Information-Request/Submittal/Release		Number	S	038-0012
Number of attached pages	20	New ☐		
Project	MACS	Revision ☒		
Originator	T. D. Pike	If revision, provide the following:		
Date	February 3, 2003	Previous Submittal		
Database Reference	038-2489	ECR/ECN		

Scope

Specification for the Revised MACS Beam Shutter

Purpose

Revised specifications for the MACS Beam Shutter to replace the original failed shutter.

Description

Text and images that specify the requirements for the Shutter revision

Filing

When filed as a submittal, this form and the information attached to it transforms into a released document when it is signed by all parties named in it. The form with attachments is kept on file in the office of the NIST chief engineer. When attachments are electronic in nature (such as electronic CAD data) that information and its hierarchical position in the project design tree shall be identified in or under this submittal. Information Requests, Submittals and Releases are numbered separately, yet sequentially.

Change Process

Anyone can propose a change to documentation that is released under this form. To such end an Engineering Change Request (ECR) is filed. A priori, the change board is composed of the individuals that signed the submittal against which the ECR is drawn. Approval of the ECR turns it into an Engineering Change Notice (ECN), which gives authority to prepare a new submittal. The new submittal covers at least the fully executed ECN. Approval of the new submittal signifies close-out (full implementation) of the ECN.

Endorsements (list composition is part of release and determines Change Board for ECR/N's)

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JOHNS HOPKINS UNIVERSITY

NATIONAL SCIENCE FOUNDATION

NIST National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

General Specification for Development of the Beam Shutter

for the

Multi-Axis Crystal Spectrometer (MACS)

National Institute of Standards and Technology

Center for Neutron Research

Specification NG-0 –1.1 SHUT

Revision 4d

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0.0 Introduction to the Revised MACS Shutter Specification **(New)**

This specification is based largely on the specification that was used to develop an earlier Shutter dated 12/30/2003 designated Specification NG-0-1 SHUT Revision 2a. In this specification, sections 1.1, 1.4 - 1.6, 2.4.2 – 2.4.6, 3.2 and 3.3 appear without any change from the original.

The primary differences involve the construction of the Shutter Drum: both the materials used and the size and shape of the components have changed significantly. Specifically, the previous design used a rotating hollow Drum that was filled with a mixture of steel shot and wax. At each of the four primary operational positions a removable tube was placed. These tubes served to pass, absorb or restrict the size of the Beam. In the present design the contents of the Drum is fabricated primarily of laminations of both steel and High Density Polyethylene (HDPE). The Neutron apertures in each of the laminations are in identical positions with regard to the original design and, with the exception of being untapered, are approximately same shape and size. Otherwise, the Shutter will have the same functional performance as in the previous design.

As in the original design, the MACS Beam Shutter system contains all elements associated with turning the Neutron Beam off and on. The Neutronic input and output is a diverging cold Neutron Beam with a circular cross section. The Shutter uses rotary motion for selection of fully open, fully closed and restricted aperture states.

Figure A has been added to illustrate the new Shutter Drum. The Shutter cross-section shows that the Neutron Beam tubes are not tapered in the new Shutter Drum Design. Original Shutter Specification figures, provided for reference, remain numbered from 1 to 9.

During the development of the original Shutter, a gear drive was adopted as superior to the chain drive cited in the original specification, section 2.4. A gear drive compatible with the original Shutter shall be used in the revised Shutter design.

The Shutter Housing is for all intents and purposes identical to the previous design. However due to radiation exposure, the original parts with some exceptions cannot be reused. A list of the parts available for incorporation into the new Shutter assembly is included in section 5.0.

1. Overall Specifications (Original Text)

The MACS Beam Shutter system contains all elements associated with turning the Neutron Beam off and on. The Neutronic input and output is a diverging cold Neutron Beam with a circular cross section. The Shutter uses rotary motion for selection of open and closed states.

1.1 Bounding Box Dimensions (Original Text)

The Shutter is comprised of three primary components: Shutter Drum, Shutter Housing and Shutter cap. The Shutter shall occupy the overall bounding box described in figure 2, as well as the solid body in the accompanying IGES file. Dimensions for the Shutter Housing within the bounding box are shown in figures 3-5. Clearance from the Shutter to the bounding box shall be at least 10 mm in the horizontal directions and above the Shutter Base by 80 mm.

1.2 Materials and General Shielding Requirements (Modified)

All volumes of the Shutter Drum, Shutter Housing and Shutter Cap that are not required for Beam transmission or mechanical clearance shall be filled with shielding material. Typical materials employed are listed below:

1. A-36 mild steel
2. Bulk shielding material:
    a. 55% (volume fraction) steel shot in 45% wax held in a closed steel containment vessel.
    b. Laminations of Steel and High Density Polyethylene (HDPE). Laminations thicknesses shall be between 10mm and 30mm. The total volume of steel and total volume of HDPE shall be equal within 3% for any general shielding region.
3. HDPE (High Density Polyethylene)
4. Tungsten
5. Boron 10 Aluminum: 1mm & 6.35mm x 300 x 1800 mm sheets (government provided)
6. Neutron Beam passage windows shall be made from 1100 aluminum and have a thickness that shall be minimized and not exceed 0.5 mm.
7. Other specialty materials as required

1.3 Shielding & Construction Considerations (Modified)

Six functional element types determine the Shutter assembly volume:

1. Shutter Housing
2. Shutter Drum
3. Primary Beam Port
4. Primary Beam Plug
5. Auxiliary Beam Ports
6. Shutter Cap

The Shutter Housing, Drum and Port Shells shall be fabricated from mild steel. The construction of the external surfaces of the Housing shall be generally a vertical projection of the rectangular plan. Unlike the Shutter Drum, which is directly in the Beam where wax cannot be used, the Shutter Housing, shall be filled with a mixture of steel shot and wax using the ratios given in section 1.2.2 a.

1.3.1 Shutter Housing: Structural Load Carrying Ability **(New)**

The top surface of the Shutter Housing shall be designed and constructed to support a load of 20,000 pounds. The load shall be treated as a uniformly applied in the vertical direction. Performance of the Shutter shall not be impaired or compromised in anyway with or without the application of the load.

1.4 Attachment to MACS **(Original Text)**

The Shutter shall be fully self-supporting on three horizontal kinematic balls (NIST to provide) & mounting pads. The nominal distance from these surfaces to Beam height shall be 750 mm, see figures 6 and 8 for dimensions. Threaded receivers for lifting eyes shall facilitate the installation and removal of the Shutter and its components using an overhead crane. The Shutter Cap (NIST to provide) is in turn directly supported by the upper surface of the Shutter. Finally, the motor and primary gear reduction are supported by and mounted to the Shutter Cap.

1.5 Alignment **(Original Text)**

The central axis of the Beam Ports and the Beam plug shall coincide with the Shutter Housing Beam axis to within ± 1.3 mm when in the active position.

1.6 General Dimensions **(Modified)**

Shutter Housing, H x W x D	1270 x 1140 x 800 mm
Shutter Cap, H x W x D	650 x 1140 x 800 mm
Shutter Base, H x W x D	200 x 1140 x 800 mm
Drum diameter	960 mm
Drum thickness	750 mm

1.7 Operating Environment **(New)**

The MACS Shutter will be located in the C-100 building, an air-conditioned, experimental facility. The Shutter will be surrounded on all sides by steel-shelled shot and wax containers (shields). The design clearance between the shields and the Shutter is nominally 10mm. Radiation heat will be removed by conduction and radiation. No forced cooling means will be provided for the MACS Shutter.

