

Fermilab National Accelerator Laboratory

Accelerator Readiness Review

for the

Neutrino Muon 120 GeV Beamline

Over the past several months, work has been performed to prepare an existing proton beamline for restart and recommissioning to support the SpinQuest (E1039) experiment. The experiment seeks to measure the Sivers asymmetry from quarks in the nucleon. The 120 GeV Main Injector proton beamline, which had been shut down since 2017, extends from the split in enclosure B through the G1, G2, and Neutrino Muon NM1 - NM3 enclosures. The experiment uses a new, commercially supplied helium liquefaction plant, but re-uses an older, refurbished target magnet and cryostat. The targets, with electronics to interrogate the polarization, are supplied by collaborating institutions. The recycled 206-ton solid iron magnet was used in the SeaQuest (E906) experiment, SpinQuest's predecessor. The large aperture spectrometer magnet is re-used from KTeV experiment. A reconfigured shielding pile was installed to support both the liquefaction plant and reduce the radiation backgrounds in the target cave and control room.

To achieve the goals of the Fermilab experimental program, the Laboratory is commissioning a limited scope Accelerator Readiness Review (ARR) for the restart of the Neutrino Muon 120 GeV Beamline. The ARR committee is requested to conduct a readiness review of the beamline to assess if the hardware, personnel, and administrative systems and programs are ready for commissioning and operations within the proposed Accelerator Safety Envelope (ASE). The scope of the review will include operational targets using CH₂ plastic. A second stage review is planned at a later date for the use of NH₃ ammonia targets.

An addendum to the original *Neutrino Muon (NM) Beamline Shielding Assessment*, v1.3, February 24, 2012, was developed and documented as *Neutrino Muon Beamline Shielding Assessment Addendum for E1039*, v2.7, December 18, 2019. The *Fermi National Accelerator Laboratory Safety Assessment Document (SAD)*, Revision 22, was updated to reflect current operations, and the Fermilab ASE were revised based on the shielding assessment and the updated SAD. The shielding assessment, SAD, and ASE have been revised in accordance with Fermilab policies and are pending approval by the Laboratory.

ARR Charge Questions:

The team is asked to perform a limited scope accelerator readiness review to identify of potential issues, with respect to the following charge questions.

1. Are the necessary program elements from DOE O 420.2C, *Safety of Accelerator Facilities*, and the associated Contractor Requirements Document (CRD) in place for beamline operations?
 - a. Approved Accelerator Safety Envelope (ASE)
 - b. Safety Assessment Document (SAD)
 - c. Clearly defined roles and responsibilities for personnel involved in accelerator activities in support of the beamline operations (e.g., machine department staff, & ES&H), including those for training and procedures
 - d. A facility Configuration Management Program that that incorporates components utilized for accelerator safety (e.g., beam permits, run permits, component control)
 - e. Credited controls and appropriate administrative processes related to accelerator safety (e.g., training, procedures, etc.)

2. Are the procedures for target setup, considering the use of CH4 plastics, well defined and understood?

The Consolidated Review and Assessment Document (CRAD) with Lines of Inquiry (LOI) for the review is attached. Findings, comments, noteworthy practices, recommendations, and specific answers to the charge questions shall be provided at a closeout meeting with Fermilab's management. All recommendations should be categorized as either pre-start or post-start recommendations. A final written report documenting the results of the review is to be provided within two weeks of the review's conclusion.

