Development of Realtime 90Sr Counter

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Abstruct - In March 2011, a large earthquake hit Japan and damaged siriously. Because of this disaster, accidents was happen at Fukushima No.1 nuclear power plant and many radioisotope has been released into the Japanese coast of the Pacific Ocean. We pay attention to 90Sr and propose the method to detect it in an hour.

I. INTRODUCTION

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

90Sr can be 100 times more dangerous than 137Cs because which can be concentrated in fishes and sea foods. 90Sr decays into 90Y with a beta ray whose energy is 0.54 MeV, and 90Y decays into 90Zr with 2.28 Mev beta ray. 90Sr remains in our bones, therefore, its biological half-life is 10~20 years. 90% of 137Cs decays into 137Ba of exited state with 0.512 MeV beta ray and transit to stable state with 0.662 MeV gamma ray, and 10% directly decays stable 137Ba with 1.174MeV beta ray. Since 90Sr does not emit γ rays, it is very difficult to measure its radioactivity. Typical beta-ray counter such as a range counter, calorimeter and spectrometer can not identify 90Sr when the sample also includes 40K, 60Co, 131I, 137Cs and/or other radioisotopes. The traditional method to detect beta rays is separating 90Sr chemically and determining radiation level directly. However, this process is too slow to sell fresh seafood at fish market. It is needed to detect 90Sr in an hour. We propose a threshold-type Cherenkov counter using silica aerogel with a refractive index n~1.04. Then, I introduce two possibility of detectimg 90Sr mechanism before introducing our detector using silica aerogel.

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II. POSSIBILITY

(i) Range Counter

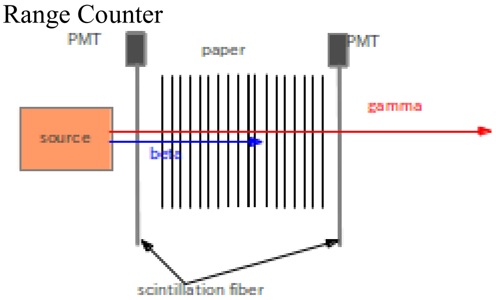

Fig. 1. Setting papers between two PMTs connected scintillation fibers. Trigger due to beta rays that penetrate two scintillation fibers.

When thickness of paper increase, we or a Compton scattering. Thus, maximum ratio between 90Sr and 137Cs is obtained at about 0.5cm, but the ratio can not be efficient and down graduatelly.

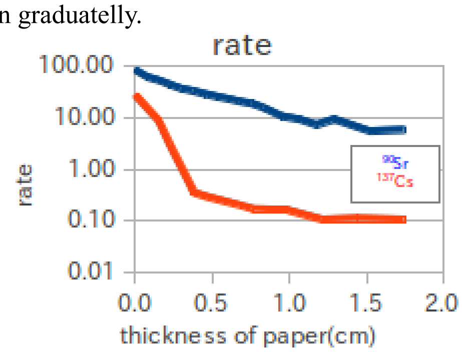

Fig. 2. Count rate of 90Sr and 137Cs. Paper stop beta rays but can not stop gamma rays.

(2) Using Scintillator

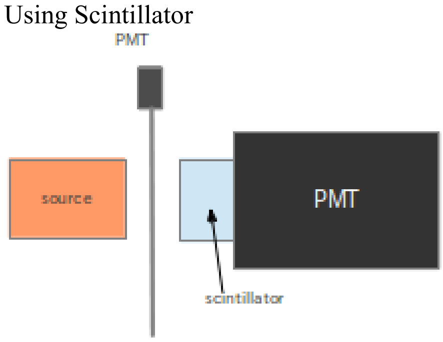

Fig. 3. Scintillator attach large size PMT directly.

Reading intensity of scintillation light from beta rays and dicide suitable threshold. Setting threshold at 1500ADCch, 137Cs's light can not be seen.