Operating Temperature,	15 ^{O}C to 60 ^{O}C
Operating Humidity, Maximum	95 % RH non-condensing

2. Internal Functionality **(Original Text)**

Table 1 specifies the locations of Neutronic components along the MACS Beam line as well as the conical incident Neutron Beam profile. Details on the functionality of all Beam line elements are provided in separate specifications that are or will be accessible via the project web site at http://www.pha.jhu.edu/~broholm/MACS/. In the following, we focus on internal Shutter interfaces.

2.1 Helium Filled Housing **(Modified)**

Helium is used to reduce the amount of Beam loss due to air scattering, and to reduce the amount of atmospheric argon exposed to the Beam. The inlet and outlet to the Shutter Housing shall be positioned to prevent stagnation of the helium gas. Fittings for inlet and outlet shall have clear

and permanent markings. The Housing leak rate shall be less than 0.75 standard cubic feet/ hour at a water gauge pressure of 0.38 inch. Non-metallic seals and gaskets shall be rated to withstand 10^6 Rad lifetime exposure.

2.2 Neutron Blocking Position **(Modified)**

In the Closed position, the Drum presents materials that attenuate the Beam more aggressively than in any other angular position. This position is diametrically opposite to the full open position. The following composition reflects the materials seen by the Beam as it follows the path from the Shutter entrance to the Shutter exit.

2.2.1	Borated Aluminum	6.35 mm	(0.25 in)
2.2.2	Steel Shell Entrance End Cap	10-25 mm	(0.38 – 1.0 in)
2.2.3	Tungsten	150 mm	(5.9 – 6.0 in)
2.2.4	Steel, Borated Aluminum & HDPE Laminations	550-560mm	(21.6 – 22.1 in)

a. Steel and HDPE laminations shall be of equal thickness and quantity ± 3%. The Steel volume shall not exceed the HDPE volume.
b. 1 mm thick disks of Borated Aluminum secured by features created on one face of each HDPE laminate
c. Both the Steel and HDPE shall have a minimum of 11 laminations each (22 laminations total)

2.2.5	Borated Aluminum	1.0 mm	(0.04 in)
2.2.6	Steel Shell Exit End Cap	10-25 mm	(0.38 – 1.0 in)
2.2.6	**Total Drum Thickness**	**750 mm**	**(29.5 in)**

All materials shall be positively secured to prevent shifting or moving within the Drum.

2.3 Shutter Drum Location Markings **(New)**

Permanent engraved markings on both faces of the Drum shall be visible with the aluminum windows removed permitting visual inspection of the Drum position, particularly in each of the four primary positions, including the closed position.

2.4 Shutter Drum **(Modified)**

The main functional unit of the Shutter is the Shutter Drum. The Beam tube, the Beam block, and two auxiliary Ports may occupy each of four possible positions. The functional positions are angularly spaced about the center of the Drum at 0, 108, 180, 252 degrees, as shown in figure 5. By rotating the Drum, the axis of the selected element is brought into alignment with the axis of the Beam. Clearances between the Drum and the Housing shall not exceed 10 mm.

When in the active position, the two rectangular Beam Ports shall be vertical to within ½ degree.

2.4.1 Actuation **(Modified)**

Drum rotation shall be effectuated by a direct drive mechanical system based on a three-element reduction, conceptually shown in figure 1. The Revised system shall be consistent with the Shutter initially delivered. The contractor in consultation with Nick Maliszewskyj shall select the drive motor and resolver.

2.4.2 Shutter Position Detection **(Original Text)**

The position of the Shutter shall be determined by the actuation of a series of switches driven by physical features on the outer surface of the Shutter Drum. A minimum of six switches are required as listed for each of the following: Primary Beam Port, 1 switch; Aux. Port 1, one switch; Aux. Port 2, one switch; in transit, one switch; Beam Plug (closed position) two switches. Access for the removal and replacement of the switches shall be from the top and West side only. Preference will be given to designs that allow switch removal and replacement without access below the surface of the Shutter Cap.

2.4.3 Range, accuracy, and speed of travel **(Original Text)**

The Shutter design shall allow continuous rotary motion. No preference is given to CW or CCW or reversible rotation. A positive detent system shall provide for positional location of each Port to within $\pm$ 0.25 degrees corresponding to $\pm$ 1.3 mm at the Beam Port axis. Maximum time to rotate through 180 degrees shall be less than 15 seconds; preferred time is 5 seconds.

2.4.4 Cable management **(Original Text)**

Cables from Drum position monitoring switches shall terminate within 300 mm of the motor shaft on the top surface of the Shutter Cap.

2.4.5 Shutter Drive Access **(Original Text)**

Access for removal and replacement of the right angle drive, drive sprocket and chain tensioning shall be possible from the top and West side only. The motor and primary reduction shall be mounted above the Shutter cap. Removal and replacement of the motor, primary reduction and drive shaft shall be accomplished without access below the surface of the Shutter Cap.

2.4.6 Lifetime and Maintenance **(Original Text)**

The motive and bearing systems shall allow for 200,000 full travel cycles for the Shutter over the anticipated device life of 20 years. Lubricants shall be selected to be unaffected by the high radiation environment for the life of the unit (or specific scheduled maintenance in not less than 3 year intervals).

2.5 Shutter Drum

2.5.1 Shutter Drum Contents **(New)**

The primary difference between the present and the prior designs is in the construction of the Drum contents. The present design employs laminations of steel and HDPE as the majority of the material filling the Drum.

2.5.2 Shutter Drum Beam Ports **(New)**

The Shutter features a primary Beam Port and two auxiliary Beam Ports. The primary Port is circular with a minimum diameter of 290 mm and permits the full Neutron Beam to pass through the Shutter unimpeded. The two auxiliary Ports are rectangular in shape and have dimensions of 50 x 286 mm and 100 x 272 mm. To aid fabrication, an internal radius of 5 mm maximum is permitted for the corners of the auxiliary Beam Ports.

Each Port is fully lined with borated aluminum and steel. The Borated Aluminum is clad to the steel and faces the axis of the Beam Port. The steel shall have a nominal thickness of 10 mm, and

the Borated aluminum shall have a nominal thickness of 1 mm. Due to the high radiation environment, only non-copper bearing metallic fastening means may be employed.

2.5.3 Shutter Drum Laminations: Two Series **(New)**

The Drum contains two series of laminations. The first series is mild steel disks that can be a single piece or made up from laminations. The second series is a stack of at least 22 equal thickness laminations of mild steel and HDPE disks.

The first series (steel only) has four holes: (1) Full Beam Transmission Tube, (2) 100mm Wide Transmission Tube, (3) 50mm Wide Transmission Tube, (4) Tungsten Plug.

The second series (steel and HDPE) has three holes: (1) Full Beam Transmission Tube, (2) 100mm Wide Transmission Tube, (3) 50mm Wide Transmission Tube. In addition, the steel and HDPE disks will have features for accommodating attachment between each other, the axle bearing and, to the Shutter Drum Shell. **See Figure A**.

2.5.4 HDPE Laminations: Special Considerations **(New)**

HDPE has a greater coefficient of thermal expansion (CTE) than steel by roughly a factor of 10. Also, HDPE is known to expand when exposed to a high radiation flux. Further, HDPE outgases hydrogen when exposed to a high radiation flux (0.3 liter/day in this application). Finally, HDPE structurally degrades due to radiation exposure, causing embrittlement, along with reduced tensile and compressive strength values. The value of linear expansion for HDPE exposed to radiation will be less than or equal to 6×10^{-3} mm/mm over the life of the Shutter Assembly.

As a result, each lamination of HDPE must be secured in such a way that the CTE, Radiation expansion, and radiation induced gas production do not compromise the integrity of the mechanical joints and fasteners. Solutions may include, but are not limited to: 1) A simple spacer system between each of the steel laminations that a given HDPE lamination sits between; 2) Radial, axial, or across chord venting grooves or holes in the disk; 3) Spring retention between single or multiple laminations of steel and HDPE.

