UT-BATTELLE

# MERIT Hg System Review

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**Neutrino Factory Muon Collider Collaboration Meeting**

**Illinois Institute of Technology**

**March 13, 2006**

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

# Executive Summary

- **Hg system design has been completed**
- **Syringe pump fabrication is nearly complete**
- **Drawing packages for remainder of system are either in fabrication or out for bid**
- **System testing at ORNL scheduled to begin in May**

***Now for some details...***

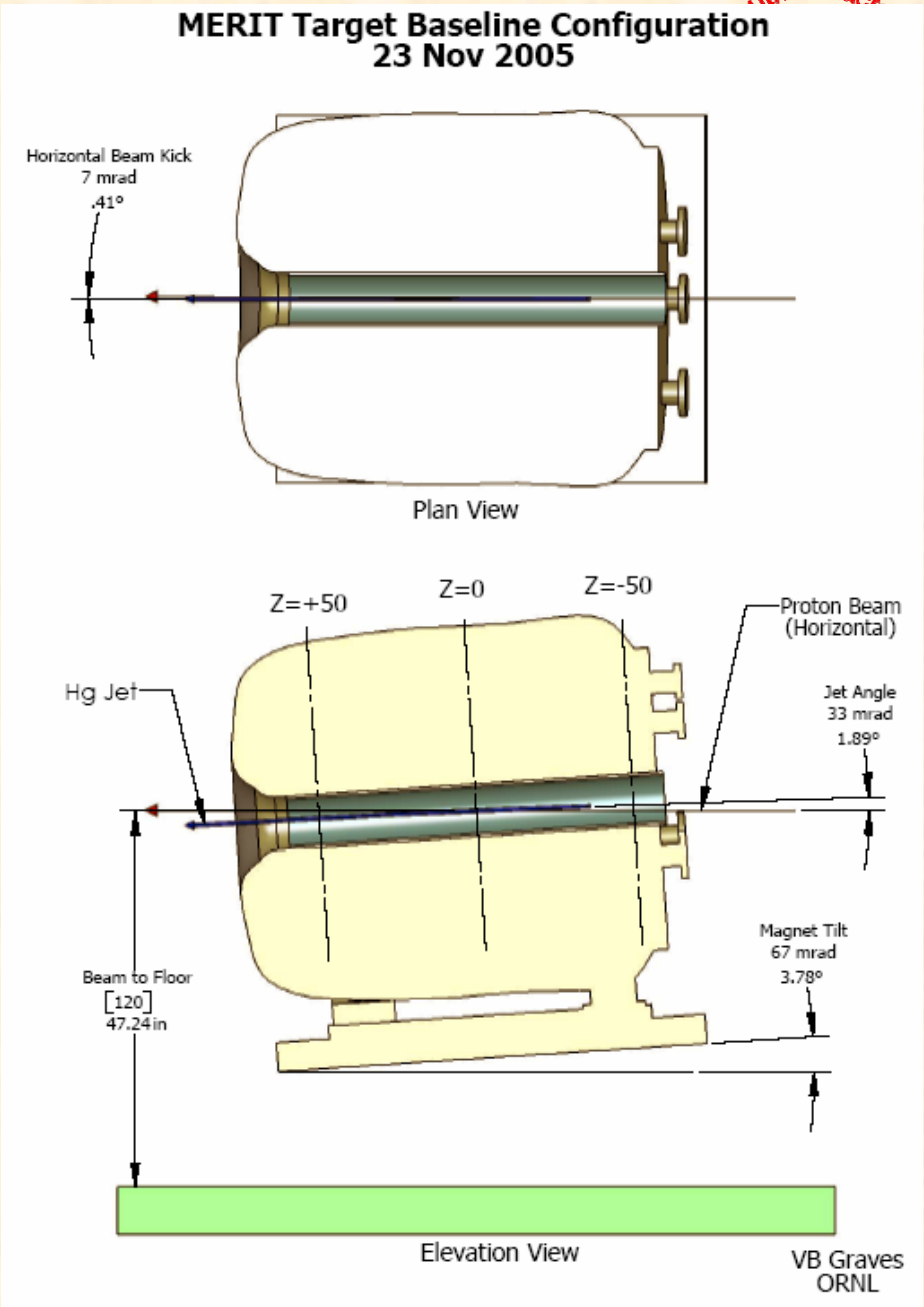
# Requirements and Operating Conditions

*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 120cm above the tunnel floor**
- **Up to 100 pulses for the CERN test, >500 operating cycles for system testing**

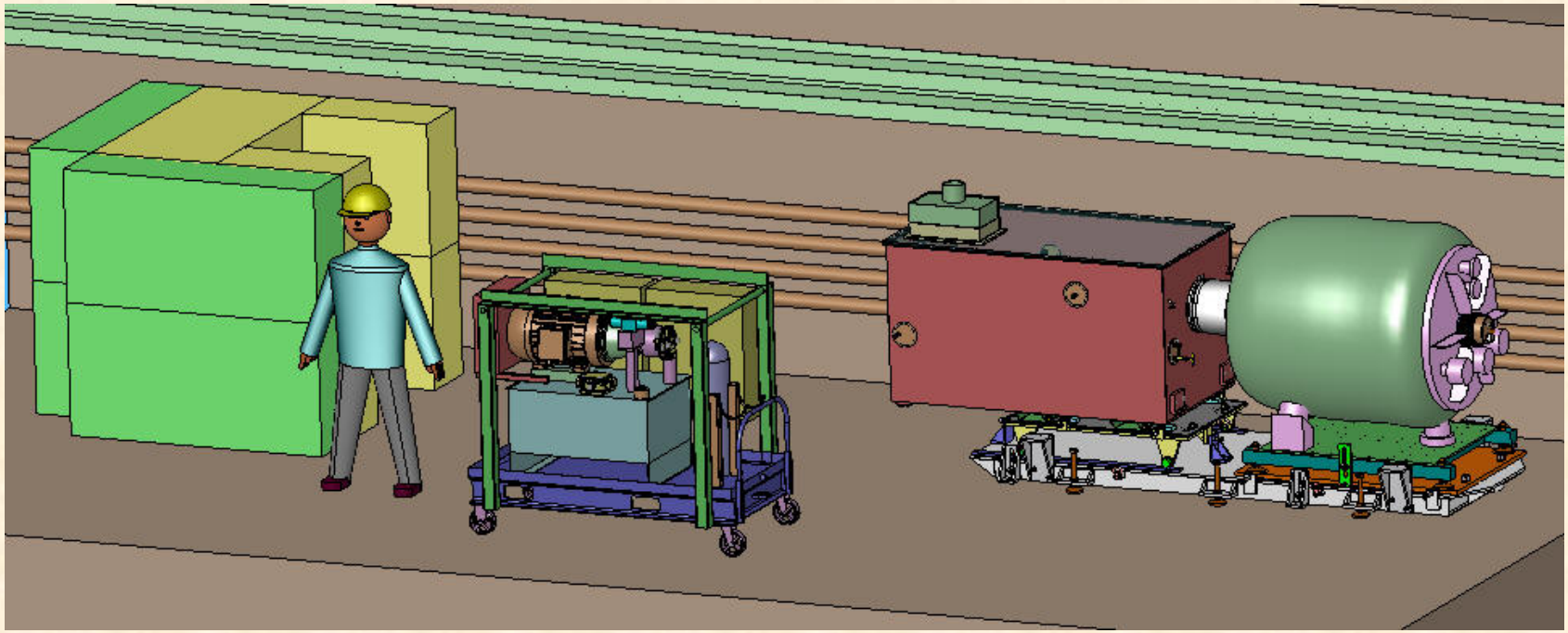
# Geometry of the Interaction Region

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

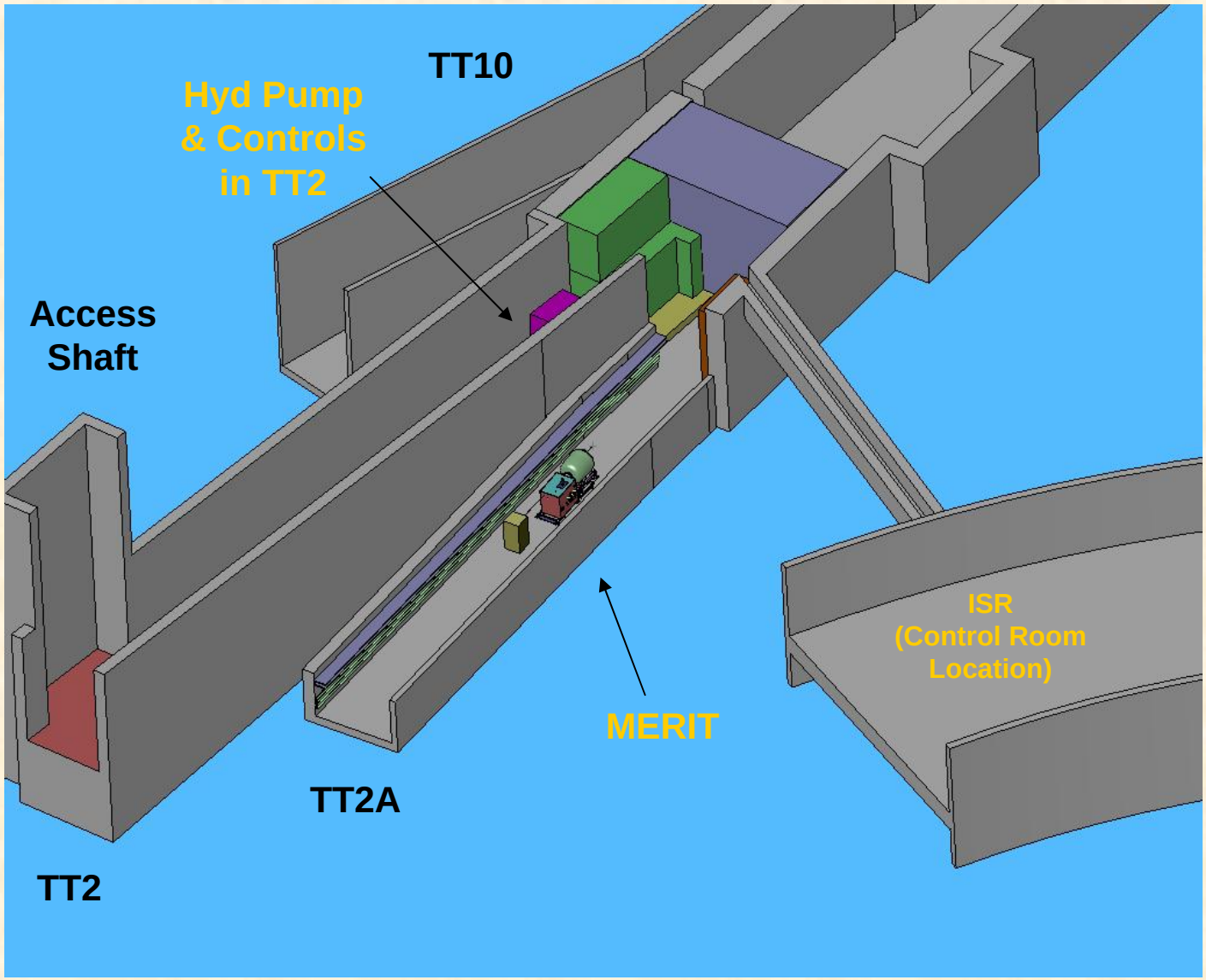


# Experiment Layout

- **Hg target is a self-contained module inserted into the magnet bore**
- **Two containment barriers between the Hg and the tunnel environment**
- **Hydraulic pump will be in adjacent tunnel, personnel in remote control room**

