WBS 1.3.1 – Production Target Reference Design

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Abstract

This document describes the basic design and performance parameters for the water-cooled Production Target, remote installation, removal, storage, and the coolant re-circulation system. We also describe how this target interfaces with other components and subsystems.

History of Changes

Rev. No.	Date	Sections	Description of changes
1.00	9/19/03	All	Initial version containing a mechanical drawing of the target and inlet & outlet pipes, a rendered 3D CAD drawing of the target without the off-magnet-axis twist, and insertion, mounting, and removal procedure, interfaces.
1.01	3/24/04	3	Added target position and rotation information.

Table of Contents

1. INTRODUCTION 4

2. REQUIREMENTS 6

2.1 Physics 6
2.2 Operational Lifetime 6
2.3 Non-Boiling Condition 6
2.4 Coolant Containment 6
2.5 Pressure Limits 6
2.6 Coolant Activity 6
2.7 Remote Transfer 6
2.8 Positioning 6
2.9 Cooling Monitors 6

3. DESIGN 7

3.1 Mechanical Design 7
3.2 Cooling 8
3.3 Installation, Removal, and Storage 8

4. INTERFACES 10

4.1 Production Solenoid Vacuum Enclosure 10
4.2 Heat & Radiation Shield 10
4.3 Target Instrumentation 10
4.4 Down Stream AGS Monitors 10
4.5 Shielding 10
4.6 Cooling Water for Secondary Loop 10

5. EXPECTED PERFORMANCE 11

5.1 Cooling 11
5.2 Pion Production 11

6. REFERENCES 12

1. INTRODUCTION

This document describes the Production Target as it is currently envisioned. GEANT simulations have shown that the MECO requirement for muon stopping rate can be achieved by delivering 4×10^{13} protons per second to a small, high-density target in the Production Solenoid. Details of the primary proton beam can be found in {cite}, but the most important parameters are the beam momentum of 7.5 GeV, the 0.5 s flat-top and 1.0 s cycle time, and the expected 1.0 mm σ_r. For the target geometry proposed below, we anticipate the average beam power deposition in the target will be 5 kW and the peak instantaneous rate will reach 10 kW. The target will utilize water-cooling to remove this heat.

Figure 1.1 illustrates the components of the target. The primary proton beam interacts in a 16 cm long, 6 mm diameter gold or platinum target cylinder with a tapered end on the upstream side. A titanium water jacket surrounds the target; together they form an annular water channel. The rod is held in the center of this channel by three small titanium "feet", 120 degrees apart, near each end. There are two titanium end caps joining the water inlet and outlet pipes to the shell. The titanium coolant supply and return pipes also serve as the mechanical support structure for the target, suspending it from the Heat and Radiation Shield {cite}.

