

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XVIII ～チェレンコフ光の位相幾何学情報の測定と ベータ・ガンマ背景事象の除去法の開発～

日本物理学会 2021年秋季大会

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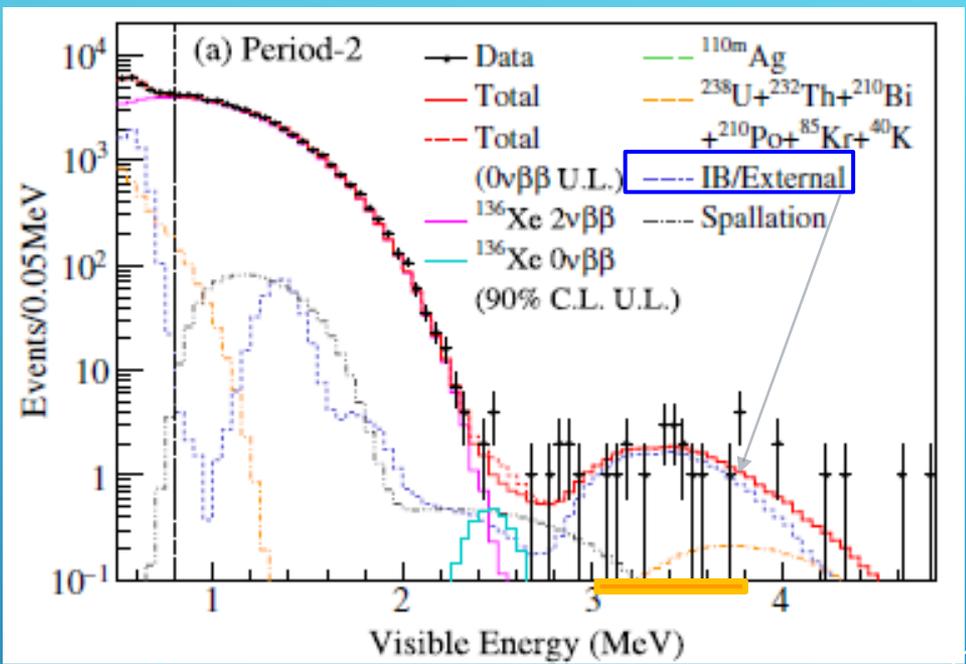
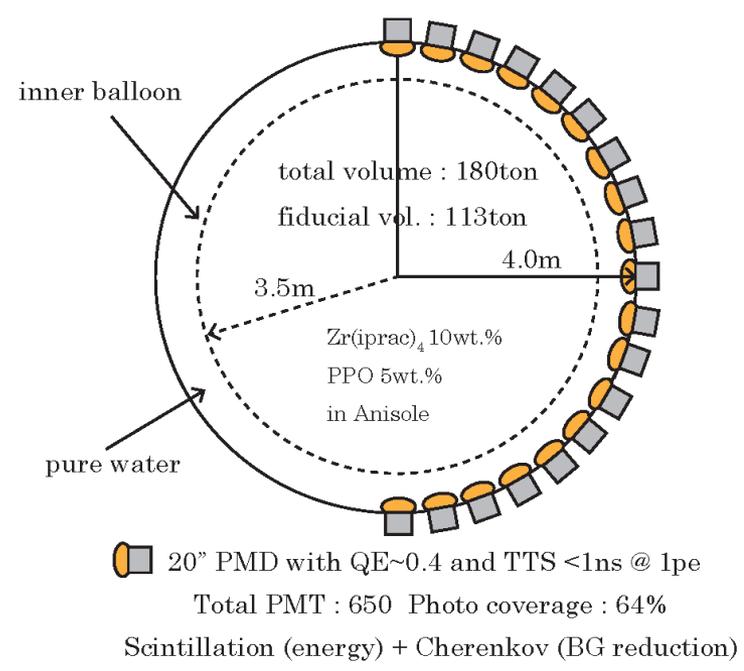
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Conceptual design of ZICOS detector

