

sPHENIX Director's Review Calorimeter Simulations

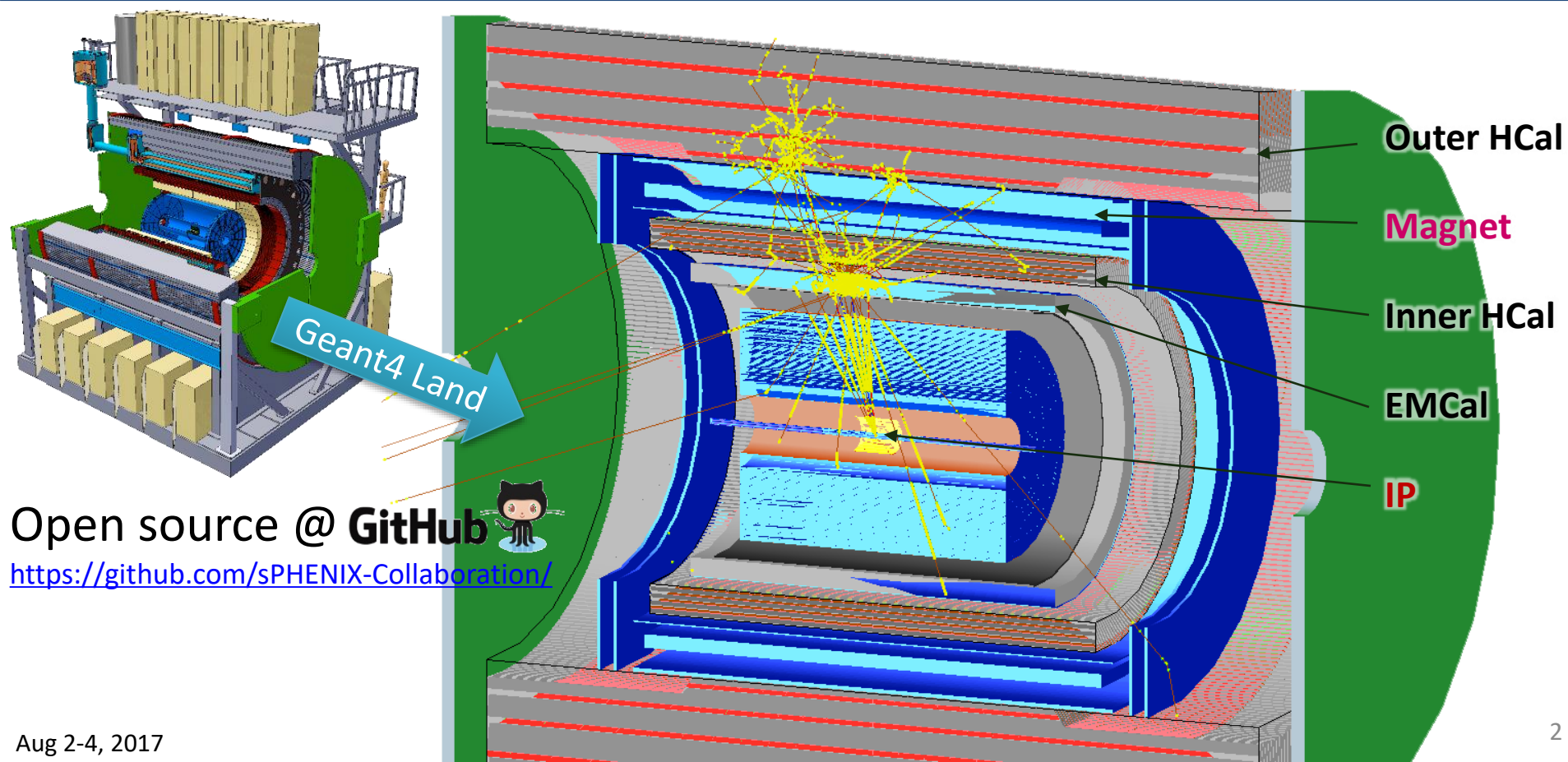
Jin Huang (BNL)

August 2-4, 2017

BNL

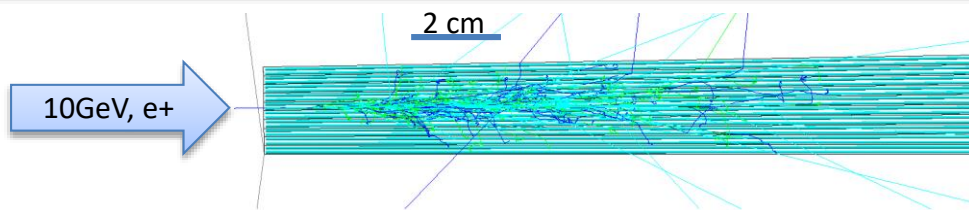
sPHENIX Calorimeters in Simulation

- EM calorimeter (EMCal) : $18 X_0$ W-SPACAL
- Inner hadron calorimeter (Inner HCal) : $1 \lambda_0$ SS-Scint. sampling
- sPHENIX coil and cryostat. (Magnet): $1.4 X_0$ Coil & Cryostat
- Outer hadron calorimeter (Outer HCal) : $4 \lambda_0$ SS-Scint. sampling

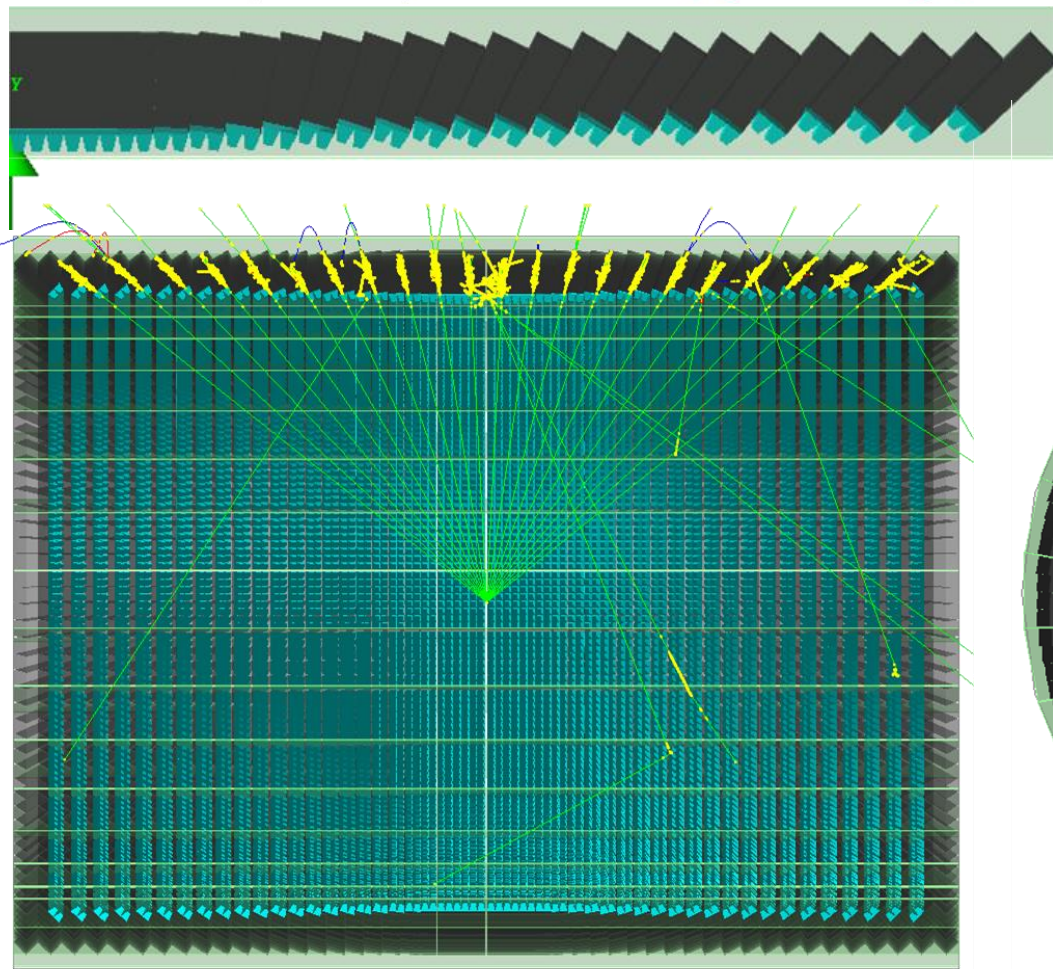


Open source @ **GitHub**
<https://github.com/sPHENIX-Collaboration/>

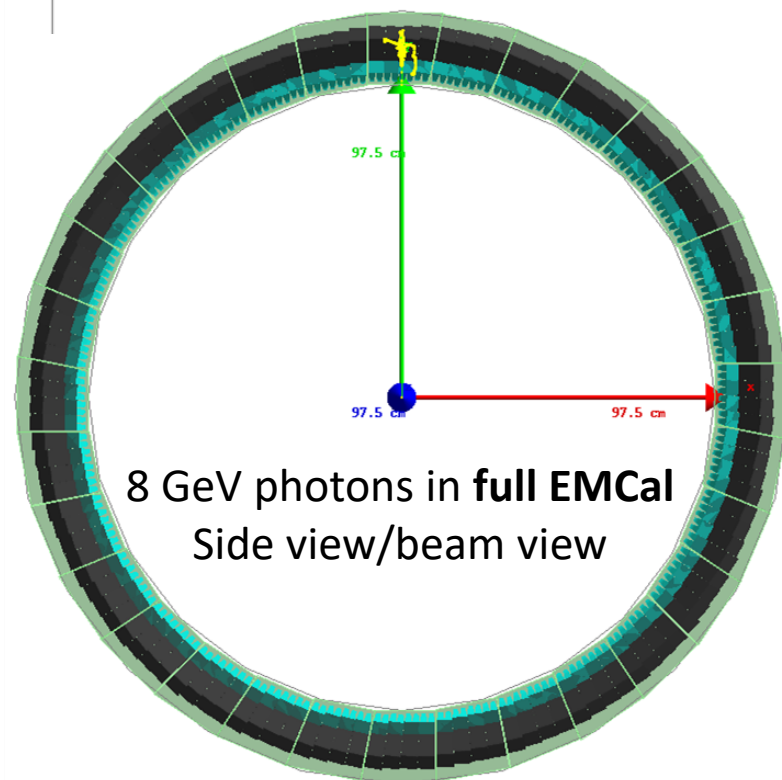
Simulation Setup: EMCal



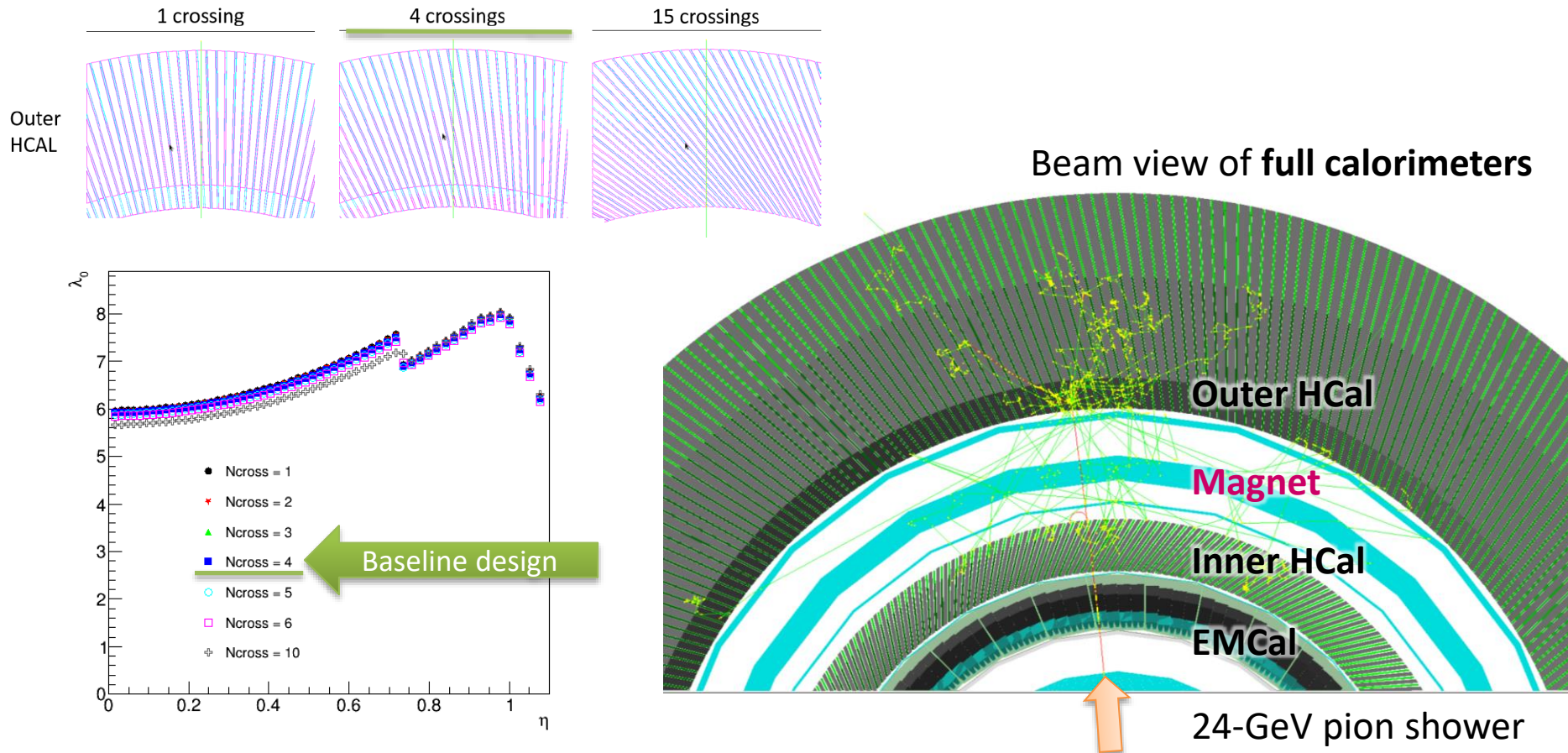
SPACAL Tower
w/ fibers displayed



EMCal Half Sector
(fibers simulated but hidden from display)



