HOLMES

an experiment for a direct measurement of neutrino mass

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HOLMES is a new experiment founded by the European Research Council to directly measure the neutrino mass. HOLMES will perform a calorimetric measurement of the energy released in the electron capture decay of ^{163}Ho with 0.4 eV sensitivity on the neutrino mass. HOLMES will deploy a large array of low temperature microcalorimeters with implanted ^{163}Ho nuclei in a Bismuth-Gold absorber coupled to a Transition Edge Sensor.

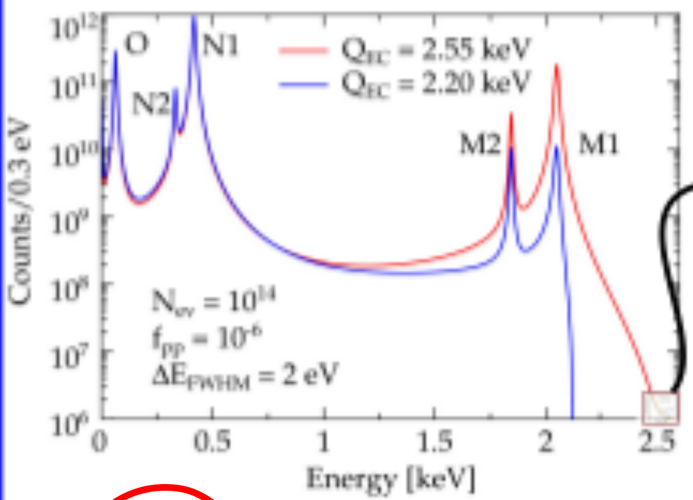
The R&D activities necessary to optimize the ^{163}Ho isotope production, the source embedding, the detector optimization and the multiplexed readout, are already in progress. We outline here the project with its technical challenges and perspectives.

the neutrino mass measurement

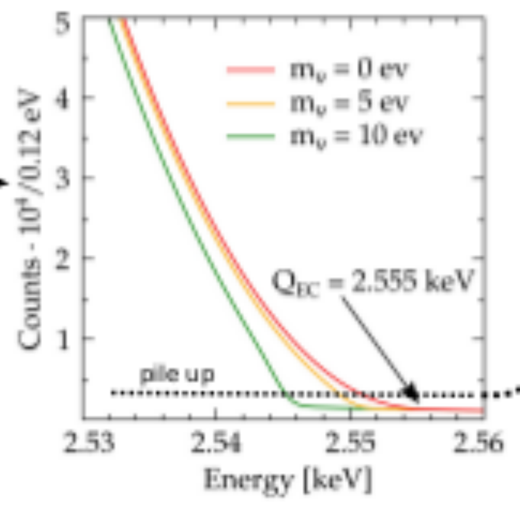
$^{163}\mathrm{Ho} + e^- \rightarrow {}^{163}\mathrm{Dy}^* + \nu_e$

$^{163}\mathrm{Dy}^* \rightarrow {}^{163}\mathrm{Dy} + \mathrm{EC}$

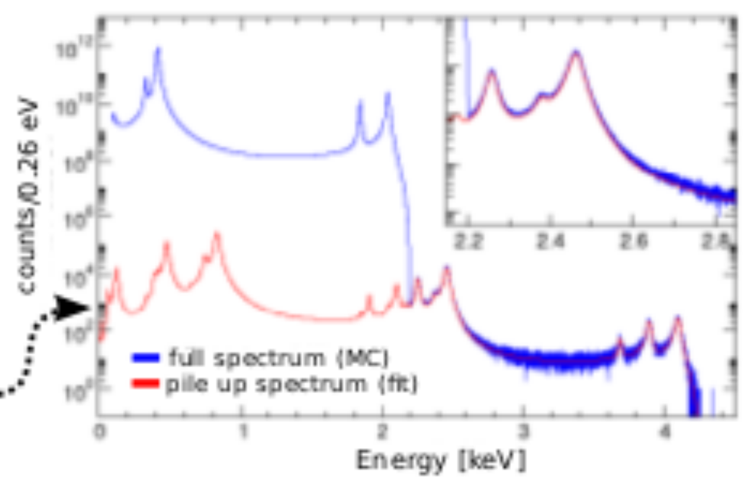
electron capture spectrum from shell ≥ M1



spectrum at the point shaped by $(Q - E_c)\sqrt{(Q-E_c)^2 - m_\nu^2}$



pile up at the end point with 300 Bq / detector $f_{\text{pile-up}} = t_{Res} * \text{Activity}$



