



Direct neutrino mass measurement

National Coordinator:

Angelo Nucciotti (INFN-MIB)

Local Coordinator:

Federica Mantegazzini (TIFPA)

Collaboration

INFN & University Milan-Bicocca

INFN Genova

INFN Roma

INRiM Torino

TIFPA Trento

NIST, U.S.

PSI, Switzerland

ILL, France



Istituto Nazionale
di Fisica Nucleare
TIFPA
Trento
Institute for
Fundamental
Physics and
Applications

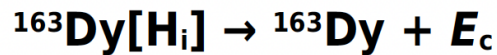
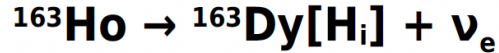


People at TIFPA

Name	Surname	Affiliation	Role	FTE
Federica	Mantegazzini	FBK	Ricercatrice FBK	0.3
Felix	Ahrens	FBK	Ricercatore FBK	0.4
Nicoló	Crescini	FBK	Ricercatore FBK	0.3
Alessandro	Irace	FBK/UniMiB	Dottorando FBK/UniMiB	0.3
Enrico	Bogoni	FBK/UniMiB	Dottorando FBK/UniMiB	0.7
Alessandro	Cian	FBK	Ricercatore FBK	0.3
Benno	Margesin	FBK	Senior Fellow FBK	0.5
Renato	Mezzena	UniTn	Tecnologo UniTn	0.4

