

ECCE Forward-going ECal (FEMC) detector design and performance

Detector 1 Calorimetry Weekly Meeting

May 12, 2022

**Nicolas Schmidt & Friederike Bock
ORNL**

Participating institutes and contacts

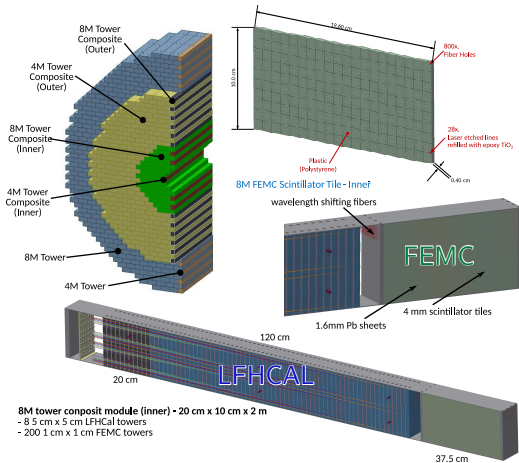
Main FEMC Contacts:

Institutes:

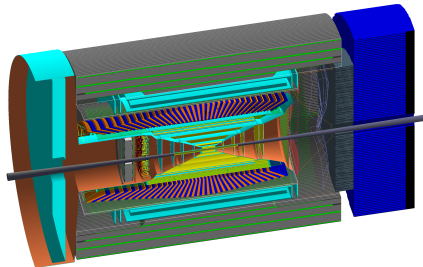
- ORNL
- ISU
- Ohio U.
- EIC-Japan
- EIC-Korea
- EIC-China
- BNL

- Fun4All Geant4 simulations:
 - N. Schmidt, ORNL (schmidtntv@ornl.gov)
 - F. Bock, ORNL (fbock@cern.ch)
 - C. Woody, BNL (woody@bnl.gov) - Tile simulations
- Costing & Risks:
 - F. Bock, ORNL (fbock@cern.ch)
- Engineering:
 - E. Fountain, ORNL (fountainej@ornl.gov)
- Foreign coordination
 - Y. Kim, UIUC (kingmking@gmail.com)
 - R. Seidl, RIKN (rseidl@ribf.riken.jp)

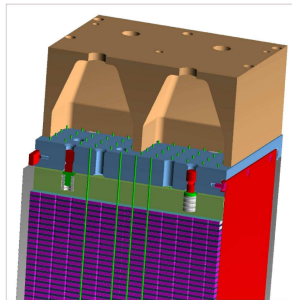
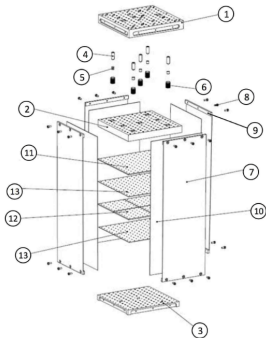
General FEMC design parameters



- Integrated design with LFHCAL towers
 - common cradle with LFHCAL
 - different module sizes (8M, 4M, 2M)
 - majority of modules is 8M
- Classical Pb-Scintillator shashlik calorimeter
 - similar to ALICE/STAR/PHENIX
- located at $z = 3.07$ m from IP
- Four WLS fibers (e.g. Kuraray Y11) per tower
 - SiPM readout



Construction Considerations

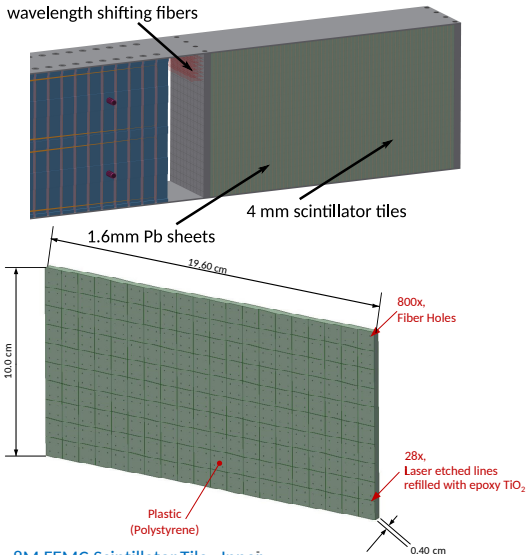


ALICE EMCal Reference

- Compression of towers between Al plates
 - similar concept to ALICE EMCal considered
 - shared frame with LHCAL for transverse alignment
- Two tower sizes depending on radius:
 - $1 \times 1 \text{ cm}^2$ ($R < 80 \text{ cm}$), $1.65 \times 1.65 \text{ cm}^2$ ($R > 80 \text{ cm}$)

