Status of MCORD detector

by Polish consortium NICA-PL

DAC meeting, 19. Oct. 2020

NARODOWE CENTRUM BADAŃ JĄDROWYCH ŚWIERK

Uniwersytet Jana Kochanowskiego w Kielcach

POLITECHNIKA WARSZAWSKA
WARSAW UNIVERSITY OF TECHNOLOGY

JINR

Outline

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2. Detector
3. Electronics
4. Laboratory tests
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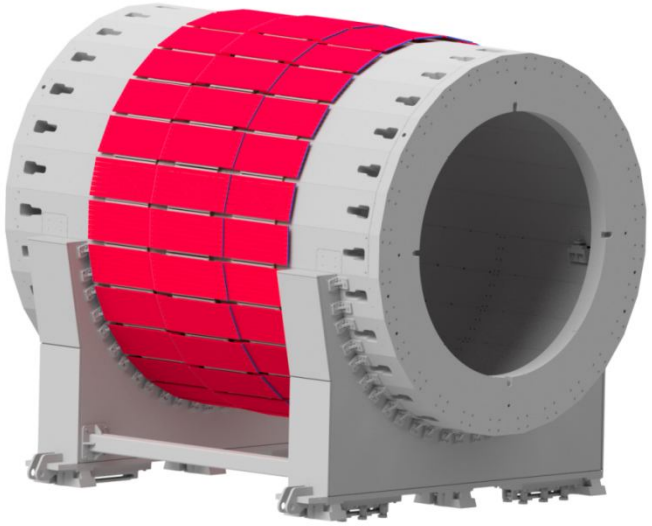
6. Simulations
7. Mechanical construction
8. Summary

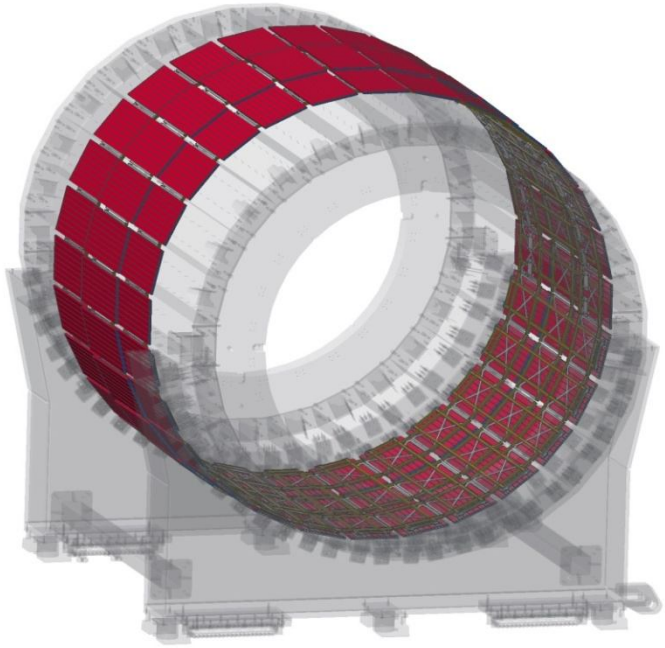


1. Introduction

MCORD applications for MPD

1. Trigger for cosmic muons for:
   - laboratory tests of MPD subsystems
     (2 separate MCORD sections)
   - MPD off-beam calibration in service position
     (6 MCORD modules) (E > 1.6 GeV)
2. Muon identifier (E > 0.8 GeV) for:
   - 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
4. Modular construction – easy upgrade and/or alternative use

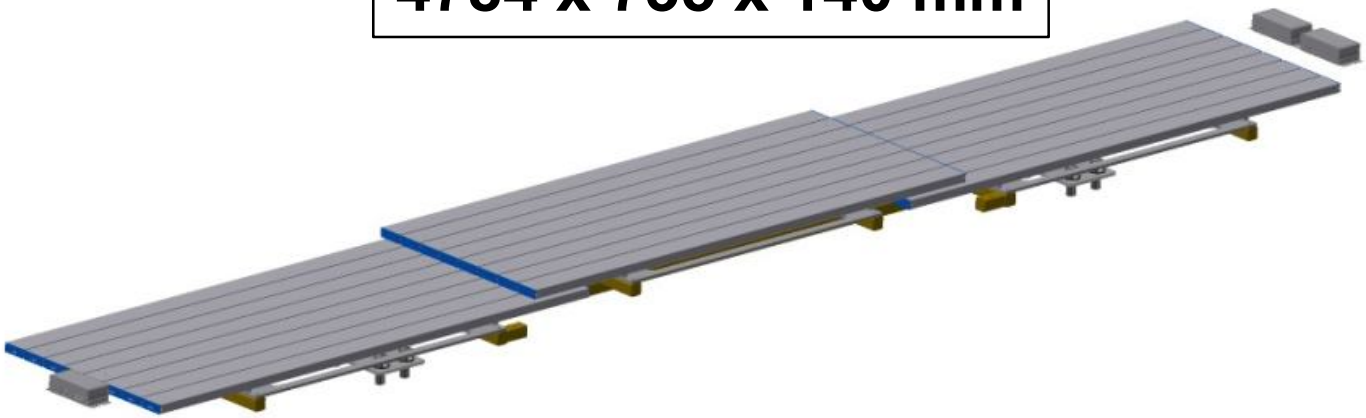
1. Introduction



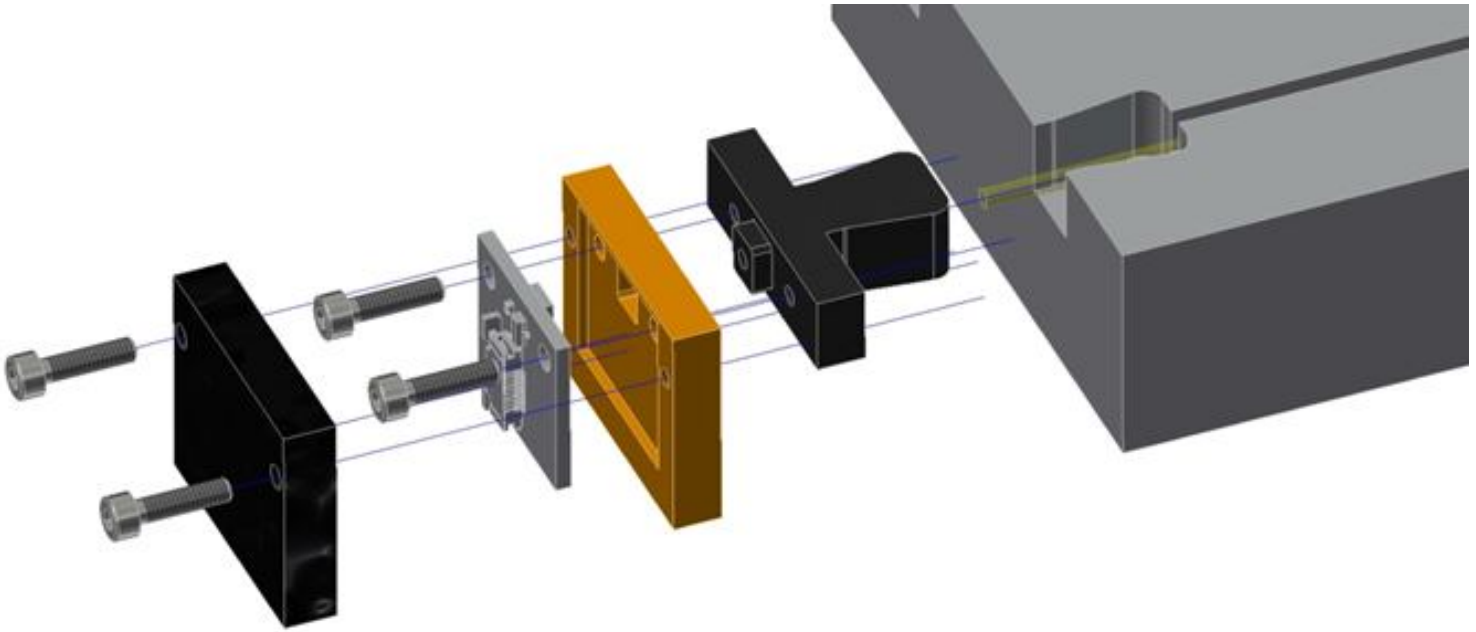
MCORD modules on MPD surface

Number of modules (3 sections x 8 scintillators): 28

Module size: 4784 x 735 x 140 mm



2. Detector

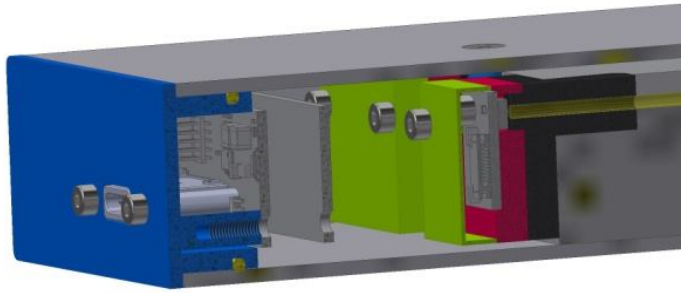


Plastic scintillator: polystyrene (Nuvia)
162 x 7.2 x 2.2 cm

WLS fiber: 1 mm dia. (Kuraray)

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

Housing: aluminum profile
174 x 8 x 3 cm

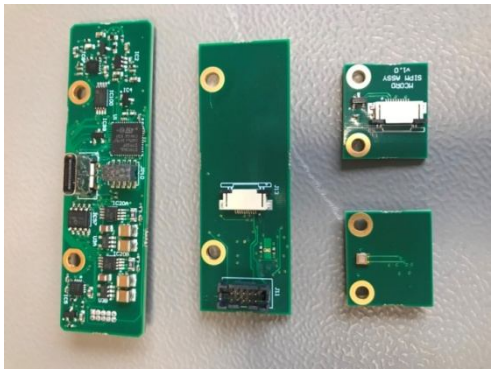


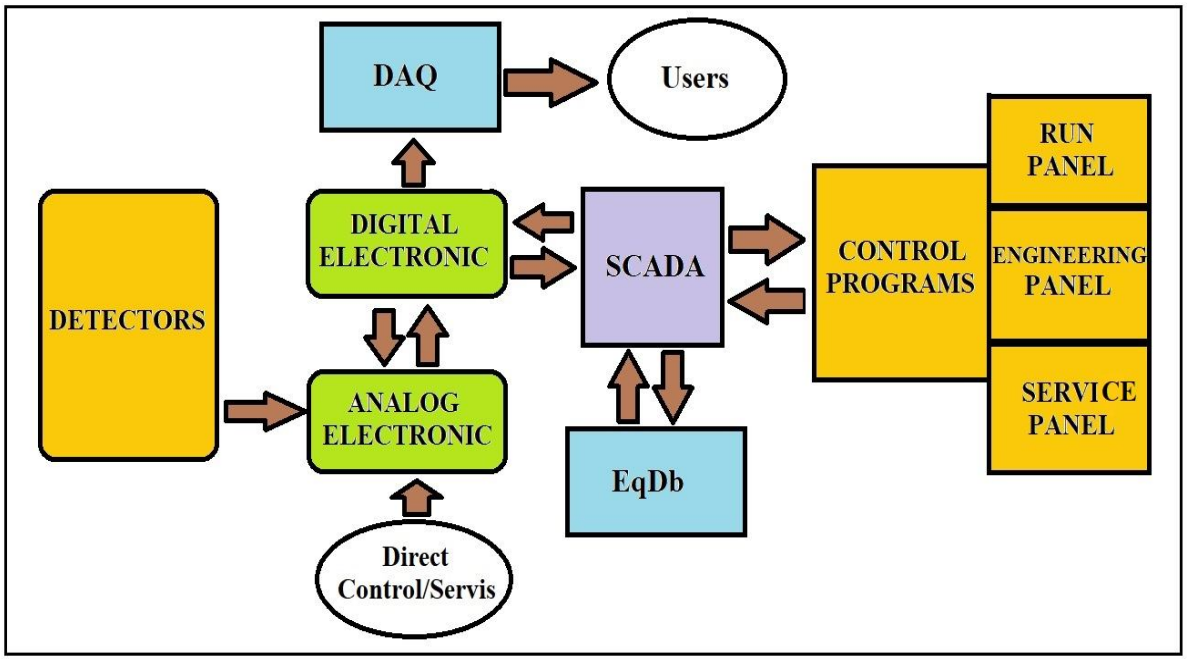
3. Electronics

Analog front-end (AFE): **custom design (WUT)**

Digital electronics (DSP): **custom design (WUT)**

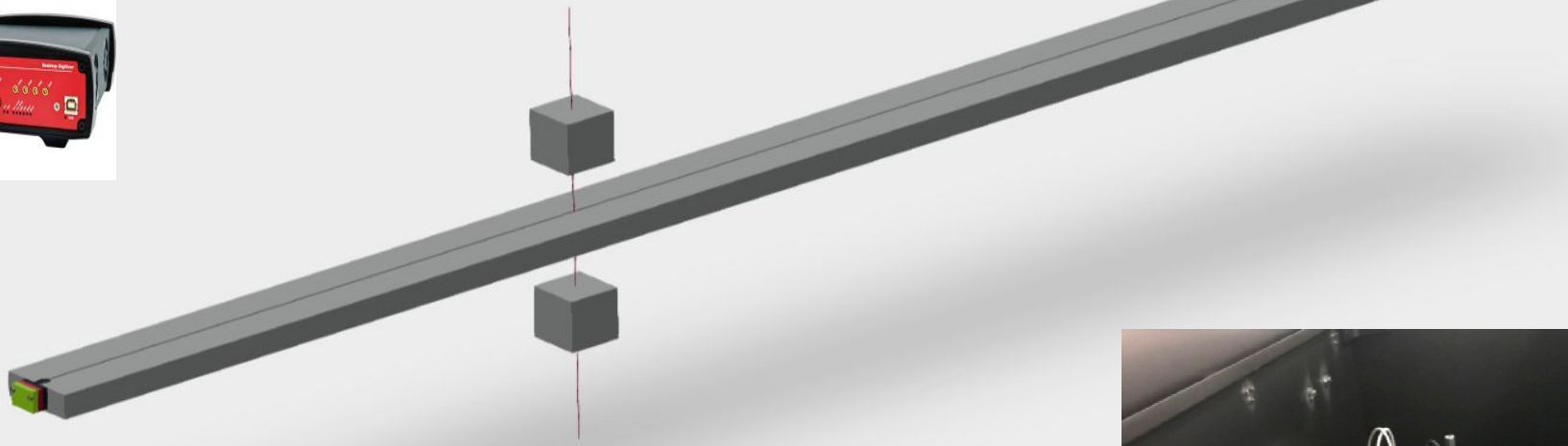
Data acquisition (DAQ): **MicroTCA**

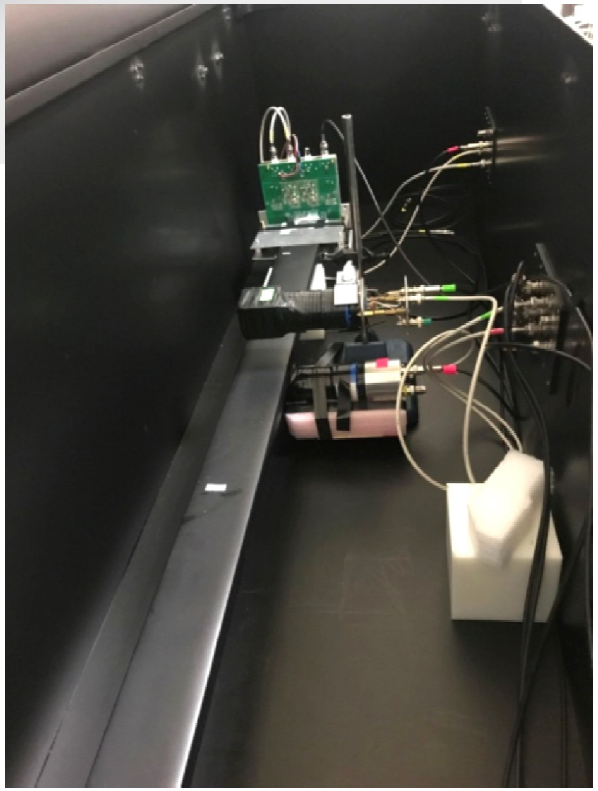




4. Laboratory tests

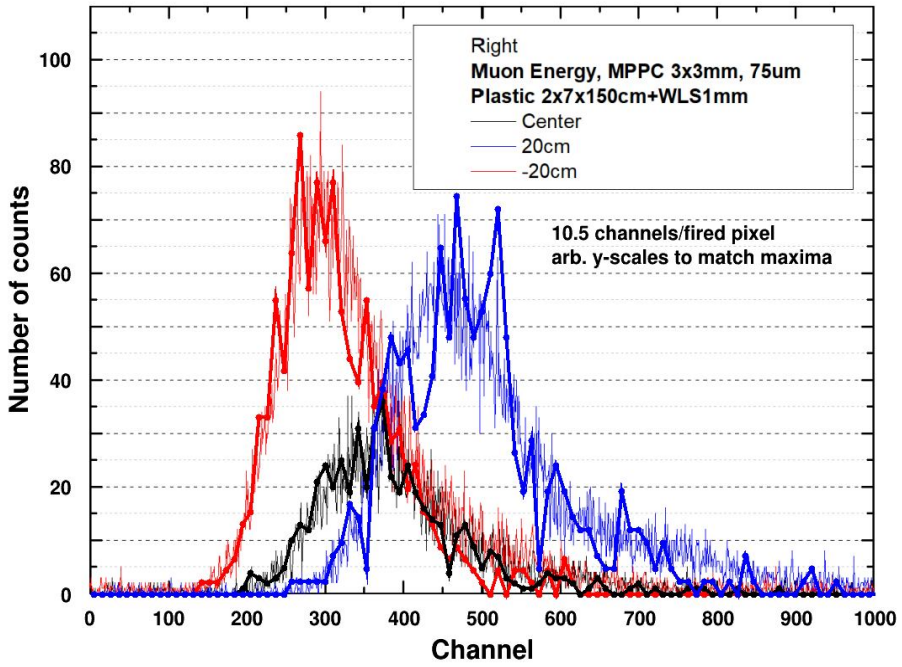
Plastic detector + 2 plastic hodoscopes (muon triggers)
DAQ: CAEN DT5730

