Development of Realtime ^{90}Sr Counter

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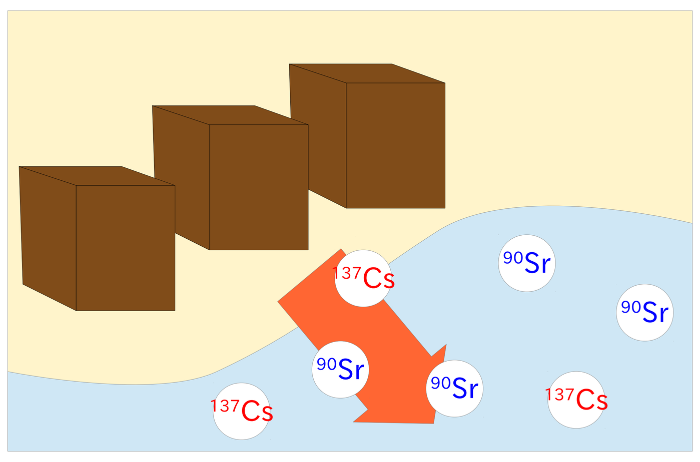
Introduction

Because of the March, 2011 disaster of Fukushima No.1 nuclear power plant, a large amount of radioactive substance(including ^{90}Sr and ^{137}Cs) was released into the Japanese coast of the Pacific Ocean.

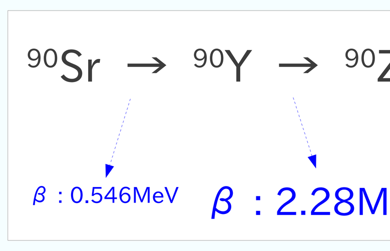


^{90}Sr can be 100 times more dangerous than ^{137}Cs because which can be concentrated in fishes and sea foods.
Since ^{90}Sr does not emit γ rays, it is very difficult to measure its radioactivity.

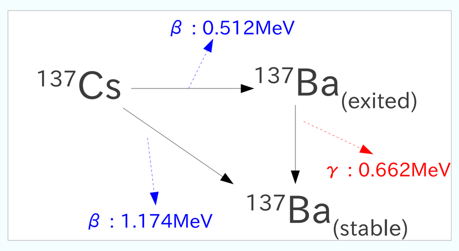
We propose a threshold-type Cherenkov counter using silica aerogel with a refractive index n˜1.04.

DANGER!!

^{90}Sr
・Remains in the bone
・Biological half-life : 10˜20 years



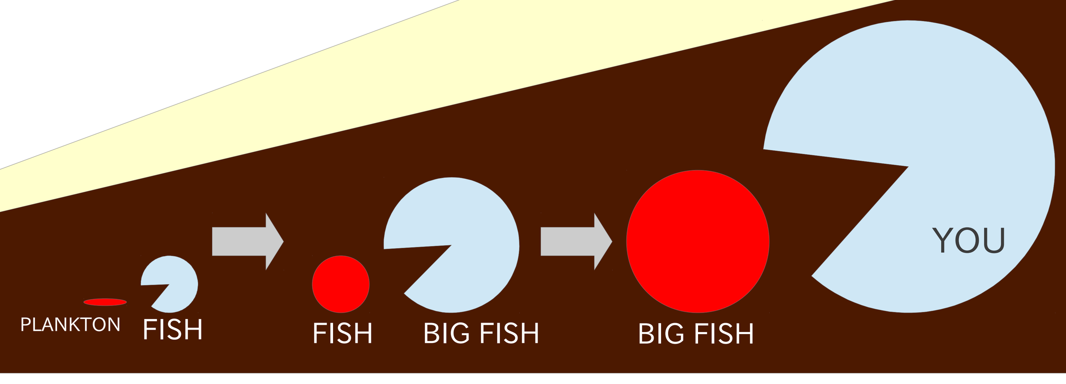
^{137}Cs
・Goes out from our body
・Biological half time : about 90days



others
^{134}Cs
^{131}I
^{60}Co
^{40}K

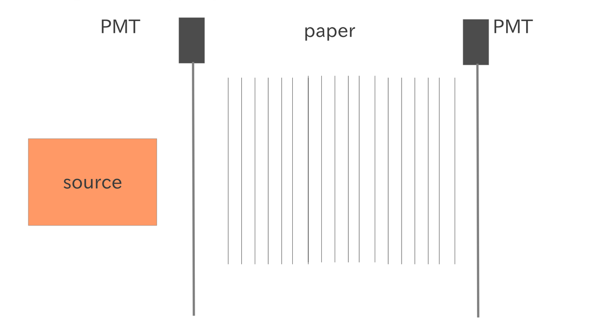
They are rarely exist in water or sea food.

