INSERTION DEVICE MAGNETIC MEASUREMENT FACILITY AT THE NSLS-II

Toshi Tanabe
NSLS-II ID group leader

IMMW17
September 18-23, 2011

NSLS-II Insertion Device Group

* Toshi Tanabe—Group Leader *

* George Rakowsky (Part Time)—ID modeling & design/mag survey
* Jim Rank, Peter Cappadoro—Mechanical Engineering
* David Harder—EE/magnetic measurement instrumentation
* Ping He —Magnetic measurement & Synchrotron Rad Calculation
* Todd Corwin—Technical support/fabrication
* Charles Kitegi—ID modeling & design/mag survey
* Craig Rhein—Fabrication/assembly

Future job openings

•Electromechanical tech—motion control
•Scientist
•Software

Associated 3D-CAD effort

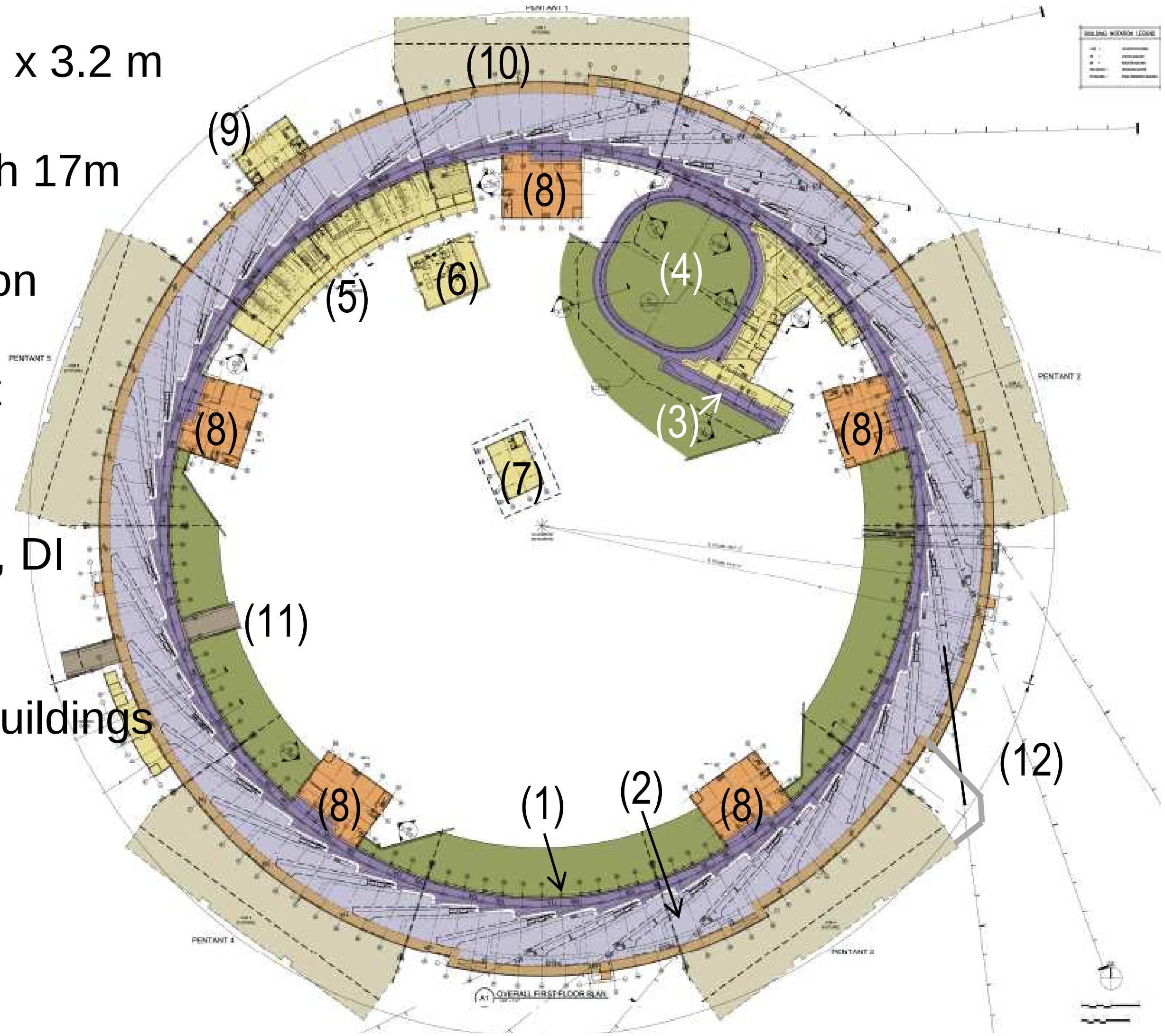
* Bill Wilds
* Cliff Meyer

Main Topics

- NSLS-II Project / ID scope
- Building 832—facilities, labs, ID access
- Environmental Enclosure—placement, specs/constraints
- Hall Probe Mapping Bench—specs, tests, considerations
- Hall Probes—selection, NMR calibration
- Wire Measurement Probes—flip-coil, moving-coil, pulsed-wire
- Permanent Magnet Characterization—Helmholtz setup
- In Vacuum Magnetic Measurement System—IVUs & CPMUs
- Vertical Test Facility—SC undulator prototypes

