Muon Collaboration

LH2 Absorber Status

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Online Now! Muons, Inc. nicadd

NFMCC
UCLA
January 31, 2007

Absorber program 2006

what program?

In the past year –

1. Re-instrumented KEK absorber for next MTA LH2 test
2. Established a new (and practical method) of window measurement
3. Completed GH2 RF test in MTA solenoid (most interesting experimental result out of NFMCC)

Overall, Mucool

1. Has a dedicated test area with a planned ~ 550W refrigeration capacity, designed for LH2
2. Has new FNAL LH2 cryogenic expertise
3. Has an established LH2 safety committee with an critical, but encouraging, attitude toward its goals
4. Has an established LH2 track record

Mucool MTA Absorber Task List

Current program:

➢ GH_2 RF tests with magnet*	Done!
➢ KEK LH_2 test (convection)	2^{nd} test in '07
➢ FF LH_2 absorber construction and tests	???
➢ FF LH_2 and RF first cooling cell test	???
➢ GH_2 beam test*	Still scheduled
➢ Cooling cell beam tests	???

+ Window tests…

Future projects:

- ➢ LH_2 HCC cryostat (Muons, Inc.)
- ➢ Lithium Hydride
- ➢ Other

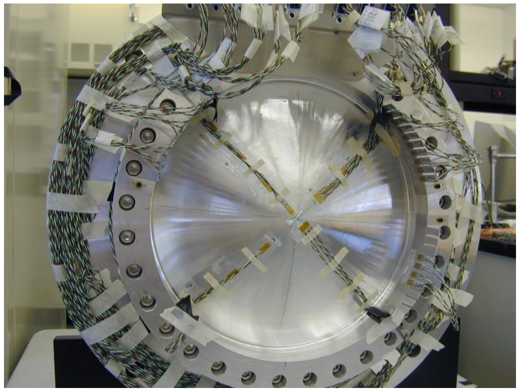
* Muons, Inc.

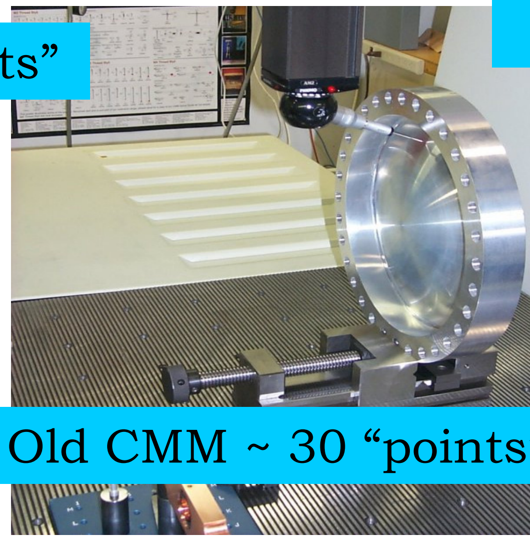
LH2 recent history

- 2004:
  - ⇒ 1.5 FT scientists, 1 FT engineer (E. Black), 1 PT engineer (M. Haney), 1 PT graduate student, undergraduates
  - ⇒ NIU machine shop, electronics shop, UIUC computer, U Miss shop
  - ⇒ FNAL cryo group, metrology group
  - ⇒ Japan-USA funding (KEK MTA convection absorber)
- 2005: (after ICAR $$ disappeared)
  - ⇒ 1 scientist PT
  - ⇒ FNAL cryo group, vaporization lab, beams group
  - ⇒ P8 lab
- 2006:
  - ⇒ 1 scientist PT
  - ⇒ FNAL cryogroup, metrology group, vaporization lab, beams group
  - ⇒ Lab 6 (K. Kephardt)
- 2007:
  - ⇒ 1 scientist <PT
  - ⇒ FNAL SciDet support, beams group
  - ⇒ Lab 6

Window measurements

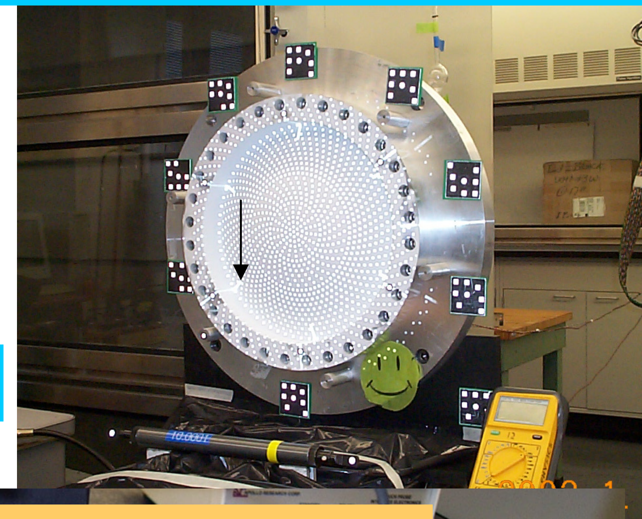
Strain gages ~ 20 “points”





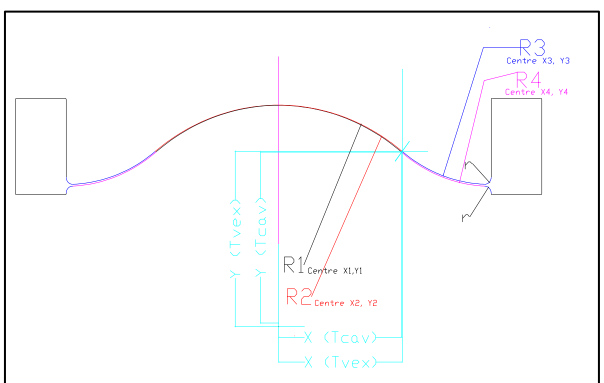
Old CMM ~ 30 “points”