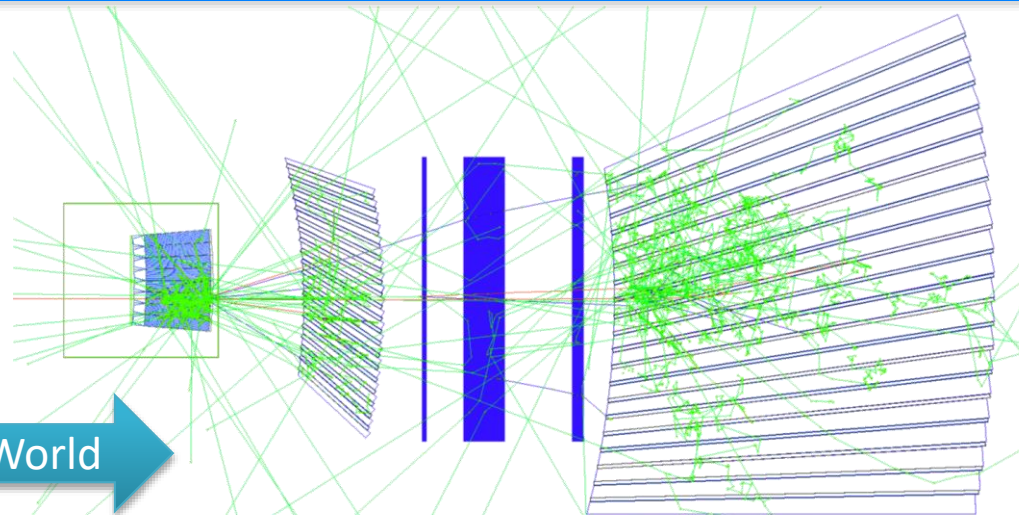
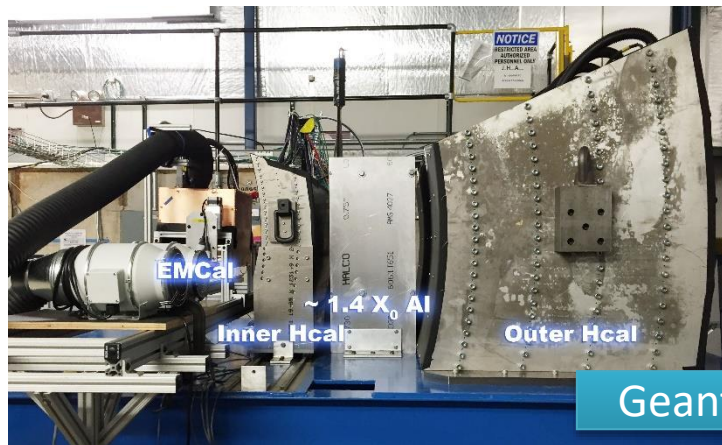
Simulation Setup: HCal



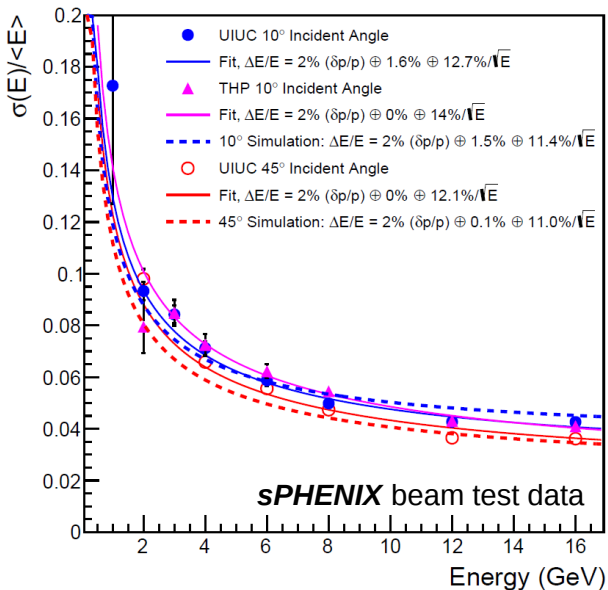
Calorimeter simulation & analysis chain:

GEANT4 hit → Scintillation light model → Light collection model → Tower readout → Digitization → Calibrated tower energy → Clustering/Track matching/Jet finding

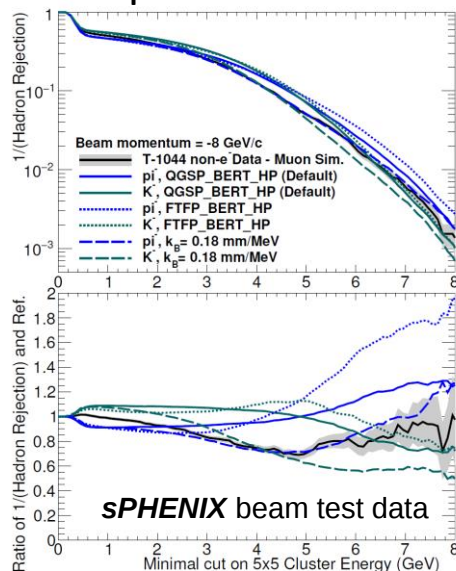
Test Beam Verification [arXiv:1704.01461]



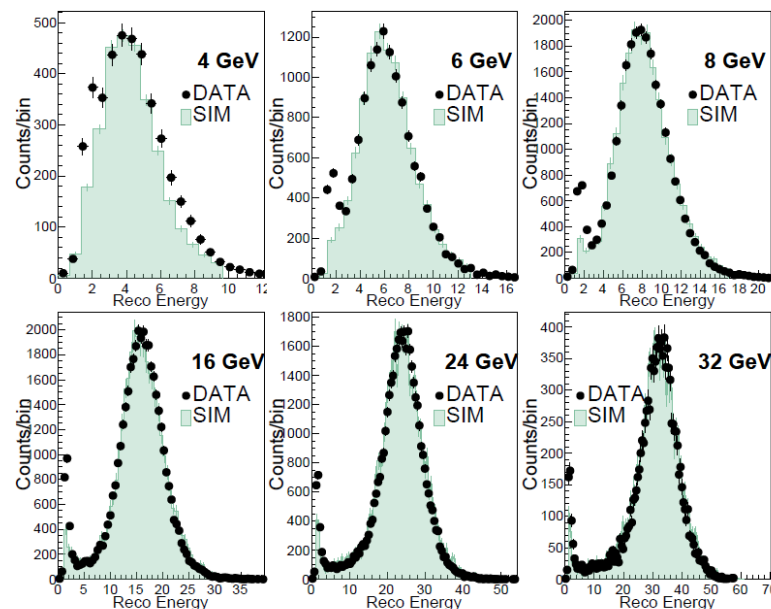
EMCal energy resolution for EM shower in tower center



EMCal rejection for pion-

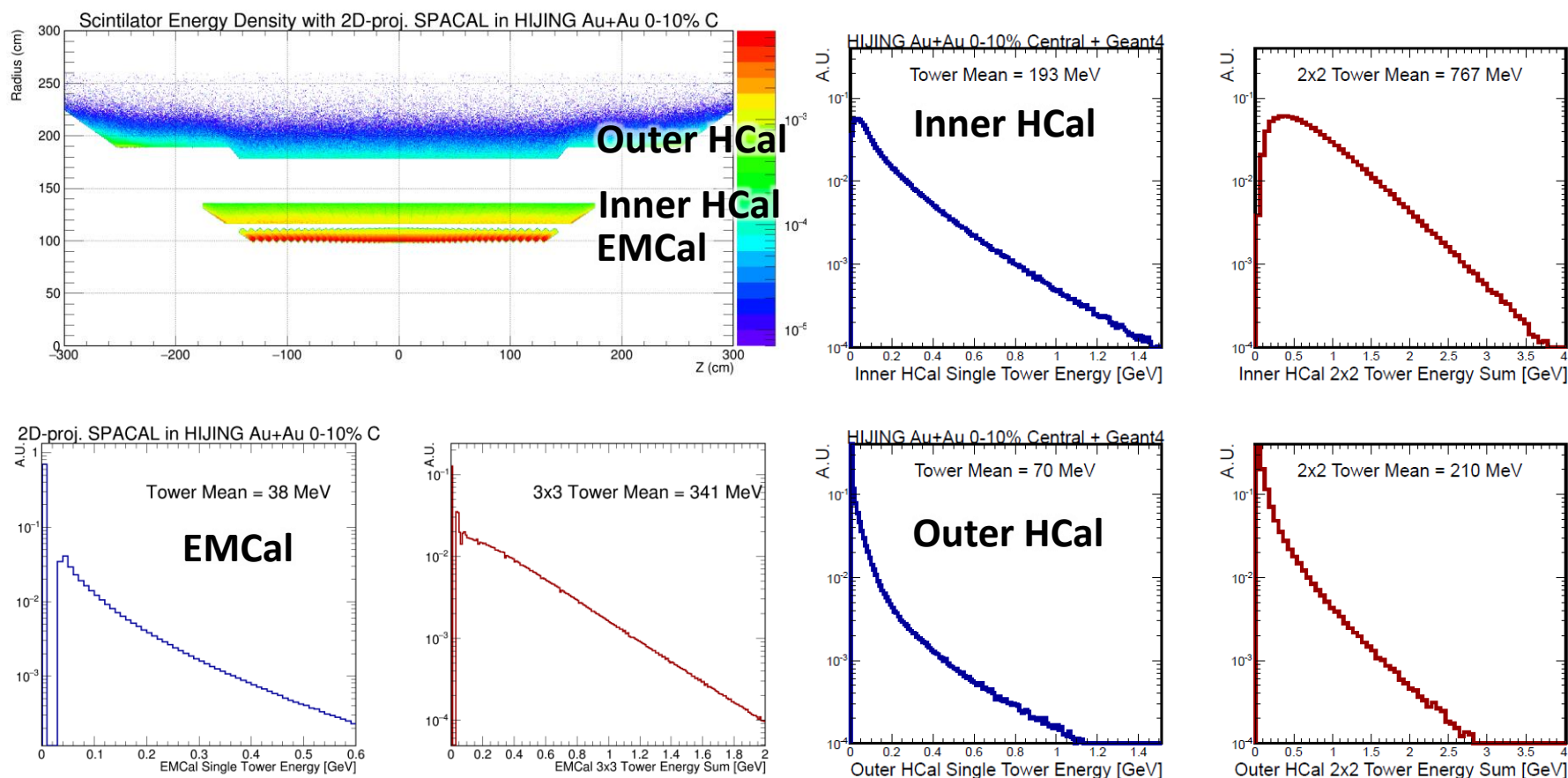


HCal energy response for pion-



Occupancy in Central Au+Au Events

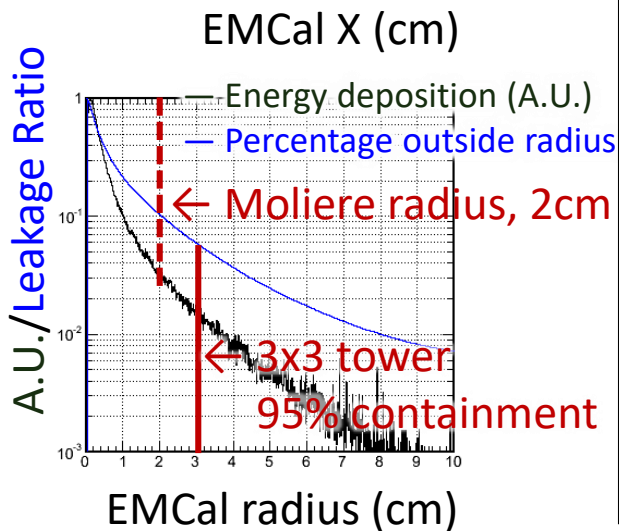
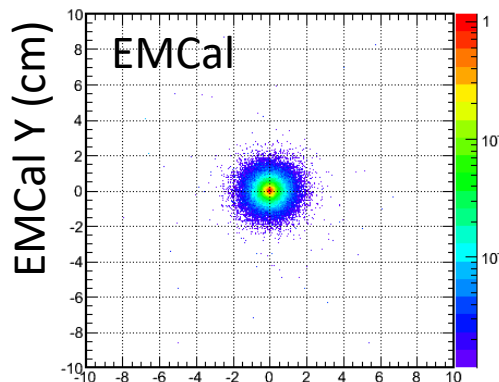
- sPHENIX is designed to handle large background environment of central AuAu collisions
- Such background is simulated with HIJING $\rightarrow$ full detector in Geant4 $\rightarrow$ full analysis chain
- Taken into account for electron ID and jet performance via embedding



