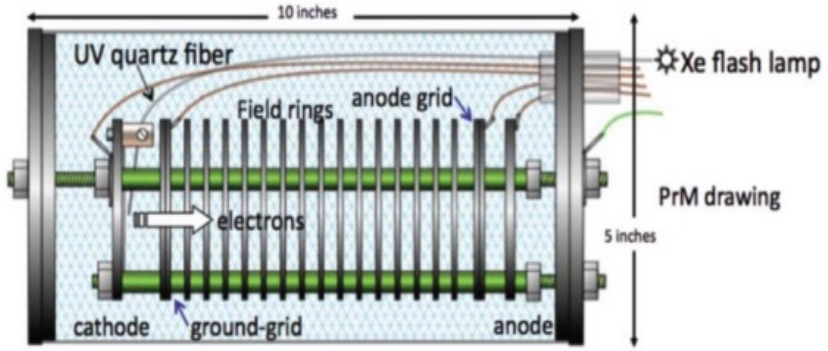
LAr purity monitor (PM)

- PMs are a double gridded TPC where an electron cloud is generated on the cathode by photoelectric effect from a pulsed UV light generated with a Xenon lamp routed to cathode by a fiber bundle.
- Both electrons leaving the cathode/ reaching the anode are measured at each pulse. The ratio of the charge and the drift time are used to measure e- attenuation

$Q_{ANODE}/Q_{CATHODE} = \exp(-t_{DRIFT}/\tau)$

- This device is widely used in almost all LAr-TPCs presently operated and it is also foreseen in future projects like DUNE.
- As an alternative we propose to use a Bi 207 radioactive source with a new better performing set-up



M. Adamowski et al., JINST 9, P07005 (2014).

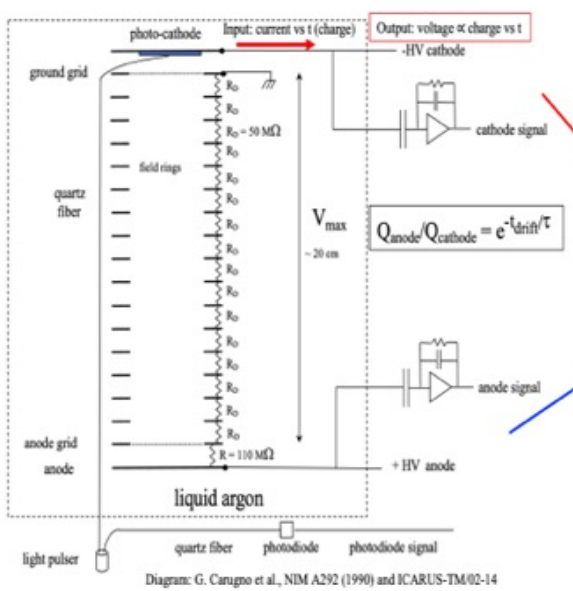
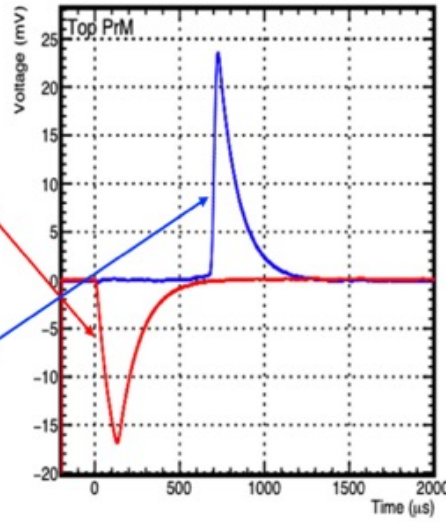


