LTD15
Workshop on Low Temperature Detectors
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Preliminary results of MARE in Milan

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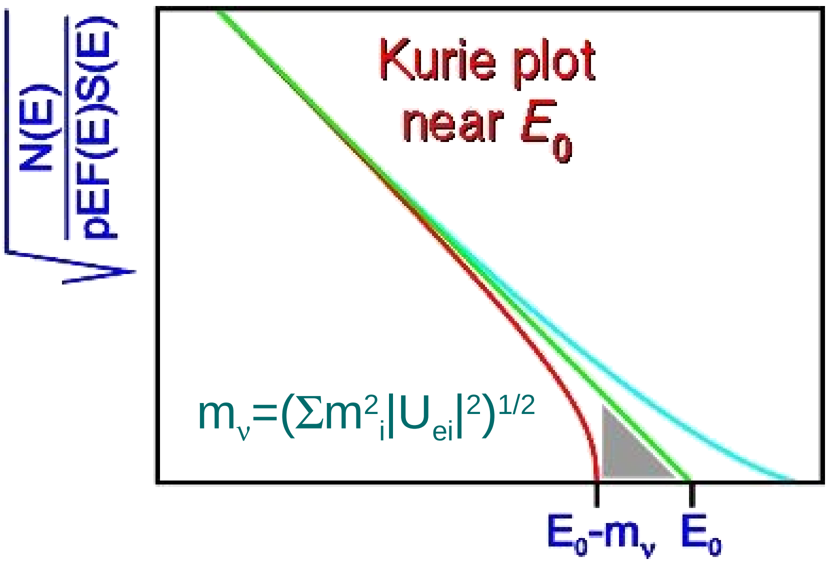
Outline

- Physical motivation and the calorimetric approach
- MARE-1 in Milano
- Re option
- Ho option

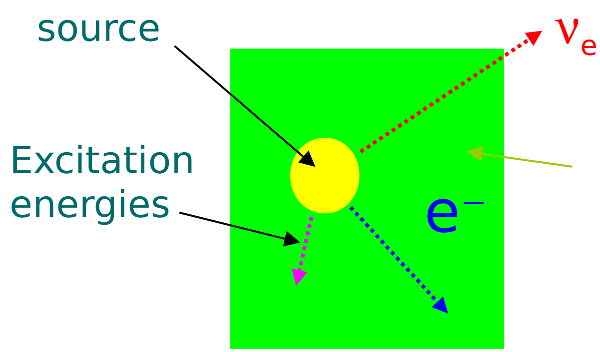
Physical motivation

direct neutrino mass measurement



15 eV → ^{187}Re (E_0=2.47keV) & calorimeters

Calorimeters: source ⊆ detector



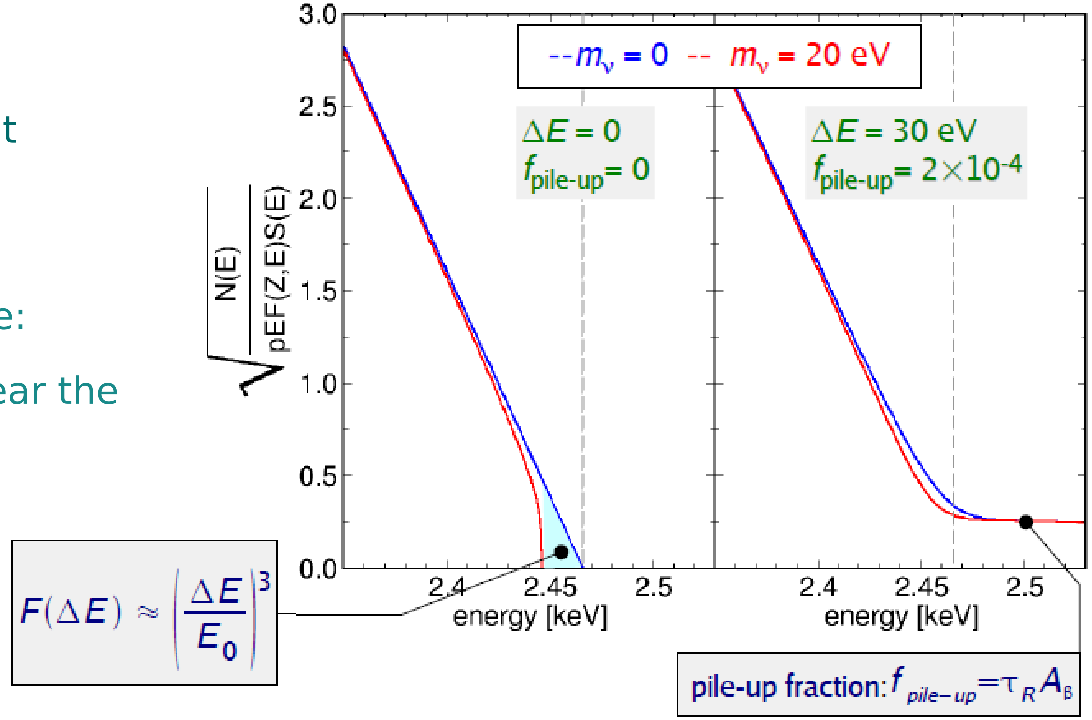
β calorimeter
ideally measures all the energy E released in the decay except for the ν_e energy

General experimental requirements:

- High statistics at the beta spectrum end-point
- high energy resolution ΔE

Calorimeters measure the entire spectrum at once:

- low E_0 β decaying isotopes for more statistics near the end-point
- best choice ^{187}Re:
  - E_0 = 2.5 keV, τ½ = 4×10^{10} y
- other option ^{163}Ho EC:
  - E_0 ≈ 2.6 keV, τ½ ≈ 4600 y



MARE

MARE-1: a few eV direct neutrino mass measurement

Two isotopes under investigations:

- 187Re – high statistics measurement
  - asses systematics
  - test large arrays
  - lower limit to few eV
- 163Ho – high statistics measurement – R&D for 163Ho production
  - measure Q_{EC}
  - study spectrum shape
  - asses systematics

MARE-1 in Milan: Milano/FBK/Wisconsin/NASA

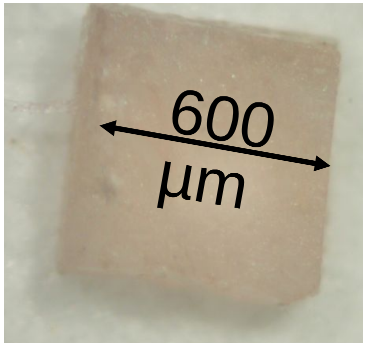
- $m_{\nu e} < 2$ eV/c^2
- 10^{10} events - 300 sensors
- 8 arrays of Si:P thermistors with $AgReO_4$ absorbers
- energy resolution 25 eV @ 2.6 keV

