NP02 beam plug monitor

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First slides taken from Lorenzo's presentation from some time ago

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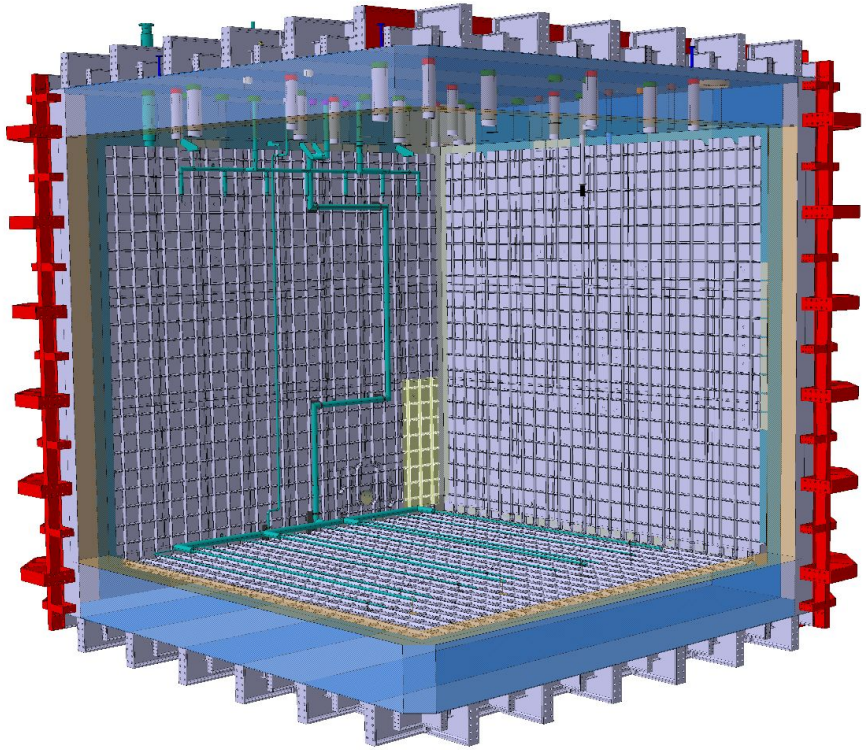
NP02

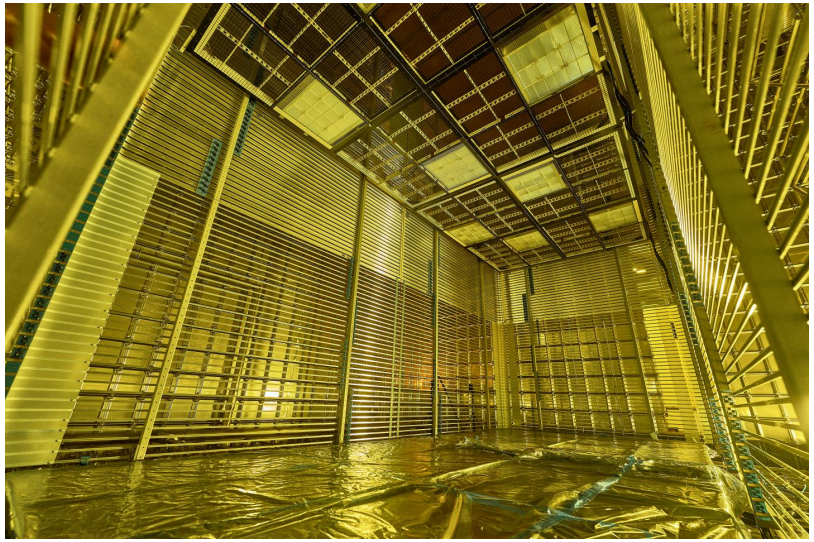
NP02 is the cryostat containing protoDUNE-VD, prototype of DUNE FD-VD (Far Detector - Vertical Drift).

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

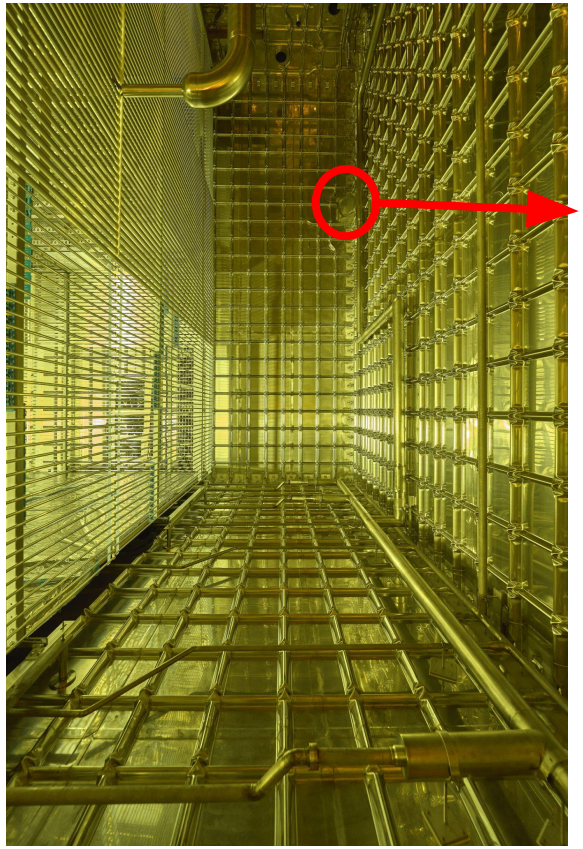
Filling with LAr is expected to start in late 2024, data taking in 2025 with both cosmics and SPS beam.



