Fermilab
Beams-doc-2392
August 15, 2006
Version 1.0

Target and Horn Configuration for SNuMI, NOvA, and MINERvA

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Updates

This is the first version of this note. Notably missing is the requirements for the MINERvA experiment.

Introduction

This note is meant to document the plans for the target and horn configurations for the NuMI beamline during operations for MINERvA and NOvA.

MINOS design configuration

The present operations (August 2006) for MINOS uses the low energy target as described in chapter 4 of the NuMI Technical Design Handbook[1] and in several notes from IHEP.[2,3] The target material is graphite, type ZXF-5Q (POCO Graphite), with a density of 1.78 g/cm^3. The main target consists of 47 vertical target segments, each 20.0 mm long with 0.3 mm of spacing between the segments giving a total length of 95.38 cm. Figure 1 shows a picture of the target and the target canister. The segments are 6.4 mm wide. Vertically the segments are between 15 mm and 18 mm tall and sculpted at the top and bottom to fit snuggly against a water cooling pipe on both the top and bottom. A cross section of the target segment is shown in Figure 2.

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[1] " NuMI Technical Design Handbook", http://www-numi.fnal.gov/numwork/tdh/tdh_index.html

[2] NuMI note NuMI-B-675, "Dynamic Stress Calculations for ME and LE Targets and Results of Prototyping for the LE target", A. Abramov, et. al., IHEP report dated August 10, 2000. In this note the width of the target segments is 3.2 mm. The target as built had 6.4 mm wide target segments.

[3] "Temperature and Stresses in the LE Target with 6.4 mm Wide Segments", IHEP report dated June 20, 2001.

In the low energy (LE) configuration design for MINOS operations the target material is located 35 cm upstream of the start of the idealized horn 1 and extends 60.38 cm into the horn[4]. Both horns are pulsed at 200 kA and the upstream ends of horn 1 and horn 2 are located 10 meters apart.

MINOS can also collect data in a pseudo medium energy (pME) or a pseudo high energy (pHE) configuration by remotely moving the target. In the pME case the target is moved upstream by 100 cm from the LE location and in the pHE case the target is moved upstream by 250 cm from the LE location. In these configurations the horns are located in the same place and pulsed at the same 200 kA current. By moving the target to one of these three positions the energy spectrum of neutrinos is changed to emphasize different ranges of energy.

The nominal beam spot size on the target is a round beam with a Gaussian distribution and an rms width of 1 mm in both the horizontal and vertical planes.

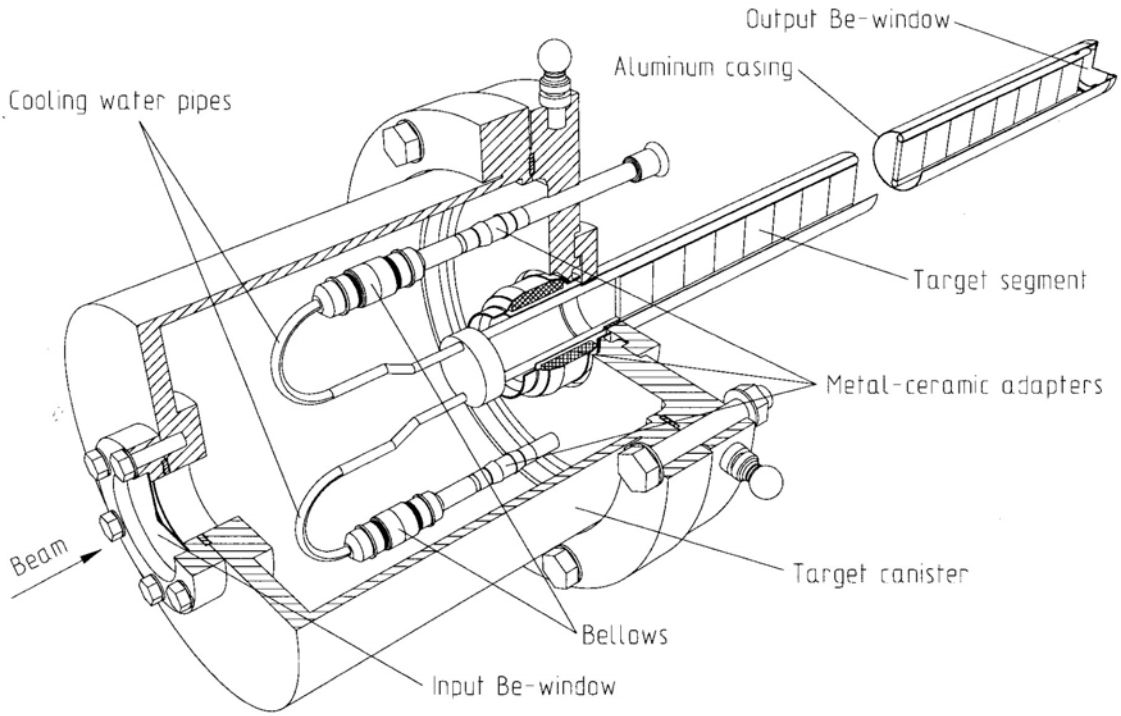

Figure 1 The low energy target and target vacuum canister.