This experiment is needed:
- because it's the only possible one with present technology
- To investigate systematics in thermal calorimeters

very important to cross-check spectrometer results

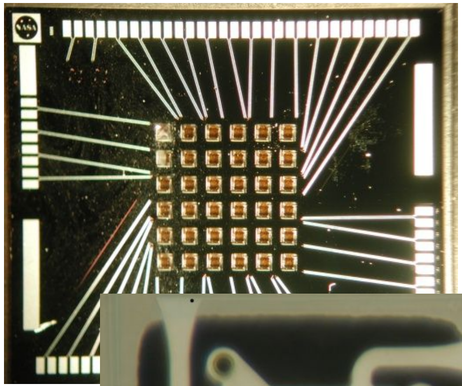
MARE-1 detectors/Re

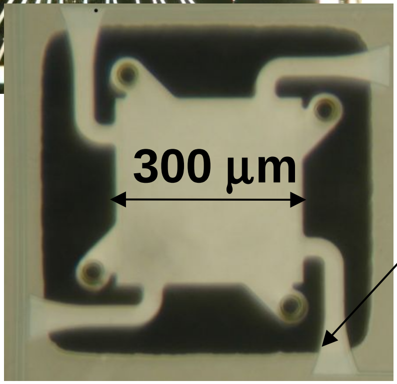
- ^{187}Re β-decay
  - $^{187}Re \rightarrow {}^{187}Os + e^- + \nu_e$ $E_0 = 2.47$ keV
  - i. a. 63% and τ=42.3 Gy



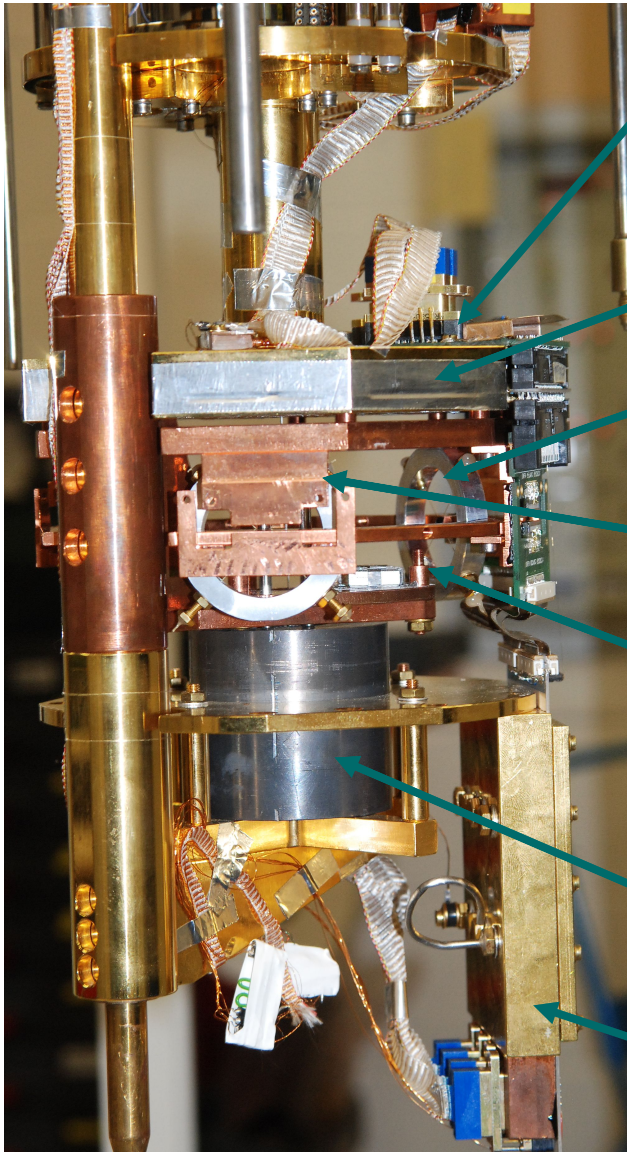
- Single crystal of silver perrhenate ($AgReO_4$)
  - mass ~ 500 μg per pixel (A_β~ 0.3 decay/sec)
  - regular shape (600x600x250 μm^3)
  - low heat capacity due to Debye law

- 6x6 array of Si:P semiconductors (NASA-GSFC)
  - pixel: 300x300x1.5 μm^3
  - high energy resolution
  - developed for X-ray spectroscopy with HgTe absorber (ASTRO-E2)

