Update on WCTE radioactive sources development

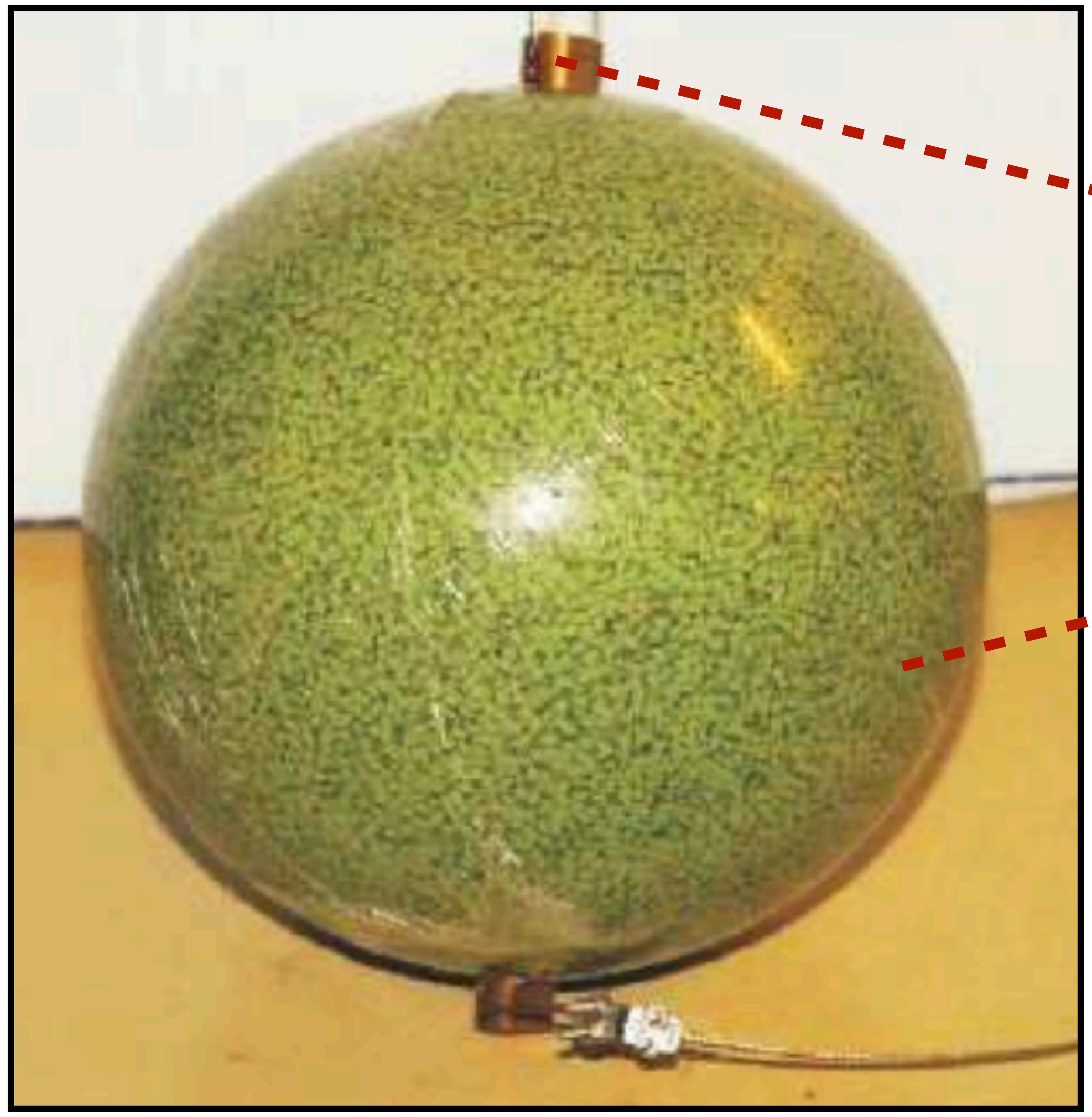
D. Costas[1], P. Fernández[2], F. López[2], F. Monrabal[2], J. Pelegrín[2], J. Renner[1], A. Taboada[2], J. A. Hernando-Morata[1], J.J. Gómez-Cadenas[2]

[1] IGFAE/Universidade de Santiago de Compostela
[2] Donostia International Physics Center (DIPC)

HyperK physics Workshop at DIPC, June 13, 2023

Nickel source - NiCf

- Goal is an isotropic source of gamma rays leading to single photon events for PMT calibration
- Thermal neutron capture on nickel: $^{58}Ni(n,\gamma)^{59}Ni$ (~9 MeV in gamma energy)
- ^{252}Cf decay provides neutrons
- Source is used for absolute and relative gain calibrations, as well as to study detector uniformity



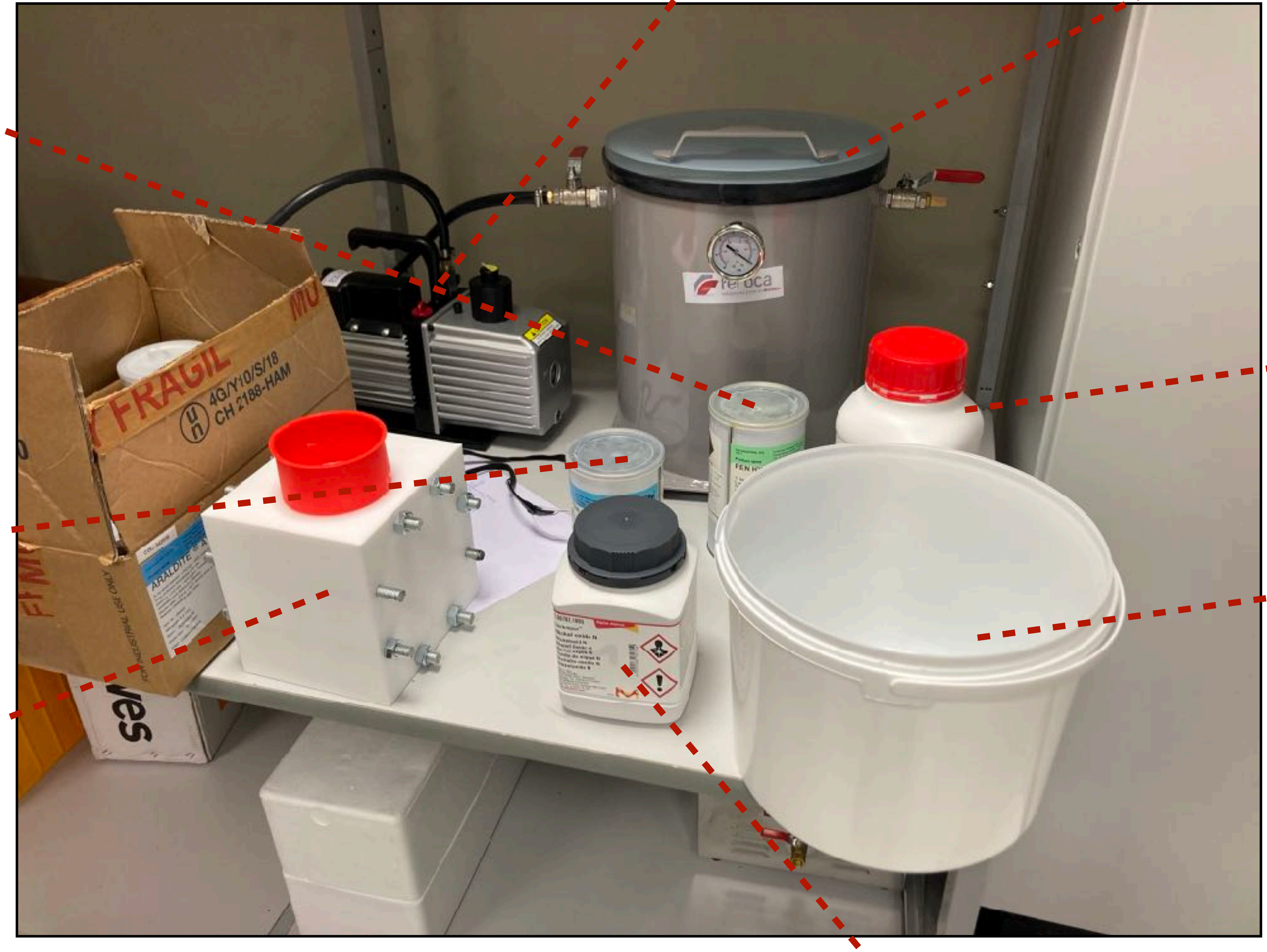
Nickel source used in SuperK (https://arxiv.org/abs/1307.0162)

Prototypes: constructed at DIPC

Vacuum pump

Vacuum chamber

HY 956 hardener
(1 kg)



Ultra-High Molecular Weight (UHMW) Polyethylene (1 kg, Sigma Aldrich)

Araldite epoxy
(1 kg)

Vacuum chamber insert

2-part teflon spherical mould

NiO (1 kg, Sigma Aldrich "Technipur”)

Procedure:

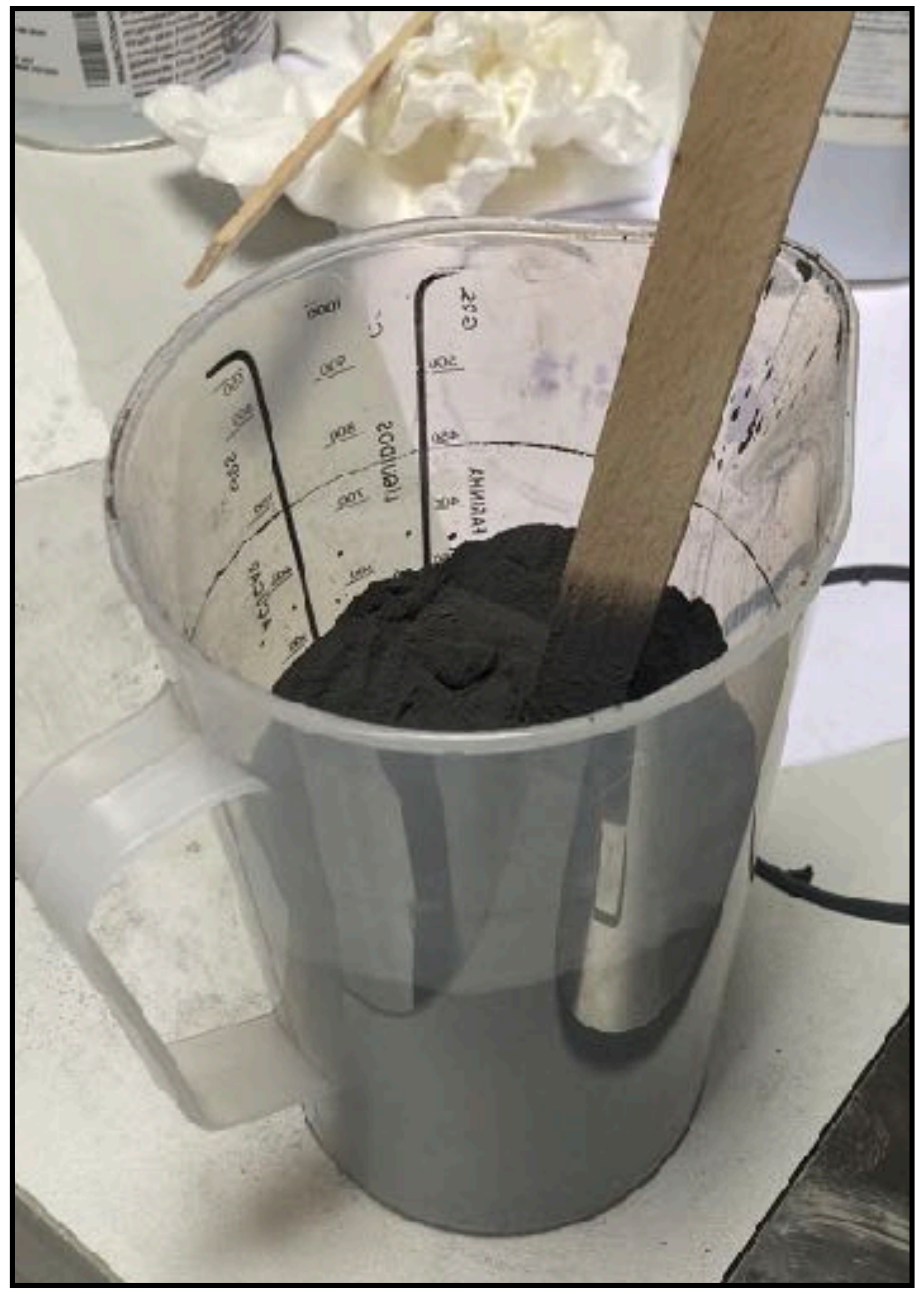
1. **Mix epoxy** (120 g araldite + 30 g hardener) in a plastic container
    - Stir
    - Place mix in vacuum chamber for 5 mins
2. **Mix solids:** 232 g NiO + 125 g polyethylene (70% mass in 2nd prototype)
3. **Stir solid mix** into epoxy in steps
4. **Place in mould** with spoon
5. **Place mould in vacuum chamber** for ~1.5 hours, add next layer
    - 4 layers in total (2 in each half of mould)
6. **Close mould** with screws and place in vacuum chamber