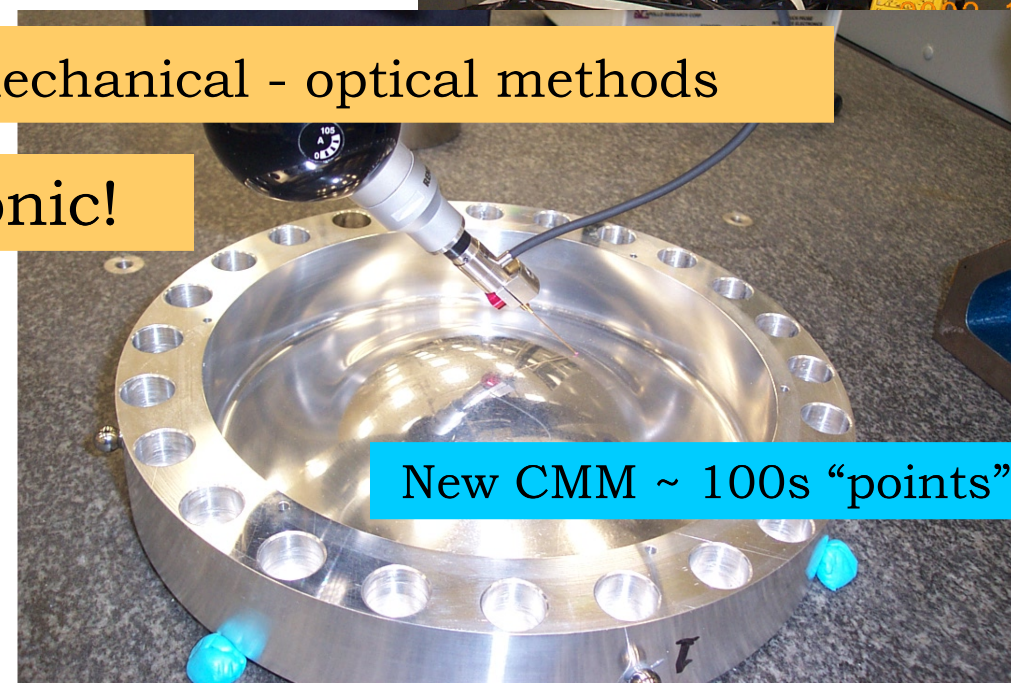
Photogrammetry ~1000 points



We have tried: chemical – mechanical - optical methods

And now – sonic!

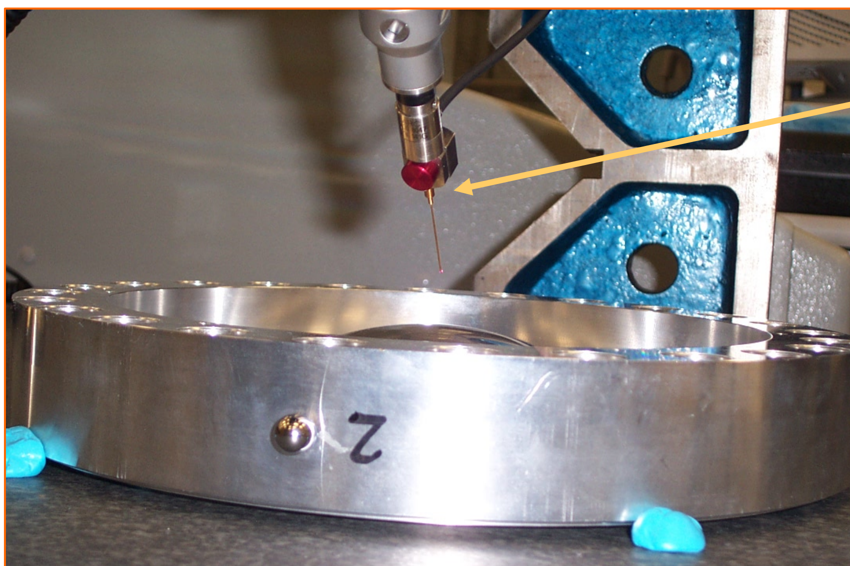




New CMM ~ 100s “points”

"Feather" probe CMM

- Apollo Research Model 1022 CMM Touch Probe System
  - ⇒ high frequency resonating stylus to detect contact with object
  - ⇒ <10 mg force applied (700g old test)
  - ⇒ contact detected by change in resonance
  - ⇒ insensitive to CMM movement
  - ⇒ ~ few micron sensitivity



At FNAL SciDet facility

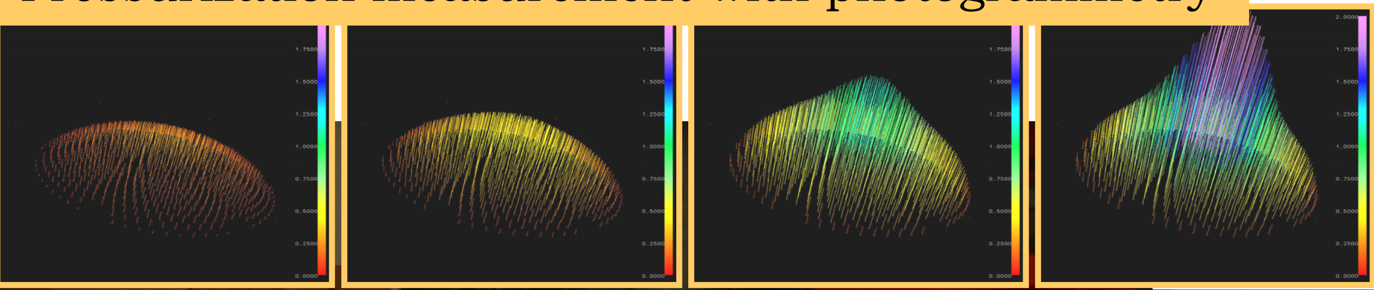
Large clearance for test setup

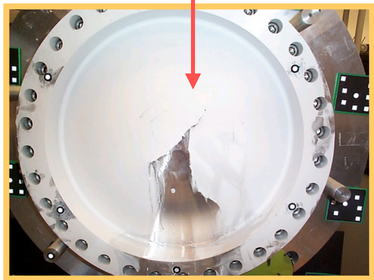
Photogrammetic Test Setup (FNAL)

Beautiful, detailed, but maybe overkill

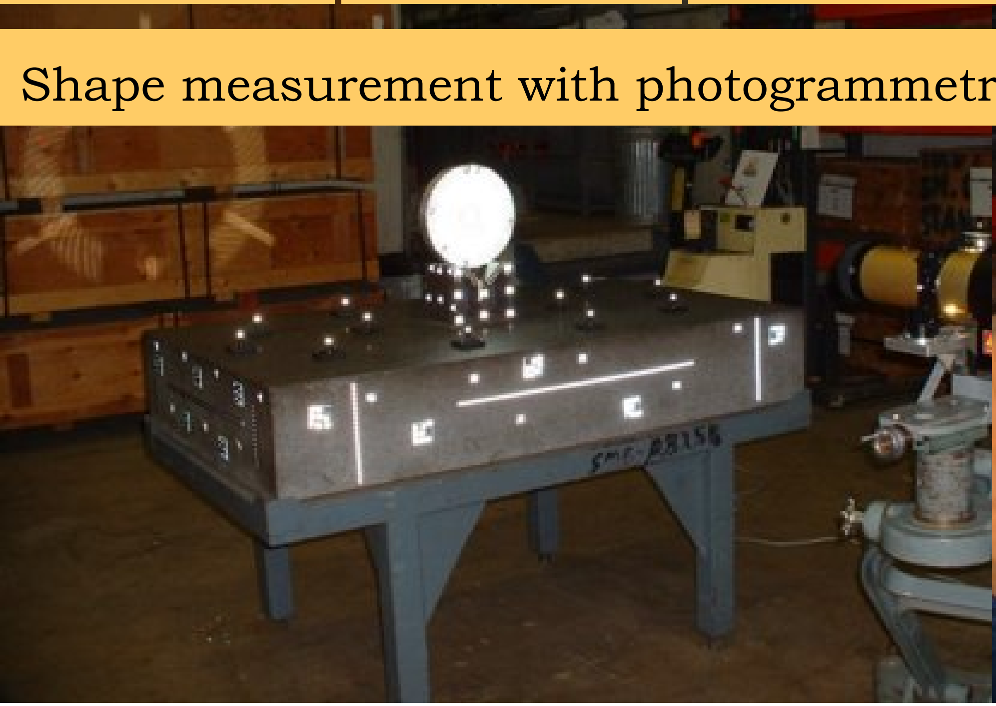
Optical coating
(another complication)

