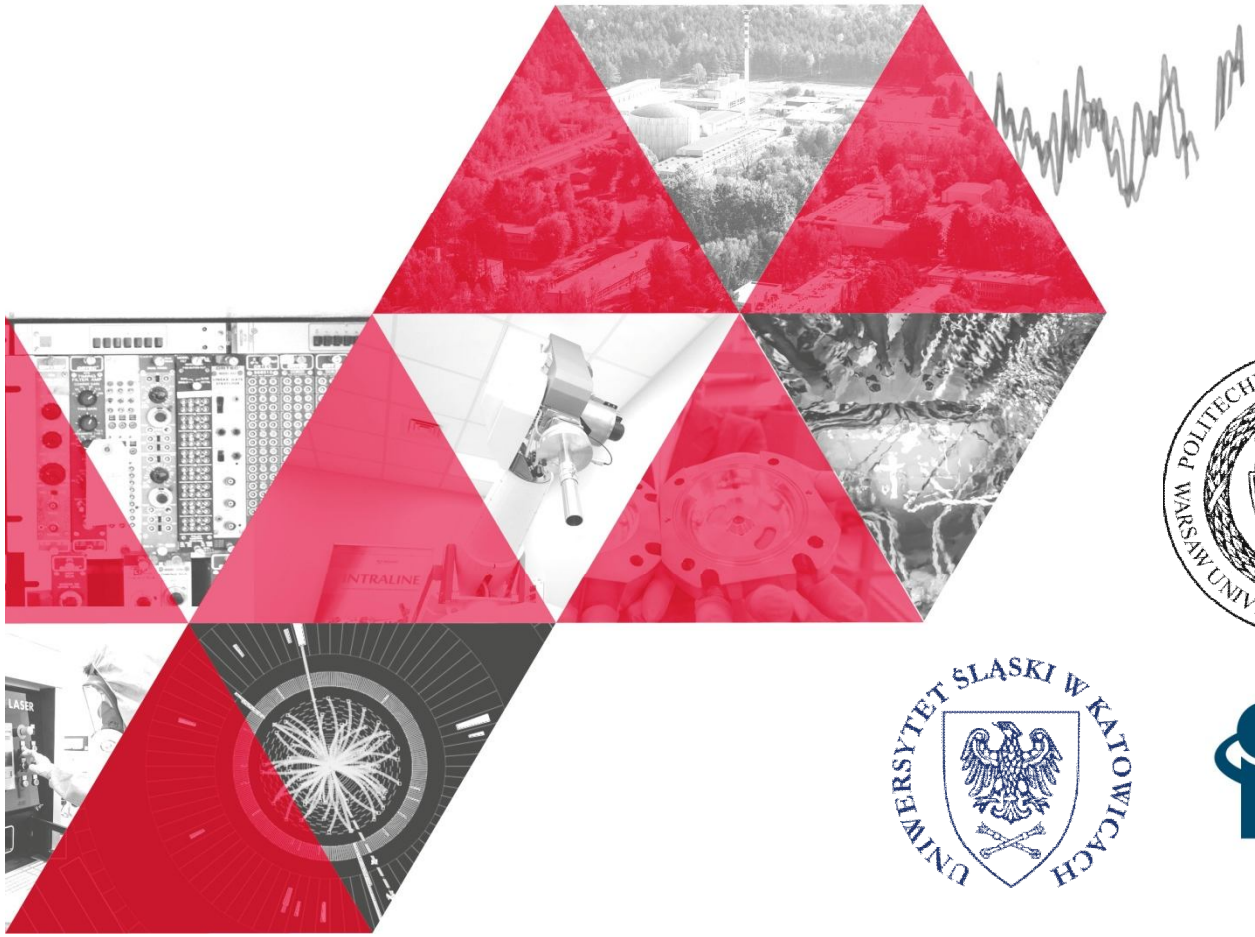
MCORD detector current status

by Polish consortium NICA-PL

MPD Collaboration Meeting, 12-14. Oct. 2021



NARODOWE CENTRUM BADAŃ JĄDROWYCH ŚWIERK

POLITECHNIKA WARSZAWSKA
WARSAW UNIVERSITY OF TECHNOLOGY

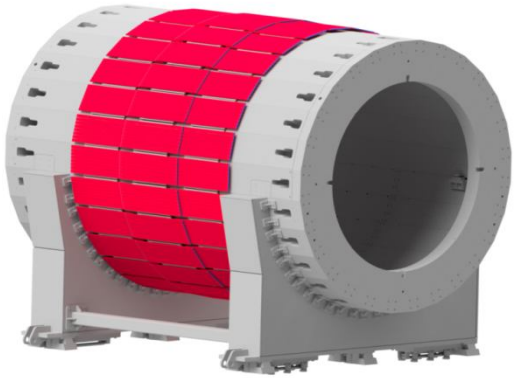
JINR
JOINT INSTITUTE FOR NUCLEAR RESEARCH

UNIWERSYTET ŚLĄSKI W KATOWICACH

Uniwersytet Jana Kochanowskiego w Kielcach

Outline

1. Introduction
2. Mechanical Construction upgrade
3. MCORD support on the MPD - Dubna
4. MCORD demonstrator – Dubna
5. Laboratory tests
6. Publications and Conferences
7. Summary



1. Introduction - TimeTable

Year	2018				2019				2020				2021				2022			
Task name	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Preliminary design																				
Detector optimization																				
AFE design																				
DAQ design																				
Detector simulations																				
Detector prototype																				
AFE prototype																				
DAQ prototype																				
Prototype integration																				
Prototype laboratory test																				
Prototype installation																				
MCORD design																				
MCORD production																				
MCORD laboratory tests																				
MCORD installation																				
MCORD operation																				
MCORD extend																				
Documentation																				
Administration																				

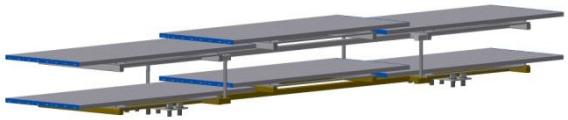
STAGE I

STAGE II

STAGE III

STAGE IV

STAGE I – Design and preliminary tests
STAGE II – Demonstrator construction
STAGE III – Construction of the first 6 modules next year
STAGE IV – Construction of additional modules

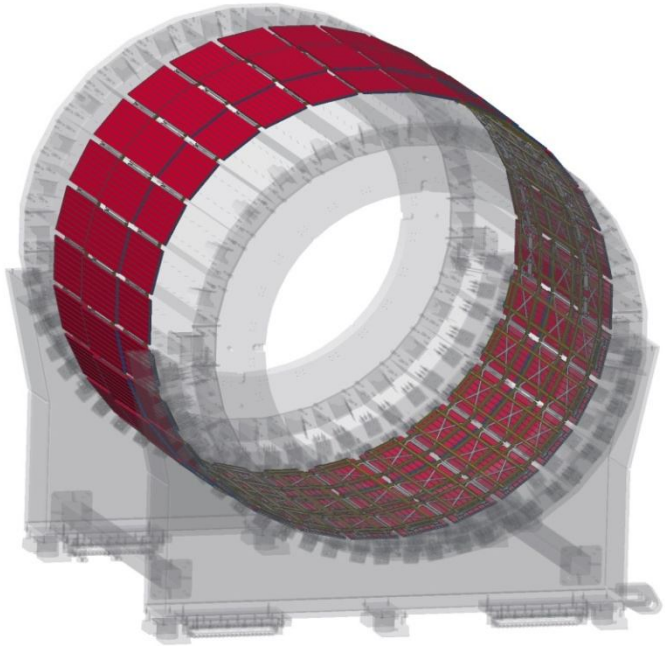


1. Introduction

MCORD applications for MPD

1. Trigger for cosmic muons for:
   - laboratory tests of MPD subsystems
     (2 separate MCORD sections – on site)
   - MPD off-beam calibration in service position
     (6 MCORD modules – about one year)
2. Muon identifier (E > 1 GeV) for:
   - pions and kaons decays
   - ***J/Ψ* particle decay**
   - rare mesons decays (η, ρ)
3. Astrophysics (muon showers and bundles)
   - **identification of extremely high energy particle sources**
4. Modular construction – easy upgrade and/or alternative use

