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Yu.K.Akimov

# COMBINED SCINTILLATION AND TRACK TECHNIQUE TO SEARCH FOR $\beta\beta$-DECAY

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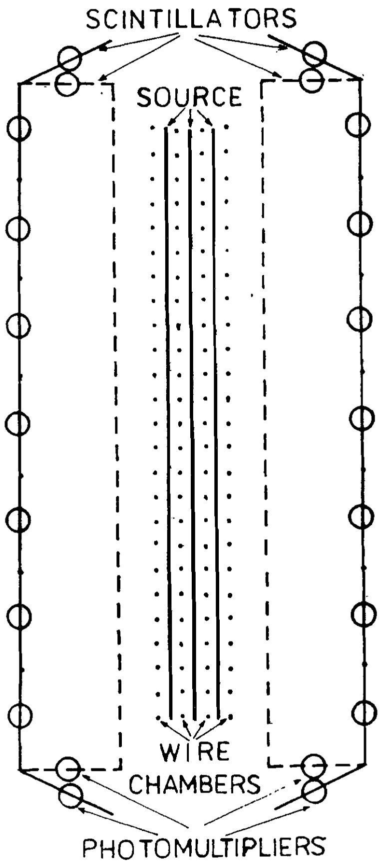
Double beta decay is one of the most powerful ways to test conservation of the lepton number. The highest half-life ($T_{1/2}$) limits for the neutrinoless ($0\nu$) $\beta\beta$-decay were obtained using /1/ germanium solid state detectors. $^{76}$Ge-isotope can give the $0\nu$ $\beta\beta$-decay with the total energy of two electrons $E_0 = 2$ MeV. But this technique does not exclude other methods of investigation with different sources of $\beta\beta$-decay. For instance a probability of the $0\nu\beta\beta$-decay for $^{150}$Nd is much higher (by two orders /2/) than for $^{76}$Ge. Besides it is not necessary to use a high resolution detector to search for $\beta\beta$-decay with $2\nu$ or Majoron ($0\nu\chi^0$), because $E \neq$ const for these modes. New limits for the $0\nu\chi^0$-mode will have some important consequences in astrophysics /3/. According to ref. /4/, a probability of the $0\nu\chi^0$-mode is even higher than that of the $0\nu$-mode, if Majoron exists. A scintillation counter with a $\sim$ 20% energy resolution is an adequate detector for a search for the $0\nu$- or $2\nu$-modes.

A scintillation spectrometer with a $^{150}$Nd-source was used in the underground experiment /5/. The $Nd_2O_3$-sample ($^{150}$Nd - 92.5%) was placed between scintillators and a two-dimensional spectrum was measured. The main background in the experiment is due to electrons produced in the scintillators by gamma-rays from natural radioactivity and n-capture.

The time-of-flight and track technique can be used to exclude such background. This approach is used in the version of the apparatus shown in the Figure 1.



Double beta decay apparatus.

There are three planes of the source (~3 $M^2$) in the center of the set-up. Four wire chambers measure particle tracks in the source region. An accuracy $\Delta\theta = \pm 5^\circ$ for measurement of the angle $\theta$ between two tracks is quite sufficient. The thickness of each plane is about 6 mg/cm$^2$. It can be $Nd_2O_3$ precipitated on 6$\mu$k-mylar (aluminized). Nd thickness is ~ 4 mg/cm$^2$ in this case. To simplify preparation of the source precipitation can be done on smaller surfaces (~ 0.1 $M^2$) in succession. Two planes are for $^{150}$Nd (M = 75 g) and the third plane is a

dummy source. Each chamber measures two coordinates. The average amount of substance (Cu) in each chamber is ~ 1 mg/cm$^2$.

