8 GeV Line

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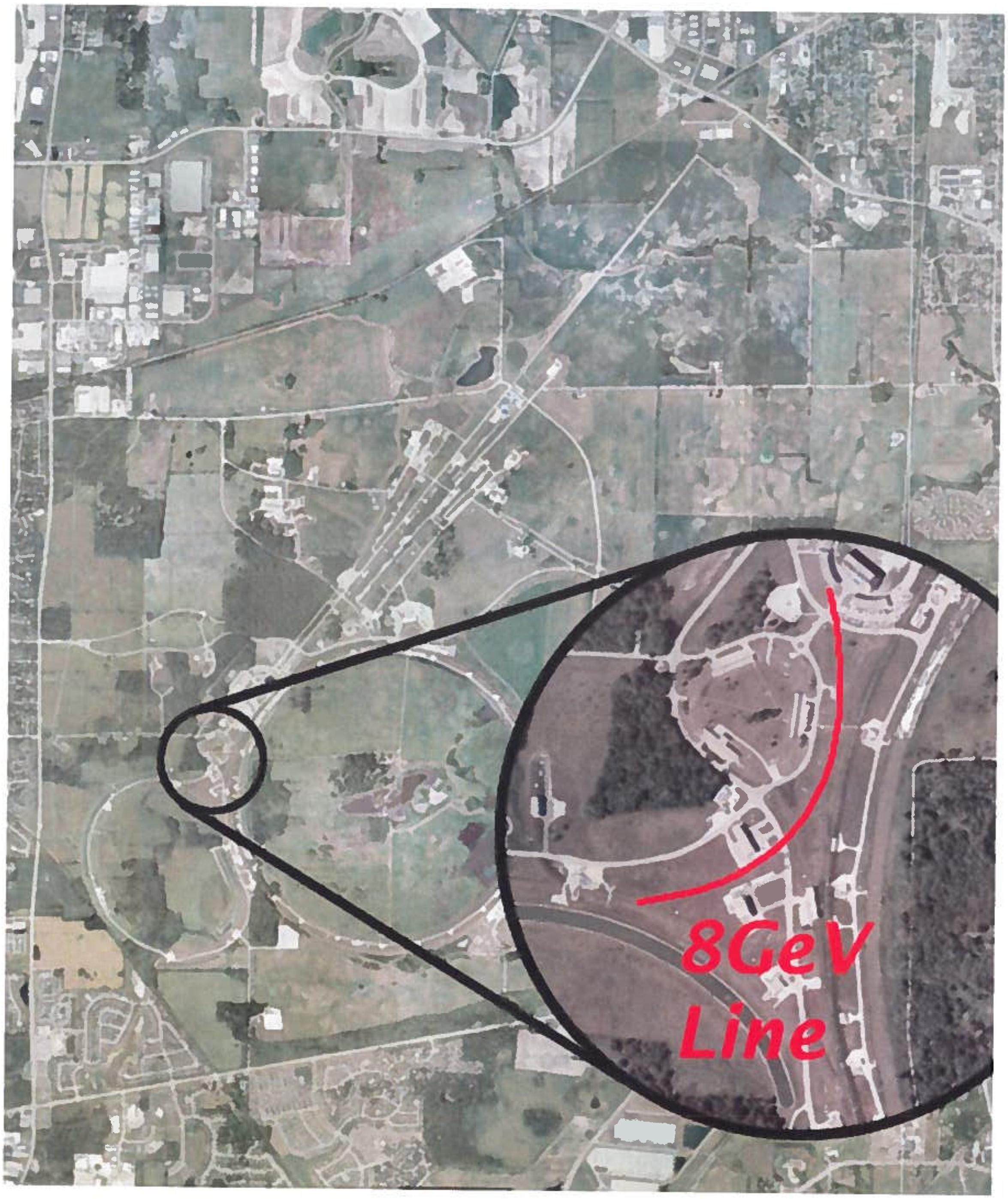
II - 4.1 8 GeV Line Area Location on Fermilab Site



II - 4.2 Inventory of Hazards

The following table lists the identified hazards found in the 8 GeV Line enclosure and support building. All hazards with an * have been adequately discussed in Chapters 1-10 of the Fermilab Safety Assessment Document and are not covered further in this section.

