Muon Collider Accelerator Facility

On behalf of the forming international muon collider collaboration[1]

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1 Motivation

Circular muon colliders have the potential to reach centre-of-mass energies in the multi-TeV range with high luminosity[2]. Following the recommendation of the recent Update of the European Strategy for Particle Physics[3] a collaboration has been initiated by the European Large National Laboratories Directors Group[4]. In the framework of the muon collider collaboration we envisage to study different options, in particular with a centre-of-mass energy of 3 TeV of 10 TeV or more.

2 Initial Work Plan

A muon collider, in particular at an energy of 10 TeV or above, is uncharted teritory. No fully integrated design of a high-energy muon collider has been devised sofar. In addition, previous studies of parts of the collider focused on energies much lower than 10 TeV. An integrated concept of the collider combined with a prioritised R&D programme that addresses the key design challenges is instrumental to open the muon collider as an option for a future highest-energy lepton collider.

The work until the next European Stratgy Update will be split in two phases, the exploratory phase, which will last about two years, and the definition phase.

In the exploratory phase, the collaboration will define goals for the muon collider performances and develop a prioritised list of key challenges to be addressed in the definition phase. Starting from a tentative list, an initial list of key issues is expected to be ready in time for the Snowmass Process and a refined one at the end of the exploratory phase. The exploration of the whole collider complex, the development of key concepts and the definition of critical parameters will be essential to identify issues and in particular to prioritise them. Synergies with other efforts, such as magnet developments for hadron colliders, will be exploited wherever possible. The key issues list serves as a basis for the work programme of the definition phase. Work on several already identified feasibility issues will commence already in the exploratory phase.

The definition phase will implement the work programme and might require an increase in resources. Studies will support the ability of reaching the performance goals. Identification and conceptual design of the key demonstration facilities and components will define the R&D path for the CDR phase and allow to assess its cost and timeline. The construction of key hardware models might be required, e.g. for fast-ramping magnets, the highest-field solenoids and the RF for the cooling complex.

Key issues that will be addressed are:

- The impact of muon decays on the experiment, the machine and the environment. Methods to mitigate this impact will be developed. These include civil engineering, shielding, optics and magnet design.
- The ability to efficiently accelerate the beam, to preserve its quality and to obtain the luminosity. This requires development of efficient magnets and power converters, RF that can accelerate the short intense bunches and maintain their quality as well as shielding and cooling development in combination with optics design to minimise the loss induced heat load.

- The production of a high-quality beam. This includes the proton target and its surrounding and the cooling; the MAP design will be reviewed and optimised also using achieved hardware performances. In particular the final cooling stage has to be improved with higher field magnets.
- Development of the positron-based muon source as an alternative.

Based on scaling from MAP parameters, initial targets for the integrated luminosities have been defined, namely 1, 10 and 20 ab^{-1} for 3, 10 and 14 TeV, respectively. These parameters will help to identify the key issues and have to be refined to include findings of the studies, e.g. budgets for the emittance growth between the source and the collider ring. A similar list of parameters for a collider using the positron-based muon sources remains to be done once this concept is sufficiently advanced.

3 Key R&D

The production of bright muon beam is instrumental for a collider. The more developed and studied proton-driven option still requires a final demonstrator and further optimisation. The appealing positron driven source, at present missing a feasible design to produce high luminosity, demands dedicated R&D studies and tests also in synergy with other ongoing projects.

The high-energy acceleration complex and the collider ring contain important performance, cost and power consumption challenges that can ultimately define the energy reach of the collider. A wide range of cutting edge technologies, detailed studies and R&D is required. In particular:

- Advanced accelerator design and beam dynamics for high luminosity and power efficiency.
- Robust targets and shielding for muon production and cooling as well as collider and detector component shielding and possibly beam collimation.
- High field, robust and cost-effective superconducting magnets for the muon production, cooling, acceleration and collision. High-temperature super-conductors would be an ideal option.
- High-gradient and robust normal-conducting RF to minimise muon losses during cooling.
- High rate positron production source and high current positron ring.
- Fast ramping normal-conducting, superferric or superconducting magnets that can be used in a rapid cycling synchrotron to accelerate the muons.
- Efficient, high-gradient superconducting RF to minimise power consumption and muon losses during acceleration.
- Efficient cryogenics systems to minimise the power consumption of the superconducting components and minimise the impact of beam losses.
- Other accelerator technologies including high-performance, compact vacuum systems to minimise magnet aperture and cost as well as fast, robust, high-resolution instrumentation.

The goal of the collaboration will be to address these challenges.

Initially, the design of the collider will focus on a green field option that allows to fully focus on technical issues. Once the design and understanding of the concept has evolved sufficiently, the option to reuse existing infrastructures will also be explored.

Contact

D. Schulte, CERN, daniel.schulte@cern.ch

References

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