protoDUNE cryostat



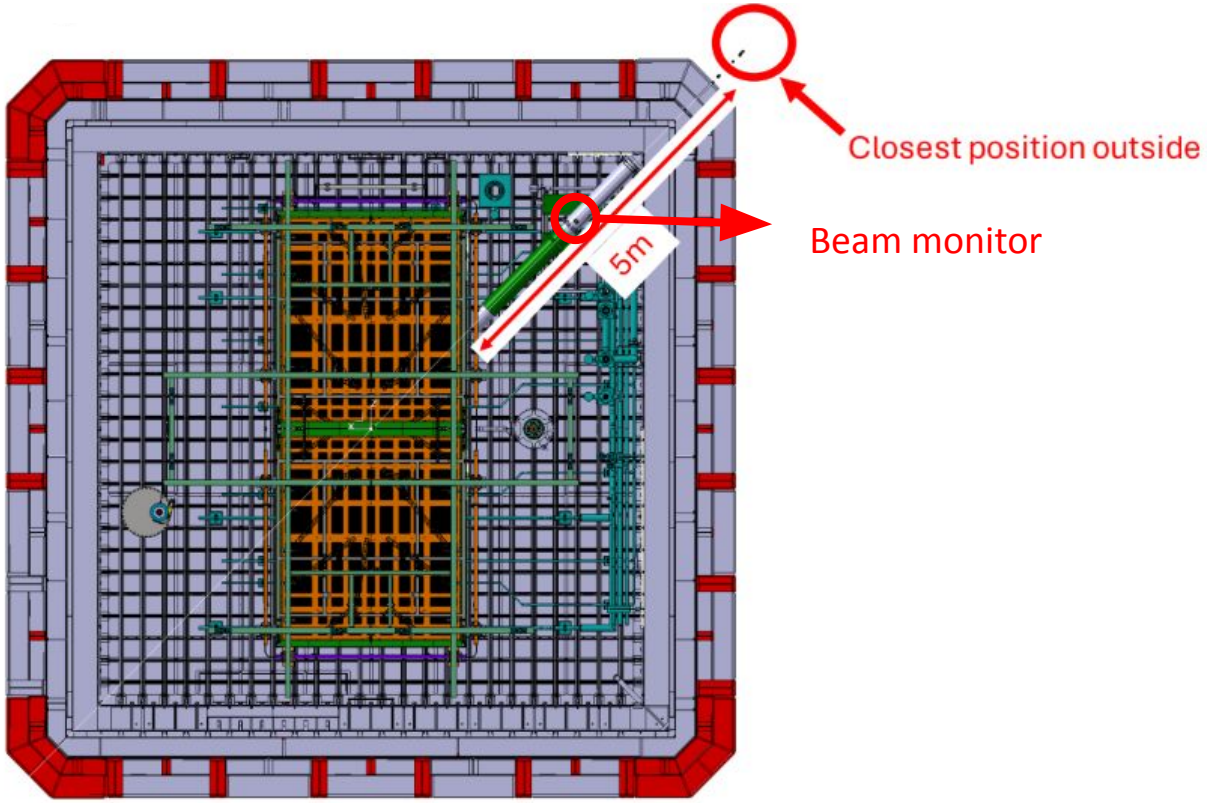
protoDUNE VD Module 0

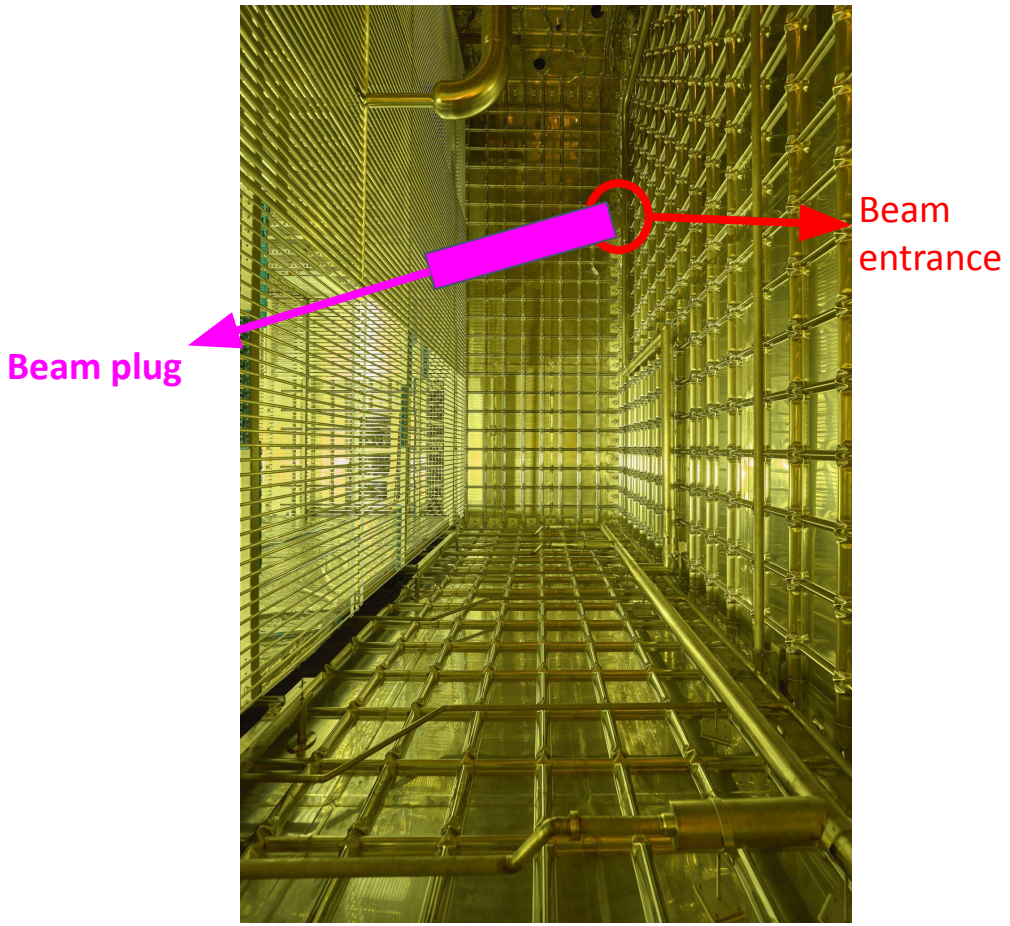


NP02 beam plug

- 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)

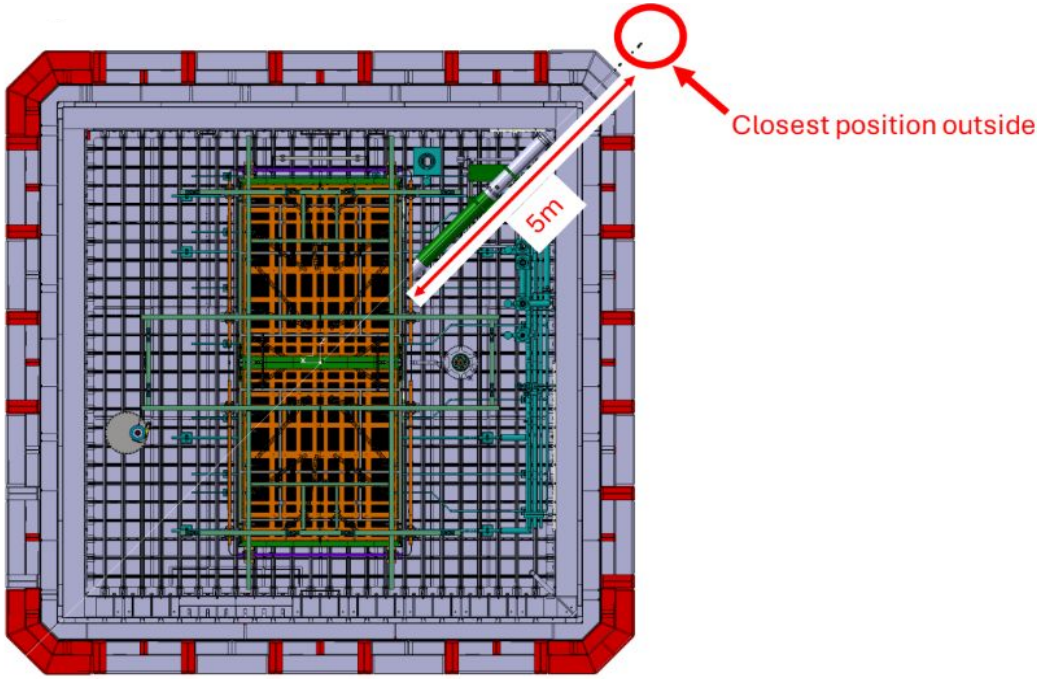
Filled with **cold nitrogen,** because:

- vacuum is risky
  - we can’t know what level we reach
  - outer liquid pressure might cause leaks
- gas argon ionizes if under HV
- 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:

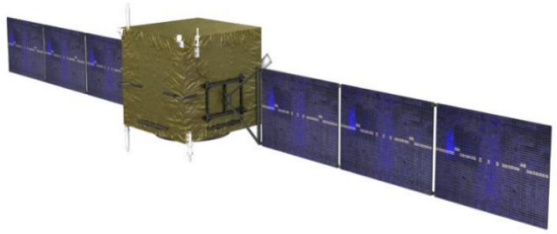
- particle rate is low (~ 1kHz)
- required spatial resolution ~5mm (CRP strips pitch)
- time resolution ~1 us (TPC sampling is 0.5us)

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)