Phys.Rev.Lett. 117 (2016) 082503

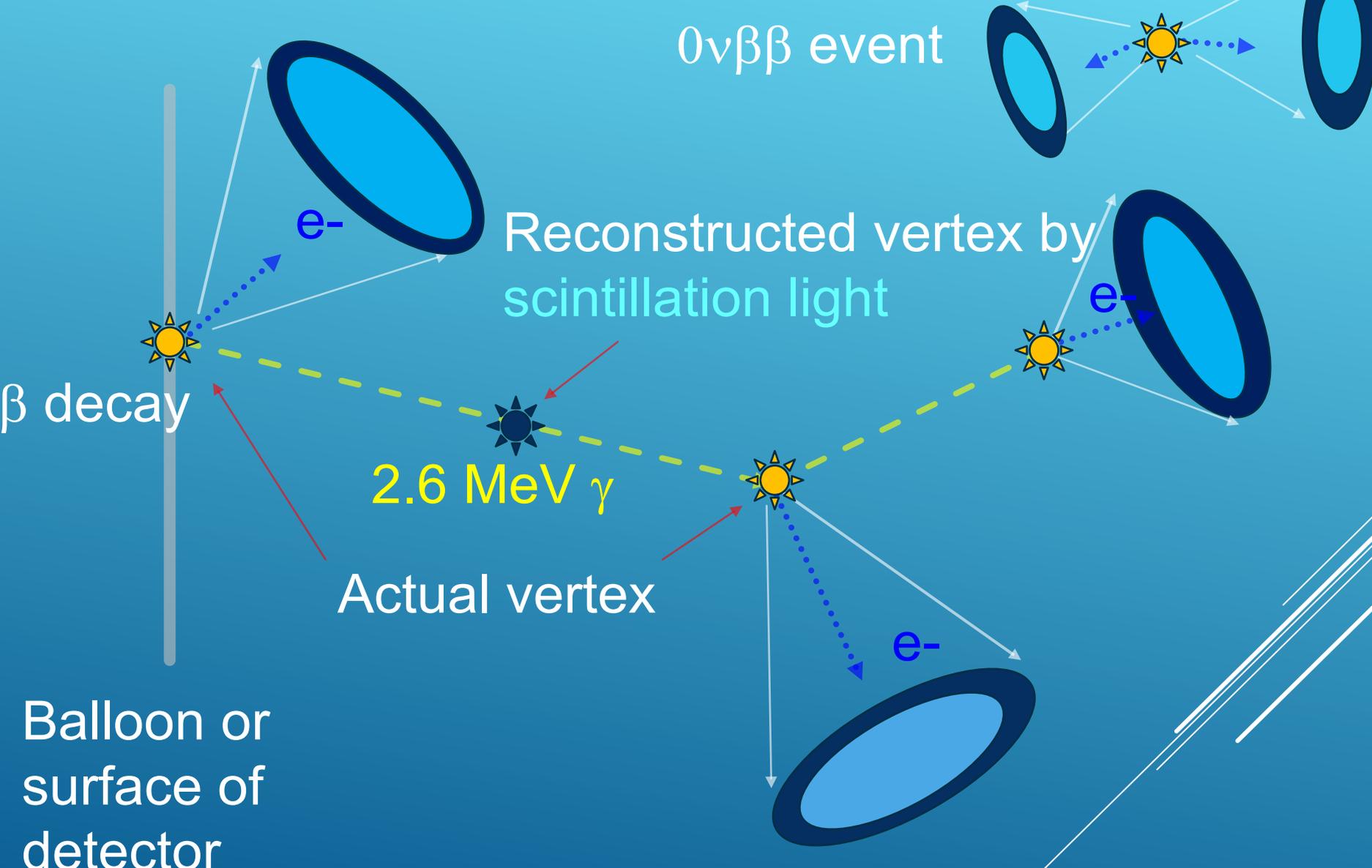
Conceptual design of ZICOS detector



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

^{96}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

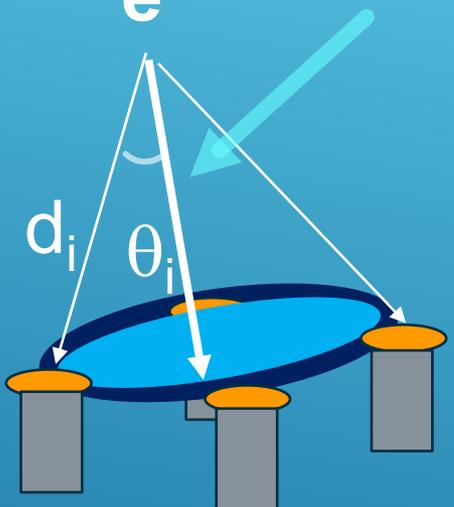
Discrimination of signal and BG



BG reduction using topological information

Average direction

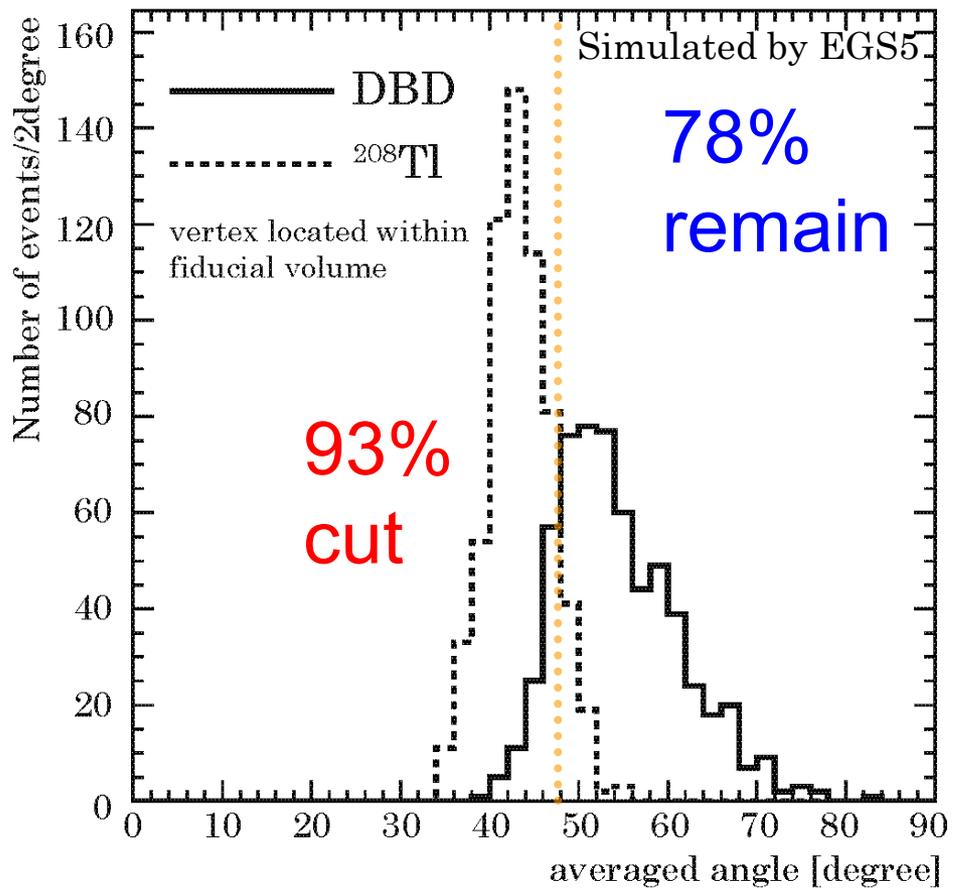
$$= \sum d_i$$



Averaged

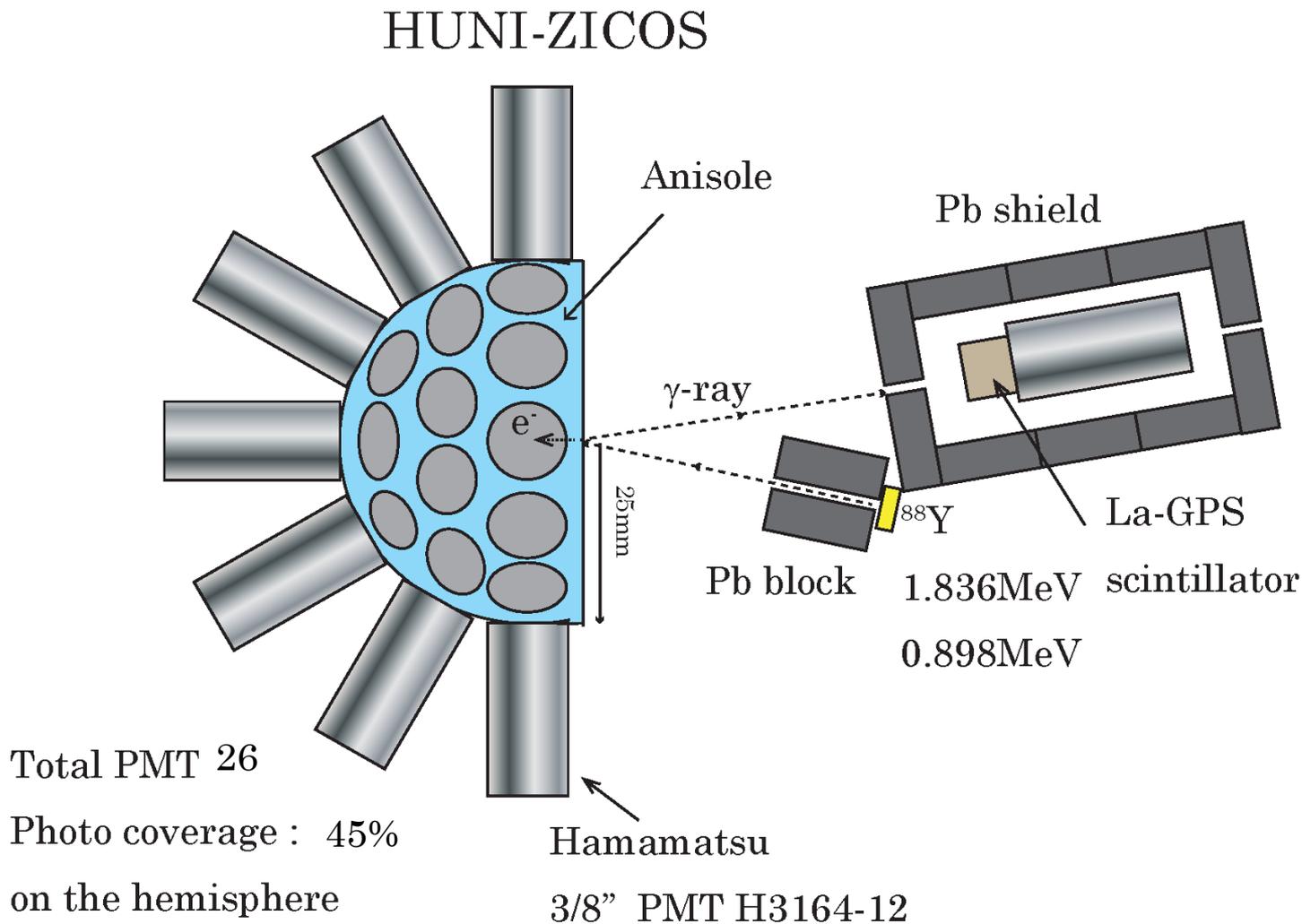
$$\text{angle} = \frac{\sum \theta_i}{N_{\text{hit}}}$$

