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Identification of ^{90}Sr and ^{40}K Based on Cherenkov Radiation at Lower Background Suppressed Cosmic Rays

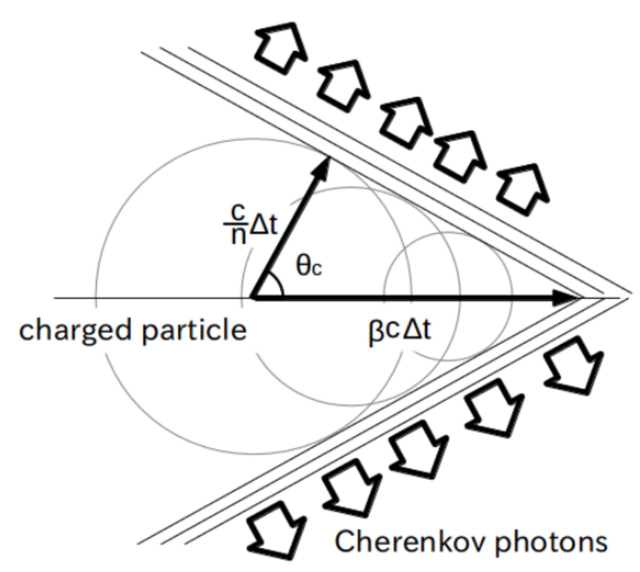
H. Ito, A. Kobayashi, H. Kawai, S. Kodama, T. Mizuno, M. Tabata
Graduate School of Science, Chiba University, 1-33, Yayoicho, Inage, Chiba, Japan

Introduction

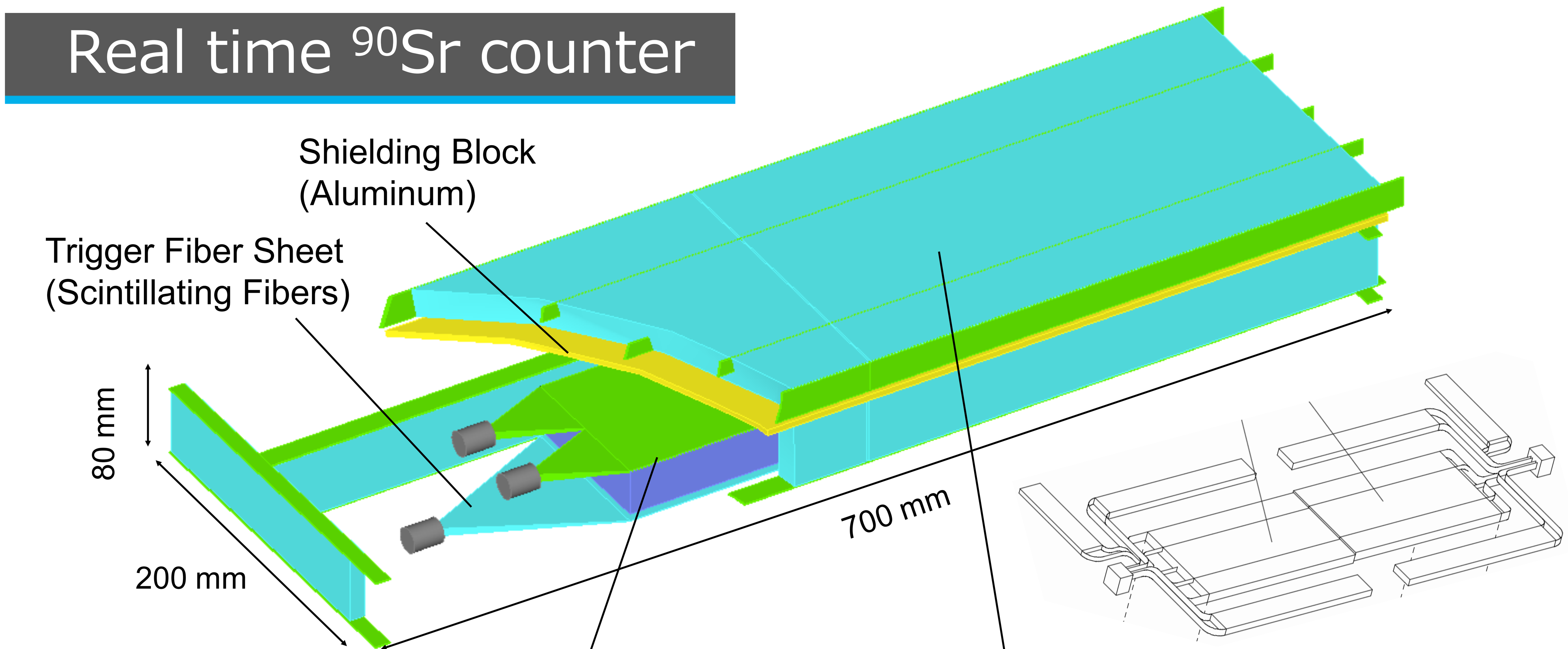
The Great East Japan earthquake caused the accident of Fukushima Daiichi Nuclear Power Plant in March, 2011, as a result, radionuclides spread around Japan and Pacific Ocean. In particularly, fisheries of Fukushima Prefecture were damaged seriously. Recently, the fisheries have not restarted yet. One of the reasons is ^{90}Sr because it is more dangerous by accumulating in the bone and difficult to measure concentration of contamination in fish or seafood.

