HOLMES: Realization of a metallic Ho target for future Ho ionic implantation: status of the art.

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Abstract:

This work shows the activity of the INFN-Genoa group in the framework of the HOLMES experiment.

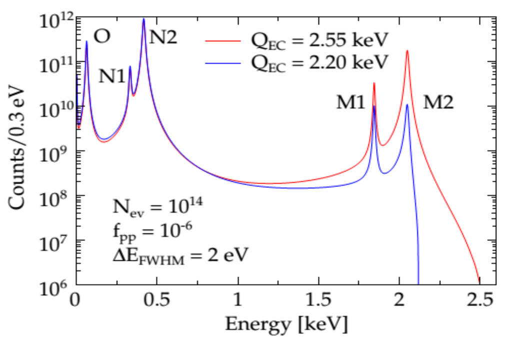
We present the reduction-distillation method to obtain metallic Holmium. The process efficiency measurement and calculation of molecular dynamic process internal the reaction/distillation cell are also presented.

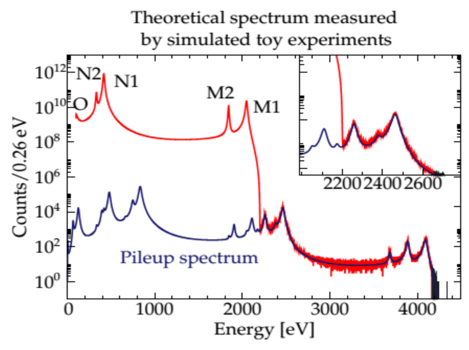
Moreover we show the state of the art of the dedicated vacuum chamber for the realization of metallic ^{165}Ho/^{163}Ho target, that will be used in the ionic implantation process of the Au absorbers.

The HOLMES project

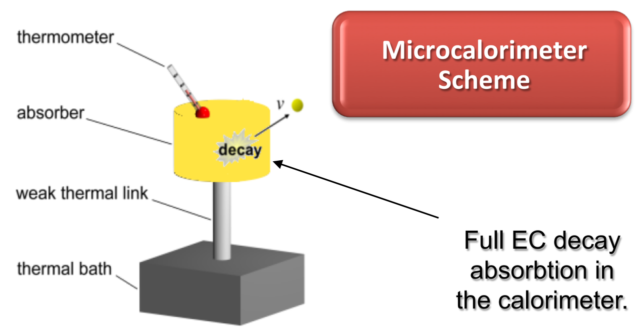
^{163}Ho decay by electron capture:

$$^{163}Ho + e^- \rightarrow {}^{163}Dy^* + \nu_e$$

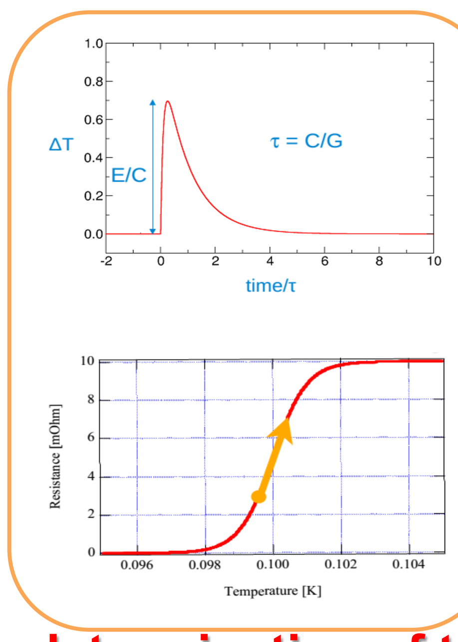




The microcalorimeter and TES detectors



Transition Edge Sensors use the resistive transition of a superconducting film.



HOLMES goals:

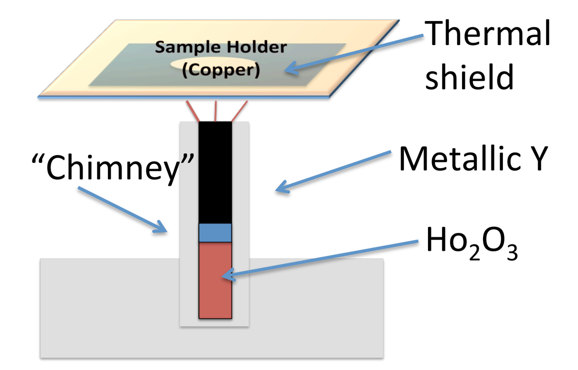
- Neutrino mass measurement with a statistical sensitivity down to 0.1 eV
- TES detectors with Au absorber implanted with ^{163}Ho
- 6.5*10^{13} Ho nuclei in each detector
- $\Delta E \approx 1$ eV
- $\tau_R \approx 1\,\mu s$
- Pilot measurement with 1000 channel multiplexed array with sensitivity of 0.4 eV
- 6.5*10^{16} Ho nuclei

