

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XXI  
~2つのニュートリノを放出する二重ベータ崩壊  
事象の観測実験の準備状況~

日本物理学会 2024年春期大会

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Miyagi University of Education Y. Fukuda, R.Sato, K.Sugawara,  
K.Takemura, K.Toyama

Kamioka Observatory, ICRR, Univ. of Tokyo S. Moriyama, K. Hiraide  
University of Fukui I. Ogawa

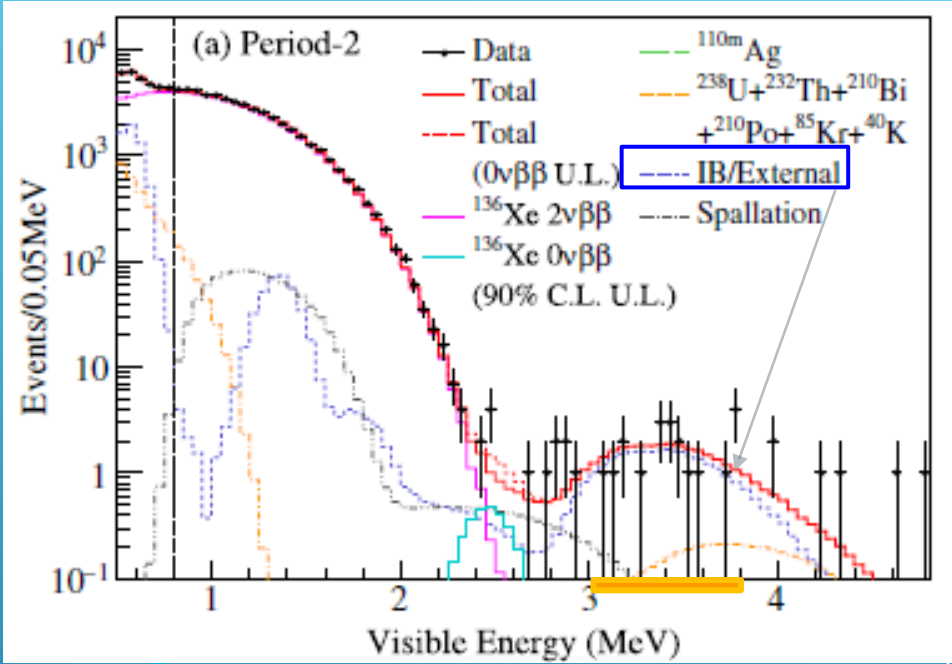
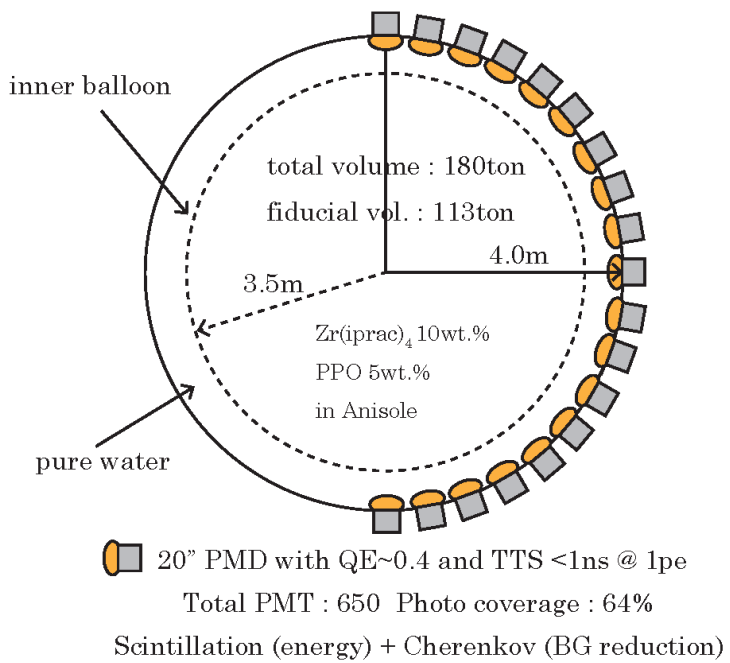
Tokyo University of Science T. Gunji

Institute for Materials Research, Tohoku University S. Kurosawa

# Conceptual design of ZICOS detector

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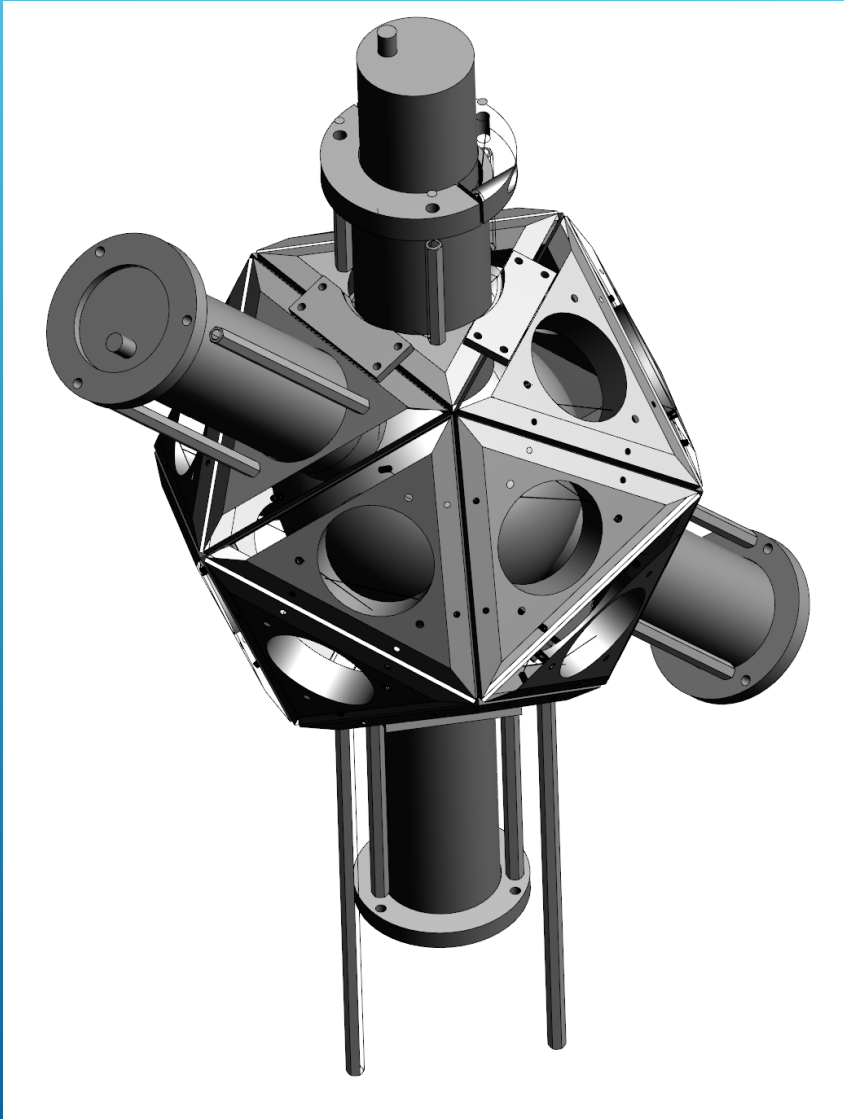
## Conceptual design of ZICOS detector



