CERN High Power Target Hg Jet Experiment - nTOF11 Facility & Safety Meeting

V.B. Graves
P.T. Spampinato
T.A. Gabriel

CERN

March 15-17, 2005

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Meeting Purposes & Goals

- **Review current design & operating assumptions**
- **Discuss safety related issues**
- **View & verify installation constraints in TT2/TT2A**
- **Define design requirements and operational constraints**
- **Discuss installation and handling issues**

Outline

- **Requirements & schedule**
- **Target design**
  - **Delivery system**
  - **Containment**
  - **Instrumentation & controls**
- **Transportation, installation & operations**
- **Safety features & issues**
  - **Hg handling**

Requirements & Schedule

The target system delivers a free (unconstrained) jet of Hg into a 1-atmosphere environment of air

- **1-cm diameter jet, delivered every 30 minutes**
- **Full-beam interaction length is 30-cm**
- **24 GeV, 1 MW proton beam, <20×10^{12} ppp**
- **Beam line is 121-cm (47.6”) above tunnel floor**
- **Up to 100 pulses for the CERN test, 500 pulses for systems tests**
- **15 Tesla field**
- **1-sec steady state jet during the magnet peak field (unresolved)**

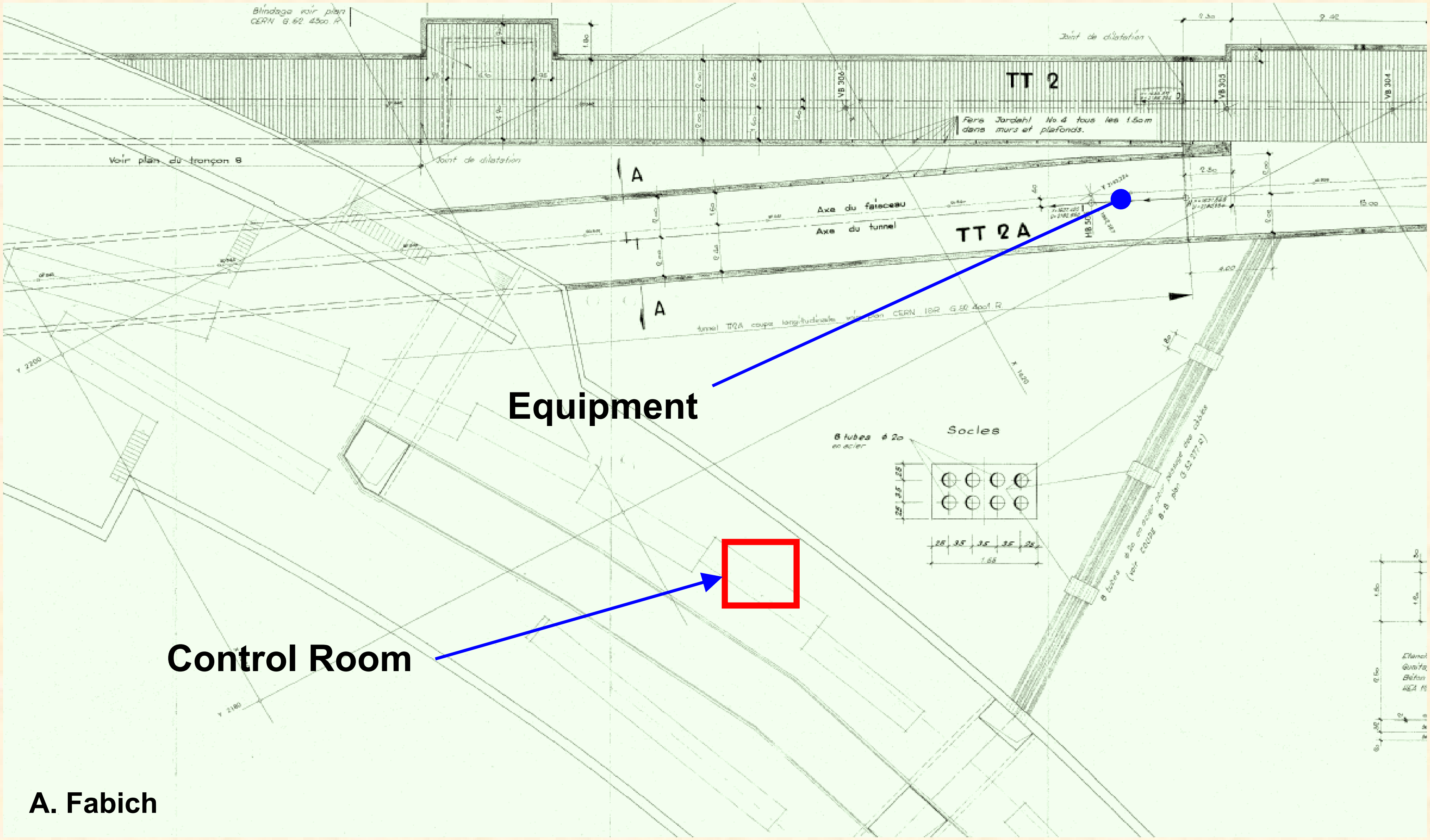
Design Requirements & Constraints

- **Hg Jet**
  - **1cm dia, 20m/s (1.57 liter/s, 24.9 gpm) in same direction as beam**
  - **Free jet created inside 15cm magnet bore**
  - **Smooth, steady-state jet duration overlaps 1-sec max field duration**
- **Integrate optical diagnostics**
  - **Fiber-optic system integrated with 5K frames/sec camera to record jet/beam interaction**
- **40-100 beam shots over 1 week period**
  - **Period between beam shots approximately 30 minutes to allow magnet cooling**
- **No target equipment on up-beam end of magnet**
- **Materials compatibility with Hg**
- **Component module size limitation is 1.3m x 3m (facility issues)**

Requirements (cont.)

- **Hg-wetted materials shall be stainless steel type 316 or 304**
- **Base support structure shall be aluminum**
- **Gaskets shall be non-reactive with Hg and radiation tolerant to 10^4 rads**
- **Operating temperature of the Hg shall be from 20°C to 100°C**
- **Installation – align and insert the target probe into the solenoid bore within ±1.0 mm, and position the target/solenoid assembly to the beam line within ±0.5 mm *(fiducials are to be located on the solenoid)***

Experiment Location – TT2A Tunnel



Target Containment is Designed To Meet ISO 2919 (per CERN)

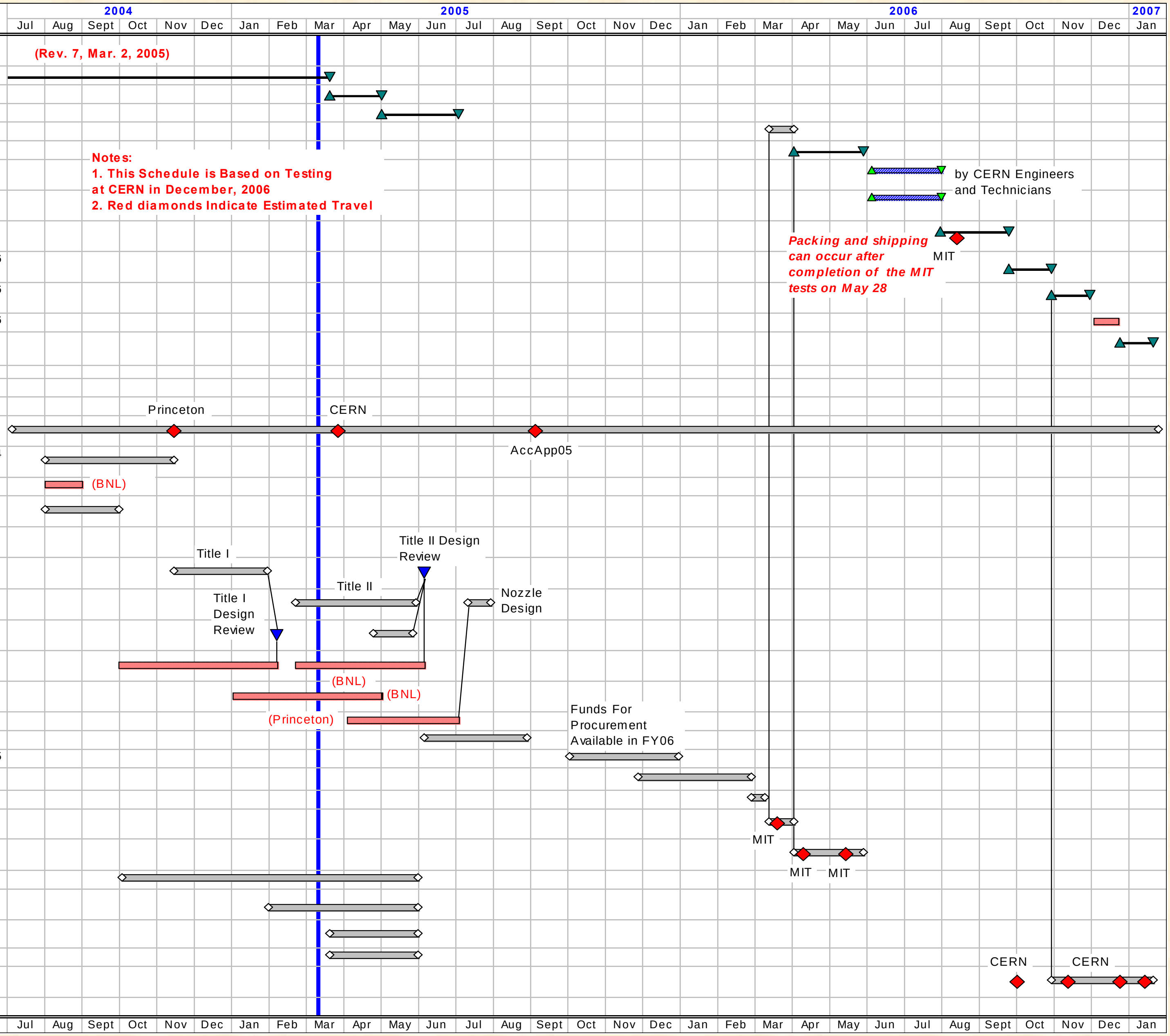
ISO 2919 "Classification of Sealed Source Performance" Table 2, Class 2

- **Temperature: -40º C (20 minutes), +80º C (1 hour)**
- **External Pressure: 25 kPa absolute (60 psi) to atmospheric**
- **Impact: 50 grams from 1 meter, or equivalent imparted energy**
- **Vibration: 3 times 10 minutes, 25-500 Hz at 49 m/s^2 (5 g_n, acceleration maximum amplitude)**
- **Puncture: 1 gram from 1 meter, or equivalent imparted energy**

Operational Requirements To Be Resolved

- **What operations are allowed in the tunnel?**
- **Opening primary/secondary containment?**
- **Are other CERN facilities available for Hg operations?**
- **What hydraulic fluids allowed?**
- **Installation details that affect design?**
- **Power available for target system?**
- **Etc?**

Hg Target System Design-nTOF11	Start Date	Finish Date
Solenoid/Cryostat Milestones		
Fabricate	5/31/04	3/20/05
Deliver/Install at MIT	3/21/05	5/1/05
Magnet System Test at MIT	5/2/05	7/3/05
Setup Target Equipment at MIT	3/13/06	4/2/06
Integrated System Test at MIT	4/3/06	5/28/06
Install/Test Power Supply at CERN (by others)	6/5/06	7/31/06
Install Cryo System Equipment & Dewar (by others)	6/5/06	7/31/06
Ship Magnet & Target System To CERN	7/31/06 8/14/06	9/24/06
Install and Test Equipment in TT2A Tunnel (or at other CERN facility)	9/25/06	10/29/06
Commission Test Equipment at CERN (verify system operational capability in TT2A)	10/30/06	11/29/06
Beam On Experiment	12/4/06	12/22/06
Decommission (remove from beamline, cooldown, dismantle, ship target/Hg to ORNL)	12/25/06	1/21/07
Hg Target System		
1. System Design		
1a. Engineering Coordination	7/5/04 11/15/04	1/25/07
1b. Establish Interfaces & Obtain Requirements	8/2/04	11/14/04
1c. Neutronics Calcs (BNL)	8/2/04	8/31/04
1d. Develop Interface Dwgs	8/2/04	9/30/04
1e. Design Hg Flow Loop System		
Title I Design	11/15/04 6/6/05	1/30/05
Title II Design	2/21/05 7/11/05	5/29/05 7/29/05
1f. Develop Procurement Specification	4/25/05 2/7/05	5/27/05
1g. Design Optical Diagnostics (BNL)	10/1/04 2/21/05	2/6/05 6/5/05
1h. Design Target Windows (BNL)	1/3/05 5/2/05	5/1/05 5/2/05
1i. Nozzle/Hg Deflector Tests (Princeton)	4/4/05	7/3/05
1j. Procurement (Bid & Award)	6/6/05	8/28/05
1k. Fabrication	10/3/05	12/30/05
1l. Assembly and Systems Test	11/28/05	2/26/06
1m. Prepare/Ship Target Assembly to MIT	2/27/06	3/9/06
1n. Install Target Equipment at MIT	3/13/06 3/20/06	4/2/06
2. Assist w/ Integrated Test at MIT	4/3/06 4/10/06	5/28/06
3. Coordinate Design Effort with CERN	10/4/04	5/31/05
4. Develop Decommissioning and Disposition Plan	2/1/05	5/31/05
5a. Develop Shipping & Installation Plan for MIT and CERN	3/21/05	5/31/05
5b. Develop System Test Plan	3/21/05	5/31/05
6. Provide Support for the High-Power Tests at CERN	10/30/06 11/13/06	1/21/07

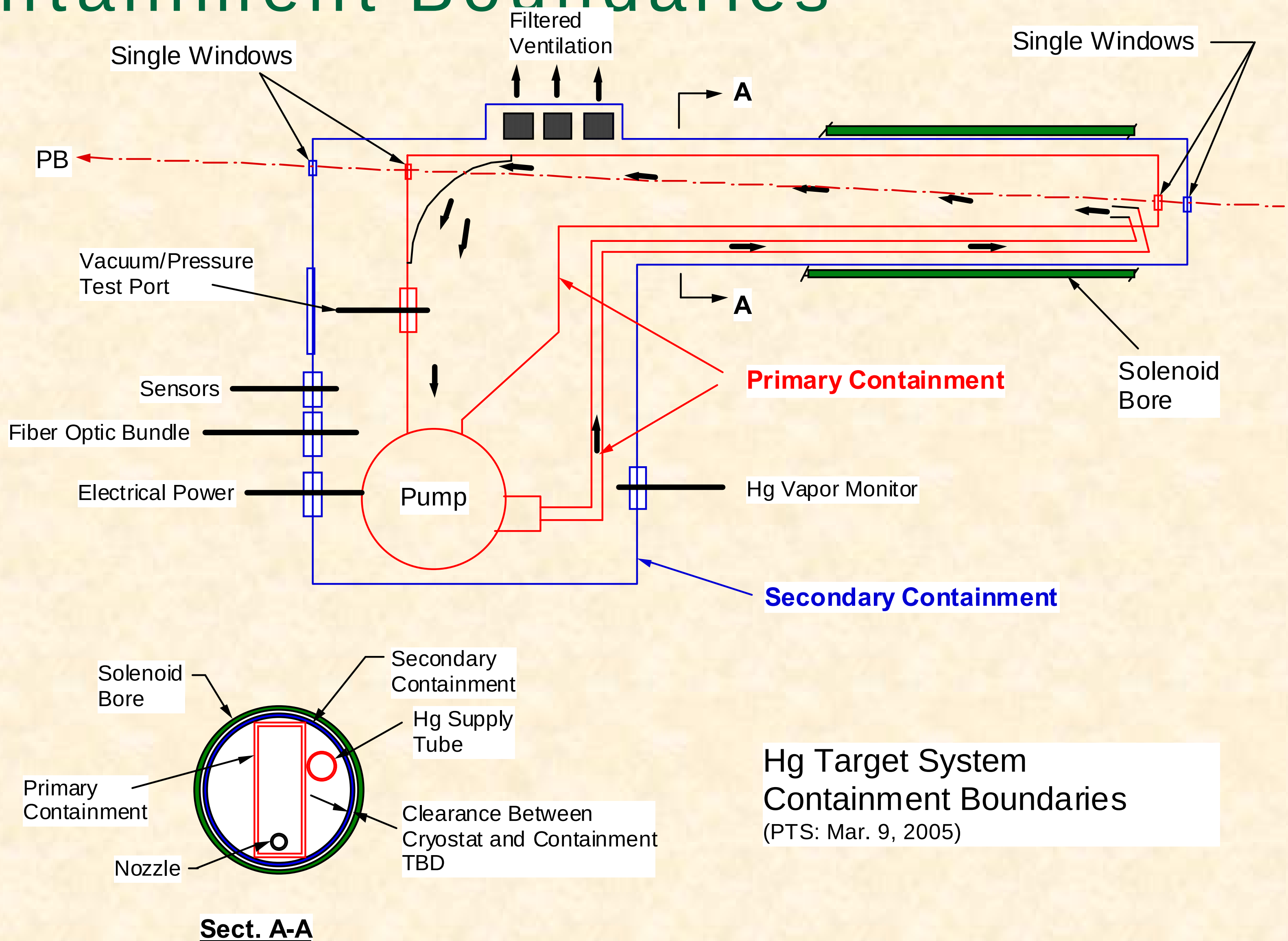


Hg Target Schedule Highlights

Title 1 Design Review at ORNL	Feb 7-8, 2005
Collaboration Mtg at CERN	Mar 15-17, 2005
Title 2 Design Review	May-June '05
Target System Procurement & Fabrication (dependent on funding)	July '05 – Dec '05
Assembly & Testing at ORNL	Nov '05 – Feb '06
Integrated Testing w/Magnet	Mar '06 – May '06
Equip. Installation at CERN	Oct '06 – Nov '06
Earliest Beam-on Tests at CERN (no beam time scheduled yet)	Dec '06

