NP02 beam plug monitor

DS/PP meeting – 31/10/2024

Partly from Lorenzo's presentation from some time ago

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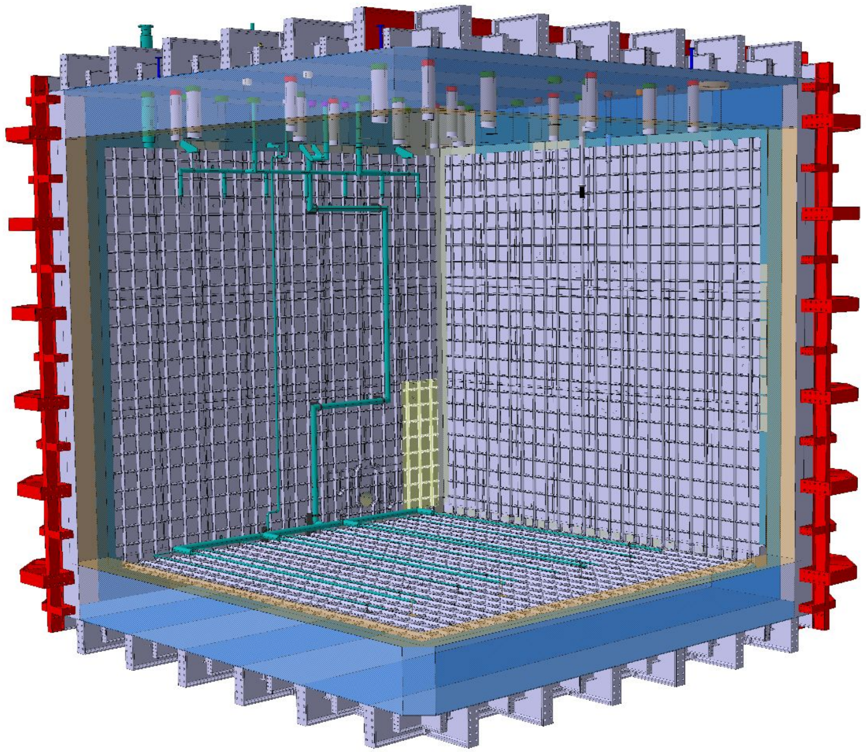
NP02

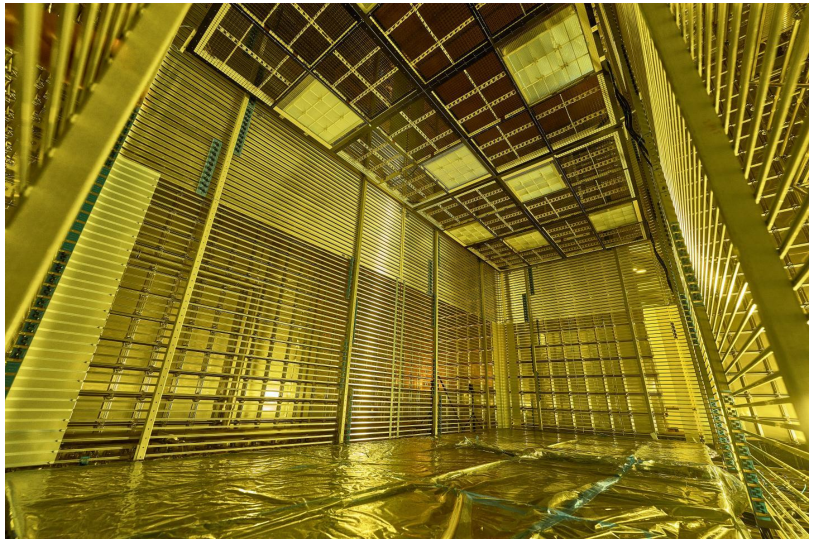
NP02 is the cryostat containing protoDUNE-VD, prototype of DUNE FD-VD (Far Detector - Vertical Drift).

TPC active volume is <50% of total cryostat volume.

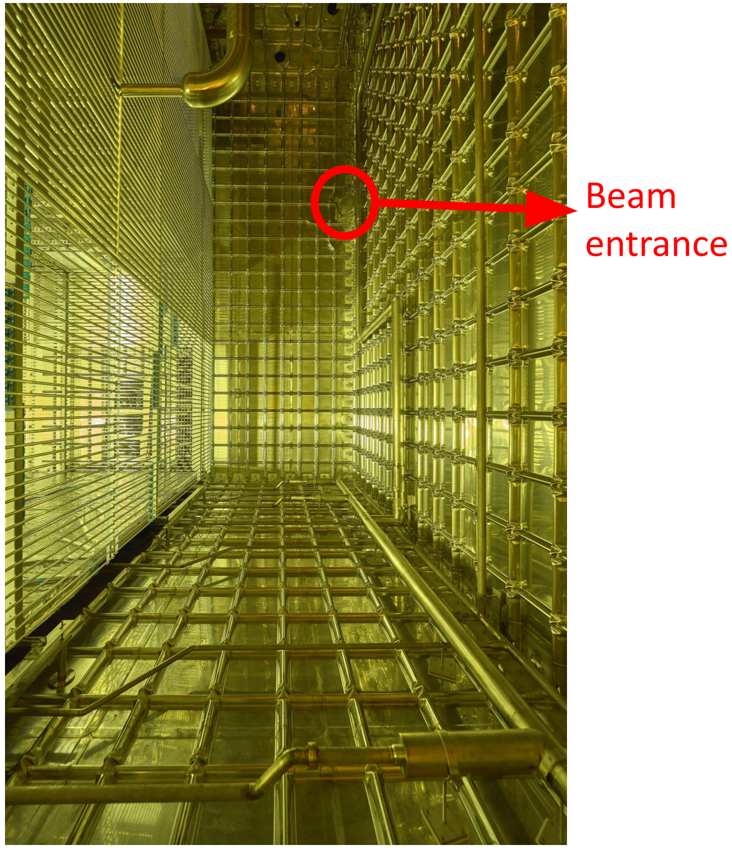
Filling with LAr is expected to start in late 2024, data taking in 2025 with both cosmics and SPS beam.



