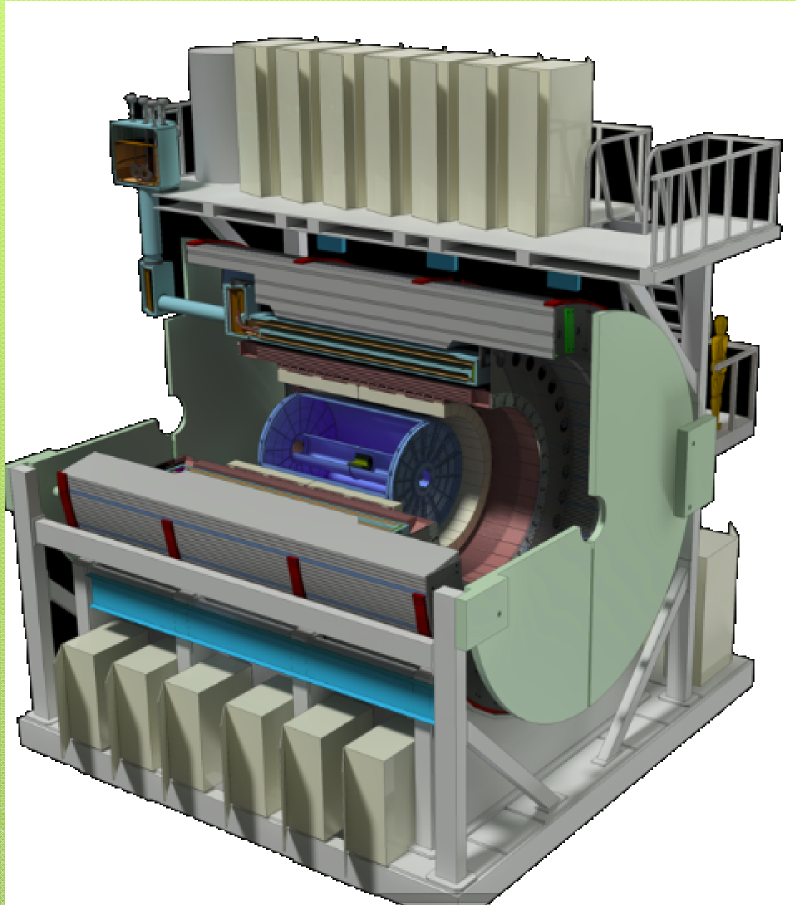


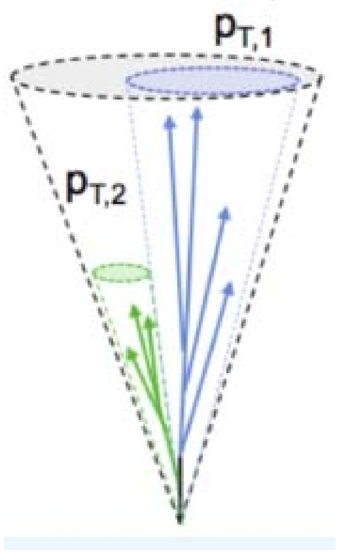
# Exciting Jet and Prompt Photon Physics Provided by sPHENIX

Justin Frantz
Ohio University
WWND ‘19
1/7/2019

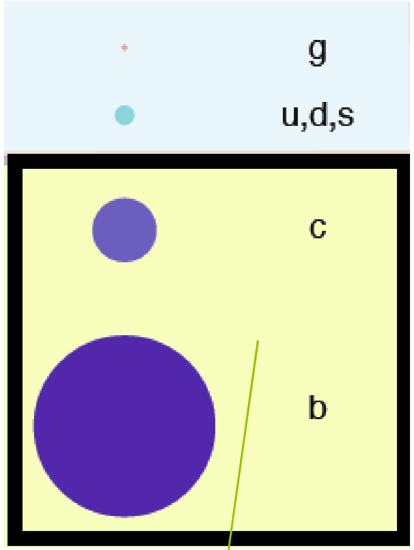
# Science Mission

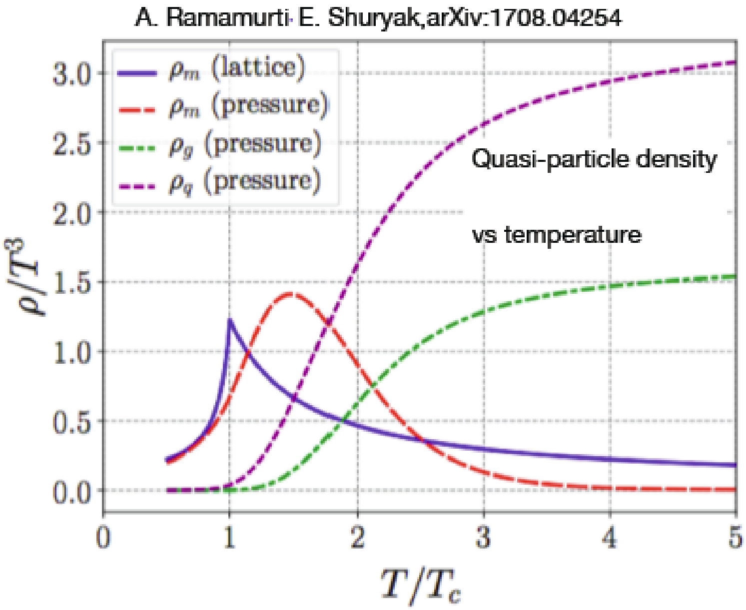
- sPHENIX Goals (LRP): **1)** Probe Inner structure of QGP with jet probes of wide range of $Q^2$ and color charge/ flavor **2)** Explore T-dependent QGP Structure by observing directly comparable jet modifications of "More $T_C$" QGP @ RHIC vs LHC

**Jet Structure**




**g/q Flavor**

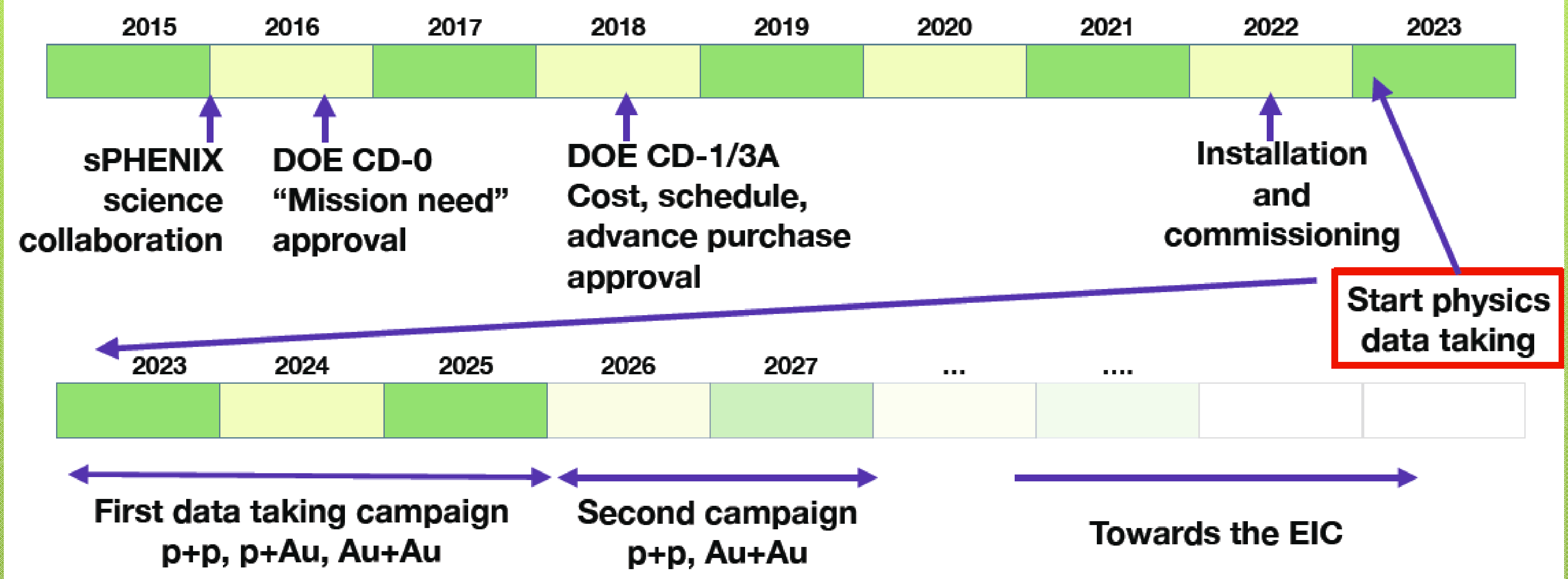



**MVTX Addition!** **Ming Liu Talk Friday**

# Schedule

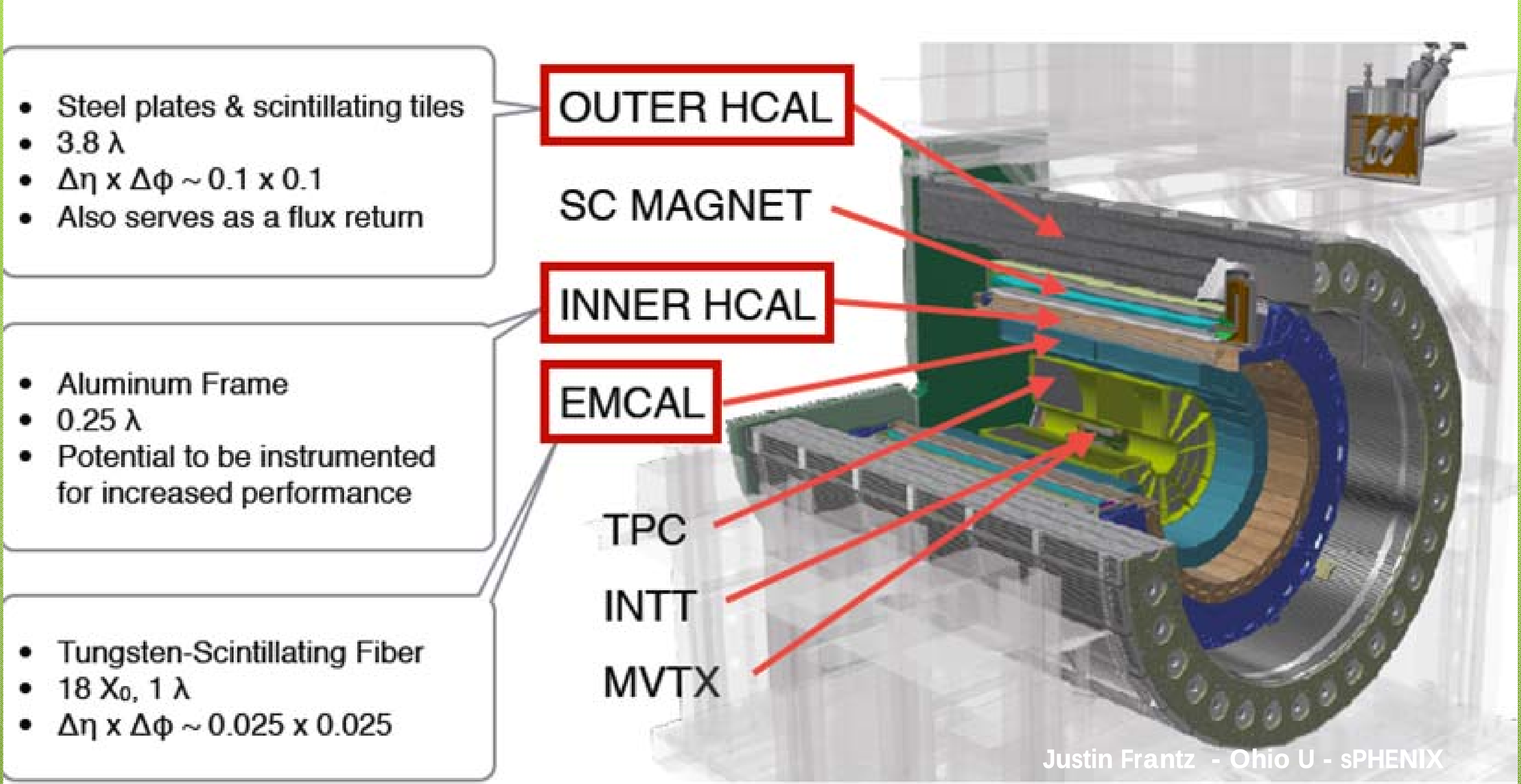
Commissioning Data Taking in ~3 years!




