Updates on the Transition Edge Sensors and multiplexed readout for HOLMES

Andrei Puiu
Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milano, Italia
INFN - Sezione di Milano Bicocca, Milano, Italia

A. Puiu[1], B. Becker[2], D. Bennett[2], M. Biasotti[4], V. Ceriaele[4], M. De Gerone[4], M. Faverzani[1], E. Ferri[3], J. Fowler[2]. G. Gallucci[4], J. Gard[2], F. Gatti[4], A. Giachero3, J. Hays-Wehle[2], G. Hilton[2], J. Mates[2], A. Nucciotti[1], A. Orlando[3], D. Schmidt[2], D. Swetz[2], J. Ullom[2], L. Vale[2].
[1] University of Milano-Bicocca & INFN Milano-Bicocca, Milano, Italy
[2]NIST, Boulder, CO, USA
[3]INFN Milano-Bicocca
[4]INFN Genova

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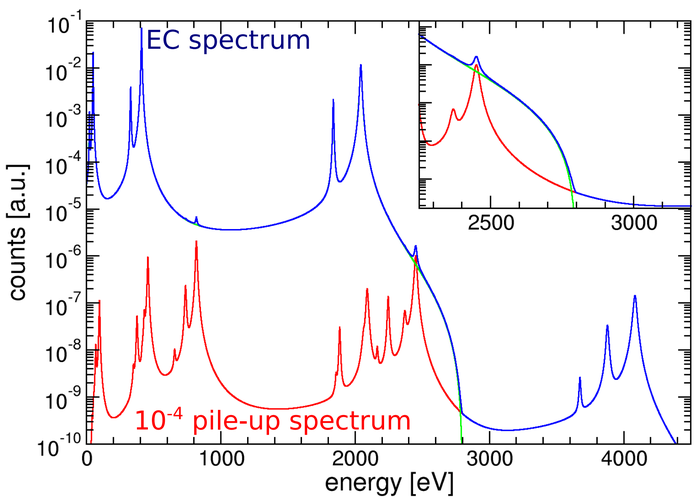
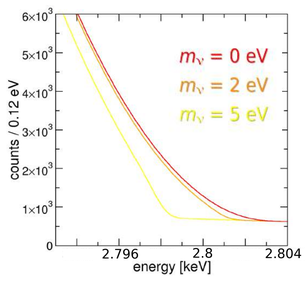
Measuring the neutrino mass is one the most compelling issues in particle physics. HOLMES is an experiment funded by the European Research Council for a direct measurement of neutrino mass. HOLMES will perform a precise measurement of the end point of the Electron Capture decay spectrum of 163Ho in order to extract information on neutrino mass with a sensitivity as low as 1 eV.
HOLMES in its final configuration will deploy a 1000 pixel array of low temperature microcalorimeters: each calorimeter consists of an absorber, where the Ho atoms will be implanted, coupled to a Transition Edge Sensor thermometer. The detectors will be kept at the working temperature of ~50 mK using a dilution refrigerator. In order to gather the required 3×10^{13} events in a three year long data taking with a pile up fraction as low as 10^{-4}, detectors must fulfill rather high speed and resolution requirements, i.e. 20 µs rise time (10-90) and ~1 eV resolution.

The neutrino mass measurement with ^{163}Ho: sensitivity and experimental requirements



The non vanishing neutrino mass deformes the Electron Capture spectrum of ^{163}Ho.
For reaching a sensitivity of 1 eV on the neutrino mass 3×10^{13} events must be gathered during the three years long measurement of HOLMES