**Consolidated Review and Assessment Document (CRAD)
and Lines of Inquiry (LOI) for the
Neutrino Muon Beamline Restart for the
SpinQuest/E1039 Experiment
Limited Scope Accelerator Readiness Review (ARR)**

- 1.0 Plenary Session Topics** (arranged to suit schedule)
- 1.1 Welcome, Introductions, Description of Accelerator Readiness Review (ARR)
Process and Plan
Maddie Schoell
 - 1.2 Discussion of Accelerator Operations in support of SpinQuest/E1039
Todd Sullivan/Rick Tesarek
 - 1.3 Tour of Relevant Portions of Neutrino Muon Beamline
Tom Kobilarcik/Rick Tesarek
- 2.0 Discussion of Required Documentation for Neutrino Muon Beamline Restart**
- 2.1 Safety Assessment Document (SAD)
Maddie Schoell
 - 2.2 Accelerator Safety Envelope (ASE)
Maddie Schoell
 - 2.3 Safety Configuration Management (SCM)
Ben Russell
- 3.0 Accelerator Systems for Neutrino Muon Beamline**
- 3.1 Training and Qualification Program for Accelerator Operations Personnel
Todd Sullivan
 - 3.2 Accelerator Operations Procedures for the Neutrino Muon Beamline
Todd Sullivan
 - 3.3 Work Planning and Control Related to Accelerator Safety
Raymond Lewis/Ben Russell
 - 3.4 Credited Controls (CC)
Ben Russell
 - 3.5 Radiological Protection
Ben Russell

2.0 Discussion of Required Documentation for Neutrino Muon Beamline Restart for the SpinQuest/E1039 Experiment

2.1 Safety Assessment Document (SAD)

Objective:

Determine if staff adequately understand the Fermilab SAD to support restart of the Neutrino Muon Beamline for the SpinQuest/E1039 experiment. Assess staff knowledge of the hazards associated with relevant portions of facility operation, and confirm that the necessary controls are in place to ensure effective the beamline's safe operation.

Criteria:

DOE O 420.2C requires that the SAD:

- (1) Identify and analyze accelerator specific hazards and identify necessary controls to eliminate or mitigate hazards to workers, the public, and the environment. Identify and analyze non-accelerator specific hazards which could serve as initiators or contributors to other evaluated accelerator accidents. Hazards from radiation and residual radioactivity associated with beam operations must be evaluated for onsite and offsite impacts from routine operations and credible accidents as appropriate. Analysis of radioactive material must consider direct radiation, contamination, and airborne dispersion as appropriate;
- (2) Provide a description of uncontrolled risk (i.e., without mitigation) and risk with controls in place associated with accelerators and their operations;
- (3) Provide detailed descriptions of engineered controls (e.g., interlocks and physical barriers) and administrative measures (e.g., training, procedures) taken to eliminate or mitigate hazards to workers, the public, and the environment from accelerators and their operations; and
- (4) Include or reference a description of the accelerator and accelerator facility function, location, and management organization in addition to details of major accelerator and accelerator facility components and their operation.

Approach

Document Reviews: Review the relevant SAD Chapters and reference information to the extent necessary to assess management and staff understanding of its content for implementation and operating activities.

Interviews and Performance Review: Interview selected staff involved in preparing the relevant chapters in the SAD, as well as those responsible for conducting operations, to review knowledge of accelerator operations and associated understanding of SAD requirements. Interview selected staff involved in facility management and operations to assess awareness and understanding of SAD requirements.

Lines of Inquiry (LOIs): LOIs are provided for each topic to guide the discussion to assure comprehensive coverage of all topics. The reviewers may choose to use the LOIs in the form of a checklist at their discretion. In the LOIs the term “interview” encompasses both informal discussions with relevant personnel and presentations.

Criterion 2.1: Safety Assessment Document
Lines of Inquiry, Status and Evidence for Each Criterion

LOI	Status/Evidence	ARR Reviewer Notes
1. Assess knowledge of management/staff involved in development of SAD and its associated implementation.	<ul style="list-style-type: none"> - Determine knowledge of SAD requirements. - Shielding Assessment Review Panel of Radiation Safety Subcommittee. - SAD Review Subcommittee. - Other FESHCom Subcommittees as needed. 	
2. Assess knowledge of management/staff in conducting operations activities as per the SAD requirements.	<ul style="list-style-type: none"> - Determine understanding of SAD requirements with those responsible for conducting those operations, Beam Permits, Running Condition, Beam Delivery Authorization, and ORC Process. 	
3. Determine adequacy of understanding of SAD requirements, to support operations.	<ul style="list-style-type: none"> - Basis for decision. 	