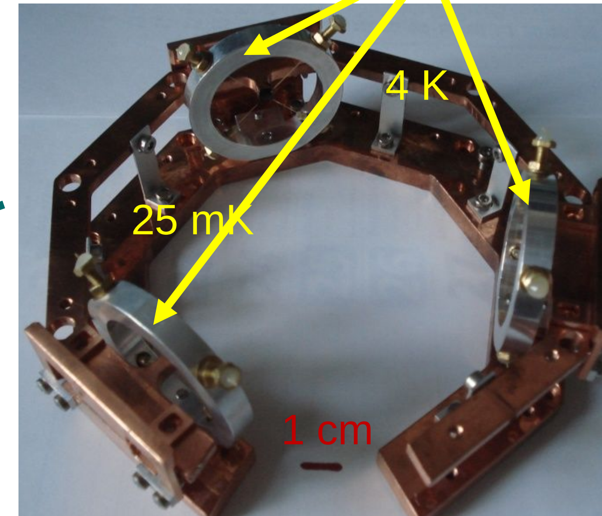


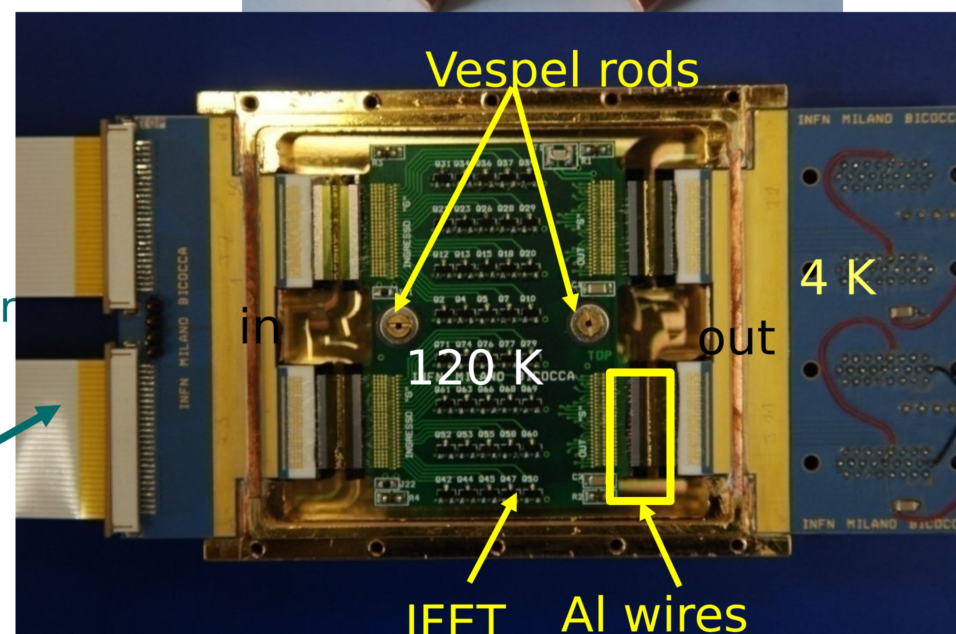


Cryogenic set-up/Re



Kevlar crosses



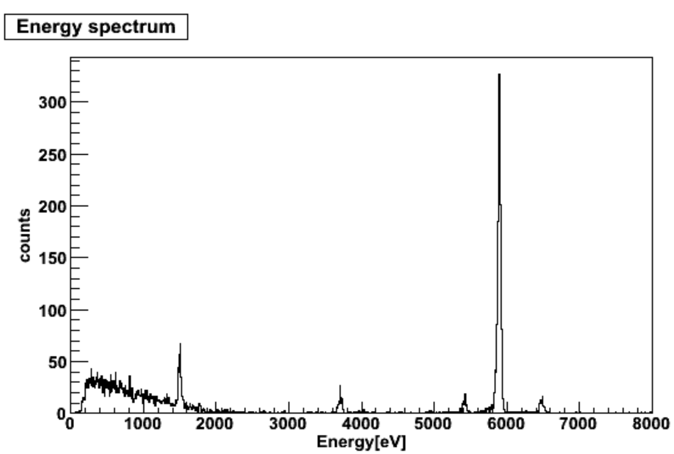


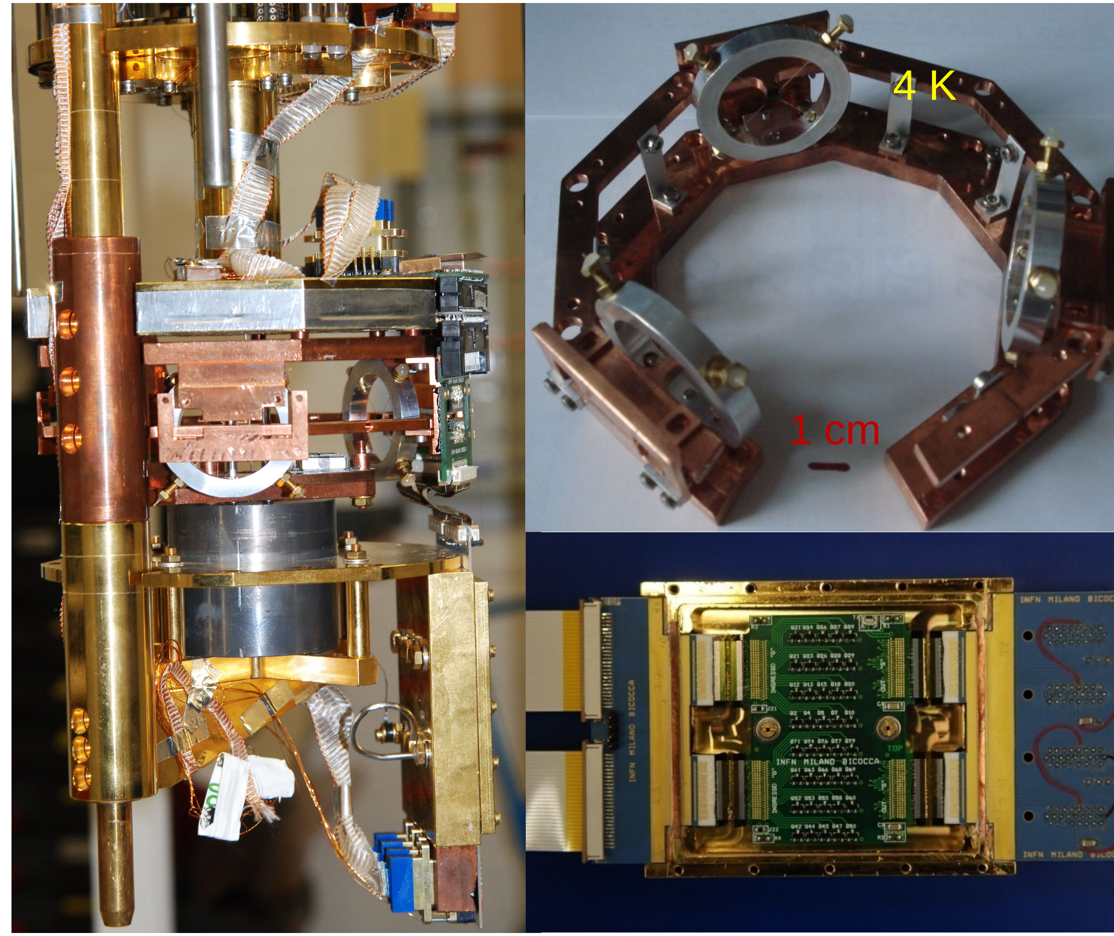
MARE 1 /Re

All the problems concerning the cryogenic set-up have been solved.

Thanks to the improvements added to the cryogenic set-up the detector target performances have been achieved.

