Development of microwave superconducting microresonators for neutrino mass measurement in the HOLMES framework [Poster G1.20]

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HOLMES

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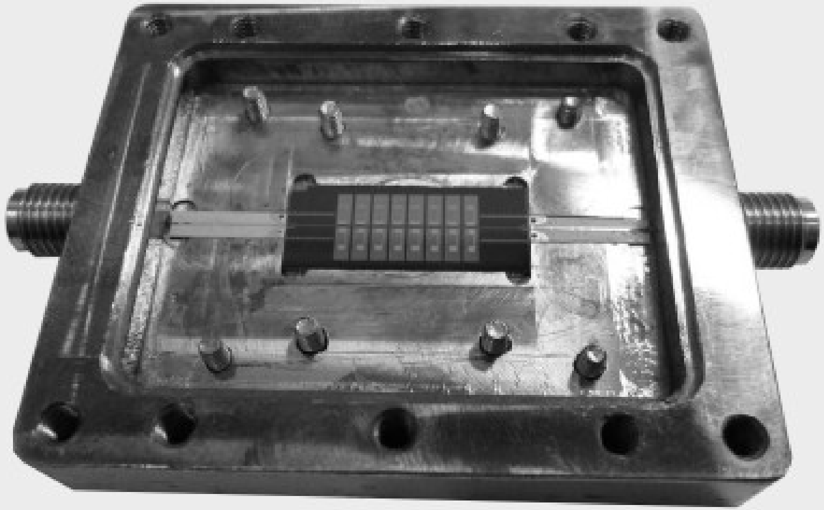

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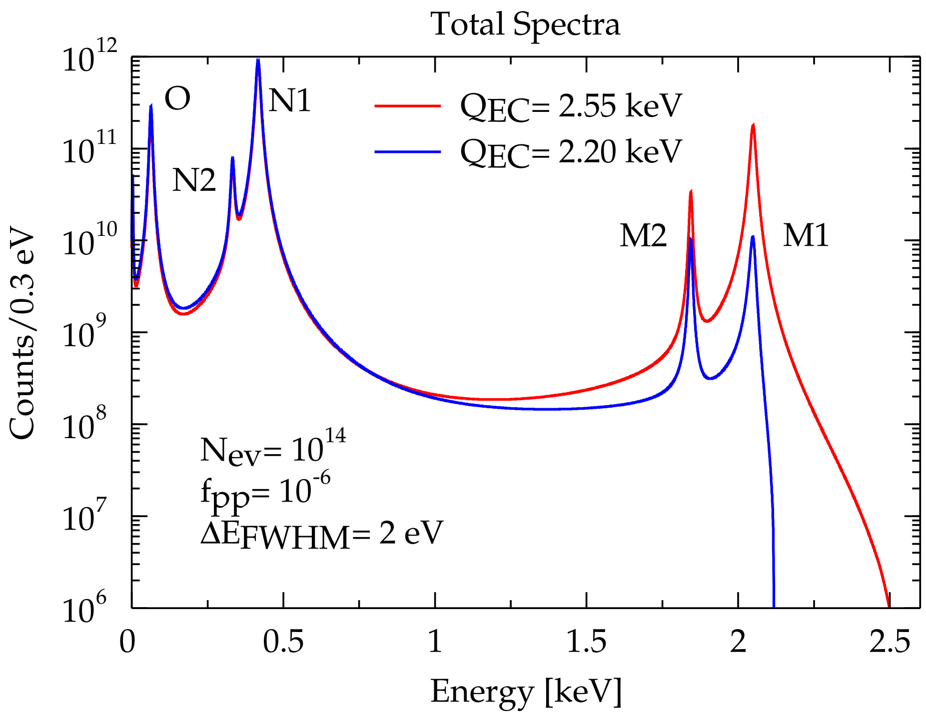
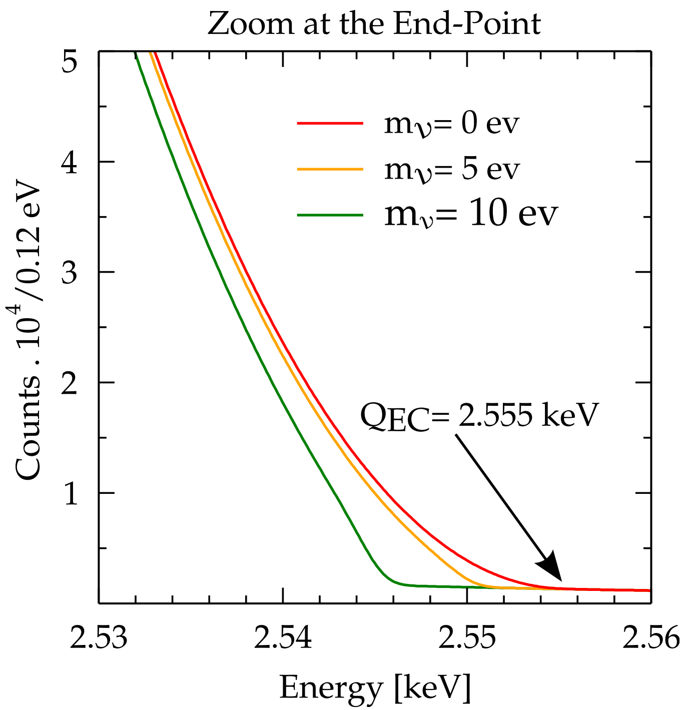
The HOLMES Experiment