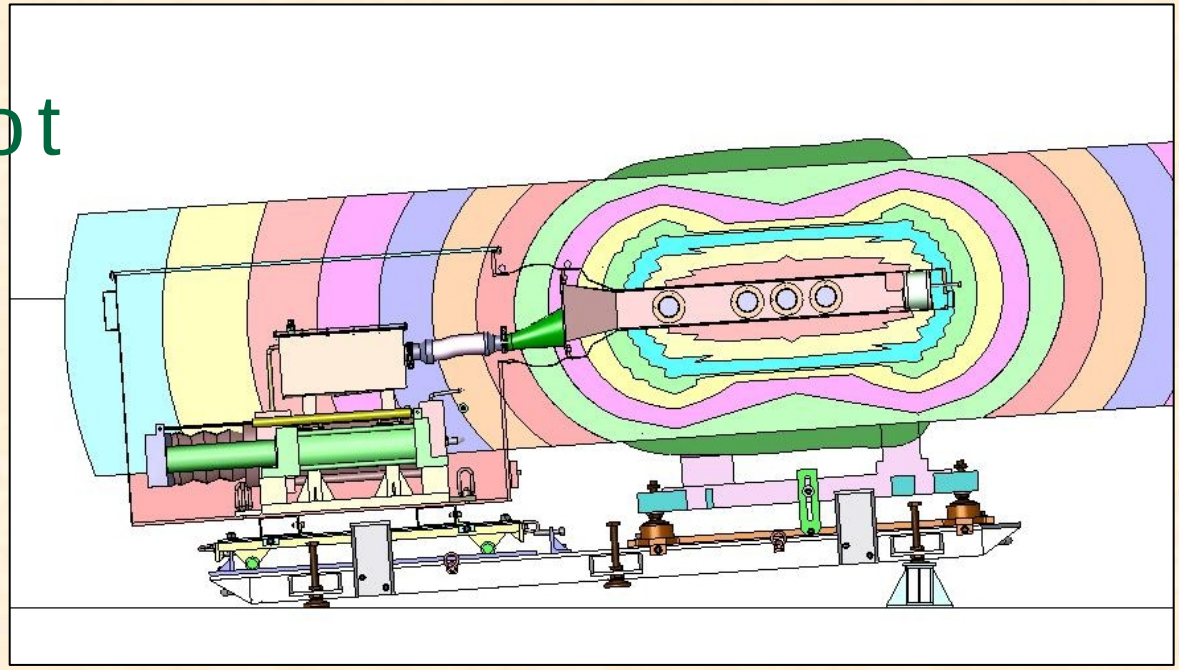


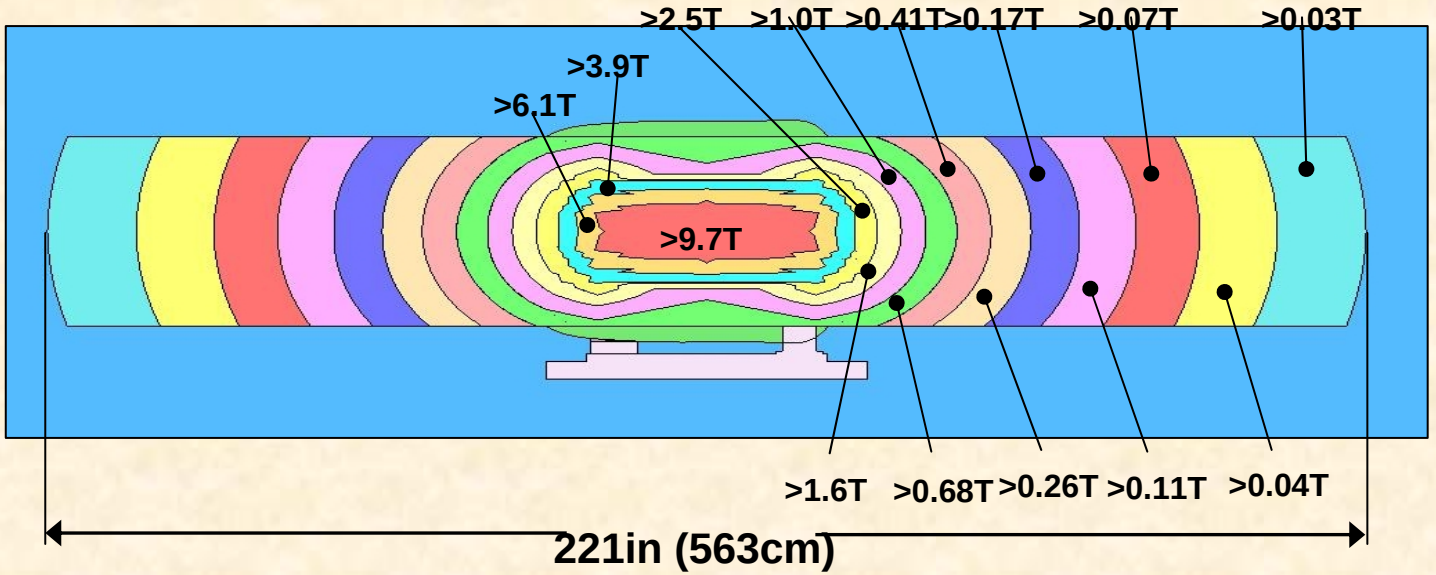
# Experiment at CERN



# Stray Field Plot

- **The pump equipment operates in a range of 3000 Gauss to 300 Gauss (*1 Tesla = $10^4$ Gauss)***
- **Hg jet starts in 6-9 Tesla field**



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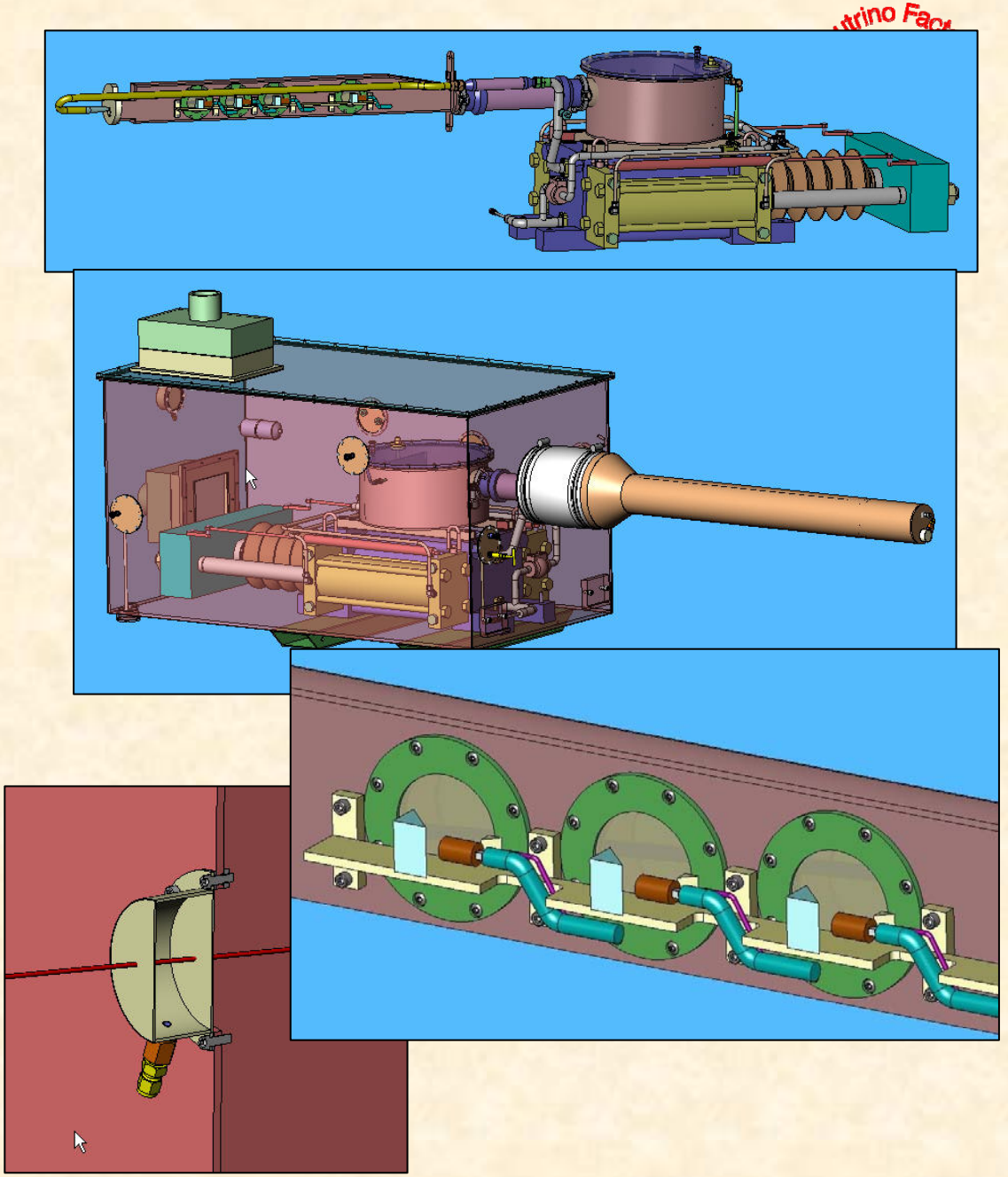
# Hg Delivery System

- **Primary containment**
  - **Hg-wetted components**
  - **Capacity 23liters Hg (~760 lbs)**
  - **Jet duration up to 12 sec**
- **Secondary containment**
  - **Hg leak/vapor containment**
  - **Ports for instruments, Hg fill/drain, hydraulics**
- **Optical diagnostic components**
  - **Passive optics**
  - **Shadow photography**
- **Beam Windows**
  - **Ti alloy components that directly interact with beam**
  - **Single windows on primary, double windows on secondary**