However, laminations of HDPE are not required to be monolithic; tight fitting joints and seams may be oriented axially, diametrically, across a chord of the disk, or any combination of these, provided that any seam or gaps along the direction of the Neutron Beam are strictly minimized. Any pattern of seams or gaps that are parallel to the axis of the Beam must be staggered or arranged in a way that prevents streaming. This also applies between layers separated by many or all laminations.

Finally, the HDPE must have features, either recessed or standing to secure the sheet of Borated aluminum. If standing features are chosen, they are not required to be HDPE. (See 2.2.4b)

2.5.5 Borated Aluminum Disks **(New)**

On the entrance side of each sheet of HDPE, a sheet of 1mm borated aluminum, 300 mm across, shall be centered on the axis of the tungsten cylinder.

2.5.6 Shutter Drum Shell **(New)**

The Shutter Drum Shell shall be fabricated to be compatible with the original Shutter drive, detent and position feedback designs. Fastening and joining methods shall be consistent with retaining any powder or debris that may be generated as a result of the HDPE being exposed to Neutrons, yet preventing a pressure buildup that will be associated with the hydrogen gas production of the HDPE.

2.5.7 Shutter Drum Fasteners; Safety Requirements **(New)**

All fasteners that locate, retain, or secure features of the Drum or items within the Drum cavity, axle, drive or Beam line components shall be "Made Safe" be a NCNR approved means. Thus, fasteners that secure the Beam windows, axle bearings, drive gears; Drum position sensing and detent rings, HDPE and Steel Lamination disks or any other features that if allowed to loosen would impede or restrict the Drum motion shall be Safetied. In general, for fastener and features that must be safetied, a ***properly installed*** safety wire is preferable to a cotter pin.

Details regarding proper installation of safety wires may be found in Chapter Seven, Section Seven of the FAA advisory circular AC 43.13 1B
http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/99C827DB9BAAC81B86256B4500596C4E?OpenDocument

A simplified overview may be viewed at: http://www.whizwheels.com/Tips/safetywiring.html

2.5.8 Shutter Drum Balancing Features **(New)**

Counterbalancing features to offset the off-axis moment generated by the Tungsten Plug may generally occupy any volume not associated with the Beam Ports or the primary Beam blocking features of the Drum.

2.6 Computer control **(Original Text)**

NIST shall take responsibility for the Shutter control system logic. The contractor is responsible for position detection, drive motor and wiring to terminal blocks. The contractor is also responsible for a temporary control system to test the operation of the Shutter.

2.6.1 General Electrical Requirements **(Original Text)**

Each of the position switches shall be wired Normally Open; that is, a given switch will indicate that the Shutter is at the position, which that switch is to detect, by closing at that time and being open all other times. A common source of power (24 VDC) may be used for all the switches. The switch wires shall terminate at a separate terminal block from the motor wires, which shall also terminate at a terminal block. The switch wire shall be a minimum #20 AWG and the motor wire shall be a minimum #18 AWG. Additional requirements and information will be provided in a separate control interface specification.

3. Additional Specifications **(Original Text)**

Additional specifications will be provided by NIST for the following:

- Paint & finish
- Steel shot & wax
- Interfaces to other MACS elements

3.1 The contractor for the Shutter shall develop specifications for the following: (Modified)

- Inspection & test procedures
- Regular and preventive maintenance schedule
- List of replacement parts

3.2 Project level approval is required for the following: (Original Text)

- Motor and power transmission elements
- Switches and electrical connectors
- Power & communications standards

3.3 Project Engineering Contacts (Original Text)

Mechanical & Systems	Timothy Pike	301.975.8373	tpike@nist.gov
Electrical & Software	Nick Maliszewskyj	301.975.3171	nickm@nist.gov
Safety Engineering	Mark English	301.975.6181	menglish@nist.gov

4.0 Pre-Shipment Inspection **(New)**

Prior to shipment of the completed Shutter assembly, an NCNR technical representative shall be given the opportunity to inspect the functional performance of the Shutter in final form. Performance criteria will include but not be limited to: Rotation time between positions, Rotary position accuracy for Beam apertures, and helium leak rate. This is **Not** to be interpreted as an NCNR acceptance inspection.

5.0 Initial Design MACS Shutter: Parts Available for Use or Reuse **(New)**

The following list contains items that may be reused in the revised Shutter design to reduce cost and improve delivery times.

5.1 Limit Switch Assembly (Merrick 4634-e-3000)

5.2 Electrical Test Assembly (Merrick 4634-e-4000), Note: This assembly contains modifications made by NIST that may require, at a minimal, the programming of the servo drive to allow the unit to function as originally intended