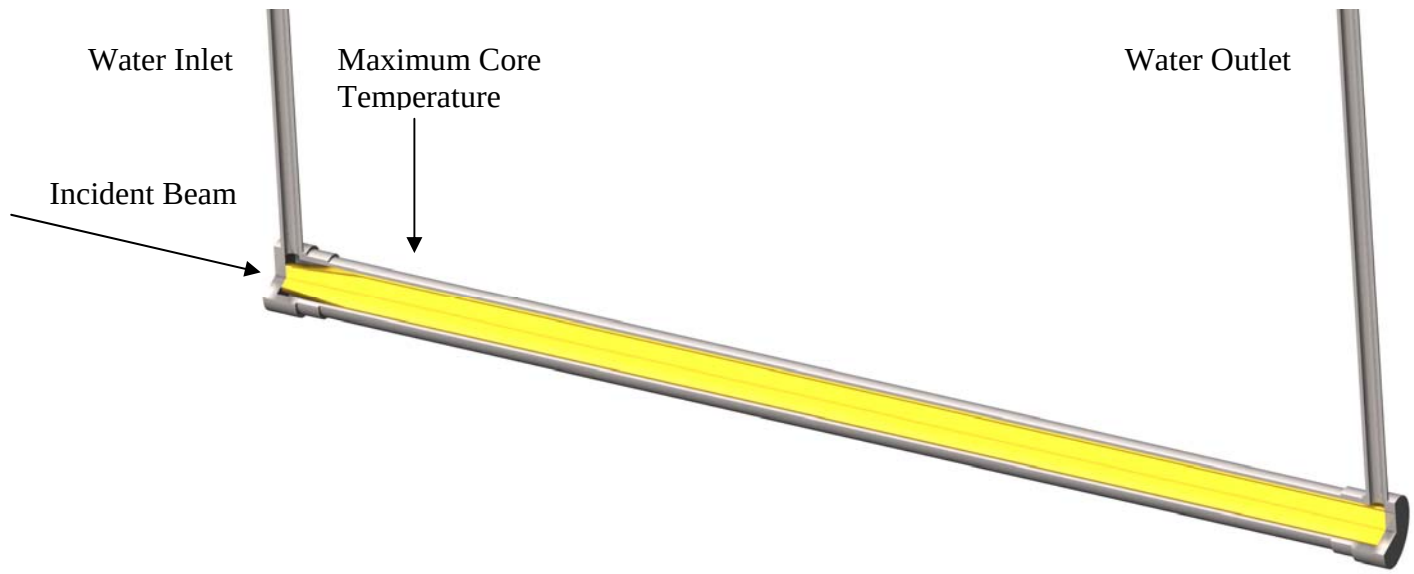

Figure 1.1 Water-cooled production target, cut-away view. Maximum energy deposition occurs within the first few centimeters along the length from the beam entry point.

The fully installed target with service pipes is shown in Figure 1.2. Note the keystone shaped mounting channel cut in the heat shield. Spacer plates between the water pipes join them together. The entire assembly rests on the spacer plates fitted to the mounting channel and the vacuum flange at the PS vacuum end wall (shown later).

The coolant re-circulating system is a closed loop coupled to a secondary supply of coolant water via a recuperative heat exchanger. Sensors will continuously monitor water temperature, pressure, and flow rate at crucial points throughout the system; among these, target integrity is safely and effectively monitored through measurements of coolant temperature and pressure on the target inlet and outlet sides, along with discharge rate. Should a significant system condition arise, proper action will be initiated by relaying the appropriate signals to the beam interlock and all affected or concerned site personnel.

Coolant in the primary loop will accumulate activated materials, producing radiation levels above background. To maintain safe radiological conditions in the event of an emergency and during routine operations, the coolant will be drained periodically from the system and replaced with fresh material in a manner certain not to interrupt cooling system operation. The chemical nature of and methods for handling the materials in the coolant water will require study; particularly, their effects on the target rod and pipes.