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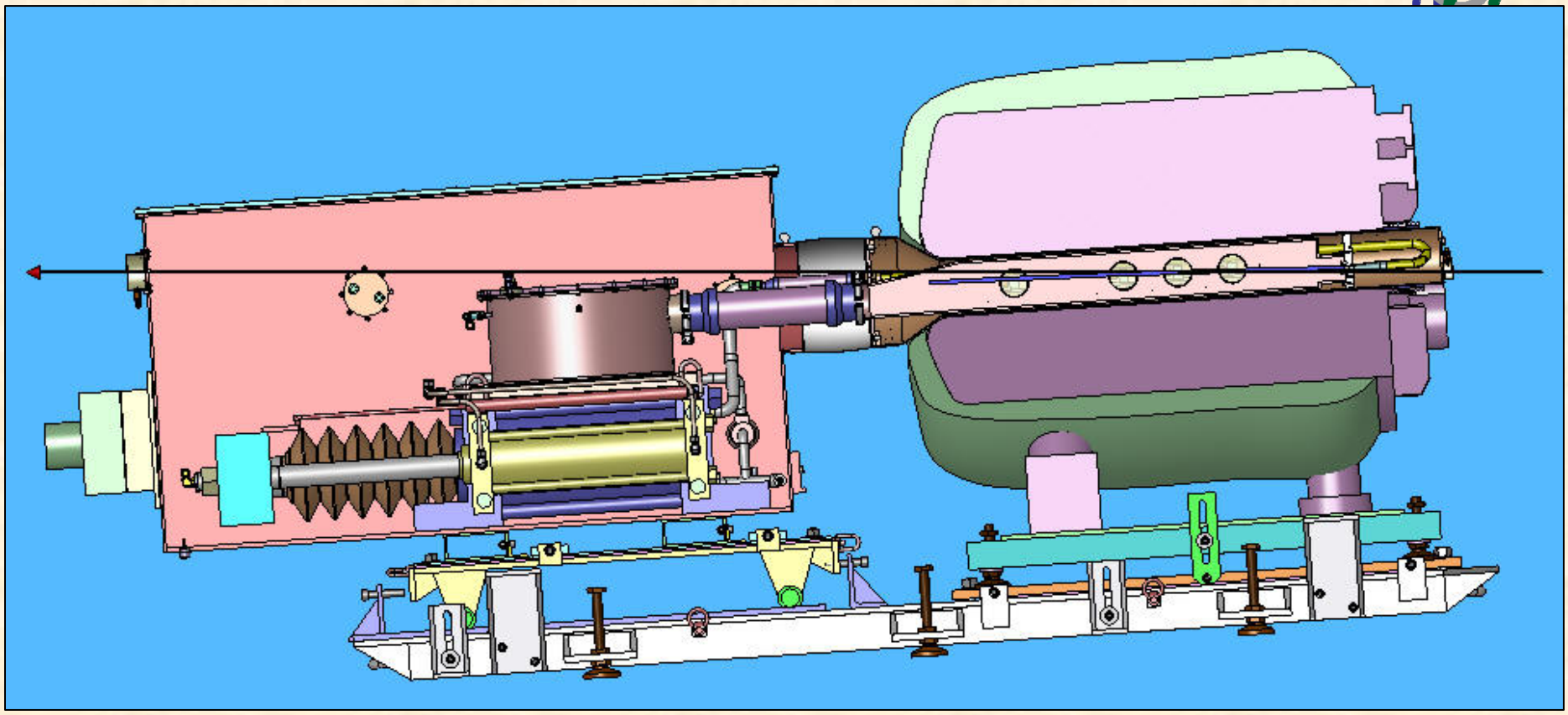
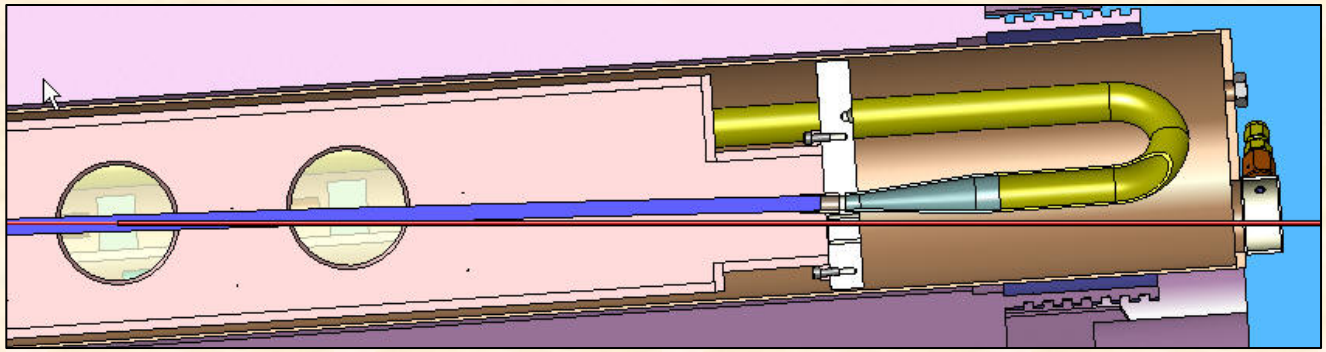
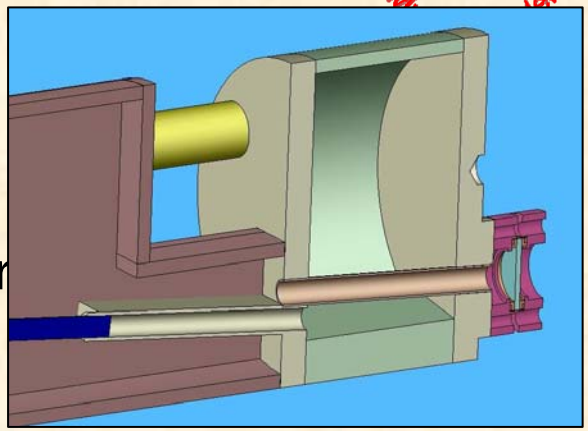
# MERIT Side View

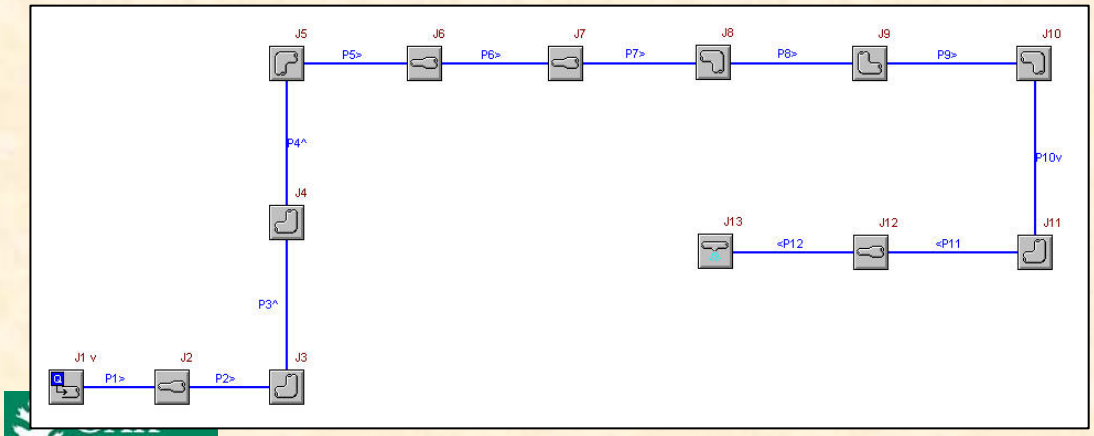


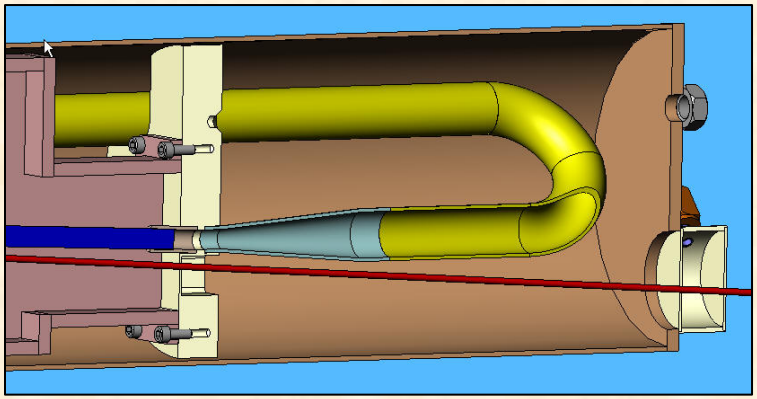


# Flow Simulation Using AFT Fathom



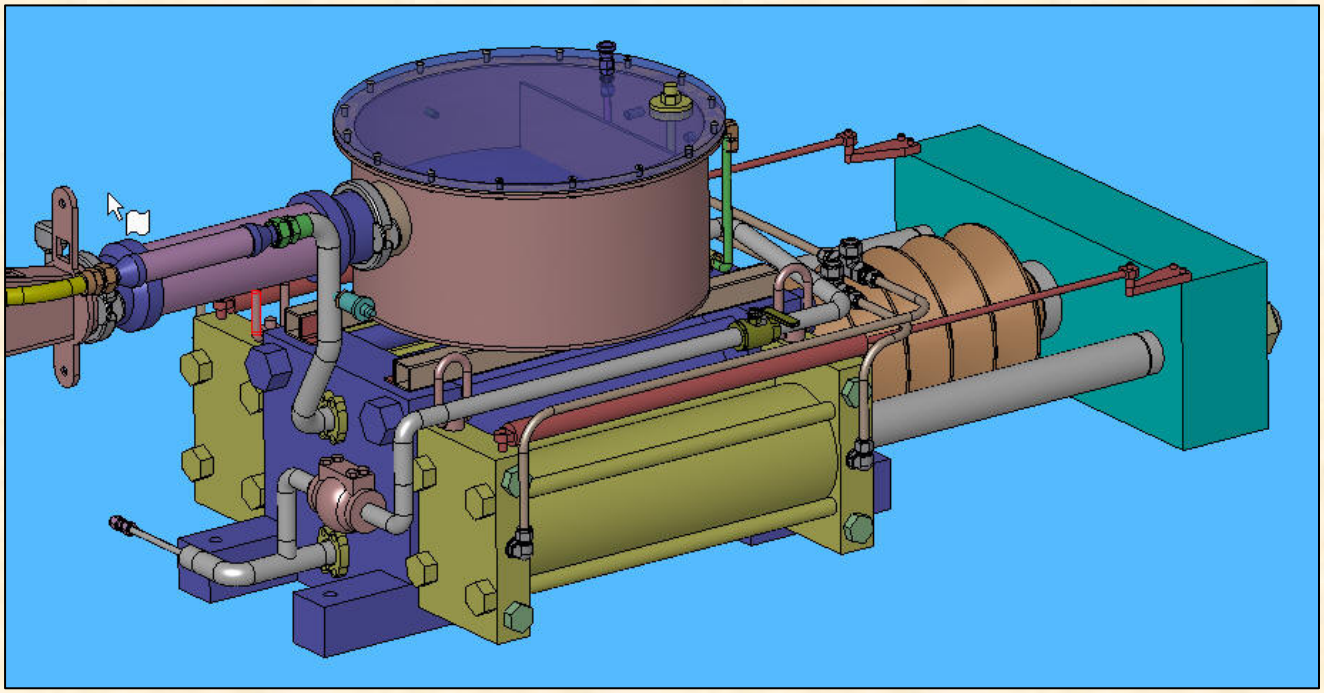
- **Simulates mechanical piping/flow losses**
  - **Does not include MHD effects**
- **Results predicted cylinder pressure of ~780 psi (50 bar) for original plenum/nozzle configuration**
- **Current nozzle configuration predicts cylinder pressure of ~500 psi (35 bar)**
- **Syringe design pressure 1500 psi (100 bar), so we have significant excess pressure capacity to accommodate losses due to field effects, which we won't know until integrated testing at MIT**



