Overview of High Intensity Neutrino Source R&D Activities in the Fermilab Meson Detector Building

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1/16/2007 Revised 4/23/2008

See Appendix 1 for revision details

1. Introduction

The High Intensity Neutrino Source (HINS) R&D Program will investigate and demonstrate accelerator technology that might find application in a high energy, high intensity superconducting Linac suitable to serve the next generation of neutrino physics experiments or muon storage ring/collider R&D. The scope of this program includes operation of a high power klystron RF power source, testing high power RF control components, testing conventional and superconducting accelerating cavities, and ultimately construction of a 65 MeV proton/H- linear accelerator and beam operations.

Klystron RF power operation is anticipated to commence early in 2007. RF component and conventional RF cavity testing will begin shortly thereafter. Beam operation of the 50 keV ion source and 2.5 MeV RFQ is expected in summer 2008. Higher energy beam operations and testing of superconducting RF cavities are not anticipated before 2009.

This note provides a general overview of the activities planned for the Meson Building and describes at a high level the safety hazards involved.

2. Description of Equipment and Activities

Facilities for the HINS R&D program will be installed and operated in the Meson Detector Building. Layout of the HINS program components and five named activity areas are shown in Figure 1.

A 325 MHz, pulsed RF power source, consisting of a 2.5 MW klystron and modulator ultimately capable of operating at a 4.5 millisecond RF pulse length with 1.5% duty cycle, occupies the “Klystron and Modulator” area.

A switched RF power distribution system from the klystron feeds the “Cavity Test Cave”, “RF Component Test Facility”, “Ion Source and RFQ”, and “65 MeV Linac Cave” areas. A diagram of the RF power distribution system is shown in Figure 2.

The “Cavity Test Cave” will be used for RF testing and conditioning spoke-resonator type accelerating cavities. Copper spoke cavities for the 2.5 MeV to 10 MeV section of the 65 MeV Linac and three types of superconducting spoke cavities for the 10 MeV to 65 MeV sections of the Linac will be individually tested to full RF gradient in this cave. The cave will house a large cryostat to be supplied with both liquid nitrogen and liquid helium for the superconducting cavity testing. As shown in Figure 2, the cave is fed by two RF power transmission lines; one with 250 kW peak power capability for superconducting cavity tests and one with 25 kW peak power capability for copper cavity tests. Vacuum equipment will be needed in the cave to achieve and maintain the vacuum required for

