A Free Jet Hg Target Operating in a High Magnetic Field Intersecting a High Power Proton Beam

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Background

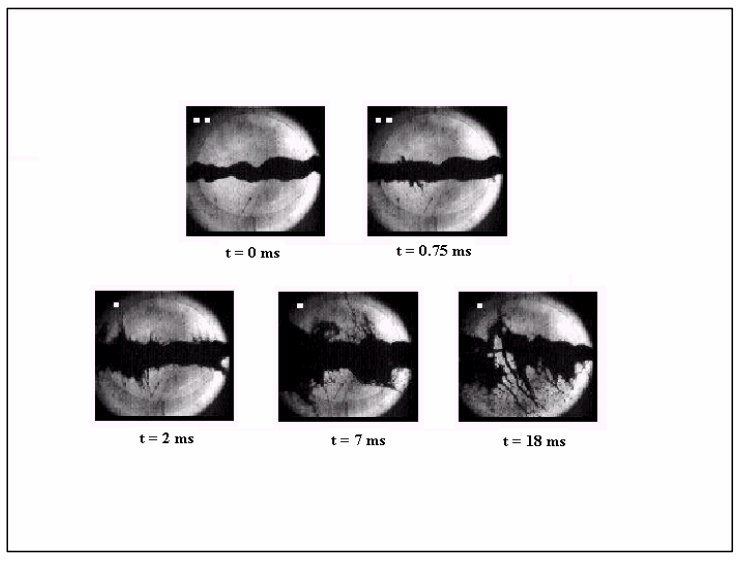
- **Proof-of-principle experiment to investigate the interaction of a proton beam with a high-Z target (Hg) inside a high-strength magnetic field**
- **Primary diagnostic for the beam-jet interaction is optical**
- **Similar to a high-power production target needed for a neutrino factory or muon collider**
- **Experiment approved by CERN Research Board**
  - **CERN designation nToF11**
  - **Collaboration designation MErcury Intense Target (MERIT)**
  - **Scheduled for April 2007**

Participants

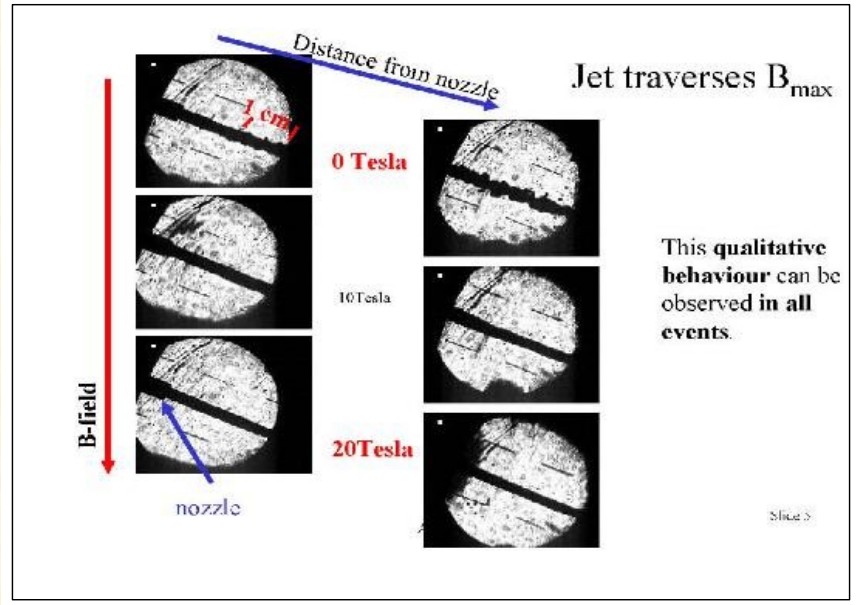
- **BNL, Princeton – project oversight, nozzle development, beam window design, optical diagnostics**
- **MIT – magnet design & fabrication**
- **ORNL – Hg target system design & fabrication**
- **RAL – magnet cryogenics**
- **CERN – proton beam & facility interfaces**

Prior Work

- **E951 Tests (H.Kirk - BNL)**
  - **1cm dia, 2.5m/s Hg jet**
  - **24 GeV 4TP beam**
  - **No magnetic field**
  - ***Jet dispersal observed***



- **CERN/Grenoble Tests (A.Fabich,J.Lettry - NuFACT'02)**
  - **4cm dia, 12m/s Hg jet**
  - **0,10,20T magnetic field**
  - **No proton beam**
  - ***Jet stabilization with increasing field***