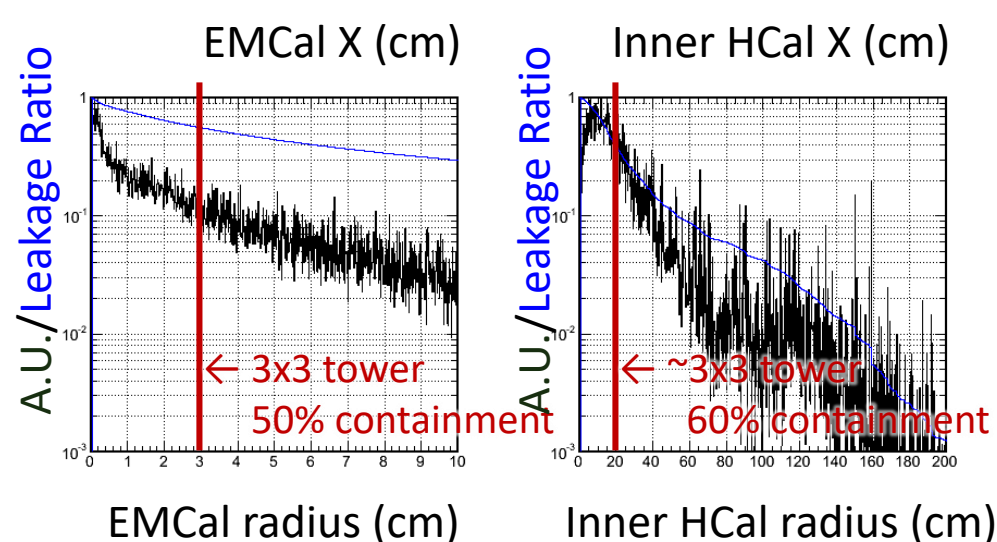
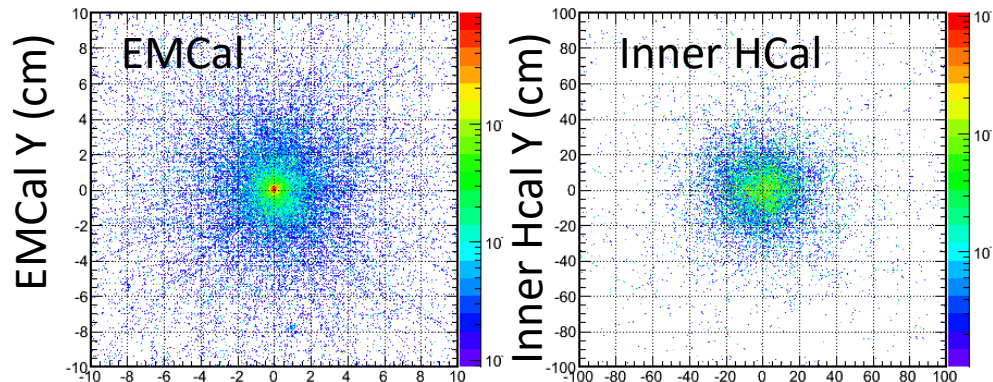
Spatial responses

EMCal design has a tight Moliere radius of 2 cm $\rightarrow$ Reduce background in Au+Au

4 GeV Electrons



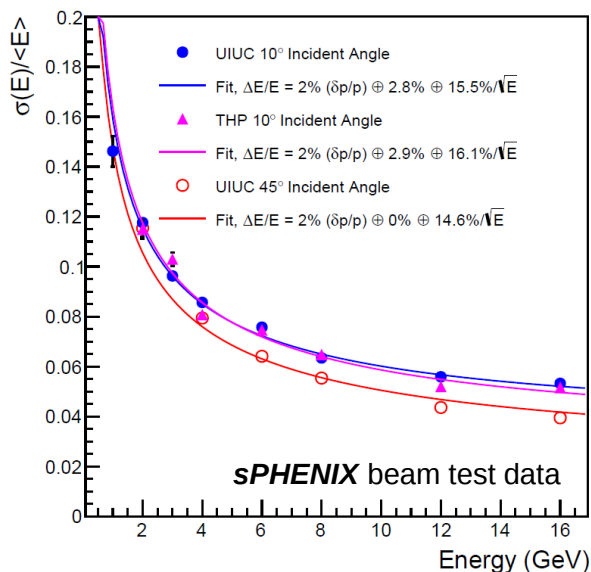
4 GeV Pions, that passed E/p electron-ID cut



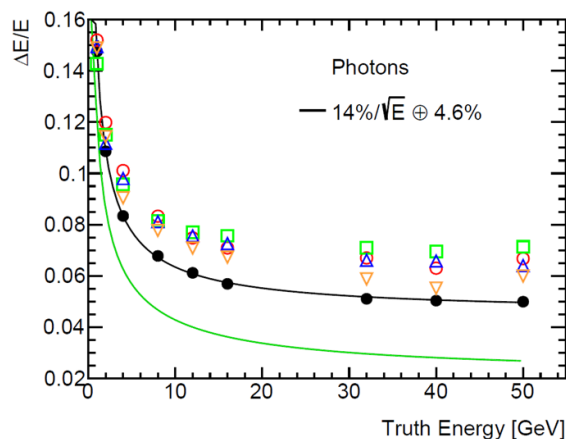
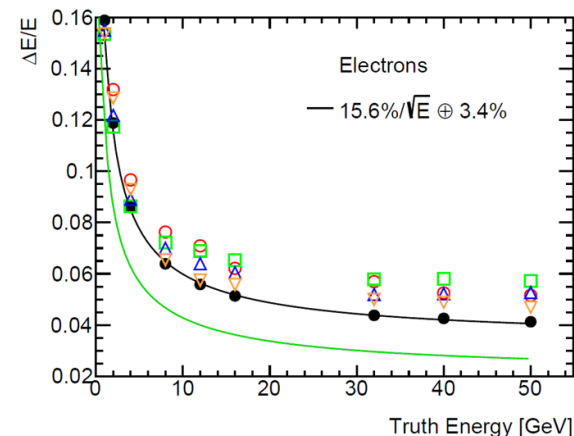
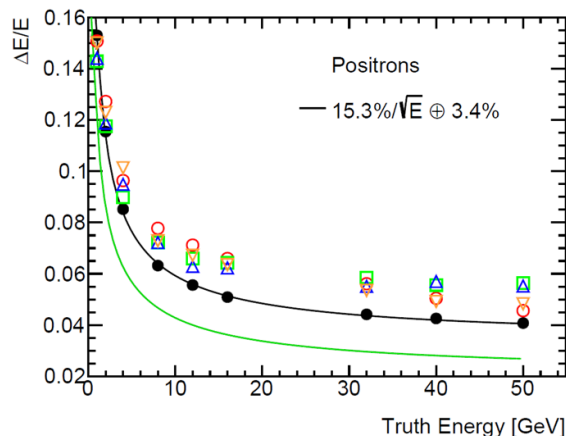
Performance : Single EM Showers

- Applied cluster-position-based non-uniformity correction as used in test beam analysis
- $dE/E \sim 15\%/\sqrt{E} + 4\%$ (meets sPHENIX goal)

Beam test [arXiv:1704.01461]



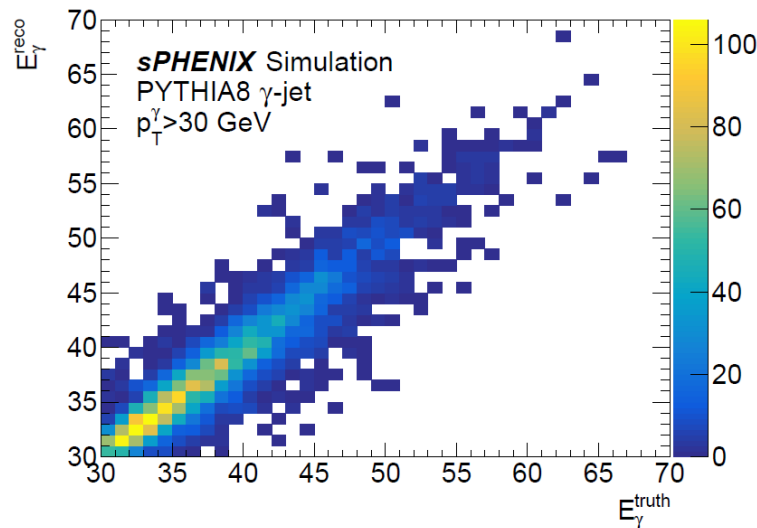
Full sPHENIX detector simulation



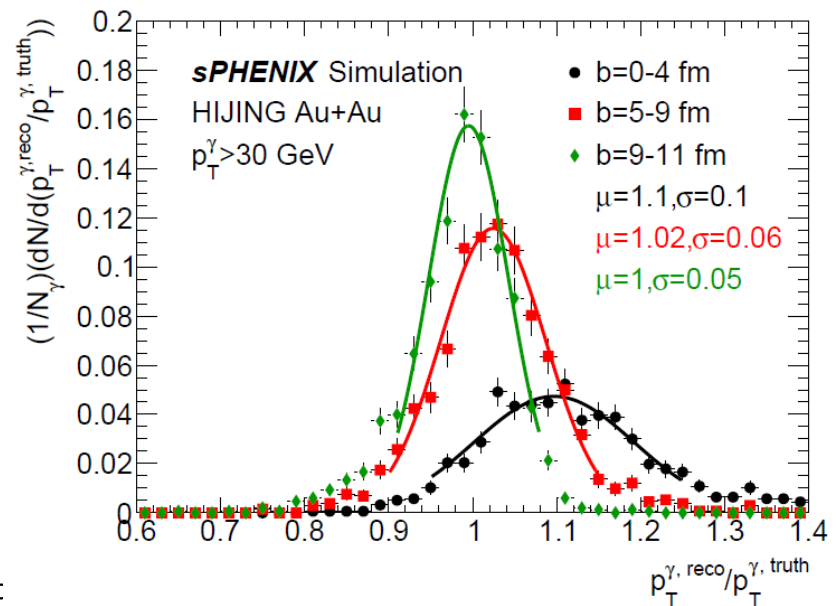
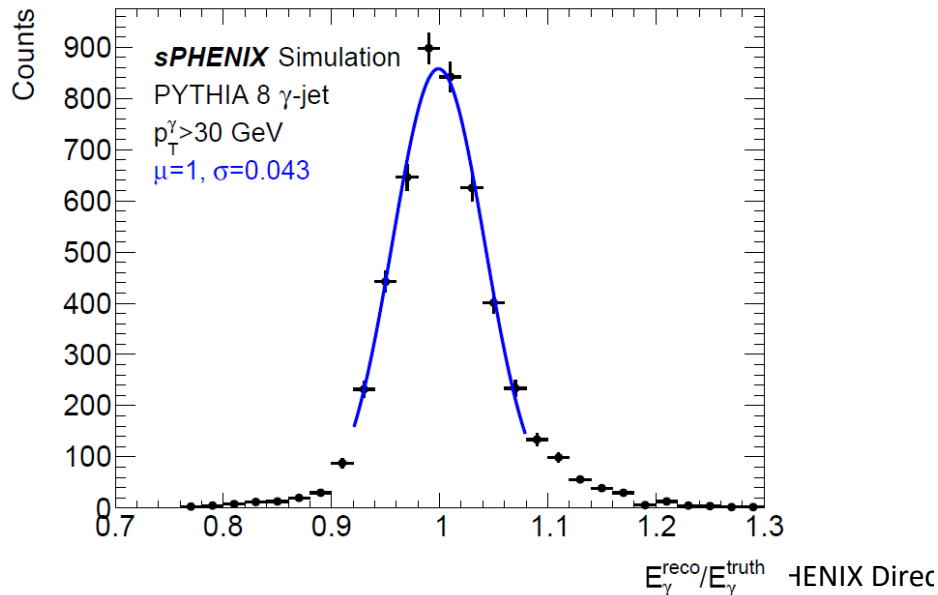
sPHENIX Simulation