averaged angle with respect to averaged direction



Topological information (averaged angle) of Cherenkov lights could be used for reduction of ²⁰⁸Tl backgrounds.

Direct measurement of topological information using HUNI-ZICOS

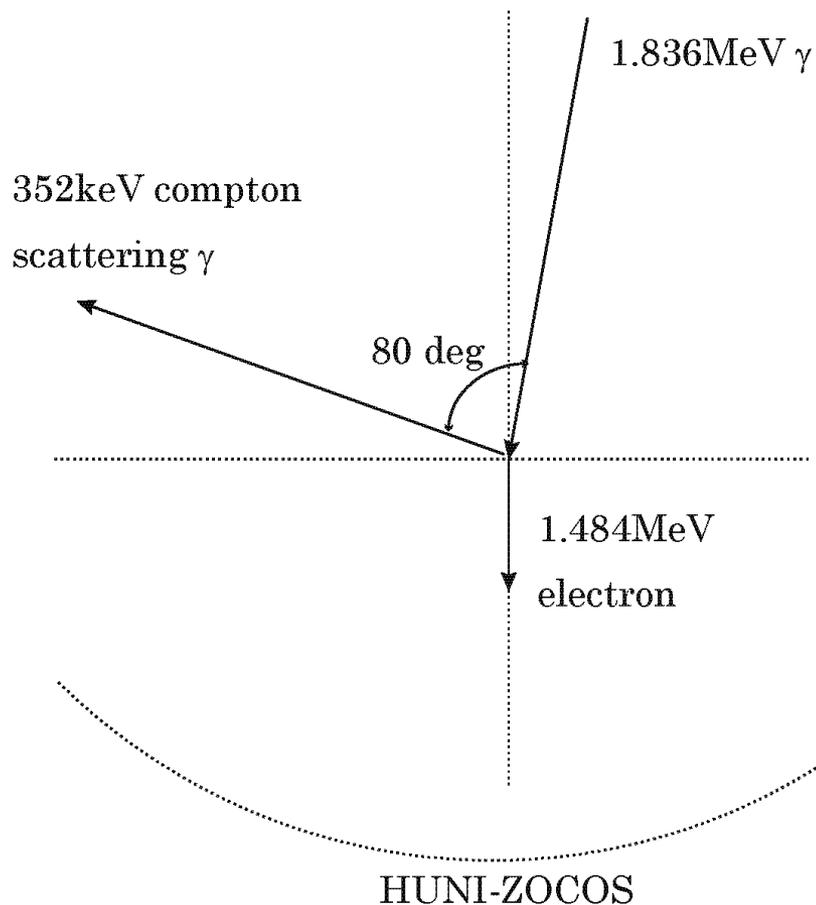


Setting hemisphere flask to jig and locate on supporting stand



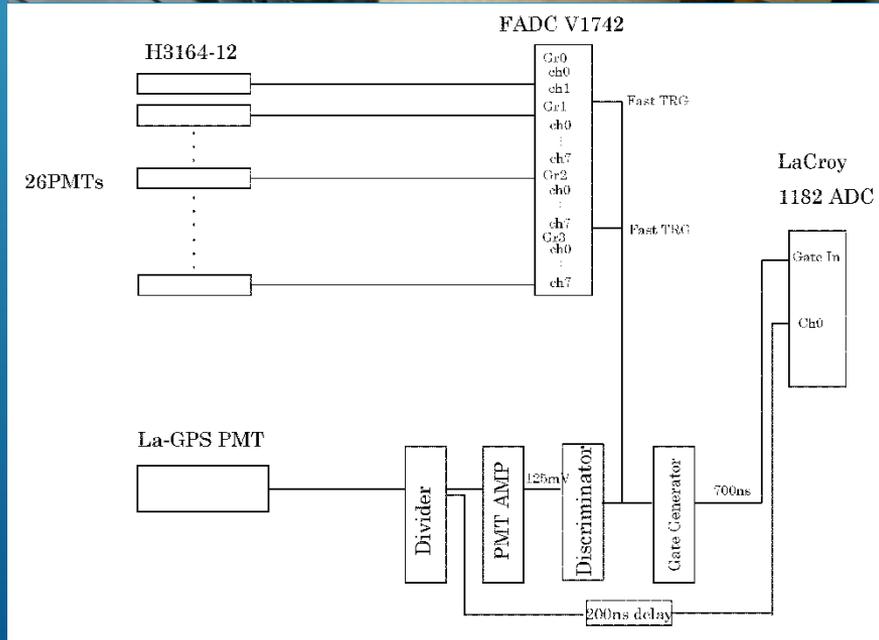
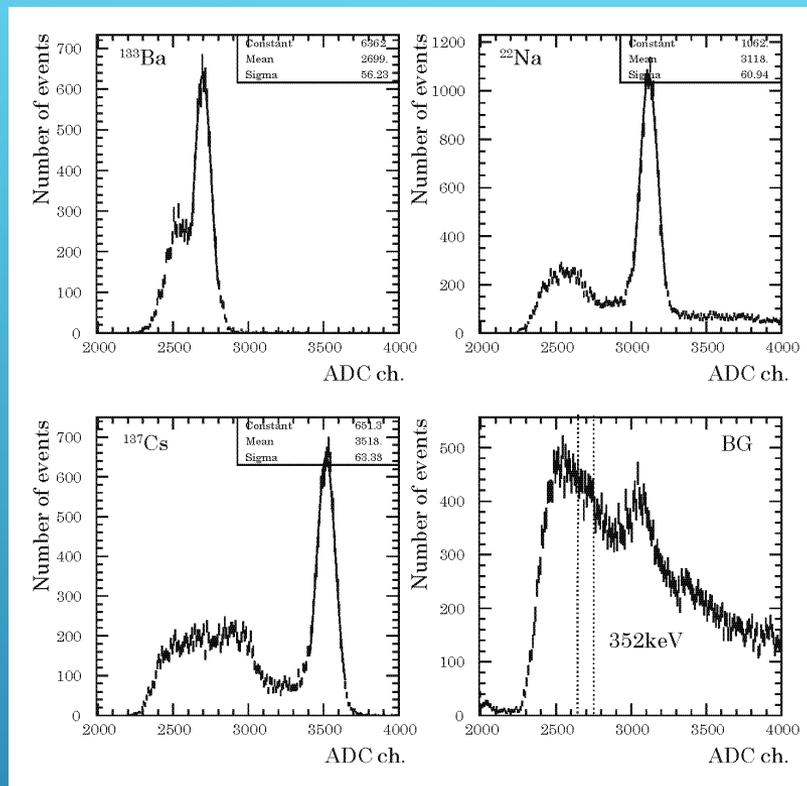
- Total 26 H3164-12 PMTs were used for HUNI-ZICOS
- In order to remove scintillation light ($\sim 300\text{nm}$), SC-37 filter was covered around the hemisphere flask
- HUNI-ZICOS was putted on flask clip and the chimney was pinched by clamp.

