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

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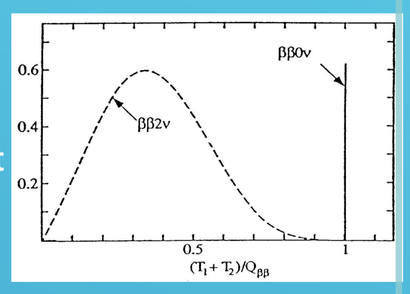
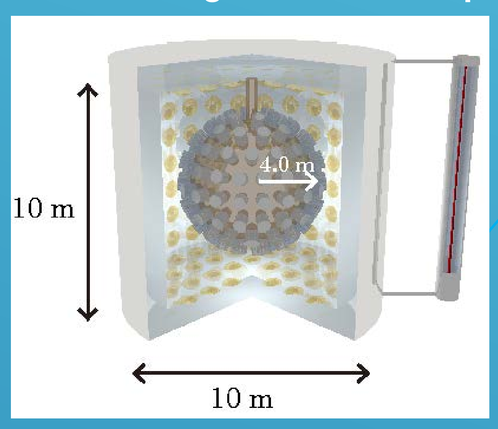
1. ZICOS (^{96}Zr DBD experiment)

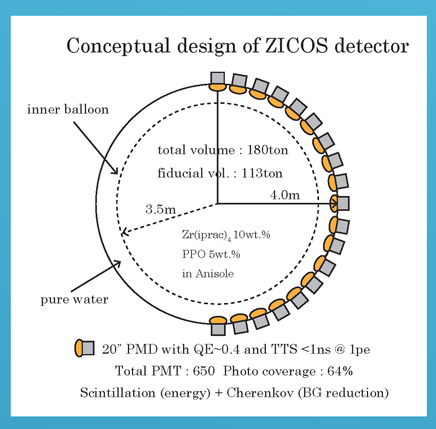
◆ **Neutrinoless double beta decay**
- **Lifetime and neutrino mass**
  $[T_{1/2}^{0\nu}(0^+ \to 0^+)]^{-1} = G_{0\nu}(E_0,Z)|M_{0\nu}|^2\langle m_\nu\rangle^2$
- **Energy spectrum and lifetime measurement**
  - monochromatic energy at Q-value
  - $T_{1/2} \sim a(Mt/\Delta EB)$ a: abundance M: mass t: meas.time ΔE: energy res. B: BG rate



Low background rate, Large target mass and High energy resolution

◆ **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 ~300ps@1pe for 64% photo coverage.

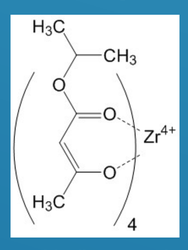
Expected performance :
1)Energy resolution ~2.8%@3.35MeV
2)$T_{1/2}(0\nu\beta\beta) > 10^{27}$years if both 1/20 BG reduction and 50% ^{96}Zr enrichment could be achieved.
3)Start experiment ~2027.

◆ **Neutrino mass sensitivity for ZICOS experiment**
- 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 (using natural abundance 2.6%)

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

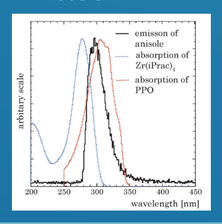
◆ **Requirements in order to realize 0νββ GEN-III experiment**
1) 50% enrichment of ^{96}Zr (e.g. 57.3% for NEMO-3)
then ^{96}Zr will be 865kg → $T_{1/2}^{0\nu} > 2\times10^{26}$y
2) ^{208}Tl background reduction
BG level < 1/20 × KL-Zen → $T_{1/2}^{0\nu} > 1\times10^{27}$y

◆ **Development of Zr loeaded Liquid Scintillator**

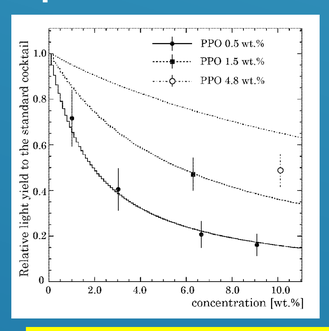


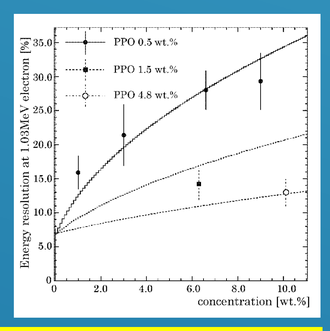
tetrakis (isopropyl acetoacetate) Zirconium : $Zr(iPrac)_4$
MW : 663.87

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 .



