Plans for Jet Measurements at sPHENIX

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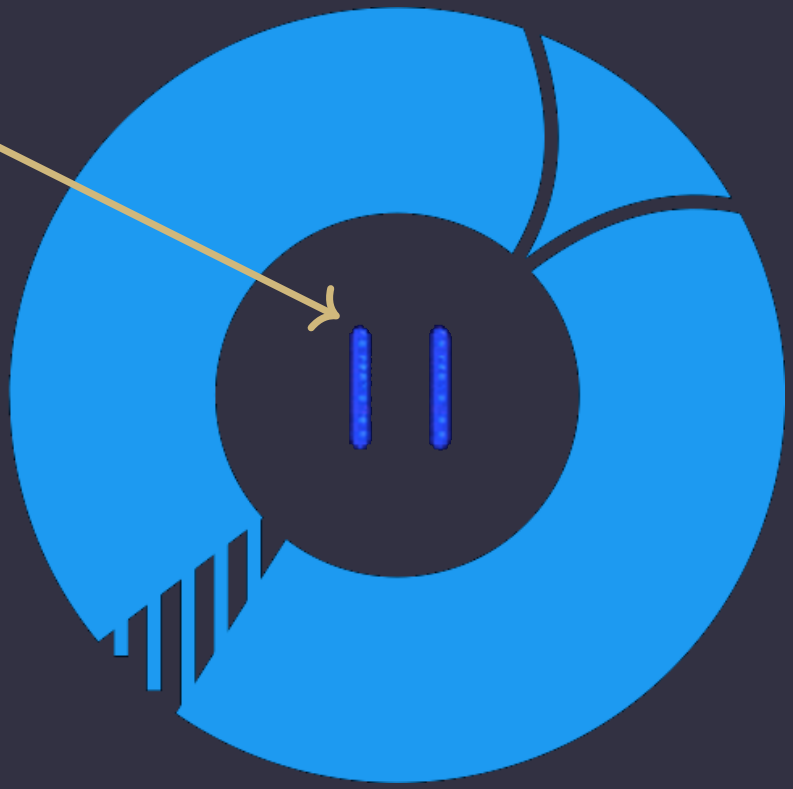
On Behalf of sPHENIX

RHIC/AGS User's Meeting

22 October 2020

Creating the QGP (I)

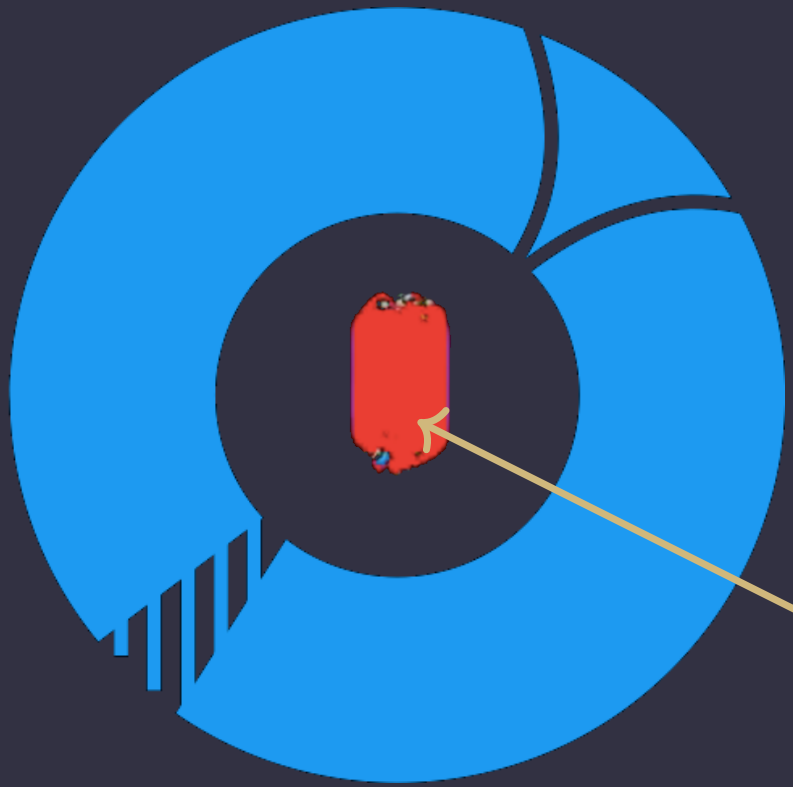
- Collide heavy nuclei
  - Pb+Pb
  - Au+Au



Cartoon via Ann. Rev. Nucl. (2018) 68:1-49

Creating the QGP (II)

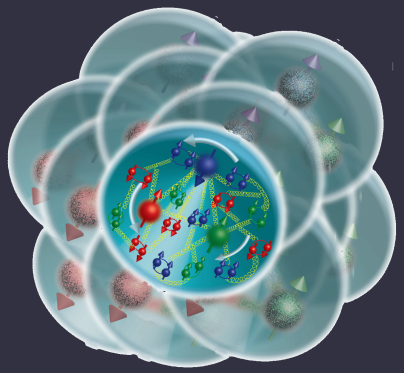
- Collide heavy nuclei
  - Pb+Pb
  - Au+Au



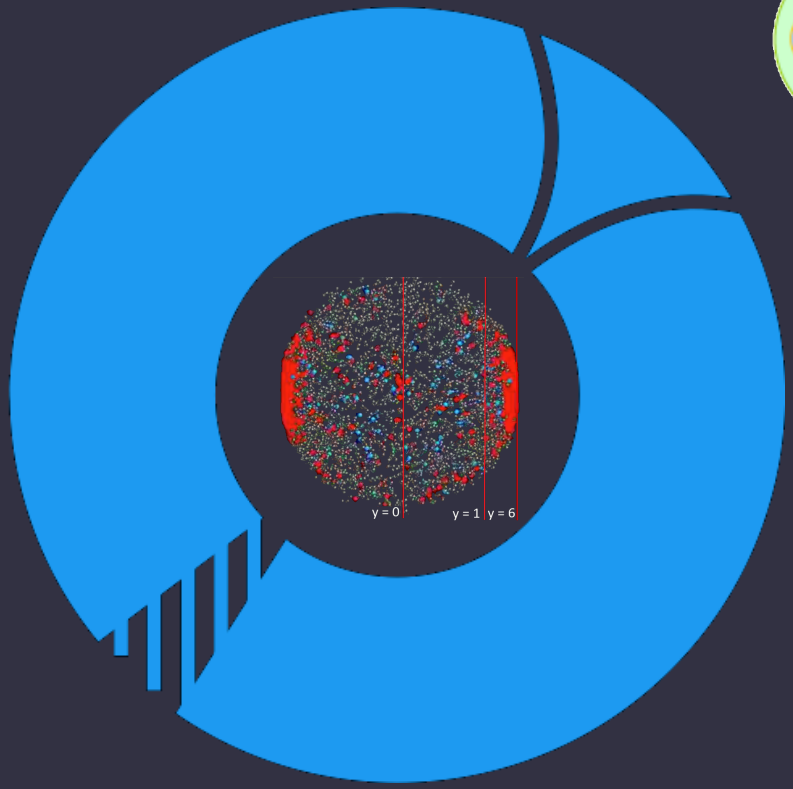
- With enough energy, form Quark-Gluon Plasma

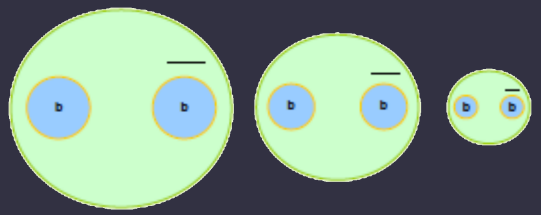
Cartoon via Ann. Rev. Nucl. (2018) 68:1-49

