Modular Cosmic Ray Detector (MCORD) possible use in the cosmo-seismic project.

Dr Marcin Bielewicz
Nacional Centre for Nuclear Research

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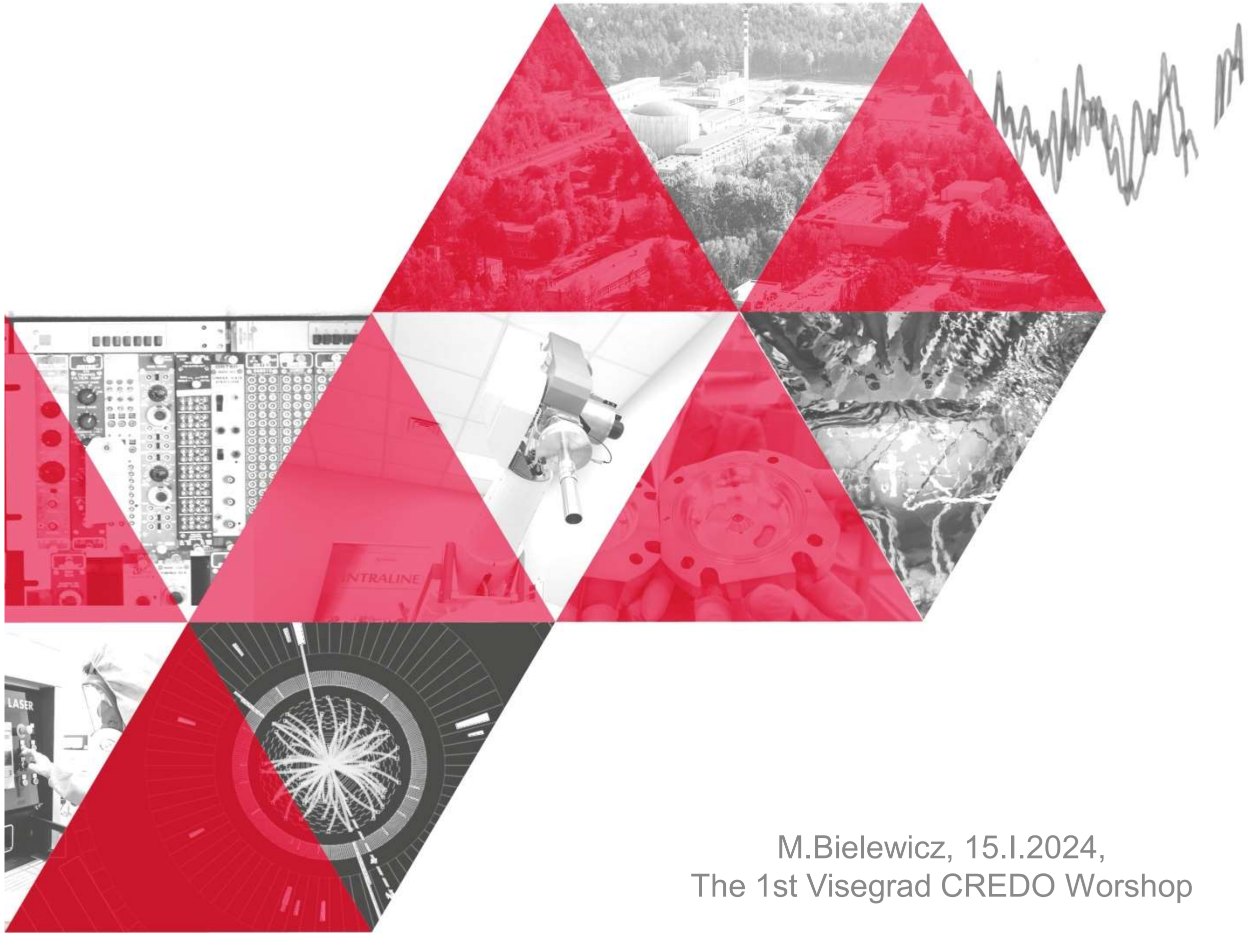

Outline

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3. Laboratory tests
4. CREDO - Mexico
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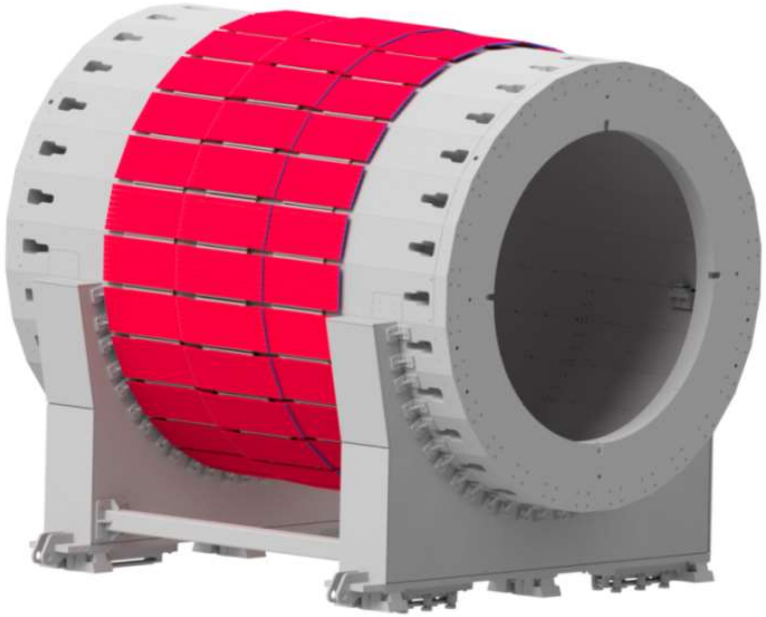
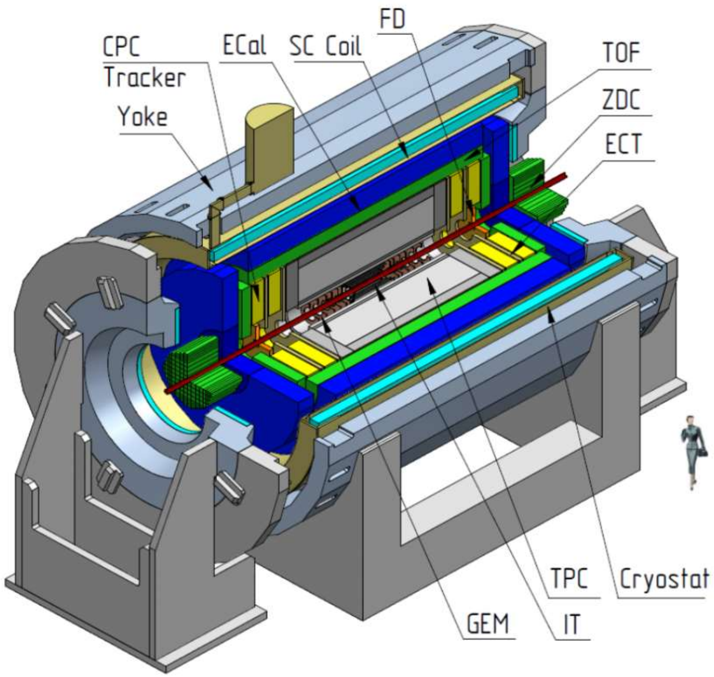
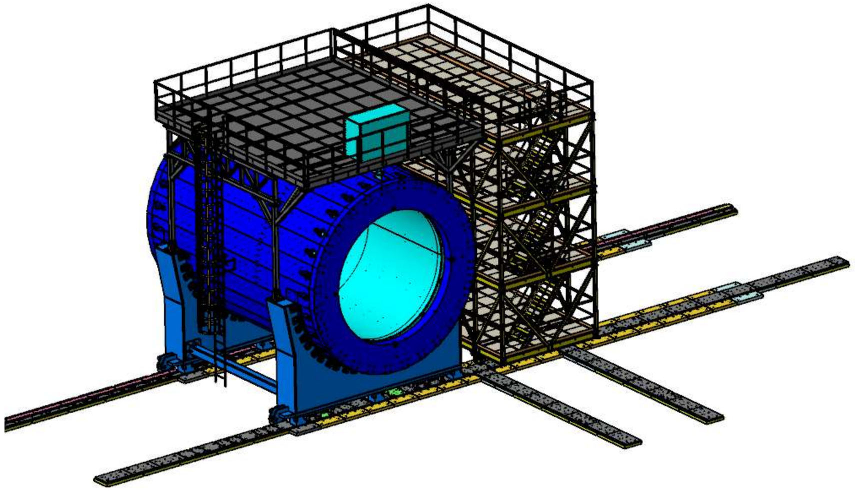
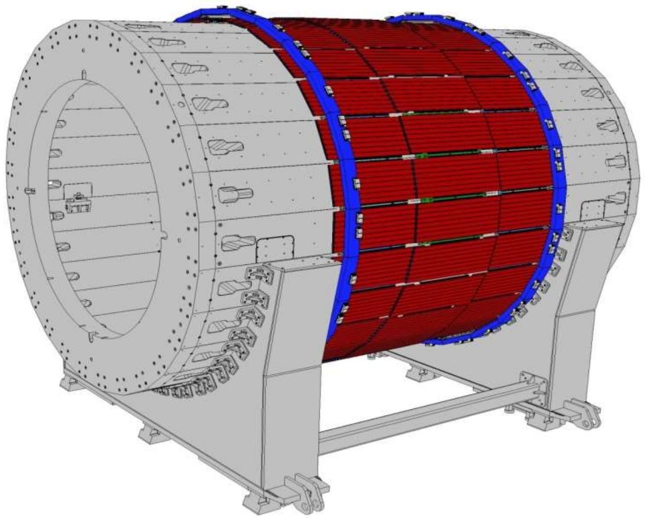


