Safety Report for the TWIST Experiment (E614)

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1. Identification

EEC Experiment 614 - Precision Measurement of Muon Decay Parameters

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2. General Description

The TRIUMF Weak Interaction Symmetry Test (TWIST) experiment, E614, will occupy the M13 beam line and area for about 5 years beginning in the fall of 2000. The experiment will make precision measurements of normal muon decay by tracking the decay positrons from stopped surface muons in a stack of wire chambers mounted in a 2-T magnetic field produced by a superconducting coil in an iron yoke. End and side views of the detector are shown in Fig. 1 and the layout of the detector in M13 is shown in Fig. 2.

The wire chamber array is comprised of planar modules of drift and proportional chambers stacked in a support cradle which is mounted on a track installed in the bore of the magnet cryostat. The cradle is brought to the magnet on a cart which includes an extension of the track. With the magnet iron yoke downstream end plate opened by means of heavy duty hinges, the cart is positioned downstream of the magnet and the detector array is rolled into position in the centre of the magnet.

The front end readout electronics (post amplifiers and discriminators) and the gas system for the wire chambers will be located on a platform beside the magnet yoke. This platform will roll parallel to the beam axis with the detector array so that the chambers can be set up and tested behind the magnet before being rolled into position. The cables and gas lines are carried on a boom (analog boom) from the platform through service slots in the iron yoke to the detector array. The signal cables from the discriminators to the Fastbus crates in fixed cooled racks are carried on a pivoting second boom (digital boom) which also carries power and supply gases to the rolling platform.

The M13 exclusion area will be modified as illustrated in Fig 2. in order to allow access to the rolling platform while beam is delivered to the detector. The exclusion area will be formed upstream by arranging shielding blocks close to the corner of the magnet. At the NE side, the 20-cm thick iron yoke plus the additional mass of the cryostat, SC coil, and detector itself are anticipated to provide sufficient self shielding in the same way that the Chicago magnet does on M9A. Downstream of the magnet, an exclusion fence and gate will be installed to prevent access to the beam path and the SE and upstream areas next to the detector. The only access to the detector will be through this fence/gate which will replace the present area gate in M13 in order to secure the area for beam delivery.

The wall between M13 and M11 has been modified to accommodate the space requirements on both sides. Part of the present shielding perimeter of the M13 area on the N wall of the area will be removed to give adequate access to the rolling platform. This requires removing and/or rerouting the services mounted on shielding blocks.

We intend to preserve the option in the future to reestablish the present exclusion area if needed by placing shielding to close off the NE corner of the area and utilizing the present gate.

3. Definition of Hazards

Safety hazards of this experiment fall into the following general categories:

- *radiation* hazards related to the changes to the M13 exclusion area described above.
- *cryogenic* hazards related to the operation of the superconducting magnet
- *magnetic field* hazards related to the 2-T central field and significant fringe fields of several kG.
- use of *flammable gases* in the wire chambers.
- *high voltage* use in wire chambers and photomultiplier tubes (PMT).
- other *electrical and industrial* hazards.

4. Detailed Description of Hazards and Safety Measures

I. Radiation

Because the M13 area will be altered in a number of ways, it will be necessary for thorough surveys to be carried out under various beam conditions to demonstrate that the new layout is safe. However the changes envisaged have been proposed with some confidence that they will be satisfactory.

The changes included the moving of the M11/M13 wall to accommodate CHAOS in M11. This was done preserving the minimum 30" thickness of concrete specified by Dave Ottewell based on previous operation.

We would like to remove the single block in front of the BL1A access door to gain the space for access to the upstream region of the experiment and obtain more room for the He filling process. The Safety Group has been requested to do a survey to see if this is possible.

The concept of relying on self shielding from the iron yoke is based on the experience in M9A with the Chicago magnet. The beams available from M13 are similar to M9A, but the maximum intensity is almost an order of magnitude lower due to the thinner T1 targets compared to those at T2. Moreover, M9A usually runs with muon and pion beams of higher momentum than the surface muon beam we plan to run in M13 for TWIST.