Prototype 1

Mixing solids into epoxy:

- Needed to add 20% more epoxy than initially planned to fully mix solid; results in a thick paste
- Further increased proportion of epoxy in later prototypes

Solid only



Some solid in epoxy

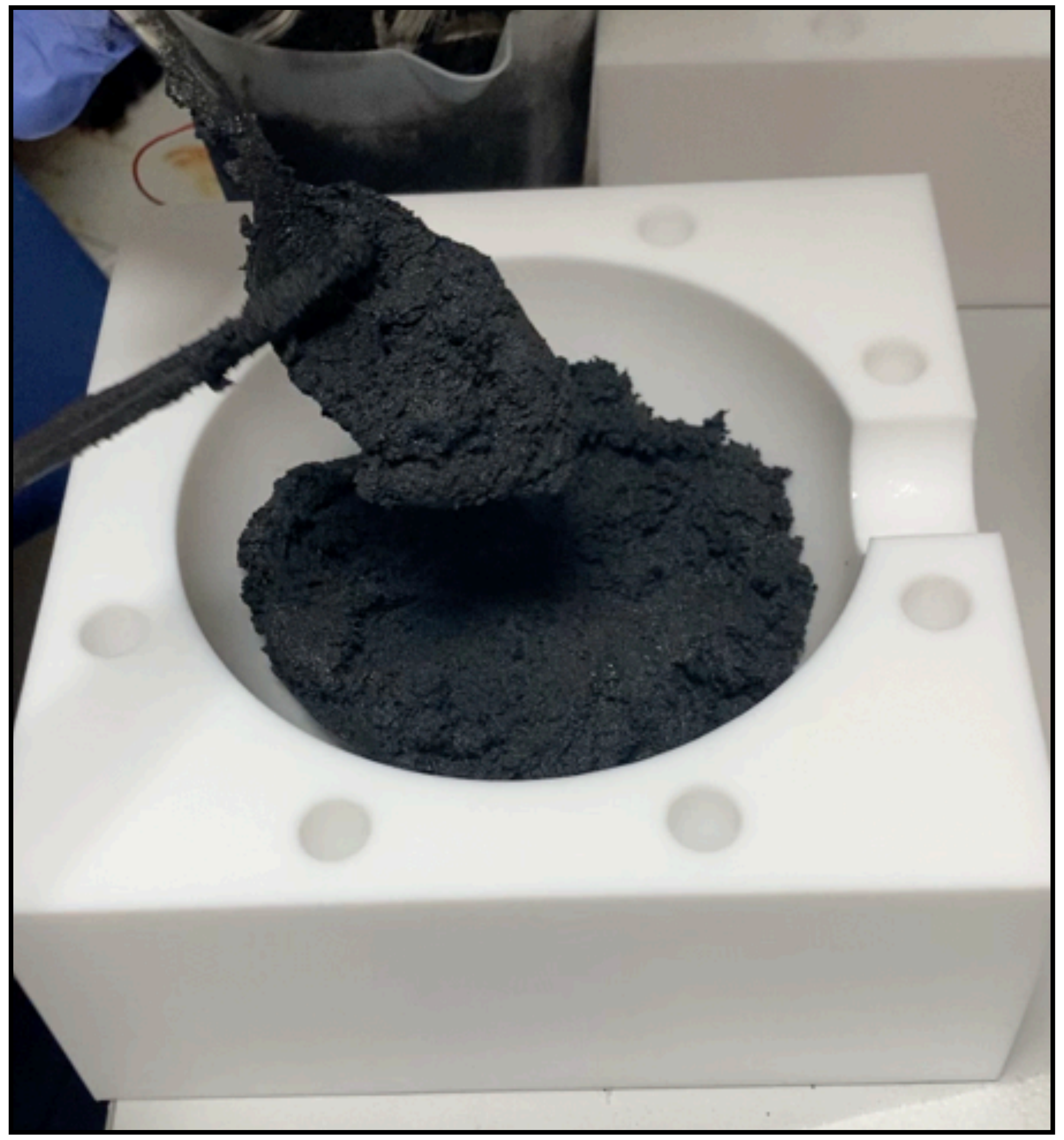
More solid in epoxy

All solid in epoxy

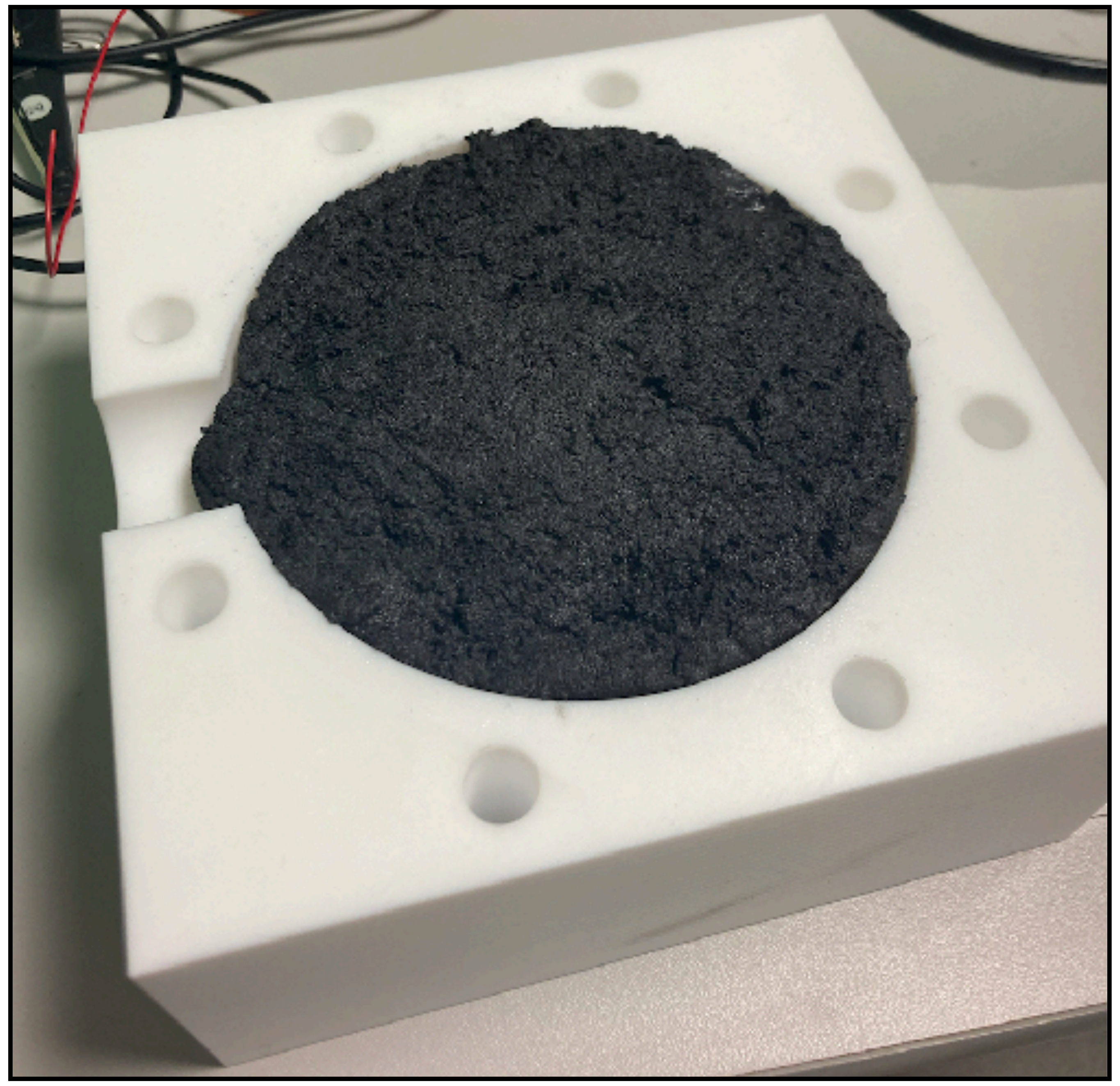
Placing solid into mould:

- With all solid mixed into epoxy for a given layer, the result is too viscous to pour and must be transferred with a spoon
- May need to use more epoxy and pour into mould

1st layer in mould



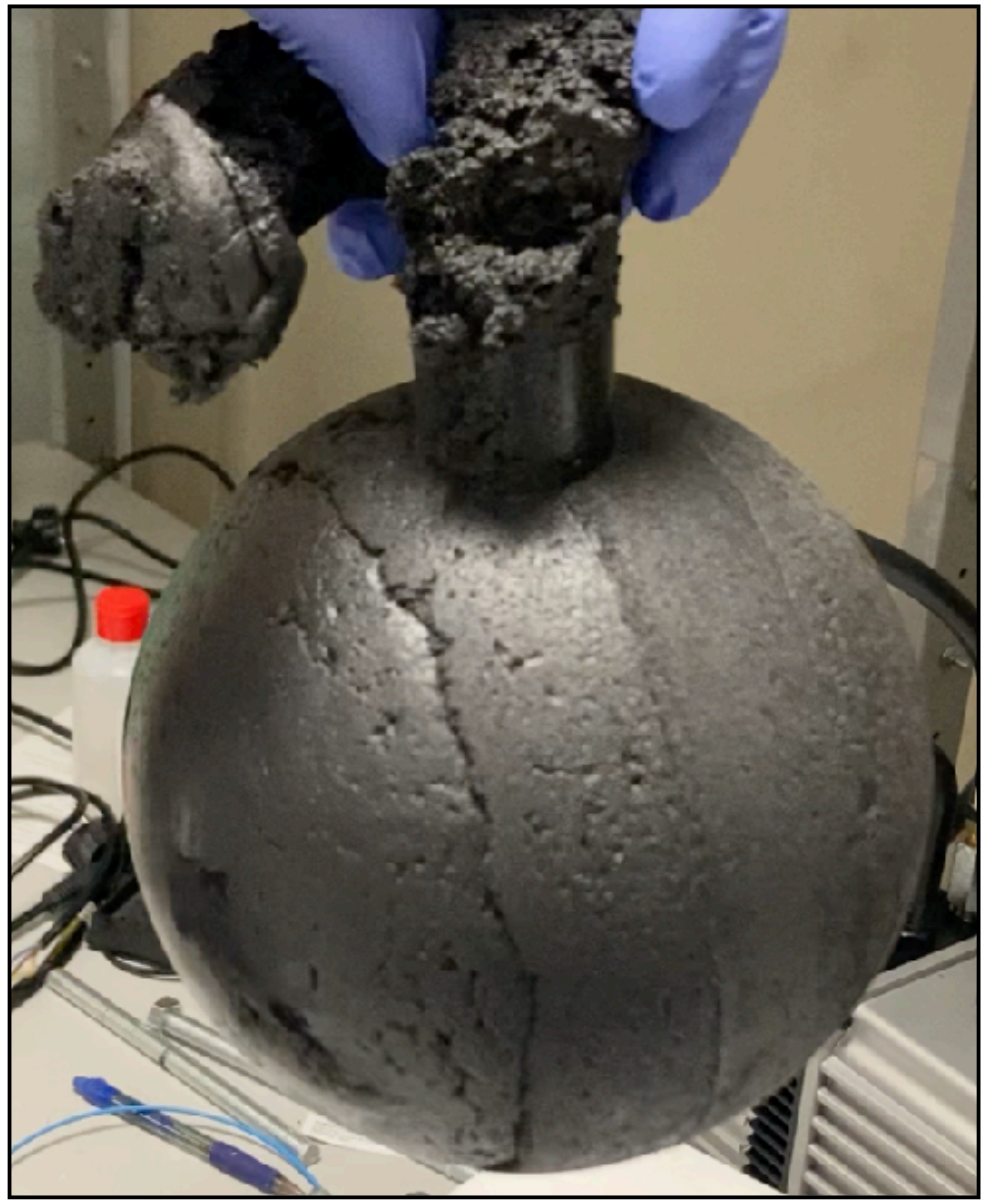
2 layers in mould (after some time in vacuum chamber)



Prototype 1:

- Some issues:
  - Interfaces clearly visible, and some are even quite rough
  - Porous surface due to thickness of mixture and expansion in vacuum
  - **Try with slightly less solid?**

