

MERIT Hg System Design

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MERIT Review Meeting

Brookhaven National Laboratory

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Outline

- **Requirements & layout**
- **Hg delivery system description**
 - Syringe pump
 - Primary/secondary containment
 - Beam windows
 - Optical diagnostics
 - Sensor & controls
- **Installation**
- **Cost & schedule**

Reqmts and Operating Conditions:

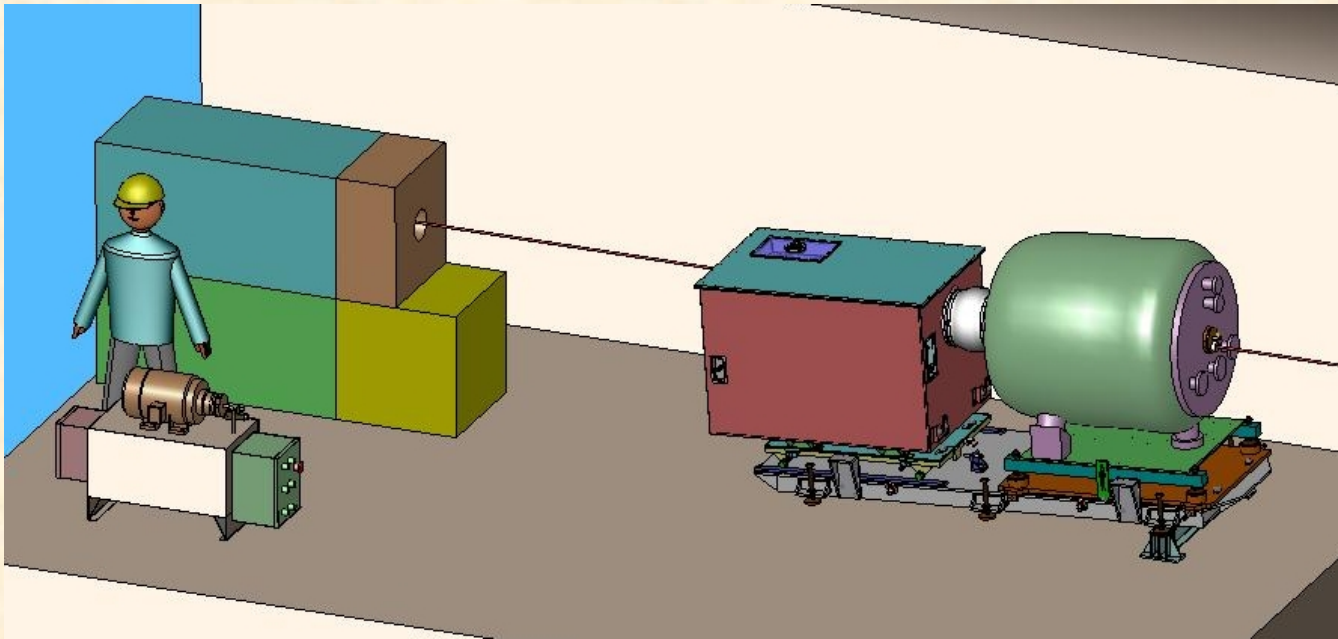


Target system must deliver a stable, unconstrained jet of Hg into a 15 Tesla field

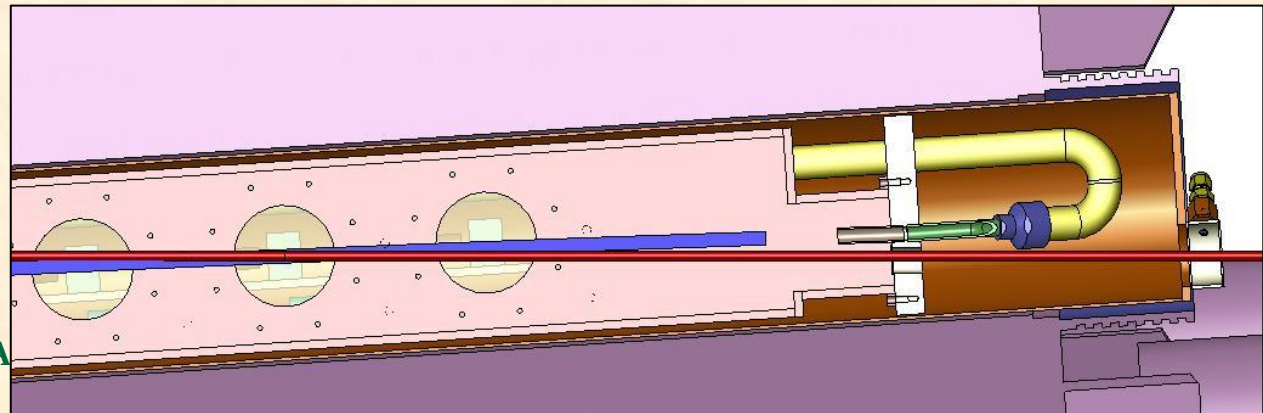
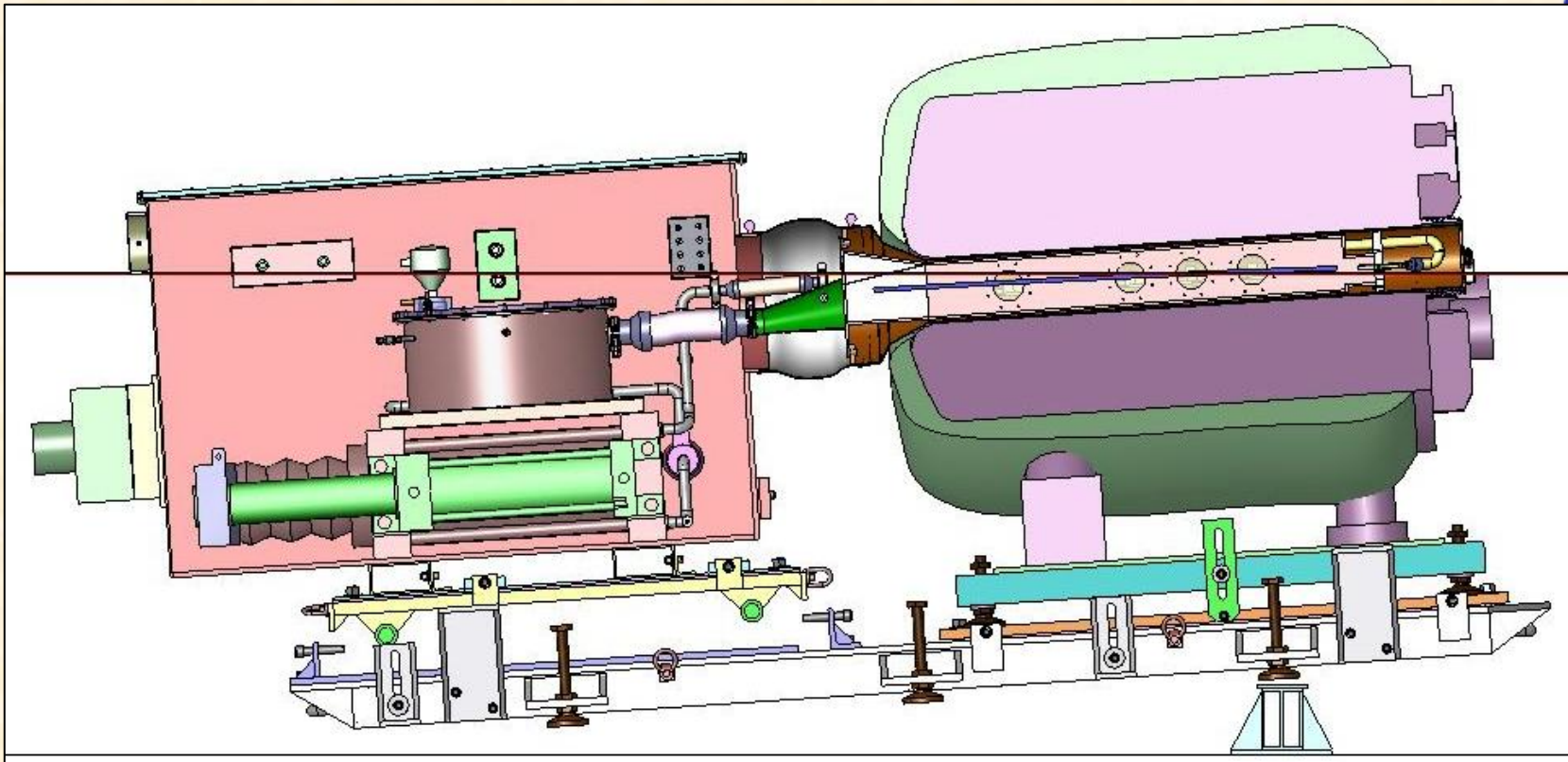
- 1-cm diameter jet at 20 m/s delivered every 30 minutes
 - $Q=1.6\text{liter/s}$, $Re\sim 10^6$
- >1-sec steady state jet during the magnet peak field
- Baseline Hg environment is 1-atm air, also considering running in rough vacuum
- Full-beam interaction length is 30-cm
- Beam line is 120-cm (47.2") above the tunnel floor
- Up to 100 pulses for the CERN test, >500 operating cycles for system testing
- The pump equipment operates in a range of 6000 Gauss to 300 Gauss ($1\text{ Tesla} = 10^4\text{ Gauss}$)

Experiment Layout

- Hg target is a self-contained module inserted into the magnet bore
- Two containment barriers between the Hg and the tunnel environment



