Multichannel SIPM readout system for MPD Cosmic Ray Detector based on MicroTCA platform with embedded sub-ns WR synchronization

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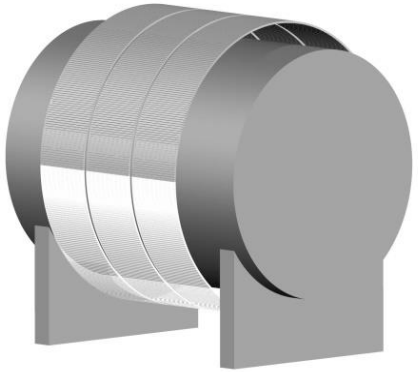
Outline

1. NICA collider & Cosmic Ray Detector – Goals
2. SIPM AFE
3. SIPM readout chain based on Open Source HW
4. Conclusion



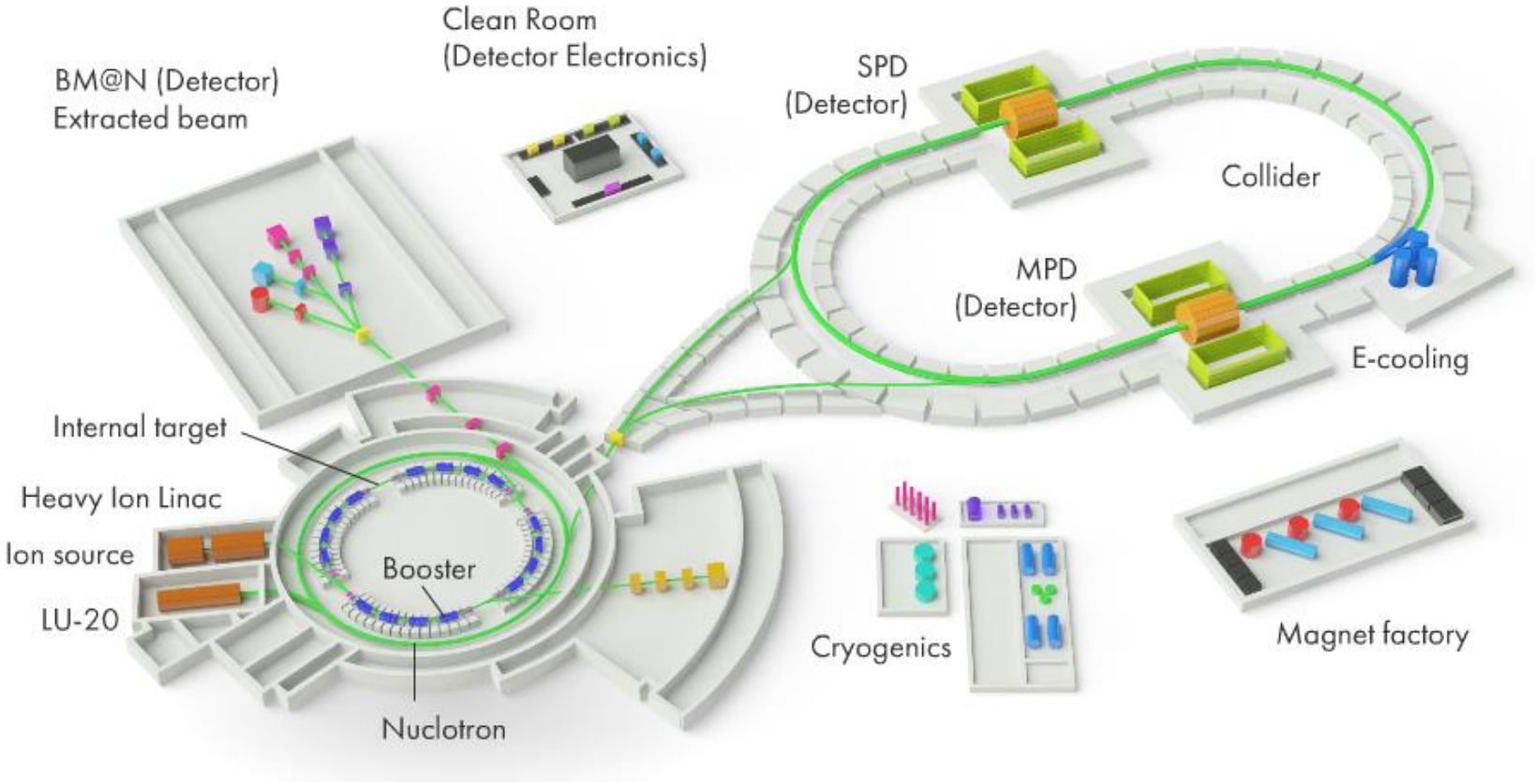
NICA - **N**uclotron **I**on **C**ollider f**A**cility