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

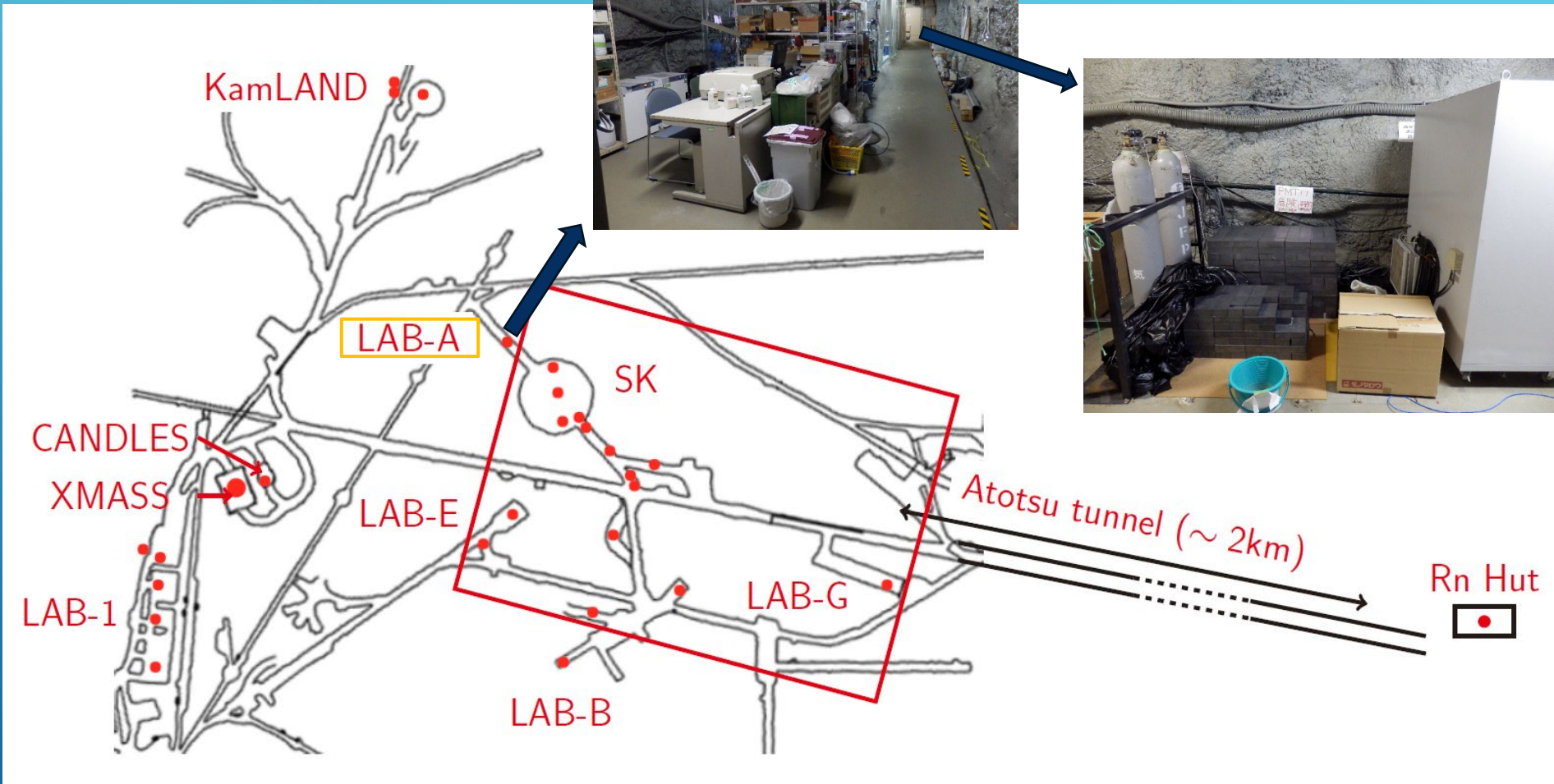
$^{96}\text{Zr}$  : 45 kg (nat.)  $\rightarrow$  865 kg (50 % enrich)  $\rightarrow$  1/20 BG  
 $T_{1/2}^{0\nu} > 4 \times 10^{25}$  yrs  $\rightarrow 2 \times 10^{26}$  yrs  $\rightarrow \sim 1 \times 10^{27}$  yrs

# Observation of $2\nu\beta\beta$ events using $^{96}\text{Zr}$



- 16 cm diameter round bottom flask using Ultra-pure quartz (GE214).
- 20 low BG 2" PMT Hamamatsu H3378-50.
- Designed mounting jig
- Filled 1.0L of ZICOS liquid scintillator loaded 100g of  $\text{Zr}(\text{iPrac})_4$  which contains 0.4 g of  $^{96}\text{Zr}$ .
- Expected number of events is  $\sim 100$  per year.
- LAB-A in Kamioka mine

# Underground laboratory in Kamioka mine



## LAB-A : Behind of LINAC control room

# Background estimation

U/Th in GE214 using ICP Mass spectrometer :

$^{232}\text{Th}$  : 15ng/g corresponds to  $6.09 \times 10^{-5}\text{Bq/g}$

$^{238}\text{U}$  : 29ng/g corresponds to  $3.58 \times 10^{-4}\text{Bq/g}$

$^{40}\text{K}$  : 0.021ng/g corresponds to  $5.59 \times 10^{-6}\text{Bq/g}$

Assuming radiation (perpetual) equilibrium :

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

The detector flask uses 530g of GE214.