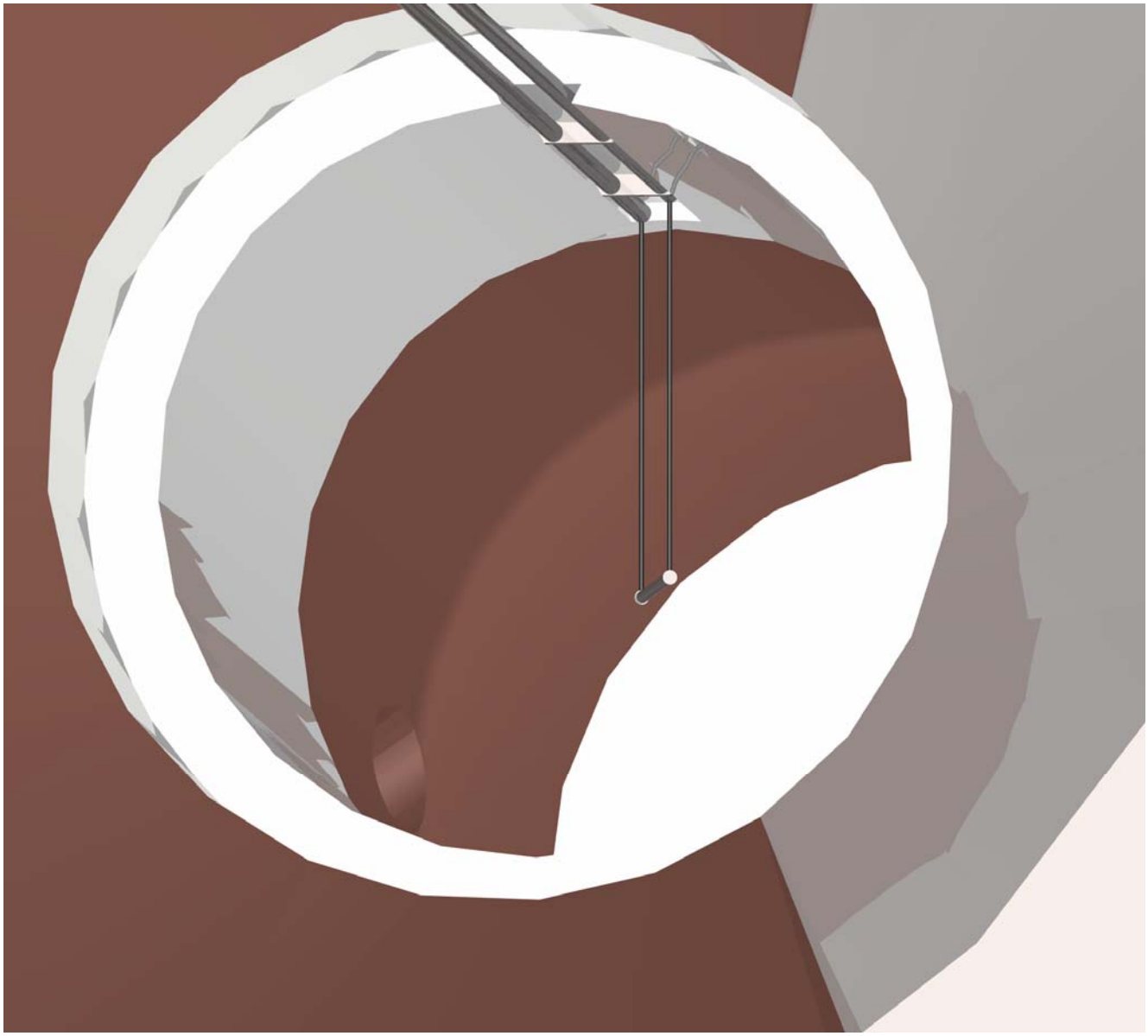

Figure 1.2 – Production target fully installed in PS, with service pipes & spacer plates, and mounting channel visible. Note the AGS beam entrance port to the left and below the target.

2. REQUIREMENTS

2.1 Physics

Regarding all equipment in the clear bore of the heat and radiation shield, including the target, particles exiting the target rod with appropriate momentum to travel to the DS stopping target and be stopped shall have no more than TBD g/cm^2 of matter along their path from the exit point to the entrance of the Transport Solenoid.

2.2 Operational Lifetime

The production target must survive energy deposition from an 8 GeV proton beam from the AGS, with a one-second machine cycle time, a duty factor of 0.5, and 40×10^{12} protons per machine cycle, during normal operating conditions for not less than **TBD** years with at least **TBD**% probability.

2.3 Non-Boiling Condition

Coolant boiling adversely affects heat transfer. For a given inlet water temperature, target radius and water gap size, minimum discharge rates have been established to avoid boiling anywhere in the target.

2.4 Coolant Containment

The cooling water must remain contained and isolated from all other systems.

2.5 Pressure Limits

Pressure at all points in the water circulation system must remain low enough to maintain coolant containment at all times.