We want to measure the neutrino mass with Q-value determination of the endpoint

The Ho-target production by Reduction-Distillation process

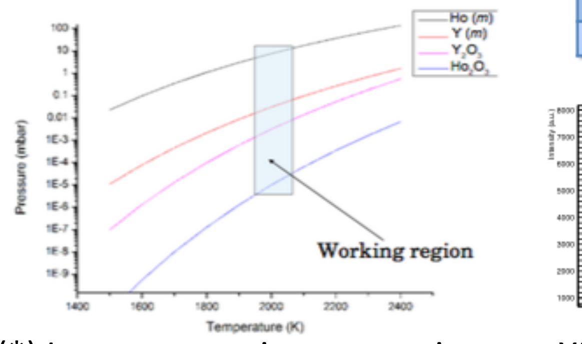
Reduction-Distillation (R-D) in syntesis:

$Ho_2O_3 + Y_{(m)} \rightarrow Ho_{(m)} + Y_2O_3$ @ 1500 °C



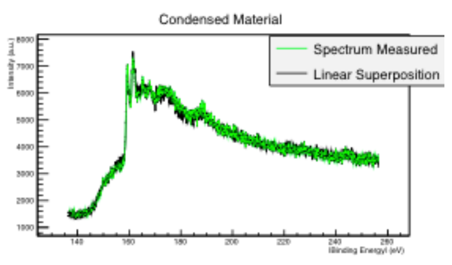
We used of a cylindrical crucible (*"chimney"*) in order to select only one chemical species

Element	ΔH oxidation (kJ/mol)
Ho(m)→Ho2O3	-1880
Y(m)→Y2O3	-1905



(*) Low pressure in evaporation process is needed in order to avoid Ho oxidization

Chemical Species	Parameter	Error
Ho(m)	0.9628	0.004
Ho_2O_3	0.03715	0.004
Y(m)	0	4 10^{-5}
Y_2O_3	0	6 10^{-5}

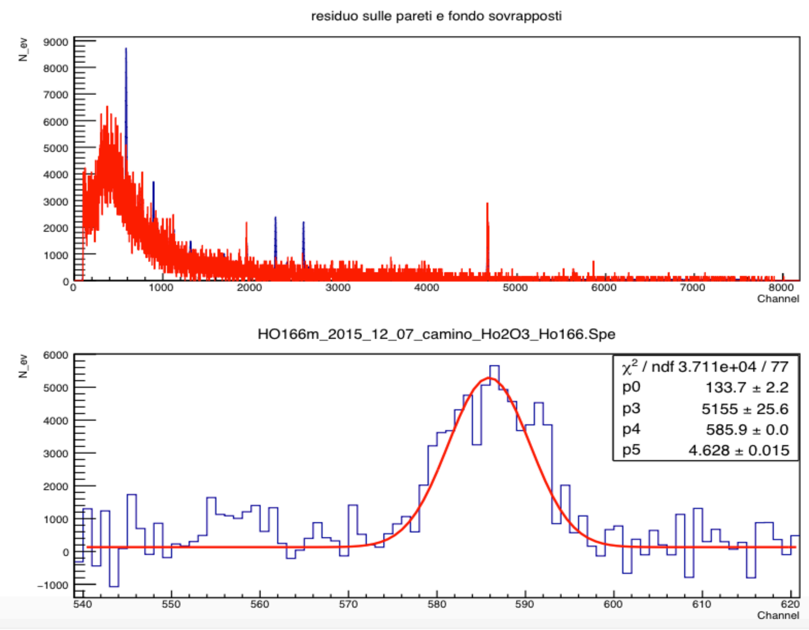


XPS analysis of condensed material to verify the evaporated species.