protoDUNE cryostat



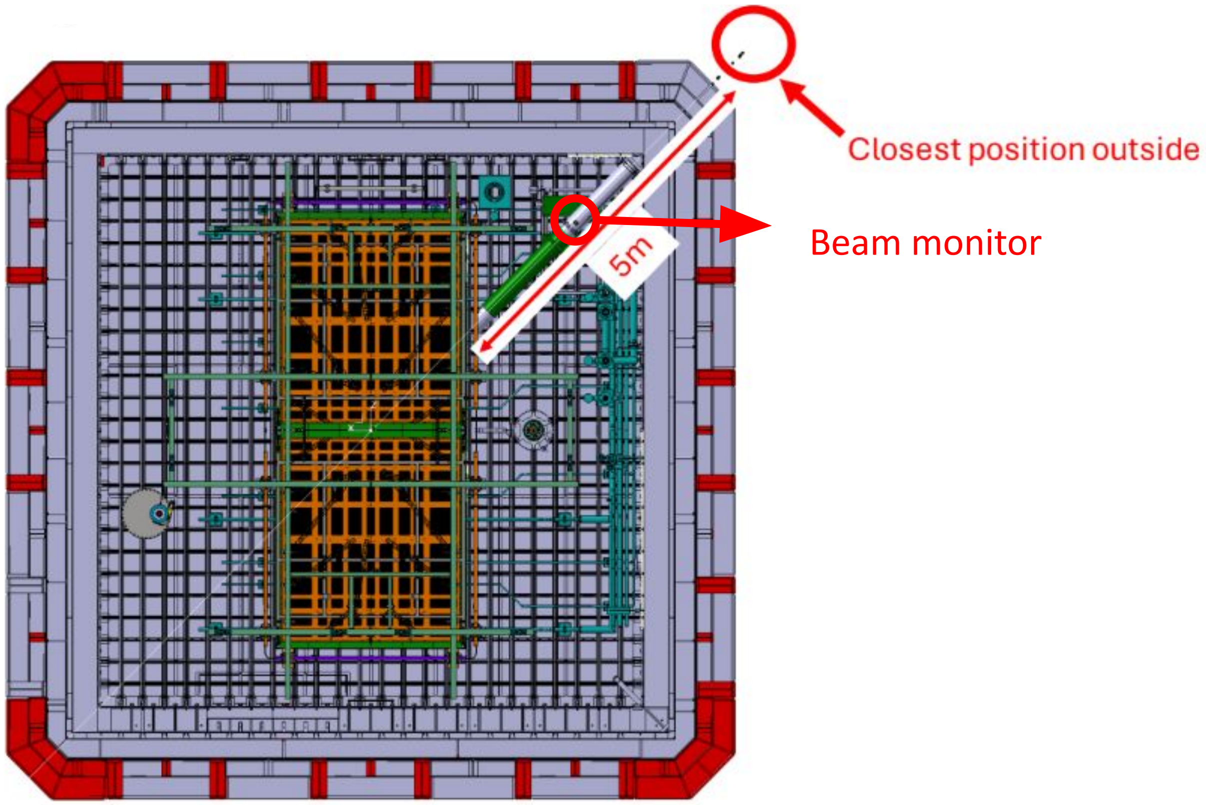
protoDUNE VD Module 0

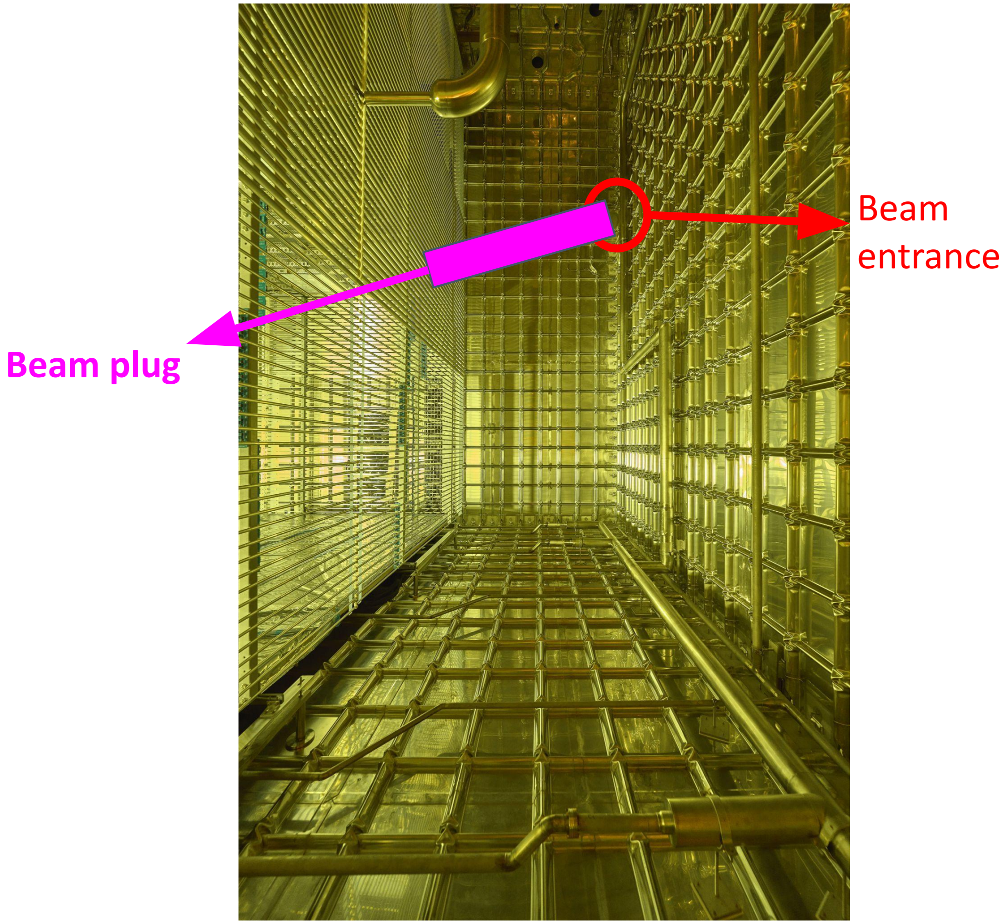


NP02 beam plug

- Large dead volume from entrance of the beam to active volume
  - Beam particles, if injected directly into cryostat, would interact before reaching the active volume.
- Beam positioning can be tuned with magnets, but how?
  - fast data analysis is challenging

➡ **Beam plug!** (already present in NP04)





NP02 beam plug

2 pieces, connected by a flange in the middle:

- fully **metallic** one connected to cryostat wall
- **G10** (plastic) one going to the field cage, with metallic end caps
  - create electrical separation between HV and ground (cryostat wall)

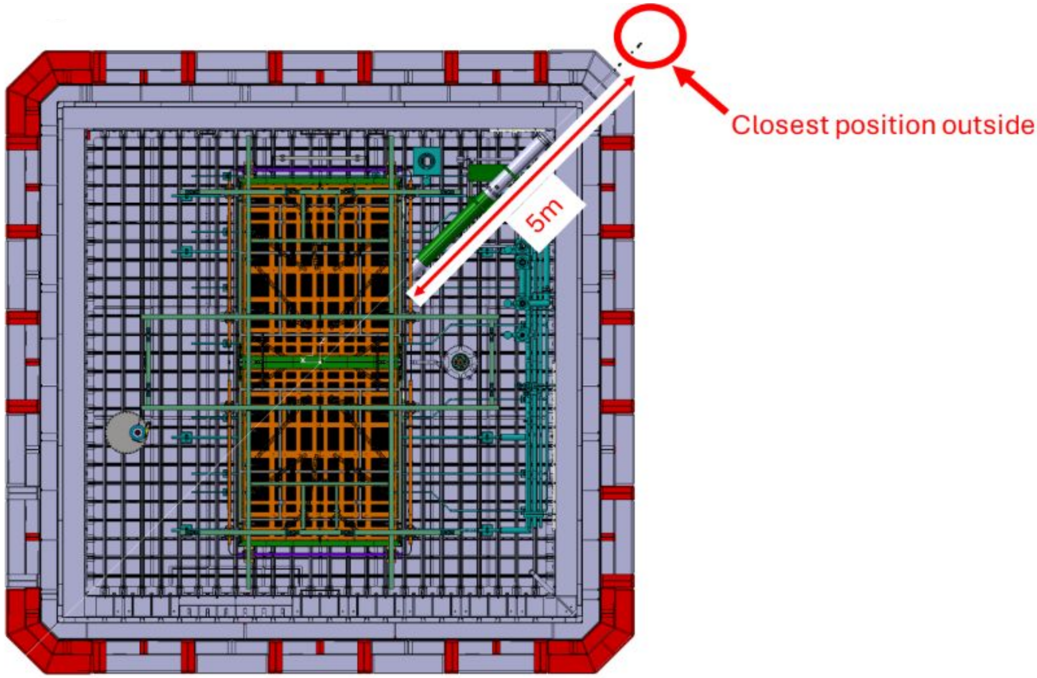
Filled with **cold nitrogen,** because:

- vacuum is risky
  - we can't know what vacuum we reach
  - outer liquid pressure might cause leaks
- gas argon ionizes if under HV, not an option
- easy to handle

NP02 beam plug monitor

- Closest beam position measurement is 5m upstream of TPC, hard to assess alignment
- There can be multiple scattering on the cryo wall and in the beam plug end cap
- More precise beam position helps in data analysis

➡ **Tracker** inside the beam plug!



