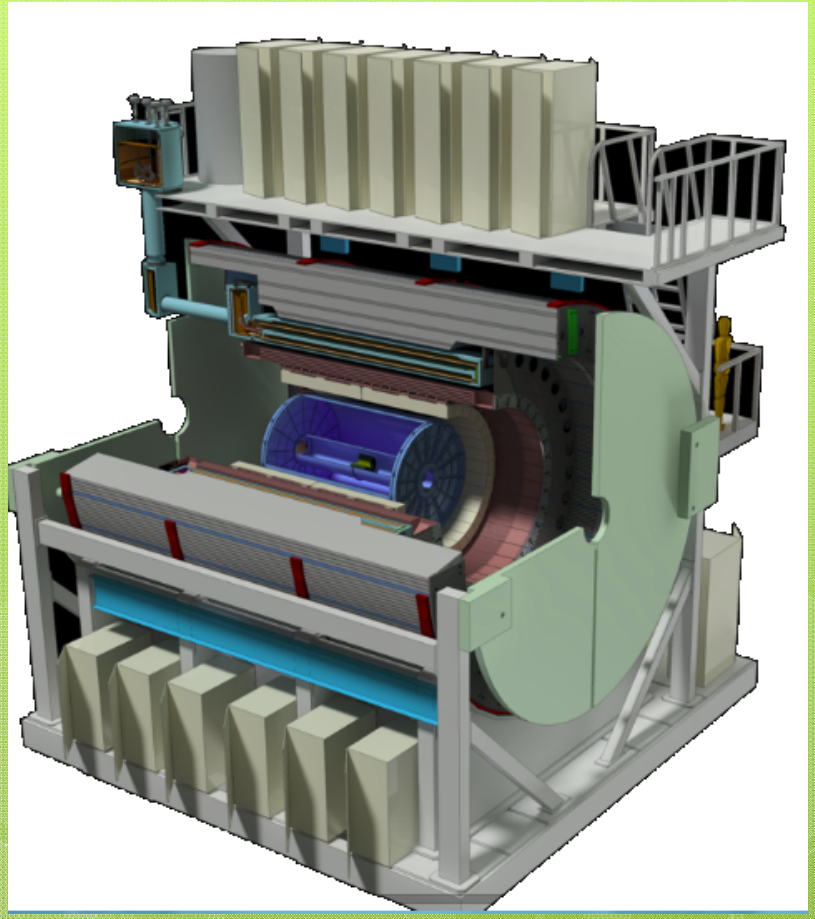


Exciting Jet and Prompt Photon Physics Provided by sPHENIX

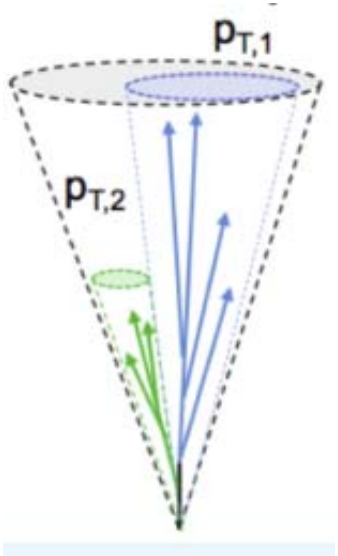
Justin Frantz
Ohio University

WWND '19 Beavercreek, CO
1/7/2019

Science Mission

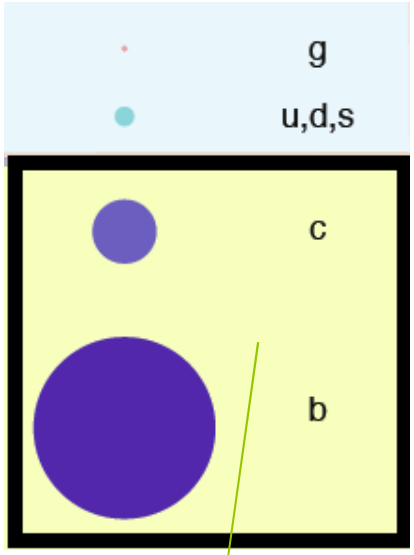
- sPHENIX Goals (LRP): **1)** Probe Inner structure of QGP with jet probes of wide range of Q^2 and color charge/ flavor **2)** Explore T-dependent QGP Structure by observing directly comparable jet modifications of longer-at-T_C QGP @ RHIC vs LHC

Jet Structure

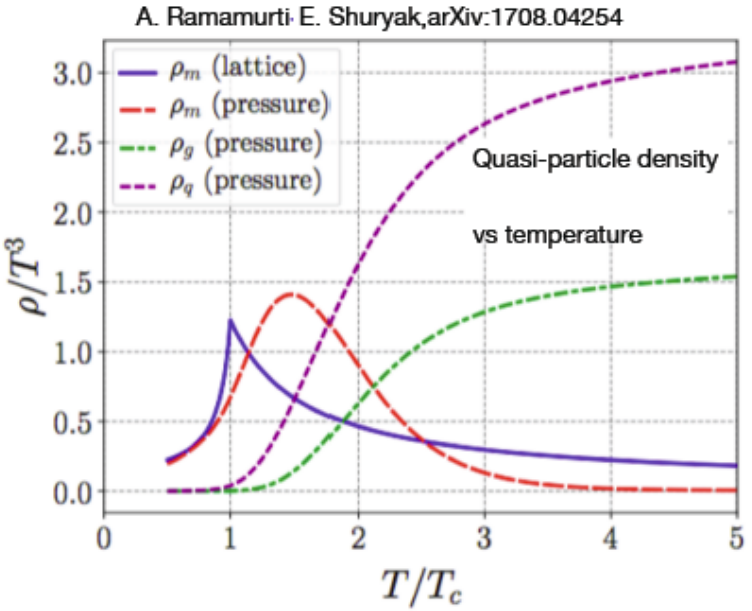


MVTX Addition!

g/q Flavor

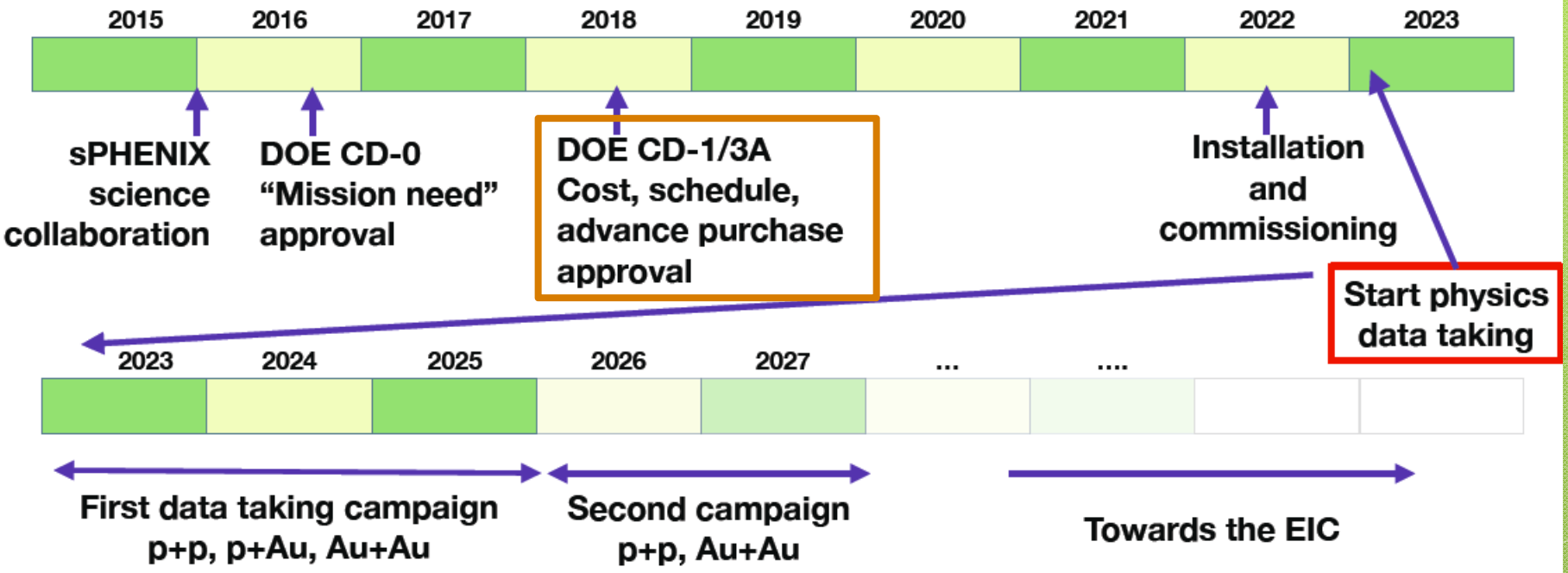


Ming Liu Talk Friday



Schedule

The milestone of CD-1 / CD-3A approval this past May means that sPHENIX is well on-track and its parts are already becoming a reality
First constructions are already underway!



Commissioning Data Taking in ~3 years!

Expanding Work on Many Fronts

In this talk I intend to give a sampling of the many on-going, and exponentially increasing, activities that are happening in sPHENIX in order to be ready for Day 1

My focus is on areas relevant to jet and prompt photon observables

Outline of talk:

- Basics
- Calorimeter Construction and Beam Tests
- EMCal
- Photon Reconstruction/Performance
- Jet Performance

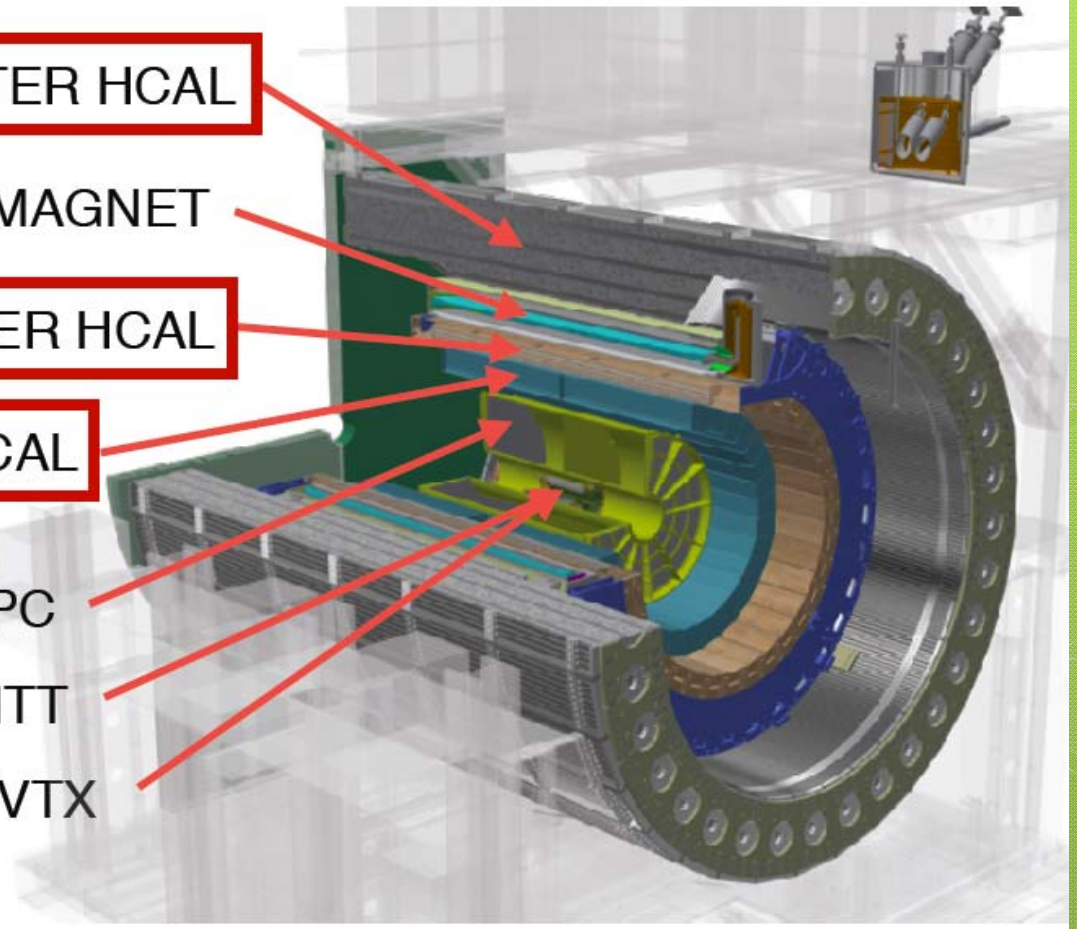
Detector

- Hermetic, Uniform 2π ϕ Acceptance:
  - $|\eta| < 0.85$ Base DOE MIE
  - $|\eta| < 1.1$ EMCal recent funding from Chinese consortium!

