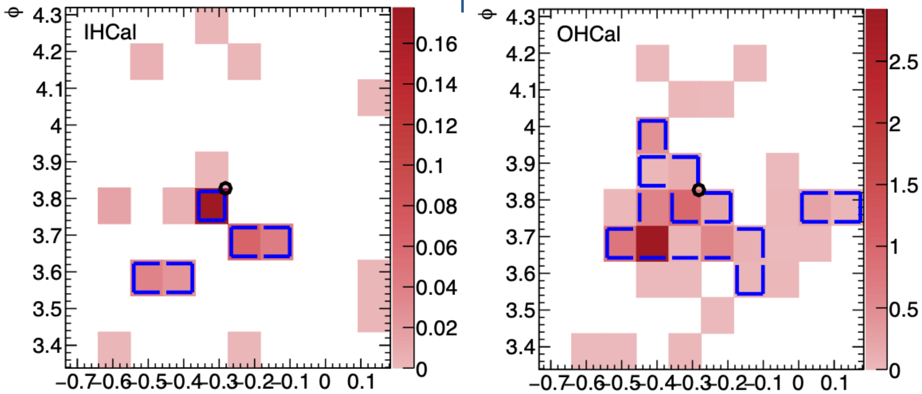
- Algorithm intended to:
  - Respect non-uniform shapes of hadronic showers
  - Still provide good separation for nearby showers
- Can better calibrate *E* at a cluster-by-cluster level by including IHCal + OHCal
- Necessary step towards Particle Flow implementation

Particle flow reconstructs all stable particle in the event: $h^{+/-}$, γ, h^0, e, μ

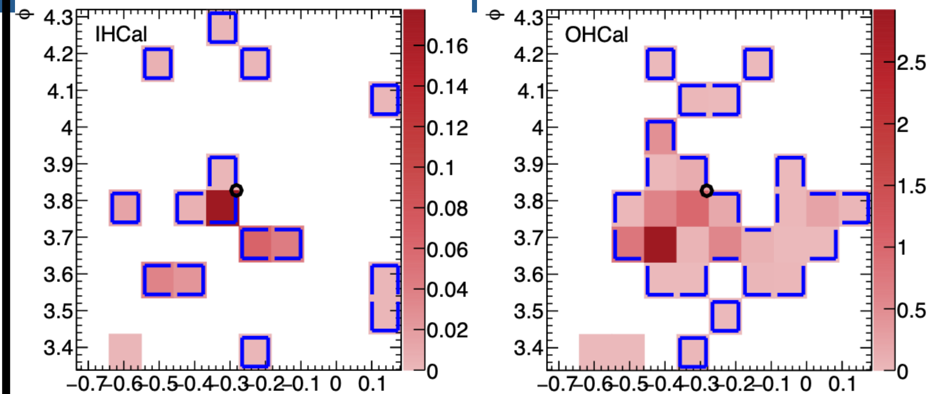
Improves resolution, avoids non-linearity/Decreases sensitivity to the fragmentation pattern of jets



Cluster reconstruction in HCal (3/3)

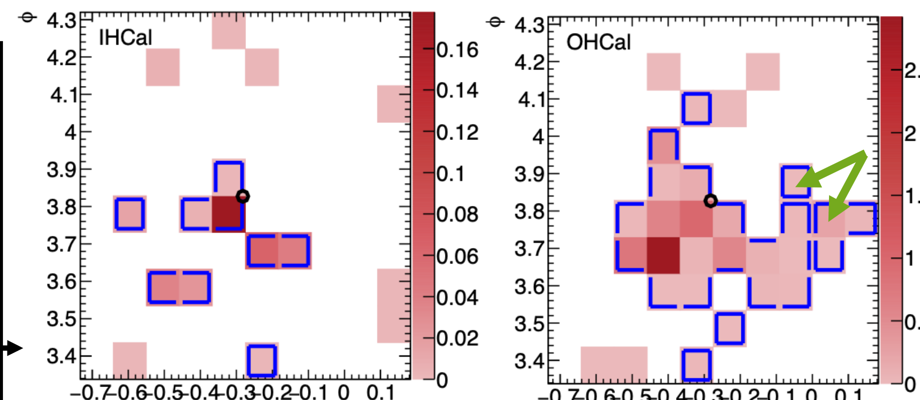


Template algorithm: 3 & 4 small clusters centered on local maxima of main pieces



Graph algorithm: 8 & 1 clusters in the two layers (all contiguous towers including diagonals)

