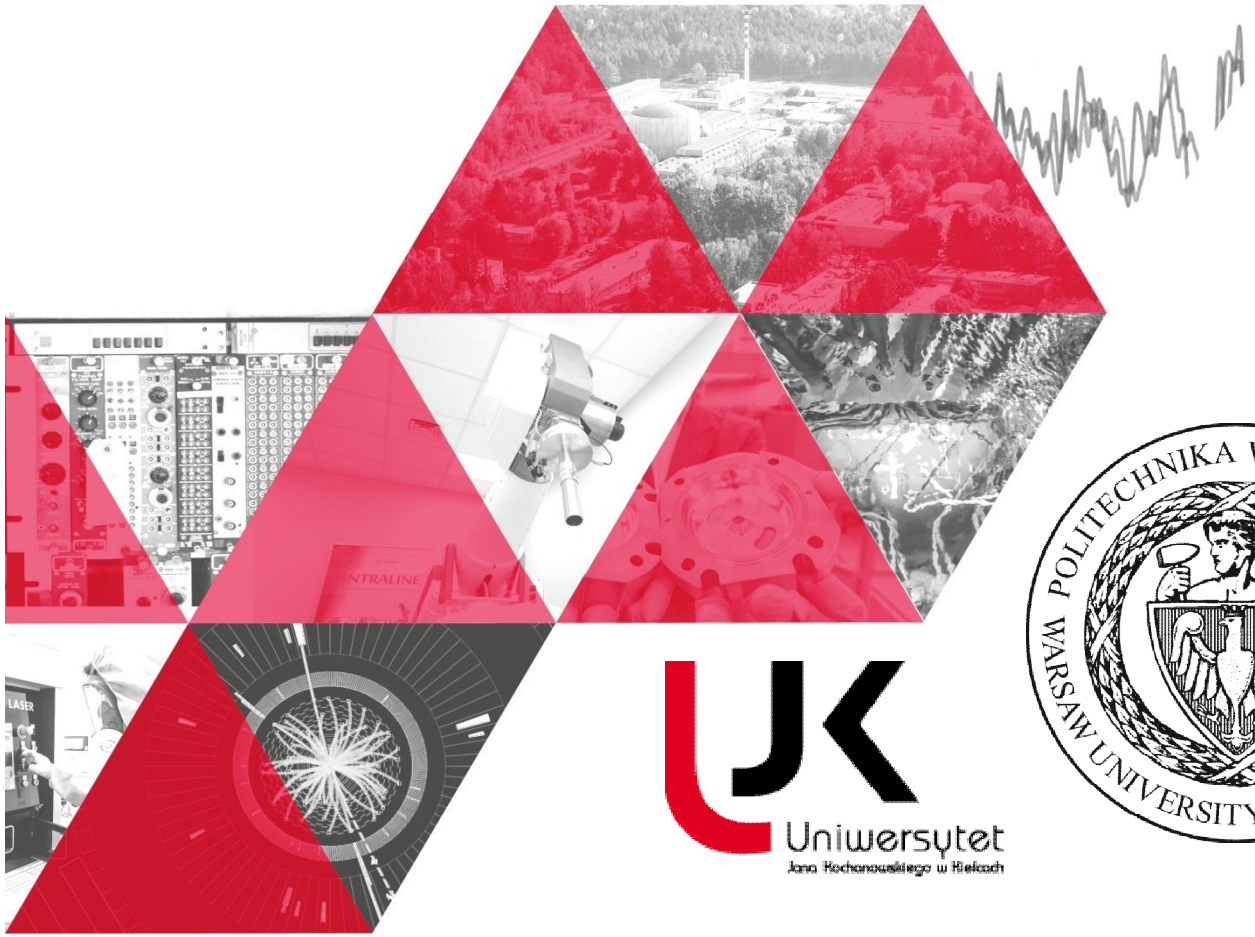
Cosmic Ray Detector for MPD (MCORD)

Dr. Marcin Bielewicz

for Polish consortium NICA-PL



NARODOWE CENTRUM BADAŃ JĄDROWYCH ŚWIERK

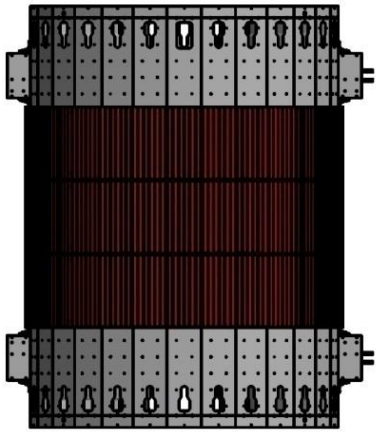
Uniwersytet Jana Kochanowskiego w Kielcach

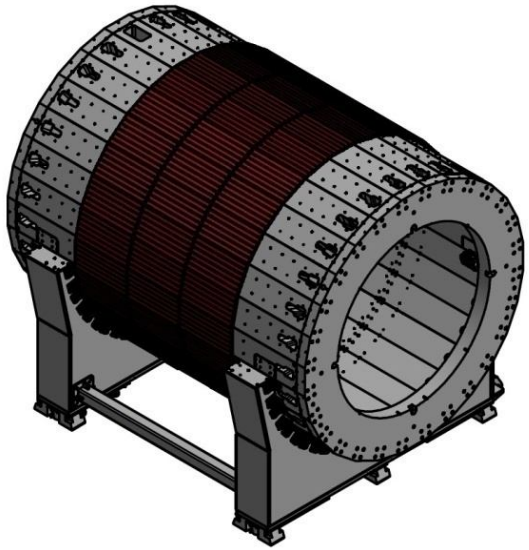
POLITECHNIKA WARSZAWSKA
WARSAW UNIVERSITY OF TECHNOLOGY

JINR

Outline

- Motivation
- MCORD
- Demonstrator
- Symulation
- Conclusions



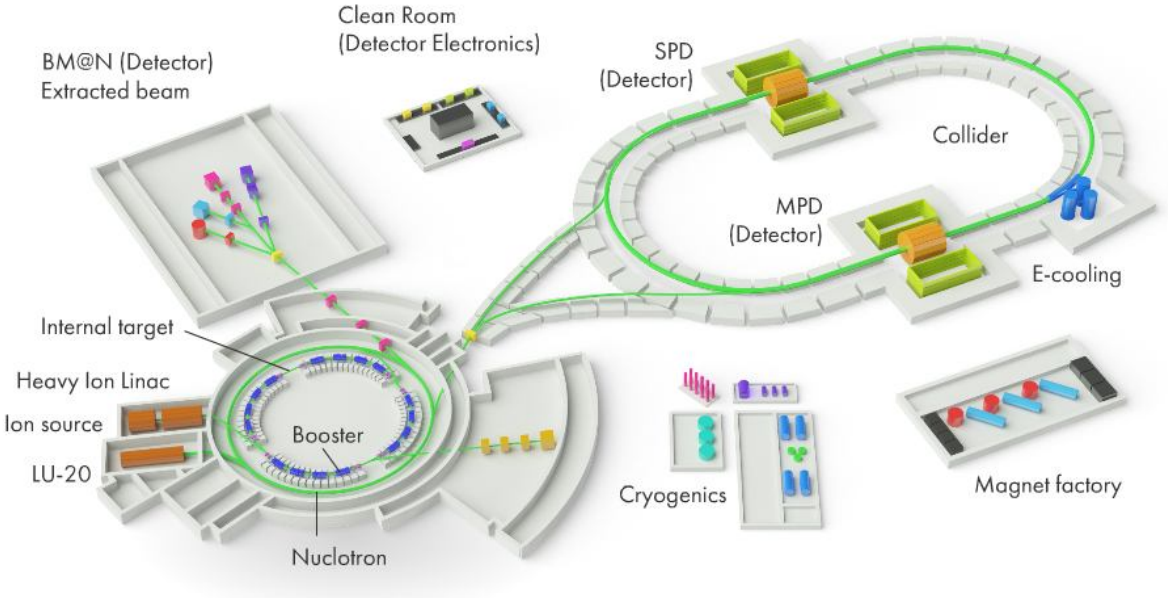


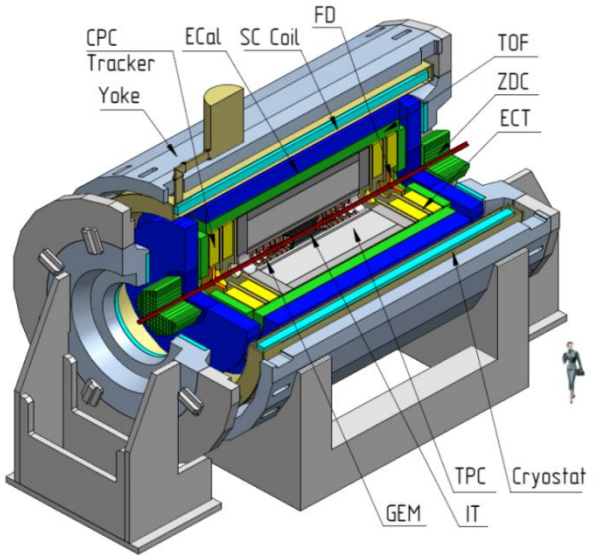
NICA complex - Glossary

NICA - **N**uclotron **I**on **C**ollider f**A**cility

MPD - **M**ulti-**P**urpose **D**etector

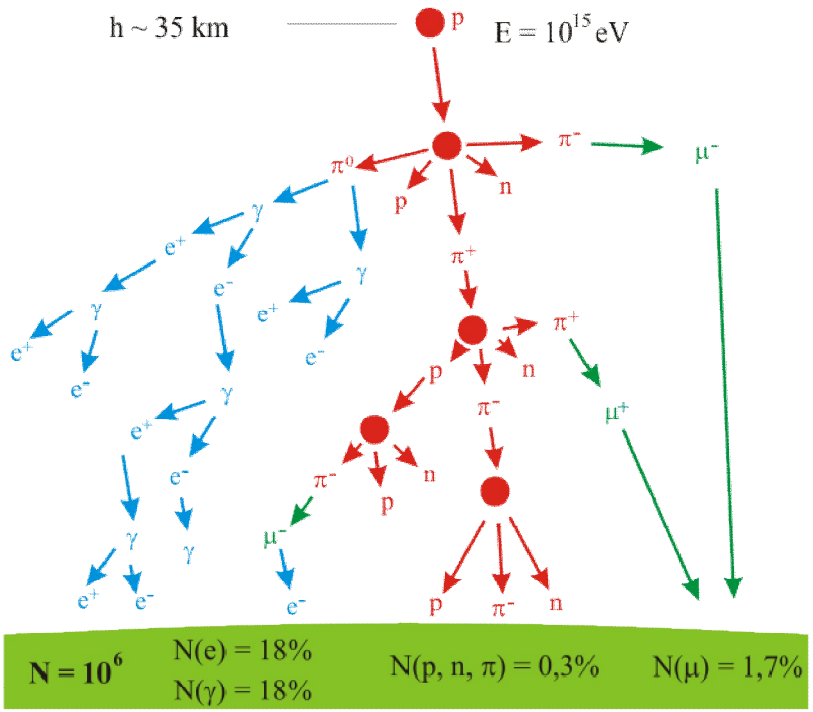
MCORD - **M**PD **C**osmic **R**ay **D**etector



