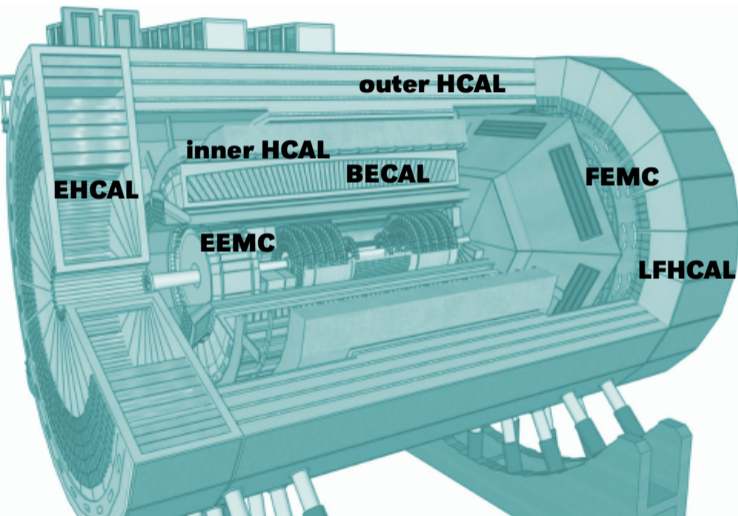


ECCE Calorimeter Design

EICUG Meeting

August 3, 2021

**Friederike Bock, ORNL
for the ECCE consortium**



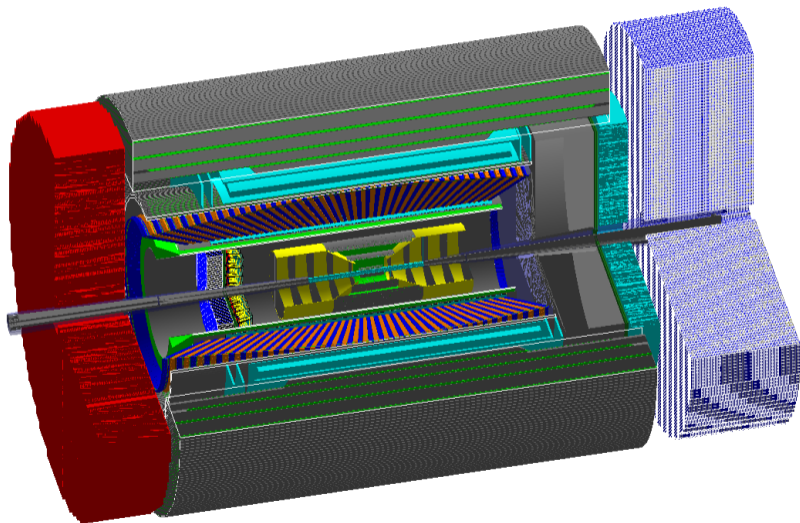
Electromagnetic Calorimeters:

- Full coverage with optimum resolution $\eta < 1.1$
- High granularity in forward & backward direction
- Cost reduction through re-use of existing calorimeters where appropriate

Hadronic Calorimeters:

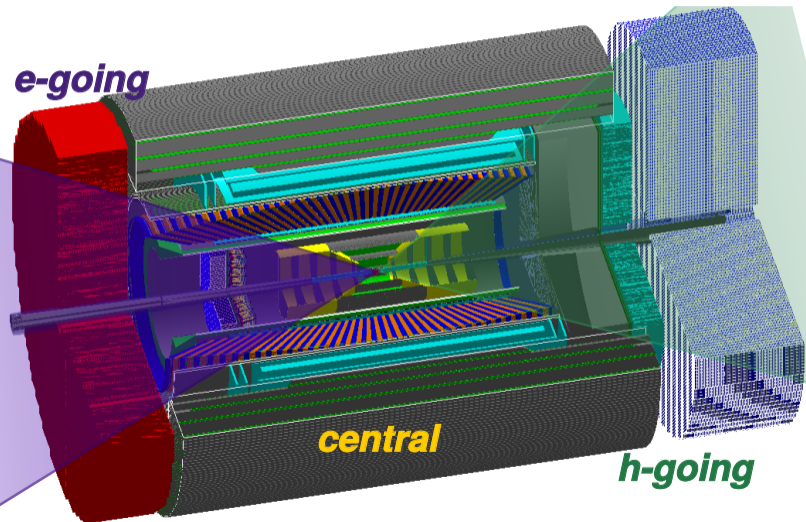
- Good energy & position resolution $\eta > 1.2$
- High granularity in forward direction
- Maximum η coverage
- Cost reduction through re-use of existing calorimeters where appropriate

First version of default setup fully implemented in Geant4!



