Metal evaporation study using the GANIL high temperature oven for intense metal ion beamsproduction.

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Abstract

A new resistive oven dedicated to the production of metal ion beams using ECR ion sources has been developed at GANIL [1]. It aims to produce beams such as $^{58}Ni^{q+}$, $^{50}Ti^{q}+$, $^{50}V^{q+}$ or $^{238}U^{q+}$ with ECR4 ion source on cyclotrons injectors and with Phoenix V3 ion source on Spiral 2 facility. Typical intensity about 1.2 10^{13} pps is requested for the Super Separator Spectrometer (S3). Evaporated atom fluxes and their angular distributions have been measured on a dedicated test bench thanks to a quartz microbalance. These investigations were carried out using three crucibles with various exit caps geometries for which the fluxes and angular distributions display distinct behaviors. Based on those results crucible will be designed to obtain a high flux of atoms while minimizing the losses of atoms on the ion source chamber. Experimental results and crucible designs will be discussed.

Objectives

High intensity beams productions :

$^{58}Ni^{N+}$, $^{50}Ti^{N+}$, $^{50}V^{N+}$ or $^{238}U^{N+}$ …

- With **Phoenix V3** ion source on **Spiral 2** facility: **1.2E13 pps** requested for **S3**.
- With **ECR4** ion source on **GANIL cyclotrons injectors**
- Intense **Uranium beams** development

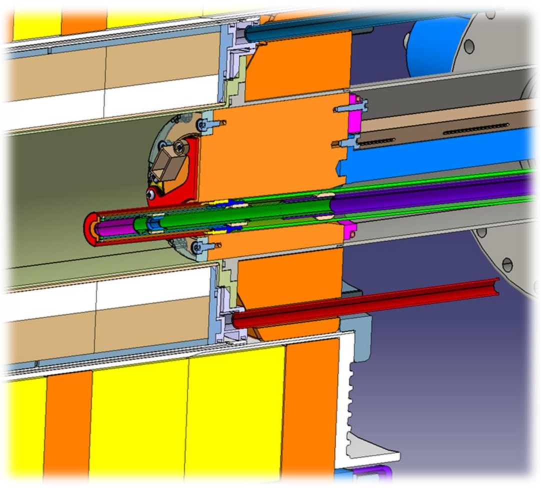
Requested temperatures

Element	T fusion °C	T (10^{-2} mbar) °C
V	1910	1826
Ti	1668	1728 (liquid)
Ni	1455	1505 (liquid)
Co	1495	1517 (liquid)
U	1132	2100 (liquid)
UO_2	2827	1990

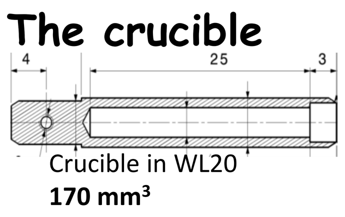
Resistive oven.

External diameter: **Φ 20**.

