

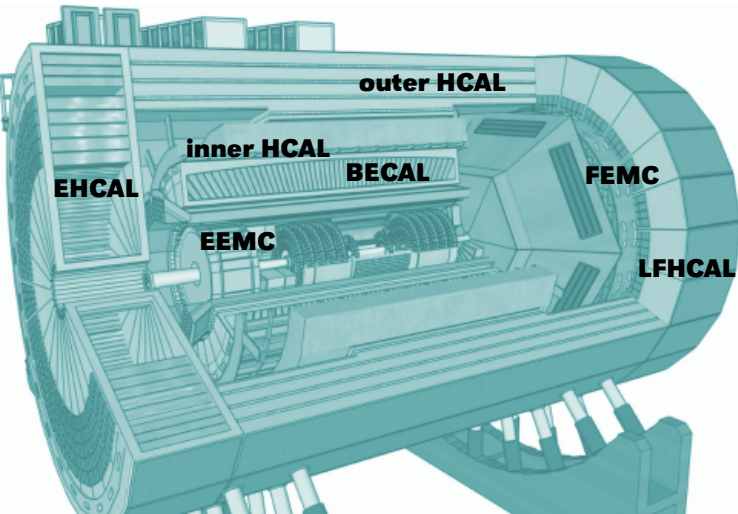
ECCE Calorimeter Design

EICUG Meeting

August 4, 2021

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

Main Ideas behind Calorimeter Concept



Electromagnetic Calorimeters:

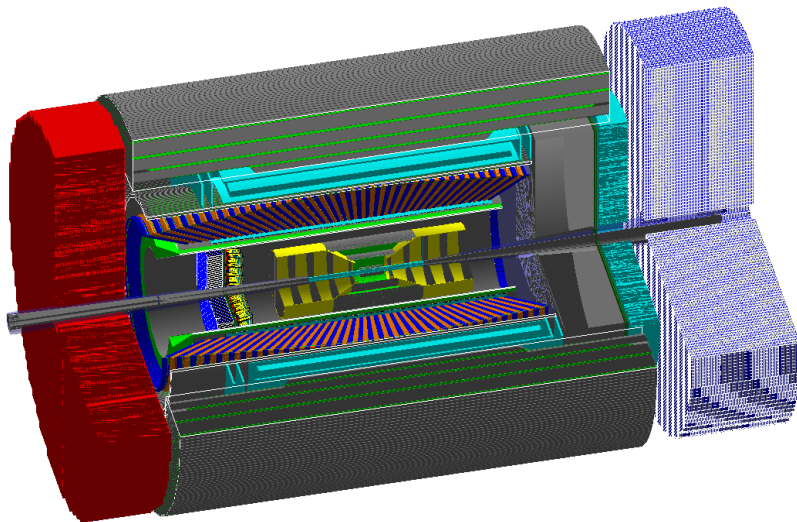
- Full coverage with optimum resolution $\eta < 1.1$
- High granularity in forward & backward direction
- Cost reduction through re-use of existing calorimeters where appropriate

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

Default Configuration

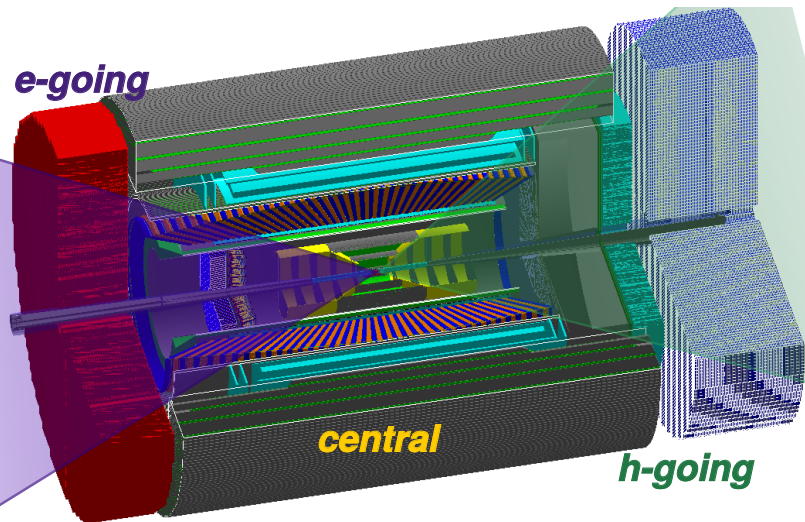
First version of default setup fully implemented in Geant4!