- Previous algorithms in sPHENIX code base not well-suited for HCal clusters
- TopoClusters better respect “1 particle” ~ “1 cluster” paradigm
- More information in 13 Dec 2019 GM
- Testing & further work on cluster splitting (& leading towards PFlow jet reco) — Dennis



Topo algorithm: one big 28-tower cluster which spans IHCal + OHCal, + one satellite cluster in OHCal at the indicated position

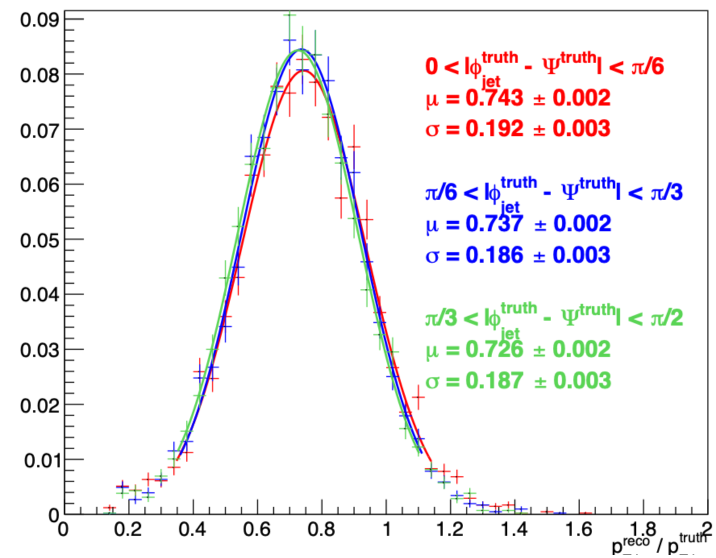
From Methodology to Implementation

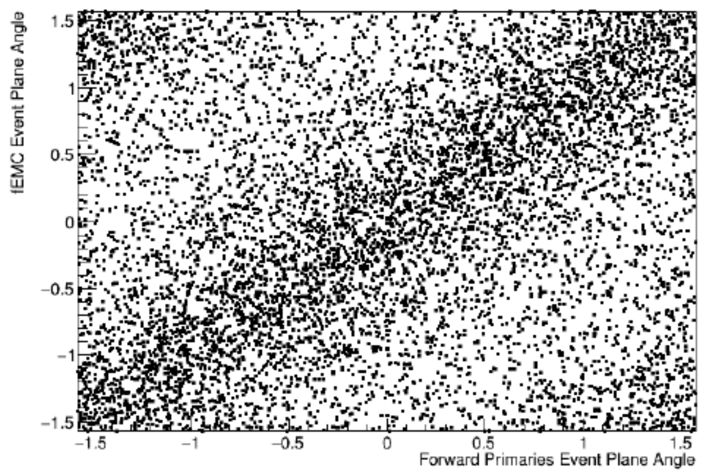
- Several task are need to improve the quality of sPHENIX jet measurements
  - Event Plane Finder
  - HCal
  - EMCal
  - Statistics
- Also some tasks need volunteers! Please sign up!

Event Plane Finder

- Put the EpFinder output on the node tree
  - Central barrel is the default with options to also calculate the EP using the fEMC
- Generate a set of calibration files for the different detector types
  - Average user wouldn't have to run 3x to get calibrated output