1. Genesis of MCORD



- FD Forward detector
- Superconductor solenoid (SC Coil)
- Inner Tracker (IT)
- Straw-tube Tracker (ECT)
- **Time-projection chamber (TPC)**
- **Time-of-Flight system (TOF)**
- **Electromagnetic calorimeter (EMC - ECal)**
- Zero degree calorimeter (ZDC).
- Cosmic Ray Detector (MCORD)



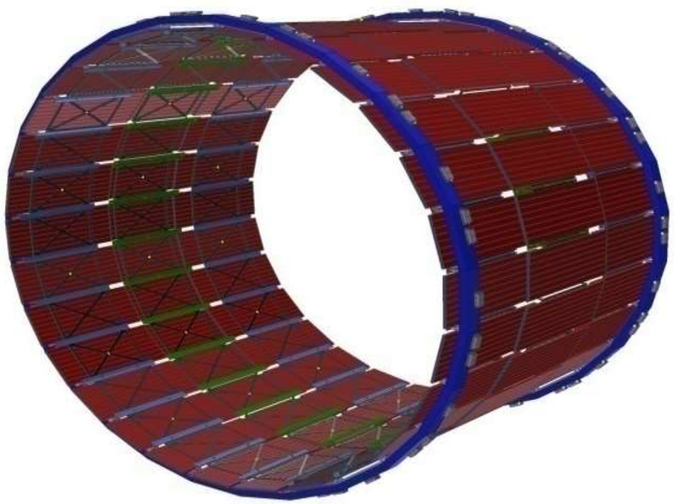


1. Examples of MCORD aplication

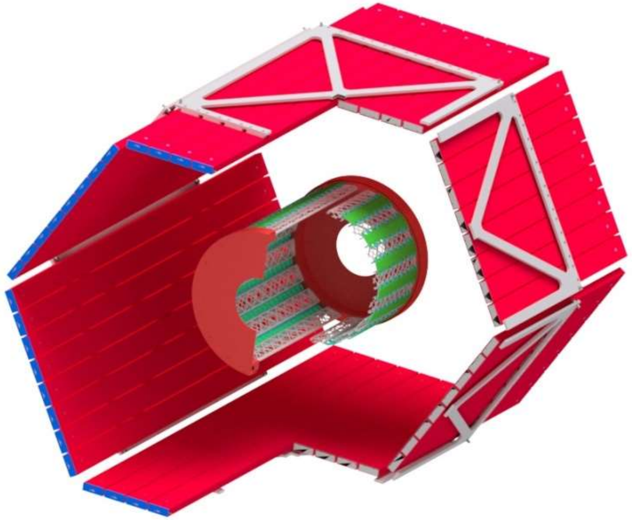
1. Trigger for cosmic muons for:
   - laboratory tests of different subsystems (2 separate MCORD sections)
   - Cosmic calibration in off-beam time
2. Muon identifier (from collision):
   - pions and kaons decays
   - rare mesons decays (η, ρ)
3. Astrophysics (muon showers and bundles)
   - Identification of extremely high energy particle sources
   - Sensitivity for horizontal events
   - Earthquake corellation
4. Modular construction – easy upgrade and/or alternative use

1. Modular construction

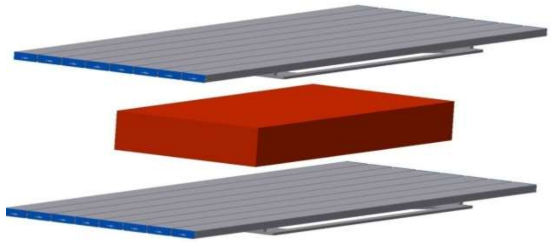
Big cylindrical detector +
28 Modules (3 section each)
Size: 4784 x 735 x 140 mm



Phase Zero conceptions
6 MCORD section + miniBeBe



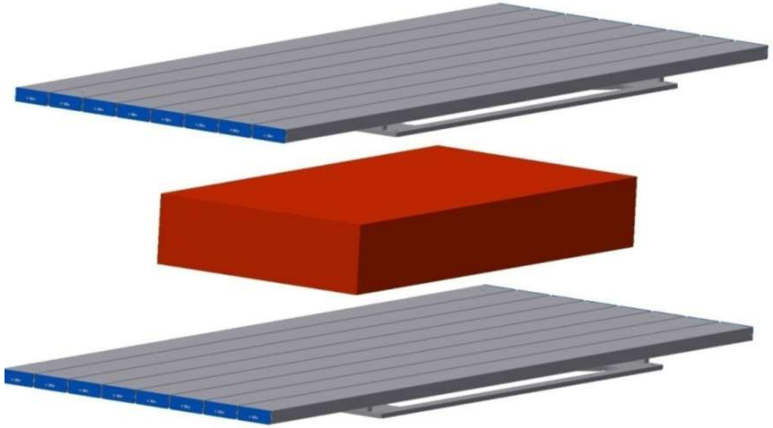
2 MCORD section + other detector



1. Introduction

MCORD HUB

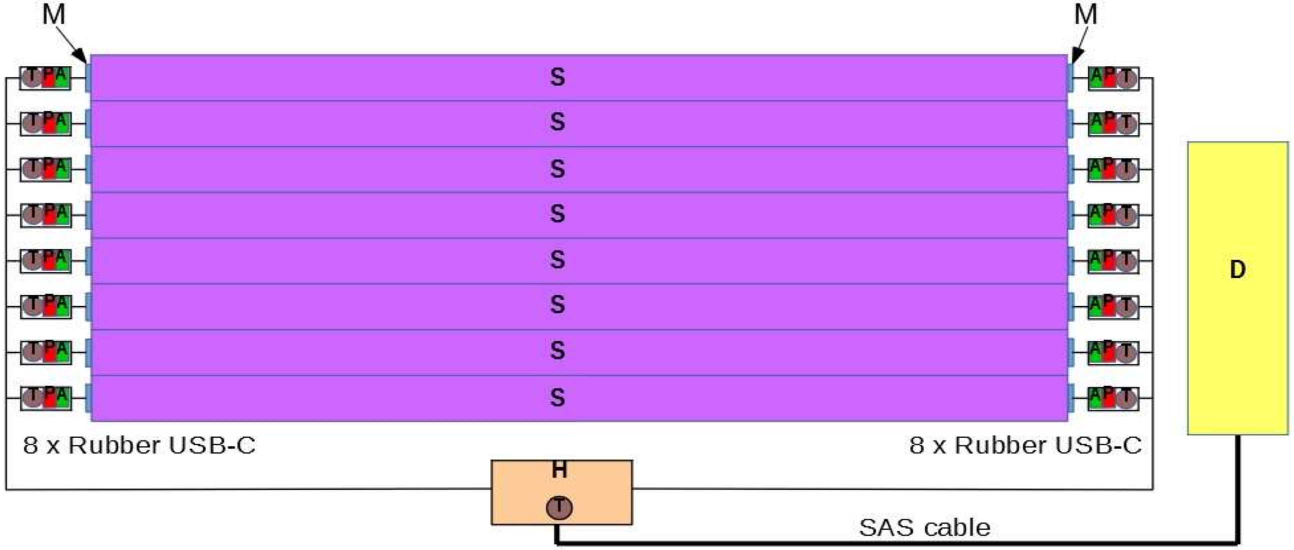
Mini MTCA (FPGA)



