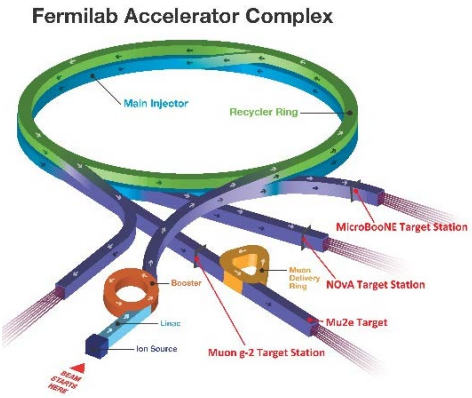
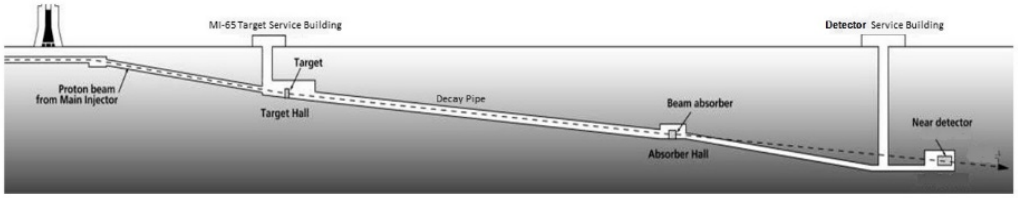
Development of Target Systems at MI-8

MI-8 is the main building at Fermilab for constructing and testing target system devices for the lab's neutrino and muon experiments, including NOvA, MicroBooNE, ICARUS, SBND, MINERvA, Muon g-2, and Mu2e. It houses machines to build and test the targets and focusing horns, including advanced tools like a CNC circumferential TIG welder, horn test stand and 3D printers. For more information visit targets.fnal.gov. Guided tours for groups of 10 or more can be arranged through the Fermilab Education Office, 630-840-5588.

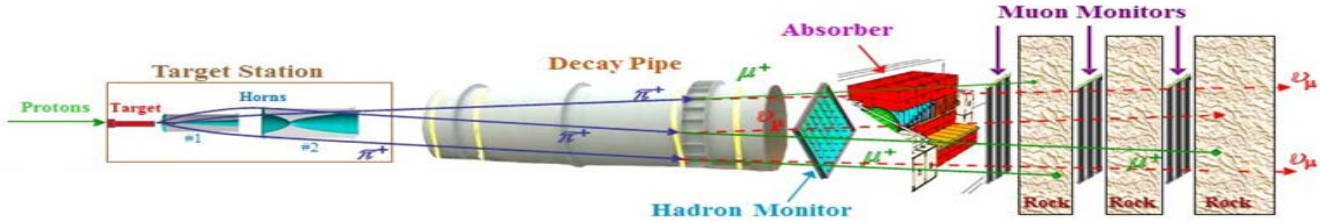


NuMI Facility

The Neutrinos at the Main Injector (NuMI) Facility uses a beam of protons to produce an intense, high-energy flux of neutrinos for experiments to detect and study neutrino oscillations.

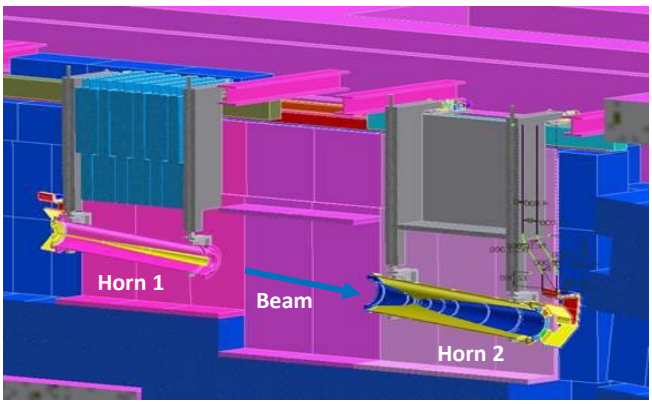


- The protons are steered into a solid carbon target to produce mesons – predominantly pions – through hadronic interactions.
- The pions are then focused by pulsed toroidal magnets called focusing horns into the decay pipe. The horns enable the selection of pions with certain energy and momentum selection.
- The pions decay into muons and muon neutrinos in the helium-filled decay pipe.
- The neutrinos travel through rock and other matter, and propagate in straight lines to the particle detectors of various experiments.
- The Hadron Monitor measures the spatial distribution of the non-interacting protons and undecayed pions, after which they are stopped in the massive Hadron Absorber made of steel, concrete and aluminum.
- The muons penetrate the absorber and continue into unexcavated rock, where they slow down and stop. The spatial distribution of muons are measured by the Muon Monitor stations and provide information on the properties of the neutrino beam.