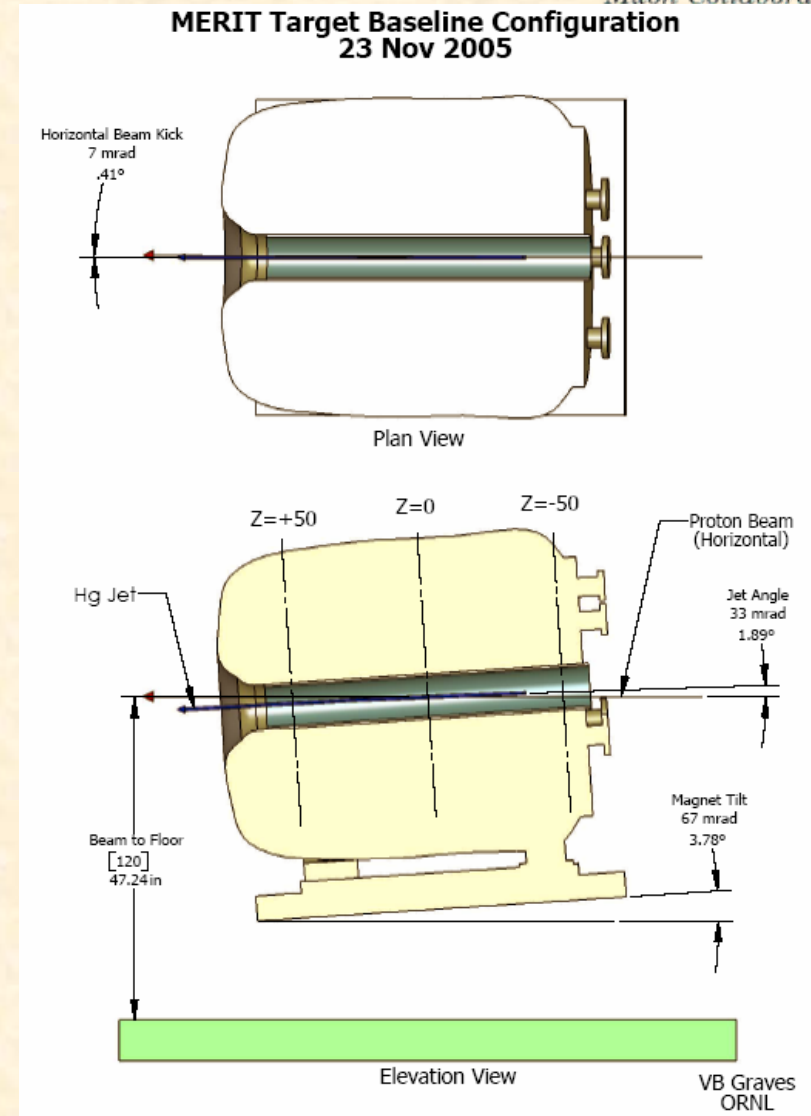
MERIT Side View



OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

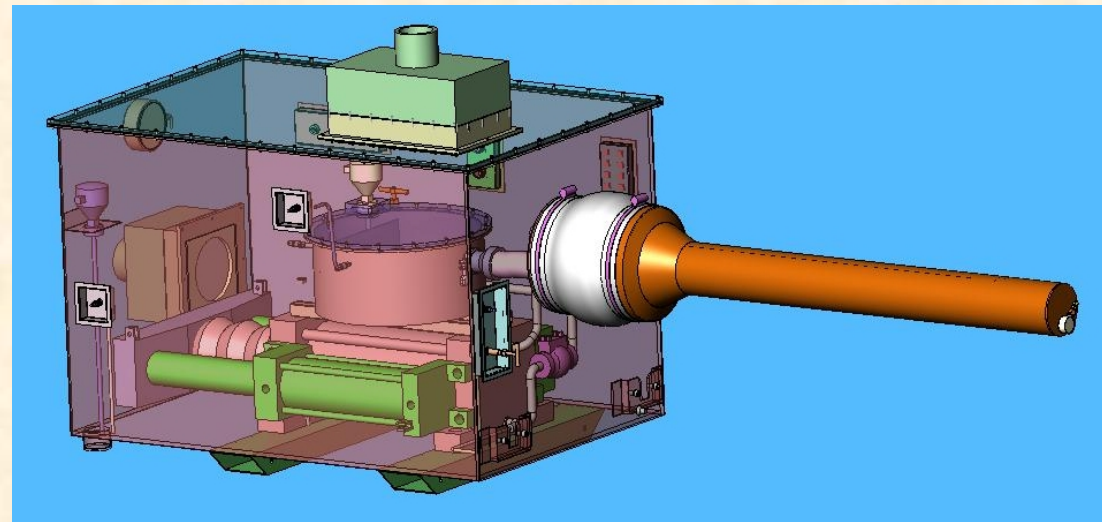
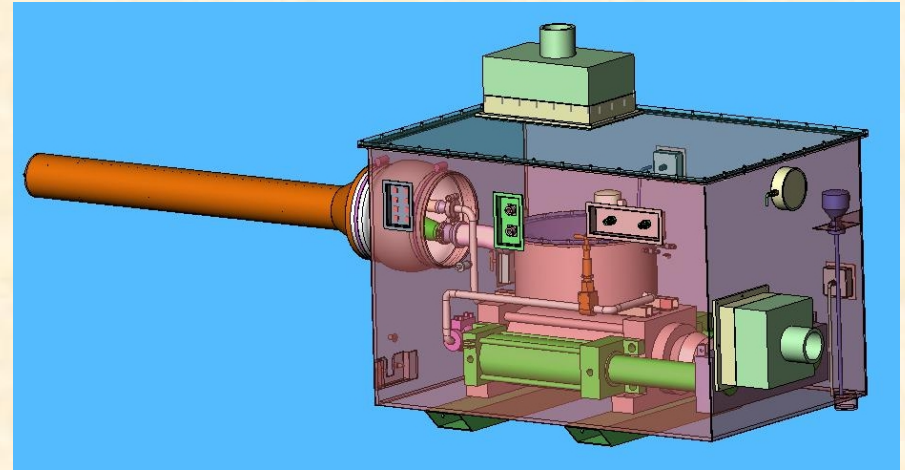
Geometry of the Interaction Region

- Horizontal proton beam
- Magnet axis to beam is 67 milliradians
- Jet to beam is 33 milliradians
 - *Recent change: Jet now starts above beam*
- The jet centerline crosses the beam center at Z=0 (center of the solenoid)
- 7 milliradian horizontal beam kick



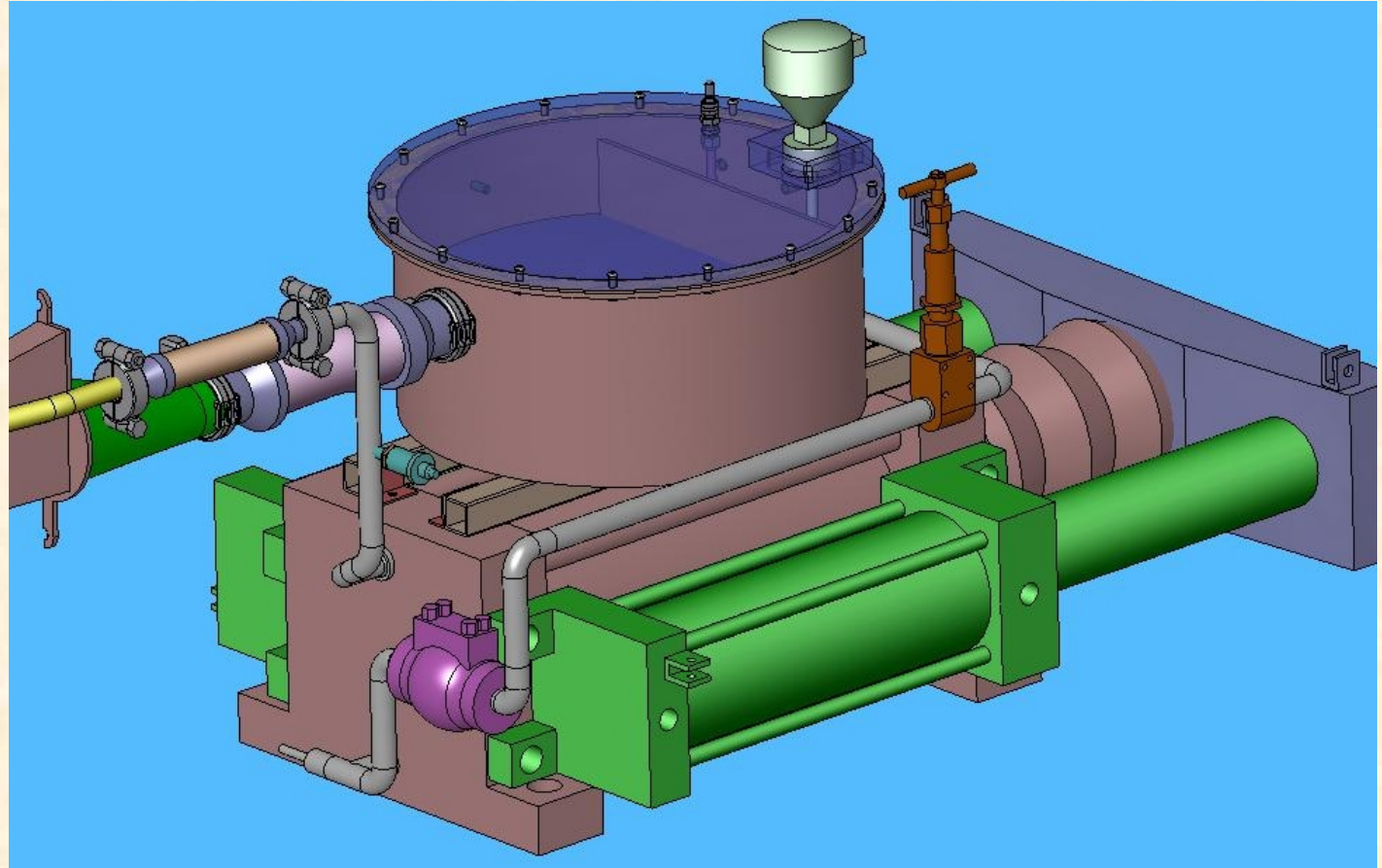
Hg Delivery System

- Capacity 23liters Hg (~760 lbs)
- Provides 1cm dia, 20m/s jet for up to 12 sec
- Secondary containment box approximately 1m x 1m x 1.5m
- Estimated weight 2T with Hg



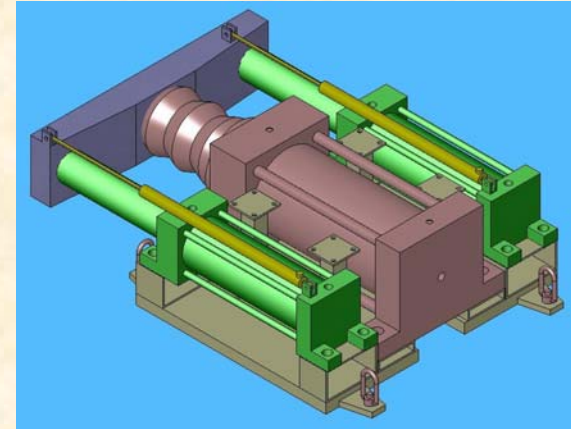
Hg Syringe Performance

- Hg flow rate
1.6liter/s
(24.9gpm)
- Piston
velocity
3.0cm/s
(1.2in/sec)
- Up to 103 bar
(1500 psi) Hg
pressure in
cylinder
- Hg cylinder
force 525kN
(118kip)

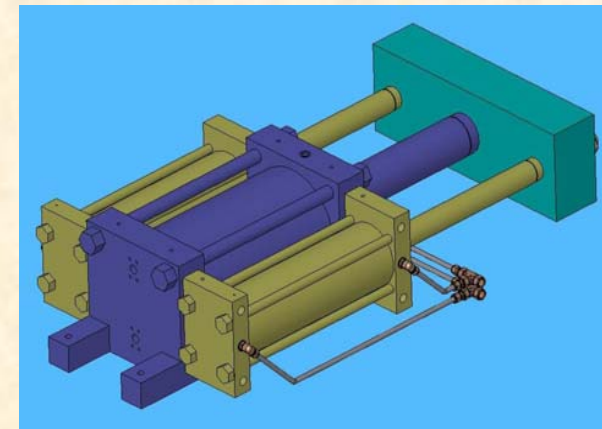
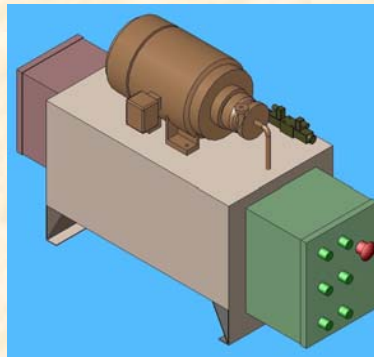