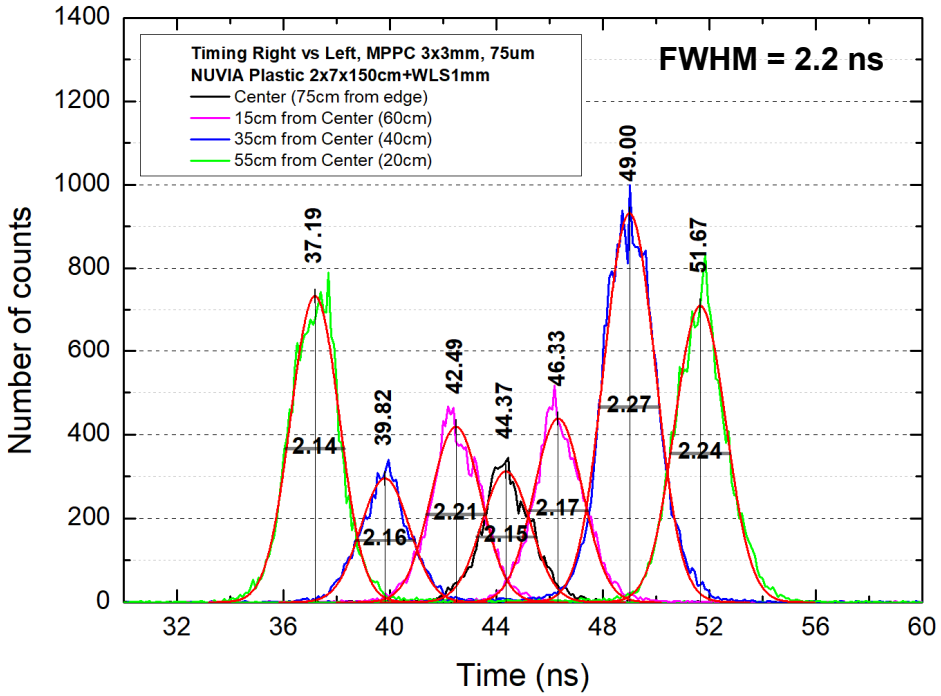




4. Laboratory tests

Plastic (150 x 7.2 x 2.2 cm) + WLS fiber (1 mm)
MPPC 3 x 3 mm (pixel size 75um)





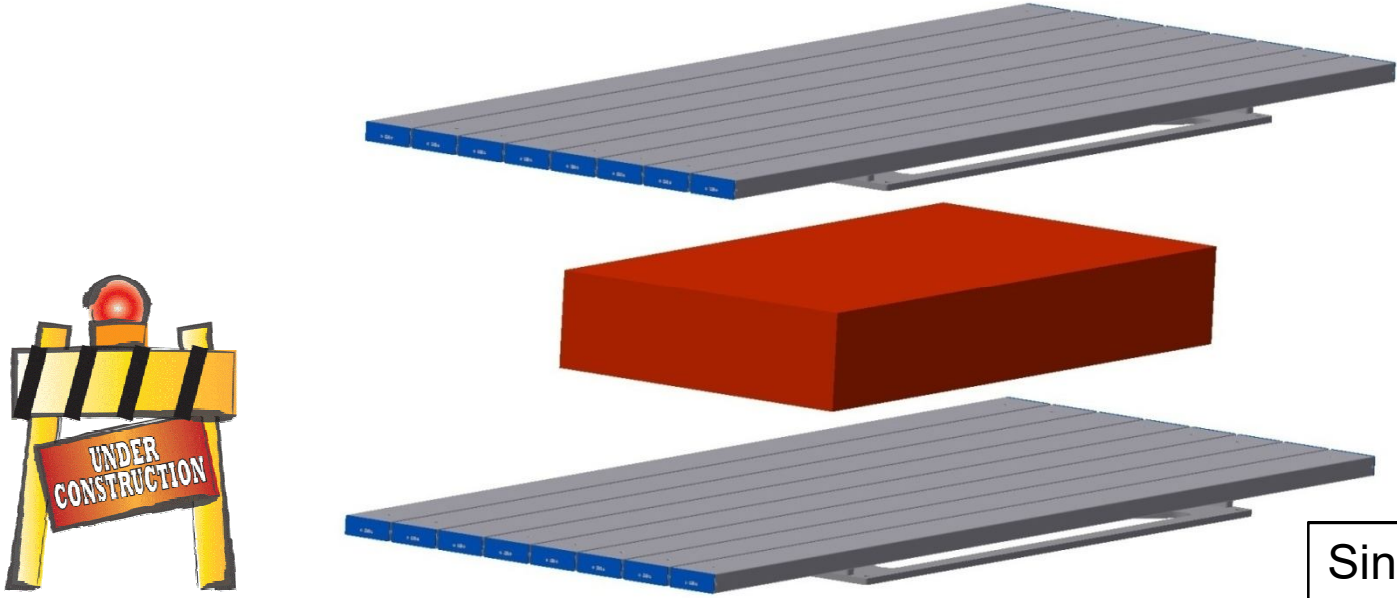
Number of detected photons = 30

CRT (σ) = 0.93 ns ===> σ_x = 7.1 cm

(still some room for improvement)

5. MCORD demonstrator

2 sections (2 x 8 scintillators) + AFE + DSP + DAQ, under construction until the end of 2020.

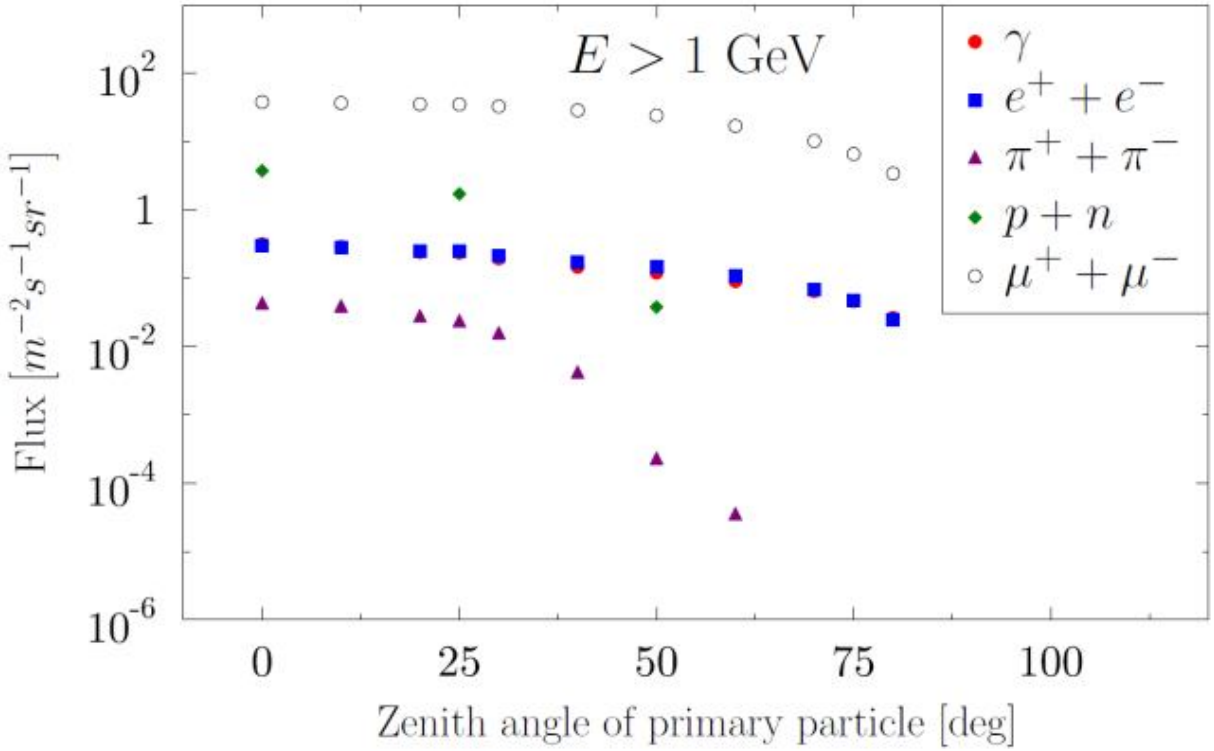


Single section –
1744x735(675)x50

! Feasible for laboratory tests of MPD subsystems !

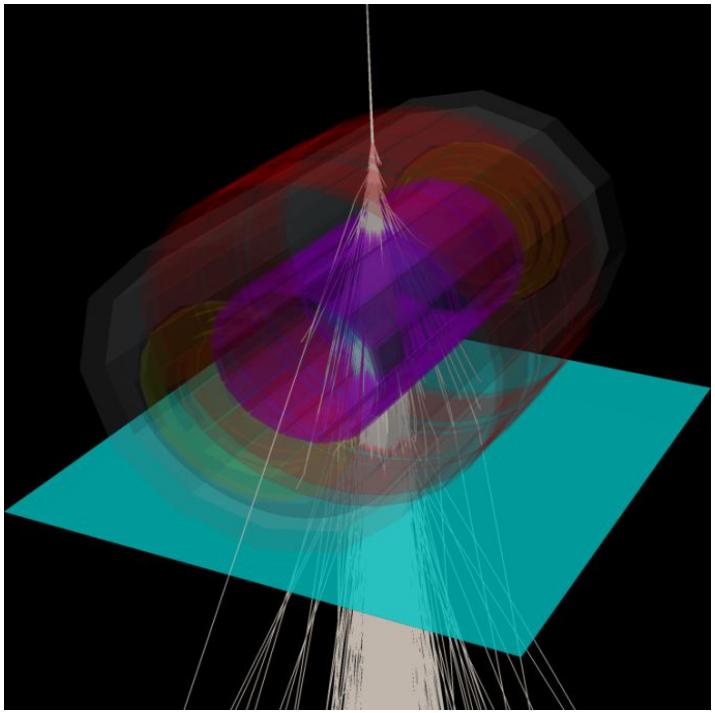
6. Simulations (EAS)

Angular distributions of Extensive Air Shower (EAS) components, calculated for location near Dubna city (at sea level).

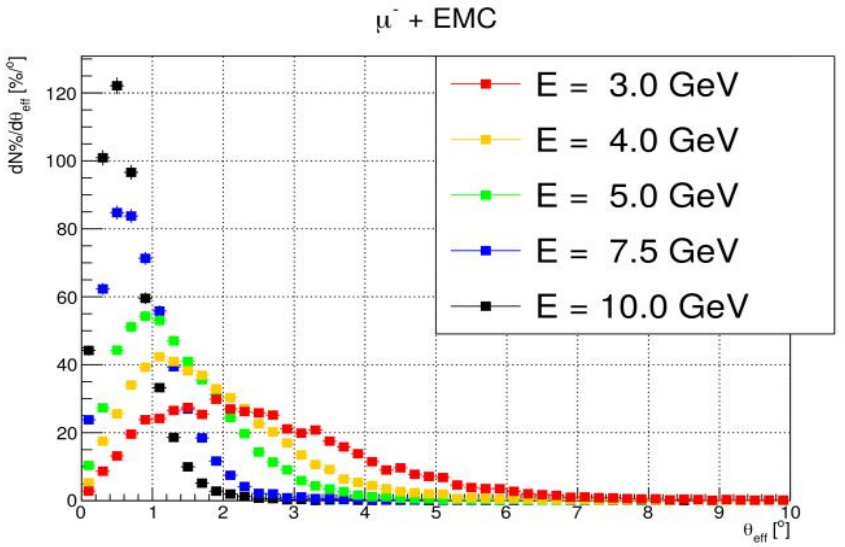


CORSIKA 7.74 code simulation
(model QGSJETII-04 + UrQMD).

6. Simulations (EAS)



Propagation of cosmic muons through the MPD - rescattering angel

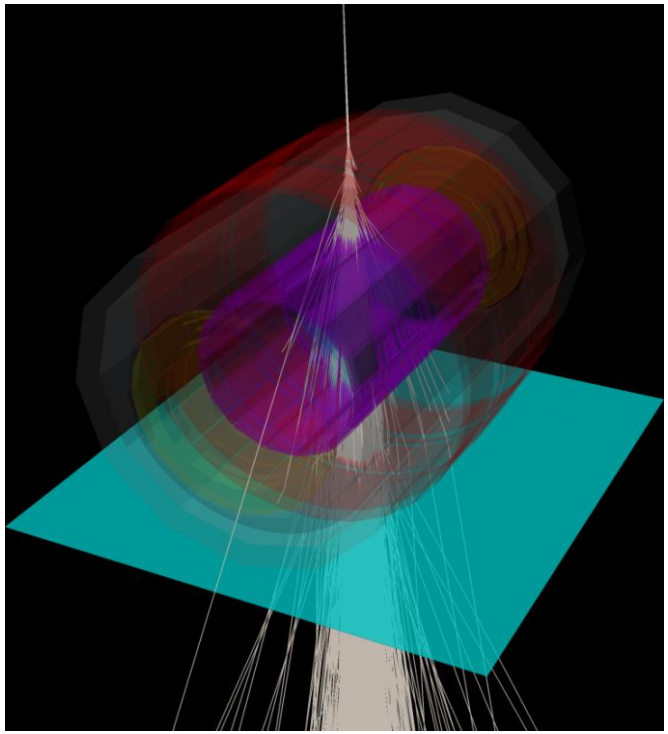


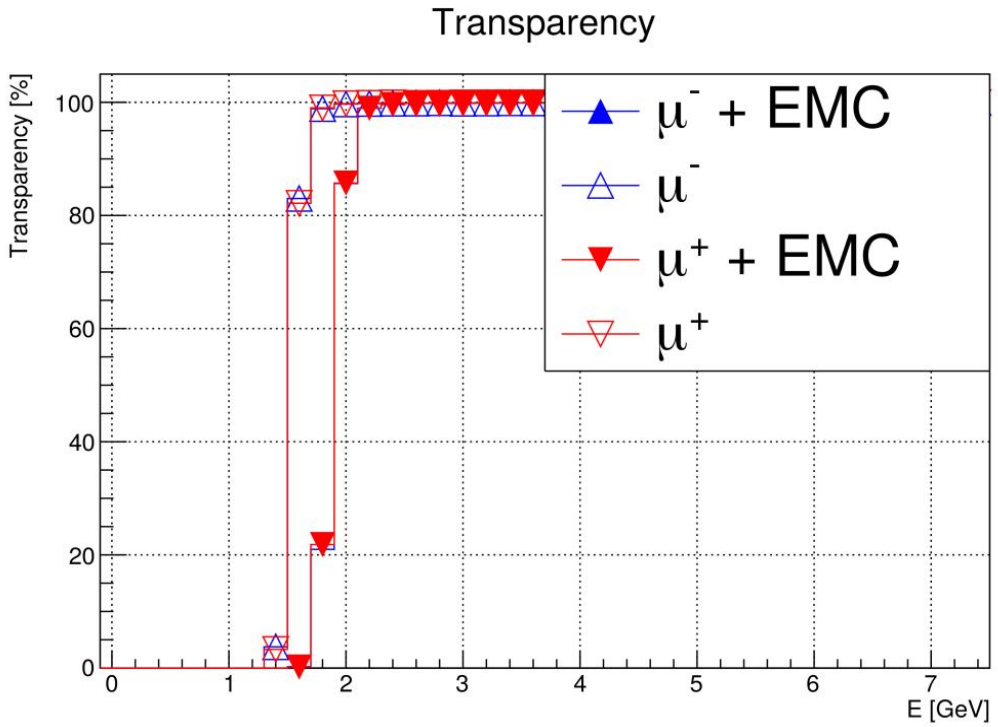
	$<\theta_{eff}>$	
μ Energy[GeV]	with ECal	without Ecal
3	**2.68**	**2.24**
4	**1.85**	**1.65**
5	**1.41**	**1.31**
7.5	**0.91**	**0.87**
10	**0.65**	**0.63**

