MCORD

MPD Cosmic Ray Detector for NICA

by Polish consortium NICA-PL

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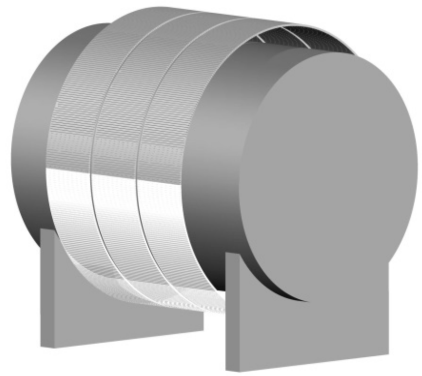
Outline

1. NICA colider
2. Cosmic Ray Detector – Goals
3. Main tasks and schedule
4. Design, modeling proposition
5. Conclusion



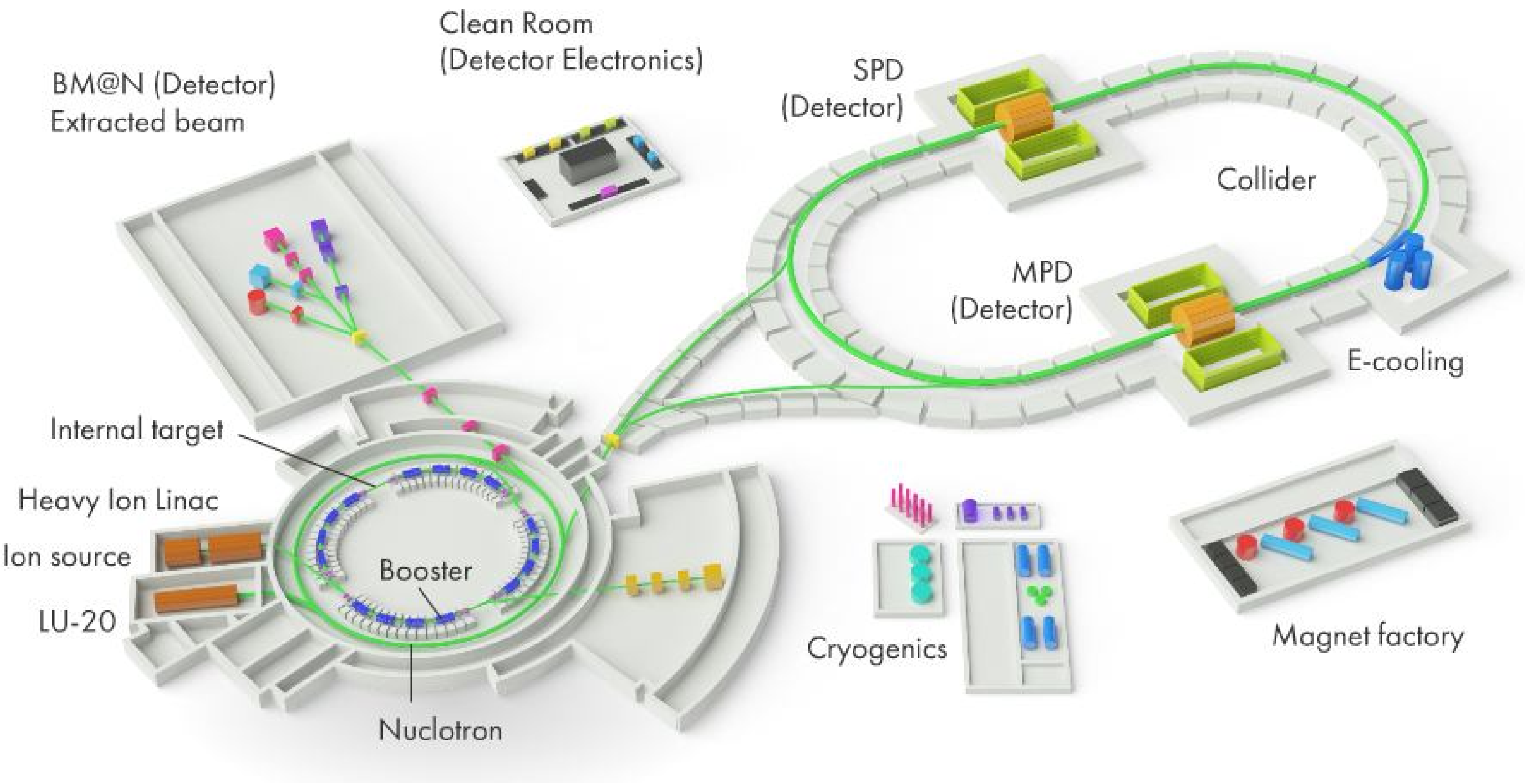
NICA - Nuclotron Ion Collider fAcility

BM@N - Baryonic Matter at Nuclotron

MPD - Multi-Purpose Detector

MCORD - MPD Cosmic Ray Detector

1. NICA complex



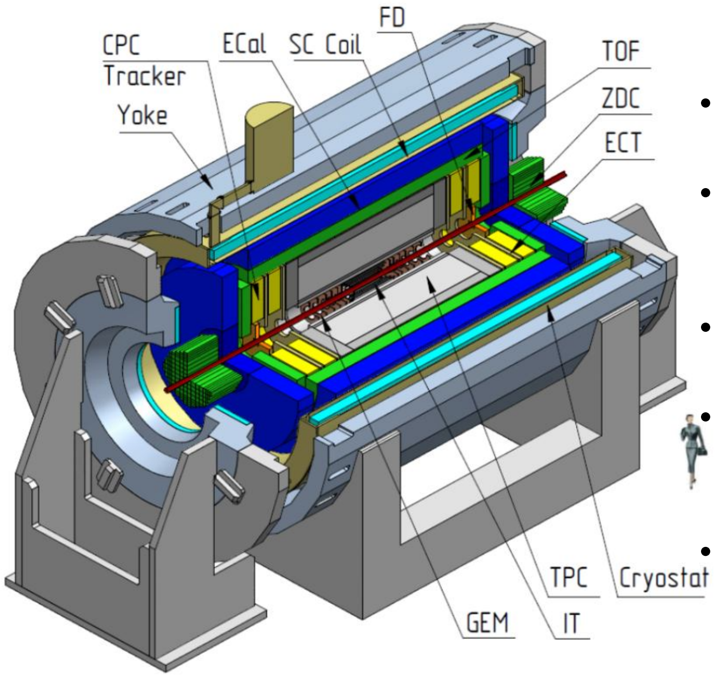
Light Ions

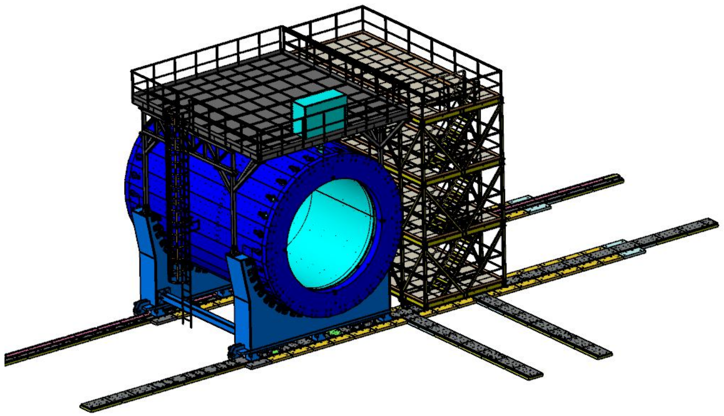
Ion source and Linac LU-20
Nuclotron
BM@N (Detector)
MPD (Detector)

Heavy Ions

Ion sourse (KRION-6T)
Heavy Ion Linac (HILac)
Booster
Nuclotron
BM@N (Detector)
MPD (Detector)

1. NICA complex



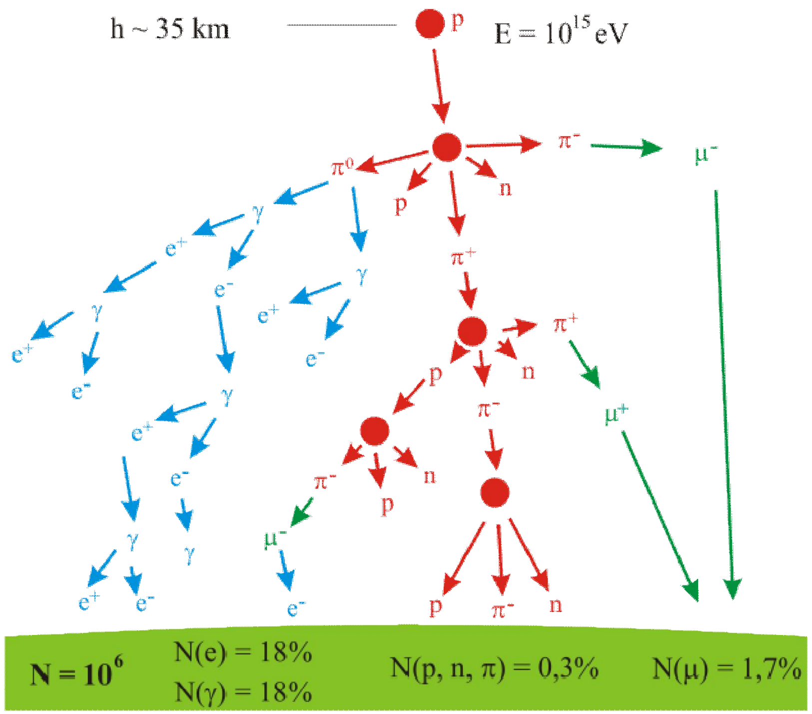


- FD Forward detec
- Superconductor solenoid (SC Coil)
- inner detector (IT)
- straw-tube tracker (ECT)
- **Time-projection chamber (TPC)**
- **Time-of-flight system (TOF)**
- **Electromagnetic calorimeter (EMC - ECal)**
- Zero degree calorimeter (ZDC).