A. D. Rujula and M. Lusignoli, *Physics Letters B*, vol. 118, 1982.

Calorimetric measurement of Dy atomic de-excitations (mostly non-radiative):
- measurement of the entire energy released except the ν energy;

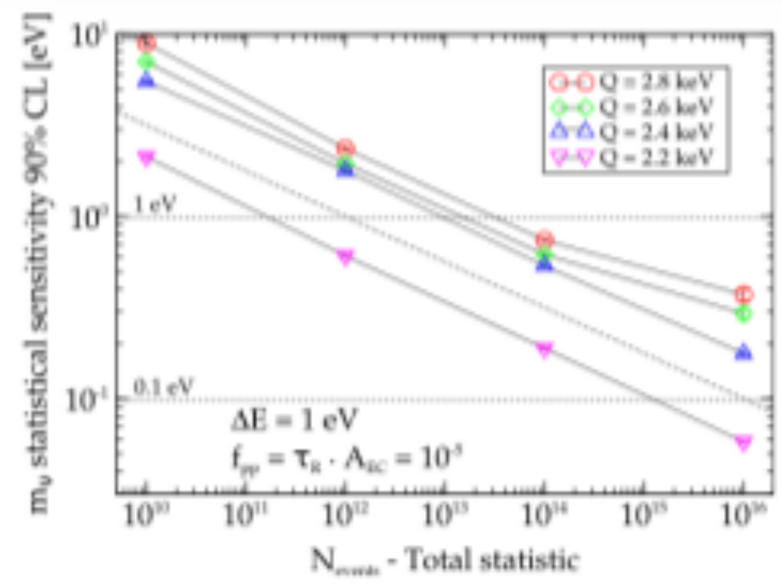
The rate at end-point and the neutrino mass sensitivity (m_ν) strongly dependent on Q value (Measured: Q_{EC} = (2.2 ÷ 2.8) keV, recommended: Q_{EC} = 2.555 keV);

HOLMES sensitivity

HOLMES GOALS

neutrino mass measurement with a m_ν statistical sensitivity as low as 0.4 eV

demonstrate technique potential and scalability



Experimental requirements for 0.4 eV

Low temperature calorimeters with

Energy resolution 1 eV @ 2 keV

Fast response detectors (t_{Res}=1 μs) to reduce pile-up

Very large detector array (1000 detectors) → multiplexing

10^{13} events in 3 years

0.4 eV sensitivity on neutrino mass

A. Nucciotti, *Eur. Phys. J. C* (2014) 74:3161, arXiv:1405.5060

HOLMES — Project Start: 1 Feb 2014

B. Alpert et al, accepted in EPJ-C, arXiv:1412.5060

http://artico.mib.infn.it/nucriomib/experiments/holmes

mid-term prototype	full scale HOMES
16 channels	1000 channels
t_M=1 month	t_M=3 years
A=300 Bq/ch	A=300 Bq/ch
statistics→ 10^{10} events	statistics→ $3*10^{13}$ events

Detectors: Transition Edge Sensors (TES) with ^{163}Ho implanted in Bi/Au absorbers