Directly from mould

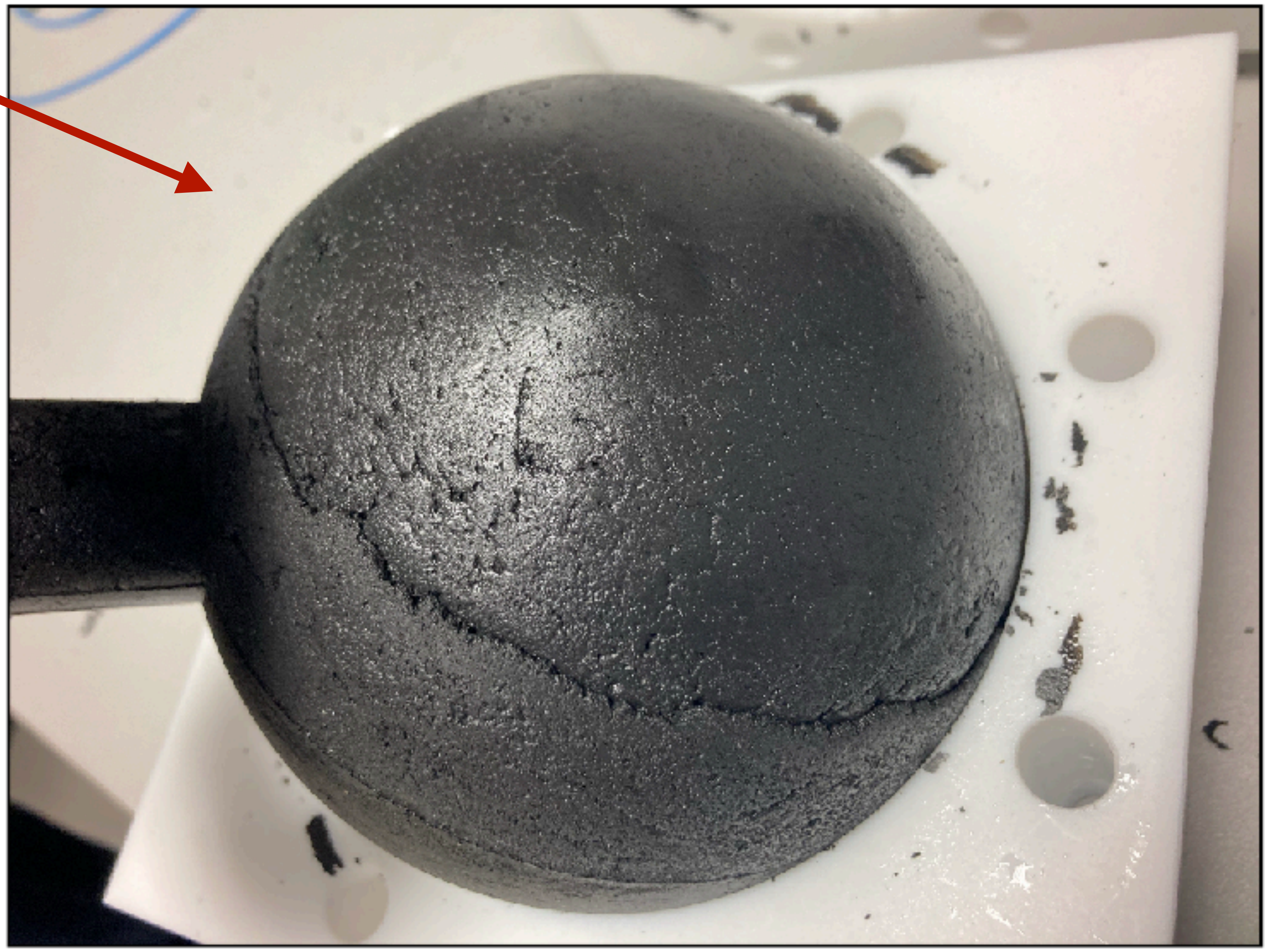


After some machining by Iñigo Alkorta et al. (Fabrikazio Mekanikoko mintegia)

Simulations for varying solid masses

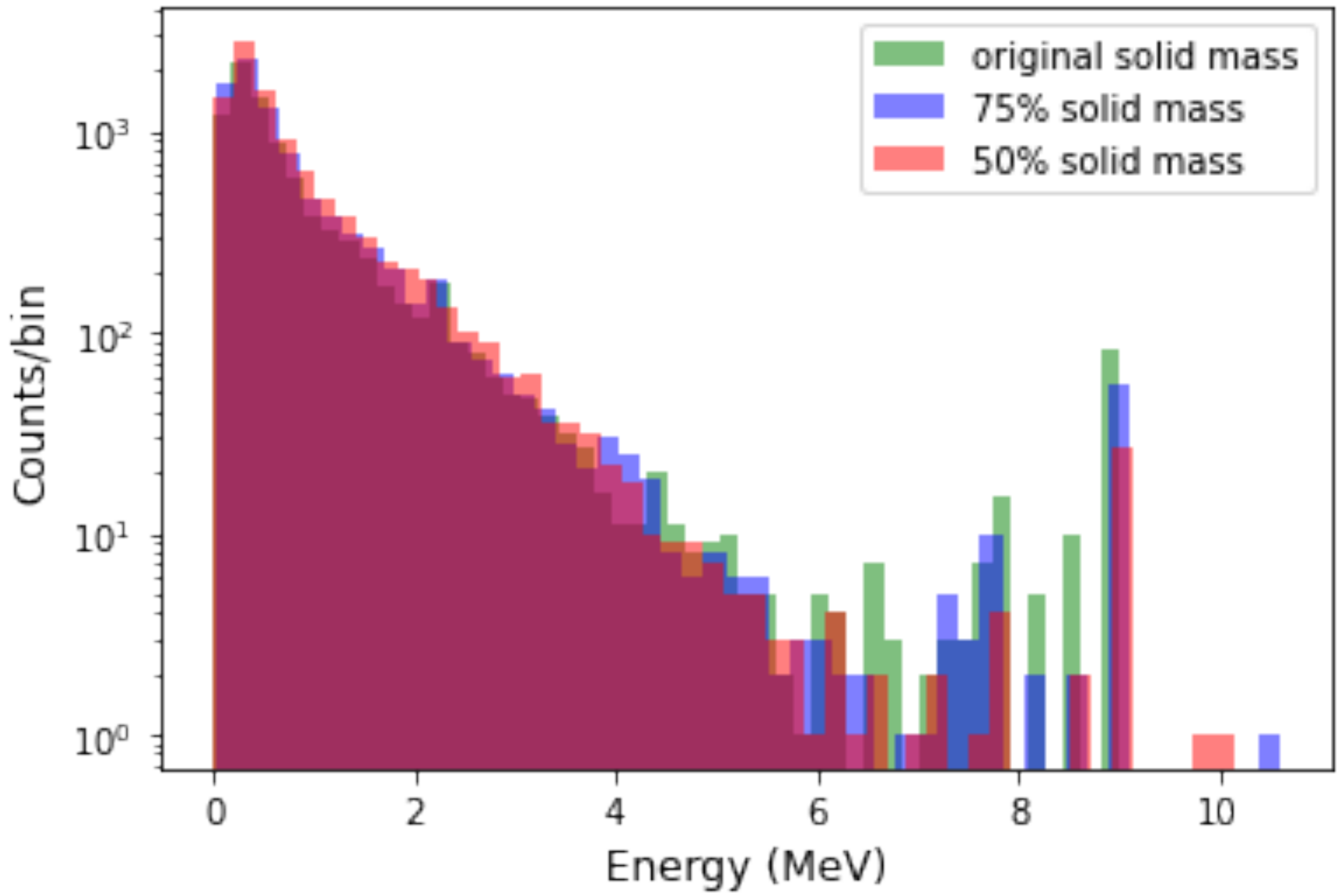
Mixtures:

- **Original (“100%”) solid mass**
  - 357 g solid, 150 g epoxy
  - 70.4% solid, 29.6% epoxy
  - 1.575 g/cm3 density
- **75% solid mass**
  - 268 g solid, 150 g epoxy
  - 64.1% solid, 35.9% epoxy
  - 1.362 g/cm3 density
- **50% solid mass**
  - 179 g solid, 150 g epoxy
  - 54.4% solid, 45.6% epoxy
  - 1.072 g/cm3 density



Gammas escaping the source (1 µCi * 1 second decays):

- Gamma must appear < ~1 hour from 252Cf decay



- **8+ MeV gammas**
  - "100%": 96 gammas
  - "75%": 60 gammas
  - "50%": 31 gammas

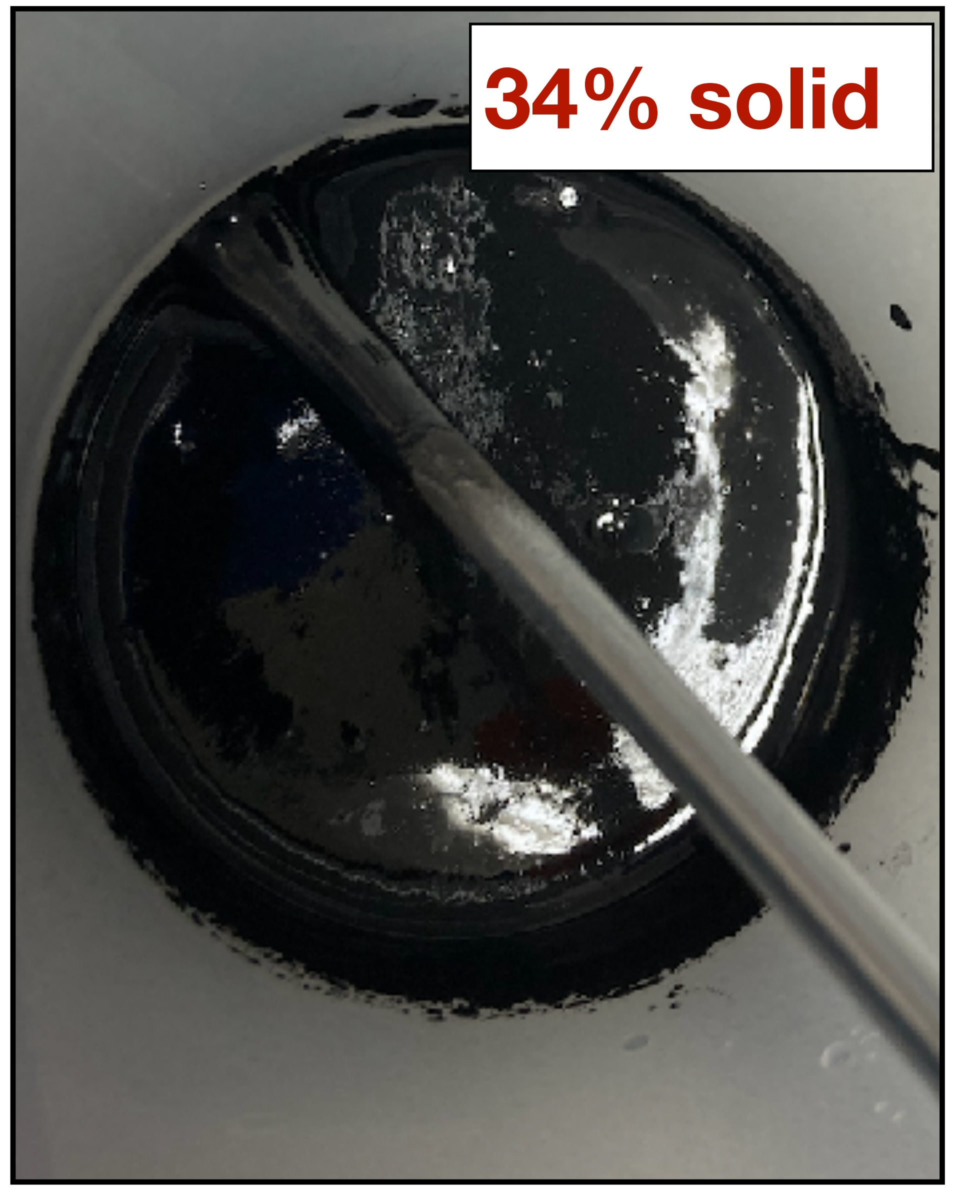
- **Try a second prototype with 70% solid mass**

