

A LAr purity monitor for DUNE

1. LAr purity monitor PrM with ^{207}Bi radioactive source
2. R&D and testing for Bi-PrM validation: Lab tests and NP02
3. Final optimization of Bi-PrM geometry
4. Planned optimal layout of the PrM in DUNE
5. Construction plan and funding: 2026-2030

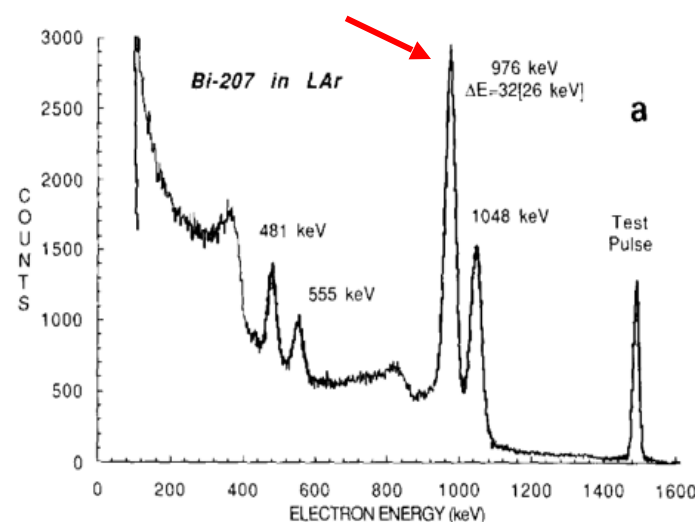
R&D proposal to include the scintillation light

B. Baibussinov, A. Guglielmi, S. Marchini, G. Meng, M. Nicoletto,
F. Pietropaolo, G. Rampazzo, R. Triozzi, F. Varanini

INFN Padova

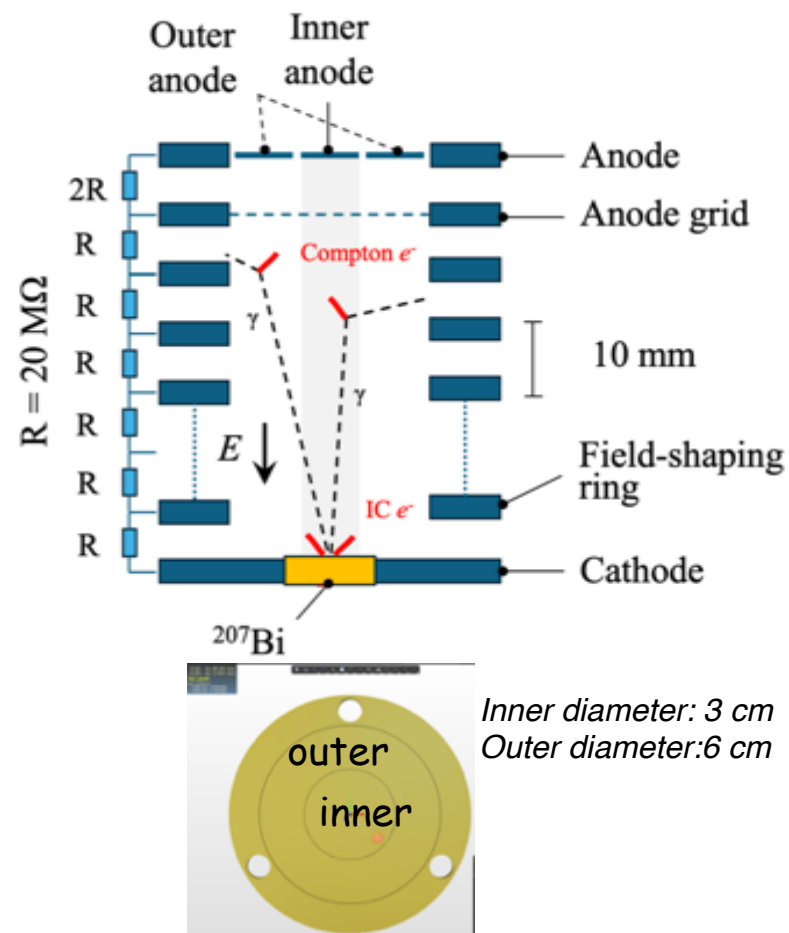
1. LAr purity monitor PrM with ^{207}Bi radioactive source

- LAr purity monitor PrM; CRUCIAL to measure τ free e- lifetime in liquid argon:
 - $\tau \sim 30$ ms (10 p.p.t. of $[\text{O}_2]$ equivalent) results in 18 % attenuation signal for e- cloud propagating over 6 m at 500 V/cm electric field.
- Present LAr purity monitors rely on charge attenuation measurement of e-cloud created by photoelectric effect from UV flash lamp, drifting from cathode to anode of a small TPC.
- A new concept Bi- PrM with a ^{207}Bi radioactive source is presented, based on the collection of monochromatic 976 KeV IC e- emitted by ^{207}Bi source at cathode and drifted to anode.
- Several advantages wrt the conventional UV based monitors:
 - Operated continuously, also during LAr filling, no interference with ph. detectors
 - Operated at the same electric drift field as the TPC and same readout electronics: a more direct measurement of LAr purity.
 - Pairs of monitors of different drift length can be used simultaneously to avoid absolute calibration (dual Bi-PRM) improving also the sensitivity to 10 ms



New Bi207 PrM concept in more details

- The ^{207}Bi source is mounted on the cathode;
- The anode is split in 2 concentric areas:
 - The inner receives e-clouds from IC e- peak and from Compton e- due to emitted γ
 - The outer only receives Compton e- with ~ same energy spectrum as inner
 - The outer energy spectrum is used to remove Compton e- bkgd from inner anode and extract a "clean" ~1 MeV gaussian peak due to IC e-
- Both anodes are readout with low noise cryogenic pre-Amps directly mounted on the back of anodes:
 - No decoupling capacitors required as $V_{\text{anode}} = 0 \text{ V}$
 - 50 keV resolution for ^{207}Bi IC e- peak at E_{DRIFT} in 200-1000 V/cm range are routinely reached.
- No cathode readout required (IC e- energy known)
 - only accurate pre-Amps calibration in LAr is needed, performed once for all in test stands.

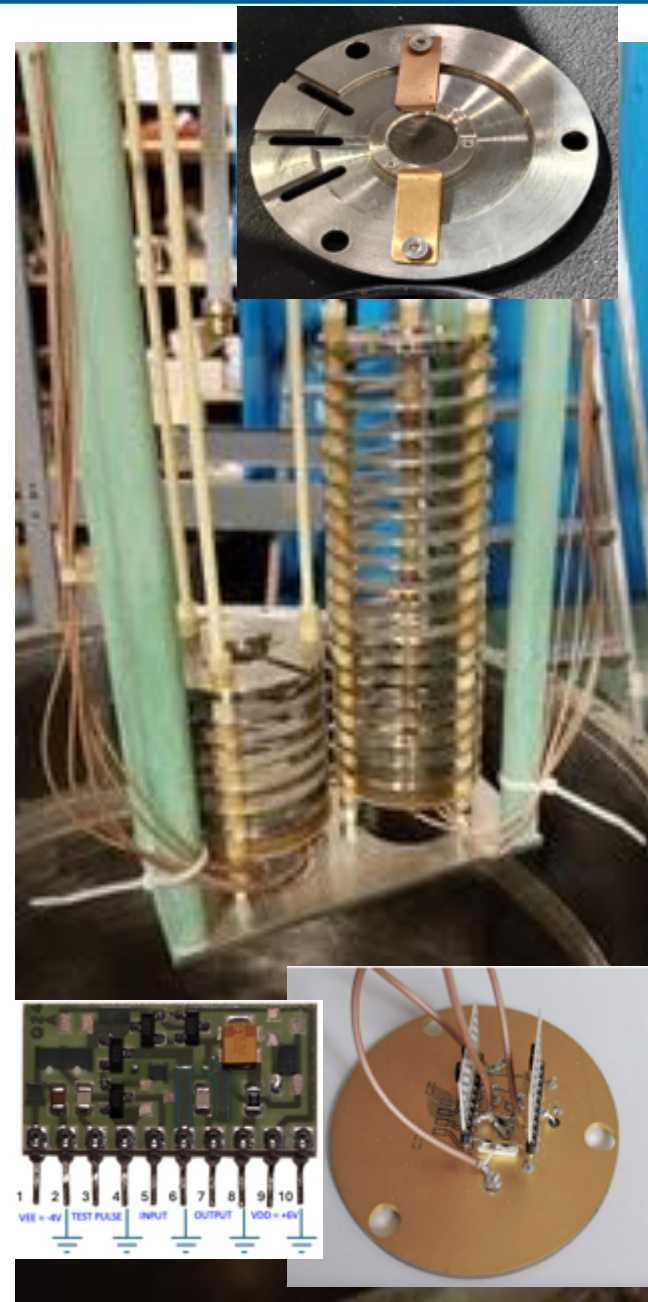


2. R&D and testing for Bi-PrM validation: Lab tests and NP02

- The Bi-PrM concept was successfully developed in the past two years in two phases:
 1. Laboratory tests (Padova and CERN) focusing on the mechanics, electronics and DAQ and proof of concept as described in JINST 20P02011;
 2. Construction and operation of a quasi-final dual PrM layout installed at CERN in ProtoDUNE NP-02 detector for long term performance, sensitivity validation and comparison with UV-based PrMs.
- Following the obtained positive results, the DUNE Collaboration plans to adopt this new Bi-PrM to be installed in several locations within the two 17 kton Far Detector modules.
- The conclusion of the Bi-PrM R&D phase before starting the monitor production for DUNE includes the final optimization of specific design features such as the best drift-length and the electronic response to 1 MeV e⁻ signals.

Dual Bi-PrM for concept validation (lab tests)

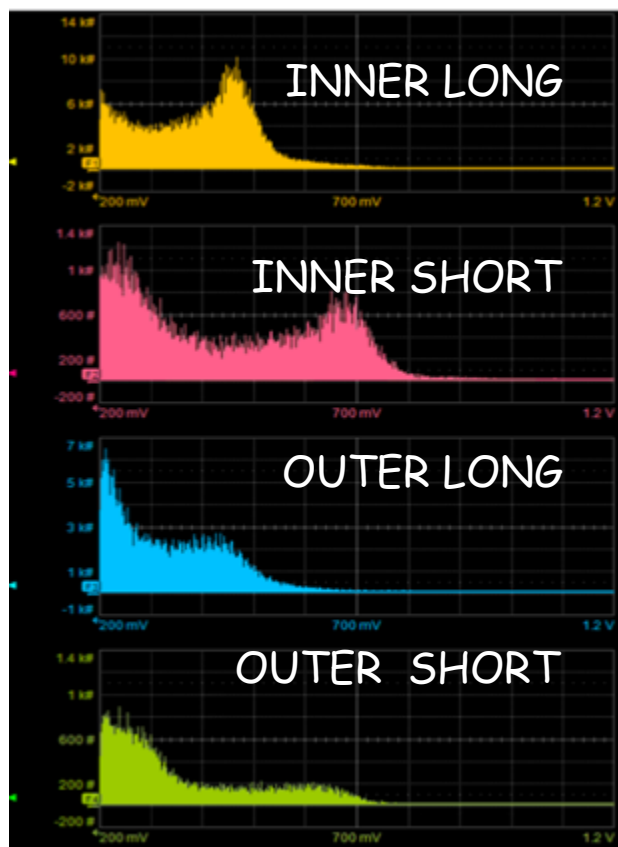
- 2 Bi-PrM built at CERN/INFN-Padova, $L_{\text{DRIFT}} = 6, 18 \text{ cm}$
used simultaneously to remove absolute calibration need:
 - Exactly same layout/E-field to minimize systematics:
HV applied only on cathode of long PrM,
short PrM rings voltage taken from long one.
- Cryogenic J-fet pre-Amplifiers with equal response/gain developed for ICARUS in the '90:
 - Directly mounted on the back of anode: $< 1000 \text{ e- ENC}$
 - Gain calibration accuracy $\delta \sim 1 \%$ achieved
 - Able to drive long output cable without loss
 - High reliability: no dead chs after numerous cryogenic cycles for 30 years.
- Dedicated feedthrough flange and warm receivers/shapers. DAQ based on 4 ch scope or Multi Channel Analyzers.
- HV cable and feedthrough for $> 20 \text{ KV}$ (industrial version also available).



