Physics Today
URL: http://ptonline.aip.org/journals/doc/PHTOAD-ft/vol_62/iss_3/22_1.shtml Published: March 2009

ISSUES AND EVENTS

Accelerators shrink to meet growing demand for proton therapy

Smaller, cheaper accelerators promise to make proton radiation therapy available to more cancer patients.

Jermey N.ýýA. Matthews
March 2009, page 22

The recent wave of newly constructed medical centers dedicated to proton radiation therapy comes as no surprise to James Slater, a radiation oncologist at Loma Linda University Medical Center. By 2010, four new US centers will start treating cancer patients. With two others that opened in 2006, that's more than double the number that had existed in the US in the first 15 years after Slater led the Southern California medical center in building the first hospital-based proton center in 1990. "I expected [this growth] to happen much sooner," he says.

Table-sized superconducting cyclotrons

In what may promise even more growth, some physics research labs and small companies are now developing room-sized proton accelerators to bring the treatment to existing medical centers. Those companies say their technology will supply a single treatment room for less than $30 million, a fraction of the $100 million to $200 million it now takes to build and equip larger proton centers. Treatments such as x-ray radiation and chemotherapy are still more available to cancer patients and less expensive than proton therapy. But x rays harm healthy tissue, and chemotherapy drugs weaken the immune system, among other things. Of late, many patients have been opting for proton therapy because of its minimal side effects when compared with the other treatments.

"Heavy lifting"

Protons penetrate human tissue to depths proportional to the incident energy, which for proton therapy ranges from 100 to 300 MeV. Because they have a relatively high mass, protons deliver most of their radiation dose to the targeted tumor. Beam-delivery methods now emerging commercially can also simultaneously adjust the dose and shape the beam, thus minimizing damage to nearby healthy tissue. To date, 55 000 patients worldwide have been treated with protons, primarily for prostate, head, neck, brain, lung, bone, and eye cancers. (For reviews of radiation oncology methods, see the special focus in PHYSICS TODAY, September 2002, pages 34, 38, 45, and 52.)

As far back as 1954, proton therapy was conducted in particle and nuclear physics research labs such as Lawrence Berkeley National Laboratory and the Harvard Cyclotron Laboratory. Although several physics labs around the world still offer the treatment, it transitioned to medical centers on the back of a combined $19 million from a congressional earmark and the US Department of Energy in 1988. That money was used to help build Loma Linda's center and acquire a 250-MeV synchrotron from Fermilab.

Since then, the US government has scaled back support for proton centers that are not affiliated with federal research facilities. But the number of proton centers in the US is growing because private investors and local governments have been willing to take the financial risk to build them. In contrast, a slower growth is seen in Europe, where proton centers receive fewer private donations and less support from national governments for the expensive treatment.

Existing proton therapy centers

The second hospital-based US proton center, established in 2001 at Massachusetts General Hospital, uses a commercial cyclotron from Belgium's Ion Beam Applications (IBA) SA. The center's construction was partially funded by the National Cancer Institute. Medical physicist Jay Flanz, the center's technical director, says that private developers needed to see that commercial accelerators could be made reliable and that their manufacturers would take responsibility for their upkeep.

Most existing centers use cyclotrons, which weigh more than synchrotrons and deliver protons at a fixed energy that can be reduced by inserting a beam-degrading object. Synchrotrons can electronically control the beam's energy, but they are more complex and more expensive to build. Although accelerator size and cost pose constraints on building new centers, "doctors really don't care about the type of accelerator," says Brookhaven National Laboratory particle physicist Stephen Peggs. He recently invented a method to rapidly cycle protons in a synchrotron and focus the extracted beam down to a 1-mm "sharp scalpel"—one-tenth the width of existing synchrotron beams.

"Loma Linda and Mass General did the heavy lifting for all the centers that followed," says Cynthia Keppel, technical director of the Hampton University Proton Therapy Institute in Virginia. Equipped with a 230-MeV cyclotron, the $200 million, four-treatment-room institute is one of the new centers opening this year; it is not owned or operated by an existing hospital. Keppel, who is also a staff physicist at nearby Thomas Jefferson National Accelerator Facility, says that a big motivation for Hampton University, a historically black institution, is the success of proton therapy in treating prostate cancer, which disproportionately affects black men. "We feel we are bringing proton therapy into a real community setting—with not one dominant hospital system," says Keppel.

Bare bones

Efforts to bring smaller and less expensive proton accelerators to market are on the rise. A compact synchrotron design by a Russian research lab was recently licensed by Texas-based ProTom International Inc. Scientists at the Lebedev Physics Institute in Moscow set out to design a "bare bones, simple [synchrotron] to be used only for proton therapy," says Flanz, who consults for the company. Unlike traditional synchrotrons, the new model is stripped of such components as sextupole magnets and has a simpler beam injector. At 6 m in diameter, the compact synchrotron can vary the beam energy up to 330 MeV, can deliver protons to multiple treatment rooms, and is small enough to fit into one room. A prototype of the synchrotron arrived at MIT's Bates Linear Accelerator Center last month for validation tests and private demonstrations for potential buyers.

