

^{163}Ho distillation and implantation for the HOLMES experiment

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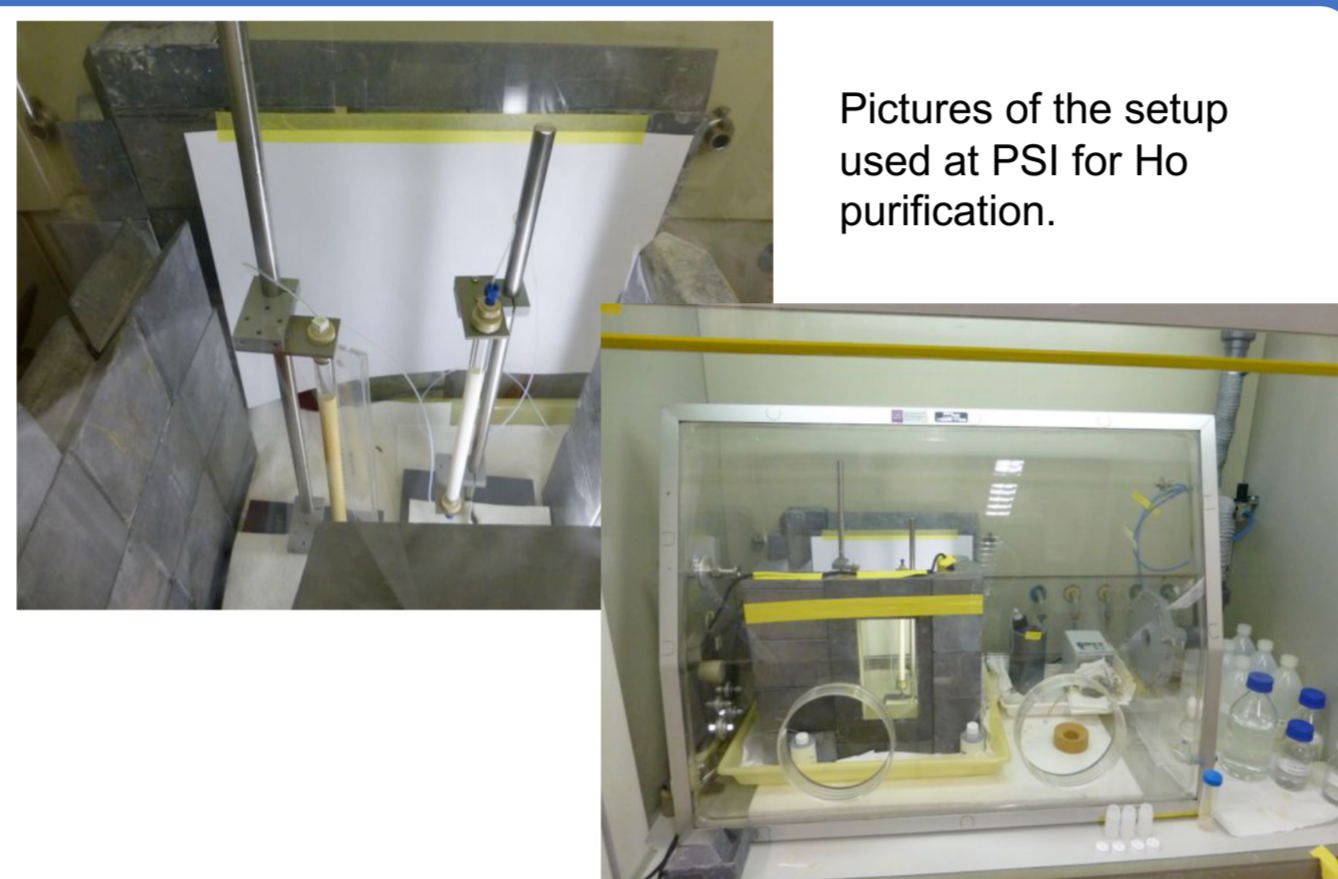
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The HOLMES experiment aims to directly measure the ν mass with a calorimetric approach [1]. The choice of ^{163}Ho as source is driven by the very low decay Q-value (~ 2.8 keV), which allows for high sensitivity with low activities ($O(10^2)$ Hz/detector),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

^{163}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 ^{166m}Ho has a beta decay ($\tau \sim 1200$ 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 whole machine.