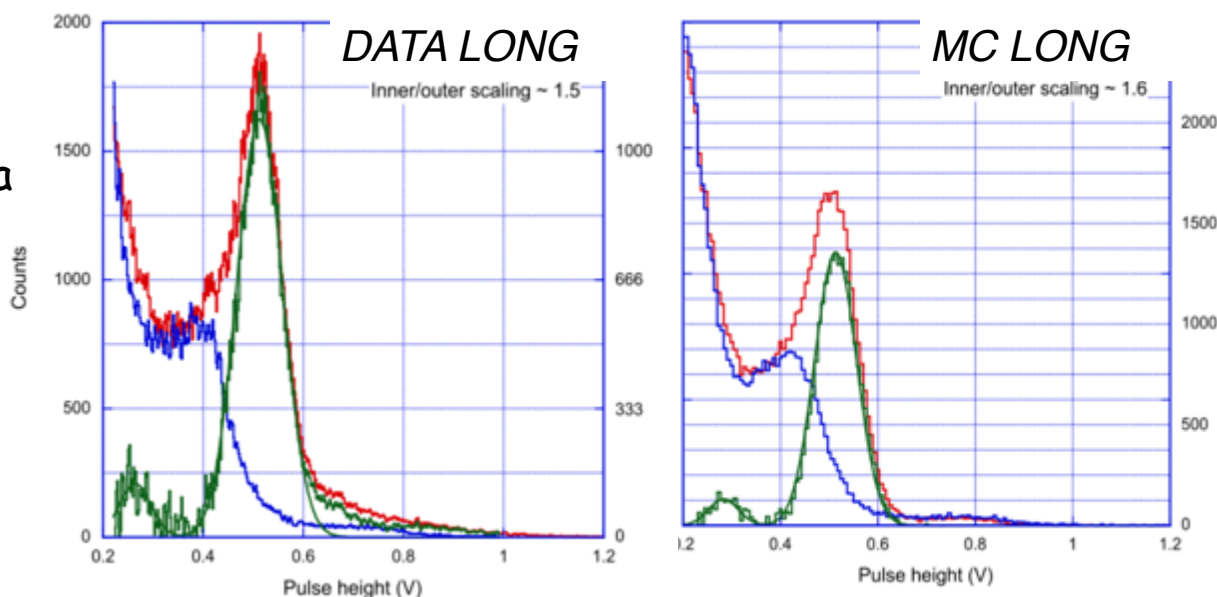
Bi-PrM operation in LAr

- Oscilloscope based DAQ

- Event by event online charge measurement and spectra
- The different ranges of the INNER, OUTER charge spectra due to free e⁻ attenuation in LAr are visible.



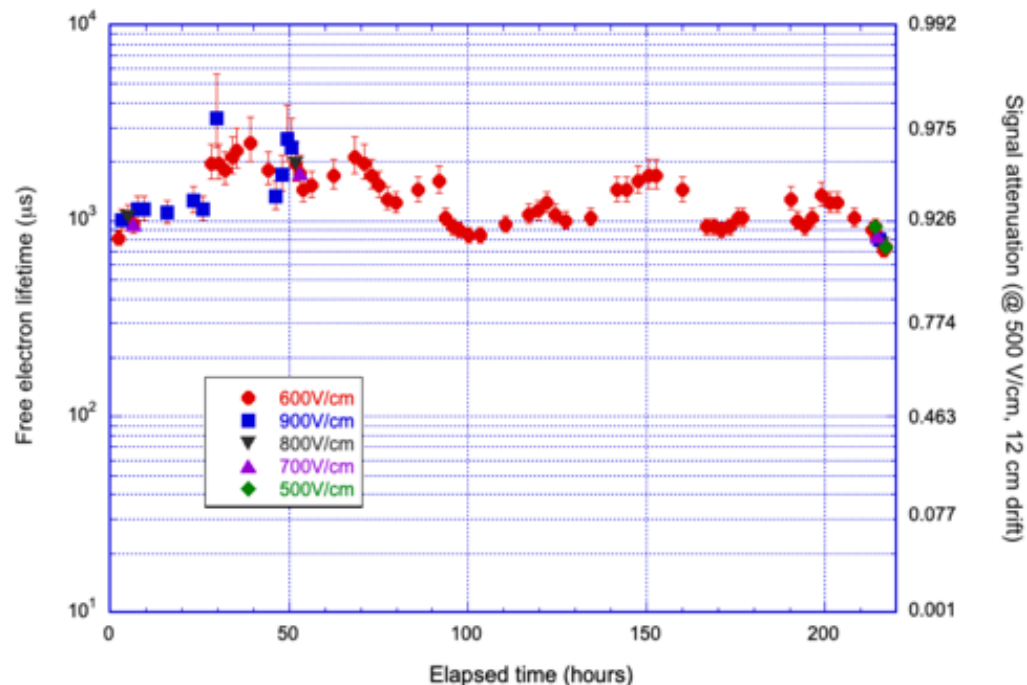
Example of MC vs DATA comparison for 18 cm PrM



- GREEN spectra: pure IC peaks subtracting OUTER spectra (Compton) from INNER ones (IC + Compton)
- LONG/SHORT IC peak value ratio used to evaluate free e⁻ lifetime over the drift length of PrM
- MC including all source decays and detector response, reproduces DATA for both drift lengths in a wide range of LAr purity values.

Bi-PrM performance from the collected lab data

- Runs taken at different E_{DRIFT} in 500-900 V/cm, lasting ~ 1 week each.
- Free e- lifetime τ is evaluated simply comparing the pulse height of the two different PrMs, 6 and 18 cm long, removing the need for absolute calibration:
 - $\text{Pulseheight}_{\text{LONG}} / \text{Pulseheight}_{\text{SHORT}} = \exp(- (18 \text{ cm} - 6 \text{ cm}) / v_{\text{drift}} / \tau)$
- The PrM detector sensitivity to LAr purity depends on $\Delta L_{\text{DRIFT}} = 18 - 6 \text{ cm} = 12 \text{ cm}$, drift velocity V_{DRIFT} and relative accuracy of electronic gain calibration, $\delta \sim 1 \%$:
 - $\tau_{\text{MAX}} \sim \Delta L_{\text{DRIFT}} / V_{\text{DRIFT}} / \ln(1 - \delta) \sim 8 \text{ ms} @ 500 \text{ V/cm}$



- ✓ Continuous data taking to follow e- lifetime evolution in detail.
- ✓ The equivalent signal attenuation between Short and Long PrM is shown on the right axis for $E_{\text{DRIFT}} = 500 \text{ V/cm}$.
- ✓ Errors are dominated by the cross gain calibration of pre-Amps δ

RECEIVED: November 16, 2024

REVISED: January 4, 2025

ACCEPTED: January 17, 2025

PUBLISHED: February 12, 2025

JINST 20P02011

A novel liquid argon purity monitor based on ^{207}Bi

B. Baibussinov,^a M. Bettini,^a F. Fabris,^a R. Gan,^e A. Guglielmi,^a G. Gurung,^{b,c} S. Marchini,^a G. Meng,^a M. Nicoletto,^a F. Pietropaolo ^{b,a,*} X. Pons,^b G. Rampazzo,^a R. Triozzi,^a F. Varanini ^a and B. Voirin ^d

^aSezione INFN di Padova e Università di Padova,
via Marzolo 8, 35131, Italy

^bCERN,
Route de Meyrin, 1211 Geneva, Switzerland

^cDepartment of Physics, University of Texas,
Arlington, TX 76019, U.S.A.

^dDepartment of Physics, École Normale Supérieure de Lyon,
Allée d'Italie, 69364 Lyon Cedex 07, France

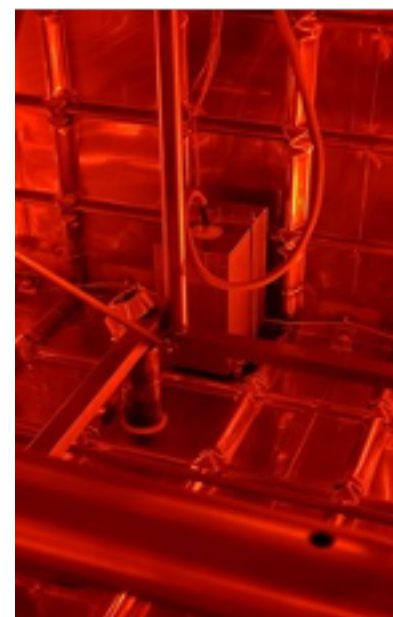
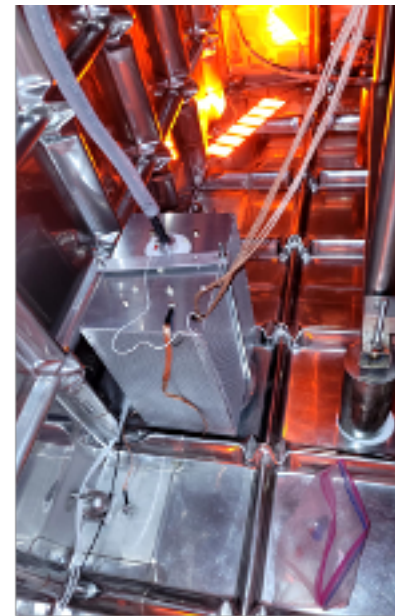
^eDepartment of Physics, Boston University,
Boston, MA 02215, U.S.A.

E-mail: francesco.pietropaolo@cern.ch

ABSTRACT: A novel liquid argon purity monitor based on a ^{207}Bi radioactive source, emitting monochromatic internal-conversion electrons, is presented. This new monitor allows for a very precise and fast measurement of the electronegative impurities concentration in liquid argon. It can be operated continuously in liquid argon TPC experiments without interfering with the main detector operation. Different drift lengths can be assembled for the proposed device, to assess a large range of liquid argon purities while minimizing systematic uncertainties. Two prototypes have been built and successfully operated in dedicated test stands. The results and performance are reported.

