

ECCE Forward Calorimeter Design Longitudinally separated Forward HCal (LFHCal)

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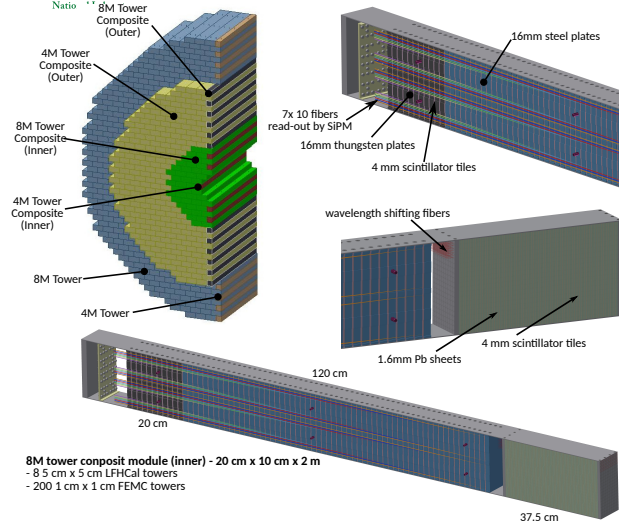
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Main FEMC Contacts:

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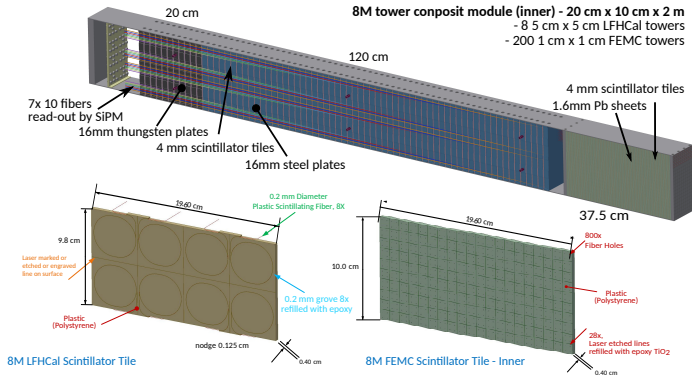
The General Idea



- Combined module design for ECal & HCal
- PSD [link TDR] inspired inspired Fe/W-Scint calorimeter
 60 layers of Steel (160 mm)-Sci plates (4mm) +
 10 layers of W (160 mm)-Sci plates (4mm)
- Multiple towers combined in one module to reduce dead areas, increase granularity
- Read-out:
 - ▶ 7 signals per tower (signals combined from 10 Sci-plates)
 - ▶ readout position: after full HCal
- Modules of different sizes (8M, 4M, 2M, 1M) to maximize coverage & assembly efficiency

Calorimeters in Numbers

LFHCAL	inner radius (envelope)	17 cm
	outer radius (envelope)	270 cm
	η acceptance	$1.2 < \eta < 3.5$
tower information	x, y	5 cm
	z (active depth)	140 cm
	z readout	20 cm
	# scintillator plates (0.4 cm)	70
	# steel plates (1.6 cm)	60
	# tungsten plates (1.6 cm)	10
	weight	~ 30.6 kg
	# towers	9040
	# read-out channels/ SiPM	$7 \times 9040 = 63\,280$
	interaction lengths λ/λ_0	6.9
	Molière radius R_M for $\pi^\pm$	21.1 cm
	Sampling fraction f	0.040
Assembly Modules		
8 LFHCAL towers (8M)	total	1091
no FEMC towers	LFHCAL only	538
200 FEMC towers	LFHCAL+FEMC (inner)	87
72 FEMC towers	LFHCAL+FEMC (outer)	466
4 LFHCAL towers (4M)	total	76
no FEMC towers	LFHCAL only	36
100 FEMC towers	LFHCAL+FEMC (inner)	16
36 FEMC towers	LFHCAL+FEMC (outer)	24
2 LFHCAL/ 50 FEMC towers (2M)	LFHCAL+FEMC (inner)	2
1 LFHCAL/ 25 FEMC towers (1M)	LFHCAL+FEMC (inner)	4

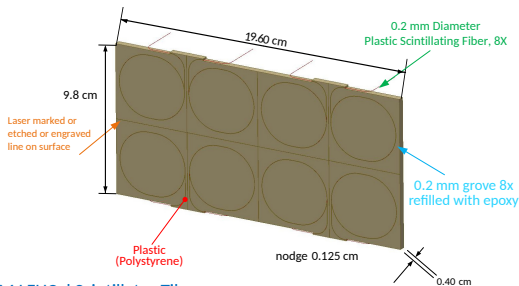


- **ECal:** $X/X_0 = 18.5$, **HCal:** $\lambda/\lambda_0 = 6.9$
- Single Towers smaller than R_M , use shower maxima to separate close particles
- Modules optimized for easy assembly with dedicated tooling