BM@N - **B**aryonic **M**atter **a**t **N**uclotron

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

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

1. NICA complex



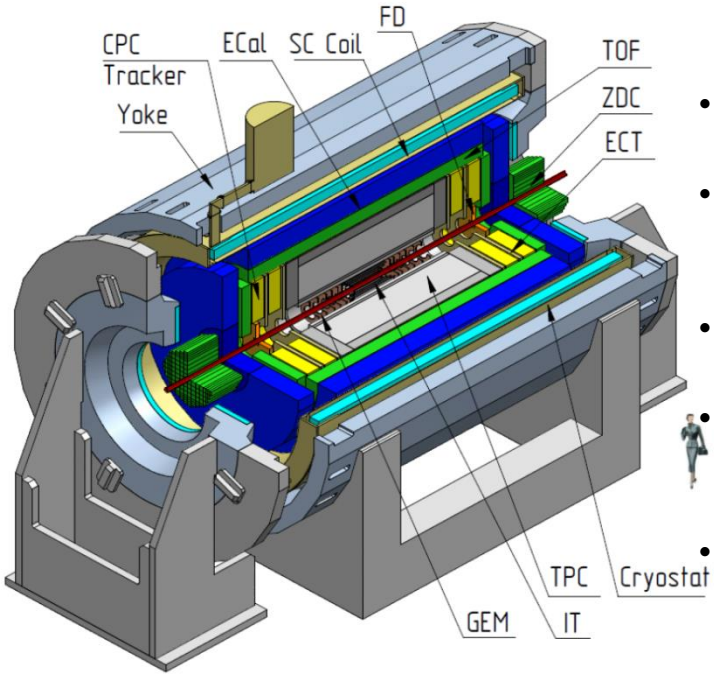
Light Ions

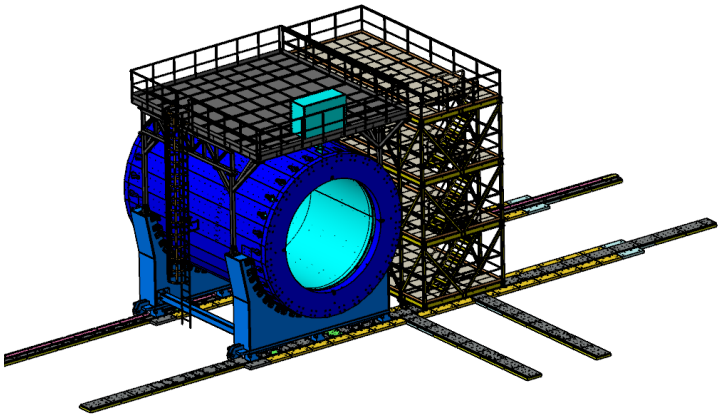
Ion source and Linac LU-20
Nuclotron
BM@N (Detector)
MPD (Detector)

Heavy Ions

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

1. NICA complex



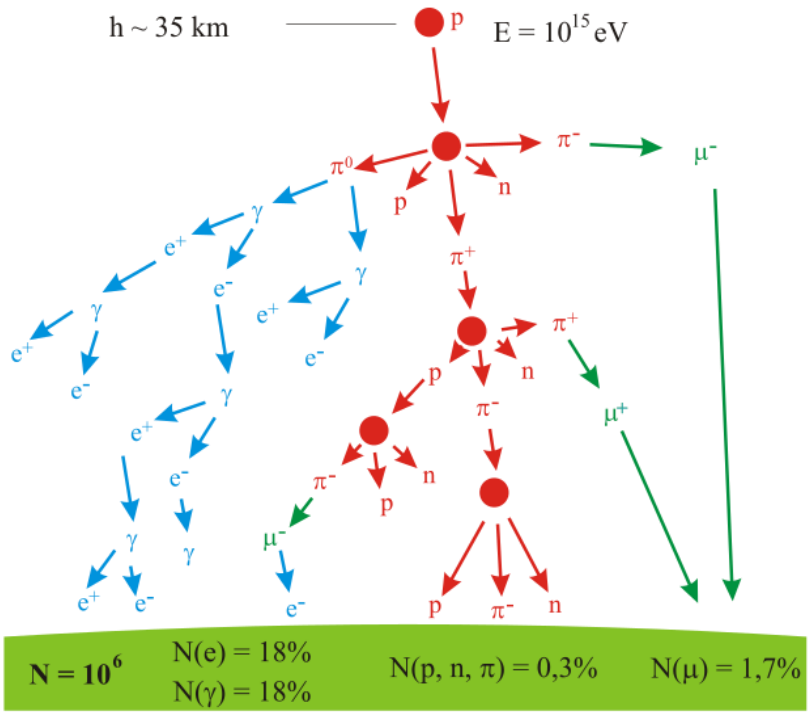


- FD Forward detec
- Superconductor solenoid (SC Coil)
- inner detector (IT)
- straw-tube tracker (ECT)
- **Time-projection chamber (TPC)**
- **Time-of-flight system (TOF)**
- **Electromagnetic calorimeter (EMC - ECal)**
- Zero degree calorimeter (ZDC).

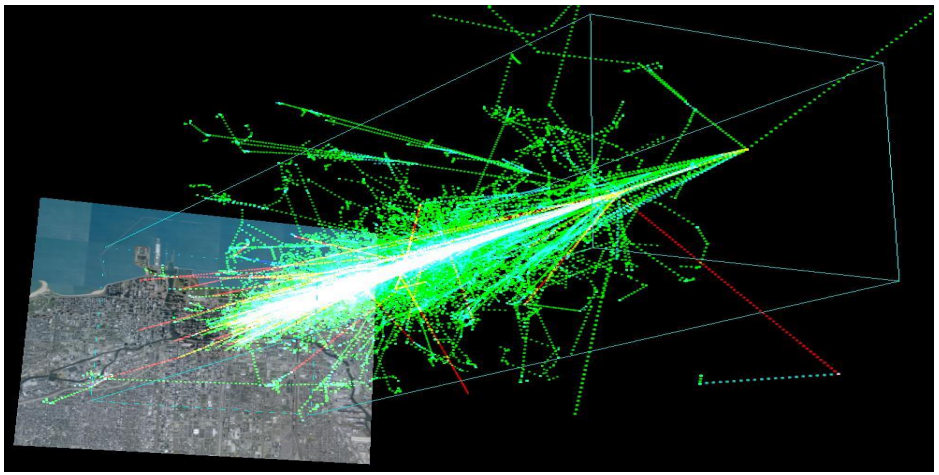
nica.jinr.ru/video/general_compressed.mp4

