Muon Beams – Preliminary Findings

9th June 2021 *C. T. Rogers* on behalf of the UK muon collider collaboration

The 2020 Update of the Strategy for Particle Physics recommended that muon beam R&D should be considered a high-priority future initiative due to the excellent potential for physics studies at a muon collider. The Laboratory Directors' Group formed a panel to deliver a prioritised R&D list in order to bring this forward for the next European Strategy. The muon beams panel has studied R&D that could lead to a muon collider, comprising working groups on accelerator systems (proton complex, muon production and cooling, high energy complex and MDI); and working groups on underlying technologies (RF, magnets, beam dynamics and radiation protection and other technologies). A working group on synergies with other facilities and technologies has also been formed.

The muon beam panel is still gathering evidence. At this stage it seems likely that the panel will find that Europe should deliver, in the next 5 years: a complete start-to-end simulation for the complex including various optimisations and risk mitigations; a technology R&D programme to deliver the necessary underlying technologies required to construct a muon collider such as high gradient RF and high power targetry; and a CDR for a test facility for muon cooling, which may include a high power target and targetry tests. The panel is also considering synergies with other facilities. A strong synergy with nuSTORM and ENUBET has been highlighted, as well as synergies with rare muon decay experiments and potential benefits that could be realised for slow muon beams. The panel seems likely to find that a muon collider Conceptual Design Report should be delivered over a 10 year time scale, together with a demonstrator facility to demonstrate muon cooling and potentially other systems.

The UK has a strong interest to contribute in a number of areas:

- nuSTORM would provide a particular opportunity to demonstrate a stored, high current, high energy muon beam including management of resulting radiation, albeit at lower power than the muon collider. The nuSTORM muon source could be used to deliver muons for a 6D cooling experiment. The UK should take the lead in preparing a CDR for nuSTORM on a 5 year timescale, so that the nuSTORM source can be considered serving a muon cooling test facility.
- The UK has a leading role in muon cooling R&D, following from MICE and neutrino factory studies. The UK should take the lead in preparing the CDR for the muon cooling test facility and for delivering a start-to-end simulation of the muon collider muon source (target to the end of cooling).
- UK leadership in high power targetry for High Energy Physics should be leveraged to deliver an R&D programme in high power targetry. This would support development of next-generation high power target schemes.
- The UK should seek to understand whether Fixed Field Accelerators (FFAs), in particular vertical orbit excursion FFAs, can be beneficial.
- The UK has expertise in high gradient RF. This should be leveraged to support the R&D programme in high gradient RF, for example including studies in high-stress vacuum surface interactions with/without DC magnetic fields. Potential for synergy with other fields is noted.
- The UK has significant expertise in proton driver design, particularly in design of accumulator and bunch compressors to produce the short proton bunch required for the muon collider, and this expertise should be leveraged to support the CERN proton driver design.
- The UK has expertise in superconducting magnets following development of MICE and ISIS-II and this should be leveraged to support the muon collider R&D. Conventional cryogenic superconductors will be limited in this application by the combination of high heat loads, magnetic fields, forces and current densities, hence we anticipate it will be necessary to advance the latest developments in this field e.g. HTS YBCO for high field inserts with small volumes in combination with MgB2 'outserts' for low fields with large volumes.