Syringe Procurement

- Awarded to Airline Hydraulics (HQ Bensalem, PA)
- Complete system design based on specified requirements
- Piston pump (inside secondary containment)
 - One 10-inch Hg Pump Cylinder
 - Two 6-inch Drive Cylinders with integrated position sensors
 - Tie beam
 - Hydraulic hoses inside secondary for operating Drive Cylinders
- Hydraulic pump (outside secondary containment)
 - Pump, motor, reservoir
 - Proportional, directional control valve
 - Hydraulic hoses between pump & secondary containment
 - Motor controller
 - Variable voltage transformer for U.S. and European operation
- Hydraulic fluid (drum)
- Integration of system components
- System testing with water
- **Expected delivery Feb/Mar 2006**



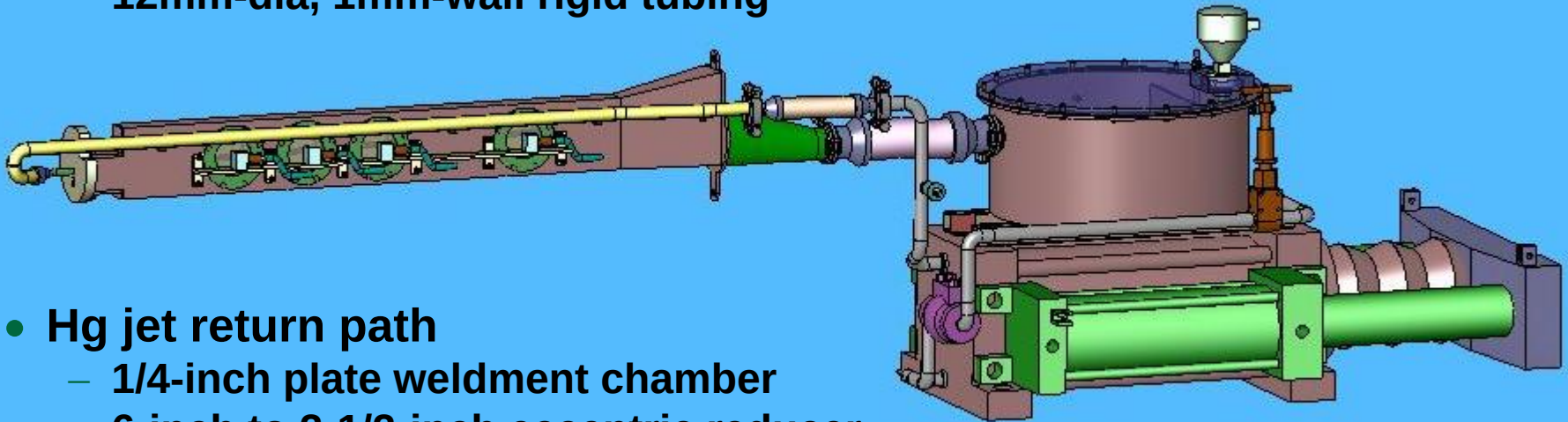
Original Concept



From Vendor

Primary Containment

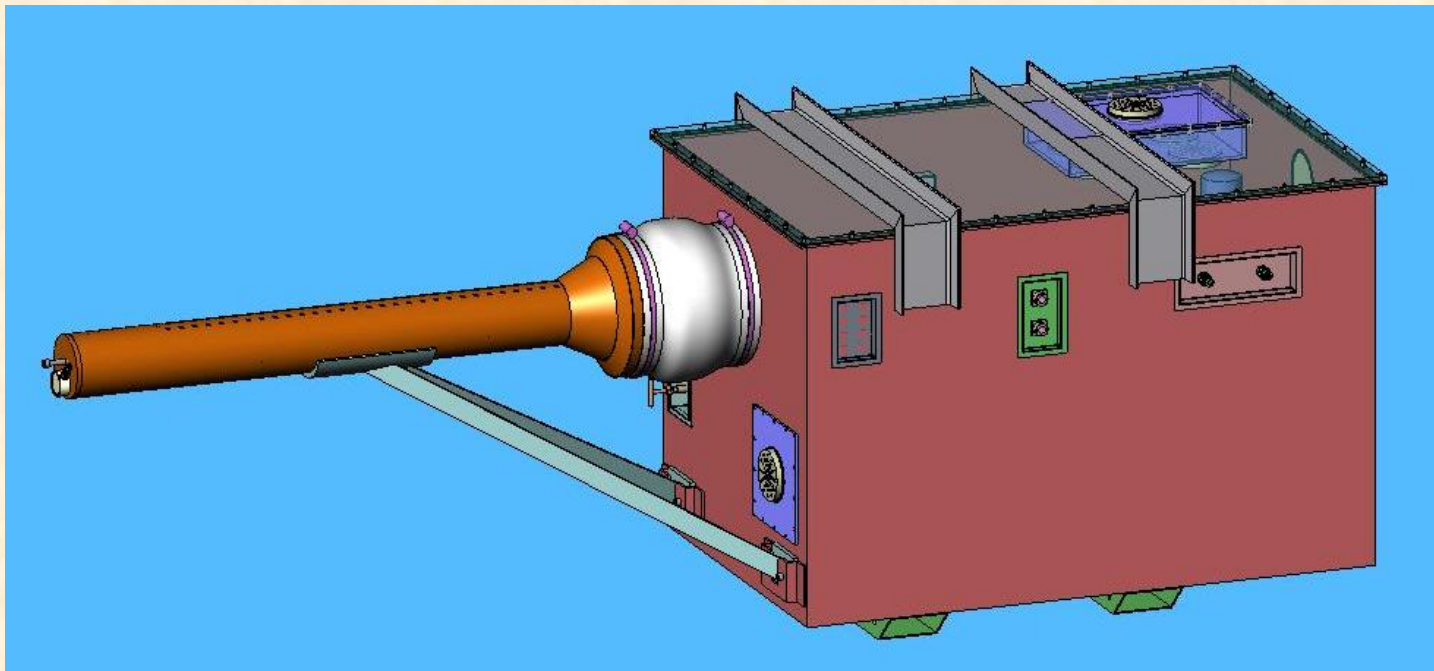
- Hg supply flow path
 - 1-inch Sch 40 pipe
 - 1-inch flex metal hose w/sanitary fittings
 - 1-inch, 0.065-wall rigid tubing
 - 12mm-dia, 1mm-wall rigid tubing



- Hg jet return path
 - 1/4-inch plate weldment chamber
 - 6-inch to 2-1/2-inch eccentric reducer
 - 2-1/2-inch flex metal hose w/sanitary fittings
 - Sump tank

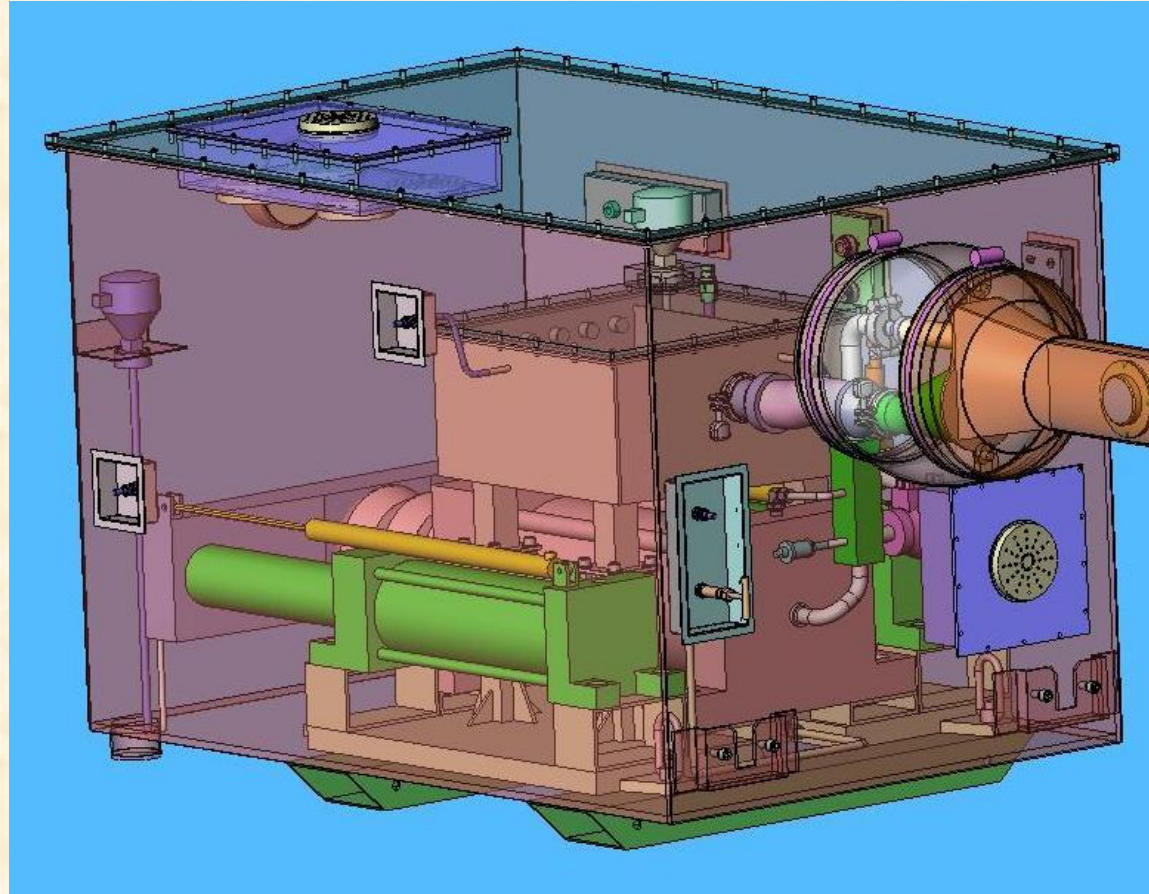
Secondary Containment

- SS304L/316L 1/2" bottom plate, 1/4" sides
- Flexible sleeve (non-metallic, combustibility issue)
- SS304L/316L cylindrical sleeve (13ga, 0.089")
- Passive filtration
 - Filtered inlet and outlet, normally capped
- **Final sizing to be completed once models from syringe vendor received**