2.6 Coolant Activity

Coolant water in the primary loop must be changed periodically to maintain radioactivity levels consistent with Laboratory safety guidelines.

2.7 Remote Transfer

As a single unit, the target, water conduit, and service pipes shall be removed, replaced, and stored remotely to minimize the radiation exposure of AGS personnel.

2.8 Positioning

The target rod positioning and orientation shall be accomplished and maintained to a tolerance of ±0.5 mm and **TBD** degrees about the nominal rotation angles.

2.9 Cooling Monitors

The state of the target, mechanically and with regard to heat transfer, shall be monitored continuously, employing sensors suitable to detect all significant performance conditions.

3. DESIGN

3.1 Mechanical Design

In this section, we provide drawings, masses, and center of gravity coordinates for each component. We also discuss allowances for thermal expansion and dimensional tolerances. At present, this information is limited to the masses of each of the component volumes from the physics simulation. Next, we discuss the coolant re-circulation system, target installation, removal, and storage.

Figure 3.1 gives all dimensions of the six main components of the MECO target. These six titanium components will be joined using electron beam welding methods to ensure good control over water channel size. For all components in contact with the coolant in the primary loop, weld joints will be continuous and then pre-tested with pressurized water before use. The inlet & outlet service pipes (not shown here) will be 0.5 inch Schedule 80 stainless steel pipes, approximately four meters long.