- 1 perfect tower simulation, $11.8\%/\sqrt{E} \oplus 2.1\%$
- Position uncorrected, $\eta=0$
- Position uncorrected, $\eta=0.3$
- Position uncorrected, $\eta=0.6$
- Position uncorrected, $\eta=0.9$
- Position corrected

Performance : Photon in Full Event



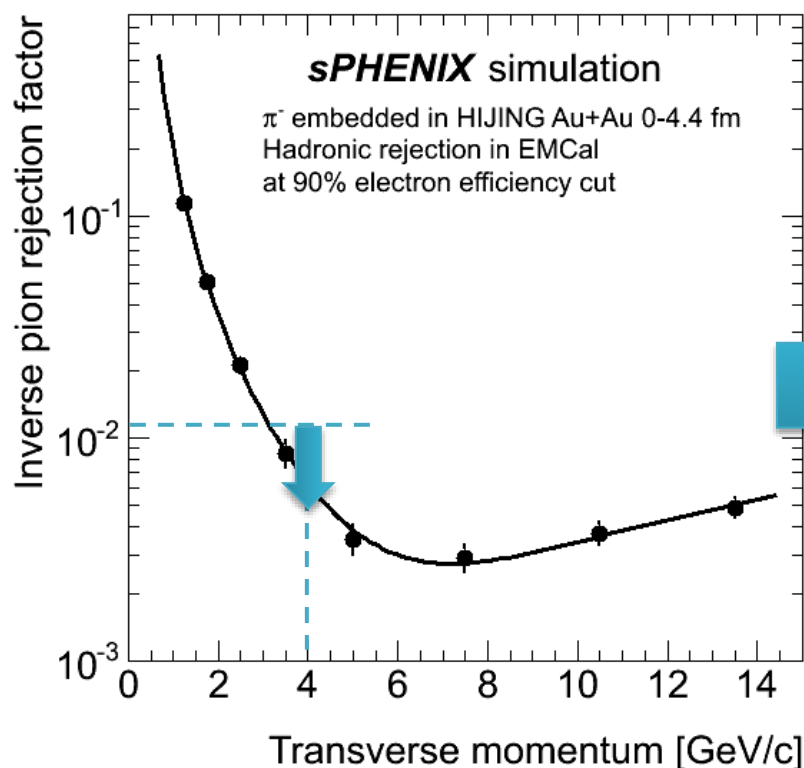
- Good linearity up to photon kinematic limit of sPHENIX
- Good photon response shown in full gamma-jet event simulations
- **In progress:** improving clustering algorithm to minimize background pickup in central Au+Au collisions.
- Nevertheless, jet energy resolution dominates precision for gamma-jet momentum balance measurements



Physics Performance : Electron-ID

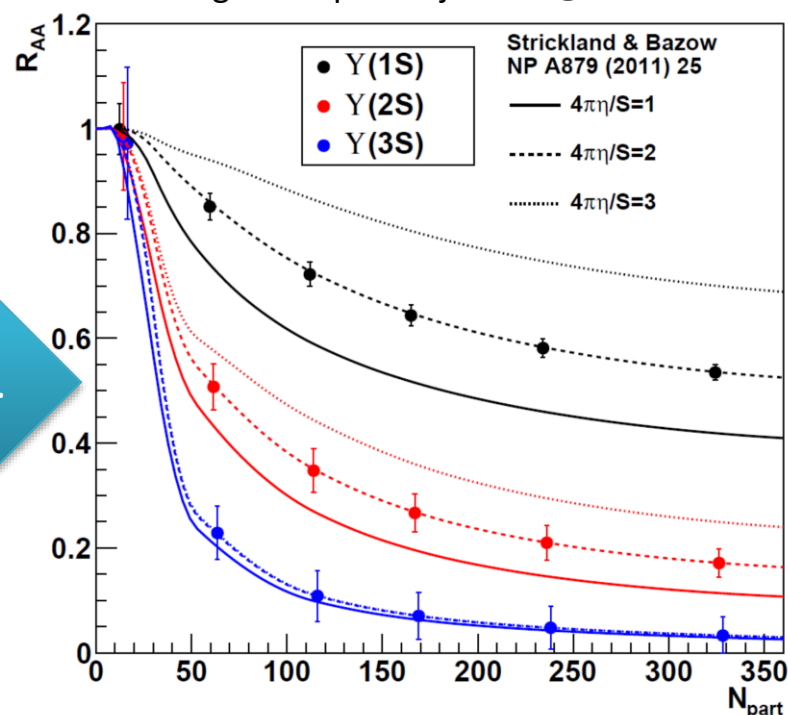
- Critical driving factor for EMCal design: Upsilon electron ID
- Satisfied detector requirement (>90:1-pion rejection @ $p_T=4$ GeV/c in central Au+Au collisions at 70% efficiency)
- Updating Upsilon background and R_{AA} projections

Pion rejection @ (improved) 90% efficiency



Updating ...

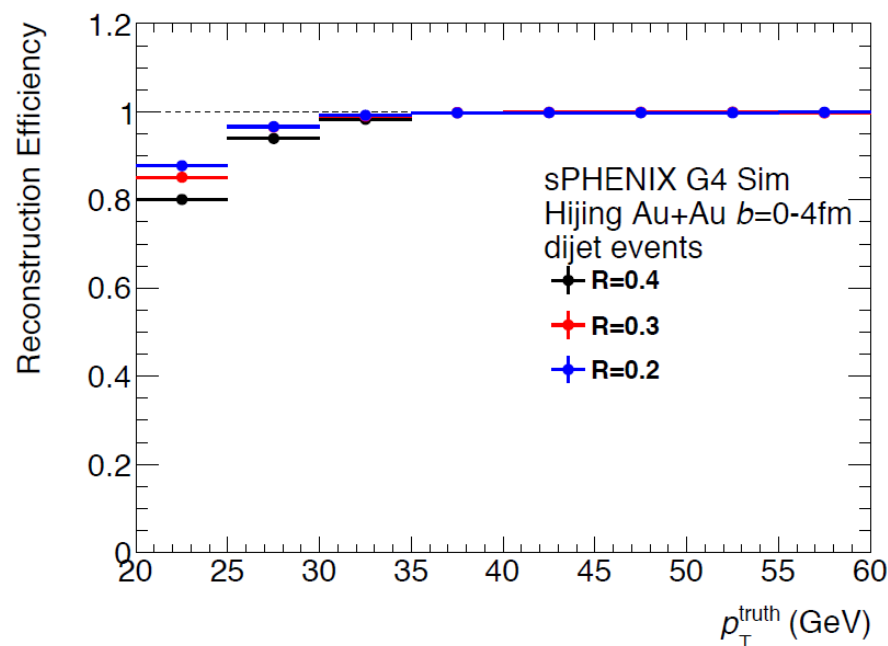
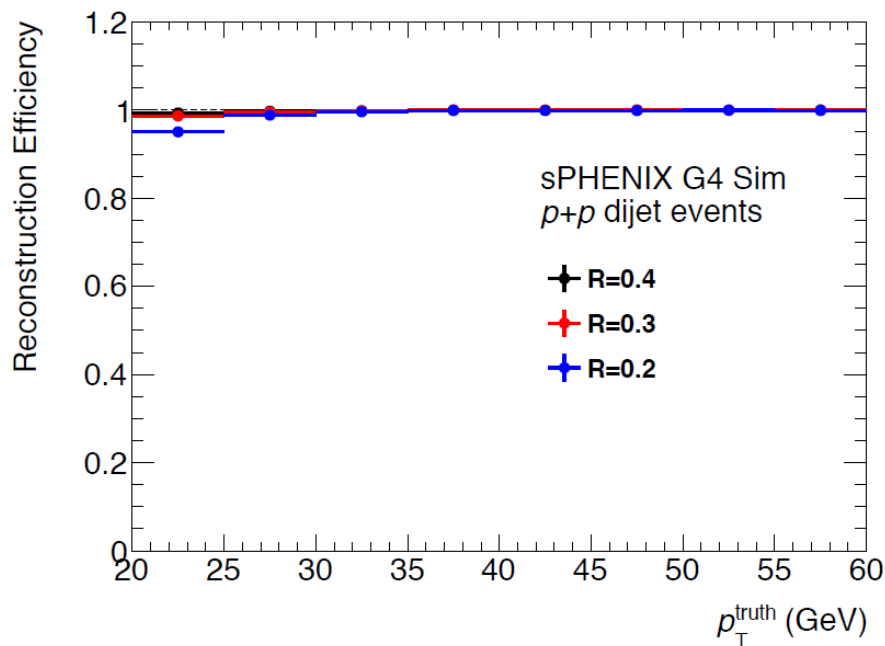
Upsilon R_{AA} projections in **sPHENIX proposal**
 Assuming 100:1 pion rejection @ 70% e-eff.



arXiv:1501.06197

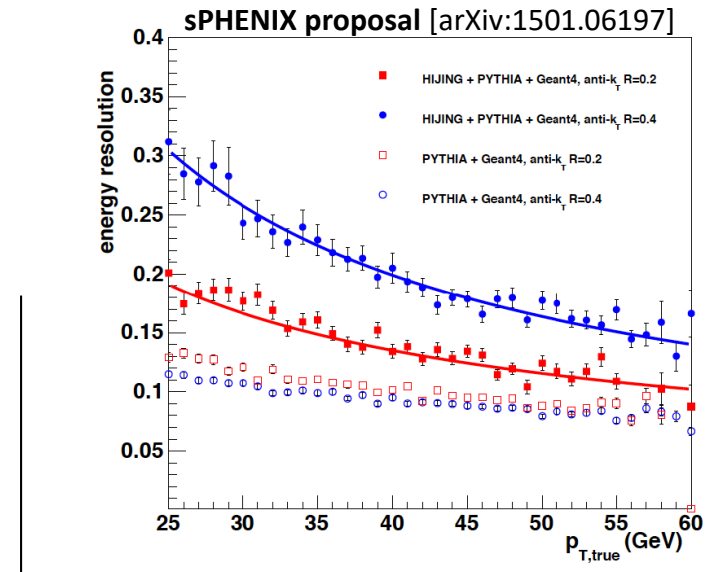
Performance : Jet Finding

- Jets in p+p and central Au+Au collisions are also studied in full detector simulations
- Jet finding followed by iterative background subtraction [[10.1103/PhysRevC.86.024908](https://arxiv.org/abs/10.1103/PhysRevC.86.024908)]
- Study are in progress updating the jet performance plots as in sPHENIX proposal
- Preliminary results show good efficiency (>80% for $p_T > 20$ GeV/c jet in central Au+Au collisions)
- Further improving underlying event subtraction and fake-jet rejection algorithm based on RHIC and LHC experiences

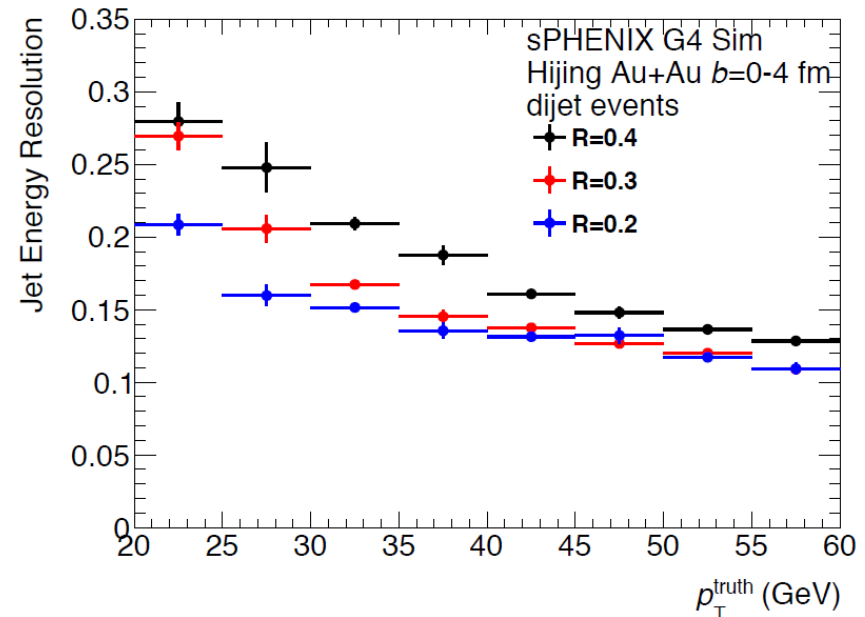
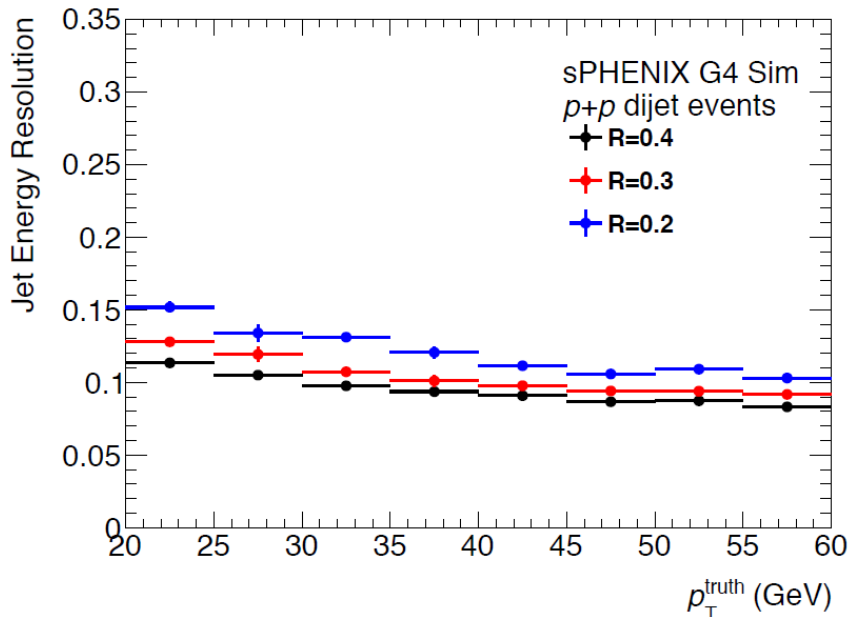