- Steel plates & scintillating tiles
- 3.8 λ
- Δη x Δφ ~ 0.1 x 0.1
- Also serves as a flux return

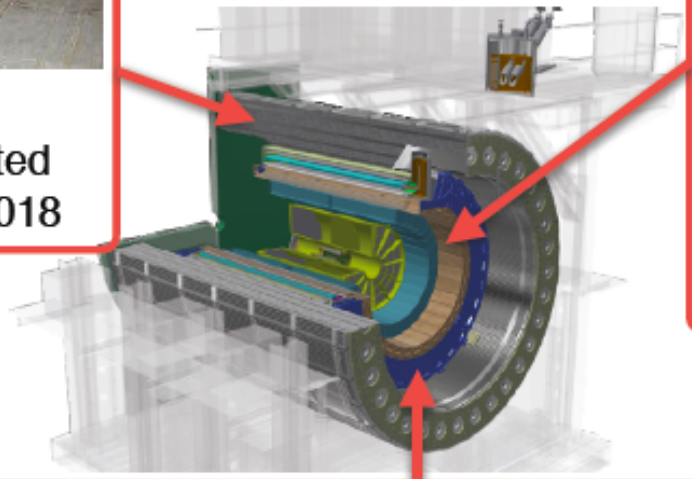
- Aluminum Frame
- 0.25 λ
- Potential to be instrumented for increased performance

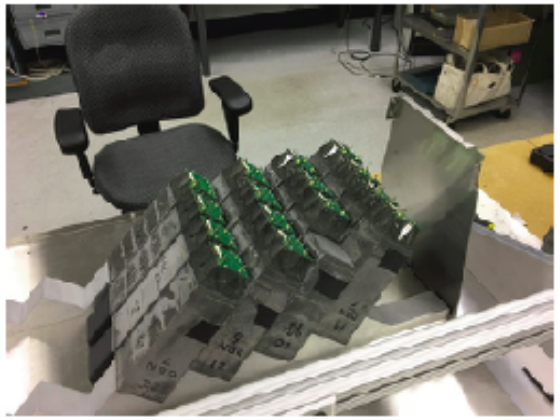
- Tungsten-Scintillating Fiber
- 18 X_0, 1 λ
- Δη x Δφ ~ 0.025 x 0.025



sPHENIX Build Underway!

OHCAL
Production sectors started arriving at BNL in Sep 2018





EMCAL
Sector 0 production underway

SC Magnet
Full field magnet test at 1.4 T at BNL in Feb 2018

Beam Tests

sPHENIX has been doing multiple beam tests since 2014 confirming performance expectations and optimizing design – reaping benefits

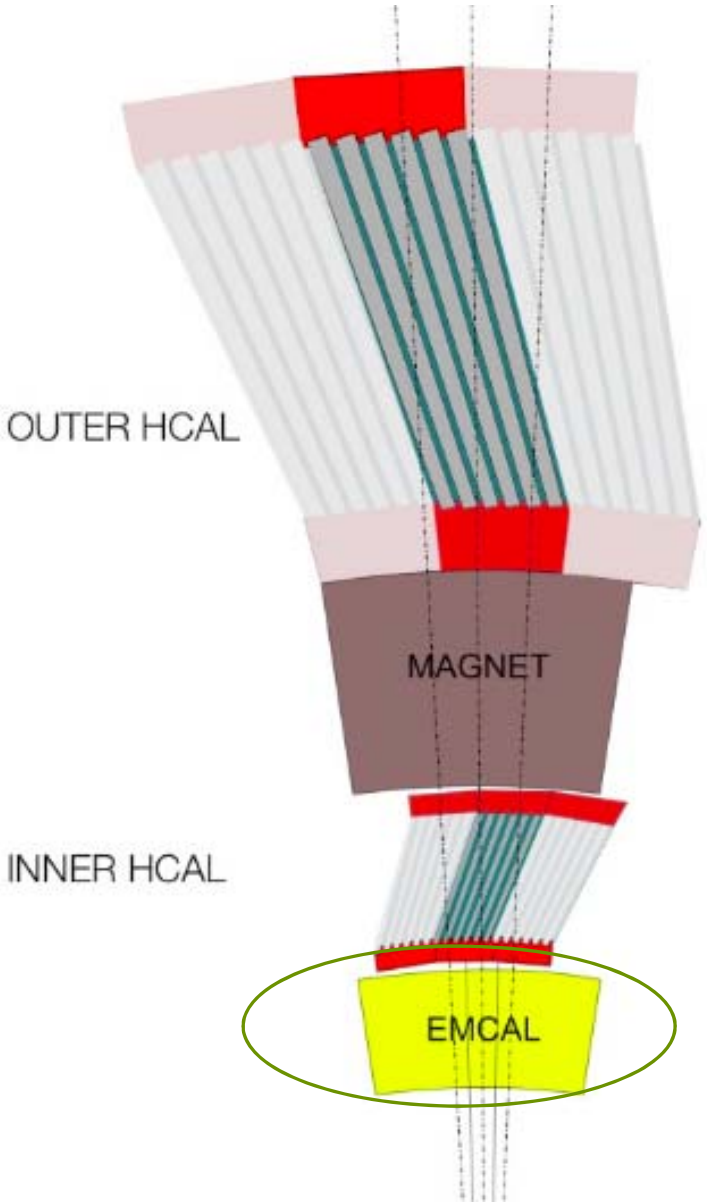
- 2014: Proof of Concept
- 2016: η~0 ϕ-projective prototype
  - arXiv.1704.01461
- 2017: η~0.9 2D η/ϕ-projective prototype
- 2018: Final prototype
  - First results already available!

Design and Beam Test Results for the sPHENIX Electromagnetic and Hadronic Calorimeter Prototypes

C.A. Aidala, V. Bailey, S. Beckman, R. Belmont, C. Biggs, J. Blackburn, S. Boose, M. Chiu, M. Connors, A. Franz, J.S. Haggerty, X. He, M.M. Higdon, J. Huang, K. Kauder, E. Kistenev, J. LaBounty, J.G. Lajoie, M. Lenz, W. Lenz, S. Li, V.R. Loggins, E.J. Mannel, T. Majoros, M.P. McCumber, J.L. Nagle, M. Phipps, C. Pinkenburg, S. Polizzo, C. Pontieri, M.L. Purschke, J. Putschke, M. Sarsour, T. Rinn, R. Ruggiero, A. Sen, A.M. Sickles, M.J. Skoby, J. Smiga, P. Sobel, P. Stankus, S. Stoll, A. Sukhanov, E. Thorsland, F. Toldo, R.S. Towell, B. Ujvari, S. Vazquez-Carson, C.L. Woody

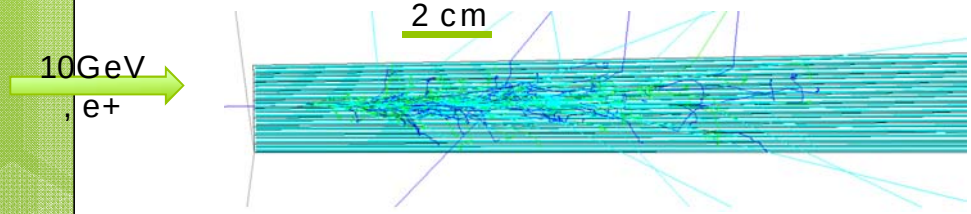
Full Calo Stack

- Very unique and complementary calorimeter design
- Unique at RHIC: full Hcal
  - Inner/Outer
  - Currently Inner de-scoped to be replaced w/ uninstrumented Al
- **Photon/EM Measurements Very Important in sPHENIX**
  - EMCal Located Inside Magnetic field region
  - SiPM Light Collection
  - Readout/SiPM temperature control inside field

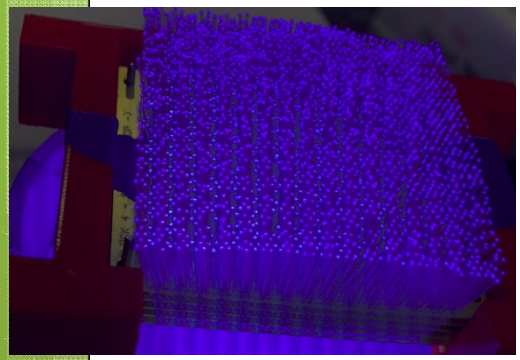


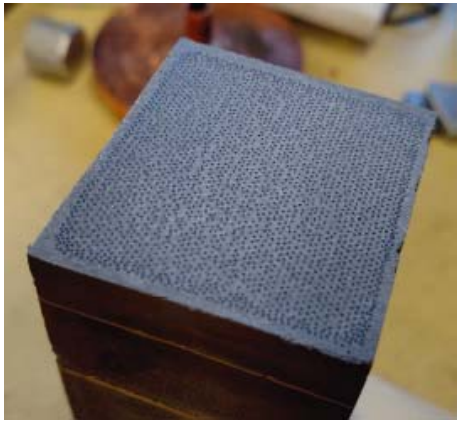
SPACAL EMCal

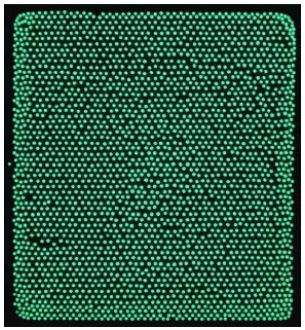
- "Heart" Technology: Novel Epoxy-bound Tungsten Powder & Fiber Spacal Design –Light collection from back end of fibers
- Block production techniques being finalized in current sector 0 prototype production



