# CERN Hg Jet System

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**MUON Collaboration Meeting**
**Lawrence Berkeley National Laboratory**
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OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

# Outline

- **Requirements / constraints**
- **Original Hg delivery concept & issues**
- **New baseline delivery system**
- **Operations / Hg handling**
- **Schedule**

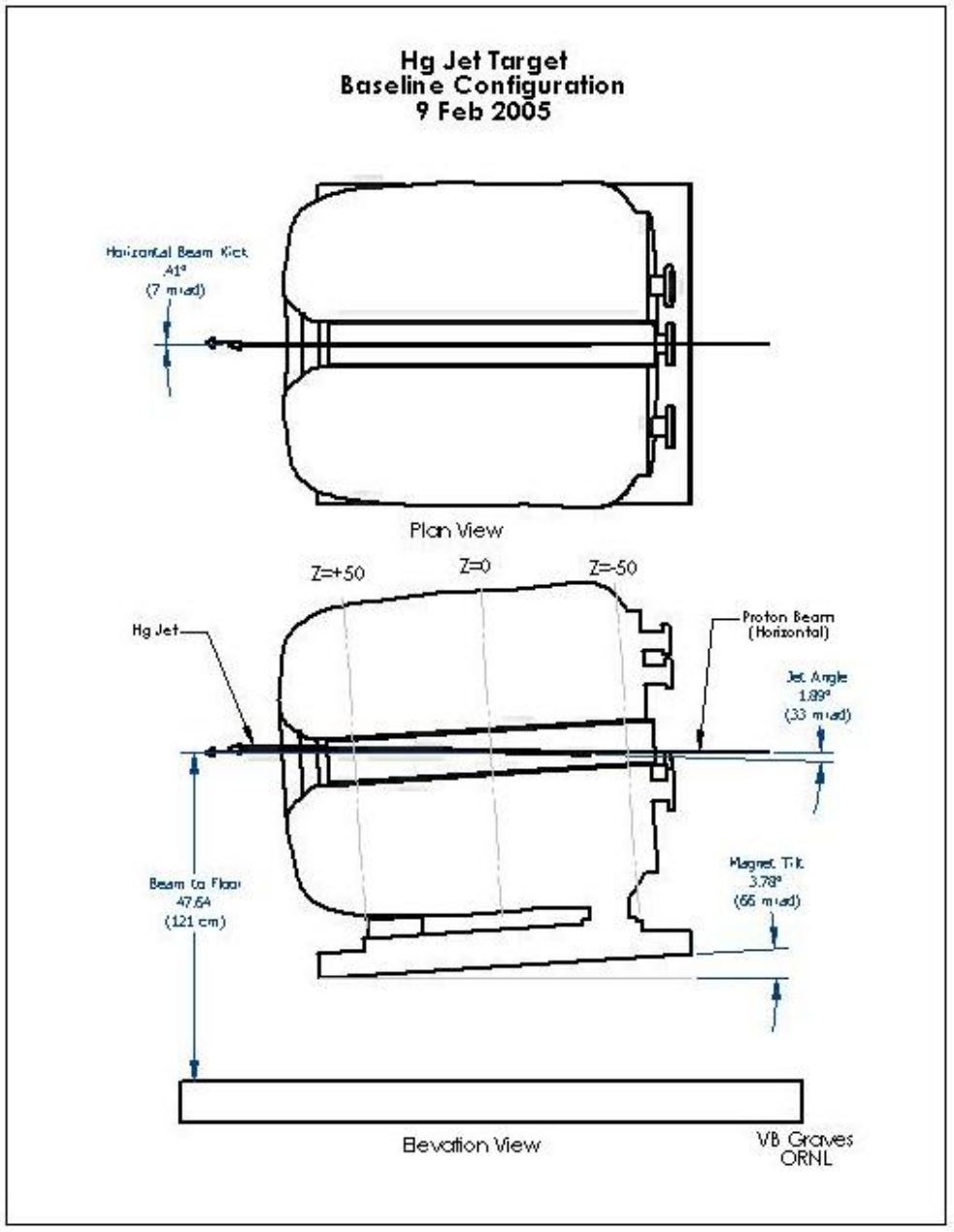
# Design Requirements & Constraints

- **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)**

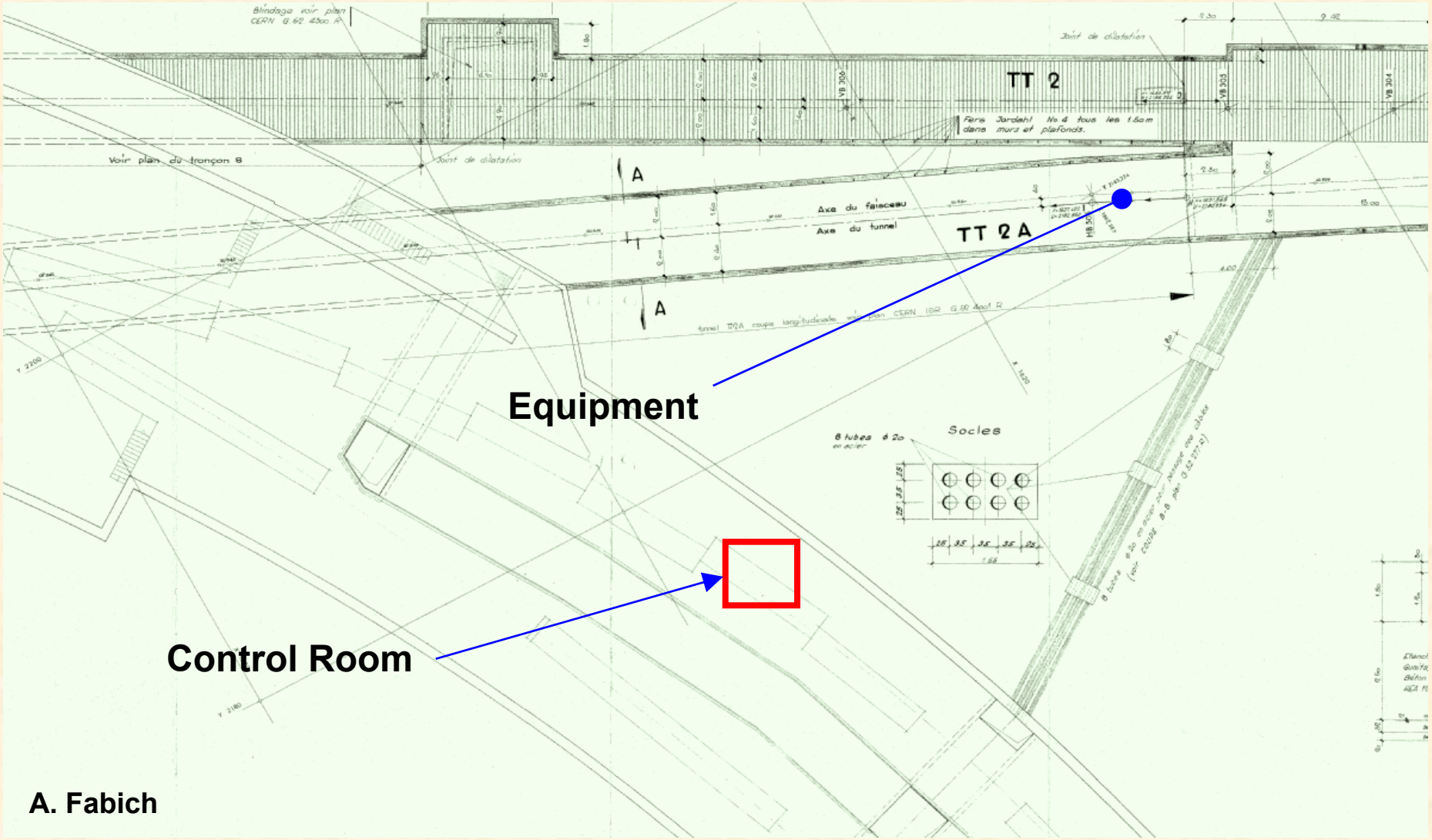
# Experiment Geometric Configuration

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

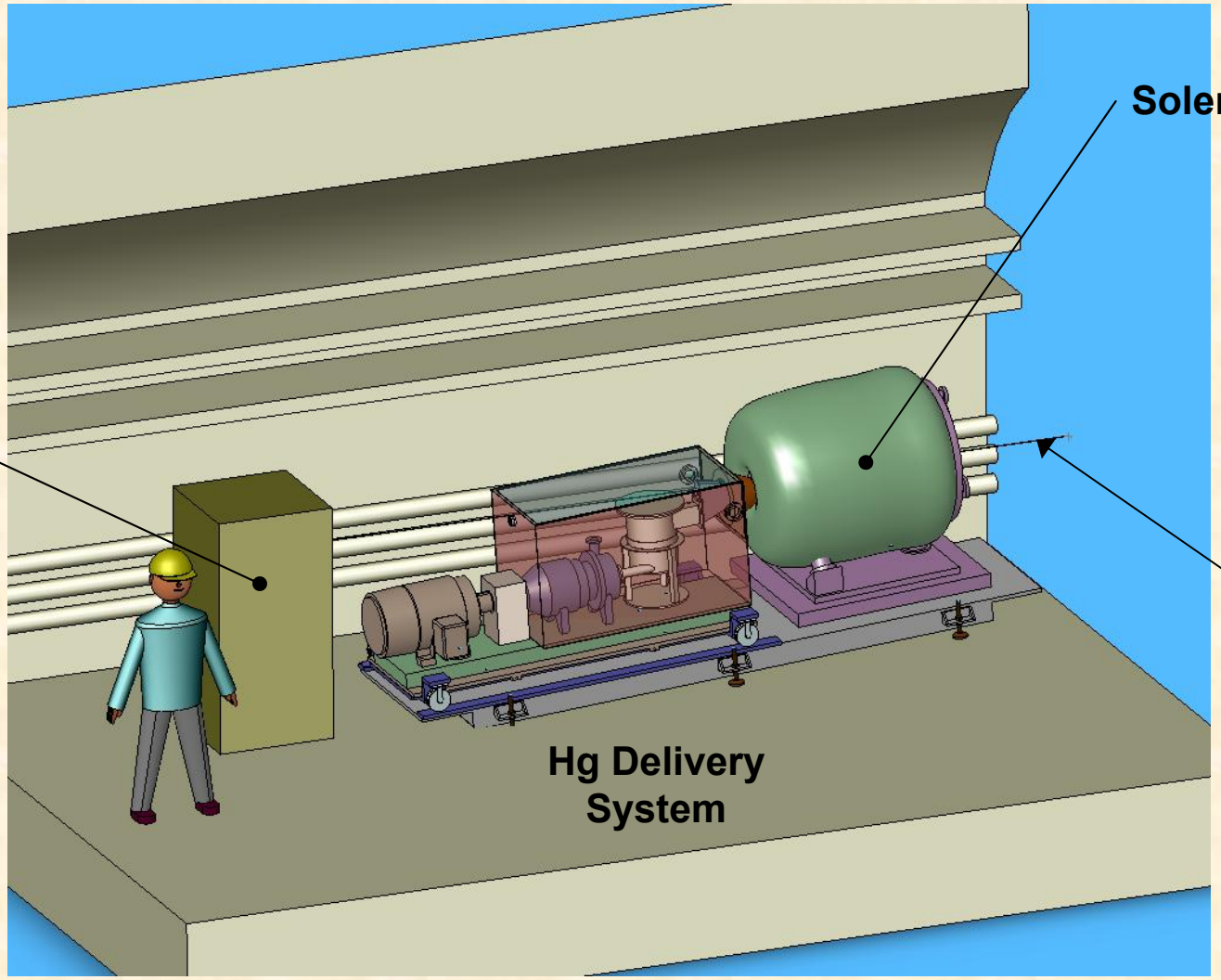
- **Magnet tilt (wrt beam) = 66 mrad (3.8°)**
- **Hg jet tilt (wrt magnet axis) = 100 mrad (5.7°)**
- **Hg jet center intersects beam center at Z=0**