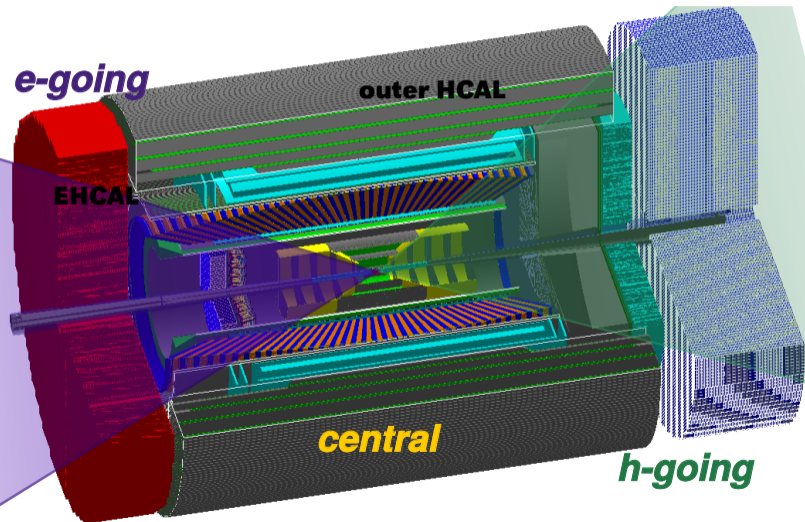
- Re-use existing outer sPHENIX & STAR forward HCal
- Re-use existing PHENIX Shalick ECal w/ upgraded readout
- Build new homogenous ECals
- Build new inner HCal in barrel ECal support frame
- Build new longitudinally separated forward HCal

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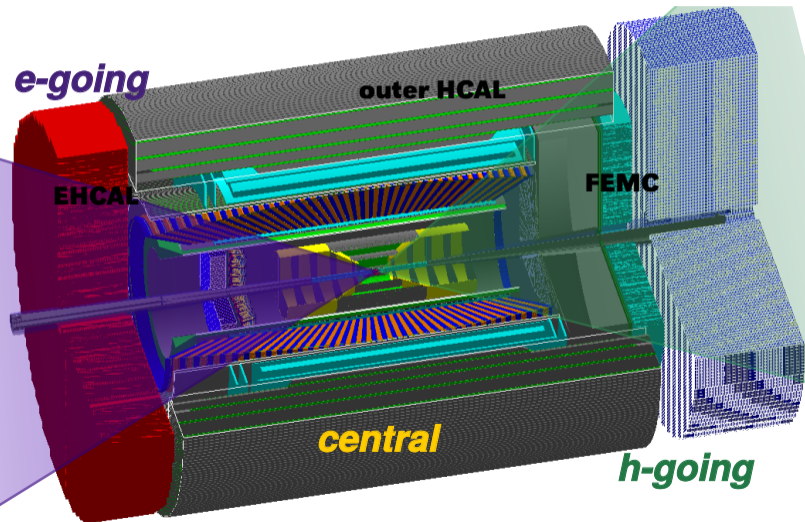
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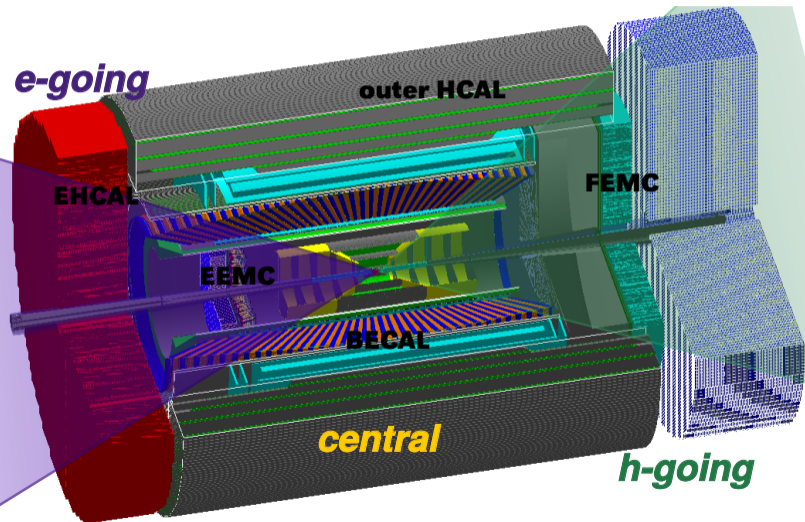
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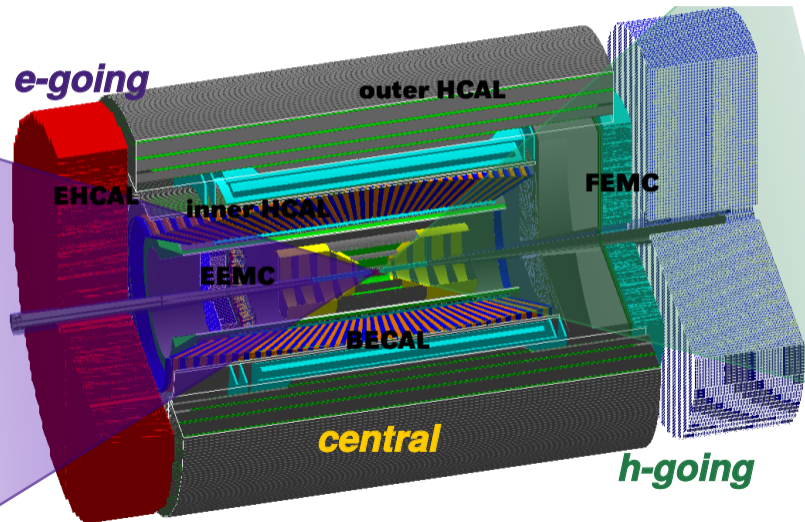
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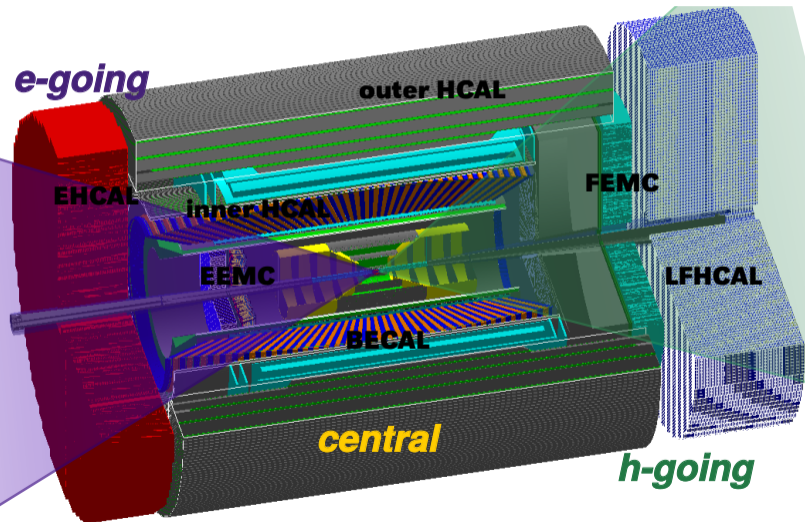
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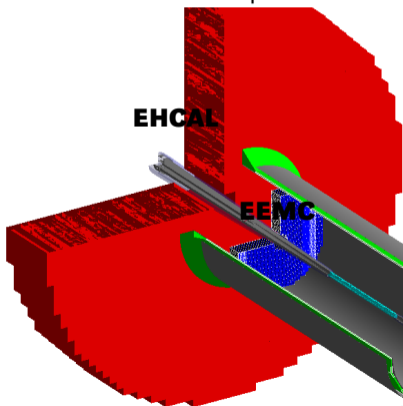
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ECAL (EEMC): PbWO_4 homogeneous calorimeter