5.3 Drive Assembly (Merrick “4634-m-1400”)

5.4 Position Detent Assembly (Merrick “4634-m-1900”)

5.5 Helium Supply Panel Assembly (Merrick “4634-m-2000”)

5.6 ***Shutter Control Switch Assembly (NCNR Fabricated)***

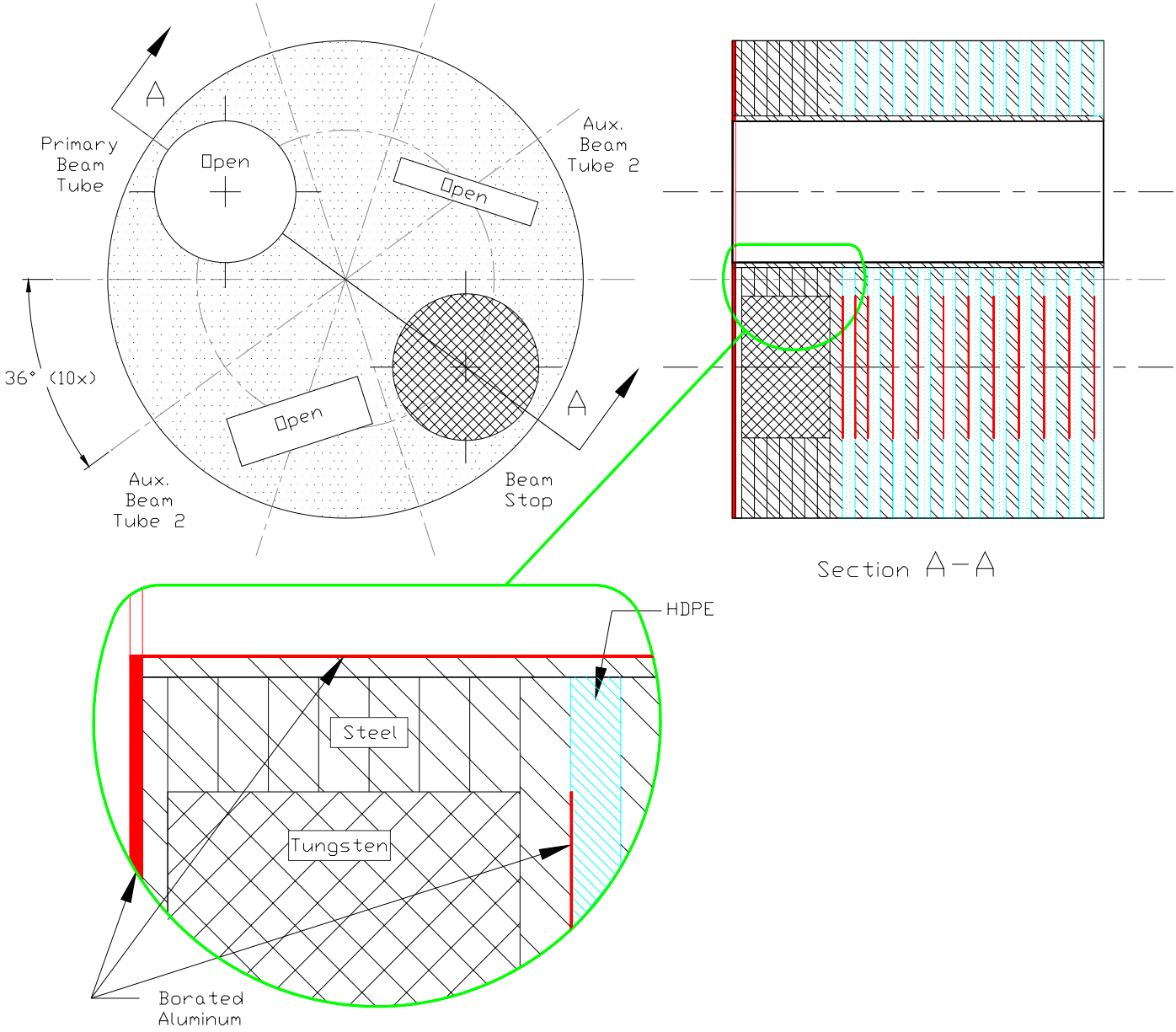

Figure A Section and Details of Revised MACS Shutter Design

Element		ΔX	ΔXi	ΣΔXi	x	y Radius	2y Diameter	2Y Clearance Diameter
Theoretical Beam Convergence Point					**-1600**	0		
Cold Source Face					0	44.7	89	101
Beam Hol	184 ref				1654	90.9	182	205
Face of Bio Shield @		781			2435	112.7	225	254
Forward Edge of Bio Shield					2600	117.3	235	264
Shutter In					**2650**	118.7	237	267
Shutter Drum (In)			25		**2675**	119.4	239	269
Shutter Drum (Out)			25		**3425**	140.4	281	316
Shutter Out			750	800	**3450**	141.1	282	317
Cryo Filter Exchanger			CFX	450	**3475**	141.8	284	319
Sapphire		43	150		**3518**	143.0	285.9	322
		7			**3668**	147.1	294.3	
Beryllium			100		**3675**	147.3	294.7	332
		7			**3775**	150.1	300.3	
Pyrolytic Graphite			100		**3782**	150.3	300.7	338
		43			**3882**	153.1	306.3	
					3925	154.3	309	347
		10						
Choke	Entrance	120			**3935**	154.6	309.2	348
	Exit				**4055**	158.0	315.9	355
		39						
Cask In					**4094**	159.0	318.1	358
		56						
In-line Collimator Exchanger			ICX	355	**4150**	160.6	321	361
			140		**4290**	164.5	329	370
		5			**4295**	164.7	329	371
			210		**4505**	170.5	341	384
		45						
Variable Beam Aperture			VBA	205	**4550**	171.8	344	387
			100		**4650**	174.6	349	393
		5			**4655**	174.7	349	393
			100		**4755**	177.5	355	399
Monochromator			DFM					
eading Edge		38			**4793**	178.6	357	402
Axis	35°	300			**5093**	187.0	374	421
Axis	90°		Total Travel		**6200**	217.9	436	490
Axis	105.4°		1757		**6413.5**	223.8	448	504
Axis	130°				**6850**	236.0	472	531
railing Edge					**7150**	244.4	489	550
		300						
Cask Out				3356	**7450**	252.8	506	569
		2150						
Beam Dump					**9600**	312.8	626	704

Table 1 1.600-Degree Divergence Beam Equation Rev. 5c

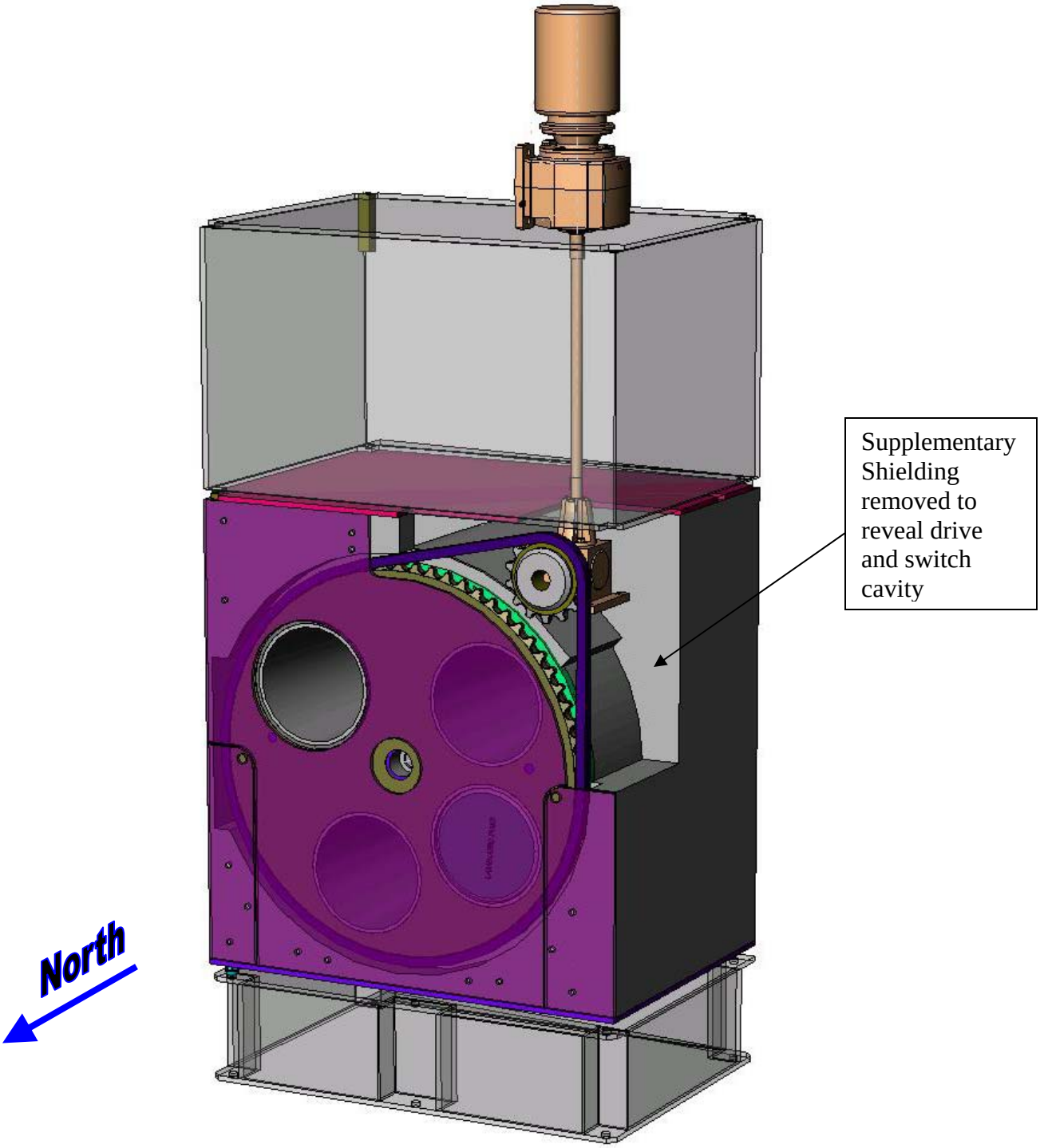

Figure 1 Perspective view of the Shutter.
Shutter Cap & Shutter Base provided by NIST

