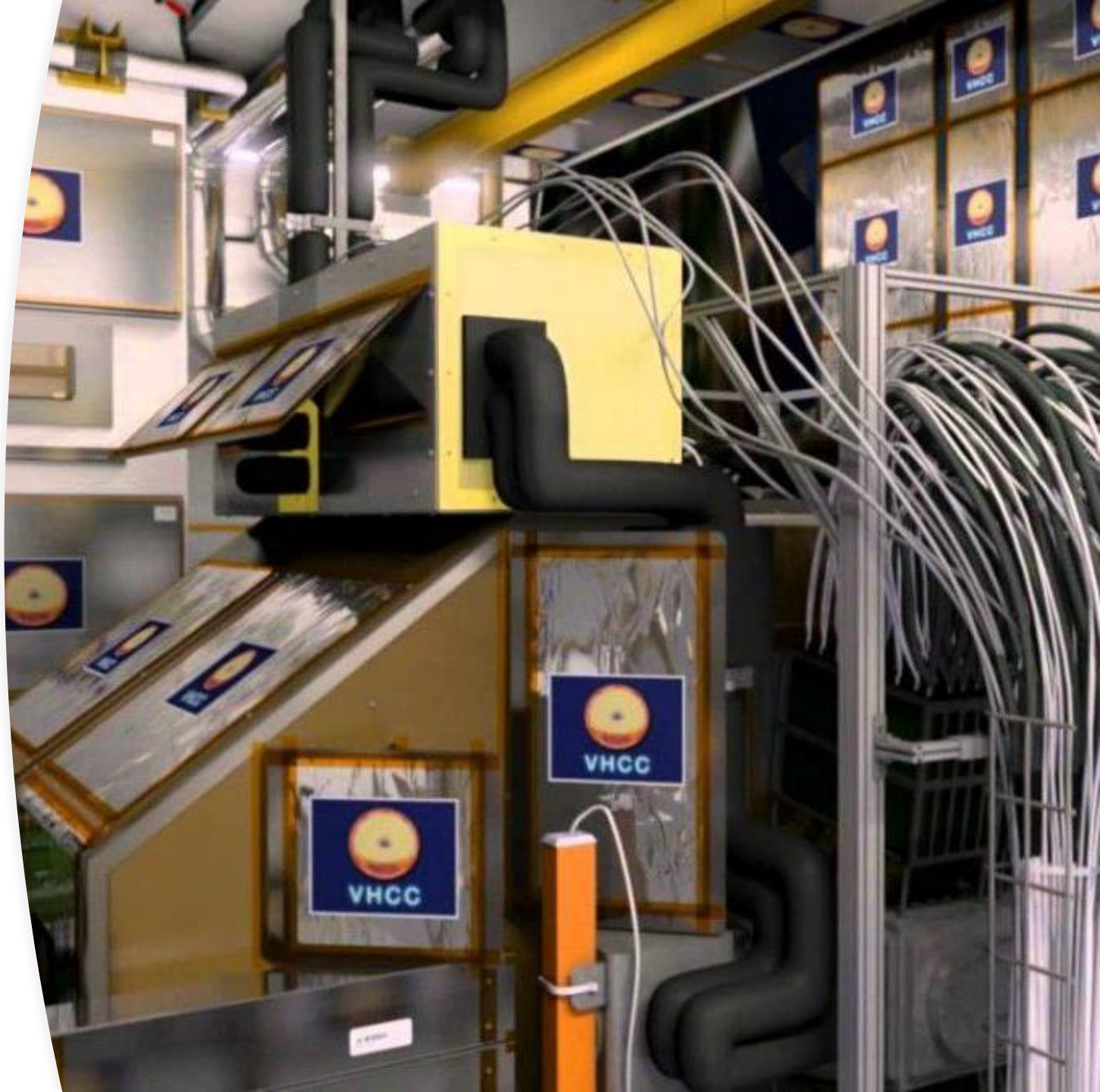
GEM-Timepix detector for MoEDAL

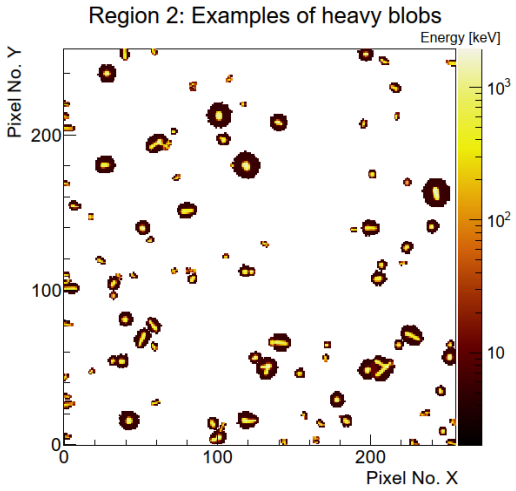
MoEDAL detectors

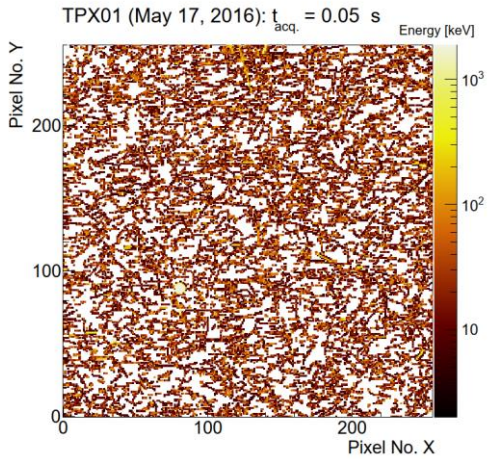
- For Runs 2 and 3 the MoEDAL experiment consisted of NTDs, MMTs and some Timepix detectors
- For Run4 the planned luminosity will increase at least by factor 5
- This will increase the radiation background
- New detectors that can be adjusted to cope the changes are proposed

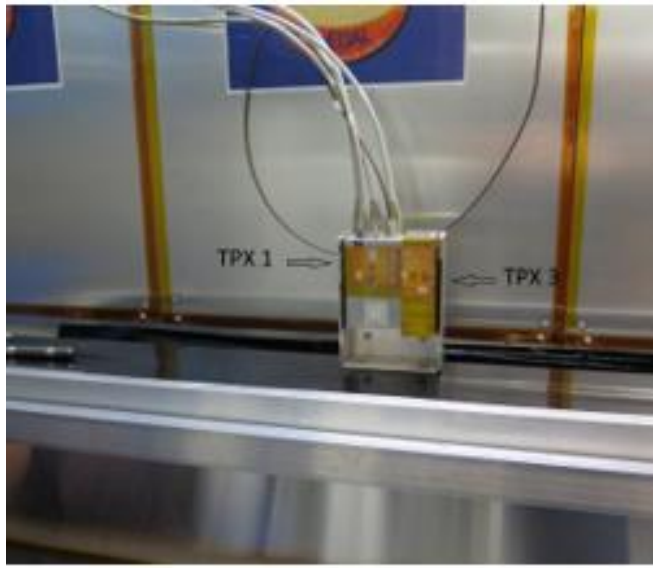


Timepix detectors at MoEDAL

- Timepix detectors have been used in the MoEDAL experiment for background radiation measurements.
- Several detectors have been installed at selected locations.
- The detectors are capable of monitoring changes in the radiation environment throughout the experimental runs.



