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RESEARCH

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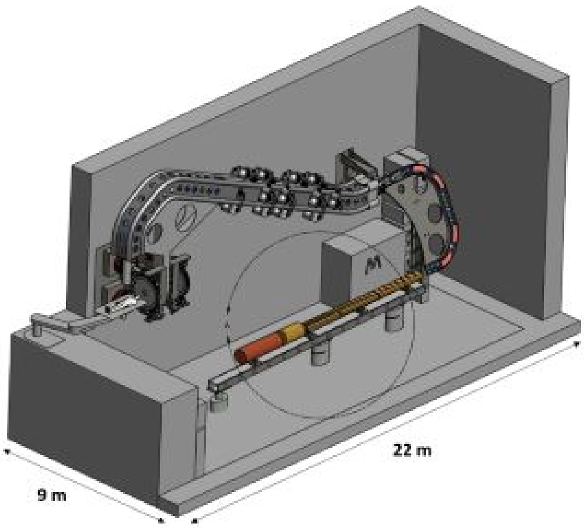
Compact linac designed for proton therapy

A design for a compact, fully linear accelerator for proton therapy has been developed by researchers at CERN (http://home.cern/). The linear design offers a higher beam quality than circular medical accelerators but – thanks to its high accelerating gradient – has a similar footprint (*Phys. Rev. Accel. Beams* 20 040101 (https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.20.040101)).



(http://images.iop.org/objects/med/news/12/6/22/pic1.jpg)
The TULIP all-linac design (http://images.iop.org/objects/med/news/12/6/22/pic1.jpg)

Hadron therapy uses beams of high-energy particles, such as protons, to kill off tumours. Presently there are two types of particle accelerator used for hadron treatments: cyclotrons and synchrotrons. Both are circular accelerators, with the former using a constant magnetic field and a spiral beam path, and the latter accelerating particles around a fixed, circular orbit that is maintained by increasing the strength of the magnetic field as the particles speed up within the machine.

Both accelerator types come with certain disadvantages. Cyclotrons have fixed beam-extraction energies, meaning that to target tumours at different depths within a patient's body, moveable absorbers must be placed in the beam's path to reduce its energy. The drawback of this, however, is that 99% of the beam energy is lost, the absorbers become activated, and beam scattering may generate secondary neutrons that can be hazardous for the patient. While synchrotrons do allow for the tuning of the output beam, adjustments take up to a whole second, making treatment times longer and more uncomfortable for patients.

Both of these issues might be overcome by using a linear accelerator instead. The key advantage of linacs over circular accelerators lies in how the energies of their output beams can be adjusted in mere milliseconds with no loss in beam intensity, allowing for quick treatments and no beam scattering. Beams are adjusted by varying the radiofrequency amplitude and phase of the linac's final accelerating structure.

Linacs typically come with a major drawback, however: the large space usually required to accommodate them is difficult to find within hospital buildings.

A previous solution to this issue, developed by the TERA foundation, combined circular and linear accelerator structures into a so-called "cyclinac" concept. The design – the turning linac for proton therapy (TULIP) – presented a single-room facility enabled by having a commercial cyclotron on the floor, accelerating protons up to tens of MeV, which are then injected into a linac mounted on a rotating frame around the patient, which boosted the particles to 70–230 MeV, suitable for therapeutic use.

Cyclotrons and linacs are not entirely compatible, however, being designed for beams with inherently different time structures, resulting in beam losses, instabilities and emittance growth. In a new study, Stefano Benedetti (https://people.epfl.ch/stefano.benedetti?lang=en) – a physicist at CERN and EPFL – and colleagues present an all-linac twist on the original TULIP design that overcomes these issues, thereby providing a higher beam quality while offering the most compact all-linac proton therapy design to date.

"The idea is to have a linac-based proton therapy facility that is as compact as possible, so to have a product that fits, ideally, into already existing hospital buildings, saving on infrastructural costs," says Benedetti. This is achieved thanks to the collaboration between TERA and CERN, which has led to the development of new accelerating structures that can support higher electric fields, and resulting accelerating gradients, without risk of electrical breakdown. The TULIP all-linac design has a footprint of only 9 × 22 m, which would make it comparable with existing single-treatment beam cyclotrons and synchrotrons.

The TULIP all-linac would be capable of delivering protons penetrating up to 33 cm into a patient's tissues, which would be comparable with other solutions. At the same time, the design results in particle losses being concentrated at energies below 5 MeV, reducing the shielding requirements in comparison with cyclotron facilities.

The researchers are presently testing a prototype of a single accelerating structure – with promising results – and moving to develop similar designs suitable for accelerating carbon ions, but Benedetti says he is unsure whether CERN will develop a full prototype of the TULIP all-linac design.

The proposed TULIP all-linac design "could stimulate new and innovative solutions for approaching the design of compact linear accelerators of protons," says Concetta Ronsivalle, a physicist from the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (http://www.enea.it/en), who was not involved in this study. Ronsivalle notes, however, that "such a delicate application as that of proton therapy will require a reduction of the complexity of the system in order to limit costs, and to increase reliability and operational simplicity."

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