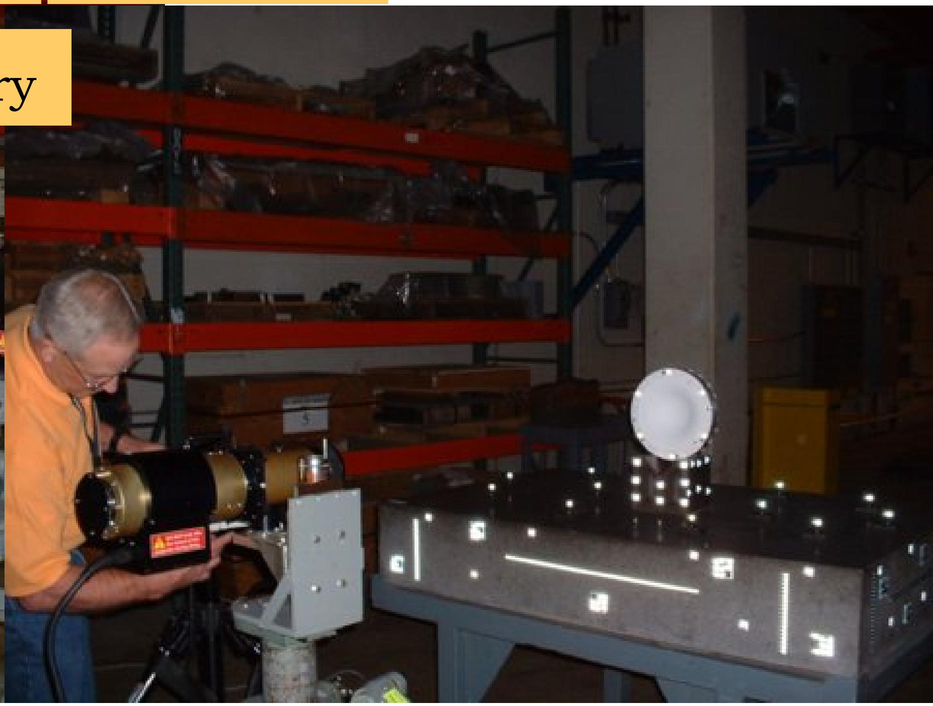
Pressurization measurement with photogrammetry





Shape measurement with photogrammetry

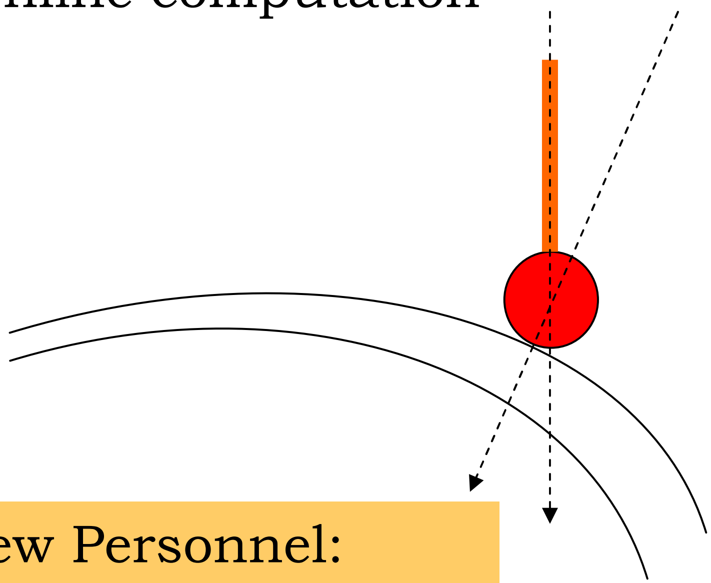


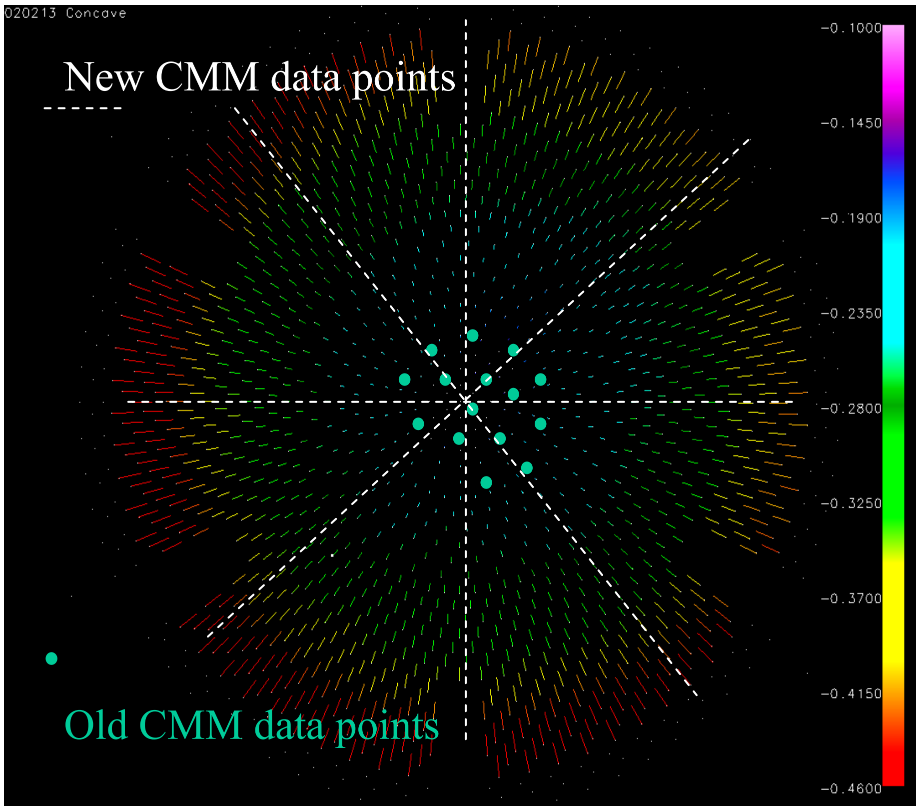


Window measurements

Initial measurements:

- calibration ball measured ~ 2 microns consistency
- 1st measurements of window profile – self-consistent, but did not match design thickness! (220 vs. 126μ - will investigate)
- correction needed (but understood) for finite probe radius – least errors at center (thinnest part)
- online computation





New Personnel:
Mike Roman (FNAL)
Mike Wojcik

FNAL Safety requirements

FNAL Design Requirements:

Vacuum

1. Burst test 5 vacuum windows at room temp. to demonstrate a burst pressure of at least 75 psid for all samples. (pressure exerted on interior side of vacuum volume).
2. Non-destructive tests at room temperature:
   a. External pressure to 25 psid to demonstrate no failures: no creeping, yielding, elastic collapse/buckling or rupture
   b. Other absorber vacuum jacket testing to ensure its integrity

Absorber

1. Room temp test: pressurize to burst ~ 4 X MAWP (25 psi at FNAL)
2. Cryo test:
   a) pressure to below elastic limit to confirm consistency with FEA results
   b) pressure to burst (cryo temp – LN2) ~ 5 X MAWP
   from ASME: UG 101 II.C.3.b.(i)

RAL Window Safety Requirements

- Mucool manufacture and measuring procedures deemed safe
- RAL window pressure test requirements (Absorber and Vacuum)

Test Pressure	Test temperature	# of tests required	Remarks
96 psi (4 x Design P)	@ 293K	3	Test to rupture. Windows to subject to thermal cycling before the test
> 96 psi (5 X Design P)	@ 77K	1 or 2	Test to rupture. If shrapnel is evident, one further test will be needed. The additional test will have the safety mesh fitted to verify that shrapnel doesn't reach the safety window.
25 psi	Room temp	1	Test for buckling (external)

**Design Pressure = 24 psid MAWP FNAL = 25 psid -

Effectively, the same for MICE and MuCool

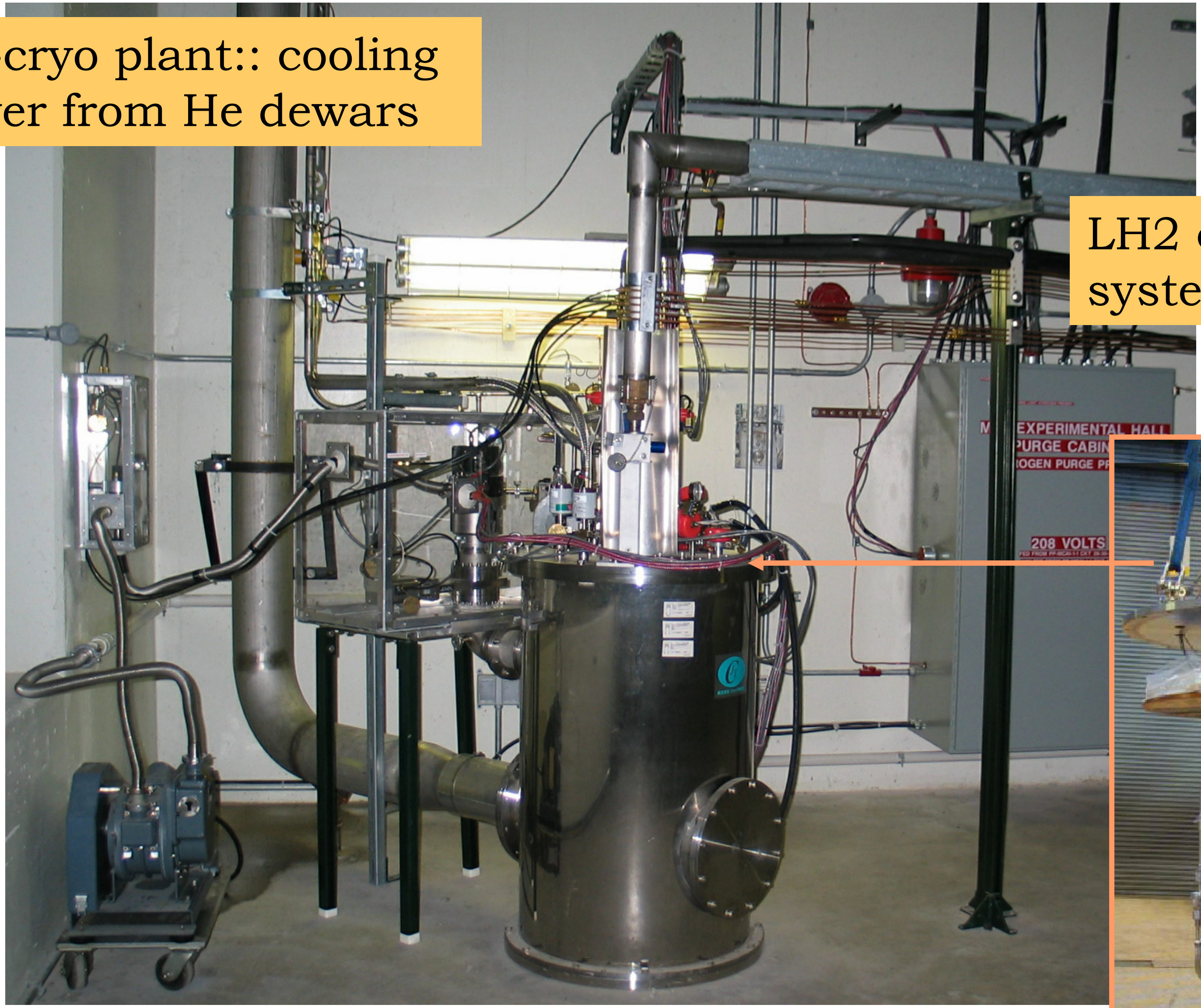
Next steps..