2.2 Accelerator Safety Envelope (ASE)

Objective:

Determine if ASE has been approved by DOE. Determine if personnel operating under the ASE understand the physical and administrative accelerator bounding conditions and controls to ensure safe operations.

Criteria:

DOE O 420.2C requires that the ASE provides a documented set of verifiable physical and administrative requirements, bounding conditions, and credited controls that ensure safe operation and address accelerator specific hazards and risks, as defined in the safety analysis referenced in the Fermilab SAD.

Approach

Document Reviews: Review the approval documentation associated with the ASE. Review the ASE to assess whether staff adequately understand the ASE facility operational requirements.

Interviews and Performance Review: Interview selected staff/management involved in facility management and operations to assess knowledge of controls, operational requirements, and ASE operating limits.

Criterion 2.2: Accelerator Safety Envelope
Lines of Inquiry, Status and Evidence for Each Criterion

LOI	Status/Evidence	ARR Reviewer Notes
<p>1. Determine if the ASE has been approved by DOE.</p>	<p>- Determine if the <i>Fermi National Accelerator Laboratory SAD, Appendix A, Accelerator Safety Envelope, Revision 13, November 2, 2022</i>, as revised for the restart of the Neutrino Muon Beamline has been approved by DOE.</p> <p>Note: It is common at Fermilab for the ASE to be approved by the Fermilab Director, but awaiting approval by DOE at the time of the ARR. If this is the situation, the review team may comment on the adequacy of the Fermilab technical review process and its current state in the approval process.</p>	
<p>2. Assess management/staff understanding of the ASE requirements, including defined controls and operating limits.</p>	<p>- Interview management/staff who must operate under ASE requirements, Beam Permits, Running Condition, and Beam Delivery Authorization to assess their understanding of controls, operational requirements, and ASE operating limits.</p>	
<p>3. Determine adequacy of staff understanding to support operations consistent with ASE requirements and operating limits.</p>	<p>- Basis for decision.</p>	

2.3 Safety Configuration Management (SCM)

Objective: Verify that there is a configuration management program that is relevant and functioning for the Neutrino Muon Beamline. Verify that the configuration management of Credited Controls and supporting documented processes, procedures, and records are consistent with the requirements in the SAD and ASE.

Criteria:

Determine that there are documented configuration management processes applied to safety related administrative and engineered Credited Controls, the management of safety-related procedures and training, and management of records. Configuration management is applied on a graded approach to defense-in-depth controls.

Approach

Record Reviews: Review installation drawings, test procedures, interlock change request documents, interlock approval documents, and records for Credited Controls. Review records and procedures associated with the maintenance, operations, and function of Credited Controls.

Interviews: Interview Fermilab ESH Radiation Physics Science and Engineering Staff regarding the application of configuration management requirements for Credited Controls.

Performance Demonstrations: Observe the configuration of Credited Controls and compare to test procedures and system drawings.

Criterion 2.3: Safety Configuration Management
Lines of Inquiry, Status and Evidence for Each Criterion

LOI	Status/Evidence	ARR Reviewer Notes
1. Determine if the configuration(s) of Credited Controls are properly managed during accelerator operation and maintenance, consistent with the requirements established in the SAD and ASE.	<ul style="list-style-type: none"> - Interlock system access controls - Interlock Change Request - Interlock log book - Interlock System Bypass procedures - MCR Hot Item Book (Operations) - JULIE Permit System - FESHM 7030 Excavation restrictions near radiological areas. - Moveable Shielding Inventory - Accelerator Startup Documents - Beam Permit - Running Condition - Start-up Sign-off Document - Labeling of bulk shielding 	
2. Determine if the accelerator controls system is protected against un-authorized access.	<ul style="list-style-type: none"> - MCR and any local controls (Operations) - Procedures and practices 	
3. Determine if configuration management is applied to defense-in-depth controls.	<ul style="list-style-type: none"> - Draft Running Condition - Shift turnover 	
4. Considering past reviews, determine if the configuration management program is adequate to support operations.	<ul style="list-style-type: none"> - Basis for decision. 	