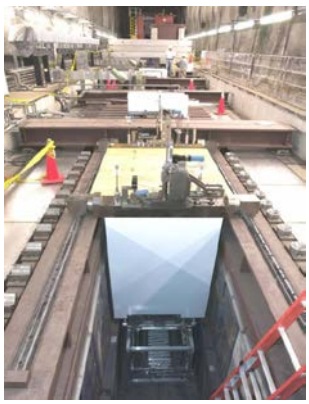


Transport of assembled target components from MI-8 to the NuMI target hall

NuMI horn 2



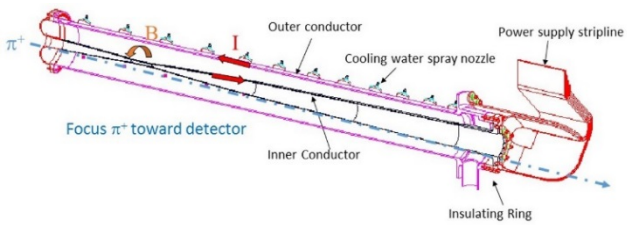
CAD rendering of two horns in the NuMI target chase



NuMI target hall before top shielding is installed

NuMI horns

The current in the horns runs from the outer to the inner conductor to form a loop, which generates a toroidal magnetic field in the volume between the conductors. The positively charged pions that enter this volume are focused and then decay to produce neutrinos.



Test stand for horns

This test stand provides electrical current pulse and cooling for horn QA verification of fabrication and assembly through a test period of 100,000 pulses and subsequent magnetic field mapping. (200 kA peak current with pulse width of 850 μsec, typical test cycle times of 1.33 and 1.89 sec)

Engineering challenges for horns

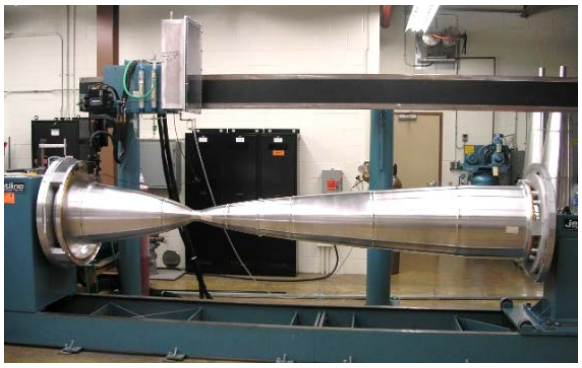
- Withstand repetitive thermal and magnetic load cycles over millions of pulses. The heat comes from electrical resistive heating and beam heating due to secondary particle interactions in the material.
- Maximize the number of neutrinos. The thickness of the inner conductor is minimized in order to reduce the absorption and scattering of secondary particles in the conductor material.
- Survive in radiation and corrosive environment. Radiation in humid air creates nitric acid and Ozone, which accelerate the corrosion on materials.
- Precision alignment to provide a high quality of field symmetry, mechanical stability in vibration
- Horn will eventually become radioactive after being in service; it will require remote handling in the event of a replacement or repair.

CNC circumferential TIG welding

The horn's aluminum inner conductor is 3 m long. It comprises several segments that are welded together with the in-house CNC (Computer Numerical Control) circumferential TIG (Tungsten Inert Gas) welding system.

Welding requirements

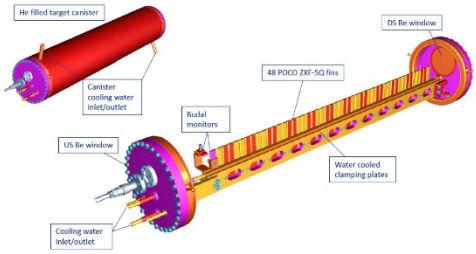
Strict straightness, in order to maintain high quality of field symmetry that the horn needs to provide; minimal internal porosity in the welds, to maintain material strength; single pass but full penetration, to minimize distortion.



Targets and remote handling system

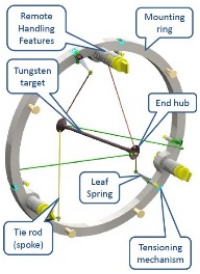
NOvA target

Produces secondary pions through proton beam interactions with graphite target fins. The airtight casing has beryllium windows for the proton beam entrance and exit. It is designed to operate at 700 kW incident proton beam power, 1.33 sec cycle time, 4.9E13 protons per pulse, to produce neutrino spectrum peak at about 2.5 GeV.



Mu2e target remote handling system

The Mu2e pion production target is mounted from a low-mass support structure with spring-loaded clamps and handling lugs that form part of the remote handling system. The remote handling system incorporates a cask, a disposable interface tooling, contamination containment box that the target is pulled back into, a long arm to reach out 13' to target, arm end de-coupling system, kinematic mounts, and X-Y-Z servo positioning axes plus pneumatic motions.



Remote handling interface tooling

3D printers

3D printing produces parts used in target systems. Materials used include clay, Plasticine, Sugru, Silicone RTV, porcelain, ABS, PLA, Nylon, NinjaFlex, and FilaFlex.

Mini robot

Micro camera