	For TPC (D=281cm) $<R_{max}>$	
μ Energy[GeV]	with ECal [cm]	without ECal [cm]
3	**12.78**	**11.00**
4	**9.07**	**8.07**
5	**6.93**	**6.43**
7.5	**4.44**	**4.25**
10	**3.21**	**3.12**

6. Simulations (EAS)

Propagation of cosmic muons through the MPD

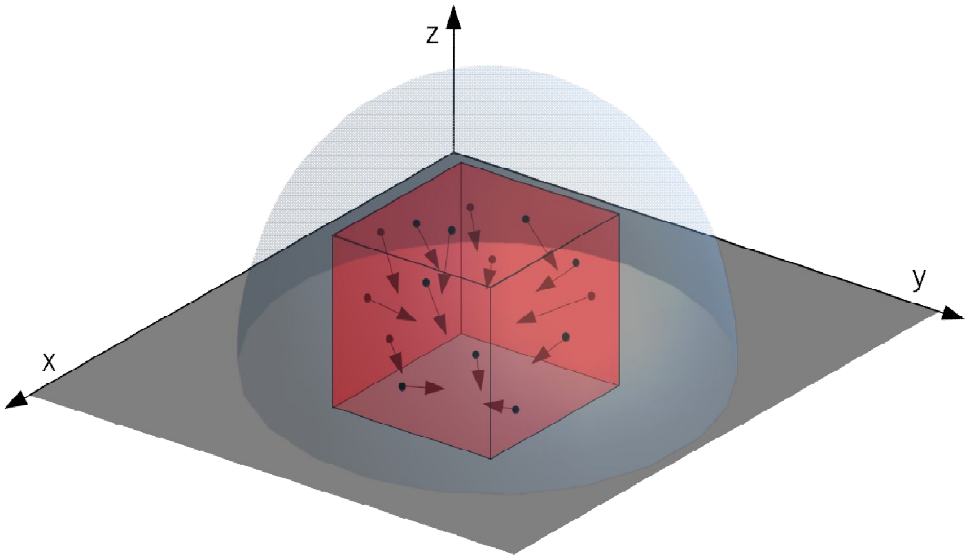




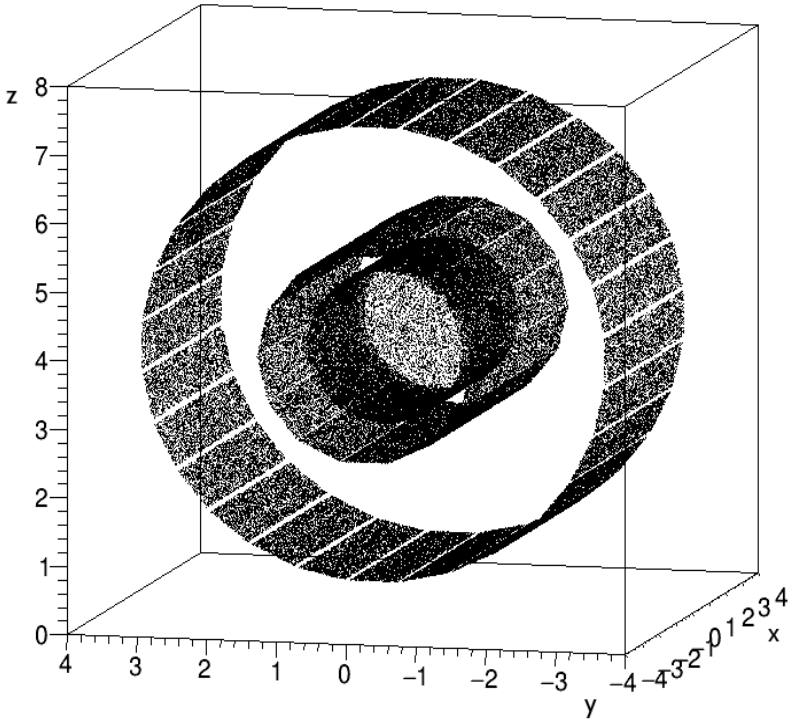
Energy threshold for muons able to pass through the MPD:
with ECal assembled: **2.0 GeV/c²**
without ECal assembled: **1.6 GeV/c²**

6. Simulations (EAS)

Cofluxim – cosmic ray generator for MPD subsystems calibration study



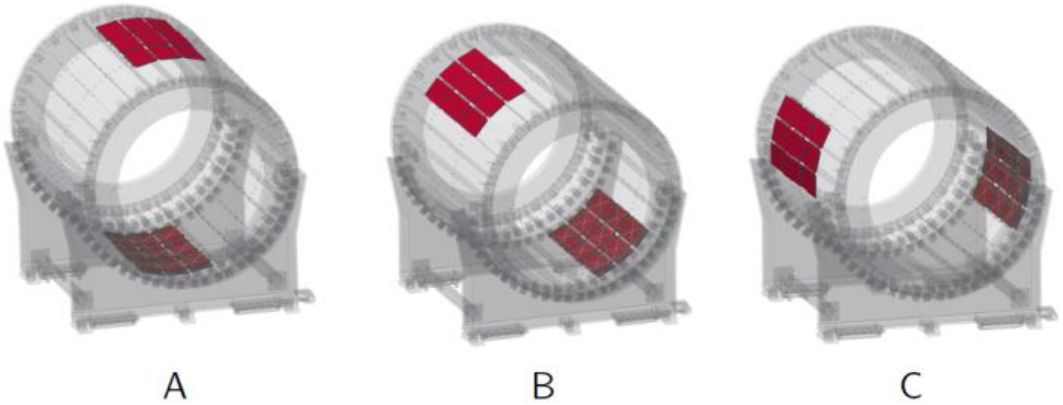
The concept of particle generation: drawing particles on the generation cube walls.

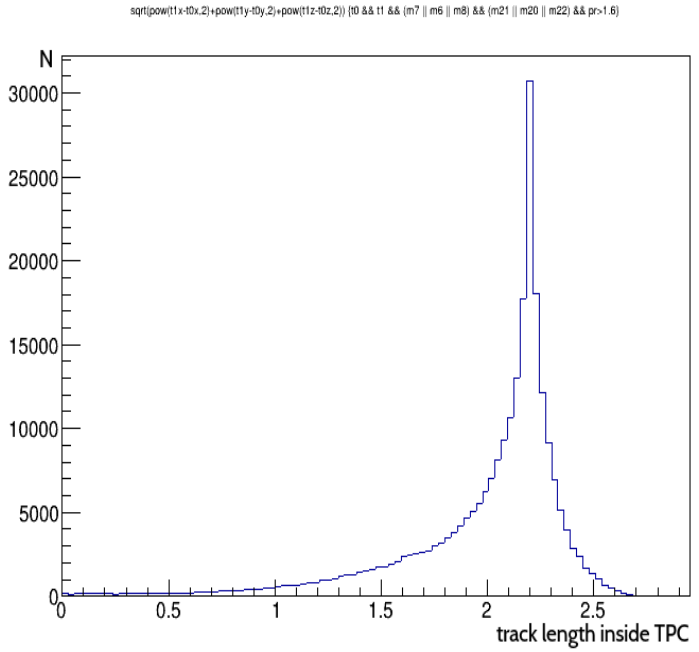


Plot of all hits on the surfaces of TPC, ToF and MCORD detectors.

6. Simulations (EAS)

TPC calibration using MCORD triggers



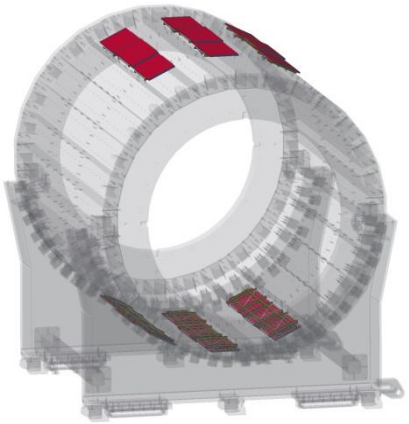


Calculated for muons with momentum
p > 1.6 GeV/c.

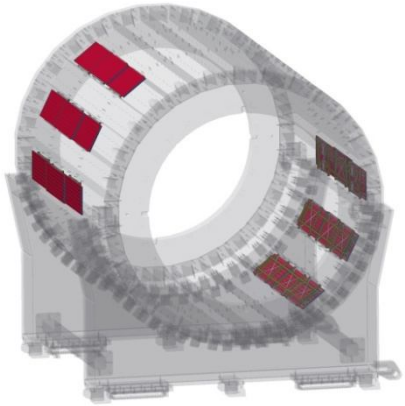
MCORD configuration	MCORD modules ID numbers	MCORD & TPC (tracks per hour)
A	(6 or 7 or 8) and (20 or 21 or 22)	**246 800**
B	(9 or 10 or 11) and (23 or 24 or 25)	**158 262**
C	(12 or 13 or 14) and (26 or 27 or 0)	**20 634**

6. Simulations (EAS)

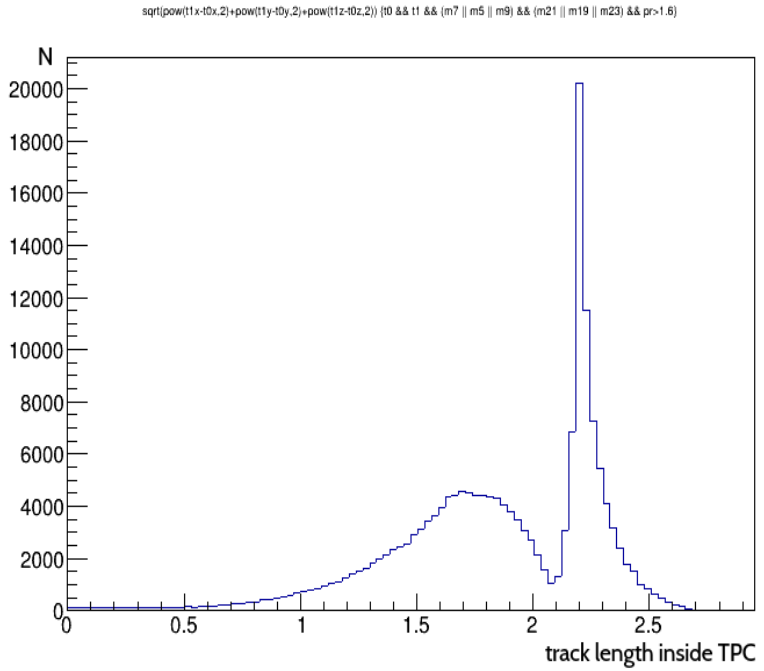
TPC calibration using MCORD triggers



D



E



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

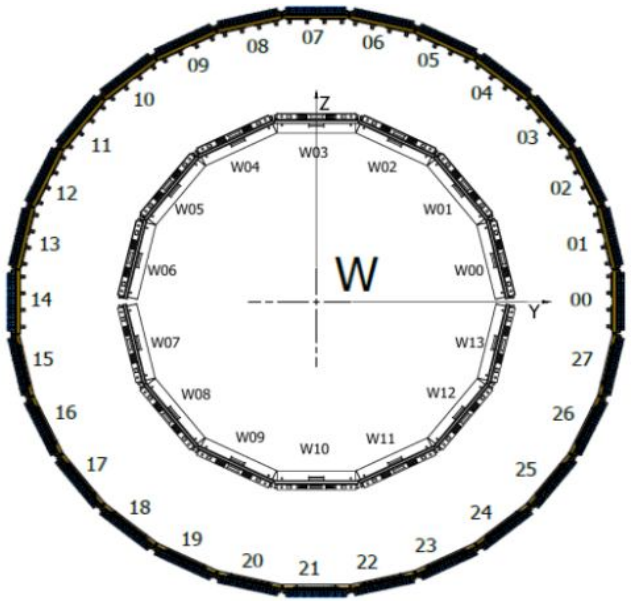
MCORD configuration	MCORD modules (ID numbers)	MCORD & TPC (tracks per hour)
D	(5 or 7 or 9) and (19 or 21 or 23)	**178 822**
E	(10 or 12 or 14) and (24 or 26 or 0)	**50 894**

6. Simulations (EAS)

TPC and ToF calibration using MCORD triggers

MCORD configuration	MCORD modules (ID numbers)	ToF modules (ID numbers)	MCORD & ToF (tracks per hour)	MCORD & ToF & TPC (tracks per hour)
F	(6 or 7 or 8) and (20 or 21 or 22)	3 and 10	43493	**39 768**
G	(4 or 5 or 6) and (18 or 19 or 20)	2 and 9	35554	**32 958**
H	(2 or 3 or 4) and (16 or 17 or 18)	1 and 8	17516	**16 254**
I	(0 or 1 or 2) and (14 or 15 or 16)	0 and 7	3143	**2 932**

Calculated for muons with momentum
p > 1.6 GeV/c



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6. Simulations (EAS)

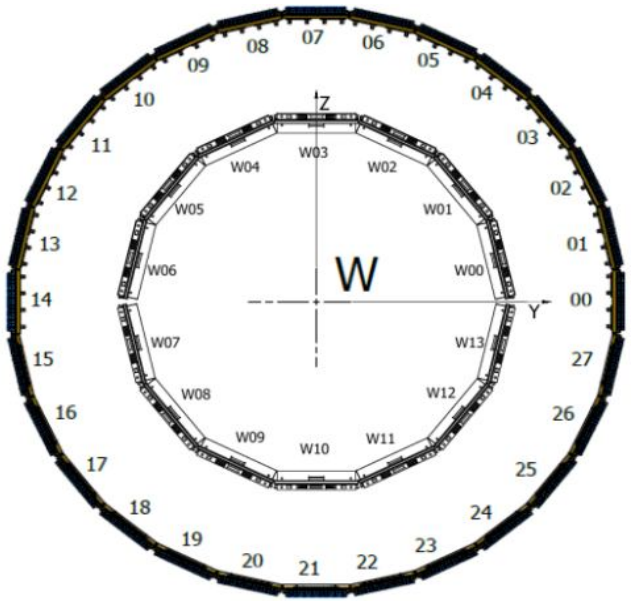
TPC and ToF calibration using MCORD triggers

MCORD configuration	MCORD modules (ID numbers)	ToF modules (ID numbers)	MCORD & ToF (tracks per hour)	MCORD & ToF & TPC (tracks per hour)
F	(6 or 7 or 8) and (20 or 21 or 22)	3 and 10	6648	**6 069**
G	(4 or 5 or 6) and (18 or 19 or 20)	2 and 9	5590	**5 196**
H	(2 or 3 or 4) and (16 or 17 or 18)	1 and 8	2713	**2 503**
I	(0 or 1 or 2) and (14 or 15 or 16)	0 and 7	480	**445**

Calculated for muons with momentum

p > 10 GeV/c

(minimum of rescattering angel)