Performance : Jet Energy Resolution

- Detector simulations has been updated with detailed engineering design and beam test tunings
- Study are in progress, **results are still preliminary**
- Preliminary energy resolution was found consistent with simulation study as in sPHENIX proposal [arXiv:1501.06197]



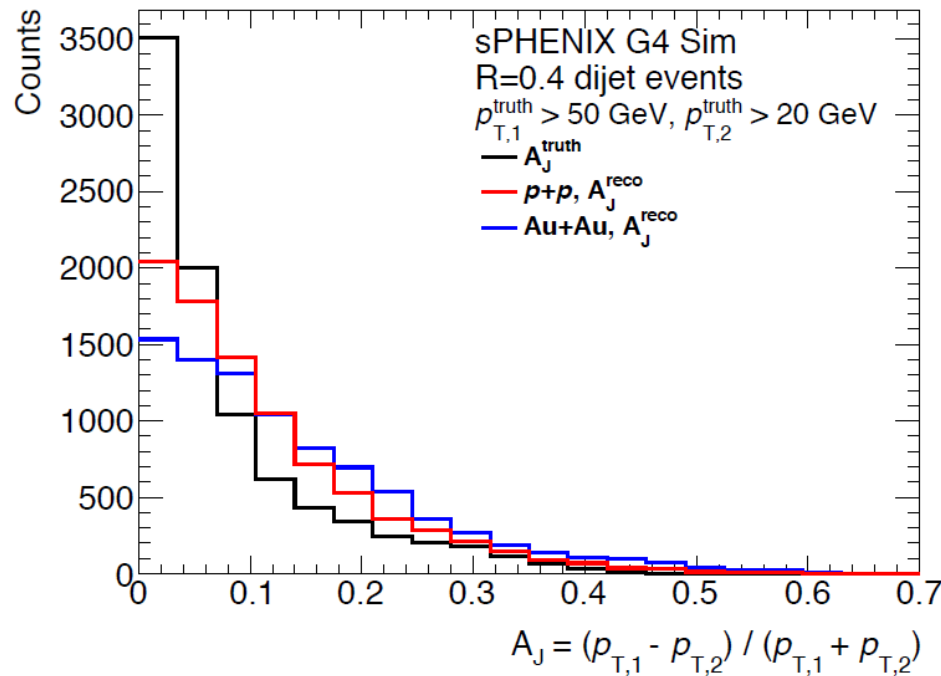
Full detector simulation with the current design



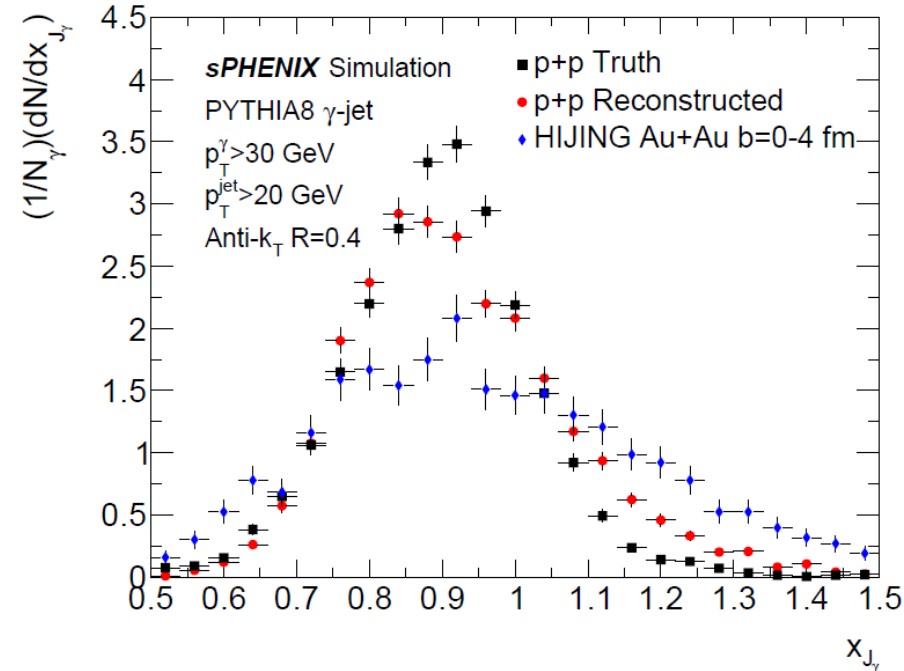
Physics Performance : Jet Observables

- Jet-balance/imbalance observables simulated in full detector events: day-1 measurement, resolution under control
- **On-going effort** in understanding the details of the jet simulations and unfolding studies.
- Expanding jet observables studied with the updated design and simulations

Di-jet transverse momentum asymmetry



γ -jet transverse momentum balance



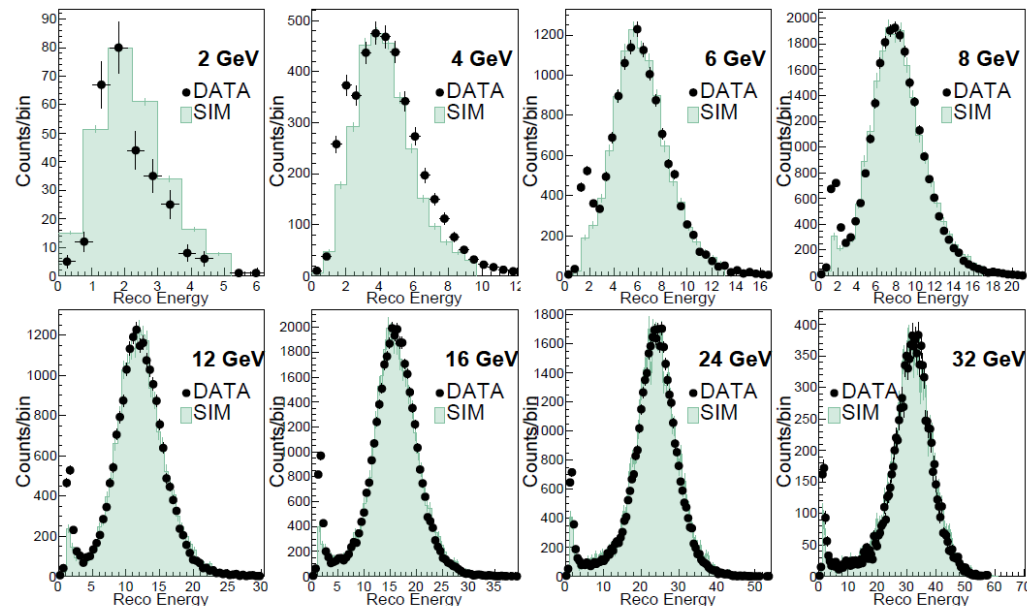
Summary

- A detailed model of the sPHENIX calorimeter has been implemented in GEANT4 and used for design and performance studies
- Good agreement with test beam data
- Calorimeter performance achieves the scientific goals
- Work in progress to update reconstruction algorithms and the physics performance plots with refined detector design and simulation

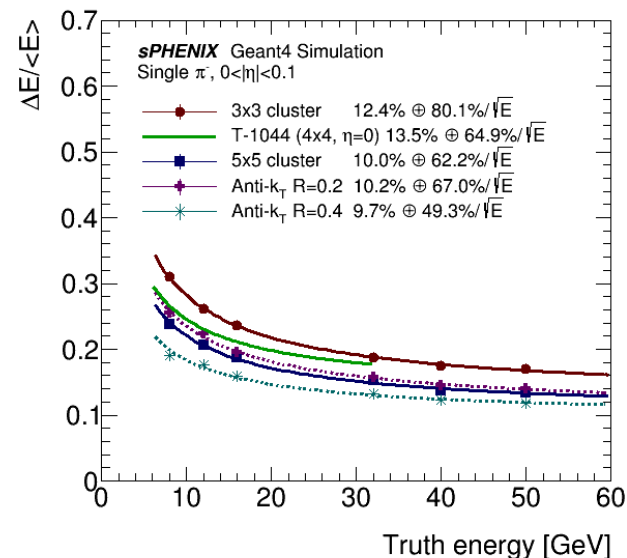
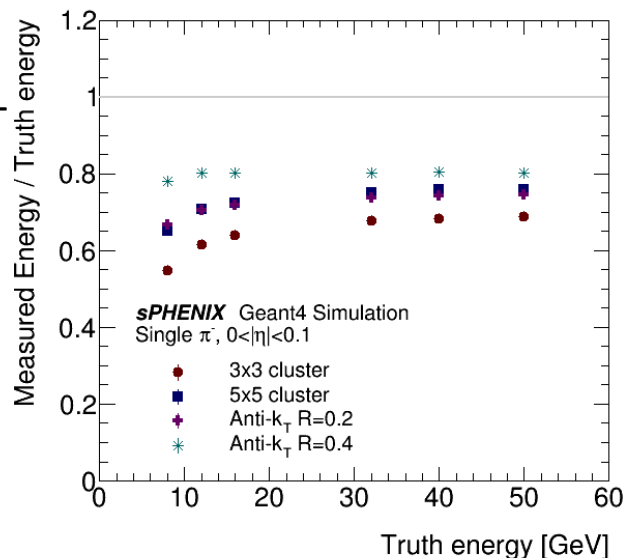
Extra information