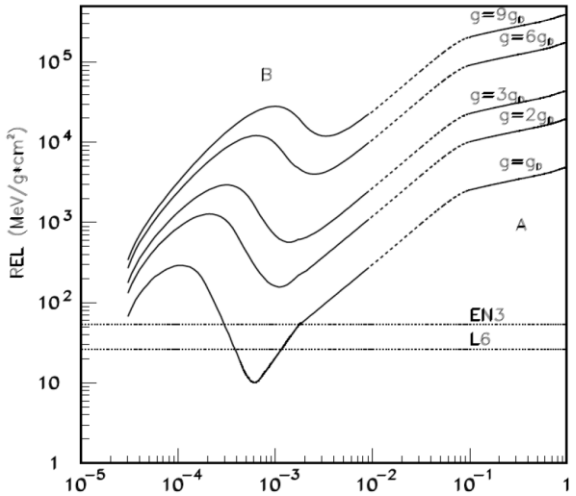




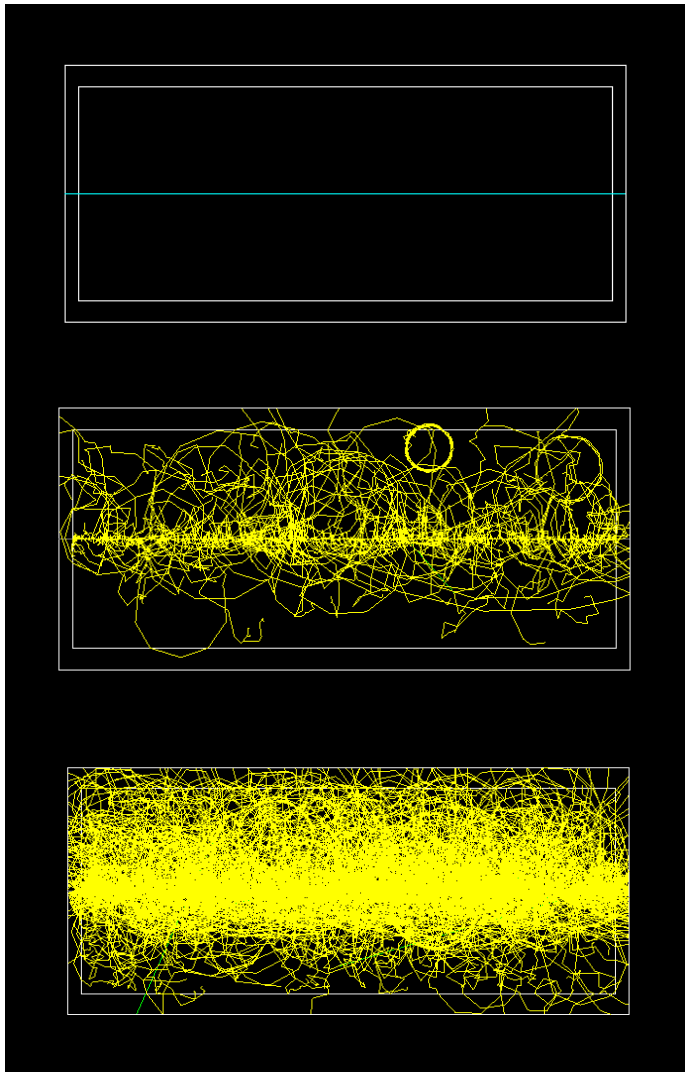
B. Bergmann et al., arXiv:2605.05936

Charge deposition from highly ionizing particles

- The properties of the enclosure have been studied using Geant4 simulations.
- The background radiation is simulated using Pythia8.
- Magnetic monopoles and other exotic particles are simulated using optimized classes from the SUMMA software.
- The response of the GEM stage and the charge collection process are simulated using Garfield++.



Restricted energy loss of magnetic monopoles
Int. J. Mod Phys. A **29** (2014) 1430050.



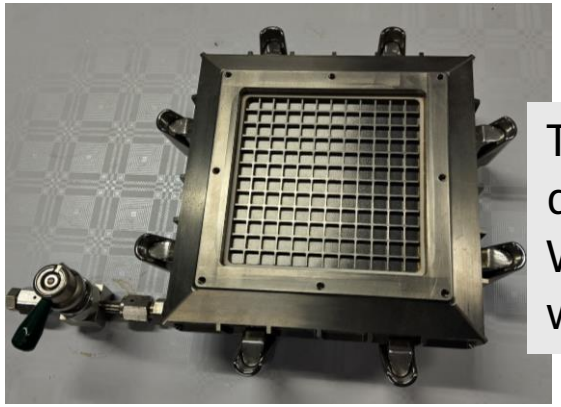
Proton
In average, 4 secondary electrons / particle
Mean energy deposition 5 keV/mm

$^{82}Pb^{82+}$
In average, 11 000 secondary electrons / particle
Mean energy deposition 1.4 MeV/mm

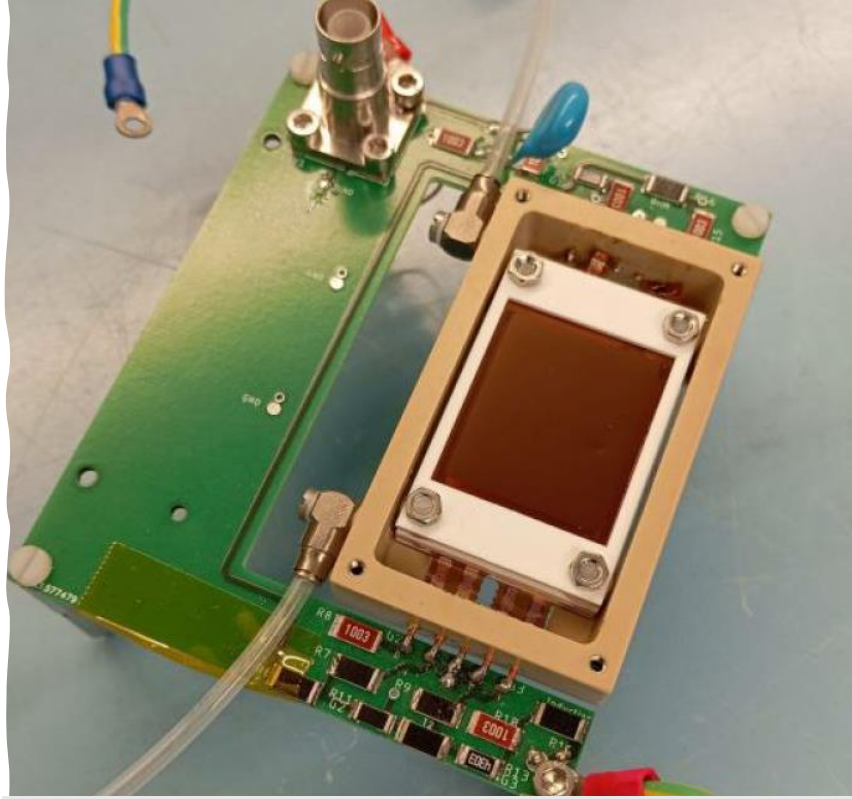
1 TeV monopole
In average, 67 000 secondary electrons / particle
Mean energy deposition 6 MeV/mm