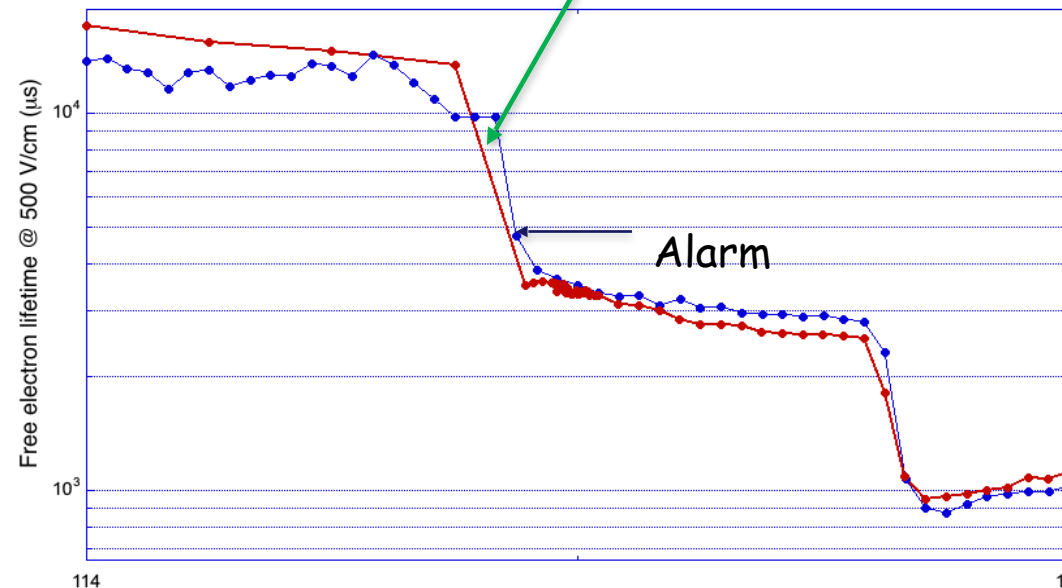
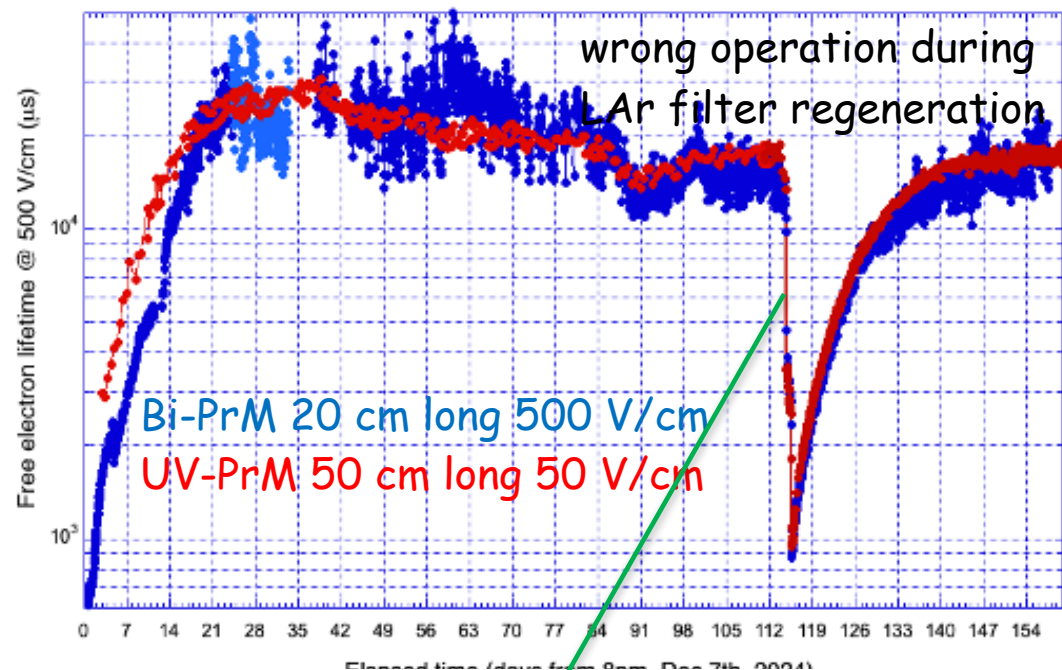
Bi207 PrM in ProtoDUNE NP02

- A dual PrM with 6, 18 cm drift installed in NP02 in Nov. '24 in a corner on the cryostat floor:
 - Shielded from external noise sources by a faraday cage, 50% opening for efficient LAr circulation
 - 10 m HV, signal/bias cables routed to cryostat roof
 - Dedicated flange hosting HV feed through, warm receiver buffer amplifiers and bias voltage supply.
 - DAQ system (oscilloscope/MCA) installed on cryostat roof allows for remote operation via internet
 - HV power supply (12 kV @500 V/cm E-field) inserted in NP02 racks with additional ripple filter box.
- A classical 50 cm long UV based PrM installed at mid height (5 m), ~ 6 m away from the Bi207 PrM:
 - Operated twice a day to avoid fiber/photocathode degradation and interference with DUNE PDS.



LAr purity measurement in NP02

- 1 data set /h acquired with oscilloscope
- e- attenuation evaluated on the ratio of IC peaks of long and short PrM.
- Long term operation since Dec '24 and comparison with UV based PrM to validate:
 - performance and sensitivity,
 - electronics stability with time and ambient temperature,
 - DAQ efficiency and data analysis.
- Continuous operation of Bi PrM in NP02 allowed to set an ~ real time alarm when purity rapidly dropping.
Monitor also activated with UV PrM



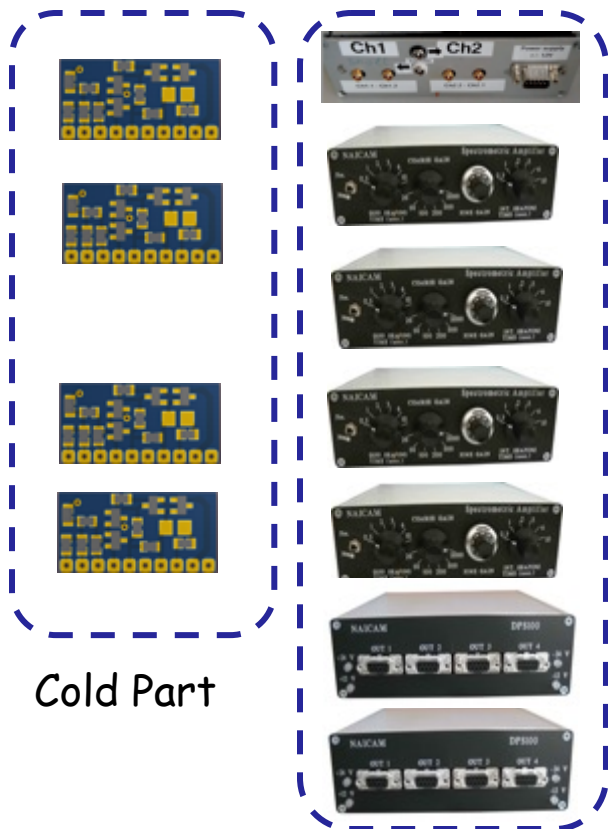
3. Final optimization of Bi-PrM geometry

- Final dual Bi-PrM optimization is under way with a 3 detectors set-up to define the best drift length of the 2 detectors and reach a pre-Amps cross calibration better than 0.5%:
 - ✓ Short, Intermediate, Long PrM : 6, 18, 54 cm
 - ✓ One single HV FT (one resistor chain).
- This prototype has been developed/realized with Padova and CERN LAr R&D funding, similarly to one in operation in NP02:
 - ✓ Mechanics, cables completed and ready to be installed in cryogenic set-up at CERN.
 - ✓ New layout cryogenic pre-Amps tested: ready for production.
 - ✓ Improved electronic chain under test in INFN Padova: check of stability in time and ambient temperature.
 - ✓ New design HV connection and feed through almost ready: tests ongoing in LNL before the use at CERN
 - ✓ CAEN multichannel analyzer DT 5781 (4 chs) under test in Padova to be moved to CERN for Cold Box test at EHN1.



Electronics Upgrade (INFN Sez. Padova)

Initial dual PrM setup in NP02 cryostat at CERN



Cold Part

Warm Part

4 cold preamplifiers,
Analog Buffer on the flange, 4
spectrometric amplifiers, 2
low noise power supplies.

On going electronics upgrade: new 6 chs module integrating Analog Buffers and Spectrometric Amplifiers with optimized shaping time as defined with lab tests.



- Installed in NP02 at CERN in the present dual PrM, 4 chs.
- Will equip the triple PrM prototype to be tested at CERN on the ColdBox at EHN1 (6 chs).

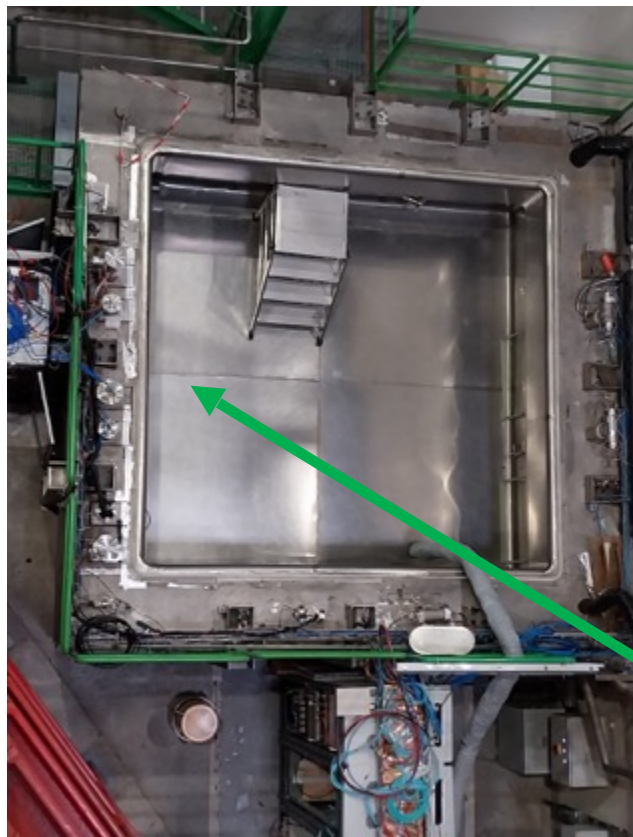
- 6 channels equipped with test pulse, in one module;
- DC-DC convertor for cryogenic preamplifiers;
- Gain 1000: stability 0,005%/C;
- Differential time 3 μ s;
- Integration time 2 μ s;
- Input RMS Noise without preamplifier < 6 μ V;
- Equivalent noise RMS with cold preamplifier 250 e-;
- One +/-12 DC low noise power supply.

being validated in Padova

Test in Cold Box in EHN1 at CERN

- 20 tons LAr Cold Box hosts a $3 \times 3 \text{ m}^2$ TPC, 25 cm of drift to test both charge/light readout units of DUNE Vertical Drift. Several tests of DUNE components planned in the following.
- The triple PrM prototype is being integrated in the Cold Box for a complete validation/study of the optimal lengths of the dual PrM detectors.
- Typical LAr purity reached in this facility $\sim$ ms free e-lifetime, well suited for studying PrM performance, also taking advantage of simultaneous measurement with cosmic μ s in the TPC.

