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A Linac-based hardron minibeam irradiation facility

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Minibeam therapy faces challenges in preserving deep-seated normal tissue due to the lateral spreading of minibeams caused by small-angle scattering. Unlike proton minibeams, helium or carbon minibeams experience less spreading, potentially reducing side effects. Studies with proton beams indicate that reaching full therapeutic potential of minibeam therapy requires high beam brightness. Assuming a similar need for helium and carbon beams, circular accelerator-based irradiation facilities are not ideal for preclinical and clinical helium or carbon minibeam therapy studies. With clinical treatment or combinations of minibeam and flash therapy, this demand increases as the irradiation time is inversely proportional to the beam brillance. This manuscript introduces a concept for a hardron minibeam therapy facility based on a Linac design for conventional carbon therapy. The Linac beam is focused into submillimeter minibeams by a quadrupole triplet. A scanning unit and dosimetry unit are included to navigate the minibeam across the target area and monitor the applied dose. TRAVEL simulations optimize the beamline, while TOPAS simulations evaluate beam-component interactions and resulting parameters at the focal plane. For carbon energies between 100 MeV/u and 430 MeV/u (approximately 3 cm and 30 cm range in water), the facility achieves a transverse beamwidth of < 100 µm (sigma) and a peak-to-valley (energy) dose ratio of > 1000, with an average beam current of around 30 nA.

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