Planar GEM-setup

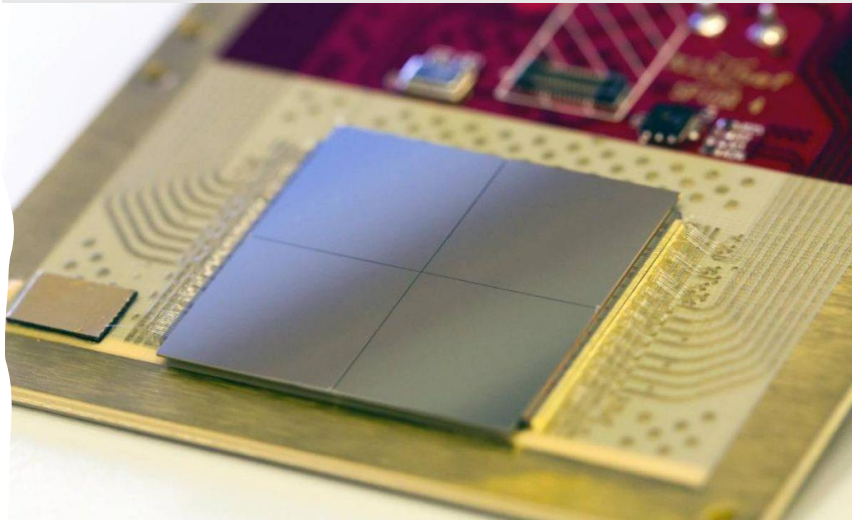
- Since Timepix4 allows multiple chips to be placed next to each other, a straightforward approach would be to build a large-area detector using multiple chips.
- A standard triple-GEM setup could be placed on top of the sensors.
- This configuration can be scaled to cover large areas.
  - However, it would require a relatively large number of Timepix4 chips.

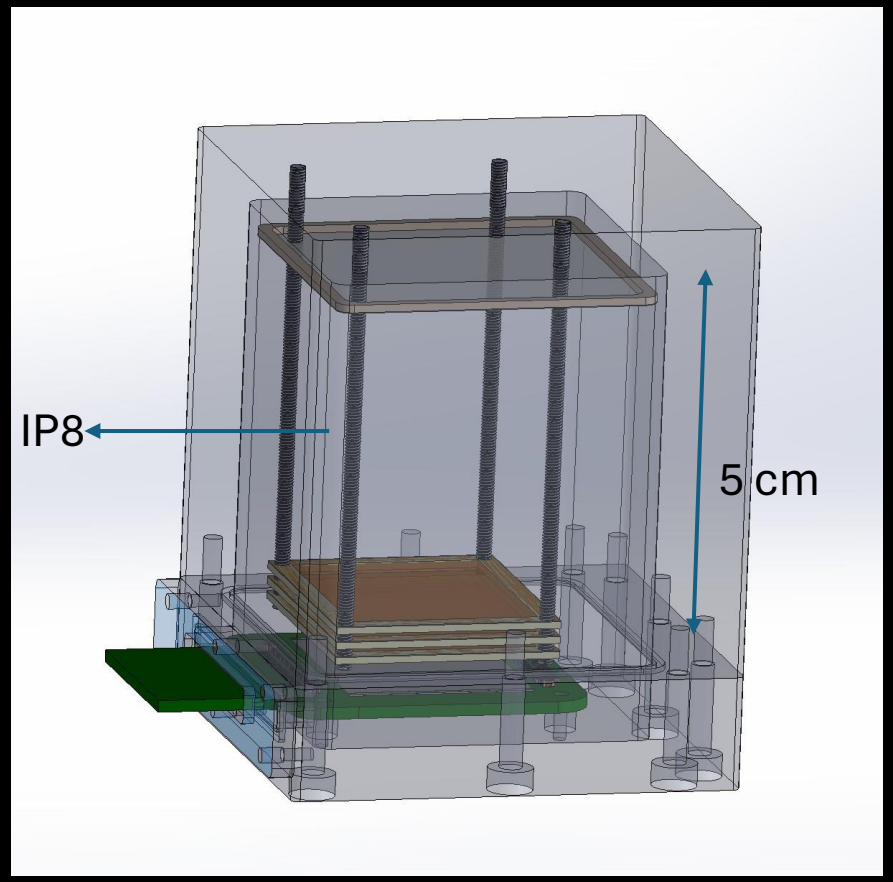


Triple-GEM detector developed at HIP.
Was able to operate months without replacement gas

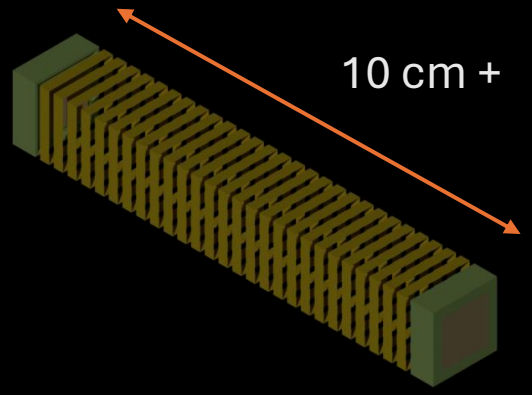


L. Scharenberg et al, MPGD 2024: https://indi.to/GVhSF
Corresponding paper: https://doi.org/10.1088/1748-0221/20/03/C03025





