UT-BATTELLE

MERIT Hg System Design

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MERIT Review Meeting

Brookhaven National Laboratory

Dec 12, 2005

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Outline

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

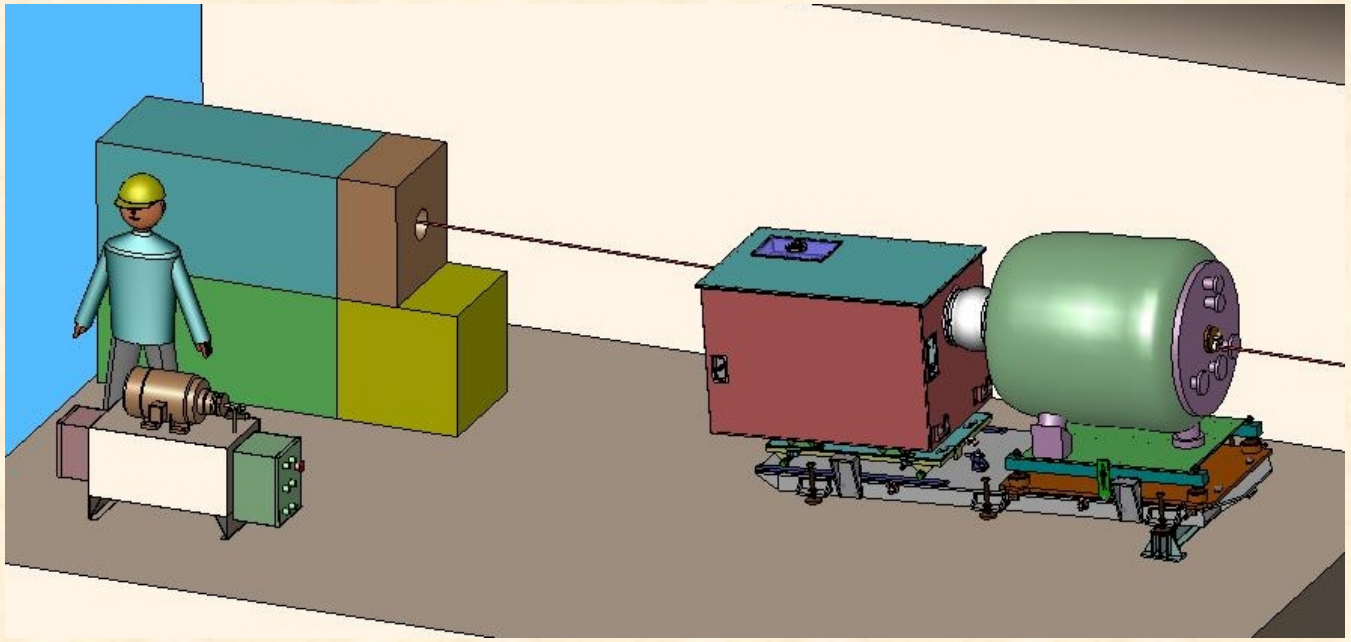
Reqmts and Operating Conditions:

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

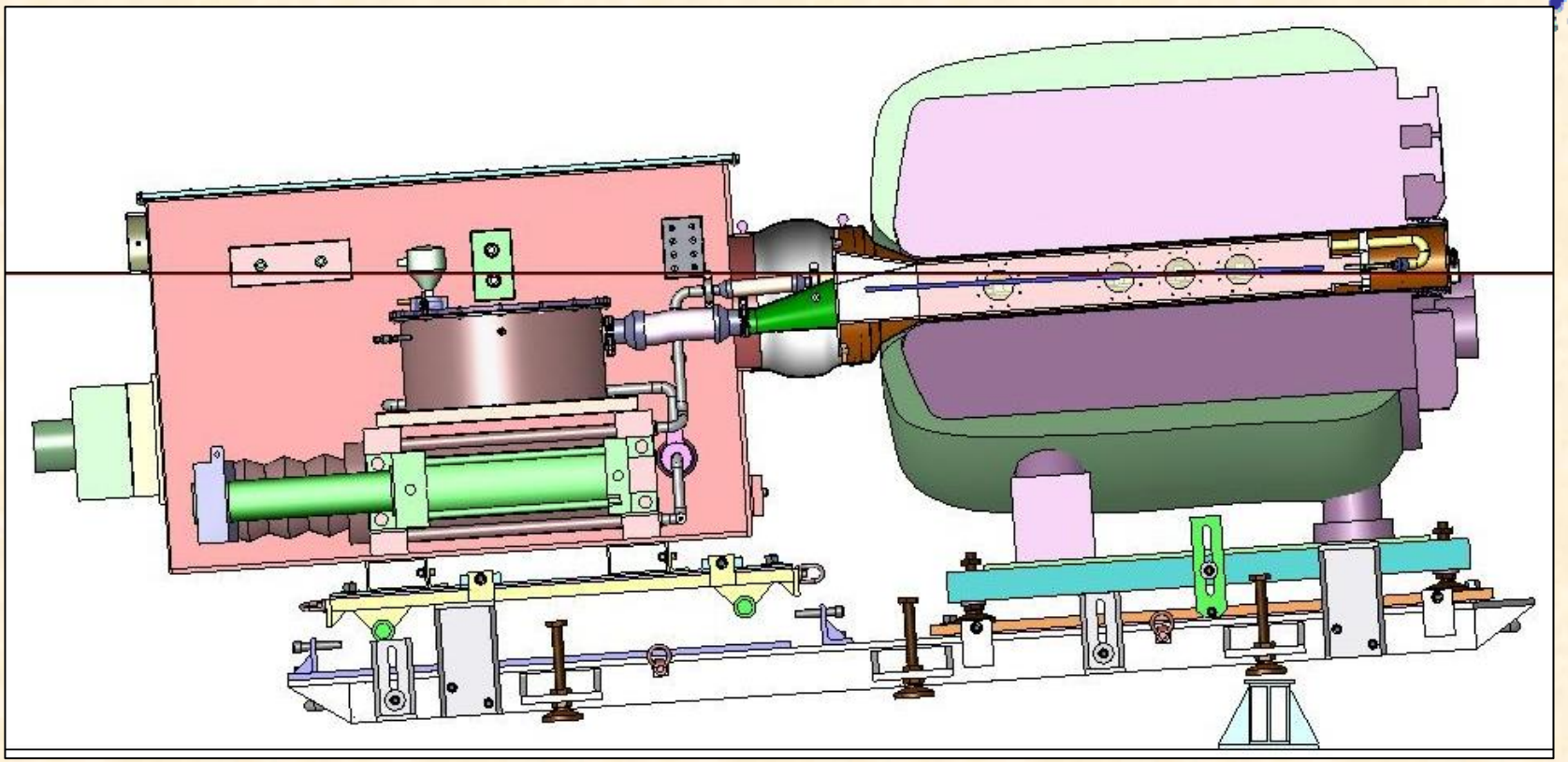
- **1-cm diameter jet at 20 m/s delivered every 30 minutes**
  - **Q=1.6liter/s, Re~10^6**
- **>1-sec steady state jet during the magnet peak field**
- **Baseline Hg environment is 1-atm air, also considering running in rough vacuum**
- **Full-beam interaction length is 30-cm**
- **Beam line is 120-cm (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 Tesla = 10^4 Gauss)***