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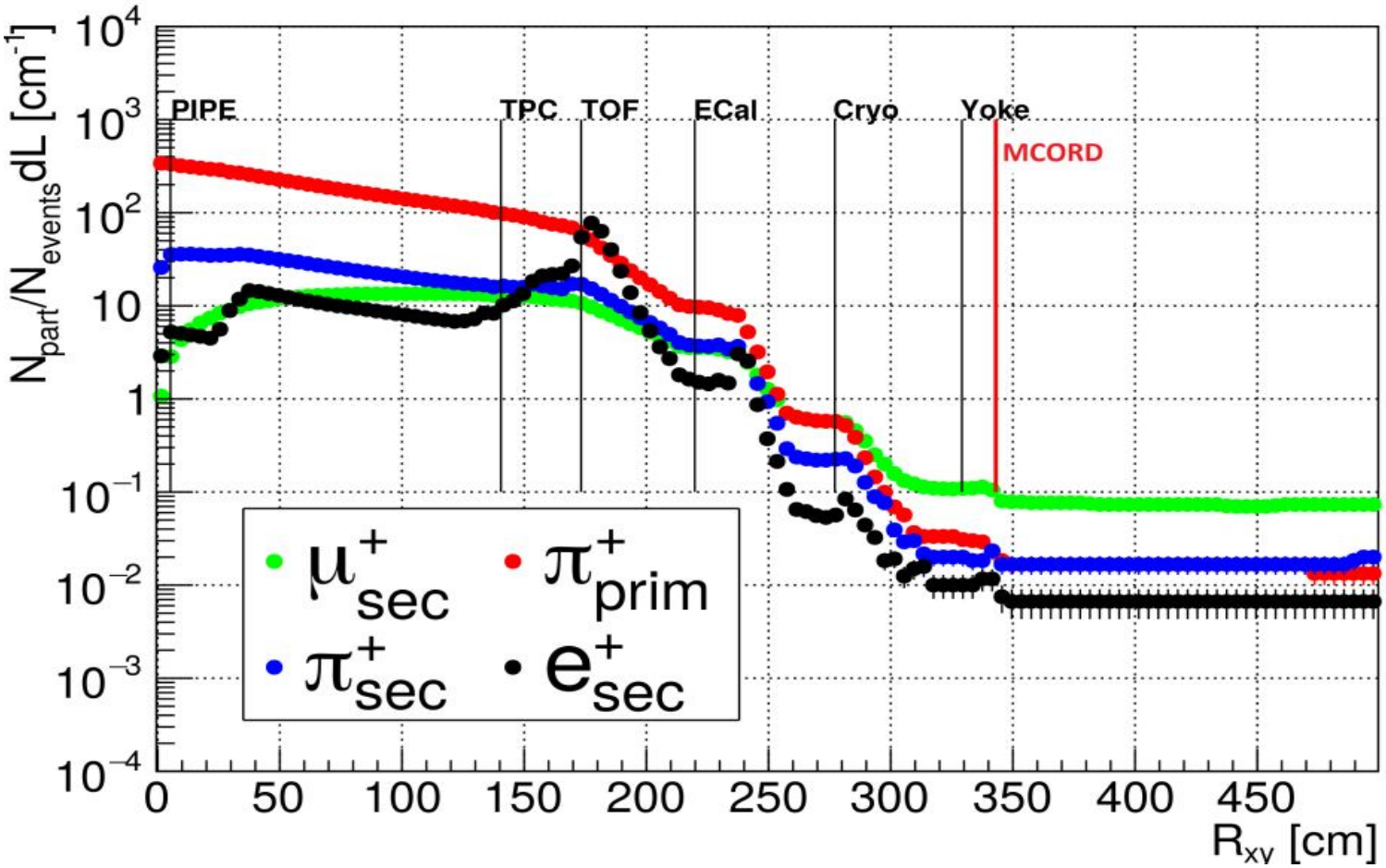
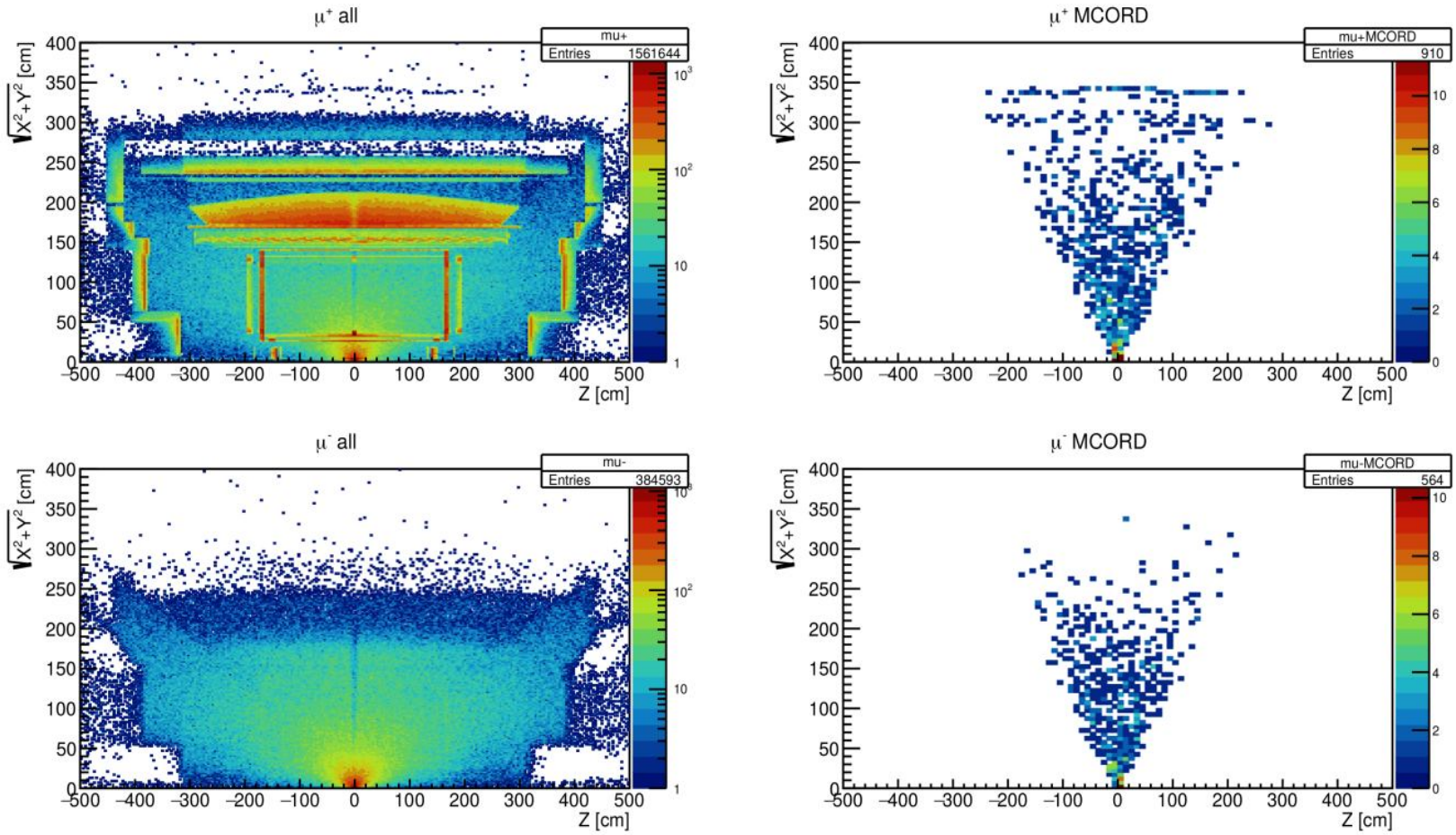
6. Simulations (Collisions)

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



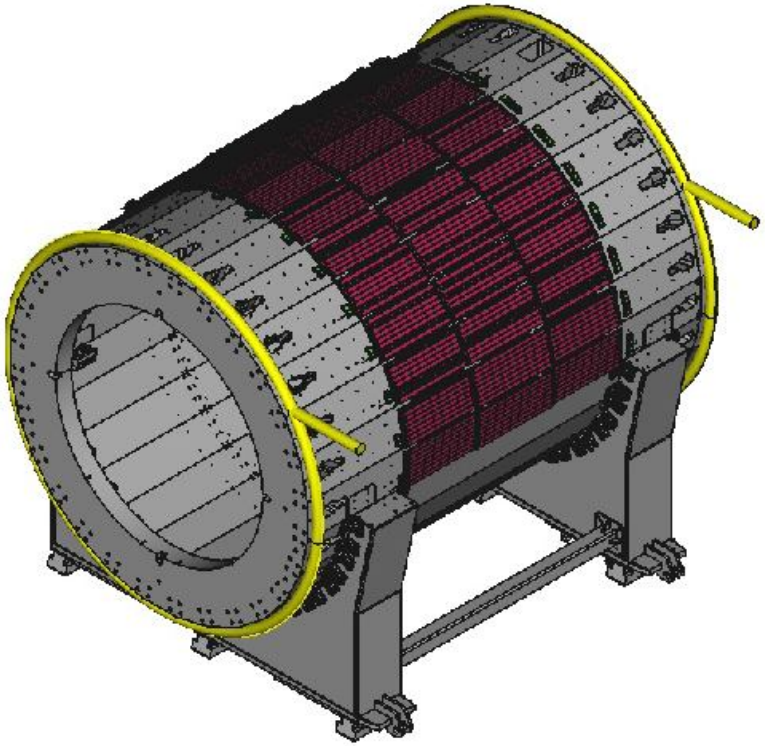
6. Simulations (Collisions)

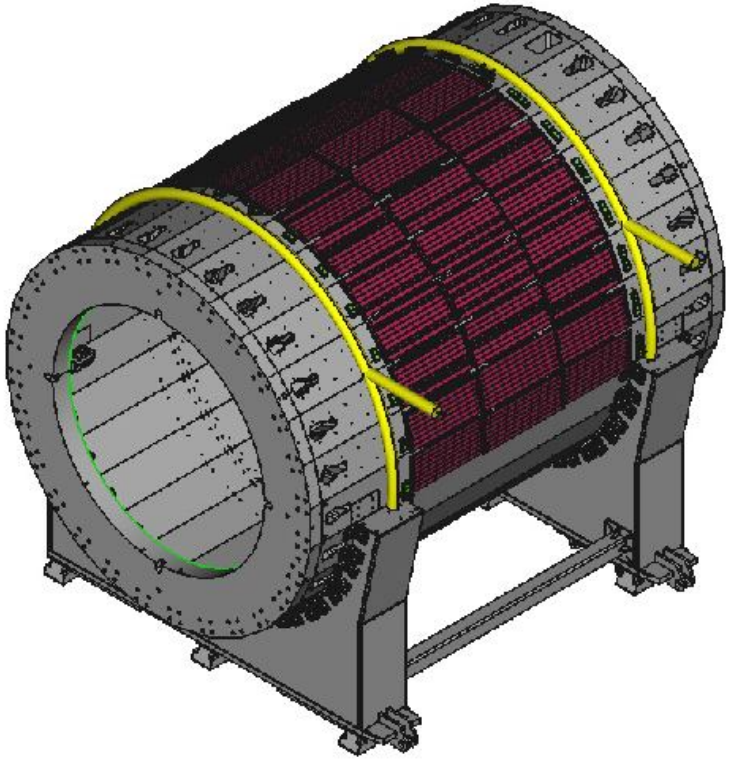


The points of creation of negative and positive muons.

Top plots corresponds to μ^+ whereas μ^- are at the bottom. Left plots represents points of creations any muon whereas right plots shows points of creations muons that can be detected by MCORD. The structure of detector (contribution from decays of "stationary" particles) is clearly visible for positive muons.

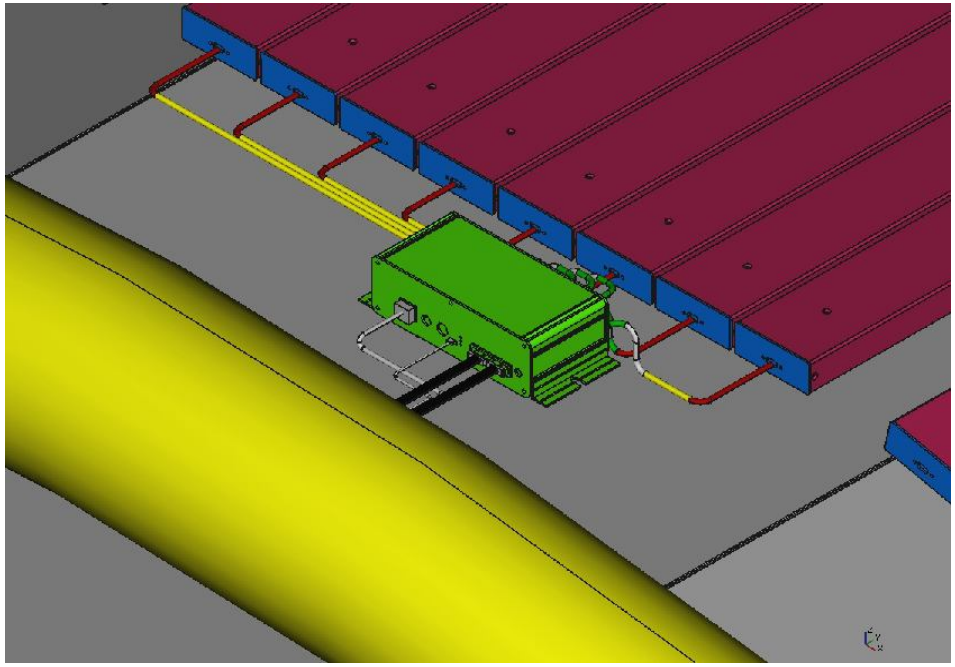
7. Mechanical construction

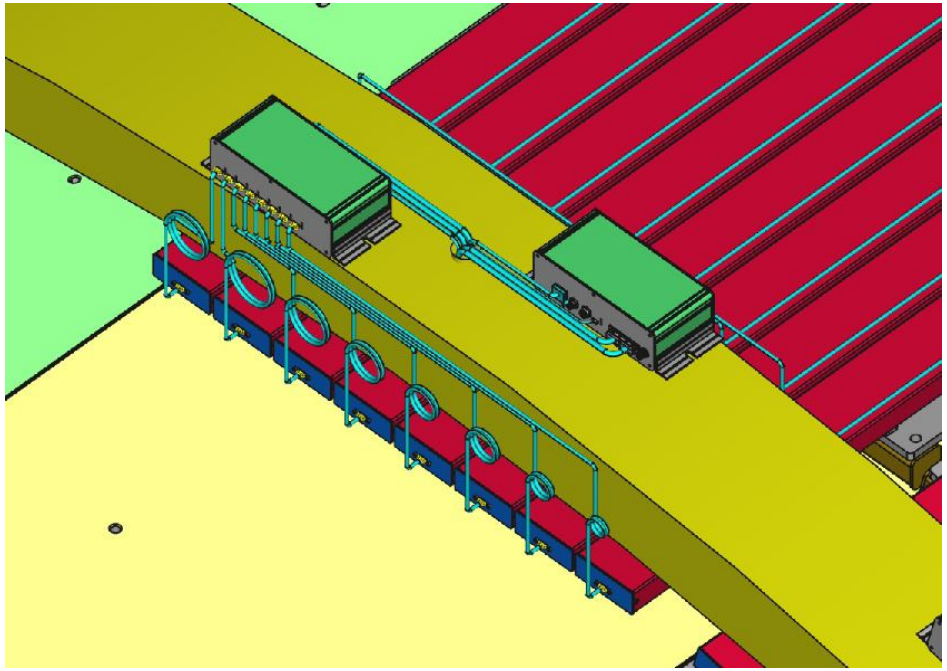




Cable routes from the MCORD to the NICA-MPD-PLATFORM.
Left: along with other cables. On the right: a separate dedicated channel.
We chose this one

7. Mechanical construction





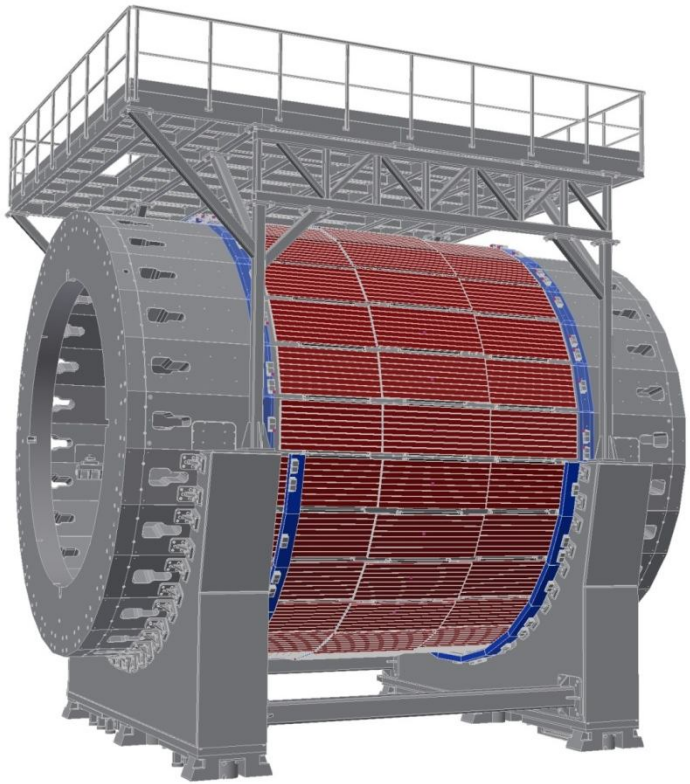
MCORD module, HUB, and cables system on the MPD surface.

