$^{23}Na(p,\alpha)^{20}Ne$

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General meeting - 02/07/2024

ASTROPHYSICAL MOTIVATION

HOW DID GLOBULAR CLUSTERS (GC) FORMED?
GCs host multiple stellar populations showing variation in light elements abundances. Second generation stars are:

- Depleted in C and O
- Enriched in He, N and Na

CNO processing

- Mostly constant [Fe/H] → No contribution from SN ejecta

Many different formation scenarios proposed (fast-rotating massive stars, a single supermassive stars, **Asymptotic Giant Branch Stars**…)

First generation stars with $M \geq 4M_{\odot}$ during AGB phase will undergo **H-shell burning** at high temperatures

Neon-Sodium + **Hot CNO** cycles will be onset at the basis of the convective envelope
(Hot Bottom Burning)

3rd dredge-up

Processed materials appear on the stellar surface and are ejected into the interstellar medium (ISM)

Second generation stars are then born out of the polluted ISM

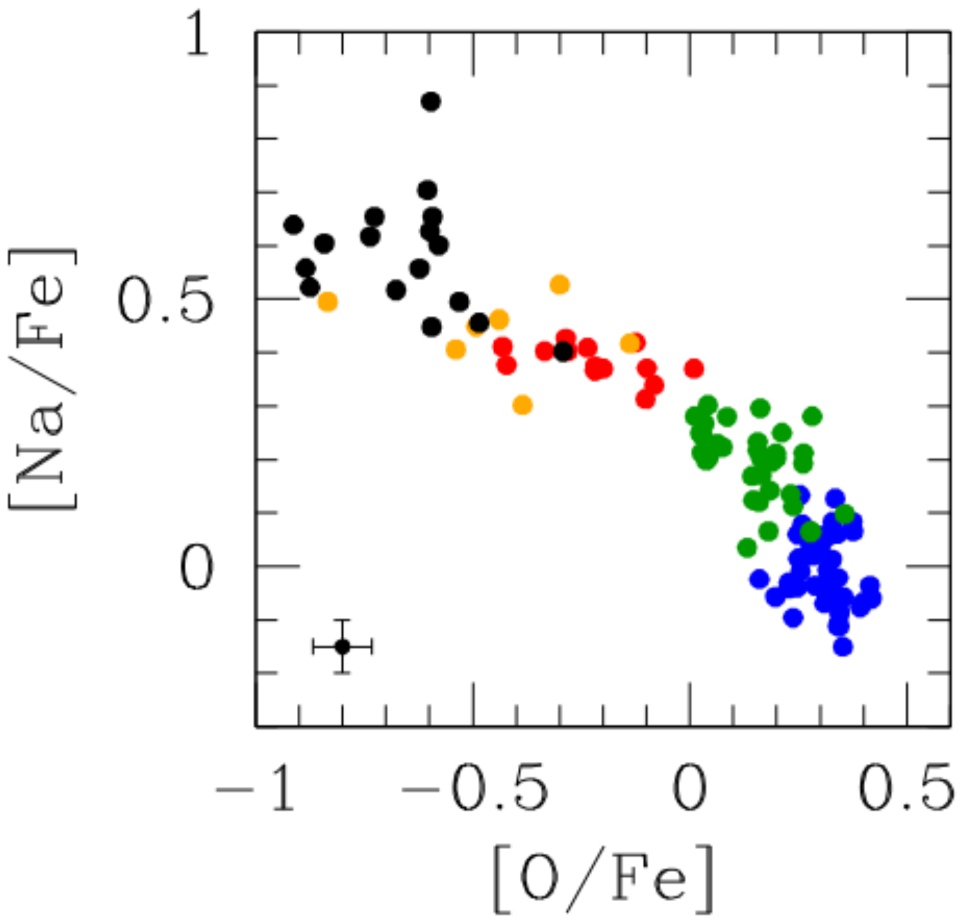
ASTROPHYSICAL MOTIVATION

MAIN PROBLEM WITH THE AGB SCENARIO:

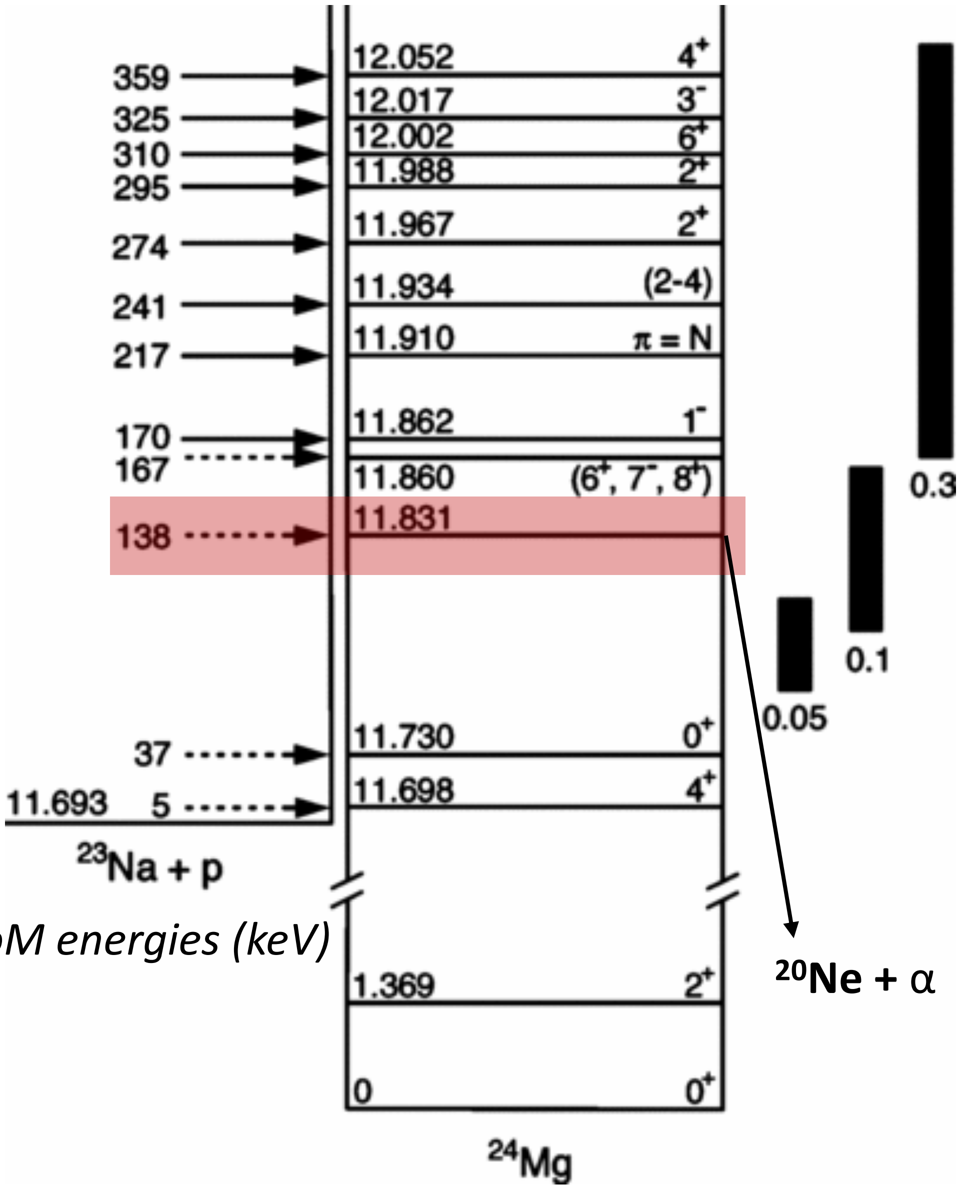
All AGB models predicts O and Na to be **both destroyed** by nuclear processing, while observations of GC's RGB stars show instead an **anti-correlation between O and Na**

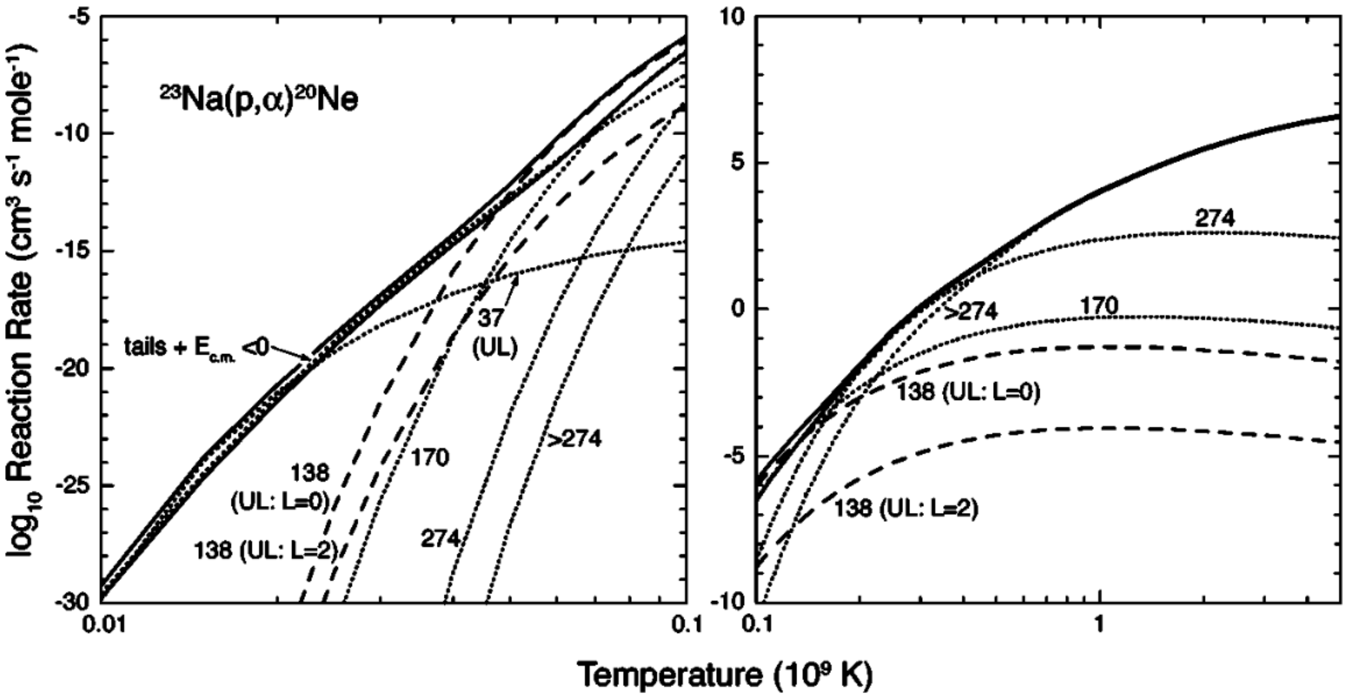
POSSIBLE SOLUTION:

A reduction of a factor of 3-5 of the $^{23}Na(p,\alpha)^{20}Ne$ reaction rate, that would increase the temperature where Na is destroyed faster than O, allowing for less massive (colder) AGBs to somehow compensate for the Na destruction by the higher mass AGB models. **The uncertainty on the rate mainly arises from the contribution from an unobserved resonance in the relevant energy range.**



THE REACTION



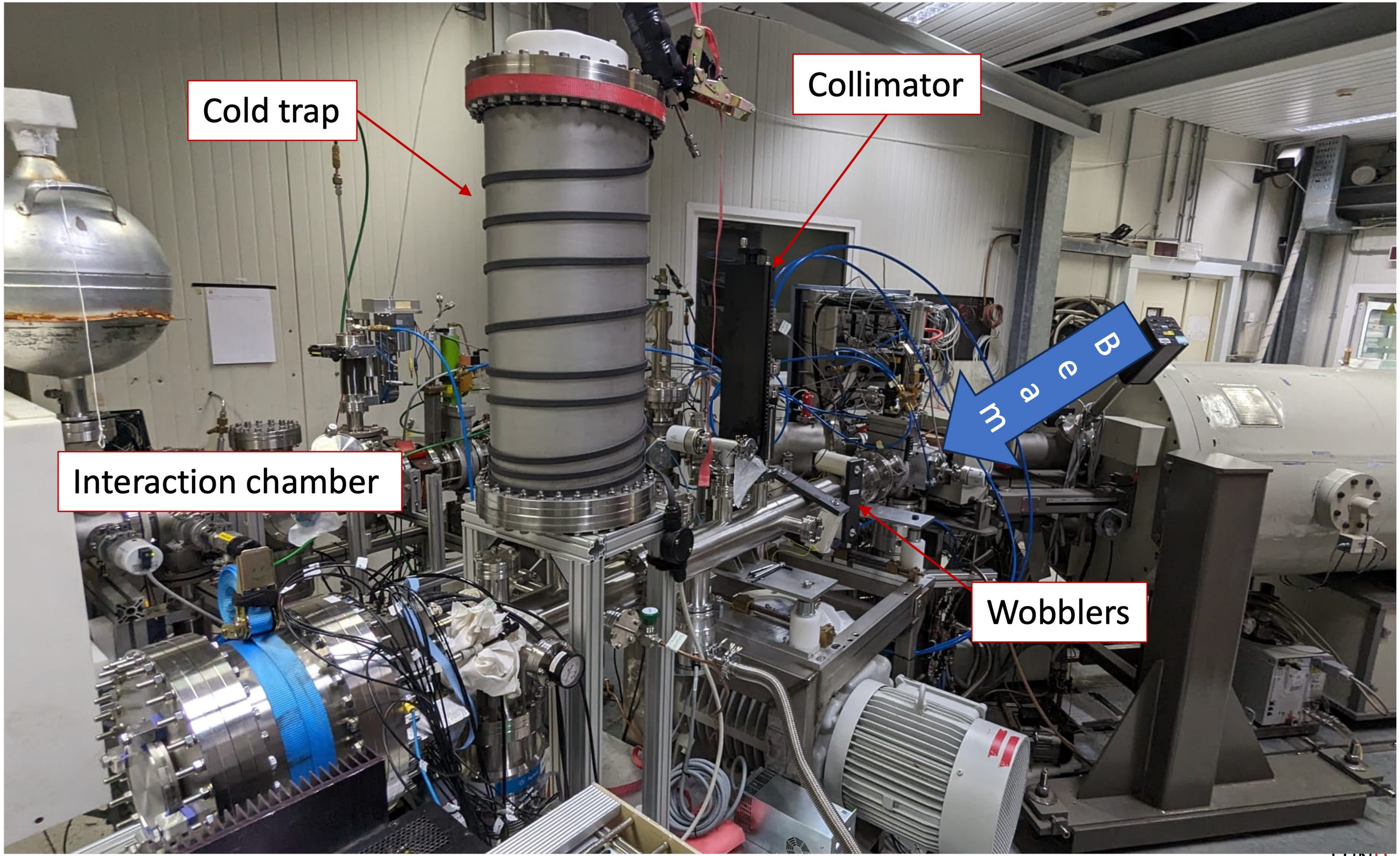


Only **tentative upper limits** to the E_{CM} = 138 keV resonance strength have been placed, depending on the value of the **unknown proton momentum transfer l_p.**

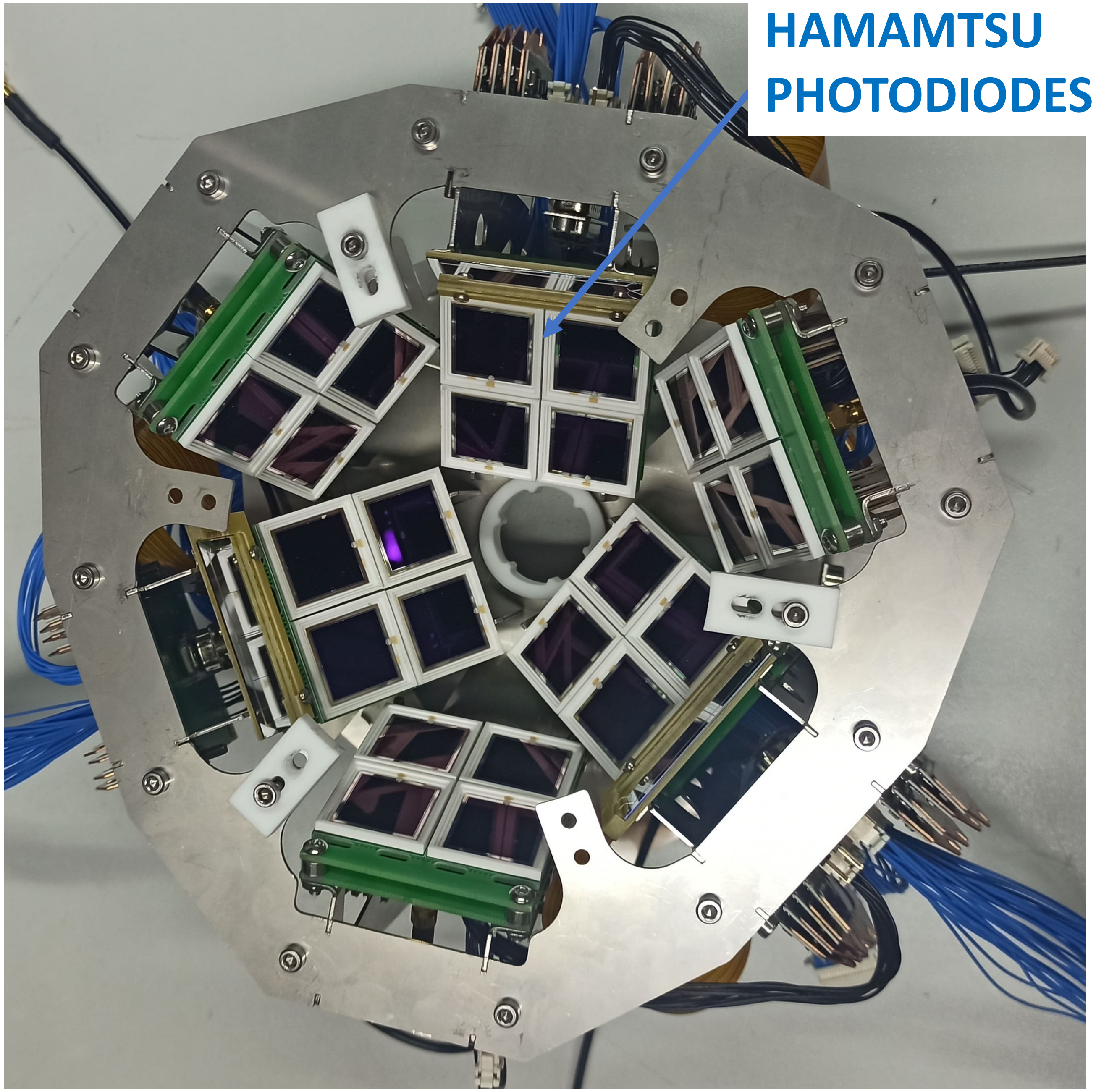
E_r [keV]	J^π	$\omega\gamma$ [eV]
37	0^+	$< 3.3 \times 10^{-20}$
138	? (l_p=0)	$< 1.6 \times 10^{-6}$
	? (l_p=1)	$< 7.5 \times 10^{-8}$
	? (l_p=2)	$< 2.8 \times 10^{-9}$
	? (l_p=3)	$< 5.4 \times 10^{-11}$
167	$(6,7,8)^+$	? (negligible)
170	1^-	$(23 \pm 5) \times 10^{-3}$