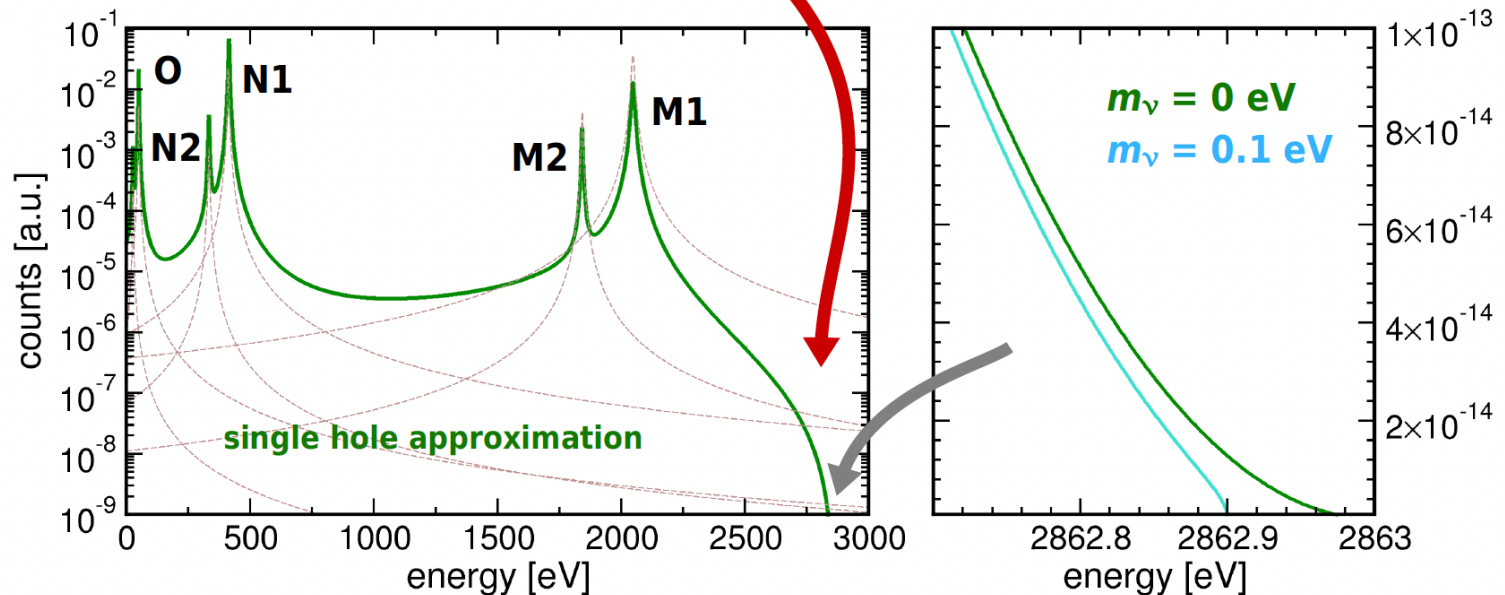
Calorimetric approach

Electron capture in ^{163}Ho



- Calorimetric measurement of atomic de-excitations (E_c)
- $Q = 2863.2 \pm 0.6 \text{ eV}$
- $\tau_{1/2} \simeq 4570 \text{ y} \Rightarrow 2 \times 10^{11} \text{ nuclei} \Leftrightarrow 1 \text{ Bq}$

$$N(E_c) = \frac{G_\beta^2}{4\pi^2} (Q - E_c) \sqrt{(Q - E_c)^2 - m_\nu^2} \times \sum_i n_i C_i \beta_i^2 B_i \frac{\Gamma_i}{2\pi} \frac{1}{(E_c - E_b(H_i))^2 + \Gamma_i^2/4}$$



From Holmes to Holmes+

Cryogenic microcalorimeter (TES) arrays with **ion-implanted ^{163}Ho**