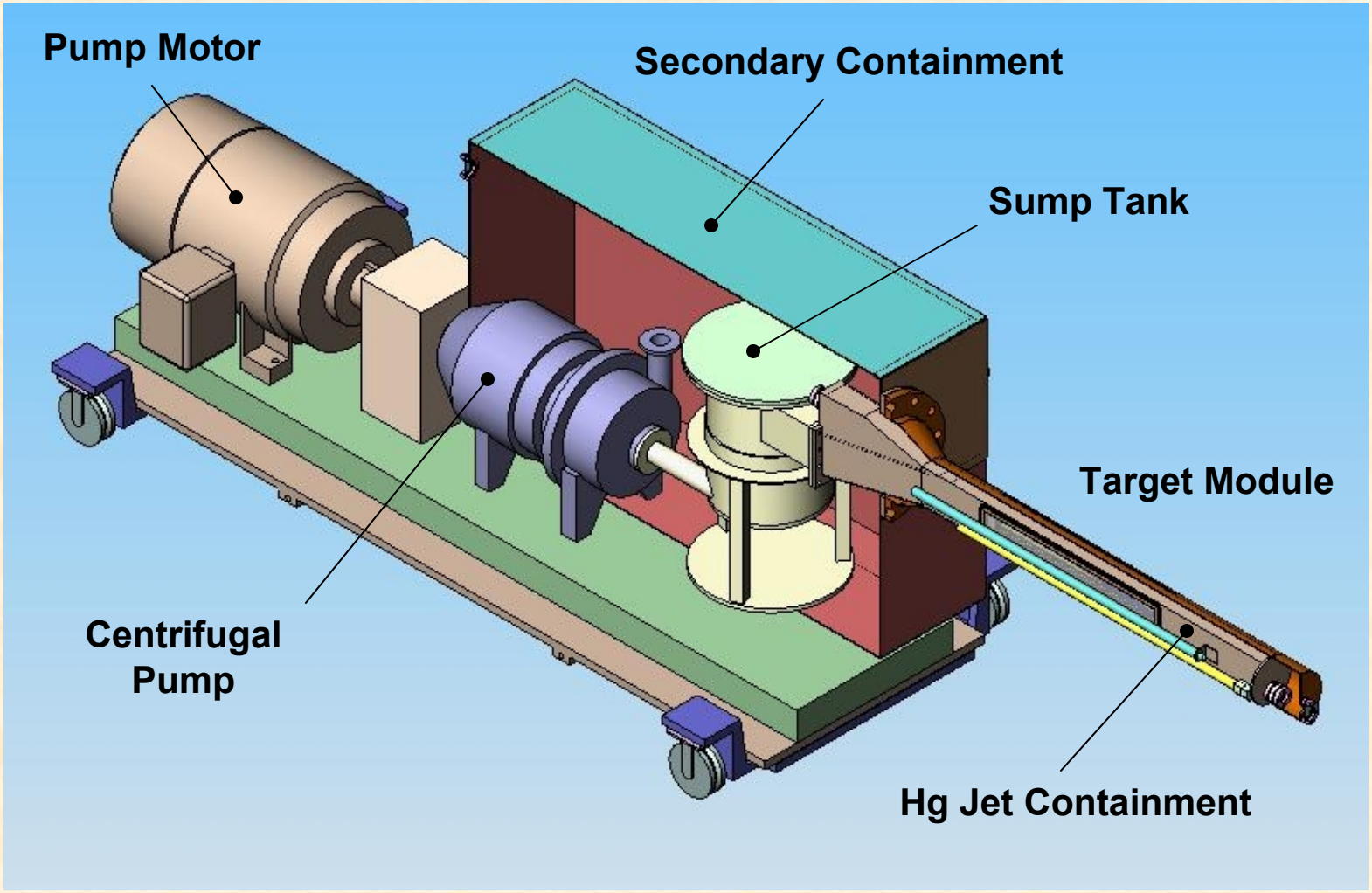
# Experiment Location – TT2A Tunnel



# System Overview



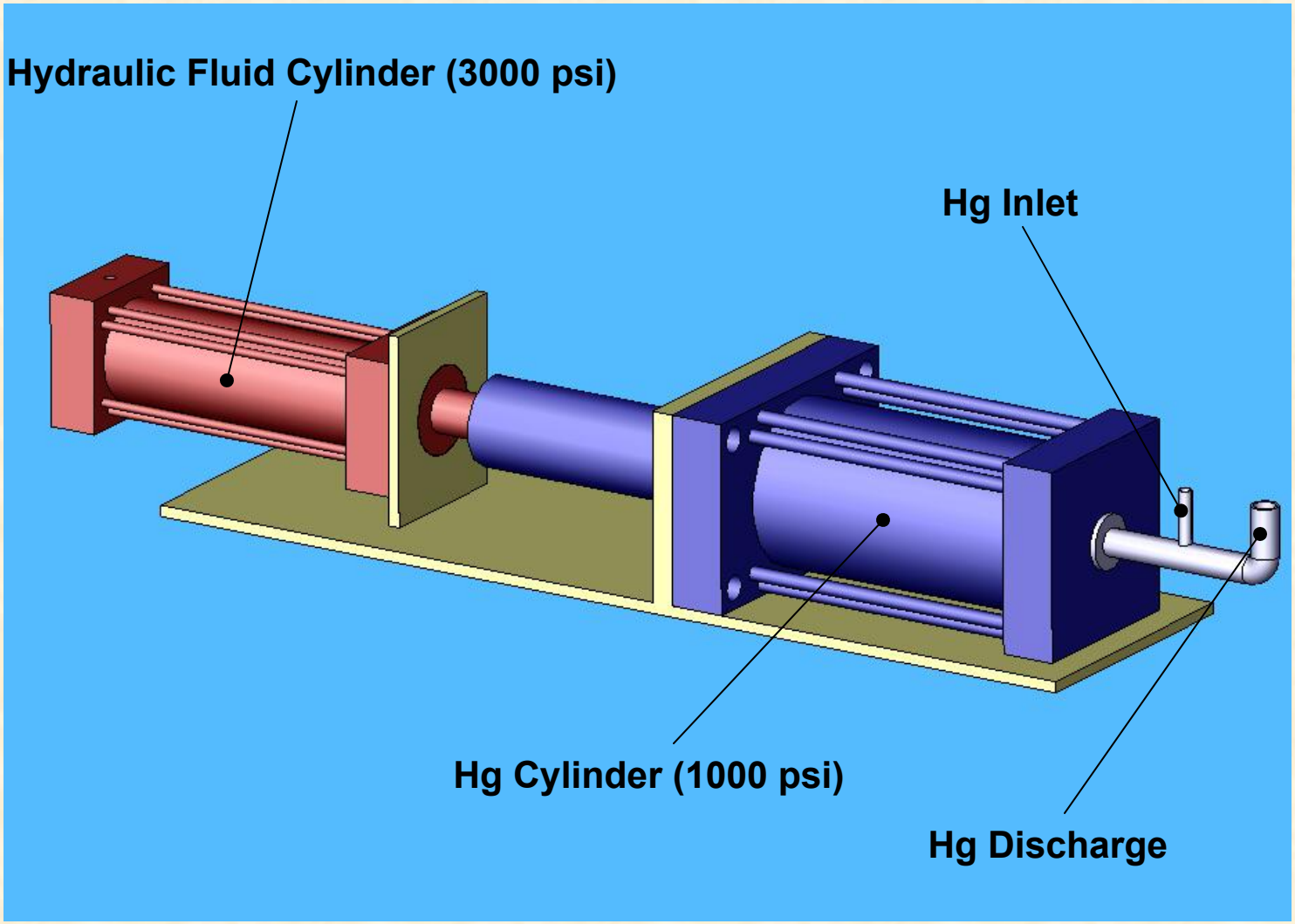
# Original Hg Delivery System



# 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**
    - **Heat exchanger might be required**
- **Max available pump output pressure is 750 psi (50 bar)**
  - **Estimated piping system pressure drop 800-850 psi**