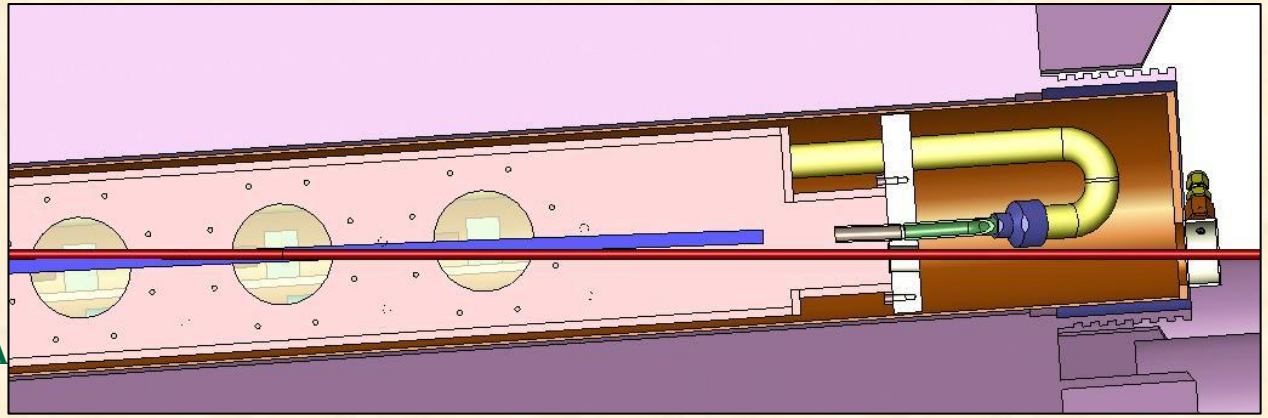
Experiment Layout

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



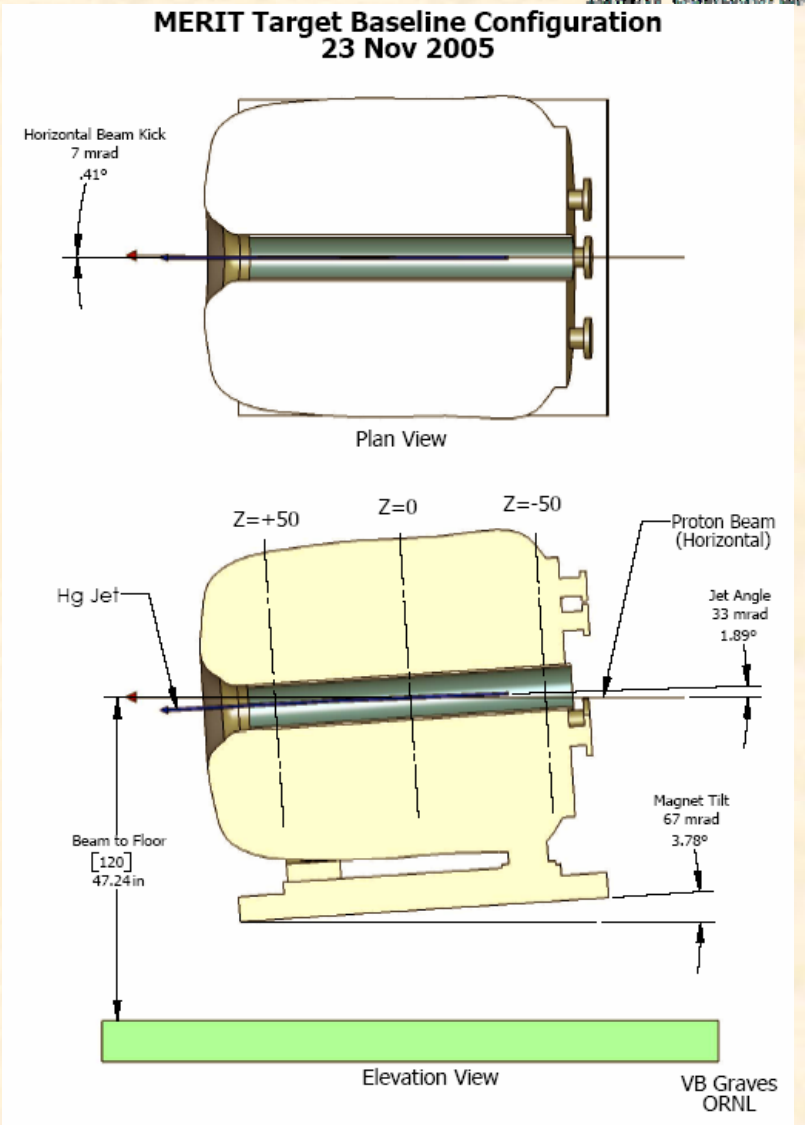
MERIT Side View





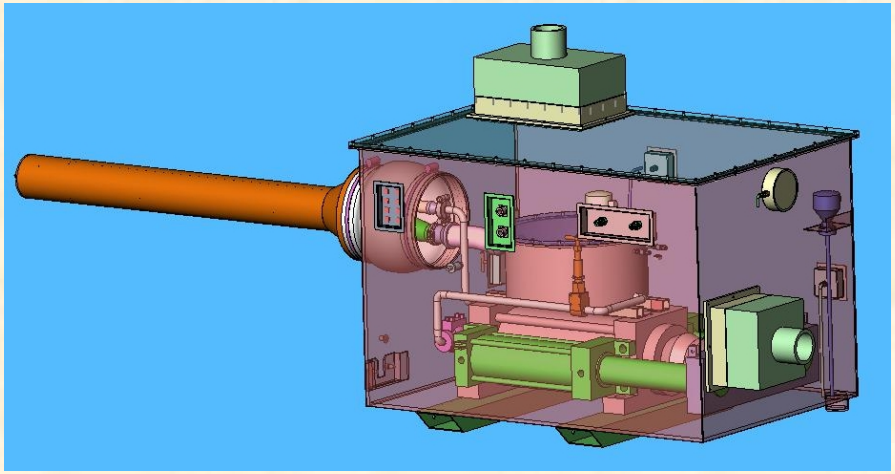
Geometry of the Interaction Region

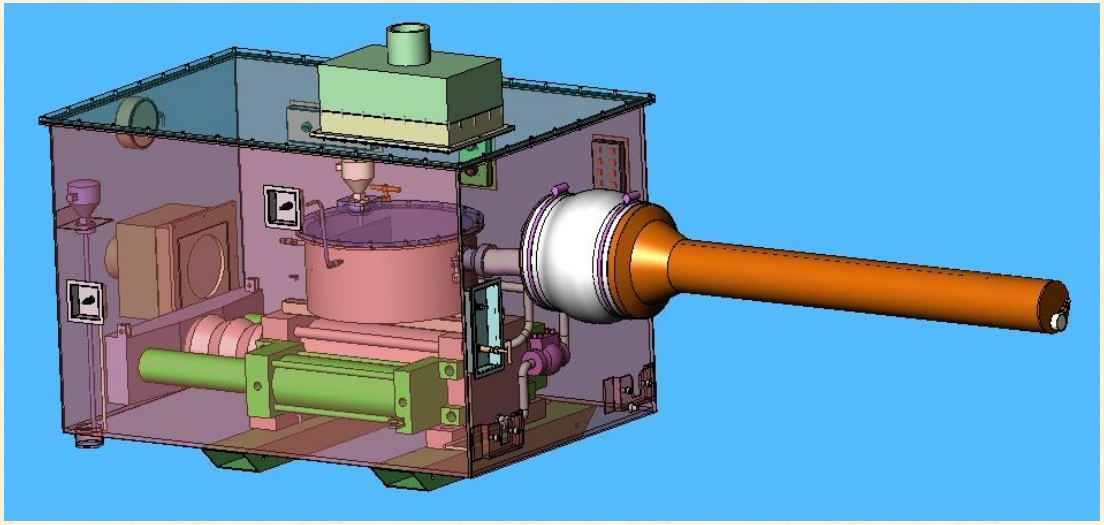
- **Horizontal proton beam**
- **Magnet axis to beam is 67 milliradians**
- **Jet to beam is 33 milliradians**
  - ***Recent change: Jet now starts above beam***
- **The jet centerline crosses the beam center at Z=0 (center of the solenoid)**
- **7 milliradian horizontal beam kick**



Hg Delivery System

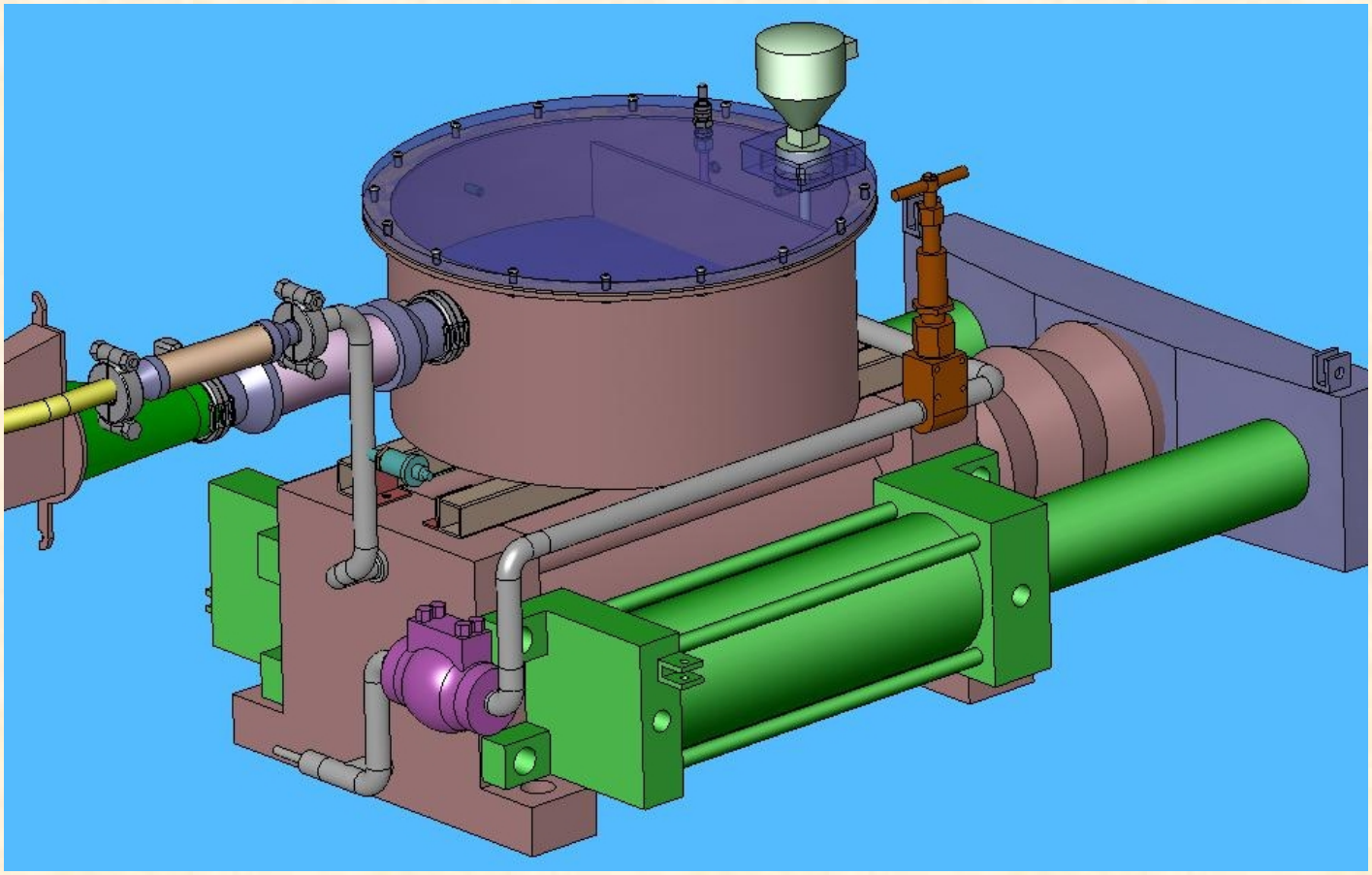
- **Capacity 23liters Hg (~760 lbs)**
- **Provides 1cm dia, 20m/s jet for up to 12 sec**
- **Secondary containment box approximately 1m x 1m x 1.5m**
- **Estimated weight 2T with Hg**





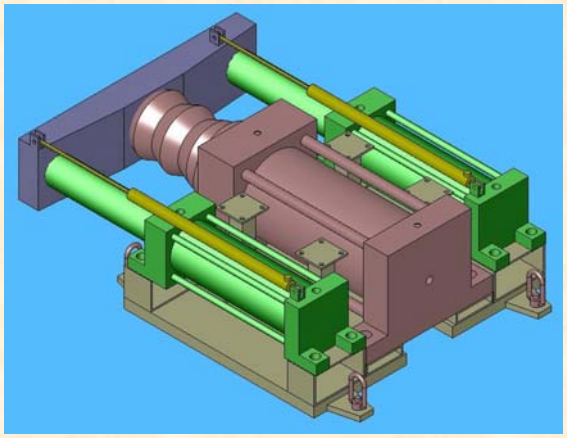
Hg Syringe Performance

- **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)**

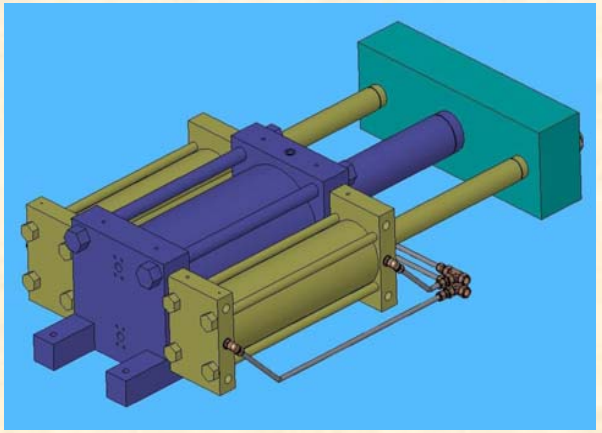


Syringe Procurement

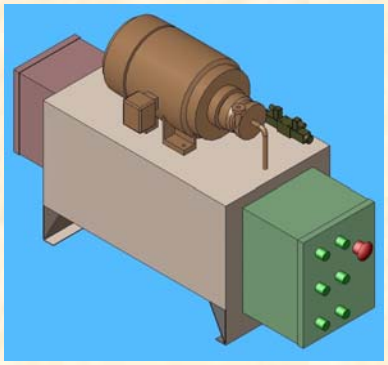
- Awarded to Airline Hydraulics (HQ Bensalem, PA)
- Complete system design based on specified requirements
- Piston pump (inside secondary containment)
  - One 10-inch Hg Pump Cylinder
  - Two 6-inch Drive Cylinders with integrated position sensors
  - Tie beam
  - Hydraulic hoses inside secondary for 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