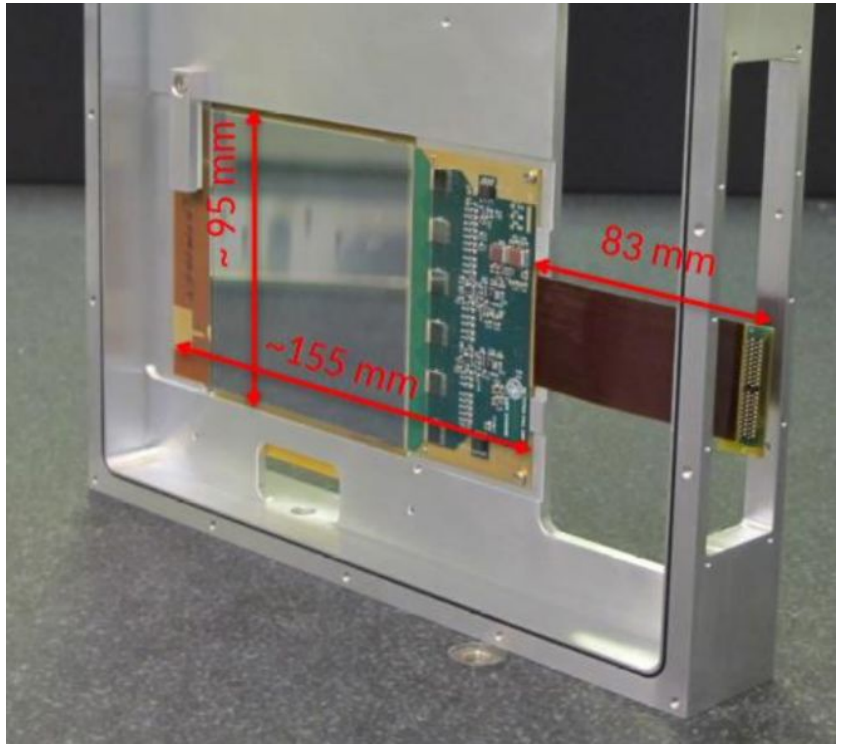
NP02 beam plug monitor



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.



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.

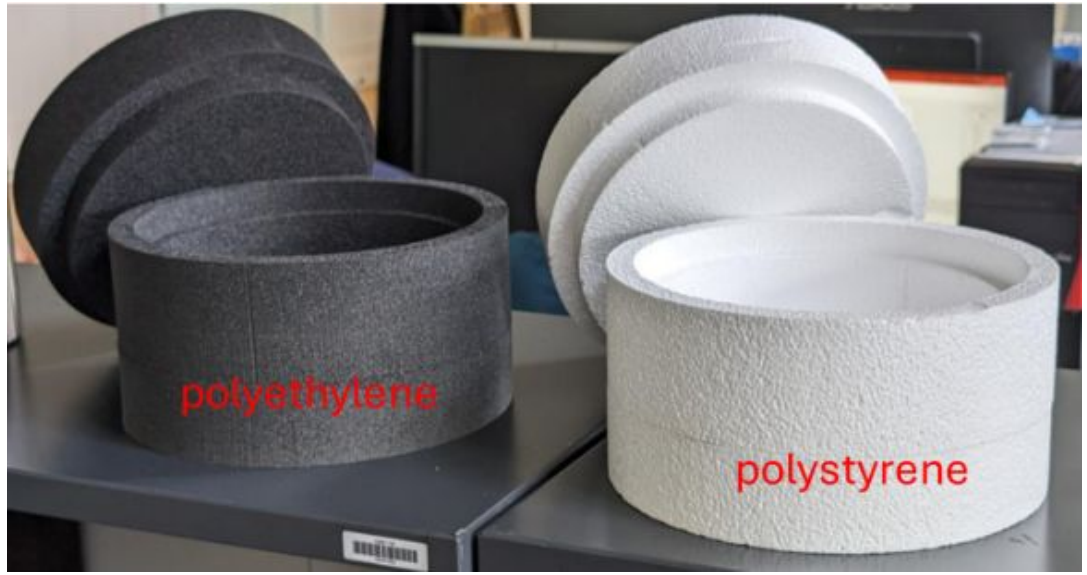
⇨ Adding **insulating box with heating strips** (20Ω)

2 boxes produced: polyethylene and polystyrene.

- No difference in **insulation** performance.
- Possible difference in **mechanical** performance (see later).

The box was placed inside the beam plug in close-to-real conditions (cold nitrogen at atmospheric pressure).

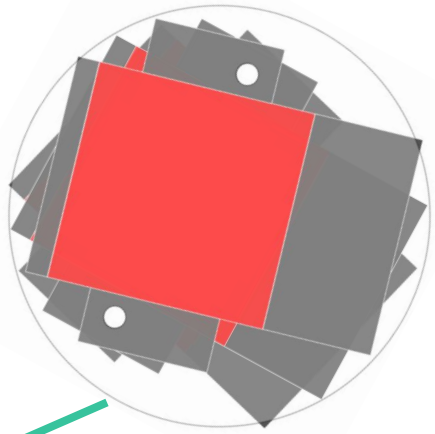
Thermal tests show that **15 W** of power are enough to maintain **20°C** in the box, ok for operations.