SPACAL Tower fibers displayed

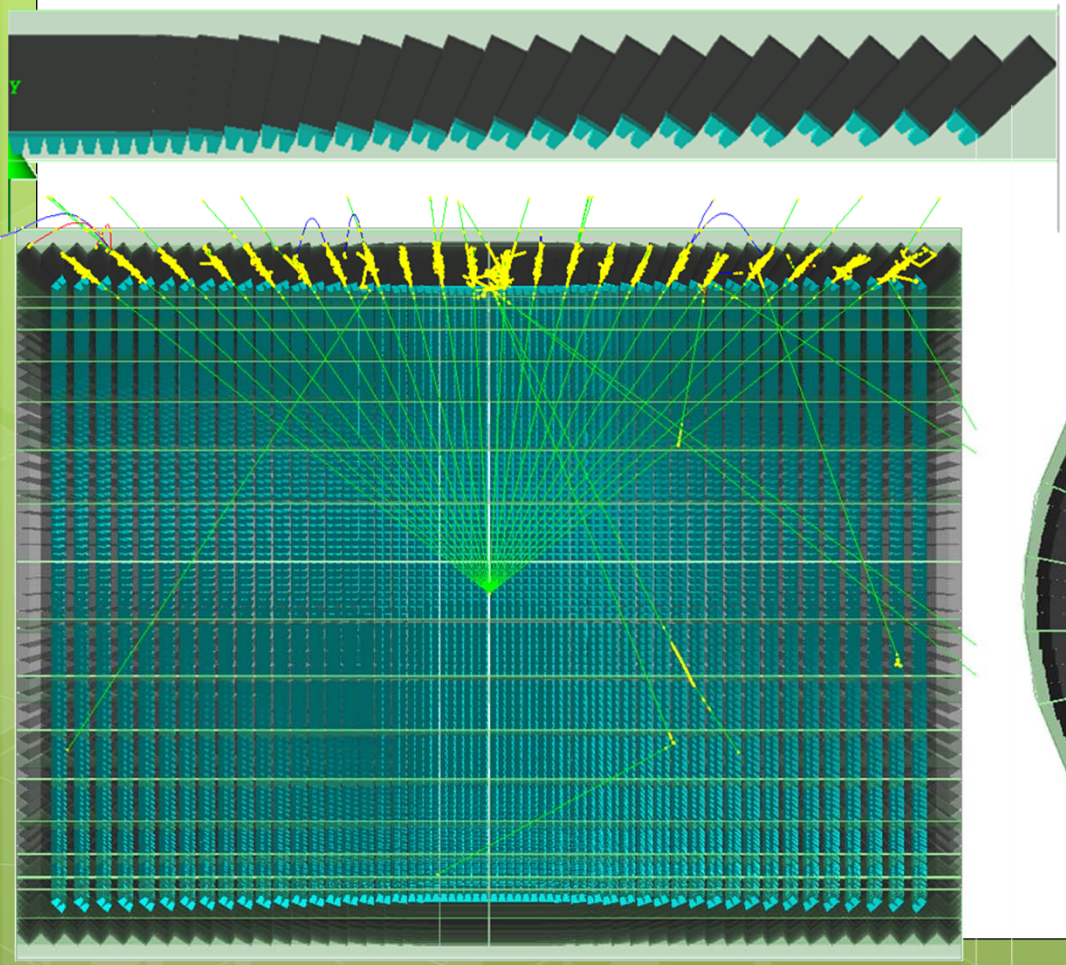




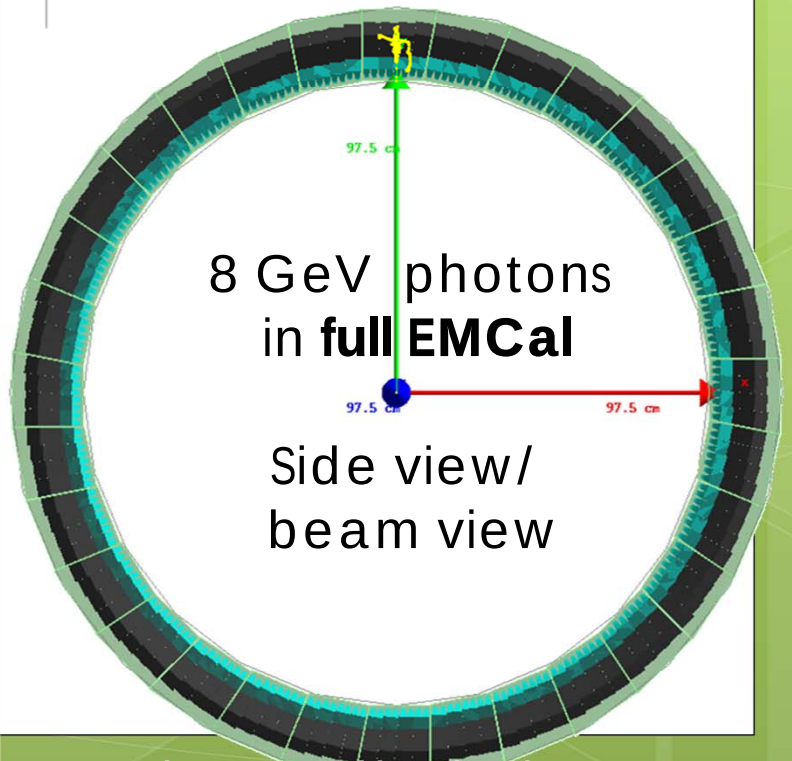


EMCal Simulations

- As with all of sPHENIX, extensive/intensive simulation iterations drive optimal detector development



EMCal Half Sector
(fibers simulated but hidden from display)

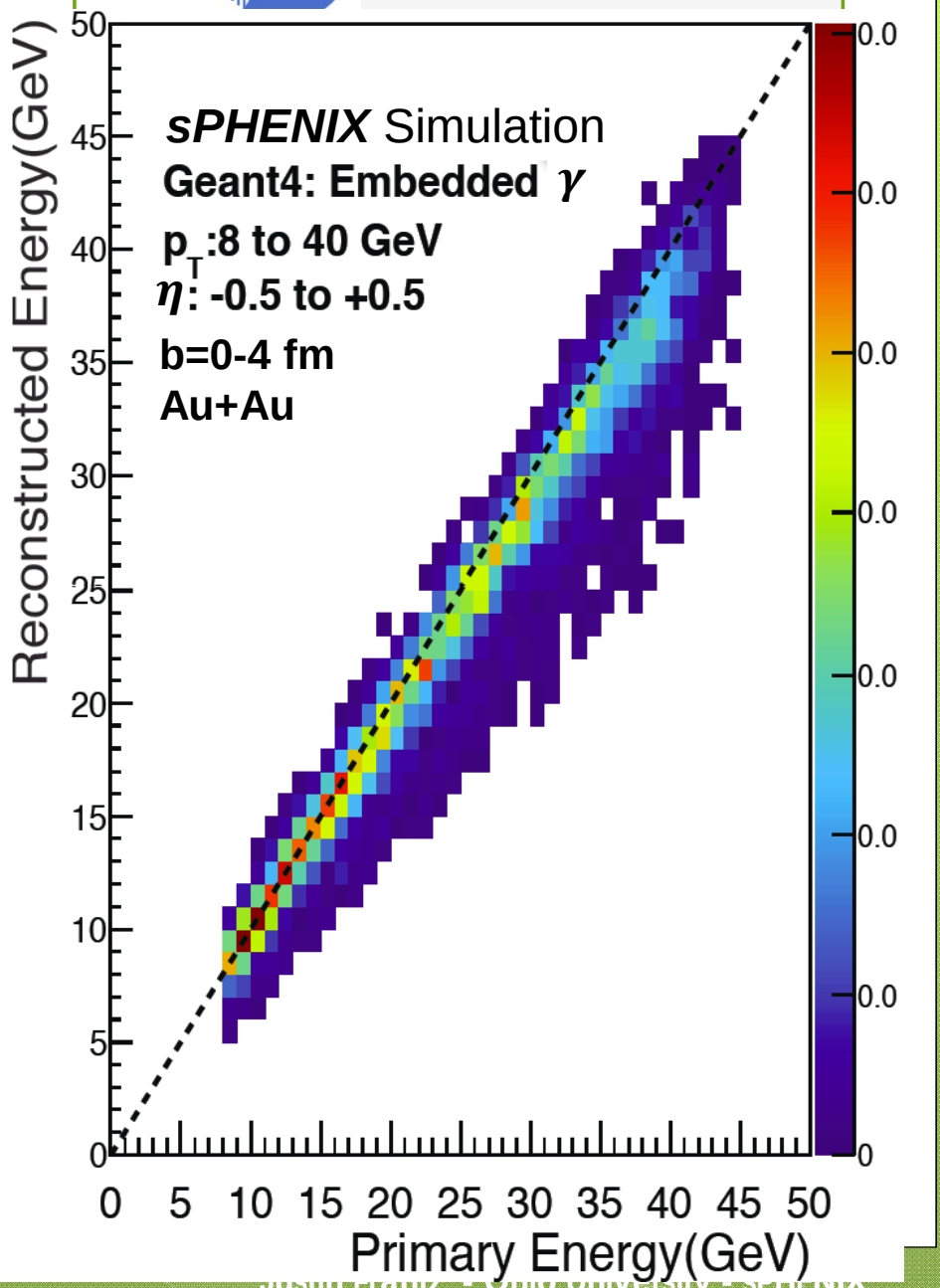


8 GeV photons in **full EMCal**

Side view/ beam view

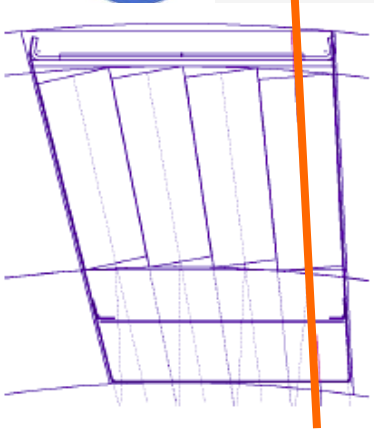
γ Response & Calibration

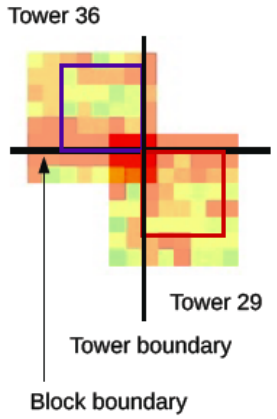
- Average response is well understood in simulation
- Well-connected to beam Tests
- Detailed calibration frameworks under development now
- Ensure detector will calibrated and ready for Day 1 data

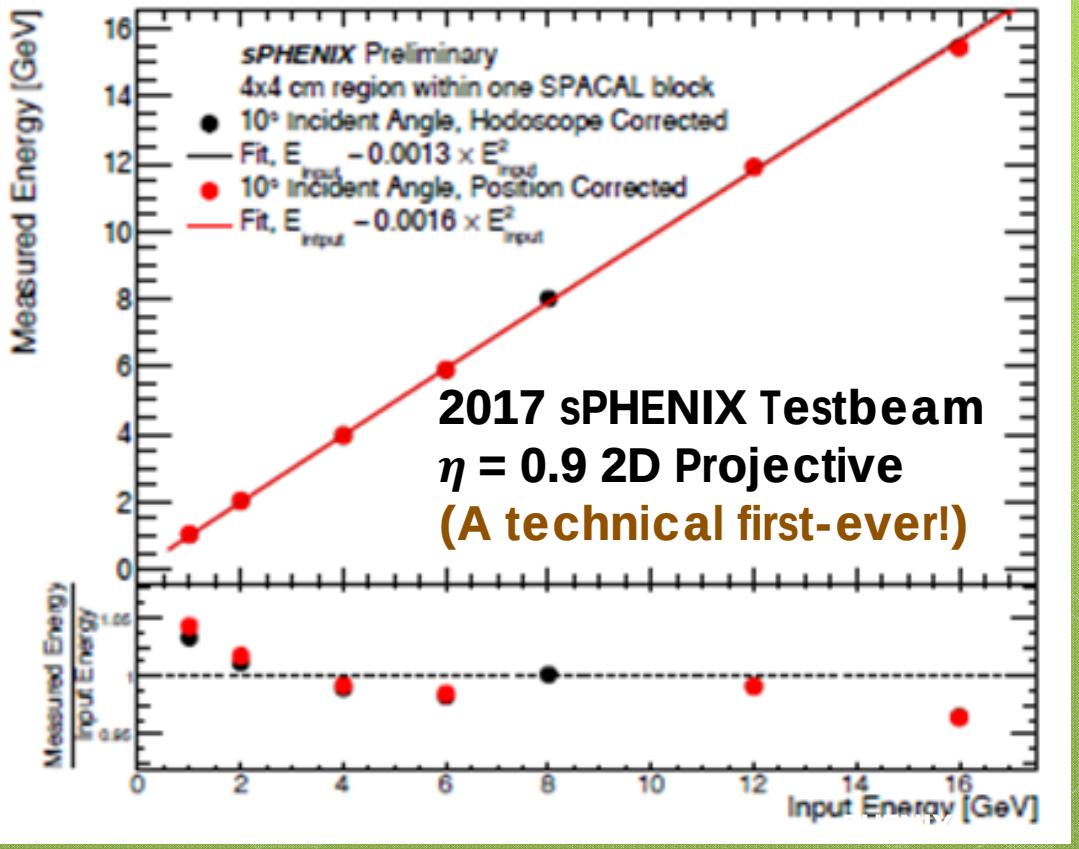


γ Response & Calibration

- Current work on detailed position-dependent response/ corrections
- Tilt angles (add slight non-projectivity) added to initial design improves uniformity
- Novel 2D (ϕ-η) projectivity improves uniformity at large η