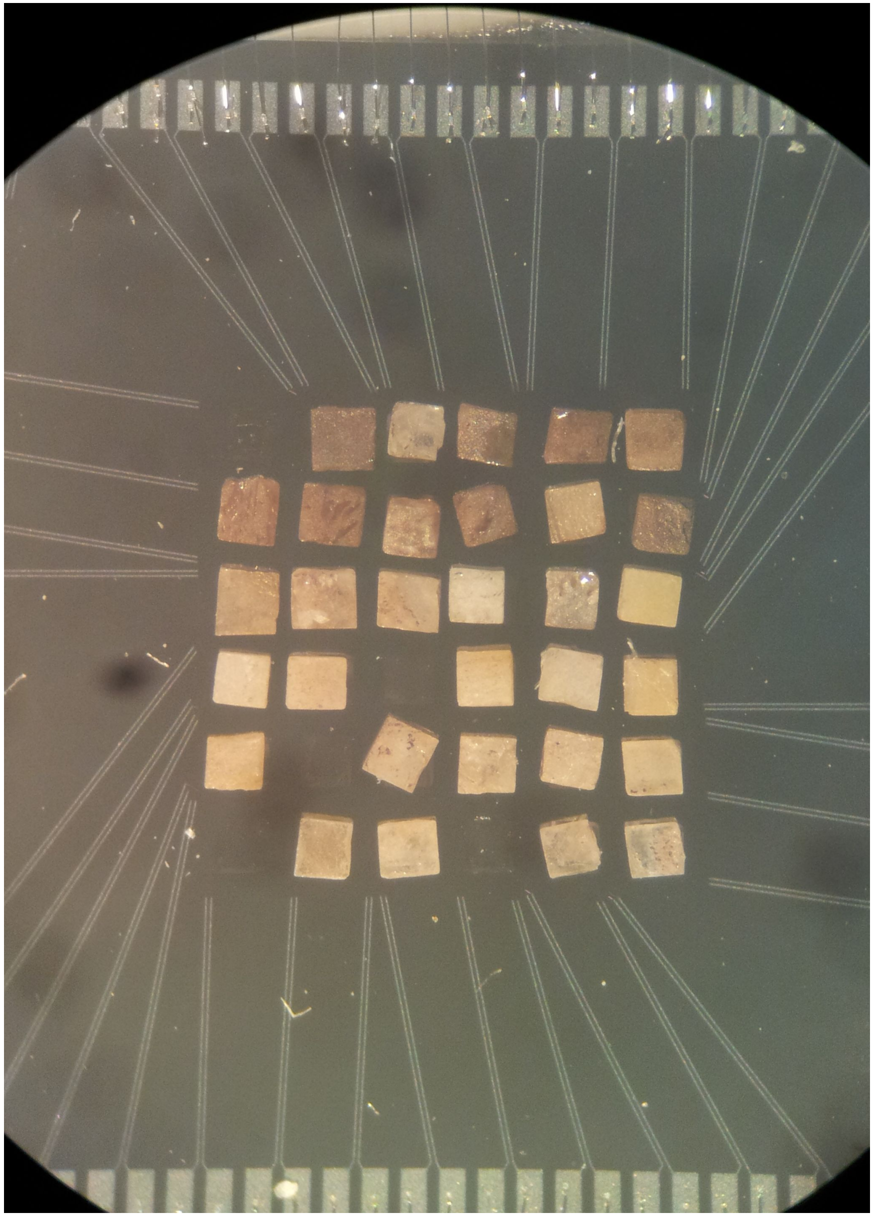
- First spectra acquired
- Completed assembly of the first array





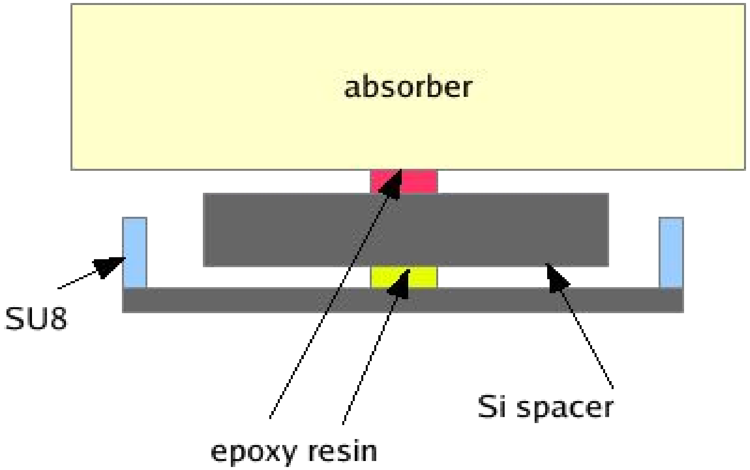
Measured 7 pixels: ΔE_{ave}~30eV @ 1,5keV

First array /Re



Thermal coupling

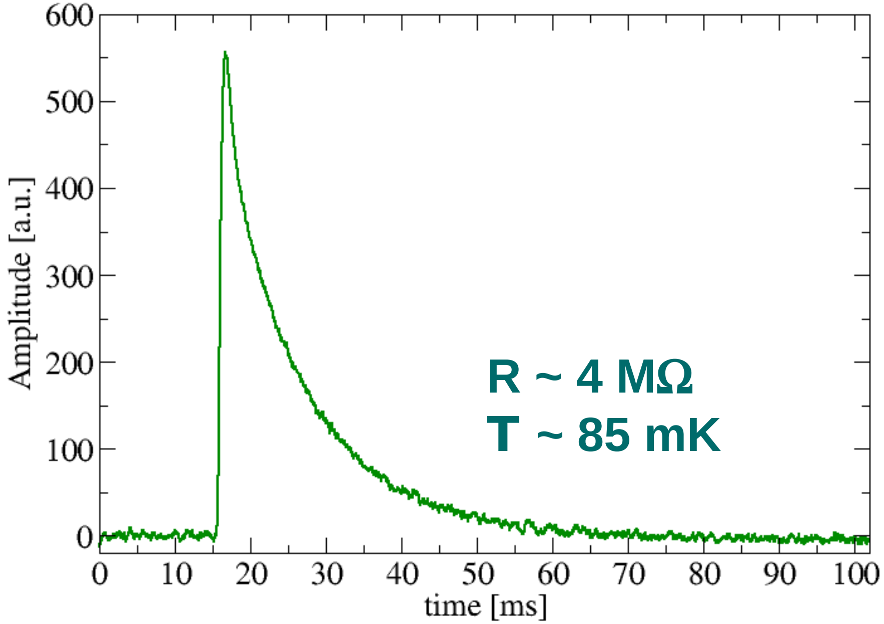
- **Araldit or ST1266:** thermistor/spacer
- **ST2850:** spacer/$AgReO_4$