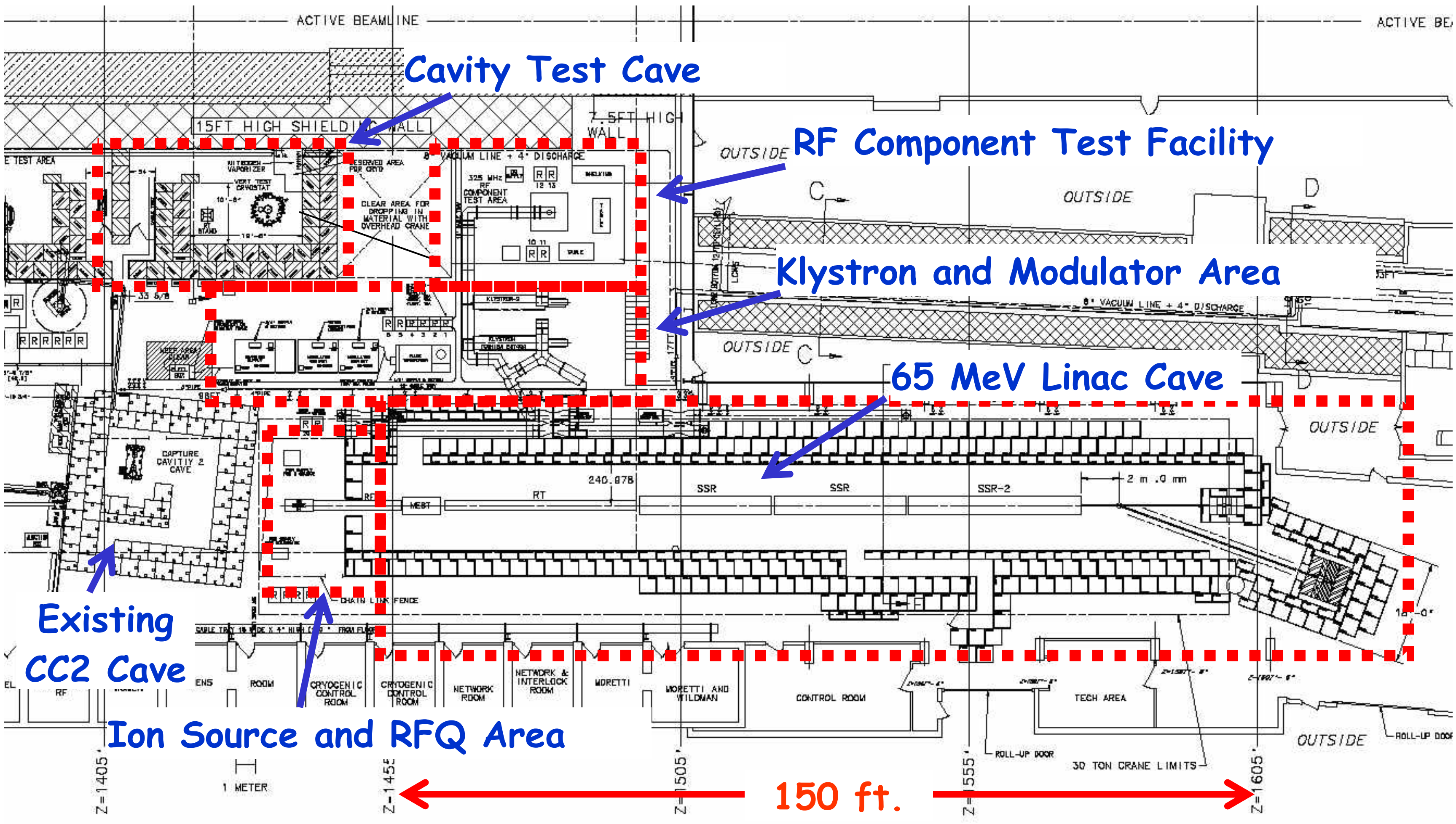

Figure 1. Meson Detector Building Layout and Identified Activity Areas for HINS R&D Program

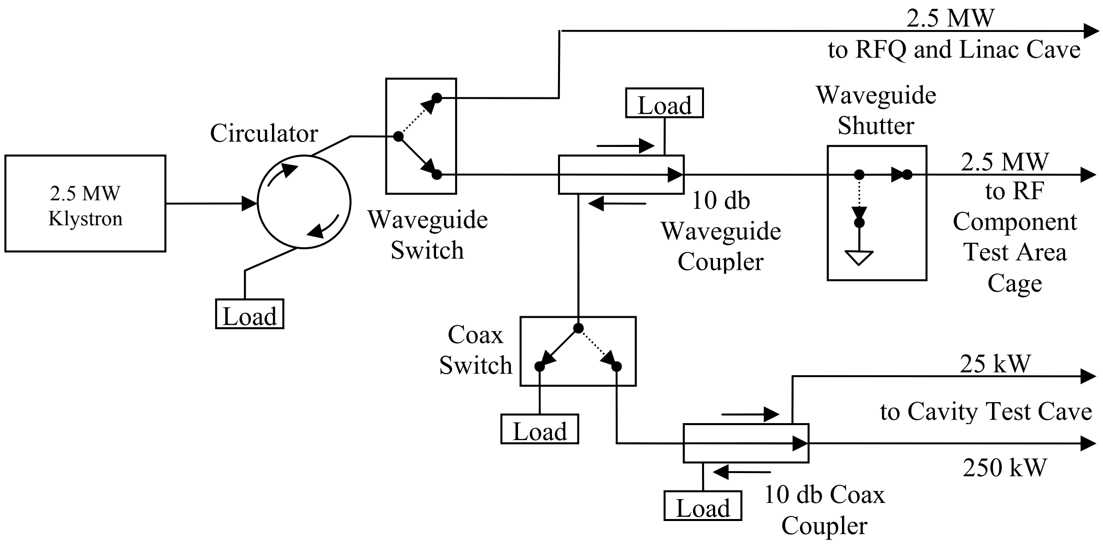

Figure 2. RF Power Distribution System

high power cavity tests and cryostat insulating vacuum. It is anticipated that up to approximately 18-20 copper cavities and 30 superconducting cavities will be tested in the cave over a period of 4-5 years. No beam will be injected into the cavities for acceleration in this cave.

