# Commissioning of the ion implanter for the HOLMES experiment

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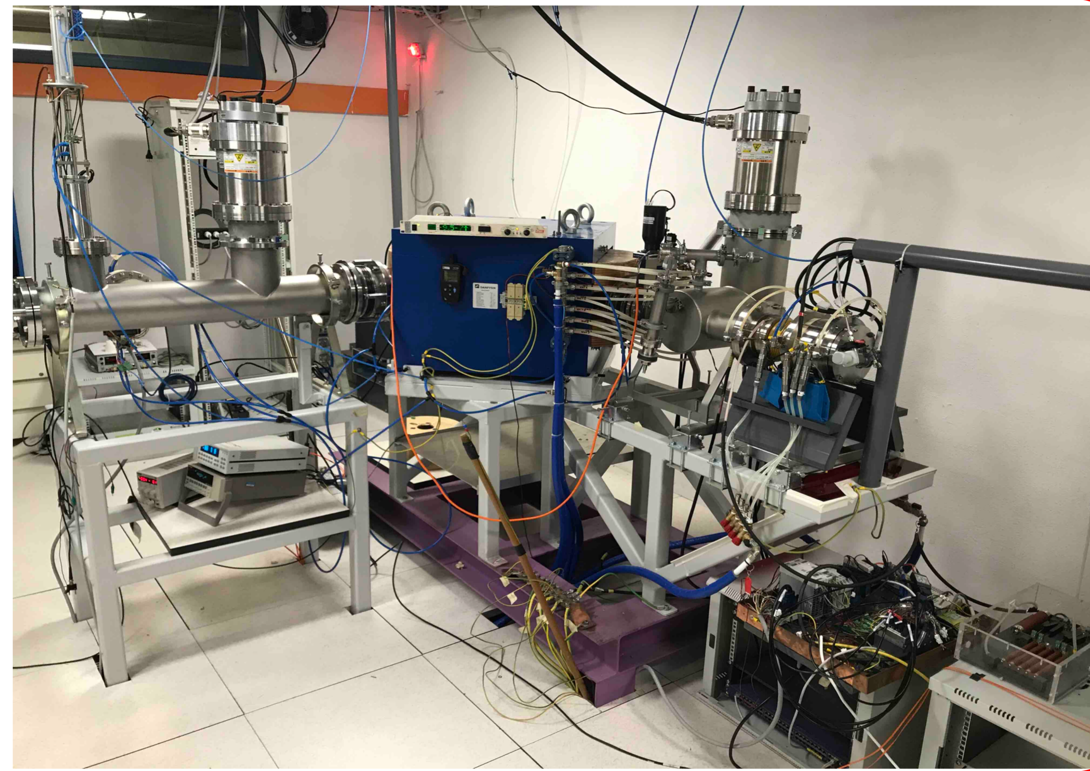
The HOLMES experiment aims to determine the ν mass directly from the $^{163}$Ho electron capture decay spectrum. For that purpose arrays of TES based micro-calorimeters implanted with O(300Bq/detector) Ho atoms are being developed. The embedding of the source inside arrays is a crucial step. Because of $^{163}$Ho production process (neutron irradiation of a $^{162}$Er sample), Ho source must be separated from a lot of contaminants. A chemical process removes every species other than Ho, but it is not sufficient to remove all background sources: indeed, $^{166m}$Ho beta decay can produce fake signal in the region of interest. For this reason, a dedicated implantation system has been set up. It is designed to achieve more than 5σ separation @163 a.m.u./166 a.m.u. allowing an efficient Ho ions implantation inside micro-calorimeter absorbers. Its main components are a 50 kV sputter-based ion source, a magnetic dipole and a target chamber. A specially designed co-evaporation system has been designed in such a way to "grow" the gold micro-calorimeter absorber during the implantation process, increasing the maximum achievable activity which can be implanted. The machine performances have been evaluated by means of calibration runs using $^{63}$Cu/$^{65}$Cu and $^{197}$Au beams. A special care has been given to the study of the more effective way to populate source plasma with Ho ions obtained from different Ho compound by sputtering process. In this work, the machine development and commissioning will be described.