2 sections (2 x 8 scintillators) + AFE + DSP + DAQ,

2. Detector

MCORD Section



Position resolution
In X axis – up to 5 cm
In Y axis – 5-10 cm

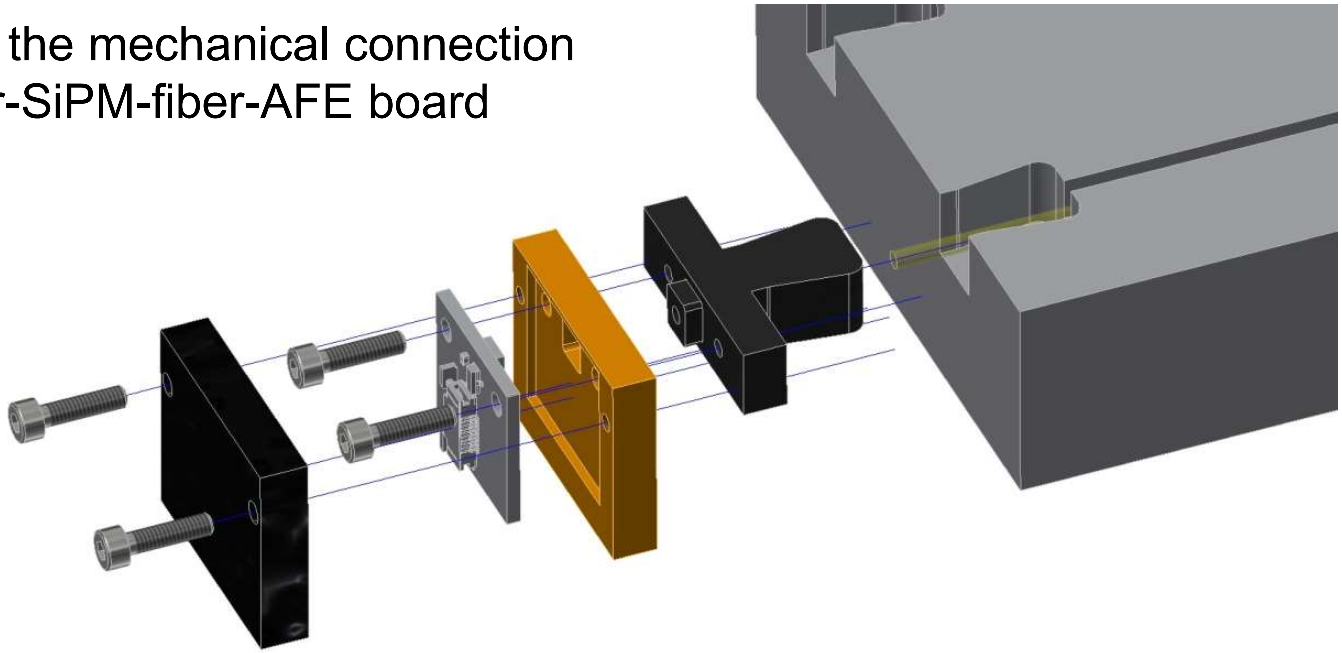
Time Resolution – about 1 ns

Legend: **S** (violet) – plastic scintillator, **M** (blue) – SiPM, **P** (red) – power supply with temperature compensation circuit, **T** (brown) – temperature sensor, **A** (green) – amplifier, **H** (orange) – Passive Signal Hub & Power Splitter, **D** (yellow) – MicroTCA system with ADC boards.

Single MCORD section 1744 x 735(675) x 50 [mm]

2. Detector

Project of the mechanical connection
scintillator-SiPM-fiber-AFE board

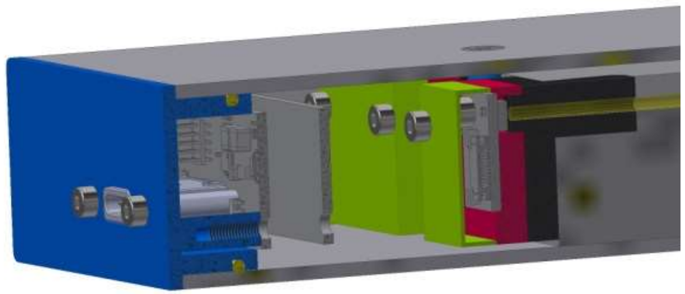


Plastic scintillator: polystyrene (Nuvia)
162 x 7.2 x 2.2 cm

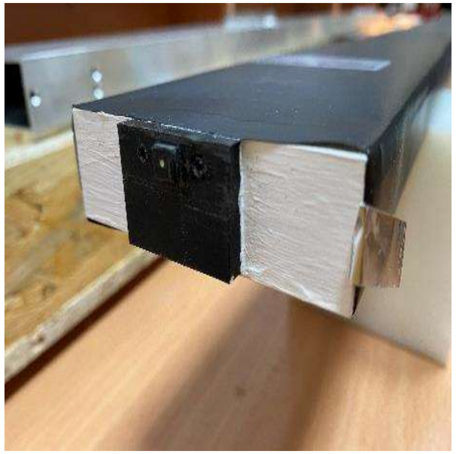
WLS fiber: **2** mm dia. (Kuraray)

SiPM (MPPC): 3x3 mm^2 (Hamamatsu)

Housing: aluminum profile
174 x 8 x 3 cm



2. Detector Slab manufacturing





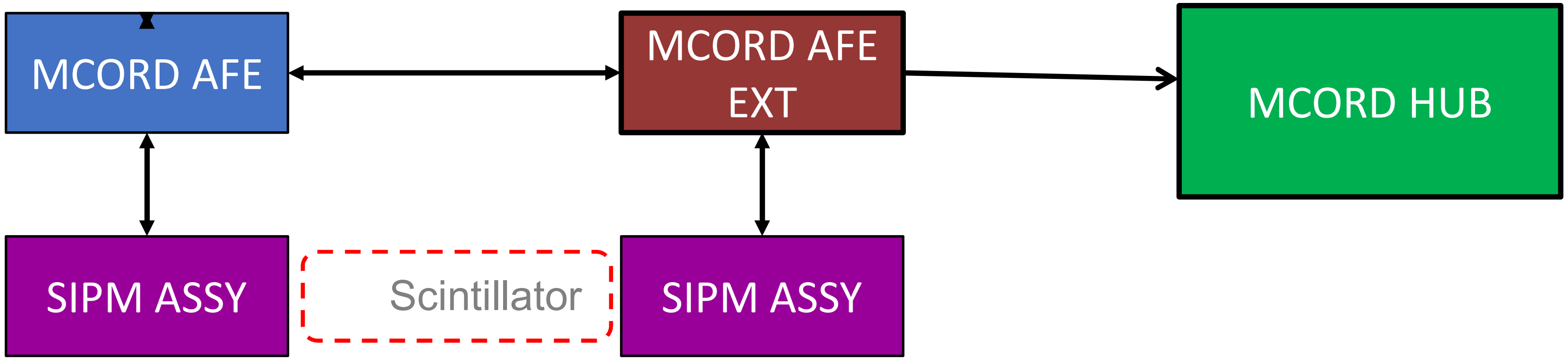


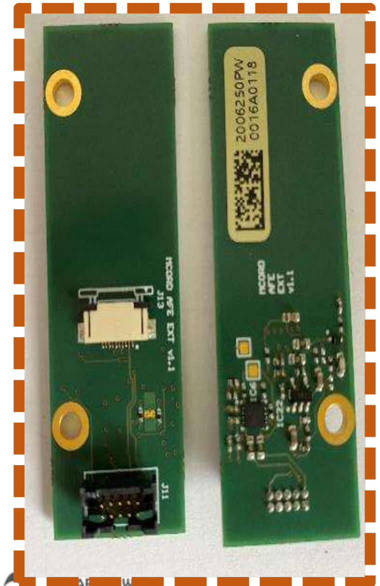


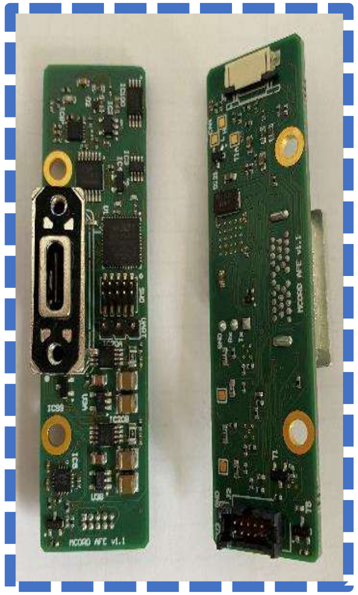
MCORD single detector assembly

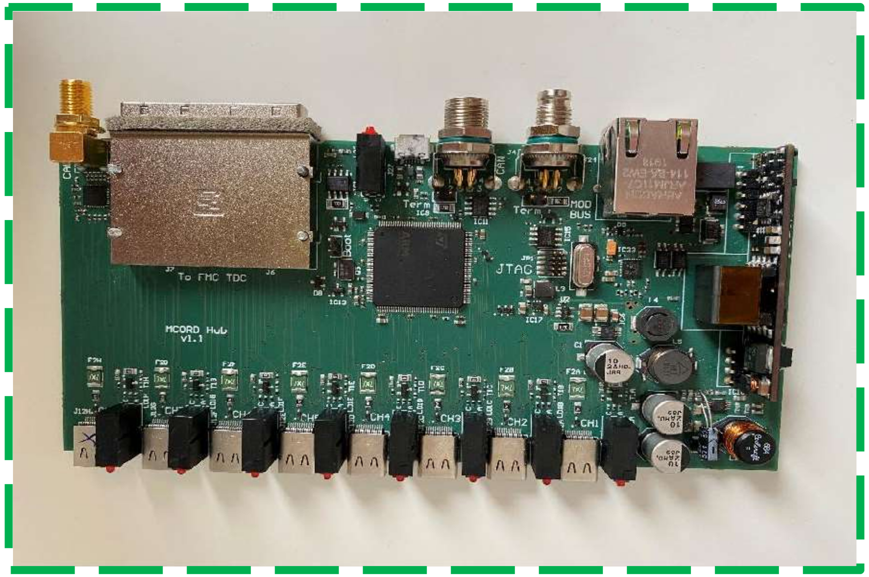
3. Analog Front End and HUB

The main boards ver.3 :