Cable channels and HUBs are located next to the MCORD modules.

Cable channels and HUBs are located on MCORD modules.

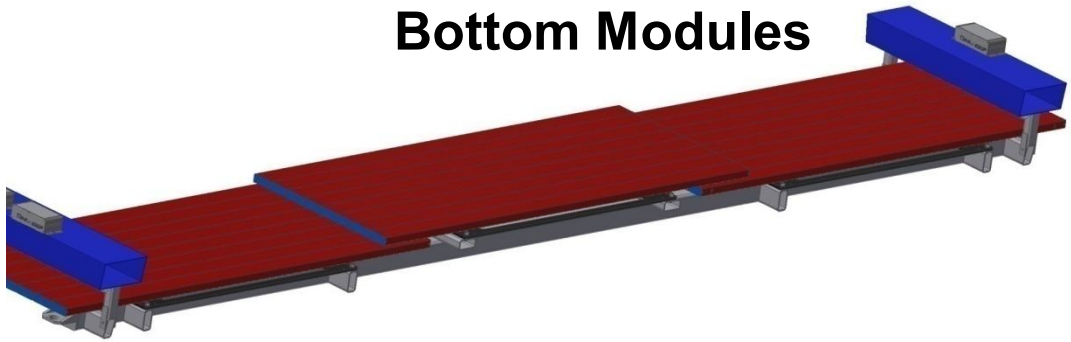
We chose an intermediate solution.

7. Mechanical construction

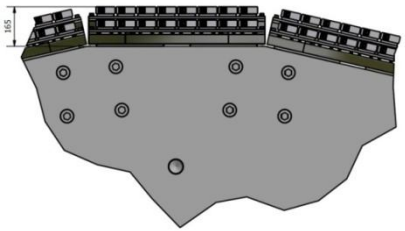


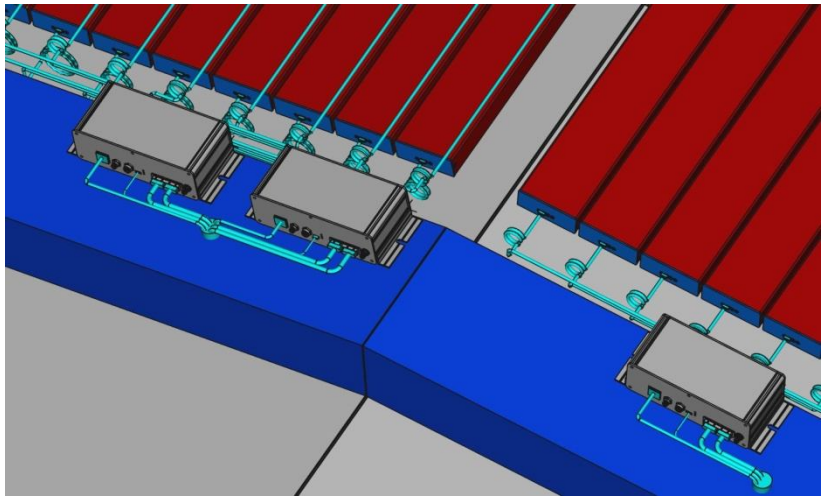
Upper Modules

Bottom Modules

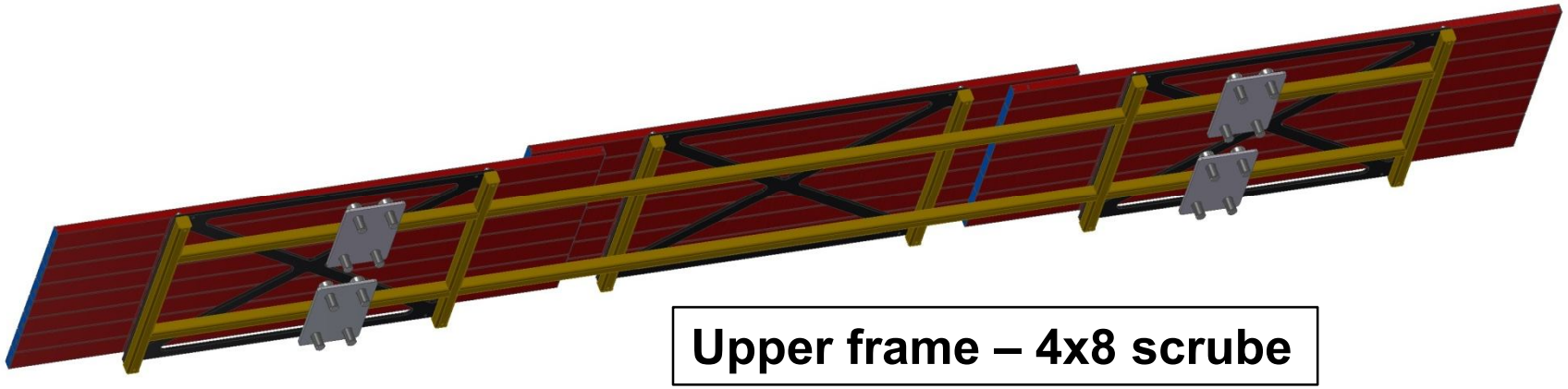


A (1 :10)



