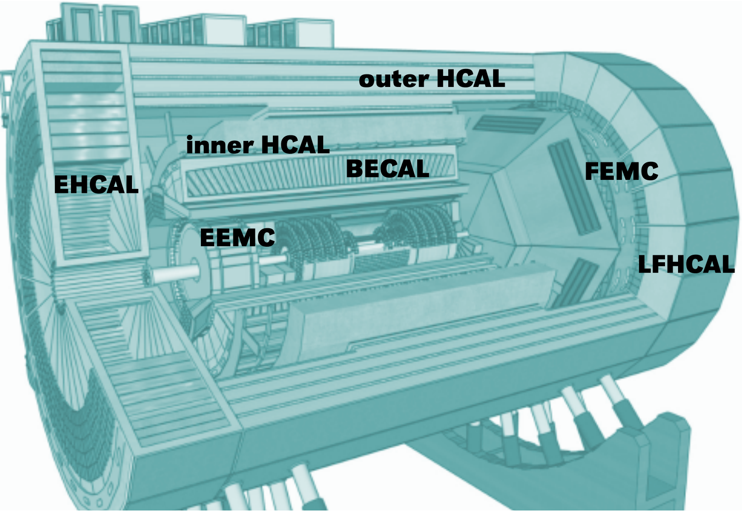
ECCE Calorimeter Design

EICUG Meeting

August 10, 2021

Friederike Bock, ORNL
for the ECCE consortium

Main Ideas behind Calorimeter Concept



Electromagnetic Calorimeters:

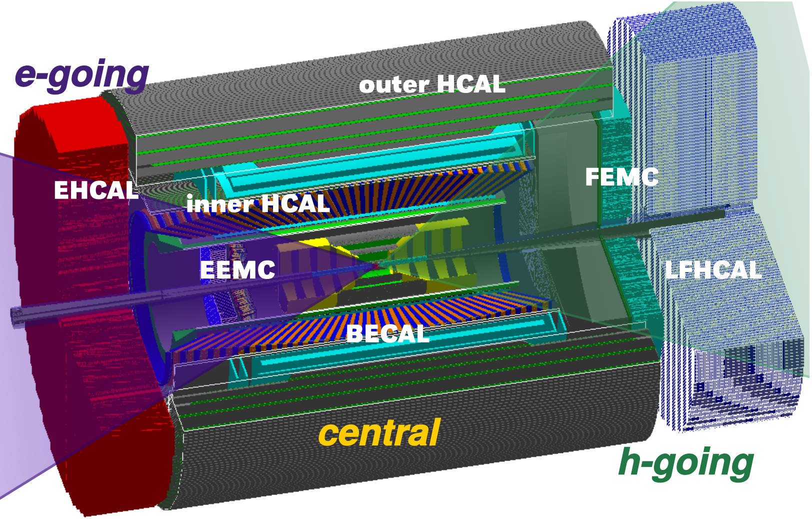
- Full coverage with optimum resolution $\eta < 1.1$
- High granularity in forward & backward direction
- Cost reduction through re-use of existing calorimeters where appropriate

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

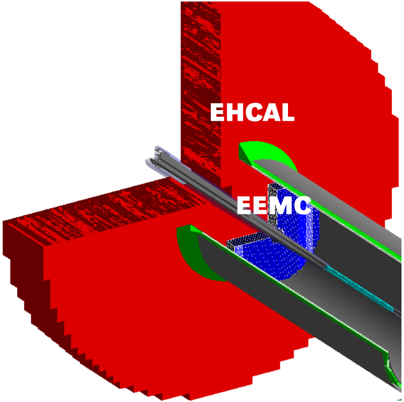
Default Configuration

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
- Build new longitudinally separated forward HCal

Calorimeter setup: e-going



Advanced mechanical design, cost & risk evaluation!