In this talk I would like to give a sampling of the many on-going activities that are increasing exponentially to ready for Day 1

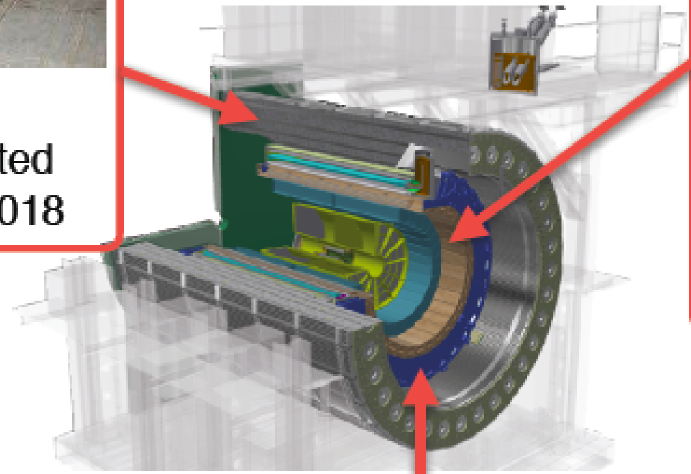
# Detector

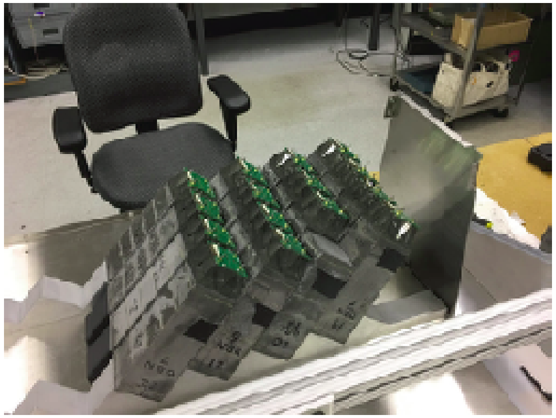
- Hermetic Uniform $2\pi\ \phi$ Acceptance:
  - $|\eta| < 0.85$ Base DOE MIE
  - $|\eta| < 1.1$ EMCal recent funding from Chinese Consortium!



# sPHENIX Build Underway

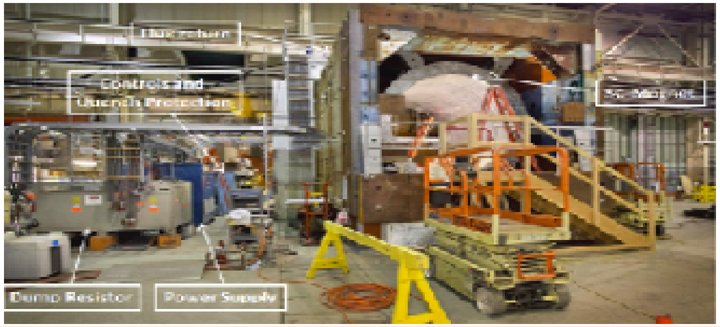
**OHCAL**
Production sectors started arriving at BNL in Sep 2018





**EMCAL**
**Sector 0 production underway**

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



# Beam Tests

sPHENIX has done multiple beam tests since 2014 to confirm performance expectations and optimize design options – reaping benefits now

Beam

- Feb 2014: Proof of Principle
- Apr 2016: η~0 prototype
  → arXiv.1704.01461
- Feb 2017: η~0.9 prototype
- Feb-May 2018: Final η~0.9 prototype

First results already available

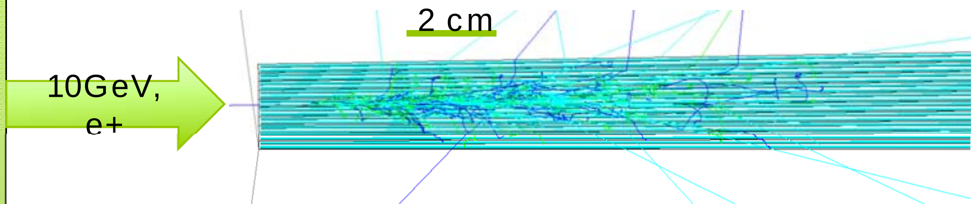
This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TNS.2018.2879047, IEEE Transactions on Nuclear Science

1

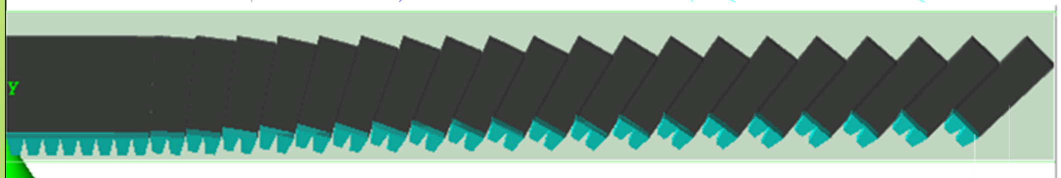
## Design and Beam Test Results for the sPHENIX Electromagnetic and Hadronic Calorimeter Prototypes

