

# $^{163}\text{Ho}$ distillation and implantation for the **HOLMES** experiment

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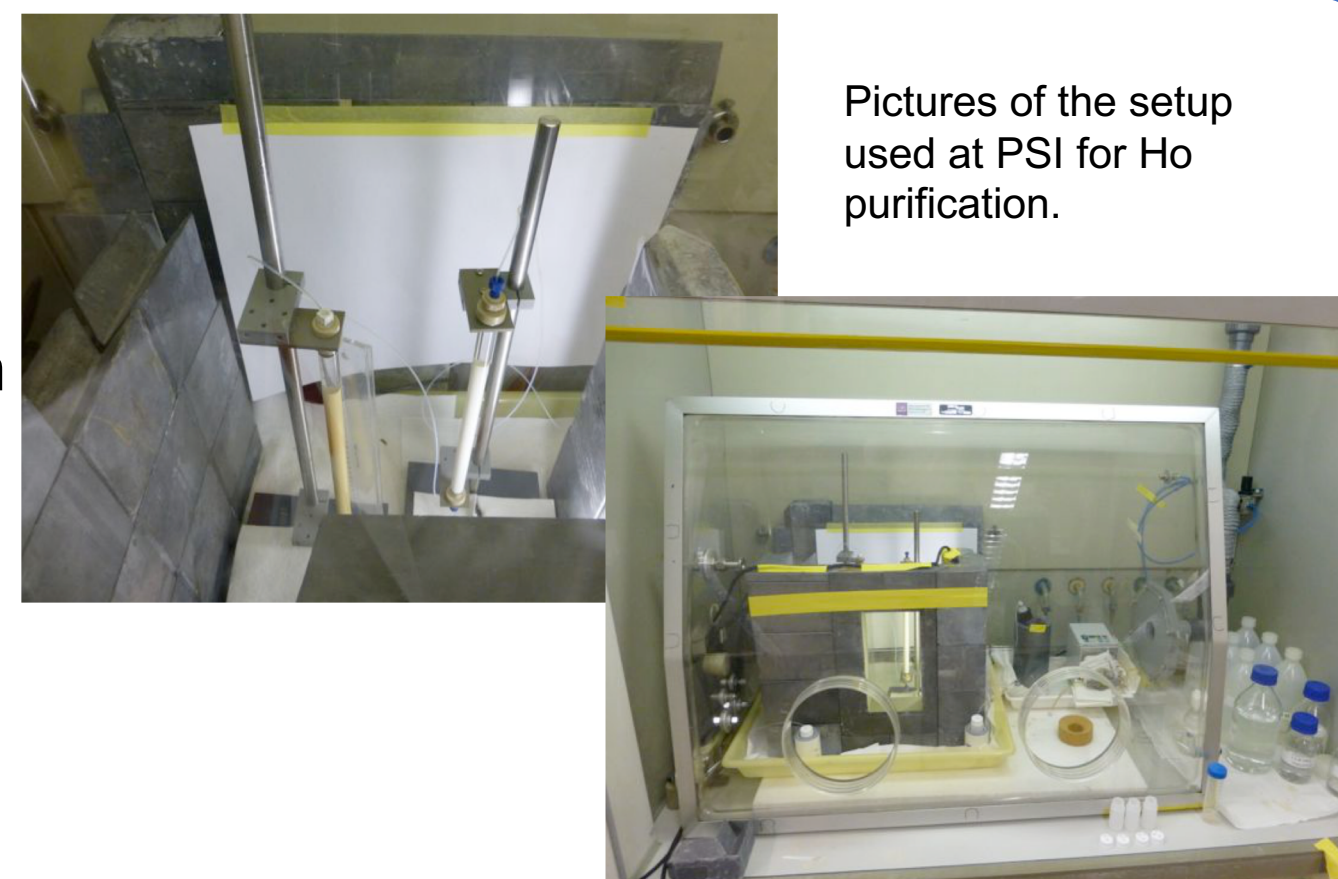
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The HOLMES experiment aims to directly measure the  $\nu$  mass with a calorimetric approach [1]. The choice of  $^{163}\text{Ho}$  as source is driven by the very low decay Q-value ( $\sim 2.8$  keV), which allows for high sensitivity with low activities ( $O(10^2)\text{Hz/detector}$ ), thus reducing the pile-up probability.