- $2 \times 2 \times 18$ cm tower, partially re-used from prev. experiments
- $10 < r$ (cm) < 60 , $z = -1.9$ m
- $-3.2 < \eta < -1.85$
- Alternative: replace outer rings with $4 \times 4 \times 40$ cm Sci-Glass towers

Interested Groups:

AANL, Charles U. Prague,
CUA, FIU, IJCLab-Orsay, JMU,
Lehigh U., MIT, UKY

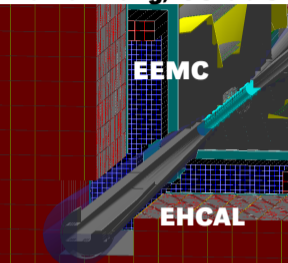


HCAL (EHCAL):

- Re-use STAR-forward HCal w/ upgraded electronics
- $10 \times 10 \times 100$ cm towers read-out with 8 Si-PMs per WLS plate,
 $L \sim 7\lambda$
- $15 < r$ (cm) < 282 , $z = -3.6$ m
- $-3.87 < \eta < 0.97$

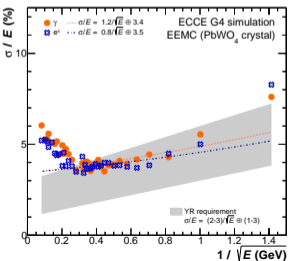
Interested Groups: ORNL, Wayne State

Pu-Kai Wang, IJCLab-Orsay

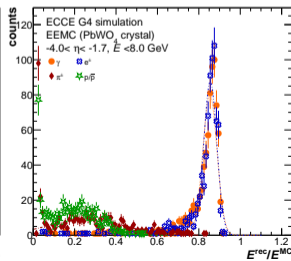
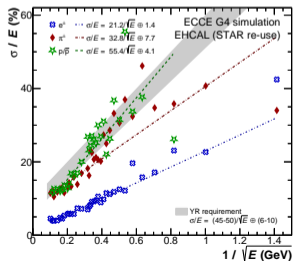


- Performance evaluation ongoing for EEMC pure crystal and hybrid design & EHCAL in full G4 simulations
- Standalone simulations show expected performance in relevant kinematic ranges
- Adding support structures & other detectors to study performance degradation/ improvement
- More sophisticated cluster reconstruction algorithms under development