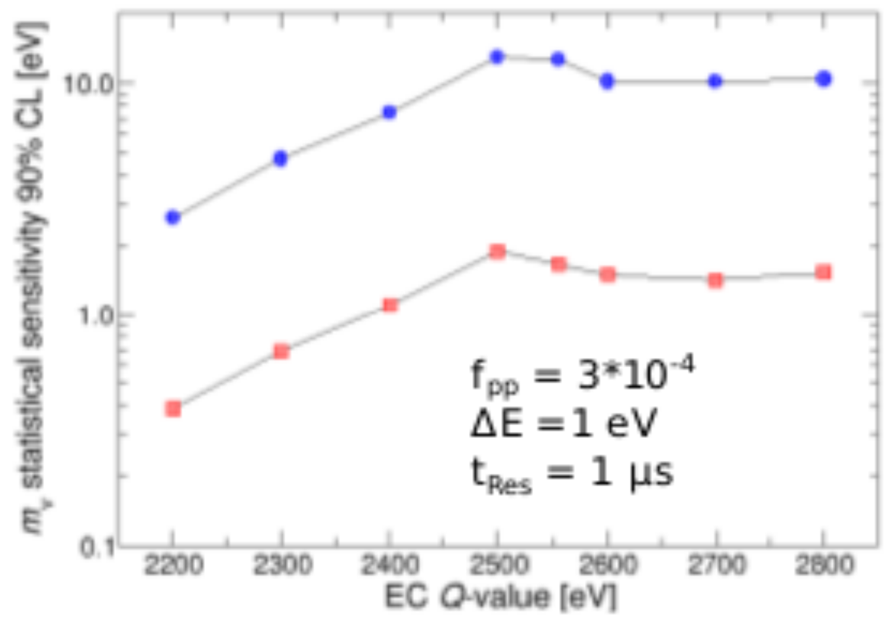
Activity: $6.5*10^{13}$ nuclei per detector → 300 dec/sec

Performance: ΔE≈1eV and t_{Res}≈1μs

Final configuration: 1000 channel array

$6.5*10^{16}$ ^{163}Ho nuclei → ≈18μg

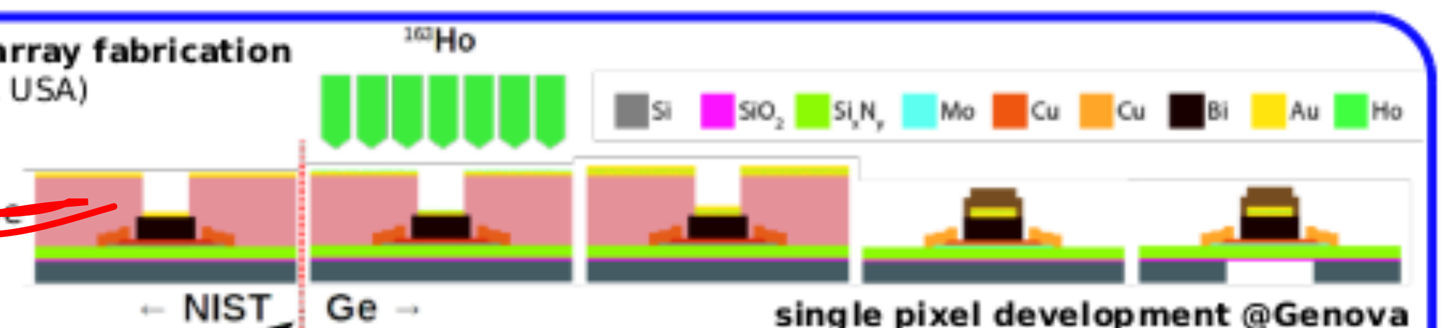
$3*10^{13}$ events in 3 year



HOLMES baseline

subcontract array fabrication (NIST, Boulder, USA)

subcontractor fabricates first layer of absorber (1 μm Au)



single pixel development @Genova

optimize design for time response and resolution

define process for ^{163}Ho implantation

Further and more detailed information on the detector fabrication: poster of Valentina Ceriale

Holmium production & embedding

^{163}Ho production by nuclear reaction

- high yield
- low by-products contaminations (in particular ^{166m}Ho, β $\tau_{1/2}$=1200 y)

^{163}Ho separation from Dy, Er, ...

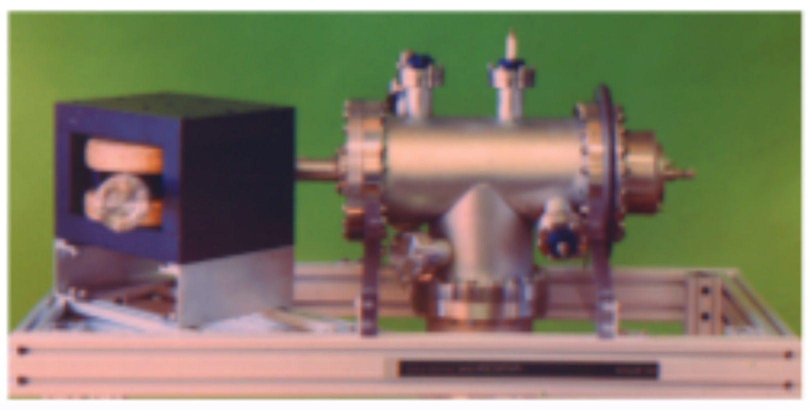
- radiochemistry (before and after irradiation)
- magnetic mass separation

