Cherenkov detector based on aerogel radiator and flat panel PMT for detection of ^{90}Sr

Rok Pestotnik, Irena Dolenc, Samo Korpar, Peter Križan, Aleš Stanovnik

***Abstract*— New developments in production of silica aerogels and single photon detectors offer possibilities to improve a method for detection of ^{90}Sr in environmental samples. The method is based on detection of Cherenkov photons emitted by the ^{90}Y beta particles in an aerogel of suitable refractive index. Preliminary results are presented.**

***Index Terms*— Cherenkov detectors, silica aerogel radiators, multichannel photomultiplier tubes, Sr-90 radioactivity analysis**

I. INTRODUCTION

STRONTIUM ^{90}Sr is a very radiotoxic isotope because it accumulates in bone tissue, has a rather long half-life of 28.2 years and its daughter ^{90}Y emits β particles of 2.27 MeV end-point energy. It is a fission product, so it may pollute the environment either as a result of a nuclear power plant accident or of a nuclear weapon explosion, both of which have unfortunately happened in the previous century.

^{90}Sr and its daughter ^{90}Y are pure beta emitters so they cannot be detected by standard and accurate methods of gamma ray spectroscopy. Other beta emitters in the sample, with overlapping spectra, will lead to erroneous results in total beta counting or would complicate matters in the usual β spectroscopy. Cherenkov radiation offers the possibility of a well defined β-energy cutoff by choosing an appropriate refractive index of the Cherenkov radiator. In addition, it has been demonstrated [1], [2] that the counting efficiency rises steeply above threshold. Not very many isotopes have β end-point energies above 2 MeV, so ^{90}Y, the daughter of ^{90}Sr, with E_γ^{max} = 2.27 MeV, seems well suited for detection through Cherenkov radiation.

Recent progress in production techniques has led to improved properties of aerogels [3], [4], most important of which is greater transparency for Cherenkov photons in the wavelength region of highest photomultiplier sensitivity. On the other hand, Hamamatsu has developed 64 channel, flat panel detectors of single photons with photosensitive area of 49×49 mm^2 [5], which allow counting of the number of Cherenkov photons for each incident β particle. In the present paper we report on preliminary results obtained with such an improved detector.

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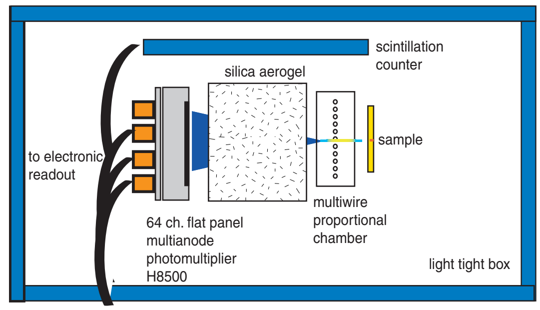

Fig. 1. Experimental setup

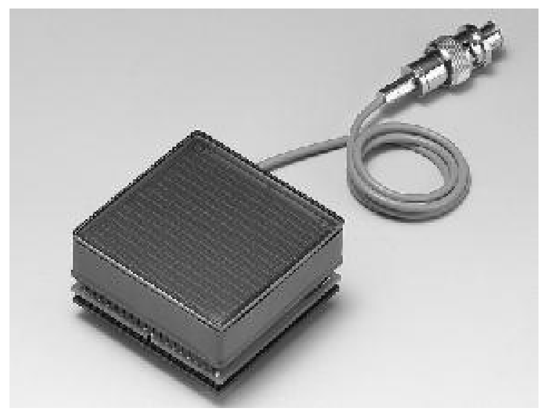

Fig. 2. The Hamamatsu 64-channel flat panel PMT (H8500).