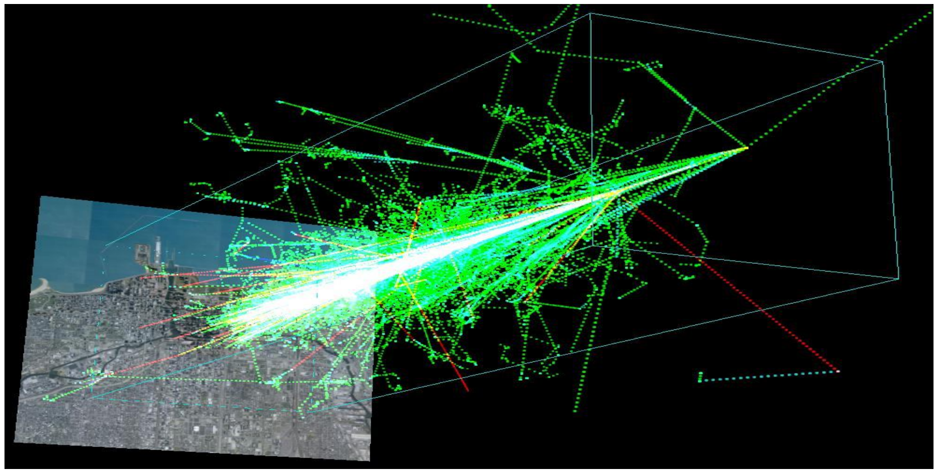
nica.jinr.ru/video/general_compressed.mp4

2. Cosmic Ray Detector – Goals

PRIMARY PARTICLE

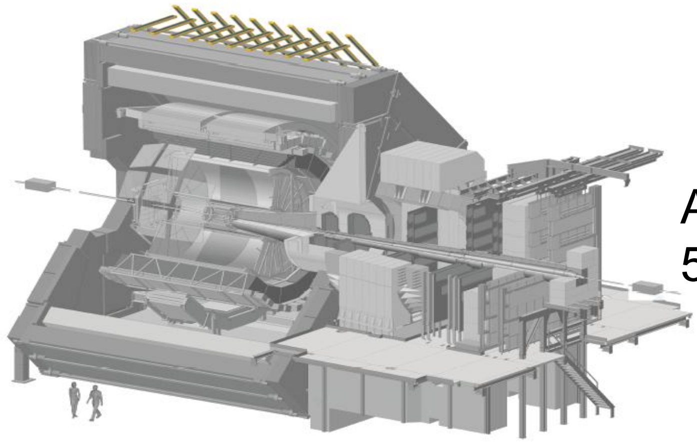


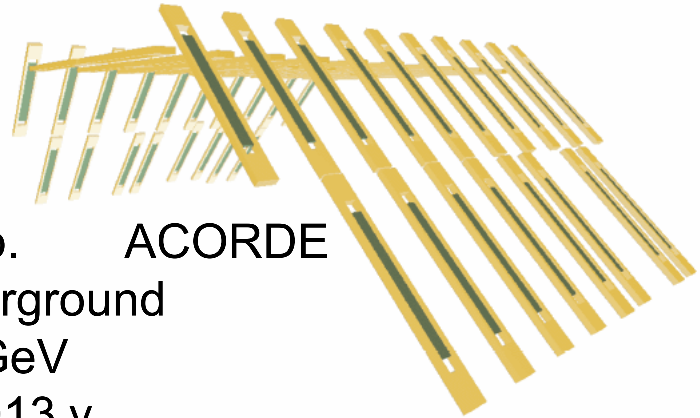
GROUND LEVEL



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.

2. Cosmic Ray Detector – Goals
examples from other experiments





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

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

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

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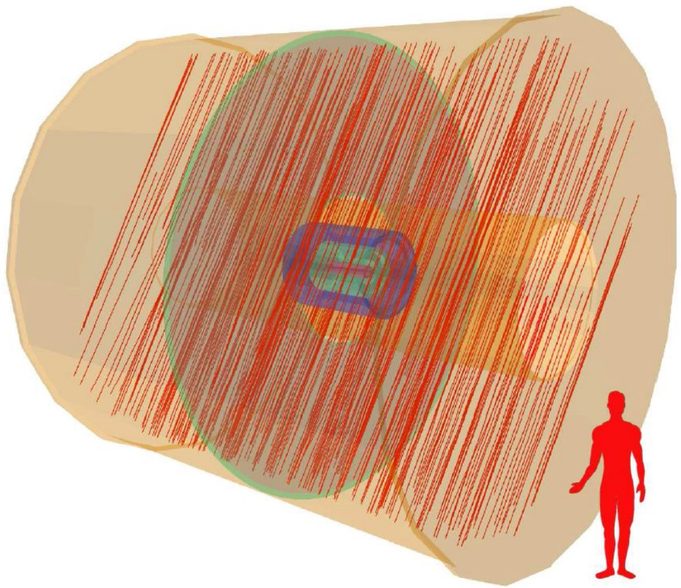
ScienceDirect
Astroparticle Physics 28 (2007) 273–286
Astroparticle Physics
www.elsevier.com/locate/astropart

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 [l], T. Albrecht [r], R. Alemany-Fernandez [i], T. Allmendinger [r], P.P. Allport [x], 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],

2.Cosmic Ray Detector – Goals



a) Trigger (for testing or calibration)
   - testing before completion of MPD
   (testing of TOF, ECAL modules and TPC)
   - calibration before experimental session

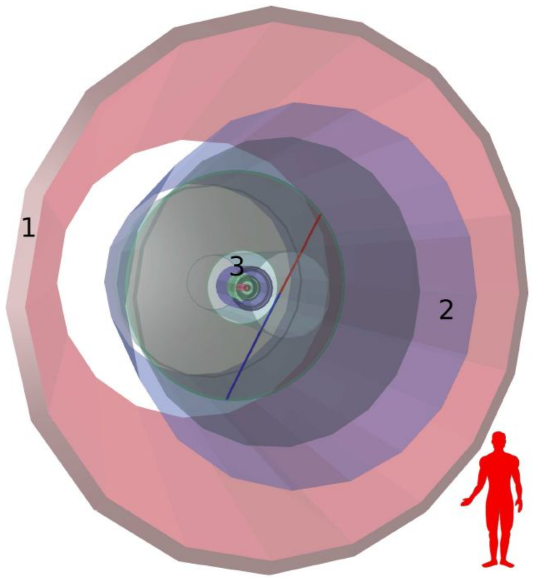
a) Veto (normal mode -
   track and time window recognition)
   Mainly for TPC and eCAL

___

Additionally

c) Astrophysics (muon shower and bundles)
   - unique for horizontal events
   Working in cooperation with TPC

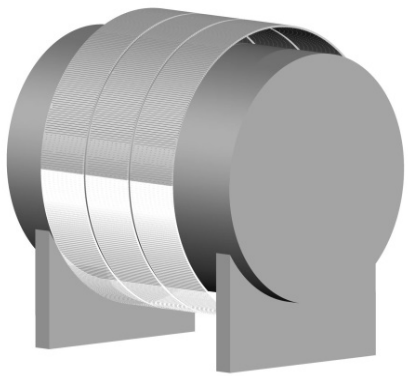
DECOR exp. 2002-2003y (near horizontal observation (60-90 deg. angular range) - 1-10 PeV primary particle)



3. Main tasks and schedule

I. **Conceptual Design** (9-12 months)
(Preliminary Technical and Electronic Design, Market Research, Literature Studies, Cost Estimates, TPC and TOF requirements)

