Analysis tool of AMoRE Pilot

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LTD 18 — MILANO 22-26 JULY 2019 — LOW TEMPERATURE DETECTORS

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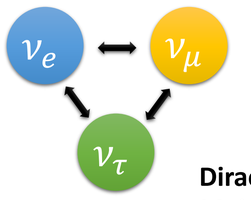
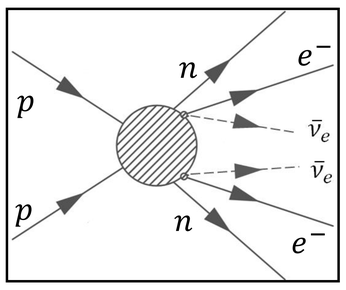
Neutrinoless Double Beta-Decay($0\nu\beta\beta$)



Discovery of neutrino oscillation
- Neutrinos have non-zero mass
- Show very small values of neutrino mass-squared differences
- Does not determine the nature of neutrinos

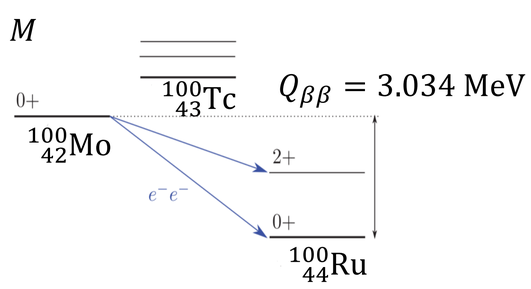
Dirac : Fermions are known to exist in two forms particle and antiparticle
Majorana : Neutrinos may be an exception, particle and antiparticle being identical.

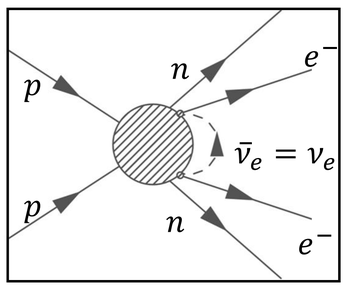
The most sensitive approach ➡ $0\nu\beta\beta$ experiment



