MERcury Intense Target (MERIT) Overview

Van Graves, ORNL

Syringe Procurement Kickoff Meeting

Airline Hydraulics

Bensalem, PA

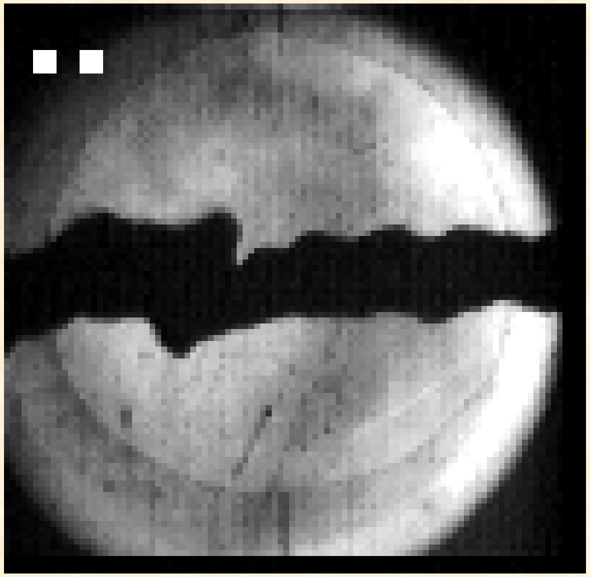
Oct 28, 2005

Background

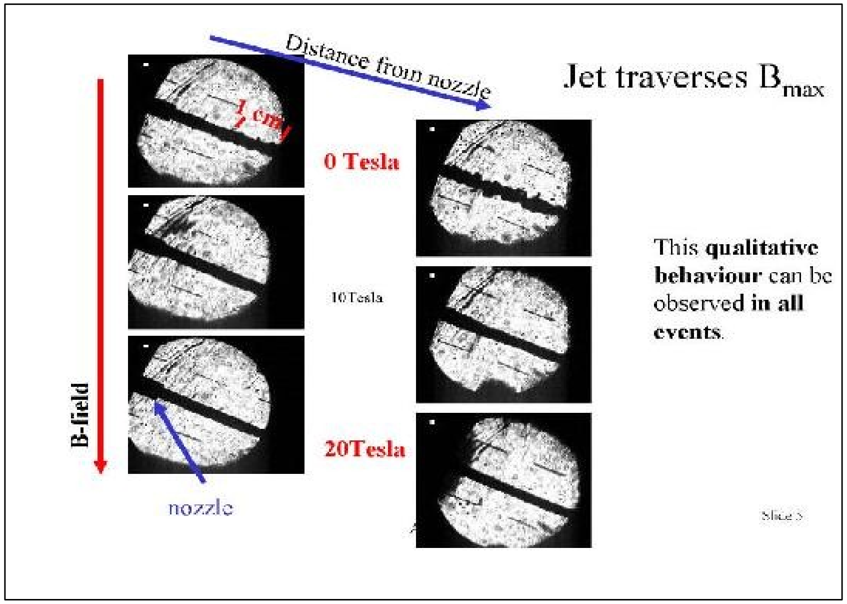
- **Proof-of-principle experiment to investigate the interaction of a proton beam with a Hg jet inside a high-strength magnetic field**
  - **If successful, method might be used as production target in new physics facility**
- **Primary diagnostic for the beam-jet interaction is optical**
  - **Multiple high-speed cameras will be used to record interaction**
- **Collaborative effort among multiple national laboratories, universities, and research facilities**
- **Experiment to be conducted at CERN (Geneva) in April 2007**

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***

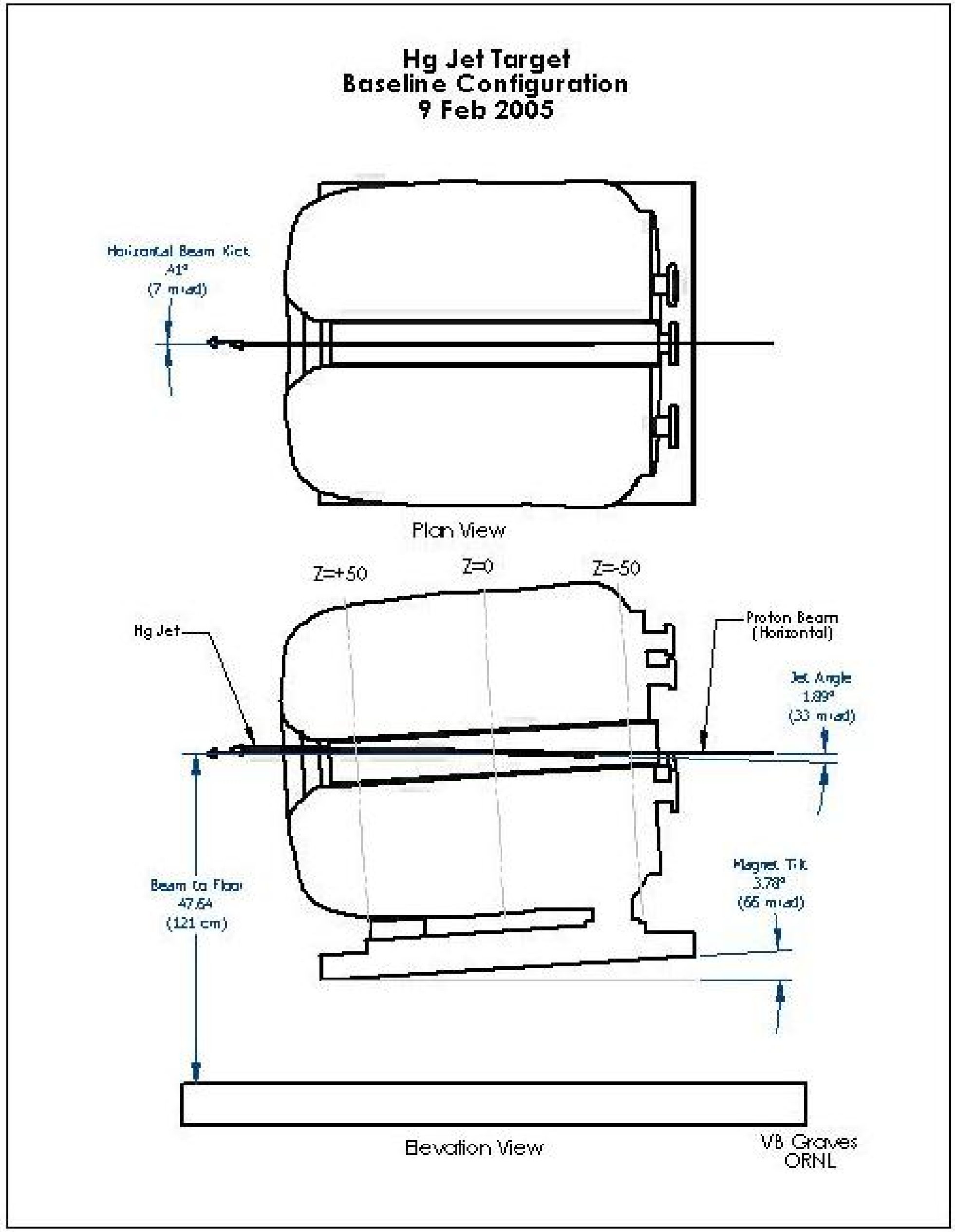


Experiment Profile

- **Hg Jet**
  - **1-cm diameter, 20 m/s, delivered to coincide with magnet peak field**
  - **Required flow rate of 1.57 liter/s (25gpm)**
- **Magnet**
  - **16-cm diameter bore that Hg system must fit within**
  - **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 milliradians off magnet axis**
  - **Proton beam 67 milliradians 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**