1. Introduction

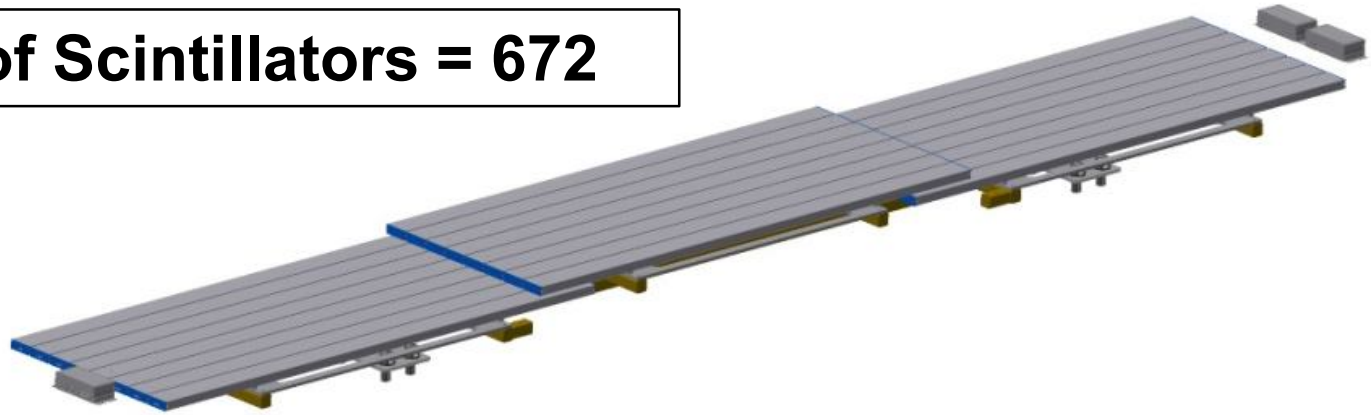


MCORD modules on MPD surface

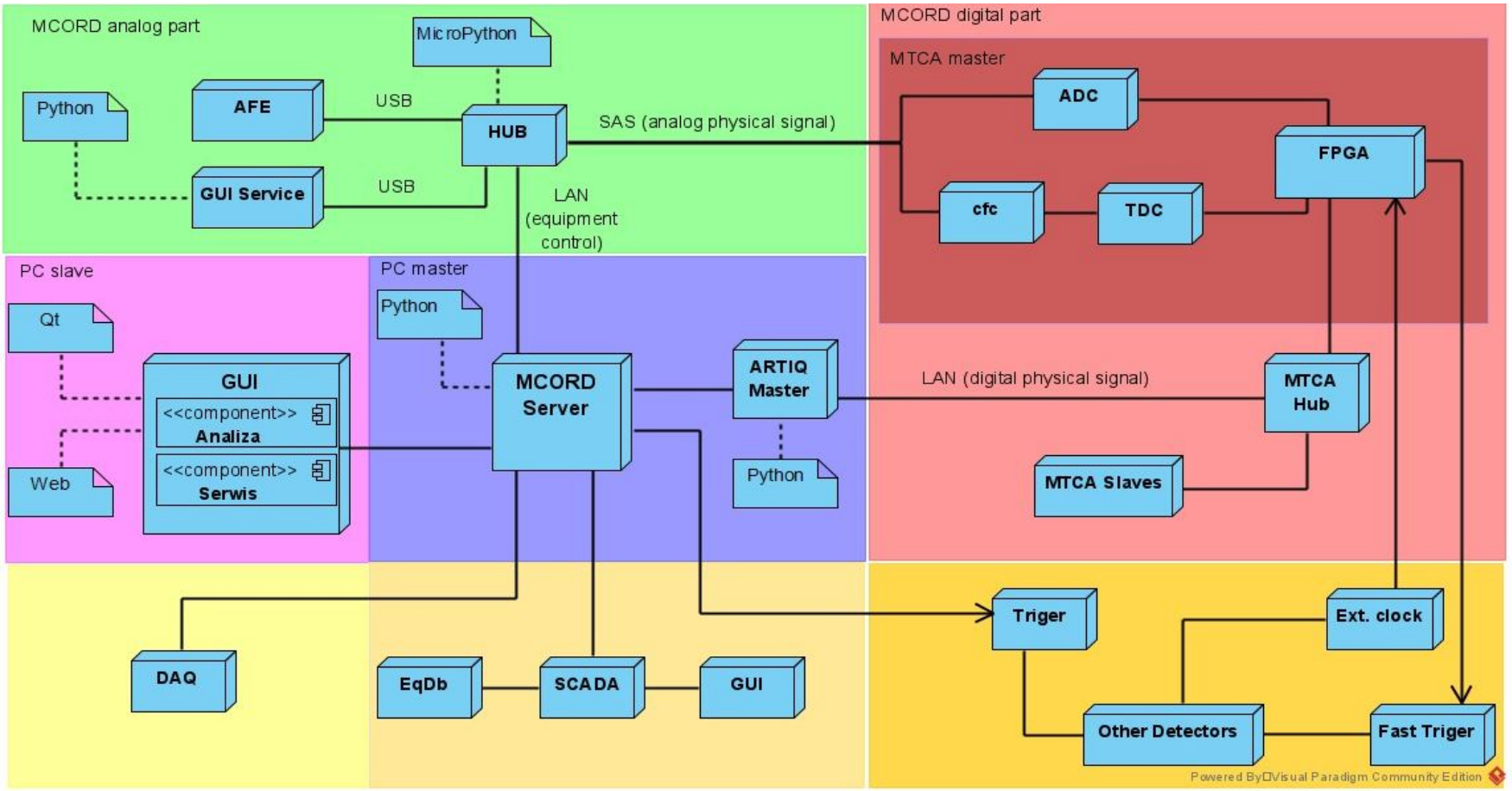
Number of modules: 28
1 module = 3 sections
1 section = 8 scintillators
1 section = 16 chanels

Module size:
4784 x 735 x 140 mm

Total number of Scintillators = 672



1. Introduction - Software Architecture



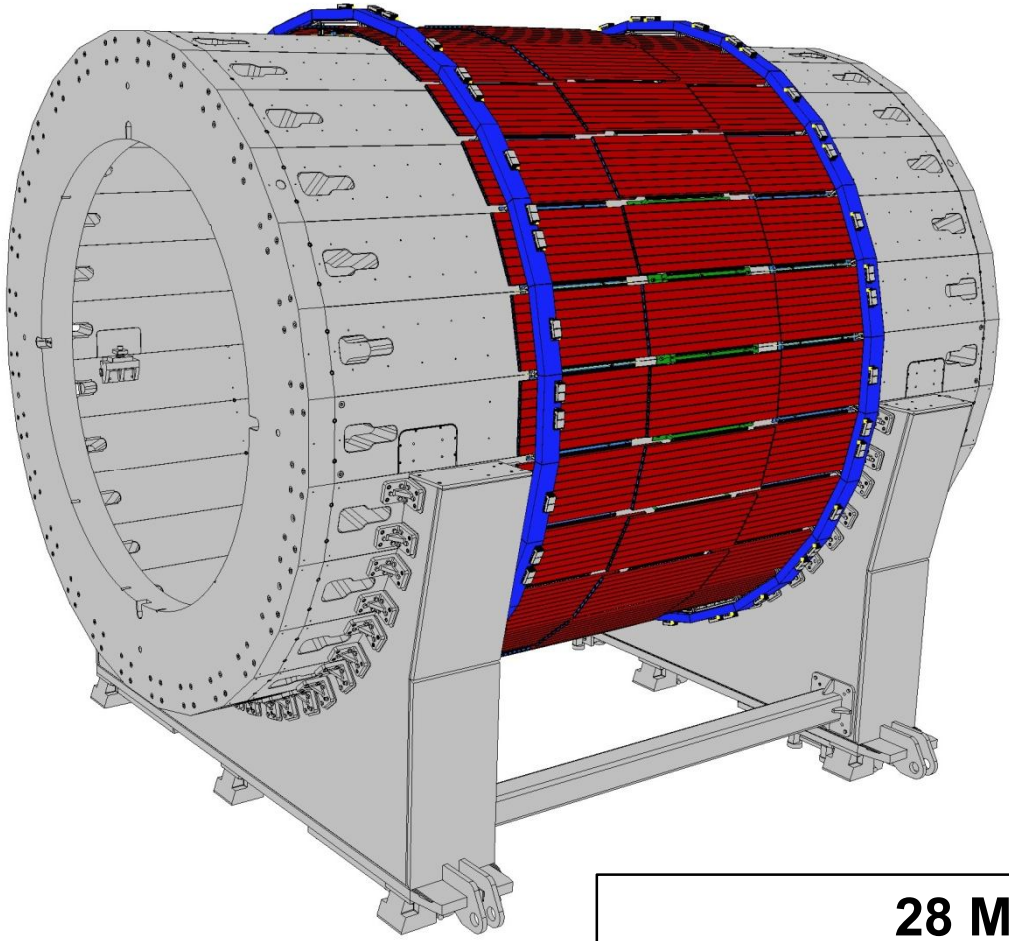
- The system is divided into parts on the basis of their role and implement. platform.
- MCORD Server is a central part controlling system elements
- In this model user interface is totally separated and can be implemented in any way (Web/App/CLI) and changed later on without modifying core MCORD funct.

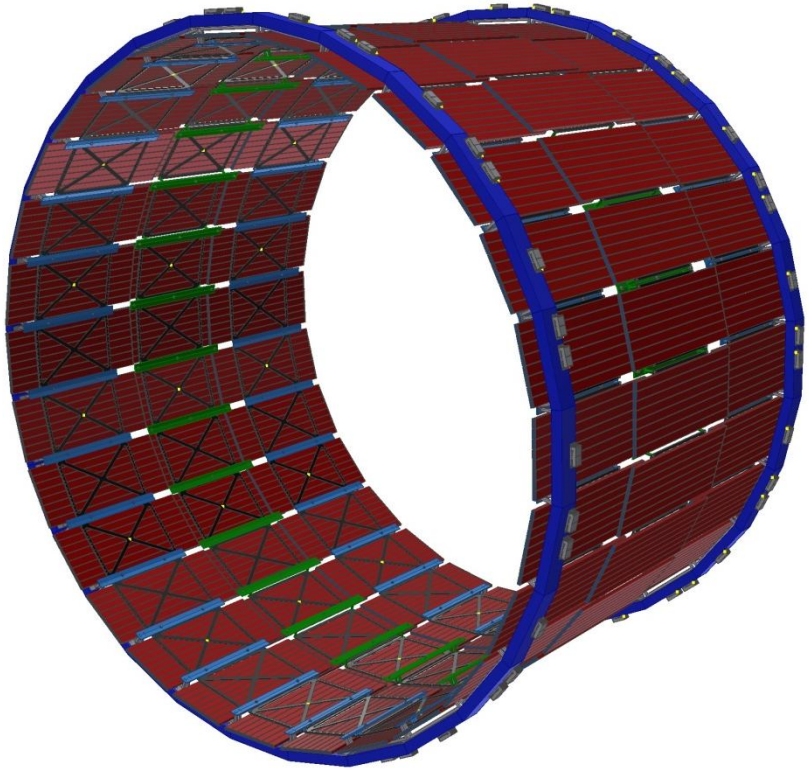
1. Introduction

MCORD status

1. CDR and TDR documentation - completed.
2. MCORD Demonstrator (1 section = 8 scintillators) - delivered to JINR.
3. MCORD support legs for MPD - manufactured (12 pcs).
4. JINR-NCBJ Agreement for construction of 6 modules - should be signed in two weeks.
5. Construction of 6 MCORD modules - in progres, first components purchased/ordered.
6. MCORD electronics:
   analog front-end – ver. 1.0 implemented, ver. 2.0 being tested
   digital data acq. – ver. 1.0 back from repair, being tested

