Light yield function of a liquid scintillator for neutrino detection in the underground experiment SNO+

The SNO+ detector is to be used to investigate diverse aspects of neutrino physics. The detector consists of a liquid scintillator tank of 12 m in diameter in which the neutrino-induced events are detected by approx. 10,000 photomultipliers. For the liquid scintillator, linear alkylbenzene (LAB) is used as a solvent, and 2,5-Diphenyloxazole (PPO) is used as primary scintillator. Within the scope of a cooperation between the Technische Universität Dresden (TUD), the Brookhaven National Laboratory (BNL), and PTB, the proton light yield from the pulse height spectrum generated by monoenergetic neutrons was determined using PTB's time-of-flight spectrometer, and investigated for different combinations of solvent, primary scintillator and other components.

The underground experiment SNO+ is located at a depth of approx. 2,000 m in the Sudbury mine in Ontario (Canada). It is intended to investigate various aspects of neutrino physics, for example the neutrinoless double-beta decay, the production of so-called "geo-neutrinos" in the Earth's core or the role of the different neutrino flavours during a supernova explosion. The SNO+ detector consists of a scintillator tank of 12 m in diameter in which the events are detected by approx. 10,000 photomultipliers. For the liquid scintillator, linear alkylbenzene (LAB) is used as a solvent, and 2,5-Diphenyloxazole (PPO) is used as primary scintillator. The PPO concentration will be 2 g/dm^3. LAB is a non-toxic, low-flammability preproduct of detergents which is available in large quantities at low cost.

In order to analyze the experiments, especially to discriminate background events, the non-linear light yield function of the scintillator is required for various charged particles, especially for protons and alpha-particles. The light yield describes the reduced production of scintillation light by these particles, so-called "quenching", as compared to the light yield of electrons which is proportional to the kinetic energy at energies above a few keV.

In the case of organic scintillators (only consisting of hydrogen and carbon), the proton light yield can be determined from the pulse-height spectrum generated by monoenergetic neutrons, since the maximum energy of the recoil protons from neutron-proton scattering is equivalent to the neutron energy. The alpha light yield function can, in contrast, be only be determined experimentally by comparing the position of the structures induced by alpha-particles from $^{12}C(n,\alpha x)$ reactions in simulated and measured pulse height spectra.

Within the scope of a cooperation between the Technische Universität Dresden (TUD), the Brookhaven National Laboratory (BNL), and PTB, these data were determined using PTB's time-of-flight spectrometer for different combinations of solvent, primary scintillator and other components. To this end, a neutron beam with continuous energy distribution was generated by means of the nuclear reaction $^9Be(p,nx)$, and the energy of the neutrons was determined with the time-of-flight method. This technique allows the proton energy range from 1.5 MeV to 17 MeV to be covered in one experiment. The absolute scintillation light yield of LAB is smaller than that of a reference scintillator such as BC501A. Furthermore, the spectral distribution of the scintillation light of LAB is, compared to that of BC501A, shifted towards smaller wavelengths, so that the quantum efficiency of the photomultiplier used to detect the light is considerably reduced. For LAB, the pulse height spectra thus show a clearly reduced pulse height resolution around the proton recoil edge. The resolution was improved by adding 15 mg/dm^3 of 1,4-Bis(2-methylstyryl)benzene (Bis-MSB) as a wavelength shifter.

Figure 1 shows the proton light yields, determined from the positions of the proton recoil edges as a function of the light yield of BC501A. In the linear part above 8 MeV, the LAB light yields are reduced by approx. 3 % to 4 % compared to the light yield of NE 213. As expected, adding the secondary scintillator Bis-MSB as a wavelength shifter does not significantly change the light yield function.

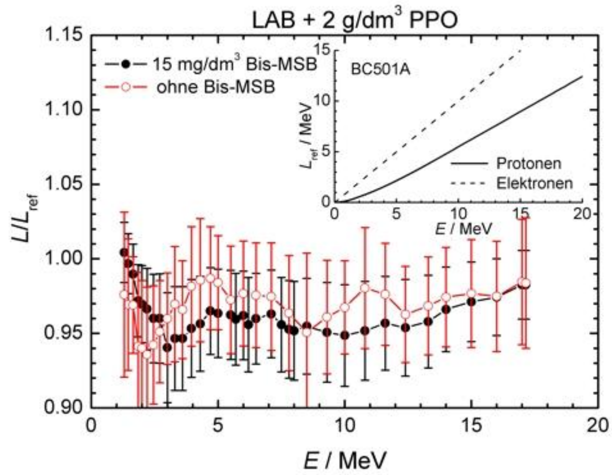

Fig. 1: Light yields of LAB + 2 g/dm^3 PPO for protons, as a function of the light yield of BC501A. The closed and open symbols show data with and without, respectively, the secondary scintillator Bis-MSB as a wavelength shifter. The light yields of BC501A for protons (continuous line) and electrons (dashed line) are shown at the top right.

Contact

R. Nolte, Department 6.4, Working Group 6.42, e-mail: ralf.nolte@ptb.de