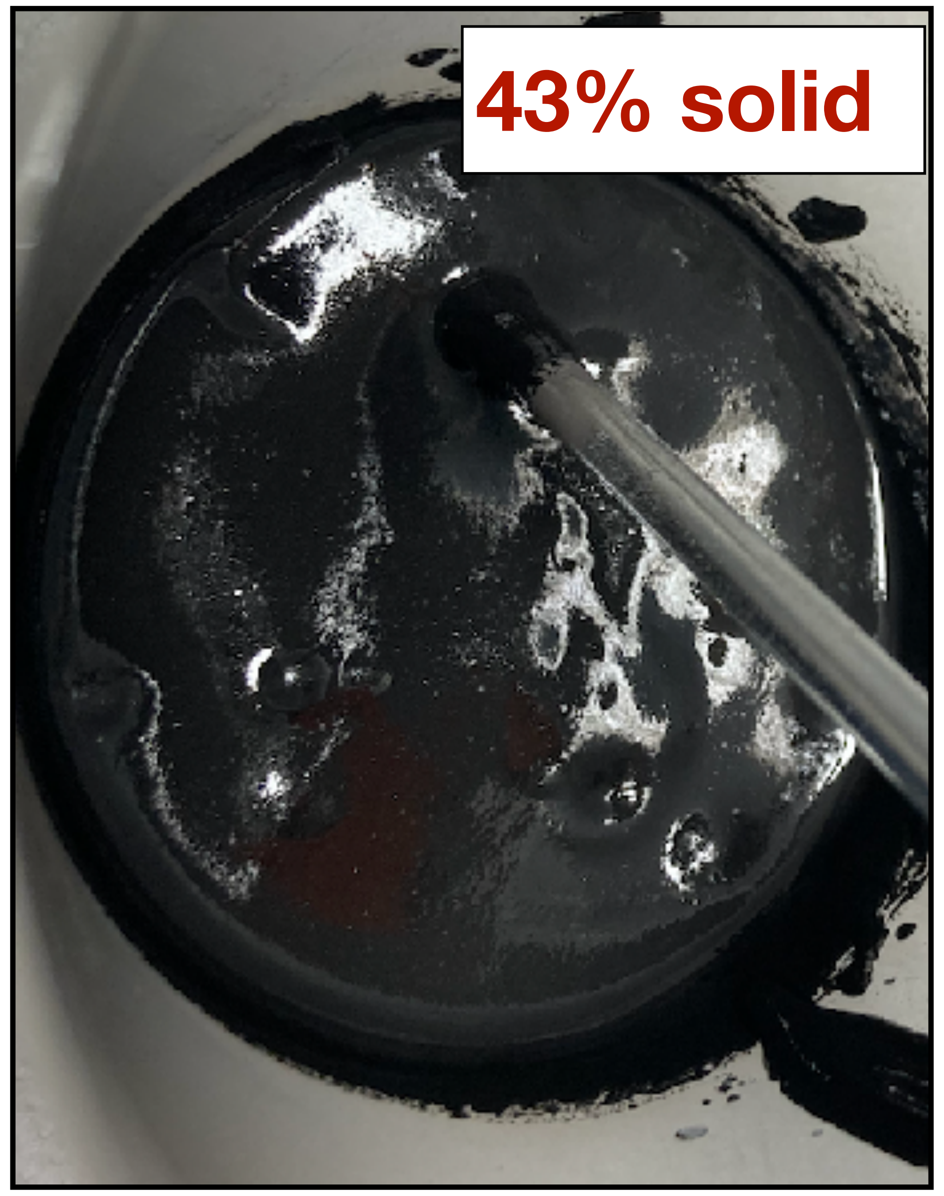
Mixture tests

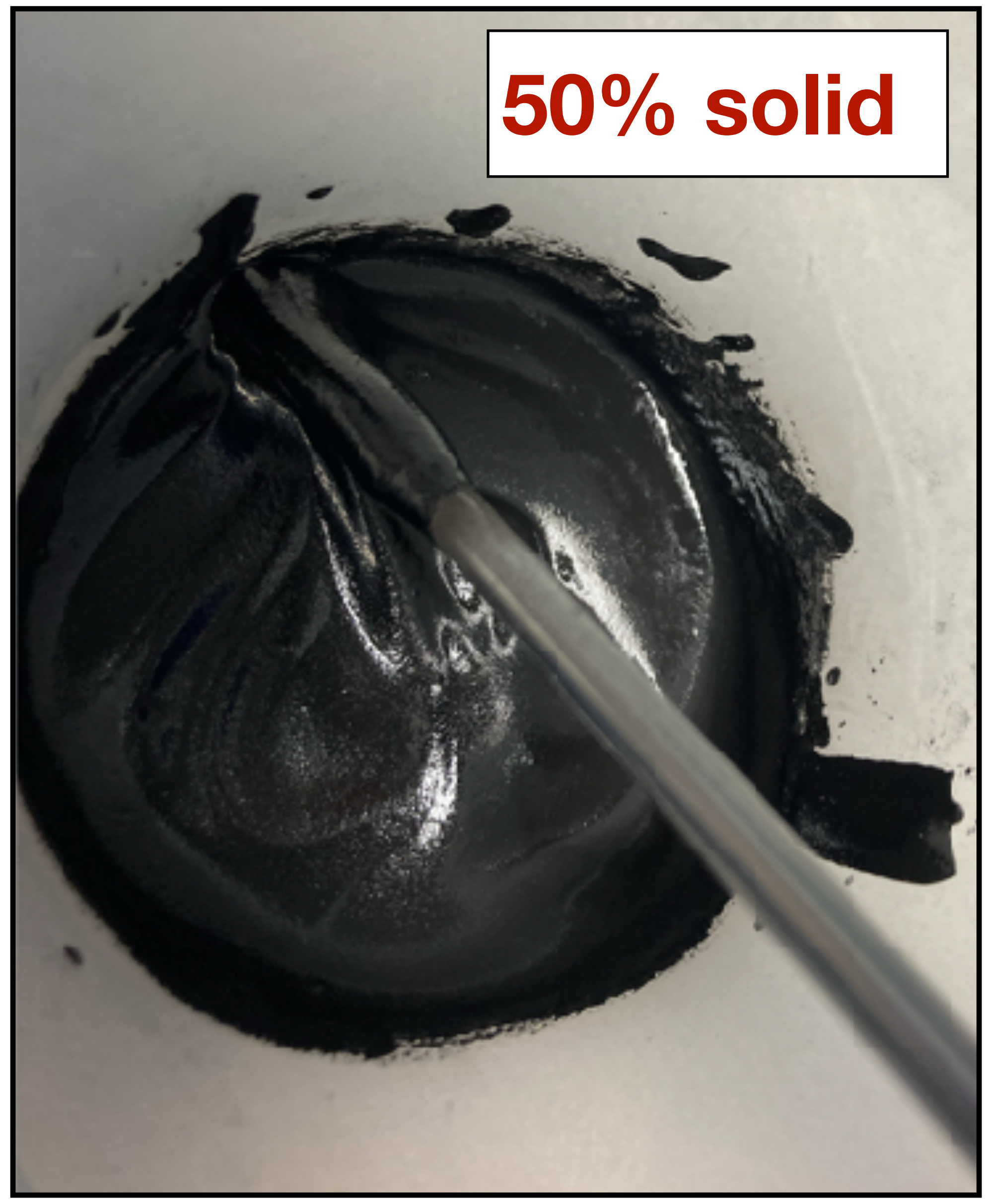
Mixture test (NiCf source):

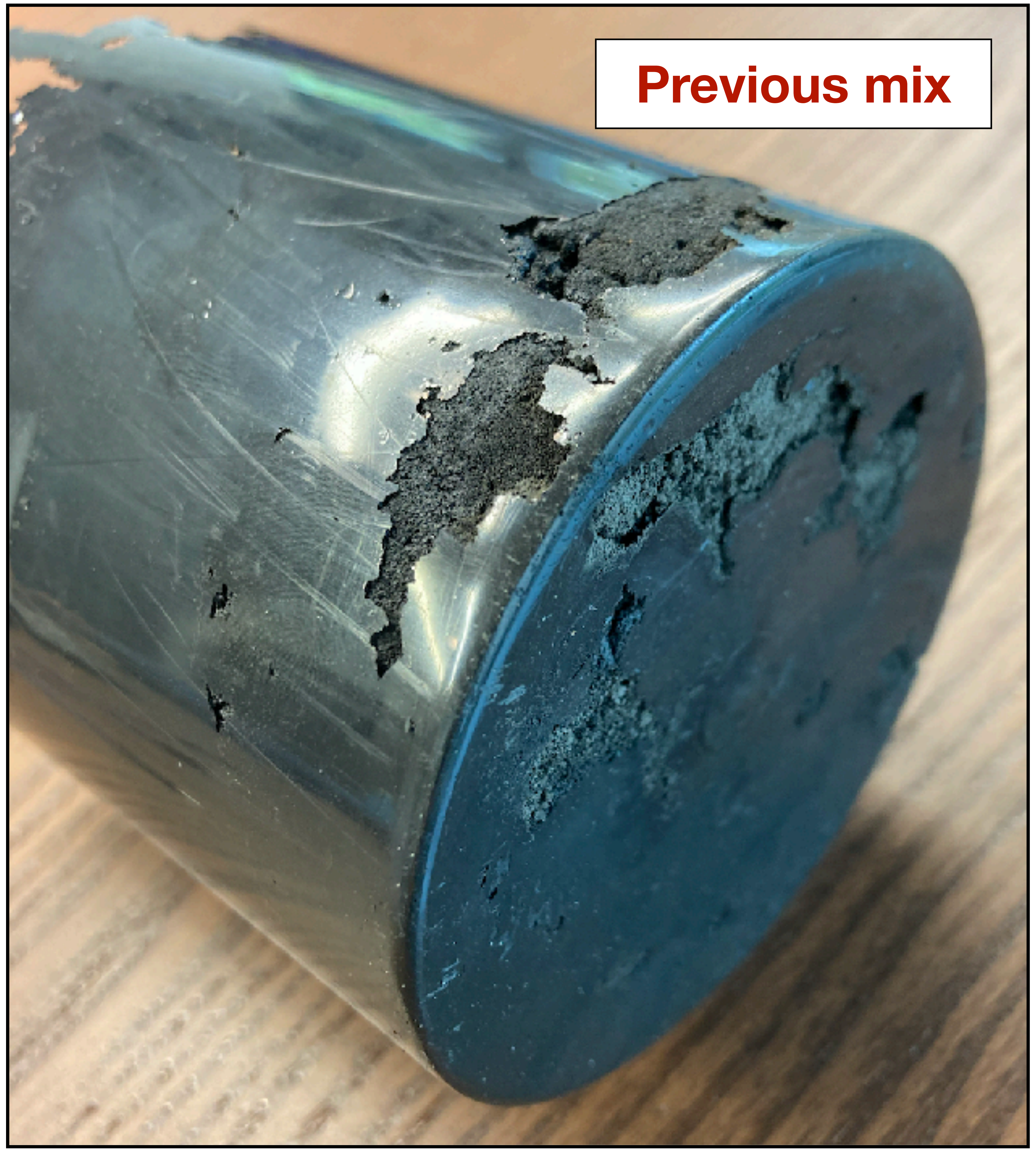
- **Test to find optimal mixture of solid + epoxy**
- **1st prototype, mixed 4 layers each containing:**
  - NiO: 232 g
  - Polyethylene: 125 g
  - Epoxy: 150 g (120 g Araldite, 30 g hardener)
- **Current test:**
  - Epoxy of 1/3 of a single layer: 40 g Araldite, 10 g hardener
  - Add solid up until mix becomes too viscous. In principle we would have a total of 77 g NiO and 42 g polyethylene (119 g solid) to produce the same mixture as in the 1st prototype

