TES detector and array production for the HOLMES experiment

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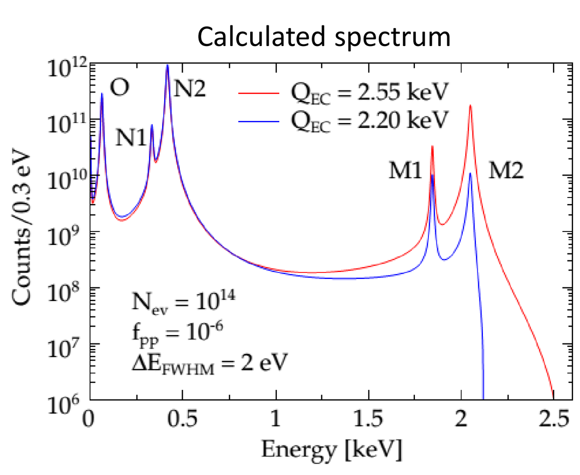
The ^{163}Ho electron capture

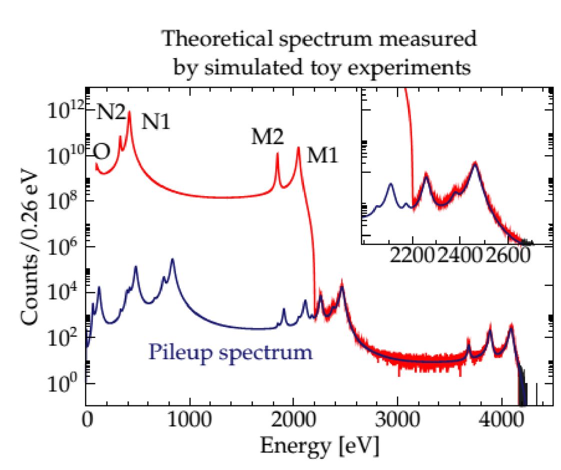
FINAL GOAL:
measure the ν_e mass
with sub-eV statistical sensitivity
using the Q-value determination of Ho decay

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

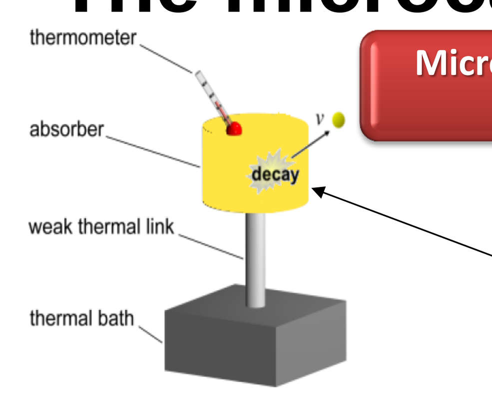
Experiment baseline:

- Transition Edge Sensors (TES) with ^{163}Ho implanted $Bi:Au$ absorbers;
- $6.5 * 10^{13}$ nuclei per detector ⇒ $300\ dec/s$;
- $\Delta E \cong 1\ eV$ and $\tau_{rise} \cong 1s$;
- $3 * 10^{13}$ events in 3 years;



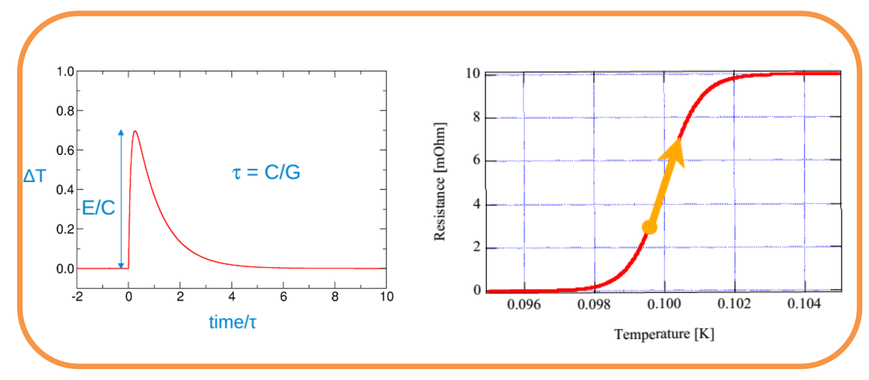


The microcalorimeter and TES detectors



Microcalorimeter Scheme

Metallic absorber is requested to ensure a < 1 eV FWHM.



