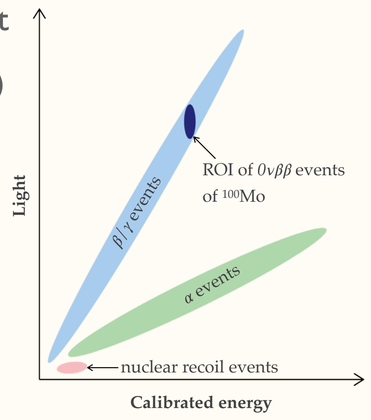
Li_2MoO_4 phonon-scintillation detection system with MMC readout

H.L. Kim[1,2],H.J. Kim[2], I. Kim[1], Y.D. Kim[1], D.H. Kwon[1],H.J. Lee[1], M.H. Lee[1], M.K. Lee[3], J.H. So[1],Y.H. Kim[1]

[1]*Center for Underground Physics, Institute for Basic Science, Korea*
[2]*Department of Physics, Kyungpook National University, Korea*
[3]*Korea Research Institute of Standards and Science, Korea*

✳ Introduction

- AMoRE (Advanced Mo-based Rare process Experiment) Project
  - ✓ Isotope : ^{100}Mo ($Q_{\beta\beta}$ = 3034 keV, Natural abundance =9.74 %)
  - ✓ Enrichment : up to 96 % by centrifuge method
  - ✓ Technique : MMC based cryogenic scintillating detector
  - ✓ Advantage : high energy resolution, significant particle identification.
- What is important for choosing the crystal
  - ✓ Low internal background.
  - ✓ Reasonable energy resolution
  - ✓ Proper particle identification by light/heat or PSD of phonon signal.
- Li_2MoO_4 can be a good candidate for its easy growing and lower internal background.
- Here, we present the test result of Li_2MoO_4 crystal using MMC readout at milli-kelvin temperature for next AMoRE project.



*ROI : Region of Interest

✳ Metallic Magnetic Calorimeter (MMC)

- Paramagnetic material with superconducting measurement circuit

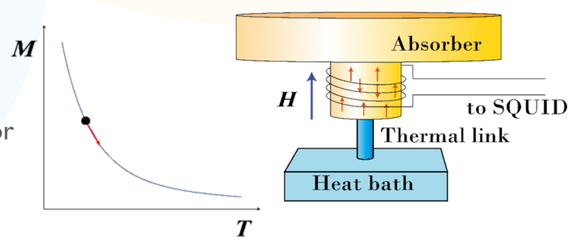
↯ δE : Occurrence of energy absorption in absorber.

➥ $\frac{\delta E}{C_{tot}} \propto \delta T$: Energy absorption -> Heat

➥ $\frac{\partial M}{\partial T}\frac{\delta E}{C_{tot}} \propto \delta M$: -> Magnetization of paramagnetic sensor

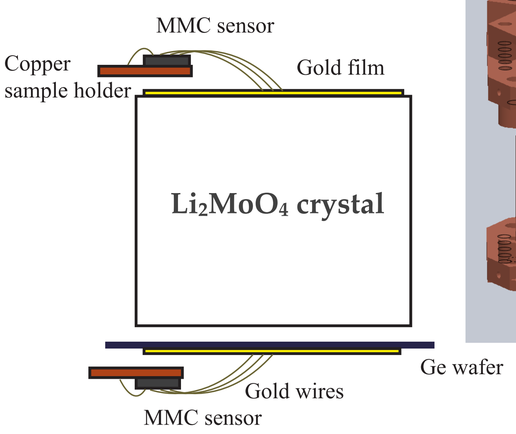
➥ $\delta M \propto \delta \Phi$: -> Magnetic flux change in a sensing SQUID.

