ACCELERATOR TEST FACILITY FOR MUON COLLIDER AND NEUTRINO FACTORY R&D*

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Over the last decade there has been significant progress in developing the concepts and technologies needed to produce, capture, accelerate and collide high intensity beams of muons. At present, a high-luminosity multi-TeV muon collider presents a viable option for the next generation lepton-lepton collider, which is believed to be needed to fully explore high energy physics in the era following LHC discoveries. This article briefly reviews the needs and possibilities for a Muon Collider beam test facility to carry out the R&D program on the collider front-end and 6D cooling demonstration experiment.

1. Introduction

1.1. *Possible timeline of the Muon Accelerator R&D in the US*

At present, two teams of accelerator scientists associated with the US-wide Neutrino Factory and Muon Collider Collaboration (NFMCC) and Fermilab's Muon Collider Task Force (MCTF) actively work on the feasibility proof of a Muon Collider (MC) needed to fully explore the physics responsible for electroweak symmetry breaking that requires a center-of-mass energy ($\sqrt{s}$) of a few TeV and a luminosity in the $10^{34} - 10^{35}$ $cm^{-2}s^{-1}$ range [1]. The NFMCC and MCTF have recently jointly proposed a US National Muon Accelerator R&D program with major goals of (i) delivering a Muon Collider Design Feasibility Study Report (MC DFSR) - interim by the end FY14 and final (with the MC cost range) by the end of FY16; (ii) 4-Dimensional Muon Ionization Cooling Experiment (MICE at RAL, UK) completion by the end of FY13; (iii) completion – by the end of FY12 - of a program of RF studies to provide input

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for down-selection of 6D cooling channel by the end; (iv) participation in an International Design Study and completion of NF-RDR in early FY14; (v) a section (unit) of a 6D muon cooling channel built and tested without beam by the end of FY16. It is thought that around 2013-2014 all of the Neutrino Factory proof-of-principle tests will be completed and if the community wishes to proceed, after a few years of additional R&D, the NF construction could start as early as the late 2010's. Around the same time, the need and feasibility of a Muon Collider will be well understood and – if the MC path found attractive for HEP community – a series of demonstration experiments with muon beams on the 6D cooling, production and collection will need to be carried out that will take (estimated) 5-7 years starting 2015-2016. In case of success at that stage and if the HEP community wishes to go down this path, a MC construction start in the early to mid-2020s is plausible.

This paper addresses the requirements and possibilities for a Muon Collider beam test facility to carry out the R&D program on the collider front-end and 6D cooling demonstration experiment (the Phase II of the Muon Accelerator R&D program).

2. Facilities for Muon Accelerators R&D

2.1. *Existing facilities, their timeline and limitations*

At present, two facilities are dedicated to the MC/NF accelerator R&D. The Mucool Test Area (MTA) at Fermilab has cryogenic capabilities, RF power at 201 MHz & 805 MHz, Liquid H_2 absorber filling capability, 5 T SC Solenoid with 30 cm bore (so, a 805 MHz Cavity fits inside) and beamline which can deliver 400MeV/c protons from Fermilab's Linac to the experimental hall about 8x20 m larger. The MTA facility has an established program of RF cavity studies and SC coils test for the next 4-5 years and keeping the activities there uninterrupted is critical for the success of the MICE. MICE facility at RAL has ~40x12 m hall which will be fully occupied by the 4D cooling demo experiment up until 2013-14 (so called Steps I-V) and, quite probably beyond 2014 for Step VI and a possible test of wedge absorbers. The hall can fit all the spectrometers, two or three liquid H2 absorbers, RF cavities and bucking coils needed for the experiment. Very low intensity muon beam generated by 800 MeV protons in ISIS hitting a target and delivered to the MICE hall via a beamline.

2.2. *Requirements for the Phase II Muon Accelerator R&D facility*

Main requirements for the Phase II Muon R&D facility are: (i) it will be available sometime after 2012-13, when the 6D cooling technology is specified so the first unit assembly and test can be started there; (ii) it should offer a low intensity muon beam for experimental studies till ~2018; (iii) it has to have modest incremental cost and enough space for the 6D cooling demonstration experiment; (iv) it has to be upgradable/expandable to take a medium to high intensity Project-X beam and generate high intensity muon bunches for consecutive R&D program until ~2024; (v) after a proper (may be, major) upgrade it should be able to be used as an operational MC or NF Front End facility.

The dimensions of the facility should be of about 80-120 meters long by 8-12 meters wide to host 6D cooling section (e.g. per Ref. [2] some 20-fold reduction of 6D emittance is expected over 120 m of the FOFO snake channel - one of the possible cooling channel schemes under consideration now). About the same length is needed for a MC/NF factory front-end facility which includes a target, drift section, buncher and rotator [3]. A short bunch (ideally, shorter than 10 ns long) of 10^7-10^{10} of ~200 MeV muons every 1-10 sec should suffice for the initial beam studies.

Several possibilities for such a facility were considered and found not adequate – the MTA (busy with its own test program, too small and wrong beam structure), upgraded MICE (not available until the experiment is over, too small, wrong time structure and very low intensity), a new facility adjoin to the mu2e target and experiment building (wrong beam structure, quite longer timescale than needed, uncertainty with location which may be not compatible with the Project-X operation) . The former KTeV hall and target area looks an ideal candidate.

2.3. *KTeV Hall and Target area*

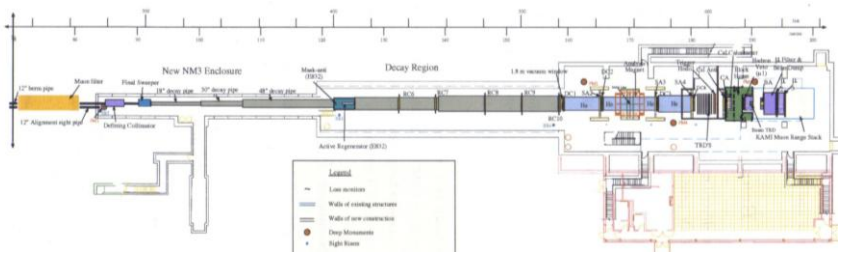

Figure 1. KTeV experimental hall area as of 2009.

The KTeV experimental hall consists of three areas with dimensions 35m x 4mx3m; 40 m x7mx6 m; 45m x 17mx12m. The building has spacious areas for a control room and power supplies; a 25-ton crane, larger LCW water infrastructure and a lot of AC power available. The experimental hall is preceded with a target area where 120 GeV high intensity proton beam can be delivered from Fermilab's Main Injector via one of the existing external beamlines. In the current plan of the Fermilab experiments, E906 (Drell-Yan) experiment will take place in the KTeV hall till 2012 (with a possible 1 year extension into 2013). So a possible strategy for the KTeV based Muon Accelerator R&D facility could be: (i) start studies with muons generated by the 120 GeV beam from MI and delivered to the KTeV hall; (ii) build a 8 GeV beam line (MI → KTeV hall); (iii) get Project X 8 GeV beam at a low repetition rate, generate muons in the KTeV target area; (iv) build a ~8GeV buncher ring for production of high intensity and very short proton bunches out of the Project X beam, deliver short proton bunches to the KTeV facility; (v) build Muon R&D/Front-end test facility in front of the KTeV building; (vi) transform it and the KTEeV hall into the MC or NF front end facility.

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