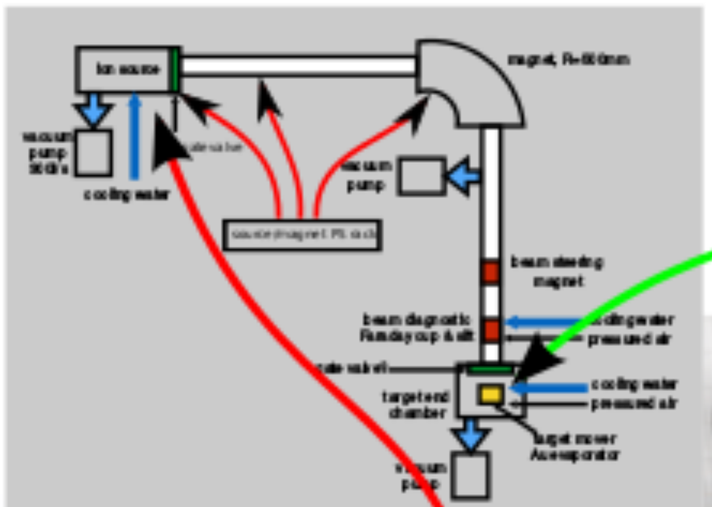
^{163}Ho embedding in detector

- implantation +magnetic separation
- Au film deposition for full containment

$^{162}\mathrm{Er}\ (n,\gamma)\ {}^{163}\mathrm{Er}$ $\quad \sigma_{thermal} \approx 20$b

$^{163}\mathrm{Er} \rightarrow {}^{163}\mathrm{Ho} + \nu_e$ $\quad \tau_{1/2 EC} \approx 75$min





TES

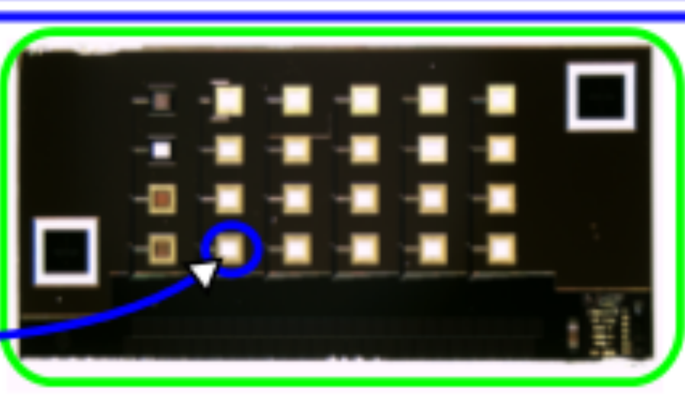
Further and more detailed information on the fabrication of the absorber: Poster of Giulio Pizzigoni

