Absorber R&D, Test Facilities, and University Participation

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ICAR

Muon Collaboration Meeting
Fermilab
May 2, 2001

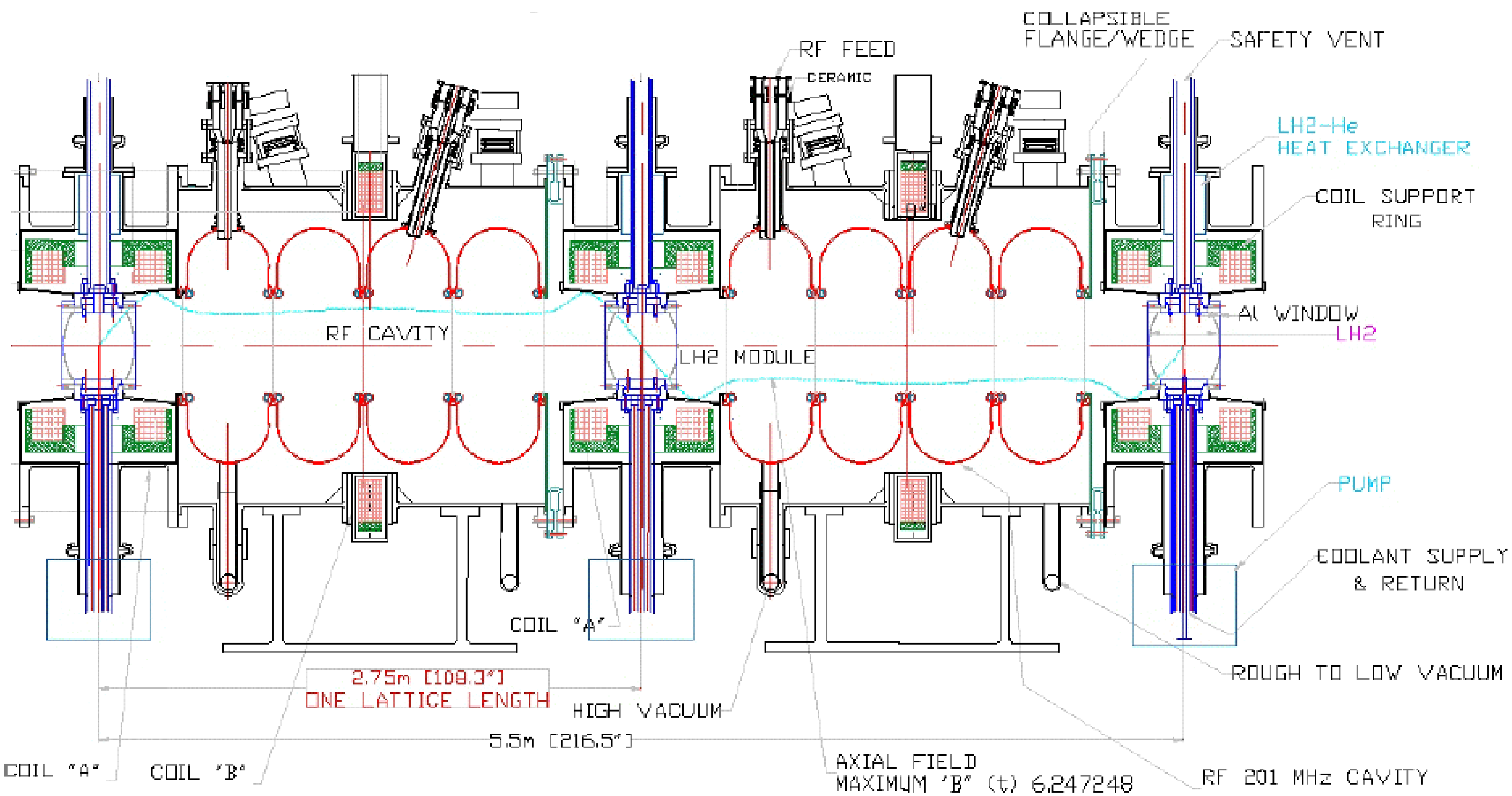
MuCool R&D Projects & Facilities

1. High-gradient RF Cavities
2. Lab G RF test facility

} J. Corlett & R. Rimmer, LBNL
A. Moretti, FNAL

3. High-power liquid-hydrogen energy absorbers
4. Linac-area Test Facility
5. Muon-beam/cooling-channel instrumentation

SFOFO Cooling-Channel Layout



Cooling-channel Lattice 1, four cavities per cell

LH_2 Absorbers – Main Issues

1. Minimize scattering-induced beam heating

   - Use LH_2
   - Use as thin and low-*Z* windows as practical

2. Remove large heat flux from muon-beam *dE/dx*

   - Need to understand fluid flow and heat transfer

3. Prototype and test to verify designs

   - Complicated engineering issues require empirical tests
   - Both bench and beam tests planned

Absorbers & Power Dissipation

- Baseline Study II design has 3 types of absorbers:

Absorber	Length (cm)	Radius (cm)	Window thickness (μm)	Number needed	Power diss. (W)
Minicool	175	30	≈300	2	≈ 5500
SFOFO 1	35	18	360	16	≈ 300
SFOFO 2	21	11	220	36	≈ 100

- Note: ~ 100 W/absorber (SFOFO)
  - Lineal power density ≈ 5–10 W/cm

→ comparable to high-power LH_2 targets
(cf. SLAC, Bates, JLab)

