High energy resolution thermal microcalorimeters for the HOLMES experiment

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on behalf of the HOLMES collaboration

Frontier Detectors for Frontier Physics
14th Pisa meeting on advanced detectors

GA n. 340321

HOLMES is an experiment aimed at directly measuring the neutrino mass through the calorimetric measurement of the ^{163}Ho electron capture decay. The final goal of the project, besides providing a sensitivity on the neutrino mass below 2 eV, is to prove the scalability of these approach to achieve a sub-eV sensitivity. The detectors performances play a key role in achieving the desired sensitivity. Indeed, for such an experiment, the following characteristics are required: short response time (~ 1μs) to solve pile-up events, great energy resolution (~ eV@2.8 keV) and compatibility to be multiplexed in large detector arrays (>1000). HOLMES will deploy 1000 Transition Edge Sensors which will be readout with the microwave multiplexing technique. In this contribution we report the latest results obtained with the TES during the characterization phase of the detectors.

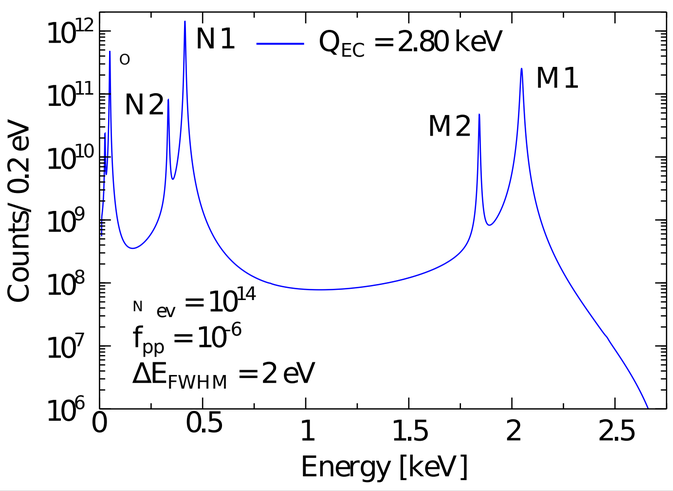
$^{163}Ho + e \rightarrow {}^{163}Dy^{*} + \nu_e$ Electron capture from shell ≥ M1

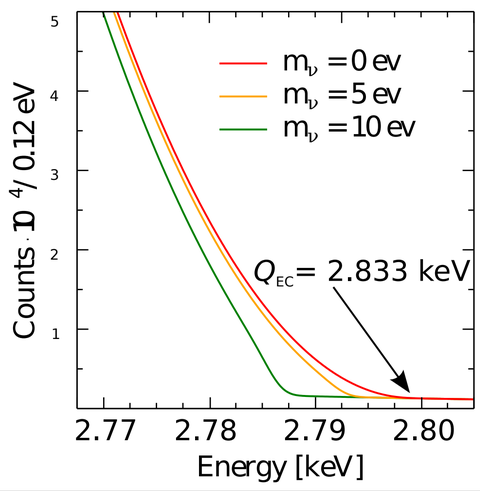
A. De Rujula and M. Lusignoli, Phys. Lett. B 118 (1982) 429

- **Calorimetric measurement of the (mostly non-radiative) de-excitation of Dy**
- Rate at the end-point depends on Q
  - ▶ Measured with Penning trap: ***Q* = 2.833 keV** Phys.Rev.Lett., 115:062501 (2015)

$\tau_{1/2} \approx 4570$ years ⟶ **few nuclei are needed**

$$\frac{d\lambda}{dE_c} = \frac{G_\beta^2}{4\pi^2}(Q-E_c)\sqrt{(Q-E_c)^2-m_\nu^2} \times \Sigma_i n_i C_i \beta_i \frac{\Gamma_i}{2\pi}\frac{1}{(E_c-E_i)^2+\Gamma_i^2/4}$$