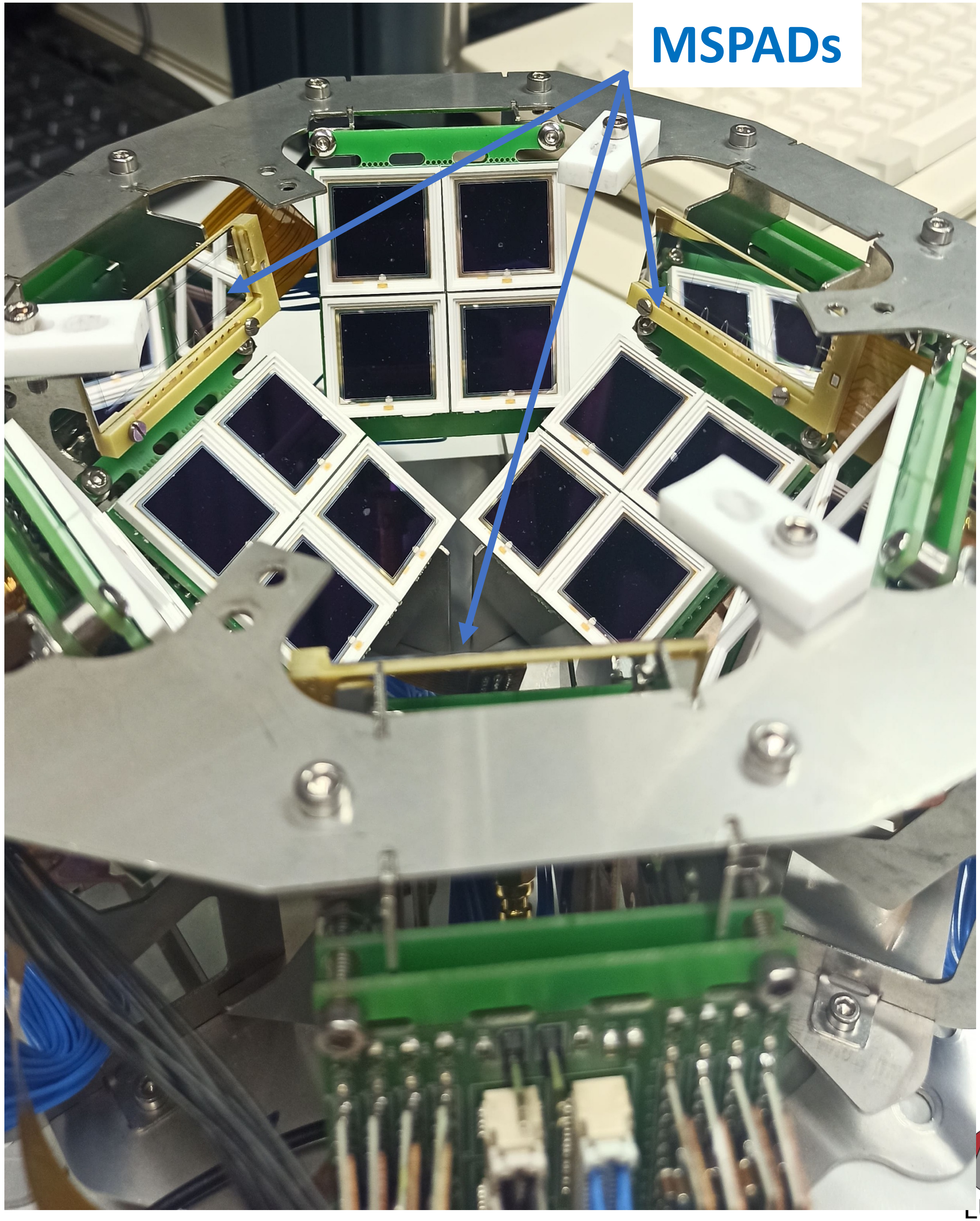
CHARGED-PARTICLES DETECTION AT LUNA400

A new beamline dedicated to the detection of charged-particles has been installed in place of the gas target beamline.