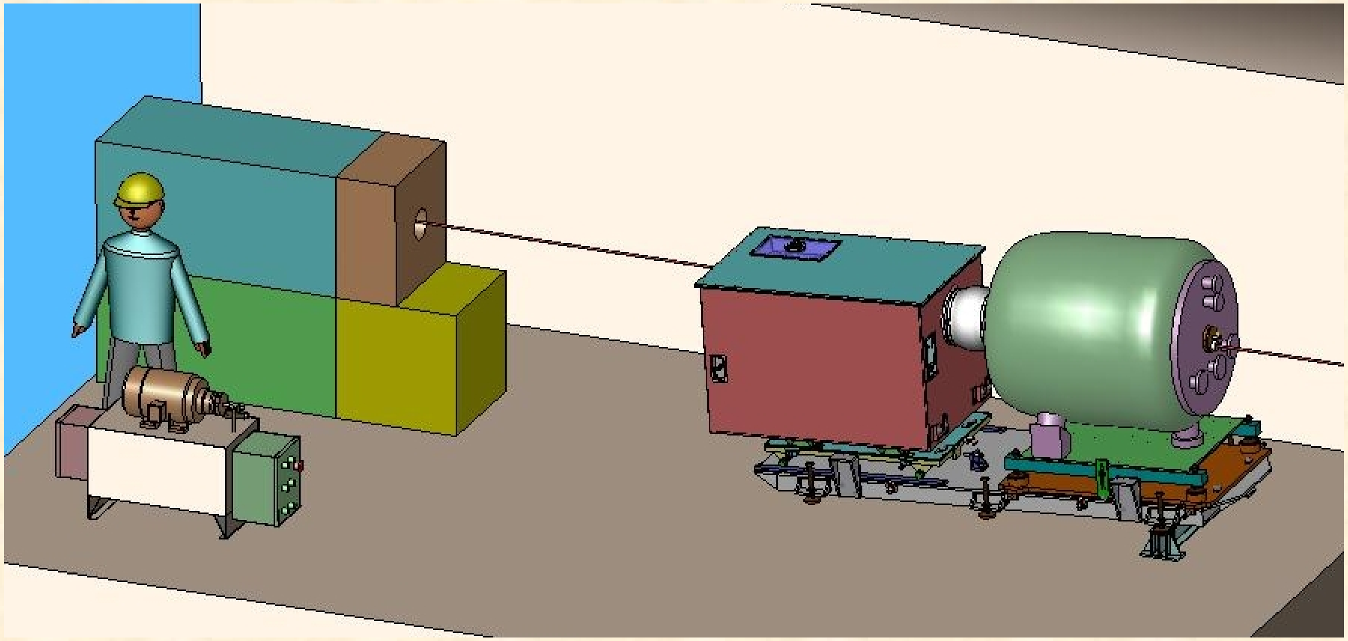
Experiment Geometric Configuration

- **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**
- **Jet in same direction as beam**

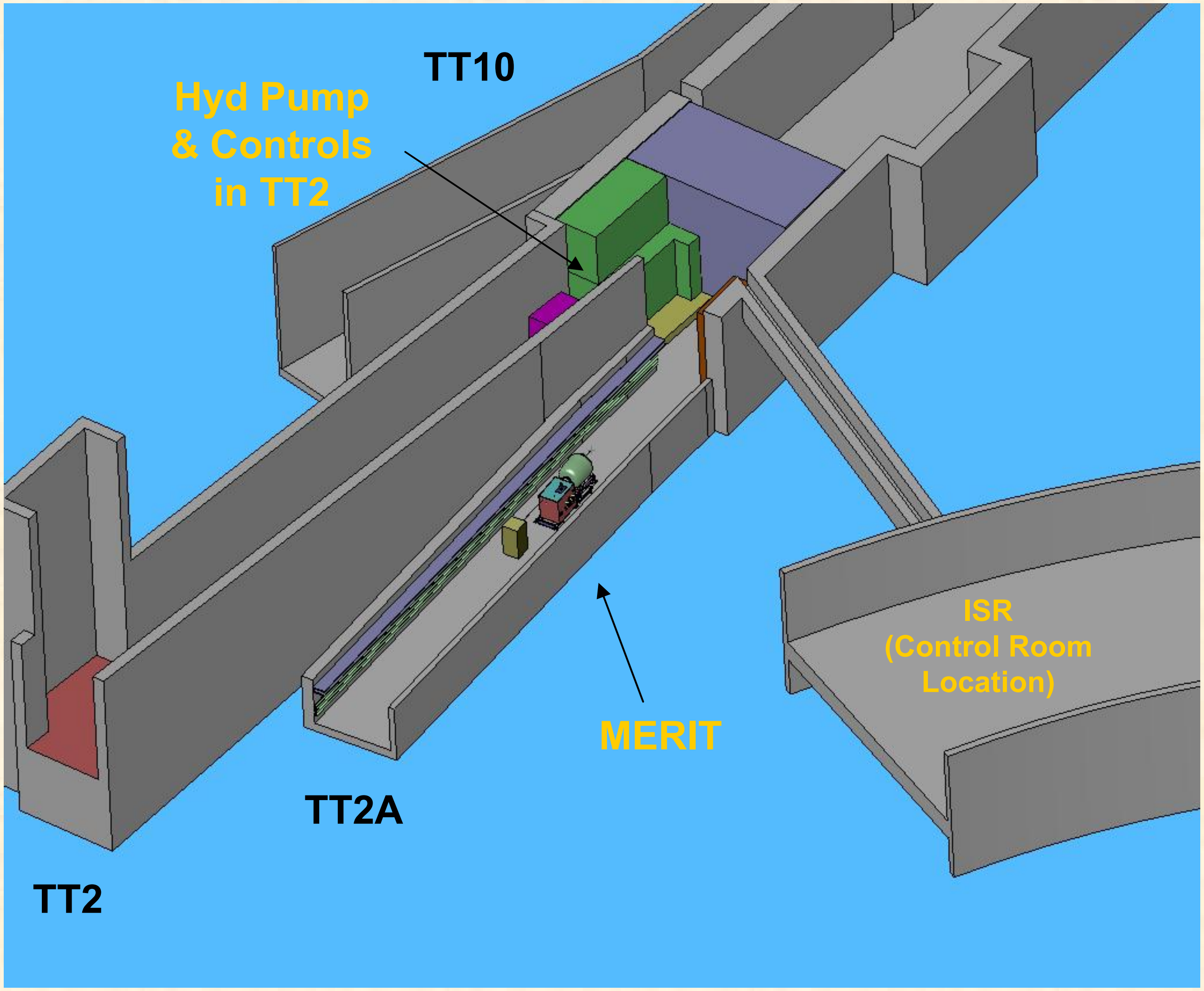


Experiment Layout

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

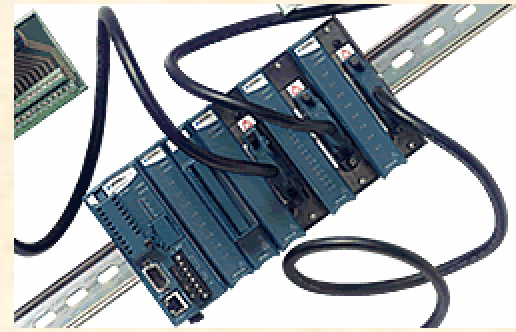


MERIT Layout

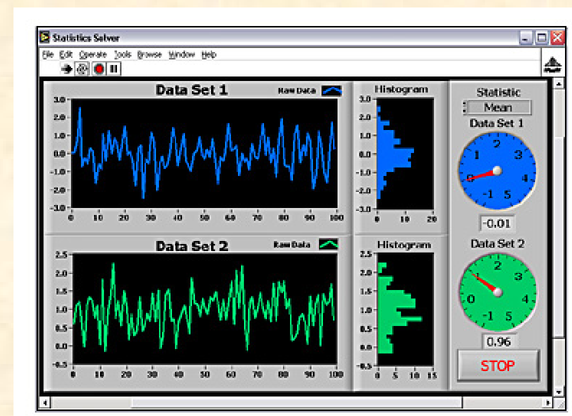


LabView-Based Control System

- **Remote control over long distance limited choices**
  - **Analog I/O modules need to be close to equipment and power supplies**



