Measurement of ^{90}Sr activity with Cherenkov radiation in silica aerogel

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April, 2003

Contents

Abstract:

The high radiotoxity of fission product ^{90}Sr requires quick and accurate measurements of its activity in environmental samples in order to block the inflow of ^{90}Sr in human food. Standard methods for measuring low ^{90}Sr activity include radiochemical methods, which can be time consuming and burdened with large errors. In this seminar I present an alternative method which is based on measuring the Cherenkov radiation emitted by β–particles in a silica aerogel as radiator. If the aerogel refractive index is suitably chosen, then the relatively high endpoint energy of the daughter nucleus' ^{90}Y spectrum permits elimination or at least considerable reduction of other β–emitters with lower endpoint energies. The interference of γ emitters can be reduced by using multiwire proportional chamber in coincidence with Cherenkov detector.

1 Introduction

The isotope ^{90}Sr is usually considered as one of the most hazardous fission products due to the fact that it is similar to calcium in its chemical behavior including its deposition in human or animal bone. Once ^{90}Sr enters the body, part of it is excreted and the remainder is deposited in newly formed bone along with calcium. ^{90}Sr deposited in bone excretes from the body very slowly and radiation it emits has a high ionizing capability. Thus its biological half–life is also long, about 22 years. That is the time it takes the human body to excrete half of the deposited ^{90}Sr.

The isotope ^{90}Sr is not a naturally occurring substance. It is a fission product and its presence in the environment is a result of human activities, such as prior testing of nuclear bombs in the air and leaks from radioactive storage and waste sites. It decays to ^{90}Y with half–life $\tau_{Sr} = 28.5$ years by emission of β^- particle:

$$^{90}Sr \longrightarrow {}^{90}Y + e^- + \overline{\nu},$$

A basic characteristic of the β–decay process is the continuous energy spectrum of the emitted β particle. This is because the available energy for the decay is shared between the β particle and antineutrino which usually goes undetected. If the small recoil energy of the daughter nucleus is ignored, the maximum energy of this spectrum should correspond to the available energy for the decay. For most β sources, this maximum value ranges from a few tens of keV to few MeV. In case of ^{90}Sr decay the endpoint kinetic energy in the β spectrum is equal $T_{max} = 0.546$ MeV.

In many β sources, the daughter nucleus is left in an excited state. The daughter nucleus in such an excited state, either falls directly to the ground state or descends in steps to lower energy states by emitting γ photons.

Most β sources are β–γ emitters. Pure β emitters exist but the list is very short [1]. ^{90}Sr is an example of pure β emitter but its daughter nucleus ^{90}Y is also unstable and in turn decays with half–life $\tau_Y = 64$ hours to ^{90}Zr which is stable:

$$^{90}Y \longrightarrow {}^{90}Zr + e^- + \overline{\nu},$$

^{90}Y is also pure β emitter and radiates β–particles with relatively higher energy ($T_{max} = 2.27$ MeV) than its parent nucleus. The decay scheme of ^{90}Sr/^{90}Y and electron energy spectrum are shown in Fig.1 and Fig.2.

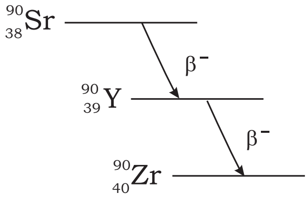

Fig. 1: *Double decay scheme of* ^{90}Sr.

In environmental samples ^{90}Sr and ^{90}Y are usually in radioactive equilibrium. Thus activity of ^{90}Sr is equal to activity of ^{90}Y. Application of the radioactive decay law to ^{90}Sr/^{90}Y decay gives the equation

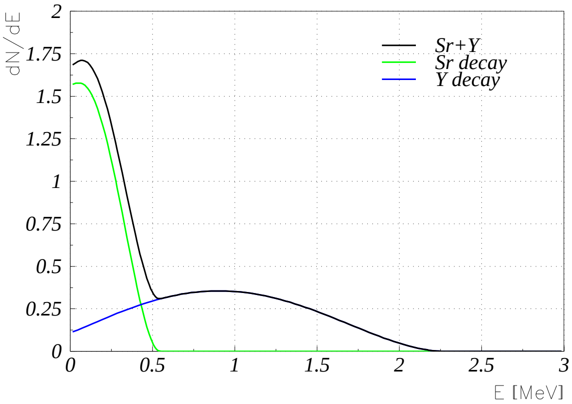

Fig. 2: *Normalized electron energy spectrum from* β *decay of* ^{90}Sr *(green line),* ^{90}Y *(blue line) and* ^{90}Sr+^{90}Y *(black line). E denotes the electron kinetic energy.*