Target System Design

Containment Boundaries

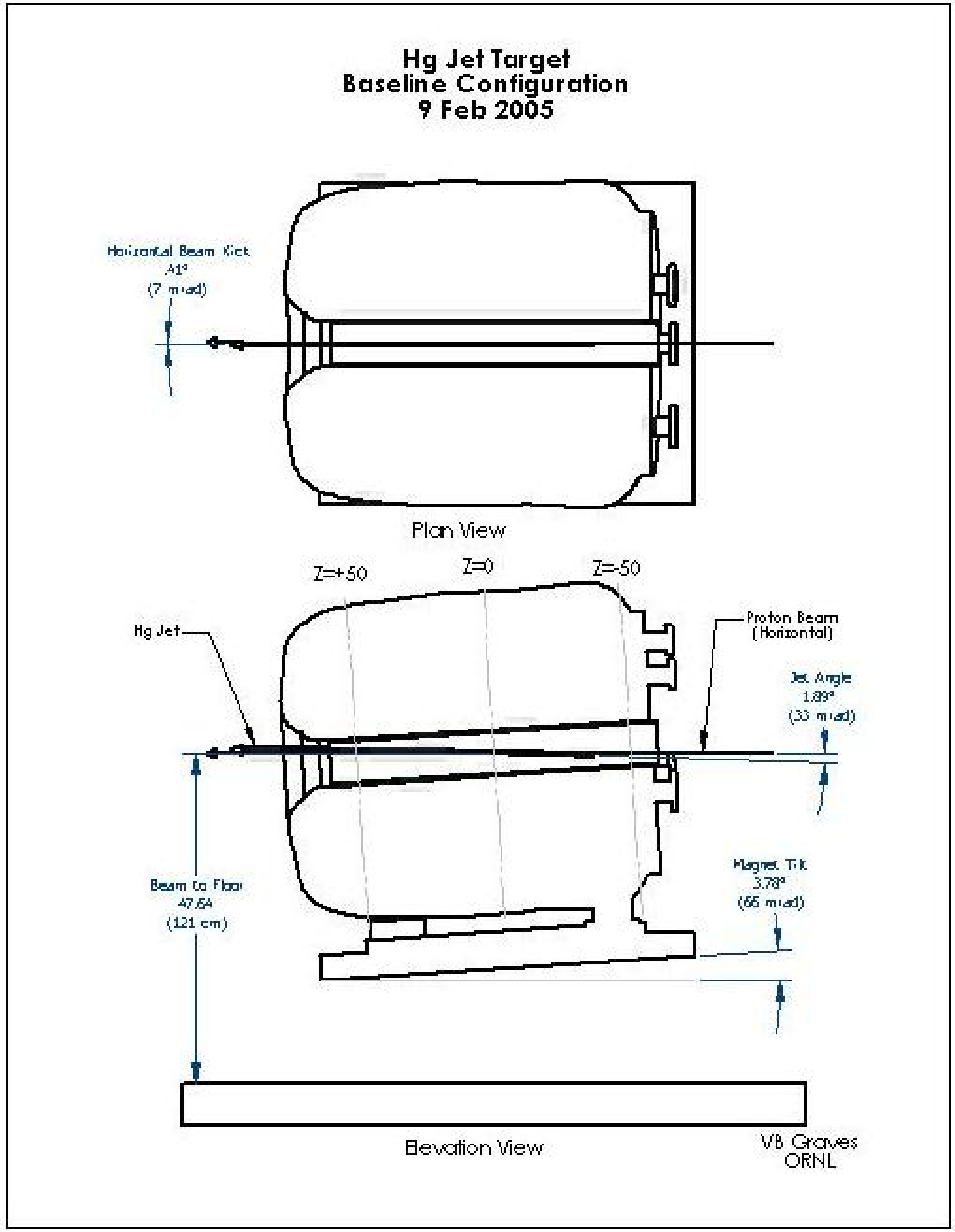


Hg Target System
Containment Boundaries
(PTS: Mar. 9, 2005)

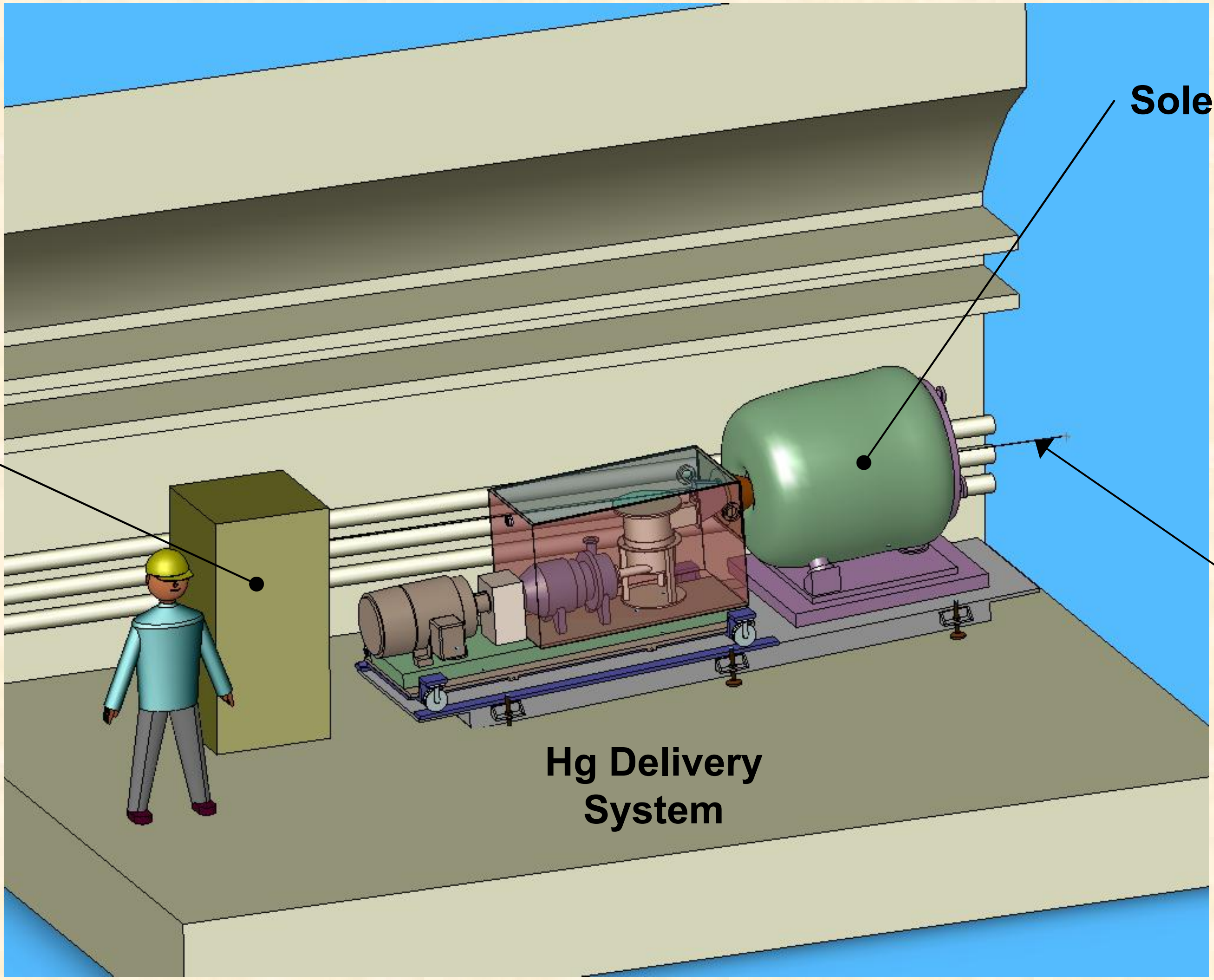
Experiment Geometric Configuration

Experiment is prototypic of a N.F. facility target layout

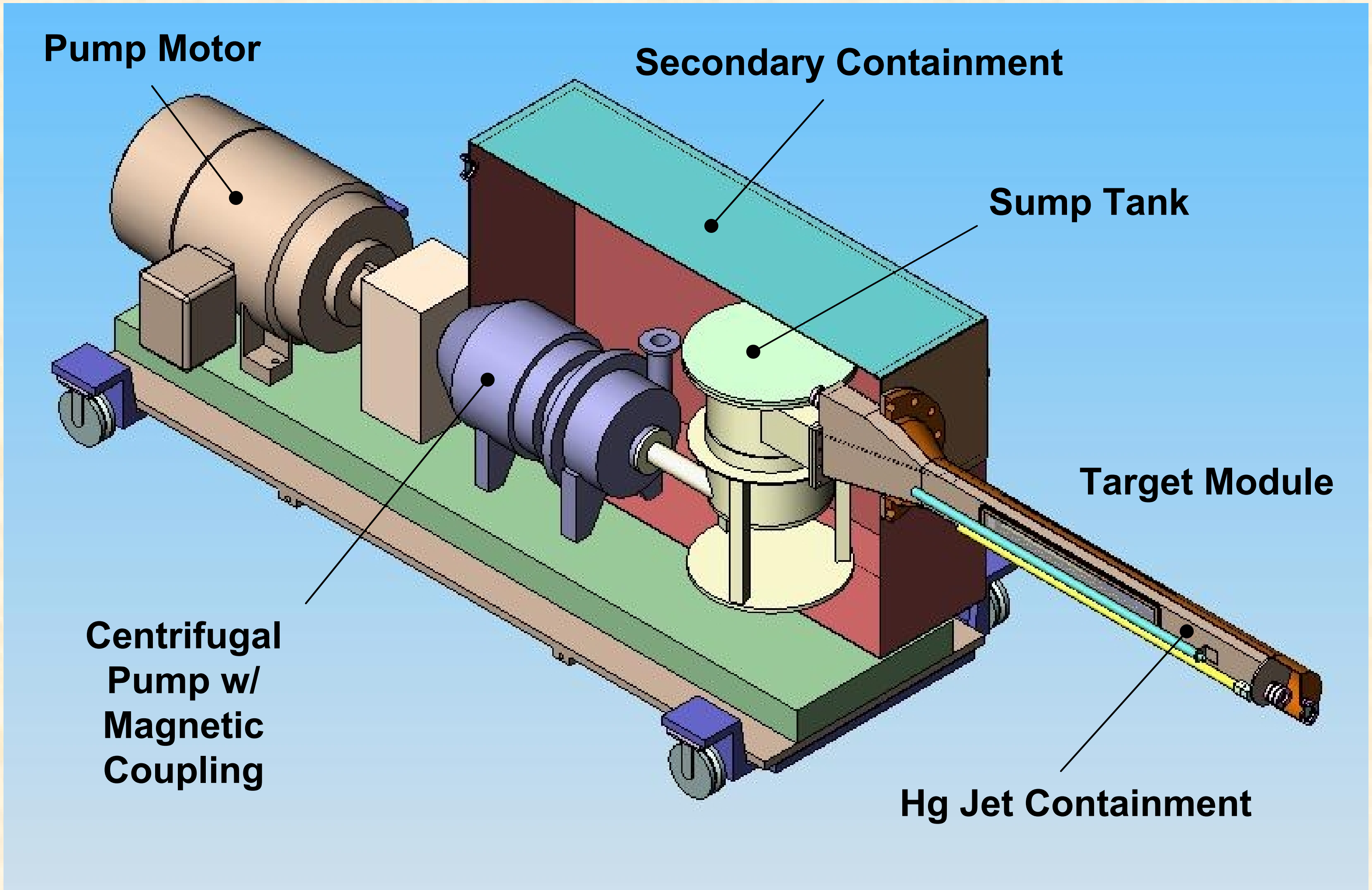
- **Magnet tilt (wrt beam) = 66 mrad (3.8°)**
- **Hg jet tilt (wrt magnet axis) = 100 mrad (5.7°)**
- **Hg jet center intersects beam center at Z=0**



System Overview



Original Hg Delivery System



Pump Issues

- **Pump adds heat to Hg**
  - **Application is low flow, high pressure → η=23%**
  - **Pump delivers nominal 51hp**
  - **Per pump vendor data, heat energy into mercury = 40.5hp (30kW)**
    - **With an assumed Vol=12liter, ΔT=2.4°F/sec (1.3°C/sec) due to pump heating only**
- **Max available pump output pressure is 750 psi (50 bar)**
  - **Estimated piping system pressure drop 800-850 psi**

Pump Issues

- **Pump adds heat to Hg**
  - **Pump delivers nominal 51 bhp at 23% efficiency (60 bhp max)**
  - **Magnetic coupling losses 5.4 hp**
  - **Heat energy into mercury**
    - **LostHP = (bhp - mag)*(1 - eff) + mag = 40.5 hp (30kw)**
    - **With an assumed Vol=12liter, ΔT=2.4°F/sec (1.3°C/sec) due to pump heating only**
- **Max available pump output pressure is 750 psi (50 bar)**
  - **Estimated piping system pressure drop 800-850 psi**

Pump Energy Balance

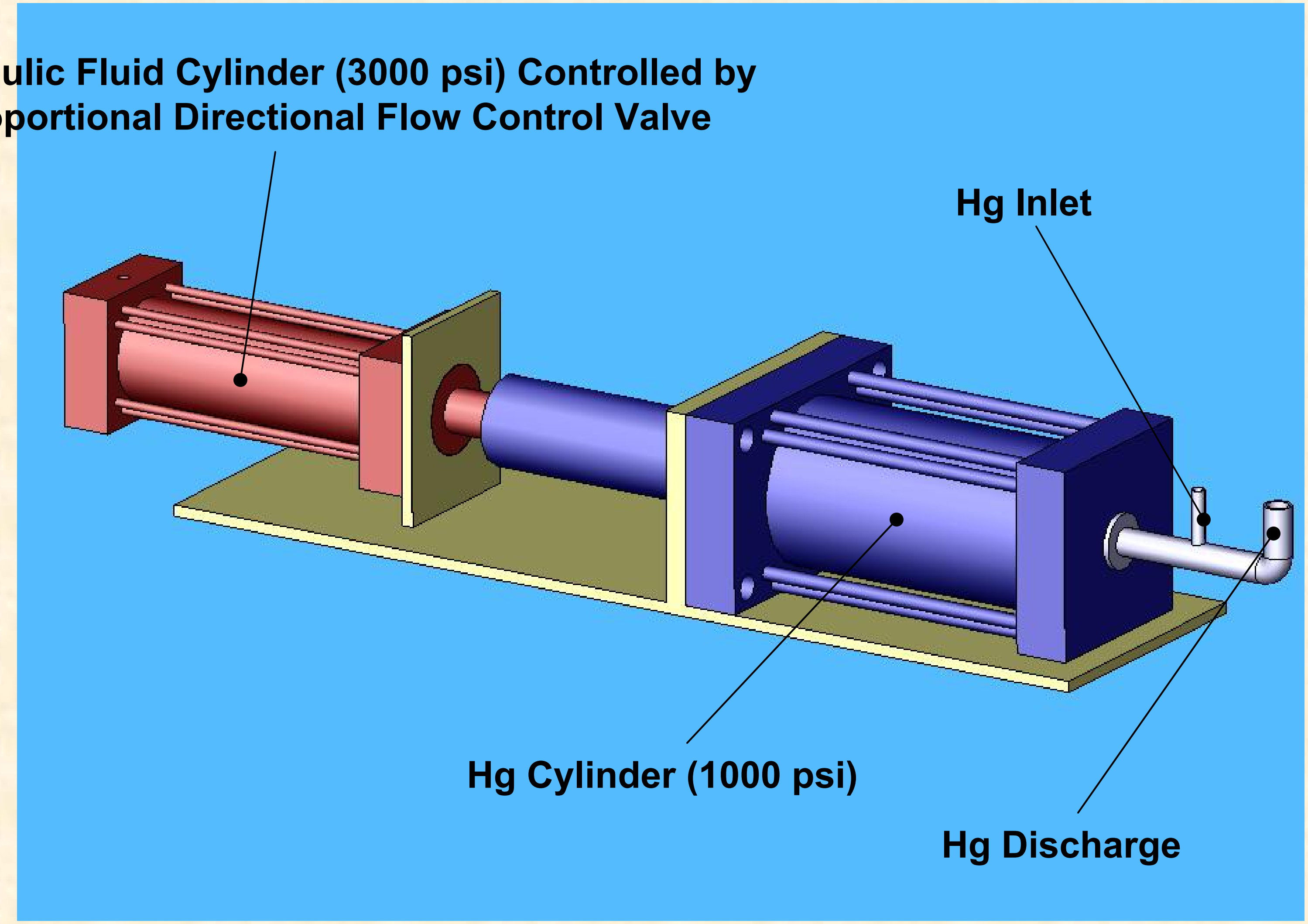
Pump	Input Energy (hp)	Losses	Lost Energy (hp)	Output Energy (hp)	Heat Direct to Tunnel BTU/min	Heat Input to Hg BTU/min	Flow Losses BTU/min	Total Heat Generated BTU/min	KW	HP	Energy to Hg BTU/min	Hg Temp Rise °F/sec
Elect Motor	60	60 hp * 5% inefficiency	3	57	127			127	2	3		
Mag Coupling		5.4hp actual coupling loss per vendor data	5.4	51.6	229			229	4	5		
Hg Pump		40.5hp actual pump loss per vendor data	40.5	11.1		1719		1719	30	40	1719	
Hg Flow		800psi*25gpm	12	-1			526	526	9	12	526	
				Totals	356	1719	526	2601	46	61	2245	3.1

