Charged Particle Detection

Detector Applications Information Note

Charged particles include electrons, muons, and atomic nuclei. These particles lose energy through Coulomb interactions with the atomic electrons in the surrounding matter.

In selecting a detector for charged particles, the primary consideration is the type of particle to be detected. For this discussion, we identify two broad categories of charged particles, list some of the general applications associated with each category, and show how detector performance can be estimated.

Weakly Penetrating Particles

This class of particles includes low energy electrons, protons, alphas, and heavy ions. The rate of energy loss increases as the charge and mass of the particle increase, but the conversion of particle energy to scintillation light decreases. For equal energies, a proton will produce only 1/4 to 1/2 the light of an electron, while alphas will produce only about 1/10 the light.

Applications include alpha/beta survey instruments, dosimetry instruments, and heavy ion dE/dx detectors.

Detector design considerations:

1. The entrance window must be very thin so that the incident radiation is not absorbed. Typically, 0.5 to 2 mg/cm^2 aluminized mylar is used. For heavy ions, the detector is best operated in a light-tight environment without a window.
2. Scintillator selection usually is determined by pulse height. Typical choices are BC-400 or BC-404 (betas and/or alphas) or ZnS (alphas). CaF_2(Eu) and CsI(Tl) are also widely used. CaF_2(Eu) is often the first part of a phoswich detector and CsI(Tl) is a total energy detector often coupled to a photodiode. YAG(Ce) and YAP(Ce) and also interesting candidates.
3. Scintillator thickness is determined by the range of the most penetrating particle to be observed. For very low energies, 1/4 mm thickness can provide near 100% efficiency for charged particles penetrating the window but almost no gamma response. Thicker scintillators may be used if gamma sensitivity is desired or is not a problem. In the case of ZnS detectors, thickness is limited to about 10 mg/cm^2 because poor light transmission of thicker layers will decrease detector efficiency.

Minimum Ionizing Particles

Particles in this group are usually singly charged, and have low mass and high energy. Their energy loss per unit pathlength is small. Common examples of minimum ionizing particles are cosmic ray muons and fast electrons. In BC-408 plastic scintillator, minimum ionizing particles deposit energy at a rate between 1.8 to 2 MeV/cm. About 10 scintillation photons are created for each keV of deposited energy

Applications include cosmic ray anti-coincidence, calorimetry, and electron spectroscopy.

Detector design considerations:

1. Entrance window material and thickness are not usually important since the particles normally pass through the window and the entire scintillator. An exception is in beta spectroscopy where energy loss in the window material must be small relative to the total energy of the particle.
2. Scintillator thickness is normally governed by desired signal levels, gamma ray efficiency (if applicable), and cost. For beta spectroscopy, the thickness of the scintillator is normally 10% to 20% greater than the estimated range of the highest energy beta.
3. Light attenuation is an important consideration in large area detectors. If a scintillator absorbs its own light, then the response will have a strong positional dependency. The use of light pipes helps to minimize positional dependency, but scintillators with good light transmission (such as BC-408 or BC-412) are recommended when the length of the detector exceeds one meter. Other considerations include the time response of the scintillator and whether special loadings are desired.

Scintillation Products

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For additional product information, request the following SGC literature:

Organics Products and Accessories brochure;
Individual Materials data sheets.

All are available in print and as PDF files on the web site.

The data presented are believed to be correct but are not guaranteed to be so.

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