$^{163}\text{Ho}$  will be produced by neutron irradiation of  $^{162}\text{Er}_2\text{O}_3$  then chemically separated; anyway, traces of others isotopes and contaminants will be still present. In particular  $^{166\text{m}}\text{Ho}$  has a beta decay ( $\tau \sim 1200\text{y}$ ) which can induce background below 5 keV. The removal of the contaminants is critical so a dedicated system has been set up. It is designed to achieve an optimal mass separation @163 a.m.u. and consists of two main components: an evaporation chamber and an ion implanter. The first item is used to reduce Ho in metallic form providing a target for the ion implanter source. The implanter is made by the sputter source, an acceleration section, a magnetic dipole, a x-y scanning stage and a focusing electrostatic triplet. In this contribution we will describe the procedures for the Holmium “distillation” process and the status of the machine commissioning.

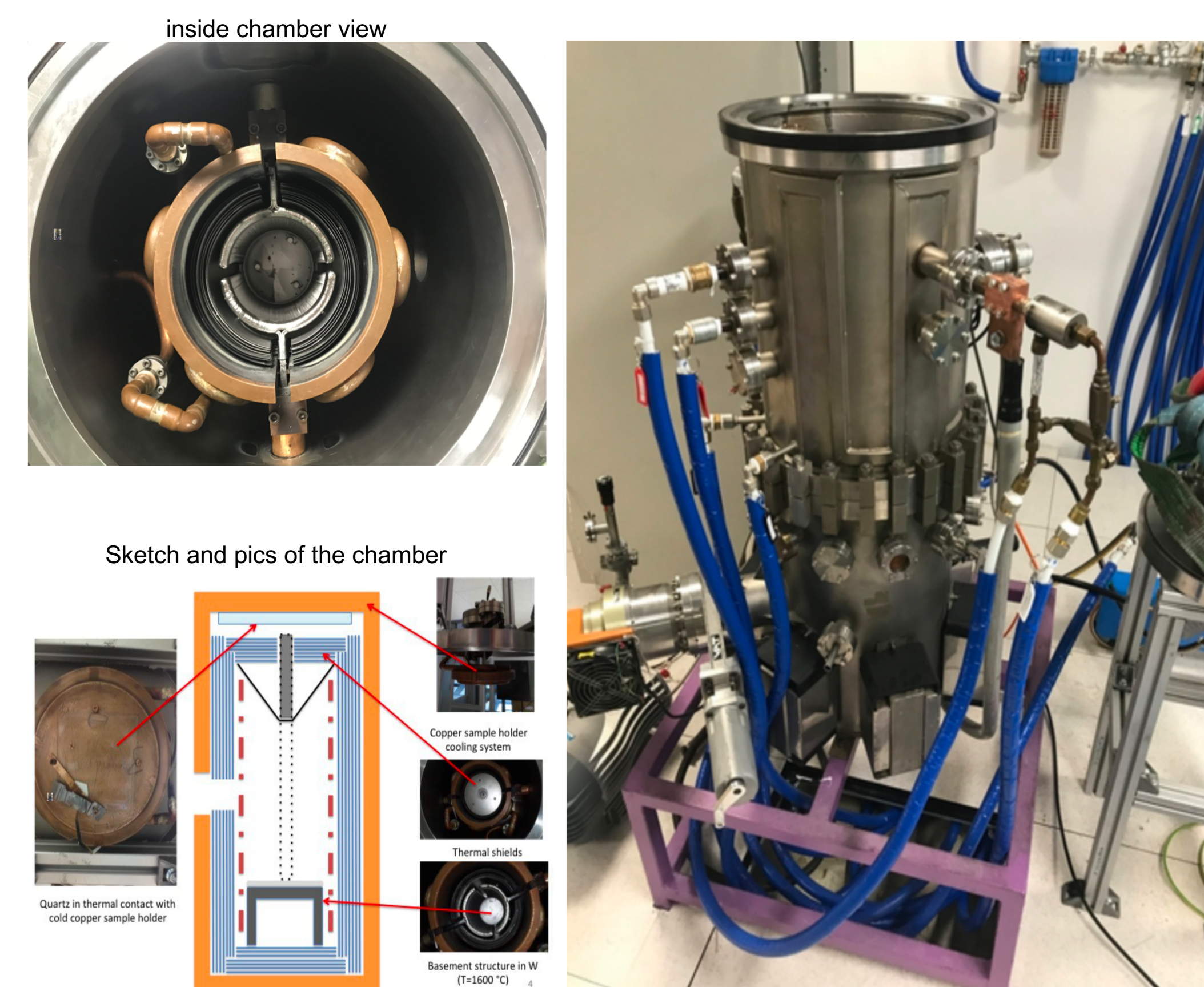
## $^{163}\text{Ho}$ production and purification.