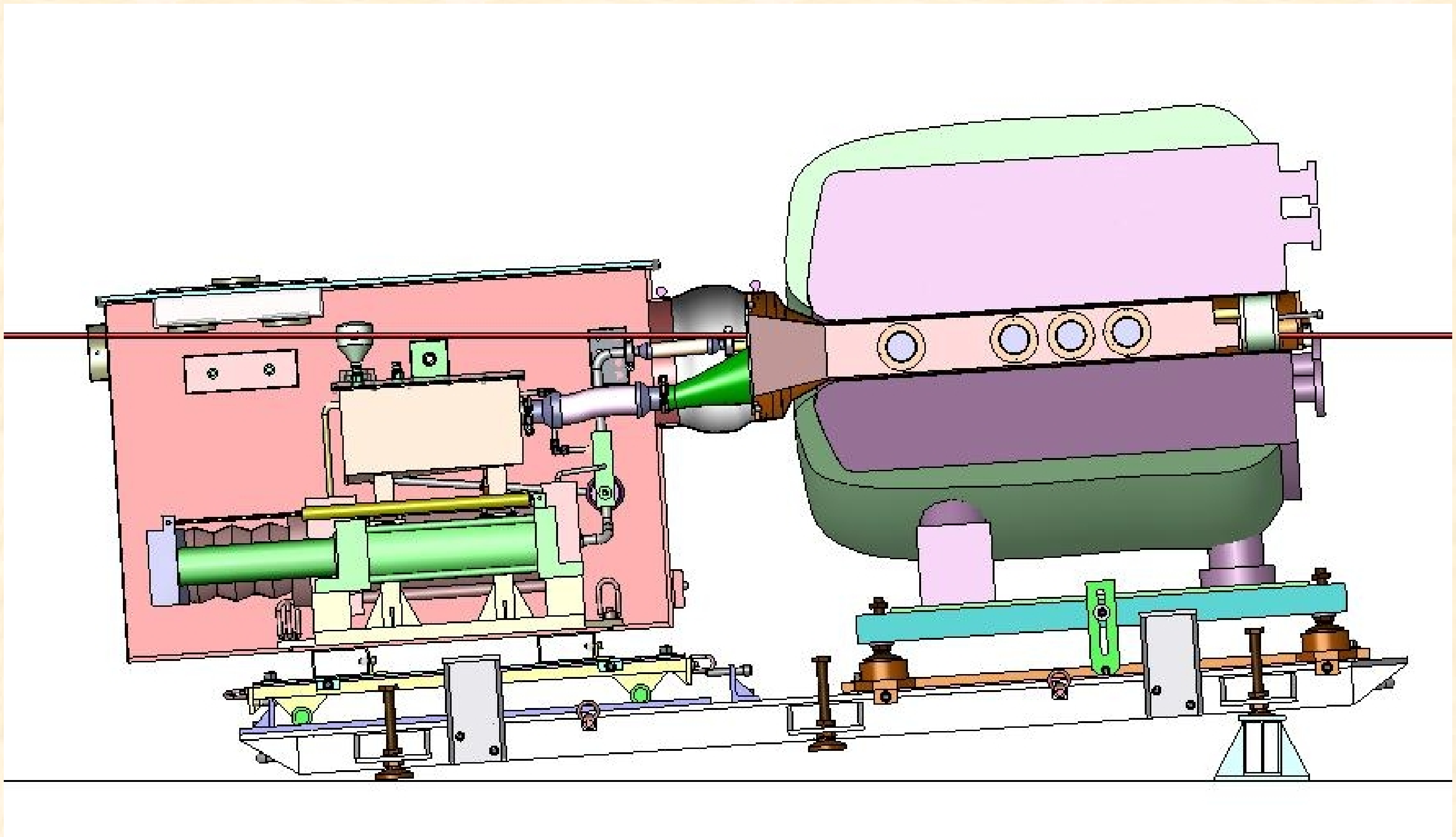
- **LabView controller on laptop computer was chosen**
  - **National Instruments recommends CompactPCI I/O modules**
  - **Communicates to laptop via EtherNet cable**
  - **Allows custom operator interface, data logging if required during development**
  - **Should allow straightforward integration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



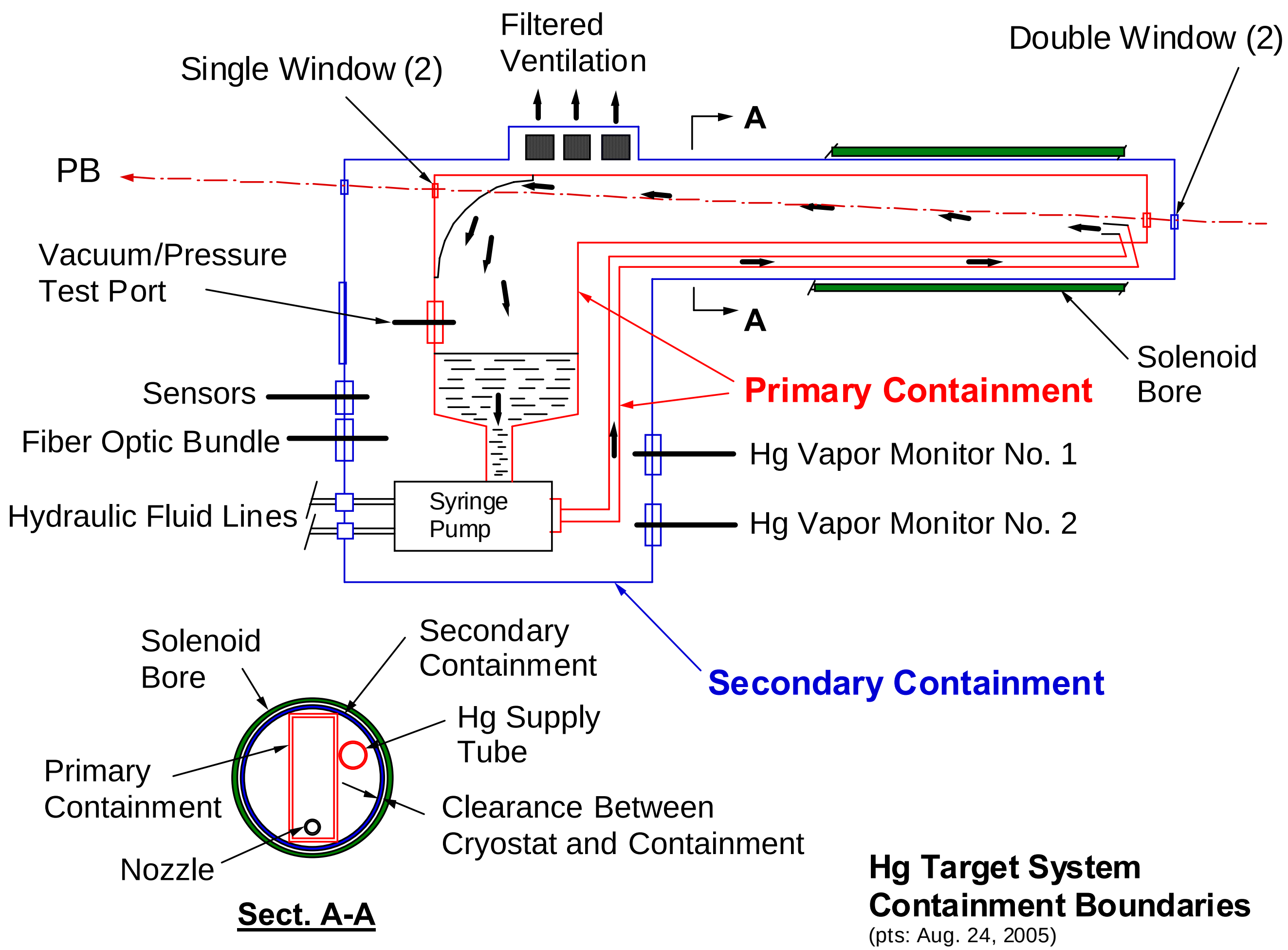
- **Control system development to begin late October**