Study of the QGP/QCD



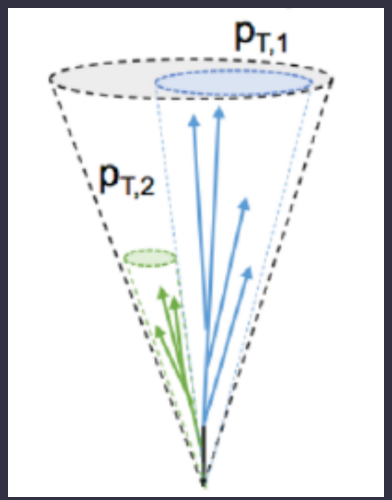
Cold QCD



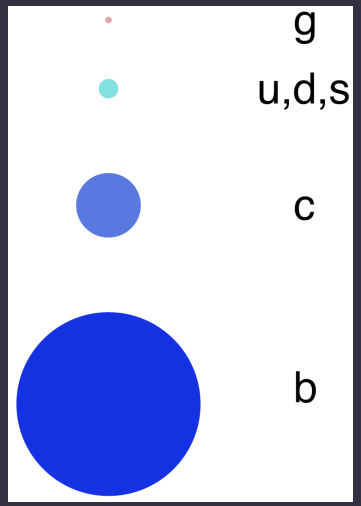


Bound States

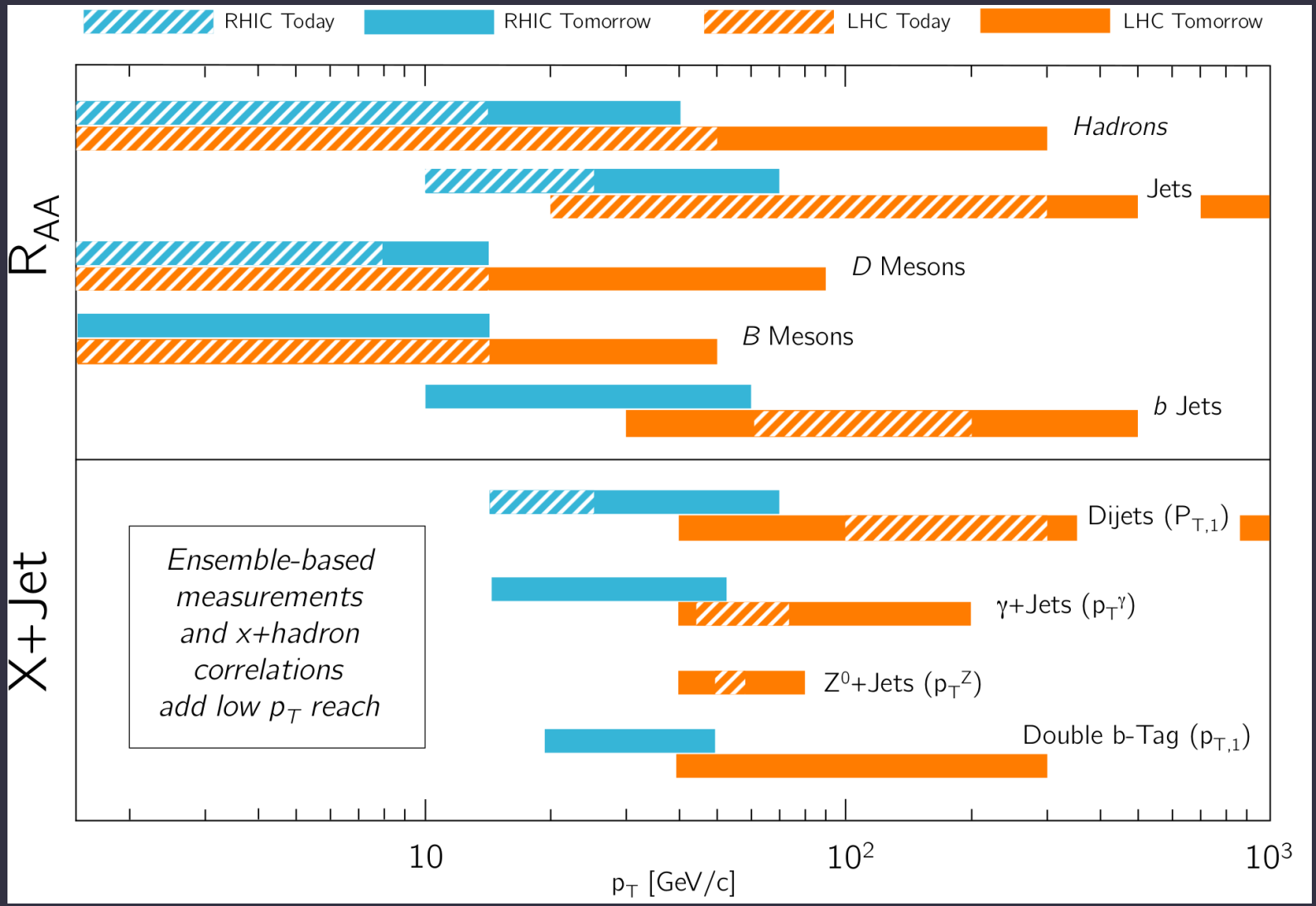
Jet substructure



Flavor/mass

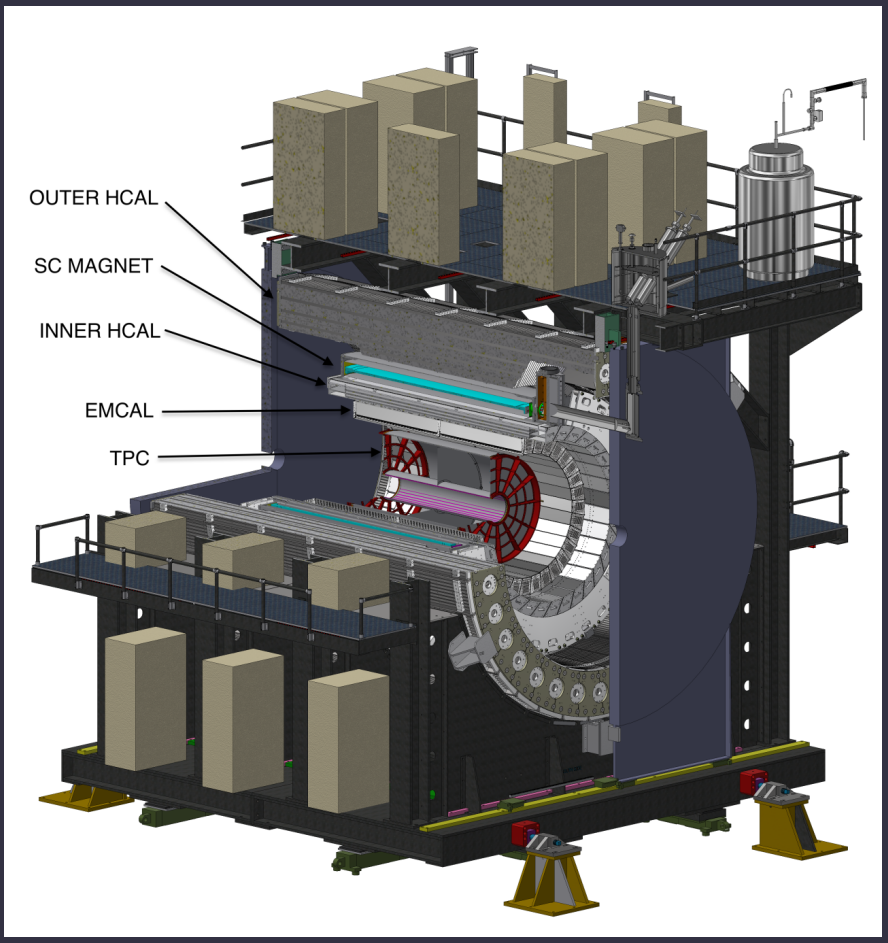


The Physics Program



- Similar probes in very different QGP!

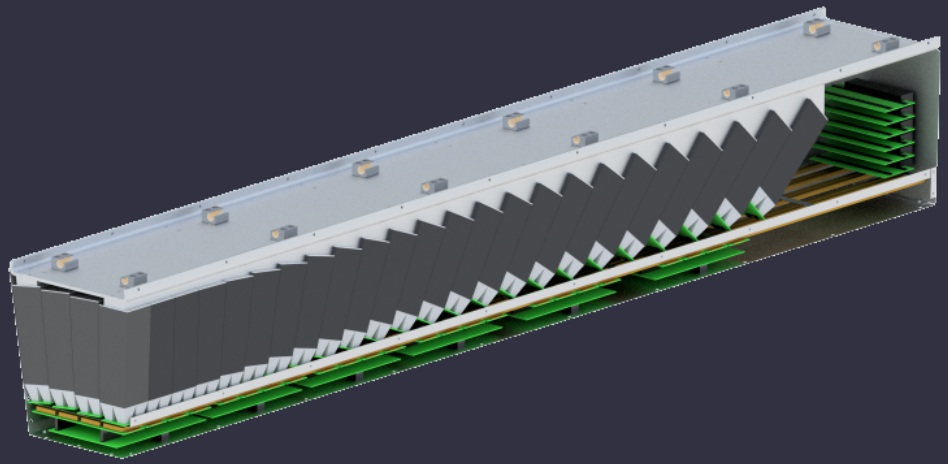
The Detector



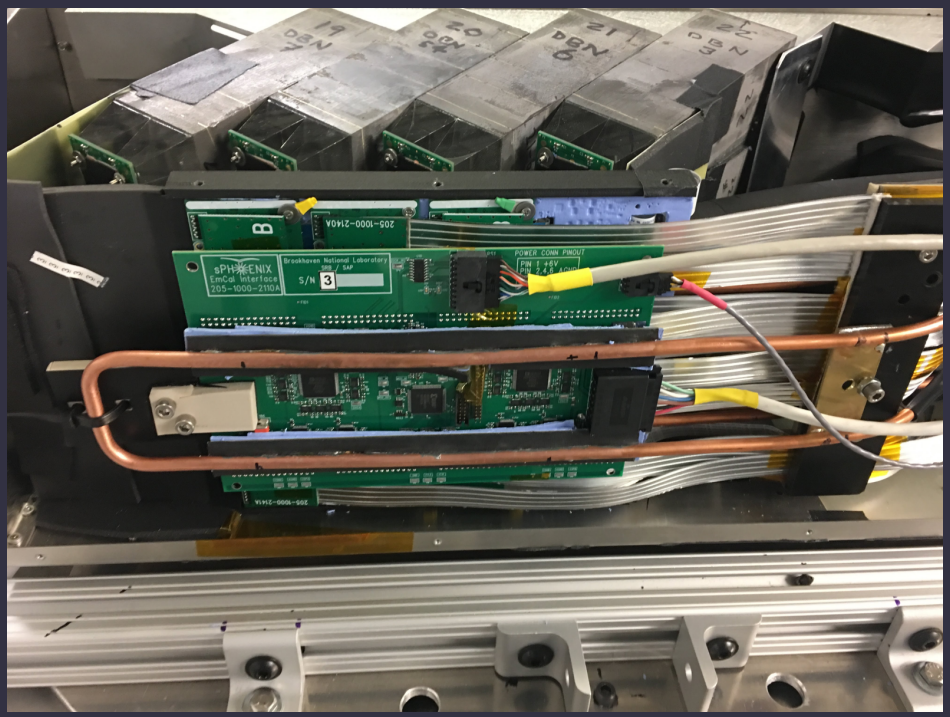
Key features for jet physics

- Full acceptance out to $|\eta| < 1.1$
  - 2π in azimuth!
- Highly granular electromagnetic calorimeter
- Hadronic calorimetery
- Unbiased jet triggering in p+p
- Large data-taking rate for maximizing statistics
  - In A+A, taken with minimum bias

Electromagnetic Calorimeter



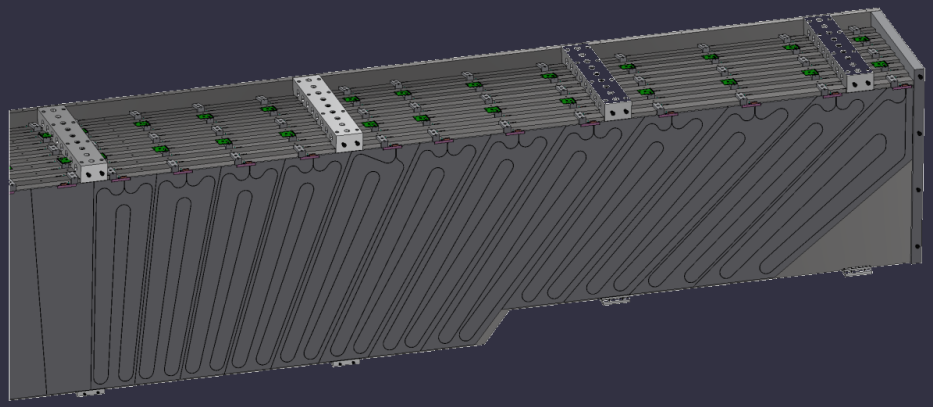
- A model of a sector of the EMCal from mid-rapidity to forward-most