Current 8M Scintillator Plate Design



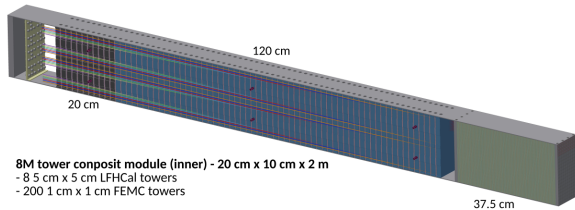
- Most Scintillator plates produced as 1 unit of 100x200mm plates (8 single tower tiles)
- Separation of tiles edged into the plate (95%) through, refilled with Epoxy-TiO₂ mix
- Wrapped in Tyvek paper and Kapton tape



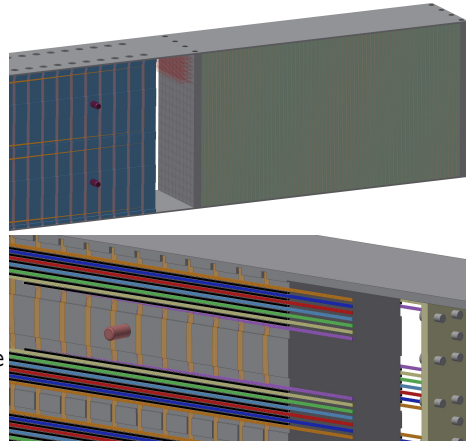
8M LFHCal Scintillator Tile

- Fiber thickness chosen for minimal light loss while bending, might be increased to 0.5mm
→ other geometries under consideration (i.e. 1/4 circle)
- Originally costed from Uniplast as 1 unit of assembly + material
- Updated estimate:
 - ▶ tile material produced, finished & groved externally
 - ▶ fiber installation: 0.25h engineering time/per tile
 - ▶ wrapping: 0.1h students time/per tile
 - ▶ necessary tooling 100K
- Exploring possible robot supported options for tile assembly

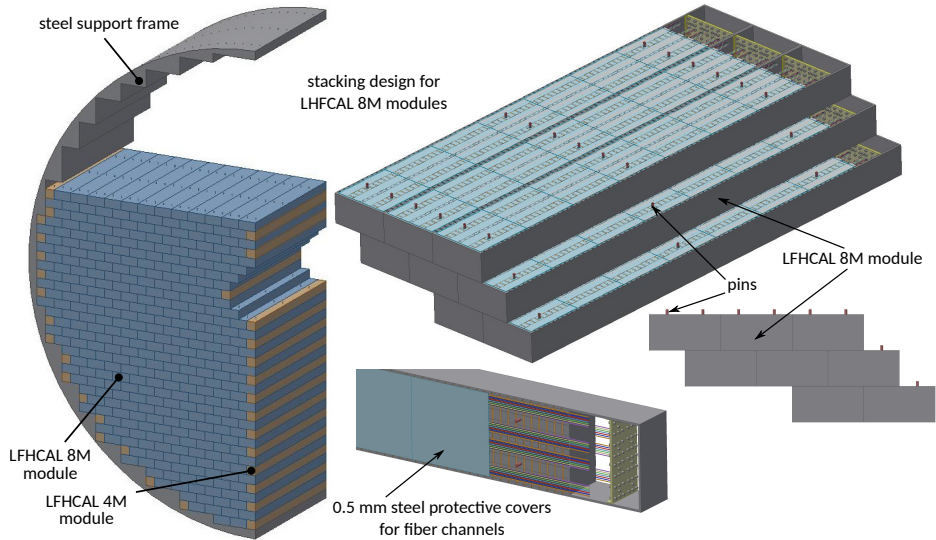
8M assembly

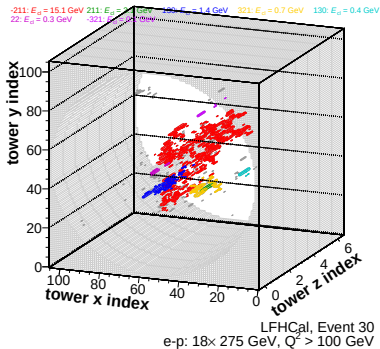


- single tile assembly (fiber embedding, glueing, wrapping)
- tile testing
- assembly of module, alternating steel plate first kept in place by pins then Scint-tile
- fiber channels on the layed out on front on back
- SiPM & read-out card installation
- tower testing
- close up module with cover plates



Assembly of Calorimeter





- High granularity needed to try to distinguish shower maxima close to beam pipe
- **HCal:**
read out in 7 layers longitudinally
desireable min measurable tower energy
3-5 MeV, max 20-30 GeV in single tower segment

- LFHCal 1 SiPM per 10 fibers (7 per tower) -i.e Hamamatsu S13360-3025PE (14.4K pixels)
- HCal readout at end of module (max. 20cm)
- Small light collection prisms might be needed infront of SiPM
- Idea use each 1 SiPM HGCROC for readout of HCal (ideally common chip/board design with FEMC & ALICE FoCal-H)

