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Neutron Detection by Large NaI Crystal

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In present days new neutron detection methods are under development due to the global shortage of 3He and the toxicity of BF3. We present an indirect method based upon detection of photons emitted in neutron reactions such as neutron capture and inelastic scattering. One of the advantages of this approach is that the detector can also be used simultaneously as a gamma spectrometer. Experimental studies were performed with a 4"x4"x8"NaI crystal and 252Cf and AmBe neutron sources. Scintillation pulses caused by charged heavy particles decay more slowly than those caused by charged lighter particles. Pulses caused by neutron scattering or neutron-induced alpha particles can thus be discriminated from pulses caused by photons. Measurements show that the most important contribution to the detector signal is coming from the neutron capture reaction by iodine in the crystal. The detection efficiency can be improved significantly by covering the detector external sides with polyethylene and polyvinylchloride. These two materials play the double role of moderator and converter. A MonteCarlo investigation devoted to the optimization of the possible converter materials surrounding the NaI detector restricted the solution to chlorine and iron but the simulations show polyvinylchloride performs better than the iron (and it is much lighter). The moderator and converter could also lower the detector background, with a further improvement of the detection limits. The MonteCarlo code pointed out that the effect of the converter is negligible if the thickness of the moderator and converter layer is less than 4 cm and with a layer thicker than 10 cm the efficiency does not improve significantly. The NaI spectrometer surrounded by the proper moderator/converter layer was compared with a standard 3He detector for portal monitor application. We found that efficiencies and minimum detectable activities are roughly of the same order of magnitude thanks to the much higher density of NaI crystal and the neutron capture cross section of iodine. The indirect detection of neutrons by photons has several advantages. First, this method can in principle be suited by any gamma spectrometer (as BGO for instance) with only slight modifications that do not compromise its spectroscopic capabilities: usual gamma spectrometry measurements and neutron detection can be performed simultaneously. Seen from this side the present method results much more convenient: we can perform two functions with the same equipment. Second, fission neutron sources and neutron generators (such as AmBe sources) can be discriminated thanks to their different gamma energy spectra, a discrimination easily done by NaI spectrometer. Third, as will shortly discuss in this paper, the indirect detection approach gives better performances if the neutron source has been shielded using hydrogen-rich or boron-rich material. In general, on-field analysis and data management are much easier to perform with only one detector type instead of having to deal with a gamma spectrometer and neutron detector (like for instance 3He). The list of these advantages makes this experimental solution based upon a portable NaI spectrometer properly shielded, especially interesting for security applications.

Collaboration

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