Compact Proton *GaToroid*: A novel concept for pre-clinical studies with a static gantry

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Introduction

- The goal of radiation therapy (RT) is to maximise dose to cancerous cells whilst minimising dose to surrounding tissues.
- The **FLASH effect** is a **promising new horizon** in radiotherapy [1]
  - **Healthy tissue sparing** with treatments at Ultra-High Dose Rates (>40Gy/s)
- Multidirectional treatment is essential for **conformal treatment**
  - Conventional gantries are incapable of carrying out treatments entirely within FLASH timescale (<0.1s)

Figure 2: Proposed installation at PARTREC

GaToroid

- Novel concept for **static gantry** [2]
- Circular symmetry of **toroidal magnets** exploited for multidirectional treatment
- Variable **vector magnet** directs beam through one of several set paths through the system and into the patient
  - Treatment timescale only dependent on vector magnet
  - Potential for **ultrafast Arc and FLASH therapy**
- Original design based on **superconducting system for hadron therapy**
  - Significant footprint and cost

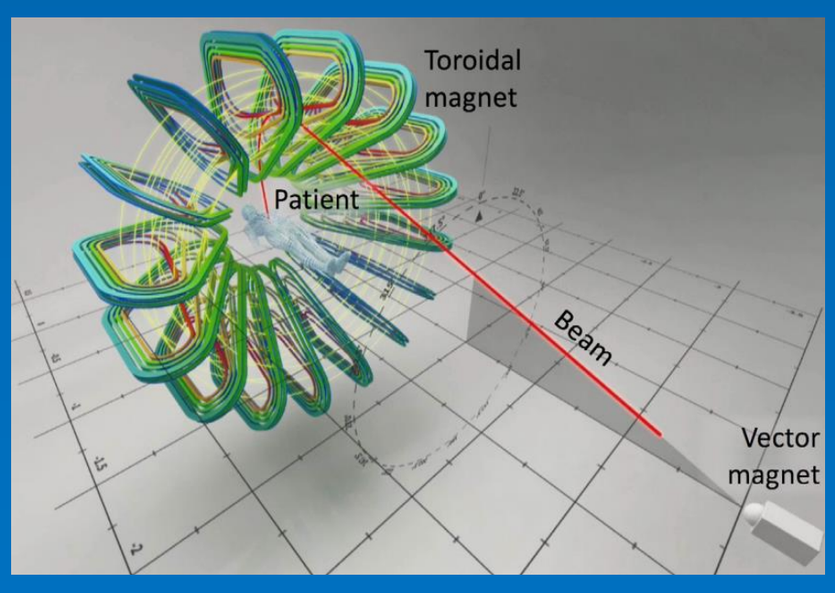

Figure 1: Original *GaToroid* concept [2]

Compact Proton *GaToroid*

- More **cost-effective** design with smaller footprint, with the aim of installation at the **PARTREC facility** [3]
- Reduced energy for pre-clinical irradiations
  - Superconducting magnets **not required**
  - Smaller bore for samples or **animal patients**
- **Novel components** for beam manipulation
  - Toroidal quadrupoles

Optics Design Study

- **Beamline optimized** for desired final conditions using MAD-X
- **90 MeV** and **190 MeV** optics investigated
- Collimation introduced to improve **uniformity** of final profile
  - Transmission through collimator maximised

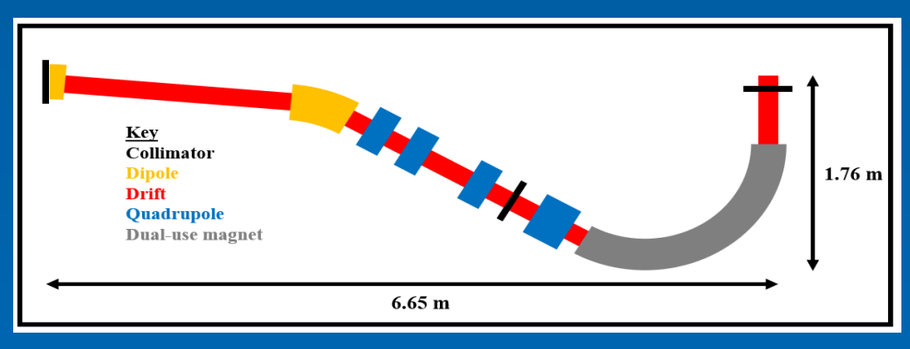

Figure 3: Proposed optics layout of compact system [4]