Two GEM-stack readout without drift foil

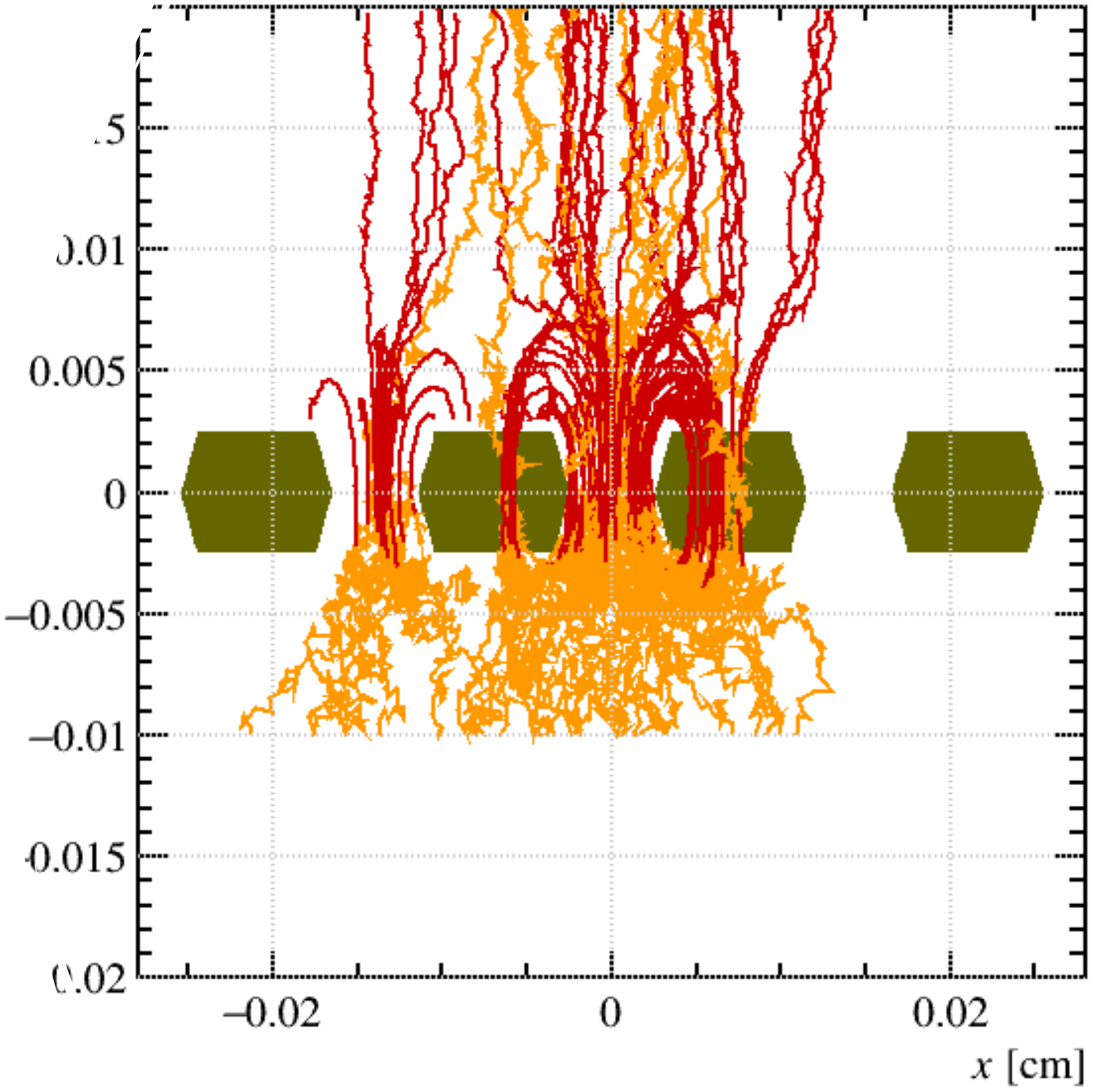


TPC type prototype design

- The detector could be oriented with its side facing the IP.
- A triple-GEM design will be used.
  - The induction gap will be 1 cm.
  - Standard transfer gaps of 1–2 mm will be used.
  - A long drift volume will be used.
  - The need for a field cage will be investigated through simulations.
- The GEM and Timepix will be biased from opposite ends of the setup.
- Gas will flow from top to bottom through sealable inlet and outlet ports.
- Ar/CO_2 (70:30) will be used as the primary gas mixture.
  - The possibility of adding nitrogen to the gas mixture will be investigated

Next steps

- Modify the design and print a mock-up to test the assembly
- Select the components for feedthroughs
- Simulation of the performance in beam tests and in MoEDAL environment
    - GEM amplification

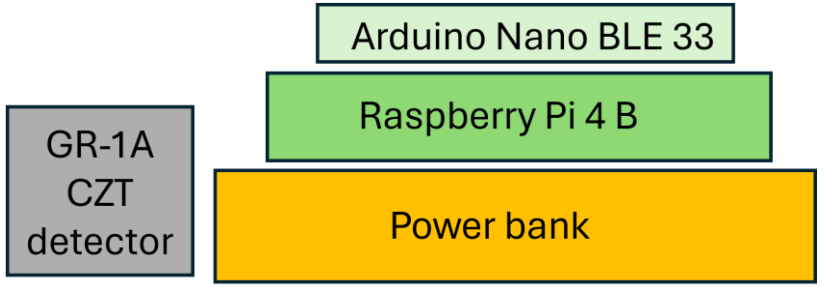


Low-weight Aranda-based Gamma-ray and Environmental Radiation system (LAGER)

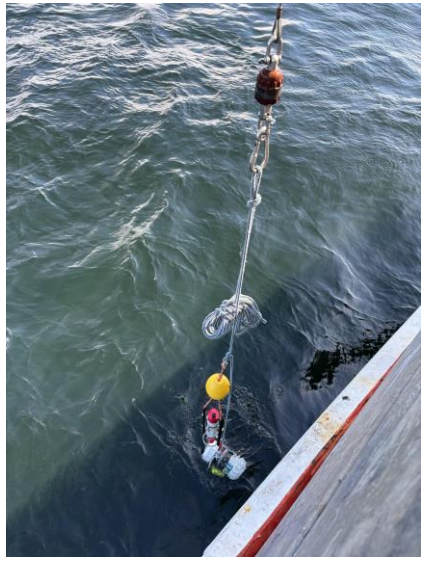
LAGER setup

- Kromek GR-1A detector
  - 1 cm^3 CZT crystal
- DAQ and control through Raspberry Pi 4B
- Auxilliary environmental monitoring through Arduino Nano 33 BLE Sense (Rev 2) microcontroller
  - Temperature, magnetic field, pressure, humidity, accelerometer and gyroscope
- Powered by a 10,000 mAh power bank
- Measurement rate 1 Hz, data stored to RasPi and external USB flash drive simultaneously