MERIT Side View

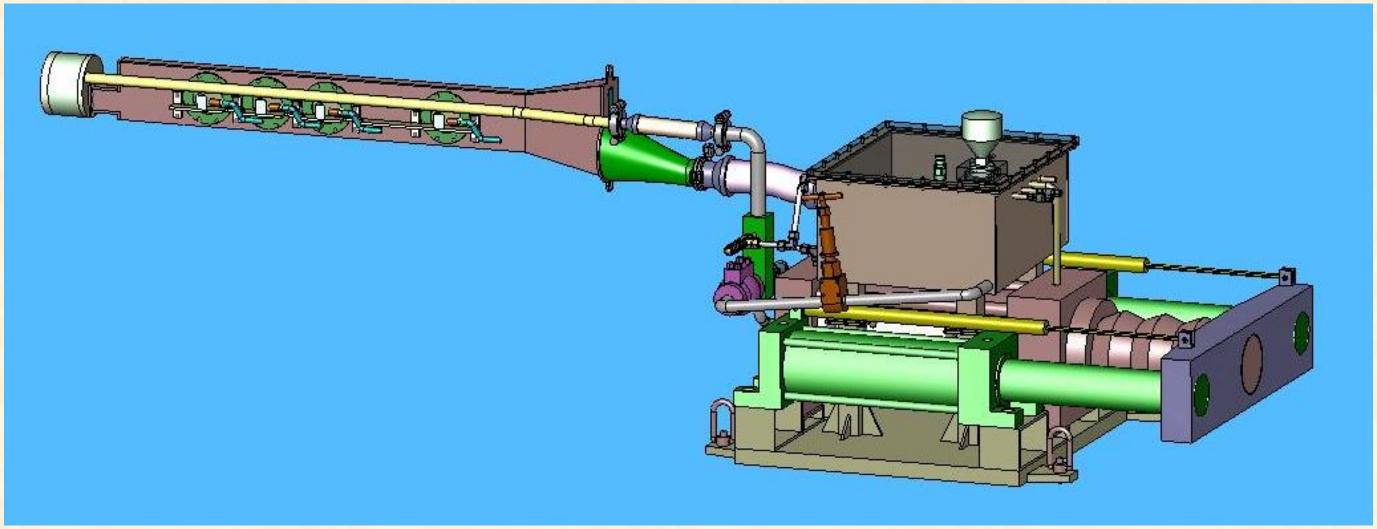
- **Tilt limited syringe length**
- **CERN facility constraints limited syringe width**