Facility Overview

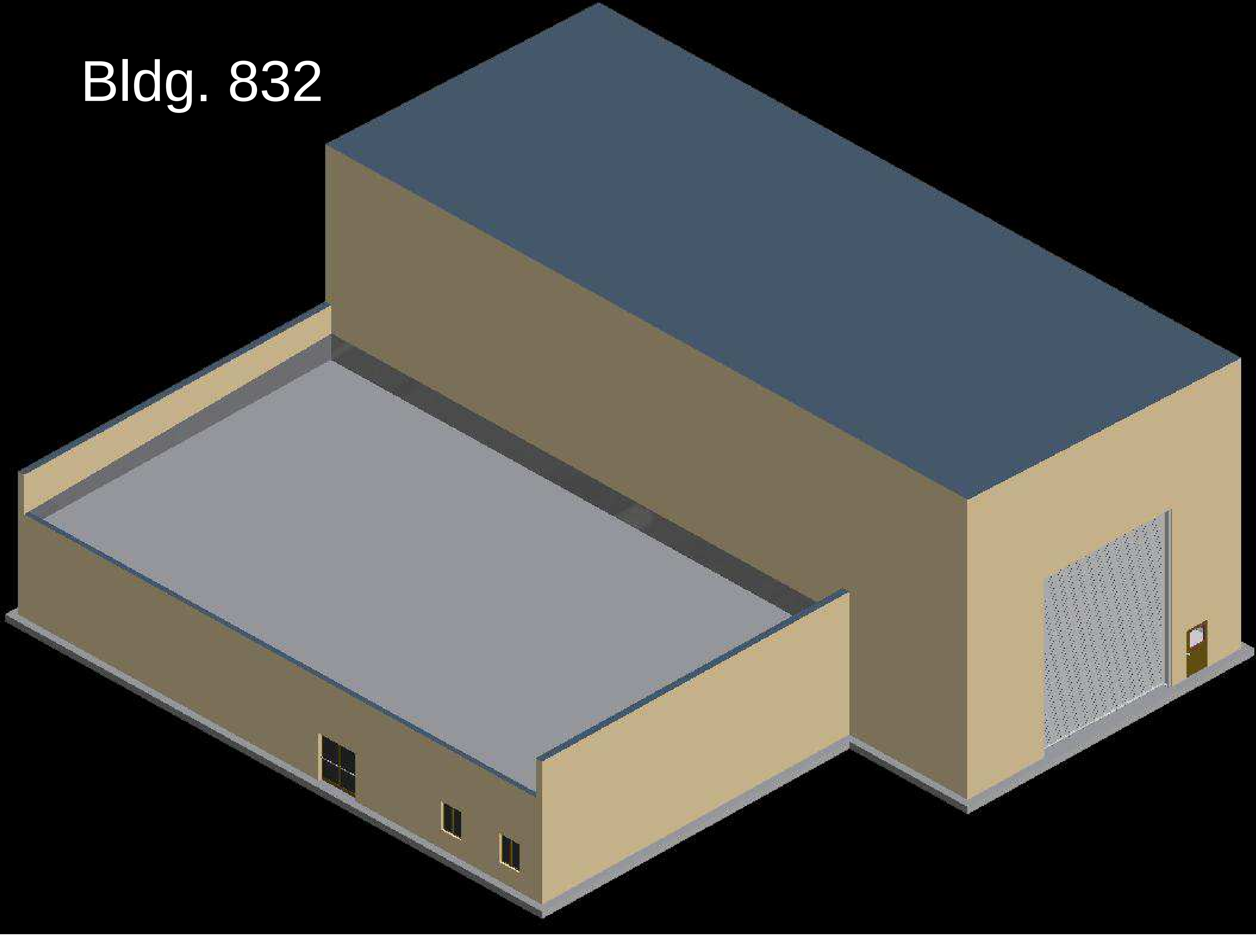
(1) Accelerator Tunnel 3.7m x 3.2 m x 792m
(2) Experimental Floor, width 17m
(3) 200MeV S-Band LINAC
(4) 3GeV Booster Synchrotron C=158m
(5) RF Building, lq. He Plant
(6) Compressor Building
(7) Central Cooling Tower
(8) Service Buildings: HVAC, DI water
(9) Lobby
(10) Laboratory and Office Buildings
(11) Vehicle underpass
(12) Extra long beam line

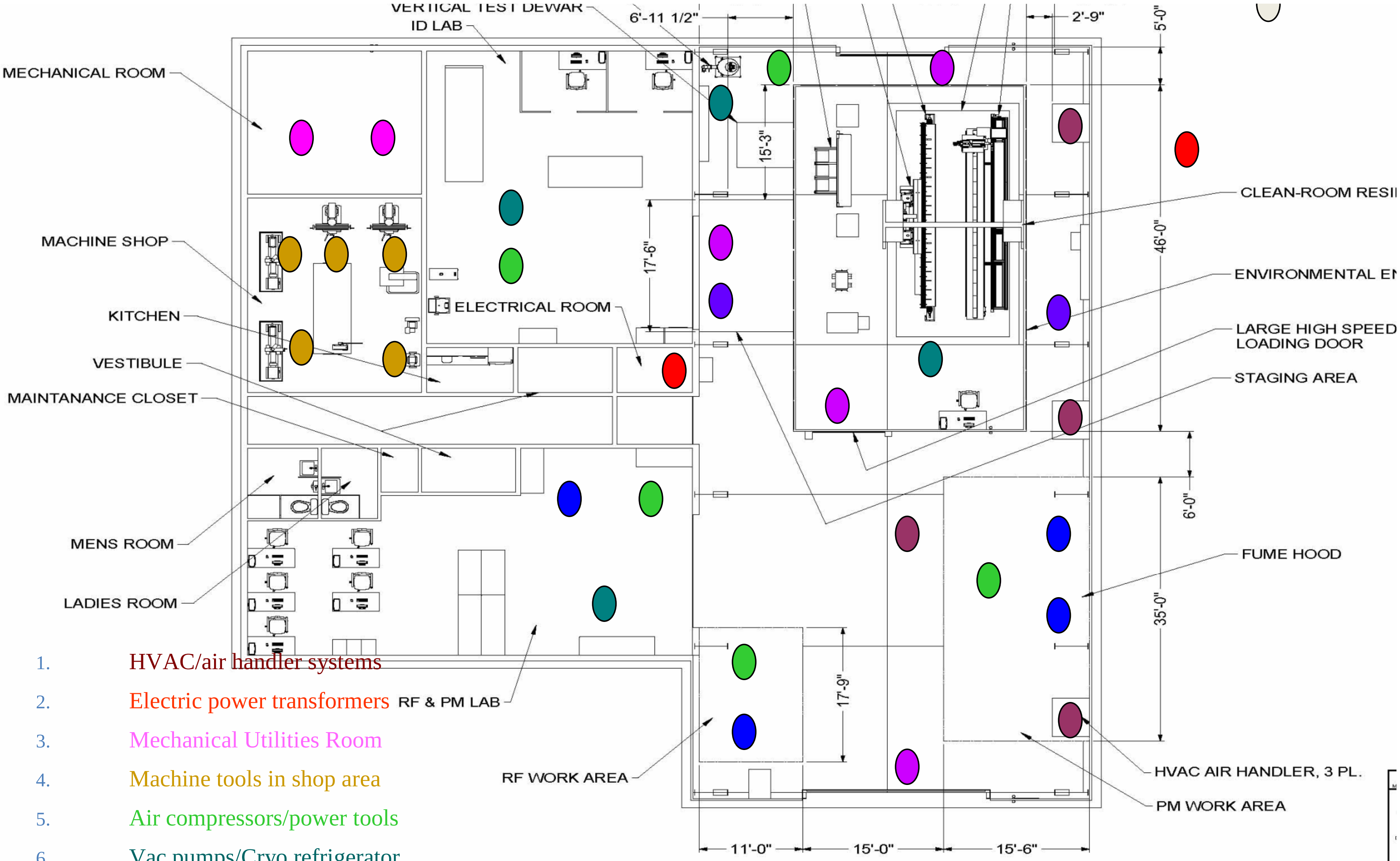


NSLS-II Insertion Devices (Baseline Project Scope)