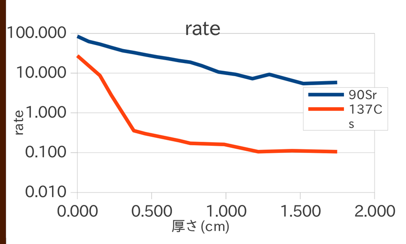
How to detect ^{90}Sr traditionally??
Standard beta-ray counters such as a rangecounter, calorimeter and spectrometer can not identify ^{90}Sr when the sample also includes ^{40}K, ^{60}Co, ^{131}I, ^{137}Cs and/or other radioisotopes. Therefore, the traditional way is separating ^{90}Sr chemically and determining radiation level directly. However the process is too slow to sell fresh seafood at fish market.
Is there an alternative method of detecting ^{90}Sr in an hour?



Possibility

Setting the paper between two PMT



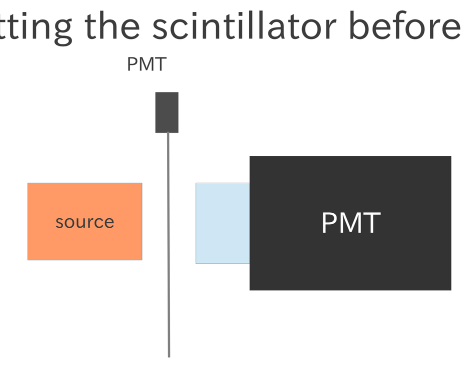


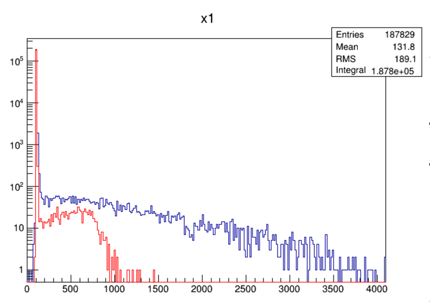
Taking two PMT's coinsidence.
Trigger due to β rays that penetrate paper.
But thicker and thicker,weak β rays can not penetrate.

problem

^{90}Sr's rate drops linearly, but, ^{137}Cs's rate does not change because of its γ beam. Paper can not stop γ beam. Thus, maximum ratio between ^{90}Sr and ^{137}Cs is obtained at about 0.5cm, but down gradually.