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

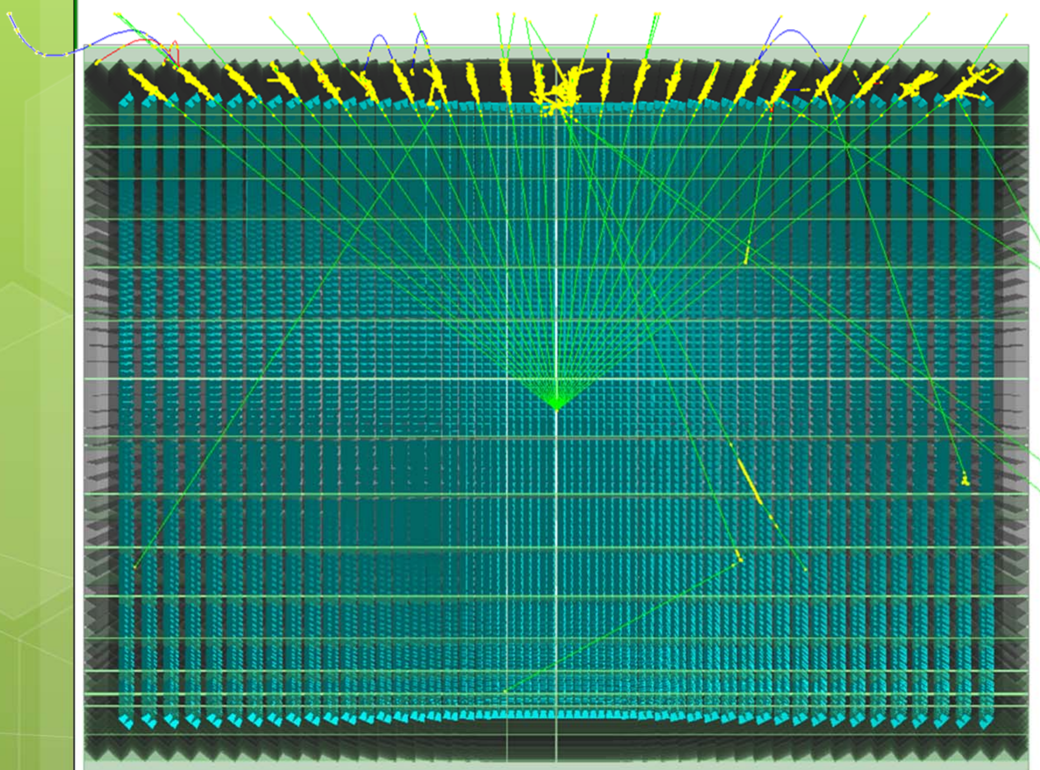
# EMCal

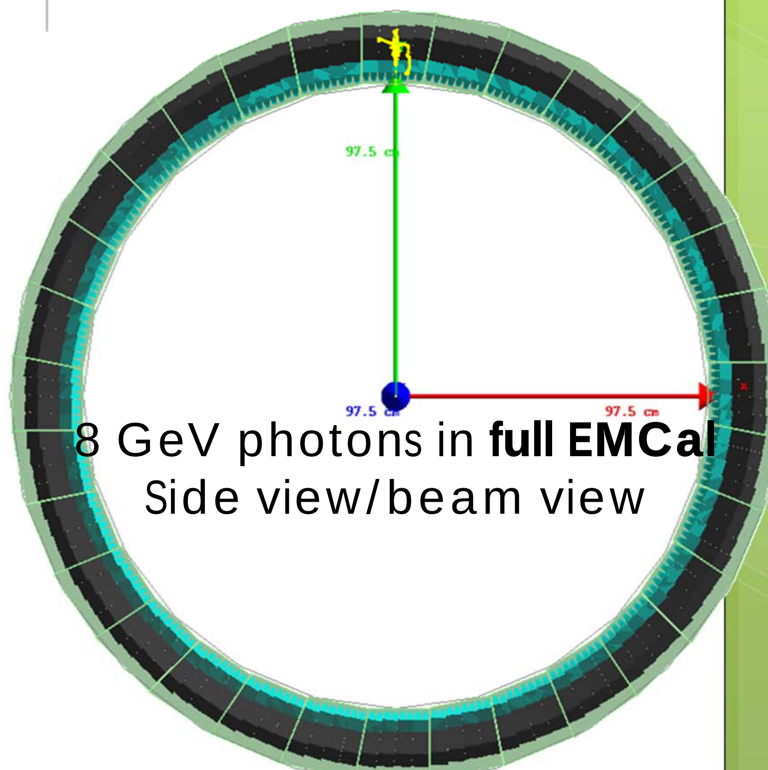



**SPACAL Tower**
w/ fibers displayed



**EMCal Half Sector**
(fibers simulated but hidden from display)

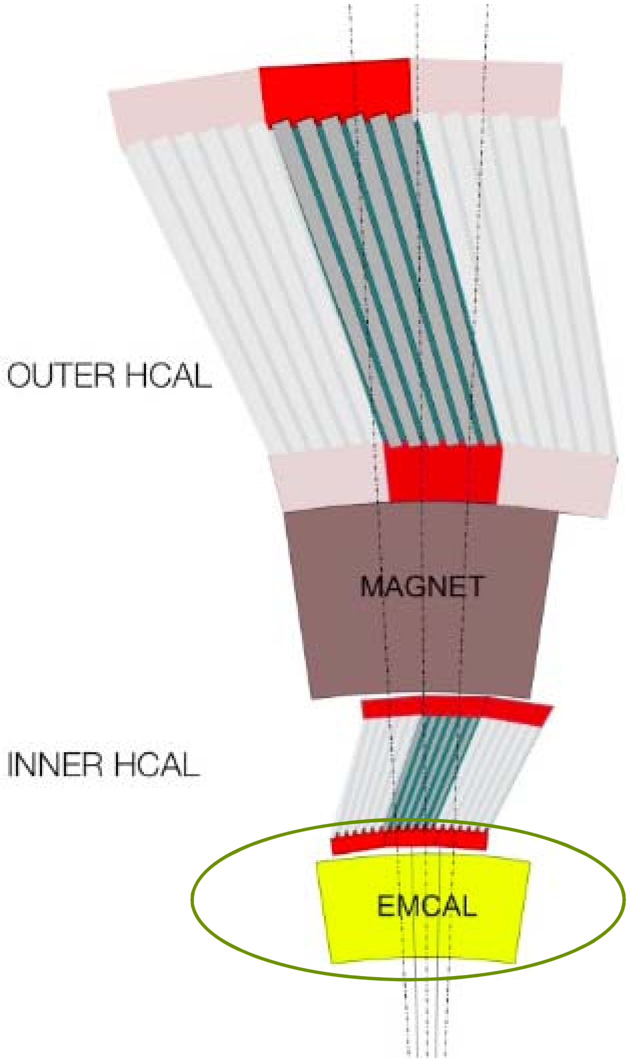





8 GeV photons in **full EMCal**
Side view/beam view

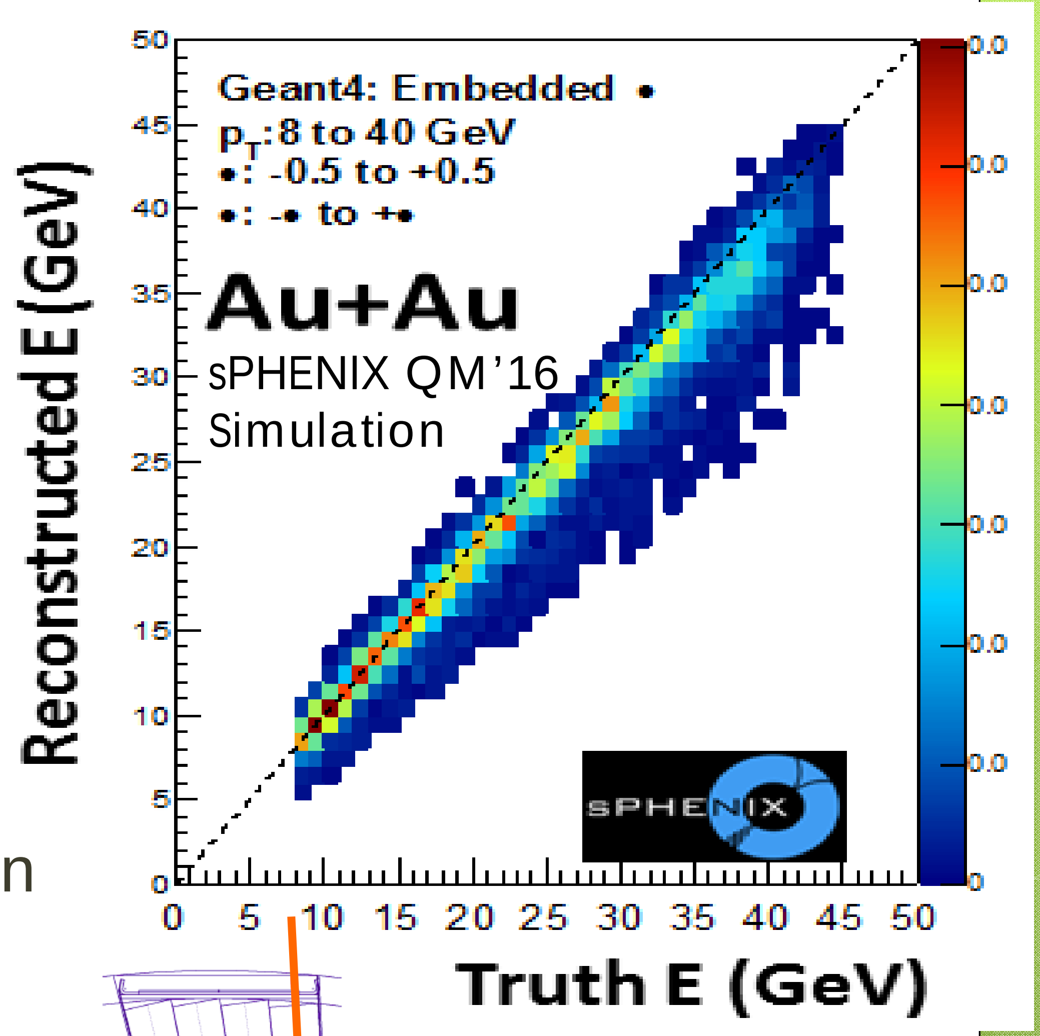
# Full Calo Stack

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



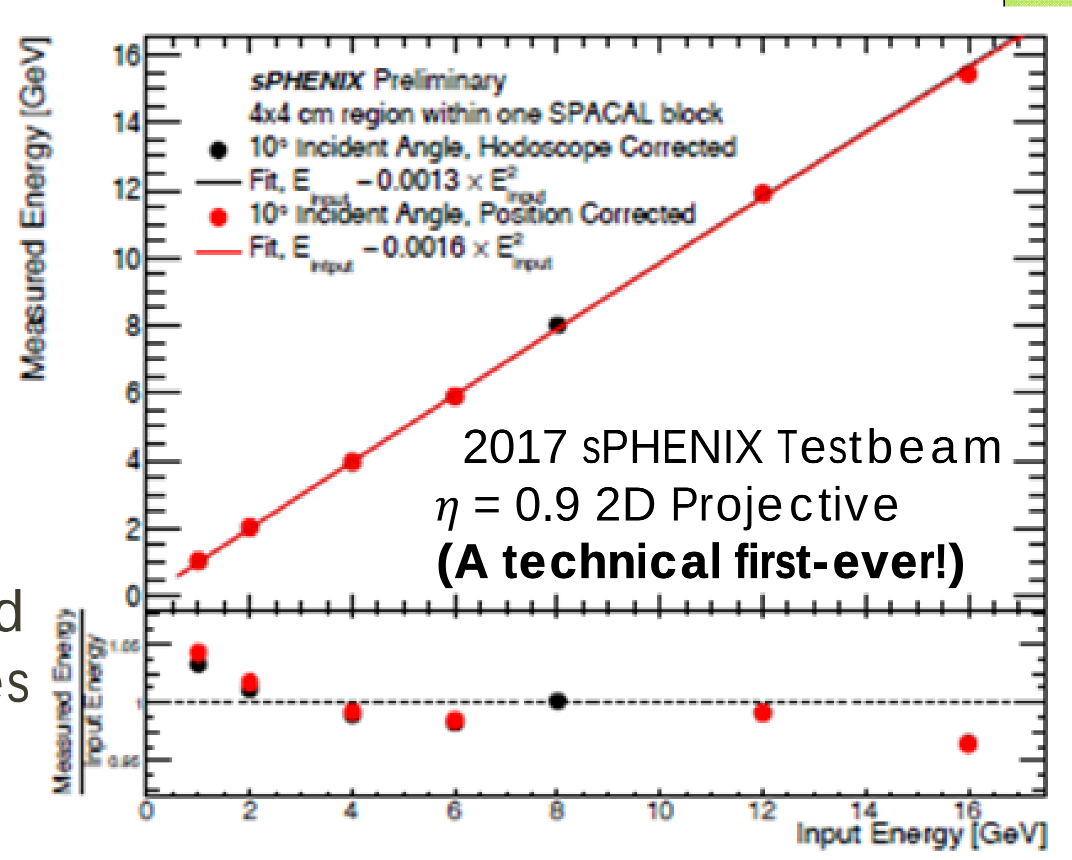
# $\gamma$ Response & Calibration

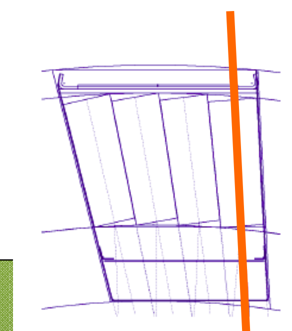
- Average response is good in simulation
- Well connected to Beam Tests
- Current work on understanding position dependent response
- Tilt angles (add slight non-projectivity) added to initial design improves uniformity




# $\gamma$ Response & Calibration

- Average response is good in simulation
- Connected to Beam tests
- Current work on understanding position dependent response
- Tilt angles (add slight non-projectivity) added to initial design improves uniformity
- 2D ($\phi$-$\eta$) projectivity improves uniformity at large $\eta$

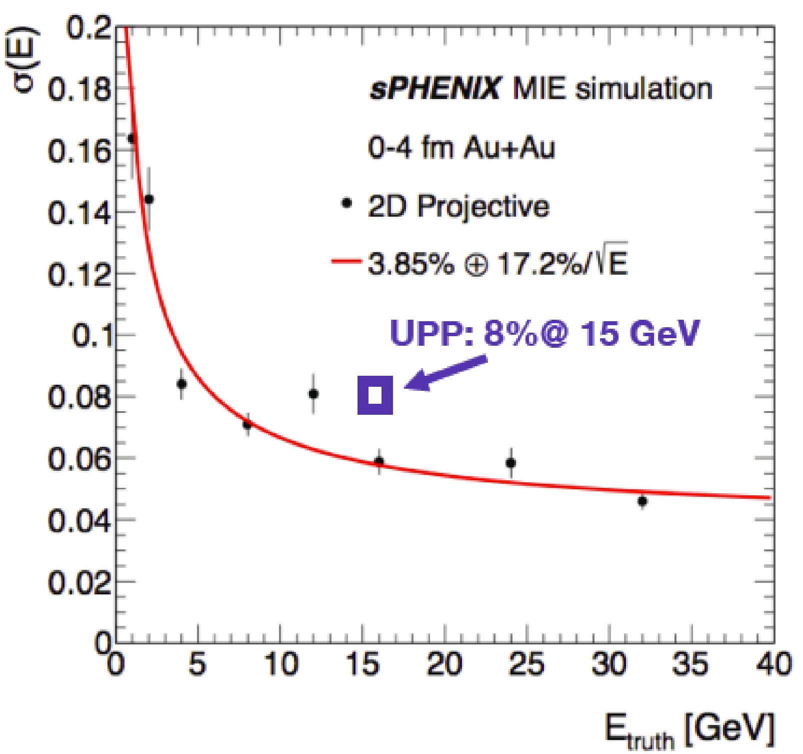


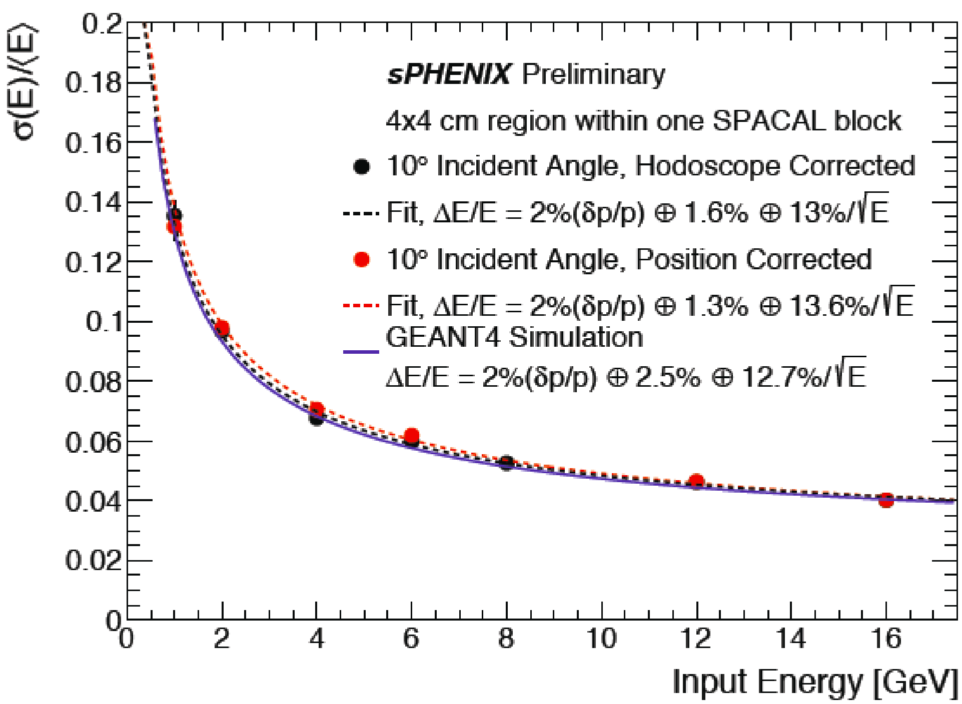



# $E_\gamma$ Resolution

- EMC Resolution at all $\eta$ Confirmed with Test Beam
- 2016 Testbeam publication results (mid-rapidity 1D)
- 2017/2018 Results at $\eta$ = 0.9/2D Testbeam Results:
- Well below “UPP” DOE Perf. Param.