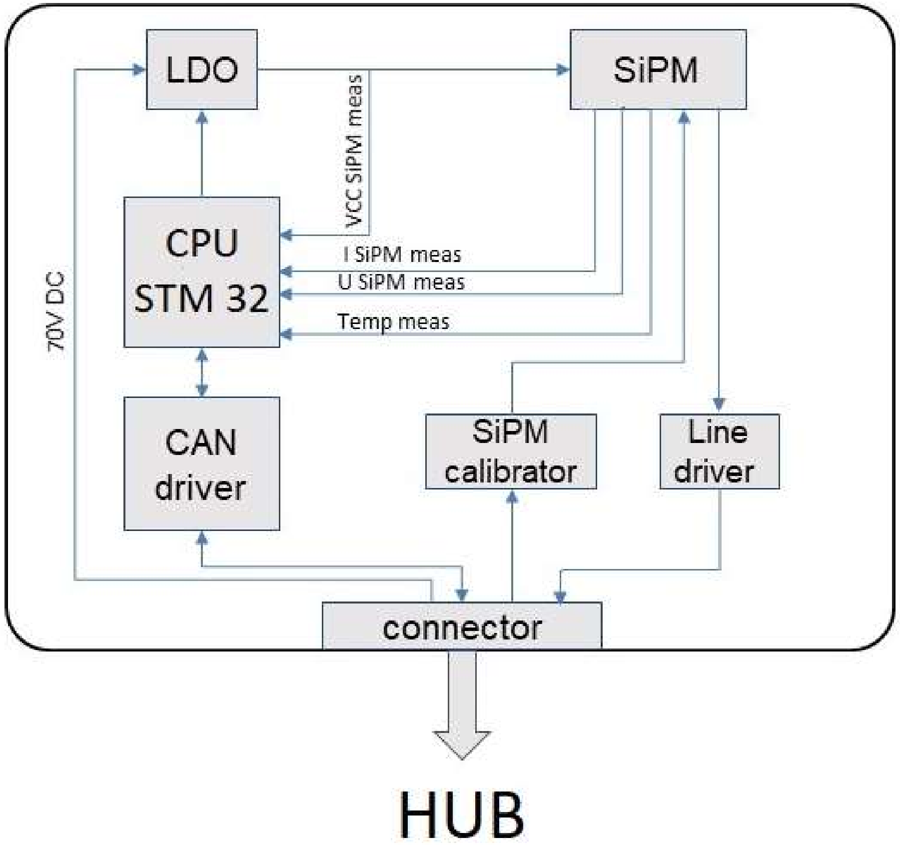






3. Analog Front End - functionality

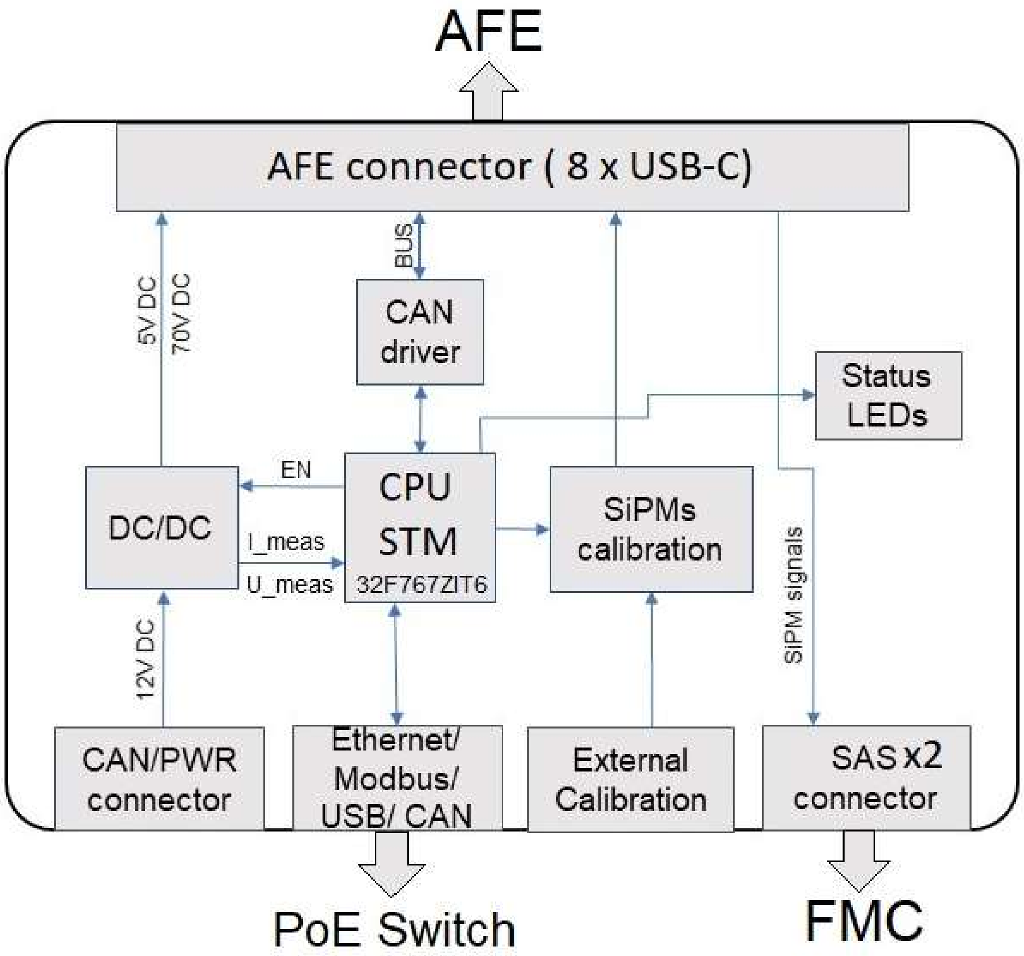
- Voltage controller for SiPMs and Amplifier physical signal
- Access to all settings and data from HUB via CAN-bus interface
- Protection for AFE