$2\nu\beta\beta$

$(A, Z) \rightarrow (A, Z+2) + e^- + e^- + \bar{\nu}_e + \bar{\nu}_e$



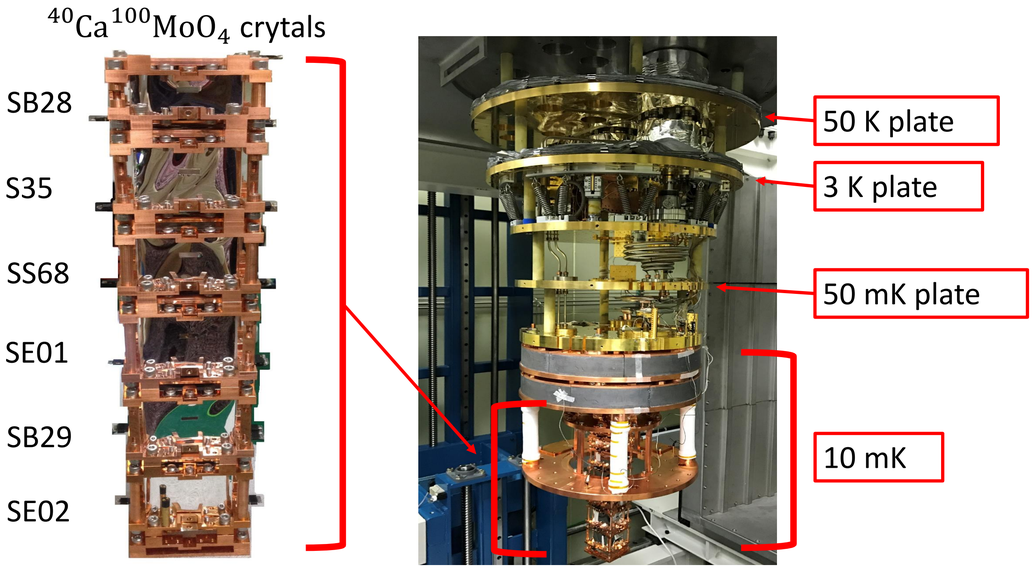


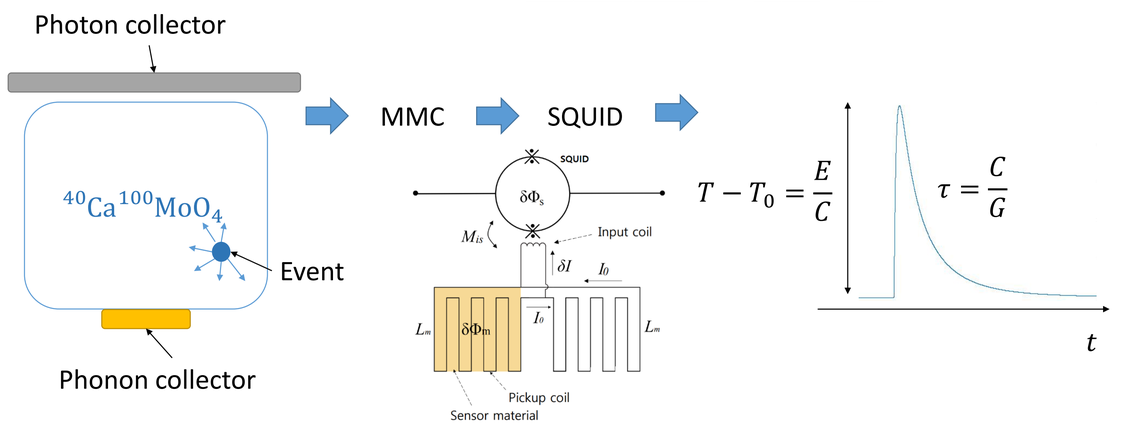
$0\nu\beta\beta$

$(A, Z) \rightarrow (A, Z+2) + e^- + e^-$

Low Temperature Detector

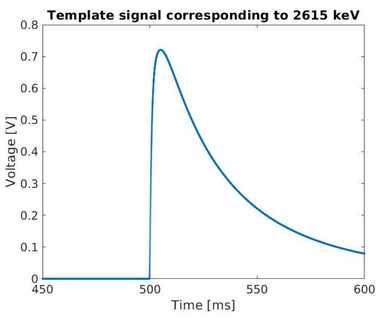
$^{40}Ca^{100}MoO_4$ crystals

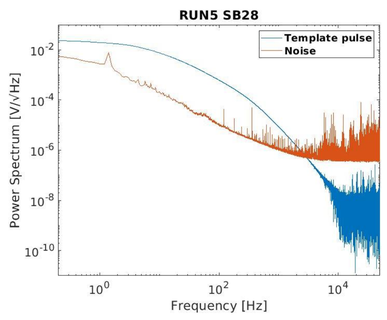




1. Metallic Magnetic Calorimeter(MMC) using paramagnetic materials(Au:Er).
2. When energy is released in the crystal, its temperature increases.
3. And it changes the MMC's magnetization.
4. Induces current change in Superconducting Quantum Interference Device(SQUID) loops.

Data processing



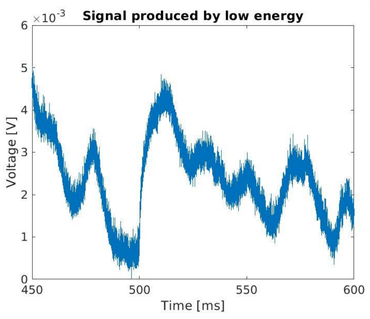


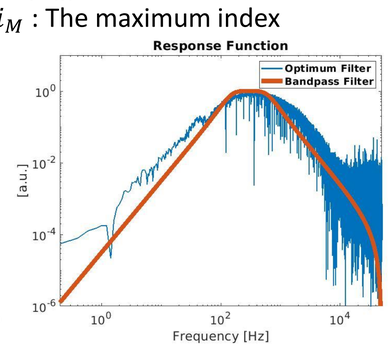
Template signal(left) obtained by averaging a set of particle signals selected in the time domain. Template signal and noise power spectrum in the frequency domain(Right).

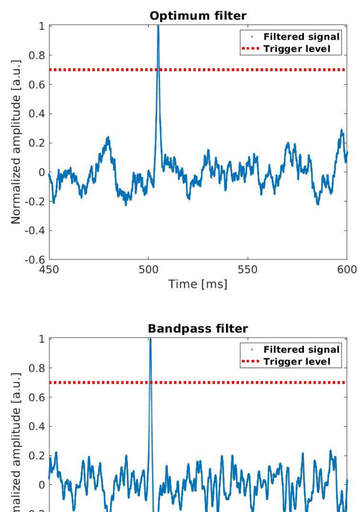
Optimum filter

$$H(\omega) = A\frac{s^*(\omega)}{N(\omega)}e^{-j\omega_k i_M}$$

$N(\omega)$: The noise power spectrum
$s^*(\omega_k)$: The DFT of template
i_M : The maximum index