» PrM test campaign at EHN1 to start on Mid Dec 2025.



Triple PrM

6 channels Shaper

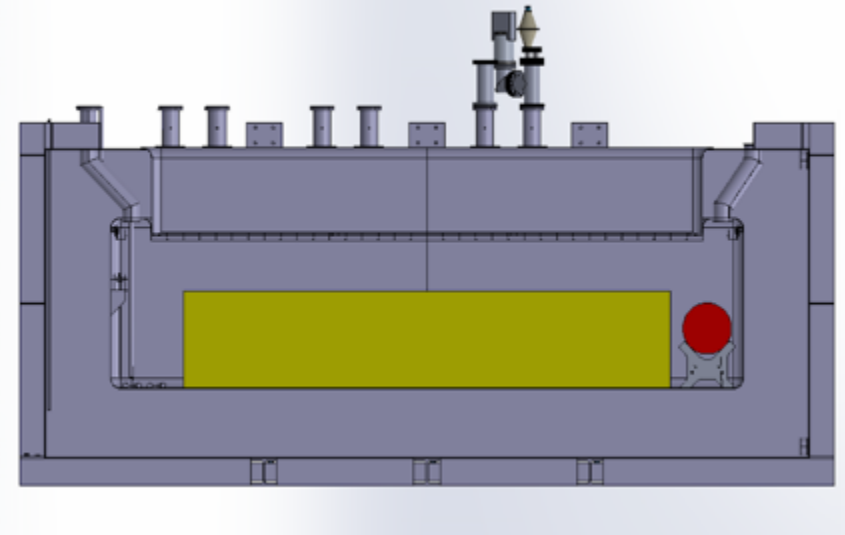
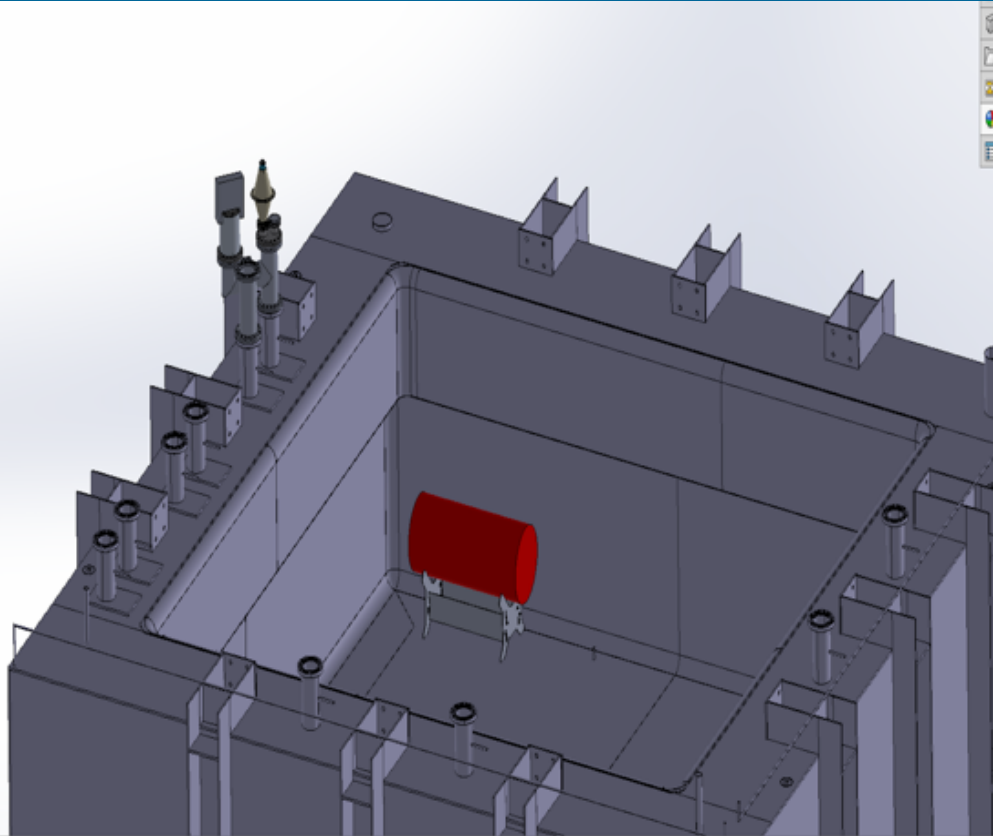


DAQ system



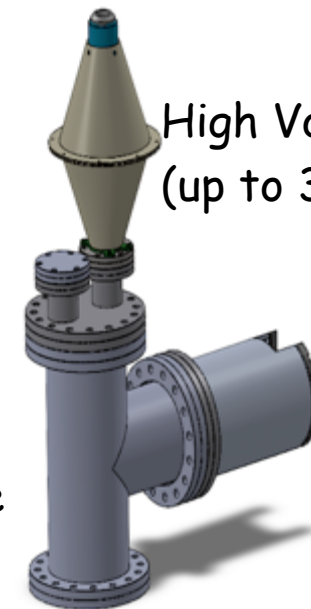
2x4 channels MCA modules

CAD simulation of Triple PrM in the Cold Box



Triple PrM is being integrated in the Cold Box
3D CAD model in SOLIDWORKS

Output Flange

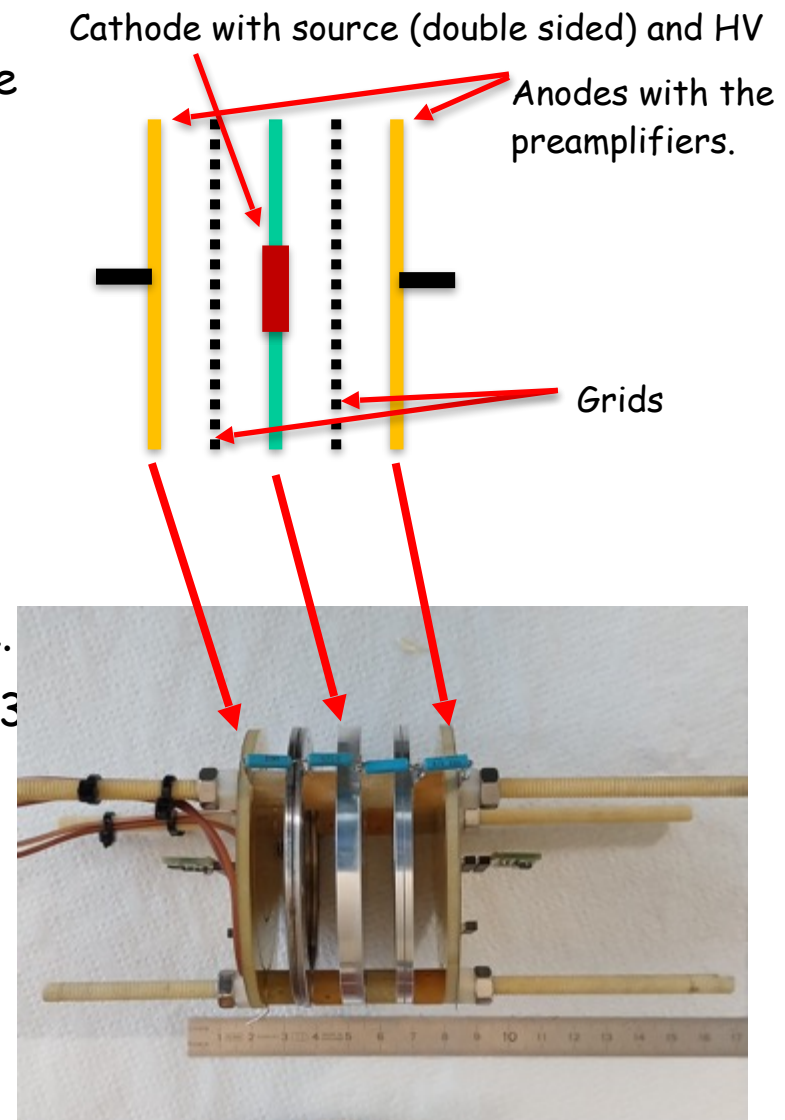


High Voltage connection
(up to 30 kV)

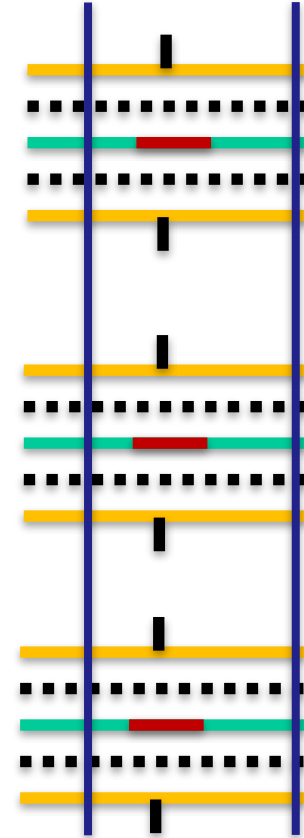
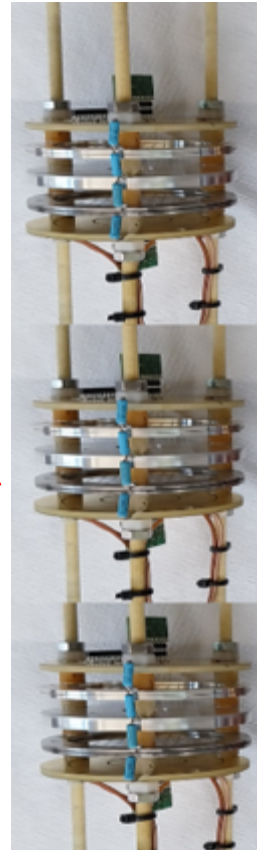
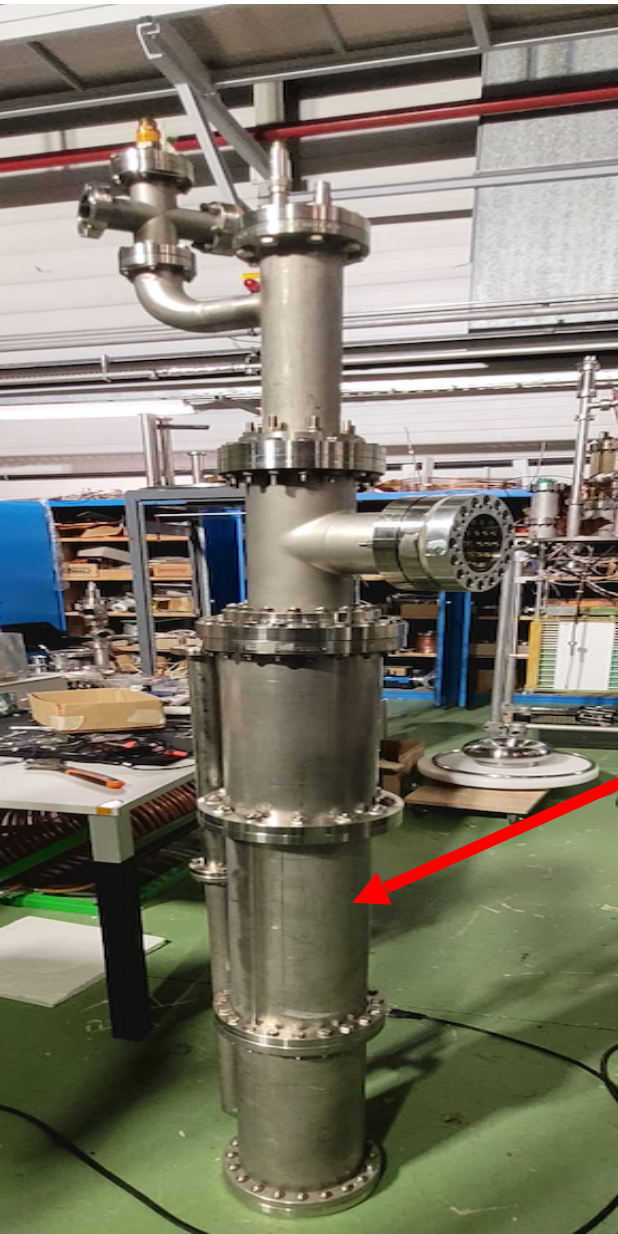
MA Thesis on Cryogenics/Mechanics Engineering in Pisa