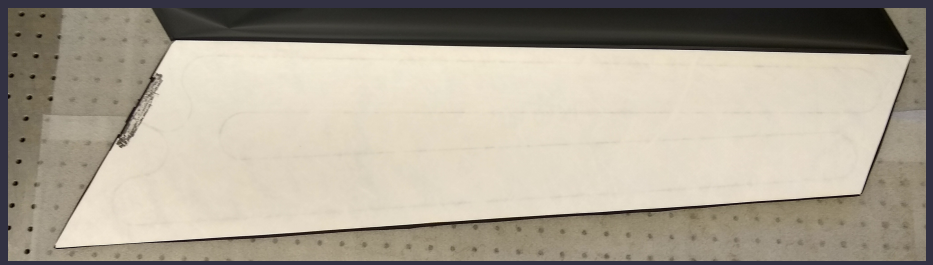
- EMCal blocks instrumented with pre-amplifier and shaping boards
  - Tungston powder w/ scintillating fibers embedded

Hadronic Calorimeter

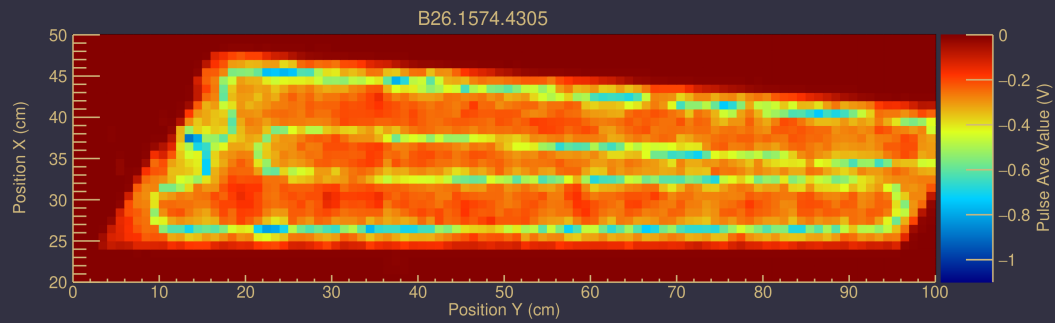
- A sector of the hadronic calorimeter from mid-rapidity to forward-most



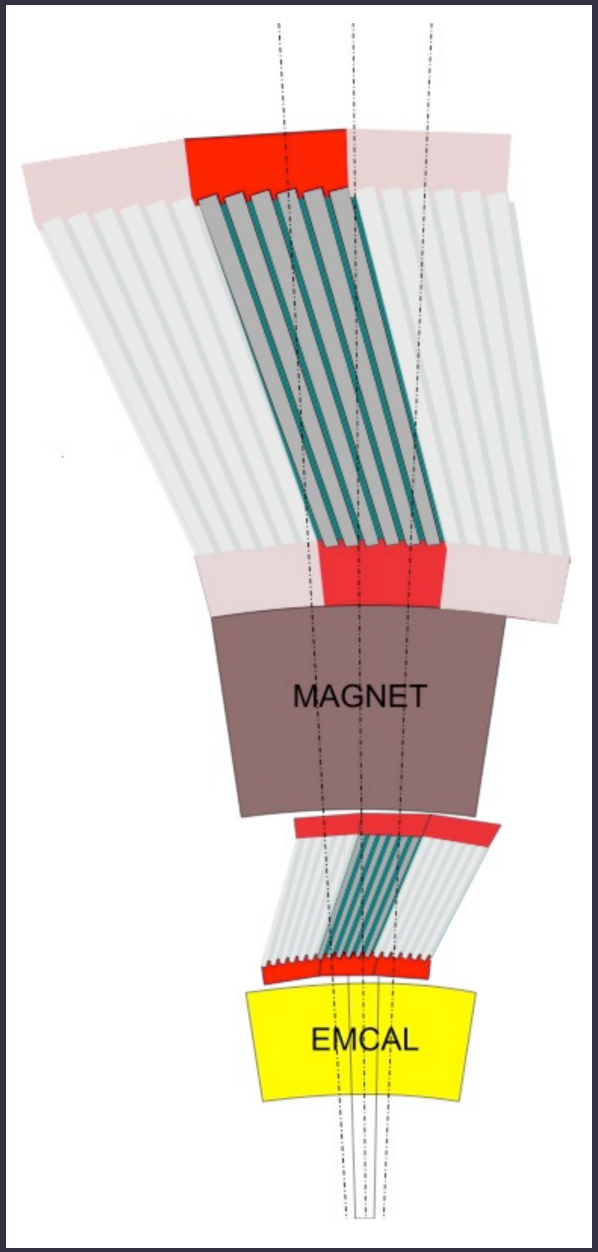
- Photo of a single scintillating tile with embedded waveguiding fiber

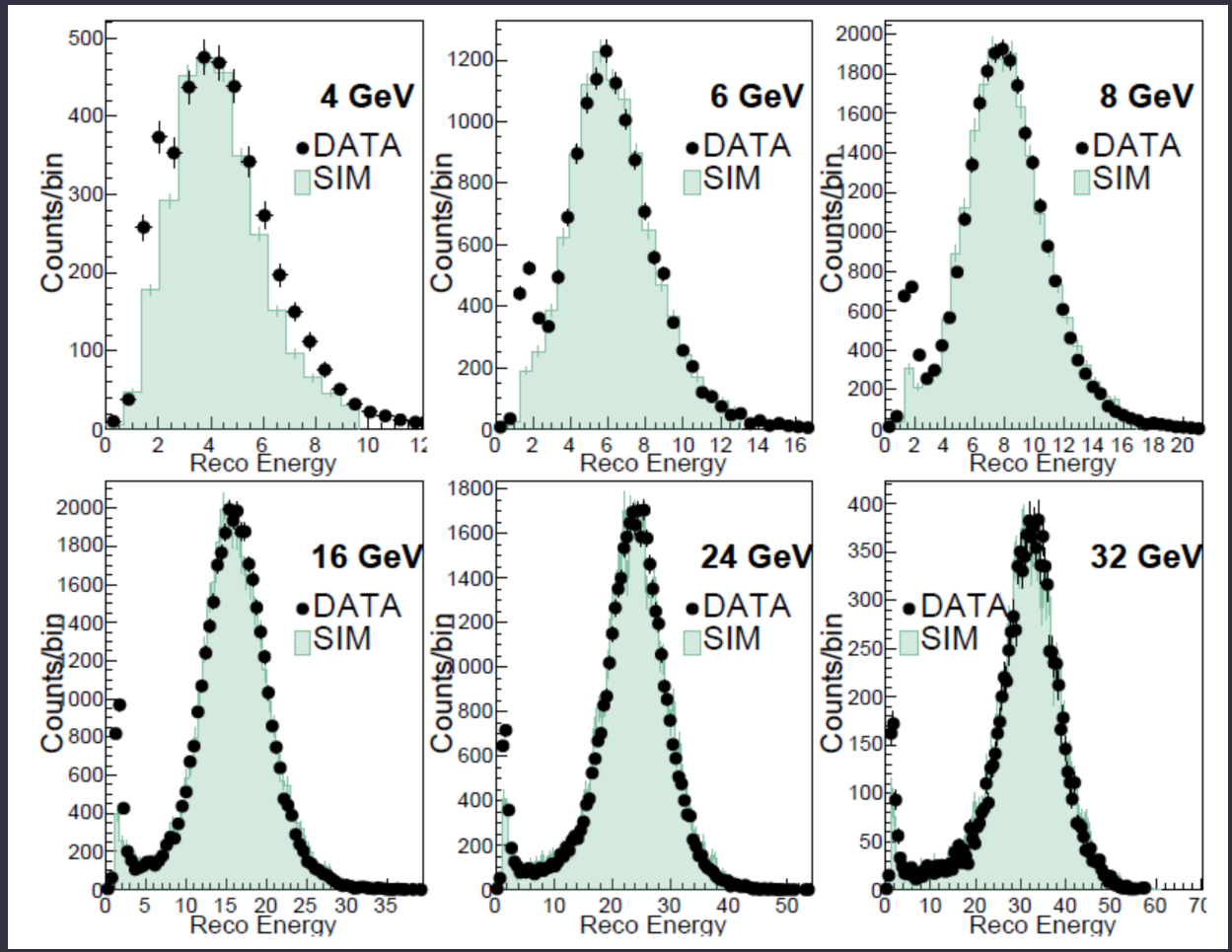


- Scan of a single HCal tile with an LED



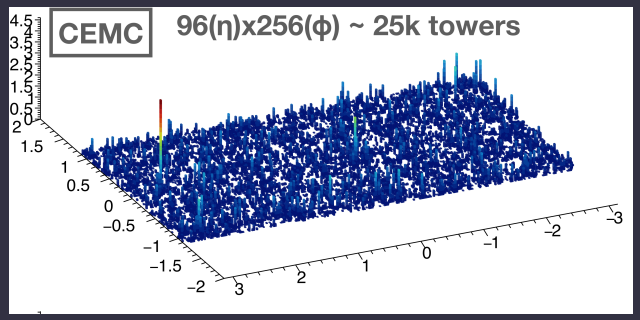
Test Beam Results

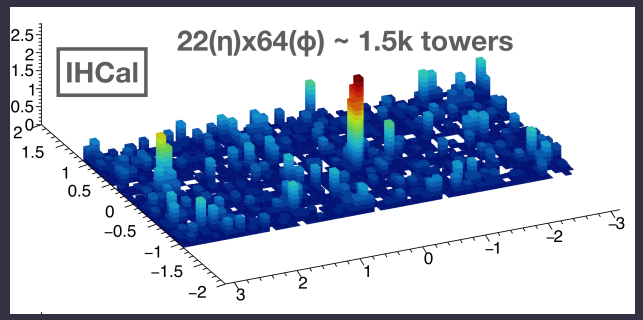


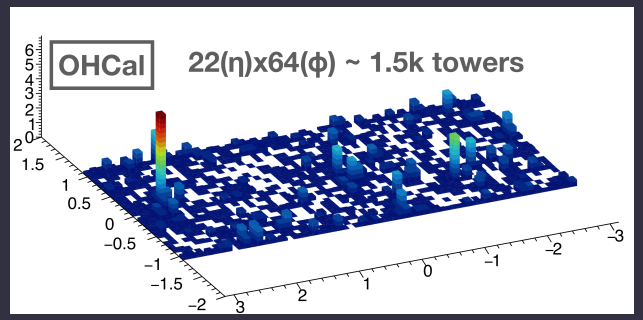


- Results of testbeam with full calorimetry show excellent agreement between simulation and data (via IEEE 65 (2018) 2901)

Tower Jet Reconstruction (I)