3.0 Accelerator Systems

3.1 Training and Qualification of Accelerator Operations Personnel

Objective:

Determine that Fermilab has implemented an effective training and qualification program, consistent with DOE O 420.2C requirements, for accelerator operations personnel, and ensure that these personnel are aware of their responsibilities.

Criteria:

DOE O 420.2C requires that accelerator and their operations establish clearly defined roles and responsibilities for accelerator activities, including those for training and procedures. The training program must provide:

- (1) training and qualification for all individuals who work in and around the accelerator facility to include site safety programs, site hazards, and emergency procedures;
- (2) specific training and qualification for operations, maintenance, support personnel, and experimenters to include job-specific procedures and controls; and
- (3) ongoing monitoring of personnel training program to assess overall effectiveness and support continuous improvement.

Approach:

Document Review: Review training and qualification documentation related to the Neutrino Muon Beamline. Review selected training procedures related to the accelerator operations. Review selected personnel training and qualification documentation to assess program effectiveness.

Interviews and Performance Review: Interview selected administrative and technical personnel regarding their experience with the training and qualification program. If possible, also interview selected personnel during training-specific job assignments to assess training effectiveness.

Criterion 3.1: Training and Qualification Program for Accelerator Operations Personnel
Lines of Inquiry, Status and Evidence for Each Criterion

LOI	Status/Evidence	ARR Reviewer Notes
1. Review training documentation and procedures relevant to the Neutrino Muon Beamline	<ul style="list-style-type: none"> - Review the Operators training program. (Operations) - Review training with respect to individual responsibilities regarding ASE and routine/emergency procedures. - Review procedure for turning the magnet on. 	
2. Interview and/or observe selected Fermilab personnel regarding training.	<ul style="list-style-type: none"> - Review training effectiveness for use of the Neutrino Muon Beamline. 	
3. Determine adequacy of training program to support operations.	<ul style="list-style-type: none"> - Basis for decision. 	

3.2 Accelerator Operations Procedures for the Neutrino Muon Beamline

Objective:

Determine that Fermilab has accelerator operational procedures consistent with DOE and contractor requirements. Determine that the Fermilab operational procedures address the accelerator operations with safety significance. Determine that Fermilab procedures are controlled, complete with processes for regular updates and revisions. Determine that procedural updates and revisions are effectively communicated consistent with the Fermilab configuration management program.

Criteria:

The operational procedures program for operations of safety significance should:

- (1) provide specific directions to ensure safe operations during routine, non-routine and emergency situations;
- (2) provide sufficient detail commensurate with the level of hazard and complexity of operation;
- (3) reflect available operational experience written in a format readily usable to MCR operator staff;
- (4) incorporate lessons learned from past operations in order to improve the procedure and identify potential need for other procedures; and
- (5) require procedures to be controlled documents with specific attention to those procedures that reflect ASE requirements.

Approach:

Document Review: Review Fermilab procedures documentation. Review selected operational procedures with safety significance.

Interviews and Performance Reviews: Interview Fermilab staff on the procedures program. Interview selected Fermilab management/staff on their use of specific procedures and the mechanisms to contribute to the program. If possible, attend selected operations/maintenance activities performed under specific operational procedures. Interview the operations/maintenance staff regarding their opportunity to modify, update or revise procedures.