HOLMES is a new experiment to directly measure the neutrino mass with a sensitivity as low as 0.4 eV. HOLMES will perform a calorimetric measurement of the energy released in the electron capture (EC) decay of ^{163}Ho.





More details in:

T4.4 A. Nucciotti

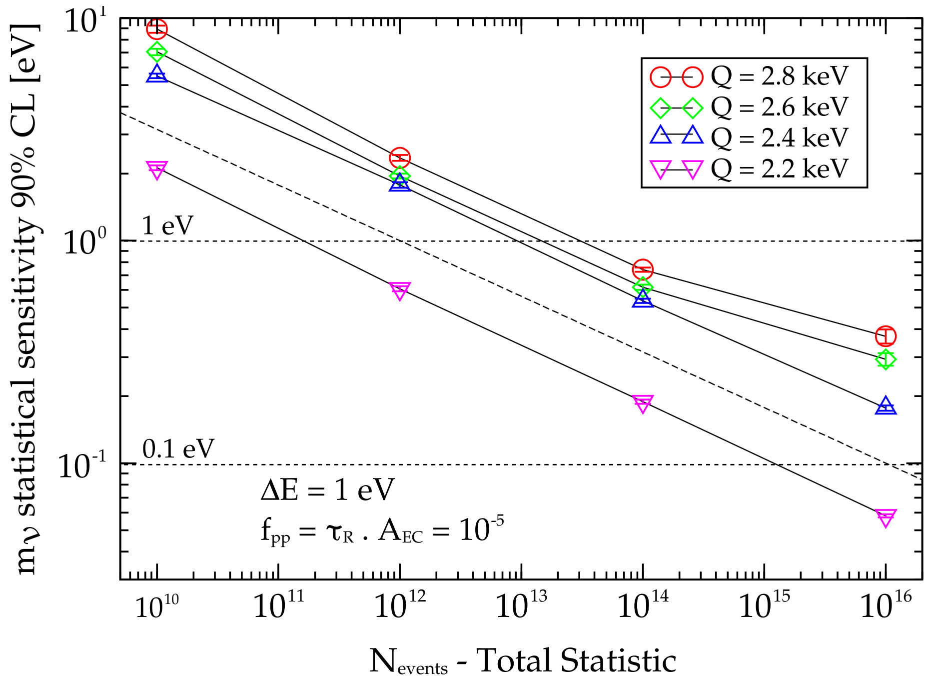
G1.6 E.Ferri

G.1.14 A. Puiu

- The method consists in searching for a tiny deformation caused by a non-zero neutrino mass to the ^{163}Ho EC spectrum near its end point (Q_{EC});
- In order to reach the sensitivity of 0.4 eV HOLMES will deploy 1000 detectors of low temperature microcalorimeters with implanted ^{163}Ho nuclei in the absorber.
- The baseline sensors for HOLMES are Mo:Cu TESs (Transition Edge Sensors) on SiNx membrane with gold or bismuth absorbers.