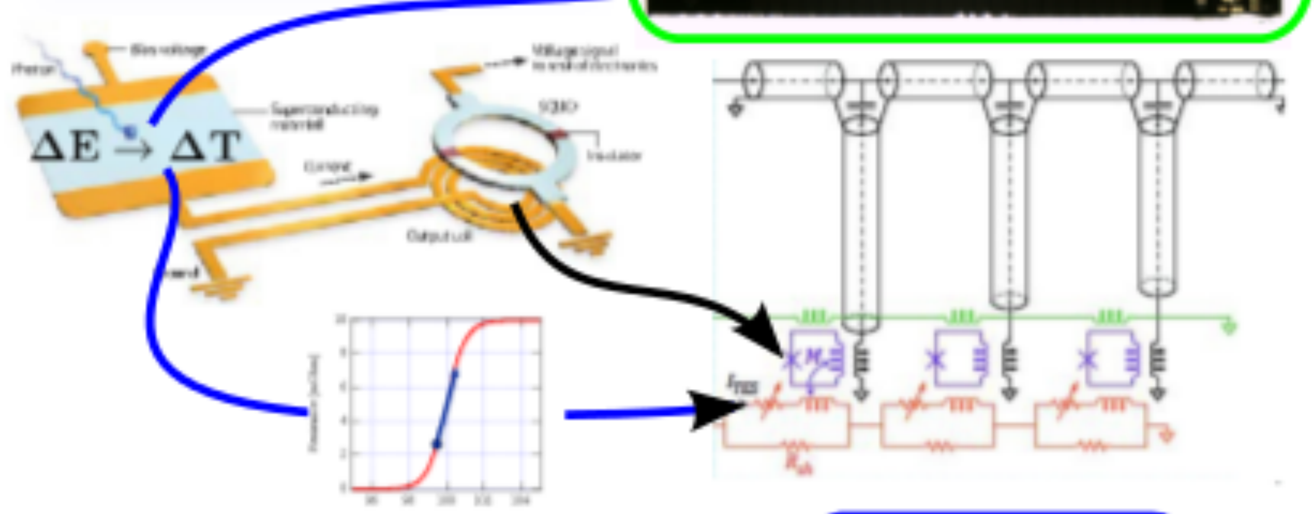
Metallic ^{163}Ho/Er/Au cathode

penning sputter source

TES operation

Principle of operation
- Superconductor kept at the bottom of the transition region
- Incoming radiation breaks cooper pairs in the superconductor
- Pair braking causes resistivity increase in the TES circuit





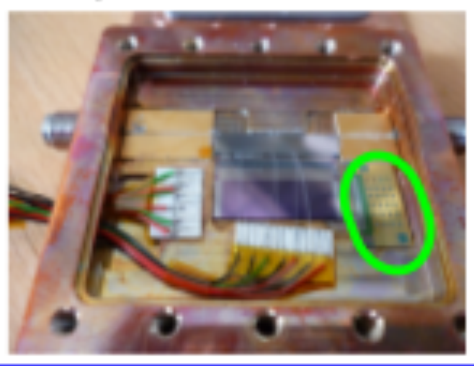
-Gold&Bismuth absorber coupled to a Transition Edge Sensor (TES)

- ^{163}Ho implanted in Au, covered with Bi for better thermal performance

- MoAu or MoCu TES, T_c≈100 mK

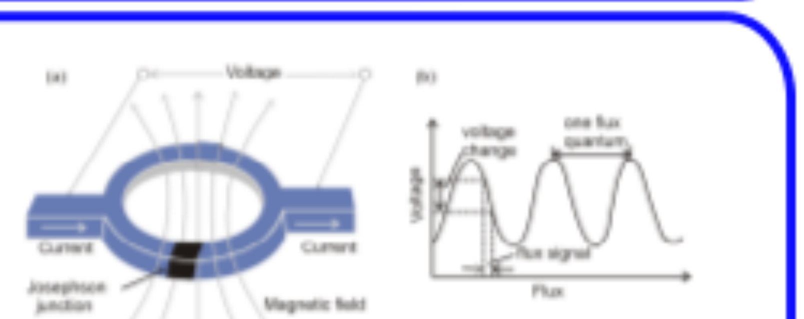
-Detectors suspended on SiN_x to reduce thermal conductance towards bath

-Rf-SQUID readout

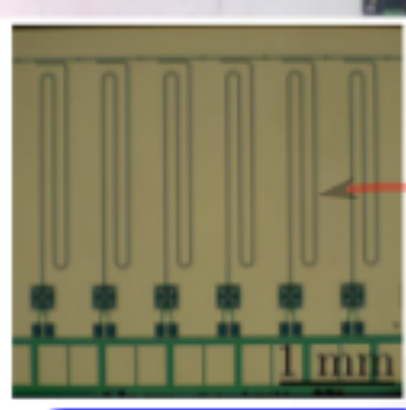


RF multiplexing

rf-SQUID read-out with microwave multiplexing
- DC biased TES
- microwave rf-SQUID read out with flux ramp modulation

