Potassium nucleus loses some of its magic

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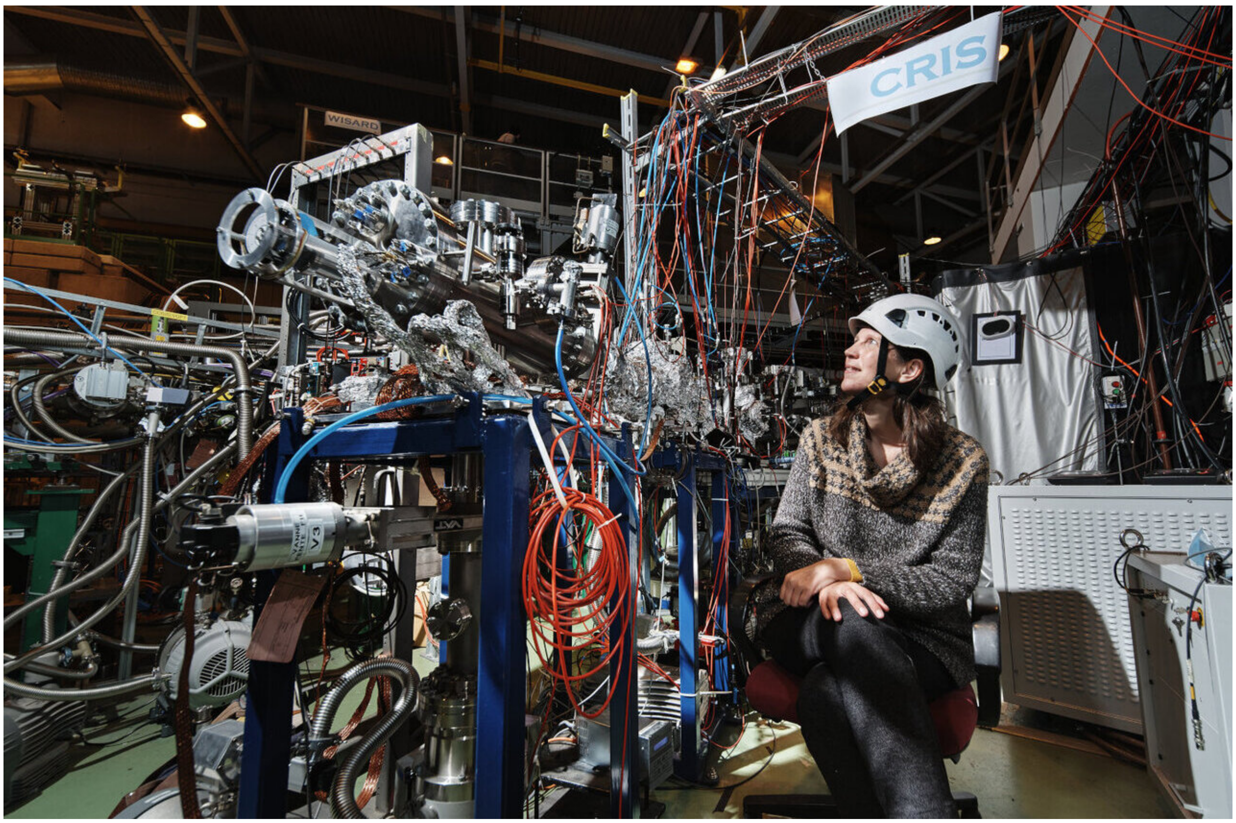

ISOLDE spokesperson Gerda Neyens at the facility's collinear resonance ionisation spectroscopy (CRIS) set-up. Credit: CERN

A new study at ISOLDE finds no signature of a "magic" number of neutrons in potassium-51, challenging the proposed magic nature of nuclei with 32 neutrons.

The magic seems to be ebbing away from some atomic nuclei. The latest measurements of the sizes of potassium nuclei rich in neutrons show no signature of a "magic" number of neutrons in potassium-51, which has 19 protons and 32 neutrons. The result, obtained by a team of researchers using CERN's nuclear-physics facility ISOLDE and described in a paper just published in *Nature Physics*, challenges nuclear-physics theories and the proposed magic nature of nuclei with 32 neutrons.

Protons and neutrons are thought to each occupy a series of shells of different energy within an atomic nucleus, just like electrons in an atom fill up a series of shells around the nucleus. In this nuclear shell model, nuclei in which protons or neutrons form complete shells, without any space left for additional particles, are termed "magic" because they are more strongly bound and stable than their nuclear neighbors. The number of protons or neutrons in such nuclei are termed magic numbers, and are cornerstones upon which physicists build their understanding of nuclei.

Previous studies indicated that nuclei with exactly or close to 20 protons and with 32 neutrons are magic on the basis of the energy it takes to remove a pair of neutrons from the nucleus or to take the nucleus to a higher-energy level. However, measurements of how the (charge) radii of neutron-rich potassium and calcium nuclei change as neutrons are added to them have challenged this indication, because they didn't display a sudden relative decrease in the radii of potassium-51 and calcium-52, which both have 32 neutrons. Such a decrease, relative to nuclear neighbors with fewer neutrons, would indicate that 32 is a magic neutron number and that nuclei with 32 neutrons are magic.

A magic neutron number of 32 could also be revealed by a sudden relative increase in the radii of nuclei that have one more neutron, that is 33 neutrons. This is exactly what the team behind the latest ISOLDE study set out to investigate. By marrying two techniques, the ISOLDE researchers were able to make radii measurements of neutron-rich potassium nuclei and to extend them to potassium-52, which has 33 neutrons. The two techniques are a type of laser spectroscopy called collinear resonance ionisation spectroscopy (CRIS), which allows neutron-rich nuclei to be studied with high precision, and β-decay detection, which involves the detection of beta particles (electrons or positrons) emitted from the nuclei.

The new ISOLDE measurements showed no sudden relative increase in the radius of potassium-52, and thus no signature of "magicity" at neutron number 32.

The researchers went on to model the data with state-of-the-art nuclear theories, finding that the data challenges these theories. "The best nuclear-physics models on the market cannot reproduce the data in a satisfactory way," says lead author of the paper Agi Koszorus. "If they get one feature of the data right, they totally miss the rest," added co-lead author Xiaofei Yang.

"This study highlights our limited understanding of neutron-rich nuclei," says co-author Thomas Cocolios. "The more we study these exotic nuclei, the more we realize that the models fail to reproduce the experimental results. It's like having a map full of highways, but as soon as you take a path off those highways, you might as well be walking on the moon for all we know."

"This result shows how much work is left for us to understand the atomic nucleus—probably the least-understood realm of physics," concludes Cocolios.

More information: Á. Koszorús et al. Charge radii of exotic potassium isotopes challenge nuclear theory and the magic character of

N = 32, *Nature Physics* (2021). DOI: 10.1038/s41567-020-01136-5

Provided by CERN

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