THE MUCOOL TEST AREA AND RF PROGRAM*

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Abstract

The MuCool RF Program focuses on the study of normal conducting RF structures operating in high magnetic field for applications in muon ionization cooling for Neutrino Factories and Muon Colliders. Here we give an overview of the program, which includes a description of the test facility and its capabilities, the current test program, and the status of a cavity that can be rotated in the magnetic field, which allows for a detailed study of the maximum stable operating gradient vs. magnetic field strength and angle.

INTRODUCTION

A crucial challenge for the Neutrino Factory and Muon Collider Front-End Design and cooling channels is the operation of high-gradient normal-conducting RF (NCRF) cavities in the presence of high magnetic field. This problem has been a focus of the MuCool [1] program. What has been observed in MuCool is that the safe operating gradient limit degrades significantly when a NCRF cavity is operated in magnetic field, dropping by as much as a factor of two at 2T (typical of the magnetic field strength in a cooling channel lattice). The cause of this effect is believed to come from field emission from emitters (surface field enhancements).

In order to address this problem, four approaches are being investigated in the MuCool program. The first is to eliminate field emission by processing the NCRF copper cavities using superconducting RF (SCRF) or more advanced techniques. This has been done in MuCool for a 201 MHz copper cavity with promising results [2]. A new concept in processing for SCRF that can, in principle, also be applied to NCRF is Atomic Layer Deposition (ALD) [3]. Initial tests of a superconducting cavity coated with 5 nm of ZrO_2 plus 30 nm of Pt were performed at TJNL. The ALD treatment greatly reduced the dark current while maintaining the achievable cavity gradient. The next step will be to operate a similarly treated normal conducting cavity in a magnetic field in order to evaluate its resistance to breakdown.

The second approach is to investigate materials other than copper for the construction of the cavity. Materials such as Be [4] may be less susceptible to the otherwise damaging breakdowns seen when copper cavities are operated in magnetic field.

The third approach for abating the magnetic field effect is to prevent the magnetic focusing. In this case, an open cell geometry is required and additional coils are used in the lattice to modify the B field direction and thus eliminate the B field focusing effect. However, the open-cell structure does mean that additional power (X2) is needed in order to reach the same on-axis accelerating gradient.

The fourth approach to dealing with the magnetic field effect is to operate RF cavities filled with high-pressure H_2 gas [5,6]. Initial tests of this concept [7] are encouraging, but such a cavity has never been tested with beam. In pure hydrogen, ionization electrons will remain in the gas for a significant portion of the RF pulse, being accelerated back and forth by the RF fields. This process can then transfer the electromagnetic energy stored in the cavity to the gas through collisions.

THE MUCOOL TEST AREA

The MuCool Test Area (MTA) is a dedicated facility built at Fermilab to support technology development for muon ionization cooling channels. The Facility is shown in Fig. 1, where the service building (cryogenics plant) is shown in the lower center, the access pit center, right and the MTA hall in the upper right. The facility now provides the following resources:

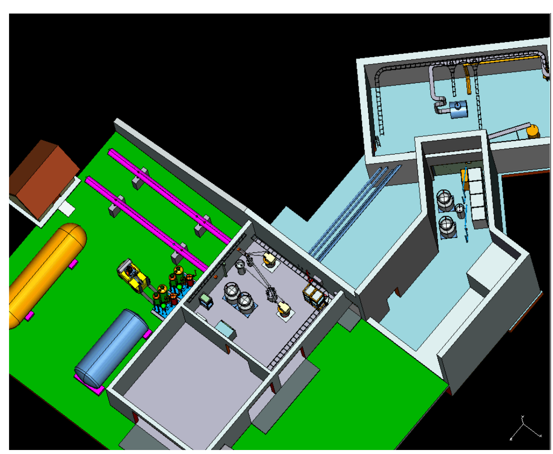

Figure 1: Schematic of the MuCool Test Area.