ECAL (EEMC): $PbWO_4$ calorimeter

- $2 \times 2 \times 20$ 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

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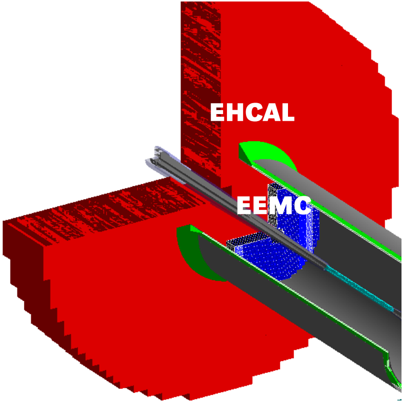

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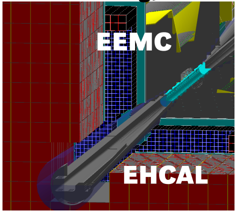
HCAL (EHCAL):

- **Re-use STAR-forward HCal** w/ upgraded electronics
- $10 \times 10 \times 100$ cm towers, $L \sim 5\lambda$
- read-out: 8 Si-PMs per WLS plate
- $-3.87 < \eta < 0.97$

Interested Groups: ORNL, Wayne State

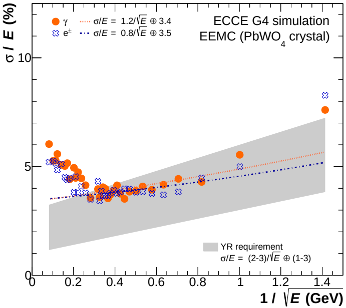
e-going Calorimeter Performance

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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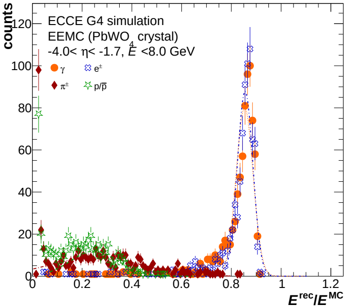

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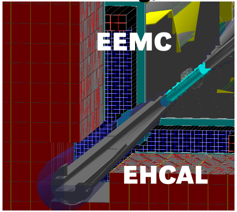

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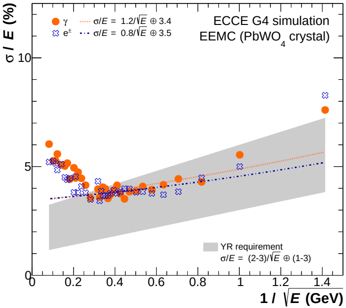
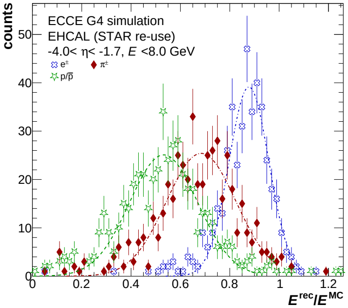


EHCAL standalone



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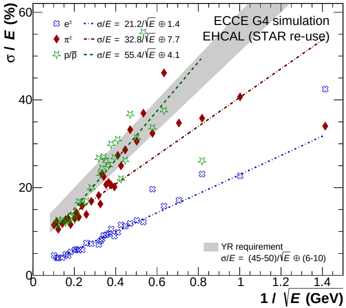

e-going Calorimeter Performance

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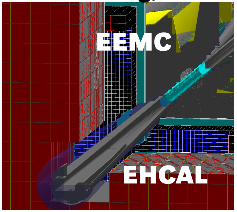

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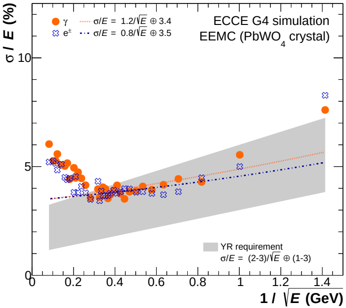
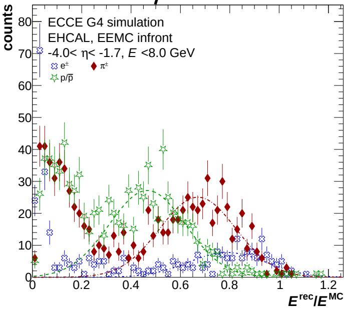