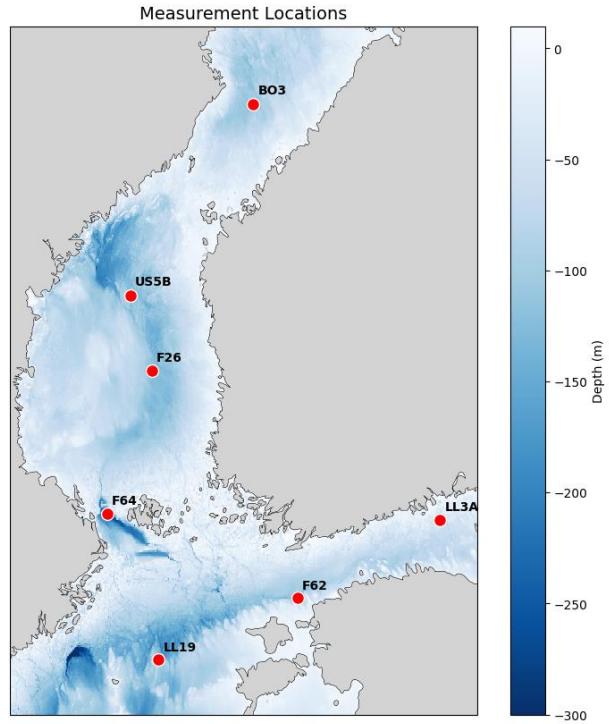


Measurements

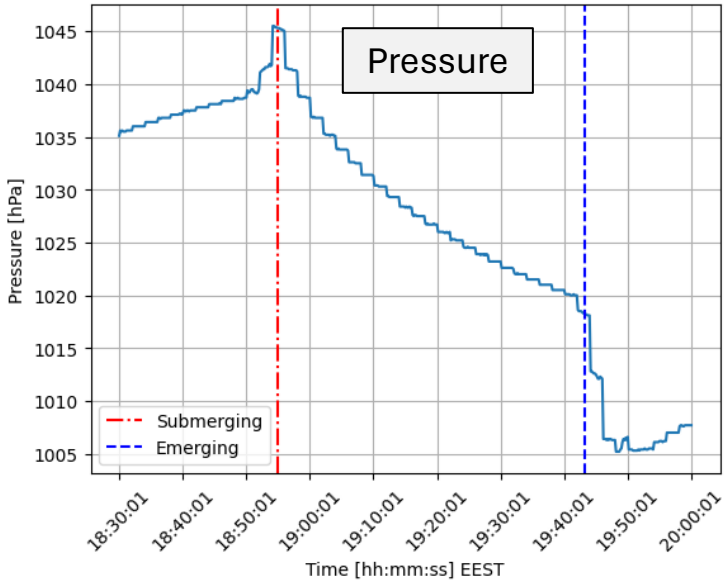


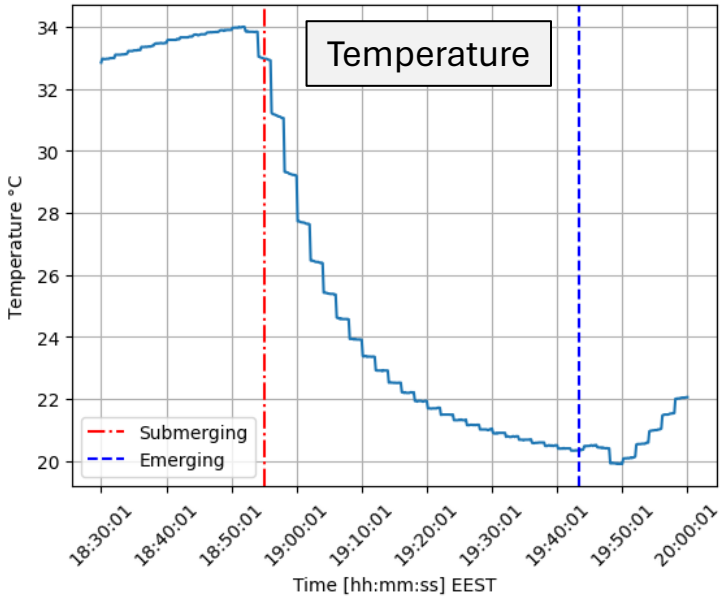
- In total 8 measurements were made
- First measurement failed due to software error
  - Most likely was caused by Arduino which was broken down after second measurement

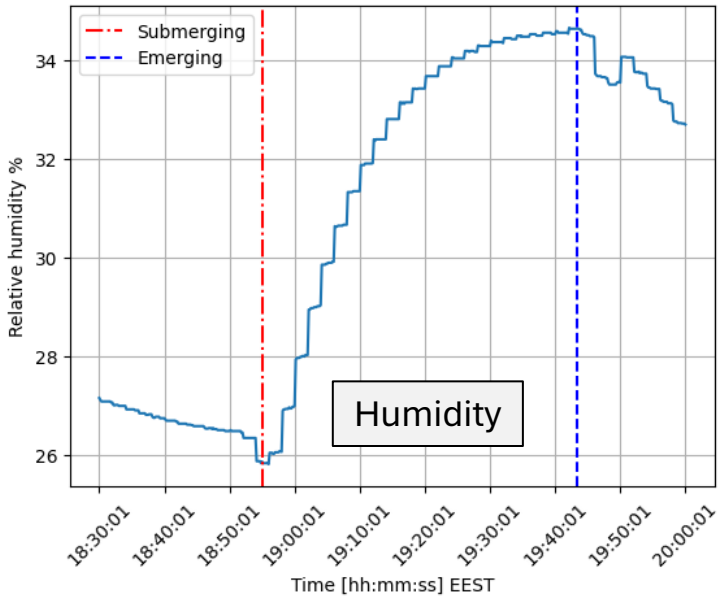
Date	Station	Depth [m]	At seafloor	Duration
Apr 15	LL3A	69	Yes	99 min
Apr 16	F62	95	Yes	60 min
Apr 17	LL19	163	Yes	36 min
Apr 17	F64	277	No	30 min
Apr 20	BO3	109	Yes	46 min
Apr 20	US5B	221	Yes	32 min
Apr 21	F26	138	Yes	15 min
Apr 21	LL12	82	Yes	4 min