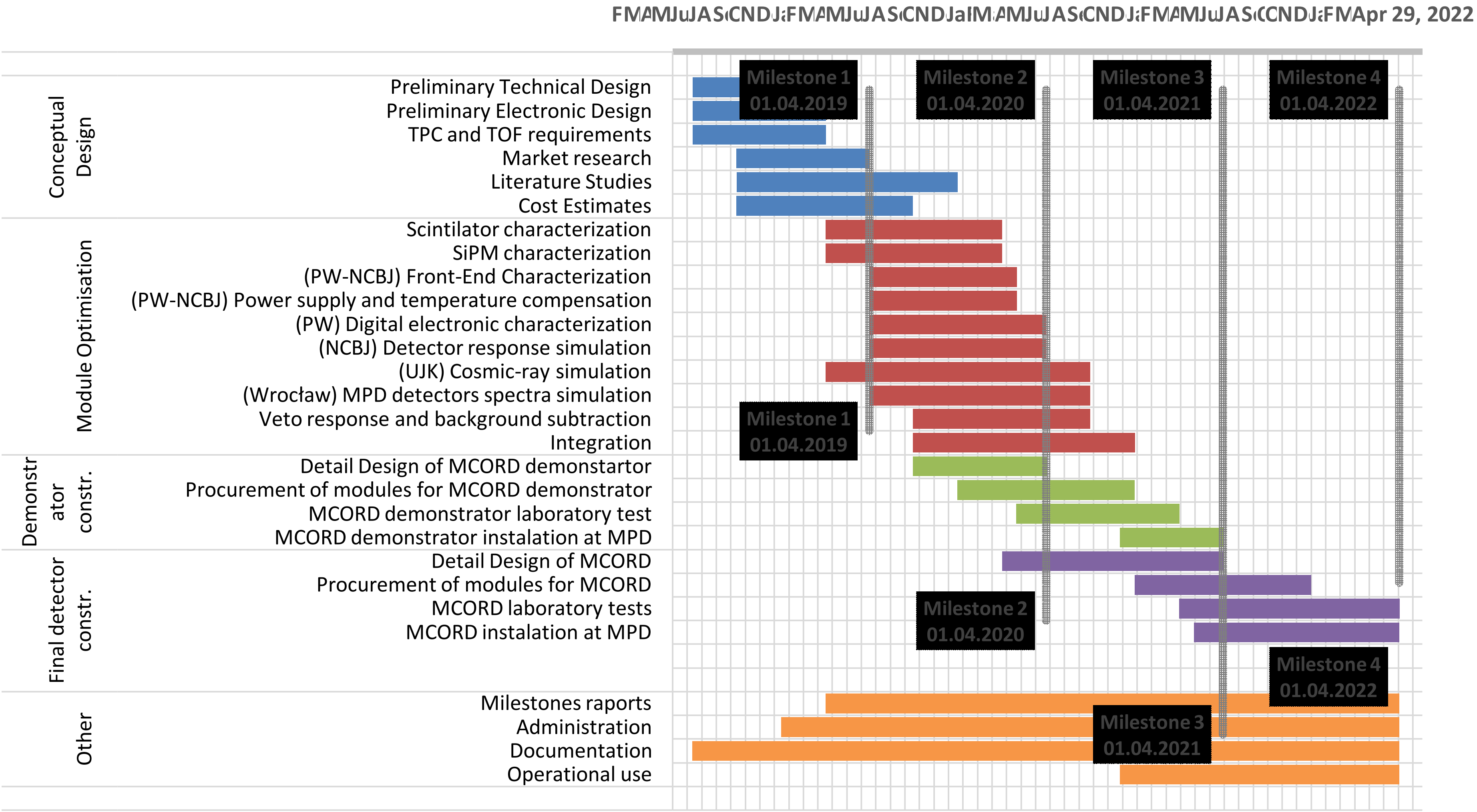
II. **Module Optimization** (9-15 months)
(Scintillator, Power Supply, Front-End and Analog electronics characterization; Detector response, Cosmic-ray and MPD spectra simulation, Veto response, Integration)



III. **Demonstrator constr.** (2-4 ready to use modules) (10-20 months) (Demo. detailed design, Procurement of Modules, Lab. Tests, Installation in MPD

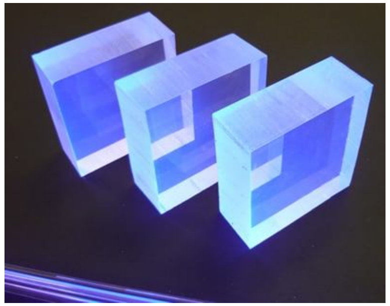
IV. **Final Detector constr.** (procurement of all modules , test installation and integration –12 months)

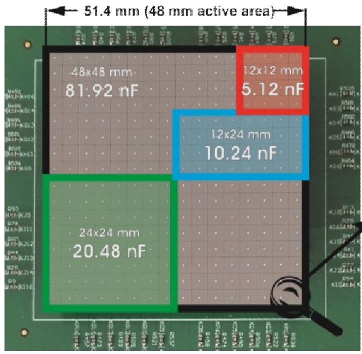
3. Main tasks and schedule

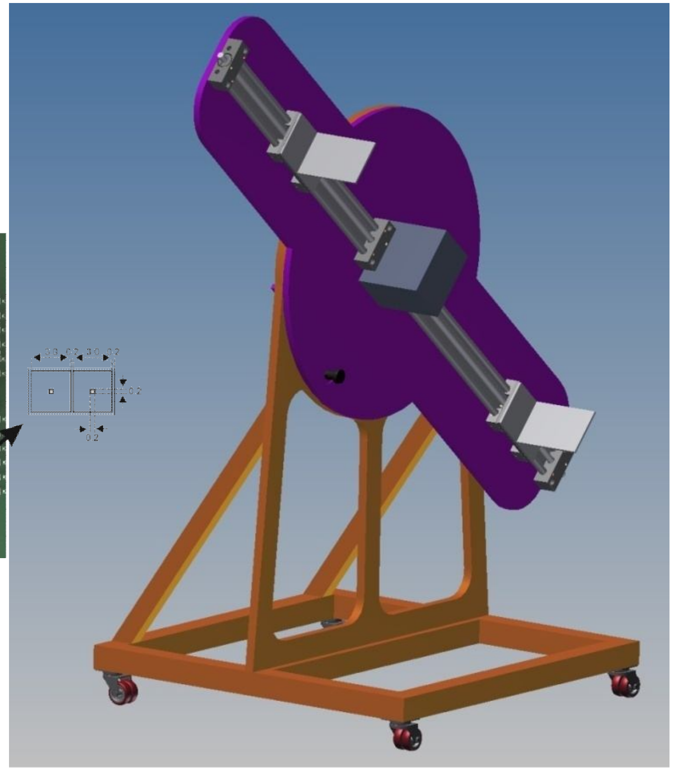


Conceptual Design and Module Opti.

1. Measurement of cosmic irradiation - Azimuthal and horizontal distribution
2. Angular influence of the building (concrete walls and ceiling)
3. Testing of scintillator shape (length, width, thickness) and scintillation response to ionizing radiation
4. Size and number of optical elements
5. Numerical calculation – simulation (MCNPX, GEANT4 and CORSIKA, Showersim)







Cooperation with scintillators manufacturers and providers:
- Uniplast (Russia)
- Amcrys-H (Ukraine)
- Saint-Gobain (FR)
- Scionix (Holland)
- Nuvia (Czech)

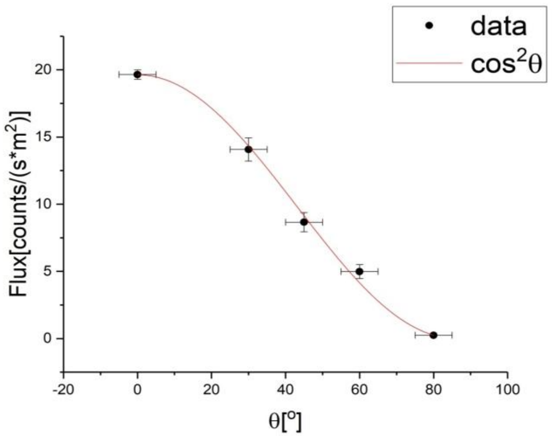
Cooperation with SiPM vendors:
- Hamamatsu (Japan)
- AdvanSiD (Italy),
- Ketek (Germany),
- SensL (Ireland)

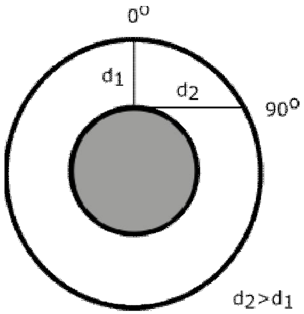
Wide range of sizes: 1×1 mm^2 to 51×51 mm^2

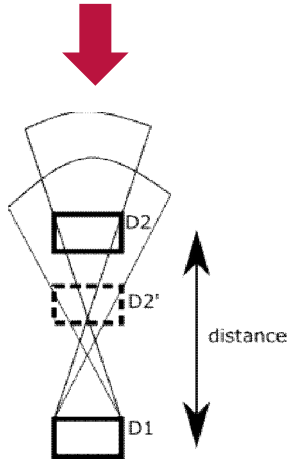
Conceptual Design and Module Opti. - measurements

