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Design and Performance of the AMoRE-II cryostat and Dilution Refrigerator

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CENTER FOR UNDERGROUND PHYSICS

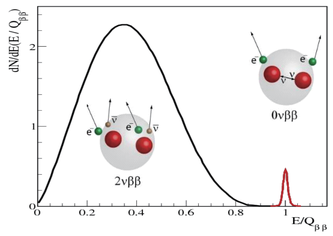
Abstract

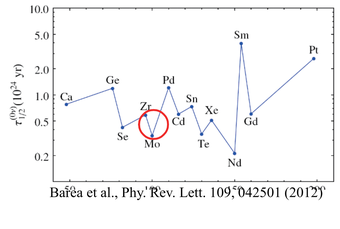
The AMoRE-II experiment searches for neutrinoless double-beta decay of 100Mo using molybdate-based crystal detectors that simultaneously measure heat and scintillation signals at millikelvin temperatures. The experiment is located at the Yemilab underground laboratory in South Korea. Achieving the required ultra-low-background environment with a 10 mK sample space necessitated the development of a custom large-scale dilution refrigerator featuring a 1-m-diameter mixing-chamber plate. A 3-ton PbCu low-temperature radiation shield has been installed below the mixing-chamber plate. The shield is suspended by individual supports consisting of stainless-steel rods and Kevlar strings, combined with soft thermal links to minimize vibration transfer while maintaining adequate thermalization. In this presentation, we discuss the design and performance of the AMoRE-II cryostat, including mechanical support structures and vibration-mitigation considerations. We also report the refrigerator performance after installation of the experimental wiring configuration and the low-temperature shield.

Indroduction

- AMoRE:
A search for neutrinoless double beta (0νββ) decay of ^{100}Mo using Mo-based scintillating crystals and low-temperature sensors.

- ^{100}Mo:
  - High Qββ = 3034 keV
  - High natural abundance: 9.7 %
  - Relatively short half life (0νββ) in theoretical expectation

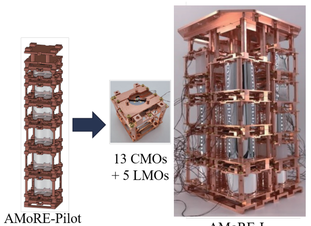


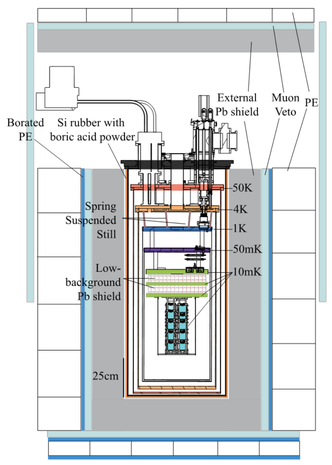


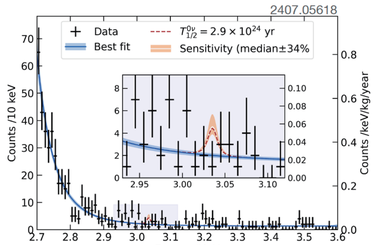
Barrea et al., Phy. Rev. Lett. 109, 042501 (2012)

AMoRE experiment

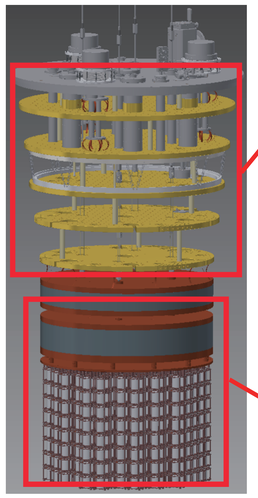
- In the AMoRE-pilot experiment, six CMO crystals were used, and in the AMoRE-I experiment, thirteen CMO crystals and five LMO crystals were used.
- Cryogen-free dilution refrigerator for AMoRE-pilot and AMoRE-I provides about 1 μW cooling power.
- As a result of the experiment the current best limit on ^{100}Mo 0νββ has been achieved.