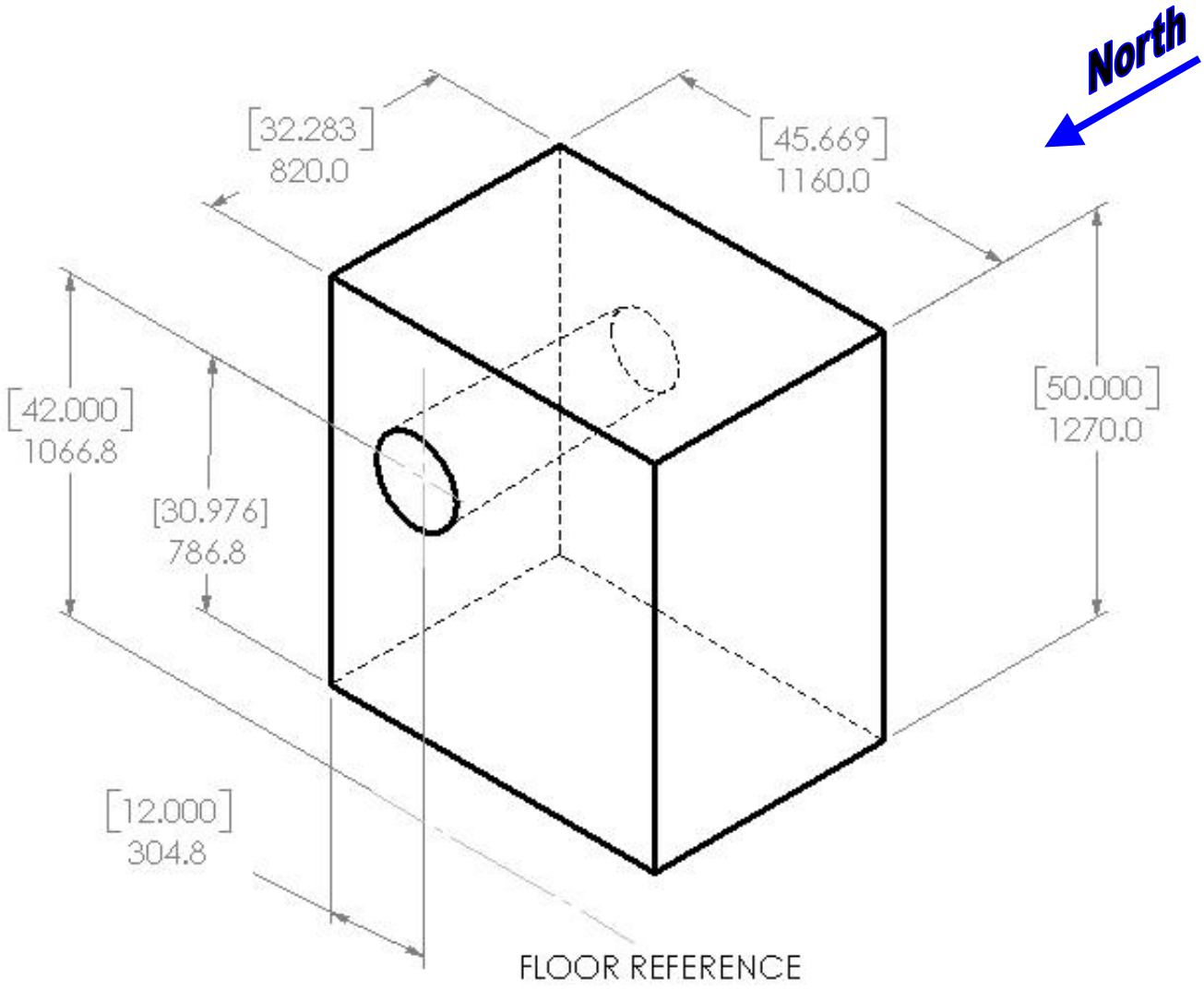

Figure 2 Shutter bounding box dimensions.

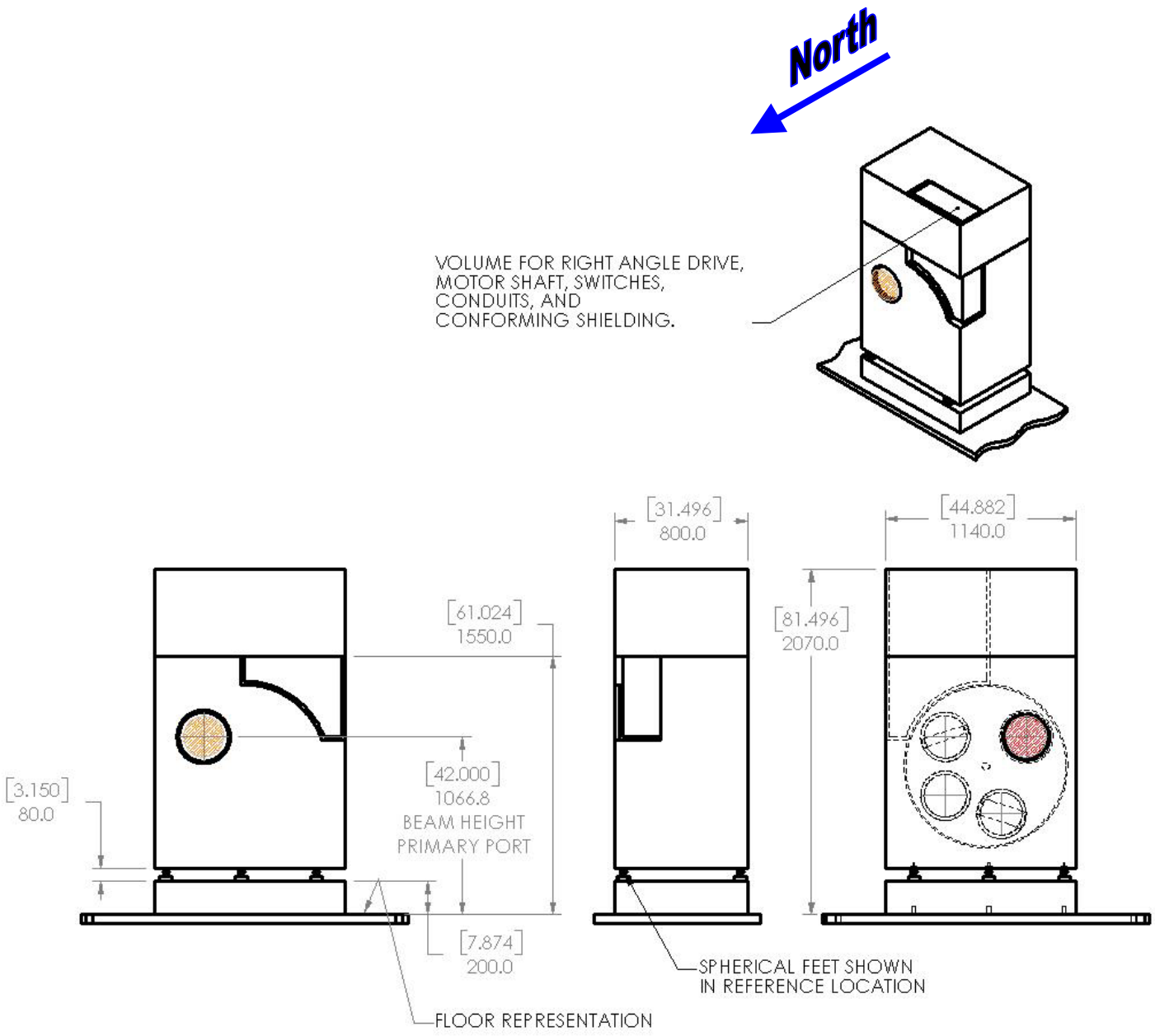

Figure 3 Shutter elevations and perspective view with reference dimensions. The Shutter is shown mounted on the Shutter Base, which is provided by NIST.