Detector specs pose no strict constraints:

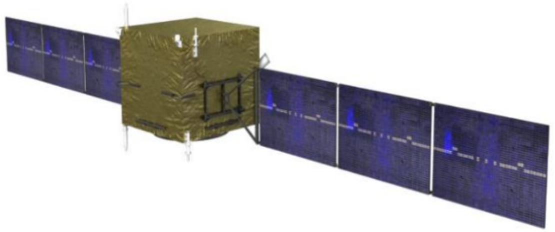
- particle rate is low (~ 1kHz)
- required spatial resolution ~5mm (CRP strips pitch)
- time resolution ~1 us (TPC sampling is 0.5us)

But, requirements:

- Operate inside the beam plug (cold environment, N gas flow)
- Readily available: existing detector
- No negative impact on ProtoDUNE schedule and performance
- Negligible risk for operations

(from Lorenzo's slides)

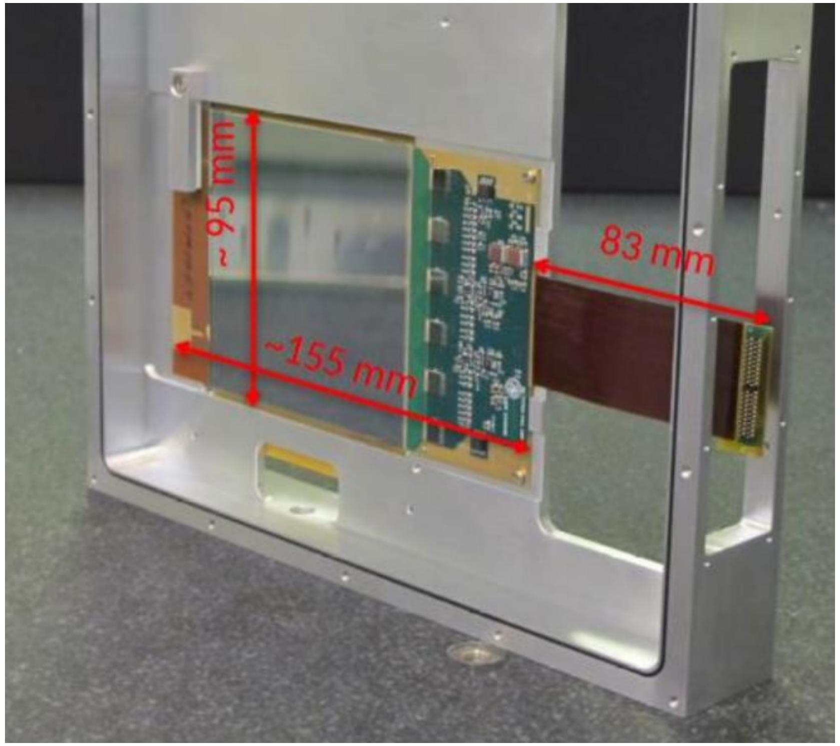
NP02 beam plug monitor



Choice: **Silicon strip detectors from** DAMPE experiment

Some silicon strip detector planes that fit inside the beam plug were made available by Dr. Philippe Azzarello (group of Prof. Xin Wu at the University of Geneva), readout by Dr. Giovanni Ambrosi (INFN Perugia).

- ~10 x 10 cm2 active area silicon strip detectors from Hamamatsu.
- Strips with 120 μm pitch.
- Extensively tested at SPS and operating on DAMPE satellite experiment since 2015.



Trigger: either random (~1 kHz) or with ext trigger (TTL 3.3V).

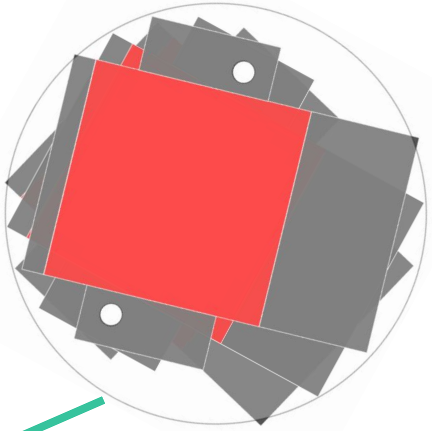
When triggering, all channels (392/detector) save ADC value of waveform peak.

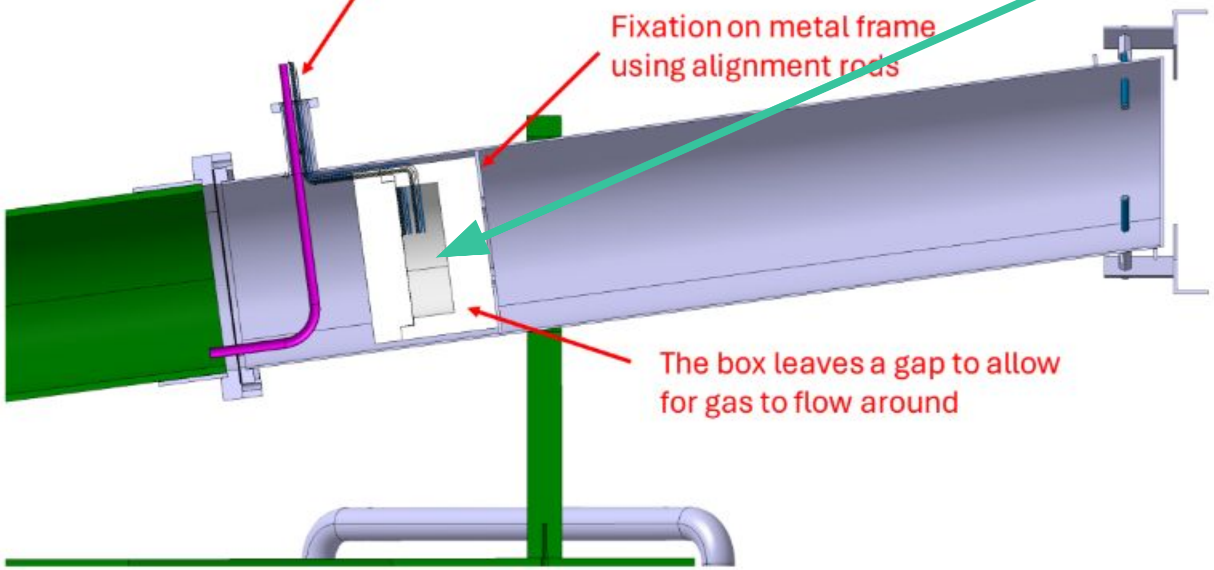
→ an event will contain a peak value for **all channels**, which one(s) triggered has to be seen at **analysis** level

Design

The proposed design uses **three detector planes** with an angle of ±15° between each other.