- **Window certification**
  - ⇒ Have a practical and sufficient measurement technology
  - ⇒ **Design certification** different for vacuum/absorber windows, and not yet completed for "inflected" window

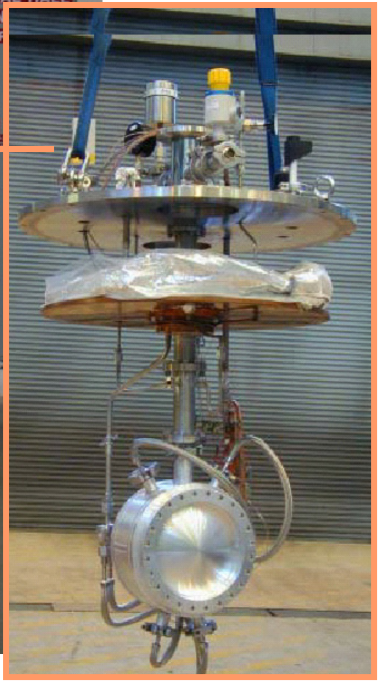
    need this be done for only one diameter?
  - ⇒ Tentative real **window certification**:
    - Materials inspection
    - Measurement
    - Sub-elastic limit pressure tests (on CMM?)
  - ⇒ Next Manufacturer?
    - U Miss.
  - ⇒ Review with Safety committee

KEK test cryostat at MTA/FNAL

Pre-cryo plant:: cooling power from He dewars

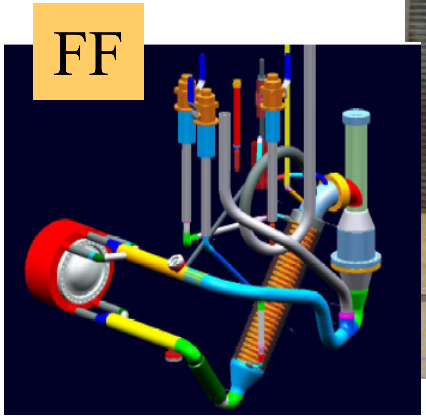


LH2 controls system in place

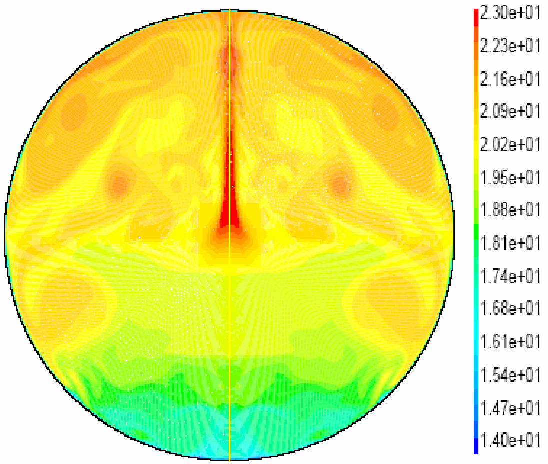


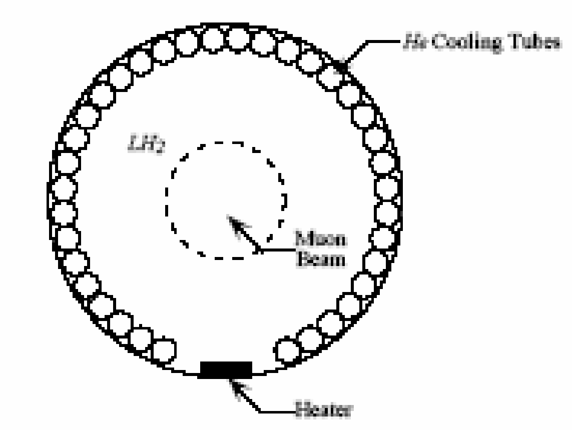
Convection Absorber

- Convection is driven by beam power and internal heaters
- GHe heat exchanger removes heat from absorber walls
- Flow essentially transverse
- Self-regulating
- Simpler system, less LH2
- Prototype exists..



Temperature Distribution:





Absorber physics issues

1. Heat absorption

Benchmark for heat deposition for MC and NF ($\mu^+\mu^-$ Collider feasibility study and NFII) in LH2

[$3.24*10^{13}\mu$/s]

$4*10^{12}$ ($\sim10^{13}$) m's/bunch * 15/s * 4.7MeVg^{-1}cm2 * 0.0708g/cm3 * $1.6*10^{-13}$J/MeV =