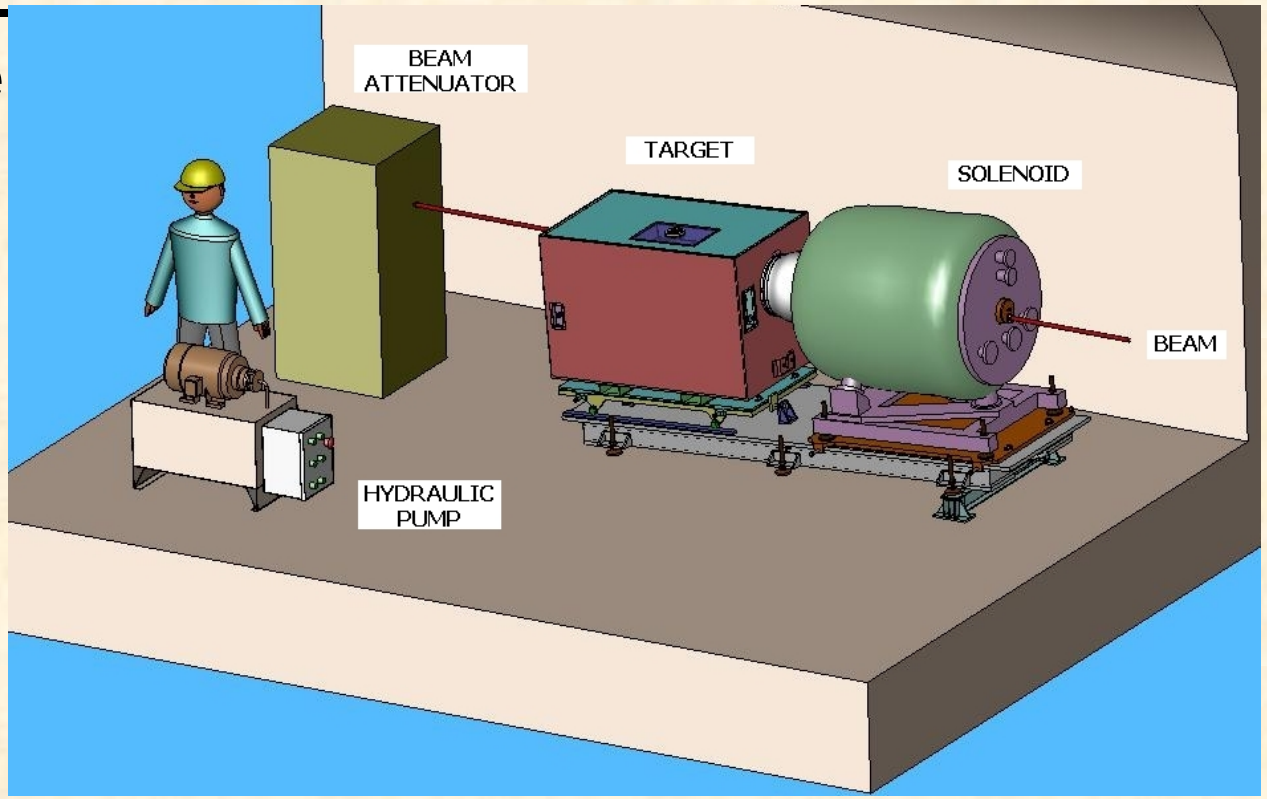


Experiment Profile

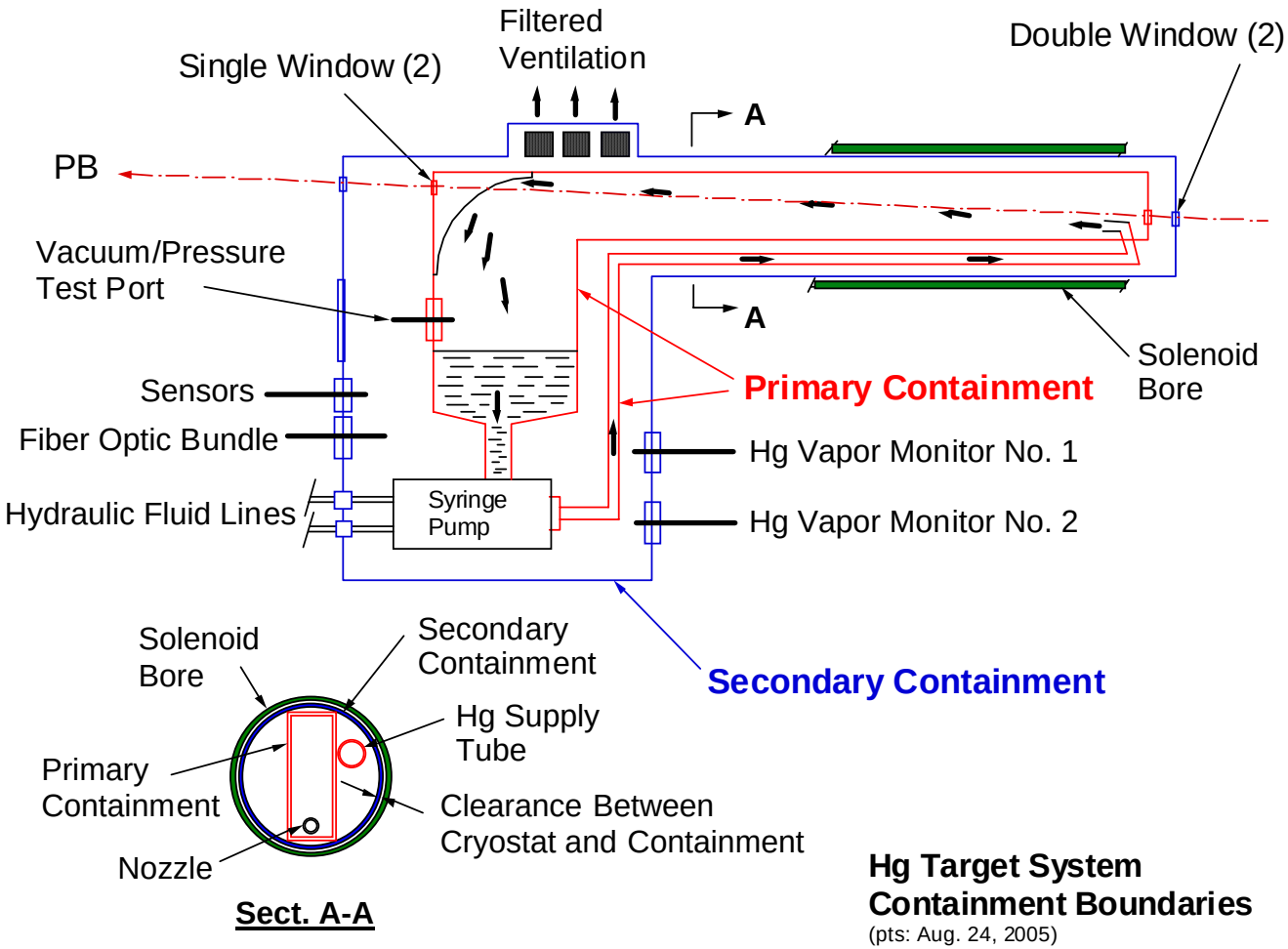
- **Hg Jet**
  - **1-cm diameter, 20 m/s, delivered to coincide with magnet peak field**
  - **Required flow rate of 1.57 liter/s**
- **Magnet**
  - **15 Tesla magnetic field**
  - **Peak field duration ~1 sec**
  - **Magnet cool-down time ~30 minutes**
- **Environment**
  - **24 GeV proton beam, up to 28×10^{12} (TP) per 2μs spill**
  - **1-atm air environment inside target delivery system primary containment**
  - **Total integrated dose 10^4 rads**
- **Geometry**
  - **Hg jet 100 mrad off magnet axis**
  - **Proton beam 67 mrad off magnet axis**
  - **Jet intersects beam at magnet Z=0**
- **Up to 100 beam pulses for the CERN test delivered in a pulse-on-demand mode**