Name	U20	U22(IXS)	EU49	U21(SRX)	DW-1.8T	3PW
Type	IVU	IVU	EPU	IVU	PMW	PMW
Photon energy range	Hard x-ray (1.9-20keV)	Hard x-ray (9.1keV)	Soft x-ray (250eV-1.7keV)	Hard x-ray (1.9-20keV)	Broad band (<10eV-100keV)	Broad band (<10eV-100keV)
Type of straight section	Short	Long	Short (canted)	Short (canted)	Long (in-line)	near 2nd Dipole
Period length (mm)	20	22	49	21	100	-
Length (m) & Number of Devices	3.0 x 2	3.0	2.0 x 2	1.5	3. 5 x 6	0.25
Number of periods	148	135	38 x 2	69	34 x 2	0.5
Magnetic gap (mm)	5	7.0	11.5	5.5	15.0	28
Peak magnetic field strength B (T)	1.03	0.78	0.57(Heli) 0.94 (Lin) 0.72(vlin) 0.41 (45°)	0.9	1.80	1.14
Keff	1.81	1.52	2.6(Heli) 4.3 (Lin) 3.2(vlin) 1.8 (45°)	1.79	18.0	-
hν fundamental, eV	1620	1802	230 (Heli) 180 (Lin) 285(vlin) 400 (45°)	1570		
hν critical, keV					10.7	6.8
Total power (kW)	8.0	4.7	8.8	3.6	64.5	0.32

Bldg. 832





1. HVAC/air handler systems
2. Electric power transformers
3. Mechanical Utilities Room
4. Machine tools in shop area
5. Air compressors/power tools
6. Vac pumps/Cryo refrigerator
7. RF/Power Supplies
8. Bridge crane, transporters
9. Overhead door motors
10. Seismic and wind excitation

Building 832-resident Sources of Vibration

Environmental Enclosure Parameters

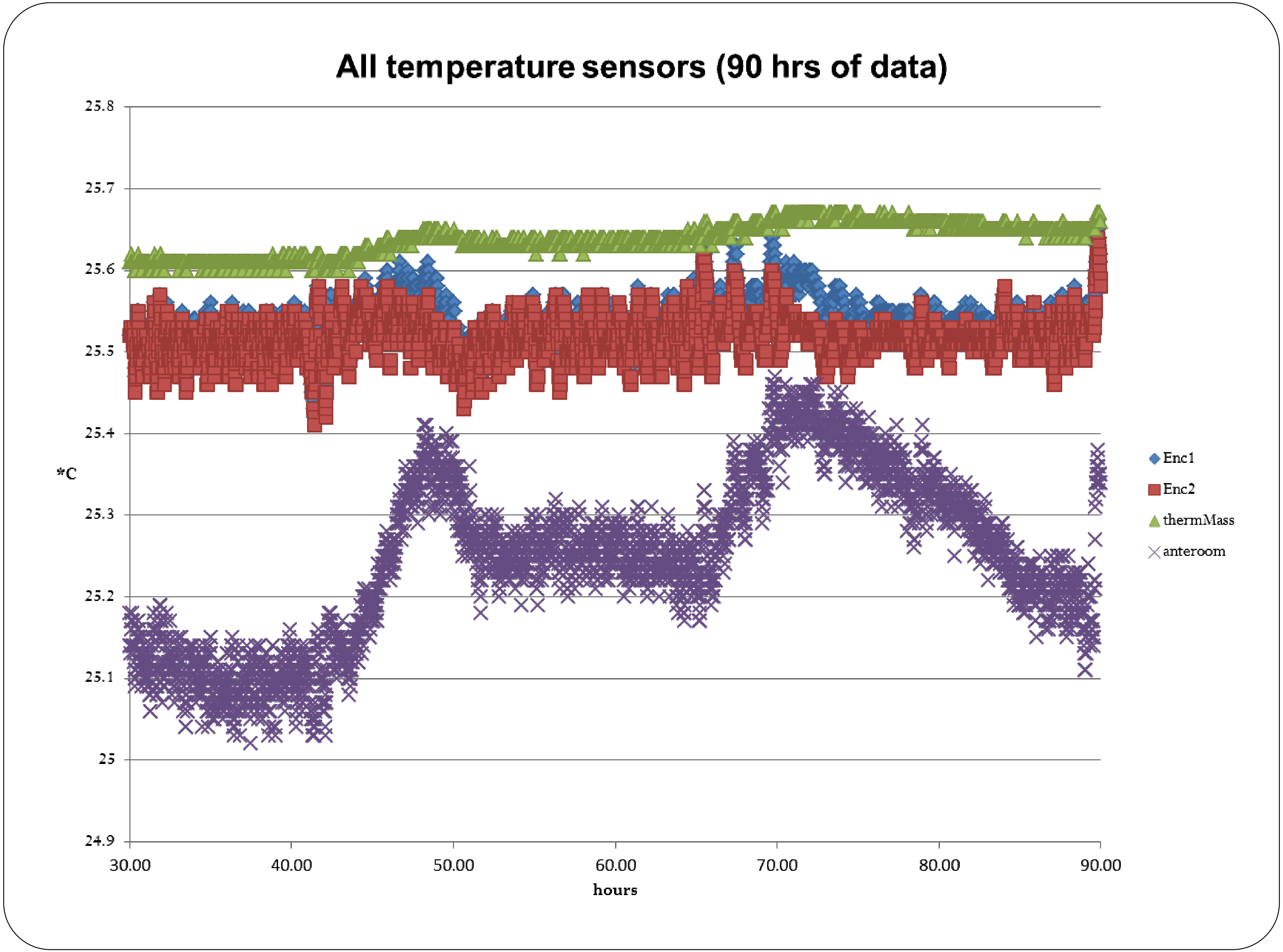
- External Dimensions—25’ (7.62m) wide x 46’ (14m)long x 15’ (4.6m) high
- Internal working space—main~1012 ft^2, antiroom~150 ft^2
- Temperature set point range—25.5 ℃ +/- 3 ℃
- Temperature regulation--+/- 0.2 ℃
- Temperature uniformity in central volume--+/- 0.2 ℃
- Maximum heat load—8 kW + 2 workers
- Humidity set point range—35% to 55% RH
- Typical humidity set point—50% RH +/-5% (comfort and static)
- Vibration control—variable freq drive, shock mounts, ext. chiller
- ISO 14644-1 Class 7 (class 10000) cleanroom