Process evaporation efficiency measurement

^{166}Ho as a marker tracker

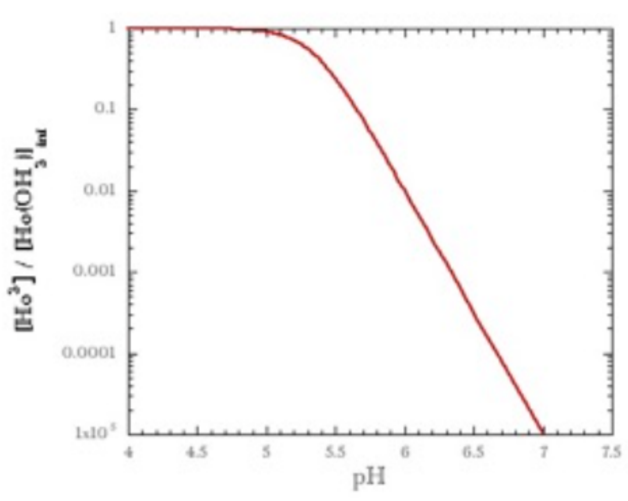
Why ^{166}Ho?
- **Gamma decay (Measurable spectrum by HpGe)**
- $\tau_{1/2}$=1200 y



A typical gamma spectrum of ^{166}Ho.

Research of the "right" acidity

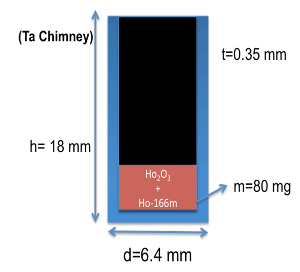
A source of **^{166}Ho** has been used to measure the solubility of Holmium in a water solution in different condition of acidity.
A complete solubility is necessary in order to embed the correct quantity of radioactive Ho during R-D process.



We observed that Ho compounds like **hydroxides** are sensitive to the **acidity of the solution.** We have calculated a complete solubility of Ho in water is **pH<5**.

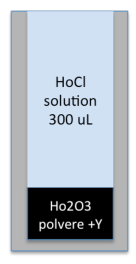
^{166}Ho embedding in "chimney" for efficiency process measurement

1



80 mg of Ho_2O_3 and 50 mg of metallic were used for RD.

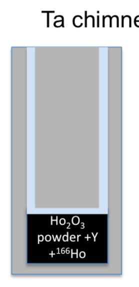
2



300 mL of ^{Ho}166 acid solution added to the Ho_2O_3 powder. Measured activity of the radiactive source before insert: **(32+-2) Bq**.

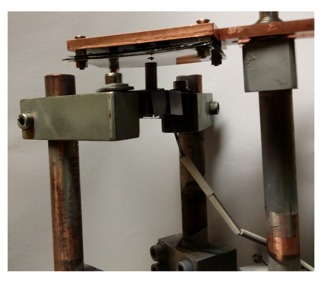
Ta chimney after driing

3



Ho_2O_3 and ^{166}Ho solution dried on a hot plate @ 90 °C for 10 h. ^{166}Ho solution precolated into Ho_2O_3 powder.

4

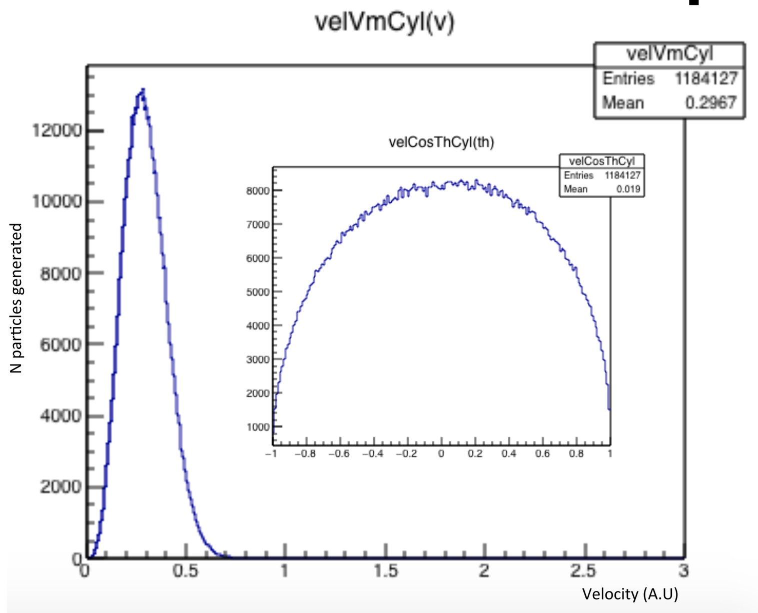


R-D process on a Ti/Au film evaporated on a Si chip.
After R-D a thin Au coating evaporated to avoid Ho oxidization.