Calibration of cryogenic pre-Amps for DUNE Bi-PrMs

- The $\sim 1\%$ accuracy achievable with standard test capacitances in LAr, can be further improved by a simple and small set-up with a double 1 cm short drift chamber calibrating pre-Amps in pairs:
 - Cross calibration performed on IC e⁻ peak in LAr
 - Performed at all required E_{DRIFT} fields
 - Several cryogenic cycles to validate stability
 - Better than 0.5 % relative accuracy achievable.
- No need for ultra-pure LAr: same drift distance and attenuation signal experienced of both sides of cathode.
- 6 pre-Amps can be calibrated at the same time with small test chambers in existing 15 liter LAr vessel already used for early PrM tests.
- 3 Bi sources available at CERN, as well as the LAr.
- 7 runs required to calibrate ~ 40 pre-Amps for both DUNE Far Detector Module: 1 run/week.



Set-up Calibration of cryogenic pre-Amps at CERN



Set-up at CERN:

3 Bi-PrM calibration chambers on common supporting rods,
40 cm long in 15 liters vessel, to test 6 pre-Amps at once.

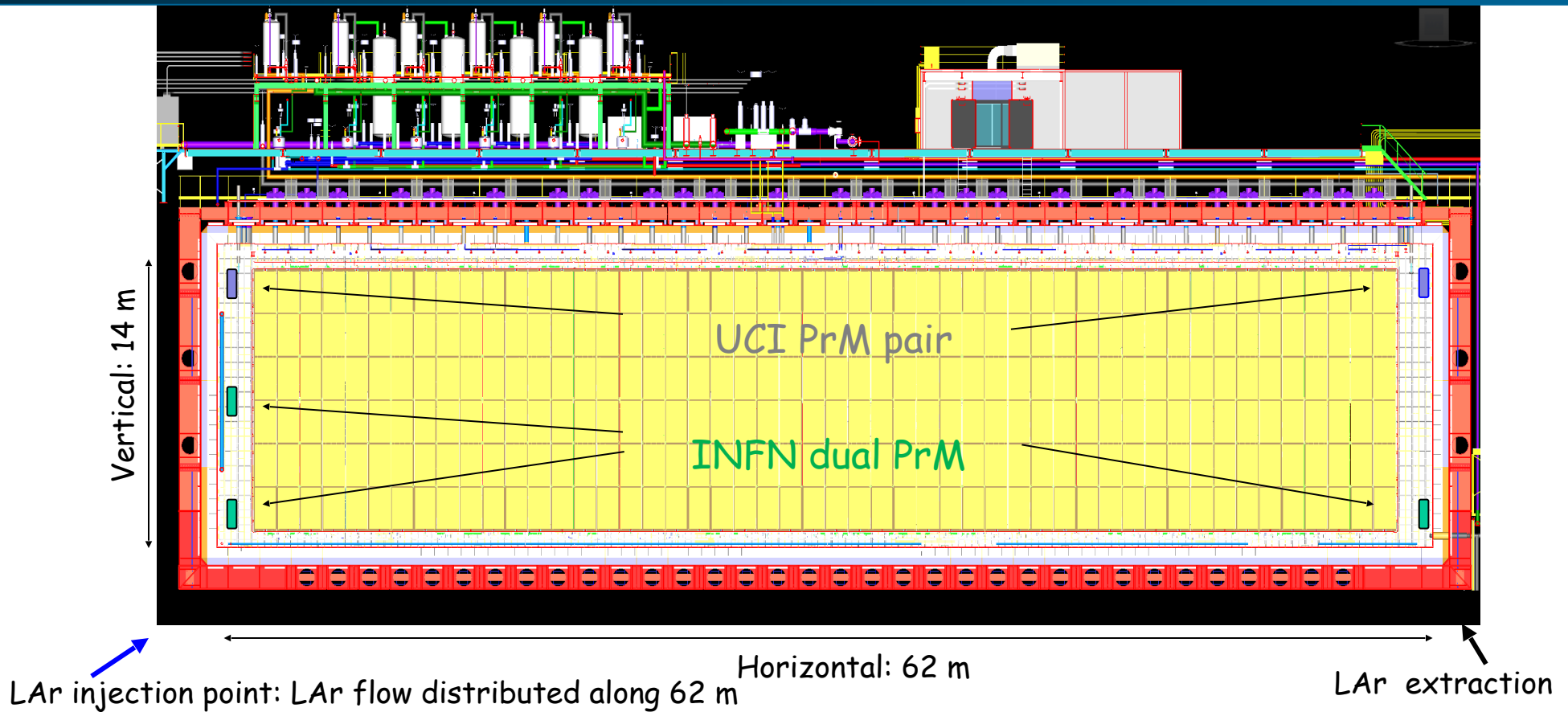
4. Planned optimal layout of the PrM in DUNE

- The obtained results paved the way for this innovative LAr purity monitor in DUNE Far Detectors where continuous and distributed LAr purity measurements during filling and operation are envisageable.
- 6 Bi-PrMs will be installed in each of 2 DUNE Far modules, each composed by either 1 or 2 detectors of different L_{DRIFT} :
 - ✓ 1 Bi-PrM with 1 single detector inline with the ultrapure LAr injection (is 1 Bi-PrM back-up needed ?);
 - ✓ 3 Bi-PrM dual detectors on the cryostat floor distributed along the 60 m length;.
 - ✓ 2 Bi-PrM single detector on two opposite cryostat corner coupled to UV Light-PrM
- Proposed sharing of deliverables between US-DOE and INFN (for each FD module):
 - UC IRVINE Group with DOE funding contributes with:
 - ✓ 2 UV light complete PrMs; 3 single-detector Bi-PrM without electronics and HV FT
 - ✓ Bi sources for all Bi-PrMs
 - INFN Padova Group would contribute with:
 - ✓ 3 dual detectors PrMs but without the source procurement
 - ✓ Full electronic chains for the additional 3 US-built single detector Bi-PrM and HV FT.

PrM positioning in DUNE

- In the proposed layout, 2 dual PrMs of INFN will be positioned on the floor of cryostats at the opposite sides, 60 m apart, one close to LAr cryo input and the other at LAr extraction.
 - They measure LAr purity as soon as the cryostat starts to be filled.
 - Main purpose: monitor e-lifetime evolution, detect possible differences between the two sides, and set real-time alarm in case of sudden degradation => no need for ultra high sensitivity.
- One dual Bi-PrM will be positioned at mid height (6 m) above one of the bottom PrMs.
 - Together with 2 pairs of PrM produced by UCI, placed close to LAr surface, it will measure vertical gradients of LAr purity when the cryostat is full and during LArTPC operation.
 - The knowledge of this gradient, beneficial to improve the energy resolution of LAr TPC detector, is not easy to be extracted from charge attenuation measurements along cosmic muons in the LArTPC.
- UCI PrM pairs consist of 1 classic PrM and 1 Bi207 PrM identical to the INFN ones. The intercalibration of these PrM pairs will be extended to INFN Bi-PrMs allowing to achieve sensitivities >> 10 ms during the detector steady state operation.
- This layout is proposed for both DUNE FD cryostats.

PrM layout in DUNE



Further details to be studied:

- PrM installation sequence inside the cryostats;
- Cables length and deployment method;
- Feed through allocations;
- Space required for warm electronics and HV.

UCI will take care of Bi sources procurement and installation, including safety procedures.

5. Construction plan and funding: 2026 - 2030

- According to the proposed DOE/ INFN sharing, INFN funding for construction of PrM for each FD module would require ~ 81 k euro (NO TVA: delivering at CERN):
 - 3 dual Bi-PrMs but without the source procurement ~ 65 k euro
 - Full electronic chains + FT for the additional 3 single Bi-PrM ~ 16 k euro
- Foreseen construction/activation plan to equip both DUNE Far Detectors with 6 Bi-PrMs:
 - 2026- 2028: production and lab test of 6 dual Bi-PrM (2/year); contribution to US-built 3 single Bi-PrMs with front-end electronics 1/year);
 - 2028: installation and test of 3 dual Bi-PrMs in DUNE Vertical Drift;
 - 2029: activation and operation of 3 dual Bi-PrMs in DUNE Vertical Drift; installation and test of 3 dual Bi-PrMs in DUNE Horizontal Drift;
 - 2030: activation and operation of 3 dual Bi-PrMs in DUNE Horizontal Drift.