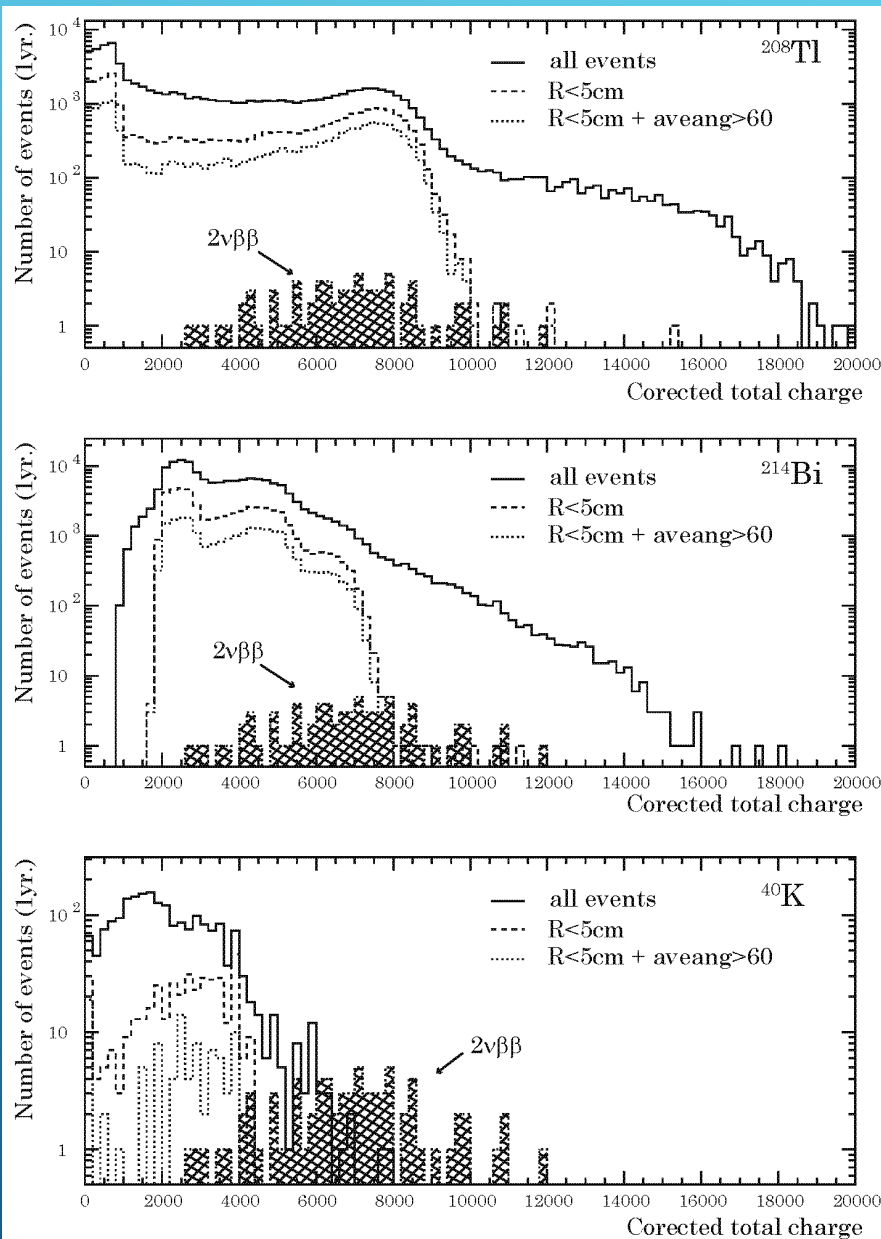
$^{208}\text{Tl}$  : 1017908 events per year

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

$^{40}\text{K}$  : 93556 events per year



# BG simulation assuming ETFE cubic bag



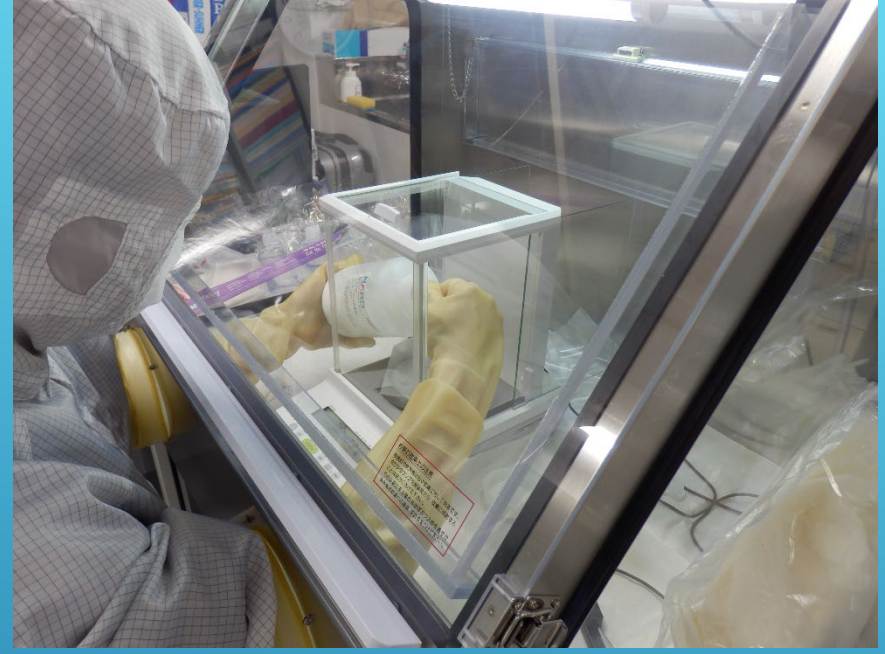
- $^{40}\text{K}$  affects only part of  $2\nu\beta\beta$  observation.
- $^{214}\text{Bi}$  is significant BG, but small fraction of  $2\nu\beta\beta$  events should be observed.
- $^{208}\text{Tl}$  is most serious BG for  $2\nu\beta\beta$ . A few events might be observed.