Electron with fixed direction and fixed energy using ^{88}Y gamma source



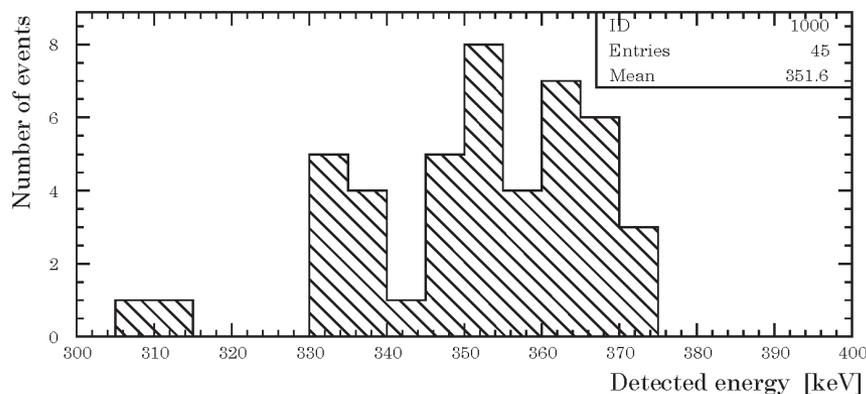
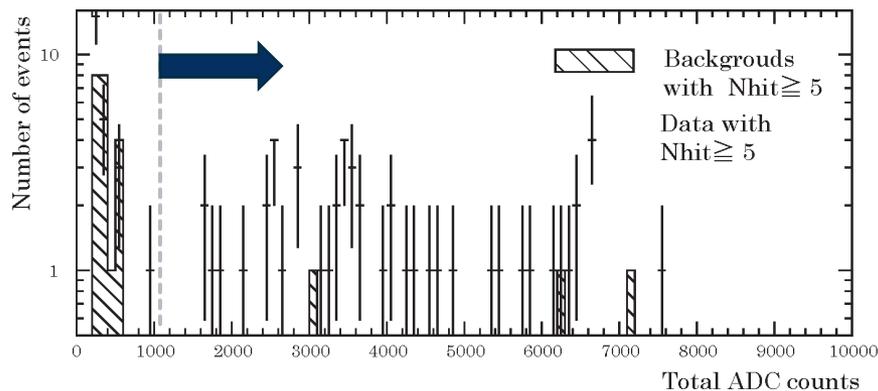
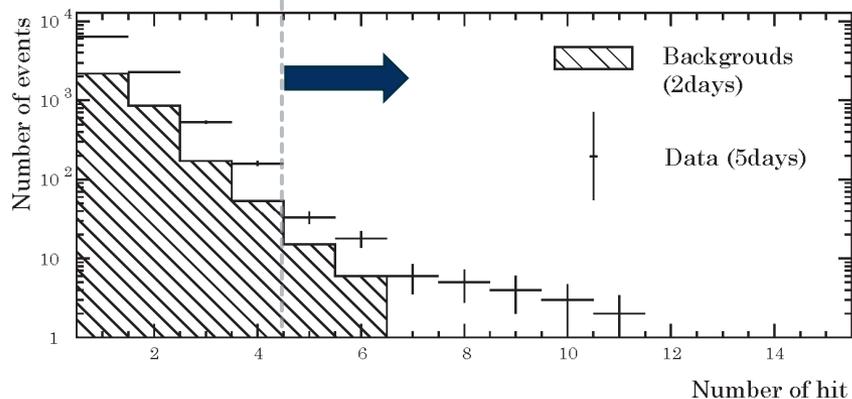
- Compton scattering with fixed direction generates fixed energy electron.
- Compton angle 100 degree corresponds to 352 keV for scattered γ and 1.484 MeV for electron.
- Cherenkov angle is 47 degree.

Measurement of averaged angle using ^{88}Y



- Scattering gammas were detected by well calibrated La-GPS scintillator through the Pb collimation.

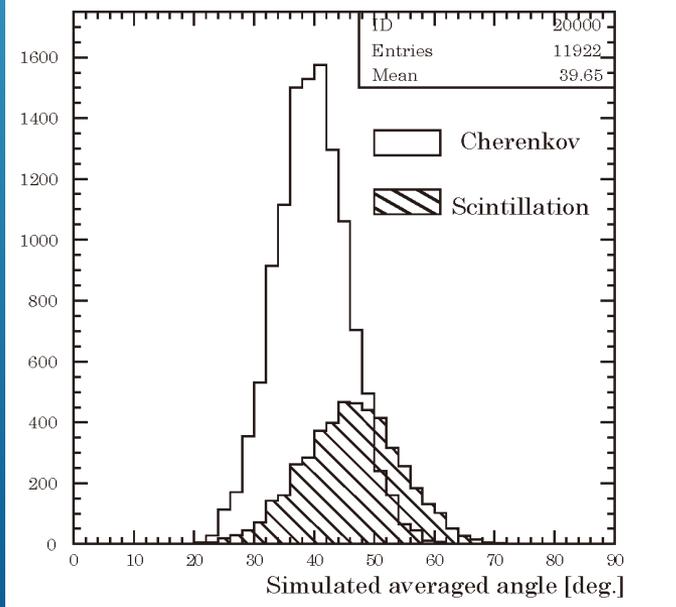
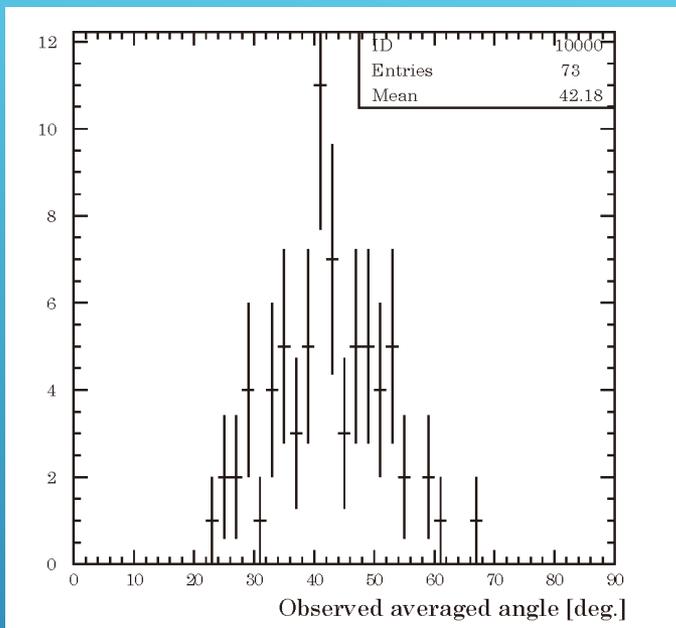
Event selection for scattered electron



Event selection criteria :

- Number of PMT hit for BG are clustered below 5 hit.
1) $N_{hit} \geq 5$
- Total ADC count for BG are also clustered below 1000.
2) Total ADC count ≥ 1000
- Observed energy of scattering gamma is clustered around 352keV.
- Due to SC-37 (UV cut) filter, we observed almost only Cherenkov light in this time.