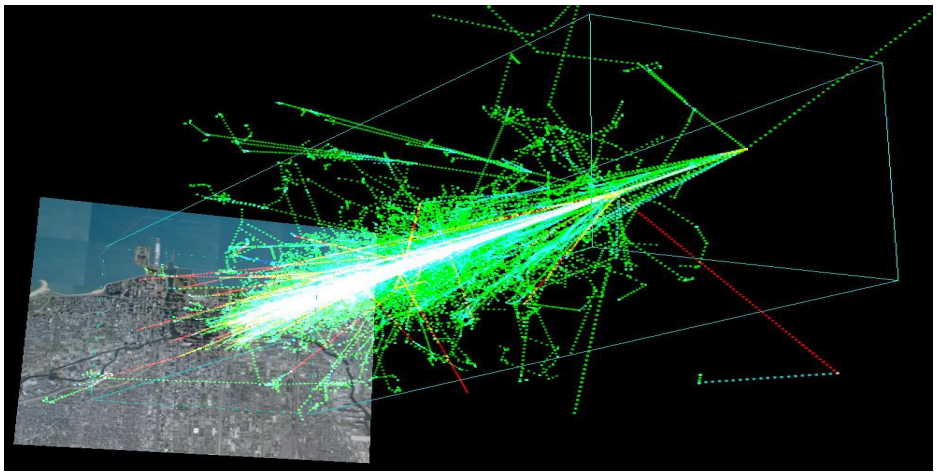


NICA complex - Cosmic Ray

PRIMARY PARTICLE



GROUND LEVEL

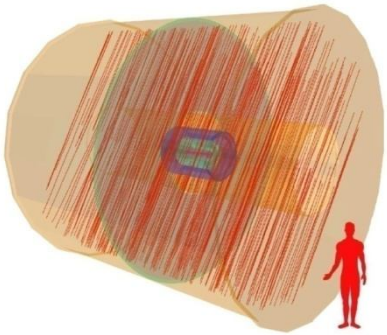


Cosmic ray air shower created by a 1TeV proton hitting the atmosphere 20 km above the Earth. The shower was simulated using the AIRES package.

1. Introduction

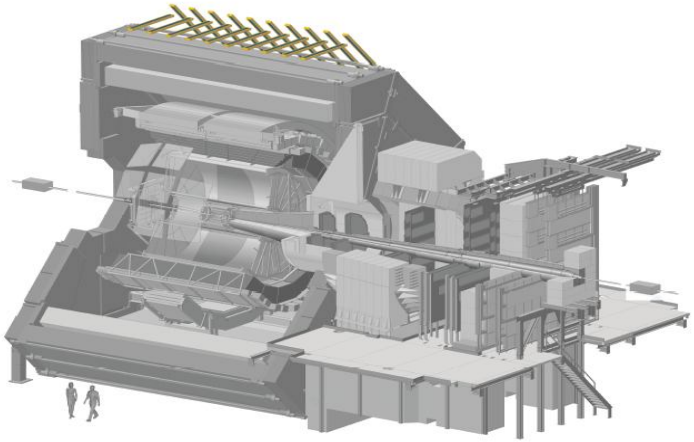
MCORD applications for MPD

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

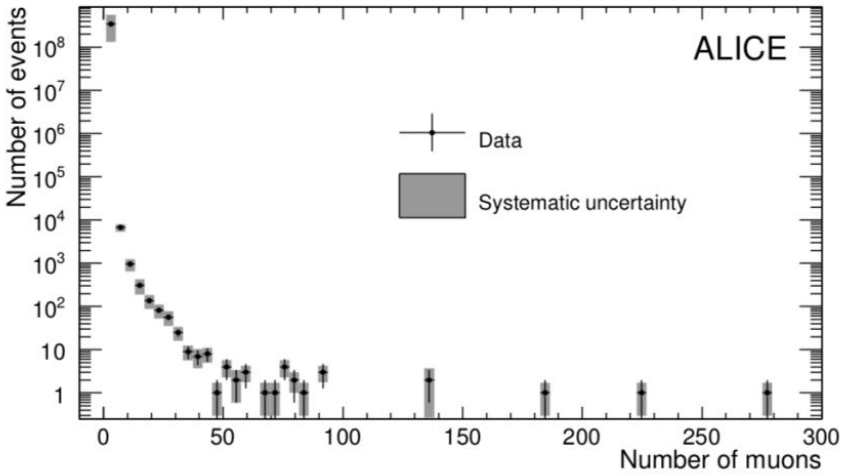


Ad. 3 Astrophysics

Examples from other experiments

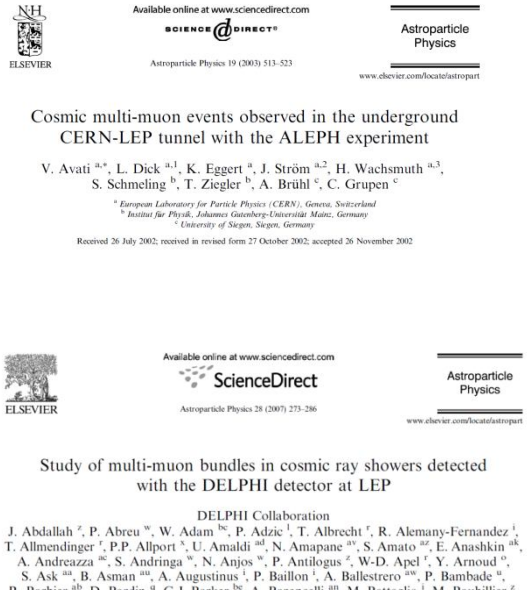


ALICE Exp.
55 m under.
thr. 16 GeV
2010-2013 y



ALEPH Exp.
140 m under. (thr. 70 GeV)
(1997-99y)

DELPHI Exp.
100 m under. (thr. 52 GeV)
(99-2000y)



Available online at www.sciencedirect.com
SCIENCE DIRECT®
Astroparticle Physics
Astroparticle Physics 19 (2003) 513–523
www.elsevier.com/locate/astropart

Cosmic multi-muon events observed in the underground CERN-LEP tunnel with the ALEPH experiment

V. Avati [a,*], L. Dick [a,1], K. Eggert [a], J. Ström [a,2], H. Wachsmuth [a,3], S. Schmeling [b], T. Ziegler [b], A. Brühl [c], C. Grupen [c]

[a] European Laboratory for Particle Physics (CERN), Geneva, Switzerland
[b] Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany
[c] University of Siegen, Siegen, Germany

Received 26 July 2002; received in revised form 27 October 2002; accepted 26 November 2002

Available online at www.sciencedirect.com
ScienceDirect
Astroparticle Physics
Astroparticle Physics 28 (2007) 273–286
www.elsevier.com/locate/astropart

Study of multi-muon bundles in cosmic ray showers detected with the DELPHI detector at LEP

DELPHI Collaboration

J. Abdallah [z], P. Abreu [w], W. Adam [bc], P. Adzic [j], T. Albrecht [r], R. Alemany-Fernandez [i], T. Allmendinger [r], P.P. Allport [s], U. Amaldi [ad], N. Amapane [av], S. Amato [az], E. Anashkin [ak], A. Andreazza [ac], S. Andringa [w], N. Anjos [w], P. Antilogus [z], W-D. Apel [r], Y. Arnoud [o], S. Ask [aa], B. Asman [au], A. Augustinus [i], P. Baillon [i], A. Ballestrero [aw], P. Bambade [u],

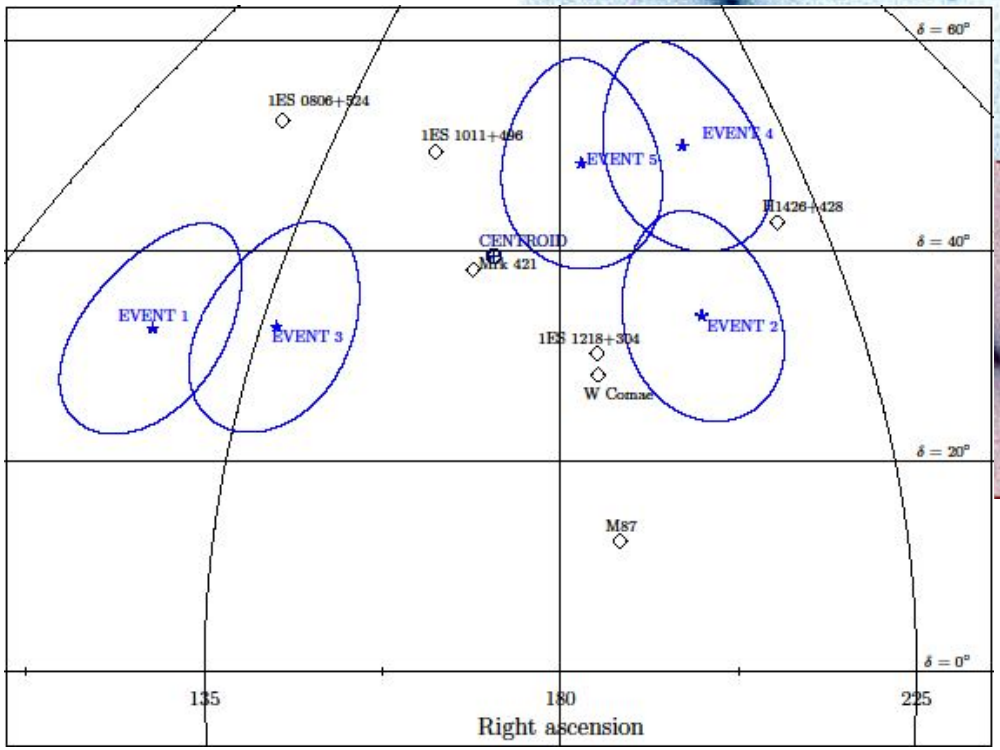
For high multiplicities (only few events) results are almost an order of magnitude above the simulations results.

