Development of Cryogenic Detector with $CaMoO_4$ Crystals for Neutrinoless Double Beta Decay

[1,2]S. J. Lee, [1]Y. H. Kim, [1]M. K. Lee, [1]Y. S. Jang, [1]I. H. Kim, [1]K. B. Lee, [1]Y. H. Lee, [3]H. J. Kim, [3]J. H. So, [4]Y. D. Kim, [2]S. K. Kim

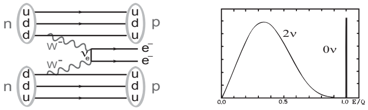
[1] Korea Research Institute of Standards and Science, [2] Seoul National University, [3] Kyungpook National University, [4] Sejong University

In search of $0\nu\beta\beta$ decay, $CaMoO_4$ crystal has some advantages. First, high transition energy of ^{100}Mo leads to low γ-ray background level. Second, $CaMoO_4$ scintillation crystal can provide light and phonon signal enabling an efficient rejection of surface events. With an MMC, phonon signals of α's and γ-rays from ^{241}Am were measured.

13th International Workshop on Low Temperature Detectors 2009 Stanford

Neutrinoless Double Beta Decay

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



Candidates : ^{48}Ca, ^{76}Ge, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{128}Te, ^{130}Te, ^{150}Nd, and ^{238}U

Observation of the decay will confirm the Majorana nature of the neutrino and provide the effective neutrino mass.

* * * * * * * * * * * * * * * * * * * *

$CaMoO_4$ Crystal Developed by KIMS Collaboration

^{100}Mo (9.63% natural abundance) : one of the most promising double beta decay candidate because of its high transition energy (Q = 3035 keV).

$CaMoO_4$ (calium molybdate) is a scintillato

Density (g/cm³)	4.2	Structural type	Scheelite
Melting point (°C)	1430	Wavelength of emission maximum (nm)	520
Debye temperature	400 ~ 440 K		

Number of ^{100}Mo in 1cm³ $CaMoO_4$ ~ 10^{21}

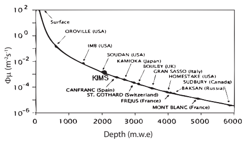
$T_{1/2}$ of double beta decay of ^{100}Mo ~ 8.5×10^{18} year

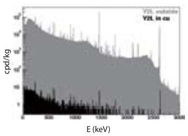
$T_{1/2}$ of $0\nu\beta\beta$ of ^{100}Mo > 4.6×10^{23} year

* * * * * * * * * * * * * * * * * * * *

Background at Yangyang Underground Laboratory (Y2L)

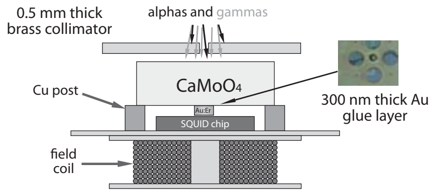
Low level of γ-ray background expected around the Q of ^{100}Mo decay





neutron flux : 8×10^{-7} /cm²/s, muon flux : 2.7×10^{-7} /cm²/s

Experiemntal Setup (MMC)



Themometer : Au:Er (800 ppm, 40 μm diameter, 30 μm height cylinder)

Crystal size : ~ 1 cm × 1 cm × 0.6 cm

Operating temperature : 13 ~ 100 mK

Applied magnetic field : 0.3 ~ 4 mT

* * * * * * * * * * * * * * * * * * * *

Radioactive Source

Thin ^{241}Am layer from Ortec (guarantees FWHM of 13 keV)

alpha energy (keV)	5388	5443	5486
intensity (%)	1.4	12.8	85.2

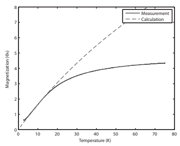
59.54 keV γ-ray intensity : 36%

Attenuation length of 60keV γ-ray in brass ~ 0.7 mm

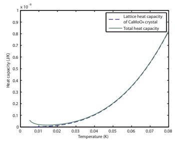
* * * * * * * * * * * * * * * * * * * *

Temperature Dependance at 1.2 mT

Magnetization dependance on temperature (800 ppm)



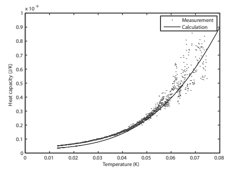
Theoretical heat capacity (Debye temperature of 420 K used)



Measured $E_0/\Delta T$ from the above M-T curve and

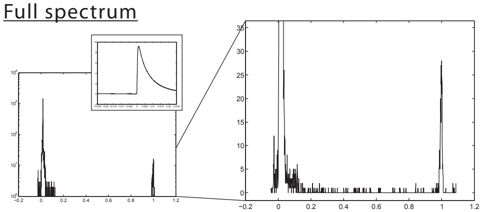
Calculated $E_0/\Delta T$ from the theoretical heat capacity of $CaMoO_4$

(Ratio of phonon/light generation not considered.)

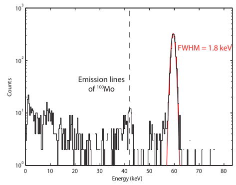


Energy Spectrum

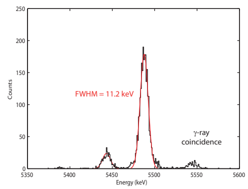
Full spectrum



Gamma spectrum

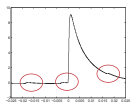


Alpha spectrum



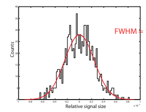
No significant count of events inbetween. Superconducting Nb can also serves as a radiation shied

Pile-up signal



broadens the peaks

Baseline spectrum

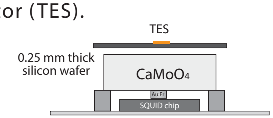


much better than signal spectrum

* *

Next Step

1) Measure scintillation light using additional detector (TES).



2) Use bigger crystal with bigger Au:Er sensor

3) Adopt meander-type SQUID system

4) Place the detector in a highly reflecting cavity