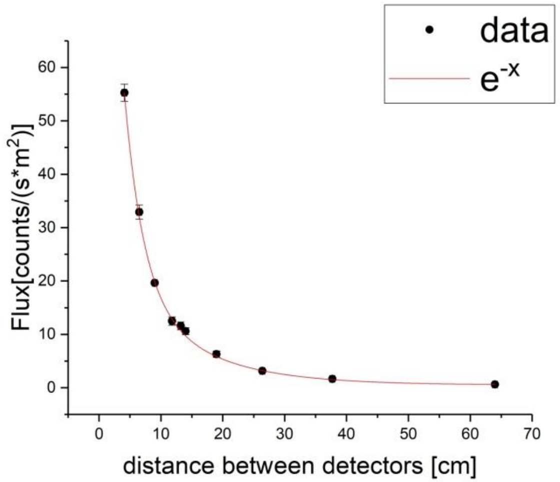
First measurements at Dubna

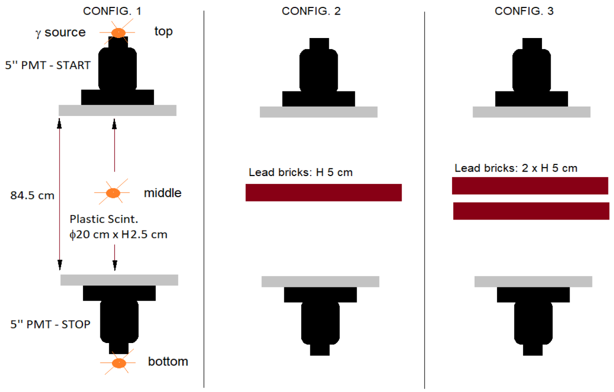
- Azimuthally and horizontal distribution
- Angular influence of the building
- With Pb filter



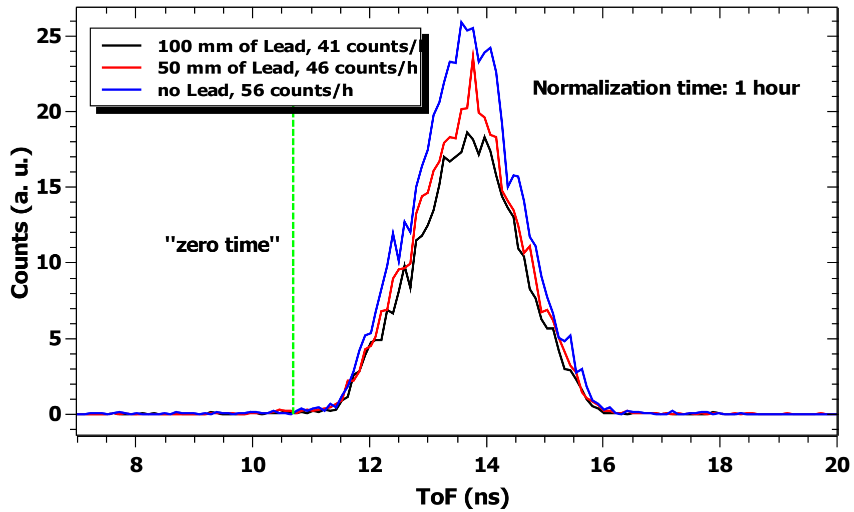




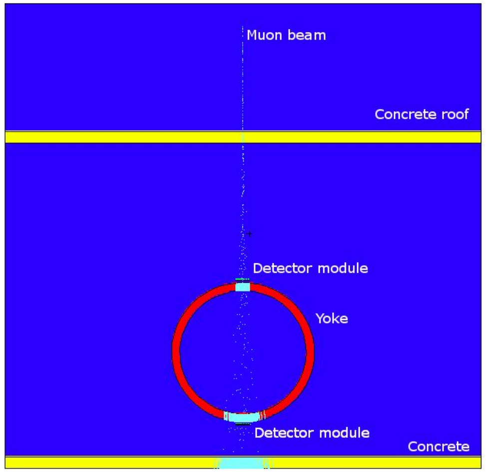


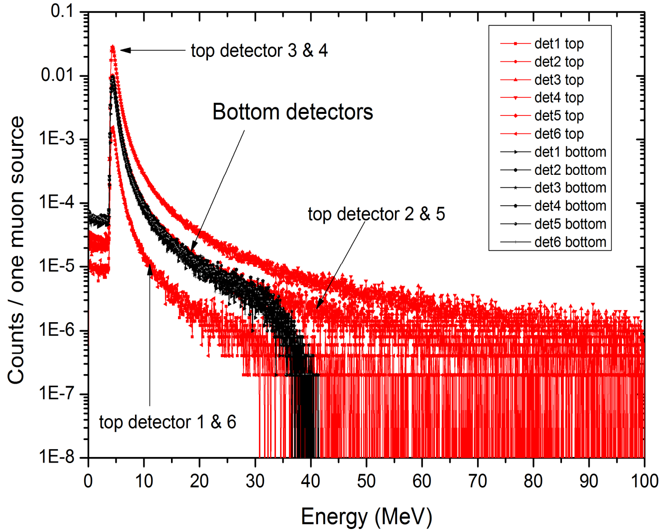


+ CAEN DT5730 digitizer with COMPASS



Conceptual Design and Module Opti. - simulations

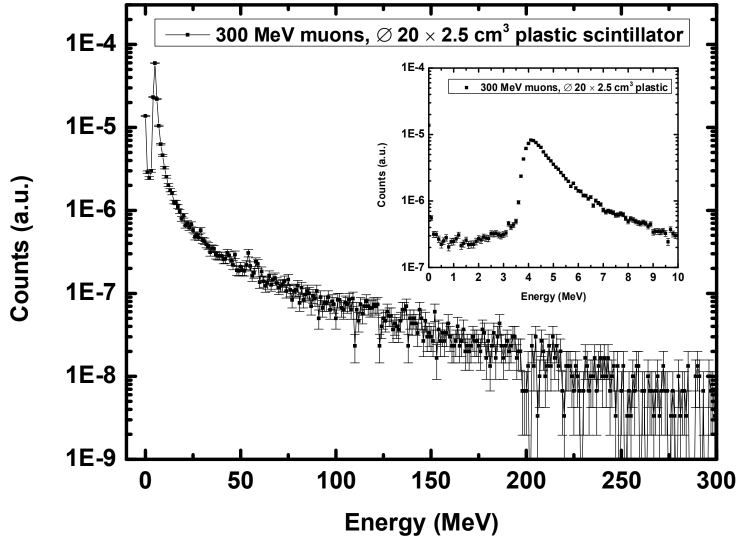




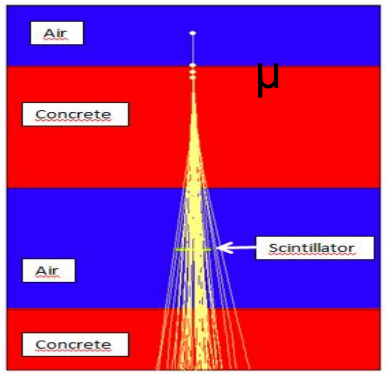
Energy deposition spectra of 2 GeV monoenergetic muons

The first MCNPX simulation of muon energy deposition in plastic scintillator for NICA Energy spectrum reconstruction

- Cylindrical plastic scintillator Ø20 × 2.5 cm^3 – the same used for experiment at NCBJ
- The maximum energy deposition centroid is around 4 MeV - reasonable result, assuming 2 MeV/cm dE/dx energy loss for muons in organic scintillator. Light generation due to ionization in plastic scintillator will be implemented in the near future.



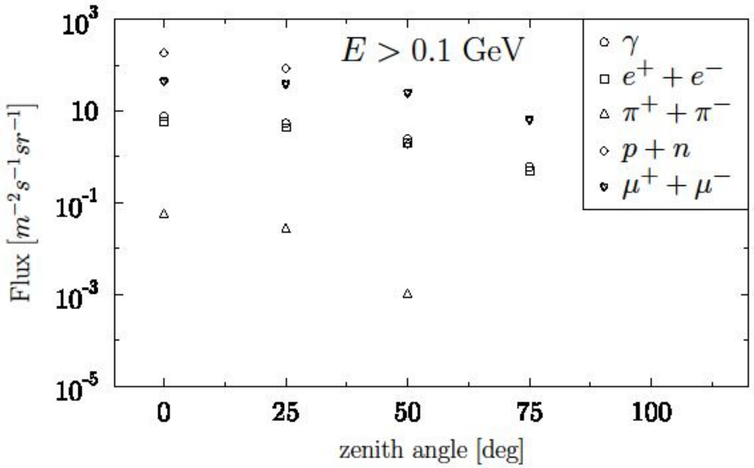
Energy deposition spectrum

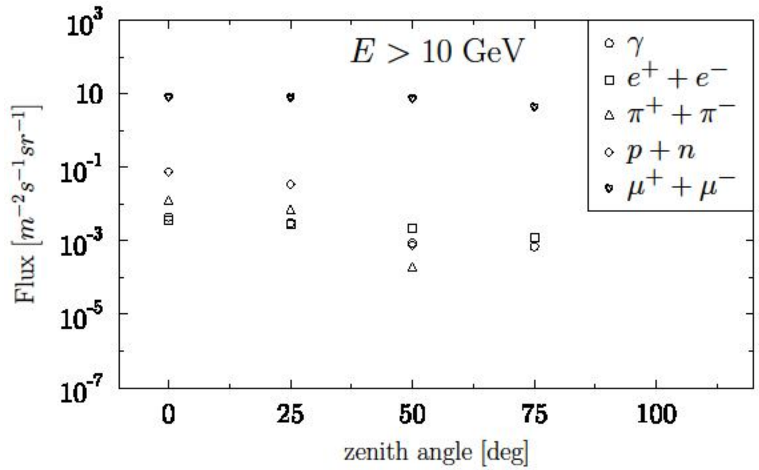


Geometry used (40000 tracks)