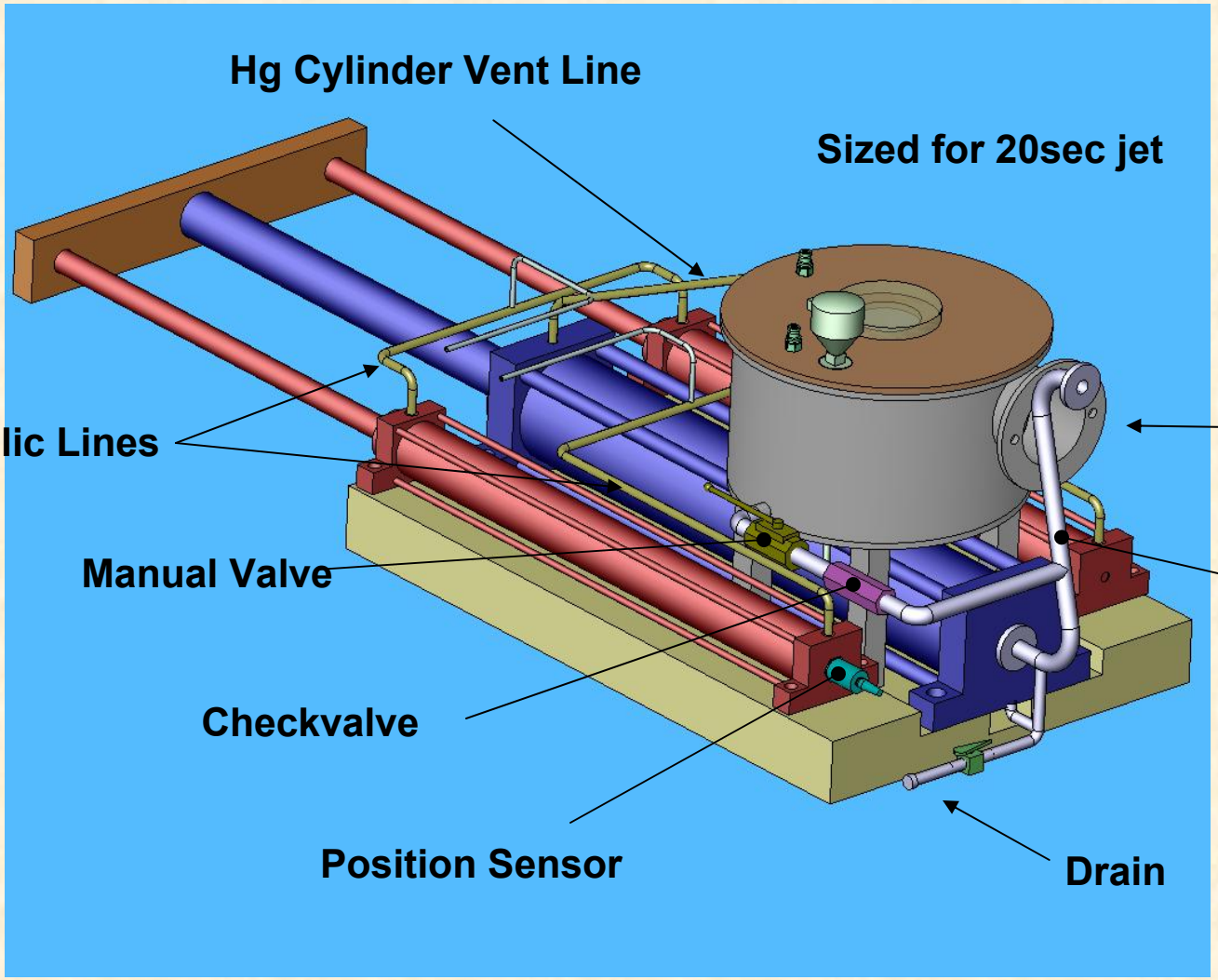
# Alternative Hg Delivery System



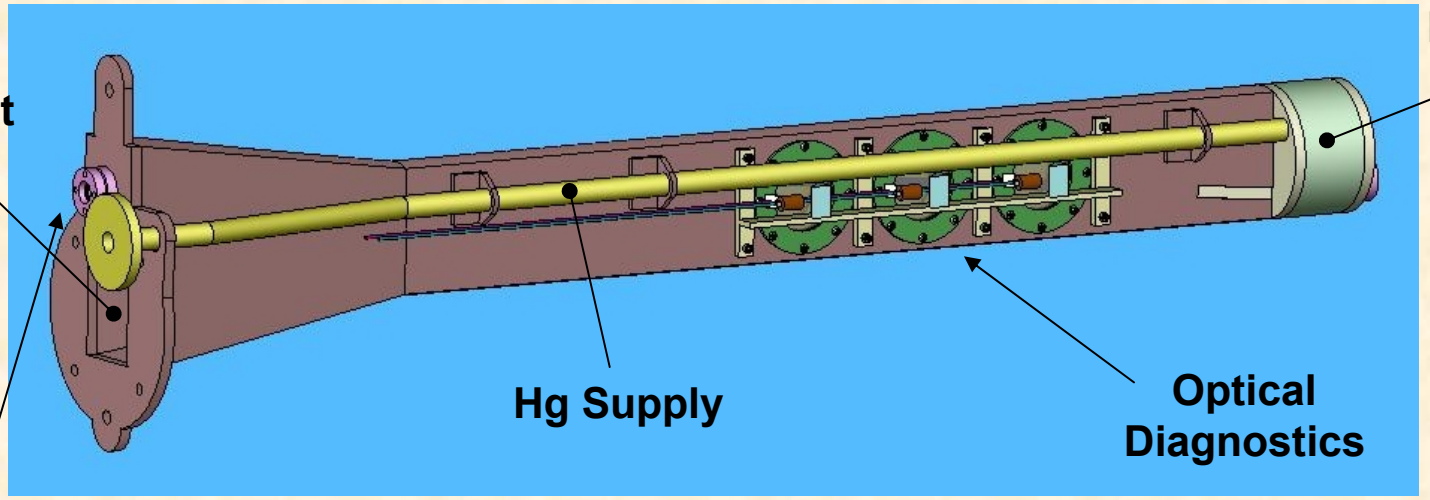
# System Energy Comparison

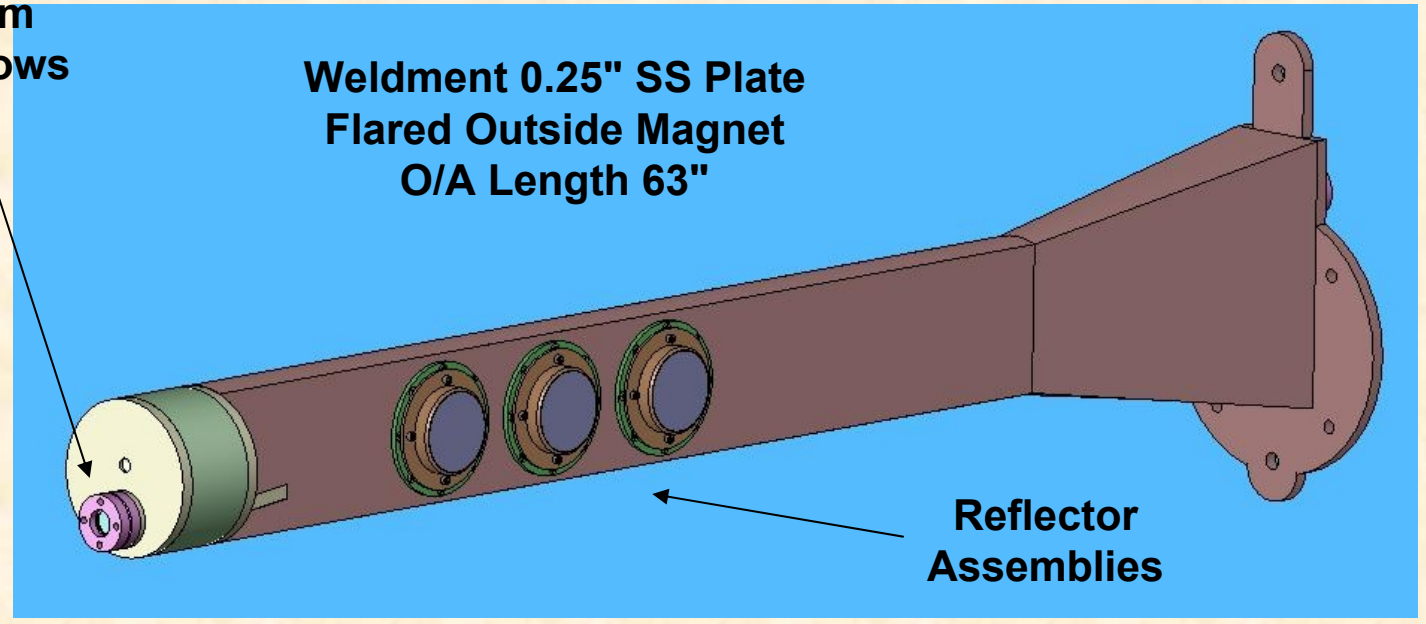
| Pump | Input Energy (hp) | Losses | Lost Energy (hp) | Output Energy (hp) | Heat Direct to Tunnel BTU/min | Heat Input to Hg BTU/min | Flow Losses BTU/min | Total Heat Generated BTU/min | KW | HP | Energy to Hg BTU/min | Hg Temp Rise °F/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| **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 |