$$\begin{aligned} \frac{\mathrm{d}N_{Sr}}{\mathrm{d}t} &= -\ln 2\frac{N_{Sr}}{\tau_{Sr}} \\ \frac{\mathrm{d}N_{Y}}{\mathrm{d}t} &= \ln 2\frac{N_{Sr}}{\tau_{Sr}} - \ln 2\frac{N_{Y}}{\tau_{Y}} \\ \frac{\mathrm{d}N_{Zr}}{\mathrm{d}t} &= \ln 2\frac{N_{Y}}{\tau_{Y}} \end{aligned} \tag{1}$$

where $\mathrm{N}_{Sr}(\mathrm{t})$ denotes the number of ^{90}Sr, $\mathrm{N}_{Y}(\mathrm{t})$ the number of ^{90}Y and N_{Zr} the number of ^{90}Zr nuclei at time t; τ_{Sr}, τ_{Y} and τ_{Zr} are the corresponding half–lives. Solution of (1) for initial conditions $N_Y(0) = N_{Zr}(0) = 0$ is shown on Fig.3 and the ratio of ^{90}Sr to ^{90}Y activity is shown on Fig. 4. Since ^{90}Sr half–life is very long compared to ^{90}Y the ratio after some time levels off to $\simeq$1. From graph it may be noted that the growth of ^{90}Y reaches the activity of ^{90}Sr after approximately 20 days.

Environmental concentrations of ^{90}Sr are very low, but it can enter the food chain. Since ^{90}Sr is highly radiotoxic, it is necessary to control its concentration in environment, especially in the food chain. In order to block the inflow of ^{90}Sr in human body a food quality assessment is needed. Standard procedures for measuring the activity of ^{90}Sr in the environmental samples include radiochemical methods which can be time consuming and burdened with large errors. This standard methods are described in section 2. However measurements of Cherenkov radiation produced by β–particles from ^{90}Y decay in silica aerogel as radiator offer a purely instrumental method for measurements of ^{90}Sr activity. It is the goal of this seminar to represent this method (section 3). There is an interesting method for determination of ^{90}Sr in situ, which is also a purely instrumental method. It is based on measuring bremsstrahlung radiation generated by deceleration of ^{90}Sr/^{90}Y beta particles in casing of germanium detector in a well. But usually methods that are based on chemical separation are used for determination of ^{90}Sr, so I will not go any further about this method. The detailes are described in [2].

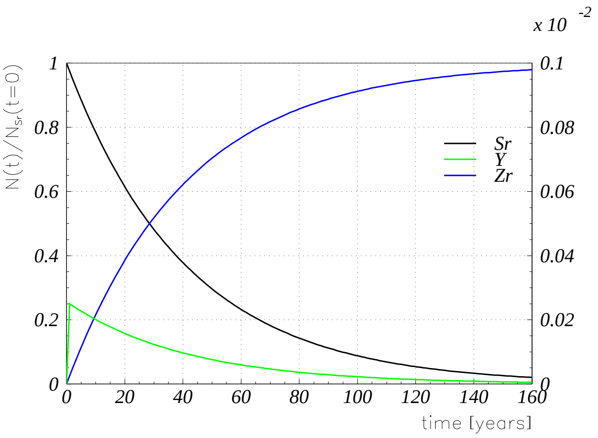

Fig. 3: *Number of nuclei relative to initial number of* ^{90}*Sr nuclei. Scale on the right side corresponds to* ^{90}*Y.*

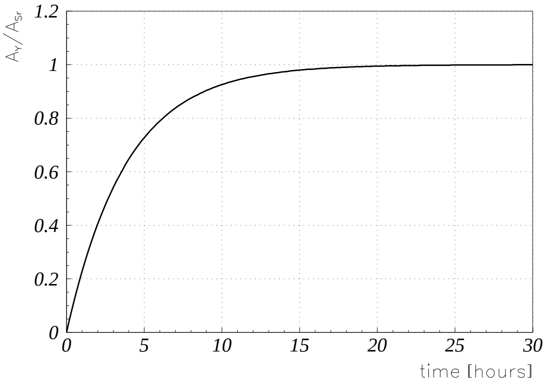

Fig. 4: *Ratio of* ^{90}*Y to* ^{90}*Sr activity.*

2 Standard methods

2.1 Measuring total activity of the sample

Because ^{90}Sr and its daughter ^{90}Y are both pure β emitters they could not be identified by usual and accurate methods of γ spectroscopy. In order to exclude other radioactive sources from the sample, isolation of ^{90}Sr by chemical separation is most often used. The exact separation scheme depends on the sample. Chemical efficiency of this method is determined by adding known amount of stable strontium ^{84}Sr to initial sample. By weighing the final product the fraction of strontium that came through procedure can be determined. This fraction represents the efficiency of the separation method.