$^{163}\text{Ho}$  is produced by neutron irradiation of  $\text{Er}_2\text{O}_3$  enriched in  $^{162}\text{Er}$  at the ILL (Grenoble, France). Unfortunately, a lot of impurities and contaminants are produced together with Ho during this process. The unwanted species different from Ho will be chemically removed at PSI (Villigen, CH) by means of an ion exchange chromatography procedure [2]. The efficiency of this process has been estimated to be around 80% on a 120  $\mu\text{g}$  Er batch and about 98% on a 18  $\mu\text{g}$  Er batch.



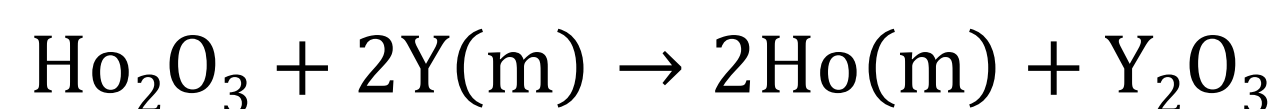
## Holmium reduction.

A dedicated evaporation chamber has been set-up for Ho reduction. The  $\text{Ho}_2\text{O}_3$  sample is placed in a small alumina crucible positioned inside a cylindrical oven that could reach temperatures as high as 2300 K. The oven is thermally isolated by nine tungsten shields from a water cooled copper support, where the quartz substrate is fixed. A hole is bored on each shield in a such a way to allow the evaporated Ho flowing from the crucible to the substrate. The whole system is set in a vacuum chamber which could reach pressures as low as  $10^{-8}$  mBar.

