The HOLMES low activity implantation

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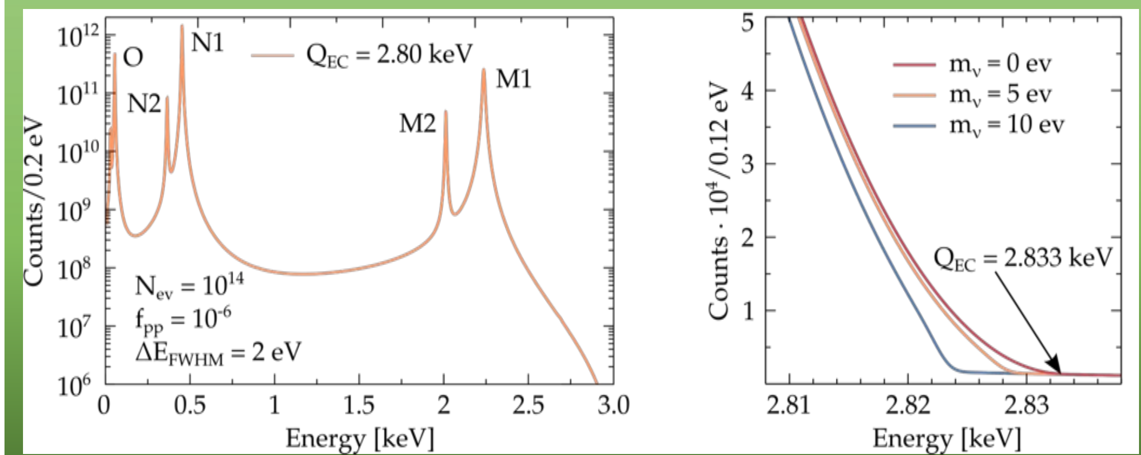
Neutrino mass limit and calorimetric approach

- From direct measurement : $\lesssim 1.1\ eV$ (KATRIN experiment)
- From Neutrinoless double beta decay: $\lesssim 0.5\ eV$ (only Majorana neutrino)
- From cosmological and astrophysical data : $\lesssim 0.2 - 1.3\ eV$ (model dependent)

General requirements for a ν mass experiment (Holmium 163) :

- High statistics near the end point (proximity to M1 resonance)
- Low Q-value (stat ~$1/Q^3$) (~2.8 keV)
- High activity/efficiency of the source (4570 y)
- Energy resolution order ~eV or below (comparable with m_ν) (see next slide)
- small systematic effects



Calorimetry: embedded source

- no backscattering
- no energy loss in source
- no solid-state excitation
- no atomic/molecular final state effects
- good energy resolution (~eV)
- limited statistics
- systematics due to pile-up and background

Holmes experiment in a nutshell

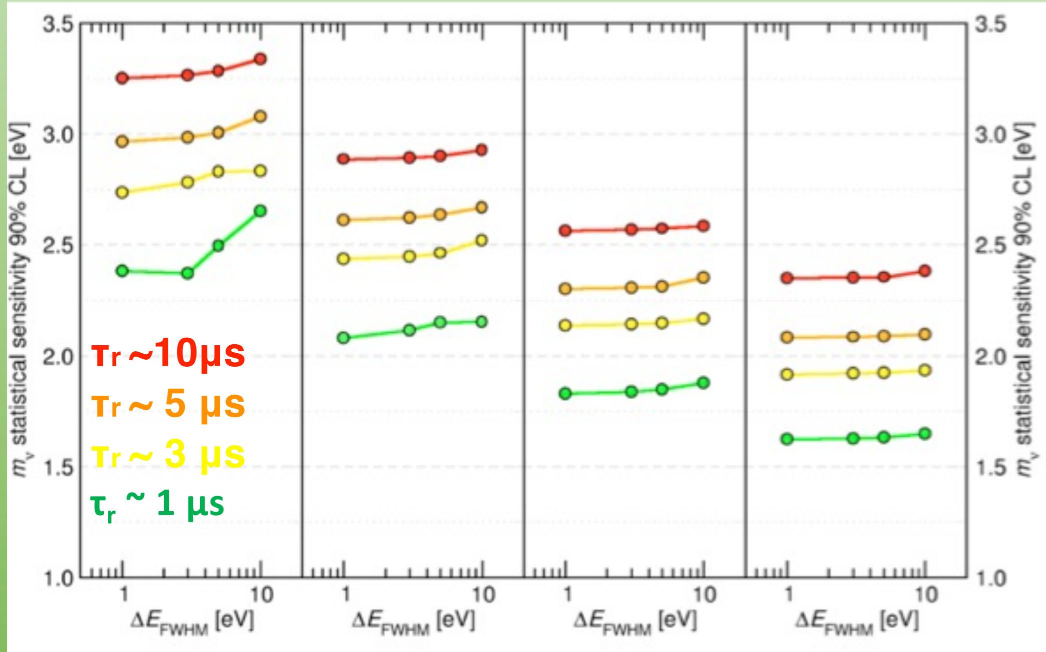
Usage of Transition edge sensor (TES) based micro-calorimeters with ^{163}Ho implanted and Au absorber:

- Energy resolution ΔE~ 1eV
- time Δt~ O (1-10)μs
- 6.5 x 10^{13} nuclei/det, A(EC) ~ 100 Bq/det
- 1000 channels array: 6.5 x 10^{16} total nuclei (≈18μg)
- O(10^{13}) events / year, data taking ~ 3 years
- Pile up fraction $f_{pp} \approx A \times \Delta t = 3 \times 10^{-4}$

Should prove the technique potential and scalability by:

- assessing EC spectral shape
- assessing systematic error
- sensitivity on m_ν ~ eV

10 Bq / det 30 Bq / det 100 Bq / det 300 Bq / det



exposure: 1000 det x 3 years

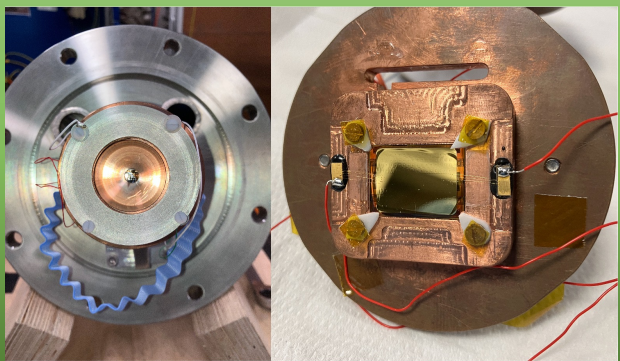
Mass separation and ion implantation

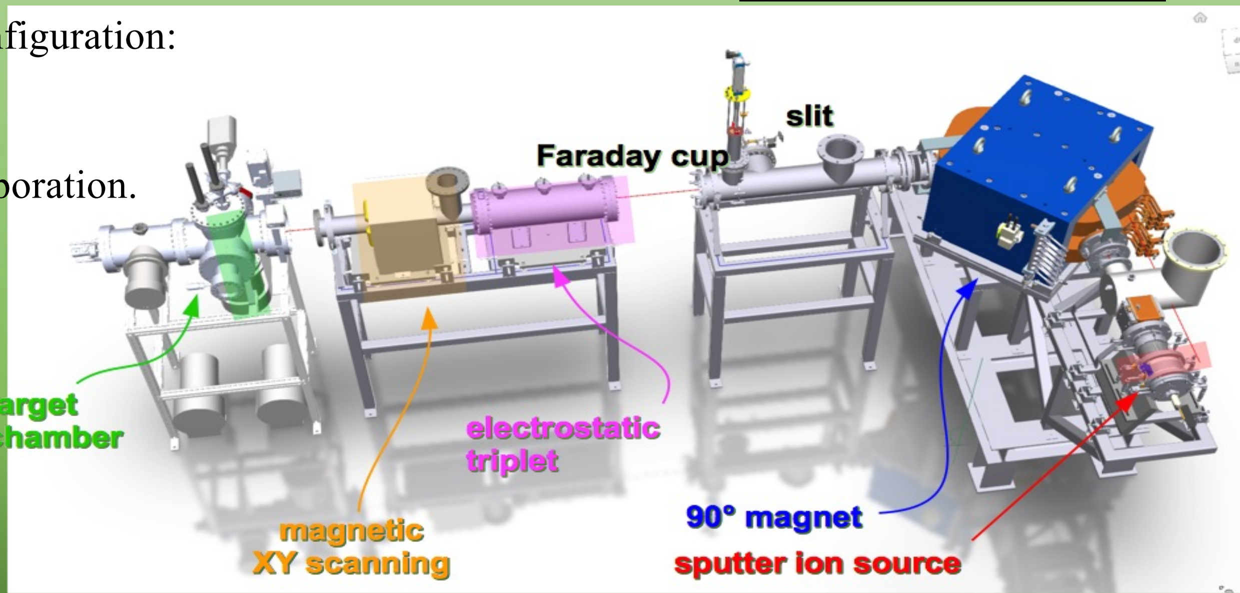
A dedicated ion implanter to remove contamination of holmium isotopes different from ^{163}Ho and other impurities.

