

Development of calcium molybdate crystal detectors for neutrinoless double beta decay experiment

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Seoul National University & Korea Research Institute of Standards and Science (KRISS)



AMoRE

(Advanced Molybdenum-based Rare process Experiment)

An international experiment to search for neutrinoless double beta decay of ¹⁰⁰Mo.

- ▶ 5 countries, 12 institutions, 85 collaborators.
- Korea (50)

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LTD people

- China(3)
 <u>Tsinghua University</u>: J.Li,Y.Li, Q.Yue(3)
- Germany(3) Heidelberg University: C.Enss, A. Fleischmann, L. Gastaldo (3)

AMoRE project

- CaMoO₄ crystals as source and detector of $0\nu\beta\beta$ of ¹⁰⁰Mo.
- \rightarrow High Q-value of 3034.40 (12) keV.
- \rightarrow high natural abundance of 9.824 (50)%.
- Low temperature detector technique with metallic magnetic calorimeter (MMC).
- \rightarrow High energy resolution, fast response.
- → Background rejection by simultaneous measurement of heat/light channels.





A MMC chip made by Kirchhoff-Institute for Physics (KIP).



Made by Korea Research Institute of Standards and Science (KRISS), Poster # 300 on Monday

Detector Concept

• MMCs are coupled to $CaMoO_4$ crystals. \rightarrow Thermally connected by a thin gold film.

▶ High energy resolution and fast response.
 → From efficient athermal phonon collection based on thermal model study.

 Simultaneous measurement of phonon/photon detectors for alpha background rejection.

 \rightarrow CaMoO₄ is a scintillating crystal. α and β events show different light yield.

Detector design



Pulse shape



- 0.53 ms rise-time at 42 mK.
- Faster rise-time will increase efficiency of random coincidence backgrounds rejection.



Energy spectrum



- Background spectrum for 194 hours measurement at the above-ground laboratory (KRISS).
- With cup lead shield of 10 cm thickness. (solid angle of ~ 5% is opened)
- Data was obtained at ~42 mK.

Energy (keV)	Baseline	1461	2615
FWHM (keV)	$\textbf{2.6} \pm \textbf{0.4}$	$\textbf{8.9}\pm\textbf{0.6}$	$\textbf{9.9}\pm\textbf{1.3}$

Energy spectrum



- Internal alpha background events from non-enriched crystal.
- Template fitting method was applied with surface alpha (external source) template.
- Higher energy peaks have worse energy resolution.
- \rightarrow Possibly due to different pulse shapes of bulk events for the template pulse.

Pulse shape discrimination



- α and β events show
 different pulse shapes.
- They are discriminated by pulse shape indicators.



Energy calibration



- ▶ Alpha/Beta events show different energy scale (~7% @ 2.6 MeV).
- The detector shows good linearity for both of alpha and gamma signals.

Recent Set-up



A MMC chip made by KRISS

- > There were minor changes for the phonon detector.
- A photon detector is installed for simultaneous measurement.

Recent result of phonon detector



- The phonon detector shows better PSD performance in this measurement.
- FWHM energy resolution for baseline is 0.55 ± 0.07 keV at 25mK.

Photon Detector





5 mm x 5mm MMC chip

substrate

- A MMC chip made by KIP/Heidelberg university is used.
- The Si substrate is used as a photon absorber.
 Bottom side of Si



Bottom Side

Coincidence Measurement



- We measured light signals but they are very small because of small covering area (5 mm × 5 mm).
- α and β particles show different light yield.

Future plans

- Further optimization of the phonon detector.
- Development with larger (up to 500g) crystal.
- Dual channels phonon detector development.
- \rightarrow 2-phonon and I-photon channels.
- Development of the photon detector with Ge/Si crystal absorber. (Poster # 200 on Friday, by J.Y. Lee)
- Development of low background detector.

Future plans of AMoRE

Now AMoRE is fully funded for 10 years by Korean Gov.

	Mass	Start	Sensitivity to $m_{etaeta}(meV)$
AMoRE – I 0	Enriched ⁴⁰ Ca ¹⁰⁰ MoO ₄ , 10 kg	After 3 years	80 - 250
AMoRE – 200	Enriched 500 g ⁴⁰ Ca ¹⁰⁰ MoO ₄ crystal × 400 = 200kg	In 10 years	20 - 50

 400 crystals 800 MMCs
 Inverted hierarchy of neutrino mass can be tested by AMoRE – 200 experiment.

Summary

- I0 keV FWHM energy resolution was obtained @ 2615 keV peak.
- PSD method shows 7.8 σ
 separation for α/β events.
- Rise-time was 0.58 ms at 42 mK.
- Simultaneous measurement for phonon/photon signals were performed and α/β events show different light yield.

Thank you for your attention.

Back-up slides

RMS analysis