Need tuning for inner ETFE cubic bag for liquid scintillator.

# Present status

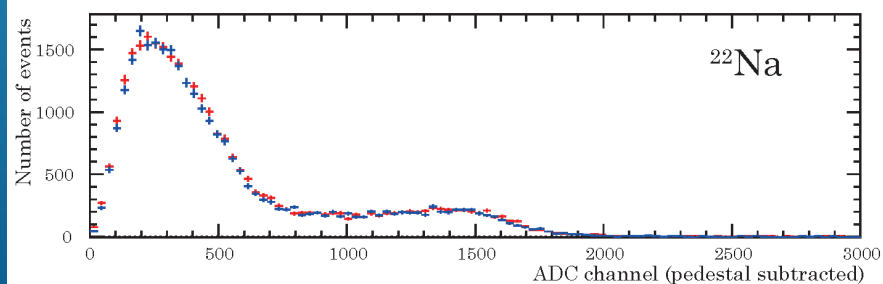
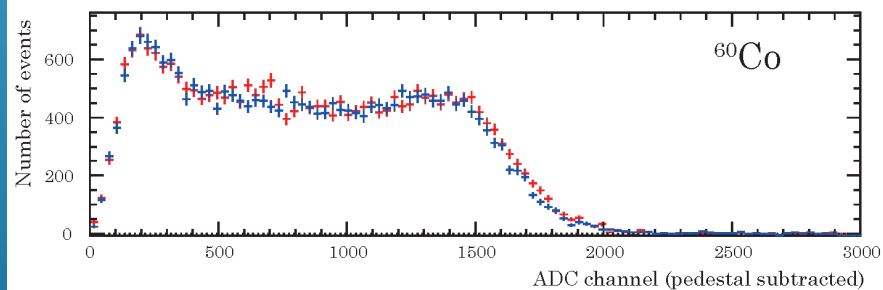
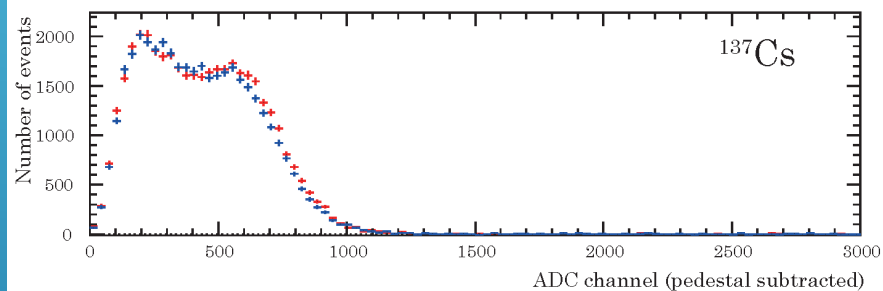
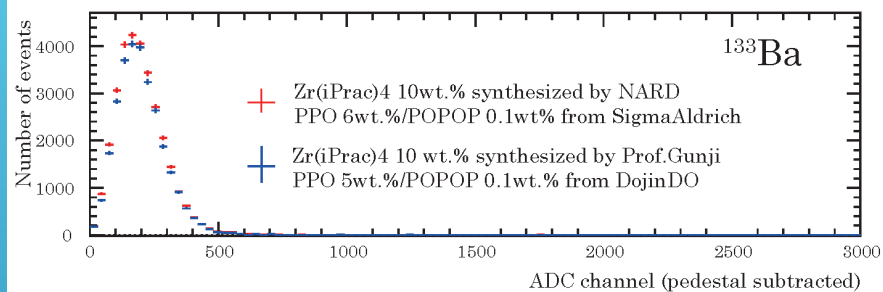
- 2 Little of ZICOS Liquid Scintillator was prepared by under graduated students for 4 months.
  - i. 10 wt.% for  $\text{Zr}(\text{iPrac})_4$  into Anisole in the globe box under  $\text{N}_2$  gas atmosphere
  - ii. 6 wt.% for PPO and 0.1wt.% for POPOP
  - iii. All procedures done in class 1000 clean room using PFA SSC bottle.
- Prototype 10cm ETFE cubic bag was produced by Taiyo Kogyo Corporation using  $100\mu\text{m}$  film.
  - i. 5% light yield loss at maximum
  - ii. Size should be tuned (not suitable in the flask)
- PMT mounting jig was prepared by CI corporation.
  - i. Need fitting to the flask (not a spherical shape)

# Preparation of ZICOS liquid scintillator





# Comparison of LY for ZICOS liquid scintillator

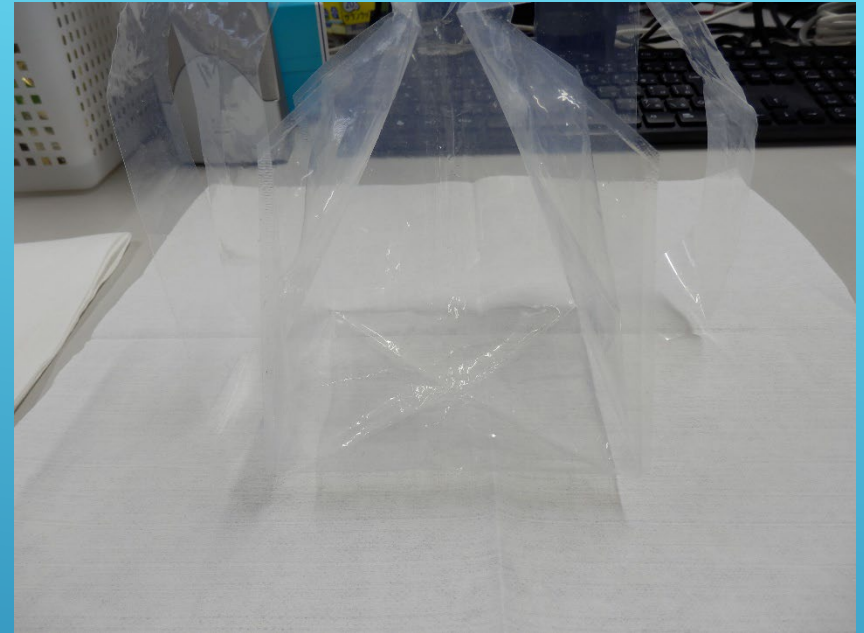
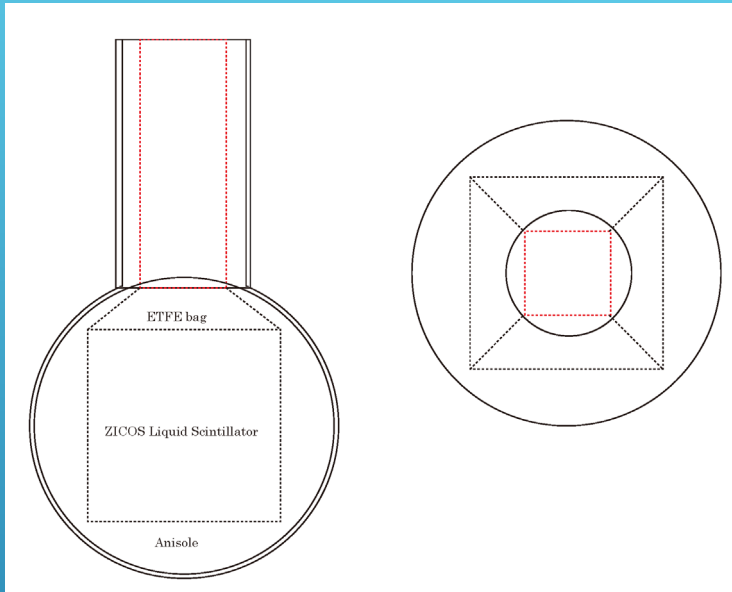