Setting the scintillator before PMT





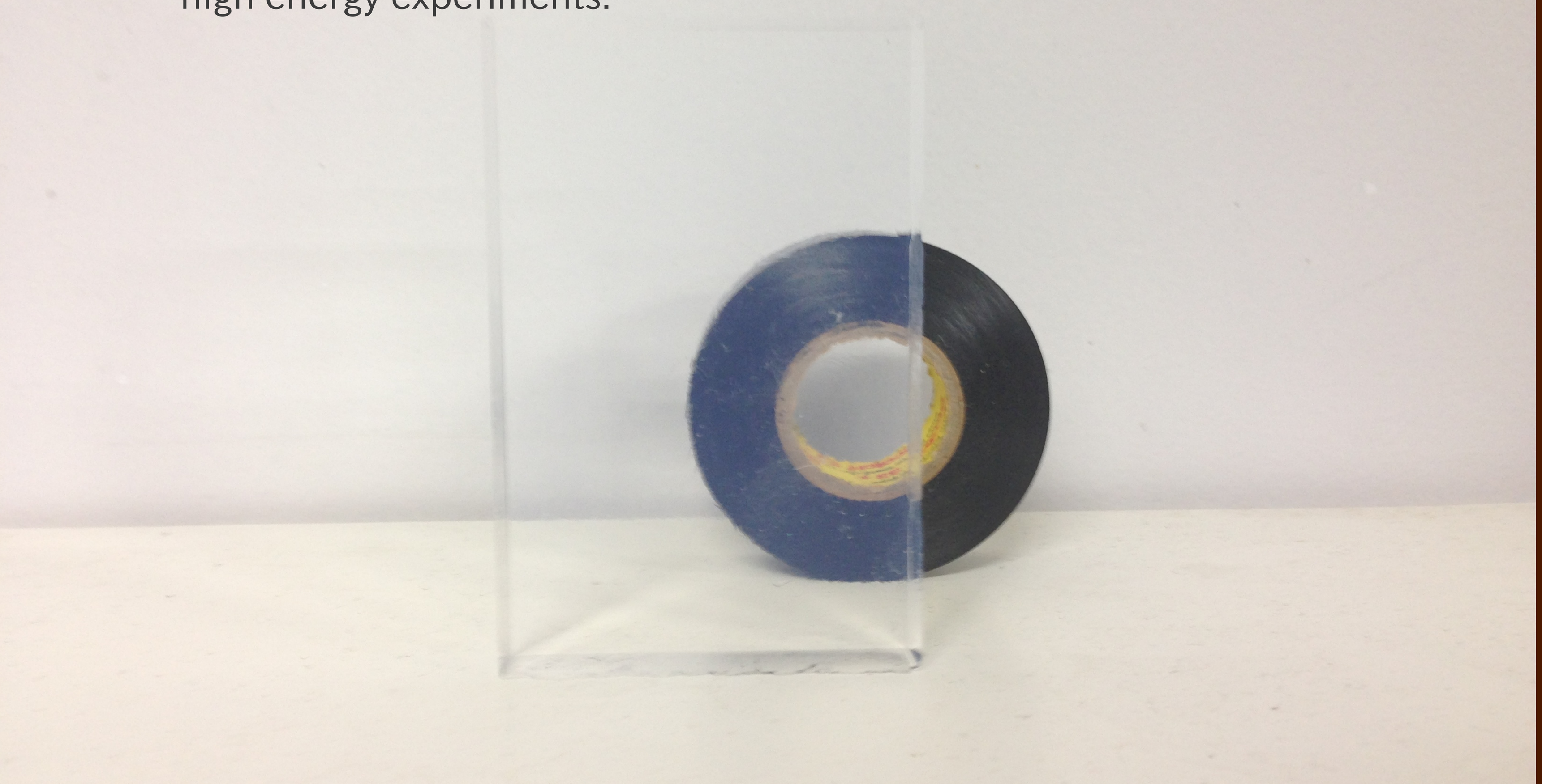
Reading intensity of scintillation light from β rays and decide threshold. Setting threshold over 1500ADCch, ^{137}Cs's light cannot been seen.

problem

If there is high radioactive concentration, we detect multiple ^{137}Cs in one time. Then it is difficult to distinguish ^{90}Sr and ^{137}Cs. On the other hand, if there is low level substance, big size source & scintillator (&money) will be necessary. But attenation length of scintillator is oder of 10cm, so concentrating light will not be optimal.

What is Silica Aerogel?

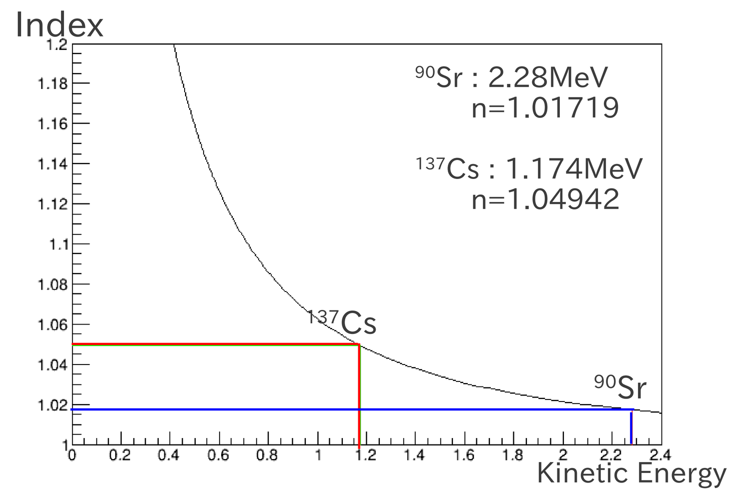
Glass with the air. It can be made very low density and arbitrary reflactive index(1.003˜1.3). Silica aerogel is widely used in many high energy experiments.



