Calibration of NICA-MPD electromagnetic calorimeter modules with cosmic muons

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Nuclotron-based Ion Collider fAcility

Under construction at JINR, Dubna, Russia

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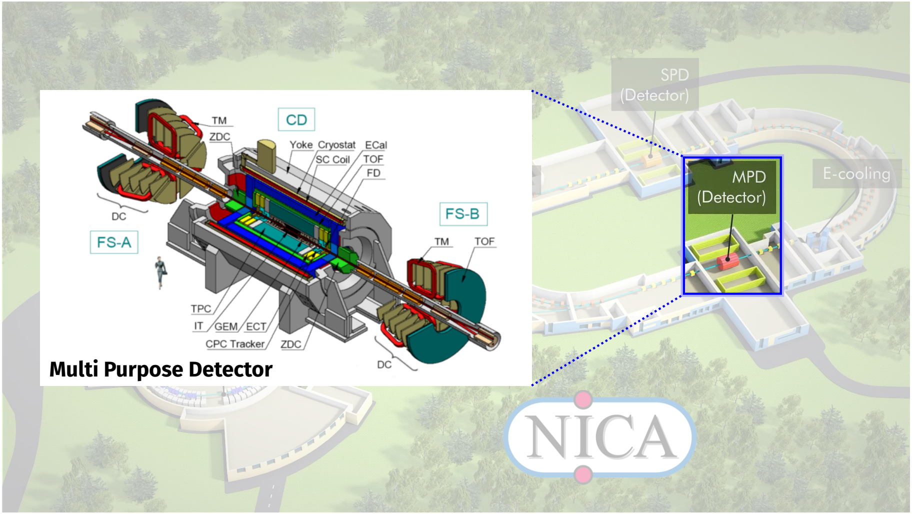


Main objectives of the ECal:

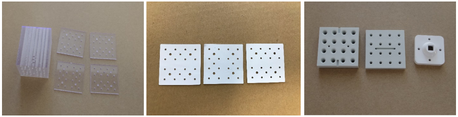
- Participation in particle (e^-) identification process as part of the MPD
- Reconstruction of some decays with participation of photons
- Measurements of the photon flux

***MPD-ECAL designed to handle high multiplicity of particles**

Design requirements for the ECal:

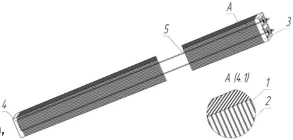
- highly segmented
- minimal shower overlaps
- time resolution below 1 nanosecond
- particle occupancy should be below 5%
- dense active medium with small Molière radius
- good spatial resolution
- calorimeter must be able to operate in the magnetic field up to 0.5T
- large enough separation to the vertex of collision

NICA-MPD: ECal module



Lead, Scintillator and support plates

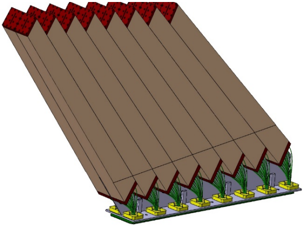
A single 'shashlyk' cell (*Tower*)



The towers taper towards the bottom
giving it a trapezoidal structure
with lower part size reducing to $\sim$33mm,
and milling angles of 0.9° and 1.2°

Design parameters for single module

Cell count (towers)	:	2x8
Tower crossection (mm2)	:	40x40
WLS fibers	:	16
Number of layers per Tower	:	210
Polystyrene scintillator thickness (mm)	:	1.5
Lead absorber thickness (mm)	:	0.3
Molière radius (mm)	:	62.0
Radiation length (X0)	:	11.3
Effective Radiation length	:	$\sim$32.0

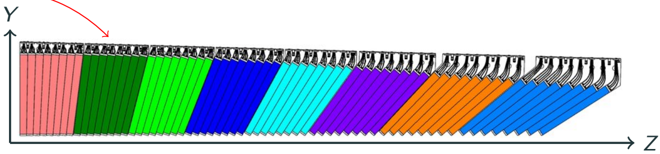


A module from 16 *Towers* stacked in two rows

NICA-MPD: ECal projective geometry

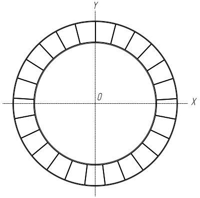
Readout electronics goes at the top of the towers;
are detachable;
requires cooling

