

LSC



Copper electroforming at Canfranc Underground Laboratory

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Low Radioactivity Techniques LRT2024



- Copper electroforming
- Top & Bottom lids – CCD Box (DAMIC-M)
- Summary & Future plans



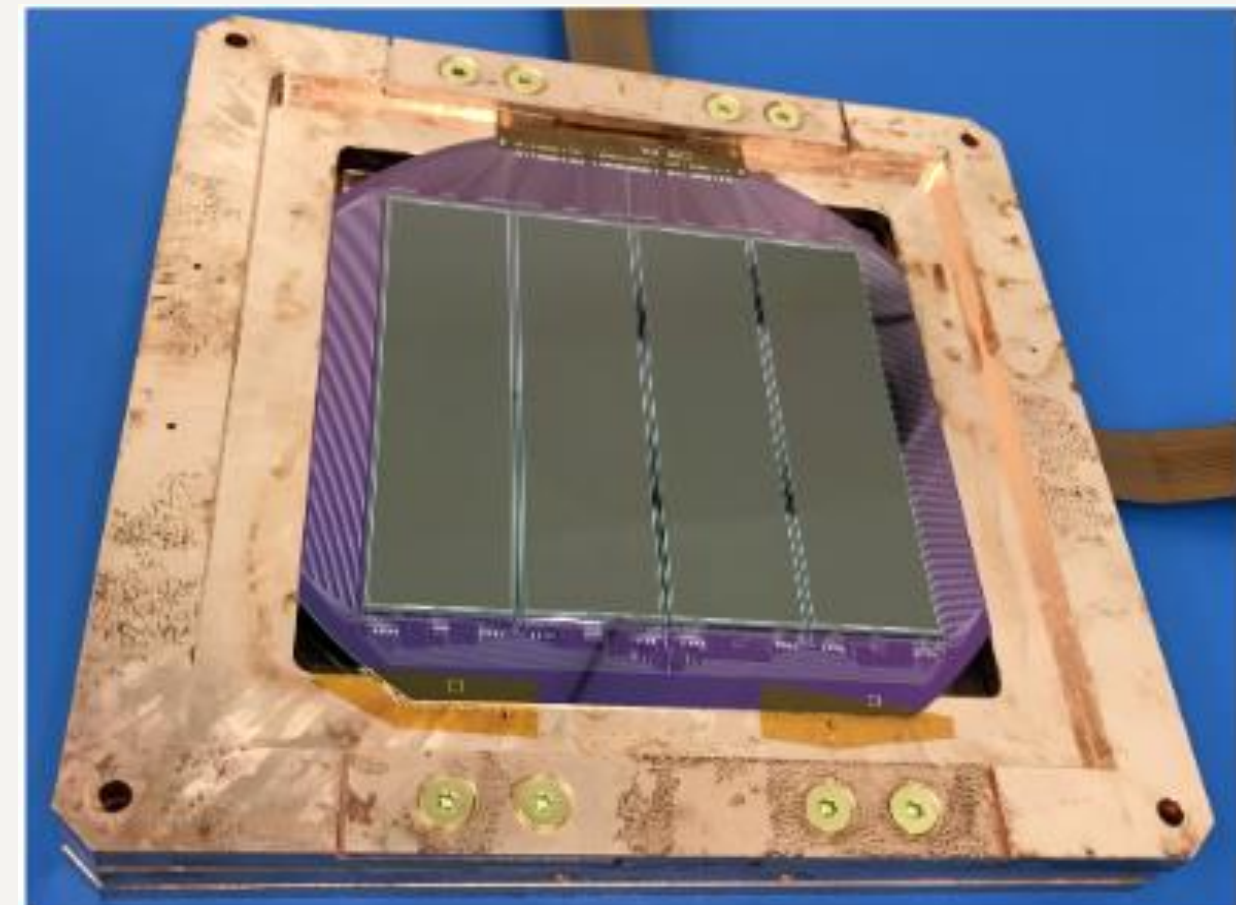
High purity copper continues to play an important role for ultra-low-background detectors on neutrino physics and dark matter experiments.

Electroforming is an electrochemical method of producing pieces by the deposition of a metal onto a mold, which is subsequently removed.

Copper Electroforming Service (CES) at Canfranc Underground Laboratory (LSC) started at 2014 and electroformed copper pieces have been performed for experiments (ANAIS, DAMIC-M) and R&D Collaborations (LNGS, Jagiellonian University).



