ジルコニウム96を用いたニュートリノを放出しない二重ベータ崩壊事象の探索XXIII
～ニュートリノを放出する二重ベータ崩壊事象の観測実験における背景事象と装置性能の評価

日本物理学会　2005年春季大会（オンライン）

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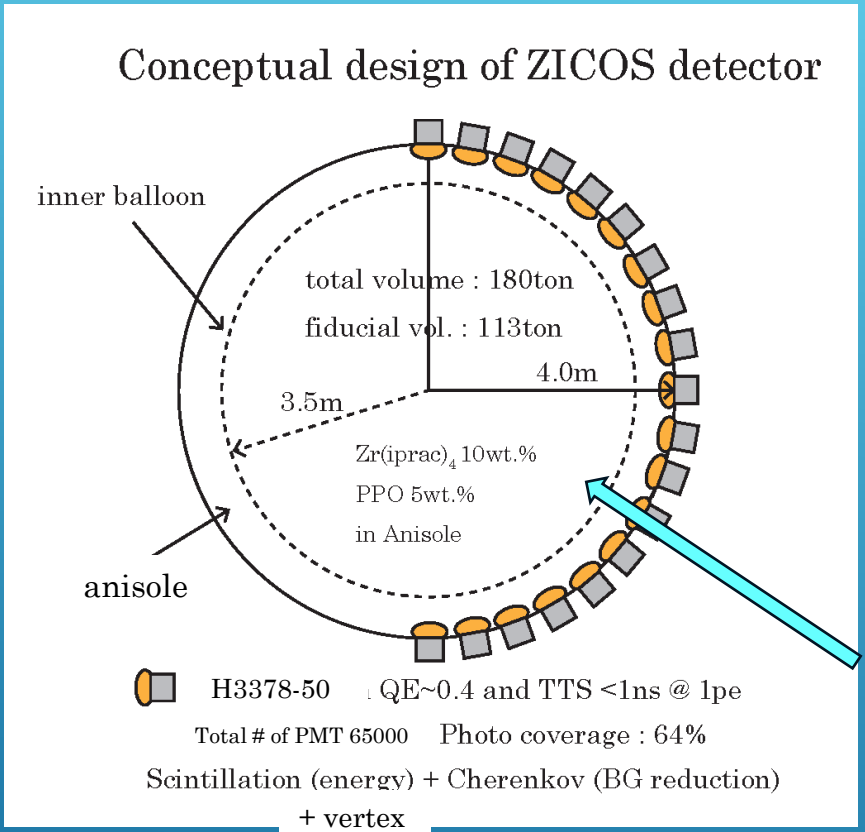
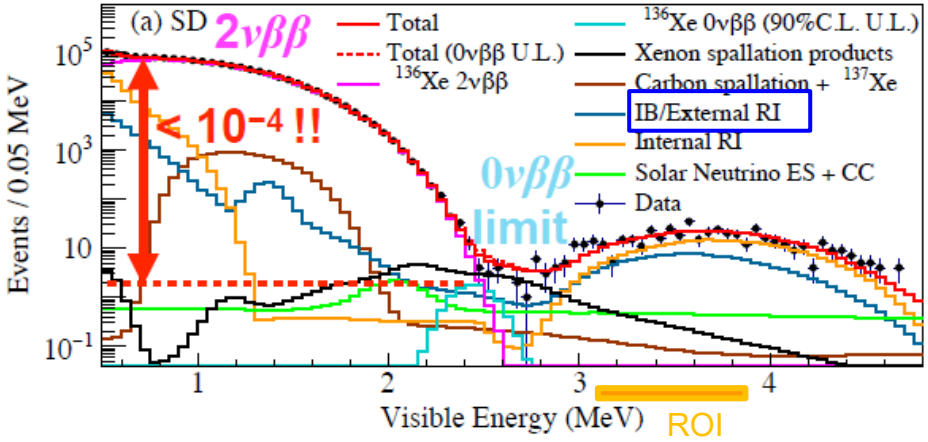
Miyagi University of Education Y. Fukuda, R. Sato, K. Takemura,
K. Sugawara, K. Toyama
Kamioka Observatory, ICRR, Univ. of Tokyo S. Moriyama, K. Hiraide
University of Fukui I. Ogawa
Tokyo University of Science T. Gunji
Institute for Materials Research, Tohoku University S. Kurosawa
University of Toyama Y. Nakano

ZICOS experiment for ^{96}Zr 0νββ observation





I.Shimizu, Plenary talk at Neutrino2024 conference.

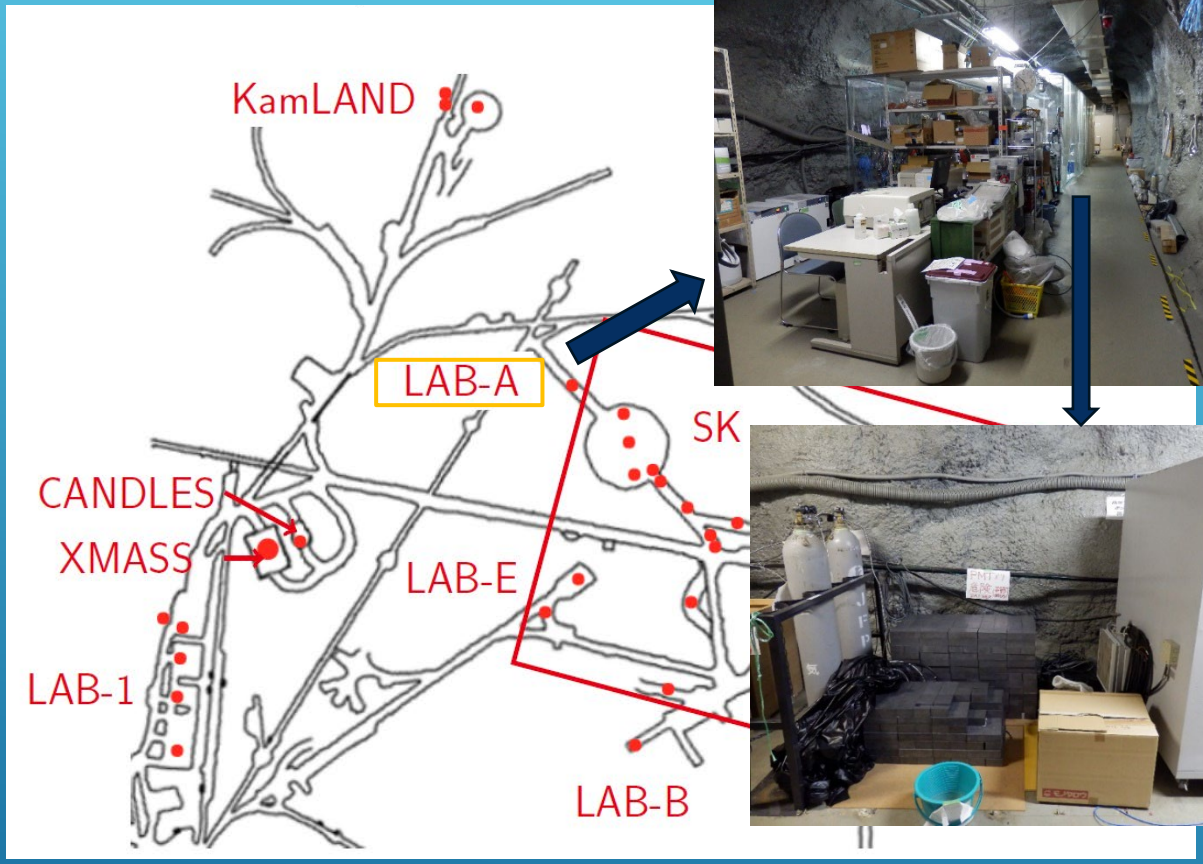
Liquid scintillator loaded ^{96}Zr

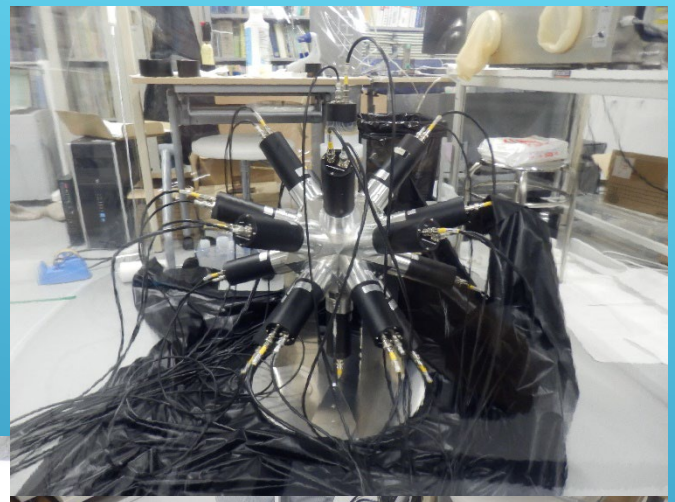
NEMO3 : $T^{0\nu}_{1/2} > 9.1 \times 10^{21}$ yrs

