ZICOS - Neutrinoless Double Beta Decay experiment using Zr-96 with an organic liquid scintillator -

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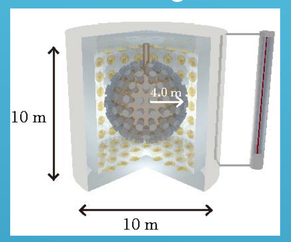
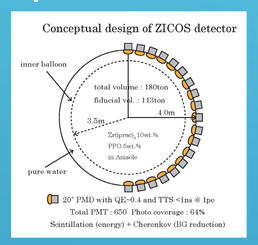
1. ZICOS experiment

◆ Detector design for ZICOS experiment





Detector :
1)180tons LS : 1.5 wt.% Zr and 5wt.% PPO in Anisole .
2)Need 500 of 20" PMT with high QE ~0.4 and TTS ~ 0.3ns@1pe for 64% photo coverage.

Expected performance :
1)Energy resolution ~2.8%@3.35MeV
2)$T_{1/2}(0\nu\beta\beta) > 10^{27}$years if both 1/20 BG reduction and 50% ^{96}Zr enrichment could be achieved.
3)Start experiment ~2027.

◆ Neutrino mass sensitivity for ZICOS experiment

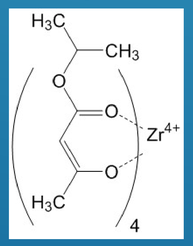
- Q-value of ^{96}Zr : 3.35MeV Abundance : 2.80%
- Total mass : 180ton (fiducial volume : 113ton)
- Measurement time: 2years
- 10wt.% of $Zr(iPrac)_4$ = 12.6ton of $Zr(iPrac)_4$ includes 1.7ton of Zirconium = 45 kg of ^{96}Zr

$T_{1/2}^{0\nu} > 4\times10^{25}$y ← Not enough for 0νββ search

◆ Requirements in order to realize 0νββ GEN-III experiment

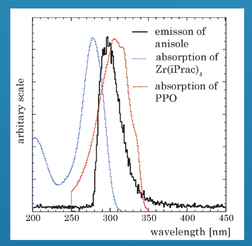
1) 50% enrichment of ^{96}Zr (e.g. 57.3% for NEMO-3) then ^{96}Zr will be 865kg ➡ $T_{1/2}^{0\nu} > 2\times10^{26}$y
2) ^{208}Tl background reduction BG level < 1/20 ×KL-Zen ➡ $T_{1/2}^{0\nu} > 1\times10^{27}$y

◆ Development of Zr loeaded Liquid Scintillator

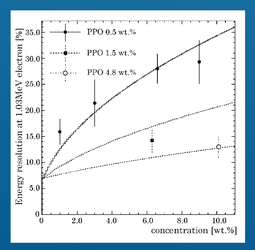


tetrakis (isopropyl acetoacetate) Zirconium : $Zr(iPrac)_4$
MW : 663.87

Zr-LS: $Zr(iPrac)_4$ 10wt.%, PPO 5 wt.% and POPOP 0.2wt% solved in Anisole.



Shorter wavelength of absorption for $Zr(iPrac)_4$ and amount of PPO recover both light yield and energy resolution of Zr-LS .



1) Light yield : 48.7 ±7.1% of BC505
2) energy resolution :
$$\frac{13.0\pm2.0\%}{\sqrt{(64\%/9.2\%)\times(3.35\text{MeV}/1.03\text{MeV})}} = 2.7\pm0.4\% \text{ at } 3.35\text{MeV (6.4\% FWHM)}$$

Need to measure real energy resolution

2. How to reduce backgrounds

◆ Main backgrounds around Q-value

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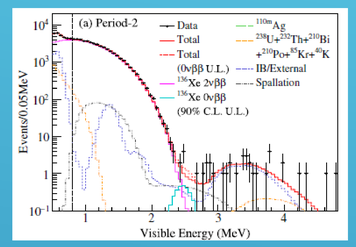
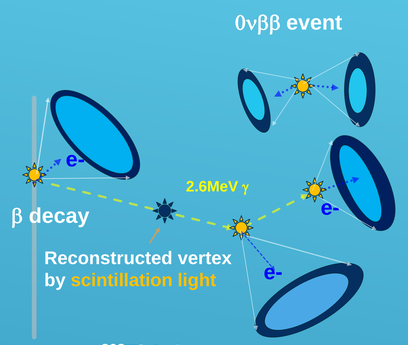
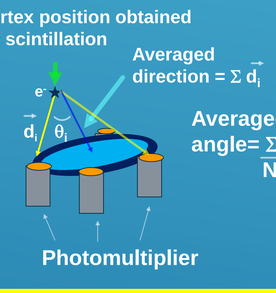


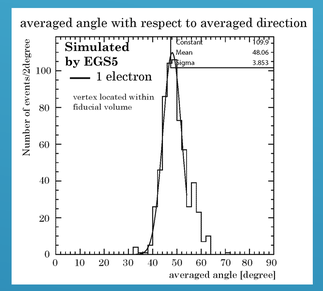
KamLAND-Zen observed ^{208}Tl β-decay background around Q-value of ^{96}Zr.