Highlights on microcalorimeters:

- The heat equation in a calorimeter:
$$C\frac{d\Delta T}{dt} + G_{eff}\Delta T = \delta E$$
$$\Delta T = \frac{E}{C}e^{-\frac{t}{\tau}}$$
- $\tau = \frac{C}{G_{eff}}$ (if no feedback is considered)
- Energy resolution:
$$\Delta E = \left(\sqrt{k_b T^2 C}\right)$$
- Heat capacity and thermal conductance:
$$C \propto \alpha T^3 + \beta T$$

Low temperature and low C are needed.

Transition Edge Sensors use the resistive transition of a superconductor

- The superconductor is biased in its transition.
- "Self-biased region": the power dissipated in the device is constant with the applied bias;
- Electrothermal feedback: if R_{TES} rises I_{TES} decreases and also Joule Power decreases.
- A cooling of the device back to its equilibrium state in the self-biased region is needed;

Detectors microfabrication and array design

Six step TES and Bismuth absorber microfabrication process by NIST and University of Genova

Phase 1 @NIST:
- Mo:Cu proximity TES ($T_C \cong 100\ mK$);
- SiO_2 stopper layer;
- Si_xN_x membrame for thermal insulation;
- Deposited in a Si substrate;

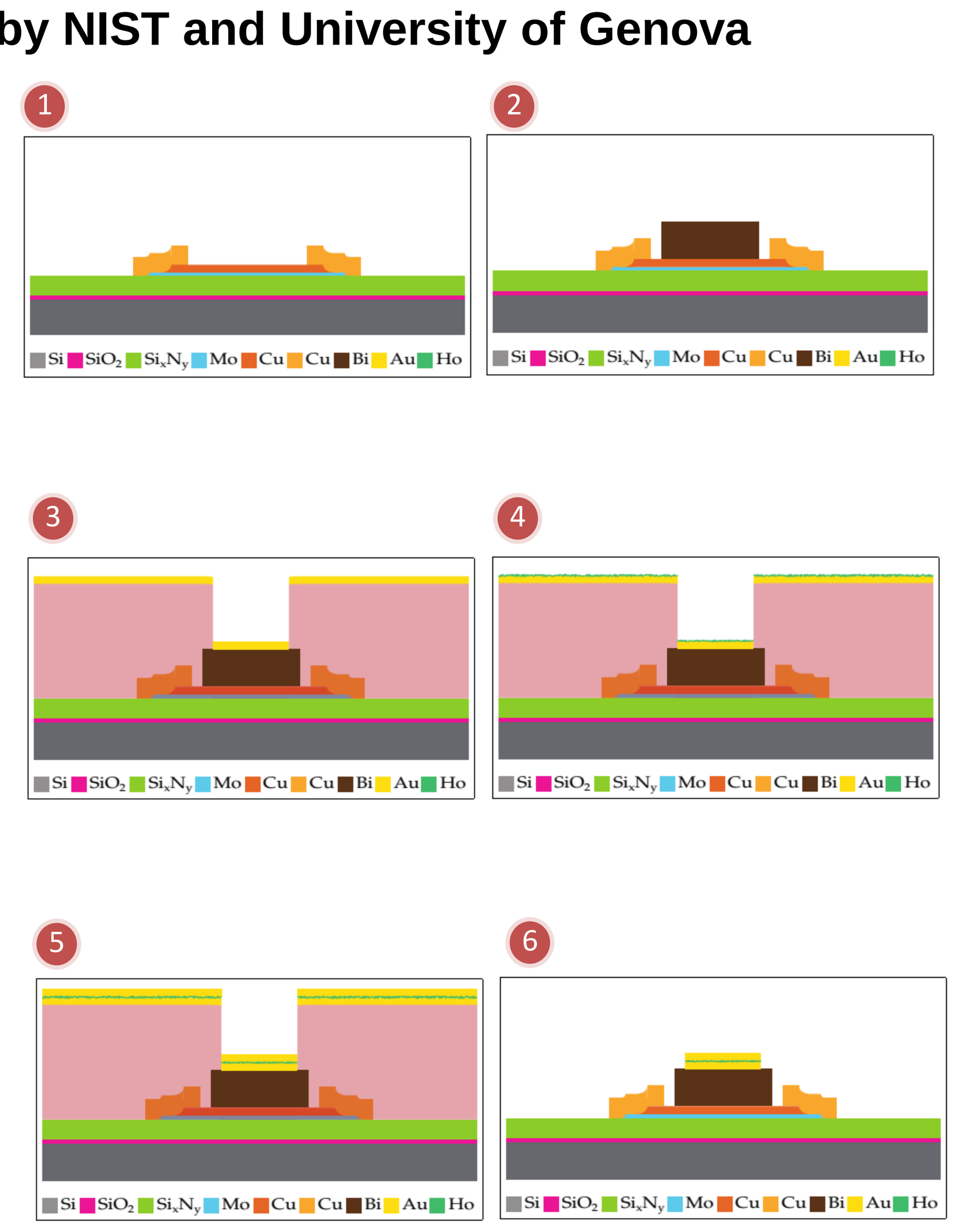
Phase 2 @NIST:
- Bismuth deposition for the first absorber layer ($2 \div 4\ \mu m$) by lift-off process:
  - Photoresist deposition (sacrifical layer);
  - Target material (Bi) deposition;
  - Wash out of the sacrifical layer;