PMT module encapsulation - ANAIS



Top and bottom lids in the CCD Box – DAMIC-M



Key Elements

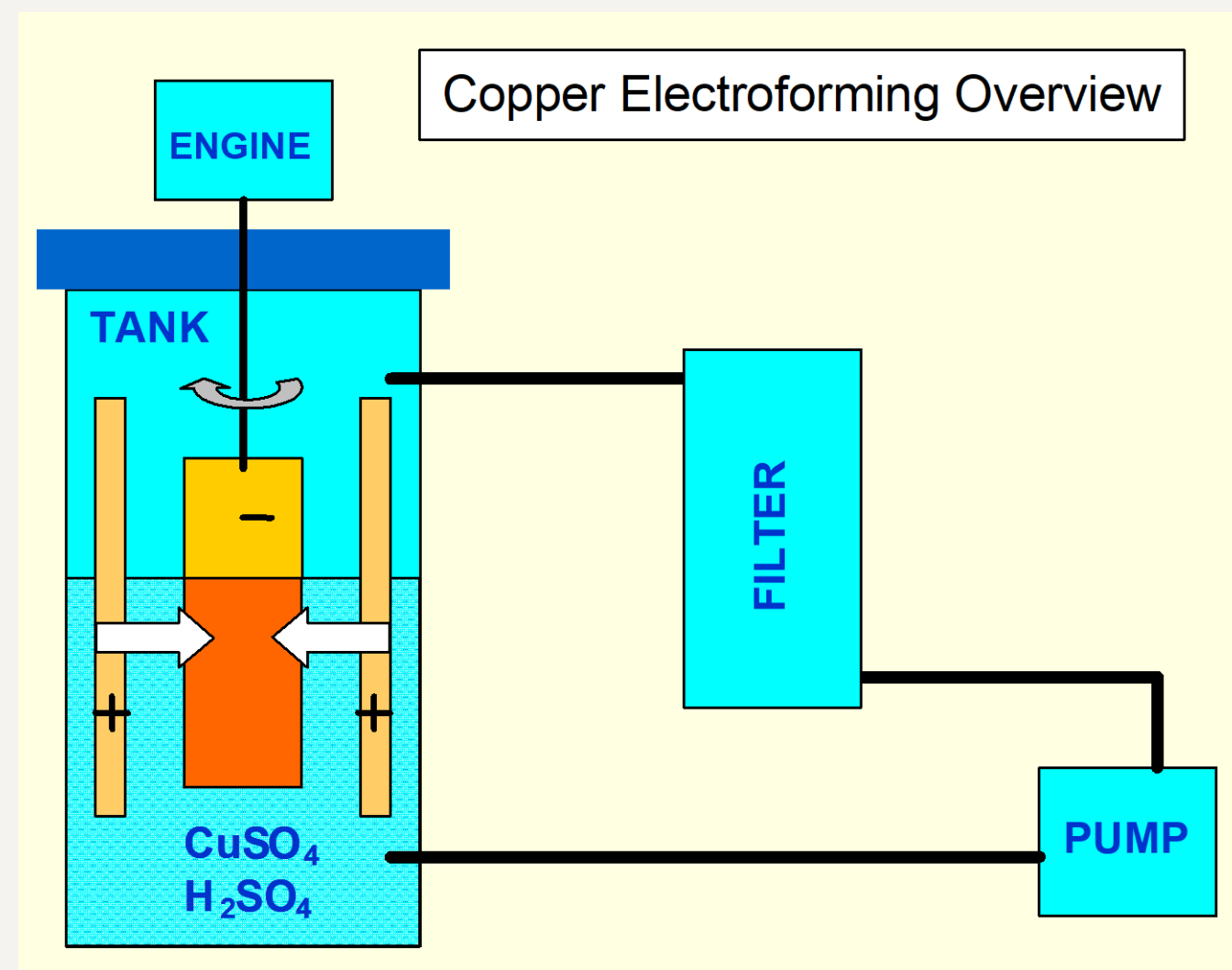
- High-purity commercial chemicals & ultra-pure water.
- Copper sulphate recrystallization.
- Bath circulates with continuous filtration to remove oxides and precipitates.
- Cu-OFHC (anodes) & stainless steel 316L (cathode).
- Glassware-free handling.
- Rigorous cleaning procedure before the set-up mounting.
- Covered bath avoids air and dust contamination.

Electrolyte

Electrodes

Set-up

Technical details published at AIP Conference Proceedings 897 (LRT2006) and 1921 (LRT2017)





Improvements from year 2021

Equipment

- Monitoring and Control System: parameters, remote connection, alarms, automatic/manual operation
 optimized process time, programmed different waveforms
- Power Supply (PSU): 120A, 12.5V, programming mode
 x6, increase EF-Cu surface

LSC Facilities

- Underground clean room (Class ISO 7).
- Radon-free air fluxed inside the bath, over the electrolyte.
- ICP-MS assays for radiopurity of materials.



EF-Cu setup



Clean Room

Radon abatement system

ICP-MS



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Current EF-Cu setup



Clean Room

Radon abatement system

ICP-MS



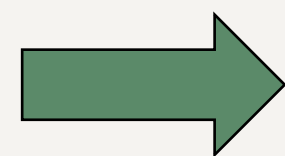
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DAMIC-M (Dark Matter In CCDs at Modane) experiment

DAMIC-M established a collaboration with the LSC (EoI-21-2018, www.lsc-canfranc.es).