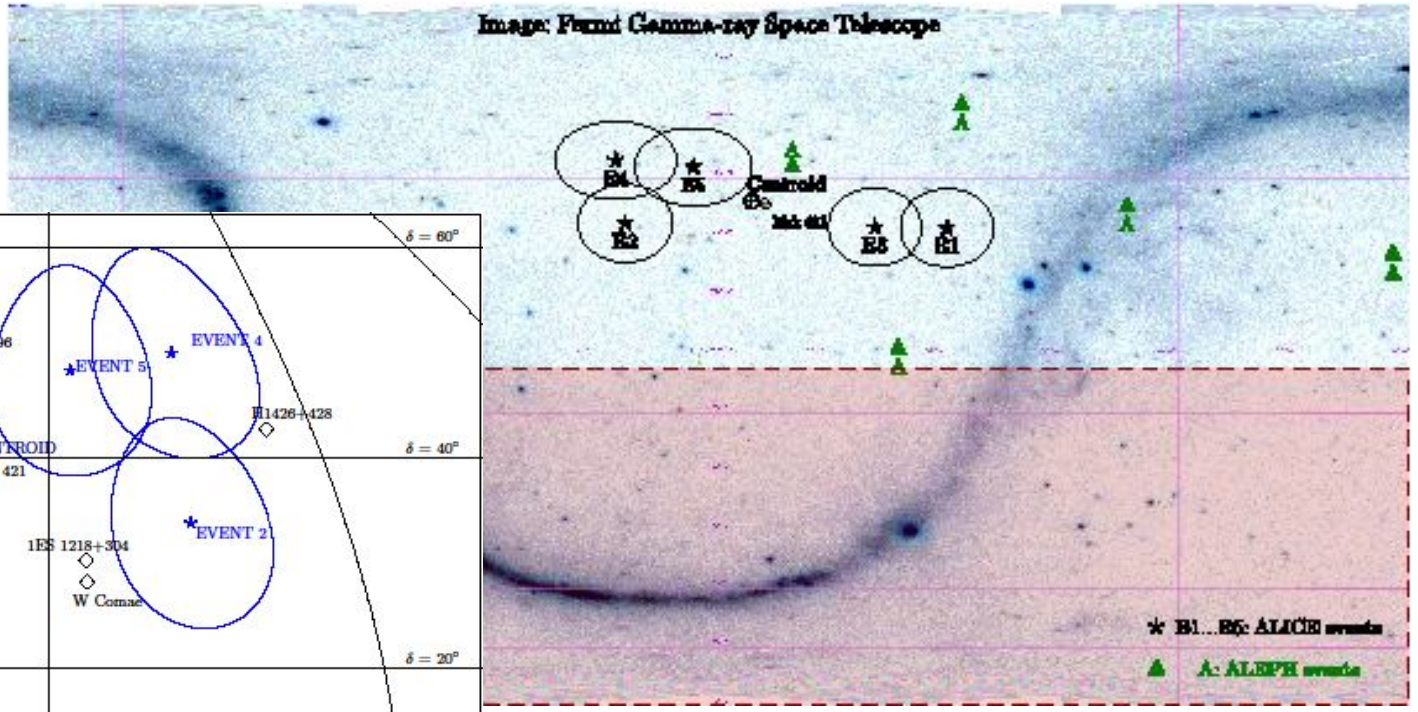
Problem with current hadronic interaction model for extremely high energy >10E15 eV ???

NARODOWE CENTRUM BADAŃ JĄDROWYCH ŚWIERK

Ad. 3 – Astrophysics

The position identification of Extremely high energy particle source





ALICE (multi events data) sphere position recognition

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

Ad. 3 – Astrophysics

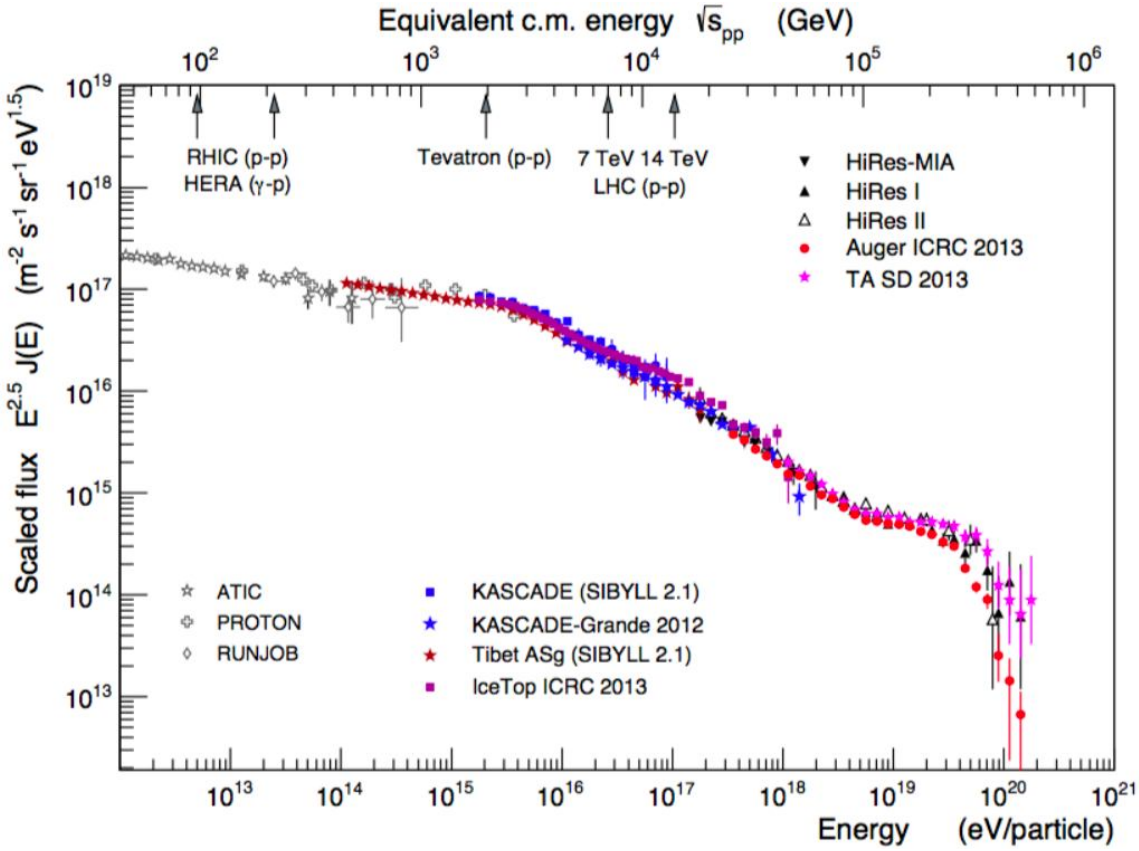
GZK-cutoff problem

- 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)

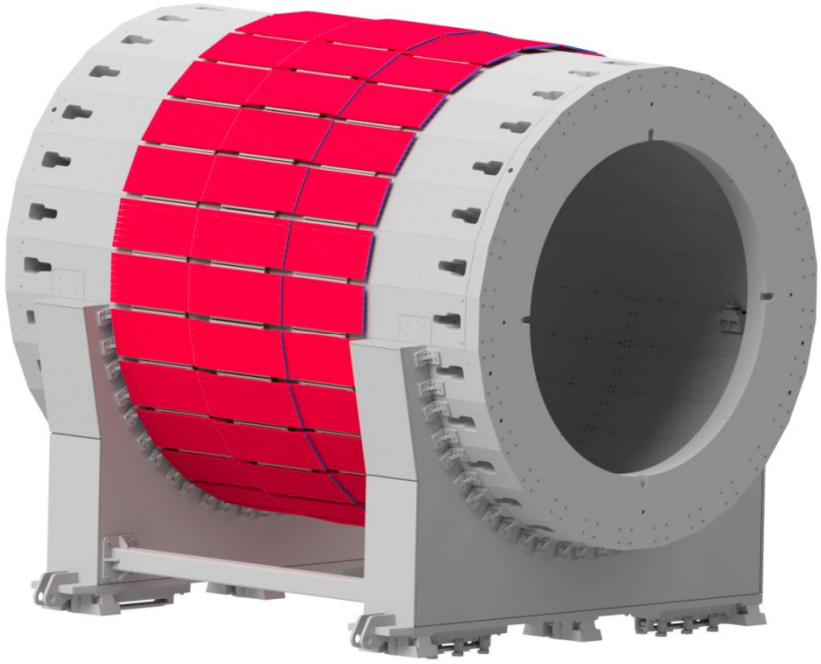
Bibliography:

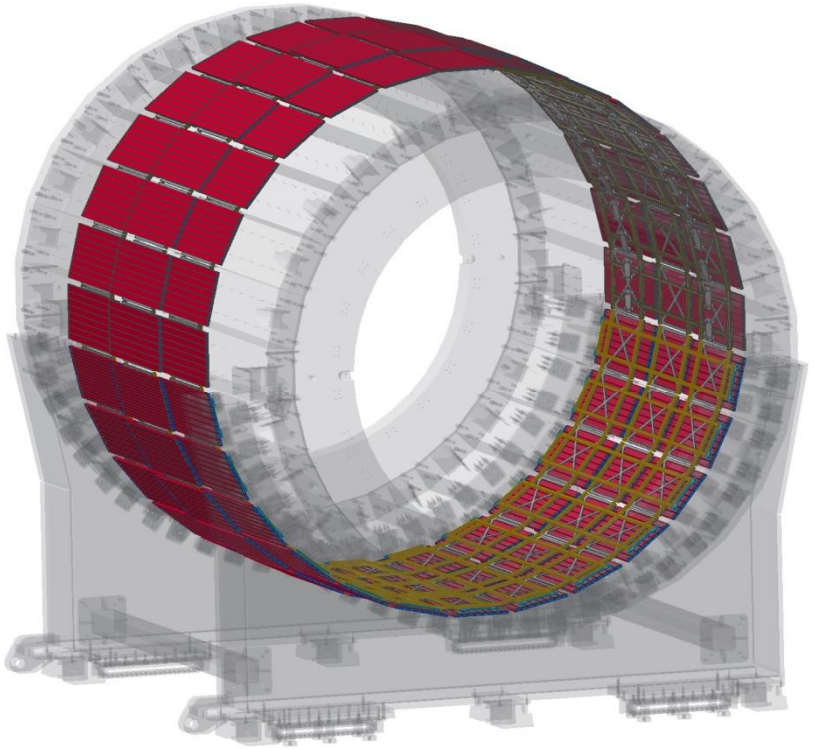
1. Pavluchenko, V. P.; Beisembaev, R. U., Muons of Extra High Energy Horizontal EAS in Geomagnetic Field and Nucleonic Astronomy, 1995 ICRC....1..646P
2. Yashin I. et al., Investigation of Muon Bundles in Horizontal Cosmic, 2005 (28) ICRC p.1147-1150
3. Neronov A. et al., Cosmic ray composition measurements, 2017, arXiv:1610.01794v2 [astro-ph.IM]
4. Shih-Hao Wang, 2017_Cosmic ray Detection ARIANNA Station, PoS ICRC2017_358