^{163}Ho production and purification:

^{163}Ho is produced by neutron irradiation of Er_2O_3 enriched in ^{162}Er at the ILL (Grenoble, France). Unfortunately, a lot of impurities and contaminants are produced together with Ho during this process. All 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 μg Er batch and about 98% on a 18 μg Er batch.



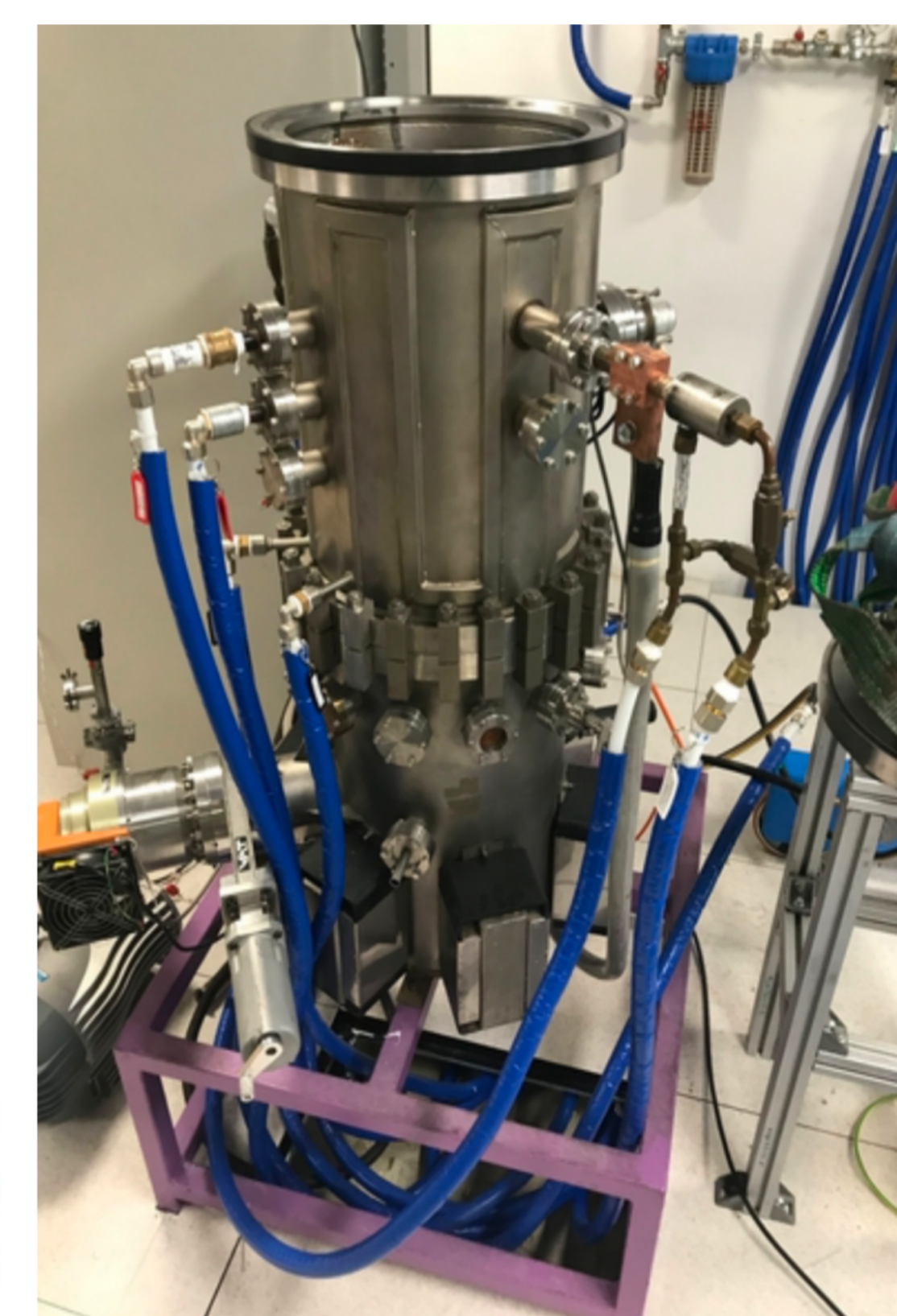
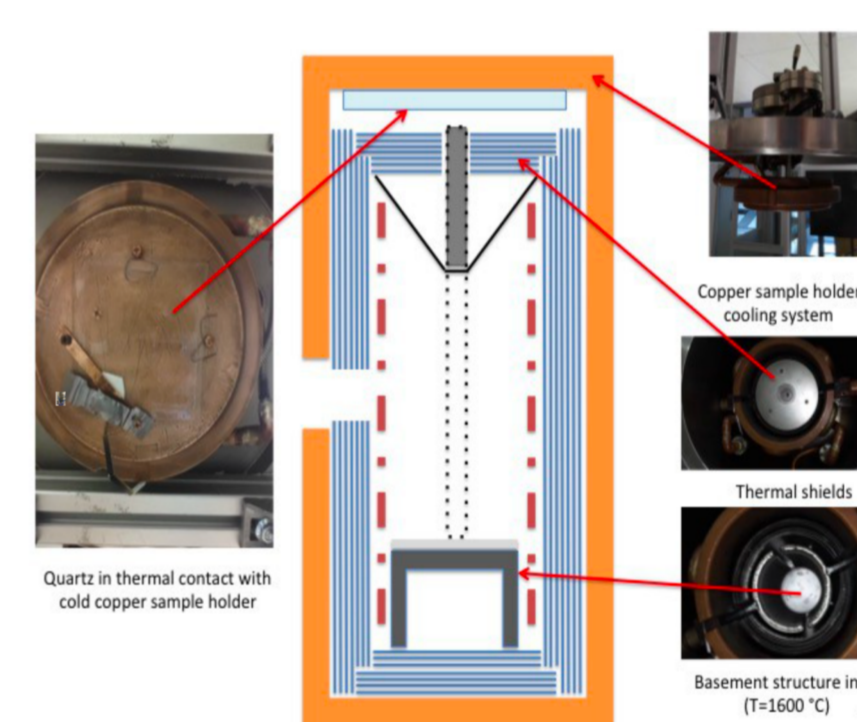
Holmium reduction:

A dedicated evaporation chamber has been set-up for Ho reduction. The oxide sample is placed in a small alumina crucible positioned inside a cylindrical oven that could reach temperatures as high as 2000 C. The oven is thermally isolated by nine W 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.

inside chamber view

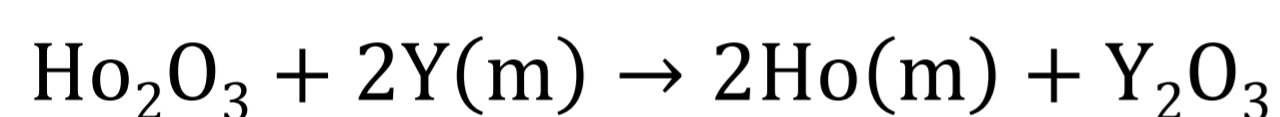


Sketch and pics of the chamber

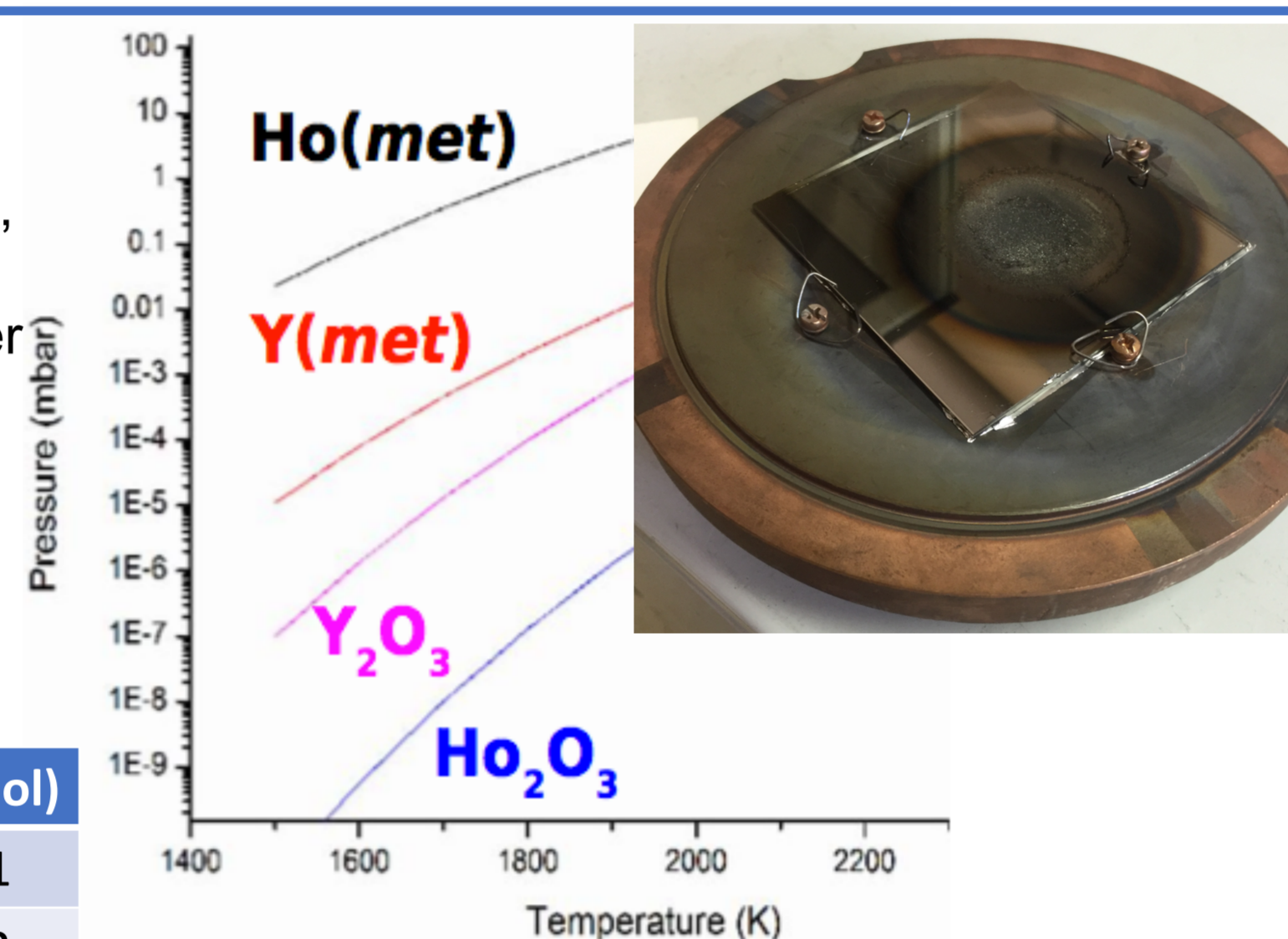


Distillation process:

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 ΔG higher than holmium one, metallic Yttrium can be used for Ho reduction by means of the reaction:



Metal	Melting Point (C)	Oxyde form	ΔG (kJ/mol)
Ho	1460	Ho_2O_3	-1791.1
Y	1526	Y_2O_3	-1816.2



