How detectors of nuclear radiation are re-calibrated

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In science, it is common practice to perform experiments to see how nature responds. In nuclear physics, these experiments commonly entail launching subatomic particles known as nuclei toward a target in hopes of studying the shrapnel that sometimes ensues. To study these subatomic debris, it is no doubt important to have well-calibrated detectors. In this thesis, the aim is to provide an accurate method to re-calibrate an array of these detectors, dubbed the GAMMASPHERE for its ability to detect nuclear light. Using the re-calibrated data of this detector, new details of nuclear structures may be discovered.

In 2020, the Argonne National Laboratory conducted a series of experiments where nuclei of Argon were launched at high speeds into a target of Magnesium, in hopes of creating Zinc through fusion. Here, the small particles known as nuclei are the core of atoms that make up all materials and matter that we encounter. Given enough speed upon collision, the two nuclei will sometimes merge to create a compound nucleus of Zinc, which will itself rapidly fall apart due to the high energy involved in the collision. Since the merged Zinc nucleus falls apart so rapidly, one needs to verify that this element was indeed created, which is done by resolving and studying the resulting debris.

There are roughly two kinds of debris that highly excited Zinc nuclei may eject. The first kind is particles such as protons or neutrons, which are essentially chunks of the nucleus itself. The second kind is high-energy rays of light, known as γ rays. This is where the GAMMASPHERE comes in, as it is specialized in detecting the energy of γ rays to a high degree of accuracy. The energy of the emitted γ rays serves as an indication of when a Zinc nucleus was created, as it emits rays at very specific energies when falling apart.

In order to successfully identify the nuclear debris created in the experiment, one needs to make sure that the energy that the GAMMASPHERE reads out is correct. Radiation damage or changing environmental conditions in the experimental hall can cause the detected energy to drift over time. Hence, it is important to re-calibrate the GAMMASPHERE regularly, by giving it γ rays of known energy and comparing that to the energy that it detects. If there is a mismatch between the known and detected energies, the gathered data can be corrected using the apparent energy difference.

Using the re-calibrated data from this detector, it may be possible to find yet unobserved γ rays that the compound nucleus emitted whilst falling apart, uncovering yet unknown nuclear structures. This is done by analyzing which of the γ rays were detected coincidentally in a process known as γ-γ correlation. With this method, one can probe the nuclear structure of the nuclei and how exactly they fall apart.

At this point, one may wonder why exactly nuclear physicists want to observe the creation and destruction of some obscure Zinc nucleus, which is a fair question. The seemingly boring answer to this question is that the research conducted will help us understand and model how nuclei behave in general. One should not underestimate the value in understanding the nature of our surroundings. Knowing and predicting how nuclei will behave is invaluable knowledge for innumerable fields of science and industry, from medicine to manufacturing.