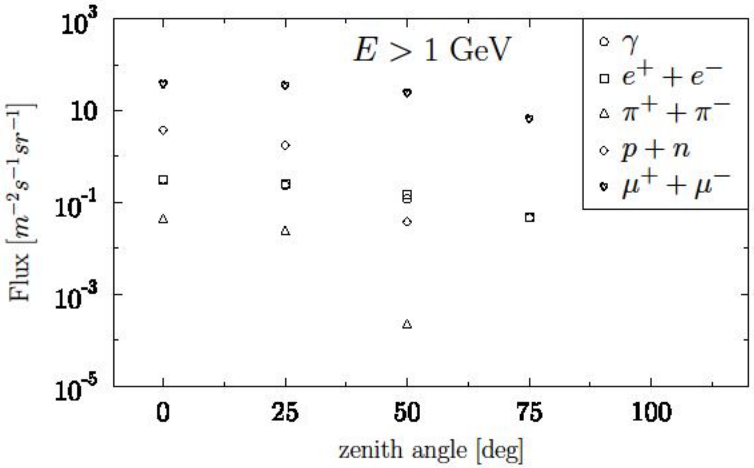
Conceptual Design and Module Opti. - simulations

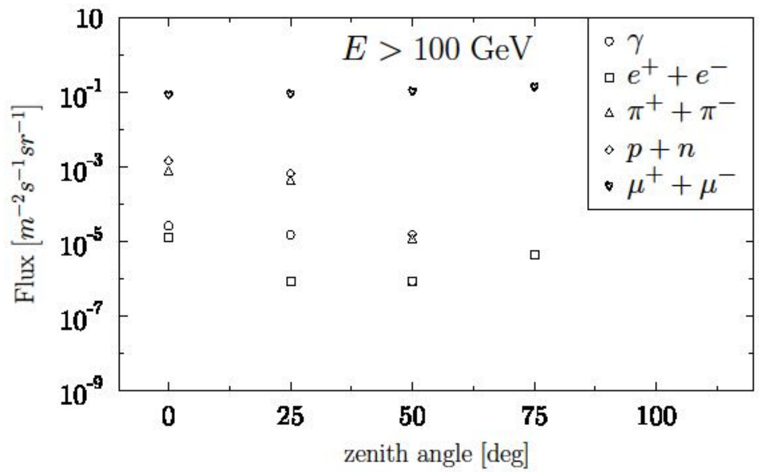
CORSIKA simulation of Cosmic Showers





Angular distribution of atmospheric cosmic shower particles





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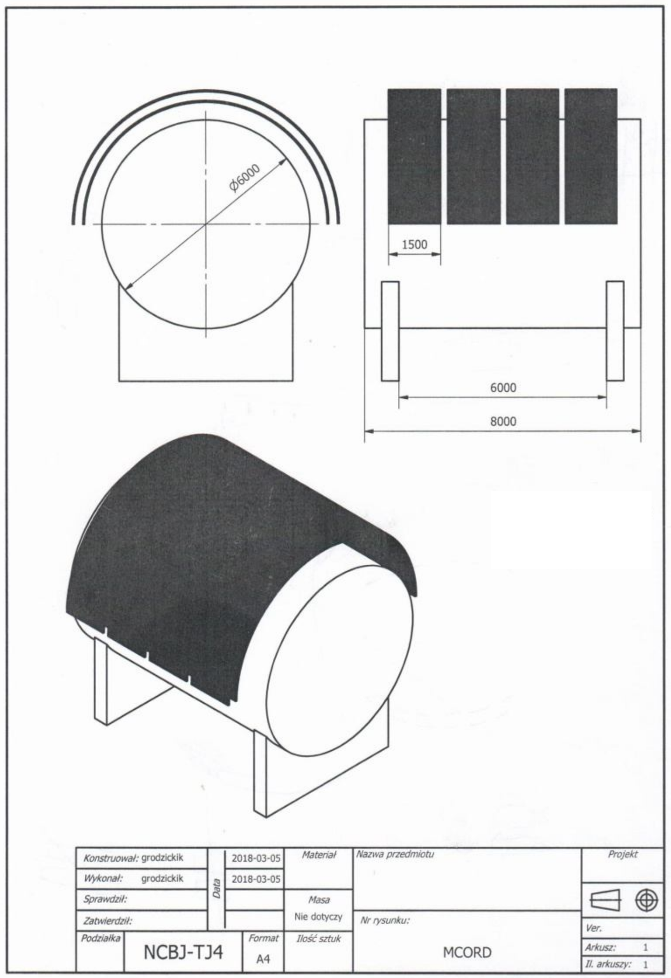
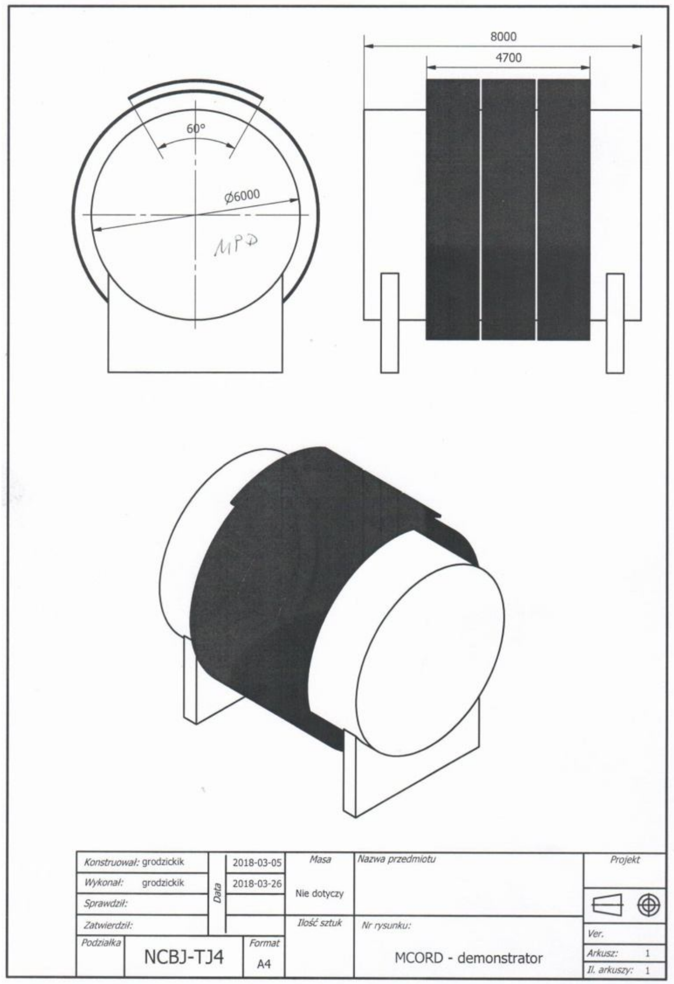
4. Design, modeling variants