The measurement of ^{90}Sr can be further complicated since ^{89}Sr ($\tau_{1/2}$=50.5 days, T_{max}=1.49 MeV) which is also pure β emitter can be present in the environmental samples and could interfere with the ^{90}Sr measurements. Thus, after chemical separation of strontium, the activity of radioactive strontium will include both contributions, ^{90}Sr and ^{89}Sr, in the sample. This is due to the fact that isotopes have the same chemical properties. In the case of ^{89}Sr presence in the sample, the isolated radiostrontium is allowed to remain in the sample without further treatment for a period of 10–14 days to allow sufficient ingrowth of ^{90}Y. After that period, the chemically separated ^{90}Y component is used to quantify the ^{90}Sr activity in the sample. This is determined from activity of ^{90}Y by calculating the ^{90}Y decay from the time of separation of yttrium from strontium (see Fig.4). Systematic errors which accompanion chemical separation and possible contamination with other radioactive sources limit accuracy of this methods.

The activity of isolated ^{90}Y can be measured using one of the gas ionization detectors (for example Geiger–Müller counter, proportional counter) or liquid scintillation counter.

- Gas ionizing detectors operate by utilizing the ionization produced by radiation as it passes through the gas. Typically, such counters consist of a gas volume in an enclosure that is either sealed or constructed in such a way as to permit a continuous flow of the filling gas. Within that gas volume electric field is applied across the electrodes. The outer wall frequently serves as cathode, while a wire rod, grid or a plate in the middle of gas volume serves as the anode. Ionizing radiation, passing through the space between electrodes, dissipates part or all of its energy by generating electron–ion pairs. If the electric field is applied, the electrons will be accelerated towards the anode and the ions towards the cathodes where they are collected. By the detection of this electric charge using a suitable electric circuit, an indication of the presence of ionizing radiation is given. There are three kinds of gas–filled detectors: ion chambers, proportional counters and Geiger–Müller counters. They differ mainly in the strength of the electric field applied between their electrodes.

- The technique of liquid scintillation counting involves placing the radioactive sample into a glass or plastic container and adding a special scintillation cocktail to form a homogeneous counting solution. The scintillation cocktail is composed of a solvent and flour solute. The first step of scintillation process is the interaction of radioactivity with the solvent molecules in liquid scintillation cocktail. The result is the formation of activated solvent molecules. The energy of excitation of the solvent is then transferred to scintillator (fluor) molecules, which upon deexcitation emit photons of visible light. The light photons are detected by photomultiplier (PMT), which converts photons into electrical signal.
  In order to distinguish instrument background from true nuclear events in a scintillation vial, usually two PMTs in coincidence are used to collect the photons. If only single PMT were used, the background level would be approximately 10000 counts per minute, but using two PMTs in coincidence reduces background to about 30 counts per minute. The principle behind coincidence counting is based on the fact that when a nuclear decay event occurs in scintillation vial, produced light is isotropic. The decay process and resultant scintillation are very rapid (approximate light decay time is 2–20 ns). Since the decay process and resultant scintillation process produce multiphoton events (about 10 photons per keV of nuclear energy dissipated in a scintillation cocktail) this photons will be detected by two PMTs in the very short time. If a signal is detected in both PMTs within coincidence resolving time of 18 ns, it is accepted as a true nuclear decay event. If, on the other hand, event occurs in only one of the PMTs within this time, it is considered as a background event.

The detector used to measure the activity of isolated ^{90}Y should have higher efficiency for β particles from ^{90}Sr/^{90}Y than efficiency for γ–rays due to contamination of the sample. Since γ–rays have higher ranges in matter than β particles, gas–filled detectors which have low surface density are more suitable than liquid scintillators. For example with proportional counters lower limits of detection that they can achieve are 0.2 and 0.005 Bq/m^3 for liquid and solid samples respectively, with experimental errors estimated as 10% for high activity and up to 30% for low activity samples [3] .

Although scintillation detectors are more sensitive to presence of γ–emitters, they are frequently used, especially if the sample is in the form of solution. As mentioned above in this case, the sample is simply added to liquid scintillator, and in this way absorption in the sample is avoided. But this in turn can effect optical properties of liquid scintillator (emission spectrum, transmission), which can increase errors ([4], [5], [6]). The liquid scintillation counting efficiency for β particles depends on the original energy of β decay. For most β particles with a decay energy above 100 keV, the counting efficiency is 90– 100%, but for lower energy β decays the efficiency is normally in the range 10-60% [7]. For ^{90}Y the liquid scintillation counting efficiency can be near 100%.

2.2 Measurements of Cherenkov radiation in aqueous solution

2.2.1 Cherenkov radiation

Cherenkov radiation is electromagnetic radiation emitted by charged particles traveling through medium with speed greater than the speed of light in that medium. This speed is given by $v = c/n$, where n is the index of refraction and c is the speed of light in a vacuum. A particle emitting Cherenkov radiation must therefore have a velocity

$$v > \frac{c}{n} \qquad \text{or} \qquad \beta > \frac{1}{n} \tag{2}$$

and the threshold kinetic energy for Cherenkov production is

$$\begin{aligned} T_{thr} &= mc^2 \left[\frac{1}{\sqrt{1-\beta_{thr}^2}} - 1 \right] = mc^2 \left[\frac{n}{\sqrt{n^2-1}} - 1 \right], \\ \beta_{thr} &= \frac{1}{n}. \end{aligned} \tag{3}$$

T_{thr} varies with index of refraction of the medium and it is lower for media of higher index of refraction. This is shown on Fig.5 for electron.