Possible Solutions

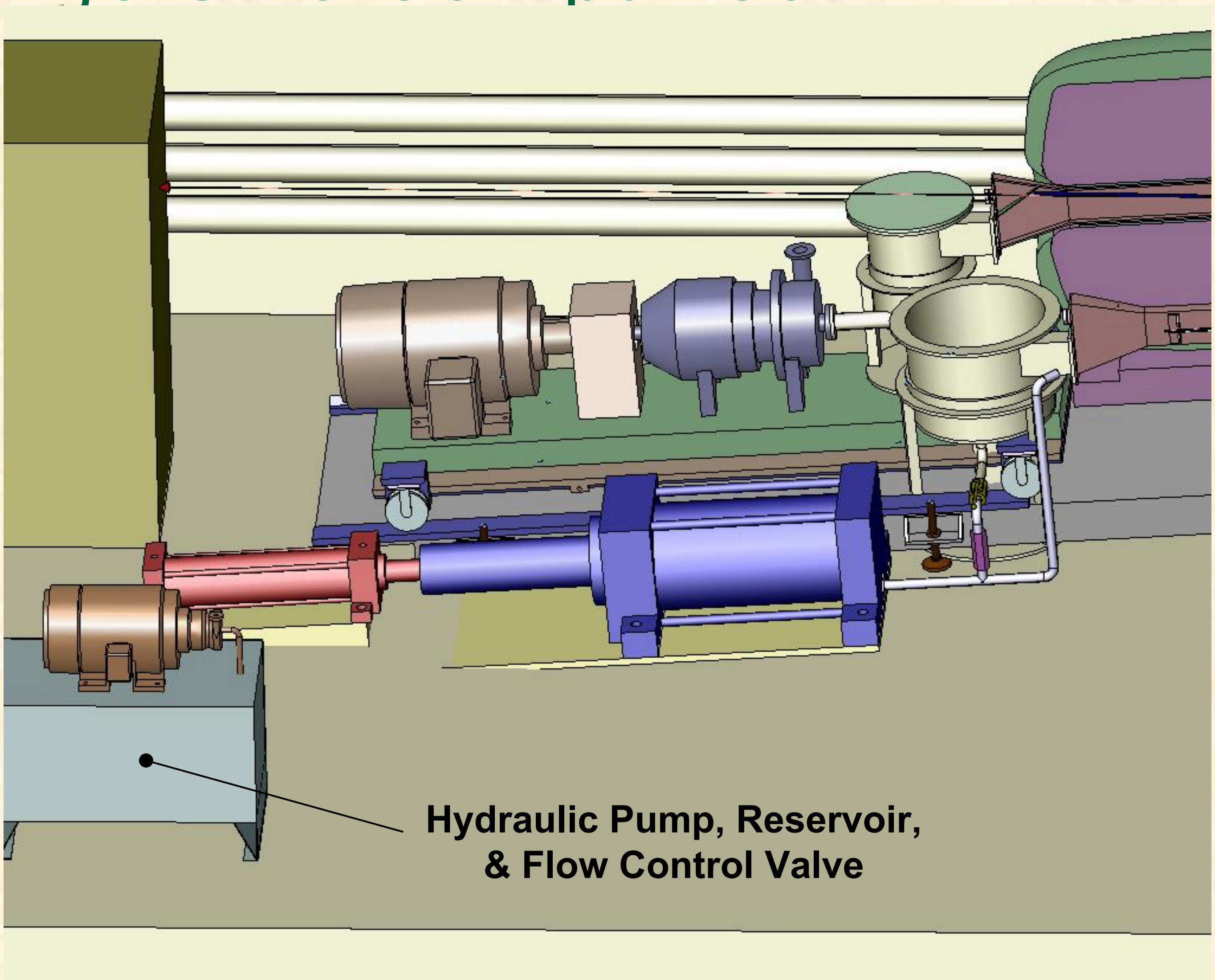
- **Heat issue**
  - **Increase Hg volume (ΔT decreases linearly with Hg mass)**
  - **Add heat exchanger for system testing**
    - **May not be needed during CERN tests**
- **Discharge pressure issue**
  - **Vendor specified magnetic-coupling pump with max discharge pressure**
    - **Same vendor designed TTF & SNS Hg pumps**
  - **Investigate alternative Hg delivery systems**

Nature of experiment lends itself to non-continuous flow approach, so…

Alternative Hg Delivery System



Syringe Size Comparison



System Energy Comparison

Pump	Input Energy (hp)	Losses	Lost Energy (hp)	Output Energy (hp)	Heat Direct to Tunnel	Heat Input to Hg	Flow Losses	Total Heat Generated			Energy to Hg	Hg Temp Rise
					BTU/min	BTU/min	BTU/min	BTU/ min	KW	HP	BTU/min	°F/sec
Elect Motor	60	60 hp * 5% inefficiency	3	57	127			127	2	3		
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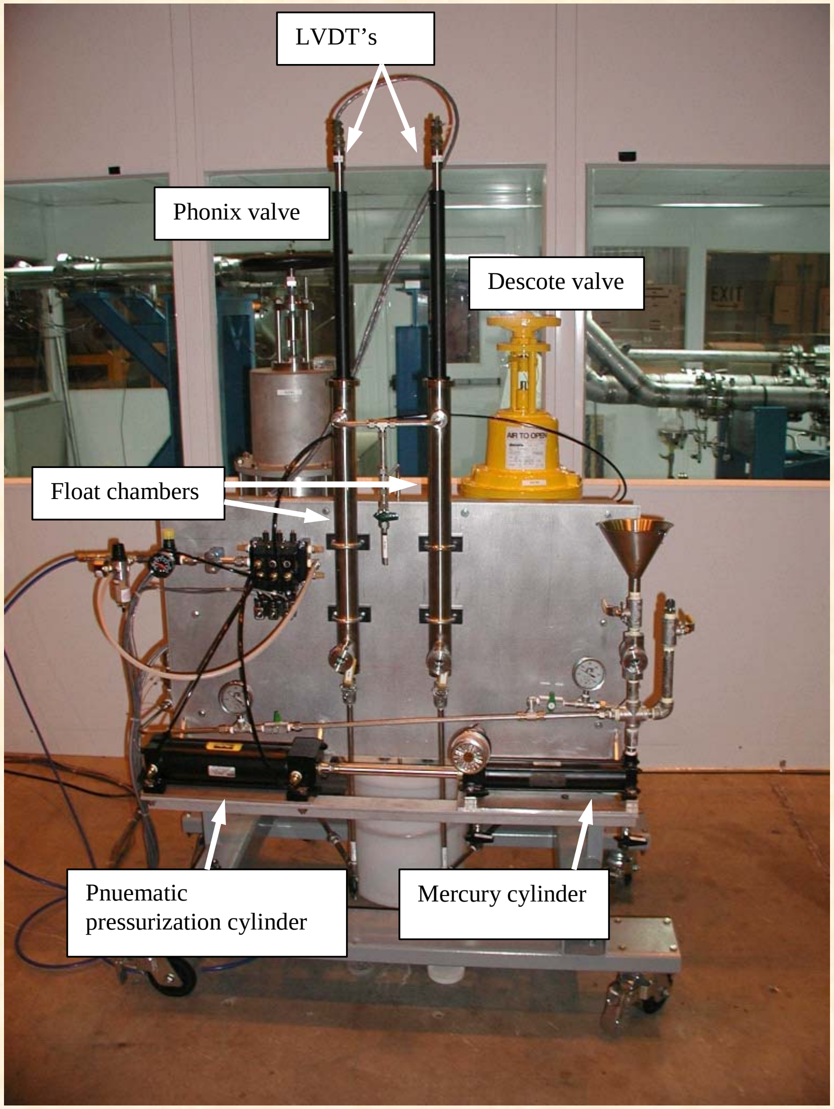
Hg Flow		800psi*25gpm	12	-1			526	526	9	12	526	
				Totals	356	1719	526	2601	46	61	2245	3.1
Syringe												
Elect Motor	20	20 hp * 5% inefficiency	1	19	42			42	1	1		
Hyd Pump		energy performed on piston = press*area*dist/time	11									
Hyd Pump		pump inefficiency	8	11	340			340	6	8		
Piston Energy to Hg		no losses		11								
Hg Flow		800psi*25gpm	12	-1			526	526	9	12	526	
				Totals	382		526	908	16	21	526	0.7

Syringe Performance Benefits

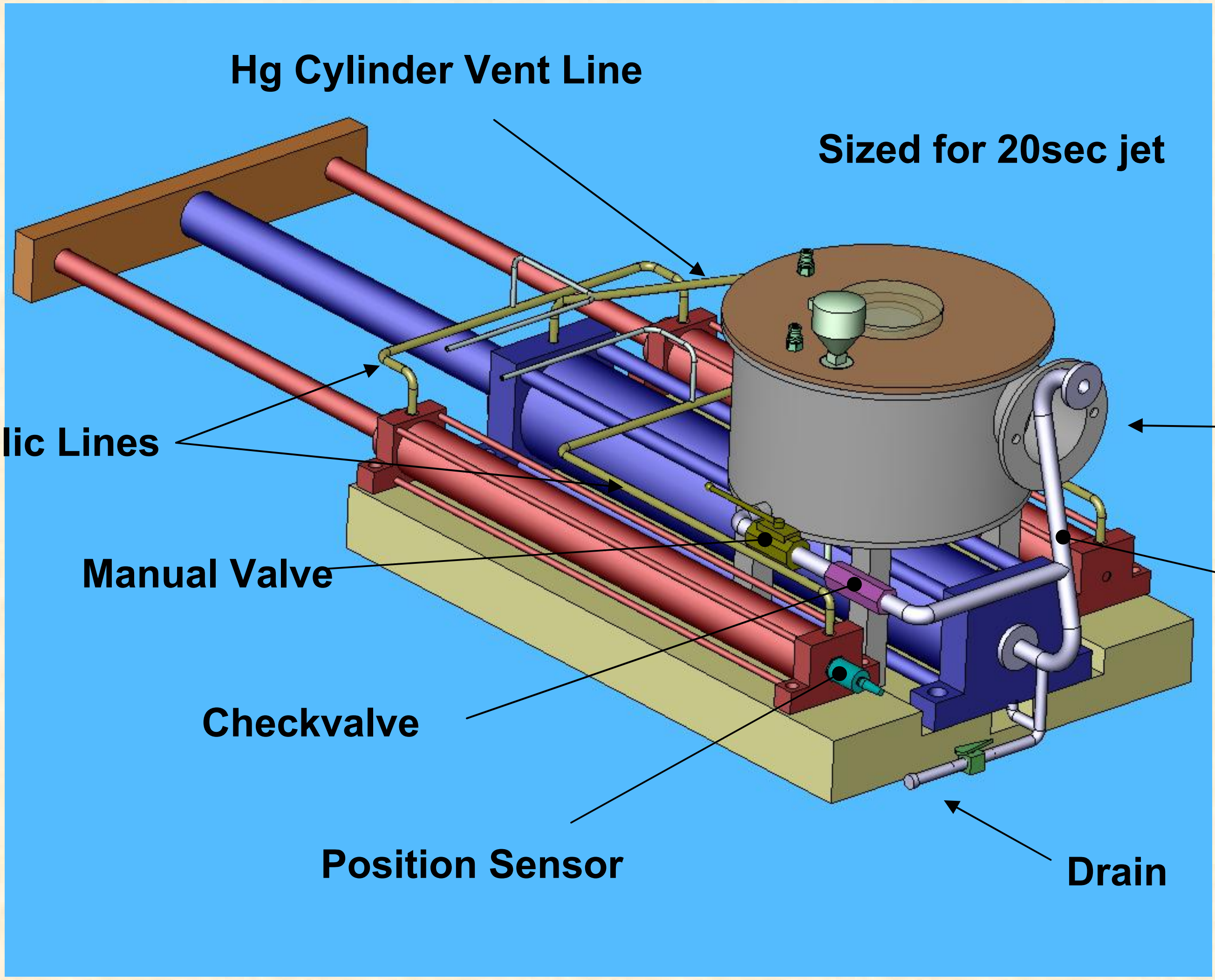
- **Piston-driven jet has excess capacity to overcome flow losses**
- **No significant heat imparted to Hg by piston**
  - **Heat losses isolated to hydraulic system**
  - **Flow losses identical to those in pump system**
  - **No heat exchanger required**
- **Syringe design may be smaller than shown, depending on Hg volume required**
  - **1.6 liter/s → 48 liter for 30sec, 24 liter for 15sec**
  - **Concept shown in size comparison was sized for 30sec jet**
- **Lower power requirements**
  - **20hp hydraulic pump motor vs. 60hp centrifugal pump motor**
- **Proportional servo control valve provides precise velocity control of hydraulic cylinders**

Hg Cylinder Experience

- **SNS test stand used pneumatic cylinders to cycle candidate drain valves several thousand cycles with no leaks**
- **Low-pressure application with automated controls**

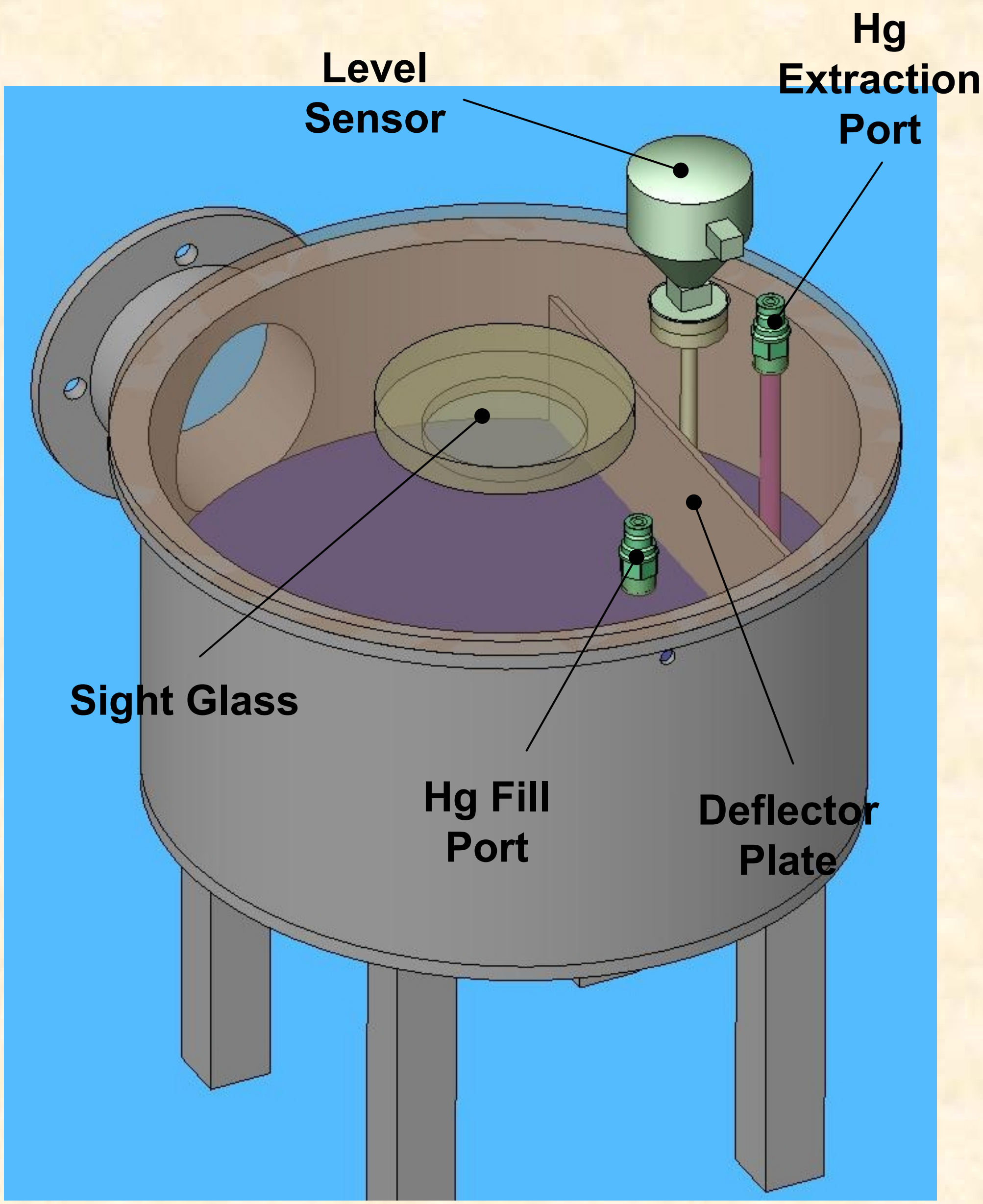


New Baseline Target System



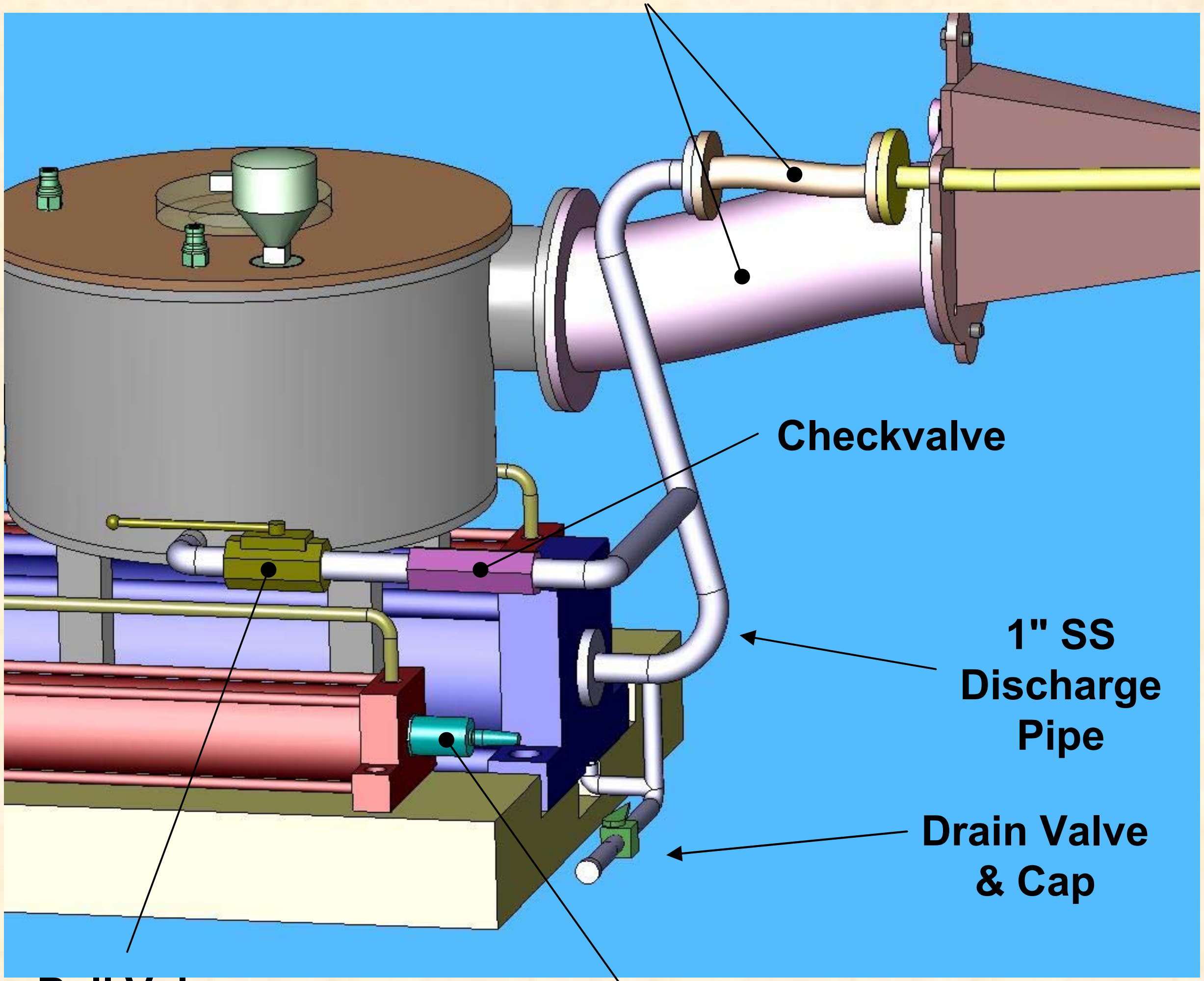
Sump Tank

- **22" SS pipe**
- **Hg inventory for 20sec jet**
  - **36 liter, 1068 lb**
  - **6 inch depth**
- **Incorporates float-type level sensor, Hg fill & extraction ports**
- **Thermocouple on sump exterior or in direct Hg contact**



