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XX
～ニュートリノの放出を伴う二重ベータ崩壊事象観測実験の準備状況～

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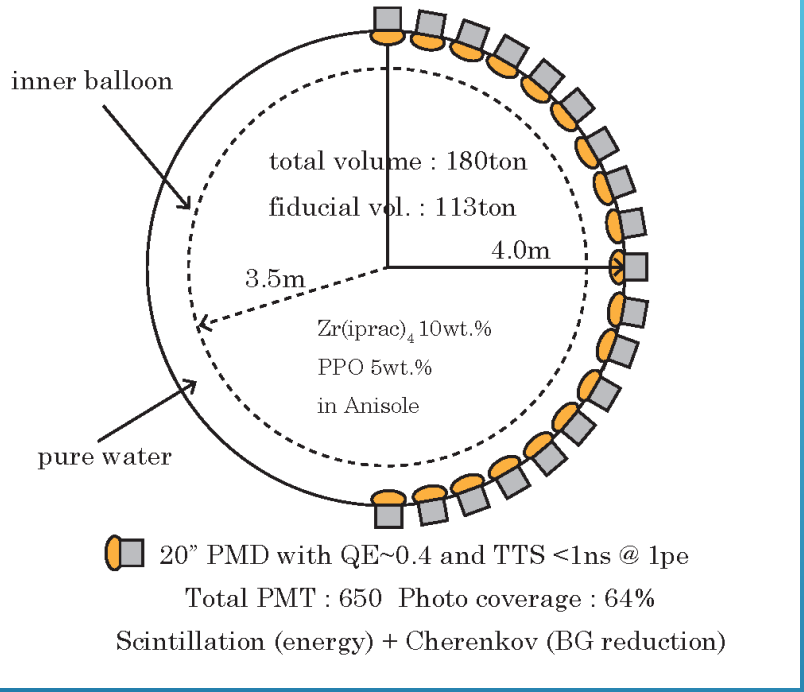
Conceptual design of ZICOS detector



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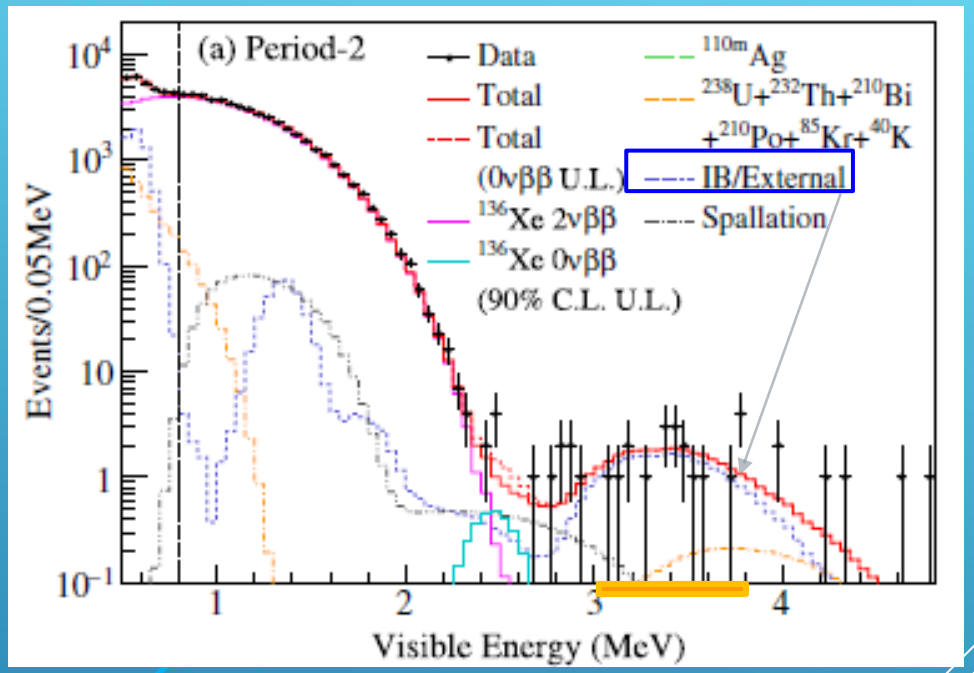
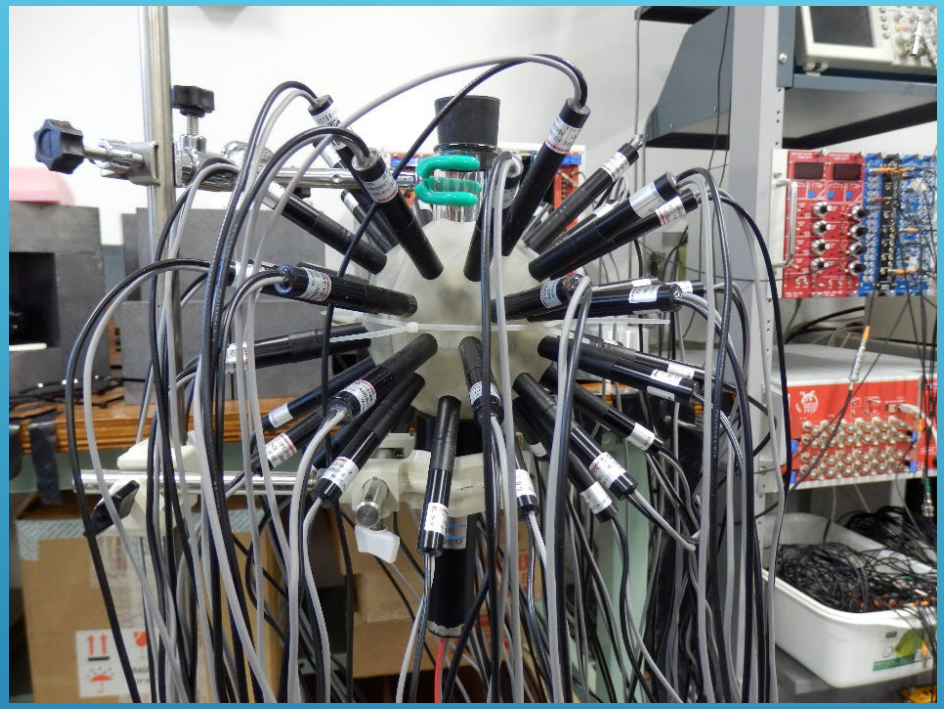