EHCAL w/ EEMC infront



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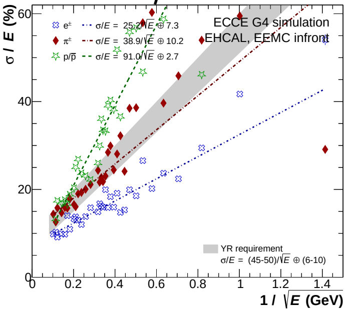
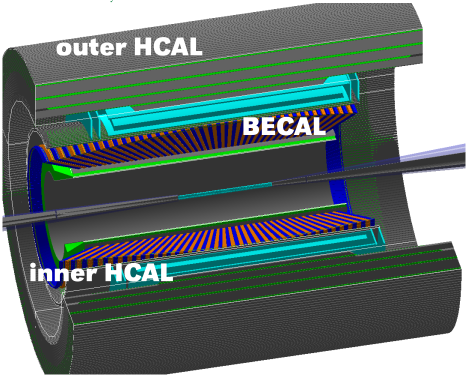


Calorimeter setup: central

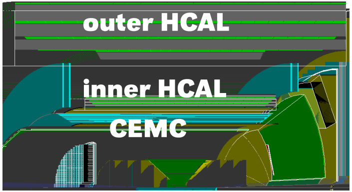


E-Cal: Sci-Glass calorimeter

- $4 \times 4 \times 45.5$ 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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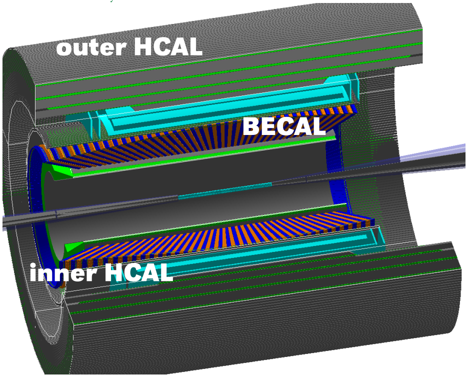

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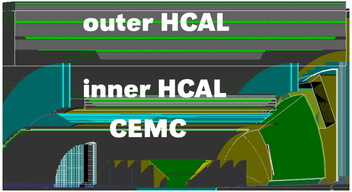
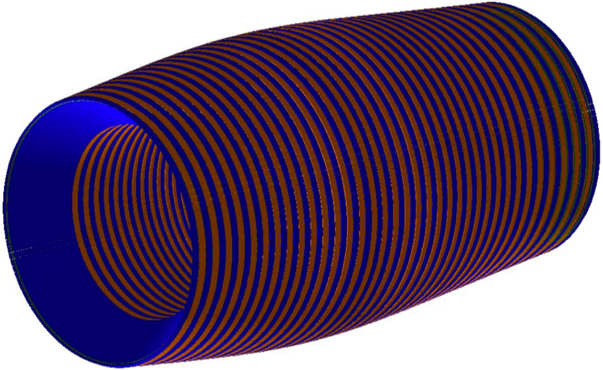
H-Cal: Fe-Scintilation-Tile Calorimeter

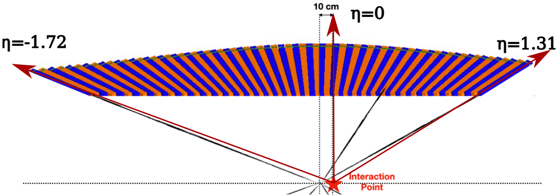
- Re-use sPHENIX outer HCal
- $-1.16 < \eta < 1.16$
- Read-out upgrade with new SiPMs