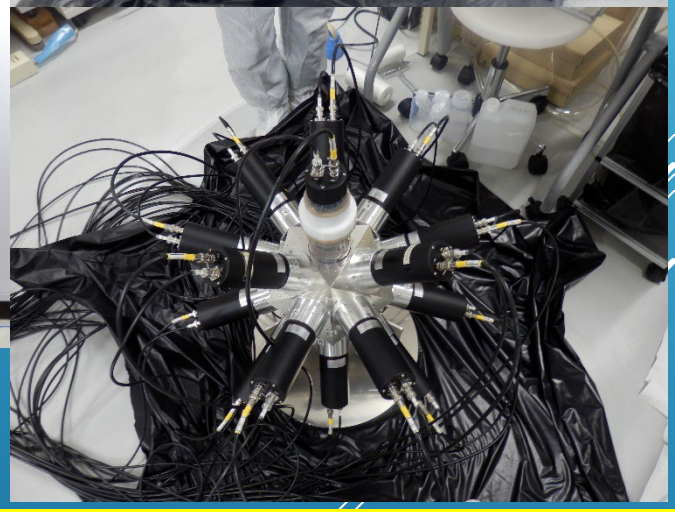
^{96}Zr : 45 kg (nat.) → 865 kg(50 % enrich)→1/20 BG

$T^{0\nu}_{1/2} > 4 \times 10^{25}$ yrs → 2×10^{26}yrs → ~1 $\times 10^{27}$yrs

2ν-ZICOS for measurement of 2νββ half-life







In Kamioka mine LAB-A : Behind of LINAC control room

Now we are testing at MUE.

Why 2ν-ZICOS will do in the Kamioka mine

There is huge backgrounds for the observation of $2\nu\beta\beta$ events on the surface of earth due to cosmic muon.

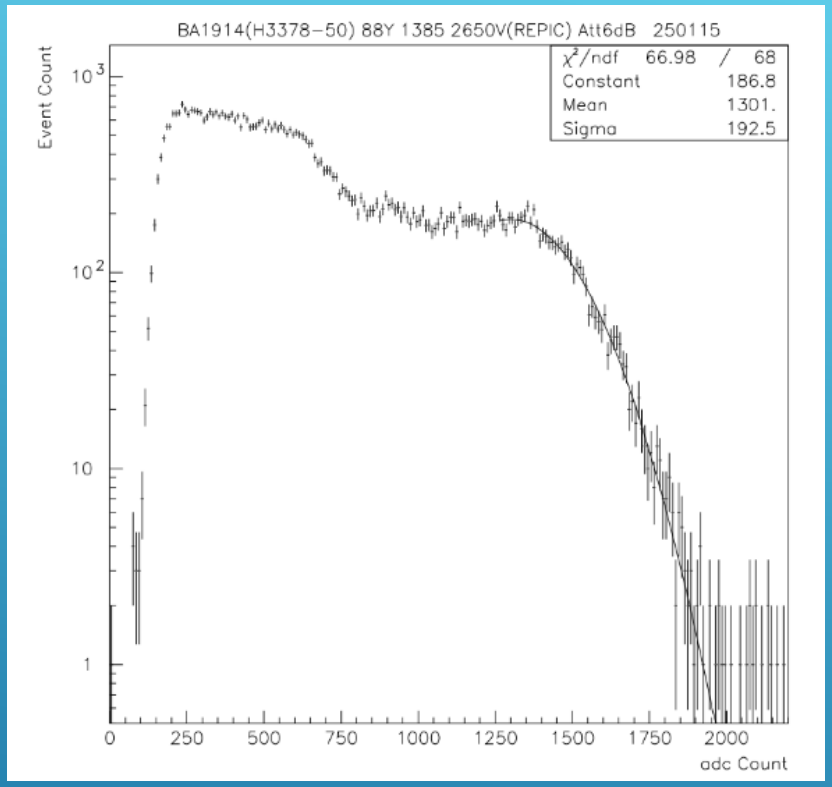
- Cosmic muon rate detector is ~2Hz at surface.
- Most significant spallation is ^{11}C which decays in beta plus and emits total energy ~2MeV.
- The half-life of ^{11}C is 1200sec and the detector should have no live-time if veto for all muons.
- In the mine, cosmic-ray muon rate will be 2×10^{-5} Hz, so dead-time is about 2.5% if veto for all muons.
- Expected event rate due to ^{11}C, which is caused by neutron produced by muon spallation, is ~20 events/yr using measured neutron flux.

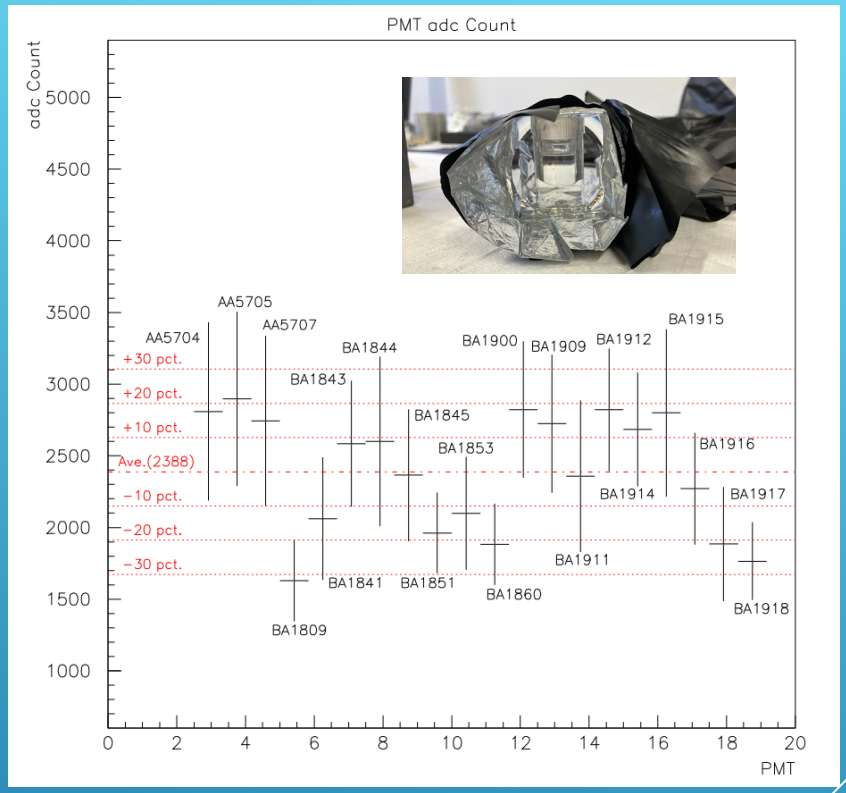
Are you ready to start 2ν-ZICOS in the mine

To show the detector performance of 2ν-ZICOS experiment, we measured following things.

1. Background events is low enough?
2. Background spectra is understood?
3. Using calibration source, observed energy spectrum is consistent with simulation?
4. energy scale is linear?
5. The reconstructed vertex position is consistent with simulation?
6. Averaged angle, which is used for BG reduction, is consistent with simulation?