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

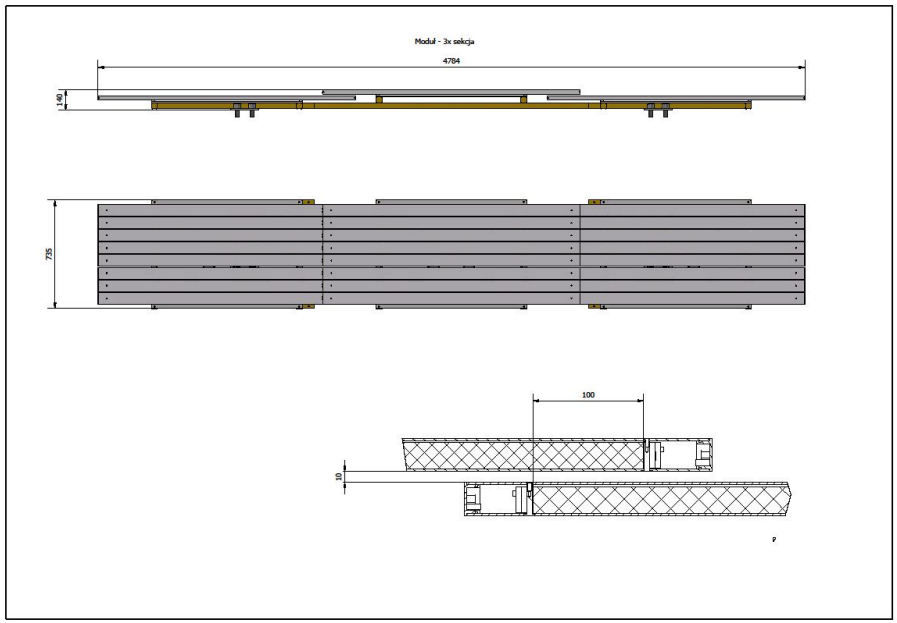
MCORD – 28 Modules

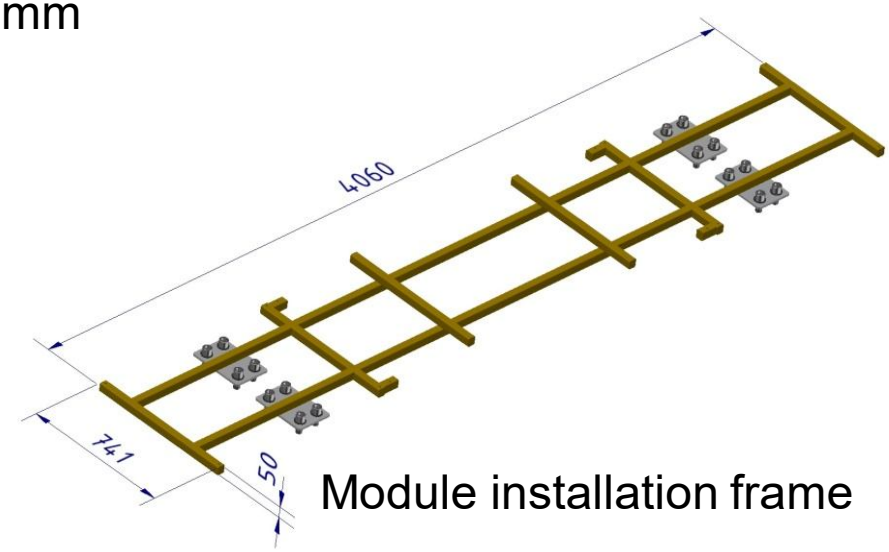




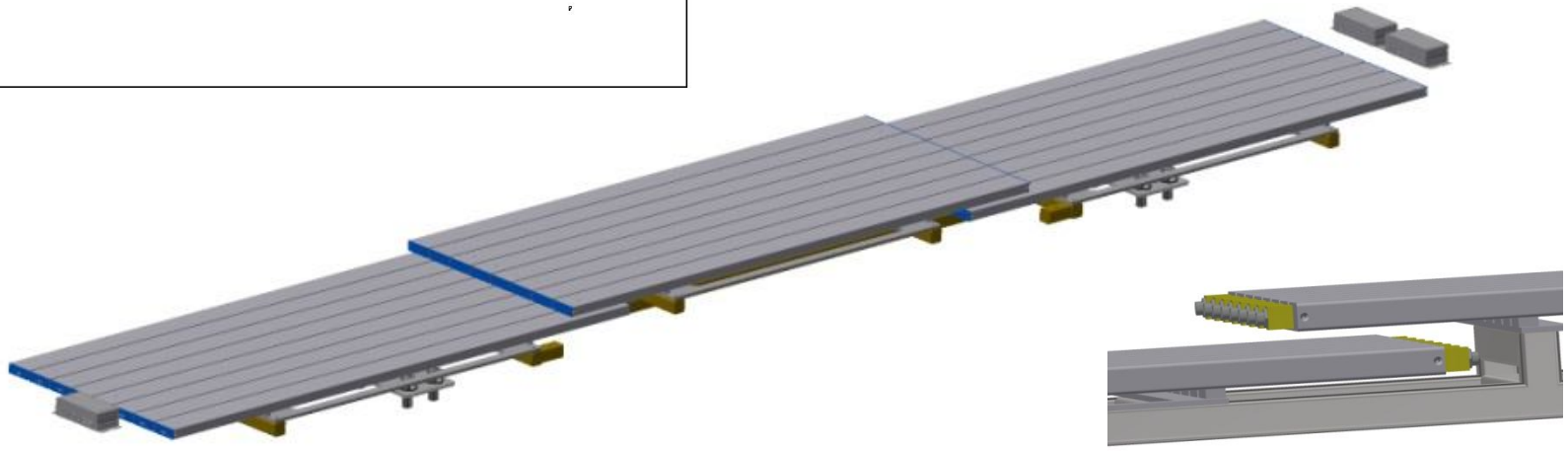
1. MCORD module

Single module on it frame – 4784x735x140mm





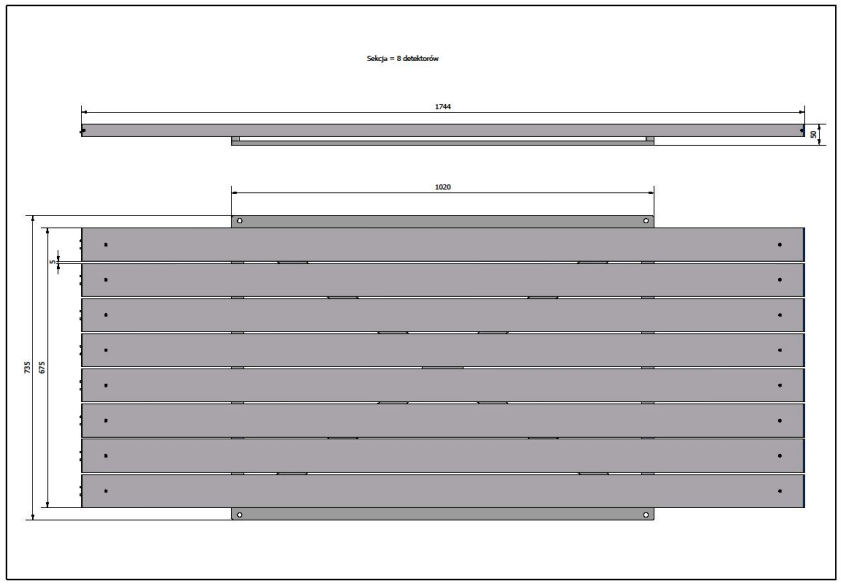
Module installation frame



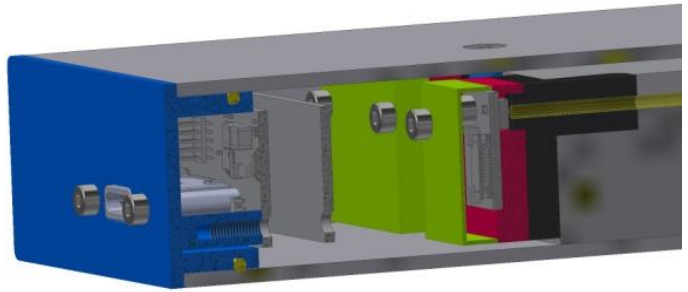
MCORD module consist three sections and installation frame.
Central section is above the first one and third one. No NULL zone.

nica.jinr.ru/video/general_compressed.mp4

1. MCORD section and detector



Single section –
1744x735(675)x50



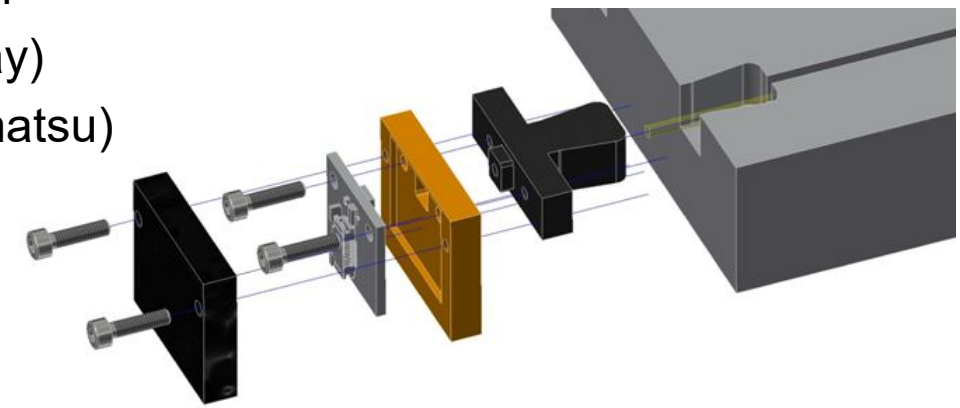
Scintillator aluminum cover (center).