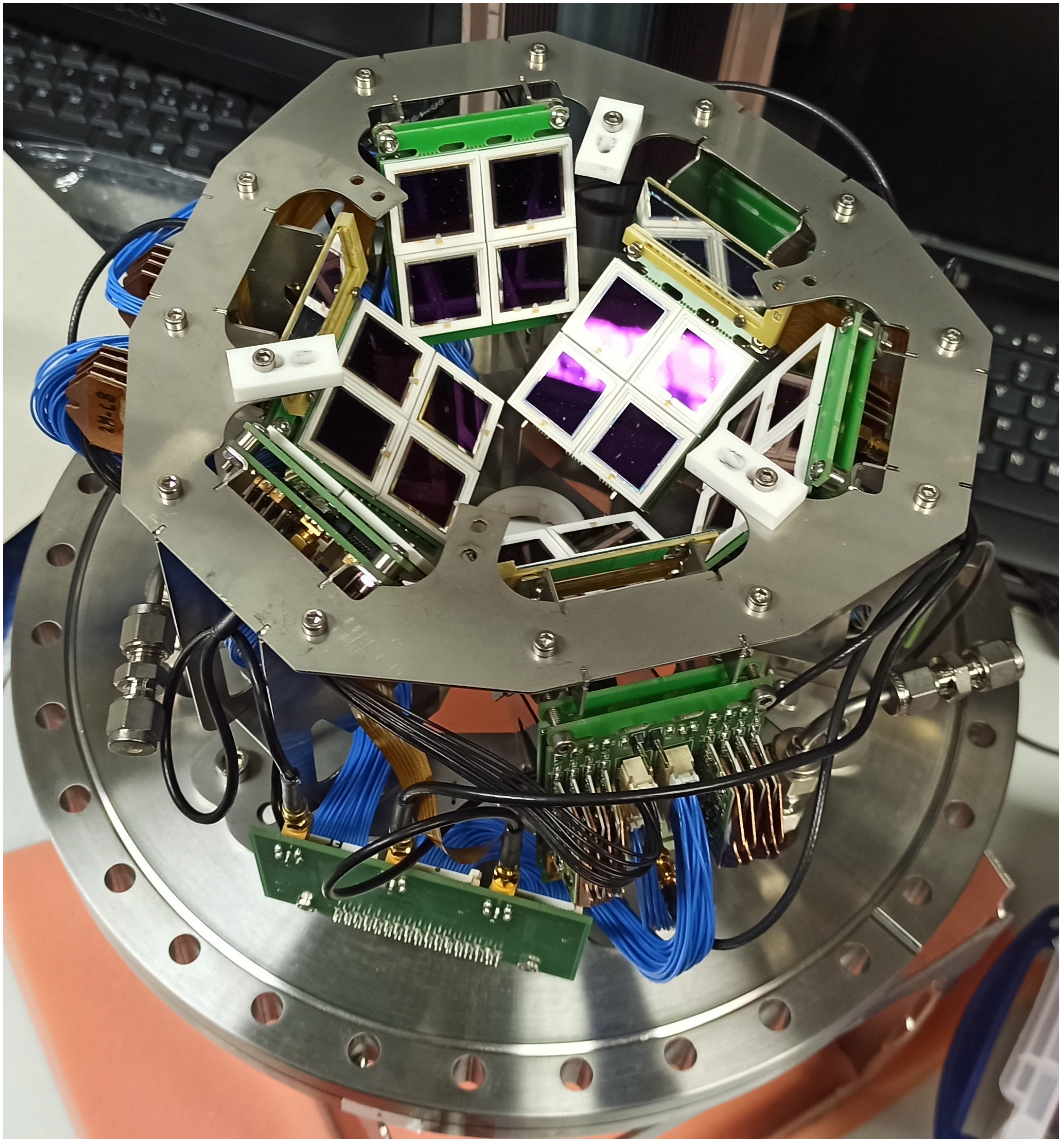


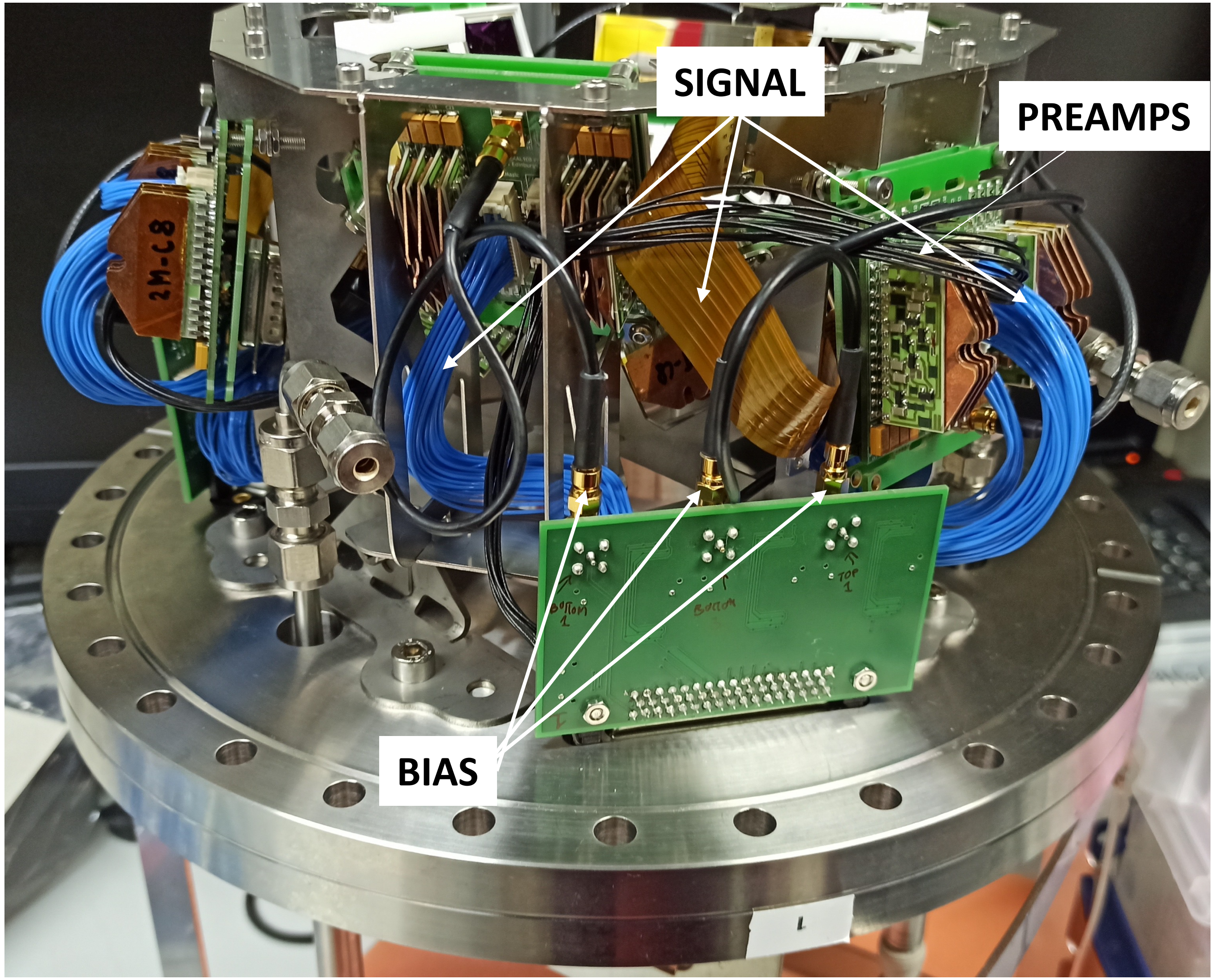
DETECTORS ARRAY



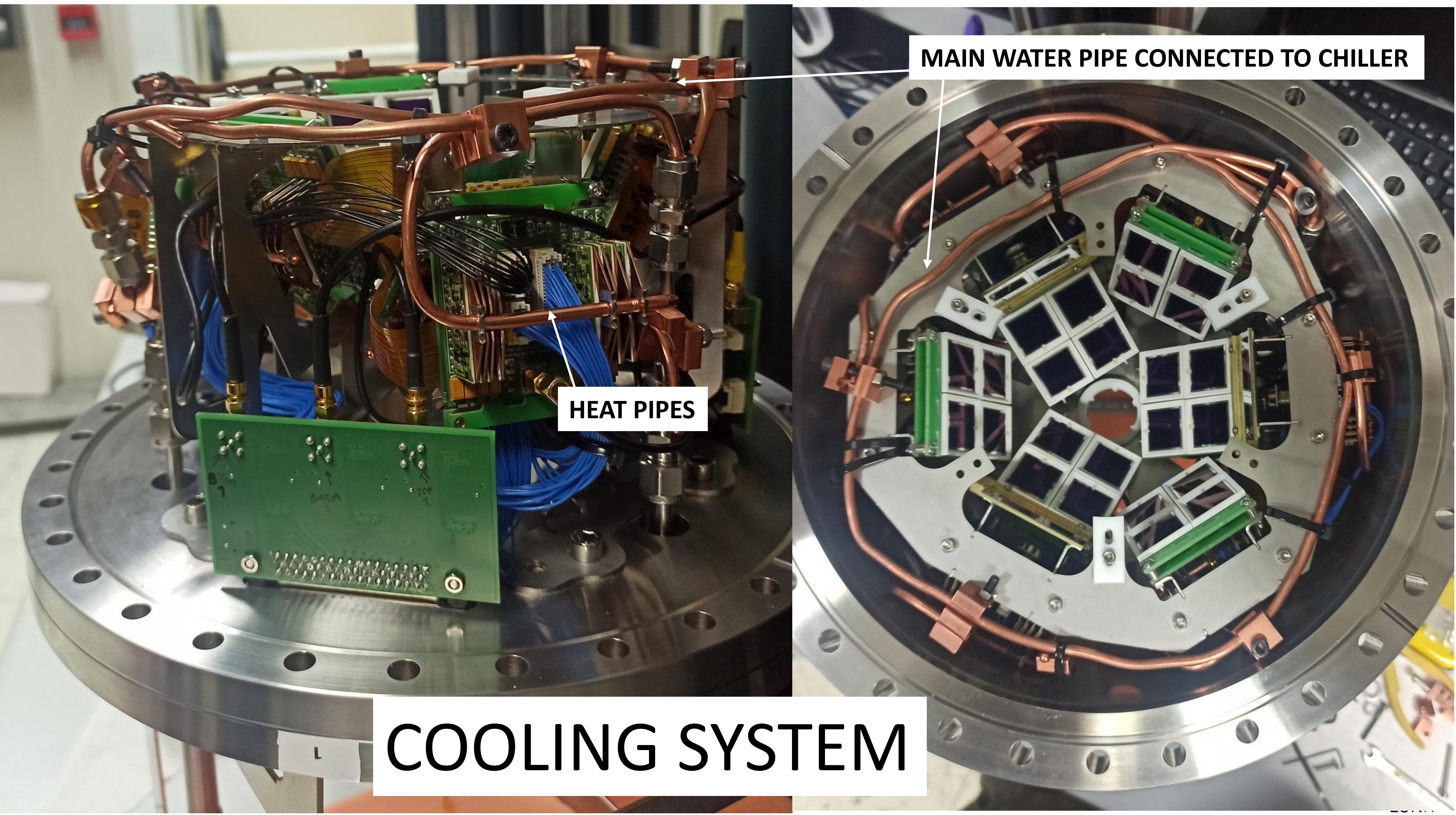


ARRAY MOUNTED ON THE CHAMBER'S UPSTREAM FLANGE



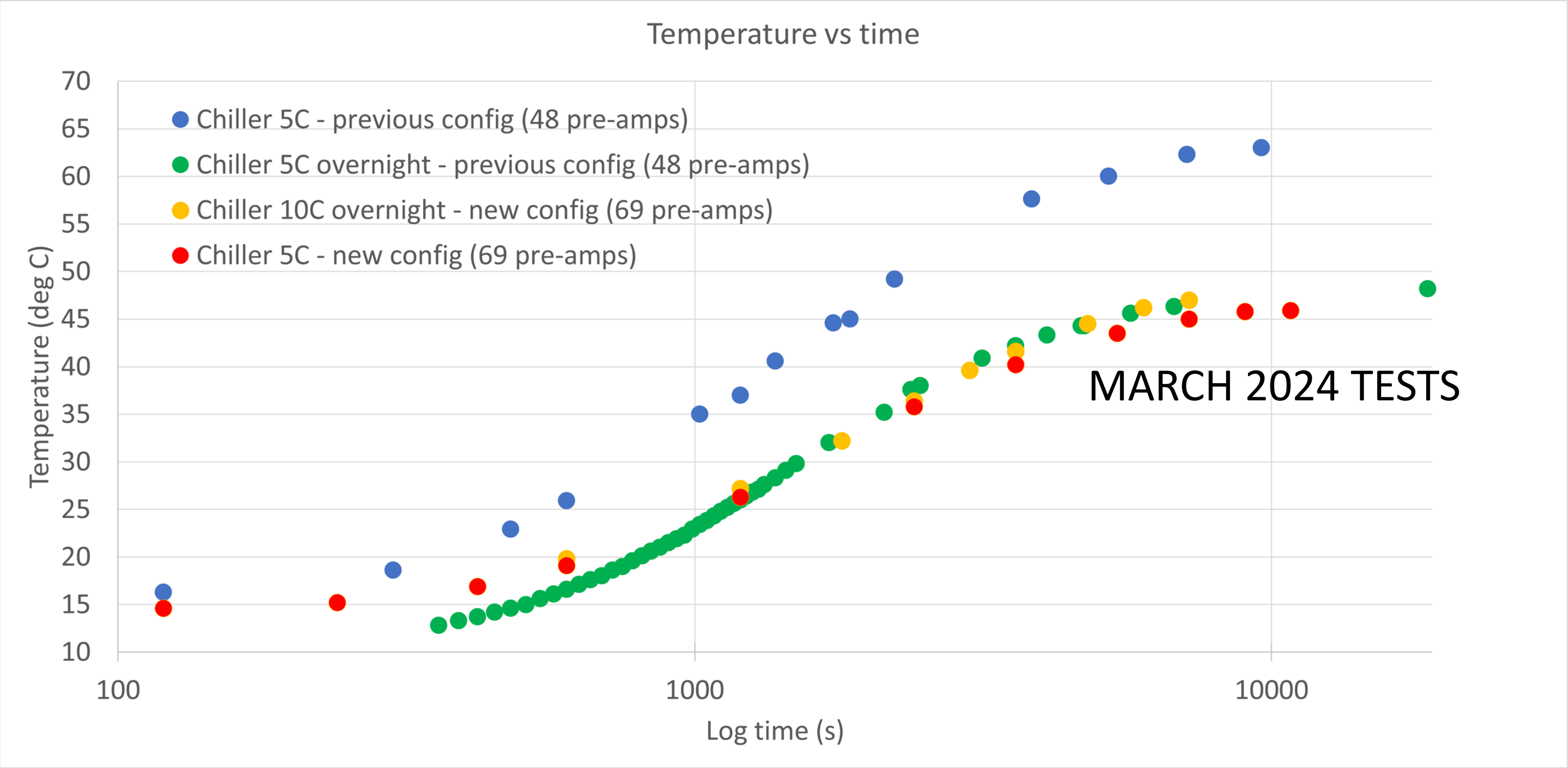


COOLING SYSTEM

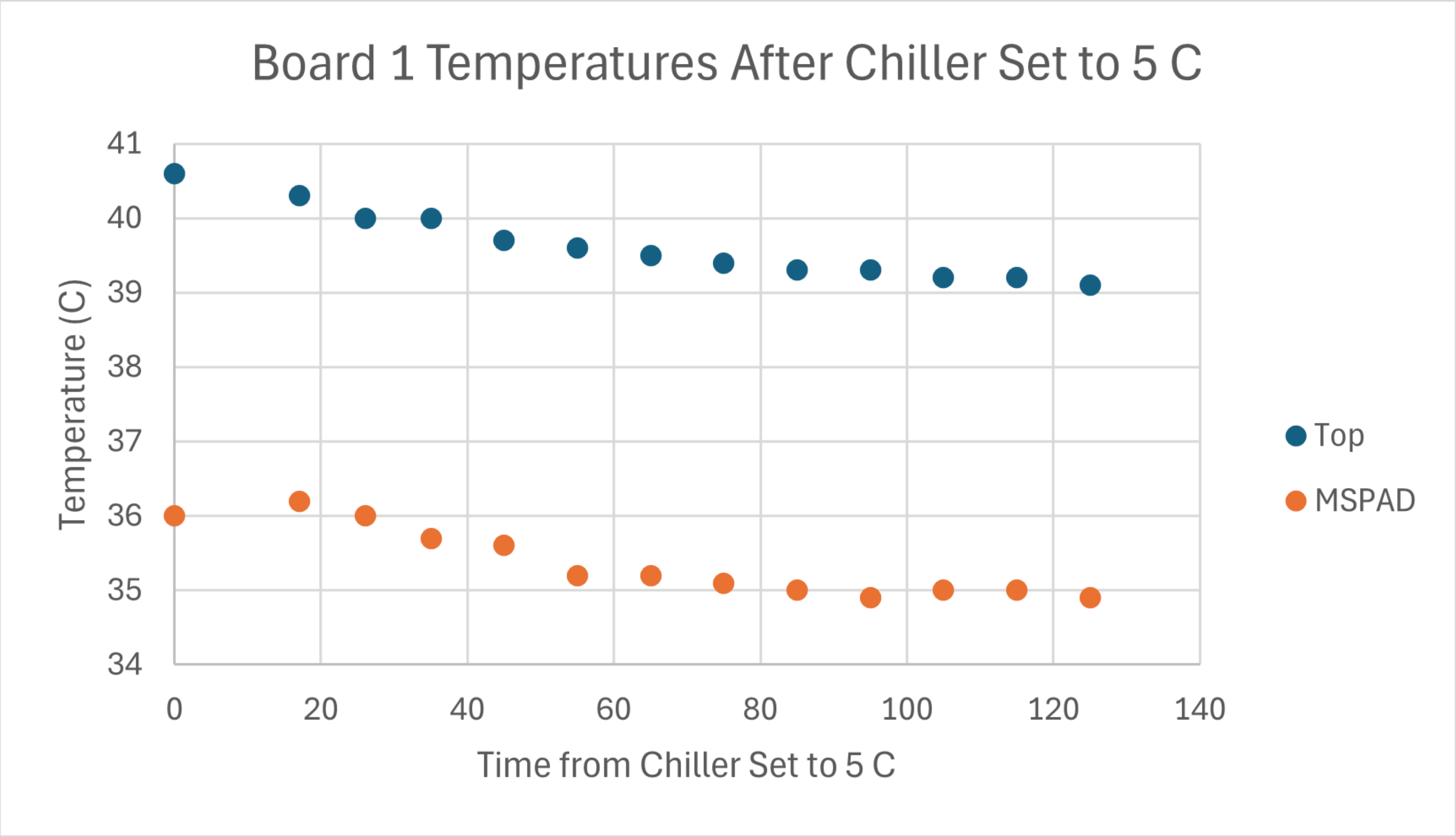


COOLING SYSTEM

Due to the powered preamplifiers' being directly placed under vacuum, **the detectors can heat up to > 60°C**, significantly degrading the resolution of the acquired spectra. The first cooling system tested (blue and green points below), tested with 48 preamps running, did not perform as well as expected. The one shown in the previous slide is the improved version, tested with 69 preamps running (yellow and red points below).



PERFORMANCE OF COOLING SYSTEM



Best performance with the new configuration, cold trap cold and the chiller running at 5° C.
During different tests, we found that the diodes' average temperature equilibrates at ca. 42°C, the MSPAD's one at ca. 38°C.

Quick test in May with chiller set to T=5°C instead of 10°C (to which it was initially set to avoid high water condensation on the chiller's pipes).

FIRST DATA ACQUIRED

We collected data with the new detection array in order to :

- Optimize **resolution**
- **Calibrate** the detectors with ^{241}Am + pulser walkthrough
- Acquire **waveforms** and try to use them to **clear the noise** from the spectra and improve the resolution.
- Three of the detectors are NTDs, which should be optimized for PSD. Attempt to implement it for Hamamatsu diodes.

/projects/23Nax5/	Waves	Real time	Diode side	Subject
run1	no	00:13:59	B-front (board 3 strange mix)	Pulser
run2	no	00:06:30	B-front (board 3 strange mix)	Pulser
run3	no	0:08:39	A-back (board 3 strange mix)	Pulser