1. **an argon sputter ion source** to create the ion beam;
2. **an acceleration section** to reach a maximum beam energy of 50 KeV;
3. **a steering magnet** to correct vertical shift of beam;
4. **a magnetic dipole mass analyser** with a field up to 1.1 Tesla and capable to guarantee ^{163}Ho/^{166m}Ho separation better than 10^5;
5. **a Faraday cup and a slit** to measure beam intensity and cut beam tails;
6. **a target holder** used for low activity implantation.

There are three parts not yet mounted in the actual configuration:

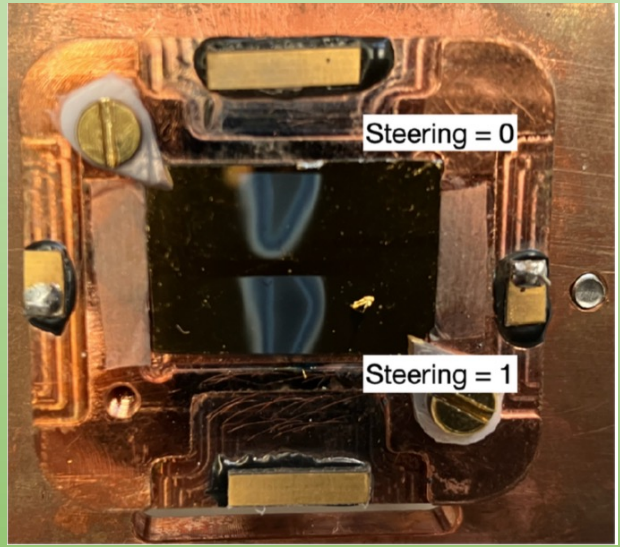
- a magnetic scanning stage;
- a focusing electrostatic triplet;
- a target chamber for implantation and gold co-evaporation.

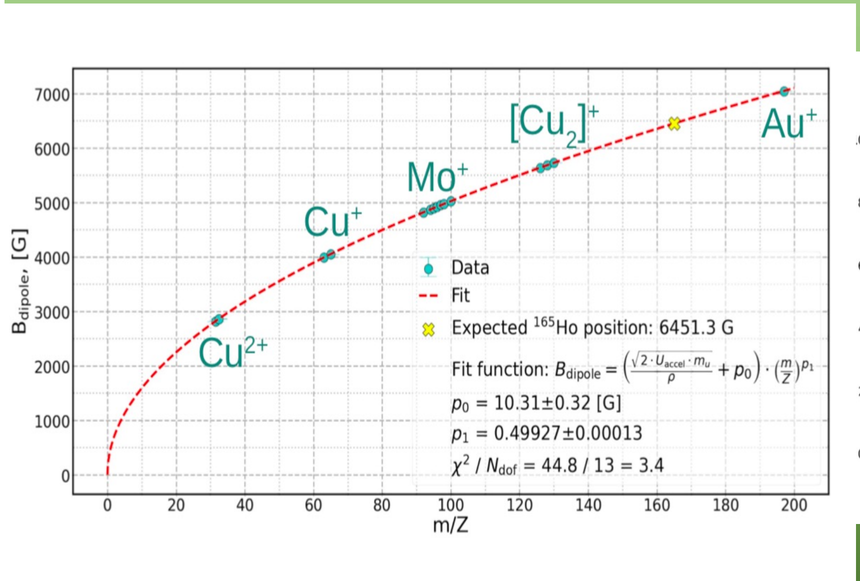


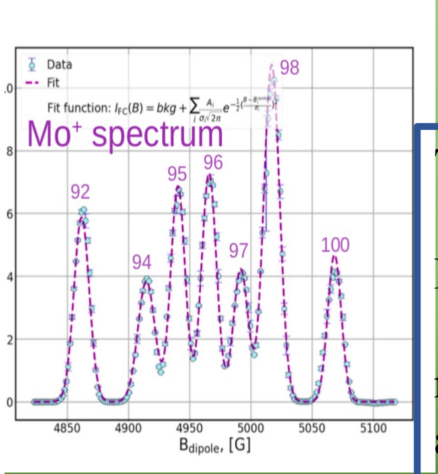


Implanter calibration and commissioning

The implanter is calibrated using the different materials inside the chamber and the target. They allowed for a magnetic field vs mass-to-charge ratio calibration.
A small offset in magnetic field corresponding to ~ mm misalignment has been measured and corrected. Using multi peaks element is useful to extract beam size ($\sigma \sim 1.3\ mm$).

