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

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The HOLMES experiment aims to directly measure the ν mass using a calorimetric approach. 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 is produced by means of neutron irradiation of a $^{162}Er_2O_3$ sample; then, it is separated from the other species generated during the irradiation process. A chemical process removes every species other than Holmium, but this is not sufficient to remove all potential background sources: infact, $^{166m}$Ho has a beta decay (τ ~ 1200y) which can induce signal below 5 keV. The contaminants removal is crucial so a dedicated implanting system has been set up. It is designed to achieve an optimal mass separation @163 a.m.u. allowing an efficient implantation of $^{163}$Ho inside the detectors arrays. The implanter is made by a sputter source, an acceleration section and a magnetic dipole followed by a x-y scanning stage and a focusing electrostatic triplet. In this poster the first results on a beam obtained with a preliminary sputter source are presented.

## $^{163}$Ho production and purification:

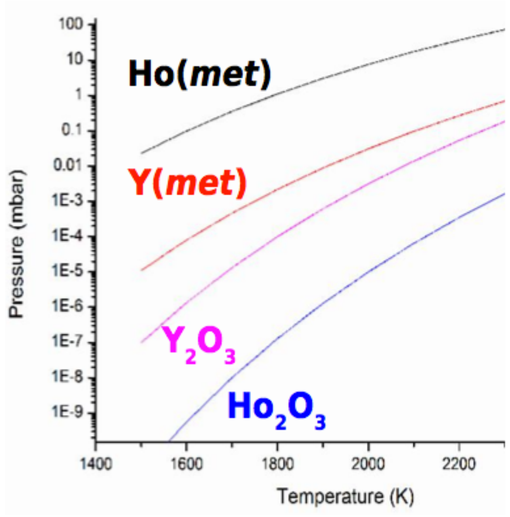
$^{163}$Ho is produced by neutron irradiation of $Er_2O_3$ enriched in $^{162}$Er at the ILL (Grenoble, FR). Impurities and contaminants are produced together with Ho during the process. All the unwanted species different from Ho will be chemically removed at PSI (Villigen, CH) by means of a high efficient (ε ~ 80%) ion exchange chromatography procedure [2].

## Distillation process:

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

$$Ho_2O_3 + 2Y(m) \rightarrow 2Ho(m) + Y_2O_3$$

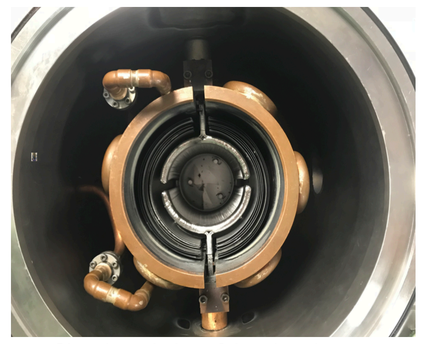
| Metal | Melting Point (C) | Oxyde form | ΔG (kJ/mol) |
|---|---|---|---|
| Ho | 1460 | $Ho_2O_3$ | -1791.1 |
| Y | 1526 | $Y_2O_3$ | -1816.2 |



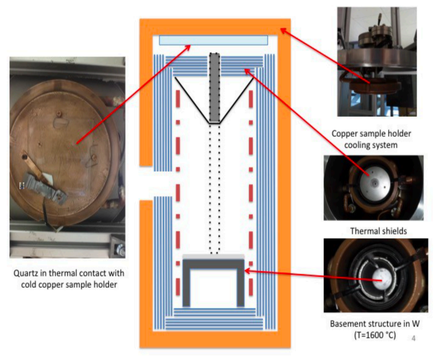

Both species are put in a crucible and heat up to 1600 °C to melt yttrium and speed up the reaction. A quartz substrate is used to collect evaporated Ho. A gold thin film has been deposited on quartz substrate in order to allow an easy Ho film removal. Moreover, the gold high reflectivity helps to avoid excessive heating of substrate. Being the Y vapour pressure 3 order of magnitude lower than Ho one, Y contaminations are minimized. The distillation efficiency is estimated to be ~ 80%, evaluated as the ratio between the mass of the condensed Ho on the substrate and the missing mass in the crucible.

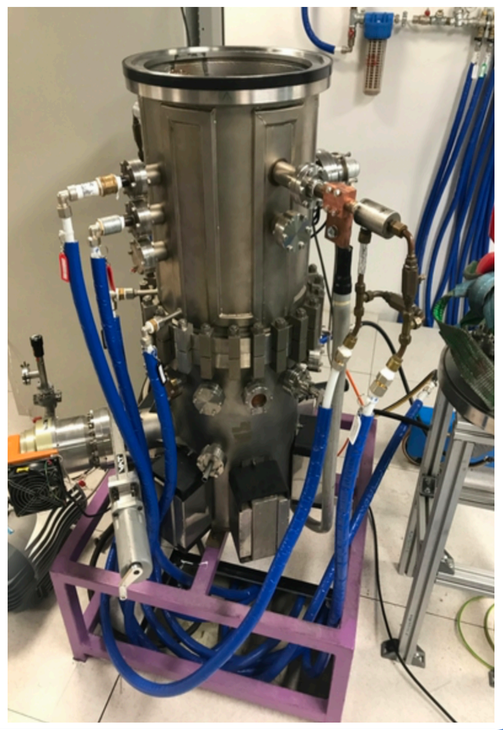
## Holmium reduction:

A dedicated Knudsen cell 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 holed W shields from a water cooled copper support, where the quartz substrate is fixed. The whole system is set in a vacuum chamber which could reach pressures as low as $10^{-8}$ mbar.



