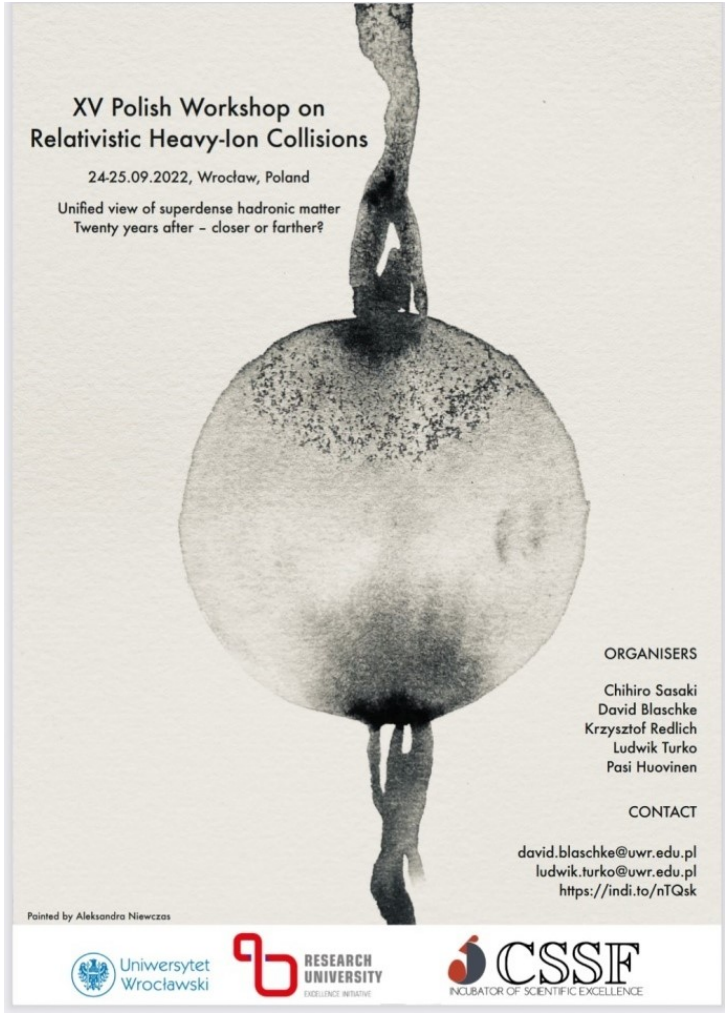
# The Modular Cosmic Ray Detector (MCORD) at physics and astrophysics experiments.

NARODOWE CENTRUM BADAŃ JĄDROWYCH
ŚWIERK

Dr Marcin Bielewicz et al..

# Outline

1. Introduction
2. Detector
3. Electronics
4. Laboratory tests



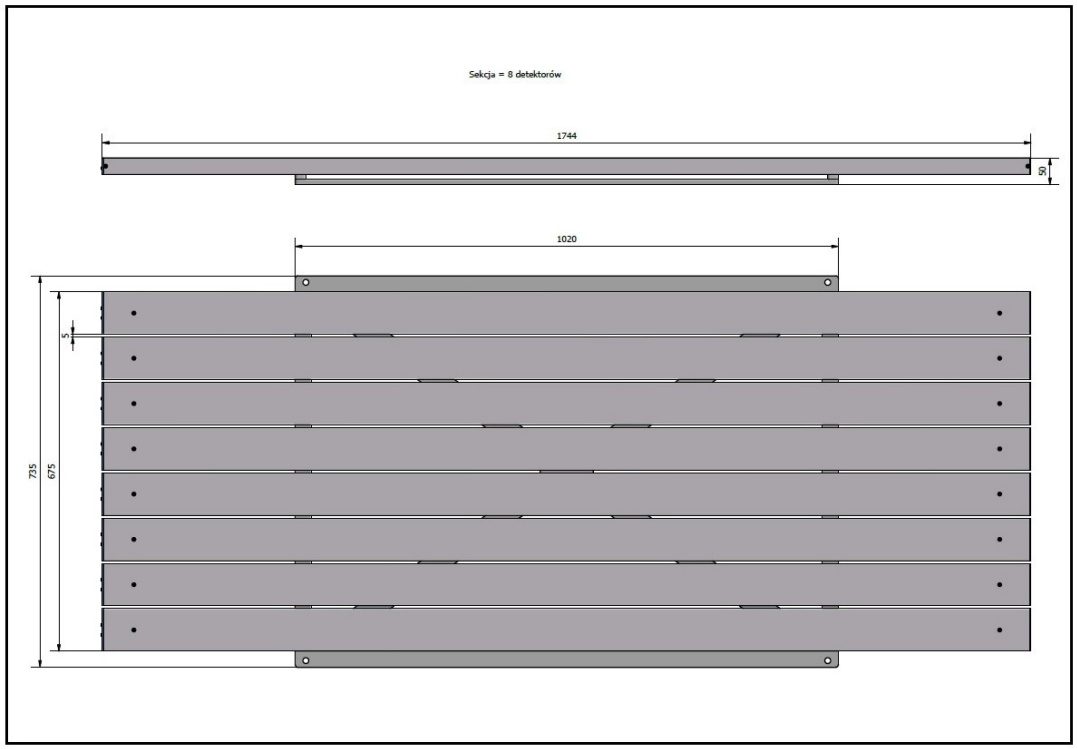
# 1. Introduction

## MCORD applications

1. Muon identifier/trigger (from collision):
   - pions and kaons decays
   - rare mesons decays ($\eta$, $\rho$, J/Psi – dual muon)
2. Trigger for cosmic muons for:
   - laboratory tests of different subsystems
   - Cosmic calibration in off-beam time
   - Veto for cosmic muons
3. Astrophysics (muon showers and bundles)
   - identification of extremely high energy particle sources
   - sensitivity for horizontal events
4. Modular construction – easy upgrade and/or alternative use

# 1. Introduction

**Sections and Scintillators,**

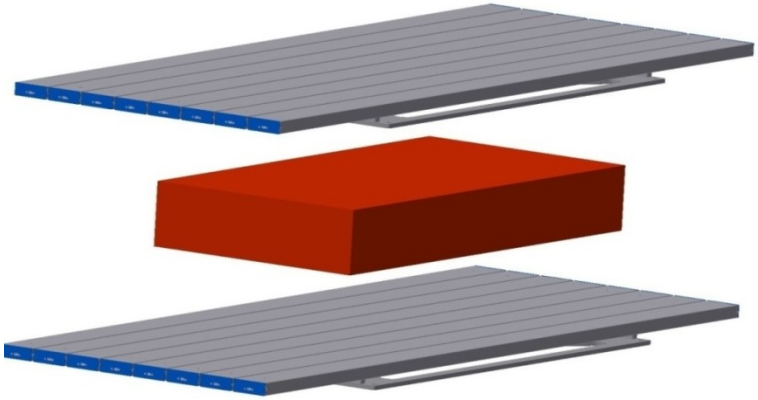



**Single MCORD section 1744 x 735(675) x 50 [mm]**

# 1. Introduction

MCORD HUB

Mini MTCA (FPGA)