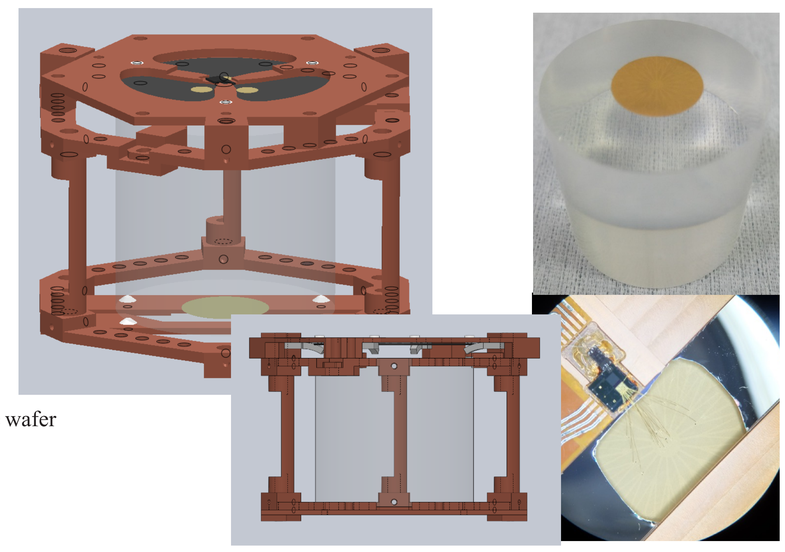
➥ $\delta \Phi \propto \delta V$: -> Voltage signals



- MMC sensors have properties of high resolution, good linearity, absorber friendly and wide operating temperature range.

✳ Experimental Setup

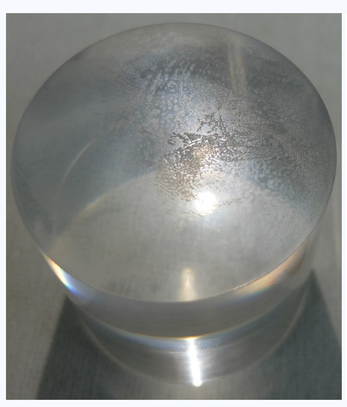


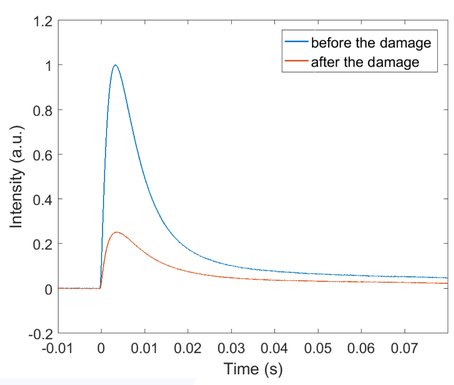


	Exposure time (H:min:s)	Humidity	Temperature
Gold evaporation	0:31:47	44 ~ 48.9 %	22.5~24.6 °C
Wire bonding & Detector assembly	1:55:13	27.1 ~ 32.2 %	23.4~24.4 °C
Installation in to DR	1:22:08	29.4%	24.6 °C
	Cooling & Data taking		

- Temperatures : 20 mK
- Crystal : Li_2MoO_4 (ϕ : 50 mm, H : 48 mm)
- Scintillation light absorber : Ge wafer (ϕ : 50.8 mm, H : 0.5 mm)
- Source : ^{232}Th Gamma source
- Vikuiti for light reflector