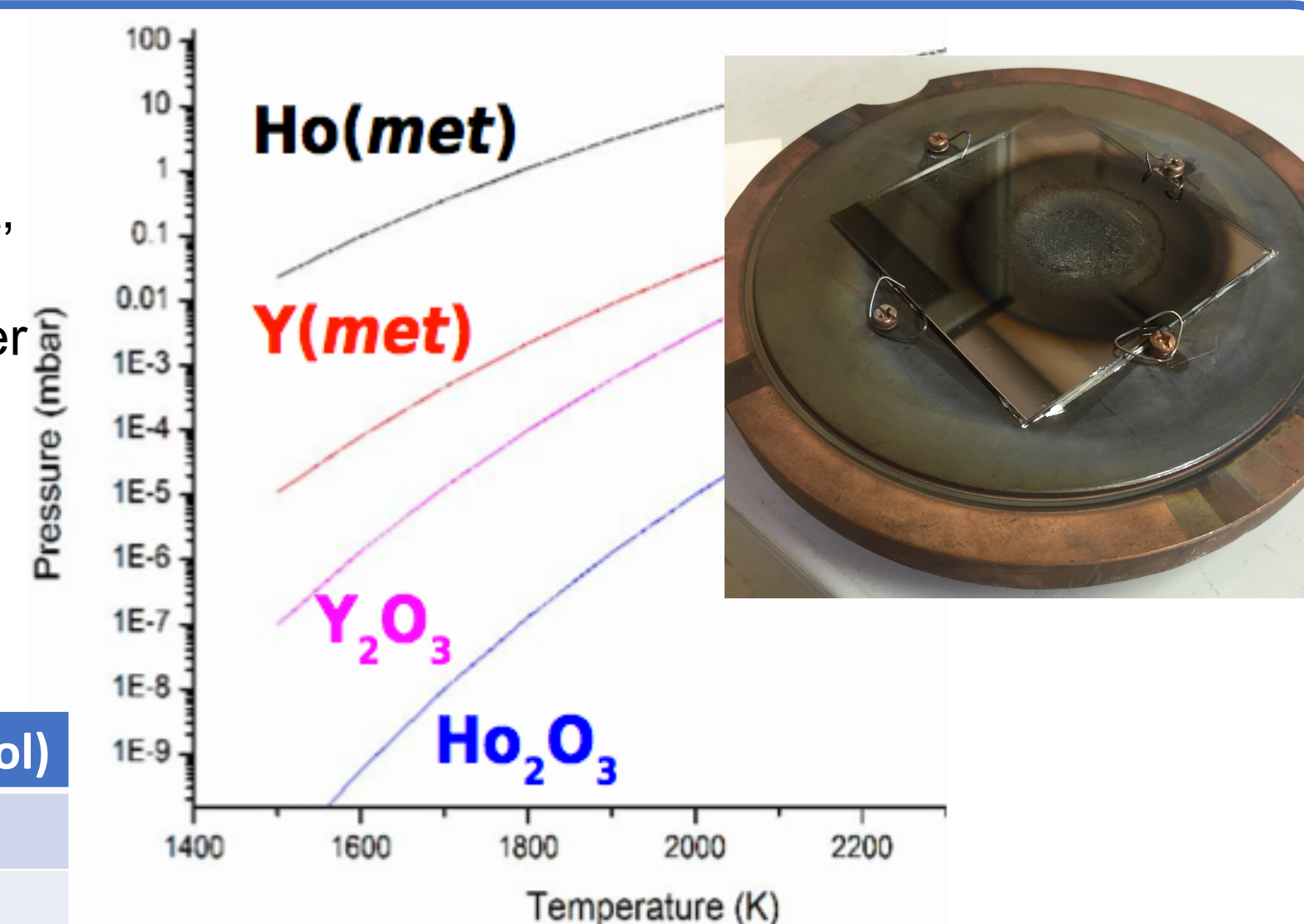


## Distillation process:

in order to avoid chemical shifts of the end-point, only Ho in metallic chemical form must be embedded in the detectors. Due to the  $\Delta G$  higher than holmium one, metallic yttrium can be used for Ho reduction by means of the reaction:



Metal	Melting Point (C)	Oxide form	$\Delta G$ (kJ/mol)
Ho	1460	$\text{Ho}_2\text{O}_3$	-1791.1
Y	1526	$\text{Y}_2\text{O}_3$	-1816.2



