Prague, Czech Republic June 21-25, 2021

Contribution ID: **86** Type: **Oral presentation**

#07-86 Design and Optimization of 4π Directional Radiation Detector based on Compton Effect

Wednesday, June 23, 2021 3:00 PM (20 minutes)

Detection of gamma ray sources is a challenging task in many applications, where monitoring and mapping of radiological and nuclear materials is required. Obtaining directional information is required for nuclear homeland security (HLS) and safety, mapping for post-accident decontamination of nuclear incident or radiological event, etc. Many of directional radiation detectors are based on directional shielding, made of lead or tungsten collimators, which introduces two main drawbacks. The first is the size and weight, that makes those detectors too heavy and irrelevant for utilization in HLS handheld devices, drone mapping or space applications requiring cosmic gamma ray directional measurements. The second drawback is the small field of view (FOV), which requires multiple detectors to cover all the required FOV or machinery to rotate the limited FOV detector.

We propose a novel 4π directional detector based on Compton Effect interactions. Instead of using various shielding methods for directional information, we use the Compton scattering event, with two or more interactions within the detector. Based on the interactions locations of a single gamma ray event, we can back-project a probability cone of source locations. Using enough events, a collection of such cones converges into a single point source. One of the main advantages of this method is the ability to see more than just one source, just like a Compton Camera (CC). Whereas collimated detectors are erroneously calculated the mean location of a few sources, missing most of them. Additional advantage of the proposed detector is the 4π directional ability, which is missing in both the shielding collimated detectors and the CC devices. Moreover, shielded detectors undergo decrease in signal to noise (SNR) at high background radiation. Nevertheless, the proposed solution is not affected severely, since non relevant background events are identified as of incorrect direction events and rejected, without entering the calculation algorithms.

In order for the defector to be accurate, we need small voxels for accurate localization of an interaction location and a large distance between the interactions of a single event for high directional angle accuracy. We suggest an efficient geometrical solution that spreads the radiation detection voxels as far as possible in the detector volume, on the faces of the cubical directional detector. Doing so, we allow the Compton scattered gamma ray photon to travel from one side to the other side of the cube, obtaining maximal distance between the voxels. Further geometrical optimization is required for an optimal voxel size. Each voxel has an impact area and an interaction depth. Maintaining the total detector size, a small voxel area provides high interaction accuracy, but requires more amplification and sampling ADC channels which introduces complexity of the electronics. For high detection efficiency an increased voxel depth is required. On the other hand, this causes an interaction location uncertainty along the depth axis and Compton interaction probability to decrease, lowering the detection efficiency.

The 4π directional radiation detector provides significant advantages over the traditional directional detectors. It presents compact and lightweight structure without heavy collimators enabling the usage in drones and satellites; Introduces a radiation background rejection abilities; Detects gamma rays in a widest FOV of 4π with the ability to detect multiple radioactive sources, simultaneously, in a single measurement without mistakenly combining them into one. Such abilities enable utilization of such detectors for HLS and mapping of post-accident decontamination.

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Session Classification: 07 Nuclear Fuel Cycle, Safeguards and Homeland Security

Track Classification: 07 Nuclear Fuel Cycle, Safeguards and Homeland Security