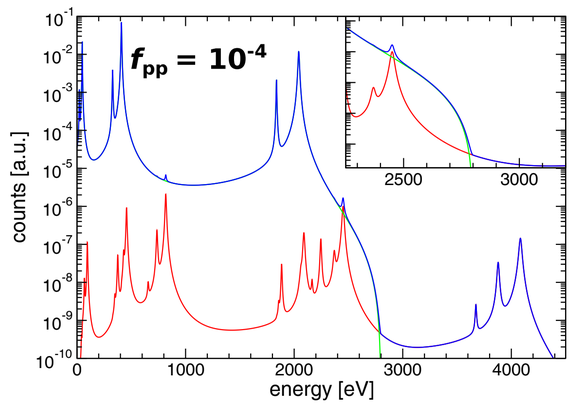


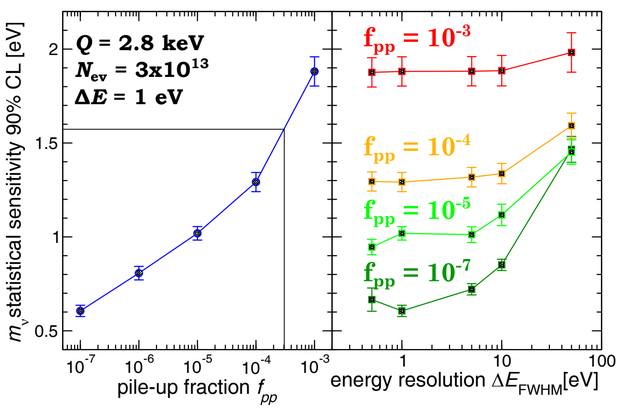


Statistical sensitivity Σ(m_ν) from MC simulations

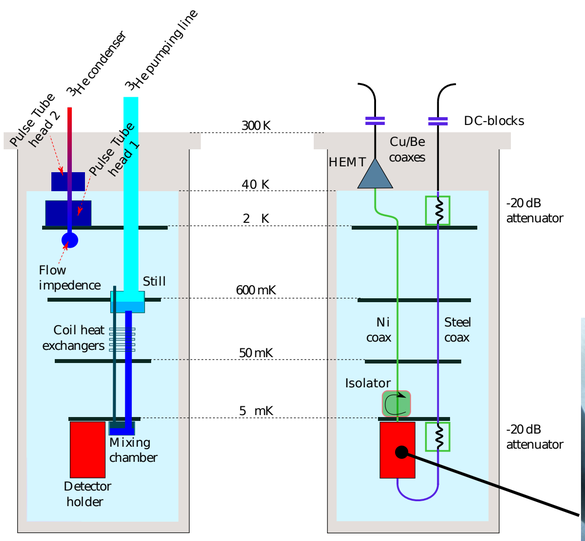
- strong on statistics $N_{ev} = A_{EC} N_{det} T_M$: $\Sigma(m_\nu) \propto N_{ev}^{1/4}$
- strong on rise time pile-up (probability $f_{pp} \approx A_{EC}\tau_R$)
- weak on energy resolution ΔE

A. Nucciotti, Eur. Phys. J. C (2014) 74:3161

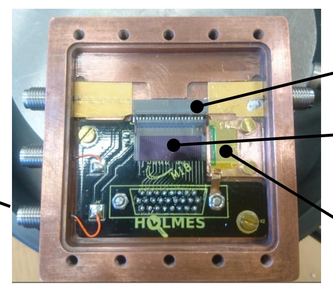




Cryogenic setup for detector testing

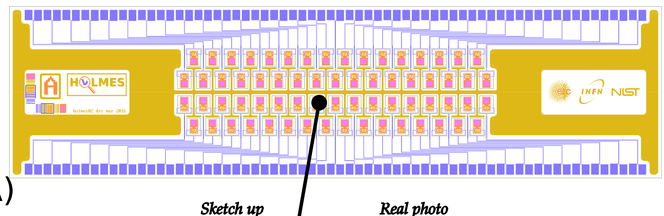


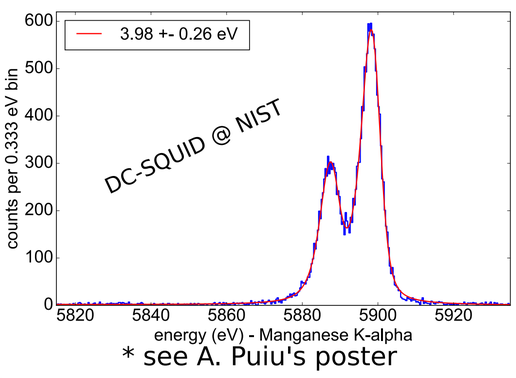
- Dry dilution refrigerator with base temperature < 10 mK
- Coaxial cables in low-thermal conductivity
- Low noise HEMT amplifier at low temperature
- PID-regulated feedback for temperature stability



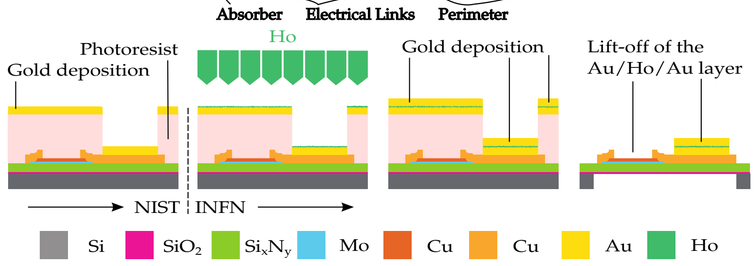
Transition edge sensors (TES)

- Thermal microcalorimeters
- Mo/Cu bilayers: $T_c \approx 100$ mK
- 2 μm thick gold absorbers
- produced @ NIST (Boulder, CO, USA)
- Implanted **^{163}Ho** (INFN)