2. Mechanical construction

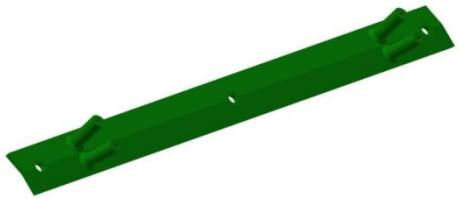


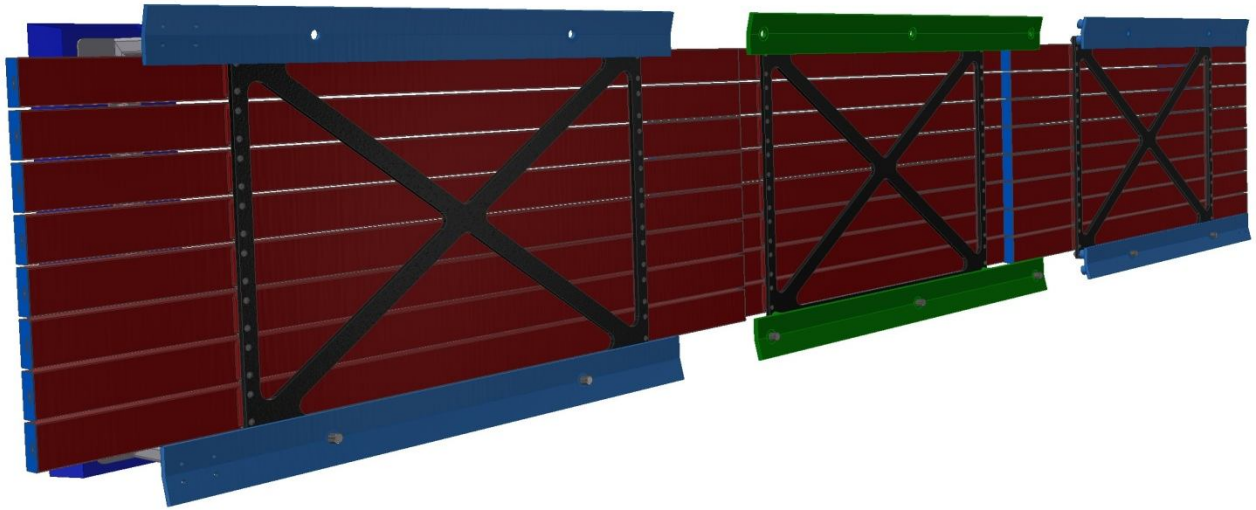


28 MCORD modules – red
Cable channels with HUBs – blue
Mounting (support) legs – light blue and green

2. Mechanical construction

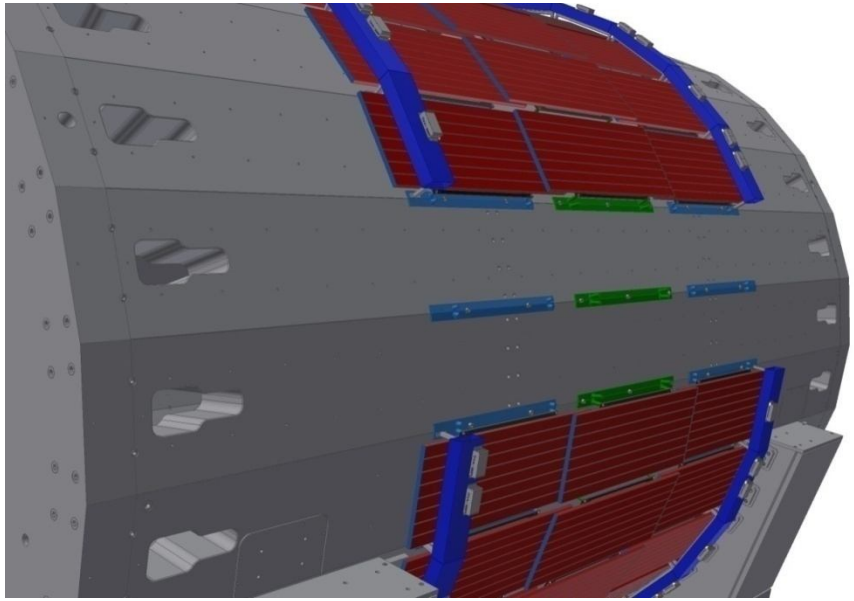
The support legs for MCORD on MPD surface





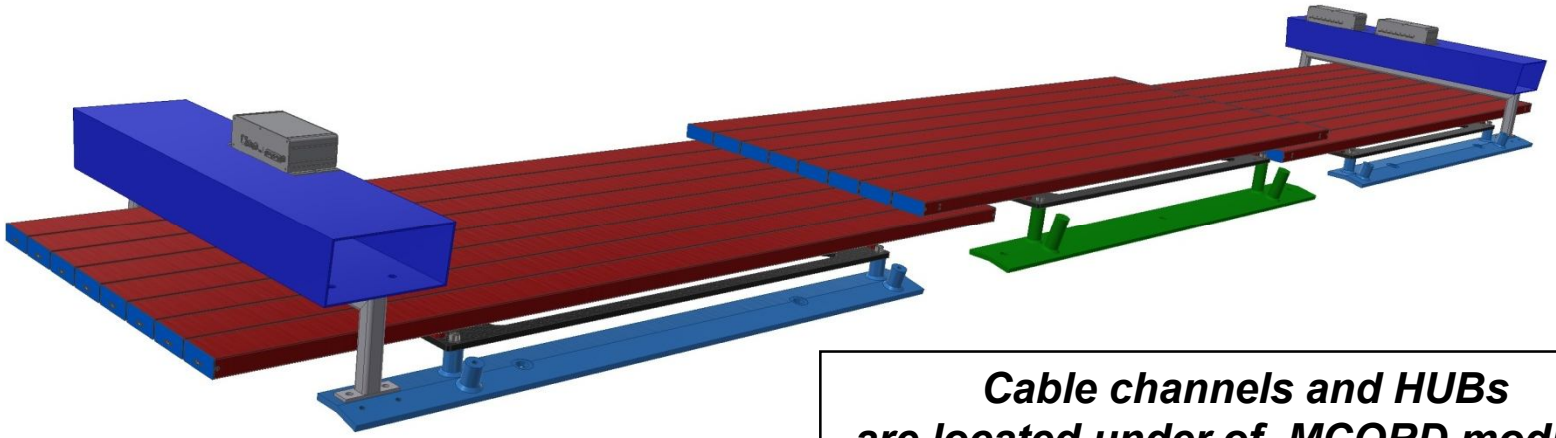
6 legs of two types: central and external

Central (green) and External (light blue) support legs

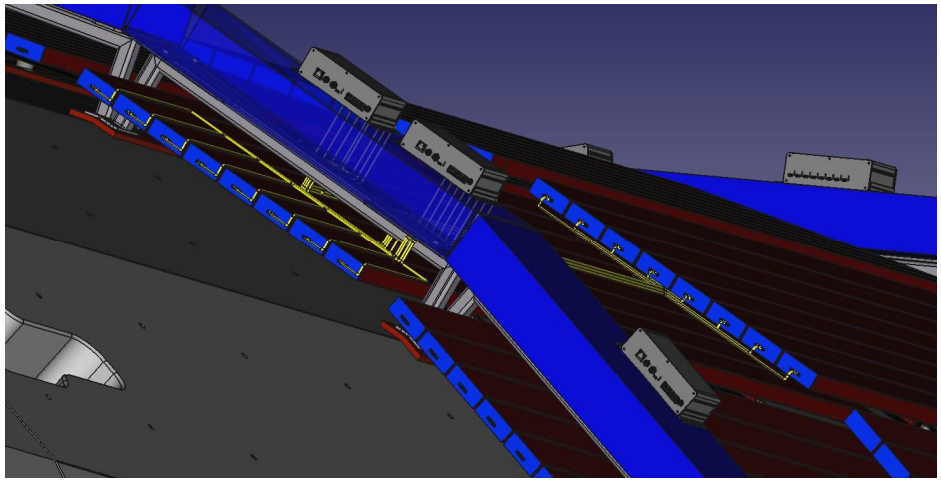


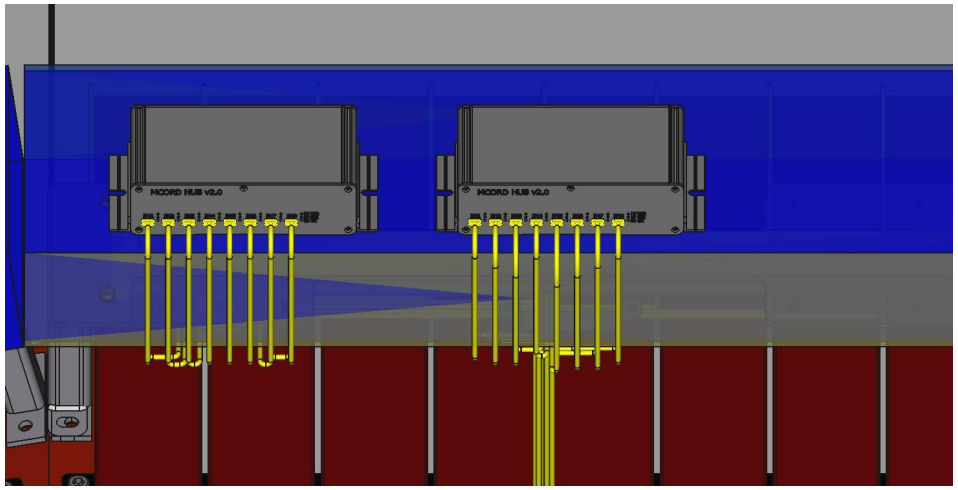
2. Mechanical construction

The cable chanel for MCORD on MPD surface



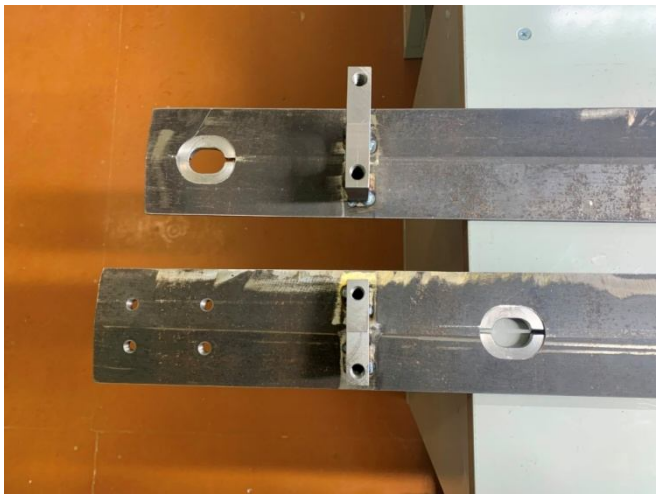
Cable channels and HUBs are located under of MCORD modules.