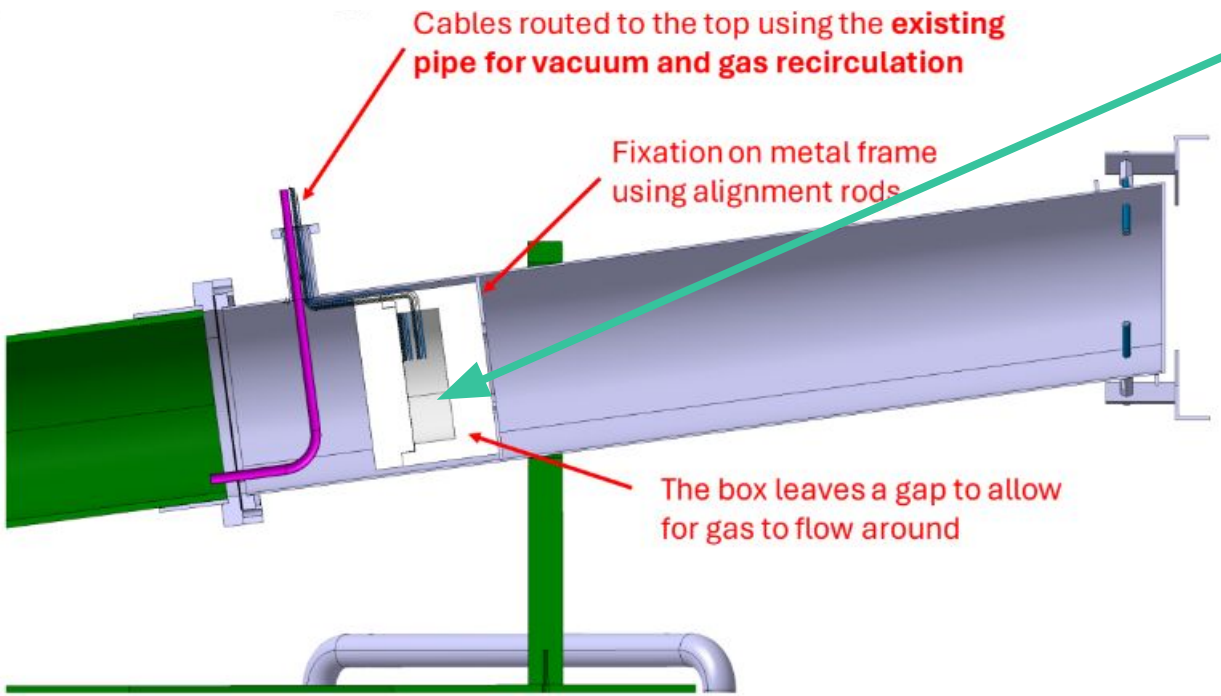


Design

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

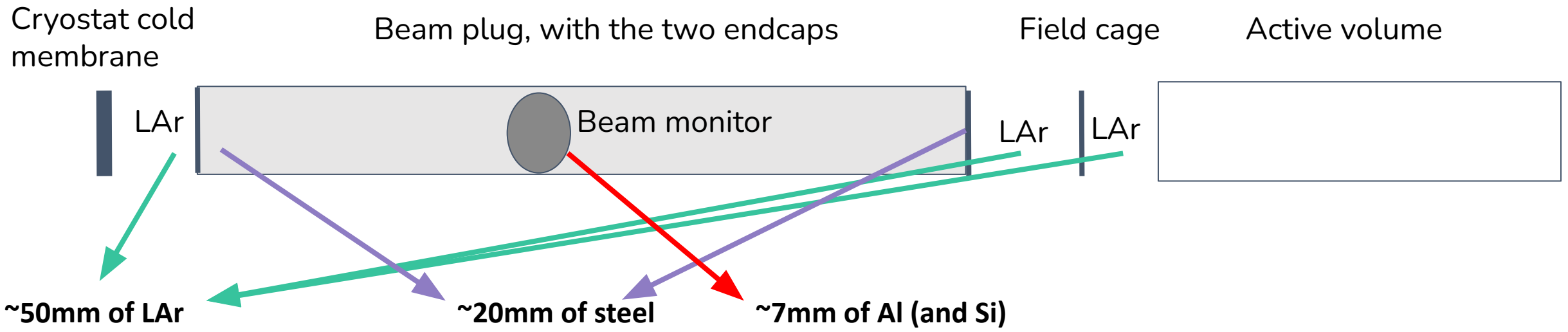
- Equivalent pitch of 125µm x 935µm (v x h).
- **Robust design** in case of **loss** of one plane (precision on measurement still achievable).
- Reference for detectors are **alignment rods,** fixed to the box and to the beam plug.
- 4m-long **cables** for readout and thermal management (PT1000, heating strips) going readout board and SC system (outside, at room temperature).