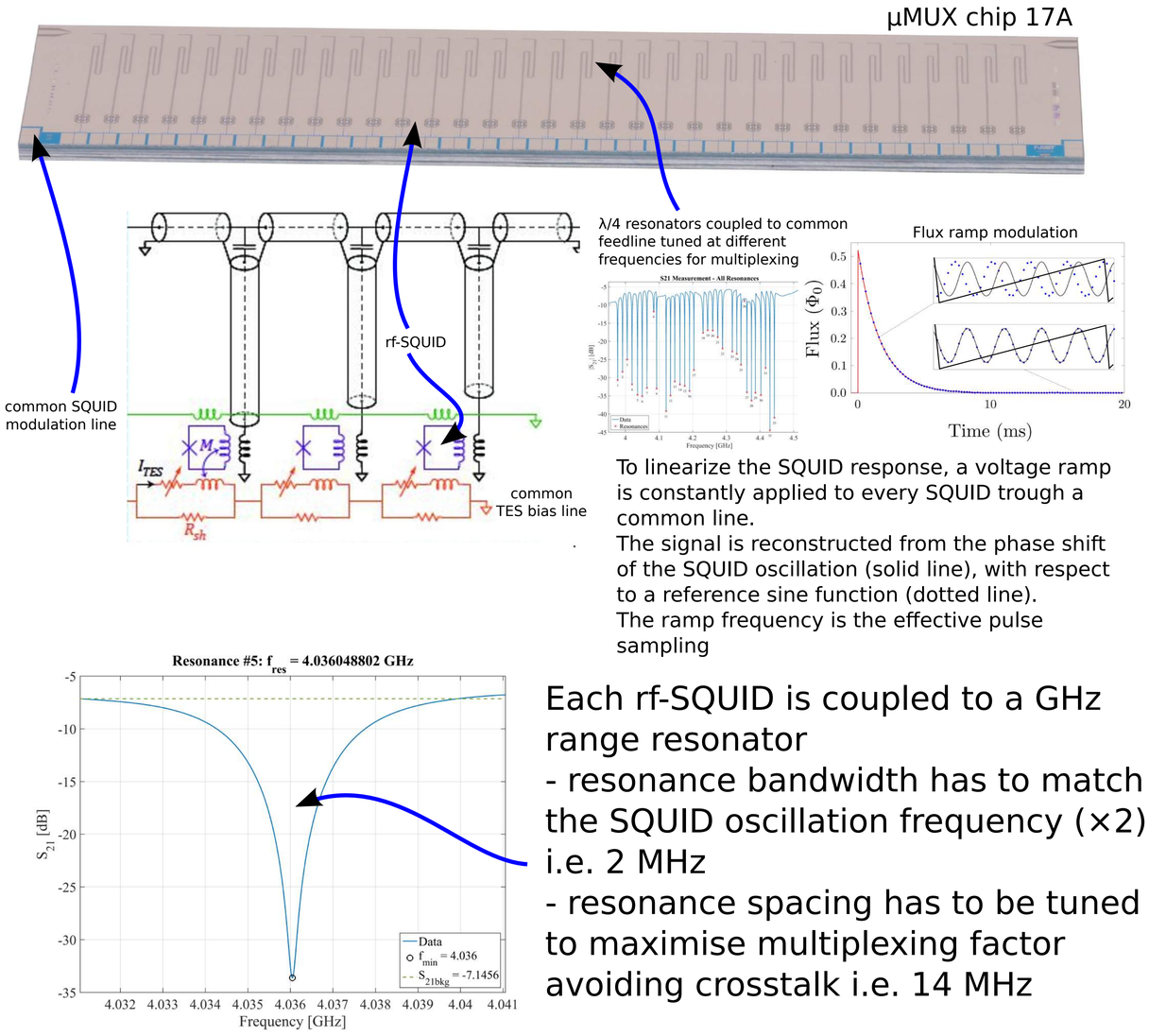


Pile up is the limitng factor on sensitivity and has to be kept as low as possible using fast detectors and rejection algorithms

Requirements for achieveing 1 eV sensitivity on neutrino mass:
- 3×10^{13} events in 3 years
- ~1 eV energy resolution
- Pile-up fraction 3×10^{-4}

Experimental requirements
- 1000 detectors
- 300 Bq/pixel
- 1 µs resolution on offline pile-up rejection: 20 µs rise time detectors sampled at 500 kHz

