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Development of a simple-material discrimination method with three plastic scintillator strips for visualizing nuclear reactors

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The Fukushima Daiichi nuclear disaster is a series of equipment failures and nuclear meltdowns, following the Tōhoku earthquake and tsunami on 11 March 2011. We present a new method for visualizing nuclear reactors. Muon radiography based on the multiple Coulomb scattering of cosmic-ray muons has been performed. In this work, we discuss experimental results obtained with a cost-effective simple detection system assembled with three plastic scintillator strips. Actually, we counted the number of muons that were not largely deflected by restricting the zenith angle in one direction to 0.8^o. The system could discriminate Fe, Pb and C. Materials lighter than Pb can be also discriminated with this system. This method only resolves the average material distribution along the muon path. Therefore the user must make assumptions or interpretations about the structure, or must use more than one detector to resolve the three dimensional material distribution. By applying this method to time-dependent muon radiography, we can detect changes with time, rendering the method suitable for real-time monitoring applications, possibly providing useful information about the reaction process in a nuclear reactor such as burnup of fuels. In nuclear power technology, burnup (also known as fuel utilization) is a measure of how much energy is extracted from a primary nuclear fuel source. Monitoring the burnup of fuels as a nondestructive inspection technique can contribute to safer operation. In nuclear reactor, the total mass is conserved so that the system cannot be monitored by conventional muon radiography. A plastic scintillator is relatively small and easy to setup compared to a gas or layered scintillation system. Thus, we think this simple radiographic method has the potential to visualize a core directly in cases of normal operations or meltdown accidents. Finally, we considered only three materials as a first step in this work. Further research is required to improve the ability of imaging the material distribution in a mass-conserved system.