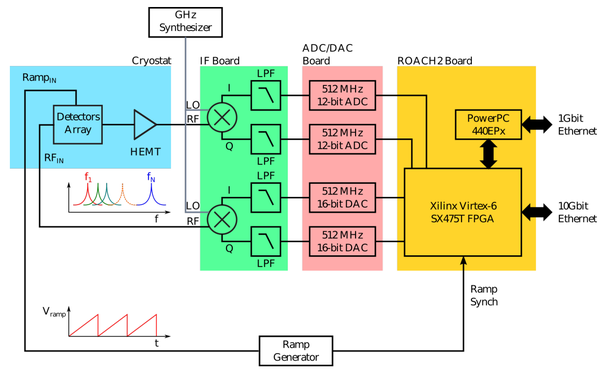
* see A. Puiu's poster

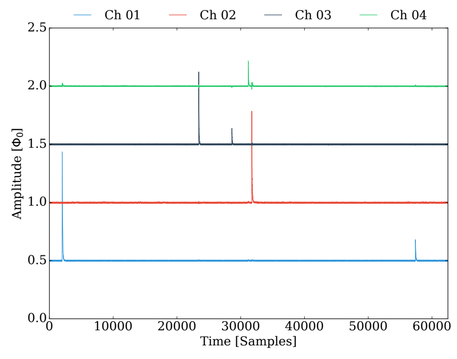


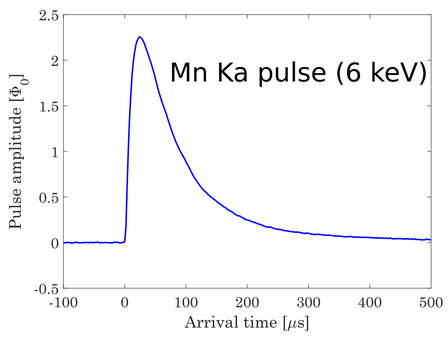
HOLMES DAQ with the ROACH2 board

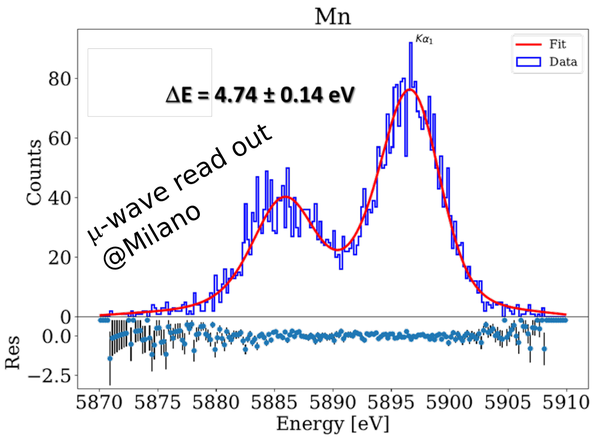
ROACH2-based acquisition system: demodulation and triggering in real time performed by FPGA Virtex-6

Temporarily the read out power of the IF board limits to 4 the number of of multiplexable detectors (new IF components are being delivered)

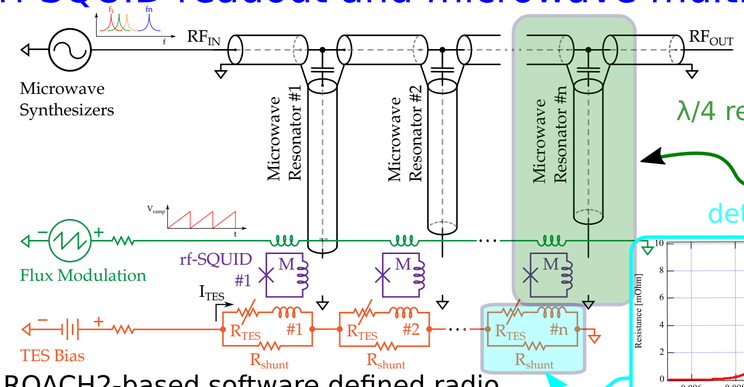


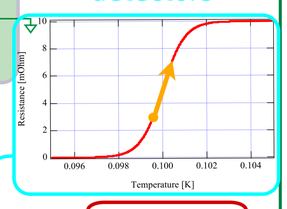


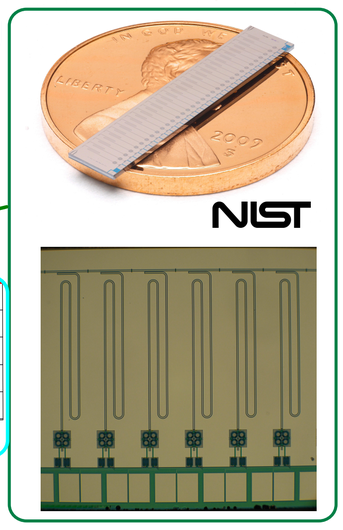




rf-SQUID readout and microwave multiplexing







ROACH2-based software defined radio

- f_{TES} bandwidth required/detector
- $f_{TES} \geq 2\, n_{\Phi_0} f_{sampl}$; $f_{sampl} \geq 5/\tau_R$
- $N_{mux} \leq f_{ADC} / 7 f_{TES}$; $f_{sampl} = 0.5$ MHz, $n_{\Phi 0} = 2$

$N_{mux} \approx 36$

- 33 resonances packed in 500 MHz
- 2 MHz BW per resonance
- spacing 14 MHz (to avoid crosstalk)