The exclusion fence and gate for the downstream region will offer the only access to the detector and cryogenic servicing. It will replace the function of the present gate in the Area Safety Unit and will be fitted with the necessary switches and keys. A portion of the fence may need to be removable (under the Work Permit procedure) in order to open the magnet.

If surveys show that additional shielding downstream is required, a 6-foot block can be located behind the magnet on the beam axis. This would not interfere with the routine access needed to fill the SC coil cryostat with He. However, such a block will need to be removed (by authorization through Work Permit) whenever the magnet is opened for access to the detector.

II. Cryogenics

The superconducting coil and power supply were designed for use as a medical MRI magnet and were provided with detailed written procedures and precautions for cooling and operation. The magnet will be installed with necessary piping to direct all vents and burst disks away from equipment and occupied areas. In the event of a quench essentially the entire LHe inventory will be vented. For that reason, until we are confident of our procedures and the stability of the magnet, we will maintain the LHe level 50 -- 70% full. With routine boil-off rates, LN2 and LHe filling will be required every 2 to 4 weeks.

Briefly, the initial cool down procedure which should take approximately 10 days is as follows:

- vacuum vessel pressure to be $<10^{-5}$ mbar.
- fill LN2 shield
- pre-cool LHe volume with LN2. and leave for 24 h to equilibrate to 77K
- flush out LN2 with He gas, pump out and He back fill three times
- LHe fill to 70% before energizing magnet.

The cryostat capacities for LN2 and LHe are 740 l and 575 l, respectively. Approximately four times the capacity volumes are required for initial cool down from room temperature. The expected He boil-off rate is approximately 7 litres/day with the power leads removed, and 10 to 20 times higher, depending on current, with the power leads connected.

Because the magnet is located in the open Meson Hall with good ventilation, the risks of asphyxiation from boil-off gases should be negligible.

III. Magnetic Fields

The downstream end plate of the magnet iron will open on hinges to give access to the detector wire chambers. It will be essential that the SC coil cannot be energized while the iron yoke downstream end plate "door" is open. Main power for the power supply (208V 3ph, approx. 6kVA) will be fed through a contactor which can be actuated by satisfying an interlock when the magnet iron is closed and secure. The main power will also be capable of a standard lockout for non-routine situations. Additional safeguards include unplugging the PS and the fact that the power leads are only connected to the coil during current ramp up/down.

During normal running, once the coil is energized, the power leads are disconnected and the magnet is run in closed-circuit persistent mode. As well as greatly reducing the He boil-off rate, this isolates the coil from any instabilities in the power supply due to power bumps or other faults which pose the most probable cause of a quench. Field decay in persistent mode is expected to stabilize at less than 0.6 ppm/h. We expect to “top up” the current approximately every two weeks.

This persistent-mode operation means that the power supply state is not a useful indicator of the presence of magnetic field; this will be obtained directly from a magnetically actuated switch. It will be essential to reliably annunciate the presence of magnetic field to people who must work near the magnet since both the central 2-T field and regions of significant fringe fields will be accessible. A supply of non-magnetic tools will be available.

It will be essential to enforce a reliable procedure to control the presence of loose magnetic materials in these areas, both while the field is on and in securing the area prior to excitation.

IV. Flammable Gases

The detector wire chambers are constructed as modules mounted in the vertical plane in the support cradle in the magnet. There are 16 drift chamber modules and 2 proportional chamber modules as well as a special target module mounted in the centre of the stack at the detector midplane. The support cradle also serves as a helium gas vessel so that the stack of chamber modules including the spaces between modules is surrounded by He. Currently two chamber gas mixtures are being considered for the drift chambers: Helium/Isobutane (70:30) and dimethyl ether (DME) (100%). The proportional chambers will use a mixture of CF_4/isobutane (80:20).