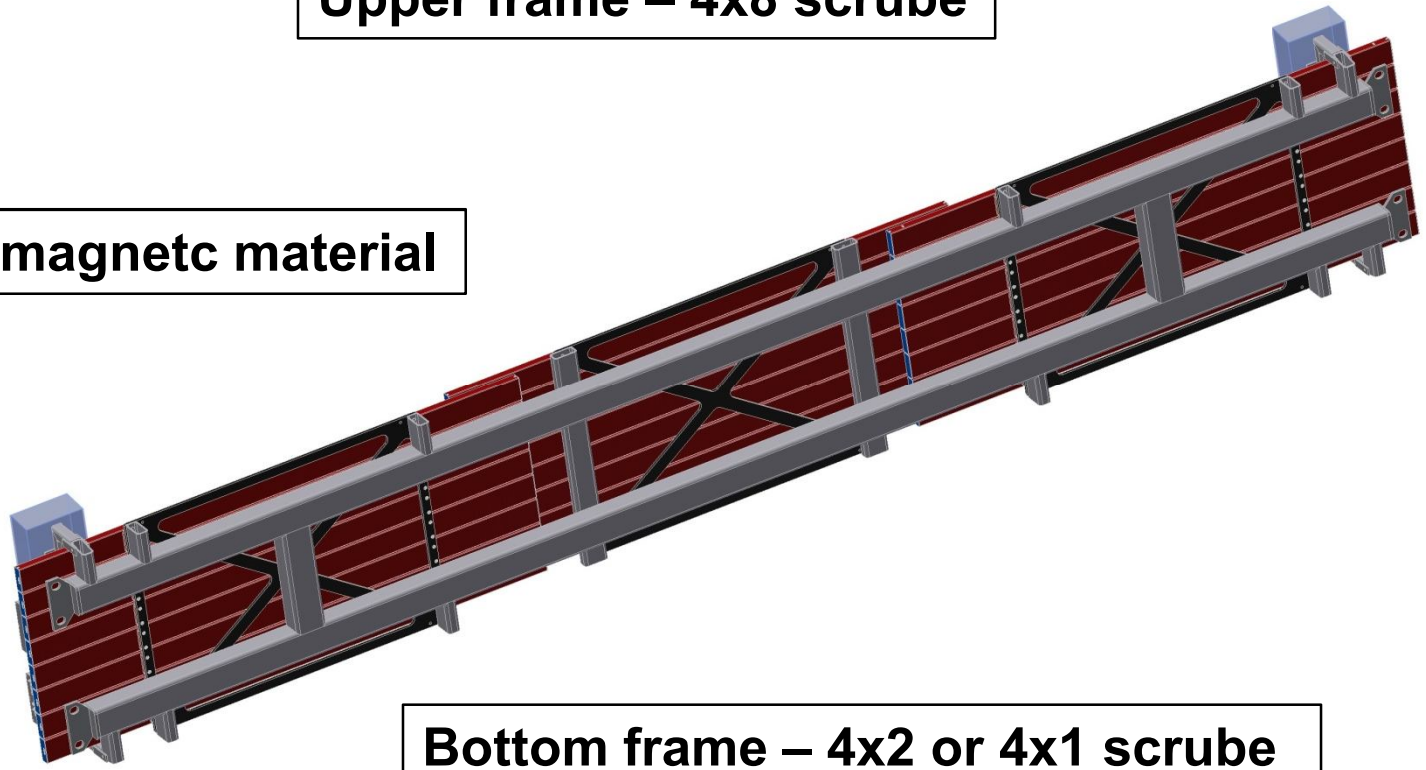


7. Mechanical construction



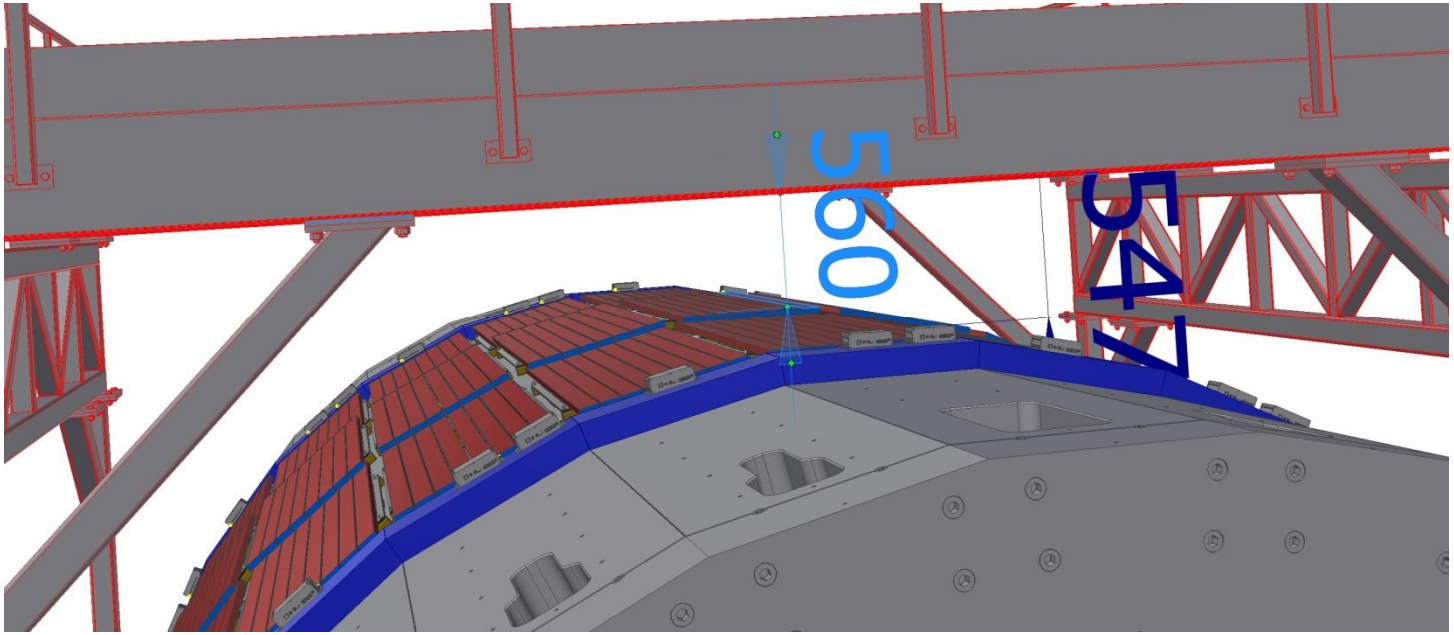
Upper frame – 4x8 scrube

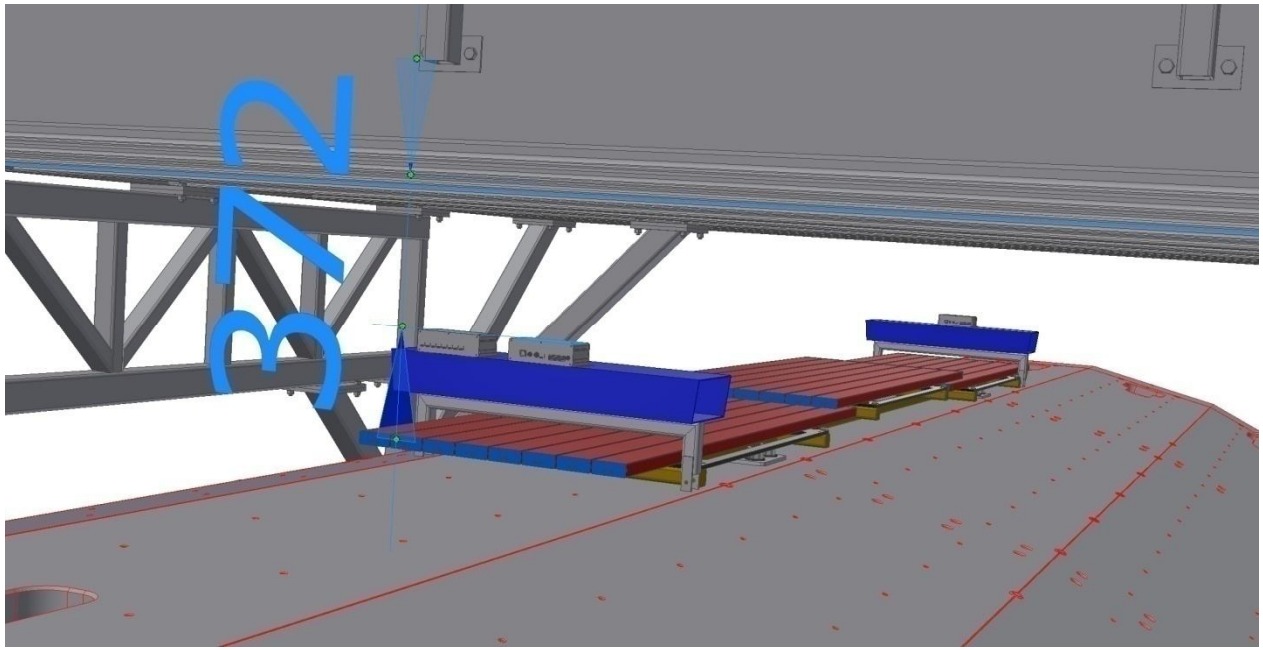
Aluminum not magnetc material



Bottom frame – 4x2 or 4x1 scrube

7. Mechanical construction





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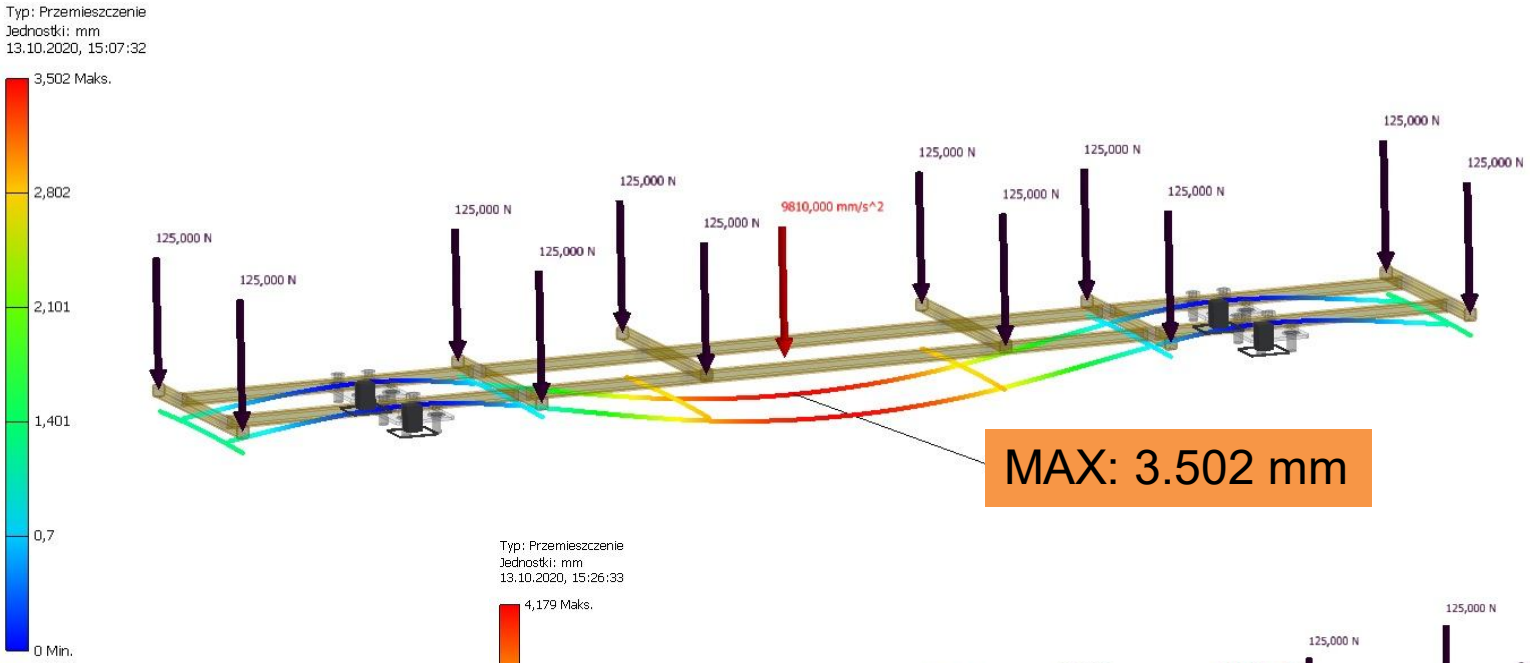
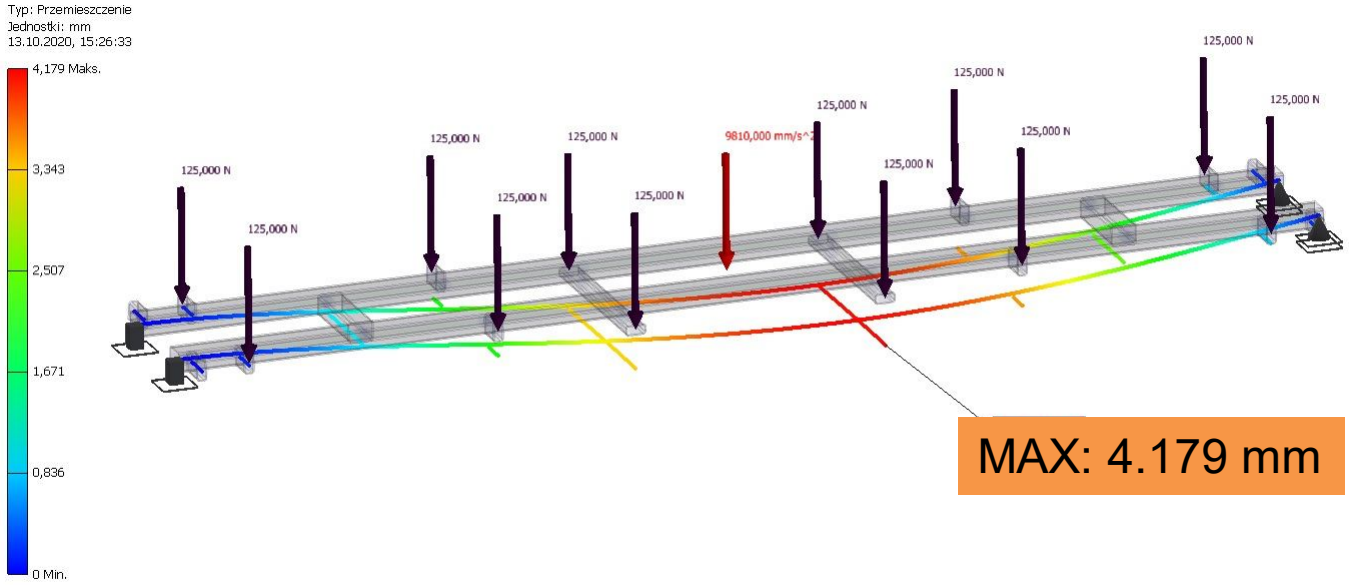
7. Mechanical construction



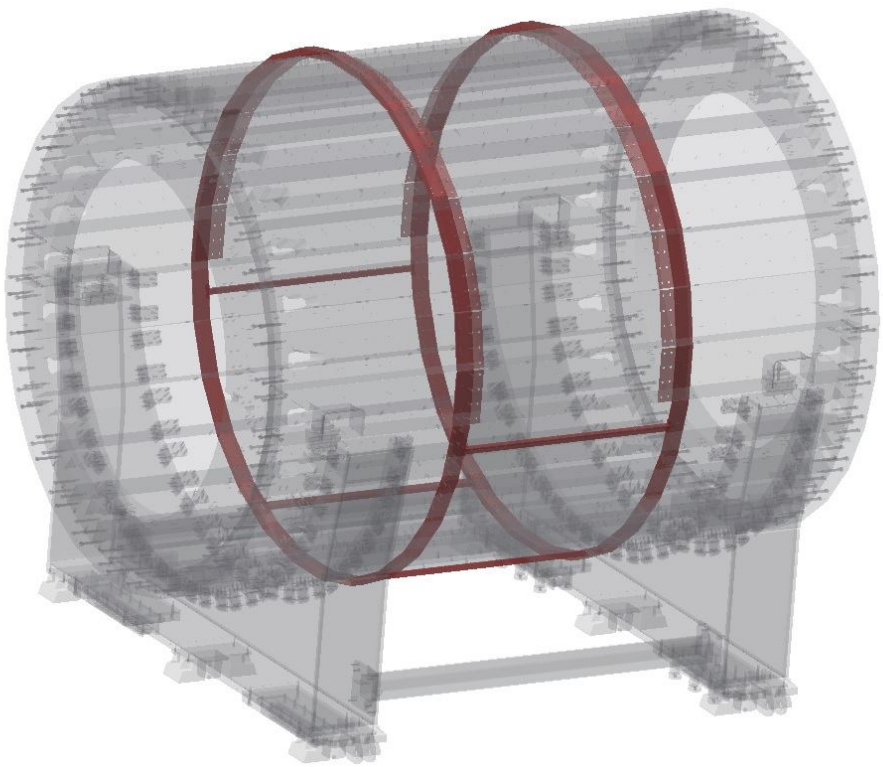


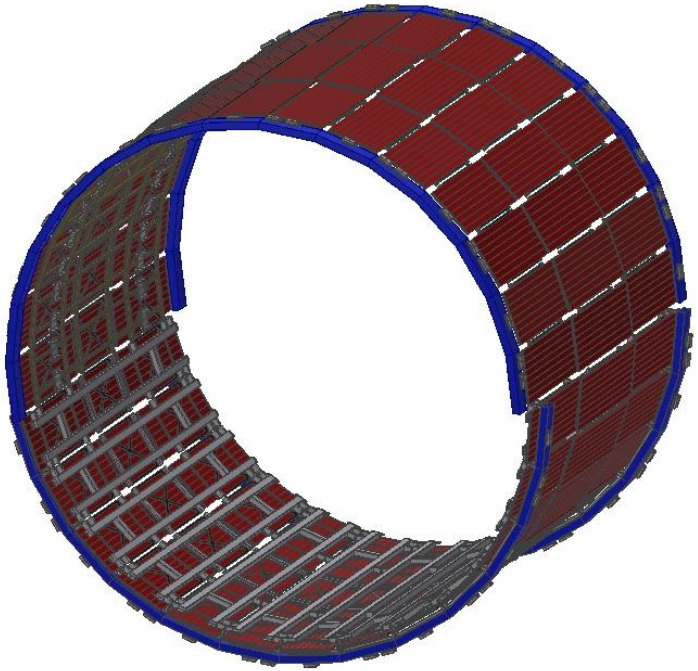
MCORD Frames strength calculations

Max. Deflection
3,5 or 4.2 [mm]
Normal stresses Smax
23,5 [MPa]
Safety factor
2,5

7. Mechanical construction

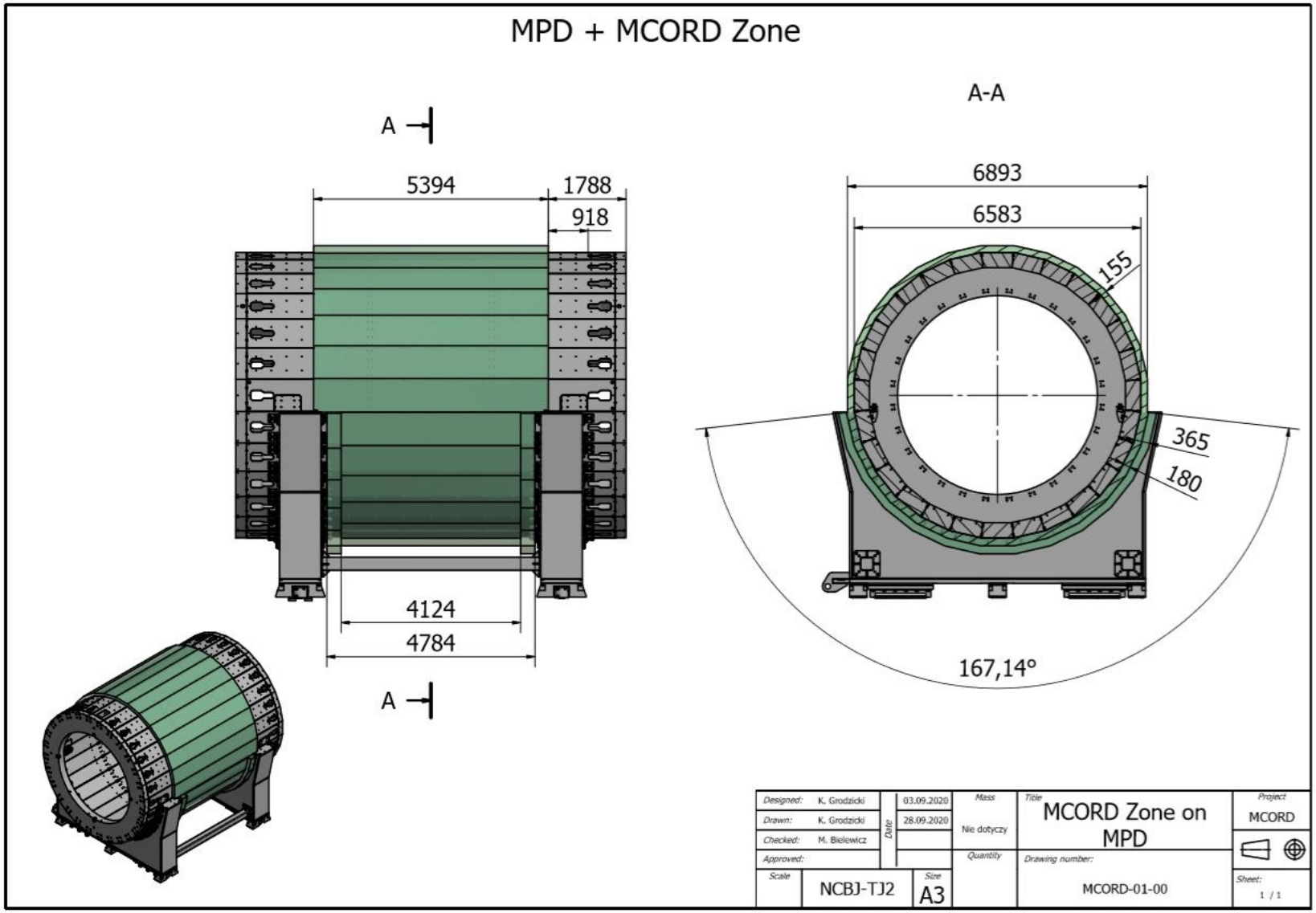
Alternative MCORD modules mounting





Alternative mounting via clasical one

7. Mechanical construction

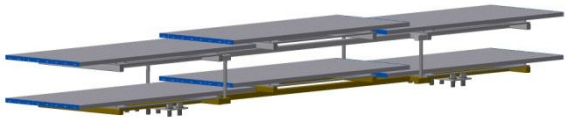


8. Summary

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



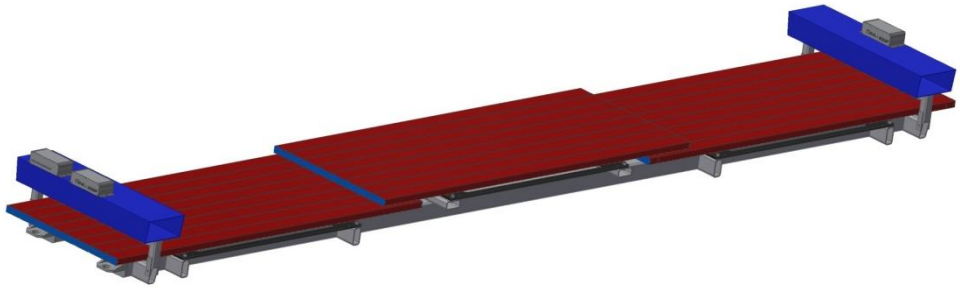
8. Summary

Description	USD
Scintillators	667 296 USD
SiPM sensors	172 200 USD
Aluminum profiles	9 408 USD
AFE modules	141 120 USD
USB-C cables	83 700 USD
Passive HUB	55 568 USD
SAS cables	55 568 USD
SMA cables	93 450 USD
FMC-TDC carts	79 976 USD
AMC-FMC carts	113 360 USD
MTCA crate	49 052 USD
PoE switch	3 845 USD
Module frames	210 000 USD
TOTAL	**1 687 475 USD**

Total cost of MCORD (without labor cost)

One MCORD Module: ~65 000 USD
One MCORD section: ~20 000 USD
First Sections: ~30 000 USD

Demonstrator: ~60 000 USD
(2 Sections)



Recommended startup setup for MPD sub-detectors calibration:

6 MCORD Modules

Total cost: ~400 000 USD

8. Summary

1. MCORD is necessary for calibration of TPC, TOF and ECAL detectors **during off-beam operation of the MPD (during and after instalation of other sub-detectors) .**

2. The demonstrator (2 MCORD sections) should be ready by the end of 2020 – **useful for TOF and ECal laboratory characterization**.

3. The first **6 MCORD modules** should be ready by the end of 2021 for **installation on MPD surface**.

4. We Ask MPD DAC for:
   Formal approval of MCORD CDR,
   Recomend finalization of MCORD TDR ,
   Recommend intensive detector construction activities

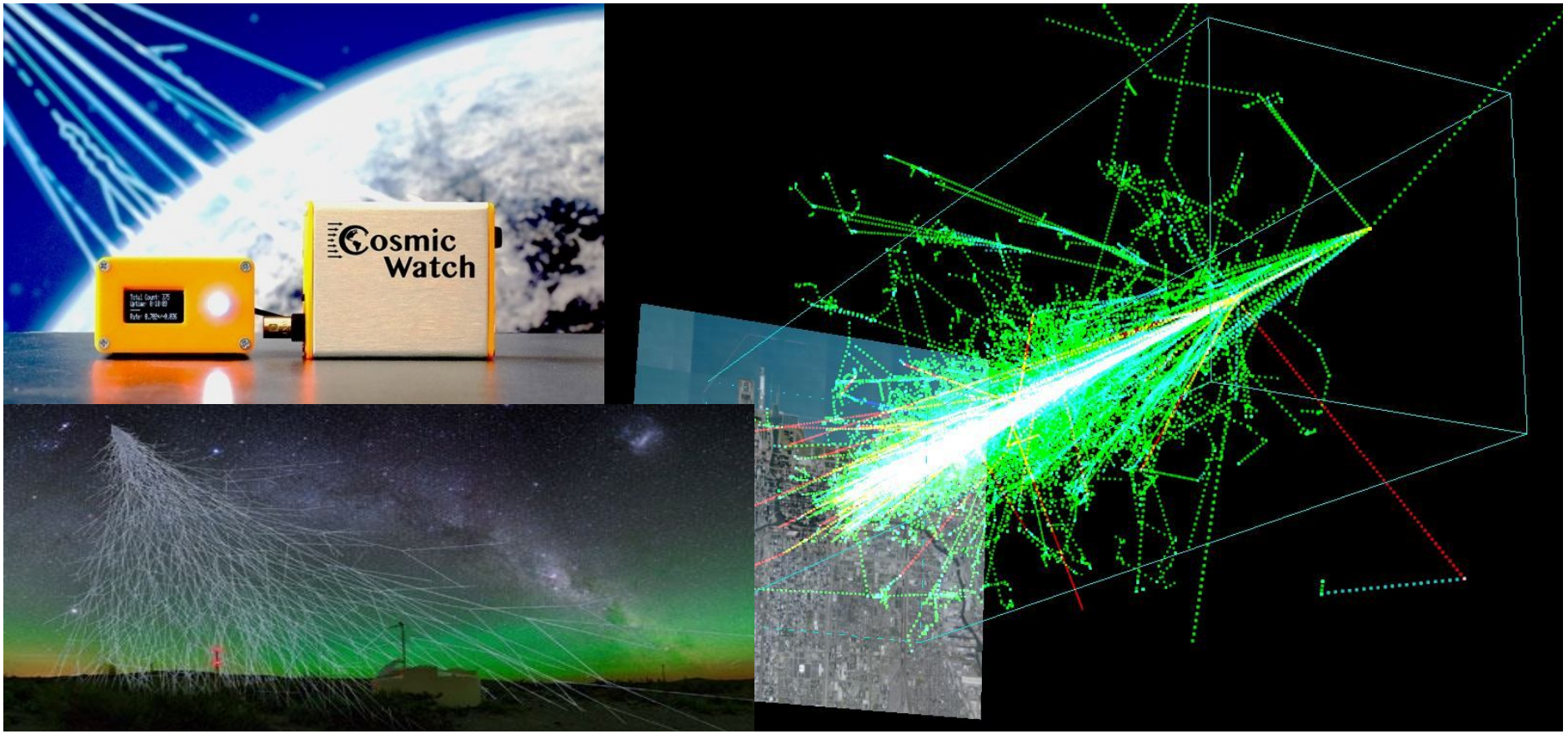
5. MCORD can be useful for identification of **high energy muons from ion-ion collisions**.