Radiation Particle beams and prompt radiation Residual component activation Ground water activation Surface water activation Radioactive waste	**Kinetic Energy** Power tools * Pumps and motors *
Toxic Materials	**Potential Energy** Crane operations * Compressed gases * Vacuum / pressure vessels * Vacuum pumps *
Flammable & Combustible Materials Cables *	**Magnetic Fields** Fringe fields *
Electrical Energy Stored energy exposure * High voltage exposure * Low voltage, high current exposure *	**Gaseous Hazards** Confined spaces *
Thermal Energy	**Access / Egress** Life Safety Egress *

II - 4.3 Introduction

This Section II, Chapter 4 of the Fermi National Accelerator Laboratory (Fermilab) Safety Assessment Document (SAD) covers the 8 GeV Beamline enclosure located southwest of the Booster accelerator.

II - 4.3.1 Purpose of the 8 GeV Line

The purpose of the 8 GeV Line is to transport 8 GeV protons extracted from the Booster accelerator for injection into either the Main Injector (MI) Ring or for use within the Booster Neutrino experimental area.

II - 4.3.2 Description of the 8 GeV Line

The 8 GeV Line is located southwest of the Booster accelerator. The enclosure is constructed of concrete approximately 8 feet high and 10 feet wide covered by at least 24.5 feet of earth. The beamline extends from the extraction stub of the Booster accelerator at location 803 to the injection area of the Main Injector location 850. The beamline path is somewhat convoluted for two reasons (see figure 1). Vertically, the Main Injector is about 11 feet below the level of the Booster accelerator ring. Horizontally, the line must avoid the Antiproton Source and pass under the Transport Enclosure.

The 8 GeV Line, also called the MI8 line, is constructed primarily with permanent magnets. This was done as a proof of concept for building permanent magnet fixed energy beamlines. Large powered magnets are used at the beginning and end of the line with dipole corrector magnets used throughout the line.

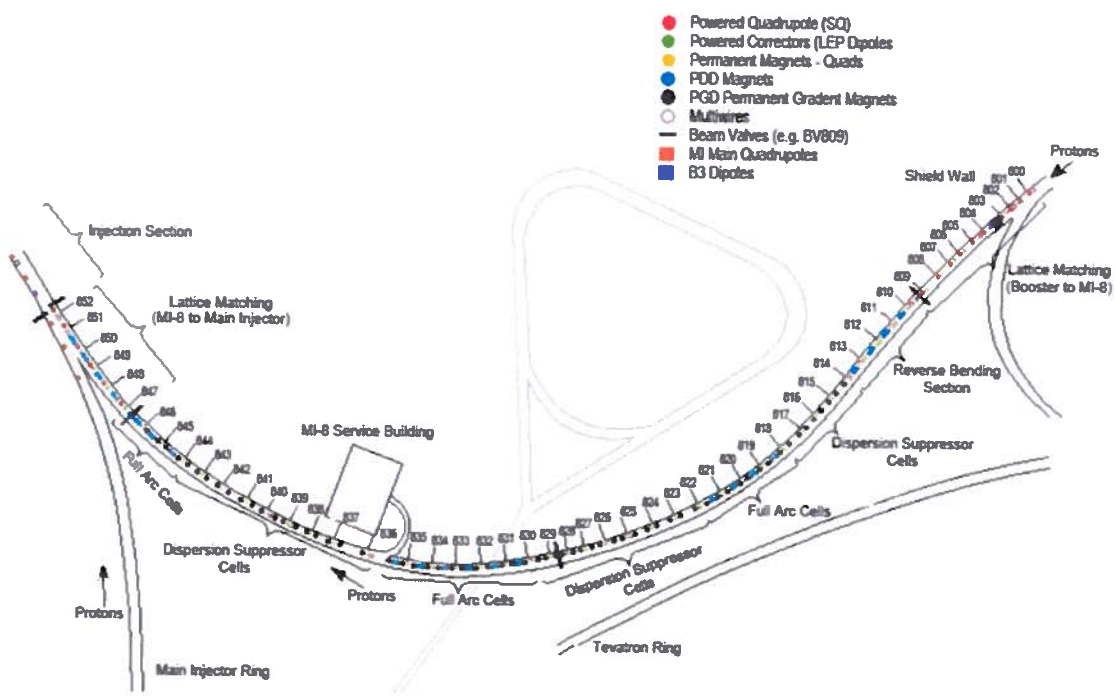


Figure 1 - 8 GeV Line Plan View

II - 4.3.3 Operating Modes

The 8 GeV Beamline is capable of receiving 8 GeV protons from the Booster extraction line at an operating intensity of ~5.3×10^{12} protons/pulse at a 15 Hz repetition rate. The beamline shielding assessment and post-assessment documents[1] demonstrate that the facility can be safely operated at intensities up to 2.84 x 10^{17} protons/hour.