Proof-of-concept with m_ν sensitivity $\lesssim 0.1$ eV

Gradual approach based on **scalability**

HOLMES

multiplexed TES 64-pixel array
 ≈ 1 Bq(^{163}Ho)/pixel

$\Delta E_{\text{FWHM}} \approx 1$ eV and $\tau_R \approx 1$ μs

B. Alpert et al., Eur. Phys. J. C, (2015) 75:112

$\rightarrow m_\nu$ statistical sensitivity $O(10$ eV)

HOLMES collab., <http://arxiv.org/abs/2503.19920>



HOLMES+

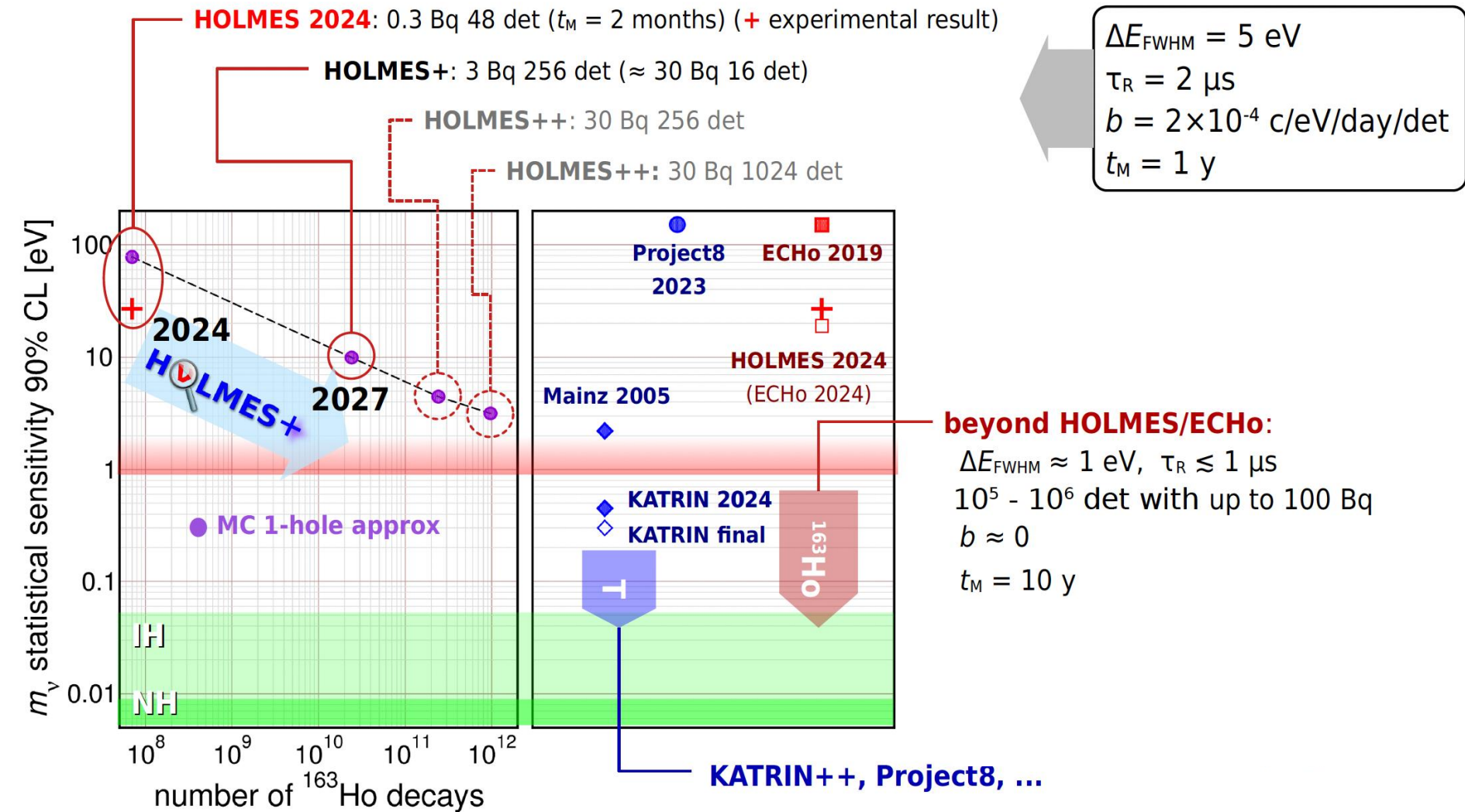
first phase of a **mid term (5y) plan for m_ν statistical sensitivity $O(1$ eV)**