Procurement of DAQ multichannel analyzers planned just before DUNE activation at Far site in 2029

Spending profile: 2026, 2027, 2028 and 2029

- R&D and first Bi-PrM prototype have been successfully performed with the available material from ICARUS and CERN, without asking additional support to INFN.
- 2026-2028: production/test of 2 complete dual Bi-PrMs (INFN built) and of the electronics for 2 single Bi-PrM (US built) every year, 42 k euro/year:
 - ✓ 2 dual Bi-PrM mechanics (2 x 4.5 k euro): **9 k euro in total, see item 1 in Offerta 1.**
 - ✓ Front-end electronics: cryogenic preamplifiers, warm buffer/shaper and stabilized Power Supply mounted on UHV flanges for 2 dual Bi-PrM (6 k euro) and for 2 single Bi-PrM (2x 2 k euro = 4 k euro) **10 k euro in total, see items 1, 2 in Offerta 2.**
 - ✓ Cryogenic HV cables, cryo-fitted HV feedthrough in UHV flange for 2 dual Bi-PrMs (7 k euro) and for 2 single Bi-PrMs (2x 3.5 k euro = 7 k euro) **14 k euro in total, see item 2 in Offerta 1.**
 - ✓ Warm HV cables, filter resistor box, HV power supply for 2 dual Bi-PrMs, (2 x 4.5 k euro) **9 k euro in total:**
 - HV cables: **see Offerta 3**
 - power supplies: **Offerta 4**
 - Filter resistor boxes estimation: **2.6 K euro**
- 2029: DAQ procurement for all 6 Bi-PrM (MCA CAEN N6781) **24 chs, 29 k euro, Offerta 5.**

HV

Plan for PrM validation, installation and activation

- Preparation, test and calibration of the PRMs will take place at CERN in 2026-2028. The activity will require a INFN Padova presence at CERN for 0.3 FTE/year. For these activities the DAQ chains already available at INFN Padova will be used.
- Consumable to carry out tests (LAr procurements, rental of lab. instrumentations) is estimated to be ~ 10 k euro per year.
- PrMs installation and activation at DUNE Far site in the Vertical drift module is expected in 2028 - 2029, followed by PrMs installation/activation inside the Horizontal drift module in 2029 - 2030. As a first rough estimation a presence of 0.3 FTE/year at Far DUNE site would be necessary in the 2028 - 2030 period.

year	2026	2027	2028	2029	2030
	Production / lab test of 2 dual Bi-PrM	production / lab test of 2 dual Bi-PrM	production / lab test of 2 dual Bi-PrM	activation/operation of 3 dual Bi-PrM in DUNE V. Drift	Activation/ operation of 3 dual Bi-PrM in DUNE H. Drift.
	production of front-end electronics for 2 single Bi-PrM	production of front-end electronics for 2 single Bi-PrM	production of front-end electronics for 2 single Bi-PrM	installation/test of 3 double Bi-PrM in DUNE H. Drift	
			installation/test of 3 double Bi-PrM in DUNE V. Drift		

**R&D proposal to include scintillation light
in LAr purity monitor**

Improvement to add scintillation light

- Present PrM's, installed in LAr TPC detectors, focus on the measurement of electronegative impurities in LAr, which affect the free e^- lifetime, hence the imaging capabilities and the energy resolution of the charge readout.
- However, the scintillation light also plays an important role in the LAr TPC, not only because it identifies T_0 of ionizing events, and contributes to the triggering system, but also because it can provide independent calorimetric information complementary to the charge readout.
- Impurities in LAr, such as N_2 , have the effect of breaking the Ar-Ar dimer before it decays emitting a VUV photons. As a consequence, predominantly the slow component of the argon scintillation is affected, resulting in a sizable decrease of its time constant and in the number of emitted photons.
- In some cases, these impurities (f.i. N_2) in LAr are not electronegative hence are not removable with the present LAr filtering system.
- Their presence, due to cryostat leakages or failure in the recirculation system, need to be detected in real time to quickly find and stop the source of pollution.
- **The new Bi207- PrM could be easily improved, adding the capability to measure the Ar scintillation light emitted by the Bi207 decay products and continuously track its stability in time.**

Charge + light PrM

- The basic concept exploits the Bi207 source emission from both sides.
- The proposed PrM layout consists on 2 double drift regions of few cm each with a central cathode in common.
- One drift is terminated with an anode structure to read-out the charge as in the present Bi-PrM.
- The opposite anode is at ground and hosts an array of SiPMs sensitive to 128 nm, ganged together in a single read out channel.
- The "light detection drift" is surrounded by an opaque cylinder to collect only direct light from source events (alternatively a reflective surface with shifter is also easily implementable).

Grounded anode
with SiPM array

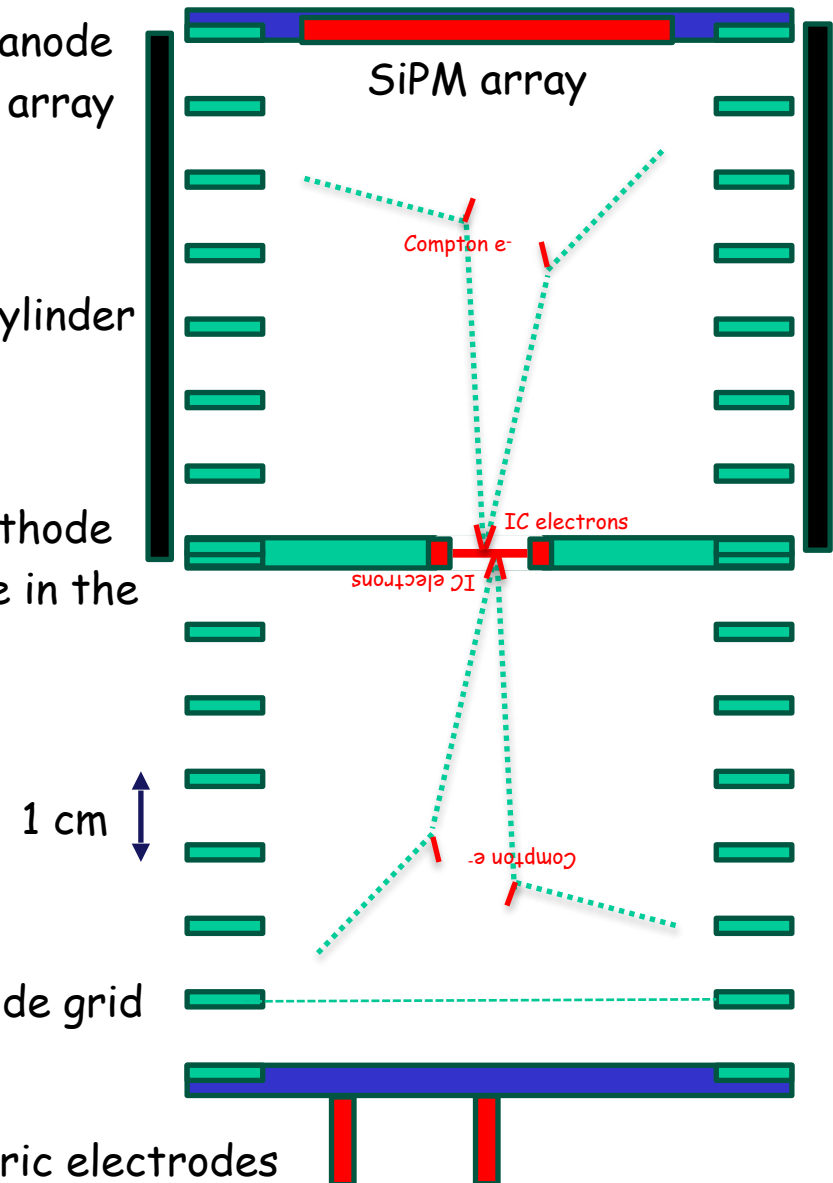
Opaque or
reflective cylinder

Common cathode
with source in the
center

Anode grid

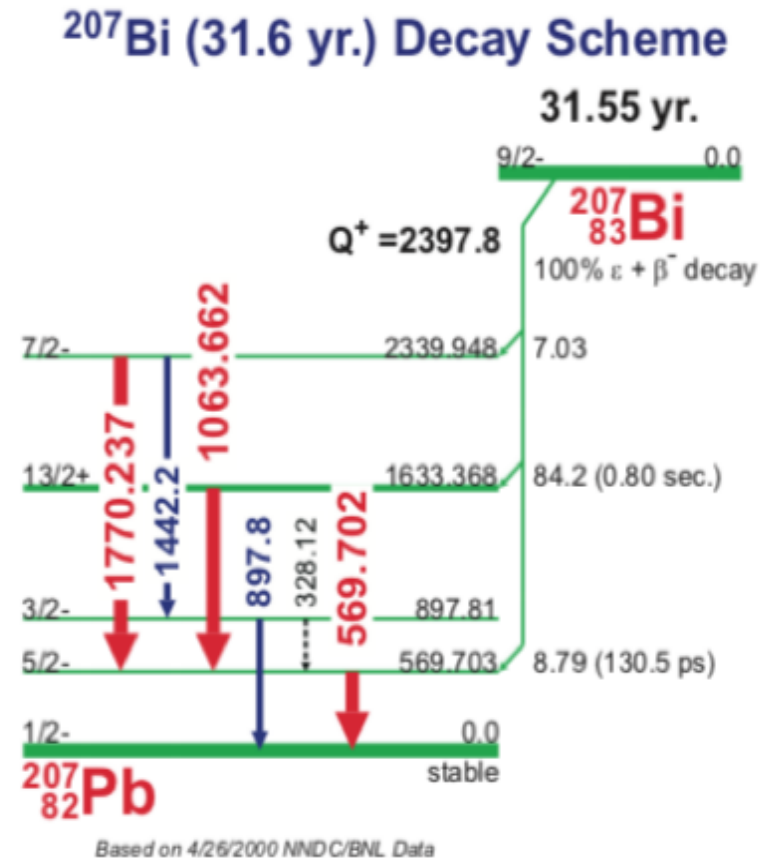
Anode for charge read out: 2 concentric electrodes
with 3 cm (inner) and 6 cm (outer) diameter

Charge amplifiers



Light measurement and performance

- Contrary to the charge, the light readout collects photons from all Bi-decay products (IC and Compton electrons) for each event within the PrM volume.
- Total emitted energy is 2.4 MeV: a simple MC indicates that most of it is released inside the PrM volume.
- 2.4 MeV: easily detectable by SiPM.
- Precise measurement of time constant of the Scintillation light slow component can be obtained in a very short time (source emission rate in 3-30 kHz range).
- The systems could also be used for energy calibration, focusing on the total energy released or on the IC e- only if the detector length is shortened to ~ 1 cm.
- The design is still to be studied in details but a prototype as the one described here could be assembled quickly for preliminary validation of the concept with available components.

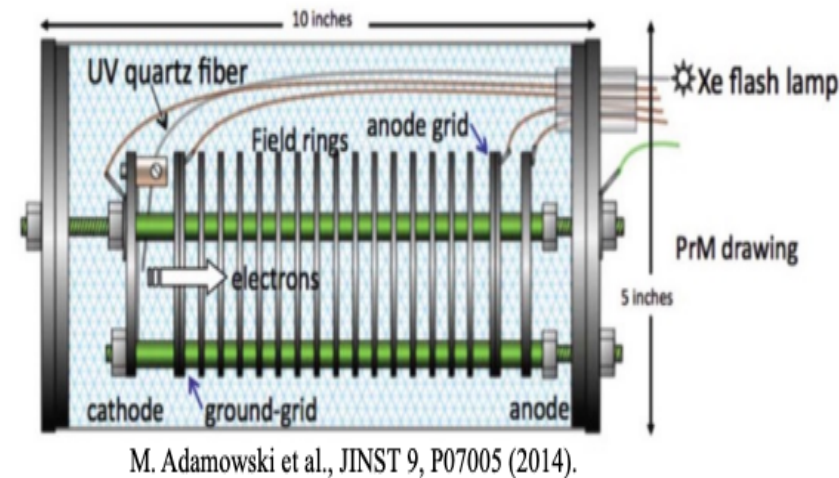


Questions & Answers

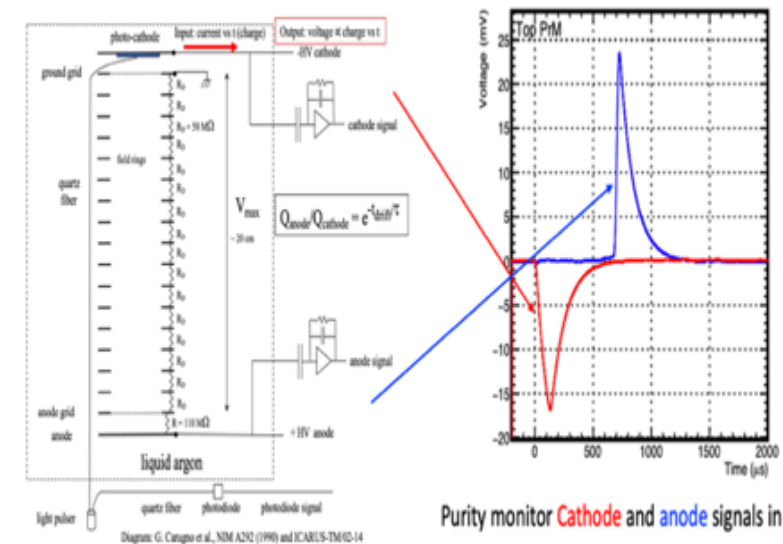
- R&D inside DUNE ?
- Interested people?
-

Present LAr purity monitor PrM

- Free e^- lifetime τ in LAr is a crucial parameter for LArTPC performance (energy resolution, imaging capability) because e^- ionization can be absorbed by electronegative impurities like O_2 along the drift, $\sim \exp(-L_{\text{DRIFT}}/v_{\text{DRIFT}}/\tau_{\text{ELE}})$,
 - $\tau \sim 30$ ms corresponding to ~ 10 p.p.t. of $[O_2]$ residual impurities would result in 18 % maximum attenuation for e^- cloud propagating over 6 m at 500 V/cm electric field.