Sensitivity below 0.1 eV

^{163}Ho decay experiments statistical sensitivity dependence on the total statistics N_{events}



Exposure required for $m_\nu = 0.1$ eV sensitivity and $Q_{EC} = 2800$ eV

A_β [Hz]	τ_{rise} [μs]	ΔE [eV]	N_{ev} [counts]	Exposure [det·year]
1	0.1	0.3	$1.2 \cdot 10^{14}$	$3.9 \cdot 10^6$
100	0.1	0.3	$6.4 \cdot 10^{14}$	$2.0 \cdot 10^5$
100	0.1	1	$7.4 \cdot 10^{14}$	$2.4 \cdot 10^5$
10	0.1	1	$4.5 \cdot 10^{14}$	$1.5 \cdot 10^6$
10	1	1	$7.4 \cdot 10^{14}$	$2.4 \cdot 10^6$

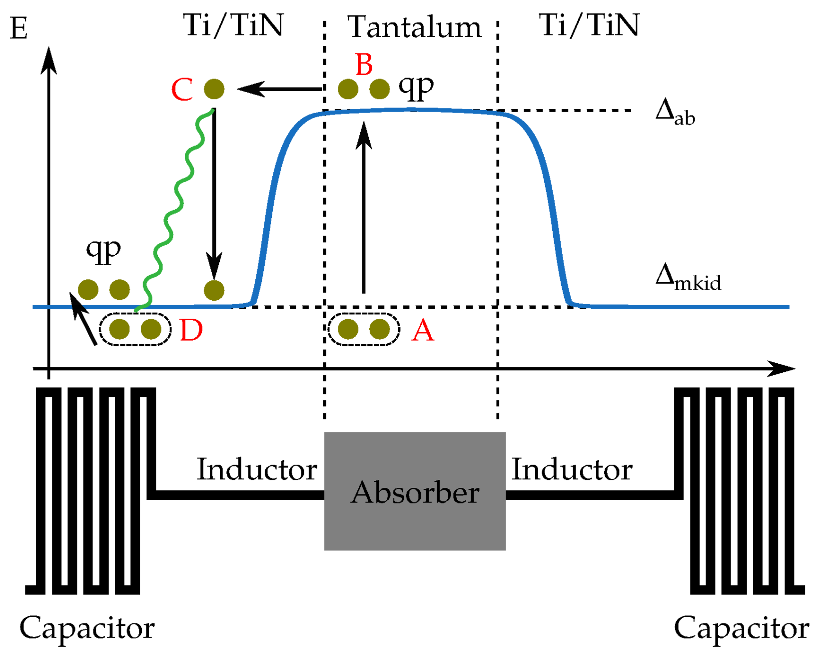
- 10^6 pixels/array;
- 6 arrays;
- 10 years of live-time;
- $8 \cdot 10^{19}$ nuclei of 163 Ho

- The HOLMES technologies are not readily scalable to Mega-pixel arrays needed for a high neutrino mass sensitivity measurement ($m_\nu < 0.1$ eV);
- An alternative solution is based on MKIDs detectors that have recently demonstrated the feasibility to build 100kpixel arrays with promising performances;

MKIDs for X-rays detection

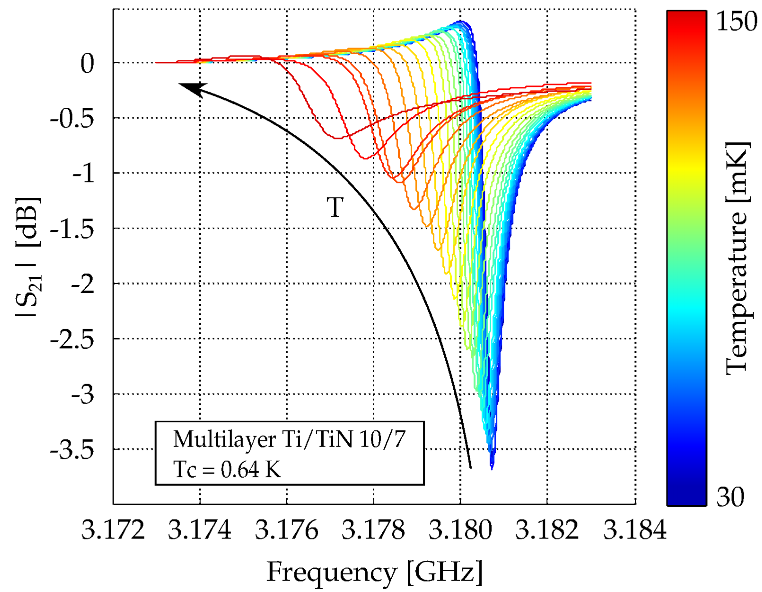
In non-equilibrium mode (**athermal mode**) the excess quasiparticles $d\sigma/dn_{qp}$ is due to an external pair breaking.