If condition (2) is satisfied, the coherent wavefront is formed, which is conical in shape and is emitted at well–defined angle with respect to the trajectory of the particle (Fig.7). This angle depends on the speed of the particle and the energy of the emitted radiation E_f

$$\cos\theta_C = \frac{(c/n)t}{\beta c t} = \frac{1}{\beta n(E_f)}. \tag{4}$$

and it is called Cherenkov angle. Dependency of Cherenkov angle on speed of the particle for different refractive indices is shown on Fig.6.

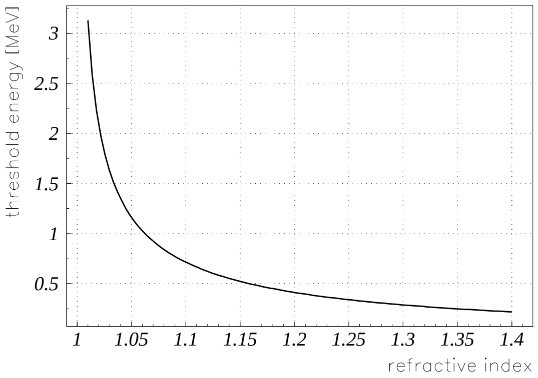

Fig. 5: *Variation of threshold energy T_{th} with index of refraction for electron.*

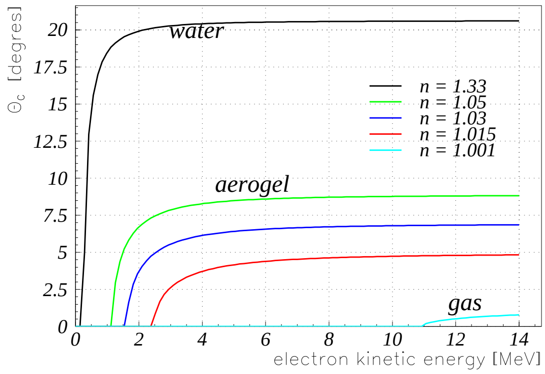

Fig. 6: *Cherenkov angle as a function of electron speed for different refractive indices*

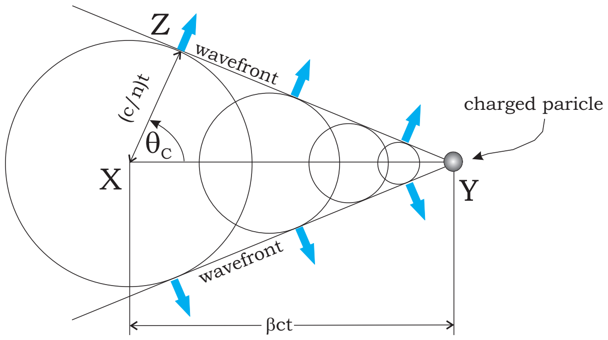

Fig. 7: *Huygens' construction of conical Cherenkov wavefront. The position of the charged particle at time t=0 is X; the distance traveled by particle from X to Y in time is* βct*; the distance traveled by Cherenkov photon from X to Z is* $(c/n)t$*.* θ_C *is the angle of emission of Cherenkov photon.*

The number of photons emitted by particle with charge ze_0 per unit length of radiator and per unit photon energy is [1]

$$\frac{\mathrm{d}^2N}{\mathrm{d}x\mathrm{d}E_f} = \frac{z^2\alpha}{\hbar c}\sin^2\theta_C = \frac{z^2\alpha}{\hbar c}\left(1-\frac{1}{\beta^2n^2(E_f)}\right). \tag{5}$$

Cherenkov radiation is generally detected by photomultipliers. A typical range of sensitivity for this devices is in the range of visible light between 350 nm and 550 nm or in terms of photon energy 2.4–3.7 eV. If we take refractive index constant over this range than integrating (5) over E_f yields

$$\frac{\mathrm{d}N}{\mathrm{d}x} = \frac{\alpha z^2}{\hbar c}\sin^2\theta_C\,\Delta E_f, \tag{6}$$

where ΔE_f is the energy interval of sensitivity for photomultiplier. This is shown for electron on Fig.8.