✳ Surface damage from the water vapor

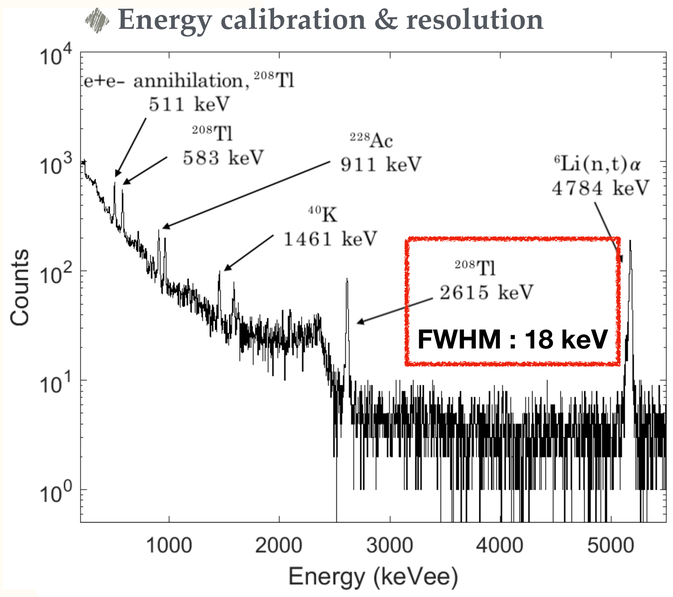


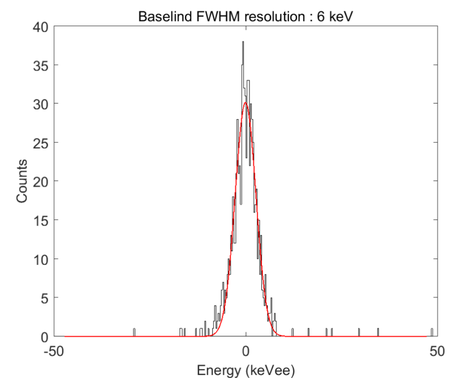


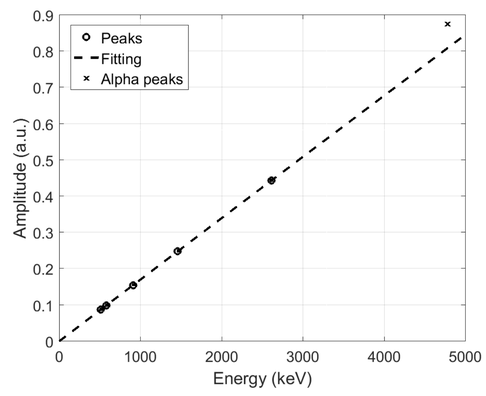
- Crystal surface was damaged by moisture condensation.
- The signal size were decreased about 4 and the energy resolution became worse by10 times after condensation.
- The hygroscopicity of Li_2MoO_4 must be considered seriously.

