THE MUON TEST AREA AT FERMILAB*

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Abstract

The construction of the Muon Test Area (MTA) at Fermilab, designed to develop and test muon ionization cooling apparatus, was finished in fall of 2003. The facility will soon allow tests of devices that are cryogenic, hydrogen-filled, have RF frequencies of 200 or 800 MHz, with magnetic fields up to 5T, and/or radiation fields produced by the 400 MeV H^- Linac. The MTA design criteria and the range of parameters available to the developer are discussed. Initial experiments to investigate the cryogenic behavior of liquid-hydrogen absorbers for the MUCOOL R&D program and a program to develop RF cavities pressurized with gaseous hydrogen are also described. Construction of the parasitic 400 MeV Linac to MTA beam line, which is to be completed in 2005, is also discussed.

INTRODUCTION

The need for bright muon beams for neutrino factories and muon colliders is well established, where the most likely techniques for beam emittance reduction rely on ionization cooling [1]. Passing the beam through an energy absorber to reduce all components of momentum and replacing only the longitudinal component using RF cavities reduces, or cools, the angular spread of a beam. The cooling continues until it is balanced by the heating caused by multiple scattering, which is least for low Z ionization absorber materials.

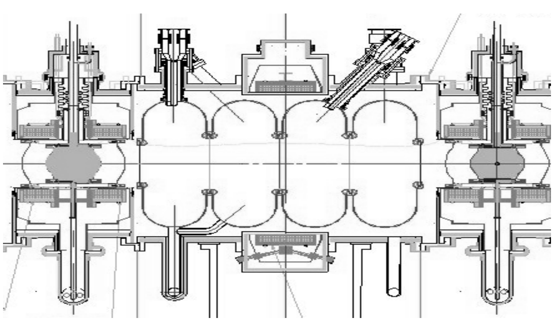

Figure 1. MICE cooling channel module showing components to be tested in the MTA: blue, LH2 energy absorber; red, 200 MHz RF cavities; magenta, superconducting coils.

One of the beam cooling schemes now under development uses liquid-hydrogen (LH2) energy absorbers alternating with evacuated RF cavities, keeping the muon beam focused as it passes through the channel by means of magnetic fields provided by superconducting solenoids. Computer simulations show that beam cooling effectiveness is very dependent on the engineering details of the elements of the channel. Therefore, a serious R&D program is necessary to work out the engineering difficulties for each of the cooling-channel components and assess the limits (or work around the limits) of various cooling-channel configurations now being considered. Figure 1 shows a cooling module design for the Muon Ionization Cooling Experiment (MICE)[2].

Another beam cooling technique being developed uses highly pressurized hydrogen filled high-gradient RF cavities to combine the energy loss and energy regeneration. Initial experiments show that the hydrogen gas suppresses breakdown and dark currents in the RF cavities, allowing higher gradients [3].

One pressing need has been a dedicated test area with special conditions for component development. For example, the LH2 absorber effort requires an area that has cryogenics and hydrogen safety features. As part of the series of tests in the development of the pressurized hydrogen filled RF cavities and the development of the LH2 absorbers, an intense particle beam is required. Ideally, muons would be best, but in practice most of the design and engineering issues can be addressed using a beam of any type of charged particle as long as the beam intensity is sufficiently high.

The MTA will provide a large and needed boost to the efforts of those working on muon cooling (essential for both muon colliders and neutrino factories), not only for the MUCOOL collaboration at Fermilab, but for the entire Muon Collaboration. In addition to developing cooling-channel components, the long-term use of this beamline and test area will help ease a critical shortage of low- and medium-energy test beams for detector and technology development, for both high-energy and other branches of physics. Figure 2 is a photograph of the MTA facility.

Table 1: MTA Available Parameters

Parameter	Maximum Value	Comment
201 MHz RF	5 MW	
805 MHz RF	12 MW	
Magnetic Field	5T	
400 MeV H^- Beam	$1.6 \times 10^{13}/50\ \mu s$	15 Hz Max
4K Helium	500 W	

EVACUATED RF CAVITY R&D

During the coming year, the MuCool collaboration plans to continue RF studies using 805 MHz test cavities. The plan is to investigate the effect of surface treatments

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and window materials on dark current and breakdown. Simulation work on grid-tube designs for RF cavity windows will also continue and prototype windows of the final design will be tested using the 805 MHz pillbox cavity. New tests with inflected "thinned-bellows" windows for LH_2 absorbers will fully study their mechanical and cryogenic properties. Construction of the first 201 MHz RF cavity is about to be completed and we hope to have it under test in the MTA in the Fall of 2004.

PRESSURIZED RF CAVITY R&D

A program of developing RF cavities pressurized with hydrogen gas at liquid nitrogen temperature that was started in Lab G will be continued in the MTA. First tests will be measurements of the Paschen curves up to hydrogen densities corresponding to one half that of liquid hydrogen. Next the high-voltage breakdown of various metals will be measured as a function of gas pressure to help understand the breakdown mechanism of metallic surfaces. Then the effect of strong magnetic fields on the gas and metal breakdown will be studied. As an existence proof of the feasibility of using gas filled RF cavities in a real muon beam, the cavity will be operated while in an intense charged particle beam as soon as the beam line is available.

HYDROGEN ABSORBER R&D

The first tests scheduled for the MTA are operational studies of a convectively cooled LH_2 absorber. The apparatus was designed and built at KEK and represents work done under the US-Japan collaboration. In addition, a LH_2 absorber with a forced flow design and now under construction will be tested in the MTA.