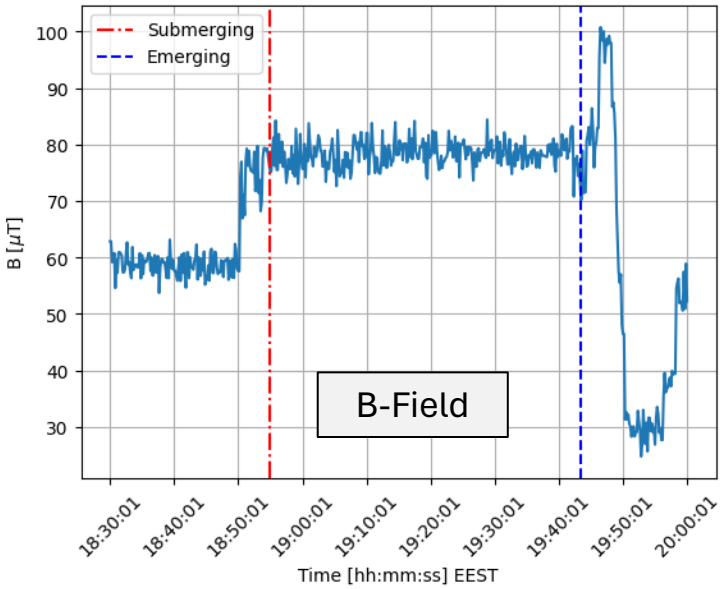


Environmental conditions



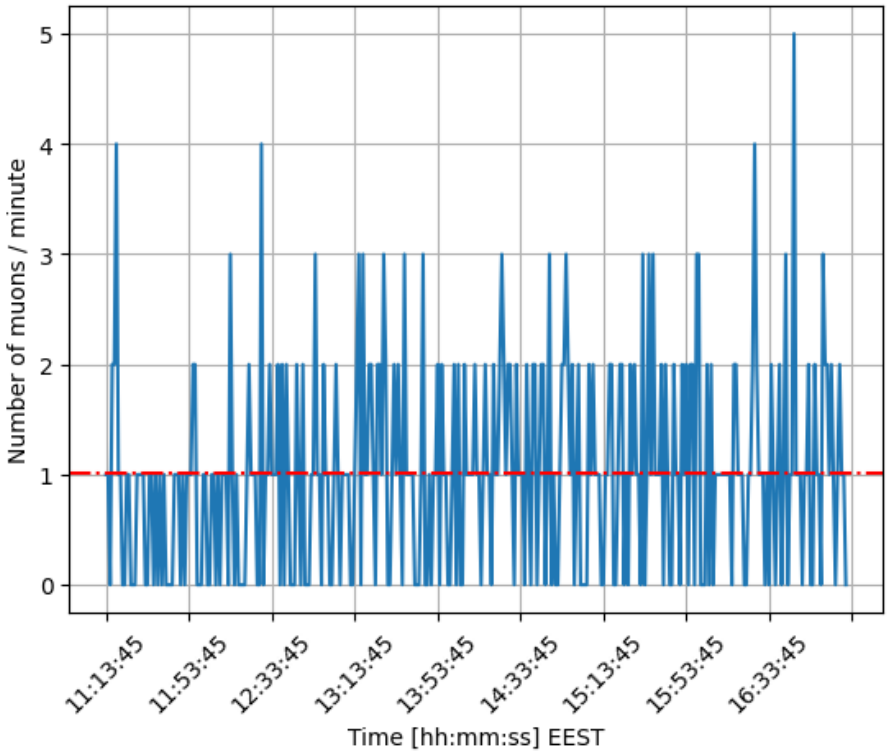




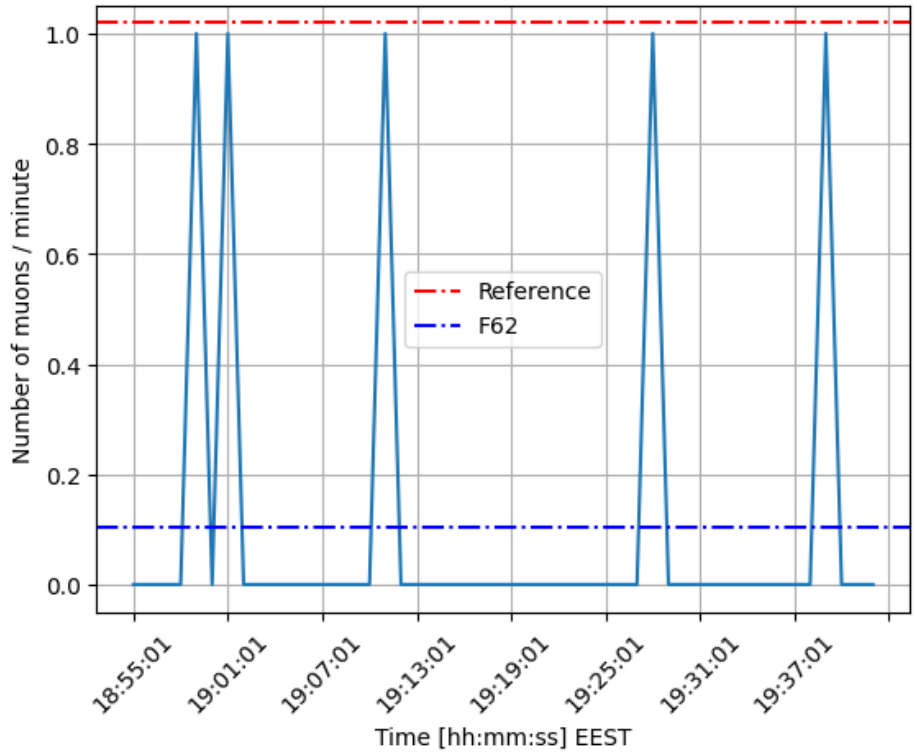


Average muon rates

Kumpula

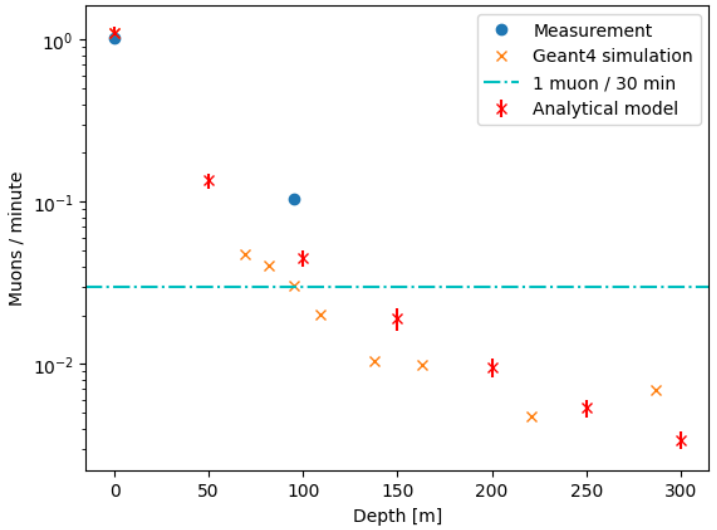


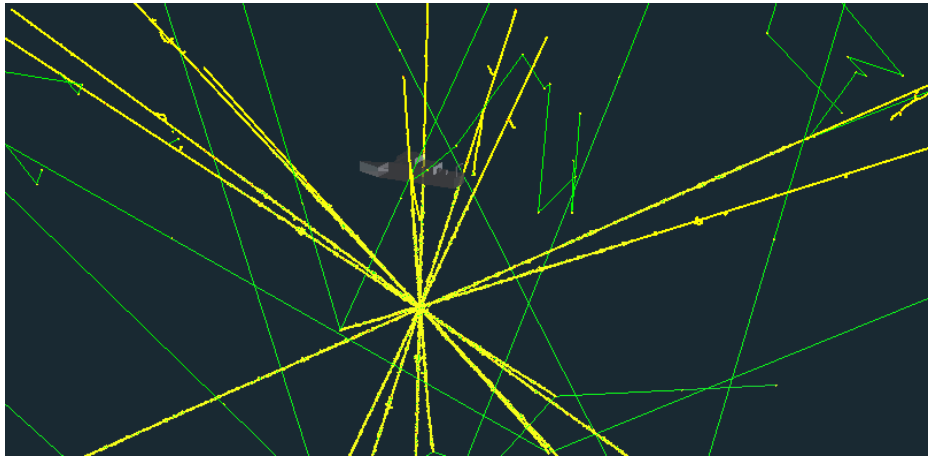
F62



Expected muon rates

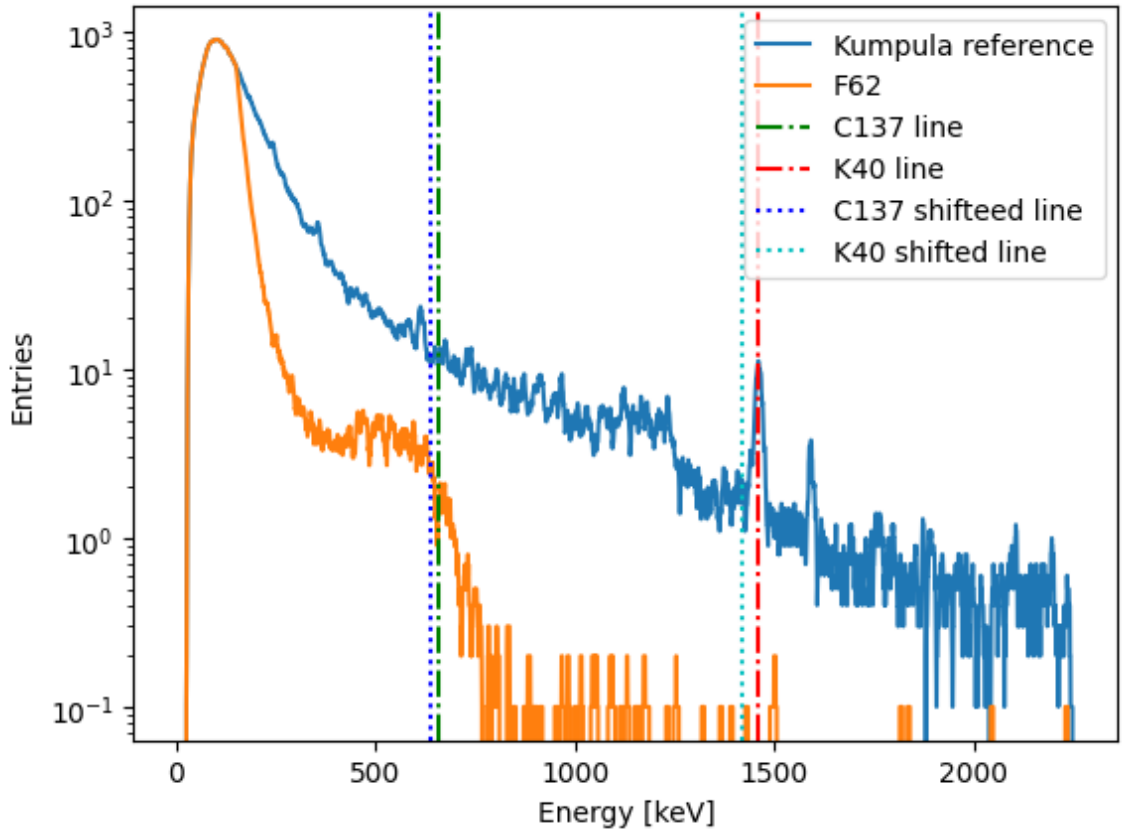
- Muon rate was counted from the saturation bit of the detector spectrum
- Overlying water column attenuates the muon rate in submerged detector