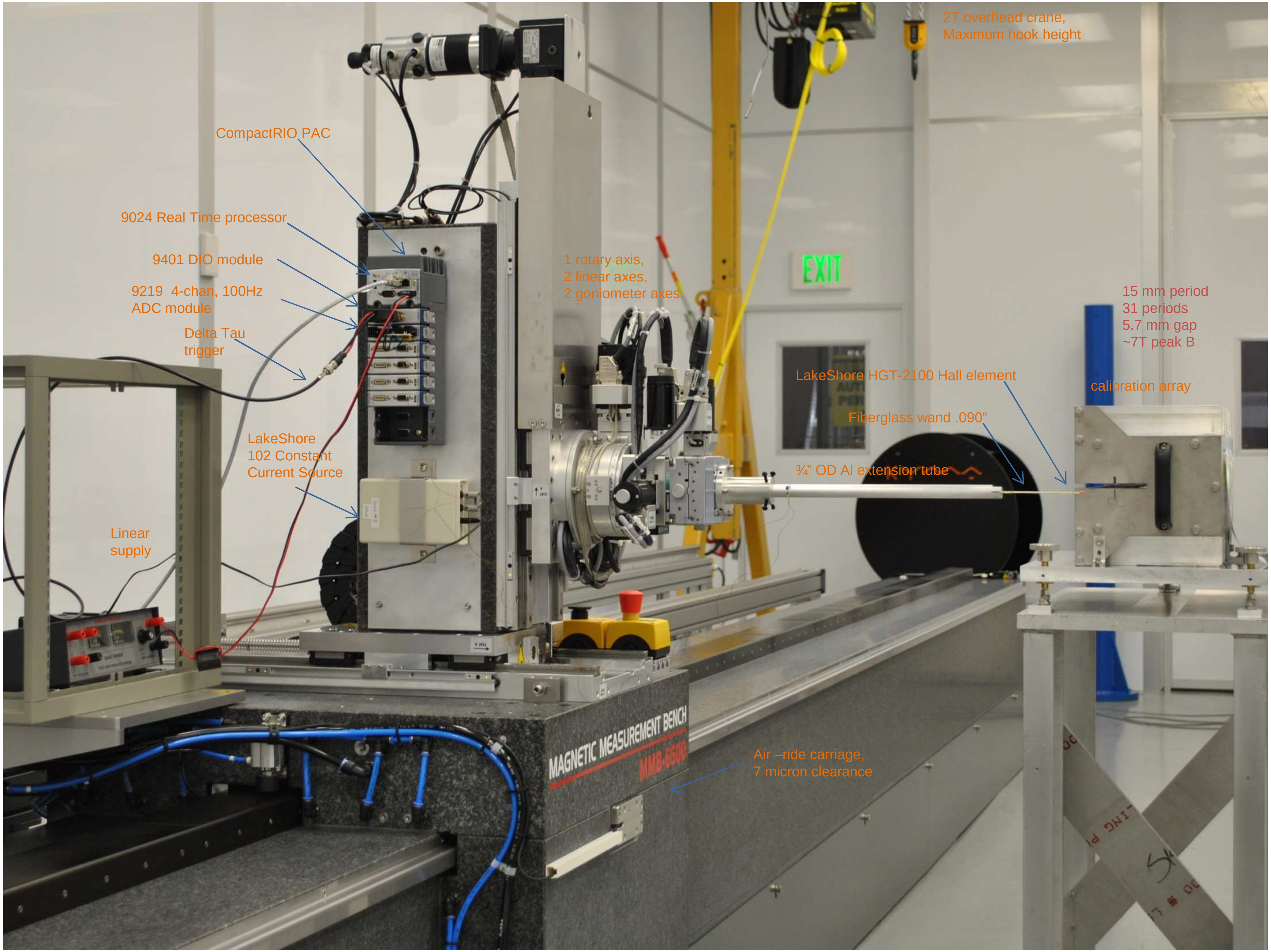
HVAC (Heating, Ventilation and AC) issues