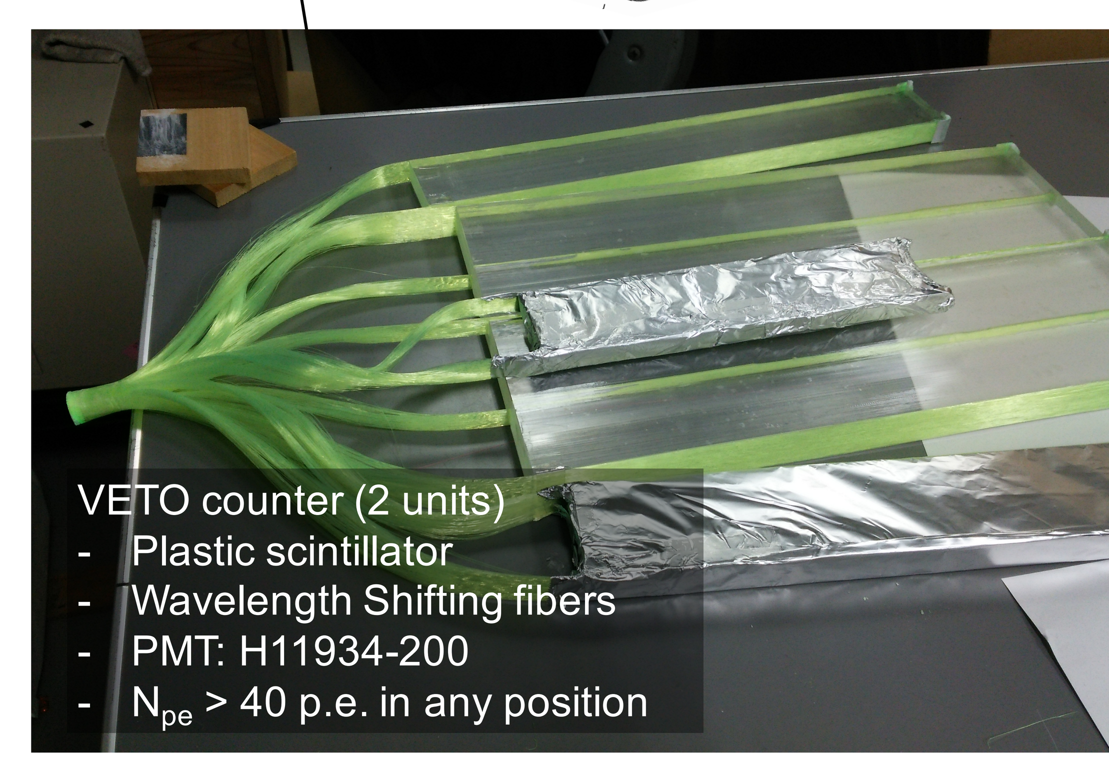
A new detector, real-time ^{90}Sr counter, was developed using threshold type aerogel Cherenkov counter. The detector can measure radioactivity of ^{90}Sr in real time, because beta rays from ^{90}Y are identified in environmental radiation such as ^{40}K.