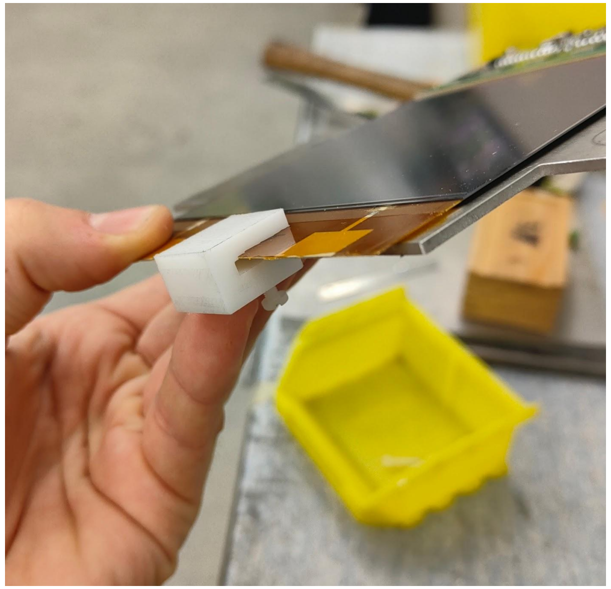
- Equivalent pitch of 125μm x 935μm (v x h).
- **Robust design** in case of **loss** of one plane (precision on measurement still achievable).
- Reference for detectors are **alignment rods,** fixed to the box and to the beam plug.
- 6m-long **cables** for readout and thermal management (PT1000, heating strips) going to readout board and SC system (outside, at room temperature).





Setup

- detectors
- readout board
- holding system
- insulation box(es)
- nylon rods
- aluminium support plates
- PCB
- cables and connectors



Tests in cold, insulation and heating

In 2023, the detector was immersed directly in lar to test its resistance to cold (mechanically and electrically).

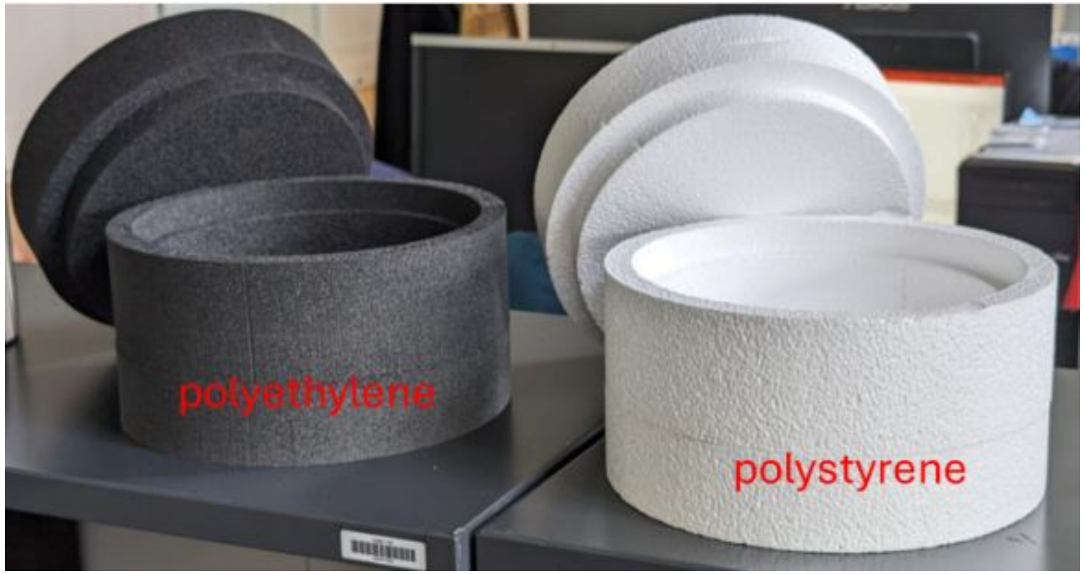
It survived, but it was observed that front-end **electronics stops operating under ~-20°** (rough measurement), recovering when going back to warm.

⟹ Adding **insulating box with heating strips** (20Ω)

2 boxes produced: polyethylene and polystyrene. No difference in **insulation** performance.

The box, with no detectors inside, was placed inside the beam plug in close-to-real conditions (cold nitrogen at atmospheric pressure).

Thermal tests show that **15 W** of power are enough to maintain **20°C** in the box, ok for operations.