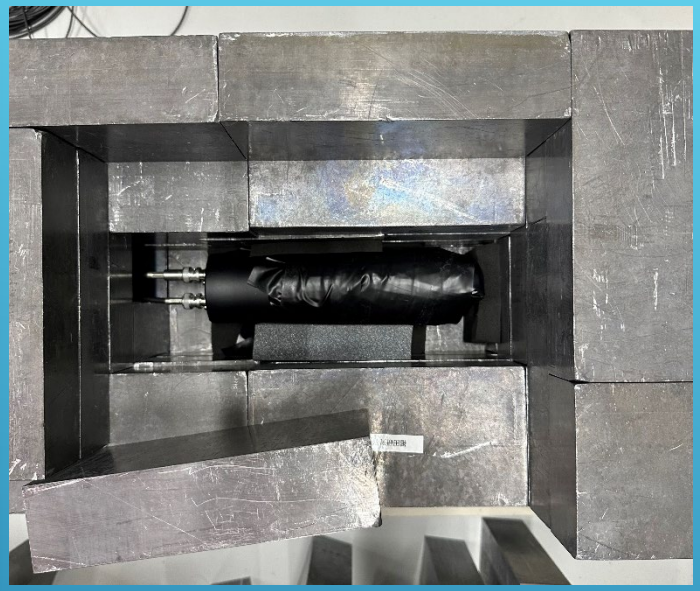
Gain adjustment for H3378-50 PMT

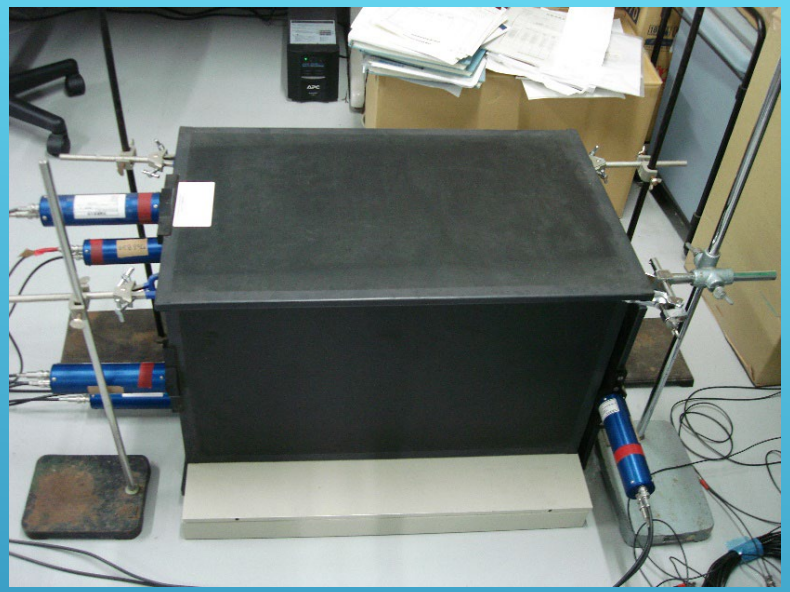




- Measured Compton edge from 1.836MeV gamma of ^{88}Y using ZICOS Liquid scintillator.
- All PMT gains were tuned within 30% by adjustment of High voltage.

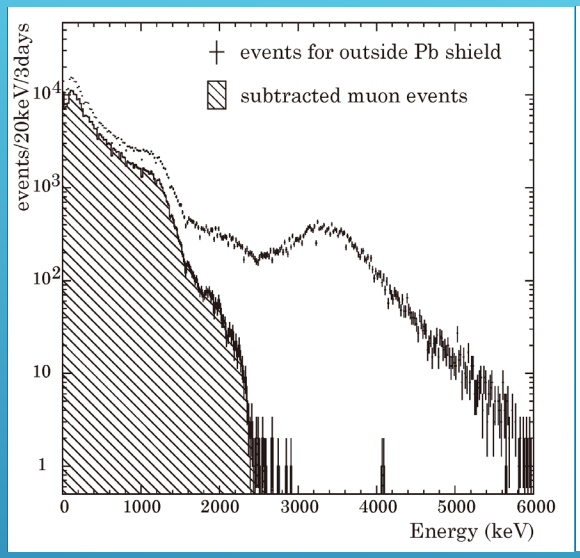
BG measurement using 20mL quartz vial

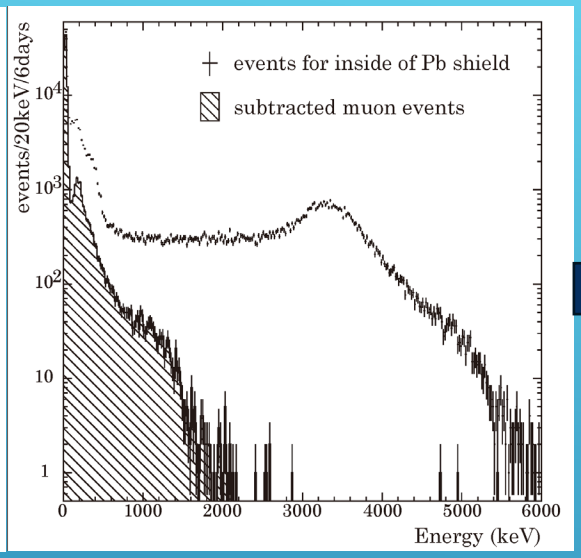


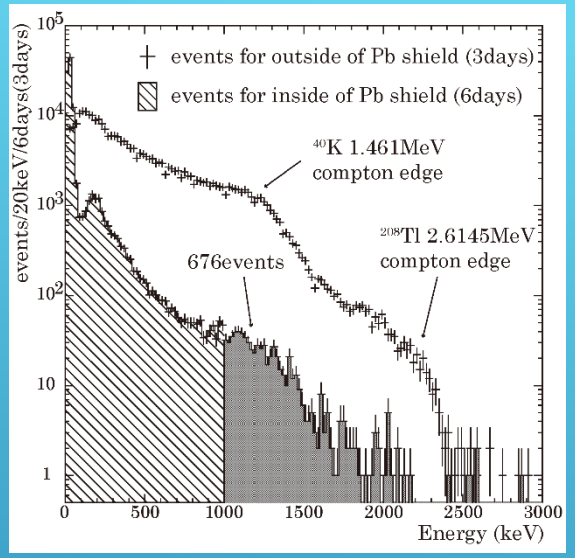


- Difficult to demonstrate 2ν-ZICOS detector inside of Pb shield due to limit of number of Pb block.
- 17.5mL ZICOS LS filled in 20mL quartz vial.
- The vial contacted with PMT covered by Myra film.
- 10cm thickness Pb radiation shield was built.
- In order to veto cosmic muon, plastic scintillators located around Pb shield. (not fully covered yet)