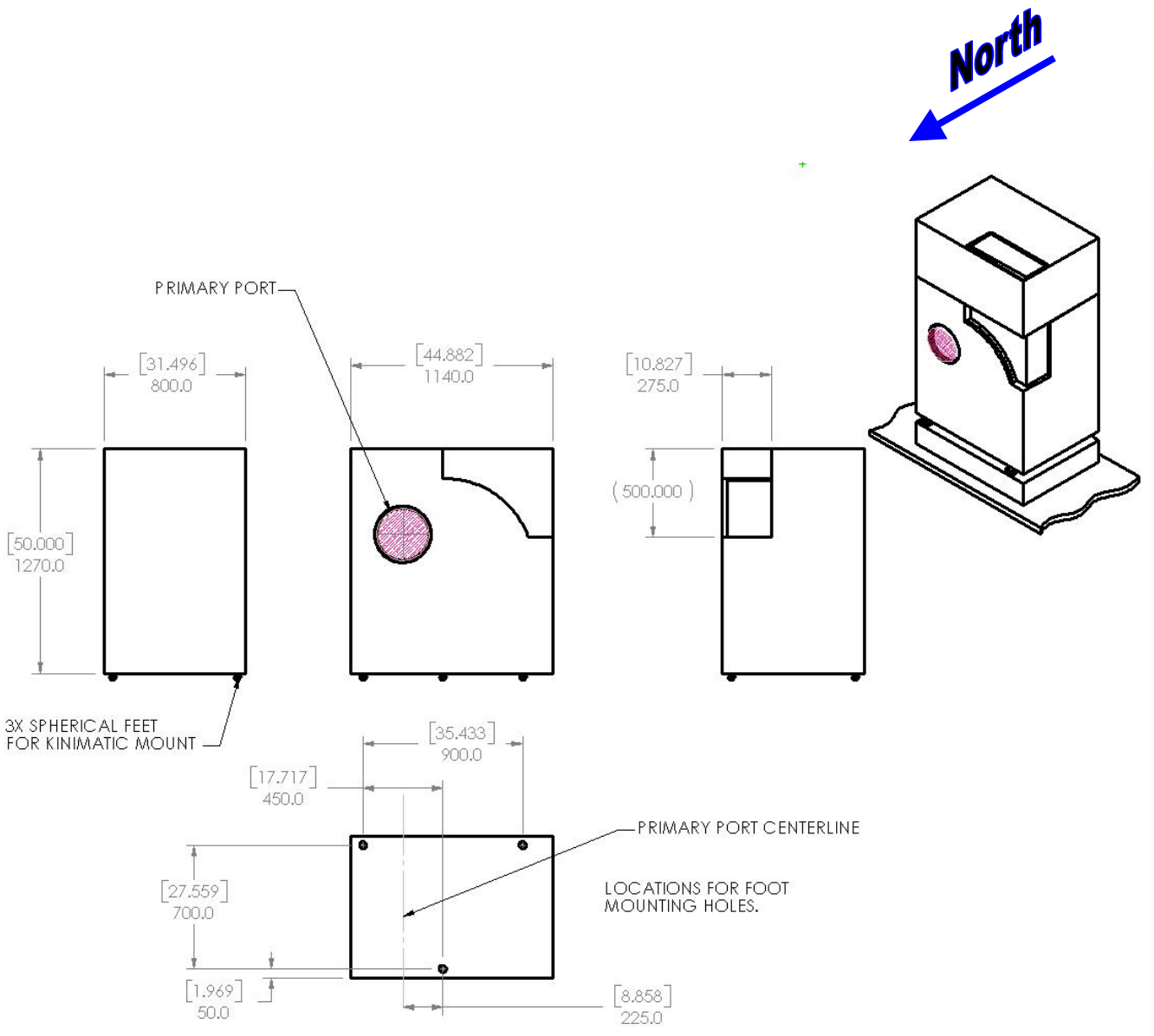

Figure 4 Shutter enclosure dimensions.

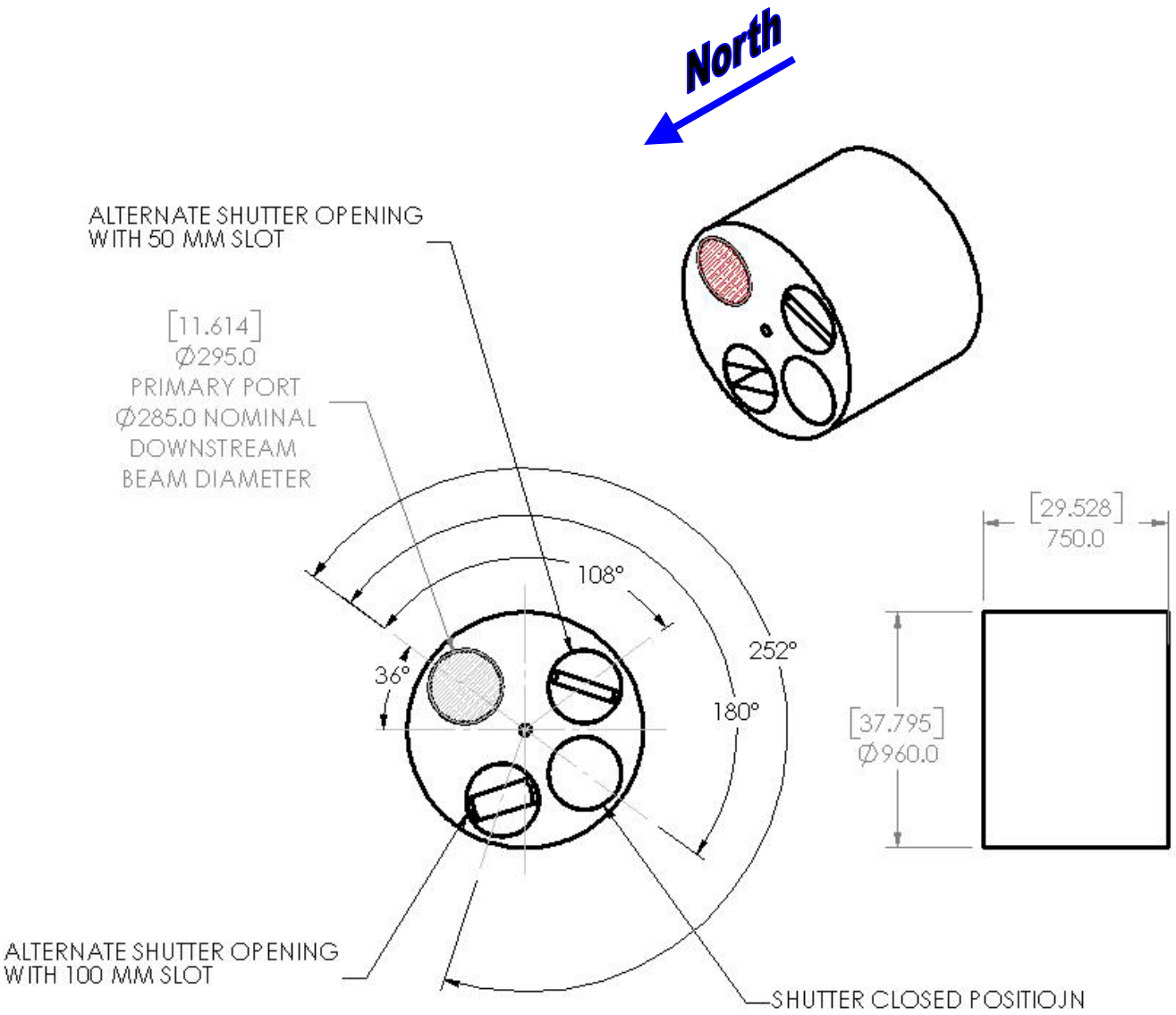

Figure 5 Shutter Drum dimensions.

