STATUS OF THE EXPERIMENT OF INR - KIAE TRITIUM BETA-DECAY NEUTRINO MASS MEASURING

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Abstract.

An installation described is intended to measure electron antineutrino mass by using an integral electrostatic spectrometer with adiabatic magnetic collimation. Also it includes an electron detector for soft electrons and gaseous tritium source.

The measured energy resolution (full width) of the spectrometer described appeared to be equal to 2.8 eV at the electron energy 18.6 keV, the luminosity is 0.3 cm^2, the background of the spectrometer electrostatic system is $(5\pm3)10^{-3}$ s^{-1}.

Preliminary tests of the proportional low-pressure detector showed that the background can be diminished below 10^{-3} s^{-1} and tests of some parts of the tritium source indicate that the surface tritium density can be made about $(3\text{-}10)\cdot10^{16}$ cm^{-2}.

1. Introduction.

One of the main problems of the experiment in elementary particle physics is to measure the antineutrino rest mass. Resently considerable efforts were applied to measure directly the electron antineutrino rest mass in tritium β-decay. Among all the experimental data only the result of the ITEP group indicates to non-zero neutrino mass (m=26 eV)[1]. All other groups (Zurich, Los-Alamos, Tokyo)[2] claim only the upper limits on the neutrino mass, their values being in the interval 11-18 eV.

The main idea of our experiment was first proposed by V.Lobashev and P.Spivak[3]. The installation consists of an integral electrostatic spectrometer with adiabatic magnetic collimation, a detector of soft electrons and gaseous molecular tritium source.

2. Spectrometer

The main characteristic feature of our spectrometer distinguishing it (Fig.1) from the usual electrostatic ones is the presence of a longitudinal magnetic field shaped in a form of an axially-symmetric magnetic trap. In the center of the trap the magnetic field is weak and equals $B_m=1.2\cdot10^{-3}$ T, the system of the electrodes of the electrostatic analyser (1,2) being mounted there. The gaseous tritium source is placed outside the spectrometer in front of the first magnetic plug (3), the field in the plug equals $B_{01}=8.5$ T. The electron detector (4) is mounted inside the second magnetic plug with the field $B_{02}=2.7$ T. The spectrometer magnetic field is formed by the system of the superconducting solenoids (5,6) and the "warm" solenoid (7).

Configurations of the carrying magnetic field and the decelerating electric field are chosen in a such way that electrons moving in spiral trajectories along the magnetic lines would conserve their adiabatic invariant $\mu=V^2\sin^2\alpha/2B$ = const , where V is the velocity of an electron, α is the angle between its velocity and direction of the magnetic line.

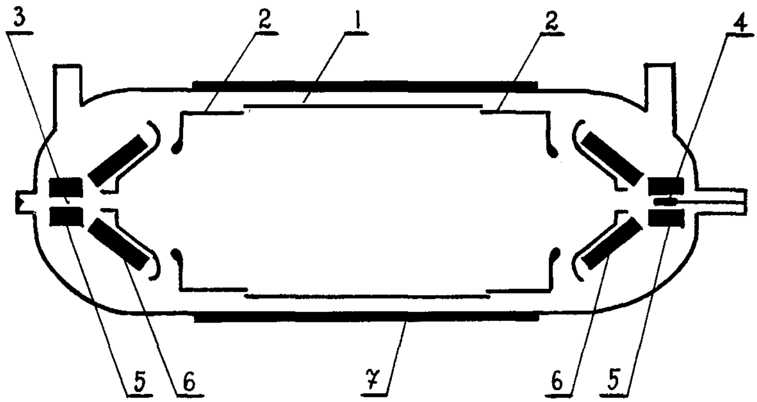

Fig.1 The Spectrometer Structure.

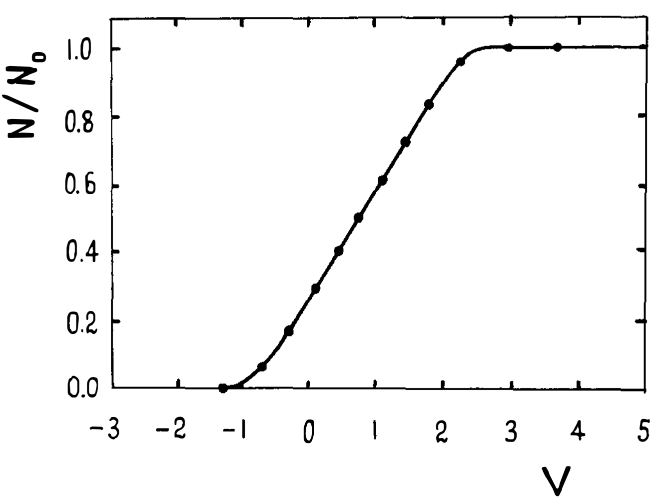

Fig.2 The Spectrometer Transmission Function.