Beam extraction from the Booster is accomplished via an upward kick to the beam from four kicker magnets, MKS05, MKS06, MKS07, and MKS08 in the Long 2 straight section (see figure 2). The extracted beam passes over the septum plate of MP02 at Long 3 and leaves at a tangent to the Booster ring horizontally at a slight upward angle. The Vertical Bend Center 1 magnet VBC1 removes the vertical kick provided by the septa. The beam continues to V803, the beginning of the 8 GeV Line, on its way to either the Booster Beam Absorber or toward the Main Injector and Booster Neutrino areas. The final beam destination, Booster absorber or 8 GeV Line, is determined by the selected Booster accelerator operating mode. Booster accelerator operating modes are discussed in the Booster chapter of this document.

The 8 GeV beamline transports the beam to location 850, the end of the 8 GeV Line, where the beam is either extracted to the Booster Neutrino area or injected into the Main Injector. Details of the Main Injector injection are discussed in the Main Injector chapter of this document and the details of Booster Neutrino area extraction are discussed in the Booster Neutrino area chapter of this document.

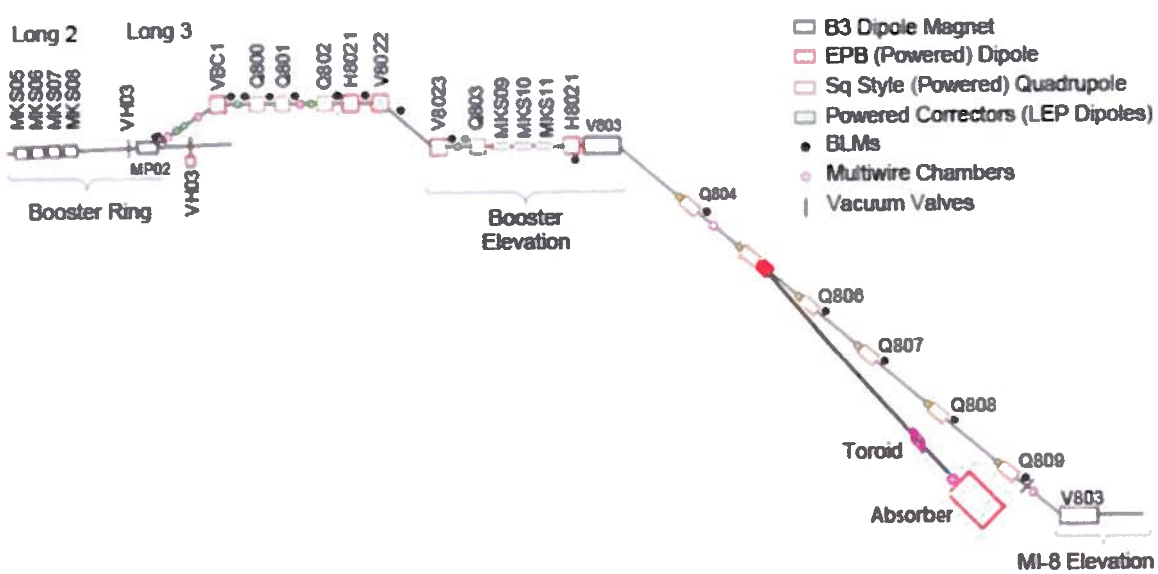


Figure 2 – Vertical Profile of the Upstream 8 GeV Line

II - 4.4 Safety Assessment

The unique accelerator specific hazards of the 8 GeV Line are analyzed in this section.

II - 4.4.1 Radiological Hazards

Radiation safety has been carefully considered in the design of the 8 GeV Line. The beamline presents radiation hazards in the form of prompt and residual ionizing radiation from particle beams, residual radiation due to activation of beamline components, and environmental radioactivity in the form of soil and potential groundwater activation resulting from operating the beam transport system.

II - 4.4.1.1 Ionizing Radiation

Prompt ionizing radiation is generated from the particle beam interaction with the materials surrounding the beam, such as the beam pipes, beamline elements, and beamline instrumentation. The interlocked 8 GeV Line enclosure is designed and constructed to provide an exclusion area around the operating beamline elements. This exclusion area limits personnel exposure to prompt ionizing radiation from beam losses to the requirements established in the Fermilab Radiological Control Manual[2] (FRCM).

The shielding provided by the enclosure and earthen overburden has been specifically and quantitatively analyzed for both normal and accidental loss conditions and documented in the 8 GeV Fixed Target Shielding Assessment and post assessment documents[1]. These documents demonstrate that that facility can safely operate within the guidelines of the FRCM at a beam energy of 8 GeV and intensities up to 2.84 x 10^{17} protons per hour.