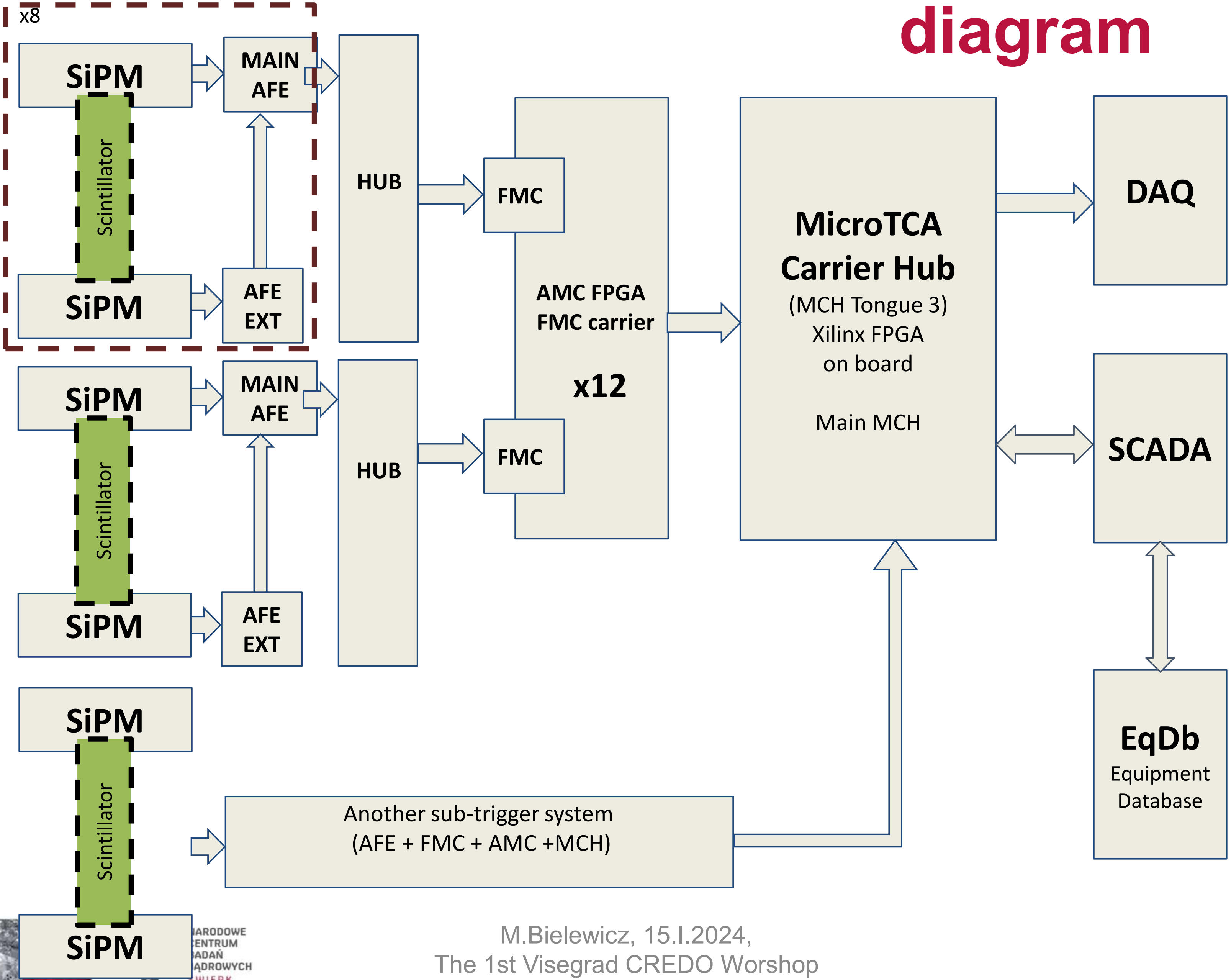
- **Main blocks**
  - Embedded CPU (STM32F072CBU6)
  - **Temperature sensor** (LM45)
  - SiPM voltage controller + LDO (Low Dropout Regulator)
  - **SiPM calibrator**
  - SiPM signal transmitter to HUB (differential signal)
  - **CAN network driver**
- **Measurements (12 bit ADC)**
  - 2 x SiPM voltage
  - 2x SiPM current
  - 2 x SiPM VCC voltage
  - 2 x SIPM temperature
- **Control (8 bit DAC)**
  - 2 x SiPM voltage

3. HUB - functionality

- **Mikro PYTHON programing**
- PoE supply
- **Generation of 5V and 70V**
- ETH <-> CAN
- Distribution of signals from AFE to SAS cables
- Status LEDs on AFE ASSY and HUB for quick fault identification
- **Generation of calibration signals to AFE**
- STM32 CPU with microPython



3. MCORD readout system schematic diagram



Data processing

- Latency estimation for **L1 trigger** (event without parameters)

✓ AFE cabling 8ns/m, with 10m cabling latency is 80ns
✓ ADC + SERDES latency: 400ns

Estimated total latency: **about 1us**

Latency estimation for **L2 trigger** (event with parameters)

✓ MGT latency: 500ns
✓ Algorithm latency : 2-5us
✓ Formatter and transmitter latency: 1us

Estimated total latency: **3.5 – 7.5us**

Latency estimation for **L3 trigger** (between MTCA systems)

✓ MGT latency: 500ns
✓ Fiber latency: 500ns + 8ns/m
✓ Algorithm latency : 2-5us
✓ Formatter and transmitter latency: 1us

Estimated total latency: **10 – 15us**

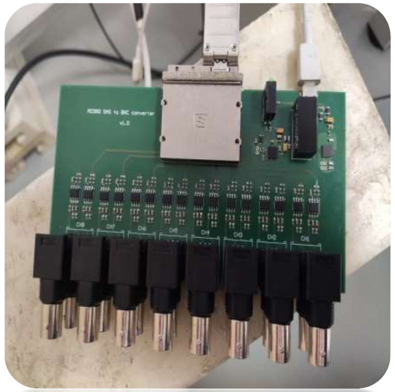
3. Laboratory tests

Measuring system

AFE Board → AFE Hub → SAS to BCN converter → Digitizer

Plastic scintillator in an aluminum housing with an AFE amplification system and a Hamamatsu MPPC photodetector

Managed control system for AFE power supplies mounted in boards. Up to 8 boards can be connected once

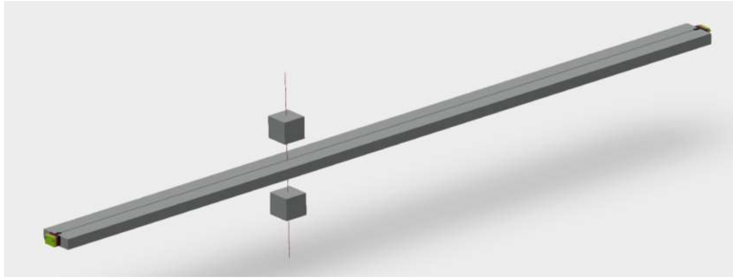


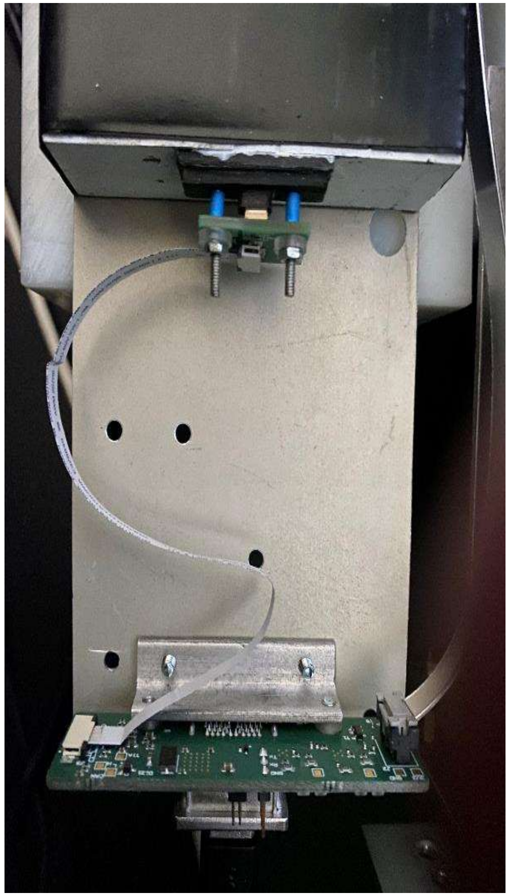
Converter of signals received by SAS cable to appropriate single BNC channels for each MPPC

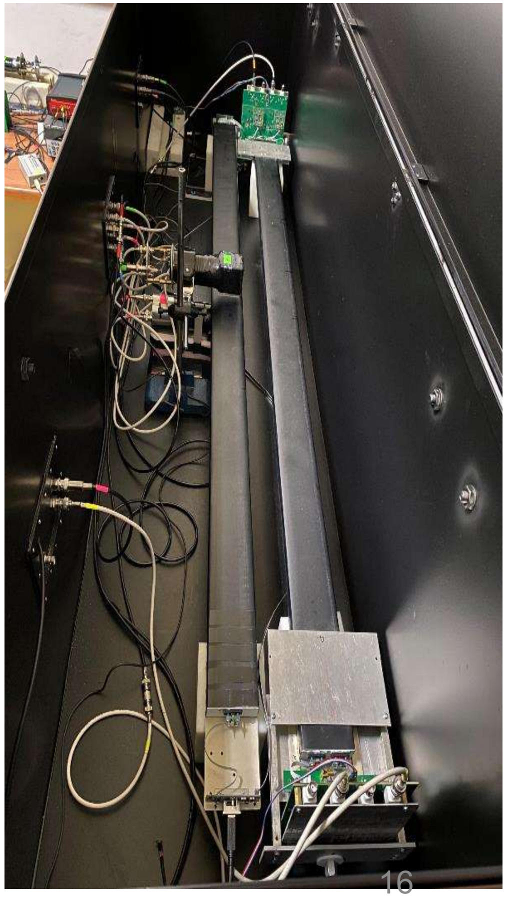
Digital multi-channel amplitude acquirer by CAEN for analysis of received signals

3. Laboratory tests – 1st step

One Plastic MCORD detector
+ 2 plastic hodoscopes (muon trigger)
+ DAQ: CAEN DT5730