- Re-use existing outer sPHENIX & STAR forward HCal
- Re-use existing PHENIX Shashlik ECal w/ upgraded readout
- Build new homogenous ECals
- Build new inner HCal in barrel ECal support frame
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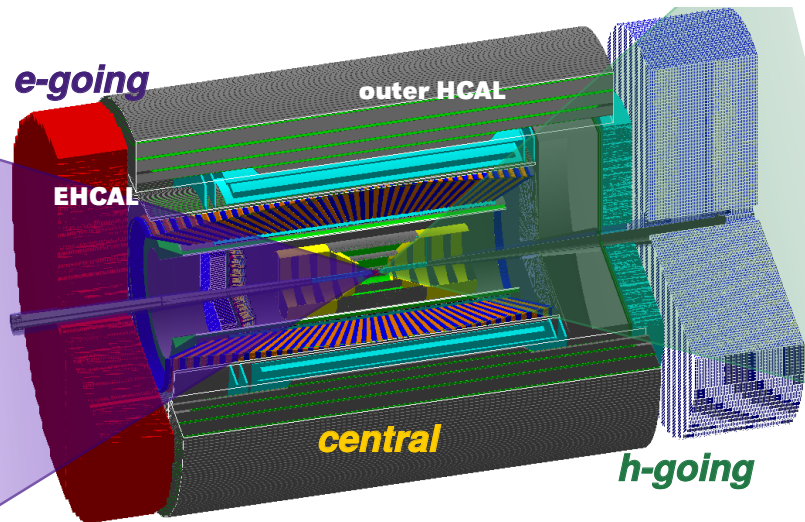
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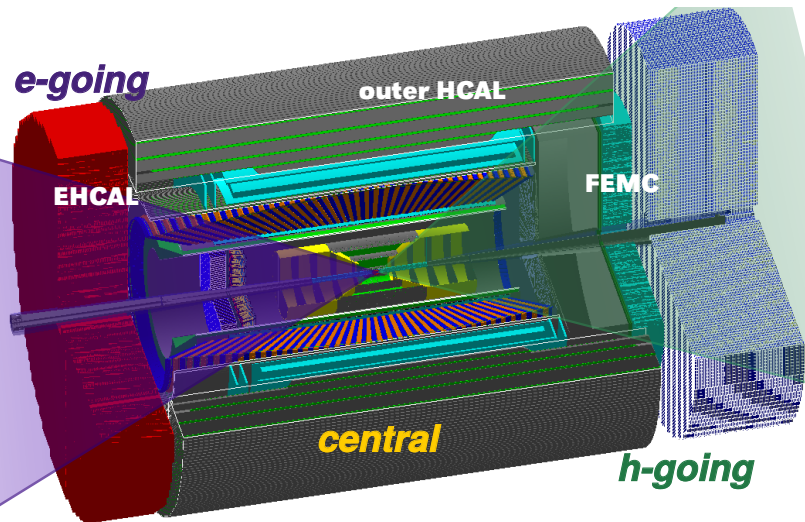
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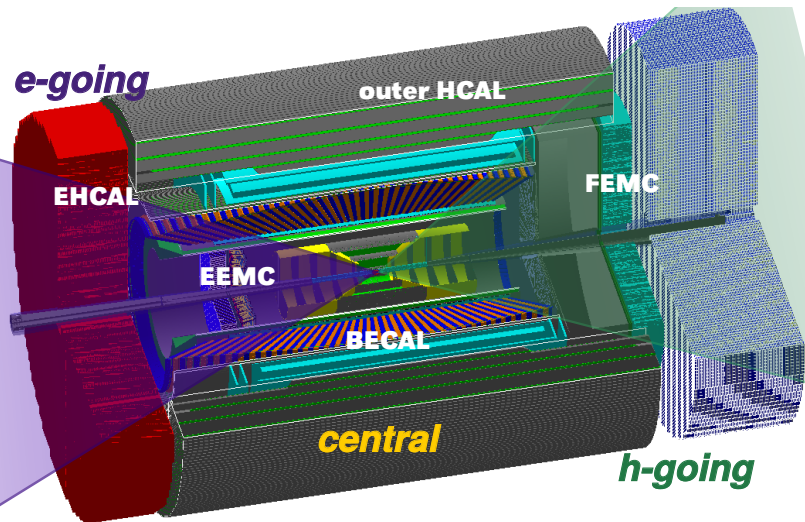
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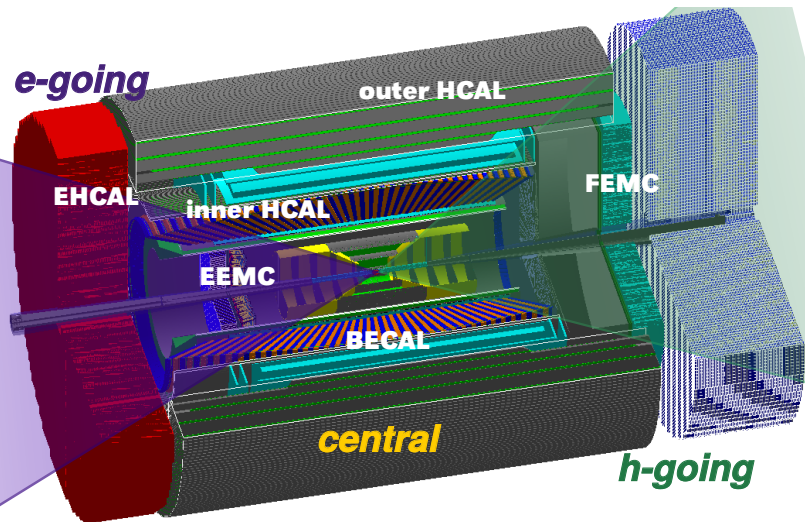
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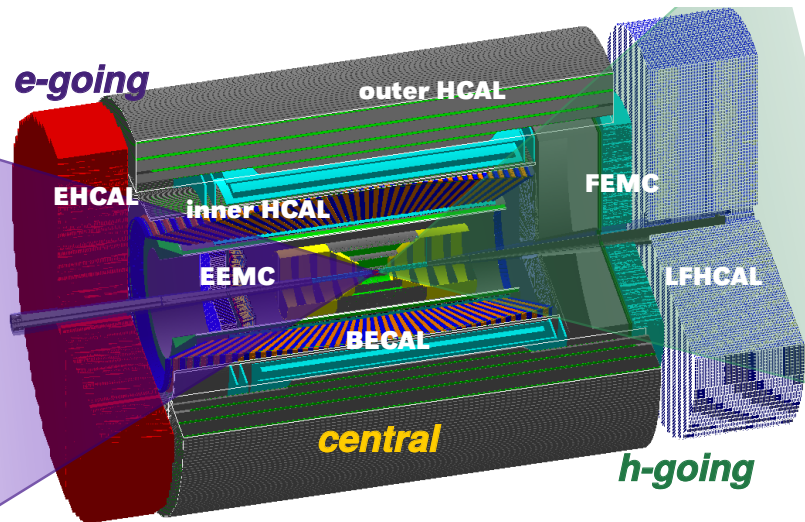
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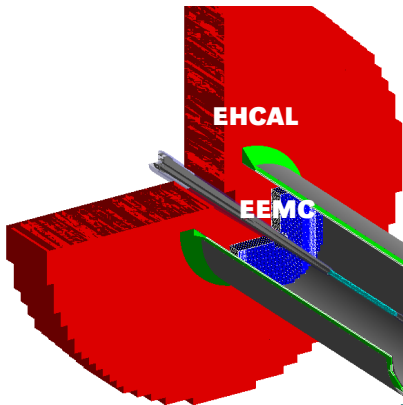
Calorimeter setup: e-going