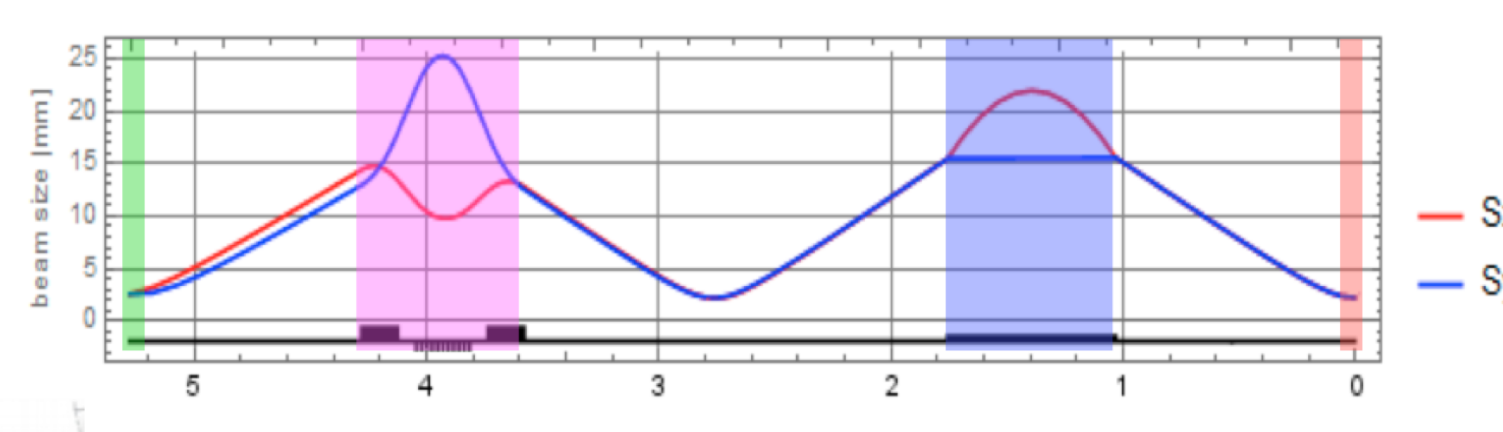
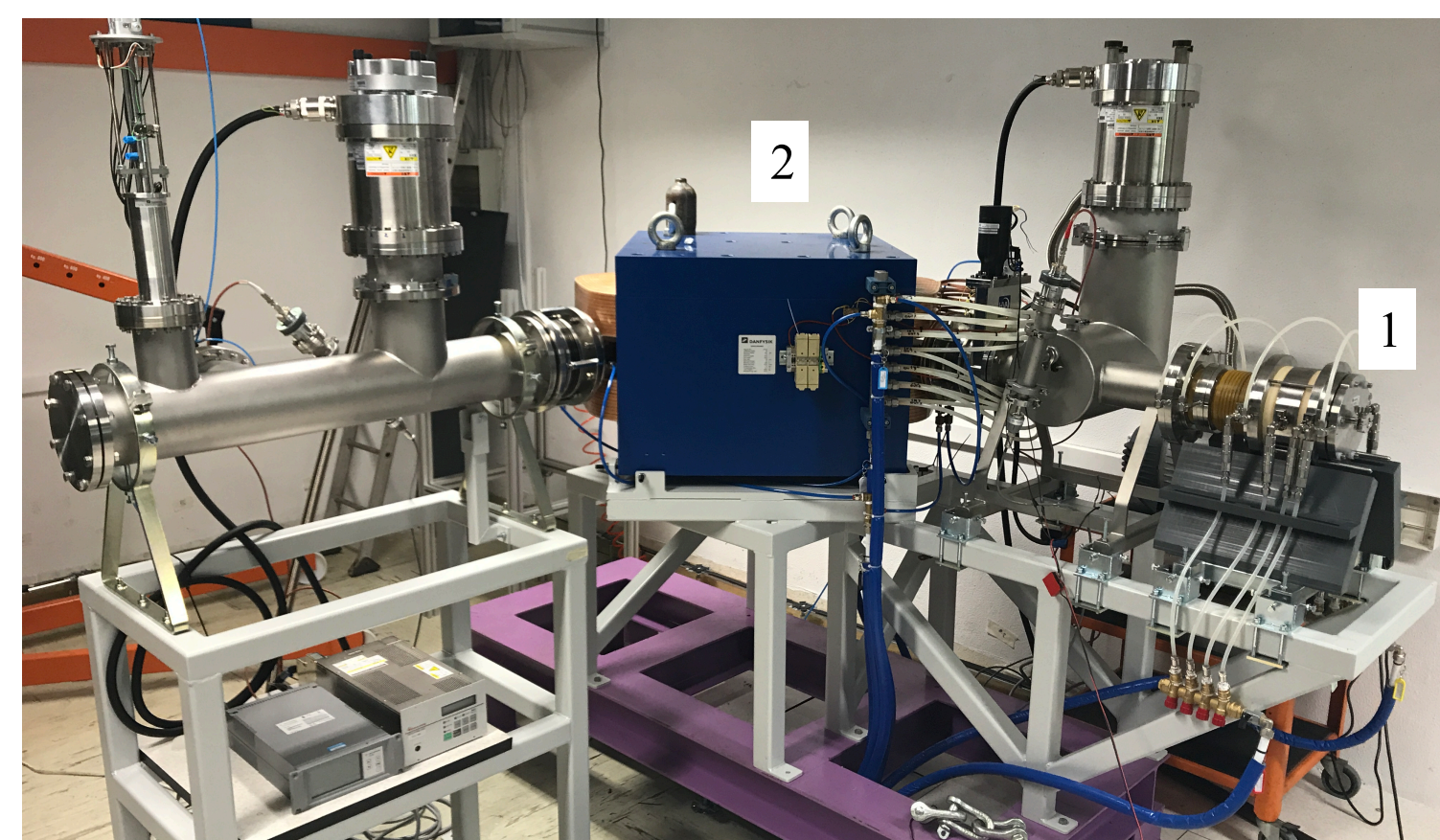
A quartz substrate is used for Ho evaporation because of its high resistivity to thermal deformation. A gold thin film has been deposited on quartz substrate in order to allow an easy Ho film removal. Moreover, the gold high reflectivity helps to avoid excessive heating of substrate. The crucible is heat up to 1900 K to melt yttrium and speed up the reaction. Being the Y vapor pressure 3 order of magnitude lower than Ho one, Y contaminations are minimized. The efficiency of the distillation process is preliminary estimated to be  $\sim 80\%$ , determined as the ratio between the mass of the condensed Ho on the substrate and the missing mass in the crucible.