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- 20' X 40' experimental hall with radiation protection (for component x-ray emission and beam experiments
- 201 MHz (4.5 MW) & 805 MHz (12 MW) RF power
- LHe plant with 385W capability and a distribution system for both LHe and LN_2
- H_2 safety systems for the operation of both high-pressure gaseous devices and LH_2 storage vessels for absorber studies
- 400 MeV high-intensity proton beam from the Fermilab Linac
- Radiation detectors consisting of ionization counters, plastic scintillation counters and a crystal scintillation counter
- A class 100 (or better) clean room [Note: The MTA hall itself is kept at better than class 2000 with HEPA filtered make-up air.]
- Additional diagnostics including vacuum instrumentation and optical fiber probes with spectroscopy analysis capability.

A photograph of the current state of the MTA hall is given in Fig. 2. In this picture, you can see the 5T superconducting magnet, the 805 MHz waveguide power feed into the box cavity (see below) that is inserted into the magnet and then downstream of the magnet, the 201 MHz cavity on its platform inside the clean room.

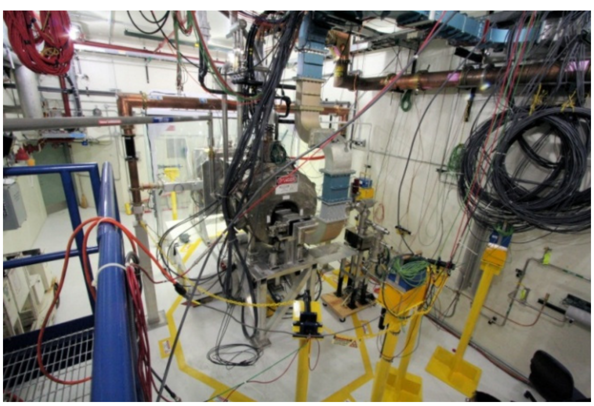

Figure 2: Current Status of the MTA Hall

MTA Cryogenics Plant

The cryogenics plant [8] for the MTA is needed to supply cryogens to support operations of the superconducting magnets in the experiment hall, and enables testing under high-deposited-power conditions various types of liquid hydrogen absorbers. Currently in operation is one Sullair compressor and one 385 W LHe refrigerator which gives us a fill capacity of 72 Liter/hr. A second Sullair compressor is already online and will be commissioned in the near future, which will allow for additional operational reliability of the system. Eventually, a second LHe refrigerator can be added to increase our cooling capacity for the needs of future experiments. Figure 3 shows the MTA refrigerator room. To date, the plant has been used to operate our 5T superconducting solenoid very successfully. In the past, this magnet has only been run in "batch-mode" off LHe dewars. The first closed-system operation of the magnet occurred in March of this year.

Figure 3: MTA Refrigerator room

Figure 4 shows a schematic of the MTA hall that includes the cryogen valve/distribution box (pink) in relation to the 5T solenoid (blue). In white is shown the eventual location of the 2.5T large-bore solenoid that will be used for future studies of our 201 MHz cavity [9] in high magnetic field. We expect that this magnet will be delivered to Fermilab in 2011.