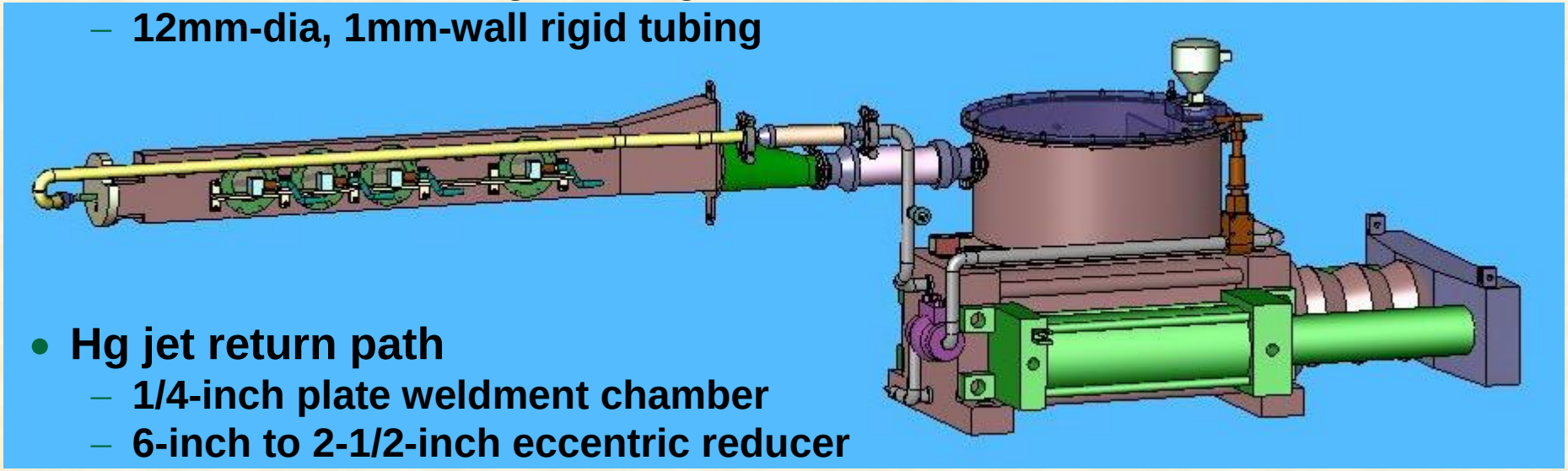


From Vendor



Primary Containment

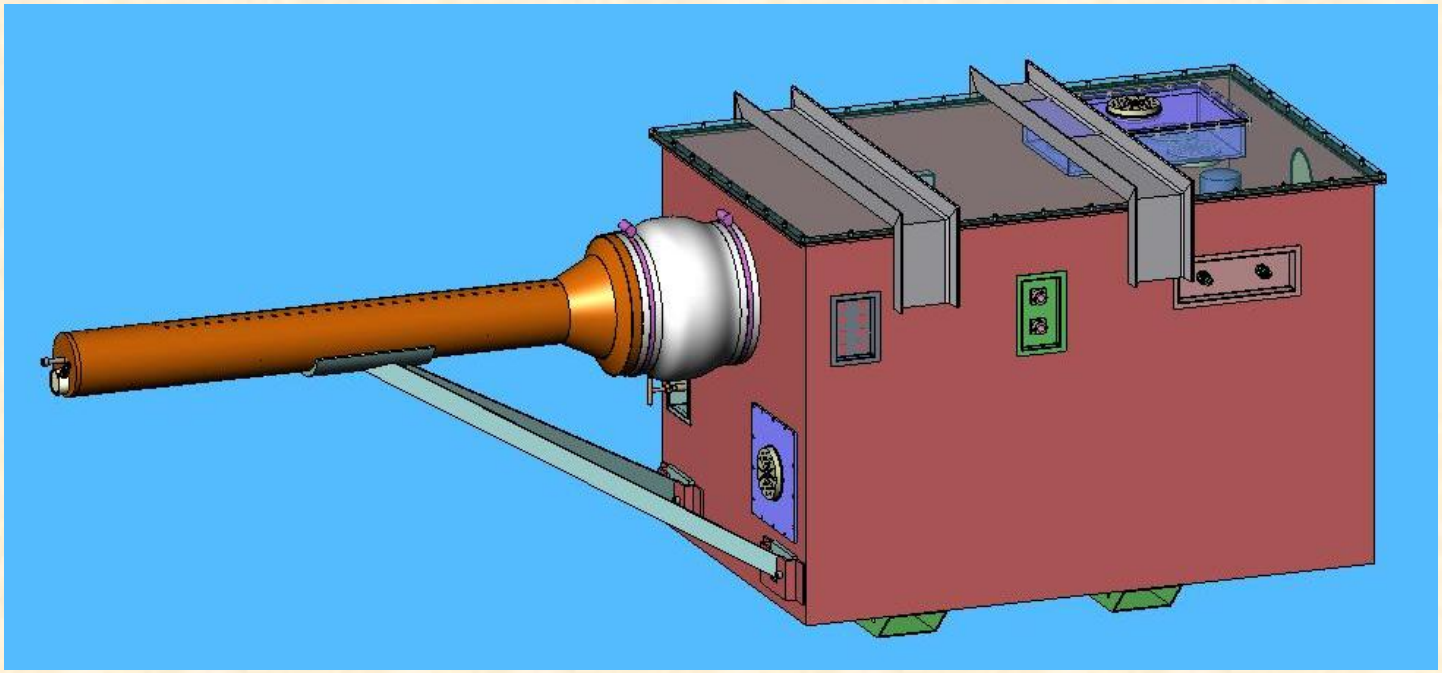
- **Hg supply flow path**
  - **1-inch Sch 40 pipe**
  - **1-inch flex metal hose w/sanitary fittings**
  - **1-inch, 0.065-wall rigid tubing**
  - **12mm-dia, 1mm-wall rigid tubing**