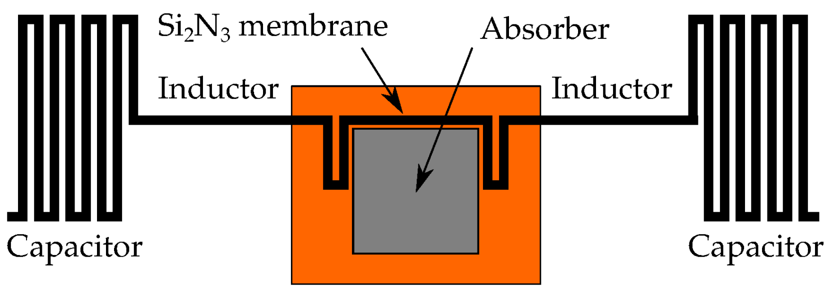
X-ray detection by using a superconducting absorber and exploiting the quasiparticle trapping.



$$\Delta E_{FWHM} = 2.355\sqrt{\frac{F\Delta}{\eta h\nu}}$$

In thermal equilibrium mode (**thermal mode**) an identical increase of quasiparticle population can be generated by a temperature change (pure calorimeter)

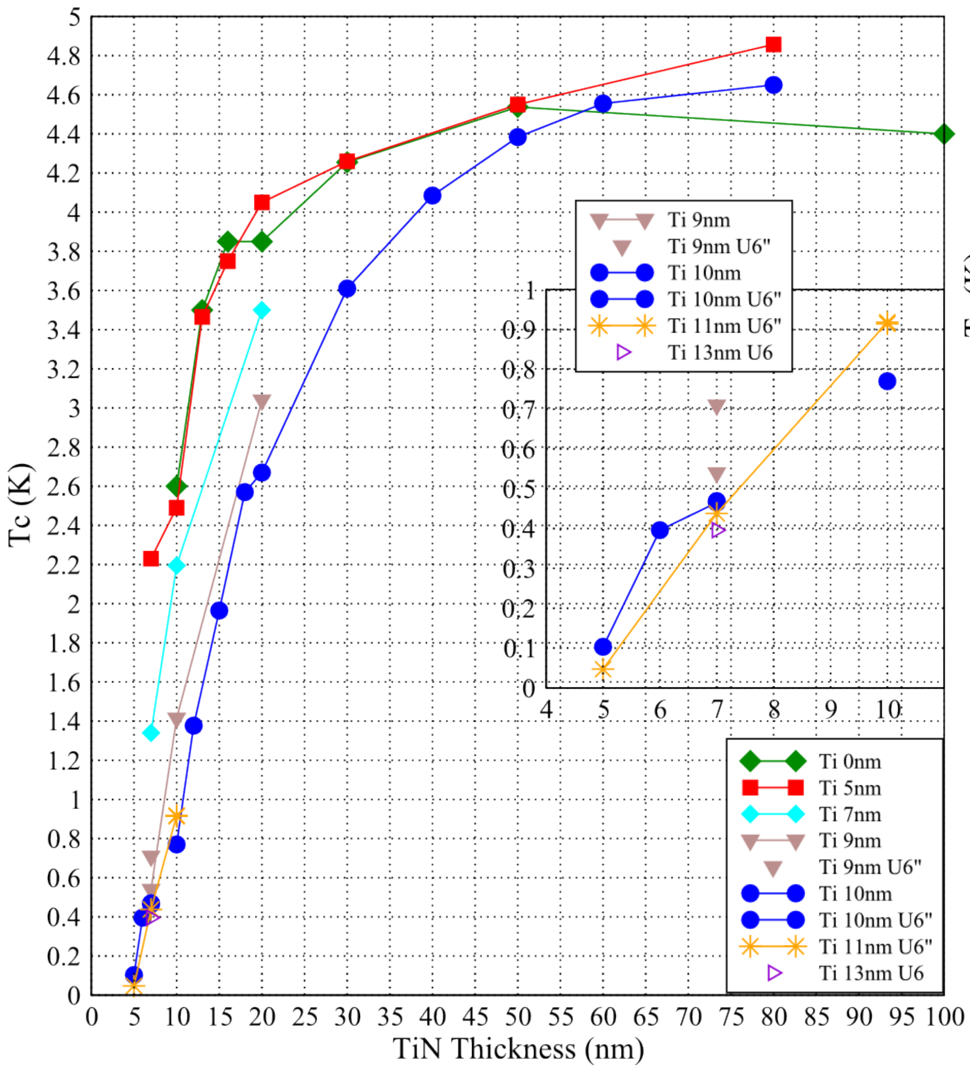


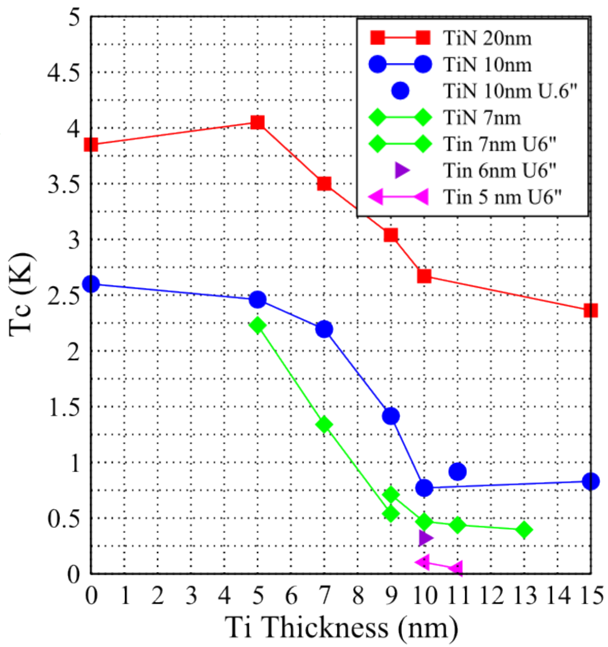


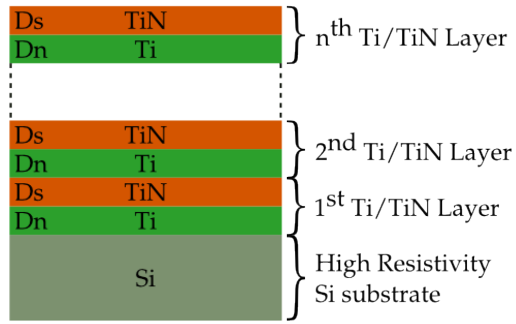
$$\Delta E_{FWHM} \simeq 2.355\sqrt{kT^2C}$$

Ti/TiN multilayer films

Superconducting films made by using multilayer composed by a superposition of bilayers of Titaniun and Titaniun Nitrate (Ti/TiN) → proximity effect





