Development of cryogenic detector for the measurement of neutrinoless double beta decay using $CaMoO_4$ crystal

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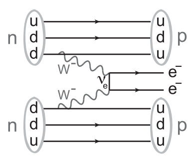
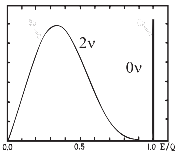
Neutrinoless Double Beta Decay

(A,Z) → (A,Z+2) + e^- + e^-





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

The observation of neutrinoless double beta decay will confirm the Majorana nature of the neutrino and provide the absolute neutrino mass scale.

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$CaMoO_4$ Crystal

^{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 scintillating single crystal.

Density (g/cm^3)	4.2	Structural type	Scheelite
Melting point (°C)	1430	Wavelength of emission maximum (nm)	520

Number of ^{100}Mo in $CaMoO_4$ of 1 cm^3 ~ 10^{21}

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

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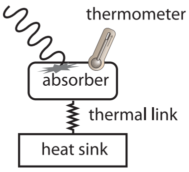
Calorimetric Detection

Energy absorption of a particle or a photon in the absorber leads to temperature increase of the system.



At low temperatures, the heat capacity of the detector becomes so small that even a low energy particle can sufficiently increase the temperature of the detector.

For 1cm^3 $CaMoO_4$ and absorption of 5.5 MeV

Temperature	Lattice heat capacity	Final temperature
300 K	82.5 J/K	-
15 mK	1×10^{-11} J/K	33 mK

Moreover, the thermal energy fluctuation can be significantly reduced.

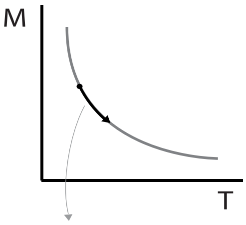
$$\Delta E = 2.35\xi(k_B T^2 C)^{1/2}$$

Metallic Magnetic Calorimeter (MMC)

Themometer : Au:Er (800 ppm)

- a dilute alloy of Er in Au

- paramagnetic material



Q ⇨ ΔT ⇨ ΔM ⇨ ΔΦ

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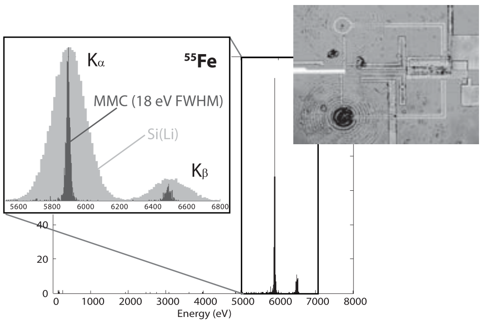
MMC Performance Compared with Si(Li)



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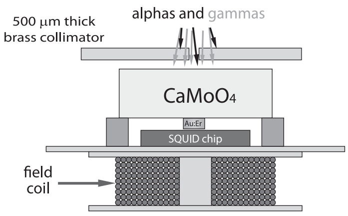
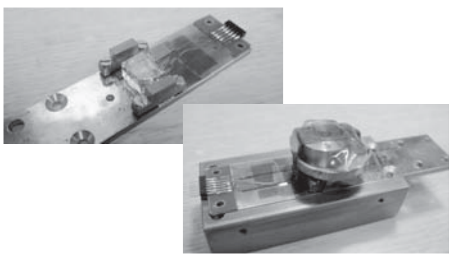
Experimental Setup





Crystal size : ~ 11 mm × 11 mm × 6 mm

Operating temperature : 13 ~ 100 mK

Applied magnetic field : 3 ~ 40 G

Radioactive Source

Electro-deposited monolayer ^{241}Am alpha decay source from Ortec

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

59.54 keV gamma intensity : 35.9%

Radiation length in brass > 0.7 mm

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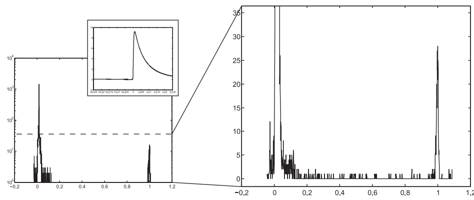
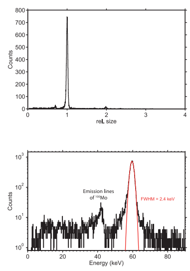
Results

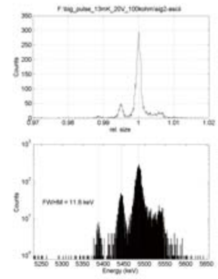
Full spectrum (gamma and alpha)



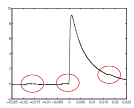
Gamma spectrum



Alpha spectrum



Pile-up signals broadened the peaks



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Discussion

High energy resolution achieved

Future Plans :

1) Use bigger crystal

2) Measure scintillation light from the crystal at the same time using TES (additional detector for background rejection)

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Dedicated to my mother So-choon, Park