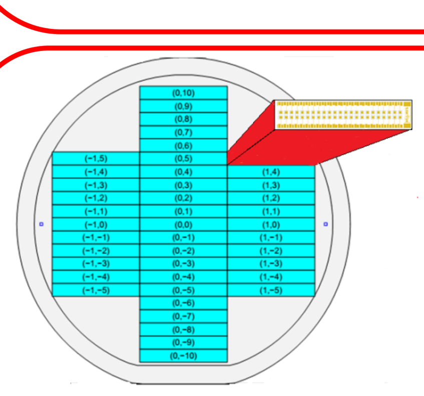
Phase 3 @NIST:
- Gold deposition for the second absorber layer ($0.1 \div 0.2\ \mu m$);
- Lift off not finished (no photoresist wash out);
- Ship to Genova (^{163}Ho implantation);

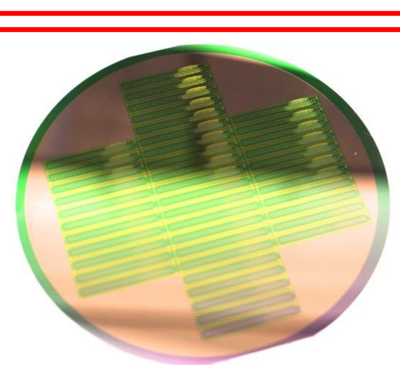
Phase 4 @Genova:
- ^{163}Hoimplantating:
- Metallic $^{163}Ho/\ Er/Au$ anode (source);
- Magnetic mass separation;
- Implantation and magnetic separation;

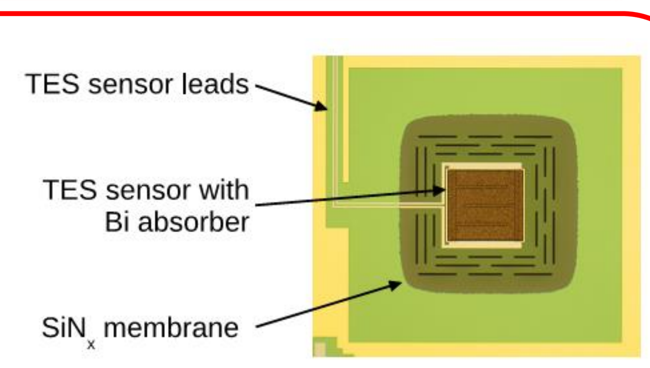
Phase 5 @Genova:
- Gold film deposition for full containment:
  - ^{163}Ho coating with thin Au ($0.1 \div 0.2\ \mu m$) layer;

Phase 6 @Genova:
- Lift off of the Au:Ho:Au layer;
  - ^{163}Ho-implanted Au-absorber.