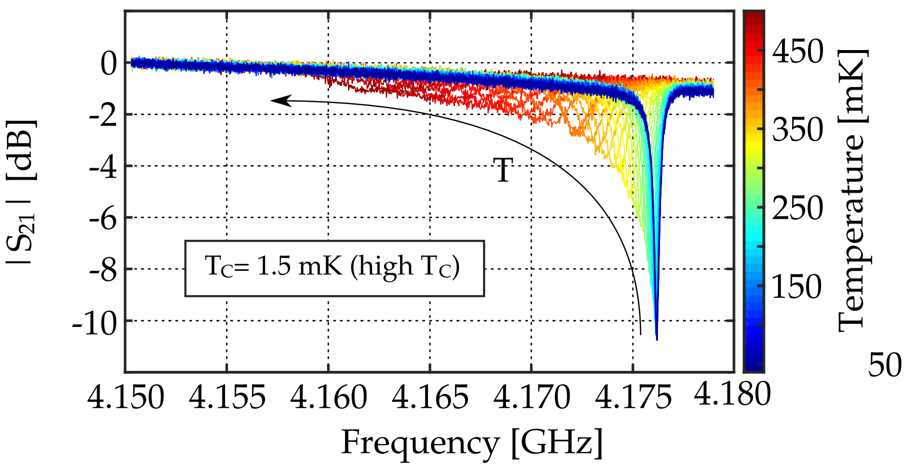


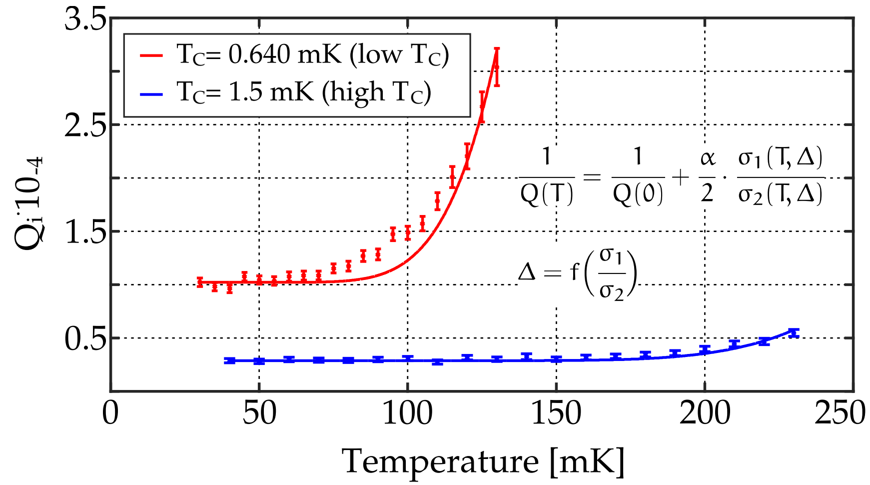
- The critical temperature can be tuned in the range (0.1 – 4.5) K by choosing properly the Ti and TiN thicknesses;
- Good reproducibility;
- Good uniformity;
- Very high kinetic inductance fraction;

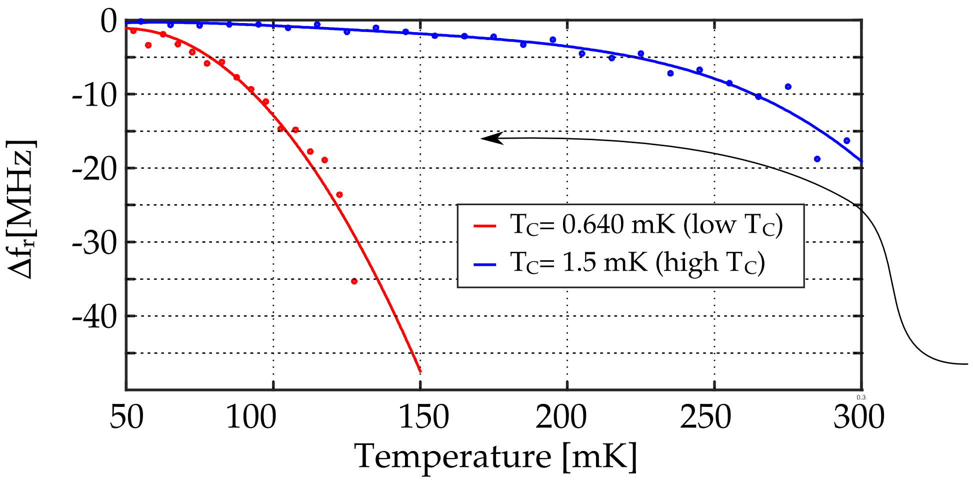
Devices Production and Characterizations

Two families: High T_c (1.5 K) to study the athermal mode (with Tantalum absorber);
Low T_c (0.6 K) to study the thermal mode (with Gold absorber);

Ti [nm]	TiN [nm]	N layers	T_C [K]
10	12	9	1.5
10	7	12	0.6







T_C [K]	Δ [meV]	α	L_S [pH/sq]	Q_i
1.5	0.200 ± 0.004	0.26 ± 0.01	13.1	$< 10^5$
0.640	0.091 ± 0.001	0.95 ± 0.01	36.9	$< 10^4$

The variation of the resonant frequency as a function of the temperature is steeper with lower critical temperatures.

Next Steps

- Optimize the layout geometry in order to improve the detector performances (kinetic fraction for the high T_C, quality factor for the low T_C , etc, …)
- Implement microresonators with absorber (Tantalum and Gold);
- Deep characterization with radioactive sources (^{55}Fe and ^{241}Am+Al foil sources);
- Development of a readout and multiplexing system based on the ROACH2 board;