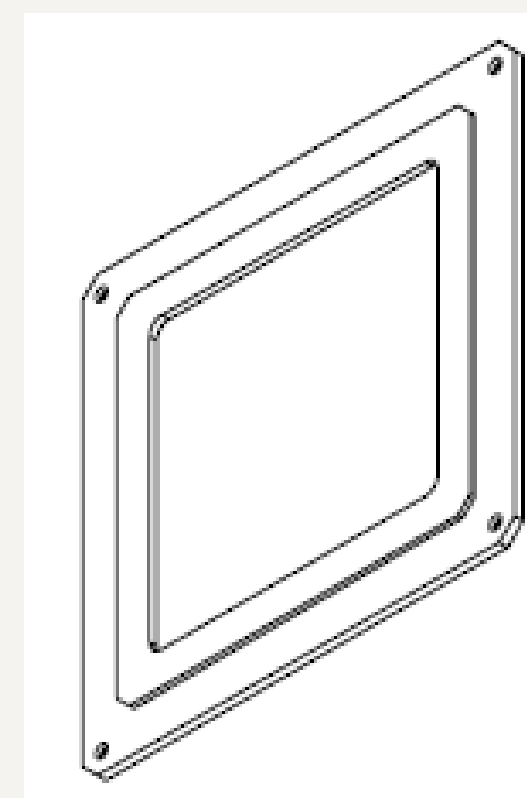
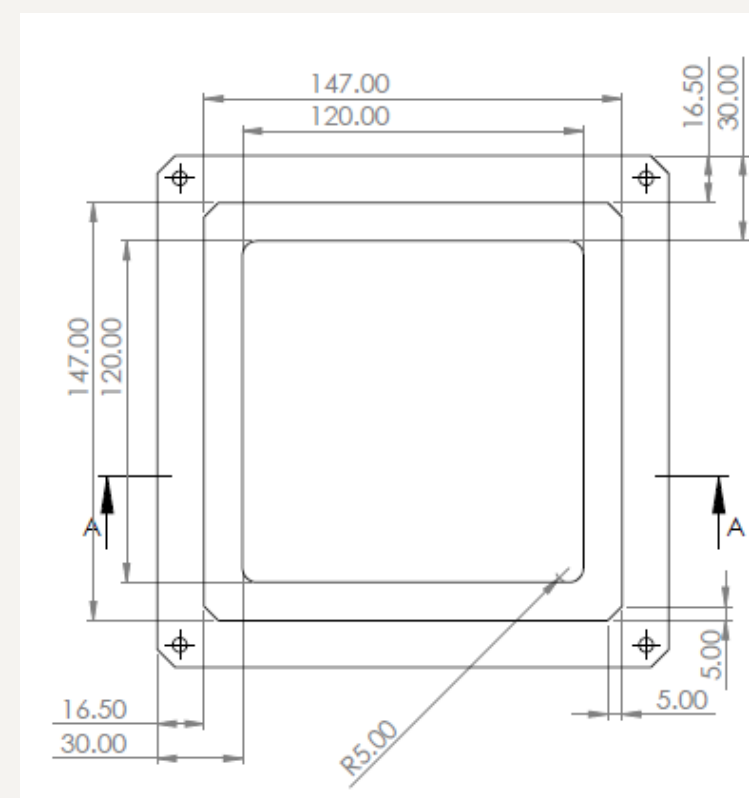
In 2021, DAMIC-M presented a LSC Copper Electroforming Service (CES) form: electroformed copper parts for the low background chamber to reduce the radioactive background from the components closest to the Charge Coupled Devices (CCDs).



ACCEPTED!

Top and bottom lids to cover the skipper CCDs

**AIM: radiopure plane electroformed copper parts with pocket and frames
(plate, 180x180 mm², 2.5-5.5 mm of thickness)**

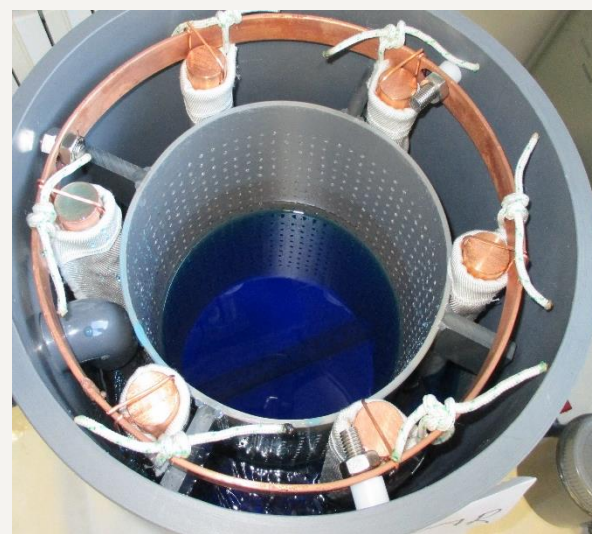


*Top lid drawings
(Courtesy of D. Baxter, DAMIC-M)*

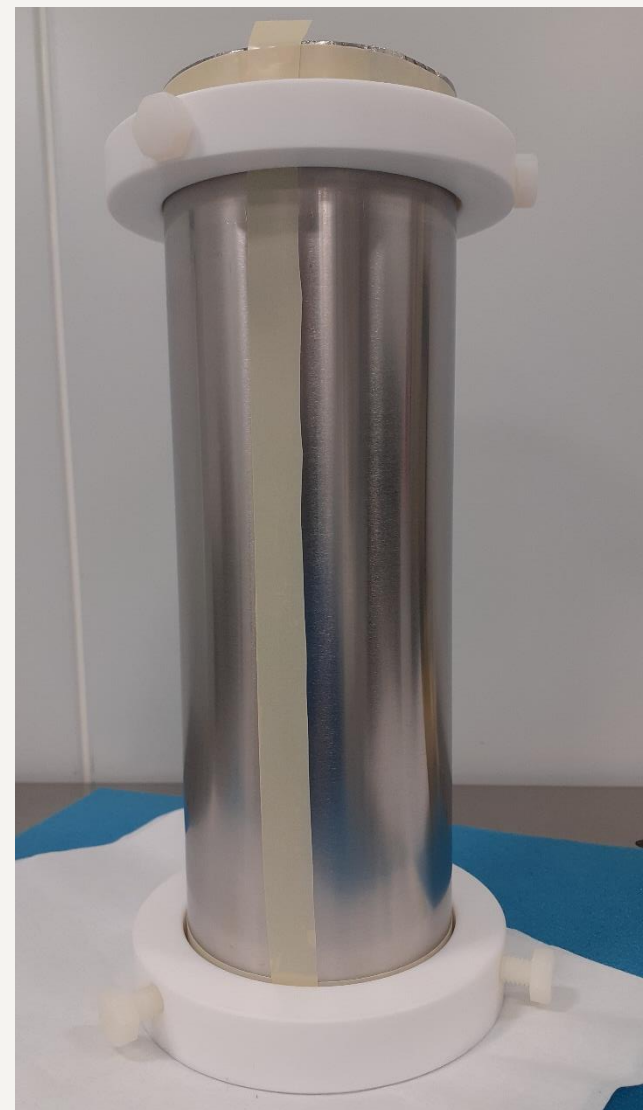
Parameters and configuration in the copper electroforming process