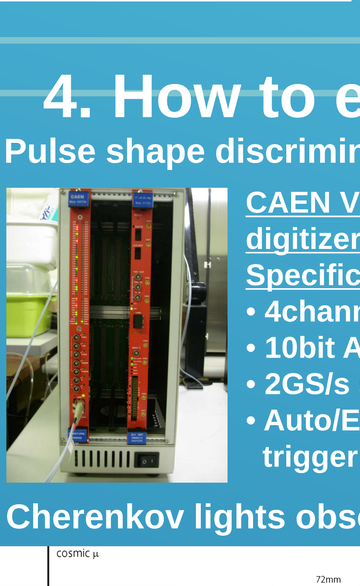


1) Light yield : 48.7 ±7.1% of BC505
2) energy resolution :
$$\frac{13.0\pm2.0\%}{\sqrt{(64\%/9.2\%)}\times(3.35\text{MeV}/1.03\text{MeV})} = 2.7\pm0.4\% \text{ at } 3.35\text{MeV} \quad (6.4\%\text{ FWHM})$$
Need to measure real energy resolution

3. Development of reduction technique

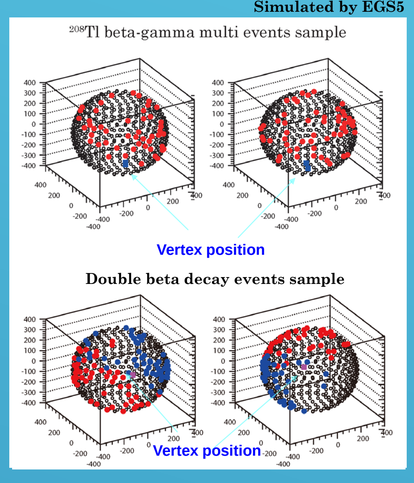
◆ **Reduction of ^{208}Tl events using Topological information from Cherenkov Lights**

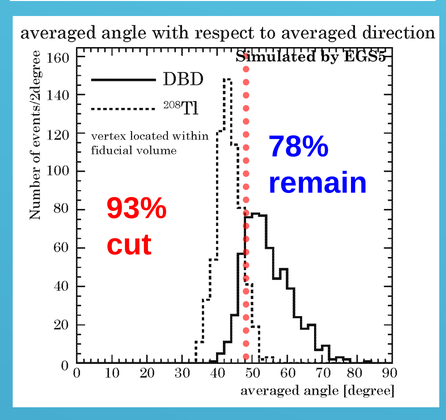
Vertex position obtained by scintillation



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

Simulated by EGS5





The averaged angle of ^{208}Tl decay is smaller than that of DBD.

Possible to reduce ^{208}Tl BG to be order of 1/20, if we can extract Cherenkov lights from scintillation.

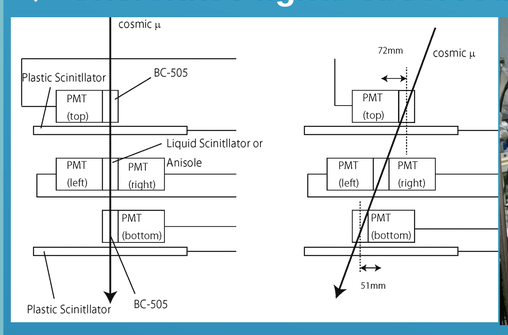
4. How to extract Cherenkov lights

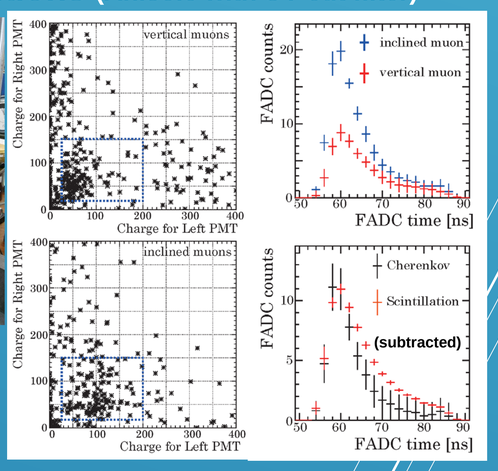
◆ **Pulse shape discrimination using fast FADC and fast PMT**