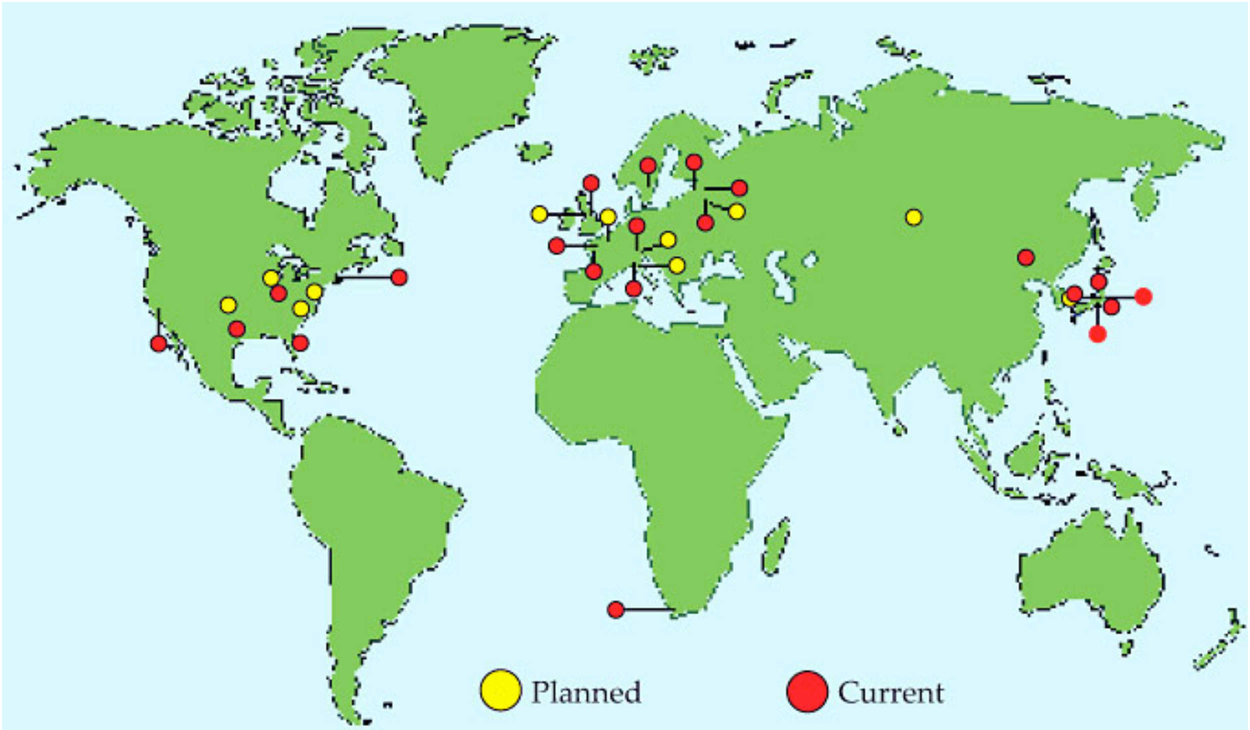
Other commercial developers are pursuing even smaller proton accelerators for medical facilities that are unwilling or unable to invest in a standalone center. One such effort has resulted in a cyclotron small enough to be mounted on the beam-delivery system that rotates around the patient. Emerging from MIT's Plasma Science and Fusion Center is a 1.8-m-diameter, 250-MeV cyclotron, which uses a superconducting high-field magnet to accelerate and bend the proton beam. The cyclotron is being developed by Massachusetts-based Still River Systems. Company founder and chief technology officer Kenneth Gall says that 15 medical centers have already signed contracts to buy the compact cyclotron, the first of which will be ready in a few months. "Due to financial constraints, people will be looking for compact systems which can be deployed one room at a time," adds Gall.

A linac technology to accelerate protons to 100 MeV in 1 m is being developed at Lawrence Livermore National Laboratory. Originally developed for x-ray radiography to image explosives, the so-called dielectric wall accelerator generates a pulsed electric field that lasts a few nanoseconds. That proton-accelerating field propagates along an insulating wall at a controlled rate, says LLNL physicist George Caporaso. Compact Particle Acceleration Corp has licensed the technology and is now funding its development for proton therapy. Because the DWA is a pulsed linac, "it is easy to control not only the beam's intensity but also its spot size and beam width," says CPAC president Thomas Mackie. Commercial DWA systems are still in early development.

Compact accelerators may "transform the proton-therapy landscape in this country" if they work and get US Food and Drug Administration approval, says Leonard Arzt, executive director of the National Association for Proton Therapy. Loma Linda's Slater adds that what matters to him is that proton therapy becomes available to as many patients as need it. "The concept is solid," he says. "It's science, good science.

Jermey N.ýýA. Matthews

Table-sized superconducting cyclotrons are being developed by Still River Systems for single-room proton-radiation treatment. (Image courtesy of Still River Systems.)



Fewer than 30 proton therapy centers exist worldwide (red), but a growing number are either planned or already under construction (yellow). (Image courtesy of Jay Flanz, Massachusetts General Hospital.)