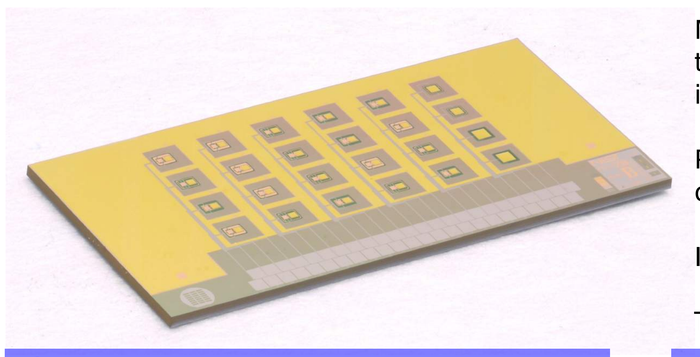
The rf-SQUID multiplexed readout



To linearize the SQUID response, a voltage ramp is constantly applied to every SQUID trough a common line.
The signal is reconstructed from the phase shift of the SQUID oscillation (solid line), with respect to a reference sine function (dotted line).
The ramp frequency is the effective pulse sampling

Each rf-SQUID is coupled to a GHz range resonator
- resonance bandwidth has to match the SQUID oscillation frequency (×2) i.e. 2 MHz
- resonance spacing has to be tuned to maximise multiplexing factor avoiding crosstalk i.e. 14 MHz

High performance detectors for HOLMES: Transition Edge Sensors



Mo/Cu Transition Edge Sensors coupled to Gold absorbers where ^{163}Ho will be implanted

Production and R&D for detectors optimization: NIST, Boulder-Co USA

Implantation: Genova

Test and measurement: Milano Bicocca

ROACH 2: The multiplexed readout for HOLMES

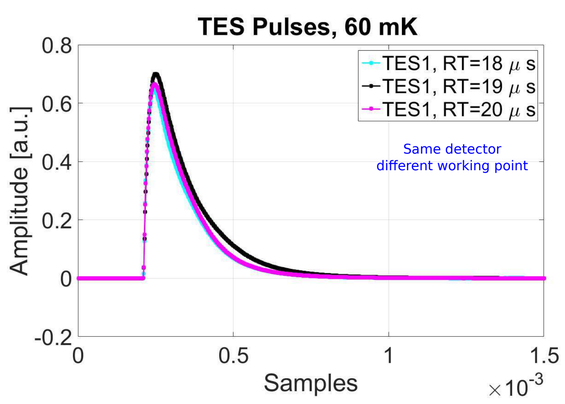
With our first ROACH 2 board we can now sample up to 32 channels at 500 kHz.

$$N_{pixels} = \frac{BW_{ROACH}}{NS \times 2 \times n_{\Phi_0} \times f_{RAMP}}$$

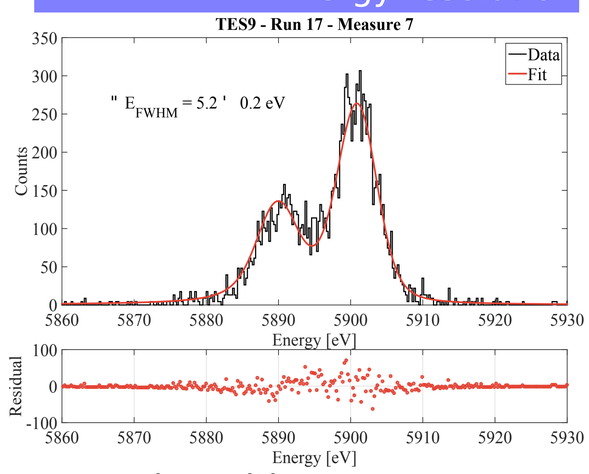
With the 550 MHz ADC bandwidth of the ROACH2:
- 500 kHz effective pulse sampling
- 14 MHz resonance spacing
- 2 MHz resonance width
- 2 Φ_0 SQUID oscillation/ramp