Cylindrical resistor in the axis of the magnetic field → no Laplace forces



The crucible

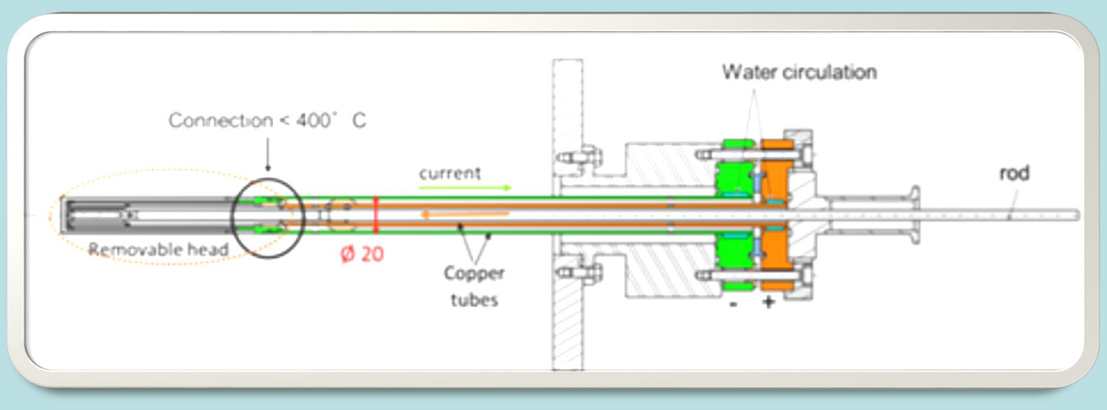


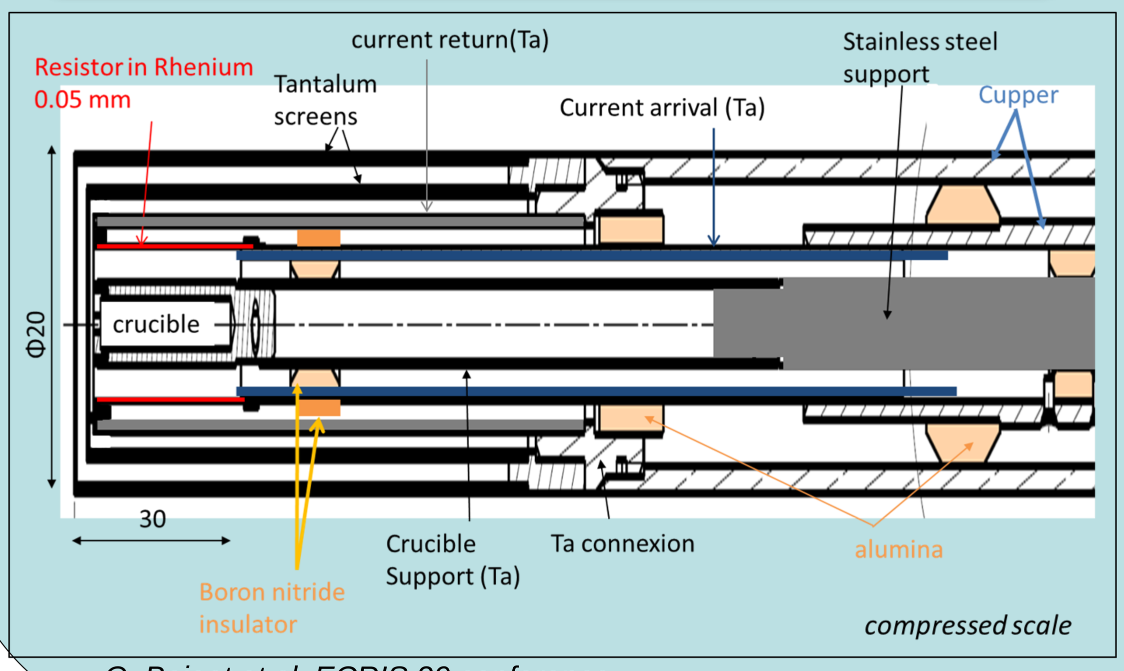
To be integrated in Phoenix V3

The resistor

Tube of Rhenium 0.05 mm thick made with a sheet melted by Laser

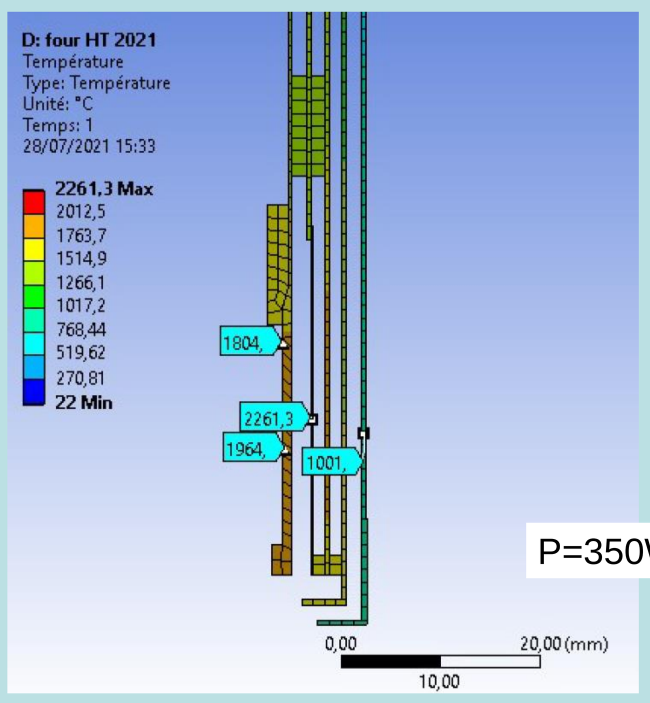
The oven design

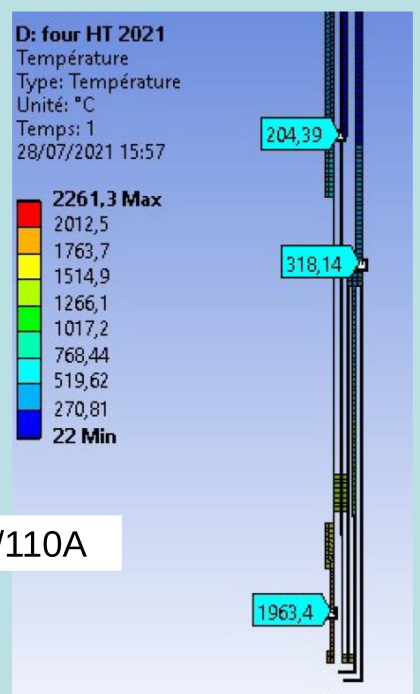




O. Bajeat et al. ECRIS 20 conference

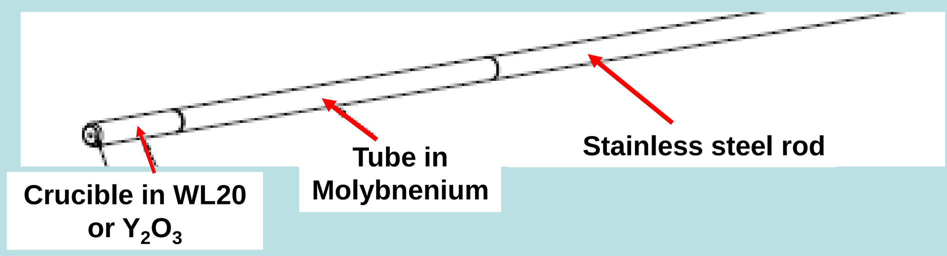