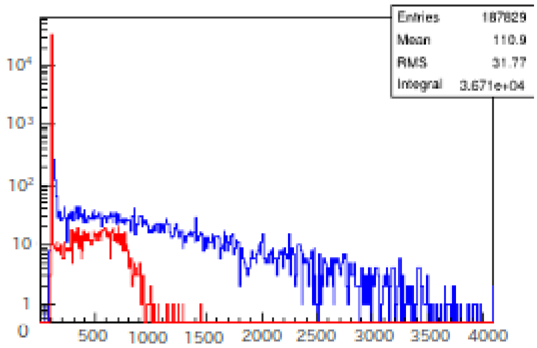

Fig. 4. The intensity of scintillation light caused beta rays from 137Cs is less than 90Sr. Over 1500ADCch, this light can not be seen.

This method also has a problem. If there is high radioactive concentration, we detect multiple 137Cs at one time and can not identify whether 90Sr is included. Then it is difficult to distinguish 90Sr and 137Cs. On the other hand, if there is low level substance, large size source & scintillator (&big money) will be necessary. But attenation length of scsintillator is order of 10cm, so concentrating light will be not optimal.

(i)Principle

Maximum energy of beta rays of 90Sr is 2.28Mev, beta rays of 137Cs is 1.17MeV. To use substance whose refractive index is between 1.017~1.049, Cherenkov light is emitted when fishies contain 90Sr.

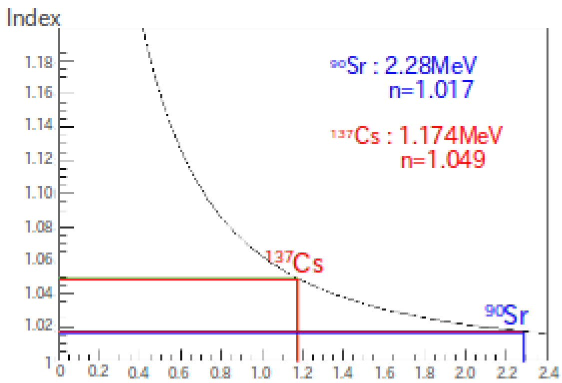

Fig. 5. Condition of Cherenkov light emission. For instance, 2.28MeV beta rays emitted by 90Sr cause cherenkov light at refractive index above 1.02.

We use silica aerogel whose refractive index is 1.042 for the experiment. Silica aerogel is an amorphous solid of quartz. It is made highly porous, and has very low density and tunable refractive index(1.003~1.25)[1]. Aerogel is widely used in many high energy experiments.

(ii) Experiment

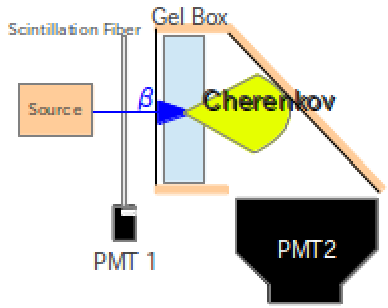

Fig. 6. Cherenkov light emitted in silica aerogel is reflected at wall of gel box and led to PMT.

We use 27 kBq 90Sr and 25 kBq 137Cs for source. PMT2 Reads cherenkov light which is led by the gel box from high energy beta rays. All beta rays from 137Cs do not emit cherenkov light because its maximum kinetic energy is 1.174MeV.

(iii) Result

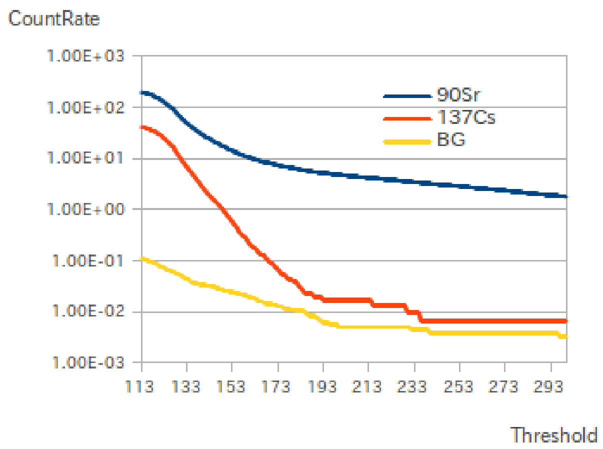

Fig. 7. Taking threshold of intensity of 90Sr, 137Cs and background. It is data that 90Sr is 27KBq and 137Cs is 25KBq.