[4] See drawing ME-363028 Rev. D for layout of the low energy target and horn. The point marked "MCZERO" is the start of the 3 m long idealized horn used of Monte Carlo Simulations.

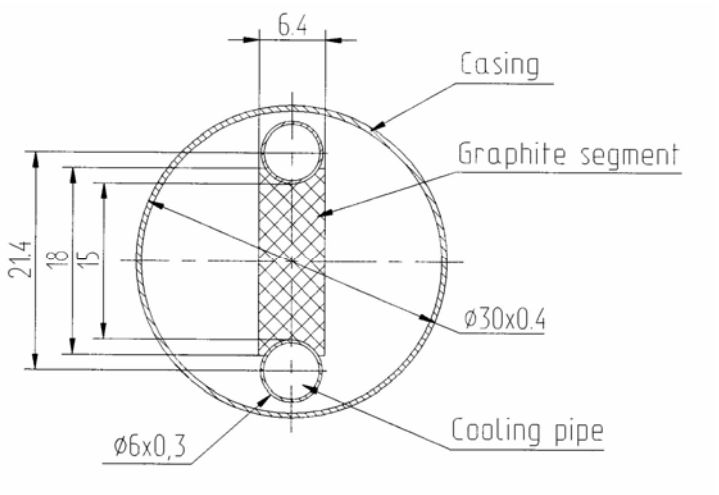

Figure 2 Cross section of the low energy target. The dimensions are in mm.

In practice, MINOS has been running slightly differently than the scenarios described above.

MINOS operating configuration

As NuMI operations began the possibility of generating a ground fault became a concern if the target shell made contact with the inner conductor of horn 1. To be conservative the low energy configuration was changed by moving the target 10 cm further upstream from the original design. To compensate for the position change of the target the current in horn 1 was reduced from 200 kA to 185 kA. Thus the low energy configuration used for MINOS (referred to as the LE-10 configuration) has the target starting at 45 cm upstream of the idealized start of horn 1 and the target extends 50.38 cm into the horn.

The MINOS experiment has also taken data in the pME configuration with the target moved 90 cm upstream from the LE-10 position and has taken data in the pHE configuration in which the target is moved 240 cm upstream from the LE-10 position.[5]

In present operations NuMI has delivered up to 3E13 protons per pulse. The beam spot size is roughly a round Gaussian with rms widths of 1 mm, but this varies somewhat from day to day. Typically the target profile monitor upstream of the target measures rms widths of the beam in the 0.9 mm to 1.2 mm range depending on the beam intensity and performance of the upstream machines.[6]

[5] In the PRL letter submitted by MINOS the refer to a "nominal", "target a 90 cm from nominal", and a "target 240 cm from nominal" as the configurations corresponding to LE-10, pME, and pHE.

[6] From a conversation with Peter Lucas.

In future MINOS operations the intensity of protons on target is expected to increase to as much as 5.5E13 per pulse with the implementation of slip stacking in the Main Injector. At these intensities the mechanical stresses and temperatures in the target become more of a concern. IHEP has begun to evaluate the integrity of the low energy target at these higher intensity operations[7]. IHEP will perform calculations of stress and temperature in the low energy target as a function of beam spot size from 1.0 to 1.5 mm rms for up to 5.5E13 protons per pulse every 2.2 seconds. This corresponds to a primary beam power of 480 kW. If the IHEP calculations indicate a problem with higher intensities and the smaller beam spot size then it would be necessary to increase the beam spot size on target. The larger beam size would reduce the mechanical stresses in the target but would also result in a reduction of the neutrino flux per proton.

NOvA design configuration

The target and horn configuration for NOvA is not completely specified and may change as the NuMI upgrade is optimized. However, the intent is to run in the medium energy (ME) configuration using the medium energy target design. The design of horn 1 and horn 2 will remain essentially the same but might be mechanically modified to handle the higher heat loads. In the ME configuration horn 1 remains in its present LE location while horn 2 is relocated 13 meters further upstream. This means that horn 1 and horn 2 upstream ends are 23 meters apart.[8,9] Both of the horns will be pulsed at 200 kA.

The target for NOvA is nominally the medium energy target designed by IHEP.[10,11] This is the fin design with 12 graphite plates 3.2 mm thick and 100 mm wide. Each graphite plate is cut into four 22 mm long and 30 cm high segments (or teeth). Thus the total length of the target is 120 cm. A view of the ME target is shown in Figure 3. Note that the can for the medium energy target is wider than the inner conductor of horn 1 and therefore operations in the low energy mode are precluded with the ME target. The expected beam spot size is not known accurately at this time since it will depend somewhat on the performance of slip stacking in the Recycler Ring. Tentatively we plan

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[7] Task A of IHEP Accord of June 2006. (Report is expected in September of 2005.)