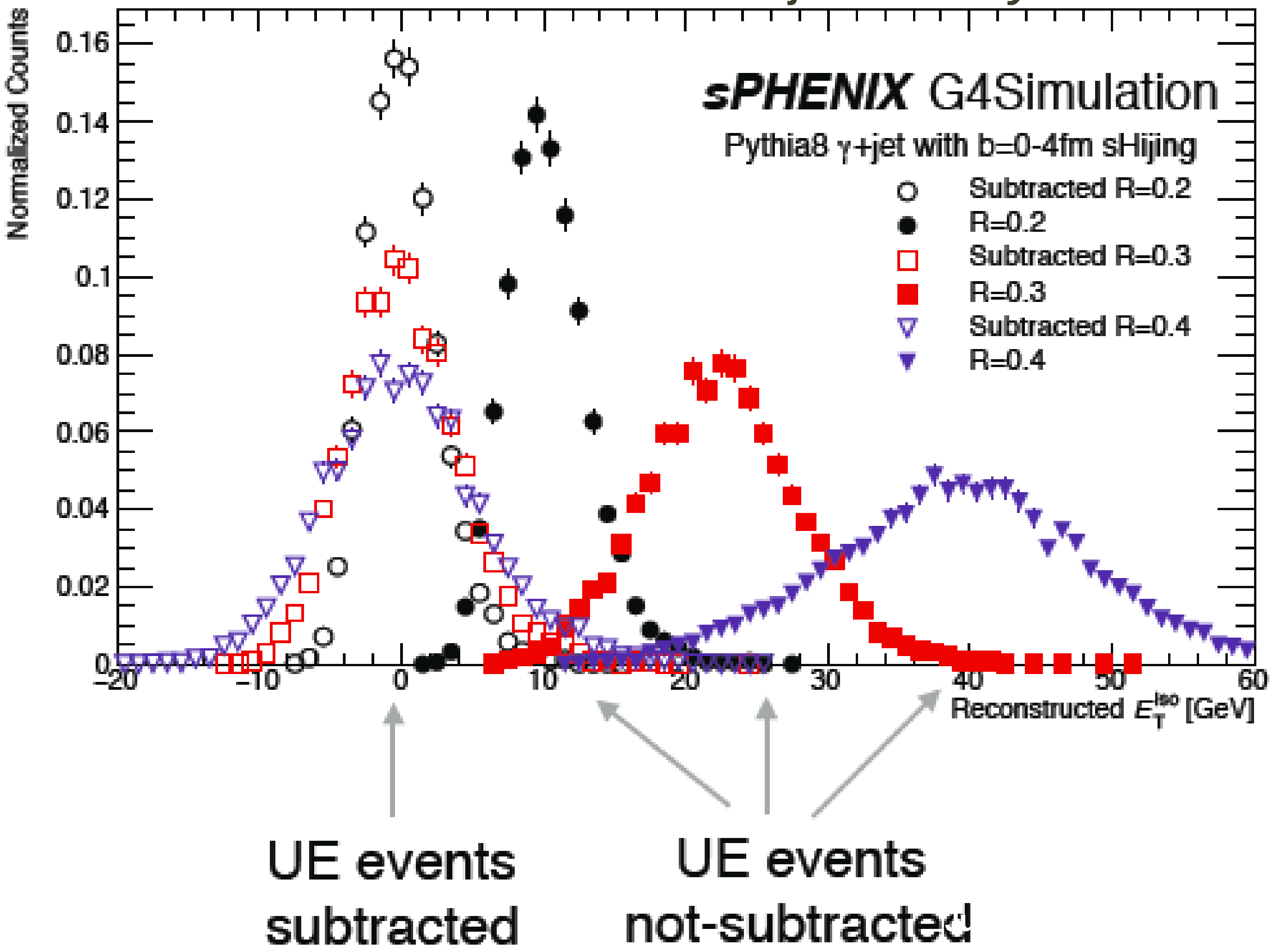
Single photon resolution (central Au+Au)

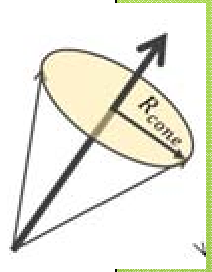


# $\gamma$ Isolation

- Prompt Photon Isolation depends on UE event subtraction performance
- Same UE subtraction as for the jet analysis



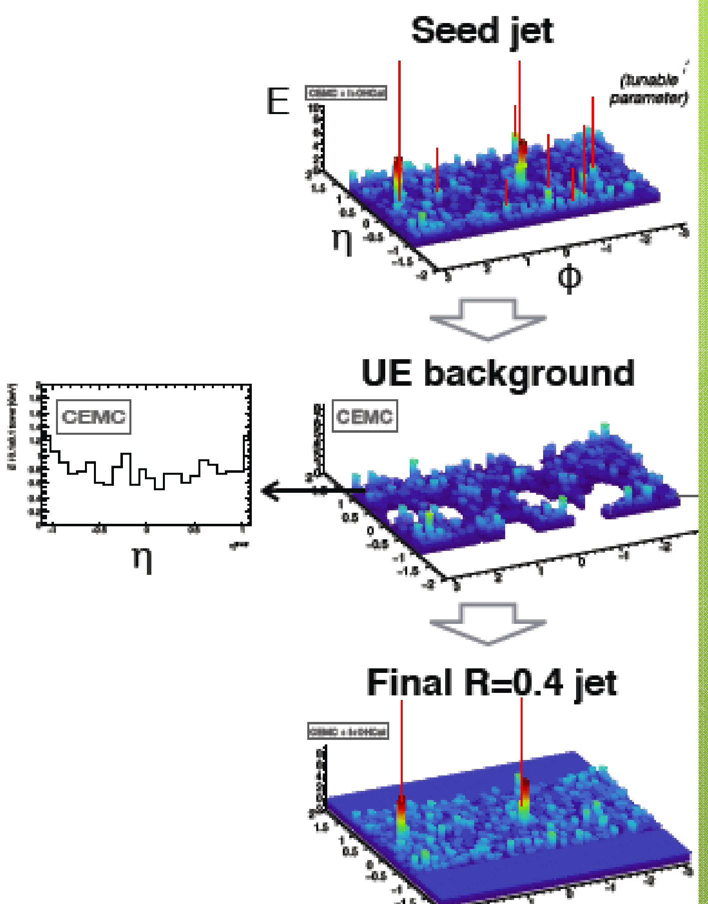



# Sim details and default UE Subtraction

- Calorimeter tower jet through full Geant4 simulation
- PYTHIA8 QCD dijet for pp, PYTHIA8+HIJING for Au+Au

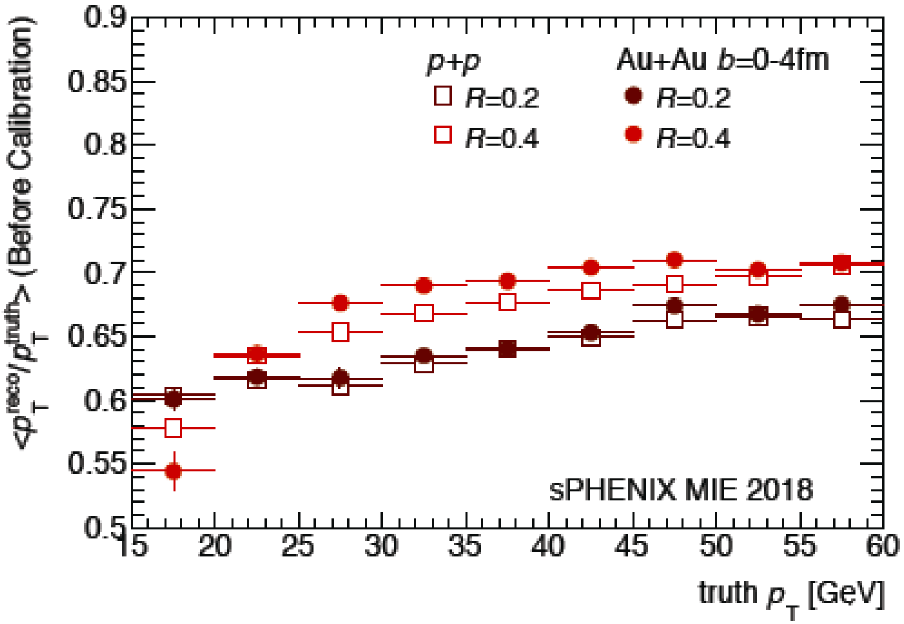
*PRC 86 (2012) 024908*

- Iterative UE subtraction algorithm based on ATLAS method
  - Reconstruct R=0.2 jet using 0.1x0.1 calo cells
  - Find seed jet with Max($E_T^{tower}$)/Mean($E_T^{tower}$) > D
  - Define background in each layer and η-ring after excluding seed region (ΔR < 0.4)
  - Determine $\Psi_2$ and $v_2$ from η-rings with full Φ
  - Subtract background tower-by-tower modulating by determined flow
  - Iterate the above step (seed jet with $E_T > E_T^{threshold}$)
  - Run jet finder with chosen resolution parameter R on background subtracted event to find final jets

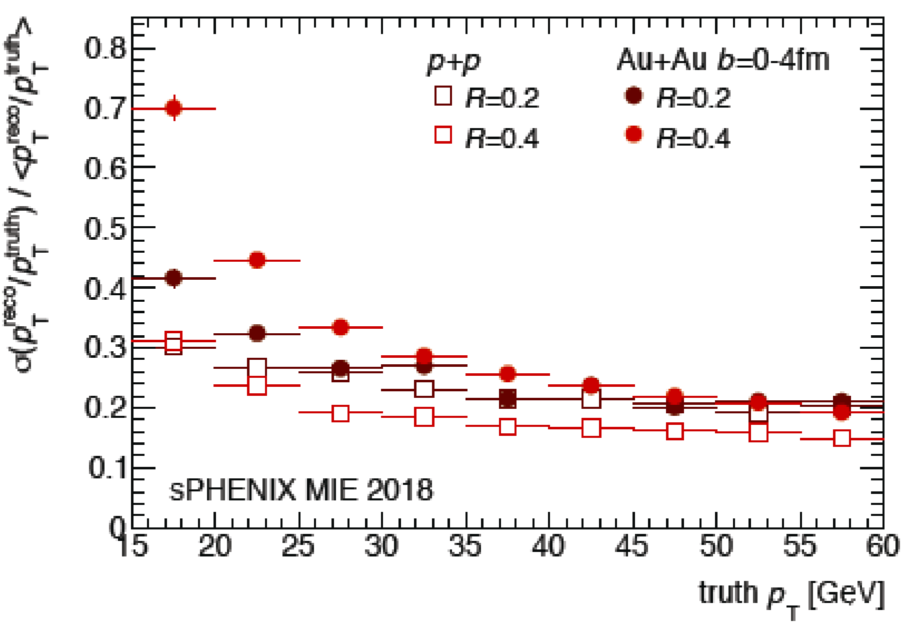


# Overall Jet Perf

## Jet Response




## Jet Energy Resolution

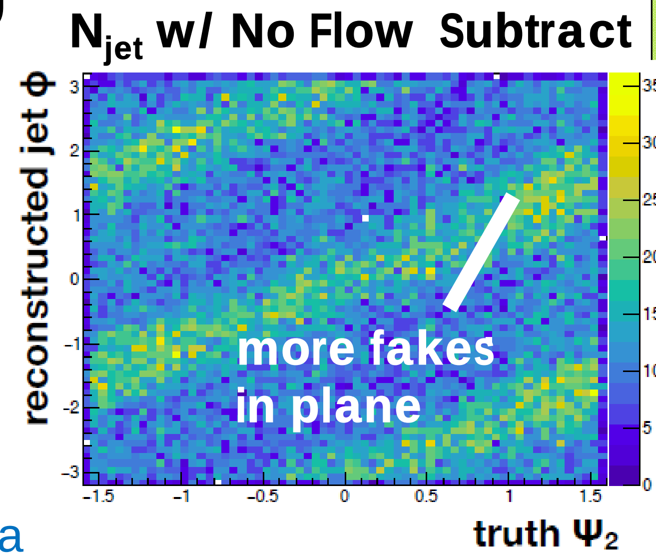



- Expected ordering in R
- Similar response in p+p and Au+Au
  → independent of UE level