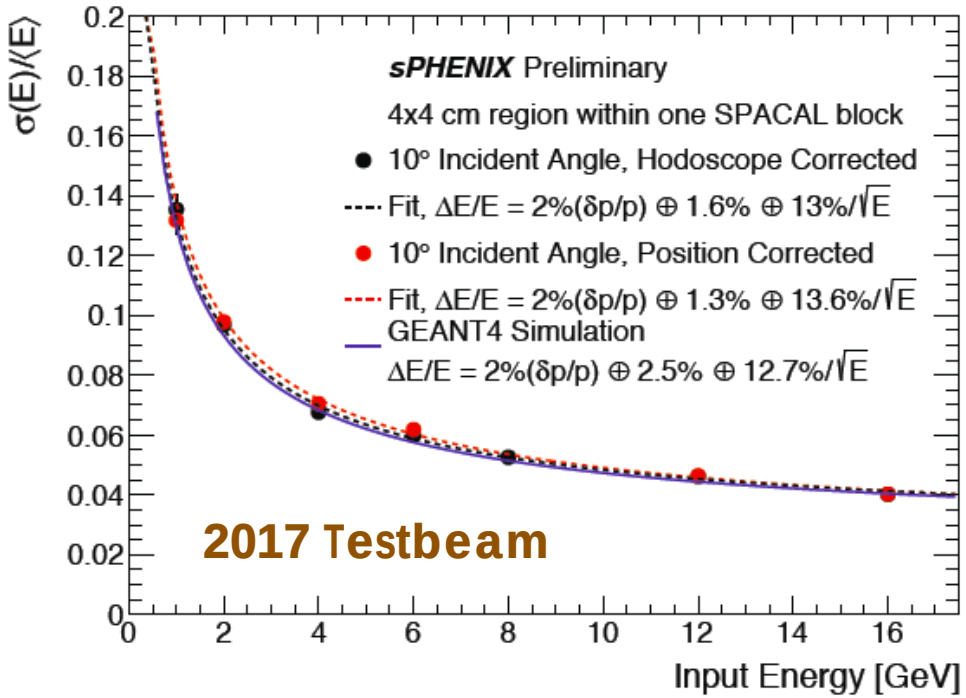


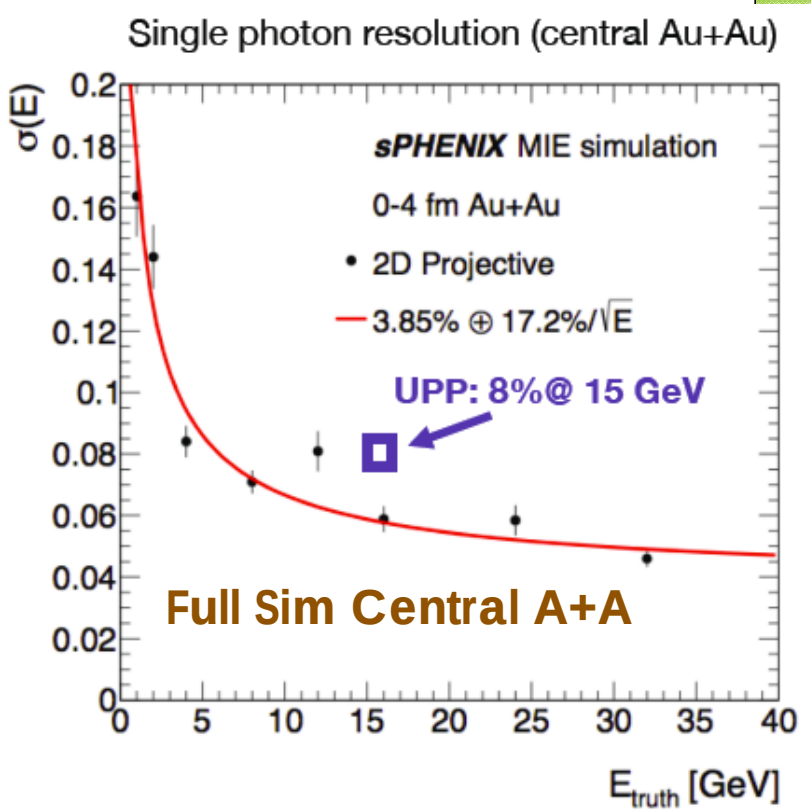




E_γ Resolution

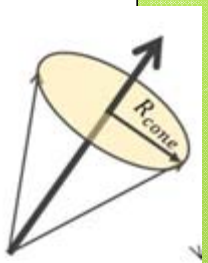
- EMC Resolution at all η Confirmed with Test Beam
- 2016 Testbeam publication results (mid-rapidity 1D)
- 2017/2018 Results at η = 0.9/2D Testbeam Results:
- Well below "UPP" DOE Performance Parameter

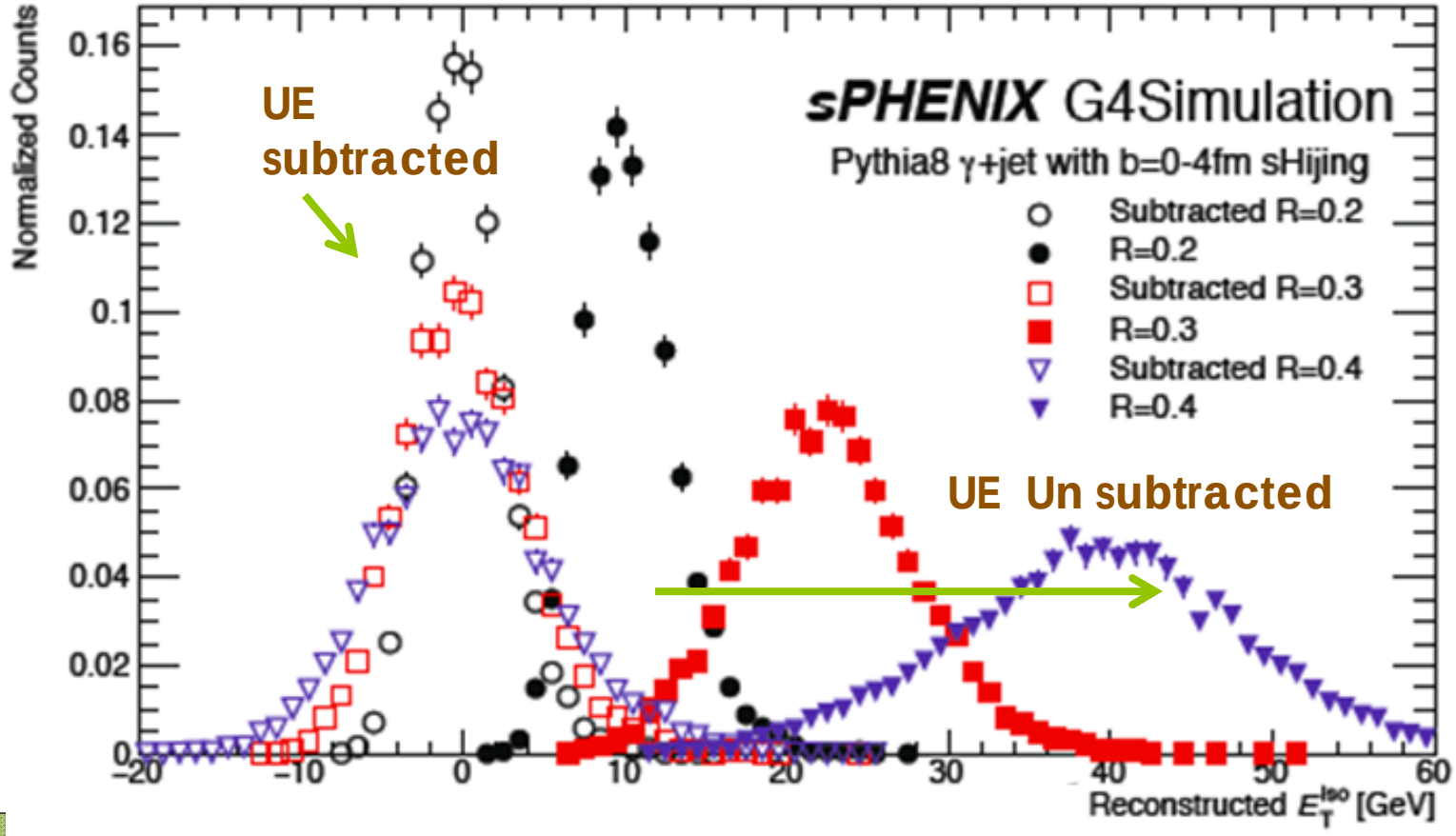




γ ID/ Isolation

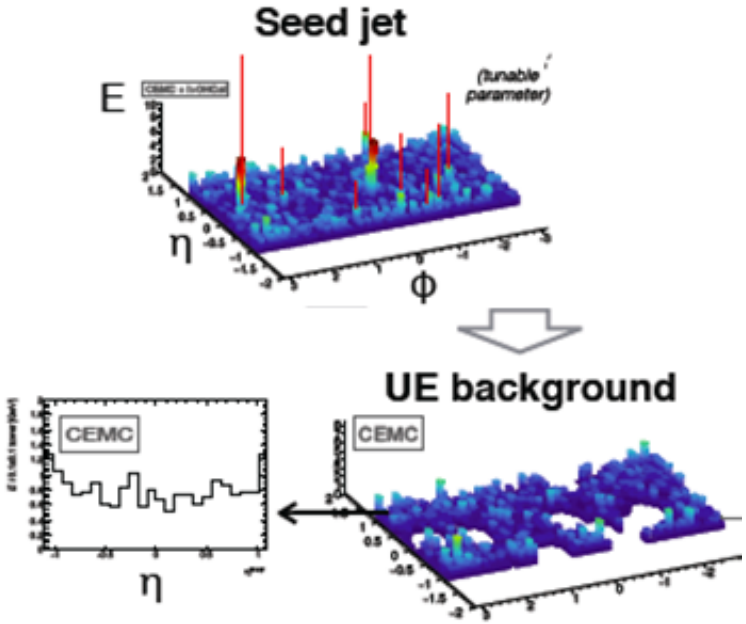
- EM Cluster shower shape ID/Isolation Cuts for γ ID currently being optimized
- Prompt photon Isolation depends on UE event subtraction performance
  - Same UE subtraction as for the jet analysis (next slide)

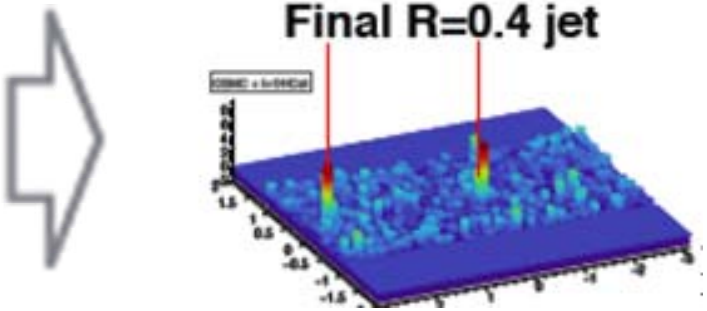




Jet Simulation & Default UE Subtraction

- Purely calorimetric jets through full GEANT Simulation
- PYTHIA8 QCD Dijet pp, Overlayed on HIJING in AuAu
- Iterative UE Subtraction algorithm based on ATLAS method. Currently being optimized for sPHENIX



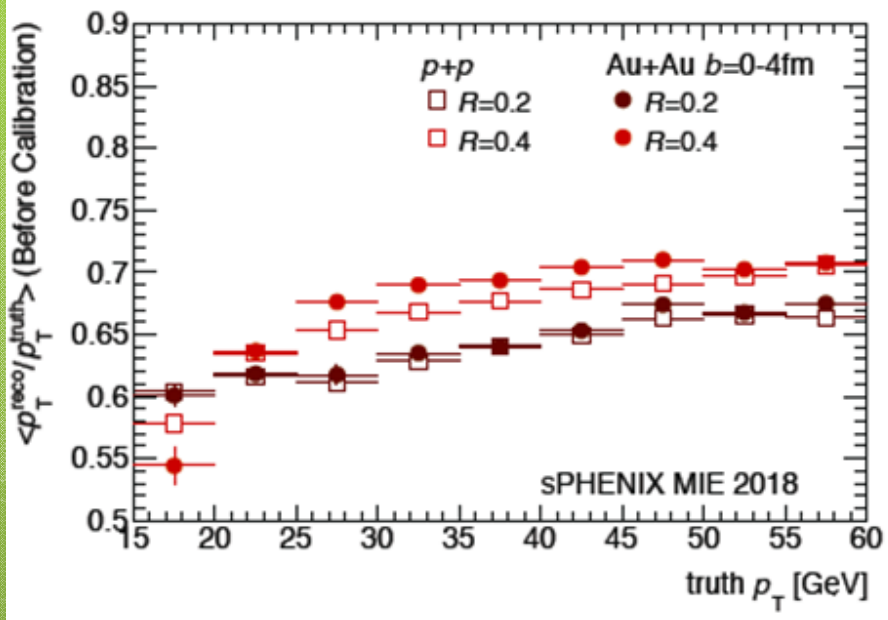


PRC 86 (2012) 024908

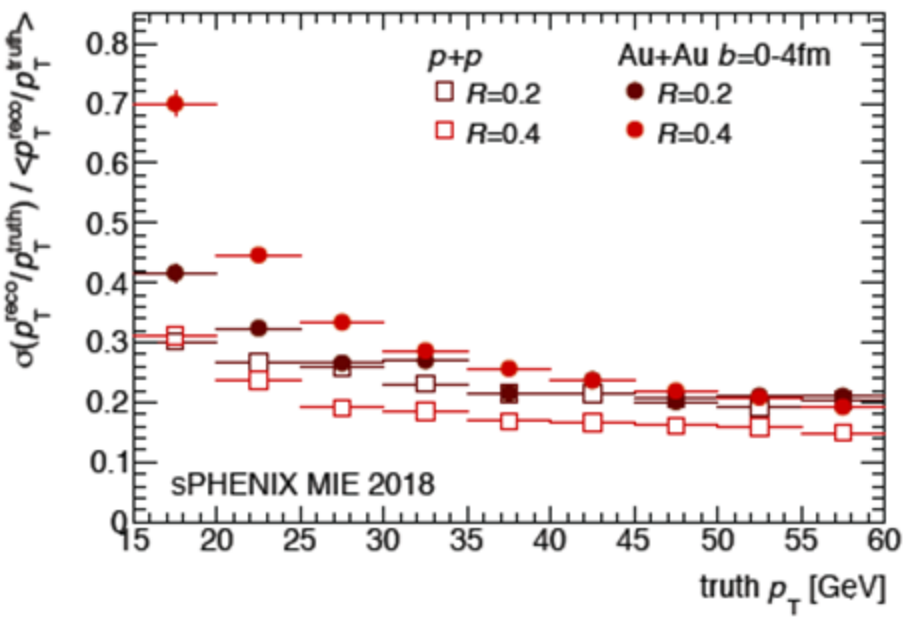
Overall Jet Perf

- Similar response in p+p and Au+Au → UE-independent
- At large R and low p_T dominated by UE fluctuations
- At small R or high p_T: dominated by intrinsic calo. resolution