When velocity of charged particles is higher than light velocity in a material with refractive index of n, as shock waves, photons are emitted. The phenomenon is Cherenkov radiation.

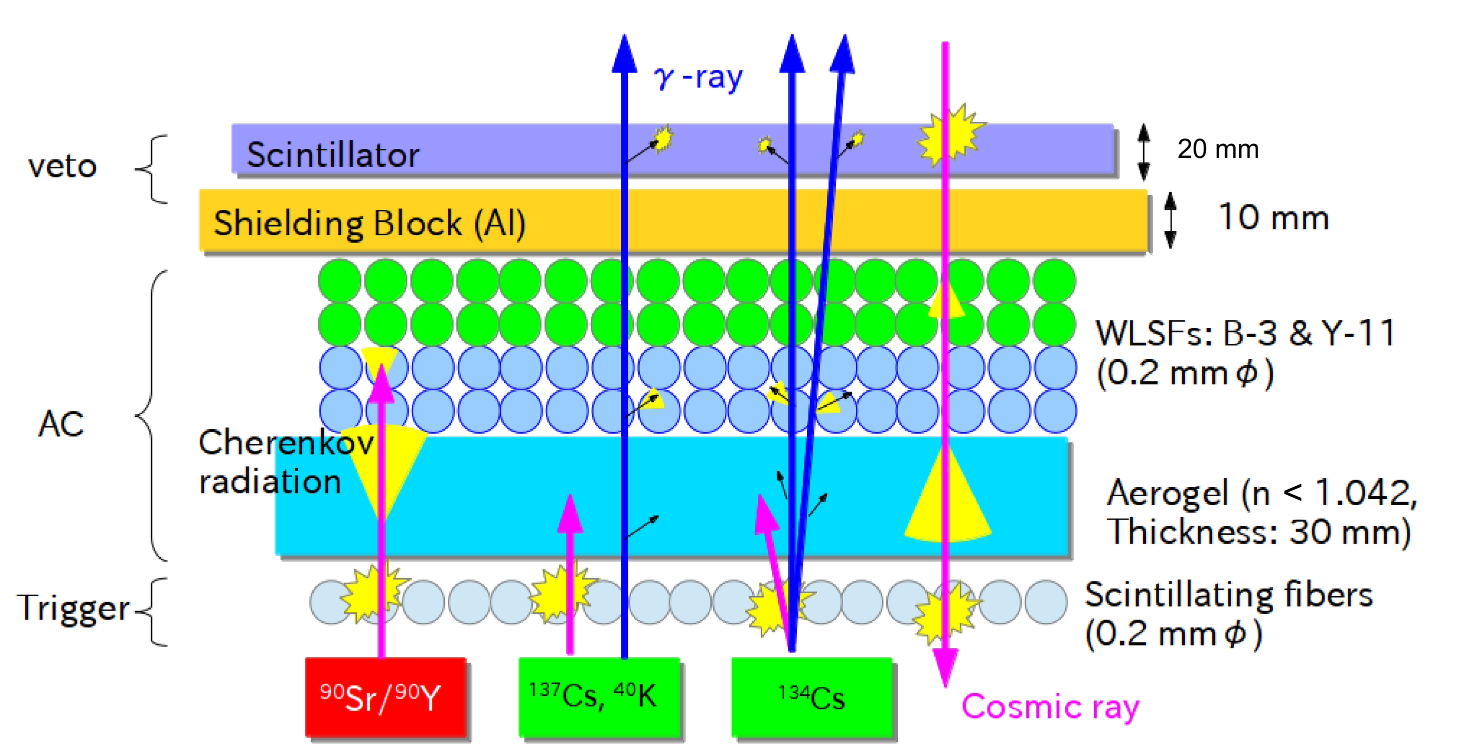


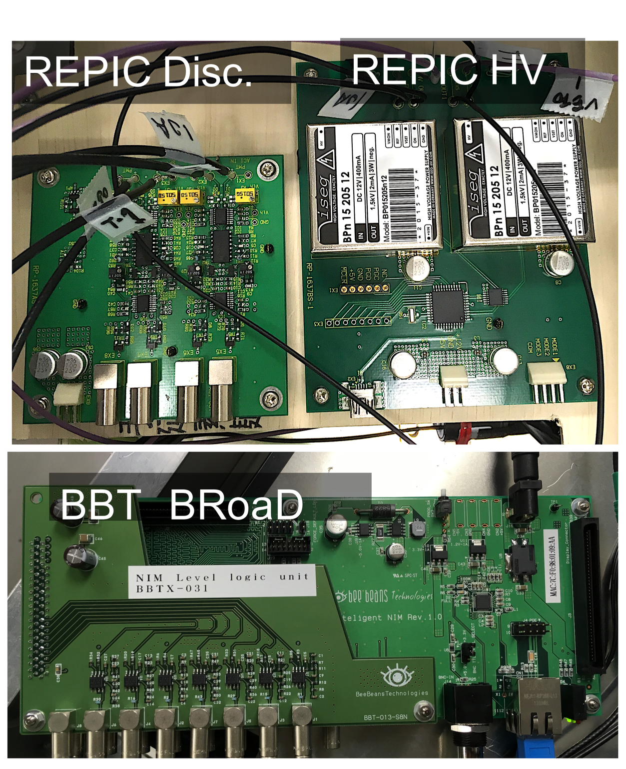
Real time ^{90}Sr counter

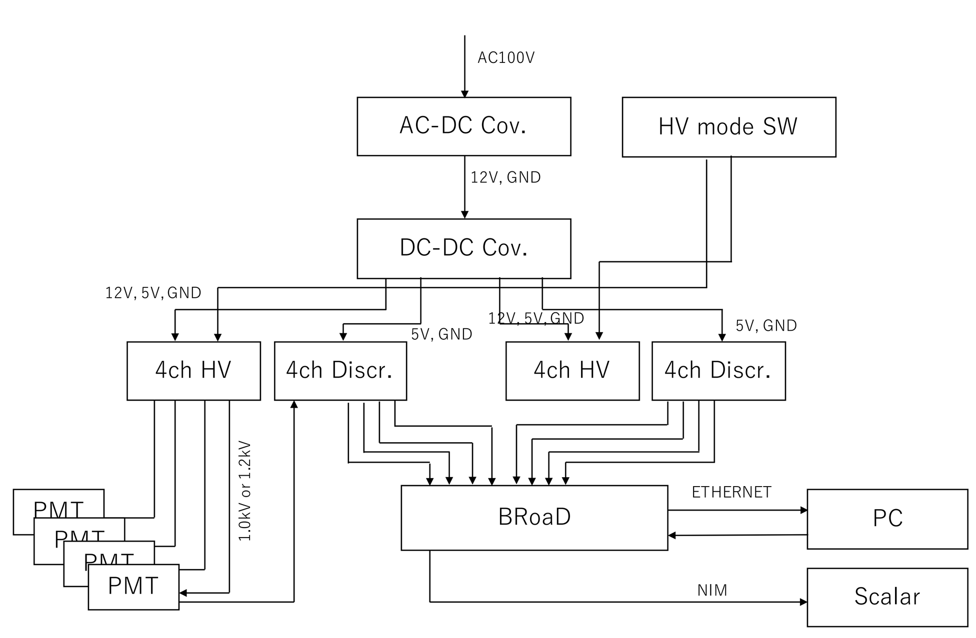