II. THE APPARATUS

The apparatus (Fig.1) is enclosed in a light tight box. It consists of the sample or source of β particles, a thin (8 mg/cm^2) 2×2 cm^2 multi-wire proportional chamber (MWPC), a stack of two 5×5 cm^2 and 2.5 cm thick aerogel radiators with refractive index n= 1.047 [6] and a 49×49 cm^2 Hamamatsu H8500 flat panel, 64 channel photomultiplier [5](Fig.2). An additional scintillation counter provides veto pulses for background-contributing cosmic particles coming from above. The MWPC, with its high efficiency for charged particles ($\sim$ 99%) and low efficiency for gamma rays ($\sim$ 0.1%) signals an incoming β particle, distinguishing it from events where a gamma photon from the source generates an energetic electron in the aerogel Cherenkov radiator or in the PMT glass window.

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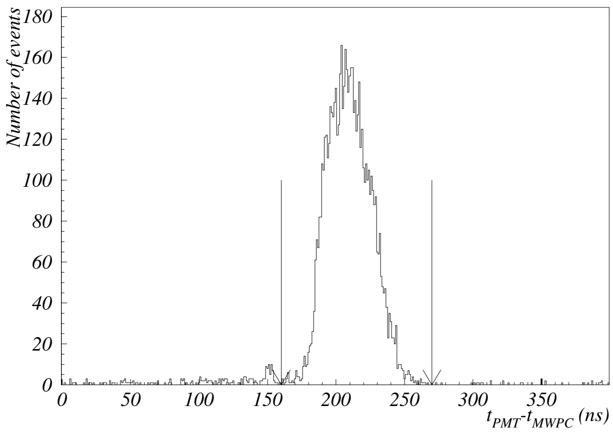

Fig. 3. Time difference between the PMT and MWPC signal. The 100 ns window for photons generated by beta particles is indicated.

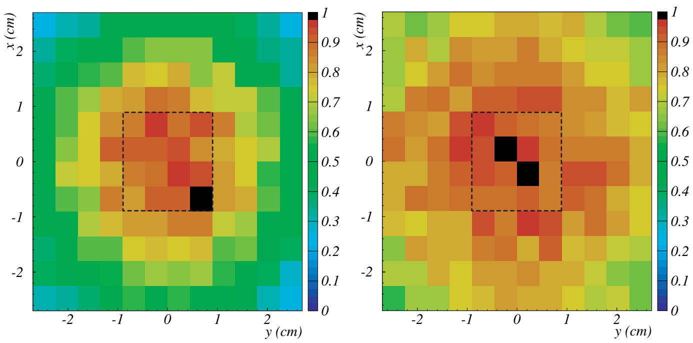

Fig. 4. Distribution of Cherenkov photons on the aerogel exit side without (left) and with (right) the aluminized mylar reflector. The position of one R5900-M16 PMT is indicated by the dashed line.

The electron kinetic energy threshold in the aerogel radiator (n= 1.047) is 1.21 MeV.

A coincidence-anticoincidence circuit triggers a time-to-digital converter for each channel in which the Cherenkov photons appear as peaks in the PMT-MWPC time difference (Fig.3). Appropriate time windows permit counting of the number of photons in each event as well as an estimate of the background count rate.

III. Analysis and Results

Simulation calculations have been performed in order to investigate the effect of an aluminized mylar reflector surrounding the aerogel radiator on all sides except the one at the PMT entrance window. The distribution of the number of Cherenkov photons on the photon exit side of the aerogel is shown in Fig.4 for the case without and with the reflector. Previous measurements performed with one 16 channel Hamamatsu R5900-M16 PMT with photosensitive area of 18×18 mm^2 [7] may obviously be improved by covering a larger surface. A step in this direction was made by using four R5900-M16 PMTs and

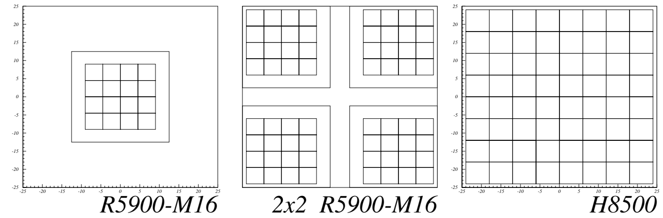

Fig. 5. Three different configurations of Cherenkov photon detectors.