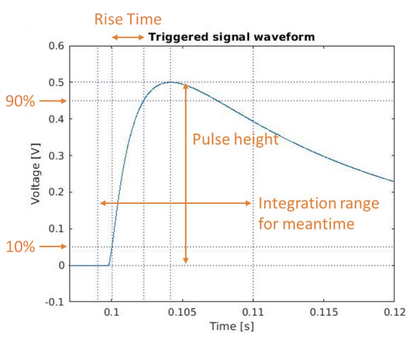


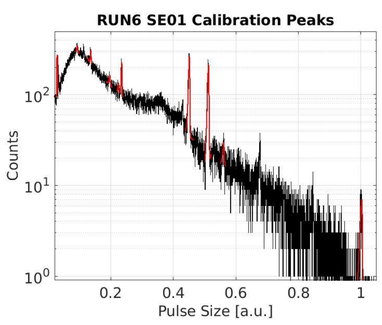




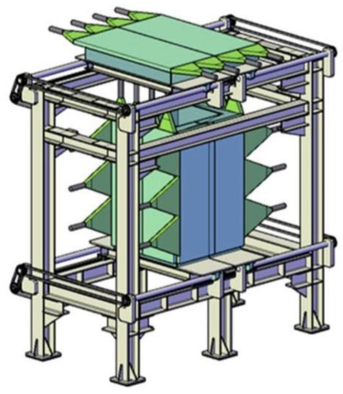
Butterworth Bandpass filter $|H(\omega)|^2 = \frac{1}{1 + \left(\frac{\omega}{\omega_c}\right)^{2N}}$

ω_c : Cutoff frequency
N : Order number

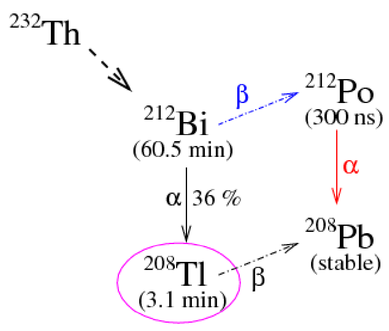




Energy [keV]	Source
75	Pb kα
239	^{212}Pb (Thorium Series)
352	^{214}Pb (Uranium Series)
511	^{208}Tl (Thorium Series)
583	^{208}Tl (Thorium Series)
609	^{214}Bi (Thorium Series)
1173	^{60}Co
1332	^{60}Co
1461	^{40}K (EC)
2615	^{208}Tl (Thorium Series)