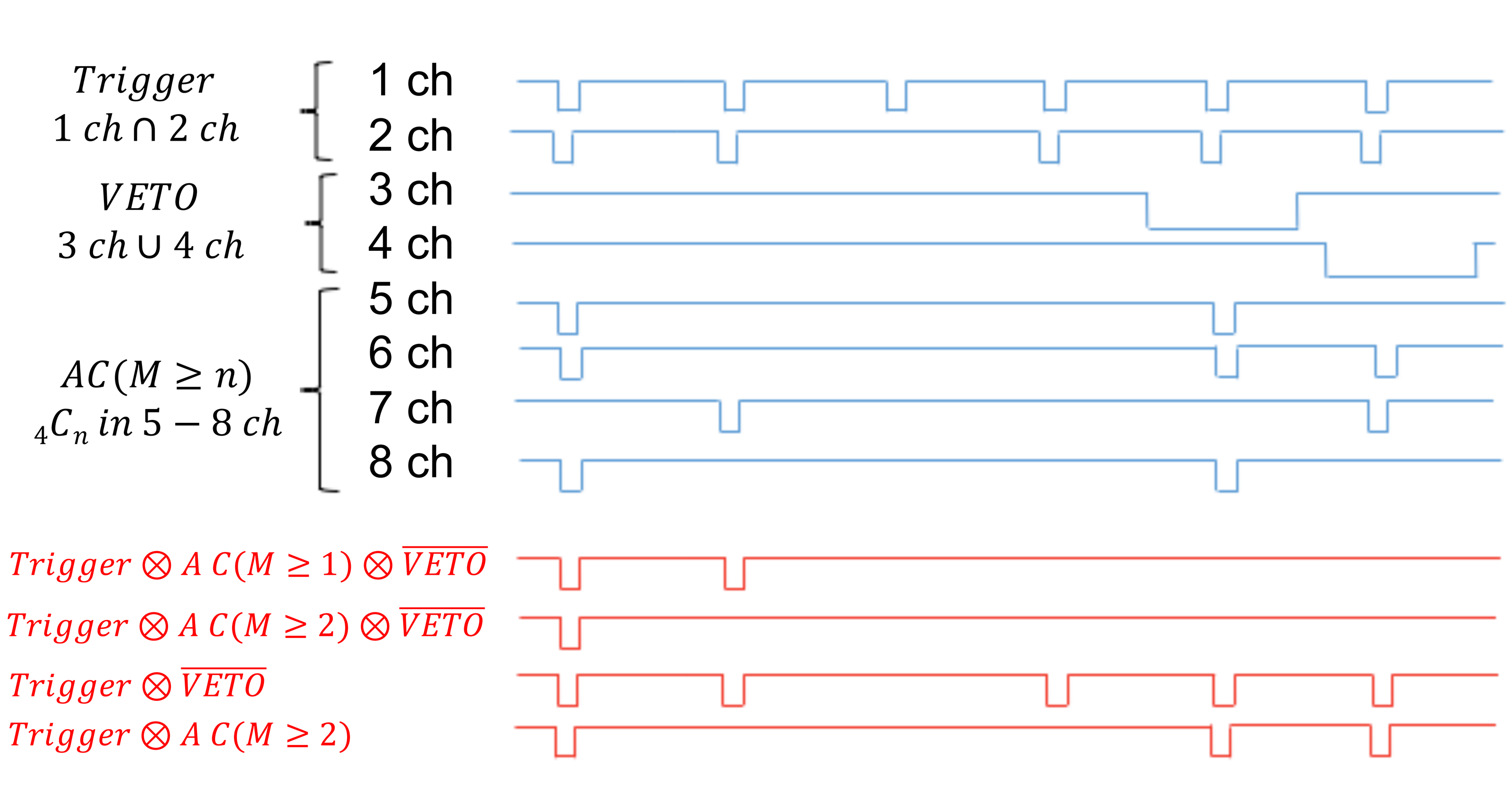


Detection Mechanism









Results

The efficiencies at the center of the detector

	$Trigger\otimes AC(M\geq 1)\otimes\overline{VETO}$	$Trigger\otimes AC(M\geq 2)\otimes\overline{VETO}$	$Trigger\otimes\overline{VETO}$	$Trigger\otimes AC(M\geq 2)$
N_{BG}/cph	454.14	132.57	24278.2	3030.79