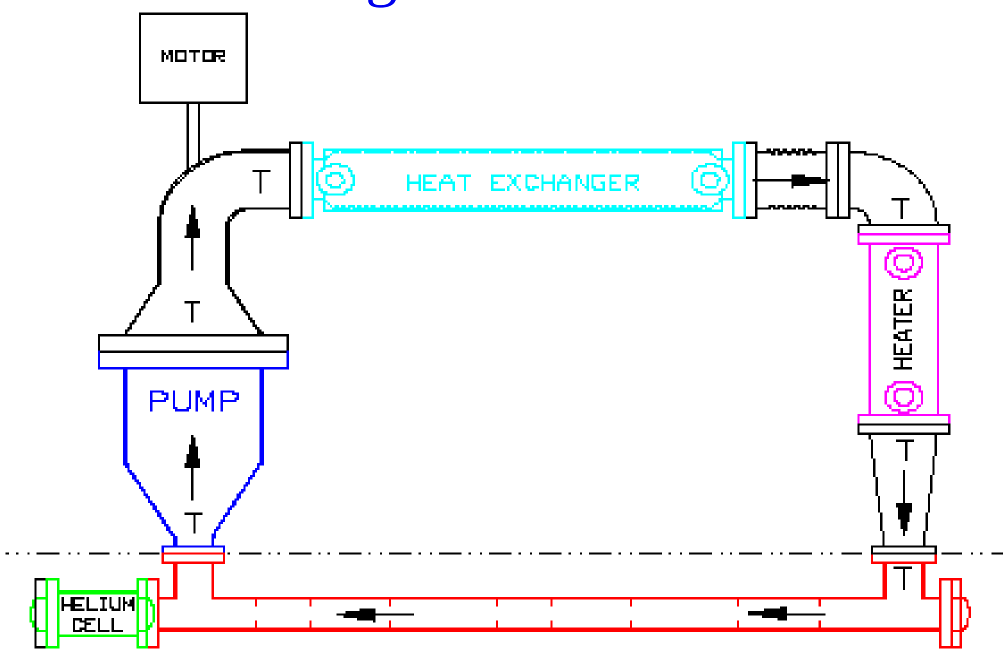
Heat Transfer

- Need to assure adequate heat transfer from core to periphery

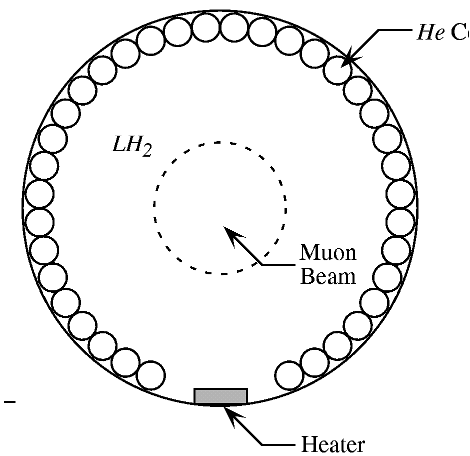
⇒ Avoid longitudinal flow

- 2 approaches:

1. Flow-through



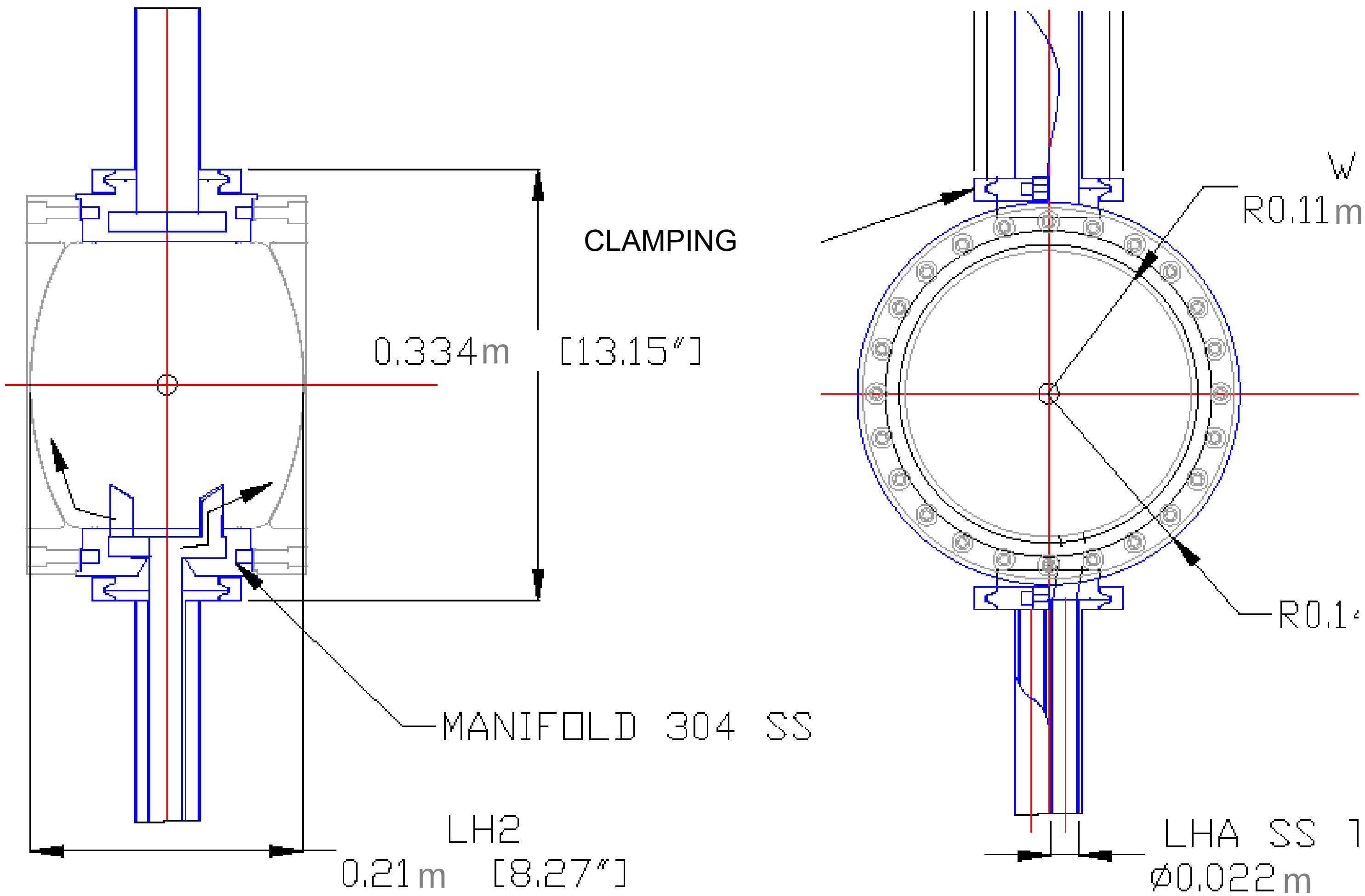
2. Convection



- Both appear feasible – further studies & tests in progress

SFOFO 2 Absorber Assembly

(flow-through example shown)

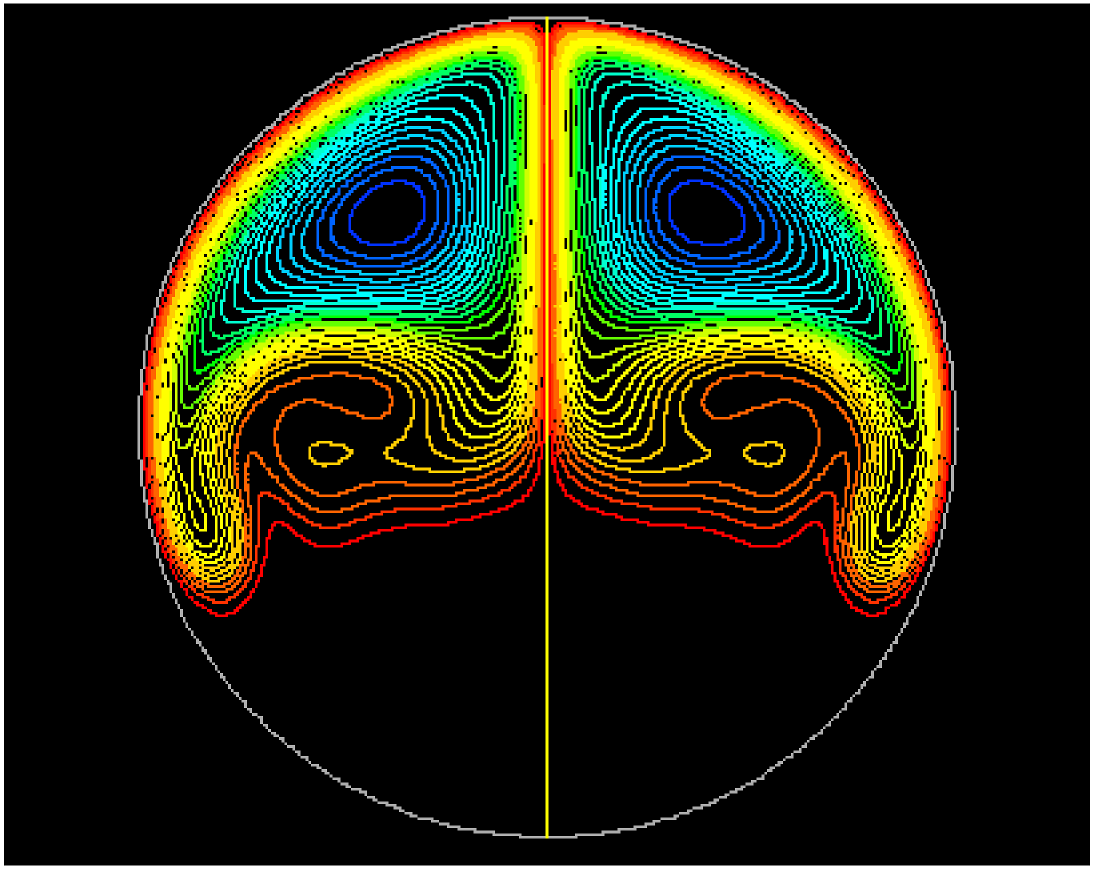


- Nozzles that determine flow pattern need to be designed and tested heuristically