run4	no	00:04:31	A-back (board 3 strange mix)	Pulser
run5				
run6	no	00:01:37	pn, B, front	Pulser
run7	no	00:02:32	pn, B, front	Pulser
run8	no	00:04:07	nn, A, back	Pulser
run9	no	00:04:48	nn, A, back	Pulser
run10	no	00:05:08	nn, A, back	Pulser
run11	no	00:04:05	nn, A, back	Pulser
run12	no	00:03:51	pn, B, front	Pulser
run13	no	00:03:56	pn, B, front	Pulser
run14	no	00:15:51	pn, B, front	Pulser walkthrough
run15	no	00:12:36	pn, B, front	Pulser walkthrough
run16				
run17	no	15:21:35	pn, B, front	241Am + pulser
run18	yes	02:30:00	pn, B, front	241Am
run19	no	00:10:47	pn, B, front	Pulser walkthrough
run20	no	00:03:14	pn, B, front	Pulser walkthrough
run21	no	00:06:54	pn, B, front	Pulser walkthrough
run22	no	00:05:45	pn, B, front	Pulser walkthrough
run23	yes	01:50:22	nn, A, back	241Am
run24	no	15:39:17	nn, A, back	241Am
run25	no	00:12:20	nn, A, back	Pulser walkthrough
run26	yes	01:40:00	nn, A, back	241Am
run27	yes		INCORRECT POLARITIES	241Am
run28	yes	01:10:01	pn-nn	241Am
run29	yes	01:10:00	pn-nn	241Am

RESOLUTION

- HAMAMATSU diodes pulser FWHM ca. **28-40 keV,** excluding some bad channels with **FWHM > 50 keV.**

- Two MSPADs out of three were biased during March 2024 tests. They mostly showed weird behaviour (multiple pulser peaks, noise throughout the spectrum, pulser FWHM ca. **200** keV …). For the few channels working properly, resolution was ca. **26-35 keV pulser FWHM.**
- Tests in Edinburgh did not show issues with the detectors themselves→ we will check their performance at LUNA during the next weeks.

Compass trapezoid's filters parameters have been mostly optimized and an HV filter has been installed on the bias module. Further specific parameters' adjustments for individual channels may further improve the resolution.