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

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

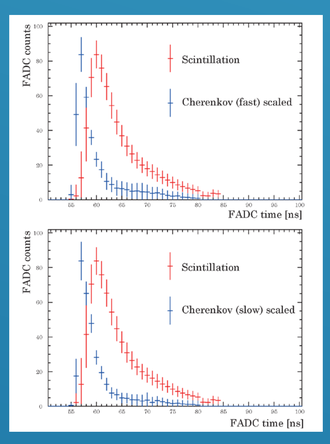
◆ **Cherenkov lights observed by cosmic muons** (Anisole with UV cut filter)





Fall time of Cherenkov lights is quite different from that of scintillation lights. (cf. PMTs were not H2431-50)

◆ **Cherenkov lights observed by electrons from ^{90}Sr/^{90}Y source using PMT H2431-50**

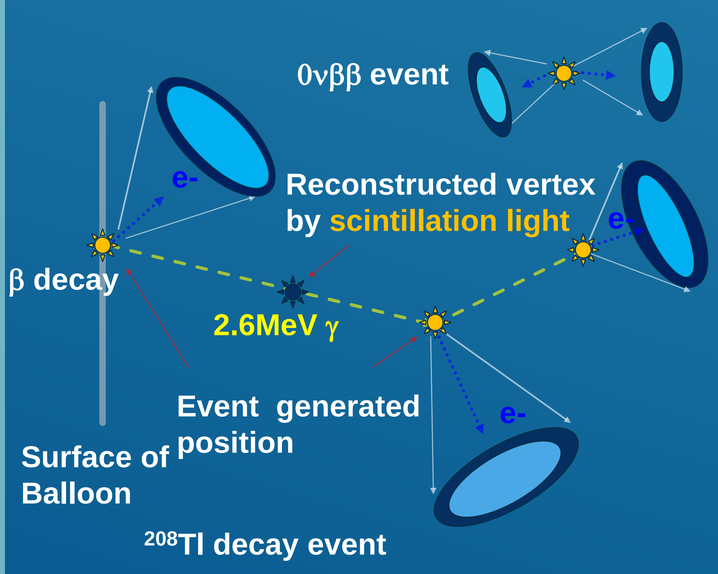


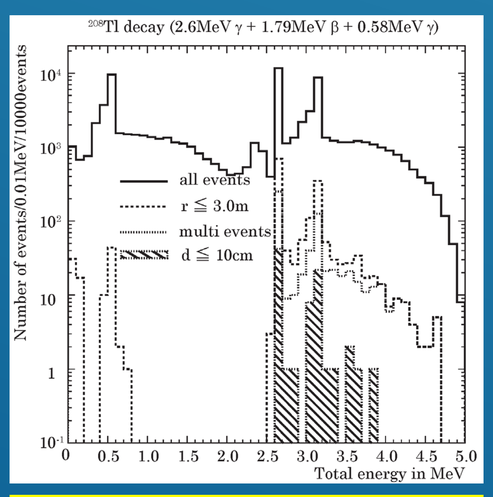
There is clear difference for both rise and fall time between Cherenkov and Scintillation light even though 1GS/s sampling.

Pulse shape discrimination will make the identification of PMT which receives Cherenkov lights real using 2GS/s sampling. (This will be checked within this year)

2. How to reduce backgrounds

◆ **Conceptional idea using Cherenkov lights**





~1/20 BG reduction could be achieved by using a topology information of Cherenkov light.

Cherenkov light could be used for tool of ^{208}Tl BG reduction.

5. Present status 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" Photo-multiplier.
- A technique further 1/20 reduction of ^{208}Tl backgrounds using PMT hit pattern of Cherenkov lights was developed.
- Direct measurement of pulse shape of Cherenkov and Scintillation light using electrons from ^{90}Sr/^{90}Y beta source was done, and both rise and fall time were quite different from each others.
- Pulse shape discrimination could be used for the identification of PMT which receives Cherenkov lights.
- Averaged angle distribution will be measured by the dedicated detector HUNI-ZOCOS in the next year.