→ Will bench-test this with room-temperature flow model

Convection Design

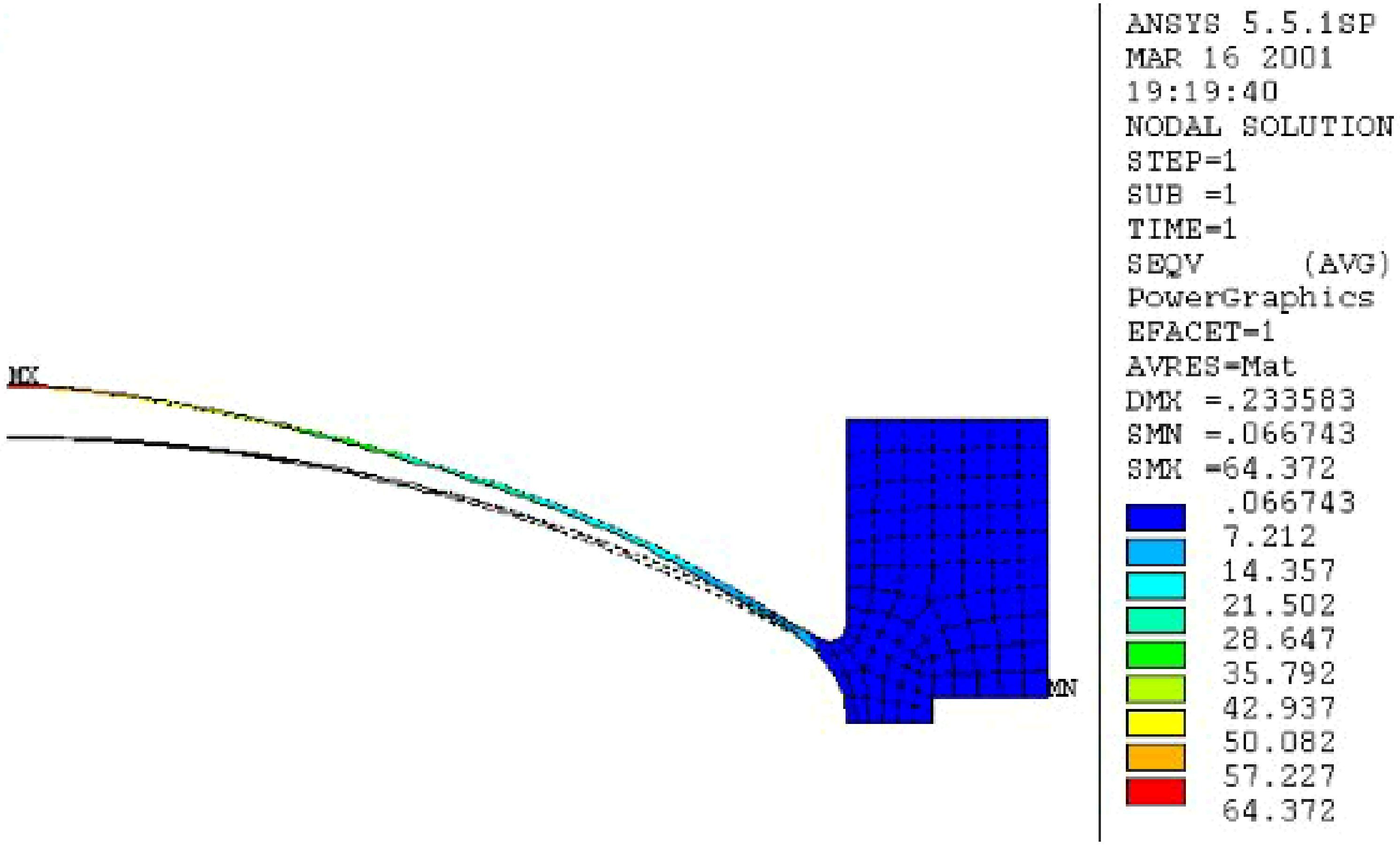
- Performance more amenable to calculation than for flow-through,
  - key question: convective heat transfer coefficient within LH_2
- 2D CFD calc by IIT engineering M.S. student (3D calc impractical):



  - Refinement of CFD calcs ongoing
- KEK-Osaka group building prototype to be tested here

Window Thickness

- ANSYS F.E.A. study (C. Darve, NWU) shows that tapered 6061-T6 Al torispherical window of 360-µm (220-µm) thickness and 18-cm (11-cm) radius safe at 1.2 atm:



Thinner Windows?

From D. Summers:

Al alloy name	Composition	Density	Yield strength @300K	Tensile strength @300K	Tensile strength @20K	Rad. Length
	% by weight	(g/cc)	(ksi)	(ksi)	(ksi)	(cm)
6061-T6	1.0Mg 0.6Si 0.3Cu 0.2Cr	2.70	40	45	68	8.86
2090-T81	2.7Cu 2.2Li .12Zr	2.59	74	82	120	9.18

