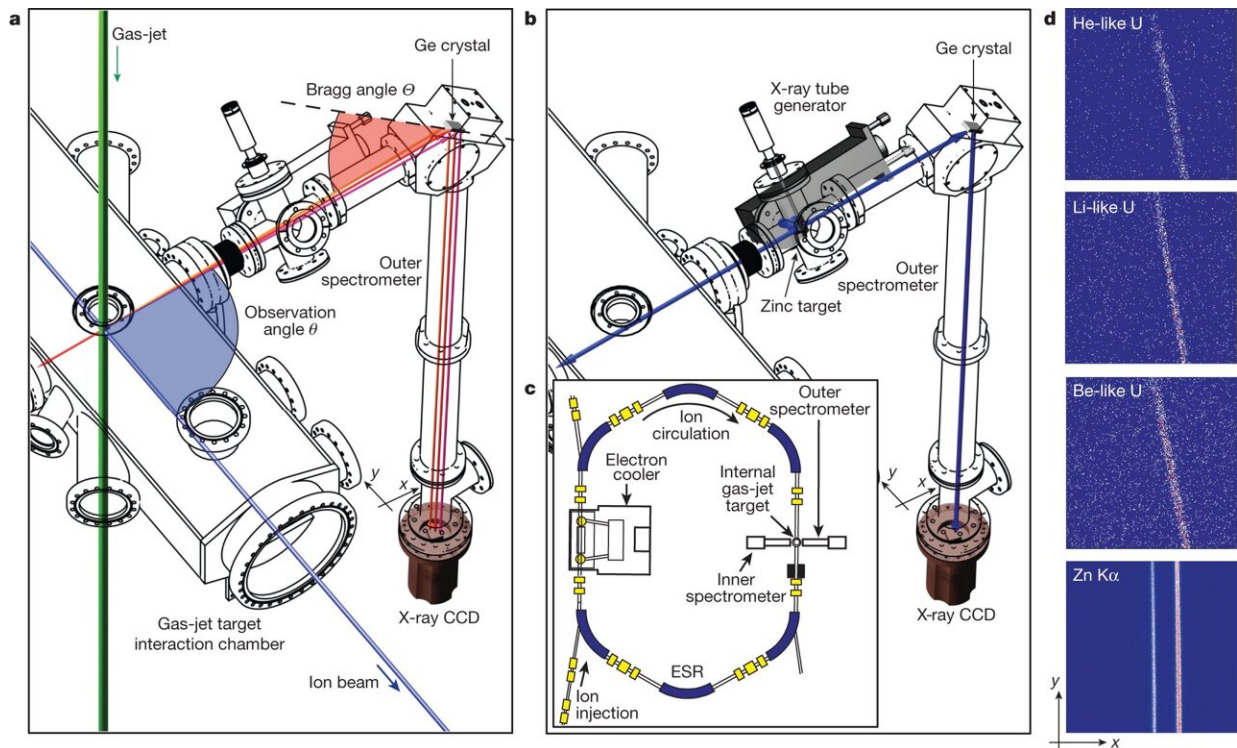


# Team accomplishes precise measurements of the heaviest atoms

January 25 2024, by Stephan Laudien



Experimental setup. The two Bragg spectrometers (only the outer one is shown in the figure) are placed in proximity of the interaction point between the ion beam and the gas-jet target of the ESR. a, X-rays emitted at slightly different angles have different energy values because of the relativistic Doppler effect corresponding to different Bragg angles. This results in a slanted spectral line on the CCD (d). b, The placement of the retractable zinc fluorescence source is also shown together with the X-ray tube used for its activation. The corresponding second-order reflection spectral line has no slope. c, Sketch of the ESR indicating the position of the two spectrometers (adapted from ref. 46). d, Spectral lines detected by the outer spectrometer corresponding to the different

intrashell transitions and the Zn  $K\alpha_{1,2}$  fluorescence lines (bottom right). The horizontal axis (x-axis) corresponds to the dispersion axis proportional to the transition energy. All images are obtained with a binning of factor 8 of the original data. Credit: *Nature* (2024). DOI: 10.1038/s41586-023-06910-y

An international research team has successfully conducted ultra-precise X-ray spectroscopic measurements of helium-like uranium. The team, which includes researchers from Friedrich Schiller University Jena and the Helmholtz Institute Jena (both in Germany), has achieved results demonstrating their success in disentangling and separately testing one-electron two-loop and two-electron quantum electrodynamic effects for extremely strong Coulomb fields of the heaviest nuclei for the first time.

The researchers have now [published](#) their results in the journal *Nature*.

The published paper details basic research into the age-old question of what holds our world together at the innermost level. Dr. Robert Löttsch, an experimental physicist at the Institute of Optics and Quantum Electronics at the University of Jena, says that the special part of this project is that measurements were conducted on the heaviest stable atoms.

"When measuring a hydrogen atom, which has the atomic number one, we can precisely measure the electron transitions to 13 [decimal places](#)," says Dr. Löttsch. He explains that for uranium, which has the [atomic number](#) 92, [precise measurements](#) have been taken to five decimal places.

The measurement focuses on the transition between different orbits. The experiments took place at the GSI/FAIR experimental storage ring in Darmstadt—a particle accelerator complex used by several European

countries. Study groups from Poland, France, Portugal and Germany were involved in the recent measurements under the leadership of Martino Trassinelli and Robert Löttsch. The Darmstadt complex includes an ion storage ring with a circumference of over 100 meters and an upstream accelerator that extends for over a kilometer.

Löttsch describes the experiment as follows: First, free ions are produced. In order to achieve this, uranium is vaporized and then vastly accelerated to around 40% of the speed of light. The resulting material is then fed through a special film, losing electrons in the process. The accelerated electrons are guided then into a storage ring, where they race around a circular path.

"The particles flash by our spectrometers up to 50 million times per second, and occasionally, there is an electron transition we can measure using a spectrometer," says Löttsch. The special Bragg crystal spectrometer used in the experiment was constructed in Jena.

## **The specifically bent crystal developed in Jena**

The linchpin in the [spectrometer](#), Löttsch explains, is a specifically bent crystal made from the element germanium. "This crystal is as thin as a sheet of paper and is held in a special glass mold," says Löttsch. This technique requires considerable expertise and was developed in Jena. Research into the development of such measurement devices has been underway for over 30 years.

The results published by the research group are the outcome of an experiment conducted in 2021. The tests ran for three weeks over Easter in conditions complicated by the COVID-19 pandemic. Nevertheless, Löttsch believes the results are well worth the effort.

He explains, "We have successfully tested whether our theoretical

understanding also applies to this exotic niche of materials." The results, he says, will therefore help to further our understanding of what "holds the world together at the innermost levels."

**More information:** R. Loetzsch et al, Testing quantum electrodynamics in extreme fields using helium-like uranium, *Nature* (2024). [DOI: 10.1038/s41586-023-06910-y](https://doi.org/10.1038/s41586-023-06910-y)

Provided by Friedrich Schiller University of Jena

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