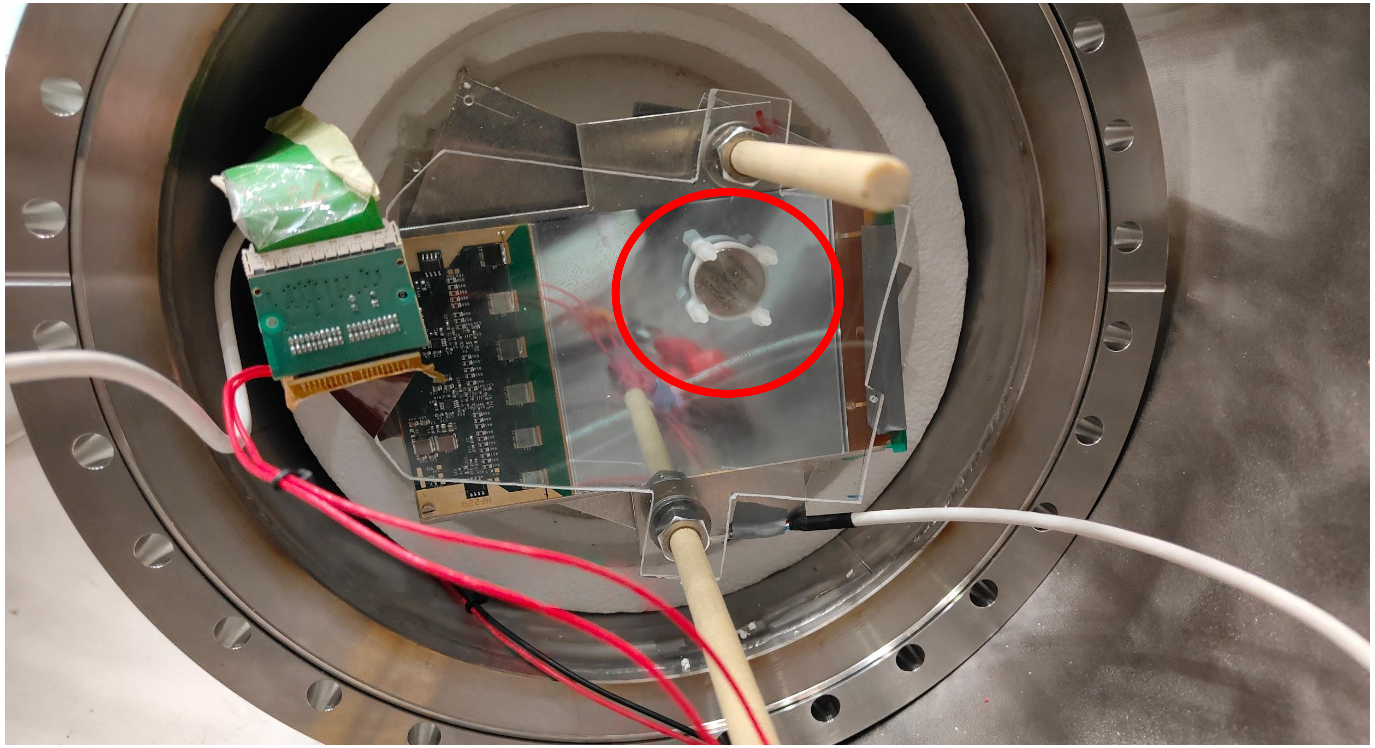


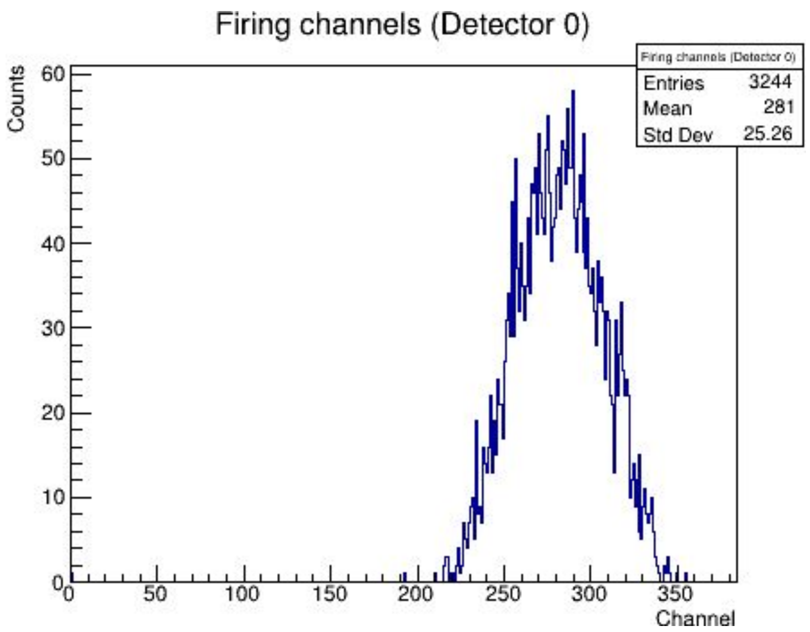
Thermal tests

An **Am241** (alpha) source was placed in front of the detector (~1cm), only for tests before installation.
Taking data with random triggers (low efficiency, it will sample randomly at any point of waveform).

Goals:

- Monitor detector response during tests
- Collect data to use as benchmark





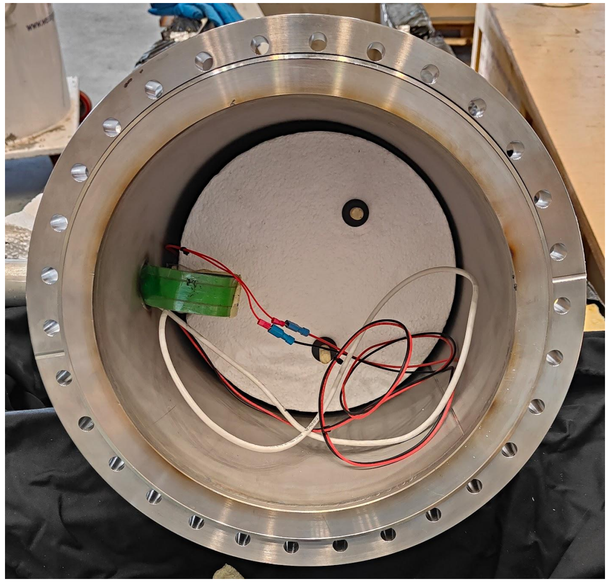
Developed a simple analysis code starting from the one by INFN Perugia: https://github.com/emanuele-villa/oca-pDUNE-dataAnalyzer/tree/master

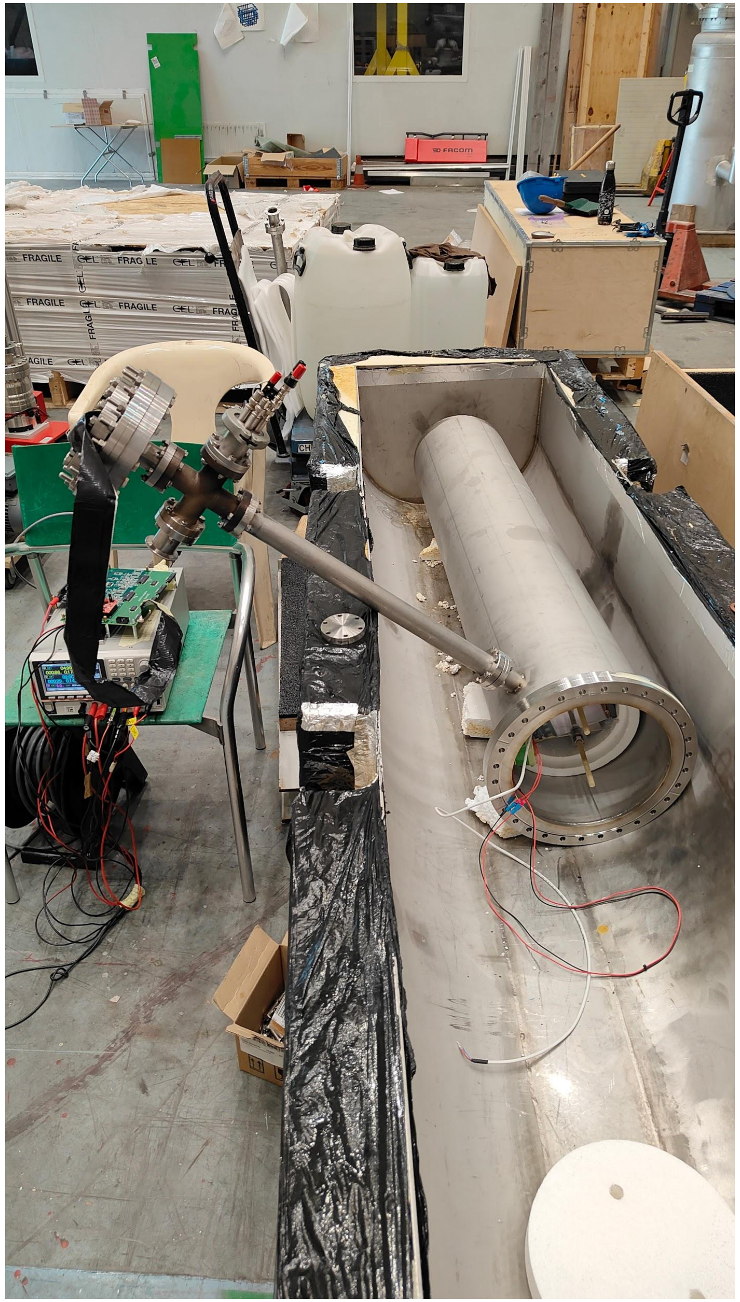
Thermal tests

Box was closed with some caps on the rods and insulant tape around it.

Setup very similar to the definitive one:
1 detector, 1 heating strip and 1 PT1000 (it will be 3, 3, 2).

System was then closed and put in a rough vacuum (1e-3).