Detecter Under Development

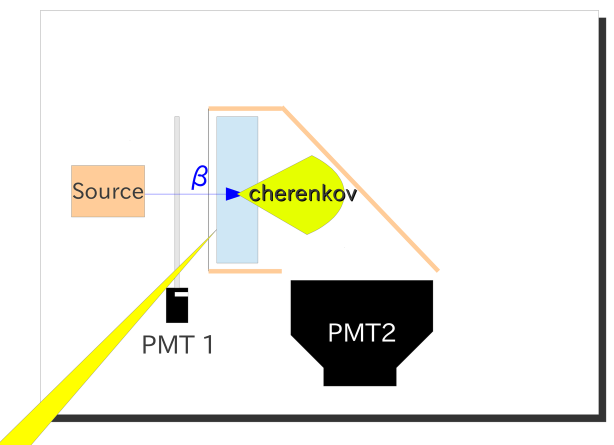
Principle & Test

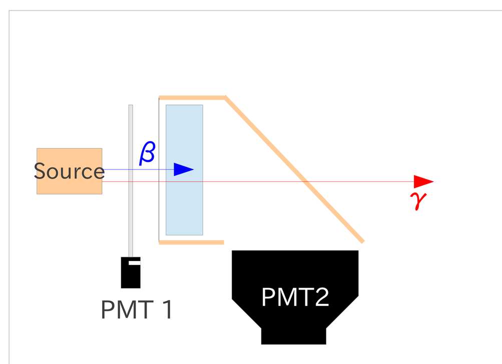
In the substance which index is n, if the velocity of charged particle exceed c/n, chelenkov light will emit. Using Silica Aerogel with refractive index n˜1.04, 2.28MeV β ray from ^{90}Sr emit cherenkov light, but 1.174MeV β ray from ^{137}Cs do not emit.

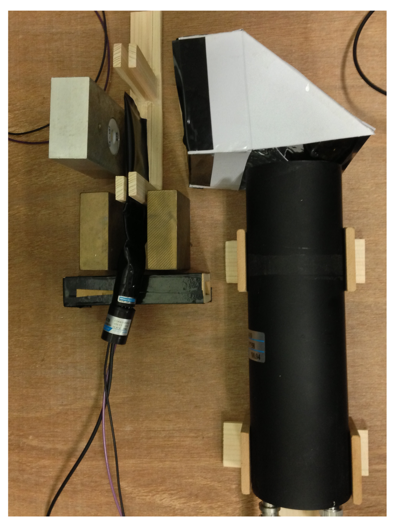


^{90}Sr → Cherenkov light!!

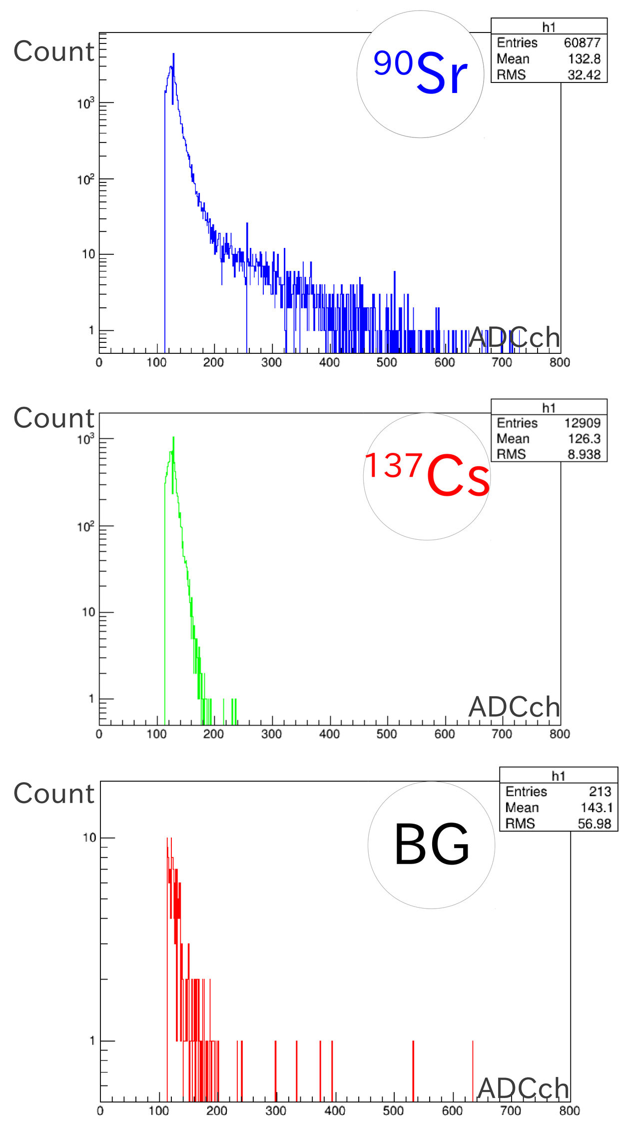
^{137}Cs → No event happen...

