

Pre-publication review of the LhARA pre-CDR

Response to the report from the review panel

The authors would like to thank the reviewers for the insightful, and constructive comments. In the preparation of this response the reviewers' comments have been numbered as indicated in the annotated copies of the Reviewers' evaluation appended to this response.

Recommendations The collaboration welcomes the recommendations made by the Panel. In particular:

1. **A wide variety of domains are implicated (Laser sources, plasma, Gabor lens, specialized magnets, RF, beam transfer, accelerator physics, beam instrumentation, controls etc.). Ensure appropriate levels of resources to ensure the required developments in all these areas.**

The collaboration notes the recommendation and will seek to secure the resources required to address the risks in each of the key areas.

General Comments

2. **LhARA has the potential to drive a change in current clinical practice by increasing the wealth of radiobiological knowledge. This in turn may be used to devise new approaches decreasing the radiotoxicity on normal tissue, while maintaining or even enhancing, the tumour-kill probability.**

The collaboration thanks the reviewers' for the positive evaluation of the potential of the LhARA initiative.

3. **I recommend strongly a commensurate and exemplary level of global connectivity and cooperation for the LhARA programme and that embryonic steps toward this ideal situation be explicitly indicated where possible.**

The collaboration agrees with the reviewers and is energetic in seeking to gain strength by attracting appropriate expertise from the UK and overseas.

4. **...suggest that, given adequate programme successes, the issues of hybrid system size and cost minimization are separate matters to be addressed later with appropriate engineering skill (this could be explicitly stated in the pre-CDR).**

The collaboration agrees with the referees' comment and will develop its strategy in line with the recommendation.

Radiobiological motivation

5. **...Can we identify (at least in part) a critical larger scale agenda that can be cooperatively addressed by member laboratories of suitable global consortium?"**

Lead author: All(!)

6. **...can researchers at this stage specify any development areas that can be good prospects for industrial collaboration? Ultimately, at the CDR level, what are some of the impactful outreach activities from which both LhARA and affected communities can benefit?**

Lead author: All(!)

Design of the LhARA facility: FFA

7. **10 Hz, variable energy, simple and efficient extraction, baseline septa and kickers parameters shown. Any possibility of increasing the repetition rate to match FLASH effect investigation requirements?**
Lead author: JPa
8. **10 Hz, variable energy, simple and efficient extraction, baseline septa and kickers parameters shown. Any possibility of increasing the repetition rate to match FLASH effect investigation requirements?**
Lead author: JPa
9. **Aimed $1e9$ protons per bunch. In particular, regarding the average dose-rate: 51.6 Gy/s for 12 MeV protons (Stage 1), 5.8 Gy/s for 127 MeV protons (Stage 2) and 52.4 Gy/s for carbon ions (Stage 2). Any possibility to exceed 40 Gy/s also for 127 MeV protons (Stage 2), therefore allowing FLASH effect investigations?**
Lead author: JPa
10. **Only certain discrete energies to be considered - not fully clear what the range and discretization foreseen is.**
Lead author: JPa
11. **Worry about field imperfections and closed orbit distortions, a problem faced by other FFA concepts such as EMMA or the KURNS 150 MeV proton machine. This is crucial in order to envisage a variable energy extraction.**
Lead author: JPa
12. **Worry about how a correction scheme can achieve a zero chromaticity while guaranteeing that the injection/extraction beamlines remain matched to the FFA optics.**
Lead author: JPa
13. **If spot scanning and/or microbeam delivery are to be implemented, will these technologies be imported or will they be developed within the LhARA programme ?**
Lead author: JPa
14. **Is there capability with the proposed hybrid system to further reduce the duration of delivered bunches or is tens of nanoseconds the limit in this case? Can alterations be made in the future to post-accelerate the laser-driven source beam even closer to the source or add an upstream chicane? Is the stated few percent energy spread set by a particular beam line optic?**
Lead author: JPa
15. **Is the $1e9$ protons per bunch delivery to end stations typical at 10 Hz operation? At the in vivo (high energy) end station what technique(s) will be used for x-ray CT irradiation as image guidance ?**
Lead author: JPa