Energy spectra using Quartz vial detector



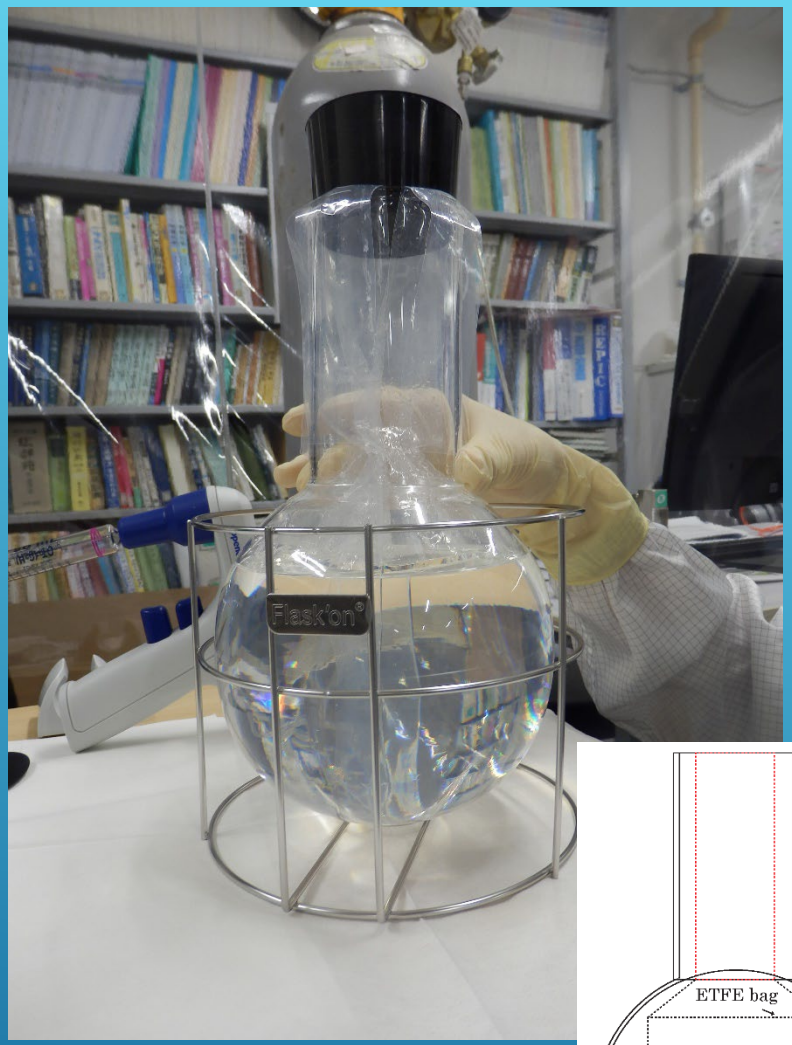




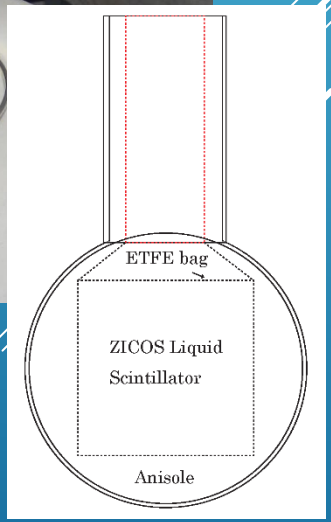
- Compton edges from ^{40}K and ^{208}Tl gamma were observed for outside of Pb shield
- Compton edge from ^{214}Bi 1.765MeV (and ^{208}Tl) gamma was observed for inside of Pb shield.
- U/Th in PMT or around the detector?

XMASS PMT will be used for this measurement.

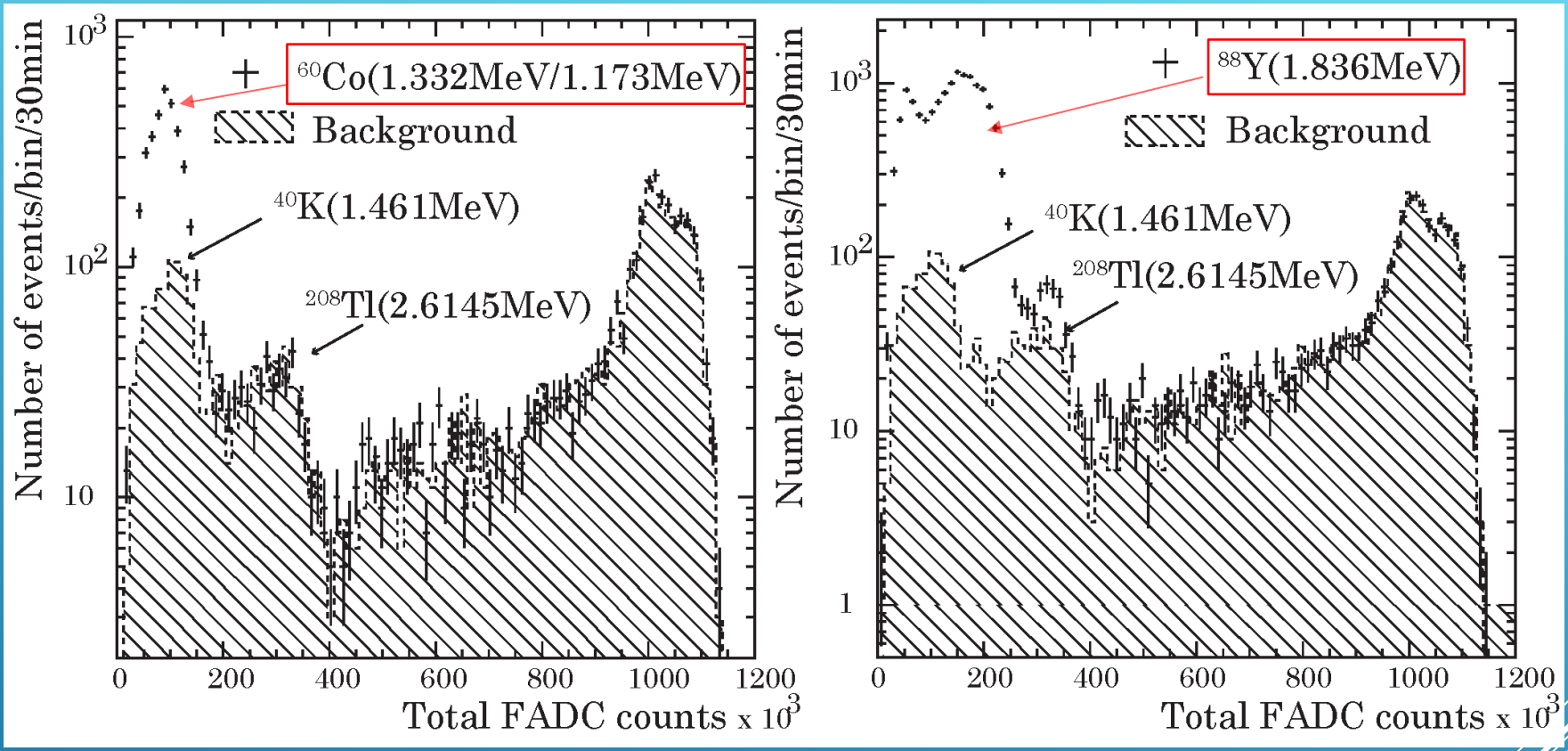
Setup for 2ν-ZICOS detector



- 16 cm diameter round bottom flask using ultra-pure quartz.
- 20 low BG 2” PMT Hamamatsu H3378-50.
- Regular icosahedron for mounting PMT jig.
- 0.73L ZICOS LS loaded 73g of $Zr(iPrac)_4$, which includes 0.3g of ^{96}Zr, inside ETFE bag.