Thermal tests

Using **liquid nitrogen** (cheaper, a bit colder) to fill the cryostat around the beam plug. Filling inside with **gas nitrogen** up to ~1.1 atm.

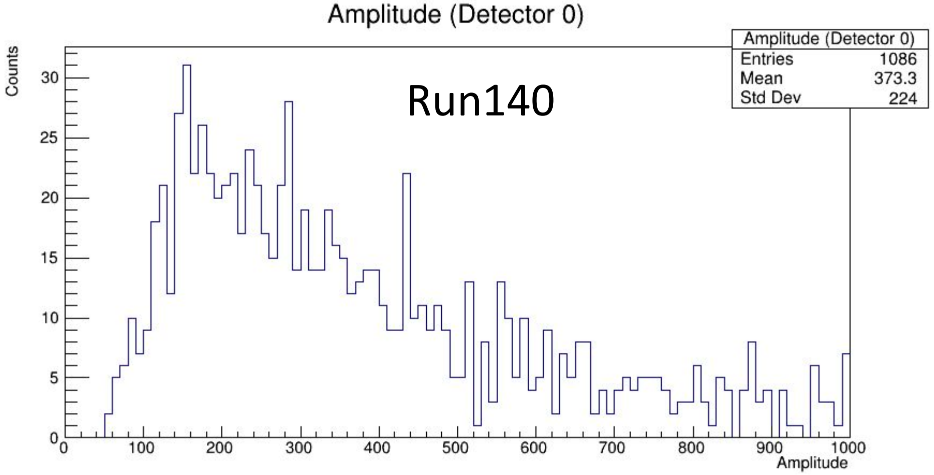
While cooling, taking data to see when electronics stops working: around **-70°C.**

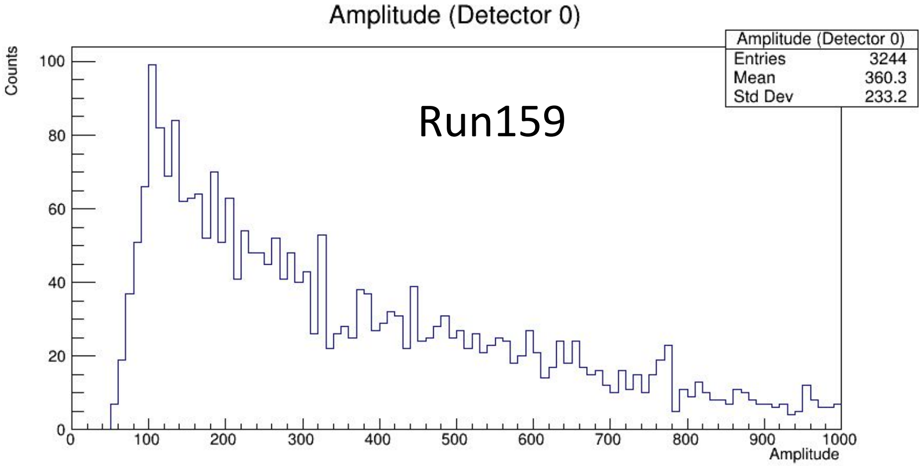
Once temperature inside box has gone down, start heating up with strips.

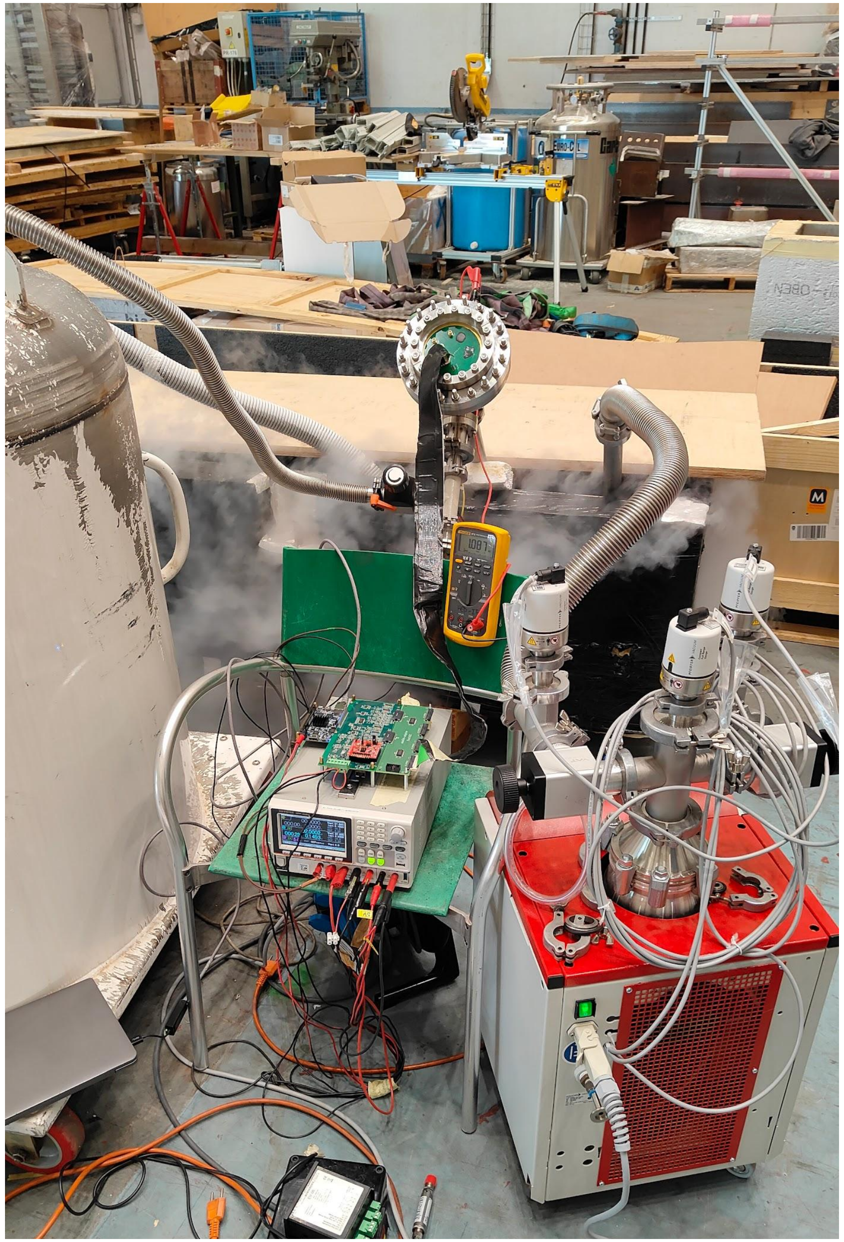
Recovering electronics around **-80°C** (PT1000 is in air, plate might have been a bit warmer).

After cycle, gains seem to be a bit lower (not considered an issue).

