Double Beta Decay of ^{48}Ca in CANDLES III
-Development of the calibration system-

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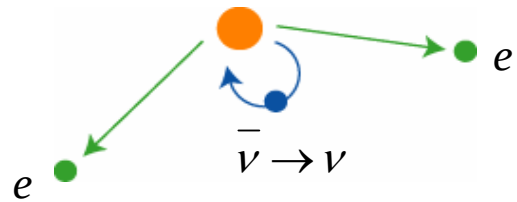
Double Beta Decay

- Neutrino-less Double Beta Decay ($0\nu\beta\beta$)

  $0\nu\beta\beta$ rate ・・・ gives the absolute ν mass scale

  $0\nu\beta\beta$ event ・・・ evidence for the Majorana nature



Beyond the Standard Model

$0\nu\beta\beta$: Neutrino-less Double Beta decay

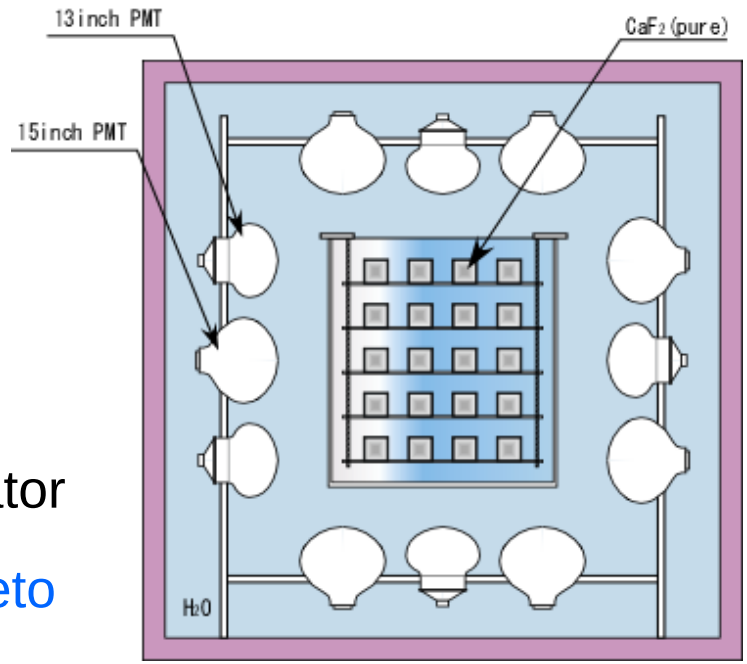
- We are aiming for detection of $0\nu\beta\beta$ with CANDLES

CANDLES System

CAlcium fluoride for studies of Neutrino and Dark matters by Low Energy Spectrometer

Double beta decay nucleus : ^{48}Ca

- CaF_2(pure) scintillator
  - → source = detector
- High Q-value (4.27MeV)
  - → Low background
- CaF_2(pure) immersed in Liquid Scintillator
  - → Liq. Scinti. act as 4 pi active veto



Energy Calibration in CANDLES

- Calibration is important task to identify $0\nu\beta\beta$ event

- Preferable to calibrate around Q-value (4.27MeV) region

  - Identify Q-value region with precision

    (CaF_2(pure) Linearity has confirmed ever with accelerator and LED)

- Stable measurement in long period due to the rare event

  - Regular energy calibration

  - Fluctuation PMTs gain and electronics ・・・

- Realization of Low background environment

  (Not install apparatus for calibration as much as possible)

Calibration system in CANDLES III (1)