## The ion implanter…

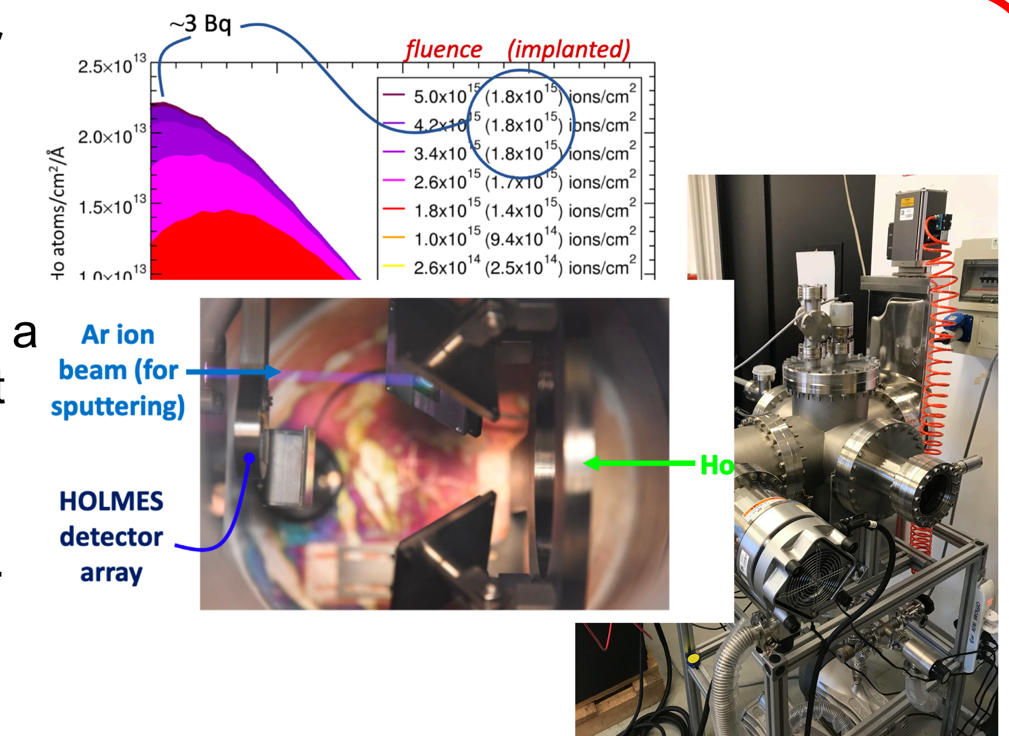
The main components of the machine are:

- **an argon Penning sputter ion source** with an acceleration section allowing to reach a maximum energy of 50 keV;
- **a magnetic dipole mass analyzer** with magnetic field up to 1.1 T;
- **A Faraday cup and a slit**;
- **a target chamber**, designed in such a way to allow simultaneous co-evaporation of Au (needed to encapsulate $^{163}$Ho in the absorber).



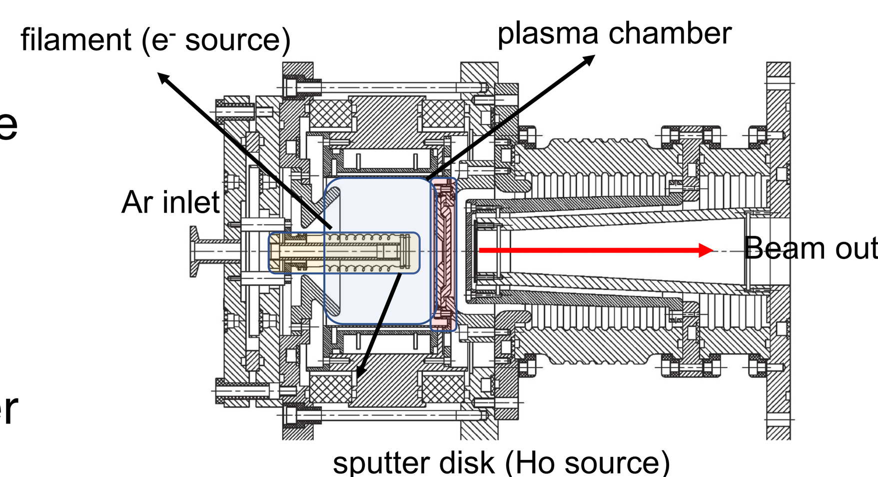
## …and the target chamber

Ho concentration in absorbers saturates because after a while incoming Ho will start to sputter the already deposited one. This effect could be compensated by a Au co-evaporation. Moreover, at the end of the process a final 1 μm Au layer will be deposited to fully encapsulate the Ho source. A dedicated chamber has been designed and commissioned.