Diagram: G. Carugno et al., NIM A292 (1990) and ICARUS-TM/02-14

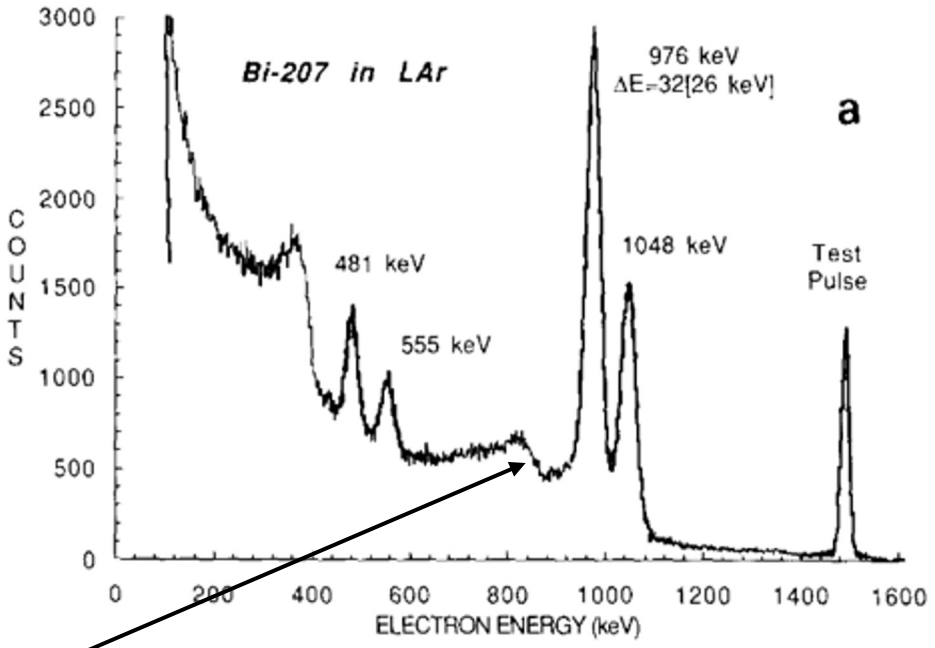


A new LAr purity monitor based on a Bi207 source

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

Decay Mode: EC, β^+		Half-Life: (11523 ± 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 Kα	Σ	74.2	58.19	24	[5]
X-ray Kβ	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 EC peak)



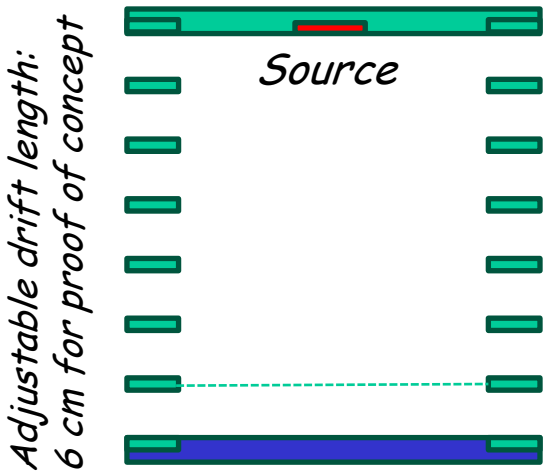
Pulse height spectrum of the Bismuth source in LAr, at E=10.9 kV/cm. The 976 keV electron peak is visible with a 32 keV (fwhm) total energy resolution.

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

A new LAr purity monitor based on a Bi207 source

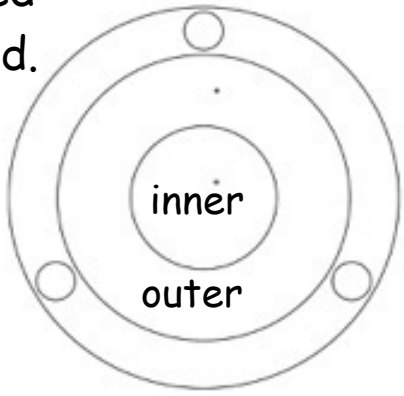
- The deposited e- energy from Bi207 can be measured with the present LAr-TPC cryogenic front-end elecronics with ~50 keV at E_{DRIFT} ~ 500 V/cm as used on most of LAr-TPCs.