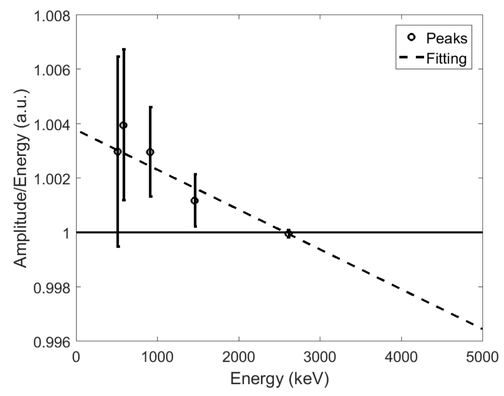
✳ Results

Energy calibration & resolution



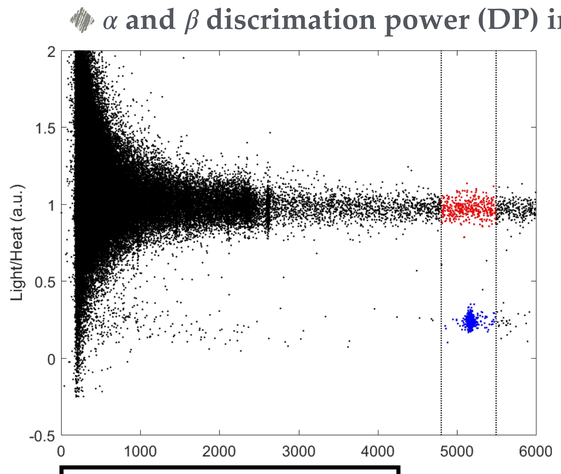


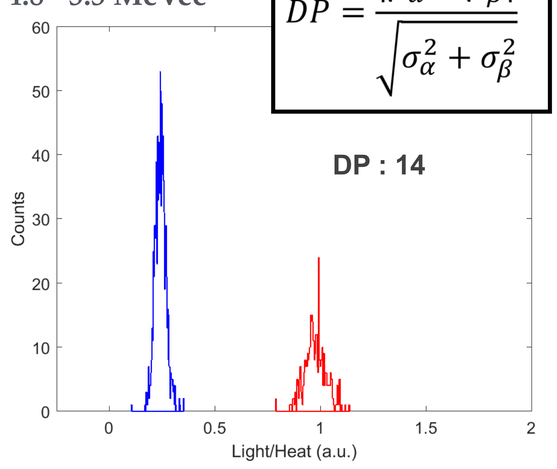




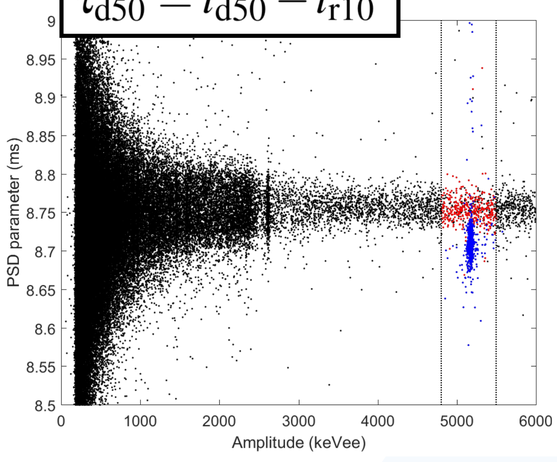
α and β discrimation power (DP) in 4.8 - 5.5 MeVee

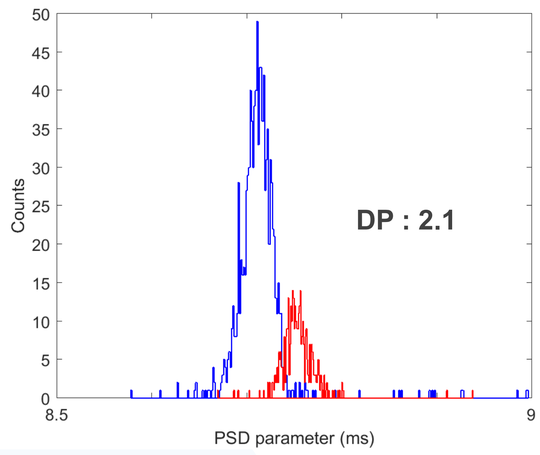
$$DP = \frac{|\mu_\alpha - \mu_\beta|}{\sqrt{\sigma_\alpha^2 + \sigma_\beta^2}}$$



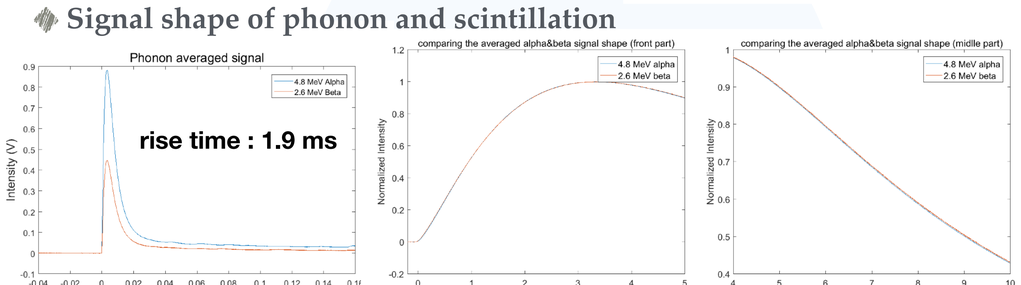


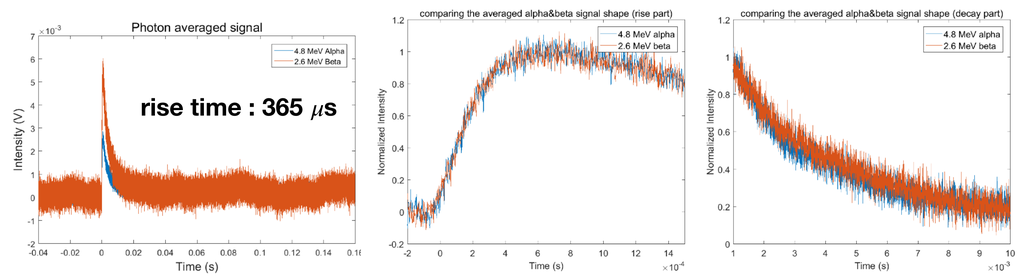
$$\tau_{d50} = t_{d50} - t_{r10}$$





Signal shape of phonon and scintillation





✳ Conclusion & Future Plan

- The Li_2MoO_4 crystals have been studied using MMC readout for its energy resolution and particle discrimination power at 20 mK temperature.
- The non-linearity of 2nd-polynomial calibration function is less then 1 %.
- Full width half maximum energy resolution of 2.6 MeV gamma peak is 18 keV.
- Discrimination power of light/heat is 14 in 4.8 - 5.5 MeVee range.
- Further study is on going to control the Li_2MoO_4 crystal for better performance from moisture damage.