Topological information from Cherenkov light could be used for ^{208}Tl reduction.

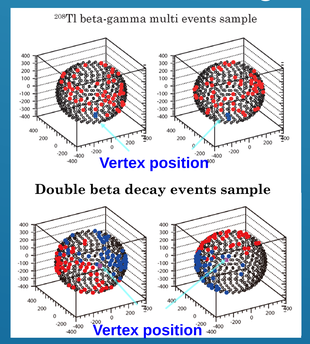
◆ Definition of averaged angle

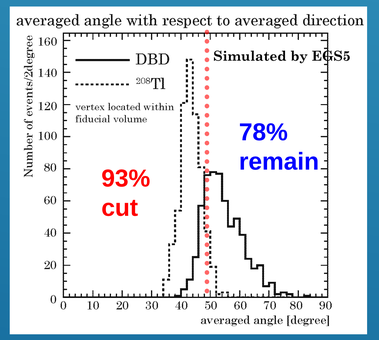




The averaged angle distribution for single electron has a peak at ~48 degree, which is almost same value as Cherenkov angle in Anisole.

◆ Reduction of ^{208}Tl events using Topological information from Cherenkov Lights





The averaged angle distribution of ^{208}Tl beta decay is clearly different from that of DBD events .

Possible to reduce ^{208}Tl BG to be order of 1/20, if we can extract PMT which receives Cherenkov lights among the scintillation signal.

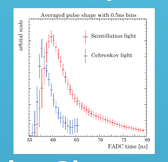
3. How to discriminate Cherenkov lights

◆ Pulse shape discrimination using FADC and PMT

CAEN V1751 Specification
- 4/8 channel
- 10bit ADC
- 2GS/s sampling
- Self/External trigger

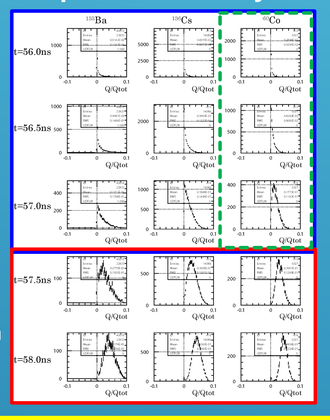
Hamamatsu H2431-50 Specification
- Line focus 8 steps
- HV : 3000V
- Gain :2.5×10^6
- TTS : 0.37ns
- Rise time : 0.7ns

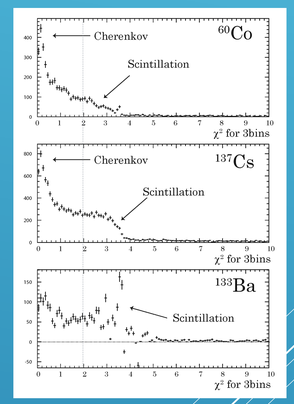
◆ Pulse Shape of Cherenkov lights and scintillation



- Measured by V1751 with DES mode (2GS/s)
- Decay time of scintillation : 4.57ns and 8.38ns
- Rise time of scintillation lights : 1.45ns
- Rise time of Cherenkov light : 0.75ns

◆ Pulse Shape measured by various energy of gammas

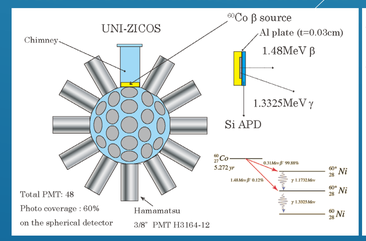


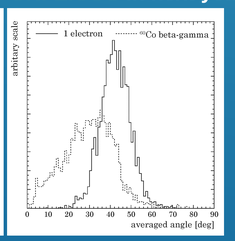


Using χ^2 for first 3bins, possible to discriminate scintillation signal whether including Cherenkov lights or not on PMT by PMT basis.

4. Summary and Future plan

- Conceptual design of ZICOS detector with 10 wt.% $Zr(iPrac)_4$ loaded Liquid Scintillator has 2.7% @3.35MeV energy resolution assuming 64% photo coverage of 20" photomultiplier.
- A technique further 1/20 reduction of ^{208}Tl backgrounds using the topological information of Cherenkov lights was developed.
- Pulse shape discrimination whether including Cherenkov lights or not in scintillation signal was also developed.
- BG reduction will be directly demonstrated by using beta-gamma events from ^{60}Co with dedicated detector UNI-ZICOS in next year.





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