[Here considering "signal" if above **15 sigma** of noise (tunable)]

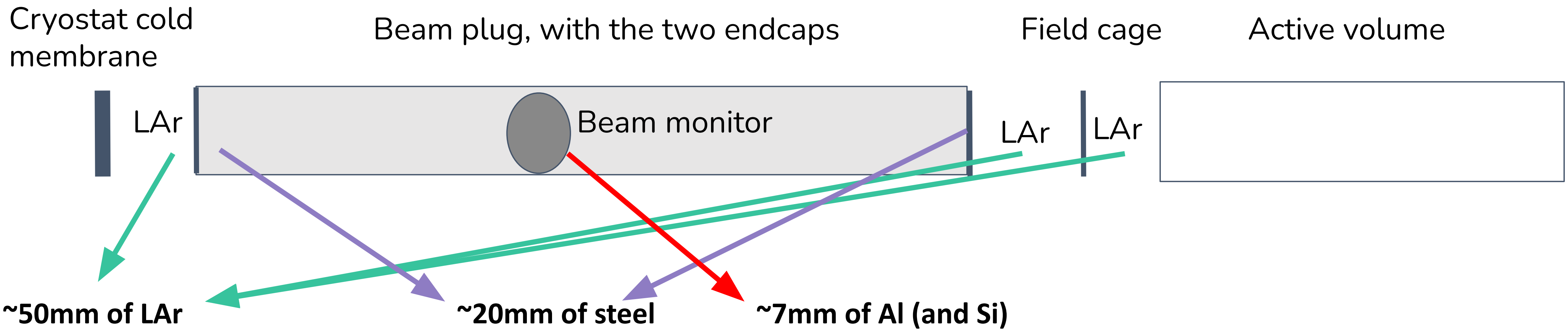






Impact on beam and operations

not to scale



Radiation length:

~0.4 X0	+	~1.0 X0	+	**~0.1X0**	=	~1.5X0
~27%		~67%		**~7%**		→ Small impact on multiple scattering

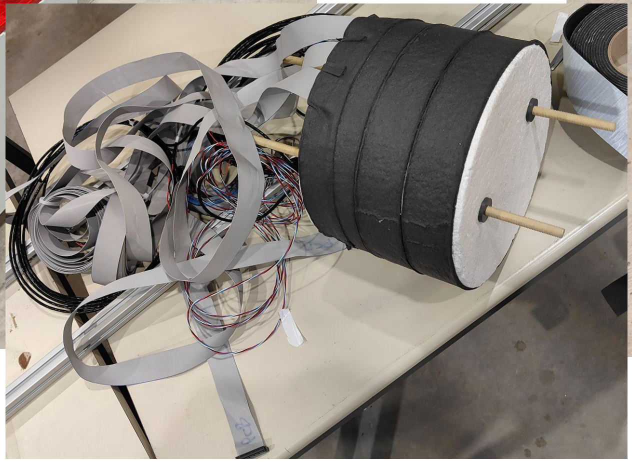
For a MIP, energy loss is:

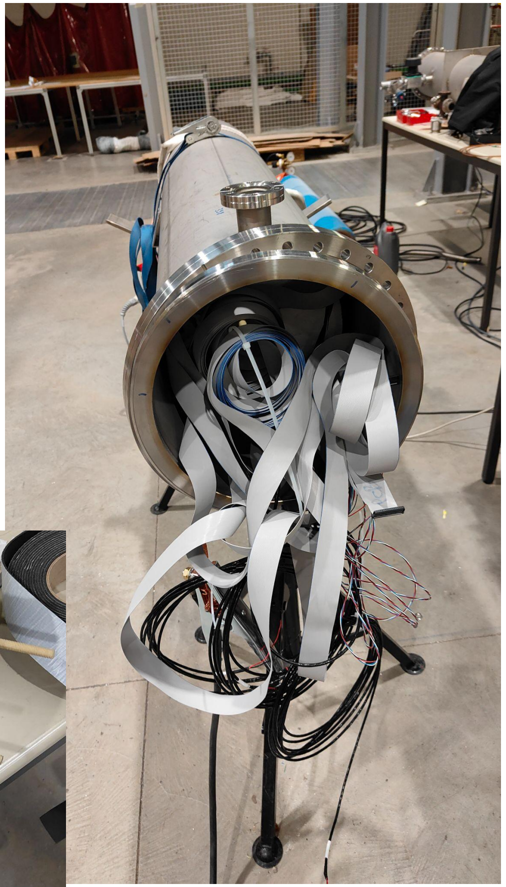
~10 MeV	+	~24 MeV	+	**~3MeV**	**=**	~37 MeV
~27%		~65%		**~8%**		→ Small impact on energy loss

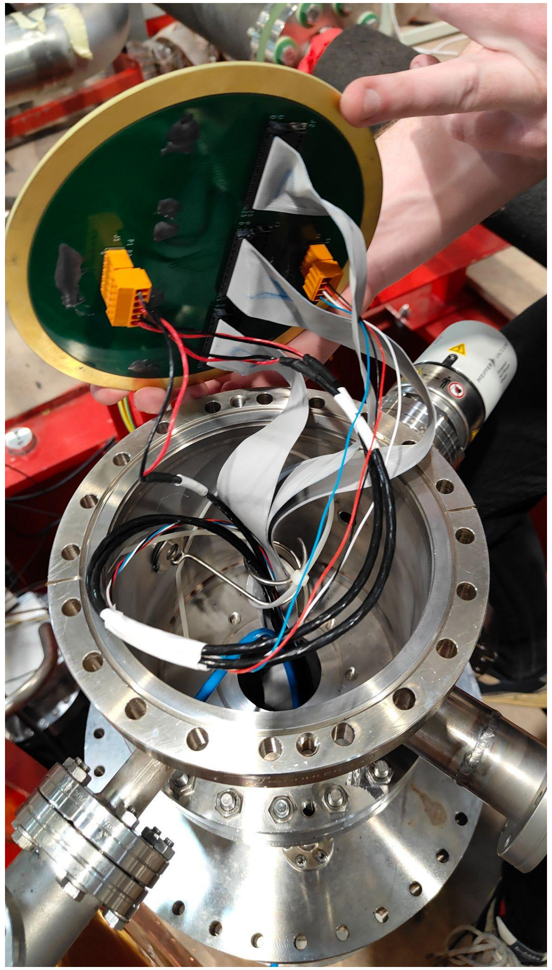
Detector will be **pre-installed** in the beam plug, no modification of the installation procedures (apart from cable routing) → No impact on operations

Installation: beam monitor

After last tests in warm with full system, the box with detectors was insulated the best we could and inserted directly in the beam plug. Cables have been pulled from inside the cryostat to the roof, to PCB and then readout.