The total drift chamber volume is approximately 60 liters, and the total drift chamber gas flow will be approximately 1 l/m. The total proportional chamber volume is approximately 15 liters, and total proportional chamber gas flow will be approximately 250 cc/min. The He volume is approx 1200 l., and helium will be flowed at approximately 1 l/min. The explosive mixture limits for DME in air are 3.4 - 27%. Pure isobutane has explosive limits in air of 1.8 - 8.4%. The explosive limits in air for the mixtures helium/isobutane (70:30) and CF_4/isobutane (80:20) are unknown, but the addition of the inert constituents would raise the LEL of the mixture relative to pure isobutane. The "worst case" (DME in drift chambers) total mass of flammable gas in the M13 area will be approximately 140 grams.

Gases will be supplied from the Meson Hall Gas Shack to the gas distribution/control system mounted on the rolling platform beside the detector. The gas lines will be stainless steel and copper except for the last 3 meters into the chambers where polyethylene tubing is required for maximum tubing flexibility. Chamber exhaust gases will be returned to the gas shack and vented to the outside. Inflow and outflow rates will be monitored in the gas shack.

The gas distribution system is required to control the relative pressure between the chamber gases and the surrounding He to a precision of +/- 5 mTorr. As a result flow rates and potential leaks will be monitored with much higher precision that in typical wire chambers. The usual sensors for explosive gases will be located in the vicinity of the detectors. Since any leaks within the chamber stack will escape into the surrounding He volume, the exhaust from the He will also be monitored for the presence of flammable gas contamination.

The CF_4/isobutane will be 90% recycled using the techniques used previously, e.g., at TRIUMF and in E787 at BNL. The possibility of DME recycling is being considered.

There are system controls both in the Gas Shack at ground level, and in the M13 area. Should a power failure occur, all mass flow controllers (MFC) in the gas shack will shut down, stopping all gas flow into the area. Chamber isolation solenoid valves will close, isolating the chambers from the gas supply and the exhaust tubing. These valves remain closed until manually reset.

If power is lost only in the Gas Shack, gas supply from the shack will be shut off. The pressure in the chambers will slowly decrease until pressure interlock systems are tripped which close the isolation solenoid valves at the chambers. If power returns in the Gas Shack flow into the closed input lines will resume until the pressure in the equals the supply pressure (~10 PSIG), at which point all flow will stop. If power is lost only in the M13 area, the chamber isolation solenoid valves will close.

V. High Voltage

The wire chambers in the detector array and PMTs used to read out scintillators all operate with a few (<3) kV provided by commercial supplies and distributed through standard connectors and coaxial cables common to most experimental setups at TRIUMF. No exposed HV will exist under normal conditions, the exception being the commissioning and troubleshooting of the wire chamber modules. This work will be carried out only by qualified experts who are thoroughly familiar with the devices.

VI. Electrical and Industrial

The experiment requires approximately 15 kW of power on the rolling platform, approximately 10 kW for the fixed Fastbus racks and and 6 kVA for the magnet powersupply (only while ramping the current up/down). This service will be installed by qualified contractors.

The magnet steel, weighing a total approximately 110,000 lb, was fabricated under contract to the specifications of a TRIUMF design which has undergone a separate engineering review. The assembly in M13 will undergo an additional engineering review before work starts. The iron has been designed so that it can be lifted with the 18,000-lb cryostat by the Meson Hall twin cranes as a unit if necessary.

5. Definition of Responsibilities

In fulfilling their responsibilities, the Experimental Spokesman and Safety Coordinator rely on the expertise associated with the various aspects of the TWIST experiment with regard to safety issues:

Wire chambers	Robert Henderson	rhend@triumf.ca	7383
Gas system	Robert Openshaw	openshaw@triumf.ca	6574
Magnet steel	Willy Andersson	draken@triumf.ca	6238
Cryostat	Willy Andersson		
M13 area	Curtis Ballard	ballard@triumf.ca	6201/6456
Electronics	Grant Sheffer	sheffer@triumf.ca	6575
Engineering overview	Guy Stanford	stanford@triumf.ca	7388

6. Decommissioning and Disposal

No special hazards exist once power is removed and the cryogens boil away. No radioactive activation of the apparatus is expected.