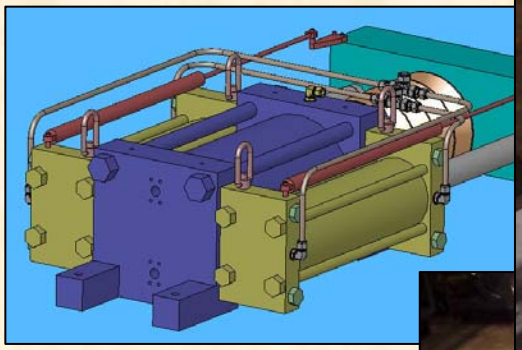
# Hg Syringe Performance

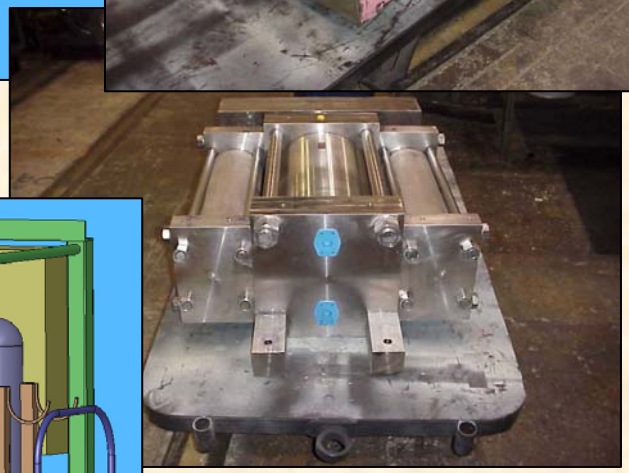
- **Hg flow rate 1.6liter/s (24.9gpm)**
- **Piston velocity 3.0cm/s (1.2in/sec)**
- **Up to 103 bar (1500 psi) Hg pressure in cylinder**
- **Hg cylinder force 525kN (118kip)**

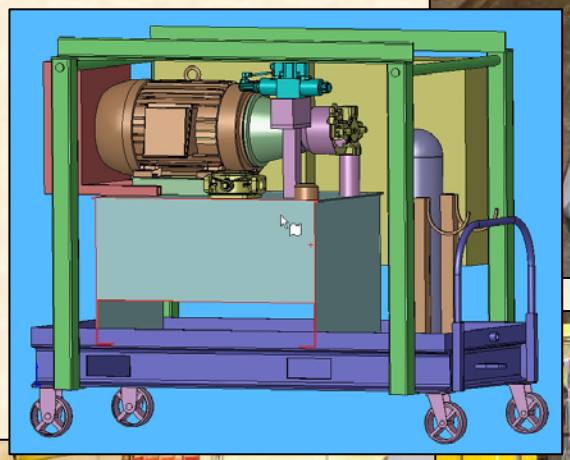


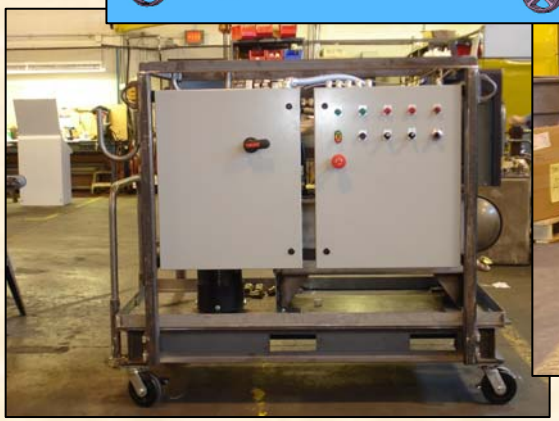
# Syringe Status

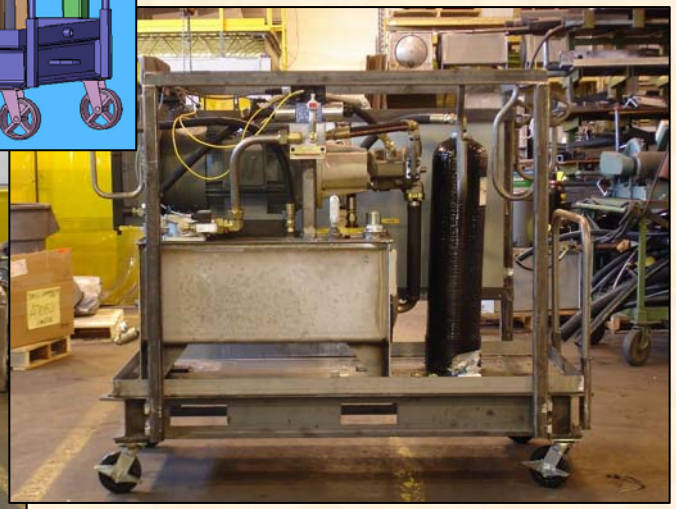
- **Syringe vendor Airline Hydraulics Corp (AHC)**
  - **Bensalem, PA**
- **AHC provided system design based on functional requirements specification**
- **System consists of all syringe pump components**
- **Status**
  - **Integration of cylinders & control system starting this week**
  - **System factory acceptance testing March 30**











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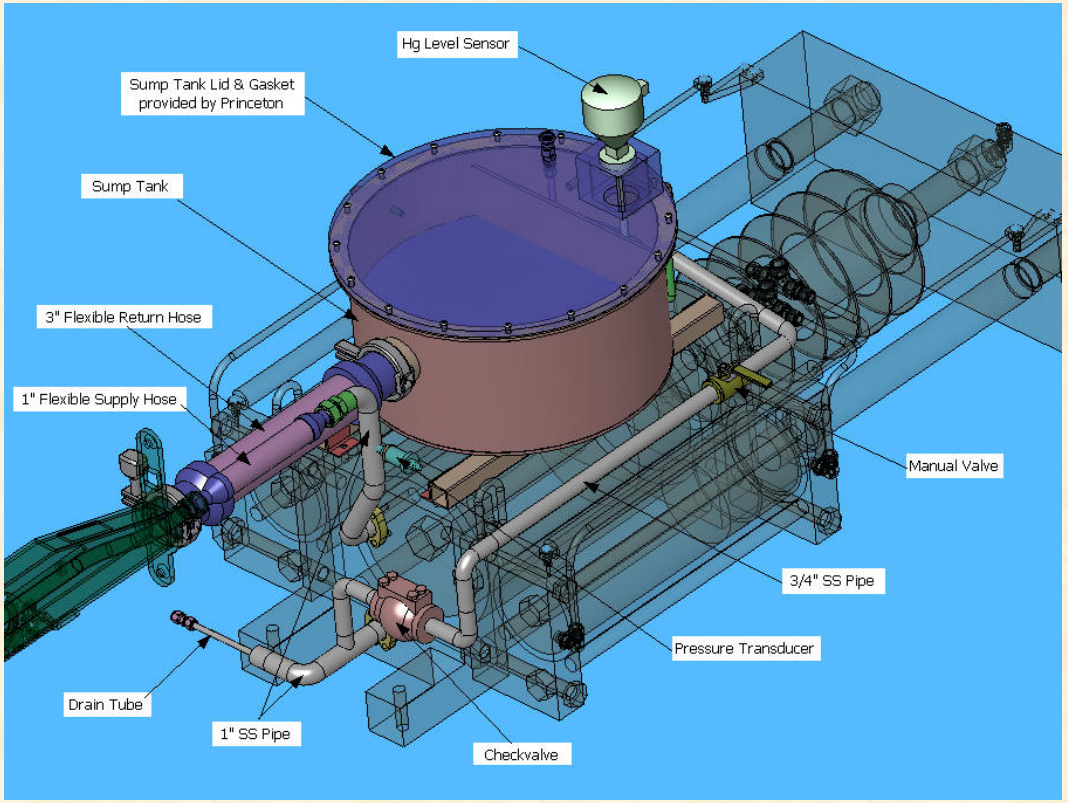
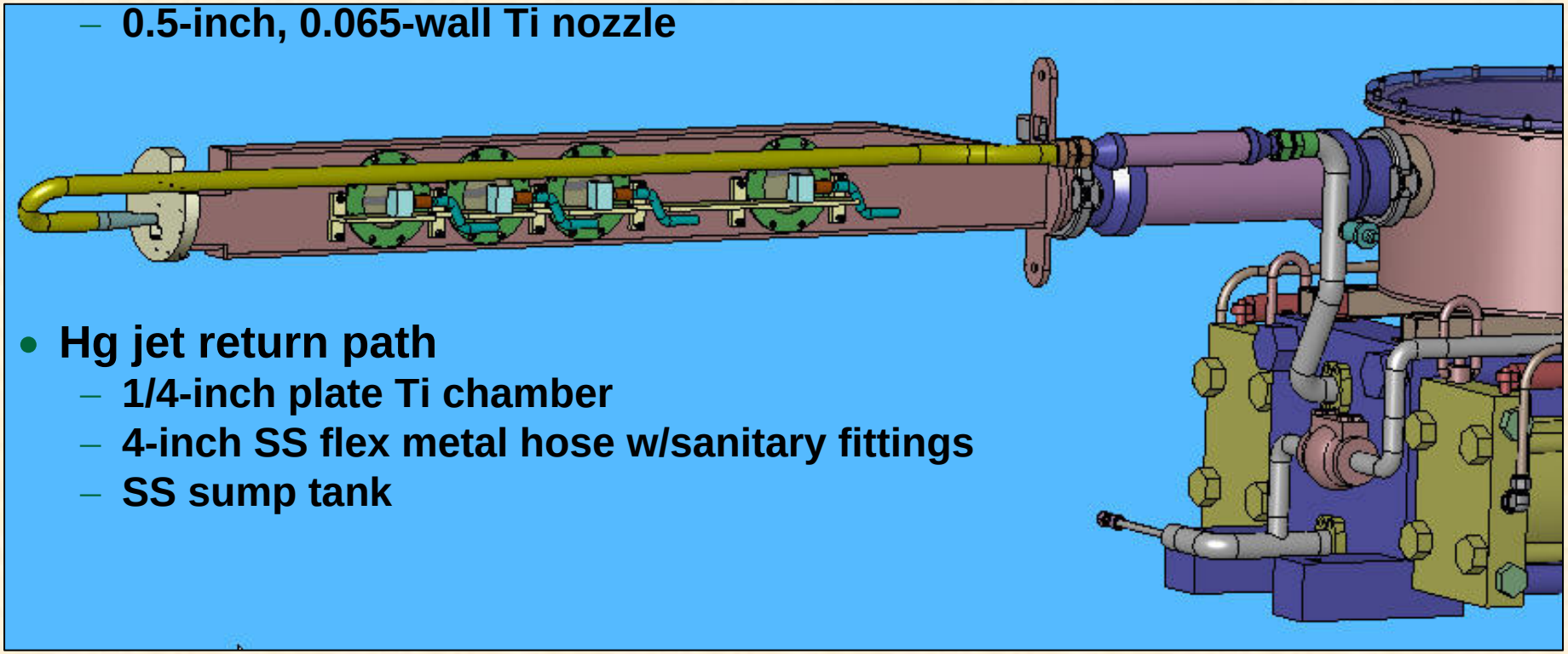
# Additional Syringe Work