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



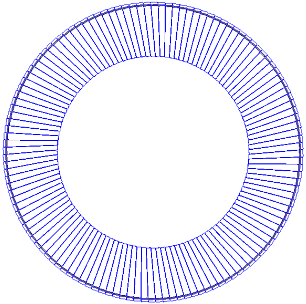
BECAL: Sci-Glass homogeneous ECal





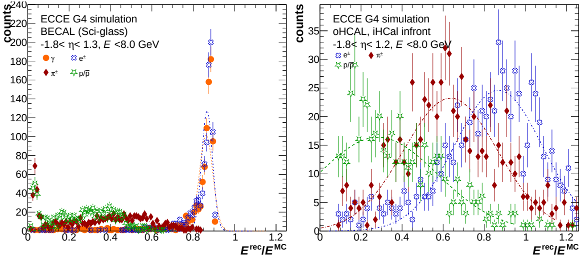
- Scintilation glass calorimeter with 45.5 cm deep towers
- **Towers projective in η to $(0, 0, -10)$ cm & tilted by 10° in φ**
- Bore radius at 85 cm

Interested Groups: MIT, CUA, OSU



Nathaly Santiesteban, MIT

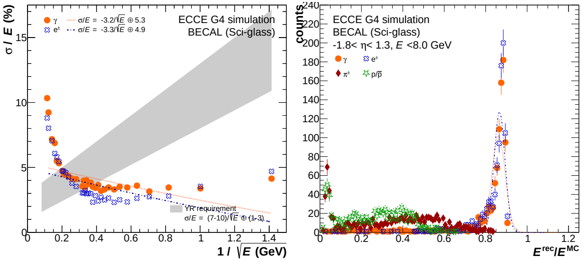
Central Calorimeter Performance



BECAL standalone **oHCAL w/ iHCAL infront**

- 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 $\rightarrow$ **tight spatial constraints need to check φ/η dependence carefully**

Central Calorimeter Performance



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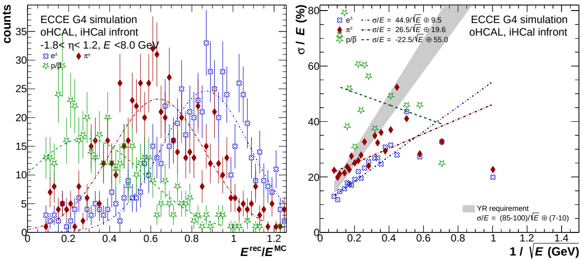

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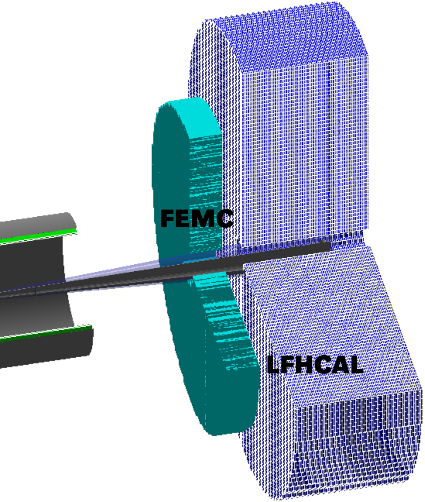
Calorimeter setup: h-going



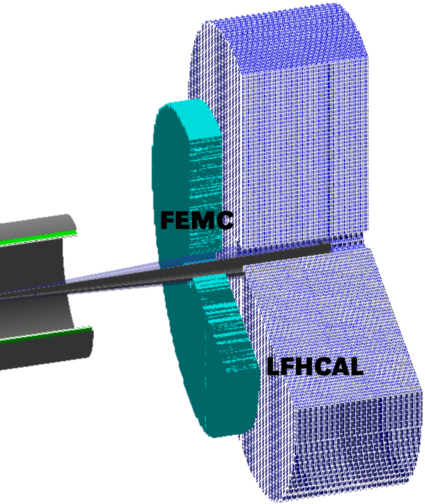
Mechanical design, cost & risk evaluation ongoing!