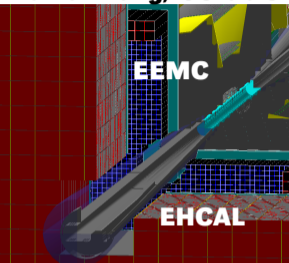
EEMC standalone



EHCAL standalone

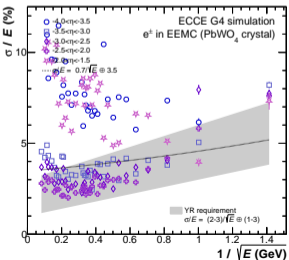


Pu-Kai Wang, IJCLab-Orsay

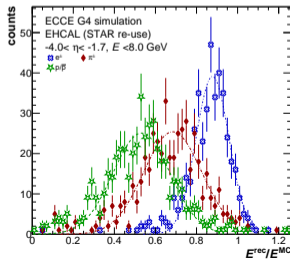
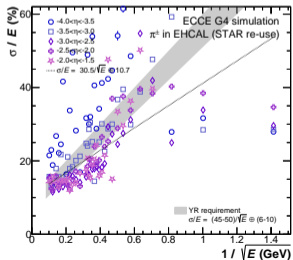


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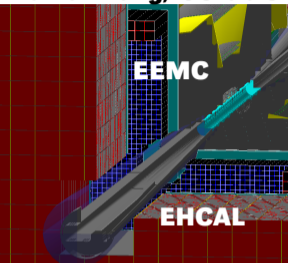
EEMC standalone



EHCAL standalone

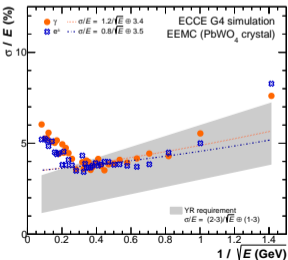


Pu-Kai Wang, IJCLab-Orsay

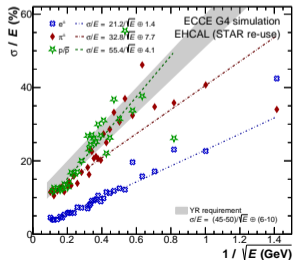


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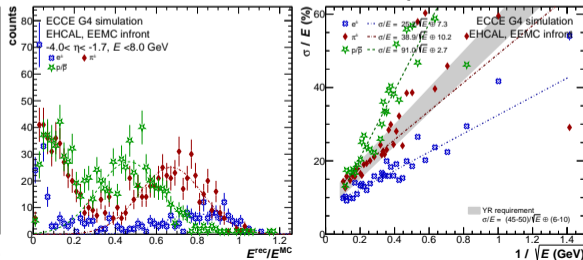
EEMC standalone



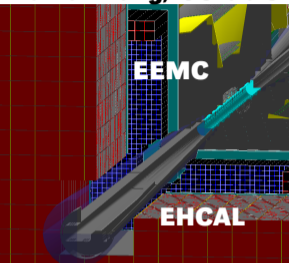
EHCAL standalone



EHCAL w/ EEMC in front

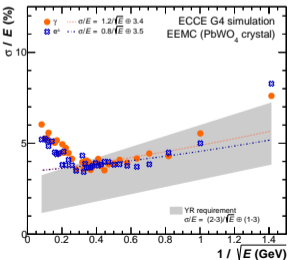


Pu-Kai Wang, IJCLab-Orsay

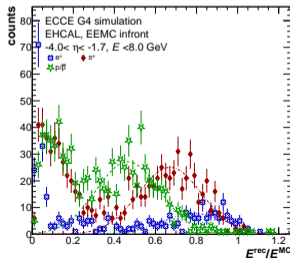
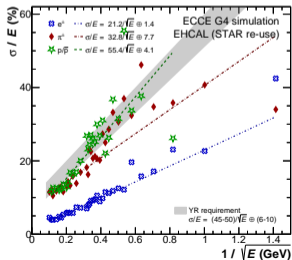


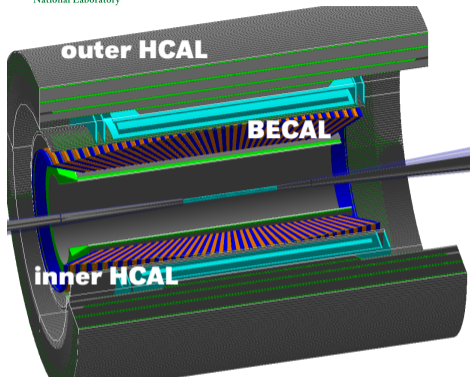
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EEMC standalone