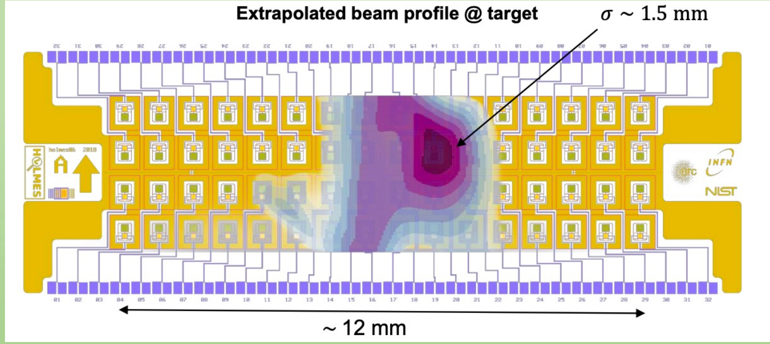




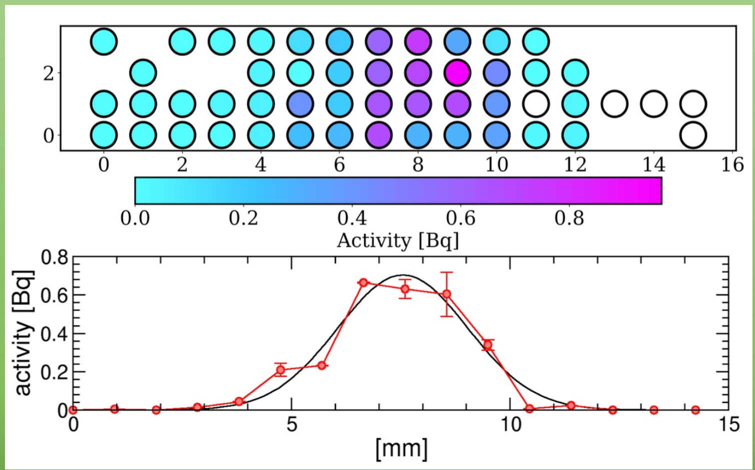


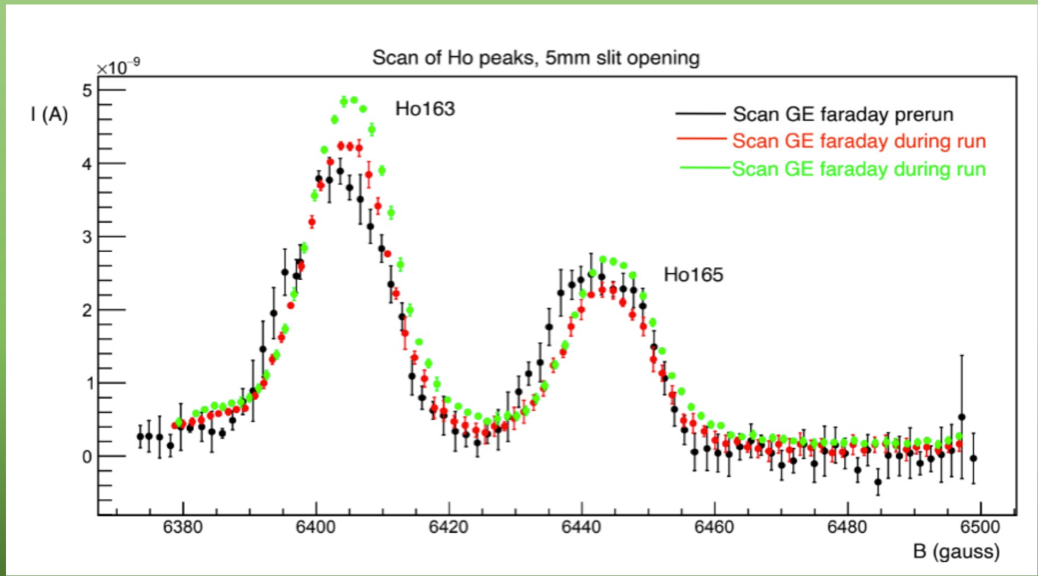
The separation and the reject power between 163, 165 and 166 a.m.u. has been evaluated by MC simulation. The expected distance from 163, at slit plane, is about 15 mm for 165 and 22 mm for 166 . The beam profile and the alignment has been checked using Mo peak on a gold-plated silicon substrate as a probe.