II - 4.4.1.2 Residual Activation

Losses along the 8 GeV Beamline will result in activation of intercepting beam instrumentation devices and other beam line components. The activation level and quantity of activated material will not be unique relative to other accelerators at Fermilab. There are no beam absorbers that are part of the 8 GeV Beamline.

Residual activation hazards will be managed within the As Low As Reasonably Achievable (ALARA) program established throughout the Fermilab accelerator complex and as prescribed in the FRCM. All potential residual activation hazards are handled operationally as in all other primary beam enclosures. These controls include verification of training, centralized authorization, and key entry. The level of control depends on the level of residual radiation. In most cases, the typical Radiation Work Permit (RWP) for accesses will suffice. A job-specific RWP and an ALARA plan will be required for work on any highly activated equipment.

II - 4.4.1.3 Radioactive Waste

Radioactive waste hazards and disposal will be managed within the program established throughout the Fermilab accelerator complex and as prescribed in the FRCM. Waste minimization is an objective of both the 8 GeV design and operational procedures. Although production of radioactive material is not an operational function of the 8 GeV Line, accidental beam loss and, in the case of some beam diagnostics devices, intentional interception of the beam will result in activation of beam line elements. Activated items that cannot be reused will be disposed eventually as radioactive waste in accordance with the FRCM requirements.

II - 4.4.1.4 Ground Water and Surface Water Activation

Radioactivity induced by the interaction of high-energy particles with the soil that surrounds the beamline is addressed in this section. The production of tritium and sodium 22 is the greatest concern due to production rate and leachability into the groundwater as well as the long half-lives of the radionuclides.

As discussed in the 8 GeV Fixed Target Shielding Assessment, a conservative assumed beam loss rate of 2% over the entire length of the beamline was used to estimate the ground water and surface water tritium activation. The results show that for a yearly beam intensity of 1.18×10^{21} protons, after 10 years of operation, the ground water tritium concentration would be less than 3.7×10^{-10} pCi/ml. This is well below the regulatory limit[3] of 20 pCi/ml. The maximum expected surface water tritium concentration using the same assumed 2% beam loss for a thirty-day period of time is 317 pCi/ml. This is sufficiently below the 1900 pCi/ml Derived Concentration Standard (DCS) set forth in DOE Order 458.1. The sump discharge locations along the 8 GeV beamline are routinely sampled as part of the Accelerator Division (AD) Routine Monitoring Program ADDP-SH-1003.

II - 4.5 Credited Controls

II - 4.5.1 Passive Controls

Passive controls are elements that are part of the physical design of the facility that require no action to function properly. These are fixed elements of the beamline that take direct human intervention to remove. The 8 GeV Line enclosure is a passive control designed and constructed as a permanent concrete and earth-covered radiation shield to protect personnel from radiological exposure during beam operations. Other passive controls within this design are discussed.

II - 4.5.1.1 Permanent Shielding Including Labyrinths

The permanent shielding encompasses the structural elements surrounding the beamline components. The concrete structure is contiguous with the Booster and Main Injector enclosures. It includes three personnel exit labyrinths, one major equipment and personnel access labyrinth at the MI-8 Service Building, utility penetrations, and earthen berms and overburden.

The permanent shielding for the enclosure is documented in the 8 GeV Fixed Target Shielding Assessment and post assessment documents. It consists of sufficient earth overburden such that unacceptable levels of prompt radiation cannot occur under the assessed beam conditions.

II - 4.5.1.2 Penetration Shielding

The beamline has several utility penetrations routing between the exclusion areas and occupied areas which were analyzed for required shielding. These penetrations were designed to eliminate the need for additional penetration shielding. In summary, the prompt dose rates at the exits of the penetrations are within the limits established in the FRCM.

II - 4.5.2 Active Controls

Active engineered controls are systems designed to reduce the risks from accelerator operations to an acceptable level. These are automatic systems that limit operations, shutdown operations, or provide warning alarms when operating parameters are exceeded. The active controls in place for the 8 GeV beamline operations are discussed below.

II - 4.5.2.1 Radiation Safety Interlock System

The 8 GeV Line enclosure is part of the Booster Accelerator Radiation Safety Interlock System. The characteristics of the system are described in Chapter I of the Fermilab SAD.

There are interlocked gates at each end of the enclosure, three interlocked exit labyrinths, and an interlocked gate at the MI-8 Service Building access labyrinth. The interlock system inhibits transport of beam beyond the Linac extraction point to Booster except when the 8 GeV Line enclosure is properly secured and locked.