Two surfaces on half circumference



One surface on full circumference

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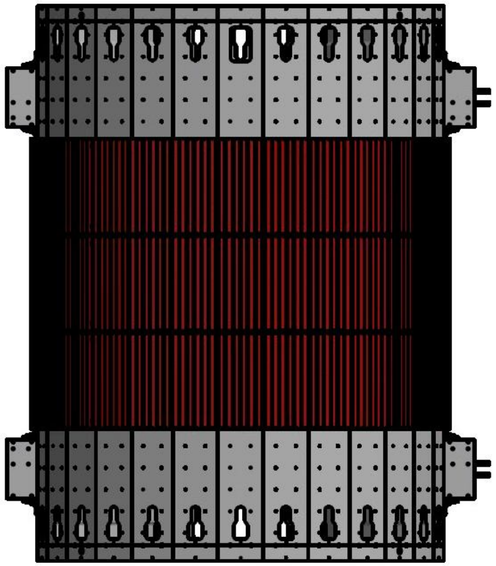
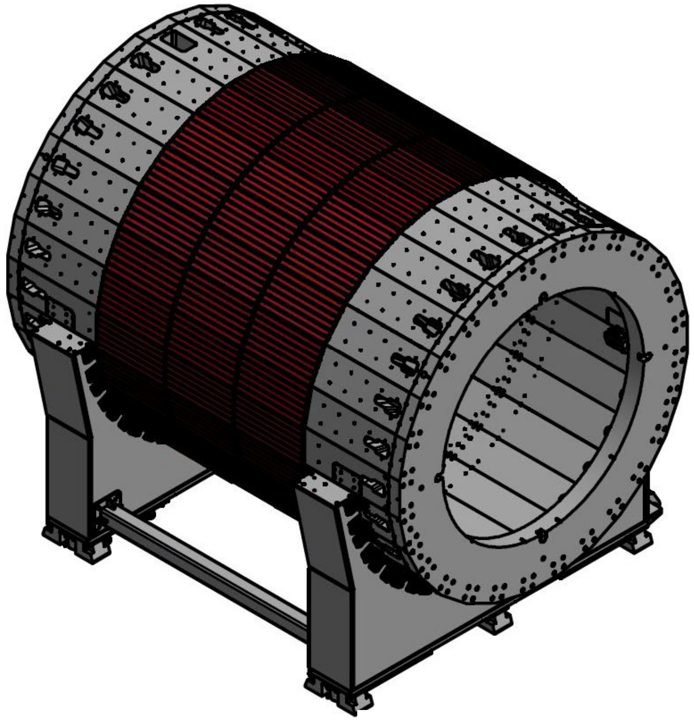
4. Design, modeling variants