- The source is integrated into the cathode of a small LArTPC with shape similar to old purity monitors and ~10 cm drift distance
- The anode is split into two concentric areas:
  - The inner one receives e-clouds from EC e- peak and from additional Compton e- due to γ also emitted by the source.
  - The outer one only receives the Compton e- with the same energy spectrum as those on the inner electrode
  - The outer energy spectrum is used to remove the Compton e- backg. from the inner anode to extrac a "clean" gaussian peak.



Anode: 2 concentric electrodes
Inner electrode diameter: 3cm
Outer electrode diameter: 6 cm

- Both anodes readout with cryogenic very low noise pre-amps directly mounted on the back of anodes: no need of decoupling capacitors as anode is at ground.
- No cathode readout (EC e- is known): only an accurate readout calibration of anode is needed, once for all. This feature allows to apply high voltage on the cathode and operate PM at the nominal E-field as in actual LArTPC.



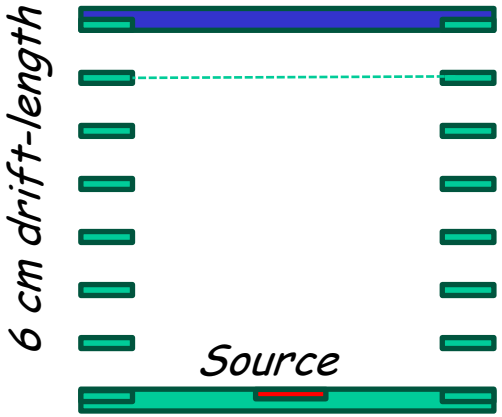
Several advantages of a Bi207 PM

- This proposed PM 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 energy of EC 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;
  - 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 interferring with the main LArTPC operation and also during LAr filling;
  - It can be operated at same E_{DRIFT} as the main LArTPC for a direct e- lifetime meas.
  - Different PM length can be assembled to measure the LAr purity in a large range of values, further reducing the systematics.

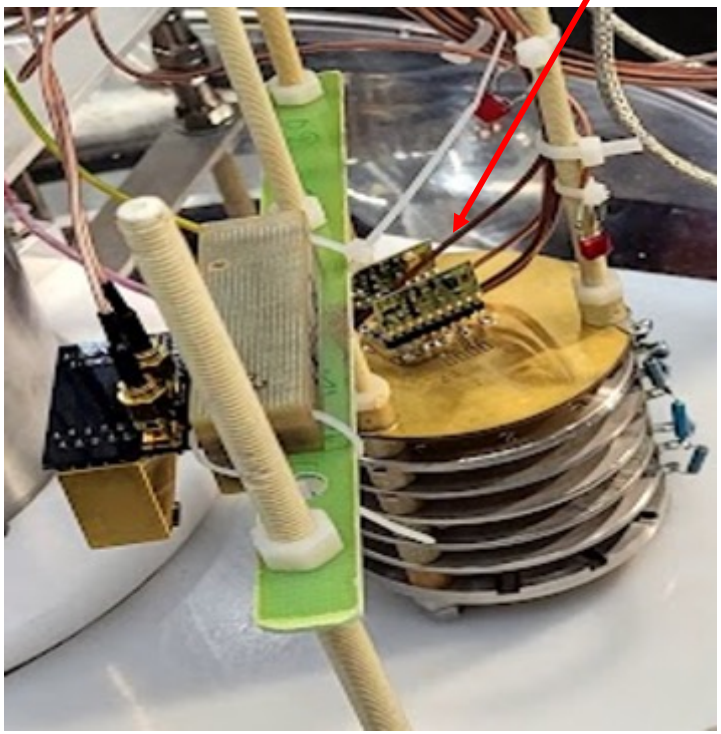
LAr purity monitor prototypes based on a Bi207 source

- PM prototype has already been produced (INFN-PD, CERN) and successfully tested at CERN in the Neutrino Platform R&D laboratory in B 182 with a 3 kBq Bi207 source.
- The drift distance in the test stand is only 6 cm and the PM has been operated at 500 to 900 V/cm (25 to 31 μs drift time). With the accuracy on the EC mean energy, electron lifetimes in excess of 1 ms are at reach.