EHCAL standalone





E-Cal: Sci-Glass calorimeter

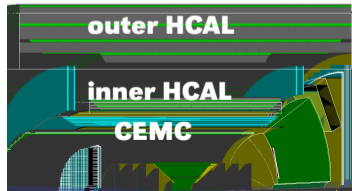
- Scintillation glass homogeneous electromagnetic calorimeter
- $4 \times 4 \times 40$ cm partially projective towers
- $r > 82$ (cm), $-1.74 < \eta < 1.31$
- Steel support frame equipped with scintiling tiles (inner HCal)
- Alternative: Re-use sPHENIX SPACAL EMC with upgraded read-out

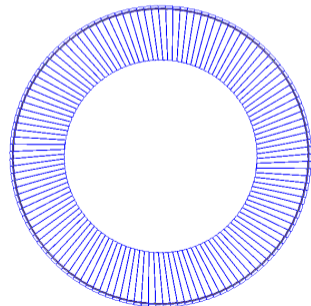
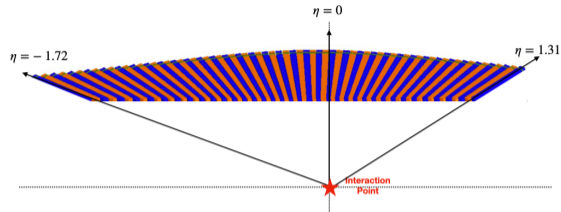
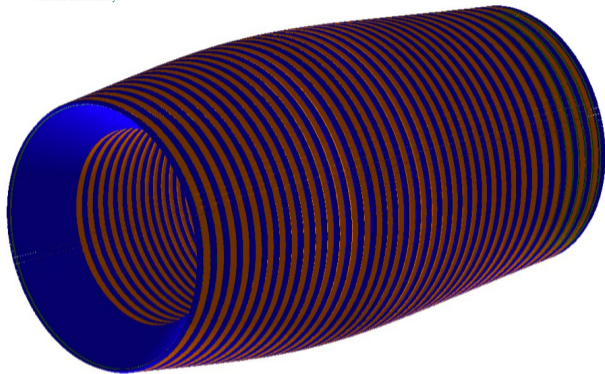
Interested Groups: MIT, CUA, OSU

H-Cal: Re-use sPHENIX HCal

- Steel-Scintillation-Tile Calorimeter
- $r = (180, 194)$, $-1.16 < \eta < 1.16$
- Read-out upgrade with new SiPMs

Interested Groups: Lehigh U., Rutgers U., ISU

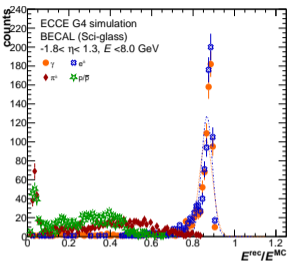




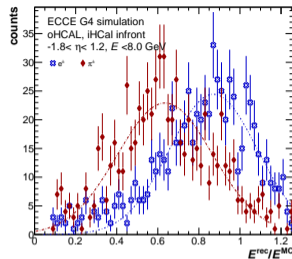
- Scintillation glass homogeneous electromagnetic calorimeter with 40 cm deep towers
- Towers projective in η to (0 cm, 0 cm, 10 cm) & tilted by 10° in φ
- Bore radius at 82 cm

Interested Groups: MIT, CUA, OSU

Nathaly Santiesteban, MIT

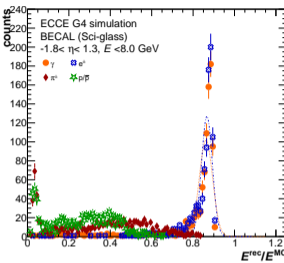


BECAL standalone

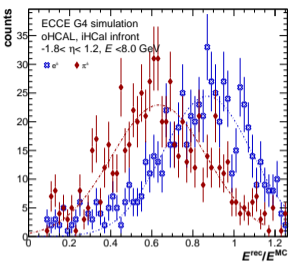
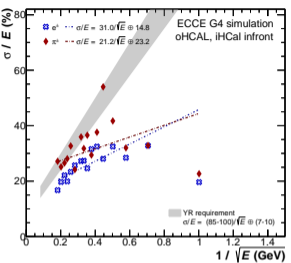
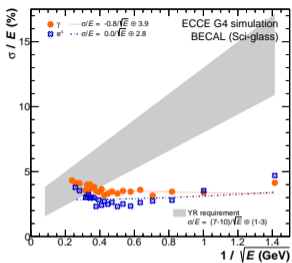


oHCAL w/ iHCAL in front

- Simultaneous performance evaluation ongoing for BECAL, inner and outer HCAL in full G4 simulations for two different configurations
- Optimizations for realistic noise & digitization for BECAL on-going
- Cross-calibrations of new iHCAL and oHCAL under evaluation
- η dependence of projective BECAL implementation under study
- Adding support structures & other detectors to study performance degradation/ improvement
→ tight spatial constraints need to check φ/η dependence carefully