Criterion 3.2: Accelerator Operations Procedures for the Neutrino Muon Beamline
Lines of Inquiry, Status and Evidence for Each Criterion

LOI	Status/Evidence	ARR Reviewer Notes
1. Review selected operating procedures controlling approval for startup, beam authorization, and safety significant controls for the restart of the Neutrino Muon Beamline	<ul style="list-style-type: none"> - Discuss use and adequacy of the specific procedure(s) as well as mechanisms to provide feedback on the procedure content, any updates, or procedure revisions. - Beam Permit, Running Conditions, and Accelerator Startup procedure. - Response to Excursions above the Accelerator Operating Limits. - Response to potential violations of the accelerator safety envelope procedure. - Search and Secure Procedures - F/KMAG LOTO Procedures 	
2. If applicable, review relationship between MCR and remote control rooms.	<ul style="list-style-type: none"> - Discuss with Neutrino Muon Beamline management the intended relationship between remote operators and the MCR. - Interview the MCR Operation Department and the Neutrino Muon Beamline control room personnel to ensure understanding of relationship and roles, responsibilities, accountabilities, and authorities (R2A2s). 	
3. Determine adequacy of procedure program to support operations.	<ul style="list-style-type: none"> - Basis for decision. 	

3.3 Work Planning and Controls Related to Accelerator Safety

Objective:

Determine that Fermilab has a work controls program consistent with both DOE and contractor requirements. Determine that Fermilab work controls are managed as part of a controlled system complete with processes for regular update and revision. Determine that work controls, updates and revisions are effectively communicated as part of the Fermilab configuration management program. The breadth of inquiries on this topic may be tailored by the ARR review team to the scope of the module being assessed in the ARR.

Criteria:

The Fermilab work control program should include:

- (1) Pre-approved work plans for proposed work particularly those systems with safety significance;
- (2) review of proposed work and management approval before starting work or the return of equipment to service;
- (3) work assignments only for qualified and authorized personnel;
- (4) management validation of work for completeness and functionality;
- (5) document control of the program, periodic updates and revisions as necessary; and
- (6) effective communication of information on controlled work scope.

Approach:

Document Review: Review the Fermilab work control program. Review selected work control procedures on those accelerator systems associated with engineered controls.

Interviews and Performance Review: Interview Fermilab staff with responsibility for the work control program. Interview selected operations and maintenance staff on their experience with the Fermilab work control program. If possible, attend operations/maintenance activities performed under specific work controls. Interview staff involved in the process to update or revise procedures. Assess process for communicating work status, completion and any modifications to work controls.

Criterion 3.3: Work Planning and Controls Program Related to Accelerator Safety
Lines of Inquiry, Status and Evidence for Each Criterion

LOI	Status/Evidence	ARR Reviewer Notes
1. Assess staff understanding related to roles in the work control program.	<ul style="list-style-type: none"> - Review procedures for review and approval of proposed experiments. - Review work control for approved procedures (i.e., target installation, running, uninstalling, storing equipment) 	
2. Observe selected job assignments with job-specific work controls applicable to this ARR.	<ul style="list-style-type: none"> - Assess use and adequacy of selected work controls and mechanisms to provide feedback, updates, or revisions. <p>Examples include ALARA Plans, Shutdown radiological dose projections, SRSO approval for high dose work activities.</p>	
3. Determine adequacy staff understanding of the work planning and control program to effectively support operations.	<ul style="list-style-type: none"> - Basis for decision 	

3.4 Credited Controls (CC)

Objective:

Verify that the Credited Controls identified in the Accelerator Safety Envelope (ASE), necessary for the respective operations phase or operations, are effectively in place (installed, operational, managed, etc.). Verify that the configuration of Credited Controls, their system interfaces, and the supporting processes, procedures, and records are managed consistent with the Accelerator Facility Safety Implementation Guide for DOE O 420.2C, Safety of Accelerator Facilities.

Criteria:

Credited Controls identified in the Accelerator Safety Envelope (ASE), necessary for the Neutrino Muon Beamline, are effectively in place (installed, operational, managed, etc.). The configuration of the Credited Controls and any related procedures, processes, training, records, etc. are managed. Configuration Management is applied to Credited Controls on a graded approach.