η_{Sr}/ Bq^{-1}s^{-1}	5.06×10^{-3}	2.03×10^{-3}	2.58×10^{-1}	2.04×10^{-3}
η_{Cs}/ Bq^{-1}s^{-1}	2.81×10^{-5}	1.87×10^{-6}	6.86×10^{-2}	2.74×10^{-6}
η_{K}/ Bq^{-1}s^{-1}	8.36×10^{-5}	1.75×10^{-5}	1.36×10^{-1}	4.42×10^{-5}
η_{Sr}/η_{Cs}	180	1083	3.75	743.3
η_{Sr}/η_{K}	60.5	115.9	1.90	46.2
$A_{Sr}^{min}\binom{fish}{wet}$ / Bq kg^{-1}	117.3	157.6	17.8	748.5
$A_{Sr}^{min}\binom{fish}{dry}$ / Bq kg^{-1}	35.3	47.4	5.97	224.7
$A_{Sr}^{min}\binom{water}{dry}$ / Bq kg^{-1}	1.2	1.6	0.37	7.50

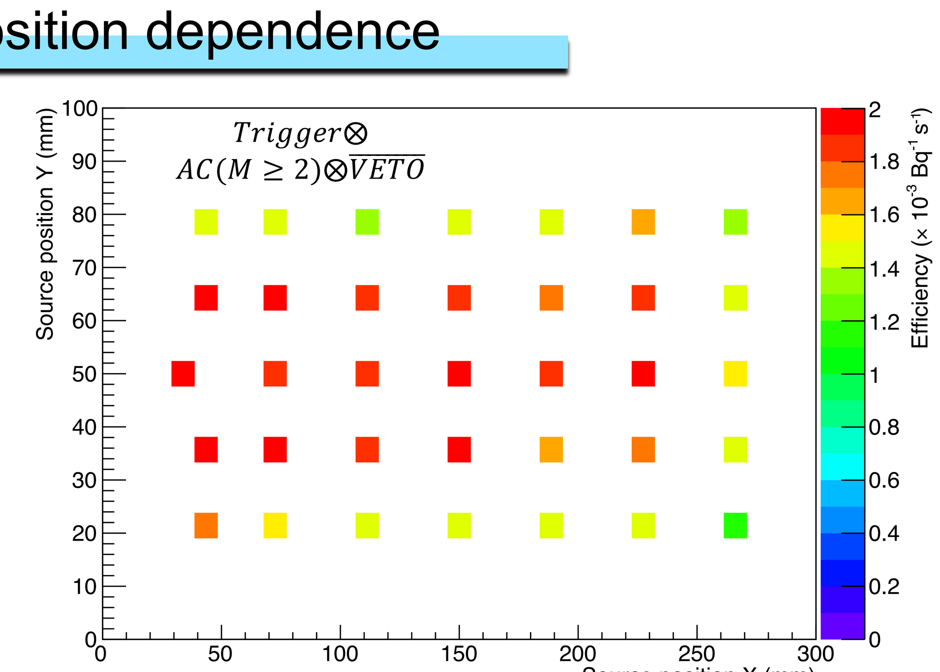
Logic signal	PMT channel number & logic signal
$Trigger$	$PMT1(Tr1)\cap PMT2(Tr2)$
$AC(M\geq n)$	$_4C_n$ in $PMT3(AC1), PMT4(AC2), PMT5(AC3), PMT6(AC4)$
$VETO$	$PMT7(VETO1)\cup PMT8(VETO2)$