- **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**

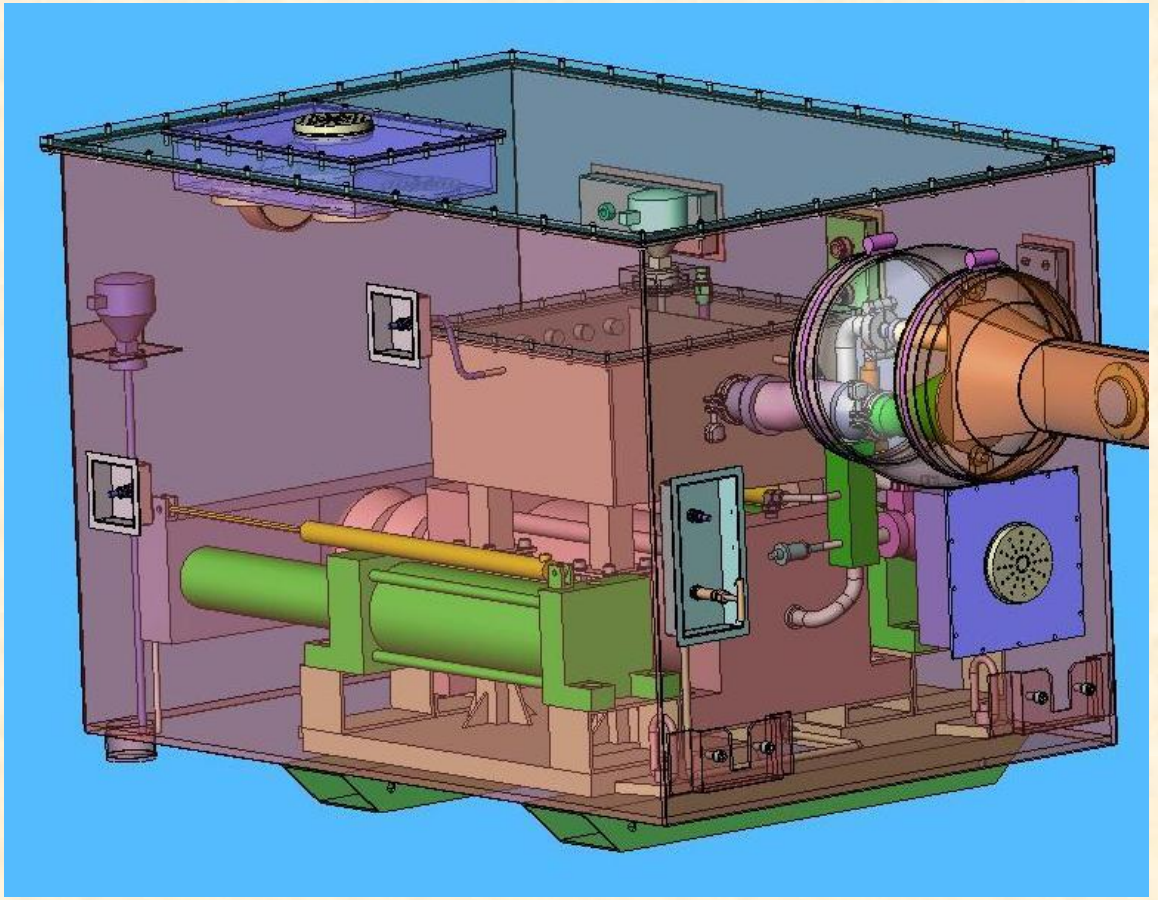
Secondary Containment

- **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**



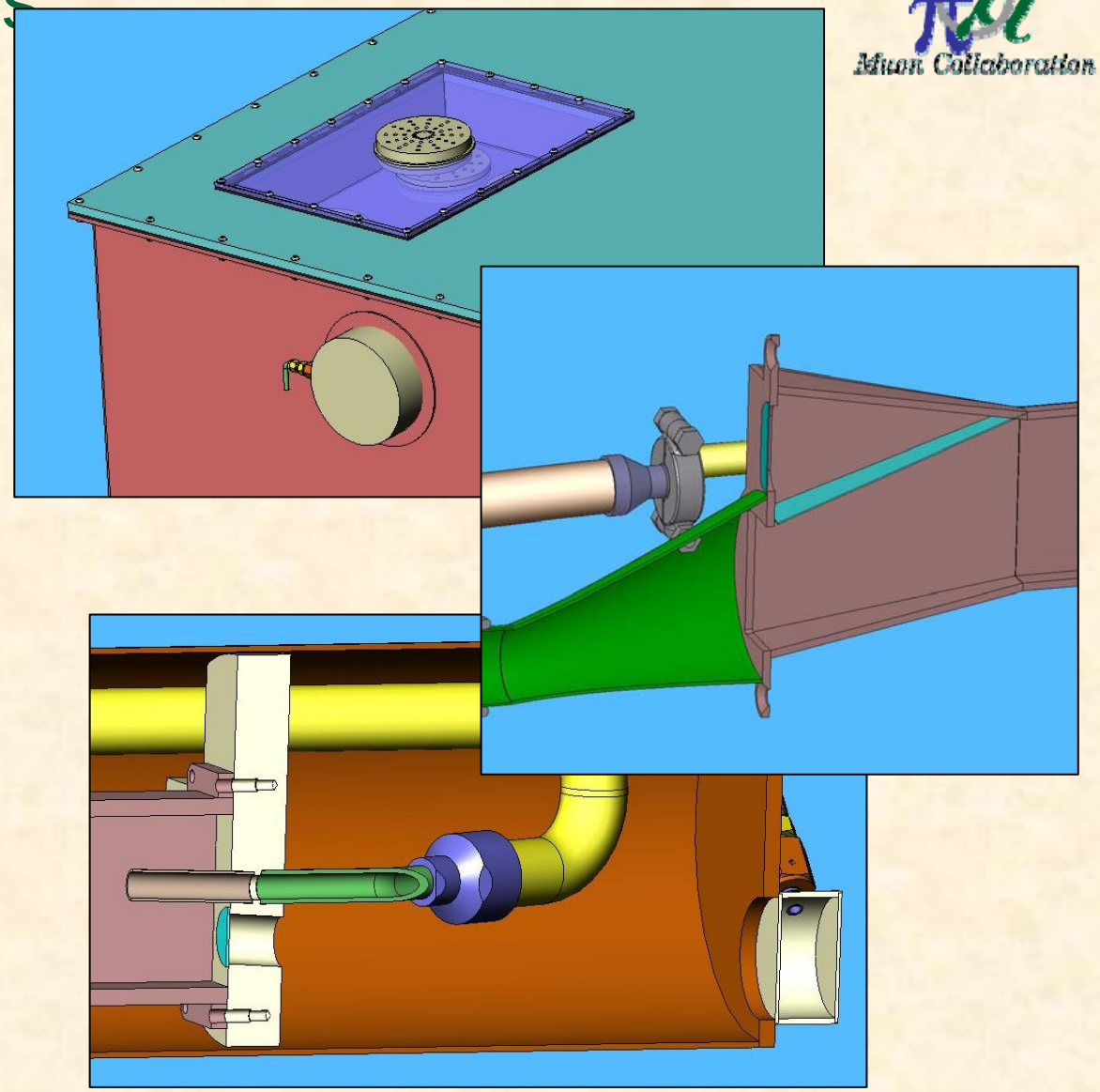
Secondary Containment Ports

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



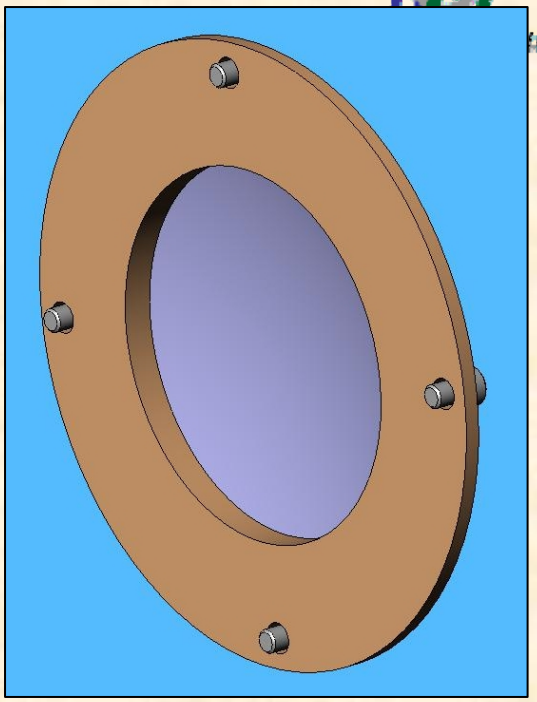
Beam Windows

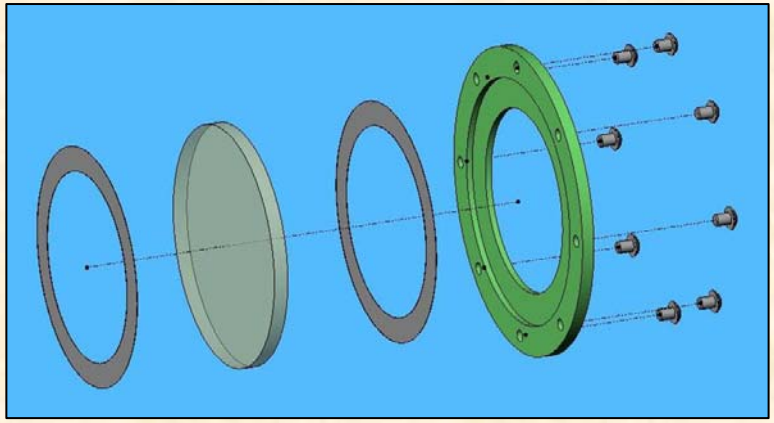
- **Currently have a simple, flexible beam window concept fabricated from titanium alloy**
- **Welded attachments provide more usable space for beam**
- **Single windows for primary containment, double windows for secondary**
- **Pressurize or evacuate secondary windows, monitor to detect failure**