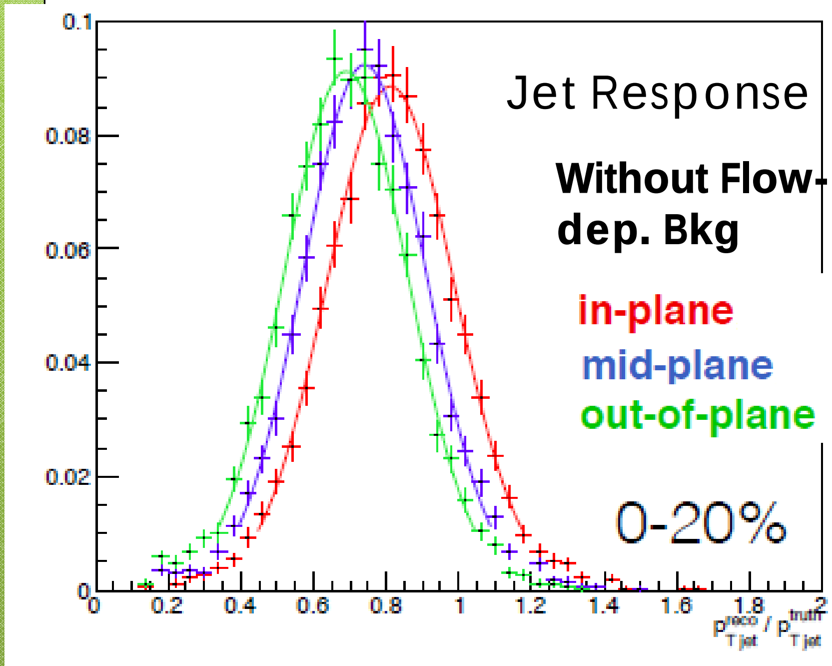
- At large R and low $p_T$: dominated by fluctuations in UE
- At small R or high $p_T$: dominated by an intrinsic resolution of calorimeter
- Response at EM scale
  (before calibration at jet level)

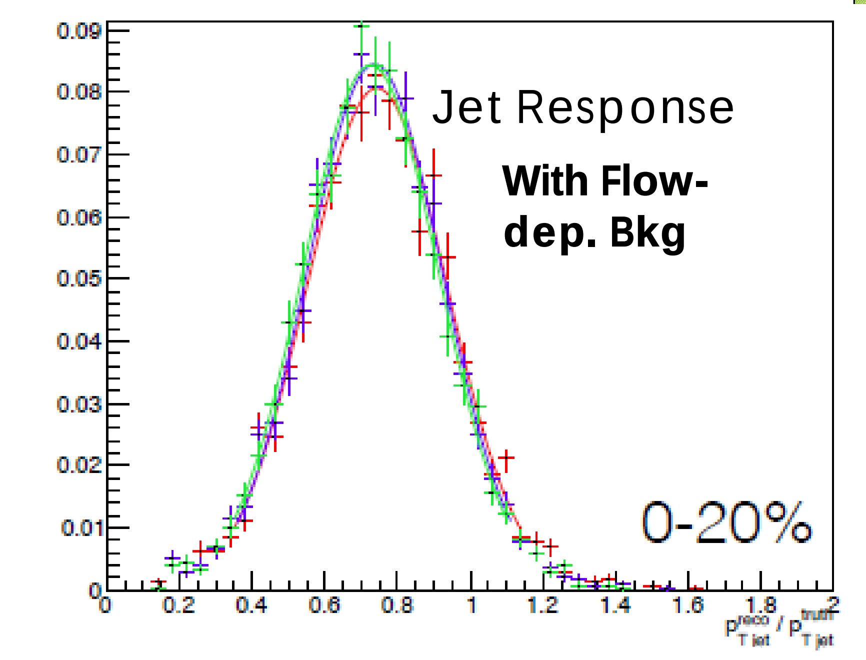
# Flow Dependent Bkg

- 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 Stucture TG --Perepiltsa

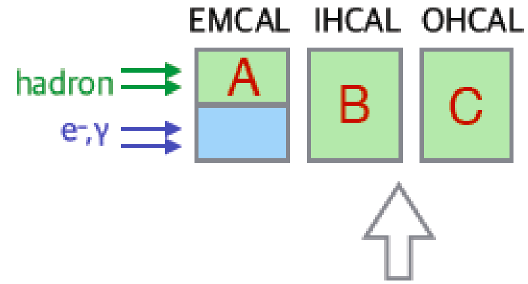


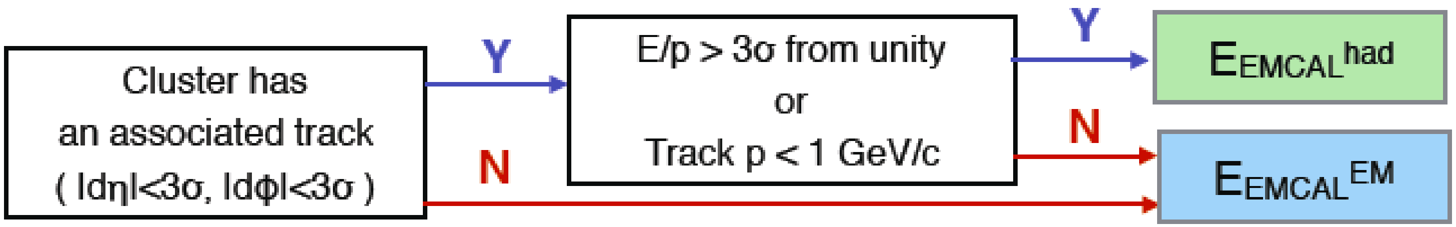
# Jet Calibration

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

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

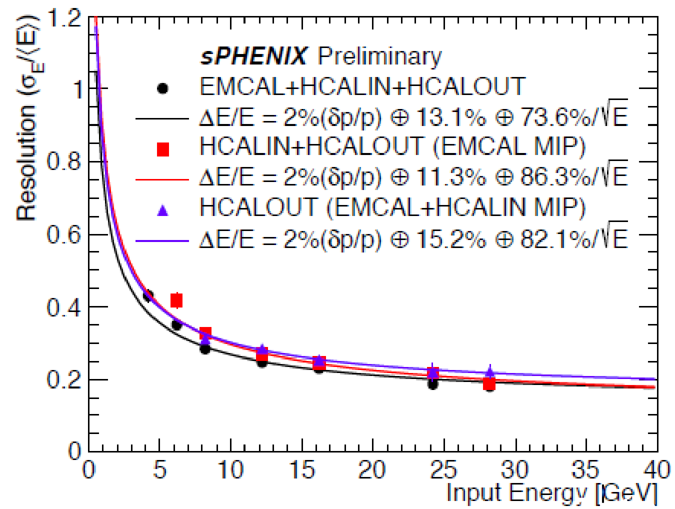



- Flow chart for EMCAL cluster selection



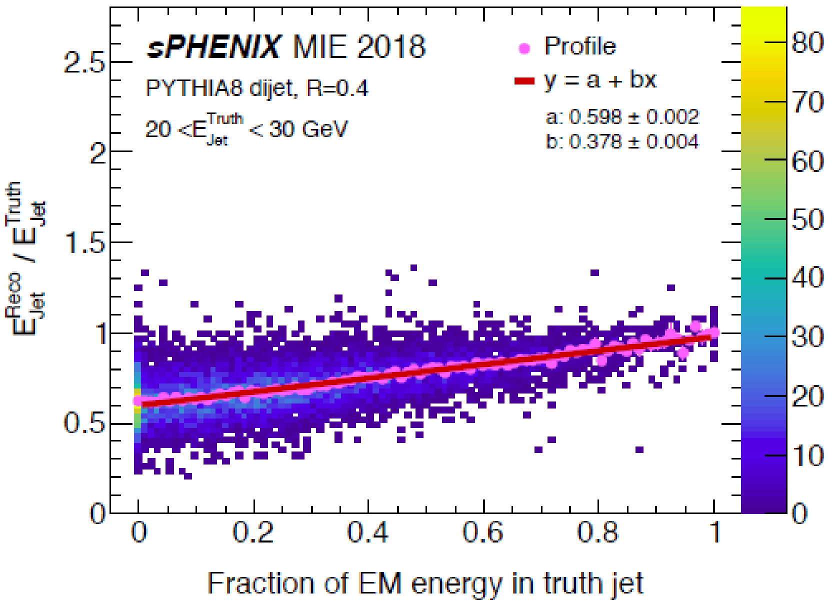

**Key Component HCal**

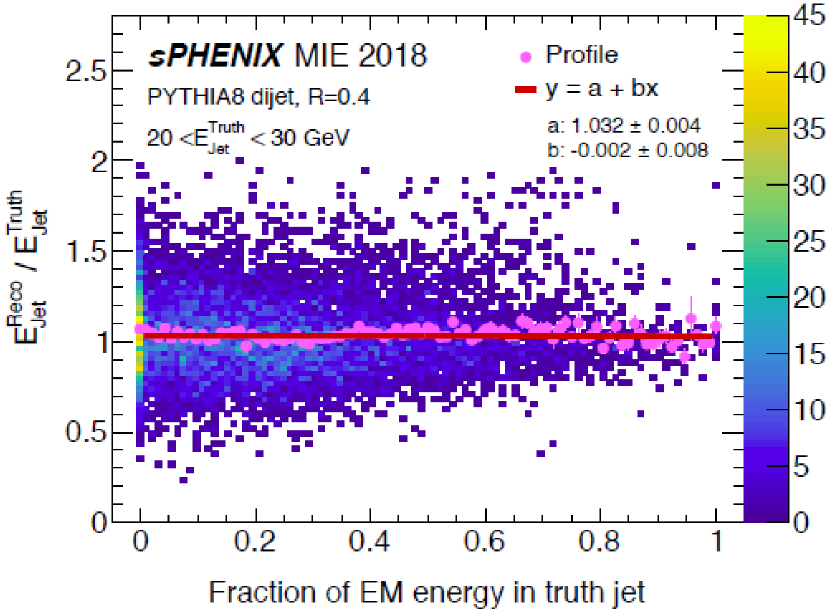
**Testbeam performance→**



# Jet Calib (cont.)

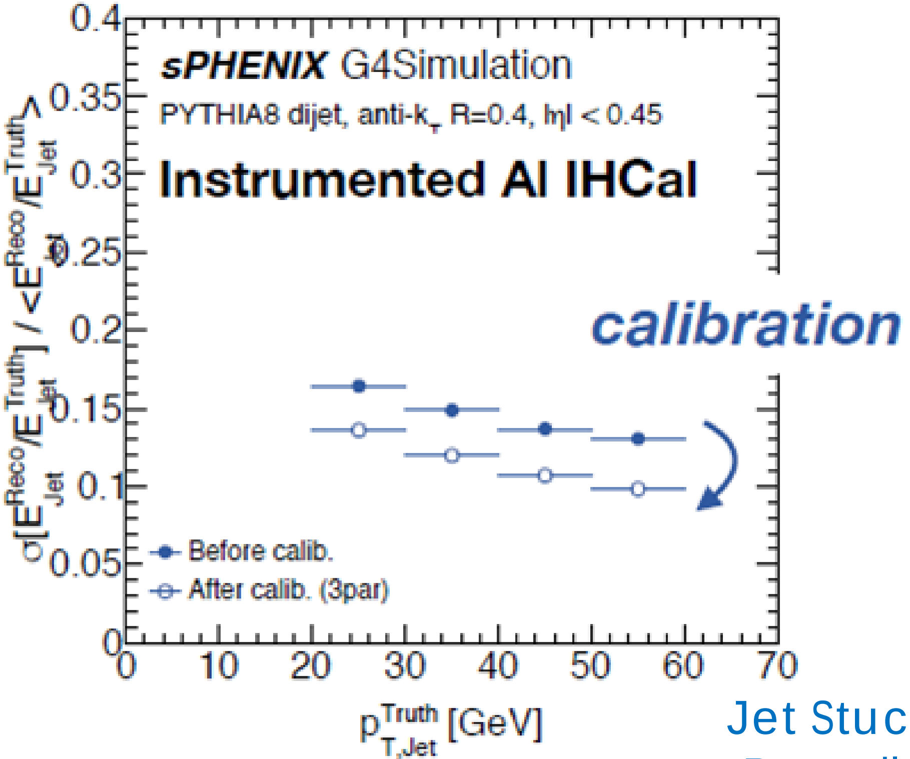
- Response dependence on EM fraction ~removed:

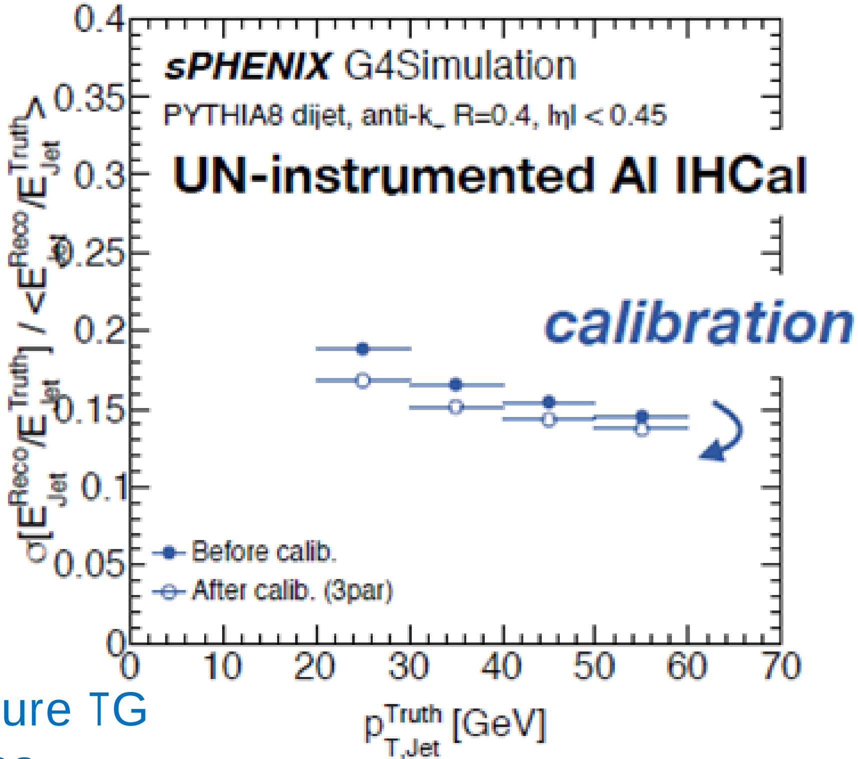


# Jet Calib in p+p

- Significant improvement in JER



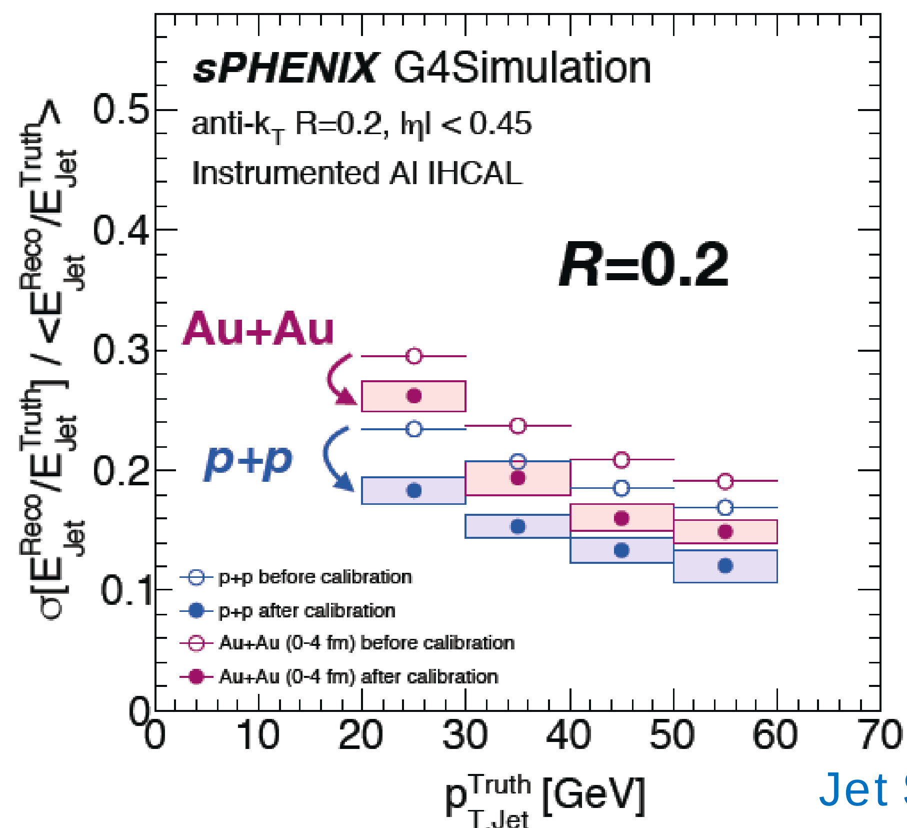



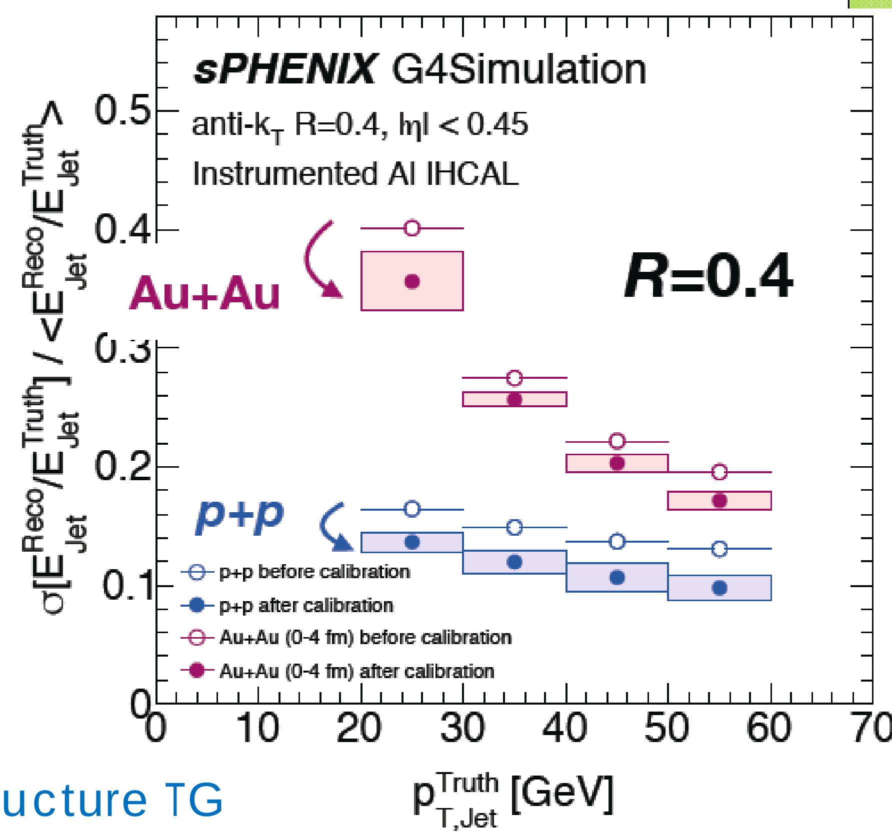

Jet Stucture TG
-Perepiltsa

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

# Jet Calib in AuAu

- Similar improvements in Central Au+Au

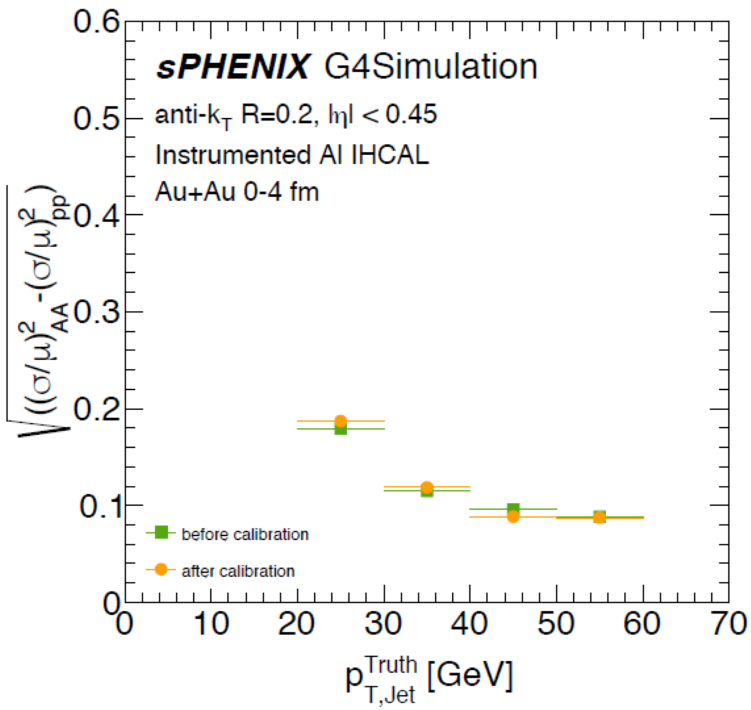


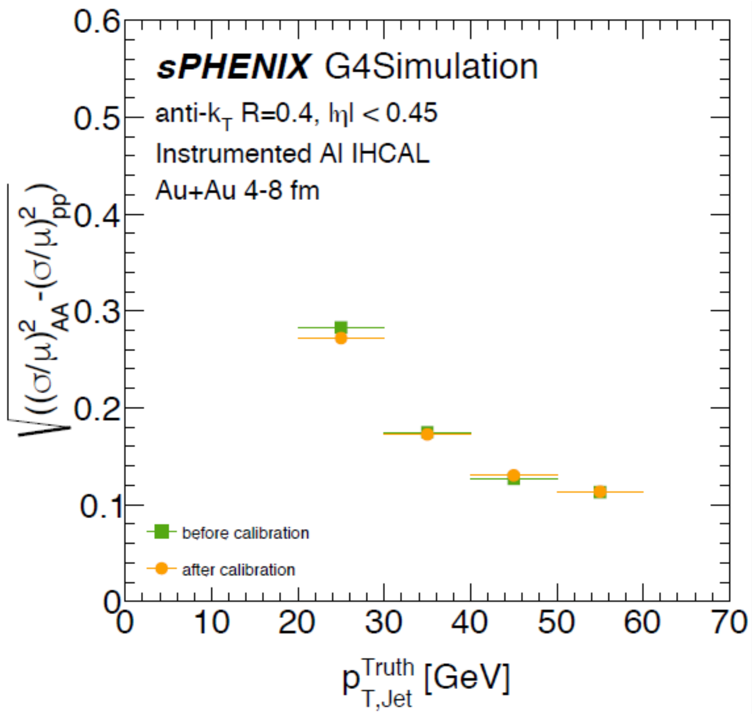




Jet Stucture TG
-Perepiltsa

# Jet Calib/UE Subtraction Interaction?

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



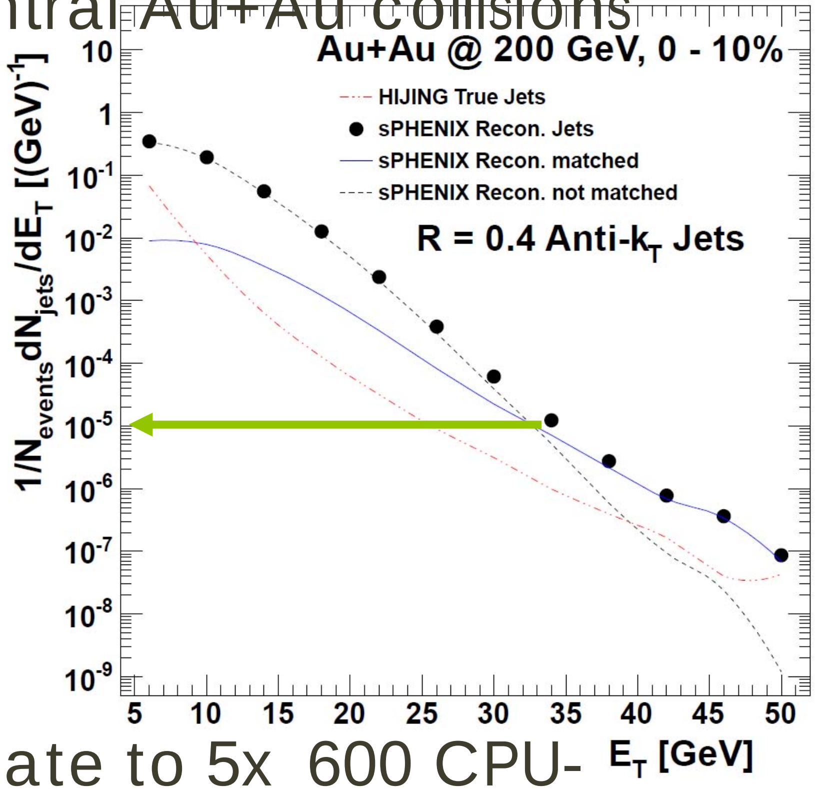

$$\frac{\sigma_{p_\mathrm{T}}}{p_\mathrm{T}} = \frac{n}{p_\mathrm{T}} \oplus \frac{s}{\sqrt{p_\mathrm{T}}} \oplus c$$

Noise Stochastic Constant

Jet Stucture TG -Perepiltsa

# Simulations required for Jet background

- CPU Needs must be considered now: Simulations
- Simulating fake-jet bkg central Au+Au collisions
- Dominant simulation resource needed: 10M central Au+Au
- Fake jets important up to $E_T$ = 30-35 GeV 5-$\sigma$ Bkg Fluctuation!