HCal simulation verification

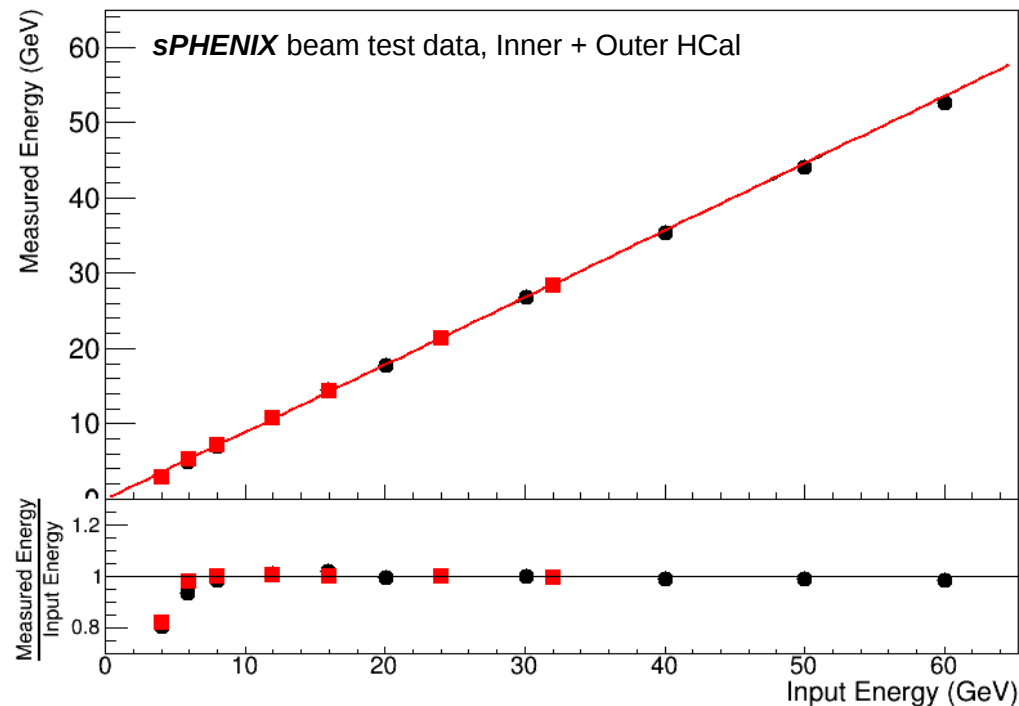
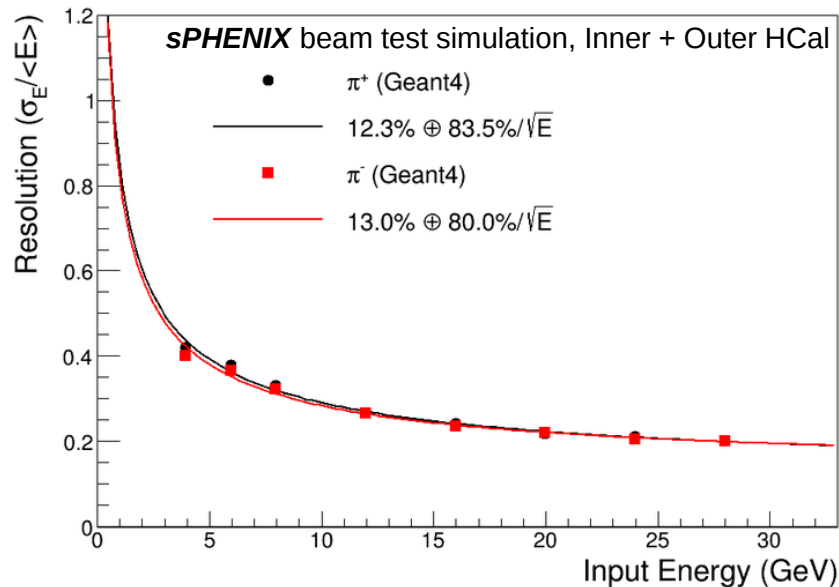
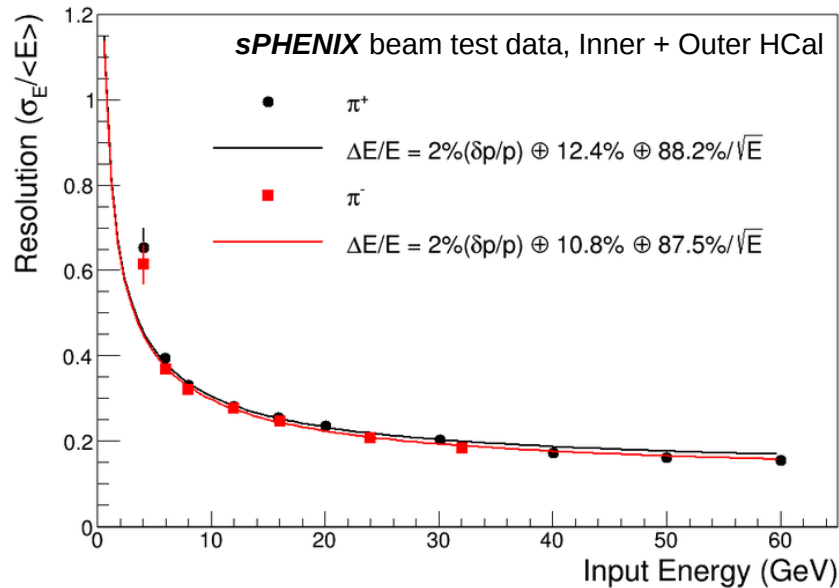
HCal prototype @ eta = 0
energy response for pion-
T-1044 test beam and simulation
arXiv:1704.01461



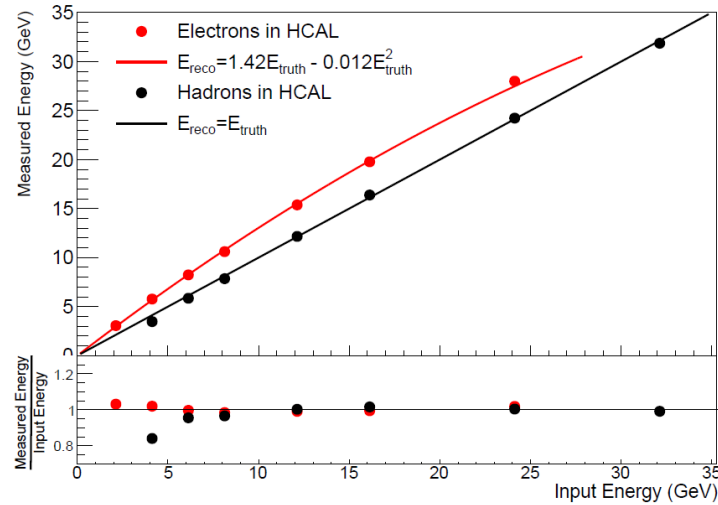
Full sPHENIX
energy response for pion-



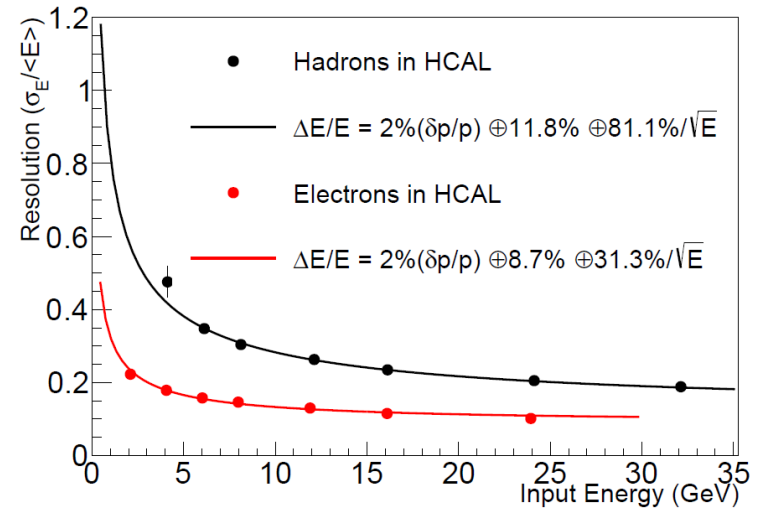
HCal prototype 3 @ $\eta = 1$



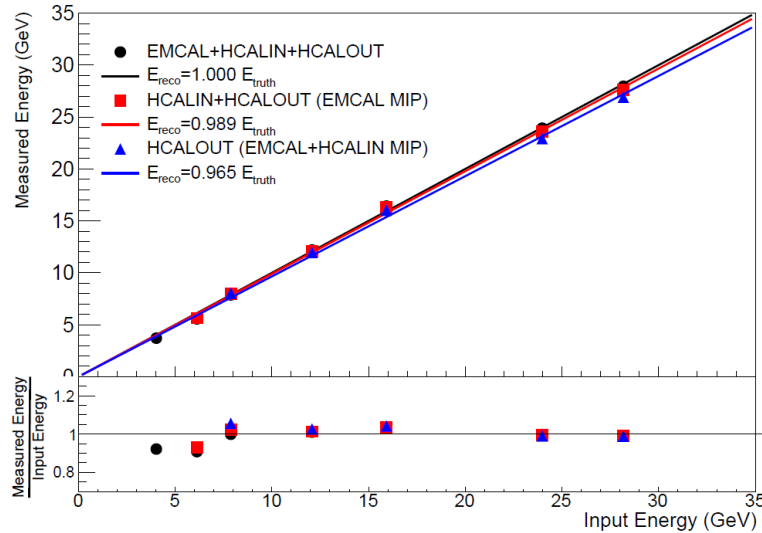
HCal prototype 2 @ $\eta = 0$



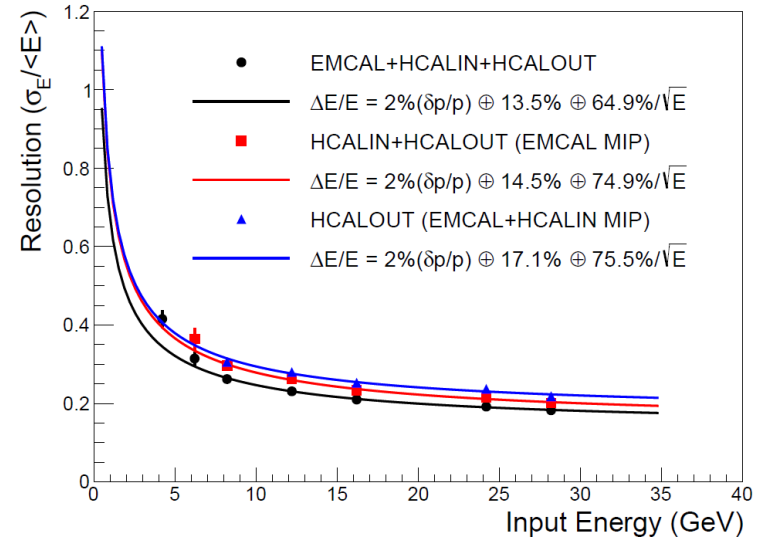
(a)



(b)



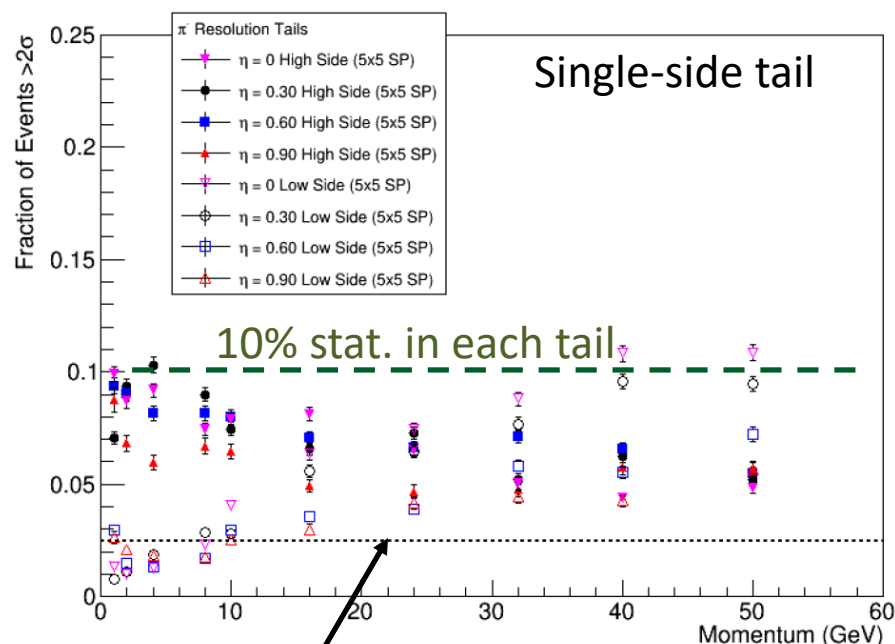
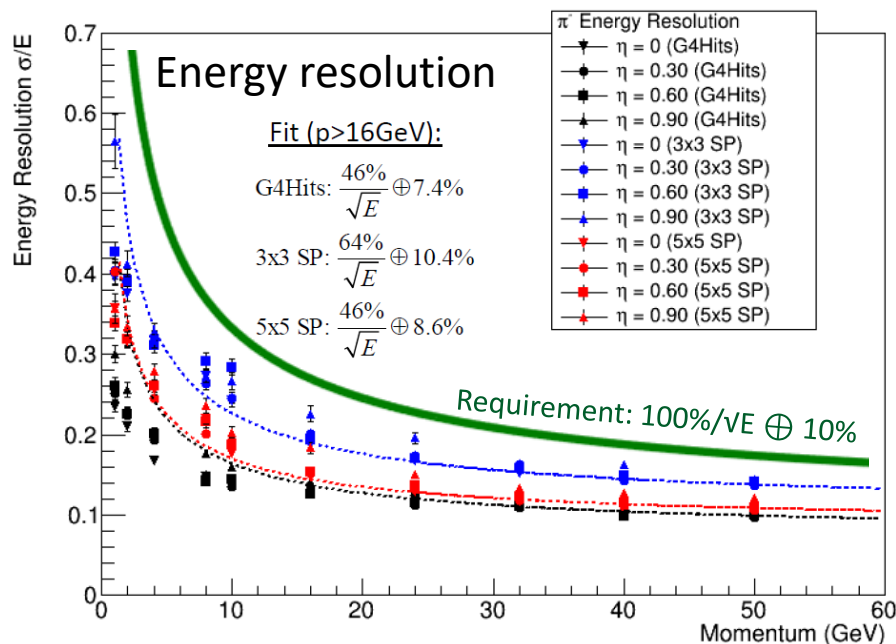
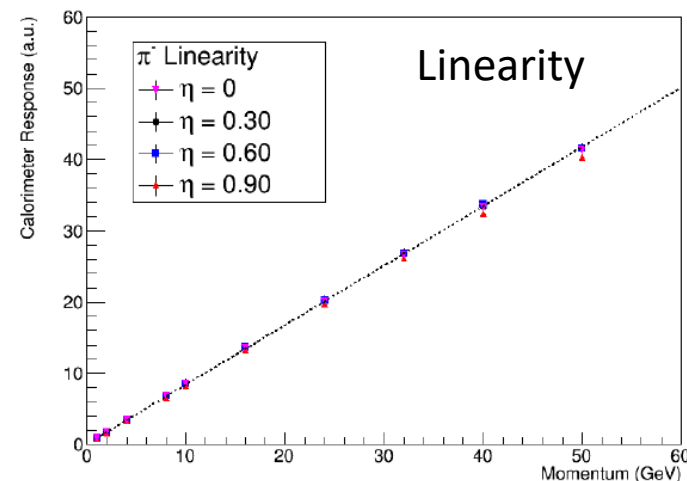
(a)