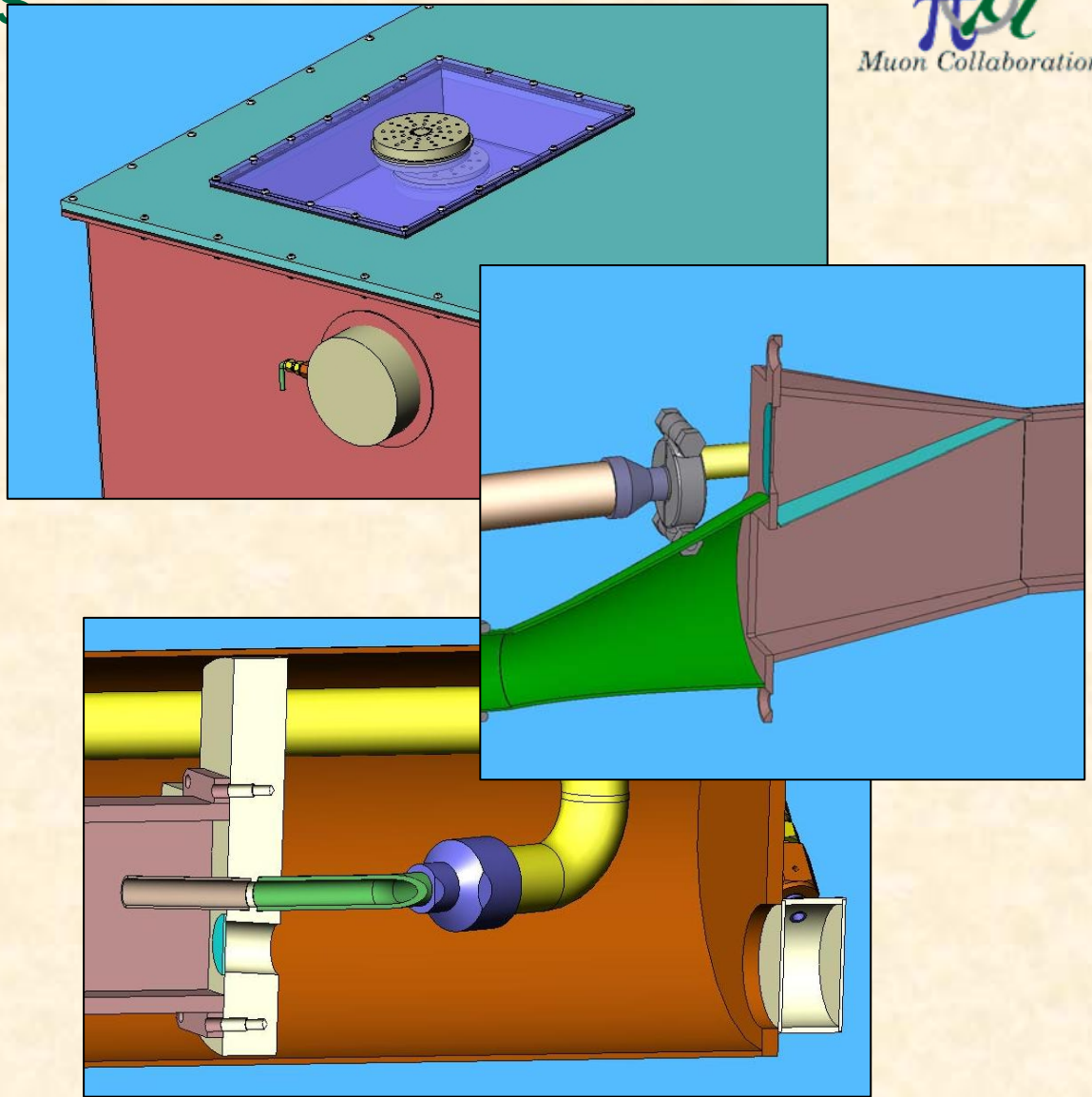
Secondary Containment Ports

- Optical diagnostics
- Instrumentation
- Hydraulics
- Hg drain & fill (without opening secondary)
- Hg extraction (in event of major leak in primary containment)
- Two filtered ventilation ports



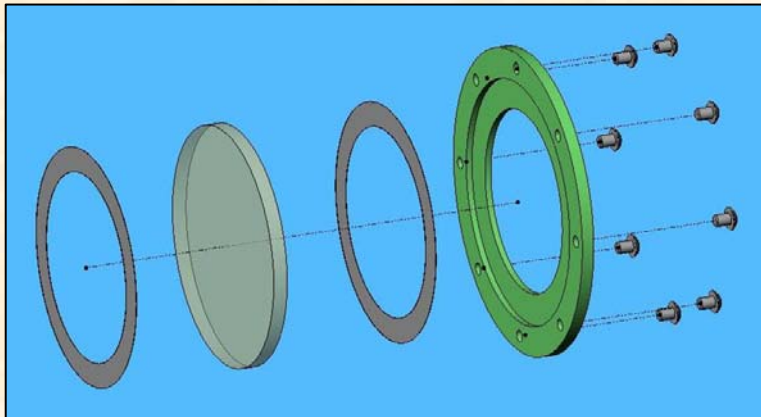
Beam Windows

- Currently have a simple, flexible beam window concept fabricated from titanium alloy
- Welded attachments provide more usable space for beam
- Single windows for primary containment, double windows for secondary
- Pressurize or evacuate secondary windows, monitor to detect failure

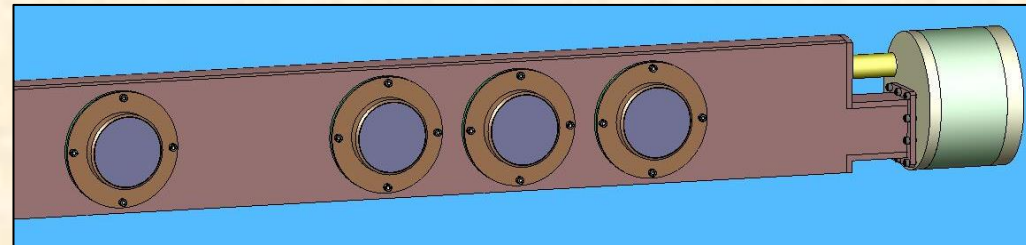
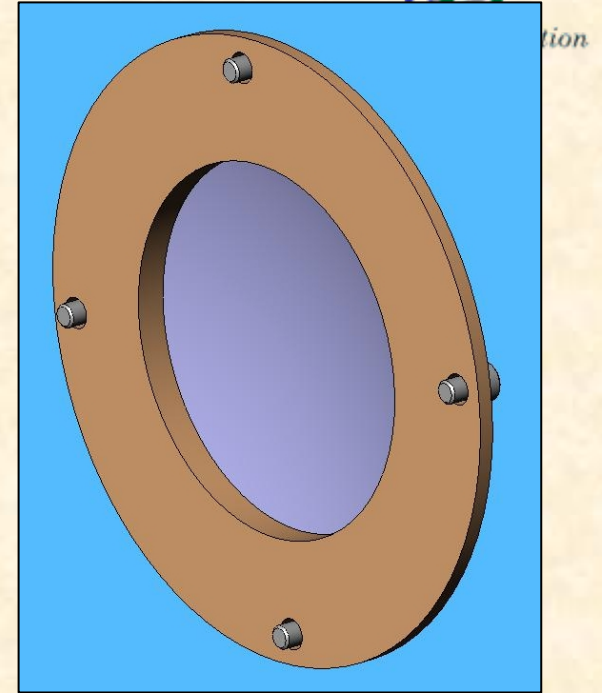


Optical Viewports

- 100mm-dia, 6mm-thick sapphire disks
- Face seals
- Mechanical fasteners
- One set of windows configured for reflector assemblies