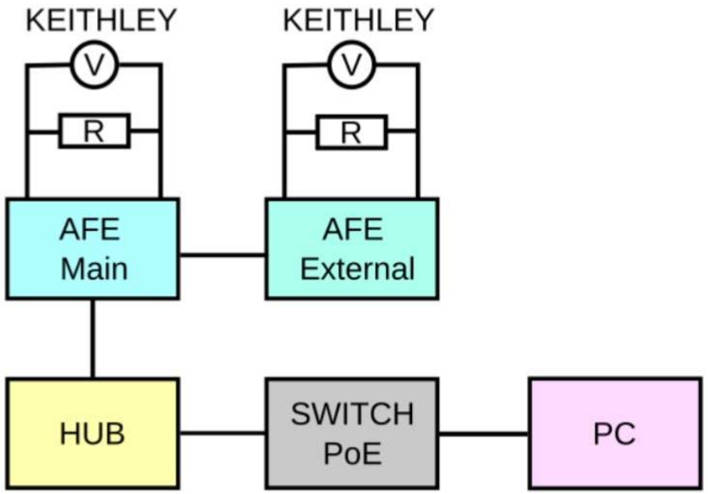


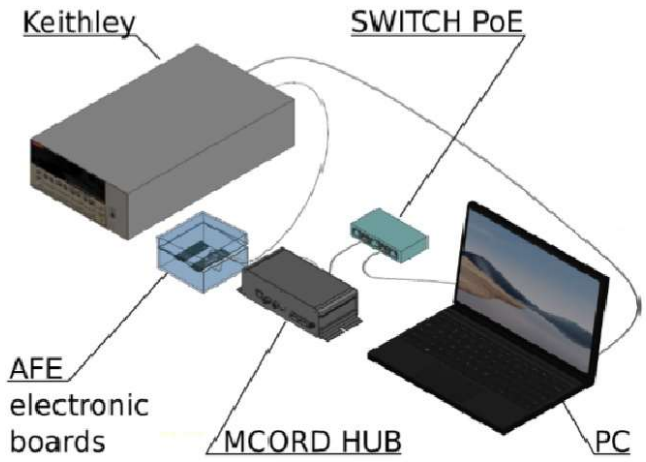




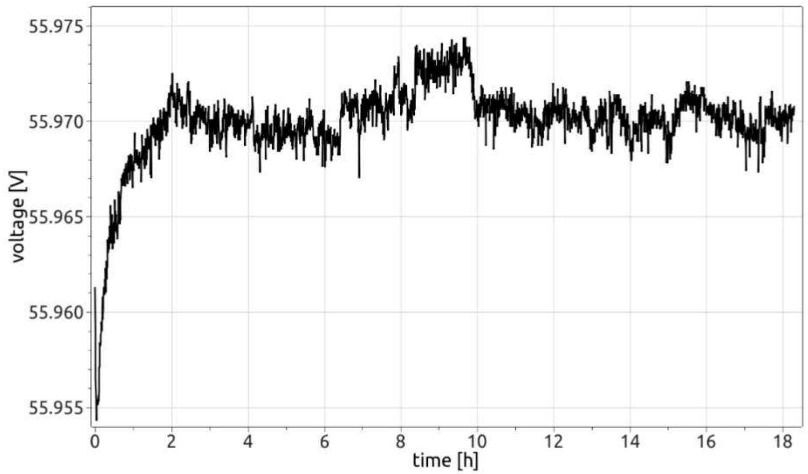
BLACK BOX test setup

3. Laboratory tests – 2nd step

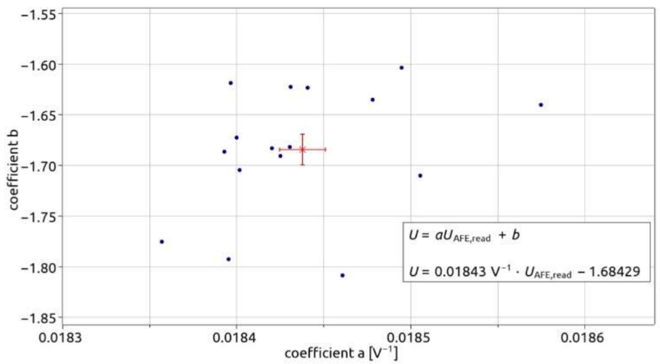




Schematic diagram of the measuring station for calibration measurements



Voltage U during heat-up of main AFE measured using the Keithley voltmeter.

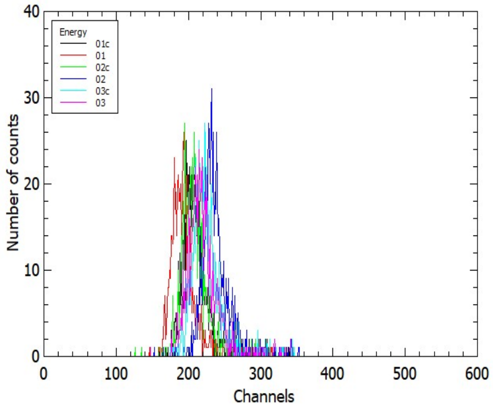


Internal voltmeter calibration coefficient distribution. The scale is limited to a narrow range to show small differences in presented values. The average value is marked with a red marker.

Callibration of A/D and D/A converters.

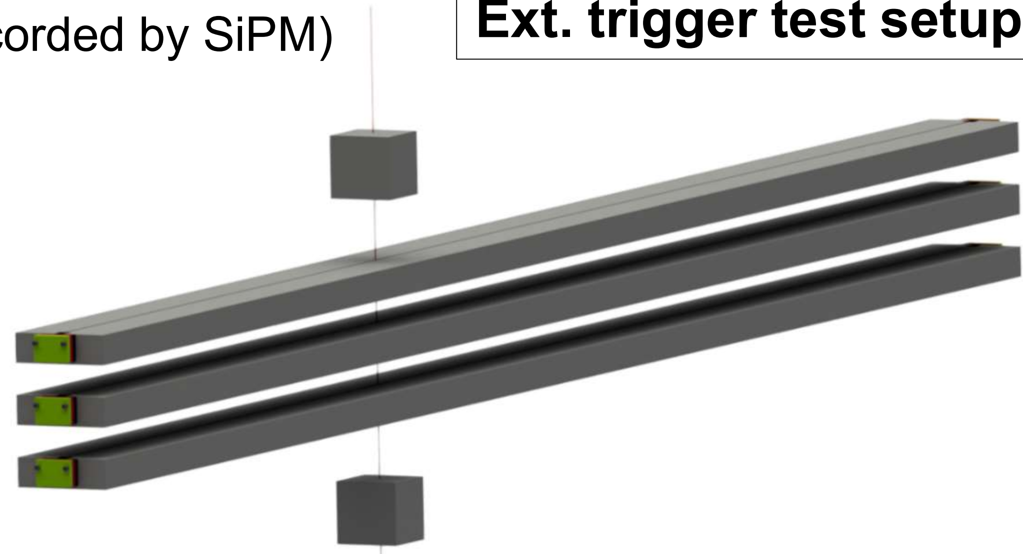
3. Laboratory tests – 3th step

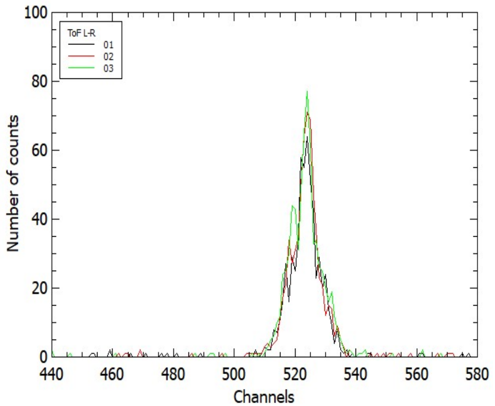
3x plastic MCORD detectors
+ 2x plastic hodoscopes (muon triggers)
+ DAQ: CAEN DT5730



Energy
(amplitude recorded by SiPM)

Ext. trigger test setup





ToF
(between both ends of a scintillator) -> Time rosolution

Plastic (162 x 7.2 x 2.2 cm) + WLS fiber (1 mm) + 2x MPPC 3 x 3 mm (pixel size 75um)
Hodoscopes: plastic (5 x 5 x 5 cm) + PMT (2" dia) → **99,5% efficiency**