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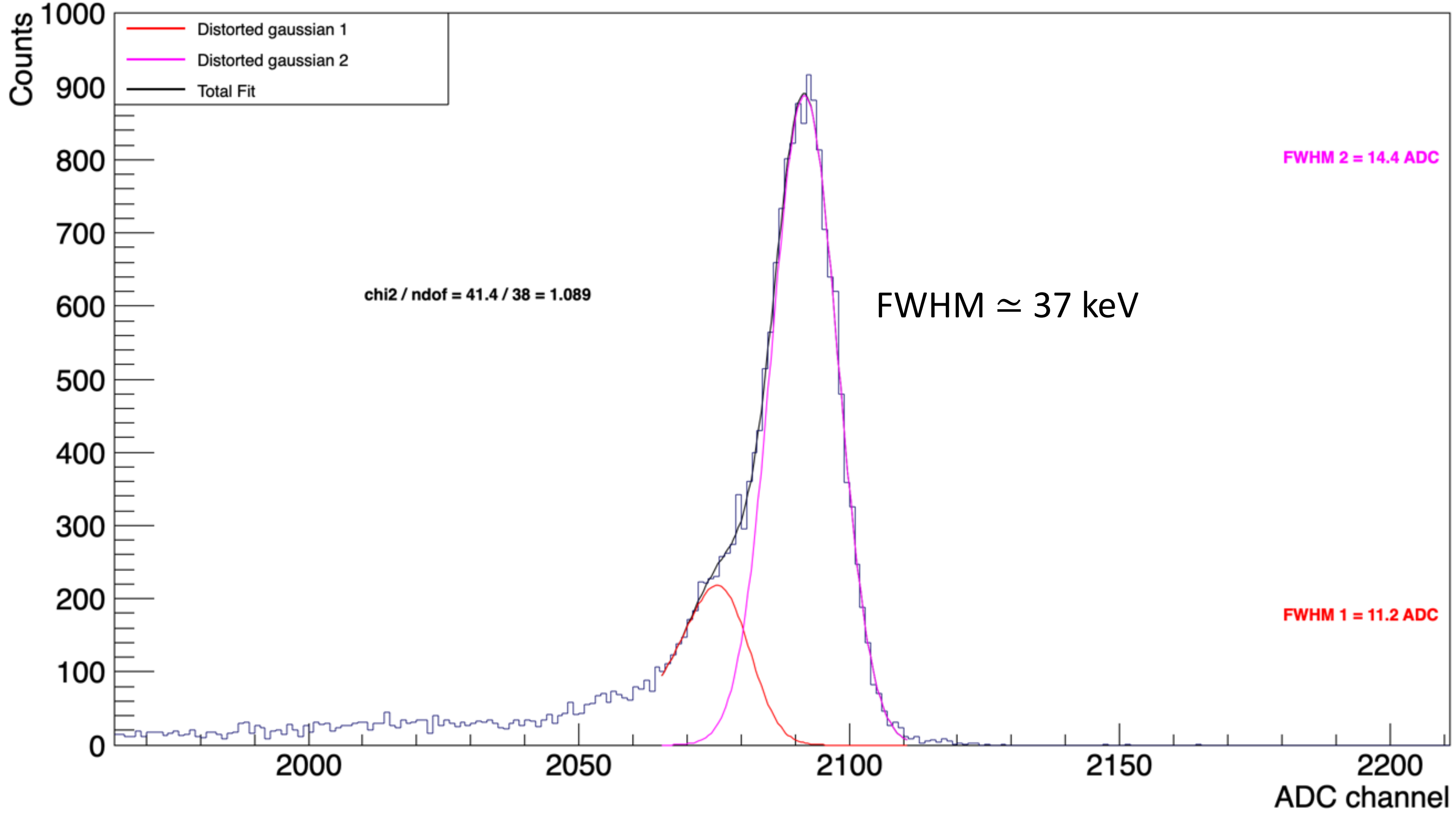
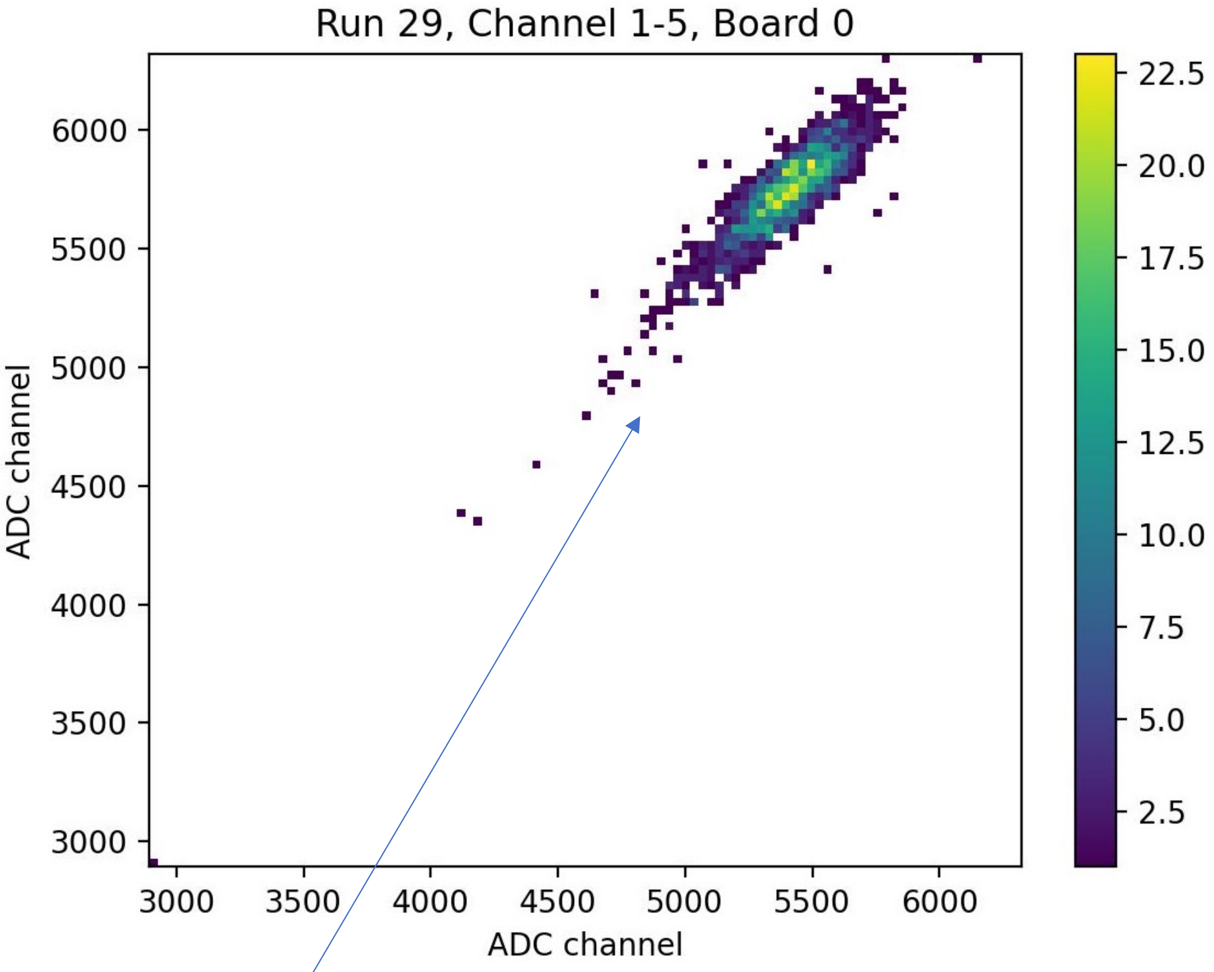
^{241}Am

From long runs, alpha FWHM for **pn side** diodes is generally **ca. 5-10 keV larger than the pulser FWHM**, also for channels with poorer resolution**. The nn side** appears overall worse, no pulser was however acquired in the same run for comparison.

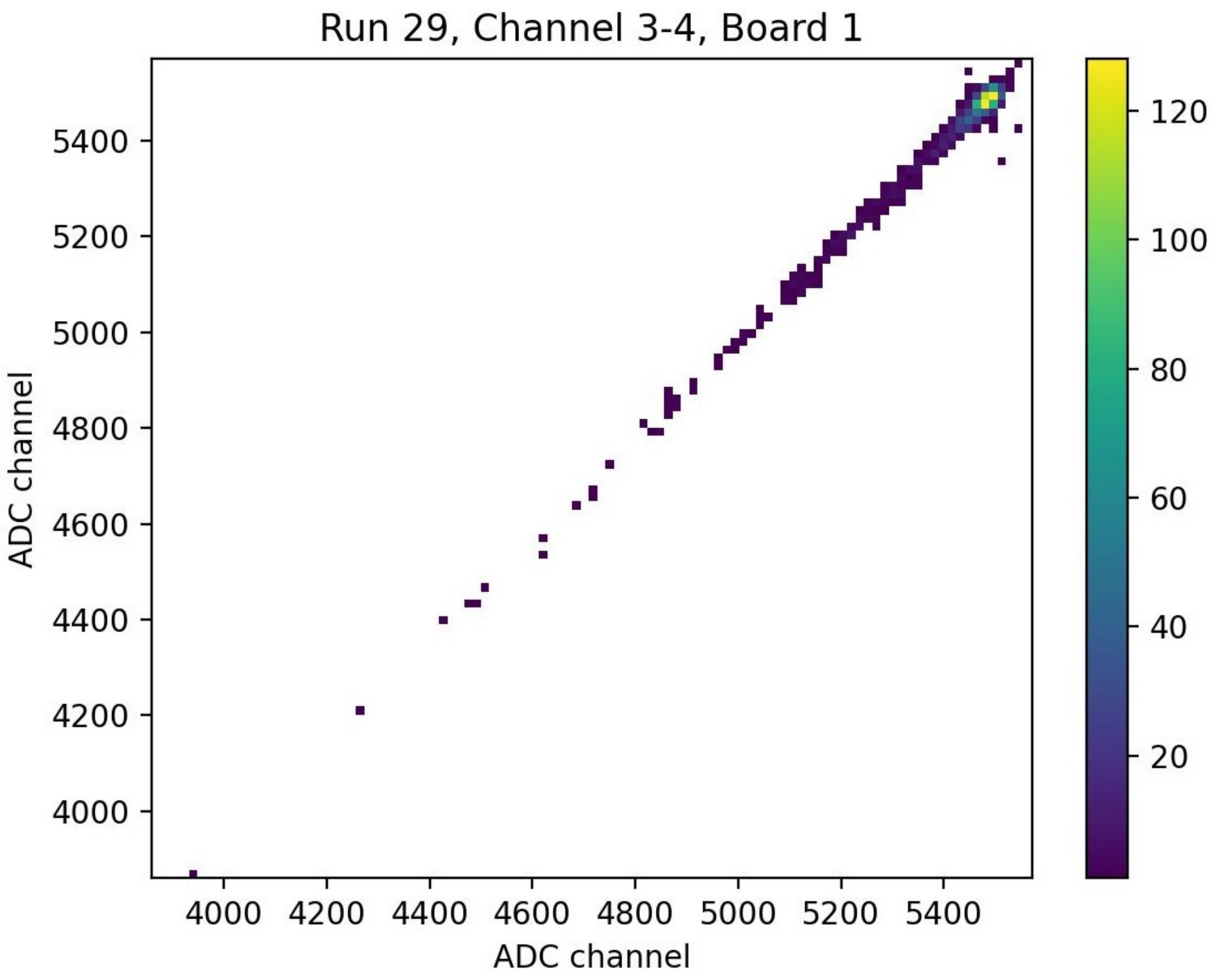
Example of a diode **pn side ^{241}Am** spectrum



PN vs NN SIDE: COINCIDENT EVENTS



Digitizer V1730 presents worse resolution on all the acquired spectra.