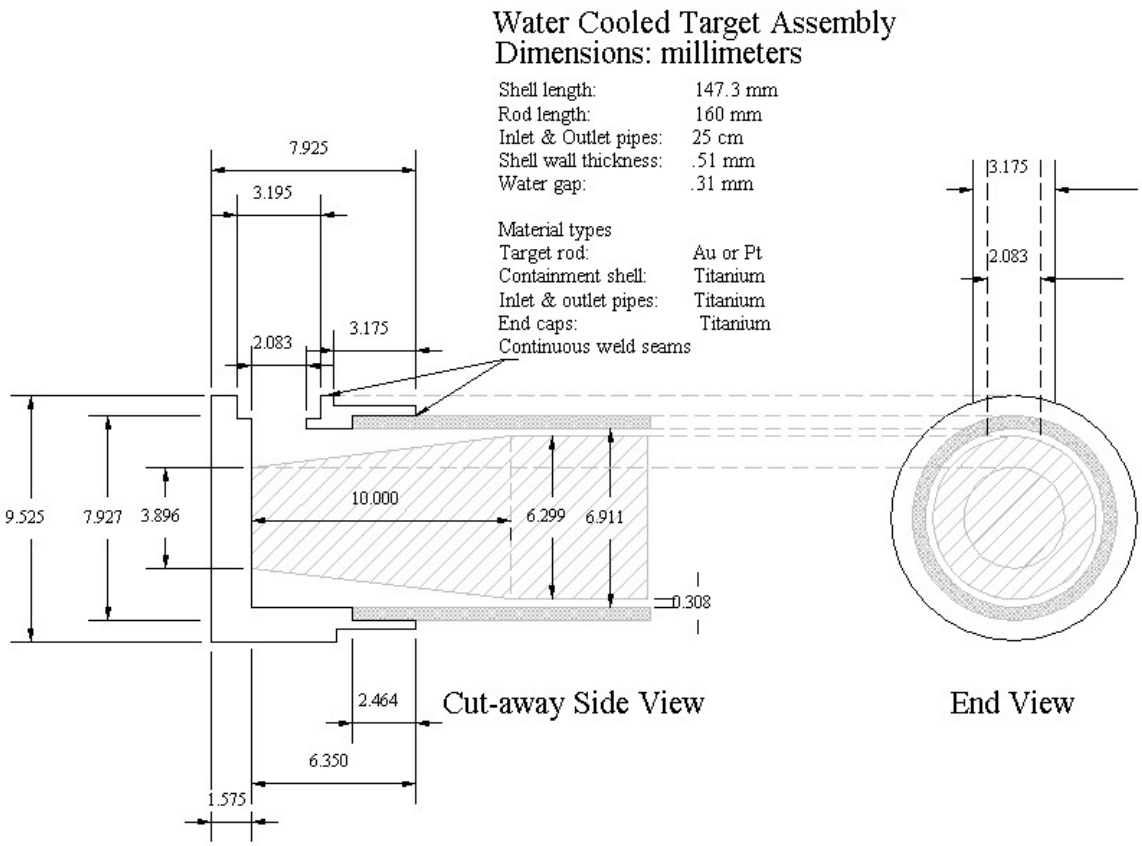

Figure 3.1 – Water-cooled target assembly drawing. The six main components with their dimensions are given here: Rod, water containment shell, two end caps, and inlet & outlet pipes.

The service pipes will be joined to each other with small steel plates, welded periodically along their entire length; additional stabilizers may be needed to ensure the rigidity of the structure. These plates and stabilizers should be mated to the mounting slot, which will run along the inner wall of the heat & radiation shield (see Figure 1.2). Service pipes will also be supported where they pass through the PS vacuum end wall, containing the AGS beam exit.

3.2 Cooling

The cooling system consists of two separate and isolated fluid flow loops. A recuperative heat exchanger passes heat from the primary to the secondary loop. This system has yet to be designed. However, it is clear that the primary loop must be completely leak tight, thus requiring all fittings to be welded continuously.

3.3 Target Location and Orientation

The location of the center point of the target rod in MECO coordinates is (x, y, z) = (390.4, 0.0, -656.45) in units of centimeters. The longitudinal axis of the target is rotated first with respect to the +y axis by 12.22° and then about the x' axis by –1.8°. Equivalently the ends of the 16 cm target rod are located at MECO coordinates given by (392.0925, 0.25129, -648.635) and (388.7075, -0.25129, -664.265). This rotation is chosen to closely match the trajectory of the primary proton beam through the axially graded PS field.

3.4 Installation, Removal, and Storage

To minimize radiation exposure of personnel, target installation, removal, and storage will be accomplished remotely, via a simple robotic arm, requiring two horizontal and one vertical translation. The process is illustrated in the figures below. The long horizontal service pipes are welded to a vacuum flange mated to a similar flange installed on the vacuum wall at the farthest upstream position on the Muon Beamline (left end of PS). The service pipes will be joined with several metal guide plates mated to the mounting channel on the heat shield.

The entire target, service pipe, and flange must be joined as a single unit for remote installation, removal, and storage. The robotic arm and shielded target box should be positioned nearby each other, and may be located in the low-radiation environment on the roof of the PS concrete shielding. In this arrangement, new targets are loaded onto the arm. Next, the target is lowered into the region between the PS and the AGS beam dump, via a single vertical translation. After preliminary target positioning, installation is accomplished in three simple translations. The first two pictures, Figure 3.2 and Figure 3.3, show the target at the end of the first horizontal translation, and a close-up of the target region of the PS. Figure 3.4 illustrates target position at the end of the second (vertical) translation. In the final (horizontal) translation, Figure 3.5, the guides are lined up with the mounting channel and the target is slid into place, completing the installation.