## The ion source…

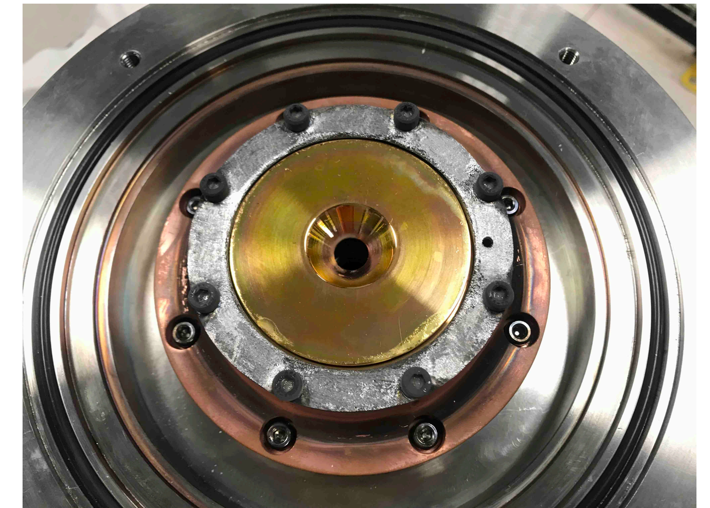
An argon Penning ion source with magnetic multipole/reflex ("bucket") configuration of the discharge chamber, allowing the creation of a quiet, cold and stable plasma of large cross section with densities suitable to form high-current, and high-brightness ion beams. The possibility to mount a negatively-biased metal disk (sputter target) inside the discharge chamber in front of the outlet hole allows to populate the plasma with metal atoms of our choise sputtered off the disk.




## …and the sputter target

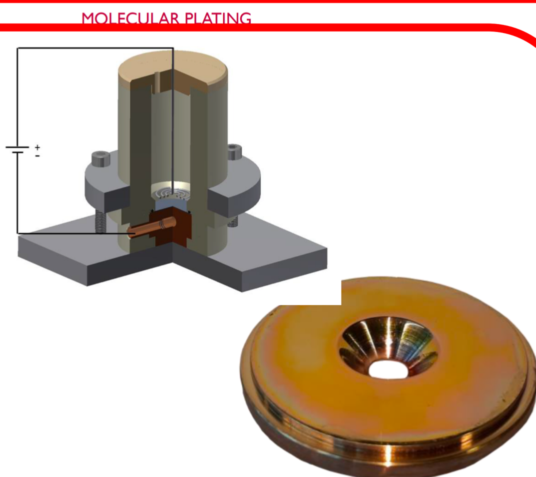
The sputter target consists mainly of a «bulk» target (best material under study: Cu, Mo?) on which Ho compound has to be deposited / embedded. Currently we are testing 3 techniques for sputter target production:

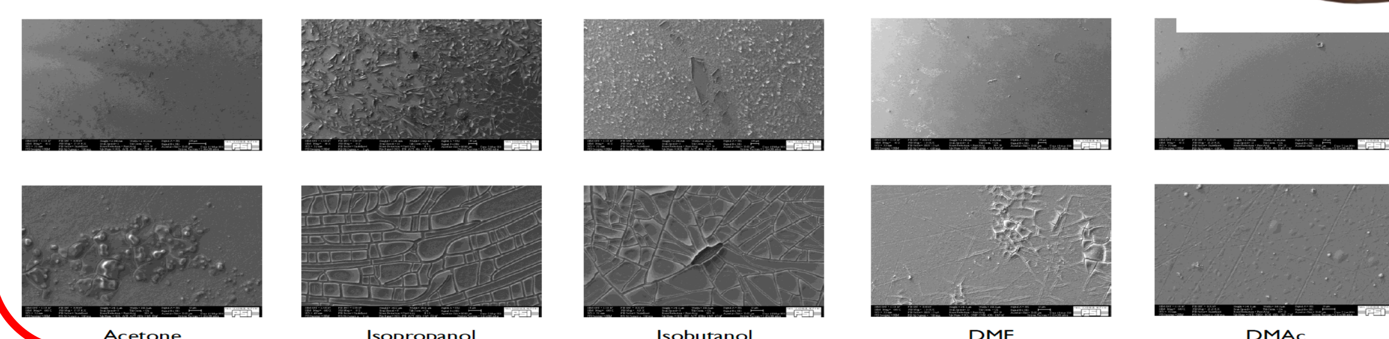
1. Molecular plating (PSI);
2. Sintered target (Chem. Department, UniGE);
3. On-demand inkjet printing (PSI).