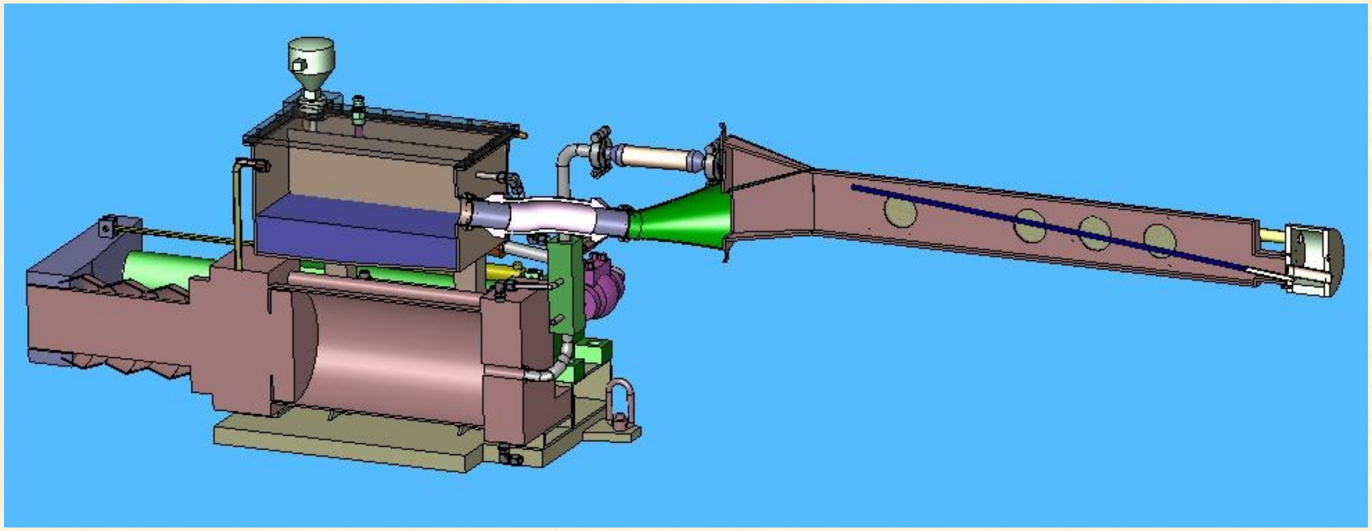


Hg System Schematic



Hg Syringe System





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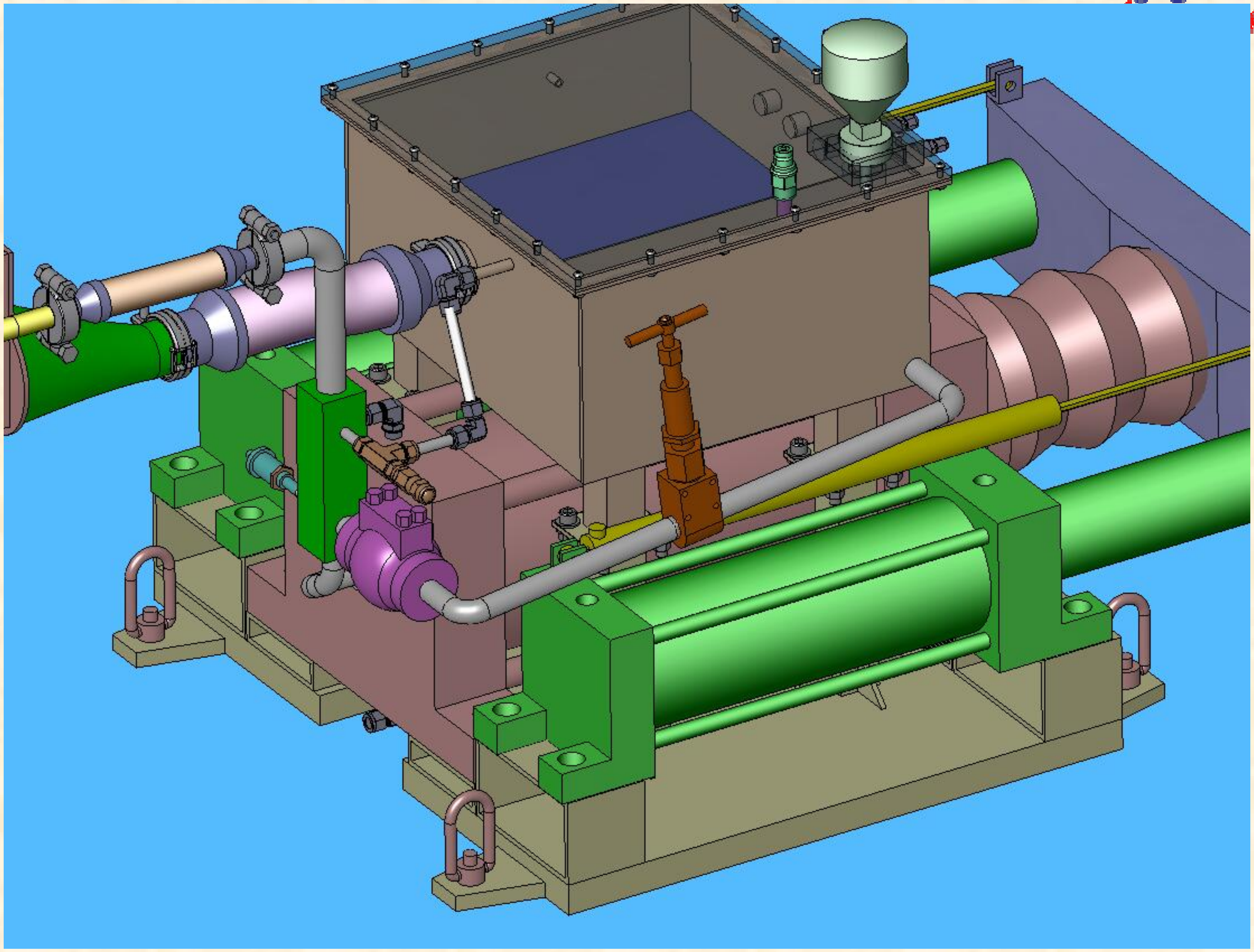
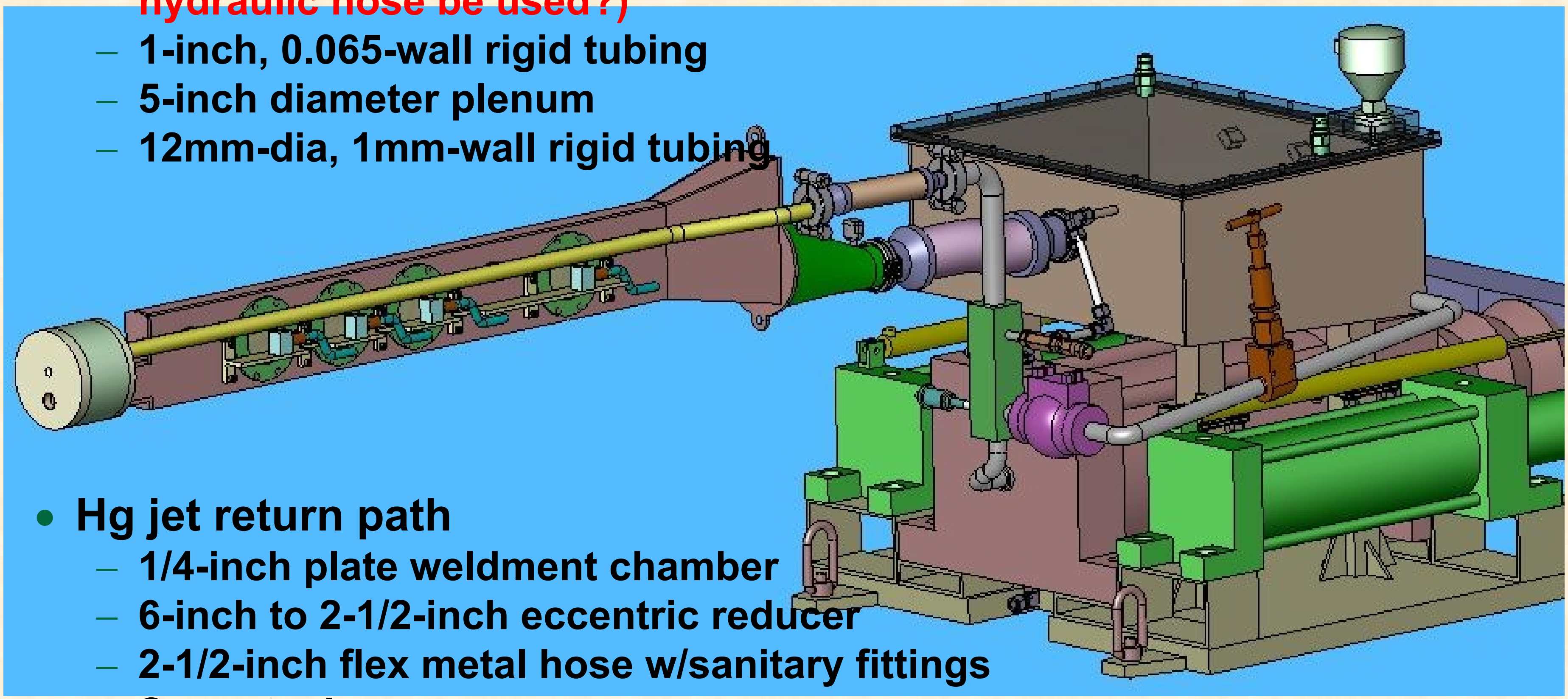
Hg Syringe System

- **Hg flow rate 1.6liter/s (24.9gpm)**
- **Piston velocity 3.0cm/s (1.2in/sec)**
- **Hg cylinder force 525kN (118kip)**