*[1.4 HCC/straight] 3.2 (~8)[2.4] W(J/s)/ cm pathlength

[] = LEMC starting point, 3 TeV

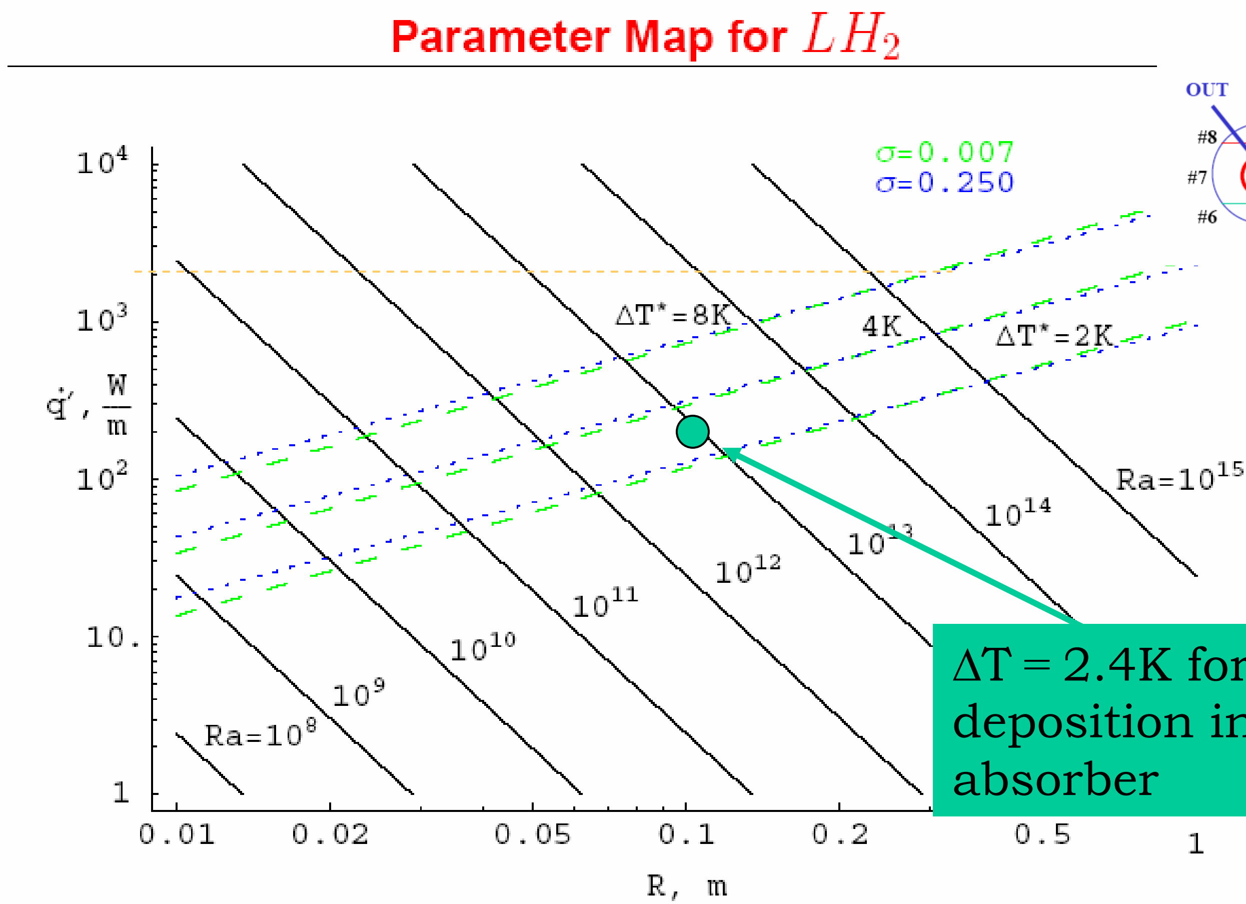
2. Density uniformity

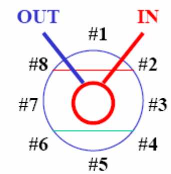
how large a temperature gradient is tolerable?

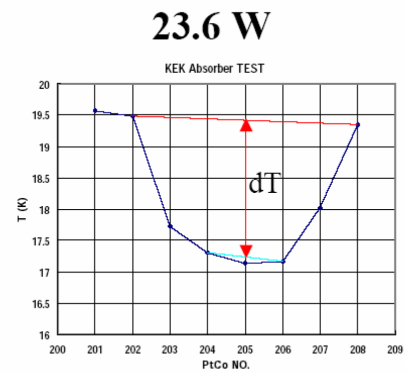
Convection absorbers push the limits of large heat deposition into relatively small volumes of LH2 – knowledge will help determine absorber design.

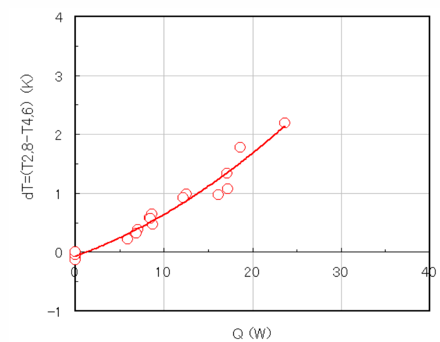
Convection theory and data..

Comparison of 1st KEK MTA LH2 test to CFD calcs (K. Cassel et al, 2004, IIT):







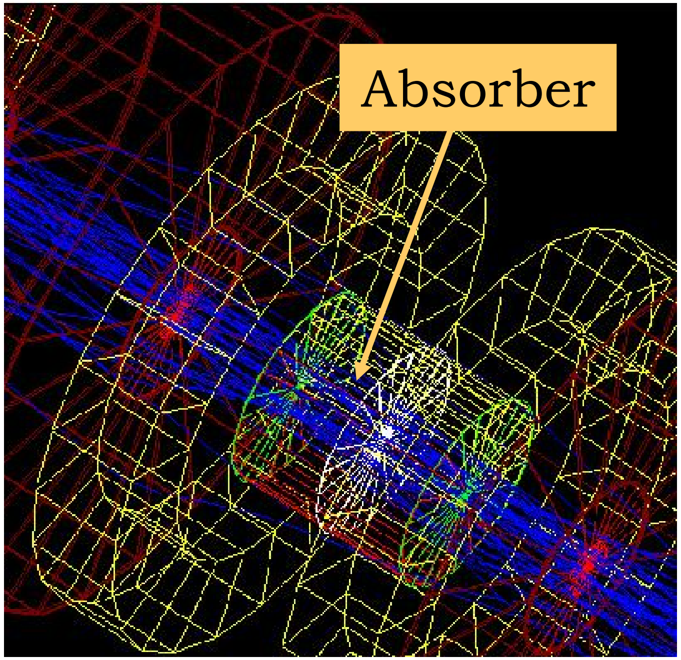


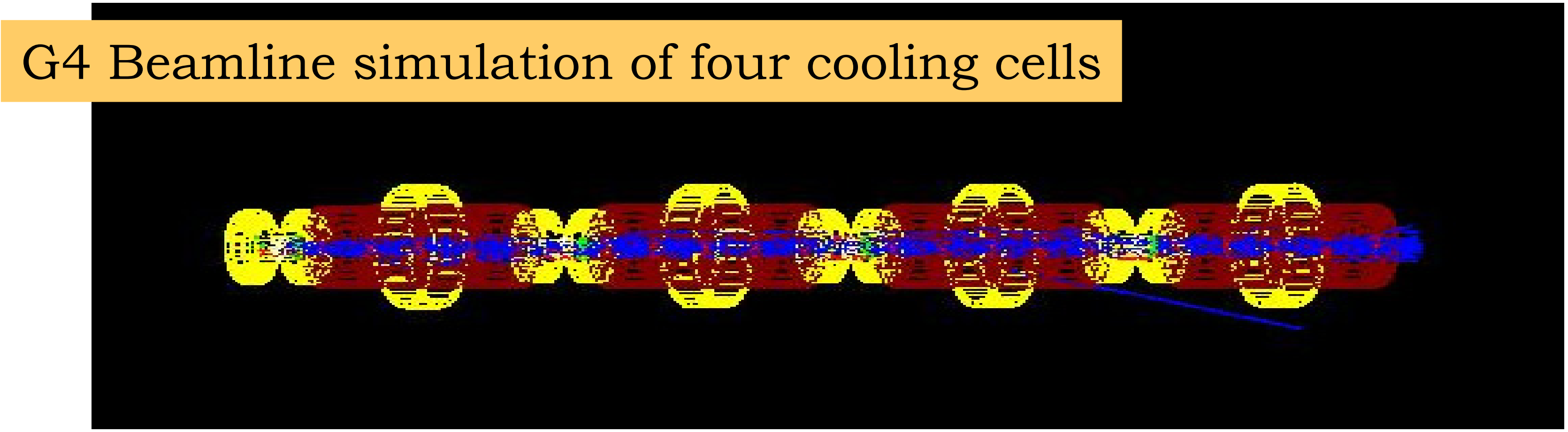
$\Delta T = 2.4$K for 22W (~147 W/m) deposition in KEK absorber

Required heat absorption for previous cooling channel: ~800 W/m but a possibility for LEMC?