The “RF Component Test Facility” has a RF screened cage that will be used for testing various, non-x-ray producing, high power RF control and distribution components. A waveguide feed supplies the “RF Component Test Facility” cage with RF power up to the full 2.5 MW capability of the klystron. It is anticipated that this test area will be used intermittently, several weeks per year, over the next several years.

The “Ion Source and RFQ Area” will contain a 50 keV H- or proton ion source, a Radio Frequency Quadrupole (RFQ) accelerator, and support equipment sufficient to generate a 2.5 MeV beam at currents up to approximately 40 mA at 1% duty cycle. The RFQ has been ordered with anticipated delivery in summer 2008. The ion source will be installed and commissioned somewhat in advance of RFQ installation. Initial beam operations will be performed to commission the RFQ and to characterize the 2.5 MeV beam that ultimately feeds the Linac.

The “65 MeV Linac Cave” will house the Linac accelerator downstream of the RFQ. This will include both conventional copper and superconducting accelerating cavities, superconducting solenoids for beam focusing, beam absorbers, and the necessary support equipment that is most appropriately located within the beam enclosure. Ancillary power supplies, controls and diagnostics equipment, and other accelerator support equipment will be located outside the cave. The Linac will most probably be commissioned in stages; e.g. room temperature section first, then with addition of one superconducting cavity cryomodule, finally with the full complement of elements to achieve 65 MeV beam. The Linac will be operated to fully achieve the technical and scientific R&D objectives of the program including long-pulse (3 msec) RF control with beam at currents up to 10 mA, high peak current operation (~20 mA) at up to 1 msec pulse lengths, and characterization of beam parameters and quality under these conditions. It is anticipated that the program progresses through these stages during the 2008-2011 period. There is currently no planning for subsequent operations beyond these objectives.

3. Hazard Identifications and Mitigations

The HINS program R&D areas, facilities, and equipment pose hazards typical of large electrical energy storage systems, high power RF systems, high gradient accelerating cavities, cryogenic systems, and accelerator beam lines and enclosures. This document provides an overview of the major hazards and the general methods that will be used to mitigate those hazards for each of the identified activity areas. All areas are subject to general conventional safety concerns.

System specific safety procedures and documents including LockOut/TagOut (LOTO) will be provided separately from this document. This document neither replaces nor supersedes safety documentation required by Fermilab ES&H manuals or Division practices

Training and qualifying workers for each activity area are key components to a comprehensive safety program.

3.1. Klystron/Modulator Area and RF Power Distribution System

The special hazards of concern to this area and equipment are associated with high voltage electrical energy storage and discharge systems and high power RF electromagnetic energy.

Electrical shock is the primary hazard associated with the modulator and its output circuit. Safe practices for working on and with this equipment and the modulator load are described in a modulator LOTO procedure document. The modulator/klystron power system accepts an operational permit signal from the AD ES&S HINS Meson Personnel Safety Interlock System (Interlock System). The modulator system includes a comprehensive set of equipment protection interlocks.

X-rays, generated at the collector end of the klystron, and high power electromagnetic energy in the RF waveguide and coaxial transmission lines are special hazards of the klystron and the RF power distribution system. The x-ray hazard is handled by shielding provided by the klystron manufacturer. The electromagnetic energy hazard is controlled by including the control and status of the high power RF energy switching devices (waveguide switch, waveguide shutter, and coax switch) in the Interlock System. An RF distribution system LOTO procedure will be provided to establish safe procedures for working on any component of the RF distribution system or RF device attached to that system. An area electromagnetic radiation monitor (located in the RF Component Test Facility) is included in the Interlock System. An independent electromagnetic radiation monitor is a part the klystron equipment interlocks. A written klystron operating procedure manual is maintained.

3.2. Cavity Test Cave

The cavity test cave provides a concrete shielded, interlocked, and access controlled exclusion area for RF testing of x-ray producing accelerating cavities. Special hazards in the cavity test cave are x-ray generation by cavities under test, high power RF electromagnetic energy, and cryogenic liquids and gases.

X-ray protection shall be afforded by controlling cave access with the Interlock System, by providing that system a means of disabling the RF power source, by the thick concrete walls and roof of the cavity test cave, and by interlocked radiation monitors. (See Beams Doc #2598, Estimate of X-Ray Shielding and Radiation Monitoring for Safe Operation of the HINS Cavity Test Cave in the Meson Detector Building.) The RF electromagnetic energy hazard shall be mitigated by including the control and status of the RF coaxial and waveguide switches in the Interlock System, by configuration control procedures, and by the RF distribution system LOTO procedure. Cryogenic and oxygen deficiency hazard (ODH) safety will handled according to the standard Accelerator Division cryogenic safety practices, including suitable ventilation, ODH monitoring and training.