up to ≈ 1000 pixels

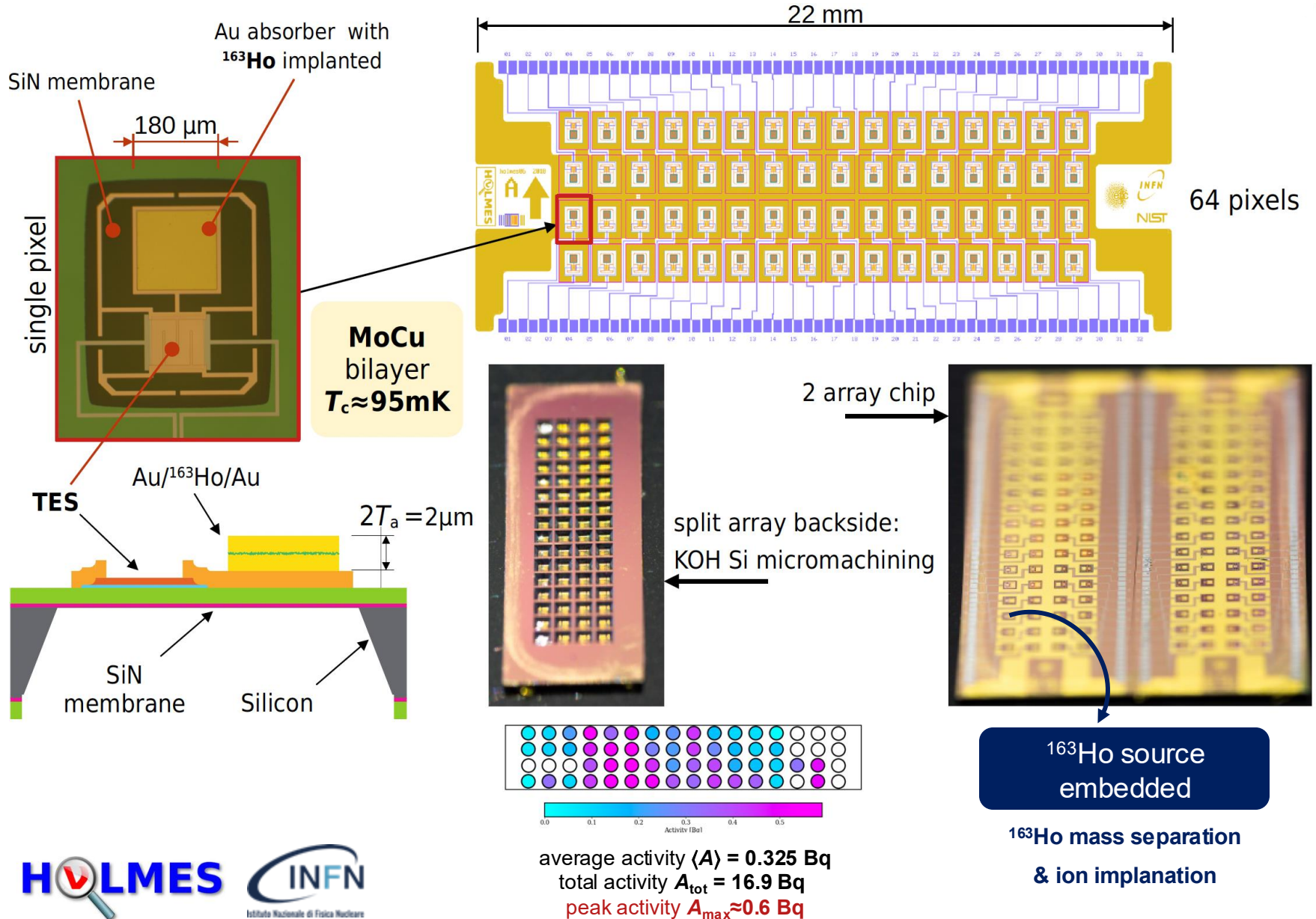
up to ≈ 30 Bq(^{163}Ho)/pixel

$\lesssim 0.1$ eV m_ν sensitivity requires scaling up
the HOLMES experiment by $\sim O(10^9)$

Towards sub-0.1 eV sensitivity



Microcalorimeter arrays



Holmes+ 3 year program (2025-2027)

improve ion implanter for better control and higher efficiency → up to few 10%

- now integrating electrostatic triplet for focusing, XY stirring magnet and target chamber for co-deposition
- upgrade ion source: Forced Electron Beam Induced Arc Discharge or Resonant Laser Ionization