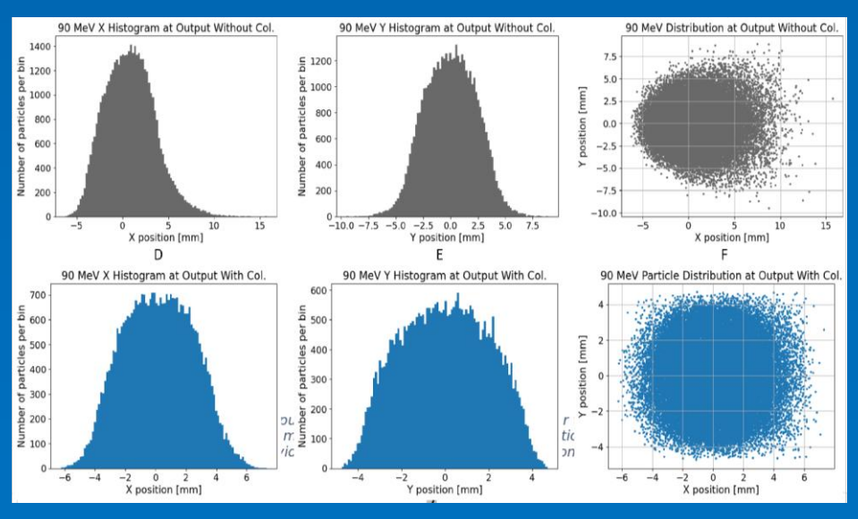

Figure 4: Predicted beam distribution at isocentre without (top) and with (bottom) collimation [4]

Future Work

- Magnet field studies ongoing
- Exploration of alternative compact GaToroid system for **200MeV electrons** underway
  - Magnetic studies show promising results [5]
- Further optical studies, and practical considerations of installation to be carried out

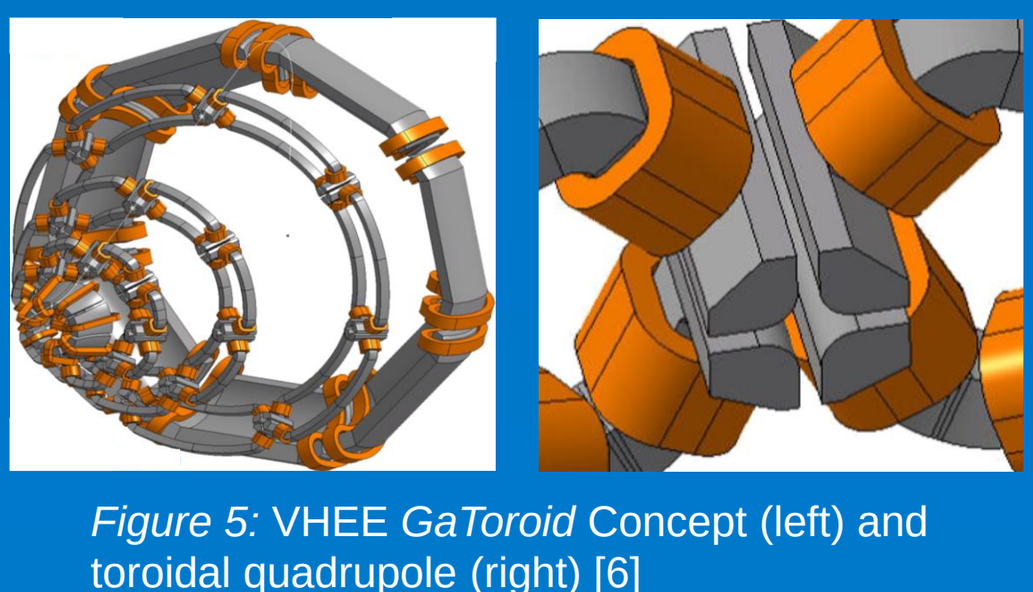

Figure 5: VHEE *GaToroid* Concept (left) and toroidal quadrupole (right) [6]

References

[1] Favoudon et al. (2014), Ultrahigh dose-rate FLASH irradiation increases the differential response between normal and tumor tissue in mice
[2] Bottura et al. (2020), GaToroid: A novel toroidal gantry for hadron therapy
[3] Gerbershagen et al. (2022), Establishment of the New Particle Therapy Research Center (PARTREC) at UMCG Groningen
[4] Butler (2023), Magnetic Optics Design for a Compact Toroidal Proton Radiotherapy Gantry (MPhys Thesis)
[5] Leadley (2023), Magnet Design for an Innovative Particle Therapy Gantry (MPhys Thesis)
[6] Bottura et al., (2023), Magnet Design of a Compact GaToroid for Very High Energy Electron and Pre-clinical Hadron Beams