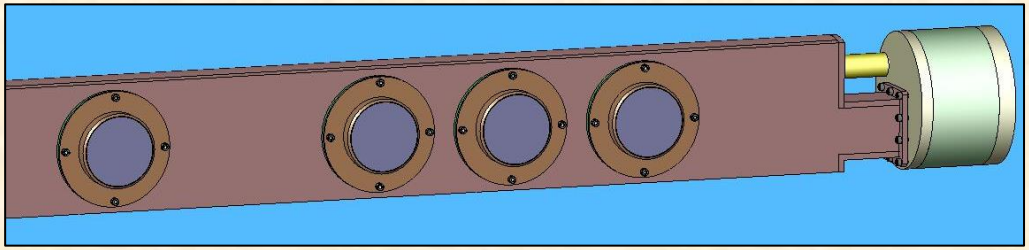
Optical Viewports

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





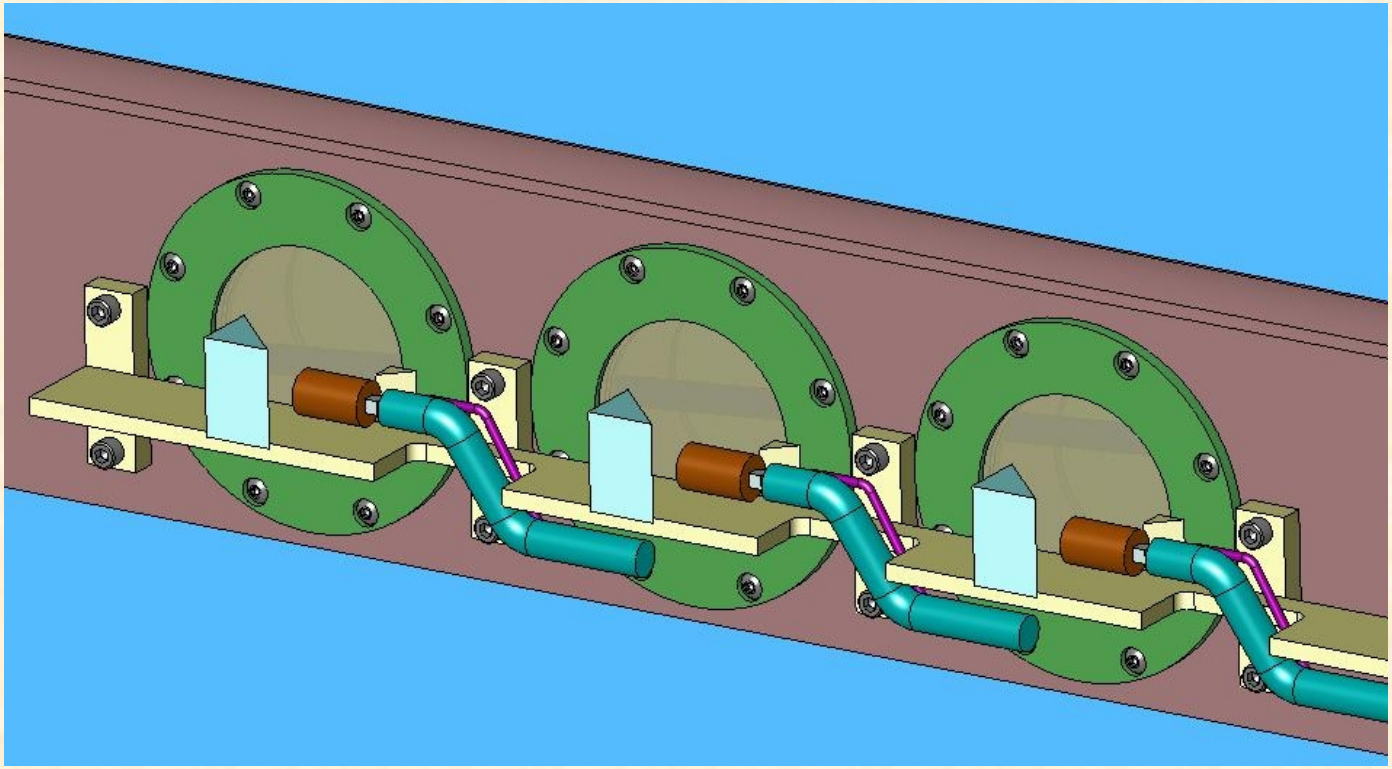
Viewport Assemblies



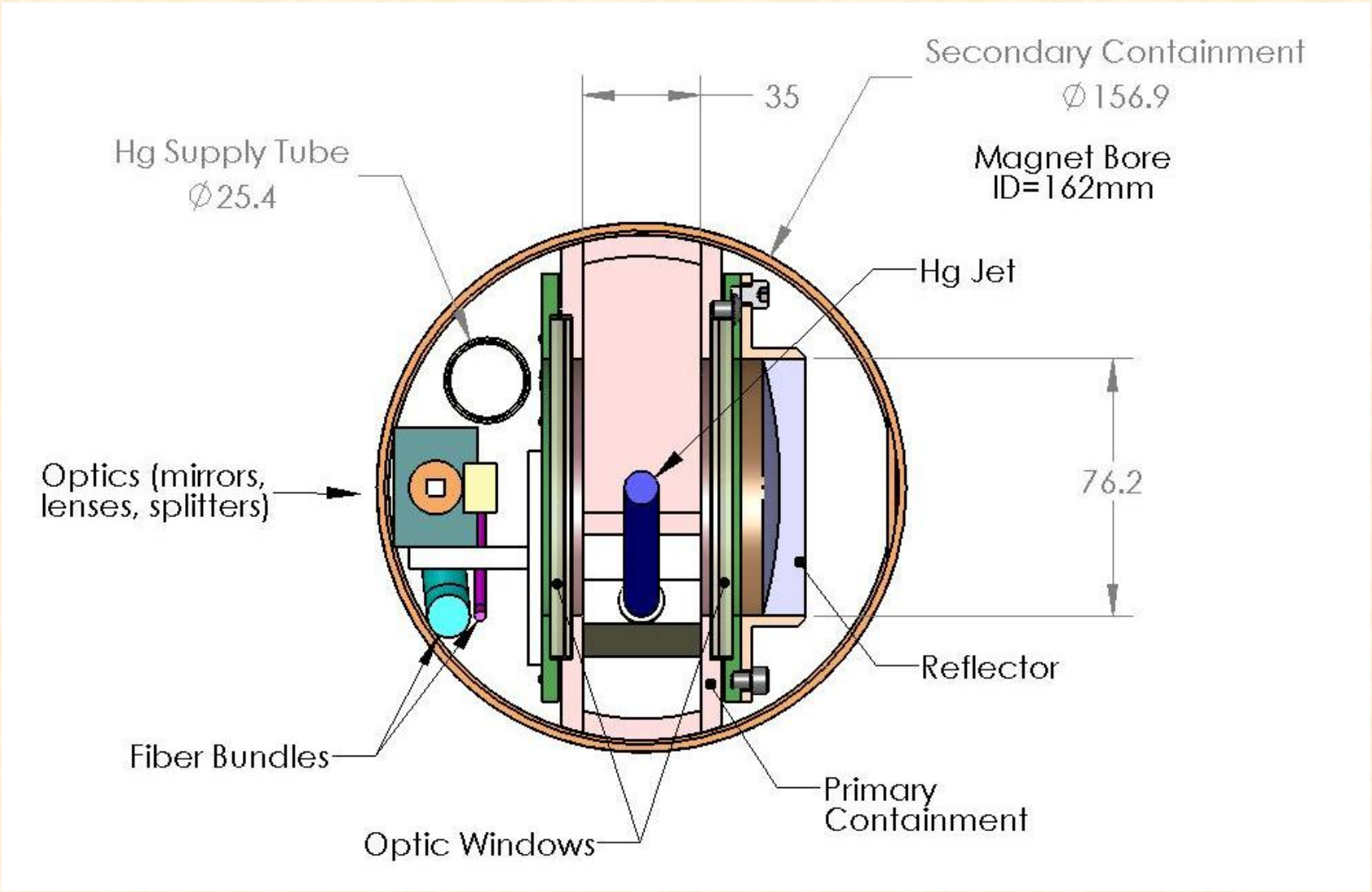
Reflector Assemblies Mounted on Viewports