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

WLS fiber: 1 mm dia. (Kuraray)

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

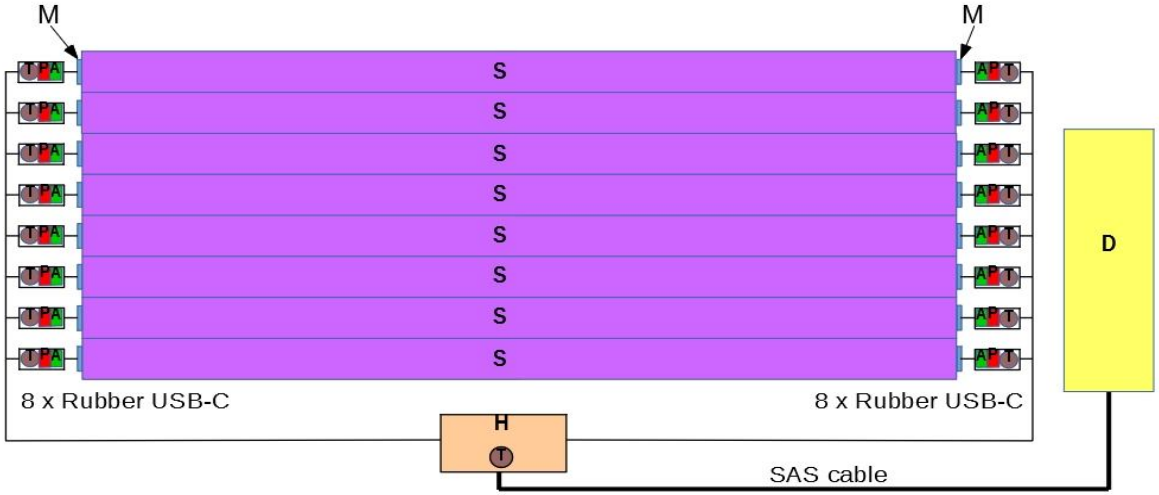
Housing: aluminum profile
174 x 8 x 3 cm



nica.jinr.ru/video/general_compressed.mp4

1. Design of detection system

ANALOG SIGNAL PATH OF MUON DETECTOR

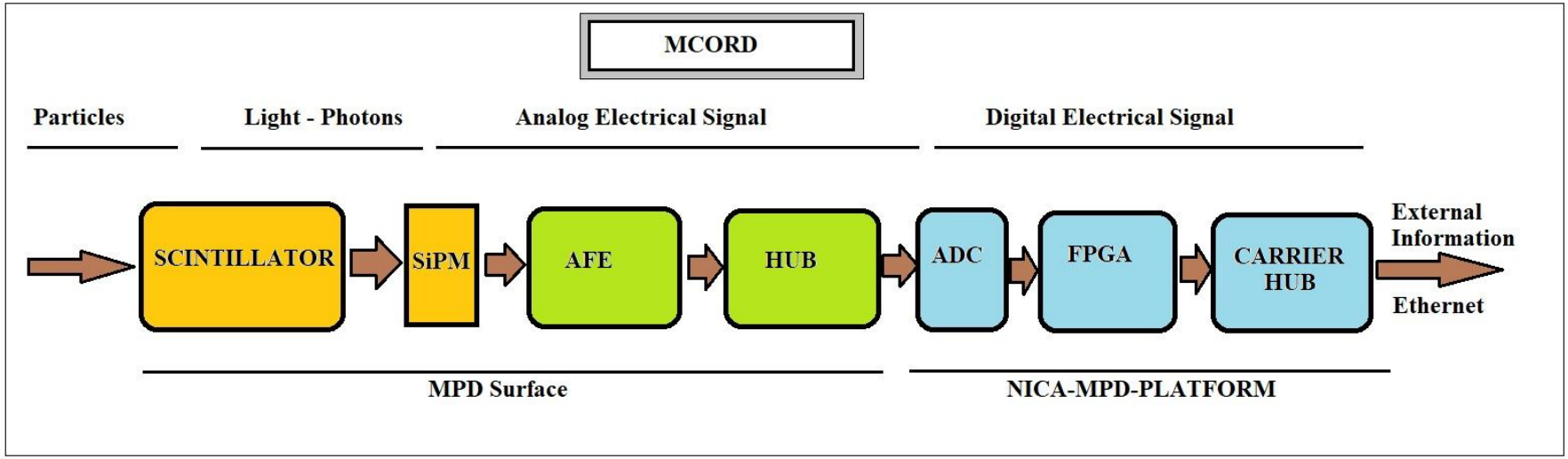


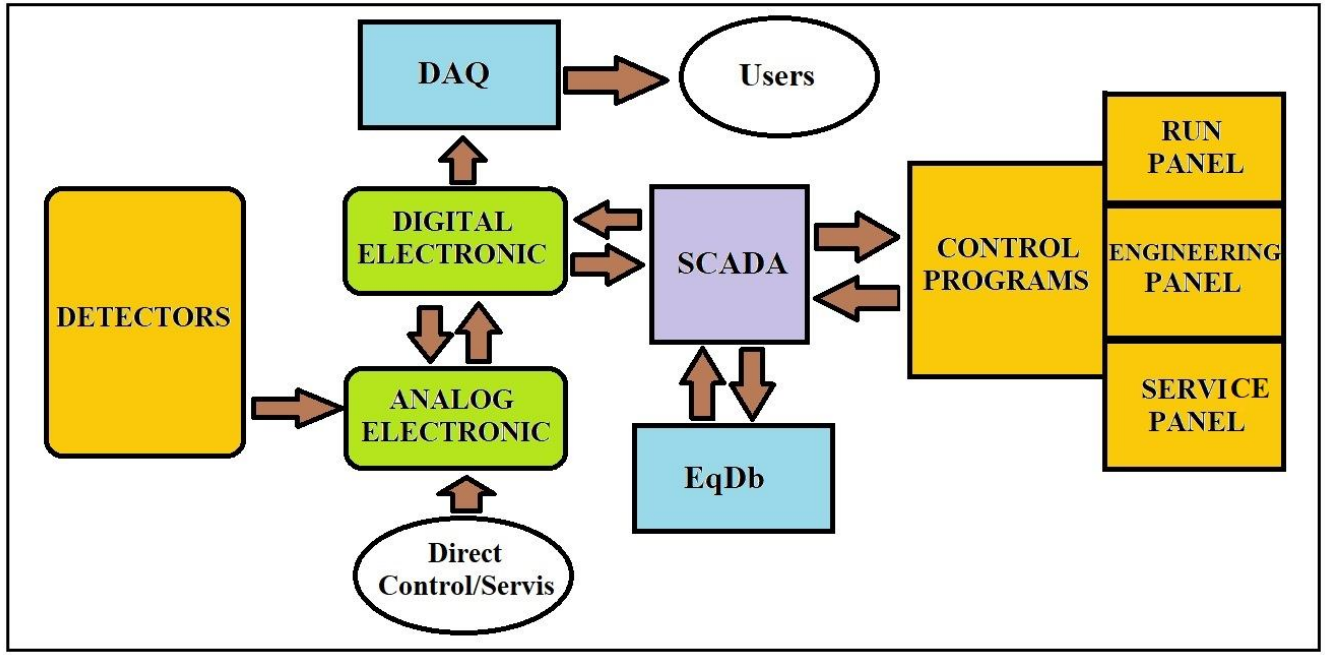
Position resolution
In X axis – up to 5 cm
In Y axis – 5-10 cm

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.

1. Idea and Logical diagram

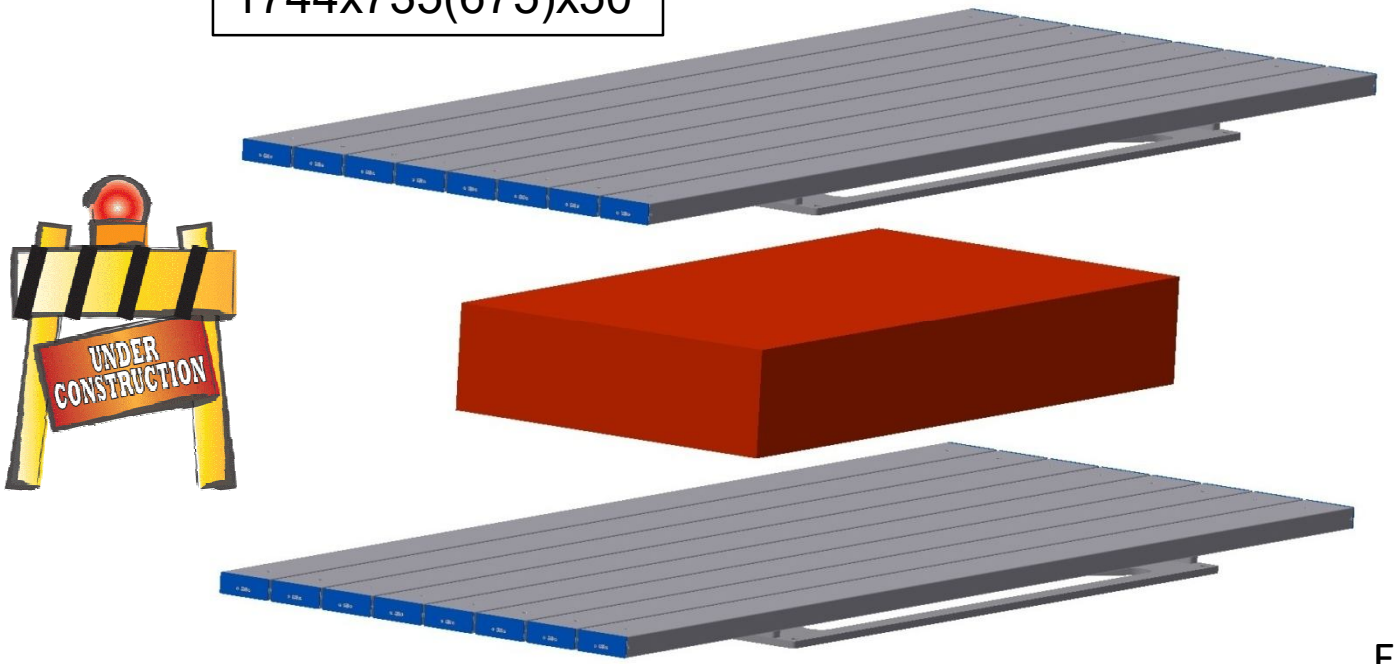




3. Demonstrator

Two sections (2x8 scintillators) will be build with dedicated electronic and full signal analysis.