Jet Response

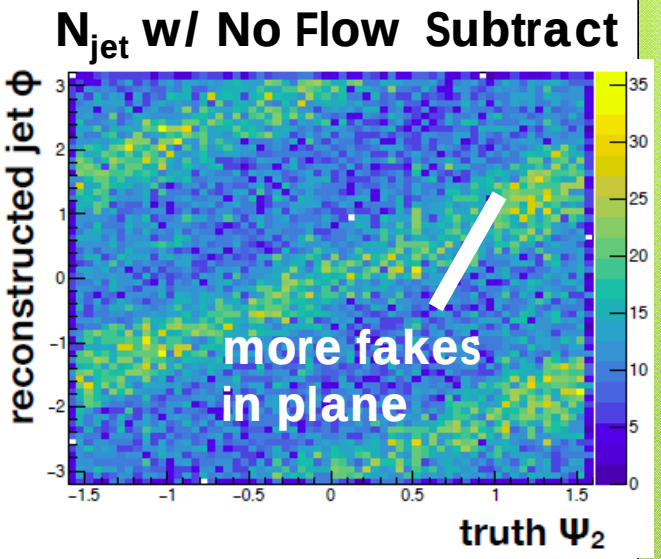


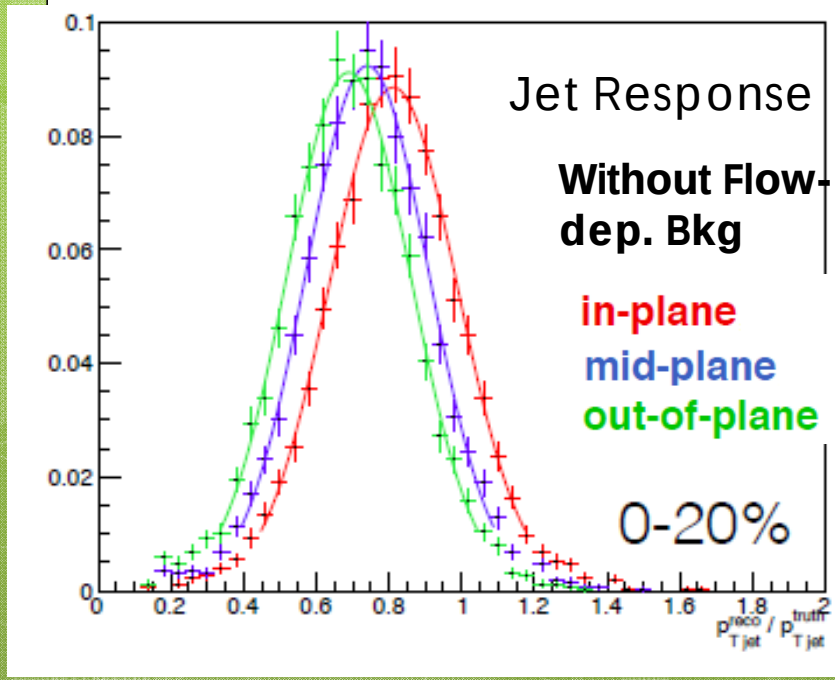
Jet Energy Resolution

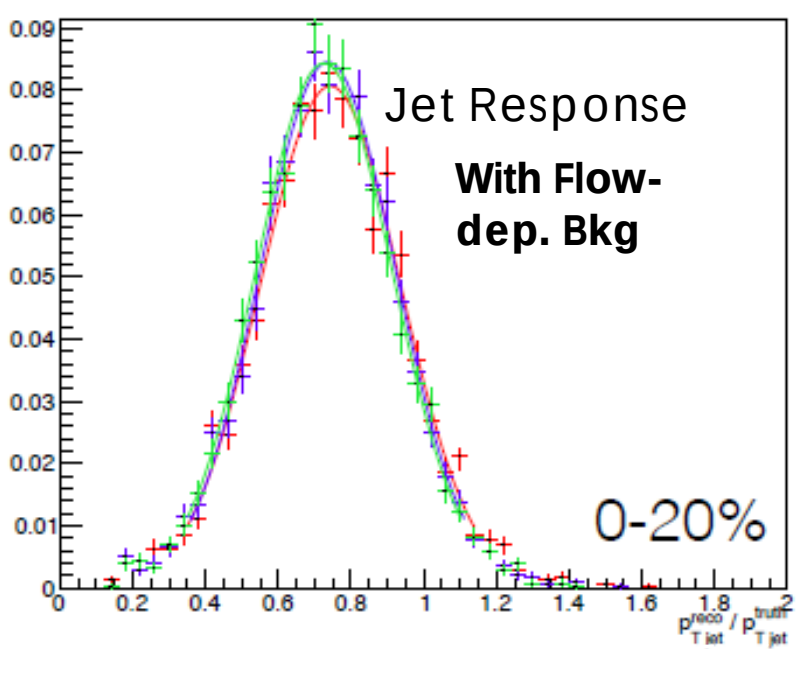


Flow Dependent Bkg

- Flow dependent bkg subtraction necessary – big resolution variation
- Using recent studies to study impacts and possible ways to provide additional event plane information if needed (in addition to BBC MinBias Detector MBD)



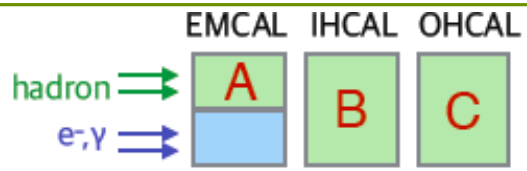




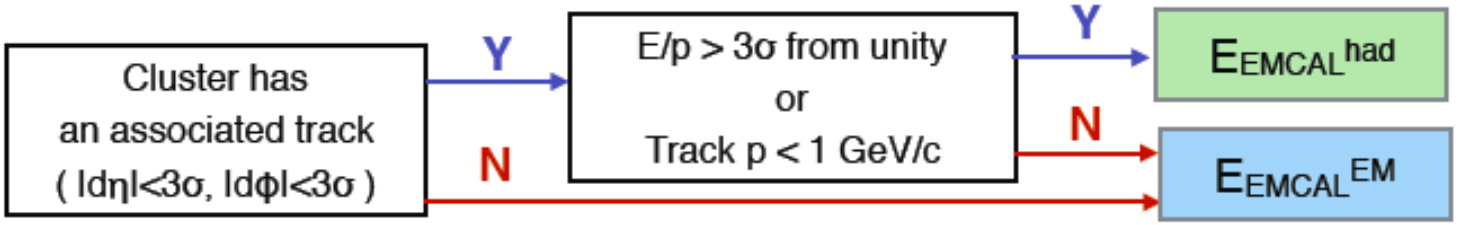
Jet Calibration

- Jet Calibration for purely calo jets:
- Account for different scale for hadronic showering in EMC vs EM showers

$$E^{RECO} = D\cdot(E_{EMCAL}^{EM} + A\cdot E_{EMCAL}^{had} + B\cdot E_{IHCAL} + C\cdot E_{OHCAL})$$

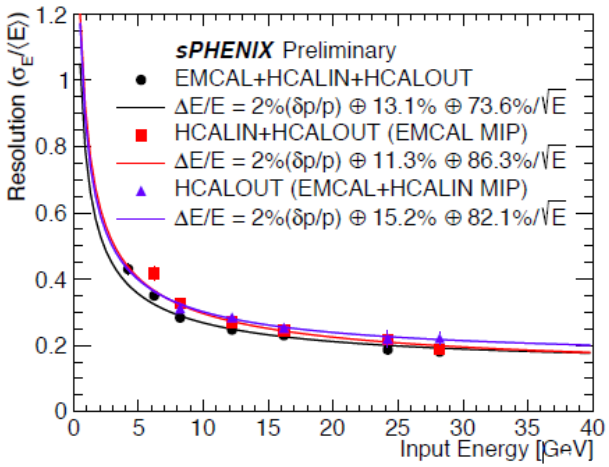


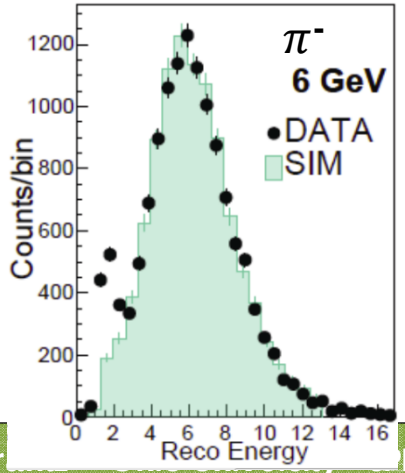
- Flow chart for EMCAL cluster selection



