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Production of rare isotope beams with aligned nuclear spins opens up new possibilities for high-energy physics research

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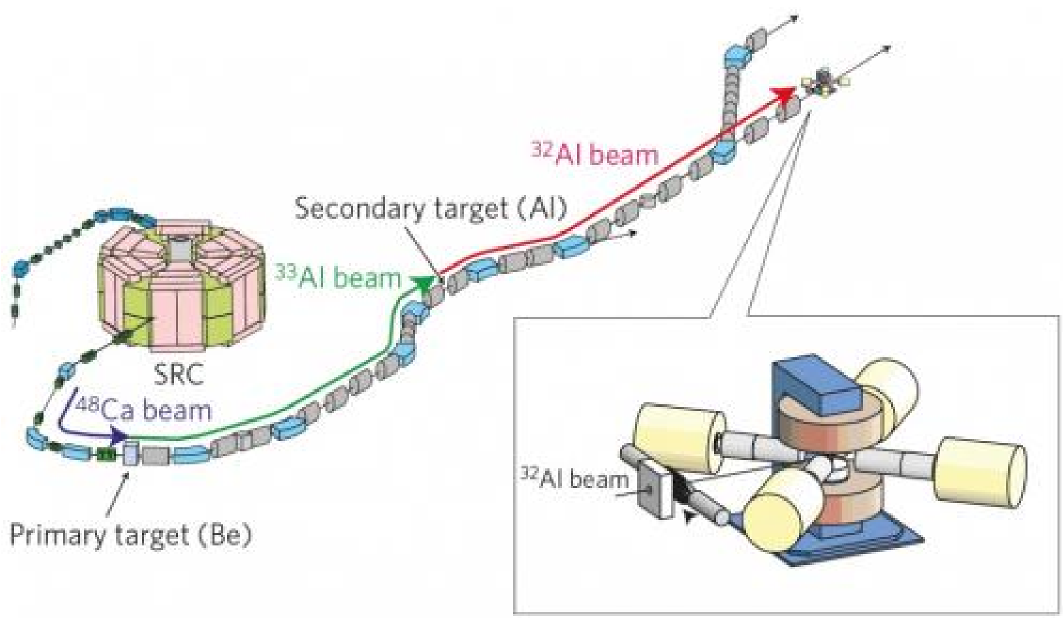

The RIBF facility. Spin-aligned beams of aluminum-32 (32Al) are produced in two stages by first bombarding a beryllium (Be) target with a calcium-48 (48Ca) beam generated by the superconducting ring cyclotron (SRC) to produce an aluminum-33 (33Al) beam, and then bombarding a secondary aluminum target and selecting a narrow band of momentum to produce a 32Al beam with high degree of spin alignment. Credit: 2012 Y. Ichikawa et al.

Particle physicists routinely and incrementally test the boundaries of what is possible in physics research. Occasionally however, they achieve a breakthrough that reveals an entirely new, uncharted field of study. Researchers at RIKEN's Radioactive Isotope Beam Factory (RIBF), part of the RIKEN Nishina Center for Accelerator-Based Science, have recently made such a breakthrough with their production of a beam of spin-aligned rare isotopes.

The nucleus of an atom consists of protons and neutrons, the numbers of which determine the element and the isotopic variant. Every element has a range of possible isotopes, but the vast majority of isotopes do not occur in nature—they can only be produced experimentally by bombarding materials such as thin metallic foils with a beam of ions using a particle accelerator.

Researchers at the RIBF have been producing beams of rare and heavy isotopes to explore the unknown 'nuclear chart' for many years. The beam of isotopes produced by the RIBF has a random alignment of spins, a quantum magnetic property of the isotope related to its angular momentum. By passing the isotope beam through a slit, the beam can be pared down to a narrow range of momentum to afford a beam with enhanced spin alignment. This technique has been applied in the past as a system consisting of two target–slit stages, but the degree of spin alignment achieved had been marginal. In their latest work, the RIKEN researchers were able to improve the spin alignment effect by a factor of 50 by replacing the first slit with a much more effective momentum dispersion matching stage that relies on the divergent spread of isotope trajectories due to their differences in momentum.

"Our method expands research into radioisotope beams and offers new possibilities to conduct microscopic investigations into physical and chemical processes that take advantage of nuclear properties such as spin," says Yuichi Ichikawa from the research team.

Not only does the new system produce a beam with a spin alignment of up to 8%, the ability of the momentum-dispersion matching stage to harvest a larger fraction of the initial isotope beam also greatly enhances the beam's overall intensity. The system can also be applied for a wide range of isotopes. "The RIBF is expected to produce 4,000 species of radioisotope beams," says Ichikawa. The production of such spin-aligned isotope beams is anticipated to open up new opportunities for research on unusual nuclear structures and the quantum dynamics of condensed matter.

More information: Ichikawa, Y., et al. Production of spin-controlled rare isotope beams. *Nature Physics* 8, 918–922 (2012). dx.doi.org/10.1038/nphys2457

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