Hg Delivery System

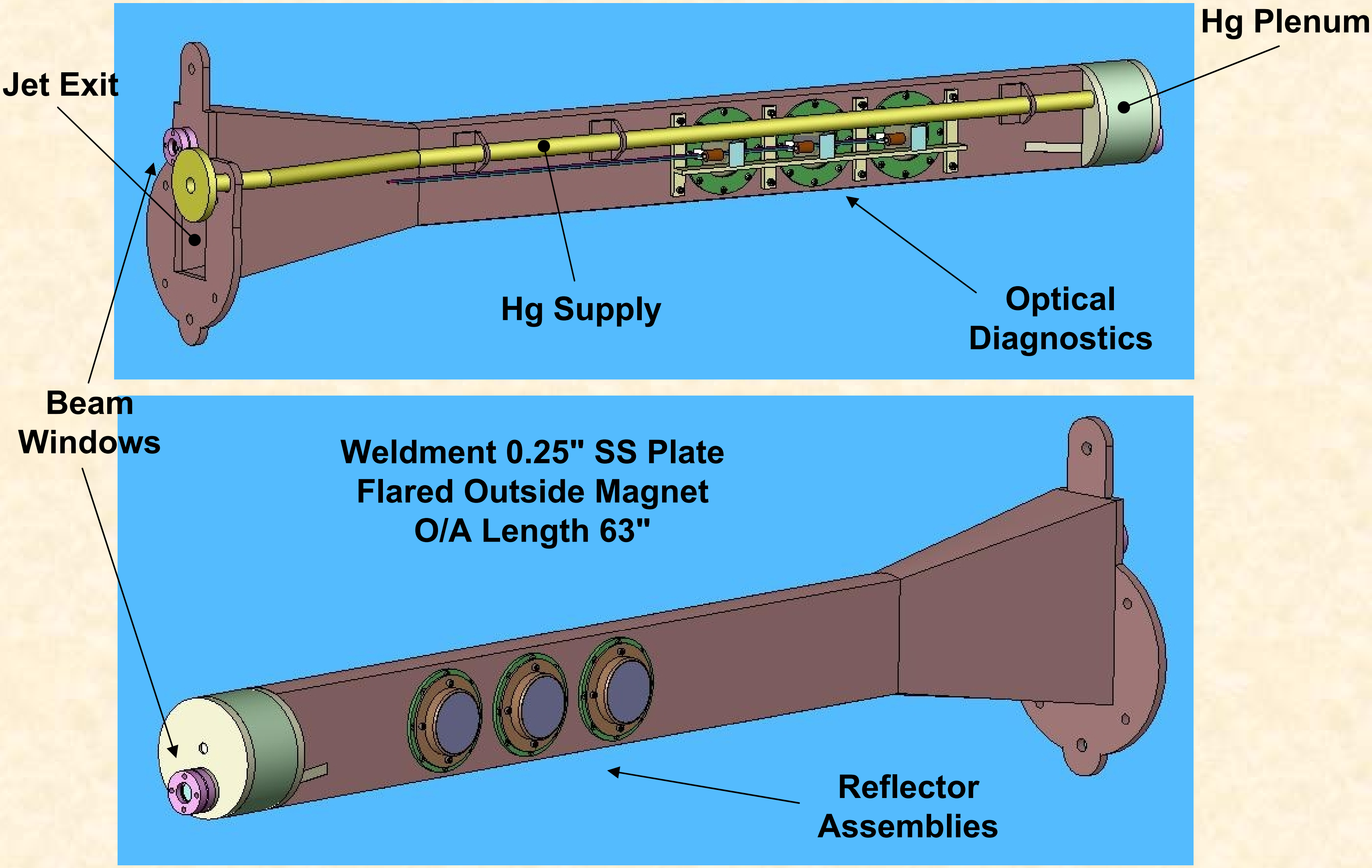
- **8" Hg cylinder, 4" hydraulic cylinders, 39" strokes**
  - **Sizes chosen based on costs**
- **Position sensor allows actual flowrate calculations**
- **Checkvalve prevents backflow into sump**
  - **Must remain submerged throughout experiment to prevent air intake in cylinder**
- **Discharge pipe will require structural supports**



Syringe Sequence of Operations

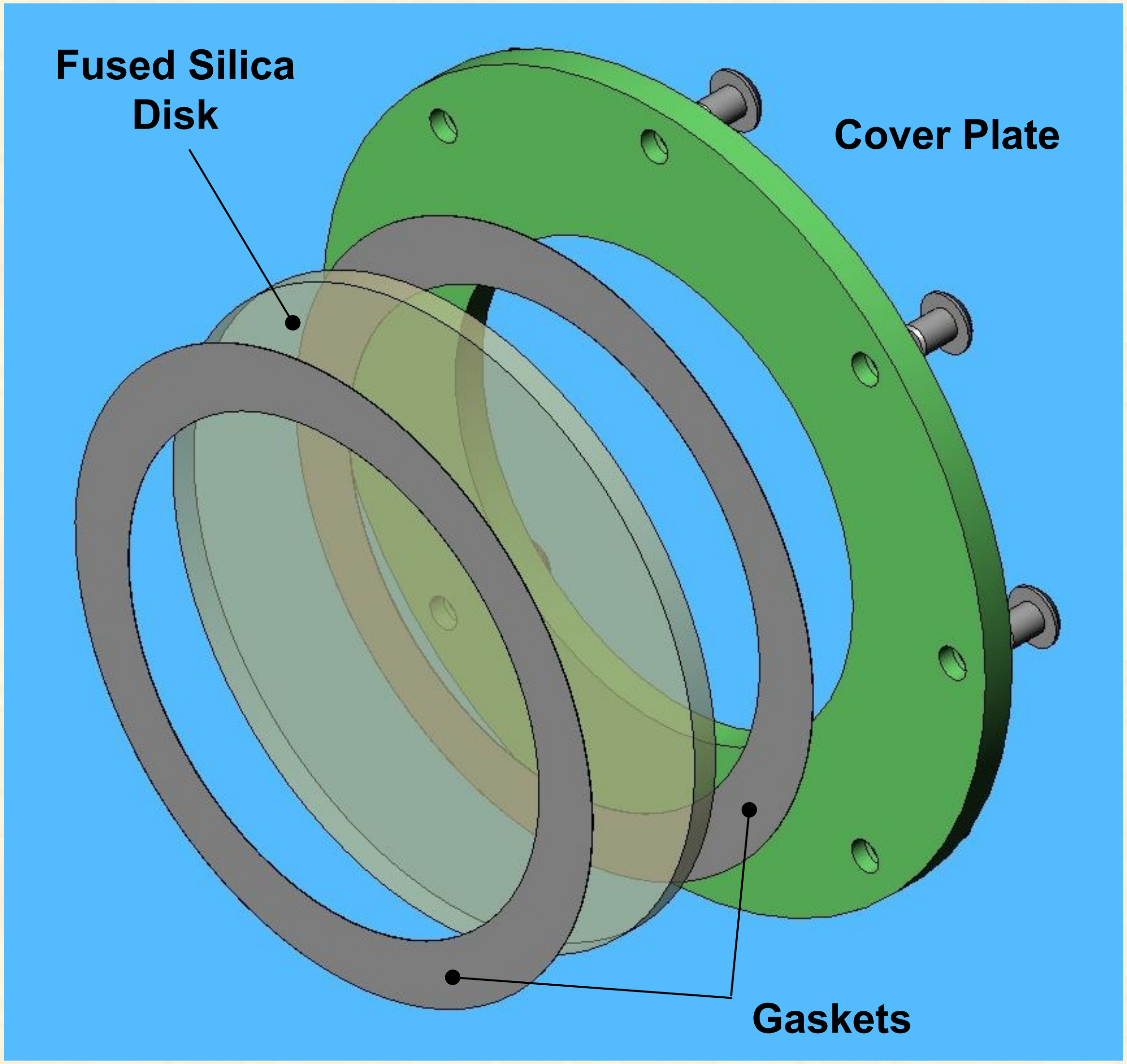
- **Retract cylinder**
  - **Checkvalve allows Hg to drain from sump into cylinder**
- **Fill supply line**
  - **Slowly move cylinder forward until Hg drips from nozzle, then stop cylinder**
  - **Prevents shock loads on piping**
- **Produce Hg jet**
  - **Coordinated with beam pulse**
  - **Ramp to full speed (~1-2 sec to remove flow transients)**
  - **SS jet**
  - **Ramp down to zero flow**
- **Piston pump idle while magnet cools**

Primary Containment

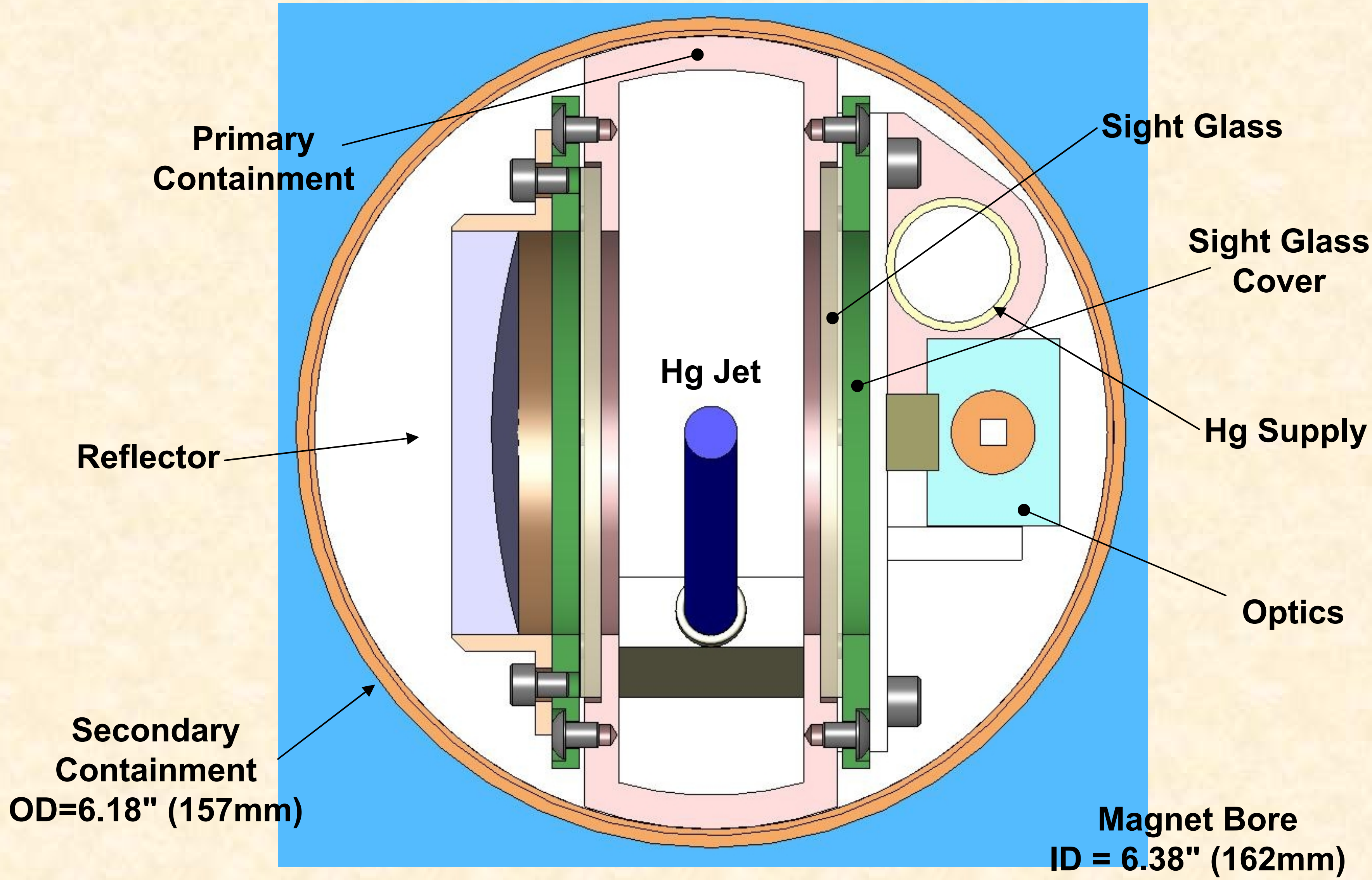


Viewports

- **Optical viewport laminated with rad-resistant gaskets**
- **Mechanically fastened cover plate**
- **Structural rigidity of disk needs further analysis**

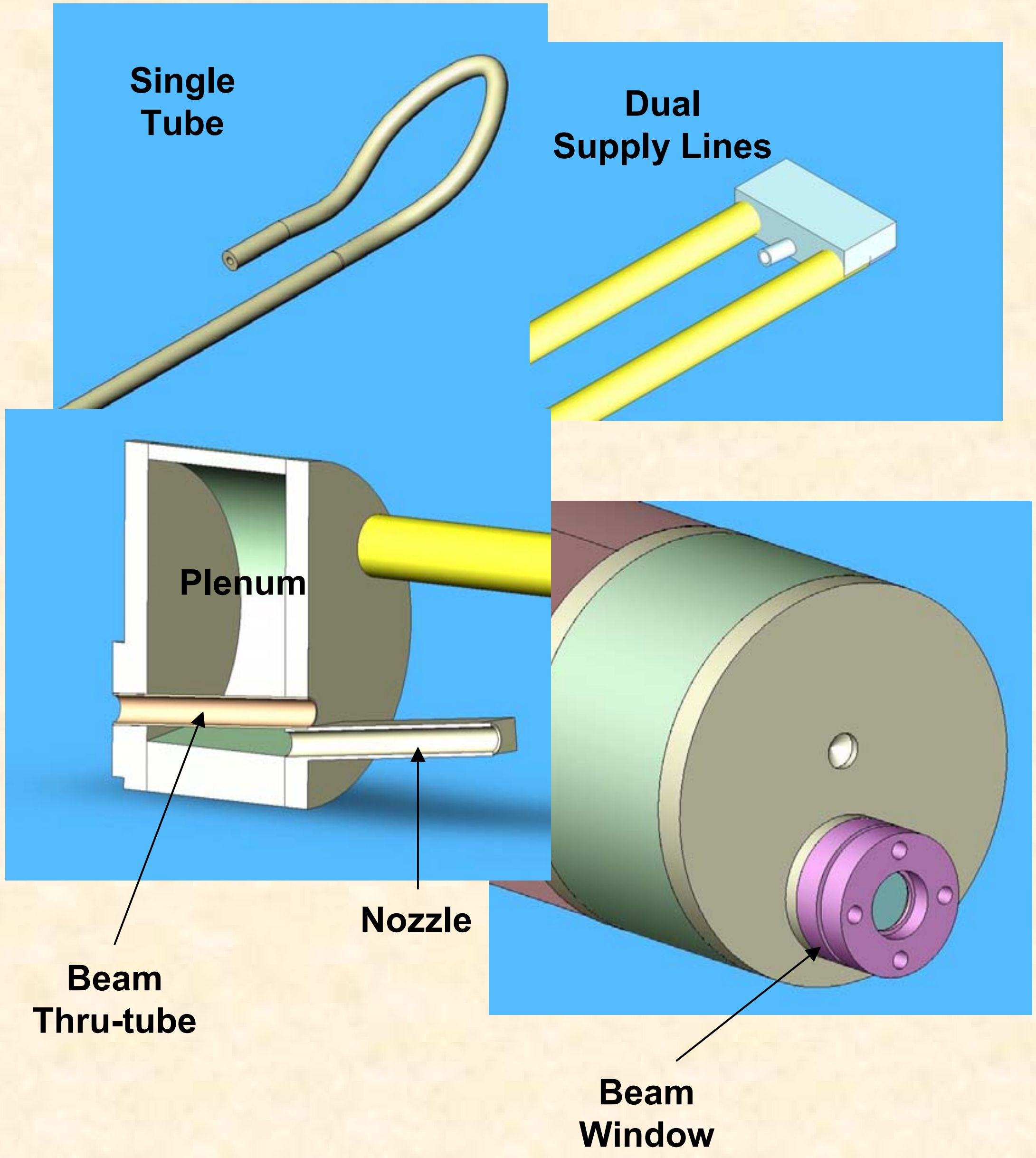


Primary Containment Cross Section



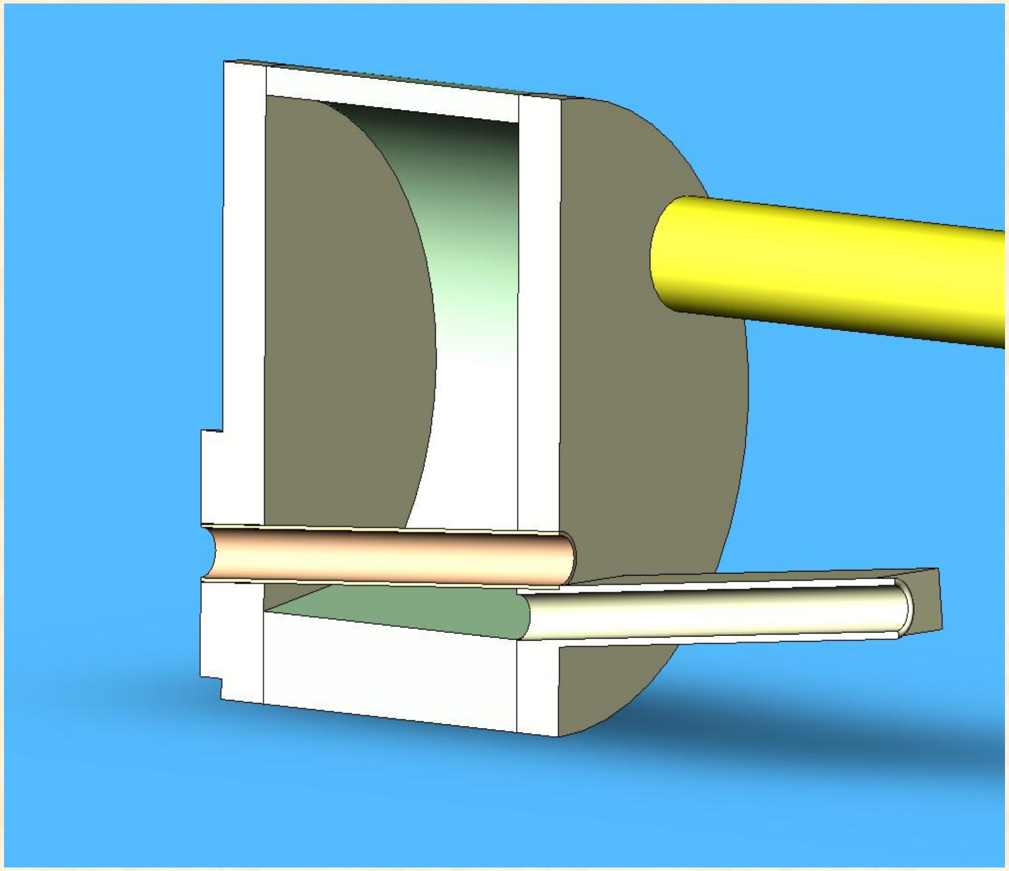
Hg Plenum

- **Purpose is to provide reservoir to allow Hg to change direction in confined space**
- **Several designs have been considered**
- **Open chamber with nozzle exit and beam thru-tube**