BEAM LINE

To test liquid hydrogen absorbers, the MuCool experimenters would ultimately like a beam of H^- or protons with 400 MeV kinetic energy, 50 mA peak current, and 50 microsecond pulse length at 15 Hz with variable beam size (from 1 to 30 cm at the device under test). Of course this beam must be delivered with tolerable beam losses. These demanding requirements, particularly the high intensity and the desired variability in beam size make the optics, operation, and shielding of such a facility particularly challenging and costly.

However, a beam with limited integrated intensity and small transverse size will satisfy the initial needs of some of the experimenters, such as tests of pressurized RF cavities and the irradiation of detector components with small intensity beams or short bursts of high intensity pulses for MuCool. Accordingly, a simple conventional beam line is being built, which is based on components that are now available as spare parts or left over from previous projects. This design can be upgraded to provide the full capabilities required for complete testing of large devices with an intense beam. The simple beam line is discussed in a MuCool Note [4], as is a way to implement the line and improve the operation of the Fermilab Booster at the same time [5].

The design is based on using eight of the fifteen spare quadrupoles from the Linac to Booster transfer line and six dipoles from the decommissioned Electron Cooling Ring. As shown in Figure 3, the beam will be directed toward the MTA using two pulsed horizontal dipole magnets with the first located after the last Linac accelerating module and just before and the second just downstream of the electrostatic chopper. At 400 MeV, this pair of magnets will produce a horizontal bend of 5 degrees. The magnets will pulse fast enough to select any of the Linac's 15 Hz beam pulses to be sent to the MTA.

INSTRUMENTATION DEVELOPMENT

A whole new generation of beam instrumentation needs to be developed, and this will be integral to the design of the cooling components themselves. Over the next three years, this test facility will be a critical focus of the entire neutrino factory/muon collider effort. In addition, it can be a facility for R&D on other major technical challenges of a neutrino factory or muon collider as well.

ACKNOWLEDGEMENTS

The MTA and the simple beamline concepts and implementations were the product of many creative people. I especially thank Dr. C. M. Ankenbrandt of Fermilab and Dr. R. P. Johnson of Muons, Inc. for their contributions.

[1] M. M. Alsharo'a *et al.*, Phys. Rev. ST Accel. Beams 6:081001,2003 e-Print Archive: hep-ex/0207031.

[2]http://hep04.phys.iit.edu/cooldemo/micenotes/public/pdf/MICE0021/MICE0021.pdf

[3] MuCool Note 285 http://www-mucool.fnal.gov/htbin/note1LinePrint

[4] MuCool Note 287 http://www-mucool.fnal.gov/htbin/note1LinePrint

[5] MuCool Note 294. http://www-mucool.fnal.gov/htbin/note1LinePrint

Figure 2. Photograph of the Muon Test Area building looking north toward the Fermilab Wilson Hall.

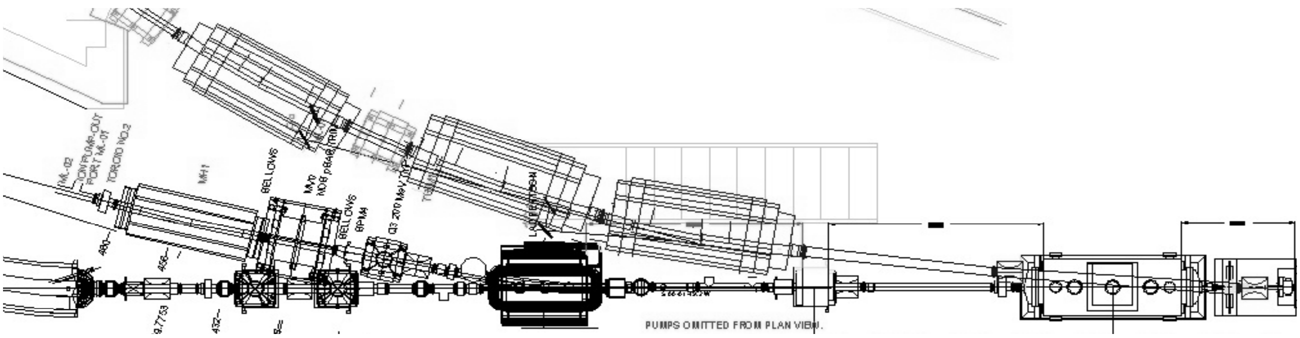

Figure 3. Diagram of the start of the new beam line from the end of the 400 MeV Linac toward the MTA.

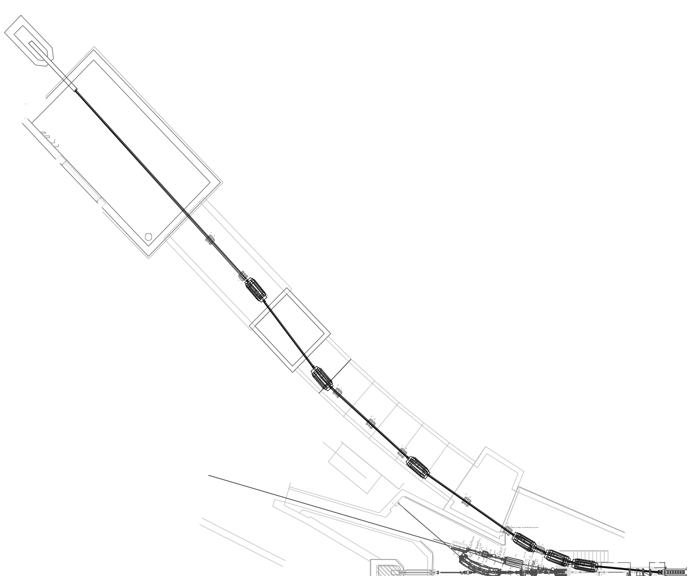

Figure 4. Diagram of the new beam line from the end of the 400 MeV Linac to the MTA.