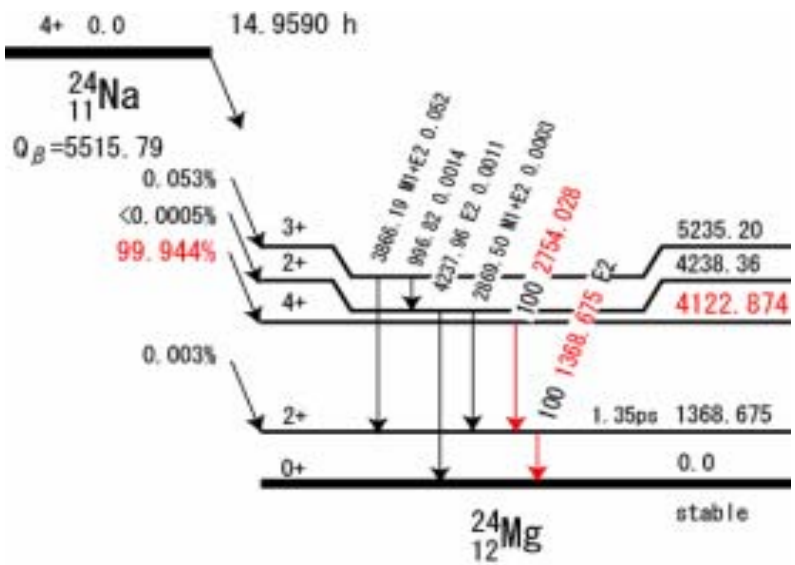
- No standard γ ray sources with energy around Q-value region

  → Sum energy of ^{24}Na

  1.36MeV + 2.75MeV = 4.11MeV, close to the Q-value (4.27MeV)

- Difficult to obtain photo-peak due to the low efficiency

  → Cut by liquid scintillator act as active veto



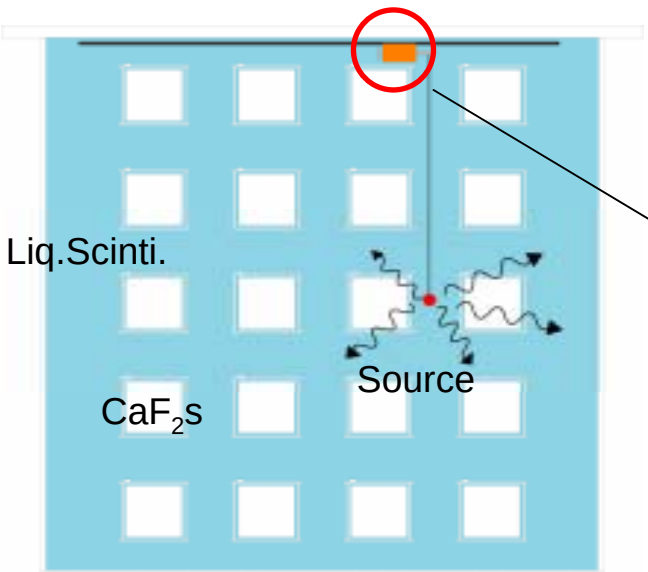
Decay scheme of ^{24}Na

Calibration system in CANDLES III (2)

- Enhance detection efficiency of sum energy peak

  → Underwater robot conveys the source close to CaF_2s

  (Possible to take it out of the Tank)

