Project Title: **Carbon ion acceleration for radiotherapy applications**

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Type of Project: EXPERIMENTAL

Helpful existing knowledge: Interest in biology/medical applications

Funding status: FUNDED (EPS Doctoral Training Programme)

Project Description

Cancer ranks as a leading cause of death worldwide, motivating research in developing more advanced and effective forms of therapy. Treatment of cancer using radiation (radiotherapy) is particularly important in this context, and is delivered most commonly employing x-ray- photons, but also, in its more advanced form, employing high energy protons or carbon ions. An emerging radiotherapy concept currently attracting a phenomenal amount of research interest is the so-called FLASH approach, where radiation dose is delivered to the patient in short pulses, at a dose rate of 10 to 1000s Gray/second. In animal models, FLASH delivery has been seen to result in significant sparing of the healthy tissues surrounding the tumour and a remarkable decrease in side effects, while maintaining a pronounced effectiveness in destroying the cancerous cells. These results have triggered a broader fundamental interest in the investigation of the biological effects of highly pulsed radiation beams.Laser-acceleration of ions provides particle pulses with an intrinsically ultrashort (typically of picosecond order or less) temporal duration. This offers the opportunity to irradiate samples at extreme dose rates never reached before, many orders of magnitude higher than even in the FLASH regimes discussed above. This opens to investigation unexplored regimes of radiobiology, where preliminary data highlight a complex scenario which challenges established understanding of radiation interaction with cellular media and requires new hypotheses and models, highlighting this regime as particularly promising for future radiotherapy.
The project is aimed to the investigation of the biological effects of exposure to ultra-high dose rate, laser-driven ion beams. In particular we will focus on carbon, a species which has high relevant to radiotherapy, as it is particularly effective in the treatment of radioresistant tumors. The project will aim to test, employing and further optimizing the latest developments in particle acceleration and delivery, the quality and quantity of cellular damage produced by ultrashort carbon bursts on a selected number of relevant cellular models. Key questions to be addressed are how the extreme spatio-temporal density of ionization tracks affects the cellular response, whether the ultrashort delivery affects the cell oxygenation, and how this is affected by the cellular microenvironment. We also aim to assess whether FLASH-type differential response between healthy and cancerous cell can be extended to the ultra-high-dose rate regime. These interdisciplinary studies will take advantage of the excellent and unique capabilities available to our group and will also be supported by researchers at QUB's Centre for Cancer Research.

This is a project at the interface between advanced accelerator science and radiobiology, and the students will acquire skills in both experimental physics and biology techniques. The project is funded as part of the Enhanced Postgraduate Skills Doctoral Training Programme (https://www.qub.ac.uk/about/Leadership-and-structure/Faculties-and-Schools/Engineering-and-Physical-Sciences/enhanced-postgraduate-skills/) with sponsorship by the Extreme Light Infrastructure (ELI), a major pan-European facility devoted to the application of high-power lasers. In particular, in addition to experiments on UK's national facilities, some of the research work will be carried out at the ELIMAIA facility at ELI Beamlines (Czech Republic), a unique infrastructure devoted to the application of laser-driven ions. As part of the EPS DTP, the project offers an enhanced stipend and dedicated research support funds.

Useful references

A.McIlvenny et al, Selective ion acceleration by intense radiation pressure, Phys. Rev. Lett. **127**, 194801(2021)

P. Chaudhary *et al*, *Cellular irradiations with laser-driven carbon ions at ultra-high dose rates*, Phys. Med. Biol., **68**, 025015 (2023)

P. Chaudhary *et al*, *Radiobiology experiments with ultra-high dose rate laser-driven protons: methodology and state-of-the-art*, Front. Phys., **9**, 624963 (2021)