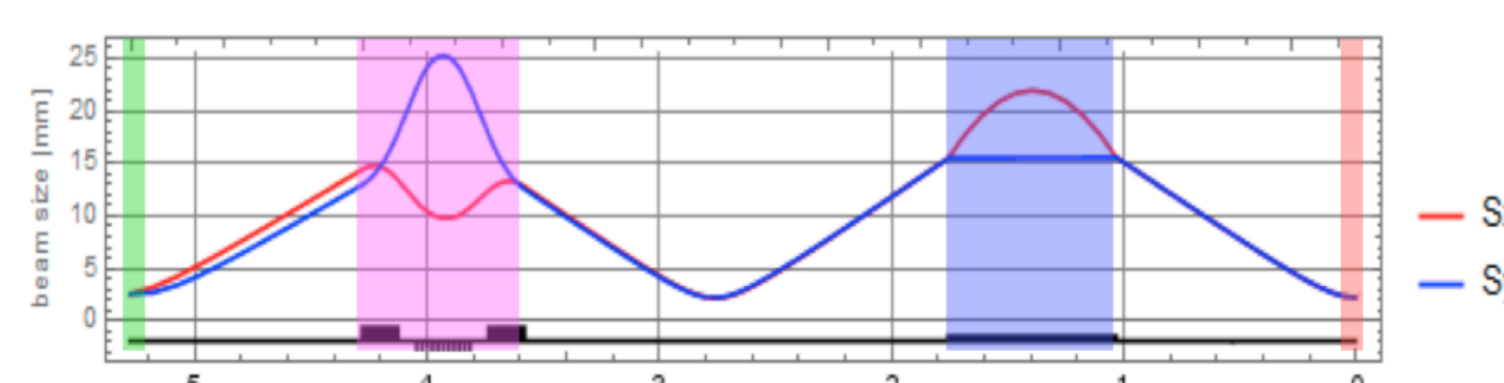
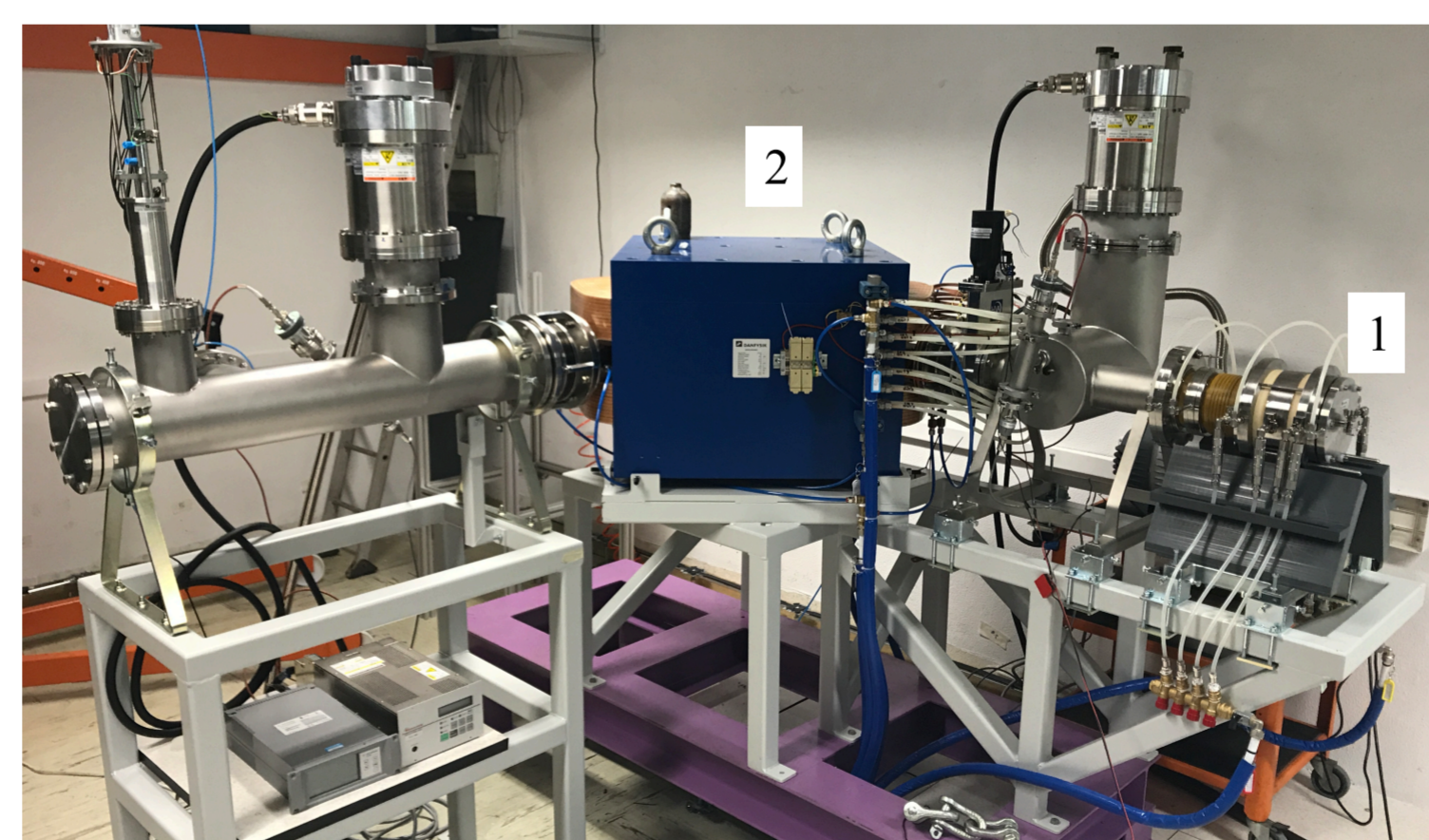
A quartz substrate is used for Ho evaporation because of its high resistivity to thermal deformation. A Au thin film has been deposited on quartz substrate in order to allow an easy Ho film removal. Moreover, the gold high reflectivity helps to avoid excessive heating of substrate. The crucible is heat up to 1600 C 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 distillation efficiency 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:

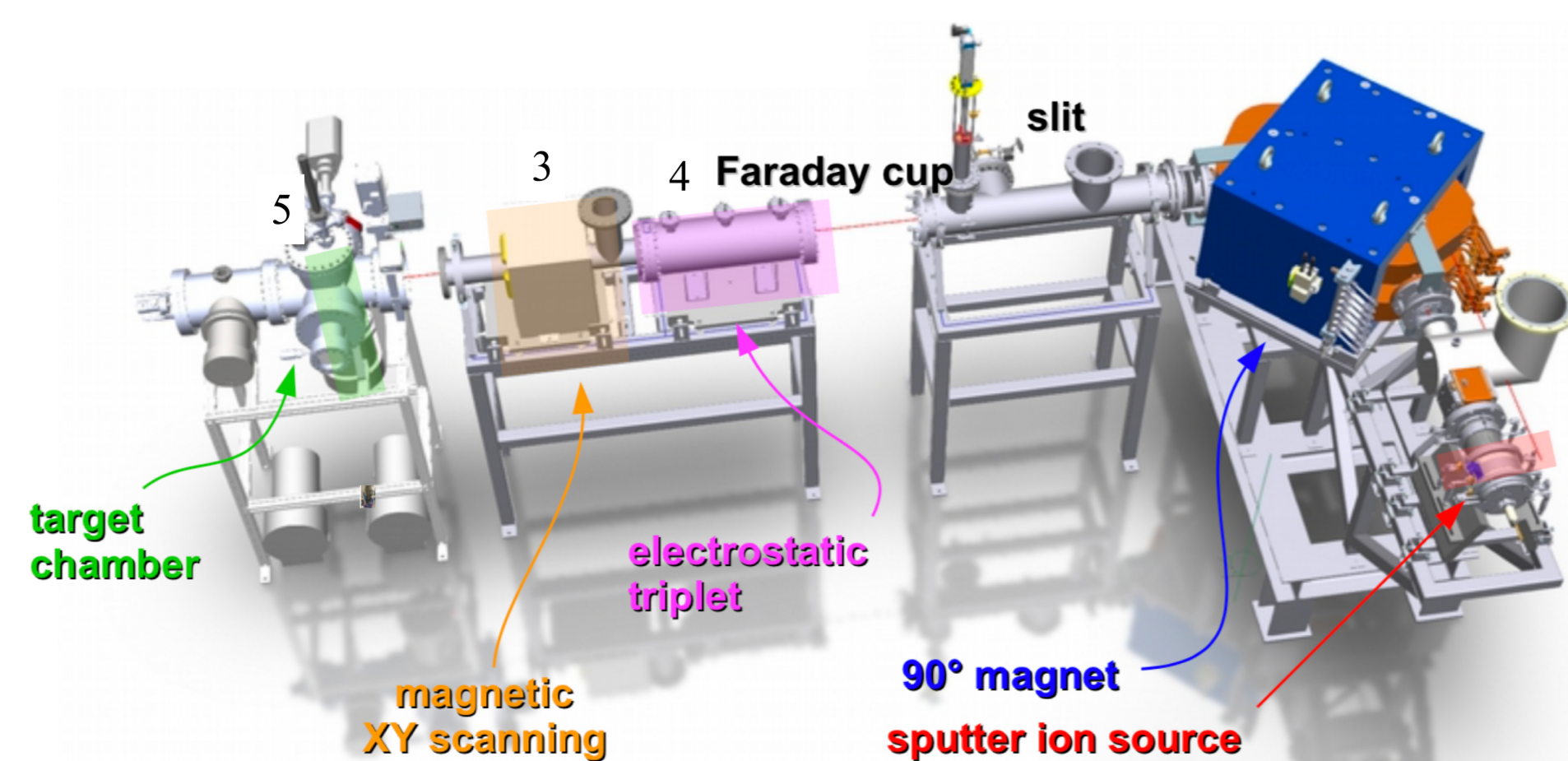
a dedicated ion implanter has been designed in collaboration with Danfysik and will be used to remove contaminations of holmium isotopes different from ^{163}Ho as well as other remaining impurities.