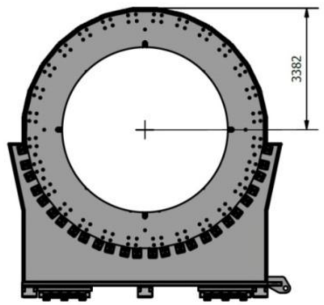


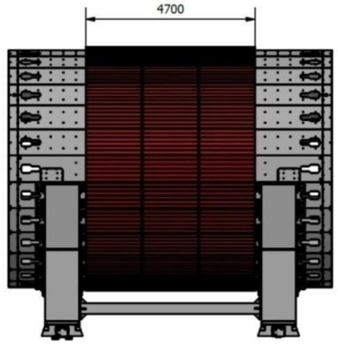


MCORD at MPD scheme

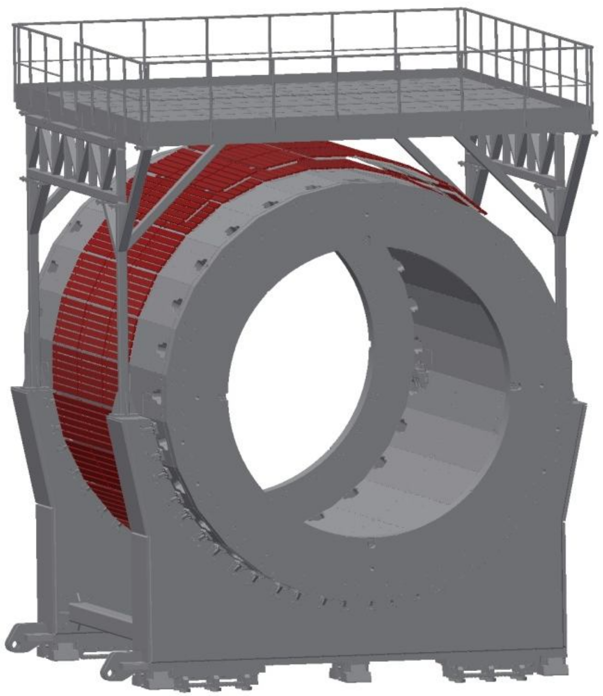
Basic vaiant

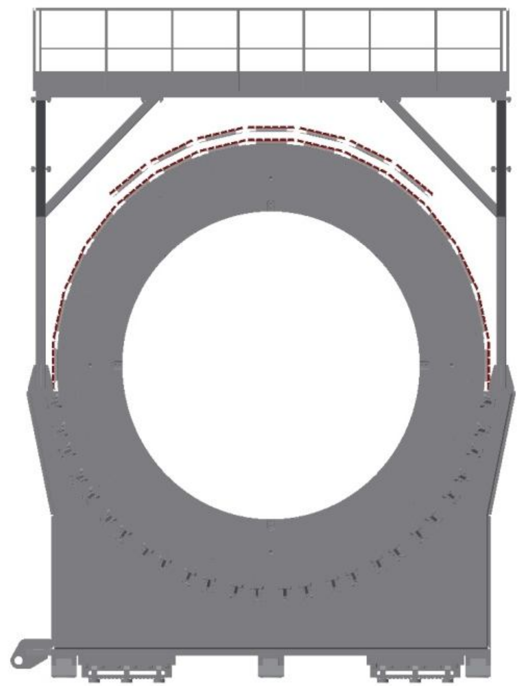
One surface on full circrumference





4. Design, modeling variants



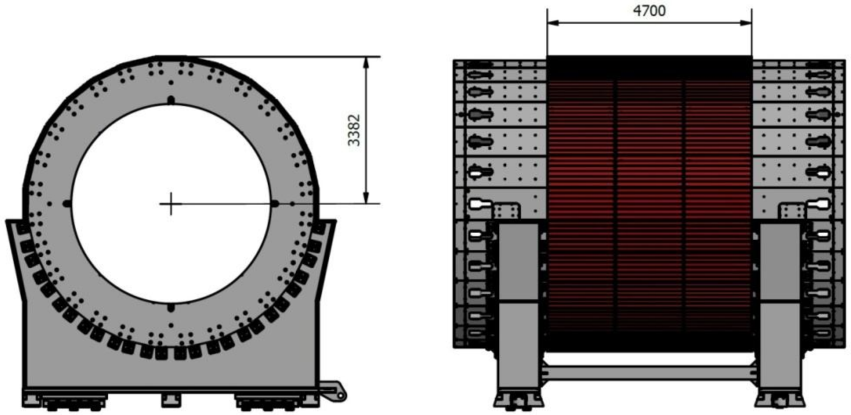


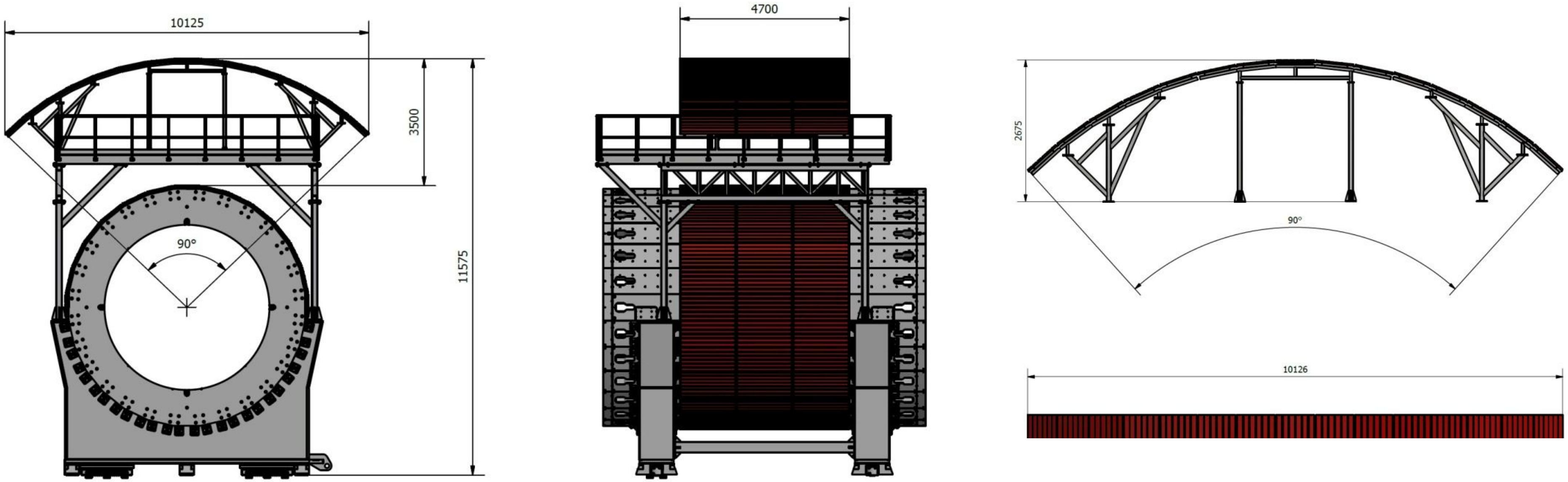
MCORD at MPD scheme

One surface on full circumference + additional surface on the top ver.1

4. Design, modeling variants

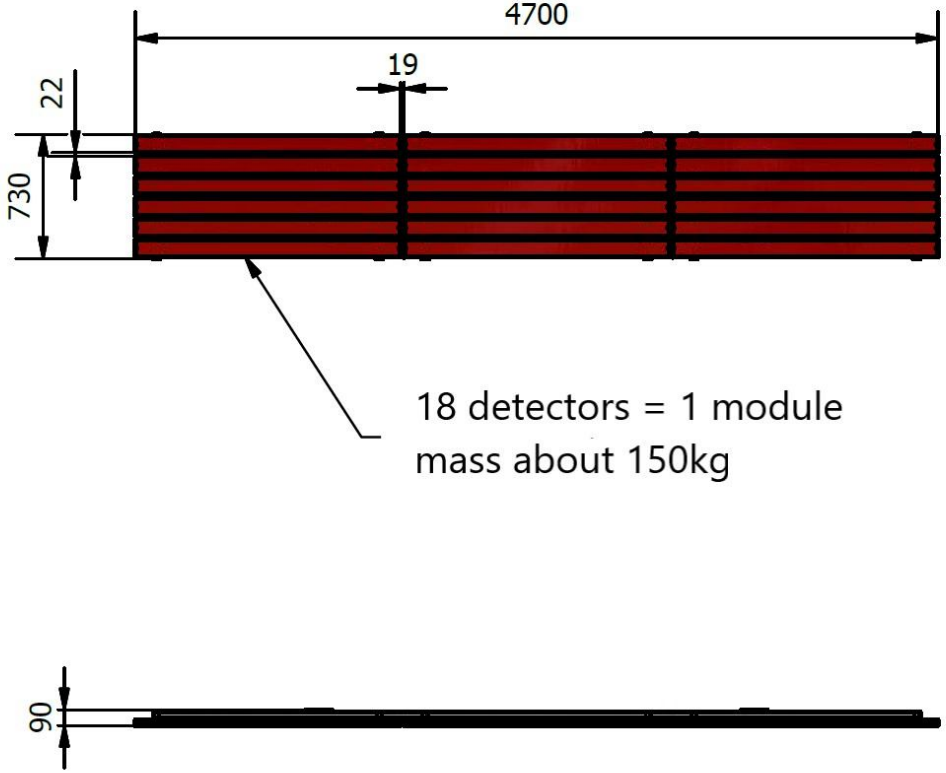
MCORD at MPD scheme



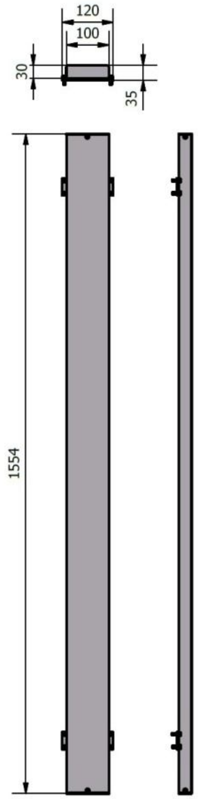


One surface on full circumference + additional surface on the top ver.2

4. Design, modeling variants

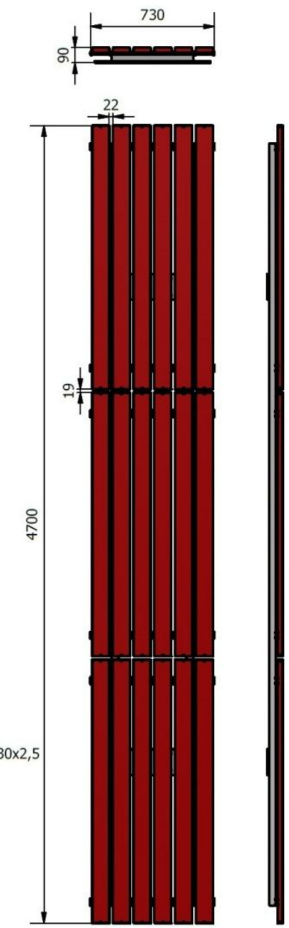


Scintilators and modules



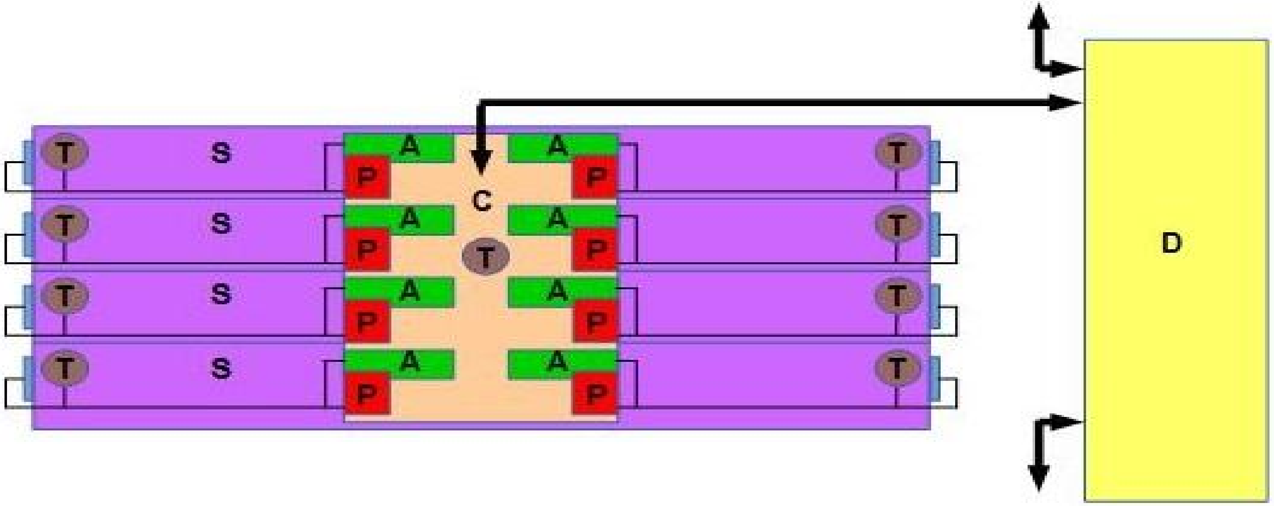
DETECTOR
Dimensions of scintillator - 95x25x15000
Dimensions of detector - 100x30x1554
Material of casing - Aluminium alloy
Scintilator placed in ractangle profile 100x30x2,5
Weight of detector - 6,5kg

Module of detectors
Number of detectors: 18
Dimensions of module: 730x90x4700
Weight of module: 150kg
Detectors mounted to steel frame.
Steel frame built with square profiles
Frame mounted to MPD by screws.



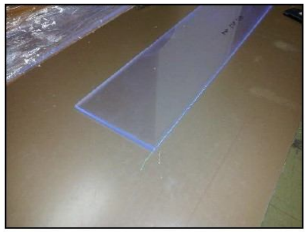
4. Design, modeling variants

THE MUON DETECTOR SCHEME OF ANALOG SIGNAL PATH

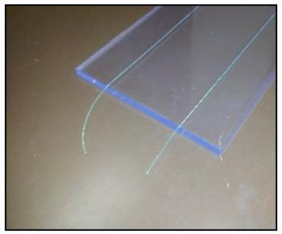


Legend: S (violet) – plastic scintillator, (blue) – SiPM, P (red) – power supply with temperature compensation circuit, T (brown) – temperature sensor, A (green) – amplifier, D (yellow) – MicroTCA system with ADC boards, C (orange) – Analog Front End Module.

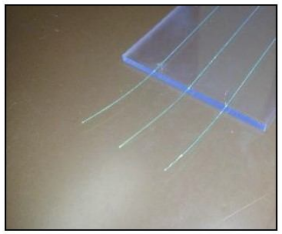
no fibers



2 side fibers



2 up fibers



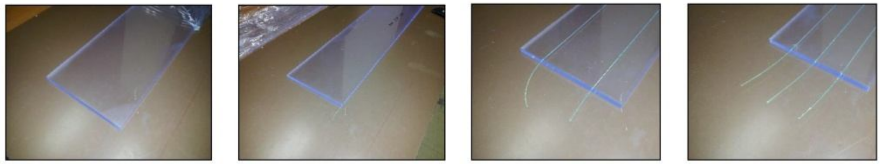
3 up fibers

With or without fiber?