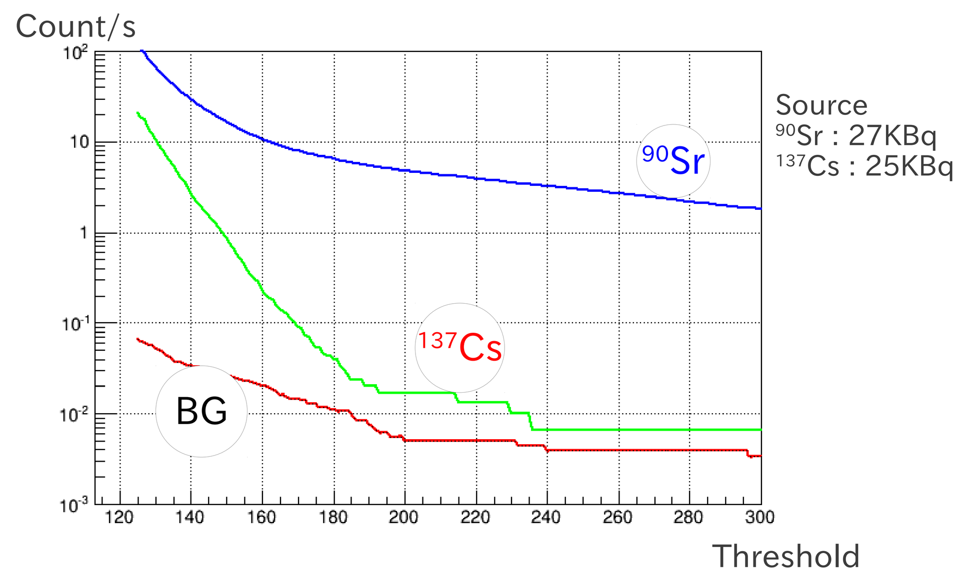






Conclusion





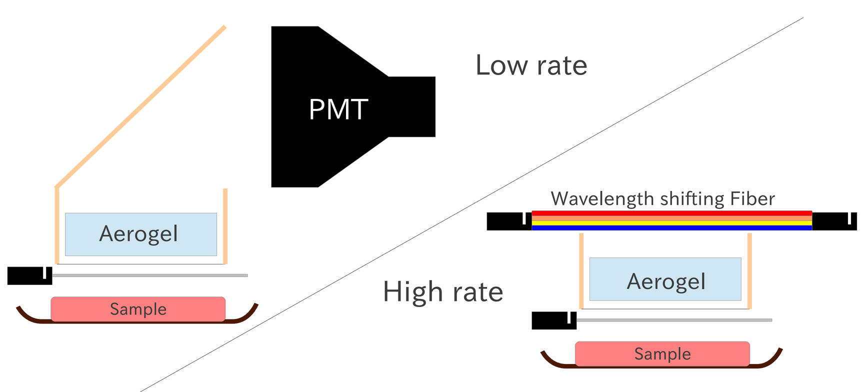
Required time to identify ^{90}Sr(lowest level)

If there is no ^{137}Cs,	There is 100Bq ^{137}Cs,
1minutes : 1.32Bq/cm^2	1minutes : 2.65Bq/cm^2
10minutes : 0.84Bq/cm^2	10minutes : 1.88Bq/cm^2
60minutes : 0.71Bq/cm^2	60minutes : 1.67Bq/cm^2

This result is the value that count of ^{90}Sr is over the background level.
Considering $3\sigma = 3*\sqrt{(CountOfBackground+CountOf^{137}Cs)}$.