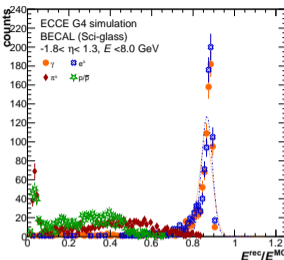


BECAL standalone

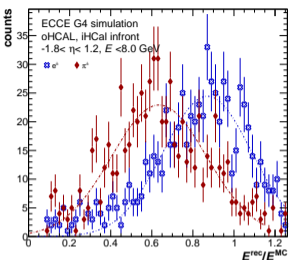
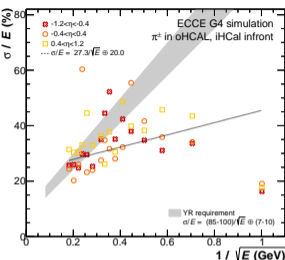
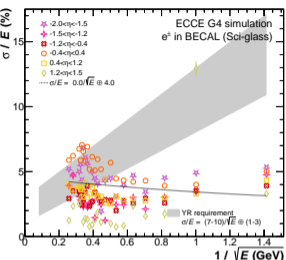


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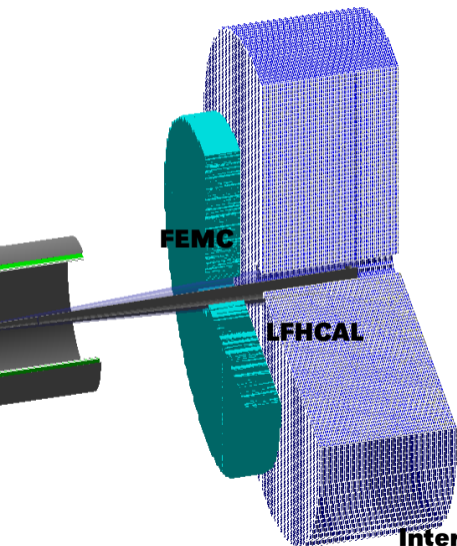


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→ tight spatial constraints need to check φ/η dependence carefully



ECAL (FEMC): Pb-Scint. Shalikh calorimeter

- PHENIX re-use
- 60 layers Pb & Scintillator
- $5.5 \times 5.5 \times 37.5$ cm towers read-out with 9 Si-PMs, $L \sim 18X_0$
- $20 < r$ (cm) < 183 , $z = 2.9$ m
- $1.24 < \eta < 3.5$

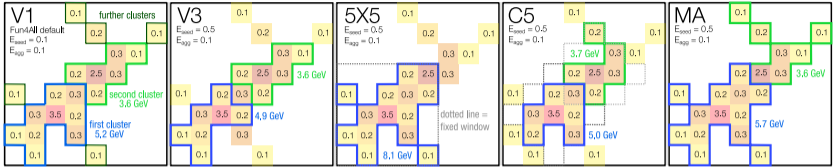
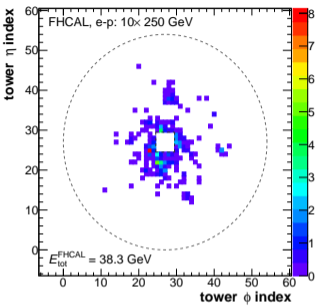
Interested Groups: ORNL, Rutgers U.

HCAL (LFHCAL):

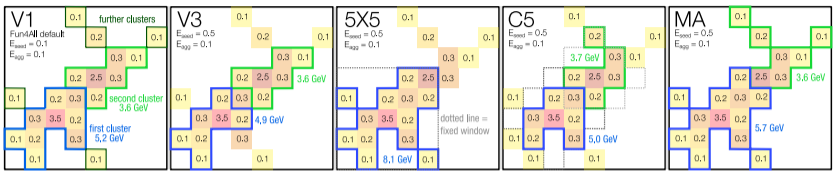
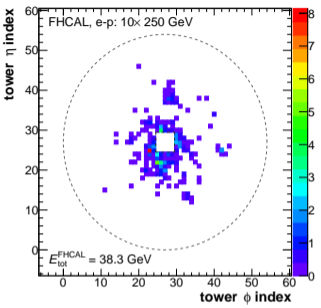
- longitudinally separated Fe-Sci tile calorimeter
- 70 layers 1.6mm Fe, 0.4mm Sci
- $5 \times 5 \times 140$ cm towers read-out with 7 Si-PMs, $L \sim 7\lambda$
- read out in 7 segments 10 layers each
- $20 < r$ (cm) < 282 , $z = 3.5$ m
- $1.11 < \eta < 3.47$