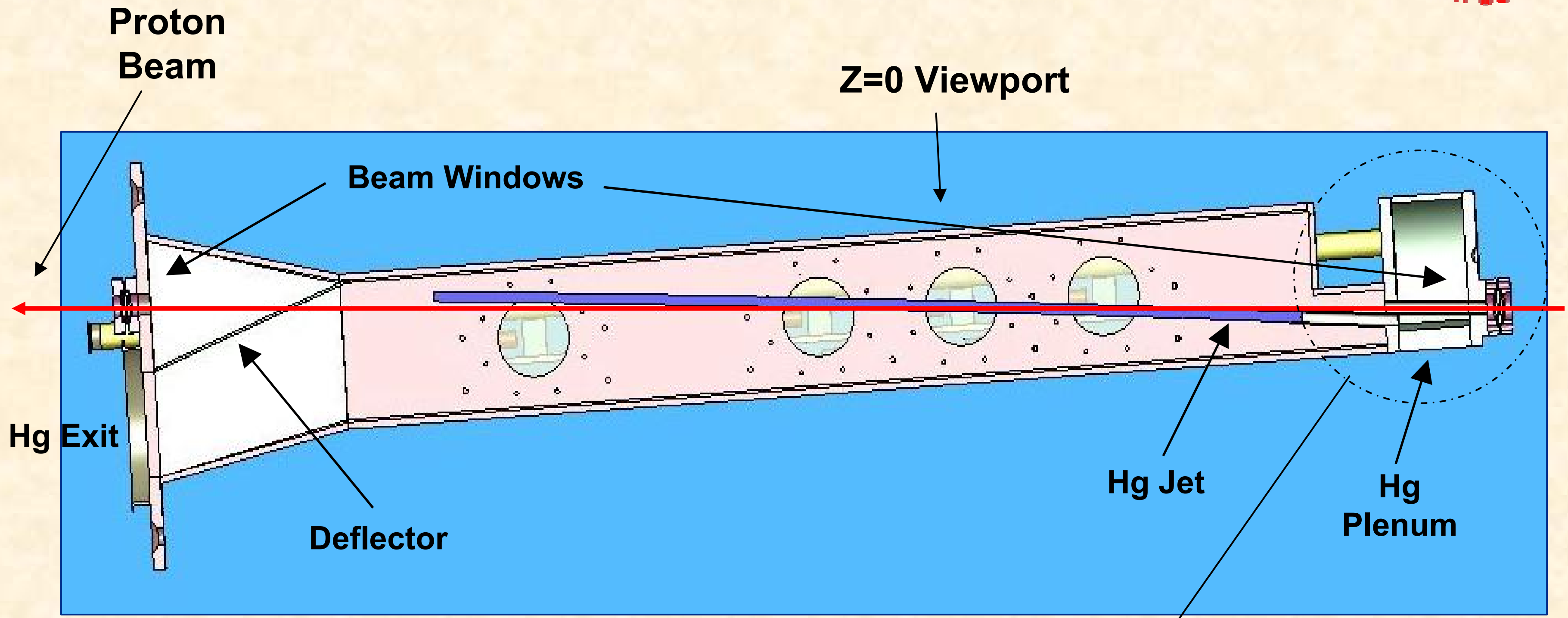
Primary Containment

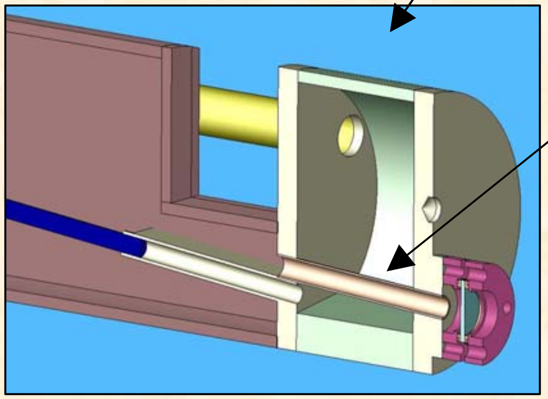
- **Hg supply flow path**
  - **1-inch Sch 40 pipe**
  - **1-inch flex metal hose w/sanitary fittings (want smooth wall – can hydraulic hose be used?)**
  - **1-inch, 0.065-wall rigid tubing**
  - **5-inch diameter plenum**
  - **12mm-dia, 1mm-wall rigid tubing**



- **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**

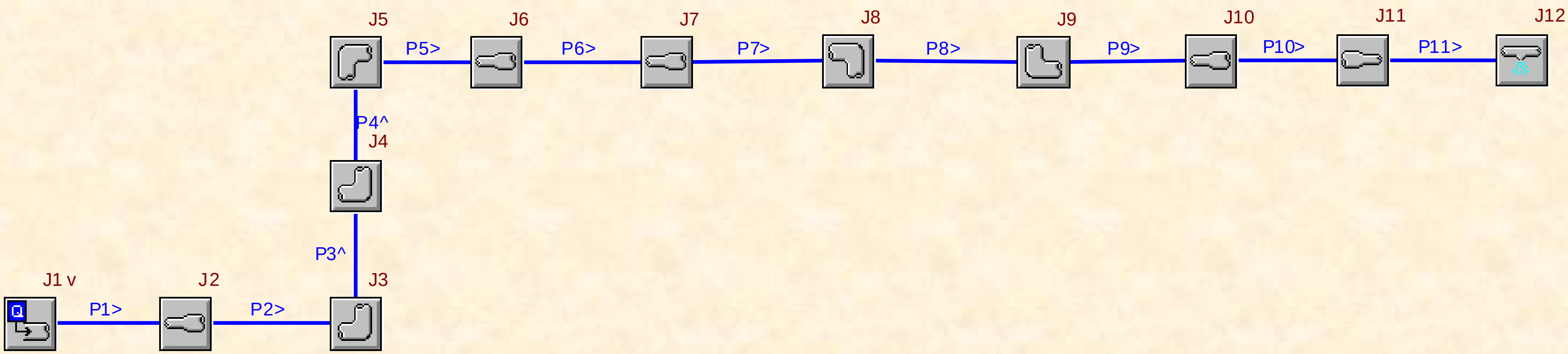
Primary Containment Xsec





Fathom Flow Simulation

- **System diagram for Hg flow**
- **Results indicate maximum pressure requirement of ~780 psi (50 bar) for baseline plenum/nozzle configuration**
- **Design system for max pressure of 1000 psig (70 bar)**



Fathom Details

Pipe Output Table

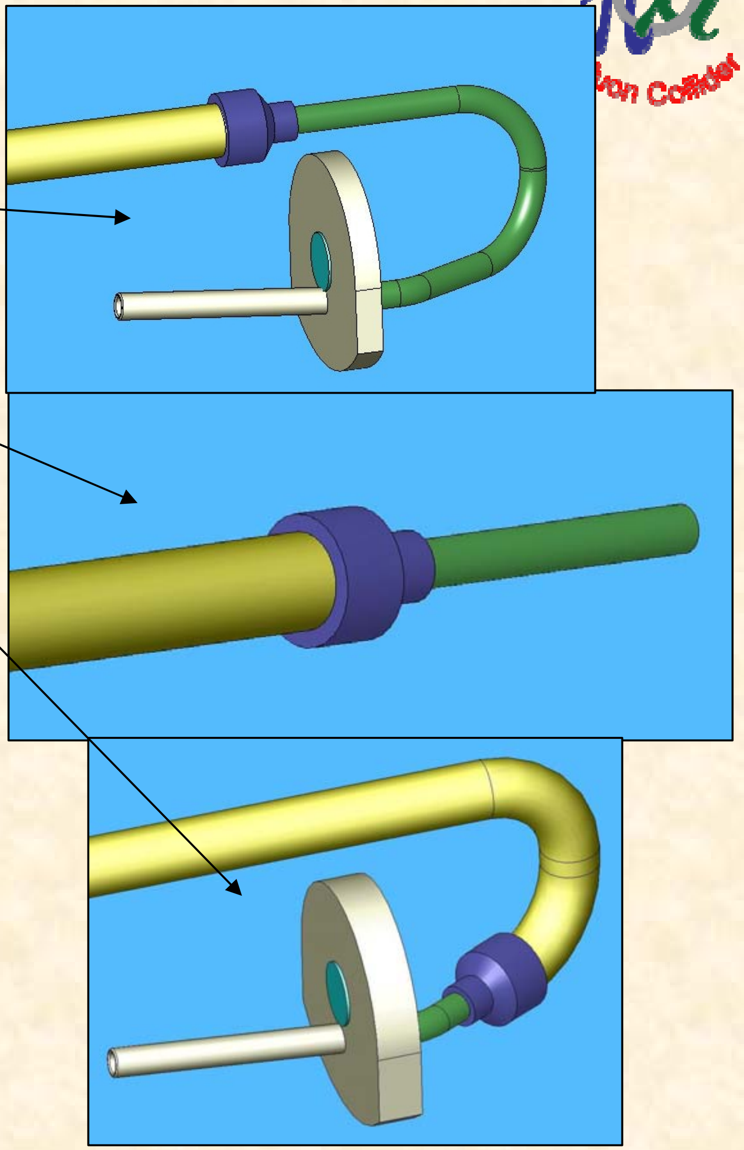
Pipe	Name	Pipe Nominal Size	Vol. Flow (gal/min)	Length (inches)	Flow Area (inches2)	Velocity (feet/sec)	Reynolds No.	fL/ D + K	P Stag. In (psig)	P Stag. Out (psig)	dP Stag. Total (psid)	P Static In (psig)	P Static Out (psig)	dP Static Total (psid)
1	Hg Cylinde	10 inch	24.9	15	78.854	0.101	6.86E+04	0.0296	784	784	2.77E-05	783.9	784	2.77E-05
2	Cylinder D	1 inch	24.9	1.5	0.864	9.24	6.56E+05	0.0256	780	780	0.199779	772.2	772	0.199779
3	Cylinder D	1 inch	24.9	0.8	0.864	9.24	6.56E+05	0.0136	777	776	0.302768	769	769	0.302768
4	Hg Manifol	1 inch	24.9	16.1	0.864	9.24	6.56E+05	0.2745	774	764	9.772281	765.9	756	9.772281
5	Hose Inlet	1 inch	24.9	2.1	0.864	9.24	6.56E+05	0.0358	761	760	0.279691	752.8	752	0.279691
6	Flex Metal	1 inch	24.9	10.5	0.945	8.449	6.27E+05	0.17	760	759	1.110492	753.7	753	1.110492
7	Hg Supply	1 inch	24.9	1.86	0.594	13.433	7.91E+05	0.0284	755	755	0.469346	738.7	738	0.469346
8	Hg Supply	1 inch	24.9	6.7	0.594	13.433	7.91E+05	0.1024	752	750	1.690654	735.3	734	1.690654
9	Hg Supply	1 inch	24.9	44	0.594	13.433	7.91E+05	0.6726	747	736	11.1028	730.8	720	11.1028
10	Plenum	5 inch	24.9	3	20.006	0.399	1.36E+05	0.0105	721	721	0.000153	720.6	721	0.000153
11	Nozzle	1/2 inch	24.9	4	0.108	74.271	1.86E+06	0.1491	469	394	75.21312	-35.3	-110	75.21312