3. MCORD support on the MPD

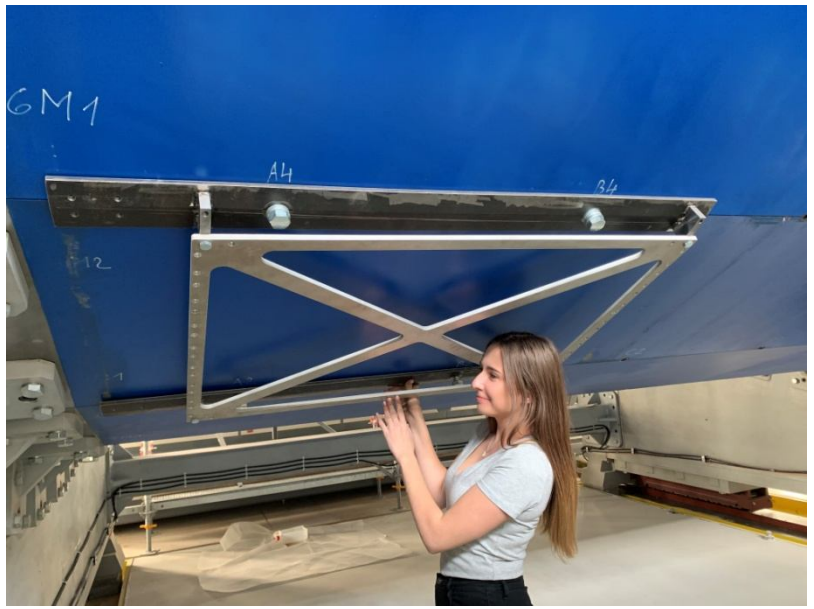
Production of Support legs for MCCORD



3. MCORD support on the MPD

Test installation of support legs and frames for the MCCORD section.

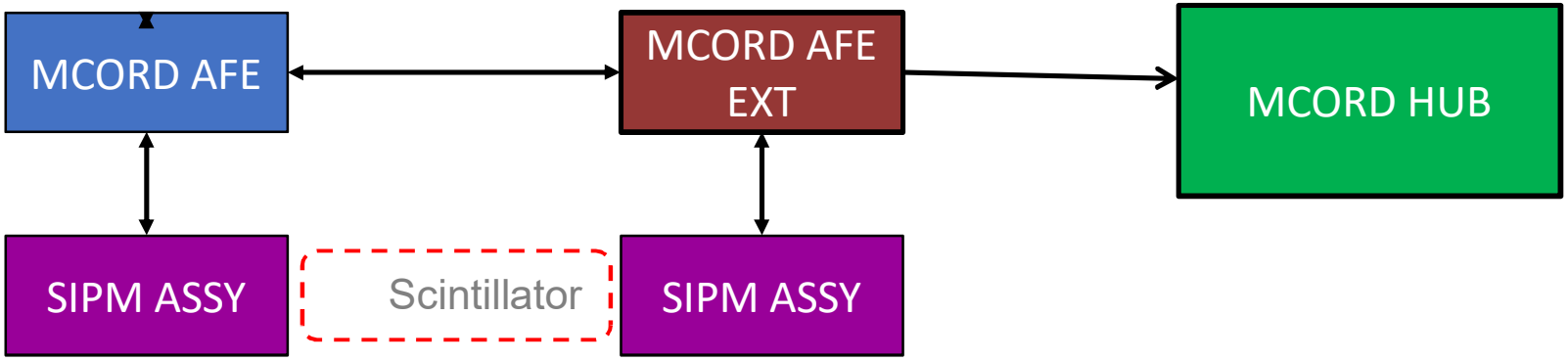
Test OK.
Support elements made correctly.
Now they will be painted

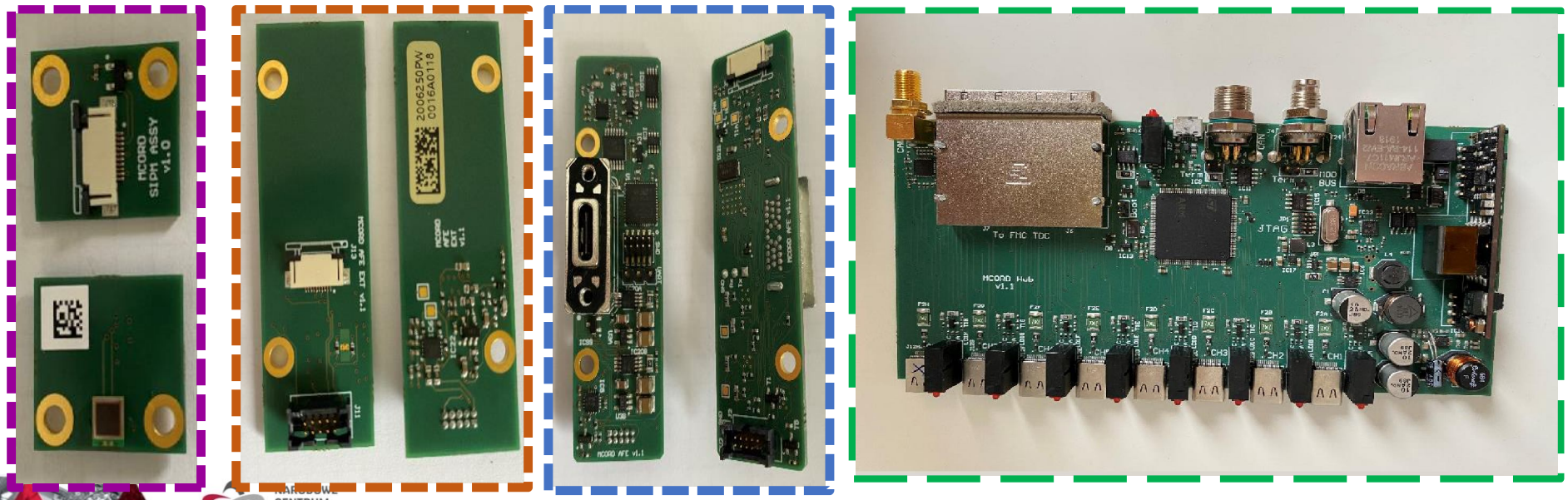


A total of 12 pieces were made:
- 8 external pieces
- 4 central pieces
Enough for the installation
of 6 MCORD sections.
Production of the next ones soon.

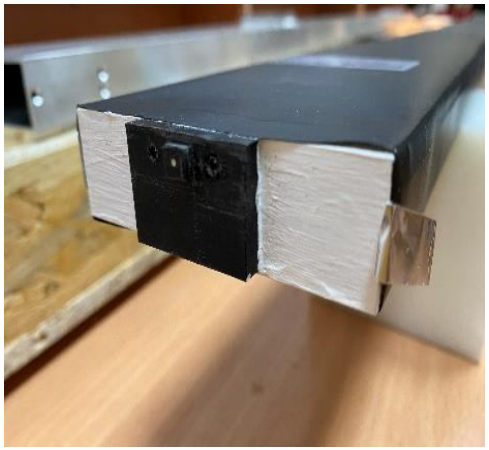
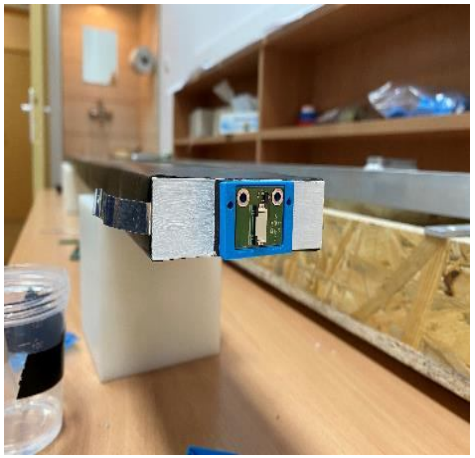
4. Demonstrator

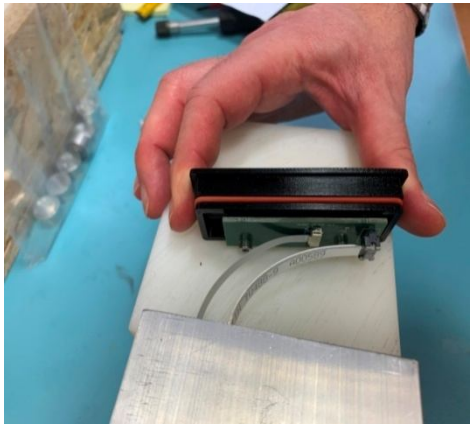
The analog electronic boards and systems