Experiment Layout

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

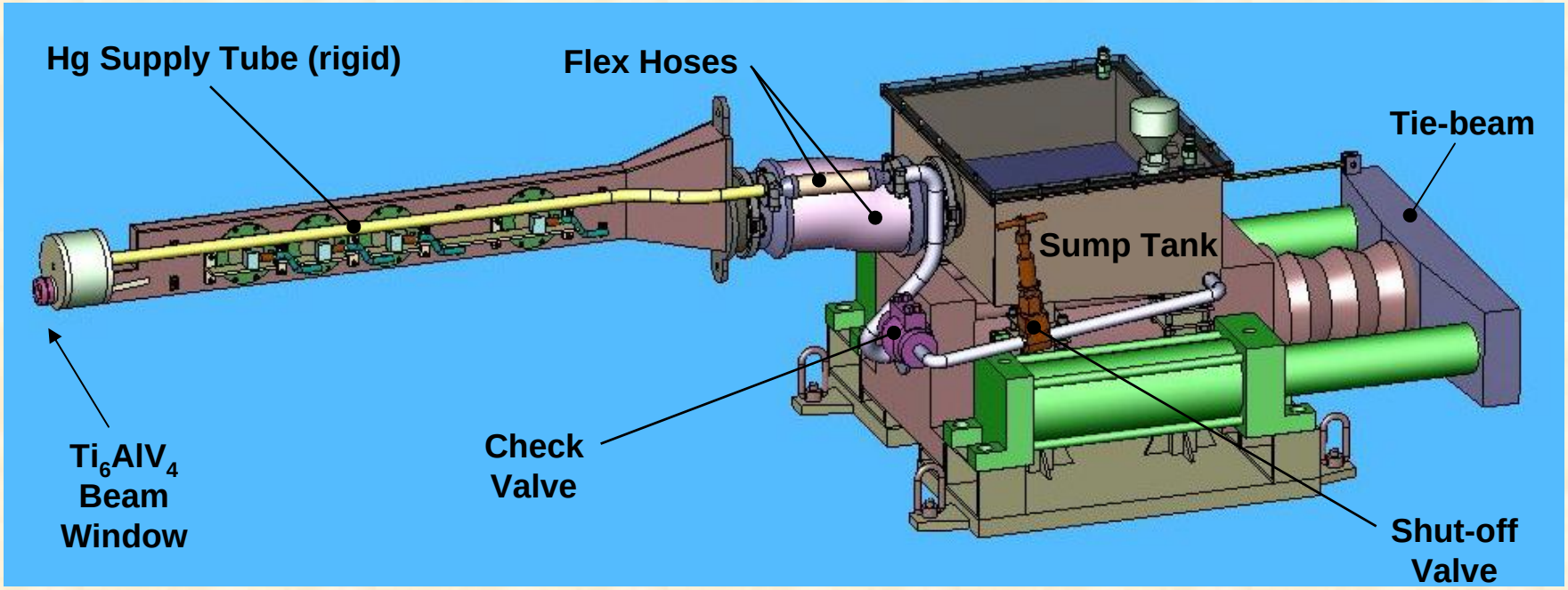


Hg System Schematic

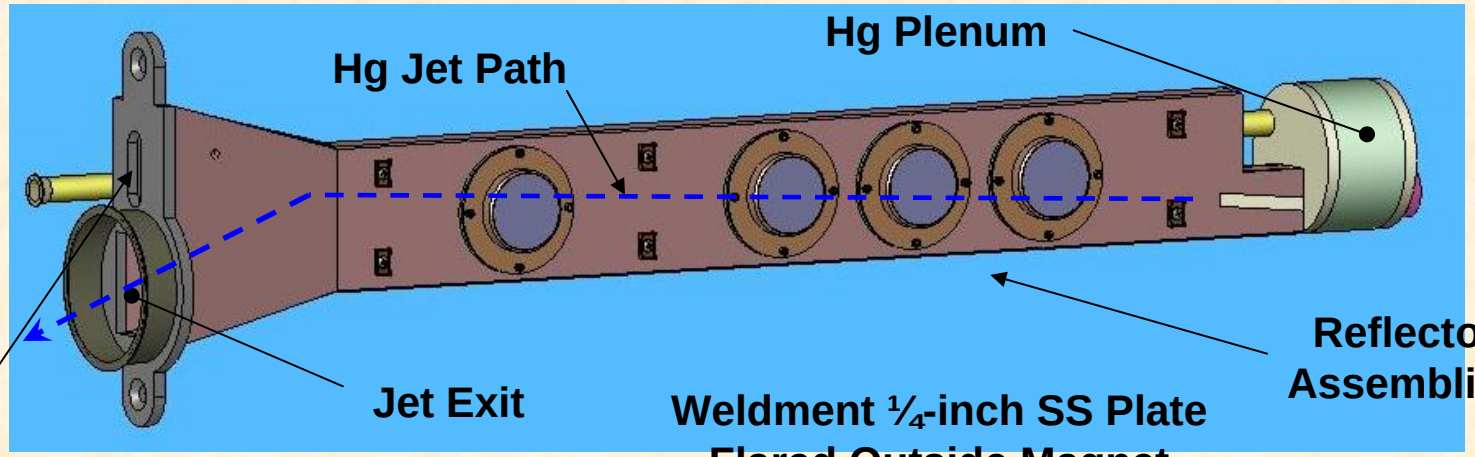


Mercury Delivery System

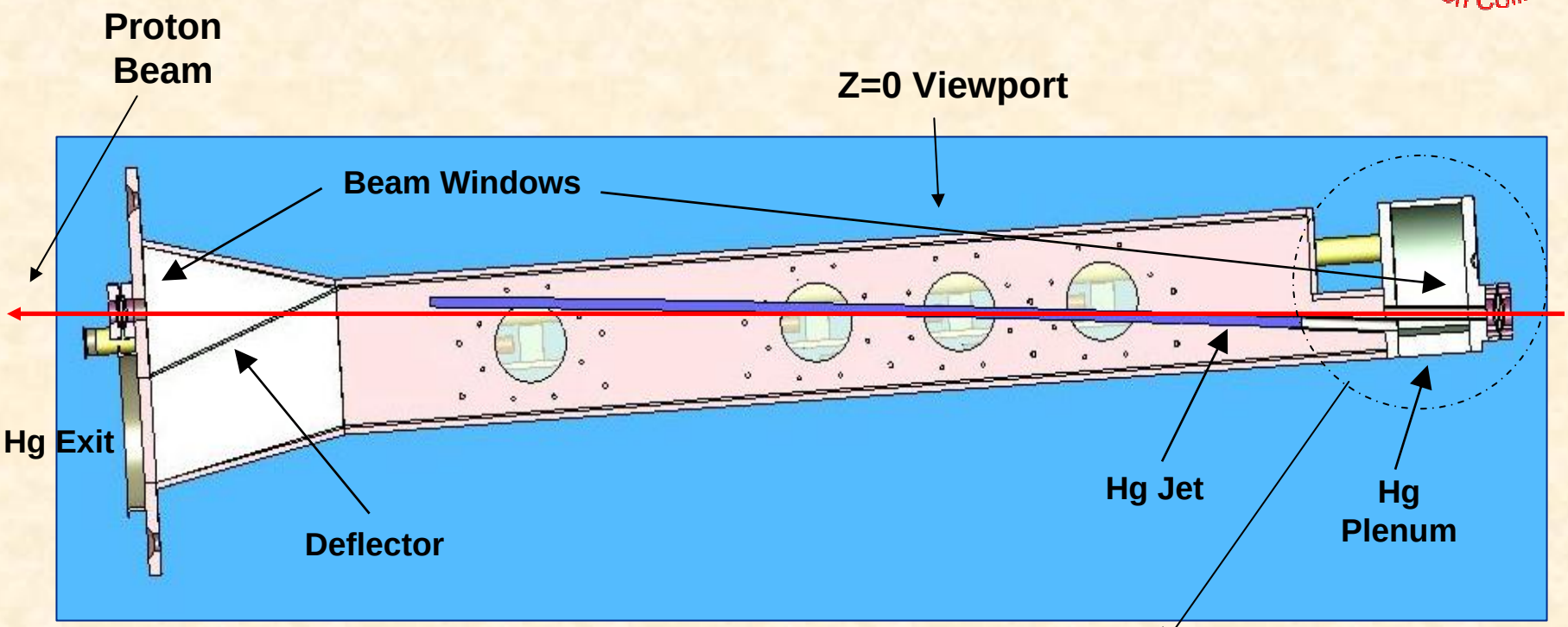
- **Hydraulically-actuated piston pump delivers Hg to the nozzle**
- **Hg cylinder 25-cm (10-inch) bore, 38-cm (15-inch) stroke**
  - **Q = 1.5 liter/s (25 gal/min), piston Vel = 3.0 cm/s (1.2 inch/s)**
  - **Provides jet duration up to 12s, requires approx 23 liters Hg**
- **Two drive cylinders 15-cm (6-in) bore, powered by 45 liter/min (12 gal/min), 2.1 MPa (3000psi) pump**
- **Primary containment SS304L/316L**
- **Gravity fed from sump tank**