6. MCORD can be used for **unique astrophysics observations** similar to past collider experiments.

Thank You for Attention!

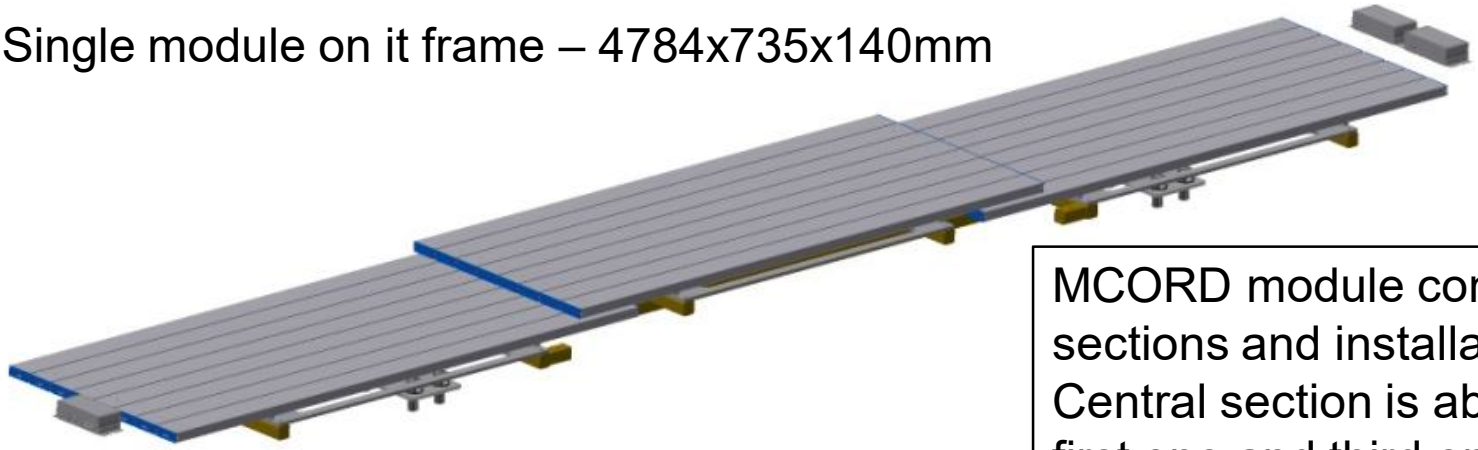
Polish consortium NICA-PL

Backup slides

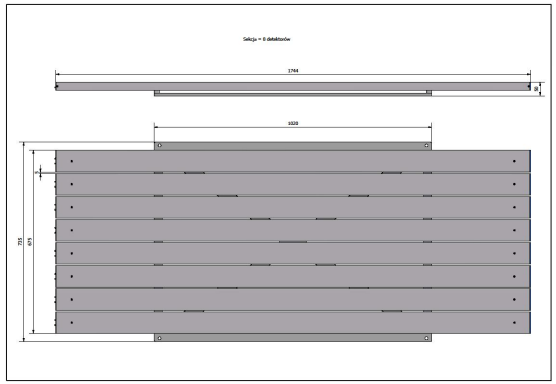


2. Detector

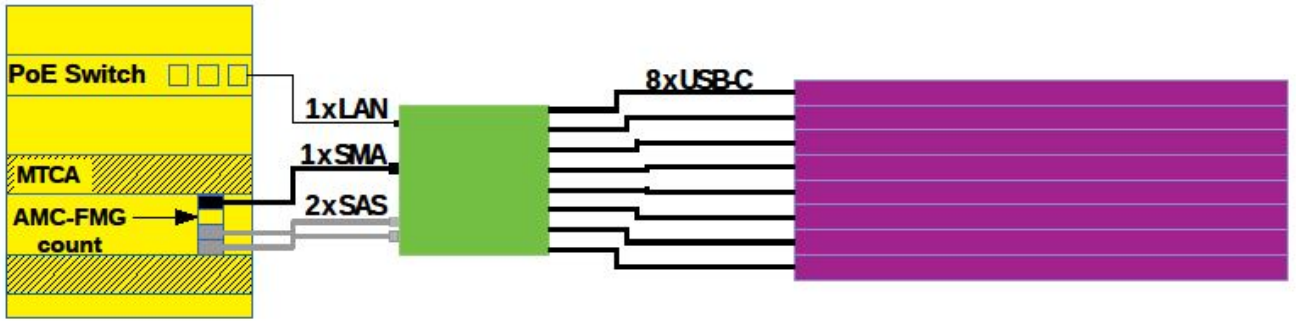
Single module on it frame – 4784x735x140mm



MCORD module consist three sections and installation frame. Central section is above the first one and third one.



Single section – 1744x735(675)x50

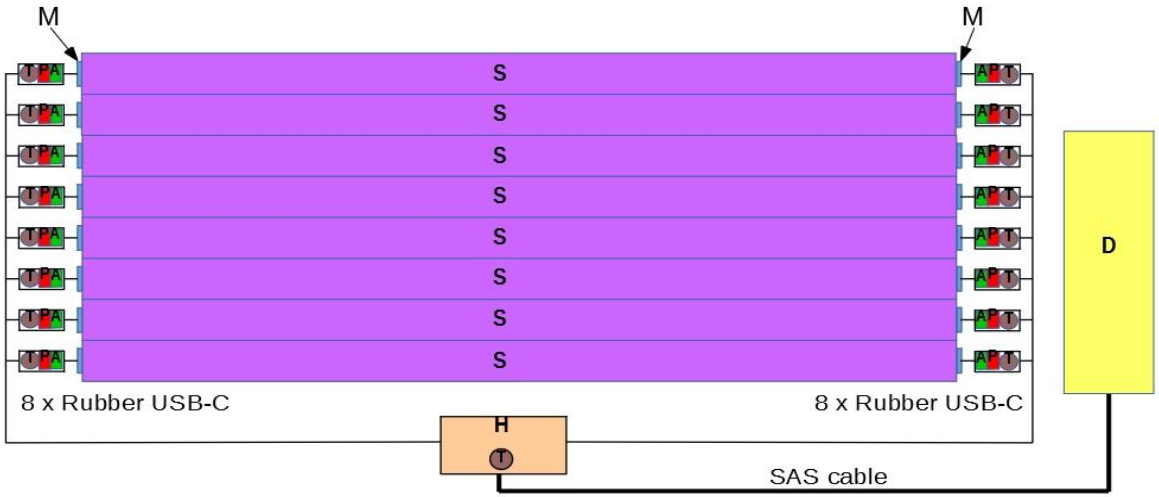


Basic element of MCORD
The Section+ electronic equip.

nica.jinr.ru/video/general_compressed.mp4

2. Detector

MCORD Section



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

Time Resolution –
about 300-500 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.

Muons detection – dileptons

Motivation for the study of muon production in nucleus-nucleus interactions with MCORD at NICA.

In the existing NICA program the study of e^+e^- dileptons is mentioned as one of important goals. When the available energy in the process is larger than the two muon mass ($2 \cdot 105 = 210$ MeV/c^2), the lepton universality lead to the production of muonic dileptons.

The major sources of dileptons are:

1. The decays of light scalar (η, η' …) and vector (ρ, ω , φ ..) mesons.
2. Open charm meson decays.
3. Drell-Yan processes.
4. Thermal muon pairs from dense, hot matter.
5. Possible decays of new, beyond SM, “dark” particles (dark photon and Higgs-like particles).

These are very rare processes

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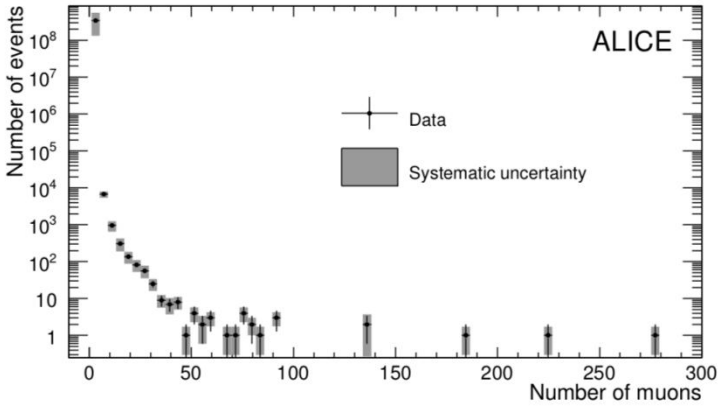
1. Astrophysics

• Recently, a new muon data type has been acquired from the extensive air showers (EAS) generated by primary cosmic rays (PRC), in particular multiplicity distribution of muons produced in EAS has been obtained.

• The existing ALEPH, DELPHI, and ALICE cosmic ray data contain information on muon production in EAS only for vertical showers (those with zenith angles not far from zero degree).



Comparisons with simulation results (KORSIKA+QGSJET) are in agreement for low multiplicities (for low energy). For high multiplicities (only few events) results are almost an order of magnitude above the simulations results.
Problem with current hadronic interaction model for extremely high energy >10E15 eV ???

• The proposed MCORD detector along with the MPD time projection show the unique opportunity of the very precise measurement of atmospheric muon multiplicity distributions as a function of the zenith angle of PRC, up to nearly horizontal showers. **Such measurements, up to now, were never possible.**

Bibliography:
Bruno Allesandro prezentation on ALICE collaboration workshop Feb 2013
ALICE Collaboration, JCAP 01 (2016) 032
K. Shtejer: CERN-THESIS-2016-371

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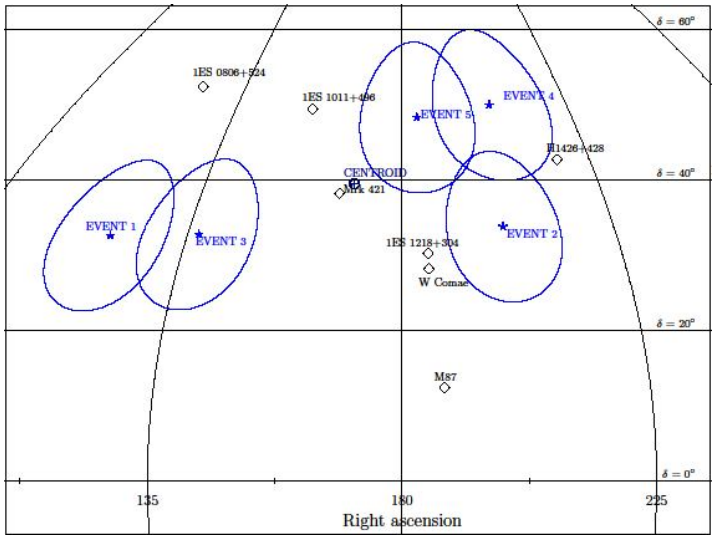
1. Astrophysics

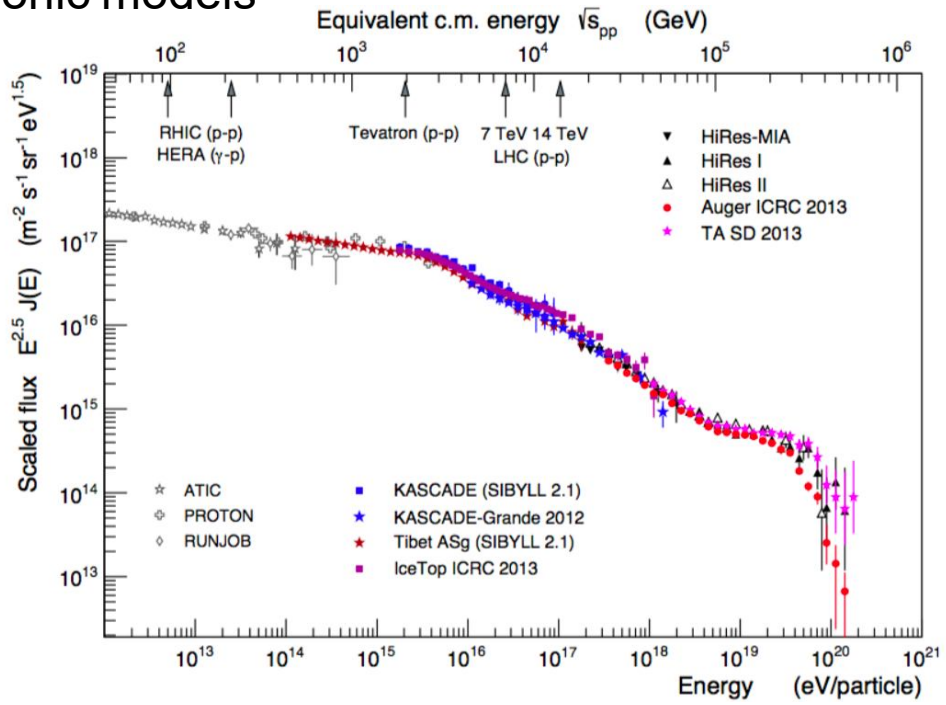
GZK-cutoff problem

- 4x10E19 eV
- 50 Mega Parsec
- Cosmic Microwave Background

Example: DECOR exp. 2002-2003y
(near horizontal observation (60-90 deg. angular range)
1-10 PeV primary particle) (see ref. 2)



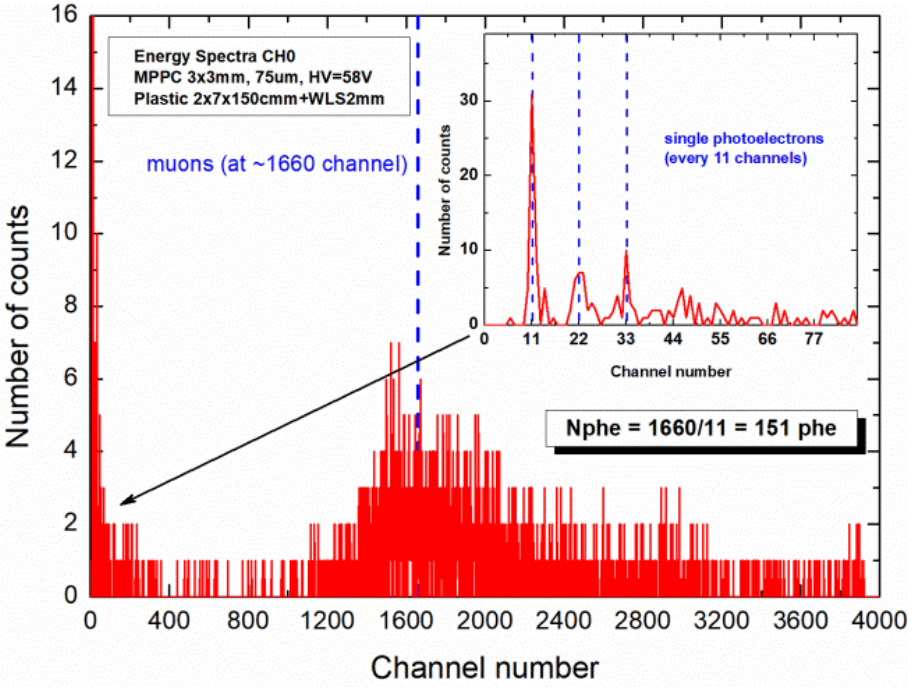
All-particle cosmic-ray energy spectrum derived from direct and indirect (air shower experiments) measurements, as well as results from different hadronic models