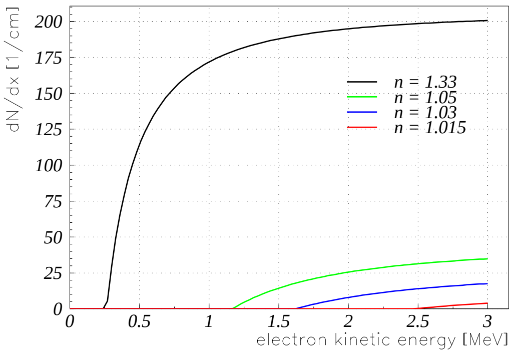

Fig. 8: *Number of photons emitted by electron per unit path in the range between 350 nm and 550 nm.*

2.2.2 Using water as Cherenkov radiator

β particles and electrons that are created by absorption or scattering of γ-rays, emit Cherenkov radiation if their energy is above the threshold. For water this is 263 keV. One of the methods for measuring ^{90}Sr/^{90}Y activity uses Cherenkov radiation in aqueous solutions in order to separate the contribution of ^{90}Sr/^{90}Y from other β–emitters. In this case the sample is dissolved in water instead of in liquid scintillator. Efficiency of this detector increases with endpoint energy in β spectrum ($\sim$70%, $\sim$1% and $\sim$40% for ^{90}Y, ^{90}Sr and ^{89}Sr respectively [7]) due to the fact that in spectrum with higher endpoint energy larger fraction of β–particles can emit Cherenkov photons. Sensitivity of this method is defined as the activity for which the counting rate is equal to background. Typical background counts are about 1/s. Thus sensitivity of this method is few Bq. Since the threshold for Cherenkov radiation in water is quite low, many isotopes contribute to measured count rates. Thus only chemically isolated ^{90}Y is usually measured. Because of the increasing fraction of ^{90}Y with time after separation, accuracy of measurement also increases with time.

3 Using Cherenkov radiation in silica aerogels

If the ratio of ^{90}Sr to ^{90}Y activity is known (e.g. the sample is in radioactive equilibrium or after chemical separation of strontium or the time from nuclear release is known) then the activity of ^{90}Sr can be determined from measurements of Cherenkov radiation produced by electrons from ^{90}Y, which has higher endpoint energy of β spectrum than parent nucleus ^{90}Sr. In this case the choice of lower index of refraction of radiator is favorable. This way it is possible to eliminate or at least strongly suppress the contribution of other β– emitters with lower β energy spectra to the signal, since lower index of refraction implies higher threshold for production of Cherenkov radiation. On the other hand the number of emitted photons decreases with decreasing index of refraction (Fig.8). Since for materials with lower densities ionization losses are smaller, lower density of the radiator implies longer path on which charged particles radiate, and thus increases the number of emitted photons.

For measurements of β particles from ^{90}Y decay the radiator with refractive index lower than water (n = 1.33) is required since water with its relatively low threshold for Cherenkov radiation (T_{thr} = 263 eV) can not strongly decrease the contribution of other β–emitters to the signal. The radiator should have refractive index about 1.005 (T_{thr} = 1.16 MeV), lower density and high transparency. Traditional gas and liquid radiators have a refractive index either smaller than 1.0018 (C_5F_{12}) or larger than 1.27 (liquid C_6F_{14}). The gap in refractive index is covered by so called aerogels which can be produced in a fairly wide range from n = 1.004 to n = 1.1 and are low density materials with high transparency.

3.1 Silica aerogel properties

Aerogel is a manmade material that can have a density as low as three times that of air. It essentially consists of grains of amorphous SiO_2 with sizes ranging from 1 to 10 nm linked together in a three-dimensional structure with tiny pockets (pores) filled by trapped air (Fig.10). As a result it is highly porous material with different pore sizes (mean pore diameter 20 nm). The huge number of tiny primary particles determines an internal surface close to 1000 m^2/g that plays the fundamental role in the aerogel chemical and physical behavior. There exists a simple relationship between the resultant index of refraction and the aerogel density in g/ cm^3

$$n = 1 + 0.21\rho. \tag{7}$$

The first step in the aerogel preparation is the formation of a wet gel called Alcogel. This is produced by hydrolysis and condensation of silicon alkoxide precursors in presence of an alcoholic solvent (usually ethanol). The most common of this precursors are tetramethyl orthosilicate (TMOS, $Si(OCH_3)_4$), and tetraethyl orthosilicate (TEOS, $Si(OCH_2CH_3)_4$). The balanced chemical equation for the formation of a silica gel from TEOS is

$$Si(OCH_2CH_3)_4\,_{(liq.)} + 2H_2O\,_{(liq.)} = SiO_2\,_{(solid)} + 4HOCH_2CH_3\,_{(liq.)}$$

The final density of the aerogel depends on the concentration of silicon alkoxide monomers in the solution.