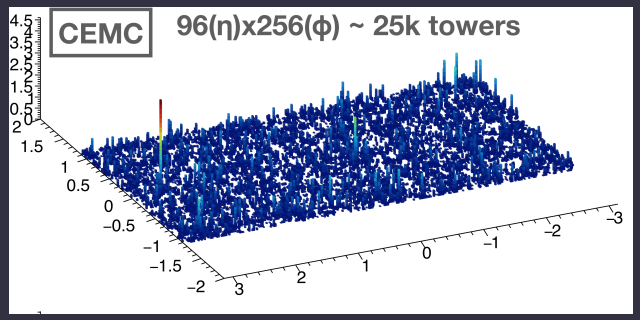


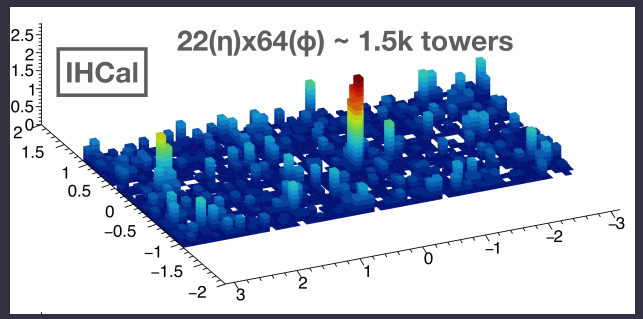


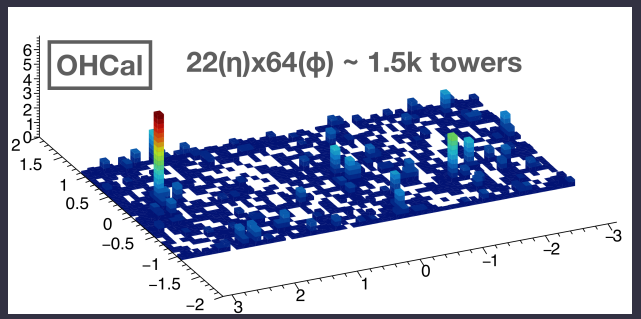


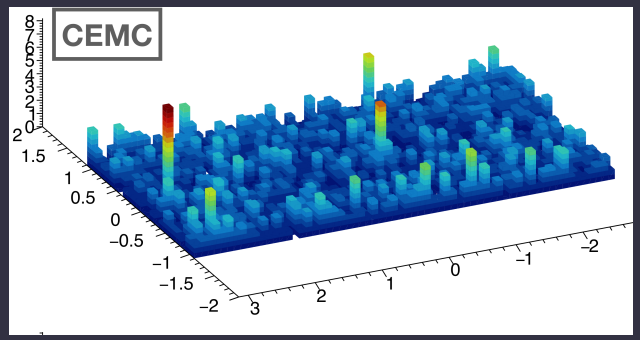
- Layer-by-layer unrolled calorimeters in Au+Au

Tower Jet Reconstruction (II)



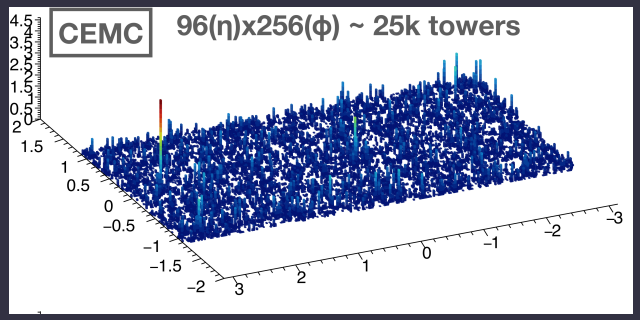


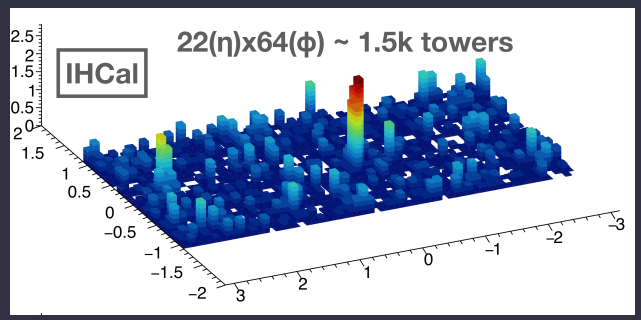


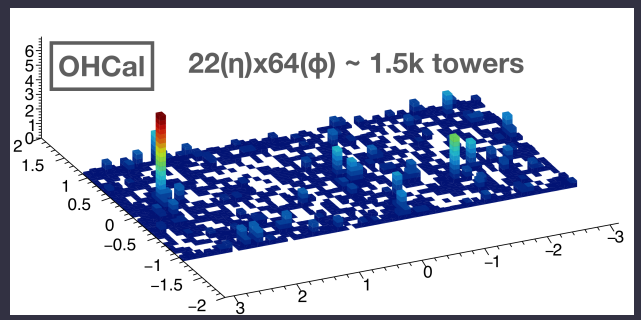


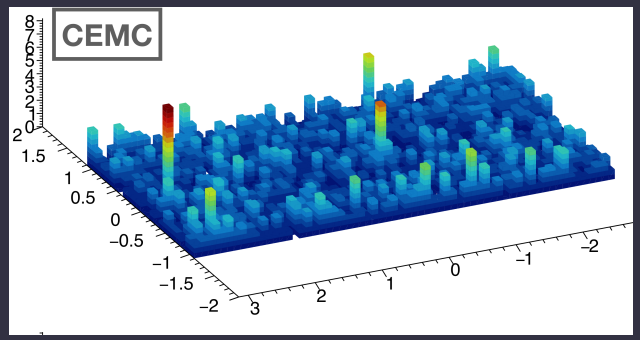
- EMCal re-towered to match HCal geometry
- Combined into 4x4; 0.1x0.1 in $\eta-\phi$

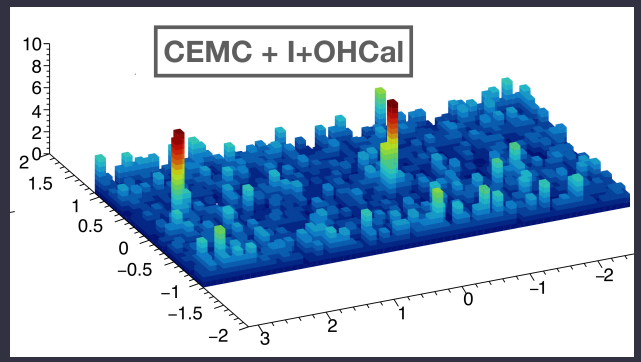
Tower Jet Reconstruction (III)





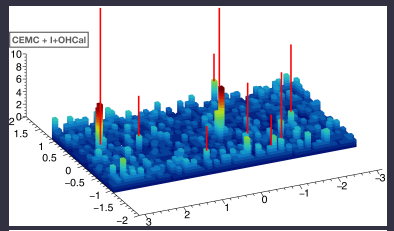


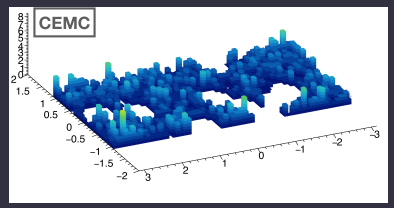


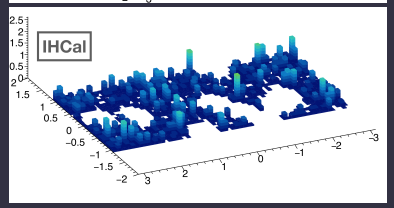


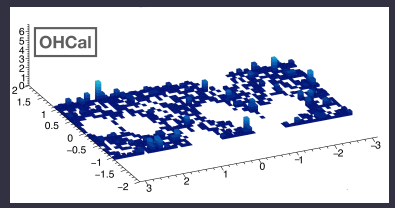
- All layers are combined for full measurement of jet energy
  - But we must subtract!