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 Tesla;
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}Ho in the absorber after evaporation).



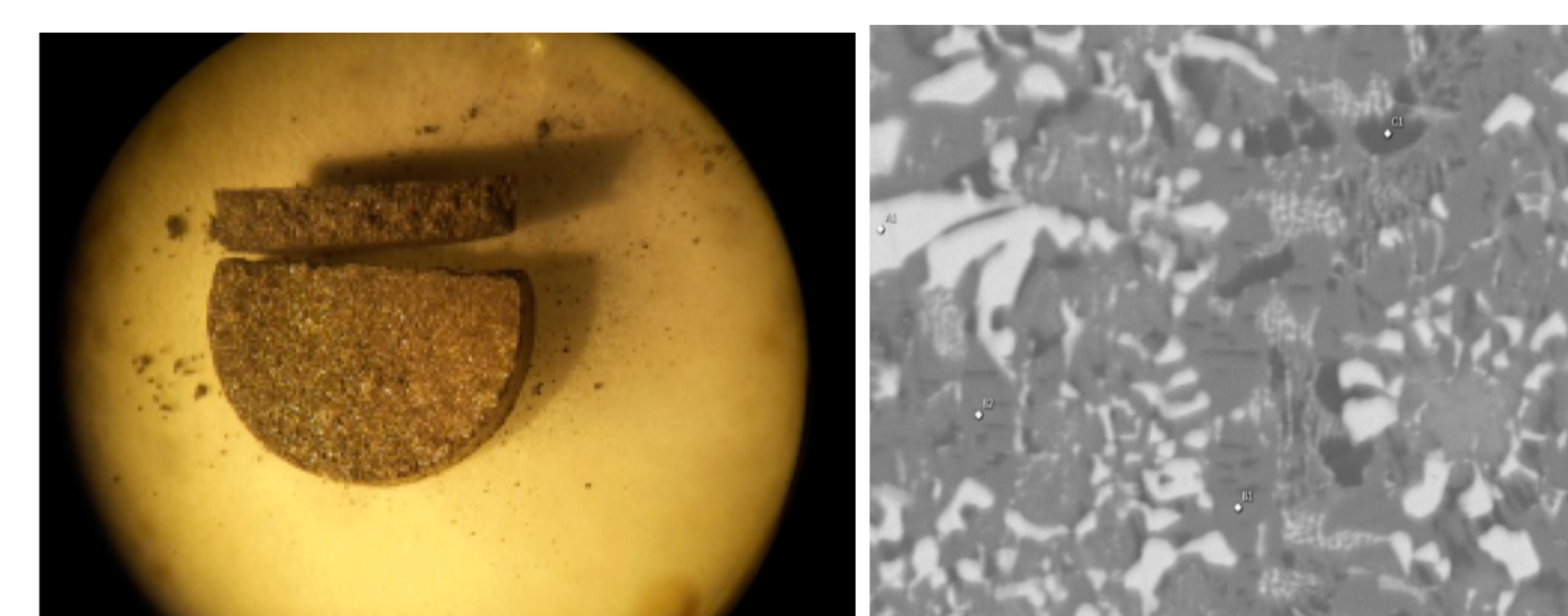
Montecarlo simulations show a beam spot of about 4mm FWHM at the target chamber. The expected 163/166m separation is supposed to be better than 5σ . The machine is currently under commissioning in Genova's INFN laboratory.



Sputter target production:

The sputter ion source needs a metallic cathode containing the ^{163}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 powder ($< 40 \mu\text{m}$). The powders compound is mixed in Ar atmosphere to prevent metal oxydation then pressed at 350 bar/cm². The obtained target is heated at 850 C 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 HoNiSn .



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