Cosmic Ray Detector – Goals

PRIMARY PARTICLE

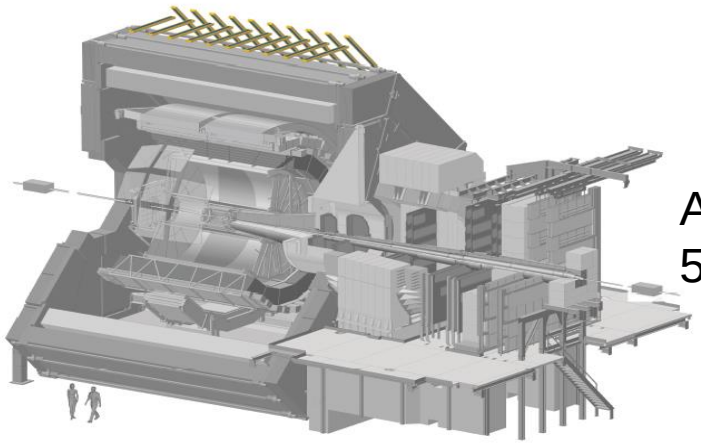


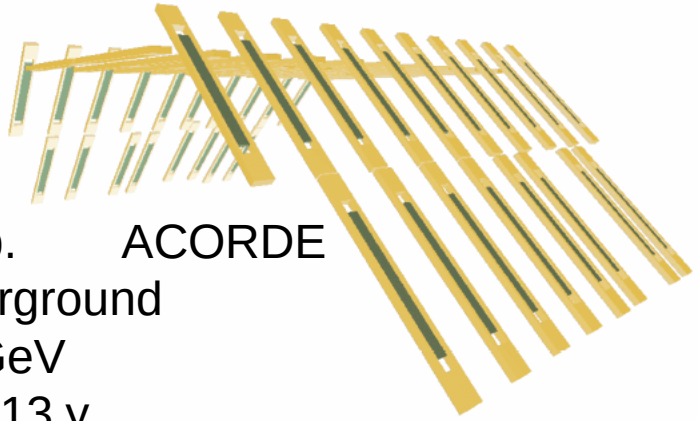
GROUND LEVEL



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.

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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[b] Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany
[c] University of Siegen, Siegen, Germany

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

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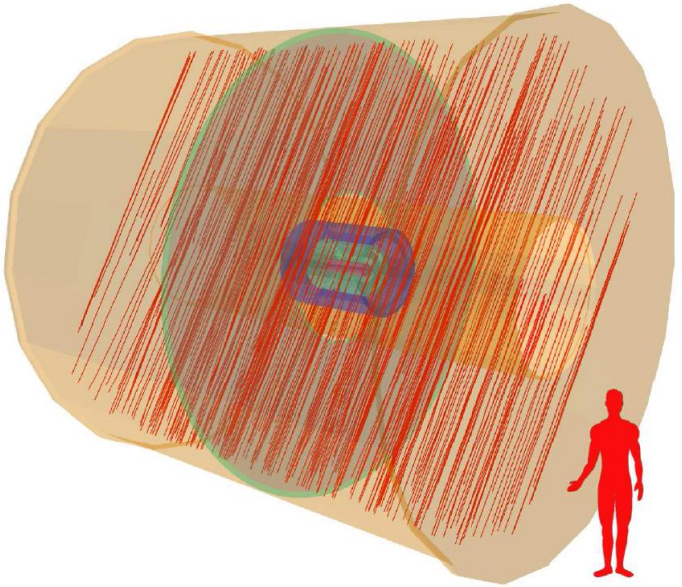
Study of multi-muon bundles in cosmic ray showers detected with the DELPHI detector at LEP

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],

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

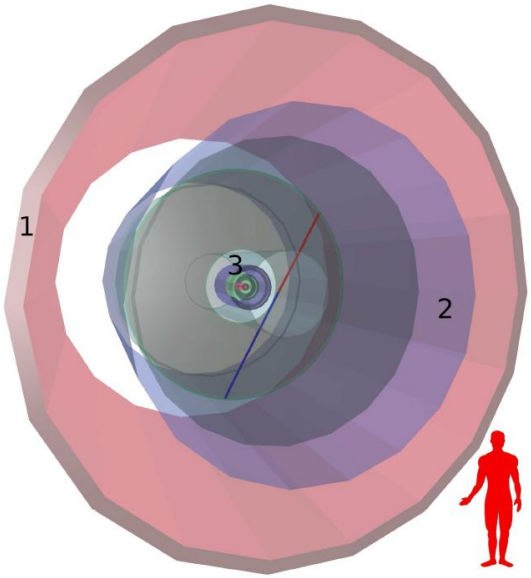


Additionally

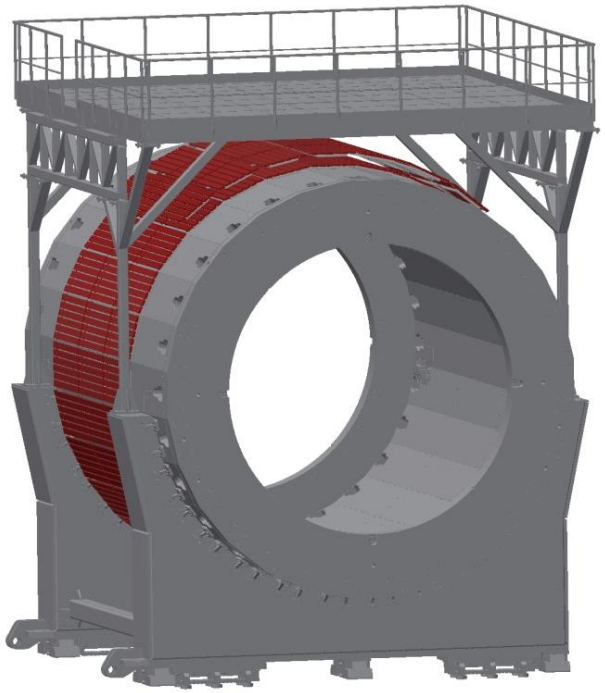
c) Astrophysics (muon shower and bundles)
- unique for horizontal events