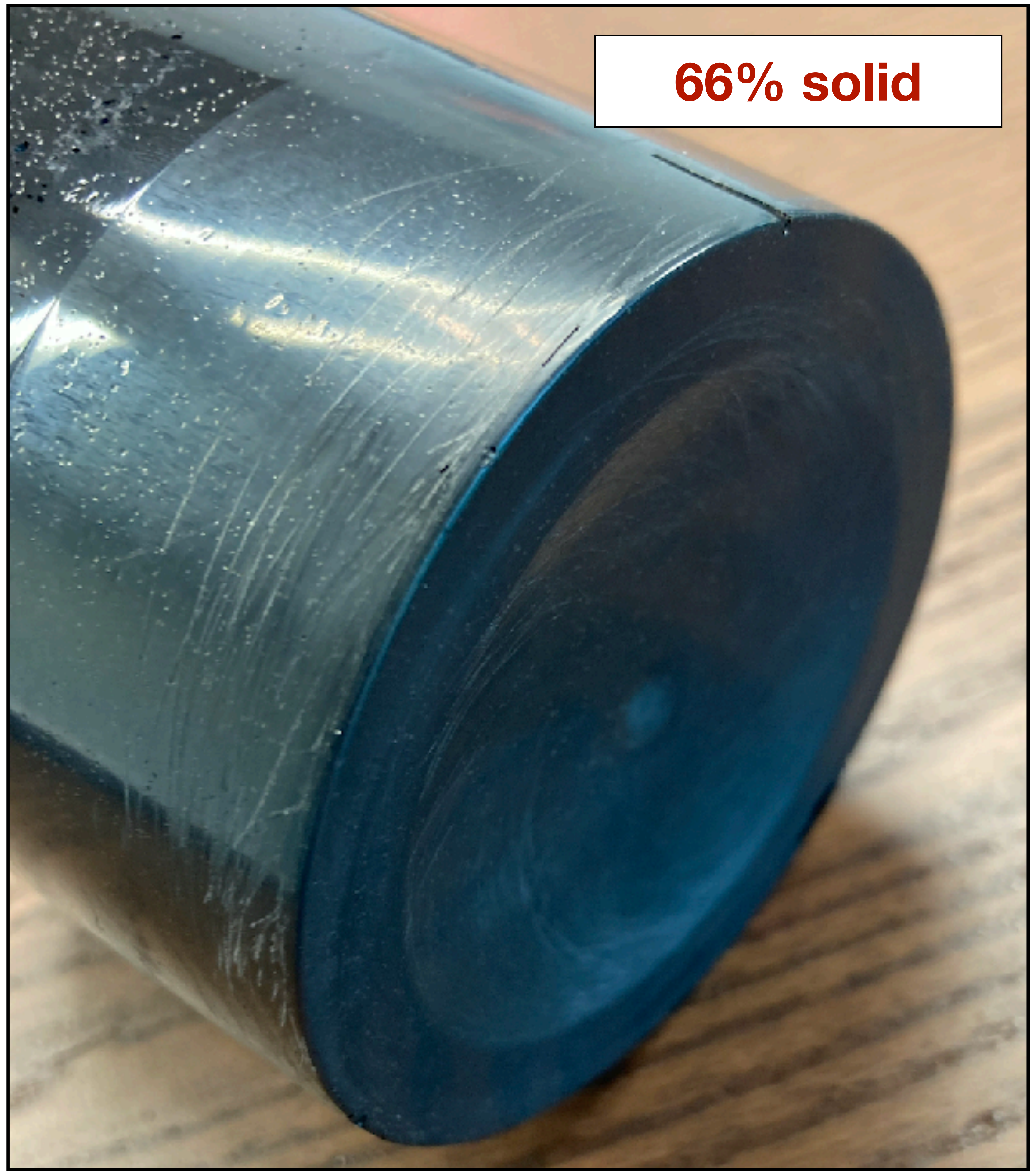
- Mix NiO and polyethylene in same proportion as used in 1st prototype (65% NiO, 35% polyethylene)
- **Percentages of total solid mass used in prototype (119 g)** are shown for this amount of epoxy











- Previous mix looks smooth in some regions in contact with container, but this is likely due to non-uniform mix (more epoxy near the sides?)
- The 66% solid mix seems to adapt more smoothly to the container

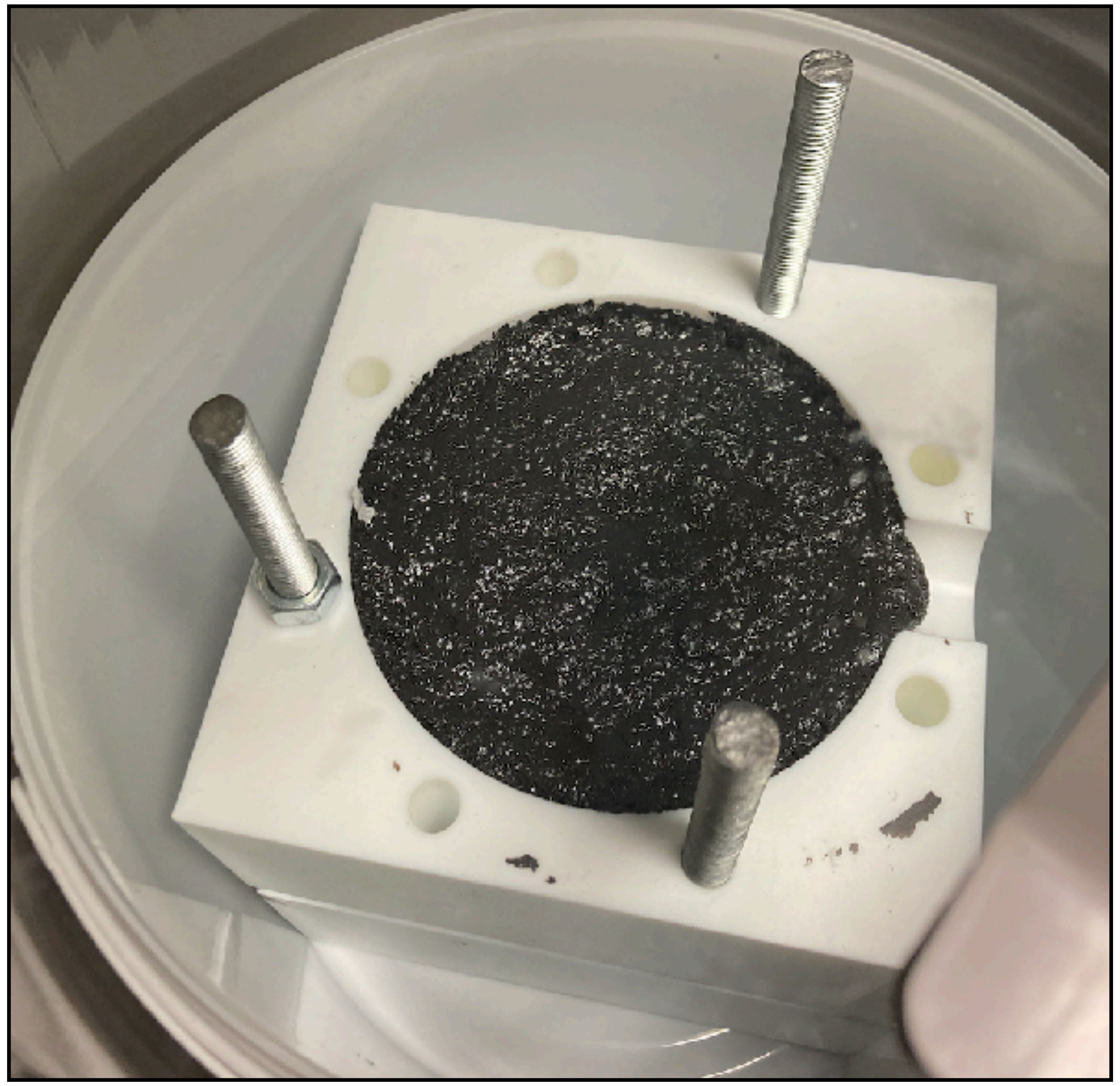
Prototype 2

Placing solid into mould:

- ***With enlarged mould*** and 70% solid mass
- Mixture is still viscous, but does “flow” slowly; still requires use of spoon to transfer to mould
- Expansion is much more dramatic when pulling vacuum

Before vacuum/curing

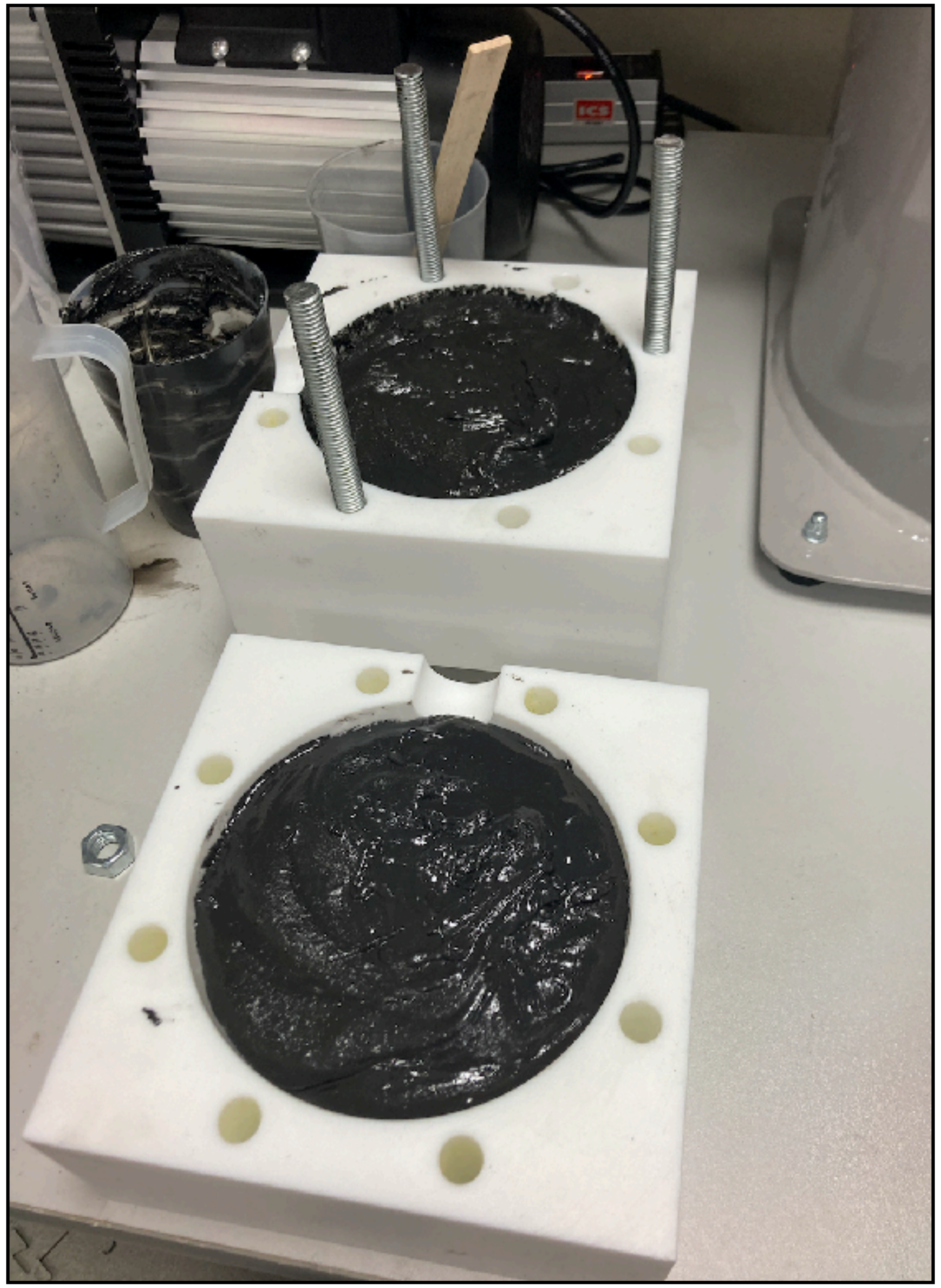
While curing in vacuum



Full sphere:

- **Too much expansion**
  - Mould was not even fully filled, and a large amount of material leaked out in vacuum chamber
- Expansion occurred in prototype 1 but is much more evident here (with relatively more epoxy
- ***Will likely need to follow same strategy except cure without vacuum***
  - Will still pull vacuum on epoxy + hardener mix before mixing in the solid