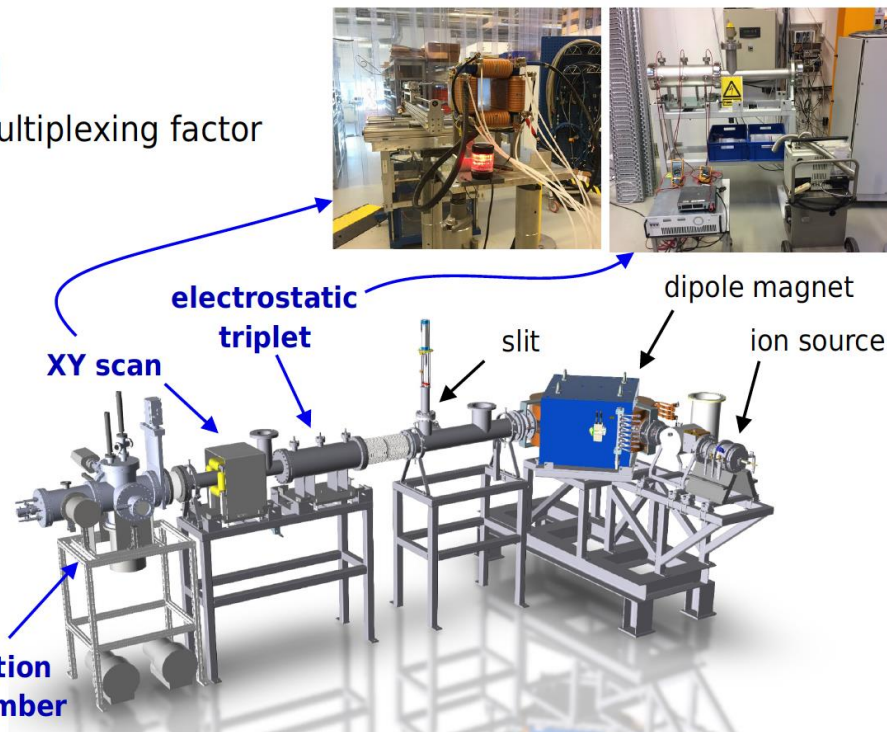
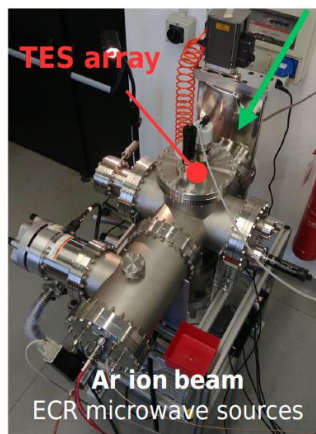
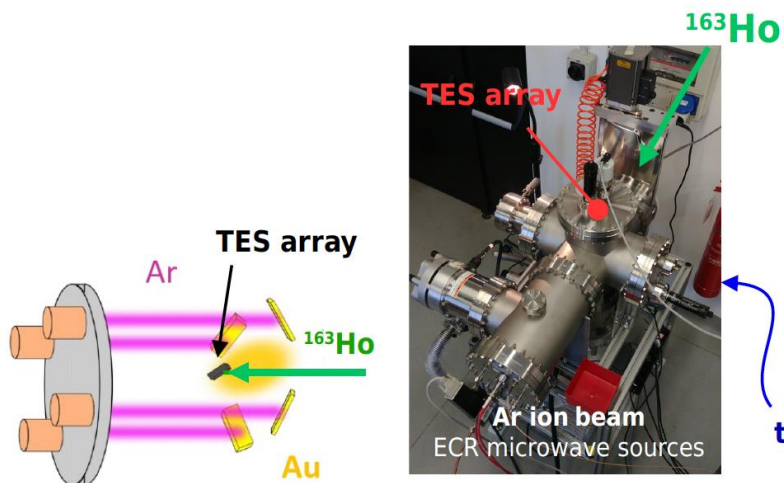
increase ^{163}Ho activity per detector → up to $O(100)$ Bq

- reduce detector operating temperature to $\lesssim 30\text{mK}$
- implement Au co-deposition

reduce readout/DAQ cost → few € per channel

- new multiplexing scheme w/o rfSQUIDs and larger multiplexing factor
- leverage new large bandwidth RFSoc boards