3.3. RF Component Test Facility

The RF screened cage in the component test facility provides a metal conductor shielded, interlocked, and access controlled exclusion area for testing high power, non-x-ray producing RF components. The principal special hazards associated with the component test facility are high power electromagnetic energy and possible radiation of the same, and sulfur hexafluoride gas (SF6) used to extend the RF power handling capability of some components.

The electromagnetic energy hazards are handled by controlling RF cage access with the Interlock System, by including the control and status of the waveguide switch and waveguide shutter in the Interlock System, by an area electromagnetic radiation monitor inside the cage, by the RF shielding afforded by the cage, by configuration control procedures, and by the RF distribution system LOTO procedure.

The volume of SF6 filling any component-under-test shall be limited to <2 cu. ft. It is expected that there will be fewer than fills and releases of this volume during the lifetime of the HINS program. SF6 hazards are mitigated by specific operational procedures to be defined in the RF Cage Operating Procedure (Beams Doc #2616).

3.4. Ion Source and RFQ Area

The special hazards of concern to this area and equipment are associated with high voltage electrical equipment and electrical energy storage elements, hydrogen gas, high power RF electromagnetic energy, SF6 gas, and proton and H- ion beam production to energies ≤ 2.5 MeV.

Electrical shock is the primary hazard associated with the ion source equipment. Safe practices for working on and with this equipment will be described in an ion source operating manual and an ion source LOTO document.

Hydrogen gas is required for ion source operation. Hazards associated with this gas will be mitigated by limiting the maximum hydrogen volume, abiding by procedures defined in the ion source operating manual, and installing and maintaining other hydrogen safety equipment or procedures recommended by a review of the system by the Fermilab flammable gas safety committee.

High power RF hazards will be controlled by including the control and status of the waveguide switch in the Interlock System, by configuration control procedures, and by the RF distribution system LOTO procedure.

SF6 will fill the RF coaxial power line and vector modulator components comprising the east-west section of the RF line, approximately 20 feet in length, between the RFQ and the southernmost end of the 6" coaxial RF power line (later to be replaced by waveguide). Total SF6 volume shall be less than 4 cu. ft. It is expected that this volume will be released and re-filled fewer than ten times during the several year life of the HINS program. Specific RF line maintenance procedures related to the SF6 shall be written and maintained.

High electric fields within the RFQ will produce x-rays. Verbal information from the manufacturer suggests that the x-ray flux outside the RFQ vacuum enclosure will be within safe levels. This must be verified during RF commissioning of the RFQ.

With a properly designed beam absorber, all hazards due to 2.5 MeV proton or H- beams are expected to be confined to within walls of the beam line vacuum vessel. 2.5 MeV beam shall operate in a pulsed mode at <40mA beam current during a pulse and <1% duty cycle.

As of April 2008, the details of any exclusion zones and/or Interlock System connections for radiation safety purposes for the Ion Source and RFQ Area are not complete. The working assumption is that none will be required. Applicable FRCM requirements and Accelerator Division practices shall be followed.

3.5. 65 MeV Linac Cave

All special hazards of accelerator beam enclosures, including ODH hazards, are anticipated in the 65 MeV Linac Cave. It is expected that cave design, beam absorber design, and hazard mitigation measures will be addressed in 2008 or, in any case, before commencement of cave construction.

Appendix 1

Document Revision Details

Substantial 4/23/2008 Revisions

1) This appendix added
2) Section 1 – schedule dates revised
3) Section 2 – Figure 2 revised to show RF line extended to RFQ and Linac Cave
4) Section 2 – schedule date revised
5) Section 3.3 – SF6 considerations added included statement that SF6 procedures shall be included in Cage Operating Procedure document
6) Section 3.4 – SF6 and hydrogen gas considerations added
7) Section 3.4 – ion source operating manual and ion source LOTO document are cited
8) Section 3.4 – 2.5 MeV beam current and duty factor limits added
9) Section 3.4 – Statement added that “The working assumption is that none (rad safety exclusion zones or interlocks) will be required” for Ion Source and RFQ Area