Sketch and pics of the chamber

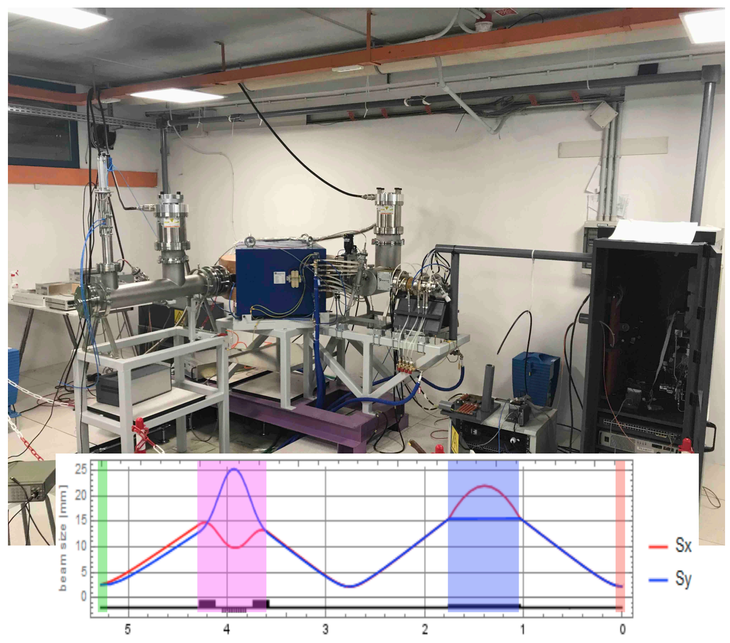


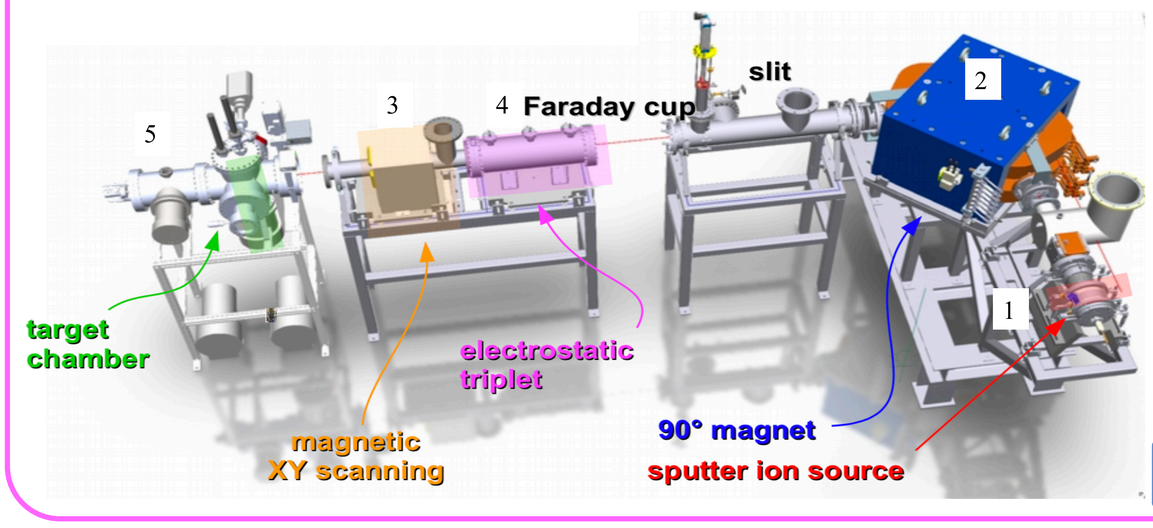



## Ion implanter:

A special designed ion implanter has been developed in Genova and it is now in comissioning phase. It 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. a target chamber, designed in such a way to allow simultaneous co-evaporation of Au (needed to encapsulate $^{163}$Ho in the absorber).

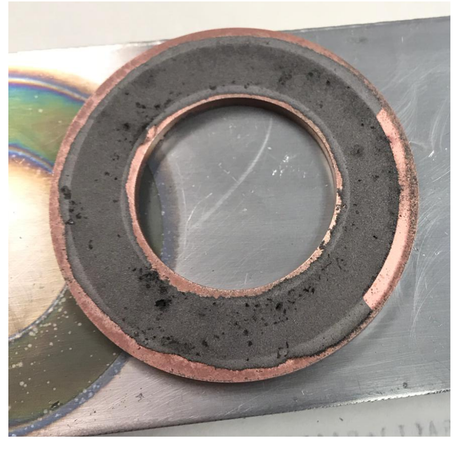



The ion implanter is designed to achieve 2 main goals: implant the Ho atoms in the microcalorimeters arrays, and select only 163 a.m.u. mass, thus avoiding contaminations from $^{166m}$Ho. From MC simulations the 163/166 separation is expected to be better than 5σ with a beam spot of 4mm FWHM. **Currently the machine has been tested with Cu beam with Ar as supporting gas. We obtained a preliminary beam current of 100uA.**

## Sputter target production:

The 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. The compound is prepared in Ar atmosphere to prevent metal oxidation then pressed at 350 bar/cm$^2$ inside a special designed mould. The obtained target is heated at 850 ° in a low oxygen environment for 24 hours to improve the mechanical properties of the sinter.



[1] B. Alpert et al., Eur. Phys. J. C (2015) 75:112 [2] S. Heinitz et al., PLoS ONE 13(8): e0200910