- **Syringe procurement initiated Sept '05 due to anticipated long delivery of cylinders**
- **Fabrication dwgs for remainder of system not completed at that time**
  - **Dwg pkg now complete**
- **Prefer to award to syringe pump vendor**
- **Being coordinated by BNL Procurement**



# Primary Containment

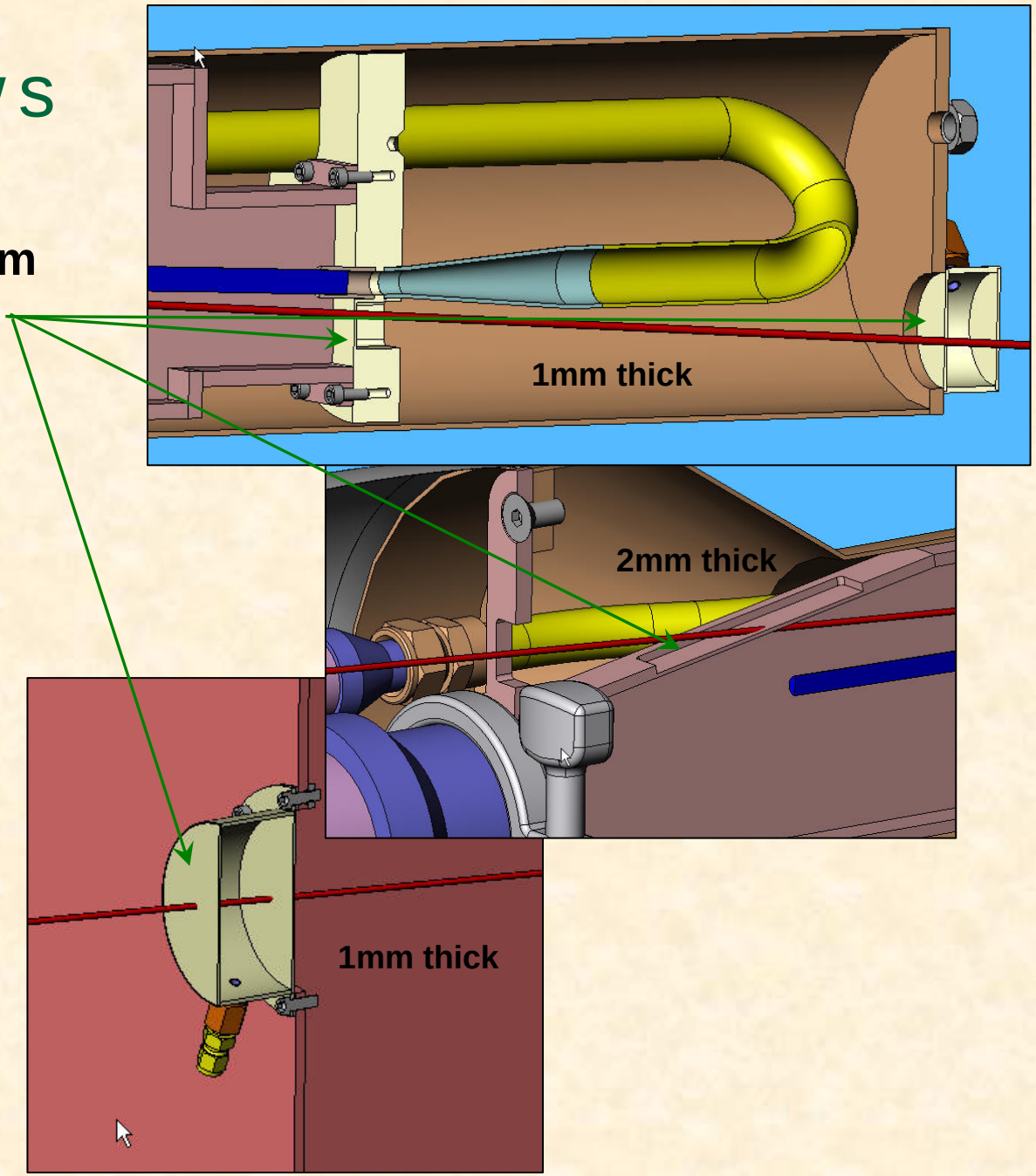
- **Hg supply flow path**
  - **1-inch Sch 40 SS pipe**
  - **1-inch flex rubber hose w/Swagelok fittings**
  - **1-inch, 0.065-wall Ti rigid tubing**
  - **Fabricated Titanium reducer**
  - **0.5-inch, 0.065-wall Ti nozzle**



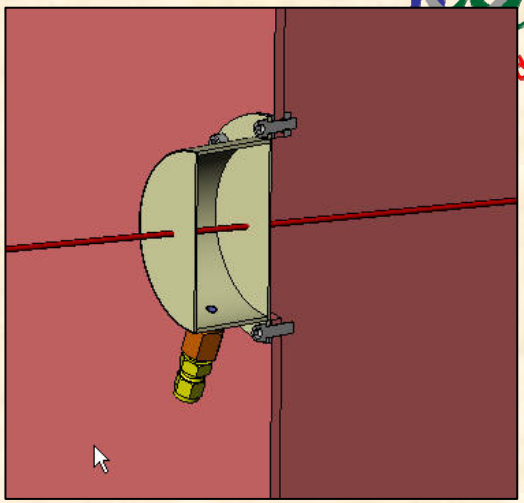
- **Hg jet return path**
  - **1/4-inch plate Ti chamber**
  - **4-inch SS flex metal hose w/sanitary fittings**
  - **SS sump tank**

# Beam Windows

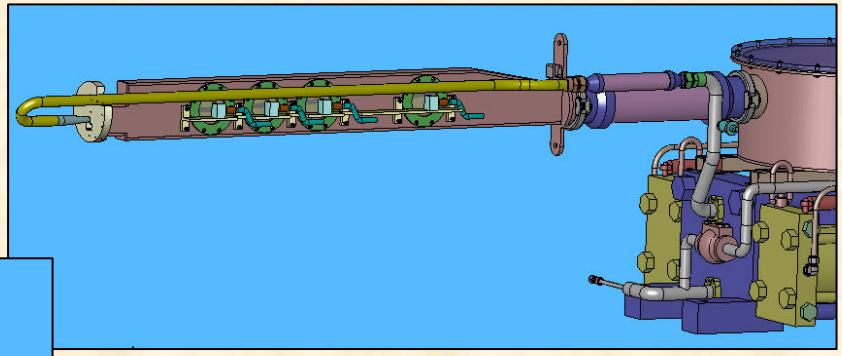
- **Windows fabricated from Ti6Al4V alloy**
- **Welded attachments provide more usable space for beam**
- **Single windows for primary containment, double windows for secondary**
- **Pressurize secondary windows, monitor to detect failure**

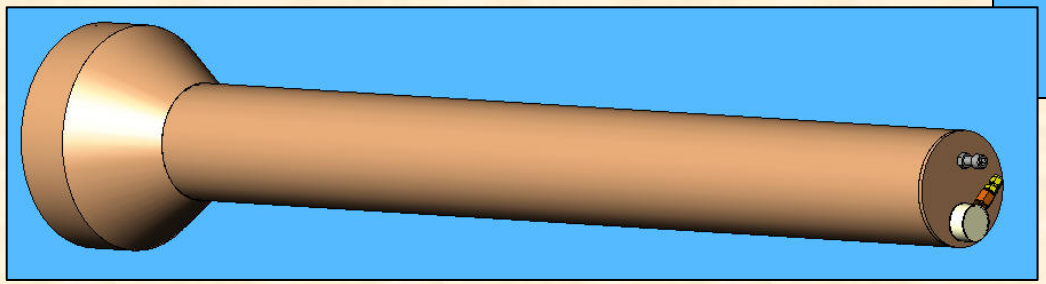


# Titanium Target Module



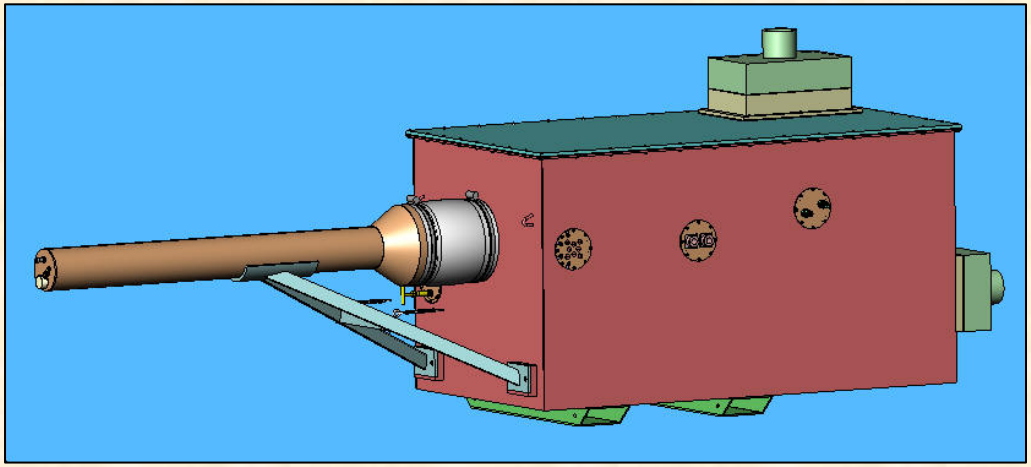
- **Current design of primary/secondary containment modules inserted into magnet utilizes Ti or Ti alloys**
  - **Alleviates issues with welding dissimilar metals**
  - **Anodized Ti minimizes some MHD effects by insulating conductive Hg from the piping**
- **Drawing package currently out for bid**
  - **Will be coordinated by Princeton Procurement**
  - **Procurement direction to be decided on cost/schedule considerations**
- **Material for 2 spare nozzle assemblies will also be procured**