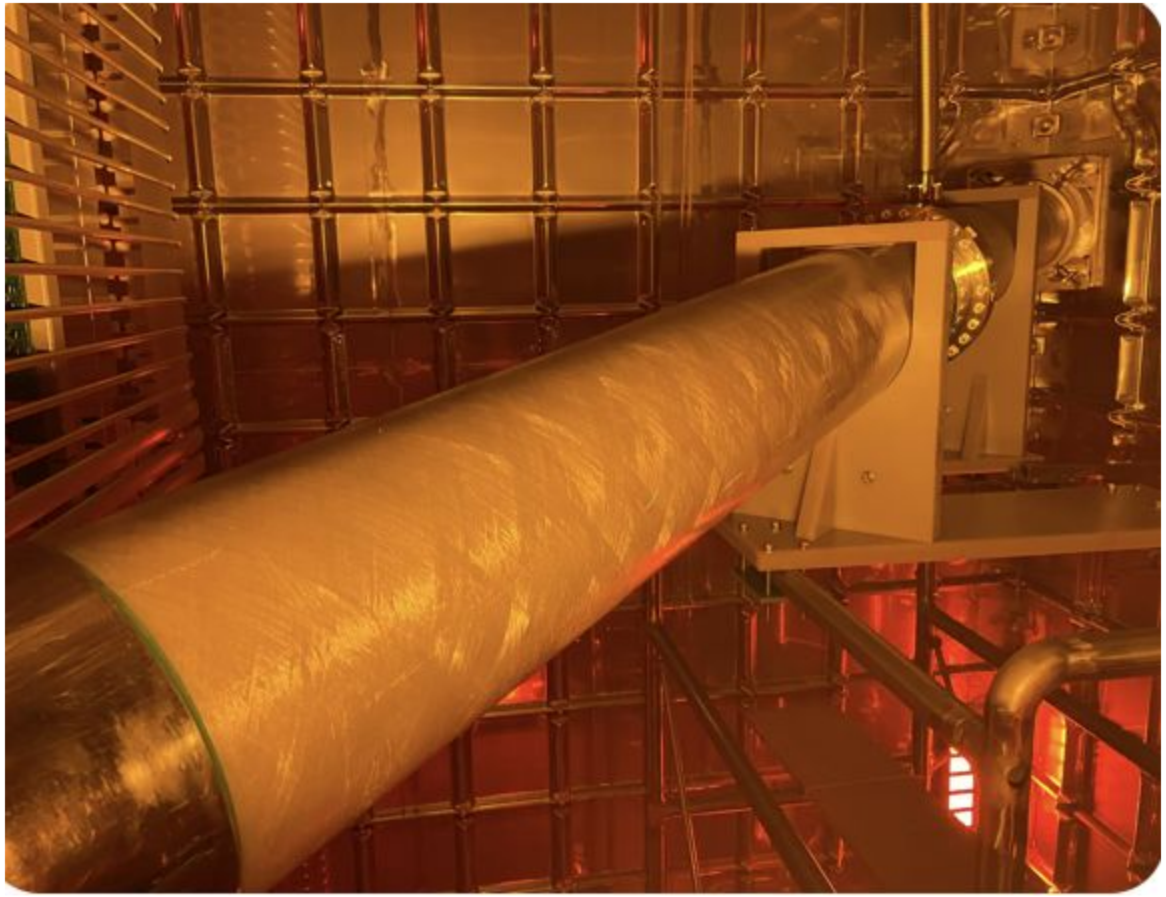






Installation: beam plug

Beam plug has been a tough customer (had to redo glueing of plastic, hard to make proper vacuum, adjustments for easier handling). In the end **all worked out fine,** installation was successful, now fully submerged in LAr.



After installation

After filling

Timeline

NP02 timeline:

15th of November:

- **beam plug installation**
- installed external structure, system under vacuum since (currently at 1e-7)

12th of December:

- started transferring argon from NP04 to NP02, completed Dec 16th

Mid-january:

- argon top-up, purging

April?

- beam operations

Beam plug monitor timeline:

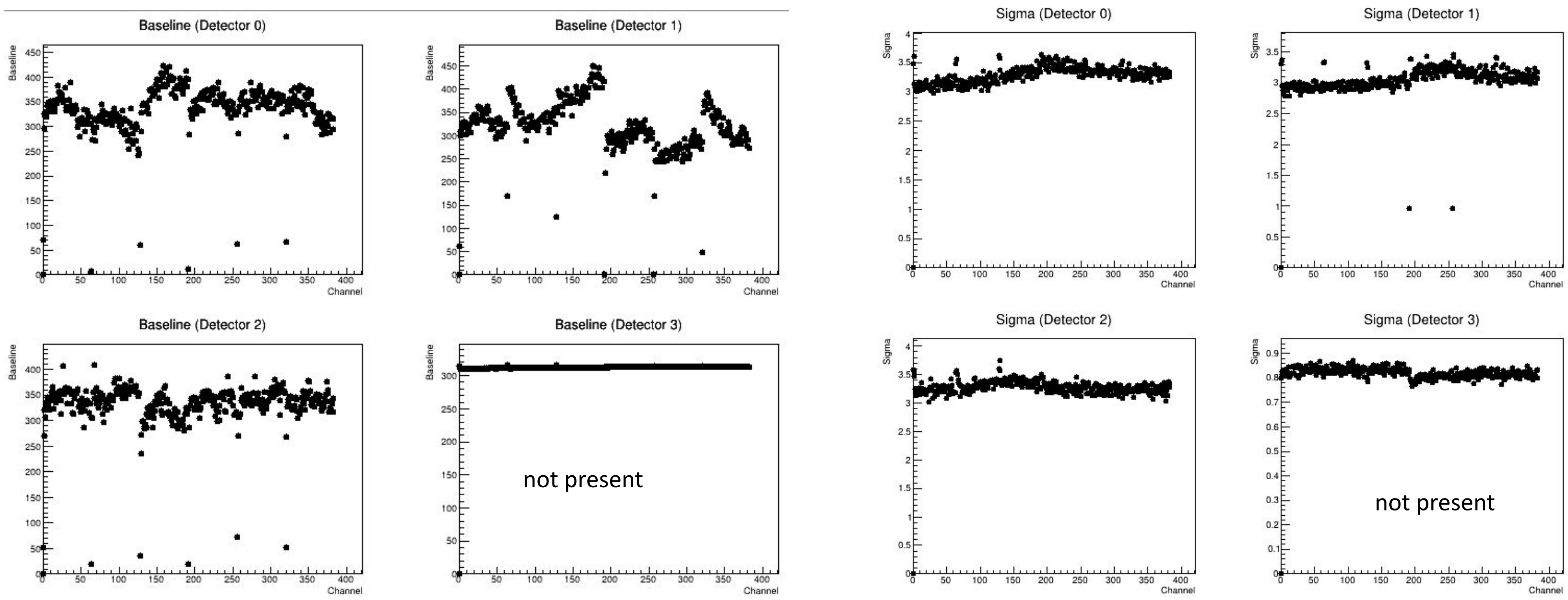
- Integration in NP02 trigger
- Improve code for the analysis

What time requirements?

Data

The readout saves the ADC value for each channel *6.5us* after the trigger (considering shaping parameters, should be the wf peak). Tunable, but shouldn't be necessary. Signal is when value is **n*sigma** above pedestal.

Calibration runs: ~minutes, to collect some statistics using random triggers, to compute pedestals and sigmas.
Beam runs: normal operation, with ext trigger. In analysis, previous calibration run pedestals and sigmas should be used to determine which channels saw something.



Pedestals and sigmas. First and last channels of each chip have slightly different behavior.

Integration in NP02 trigger

INPUT**:** TTL 3.3V trigger signal.

OUTPUT: no analog trigger out.

The way I imagine operations (not too sure, **here to discuss and receive inputs**):

- beam centering:
  - take run
  - see beam alignment
  - tune magnets
  - repeat

- software trigger (to add a condition to trigger):
  - fetch event by event from output file
  - fast analysis to see triggered channels (how fast does it have to be?)
  - propagate info to trigger (through CTB?)

Backup

Data analysis

What to look at?

- could vary the time at which the signal is sampled to see if 6.5us are ok
- place source at different distances to find a precise calibration ADC->energy? Overkill?
- define how many sigmas over noise are the threshold (separation signal-noise)
- expected signal from SPS particles (mip)?

  -> test detector with Bi207 (e- at 500 keV) and cosmics -> done, have data

Parameters to look at:

- shape of amplitude plot? Peak?