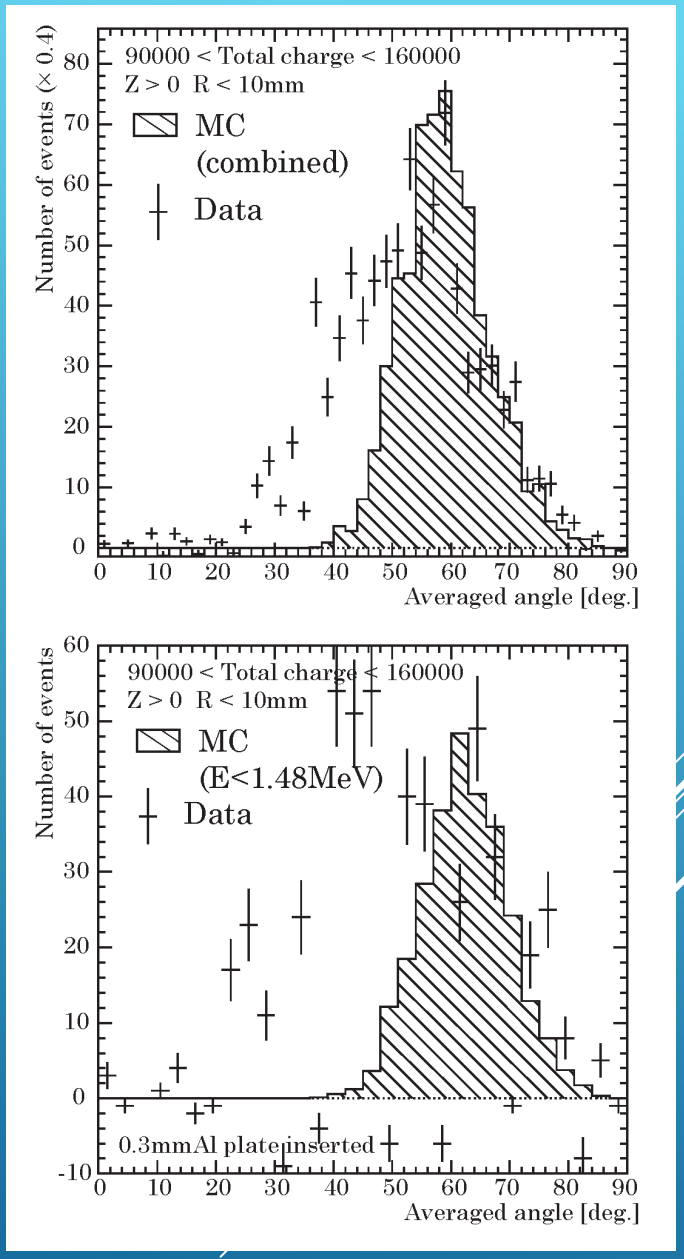
NEMO3 : $T_{1/2}^{0\nu} > 9.1 \times 10^{21}$ yrs

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

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

Measurement of averaged angle with UNI-ZICOS

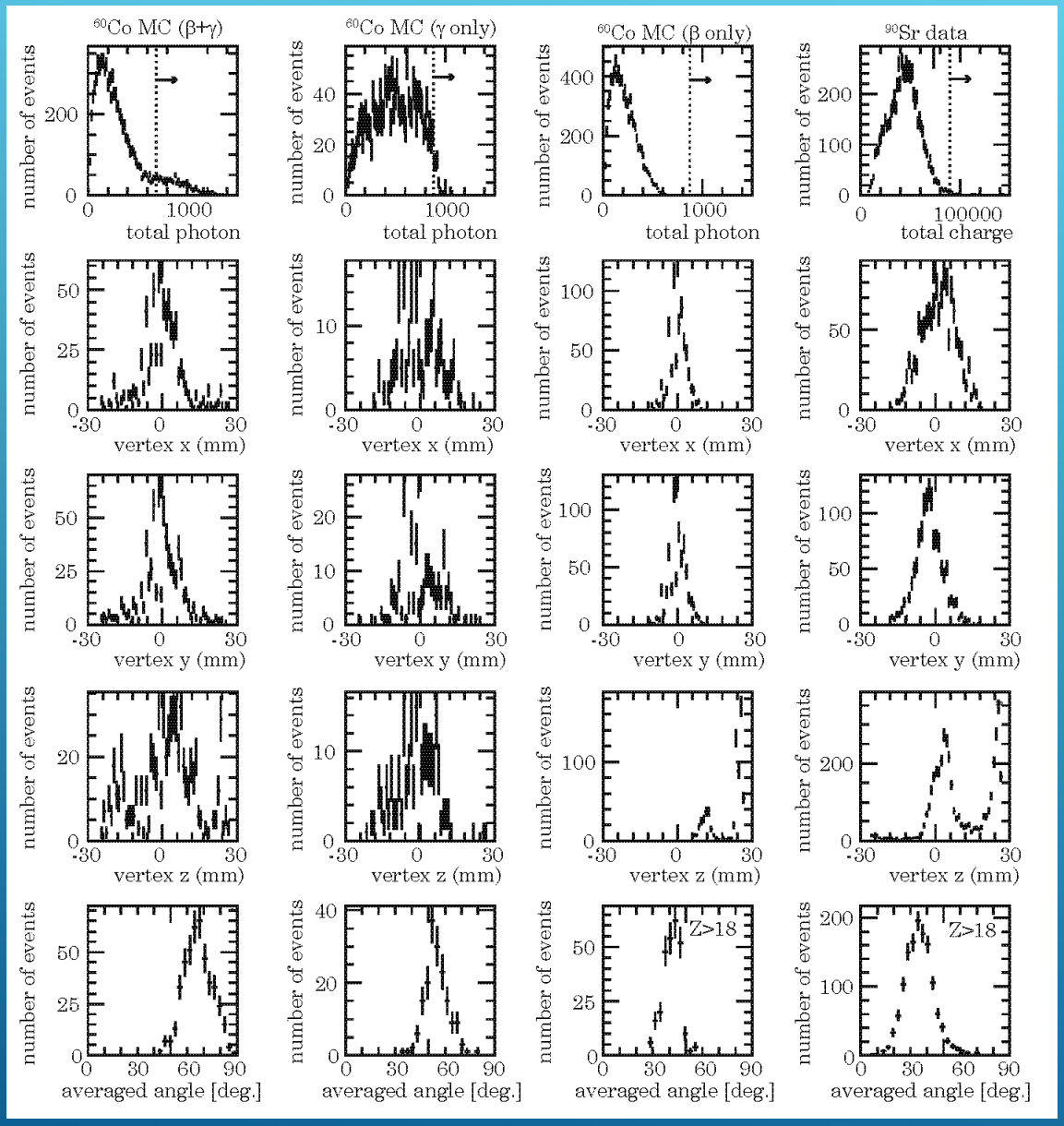




MC(β + γ) does not reproduce the small bump around 40 degree.

They might be caused by beta only events which don't have enough light yield as indicated by MC. (at last JPS)