Low activity implantation

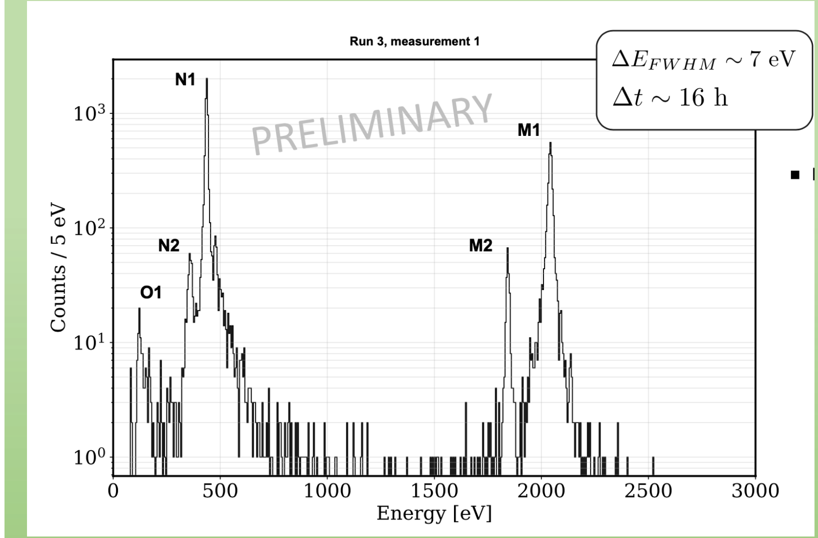


An array of 64 TES has been implanted with a single spot.
The geometrical efficiency has been evaluated from MC simulations.
The mass separation between 163/165 was measured on data during implantation run and it was ~45 G corresponding to ~15 mm, as expected. The beam current was measured online during implantation, and we expected to have ~2Bq on central TES but measured an activity of ~1 Bq, a factor 2 discrepancy which is under study. From activities map we were able to extract a beam size of ~ 1.5mm sigma, in good agreement with expectation.

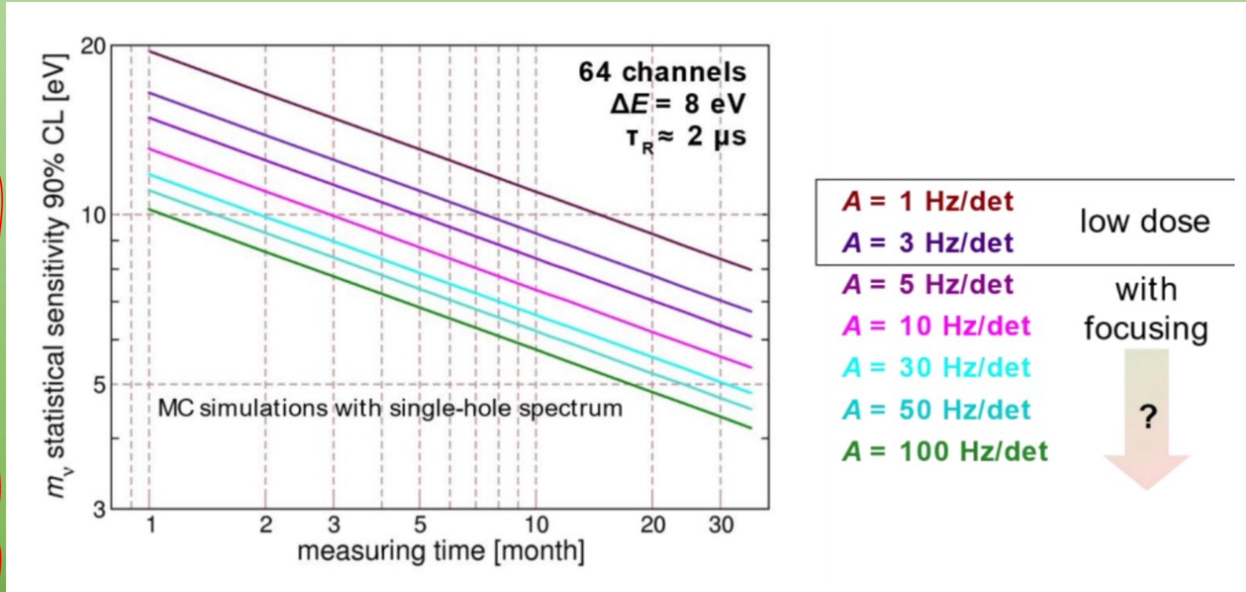




Conclusions



We obtained preliminary spectra of holmium 163 and we measured energy and timing resolution of implanted TES with a ^{55}Fe calibration source.



- Three other arrays has been implanted with low activity and different «geometries» (3-spots, 4-spots, vertical spot).
- A first long run measurement is on going to reach a first limit on neutrino mass with an expected sensitivity around 10 eV (best calorimetric neutrino mass limit).
- We will upgrade the implanter facility by adding a focusing stage and a co-evaporation chamber.