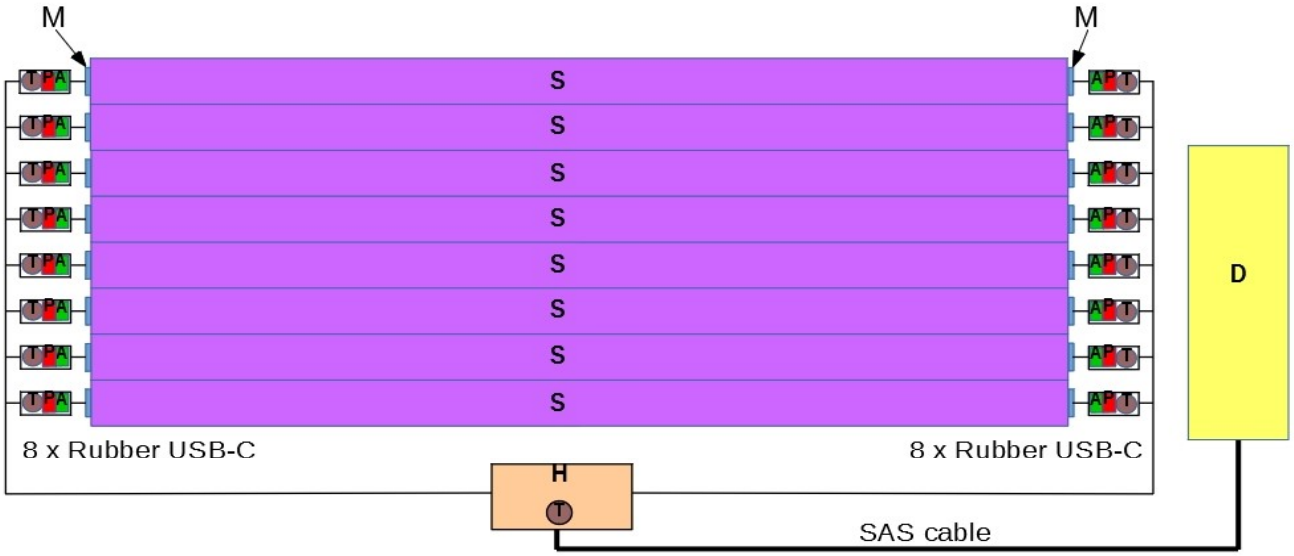


**2 MCORD sections (2 x 8 scintillators) + AFE + DSP + DAQ,**

**! Feasible for laboratory tests of different subsystems**

# 2. Detector

## MCORD Section



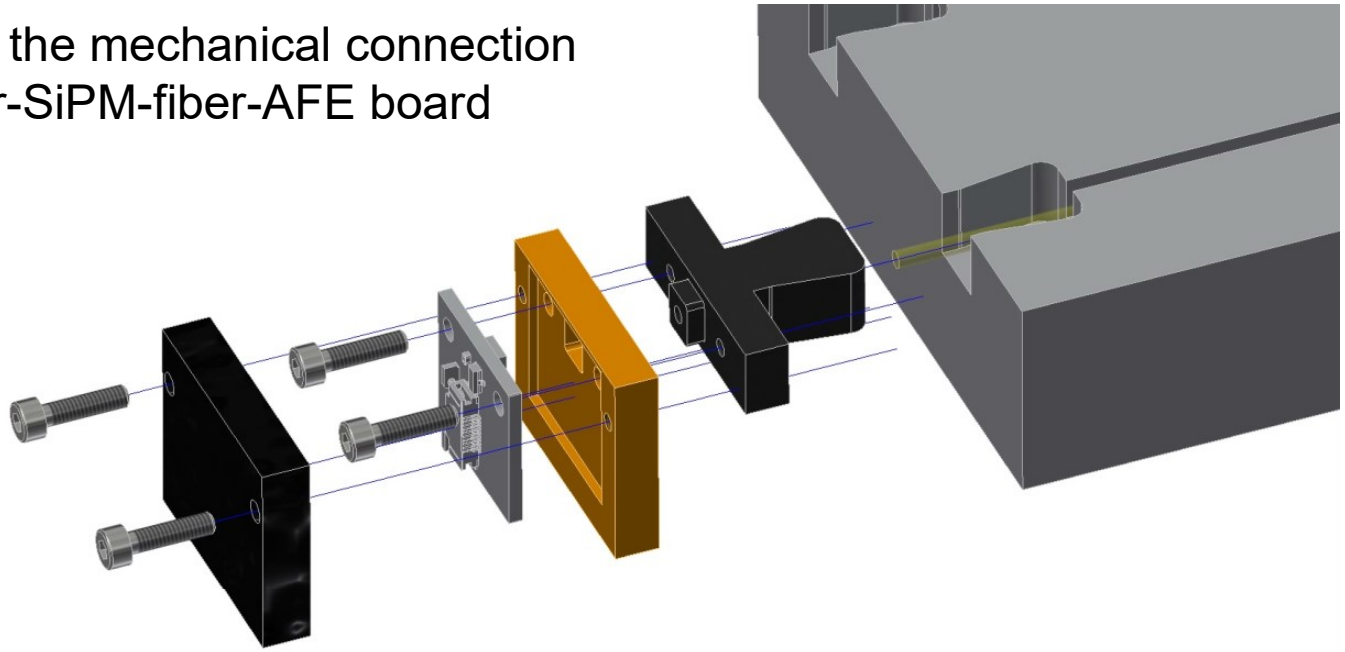

Position resolution
In X axis – up to 5 cm
In Y axis – 7 cm

Time Resolution –
sigma on the level
700 - 900 ps

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.