parameter	FEMC
inner radius (envelope)	17 cm
outer radius (envelope)	170 cm
η acceptance	$1.3 < \eta < 3.5$
tower information	
x, y ($R < /> 0.8 \text{ m}$)	1 cm/ 1.65 cm
z (active depth)	37.5 cm
z read-out	5 cm
# scintillator plates	66 (0.4 cm each)
# absorber sheets	66 (0.16 cm Pb)
weight	$\sim 6.4 \text{ kg}$
radiation lengths	$18.5 X/X_0$
interaction lengths	$1.0 \lambda/\lambda_0$
Molière radius R_M	5.2 cm ($e^\pm$ shower)
Sampling fraction f	0.220
# towers (inner/outer)	19,200/ 34,416
# read-out channels	53,616

Detailed FEMC design parameters



8M FEMC Scintillator Tile - Inner

- Large scintillator plate subdivided into tower segments via groves
 - CNC cutting or laser etching to 92% of tile thickness
 - groves filled with e.g. TiO_2 +epoxy
 - light crosstalk/other separation methods to be studied
- 1.1mm holes for 1mm WLS fibers machined
 - 1mm WLS fibers (exact fibers to be determined)
- 4 fibers per tower readout via SiPM (e.g. Hamamatsu S14160-3050HS)
 - need for light guide/diffuser to be determined
- Signal processing possibly with CMS HGCROC in gap between FEMC and LFHCAL
 - data transmission via optical fiber

Example 8M module costs:

Material procurement	Units	Unit Pricing
Absorber plates	66	\$8
Scintillator plates	66	\$30
tyvek + capton	2.64	\$0
WLS fibers	304	\$3
Bellville Washers	16	\$1
Plungers	8	\$2
Compression screws	8	\$3
Compression plate	1	\$130
8M module cost:	553	\$3,484

Assembly labor & hours	cost
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:	553 \$428

Electronics	Units	Unit Pricing
SiPMs	72	\$10
mounting boards	1	\$10
cable+HV/LV	1	~ \$360
8M module cost:	553	\$428

Costing

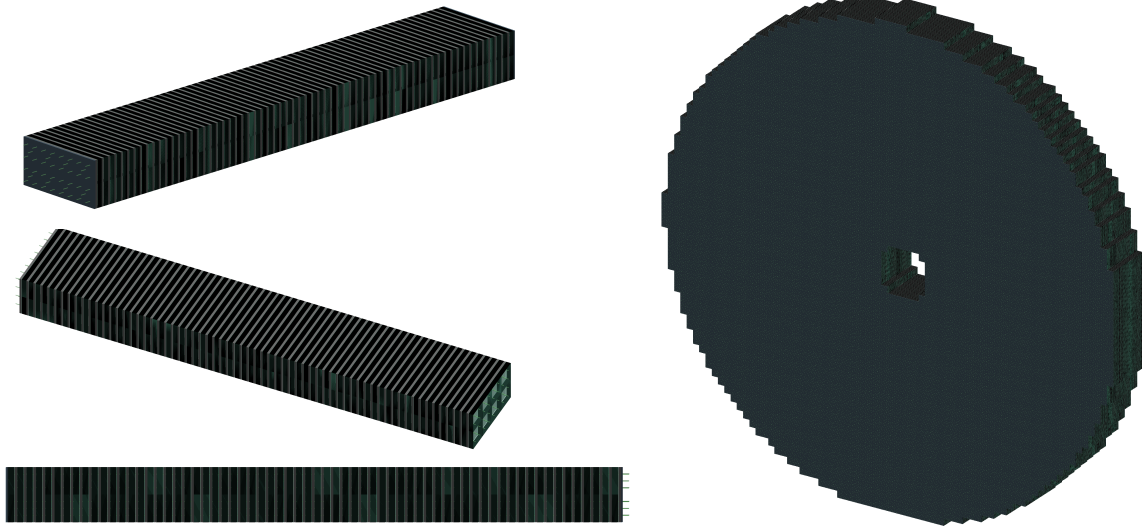
Additional costs:

- R&D cost: 230K
- Tooling: 200K
- Installation: 307K

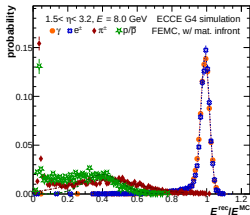
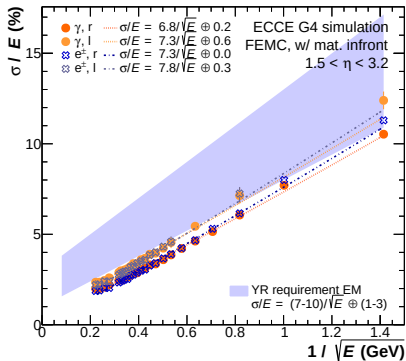
Total costs [\[link to sheet\]](#):

- estimated for:
553x8M module, 40x4M modules, 2x2M modules, 4x1M modules
- Module prices don't exactly scale as labor doesn't scale (fraction of 8M modules assumed with 200 SiPMs)
- Sci-plate costs expected to increase by factor 1.5–2 due to unavailability of UNIPLAST
- Assumes similar assembly and corresponding tooling as for ALICE EMCal
- **total unescalated cost: \$1,640,964**

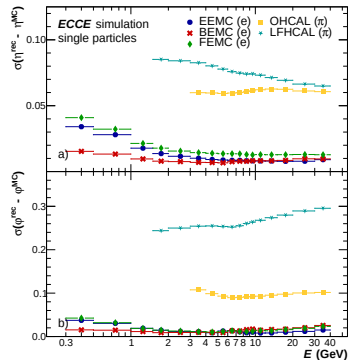
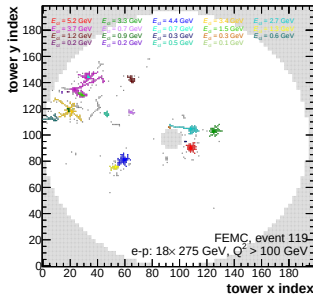
GEANT Implementation



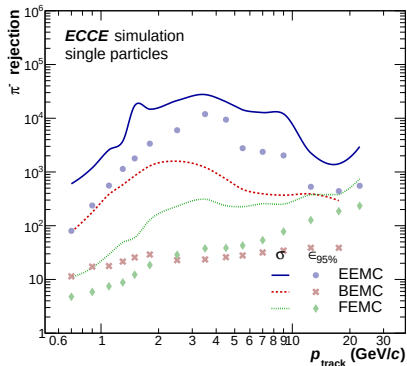
Performance - Energy and Position Resolution



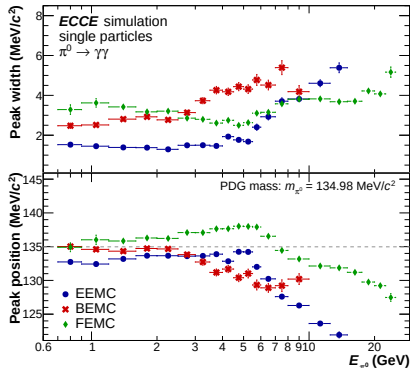
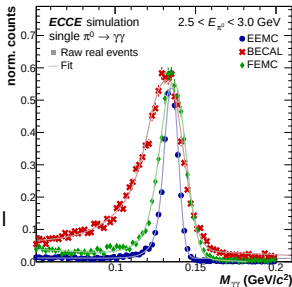
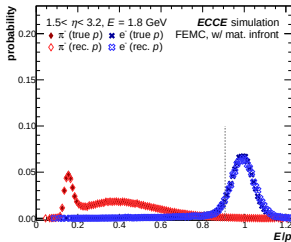
- Clusterization based on MA clusterizer
→ further improvements using ML being studied
- Energy resolution meets YR requirement
→ resolution: $\sigma_E/E = 7.8/\sqrt{E} \oplus 0.3$
- Good position resolution of clusters
→ needed for track matching and particle flow



Performance - PID



- Charged pion rejection factor 10–1000 depending on energy
- Possible improvement via additional TTL disk $R = 60\text{cm}$



- π^0 reconstruction up to high energies
→ late cluster merging due to large distance from vertex and high granularity

Conclusion

- Pb-Scintillator shashlik calorimeter FEMC fulfills required performance by YR
- Forward EM calorimeter needed for photon, meson, and neutral jet reconstruction (and more)
- Design based on previous successful calorimeters (e.g. ALICE EMCal) with modern elements like SiPMs
- Detailed risk and costing assessment performed

Backup - ALICE EMCal