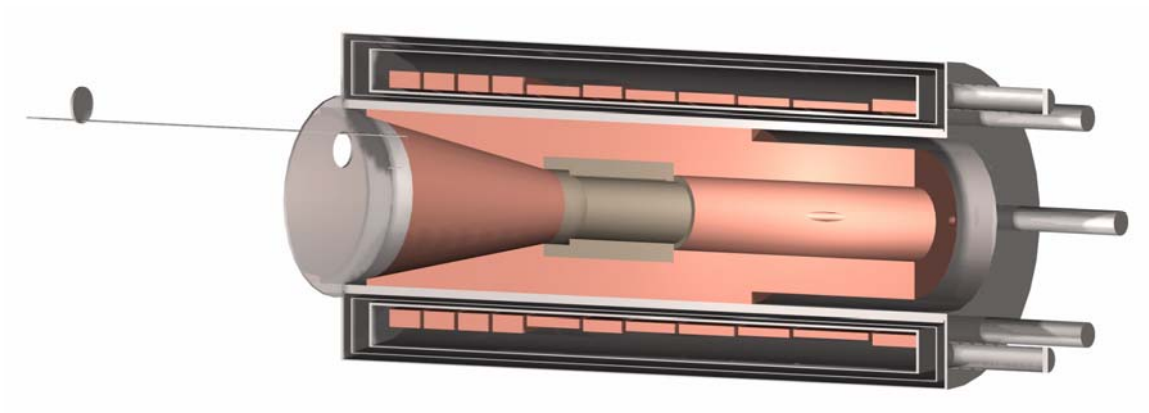

Figure 3.2 – Installation Step 1: Final position of target in Production Solenoid after the first horizontal translation.

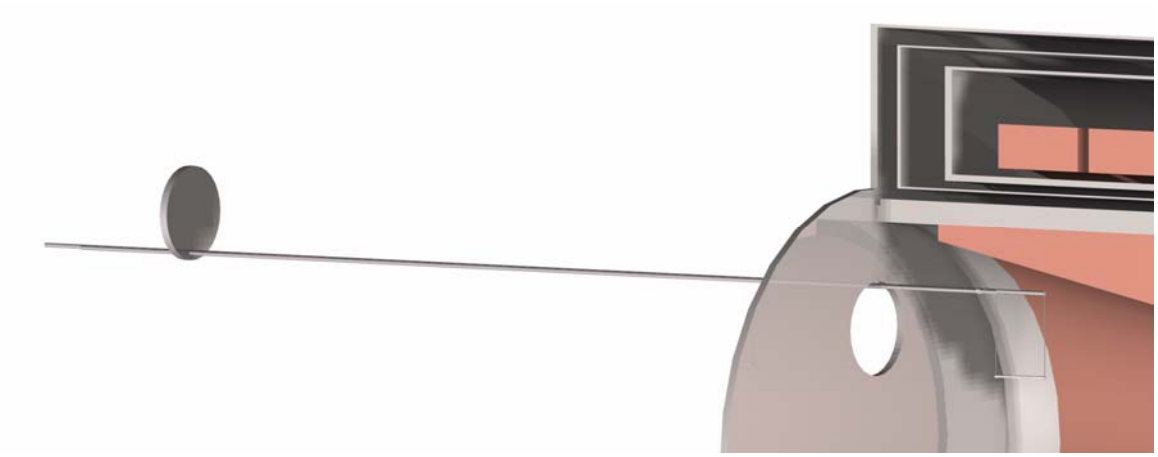

Figure 3.3 – Installation Step 1 – Detail: Target position at end of first horizontal translation.