Another Key Component : HCal

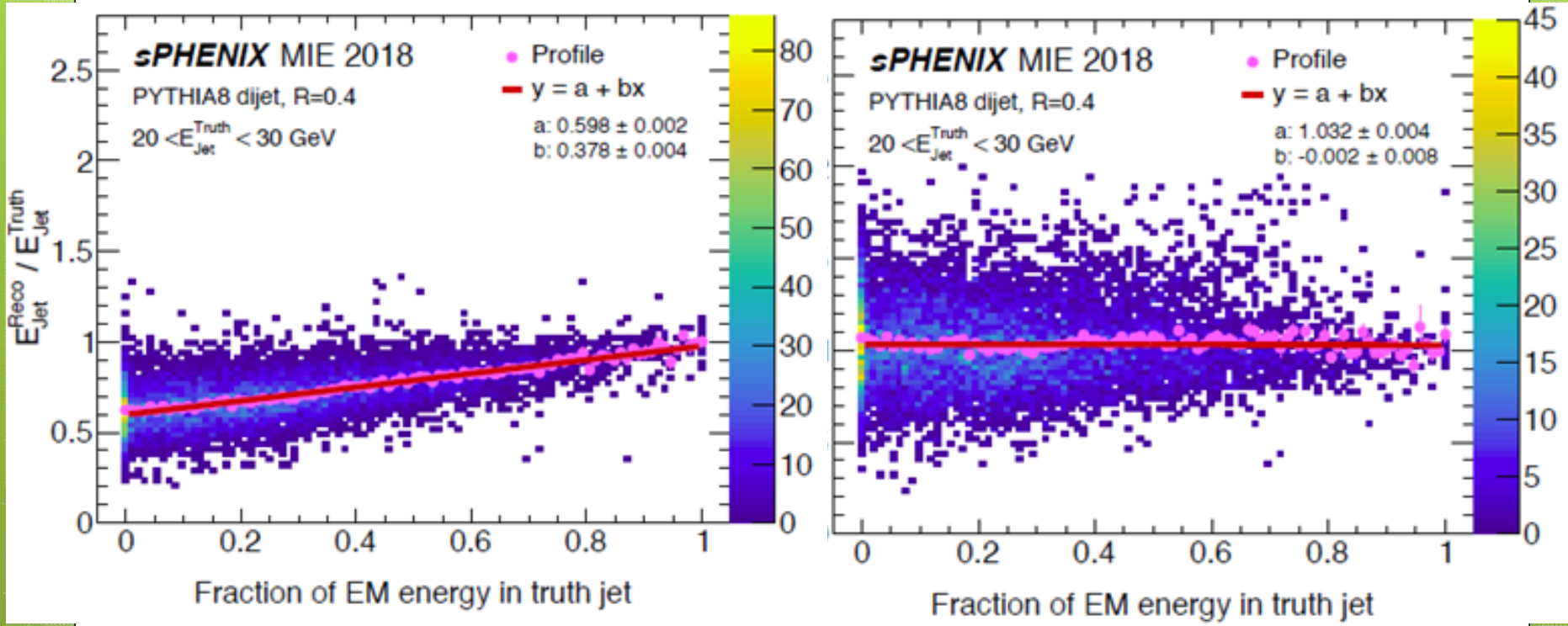
Testbeam performance→





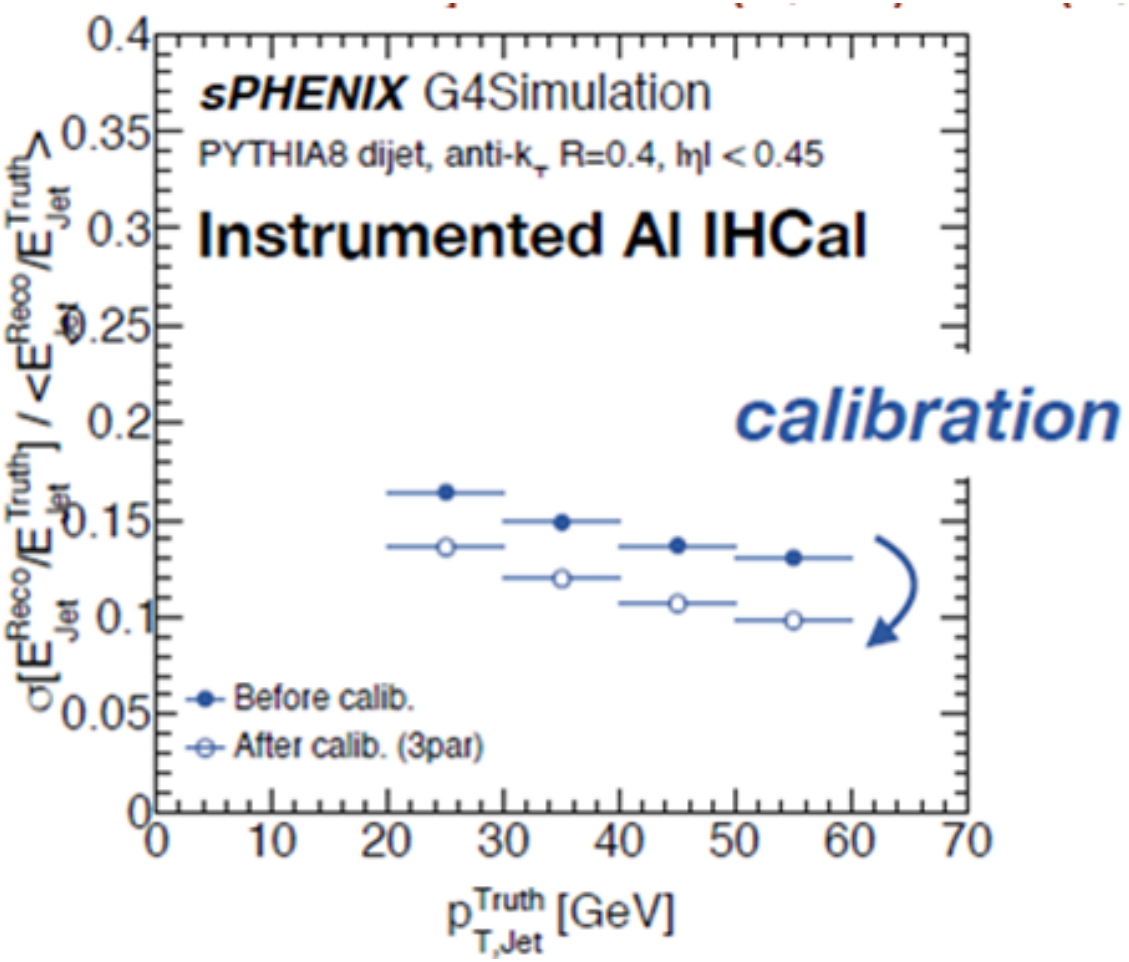
Jet Calib (cont.)

- Calibration Technique works well
- Response dependence on EM fraction ~removed
- Development of in-situ γ-jet methods for use with real-time data



Jet Calib in p+p

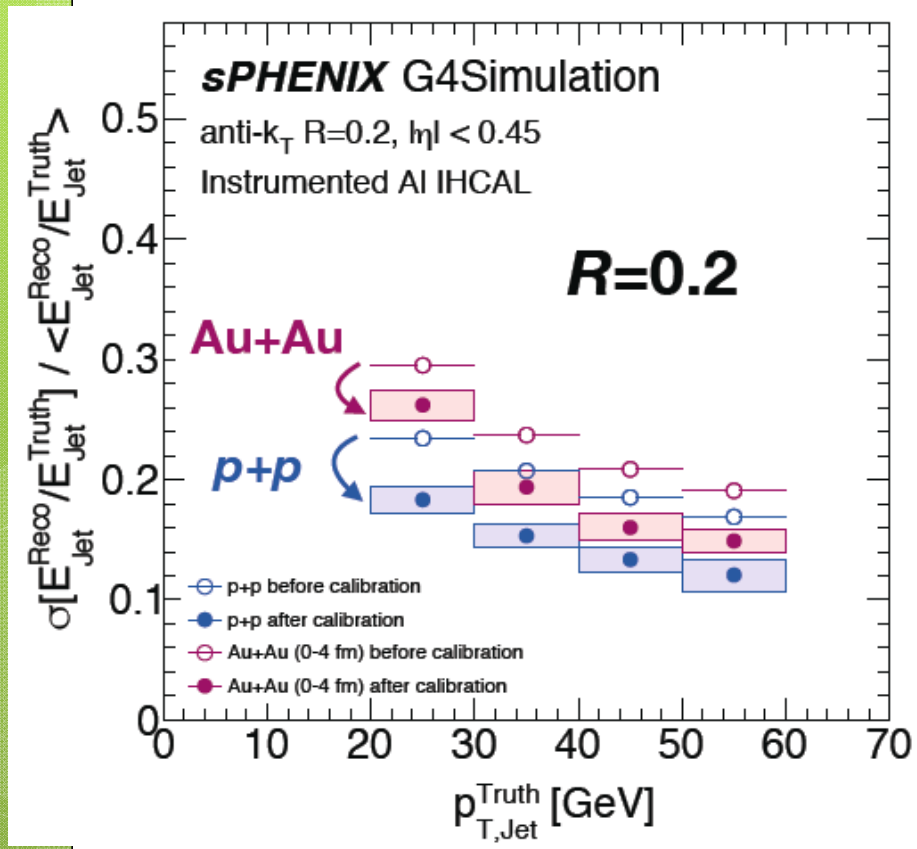
- Significant improvement in JER

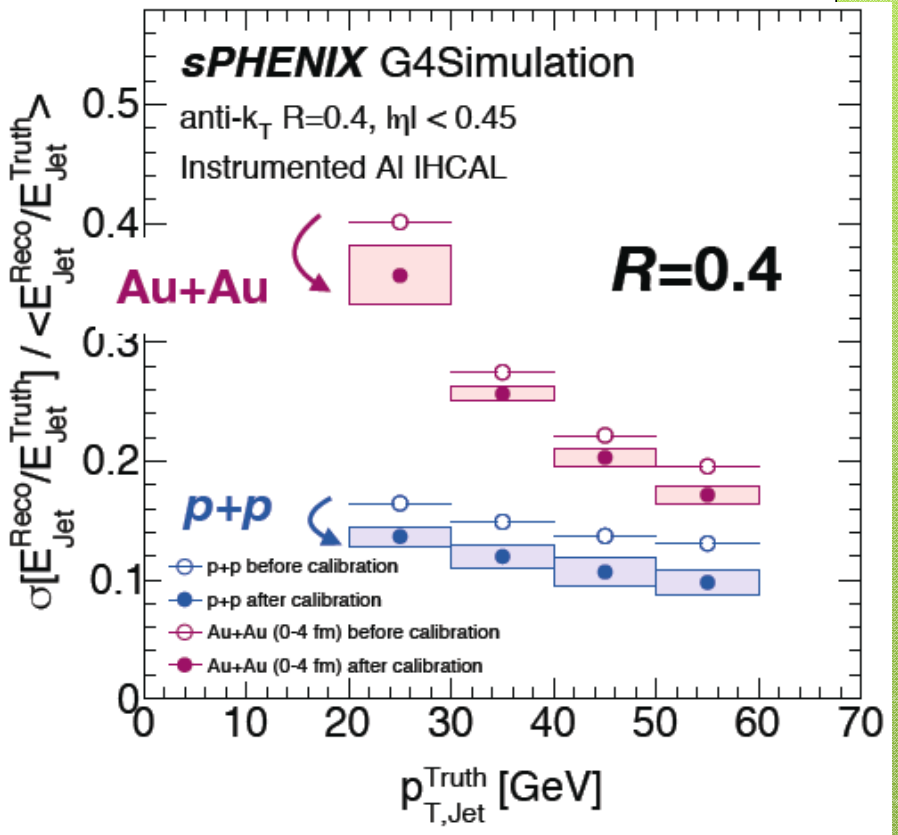


- **Descoping of Inner Hcal** Instrumentation **makes big difference** → NSF MRI for re-scoping

Jet Calib in AuAu

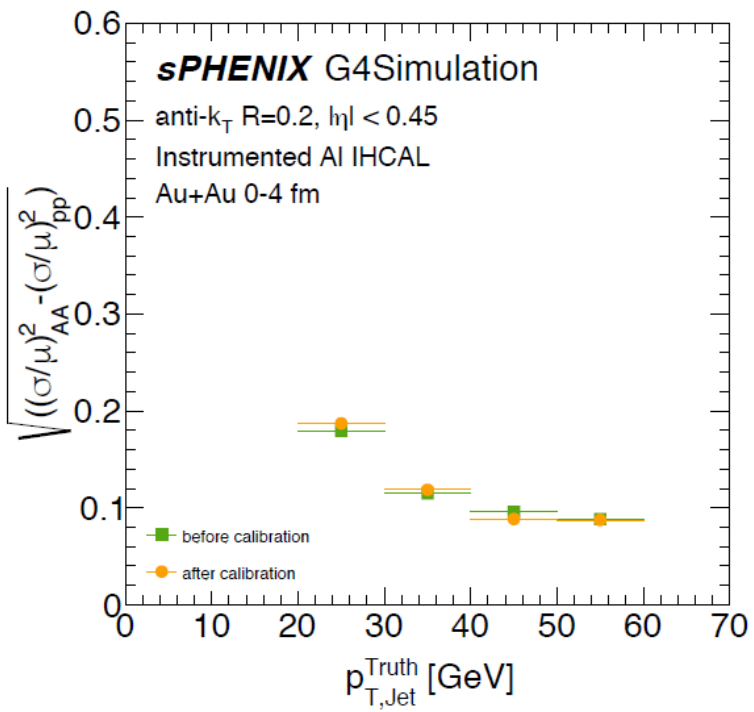
- Similar improvements in Central Au+Au

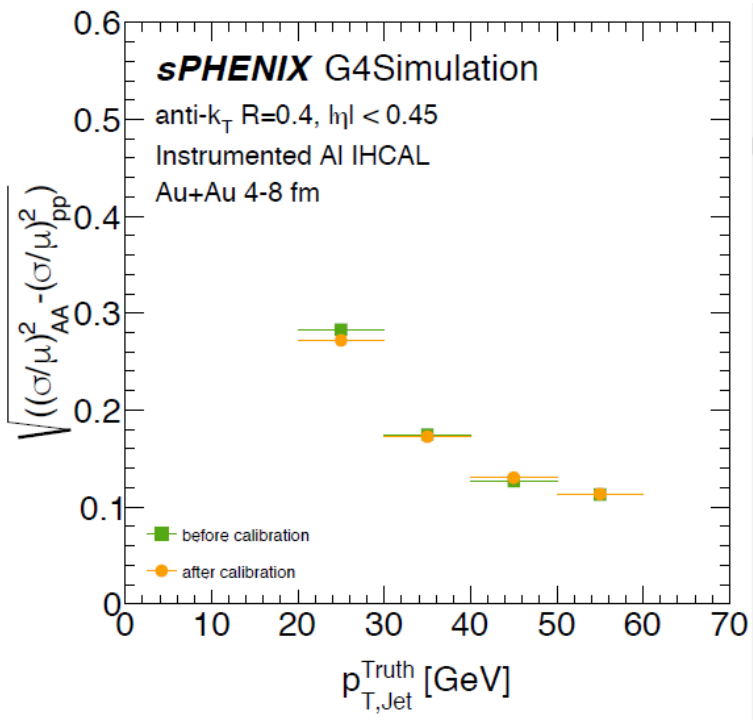




Jet Calib/UE Subtraction Interaction?