ECAL (EEMC): PbWO_4 calorimeter

- $2 \times 2 \times 18$ cm tower, **partial re-use**
- $-3.2 < \eta < -1.85$
- **Alternative study:** outer rings $4 \times 4 \times 40$ cm Sci-Glass towers

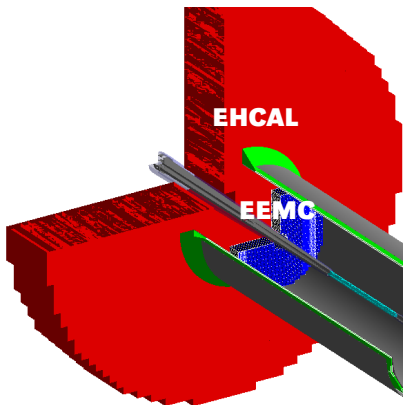
Interested Groups:

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



**Advanced mechanical design,
cost & risk evaluation!**

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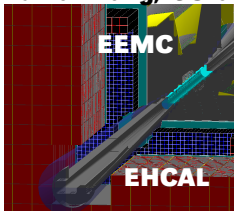
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HCAL (EHCal):

- **Re-use STAR-forward HCal** w/ upgraded electronics
- $10 \times 10 \times 100$ cm towers, $L \sim 7\lambda$
- read-out: 8 Si-PMs per WLS plate
- $-3.87 < \eta < 0.97$

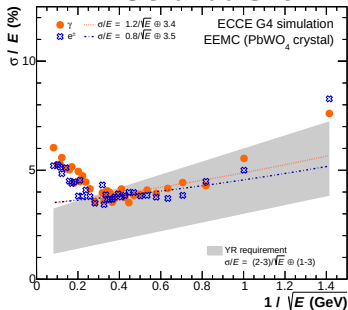
Interested Groups: ORNL, Wayne State

Pu-Kai Wang, IJCLab-Orsay

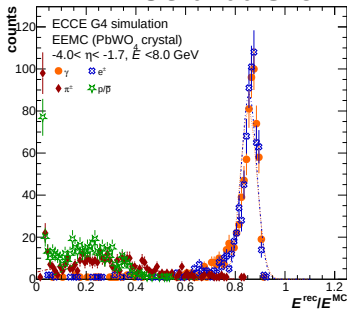


- Performance studies for EEMC (crystal/hybrid) & EHCAL with full G4 simulations
- Standalone simulations **meet/exceed YR requirements** & slightly outperform available test beam results
- Addition of support structures & other detectors for further performance studies