## Molecular plating

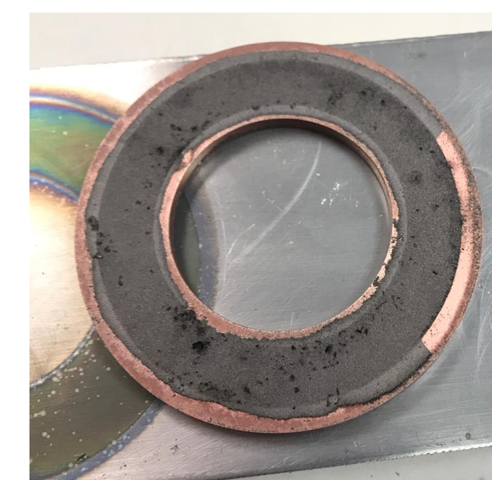
- High yield (> 90%) electrodepositon from an organic solvent;
- Produces very thin and uniform layer;
- Uniformity as a function of solvent: the lower the vapour pressure is, the more stable is the deposition.



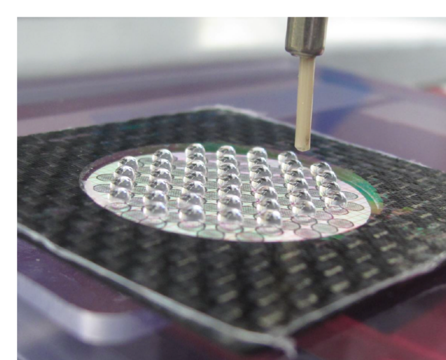

## Sintered target

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 and then is compressed at 350 bar/cm² inside a specially 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.