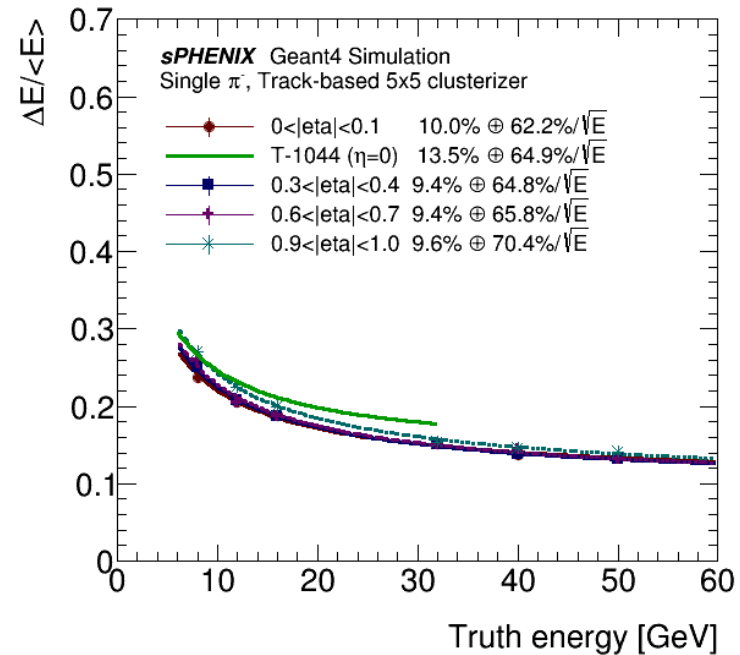
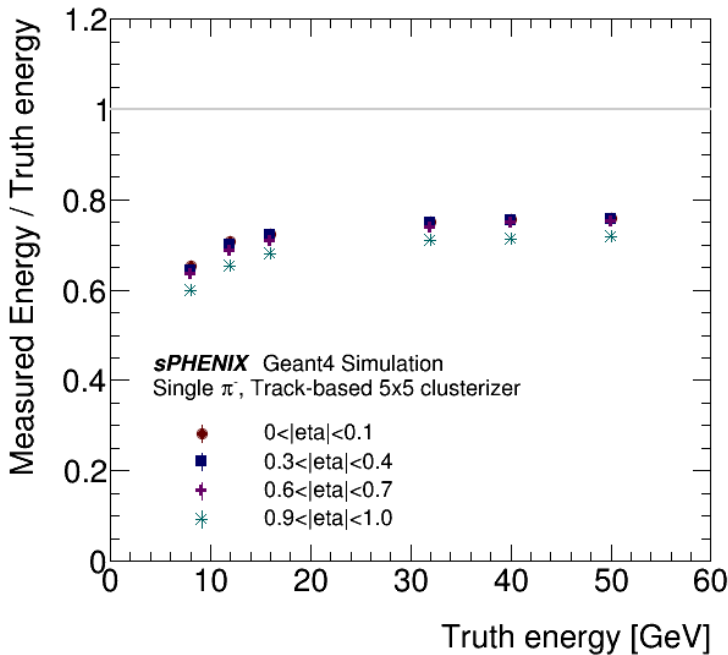
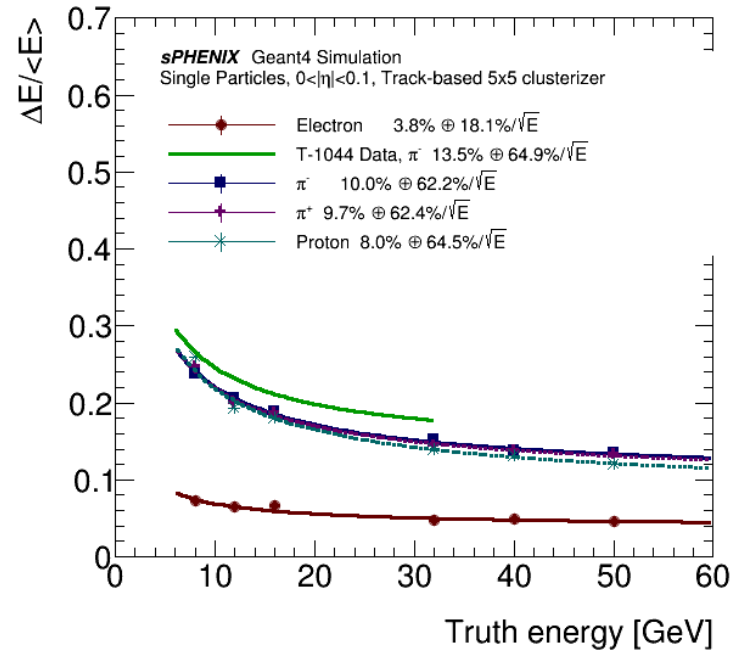
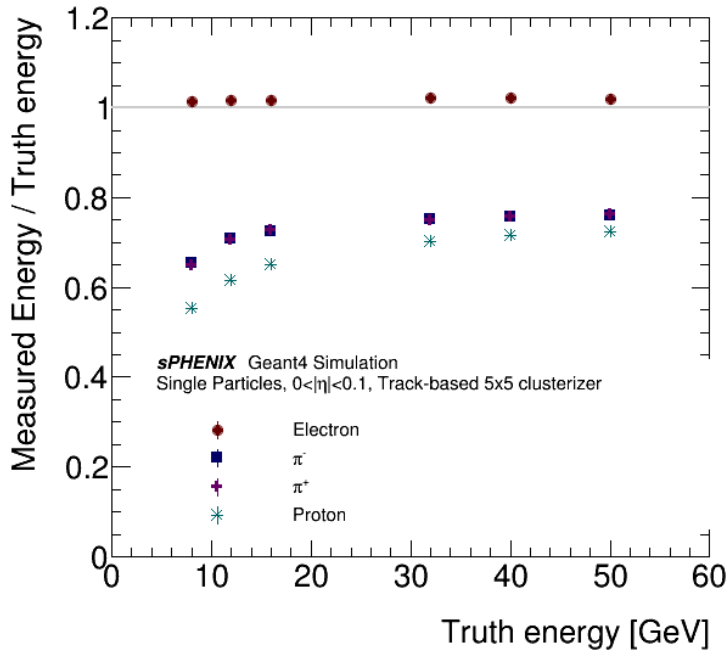
(b)

Performance : Single Hadron showers

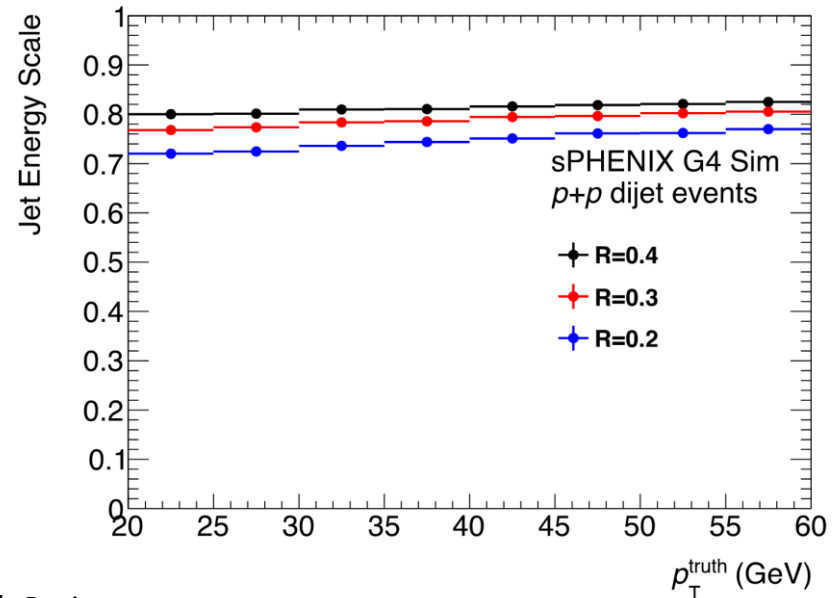
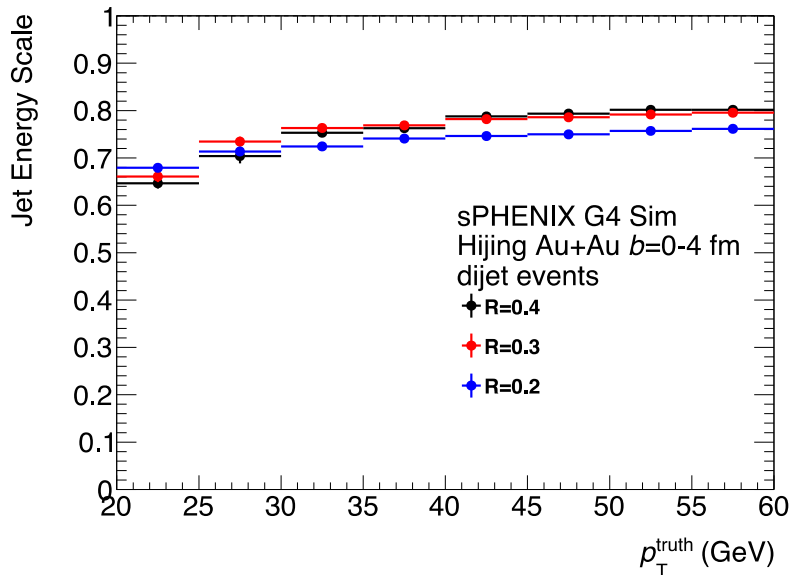
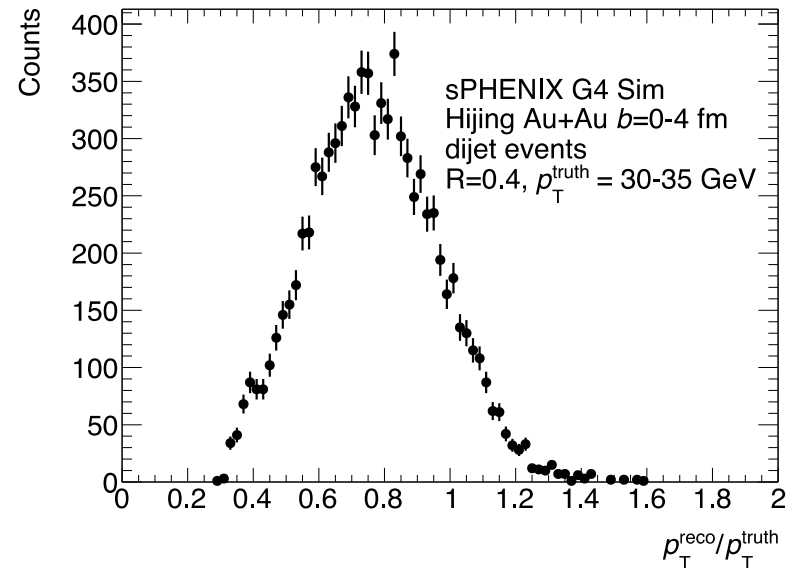
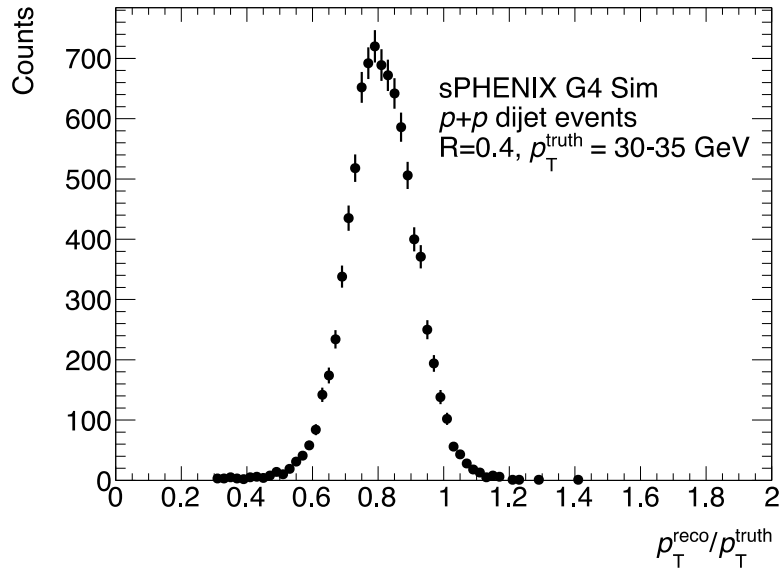
- Single pion shower studied with clusters of digitized towers (3x3 and 5x5 clusters), which is compared with ideal sum of Geant4 hit in scintillator (label G4Hits)
- Energy resolution satisfied design goal.
Tails $\leq 10\%$