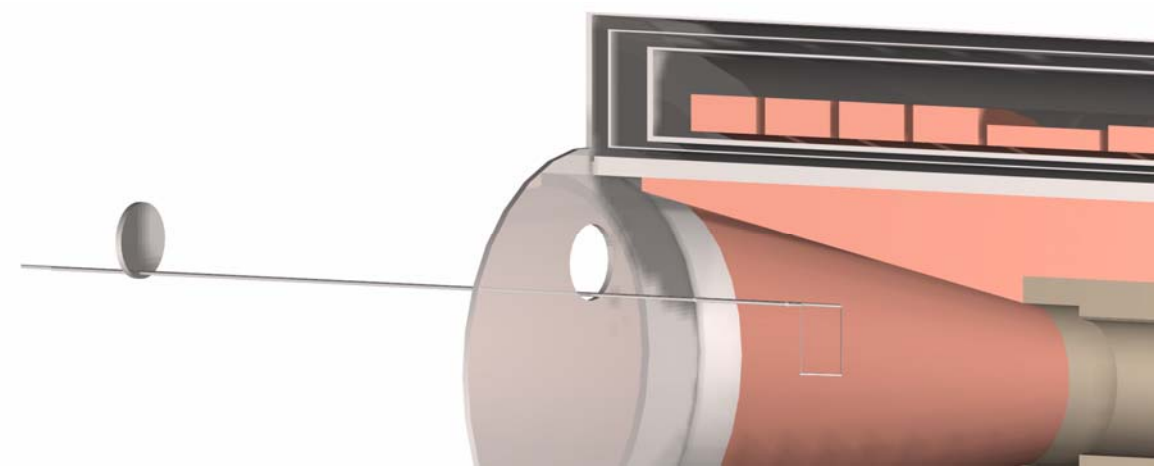

Figure 3.4 – Installation Step 2: Final position after vertical translation.

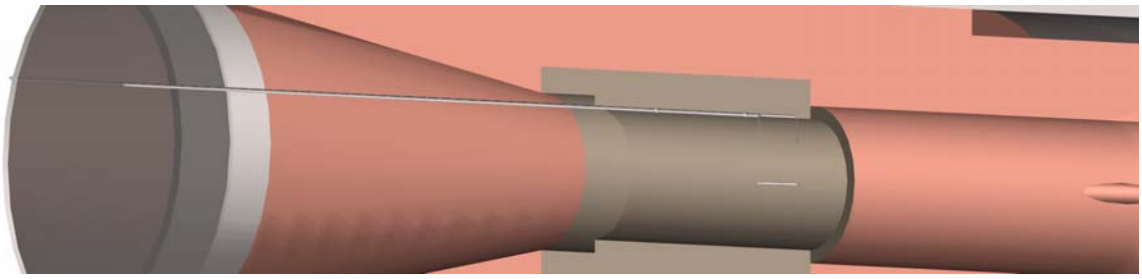

Figure 3.5 – Installation Step 3: Fully installed after second horizontal translation. Note that the vacuum flange welded to the two long service pipes is now in place.

4. INTERFACES

A detailed list of interfaces and the docs that govern each of them, including tolerances in envelopes.

4.1 Production Solenoid Vacuum Enclosure

The service pipes are welded to a vacuum flange mated to one welded to the PS vacuum end wall, at the upstream end of the Muon Beamline. These flanges will be bolted for target removal and replacement. This connection will also provide target support.

4.2 Heat & Radiation Shield

A mounting and guide slot will be made on the inner wall of the heat and radiation shield. This slot must provide support, stability and at least axial positioning for the target.

4.3 Target Instrumentation

Target sensors TBD.

4.4 Down Stream AGS Monitors

Located between the vacuum end wall (part of which also serves as the AGS beam exit) of the PS and the AGS beam dump, these sensors provide feedback to the AGS control room for beam focusing. Target cooling must not interfere with the operation of these detectors.

4.5 Shielding

The location of a remote arm and target sarcophagus is likely to be on the top of the concrete roof of the shielding surrounding the PS. When access to the area between the PS and AGS beam dump is needed for target replacement, some concrete blocks forming the roof to the shielding structure may be removed and later replaced. This location for the robotic arm will eliminate severe radiation survival requirements and make servicing this equipment faster and safer.

4.6 Cooling Water for Secondary Loop

The same source of cooling water for AGS magnets can serve this portion of the cooling system.

5. EXPECTED PERFORMANCE

5.1 Cooling

For a 16 cm long target rod of radius 3.0 mm, water gap of 0.3 mm, and inlet water temperature 20 C, a flow rate of 1 gallon per minute will result in a maximum local water temperature of 72 C; the critical temperature of water at that same location, assuming the pressure at the end outlet end of the target is approximately 80 psi, is 180 C.