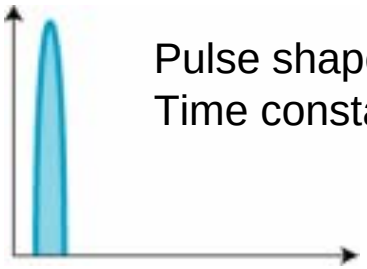


Conceptual diagram of Calibration system

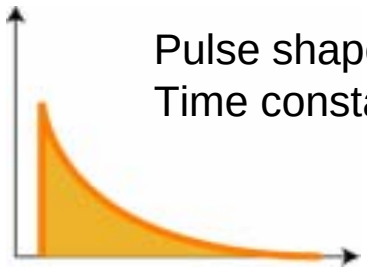
Underwater robot

No source and robot at measurement time

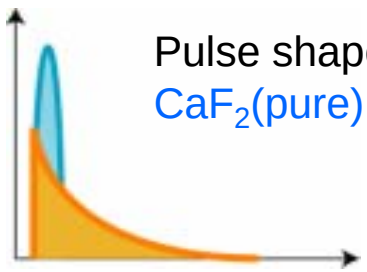
Pulse Shape Discrimination in CANDLES



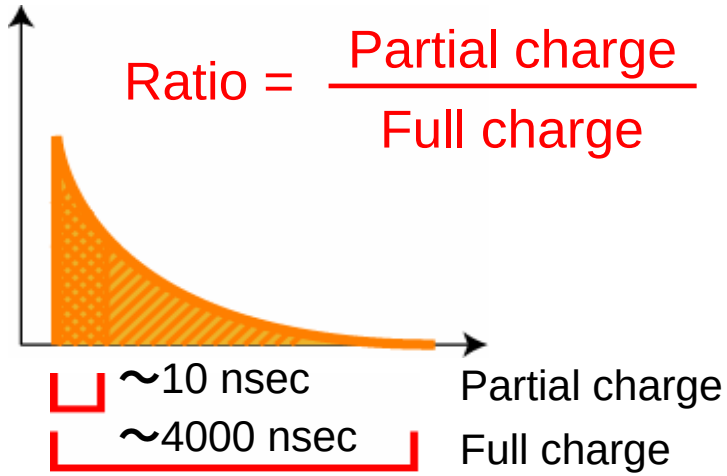
Pulse shape of Liq. Scinti.
Time constant 10 nsec



Pulse shape of CaF_2(pure)
Time constant 900 nsec



Pulse shape of
CaF_2(pure) + Liq. Scinti.

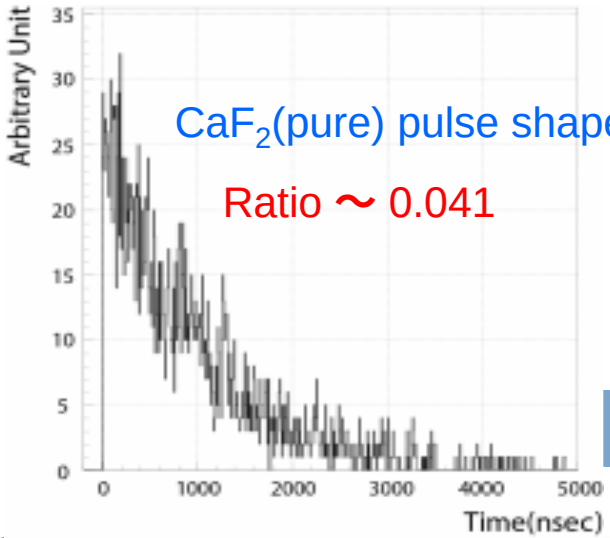


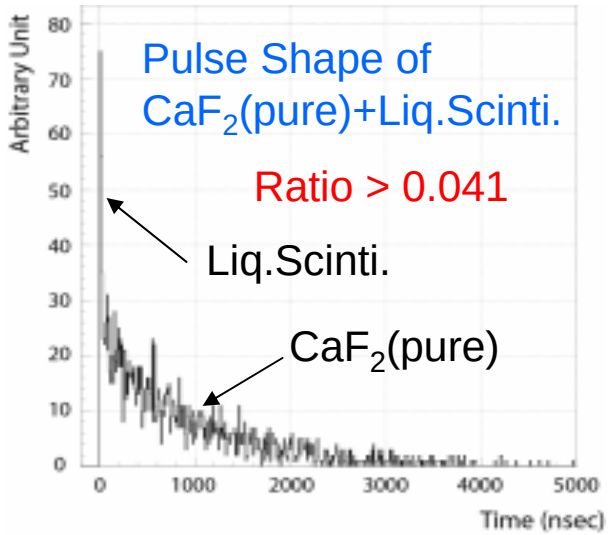
- Possible to discriminate these pulses by using of the Ratio
- Comparison of Ratios