- At depths below 100 meters no muons were expected to be seen based on the Geant4 simulations

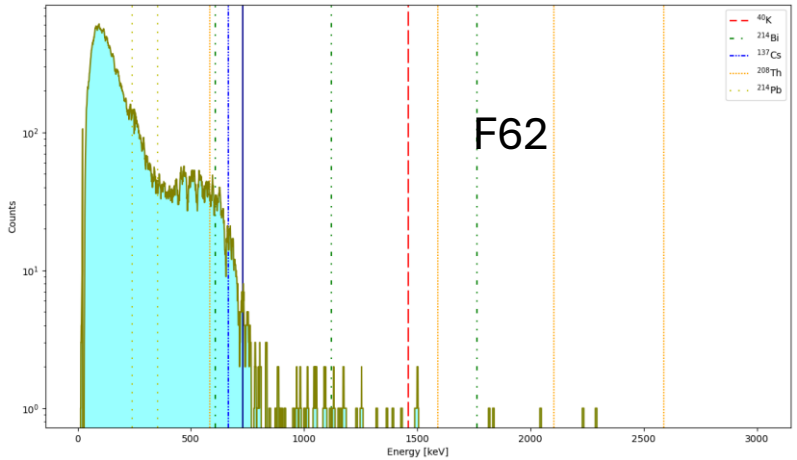


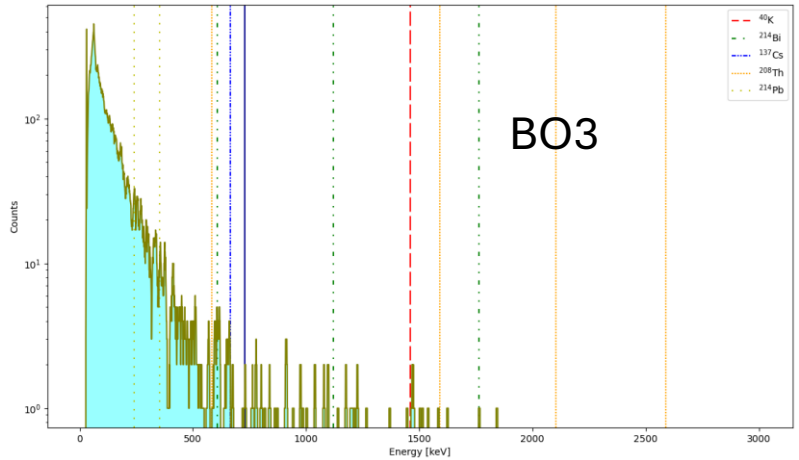


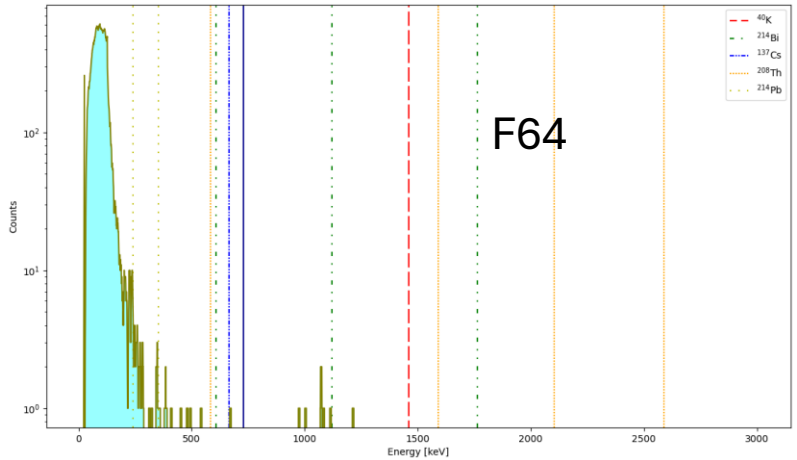
Radiation measurements

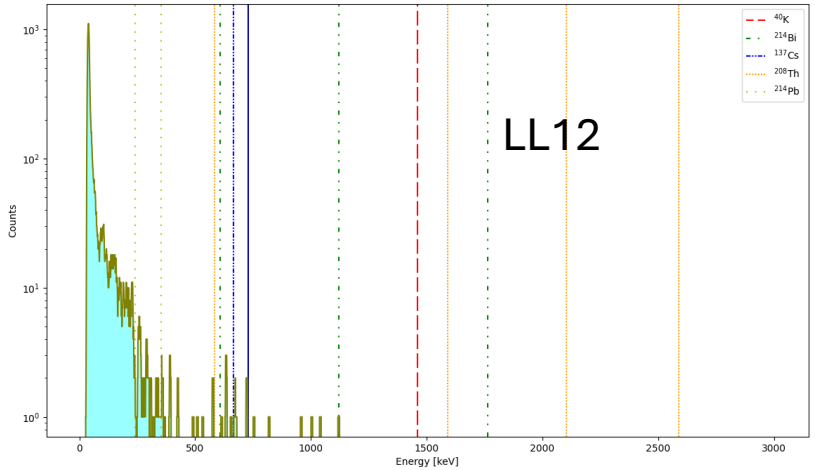
- First two measurements were done together with Arduino
- In addition, a Mirion RDS-32 was lowered along the LAGER setup
- This created low-energy electronic noise to each measurement