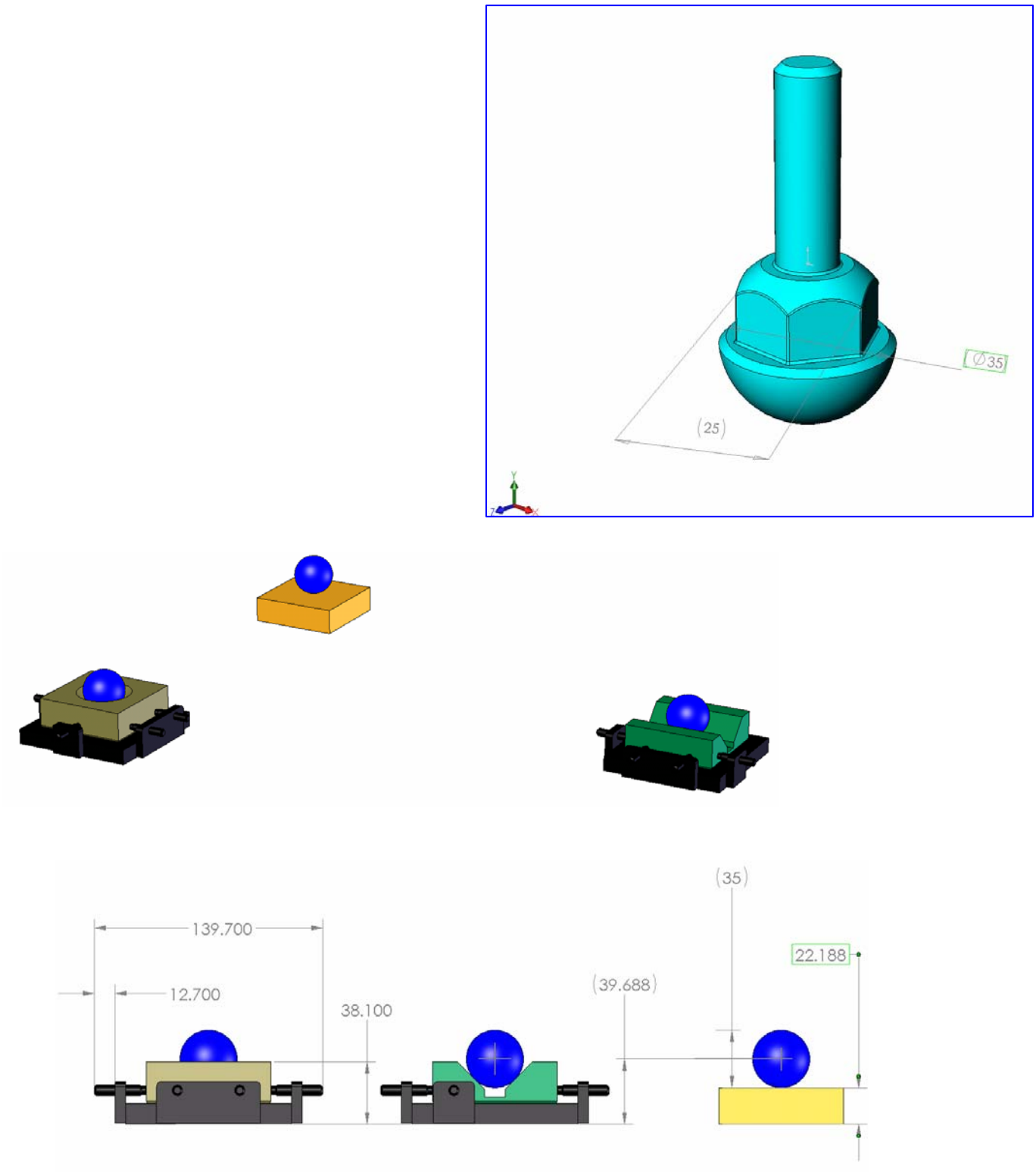

Figure 6 Kinematic Mounting Systems

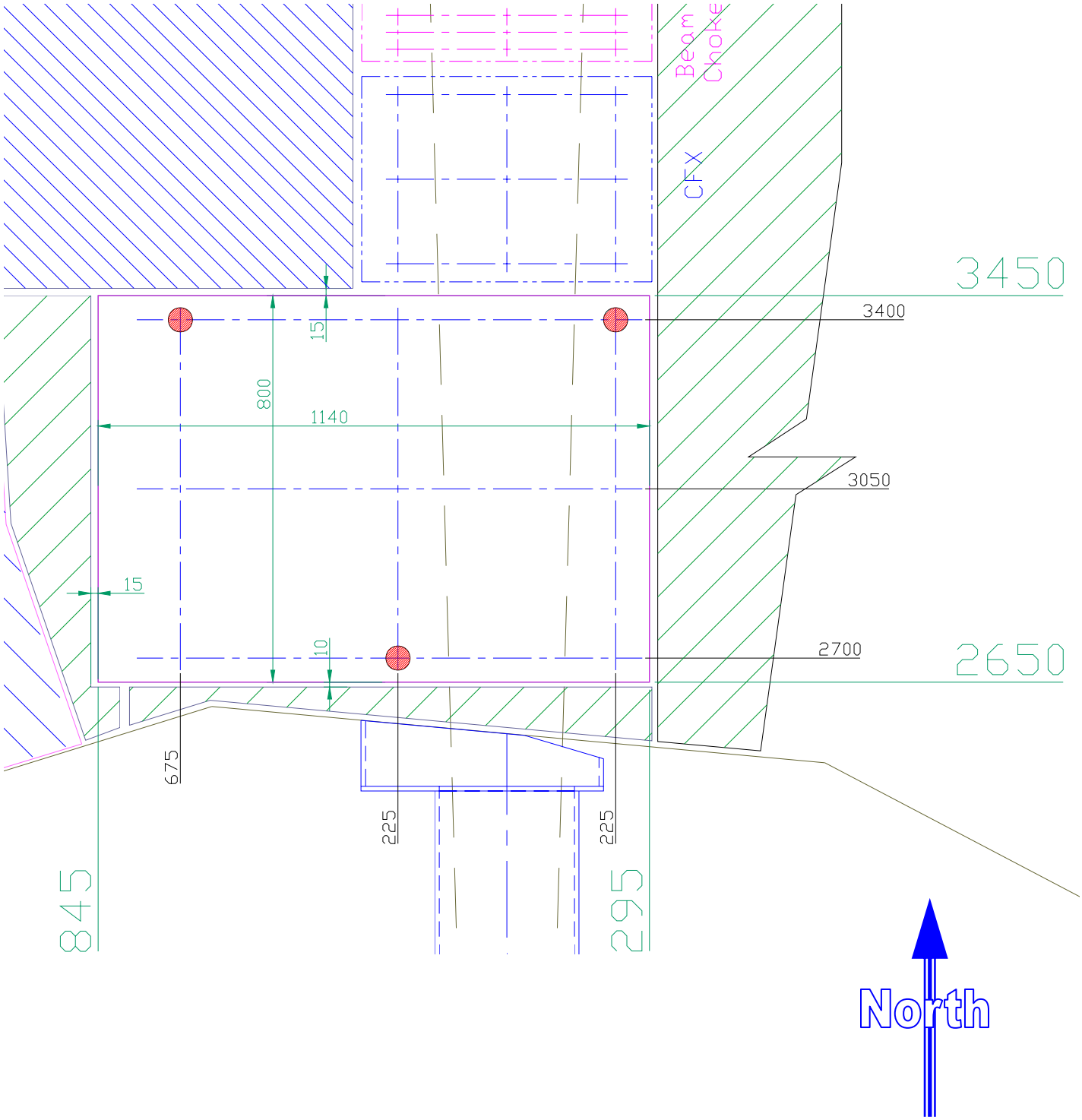

Figure 7 Shutter plan view A