The oven is constituted of a removable head connected on two concentric copper tubes (CuCr1Zr) for the current supply. Copper tubes are cooled by water circulation in their extremities. The crucible is fixed on a sliding rod and is inserted in the center of the resistor.



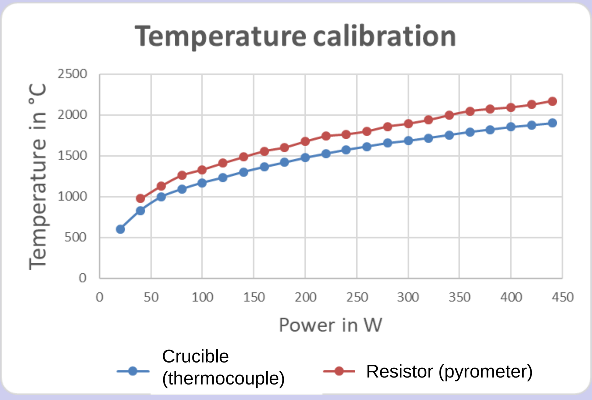


P=350W/110A

The sample-holder



Heating calibration



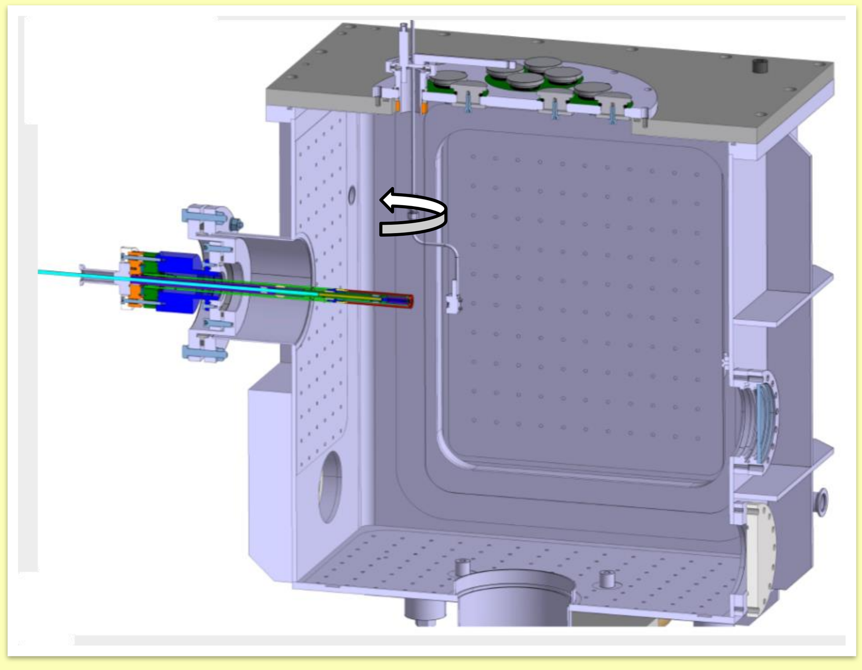
Design optimization has been done using ANSYS thermal simulations.