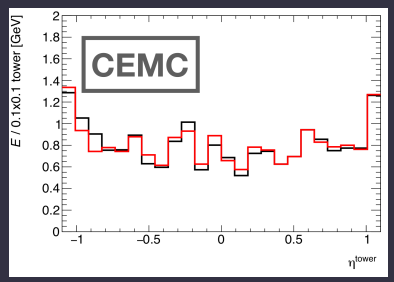
Tower Jet Subtraction

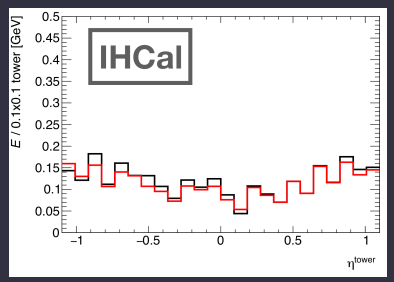


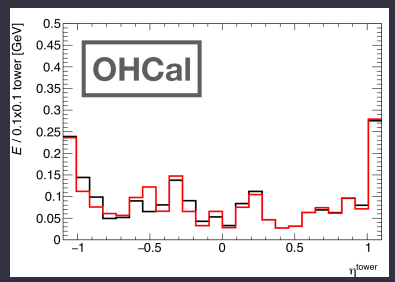


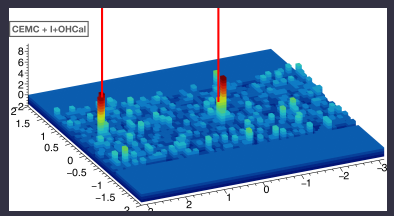








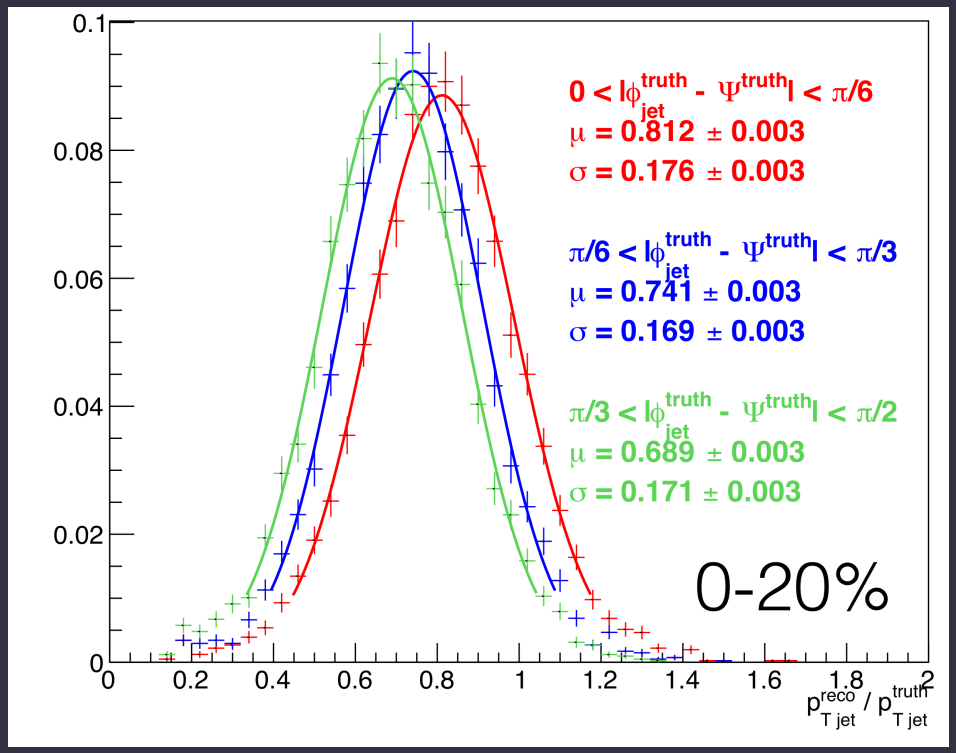


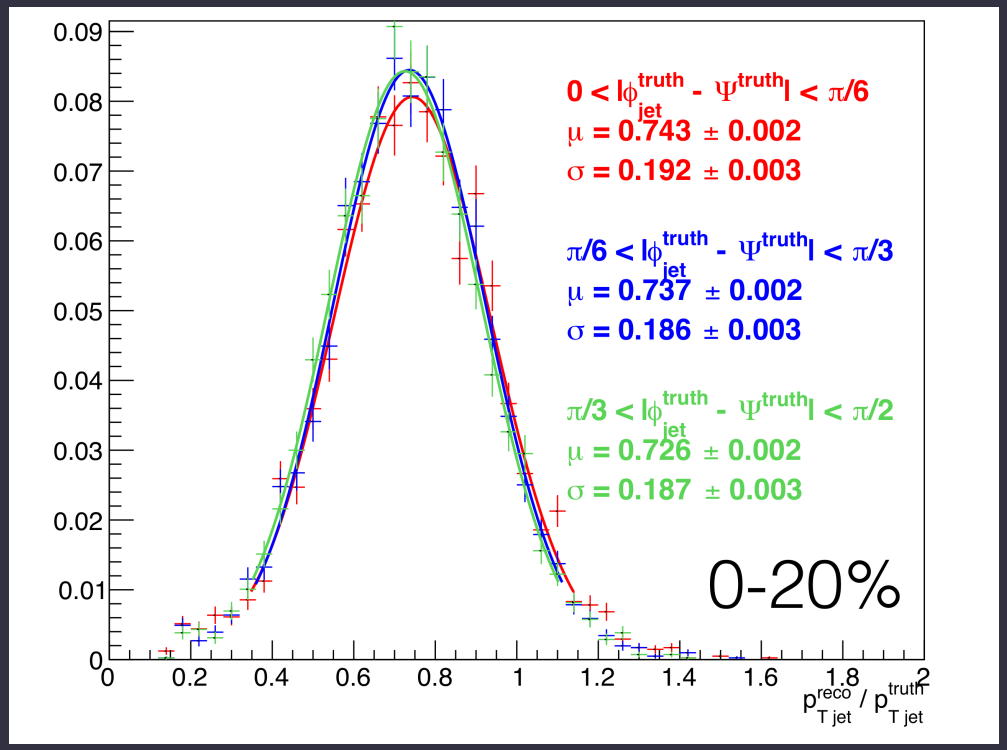


1. Identify 'jetty' regions and exclude
2. Estimate background in η, layer dependent way
3. Subtract estimated background and run jet finding

- Iterate using new jets as exclusion regions

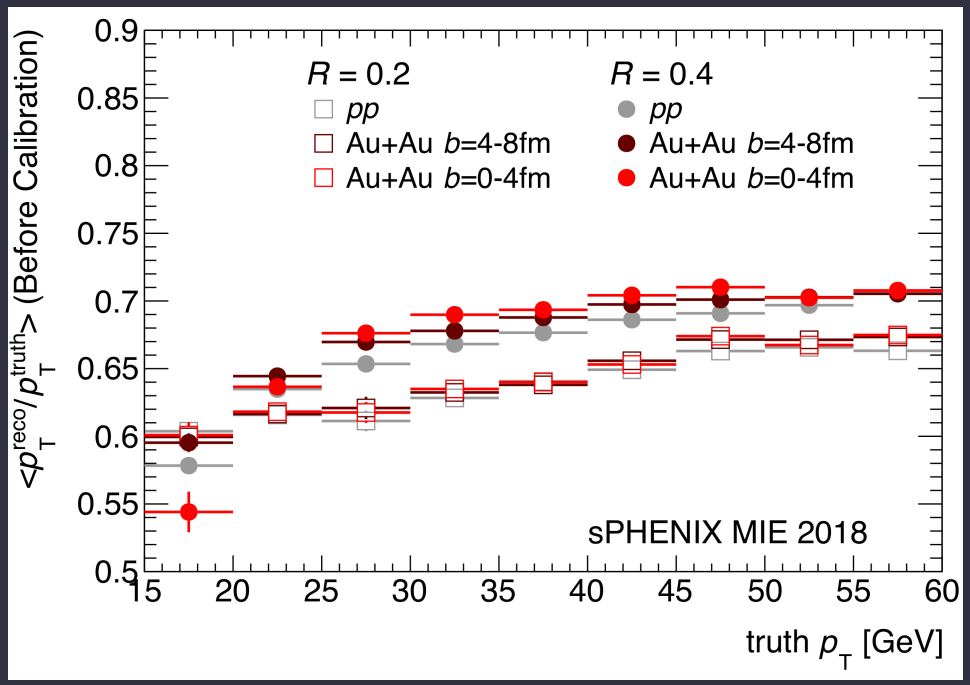
Flow Modulation

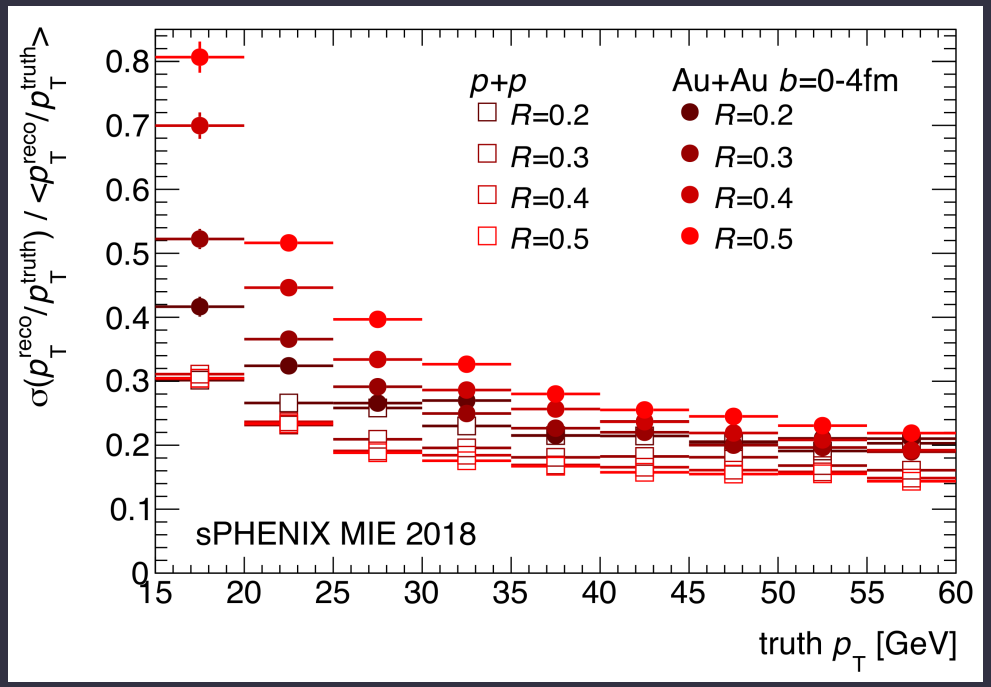




- Control for the underlying event modulation from hydrodynamic flow
  - In addition to subtracting in η, layer
- Reduced event-plane jet energy scale dependence
- Removes artificial increase in jet energy resolution

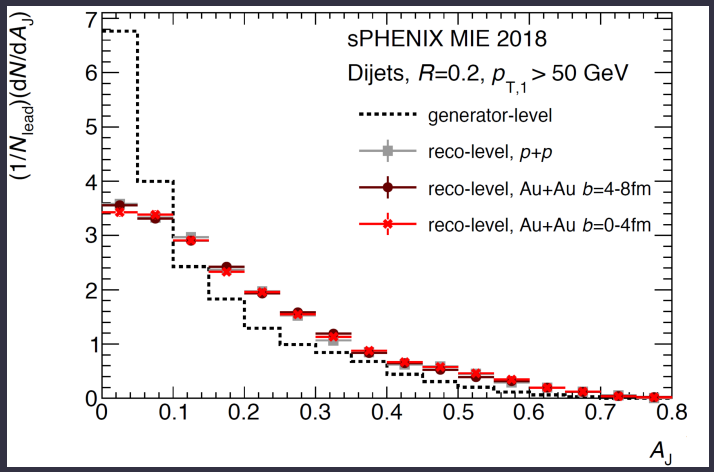
Tower Jet Performance

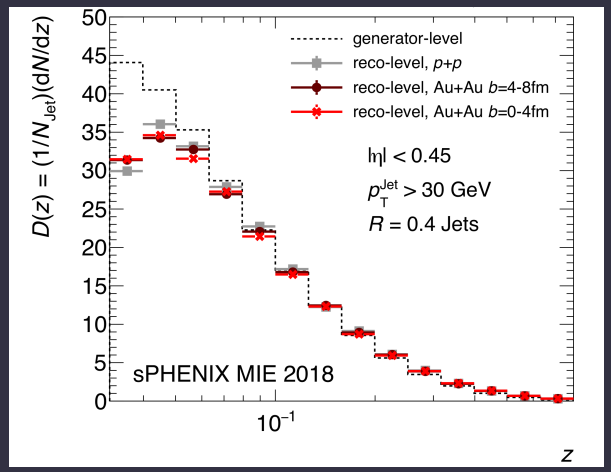


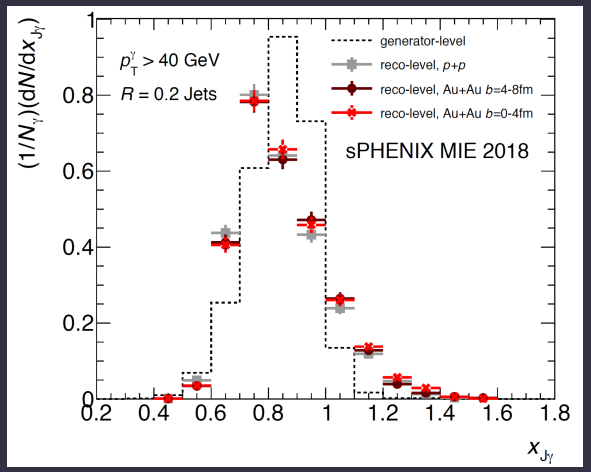


- Stable mean response in all centrality
- Resolution dependence on R + centrality as expected