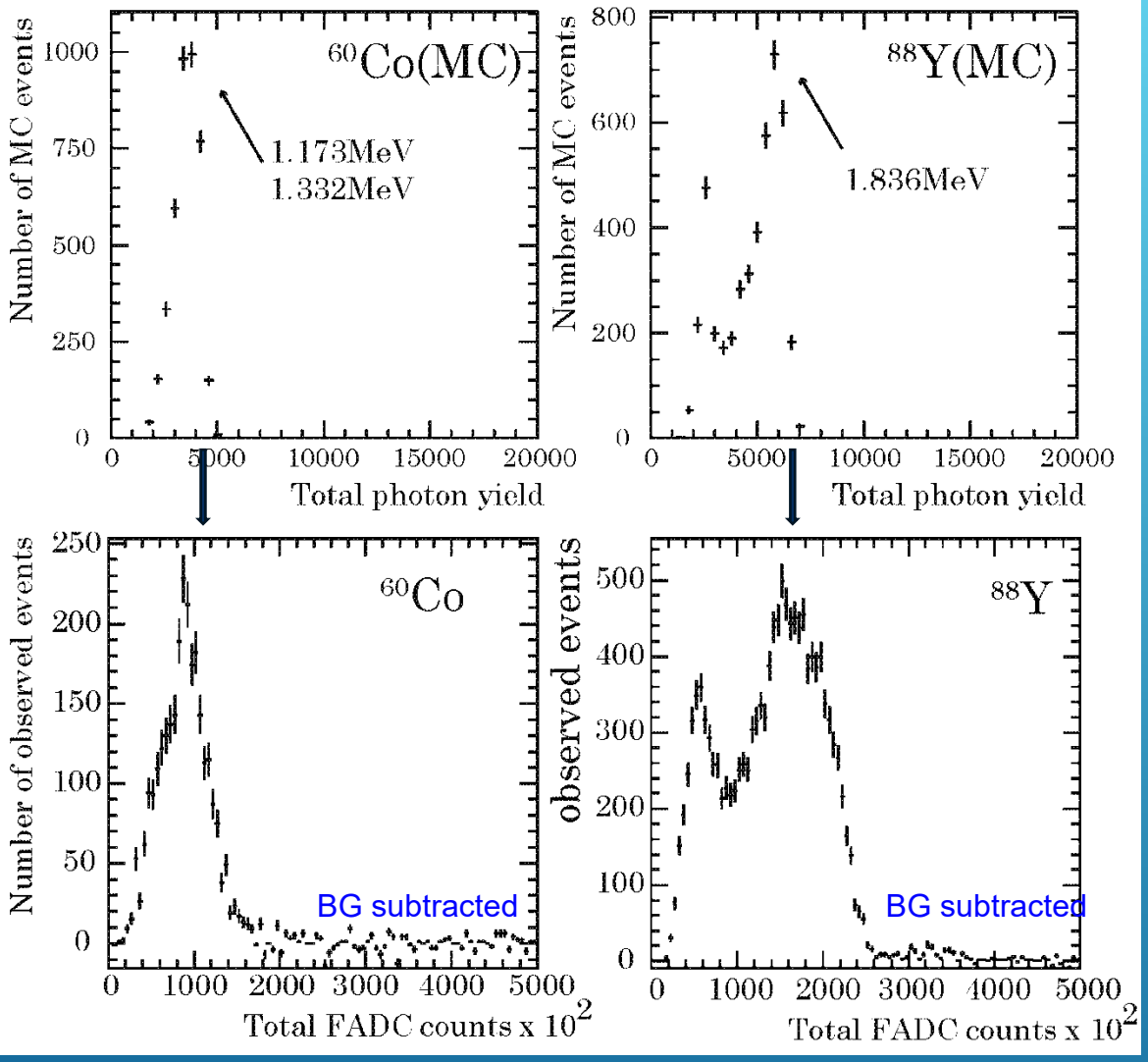
Energy spectra for 2ν-ZICOS detector



- Energy spectra for BG and calibration source
- Compton edges of both BG ^{40}K / ^{208}Tl gamma and calibration source were observed.

Energy scale looks good.

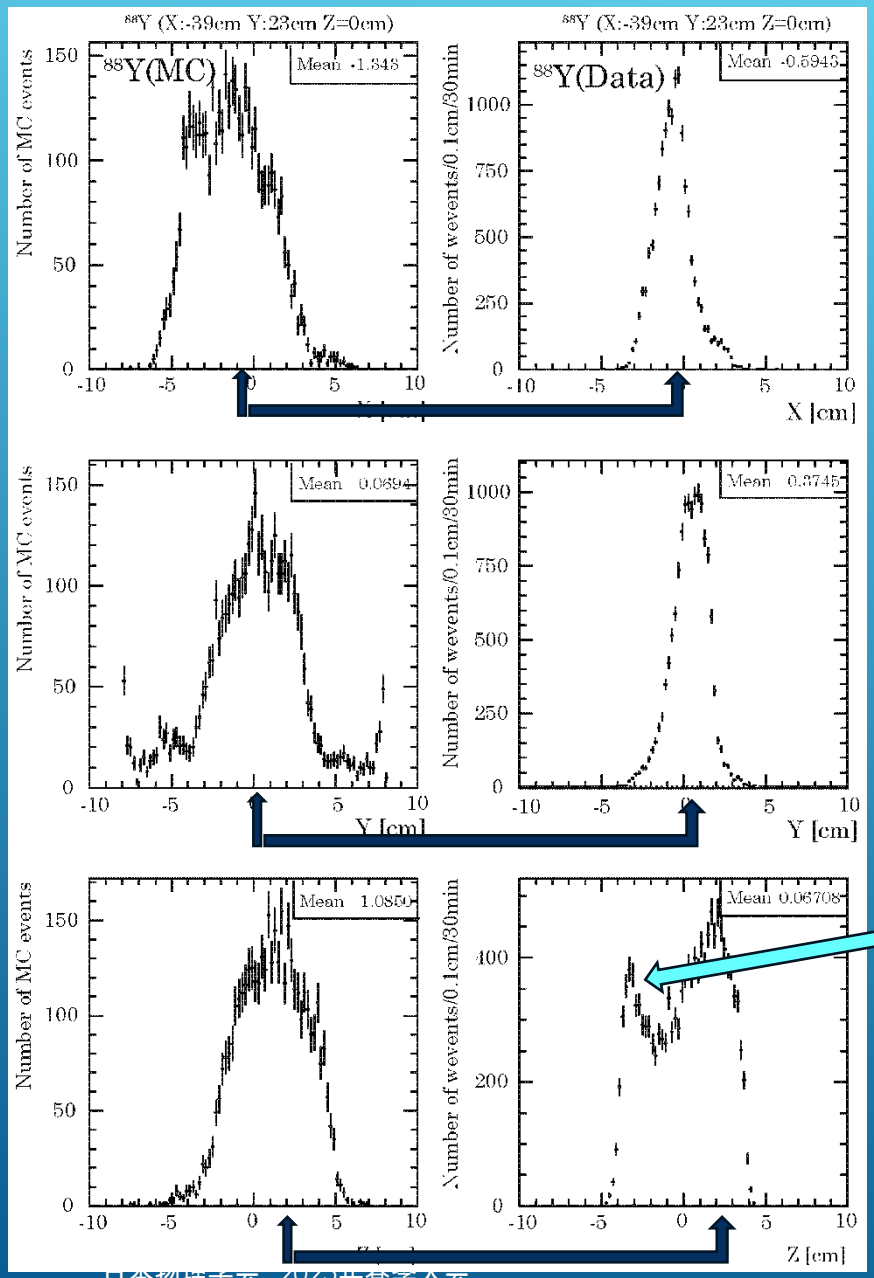
Energy calibration for 2ν-ZICOS detector

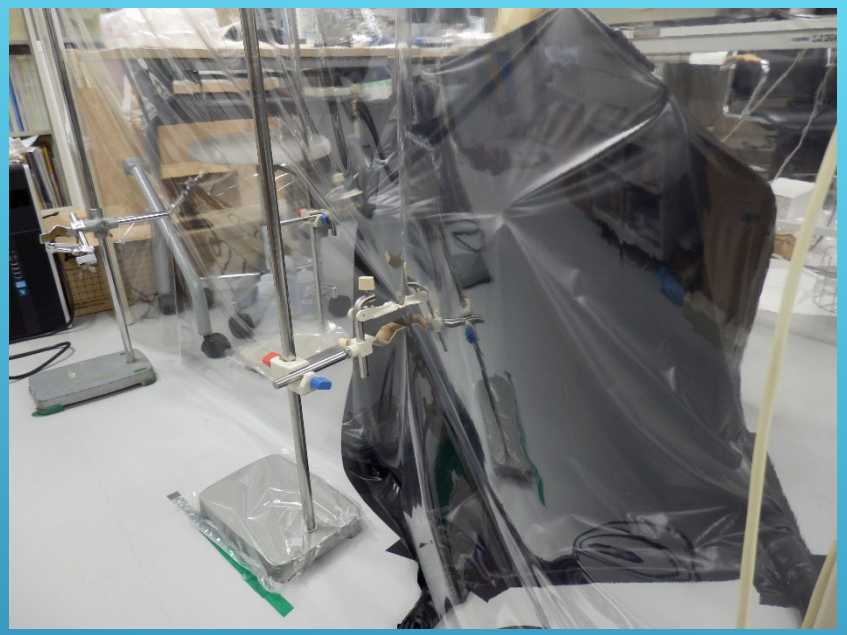


- Found clear Compton edge of gamma sources.
- Trigger simulation was also applied for MC data.
- Energy resolution was worth than simulation which does not consider the fluctuation of light intensity for PMT.

Energy scale seems to be good including BG data.