# 2. Detector

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

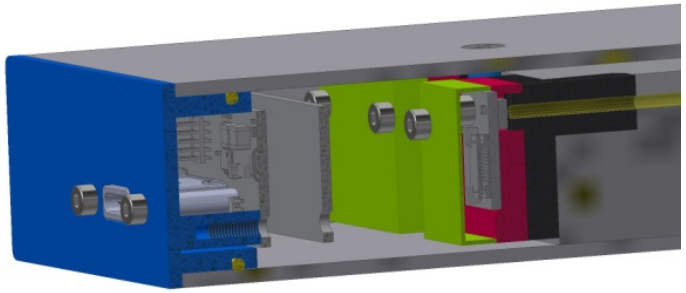


**Plastic scintillator:** polystyrene (Nuvia)
162 x 7.2 x 2.2 cm

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

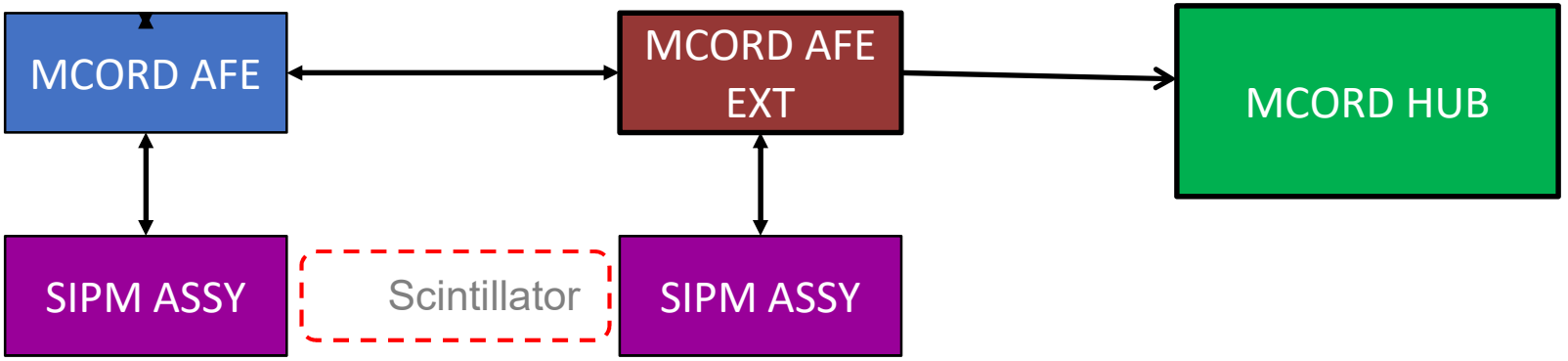
**SiPM (MPPC):** 3x3 $mm^2$ (Hamamatsu)

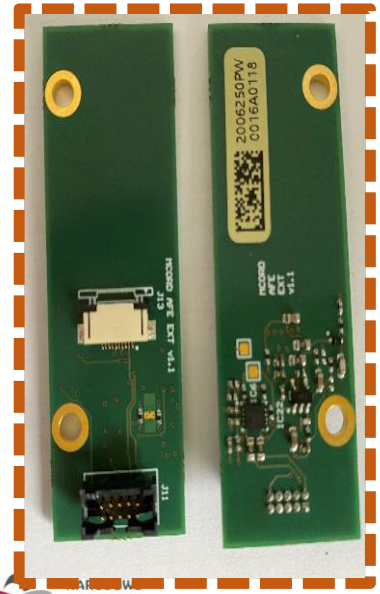
**Housing:** aluminum profile
174 x 8 x 3 cm