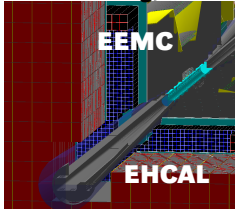
EEMC standalone



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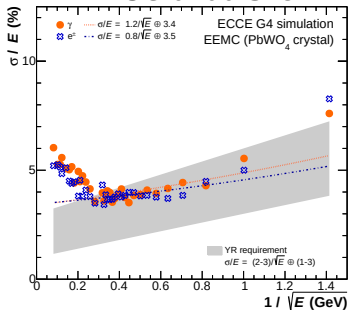


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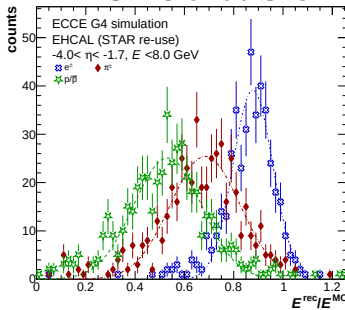


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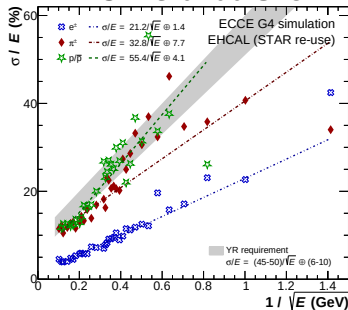
EEMC standalone



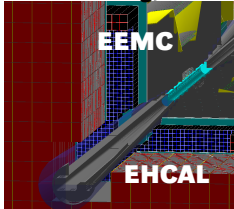
EHCAL standalone



EHCAL standalone

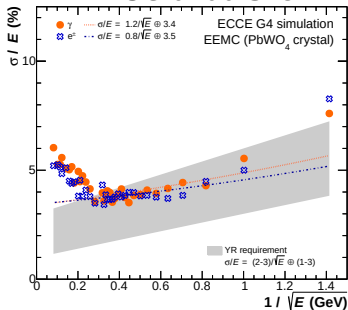


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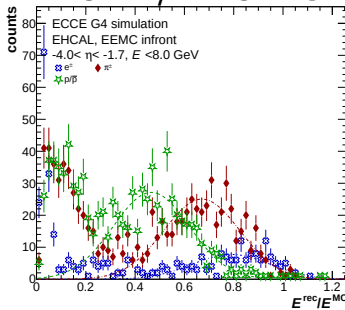


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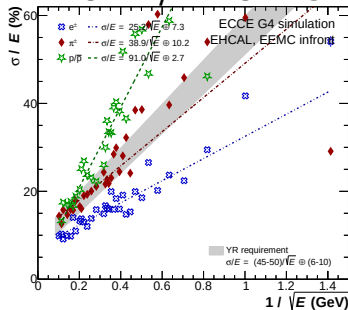
EEMC standalone



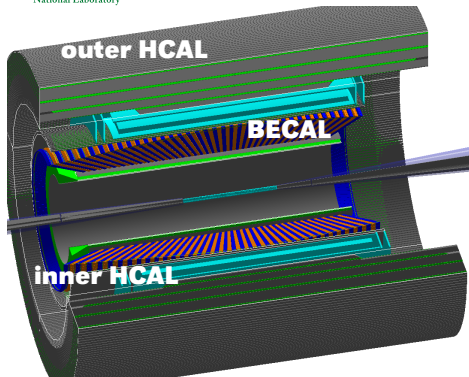
EHCAL w/ EEMC infront



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Calorimeter setup: central

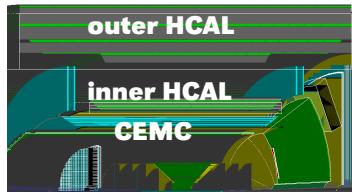


E-Cal: Sci-Glass calorimeter

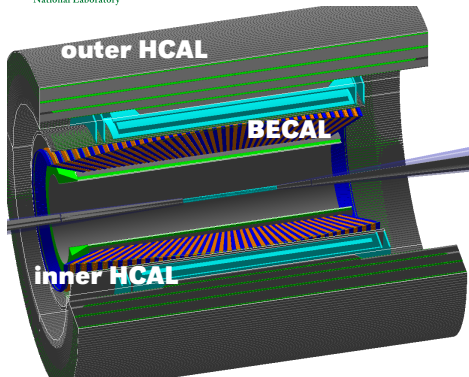
- $4 \times 4 \times 45.5$ cm partially projective towers
- $-1.74 < \eta < 1.31$
- iHCal in steel support frame
- **Alternative:** Re-use sPHENIX SPACAL EMC with upgraded read-out

Interested Groups: MIT, CUA, OSU

Mechanical design, cost & risk assessment ongoing!