Preparation “in steps”:

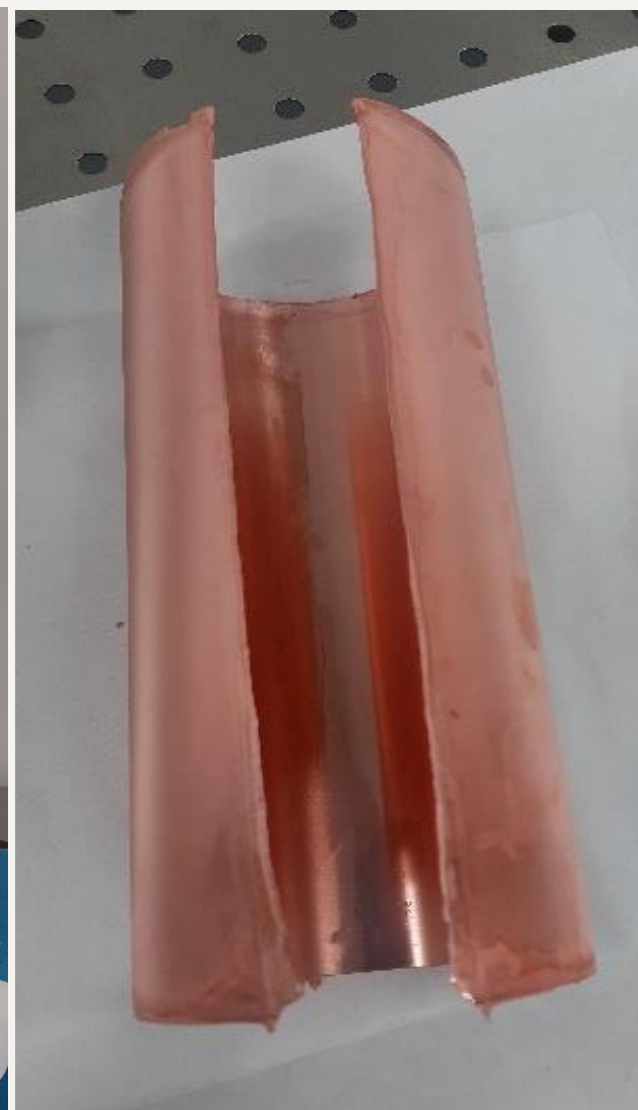
1st step: EF-Cu thin layer preparation, removed from the mold, cut and flatten



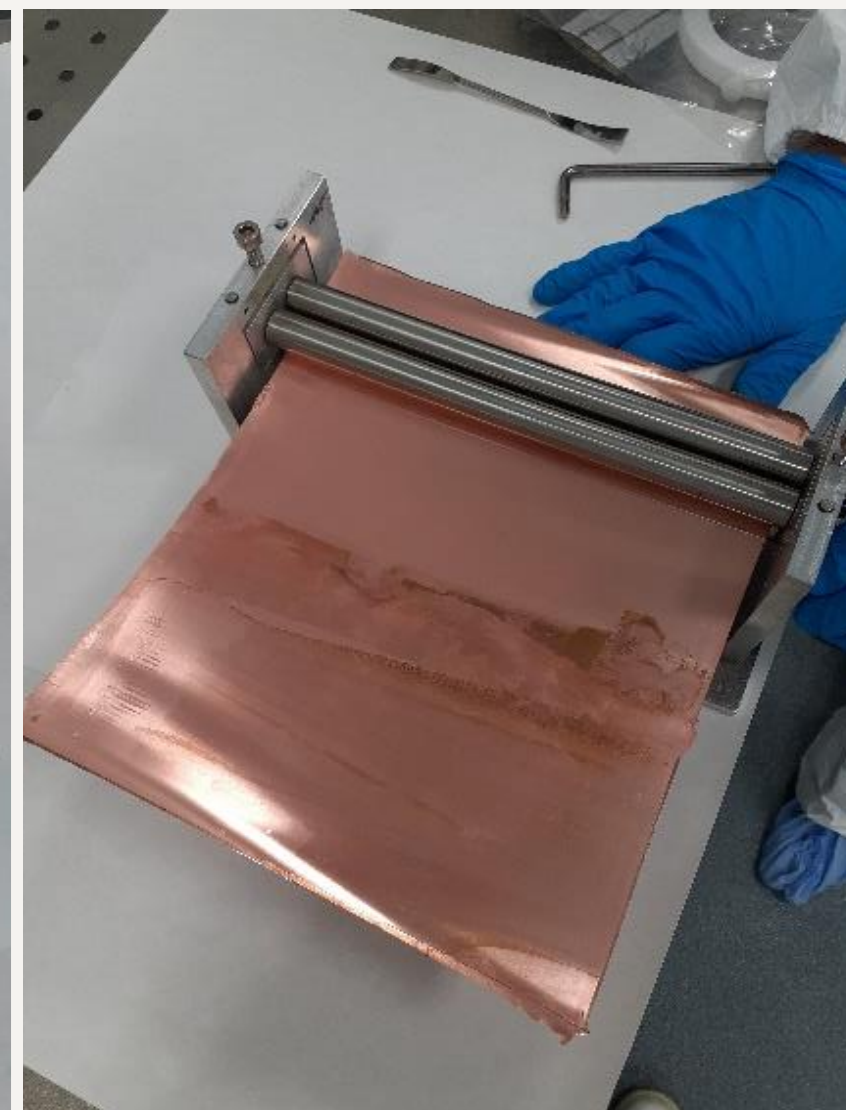
Circular configuration



SS mold



EF-Cu thin layer



Flatten the EF-Cu layer

Direct plating (2 A dm^{-2} , 2h) + Pulse-reverse electroplating ($2\text{-}4 \text{ A dm}^{-2}$, 17-19h)