Interested Groups: ORNL, WSU, Sejong U., KNU, Yonsei U., PNU

Clusterization performance

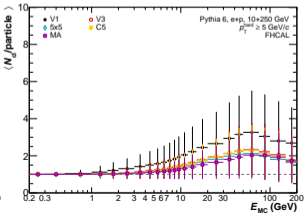
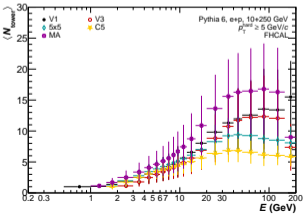
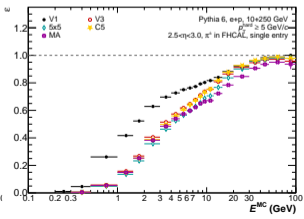
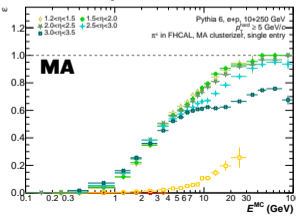


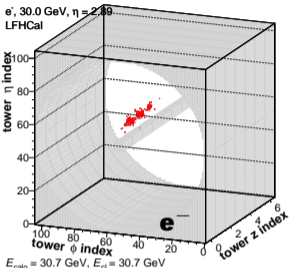
- Cluster finding and association to single particle challenging task in forward/backward direction - opportunity for AI
- Software developments important - implemented different algorithms:
 - Fun4All default w/o thresholds (V1)
 - areas based: square (NxN) or circle (CN)
 - simple splitting w/ thresholds (V3)
 - splitting including diagonals w/ thr. (MA)
- Different cluster finding efficiencies, resolutions & other properties



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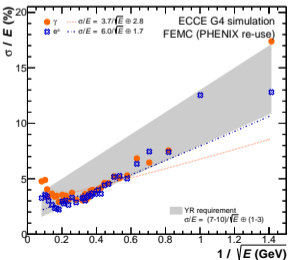
FHCAL/EHCAL



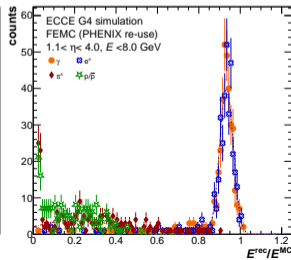
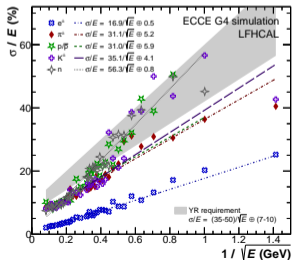


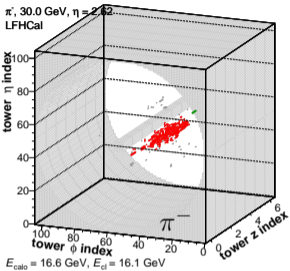
- 3D-cluster reconstruction could allow for significantly better shower separation
- Potential for meson/baryon separation in LFHCAL through shower development
- Simultaneous performance evaluation ongoing for FEMC & LFHCAL in full G4 simulations
- Adding support structures & other detectors to study performance degradation/ improvement

FEMC standalone



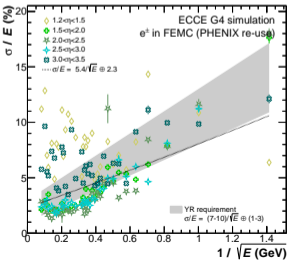
LFHCAL standalone



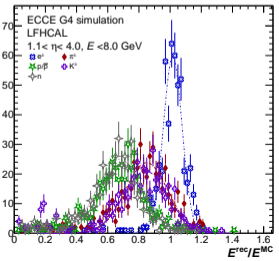
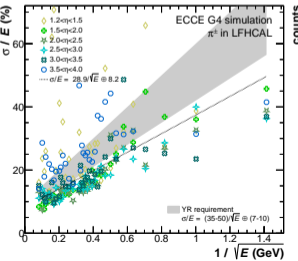


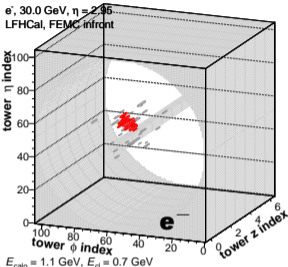
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FEMC standalone



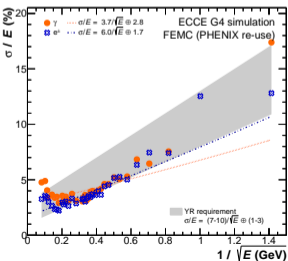
LFHCAL standalone



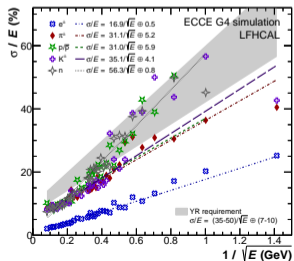


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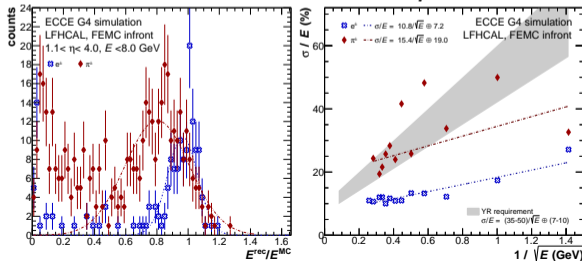
FEMC standalone