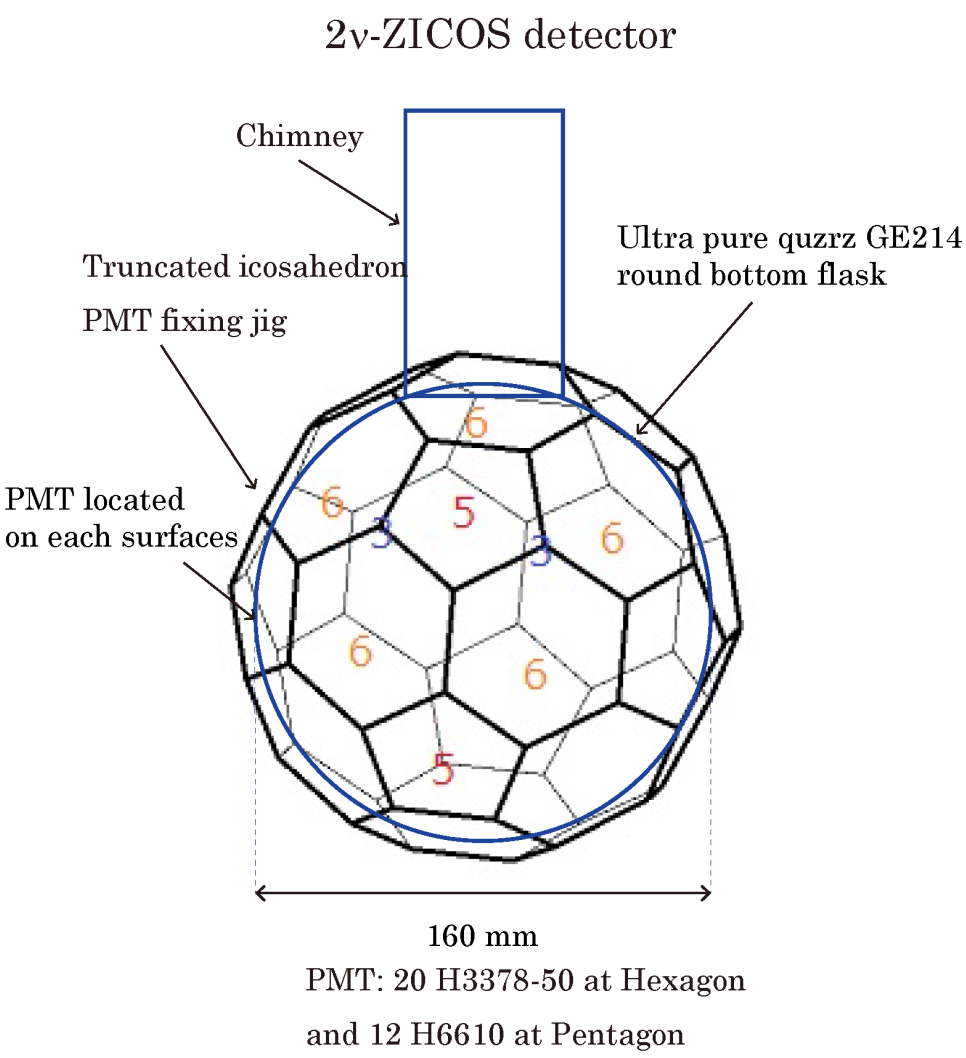
Simulations and data for beta



- Beta MC indicated poor light yield to detect beta only events.
- ^{90}Sr real data confirmed poor light yield even though higher energy than ^{60}Co.

Still there is no clear source to explain around 40deg event.

Observation of 2νββ events using 2ν-ZICOS



- 16 cm diameter round bottom flask using Ultra-pure quartz.
- 20 low BG 2” PMT Hamamatsu H3378-50 and 12 low BG 1” PMT H6610.
- Filled 2.2L of ZICOS liquid scintillator loaded 220g of $Zr(iPrac)_4$ which contains 0.85 g of ^{96}Zr nuclei.
- Expected number of events is 200 per year.

Measurement of U/Th/K contamination

Goal : U/Th ~1ng/g

東芝ナノアナリシ
材料分
JOB No.G8

【速報】石英ガラス中のU　Th量測定

[試料]
石英ガラス
・RQ200
・GE214

計2試料

[方法]
酸分解－ICP質量分析法（パーキンエルマー社製 NexION350S）

[結果]
下表に分析結果を示します。

表　分析結果

単位：ng/g

試料名	K	Th	U
RQ200	330	42	64
GE214	180	15	29
定量下限	5	1	1

東芝ナノアナリシス株式会社
材料分析技術ラボ
JOB No.G800G11203

【速報】テトラキス（アセト酢酸イソプロピル）ジルコニウムと四塩化ジルコニウム中のU/Th量測定

[試料]
・テトラキス（アセト酢酸イソプロピル）ジルコニウム
・四塩化ジルコニウム

計2試料

[方法]
試料調製－ICP質量分析法（パーキンエルマー社製 NexION350S）

[結果]
下表1,2に分析結果を示します。

表1　分析結果

単位：ng/g

試料名	K	Th	U
テトラキス（アセト酢酸イソプロピル）ジルコニウム	-	-	-
定量下限	400	50	50

※表中の「－」表記は、定量下限以下であることを示します。

表2　分析結果

単位：ng/g

試料名	K	Th	U
四塩化ジルコニウム	-	-	-
定量下限	200	50	50

※表中の「－」表記は、定量下限以下であることを示します。

Background estimation

ICP Mass spectrometry analysis results:

^{232}Th : 15ng/g corresponds to 6.09×10^{-5}Bq/g

^{238}U : 29ng/g corresponds to 3.58×10^{-4}Bq/g

^{40}K : 0.021ng/g corresponds to 5.59×10^{-6}Bq/g

Assuming radiation (perpetual) equilibrium :

$\lambda_A N_A = \lambda_B N_B$ (Decay rate should be same)

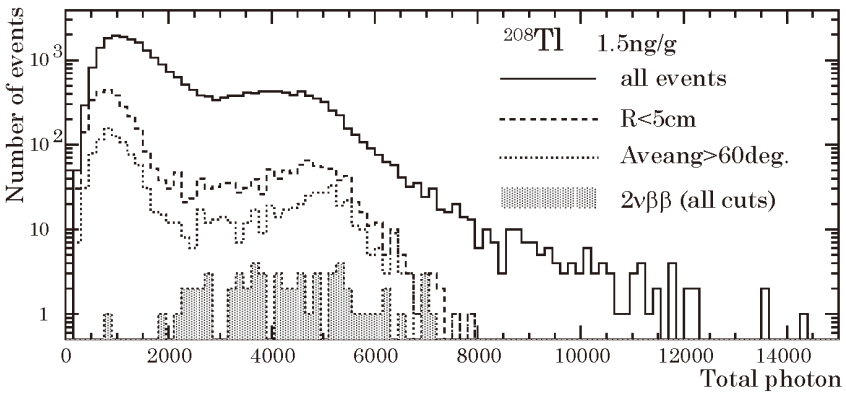
If the detector flask use 530g of GE214,

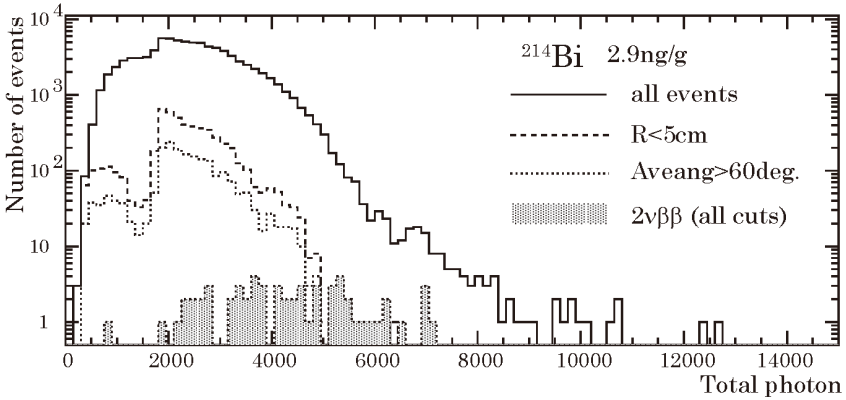
^{208}Tl : 1017908 events per year

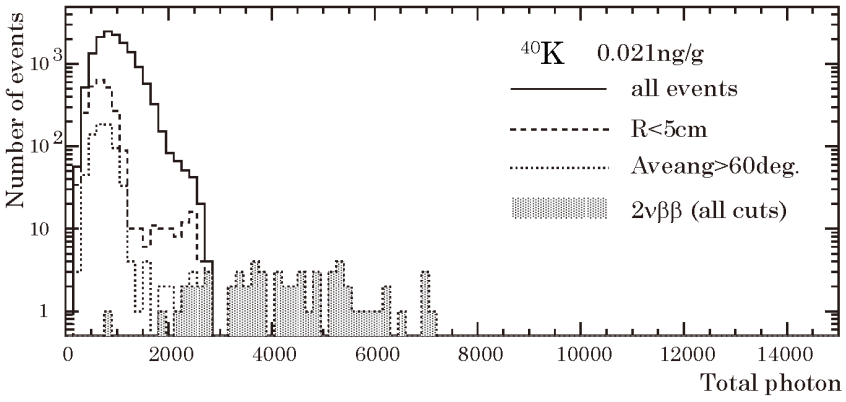
^{214}Bi : 5988404 events per year will occur.