An alcogel can stand on its own and consists of two parts, a solid part and a liquid part. The solid part is formed by the three-dimensional network of linked oxide particles. The liquid part fills the free space surrounding the solid part. Aerogel is then obtained by removing the liquid. But evaporating liquid causes the alcogel's solid silica component to collapse by capillary action. This means that after the liquid has been completely taken out of the gel, the gel has collapsed and formed a dense solid that has about 10% of the original volume of the gel. Instead of evaporating the solvent, the gel can be supercritically dried. Supercritical fluids are semi-liquids/semi-gases that are usually high pressure and high temperature, expand like gases and have lower surface tension than liquids. Supercritically drying alcogel is a way for the liquid in the gel to slowly sneak out of the solid silica matrix without causing the silica matrix to collapse from capillary action. This is done by heating the gel above its liquid's triple point. Once the liquid has snuck out of the gel it can be vented off as a gas.

The behavior of visible light in aerogel is dominated by Rayleigh scattering. Scattering is more effective when the size of the scattering center (actual entity that causes scattering) is similar to the wavelength of the incident light. This occurs in small particles (∼400-700 nm in diameter for visible light) that are separated from on another, or by larger, macroscopic, particles with inherent irregularities. When scattering centers are smaller in size than the wavelength of the incident light, scattering is much less effective. In silica aerogels, the primary particles have a diameter of ∼2-5 nm, and do not contribute significantly to the observed scattering. However, scattering does not necessarily arise from solid structures. In silica aerogels there is a network of pores, which can act as scattering centers. The majority of these are much smaller (∼20 nm) than the wavelength of visible light. There is, however, a certain number of larger pores that scatter visible light. As scattering efficiency is dependent on the size of the scattering center, different wavelengths will scatter with varying magnitudes. This causes the reddening of transmitted light (red light has a longer wavelength, and is scattered less by the fine structure of aerogels) and the blue appearance of the reflected light off silica aerogels. Thus the bluish haze that surrounds aerogel samples, is an effect of the Rayleigh scattering, since short wavelengths are the most severely affected by the scattering mechanism.

The internal absorption does not play a significant role in the visible region, while weak absorbances appear in the infrared. Transmittance of aerogel can be expressed in terms of attenuation coefficient μ, which is wavelength dependent

$$T = \exp(-\mu(\lambda)d), \tag{8}$$

where d is the thickness of aerogel. The attenuation of light in the visible light range is dominated by Rayleigh scattering, which in turn shows a characteristic dependence on the wavelength

$$\mu \propto \frac{1}{\lambda^4} \tag{9}$$

Since in the visible range of light absorption is negligible, the measured transmittance T of an aerogel sample of thickness d as a function of the light wavelength is fairly fitted by the expression:

$$T = A\exp\left(-\frac{Cd}{\lambda^4}\right) \tag{10}$$

in the range from 300 nm to 700 nm. Here A is wavelength independent transmission factor that represents absorption process, C is intensity of Rayleigh scattering. Aerogels with a high value of A and a low value of C will be the most transparent (Fig.9).

Since the wavelengths of interest in Cherenkov detectors are in the visible range aerogel as a radiator can be treated as a homogenous medium since the wavelength of visible light is still much smaller than size of pores and primary particles.

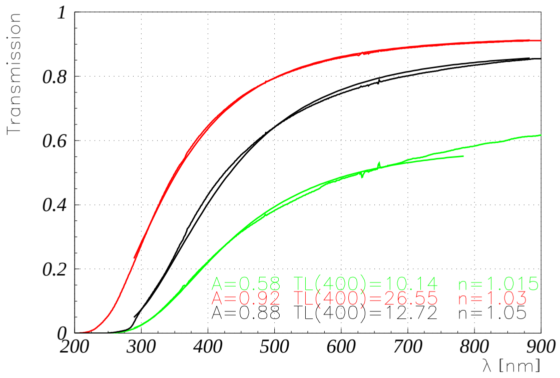

Fig. 9: *Transmission of 1 cm thick aerogel tiles with* $n = 1.015$*,* $n = 1.03$ *and* $n = 1.05$*. Value of* A *and transmission length at* $\lambda = 400$ *nm TL(400) are also written. TL(400) is defined as* $T = A\exp(-\frac{d}{TL(400)}\left(\frac{400}{\lambda}\right)^4)$*, where* λ *is in nm.*

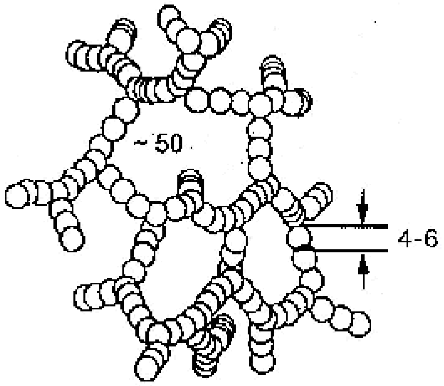

Fig. 10: *Aerogel structure.*

3.2 Description of method

Investigation of possibilities to determine activity of ^{90}Sr in environmental samples with Cherenkov radiation of β–particles using silica aerogel as a radiator was done at J. Stefan Institute [8].