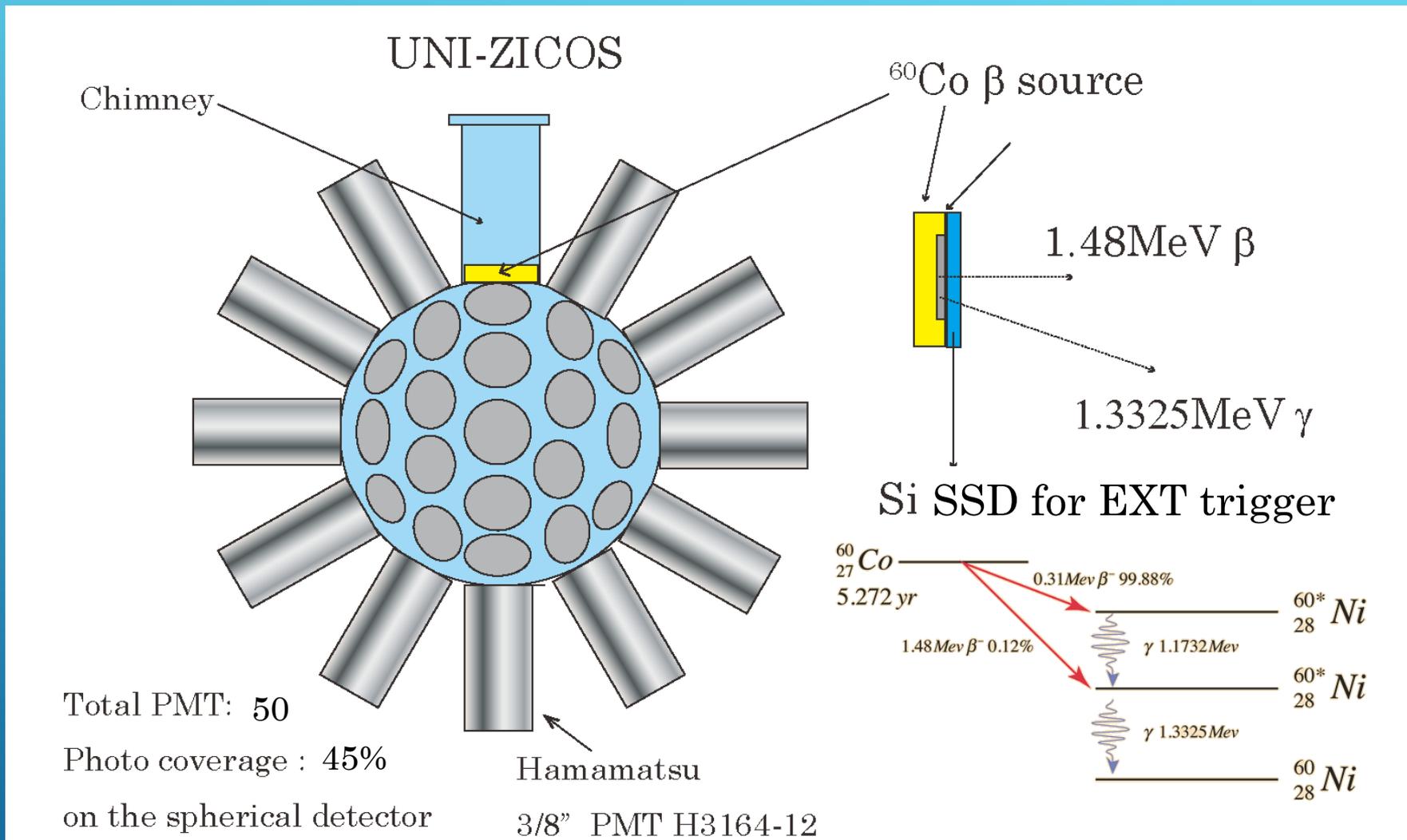
Measured averaged angle and simulation



- Averaged angle measured by HUNI-ZICOS has a peak at 40 degree. This is not consistent with the Cherenkov angle. This is due to PMT geometry of HUNI-ZICOS detector.
- Averaged angle obtained by EGS5 simulation of Cherenkov light has a peak at 40 degree. This is consistent with above measurement.
- Averaged angle obtained by EGS5 simulation of scintillation has a peak around 48 degree. This is quite different from Cherenkov light.

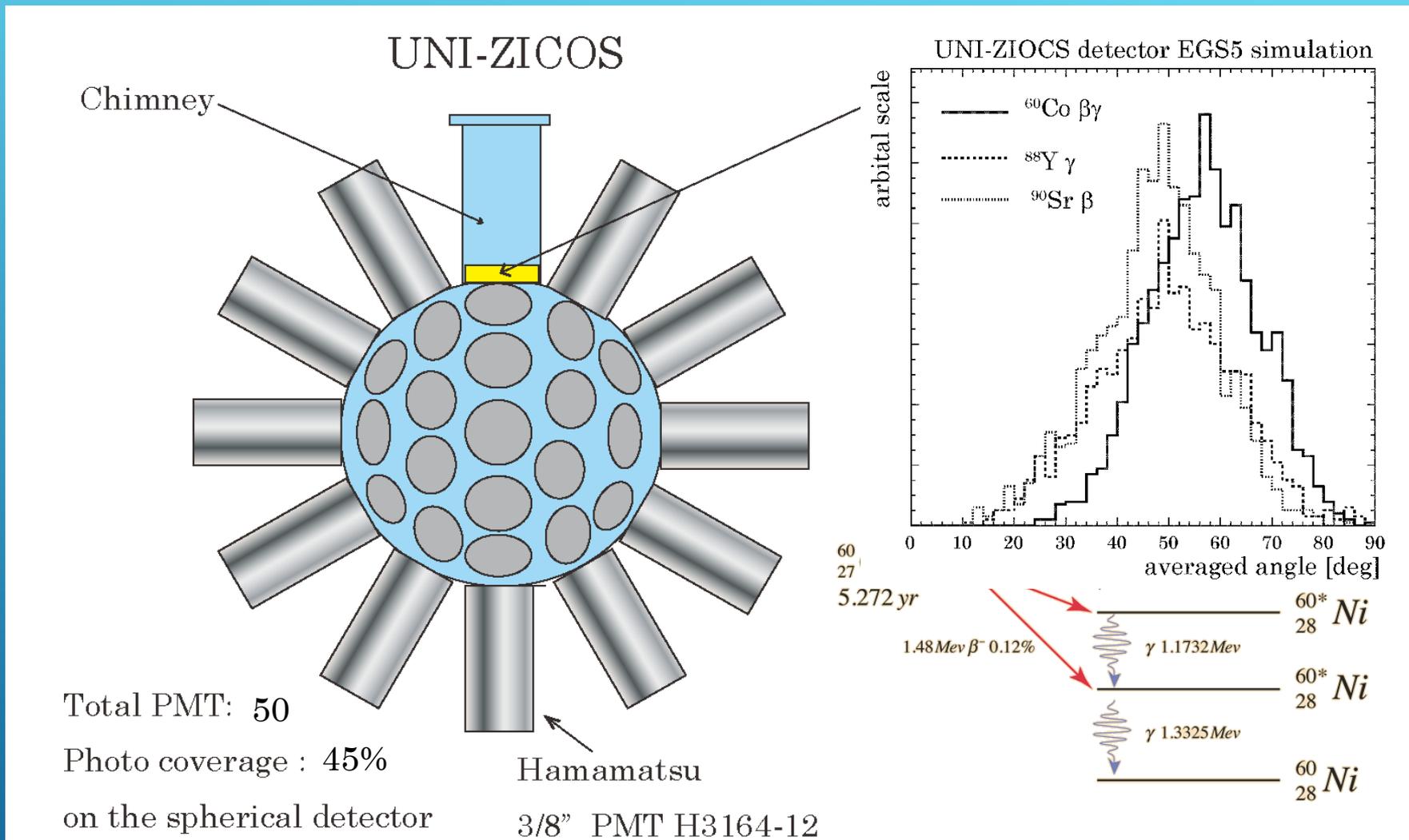
Verified Cherenkov lights emitted from 1.484 MeV electron really keep their topology.