No difference between old liquid scintillator (Zr(iPrac)<sub>4</sub> synthesized by Prof.Gunji) and new liquid scintillator (Zr(iPrac)<sub>4</sub> synthesized by NARD)

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# ETFE cubic bag

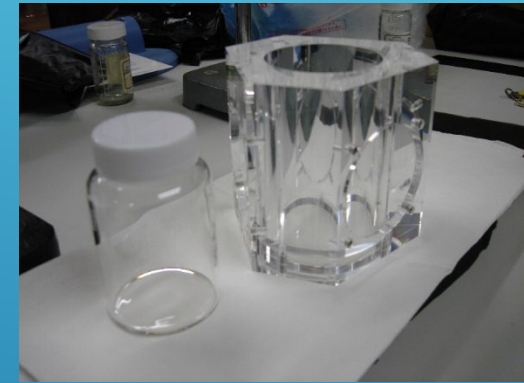
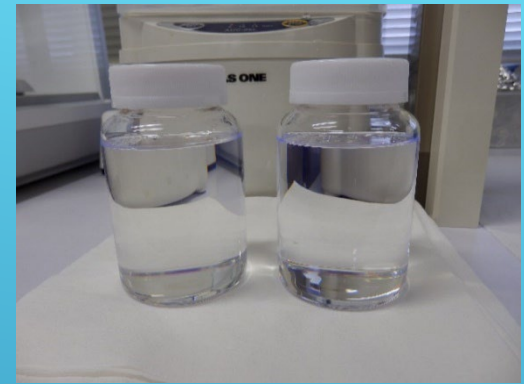
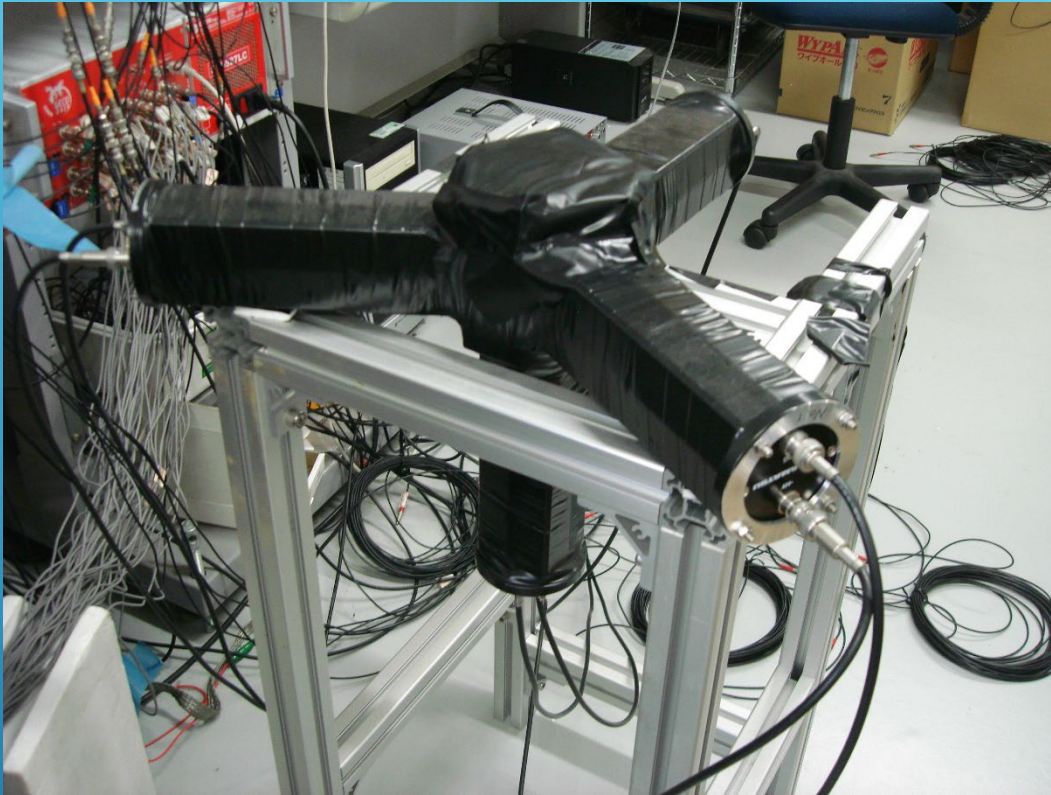


