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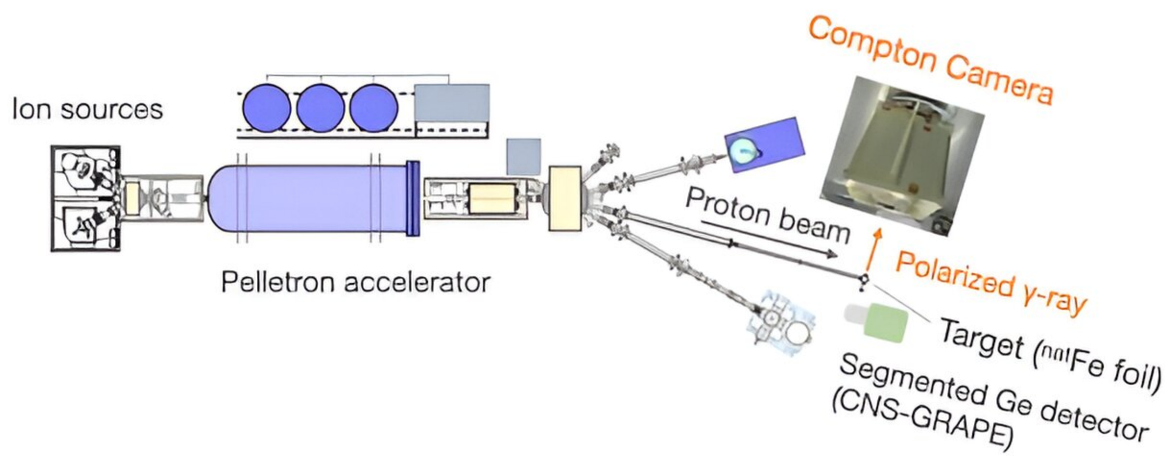
Astronomy observation instrument used to uncover internal structure of atomic nuclei

February 13 2024



The RIKEN tandem (Pelletron) accelerator and beam lines. Credit: RIKEN

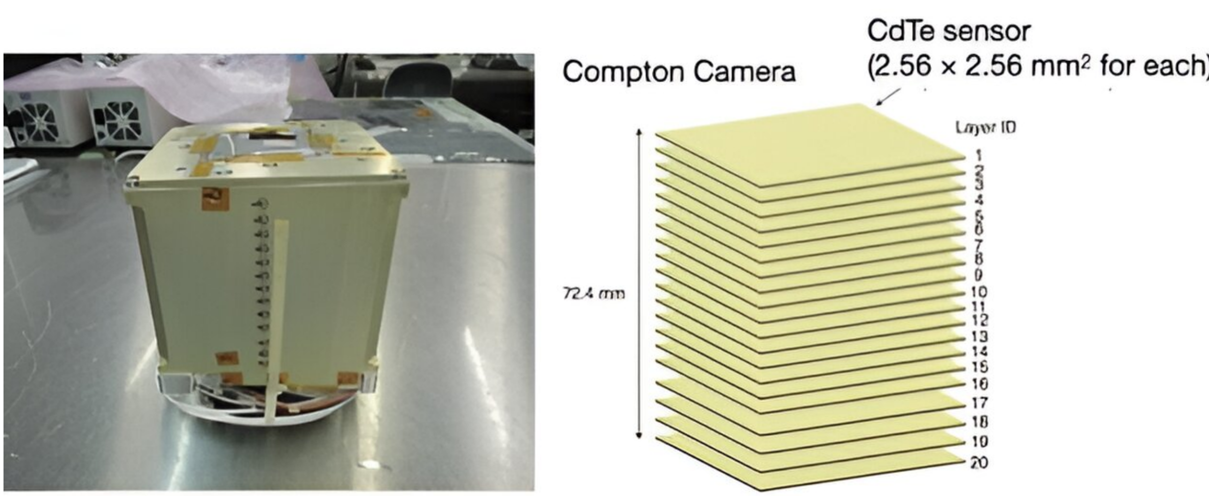
A group of researchers has used equipment originally intended for astronomy observation to capture transformations in the nuclear structure of atomic nuclei, reports a new study in *Scientific Reports*.

A nucleus is made up of protons and neutrons. About 270 stable nuclei exist in nature, but this number bounces up to 3,000 if you include unstable nuclei. Recent research on unstable nuclei has uncovered phenomena not observed in stable nuclei, including anomalies in energy levels, the disappearance of magic numbers, and the emergence of new magic numbers.

To study these structural changes, it is important to determine the quantum states, internal energy, spin, and parity of the state. Conventional methods have been limited by the difficulty of balancing sensitivity and detection efficiency when analyzing electromagnetic characteristics of transitions.

Now researchers have utilized their multi-layer semiconductor Compton camera to capture the polarization of gamma rays emitted from atomic nuclei. This reveals the internal structure of the atomic nuclei.

This method significantly reduces uncertainties in determining spin and parity for quantum states in rare atomic nuclei, making it possible to capture transformations in nuclear structure.