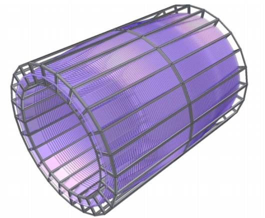
Towers are oriented towards the beam interaction zone;
Tower positions in Z-direction gives them unique angles



Slice of 64 different types of Towers sorted in to 8 types of modules

Modules are divided into sectors based on their position along XY-axes



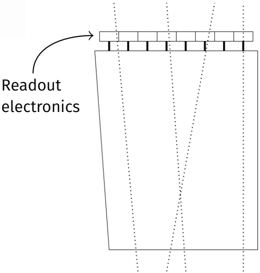


Various types of towers in all modules and sectors by their XYZ position and orientations placed together give the ECal a barrel shape

Total of 38400 towers need to be calibrated before assembling them into the ECal inside MPD.

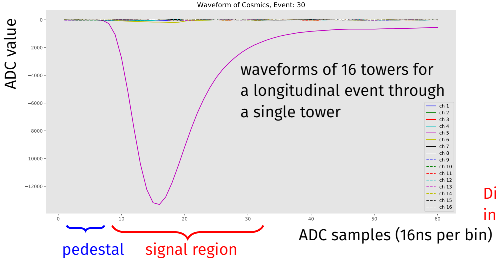
****Need to calibrate around 2400 ECal modules before assembly, using cosmic muons can be a fast approach**

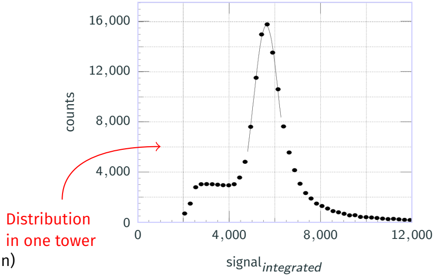
Side View (longitudinal cosmics)



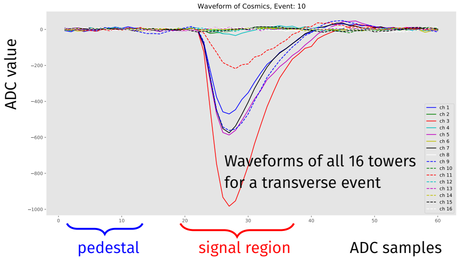
Calibration steps (Longitudinal cosmic):

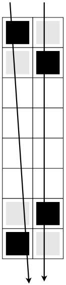
- Photons from each tower are deposited on surface of MAPD
- Readout electronics + ADC records cosmic muons passing through the module
- Events through multiple towers are rejected. Single tower illuminated by cosmics are selected, triggers above and below towers longitudinally are applied for selection.
- Signal region is integrated and average pedestal is subtracted
- Obtained distribution is great but need long time for sufficient statistics.



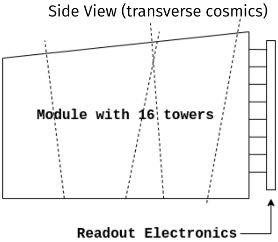


ECal: Calibration of modules with cosmic muons



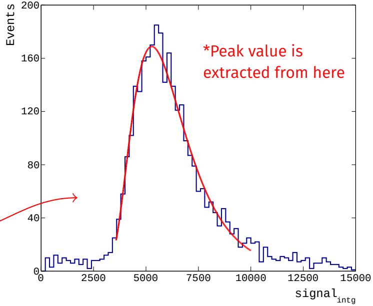


Front View

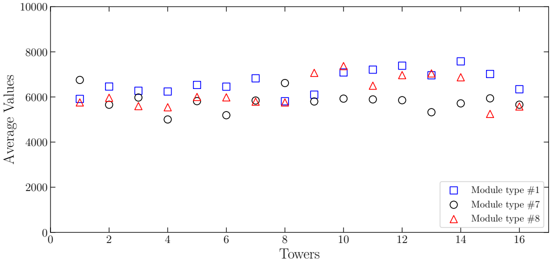


Calibration steps (Transverse cosmic):