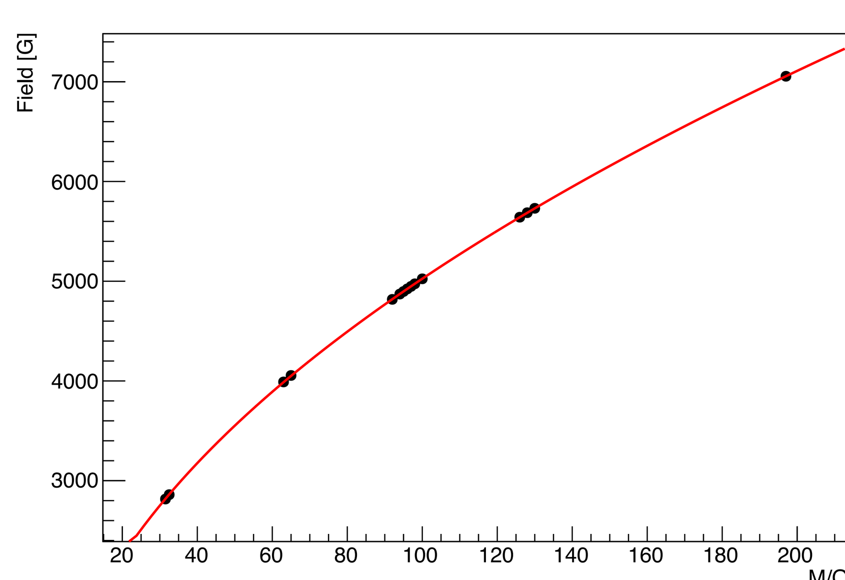
## On-demand inkjet printing

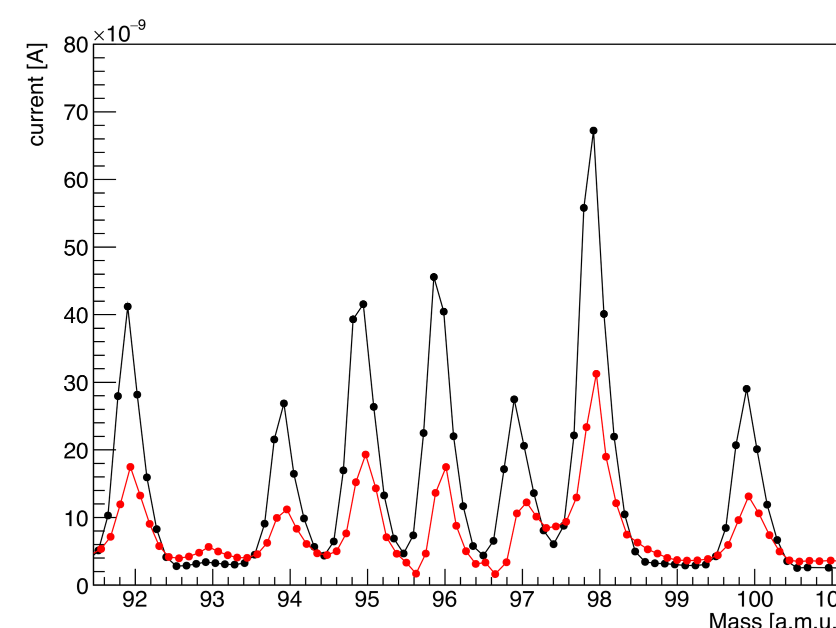
Put droplets of solution containing Ho compound on a (even non-conductive) substrate. Further developments are on-going.

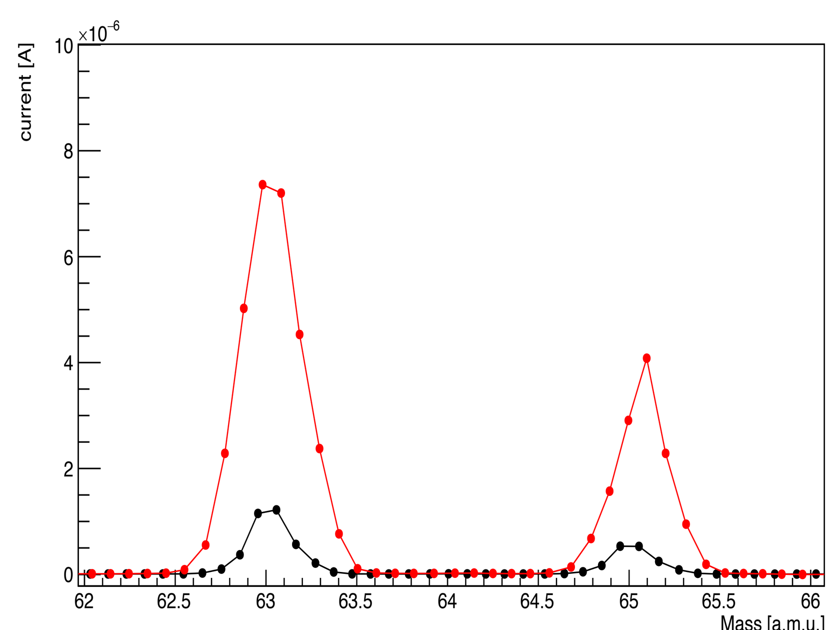


## Implanter calibration:

The machine is calibrated using peaks from Cu, Au and Mo. These materials are always available (Cu, Au from sputter target bulk, Mo from source anode). From those peaks one could obtain a field vs M/Q relation and correct for misalignment: a small offset in magnetic field corresponding to ~ mm misalignment has been measured and corrected. Expected 165 a.m.u. peak at 6458 G. Adjacent peak separation at 63 a.m.u. is 31 G, corresponding to 15 mm from MC simulation. Extrapolation to 163 a.m.u. / 166 a.m.u. gives 18.8 mm separation.




## Some results @165 a.m.u.:

With molecular plated target: monitoring 165 a.m.u. beam behavior from the start of sputtering process demonstrated quite large and unstable current values for a few minutes followed by a fast hundredfold decrease.

Target warm-up could be an isse? Deposited material could be suddenly evaporated? More studies on going…

Magnetic field scan around the corresponding 165 a.m.u. position showed the peak presence even after the above-described burst.