~ 0.3 mm of thickness, total process time= 19-21h

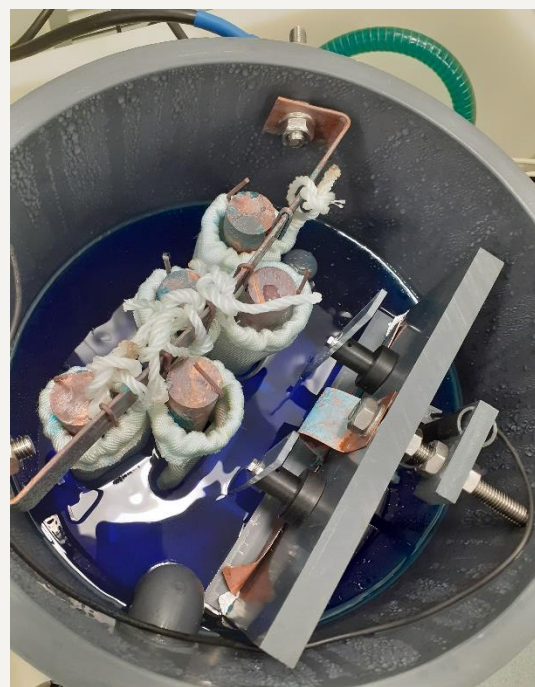


Parameters and configuration in the copper electroforming process

Preparation “in steps”:

1st step: EF-Cu thin layer preparation, removed from the mold, cut and flatten

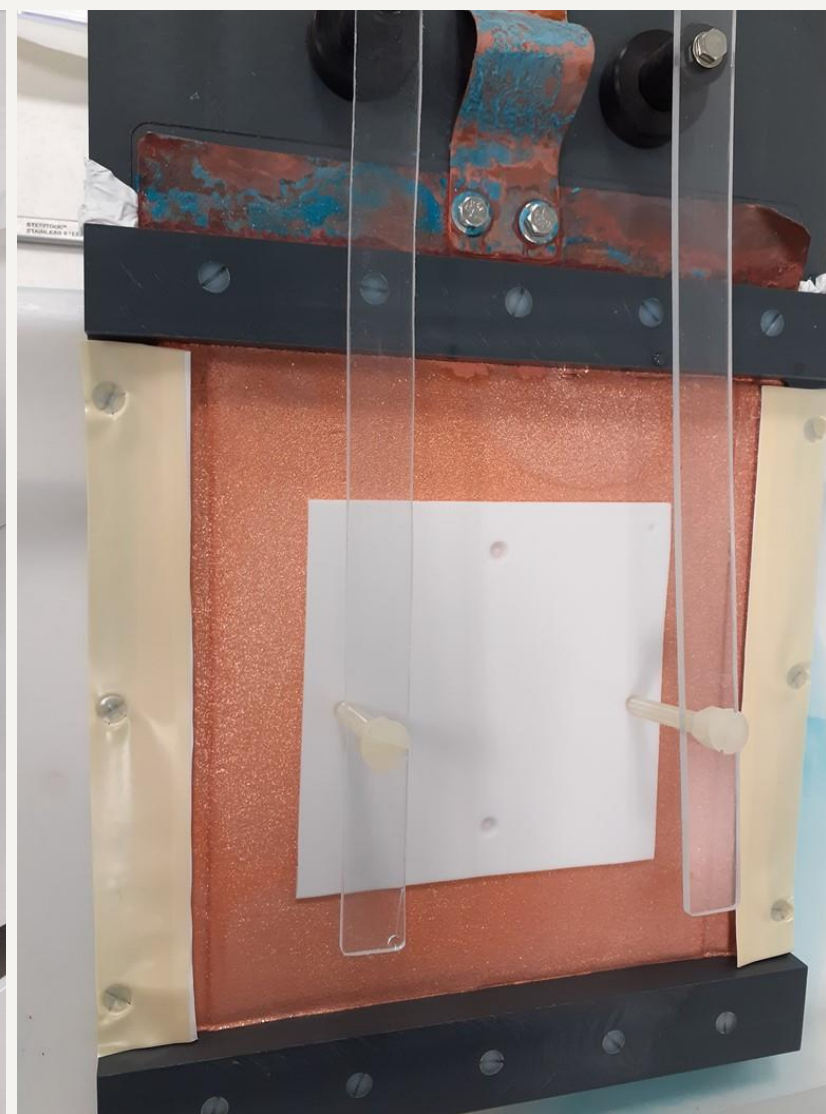
2nd step: EF-Cu thin layer as mold for the lid + plastic masks (isolating areas) the frame and pocket



Linear configuration



EF-Cu mold



Isolating mask (pocket)