33 multiplexable channels per ROACH 2 board

Time response

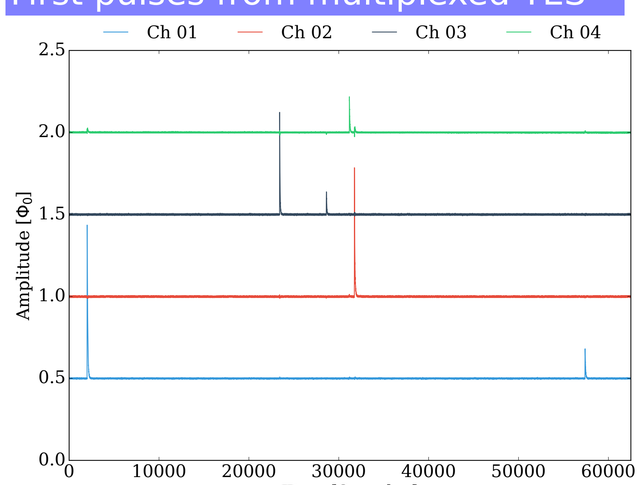


Energy resolution



TES average response to a 2.6 keV energy deposition

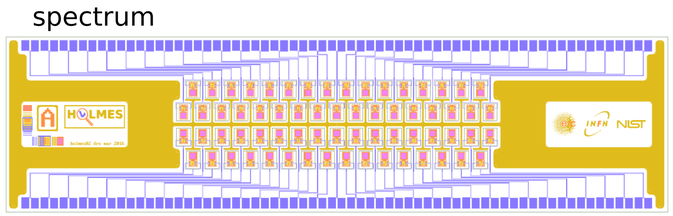
First pulses from multiplexed TES

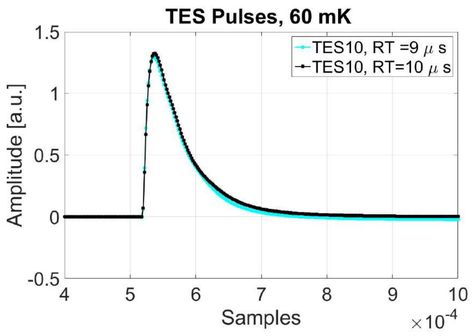


The target 20 µs 10-90 rise time has been reached (10 µs τ+).
Changing the working point allows to operate the TES with even faster rise time, as long as the slew rate is below 0.5 Φ_0/sample

Next detector steps

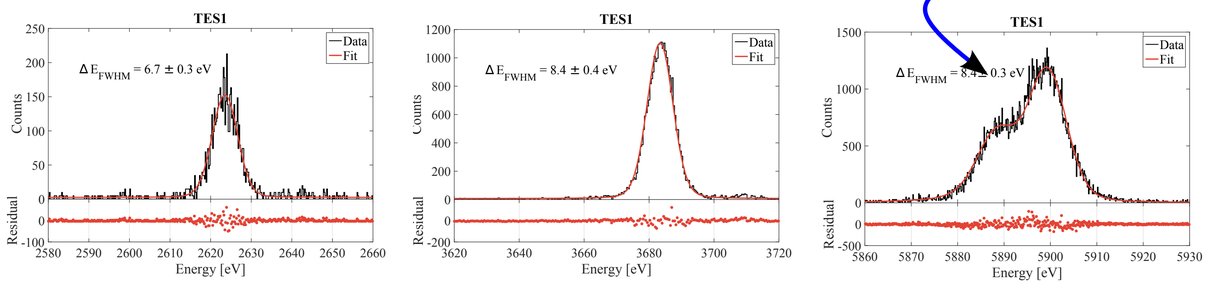
- Production and test of the final HOLMES array
- Test on first implanted detectors
- 16×4 detector array with implanted ^{163}Ho for short calorimetric measurement of EC spectrum





TES array and multiplexed are readout ready to measure the first batch of implanted detectors

X ray spectra acquired with TES not specifically designed for HOLMES to test the ROACH 2 multiplexed readout



Cl K-α | Ca K-α | Mn K-α

17th International workshop on Low Temperature Detectors
Kurume, 17th -21st July 2017