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:

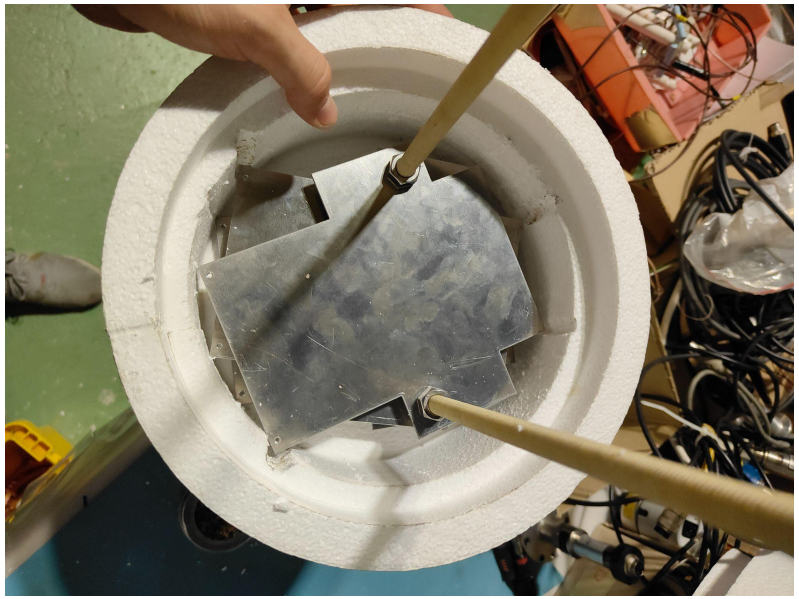
~10 MeV	+	~24 MeV	+	**~3MeV**	=	~37 MeV
~27%		~65%		**~8%**	→	Small impact on energy loss

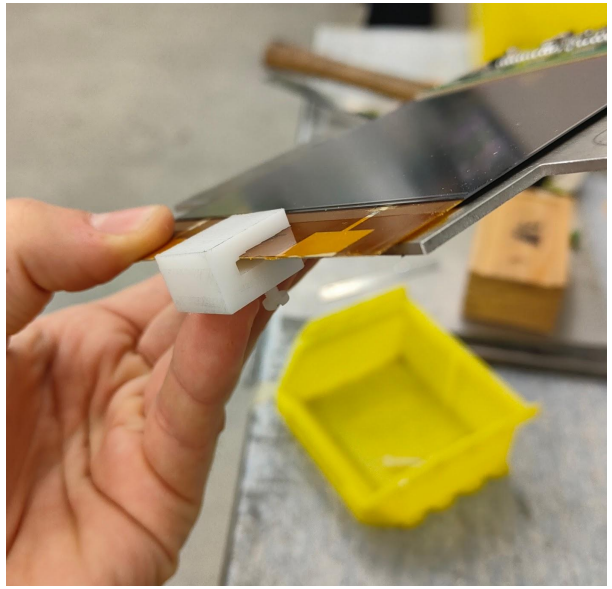
Detector will be **pre-installed** in the beam plug, no modification of the installation procedures (apart from cable routing) → No impact on operations

Setup

The setup is mostly ready:

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

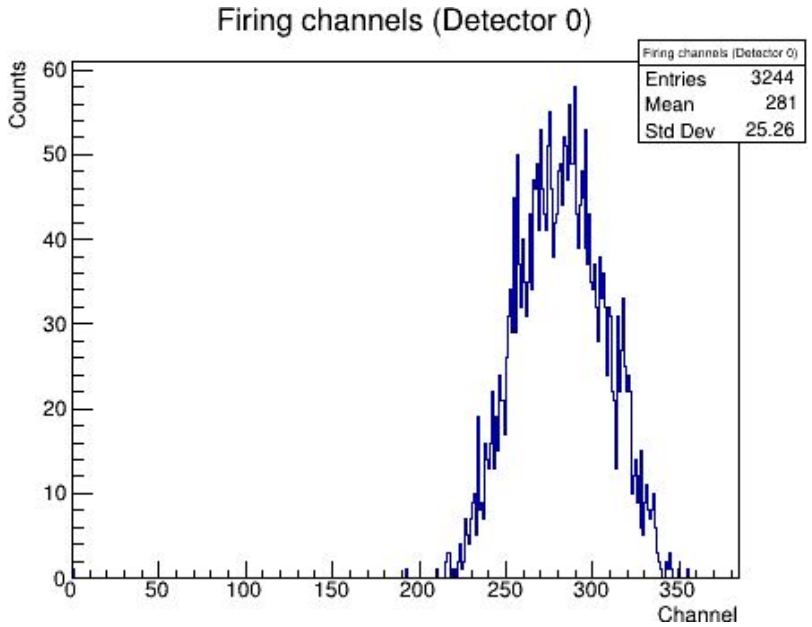




Performance tests with source

An **Am241** (alpha) source was placed in front of the detector (~1cm), only for tests before installation. Goals:

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



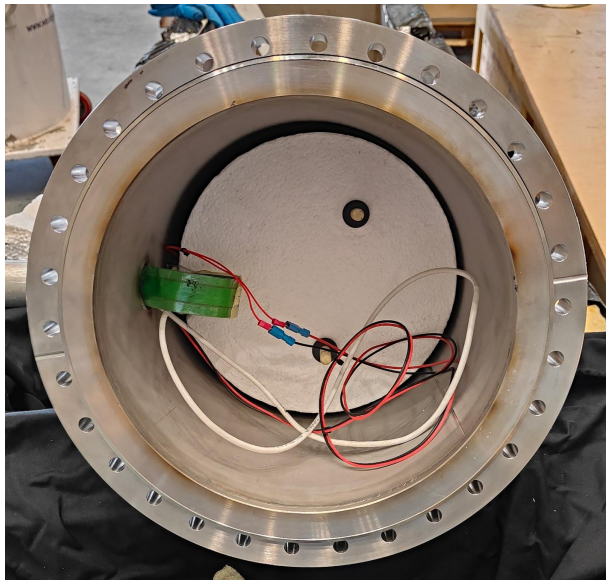
Developed a simple analysis code starting from the one by INFN Perugia: https://github.com/emanuele-villa/oca-pDUNE-dataAnalyzer/tree/master