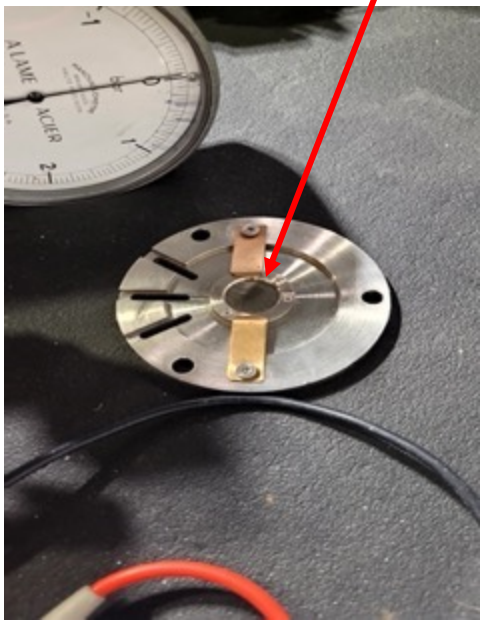
Schematic of the LAr PM prototype



J-fet preamplifiers (2 channels) directly mounted on the back of the anode plate



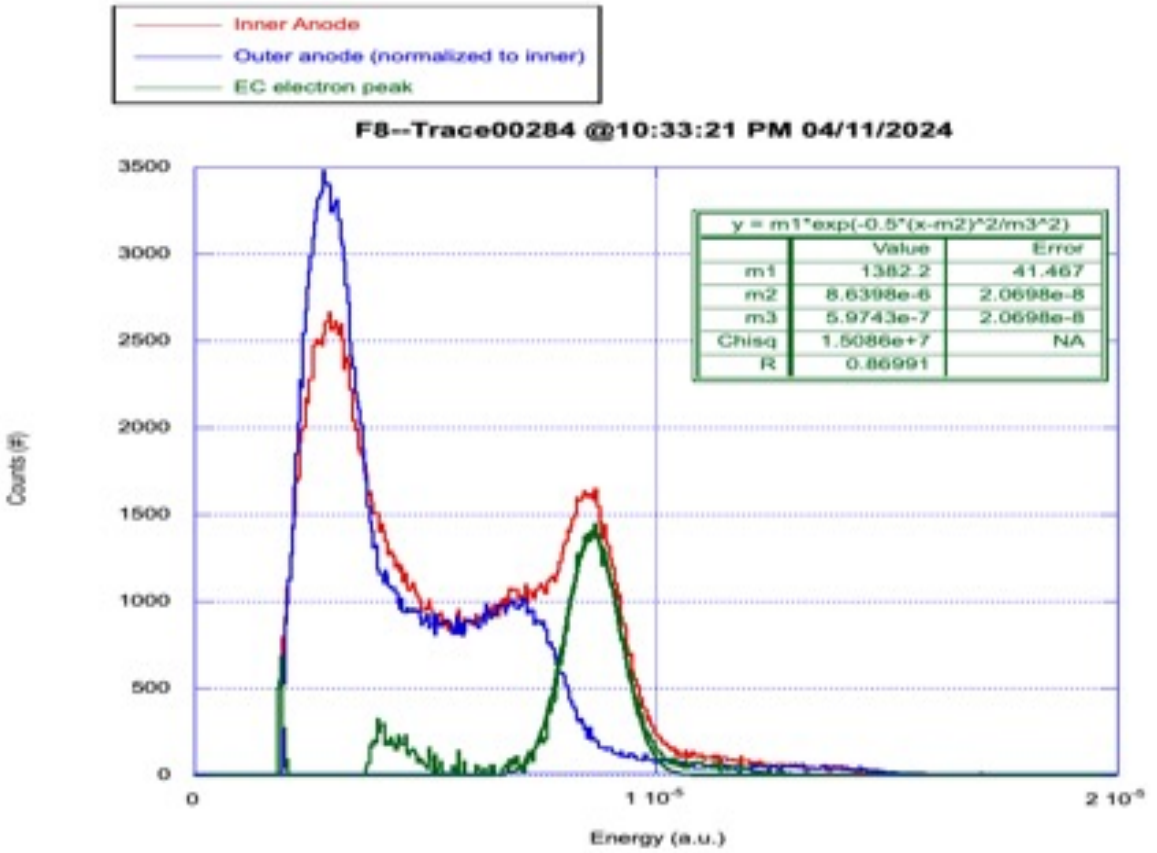
Cathode plate with Bi207 source

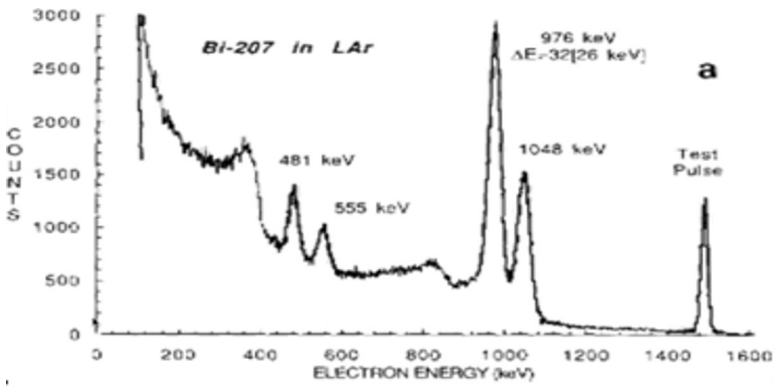


LAr purity monitor prototypes based on a Bi207 source

- It has been demonstrated the the EC peak width of 50 keV is actually achieved, resulting in a determination of the EC peak mean energy of ~0.1% in tens of minutes (the source in the test has an activity of 3 kBq, 150 Hz for the EC electron peak).

- We are preparing in Padova using the test facility of ICARUS at LNL lab/CERN, a new advanced prototype to be tested and inserted asap in the Vertical Drift.





PM: cost and timescale

- We plan to continue our tests finalized to first PM production in 2025.
- The foreseen cost for 10 PMs (not included the source procurement) for 1 cryostat is < 90 K euro to be split in 2 years

Item description	cost/pc(€)	Quantity	Total cost (€)	Year
1 Prototype Purity Monitor with 2 chambers 6 cm and 12 cm	10 k	1	Mostly covered with some ICARUS/DUNE existing components	2024