Liq. Scinti. > Liq. Scinti.+CaF_2(pure) > CaF_2(pure)

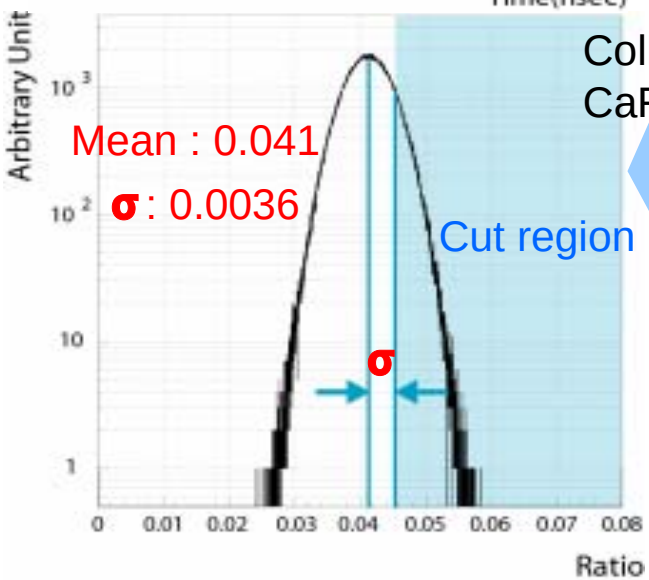
- To Obtain CaF_2(pure) spectrum cutting by Liquid Scintillator (active veto)

Simulation of Pulse Shape (FADC output)





Collect ratios of CaF_2(pure)

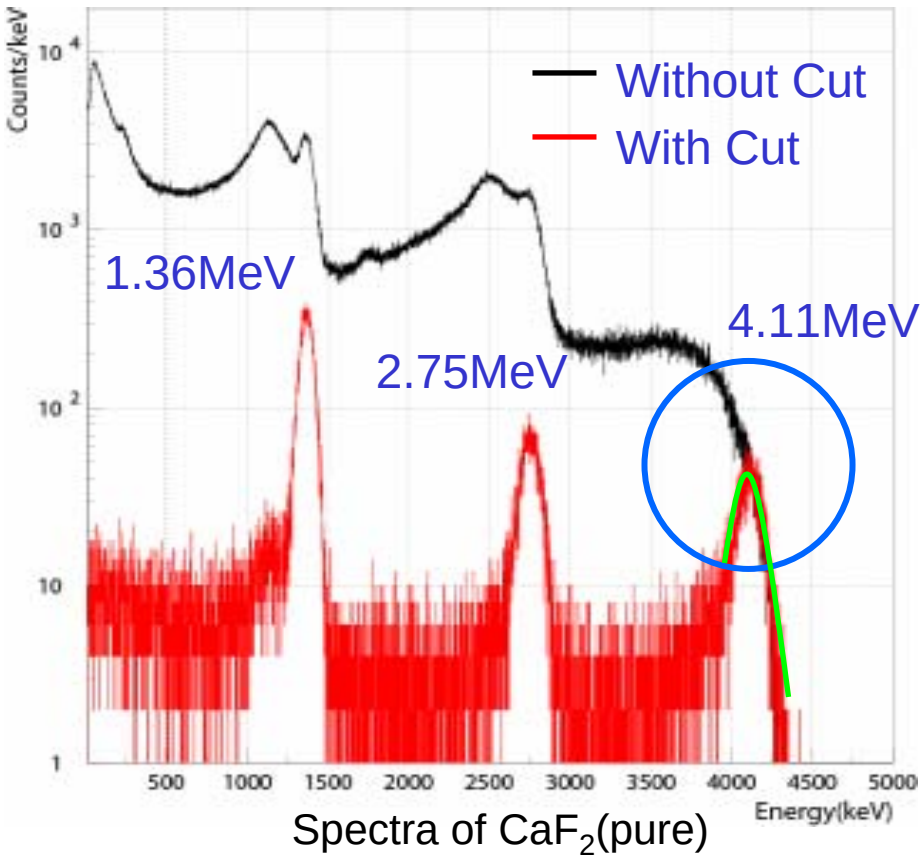


Distribution of Ratio of CaF_2(pure)

