The HOLMES project aims to directly measure the neutrino mass using the $e^+$ capture decay (EC) of $^{163}$Ho down to the eV scale. It will perform a precise measurement of the endpoint of the Ho calorimetric energy spectrum to search for the deformation caused by a finite electron neutrino mass. The choice of $^{163}$Ho as source is driven by the very low Q-value of the EC reaction, which allows for high sensitivity with low activities (O(10)$^4$Hz/detector), thus reducing the pile-up probability. A large array made by thousands of TES based micro-calorimeters will be used. The calorimetric approach eliminates systematic uncertainties arising from an external beta-source, and minimizes the effect of the atomic de-excitation process. The commissioning of the first implanted sub-array is scheduled for the end of 2018. It will provide useful data about the EC decay of $^{163}$Ho together with a first limit on neutrino mass. In this presentation the current status of the main tasks will be summarized: the TES array design and engineering, the isotope preparation and embedding, and the development of a high speed multiplexed SQUID read-out system for the DAQ.

### Holmium production and embedding chain:

- $^{160}$Ho is produced by n-activation of $^{160}$Er sample: $^{160}$Er($n$,$\gamma$)$^{160m}$Ho. $^{160m}$Ho is the main source of background. 
- $^{160}$Ho($n$,$\gamma$)$^{160}$Ho (8.12 × 1200y).
- $^{160}$Ho($n$,$\gamma$)$^{160}$Ho (2 steps purification procedure has been developed: 

#### Holmium production and embedding chain:

- Radiochemical purification and post irradiation, based on ion exchange chromatography: eliminates all species other than Ho, leaves a 166:163 ratio better than 1:1000

#### TES design and production:

- 2 $\mu$m Au absorber for full e/$\gamma$ absorption, usage of «sidecar» configuration to avoid TES proximation and allow G engineering for $\tau$ control:
- Desing optimization: obtain best compromise between energy resolution and time response: $\Delta E$ O(eV), $\tau$ ~ 1µs

#### Multistep production:

1. TES array is produced up to first 1µm Au layer;
2. $^{164}$Ho implantation
3. 1µm Au final layer deposition
4. Membrane release with KOH or DRIE process.
   - 4 x 16 linear array for low parasitic L and high implant efficiency

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**RF SQUID readout with microwave multiplexing: SQUID coupled with DC biased TES and a A/4 wave resonant circuit:**

- readout with flux ramp demodulation (common flux line inductively coupled to all SQUIDs);
- signal reconstructed by Software defined Radio Technique (ROACH2, ADC bandwidth 550MHz).
- Energy deposit in the absorber increases the temperature and therefore the TES resistance.
- Change in TES current = change in the input flux to the SQUID;
- The RF-SQUID transduces a change in input flux into a variation of resonant frequency;
- The ramp induces a controlled flux variation in the RF-SQUID, which is crucial for linearizing the response.

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**Status and perspectives:**

Source production: 3 batches have been already irradiated at ILL (Grenoble, FR), for a total of 140 MBq of $^{163}$Ho. The radiochemical separation process has been proved to work with an efficiency $>$ 79%.

Ion implanter: the setup of the machine is ongoing in Genova’s INFN laboratory. All devices have been separately tested (source, acceleration process, magnet).

Microcalorimeter test: several geometries were tested using $^{56}$Fe (5.9 eV) and fluorescence source (Mn ~ 5.9 keV, Ca ~ 3.7 keV, Cl ~ 2.6 keV, Al ~ 1.7 keV). A 3.5 to 5 eV energy resolution have been evaluated on those lines.

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**References:**