^{40}K : 93556 events per year

Monte Carlo simulation







- Decay of ^{40}K does not affect 2νββ observation.
- Decay of ^{214}Bi has significant BGs for 2νββ even if 1/10 level.
- Decay of ^{208}Tl has most serious BGs for 2νββ even if 1/10 level.

Need 1ng/g for U/Th cont. for quartz and improve the vertex reconstruction method (or larger flask)

Present status

- Small lot synthesis of $Zr(iPrac)_4$ was succeeded by NARD. Over 200g has been ordered and it will be delivered at the end of April.
- Clean booth (class 1000) was constructed for preparation of Liquid Scintillator and detector.
- 8 PMTs of Hamamatsu H3378-50 will be delivered at the end of this month.
- Test round bottom flask using GE214 has been ordered and it will be delivered at the end of this month. But need more clean quartz and larger flask.
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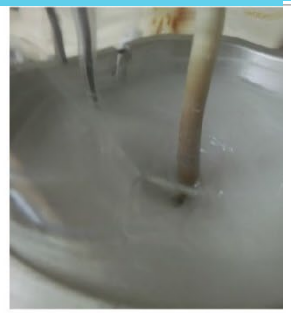
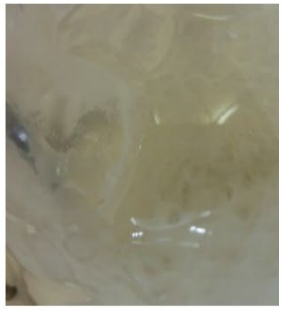
- Centrifuge for ^{96}Zr enrichment has been discussed by JNFL and 50% enrichment is not impossible.

$ZrCl_4$分散後

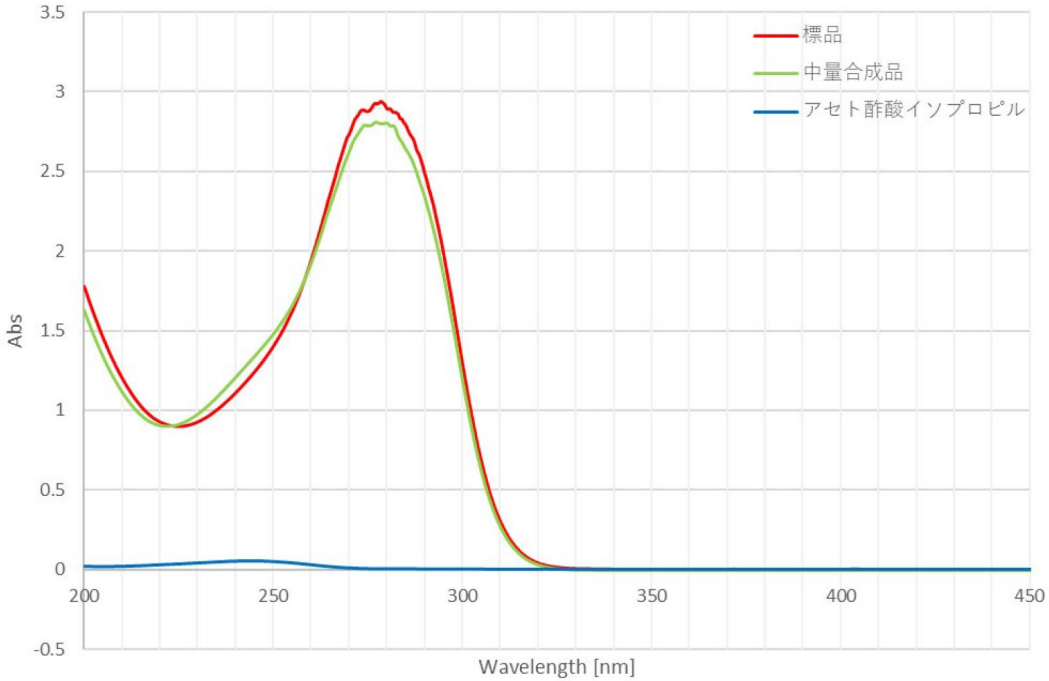


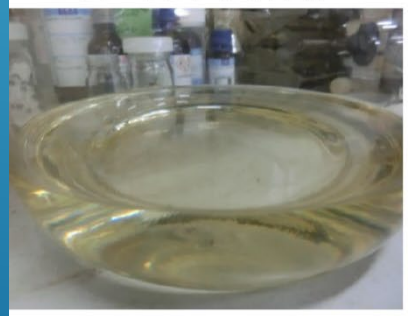
アセト酢酸イソプロピル

トリエチルアミン滴下後

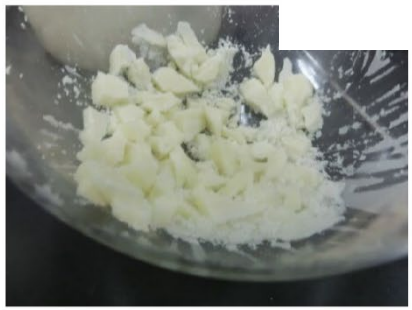


反応終了時

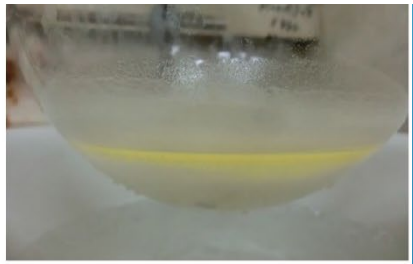




ろ過後ろ液



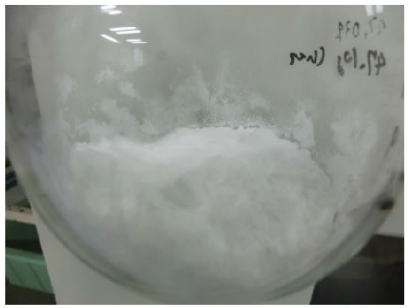
ろ液濃縮後



再結晶の様子

再結晶ろ液

再結晶ろ物



ろ物乾燥後

Synthesis of $Zr(iPrac)_4$ was succeeded.

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- Vertex reconstruction method should be improved.
- Centrifuge for ^{96}Zr enrichment has been discussed by JNFL and 50% enrichment is not impossible.

Clean booth

- Glove box with N_2 gas circulation has been installed.
- Electrical balance was also installed in glove box.
- 8 Hamamatsu H3378-50, round bottom flask, and chemical storage for $Zr(iPrac)_4$ will be installed.