EF-Cu final piece

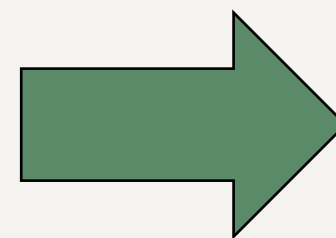
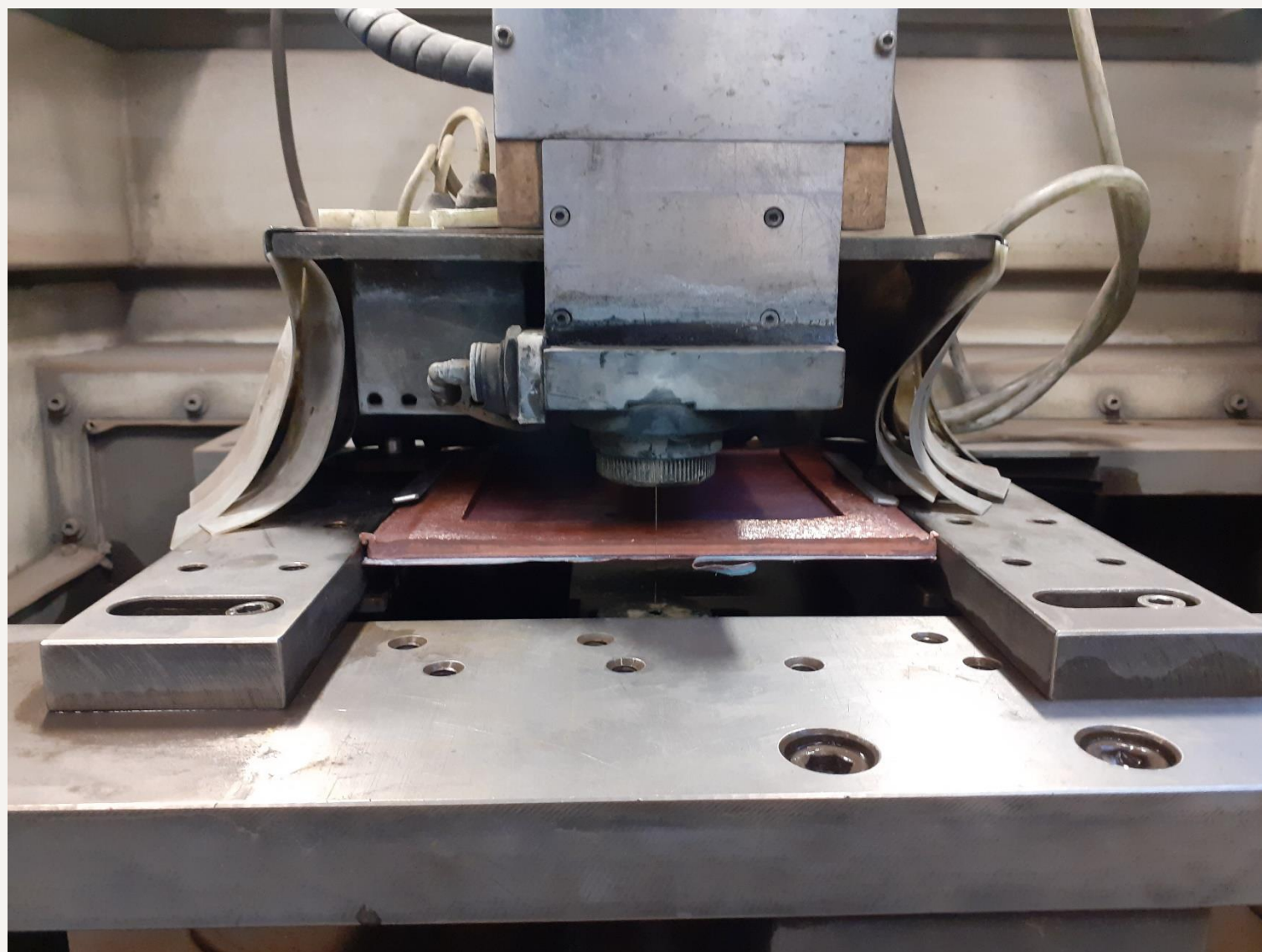
Pulse-reverse electroplating (2-4 A dm⁻²)