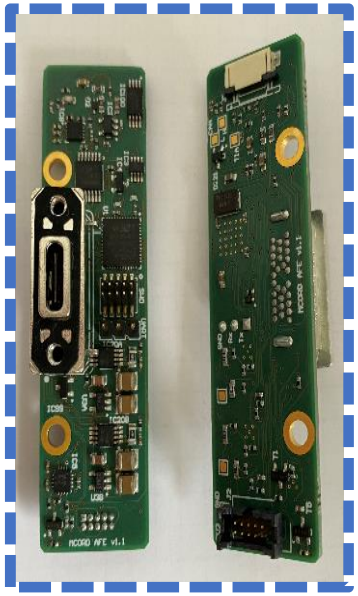


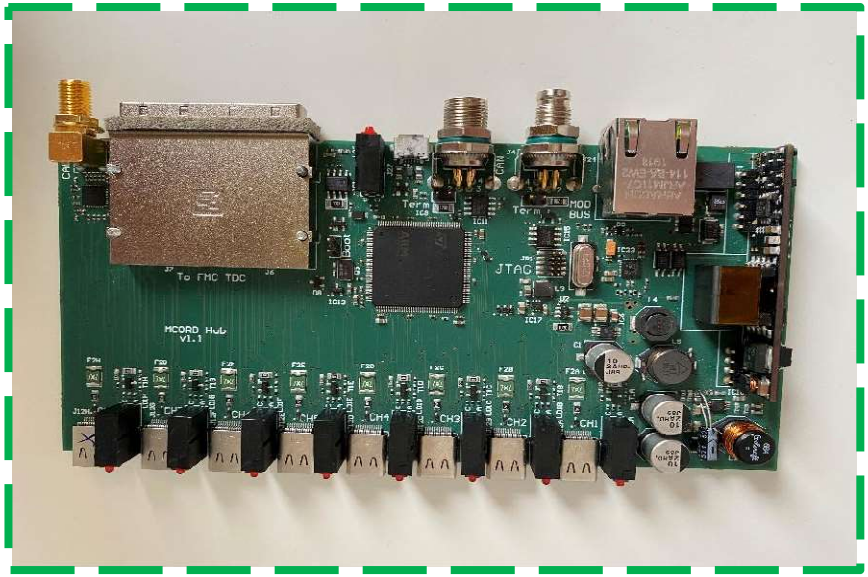
# 3. Analog Front End

**The main boards ver.3 :**



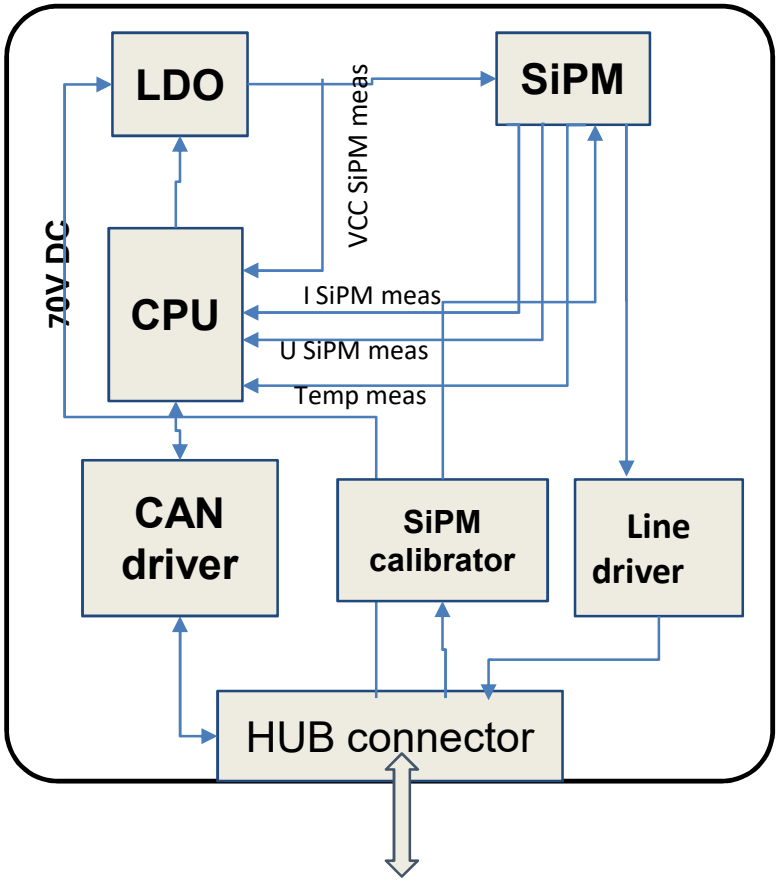







# 3. Analog Front End - functionality

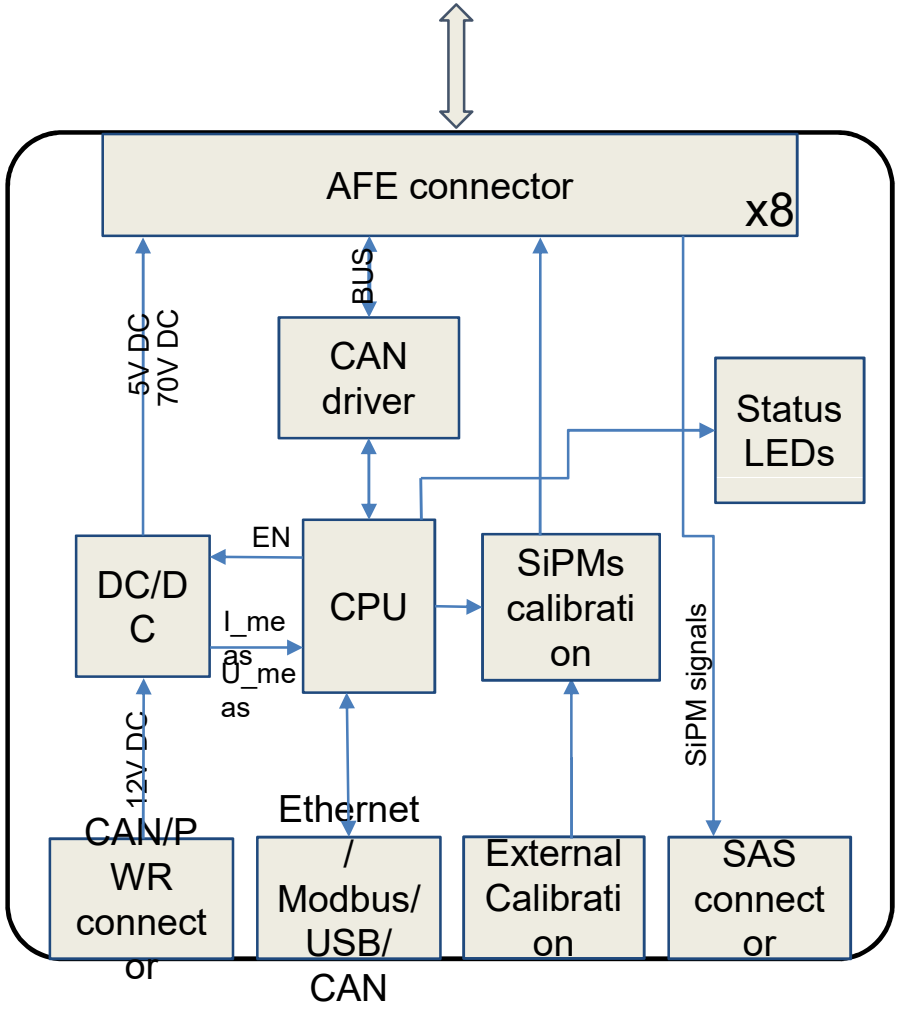
- Voltage controller for SiPMs
- Access to all settings and data from HUB via CAN-bus interface
- Protection for AFE