6. Demonstrator


MCORD single detector assembly

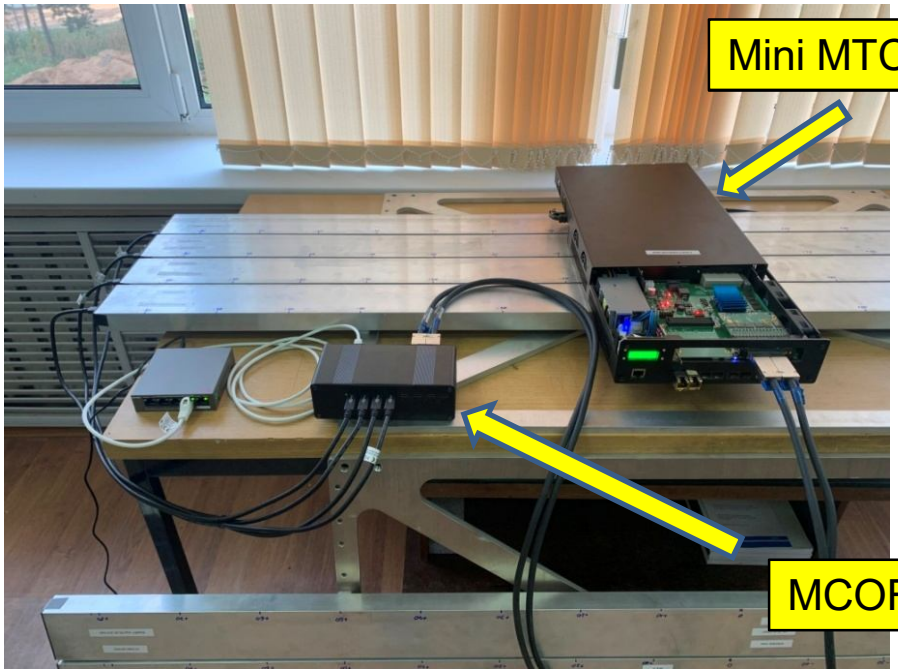
4. Demonstrator

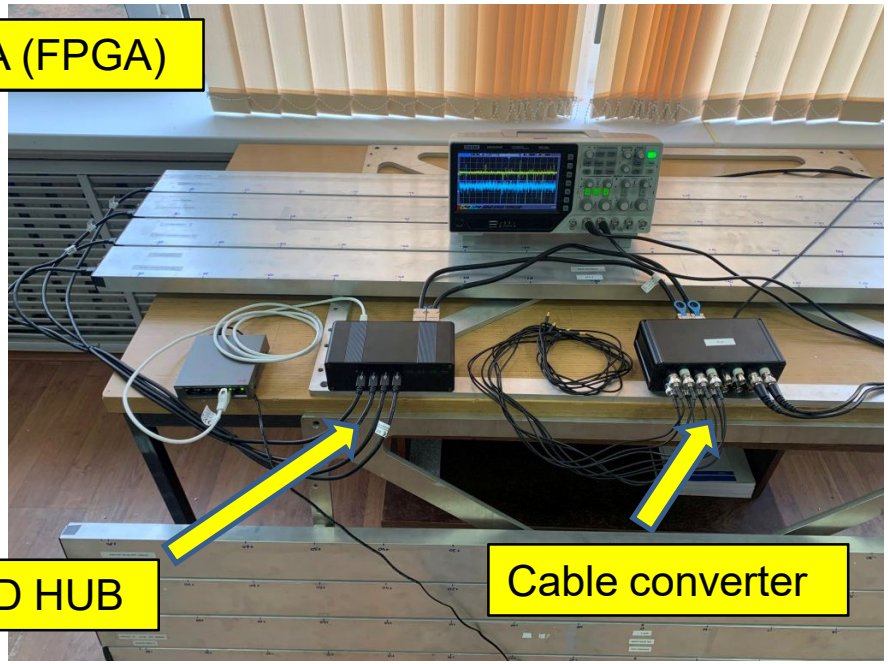
The first shipment reached Dubna

Two MCORD sections have arrived with the necessary electronics

4. Demonstrator

Two modes of demonstrator operation.

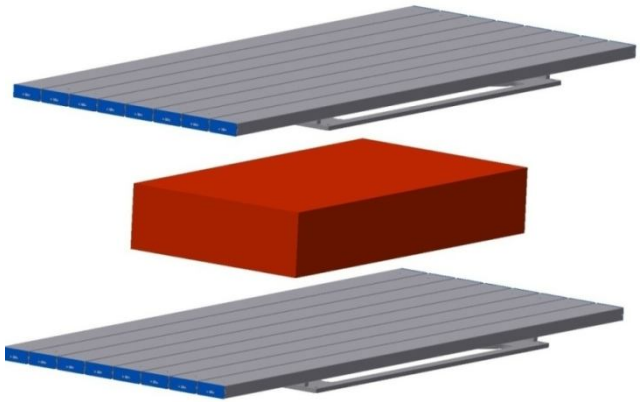


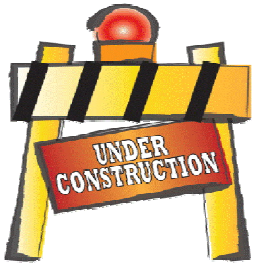


Standard mode: signal from scintillators (silver) to MCORD HUB and then to digital signal analysis system.

Laboratory mode: signal from the scintillators (silver) to the MCORD HUB and then to the cable converter. The analog signal can be sent from the converter to an oscilloscope or other digital analyzer (e.g. TOF).

4. Demonstrator





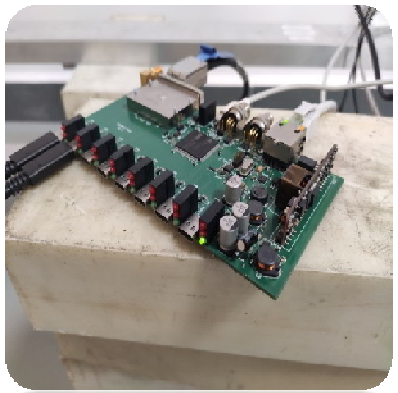
MCORD two section as a trigger for TOF test

5. Laboratory tests

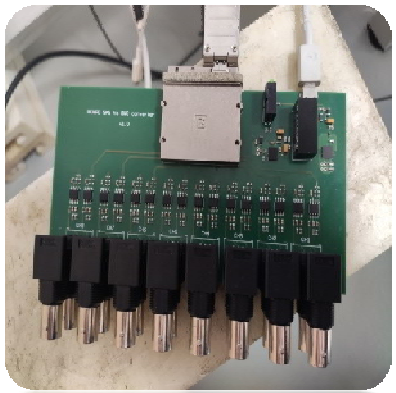
Read-out electronics

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



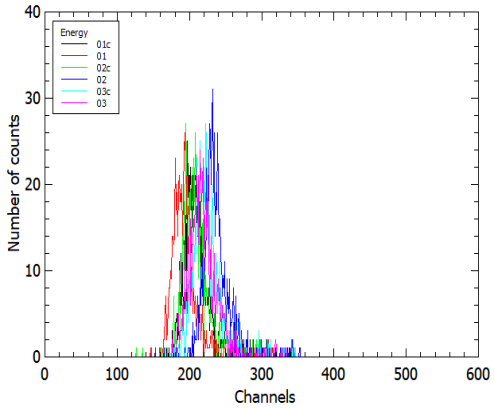
Converter of signals received by SAS cable to appropriate single BNC channels for each MPPC

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

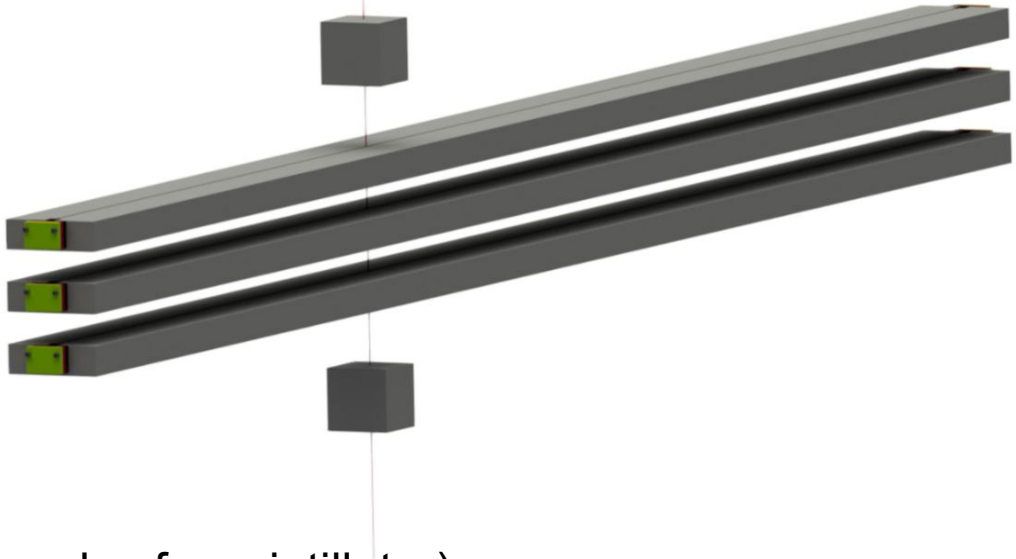
5. Laboratory tests – phase 2

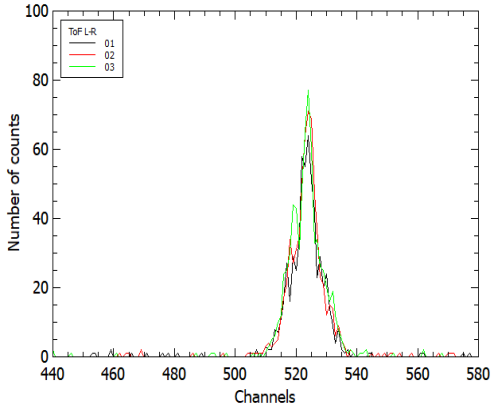
3x plastic MCORD detectors
+ 2x plastic hodoscopes (muon triggers)
+ DAQ: CAEN DT5730

Ext. trigger test setup



Energy
(amplitude recorded by SiPM)





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)

5. Test procedure (phase 2)

detector S/N	AFE ID	CRT resolution [ns]
D3036	01	0.97
D3040	02	0.99
D3033	03	1.05
D3047	04	0.96
D3048R	05	1.49
D3046	06	1.06
D3042	07	1.17
D3034	08	1.04
D3035	09	1.01
D3044	10	1.11
D3041	11	1.03
D3043	12	1.00
D3038	13	1.19
D3037	14	1.03
D3045	15	0.92
D3039R	16	1.40

- 4 out of 16 detectors (ID = 1, 2, 4, 15) show CRT resolution below 1.0 ns,
- 7 out of 16 detectors (ID = 3, 6, 8, 9, 11, 12, 14) show CRT resolution between 1.0 ns and 1.1 ns,
- 3 out of 16 detectors (ID = 7, 10, 13) show CRT resolution between 1.1 ns and 1.2 ns,
- 2 out of 16 detectors (ID = 5, 16) show CRT resolution between 1.4 ns and 1.5 ns, despite repair by the manufacturer,
- 4 out of 16 detectors (ID=5, 10, 11, 14) show shifts in CRT distribution centroids in the range between 1 ns and 4 ns, the reason for this will be studied further on.