- Rotating the module and allowing cosmics to pass through all 8 towers in a row. Event rate is high (500-600 events/hour)
- Readout electronics + ADC record cosmic muon events transversing through the module
- Events satisfying trigger conditions (top & bottom tower signal $>$ a min_value) are selected for processing
- Signal region is integrated and average pedestal is subtracted
- Integrated signal are aggregated for large number of events

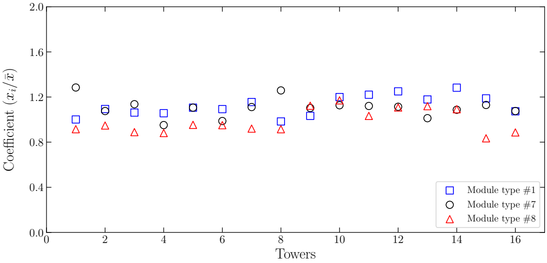


ECal: Calibration of modules with cosmic muons



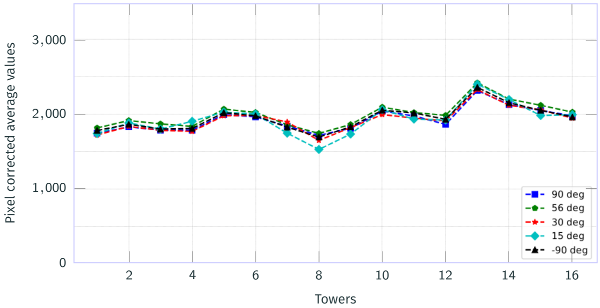
*Extracted peak values from towers of a module type vs. tower no. in module

*Systematics error is low (<100) error bar within the markers



*Need to calibrate thousands of towers in modules for normalization of performance w.r.t. each other

ECal Calibration: Different orientations



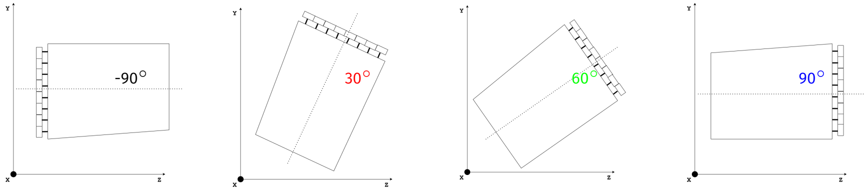
∗error bars within the markers

∗trigger algorithm is same as before (top+bottom towers)

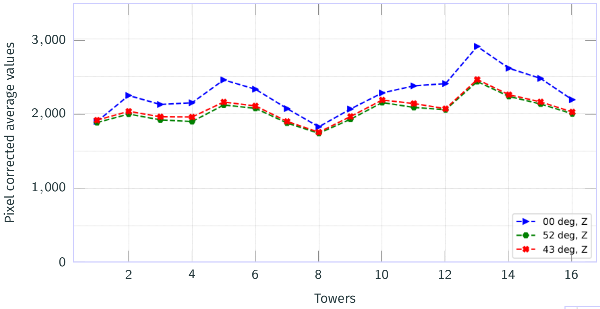
∗Angles are between the Y-axis and center of module

$$N_{pixel\_corrected} = -N_{total} * \ln(1 - \frac{N_{experimental}}{N_{total}})$$

$N_{experimental}$ is the extracted peak value from distribution of integrated signals and $N_{total} = 15000$

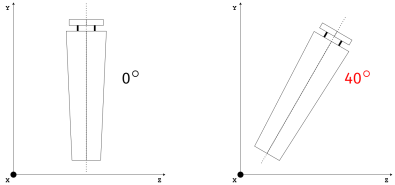


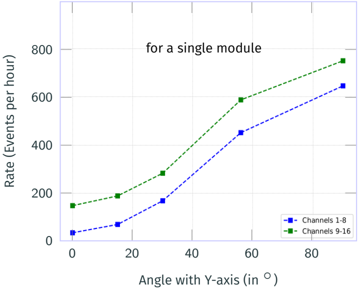
ECal Calibration: Different orientations