Day-1 Measurements



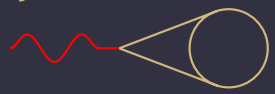




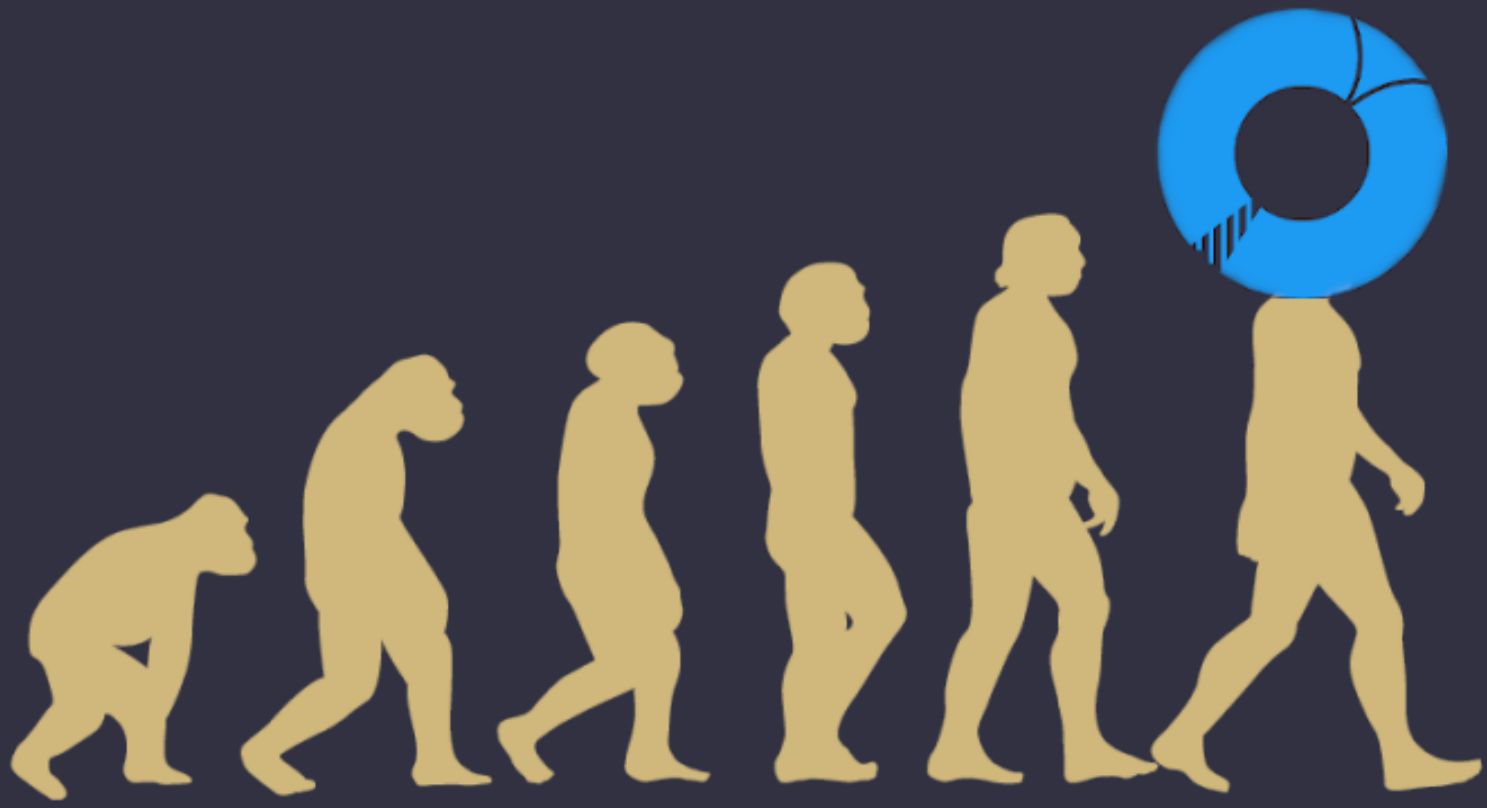
Dijet Asymmetry

Jet Fragmentation

γ+jet Balance

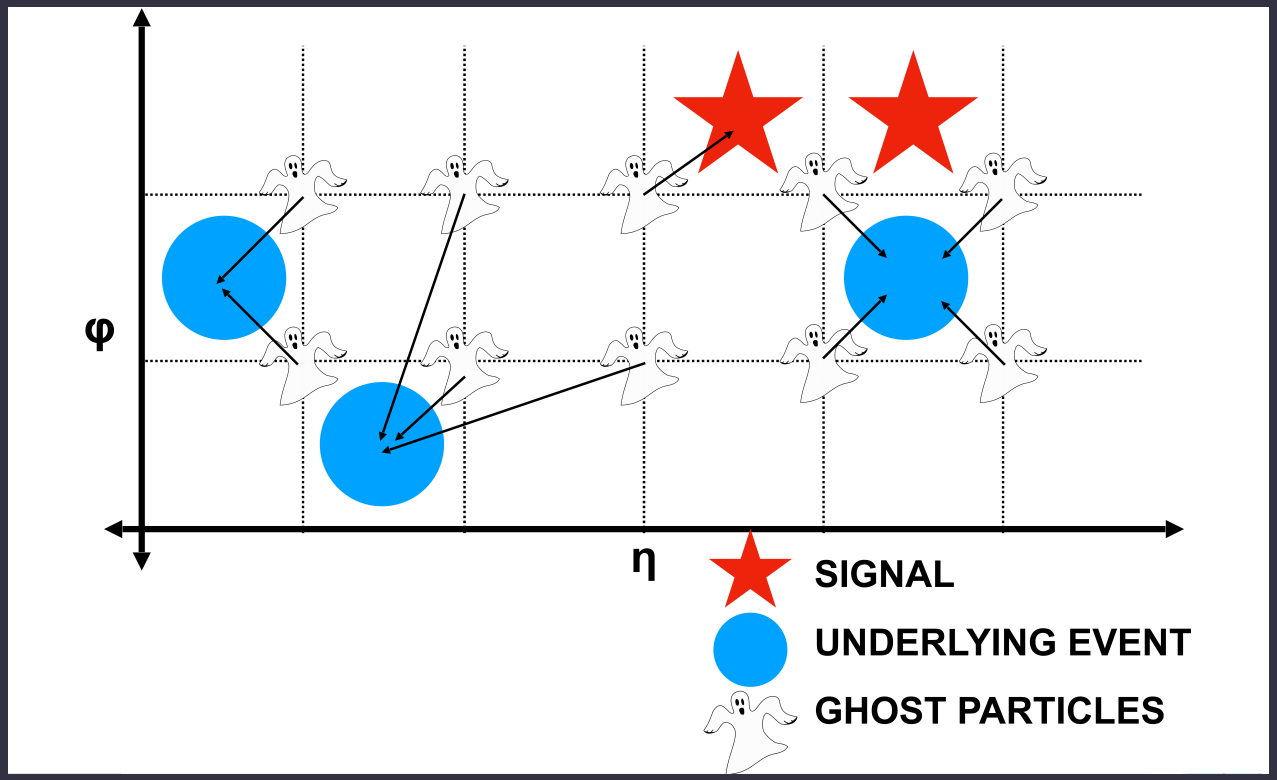


- With current tower jets, performance of some possible first measurements
- In particular, with colorless tag as in γ+jet:
  - sPHENIX can immediately provide complementary, comparable measurements w/ LHC program



Evolving developments...

Constituent Subtraction (I)

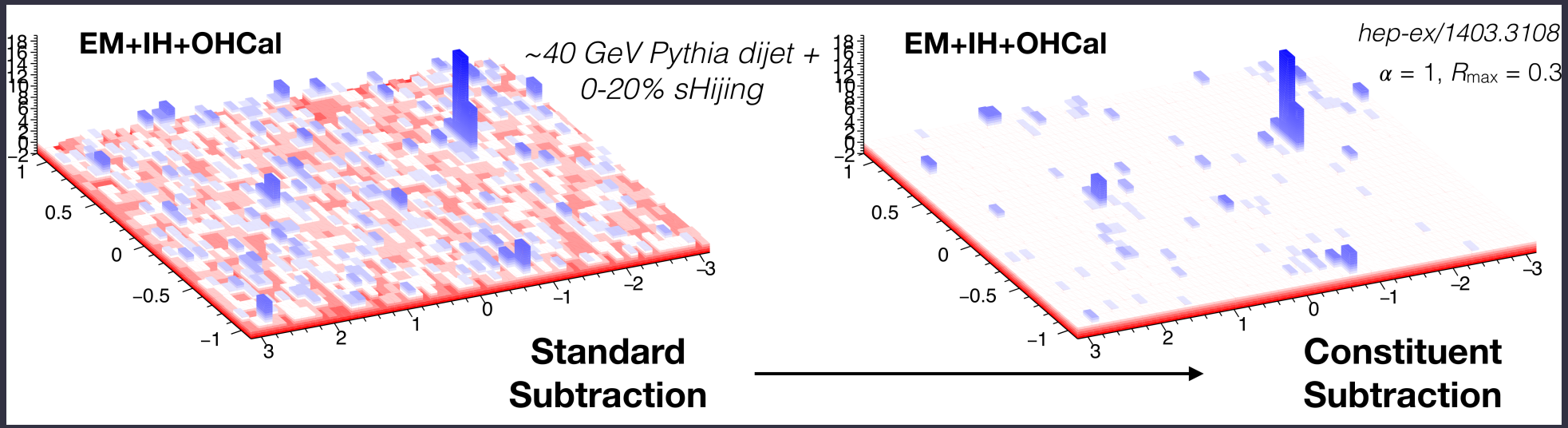


- As in JHEP 06 (2014) 092 and JHEP 08 (2019) 175.
- Ghosts are iteratively subtracted from real particles until either real or ghost particles are exhausted, according to pair minimizing:

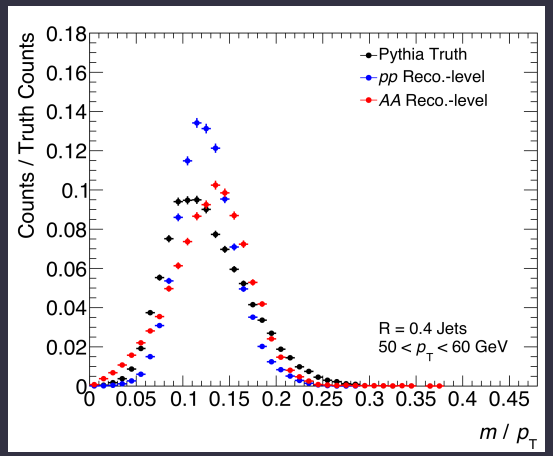
$$\Delta R_{i,k} = p_{T,i}^{\alpha} \sqrt{(y_i + y_k^g)^2 + (\phi_i + \phi_k^g)^2}$$

- Useful when constituent area is not clearly defined.