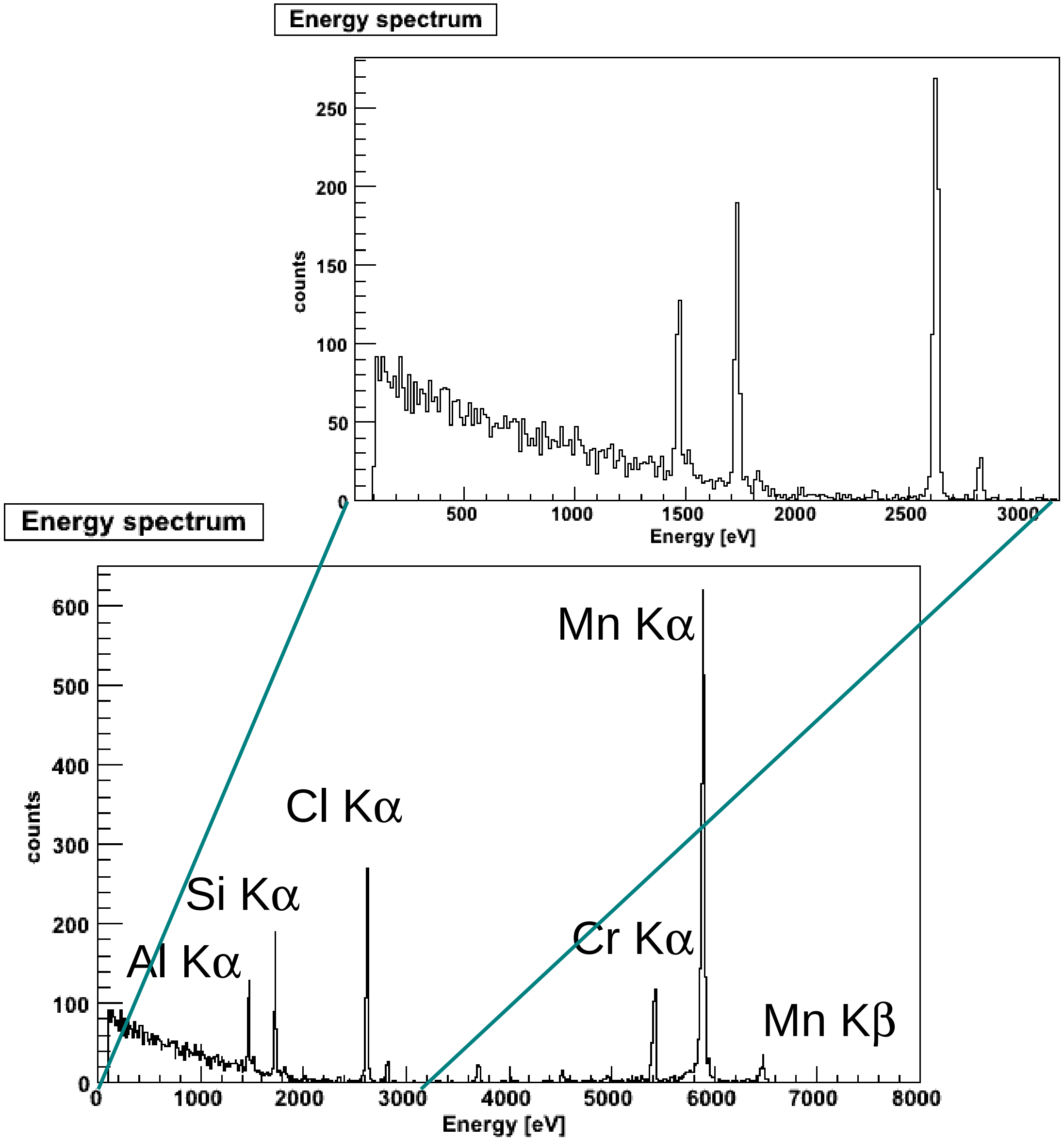


- 6 silicon spacers are attached with **Araldite Normal**
- 10 with **Araldite Rapid**
- 15 with **ST1266**

First array/Re

A run aimed to test the performance of this setup is ongoing, after which the absorbers will be glued also on the second array. With two arrays, a sensitivity of 4.5 eV at 90% C.L. is expected in three years running time.



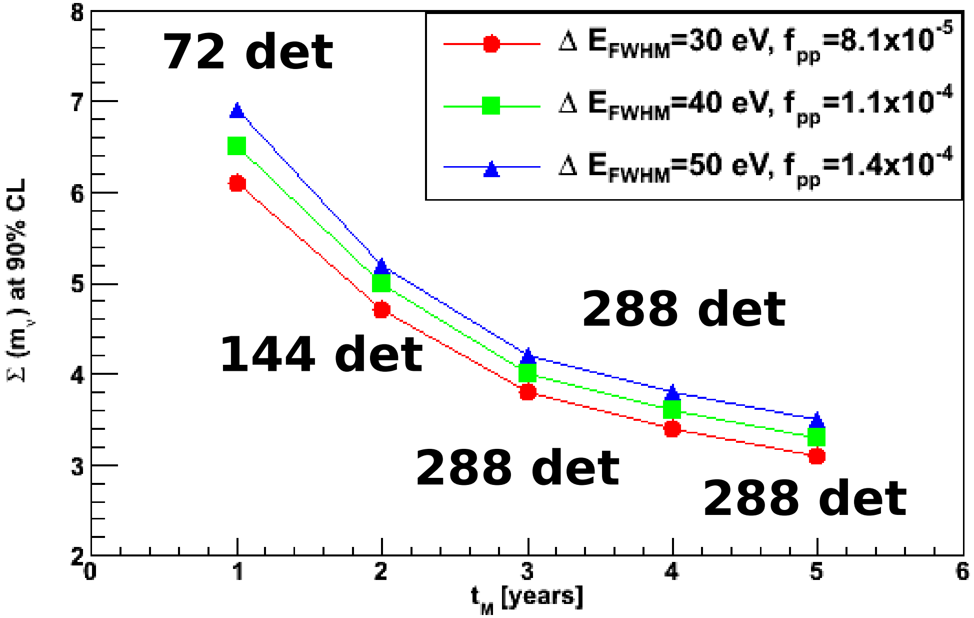


- Working temperature T ≈ 85mK
- $\Delta E \approx$ 28 eV @ 1.5 keV
- $\tau_R \sim 1$ ms

MARE 1 with Rhenium: sensitivity

Estimation of the sensitivity on neutrino mass over the years by increasing the detectors number from year to year.

