THE MUCOOL TEST AREA LINAC EXPERIMENTAL FACILITY AT FERMILAB

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Abstract

The initial phase of civil construction has begun on a new Linac Experimental Facility at Fermilab with beneficial occupancy anticipated in fall, 2003. This facility is being designed for multipurpose use by establishing direct and independent control over incident beam parameters; for example, pulse duration from 1 – 50 μsec, and beam transverse sizes from 1 – 15 cm (95% of beam). The facility will be capable of accepting up to the full Fermilab Linac beam intensity (1.6 x 10^{13} protons/pulse @ 15 Hz) making it one of the few areas where a primary beam is available for high intensity experiments. The purpose of the facility initially is to test the basic techniques and components proposed for muon ionization cooling in a proton beam judged equivalent in impact to a muon beam for a Neutrino Factory or Muon Collider. As such, the facility will provide the advanced cyogenic capability and safety systems required to perform R&D on liquid hydrogen targets. However, parallel future experiments are invited and, as a general facility, many areas of physics including radiation, medical, nuclear, atomic and beam diagnostics and control will be supported.

INTRODUCTION

A new test beam facility is under construction currently at Fermilab. The Mucool Test Area (MTA) consists of an experimental hall and a support building housing the cryogenic facilities. The MTA has megawatt power capability. It uses the fully diverted Linac 15 kW proton beam. Construction is expected to be completed in Fall of 2003 and the facility made available to the Mucool experiment for muon ionization cooling channel component testing. Thereafter others users are invited to make use of the test beam facility, to be one of the only full intensity linac test beams available in the world.

FACILITY DESCRIPTION AND USE

The MTA is a test beam facility located southwest of the Fermilab Linac. The experimental hall (Figure 1) was designed to have the capacity to perform tests on the liquid hydrogen absorbers of the Mucool (muon ionization cooling) experiment. This includes all safety requirements associated with the handling of liquid hydrogen and liquid helium. Filling tests and flow tests of different types of hydrogen absorbers are scheduled in the MTA initially. Others include high power tests from both heat sources and the high intensity beam available from the Linac beam. Linac beam parameters are listed in Table 1[1]. Beam design parameters requested by the

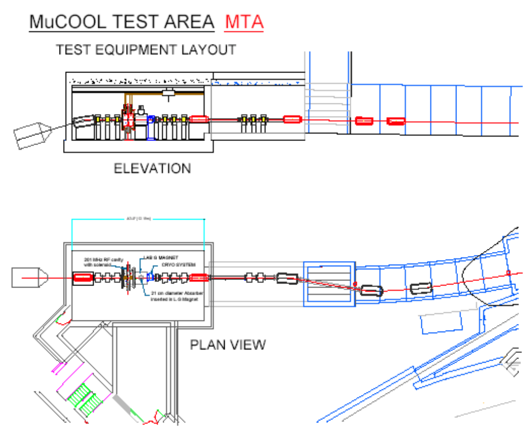

Figure 1: Plan and elevation layout of MTA.

Figure 2: Solenoid and 805 MHz RF cavity

Table 1: General Linac beam parameters

Parameter	**Value**	**Unit**
Kinetic Energy	401.5	MeV
Energy Spread	1	MeV
Peak Current	52	mA
RF Structure	201.24	MHz
Bunch Length	0.208	ns
Pulse Length	50	μs
Max Particles/Bunch	1.6	10^9
Max Particles/Pulse	1.6	10^{13}
Max Beam Power	15.7	kW
Beam Emittance(95%)	8	mm-mrad
σmax (rms)	9	mm

Table 2: Beam parameters proposed for Mucool Test Area

Parameter	**Minimum**	**Maximum**	**Unit**
Beam Size ± 3 σ	1	30	cm
Beam Divergence ± 3 σ	± 0.5	± 14	mr
#pulses/sec	0	15	Hz
#protons/pulse	1.6	16	10^{12}
Pulse duration	5.0	50	μs

the initial users of this new test beam facility are listed in Table 2[1].