- It is difficult to obtain Photo peak due to the low efficiency
- If the ratio is higher than 0.041+1(or2) **σ**, the event is cut

PSD Simulation in CANDLES III

- CANDLES III ・Resolution : 4% @4.27MeV
  ・Liq. Scinti. Veto Phase (〜50cm)



Spectra of CaF_2(pure)

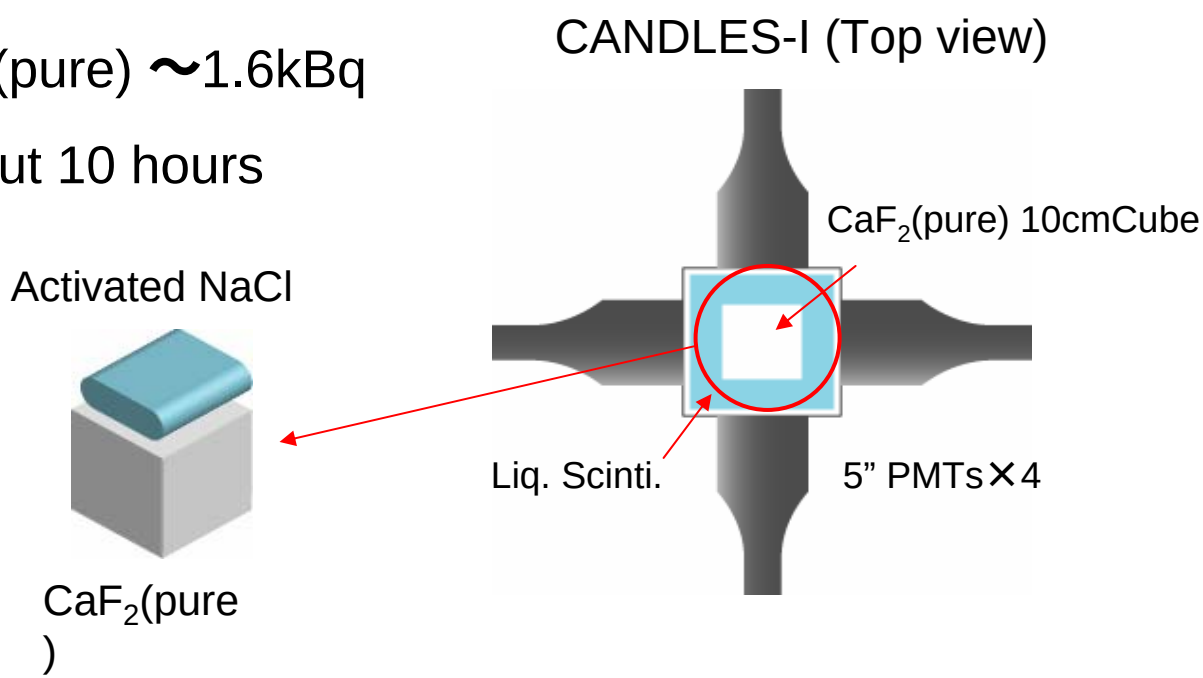
2σ Cut (Liq.Scinti. Th. = 25keV)
Chi square ・・・ 1.65
Mean ・・・ 4.09MeV
FWHM ・・・ 4.3%

1σ Cut (Liq.Scinti. Th. = 50keV)
Chi square ・・・ 1.83
Mean ・・・ 4.11MeV
FWHM ・・・ 4.1%
Correspond to Sum energy

- Possible to calibrate around Q-Value with ^{24}Na !