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

Calorimeter setup: h-going



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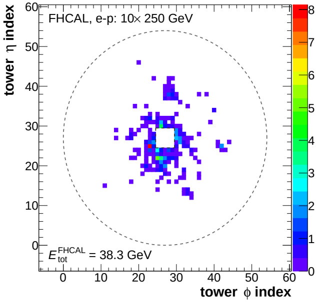
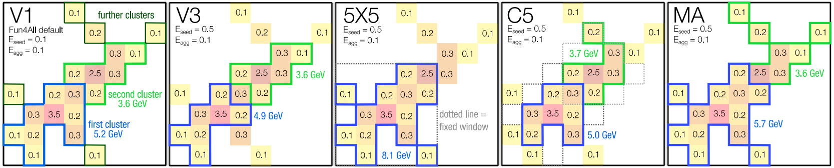
HCAL (LFHCAL):

- 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

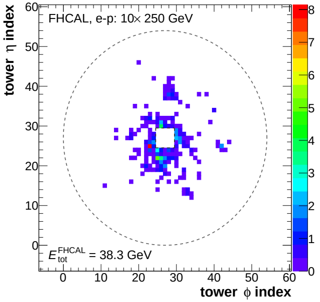
Clusterization performance

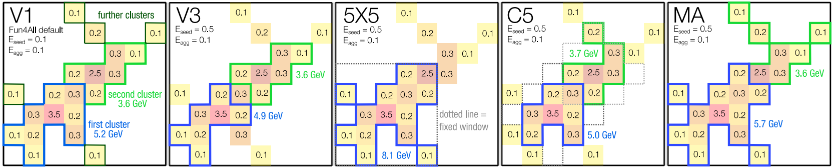




- **Cluster finding and association to single particle challenging task in forward/backward direction** - opportunity for AI
- **Software developments crucial** - implemented different algorithms:
  - Fun4All default w/o thresholds (V1)
  - simple splitting w/ thresholds (V3)
  - areas based: square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

Clusterization performance





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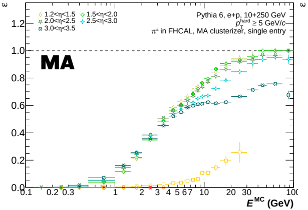
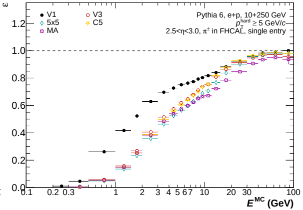
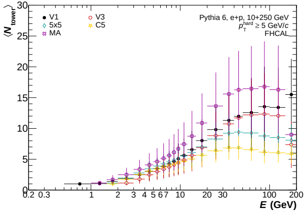
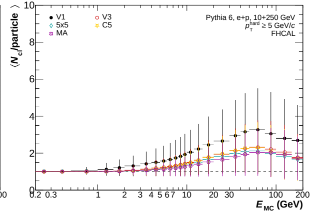
FHCAL/EHCAL

- Different cluster finding efficiencies, resolutions & other properties

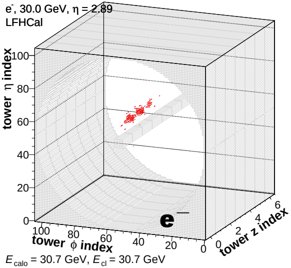


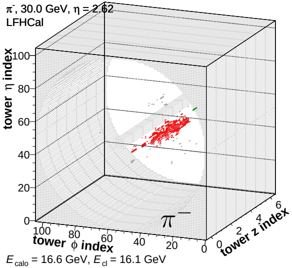






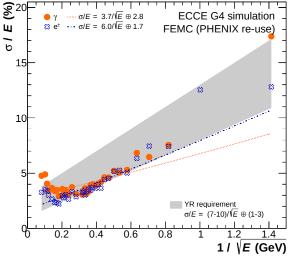
h-going Calorimeter Performance

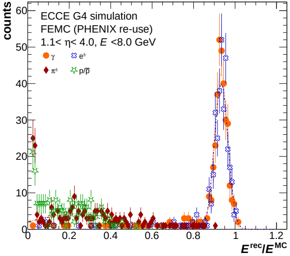




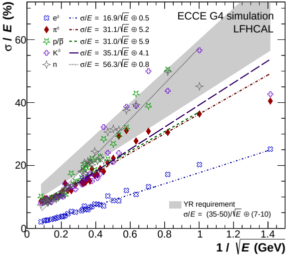
- **3D-cluster reconstruction** could allow significantly better shower separation
- Potential for **meson/baryon separation** using shower depth/width
- Adding support structures & other detectors to study performance degradation/ improvement