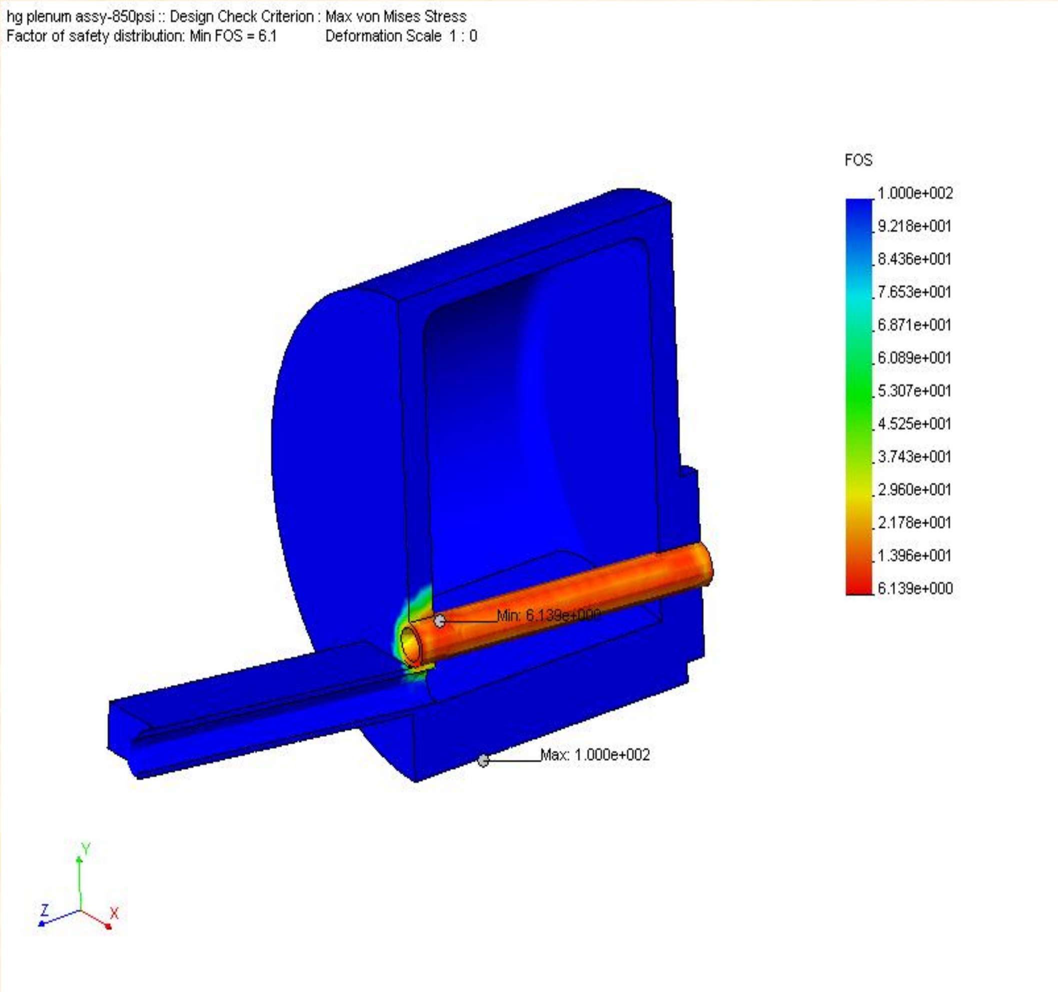
Plenum Issue

- **Trapped air in plenum**
  - **Swept out with Hg**
  - **Compressed and acts like spring**
- **Solutions**
  - **Evacuate system prior to operation**
    - **Hg vapor issue**
  - **Provide means to quickly move air out nozzle**



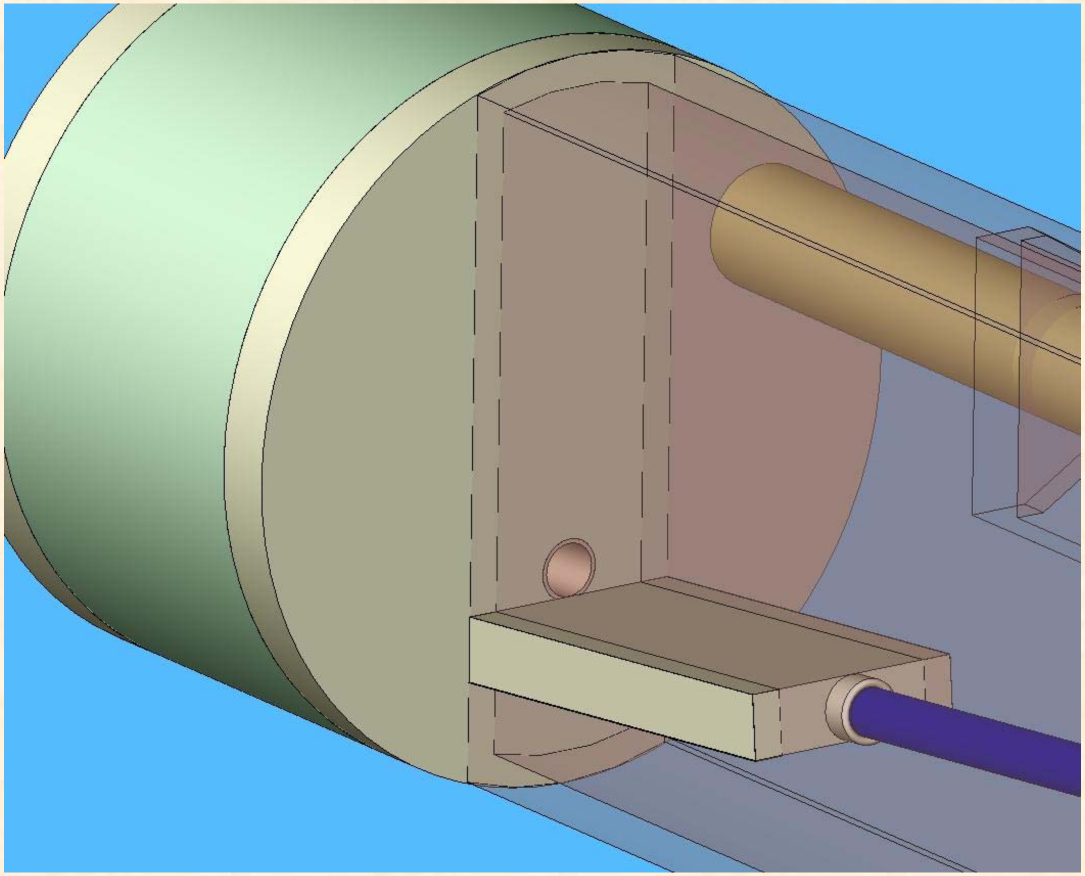
Plenum Structural Design

- **Static FEA performed using pressure load of 850psi on interior surfaces**
- **Minimum FOS = 6 around beam thru-tube**
- **Flow analysis presented by M. Wendel**

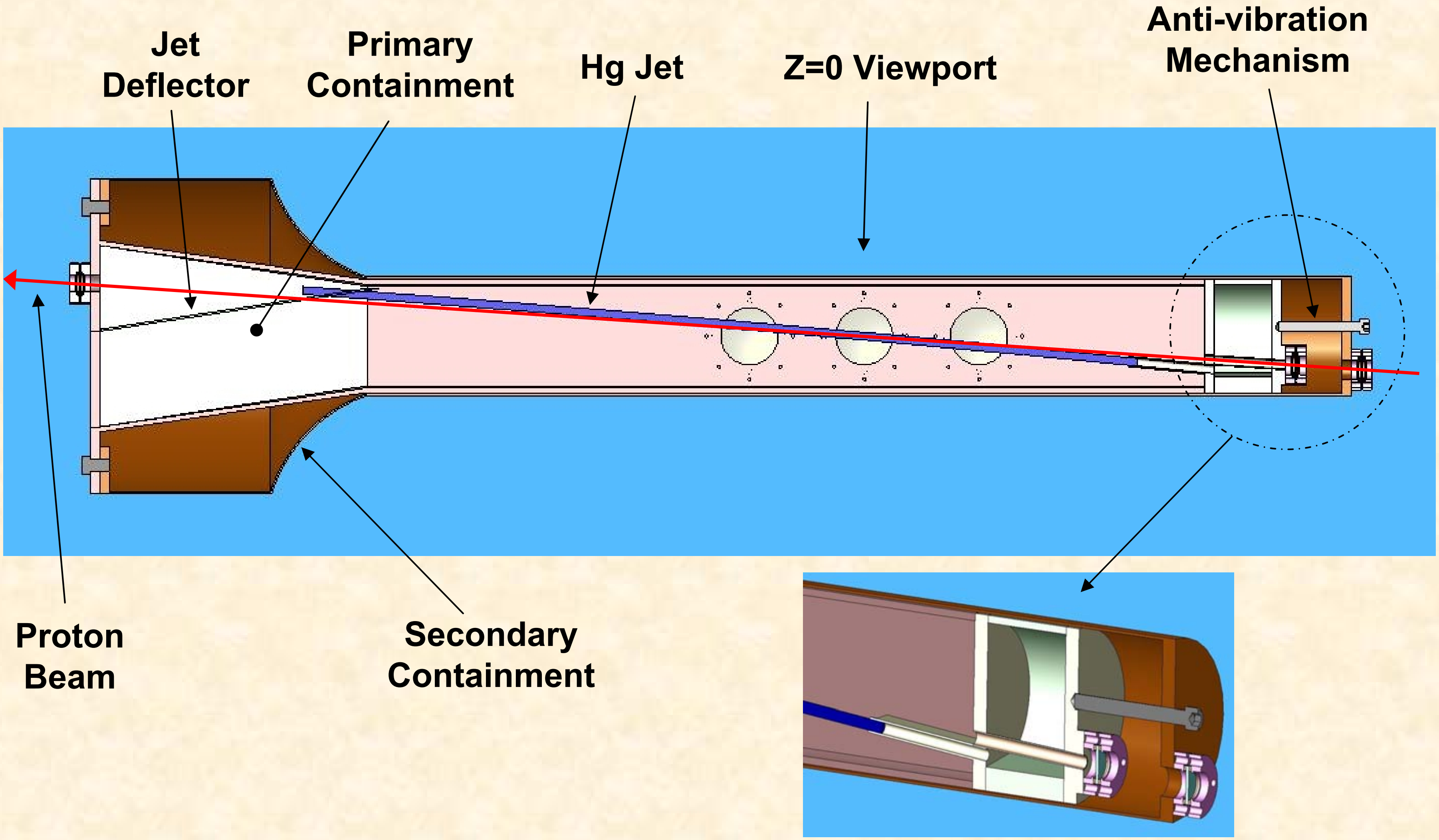


Plenum/Nozzle Integration

- **Plenum & nozzle welded to primary containment – no nozzle replacement**
- **Nozzle side restraints resist field-induced motion in Hg**
- **Length set at 10X dia = 4"**
- **Changes to inlet/exit required based on flow analysis**