Vertex reconstruction using calibration data

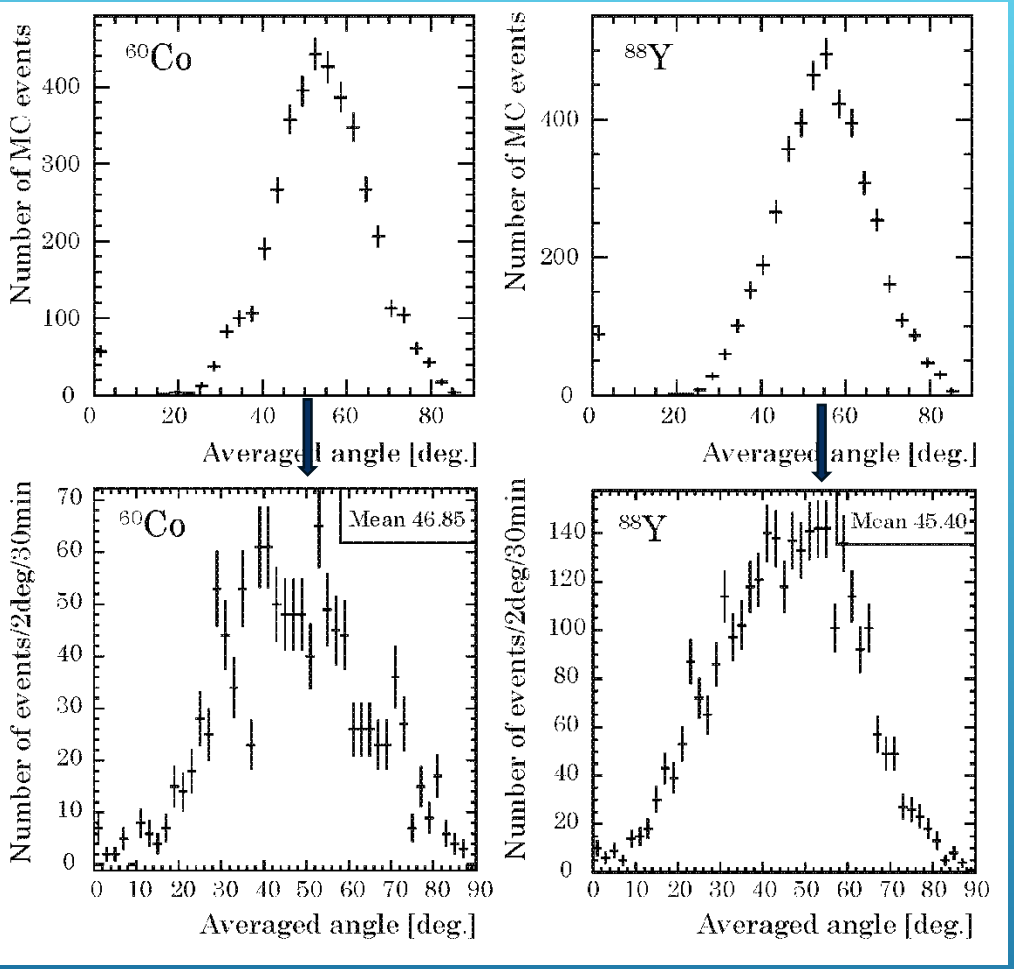


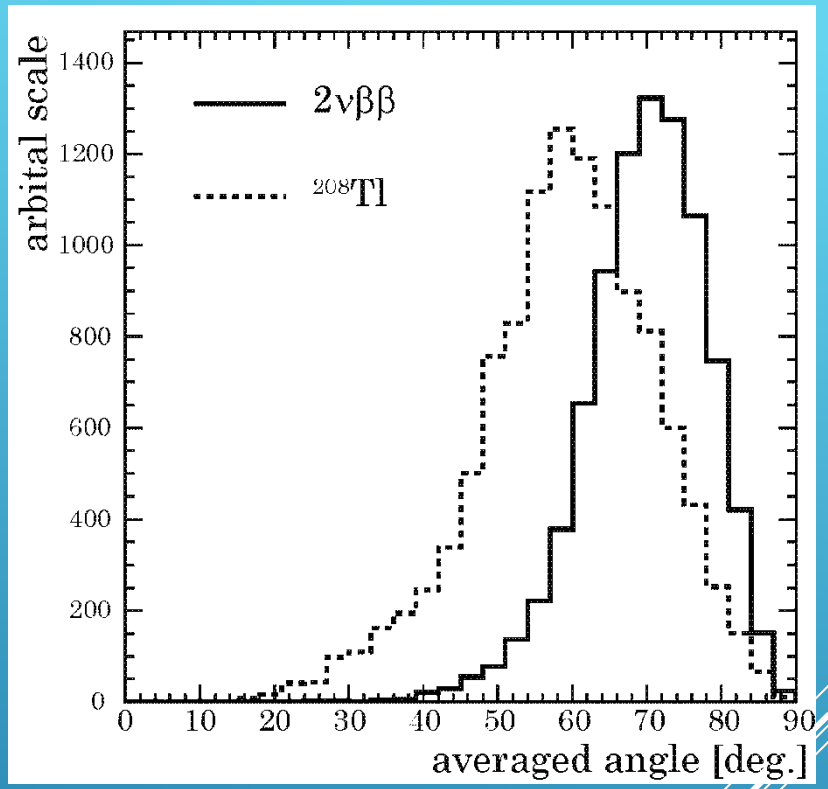


- Simulation vertices roughly reproduce the data.
- Extra cluster was found at Z<-3cm for data.

Need precise tuning or adjustment of PMT gain.