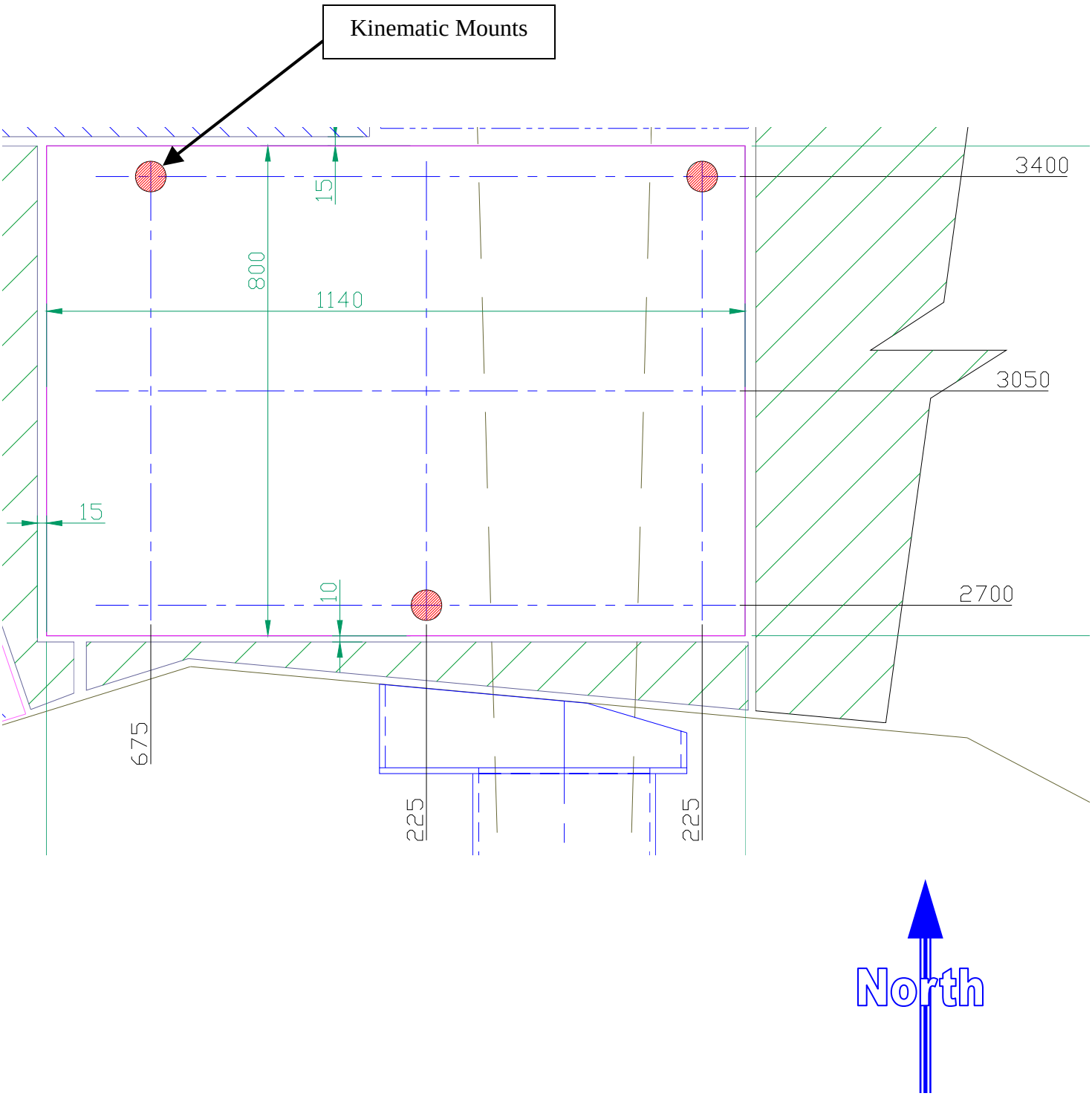

Figure 8 Shutter plan view B

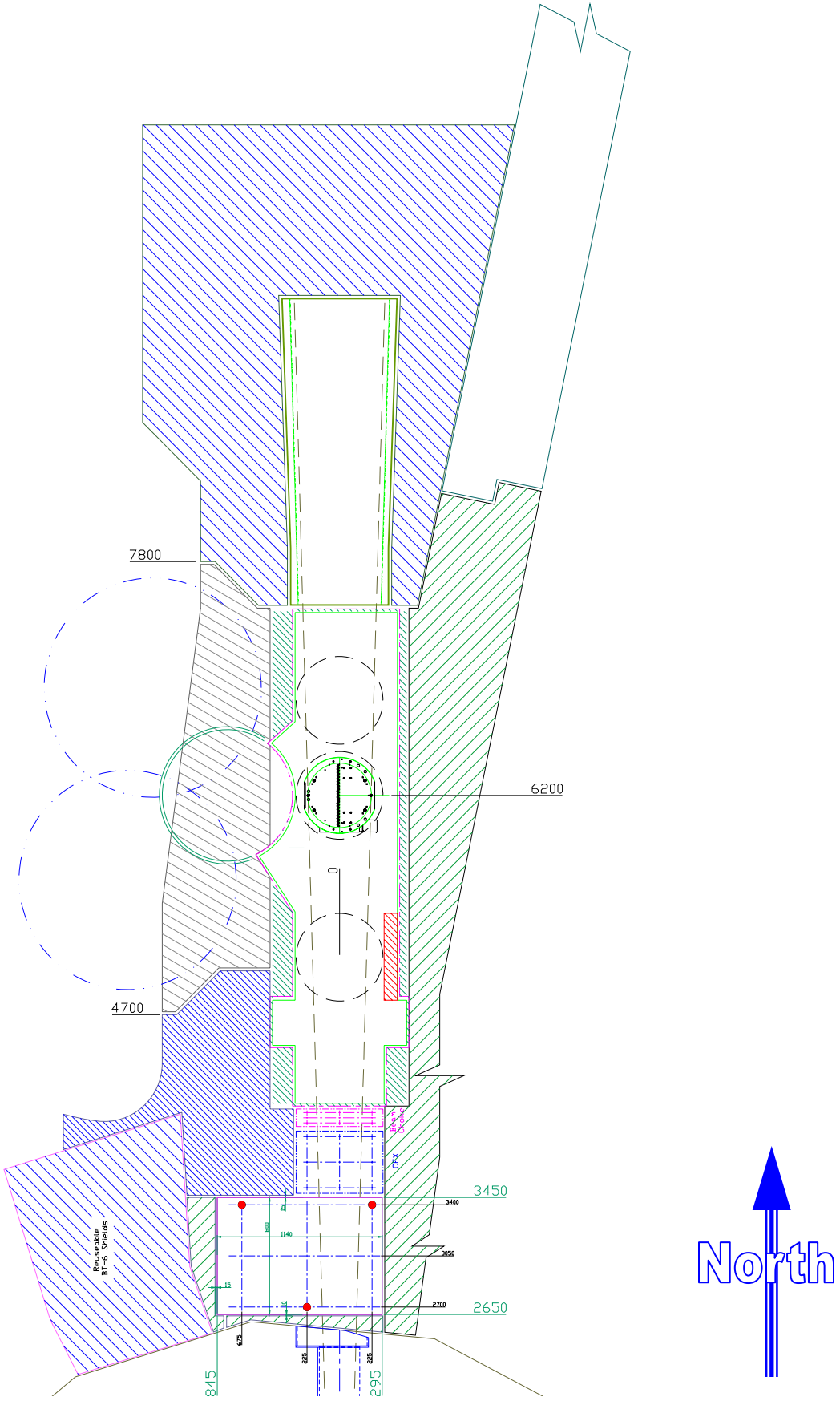

Figure 9 MACS General Layout.