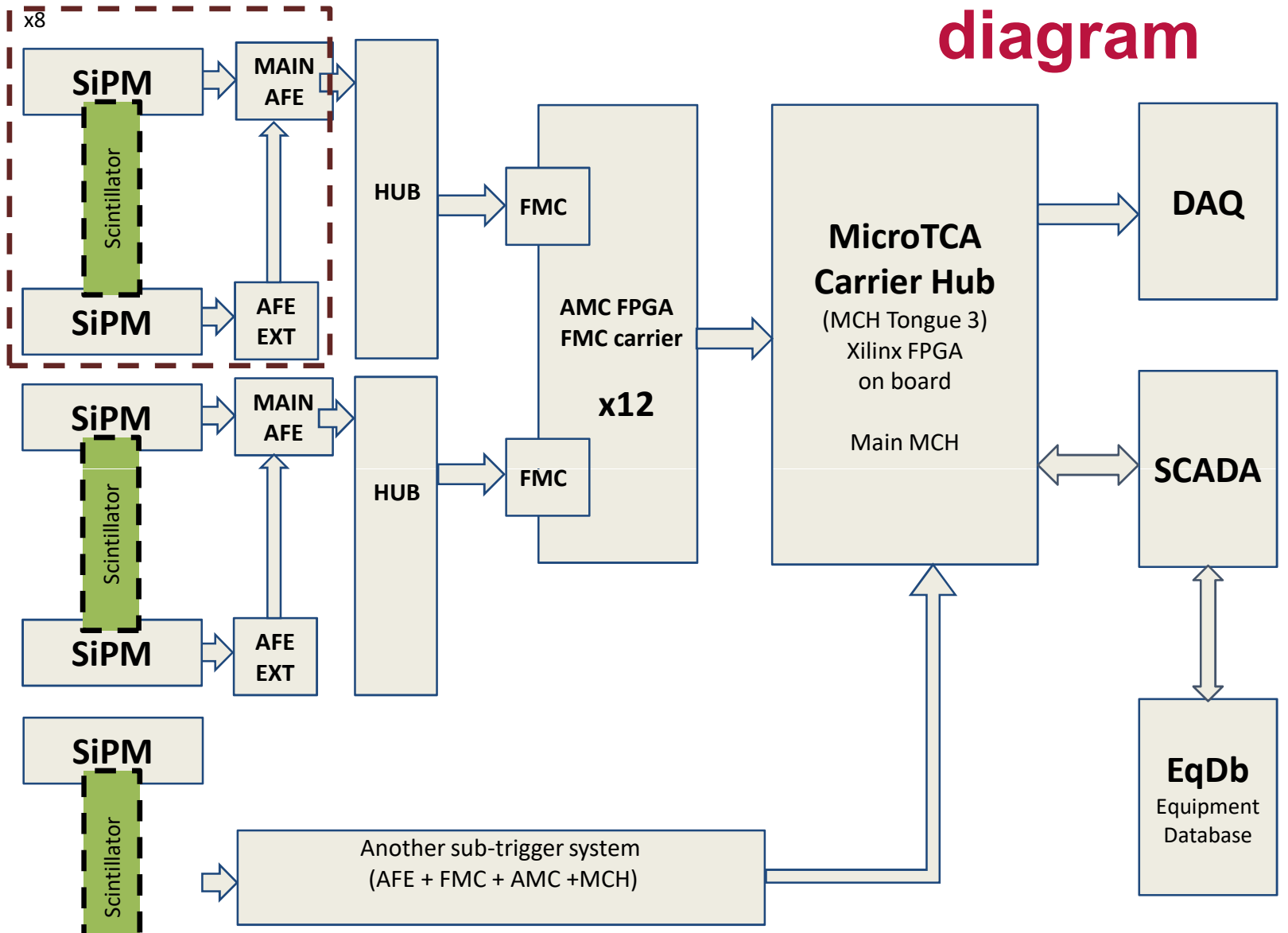

- **Main blocks**
  - Embedded CPU (STM32F072CBU6)
  - **Temperature sensor** (LM45)
  - SiPM voltage controller + LDO (Low Dropout Regulator)
  - **SiPM calibrator**
  - SiPM signal transmitter to HUB (differentia signal)
  - **CAN network driver**
- **Measurements (12 bit ADC)**
  - 2 x SiPM voltage
  - 2x SiPM current
  - 2 x SiPM VCC volatege
  - 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 for fast trigger: 1us or better**

- 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

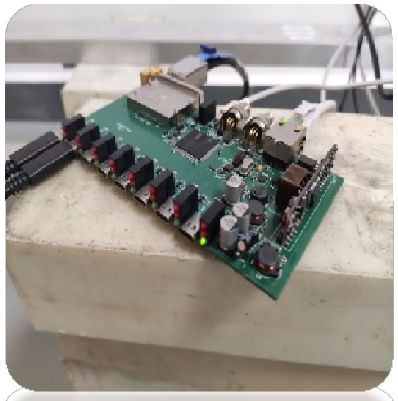
Estimated total latency: 10 – 15us

# 4. Laboratory tests

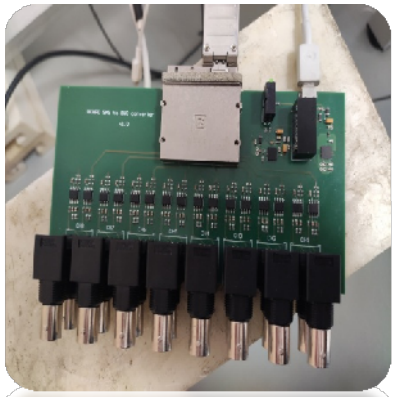
## Measuring system

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

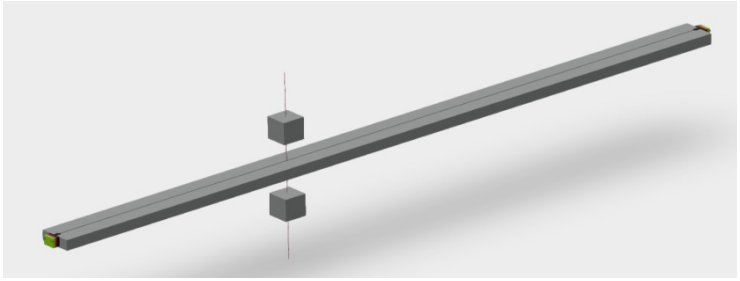


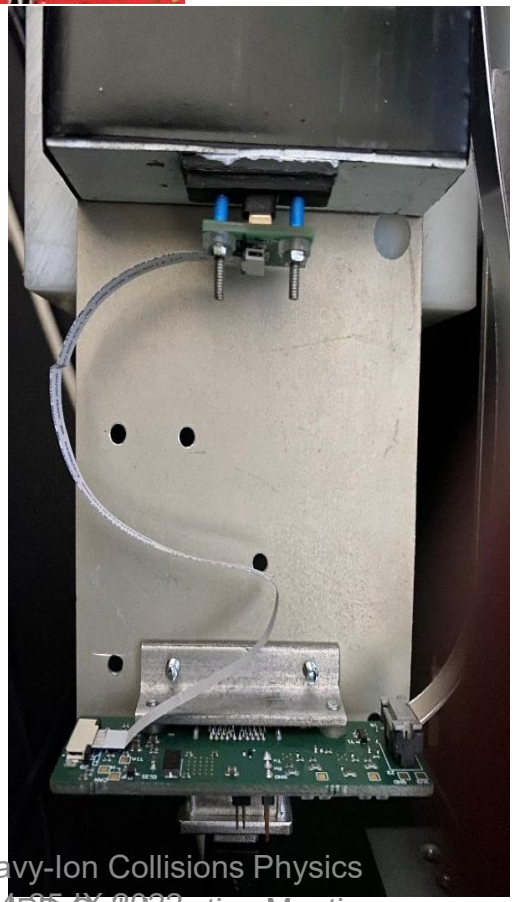
Converter of signals received by SAS cable to appropriate single BNC channels for each MPPC

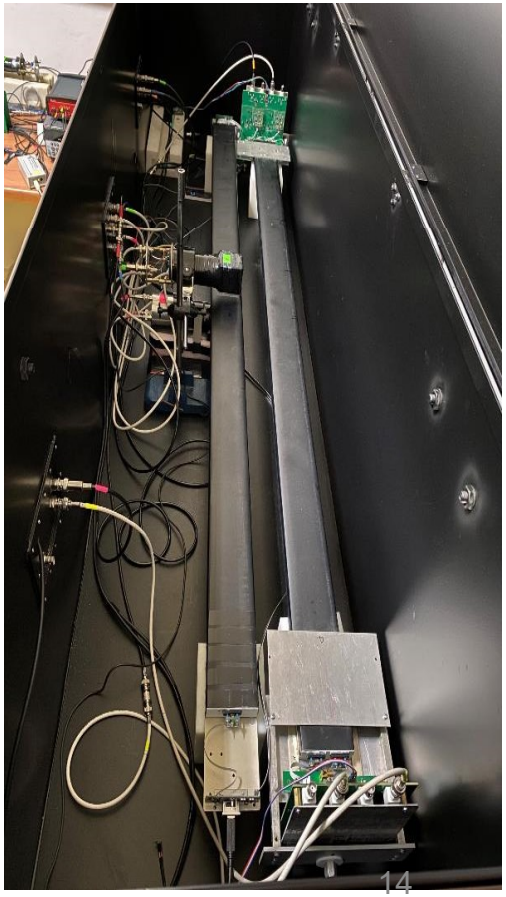
Digital multi-channel amplitude acquirer by CAEN for analysis of received signals