Temp. gradient on performance

- Exaggerate and simplify temperature gradient by replacing uniform absorber with 2 different density halves (14% higher/lower diff) but same average density and compare with uniform density absorber
- < 1% change in momentum and space distributions (average and sigmas)
- "Large" temp gradient may be tolerated if it is stable



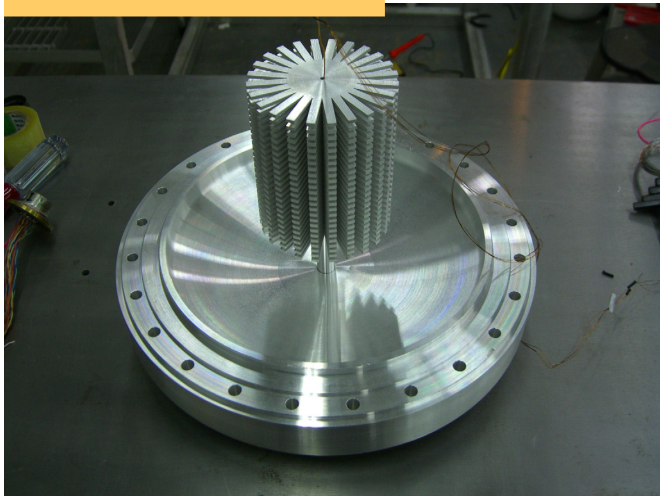


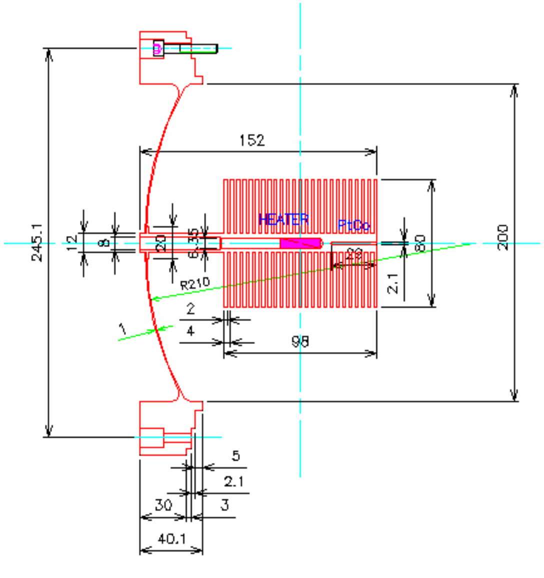
MTA/FNAL 2nd Cooling Test

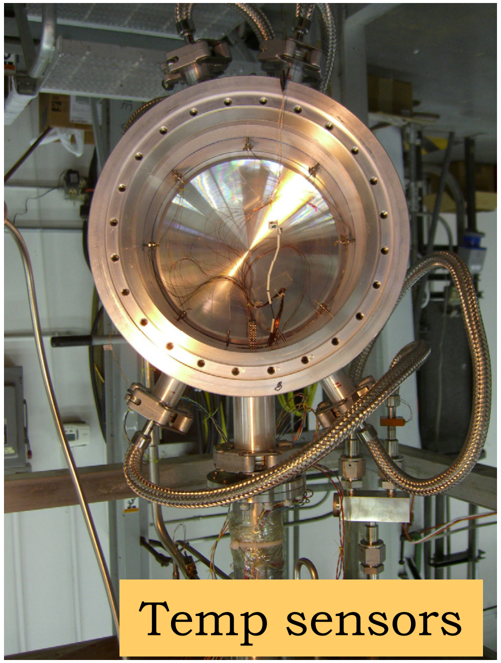
Shigeru Ishimoto, Shoji Suzuki
and Nobuaki Tanaka
at LAB-6/FNAL
Feb-10, 2006

KEK upgrades

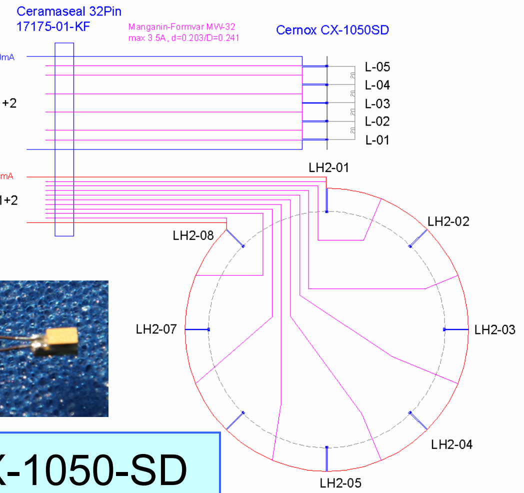
Electric heater

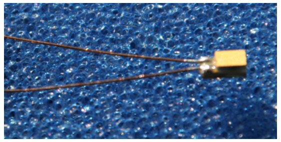






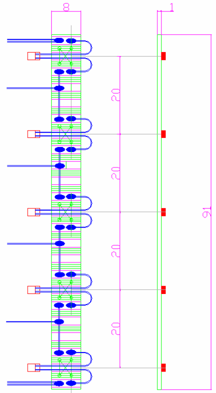
Temp sensors





CX-1050-SD

Electric heater installed



L-H2/LHe Level sensor in absorber

2007 MTA KEK LH2 Absorber tests

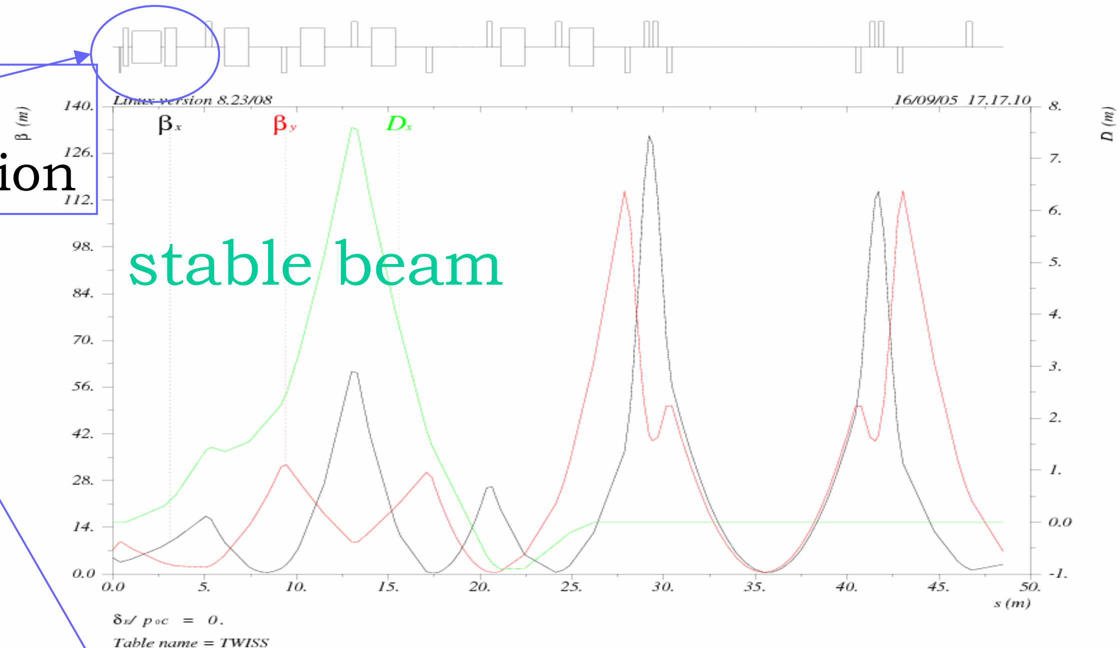
- February 2006 upgraded instrumentation
- January 2007 installed heater
- Preliminary safety review approved
- Preliminary safety check list completed
- Schedule for 2007 MTA LH2 test to be determined