Optical Components

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

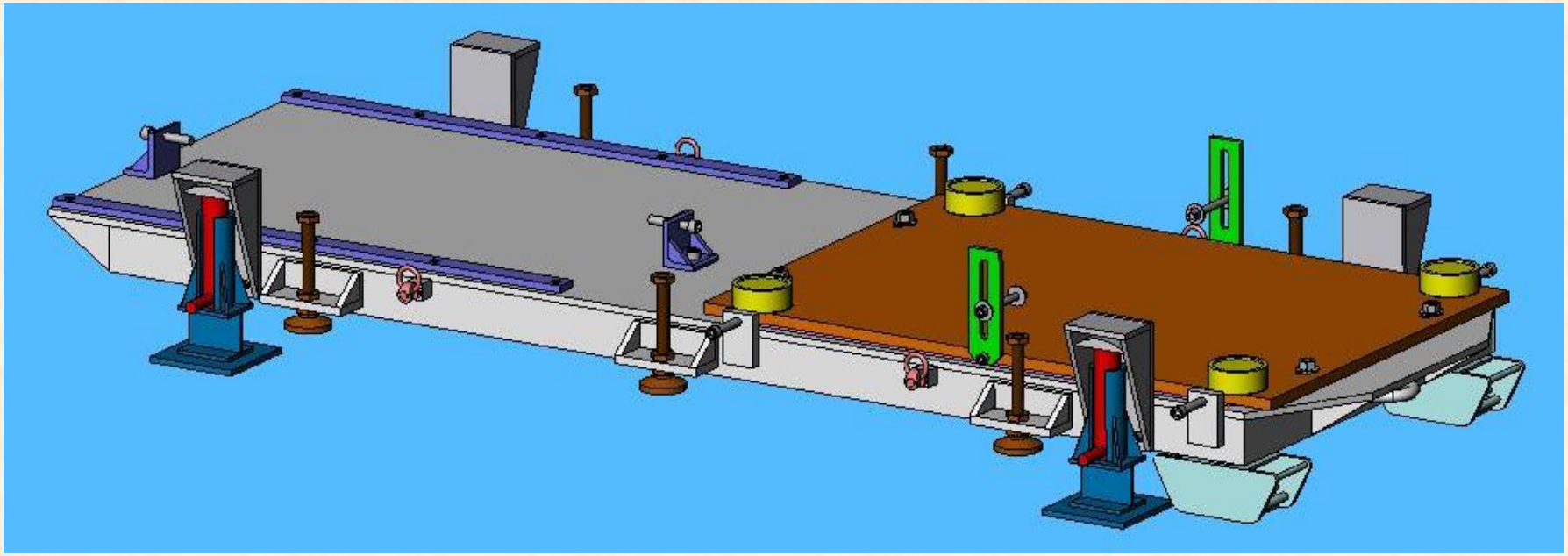


Z=0 Section Cut



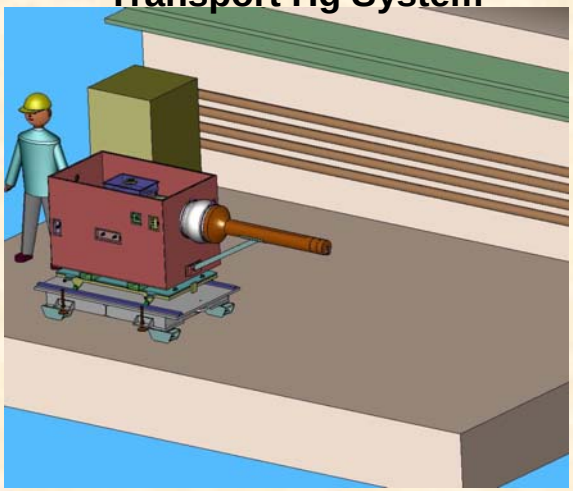
Common Baseplate

- **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**

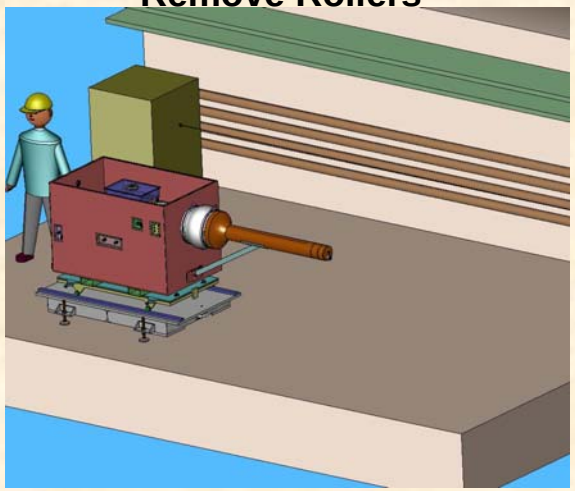


Installation Sequence

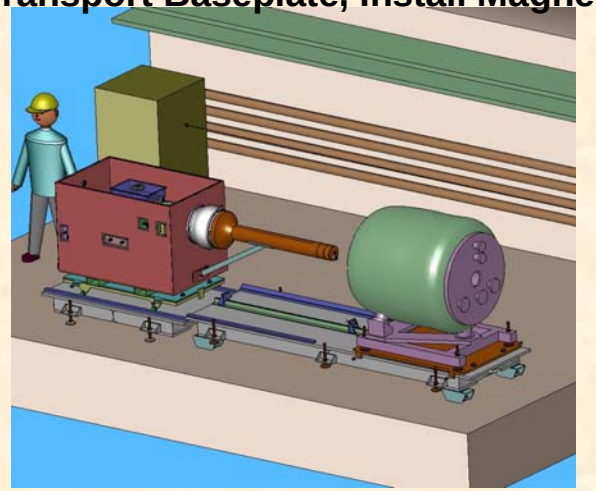
Transport Hg System

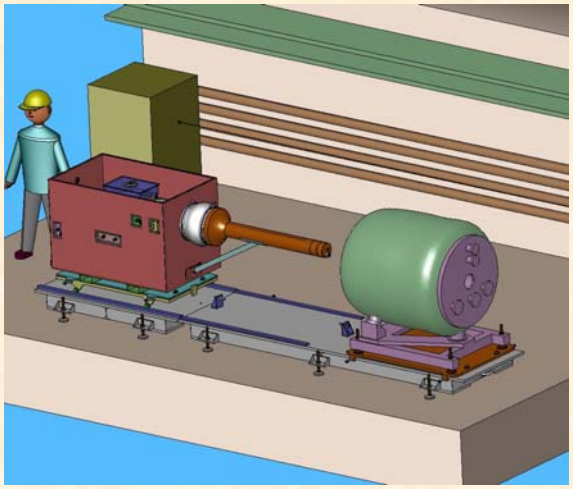


Remove Rollers

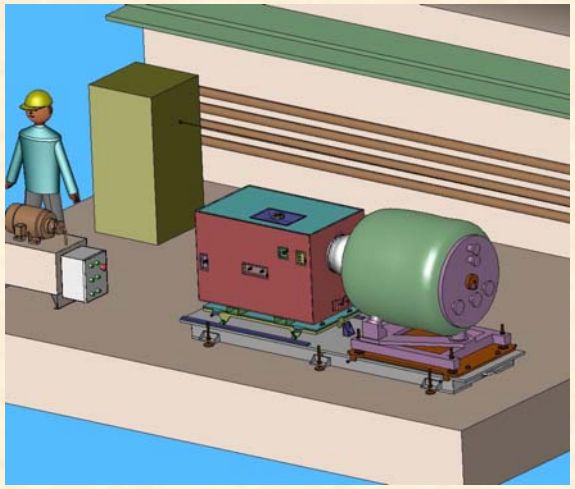


Transport Baseplate, Install Magnet

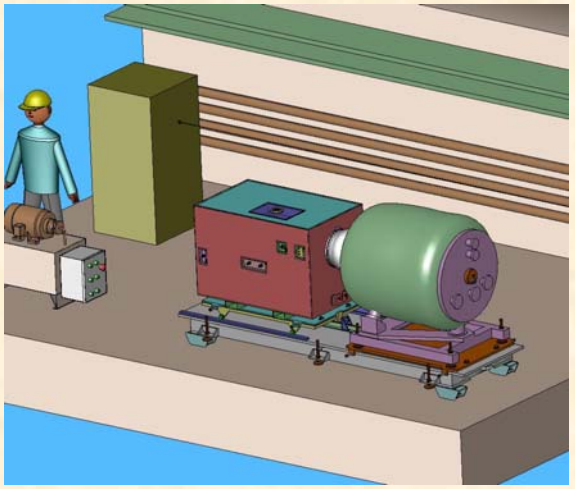




Remove Rollers, Level Magnet



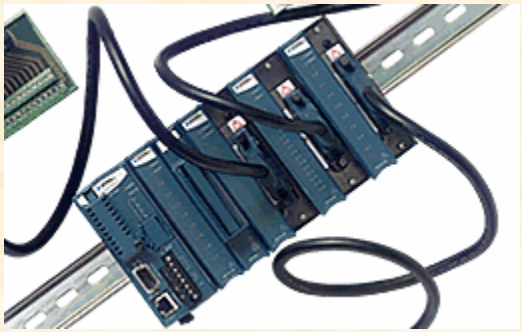
Roll Hg System into Magnet

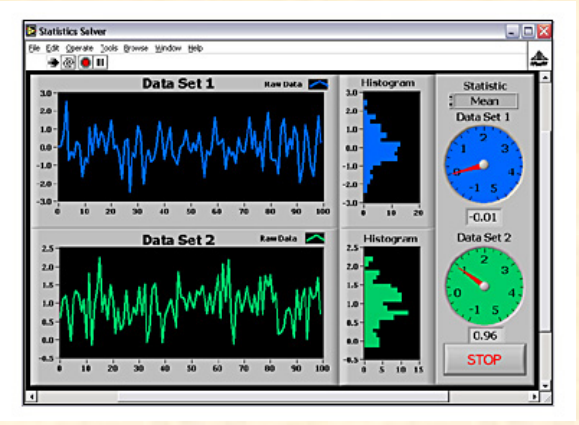


Add Rollers

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

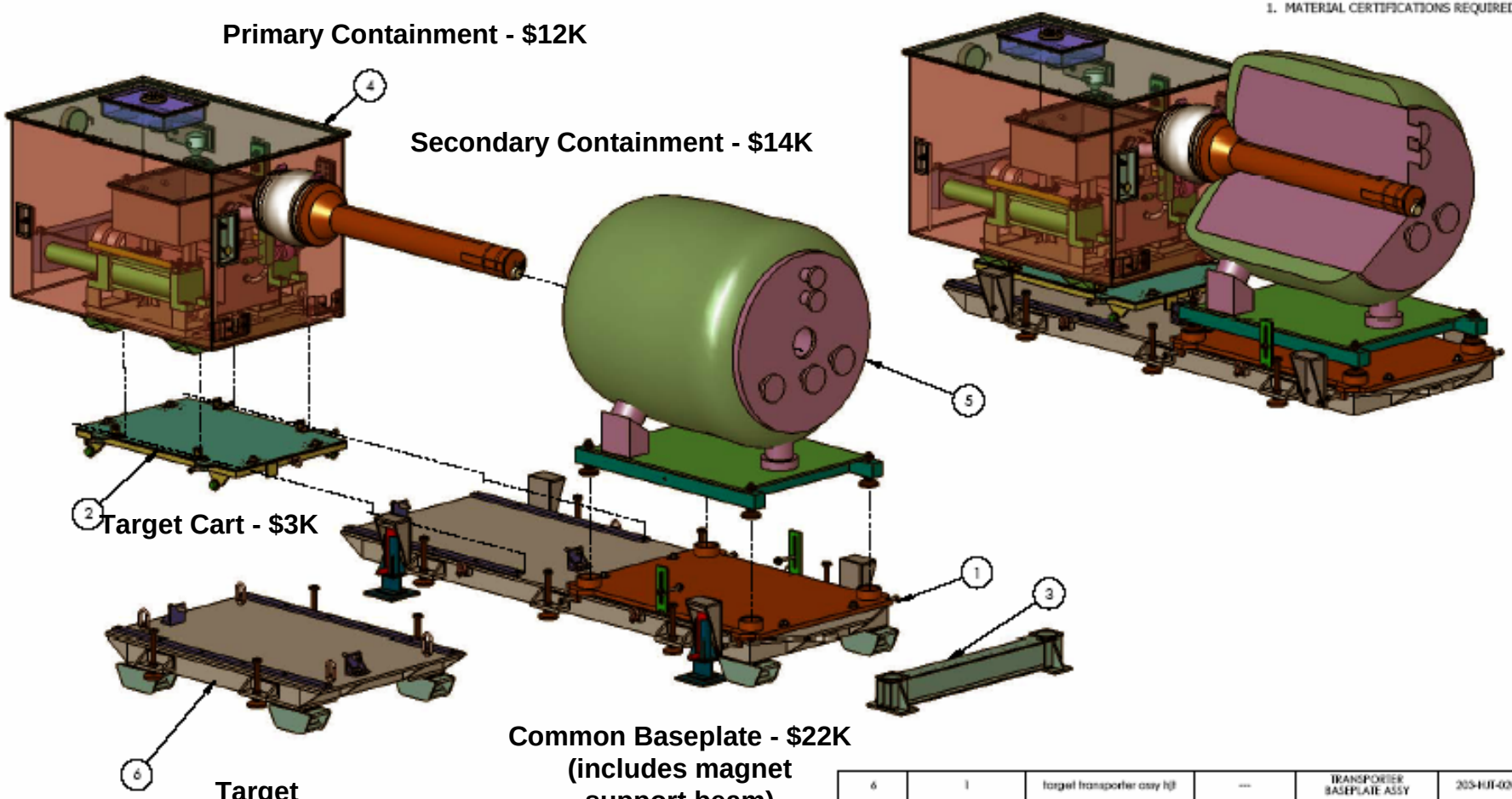
THIS DRAWING PRODUCED ON SOLIDWORKS

NOTES

1. MATERIAL CERTIFICATIONS REQUIRED

Primary Containment - $12K

Secondary Containment - $14K



Target Cart - $3K

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

Target Transporter - $5K

ITEM	for dwg with carrier/QTY.	NAME	MATERIAL	DESCRIPTION	DWG
6	1	target transporter assy hjt	---	TRANSPORTER BASEPLATE ASSY	203-HJT-0200
5	1	magnet assy hjt	---	PROVIDED BY M.I.T.	---
4	1	hg delivery system hjt	---	HG DELIVERY SYSTEM	203-HJT-0500
3	1	magnet end support hjt	---	USED TO RAISE MAGNET END	203-HJT-0400
2	1	cart assy hjt	---	TARGET CART ASSY	203-HJT-0300
1	1	common base assy hjt	---	---	203-HJT-0100

THIRD-ANGLE PROJECTION

UNLESS OTHERWISE NOTED
1. ALL DIMENSIONS ARE IN INCHES
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M
3. MACHINED FINISH 125 MICRO-INCHES RMS
4. CONCENTRICITY .010 TIR
5. MACHINED ANGLES ±1/2°
   FORMED ANGLES ±1°
6. BREAK SHARP CORNERS AND REMOVE ALL BURRS
7. WHOLE NUMBERS AND FRACTIONS ±1/16
8. X DECIMALS ±.030
9. XX DECIMALS ±.010
10. XXX DECIMALS ±.005

DES	V GRAVES	06/04/2005
DRW	T OQUIN	06/04/2005
CHK		
ENG	V GRAVES	06/04/2005
QA		
-	-	-
DRAWING APPROVALS		DATE

OAK RIDGE NATIONAL LABORATORY
operated for the U.S. Department of Energy under contract DE-AC05-00OR22725 Oak Ridge, TN