enlarge the international collaboration



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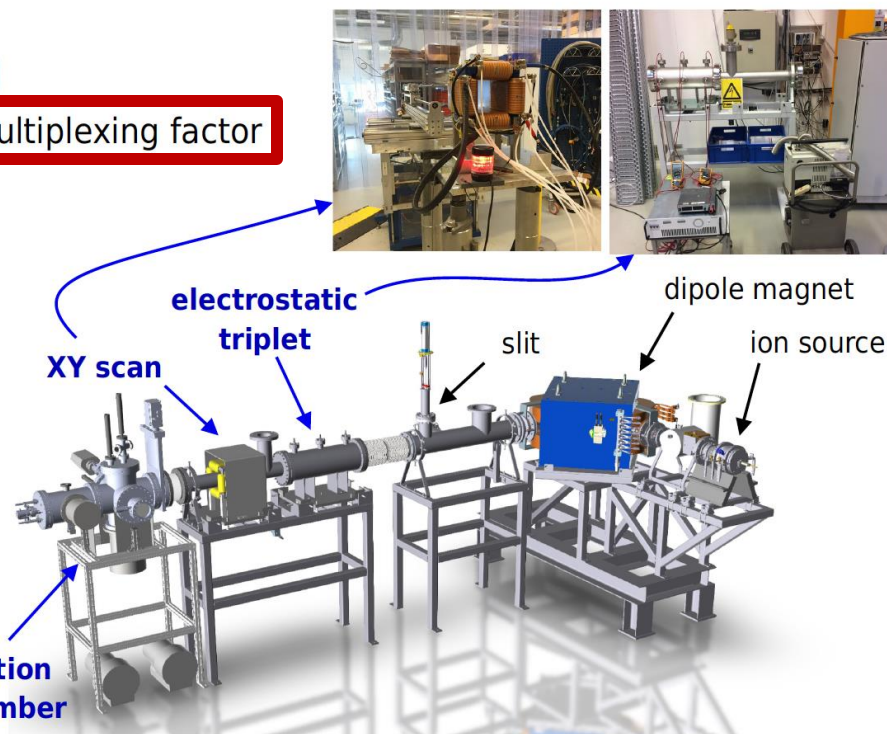
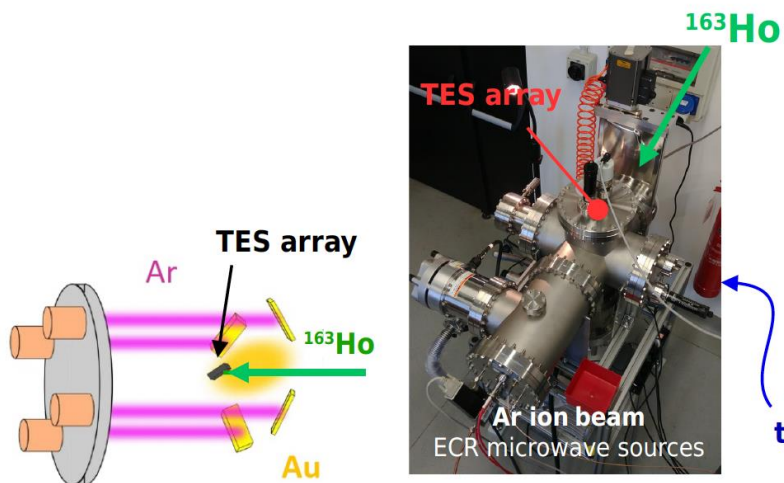
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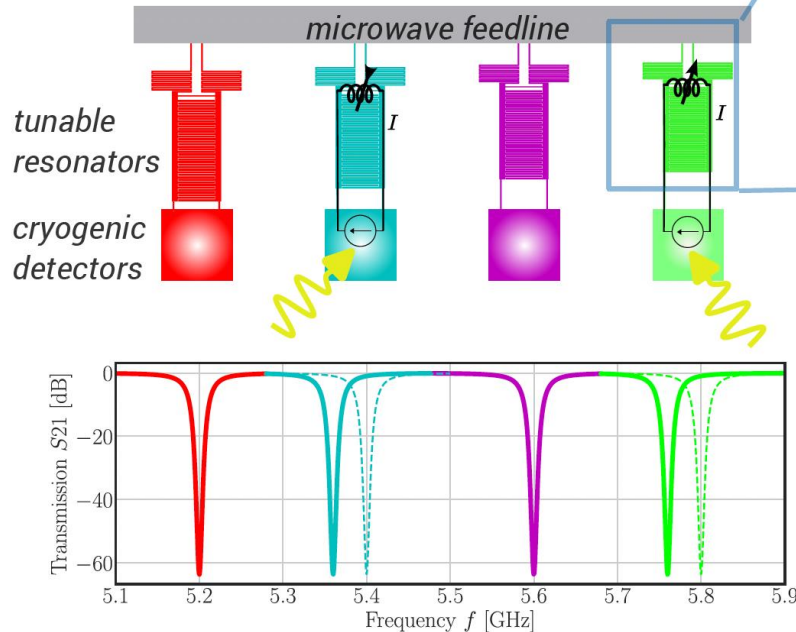