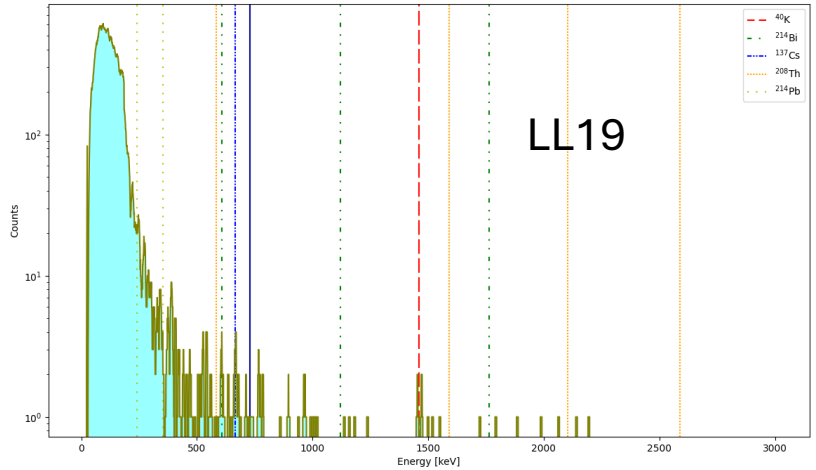


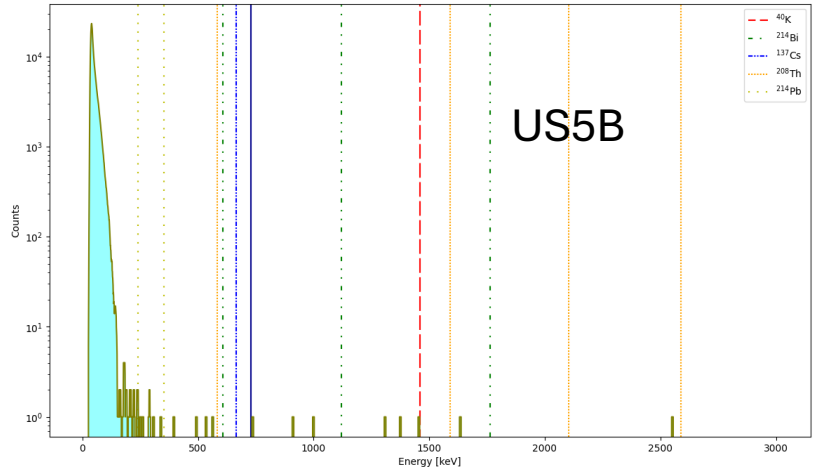

F62
Counts
Energy [keV]
^{40}K
^{214}Bi
^{137}Cs
^{208}Th
^{214}Pb


BO3
Counts
Energy [keV]
^{40}K
^{214}Bi
^{137}Cs
^{208}Th
^{214}Pb


F64
Counts
Energy [keV]
^{40}K
^{214}Bi
^{137}Cs
^{208}Th
^{214}Pb

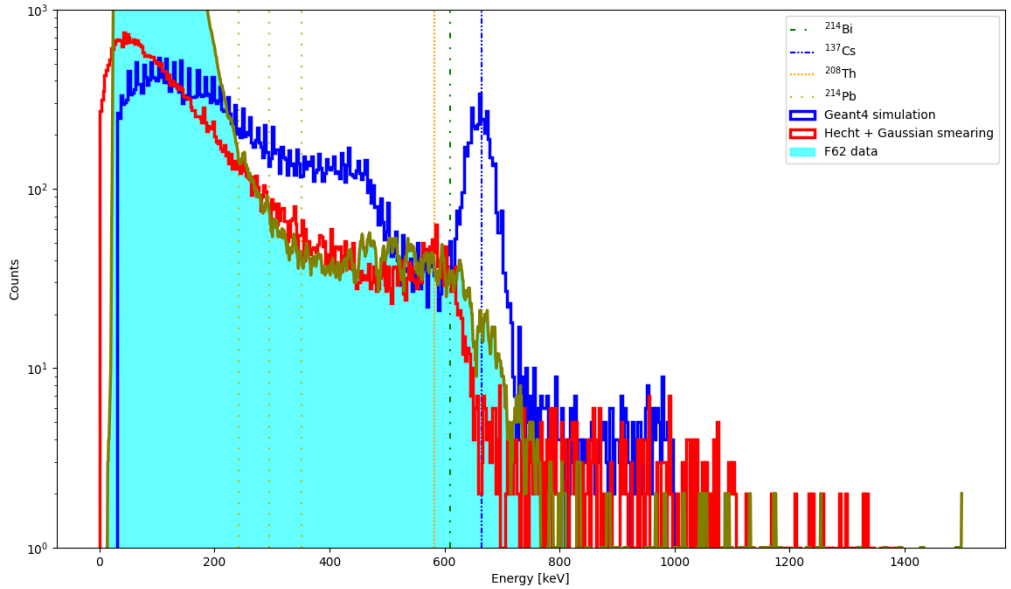

LL12
Counts
Energy [keV]
^{40}K
^{214}Bi
^{137}Cs
^{208}Th
^{214}Pb

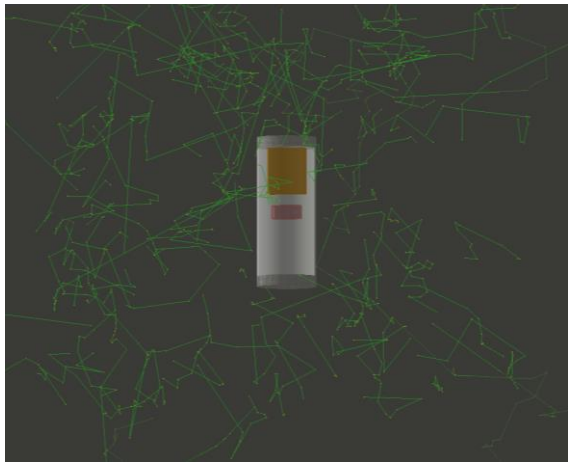

LL19
Counts
Energy [keV]
^{40}K
^{214}Bi
^{137}Cs
^{208}Th
^{214}Pb


US5B
Counts
Energy [keV]
^{40}K
^{214}Bi
^{137}Cs
^{208}Th
^{214}Pb

Comparison to Geant4 simulations

- Full Geant4 simulation shows perfect spectrum when the detector is placed at the seafloor
- When introducing Gaussian smearing and Hecht equation for incomplete drift, the resemblance between the distributions increase





Next steps

- The setup should be remeasured in the temperature cycle chamber
  - Set the chamber temperature to 30 degrees and lower it down to 20
  - Changes in the spectral properties
- New design with a heater and a Faraday cage needs to be studied
  - Must still fit in the same enclosure
- Radon measurements in FMI pool
  - Depth about 3 meters
- Finalize design for possible ocean floor measurements
  - Depths down to 1500 meters
  - Fix the problems with Arduino
  - Install camera system to the setup
- Come up with a new name for the setup e.g.
  - LAGER-ALE (Azores Low-energy Environmental spectrometer)
  - LAGER-PORTER (Pelagic Oceanic Radiological Tracer and Environmental Reader)