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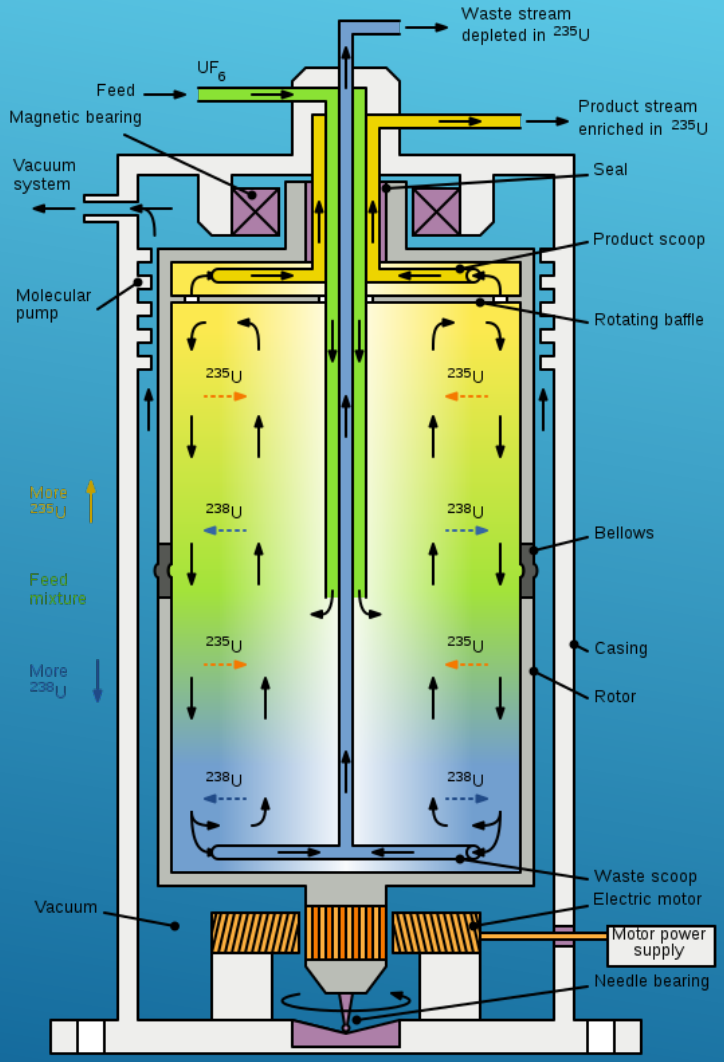
Centrifuge plant of JNFL at Rokkasho-village

https://www.jnfl.co.jp/ja/business/about/uran/summary/development-center.html

^{96}Zr enrichment by Gas Centrifuge

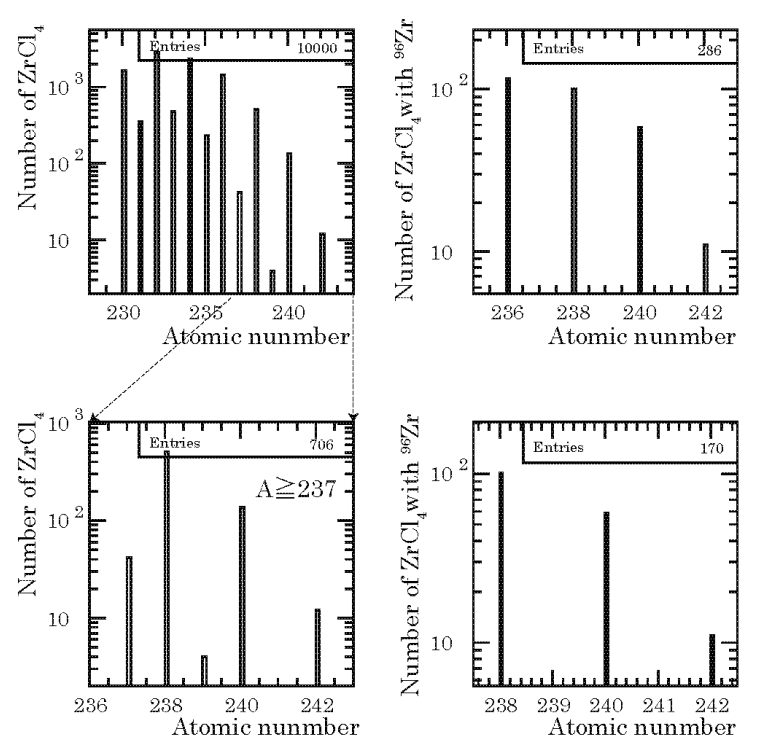


Meeting with JNFL staffs of technical development center for Uranium enrichment on 18th Nov.

They are looking for new idea for isotope separation using their Centrifuge plant.

Proposed ^{96}Zr enrichment using $ZrCl_4$ (bp 331 ℃) : 24-50% enrichment maybe possible by gas centrifuge.

^{96}Zr enrichment by Gas Centrifuge



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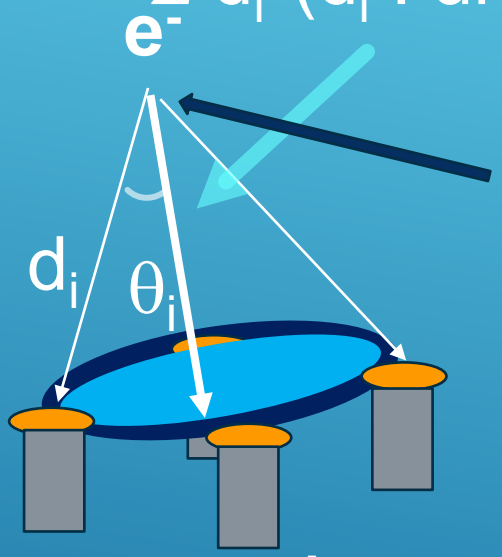
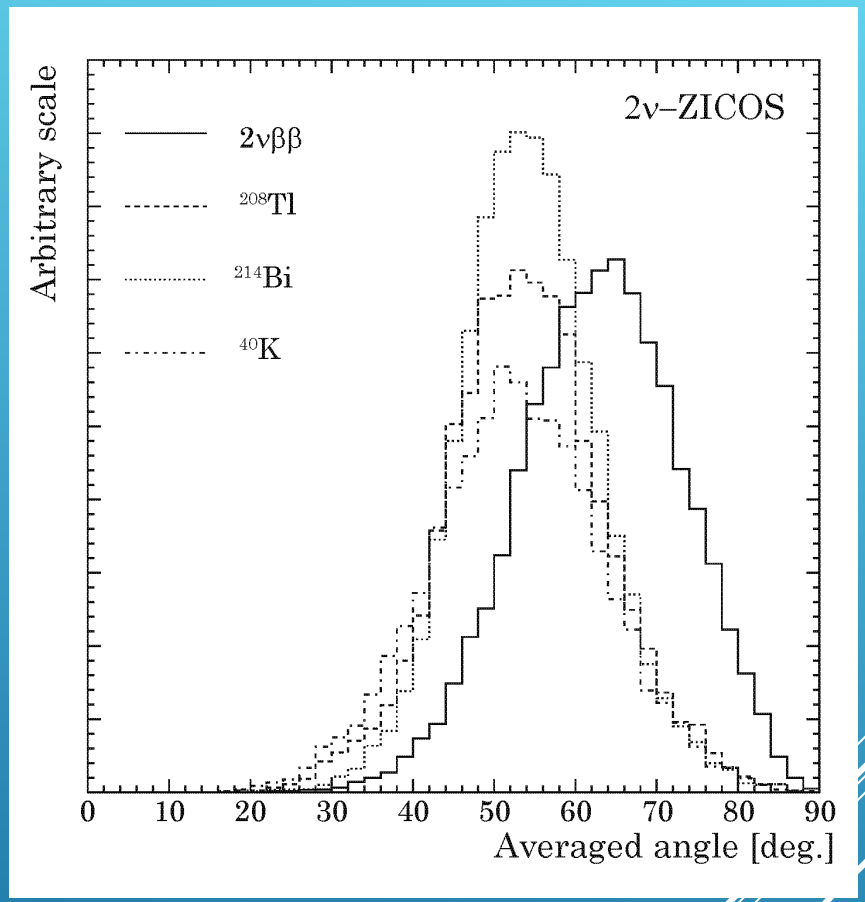
backup