J. Lajoie





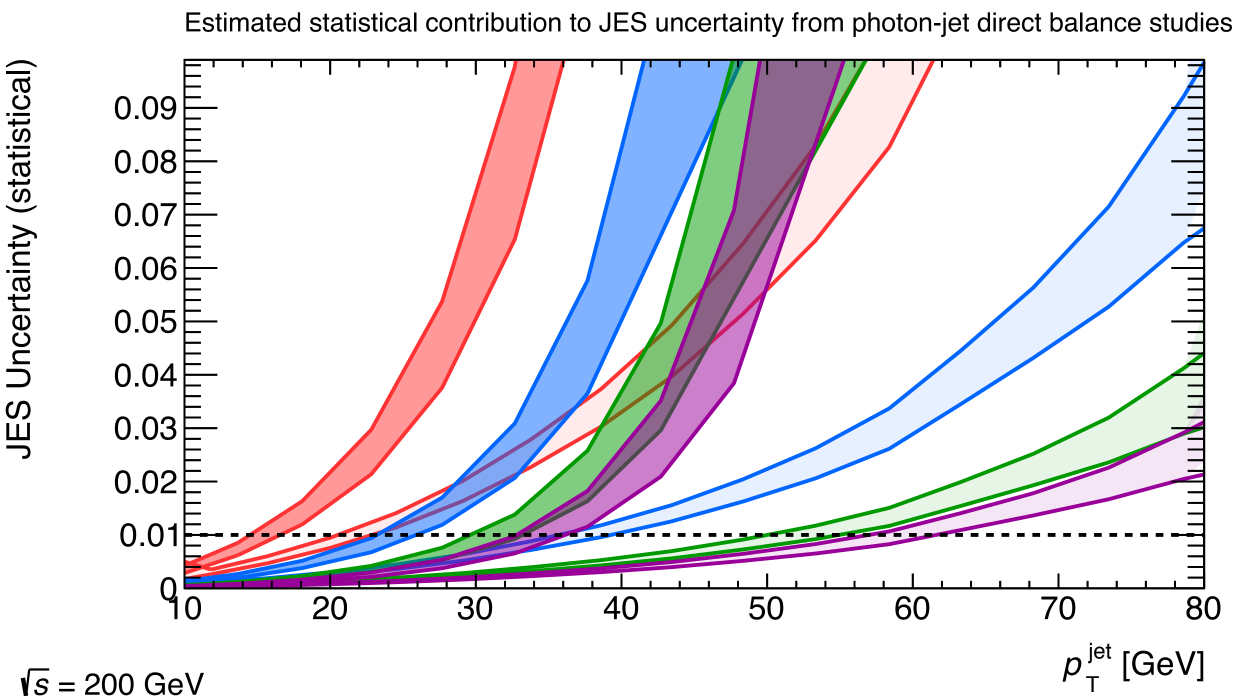
Calibration Goals By End of Workfest

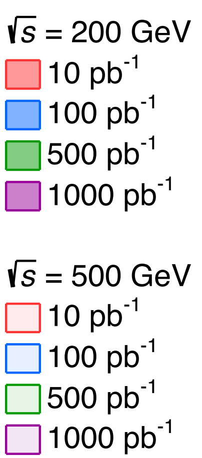
- What is current uncertainty on on key jet observables due to the effect of calibrations?
  - Including HCal non-linearity
- How to initially calibrate, monitor and data-calibrate the HCal?
  - Current method: how good?
  - Data MIPs :
    - Statistics per week
    - Response
  - Isolated charge hadron showers :
    - Properties or response
    - Statistics per week

Calibration Goals By End of Workfest

- Do we need further test beam studies?
  - How much better will knowing EM Scale of the HCal will improve our energy scale?
- J/ψ for EMCal Calibration?
- Is there a case for 500 GeV p+p calibration?
  - At $\sqrt{s}$ = 500 GeV calibration run ~5-10 x shorter
  - How well can calibration @ 500 be translated to 200 GeV?
  - Increased pile-up?

JES at √s = 200 vs 500 GeV

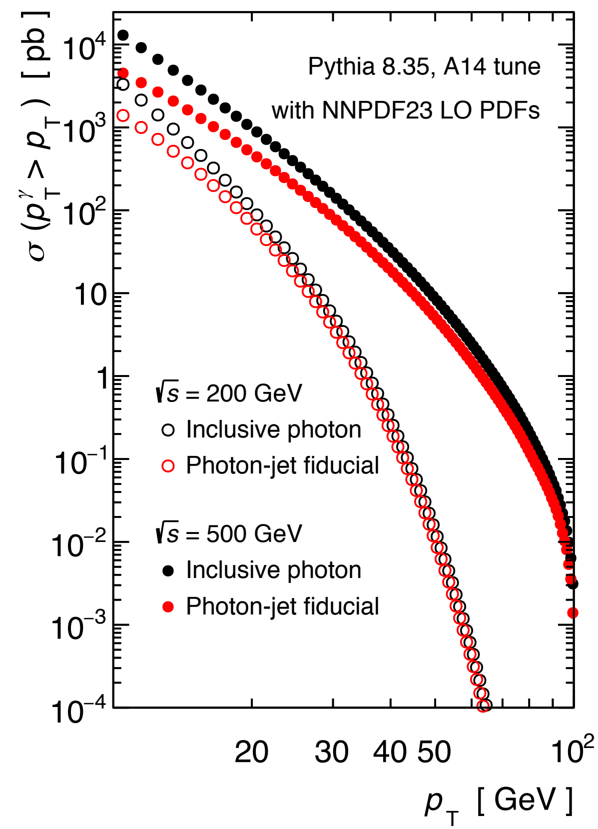




Indicates using higher energy is reasonable

- How to translate into improved jet observables? (Use Dennis's method from IHCal studies?)

