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Development of light detector using superconducting thermometer for rare event search in scintillating $CaMoO_4$ crystal

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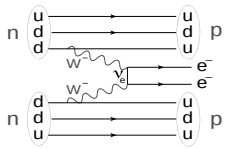
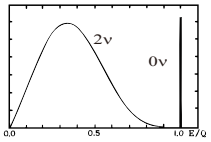
Neutrinoless Double Beta Decay ($0\nu\beta\beta$)

(A, Z) -> (A, Z+2) + e- + e-





Measurement of half-life of $0\nu\beta\beta$ will confirm the Majorana nature of neutrino and yield the effective neutrino mass.

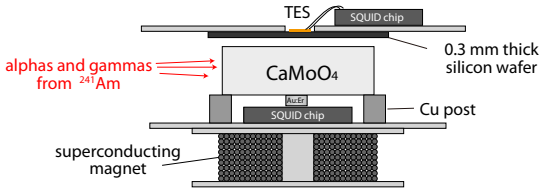
$CaMoO_4$ Crystal Scintillator

: One of the most promising material to study $0\nu\beta\beta$

1) ^{100}Mo : one of the highest transition energy (3,034 keV)
9.82% natural abundance

2) Scintillation light can be used for the active rejection of alpha background

Combination of Metallic Magnetic Calorimeter (MMC) and Transition Edge Sensor (TES) for the detection of alpha particles from ^{241}Am



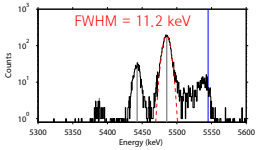
1 cm X 1 cm X 0.6 cm radiopure crystal

MMC Measurement (Heat Signal)

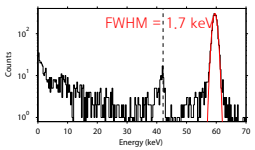
Sensor material - Au:Er (800 ppm)

Alpha signal (5.5 MeV) and gamma signal (60 keV) were measured simultaneously.

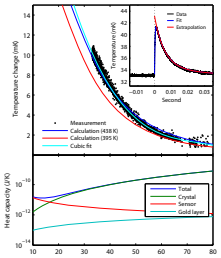
alpha spectrum



gamma spectrum



- The feasibility of sizing up the crystal is guaranteed by heat capacity analysis.
- Larger sensor material can be used for higher sensitivity.
- 100 times larger crystal will be tested soon.



- Due to low energy threshold, it can be simultaneously used for dark matter search.

TES Measurement (Light Signal)

Silicon wafer as a scintillation light absorber

- intrinsic and double-polished for small heat capacity
- cut into 10 mm X 10 mm X 0.3 mm

TES in the middle

- bilayer of Ti/Au (Ti : 20 nm, Au : 100 nm)
- area : 1.2 mm X 0.4 mm

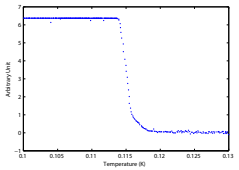
Electrode : bilayer of Ti/Au (Ti : 200 nm, Au : 50 nm)

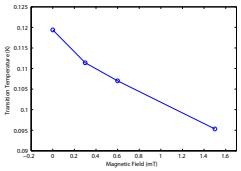
- area : 0.5 mm X 0.5 mm

Transition temperature (Tc) : ~ 120 mK, width (ΔT) : ~ 4 mK

- Tc and ΔT is a function of magnetic field applied for MMC
- ΔT increased to larger than 10 mK at 1.5 mT

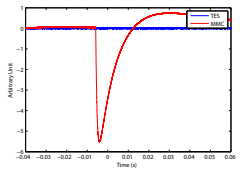
Optimal condition of magnetic field should be found.



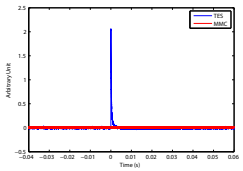


Simultaneous Measurement of MMC & TES

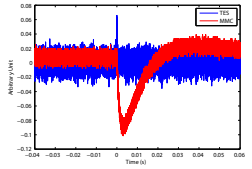
MMC signal



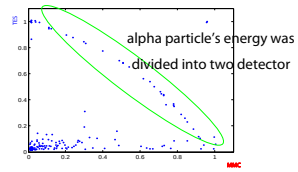
TES signal



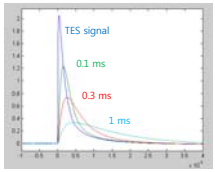
Coincidence signal



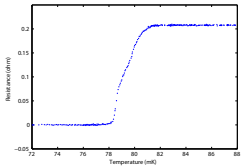
Coincidence spectrum

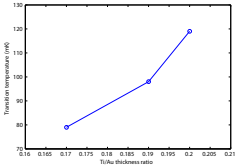


- No coincidence event between heat and light signal found.
- Instead, alpha events hitting the crystal after hitting the silicon wafer were observed.
- Main reasons for non-observation of coincidence events :
  high transition temperature and collimation mistake
- Solution : lowering transtion temperature
  total heat capacity (silicon wafer + TES + electrode)
  at 120 mK : ~ 3.2 X 10^{-11} J/K, at 80 mK : ~ 1.0 X 10^{-11} J/K
  major heat capacity in silicon wafer
- One more thing to consider :
  Decay time constant of scintillation was measured to be ~ 340 μs at 20 mK by CRESST



On-going and future experiments





- Ti/Au TES with Tc of about 80 mK has been fabricated on a silicon wafer.
- Dual-channel (heat and light) sensor with an enriched large crystal ($^{40}Ca^{100}MoO_4$) will form a detector unit for the AMORE collaboration