- PrM purity monitors, first developed in 1988 by ICARUS R&D team, NIM A292 (1990) 580, are a double gridded TPC where an e^- cloud is generated on the cathode by photoelectric effect via a Xenon lamp pulsed UV light routed through a fiber bundle
 - e^- attenuation is estimated by charge and drift time as $Q_{\text{ANODE}}/Q_{\text{CATHODE}} = \exp(-t_{\text{DRIFT}}/\tau)$



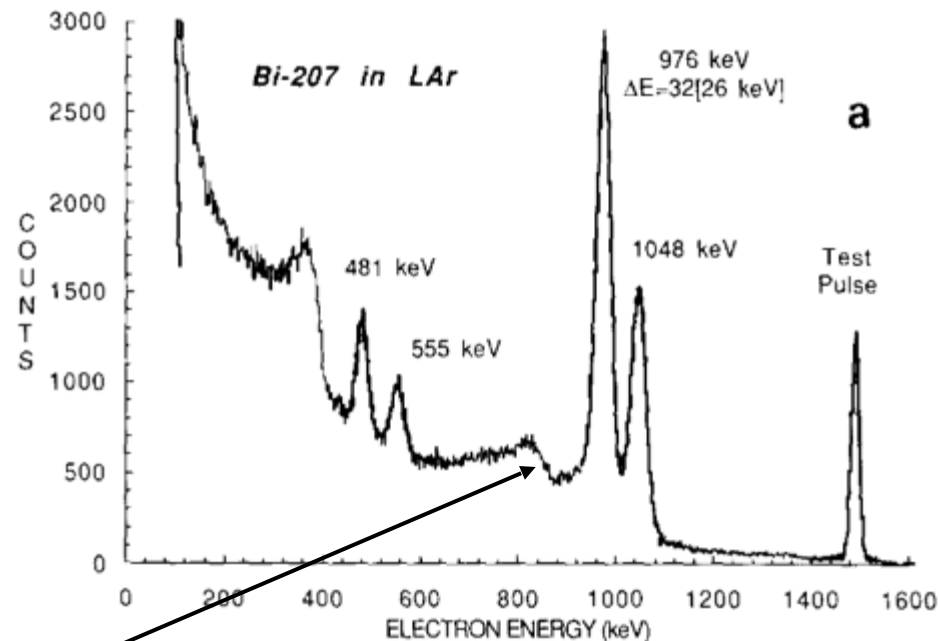
- As an alternative a ^{207}Bi radioactive source can be exploited to generate e^- signals.

A new LAr purity monitor based on a Bi207 source

- We propose to exploit the Bi207 radioactive source which emits monochromatic IC e- at 976 keV to build a new PM concept.

Decay Mode: EC, β^+		Half-Life: (11523 $\pm$ 1) d				[1]
Radiation Type		Energy (keV)		Intensity (%)		Ref.
Auger-L		5.2	15.7	53.8	14	[5]
Auger-K		56.0	88.0	2.8	3	[5]
ec-K-1		481.7		1.52	2	[5]
ec-L-1		553.8	557.7	0.440	6	[5]
ec-M-1		565.8	567.2	0.15	2	[5]
ec-K-2		809.8		0.003	1	[5]
ec-K-3		975.7		7.03	13	[5]
ec-L-3		1047	1051	1.84	5	[5]
ec-M-3		1059	1061	0.54	7	[5]
ec-K-4		1682		0.02	1	[5]
β +max		806.5		0.012	2	[5]
β +av		383.4				[5]
X-ray L	Σ	9.18	15.8	33.2	14	[5]
X-ray K α	Σ	74.2		58.19	24	[5]
X-ray K β	Σ	84.4	87.6	16.22	25	[5]
γ		328.11		0.00076	8	[5]
γ	Annih	511.0		0.0024	4	[5]
γ		569.70		97.76	3	[5]
γ		897.8		0.131	6	[5]
γ		1063.7		74.58	49	[5]
γ		1442.2		0.131	2	[5]
γ		1770.2		6.87	3	[5]

Common used source for calibration
(intense monochromatic IC peak)

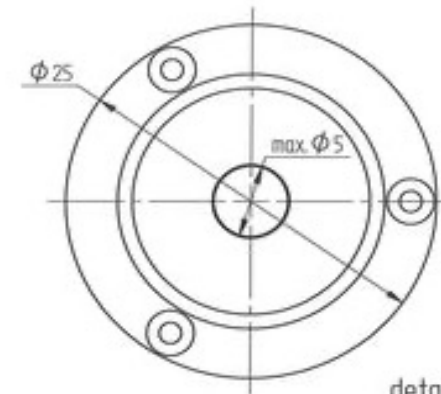
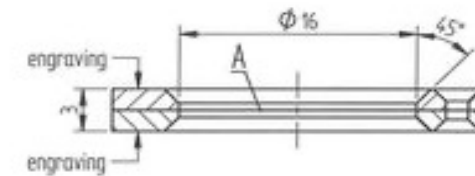


Pulse height spectrum of Bismuth source in LAr, at $E=10.9 \text{ kV/cm}$. The 976 keV IC e- peak is visible with a 32 keV (fwhm) total energy resolution.

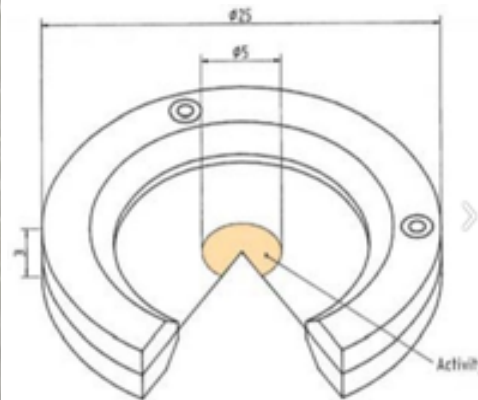
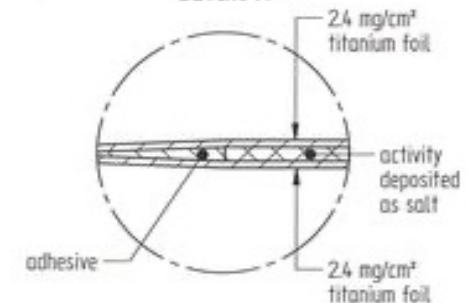
E. Aprile et al, NIM 261 3 (1987) 519-526

Characteristics of the selected ^{207}Bi sources

- ^{207}Bi radioactive sources up to 400 kBq are available from Eckert & Ziegler:
 - Certified for cryogenic, vacuum and HV use
 - Half-life: 31 years, compatible with DUNE runtime
 - Sources are protected by titanium or metalized mylar thin foils (IC e- loose up to 4 keV in passing through).



detail A



Scale 3:1	Tolerance ISO 2768-m	Surface	Material aluminium
Nuclide	Document Verkaufszzeichnung	Responsible Dept. Isotrok	Drawn DStapper
		Creation Date 17.05.2018	Approval <i>[Signature]</i>
Eckert & Ziegler		CONVERSION ELECTRON SOURCE	
VZ-0392-001		Rev. c	Issue Date 16.05.18
Sheet 1/1			

File No.: V:\e\z\germany\local\data\207Bi\production\public\exchange\Zeichnungen\207-0500\Verkaufszzeichnung\Z-0392-001.dwg
The contents of this drawing and its enclosures are our property. The drawing and its enclosures may not be duplicated without our written approval nor be made accessible to any third party. And unauthorised usage is unlawful and will be prosecuted.

Conventional LAr purity monitor vs new Bi-PrM -1

- Several cons of conventional PrM are recognized in case of large LArTPCs:
 - PrM usually operates at very low voltage to reach good lifetime sensitivity. This means that the actual e-attenuation at nominal E-field is not really measured because the e-capture cross section on LAr impurities depends on external E-field;
 - In addition, the amount of produced phe is highly reduced at low E-field, generally compensated by high repetition rates with PrM long exposure, ~ tens of minutes;
 - During the PrM operation, LArTPC photon detectors have to be switched OFF due to the intense UV light dispersed from the fiber bundle, hence the PrM cannot be used in parallel to the TPC operation..
 - The photocathode tends to degrade in time, requiring even longer exposure as time goes by. It is also sensitive to oxidation during the installation period.
 - The long fibers are fragile and the UV attenuation is not negligible.
 - The long electronic cables introduce sizable noise due to capacitance to the warm front-end electronics that is sitting on the cryostat roof.
- New ^{207}Bi based PrM allows to overcome these issues.

Conventional LAr purity monitor vs new Bi-PrM - 2

- The proposed Bi-PrM concept presents several advantages:
 - The Bi207 source can be obtained with activities up to 400 kBq and can be easily shielded during the detector assembly and installation;
 - The half-lifetime of Bi207 (31 ys) is well in excess of the expected time exposures of any future detectors (also DUNE);
 - The monitor can be operated continuously without interfering with the main LArTPC operation (both charge and light readout) and also during LAr filling;
 - It can be operated at same E_{DRIFT} as the main LArTPC for a direct e^- lifetime measurement;
 - Different PrM lengths can be assembled to further reduce systematic errors due to the calibration of the front-end electronics;
 - The energy of IC e^- is similar to a typical MIP on a 5 mm anode readout channel: the same front-end electronics of the LArTPC charge readout can be used.

Costs for one dual Bi-PrM module: 28 k euro

- Breakdown of costs for one dual Bi-PrM (no TVA):
 - ✓ PrM mechanics: cathode (with source support), rings, spacers, rods, voltage degrading resistors, anode PCB, flange with feedthrough DSUB25, 10 m coax cabling, Faraday cage, similarly to "classic" PrM (4.5 k euro)
 - ✓ ^{207}Bi radioactive sources (6.5 k euro)
 - ✓ Front-end electronics: cryogenic preamplifiers, warm buffer/shaper/stabilized Power Supply mounted on UHV flanges (3 k euro)
 - ✓ Cryogenic HV cables, cryo-fitted HV feedthrough in UHV flange (3.5 k euro)
 - ✓ Warm HV cables filter resistor box, HV power supply (4.5 k euro)
 - ✓ DAQ: multichannel analyzers CAEN N6781 for 4 chs (6 k euro).