MTA Beam

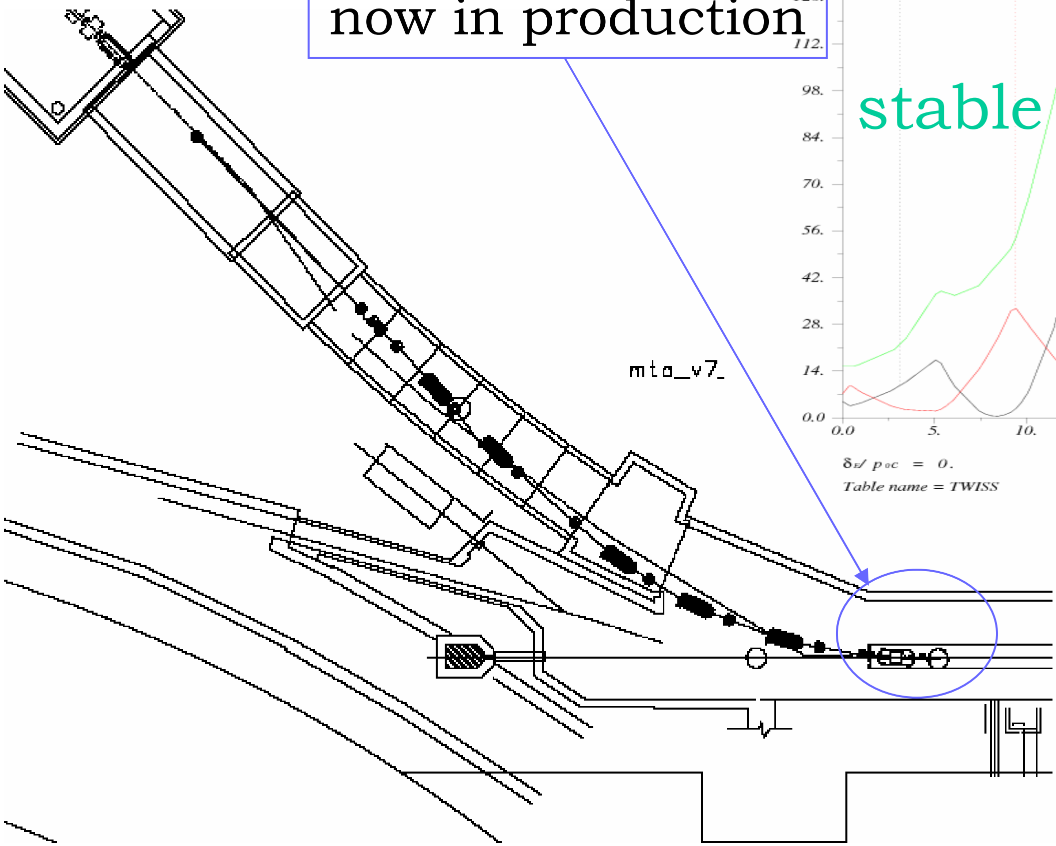
Beamline designed and costed by C. Johnstone for the MTA.
Part of the Linac Instrumentation Test Program

MTA

New magnets now in production



stable beam



In 2007 Budget

Linac beam

Lithium hydride

- LiH reacts violently with water, so water cooling must be carefully designed and implemented (it's not certain it can be done safely). Halon fire suppression is probably required.
- Handling of prefabricated LiH is not terribly hazardous (gloves and dust masks); fabrication (casting) will require QC, should be left to experts.
- Bare LiH can be pumped down to vacuum; it is best to repressurize with dry Nitrogen, but room air is OK.
- LiH cannot be in direct contact with aluminum (Al migrates).
- Thermally-induced stresses could be a problem for high rate beams
- Surface oxidation from air moisture is almost inevitable; how will it affect the cooling performance?
- LiH is a hazardous material; the safety issues are very different from those of liquid Hydrogen, but comparable in difficulty.

Substantially less hazardous $\neq$ substantially less safety work!

If it were up to me…

- Window measurement will proceed with the new CMM system and probes
- The KEK LH2 absorber test will be completed by this spring
- The first "cooling cell" component test will be the GH2 RF cavity inside the MTA solenoid in the MTA beam – and make this a priority
- Put the KEK LH2 absorber in the MTA beam

IF everything, including 6D MANX, "slides" indefinitely

- Build a "one turn" HCC prototype and fill it with H2 (why not?)
- Any other possible cooling component that exists we should consider testing at MTA

These are administrative issues..

Safety

- For H_2, two principles driving system design :
  - ⇒ O_2 and H_2 separation
  - ⇒ No ignition sources
- At FNAL: guidelines for the LH_2 absorber system
  - ⇒ America Society of Mechanical Engineers (pressure and vacuum vessels, etc.)
  - ⇒ National Electrical Code <= (Class I Division II, or "instrinsically safe")
  - ⇒ Compressed Gas Associates
  - ⇒ Fermilab Environment Safety and Health Code

FERMILAB: " Guidelines for the Design, Fabrication, Testing, Installation and Operation of LH2 Targets – 20 May 1997" by Del Allspach et al. Fermilab RD_ESH_010– 20 May 1997

NASA: " SAFETY STANDARD FOR HYDROGEN AND HYDROGEN SYSTEMS: Guidelines for Hydrogen System Design, Materials Selection, Operations, Storage, and Transportation"

- ⇒ Ignition sources – electrical, friction, impact, auto-ignition
- ⇒ Minimum energy for ignition of H_2 is 0.017 mJ at 1 atm.
- ⇒ Combustion H_2 /air ratio from 4% to 75%

PRIMARY SAFETY MECHANISM IS CONTAINMENT: "EXCEPTIONS HANDLED BY VENTING LH_2 OUT OF THE AREA