[8] This spacing of the horns comes from NuMI note NuMI-B-1002, IHEP report, "Optimization Studies of Beam Optics for the Low Energy Neutrino Production", September 10, 2001. This is the same spacing used in the beam sheets in the NuMI Technical Design Report.

[9] This is the same spacing used in the beam sheets of the NuMI Technical Design Report.

[10] The medium energy target is documented in NuMI-B-675, IHEP report, "Dynamic Stress Calculations for ME and LE Targets and Results of Prototyping for the LE Target." August 10, 2000.

[11] See drawing 7538-00-00-00.dwg for the ME target. (/afs/fnal.gov/files/home/room2/garkusha/ME_target). In this drawing there are 14 graphite plates and the drawing has not been updated to reflect the change to 12 graphite plates. In this drawing there is also a special graphite plate at the downstream end for vertical alignment. The drawing has not been updated with this piece removed.

for a round Gaussian beam with 1 mm rms width in both planes but the spot size may become larger if it is necessary to reduce the stress in the target. In the ME configuration the target material begins 135 cm upstream of the start of the idealized horn 1 and extends to 15 cm upstream of horn 1. When the end effects of horn 1 and the ME target can are considered there is only about 2.8 cm of mechanical clearance between the horn and the target.[12]

The longitudinal position of the ME target will remain fixed and will not be remotely moveable. Remote motion capability in the transverse plane will still be provided in order to perform target scans and horn scans. The design of the carrier and motion apparatus must allow enough travel to completely remove the target and target can from the path of the beam in order to perform horn scans.

With the primary beam power reaching up to 1.2 MW the mechanical stresses and temperatures in the target become more of a concern. As a result it is likely that the target width will be increased from 3.2 mm to 6.4 mm. IHEP has begun to evaluate the integrity of the ME target at these higher intensity operations with the wider target[13]. IHEP will perform calculations of stress and temperature in the ME target as a function of beam spot size from 1.0 to 1.5 mm rms for up to 5.5E13 protons per pulse every 1.3 seconds. This corresponds to a primary beam power of 780 kW. If the IHEP calculations indicate a problem with higher intensities and the smaller beam spot size then it would be necessary to increase the beam spot size on target. The larger beam size would reduce the mechanical stresses in the target but would also result in a reduction of the neutrino flux per proton. (The same calculation will also be done for 9E13 protons on target.)

The basic plan for the NOvA experiment is to run in the medium energy configuration with a fixed location for the medium energy target. However, MINERvA will also be taking data about the same time that the NuMI upgrade is complete. At this time the needs of MINERvA have not been included in the conceptual design of the NuMI upgrades. Most likely MINERvA will run for some time using the low energy target before the NOvA detector has been completed. MINERvA may also want to run in a "high energy" configuration as well.

[12] Horn 1 extends 3.2 cm beyond MCZERO and the target can extends about 9 cm beyond the target material.

[13] Tasks B and C of the IHEP Accord of June 2006. (Report is expected in November of 2005.)

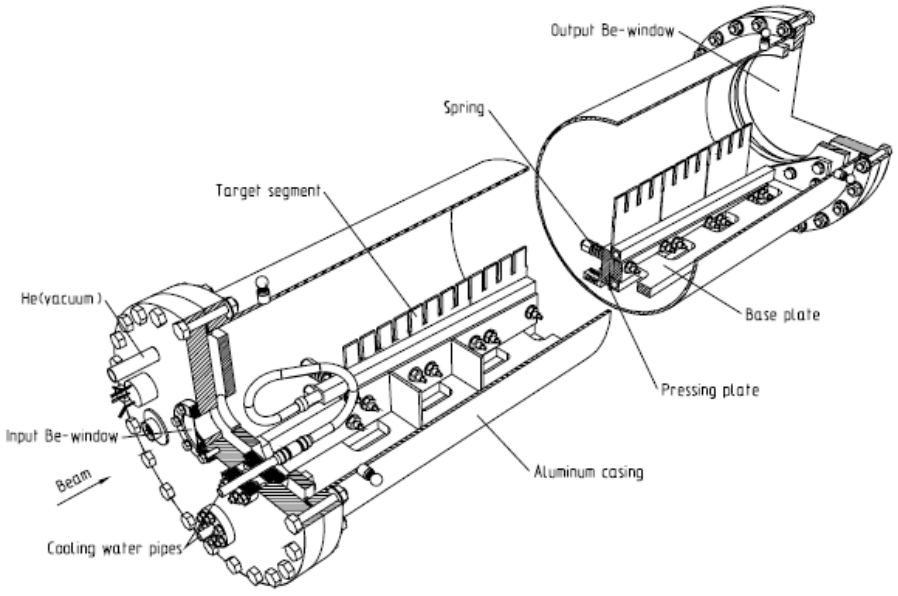

Figure 3 View of the medium energy target.