Topological information of Cherenkov lights

Average direction =
$\Sigma\, d_i$ (d_i : unit vector)

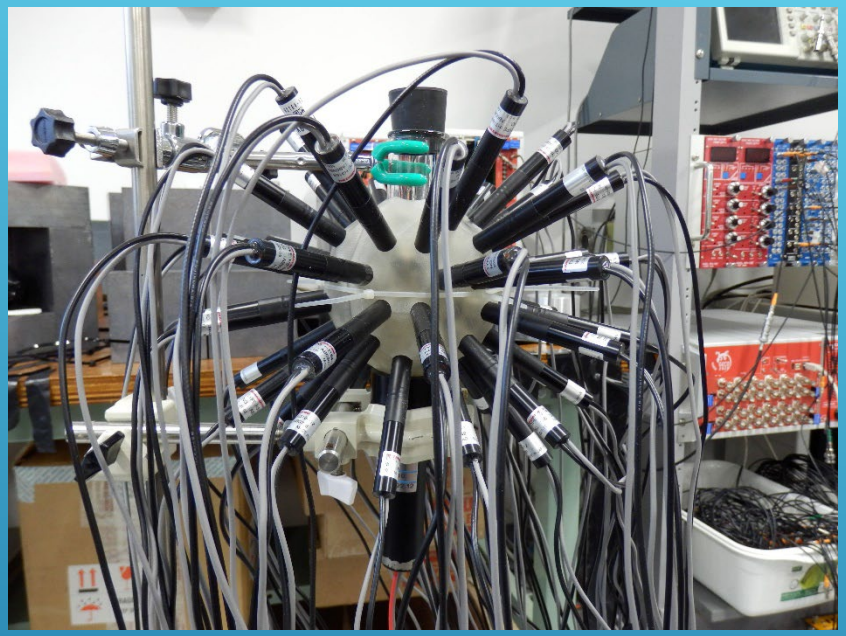


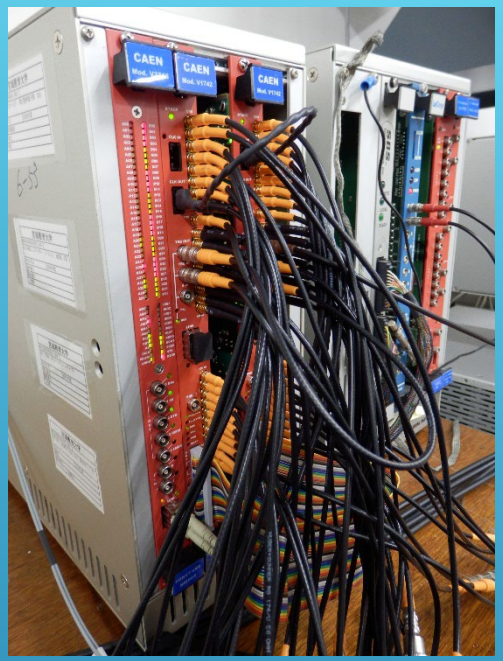
Averaged angle= $\dfrac{\Sigma\, \theta_i}{\text{Nhit}}$

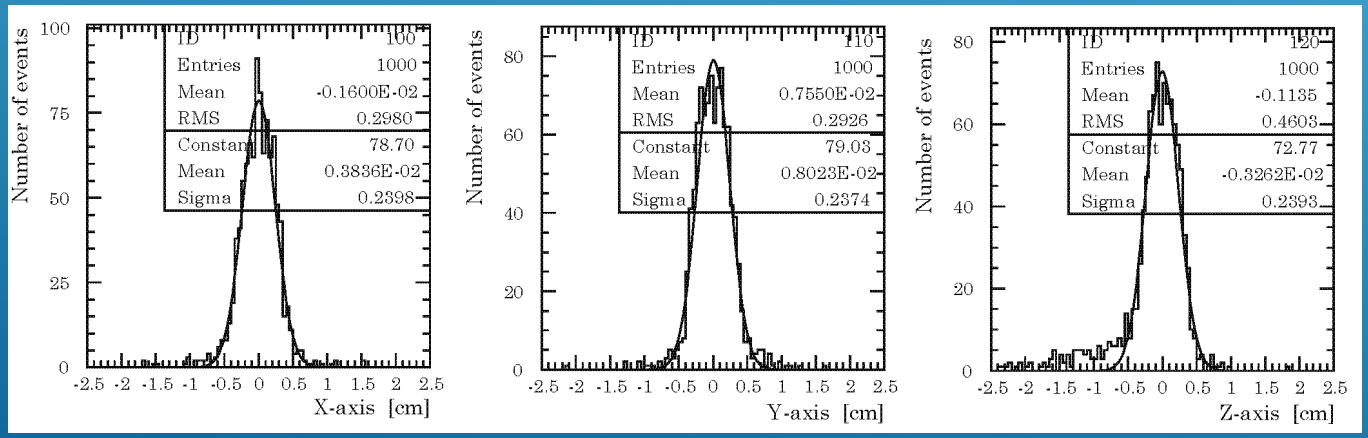


Topological information (averaged angle) of Cherenkov lights should be different between $2\nu\beta\beta$ and $\beta + \gamma$ event.