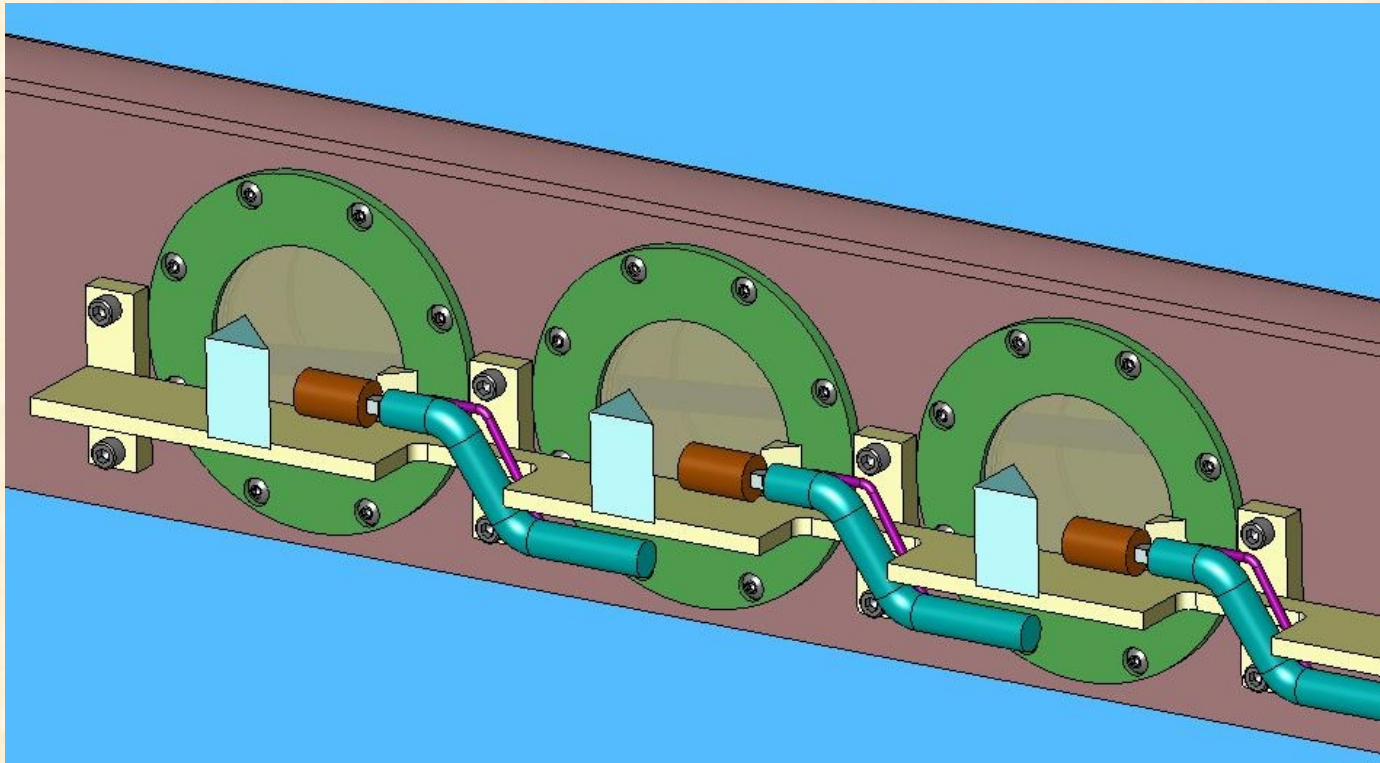
Viewport Assemblies



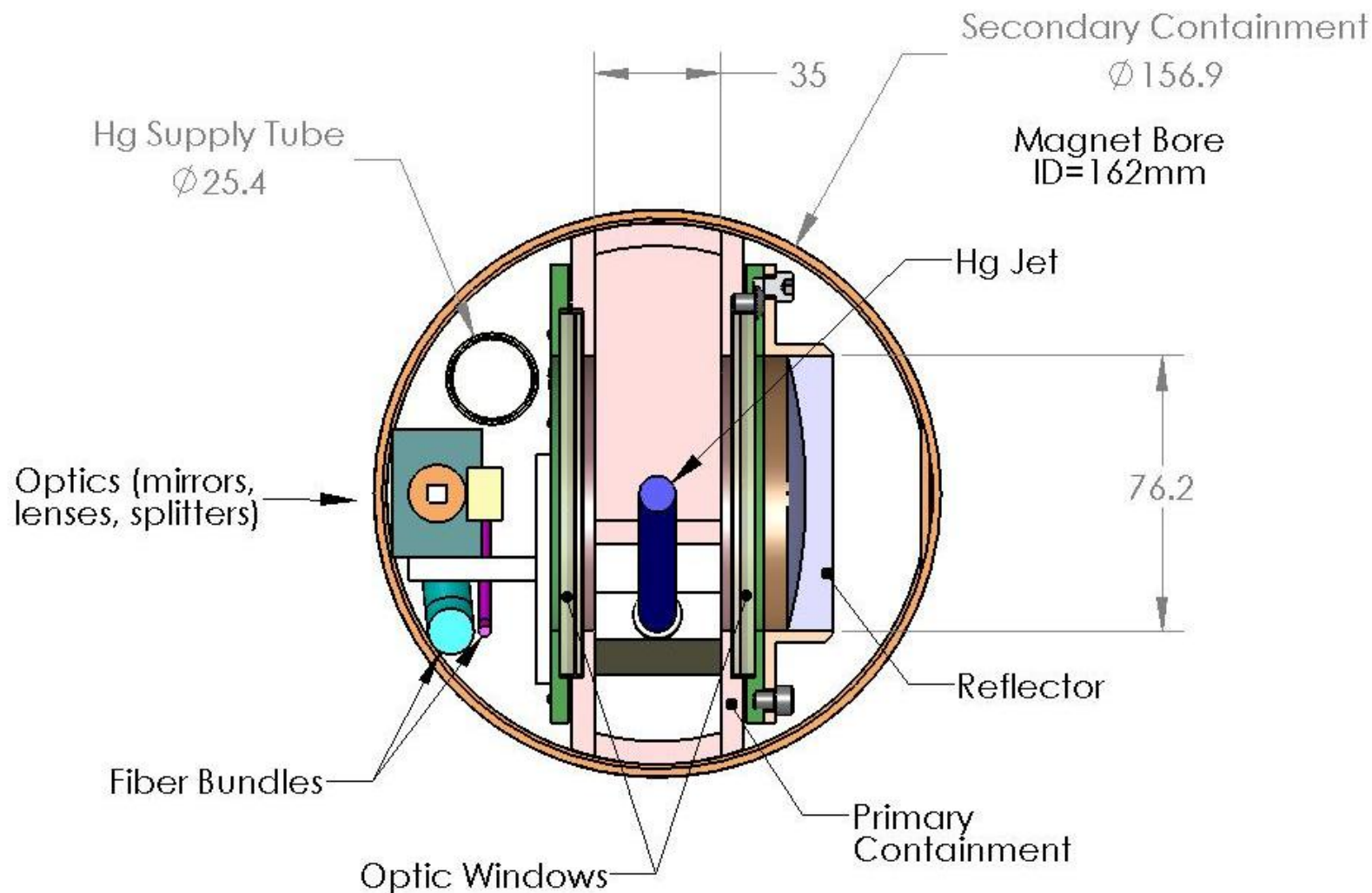
Reflector Assemblies Mounted on Viewports

Optical Components

- BNL to provide splitters, prisms, lenses, bracket, mounting hardware & adjustment mechanisms

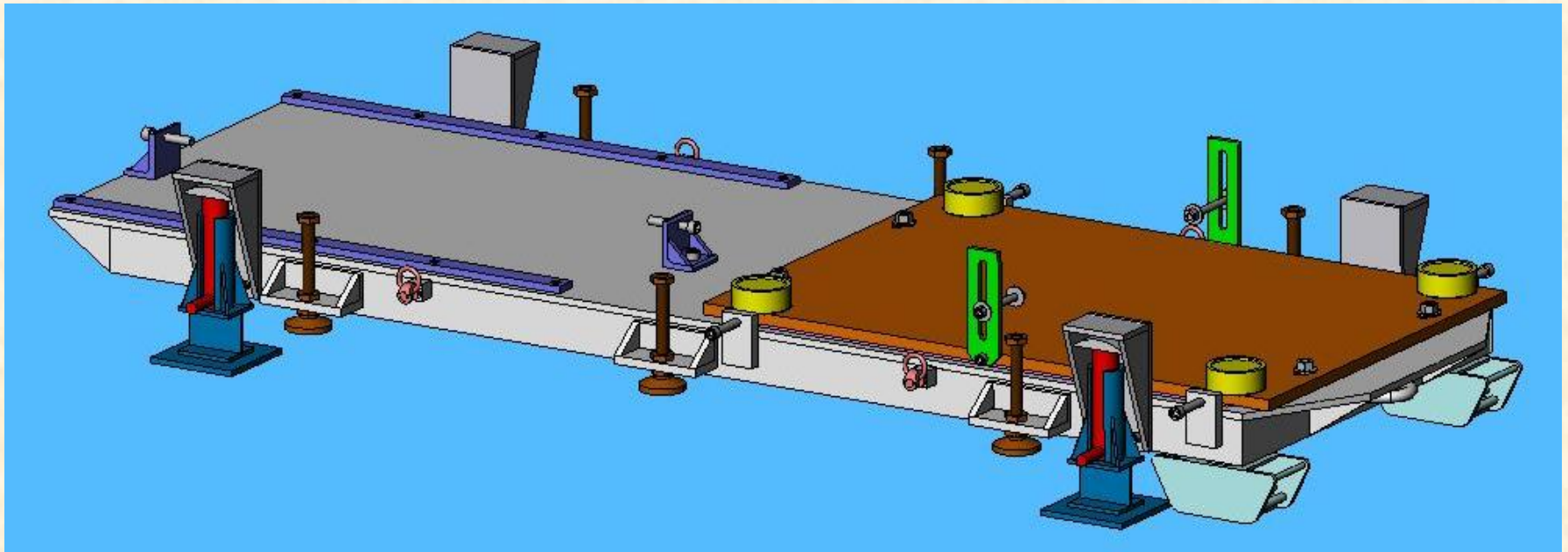


Z=0 Section Cut



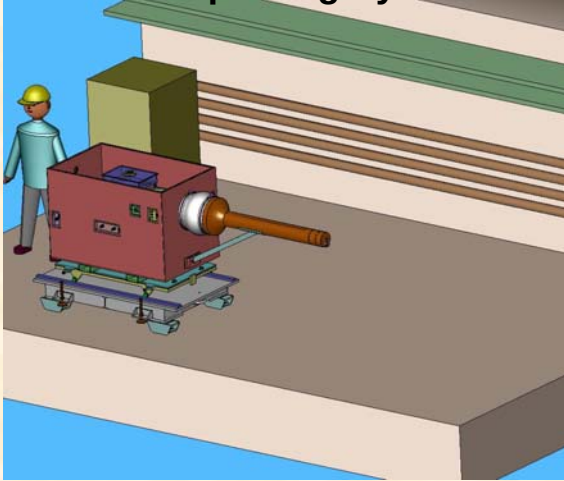
Common Baseplate

- Supports both magnet and Hg system
 - O/A length 3.15m (124")
- Rollers used to grossly align solenoid to beam
- Provides lateral movement of solenoid for alignment to beam once rollers removed

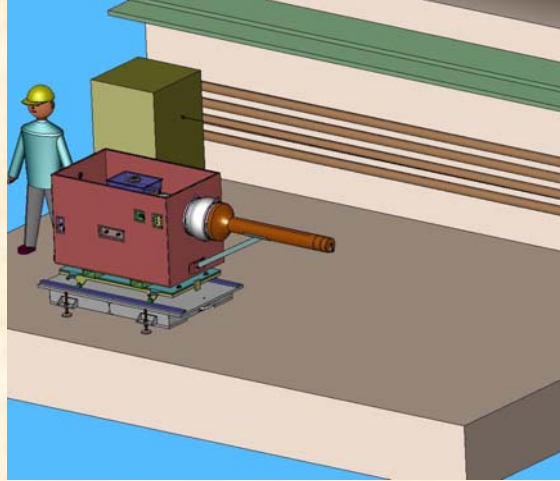


Installation Sequence

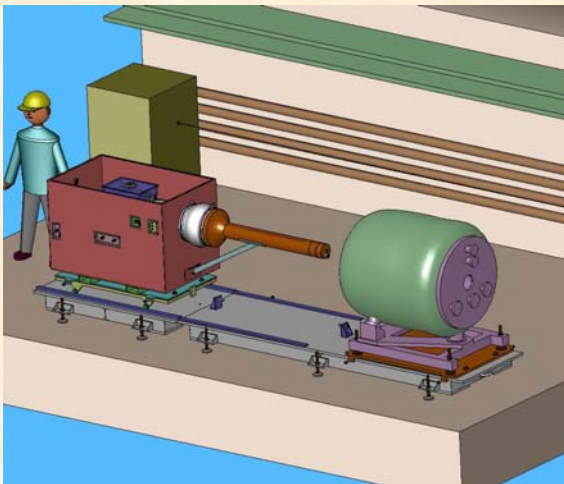
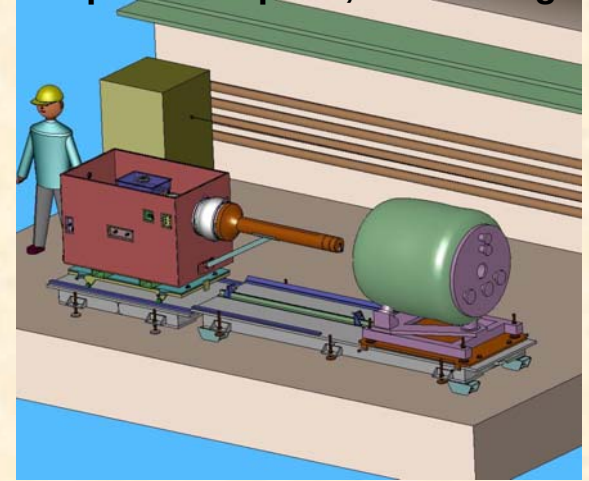
Transport Hg System



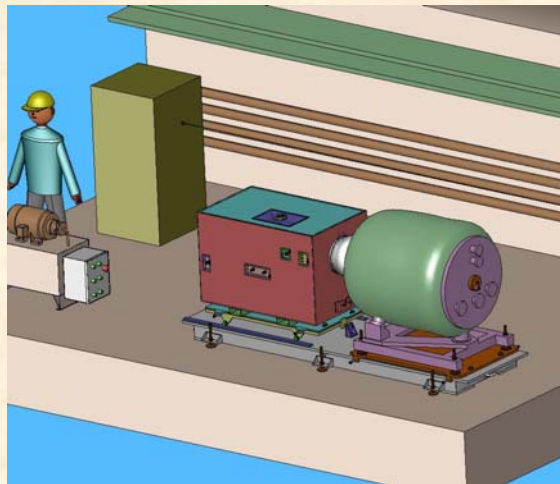
Remove Rollers



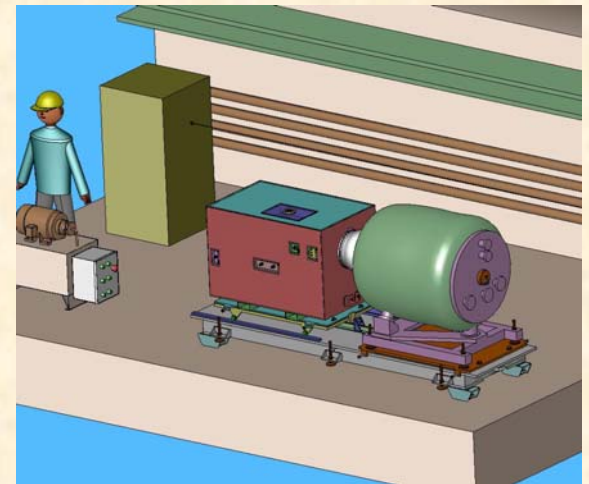
Transport Baseplate, Install Magnet



Remove Rollers, Level Magnet



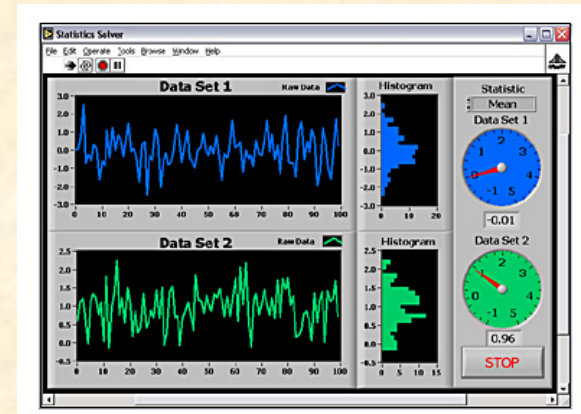
Roll Hg System into Magnet



Add Rollers

LabView-Based Control System

- Remote control over long distance
limited choices
 - Analog I/O modules need to be close to equipment and power supplies
- LabView controller on laptop computer was chosen
 - National Instruments recommends CompactPCI I/O modules
 - Communicates to laptop via EtherNet cable
 - Custom operator interface will be develop
 - Should allow straightforward integration with other control systems