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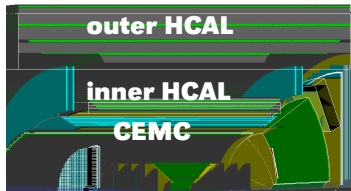
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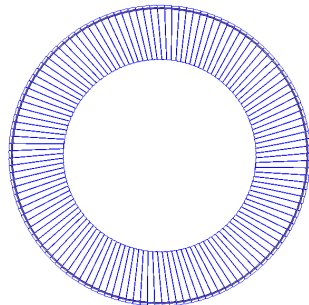
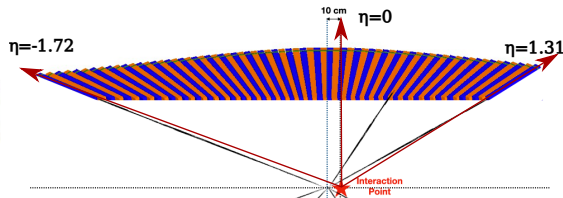
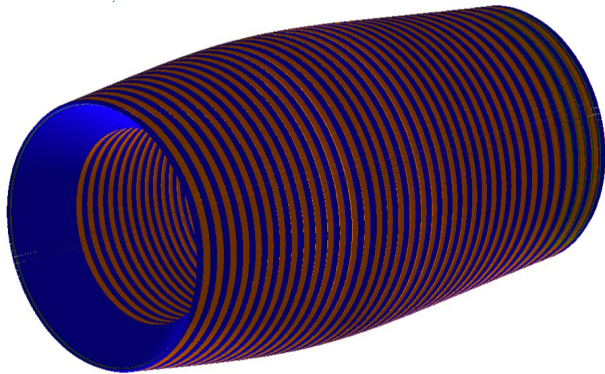
Mechanical design, cost & risk assessment ongoing!

H-Cal: Fe-Scintillation-Tile Calorimeter

- Re-use sPHENIX outer HCal
- $-1.16 < \eta < 1.16$
- Read-out upgrade with new SiPMs

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



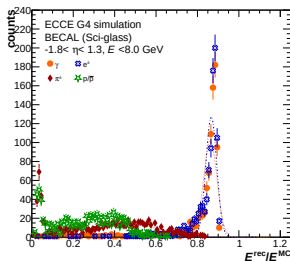


- Scintillation glass calorimeter with 45.5 cm deep towers
- **Towers projective in η to $(0,0,-10)$ cm & tilted by 10° in φ**
- Bore radius at 85 cm

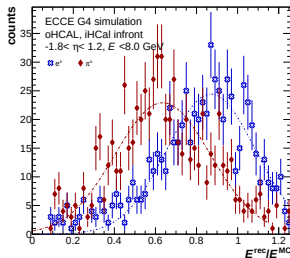
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Nathaly Santiesteban, MIT

Central Calorimeter Performance



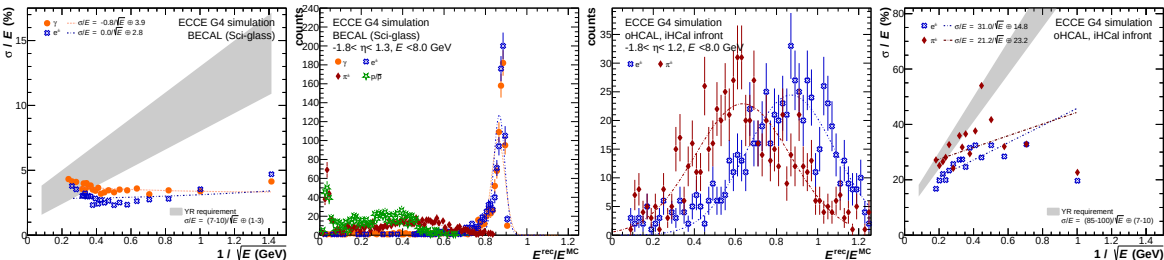
BECAL standalone



oHCAL w/ iHCAL in front

- Simultaneous performance studies for BECAL, inner & outer HCAL in **full G4 simulations for two different configurations**
- **Standalone performance surpasses YR requirements**
- Optimizations for realistic noise, digitization & calibration on-going
- Adding support structures & other detectors to study performance degradation/ improvement
→ **tight spatial constraints need to check φ/η dependence carefully**

Central Calorimeter Performance

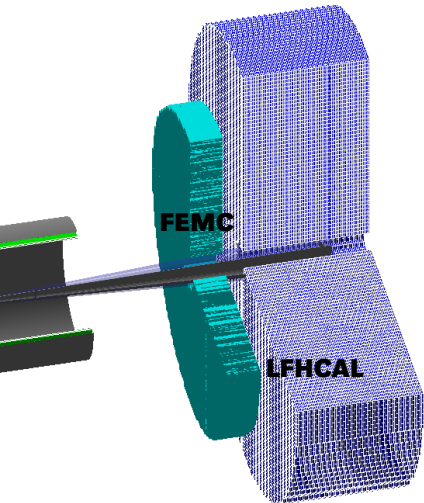


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Calorimeter setup: h-going



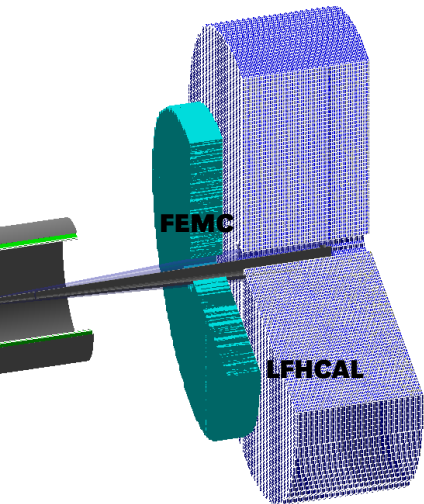
ECAL (FEMC): Pb-Scint. Shashlik calorimeter

