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Conceptual Design of a Spectroscopy-type Non-rotating Gantry System

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Objectives

In particle therapy, rotating gantries are commonly used to deliver multiple treatment angles but face limitations in speed, cost, and complexity. These constraints limit the optimal implementation of proton arc therapy (PAT), one of the most promising innovations in proton therapy. Fast and precise control of beam angles may further enable efficient integration of PAT with other advanced techniques, such as stereotactic irradiation and potentially FLASH therapy, while benifiting motion mitigation strategies as well. To address these limitations, we propose a novel non-rotating gantrysystem capable of rapid, non-mechanical azimuthal angle modulation through magnetic field manipulation.

Methods

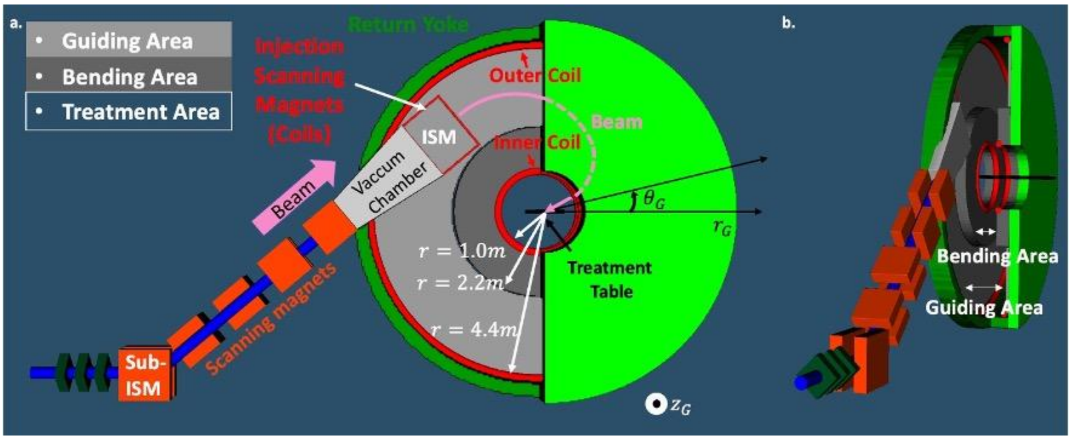
As illustrated in Fig.1, in this system, the beam is directed to the desired angle by a cylindrical magnetic field surrounding the patient, with treatment angles controlled by varying the strength of Injection Scanning Magnets (ISM). Magnetic fields were modeled using Opera3D, and beam transport was evaluated through particle tracking based on a custom Ellipse Edge Sampling method. Key beam characteristics such as envelope size was analyzed. We then applied a hard edge model to analytically optimize magnet parameters, including **Azimuthal Varying Field (AVF) and Radial Varying Field (RVF) components**. These optimized parameters were iteratively fed back into the Opera3D model for updated field simulation and re-tracking, forming a closed-loop optimization cycle for the magnetic steering system.

Results

This iterative approach enabled successful beam steering across a **full 180-degree azimuthal range** without mechanical rotation. In the most demanding case—180-degree beamline—we achieved effective transverse focusing in the non-bending plane, resulting in an on-target beam spot size suitable for clinical application. These results validate **the feasibility of the concept for delivering high-quality therapeutic beams under arc-like conditions.**

Conclusions

The proposed spectroscopy-type non-rotating gantry system offers a compact, fast, and cost-effective approach to facilitating efficient proton arc therapy (PAT). By enabling rapid azimuthal beam angle modulation without mechanical rotation, it addresses key limitations of conventional gantry systems in delivering PAT. This capability may further support the integration of PAT with techniques such as stereotactic irradiation, FLASH therapy, and motion mitigation strategies. Overall, **this concept has the potential to enhance the clinical accessibility and versatility of precision particle therapy.**


a.
Guiding Area
Bending Area
Treatment Area
Return Yoke
Injection Scanning Magnets (Coils)
Outer Coil
Beam
ISM
Inner Coil
Vaccum Chamber
Beam
θ_G
r_G
$r = 1.0m$
$r = 2.2m$
$r = 4.4m$
Treatment Table
Scanning magnets
Sub-ISM
z_G
b.
Bending Area
Guiding Area