Approach:

Record Reviews: Review installation records, test procedures, operations records for Credited Controls where applicable. Review records and procedures associated with the maintenance, operations, and function of Credited Controls.

Interviews: Interview Fermilab ESH RPE Interlock Group, RSOs, and MCR operator staff regarding the installation, maintenance, and operation of configuration management of Credited Controls.

Performance Demonstrations: Physically observe Credited Controls installed in the workplace. Where possible, observe the function/actuation (or the result of actuation) of Credited Controls.

Criteria 3.4: Credited Controls (CC)
Lines of Inquiry, Status/Evidence and ARR Notes

LOI	Status/Evidence	ARR Reviewer Notes
1. Verify that Credited Passive, Active, and Administrative Controls in the ASE are installed and operational.	<ul style="list-style-type: none"> - Observation of Credited Controls installed for the Neutrino Muon Beamline. - Observation of function/actuation of selected Credited Controls - Review Interlock System test records as applicable. 	
2. Verify that Credited Passive, Active, and Administrative Controls in the ASE are properly managed.	<ul style="list-style-type: none"> - Discuss how off-normal conditions are managed - Review Interlock System test records - Discuss operations interaction with the RSO and Interlock Group 	
3. Verify that defense-in-depth controls also have Configuration Management applied.	<ul style="list-style-type: none"> - Review Running Conditions to identify safety significant systems. 	
4. Determine adequacy of Credited Controls to support operations.	<ul style="list-style-type: none"> - Basis for decision. 	

3.5 Radiological Protection for the Neutrino Muon Beamline

Objective:

Determine that the Fermilab Radiological Protection Program has adequately evaluated and addressed the impact of accelerator operations with the restart of the Neutrino Muon Beamline.

Criteria:

The Fermilab Radiological Protection Program has:

- (1) Evaluated the necessary shielding for the facility modifications;
- (2) Evaluated operational and environmental impact associated with the restart;
- (3) Identified and incorporated or facilitated the necessary changes in structures, infrastructure, processes, and procedures for the restart;
- (4) Identified and planned necessary tests, measurements, and activities to verify calculated and modeled radiation shielding and installed shielding effectiveness; and
- (5) Worked with AD/Operations and the experiment to effectively integrate shielding studies.

Approach:

Document Review: Review Fermilab documents that serve as the evaluation and technical basis for the Neutrino Muon Beamline operations. Review procedures and processes that address these operations.

Interviews: Interview the Shielding Assessment Review Panel Chair and selected staff regarding evaluation of operational and environmental impact for the facility modifications. Interview selected accelerator operations management/staff on their interface with Radiation Safety personnel, with emphasis on effective communication of changes associated with the facility modifications.

Performance Demonstrations: Participate in tabletop discussions with radiation safety and MCR Operator staff to review changes to radiological protection practices associated with the restart. Conduct selected facility/building walk-throughs and observe implementation of shielding assessment generated changes to the facilities.

Criteria 3.5: Radiological Protection for the Neutrino Muon Beamline
Lines of Inquiry, Status/Evidence and ARR Notes

LOI	Status/Evidence	ARR Reviewer Notes
1. Determine if relevant radiation shielding assessments have been fully reviewed and assessed.	<ul style="list-style-type: none"> - Fermilab SAD, ASE - Technical basis for shielding design - Applicable Shielding Assessment 	
2. Determine if the operational and environmental impacts associated with the facility have been evaluated.	<ul style="list-style-type: none"> - Applicable Shielding Assessment 	
3. Determine if the restart and program changes have been effectively communicated and implemented.	<ul style="list-style-type: none"> - Beam permits - Running conditions - Interviews of MCR Operators 	
4. Determine if there is a plan to test assumptions regarding the effectiveness of the shielding.	<ul style="list-style-type: none"> - Interviews with assigned RSO and MCR Operators. - Shielding verification plans. 	
5. Determine adequacy of the radiation protection program to support operations.	<ul style="list-style-type: none"> - Basis for decision. 	