10 Purity Monitors with 2 chamber 6 cm and 12 cm	8.5 k	10	85 k	2025-2026
1 Radioactive source BI207 *	3 k	1	3.5 k	2025-2026

* to test the PM production

Cost of radioactive sources not included: to be covered by DUNE Collaborators

TOTAL REQUESTS FOR 2025 (sub-judice to the test progresses)

- 40 k€ for device construction (first 4 PMs)
- 15 k€ "consumo" (Lar etc.)
- 15 k€ travel to CERN (extended tests with sources...)

Percentuali

SITUAZIONE 2024:

SEDE	NOMINATIVO	TIPO	CONTRATTO	QUALIFICA	RICERCATORI	TECNOLOGI	NOTE
PD	Baibussinov Bagdat	DIP	Ricercatore	Ricercatore	60		
	Cicerchia Magda	ASSOC	Incarico di Ricerca scientif...	Ricercatore A Temp...	80		
	Meng Guang	DIP	Tecnologo	Tecnologo		10	
	Stanco Luca	DIP	Ricercatore	Dirigente di Ricerca	30		scadenza contratto 2024-04-30
	Varanini Filippo	DIP	Ricercatore	Ricercatore	20		
					1.9 fte 4 pers.	0.1 fte 1 pers.	
PD (5 PERSONE - 2 FTE)					2.00 fte / 5 pers. (media 0.40)		

Per il 2025 spostamento da ICARUS (stabilmente in presa dati) a DUNE

- Varanini 0.2 -> 0.3
- Meng 0.1 -> 0.2
- Guglielmi 0 -> 0.2

Totale: 2 -> 2.4 FTE