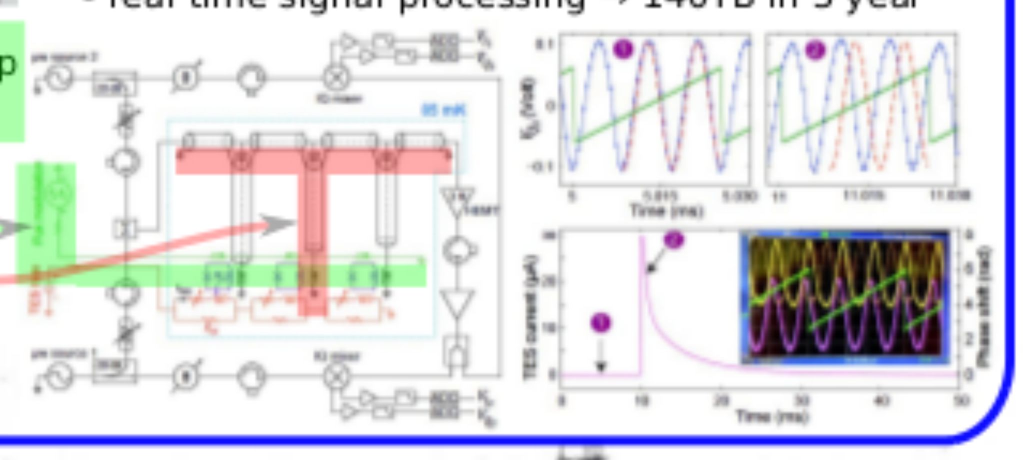


ROACH2-based Software Defined Radio
- Xilinx FPGA based digital data processing
- frequency comb generation (up to ≈60 in 0 – 550 MHz)
- GHz band up/down conversion (5 – 5.5 GHz)
- I-Q signals (homodyne detection) de-multiplexing
- signal channelizing and rf-SQUID signal de-modulation
- real time signal processing → 140TB in 3 year

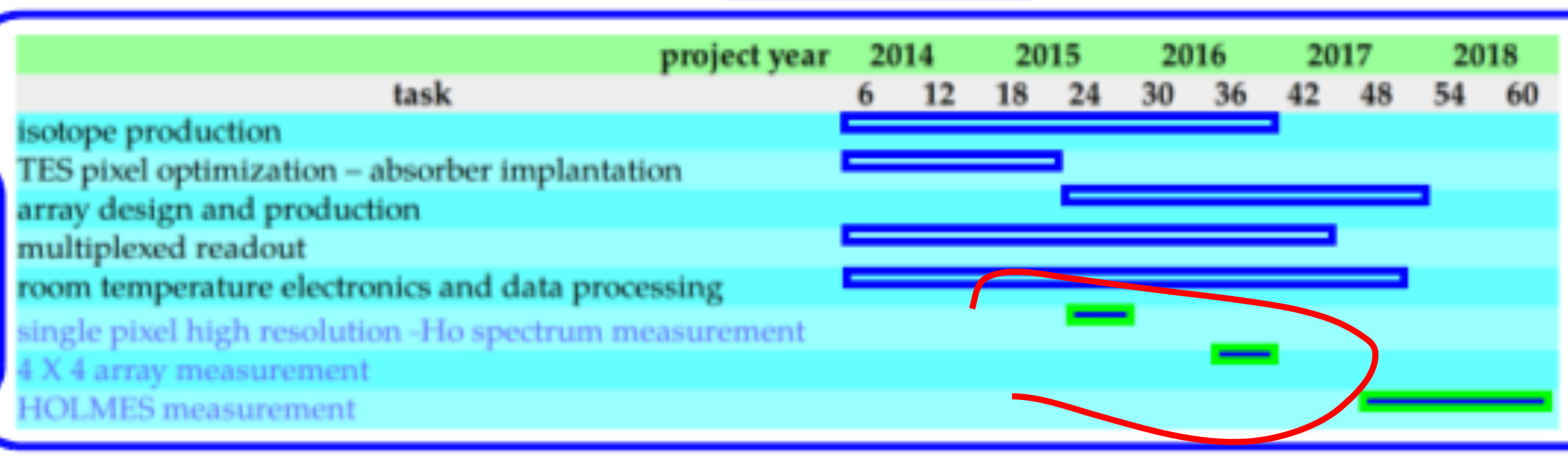


MHz flux ramp modulation

GHz LC resonator



timetable



XVI International workshop on Neutrino Telescopes 2015 Venice