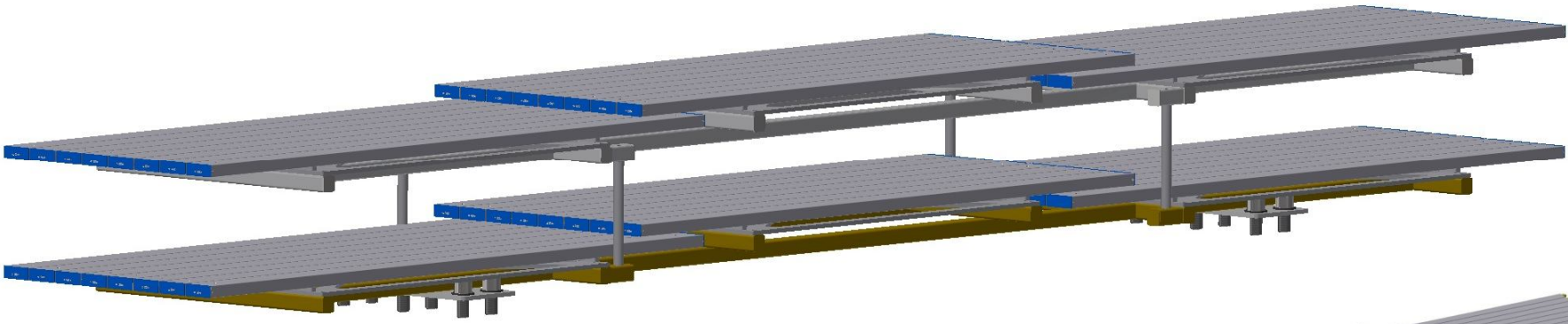
Single section –
1744x735(675)x50

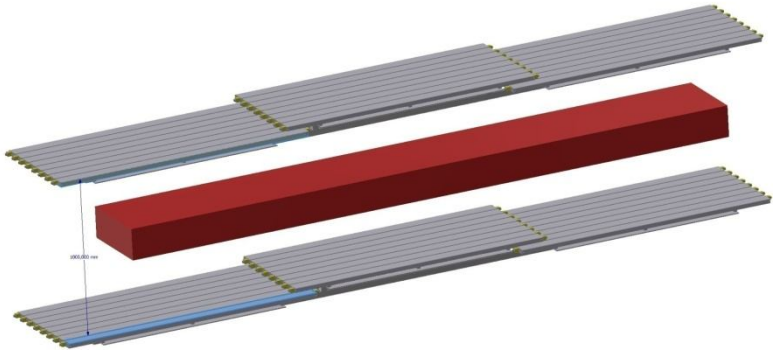


Example: testing of the TOF module

Demonstrator

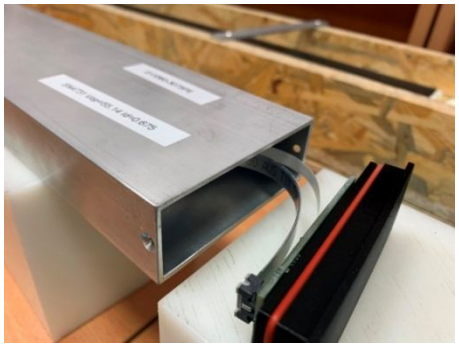
- Full modules that comprise 3x8 scintillators are foreseen to allow installation on MPD yoke surface, but ...
- It can also be used separately, e.g. in **Phase-0 experiment** on the beam provided by NICA.
- 6 MCORD modules should be ready by the end of 2021 year.

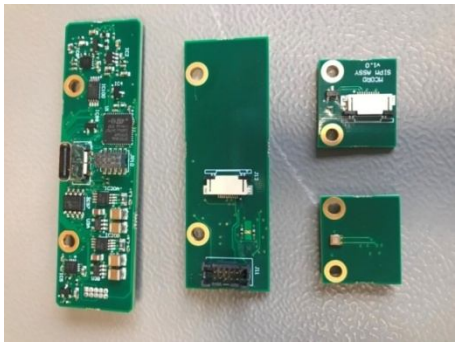


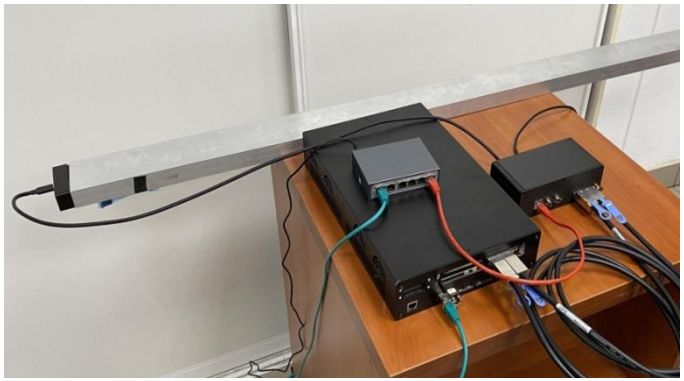


NARODOWE CENTRUM BADAŃ JĄDROWYCH ŚWIERK

4. Present status of work

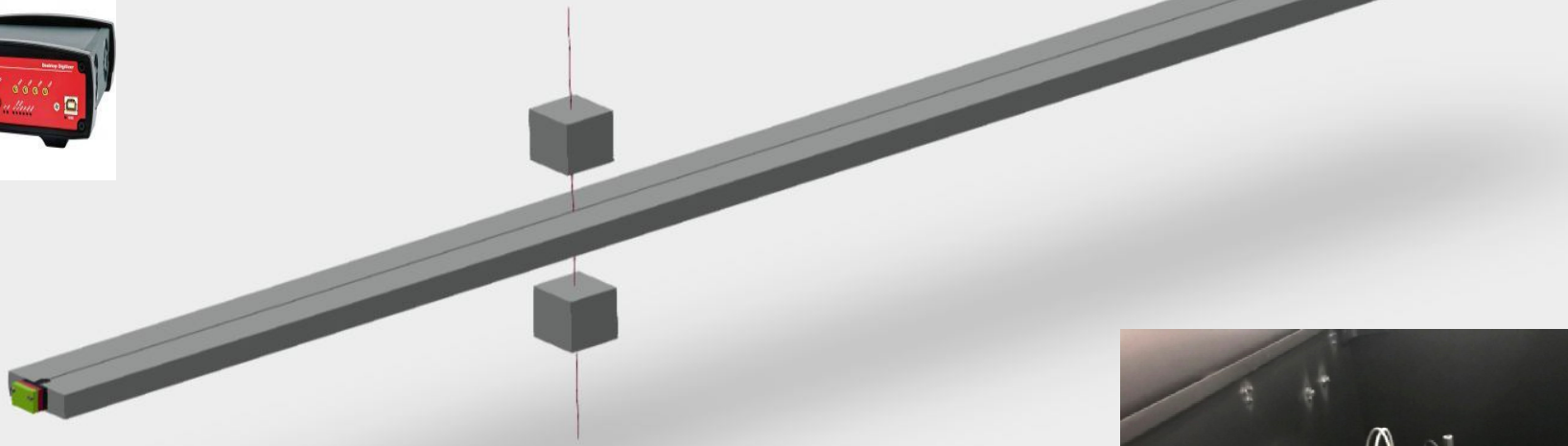


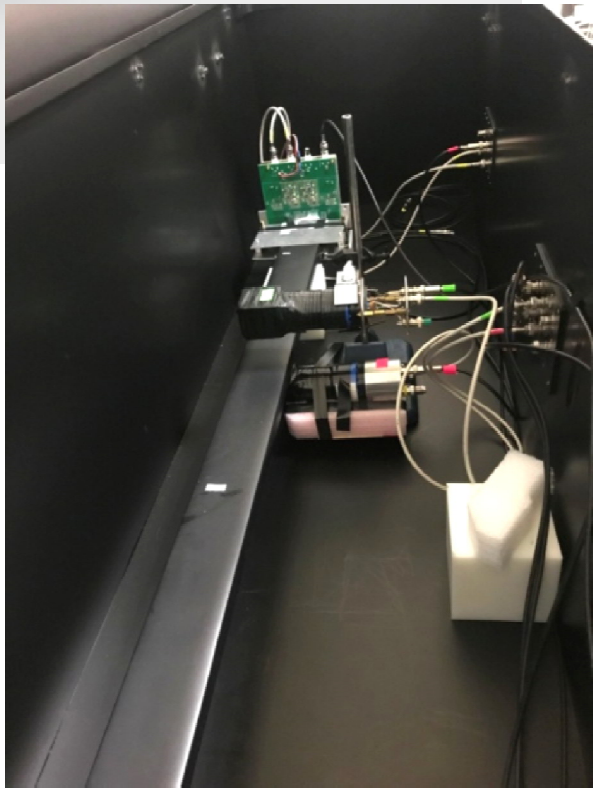




4. Laboratory tests

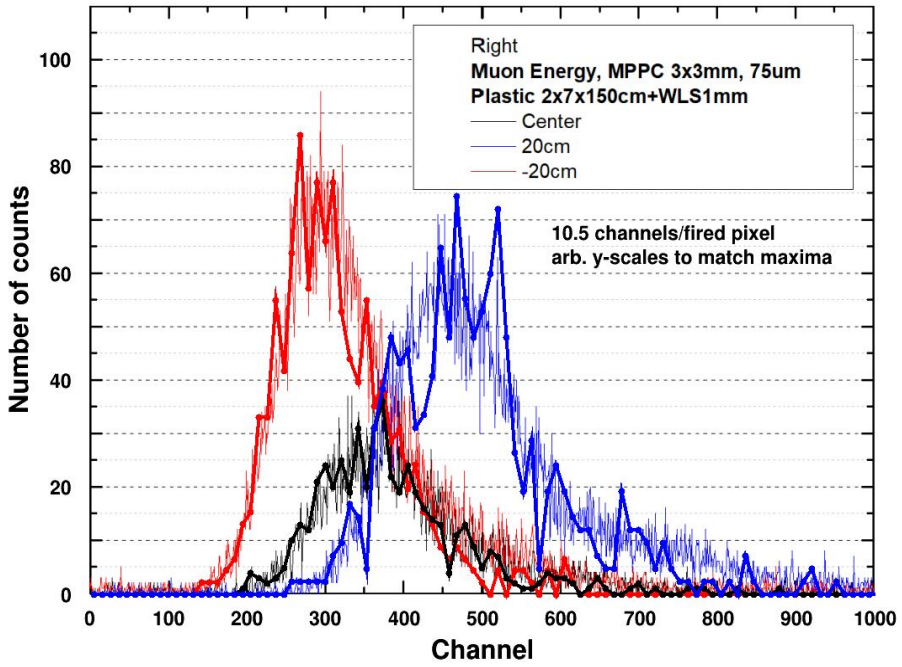
Plastic detector + 2 plastic hodoscopes (muon triggers)
DAQ: CAEN DT5730