# New Baseline Target System



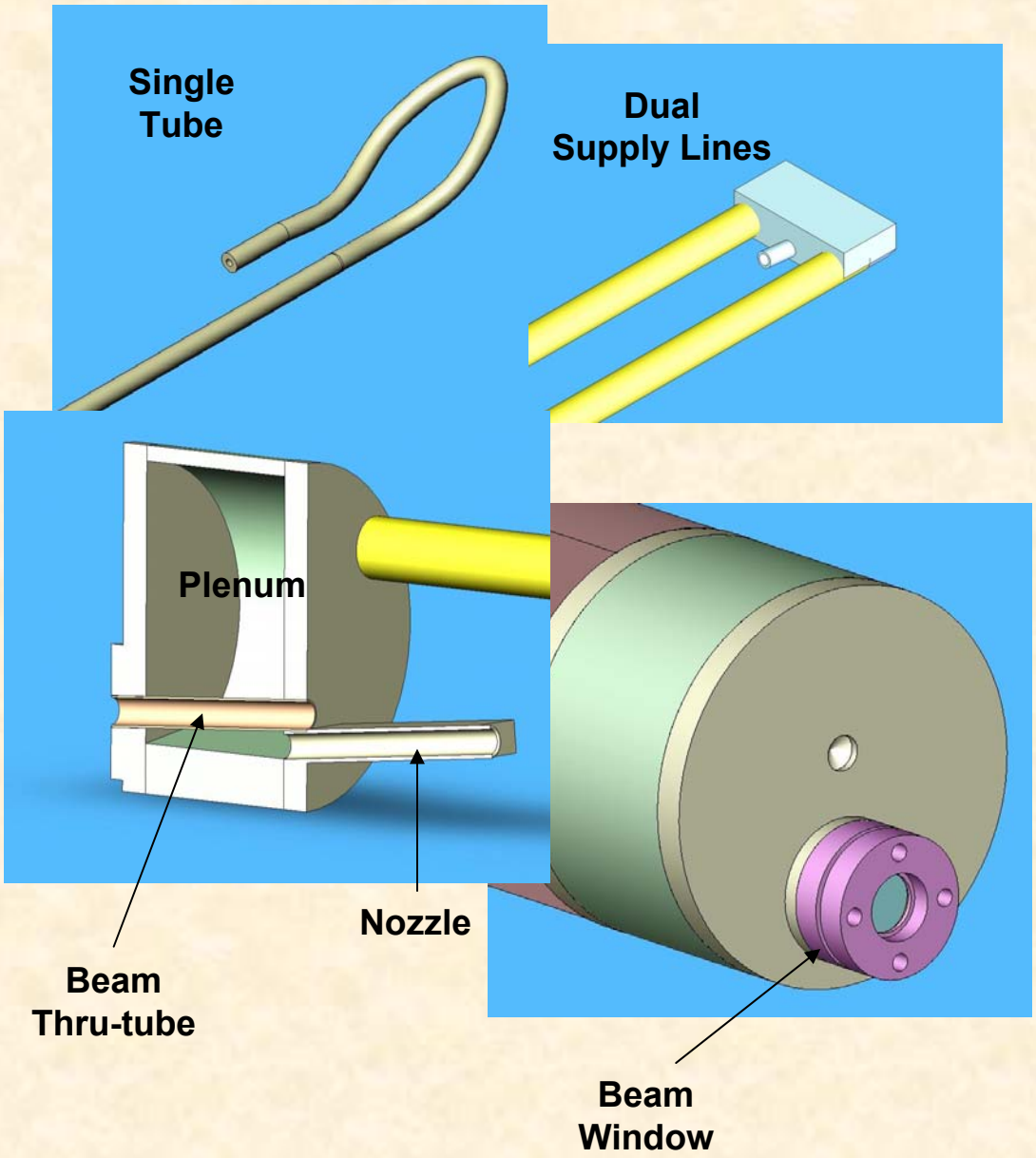
# Primary Containment



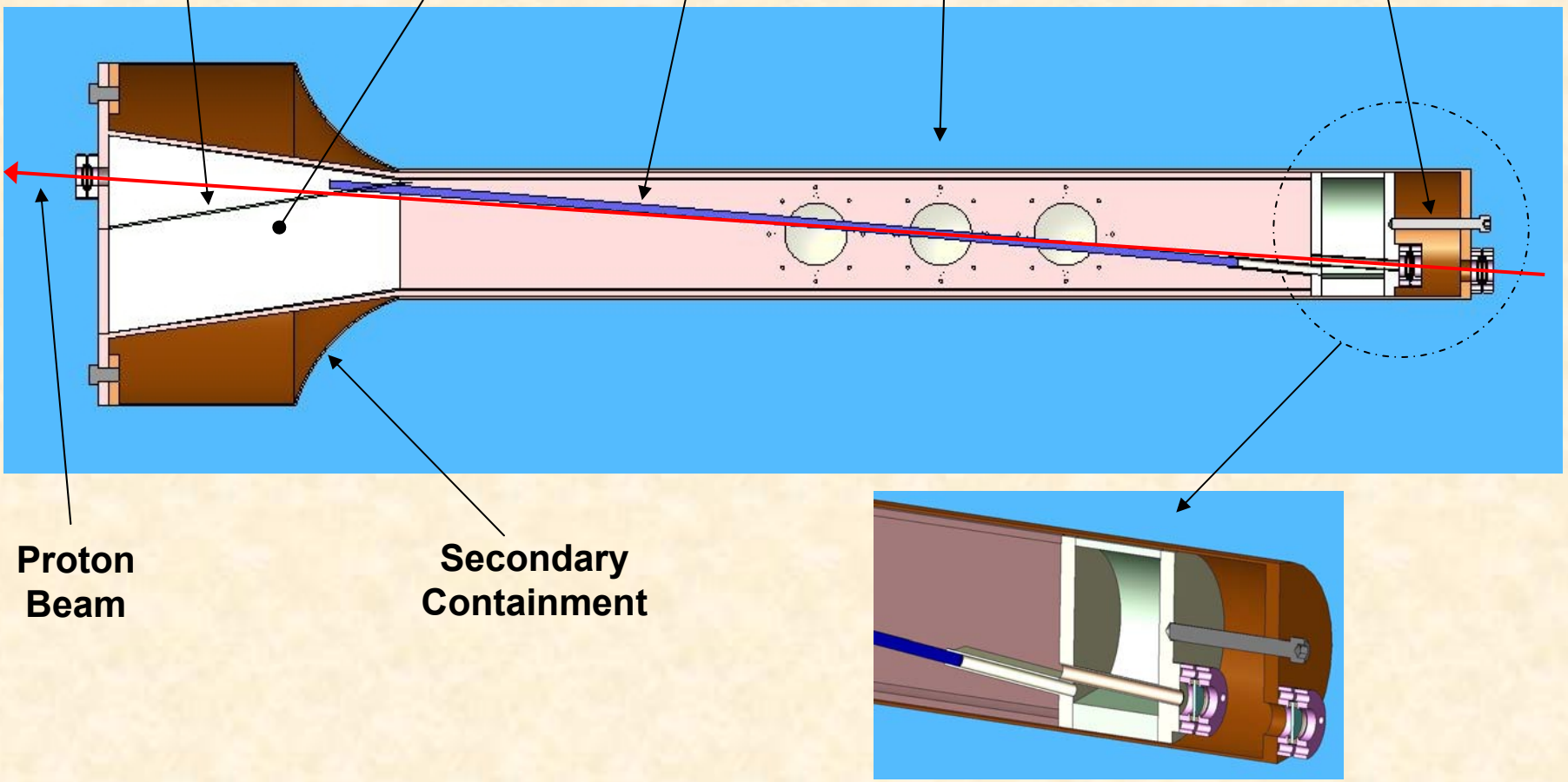



# Hg Plenum

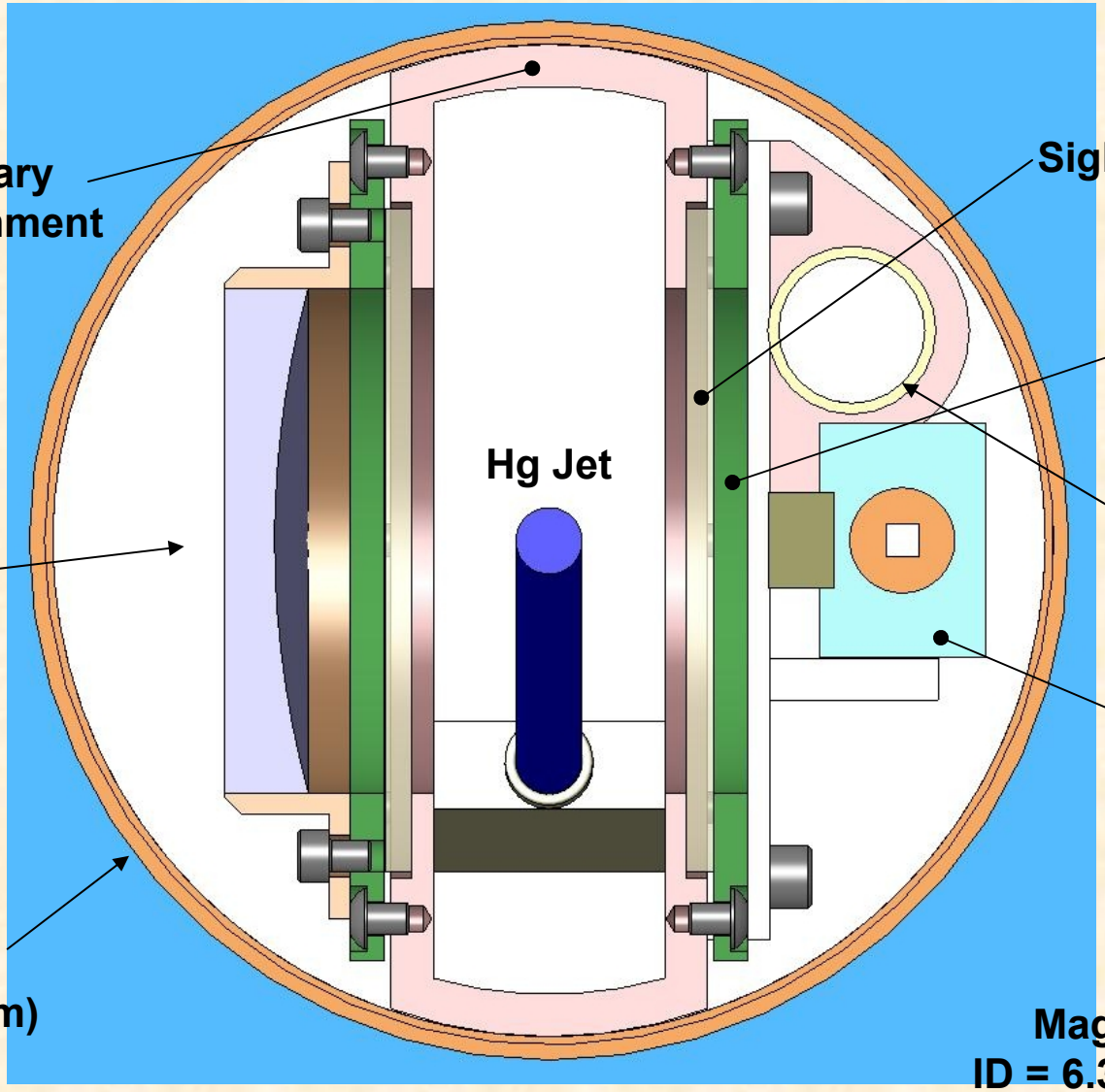
- **Purpose is to provide reservoir to allow Hg to change direction in confined space**
- **Several designs have been considered**
- **Open chamber with nozzle exit and beam thru-tube**