Analytic approach (1st order)



Detectors

ΔE_{FWHM} ~ 50 eV and τ_R ~ 500 μs

1 year and 72 channels → $\Sigma(m_\nu)$ ~7eV

3 years and 288 channels → $\Sigma(m_\nu)$ ~ 4.2eV

ΔE_{FWHM} ~ 30 eV and τ_R ~ 300 μs

1 year and 72 channels → $\Sigma(m_\nu)$ ~6eV

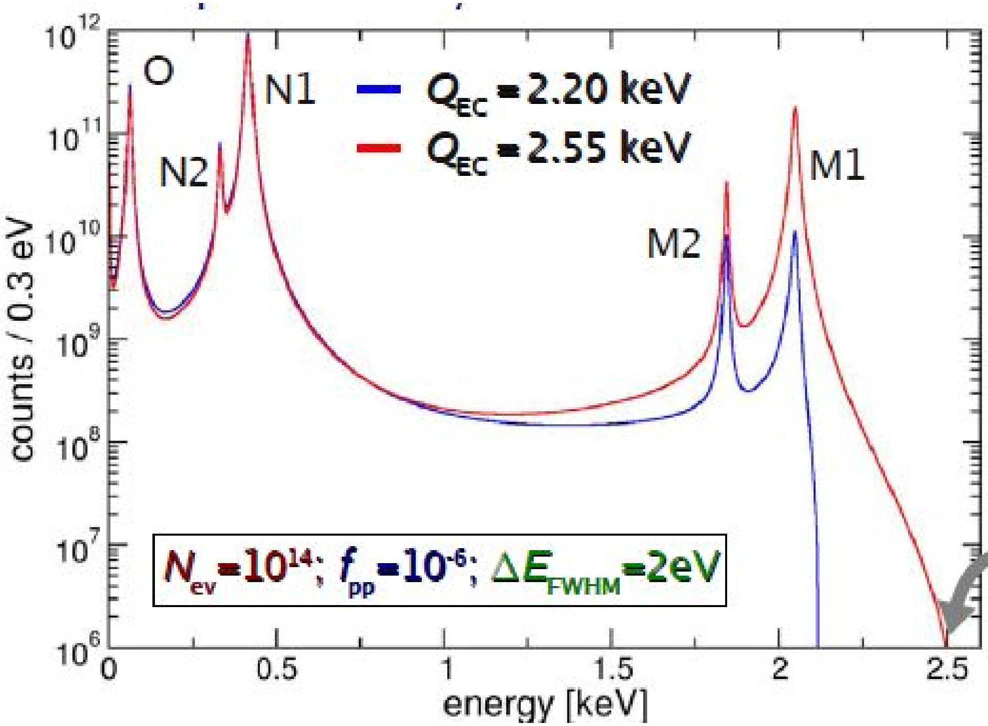
3 years and 288 channels → $\Sigma(m_\nu)$ ~ 3.8eV

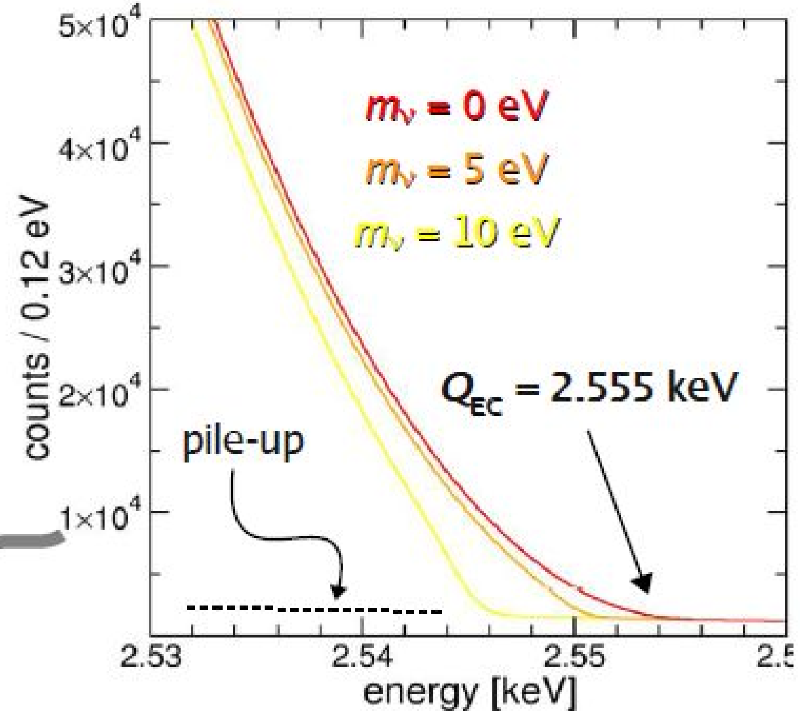
MARE-Ho: ^{163}Ho EC measurement

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

electron capture from shell ⩾ M1

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





- Calorimetric measurement of non-radiative Dy atomic de-excitations
- Breit Wigner M,N,O lines have an end-point at the Q value
- rate at end-point may be as high as for ^{187}Re but depends on Q_{EC}
  - Q_{EC}? Measured: Q_{EC} = 2.3÷2.8 keV. Recommended: Q_{EC} = 2.555 keV
- $\tau_{1/2} \approx$ 4570 years: few active nuclei are needed
  - can be implanted in any suitable microcalorimeter absorber
- ^{163}Ho production by neutron irradiation of ^{162}Er enriched Er

MARE-Ho

Goals:
Production of metal absorber with Ho-163 metal homogeneously embedded in.