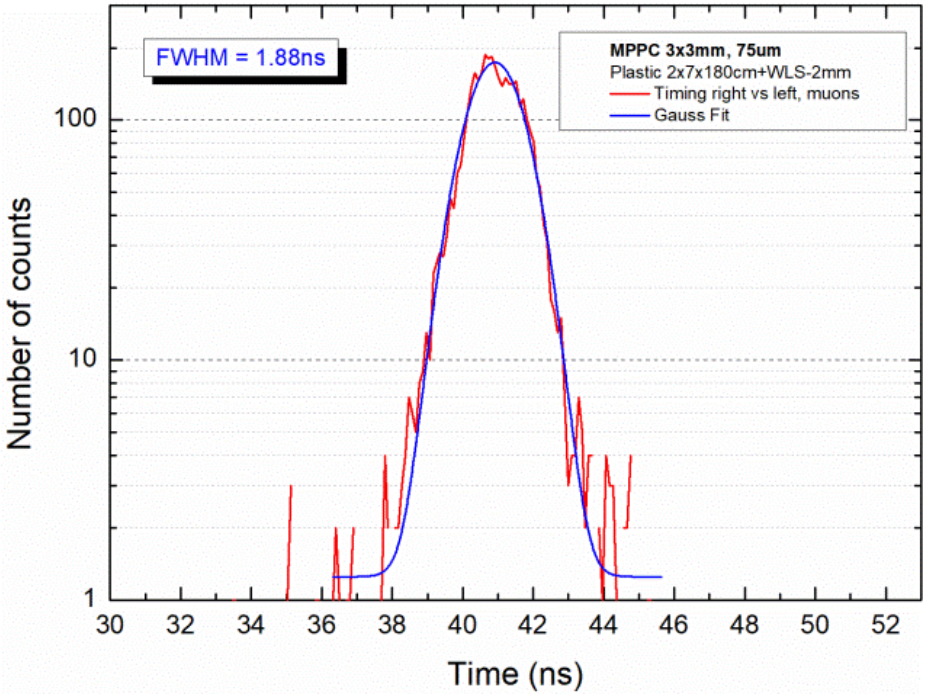


Very low statistics – many years of observation.
A special attention is paid to muon groups of large multiplicity.
Horizontal Events Experiments needs more data.

4. Laboratory tests

Plastic (150 x 7.2 x 2.2 cm) + WLS fiber (2 mm)
MPPC 3 x 3 mm (pixel size 75um)

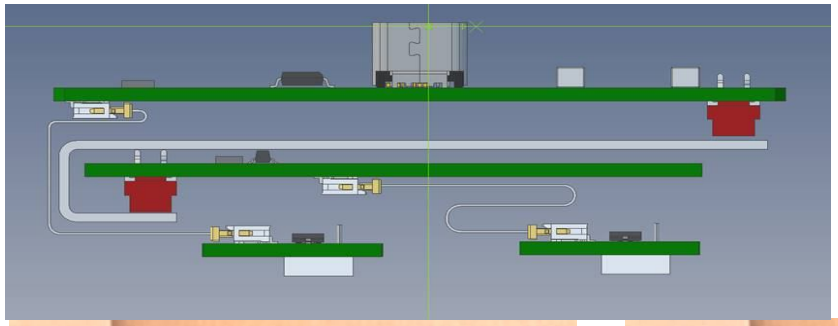


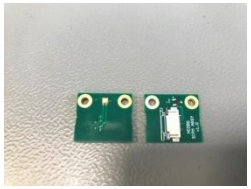


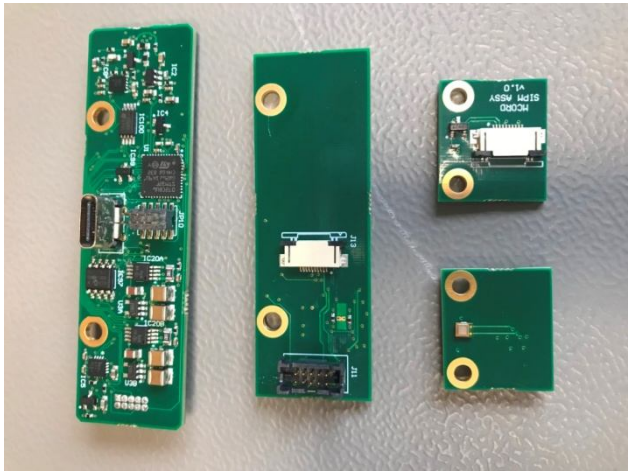
Number of detected photons = 150
CRT (σ) = 0.80 ns ===> σ_x = 6.1 cm

2. Present status of work

Fron-End electronic equipments and PCB bords







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2. Testing procedure

Laboratory tests at NCBJ Swierk

Summary of Tests of Silicon Photomultipliers for MCORD

Test procedure

1. Installation of SiPM sensors on electronic boards - checking if SiPM works (in a dark chamber or on a prepared stand), power connection. Is there a signal from SiPMa? What current (range)? Are there noises?

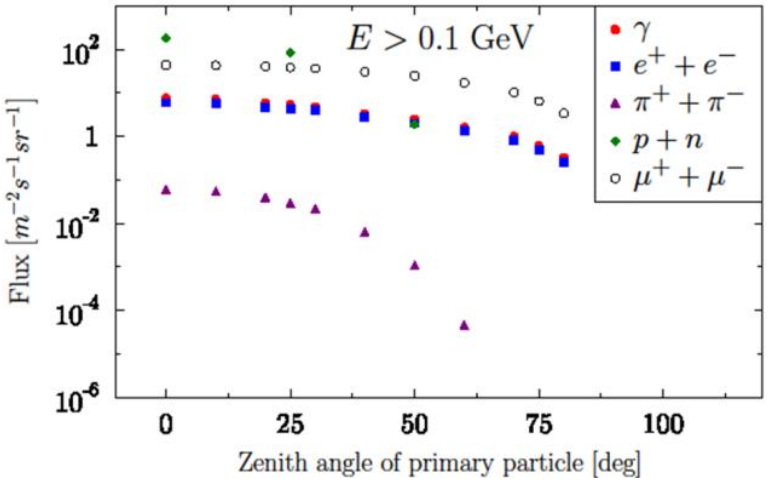
2. Testing a scintillator with optical fiber - light source and receiver

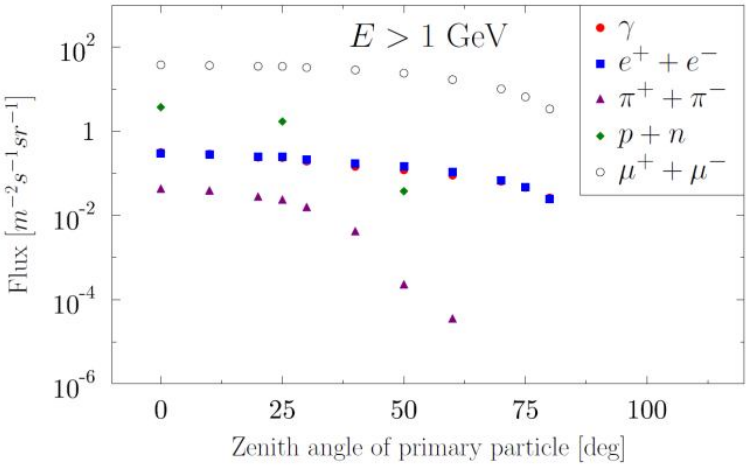
3. Installation in an aluminum profile and dedicated electronics and fixings - the last test on the table. SiPMa test - single photoelectron spectrum - dark current (few minutes). Cobalt test - energy spectrum and timing (several minutes). Cosmic muons (trigger plus up to 3 scintillators on top of each other) (24 hours)

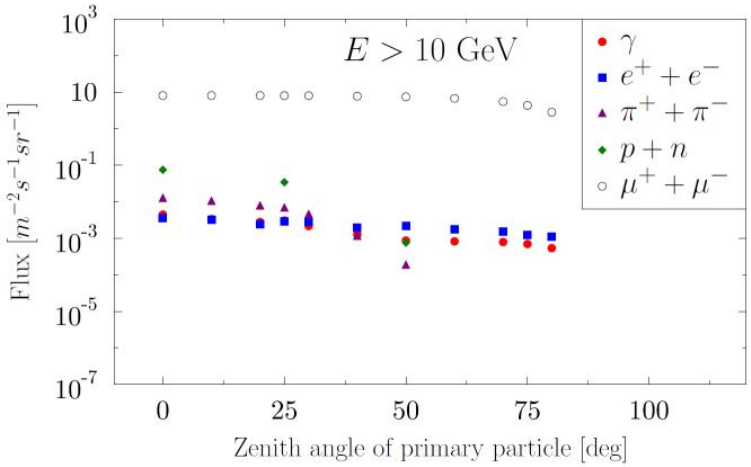
4. Test of several scintillators (4 or 8 pcs) placed crosswise (or two sections of 16 pcs). The test if the software detects the passage of particles through any two pairs. When the scintillators are placed crosswise, we get as many signals as there are intersection points.

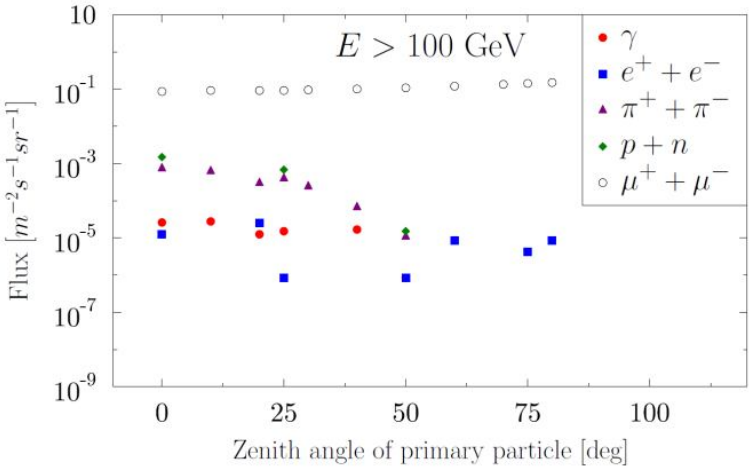
5. Assembly of sections plus test documentation.

6. Simulations









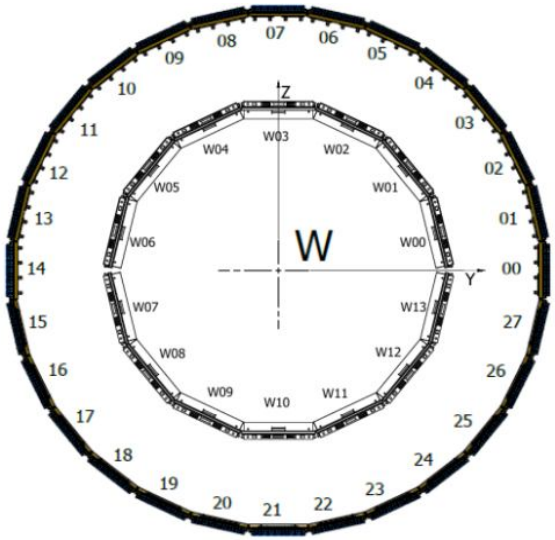
Angular distributions of Extensive Air Shower components.
Location near and see level at Dubna city, with energies above fourth thresholds.
Corsika 7.74 code sumullation (model QGSJETII-04 + UrQMD).

6. Simulations

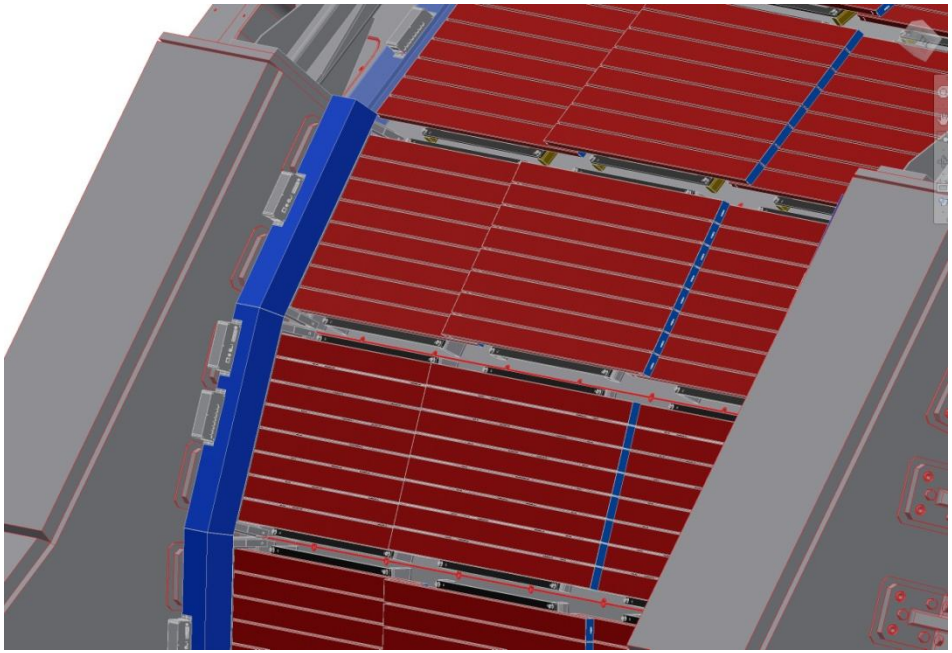
TPC and ToF calibration using MCORD triggers

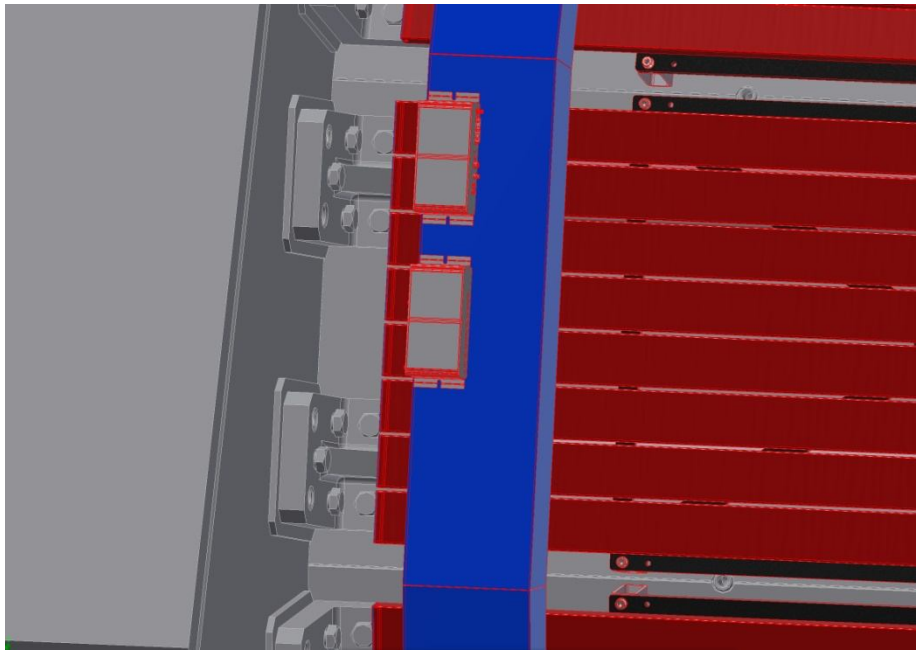
MCORD configuration	MCORD modules (ID numbers)	ToF modules (ID numbers)	MCORD & ToF (tracks per hour)	MCORD & ToF & TPC (tracks per hour)
F	(6 or 7 or 8) and (20 or 21 or 22)	3 and 10	84558	77460
G	(4 or 5 or 6) and (18 or 19 or 20)	2 and 9	68853	63792
H	(2 or 3 or 4) and (16 or 17 or 18)	1 and 8	34244	31740
I	(0 or 1 or 2) and (14 or 15 or 16)	0 and 7	6136	5682

Calculated for muons with momentum
p > 0.1 GeV/c.



7. Mechanical construction





7. Mechanical construction

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