First Test of a Large-volume $CdMoO_4$-based Low Temperature Detector for Neutrinoless Double Beta Decay Search

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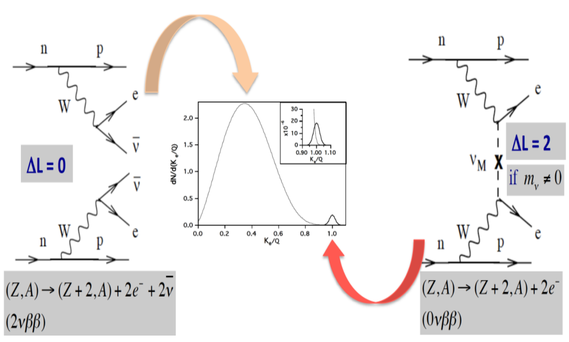
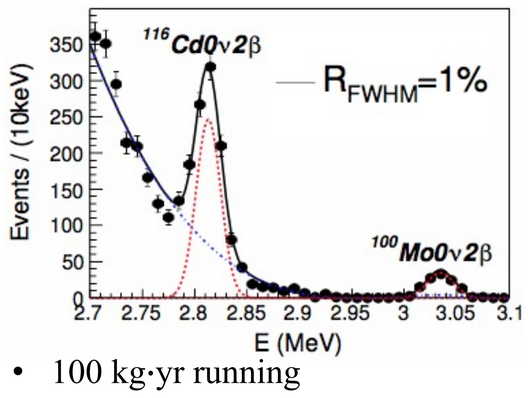
Abstract

The applicability of a large cylindrical $CdMoO_4$ crystal with natural isotopic abundance as a cryogenic scintillating bolometer was checked for the first time. Both the heat and scintillation light signals were observed proving $CdMoO_4$ material a promising absorber in search of neutrinoless double beta decay based on both $^{100}_{42}$Mo and $^{116}_{48}$Cd target nuclides. We also present the achieved energy resolution with FWHM 13 keV@2615 keV, the discrimination power for α versus β/γ events, and the low internal trace contamination of the $CdMoO_4$ crystal.

Motivation

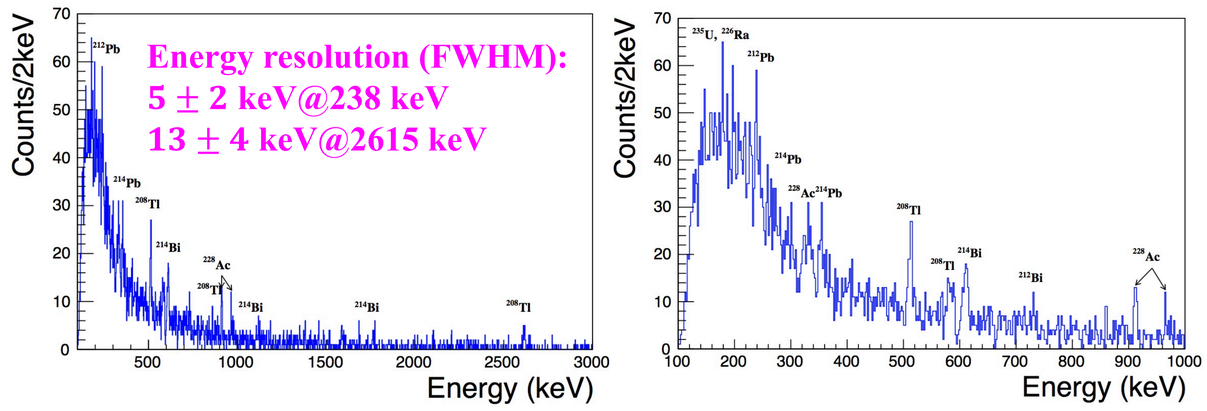




- $\Delta L = 2$, new physics beyond SM
- Absolute value and hierarchy of the neutrino masses
- ν is Majorana or Dirac particle…

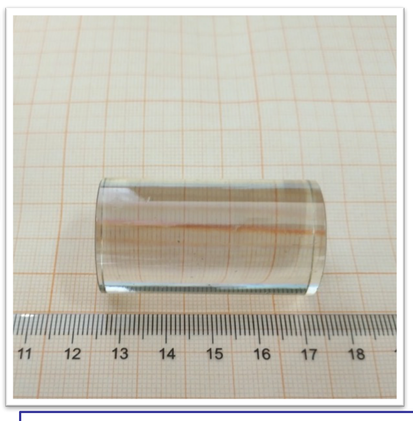
- 100 kg·yr running
- Geant4 simulation results indicate that $CdMoO_4$ scintillator with double nuclides is very attractive