Detection Limit (A_{Sr}^{min}) was defined

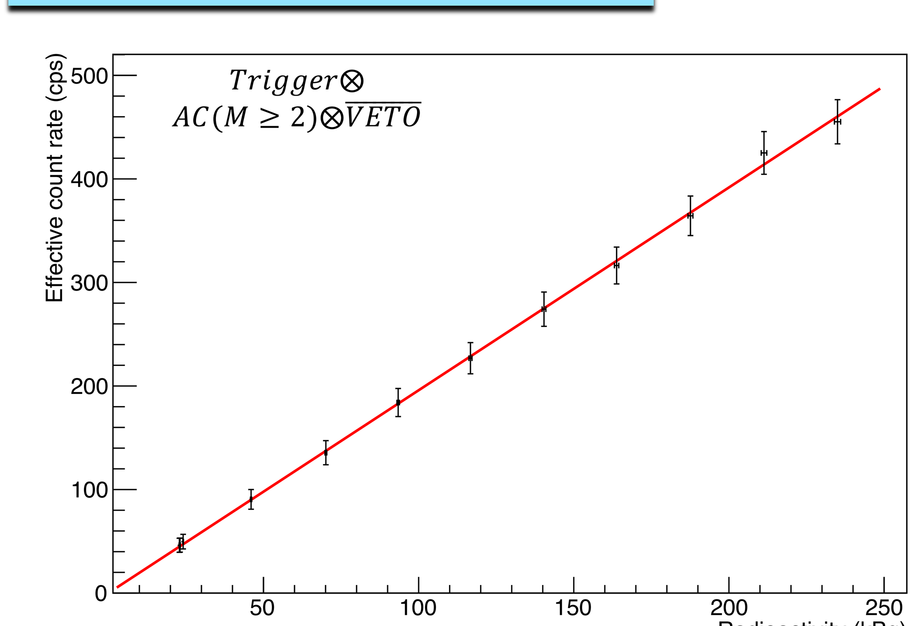
$$A_{Sr}^{min}=\frac{3\sqrt{N_{BG}+(\eta_{Cs}A'_{Cs}+\eta_{K}A'_{K})\,m\varepsilon^{-1}T}}{\eta_{Sr}\,m\varepsilon^{-1}T}$$

where η_x dnots an absolute efficiency of radionuclide (x=^{90}Sr, ^{137}Cs, ^{40}K), N_{BG} is background rate at empty, m is sample weight (30 g), ε is compression ratio (wetted fish: 1, dried fish: 0.3, dried seawater: 0.01), T is measurement time of 3600 seconds, A'_x is radioactivity of the radionuclide x.

Position dependence



Response linearity



Mean efficiencies

	$Trigger\otimes AC(M\geq 1)\otimes\overline{VETO}$	$Trigger\otimes AC(M\geq 2)\otimes\overline{VETO}$	$Trigger\otimes\overline{VETO}$	$Trigger\otimes AC(M\geq 2)$
η_{Sr}/ Bq^{-1}s^{-1}	4.28×10^{-3}	1.68×10^{-3}	0.25	1.69×10^{-3}
$A_{Sr}^{min}\binom{fish}{wet}$ / Bq kg^{-1}	138.6	190.6	18.3	905.0
$A_{Sr}^{min}\binom{fish}{dry}$ / Bq kg^{-1}	41.7	57.3	6.15	271.6
$A_{Sr}^{min}\binom{water}{dry}$ / Bq kg^{-1}	1.4	1.9	0.38	9.1

	$Trigger\otimes AC(M\geq 1)\otimes\overline{VETO}$	$Trigger\otimes AC(M\geq 2)\otimes\overline{VETO}$	$Trigger\otimes\overline{VETO}$	$Trigger\otimes AC(M\geq 2)$
η_{Sr}/ Bq^{-1}s^{-1}	$(4.87\pm0.06)\times10^{-3}$	$(1.96\pm0.04)\times10^{-3}$	0.257 ± 0.001	$(1.96\pm)\times10^{-3}$
χ^2/NDF	0.924/11	0.672/11	29.0/11	0.378/11

Conclusion

A new detector, real-time ^{90}Sr counter, was developed using threshold type aerogel Cherenkov counter. As the result of performance estimation, the efficiency ratio was evaluated as $\eta_{Sr}/\eta_{Cs}=1083$, $\eta_{Sr}/\eta_{K}=116$, source position dependence of the efficiencies as expected, and good response linearity. The detection efficiency was estimated as 1.9 Bq/kg (dried seawater) and 57.3 Bq/kg (dried fish).

Reference
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Acknowledgments
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