# Primary Containment – Side View

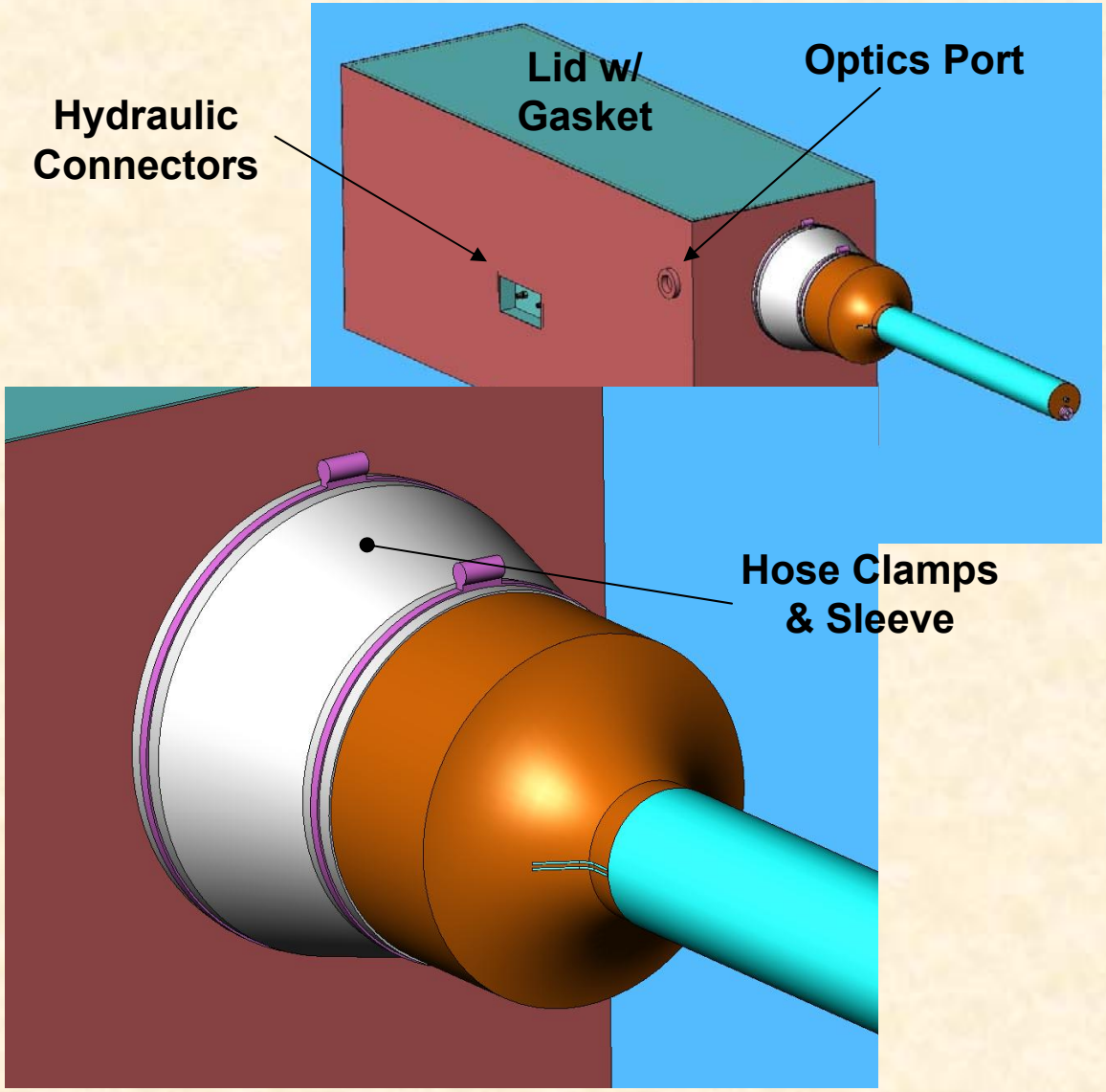


# Primary Containment Cross Section



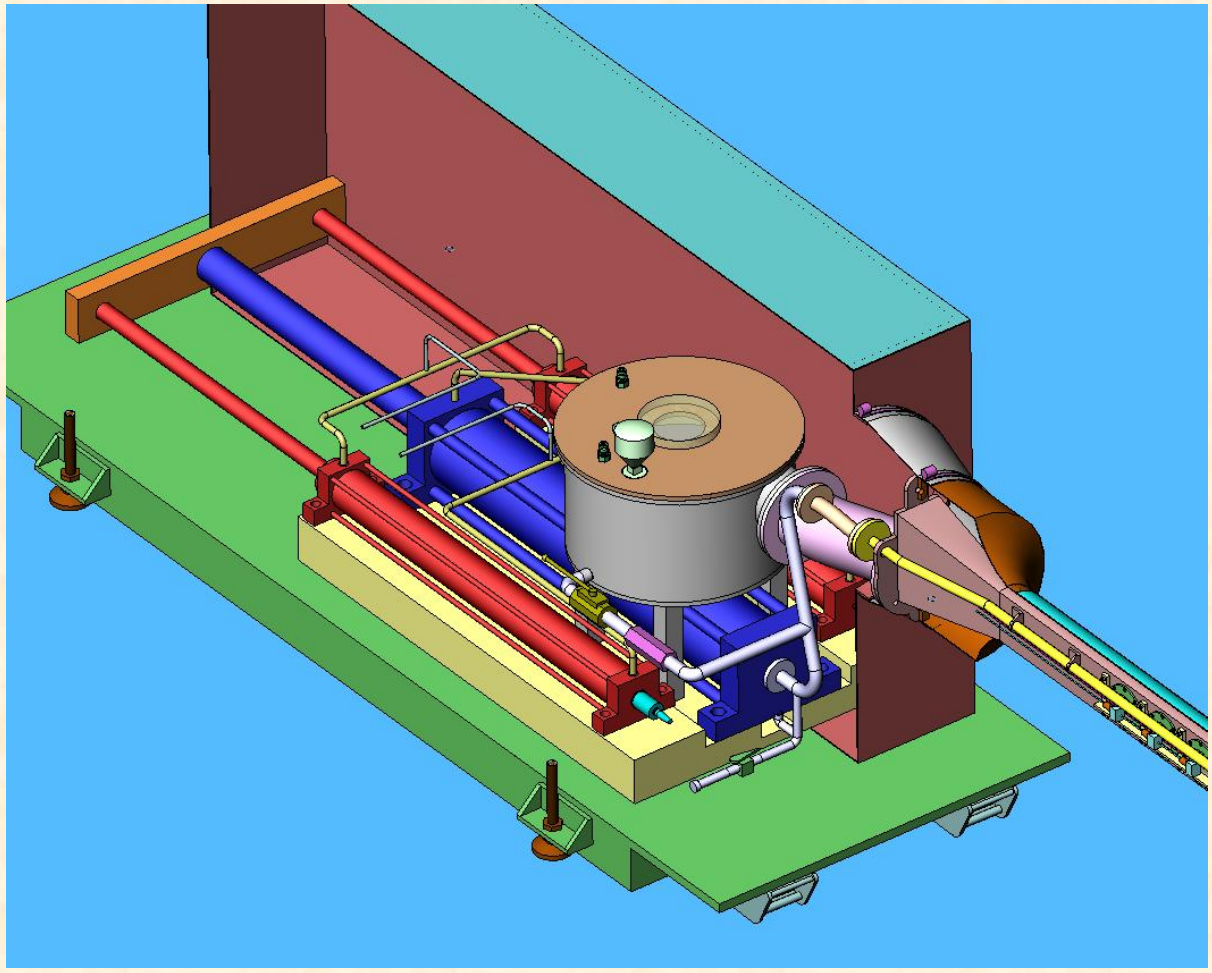
# Secondary Containment

- 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

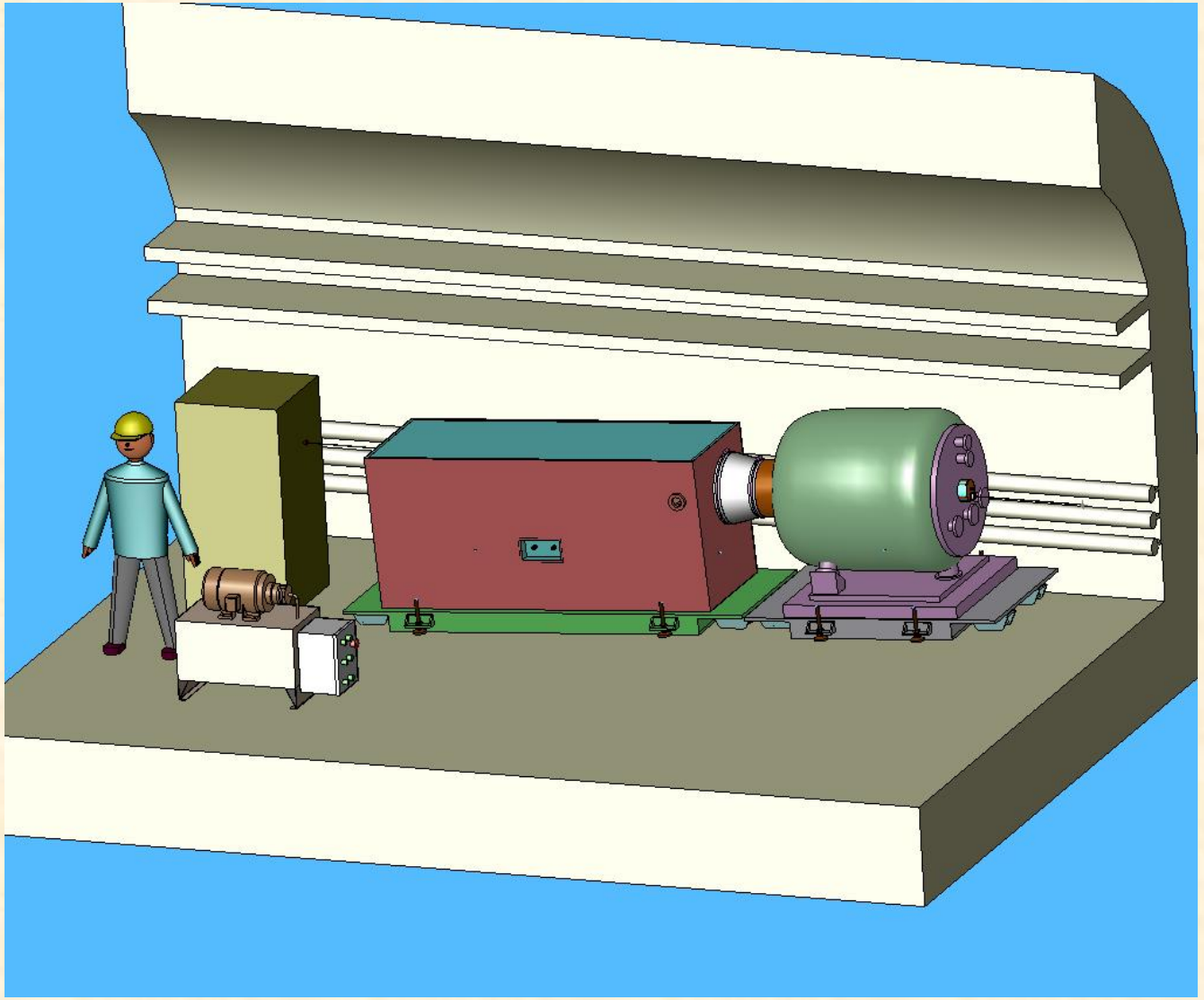


# New Baseline Hg Target System

- **Secondary tank dimensions 102x36x45" (2.6x0.9x1.1m) without support base**
- **Need to reduce footprint**
  - **Facility limits are 3m x 1.3m**