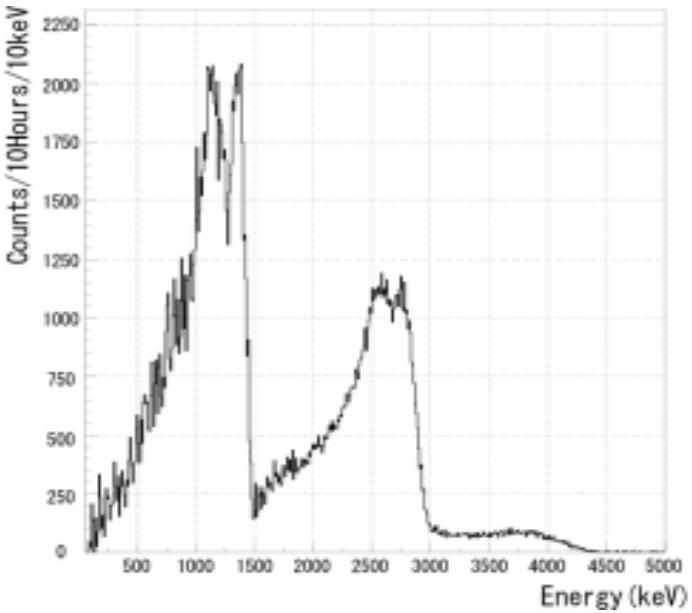
Experiment : Prototype CANDLES

- To confirm the simulation reproduce experiment
- CANDLES - I
  - 10 cm Cube : CaF_2(pure)
  - Liq. Scinti. Veto Phase ～4 cm
  - 5 inch PMT ✕ 4
- Activate NaCl
- Put NaCl on CaF_2(pure) ～1.6kBq
- Measurement about 10 hours

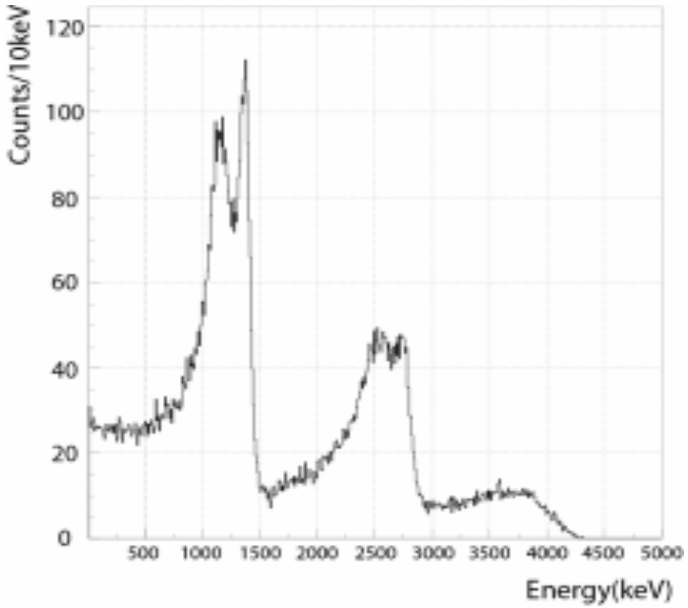


Result of Experiment

Spectra of CaF_2(pure)



Experiment with Liq. Scinti. Cut



Monte Carlo Simulation with Liq. Scinti. Cut

- Sum peak has not seen, because・・・
  - -Thin of Liq. Scinti. Veto phase
  - -Resolution was not so good 12%@662keV
  - -Insufficient statistics
- The Simulation reproduce the Experiment

Summary

- We are looking for Neutrino-less double beta decay
- The detection system is CANDLES
- To calibrate around Q-value, we use sum energy of ^{24}Na
- Possible to calibrate around Q-value in CANDLES III
- Sum peak has not seen with prototype CANDLES
- The Simulation reproduce the experiment