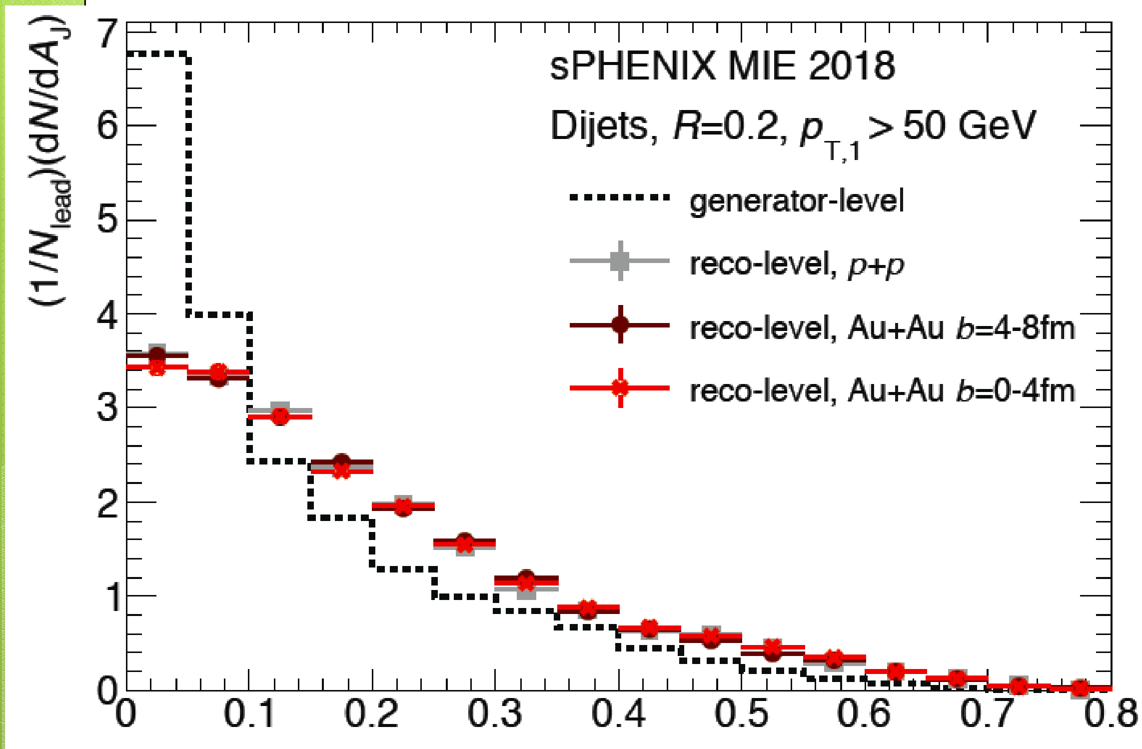



- 5x 2M central Au+Au translate to 5x 600 CPU-Core*year & 5x 200 TB storage x 5
- Small compared to sPHENIX reconstruction needs

# Dijet Asymmetry

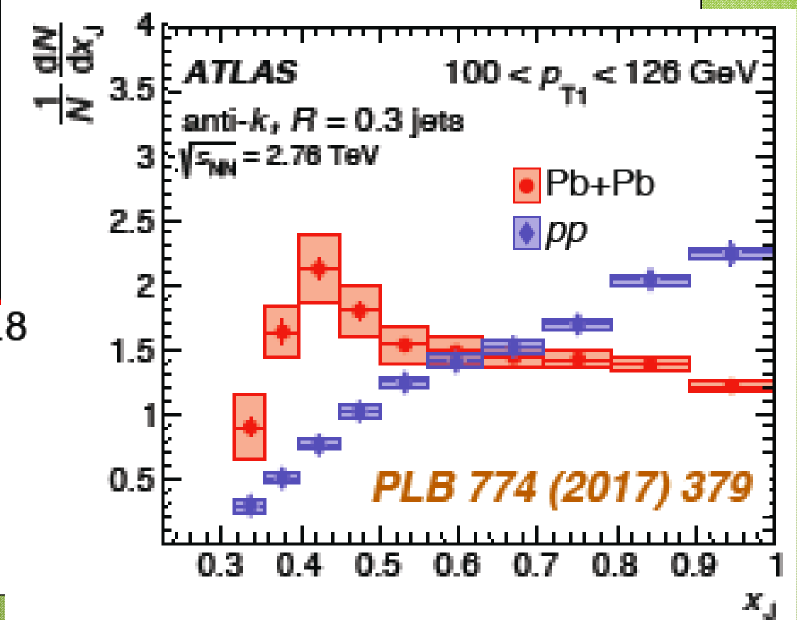
Now go through some jet performance plots....

- Di-jet asymmetries, reco-level




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

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

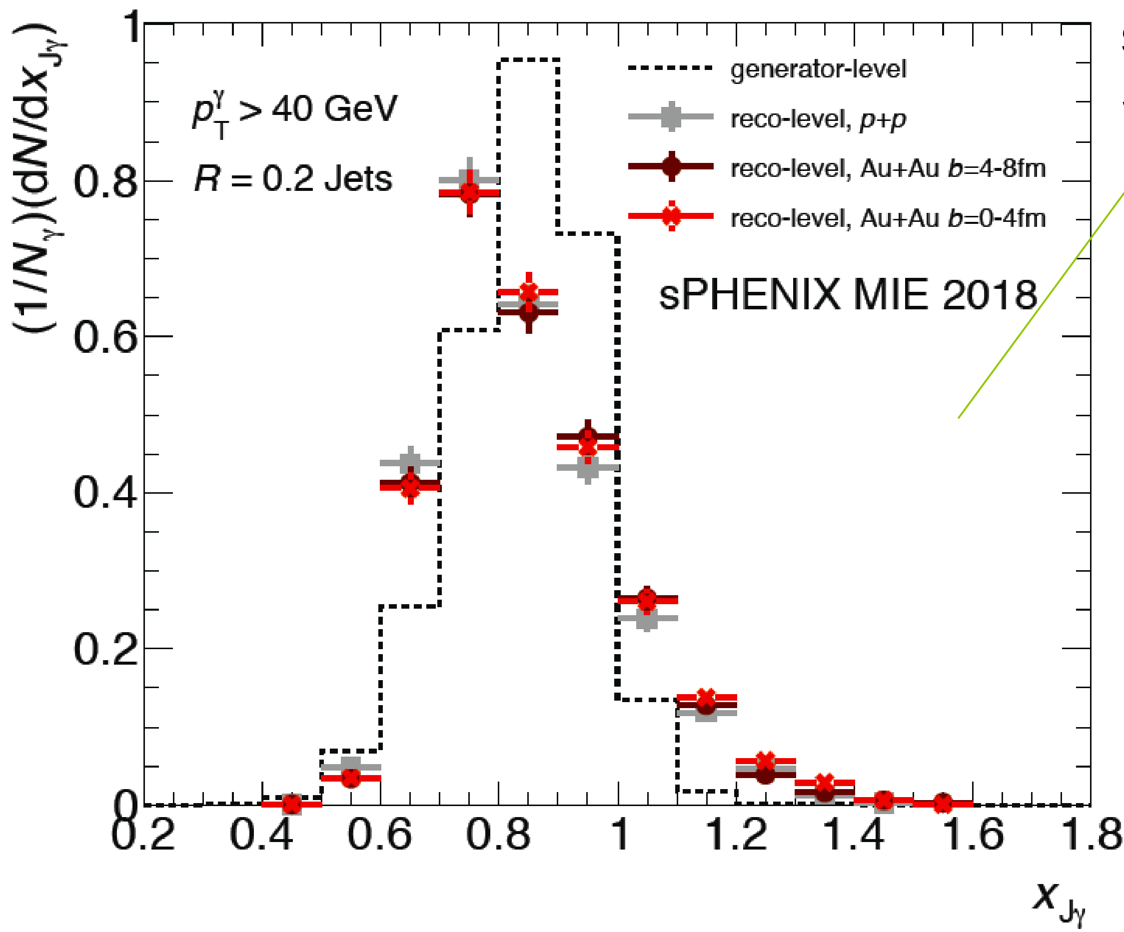



UE Subtraction/multiplicity effects in Au+Au under control

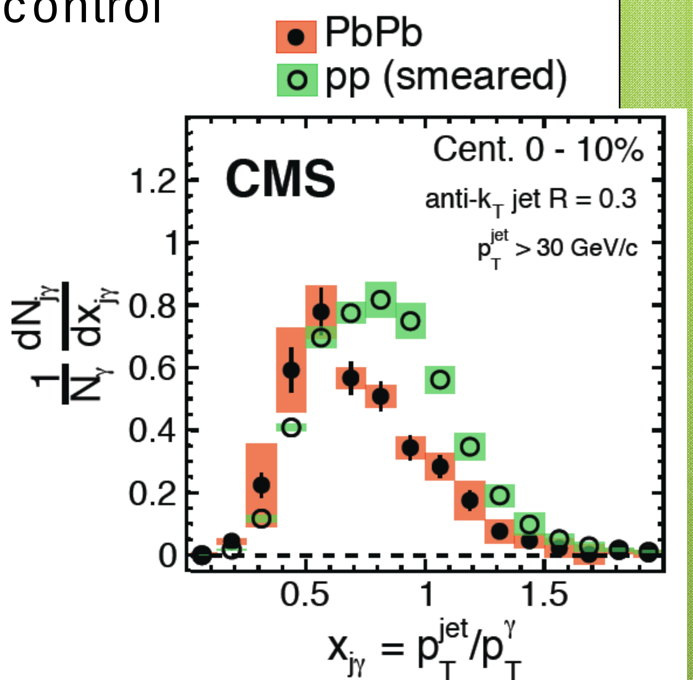
Eventually fully unfolded $x_J$ distribution