Demonstration of ^{208}Tl BG reduction



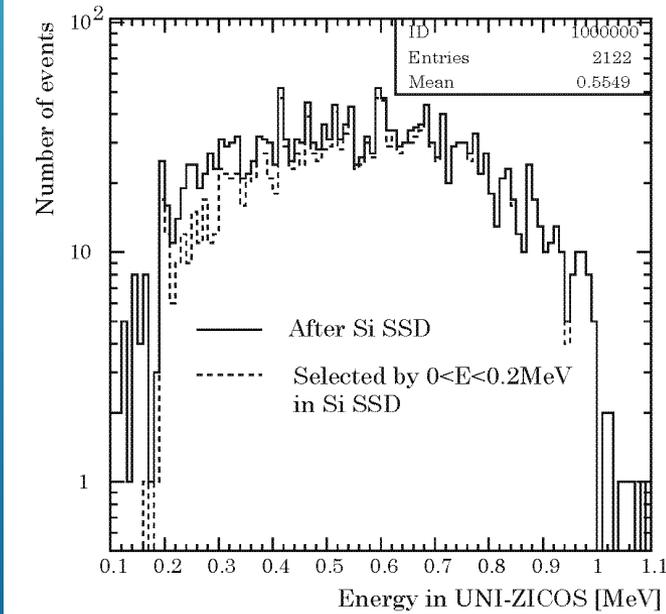
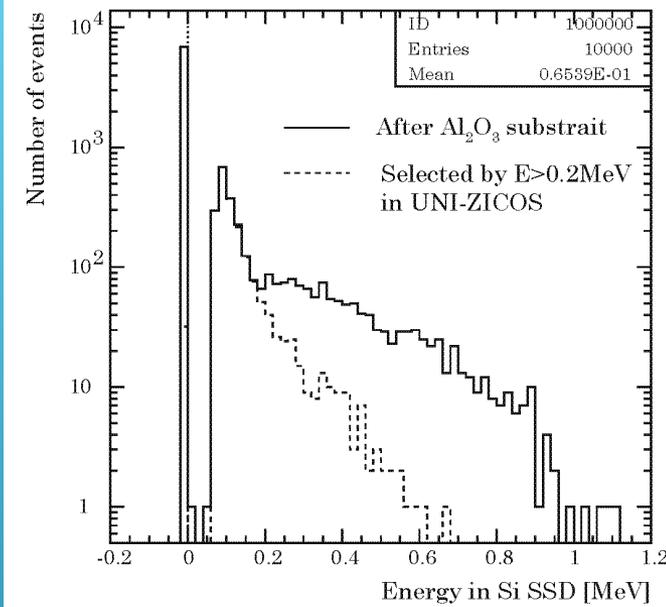
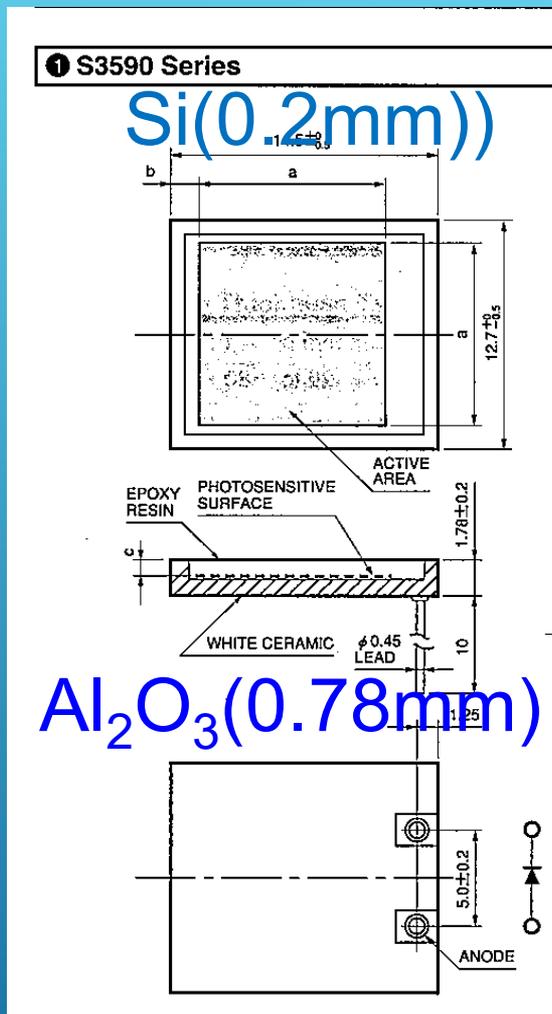
- Data taking will start in this autumn.

Demonstration of ^{208}Tl BG reduction



- Data taking will start in this autumn.