Instrumentation & Sensors

Controlled Components			
Hydraulic pump	Proportional control valve*	Heater foil	
Analog Sensor Inputs			
Hg discharge pressure	Hg level	Hg sump thermocouple	Secondary containment thermocouple
Cylinder 1 position*	Cylinder 2 position	Hg vapor 1	Hg vapor 2
Hydraulic fluid high pressure	Hydraulic fluid low pressure	Beam window 1 pressure*	Beam window 2 pressure*
Digital Sensor Inputs			
Hydraulic filter dirty switch	Hydraulic low level switch	Conductivity probe	

*** Critical for system operation or safety**

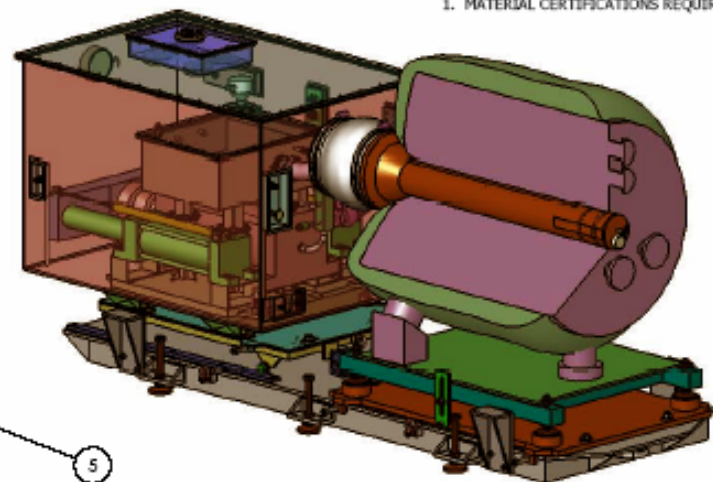
Primary Containment - \$12K

Secondary Containment - \$14K

Target Cart - \$3K

Target
Transporter - \$5K

Common Baseplate - \$22K
(includes magnet
support beam)



6	1	target transporter assy h/j	---	TRANSPORTER BASEPLATE ASSY	203-HJT-0000
5	1	magnet assy h/j	---	PROVIDED BY MLL	---
4	1	hg delivery system h/j	---	HG DELIVERY SYSTEM	203-HJT-0500
3	1	magnet end support h/j	---	USED TO RAISE MAGNET END	203-HJT-0400
2	1	cart assy h/j	---	TARGET CART ASSY	203-HJT-0300
1	1	common base assy h/j	---	---	203-HJT-0100
ITEM	for dwg with count/QTY.	NAME	MATERIAL	DESCRIPTION	DWG

**THIRD-ANGLE
PROJECTION**

UNLESS OTHERWISE NOTED

- ALL DIMENSIONS ARE IN
INCHES
- INTERPRET DIMENSIONS AND
TOLERANCES PER Y14.5M
- MACHINED SURFACE TO MACHINED
SURFACE
- CONCENTRICITY .010 DIA
- MACHINED ANGLES 21/2°
- FORMED ANGLES 21/2°
- SPECIFIC SHARP CORNERS AND
RADIUS ALL BURS
- REMOVE ALL BURS
- REMOVE NUMBERS AND
FRACTIONS
- 1/16"
- 1/32"
- 1/64"
- 1/128"
- 1/256"
- 1/512"
- 1/1024"
- 1/2048"
- 1/4096"
- 1/8192"
- 1/16384"
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- 1/524288"
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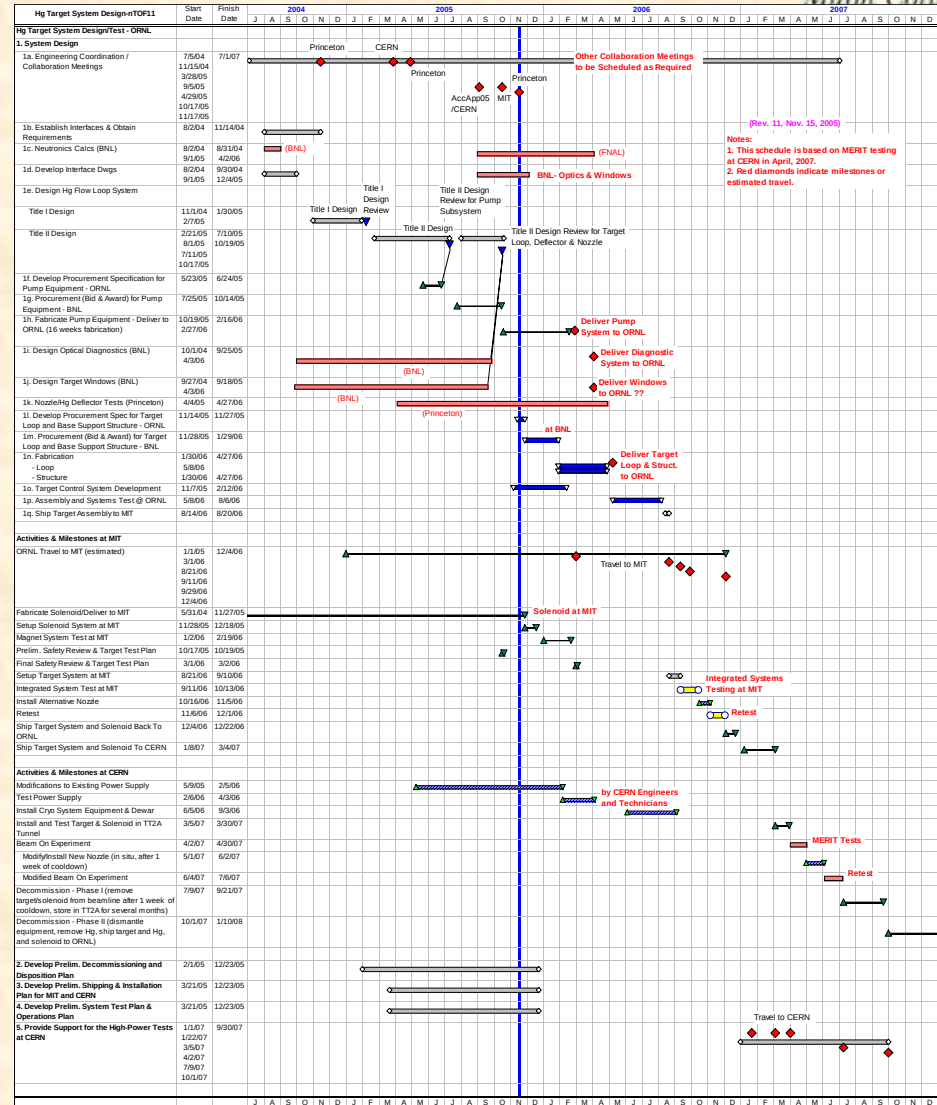
Hg System Costs

- Syringe ~\$80K
- Remaining BNL procurement estimates
 - Fabricated item cost estimates from ORNL fabrication expert (hopefully conservative)
 - Common baseplate (\$22K)
 - Target transporter (\$5K)
 - Target cart (\$3K)
 - Primary containment (\$12K)
 - Secondary containment (\$14K)
 - Miscellaneous equipment incl. jacks, Hilman rollers (\$3K)
 - Total \$60K
- Additional ORNL funding needed for "toolbox" that will travel with equipment to MIT/CERN (includes PPE/safety equipment, etc), also covers costs for some modifications to Hg system uncovered during ORNL testing
 - Requested \$10K
- Crating / shipping costs to transport system to/from MIT
 - Requested \$10K

Schedule – Major Milestones

Highlights

- Solenoid Tests at MIT Jan '06
- Target Tests at ORNL May-Aug '06
- Integrated Tests at MIT Sep-Oct '06
 - Retest, if needed Nov '06
- Beam Tests at CERN Apr '07
 - Retest, if needed Jun '07