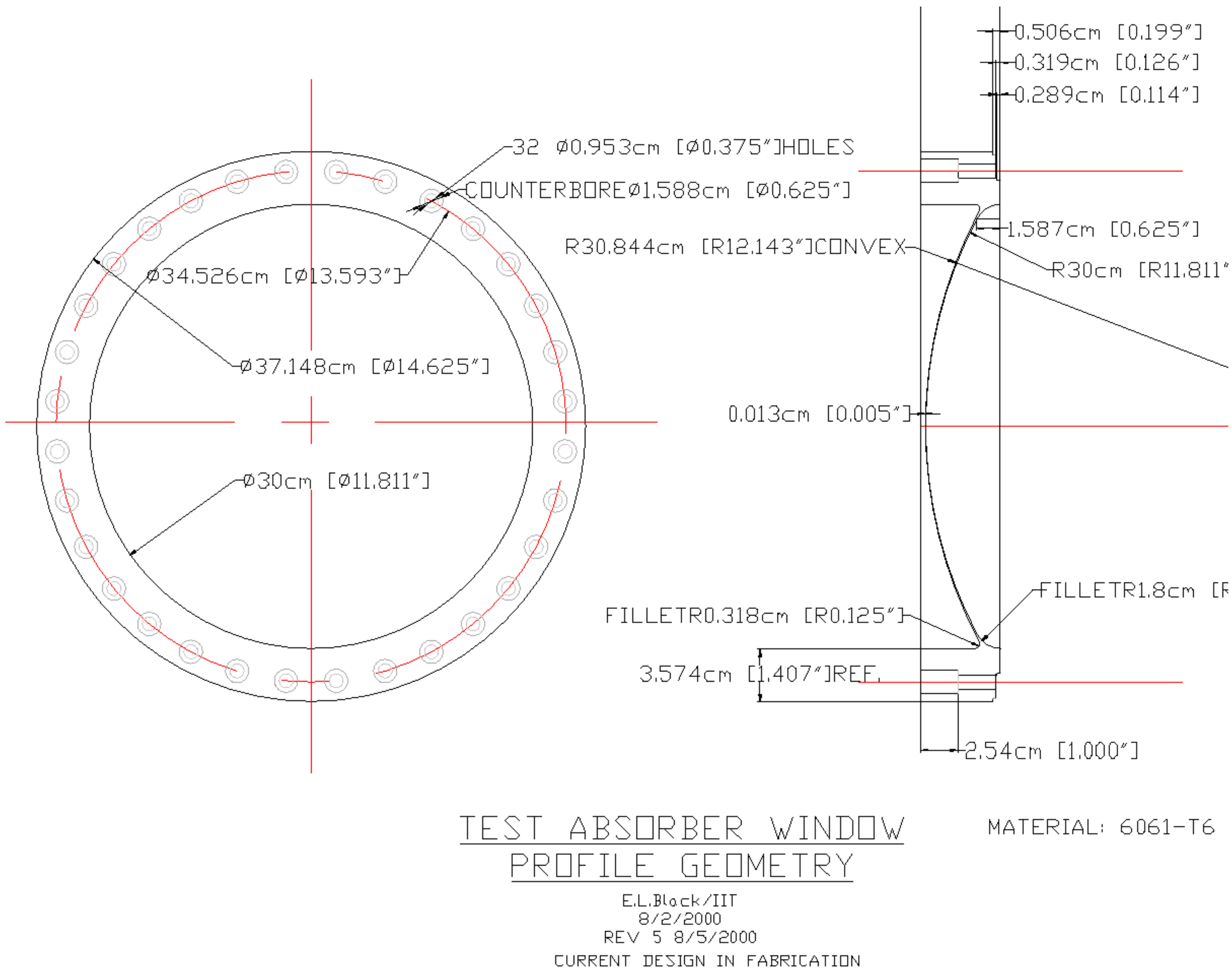
- "Aircraft alloy" 2090-T81 80% stronger than 6061-T6

  ⇒ Thickness can be reduced by ≈ 45%

  ⇒ 200 µm thickness at 18-cm radius
  125 µm thickness at 11-cm radius
  at 1.2 atm

  IF design scales ≈ linearly and
  IF such thin foils can be manufactured from this material

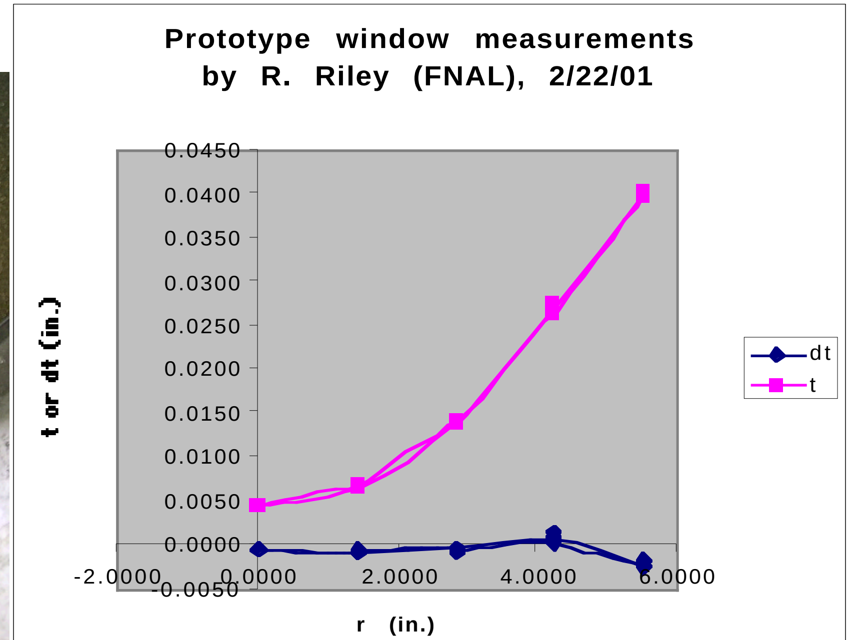
Prototype Window Design

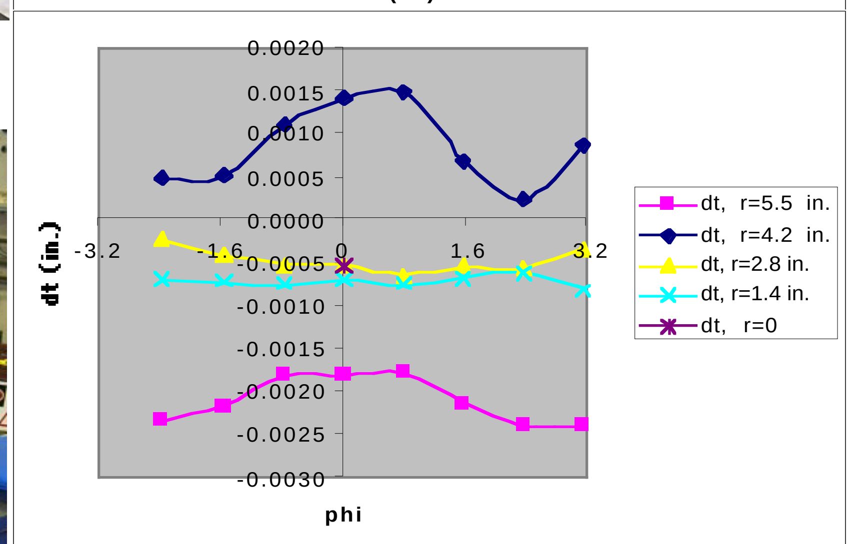


Prototype Window – as built

- Fab: NC machine (U. Miss.):