The basic components of experimental set-up were enclosed in a tight light box (Fig.11). The main part of the detection system are silica aerogel as radiator, where Cherenkov radiation is

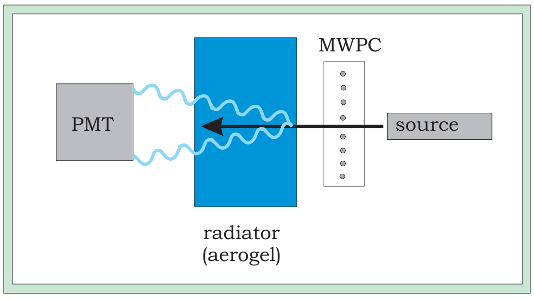

Fig. 11: *Experimental set-up: PMT stands for photomultiplier and MWPC for multiwire proportional chamber.*

emitted by β–particles and photomultiplier (PMT) which converts photons into electrical signal. In order to suppress the background and increase the sensitivity of the detection system, multiwire proportional chamber (MWPC), which is a type of gas ionizing detector, in coincidence with photomultiplier was used.

Energy loss of β–particles in chamber are low (about 10–15 keV) due to low surface mass density of chamber (about 8 mg/cm^2). The probability for detection of β–particles in chamber is above 95%. On the other hand, due to low surface mass density of chamber, the probability for absorption of γ–rays in the chamber is very low (less than 0.1% for E_γ >100 keV). This comes as an advantage since the presence of γ–emitters makes determination of ^{90}Sr/^{90}Y activity more difficult, since it is a pure β–emitter. Thus, chamber detects all charged particles while Cherenkov detector (PMT in combination with aerogel) detects only part of charged particles which have energies higher than threshold energy for production of Cherenkov radiation.

As radiator they used silica aerogel with n = 1.05. Such high threshold (T_{thr} = 1.16 MeV) discriminates almost all other β emitters, especially ^{137}Cs. As mentioned before in aerogels scattering of photons is much more efficient than absorption. Thus the entrance and side walls of aerogel were covered with aluminium foil to reflected photons towards the PMT, achieving higher collection of Cherenkov photons.

Efficiency of this method is defined as the ratio of the measured count rate to known activity of the source. Fig.12 shows the measured efficiency as a function of the β–spectrum end–point energy, where four point sources were used: ^{42}K, ^{32}P, ^{90}Sr/^{90}Y and ^{137}Cs. Here ^{32}P and^{137}Cs are considered as a background to ^{90}Sr. Among the sources used, the only pure one–branch β–emitter is ^{32}P. For the other sources, only the higher energy branch has been considered, as the lower energy branch is either below threshold (^{90}Sr/^{90}Y and ^{137}Cs) or is expected to represent a minor correction (few % for ^{42}K). As expected the efficiency increases with increasing endpoint energy of the β spectrum.

β–γ emitters might trigger a coincidence of β in MWPC and γ converted in the PMT glass window, where the resulting electron emits Cherenkov photons.

The distribution of number of coincident events as a function of the number of PMT channels hit is shown in Fig.13. Number of coincident events with one, two, three and four PMT channels hit as a function of endpoint energy of β spectrum is shown on Fig.14. It is seen that higher energy β-spectrum of ^{42}K yields more Cherenkov photons than lower energy spectra of ^{90}Sr/^{90}Y and ^{42}P. Thus this is the way to separate the contribution of different sources. A relatively large number of events with more than one PMT channel hit for the lowest energy β spectrum of ^{137}Cs points to a rather important contribution β– γ coincidences in this case.

The PMT and MWPC background count rates were less than ∼ 100 s^{-1} each, with coincidence rate being less than 2 per hour which looks promising for measurements of low activity samples.

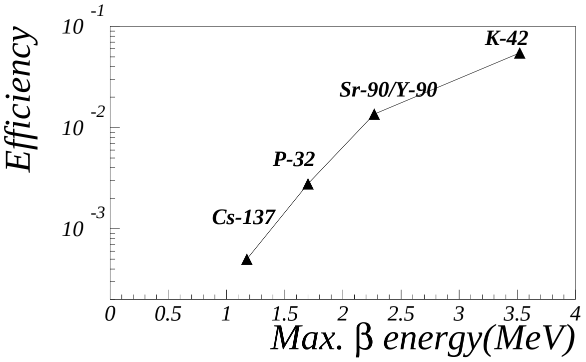

Fig. 12: *Efficiencies for different sources as a function of endpoint energy of β spectrum*

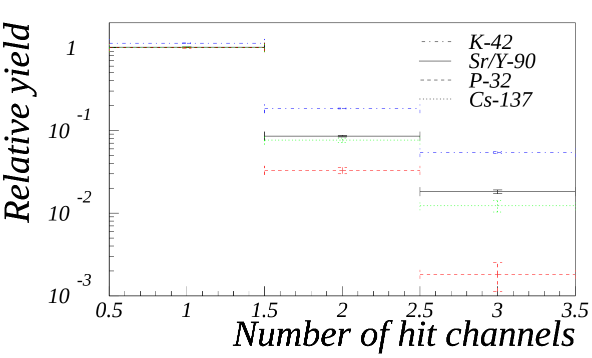

Fig. 13: *The distribution of coincident events as a function of the number of PMT channles hit, normalized to one channel hit.*