## Ion implanter.

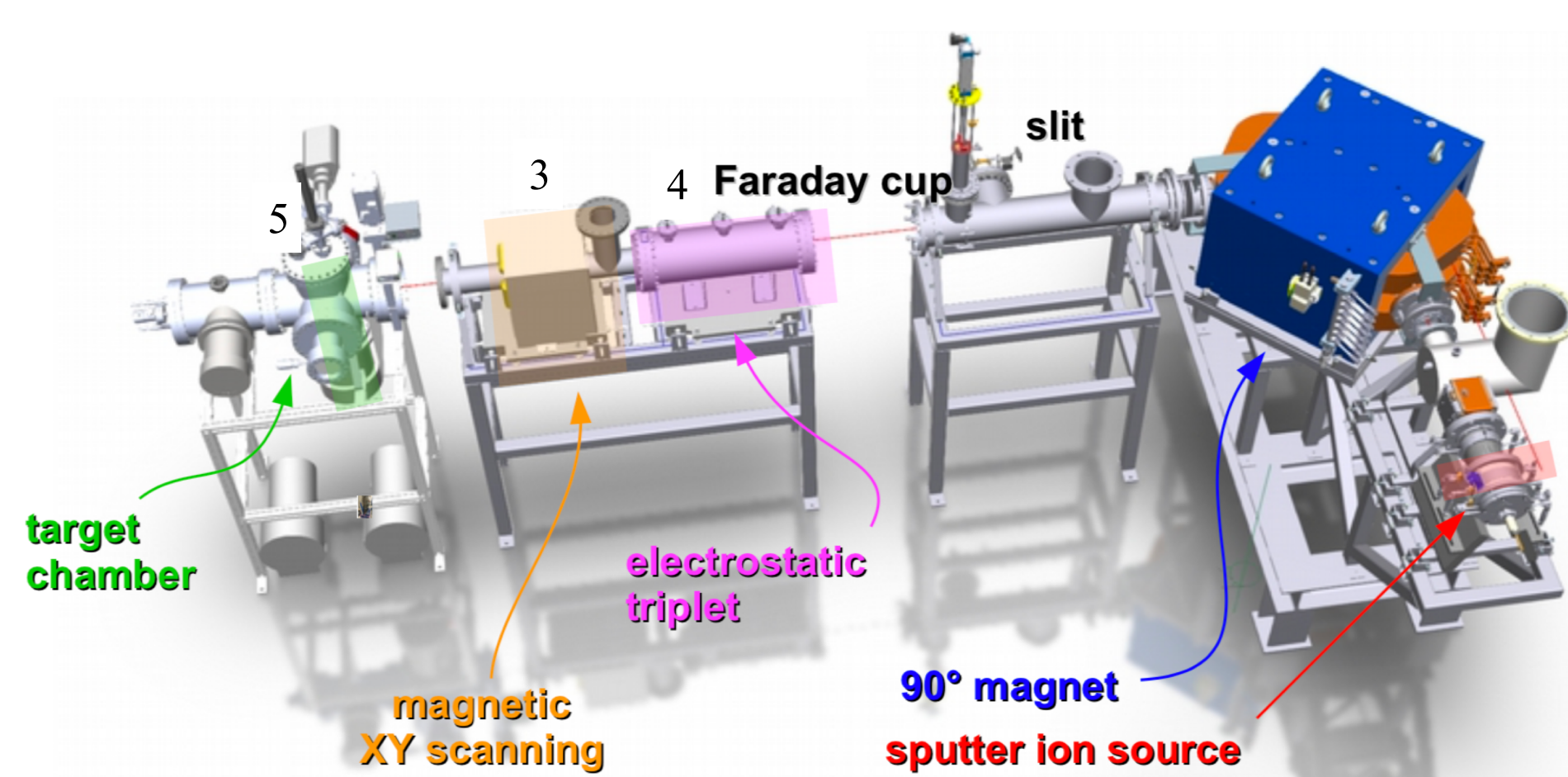
A dedicated ion implanter has been designed in collaboration with Danfysik and will be used to remove contaminations of holmium isotopes different from  $^{163}\text{Ho}$  as well as other remaining impurities.

The ion implanter consists of five main components:

1. an argon penning sputter ion source with an acceleration section allowing to reach a maximum energy of 50 KeV;
2. a magnetic dipole mass analyzer with magnetic field up to 1.1 T;
3. a magnetic scanning stage;
4. a focusing electrostatic triplet;
5. the target chamber, designed in such a way to allow simultaneous co-evaporation of gold (needed to encapsulate the  $^{163}\text{Ho}$  in the absorber after evaporation).

