Radioactive ion beam enables monitoring of a cancer treatment as it's performed

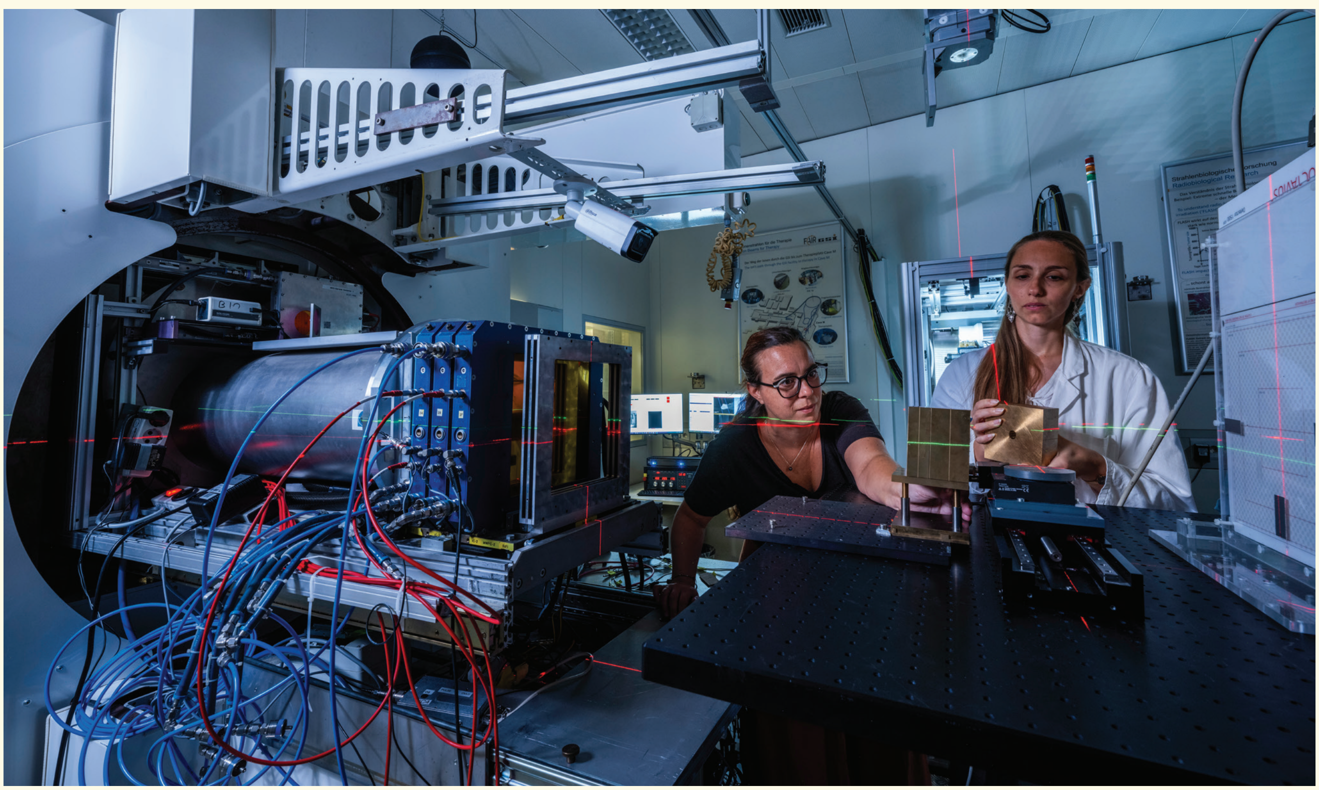
Using radioactive ions for particle therapy could lead to real-time imaging of radiation doses to improve the precision of treatment.

Among the radiation therapies used to treat cancer, particle therapy is notable for delivering radiation to a highly targeted location in the body while conveying limited radiation to surrounding tissue. That radiation is more targeted than photon radiation because, unlike gamma rays or x rays, accelerated particles release the most energy just before they come to a stop. Doctors use CT and MRI images, immobilization devices, dosage calculations, and robotic adjustments to target tumors with the greatest possible precision. But with no way for doctors to measure the location of the radiation peak as it's being applied, delivering it to the ideal place in the body poses a challenge.

