Introduction

An analysis of the electron antineutrino spectrum emitted by nuclear reactors provides a means to estimate the operational status and thermal power output of that reactor. Furthermore, it has been demonstrated that it is possible to estimate the direction of the incoming neutrino. This means that an antineutrino detector can be used for the monitoring of processes inside nuclear reactors for both operational purposes and the reactor safeguards regime setup by the International Atomic Energy Agency.

Reverse beta decay

An antineutrino reacts with a proton to form a positron and neutron. The positron is annihilated almost instantly, while the neutron undergoes thermalisation over several centimeters before it encounters a neutron capture agent. By measuring the time difference between the positron and neutron signals, it is possible to screen for the distinct signature of neutron capture.

Neutron capture agent

Until recently, neutron capture agents that were used employed unstable compounds. These systems needed constant purification and checking. Recently, it was shown that beta-diketone gadolinium coordination compounds improved the overall stability of the system. However, current Gd systems are not stable in polymers. These systems needed constant checking. Recently, it was shown that beta-diketone gadolinium coordination compounds improved the chemical stability.

Fluorescent compounds

Presently used fluorescent compounds and wavelength shifters have been in use since the beginning of scintillation counting. These compounds which have recently been developed are synthesized with cost, durability and quantum efficiency in mind. These substances are easy to tune to specific wavelengths and are chemically stable.

Objectives / Signal processing

The reverse beta decay process produces two time differentiated signals due to positron annihilation and the energy deposition of a gamma-ray or alpha particle. Due to the specific timing and spatial distance between these two signals, it is possible to differentiate between real and random events. With the use of boron as neutron capture agent and pulse shape discrimination, it is possible to screen for the distinct fingerprint of an alpha particle signal and reject the signals coming from gamma rays.

Current status

Existing antineutrino detectors have overall efficiencies ranging from 10 to 70% for the detection of antineutrinos. The range stems a.o. from their different sizes. With small detectors (1 m³) a significant amount of the gamma radiation travels outside the detection area and is lost for measurements. To enable higher efficiencies with small detector systems, a system where almost all of the deposited energy is preserved inside the area of detection is essential.

Gamma versus Alpha

A neutron produced by reverse beta decay will undergo thermalisation via collisions with other atoms till it can be captured by a nucleus. Depending on the specific nucleus, a gamma-ray or alpha particle is emitted.

Fluorescent compounds

Presently used fluorescent compounds and wavelength shifters have been in use since recent years new technologies including solar cells, OLEDs and Qdots have provided new fluorescent materials which may also be of interest for scintillation purposes.

Fluorescent Qdots emitting different colors upon irradiation with UV light

References


Contact Information

a. INCAS³, Dr Nassaulaan 9, 9401 HJ, Assen, The Netherlands. E-mail: peterdijkstra@incas3.eu
b. Strategic Institute for Chemistry, Faculty of Mathematics and Natural Sciences, University of Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands

Visit www.incas3.eu for more information.