2.5-5.5 mm of thickness, total process time= 500-700h

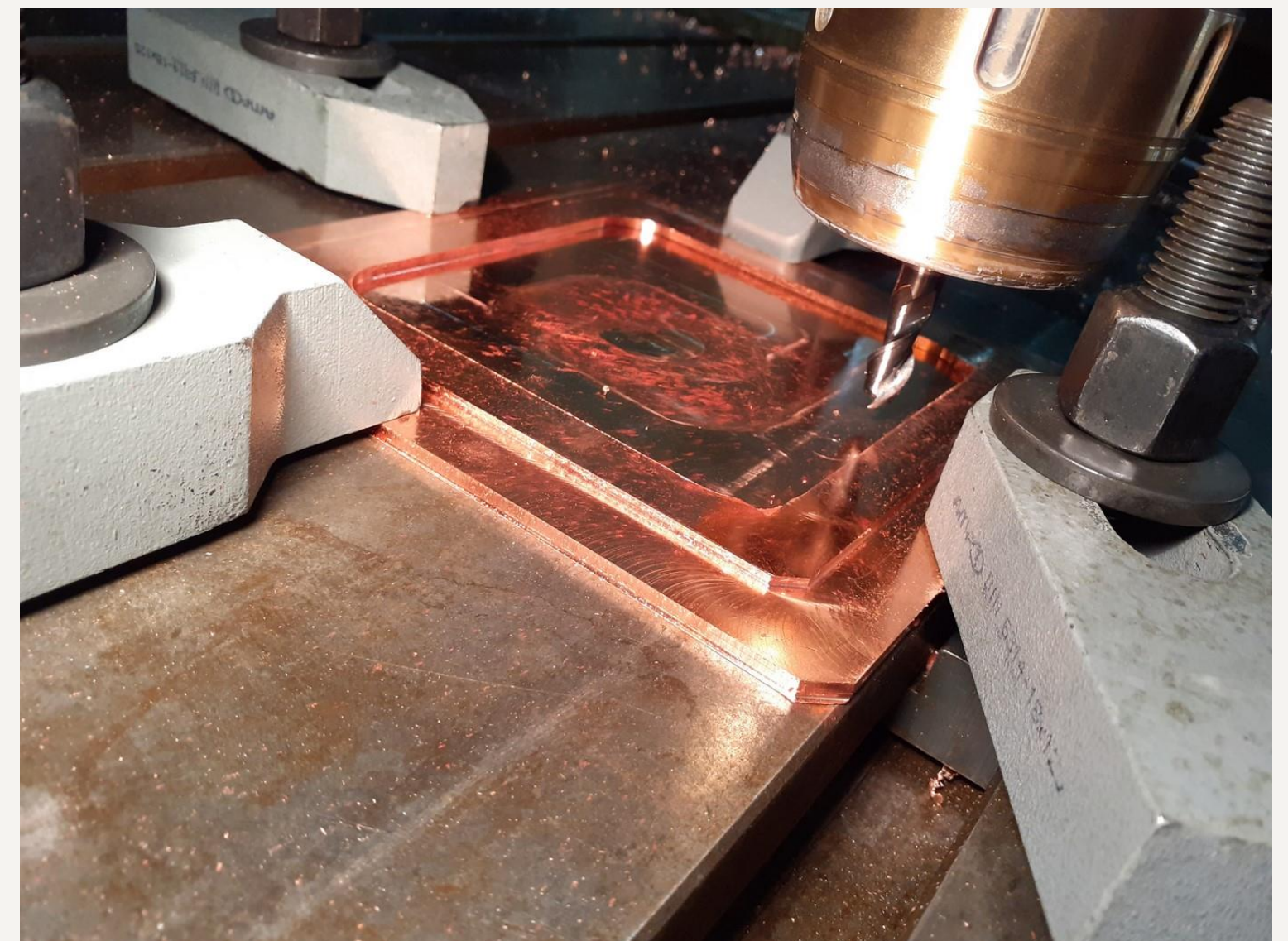
Machining the EF-Cu lids

- Shear or Electrical Discharge Machining (EDM): external dimensions on surface, at the University of Zaragoza (150 km from LSC)
- Milling machine: surface, corners, the pocket and frames, and holes on surface, at LSC machine workshop

EDM cut



Final machining



Surface exposure time: 1.5 – 4.5 days

Stored underground in double plastic bag with N² till their transport to Grenoble (France)



Top & Bottom lids – CCD Box (DAMIC-M)

Transportation

- Ground transport from LSC to Grenoble

Cleaning procedure

- Pacific Northwest National Laboratory method (E. W. Hoppe et al., NIM A 579, 486,2007)
- Clean room at Laboratoire de Physique Subatomique & Cosmologie (Grenoble, France).
- Cleaned, dried and packed in double plastic bags before their transport to Modane.

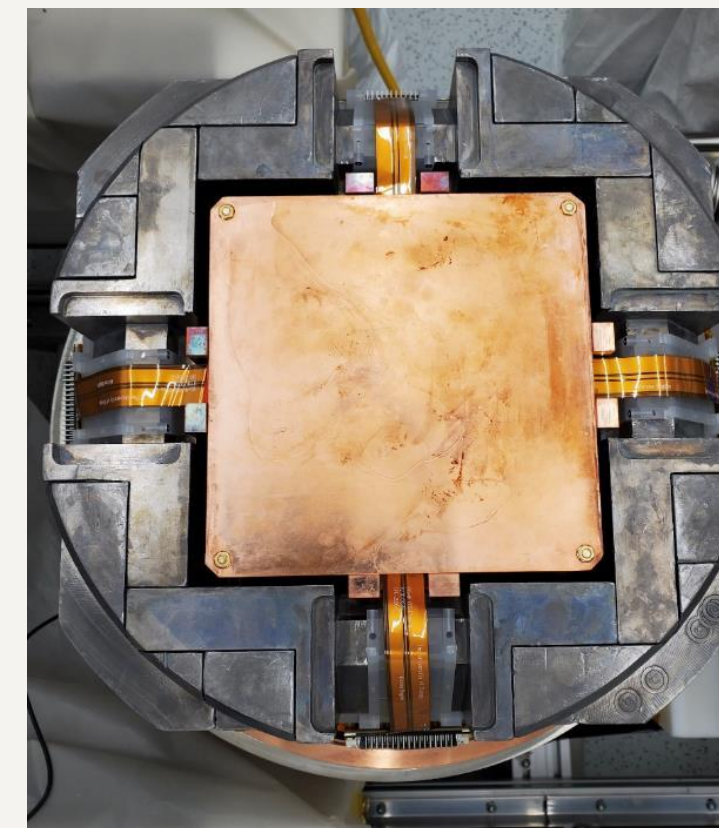
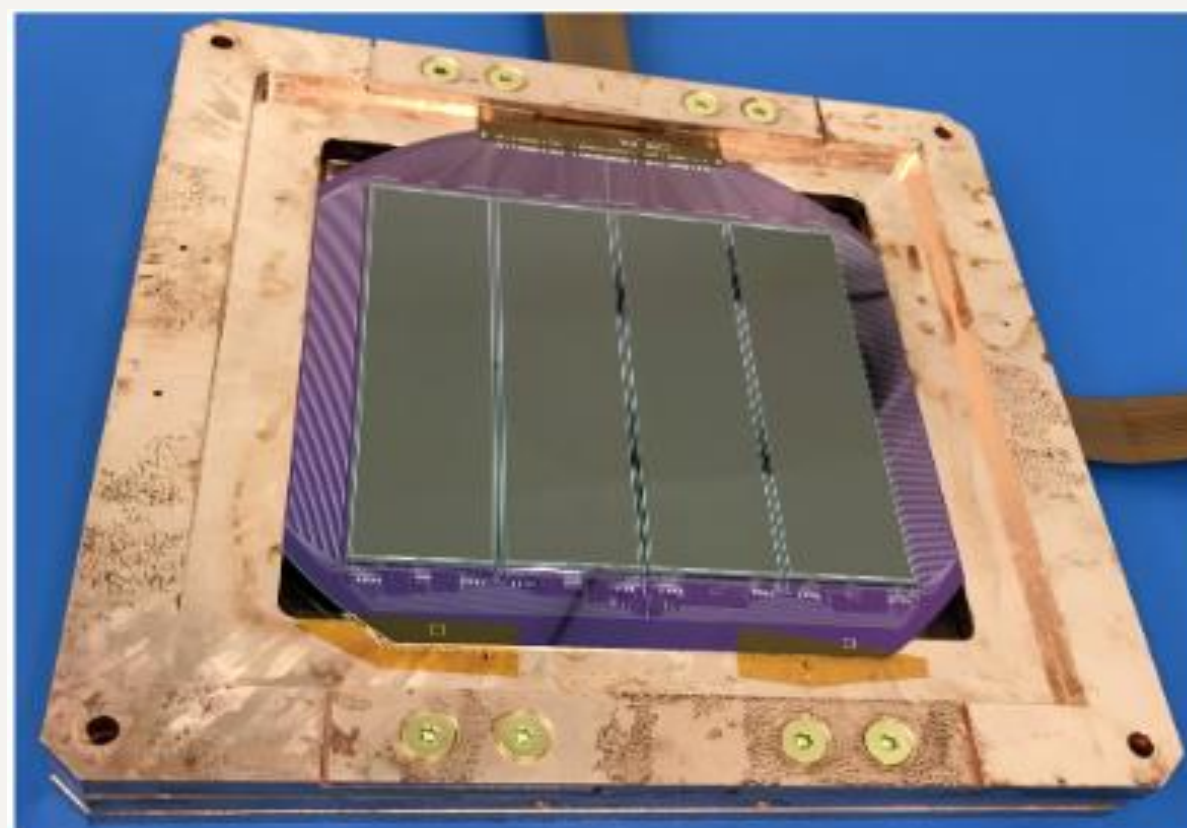
Total surface exposure time: 3.1 – 6.5 days