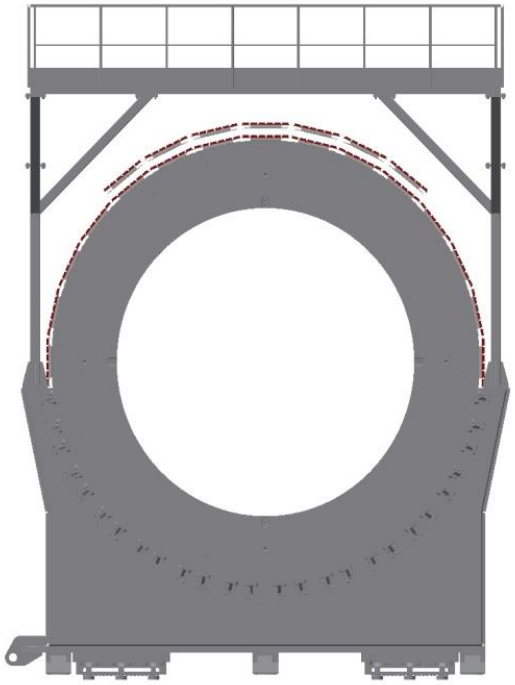
Working in cooperation with TPC

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



Design, modeling variants

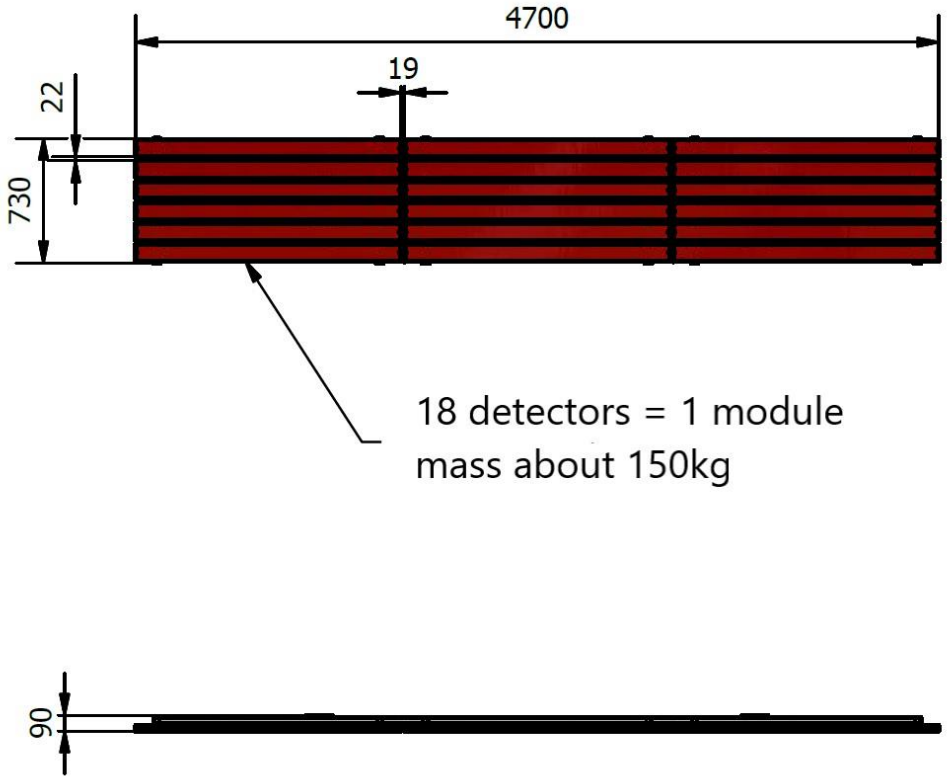


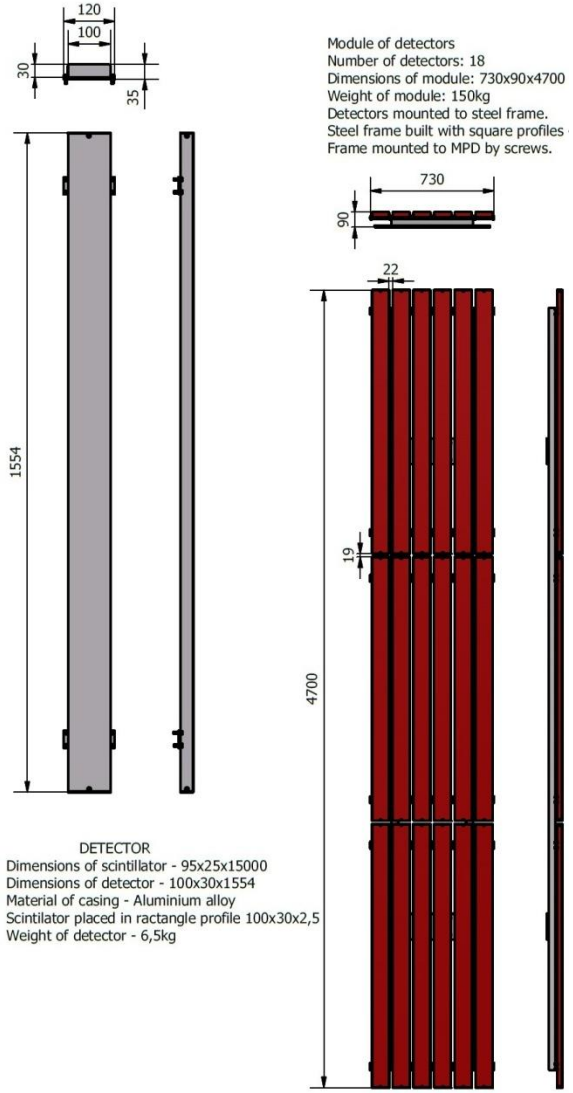


MCORD at MPD scheme

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

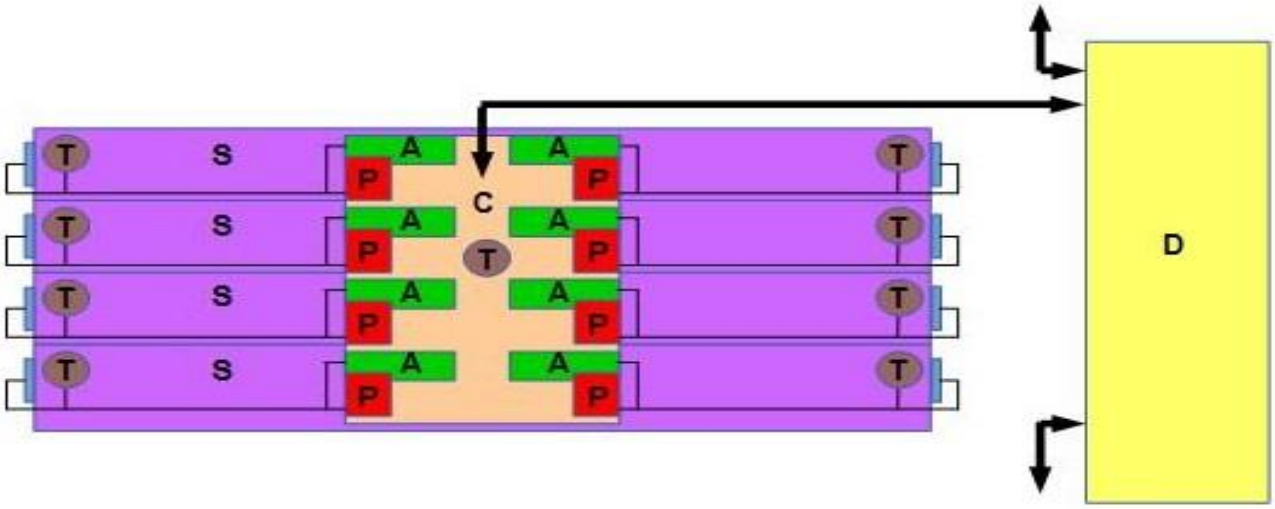
Scintillators





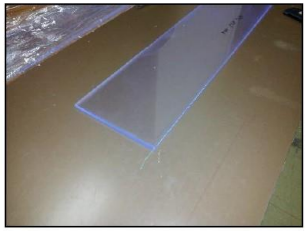
Scintilators and modules

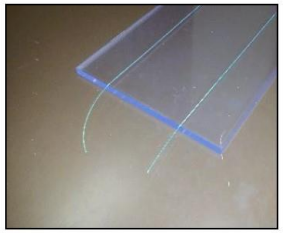
Scintillators readout

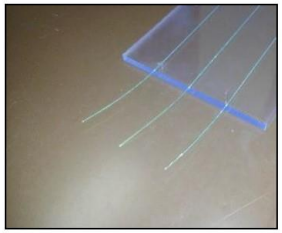


Legend: S (violet) – plastic scintillator, (blue) – SiPM, P (red) – power supply with temperature compensation circuit, T (brown) – temperature sensor, A (green) – amplifier, D (yellow) – MicroTCA system with ADC boards, C (orange) – Analog Front End Module.