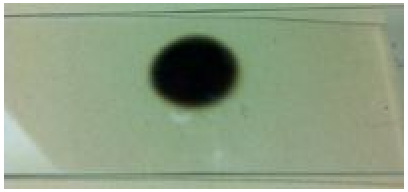
Issues:
✔ Production of Ho-163: neutron activation of enriched Er-162 oxide
Er-162(n,γ)Er-163 ➔Ho-163 (3 processes in the last 2 years)
- Purification: under study with different methods (PSI, LANL)
✔ Reduction to metal form: recently demonstrated (Genova) **[see G. Pizzigoni Poster D208].**
- Embedding in the absorber: first test done

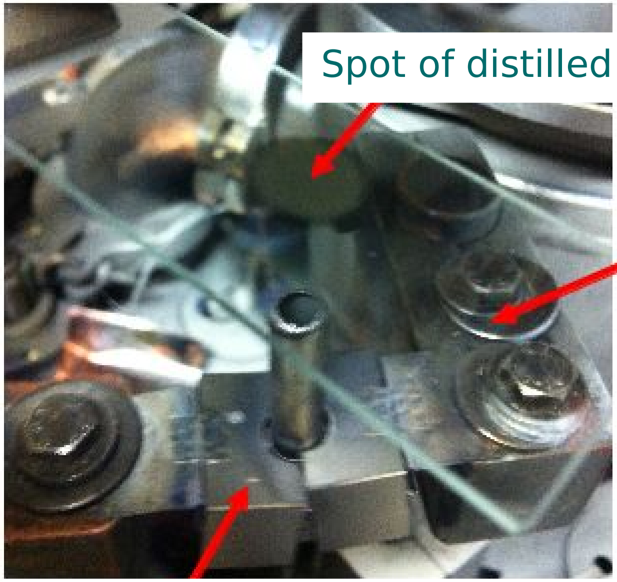
In a Knudsen Cell at about 2000 C

$HO_2O_3 + 2Y(m) \rightarrow 2Ho(m) + Y_2O_3$

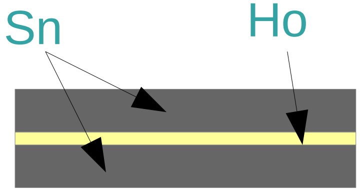
Ho*(m)* is then distilled onto cold target

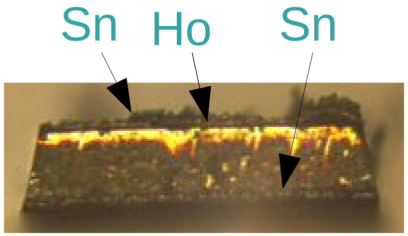
Spot of the distilled holmium

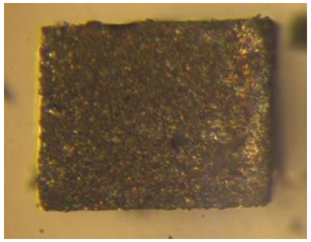




Tantalum Knudsen cell used for distillation of Ho(m)



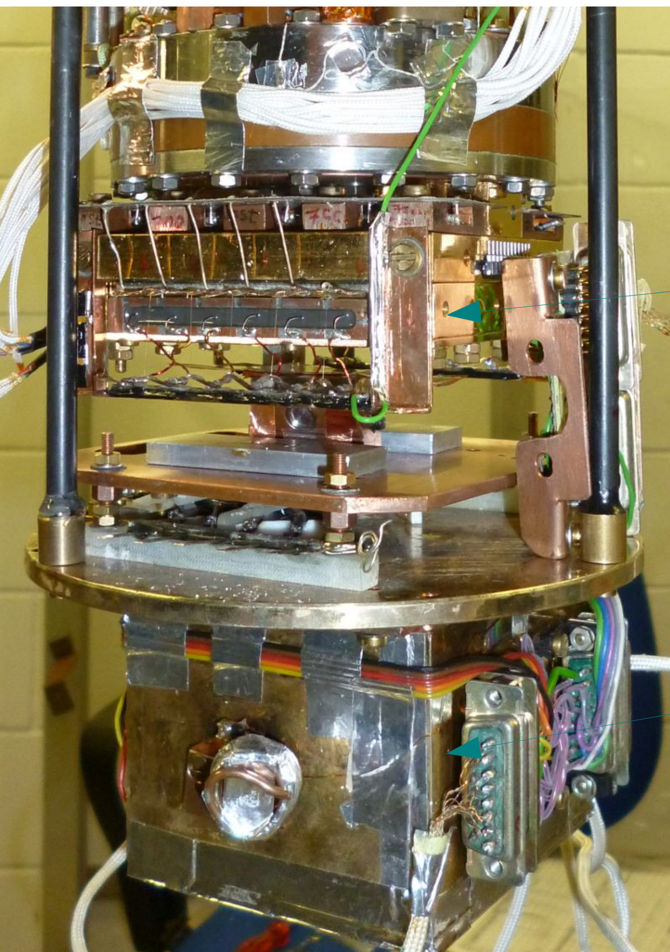




MARE /Ho option

A run aimed to test the new absorbers made of Sn/Ho/Sn is ongoing @ Milano-Bicocca. The absorbers are glued on Si thermistors.

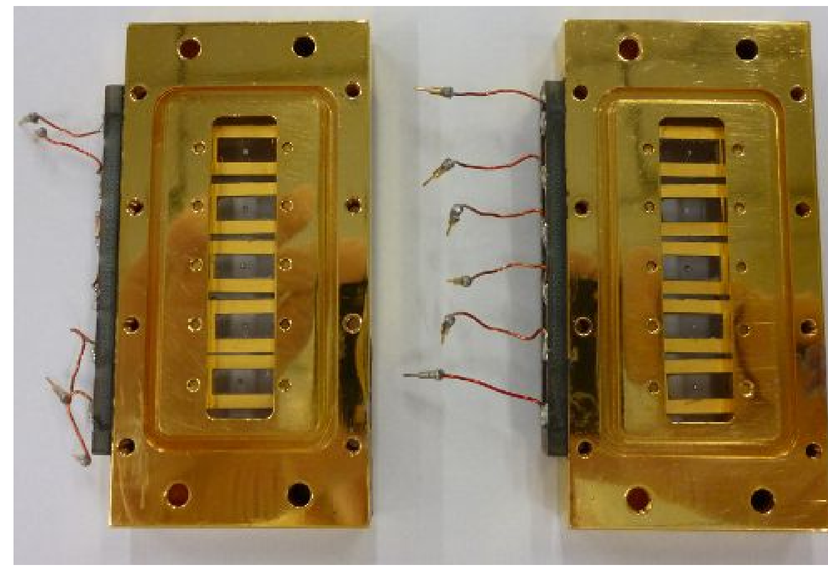
The cryogenic set-up and electronics are the one used in the Mibeta experiment as well as the dilution unit.