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  - i. 10 wt.% for  $\text{Zr}(\text{iPrac})_4$  into Anisole in the globe box under  $\text{N}_2$  gas atmosphere
  - ii. 5 wt.% for PPO and 0.2wt.% for POPOP
  - iii. all procedures done in class 1000 clean room using PFA SSC bottle.
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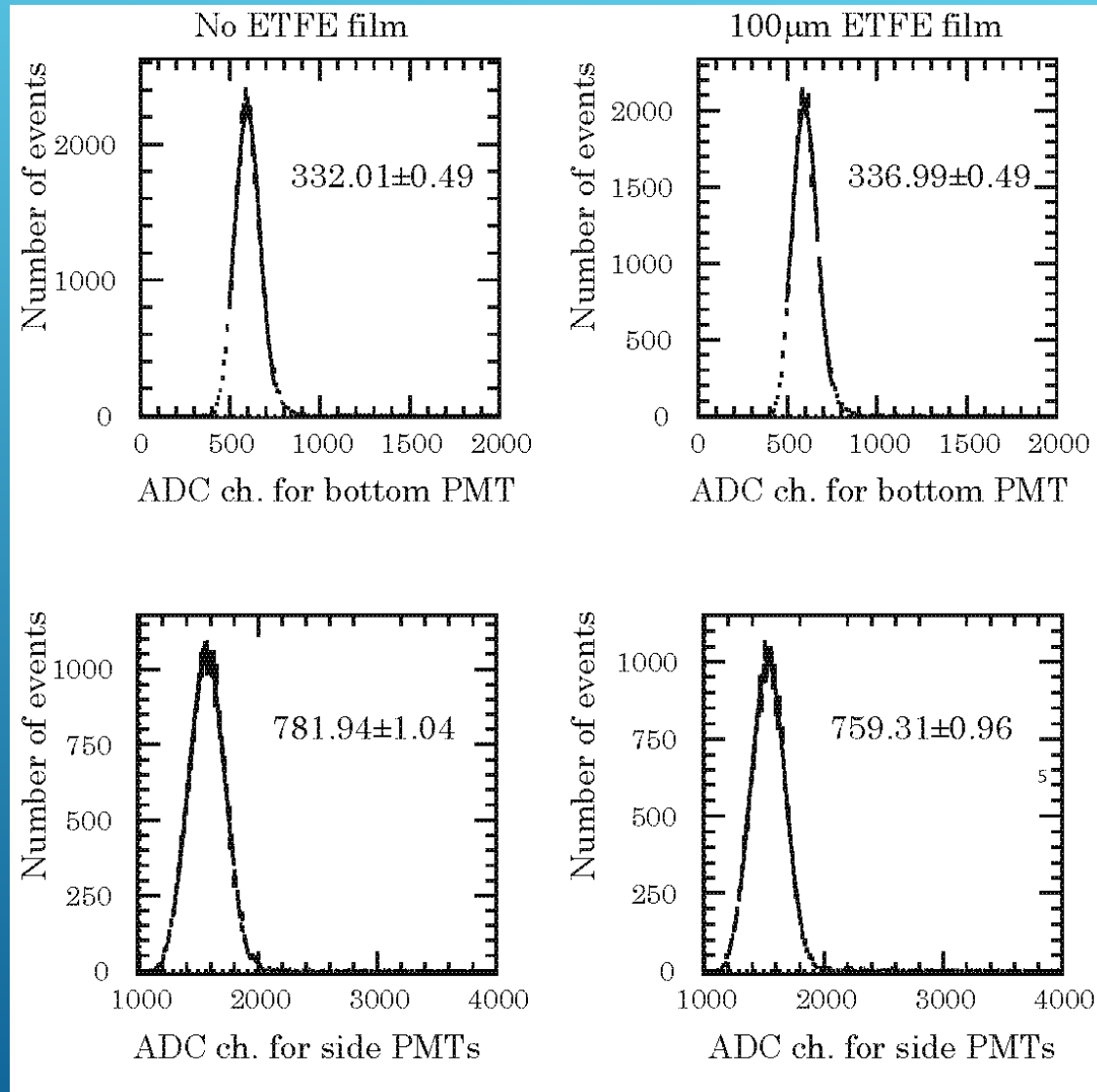


# Measurement of transparency for ETFE film



- Transparency of ETFE 100 $\mu\text{m}$  film using Liquid Scintillator.
- Peak for  $^{137}\text{Cs}$   $\gamma$  for PMTs covered side wall.
- Bottom PMT was always without ETFE film.

# Light yield transparency of ETFE 100 $\mu$ m film



The transparency of ETFE 100 $\mu$ m thickness film is obtained as following value:

$$0.9566 \pm 0.0027$$

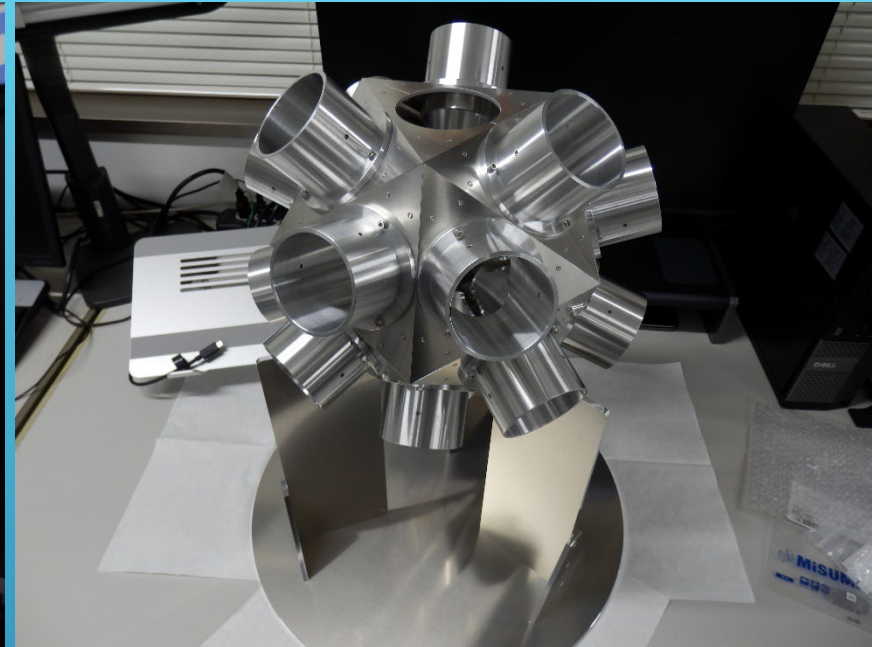
**5% loss at maximum**

# Present status

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  - i. 5% light yield loss at maximum
  - ii. Size should be tuned (not suitable in the flask)
- PMT mounting jig was produced by CI corporation.
  - i. Need fitting to the flask (not a spherical shape)



# PMT mounting jig



- Aluminum was used for all materials.
- Support jig for PMT inserted via chimney was made by POM.
- Need fitting to the flask



# Plans for near future

- Pb block and oxygen free copper for radiation shield will be produced by CI corporation in this April.
- 9cm ETFE cubic bag will be prepared by Taiyo Kogyo Corporation soon.
- All stuffs will be moved to Lab-A in Kamioka mine at beginning of May.
- Build clean booth and setup the radiation shield in the clean booth at that time.
- $2\nu$ -ZICOS detector will be built in June.
- The pilot run including calibration and DAQ program with unformatted data will be done in July - August.
- Physics run will start in September.