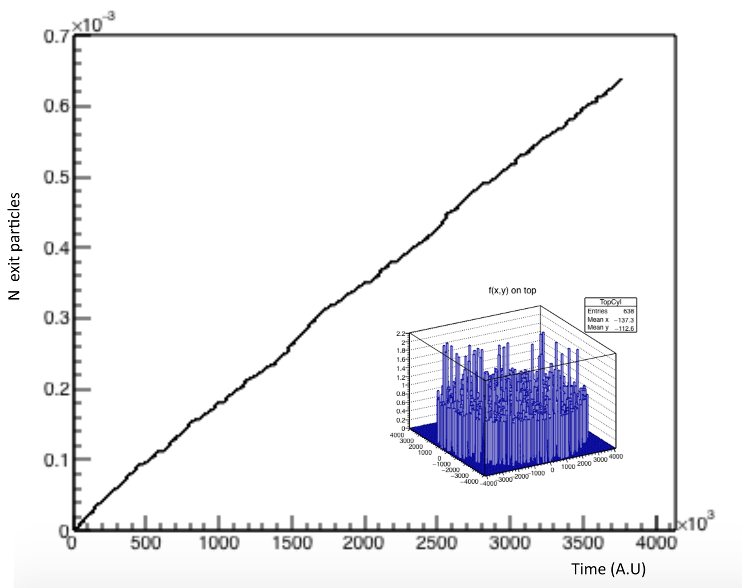
Final results

- 2 mg of metallic Ho were evaporated.
  It corresponds to the (2.73+-0.01)% of the Ho total mass (78 mg).
- Activity measured on thermal shields and on sample: **1.47+-0.11 Bq**
- Attended activity if we suppose that 166Ho liquid source percolate the Ho_2O_3 powder
- **$A = A\_in * W_{Ho\_evap}/W_{Ho\_tot}$=(0.87 +-0.07) Bq**
- **It is possible that part of ^{166}Ho source did not percolated inside Ho_2O_3 powder. More accurate measurements with a bigger quantity of reagents are necessary.**

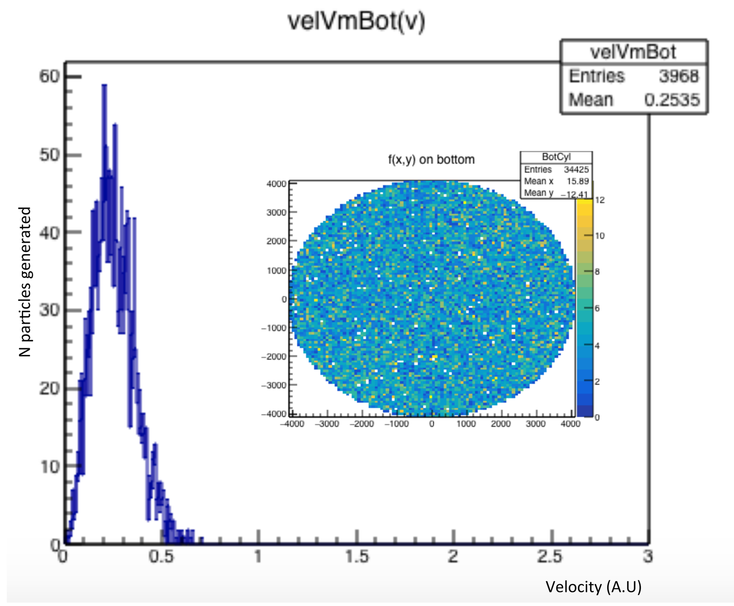
Molecular dynamic simulation of the evaporation process



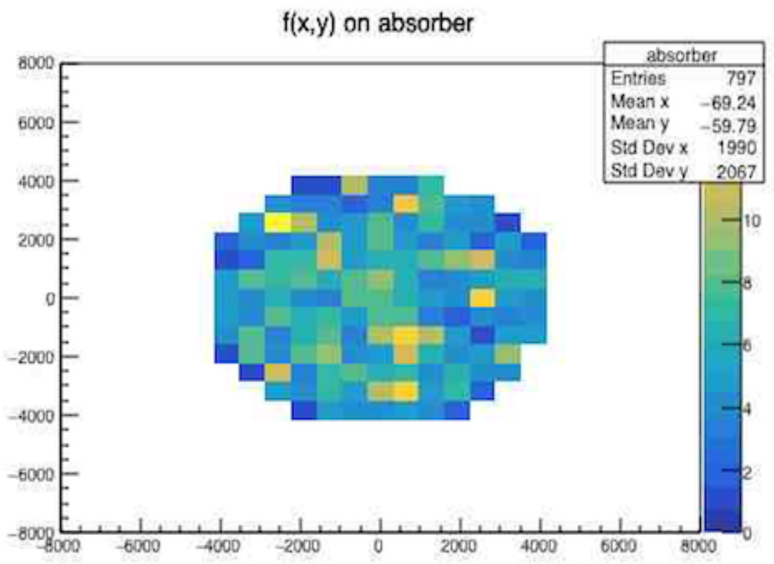
Particles Boltzmann distribution on walls. A Cos(theta) distribution has been simulated.