All Junction Table

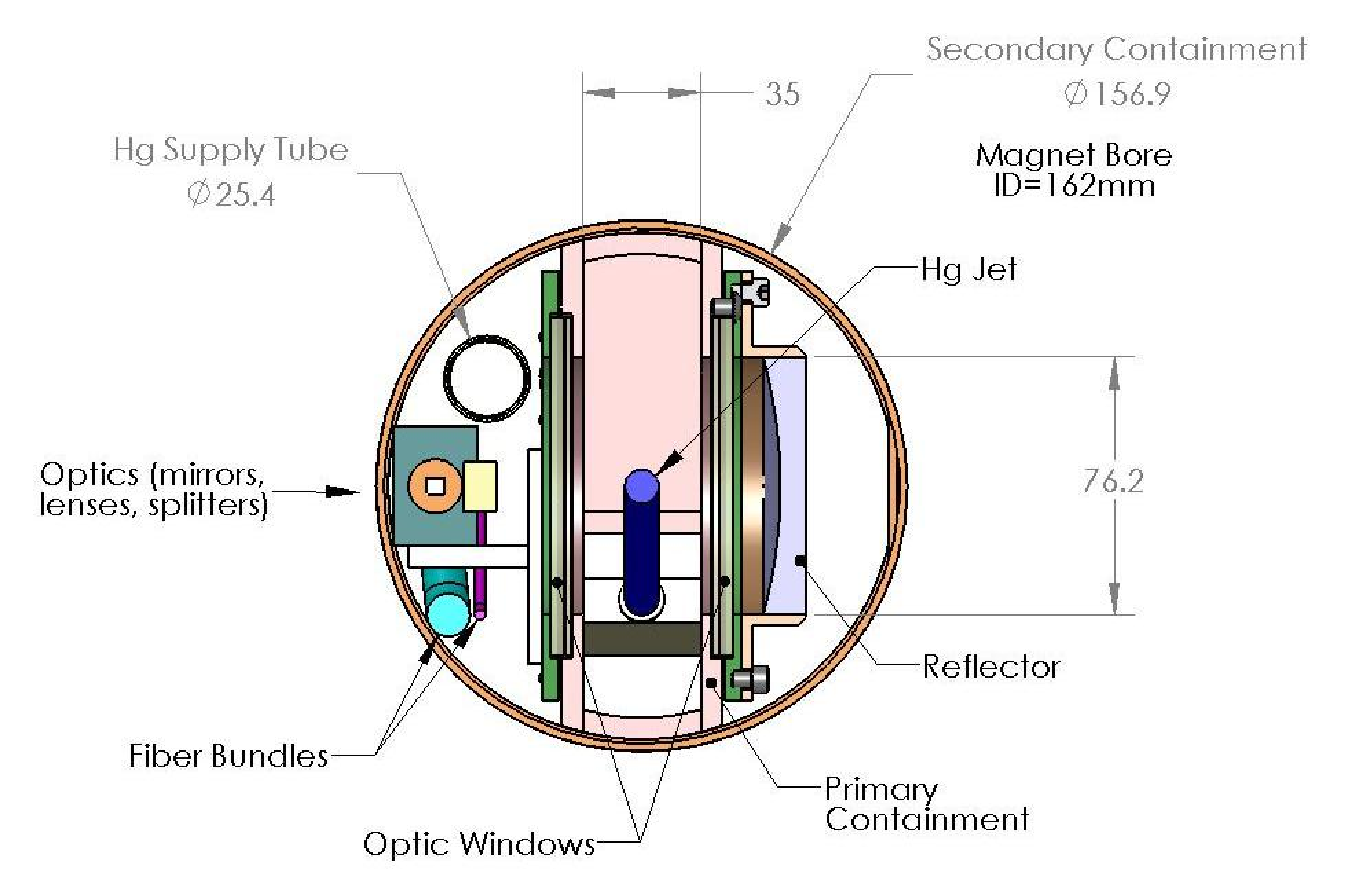
Jct	Name	Junction Type	Elevation Inlet (inches)	Loss Factor (K)	dH (inches)	P Stag. In (psig)	P Stag. Out (psig)	dP Stag. Total (psid)	P Static In (psig)	P Static Out (psig)	dP Static Total (psid)	T Inlet (deg. F)
1	Syringe Pi	Assigned F	0	0	0	784	784	0	784	783.9	0	68
2	Area Chan	Area Chan	0	4,128.12	7.895	784	780	3.8729	784	772.2	11.682	68.2
3	Bend 1	Bend	0	0.33841	5.388	780	777	3.011	772	769	3.011	68.2
4	Bend 2	Bend	1.15	0.27347	4.354	776	774	2.7736	769	765.9	2.774	68.2
5	Bend 3	Bend	18	0.33841	5.388	764	761	3.3789	756	752.8	3.379	68.3
6	Pipe to Fle	Area Chan	19.5	0.00733	0.117	760	760	0.0572	752	753.7	-1.223	68.3
7	Flex to Tul	Area Chan	19.5	0.60087	7.999	759	755	3.924	753	738.7	13.901	68.3
8	Tubing Ber	Bend	19.5	0.17406	5.857	755	752	2.8734	738	735.3	2.873	68.3
9	Tubing Ber	Bend	19.5	0.17406	5.857	750	747	2.8734	734	730.8	2.873	68.3
10	Plenum Inl	Area Chan	19.5	0.94145	31.682	736	721	15.5414	720	720.6	-0.952	68.3
11	Nozzle Inle	Area Chan	19.5	17,240.17	512.271	721	469	251.2909	721	-35.3	755.894	68.3
12	Spray	Spray Disc	19.5	0.78106	802.957	394	0	393.8837	-111	-504.6	393.884	75

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)**
- **Any non-plenum design should minimize number of bends & length of nozzle tubing**
- **Don't let syringe pump limit nozzle configuration – desire to change syringe design pressure to 1500 psi (103 bar) to match Hg cylinder rating**