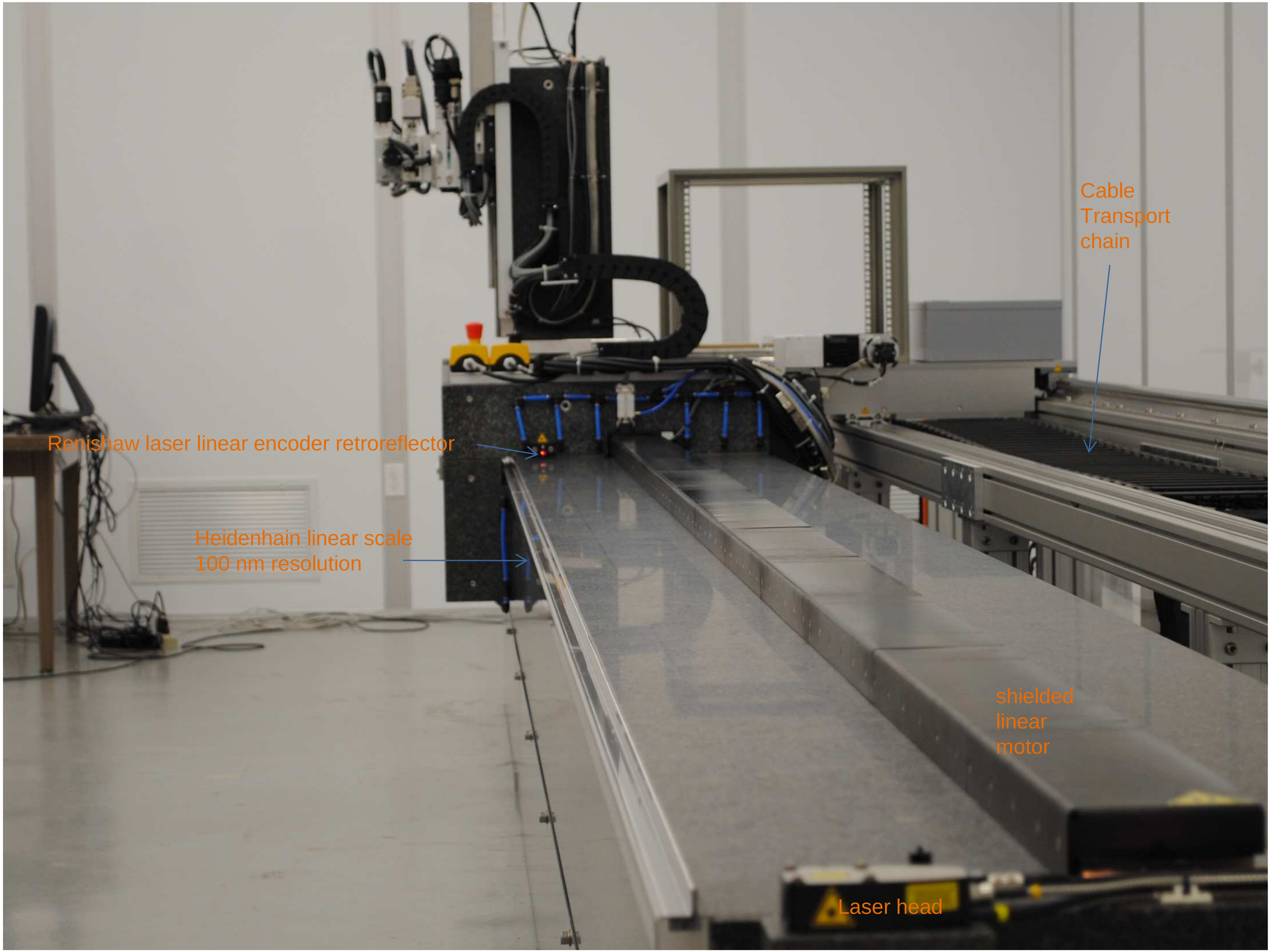
- Chilled water system
- 10 ton unit
- Minimize/homogenize internal airflow
- Current @ 480 VAC < 105 amps

Inside American Cleanroom Systems Environmental Enclosure

Photo taken on 8/23/11


All temperature sensors (90 hrs of data)
25.8
25.7
25.6
25.5
25.4
25.3
25.2
25.1
25
24.9
*C
30.00
40.00
50.00
60.00
70.00
80.00
90.00
hours
Enc1
Enc2
thermMass
anteroom


2T overhead crane,
Maximum hook height
CompactRIO PAC
9024 Real Time processor
9401 DIO module
9219 4-chan, 100Hz
ADC module
Delta Tau
trigger
1 rotary axis,
2 linear axes,
2 goniometer axes
EXIT
15 mm period
31 periods
5.7 mm gap
~7T peak B
LakeShore HGT-2100 Hall element
calibration array
Fiberglass wand .090"
LakeShore
102 Constant
Current Source
¾" OD Al extension tube
Linear
supply
MAGNETIC MEASUREMENT BENCH
MMB-6600
Air –ride carriage,
7 micron clearance

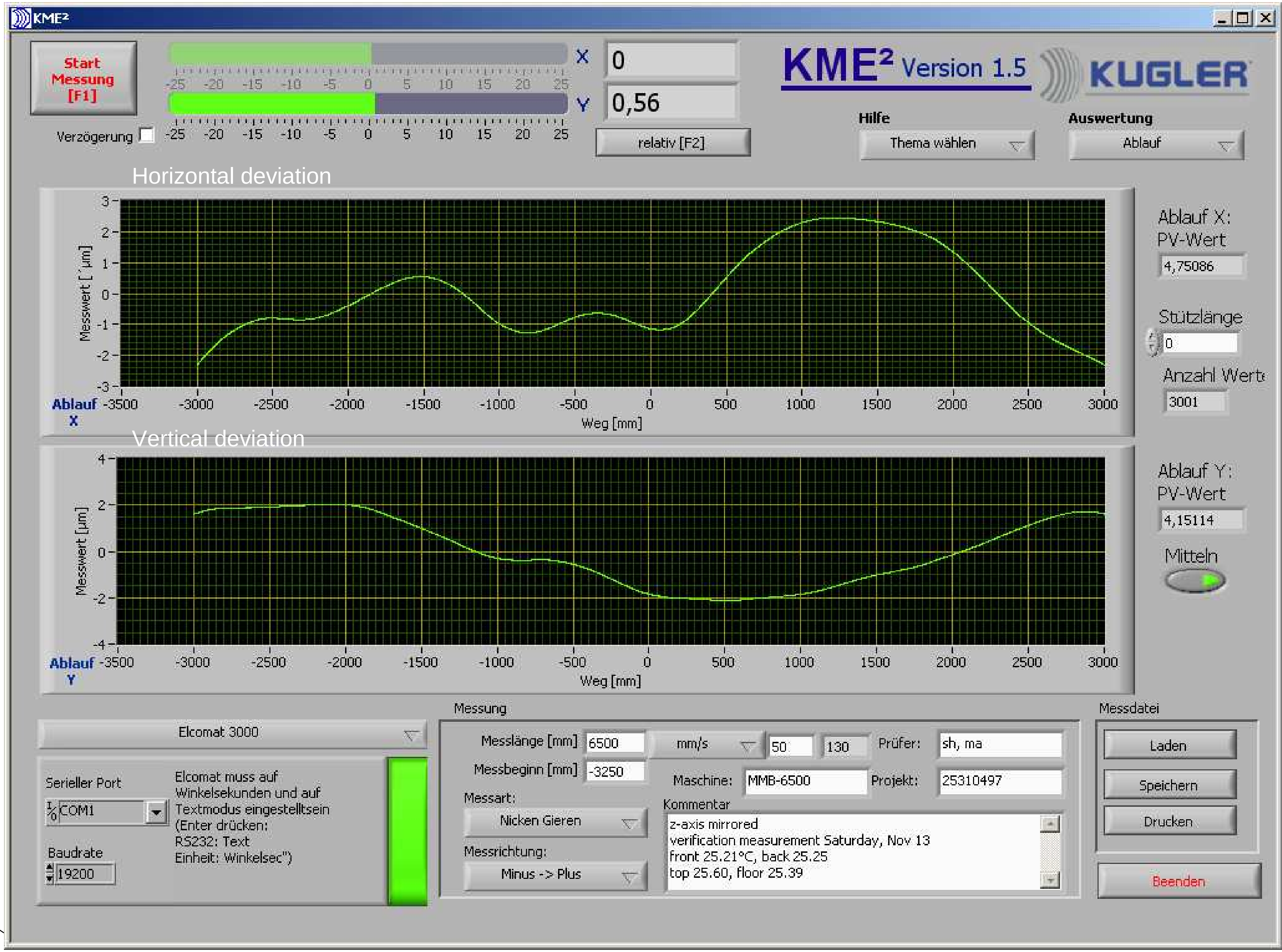

Cable Transport chain
Renishaw laser linear encoder retroreflector
Heidenhain linear scale 100 nm resolution
shielded linear motor
Laser head