KICS – Kinetic Inductance Current Sensors

IDEA: microwave multiplexing of several cryogenic detectors

Lumped elements tunable resonator, galvanically coupled to detectors

WORKING PRINCIPLE



- Each **detector pixel** is coupled to a unique **resonator**
- Events in each pixel are reconstructed by **monitoring the frequency shift** of the resonator's resonance frequency

KICS – Kinetic Inductance Current Sensors

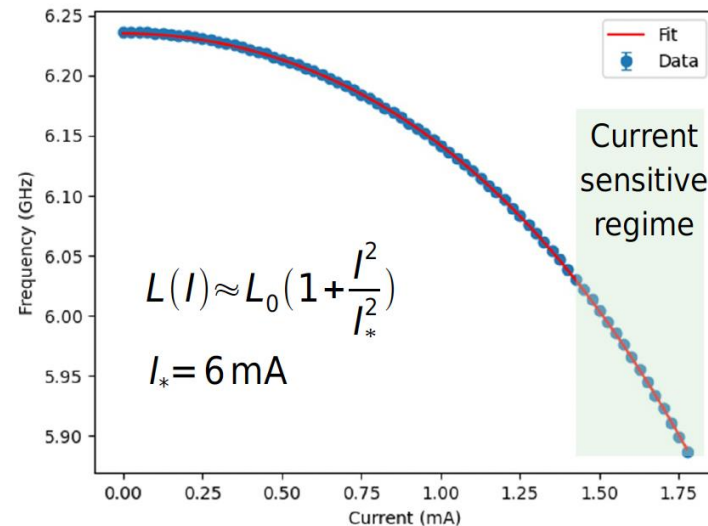
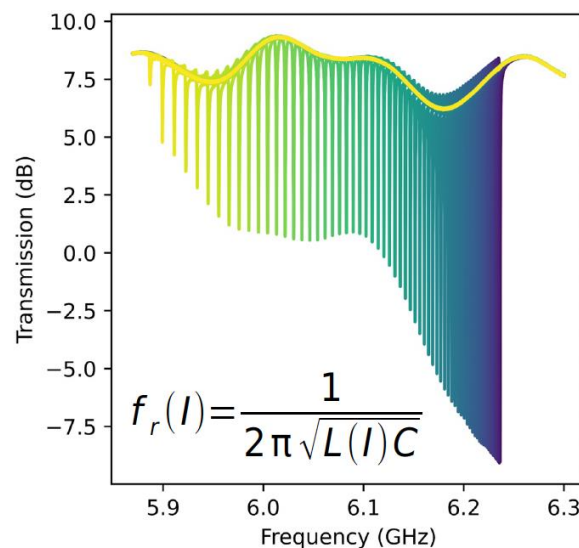
First results at TIFPA:

- First current tunable resonators **successfully microfabricated** and **tested** at TIFPA
- In progress: **KICS design** to read out HOLMES TESs

microfabricated device



Optical darkfield microscope image



Financial status 2025

Project duration: 3 years

Assegnazioni TIFPA, first year (2025)



Category	Description	Request
Consumabili	Materiale di consumo per misure di screening con cryocooler	5 kE
Microfabbricazione	Microfabbricazione di dispositivi presso FBK (convenzione INFN-FBK)	15 kE SJ
Missioni	Missioni presso altri laboratori	3.5 kE
	Total	23.5 kE

Financial request 2026

Project duration: 3 years

Financial requests for TIFPA, second year (2026)

(to be confirmed)



Category	Description	Request
Consumabili	Materiale di consumo per laboratorio per misure RF	8 kE
Microfabbricazione	Microfabbricazione di dispositivi presso FBK (convenzione INFN-FBK)	25 kE
Missioni	Missioni presso altri laboratori	3 kE
	Total	35 kE



Thank you!



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