Beta decay blackbody model

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Abstract

The energy beta spectrum of radioactive beta emitters is similar to the continuous spectra of thermal radiation, thermionic emission and bremsstrahlung. A useful and universal way of describing such spectra is the blackbody model.

Introduction

Figure 1 shows a typical spectrum of a radioactive beta emitter. Beta decay is the main decay channel of 210Bi isotope, the contribution of alpha decay does not exceed 10^-4%. The half-life of 5 days.

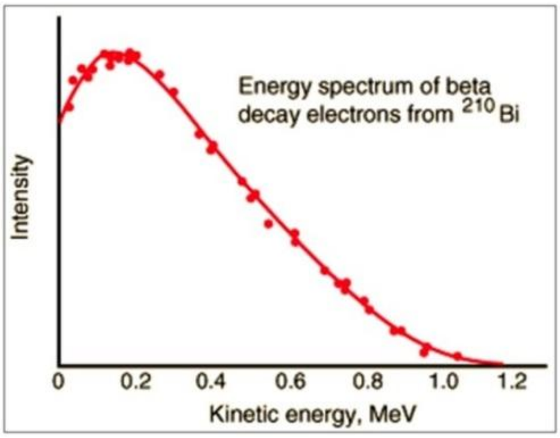

Fig. 1. Energy Spectrum of 210Bi Beta Decay Electrons from G.J. Neary.

Model

Let's say a beta emitter is a black body with a nuclear Fermi gas. Gas quasiparticles have a charge, not necessarily a whole, and obey Fermi-Dirac statistics. The presence of a charge allows the kinetic energy to be expressed in electrical units. The following is a fragment of a mathcad file with the simplest blackbody formula for 210Bi beta power density depending on the kinetic energy of the beta particles:

$$fm := 10^{-15} m \qquad AMU := 1.66053886 \cdot 10^{-27} \cdot kg$$

$$h := 6.6260693 \cdot 10^{-34} \cdot J \cdot s \qquad k_b \equiv 1.3806505 \cdot 10^{-23} \cdot \frac{J}{K}$$

$$eV \equiv 1.602176565 \cdot 10^{-19} J \qquad MeV \equiv 10^6 eV$$

$$m_{Bi} := 210 AMU \qquad r_{Bi} := 1.23 fm \cdot \sqrt[3]{210} \qquad r_{Bi} = 7.311 fm$$

$$n_{fg} := \frac{1}{r_{Bi}^3} \qquad n_{fg} = 2.559 \times 10^{42} \frac{1}{m^3}$$ fermi-gas concentration in 210Bi

$$E_{peak} := 0.23 MeV \qquad T_K := 0.80 \cdot 10^9 \cdot K$$

$$PD(E, T_K) := \frac{E^2 \cdot n_{fg}}{h} \cdot \frac{1}{e^{\frac{2 \cdot E}{3 \cdot k_b \cdot T_K}} + 1}$$ black body formula for beta spectrum 210Bi

$$PD(E_{peak}, T_K) = 5.118 \times 10^{47} \frac{W}{m^3} \qquad PDa(E, T_K) := \frac{PD(E, T_K)}{PD(E_{peak}, T_K)}$$

Figure 2 allows you to visually compare the beta spectrum of 210Bi according to the blackbody formula with the experimental spectrum from the article by G.J. Neary.

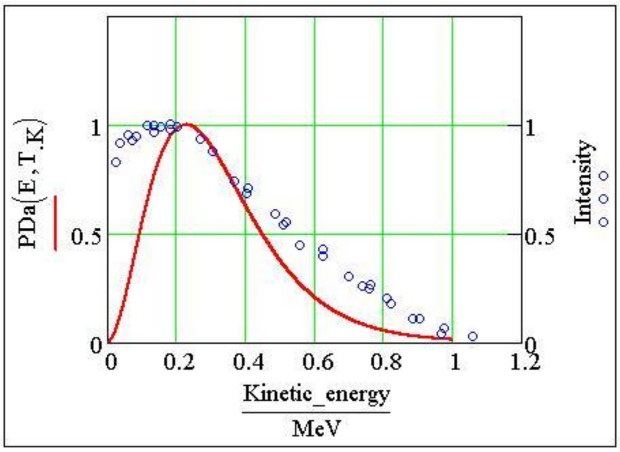

Fig. 2. The energy spectrum of 210Bi beta decay electrons according to the blackbody formula (red line) and the experimental spectrum from G.J. Neary's article (blue dots).

Conclusions

It seems that it is possible to search neutrino of beta decay in details of the shape of experimental spectrum that distinguish it from blackbody model.

A curious prediction of the model is the very high temperature of the nuclear Fermi gas. If this is true, then experimentally detecting the dependence of beta decay on temperature will not be a very simple task.

References

Neary, G.J. The beta-ray spectrum of radium E. 1940. Proc.Roy.Soc.(London),A175,71
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