Elcomat 3000 2-axis

Operating distance =10m
Accuracy = +/- 0.1 arcsec over any 20 arcsec range
Resolution = 0.05 arcsec
measurement range = +/- 250 arcsec @10m
LabVIEW software available
portable

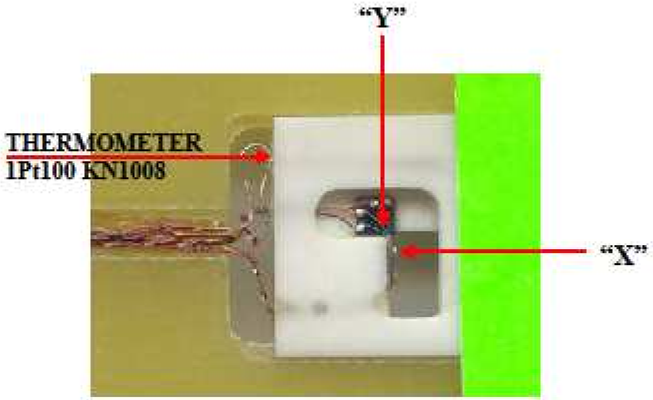
Acceptance test data

MMB6500 Carriage trajectory straightness



Arepoc 2D probe

POSITION OF HALL SENSORS AND THERMOMETER:



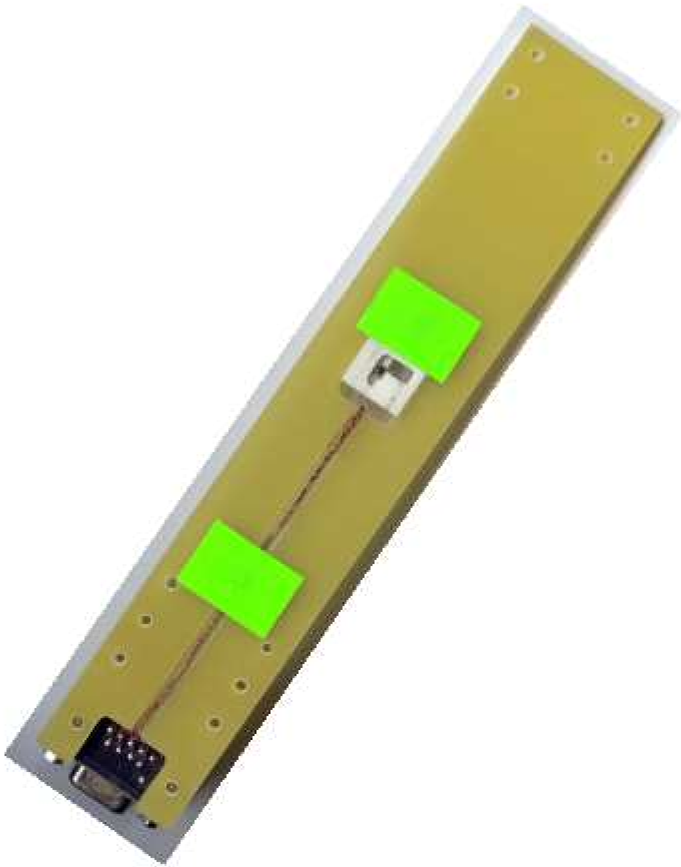
Hall sensors active area dimensions [mm]: 0.05 x 0.05

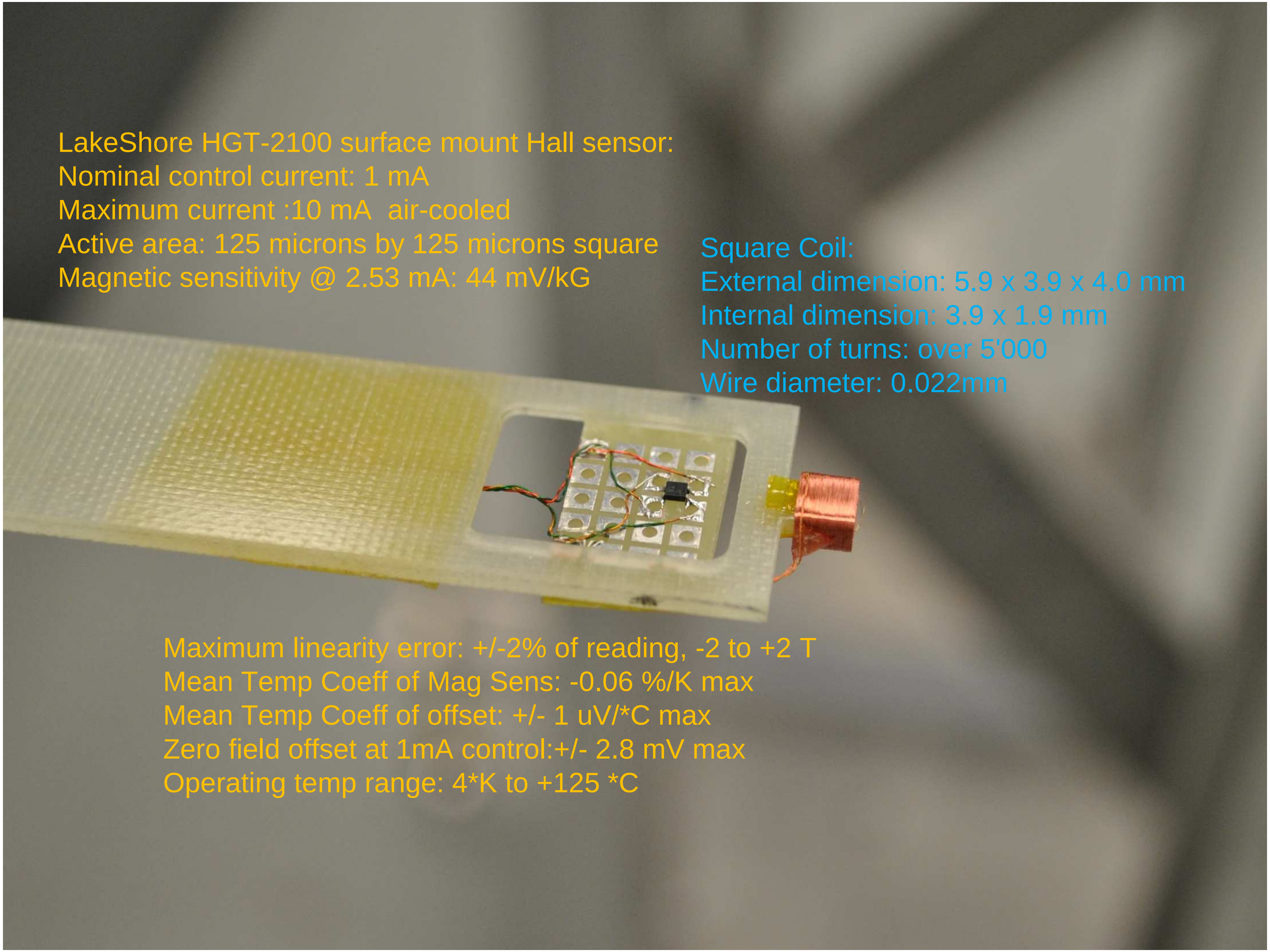
CAUTION !