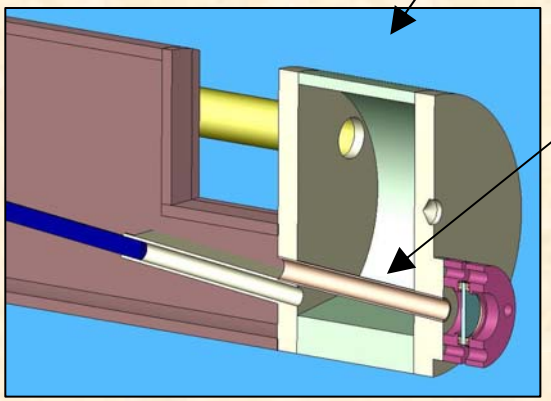


Target Module Primary Containment

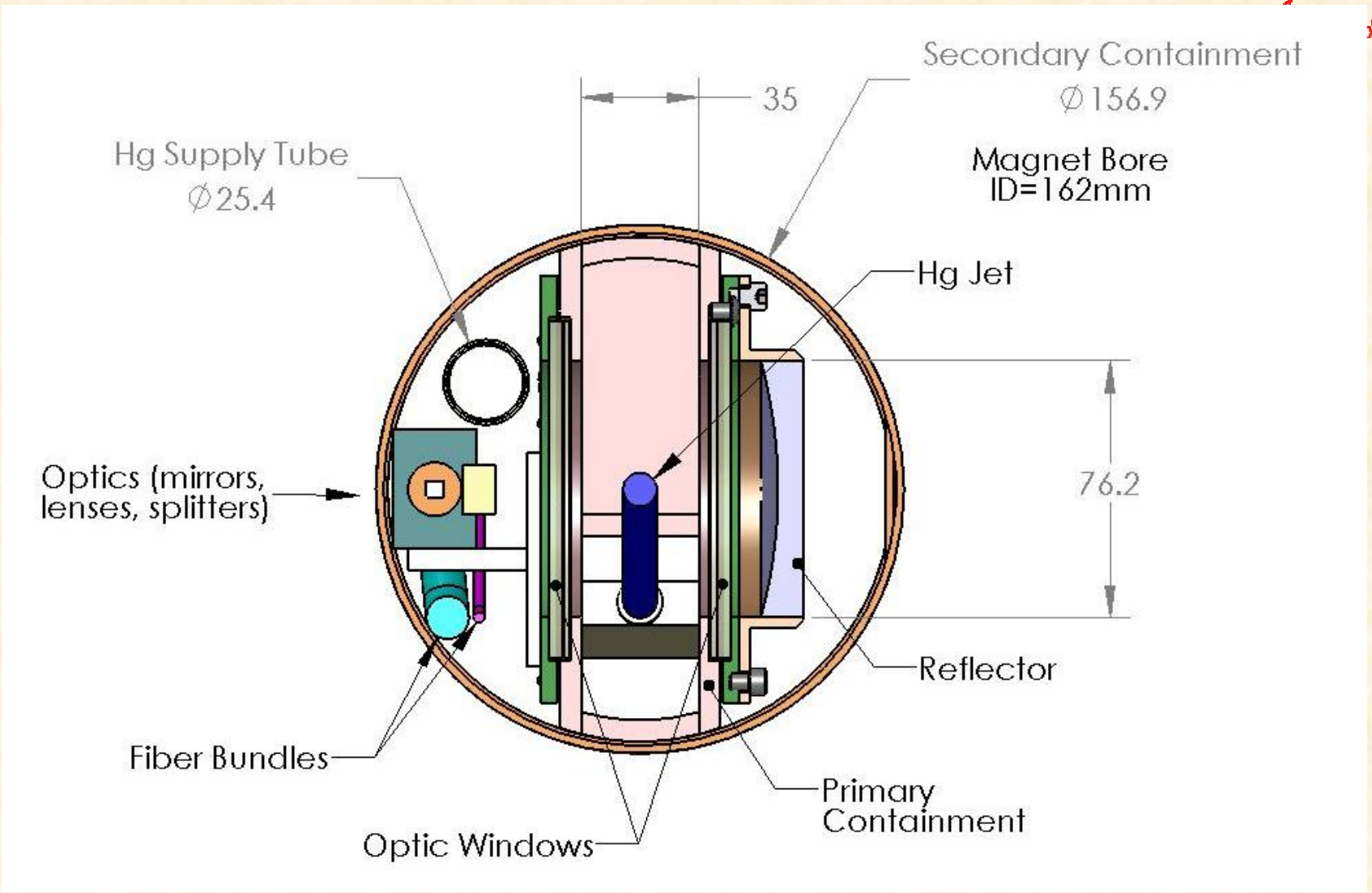


Primary Containment Xsec



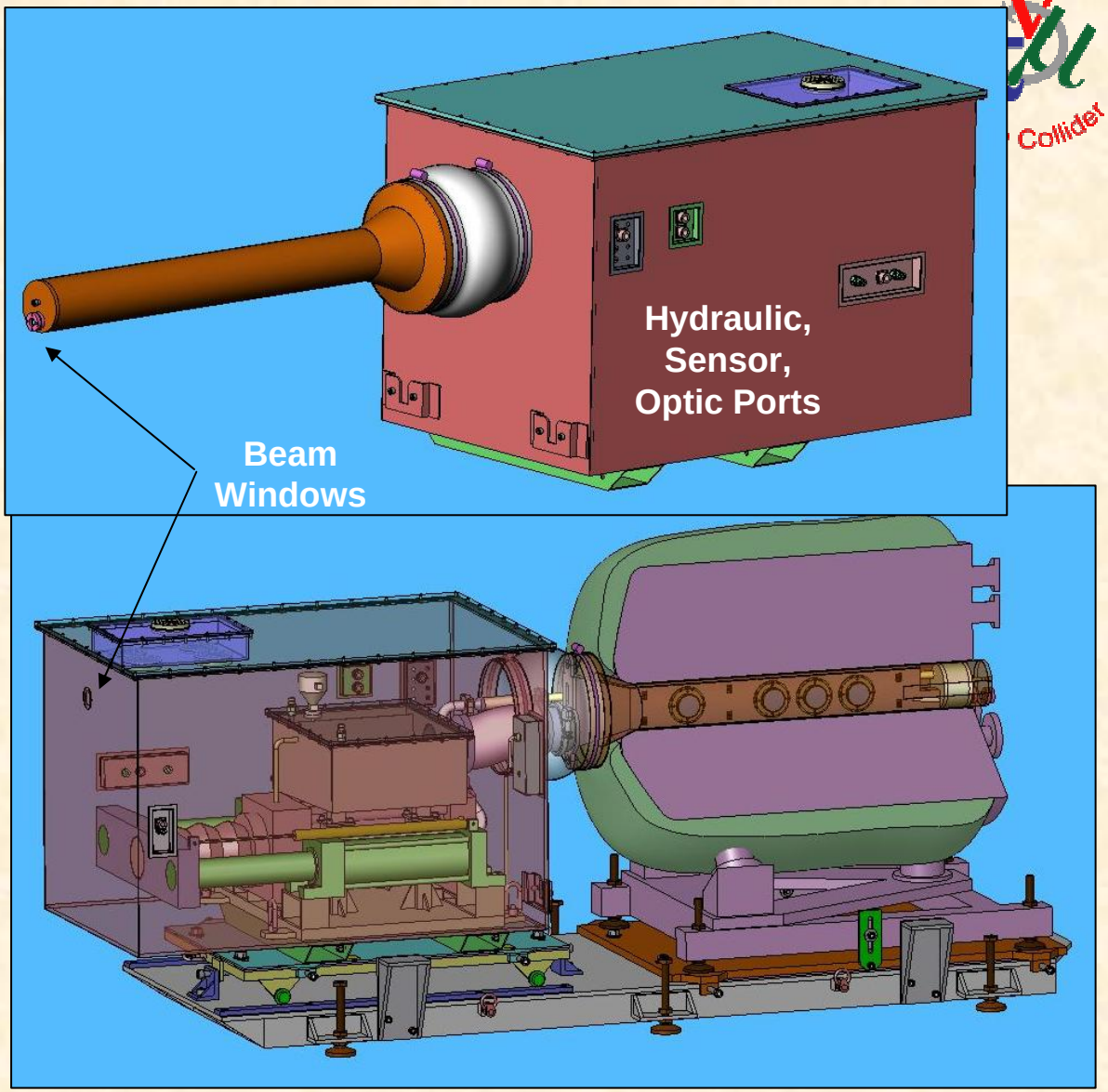


Primary Containment Cross Section



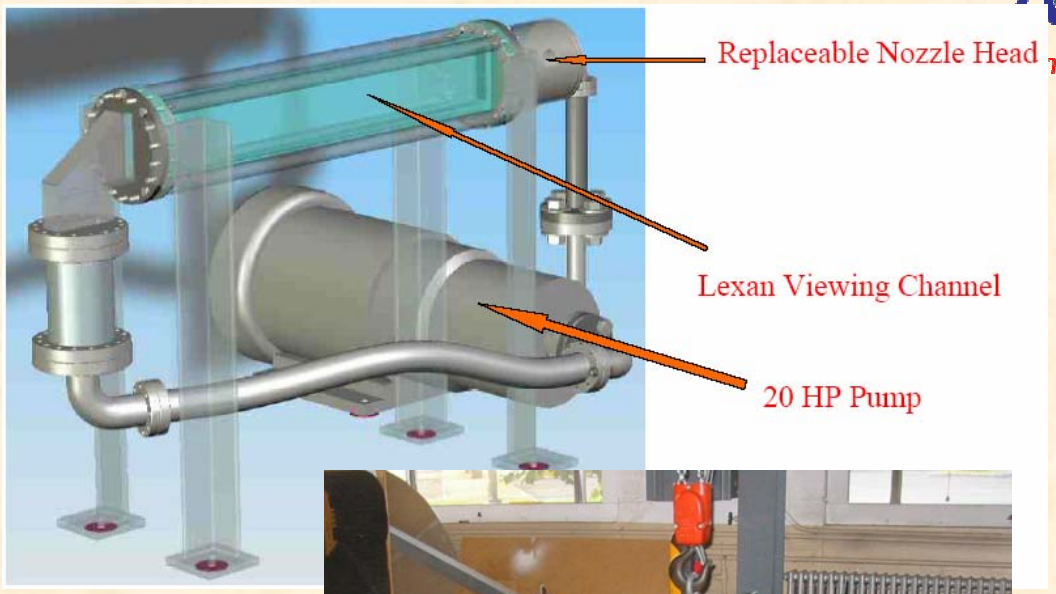
Secondary Containment

- **SS and Lexan enclosure around entire primary system**
- **Contains Hg vapors/leaks, provides access to monitor Hg vapors**
- **Provides access to optical diagnostics, hydraulics, and sensors**
- **Incorporates beam windows**



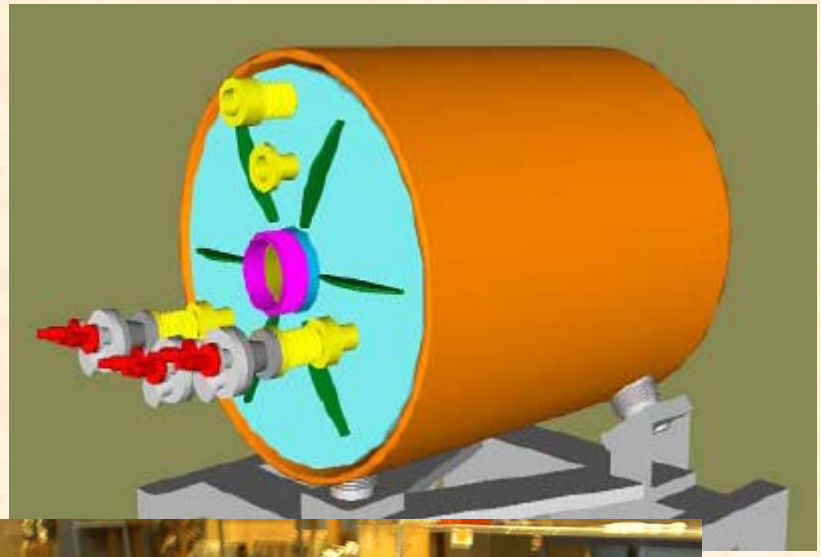
Nozzle Tests at Princeton

- **R&D setup to test various nozzle configurations with mercury**
- **Water testing initiated**



Magnet Description

- **15-T pulsed solenoid**
- **3-segment, layer-wound fabrication**
  - **Conductor: ½-inch square, cold worked OFHC copper**
  - **15-cm warm bore**