# Syringe Layout



# Title 1 Design Review Comments

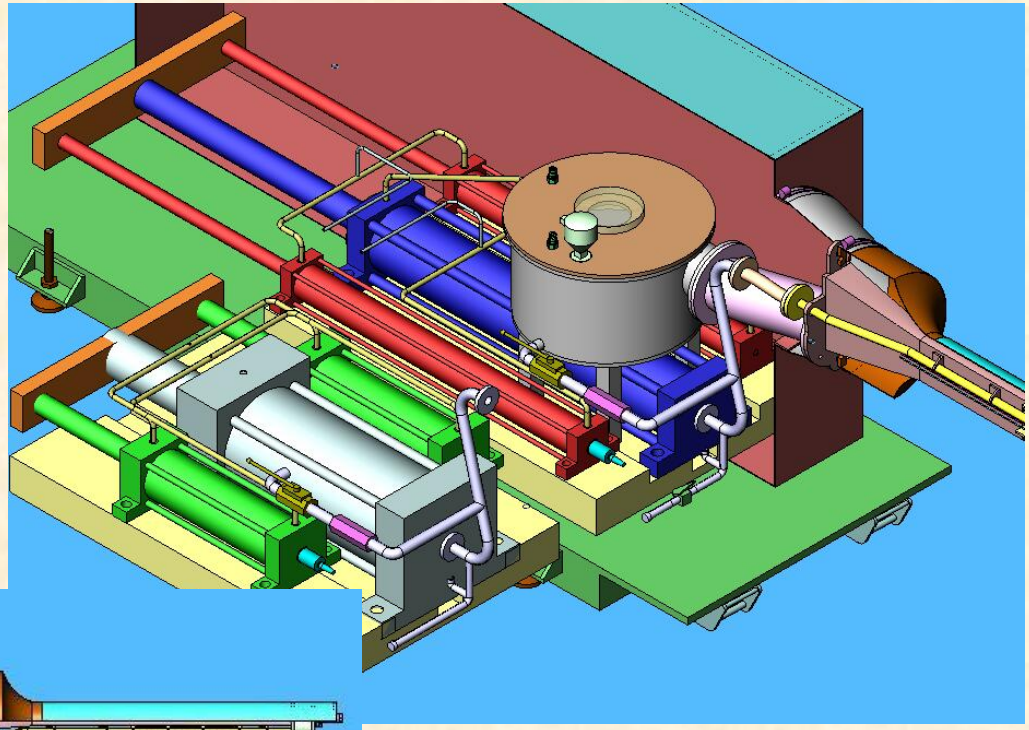
- **Nozzle design**
  - **More analysis needed**
  - **Nozzle/deflector designs need validation**
  - **Replaceable or adjustable nozzle**
- **Viewports**
  - **Structural rigidity of viewport optics**
  - **May require testing**
- **System sizing**
  - **Footprint for 20sec syringe too large**
  - **Increase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