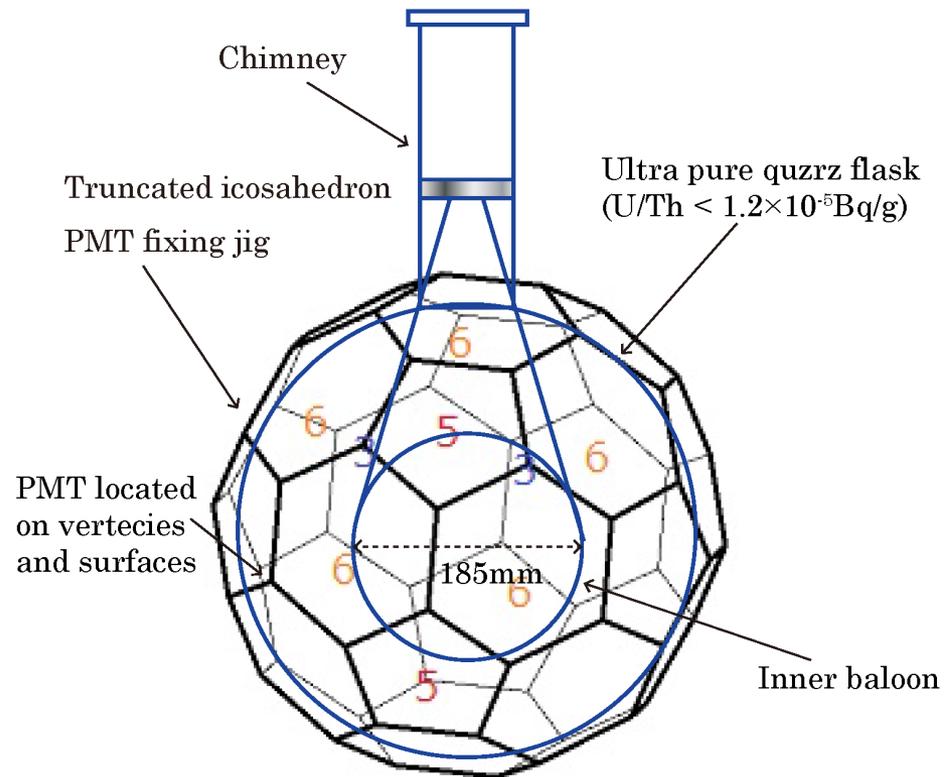
Status of UNI-ZICOS experiment



- ^{60}Co (100kBq)
- $100\text{kBq} \times 0.12\% \times 2000/10000 = 24\text{Hz}$
- γ det.eff $\sim 3\% = 0.7\text{Hz}$

Observation of $2\nu\beta\beta$ signal using 2ν -ZICOS

2 ν -ZICOS detector



280 mm

185 mm

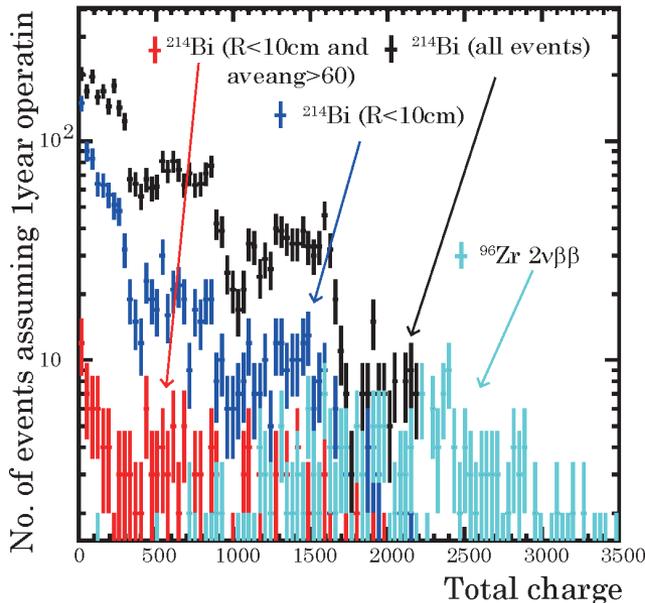
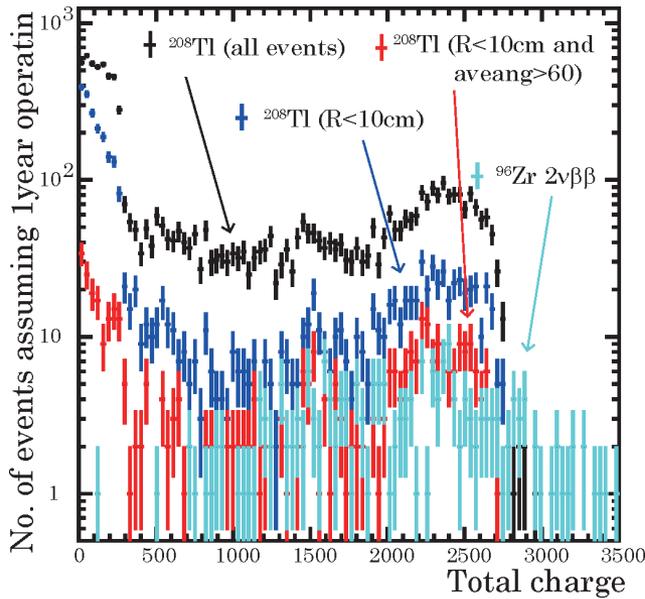
Total PMT: 75 (H3378-50) + 12 (H6610)

Photo coverage : 64%

- 28 cm diameter flask using Ultra-pure quartz (U/Th < 0.05ng/g) and 60 2inch R3378-50 on vertex of truncated icosahedron.
- 18.5cm inner balloon
- 300g Zr(iPrac)₄ loaded liquid scintillator which contains 1.1 g of ⁹⁶Zr
- 180 $2\nu\beta\beta$ events per year is expected
- Location: Kamioka mine
- Start time: FY2024

Observation of $2\nu\beta\beta$ signal using 2ν -ZICOS

simulation of 2ν -ZICOS detector



- 28 cm diameter flask using Ultra-pure quartz (U/Th < 0.05ng/g) and 60 2inch R3378-50 on vertex of truncated icosahedron.
- 18.5cm inner balloon
- 300g $\text{Zr}(\text{iPrac})_4$ loaded liquid scintillator which contains 1.1 g of ^{96}Zr
- 180 $2\nu\beta\beta$ events per year is expected
- Location: Kamioka mine
- Start time: FY2024