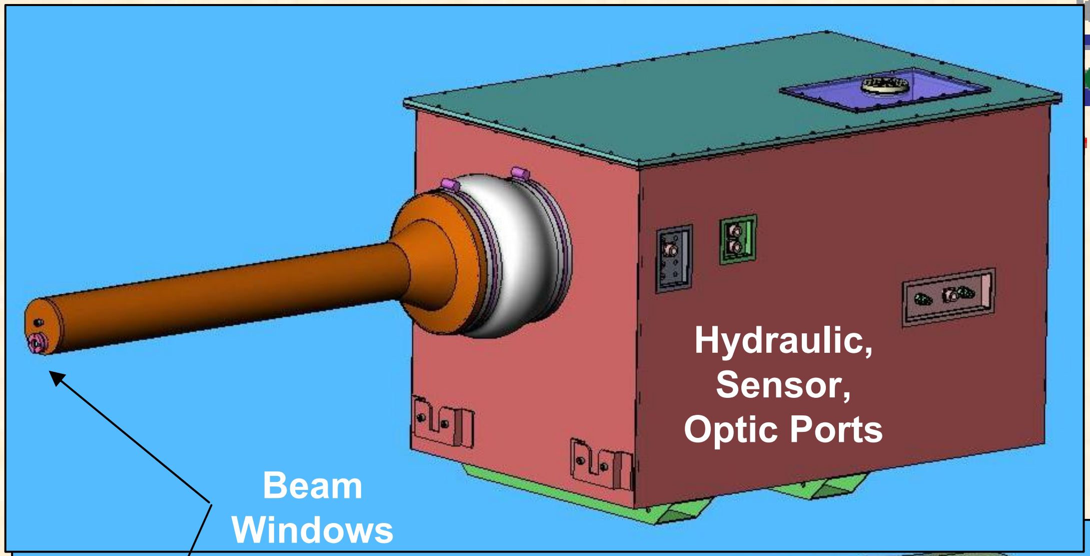


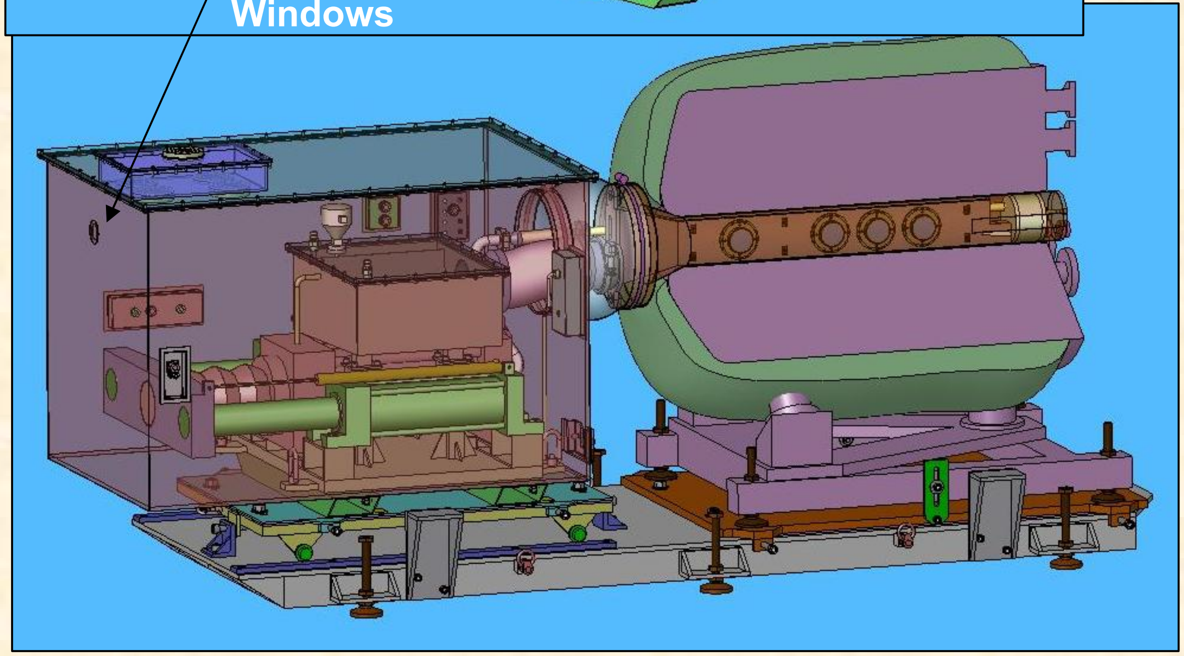
Primary Containment Cross Section



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**





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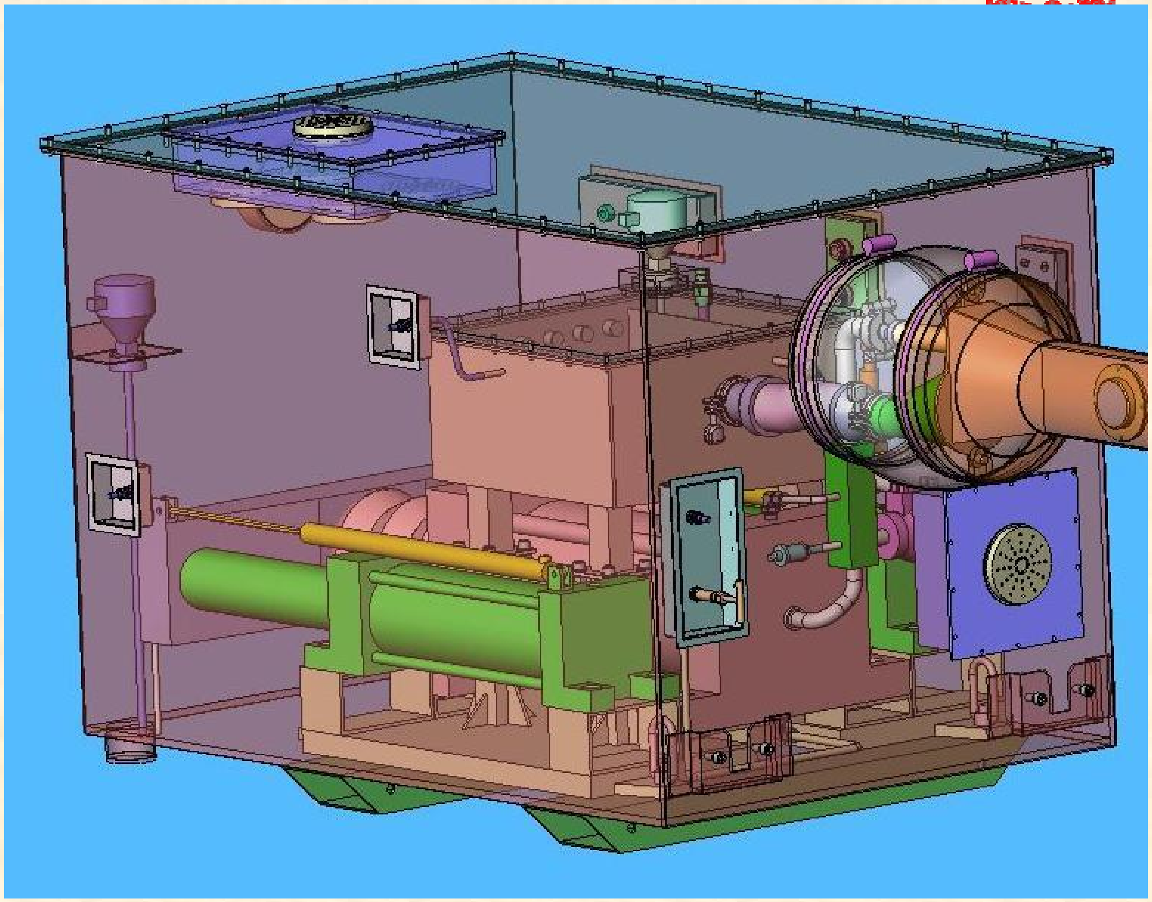
Secondary Containment Access Ports

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



Hg Delivery System Procurement Plan

- **Syringe system procured first because of expected long lead time on cylinders**
- **Details of primary/secondary containments & baseplate being finalized**
  - **Expect to begin procurement process in Nov/Dec**
- **Syringe system to be integrated by containment fabricator**

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**