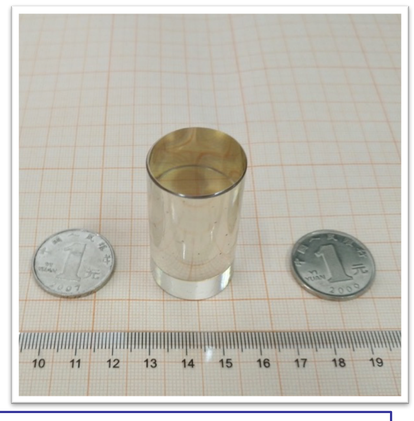
Energy Calibration



- For LD, using cosmic rays to do energy calibration
- Optimization: underground measurements, lowering the testing temperature
- Long time measurement is necessary as well

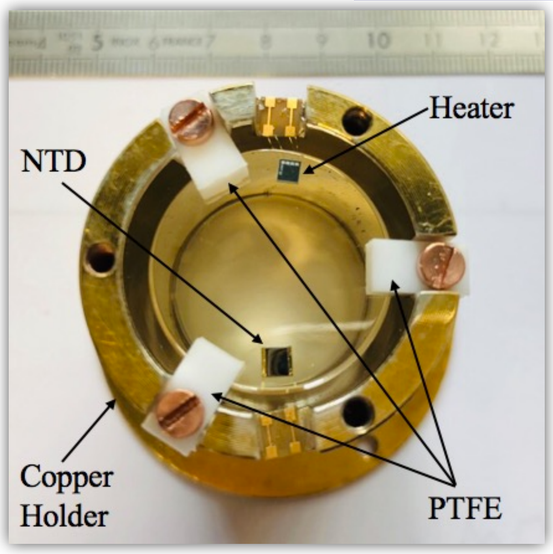
Bolometer Assembly

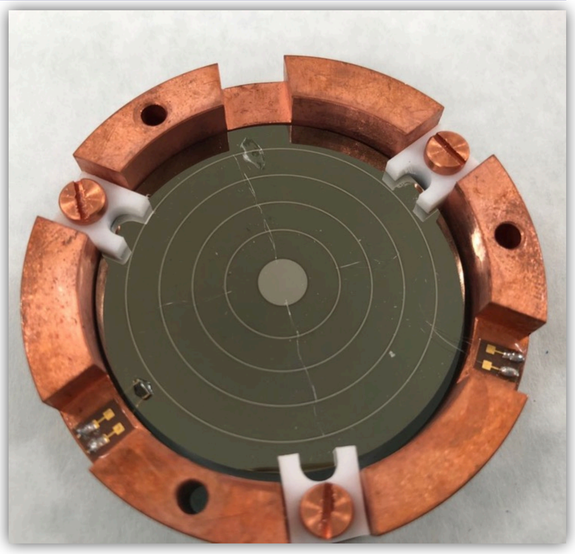




- Bridgman growth
- Size ϕ25×45 mm
- Mass 134 g
- Density 6 g/cm^3
- Polished

$CdMoO_4$ crystal provided by Ningbo University

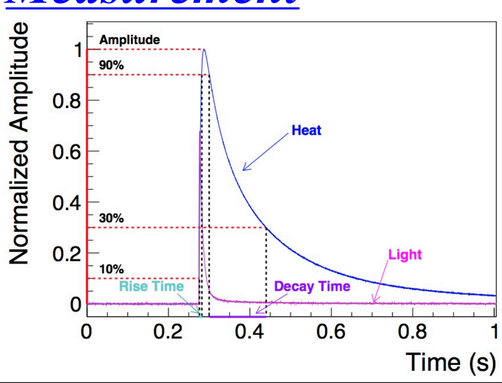




- Copper holder coated with gold
- Inner surface covered by Ag to improve light collection
- PTFE clamps as a thermal link and fixed the crystal with screws
- NTD-Ge sensor with size 3×3×1 mm^3 to read out heat signal
- Silicon heater to monitor the system and to do stabilization
- Light Detector (LD), the HP Ge wafer, with size ϕ44×0.17 mm
- Three-times-smaller volume NTD-Ge to read out light signal