Scintillation counters are made of long plates. Typical thickness is 1 cm, width is 4÷5 cm. Scintillations in each plate are detected by a small photomultiplier, taking off ~10% of collected light. Four such plates form a counter with two fast photomultipliers on both edges. A time resolution $2.35\,\sigma \leq 1$ ns is expected for the energy of electrons T = 0.5÷3 MeV. The time of flight of electrons between the scintillators is 2÷5 ns depending on the angle of emission. The energy of two electrons $E_0$ = 3,4 MeV for the $0\nu$ $\beta\beta$ -decay of $^{150}$Nd. The most probable energy of one electron is 0.5 $E_0$. Timing allows determining a position of the scintillation in the counter.

Background electrons with the energy about $E_0$ produced in the scintillators will have the r.m.s. scattering angle ~ 10° after traversing the source. A major part of these electrons can be rejected if opening angles $\theta > 155^\circ$ are excluded. Only 10% of the true events are found at $\theta > 155^\circ$ in the distribution with the angular correlation (1 - cos $\theta$ ) /6/. Timing can make the electron background negligible for $\theta > 155^\circ$. The main background will be caused by pair production in the source. But there are 90% of pairs and only 20% of the true events for $\theta < 80^\circ$. Multiple scattering will not change the angle distribution very much because of small thickness of the source planes.

The apparatus efficiency for $80^\circ < \theta < 155^\circ$ is about 1/3. If $T_{1/2} = 10^{22}$ y. and M = 75 g one will record N = 7 events of the $0\nu$ $\beta\beta$-decay for the measuring time t = 1 y.

Let's take data of /5/ to estimate the background. Events occurred at a rate of 1.5/h for E = 3÷3.5 MeV with the scintillator of mass $M_s$ = 6.2 kg. Taking into account the ratio $M_{Nd}/M_s$, the pair production cross section and efficiency for $80^\circ < \theta < 155^\circ$

($\sim 6\%$) one can expect $\sim 0.5\,N$ of $e^+e^-$-pairs for $t = 1$ y. But the real background can be higher. Active scintillation shielding (20÷30 g/cm$^2$) can be made for suppressing the background. There will be a high probability of detecting one of the two annihilation gamma-quanta (0.5 MeV).

In the case of the $0\nu$ $\beta\beta$-decay two electrons have a total energy $E = (\sim 0.5\text{-}1)E_0$. Gamma-quanta must have energies $E_\gamma \geq 1.5\,E_0$ to produce pairs with $E \geq 0.5\,E_0$. It is higher than the natural radioactivity boundary and the background is much lower in this region. The number of single background electrons will be larger than for the $0\nu$ -mode. But this kind of background can be effectively excluded by the time-of-flight and track technique.

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Акимов Ю.К. E13-87-309

Комбинированная сцинтилляционная и трековая техника для поиска $\beta\beta$-распада

Рассматривается вариант сцинтилляционного спектрометра с проволочными камерами для поиска $\beta\beta$-распада. Предложена времяпролетная техника для подавления фона. Источник ($\sim 3$ М$^2$), расположенный в центре установки, состоит из трех плоскостей. Четыре проволочные камеры измеряют треки частиц в центре источника. Весь объем заполнен гелием. Сцинтилляционные счетчики изготовлены из длинных пластин. Четыре таких пластины образуют счетчик с двумя быстрыми фотоумножителями на обоих торцах. Время пролета электронов между сцинтилляторами составляет 2-5 нс. Если масса источника ($^{150}$Nd) равна 75 г, то может быть измерен период полураспада $T_{1/2} = 10^{22}$ лет.

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Akimov Yu.K. E13-87-309

Combined Scintillation and Track Technique to Search for $\beta\beta$-Decay

A version of the scintillation spectrometer with wire chambers for the search for $\beta\beta$ -decay is considered. The time-of-flight technique for suppression of a background is proposed. There are three planas of the source ($\sim 3$ m$^2$) in the center of the set-up. Four wire chambers measure particle tracks in the source region. The whole volume is filled with helium. Scintillation counters are made of long plates. Four such plates form a counter with two fast photomultipliers on both edges. The time of flight of electrons between the scintillators is 2÷5 ns. If a sourse mass ($^{150}$Nd) is 75 g, a half-life $T_{1/2} = 10^{22}$ y. can be measured.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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