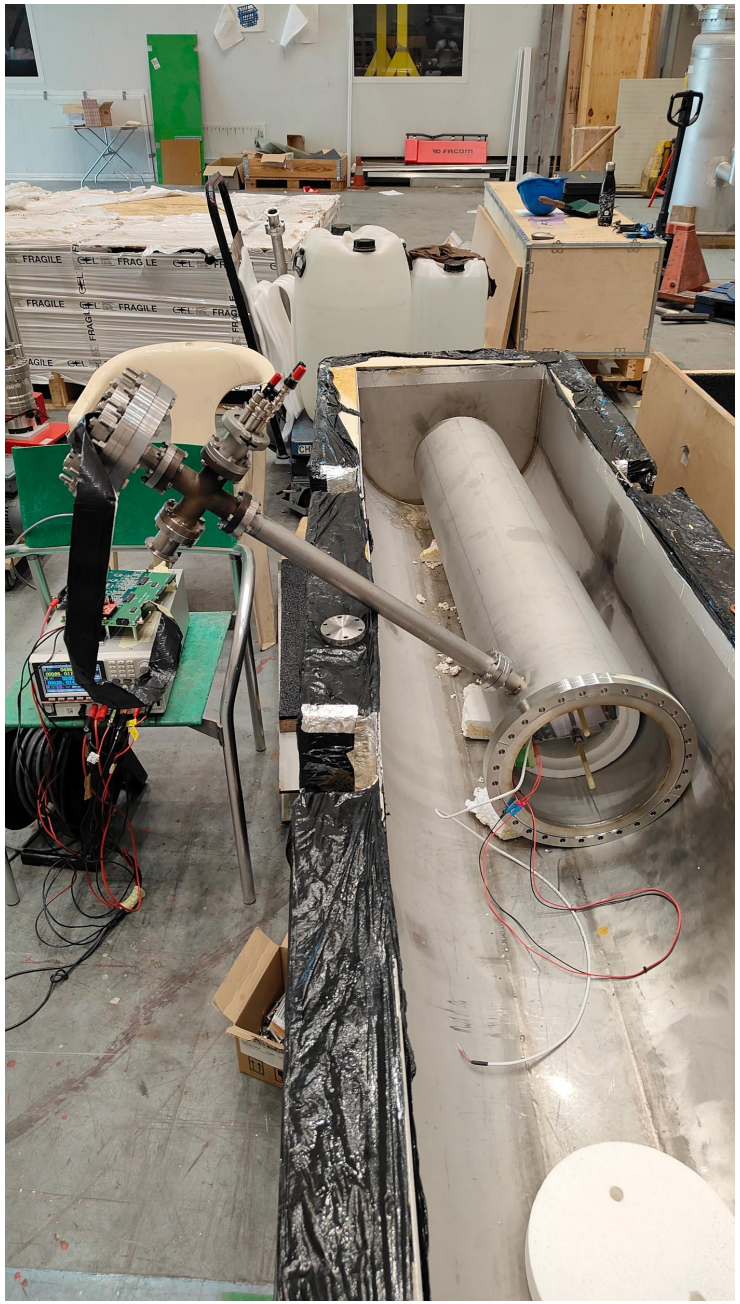
Thermal tests

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.

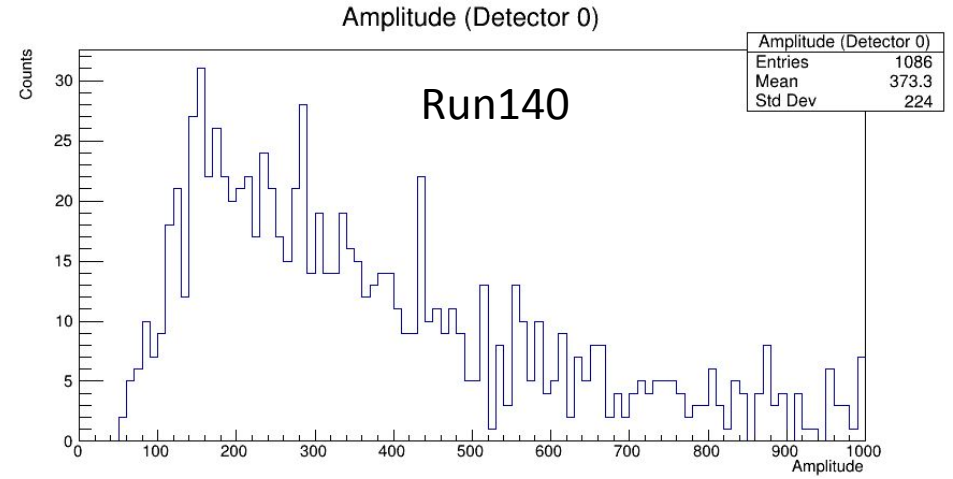
While cooling, taking data to see when electronics stops working: around **-70°C.**