∗trigger algorithm is same

∗Angles here are between the plane passing through Y-axis and center of module, but module is rotated as in fig (lower left)

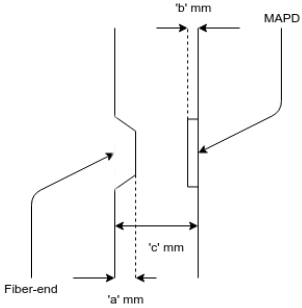


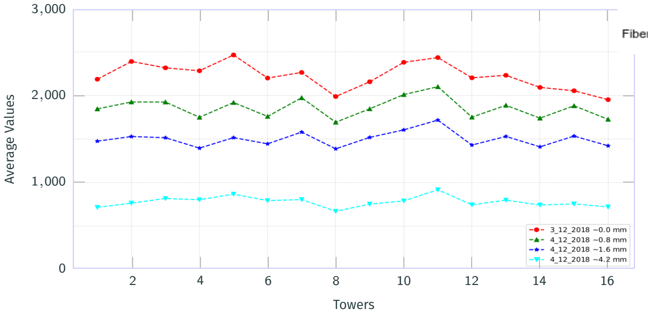


ECal calibration: WLS Fiber-MAPD separation

Separation test:

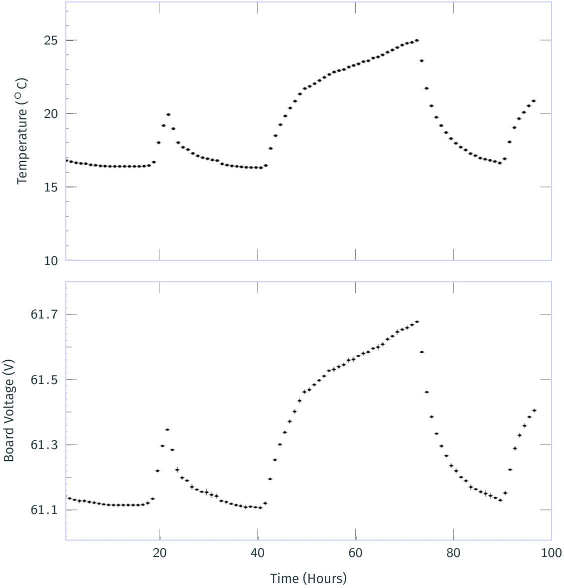
- Obtaining maximum signal without the damaging MAPDs in a module
- Cosmic data collected for distance of separation of: $\mathrm{d} = \mathrm{c} - (\mathrm{a} + \mathrm{b})$
- d = 0.0 mm, 0.8 mm, 1.6 mm, 4.2 mm for module type 1
- Separation between Fiber-end and MAPD varies tower-wise, so 'd' value is approximate.
- d<0.8 mm is ideal, if tolerances permit





∗signal variation at few hundred microns was higher for this module.
A problem with fibers was fixed and variation has reduced. Final results for the newer modules will be ready in the near future