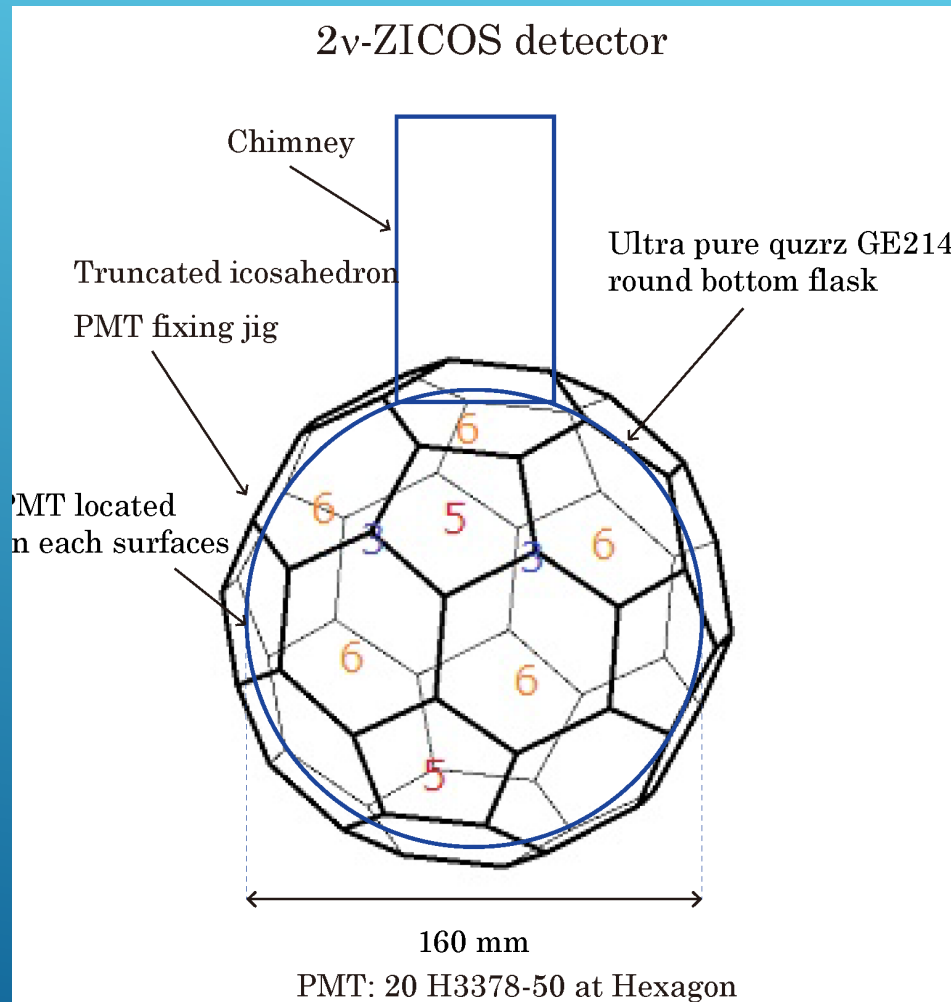
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- Build clean booth and setup the radiation shield in the clean booth at that time.
- 2 $\nu$ -ZICOS detector will be built in June.
- The pilot run including calibration and DAQ program with unformatted data will be done in July - August.
- **Physics run will start in September.**