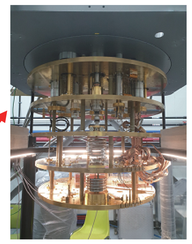




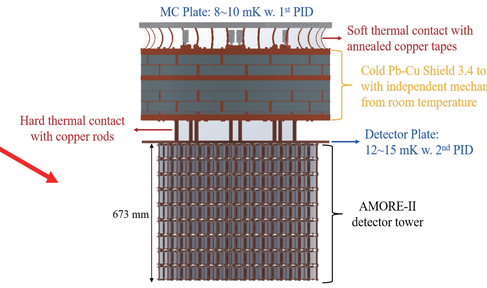


Cryostat for AMoRE-II

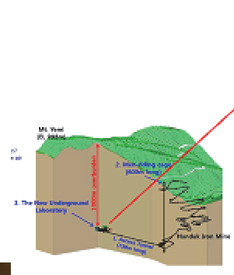


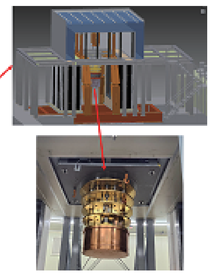


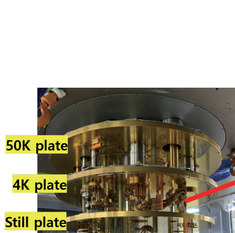
- The cryostat used in the AMoRE-II experiment is cooled using three PTRs.
- Lead shield in low temperature.
  : 26 cm thickness
- Copper plates are placed between the lead for cooling.
- LMO crystals will be used, with 90 modules installed in the first stage and 360 modules in the second stage.



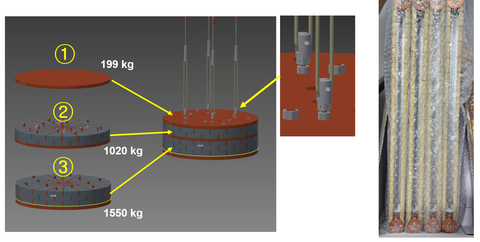
- The cryostat was moved to the underground laboratory in Jeongseon in August, 2024.
- Installation of the D.R system and facilities are finished.





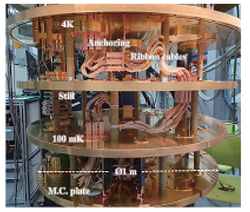


- Low temperature shield installation with SS rods and Kevlar strings.

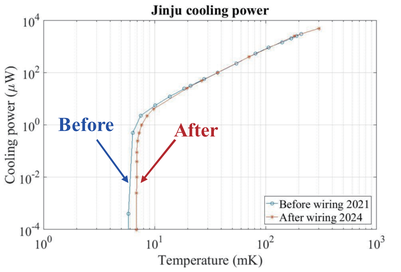


Cooling power of the cryostat

- The temperature of the M.C. reached 7.5 mK after wiring.
(The temperature was measured using a CMN thermometer.)
- The cooling power measurement of the M.C. plate was conducted; it provided a cooling power of 5.5 μW at 10 mK before wiring, which decreased to 4.0 μW after wiring.

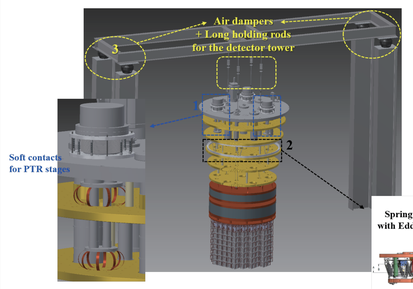


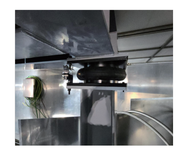
	Before wiring	After wiring
Still	750 mK	742 mK
100mK	101mK	106 mK
M.C.	5.9 mK	7.5 mK

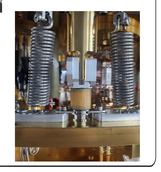


Vibration dampers

- To further reduce mechanical vibrations, dampers will be installed.
  1. Soft contacts for PTR stages
  2. Spring-suspended still & Eddy current damper :
     isolate the still plate from external mechanical noise.
  3. Air dampers :The vibration caused by the PTR is mechanically reduced.
     Independent support of Kevlar strings + STS rods from room temp.







Summary

- The cryostat for the AMoRE-II experiment was tested both at the HQ and in the underground laboratory.
- A base temperature of 7.5 mK was achieved, and a cooling power of 5.5 μW was measured at 10 mK.
- Dampers will be installed to reduce vibrations generated by the pulse tube refrigerator, which will help minimize vibration-induced noise.