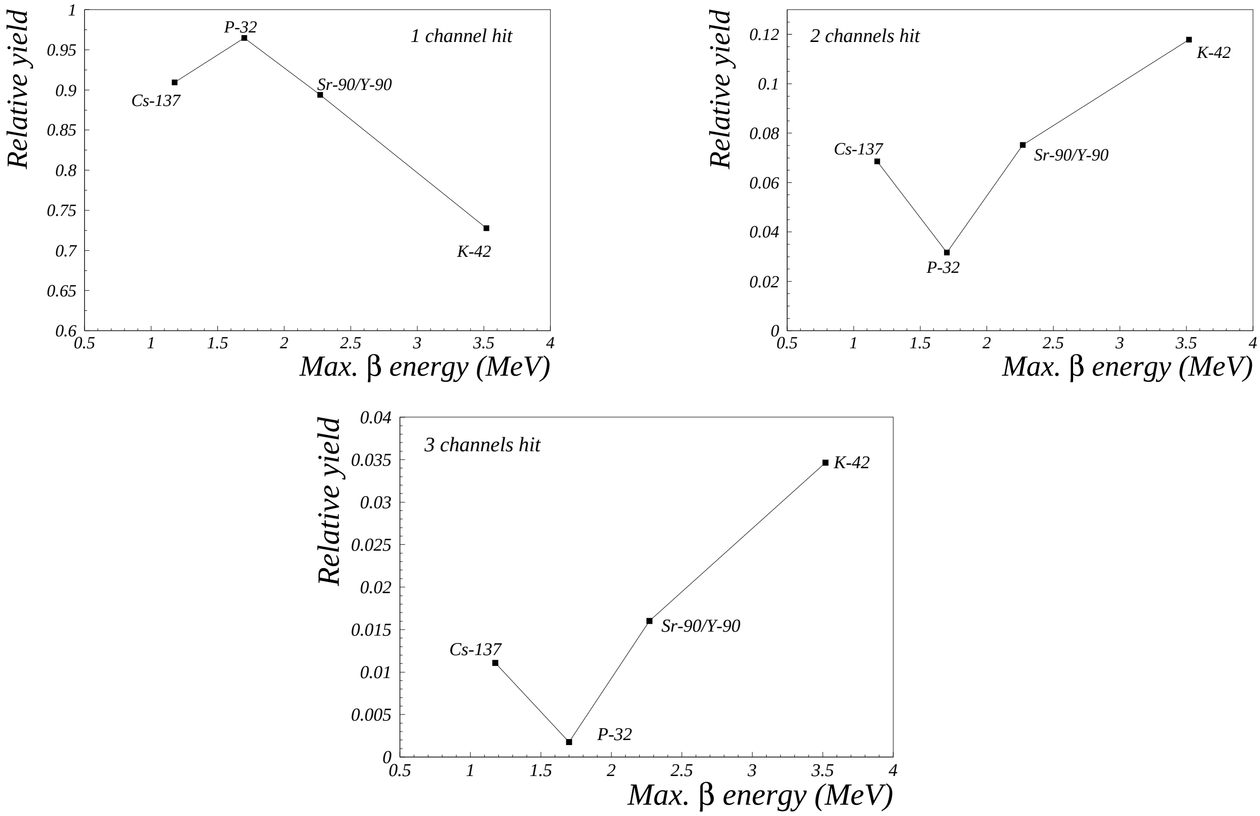

Fig. 14: *Coincident events with one, two and three PMT channels hit as a function of endpoint energy β spectrum, normalized to all coincident events.*

4 Conclusion

The method for determination of ^{90}Sr activity in environmental samples described here is based on Cherenkov radiation of β–particles in the aerogel as radiator. With the use of multiwire proportional chamber in coincidence with photomultiplier, which collects Cherenkov radiation, the background can be highly suppressed (coincidence rate < 2 per hour). This looks promising for measurements of low activity environmental samples. Although the detection efficiency of ^{90}Sr/^{90}Y was low (≈ 0.01) it was much higher than for majority of other β, β–γ sources. The exceptions are isotopes that have endpoint energies of β spectrum larger than ^{90}Sr/^{90}Y ($T_{thr} = 2.27$ MeV). The number of such isotopes is low and its presence in the sample is indicated by considerable change in distribution of number of coincident events as a function of the number of PMT channels hit. Since the efficiencies for ^{90}Sr/^{90}Y detection were low due to poor coverage of the aerogel area with photon detector, this can be improved either by increasing the number of photomultipliers or by using a photon detector that covers a larger area (flat PMT).

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