2 layers in each half



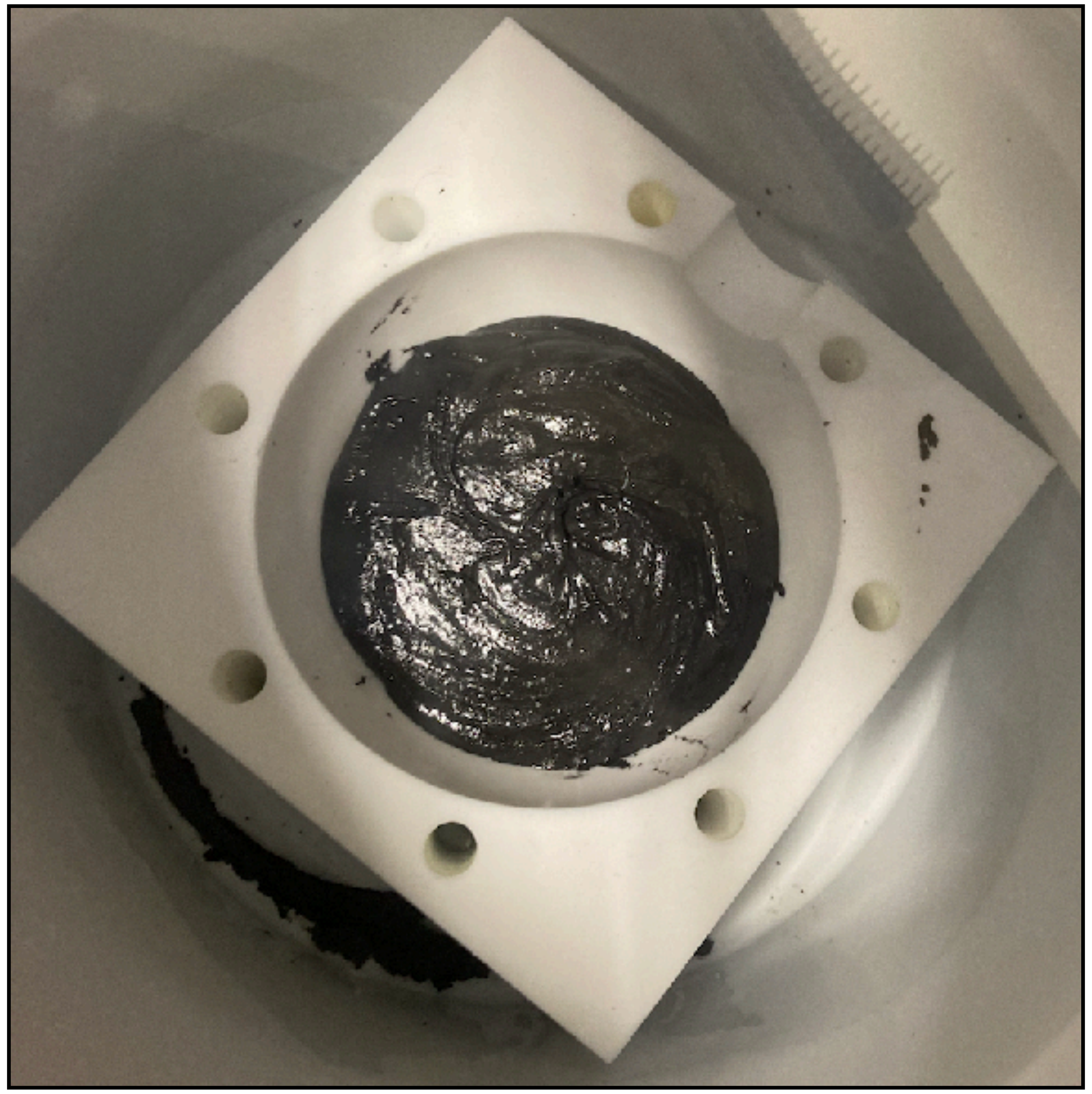
Final sphere, after curing

Prototype 3
(Definitive?)

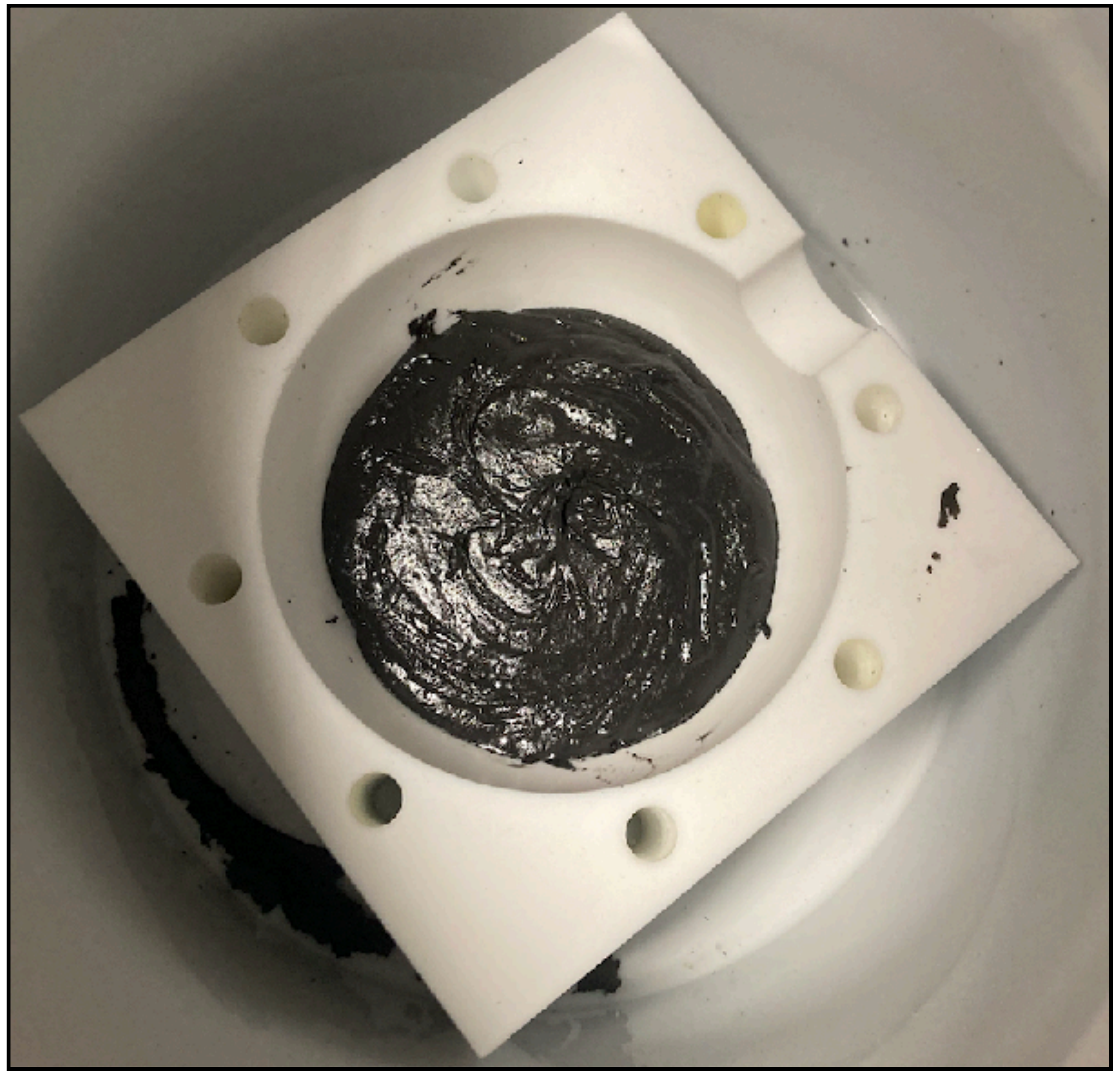
Test layer for prototype 3:

- ***Cured with no vacuum***
- Some holes visible when cut →

Before vacuum/curing



After curing (no vacuum)



Soak tests
(preparation)

Cleaning of samples:

- *Clean in bags filled with isopropyl alcohol + ultrasonic bath (10 mins)*

Before ultrasonic bath

After ultrasonic bath

Cleaning of samples:

- ***Clean in bags filled with isopropyl alcohol + ultrasonic bath***

Before ultrasonic bath

Plastic, after ultrasonic bath

- ***Still some (red) residual from hand saw***

Cleaning of samples:

- ***Clean in bags filled with isopropyl alcohol + ultrasonic bath***

Before ultrasonic bath

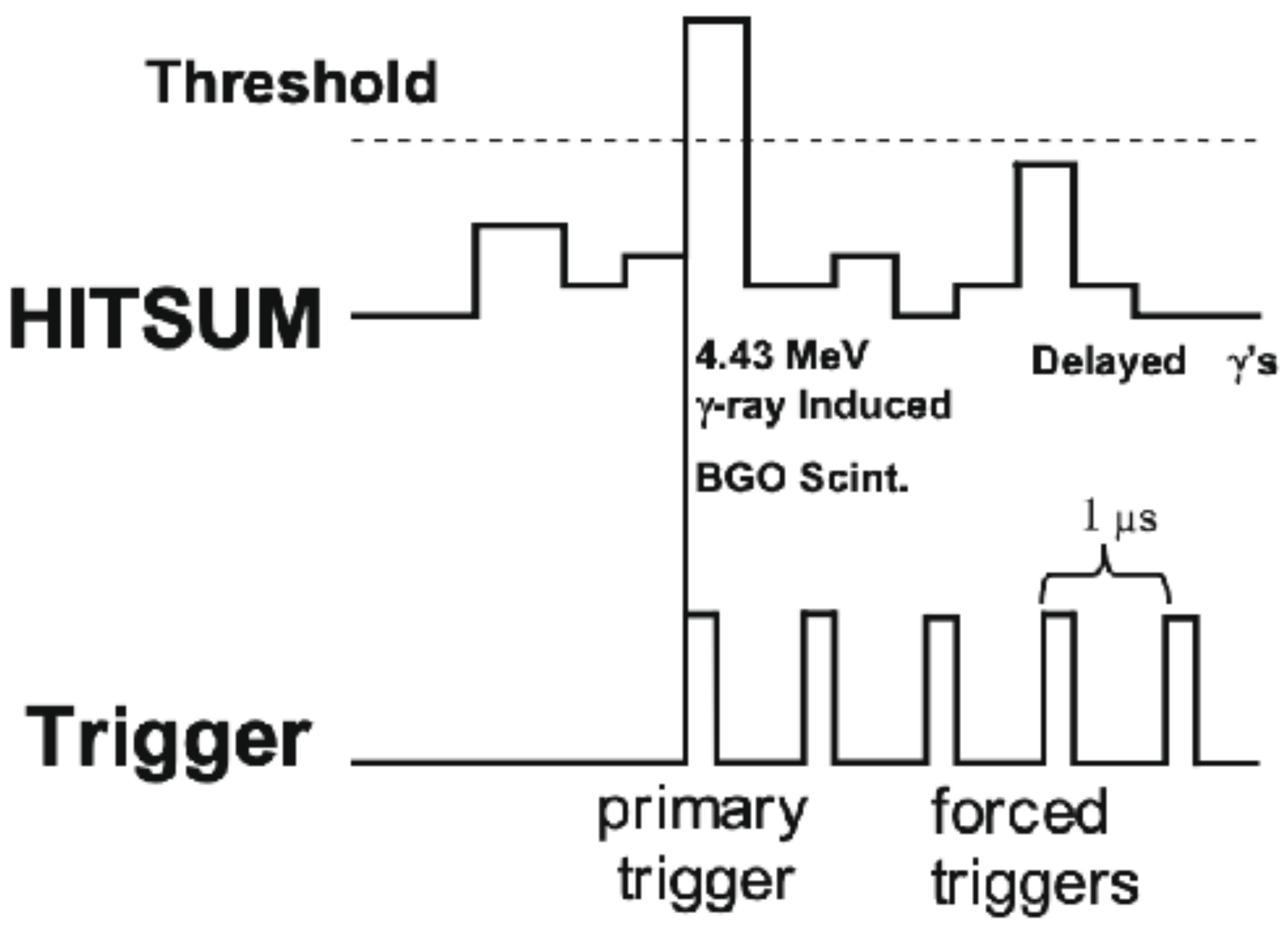
Plastic, after ultrasonic bath + sanding