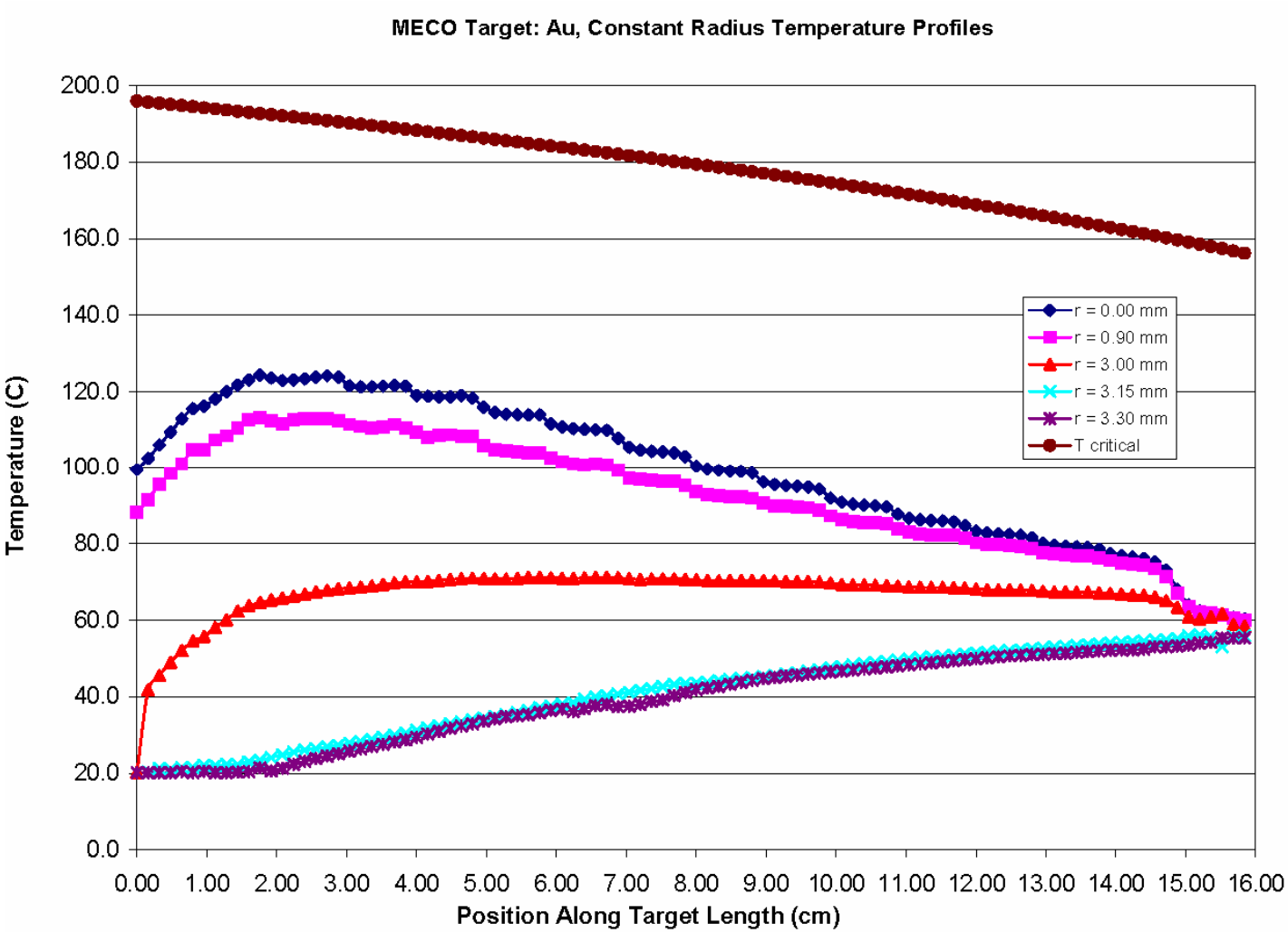

Figure 5.1 – Estimated steady state target temperatures at different radii as a function of axial position.

5.2 Pion Production

TBD.

6. REFERENCES