Setup for measurement with UNI-ZICOS



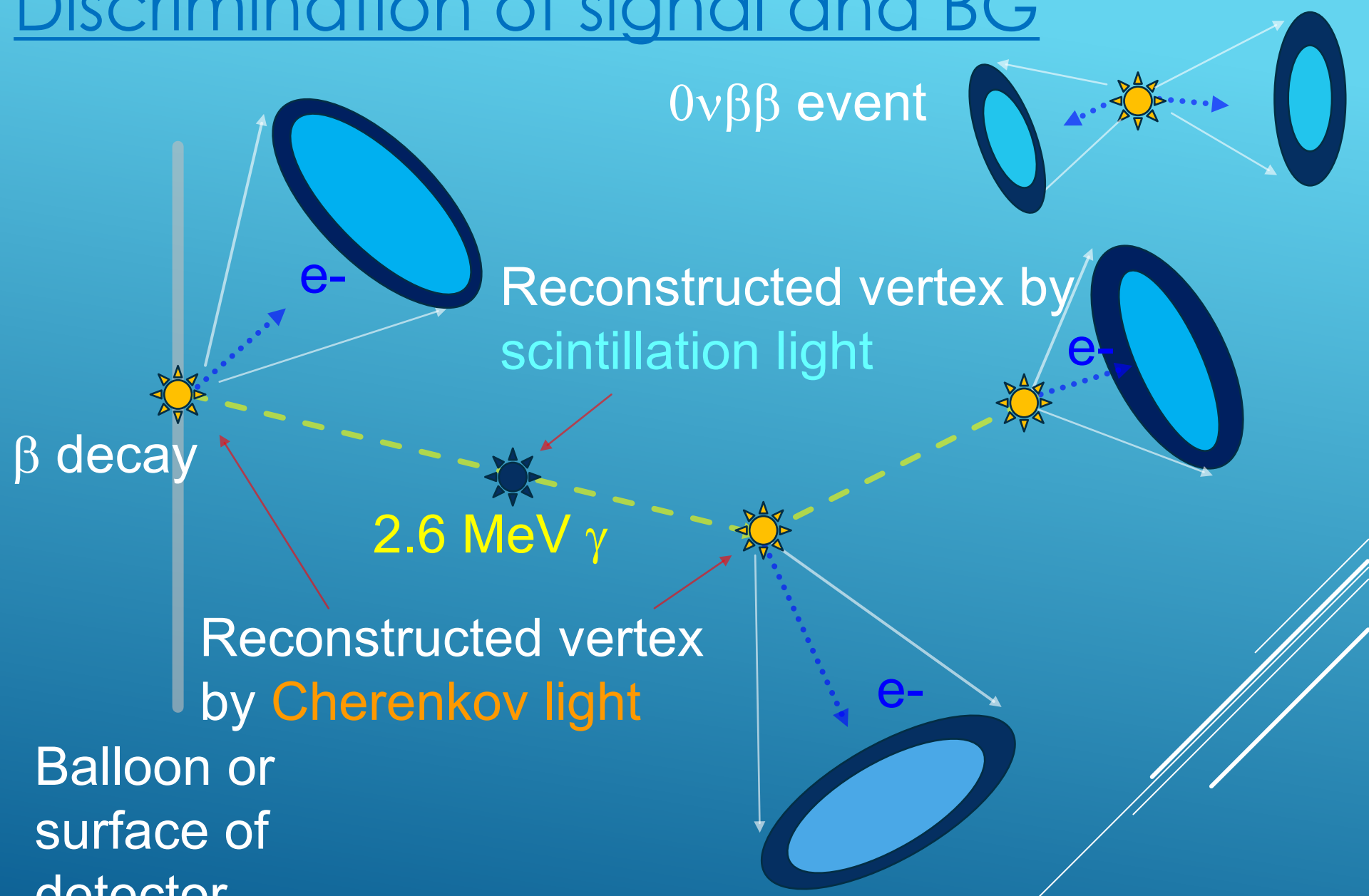




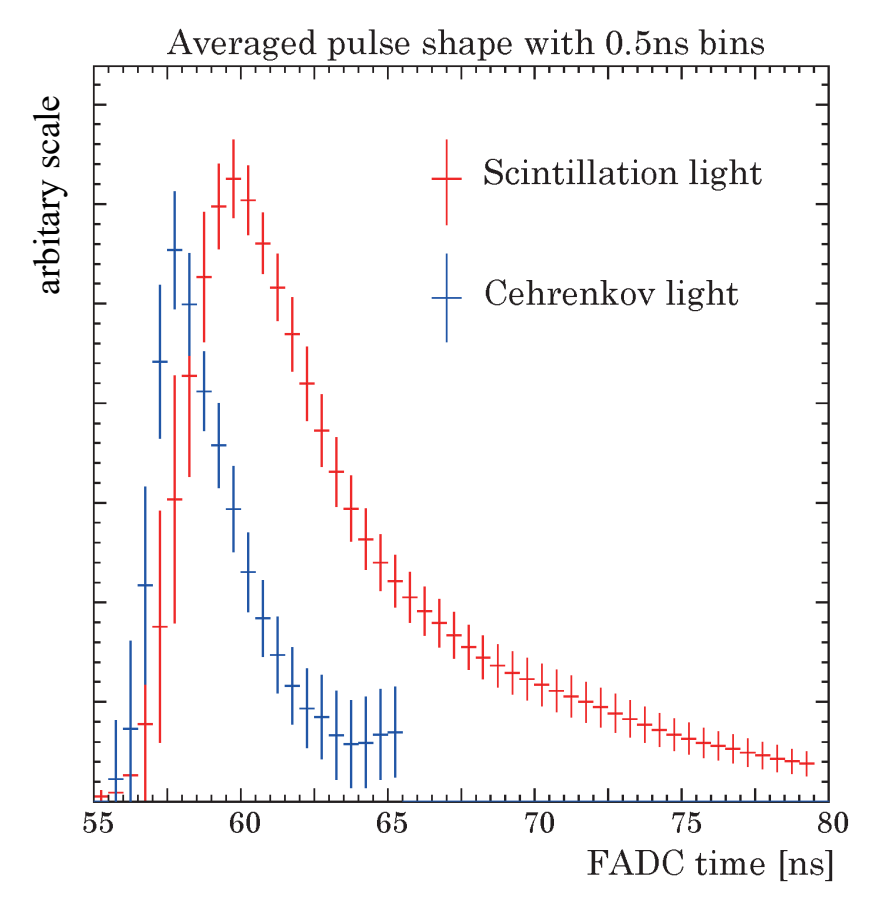
Source holder has a hole, and it can be covered by Al plate (0.3mm and 2mm) to terminate betas.

The vertex position could be reconstructed by assuming that all PMTs should have same effective charge which is corrected by the distance between PMT and vertex.

Discrimination of signal and BG



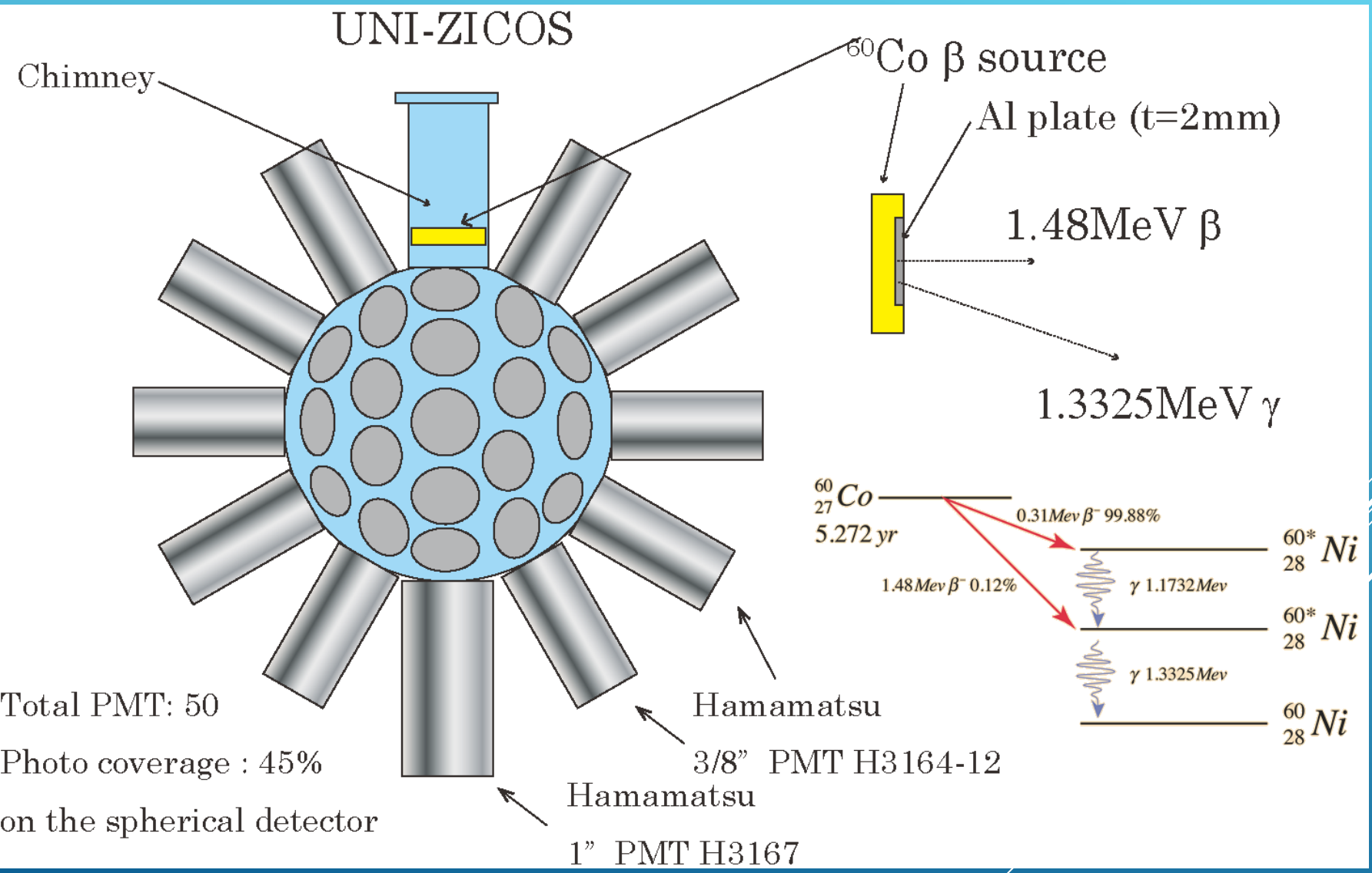
Pulse shape of Cherenkov and scintillation