- PHENIX re-use
- $5.5 \times 5.5 \times 37.5$ cm towers, $L \sim 18X_0$
- read-out upgrade 9 Si-PMs,
- $1.24 < \eta < 3.5$

Interested Groups: ORNL, Rutgers U., BNL

**Mechanical design, cost & risk
evaluation ongoing!**

Calorimeter setup: h-going



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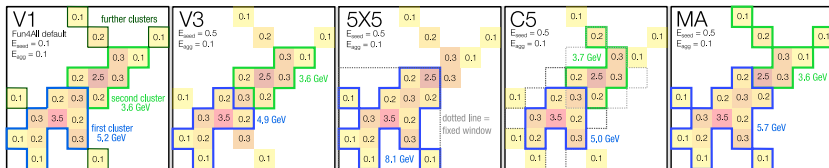
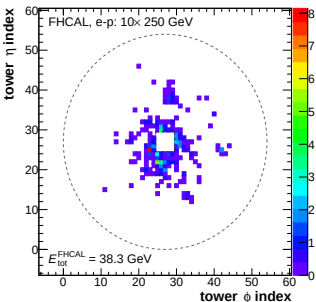
Interested Groups: ORNL, Rutgers U., BNL

HCAL (LFHCAL):

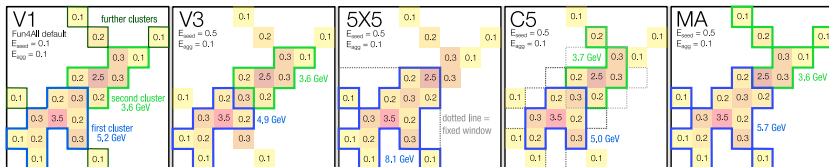
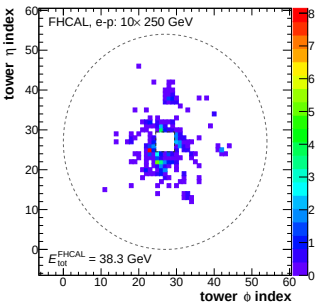
- longitudinally separated Fe-Sci tile calorimeter
- $5 \times 5 \times 140$ cm towers $L \sim 7\lambda$
- read out: 7 SiPMs per tower, 10 layers each
- $1.11 < \eta < 3.47$

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

Clusterization performance

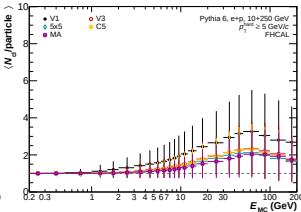
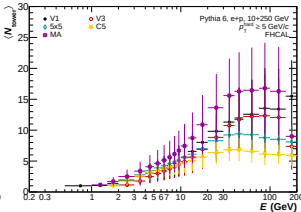
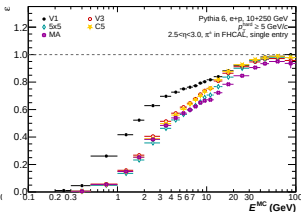
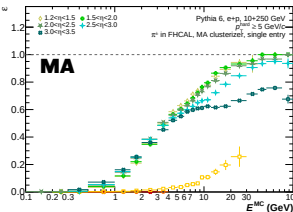


- Cluster finding and association to single particle challenging task in forward/backward direction - opportunity for AI
- Software developments crucial - implemented different algorithms:
 - Fun4All default w/o thresholds (V1)
 - simple splitting w/ thresholds (V3)
 - areas based: square (NxN) or circle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

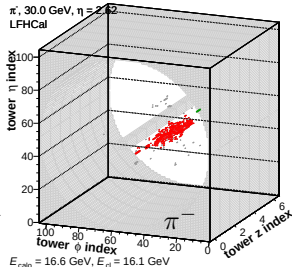
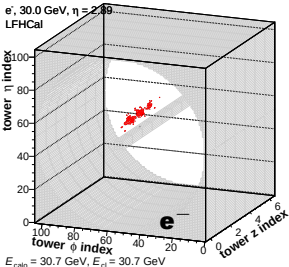