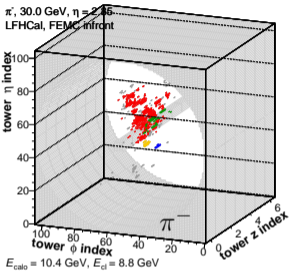


LFHCAL standalone



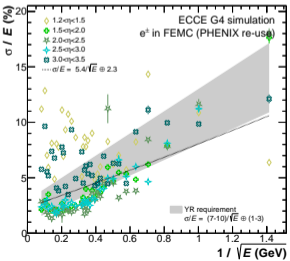
LFHCAL w/ FEMC in front



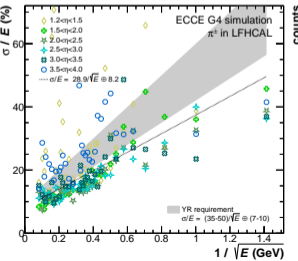


- 3D-cluster reconstruction could allow for significantly better shower separation
- Potential for meson/baryon separation in LFHCAL through shower development
- Simultaneous performance evaluation ongoing for FEMC & LFHCAL in full G4 simulations
- Adding support structures & other detectors to study performance degradation/ improvement

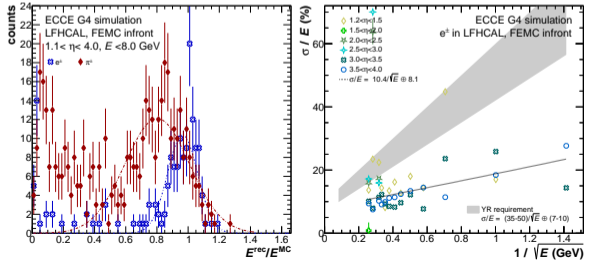
FEMC standalone



LFHCAL standalone

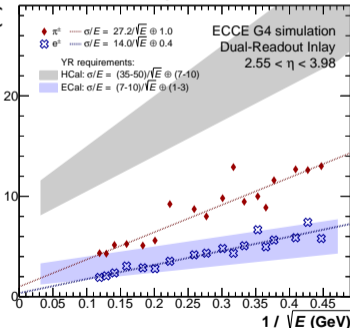
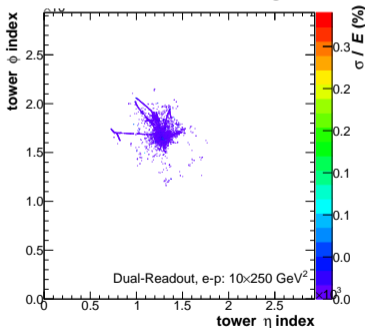
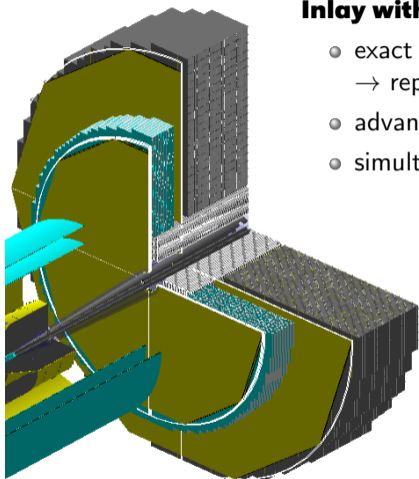


LFHCAL w/ FEMC in front



Inlay with Dual Readout Calorimeter

- exact design still to be chosen depending on production costs
→ replacing parts of FEMC and LFHCAL
- advantage of small constant term in resolution
- simultaneous readout of electro-magnetic and hadronic response



Interested Groups: ORNL, Sejong U., KNU, Yonsei U., PNU

Nicolas Schmidt, ORNL

Mechanical Integration and Optimizations:

- Evaluate with engineers construction routines, cable routing, support structures
- Integrate realistic support structures from inner detectors in G4 simulations
- Minimize gaps for installation rails, cable channels & cooling at edges of calorimeter to minimize gaps in η coverage

Realistic Calibrations:

- Evaluate from existing test-beam campaigns (i.e. STAR fwd. E/HCAL & sPHENIX E/HCAL) realistic noise levels for electronics
- Cross check digitization cut-off with latest generation off electronics
- Implement timing response for all calorimeters
- Prepare necessary test-beam campaigns for next year

Performance Evaluations:

- Continue performance evaluations for relevant physics observables in full detector setup
- Integrate calorimeter response in PID algorithms

Participate in this essential process!

There is still a lot of work ahead of us!

- **Contact us:**

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- **Mattermost channels:**

[Fun4All-Calorimeters](#)

[ECCE-Calorimeters](#)

- **Meetings:**

[ECCE detector WG-meetings](#)