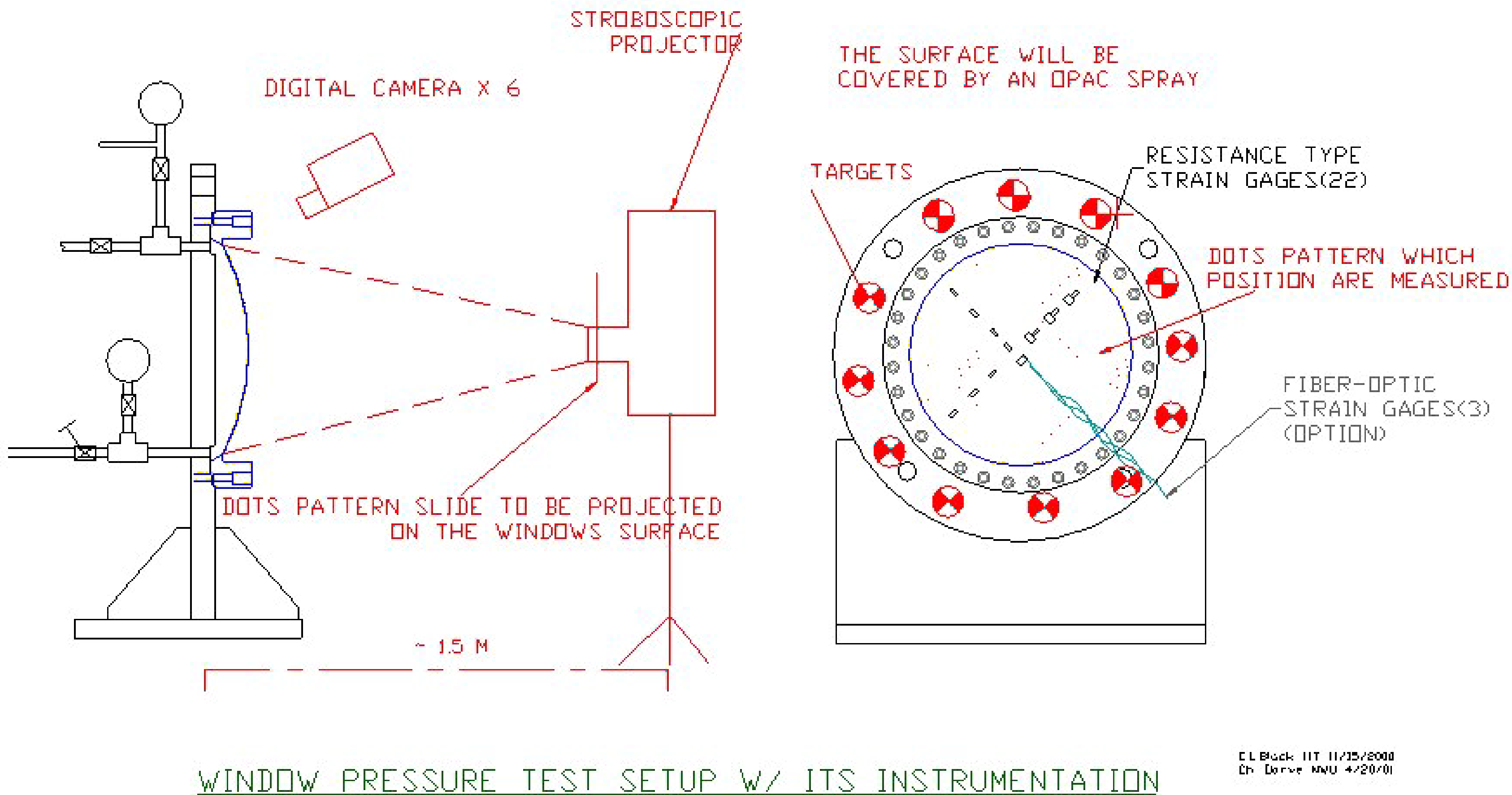
- Pressure-test back plate:





Window Overpressure Test

- Pressurize window prototype with H_2O to certify F.E.A. calculation
- To take place later this month
- Monitoring techniques:
  - Strain gauges
  - High-speed photography
  - ΔV (observe change in H_2O height in graduated cylinder)
  - Photogrammetry:

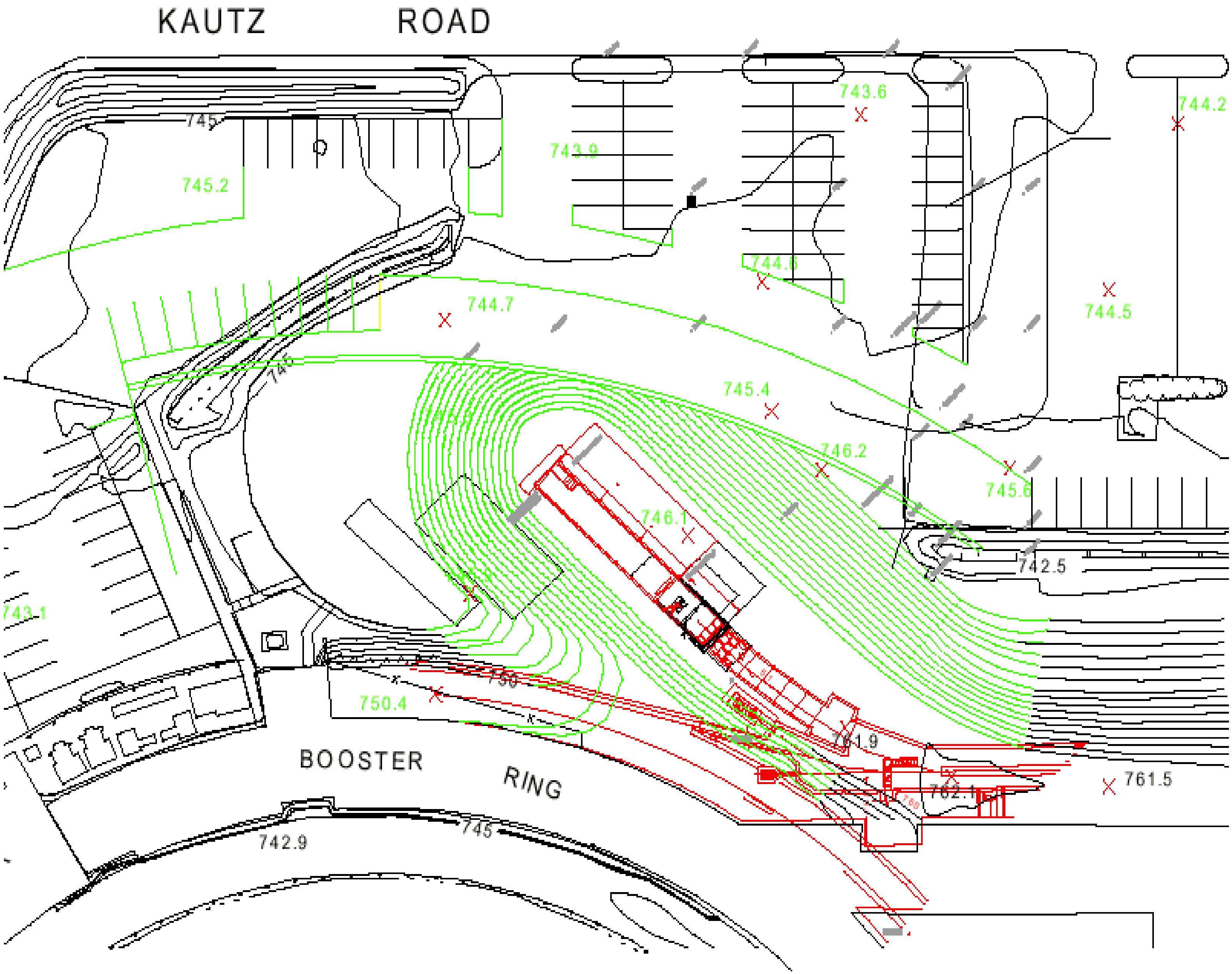


Linac-area Test Facility (LTF)

- View to southwest from Wilson Hall showing parts of Linac berm and gallery, Booster, and parking lot

- Zoomed view showing Linac access area to be converted into Linac-area Test Facility

LTF Layout



KAUTZ ROAD
BOOSTER RING
745
745.2
743.9
743.6
744.2
744.6
744.7
744.5
745.4
746.2
745.6
746.1
742.5
743.1
750.4
750
761.9
762.1
761.5
742.9
745

LTF Program

Current plans:

1. Liquid Hydrogen Absorber test facility

a. Engineering Tests (no beam) — starting ~ June 2001

b. Hydrogen Absorber beam test — could start ~ June 2002

c. Short Fully Integrated Cooling Section: LH_2 Abs., Be-Window RF Cavity, SC Solenoid — 2002–2003

2. High Power RF Testbed, 200 MHz and 805 MHz

a. Be-Window RF Cavity, High-Power RF Test

b. Grid-Based RF Cavity, High-Power Test

c. Cryo-Cold Copper Cavity

Options for the future:

1. Superconducting Test Facility

200 MHz Superconduting Cavity, NSF-Cornell

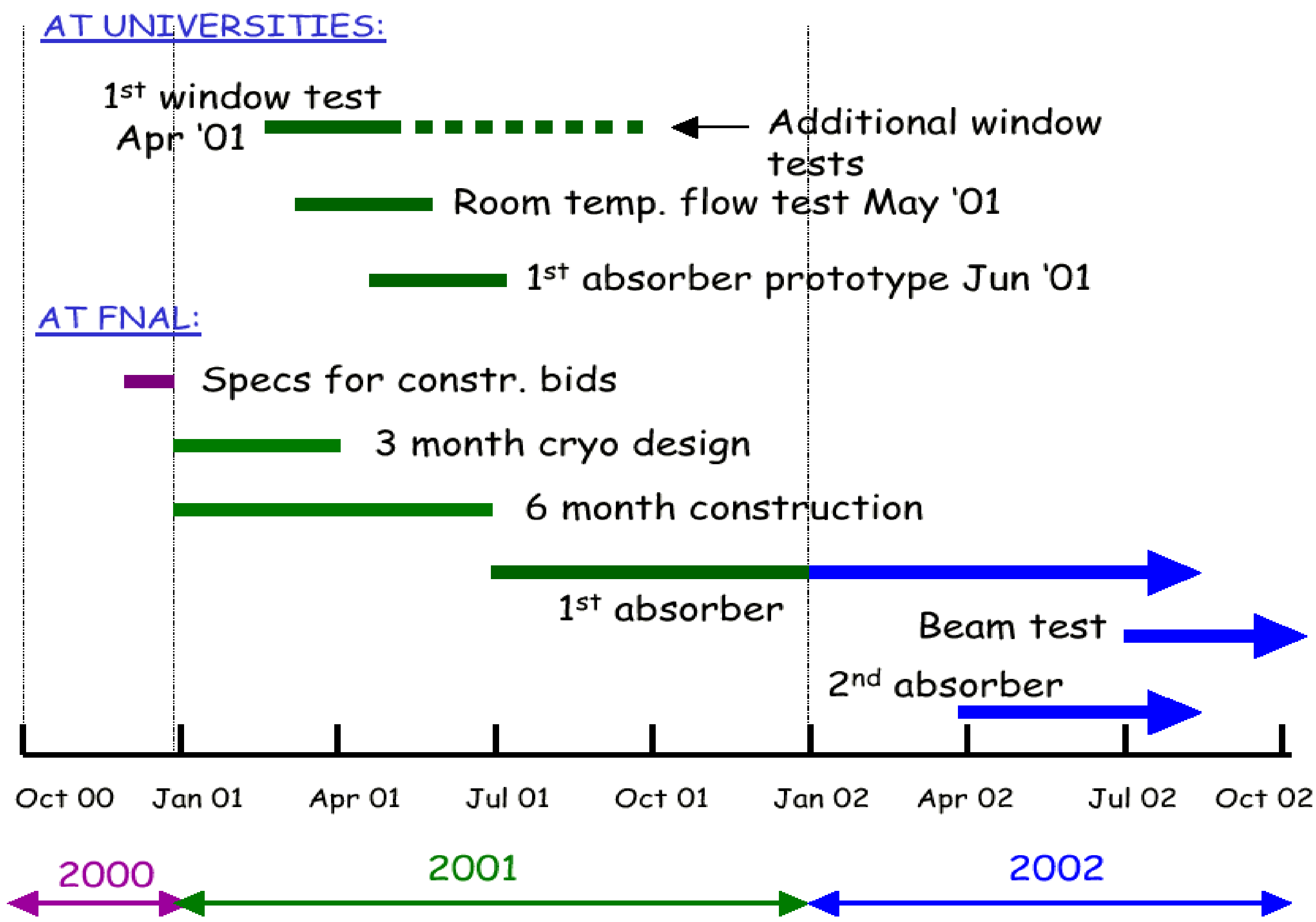
805 MHz Cavity for Linac Energy Upgrade

2. Any H^-, 400-MeV-Beam-Related Experiment

LH$_2$ Timelines

- Initial tests:
  1. Window overpressure test (IIT/NIU/NWU)
  2. Fluid-flow test (IIT/NIU)
  3. 1st-absorber cryogenic bench tests (IIT/NIU/NWU/UIUC/FNAL/KEK)

{ instrument with strain gauges, high-speed camera, maybe bolometry

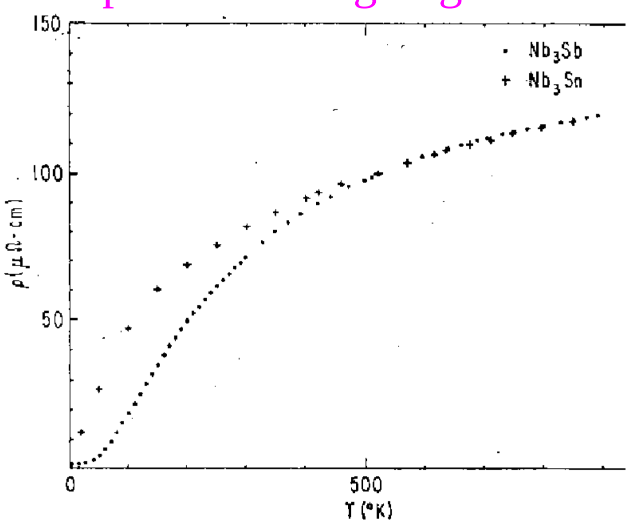


Instrumentation Ideas

- Instrumenting a muon cooling channel will be challenging:
  - close quarters
  - high *B* fields
  - high particle flux
  - high x-ray flux from RF cavities
  - high RF EM background

- Workshops held at CERN 7/00, IIT 11/00, Rutherford 2/01
  - some promising ideas proposed:
  - LH_2 scintillation
  - SEMs & Faraday cups
  - transition radiation from windows
  - high-stability gas or solid-state detectors
  - superconducting-edge bolometry:

To be tested in Lab G starting this year



Idea: superconductor with rapidly-varying conductivity near LH2 temp gives high sensitivity to heating of absorber windows

Could also be resistive material

– in either case apply to window surface as thin film

Illinois Consortium for Accelerator Research

- **Founded in 1999, funded in 2000 (NSF, Illinois DCCA, IBHE)**
- **Institutions and principal personnel**

Institutions and principal personnel	Topics
1. Illinois Institute of Technology E. Black, K. Cassel, D. Kaplan, T. Morrison	Cooling studies, absorber development, instrumentation, system engineering & integration
2. Northern Illinois University G. Blazey, M. A. Cummings, D. Hedin, D. Kubik	Absorber development
3. Northwestern University C. Darve, H. Schellman, M. Velasco	Instrumentation, neutrino physics, absorber engineering
4. University of Chicago K.-J. Kim, M. Oreglia, Y. Wah	Cooling theory, instrumentation
5. University of Illinois at Urbana-Champaign D. Errede, M. Haney	Beam optics, absorber tests

(+ non-ICAR MuCool universities: FSU, IU, U. Miss., Princeton, UCB, UCLA)

...all working in close collaboration with Fermilab and the NFMCC