Installation in the CCD Box at LSM – September 2022

Results

Background decrease by 3.6 dru ($1 < E < 6$ keV) after exchanging OFHC copper lids in the CCD box for EF-Cu ones.

<https://arxiv.org/abs/2407.17872> Submitted to JINST



*Pictures by courtesy of
DAMIC-M Collaboration*



ICPMS assays

Inductively-Coupled Plasma Mass Spectrometry (ICP-MS) assays carried out at LSC to analyze the Th and U contamination at bulk in copper samples.

Sample: remains of the EF-Cu lids after the edge cut, without machining or cleaning procedures.

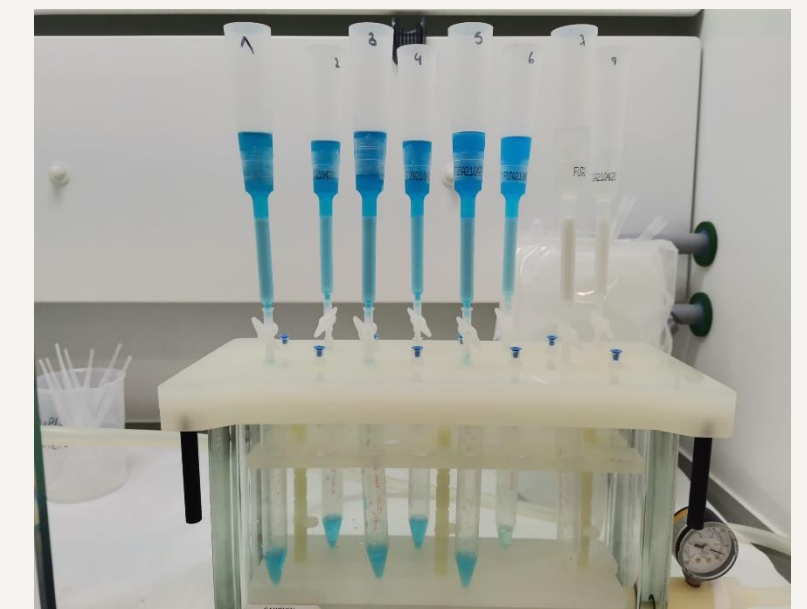
Sample preparation

- Nitric acid etching *
- Chromatographic extraction resins
- Eluted from the columns by diluted nitric acid

*Bulk assay: samples etched three times
 ~1 g copper measured



Final EF-Cu lids and remains



UTEVA® resin (Triskem)

sample	Th		U		Th		U	
	ppt	+/- sd	ppt	+/- sd	µBq/kg	+/- sd	µBq/kg	+/- sd
EF-Cu bottom lid	0.83	0.05	0.40	0.05	3.4	0.2	5.0	0.6
	1.11	0.07	0.63	0.04	4.5	0.3	7.8	0.5

“Low radioactivity measurements based on ICP-MS at LSC” by L. Cid-Barrio (Tuesday 1st October)



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The CES facilities allow to carry out **R&D activities and give support** to experiments working at LSC and other collaborations.

Radiopure plane electroformed copper parts have been **prepared** by electroforming in steps without intermediate machining.

The **background level decreased by 3.6 dnu** ($1 < E < 6$ keV) after exchanging OFHC copper lids for electroformed copper ones in the CCD box (**DAMIC-M** Low Background Chamber).

Upgrade set-up with high purity plastic materials (HDPE, PFA and PTFE) in tubing and bath components is ongoing.

QA by ICPMS assay program is carried out to evaluate systematically the contamination level in electroformed copper parts as well as the precursors (chemicals and electrolyte) in the electroforming process.

DAMIC-M and LSC maintain a close collaboration in electroforming of copper.

Laboratorio Subterráneo Canfranc



Thank you!