4. Design, modeling variants – FIBER?

<u>OPTION 1</u>

Scintillator: **PVT or PS plastic (no fibers)**
- length: **150 cm**
- width: **10 cm**
- thickness: **2.5 cm**



no fibers | 2 side fibers | 2 up fibers | 3 up fibers

<u>Light Yield estimation</u> Muon dE/dx = 2 MeV / (g·cm^2) - light production by one particle (muon)

Muon Energy Deposition	Scinti. Light Yield (LY)	Muon LY
~5 MeV	× ~8000 ph/MeV	~40000 ph

Light collection eff.: ~20% (?) **Attenuation length (λ): ~75 cm** Light atten.: LY/[2exp(x/λ)]

LY_{mid}: LY × 0.2 / (2e) ≈ **7000 ph** LY_{end}: LY × 0.2 / (2e^2) ≈ **2500 ph**

Photodetector: **SiPM** size: **25×25 mm^2** **(¼ scintilators end area)**

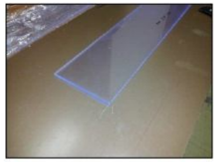
Dark Count Rate (DCR): ~50 Mcps (@ 0.5 phe)

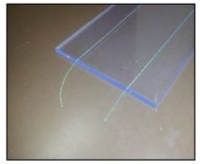
DCR **@ 5 phe (theshold level):** **~10 kcps**

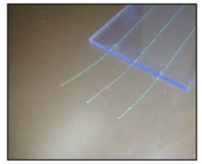
Light Yield (LY)	Photodetector QE: ~25%	Photoelectron Yield (PHE)
	Relative area: 25%	
~7000 ph	×25% ×25%	**~500 phe**
~2500 ph	×25% ×25%	**~150 phe**

4. Design, modeling variants – FIBER?


no fibers


2 side fibers


2 up fibers


3 up fibers

OPTION 2

scintillator: **PVT or PS plastic + WLS (fibers) (fi:1 mm)**

length: **150 cm**

width: **10 cm**

thickness: **1 cm (less thickness)**

Light Yield estimation Muon dE/dx = 2 MeV / (g·cm^2) - light production by one particle (muon)

Muon Energy Deposit	Scinti. Light Yield (LY)	Muon LY
~2 MeV	× ~8000 ph/MeV	~16000 ph

Light collection eff.: ~10% (?) **Atten. length (λ): ~350 cm** Light atten.: LY/[2exp(x/λ)]

LY_{mid}: LY × 0.1 / [2exp(75/350)] ≈ **600 ph** **LY_{end}:** LY × 0.1 / [2exp(150/350)] ≈ **500 ph**

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photodetector: **SiPM** size: **1 × 1 mm^2 (100% fiber end area)**

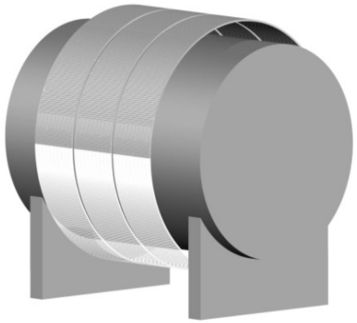
dark count rate (DCR): ~0.5 Mcps (@ 0.5 phe)

DCR **@ 3 phe (less threshold level)** : **~10 kcps**

Light Yield (LY)	Photodetector QE: ~25%	Photoelectron Yield (PHE)
	Relative area: 100%	
~600 ph	×25% ×100%	**~150 phe**
~500 ph	×25% ×100%	**~120 phe**

4. Design, modeling variants – FIBER?

Size estimation	**Detector MCORD**
Diameter:	7 m
Length:	4.5 m
Circumference:	22 m
No. of scintillators:	**660 pcs**
No. of SiPM:	**1320 pcs**
No. of mTCA:	**4 crates**



False trigger rate (FTR) estimation

SiPM-SiPM coinc_gate: 20 ns (two ends of a one scintillator)

scintillator trigger_gate: 100 ns (two scintillators on MCORD cilinder)

cosmic muon rate: **<150 cps/m2**

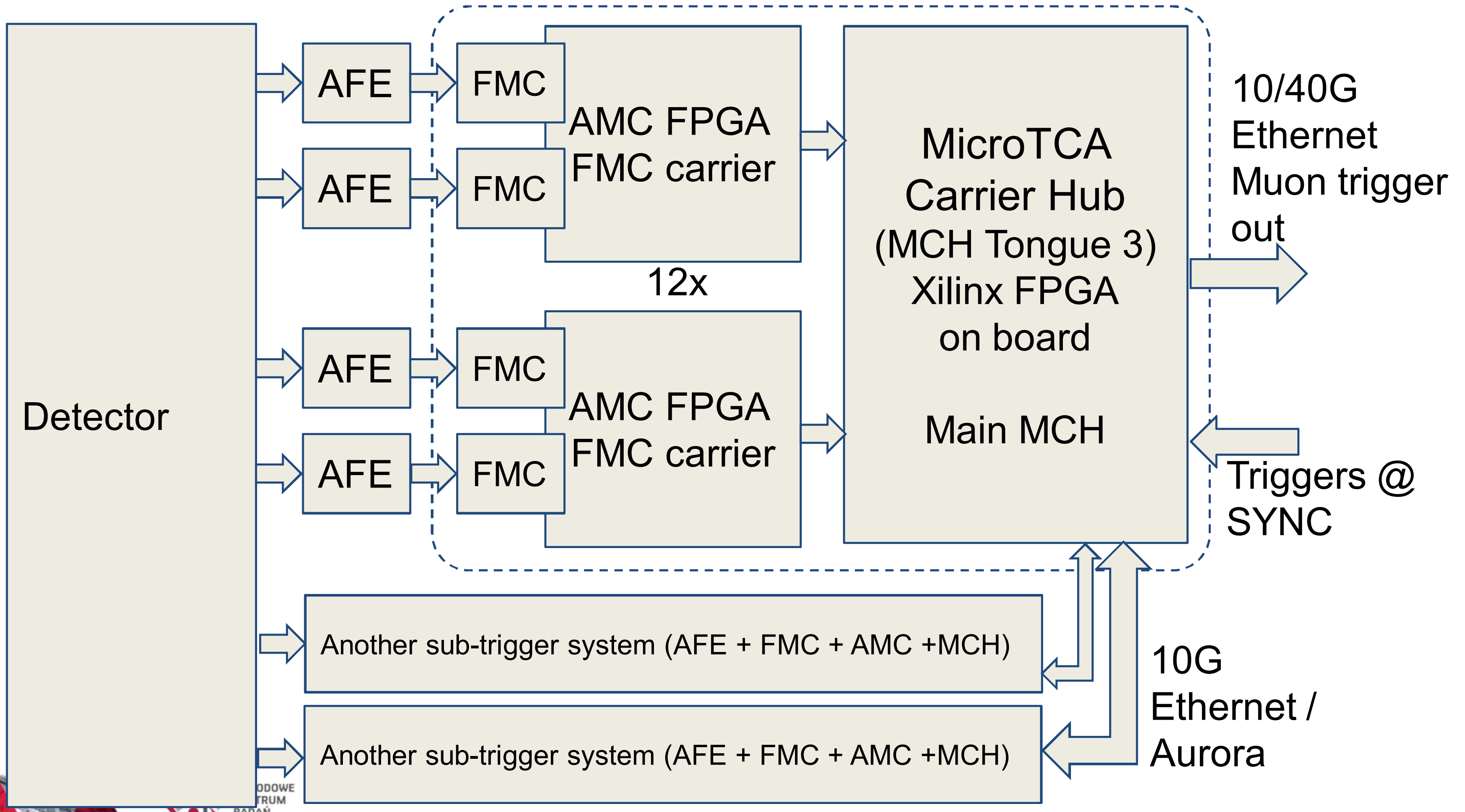
DCR (dark count rate)

PVT or PS plastic	(No fiber)	PVT or PS plastic + WLS	
DCR (@ 5 p.e.)	~10 kcps	DCR (@ 3 p.e.):	~10 kcps
noise-noise FTR:	**<0.1 cps (8,67xE-2)**	**noise-noise FTR:**	**<0.1 cps**
noise-cosmic FTR:	**<0.1 cps (7,81xE-2)**	**noise-cosmic FTR:**	**<0.1 cps**

4. Design, modeling variants

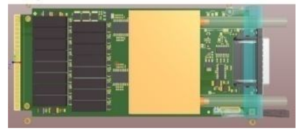
THE MUON DETECTOR SCHEME OF DIGITAL SIGNAL PATH

uTCA based modular muon trigger



MicroTCA (MTCA) configuration

Analog Front-End module



FPGA mezzanine card (FMC)

AMC FMC carrier board

MTCA Carrier Hub

- Standard MTCA crate (14U)
  (cable fi1,5cm 24 channels +8)
  (additional cable for 5V and 40V power)
- Crate number depends on channel count and sampling speed

At 250MS/s: 192 channels / crate
At 125MS/s: 384 channels / crate
(16 cables)
At 80MS/s: 576 channels / crate
At 50MS/s: 768 channels / crate

For several MTCAs one main MCH concentrate data from slaves MHCs to generate final muon trigger

5. Team

30 people
Including
18 scientists (professors and doctors)
12 engineers
from
3 universities and 2 science institutes

With knowledge and experience in digital and analog electronics, scintillators and photodetectors, nuclear and astrophysics, data acquisition and analysis, simulation and experiments.

Our group is a member of Polish consortium NICA-PL

5. Conclusions

1. Cosmic ray detector is necessary for good calibration of TPC, TOF and ECAL, MPD detectors before completion of MPD .
2. Cosmic ray detector is helpful for better calibration of TPC TOF, before each experimental session.
3. Additionally MCORD can be use for astrophysics observations similar to past colider experiments. In our case, especially for investigations of near horizontal muon bundles (research of main trivial mechanism of multi-muon event generation (EAS muons).
4. Our team has a realistic plan and is capable of building this detector.
5. Projected cosmic ray detector will be designed to have required time resolution and position accuracy

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Thank You for Attention