Example 8M module costs:

Material procurement	Units	Unit Pricing
Absorber plates + support	1	\$1750
Scintillator plates	70	\$65
tyvek + capton	4.04	\$0.4
WLS fibers	1360	\$3
8M module cost:	1091	\$9822

Assembly labor	hours	cost
installing fiber mech. engineer	17.5 h	\$2680.5
tile wrapping PhD students	7 h	\$140
tower assembly mech. engineer	0.083 h	\$12.8
tower assembly PhD Student	1.92 h	\$38.4
tower assembly Undergrad	11 h	\$220
tower assembly Postdoc	1 h	\$71
tower assembly PhD Student	4.5	\$90
8M module cost:	1091	\$2252.7

Electronics	Units	Unit Pricing
SiPMs	56	\$10
mounting boards	1	\$10
cable+HV/LV	1	~\$822
8M module cost:	1091	\$1392

Costing

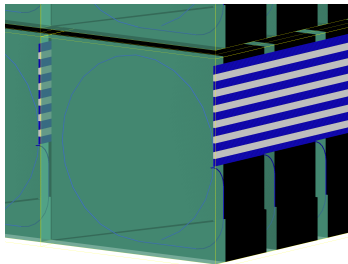
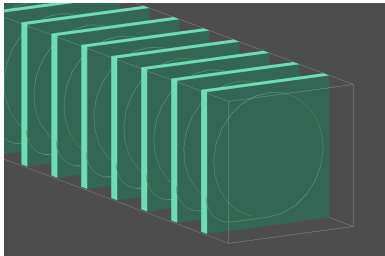
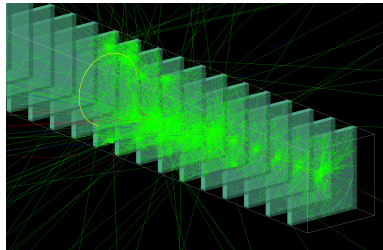
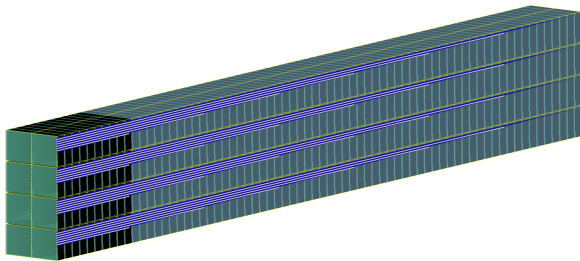
Additional costs:

- R&D cost: 393K
- Tooling: 200K
- Support Structure: 100K
- Installation: 382K

Total costs:

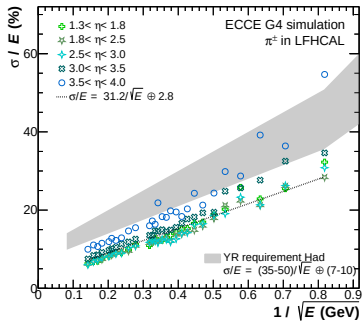
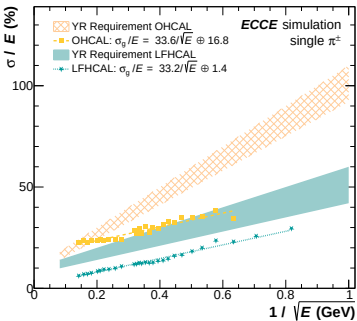
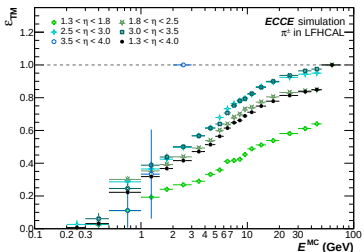
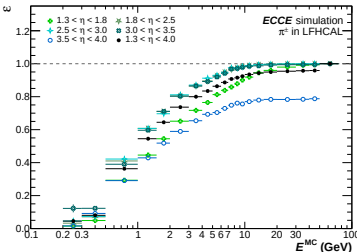
- estimated for:
1091x8M module, 76x4M modules, 2x2M modules, 4x1M modules
- Module prices don't exactly scale as labor doesn't scale
- Cost adapted to US prices w/o relying on Uniplast
- **total unescalated cost: \$17.7M**
→ estimates w/ Uniplast quotes \$11.2M

GEANT Implementation



- largely realistic implementation of geometry (Nico), refinements for module edges needed
- first light propagation studies with Nico & soon Craigs students, cross check with test sub-tiles at ORNL (fiber routing)

LFHCAL Performance



- Cluster finding and track matching efficiencies good in center of LFHCAL, losses towards edges
- Meeting YR energy resolution requirements even without ML based clusterizer optimization
- Small η dependence for energy resolution
- Studies to improve clusterization further using ML started

Thanks!