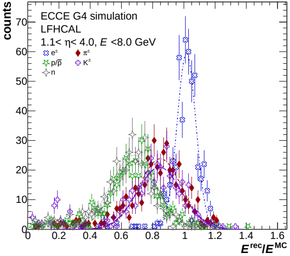
FEMC standalone





LFHCAL standalone





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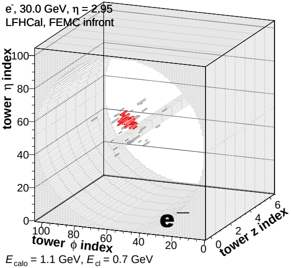

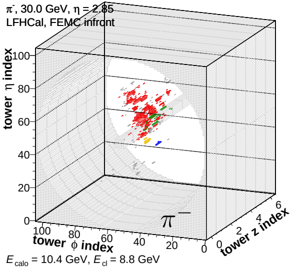

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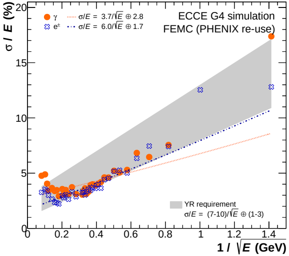
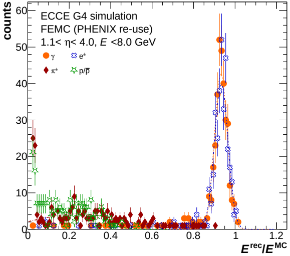
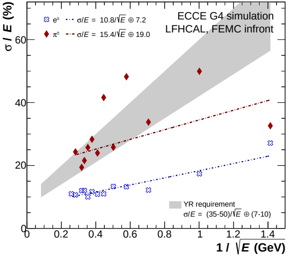
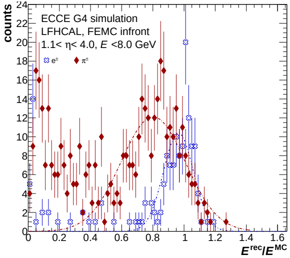