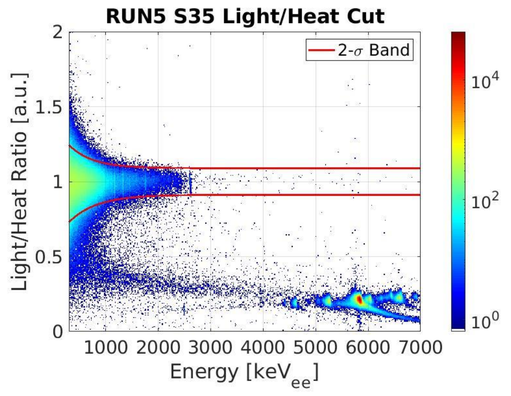


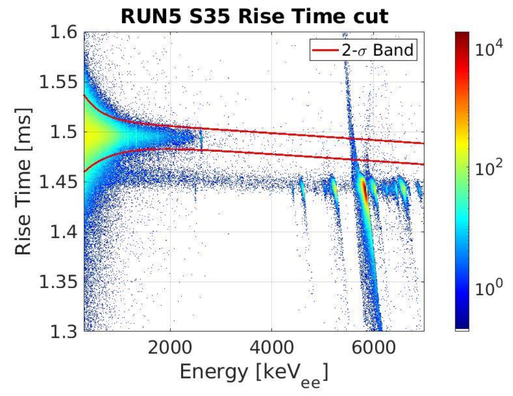
Muon veto system



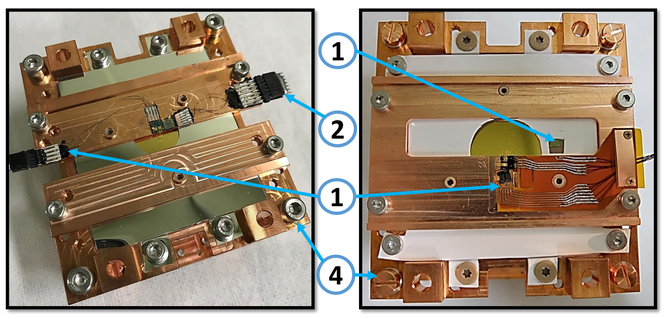
^{212}Bi tag

Event-by-Event identification





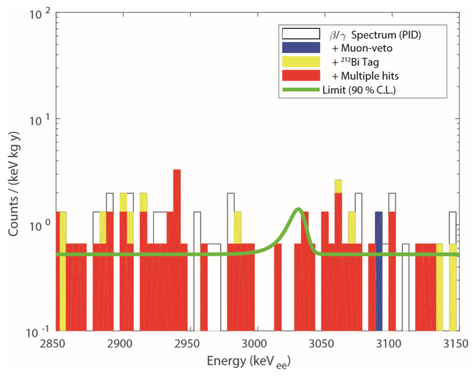
Changes from Run 5 to Run 6



1. Stabilization heater
2. Pin connector
3. Stycast → Lead-tin solder
4. Stainless steel screw → Cu screw

Neutron Shielding
- Boric acid (H_3BO_3)
- Borated PE (Boron 28%)

Detection sensitivity on the AMoRE Pilot – Run 5



$$T_{1/2}^{0\nu} = \log 2 \cdot \frac{a \cdot \epsilon \cdot \eta \cdot N_A}{A_{\mathrm{det}}} \cdot \sqrt{\frac{M_{\mathrm{det}} \cdot t}{b \cdot \Delta E}}$$

a : The abundance of the isotope of interest
ϵ : The detector efficiency
η : The number of the nuclide of interest in one absorber molecule
A_{det} : The total molar mass of the detector material
$M_{\mathrm{det}} \cdot t$: Exposure
b : The level of background
ΔE : The energy resolution

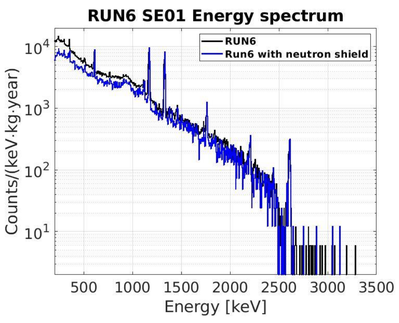
The solid green line is the fitted response function describing the flat background and the excluded $0\nu\beta\beta$ peak corresponding to the 90% confidence level (C.L.) limit of $T_{1/2}^{0\nu} > 9.5 \times 10^{22}$ y.

Official $(52.1\ \mathrm{kg \cdot d\ of\ ^{100}Mo})$	Additional $(67.1\ \mathrm{kg \cdot d\ of\ ^{100}Mo})$
$T_{1/2}^{0\nu} > 1.1 \times 10^{23}$ y	$T_{1/2}^{0\nu} > 1.2 \times 10^{23}$ y

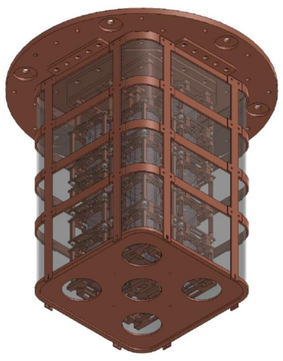
Background level

Background Level (ROI) $[\mathrm{Counts/(keV \cdot kg \cdot y)}]$	Run5	Run6	Run6 with neutron shield
SE01	1.5 ± 0.39	0.60 ± 0.25	0.61 ± 0.35

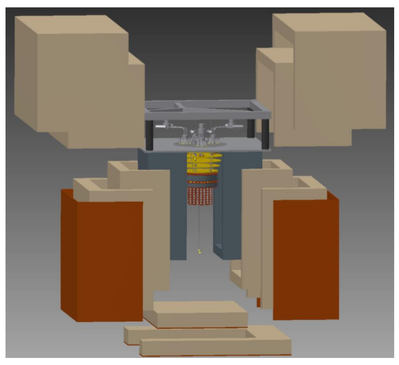
The neutron shield is more effective in a wide energy region.



Summary & Future plans for the AMoRE



AMoRE-I
- 18 crystals
- CMO, LMO
- ~2.9 kg of ^{100}Mo



AMoRE-II
- Total 200 kg

- We are continuing our MMC and light detector research to improve the resolution.
- Improved low background by using low-radioactivity materials and shielding against external radioactivity.
- The AMoRE-I, the next phase of the project, which has a larger mass of crystals, is being prepared.