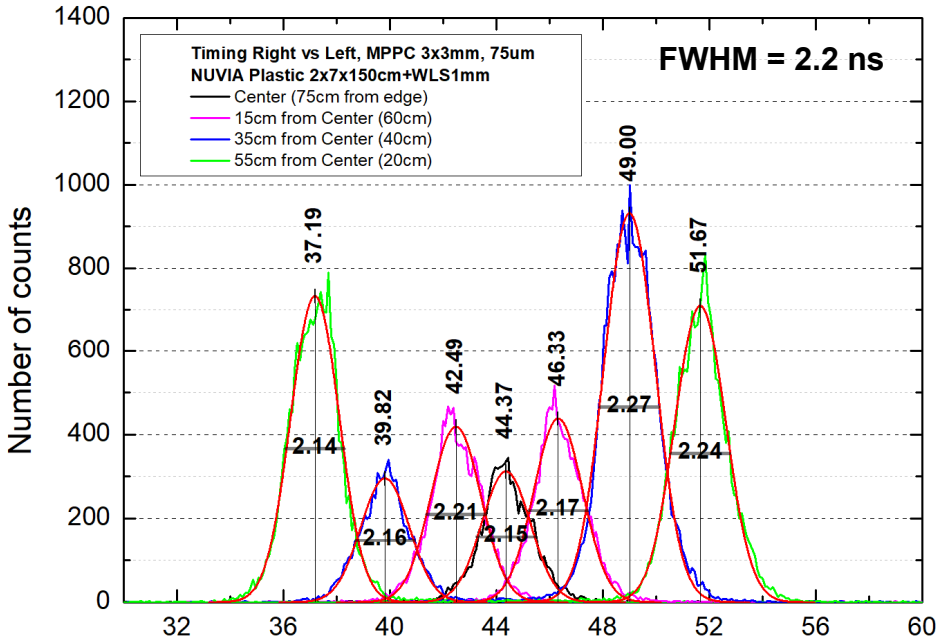


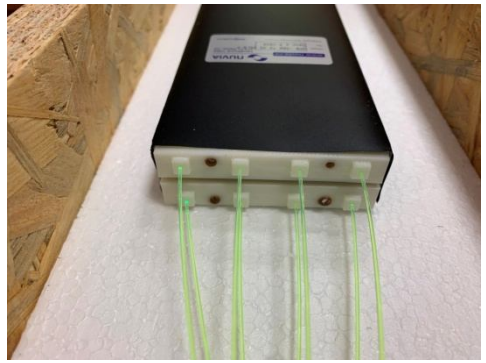


4. Laboratory tests

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







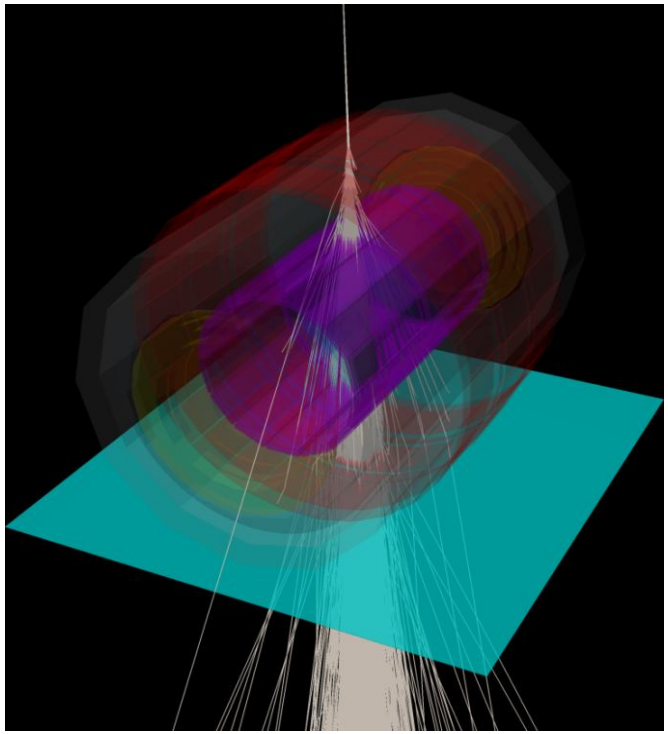
Number of detected photons = 30

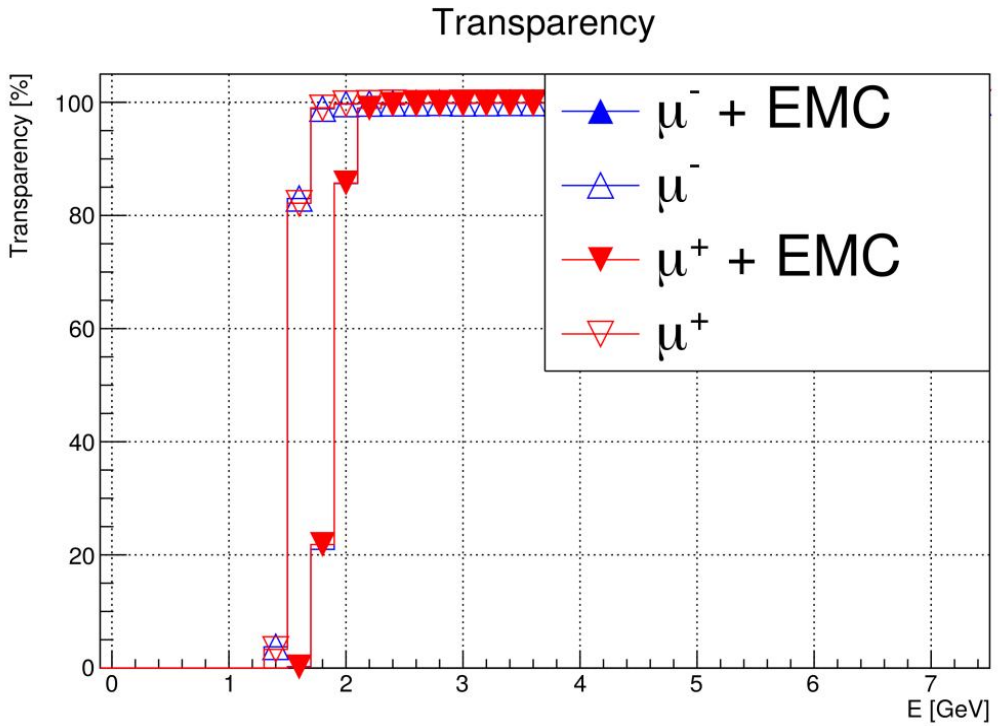
CRT (σ) = 0.93 ns ===> σ_x = 7.1 cm

(still some room for improvement)