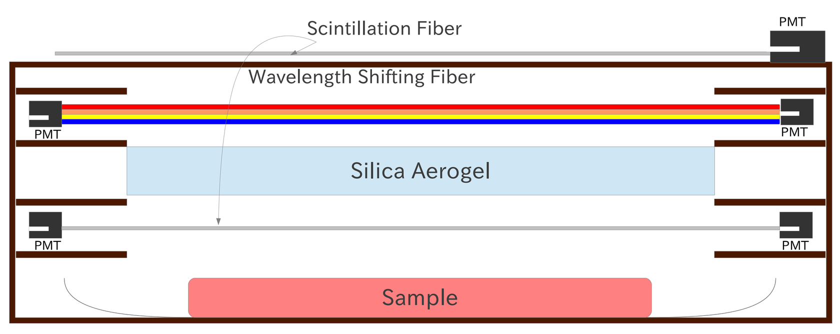
Plans for the future

Handy type



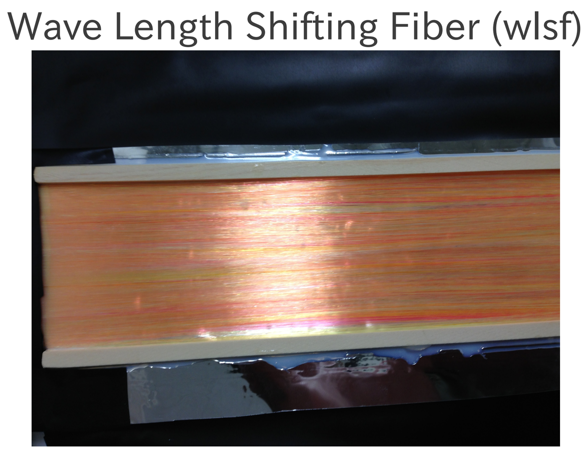
We will make a two handy type detecters as light as possible because it is necessary to use it at fish market, and investigate ^{90}Sr is inside the fish instantly. One type will be used at low radioactive rate. This detecter reads cherenkov light by PMT directly because of raising efficiency. Another type use wave length shifting fiber(wlsf), and will be used at high radioactive rate.

Large type



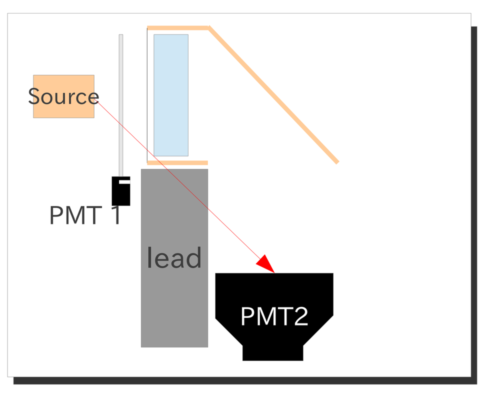
Putting big size sample to raise rate of β ray from ^{90}Sr. It needs big size of aerogel and PMT, but this is solved by using wlsf. Setting this fiber above the aerogel to absorve cherenkov light and transmit reemission light to PMT at both side. Because of using wlsf, intensity become 1/10, however, sample size is arbitrary changed. If we set sample size 1m*2m, required lowest count of ^{90}Sr will be 1/800.

Wave Length Shifting Fiber (wlsf)



Improvement

・Putting the lead plate on a course of γ ray from ^{137}Cs because of reduce cherenkov right at glass of the PMT. (Actually, it can not ignore that cherenkov from γ ray. We used PMT which shielded to stop the light, but it do not have an effect.)



・Narrowing width of discriminator and reducing the thermal noise.

・Setting scintillator for veto of muon.