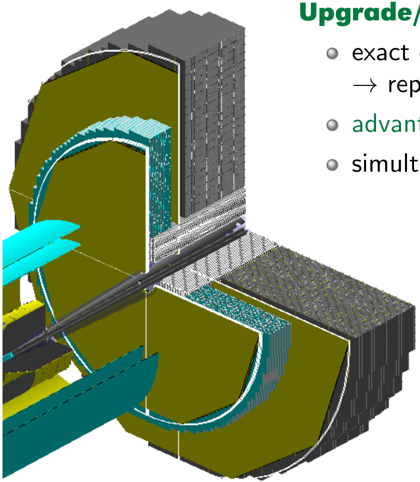


LFHCAL w/ FEMC infront



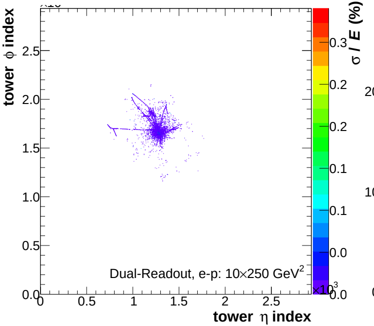


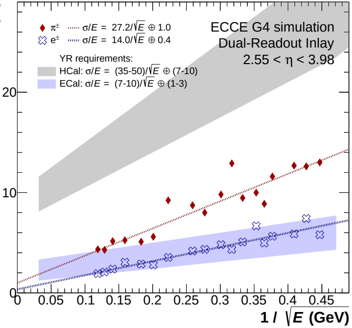
Inlay with Dual Readout Calorimeter



Upgrade/Alternative in h-going Direction

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

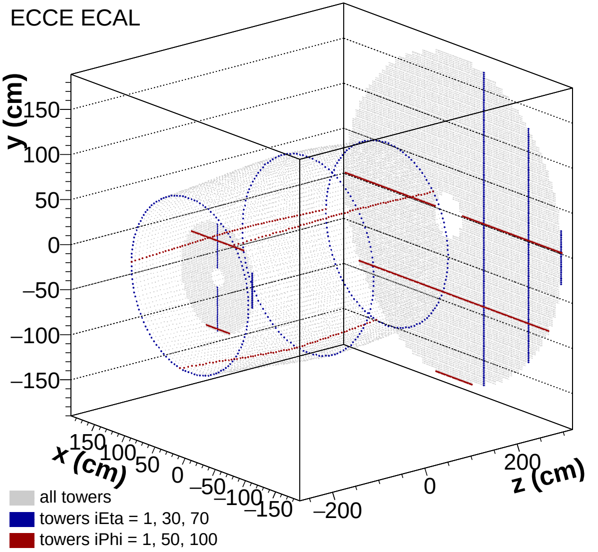


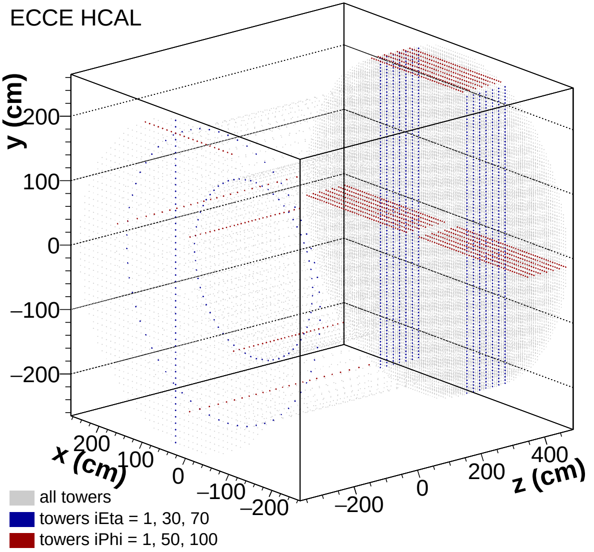


Interested Groups: ORNL, Sejong U., KNU, Yonsei U., PNU

Nicolas Schmidt, ORNL

Acceptance


ECCE ECAL
y (cm)
150
100
50
0
−50
−100
−150
x (cm)
150
100
50
0
−50
−100
−150
−200
0
200
z (cm)
all towers
towers iEta = 1, 30, 70
towers iPhi = 1, 50, 100


ECCE HCAL
y (cm)
200
100
0
−100
−200
x (cm)
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100
0
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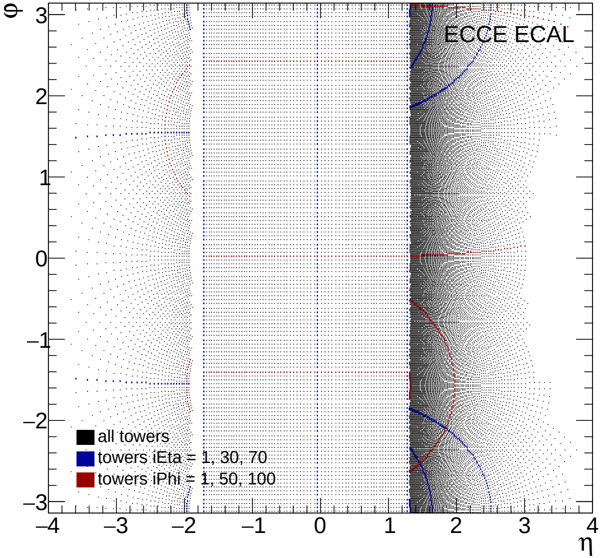

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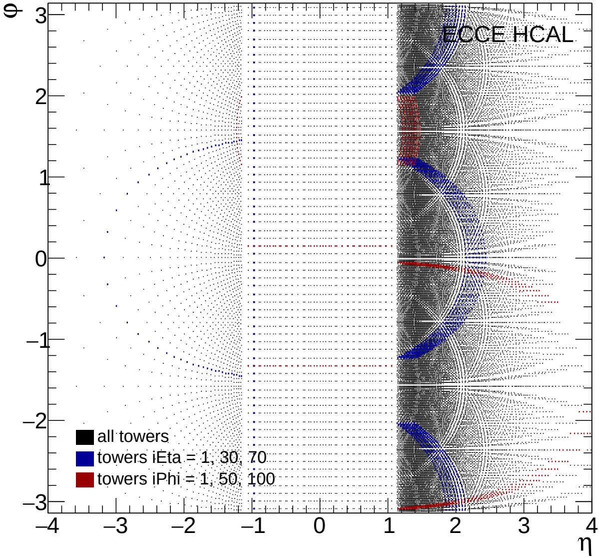
all towers
towers iEta = 1, 30, 70
towers iPhi = 1, 50, 100
φ
η