6. Simulations (EAS)

Propagation of cosmic muons through the MPD

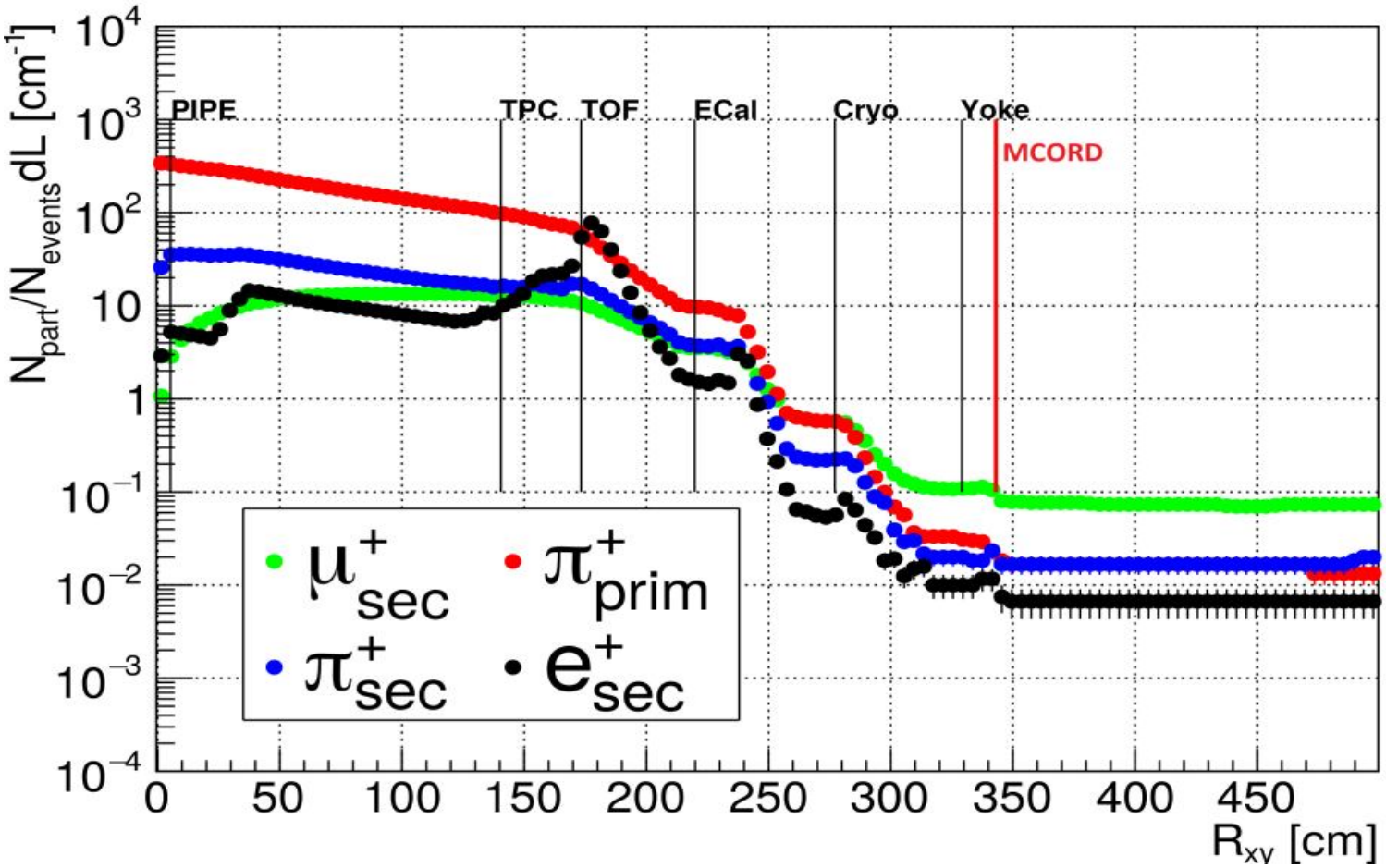




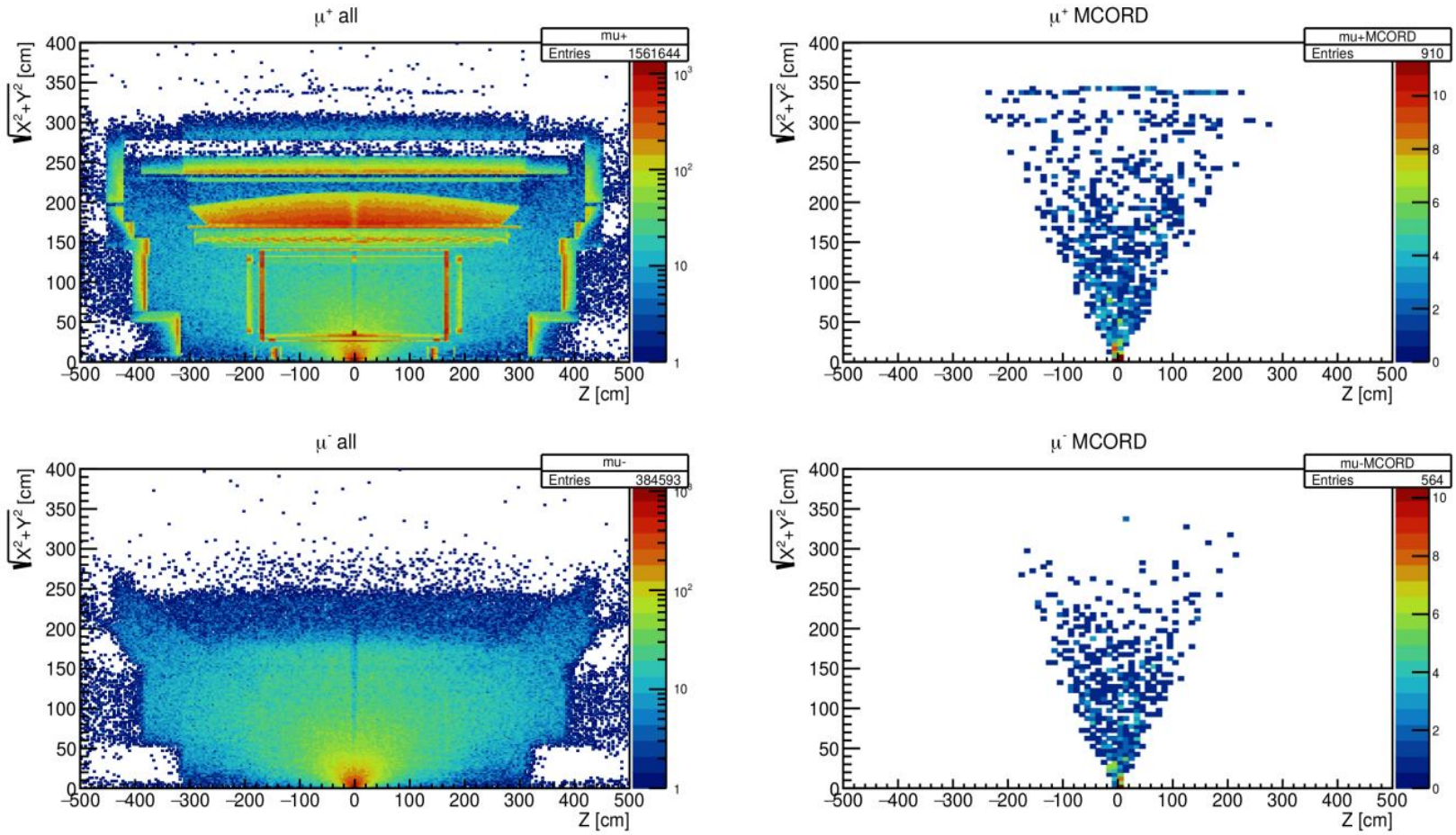
Energy threshold for muons able to pass through the MPD:
with ECal assembled: **2.0 GeV/c²**
without ECal assembled: **1.6 GeV/c²**

6. Simulations (Collisions)

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



6. Simulations (Collisions)

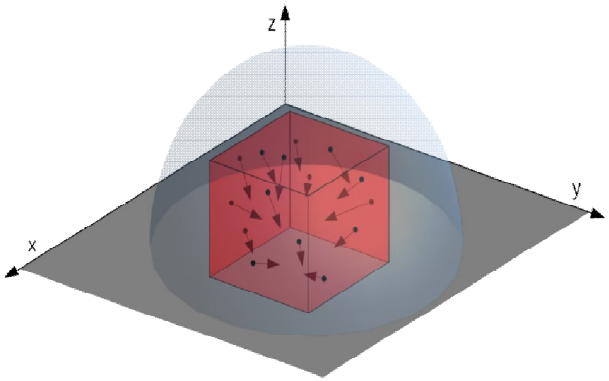


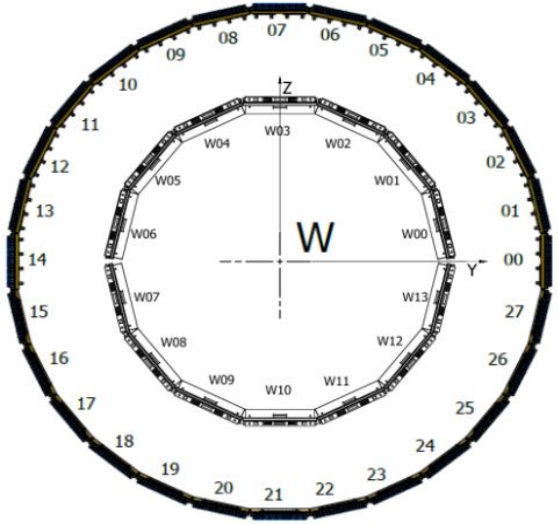
The points of creation of negative and positive muons.

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.

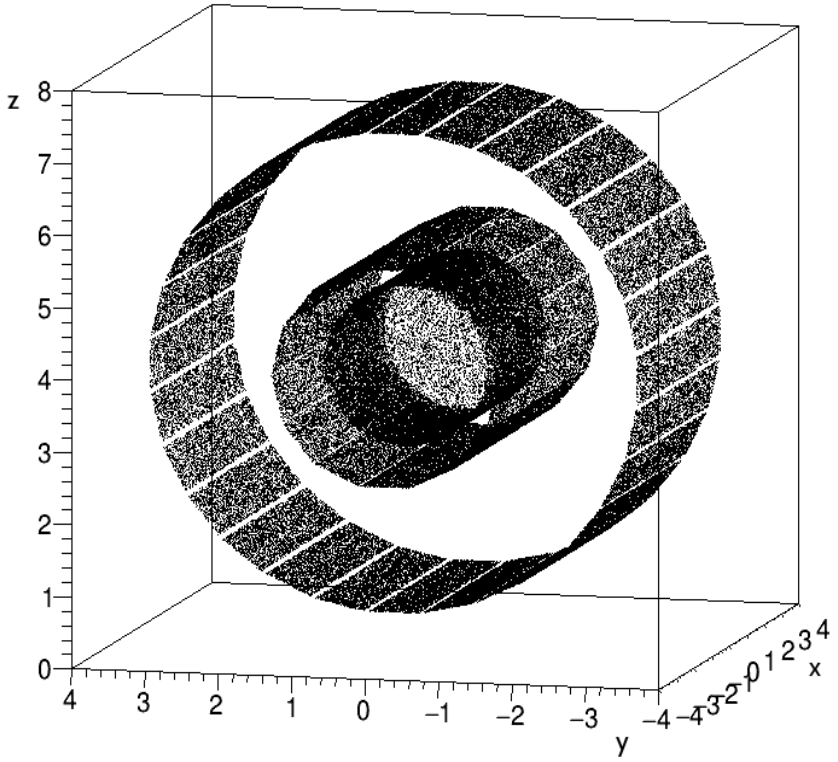
6. Simulations (EAS)

Cofluxim – cosmic ray generator for MPD subsystems calibration study





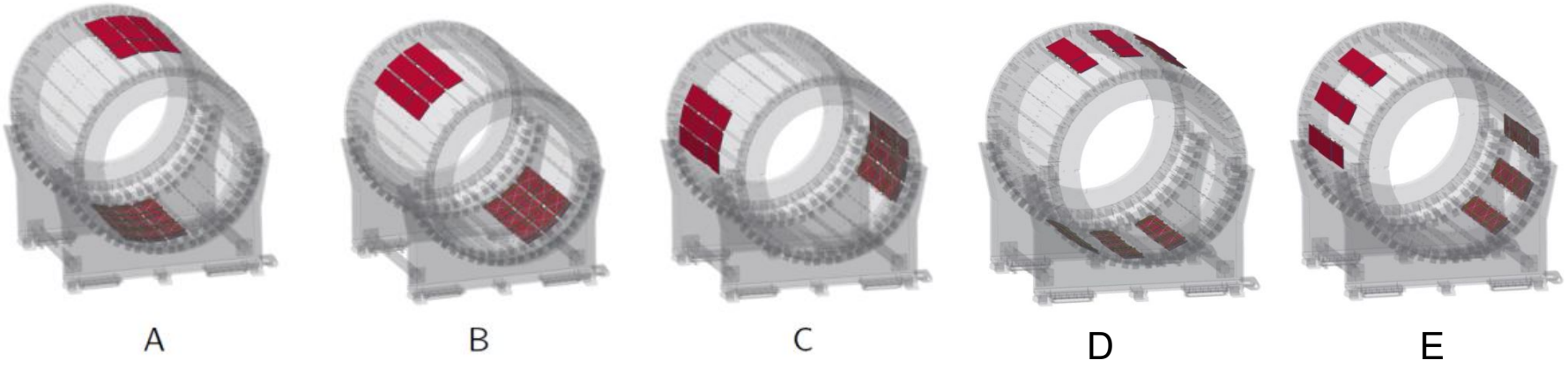
The concept of particle generation: drawing particles on the generation cube walls.



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

4. Symulacje (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**

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 begining of 2021 – **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. MCORD can be useful for identification of **high energy muons from ion-ion collisions**.

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

Polish consortium NICA-PL

Thank You for Attention!