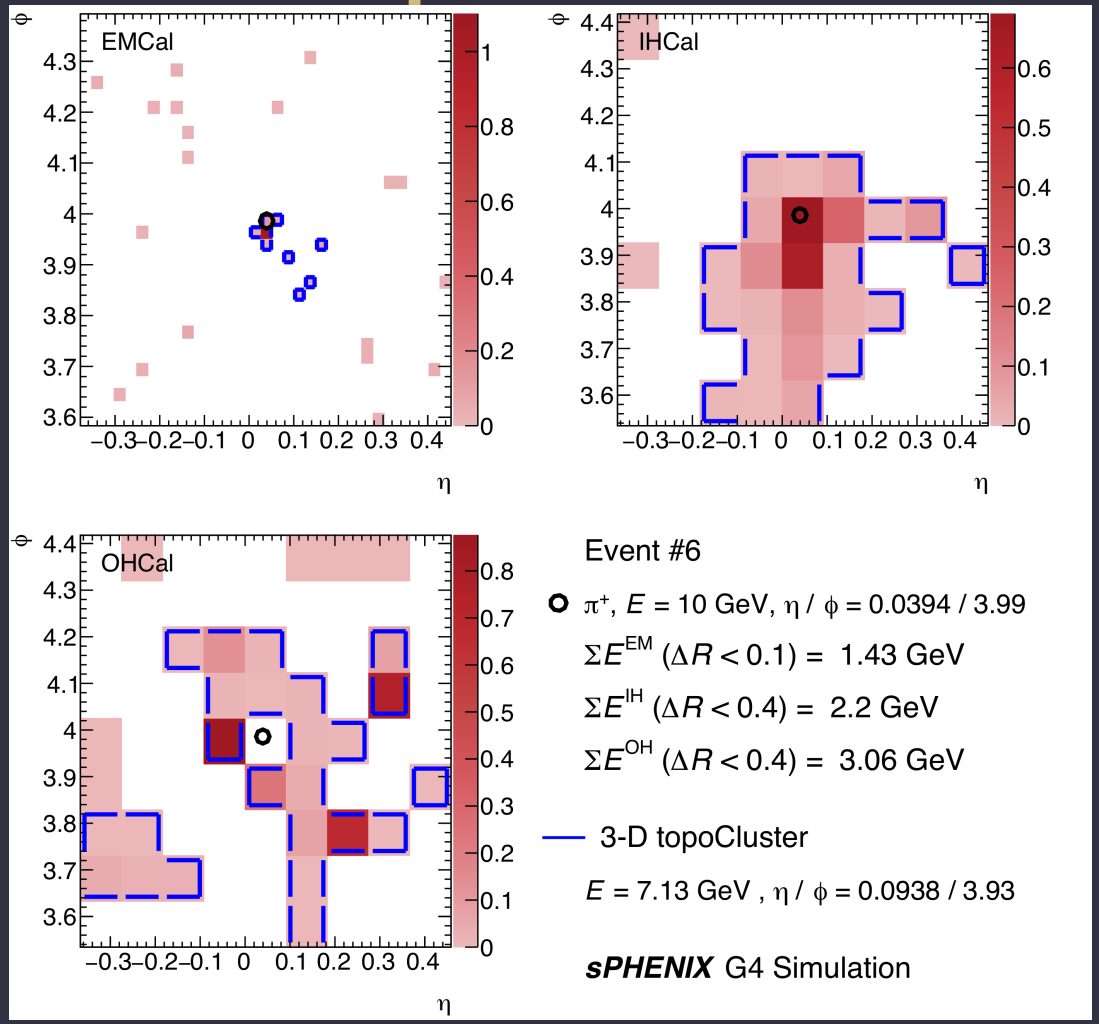
Constituent Subtraction (II)



- Event remains fully positive
  - Contrast w/ current subtraction where negative towers are possible!
- Distortions to mass distribution reasonable as compared to benchmarks in proposal paper here

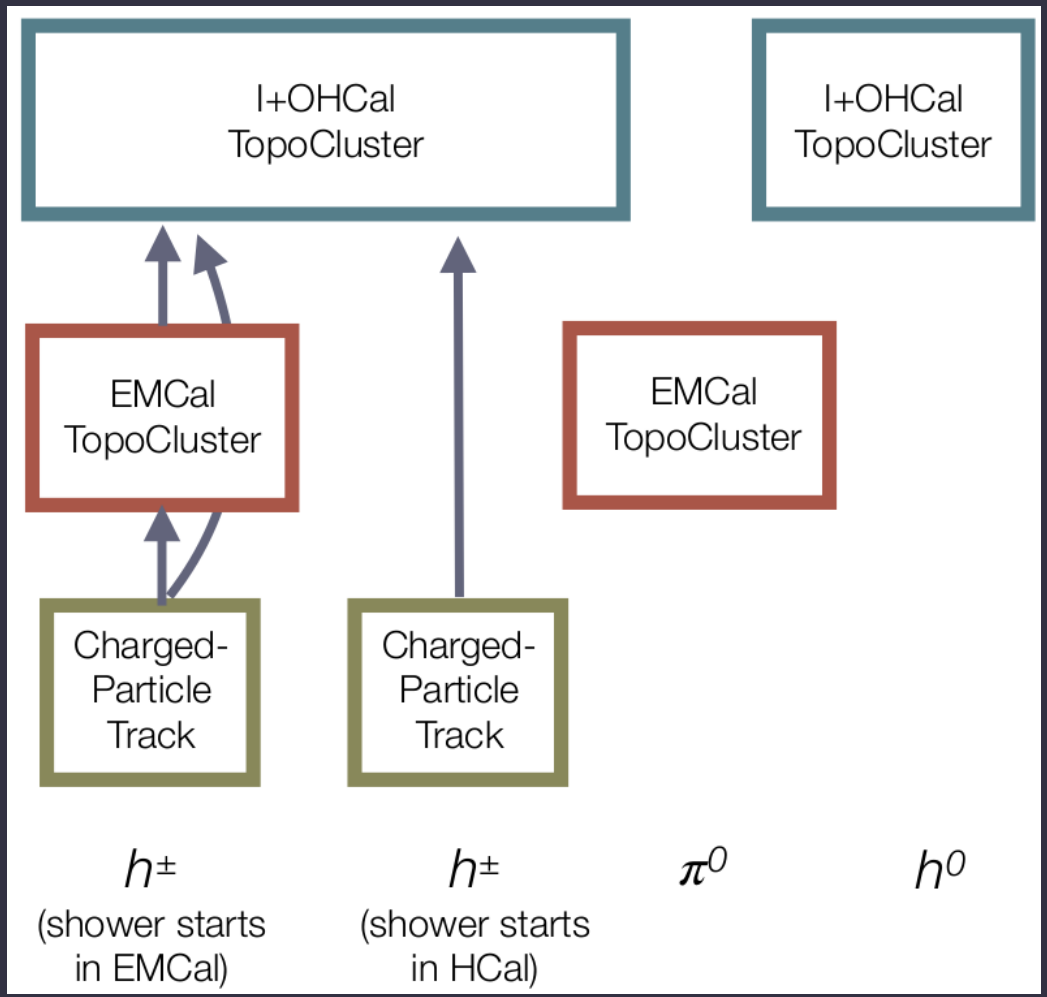


3-D Topoclusters



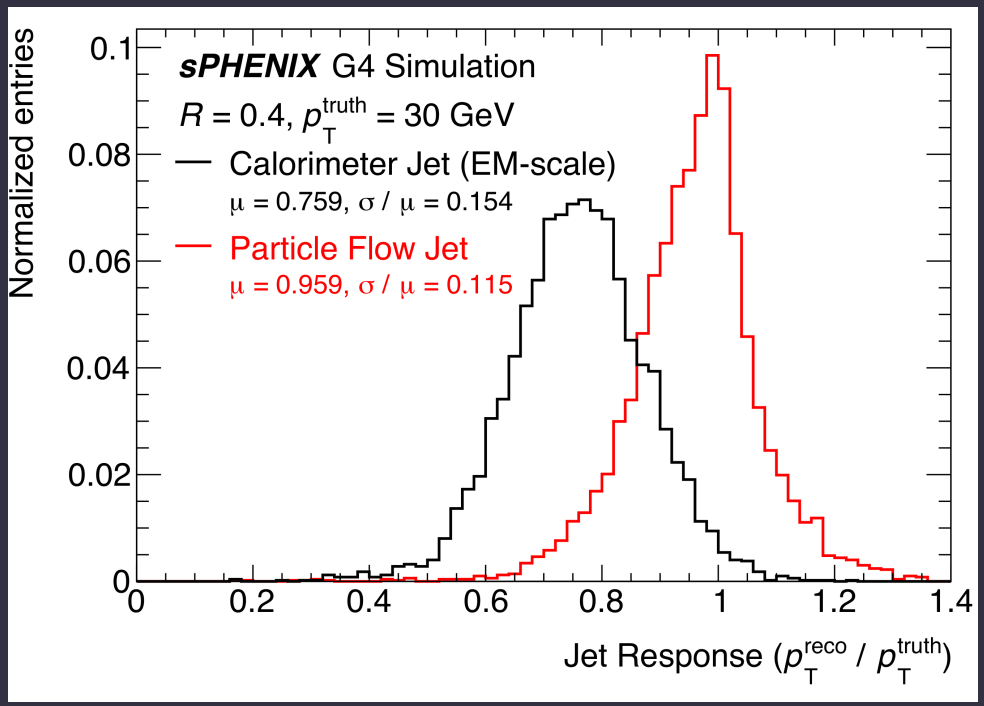
- Clustering specific to jet reconstruction
- Ideal for combining info across calorimeter layers
  - Step towards particle-flow