An electron, escaped from the first plug with the momentum almost perpendicular to the magnetic line, will have in the center of the spectrometer the energy, connected with its transverse motion $\Delta E=E_0\sin^2\alpha=E_0B_m/B_{01}$, where E_0 is its initial energy. The value of ΔE determines the resolution of this kind of the spectrometer.

After passing the medium plane of the analyser, the electrons are accelerated up to their initial energy and then are registrated by the electron detector.

Investigation of the spectrometer characteristics (its energy resolution, luminosity, background) was carried out with the aid of a quasimonochromatic photoemission electron source ($\Delta E<0.5$ eV) and Si(Li)detector with a sensitive region of 16 mm in diameter and 3 mm depth.

In Fig.2 the spectrometer transmission function is presented. The energy resolution was measured at the maximal magnitude of the magnetic field in the first plug $B_{01}=8.5$ T and the ratio $B_{01}/B_m=7\cdot10^3$. In this case the expected energy resolution ΔE equals 2.5 eV for the electron energy E=18.6 keV. The measured resolution (full width) was found to be 2.8 eV (see Fig.2).

The spectrometer luminosity measured with the Si(Li) - - detector with the sensitive region diameter of 16 mm, was found to be 0.15 cm^2. The maximal spectrometer luminosity for the above-mentioned magnetic fields is expected to be 0.3 cm^2 in the case of using an electron detector with its sensitive region diameter of 23 mm.

The spectrometer intrinsic background due to the electrostatic analyser high voltage electrode system was found to be $(5\pm3)\cdot10^{-3}$ s^{-1}. This background was determined as the difference between the counting rates with the high voltage at the analyser turned on and turned off. The background was measured for the energy range 15-21 keV. The energy resolution of the Si(Li)-detector was about 20% for this electron energy region. The background of the Si(Li)-detector itself was found to be $1.2\cdot10^{-2}s^{-1}$, which is much greater than the spectrometer background. The considerable detector background can be caused by a large mass of the working substance.

3. Proportional Counter.

To decrease the background we investigated the proportional low-pressure (12 torr) electron detector with a thin (25 $mkg \cdot cm^{-2}$) entrance window. The detector must operate in a strong (2-3 T) magnetic field in high ($<10^{-8}$ torr) vacuum at liquid nytrogen temperature.

We investigate the cylindrical detector with an entrance window on its end. The diameter of the window with the armour grid was 23 mm. The length of the detector operating region was 113 mm, its diameter - 30 mm. Such a detector volume at low density of the working substance allows us to registrate electrons with energy of 18.6 keV, and not to registrate the background relativistic particles flying through the detector due to their considerably low energy losses.

The detector background while the magnetic field is turned off was found to be $2.4 \cdot 10^{-4} s^{-1}$ at the energy region 17.6-19.6 keV.

During the registration of soft electrons in a strong (>0.5 T) magnetic field the dependence of the detector signal magnitude on the location of the point of ionization in the operating region was revealed. It could be attributed to the dependence of the electron gas multiplication coefficient on the angle between the electric and magnetic field lines in the multiplication region. At present we modify the geometry of the detector electrodes to diminish this effect.

4. Tritium Source.

Gaseous tritium at temperature of 30-40 K and with density of about $10^{14} cm^{-3}$ is pumped into a pipe (its length is 3 m and diameter is 50 mm) with two open ends.

At each end of the pipe the diffusion mercury pumps are mounted to carry out the differential pumping out of tritium and then to return it to the center of the pipe. To make the tritium interception between the source and the spectrometer more reliable we use in addition a turbomolecular pump and a cryogenic pumping out (T=4.5 K) of tritium in the curved channel. The equivalent surface tritium density in the source is expected to be $(3\text{-}10)\cdot10^{16}cm^{-2}$.

To transport the electrons from the source into the spectrometer the longitudinal (along the source channel) magnetic field is used. Its intensity equals 1T for the rectilinear part of the source and 5T for the curved channel.

At present the tritium source is mounted and its testing is started. Before mounting the superconducting solenoids and pumping system were tested. Tritium circulation was simulated through the use of hydrogen, helium and deuterium. The stable gas circulation was obtained at the flow rate of 10^{-2} $torr\cdot l\cdot s^{-1}$.

5. Conclusion.

The achieved spectrometer characteristics along with the results of the preliminary tests of the proportional detector and of some parts of the tritium source allow us to expect the installation sensitivity to the neutrino mass to be less than 5 eV.

Reference.

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