REMOTE SYSTEMS GROUP
NUCLEAR SCIENCE & TECHNOLOGY DIVISION

NUFACT HG JET EXPERIMENT

CAD FILE	PREV ASSY	SCALE	SHEET
COMMON BASE LOADED HJT	---	1:16	1 of 2

SIZE	DWG NO.	REV
C	203-HJT-0001	9b

DWG NO. 203-HJT-0001

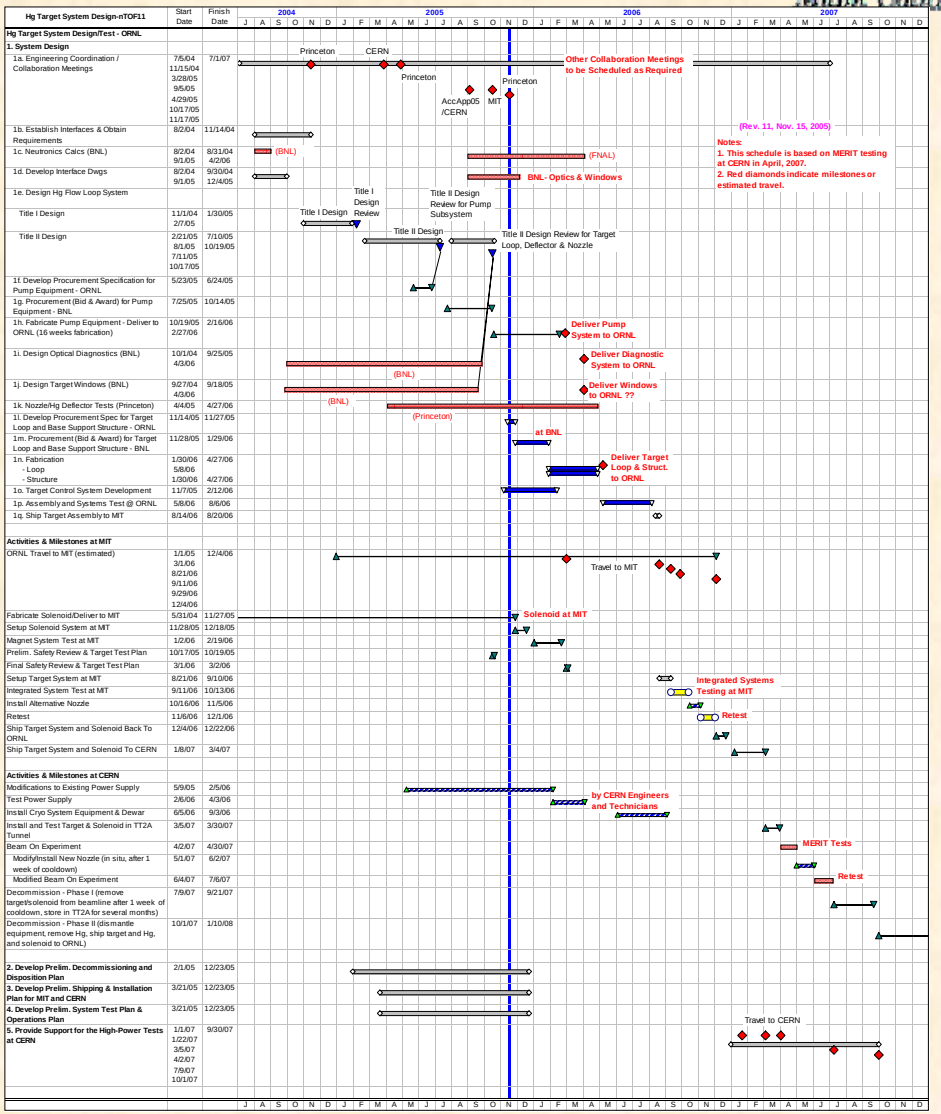
Hg System Costs

- **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**

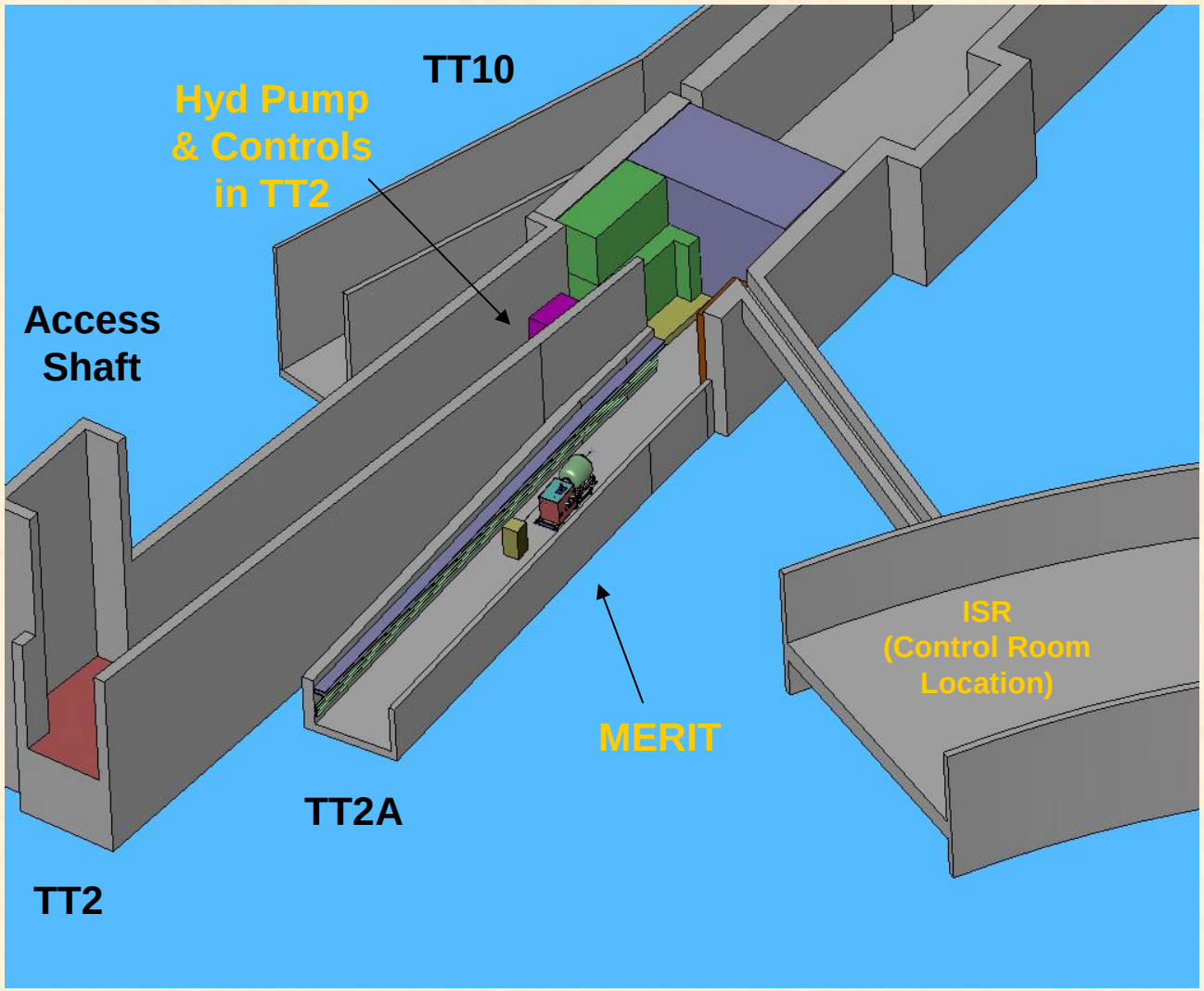


Conclusions

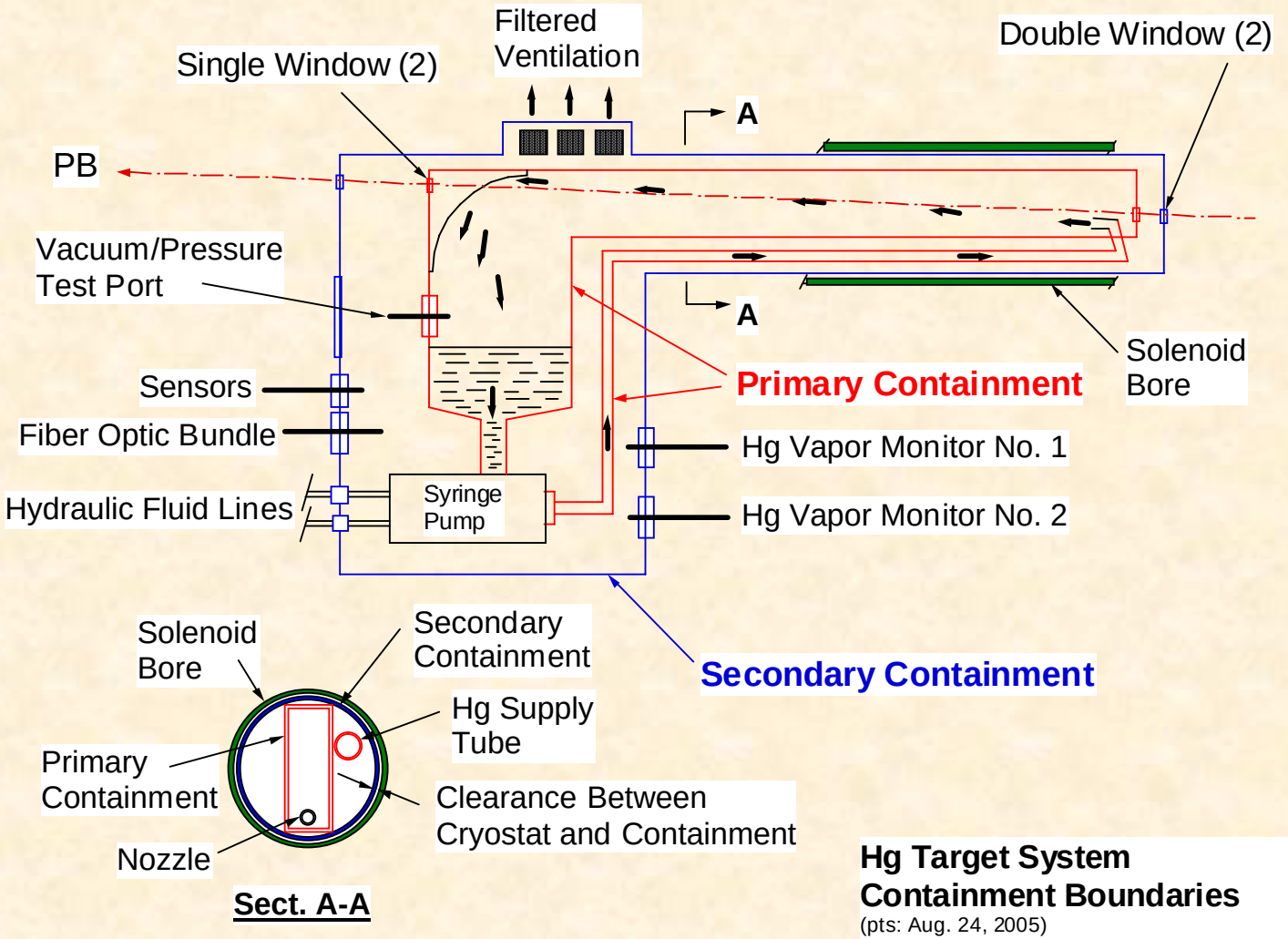
- **Final design details of Hg system must be completed**
  - **Nozzle details (position, orientation, length, etc.)**
  - **Some changes may be required based on Princeton Hg testing**
- **Fabrication drawings must be completed soon so procurement process can begin**
  - **Baseplate design complete, 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

