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COMBINED SCINTILLATION AND TRACK TECHNIQUE TO SEARCH FOR ββ-DECAY

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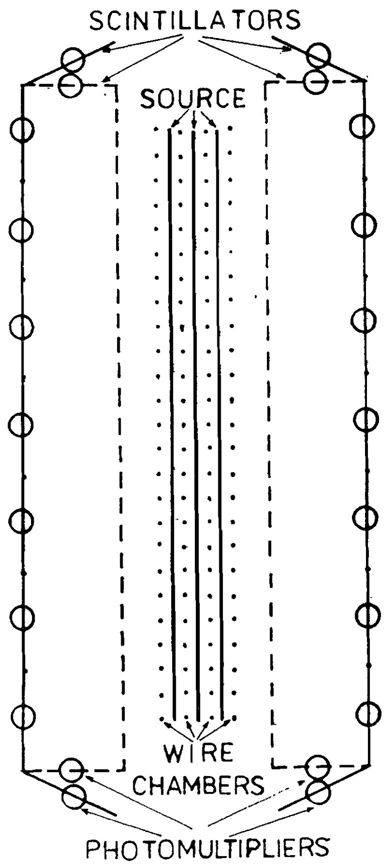
Double beta decay is one of the most powerful ways to test conservation of the lepton number. The highest half-life ($T_{1/2}$) limits for the neutrinoless (0ν) $\beta\beta$-decay were obtained using /1/ germanium solid state detectors. ^{76}Ge-isotope can give the 0ν $\beta\beta$-decay with the total 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 ν 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 0ν-mode, if Majoron exists. A scintillation counter with a $\sim$ 20% energy resolution is an adequate detector for a search for the 0ν- or 2ν-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 a 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 θ 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 $\sim$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 $\sim 10^\circ$ 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 0ν $\beta\beta$-decay two electrons have a total energy $E = (\sim 0.5-1)E_0$. 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 0ν -mode. But this kind of background can be effectively excluded by the time-of-flight and track technique.

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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.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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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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