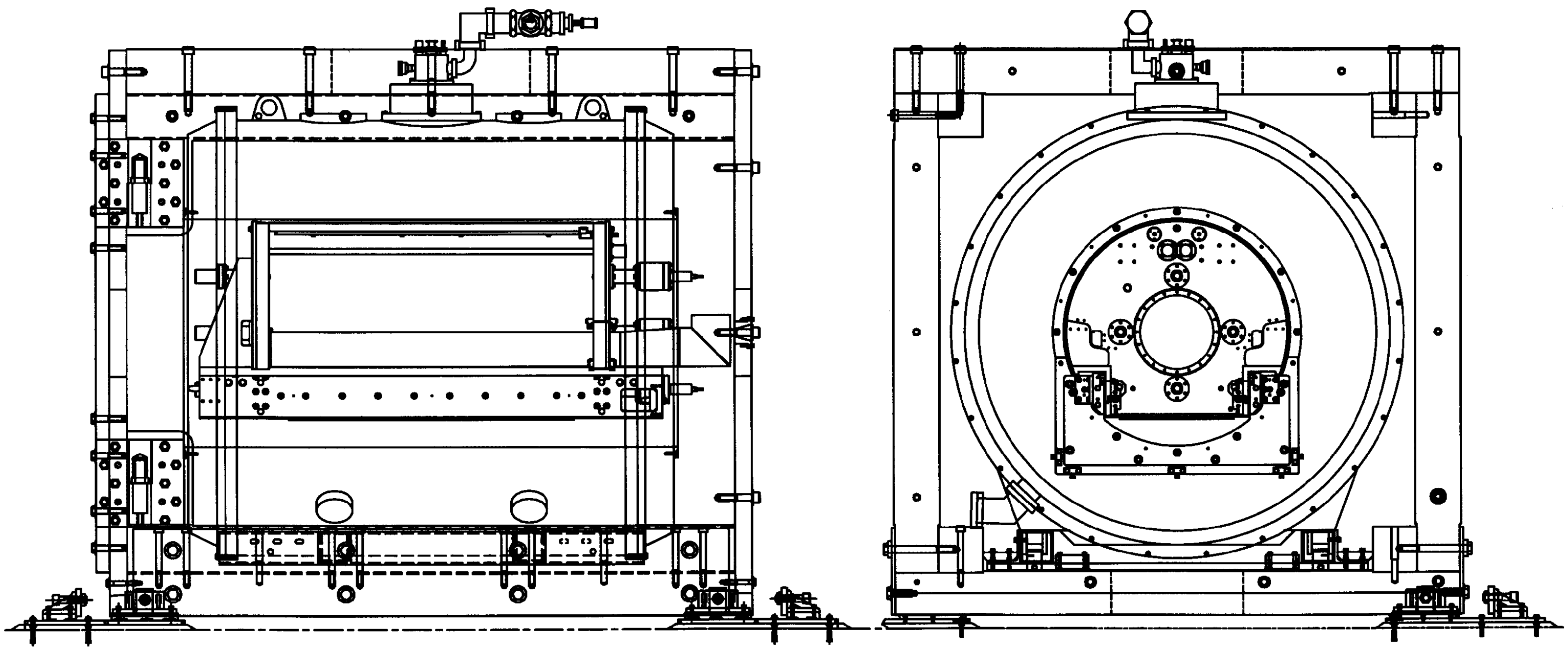

Fig. 1. Side and end views of the TWIST spectrometer.