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FHICAL/EHCAL

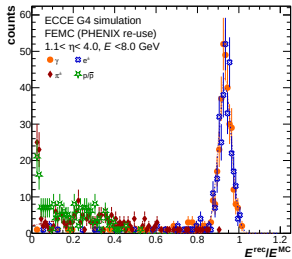
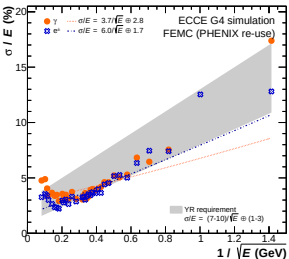


h-going Calorimeter Performance

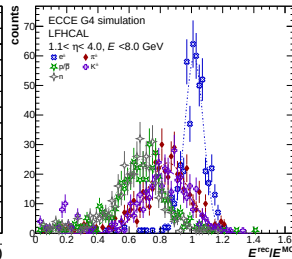
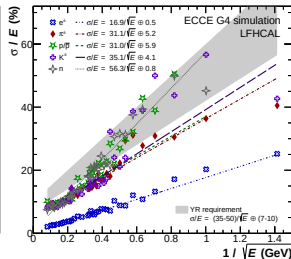


- **3D-cluster reconstruction** could allow significantly better shower separation
- Potential for **meson/baryon separation** using shower depth/width
- Adding support structures & other detectors to study performance degradation/ improvement

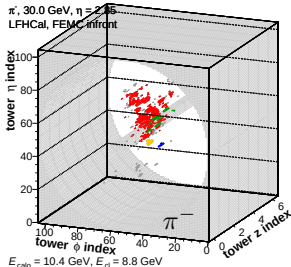
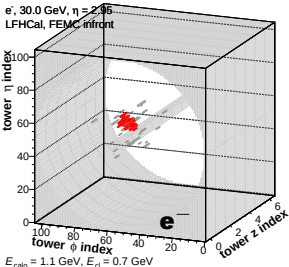
FEMC standalone



LFHCAL standalone

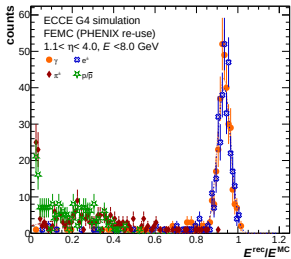
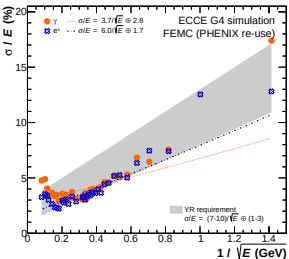


h-going Calorimeter Performance

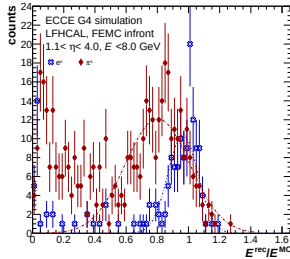
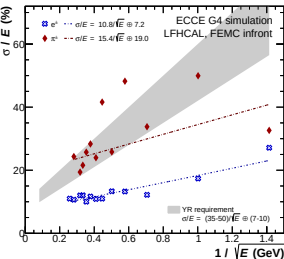


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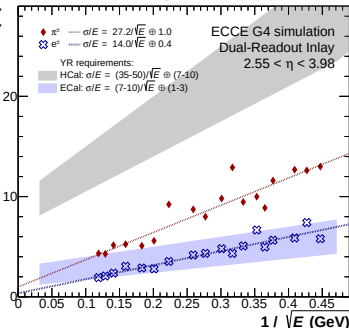
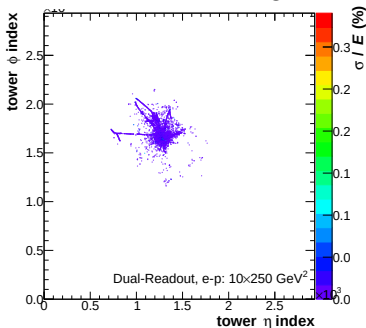
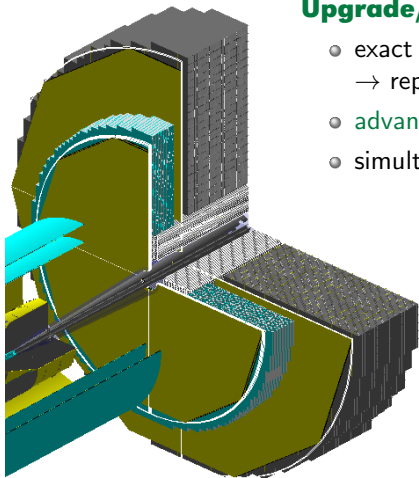


LFHCAL w/ FEMC in front



Upgrade/Alternative in h-going Direction

- 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

Performance Evaluations:

- ECCE calorimetry systems **meet or exceed YR performance over full coverage area**
- Extensive performance studies using high statistics **full G4 simulations**

Mechanical Integration, Costing and Optimizations:

- Experienced team of mechanical engineers from multiple institutes
- Optimizations of installation rails, cable channels & cooling at edges to **minimize gaps in η coverage**
- Extensive integration studies for maximizing coverage whilst allowing for **realistic services & support structures for inner detectors**
- **Activities, cost, schedule & risks** continue to be **collected/refined/studied** by experts working with experienced ECCE project management support team
- On track for realization for CD4-a with **high-performance & feasible design**

General:

- Very large, international, inclusive consortia of institutes with extensive calorimeter experience

Participate in this essential process!