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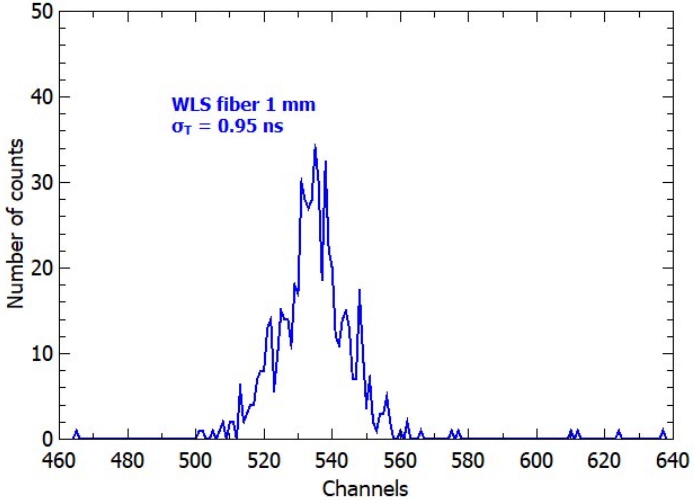
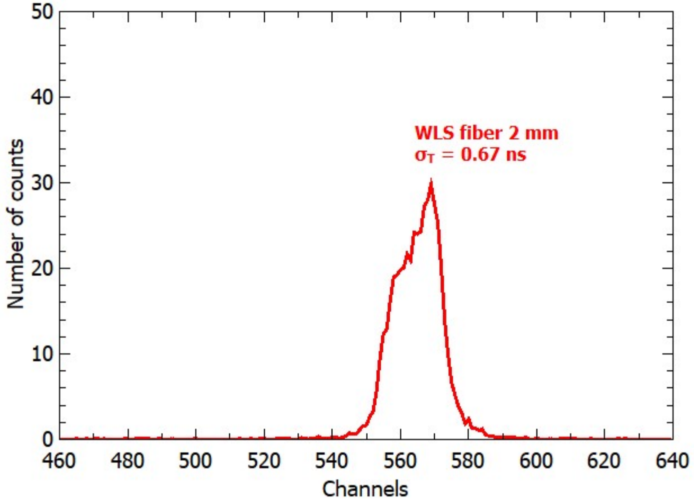
3. Laboratory tests – 3th step



WLS fiber (**1 mm**)

CRT (σ) = 0.95 ns ===> σ_x = 7.1 cm

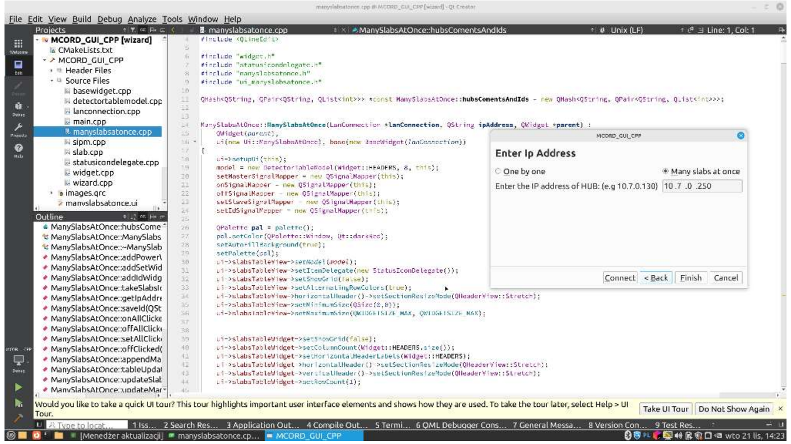


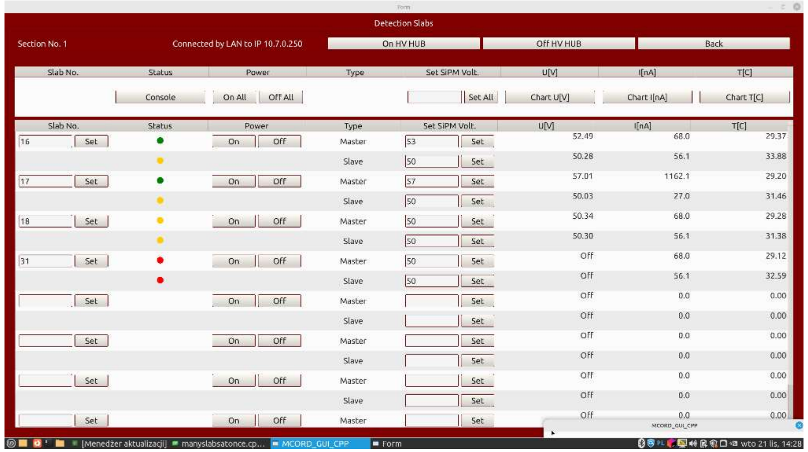
WLS fiber (**2 mm**)

CRT (σ) = 0.67 ns ===> σ_x = 5.1 cm

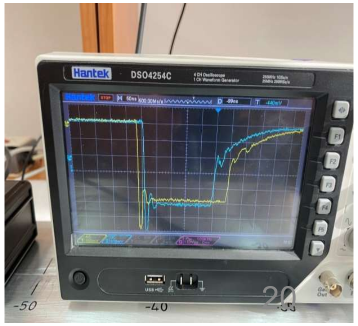
(!) improved timing resolution for 2 mm WLS fiber (!)

3. Laboratory tests – 4th step





MCORD demonstrator and GUI program



4. Earthquake - Cosmic ray corellation

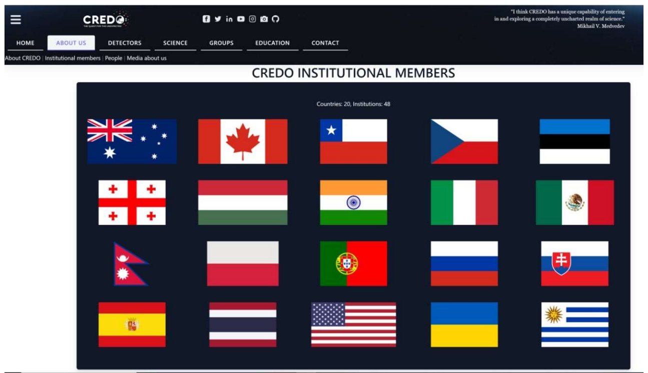
Earthquake Precursors

Large scale correlations between cosmic rays and earthquakes presumably related to earthquakes precursors has been observed. The found periodicity is rather similar to the sun spots solar cycle.

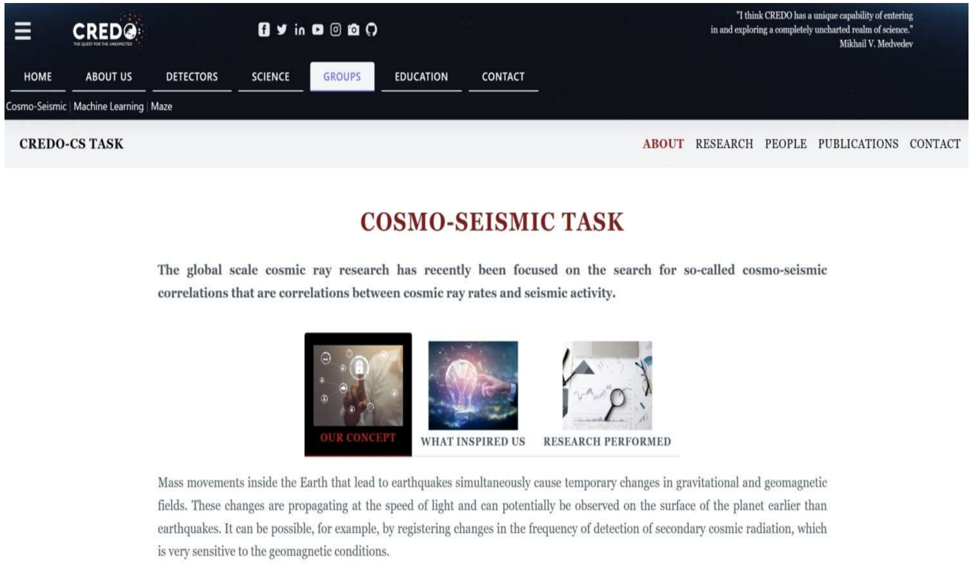
Cosmic ray data correspond to the measurements at the Pierre Auger observatory in Malargüe, Argentina, whereas seismic data is taken from Moscow and Oulu stations located in Russia and Finland, respectively.

A 6σ correlation effect has been observed in a period of about 4.5 years. Details can be found in a the publication

Observation of large scale precursor correlations between cosmic rays and earthquakes with a periodicity similar to the solar cycle, P. Homola, et al., *J ATMOS SOL-TERR PHY[70] Vol. 247 (2023) 106068*



4. CREDO-MEXICO-CHILE program



The use of the Mexican and Chile cosmic ray observatory + several MCORD coincidence detectors installed in universities + several smaller detectors for schools etc. - Creation of a measurement network collecting data simultaneously with seismographic stations

The scope of research and the list of institutions are discussed. Currently, we are preparing the text of the **Memorandum of Understending**, which will become the basis for obtaining the grant.