# 4. Laboratory tests – 1st step

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



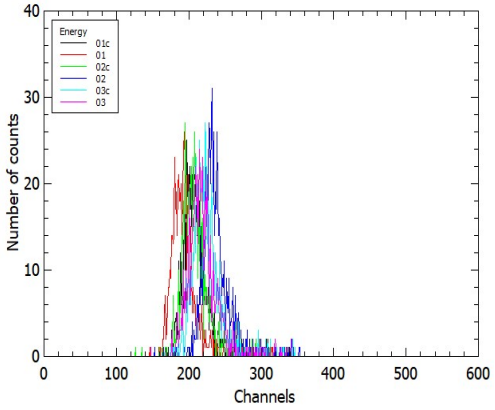




**BLACK BOX test setup**

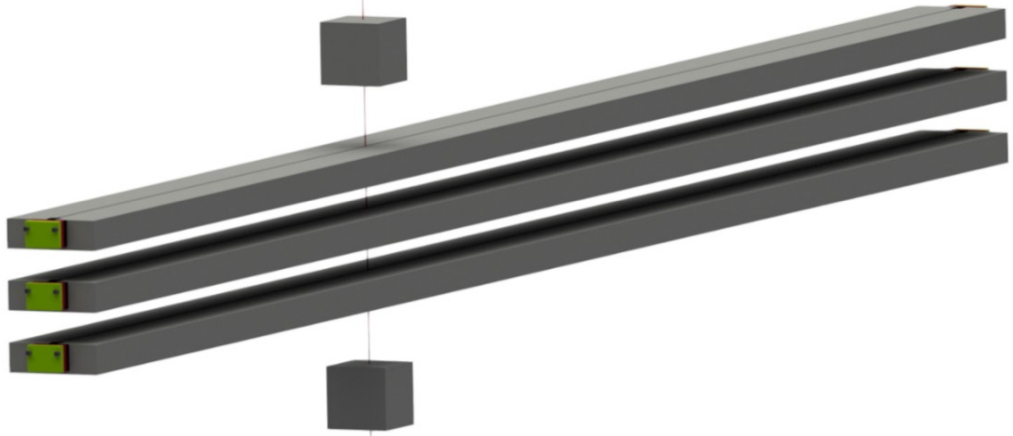
# 4. Laboratory tests – 2nd step

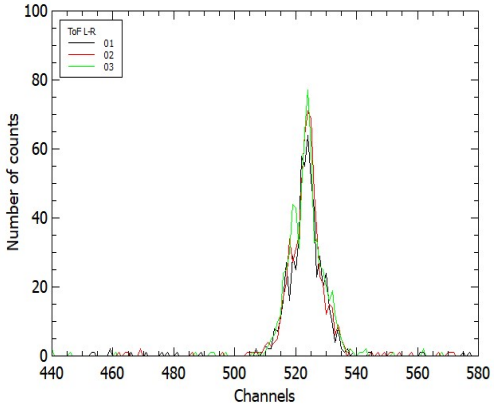
**3x plastic MCORD detectors**
**+ 2x plastic hodoscopes (muon triggers)**
**+ DAQ: CAEN DT5730**




Energy
(amplitude recorded by SiPM)

**Ext. trigger test setup**



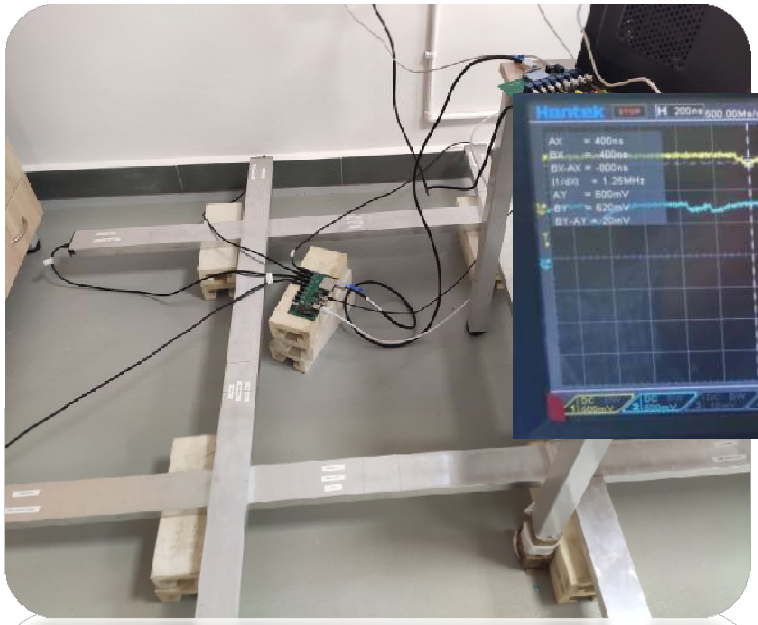



ToF
(between both ends of a scintillator)

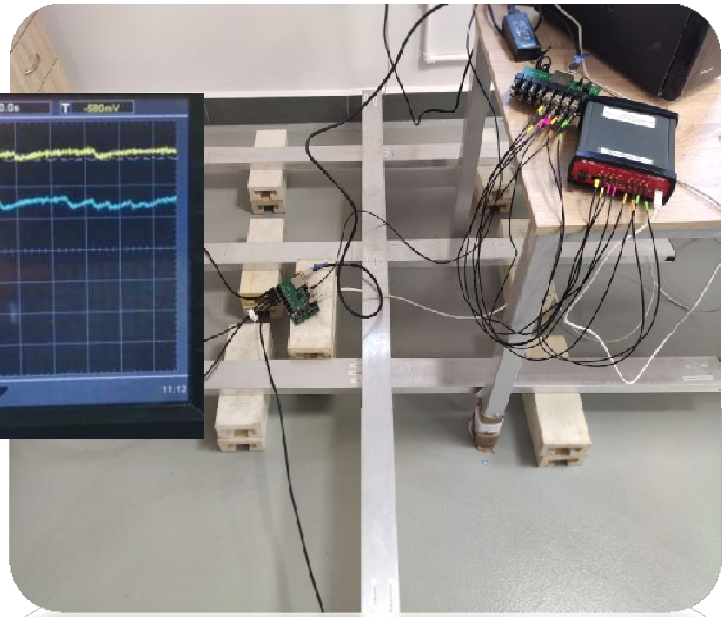
**Plastic (162 x 7.2 x 2.2 cm) + WLS fiber (1 mm) + 2x MPPC 3 x 3 mm (pixel size 75um)**
**Hodoscopes: plastic (5 x 5 x 5 cm) + PMT (2” dia)** **→ 99,5% efficiency**