Primary Containment – Side View

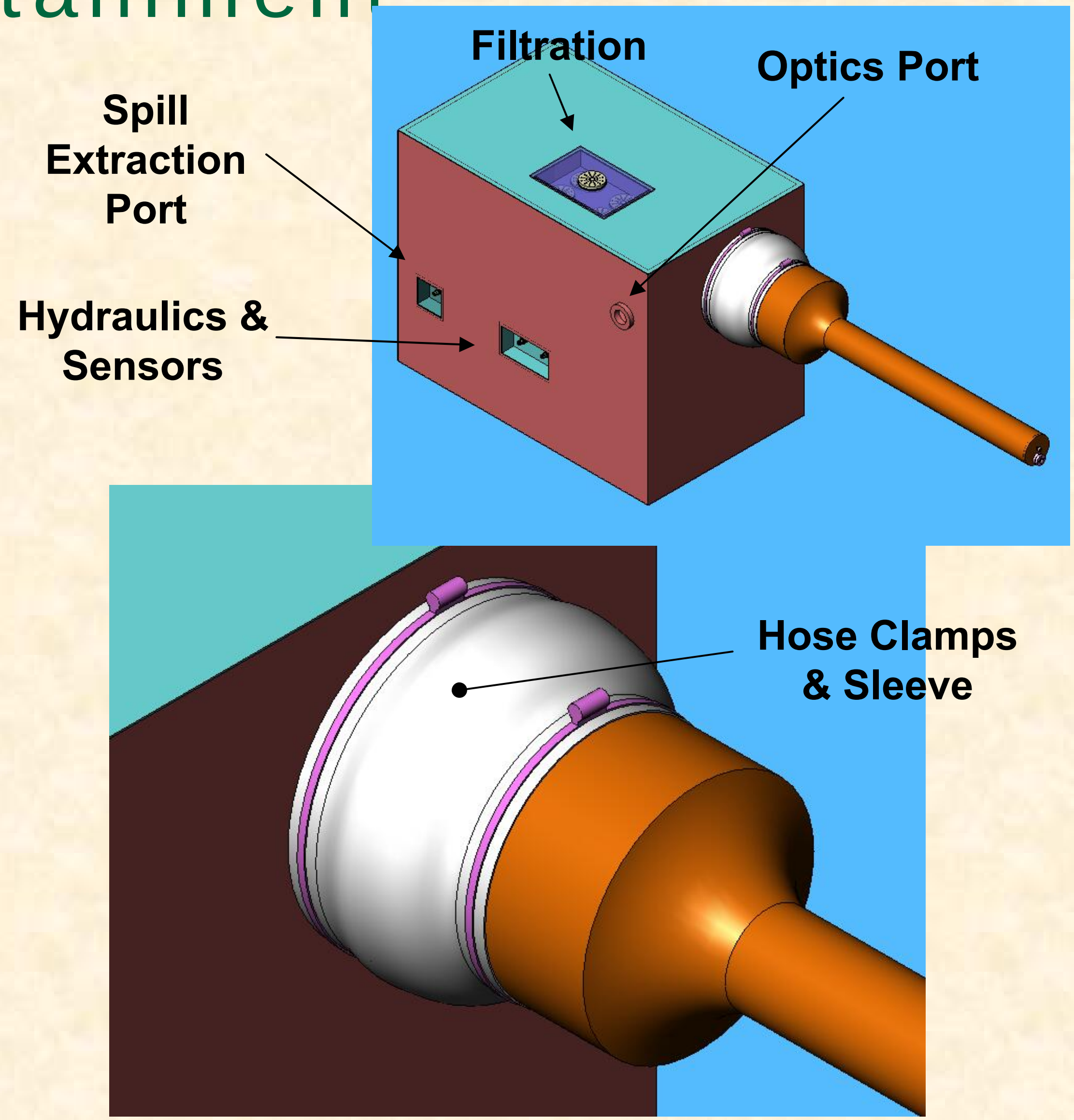


Deflector

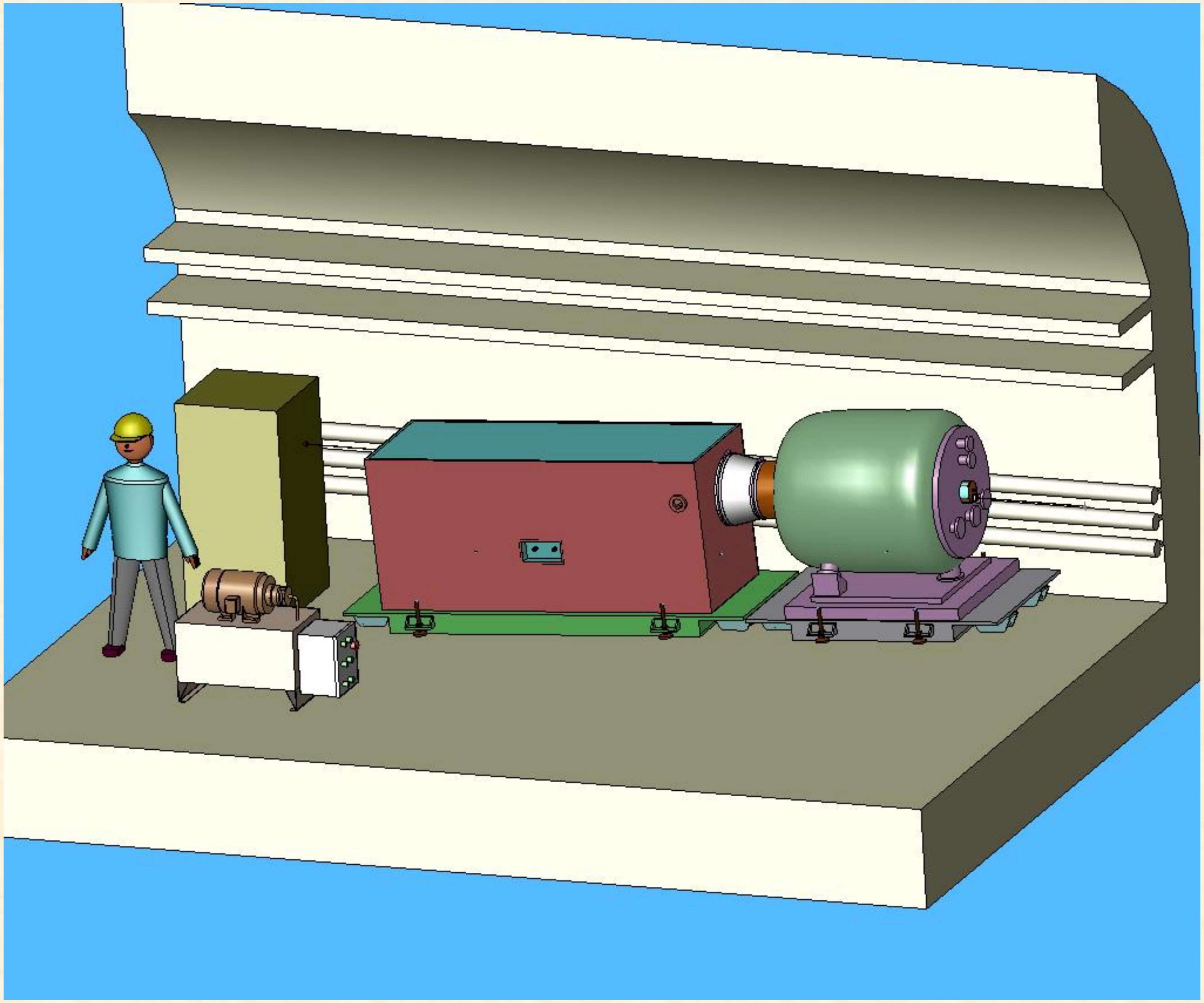
- **Purpose is to enhance Hg drainage into sump tank by minimizing splashing and Hg drops back into magnet bore**
- **Material is Ti6Al4V, same material used for beam windows**
- **Designed as flat plate with low angle of incidence**
  - **Some curvature may be needed to aid in flow control**
  - **Princeton tests can be used to provide design feedback**
- **Stress calculation indicates Hg jet impact force <100lb**
  - **Deflector thickness of 0.1" provides FOS=5.5**

Secondary Containment

- **SS sheet metal enclosure around entire primary system**
- **Contains Hg leaks, provides access to monitor Hg vapors**
- **Provides access to optical diagnostics, hydraulics, and sensors**
- **Incorporates beam windows**
- **3 components: hydraulics box, target cover, connecting rubber sleeve**



Syringe Layout



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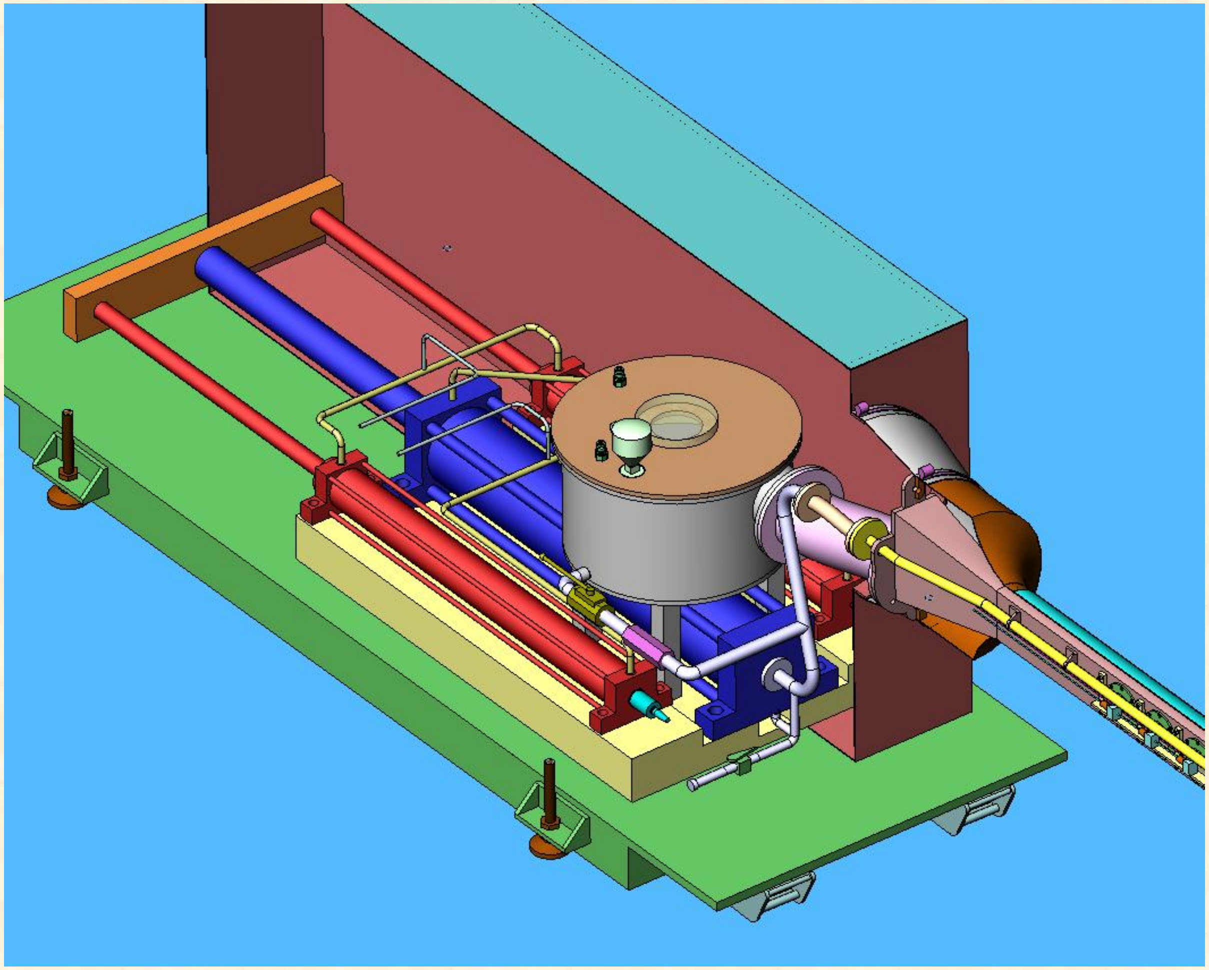
Hg Target System Design Issue

- **Target system exceeds 3m length constraint**
- **Requires that primary containment be handled as two pieces & reassembled during installation**



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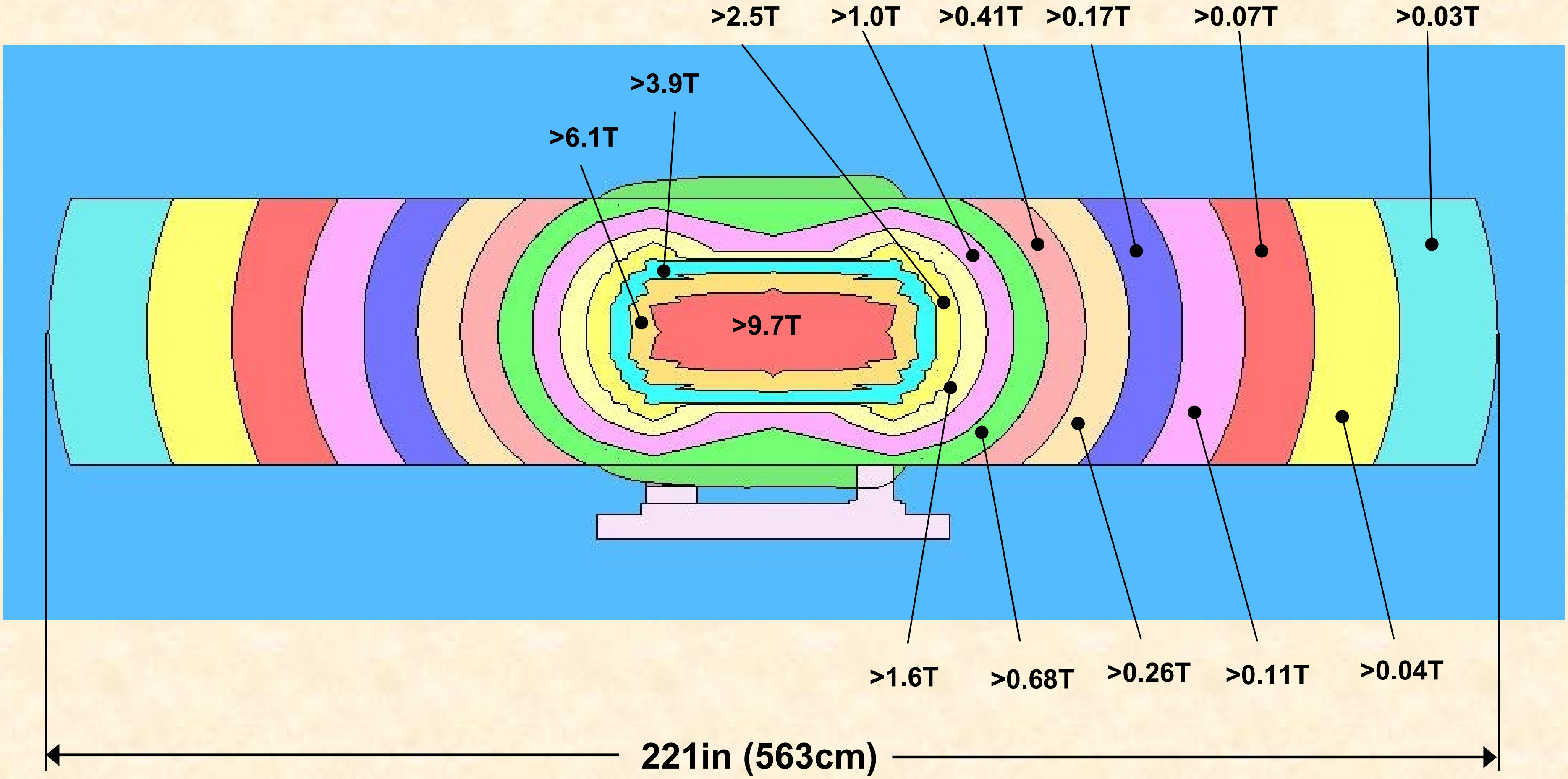
Magnet Field Plot

$\left(xyz_0, xyz_1, \log\left(xyz_2\right)\right)$

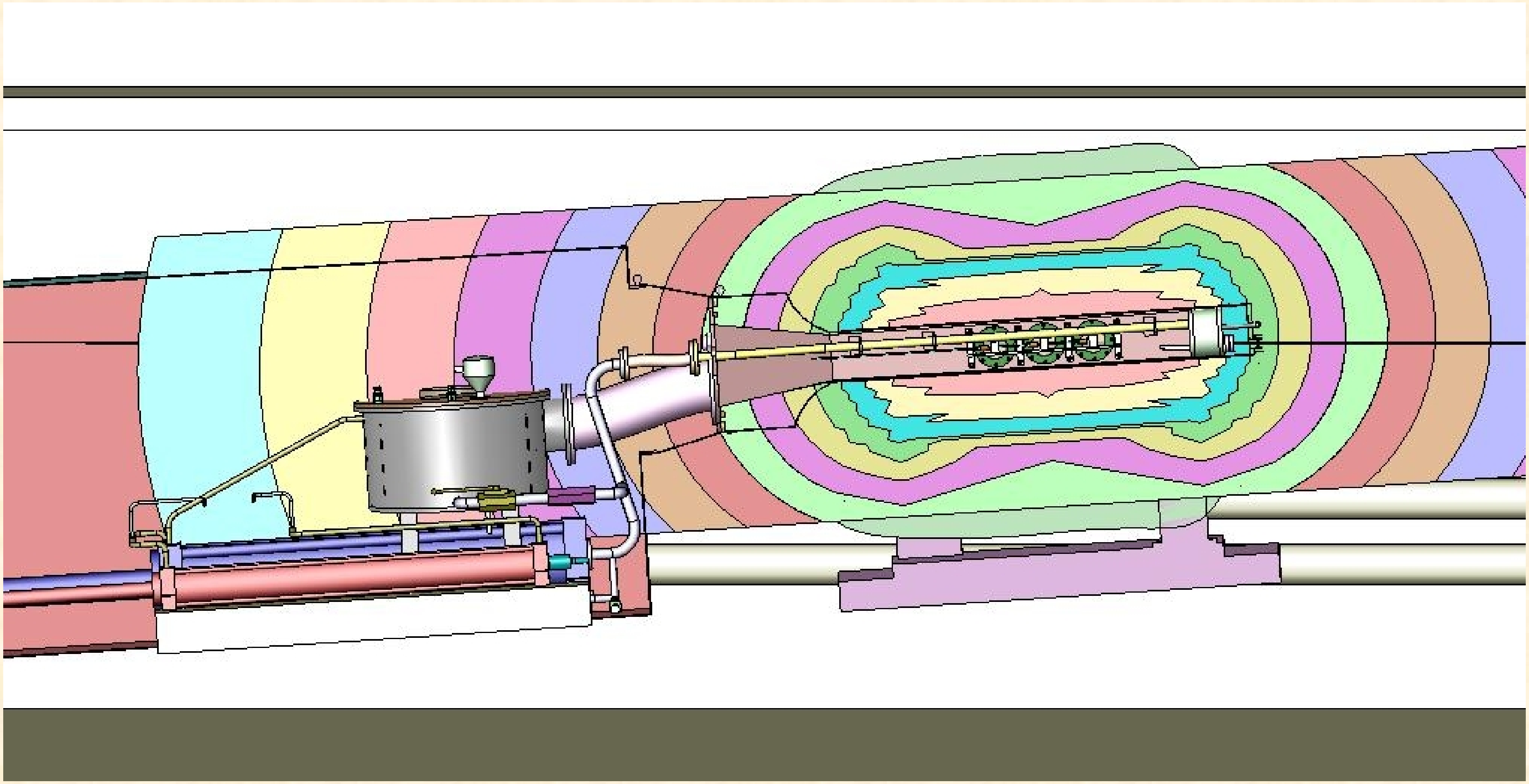
Magnetic field distribution: the axes are in meters; the rectangle is one half of the solenoid.

- **The volume within the conductor is > 9.7 T (red), > 6.1 T (orange).**
- **The field at Z=0, R=0.6 is >0.6 T, at R=1.0 (base support structure), B> ~0.1 T (1000 G).**
- **The field at Z=-2.5, R=0.4 (pump motor) is 0.03<B<0.07 T (300-700 G).**

Fields with Solenoid



Field Near Equipment



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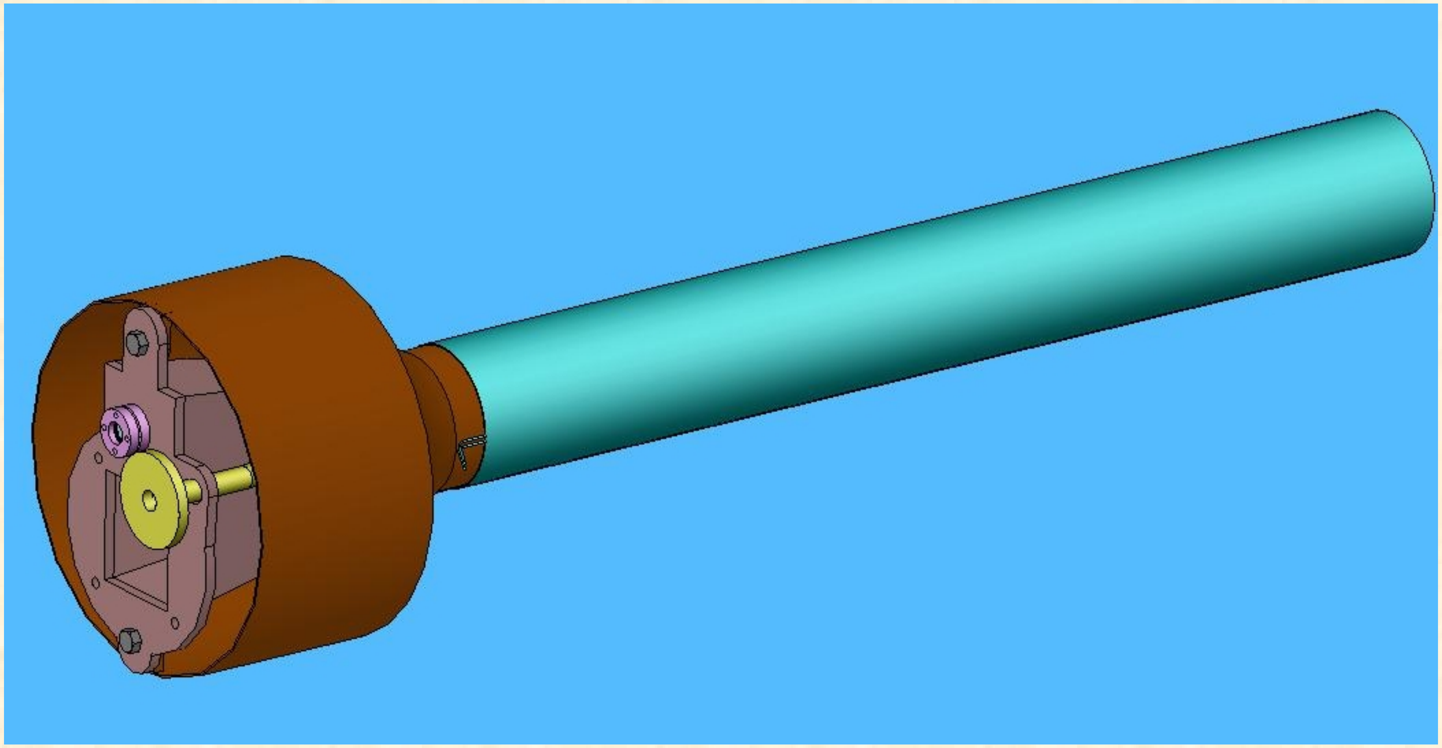
Target Module Insertion