- Calibration and current UE bkg subtraction ~independent of one another





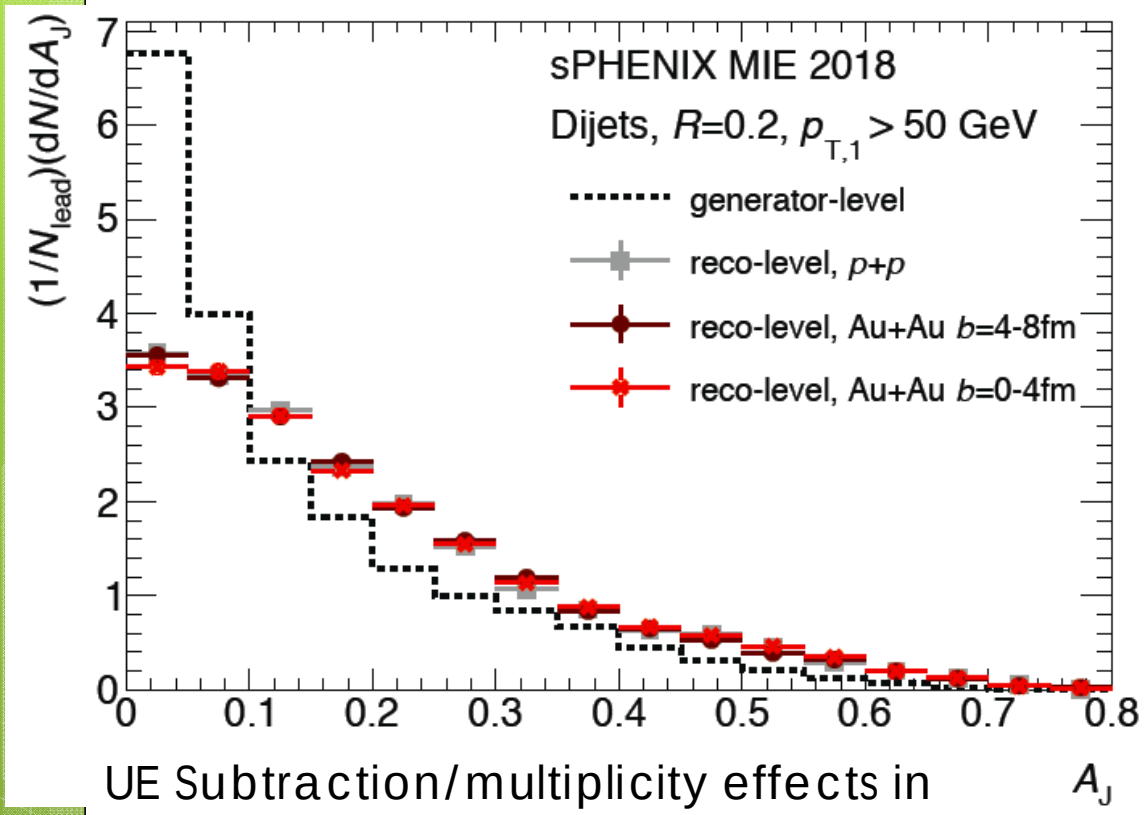
$$\frac{\sigma_{p_T}}{p_T} = \frac{n}{p_T} \oplus \frac{s}{\sqrt{p_T}} \oplus c$$

Noise Stochastic Constant

Dijet Asymmetry

Now go through some jet performance plots....

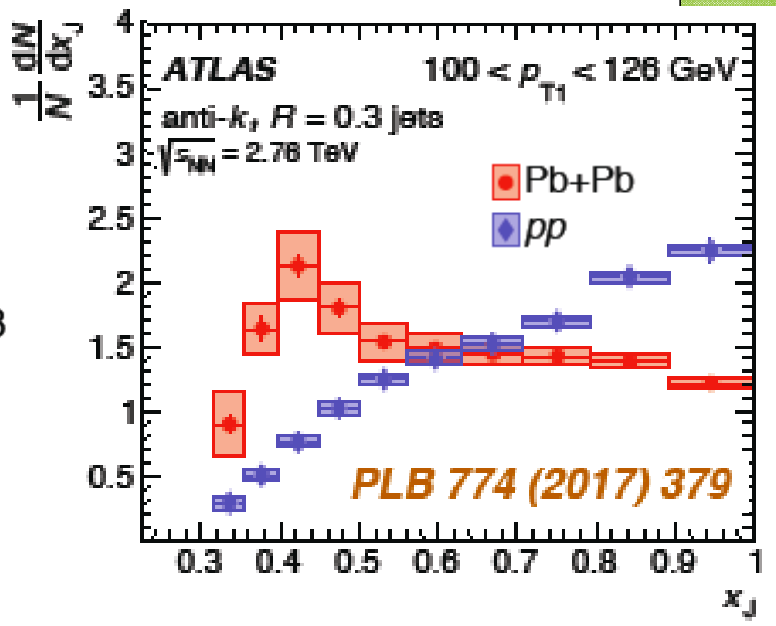
- Di-jet asymmetries, reco-level



$$A_J = \frac{p_{T1} - p_{T2}}{p_{T1} + p_{T2}} = \frac{1 - x_J}{1 + x_J}$$

$$x_J = \frac{1 - A_J}{1 + A_J} = \frac{p_{T2}}{p_{T1}}$$

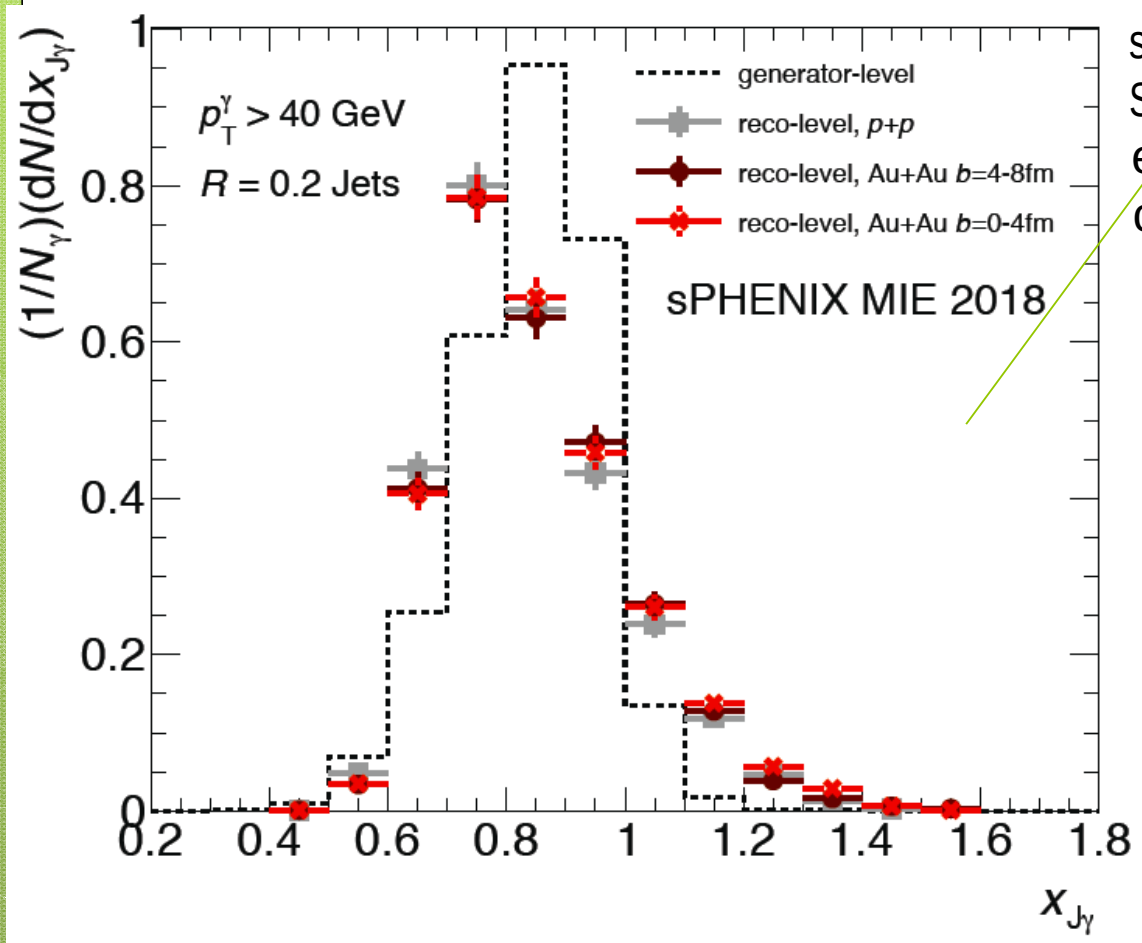
UE Subtraction/multiplicity effects in Au+Au under control



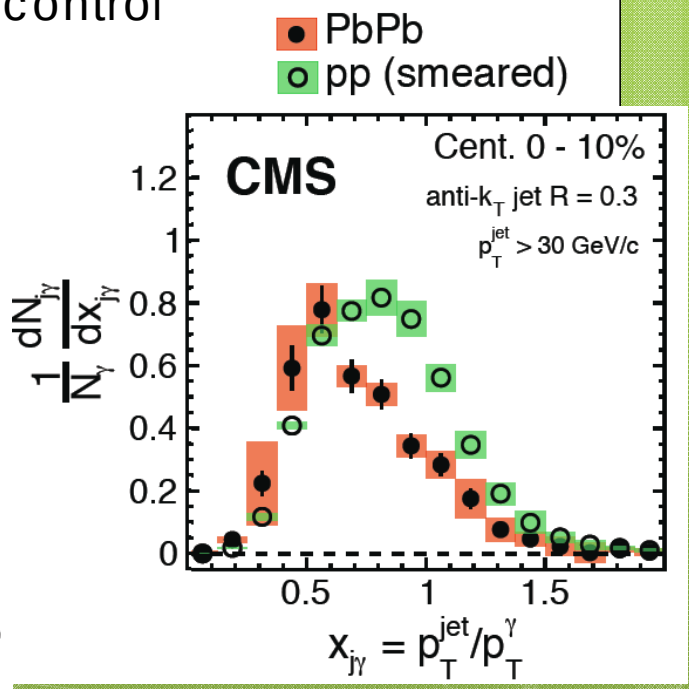
Eventually fully unfolded x_J distribution

Prompt γ (1)

- Keep probe quark flavor constant between LHC/RHIC by looking at γ-Jet
- $x_{J\gamma}$ (= $p_{T\,jet}/p_{T\gamma}$) distributions