# 4. Laboratory tests – 3rd step

## Self trigger multi test setup

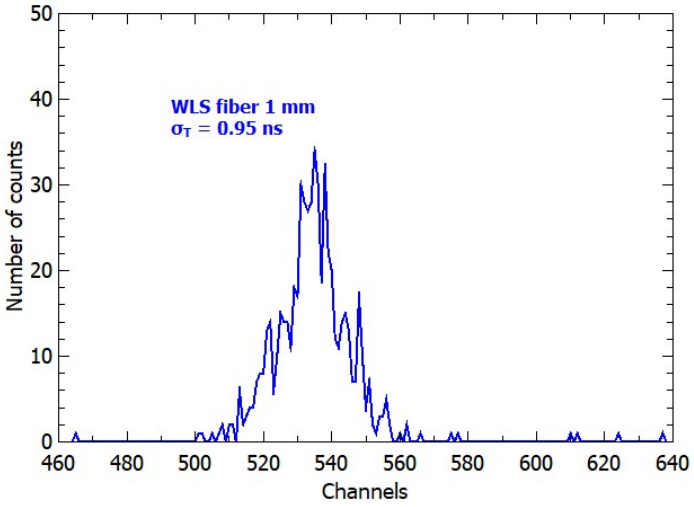


Target geometry of the measurement system. There is an area of coincidence between the boards at each crossing of the boards. In this juxtaposition, each board is in a coincidence with two different boards



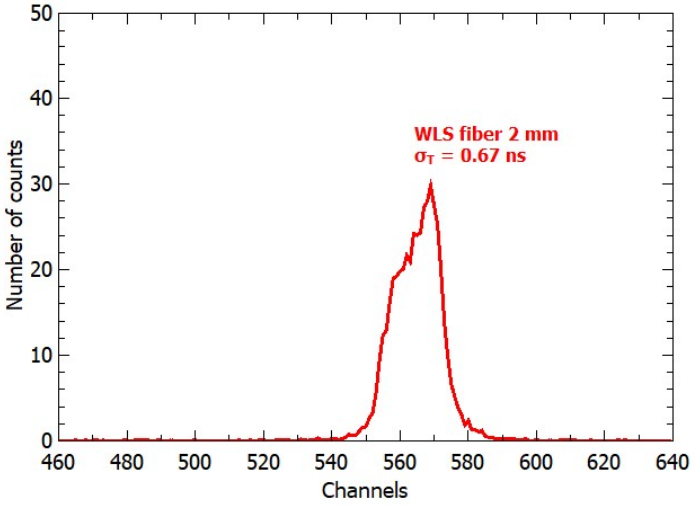
Alternate geometry. One of the boards is responsible for the gate to the others, creating with them appropriate areas of coincidence at their intersections

# 4. Laboratory tests - summary




WLS fiber (**1 mm**)

**CRT (σ) = 0.95 ns ===> $\sigma_x$ = 7.1 cm**




WLS fiber (**2 mm**)

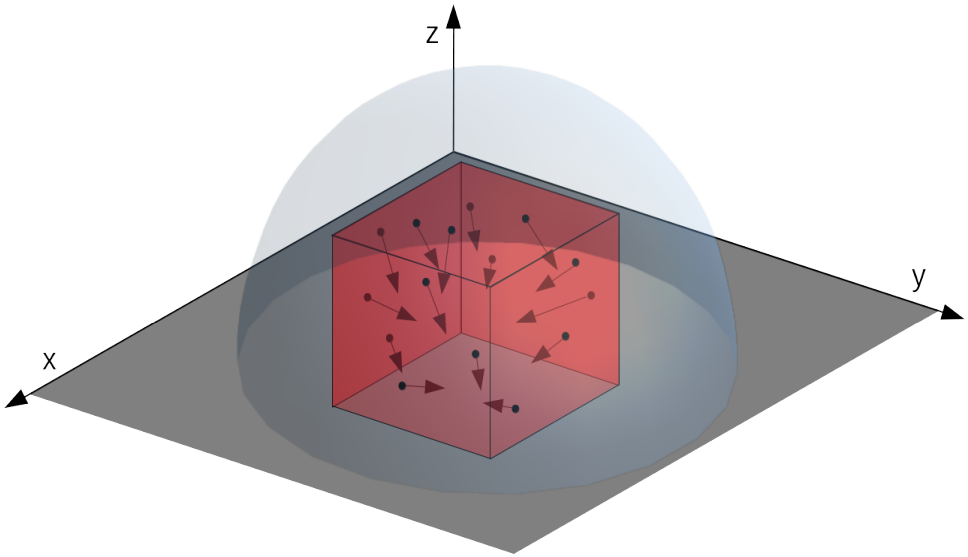
**CRT (σ) = 0.67 ns ===> $\sigma_x$ = 5.1 cm**

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

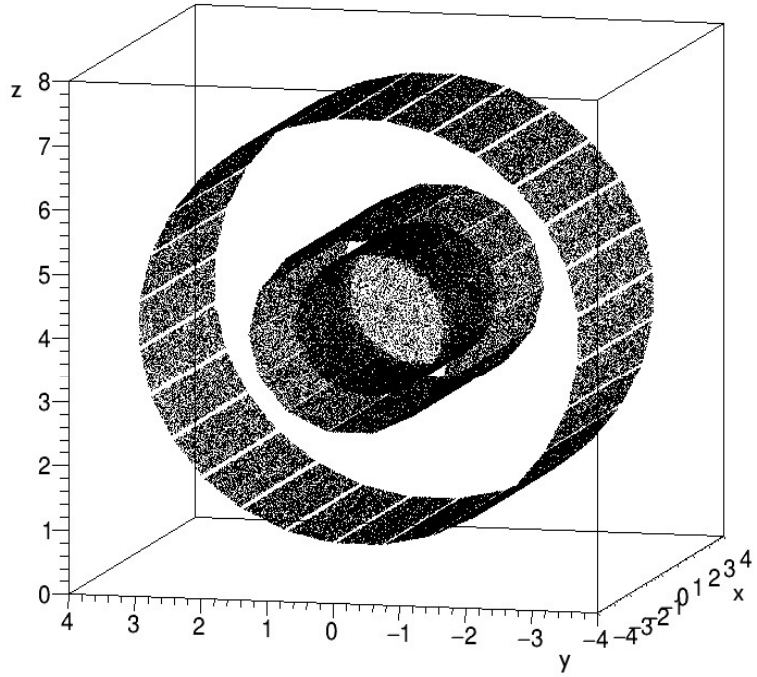
# 4. Laboratory tests - Simulations (EAS)

**Cofluxim – cosmic ray generator**

for subsystems calibration study



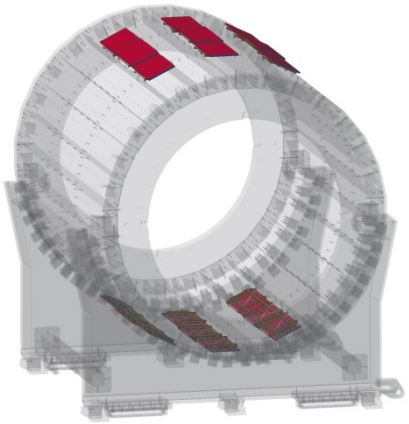

The concept of particle generation: drawing particles on the generation cube walls.