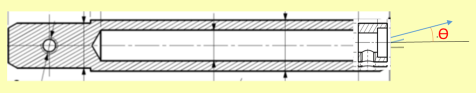
→T > 2000°C in the crucible

→T < 300°C at the junction between the removable head and the cooled copper current supplies.

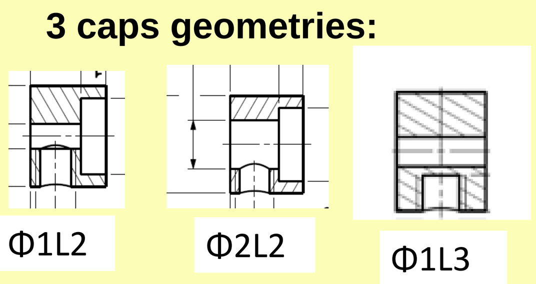
Evaporation measurement

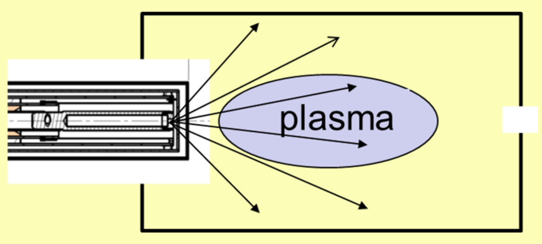
A quartz microbalance (Q-pod / 6 MHz quartz crystal) on a cooled rotating support → flux in ng/cm²/s at each angle.

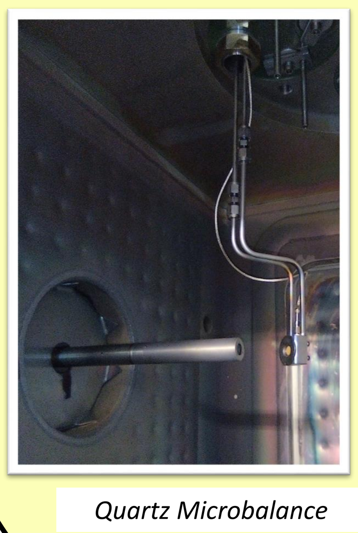




3 caps geometries:







Quartz Microbalance

Flux in $at.s^{-1}$ *in a* α *angle cone:*

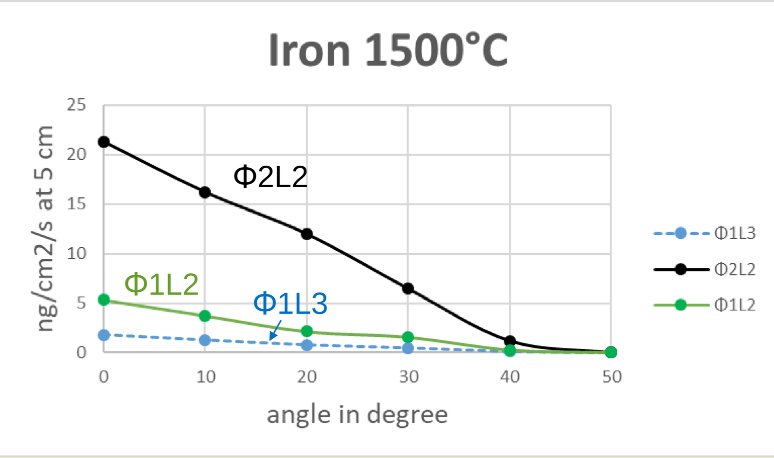
$$\phi_\alpha = 2\pi D^2 \int_0^\alpha \sin\theta\, f(\theta) d\theta$$