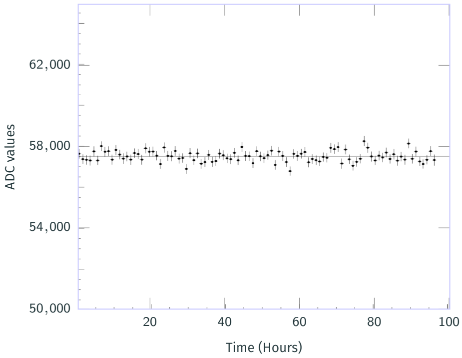
ECal Calibration: Stability tests

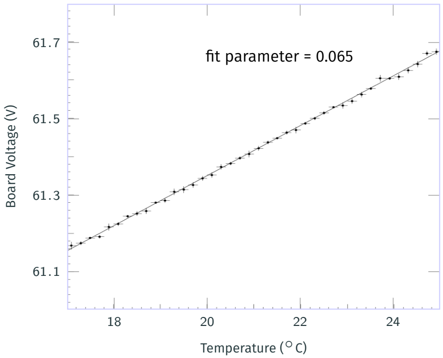


∗As temperature was increased, the system voltage followed the changes linearly

∗Plots are magnified along axes as variations are small

from: I. Tyapkin



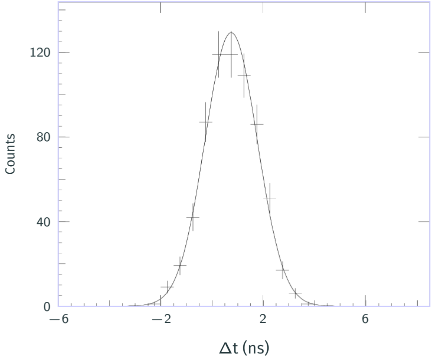


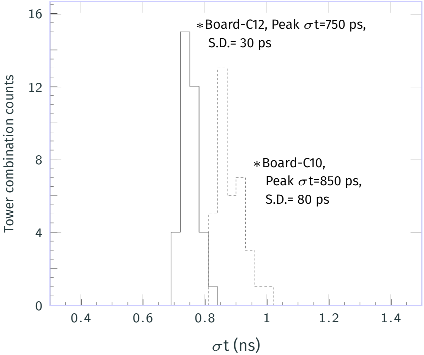
∗axes are magnified

from: I. Tyapkin

ECal Calibration: Time resolution

∗Transverse cosmic events which tag all towers in a row of a module are selected.
Time difference (Δt) distribution is from two towers in Board C12 (lower left)

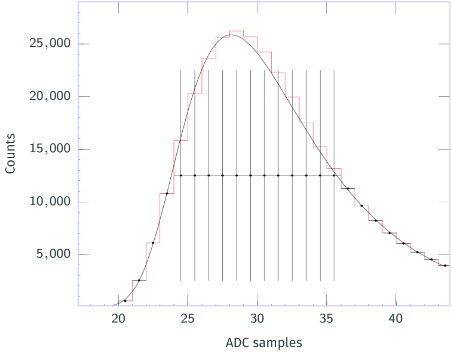


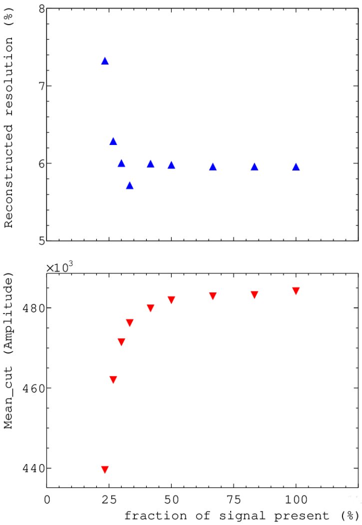


'σt' is extracted from distributions of multiple combinations of any two towers. Distribution of 'σt' for two electronic boards (C10, C12) for same module type is compared (upper right). Differences due to noise in electronics.

from: I. Tyapkin

∗Waveforms in events can reach maximum and the response may get cut, but it can be reconstructed (lower left) to get the signal integral.





∗Considering different levels of cut on waveforms, resolution obtained after reconstructing remaining signal and integrating the signal (upper right)

from: I. Tyapkin, DESY 2018, 1.6 GeV

Conclusions

Calibration and stability study conclusions

- MPD-ECal module calibration using transverse cosmics is faster and efficient.
- Multiple types of modules were tested.
- Tower responses are similar and steady for different types of modules.
- Different orientation of modules give similar result, event rate is low for longitudinal cosmics.
- A gap within few hundred microns ($<$0.8 mm) between readout board and fiber-end gives best results
- Good stability over long time ($\sim$100 hours)
- Time resolution of <1 ns can be achieved for very low energy

Thank You!