The radiation safety interlock system inhibits beam by controlling redundant critical devices. In this case, the B:LAM power supply feeds the extraction lambertson string and the

B:MH1 horizontal down bend power supply located at the end of the Linac enclosure. In the event of a critical device failure, the system has a failure mode function that will reach back and inhibit beam to the Linac, and thus eliminate the possibility of beam reaching the 8 GeV Line enclosure.

Trained and qualified personnel from the AD Operations Department are required to search and secure the enclosure before permits from the radiation safety interlock system may be reestablished following any personnel access to the enclosure, except under strictly specified controlled access conditions. The radiation safety interlock systems including requirements for hardware and system testing, inventory of interlock keys, search and secure procedures for the beamline enclosure, controlled access procedures, personnel training requirements, and procedures for maintenance of interlock systems, are in conformance with the requirements stated in the FRCM.

II - 4.5.3 Administrative Controls

All 8 GeV beamline operations with the potential to affect the safety of employees, researchers, or the public, or to adversely affect the environment, are performed using approved laboratory, division, or department procedures. These procedures are the administrative controls that encompass the human interactions that define safe accelerator operations. The administrative procedures and programs considered necessary to ensure safe accelerator operations are discussed below.

II - 4.5.3.1 Summary of Beam Operating and Safety Envelope Parameters

The 8 GeV beamline is assessed for a pulsed proton beam with a maximum kinetic energy of 8 GeV, with a beam intensity of 5.3×10^{12} protons per pulse, and a maximum spill rate of 15 Hz, which equates to an hourly intensity rate of 2.84×10^{17} protons/hour. The beamline is assessed for continuous operations at this intensity.

Accelerator operational approvals shall be obtained by following the AD Procedure ADAP-11-0001 Beam Permits, Run Conditions, and Startup administered by the AD ES&H Department and AD Head. Beam Permit and Run Condition documents shall identify the beam power and operating parameters allowed for the 8 GeV Line within the current Accelerator Safety Envelope. The Beam Permit specifies beam power limits as determined and approved by the AD Head in consultation with the AD ES&H Department Head, AD RSO, AD Operations Department Head, and AD MI Department Head. The Run Condition for the 8 GeV Line describes the operating configuration as reviewed by the AD RSO, AD Operations Department Head, and as approved by the AD Head.

II - 4.5.3.2 Beamline Operations

Commissioning, normal operations, and emergency management of the 8 GeV Line are all conducted under the auspices of the AD Headquarters, the AD ES&H Department, and the AD Operations Department in accordance with the Fermilab SAD.

II - 4.6 Summary & Conclusion

Specific hazards associated with operation of the 8 GeV beamline enclosures are identified and assessed in this chapter of the Fermilab Safety Assessment Document. The designs, controls, and procedures to mitigate 8 GeV beamline specific hazards are identified and described. In addition to these specific safety considerations, the 8 GeV beamline is subject to the global and more generic safety requirements, controls and procedures outlined in Section 1 of this Fermilab Safety Assessment Document.

The preceding discussion of the hazards presented with the 8 GeV beamline operations and the credited controls established to mitigate those hazards demonstrate that the beamline can be operated in a manner that will produce minimal hazards to the health and safety of Fermilab workers, visiting scientists, and the public, as well as to the environment.

II - 4.7 Glossary, Acronyms

AD	Fermilab Accelerator Division
ALARA	As Low As Reasonably Achievable
ES&H	Environment, Safety and Health
FRCM	Fermilab Radiological Control Manual
GeV	Gigaelectronvolt
RSO	Radiation Safety Officer
RWP	Radiation Work Permit
SAD	Safety Assessment Document

II - 4.8 References

[1] 8 GeV Fixed Target Shielding Assessment, C. Moore, page 1, April 19, 2002. MiniBooNE-Era Doses for MI8 Labyrinths & Penetrations, B. Higgins, June 3, 2002. Safety Envelope for 8 GeV Line and MiniBooNE Operation, Michael A. Gerardi, December 4, 2009. 8GeV Line and MiniBooNE Nova-Era Operational Limits, Michael A. Gerardi, December 4, 2009.

[2] Fermilab Radiological Control Manual. - The current web link is: http://www-esh.fnal.gov/home/esh_home_page.page?this_page=900

[3] ^{3}H value taken from USEPA regulations 40 CFR 141 where a specific limit is stated for this nuclide for drinking water supplies. All other value are 4% of the DOE-STD-1196-2011 to obtain a dose 4 mrem y^{-1} to the user of such water.