no fibers

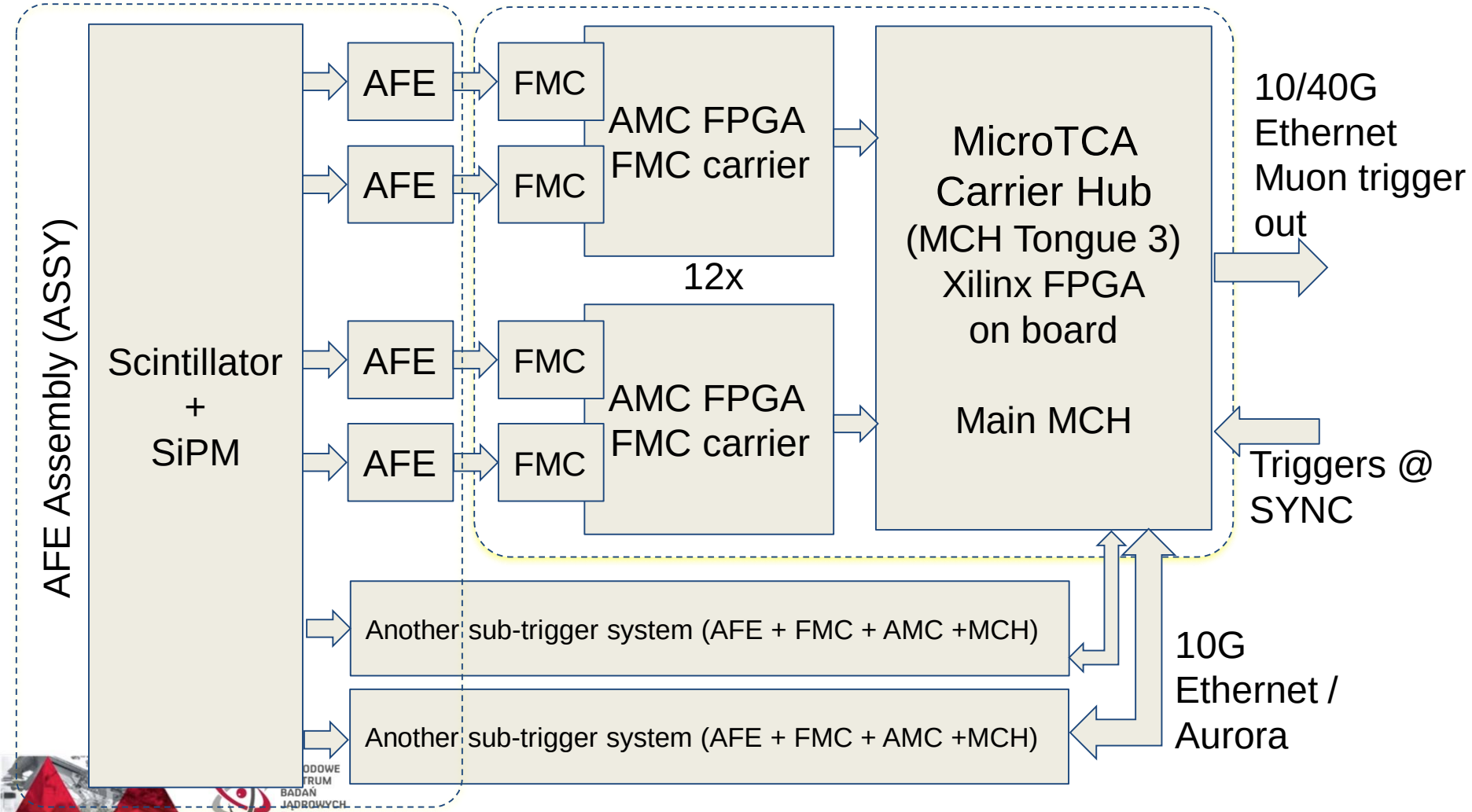

2 side fibers


2 up fibers


3 up fibers

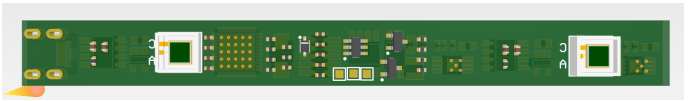
With or without fiber?

MTCA based modular muon trigger (signal flow only)



MicroTCA (MTCA) and OHWR

Analog Front-End module



FPGA mezzanine card (FMC)

AMC FMC carrier board

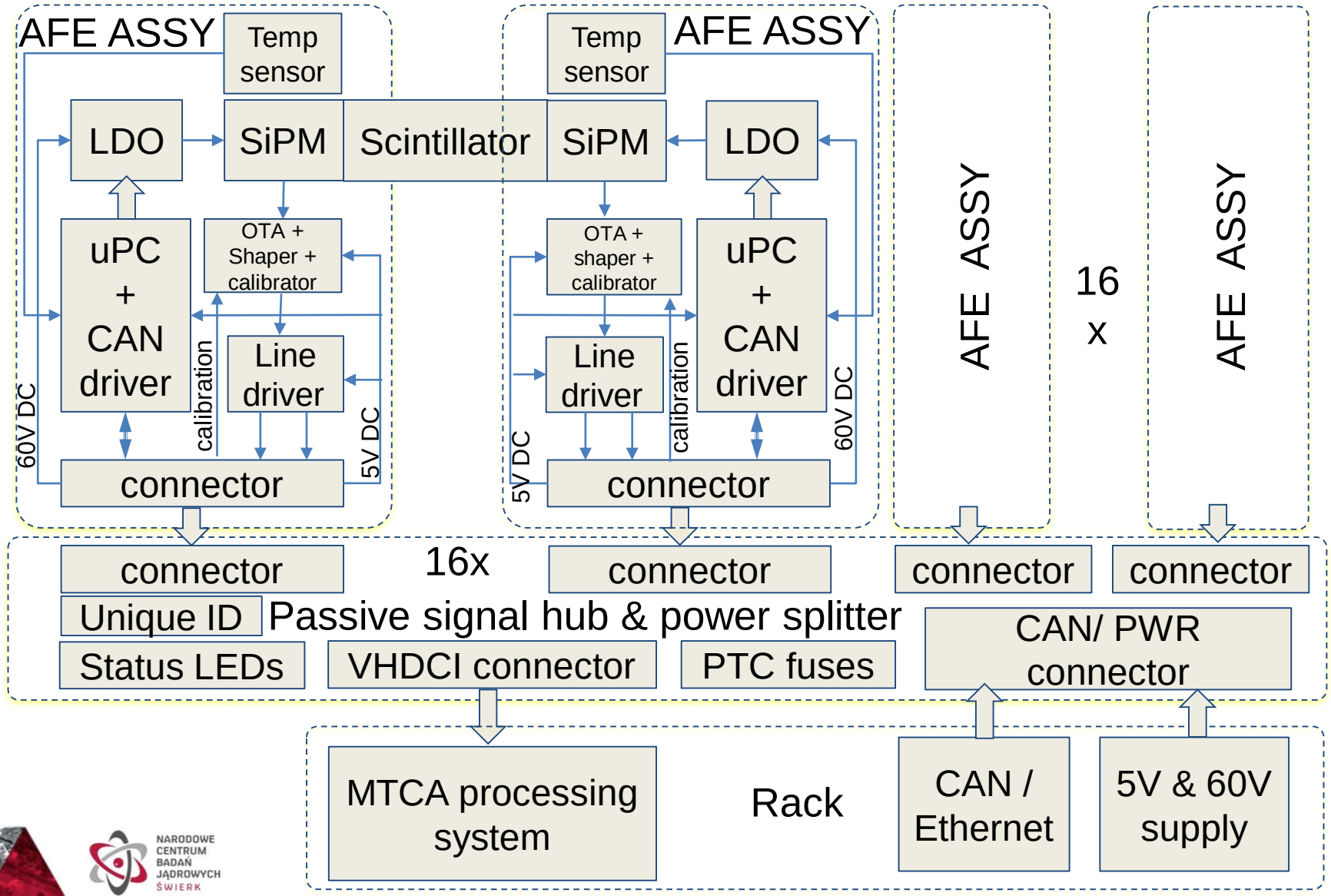
MTCA Carrier Hub

- Standard MTCA crate (14U)
(cable fi1,5cm 24 channels +8)
(additional cable for 5V and 70V 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 concentrates data from slave MCHs to generate final muon trigger