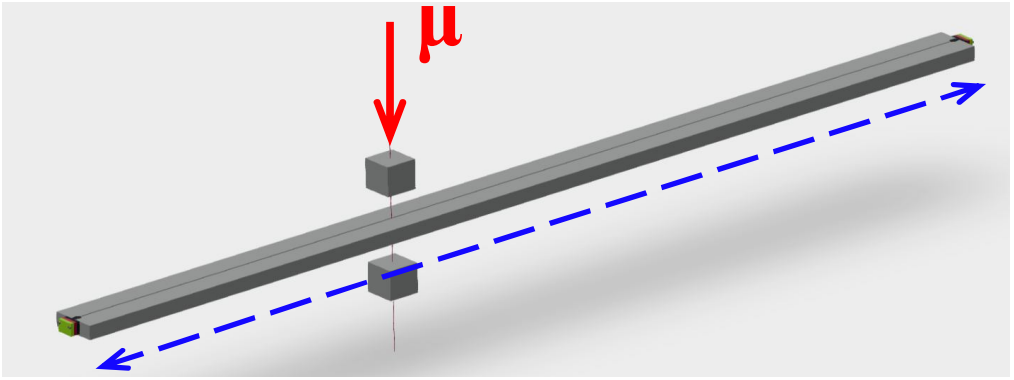
CRT (σ) = 1.0 ns ==> σ_x = 7.6 cm

5. Laboratory tests (phase 2)

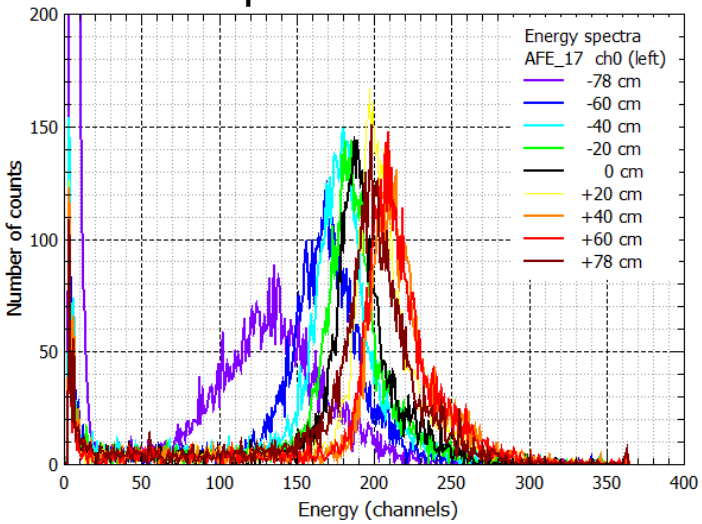
8 out of 16 detectors (MCORD demonstrator) just arrived: ready for laboratory tests and MPD subsystems calibratior

5. Laboratory tests (phase 3)

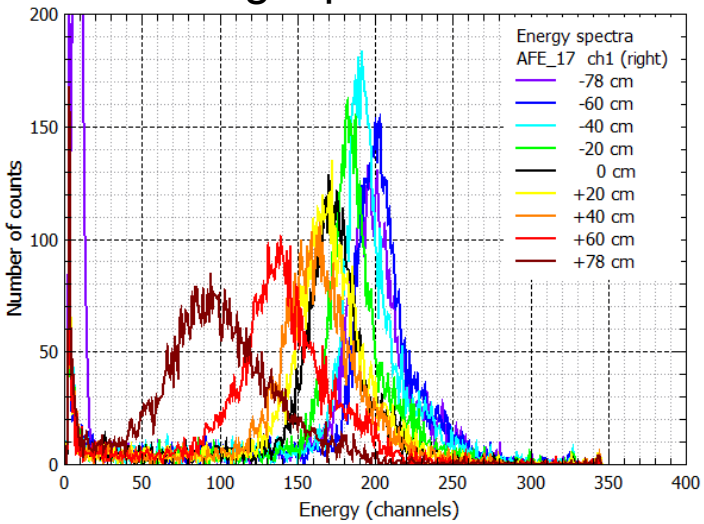
Muon response (energy spectra): new design with 2 mm WLS fil



Left photodetector



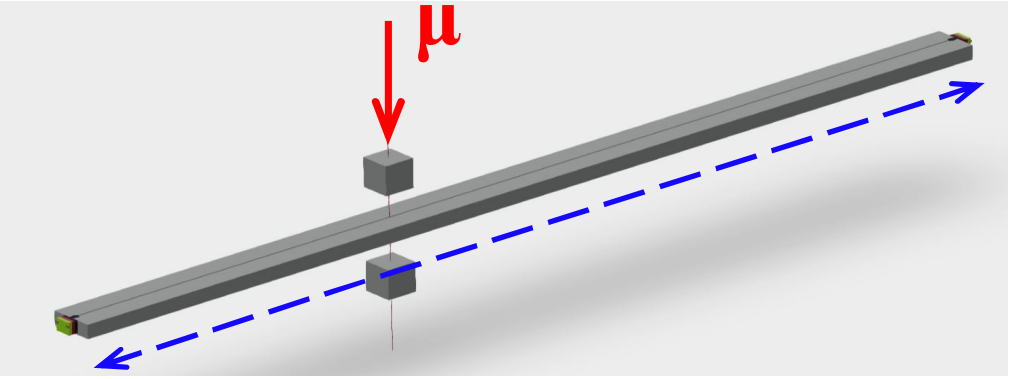
Right photodetector



Slight dependence on the muon interaction point – none of concern for timing measuren

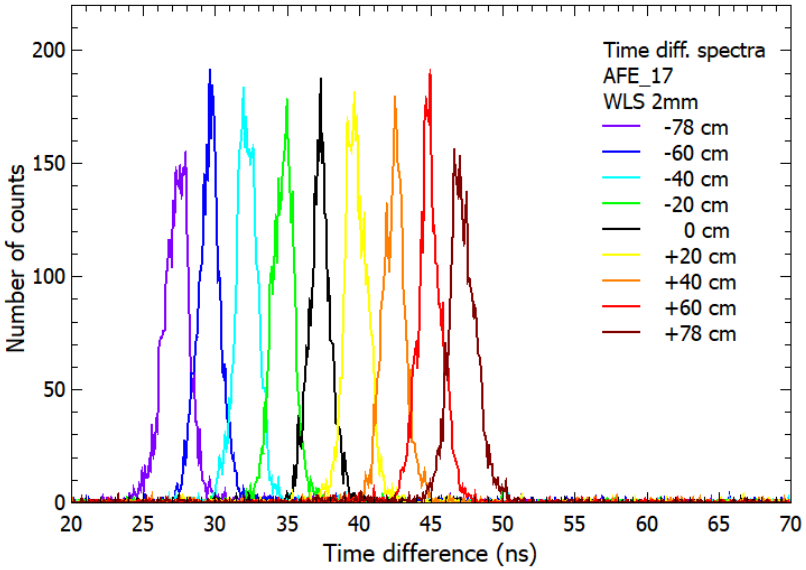
5. Laboratory tests (phase 3)

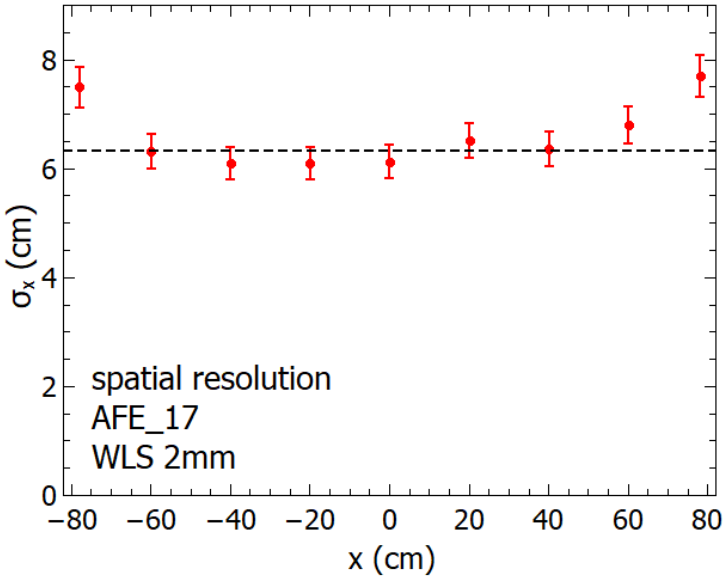
Muon response (CRT measurements):
improved timing resolution
for 2 mm WLS fiber



WLS fiber (**2 mm**)