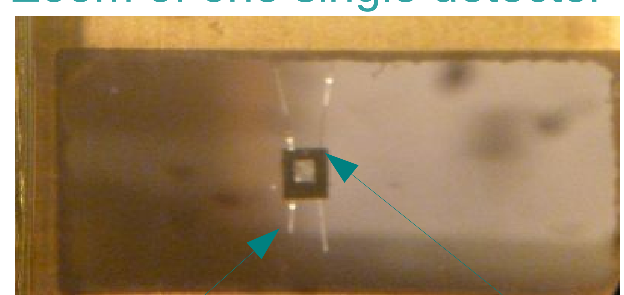
Detector holders mounted under the MC

Cold electronic JFET

10 detectors: 9 with Ho and 1 with Sn



Zoom of one single detector

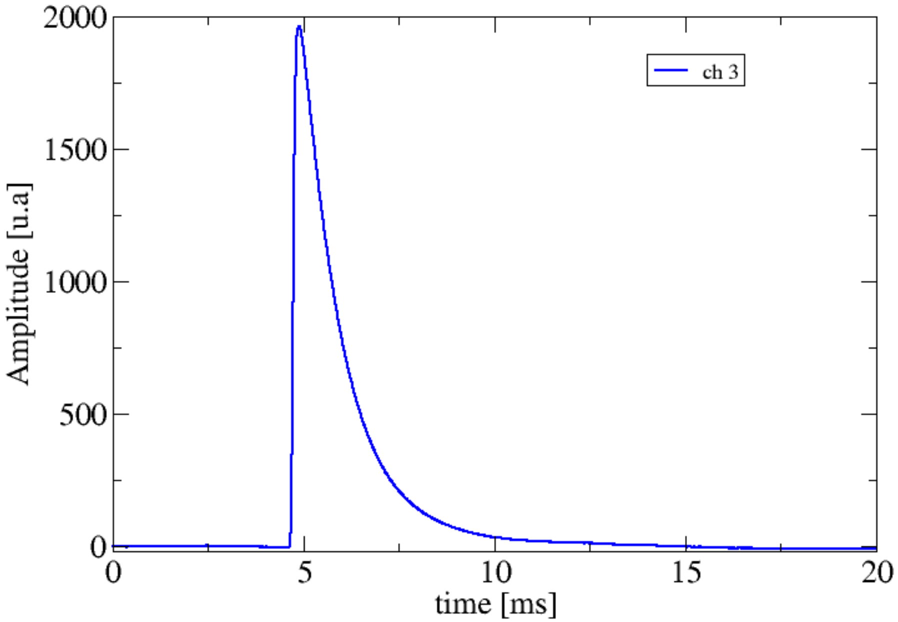


Al bonding wires

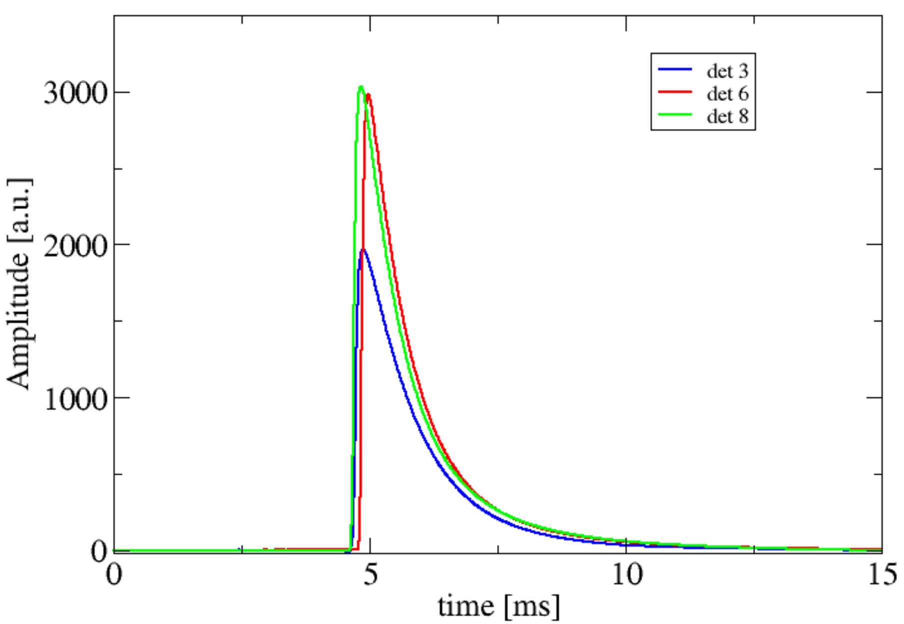
Sn/Ho/Sn absorber Glued on Si thermistor

Average pulses and first spectra

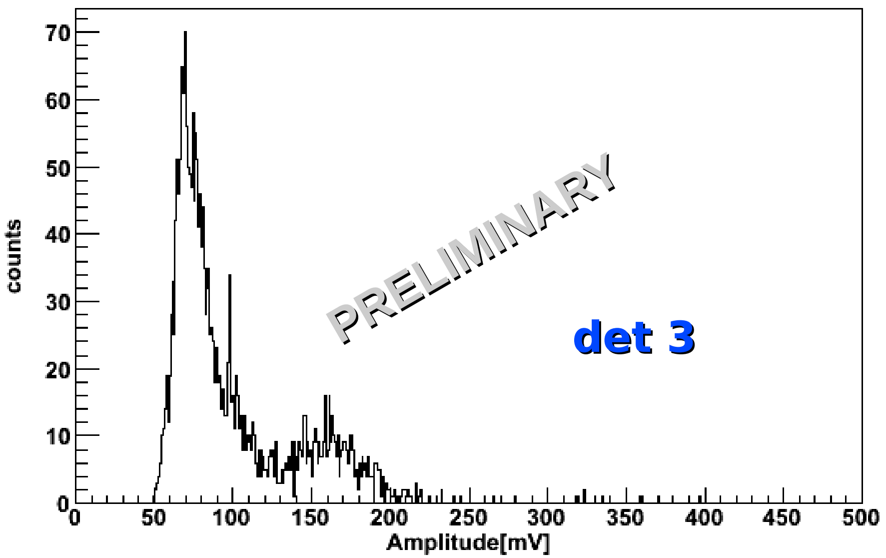
Average pulse of detector 3



Average pulses of detector 3, 6 and 8



Preliminary spectrum with background subtraction



Measure time: 22 h

Conclusion

First array of MARE-1 has been assembled

$\rightarrow$ 31 thermistors are equipped with AgReO4 absorbers

The goal performances of the detectors have been achieved

$\rightarrow$ first spectra were acquired obtaining a resolution of ~28eV @ 1,5keV

First samples of Ho(m) are produced and embedded into absorbers

$\rightarrow$ A first run to test Ho absorber produced by Genova is ongoing

In the meanwhile new detector technology under investigation

$\rightarrow$ Ho EC measurement with MKIDs

(M. Faverzani poster B306)