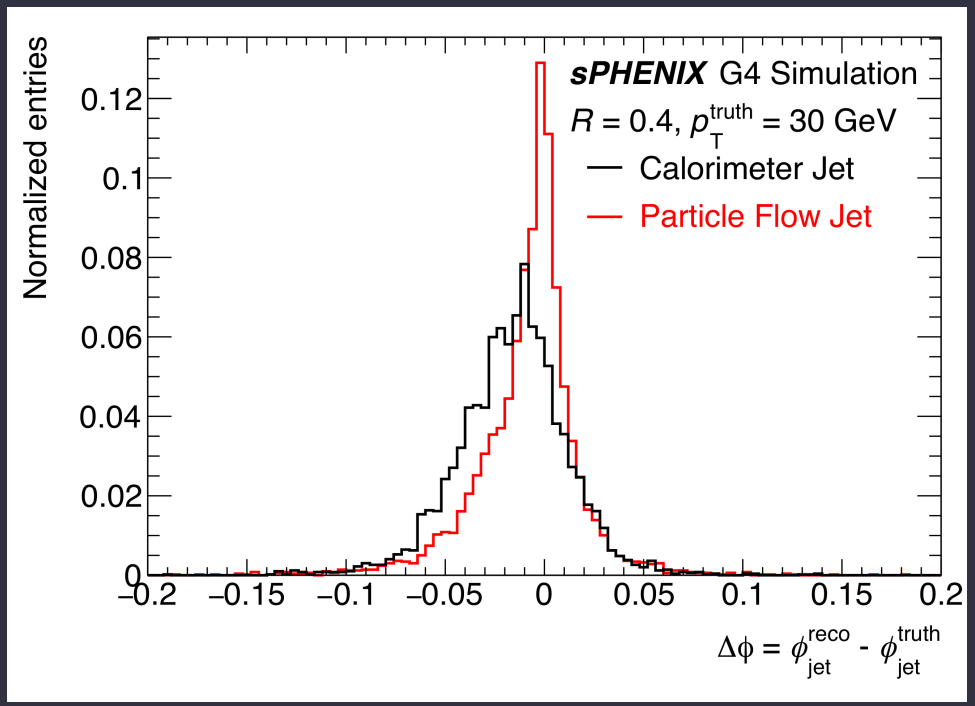
Particle Flow w/ sPHENIX



- Combine information from all subdetectors
- New composite constituent called a "particle-flow" object
- Mitigates fragmentation biases to energy response

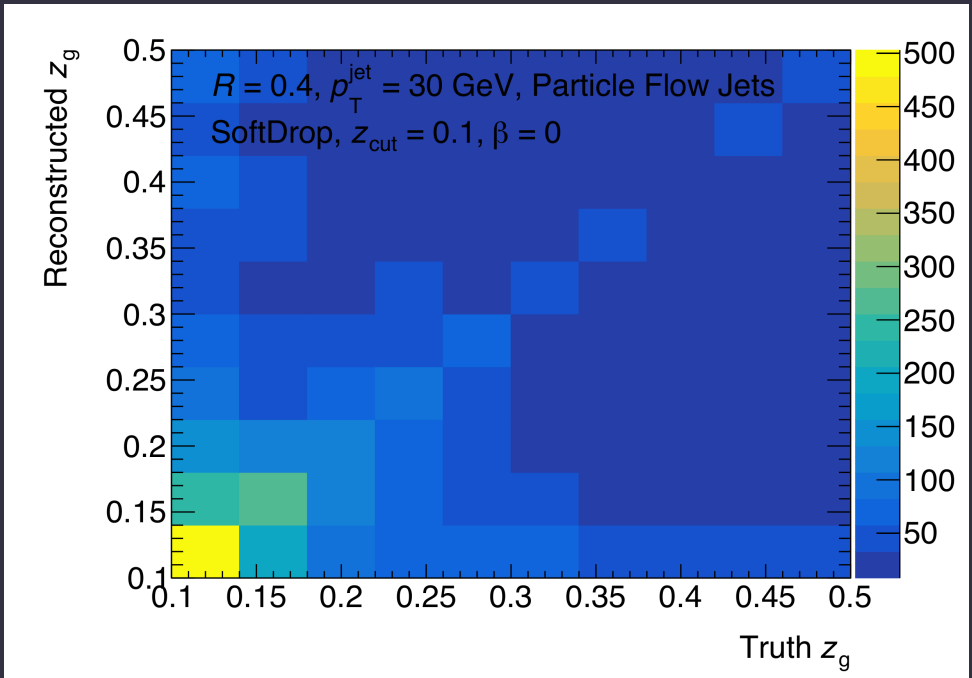
Particle Flow Performance

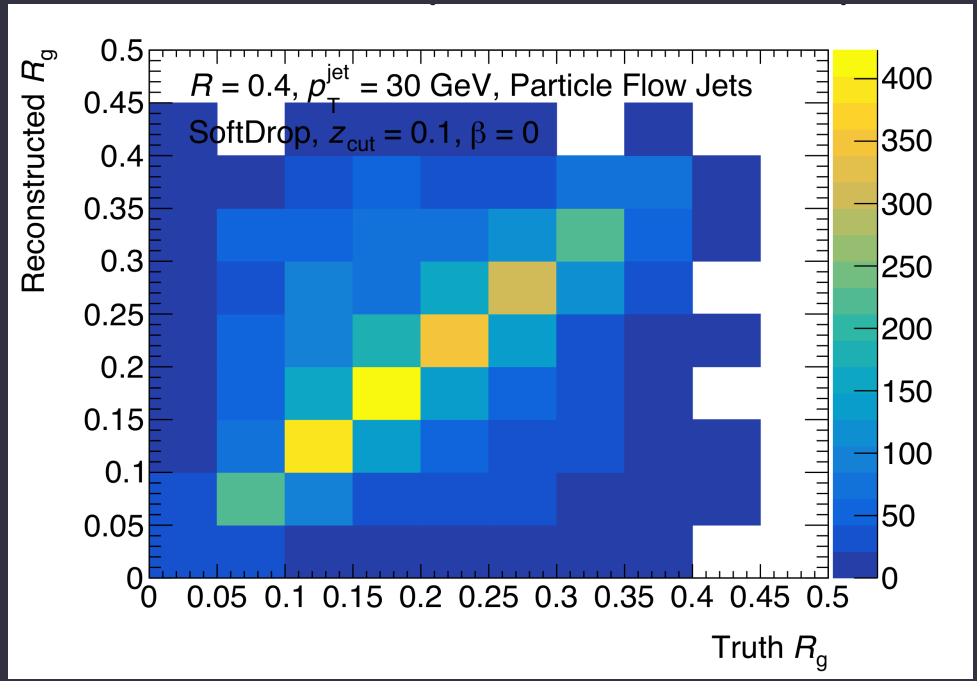




- Mean energy response closer to unity pre-correction
- Energy response narrows with addition of tracking
- Angular resolution narrows

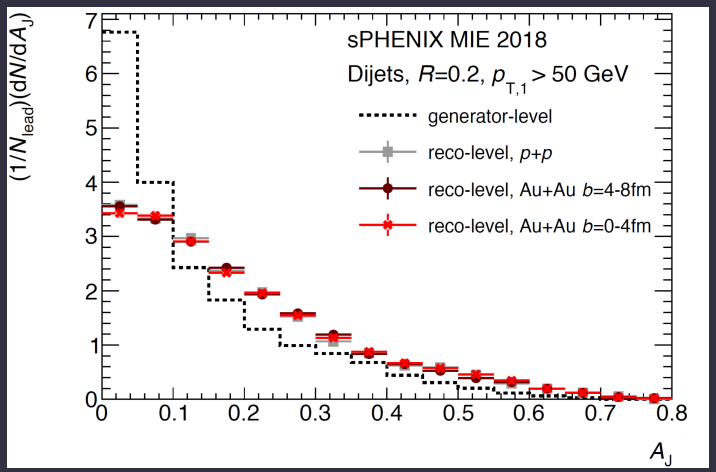
Particle Flow Substructure

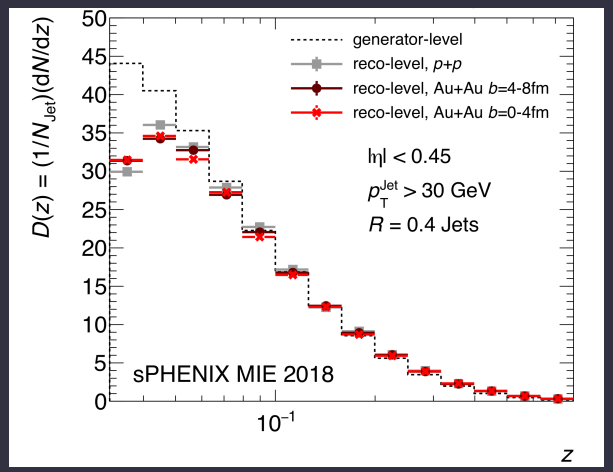


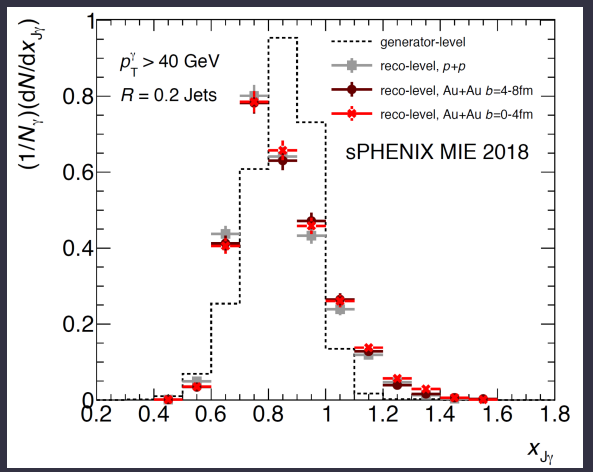


- Significant improvement in correlation as compared to tower jets

Going Forward...



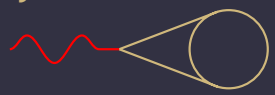




Dijet Asymmetry

Jet Fragmentation

γ+jet Balance



- sPHENIX construction continues!
- Preparation for jet measurements immediately with startup in 2023
  - Tower jet reconstruction already in hand
  - New tools being added daily!
- Exciting physics program ahead – stay tuned!