HIGH-TEMPERATURE GRAPHITE TARGET FOR MUON PRODUCTION: E-951

G. A. Greene and C. C. Finfrock
E-951 Collaboration
Brookhaven National Laboratory
Upton, NY 11973

December 15, 2000

Introduction

Joined E-951 in Fall 2000 to provide support for various targetry designs and fabrication issues.

- Experience in AGS experiments and in fielding experiments. Considerable experience in novel one-of-a-kind designs.
- Laboratory facilities for fabrication, machining, assembly and testing. Machine shop facilities co-located with labs.
- Cryogenic and ultra-high temperature experimental experience. Extensive experience with mercury experiments and high-temperature graphite experiments.
- Experienced in engineering computer data acquisition: Test Point, Work Bench, Lab View.

Accelerator Parameters and Target Issues

- E-951 beam parameters:
  - FEB protons, 24 GeV/c
  - 16×10^{12} protons/bunch desired
  - single bunch extraction, possibly multiple bunches
  - 1 mm radius rms beam spot, 👓 = 50 cm
- Significant issues for high-temperature graphite target:
  - mechanical integrity and contamination control
  - sublimation control and fire suppression
  - high-current power feed through
  - heat shielding and containment cooling

Conceptual Design Approach

External target containment:

- use commercial conflat vacuum components
- blind-flange beam windows
- standard instrumentation and power feedthroughs
- thermal radiation shielding and cooling

Design approach:

- design to reduce beam intensity on containment
- optimize materials to insure survivability
- materials compatibility and contamination control
- fiducial registration for routine target change-out

Targets Under Consideration

Mercury jet: pneumatic, 1 cm ☠, 2 m/s, 15 cm beam interaction length, later to be continuously pumped jet, then pulsed: design almost complete.

Graphite cylinder at 1900°C: design in conceptual stage, to begin once jet is finalized.

Mercury “waterfall”: similar in concept to horizontal jet, initially pneumatic, then pumped, then chopped, will commence following graphite tests.

Materials Considerations

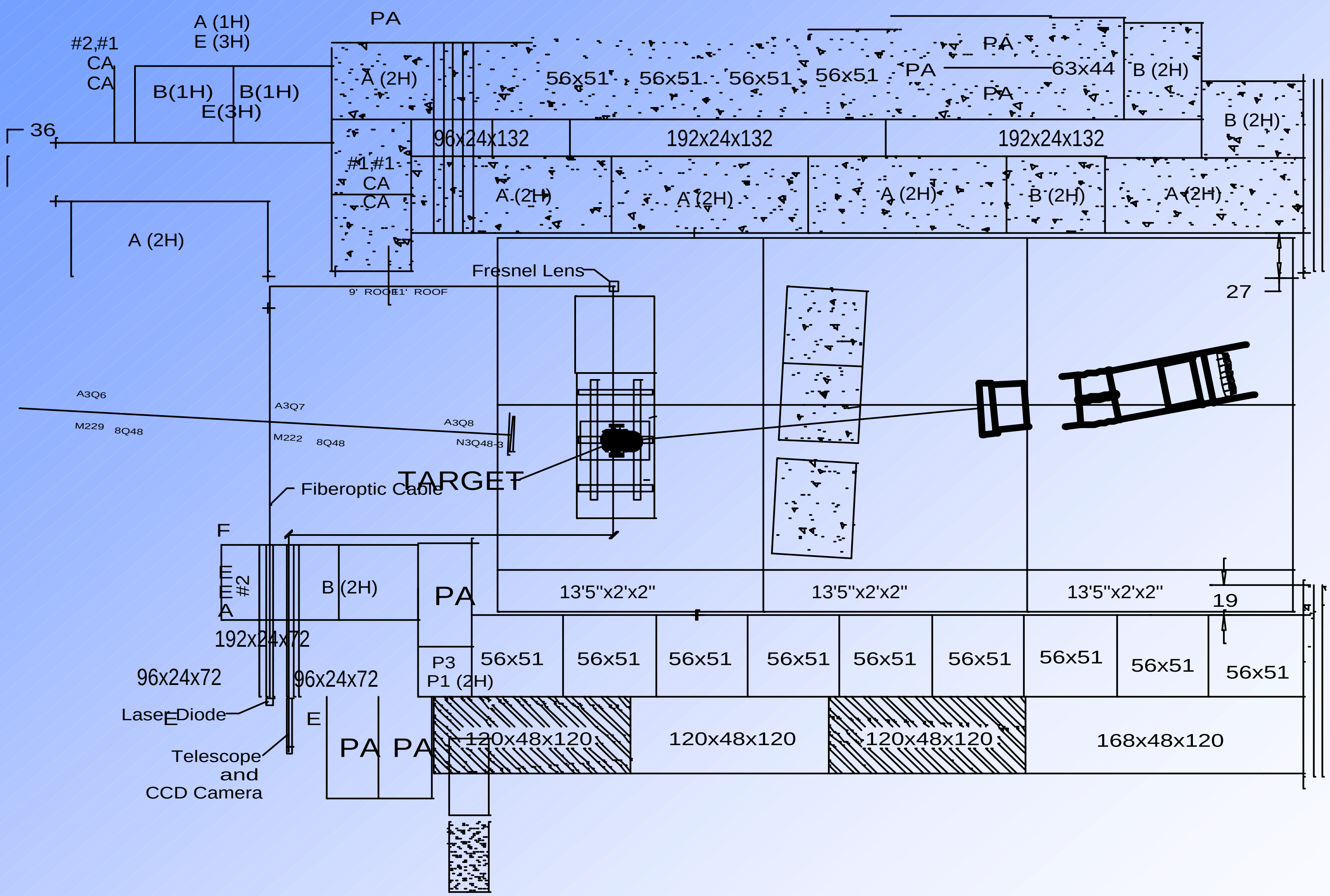
General containment considerations:

- commercially available spool pieces.
- Inconel-718 external beam windows.
- Lexan view ports for mercury tests only.
- containment under inert atmosphere and cooled.

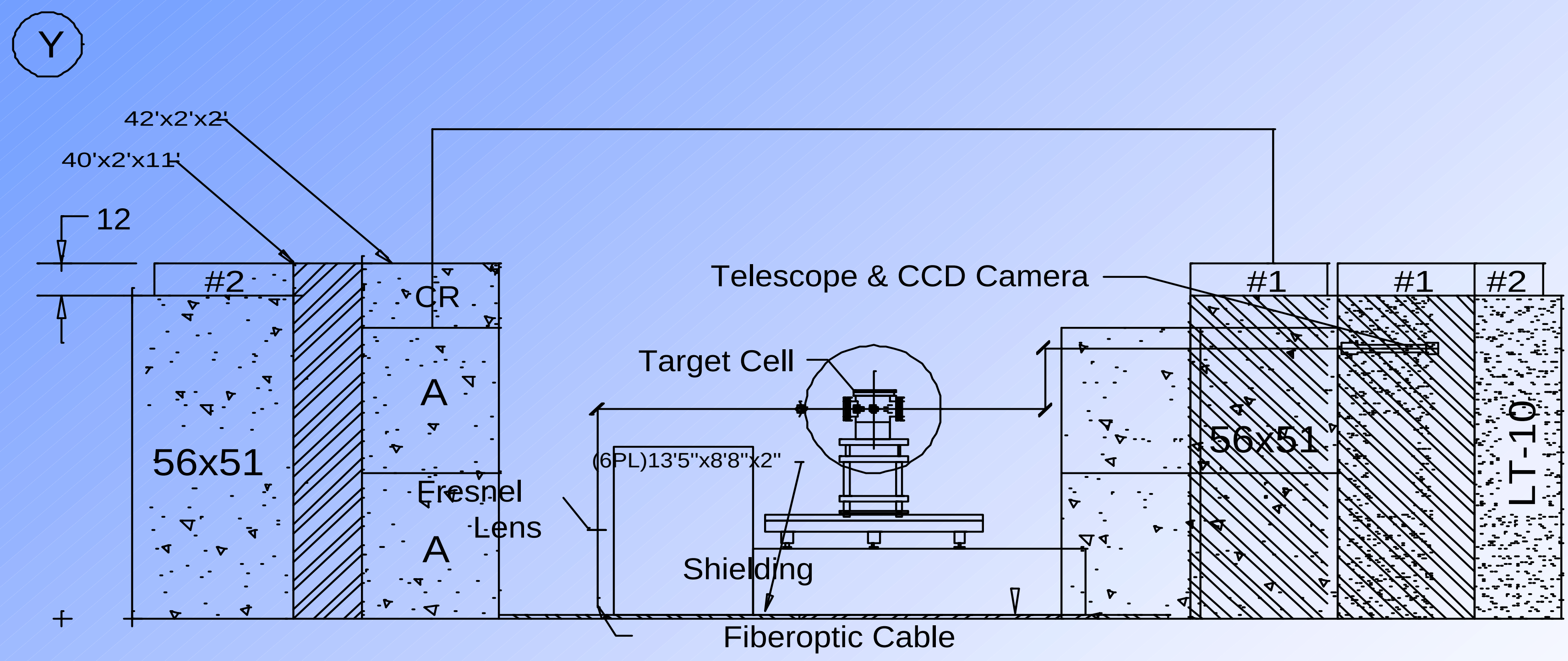
Considerations for the graphite targets:

- solid targets under inert atmosphere, no internal confinement, no view ports.
- radiation shielding and electrical bus cooling.
- Cooling of the containment shell.

Overall Beam Line Layout

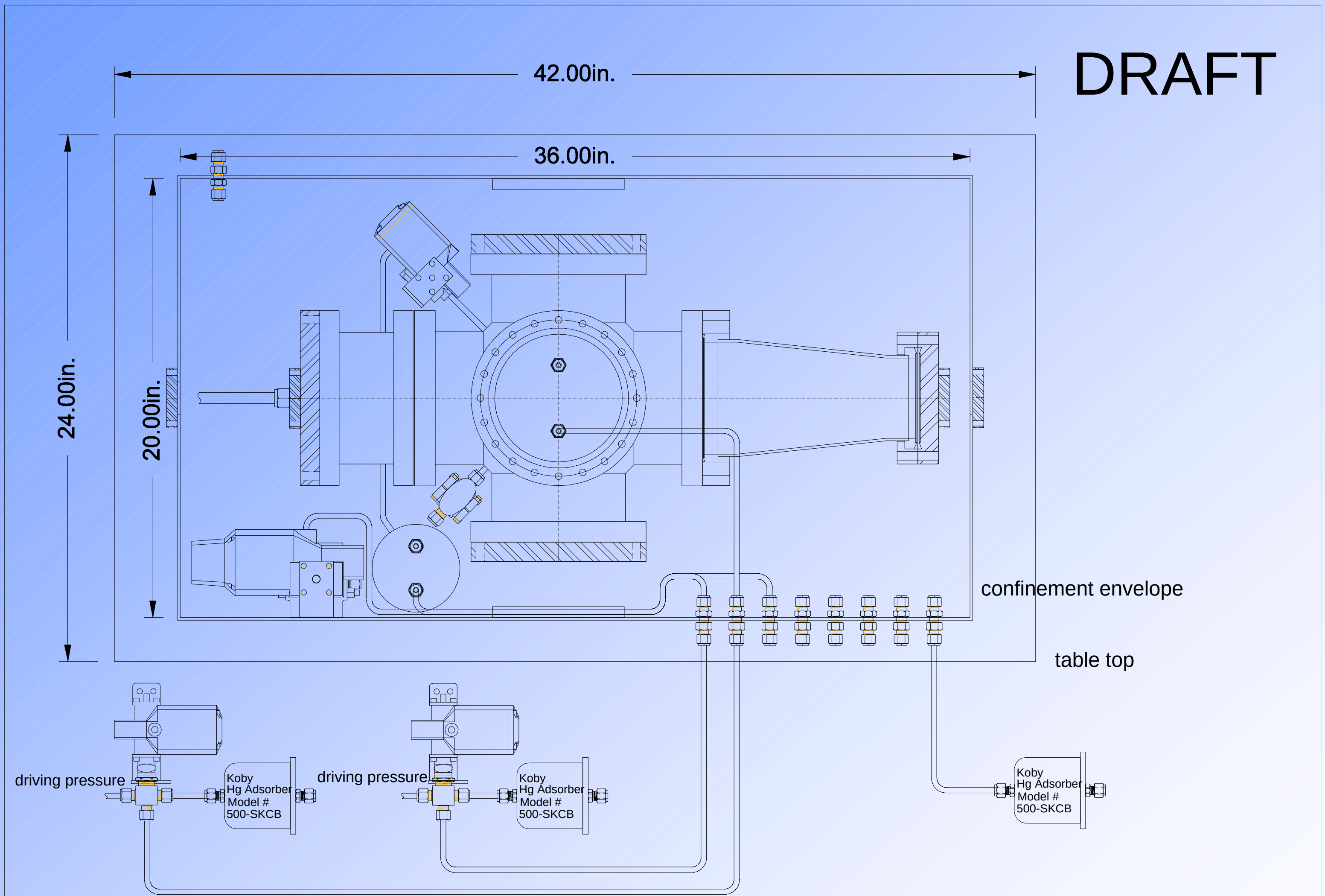


Schematic of Traversing Table Layout



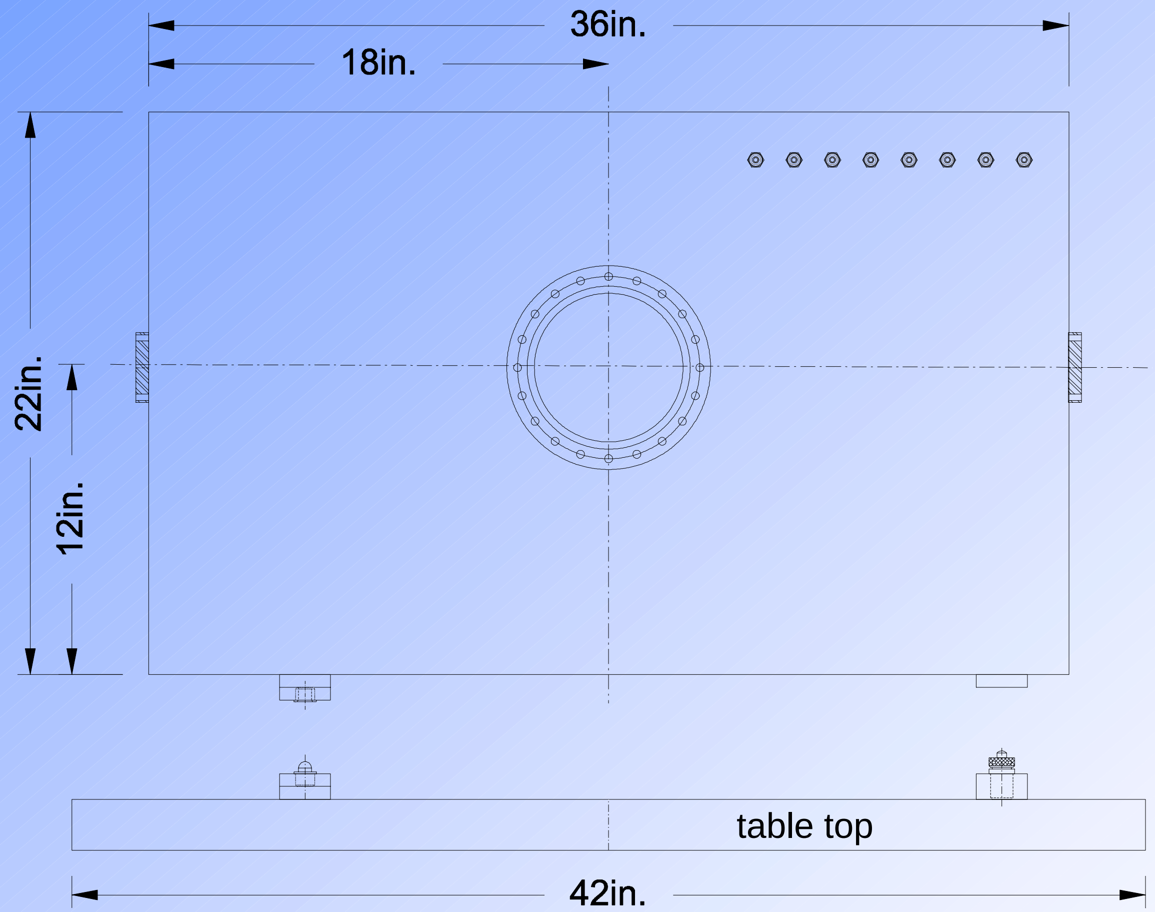
ELEVATION SECTION FF

Top View Into the Secondary Confinement



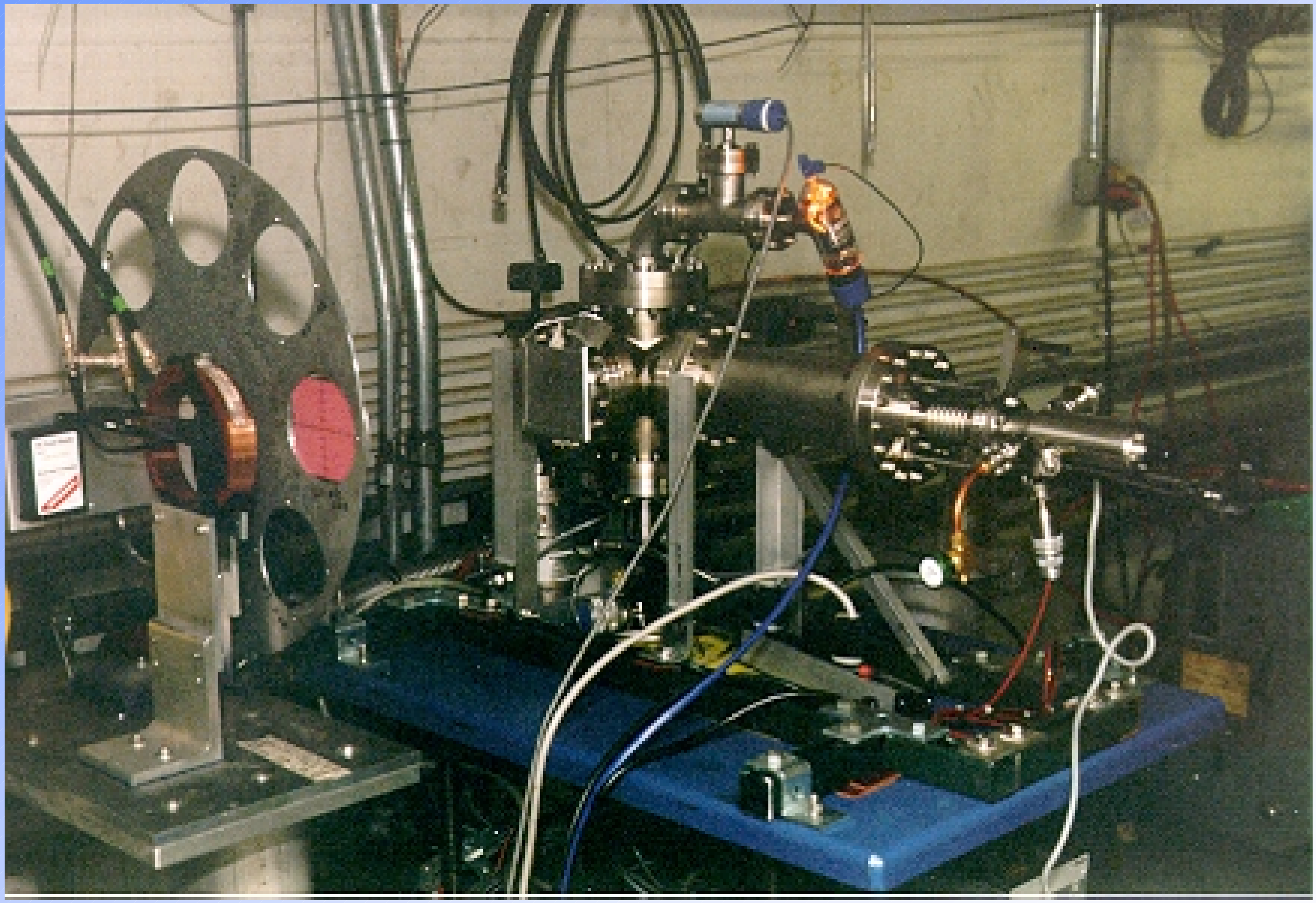
E-951 Muon Muon Collider Targetry	Hg Jet Component Layout in External Confinement, Plan View	Date : 12/06/00 Revised : 12/14/00
particle trajectory from left to right		drawn by : C. Finfrock