- **Primary and secondary containment mechanically fastened (weight ~ 160 lbs)**
- **Flexible metal hoses probably already attached**
- **Could be inserted either before magnet aligned to beam or after**



Title 1 Design Review Comments

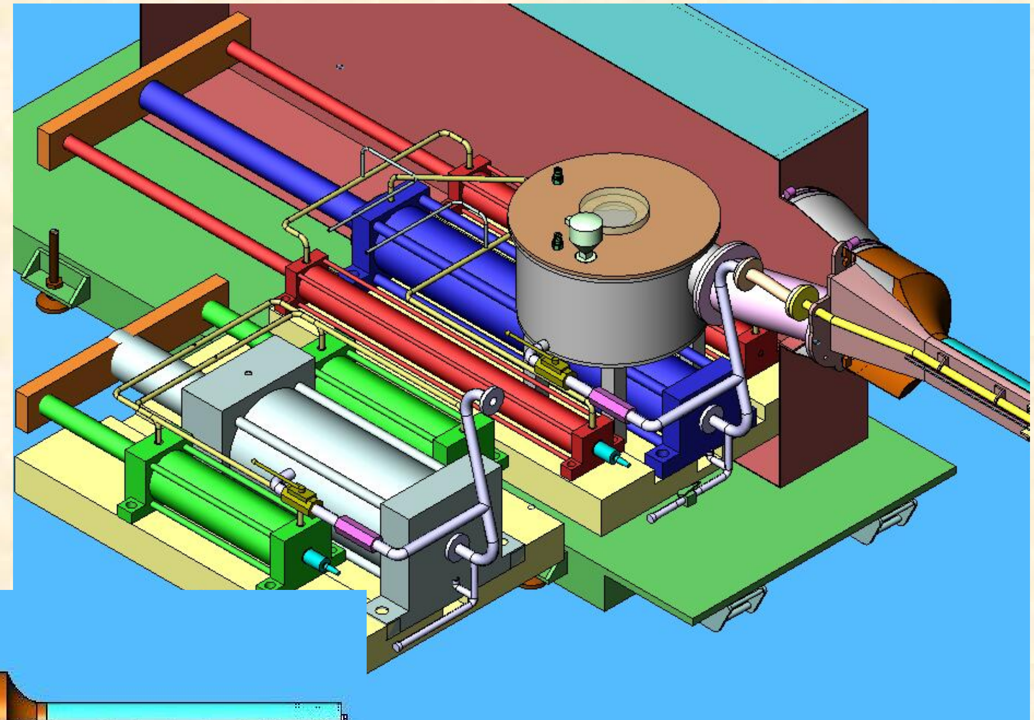
- **Nozzle design**
  - **More analysis needed**
  - **Nozzle/deflector designs need validation**
  - **Replaceable or adjustable nozzle**
- **Viewports**
  - **Structural rigidity of viewport optics**
  - **May require testing**
- **System sizing**
  - **Footprint for 20sec syringe too large**
  - **Increase cylinder diameter (from 8" to 12") to decrease required stroke**
  - **Decrease required jet duration**
- **Add filtered breather system to primary containment**
- **Clarify CERN facility requirements**
  - **Operational logistics affect system design**
  - **Prepare failure analysis**

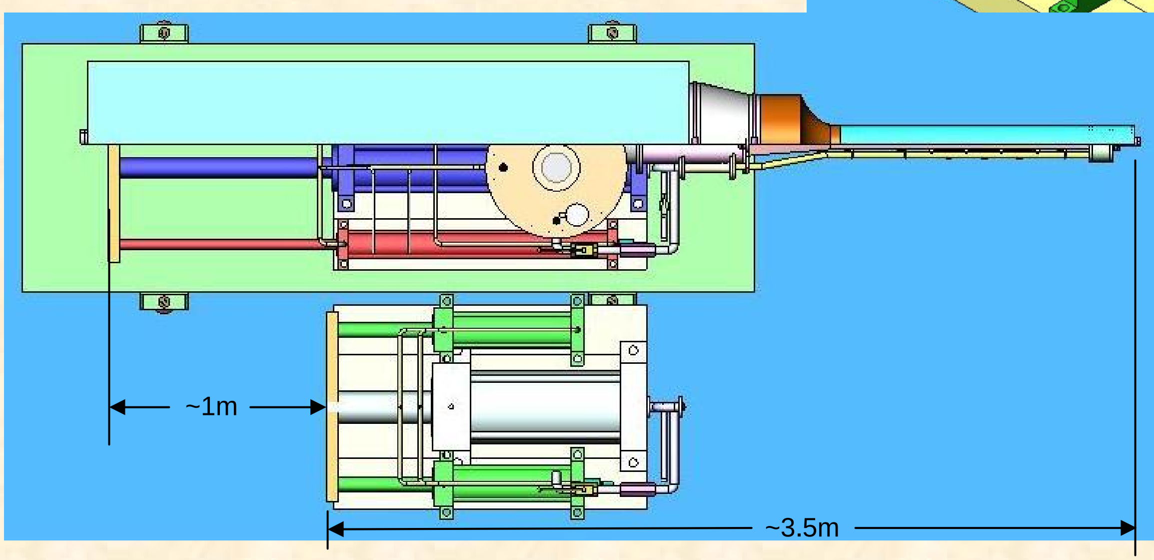
Hg Cylinder Upsizing

Original: 8” Hg cylinder

Updated: 12” Hg cylinder

Both with 20sec capacity





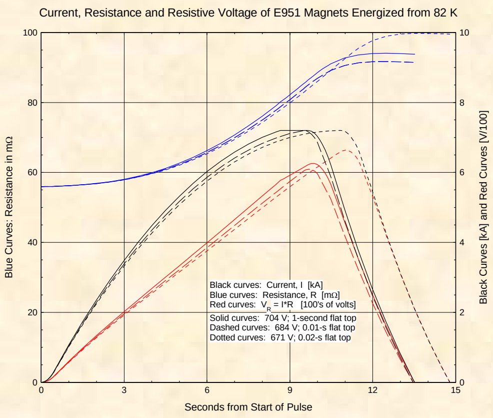
Control System Requirements & Constraints

- No existing power available in tunnel
- Power system mounted on hydraulic pump reservoir
- Operator controls 60m away
- Will require some level of communication with other control systems (solenoid, beam, diagnostics)

Operation – Full Field

(Approx.) Time (sec.)	Solenoid		Target Pump System	Proton Beam	Optical Diagnostic
	Cryogenics	**Power Supply**			
minus 30	Magnet full of LN_2 @ 80ºK	Standby	Refill syringe pump w/ Hg	Call for beam	Off
minus 10	Purge LN_2 with gaseous He	Standby	Standby	Wait for beam	Standby
0 to 6.5	Magnet full of He gas	Ramp to full current	Standby	Wait for beam	Standby
6.5 to 8.5	Magnet full of He gas	Ramp to full current	Ramp to full speed jet	Wait for beam	Standby
8.5 to 9.5	Magnet full of He gas	At full current	Steady state Hg jet	24 GeV, 1 MW	Operate laser and high speed camera
9.5 to 10.0	Magnet full of He gas	Begin de-energizing	Shut down syringe pump	Standby	Off
10.0 to 13.5	Magnet full of He gas	De-energize to zero	Standby	Standby	Off
13.5 to 1800.0*	Fill magnet with LN_2 @ 80ºK	Cool down to ~80°K	Standby	Standby	Off

* Assumes a 30-minute dwell period.



Power Requirements

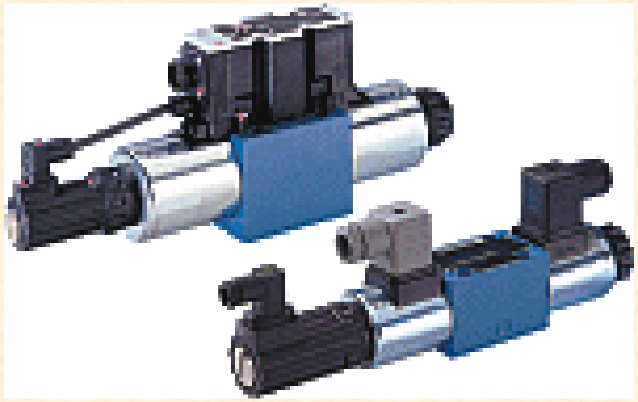
- **Hydraulic pump – 460VAC, 50-60Hz, 60A**
  - **Transformer available?**
- **Proportional control valve – 24VDC**
- **Heater foil – 120VAC**
- **Hg vapor monitor – 120VAC**
- **Instruments – 24VDC**

Instrumentation & Sensors

- **Cylinder position sensor**
- **Hg level sensor**
- **Thermocouple**
- **Hg vapor monitor(s)**
- **Conductivity probe**

Proportional Directional Control Valve

- **Bosch Rexroth 4WREE**
  - **Operating pressure: up to 3000psi (210 bar)**
  - **Nominal flow: 8.45gpm (32 l/min)**
  - **Sensitivity: <= 0.05% (equates to 0.003 m/sec nozzle velocity)**
  - **Supply voltage: +24VDC**
  - **Command signal: ±10VDC**



Position Sensor

- **Temposonics G-series linear position sensor**
  - **Measured variable: displacement**
  - **Measuring range: 2-100in**
  - **Repeatability: 0.001% full stroke**
  - **Output: voltage or current**
  - **Update time: <1ms**
  - **Supply voltage: +24VDC**

Hg Level Sensor

- **Omega Instruments LVR50-PP two wire liquid level float transmitter**
  - **Accuracy: 0.25" over span in water**
  - **Specific gravity: 0.75 minimum**
  - **Supply voltage: 10-40 Vdc**
  - **Signal output: 4-20mA**
  - **Stainless steel construction, choice of head materials**
- **This particular instrument is too long, but is indicative of a simple Hg level sensor**

Hg Vapor Monitor

- **Specifications**
  - **Resolution 0.001 mg/m3**
  - **Detection range 0.003-0.999 mg/m3**
  - **Accuracy ± 5% at 0.100 mg/m3**
  - **Response Time13 s in sample mode; minimum auto sample time 5 min**
  - **Flow rate 750 cc/min**
  - **Power requirements100-120 V ~ 50/60 Hz, 1A**

Hg Vapor Monitor – *Mercury Instruments GmbH*

<u>Basic Specs</u>

- **UV-Absorption method**
- **0-100 µg/m^3 / <0.1 µg/m^3**
- **1 sec response**
- **RS 232 bidirectional for PC, parallel for printer**
- **1.5 l/min membrane pump**
- **Built-in rechargeable or external 12V DC sources, or 110-240V (50/60 Hz) power supply**
- **425x150x340 mm, 9kg**

Mercury Tracker 3000

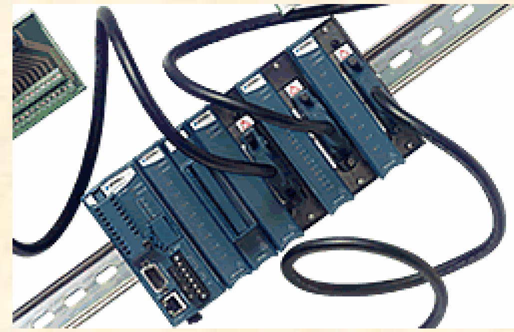
Conductivity Probe For Leak Detection

VEGA Conductive level switches: electrodes with 1 … 5 probes in rod or cable version

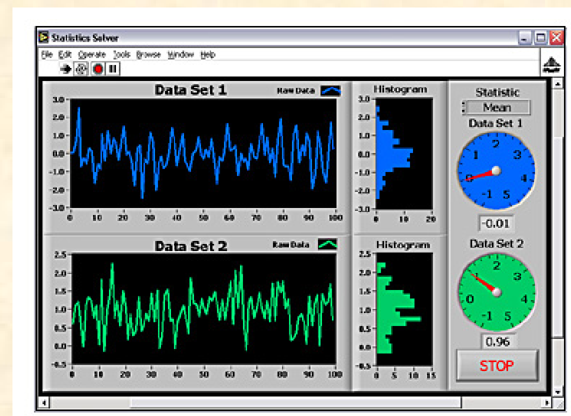
- **One electrode can detect up to 5 different levels**
- **Approved for hazardous areas- certified acc. to ATEX**
- **Approved as overfill protection to WHG**
- **Suitable housing versions in different materials**
- **Rod electrodes up to 4 m length**
- **Cable electrodes up to 30 m length**
- **Suitable for product temperatures up to 130°C**
- **Operating pressure up to 63 bar**
- **Protection IP 66/IP 67**

Preliminary Control System Scheme

- **Remote control over long distance limits choices**
  - **Analog I/O modules need to be close to equipment and power supplies**
- **PLC may be adequate, investigating capabilities and functionality over required distance**



- **LabView controller on laptop computer is suggested**
  - **National Instruments recommends CompactPCI I/O modules**
  - **Communicates to laptop via EtherNet cable**
  - **Allows custom operator interface, data logging if required during development**
  - **Should allow straightforward integration with other control systems**



Transportation, Installation, and Operations

System LifeCycle

- Shipping ORNL to CERN
- System setup/testing at CERN
- Installation/integration with magnet
- Post-experiment operations
- Shipping from CERN to ORNL

Transportation

- **Ship target system from ORNL to CERN and back to ORNL, via surface transport in a 20 ft. sealand container**
  - **Uncontaminated/non-radioactive Hg will be shipped in standard 2-liter steel flasks (maximum 17) with appropriate overpack containers (1 per flask)**
  - **All equipment and materials will be on pallets designed for reuse**
  - **The activated target system and Hg will be stored at CERN until activation levels permit shipping to ORNL as low-level radioactive material**

Target System Setup and Testing

- **Perform all Hg loading/unloading in separate CERN facility**
- **System can be leak checked prior to Hg loading – requires opening secondary containment**
- **If adequate electrical power available, target system and optical diagnostics could be fully operated prior to installation in tunnel**
- **Due to potential Hg vapors, temporary hut may be erected to house target system**
- **Target system transported to tunnel shaft loaded with Hg**

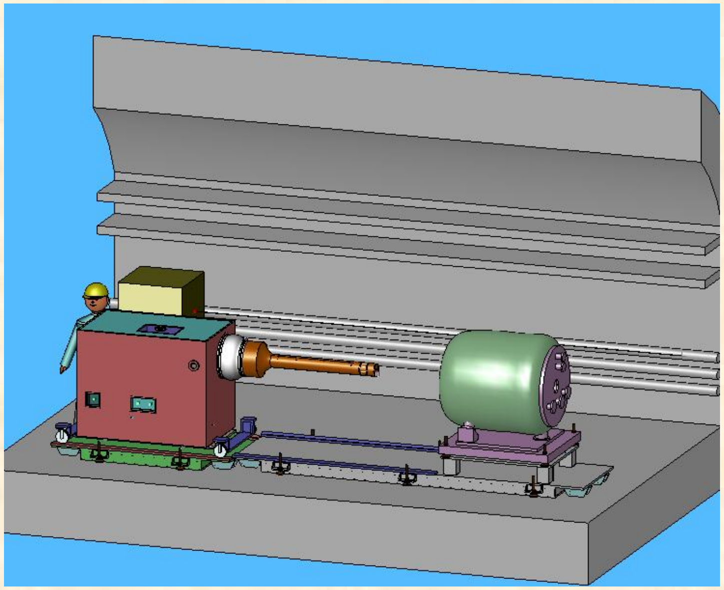
Facility Constraints

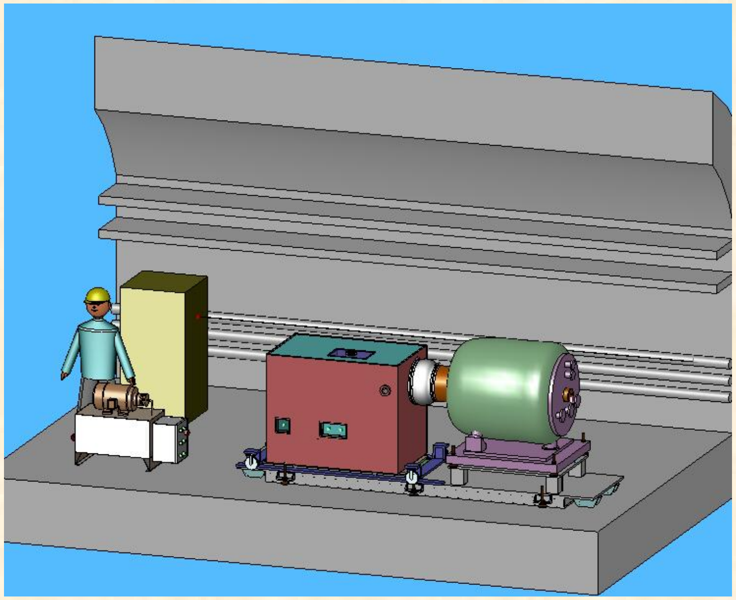
- **No overhead lifting capability within tunnel**
- **Mobile crane used to lower equipment from ground level to tunnel floor**
  - **All components must have lifting points**
- **Components moved manually**
- **Modularity required**
  - **Component footprint size limitation is 1.3m x 3m**