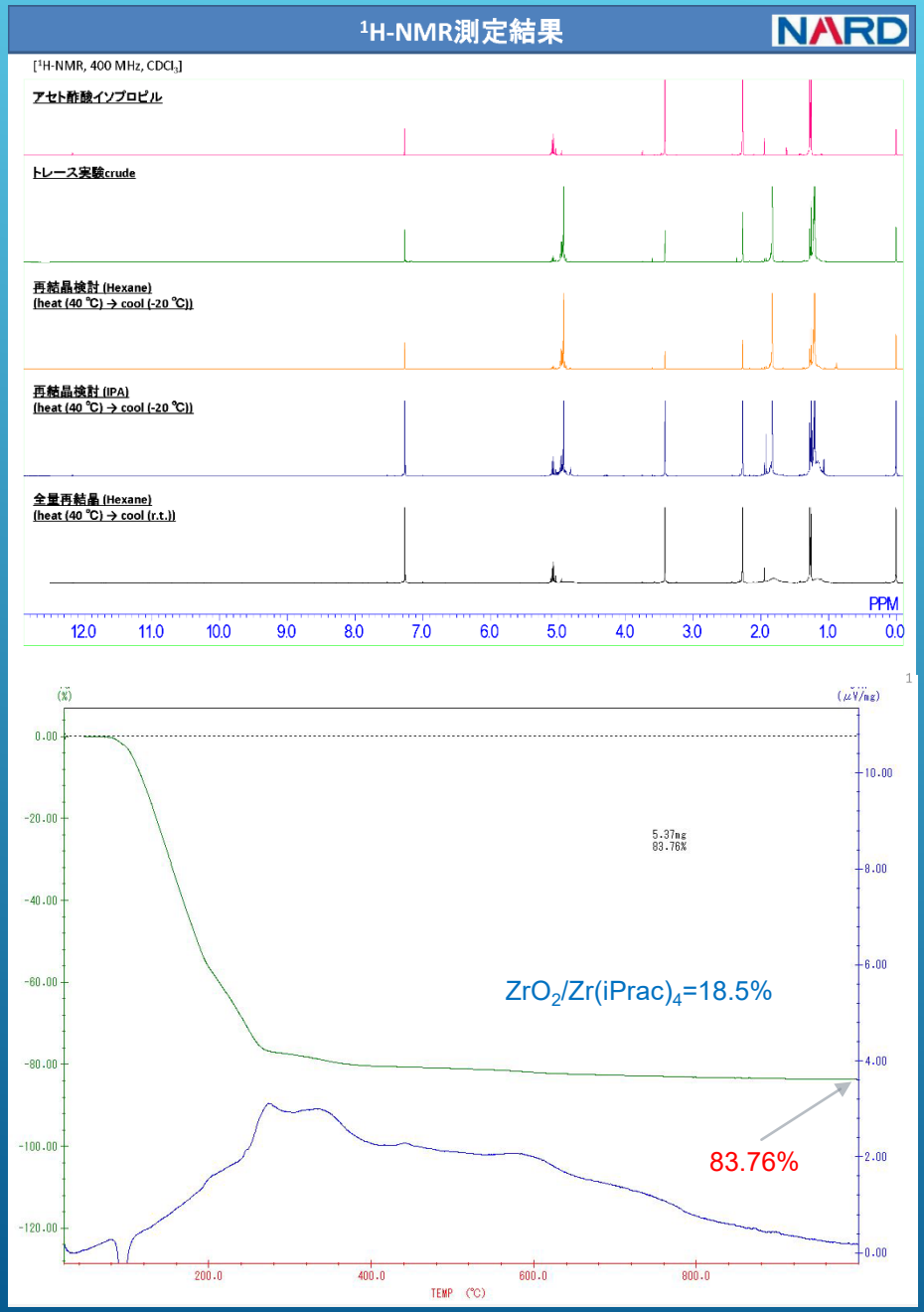
- Pulse shape of ^{90}Sr using H2431-50 measured by V1751 with DES mode (2GS/s)
- Decay time of scintillation : 4.57 ns and 8.38 ns
- Rise time of scintillation : 1.45 ns
- Rise time of Cherenkov : 0.75 ns

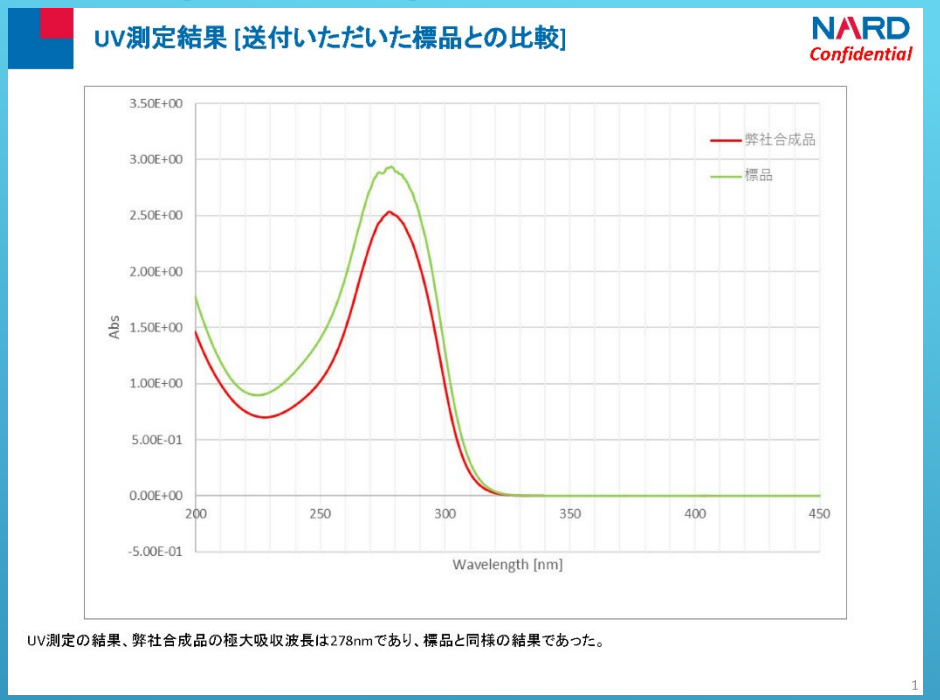
Use the charge ratio Q_{time}/Q_{total}. Here, Q_{time} is FADC count in each time, and Q_{total} is sum count of FADC between 55 ns and 80 ns.

Demonstration of ^{208}Tl BG reduction using UNI-ZICOS detector



Results of test synthesis of Zr(iPrac)4 by NARD





Synthesis of $Zr(iPrac)_4$ was succeeded.