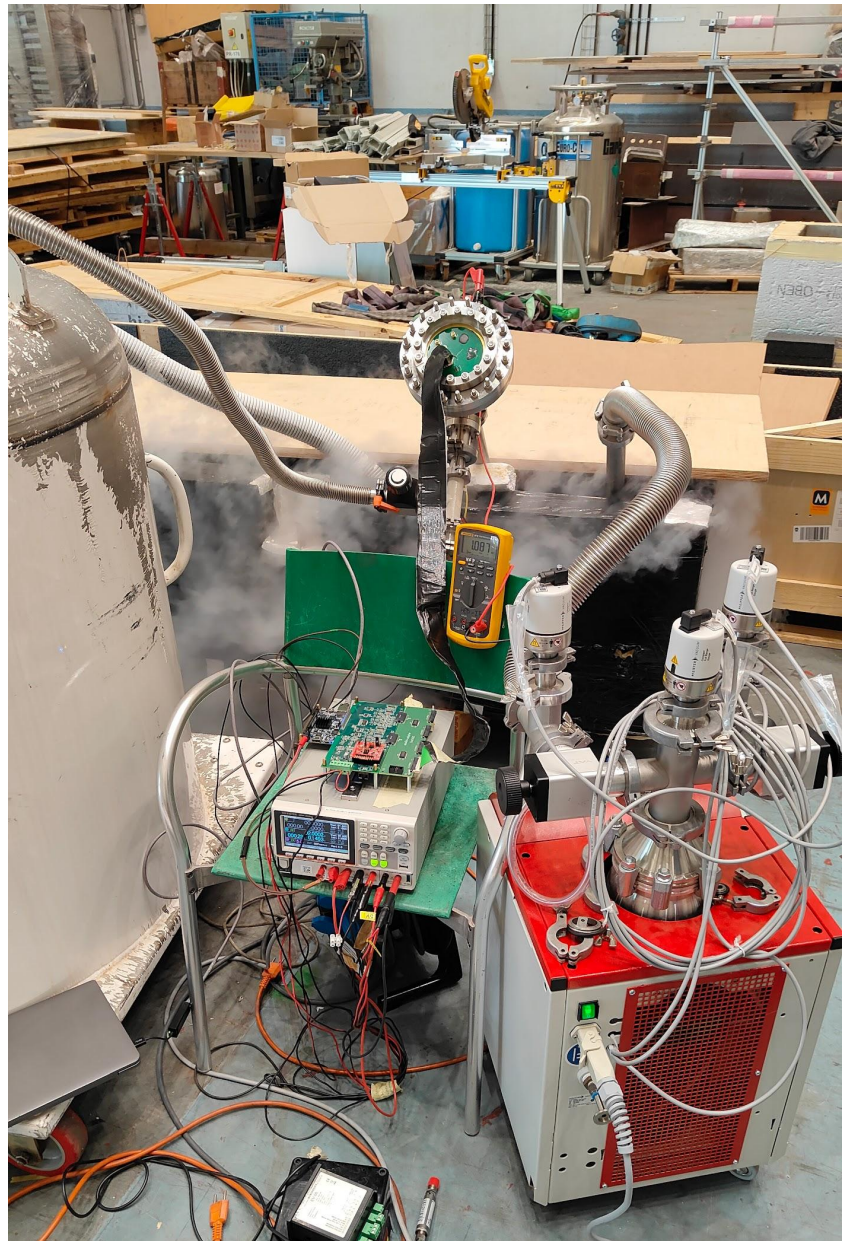
Once temperature inside box has gone down, start heating up with strips.

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 (adding more quantitative details).

Here considering signal if above **20 sigma** of noise (tunable).





(Rough) timeline

	NP02 timeline:	**Beam plug monitor timeline**:
Week of the 4th of November:	• Final vacuum/cold tests of plastic beam plug	• Finalize definitive setup • Test of whole system inside beam plug (vacuum/cold), with cosmics • Final complete test in cold and vacuum, with cosmics
Week of the 11th of November:	• **beam plug installation** • installation of 207Bi source PrM • alignment of Field Cage • test of HV continuity and installation of HV feedthrough • removal of access scaffold, false floor and final clean up	
Week of the 18th of November:	• remove bottom CRP protection and bias test • installation of PMTs • Test PD modules and PMT in dark	[...]
Week of the 25th of November:	• installation of the laser periscope • start purge • final leak tests with argon in overpressure	• Start of integration in NP02 trigger • Improve analysis code, tune reconstruction

Integration in NP02 trigger

After hardware installation, start thinking about integration in trigger.

INPUT: Detector can accept a TTL 3.3V trigger signal, then it records the ADC value for each channel after 6.5us (considering shaping parameters, should be the peak) (tunable).

OUTPUT: no analog trigger out, need to think of something different. Options:

- fast analysis during beam commissioning:
  - take run
  - see beam alignment
  - tune magnets
  - repeat
- software trigger:
  - fetch event by event from output file
  - fast analysis to see triggered channels
  - propagate info to trigger

Backup

Data analysis

What to look at?

With source:

- could vary the time at which the signal is sampled to see if 6.5us are ok
- place it 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) -> done, have data

Parameters to look at:

- shape of amplitude plot? Peak?