- **Cool down the sensor slowly in dry atmosphere within 2 - 5 minutes!**
- **The bias current must be switched off during rapid temperature changes (cooling and heating) of the sensor!**
- **After the measurements warm up the sensor using the stream of dry gas!**
- **Do not submerge the Hall probe in organic solvents (ethanol, methanol a. o.)**

AREPOC s.r.o., Iljusinova 4, 851 01 Bratislava, SLOVAKIA
FAX: +421 2 6382 4613 E-mail: arepoc@zmail.sk
http://www.arepoc.sk

ELECTRICAL SPECIFICATIONS OF THE HALL PROBE
HHP-TNK



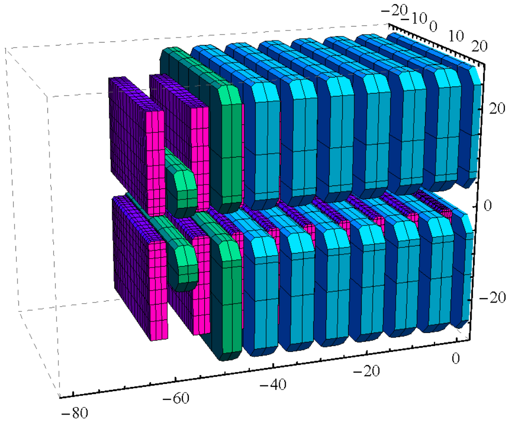

LakeShore HGT-2100 surface mount Hall sensor:
Nominal control current: 1 mA
Maximum current :10 mA air-cooled
Active area: 125 microns by 125 microns square
Magnetic sensitivity @ 2.53 mA: 44 mV/kG
Square Coil:
External dimension: 5.9 x 3.9 x 4.0 mm
Internal dimension: 3.9 x 1.9 mm
Number of turns: over 5'000
Wire diameter: 0.022mm
Maximum linearity error: +/-2% of reading, -2 to +2 T
Mean Temp Coeff of Mag Sens: -0.06 %/K max
Mean Temp Coeff of offset: +/- 1 uV/*C max
Zero field offset at 1mA control:+/- 2.8 mV max
Operating temp range: 4*K to +125 *C

Calibration array partially assembled

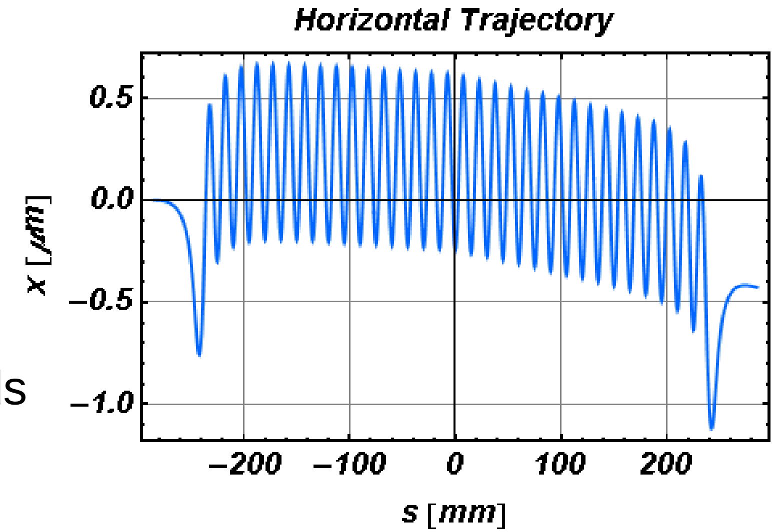
15 mm period
31 periods
5.7 mm gap
~ 0.7 T peak B