In order to simulate the effects of a large precooled muon beam depositing energy into the hydrogen absorber the proton beam must be adjustable just prior to the devices. For instance the beam must be able to cover the entire face of the absorber for which present designs vary from 11 to 18 cm in radius. A triplet of large-aperture quadrupole magnets before the experiment increases the beam size. Downstream of the experiment a similar set of quadrupoles focuses the beam down into an absorber designed to stop the full Linac beam, which requires more than nineteen feet dirt equivalent of shielding. A primary collimator scrapes the beam to within 3σ upstream of the shielding wall. A secondary collimator is recommended downstream of the shielding to prevent unnecessary activation of other equipment in the experimental hall.

The Mucool experiment also includes an 805 (201) MHz NCRF copper cavity to be tested in the magnetic field of a superconducting solenoid (see Figure 2 and 3) which can be run in “solenoid mode” at 5 Tesla or “gradient mode” at 2.5 Tesla. At 2.5 Tesla the two coils’ fields are opposing. The MTA is equipped with a 1500 kVA power transformer to handles the needs of the facility (not including the RF).

The experimental hall is 840 sq-ft and the service building is 1225 sq-ft. There is a sloped access from the equipment lift area (elevation 745’-6”) to the experimental hall (elevation 736’-6”).

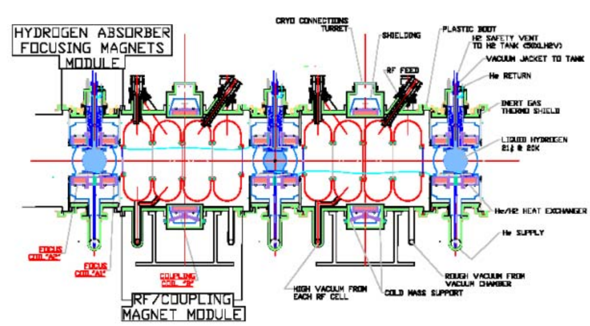

Figure 3: Mucool/MICE SFOFO lattice cell

Other constraints on the facility include the radiation environment of the experimental hall and hands-on maintenance issues associated with highly-irradiated components. With respect to hands-on maintenance issues associated with the hydrogen absorber, a surface contact dose of 40mr/hr has been suggested as the limiting activation of exposed surface areas, such as the cryostat surface. From a MARS simulation[3] performed on the experimental hall, hall components, and the full-beam absorber, this residual activation limit was reached after approximately 100 days of Linac beam. Table 3 presents residual activation results for 30 days of beam and 1 day of cooling for 10^{13} protons per pulse at 15 Hz for various elements of a typical Mucool experiment and MTA configuration[3]. As a result, an operational limit of 10^{21} protons/year was established for the facility.

Table 3: Peak dose (mSV/hr) on contact after 30 days irradiation and 1 day of cooling for 10^{13} ppp at 15 Hz (1mSV = 100 mrem)

Averaged over pump and heat exchanger cryostat	0.11
SC solenoid inside vessel (downstream end)	160
SC solenoid inner coils (downstream end)	54
SC solenoid outside vessel (downstream end)	10
Downstream beamline magnets, inner radius	100
Downstream beamline magnets, outer radius	3
Beam dump core	90000

This yearly limit was then applied in the design of the full-beam absorber to meet ground and surface water, and occupational limits associated with the facility. Since users and employees at Fermilab are limited to 100 mr/week and 1500 mr/year and, further, radiation exposure at or above 5 mr/hr constitutes a defined radiation area with full radiological controls, proper design of the full-beam absorber became important to ensure sufficient access to the facility. (Staying well below this limit allows workers to remain the experimental hall for a typical 40 hour work week.) The final beam absorber design was fully simulated in MARS and these results were applied in a Concentration Model[4] and ANSYS analysis[5] for a full radioisotope and thermal assessment of the beam absorber.

SCHEDULE

Approval of the Mucool Test Area project came on January 6, 2003. Construction of the MTA began in February 2003. The project is on schedule and beneficial occupancy is expected in September 2003.

CONCLUSIONS

The Mucool Test Area is presently under construction at Fermilab. Beneficial occupancy is expected fall of 2003 for the testing of components of the Mucool experiment. The MTA is to be one of the only test facilities in the world that uses a full intensity Linac beam (15 kW, 1.6 x 10^{13} ppp @ 15 Hz). After the Mucool component testing is complete others users are invited to make use of the test beam facility for many areas of physics including radiation, medical, nuclear, atomic and beam diagnostics and control.

ACKNOWLEDGEMENTS

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