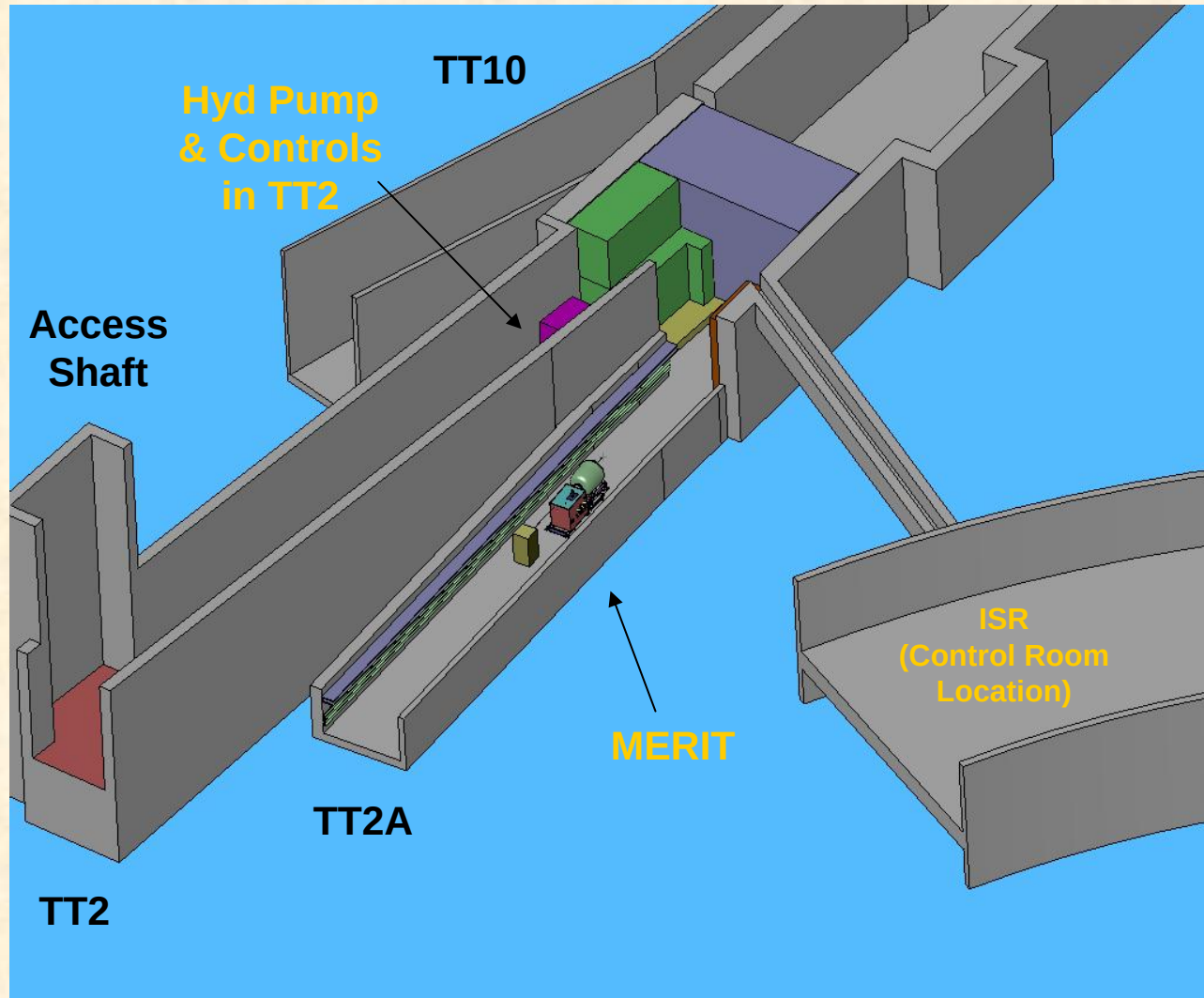


Conclusions

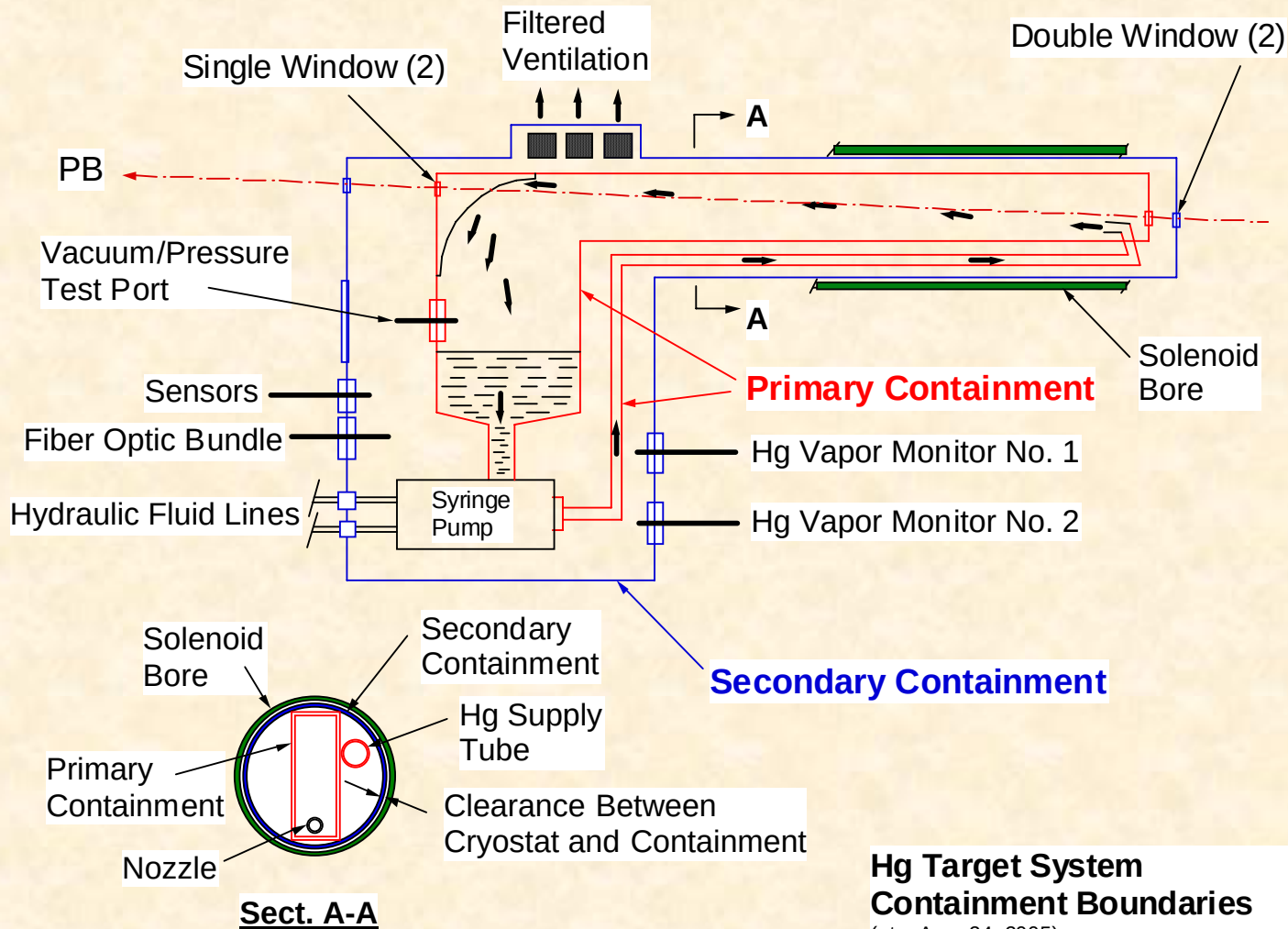
- **Final design details of Hg system must be completed**
 - Nozzle details (position, orientation, length, etc.)
 - Some changes may be required based on Princeton Hg testing
- **Fabrication drawings must be completed soon so procurement process can begin**
 - Baseplate design complete, drawings to be ready by end of year
 - Secondary containment drawings can be finalized now that syringe dimensions are known

Backup Slides

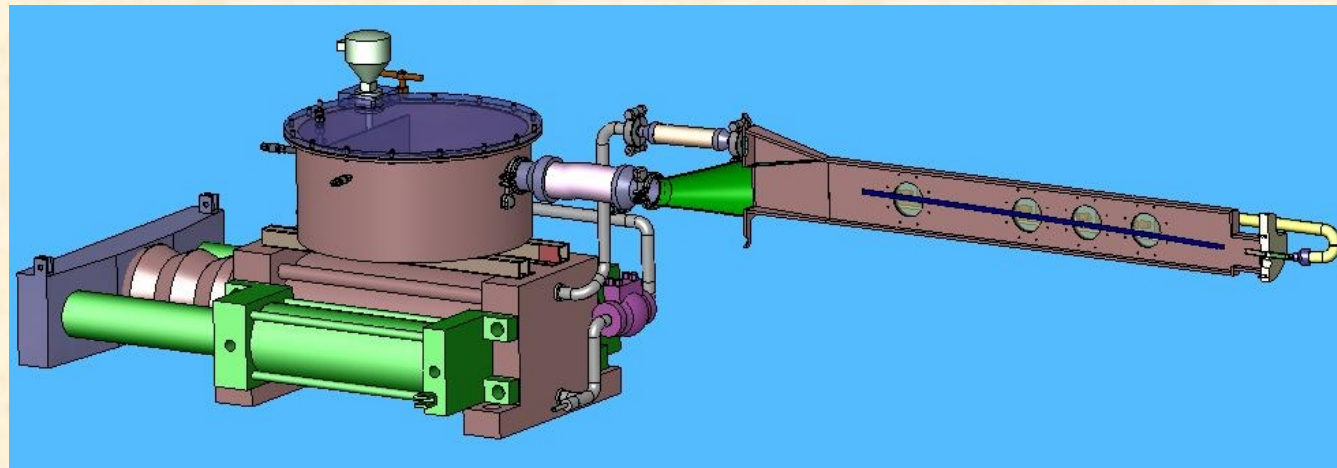
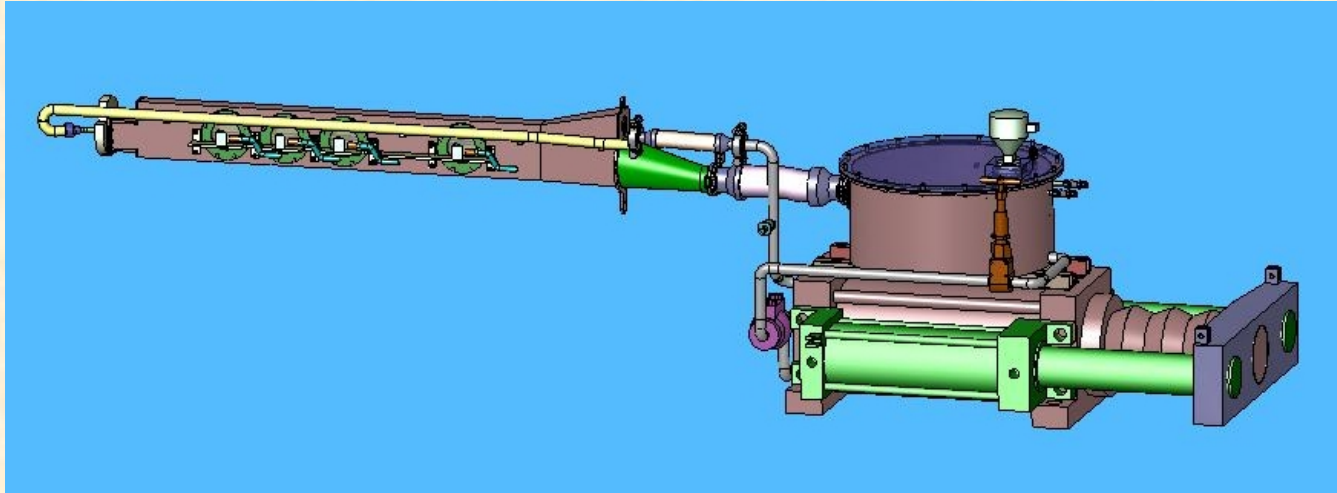
Experiment at CERN