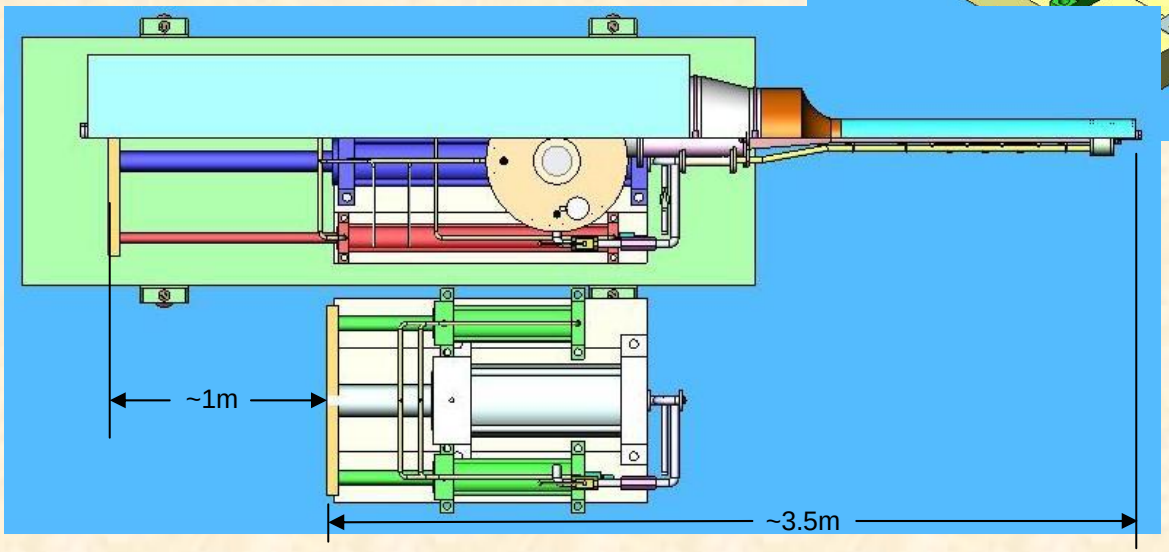
# Hg Cylinder Upsizing

**Original: 8” Hg cylinder**

**Updated: 12” Hg cylinder**

**Both with 20sec capacity**





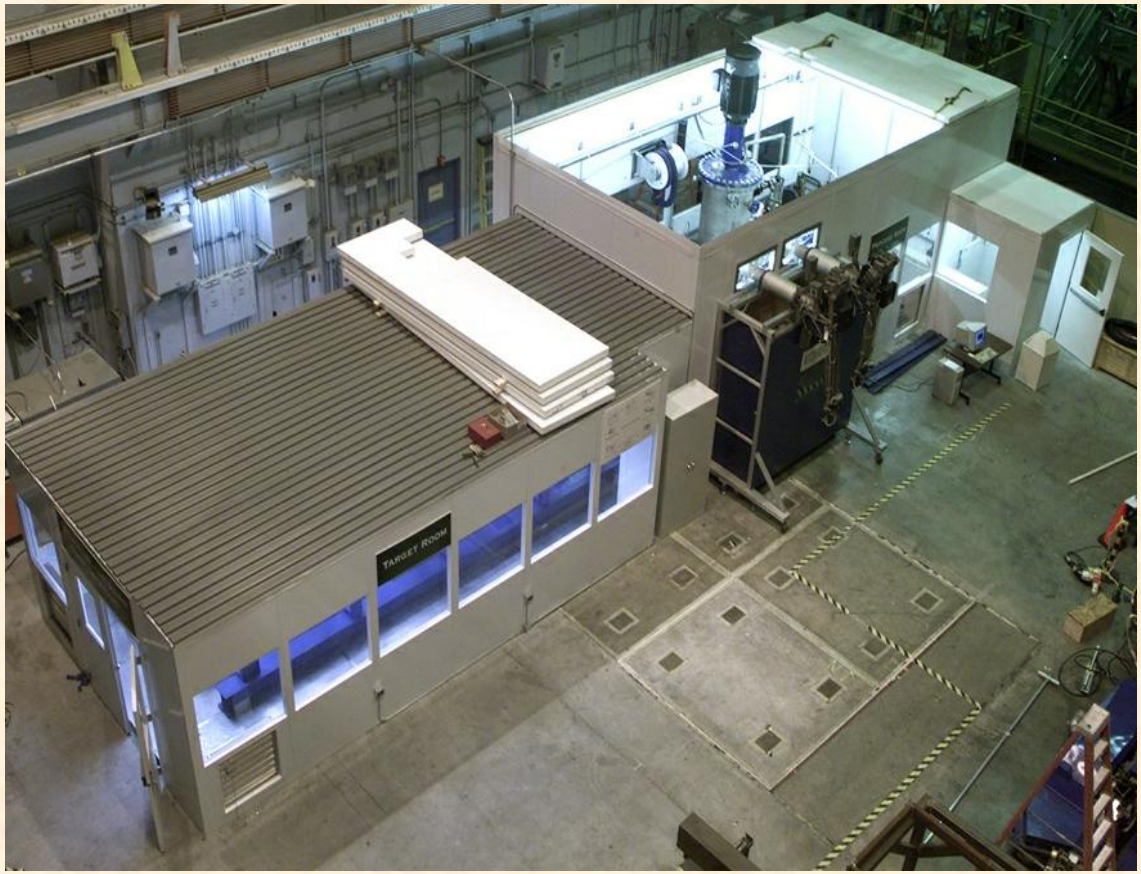
# Hg Handling Issues

## 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**

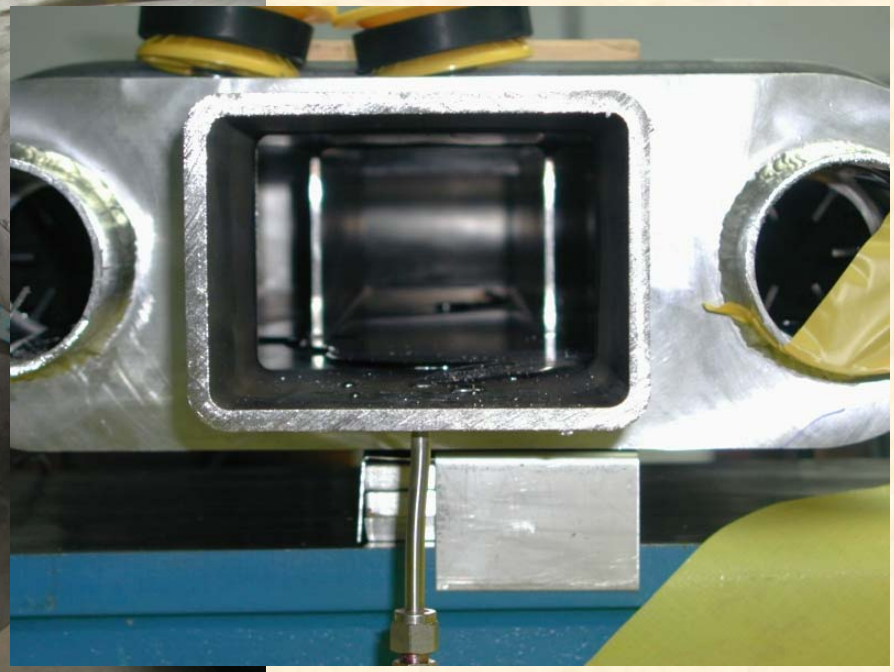
- **Lower risk than manual loading or using a pump**
- **Faster operation, ~ 1-1/2 minutes per flask (over 500 flasks required for TTF)**

# 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**



# Mercury Monitoring

- **TTF Uses Three Stationary Jerome 431-X Vapor Analyzers**
  - **One monitor dedicated to each room and exhaust vent, connected to the Target Test Facility PLC**
  - **A portable monitor used during loop maintenance activities**
- **The Jerome analyzer has a range of 0.000 – 0.999 $mg/m^3$**
  - **Sensitivity is 0.003 $mg/m^3$**
  - **Measures the change in resistance across a gold film as a function of Hg vapor**
- **Other monitor types are available**

# 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**

# 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 – Oct '05** |
| **Assembly & Testing at ORNL** | **Nov '05 – Jan '06** |
| **Integrated Testing w/Magnet** | **Feb '06 – Apr '06** |
| **Equip. Installation at CERN** | **Oct '06 – Nov '06** |
| **Earliest Beam-on Tests at CERN (no beam time scheduled yet)** | **Dec '06** |