# Prompt γ (1)

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

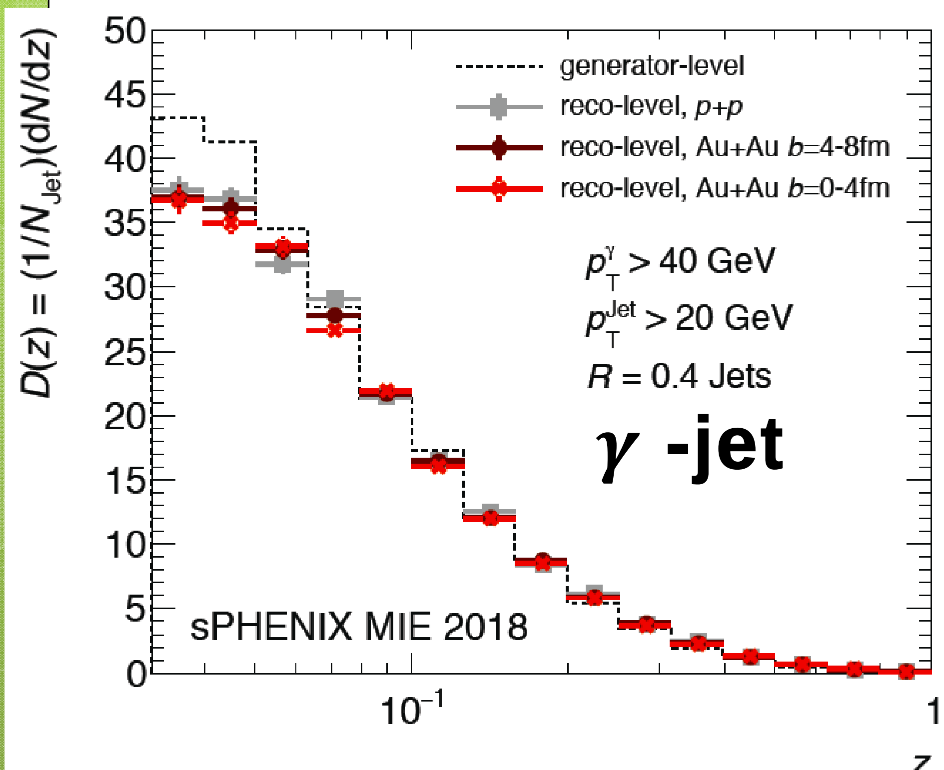


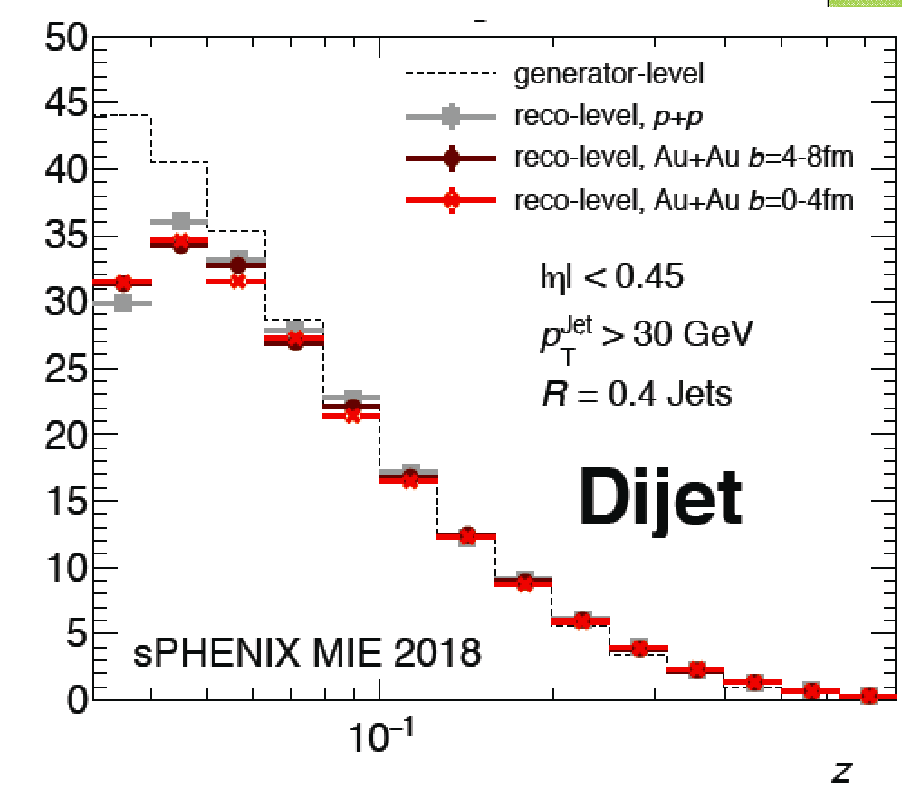

sPHENIX UE Subtraction/multiplicity effects in Au+Au under control



# Prompt $\gamma$ (2)

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

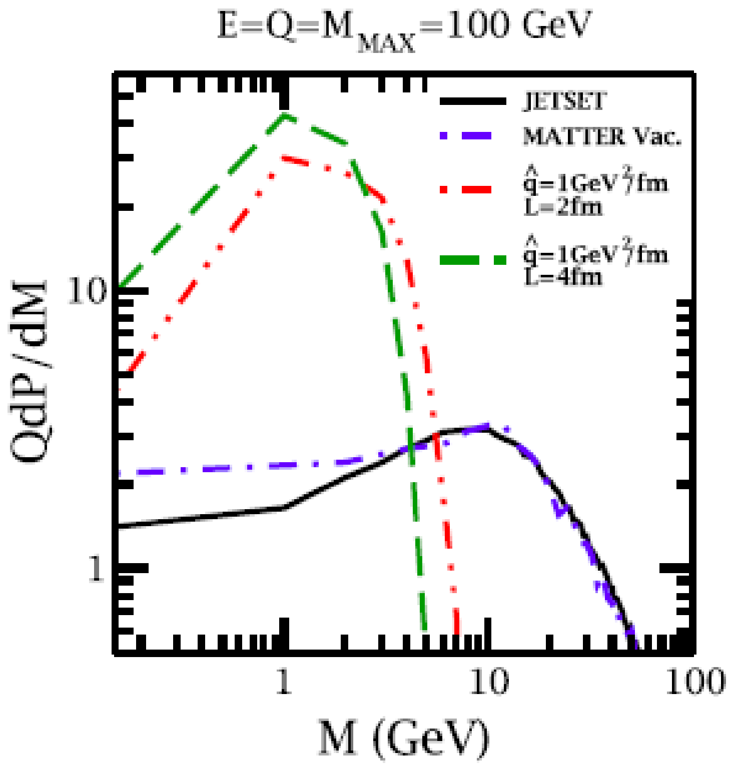


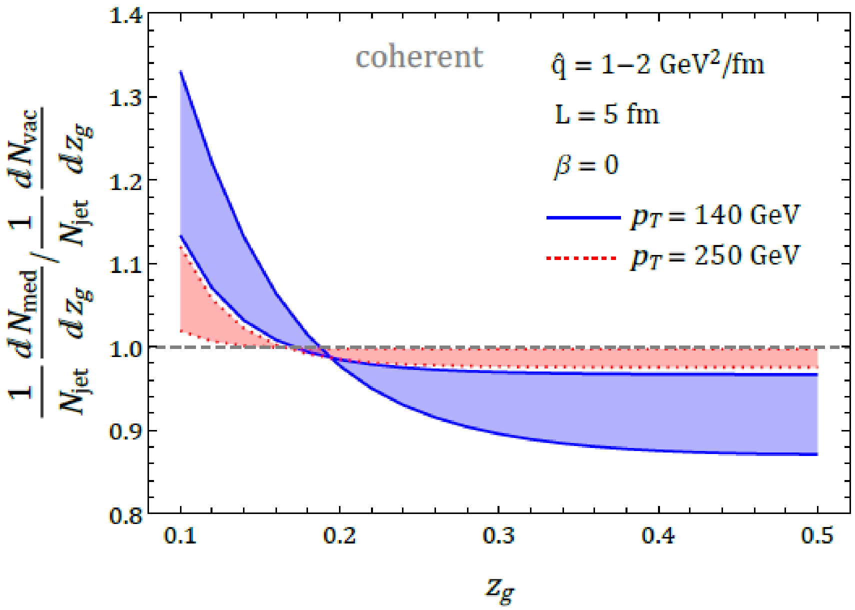
# Other Observables?

- Evaluating capabilities for other observables

**Jet Mass**

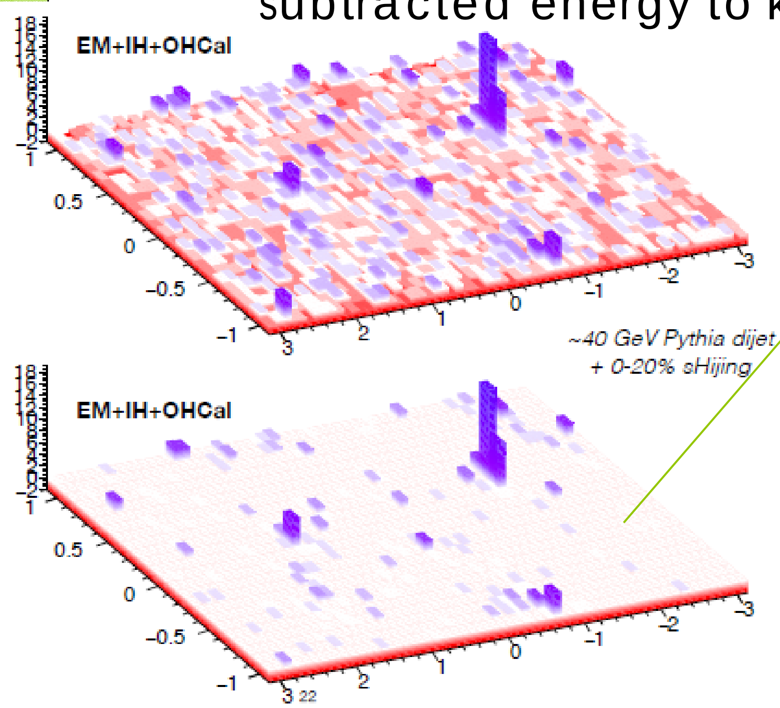



**Jet Grooming**

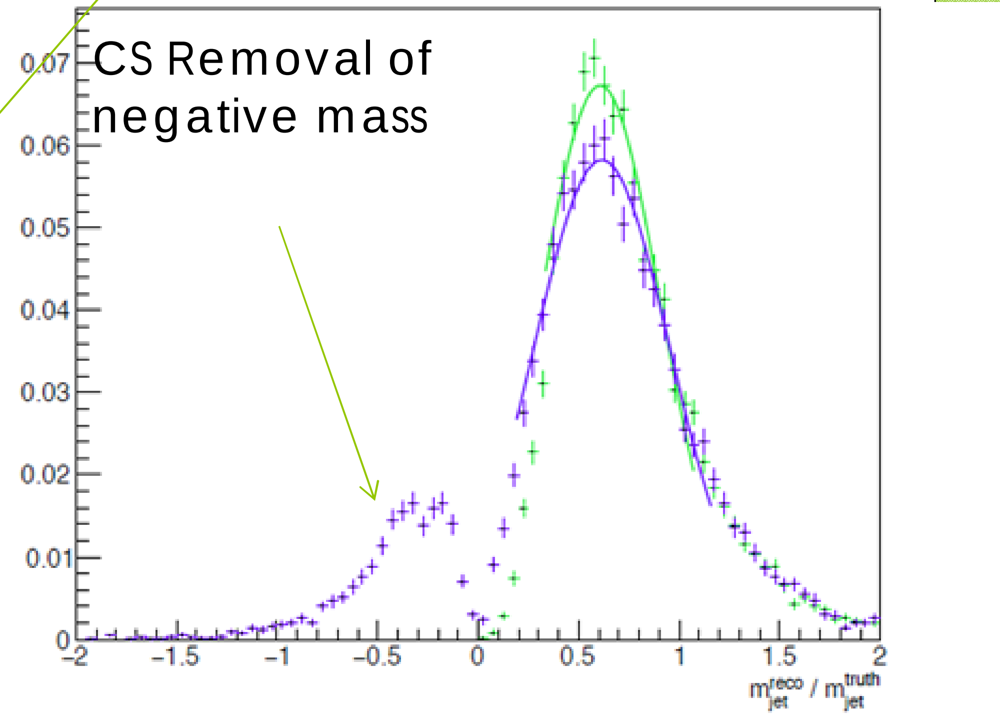


# First Look
# Alt Constituent UE Subtraction Method

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




**Jet Mass?**




*Absolute (ungroomed) mass response*

sPHENIX Jet Structure group first look - Peripelitsa

# Conclusions

- sPHENIX CD-1/3A Approval in 2018:
- **sPHENIX Construction has begun** and is already ramping up into production mode for calorimeter systems
- 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 comparison of LHC vs RHIC QGP as seen with jet observables !

# Backup

- > Exciting Jet and Prompt Photon Physics Opportunities Provided by
- > sPHENIX at RHIC.
- >
- > The sPHENIX detector currently under construction at the Relativistic
- > Heavy Ion Collider (RHIC) will allow a larger kinematic reach and new
- > measurement capabilities at RHIC for jet-related measurements.
- > Precise tracking and superb hadronic and electromagnetic calorimetry
- > will be allow for new observables that will be directly comparable to
- > similar data at the Large Hadron Collider (LHC) and allow us to
- > observe how jets with the same properties respond to a QGP created
- > with different initial conditions. The different jet observables
- > sPHENIX will measure will be discussed in this talk, such as those
- > which focus on the jet fragmentation pattern and especially those
- > which involve prompt photons. The properties of the relevant
- > sPHENIX detectors, especially calorimetry, and their implications on
- > their performance with respect to jet and photon-jet observables as
- > determined through informative sPHENIX simulations, will be explained.