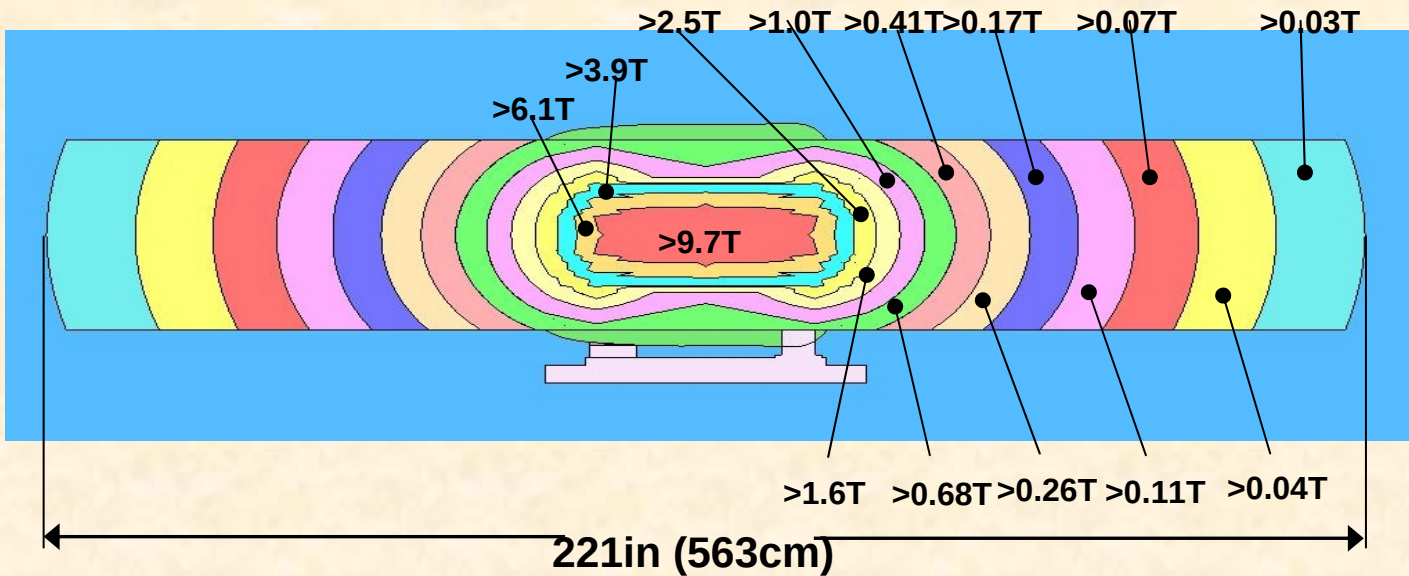
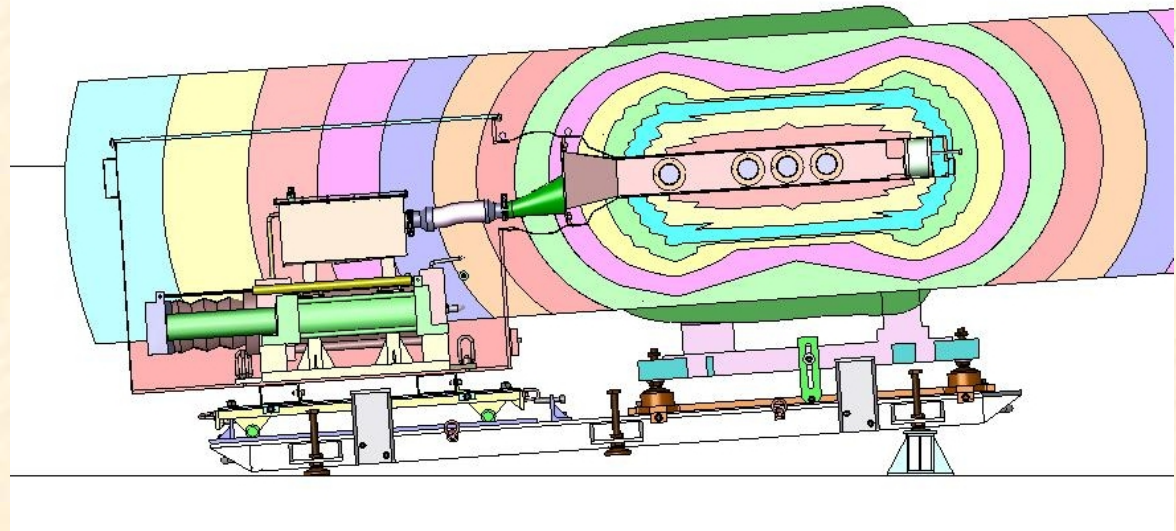
Containment Schematic



Hg Syringe System

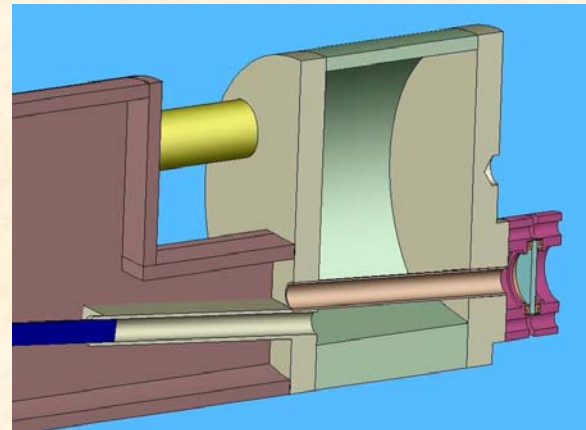
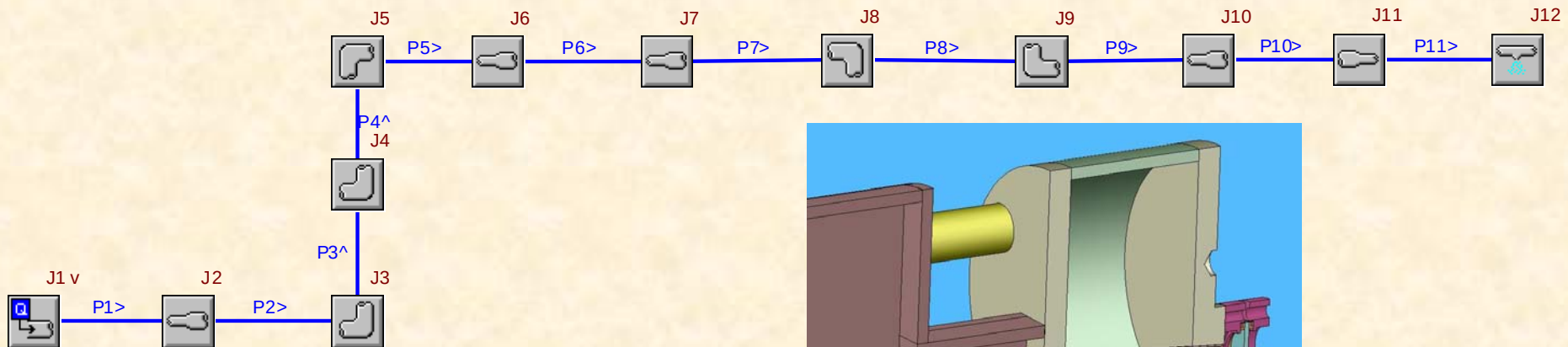


Stray Field Plot



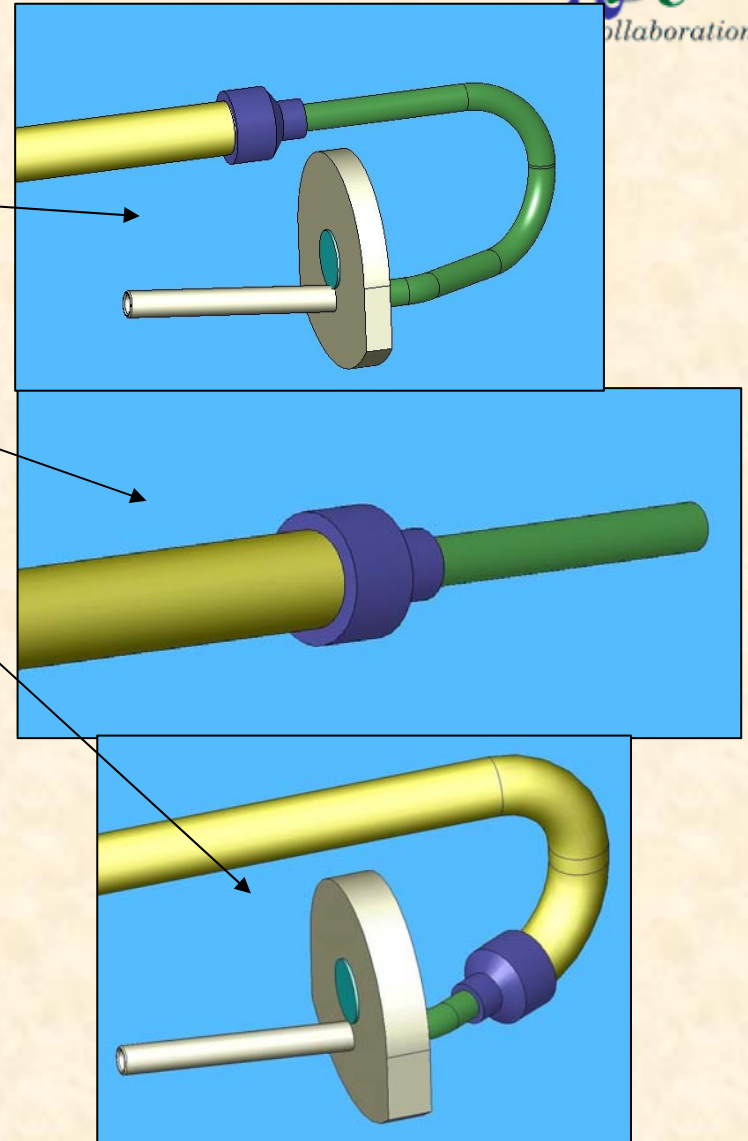
Flow Simulation Using AFT Fathom

- System diagram for Hg flow
- Results indicate maximum pressure requirement of ~780 psi (50 bar) for baseline plenum/nozzle configuration
- Original system design for max Hg pressure of 1000 psig (70 bar)



Other Fathom Simulations

- **1/2" tubing bend**
 - Cylinder pressure 1200 psi (83 bar)
- **No-bend short 1/2" tube**
 - Cylinder pressure 710 psi (48 bar)
- **1" tubing bend**
 - Cylinder pressure 780 psi (54 bar)
- **All 1/2" tubing from end of flex metal hose, no plenum**
 - Cylinder pressure 1910 psi (130 bar)
- **No MHD effects included**
- **Changed system design pressure to 1500 psi (100 bar)**



Secondary Containment Monitoring and Filtering

- Two Hg vapor monitors for secondary volume
- Passive filtration with shutoff, can connect to active filtration system
 - Will have single cartridge rather than respirators
- Third vapor monitor for passive filter exhaust and/or tunnel monitoring
- Investigating whether monitors can be moved away from experiment

Normal Syringe Operations

- **Slowly extend cylinder to fill Hg cylinder from sump**
- **Slowly retract cylinder to starting position & pre-fill Hg supply piping, wait for trigger**
- **Some time after trigger is received, ramp cylinder to full speed**
- **Steady-state jet for 1sec**
- **Ramp cylinder to zero velocity**
 - **Sudden stop can cause flow separation & Hg hammer**

Current Toolbox List

List of Miscellaneous Support Equipment for the Target System

Large Items	Small Items
Vacuum Cleaner	Merc-X Cleaning Solution
Portable Snorkel	Sponges
Spare Filters (qty. TBD)	Plastic Buckets
Glove Box ??	Plastic Pans
Vacuum Pump ??	Gauze – roll
2 Vapor Monitors	Small Tools
Vapor Monitor Calibration Kit	Vinyl Tape
	Herculite
	Plastic Bags – asst'd (1 gal. – 20 gal.)
	1-Liter Plastic Bottles
Hydraulic Fluid – 55 gal. Drum	Lab Coats
	Shoe Covers
	Safety Glasses
	Tyvek Hooded Suits
	Nitrile Gloves
	Full Face Mask/Respirator Cartridges