Solenoid/Target Assembly Sequence

Assumes Hg already loaded into primary containment

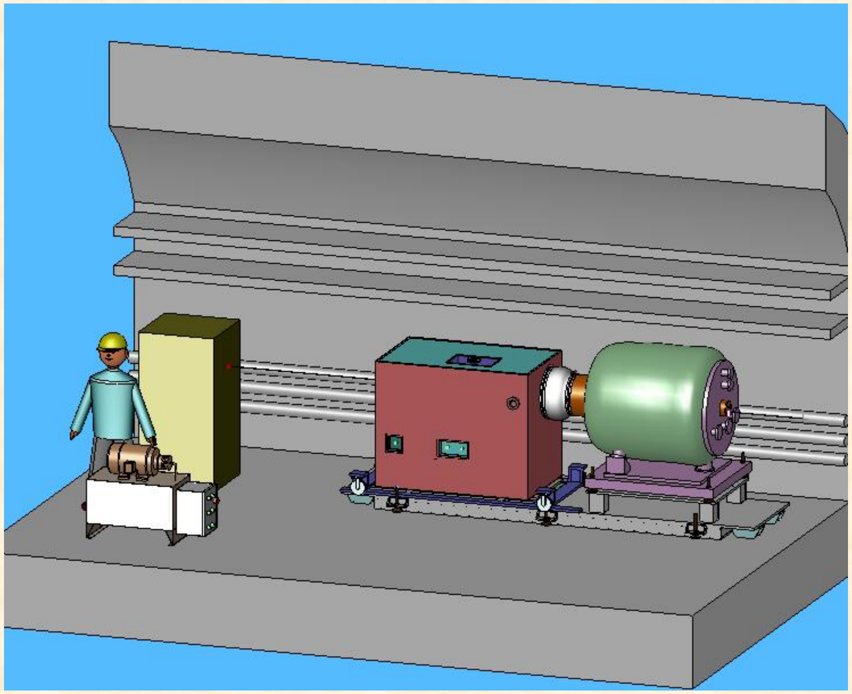
- **Bring all equipment into TT2A**
- **Position solenoid beside beam on common baseplate**
- **Manually insert target into bore of solenoid**
  - **Transfer target from carrier baseplate to common baseplate**

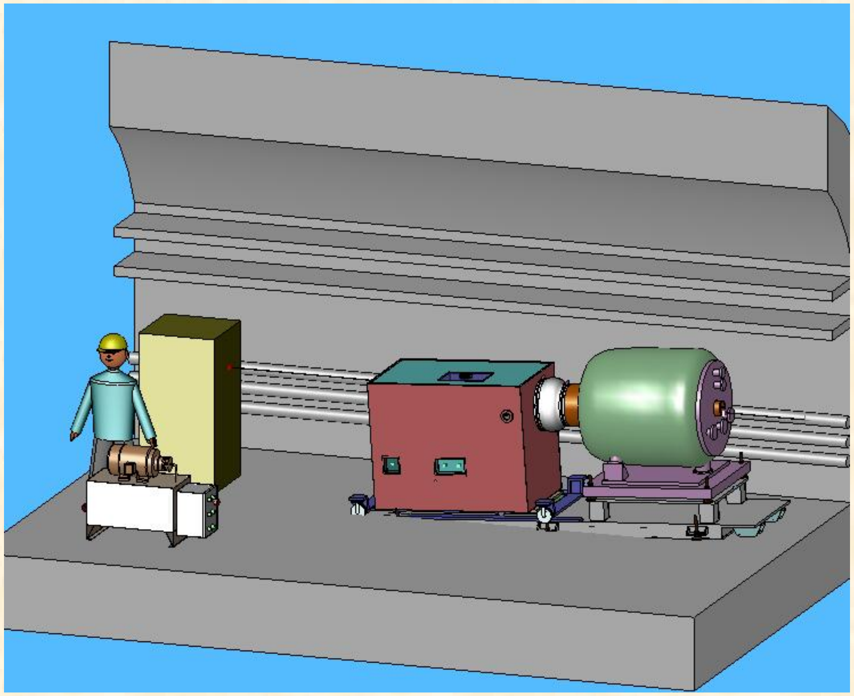




Solenoid/Target Assembly Sequence 2

- **Move common baseplate into beamline, set elevation and tilt**
  - **Alignment fiducials on solenoid**
- **Position hydraulic reservoir**
- **Connect hydraulics & instruments**
- **Connect power, set up controls**





TT2/TT2A eDrawing

Target System Decontamination, Dismantling, and Disposal (DD&D)

- **1-2 weeks of activation cool down while target equipment is still located in the beam line position**
  - **After cool down disconnect services hands on, lower baseplate, and move to the side of TT2A tunnel**
  - **Minimize operator time near equipment**
- **6-12 months of additional activation cool down while located in the TT2A tunnel, but out of the beam line position**
- **Move to a suitable facility out of the TT2A tunnel for hands on DD&D tasks, in preparation for packing and shipping to ORNL**

Equipment Decommissioning/Disposal

- **The target equipment (and the solenoid) will have neutron-induced activation**
- **Based on (H. Kirk 9/01/04)**
  - **200 pulses**
  - **16 x 10^{12} protons/pulse (avg.)**
  - **30 days of operation**
- **Contact dose rate on the iron exterior will be:**
  - **after 1 hr 40 mrad/hr**
  - **after 1 day 21 mrad/hr**
  - **after 1 week 13 mrad/hr**
  - **after 1 mo. 5 mrad/hr**
  - **after 1 year 1 mrad/hr**
- **ORNL will take back the Hg target system and dispose of activated Hg and components**
- **Magnet, power supply, and cryosystem should be available for other uses … may be sent to KEK**

Proposed CERN Support

- **Installation**
  - **Rigging crew to move equipment from ground level into TT2A tunnel**
  - **Electrical engineer / technician to connect power**
  - **Instrument engineer to certify proper function of the target controls, integrated into the solenoid system**
- **Operation**
  - **Grad student(s) to operate and monitor equipment**
- **Decommissioning Tasks**
  - **Rad-trained technician(s) / grad student(s)**
    - **Disconnect power**
    - **Move equipment out of beamline**
    - **Transfer Hg into storage flasks**
- **Packing/Shipping**
  - **Prepare target equipment and Hg for shipment to ORNL**

Safety Features & Issues

Requirement

- **Conduct experiment while leaving no traces of Hg contamination in CERN facilities**
  - **Set up equipment**
  - **Load Hg**
  - **Install in tunnel**
  - **Conduct experiment**
  - **Remove from beam line**
  - **Allow radiation decay**
  - **Remove from tunnel**
  - **Unload Hg and package for shipment**
- **Must consider Hg liquid and vapor**

Target Design Specifics

- **Primary & secondary containment for liquid Hg**
- **System designed for 1atm overpressure**
- **Hg vapor filtration system**
- **Sensors to monitor for leaks or spills**
- **Hg loading/unloading with minimal openings**
- **If major leak occurs, Hg removal from secondary will be possible without opening secondary**

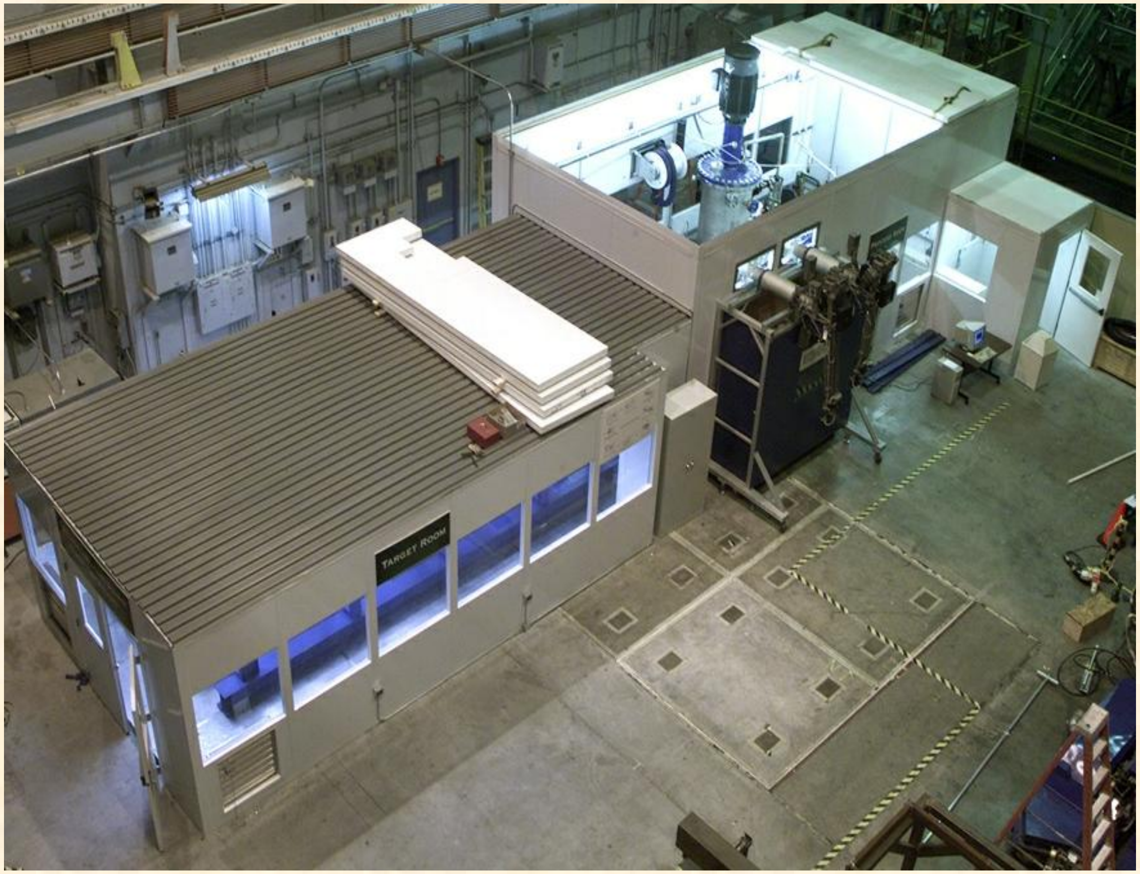
Hg Handling Issues

Properties, Safety Limits, Standards

- **Atomic Weight: 200.59**
- **Boiling Point: 357 degree C**
- **Specific Gravity: 13.6**
- **Vapor Pressure: 0.0012 mm Hg**
- **Vapors: colorless, odorless**
- **Solubility: insoluble in water**
- **NIOSH/OSHA limits: 0.05 mg/m^3, 10 h/day; 40 h/wk**
  - ***ORNL: 0.025 mg/m^3, respirators at 0.012 mg/m^3***

The Target Test Facility (TTF) - Basis For ORNL's Hg Handling Experience

- **Full scale, prototype of SNS Hg flow loop**
- **1400 liters of Hg**
- **Used to determine flow characteristics**
- **Develop hands on operating experience**
- **Assess key remote handling design issues**



TTF Pump Room and Target Room

- **75 Hp centrifugal pump**
- **Nominal flow at 1450 liters/min (380 gpm)**
- **Completed several major equipment upgrades for piping and target configuration**

Hg Transfer

TTF vacuum pump was used to transfer Hg directly into the storage tank

- **Lower risk than manual loading or using a pump**
- **Faster operation, ~ 1-1/2 minutes per flask (over 500 flasks required for TTF)**

Hg Vapor Filtration

- **Primary and secondary containments have air at 1 atmosphere**
  - **Air activation is not an issue since the air is not purged after each pulse and 1 hour of waiting is sufficient for decay**
  - **May require cartridge filtration like the WNR Bubble Test Loop**
- **ORNL testing will determine efficiency of system**
  - **Filtration system may require cap in tunnel**
  - **Additional vapor monitor for filtration exit may be needed**

Other Req'mts

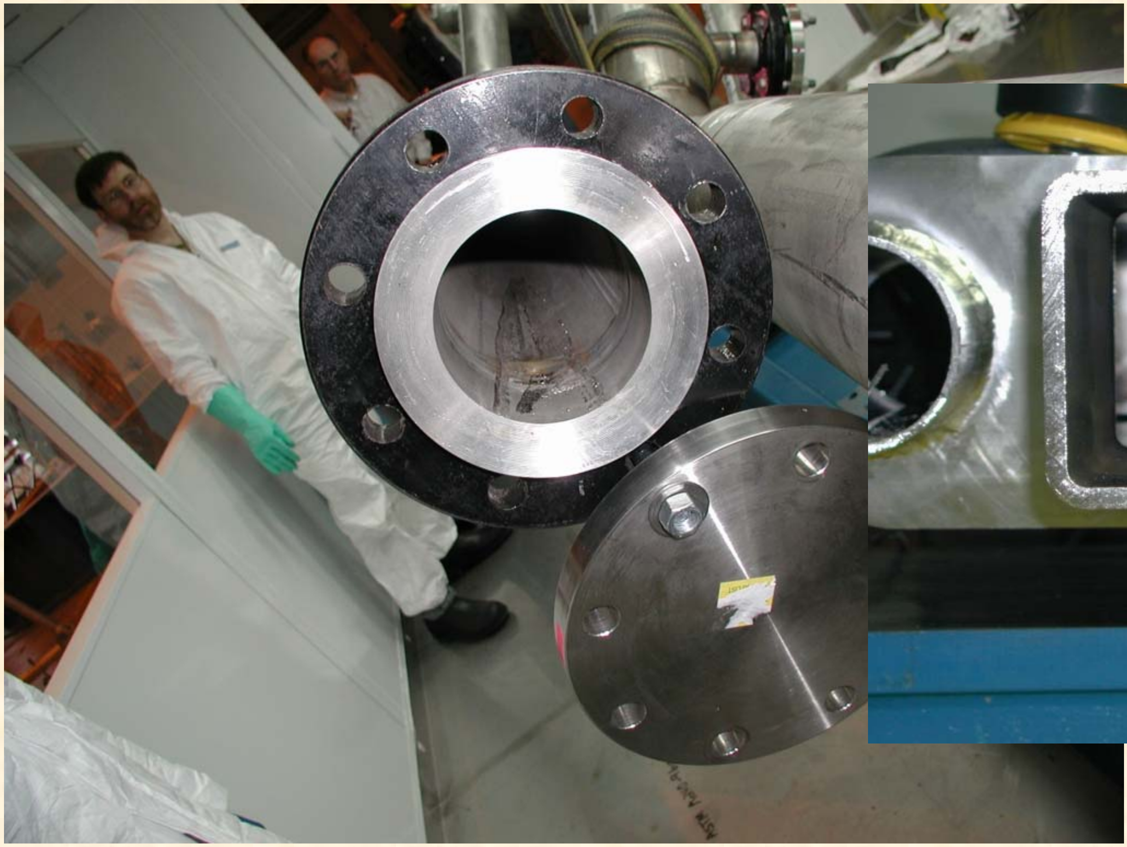
- **Filling/Draining Hg – vacuum pump or peristaltic pump**
- **Maintenance/Handling - equipment is assembled hands on but maintained and operated with minimal contact by personnel**
- **Design Life – designed for 10,000 start/stop cycles**
- **Operating Cycle – up to 20 seconds of 1-cm jet every 30 minutes, up to the temperature limit of the Hg inventory**

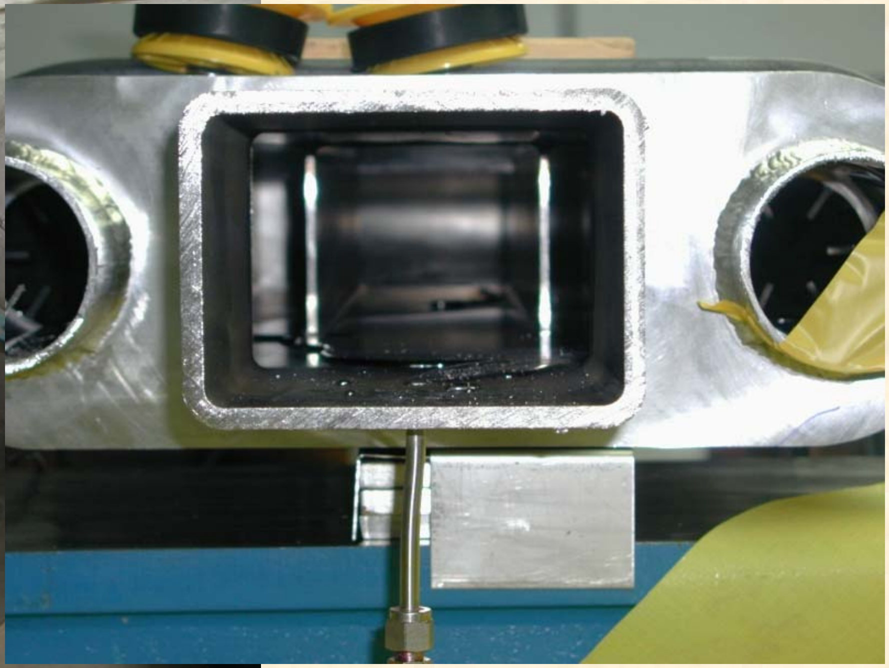
Proper PPE Is Mandatory

- **Overalls, gloves, and overshoes are the minimum requirement, respirators used if indicated by Hg vapor monitoring**

Mercury Puddling

- **Mercury will collect into small droplets and large puddles even in pipes sloped at 1 degree**





Problem Indications

Indicator(s)	Possible Cause(s)	Remedial Action
Hg vapor level increase in secondary	Small leak in primary containment Residual Hg vapor on primary containment	None – continue instrument monitoring during experiment
Hg temperature increase	Expected behavior	None – continue monitoring, look for increase Hg vapor levels
Sump level decrease	Substantial leak in primary containment	Continue experiment, but monitor sump level
Conductivity probe	Primary containment failure – verify with sump level sensor	Experiment suspended

Target System Design Requirements Include Off-Normal Events

- **Postulate Worst Credible Event**
  - **The full inventory of Hg leaks from primary containment into secondary containment … 34 liters will result in ~1.5 cm deep pool of Hg in secondary containment**
    - **Close the ventilation pathway through the filter pack**
    - **Wait for sufficient rad cooldown before moving the equipment out of the beamline**
    - **Drain/pump activated Hg from the secondary containment into storage flasks**
    - **Move the target equipment to an area out of TT2A that has suitable ventilation apparatus**
    - **Decon the target system, determine the reason for leakage, repair if possible**