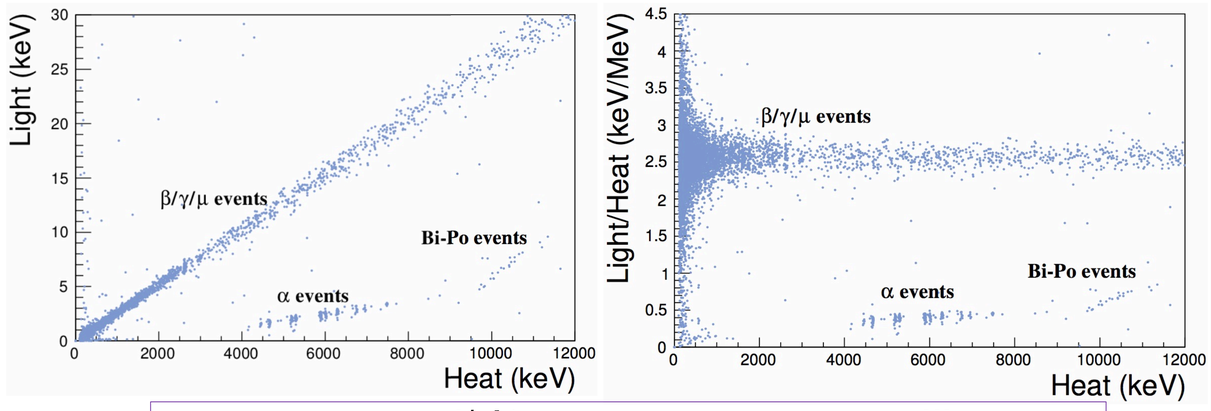
@CSNSM (Orsay, France)

Measurement



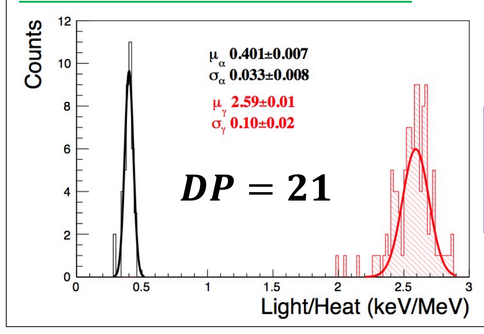
- at working temperature 25 mK
- Above ground measurement at CSNSM
- shielding made of low radioactivity lead
- a 16-bit ADC
- a 10-kHz sampling frequency
- 8 h data taking
- ^{232}Th radioactive source

α vs. β/γ Discrimination

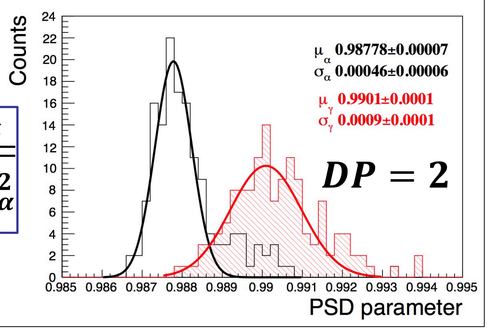


$$Light\ Yield\ (LY) = \frac{Light}{Heat} = 2.55\ keV/MeV,\ QF_\alpha = \frac{LY_\alpha}{LY_{\gamma(\beta)}} = 16\%$$

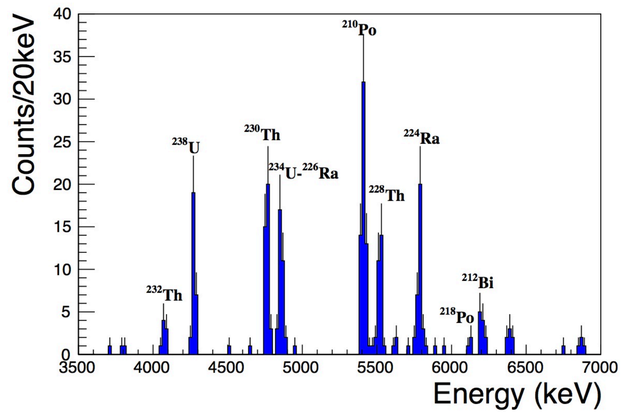
Discrimination Power



$$DP = \frac{\mu_{\gamma/\beta} - \mu_\alpha}{\sqrt{\sigma^2_{\gamma/\beta} + \sigma^2_\alpha}}$$



α Contamination



Isotopes	Q keV	Activity mBq/kg
^{238}U	4269	10 ± 3
^{230}Th	4769	14 ± 4
^{234}U, ^{226}Ra	4859/4870	12 ± 3
^{210}Po	5407	22 ± 5
^{232}Th	4081	3 ± 2
^{228}Th	5520	11 ± 3
^{224}Ra	5788	12 ± 3

Summary and Discussion

- A 134 g cylindrical $CdMoO_4$ crystal has been tested as a scintillating bolometer
- A high energy resolution, with FWHM from 5 keV to 13 keV in 0.2-2.6 MeV
- Good particle identification capability, α versus β/γ
- Low trace radioactive contamination in U/Th chains, mBq/kg
- Crystal purification, and the ongoing negotiation of underground measurement in China Jinping Underground Laboratory or others

References

- **Chinese Physics C, 2017, 41(4): 046002**
- **arXiv:1907.08039**

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