All these signals are true signals

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TARGETS

We have tested two types of targets: $Na_xNb_yO_z$ sputtered targets from Legnaro (unknown stoichiometry) and Na_2WO_4 evaporated targets from Atomki.

Sputtered targets seemed to be more resistant to humidity. Evaporated targets exhibit humidity effects in their resonance scans.
We may use the former for data taking and the latter for normalization exploiting the known stoichiometry.

We already tested both types of targets with the E_p=309 keV resonance in the (p, ɣ) channel during 2023.
Further tests in January 2024 showed behaviour consistent with previous tests and proved stability under beam bombardment for sputtered targets..

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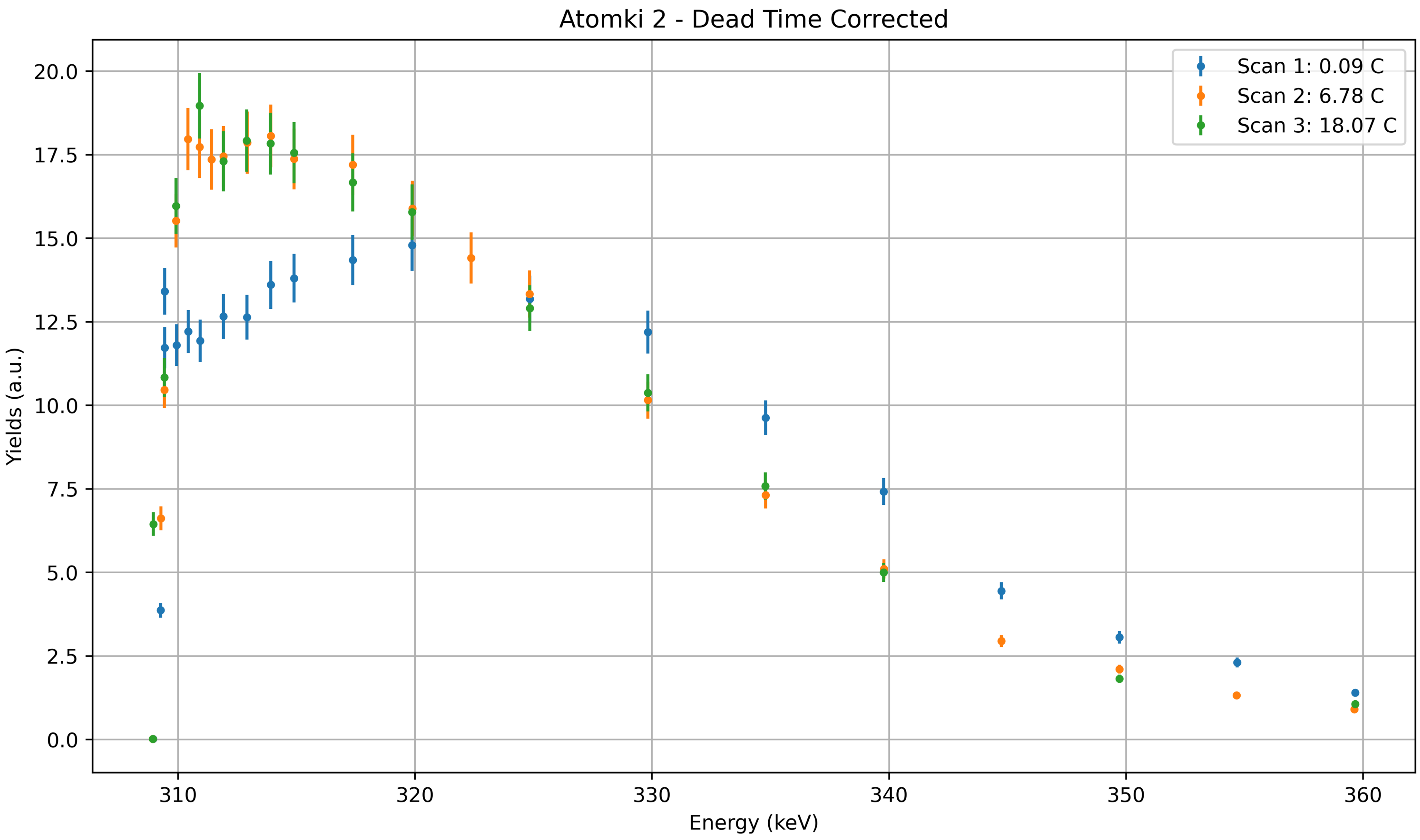
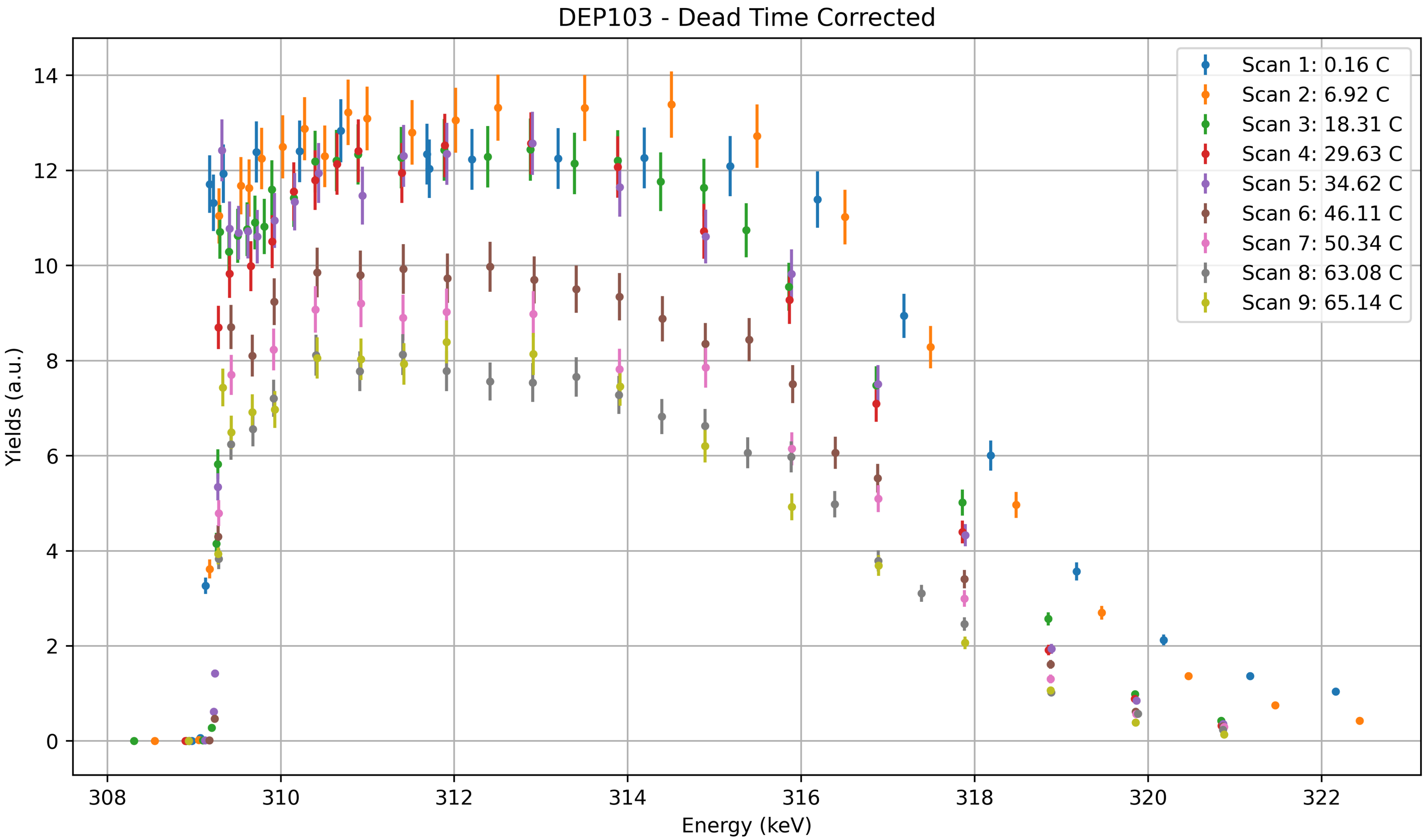
TARGETS – JANUARY 2024 TESTS



For ATOMKI evaporated targets, **U + triangular profile shape** as before (humidity penetrating deeper in the target and evaporating from the surface during irradiation).
Still overall good performance even after months stored in air.