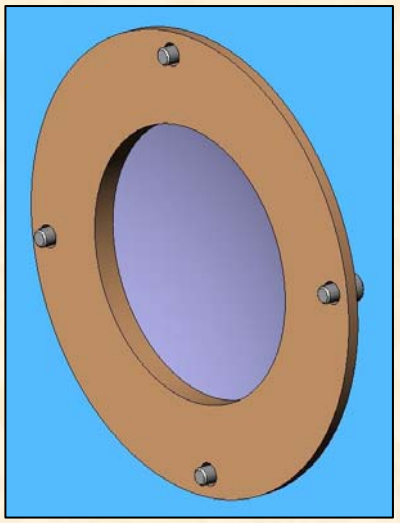
# Secondary Containment

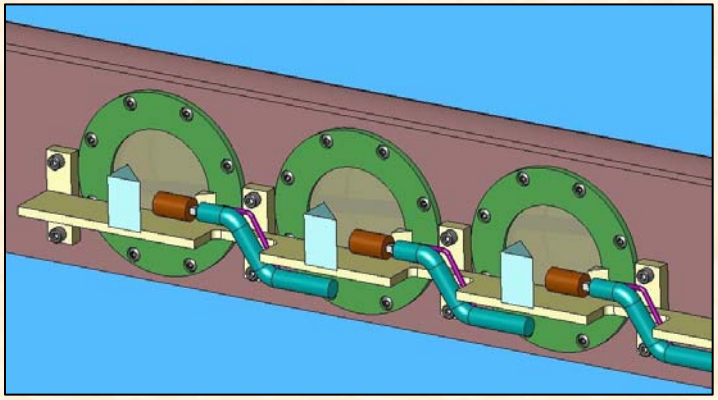
- **SS304L/316L 1/2" bottom plate, 1/4" sides**
- **SS flexible sleeve**
- **Ti cylindrical sleeve**
- **Lexan top**
- **Ports**
  - **Optical diagnostics**
  - **Instrumentation**
  - **Hydraulics**
  - **Hg drain & fill (without opening secondary)**
  - **Hg extraction (in event of major leak in primary containment)**
  - **Passive filtration**
- **Fabrication underway at Princeton (except Ti sleeve)**

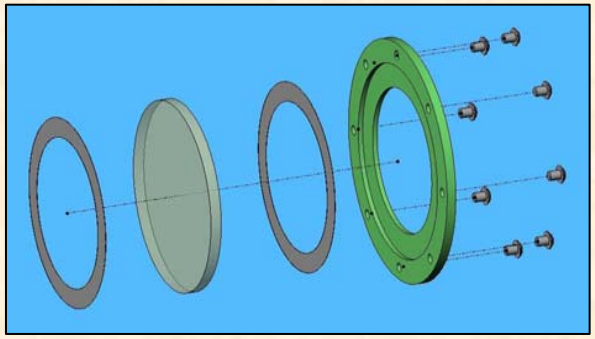


# Optical Diagnostics

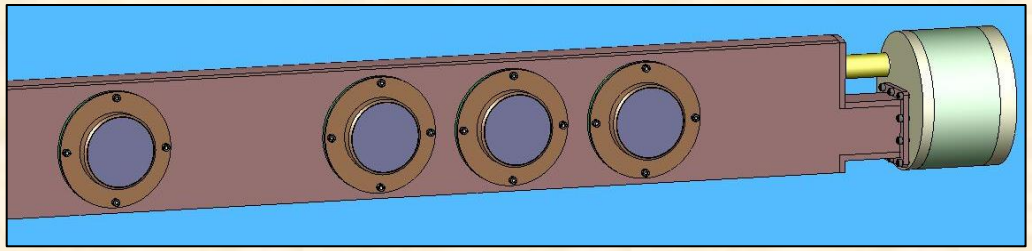
- **8X 100mm-dia, 6mm-thick sapphire disks with cover plates mechanically attached to jet chamber**
  - **Disk has been impact-tested at Princeton**
- **One set of windows configured for reflector assemblies**
- **BNL to provide splitters, prisms, lenses, bracket, mounting hardware & adjustment mechanisms**





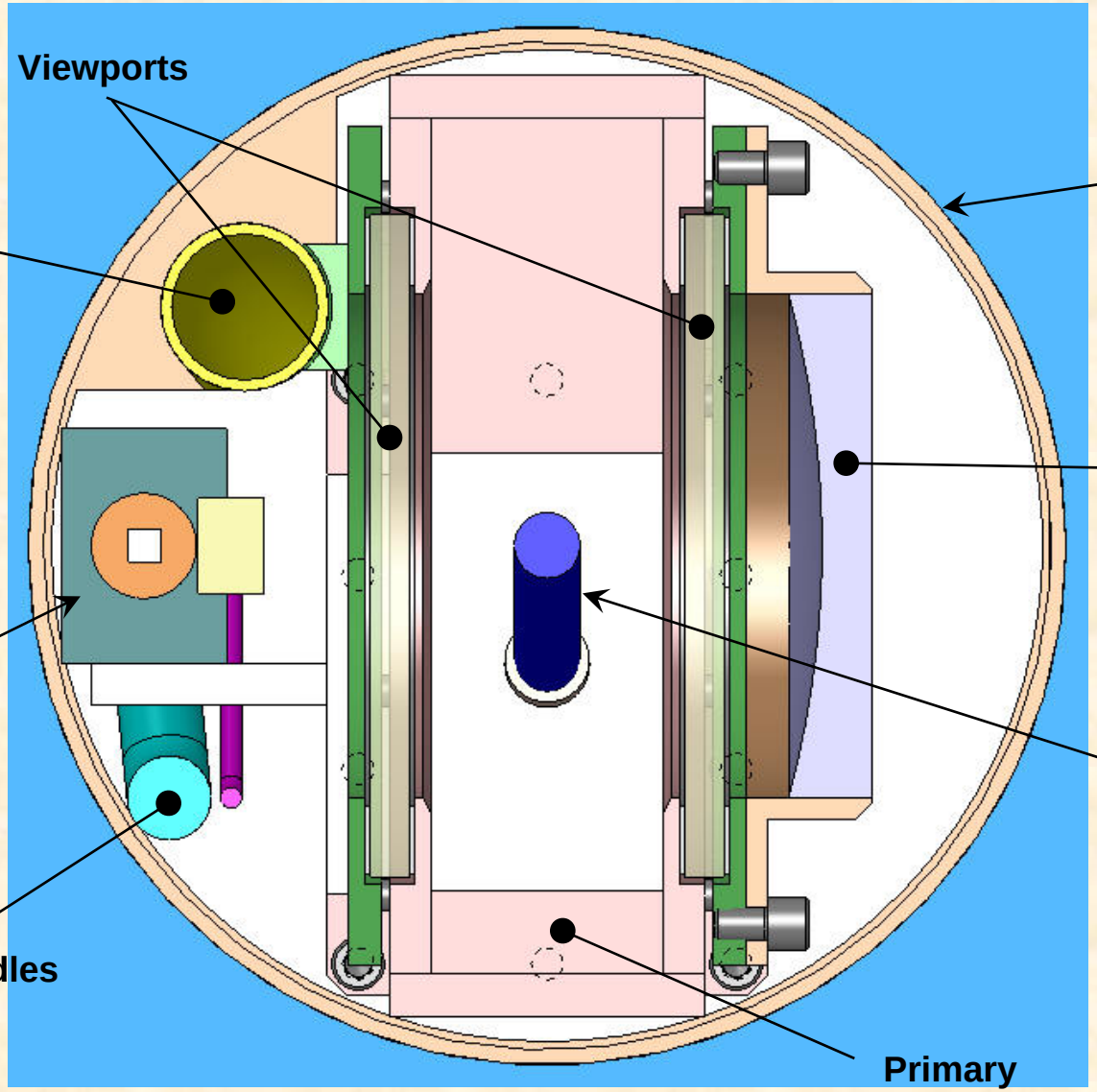


**Viewport Assemblies**



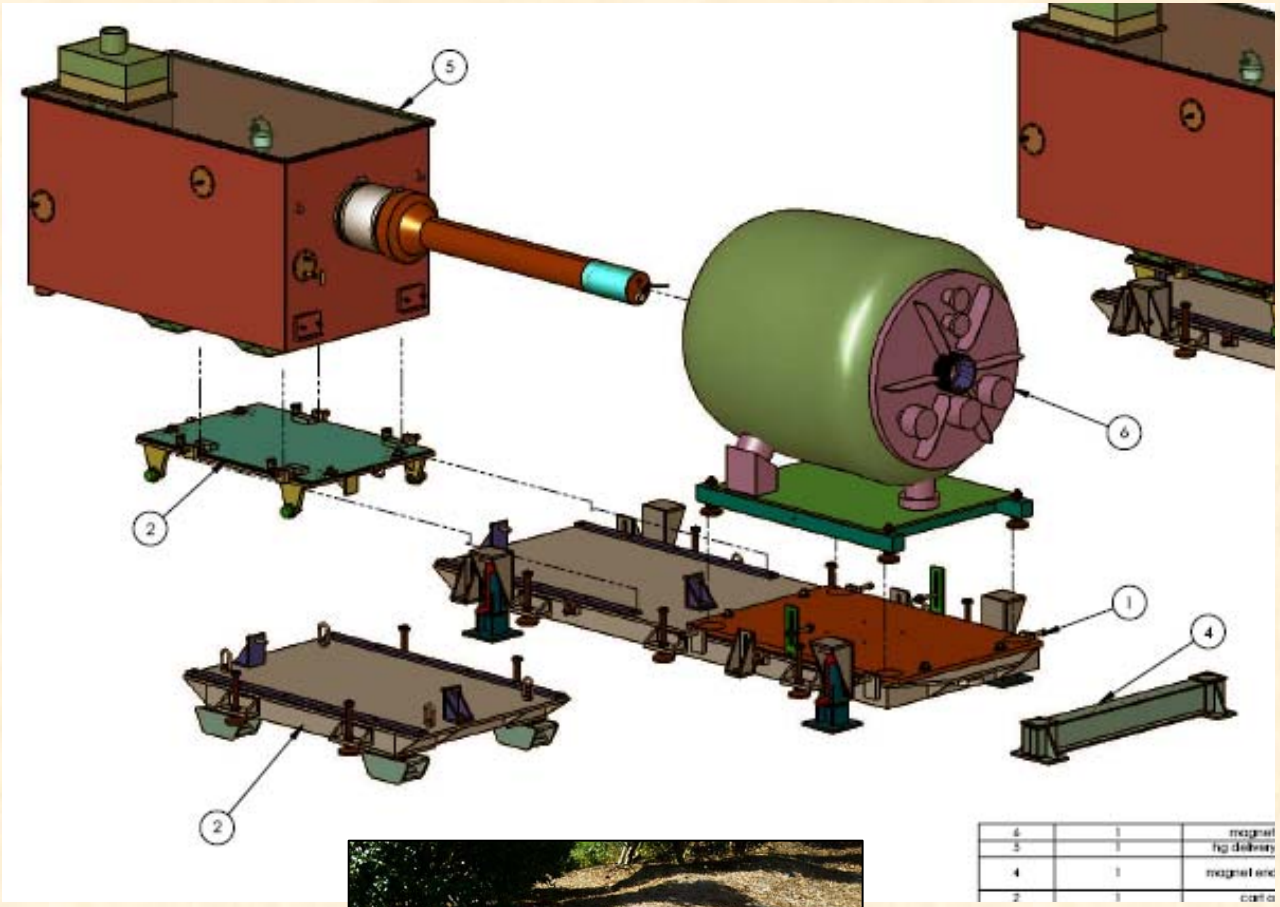
**Reflector Assemblies Mounted on Viewports**