- ***Red residual has been removed***

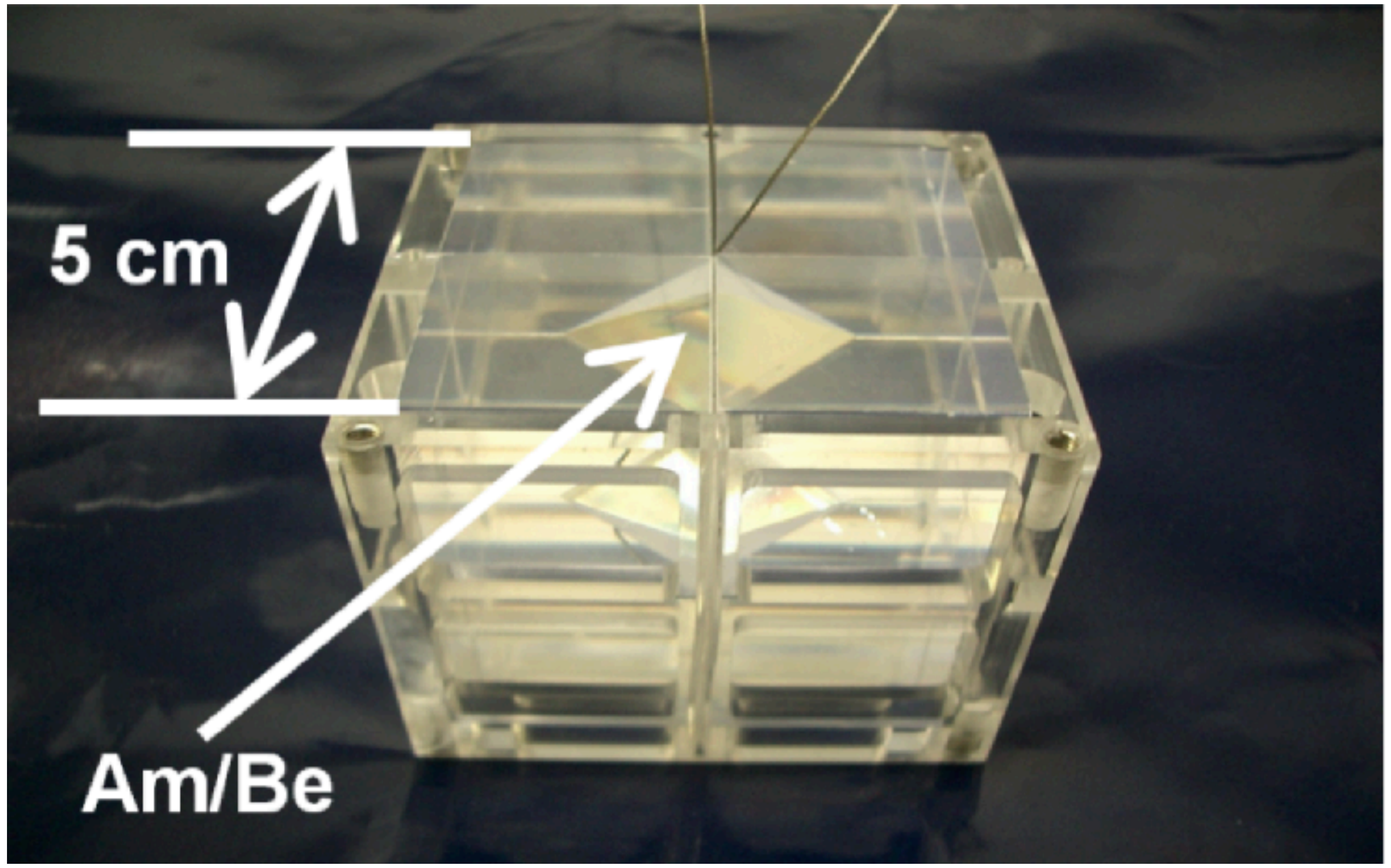
AmBe source

AmBe source

- Acrylic case containing BGO scintillators surrounding an AmBe neutron source
- Tagging (~4.4 MeV gamma emitted in coincidence with a large fraction of neutrons) was done by SK PMTs

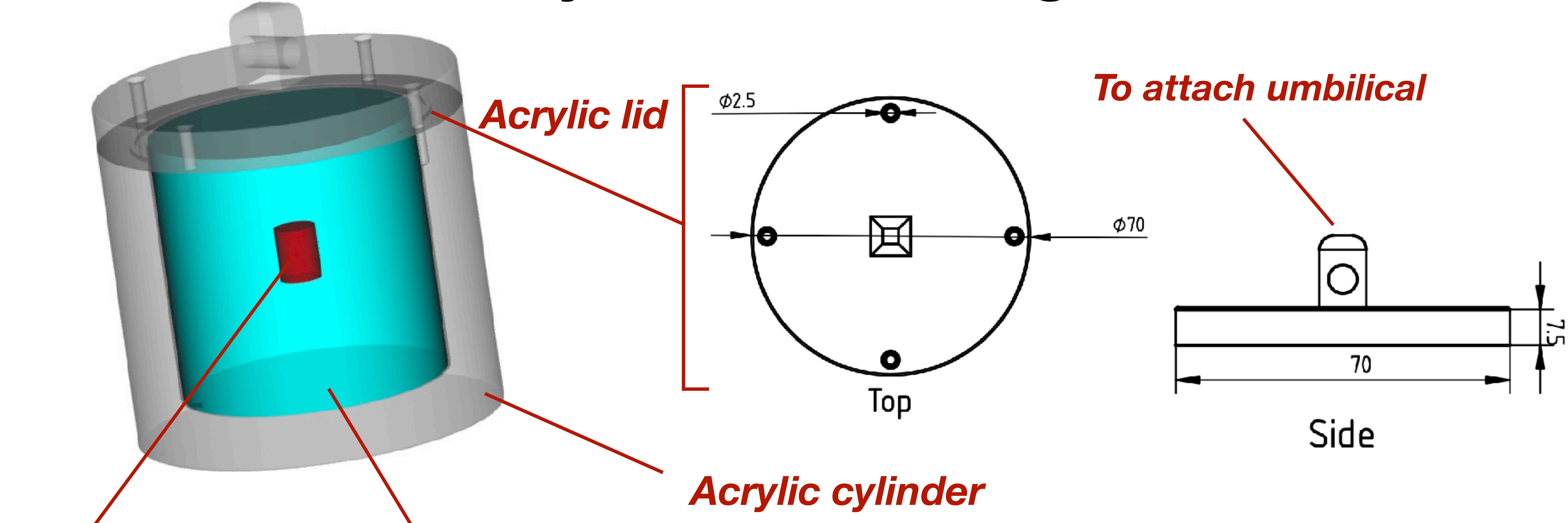


Tagging: *trigger on sum of analog PMT signals within 200 ns, (from H. Watanabe et al. Astropart. Phys. 31, 320 (2009))*

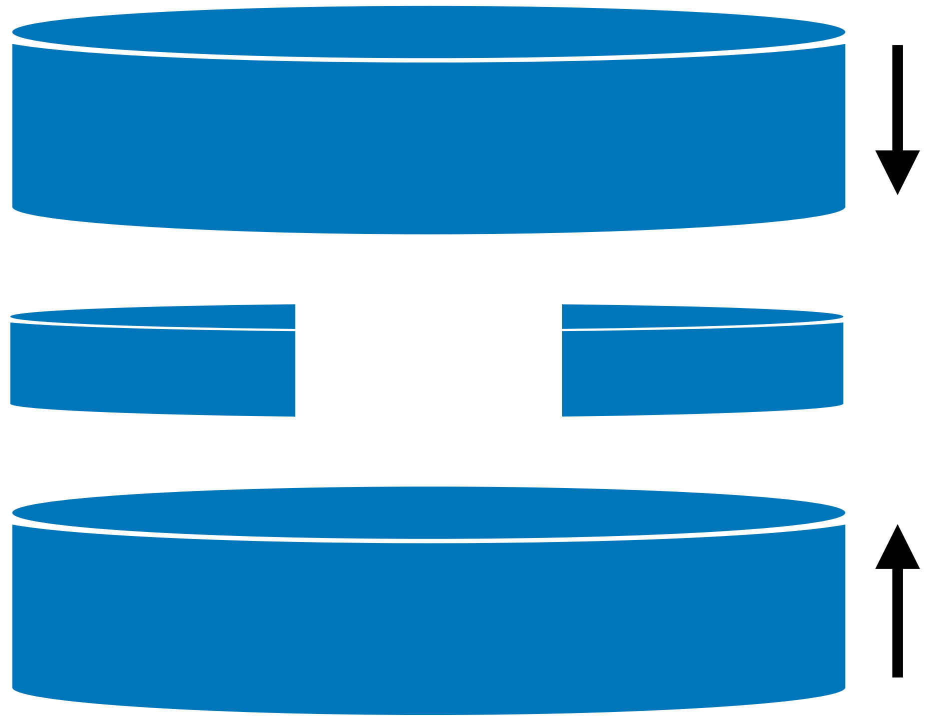


SK AmBe source *(from arXiv:2209.08609)*

AmBe source: cylindrical design



- Current plan is to use 3 crystals, 1 containing a hole for the encapsulated source

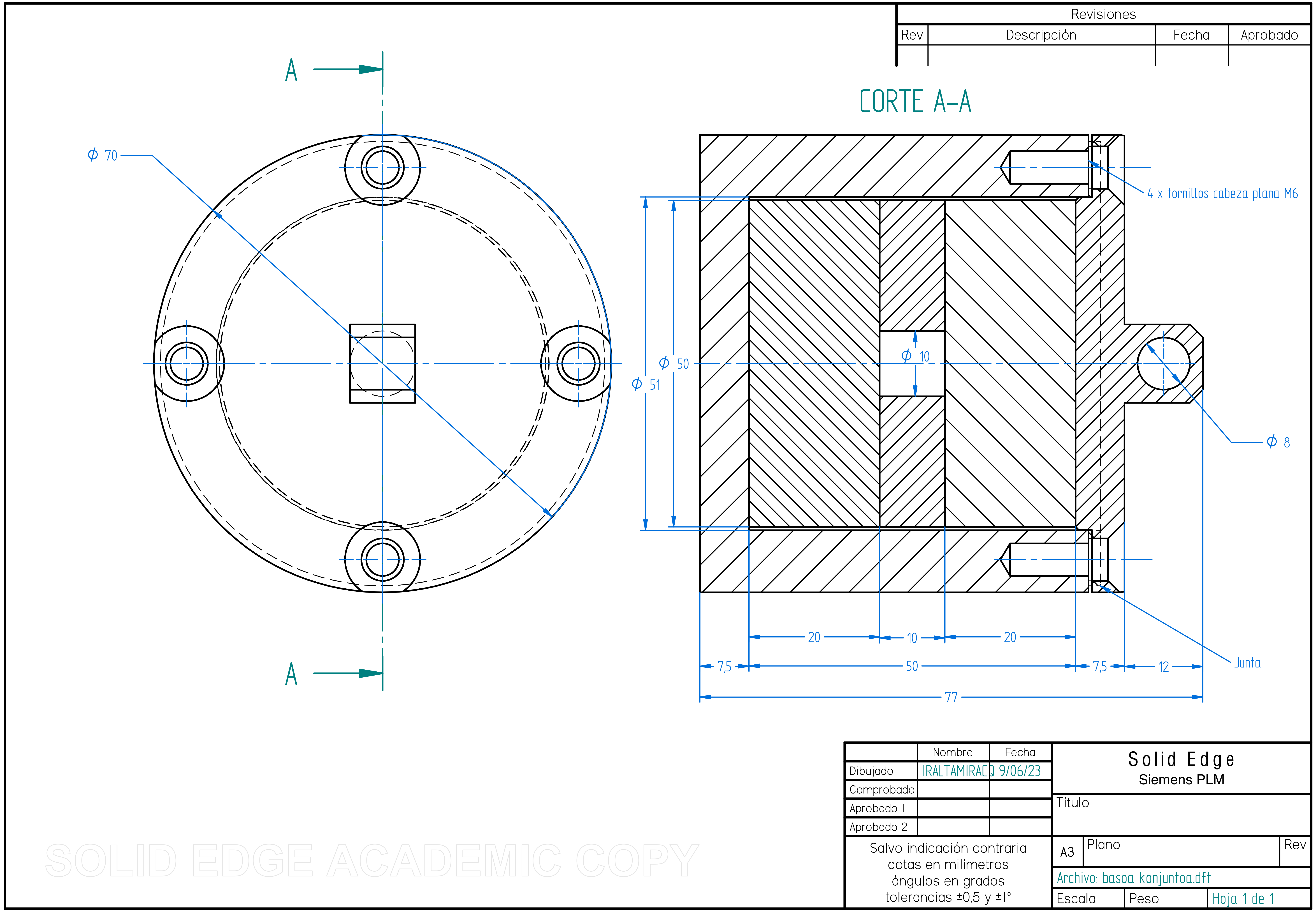


Current status:

- **Ordered and received a bar of cast methacrylate (7 cm diameter) to be machined into enclosure and lid**
  - Cut a 30 cm piece to be sent for machining
- **BGO crystals:**
  - Will use 3 crystals (2 cm length + 1 cm length with hole for source + 2 cm length)
  - Initial quote of approx. 5700€
  - Second quote of approx. 4115€: just received two 2 cm length crystals from this company

Current status:

- Updated plans for machining methacrylate bar, from **Iñigo Alkorta et al.** (Fabrikazio Mekanikoko mintegia, Izarraitz Lanbide Heziketa)



Encapsulated sources

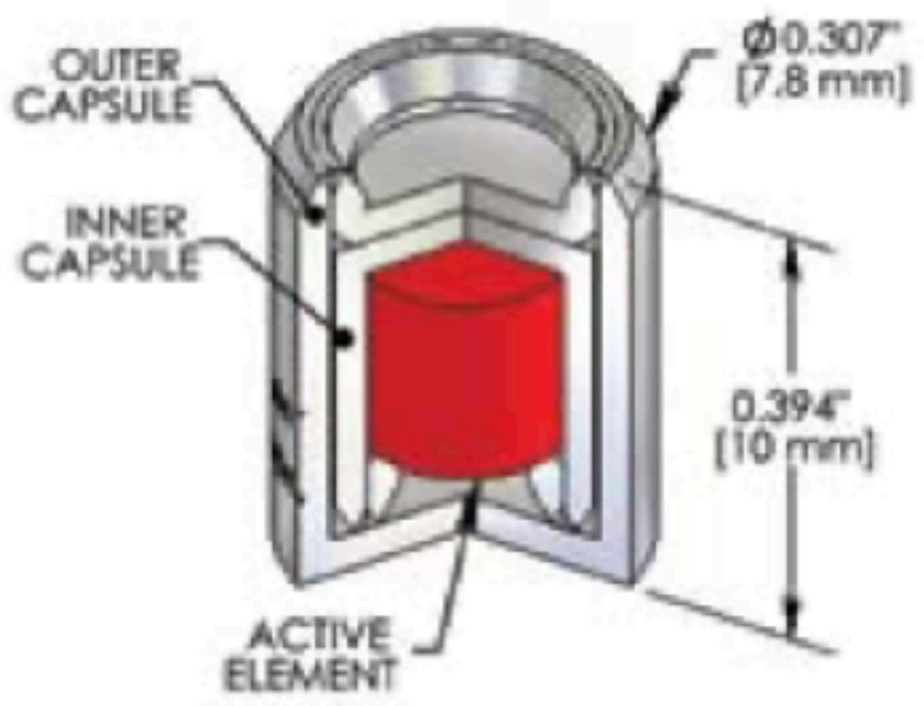
(From Eckert and Ziegler)