Recent Developments within The Cosmic-Ray Extremely Distributed Observatory(CREDO),
O. Suchanov, P. Homola, D.E. AlvarezCastillo, M. Bielewicz et al.,
Revista MEX FIS[20] Vol. 4 No 2 (2023) 1

5. CDR publictation

Conceptual design report of the MPD Cosmic Ray Detector (MCORD)

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Conceptual design report of the MPD Cosmic Ray Detector (MCORD)

M. Bielewicz,[a,e,*] A. Bancer,[a] M. Barabanov,[e] A. Chlopik,[a,e] M. Czarnynoga,[b,e] D. Dabrowski,[b,e] A. Dudzinski,[a] A. Dziedzic,[a] M. Grodzicka-Kobylka,[a] J. Grzyb,[a] K. Grodzicki,[a] E. Jaworska,[a] P. Kankiewicz,[c] G. Kasprowicz,[b] A. Kisiel,[b,e] P. Kolasinski,[b] S. Kowalski,[f] M. Krakowiak,[a] M. Kuich,[d] M. Kutyla,[b,e] J. Lukasik,[g] B. Maksiak,[a] J. Marzec,[b] T. Matulewicz,[d] S. Mianowski,[a] M. Milewicz-Zalewska,[b,e] M. J. Peryt,[b,e] M. Piatek,[e] A. Pollo,[a] K. Pozniak,[b] F. Protoklitow,[b,e] D. Pszczel,[a] S. Pulawski,[f] R. Romaniuk,[b] K. Roslon,[b,e] M. Rybczynski,[c] J. Rzadkiewicz,[a] S. Satybaldyeva,[e] D. Shchegolev,[e] I. Shmyrev,[e] M. Sitek,[a] M. Sowinski,[b] G. Stefanek,[c] J. Stepaniak,[a] E. Strugalska-Gola,[a] L. Swiderski,[a] A. Syntfeld-Kazuch,[a] T. Szczesniak,[a] M. Szuta,[a] A. Vodopyanov,[e] D. Wielanek,[b] Z. Wlodarczyk,[c] K. Wojcik[f] and W. Zabolotny[b]

[a] *National Centre for Nuclear Research, A. Sołtana 7 str., 05-400, Otwock-Świerk, Poland*
[b] *Warsaw University of Technology, Pl. Politechniki 1, 00-661, Warsaw, Poland*
[c] *Jan Kochanowski University, Żeromskiego 5 str., 25-369 Kielce, Poland*
[d] *Warsaw University, Krakowskie Przedmieście 26/28 str., 00-927, Warsaw, Poland*
[e] *Joint Institute of Nuclear Research, Joliot-Curie 6 str., 141980, Dubna, Russia*
[f] *University of Silesia in Katowice, Bankowa 12 str., 40-007, Katowice, Poland*
[g] *Institute of Nuclear Physics PAN, Radzikowskiego 152 str., 31-342, Krakow, Poland*

E-mail: Marcin.Bielewicz@ncbj.gov.pl

ABSTRACT: This report presents a concept of constructing a detector dedicated for detection of muons observed during measurements carried out at the MPD (Multi-Purpose Detector) detector that is currently under construction at the NICA facility, Russia, Dubna. It has been proposed to design and build an additional detector that will complement the current MPD set and increase its measurement capabilities. The main goal of this project is to provide information from cosmic muons that pass

*Corresponding author.

https://doi.org/10.1088/1748-0221/16/11/P11035

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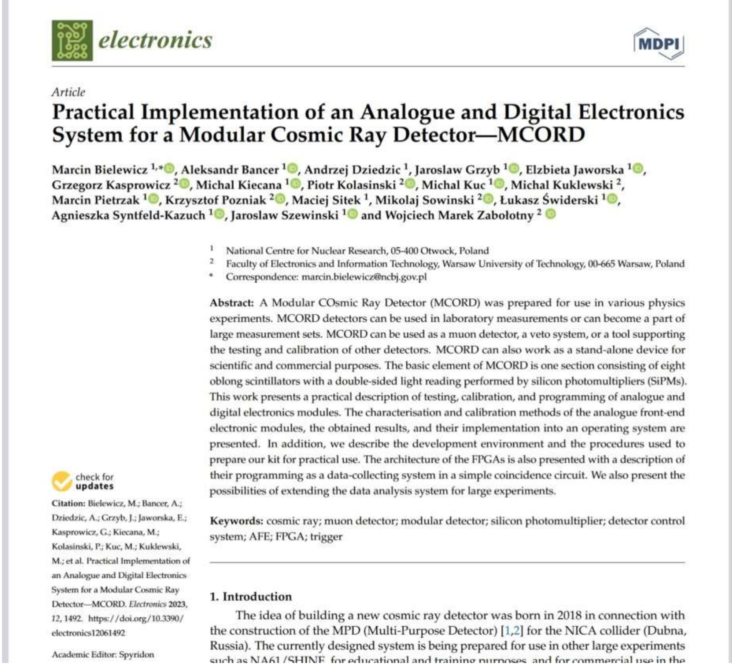
5. Electronic analysis publications

Practical Implementation of an Analogue and Digital Electronics System for a Modular Cosmic Ray Detector—MCORD

Published 22 March 2023

Electronics **2023**, *12*(6), 1492;

https://doi.org/10.3390/electronics12061492



electronics

MDPI

Article

Practical Implementation of an Analogue and Digital Electronics System for a Modular Cosmic Ray Detector—MCORD

Marcin Bielewicz [1,*], Aleksandr Bancer [1], Andrzej Dziedzic [1], Jaroslaw Grzyb [1], Elzbieta Jaworska [1], Grzegorz Kasprowicz [2], Michal Kiecana [1], Piotr Kolasinski [2], Michal Kuc [1], Michal Kuklewski [2], Marcin Pietrzak [1], Krzysztof Pozniak [2], Maciej Sitek [1], Mikolaj Sowinski [2], Łukasz Świderski [1], Agnieszka Syntfeld-Kazuch [1], Jaroslaw Szewinski [1] and Wojciech Marek Zabołotny [2]

1 National Centre for Nuclear Research, 05-400 Otwock, Poland
2 Faculty of Electronics and Information Technology, Warsaw University of Technology, 00-665 Warsaw, Poland
* Correspondence: marcin.bielewicz@ncbj.gov.pl

Abstract: A Modular COsmic Ray Detector (MCORD) was prepared for use in various physics experiments. MCORD detectors can be used in laboratory measurements or can become a part of large measurement sets. MCORD can be used as a muon detector, a veto system, or a tool supporting the testing and calibration of other detectors. MCORD can also work as a stand-alone device for scientific and commercial purposes. The basic element of MCORD is one section consisting of eight oblong scintillators with a double-sided light reading performed by silicon photomultipliers (SiPMs). This work presents a practical description of testing, calibration, and programming of analogue and digital electronics modules. The characterisation and calibration methods of the analogue front-end electronic modules, the obtained results, and their implementation into an operating system are presented. In addition, we describe the development environment and the procedures used to prepare our kit for practical use. The architecture of the FPGAs is also presented with a description of their programming as a data-collecting system in a simple coincidence circuit. We also present the possibilities of extending the data analysis system for large experiments.

check for updates

Citation: Bielewicz, M.; Bancer, A.; Dziedzic, A.; Grzyb, J.; Jaworska, E.; Kasprowicz, G.; Kiecana, M.; Kolasinski, P.; Kuc, M.; Kuklewski, M.; et al. Practical Implementation of an Analogue and Digital Electronics System for a Modular Cosmic Ray Detector—MCORD. *Electronics* **2023**, *12*, 1492. https://doi.org/10.3390/electronics12061492

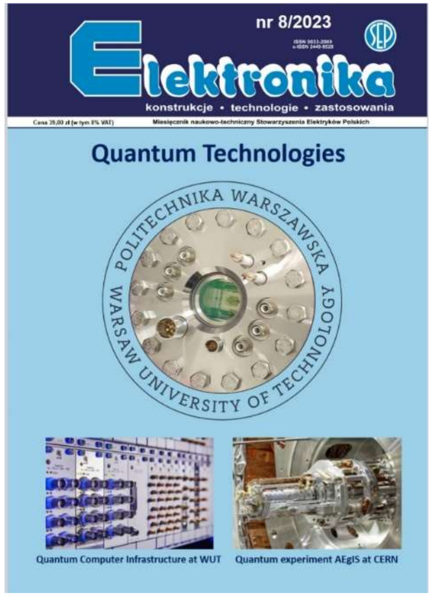
Academic Editor: Spyridon

Keywords: cosmic ray; muon detector; modular detector; silicon photomultiplier; detector control system; AFE; FPGA; trigger

1. Introduction

The idea of building a new cosmic ray detector was born in 2018 in connection with the construction of the MPD (Multi-Purpose Detector) [1,2] for the NICA collider (Dubna, Russia). The currently designed system is being prepared for use in other large experiments such as NA61/SHINE, for educational and training purposes, and for commercial use in the

APPLICATION OF ARTIQ CONTROL SYSTEM IN MODULAR COSMIC RAY DETECTOR – MCORD
DOI 10.15199/13.2023.8.19, ELEKTRONIKA 8/2023, p.93



Thank You for Attention!