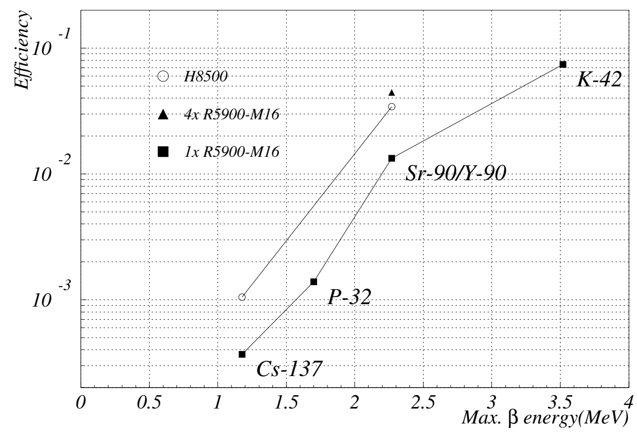

Fig. 6. Efficiency defined as count rate divided by appropriate activity as a function of beta spectrum end-point energy for the three configurations of Fig.5.

a factor of about 3 increase in efficiency was obtained. In order to cover also the gaps between the photocathodes of these four PMTs (Fig.5), they were substituted with a Hamamatsu H8500 64 channel, a flat panel PMT with the active area of 49×49 mm^2. The result however, was not the expected increase in efficiency (Fig.6), possibly due to a lower collection efficiency of the H8500 dynode system. This question will be further investigated.

The efficiencies obtained with the three configurations of Fig.5, are given in Fig.6. Although the ^{137}Cs β end point energy is below the Cherenkov threshold, some counts have been registered also for this isotope. That they are due to photons coming from the aerogel, has been verified by covering the aerogel photon exit window with black paper which resulted in a considerable reduction of the count rate. A possible explanation could be scintillations in the aerogel generated by the β particles.

Monte Carlo simulation and measurement also do not quite agree in the distribution of the number of events versus the number of detected photons produced by a single β particle. From Fig.7, it is seen that simulation does not reproduce events with large numbers of detected photons. This and other open questions are the subject of further studies, which will hopefully produce answers required for an efficient detector of low level ^{90}Sr activity as required for environmental samples.

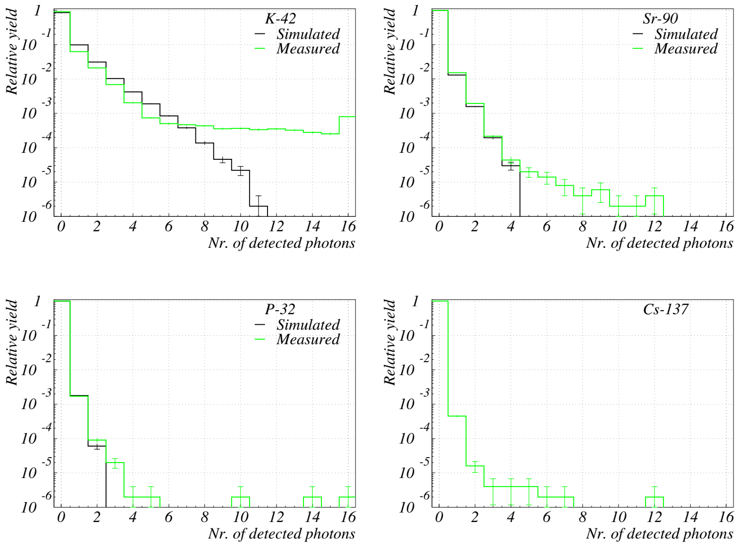

Fig. 7. Simulated and measured distribution of the number of hit channels per triggered particle: ^{42}K (top left), ^{90}Sr/^{90}Y (top right), ^{32}P (bottom left) and ^{137}Cs (bottom right).

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