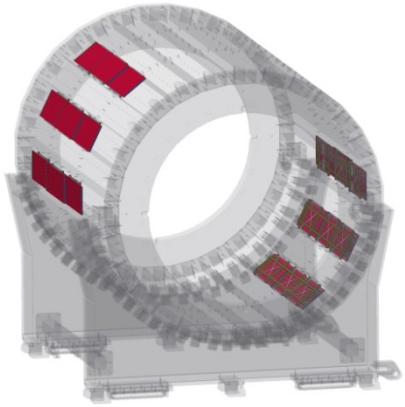

Plot of all hits on the surfaces of TPC, ToF and MCORD detectors.

# 4. Laboratory tests - Simulations (EAS)

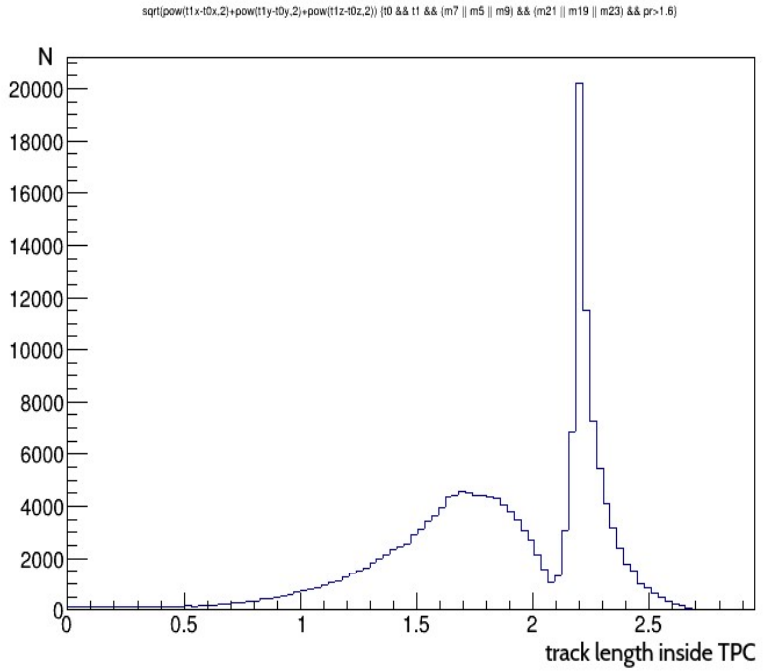
## TPC calibration using MCORD triggers



D



E

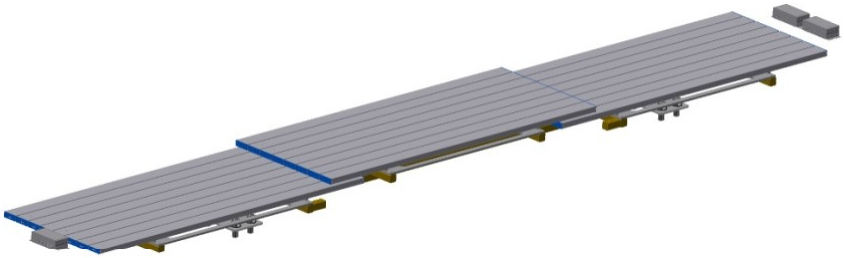


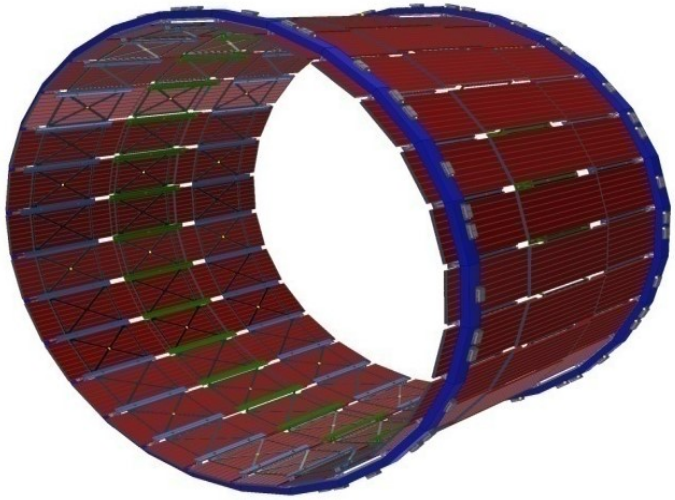

Calculated for muons with momentum
**p > 1.6 GeV/c.**

| MCORD configuration | MCORD modules (ID numbers) | MCORD & TPC (tracks per hour) |
|---|---|---|
| **D** | (5 or 7 or 9) and (19 or 21 or 23) | **178 822** |
| **E** | (10 or 12 or 14) and (24 or 26 or 0) | **50 894** |

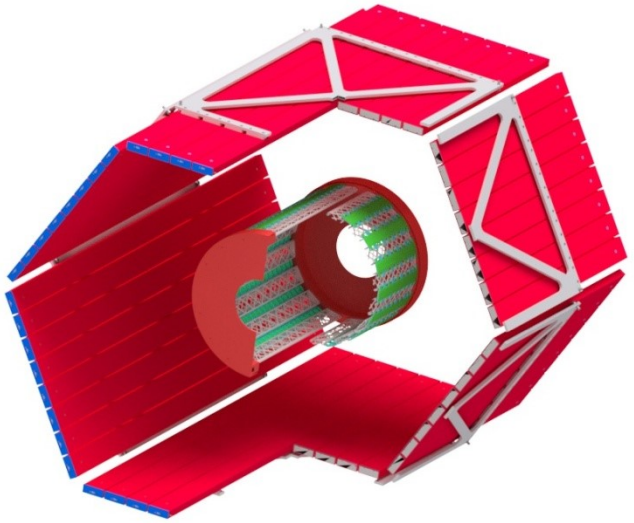
# An example of a possible application of the MCORD sections

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

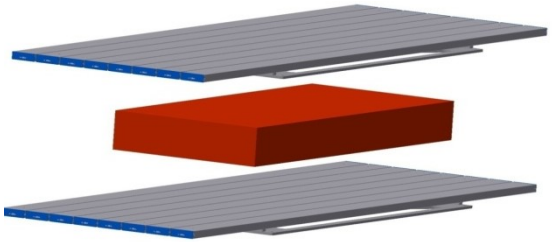




Phase Zero conceptions
6 MCORD section + miniBeBe



2 MCORD section + other detector



# 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)**

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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.



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# Thank You for Attention!