SiPD readout chain – Analog Front End



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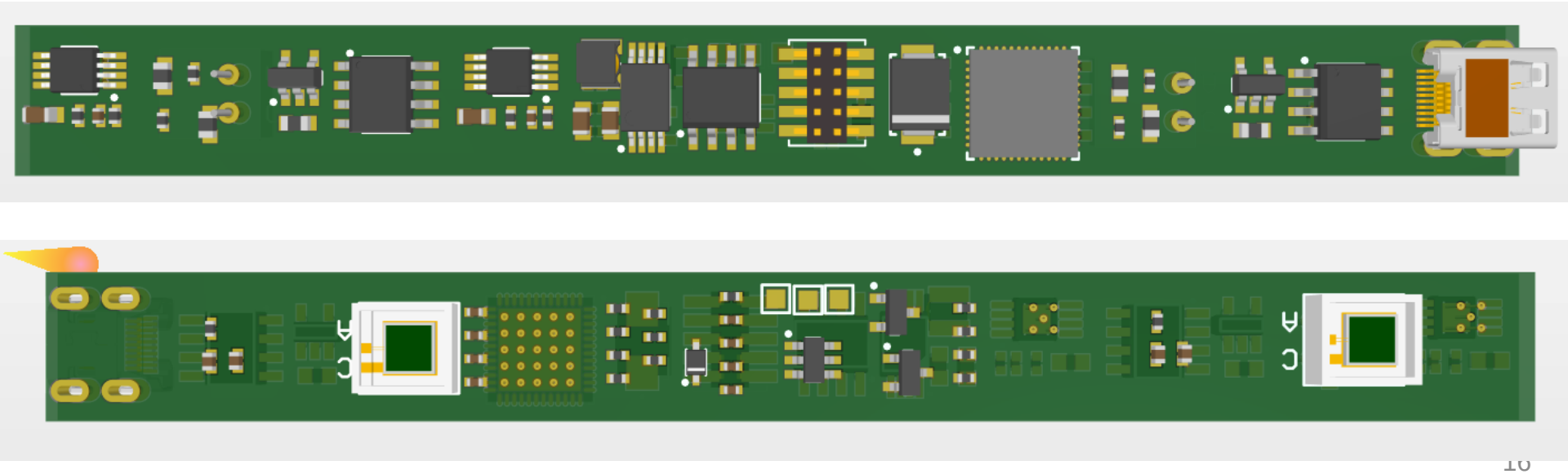
Analog Front End configuration

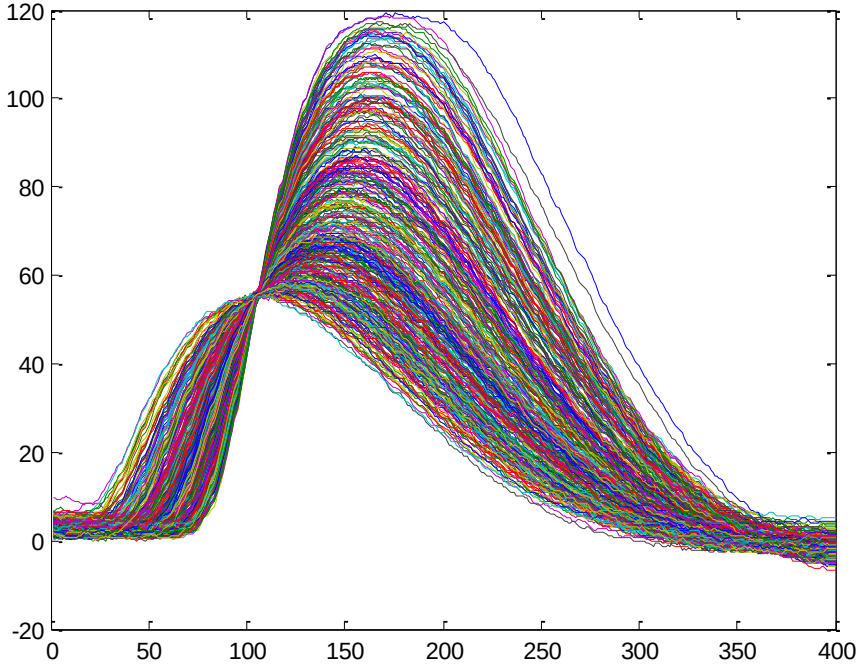
- Dedicated AFE Assembly per two SiPM
- Embedded uPC + temperature sensor + LDO for SiPM set point adjust
- CAN network connectivity with unique ID chip as CAN address
- Unique ID in every hub for VHDCI cabling checking and identification
- Hardware ID for every AFE ASSY
- Low cost LDO instead of expensive switching power supply. No inductors required and lowers EMI.
- SiPM voltage, AFE current monitoring, latchup detection & protection for AFE
- Low cost shielded VHDCI cables – COTS components available as 1-10m length and custom versions
- Local passive hub with PTC fuses for 5V and 60V rails, distribution of power, CAN and signals from 16 AFE ASSY to single VHDCI cable
- Status LEDs on AFE ASSY and hub for quick fault identification
- Central power supply – custom built 2U rack box with COTS resonant 5V SMPS, 60V flyback SMPS, IEC outlets and fuses.
- CAN to Ethernet converter – standard COTS component.