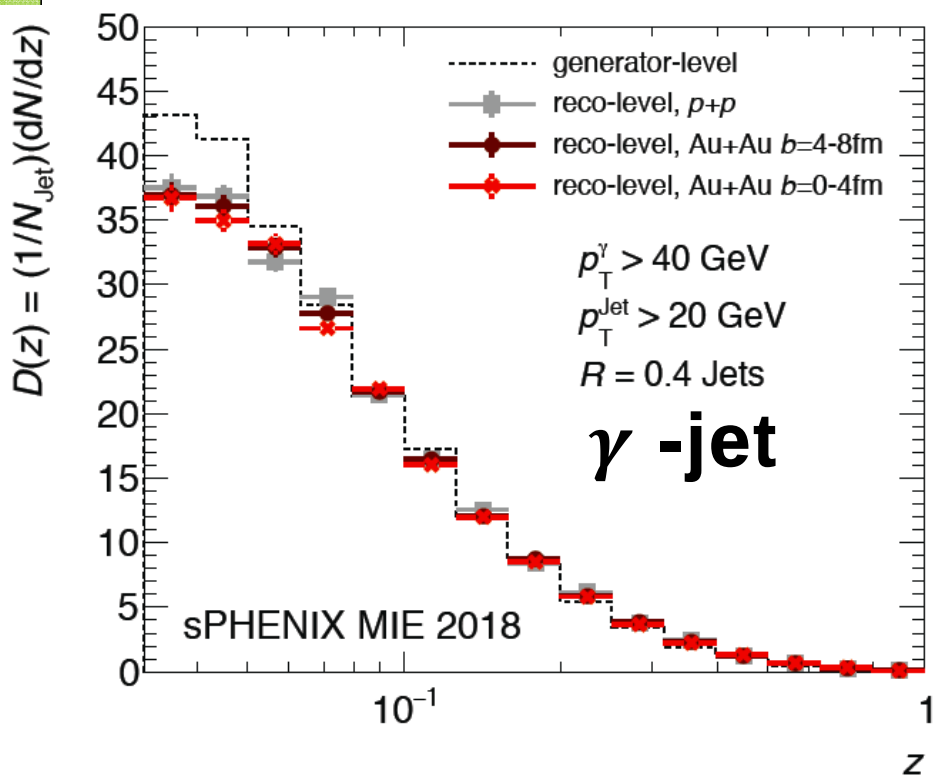


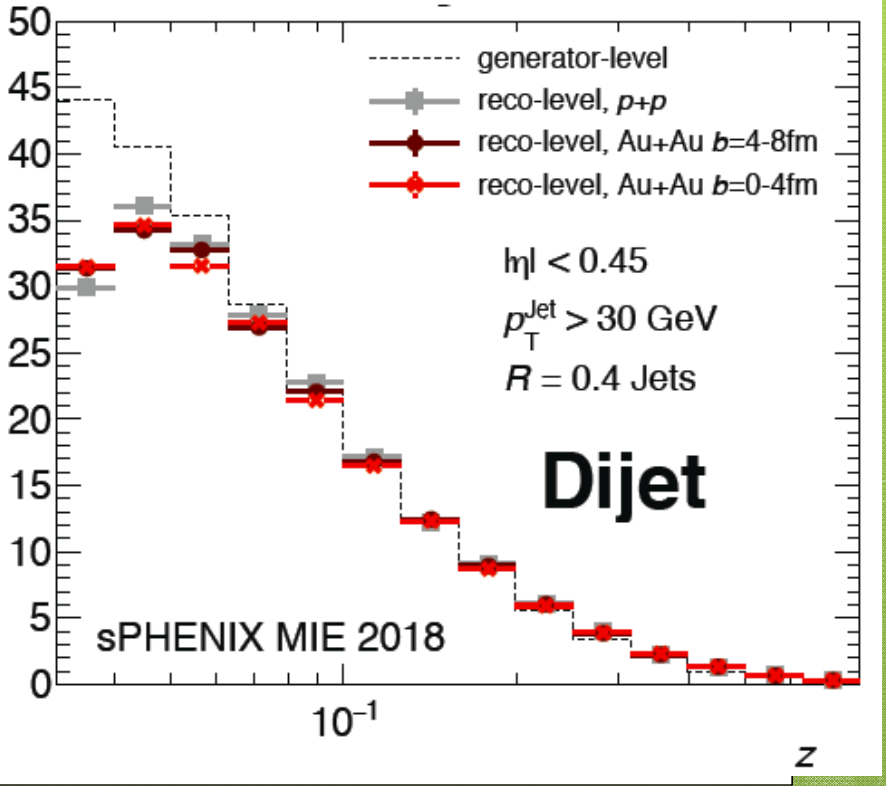
sPHENIX UE Subtraction/multiplicity effects in Au+Au under control



Prompt γ (2)

- Keep probe quark flavor constant between LHC/RHIC by looking at γ-Jet
- γ –jet and Dijet performance same from p+p through high multiplicity Au+Au

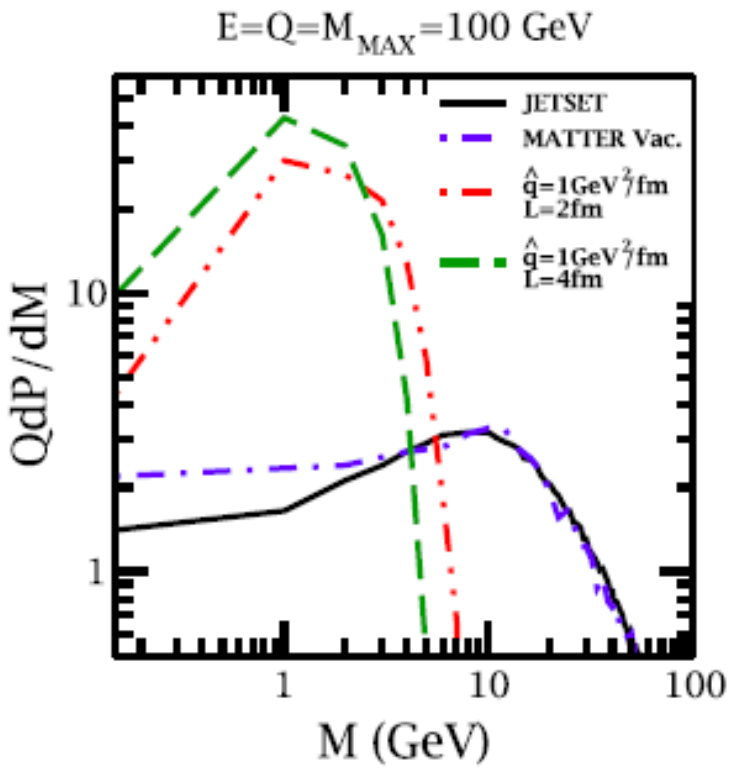




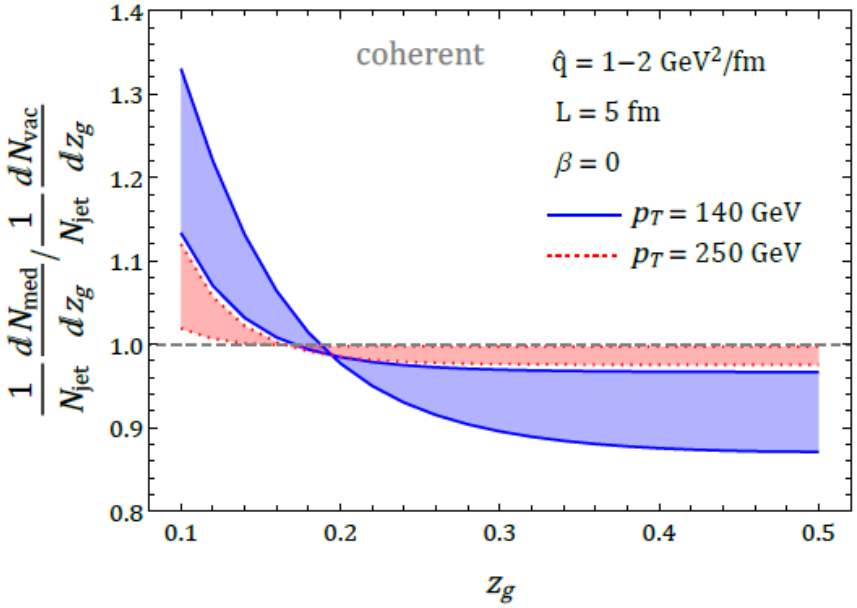
Other Observables?

- Evaluating capabilities for other observables

Jet Mass

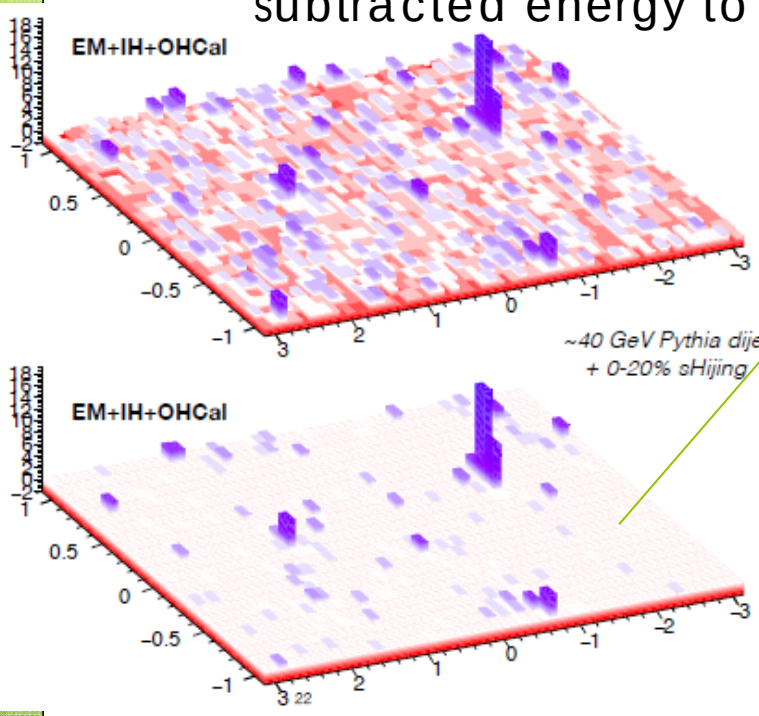


Jet Grooming

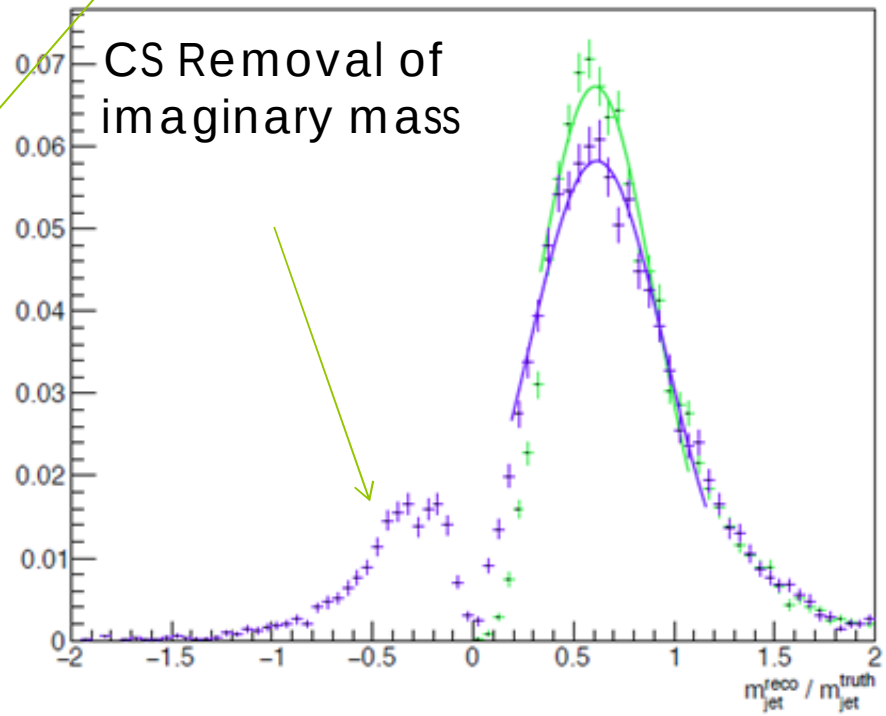


First Look: Alternative Constituent UE Subtraction Method

Alternative background subtraction technique redistributes subtracted energy to keep subtracted E > 0 everywhere



Jet Mass?



Absolute (ungroomed) mass response

Conclusions

- sPHENIX CD-1/3A Approval in 2018!
- **sPHENIX Initial Construction has begun** and is already ramping up into production mode for calorimeter systems
- Calorimeter design tweaks ~finalized through comprehensive beam tests
- **Software preparations** such as **calibration techniques** and background subtractions for calorimeters, photons, hadrons, and jets, are reaching new levels of sophistication matching the physical construction rate
- sPHENIX poised to make exciting comparisons of LHC vs RHIC QGP as seen with jet observables !

Backup