Averaged angle using calibration data

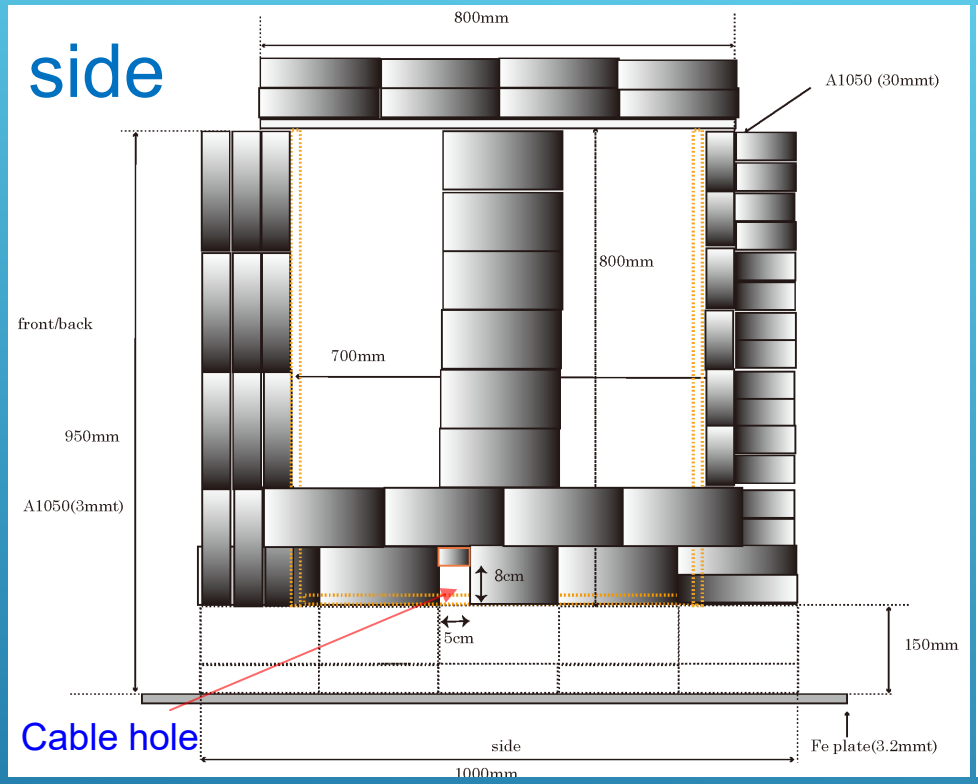


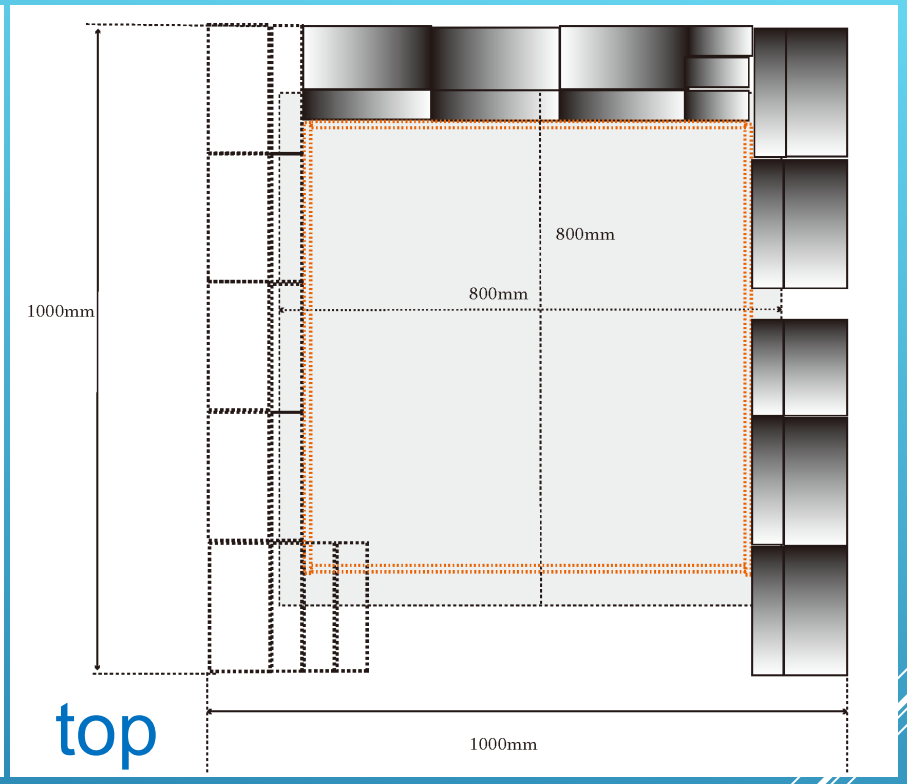


The peak position were seen at 58 and 70 degree for 2νββ and ^{208}Tl β decay, respectively.

Averaged angle of simulation seems to roughly reproduce the calibration data,(Selection of PMT which receives Cherenkov light could be OK) but vertex still does not reproduce well.

Pb shield for 2ν-ZICOS experiment

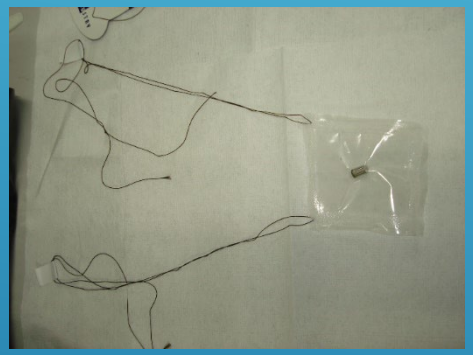




- 15cm thickness of Pb shield will be constructed.
- 3.2mmt Fe base board has been prepared.
- A1050 aluminum box will be used for both structure of Pb shield and N_2 gas filling with fire safety.

Things to do before starting 2ν-ZICOS

- Use XMASS PMT for BG measurement to identify source of remaining background events.
- Verify vertex reconstruction and averaged angle with more tuning or adjustment of PMT gain.

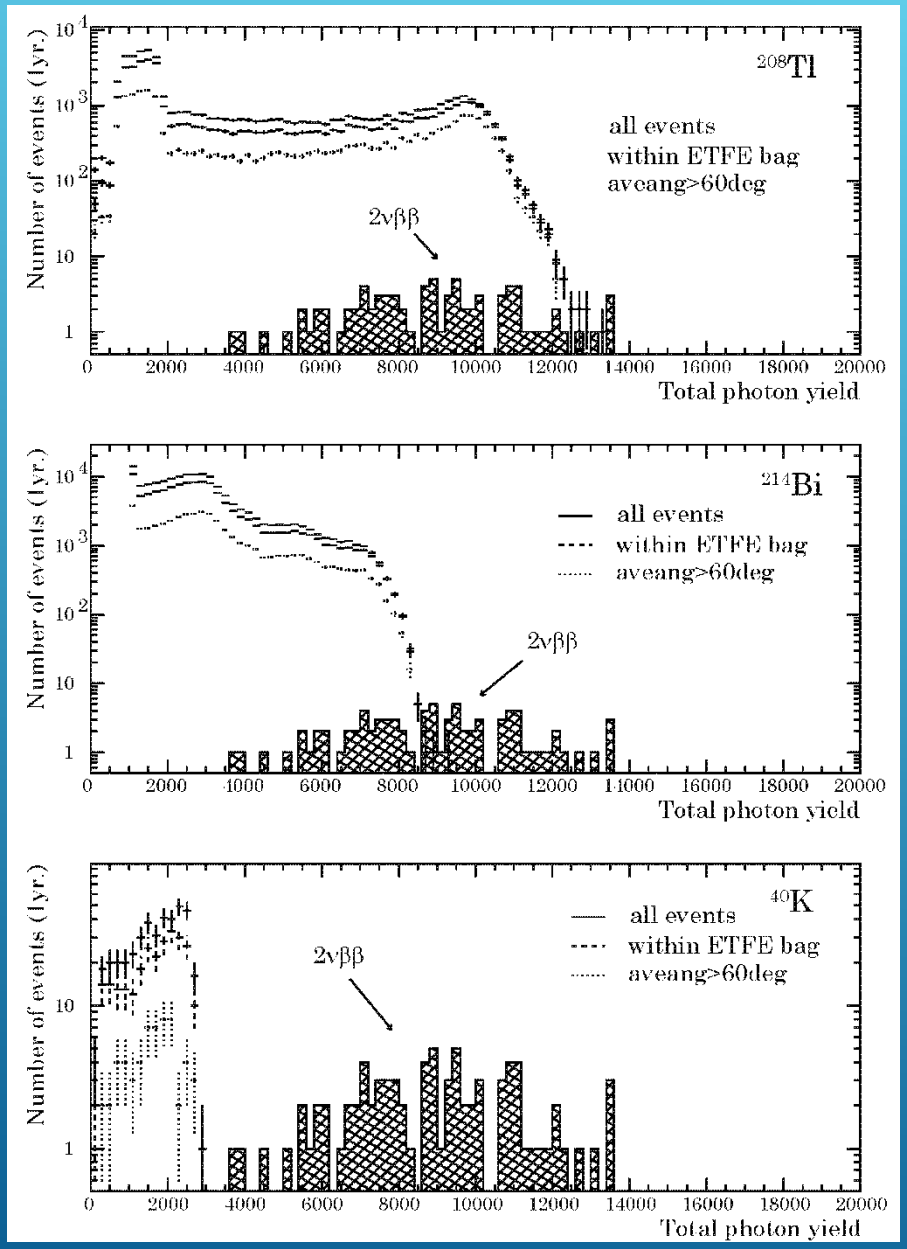


^{137}Cs small source was prepared for this, but under trigger threshold..