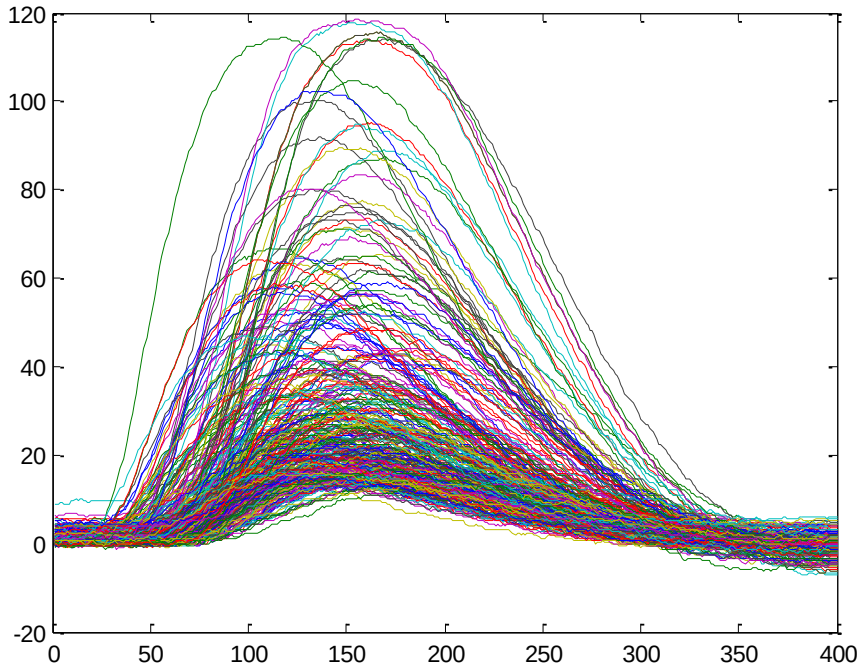
Analog Front End configuration

- Dedicated AFE Assembly per 2 SiPM
- Low cost HDMI cables between AFE and hub
- Cable length TOF measurement for each channel
- Calibration pulse injected to the AFE entry.



Analog Front End – first results with scintillators and readout chain





- Dedicated AFE Assembly per 2 SiPM
- Low cost HDMI cables
- Cable length TOF measurement for each channel
- Calibration pulse injected to the AFE entry.

Data processing

Latency estimation for L1 trigger (event without parameters)

- ✓ AFE cabling 8ns/m, with 10m cabling latency is 80ns
- ✓ ADC + SERDES latency: 400ns

Latency estimation for L2 trigger (event with parameters)

- ✓ MGT latency: 500ns
- ✓ Algorithm latency : 2-5us
- ✓ Formatter and transmitter latency: 1us

Estimated total latency: 3.5 – 7.5us

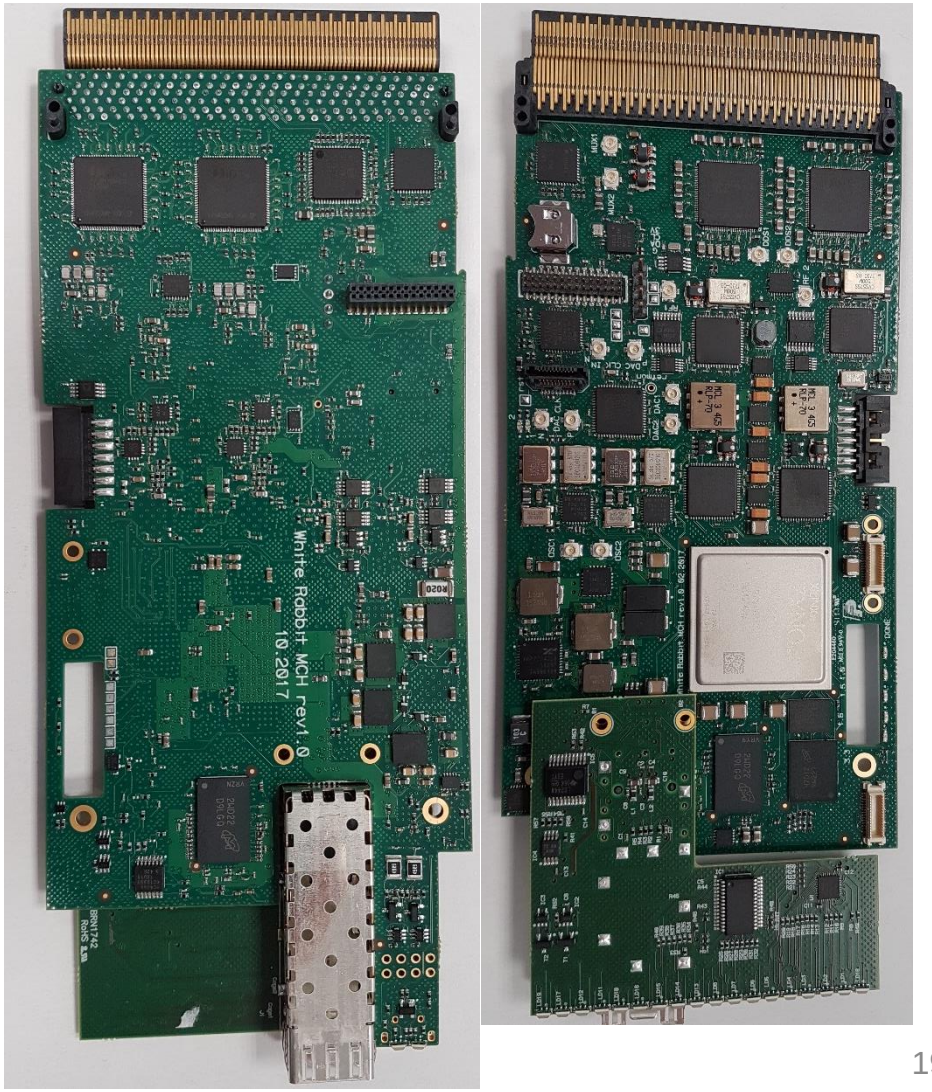
Latency estimation for L3 trigger (between MTCA systems)

- ✓ MGT latency: 500ns
- ✓ Fiber latency: 500ns + 8ns/m
- ✓ Algorithm latency : 2-5us
- ✓ Formatter and transmitter latency: 1us

Estimated total latency: 10 – 15us

White Rabbit synchronization

- WR node timing module resides on top of NAT MCH
- Two WR nodes working in parallel
- Each node connected to different switch
- In case of link failure other node takes over
- Trigger inputs (outputs) available on front panel
- Dedicated WR-enabled crates available commercially from N.A.T
- ~400ps crate – crate synch
- ~150ps channel-channel match.
- ~5ps jitter
- Open source design



Polish consortium NICA-PL

Thank You for Attention