  - **1-m beam pipe**
- **LN_2 cooled (80K) between pulses**
- **For detailed information**
  - **http://www.psfc.mit.edu/people/titus/#BNL%20Memos**



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**
- **Move experiment out of beam line several days after conclusion**
- **Extract Hg & prepare for shipment after several month cool-down**
- **ORNL will take back the Hg target system and the activated Hg and components**

Test Plan

Magnet testing at MIT	**Oct - Dec 2005**
Hg nozzle tests at Princeton **–Iterate nozzle design as needed**	**Oct - Dec 2005**
Hg target system testing at ORNL **–Includes optical diagnostics** **–Initially test with water to develop syringe control system** **–Incorporate Princeton nozzle design, iterate if necessary** **–Practice Hg fill and extraction** **–Hg jet characterized**	**April - June 2006**
Integrated test at MIT **–Practice CERN installation sequence** **–Hg jet in magnetic field characterized**	**Aug - Sept 2006**
Ship system to CERN	**Nov 2006**
Experiment scheduled at CERN	**April 2007**
Prepare Hg system for shipment to ORNL for decommissioning	**Fall 2007**

Status

- **Magnet**
  - **Assembly nearing completion**
- **Hg target system**
  - **Syringe procurement specification completed**
    - **Expect to award fabrication contract in Oct 2005**
    - **Estimate delivery to ORNL Feb 2006**
  - **Remainder of system design complete Oct 2005**
  - **Fabrication & delivery to coincide with syringe scheduled delivery**
- **Optical diagnostics**
  - **Most components have been selected**
  - **Investigating rad-hard fiber bundles**
- **CERN**
  - **Facility interfaces being defined**
  - **Preparations being made for magnet power supply installation**