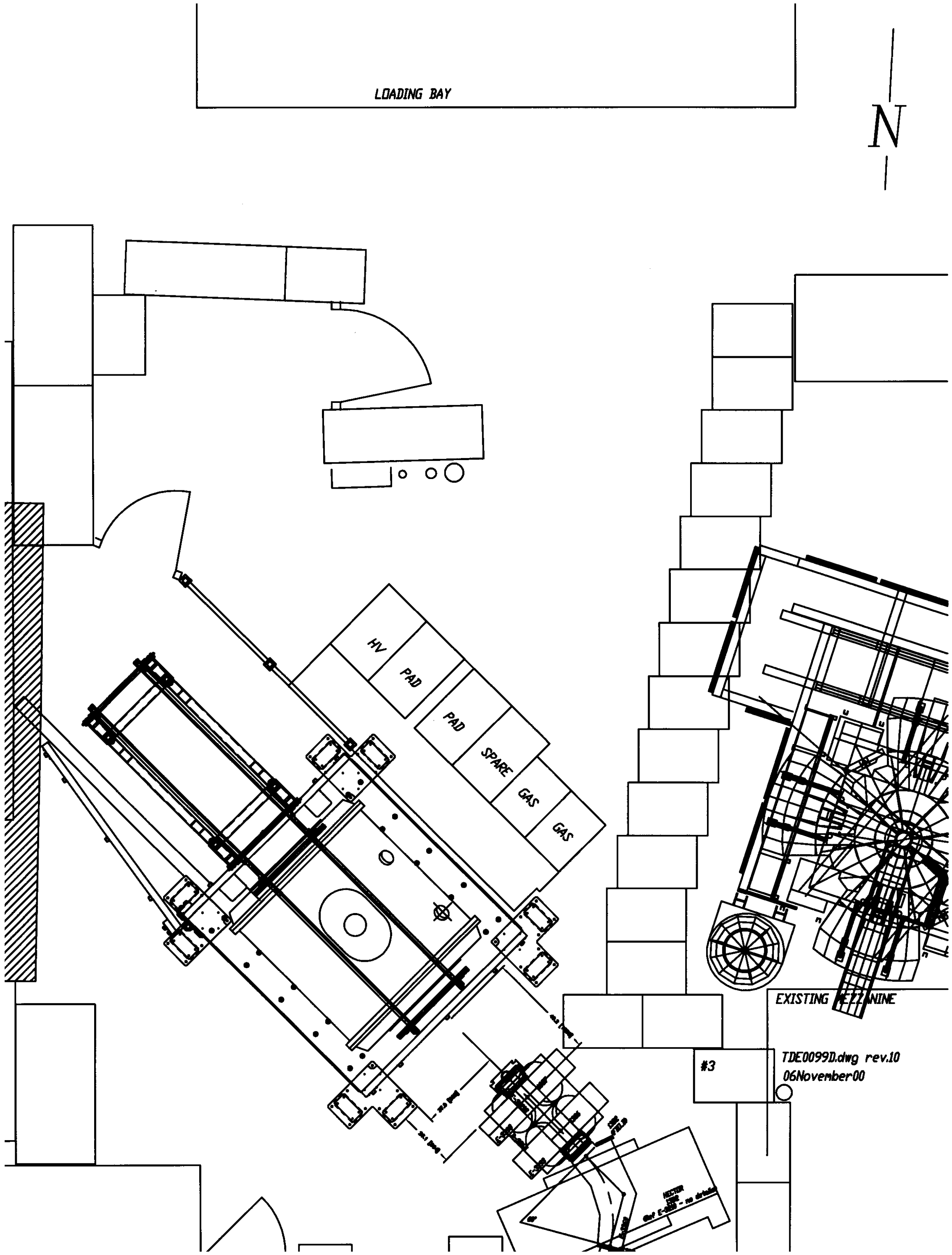

Fig. 2. M13 layout with the TWIST Spectrometer.