Offerta 1, 2



SUPPLIER
Naicam S.r.l.
VAT no.: IT04837230285
Tax Code: 04837230285
via Aosta 14
35142 - Padova (PD) - IT
Telephone: 0492050437
Fax: 0492050437
amministrazione@naicam-tech.com

CUSTOMER
CERN EUROPEAN ORGANIZATION for NUCLEAR RESEARCH
VAT no.: CH108967751
Tax Code: FRCH394610661
CH-1211 23
Geneva - CH
Recipient code: XXXXXXX

QUOTATION
no. PREV 23/2025 del 08/07/2025
EXPIRY DATE: 07/08/2025

PRODUCTS AND SERVICES							
NO	CODE	DESCRIPTION	QUANTITY	PRICE	AMOUNT	VAT	VAT TYPE
1	PRM_mech	PRM mechanics: cathode (with source support), rings, spacers, rods, voltage degrading resistors, anode PCB, flange with feedthrough DSUB25, 10 M coax cabling, Faraday cage,	1 PZ	4.500,00 €	4.500,00 €	0 %	N3.1
2	CRY_HV	Cryogenic HV cables 2124 30 KV AC, HV feedthrough 30 KV with Lemo type ERA.34.430	1 PZ	3.500,00 €	3.500,00 €	0 %	N3.1

PAYMENT METHOD							
NO. INST.	METHOD	PAYMENT	BANK	IBAN	BIC/SWIFT	EXPIRY DATE	AMOUNT
1	Bank transfer	Single payment	BANCA ADRIA COLLI EUGANEI - CREDITO COOPERATIV O SOCIETA' COOPERATIV A	IT08Z0898262960038000000177	CCRTIT2T9 7A	08/07/2025	8.000,00 €

TAX REGIME
RF01 - Ordinary

VAT SUMMARY				CALCULATION QUOTATION	
VAT	TYPE	REGULAT.	CHARGE	TAXABLE	DUTY
0%	N3.1	non-taxable - exports art. 8, c. 1, Let. A) DPR 633/72		8.000,00 €	0,00 €
				Amount of products or services	8.000,00 €
				Total taxable amount	0,00 €
				Total non-VAT taxable (N3)	8.000,00 €
				Total VAT	0,00 €
				Total document	8.000,00 €
				Net payable	8.000,00 €



SUPPLIER
Naicam S.r.l.
VAT no.: IT04837230285
Tax Code: 04837230285
via Aosta 14
35142 - Padova (PD) - IT
Telephone: 0492050437
Fax: 0492050437
amministrazione@naicam-tech.com

CUSTOMER
CERN EUROPEAN ORGANIZATION for NUCLEAR RESEARCH
VAT no.: CH108967751
Tax Code: FRCH394610661
CH-1211 23
Geneva - CH
Recipient code: XXXXXXX

QUOTATION
no. PREV 20/2025 del 02/07/2025
EXPIRY DATE: 01/08/2025

PRODUCTS AND SERVICES							
NO	CODE	DESCRIPTION	QUANTITY	PRICE	AMOUNT	VAT	VAT TYPE
1	PM_2CHAN N	Purity Monitor: 2 cryogenic preamplifiers, warm buffer, 2-Channel Shaper	1 PZ	2.000,00 €	2.000,00 €	0 %	N3.1
2	PM_4CHAN	Purity Monitor: 4 cryogenic preamplifiers CA05, warm buffer, 4-channel shaper DSDIG60	1 PZ	3.000,00 €	3.000,00 €	0 %	N3.1

PAYMENT METHOD							
NO. INST.	METHOD	PAYMENT	BANK	IBAN	BIC/SWIFT	EXPIRY DATE	AMOUNT
1	Bank transfer	Single payment	BANCA ADRIA COLLI EUGANEI - CREDITO COOPERATIV O SOCIETA' COOPERATIV A	IT08Z0898262960038000000177	CCRTIT2T9 7A	02/10/2025	5.000,00 €

TAX REGIME
RF01 - Ordinary

VAT SUMMARY				CALCULATION QUOTATION	
VAT	TYPE	REGULAT.	CHARGE	TAXABLE	DUTY
0%	N3.1	non-taxable - exports art. 8, c. 1, Let. A) DPR 633/72		5.000,00 €	0,00 €
				Amount of products or services	5.000,00 €
				Total taxable amount	0,00 €
				Total non-VAT taxable (N3)	5.000,00 €
				Total VAT	0,00 €
				Total document	5.000,00 €
				Net payable	5.000,00 €

Offerta 3, 4

Carrello 08/07/25, 09:58

011725703 " info@labo-system.it Italiano " # Iscriviti o accedi



Cerca nel nostro catalogo



%2

HOME AZIENDA MISURE & PROVE CAVI ALTA FREQUENZA ALTA TENSIONE MEDICALE

MISURE KELVIN & METROLOGIA PINZE PER BATTERIE E MESSA A TERRA ALTA CORRENTE CONTATTI

LABO SYSTEM

CARRELLO

20 ARTICOLI 1.000,00 €

SPEDIZIONE 10,50 €

TOTALE (TASSE ESCLUSE)
1.010,50 €

TOTALE (TASSE INCL.)
1.232,81 €

TASSE: 222,31 €

HAI UN CODICE SCONTO?

Cavo A.T.
schermato, 30kV
AC/100kV DC,
1,31mm² (AWG
16).



20 €

50,00 €

\$ Continua lo shopping

Procedi con il
checkout

<https://shop.labo-system.com/it/carrello?action=show>

Page 1 of 2

Model 130NF | Single output high voltage power supply with floating ground: -30 kV @ 500 µA

08/07/25, 09:52

CPS
HIGH VOLTAGE

MODEL 130NF/1314



PRODUCTS & RESOURCES

Products

- Power Supplies
- Probes and Accessories
- Cables and Viewing Blocks

Resources

- Sales & Support
- Company

FEATURES

Single output high voltage power supply with floating ground: -30 kV @ 500 µA

- Single output 0 to 30 kV
- Uses only 500 µA at max voltage
- AC input
- Ripple under 200 mV at full load
- Arc- and short-proofed
- Local/remote programming
- HV output cable included
- Floating grounding wire

DESCRIPTION

Model 130NF/1314 is a high voltage power supply ideal for system component or laboratory use in applications requiring a highly stable, highly regulated, low-noise source of high voltage power. Features include remote programming, ripple under 200 mV, short-circuit and arc protection, and a wide range of precision and ultra-precision configurations available for system and laboratory use. Typical applications include focused ion beam machines, electron microscopes, and electron-beam lithography.

Also see our **Model 130N** for applications in which the grounding wire need not be separated from the case. The 130N also provides built-in metering outputs, whereas the 130NF/1314 does not. The 130 Series also includes the 130P, a positive-output 30 kV power supply. Please contact CPS to discuss other customization options for the 130 Series of power supplies.

SPECIFICATIONS

Input	
Input voltage	115/220 VAC
Input current	1.4 A maximum
Output	
Output voltage	30 kV maximum (programmable)
Output current	500 µA maximum
Line regulation	0.005% for ±10% change in input voltage
Load regulation	0.005% for full swing from no load to full load
Output ripple	< 200 mV peak-to-peak at full load
Time stability	0.005% in 1 hour 0.01% in 8 hours
Temperature coefficient	< 50 ppm/°C
Program voltage	0 to 9 VDC
General	
Dimensions	8 × 4 × 9 in.
Weight	16.1 lb (7.3 kg)
Operating temperature	0 to 45 °C
Ground to chassis	Floating
Output connector	CPS Model 130CBL-01

<https://www.cpslv.com/products/1314.htm>

Page 1 of 2

Offerta 5



Costruzioni Apparecchiature Elettroniche Nucleari C.A.E.N. S.p.A.
Via Vetraila, 11 - 55049 Viareggio (LU) - Italy
tel. +39.0584.388.398 - fax +39.0584.388.959
info@caen.it - www.caen.it

Nr. Offerta 25OFC.00622

Pagina 1

Spettabile
INFN - PADOVA
VIA MARZOLO 8
35131 PADOVA PD
Italy

Luogo di destinazione
CERN
SITE DE MEYRIN
1211 GENEVE 23
CH
SWITZERLAND
C.A.: Dr. Alberto Guglielmi

Viareggio, 02/07/2025

Come da Voi richiesto, Vi sottoponiamo la nostra migliore offerta per la fornitura di:

Codice Prodotto *	Descrizione	Cons. **	Cons. ***	Q.tà	Prezzo unitario	sconto %	Totale	Codice IVA
WN6781XAAAAA	N6781 - Quad Digital MCA Paese di Origine: Italy ** Sconto speciale, unico e non ripetibile ** Tempo di consegna: da comunicare			9	6.580,00	10	53.298,00	N8A
LOTTO2	ACCORDO QUADRO - LOTTO 2 - CIG 8693158CE9							

CLAUSOLA "NO RUSSIA BIELORUSSIA":
E' fatto divieto di vendere, esportare o riesportare in Russia o Bielorussia o per uso in Russia o Bielorussia i beni del presente accordo che ricadono:
nell'art. 12-octies del Regolamento UE 833/2014
nell'art. 8-octies del Regolamento UE 765/2006

INFORMATIVA BREVE:
CAEN S.p.A. - con sede in via Vetraila, 11 - 55049 Viareggio (LU), Tel +39 0584 388 398 - nella qualità di Titolare del trattamento dei Suoi dati personali, ai sensi e per gli effetti della normativa vigente in materia di privacy, La informa che i dati personali da Lei forniti saranno trattati nel rispetto delle finalità, modalità e dei tempi previsti dagli obblighi legislativi o contrattuali. Per maggiori informazioni La invitiamo a prendere visione dell'informativa estesa allegata e/o consultabile sul sito www.caen.it.

Descrizione IVA		Imponibile	Importo IVA	Totale imponibile	Totale IVA
NIBA N.I.art.8 co.1 lett.a DPR 633		53.298,00	0,00	53.298,00	
		Totale Fattura			
		53.298,00 EUR			
Condizioni pagamento		Coordinate bancarieCassa di Risparmio di Volterra S.p.a.			
Bonifico - 30gg d.f.f.m.		IBAN: IT05F0637024800000010000042 SWIFT: CRVOIT3V			
Prezzi		Validità dell'offerta	Garanzia		
Reso al luogo di destinazione		60G	3A		
Note ****					

(*) In caso di ordine si prega di riportare il codice prodotto.
(**) Tempo di consegna in caso di ricezione ordine entro 5 giorni (i tempi di consegna si intendono dal ricevimento ordine)
(***) Tempo di consegna in caso di ricezione ordine oltre 5 giorni (i tempi di consegna si intendono dal ricevimento ordine)
(****) L'acquirente intende accettate le condizioni di vendita visibili sul sito web.
In attesa di Vostre gradite notizie, porgiamo distinti saluti.

Alessandro Cortopassi .0