PMT on ve and s

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EXVIII

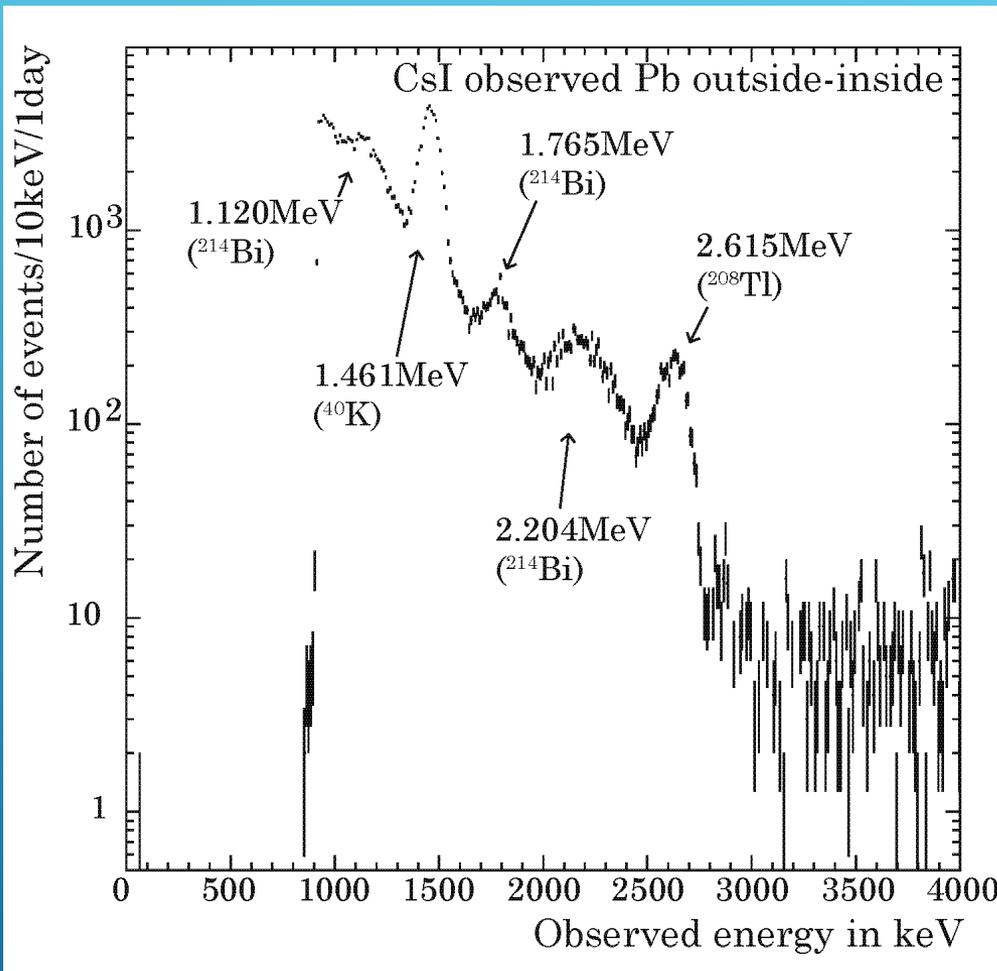
2021年9月15日

Summary

- Topological information (averaged angle) of Cherenkov light was directly measured by HUNI-ZICOS using actual low energy electron.
- Averaged angle distribution using fixed direction and fixed energy (1.484MeV) electron using ^{88}Y source has peak at **~40 degree**. This is not Cherenkov angle due to hit PMT geometry. They also agree with the simulation.
- **It is verified that Cherenkov light emitted from 1.484MeV electron really have their topology, in other words, it is possible to reduce ^{208}Tl BG using averaged angle for small experimental size. Need check this in the lab level.**
- Demonstration of $\beta\gamma$ BG reduction using ^{60}Co source by HUNI-ZICOS will start in this autumn and the result will be reported at next JPS meeting.
- Next program to observe $2\nu\beta\beta$ decay will start in FY2024 after 2 years preparation. Stay tuned!

Backup slides

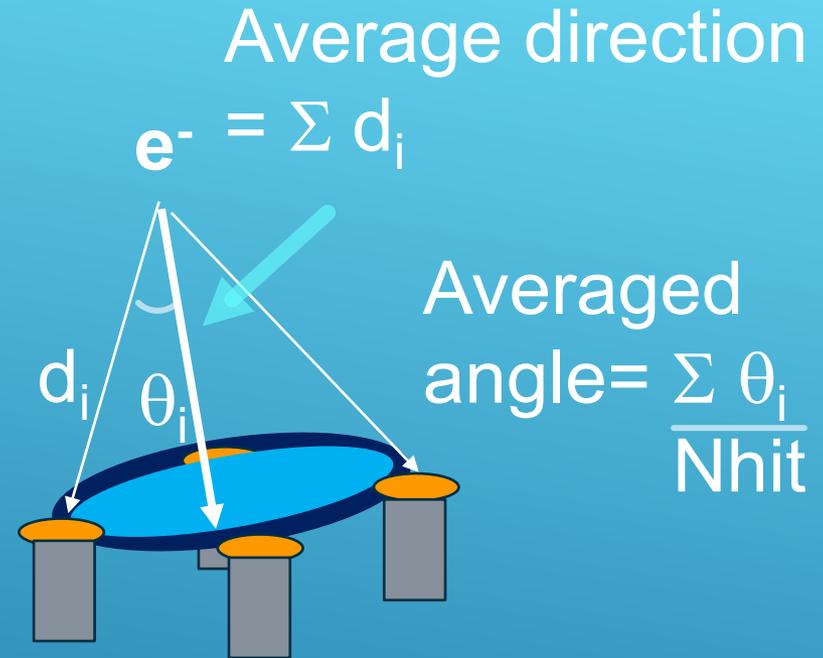
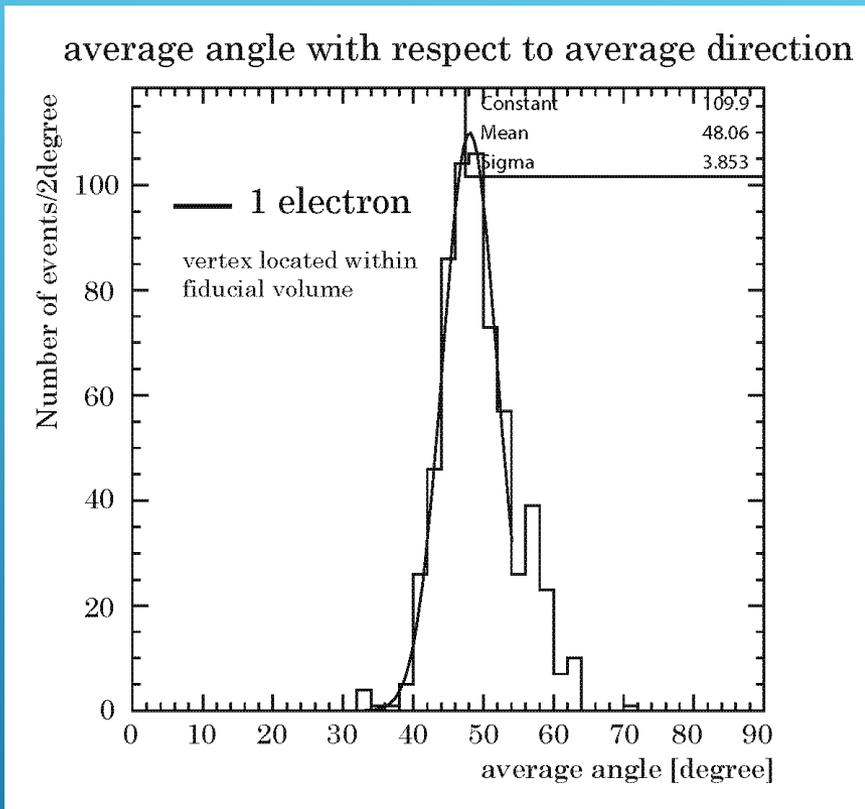
Ultra low background environment



SKのタンク内以上のレベル

環境中のU/Thから放射されるガンマ線に対し、CsI検出器を用いて5cm鉛シールド内外のスペクトルの差を観測した結果、図7の分布が得られた。2MeV付近のガンマ線の鉛に対する透過率は8%、CsI検出器の検出効率が60%程度であることから、2.615MeVの ^{208}Tl のガンマ線を基準に考えると、年間 2.2×10^6 個のガンマ線が表面積 150cm^2 のCsI検出器に入射している。検出器内のバルーンの表面積は 1075cm^2 となるので、年間当たり約 2.4×10^6 事象が検出されることになる。そこで、厚さが20cmの鉛遮蔽体内に検出器を設置すると、**年間30事象程度**まで低減できる。一方、CsI検出器で観測された ^{40}K 事象数から、同鉛遮蔽体内では**年間約20事象**が観測されることが予想される。

Topological info : averaged angle



Average angle with respect to averaged direction for single electron seems to have a peak at 48 degree which is almost same as Cherenkov angle.