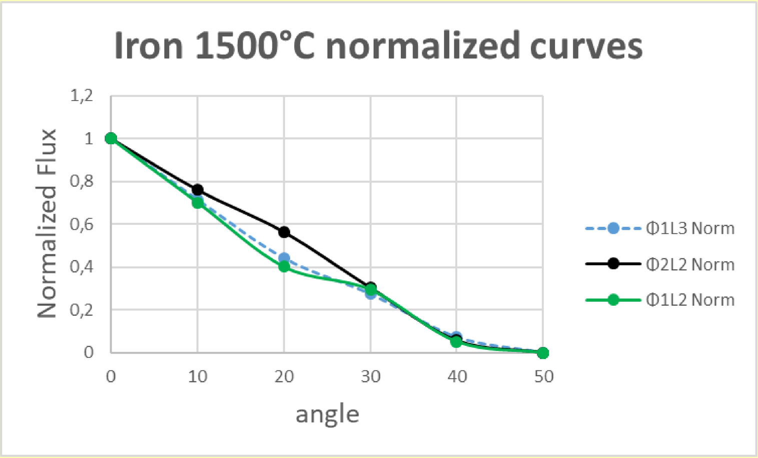
D: distance crucible exit/quartz detector

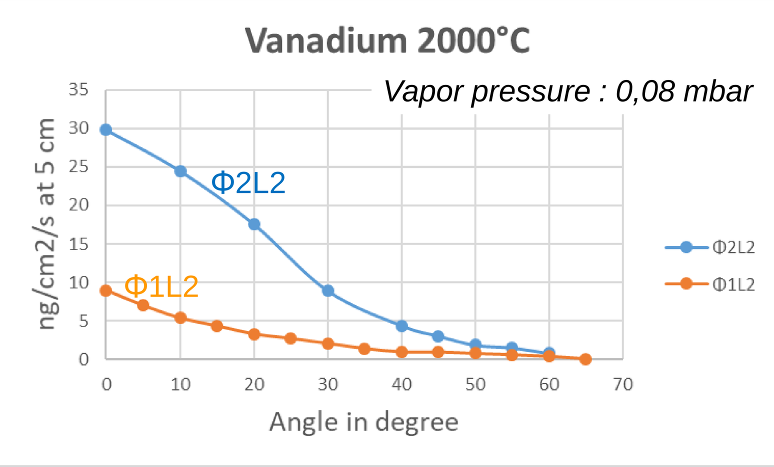
f(θ): number of at/cm2/s on the quartz at an angle θ.

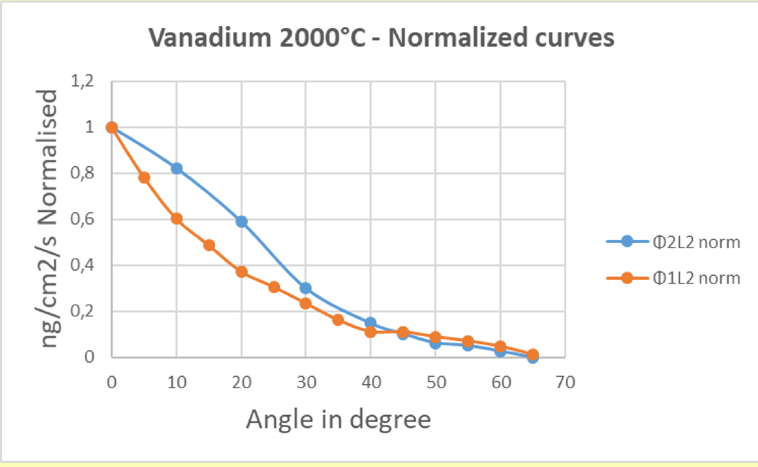
Vanadium 2000°C	Flux in 20°	Fraction emitted in the 20° cone
Cap Φ2L2	$2{,}3.10^{15}$	~ 37 %
Cap Φ1L2	$5{,}2.10^{14}$	~ 33 %

Angular distributions

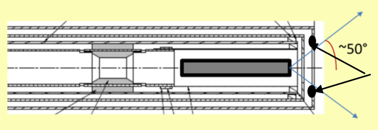








- Vanadium consumption rate deducted from flow measurements: **1.9 mg/hour** at the beginning – **0.85 mg/hour** after 19 hours
- Real consumption weighed after 22 hours of heating: **2.3 mg/hour** (losses onto screens)



- The oven reliability at the requested temperature for Vanadium has been confirmed.
- The hole Φ2 cap seems the best choice (larger flow and no big differences on losses at large angles)

Vanadium beams production with ECR4 on Ganil injector

Validation of the oven integrated in ECR4 on Ganil Injector for Vanadium beam production.

- Support gas: **Helium**
- Oven heating power : ~ **330W** / 111A (**T > 2000°C**)
- V^{n+} beam up to **120 µAe (V^{7+})**
- Duration limited by the deformation of the sample-holder

Underway → new test for long duration using modified sample-holder: support tube in Molybdenium instead of Tantalum.