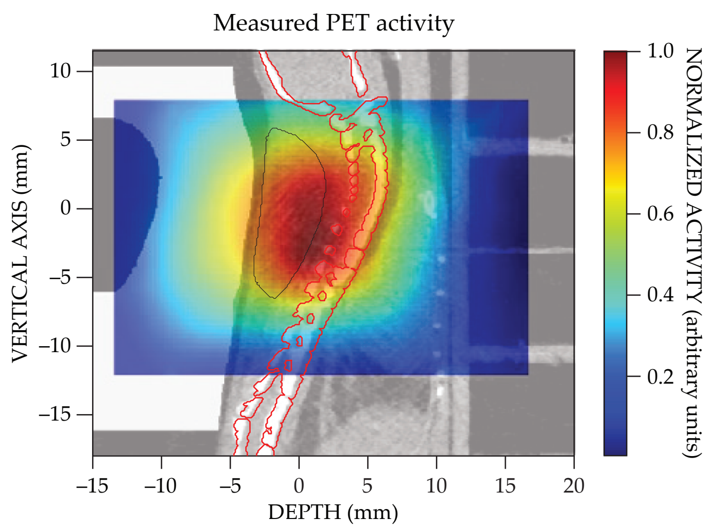
Now researchers in the lab of Marco Durante at the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany, have shown, in living mice, how using a beam of radioactive ions enables measurement of the radiation peak during treatment. "If I can see where I'm shooting, I can correct," Durante says.

Particle therapy is typically administered using protons, neutrons, or carbon-12 ions. The researchers used carbon-11, a radioactive isotope that undergoes positron-emitting beta decay. Recent upgrades to the FAIR (Facility for Antiproton and Ion Research) particle accelerator at GSI enabled the generation of a ^{11}C beam with the necessary intensity to perform radiotherapy. The researchers used a positron emission tomography (PET) scanner to detect the dose of ions as they were delivered. PET is usually used for diagnostics to measure beta decay produced by small doses of radioactive drugs given to patients before a scan (see "Medical imaging with antimatter" by John Sunderland, Physics Today, September 2025, page 28).

The experiment was performed on osteosarcoma tumors, which are radioresistant and often treated with ^{12}C ions. Tumor cells were implanted in the mice's necks, next to the spinal cord, and allowed to grow for a few weeks. Damage to the spine from errant radiation could cause paralysis. The research team was able to precisely measure the delivered dose of radiation, as shown in the figure on the next page, and monitor as the ions decayed and got carried away by the blood. None of the mice exhibited paralysis. A single high-dose treatment was most effective in preventing tumor regrowth. The treatment had the same effi-



A HIGH-ENERGY BEAM OF CARBON-11 produced at the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany, was used to treat cancer in mice. Researchers Daria Boscolo (left) and Tamara Vitacchio (right) are shown arranging the components of the experimental beamline. (Photo © J. Hosan, GSI/FAIR.)



RADIOACTIVE ION BEAM THERAPY directed at a tumor (outlined in black) in a mouse delivered radiation that was measured in real time with a positron emission tomography (PET) scan. By measuring the radiation as it was delivered, the researchers were able to target a precise part of the body and minimize damage to the nearby spinal cord (outlined in red). (Figure adapted from D. Boscolo et al., *Nat. Phys.*, 2025, doi:10.1038/s41567-025-02993-8.)

cacy as traditional particle therapy but with higher precision. Clinical trials would be needed to test the technique on humans.

The researchers plan to investigate the use of other radioactive ions for cancer treatment, including carbon-10 and oxygen-15. Both have a shorter half-life (about 20 seconds and 2 minutes, respectively) than ^{11}C, which has a half-life of about 20 minutes. The shorter decay time would allow faster real-time tracking of the treatment. Plans are also in the works at CERN to create ^{11}C sources that could be used at existing ^{12}C-ion therapy synchrotrons. There are currently 17 carbon radiotherapy centers in the world—all in Asia and Europe. The first carbon radiotherapy facility in the US is under construction at the Mayo Clinic in Jacksonville, Florida, and slated to open in 2028. (D. Boscolo et al., *Nat. Phys.*, 2025, doi:10.1038/s41567-025-02993-8.)

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