CRT (σ) = 0.87 ns ===> σ_x = 6.3 cm





6. Publication

1. M. Bielewicz et al., MCORD: MPD cosmic ray detector for NICA, Proc. SPIE 10808, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments, 1080847 (2018), https://doi.org/10.1117/12.2501720
2. M. Bielewicz et al. MCORD - MPD Cosmic Ray Detector a new features, European Physical Journal Web of Conferences, 204, 07016(2019).
3. M. Bielewicz et al., The cosmic ray detector for the NICA collider, EPJ Web of Conferences 239, 07004(2020), https://doi.org/10.1051/epjconf/202023907004
4. **P. Kolasinski et al., Electronic readout system designed for MCORD in NICA experiment , Proc. SPIE 11581, Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments, 115811H (2020); doi: 10.1117/12.2580615**
5. M. Bielewicz et al., MCORD – detektor promieniowania kosmicznego w projekcie NICA-MPD, monography , Lublin (2021), ISBN 978-83-66489-69-1
6. **M. Bielewicz, P. Kankiewicz, A. Chlopik, Minimum Resolution of MCORD as a Consequence of Astrophysical Observation Requirements, Acta Phys. Pol. B Proc. Suppl. 14, 543 (2021)**
7. C.M. Cordun et al., The First cosmic ray measurements for future MCORD project, Acta Phys. Pol. B Proc. Suppl. **14**, 543 (2021)
8. **M. Bielewicz et al., Conceptual Design Report of the MPD Cosmic Ray Detector (MCORD), Journal of Instrumentation (JINST) (2021) – In review**

6. Conferences and Seminars
Presentation about the MCORD

1. 2018.IX – Int. Conf. XXIV Baldin Seminar (Dubna, Russia) – conference talk
2. **2019.V – Int. Conf. Nuclear Data 2019 (Beijing, China) – conference talk**
3. 2019.X – Int. Conf. NICA Days (Warsaw, Poland) – conference talk
4. 2020.XII – Loc. Conf. Natura Mater (Lublin, Poland) – conference talk
5. 2021.IX – Int. Conf. Polish Astronomical Society (Szczecin, Poland) – Poster and short talk

1. 2018.X – NICA-PL meeting (Kielce, Poland) – meeting talk
2. 2018.X – NCBJ general seminar (Warsaw, Poland) – seminar talk
3. 2018.XI – LHEP seminar (Dubna, Russia) – seminar talk
4. 2019.X – NCBJ Astrophysics division (Warsaw, Poland) – seminar talk
5. 2020.VI – NCBJ division seminar (Warsaw, Poland) – seminar talk
6. 2020.XII – MEXNICA meeting (Online, Mexico) – meeting talk

And all MPD meetings and many seminars for students

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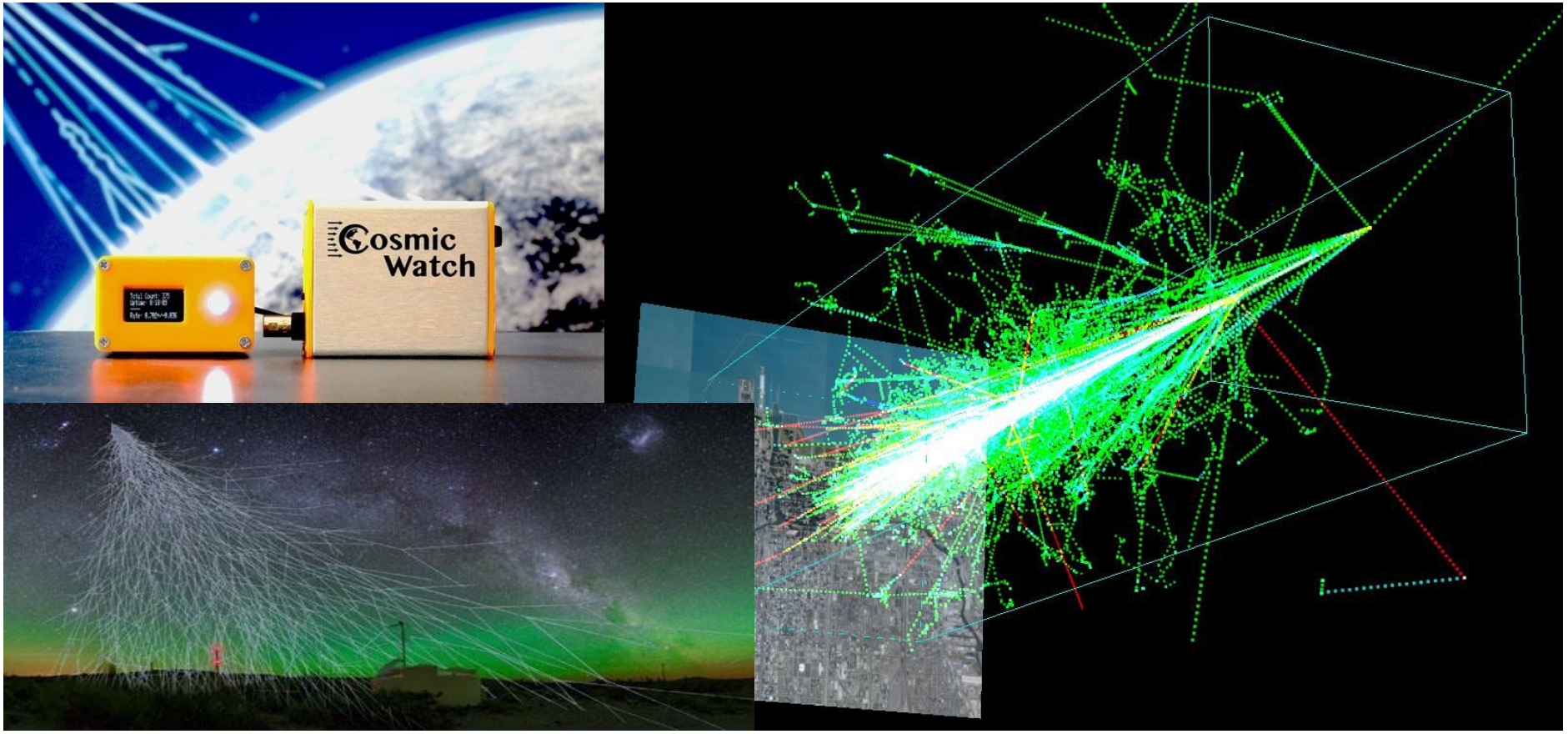
7. Summary

- MCORD is useful for calibration of TPC, TOF and ECAL detectors **during off-beam operation of the MPD** (during and after installation of other sub-detectors).
- MCORD demonstrator (STAGE 2: 2 sections = 16 scintillators) assembled and tested, 1 section delivered to JINR – **ready for TOF laboratory characterization**.
- The first **6 MCORD modules** (STAGE 3: 18 sections = 144 scint.) should be ready by Q4 2022 for installation on MPD surface.
- MCORD eligibility for identification of high energy muons from ion-ion collisions will be verified for **J/Ψ production**.
- MCORD can be used for **unique astrophysics observations** similar to past collider experiments.
- Implementation of **MCORD trigger** into MPD trigger system will be carried on during next months.

Thank You for Attention!



Polish consortium NICA-PL

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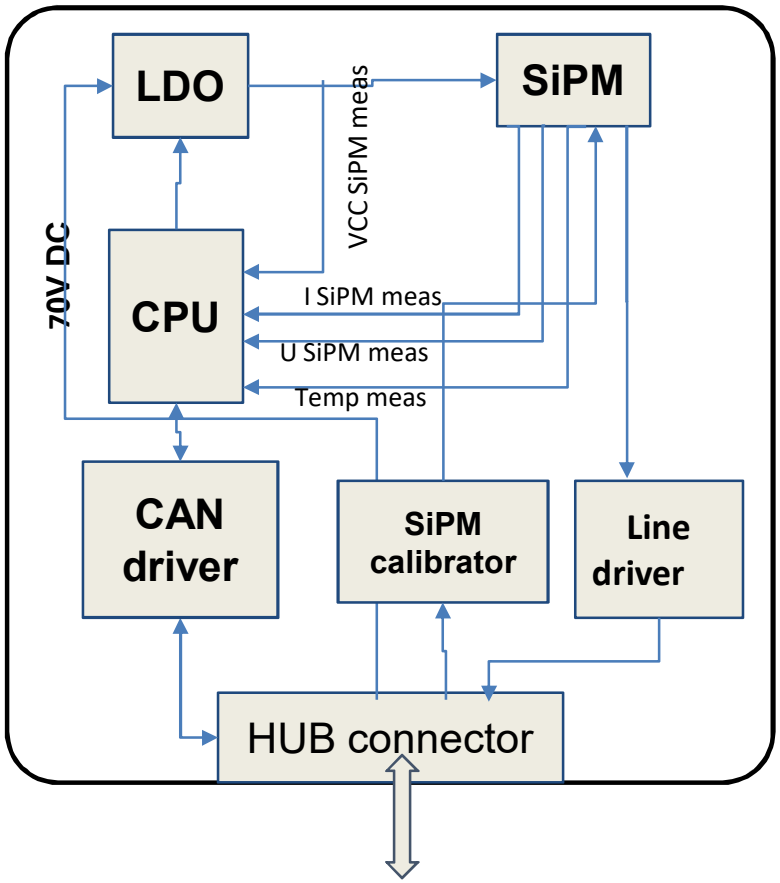
Supplements