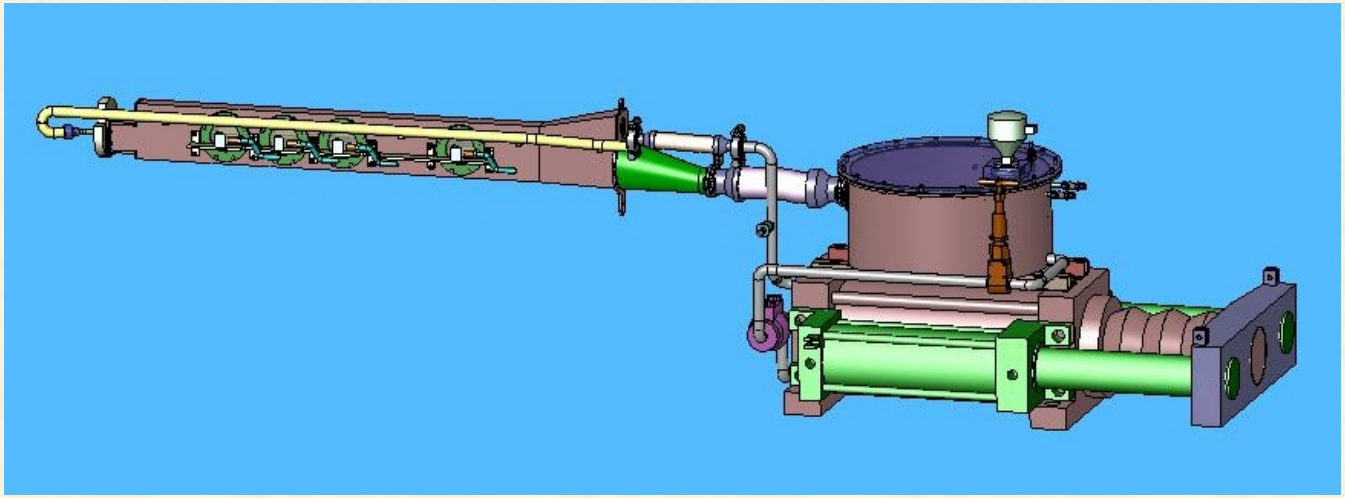


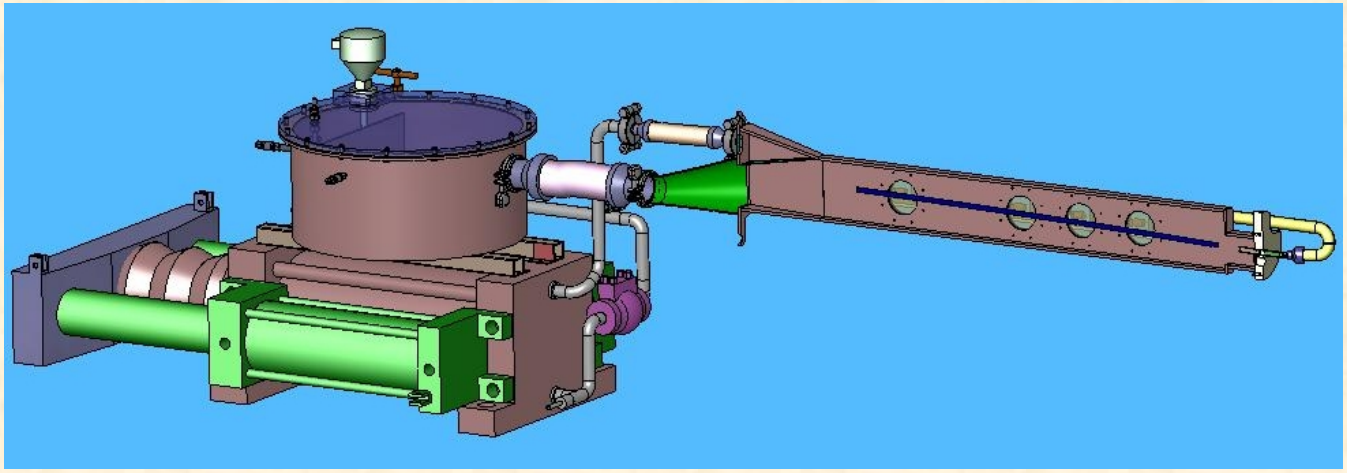
Containment Schematic



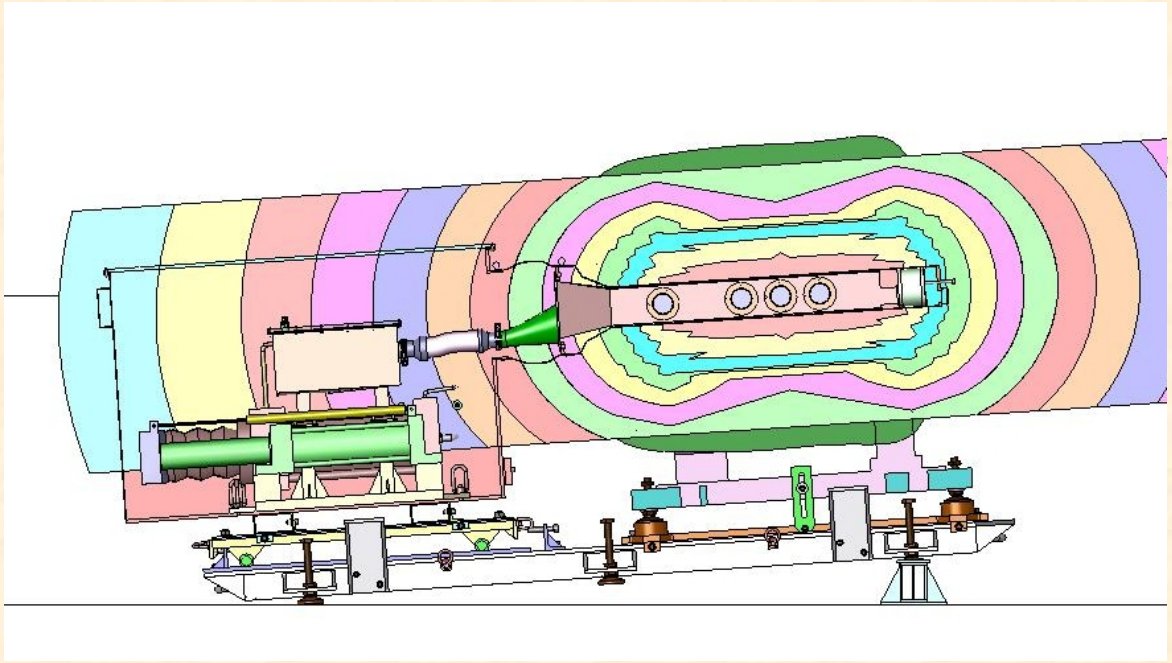
Hg Target System Containment Boundaries
(pts: Aug. 24, 2005)

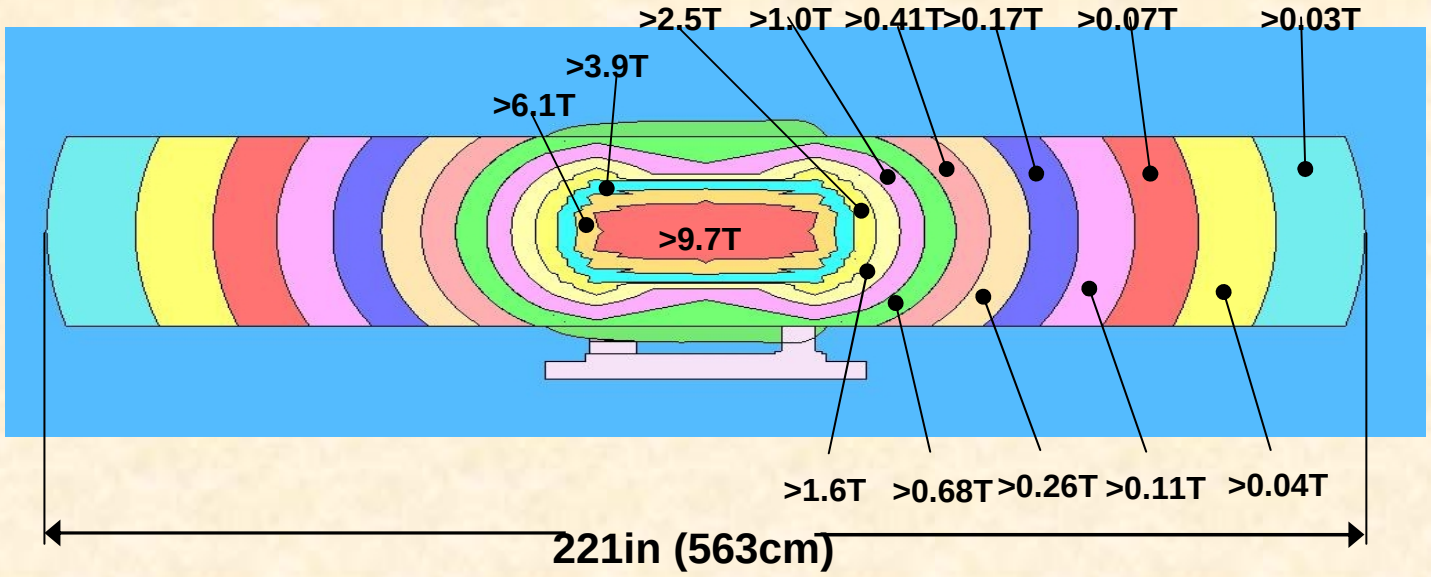
Hg Syringe System





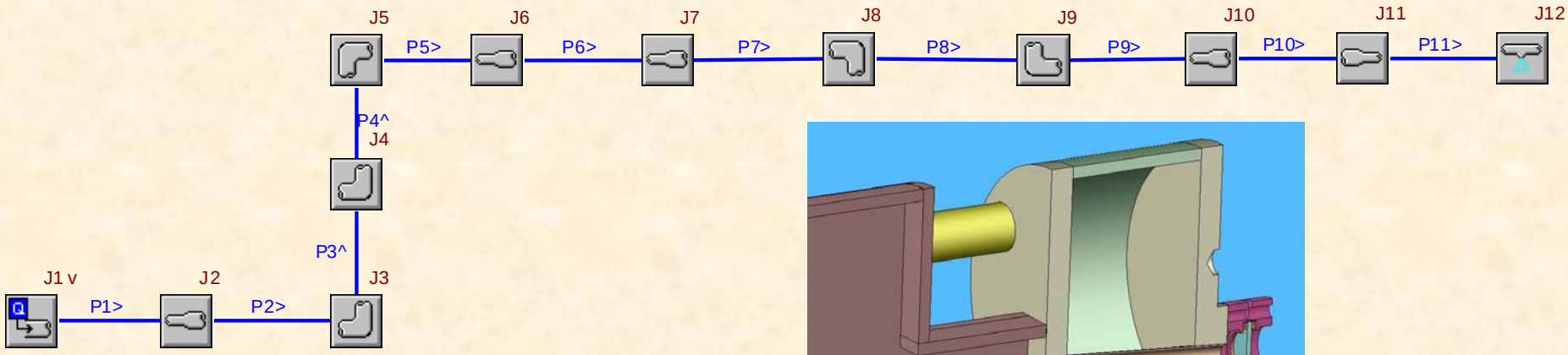
Stray Field Plot





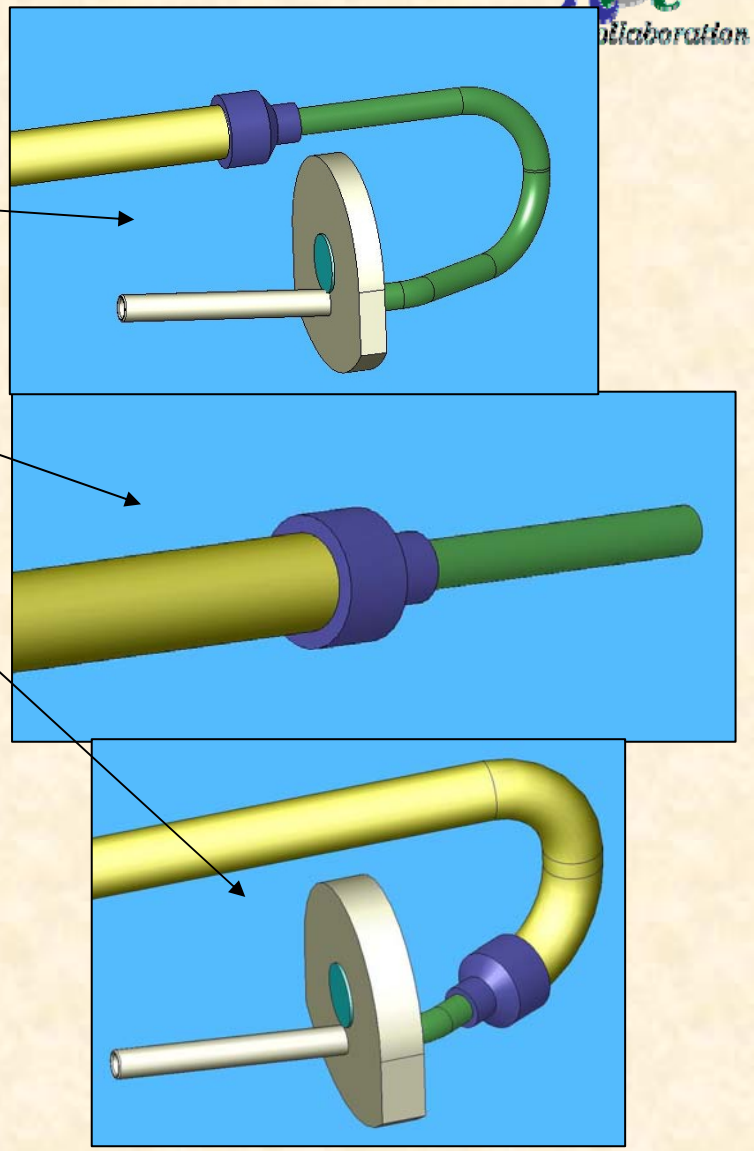
Flow Simulation Using AFT Fathom

- **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