There is still a lot of work ahead of us!

- **Contact us:**

Yongsun Kim - kimy@cern.ch

Friederike Bock - friederike.bock@cern.ch

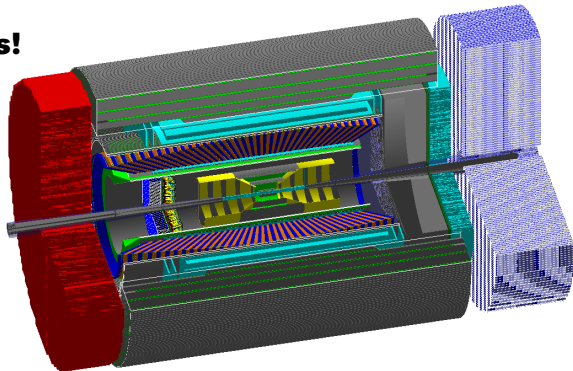
- **Mattermost channels:**

[Fun4All-Calorimeters](#)

[ECCE-Calorimeters](#)

- **Meetings:**

[ECCE detector WG-meetings](#)



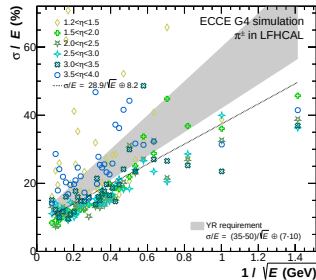
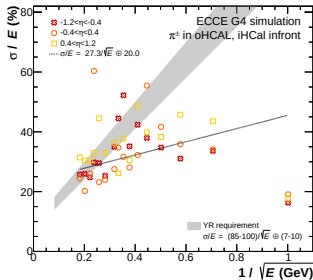
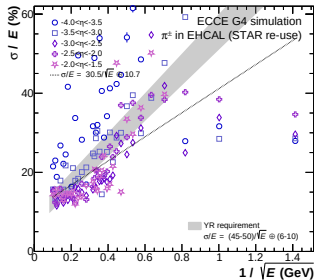
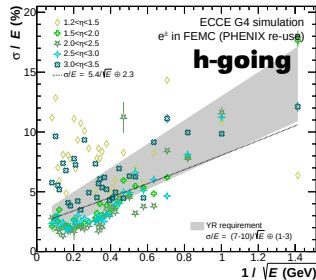
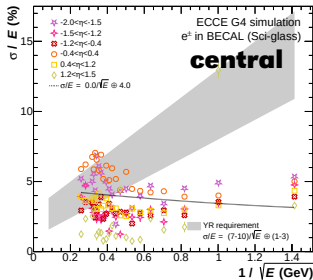
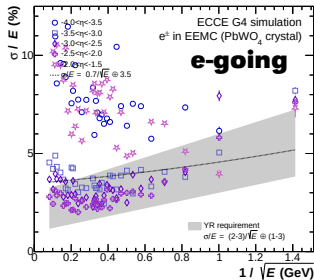
Back-up

Detailed Locations



	z/r [m]/	depth [cm]	radial coverage [cm]	pseudorapidity	tower size [cm]
ECAL e-going					
PbW0 ₄	$z = -1.9$	18 (40)	$14.95 < r < 66$	$-3.2 < \eta < -1.85$	2x2
hybrid:					
PbW0 ₄	$z = -1.9$	18 (60)	$14.95 < r < 51$	$-3.2 < \eta < -2$	2x2
Sci-Glas	$z = -1.9$	40 (60)	$51 < r < 66$	$-2 < \eta < -1.85$	4x4
HCAL e-going					
STAR reuse	$z = -3.6$	100	$15 < r < 260$	$-3.87 < \eta < 0.97$	10x10
ECAL central					
Sci-Glas	$r = 0.85$	45.5(60)	$-251 < z < 169$	$-1.74 < \eta < -1.31$	4x4
sPHENIX (w/ iHCal) reuse	$r = 0.92$	20(50)	$-251 < z < 169$	$-1.69 < \eta < -1.28$	4x4
HCAL central					
sPHENIX reuse	$r = (1.8, 1.94)$	87(73)	$-320 < z < 320$	$-1.16 < \eta < 1.16$	10x10?
ECAL h-going					
PHENIX/ALICE reuse	$z = 2.9$	37.5	$20 < r < 183$	$1.24 < \eta < 3.50$	5x5 (6x6)
HCAL h-going					
LHCAL	$z = 3.5$	140	$20 < r < 262$	$1.11 < \eta < 3.47$	5x5
DRCALO					
(inlay)	$z = 3.0$	150	$20 < r < 50$	$2.70 < \eta < 3.70$	0.3x0.3

η -dependent Resolution Studies



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