- Need permission of Kamioka observatory to start experiment.
- After fixing above items, all equipment will be packed and will be sent to Kamioka at the end of this April.

backup

BG simulation assuming ETFE cubic bag

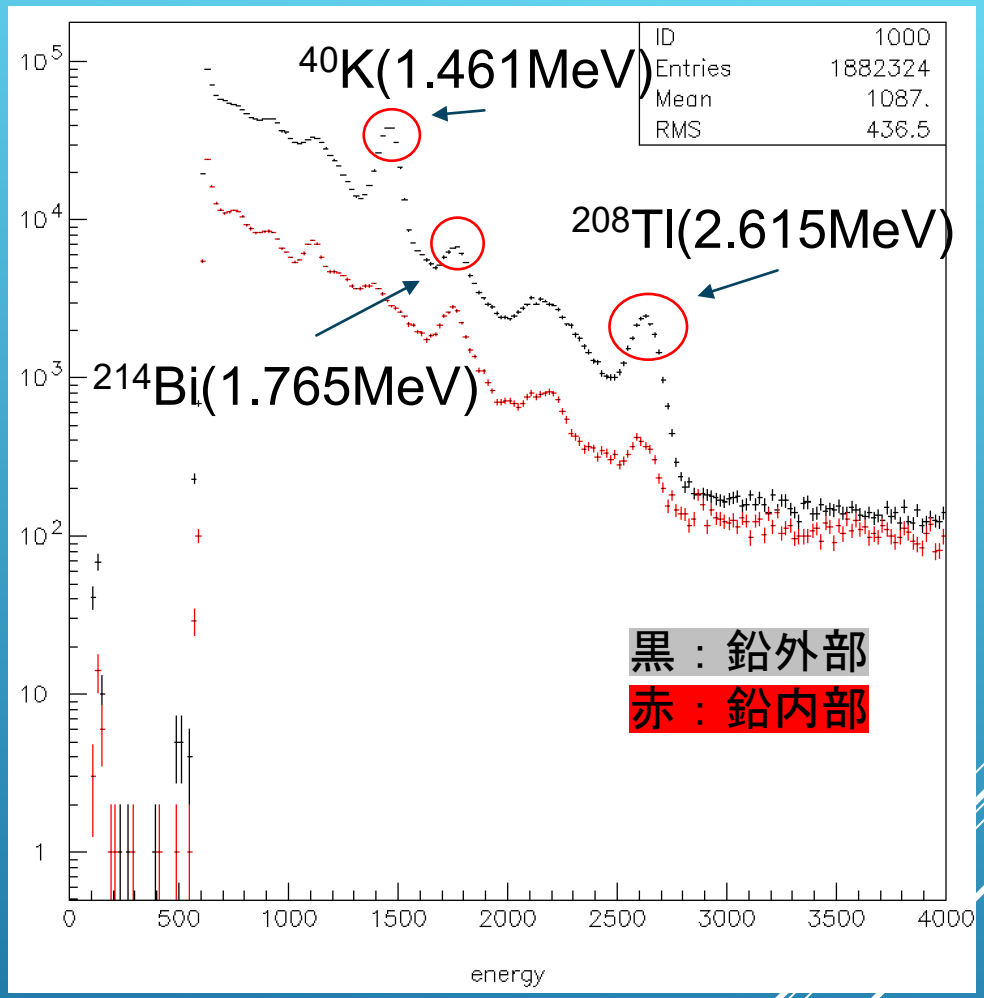


Assuming BGs from flask

- ^{40}K affects only part of 2νββ observation.
- ^{214}Bi is significant BG, but small fraction of 2νββ events should be observed.
- ^{208}Tl is most serious BG for 2νββ. A few events might be observed.

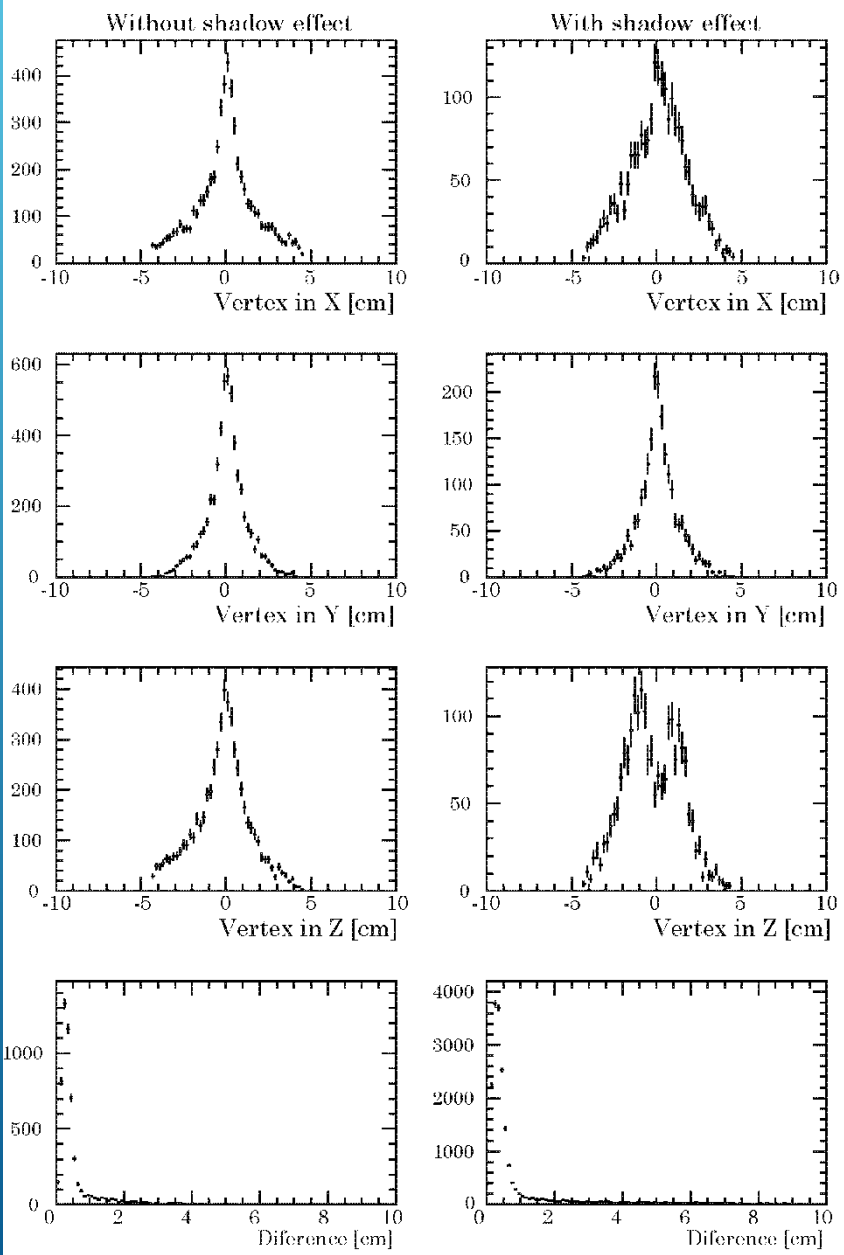
Need 1/100 U/Th contamination in ultra-pure Quartz.

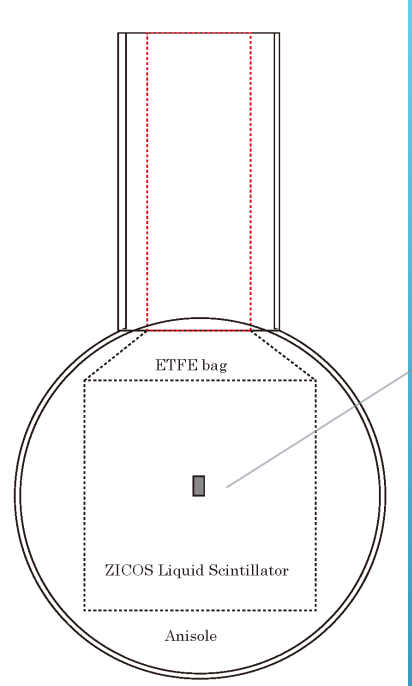
10cm mini Pb shield and CsI detector

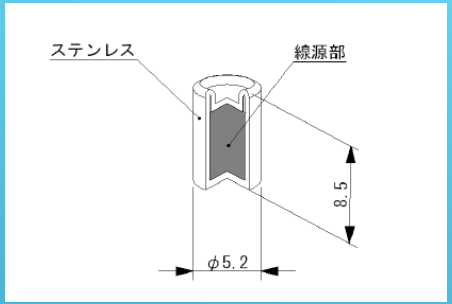


Due to limit of number of Pb block, we will use 15cmm thickness

Calibration of vertex reconstruction







日本アイソトープ協会　標準ガンマ線　516タイプ
100kBq！

Larger pulse signal from ^{137}Cs type 516 source will be used for calibration of vertex reconstruction.