# Z=0 Section Cut



# Baseplates

- **Multiple baseplates required for transport, assembly, and equipment support**
- **Primarily fabricated from Al 6061-T6**
- **Fabrication underway at University of Mississippi**

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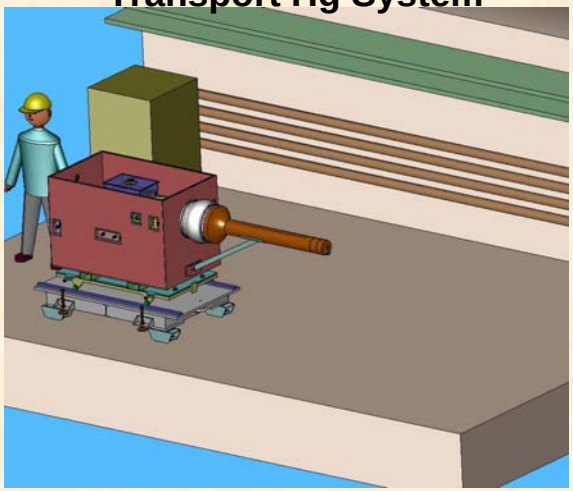
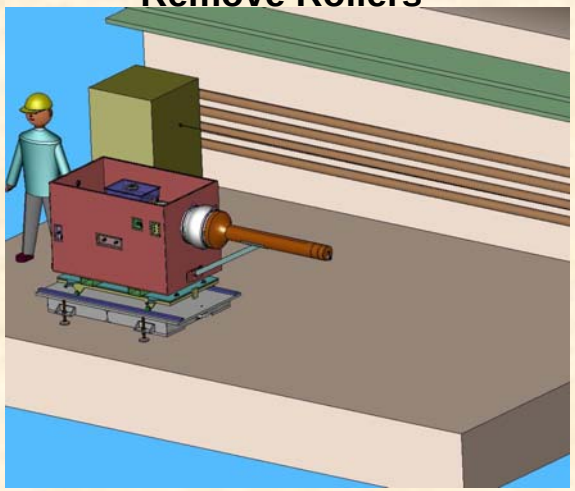
# Installation Sequence

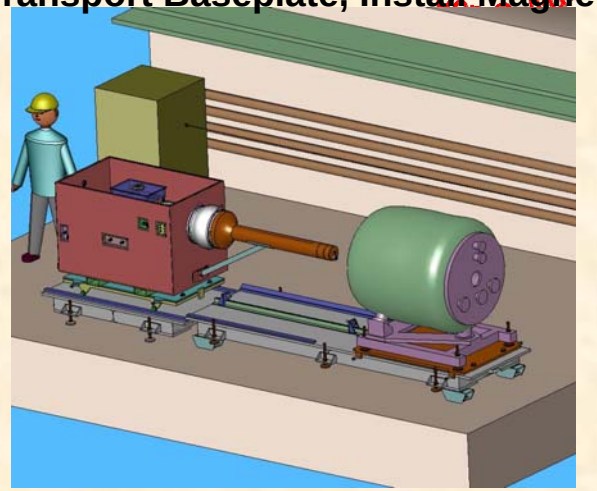
**Transport Hg System**

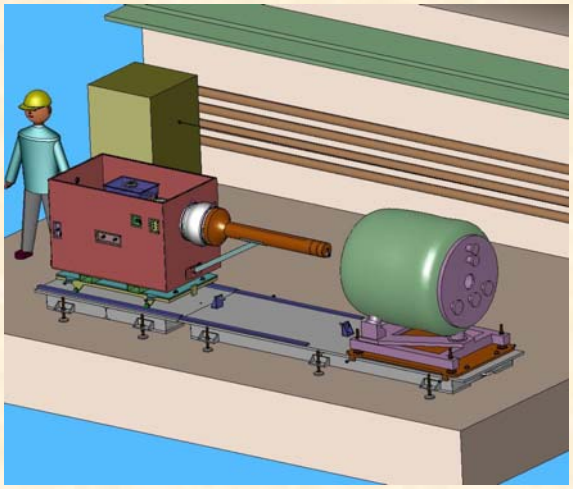


**Remove Rollers**

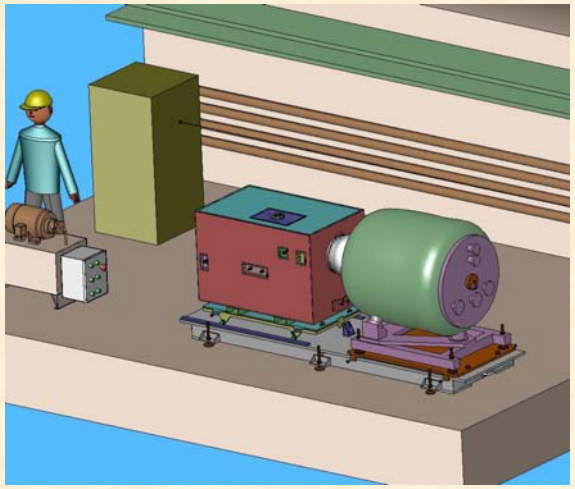


**Transport Baseplate, Install Magnet**

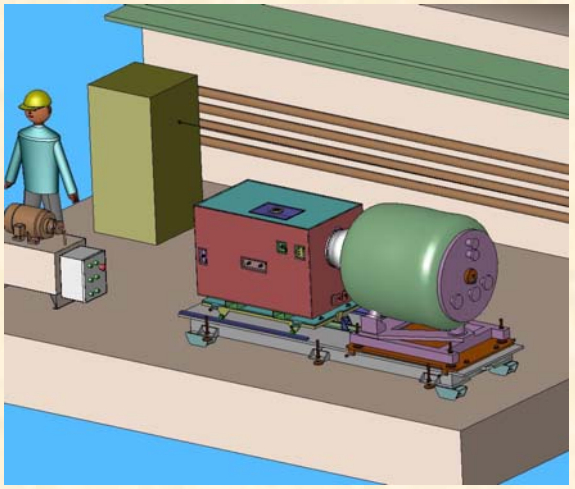




**Remove Rollers, Level Magnet**



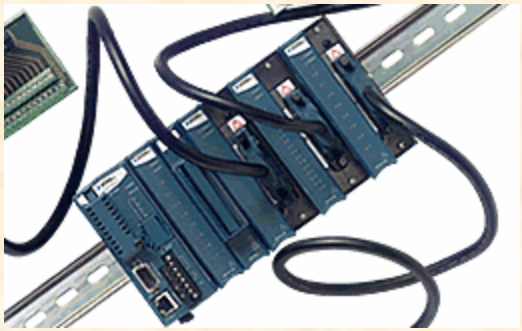
**Roll Hg System into Magnet**



**Add Rollers**

# LabView-Based Control System

- **Remote control over long distance limited control choices**
- **LabView on laptop computer was chosen as system controller**
  - **CompactPCI I/O modules at syringe pump control station**
  - **Communicates to laptop via EtherNet cable**
  - **Should allow straightforward integration with other MERIT control systems**