backup

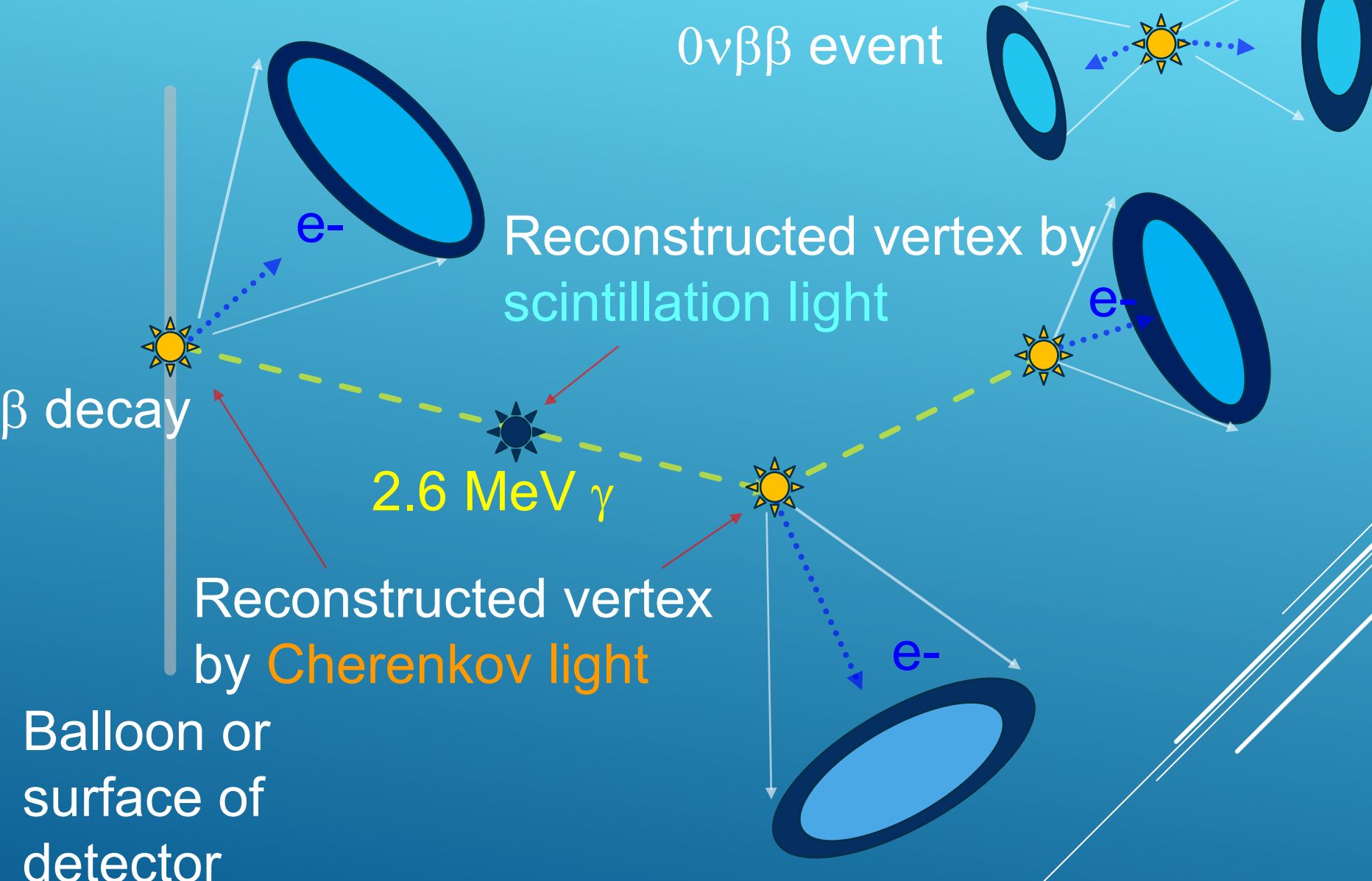


# Observation of $2\nu\beta\beta$ events using $2\nu$ -ZICOS



- 16 cm diameter round bottom flask using Ultra-pure quartz.
- 20 low BG 2" PMT Hamamatsu H3378-50.
- Filled 1 Liter of ZICOS liquid scintillator loaded 100g of  $Zr(iPrac)_4$  which contains 0.5 g of  $^{96}Zr$  nuclei.
- Expected number of events is 100 per year.

# Discrimination of signal and BG



# Results of test synthesis of Zr(iPrac)<sub>4</sub> by NARD

## <sup>1</sup>H-NMR測定結果

NARD

[<sup>1</sup>H-NMR, 400 MHz, CDCl<sub>3</sub>]

アセト酢酸イソプロピル

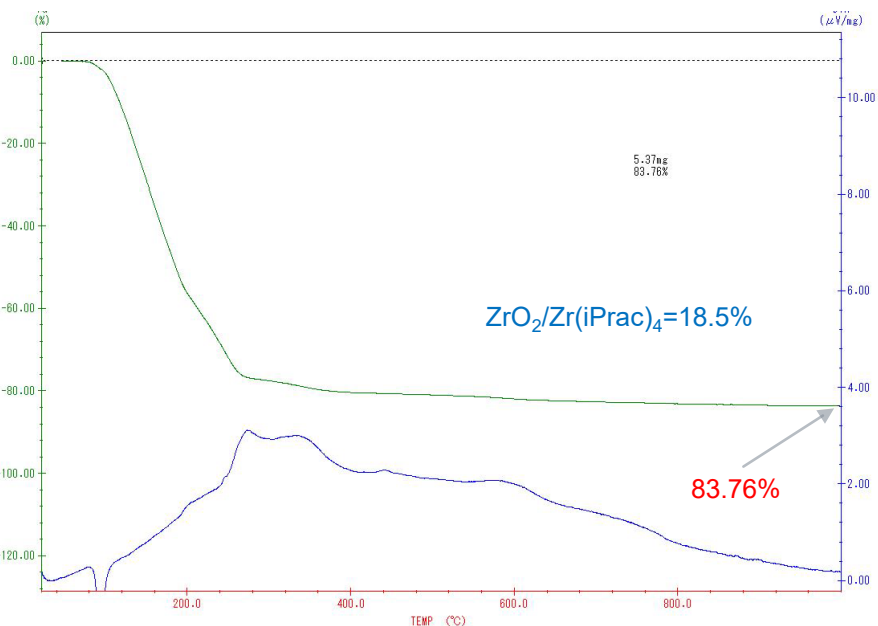
トレース実験 crude

再結晶後 (Hexane)  
(heat 40 °C → cool (-20 °C))

再結晶後 (IPA)  
(heat 40 °C → cool (-20 °C))

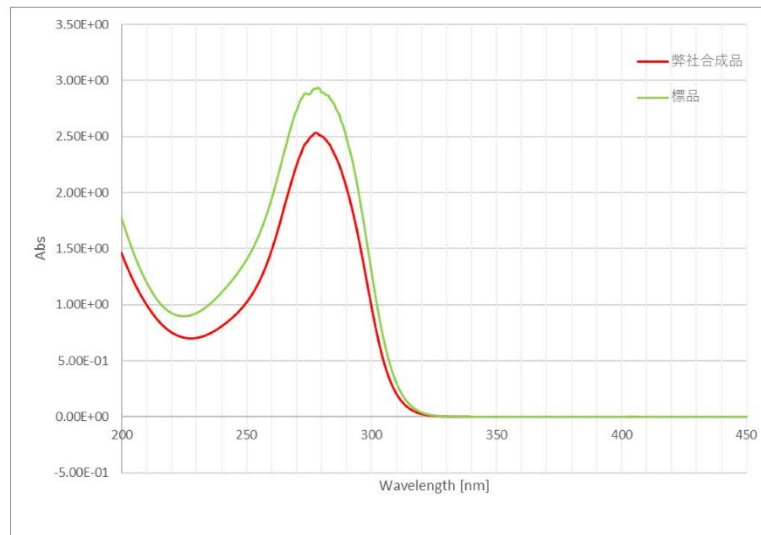
全量再結晶 (Hexane)  
(heat 40 °C → cool (r.t.))

PPM



## UV測定結果 [送付いただいた標品との比較]

NARD  
Confidential



UV測定の結果、弊社合成品の極大吸収波長は278nmであり、標品と同様の結果であった。

Synthesis of Zr(iPrac)<sub>4</sub>  
was succeeded.