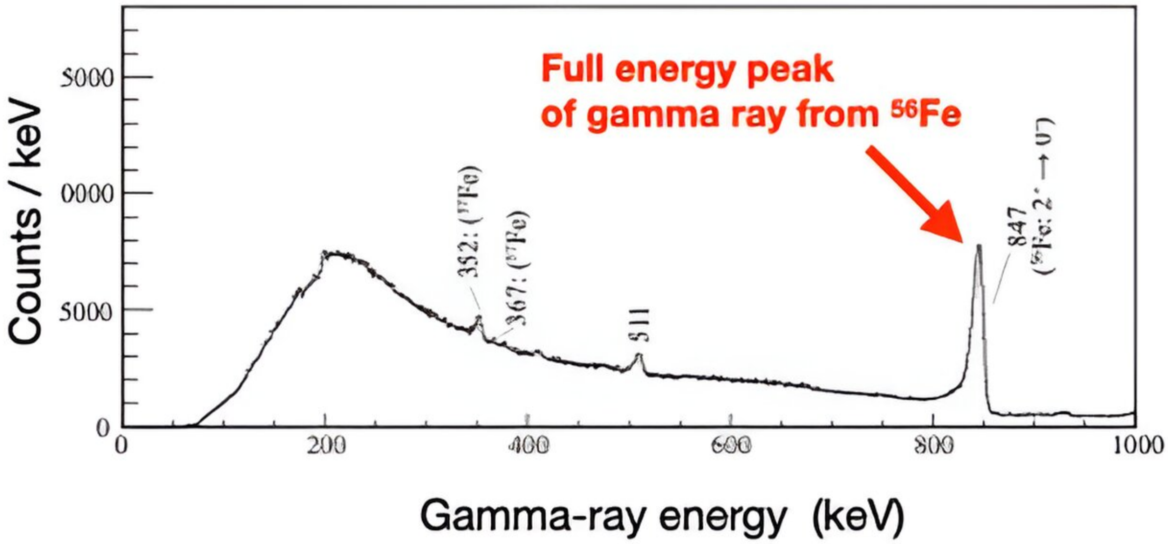


The CdTe Compton Camera (left) and the 20 layers inside (right). Credit: RIKEN

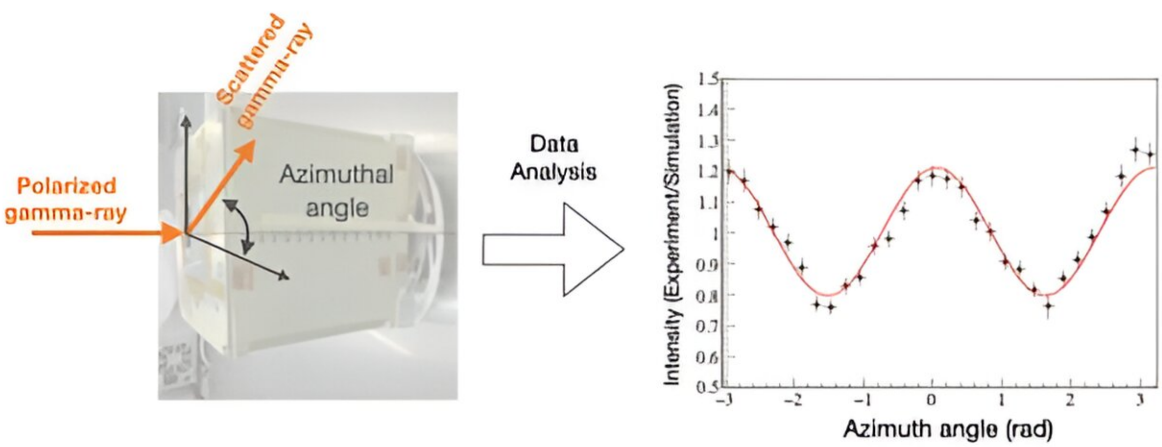
The Compton camera includes a Cadmium Telluride (CdTe) semiconductor imaging sensor, which was originally designed for astronomy observation. It has a high detection efficiency and precise position determination accuracy. The research group used this camera in nuclear spectroscopy experiments with controlling both the position and intensity of gamma-rays emissions from the target artificially, allowing for a detailed analysis of scattering events and realizing a highly sensitive polarization measurement.

The researchers capitalized on the positional accuracy of a pixel-type imaging sensor, and used accelerator experiments at the RIKEN Pelletron accelerator to evaluate the camera's performance. Proton beams were directed at a thin iron film target, generating the first excited state of 56Fe nuclei. The emitted gamma rays were measured, revealing a peak structure.

The team succeeded in extracting the distribution of scattering azimuth angle. The remarkably high sensitivity to capture the polarization of gamma ray was obtained with reliable detection efficiency. This performance is crucial for investigating the structure of rare radioactive nuclei.



Gamma-ray spectrum obtained in the present work. Credit: RIKEN



Scattering angle distribution (right) of polarized gamma rays as captured by the multi-layer Compton camera (left). The black dots show the distribution and red line shows the modulation curve. Credit: RIKEN

This research could pave the way for a more profound comprehension of the fundamental principles underlying the formation of the universe and the characteristics of matter, including the disintegration process of magic numbers in exotic, unstable nuclei.

The research team included Kavli Institute for the Physics and Mathematics of the Universe (WPI-Kavli IPMU) Professor Tadayuki Takahashi and graduate student (at the time of research) Yutaka Tsuzuki, along with RIKEN Cluster for Pioneering Research Ueno Nuclear Spectroscopy Laboratory researchers Shintaro Go and Hideki Ueno, RIKEN Nishina Center for Accelerator-Based Science Cosmic Radiation Laboratory Hiroki Yoneda, Kyushu University Associate Professor Yuichi Ichikawa, and Tokyo City University Associate Professor Tatsuki Nishimura.

More information: S. Go et al, Demonstration of nuclear gamma-ray polarimetry based on a multi-layer CdTe Compton camera, *Scientific Reports* (2024). DOI: 10.1038/s41598-024-52692-2

Provided by Kavli Institute for the Physics and Mathematics of the Universe, The University of Tokyo