In the actual situation like seafood market, since limit of 137Cs included in the food is 100Bq/kg, it is too strong to use 25KBq Cs. We considered there is 100Bq Cs for the result. Table1 shows the Required time if the sample has more than the value shown in the table1. This result is the value that count of 90Sr over the background level.

Table1. Required time to identify ^{90}Sr

Time	Radioactivity(no Cs)	Radioactivity(100Bq Cs)
1minute	1.32Bq/cm^2	2.65Bq/cm^2
10minutes	0.84Bq/cm^2	1.88Bq/cm^2
60minutes	0.71Bq/cm^2	1.67Bq/cm^2

(iv) Improvement

· Putting the lead plate on a course of gamma rays from 137Cs because of reduce cherenkov light at glass of the PMT.

· Narrowing width of the discriminator and lessen the thermal noise.

· Covering around body by alminium and setting scintillator above for veto the muon.

IV. PLANS FOR THE FUTURE

We propose two handy type detectors and one large type detector.

(i)Handy type

Handy type ditectors will be made as light as possible because it is necessary to use it at fish market, and investigate wether 90Sr is inside the fish instantly.

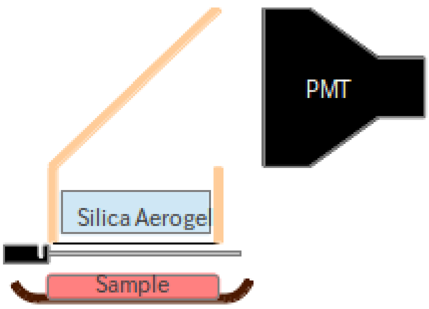

Fig. 8. Detector1-1 is used at low active rate.

Detector1-1 is used at low radioactive rate. Because of using large PMT, it can react if the sample have small amount of radiation.

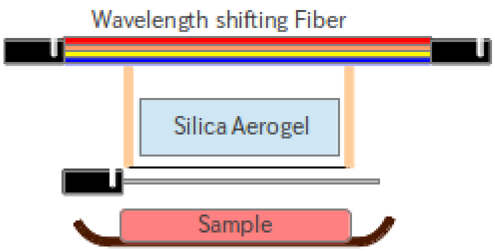

Fig. 9. Detector1-2 is used at high active rate.

Detector1-2 can be made without large size PMT by using wavelength shifting fiber(WLSF). Wavelength shifting fibers are the fiber that absorb the light and lead re-emission light at both ends of fibers. The diameter of each fiber is 0.2mm. We set the fibers side by side to make the shape of sheet. Putting this fiber sheet above silica aerogel to absorb cherenkov light from beta rays of 90Sr. Intensity become 1/10 because of using wlsf. However, small PMT can be used and less the miss count caused by gamma ray.

(ii)Large type

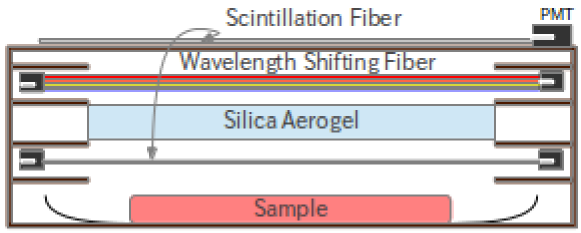

Fig. 10. Extending wlsf and setting the detector side by side, It can be made large endlessly.

Large type detector will be used for very high rate radioactive substance like conterminated water for the sample because this detector can use large size sample. Extending wlsf and setting the detector side by side, It can be made large endlessly. Therefore, large size aerogel will be needed, but we do not have to use large PMT due to wlsf.

REFERENCES

[1] M. Tabata , “Progress in the development of silica aerogel for use as cherenkov counter”, Grant-in-Aid for scientific research innovative areas, Mar. 2013.