Side View into the Secondary Confinement



E-951 Muon Muon Collider Targetry	Hg Jet External Confinement Side Elevation View	Date : 12/14/00
particle trajectory from left to right		drawn by : C. Finfrock

Picture of an Internal Target Containment



Technical Issues and Experimental Approach

Technical issues:

- macroscopic shock effects of FEB protons on graphite.
- morphological changes in crystal structure of graphite.
- sublimation effects and control, radiation damage, activation and target life time.
- amorphous depositions and control of contamination.
- effects of thermal cycling on mechanical strength.

Experimental approach:

- phenomenological experiments in the laboratory.
- high-energy proton experiments in beam line.

Sublimation Issue

- Graphite target will be passively cooled by thermal radiation.
- Target temperature could approach or exceed 1900°C. Sublimation rates could be excessive at these temperatures.
- Can rate of graphite mass transfer be controlled by altering the composition and pressure of the atmosphere?
- Surface layer will transform into an amorphous form even under thermal equilibrium.
- Does this lead to limiting conditions?

Other Issues

Radiation damage and defect production rates at high temperatures ~ 1900°C.

Is graphite self-annealing or will it fail upon cooling after an unknown fluence?

Can the thermal radiative heat transfer be enhanced at 1900°C?

What are the effects of irradiation on materials performance at other temperatures, down to liquid helium temperatures?

Experimental Approach: Laboratory Testing

Induction heating tests of graphite rods in RF laboratory. Temperatures up to 3000°C easily achievable. System is already interfaced to all necessary data acquisition and control hardware and software. Rapid turn-around.

Study effects at various temperatures in controlled atmospheres. Measure sublimation rates and evaluate mass transfer control schemes.

Perform thermal cycling, fatigue and quench tests.

Examine morphological changes in materials properties in SEM/TEM microscopy lab.

Experimental Approach: Beam Line Testing

FEB protons, 24 GeV/c, $16x10^{12}$ protons per bunch, duration of bunch about 20 ns.

Graphite rod at 1900°C by high-current direct electrical heating.

Test for survivability; PIE for morphological changes in hot cell/hot lab.

Current Status

Materials chosen for beam intensity and materials compatibility: Inconel 718 and Lexan.

Starting conceptual designs for graphite tests. Laboratory tests will start shortly.

Test stand will be installed in beam line soon.

Do not foresee any technical obstacles to fielding the mercury jet and high-temperature graphite tests in the beam line, other than beam window issues.

Future Activities and Other Considerations

Experiments are planned to be parasitic to g-2, lends itself to staged testing.

Order of priority of beam line tests:

- #1 mercury jet test: design nearly completed
- #2 high-temperature graphite test: design starting
- #3 mercury waterfall tests: to follow

Order of priority of laboratory tests:

- #1 pneumatic mercury jet conceptual tests done
- #2 high-temperature RF graphite sublimation tests beginning
- #3 preparation for high-magnetic field tests at NHMFL
- #4 mercury waterfall and pumped/pulsed jet tests to follow