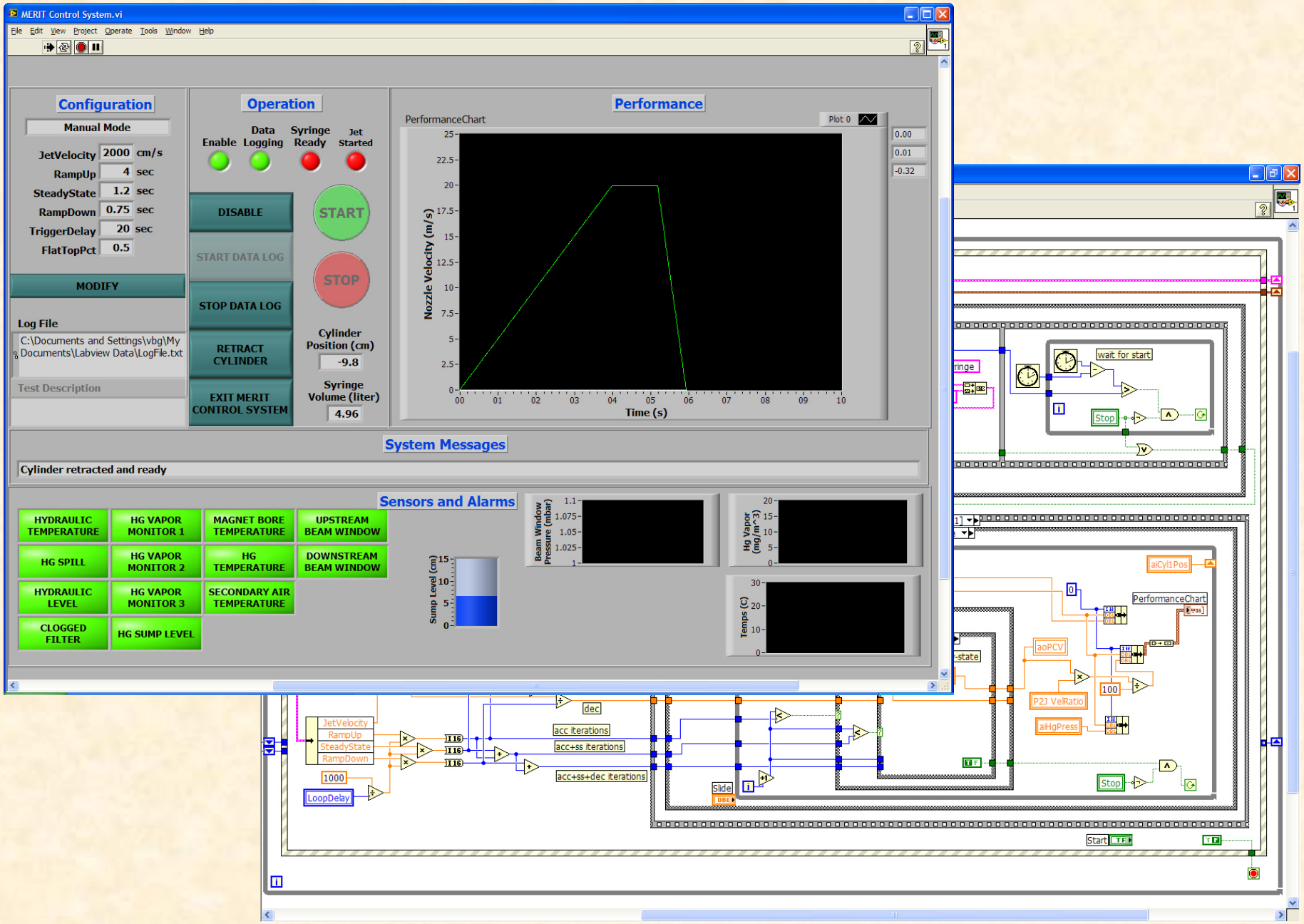


# Instrumentation & Sensors

| 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**

# Hg Syringe Control System Development Underway

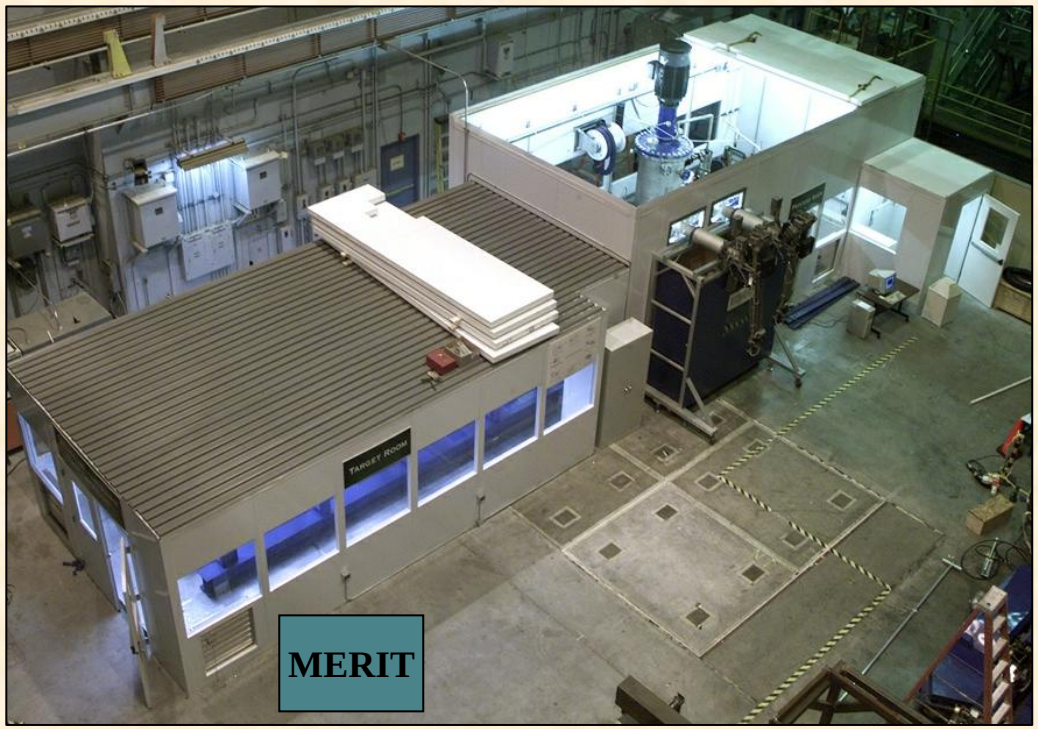


# Hg Handling - Properties and Safety Limits

- **Atomic Weight: 200.59**
- **Boiling Point: 357° C**
- **Specific Gravity: 13.6**
- **Vapor Pressure: 0.0012 mm Hg**
- **Vapor Density: 7.0 (air = 1.0 @ 20° C)**
- **Vapor: colorless, odorless**
- **Solubility: insoluble in water**
- **NIOSH/OSHA: 0.05 mg/m3, 10 h/day; 40 h/wk**
  - **ORNL: action level is set to 0.0125 mg/m3**
    - **Use respirator with Hg cartridge**

# Target Test Facility (TTF) – Basis for ORNL's Hg Handling Experience

- **Full scale, prototype of the SNS Hg flow loop**
- **1400 liters of Hg**
- **Used to determine flow characteristics**
- **Develop hands on operating experience**
- **Major system renovations with Hg-contaminated equipment**
- **MERIT assy & testing will occur in or near TTF**

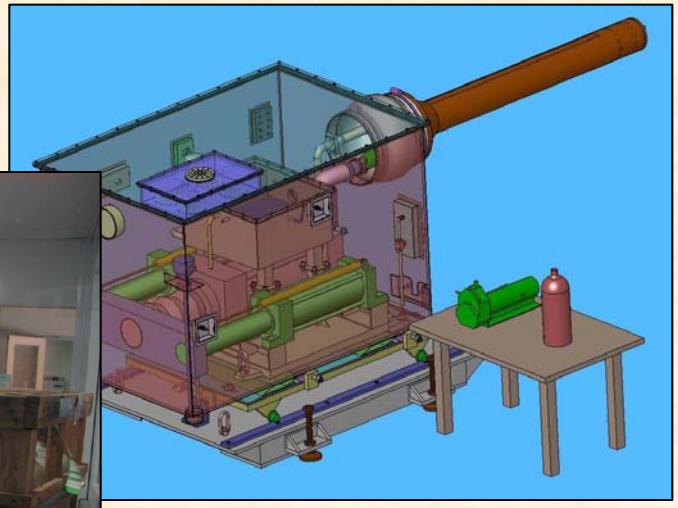


# Mercury Containers/Shipping

- **Standard flask is 2.5 liters**
- **Flask + Hg weighs ~35 kg**
- **Shipping requirements coordinated by ORNL Transportation Group**
- **MERIT will require a short (20ft) Sealand container for transport to CERN**
  - **Ship magnet with Hg system**


# TTF Operations – Hg Filling

- **A peristaltic pump for transferring Hg was successfully tested**
  - **This is the preferred approach for filling & draining MERIT**
  - **System designed to fill/drain without opening secondary containment**
- **Hg handling requires multiple spill/drip precautions and ventilation equipment**



# Mercury Vapors – Filtering & Monitoring

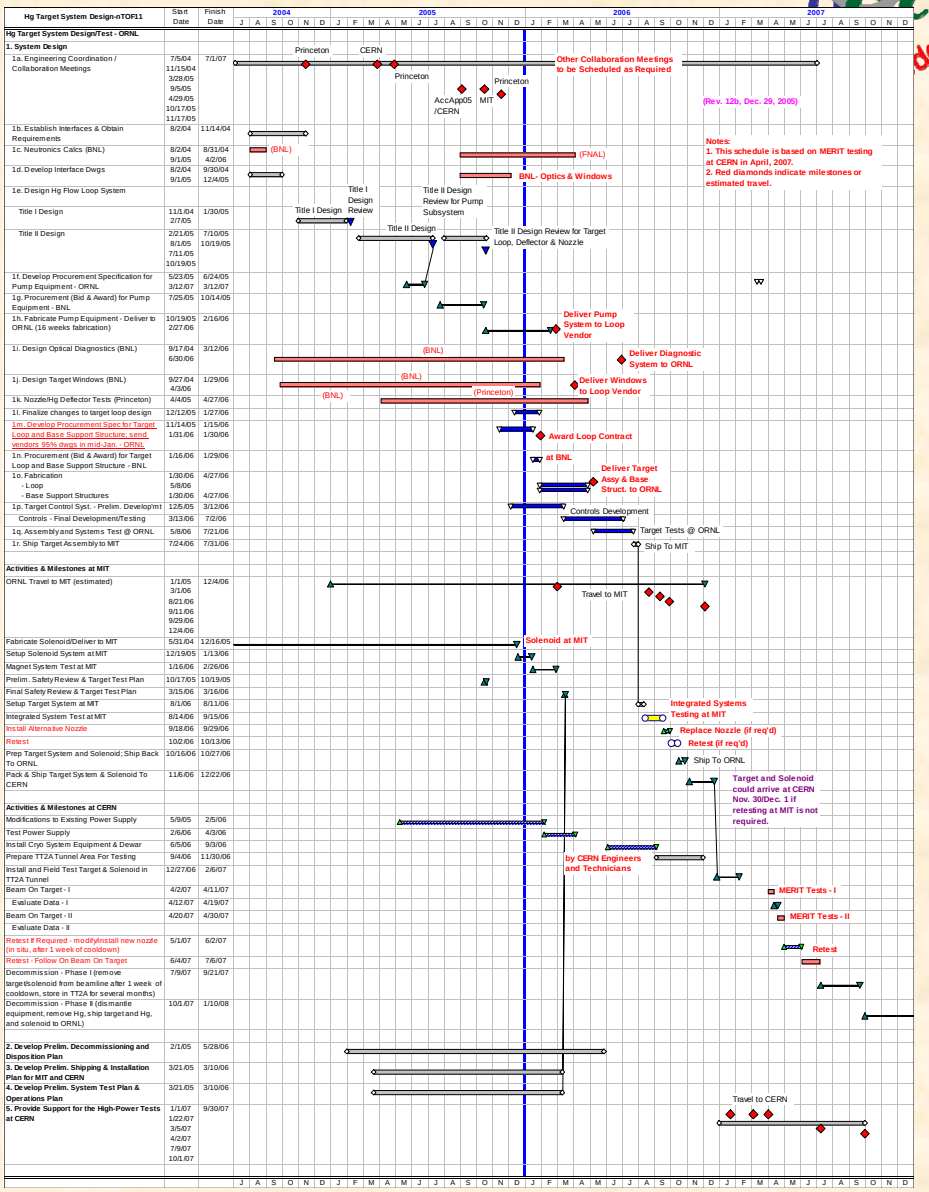
- **Two vapor monitors to be used**
  - **One for secondary volume, one for tunnel environment**
  - **Will communicate with control system**
- **Scavenger portable ventilation system will be used**
  - **Can be used as stand-alone system or connected to secondary containment**
  - **Already procured by Princeton**
- **Passive filtration on secondary containment**
  - **Sulphur-impregnated charcoal & HEPA filtration**


# MERIT at MIT and CERN

- **Dialogue with CERN & MIT Safety Engineering Group has begun**
  - **Presentation/discussion with CERN in August ’05**
  - **Presentation/discussion with MIT at the October Collaboration Meeting**
- **Formal safety reviews and test/operation plans to be presented to MIT and CERN during summer 2006**

# Schedule – Major Milestones

- **Target Tests at ORNL May-Jul '06**
  - **Integrated with optical diagnostics system**
- **Integrated Tests at MIT Aug-Sep '06**
  - **Retest Oct '06 if nozzle reconfiguration needed**
- **Ship MERIT equipment to CERN Nov-Dec '06**
- **Beam Tests at CERN Apr '07**
  - **Retest Jun '07, if needed**



# Conclusions

- **Syringe pump system fabrication nearly complete, integration to begin this week**
  - **Factory acceptance testing March 30**
- **Final design details & fabrication dwgs of Hg system have been completed**
  - **Initial nozzle configuration determined**
  - **Fabrication is underway on baseplates & secondary containment**
  - **Sump tank assy pkg should be awarded soon**
  - **Titanium pkg out for bid, delivery could possibly affect testing schedule**
- **Control system development started, need guidance regarding integration with supervisory experiment control system**
- **Hg system testing at ORNL will begin as soon as equipment becomes available**
  - **Water testing followed by Hg**