Particle rate emission as a function of time. 3D plot of particle emission on top.

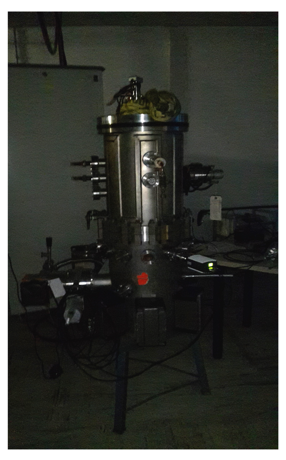


Particles Boltzmann distribution on bottom wall. Random hits on bottom of the cylinder.

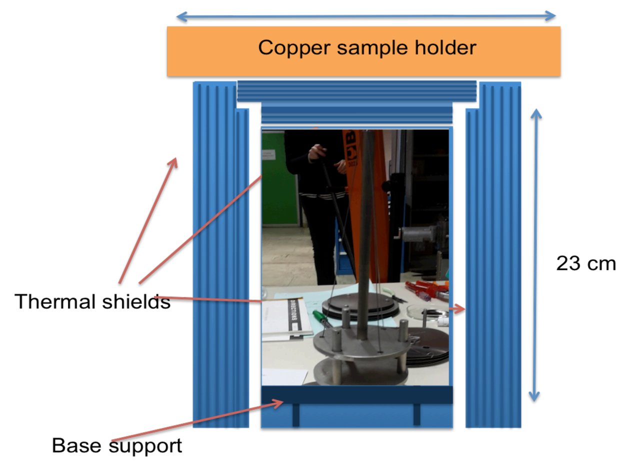


Real distribution of particles on absorber at 20 mm of distance.

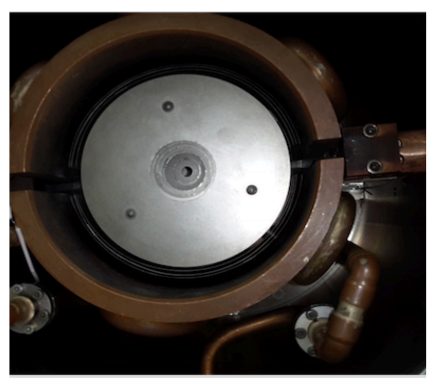
The dedicated Ho evaporation chamber:



A vacuum pressure of 10^{-9} mBar has been reached. We control the inner temperature with 2 thermocouples and a pirometer.
A power supply of 40 KW is needed in order to achieve 1500 °C in the inner of the vacuum chamber.



A total of 33 tungsten thermal shield embed the hot source.
As shown in picture a tungsten base support for the "chimney" has been prepared.



A conical-aperture in thermal shields is needed in order to have the mimimal loss of metallic Ho and the maximal thermal shielding during evaporation .
The slope has been calculated considering the minimum opening angulus α=D/L, where D and L are respectively the diameter and the length of the "chimney".

Conclusions

- A curve of Ho solubility in water as a function of pH has been calculated. Results show that a pH<5 ensure complete soublity of Ho, which is essential to embed the correct number of ^{163}Ho ions inside the Ho target.
- Metallic Ho will be produced in a dedicated vacuum chamber, which can reach a vacuum pressure of 10^{-9} mBar, essential to properly select the correct species during evaporation, as shown in (*).
- Efficiency measurements were pursued using ^{166}Ho as radioactive marker tracker. Assuming ^{166}Ho uniform inside the Ho_2O_3 powder (see fig. 3) the calculated activity of "lost" Ho mass is lower than the measured activity on sample. More accurate measurements with a bigger quantity of reagents are necessary.
- From Molecular dynamic simulation of the Reduction-Distillation process we extrapolated curve of the vapor emission profile. Moreover a plot of the rate emission of molecules has been calculated.