ECCE HCAL
all towers
towers iEta = 1, 30, 70
towers iPhi = 1, 50, 100
φ
η

Summary

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:

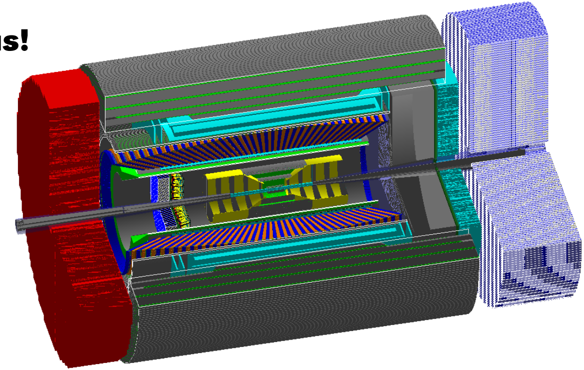
- Very large, international, inclusive consortia of institutes with extensive calorimeter experience

Join us!

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

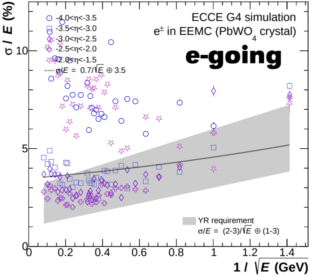


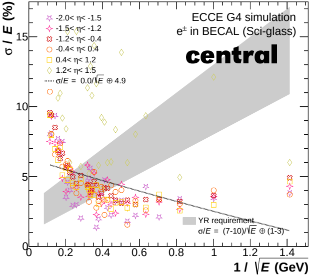
Back-up

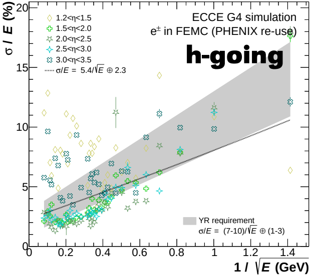
Detailed Locations

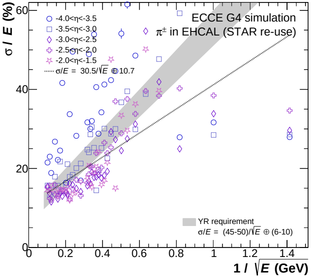
	z/r [m]/	depth [cm]	radial coverage [cm]	pseudorapidity	tower size [cm]
ECAL e-going					
$PbW0_4$	z = -1.9	20 (40)	$14.95 < r < 66$	$-3.2 < \eta < -1.85$	2x2
hybrid:					
$PbW0_4$	z = -1.9	20 (60)	$14.95 < r < 51$	$-3.2 < \eta < -2$	2x2
Sci-Glas	z = -1.9	40 (60)	$51 < r < 66$	$-2 < \eta < -1.85$	4x4
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

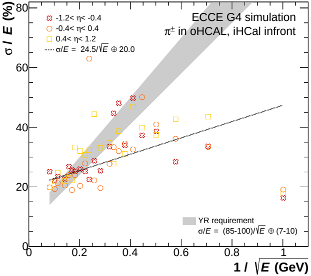
η-dependent Resolution Studies

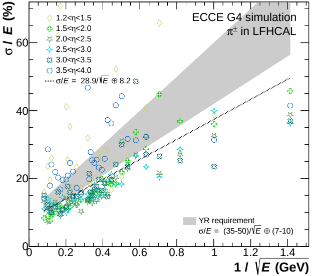












What's next?

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