- **Am/Be**

~100 µCi Am activity in WCTE

N02 capsule

Double-encapsulated stainless steel source; stable, homogeneous active element. ISO rating: C66545



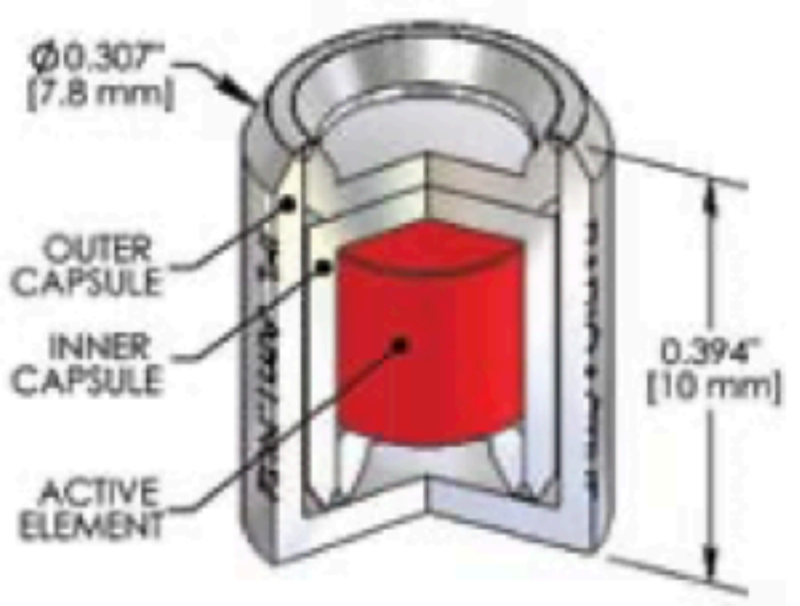
Nominal Activity		Part Numbers	Regulatory
mCi	MBq	N02	SS&DR / SFC
1	37	AM1N020001M	Yes / Yes
10	370	AM1N020010M	Yes / Yes
40	1480	AM1N020040M	Yes / Yes
100	3700	AM1N020100M	Yes / Yes
			Availability: 8-10 weeks

- **252Cf**

~5-10 µCi in WCTE

3036 capsule

Double-encapsulated stainless steel source. ISO rating: C66545



Nominal Activity		Part Numbers	Regulatory
mCi	MBq	3036	SS&DR / SFC
0.0001	0.0037	CF230360100N	No / No
0.005	0.185	CF230360005U	No / No
0.01	0.37	CF230360010U	No / No
0.5	18.5	CF230360500U	No / No
1	37	CF230360001M	No / No
			Availability: 4 weeks

Intermediate activities are available upon request.

Summary

- **NiCf source:**
  - Two attempts at a prototype source have been carried out
  - 1st prototype sent to a company for machining (smoothing surface, drilling hole for rod): initial results show improved surface; will drill 1 cm hole
  - 2nd prototype looks unusable (too much expansion in vacuum)
  - Will attempt a 3rd prototype without applying vacuum

- **AmBe source:**
  - Materials being ordered for prototype
    - Methacrylate rod for enclosure has arrived and is being machined
    - Ordered 2/3 BGO crystals

Future plans / comments

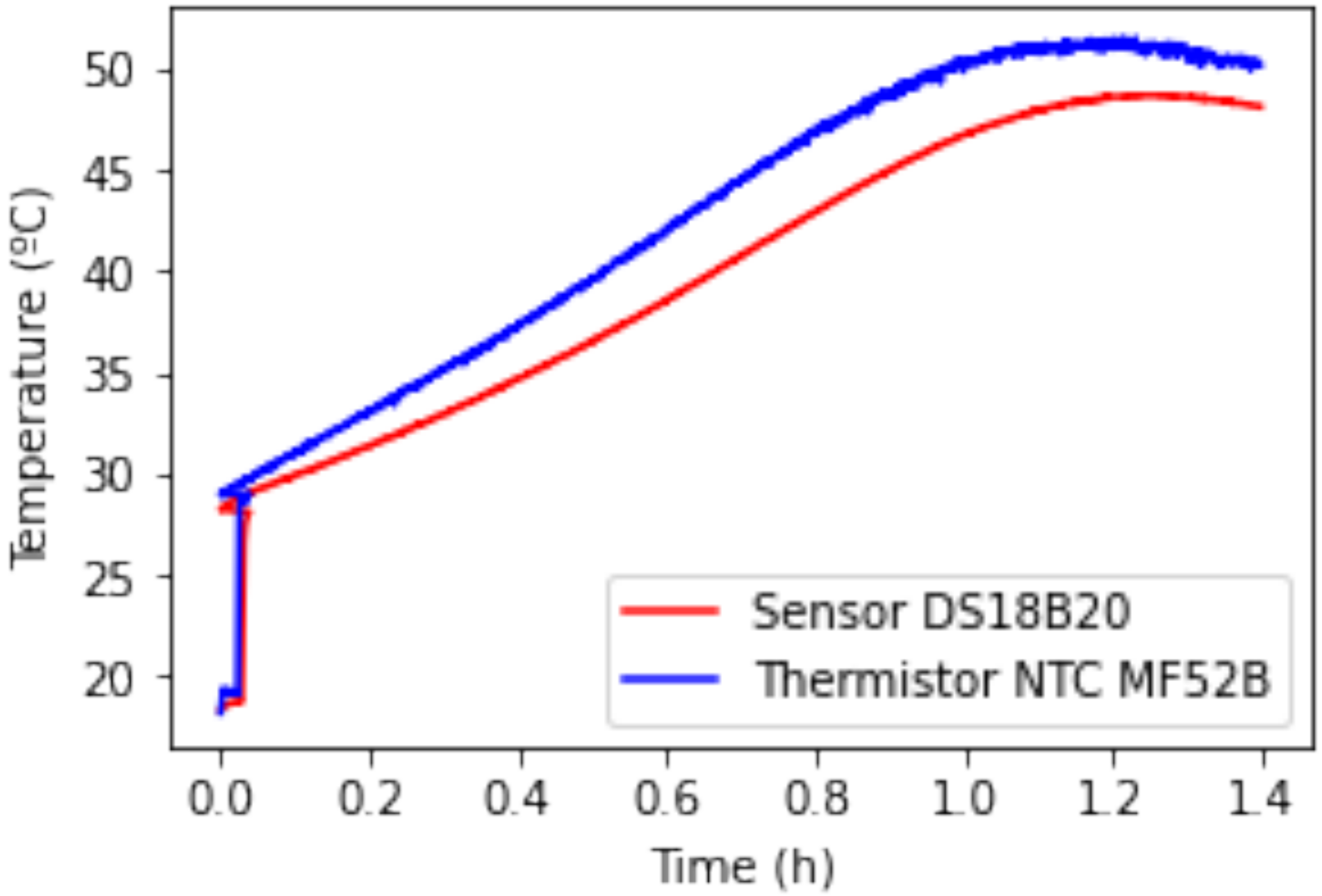
- **Items currently in process:**
  - Final NiO ball (to be made + machined in September)
  - AmBe enclosure machining
  - Soak tests (samples prepared, to be sent to Sheffield)
- **Items to be addressed:**
  - Encapsulated sources (purchase through CERN)
  - Final (1 cm) BGO crystal for AmBe source (depends on final capsule size)
  - Umbilical connector (talk to Oliver)
- **Important items for which plans are less developed:**
  - **Rod for nickel source (Izarraitz group will help construct)**
  - **Tests**

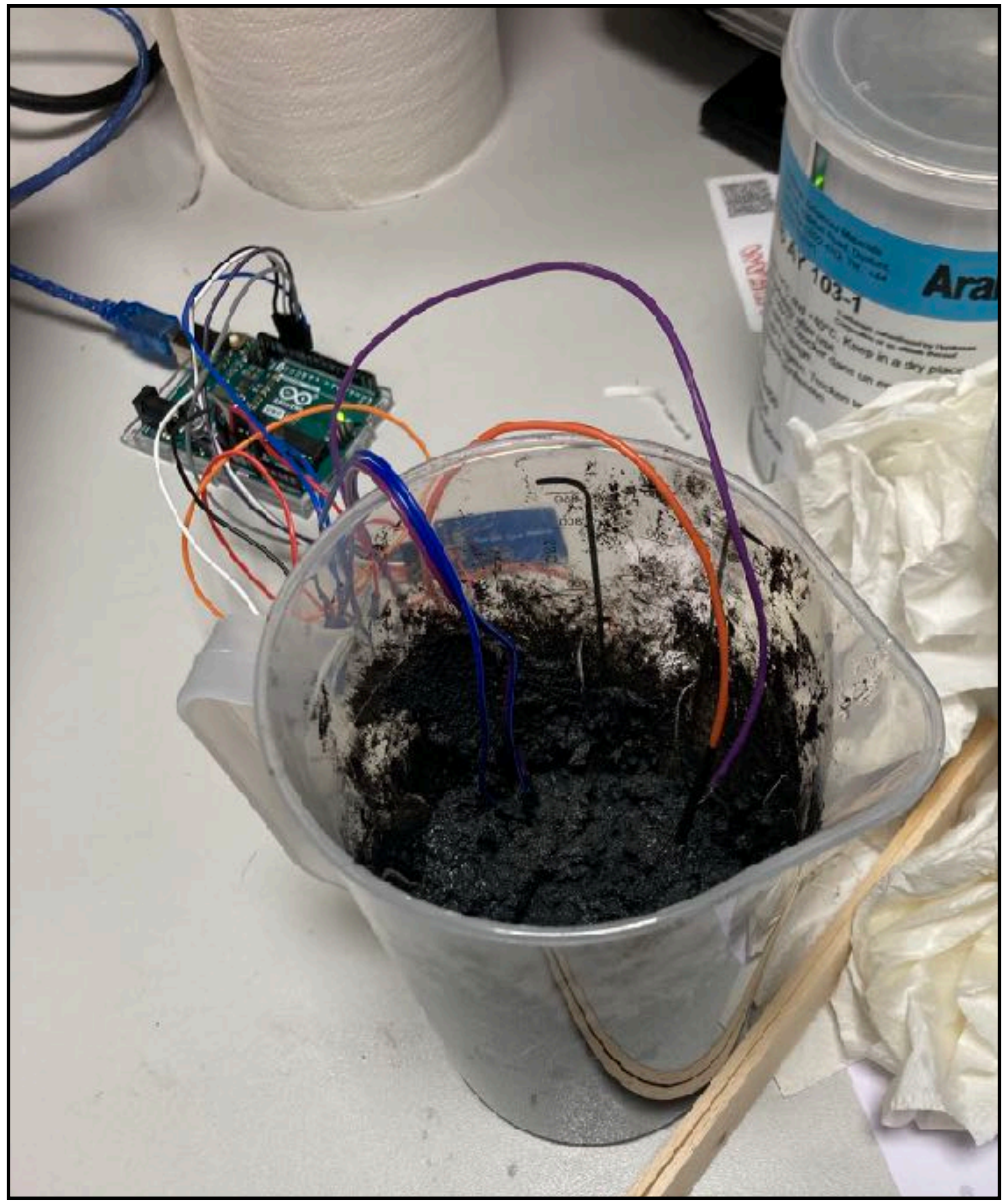
First prototype:

- Rough surface
- One interface between 2 layers clearly more discontinuous than the others
- The side of the mould that was packed more firmly turned out better

Temperature measurement:

- Measured temperature in a test layer with 2 sensors





Budget for NiCf source (principal items):

Component	Cost (€)
Teflon mould	935.72
Vacuum chamber + pump (approx)	726
Electronics	651.22
NiO (2 kg)	371.47
HDPE (1 kg)	348.48
Hardener HY956 (1 kg)	51.73
Araldite epoxy (1 kg)	627.75
Total	**3712.37**