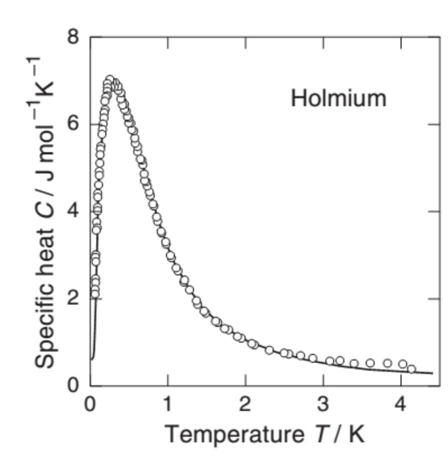


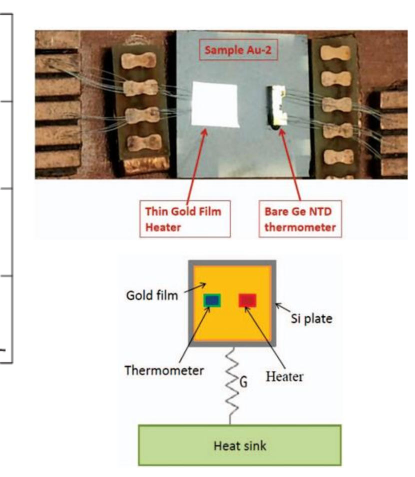


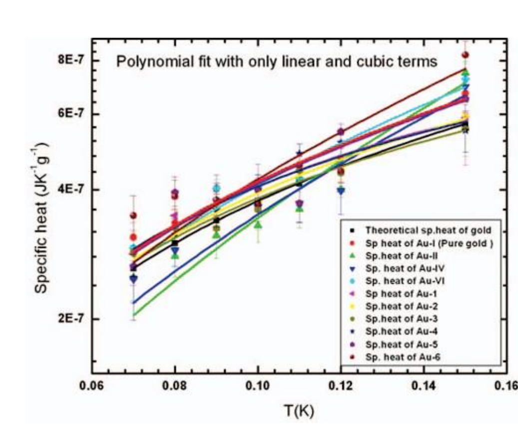
TES array: 2 · 23 detectors on a chip.
A total of 43 stripes can be inserted on a 3'' wafer

The absorber heat capacity

The specific heat of ^{163}Ho

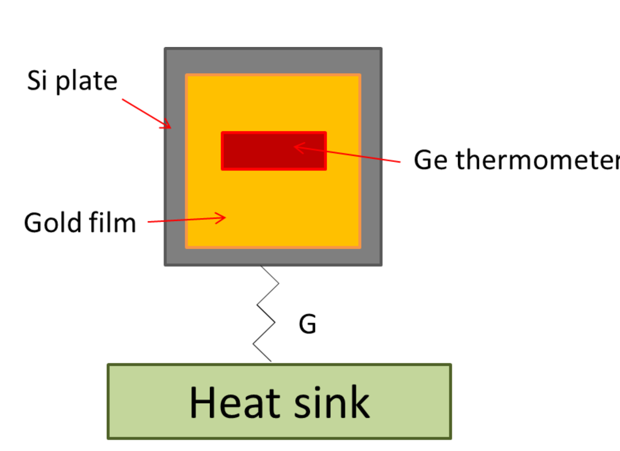






1. Because Ho presents J=7/2 due to hyperfine level splitting an high concentration in the metallic absorber may cause an excess in the measured total heat capacity .
2. Old specific heat measurement setup: a gold foil glued on the sample was used as heater.
3. Preliminary C_p measurements on Si:Au implanted samples show no influence from Ho. However **more detailed curves of C_p on the same Si/Au implanted samples are needed!**

A more precise measurement…



Samples will be heated in 3 ways:
- α source
- Ligth pulse
- Joule heating

^3He- ^4He dilution cryostat will be used:
- T=5 mK can be reached.
- 200 μW refrigerating power.

Conclusions

- *We need 300 decays/s per sample in order to reach <1 eV neutrino mass statistical sensitivity* ***(see also A.P. Puiu's poster n. 032515)****;*
- *We optimized the microfabrication process and the TES array design in order to maximize the number of detectors.*
- *A dummy 3'' wafer with a total of 43 stripes (1978 detectors) has been fabricated by NIST, and should be tested and implanted in Genoa* ***(see G. Pizzigoni's poster n. 032315);***
- *New C_p measurements on Si:Au implanted samples should be achieved in order to be sure that no excess specific heat arises at T<100 mK.*