TARGETS – JANUARY 2024 TESTS



No degradation up to ca. 35 C

LNL sputtered target with 10’ deposition

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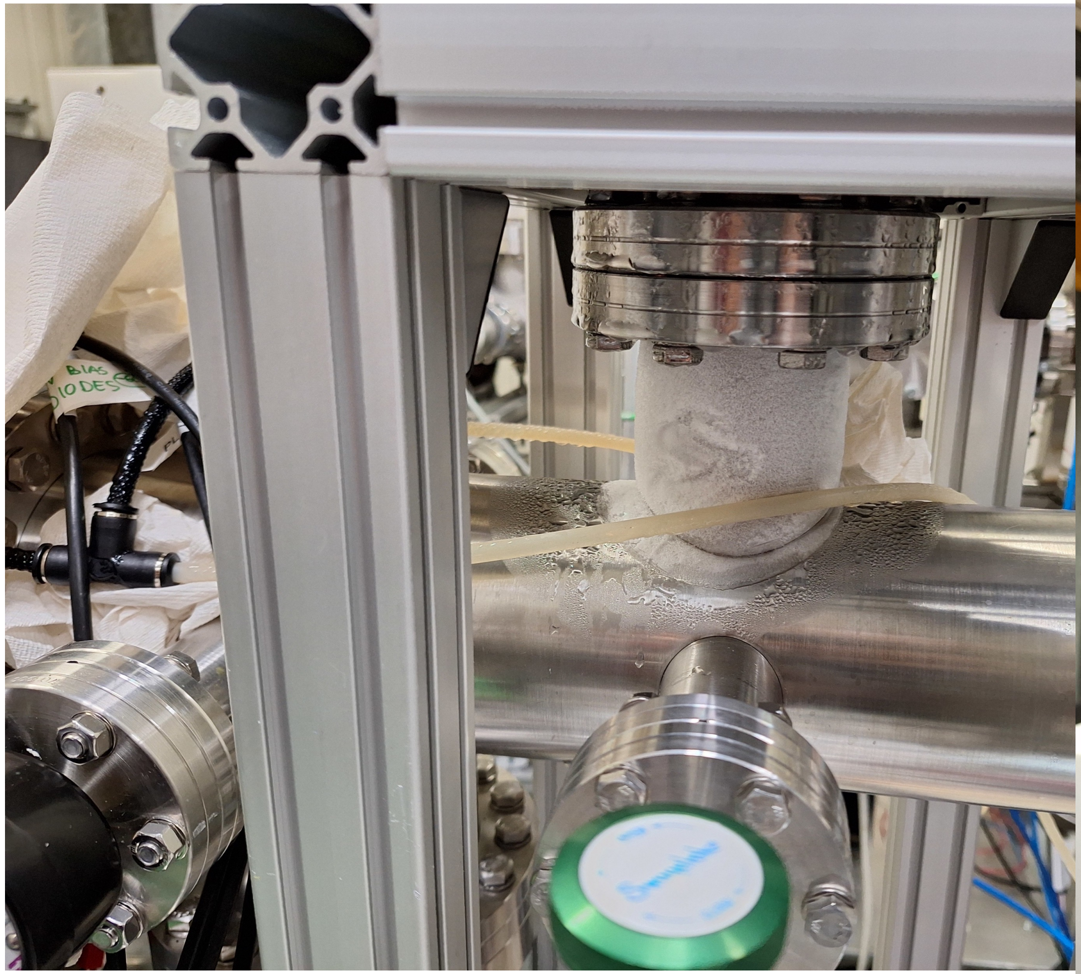
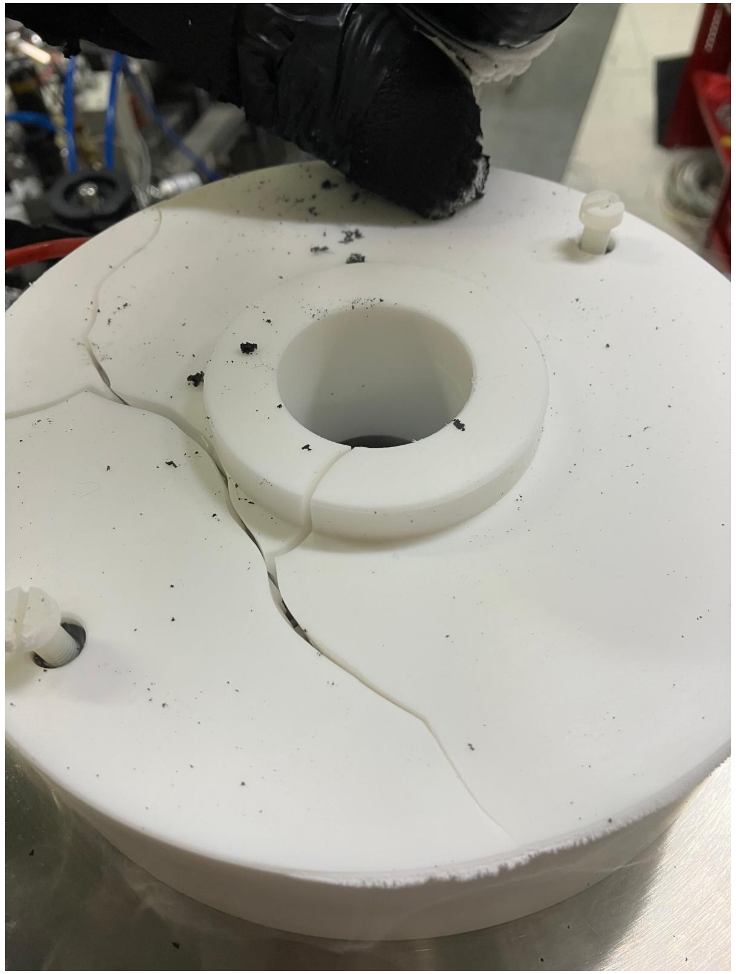
INSULATION PROBLEM WITH COLD TRAP

Pressure rises from 10^{-7} mbar to 3 mbar when the cold trap is full. Vacuum recovers nicely when the cold trap is warmed up again.

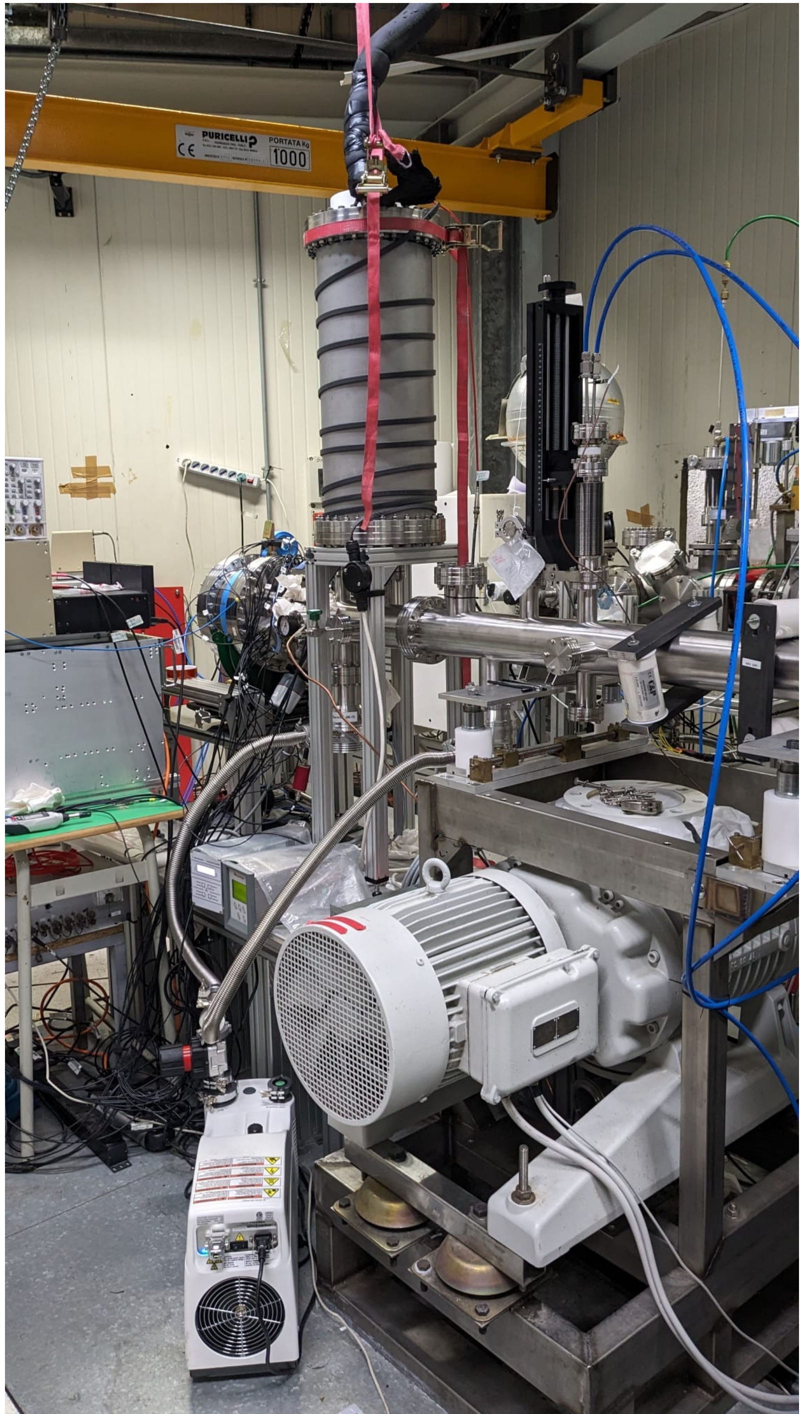




TO DO LIST

- Fixing the insulation problem with the cold trap. If the problem is solved in 1 or 2 weeks, we should be on track. If not, we may need more measurements time in 2025.
- Installing the wobblers' supports.
- **First beam on oxygen targets→ ^{18}O (p, α)**

THANK YOU FOR YOUR ATTENTION!



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