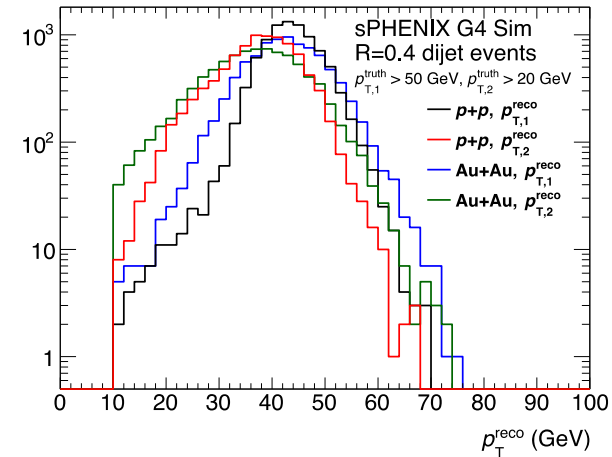
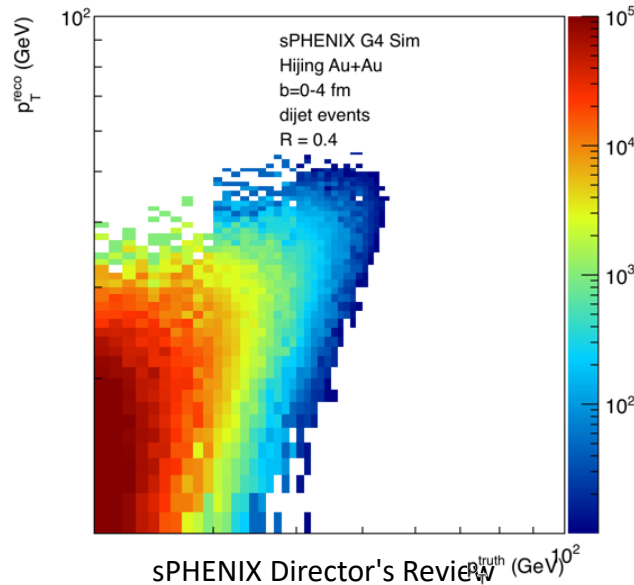
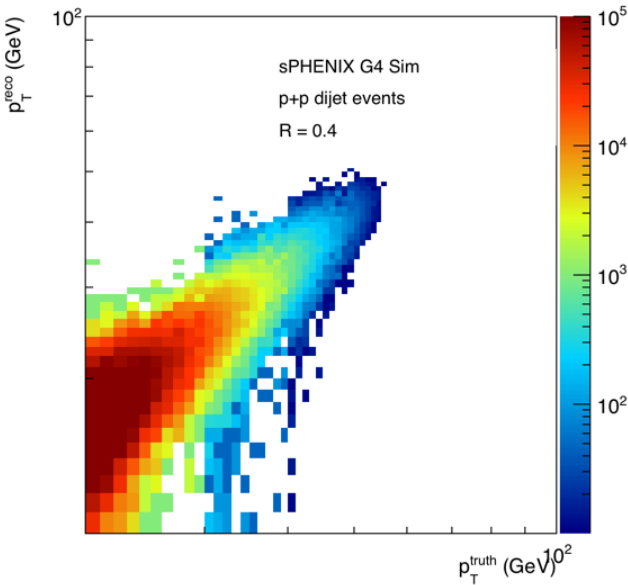
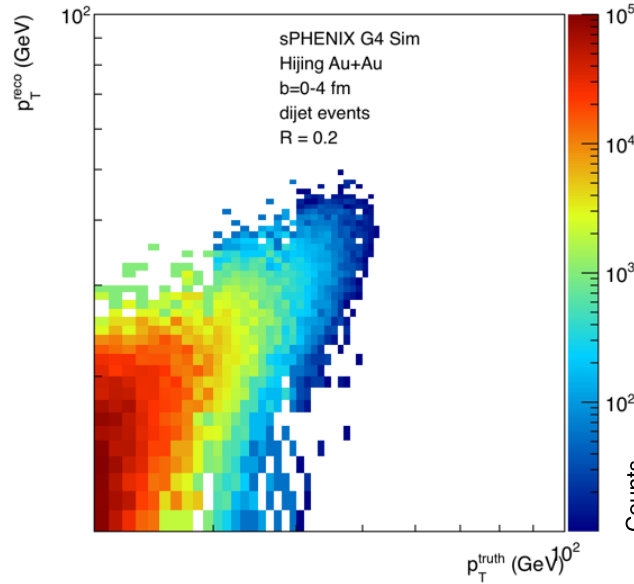
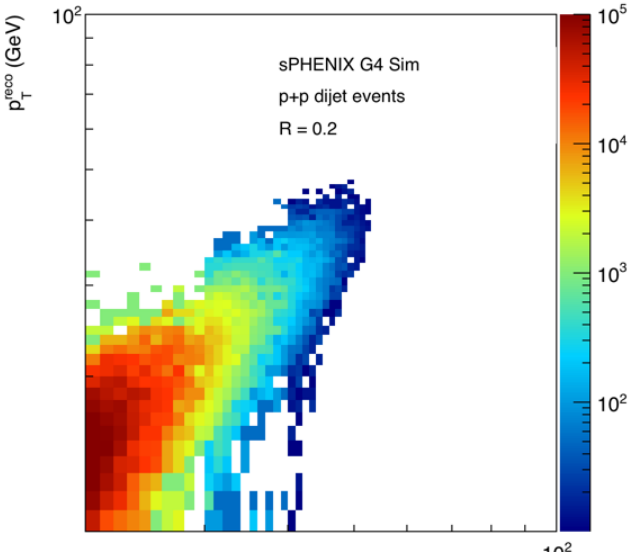
2.5% stat. in tails as expected from Gauss shape



Jet energy response and scale

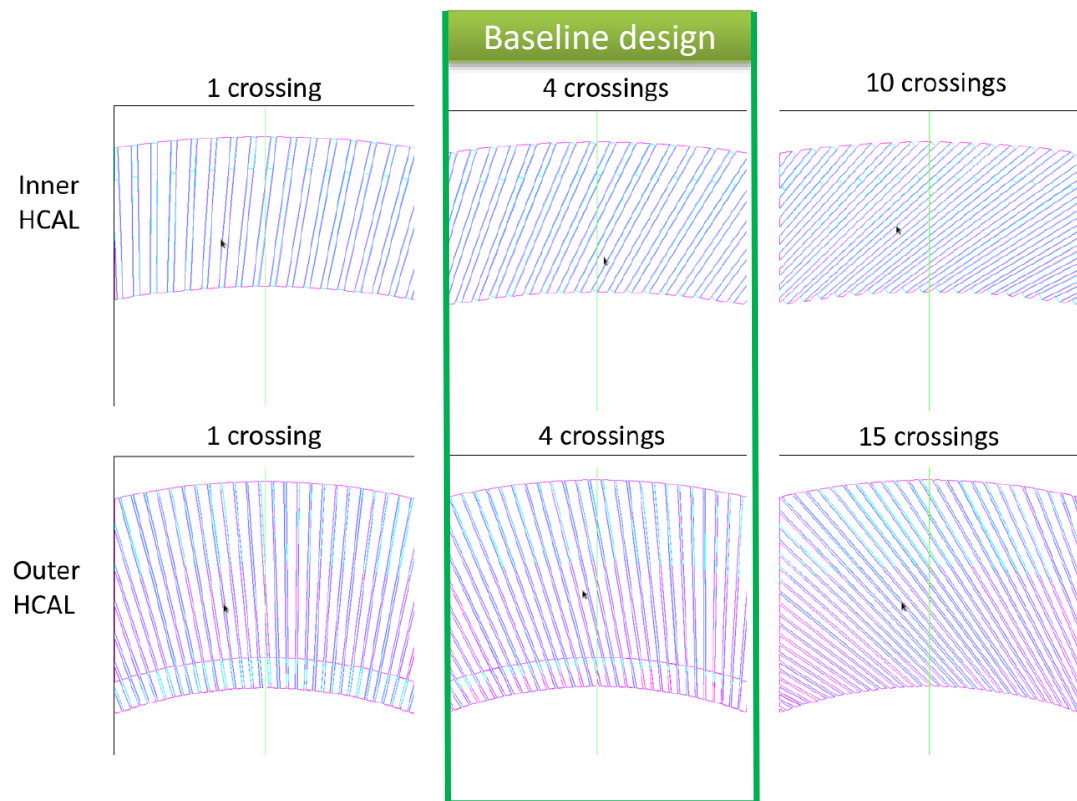


Jet and di-jet response



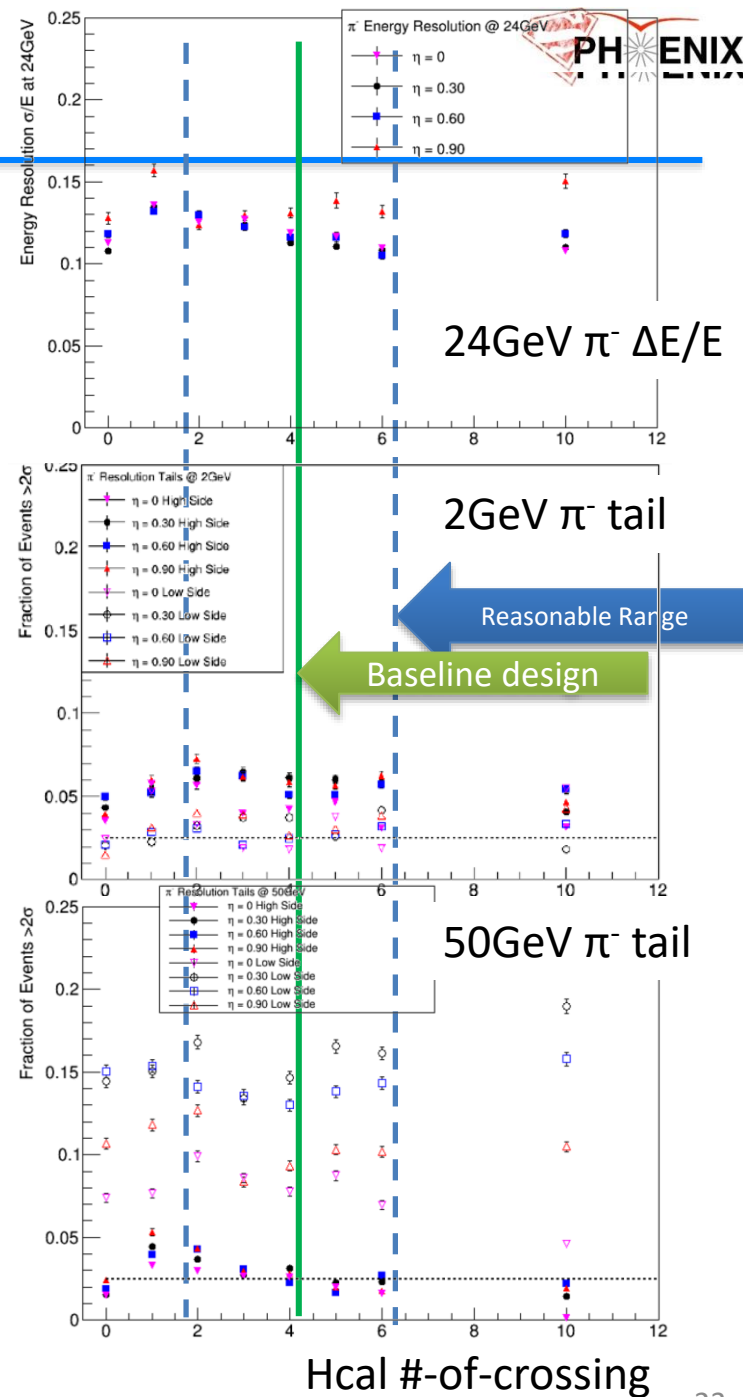
Tilt angle optimization

- Performance not a strong function of tilt angle of Hcal iron plates
- Baseline design (4-crossing tilt angle) is a reasonable choice



Aug 2-4, 2017

sPHENIX Director's Review



Fast simulation for Jets in central Au+Au

- Algorithm developed based on ATLAS and CMS heavy ion experience
- Good efficiency and purity
- Resolution/tails fit for unfolding jet spectrum
- Need to keep updated as detector design/performance evolves