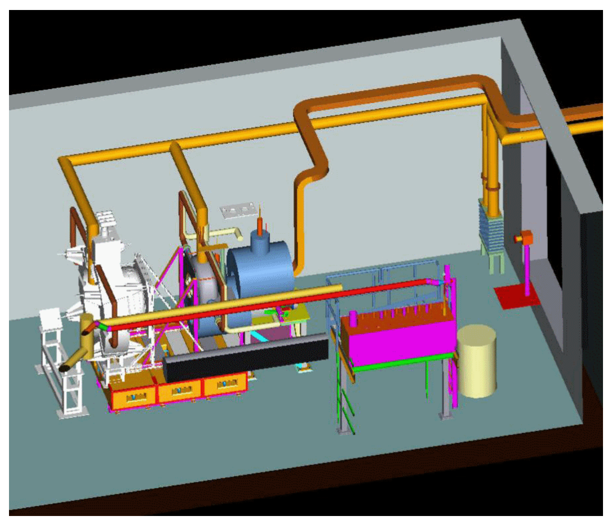

Figure 4: Schematic of MTA Hall

MTA Beam Line

The beam line coming into the MTA uses a primary, 400-MeV H^- beam extracted directly from the Fermilab Linac [10]. The MTA was envisioned to accept the full Linac beam intensity (1.6 x 10^{13} protons @ 15 Hz). However in order to meet radiological limits, initial experiments will use much lower integrated intensity. This is driven by the current state of the shielding and certain control issues. The first experiment with the beam will be to test a H_2 filled RF cavity (see Yonehara, these proceedings [11]. hall. The beam line installation is complete and commissioning is ongoing. In addition to providing beam to experiments in the MTA, this beam line will also allow for a measurement of the emittance of the Linac beam. Instrumentation for this purpose has been installed in the section of the beam line that is in the tunnel stub leading into the MTA hall (see Fig. 5).

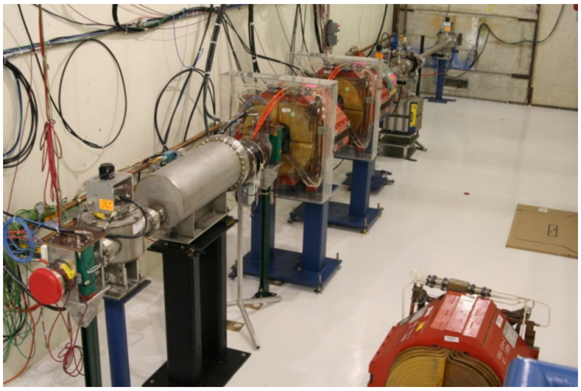

Figure 5: MTA beam line section in MTA hall stub.

THE RF PROGRAM

As mentioned in the introduction, the MuCool RF program seeks to mitigate the deleterious effects of operating NCRF cavities in magnetic field and four approaches are being pursued:

1. Surface processing utilizing SCRF techniques and ALD
2. Material studies
3. Magnetic Insulation
4. Operation of cavities with high-pressure H_2 gas

Work continues in all these areas and detailed reports are given in these proceedings [11-12] . Currently, we are running experiments on magnetic insulation using an 805 MHz rectangular box cavity (Fig. 6).

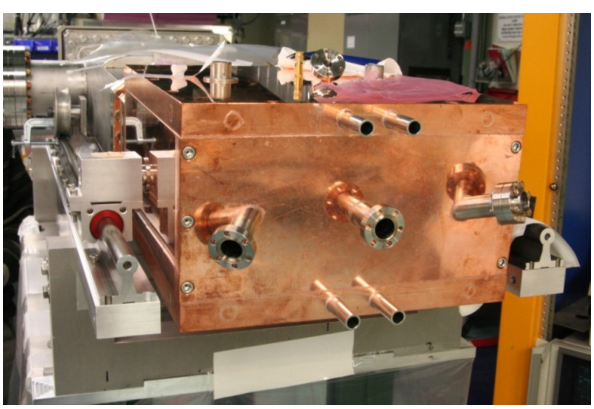

Figure 6: 805 MHz box cavity for magnetic insulation tests

We have operated the cavity in a horizontal orientation in the magnet such that the electric and magnetic fields are perpendicular. In this orientation, the magnetic insulation should be perfect. Operation at approximately 33MV/m accelerating gradient in a field of 3T has been demonstrated [12]. The cavity can be rotated up to 12 degrees (Fig. 7) relative to the B field axis.

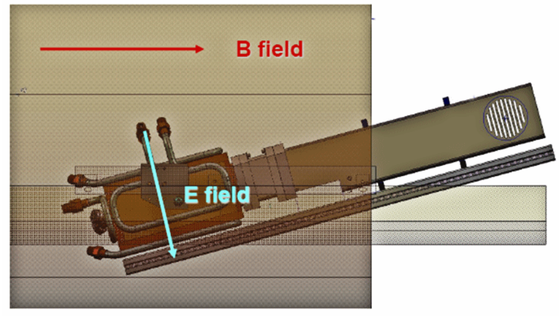

Figure 7: Box cavity set at angle to B field

Modelling indicates that at this angle (12^{o}) and at 3T magnetic field, damaging breakdowns can occur at gradients as low as 15 MV/m.

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