Polish consortium NICA-PL

1. Introduction - Analog Front End module

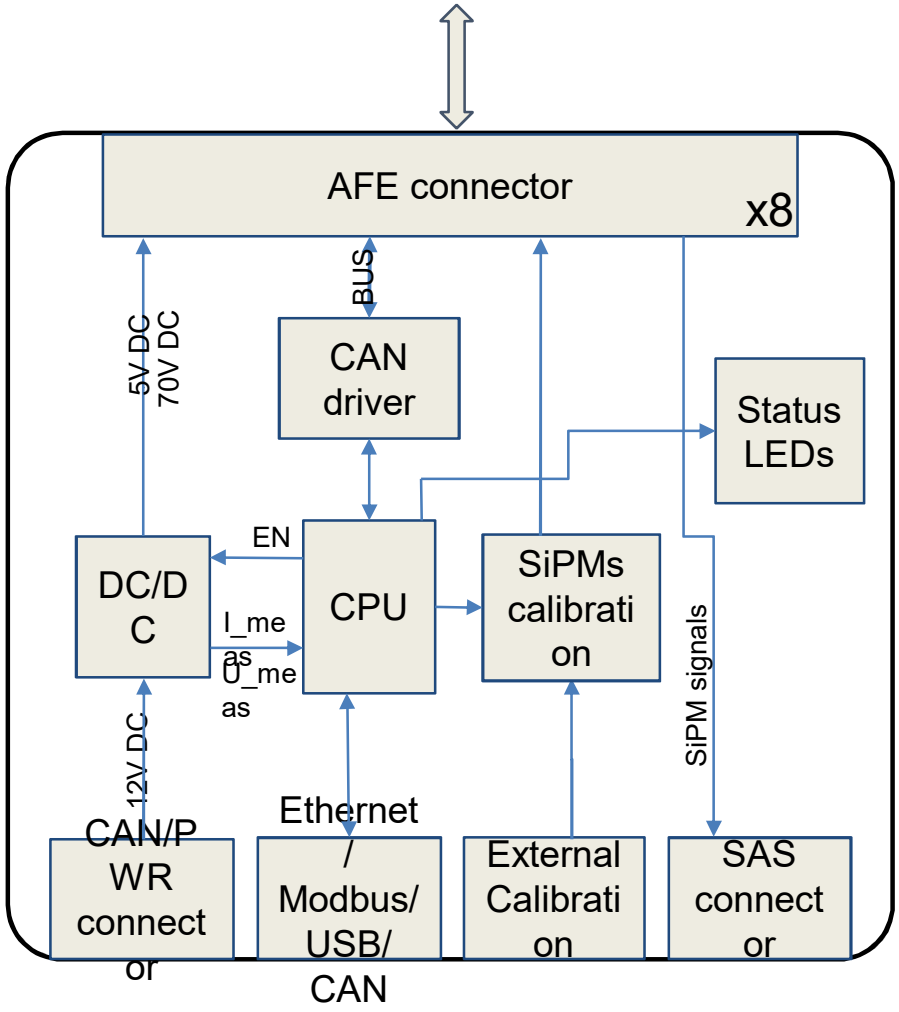
- Voltage controller for SiPMs
- Access to all settings and data from HUB via CAN-bus interface
- Protection for AFE



- **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

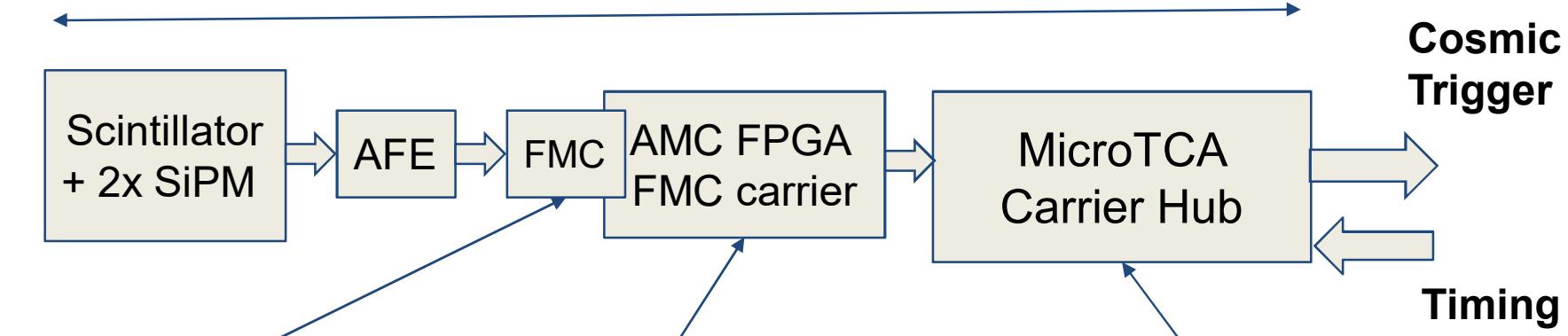
1. Introduction - HUB module

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



1. Introduction - FPGA data analizer

Estimated total trigger latency: 3.5 – 7.5us (max 15us)



ADC: 10b,
100Ms/s
TDC: 1ps time
resol.

Functionality:
- signal level threshold
- coincidence time window
- TDC & ADC correlation

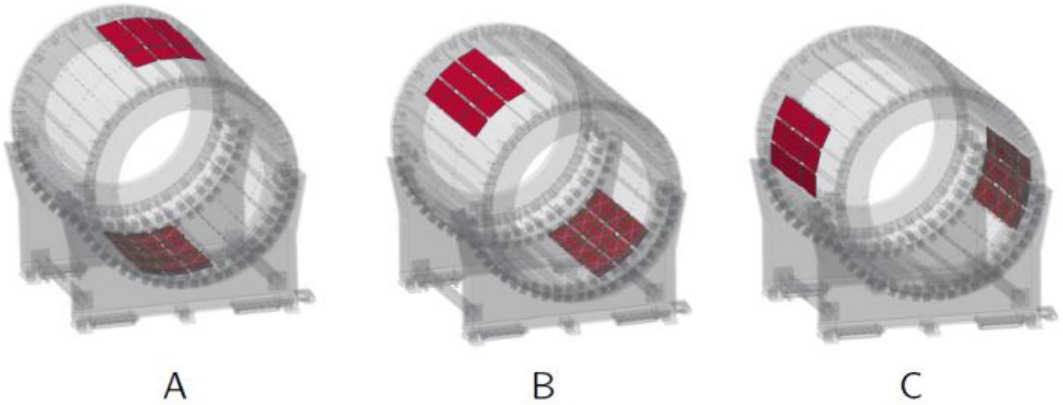
output: scintillator trigger
- position identification
- (relative) time identifier

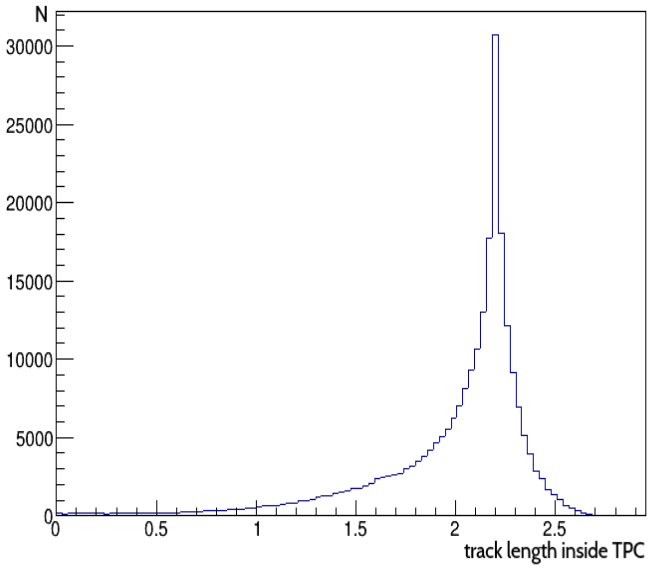
FPGA functionality:
- scintillator triggers time correction
- cosmic track finder algorithm

output: (multi) cosmic trigger
- track trajectory identifier
- (relative) time identifier

2. Mechanical construction - advantages

TPC calibration using MCORD trigger.
Faster movement of MCORD elements.





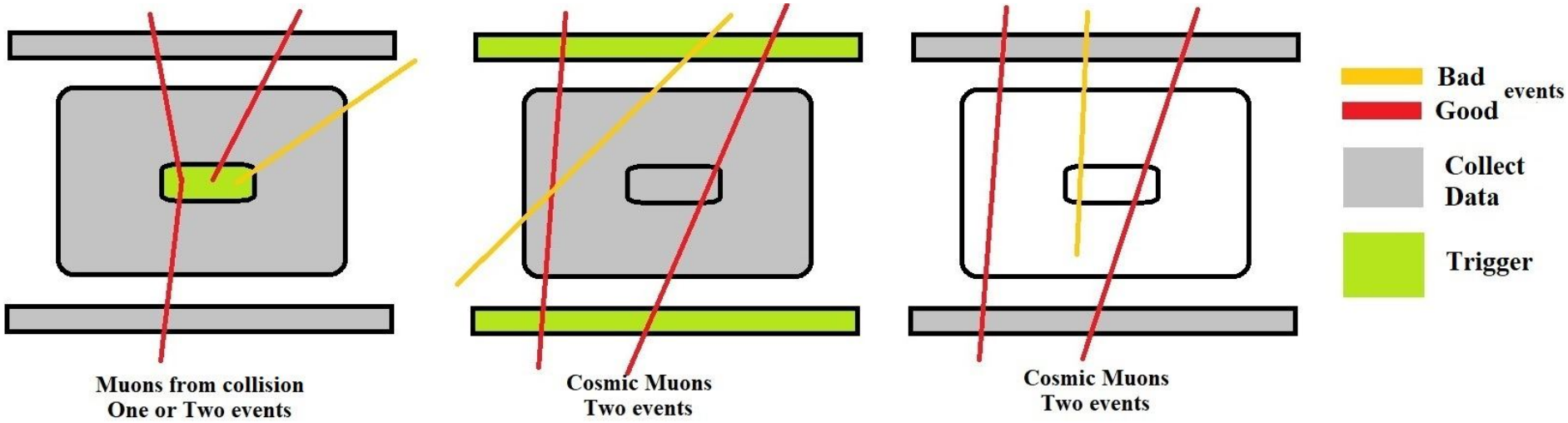
Calculated for muons with momentum **p > 1.6 GeV/c** by **Cofluxim Program.**

MCORD configuration	MCORD modules ID numbers	MCORD & TPC (tracks per hour)
A	(6 or 7 or 8) and (20 or 21 or 22)	**246 800**
B	(9 or 10 or 11) and (23 or 24 or 25)	**158 262**
C	(12 or 13 or 14) and (26 or 27 or 0)	**20 634**

4. MCORD trigger and acquisition

Three modes of operation:

experiment | calibration | astrophysics



Collect data after collision inside MPD

MCORD trigger

MCORD collect Data

Single or dual muons
E > 1GeV

Energy threshold for cosmic muons E > 2 GeV

Beam Time

All type in the same time
in Beam Time experiment

6. Simulations (Collisions)

Muons and pions distribution from ion-ion collisions inside the MPD.