A. Angerami



HCal Calibration Goals By End of Workfest

- Determine statistics needed for gamma-jet calibration using full jet reco (1st results by Aaron/Songkyo)
  - What further studies are needed?
  - What further needed to make case for 500 GeV
- Get Fernando's code/Songkyo's code running to better quantify effects of nonlinearities/decalibration on key jet observables
  - Including realistic decalibration
- Determine Data MIP response, performance, and available statistics for data-based calibration and monitoring (Justin/Megan)
  - Determining potential MIP to Hcal EMScale mapping

HCal Calibration Goals By End of Workfest

- For Isolated Charge Track Shower:
  - Get Dennis's new "TopoCluster" code running
  - Monitor statistics/shower properties for HCAL relative calibration
- Lower priority tasks:
  - Non-uniformities in HCal as a function of position
  - Redo non-uniformities plot with recent tracking configuration

EMCal Calibration Tasks/Goals

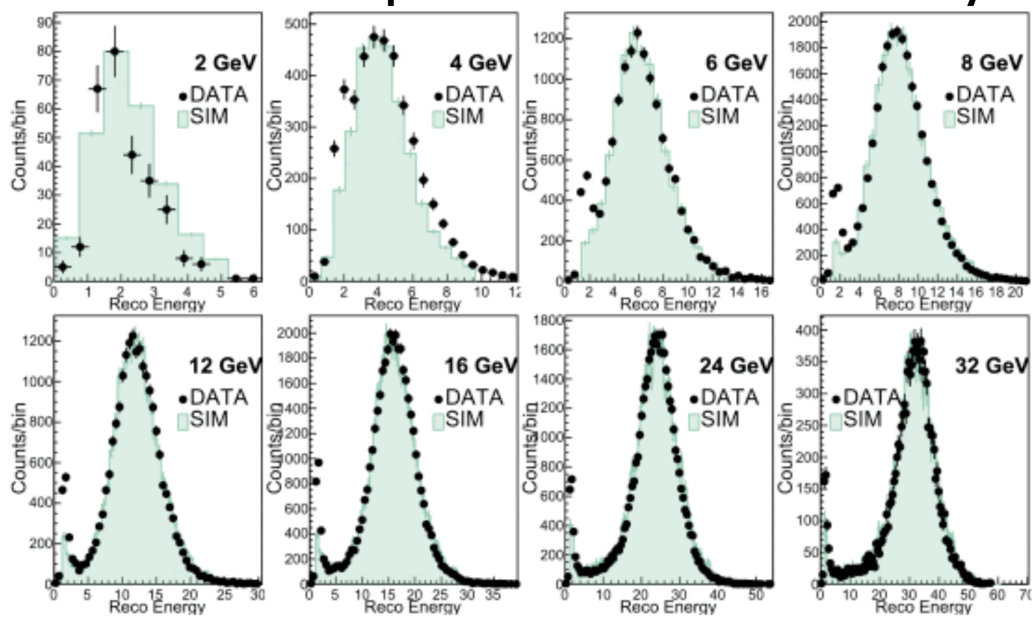
- Simulate close to a full simulation test of full decalibration/re-calibration from low E π^0's (relative calibration) + η/J/ψ (absolute calibration) – (Bing Xia)
- Determine EM Photon Energy scale uncertainty at highest p_T
- Correct position dependence of response

Volunteer Task #1
Validate the next Geant4 version, v4.10.05

- Preparing the next Geant4 version (v4.10.05) currently under evaluation as "play" builds
  - GEANT 10.06 is on the near horizon
- Before switching to that version, we need to check stability of calorimeter/jet performance, e.g. sampling fraction
- If needed update calibration, e.g. the EM energy scale calibration.
- Chris has prepared high statistics sample to help check the performance difference in detail.
- **Need volunteers to look into them.**

Volunteer Task #2
Weekly verification using test beam data

- Currently only check a reference simulation vs new software builds: https://web.racf.bnl.gov/jenkins-sphenix/job/sPHENIX/job/test-calo-single-qa/QA_20Report/
- It would be nice to check plots like this weekly:



- Need a volunteer familiar with the test beam analysis to help import the code as weekly check setup.

Conclusions

- Jet finding and Calorimeter clustering techniques are robust within sPHENIX
  - Particle Flow
  - Improved Calibration
- Key questions over necessary data sets and measurements required for calibration are still being answered
- Mapping improvements in energy scales/ calibrations to jet observables is not trivial