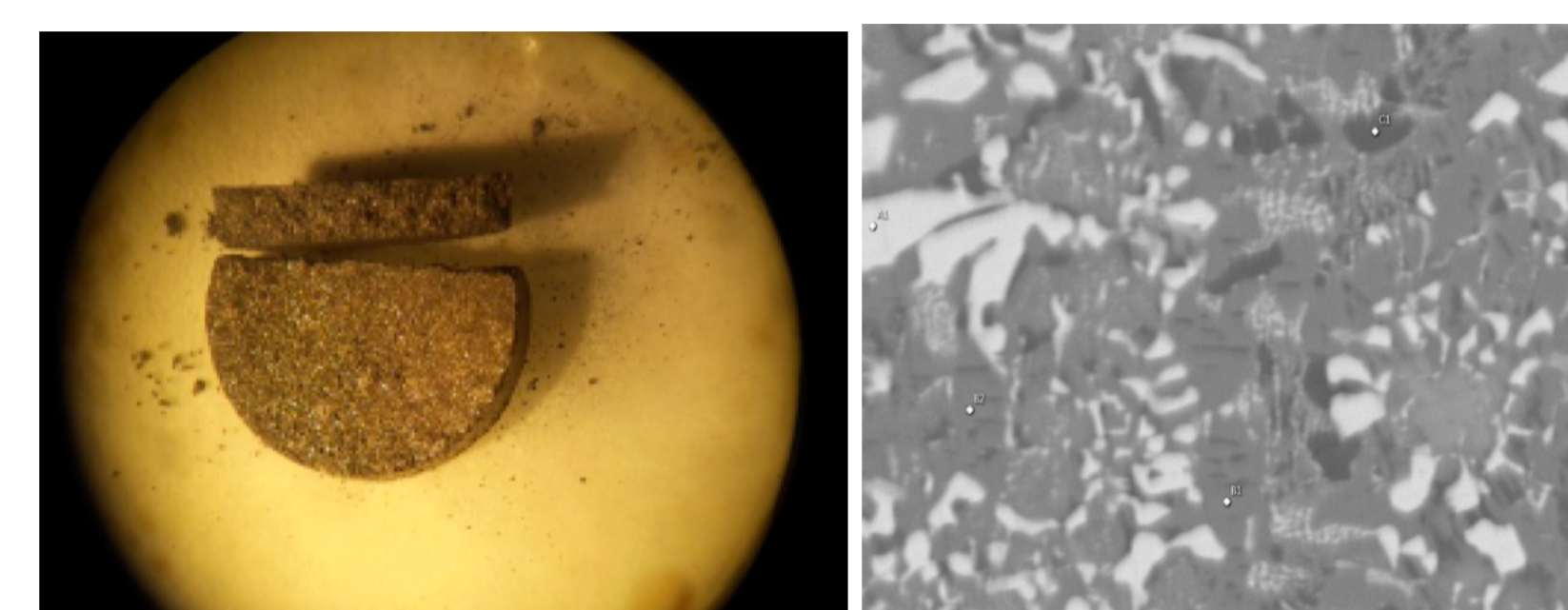


Montecarlo simulations show a beam spot of about 4mm FWHM at the target chamber. The expected 163/166m separation is supposed to be better than  $5\sigma$ . The machine is currently under commissioning in Genova's INFN laboratory.



## Sputter target production.

The sputter ion source needs a metallic cathode containing the  $^{163}\text{Ho}$  for its operation. We decided to realize a sintered sputter target, including Ho(5%) in a metallic mixture of Ti(36%), Ni(41%) and Sn(18%) fine grained powders ( $< 40 \mu\text{m}$ ). The powders compound is mixed in Ar atmosphere to prevent metal oxidation then pressed at 350 bar/cm<sup>2</sup>. The obtained target is heated at 1150 K in a low oxygen environment to improve the mechanical properties of the sinter. The crystallographic measurements and SEM-EDS analysis show two different phases: a  $\text{Ti}_2\text{Ni}_2\text{Sn}$  matrix with homogeneously distributed «islands» of  $\text{HoNiSn}$ .



- [1] B. Alpert et al., Eur. Phys. J. C (2015) 75:112  
[2] S. Heinitz et al., submitted to PLOS