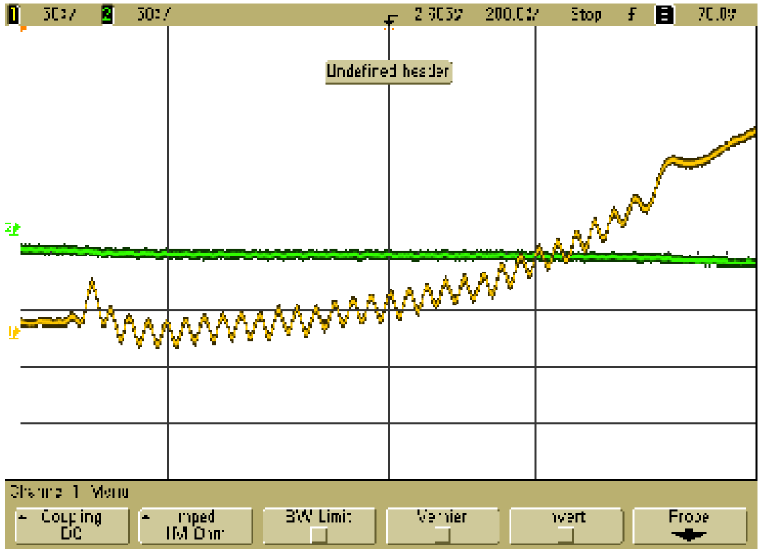
Pulsed-wire survey of Calibration Array

Radia Model



λ_u = 15.0mm
Gap=5.7mm
30 full strength periods

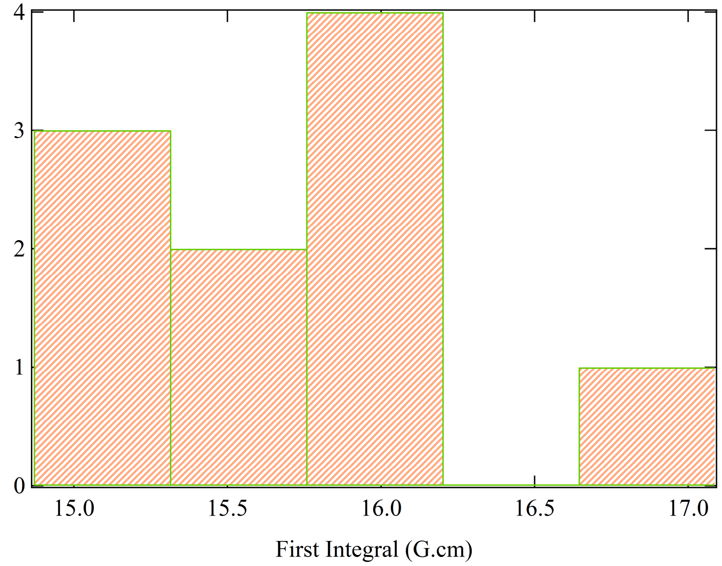


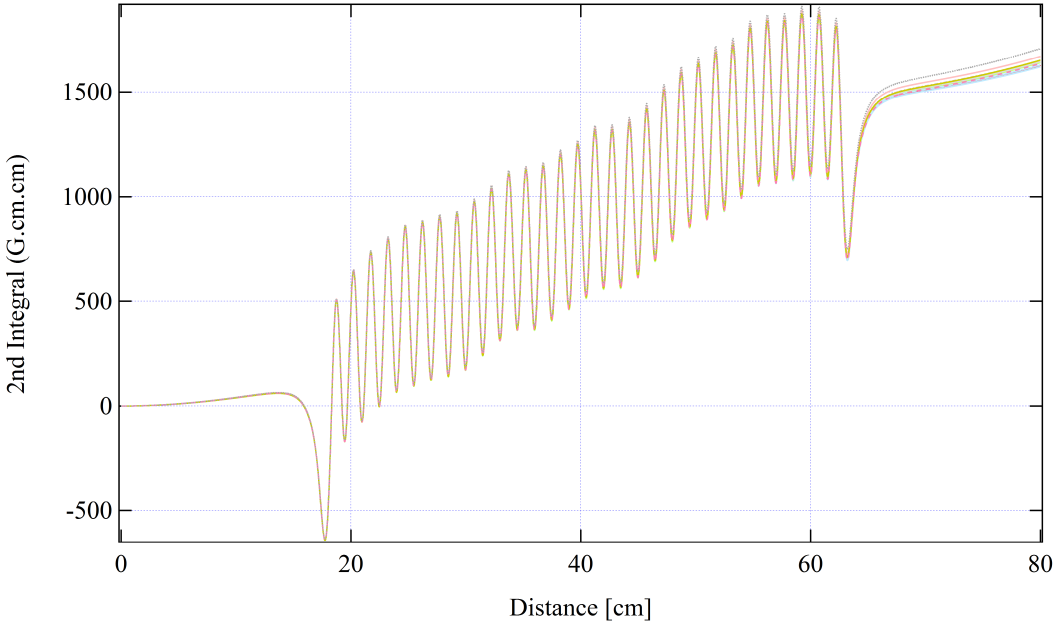


10 Hall Probe Scans of the Calibration Arrays

Hall sensor : LakeShore HGT-2100
Analog Input: NI 9219 (Compact RIO 24bit)
Current source: LakeShore model 102
Scan speed: 10 mm/s
Trigger spacing: 10 / mm
Sampling speed: 100 samples/s

10 scans took approximately 40 minutes



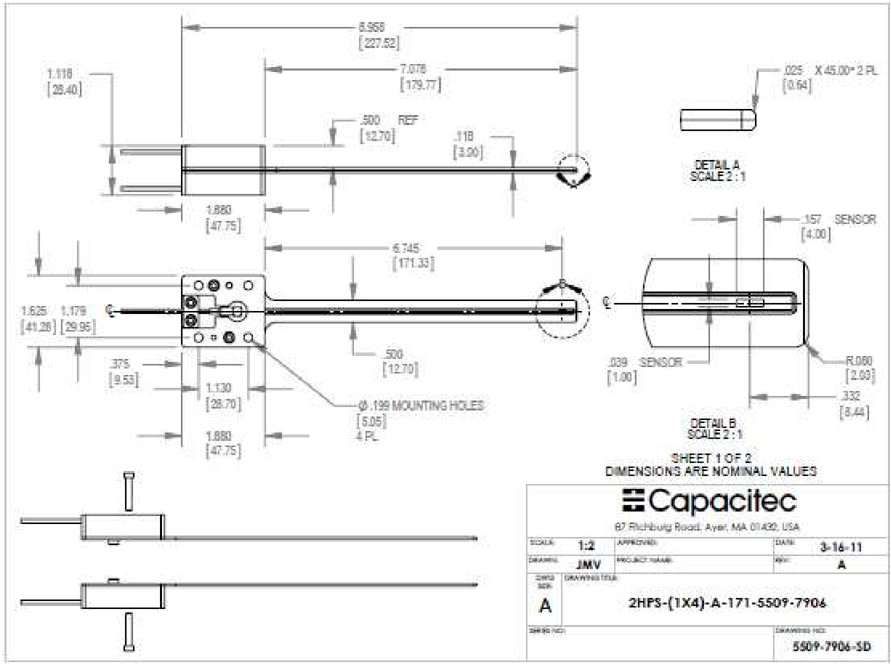


$\Delta\ Iy_{std} = 0.6$ G.cm
$\Delta\ Iy_{pp} = 2.2$ G.cm

$\Delta\ Jy_{std} = 25.5$ G.cm.cm
$\Delta\ Jy_{pp} = 87.5$ G.cm.cm

$\langle\phi_{error}\rangle = 3.15$ deg., $\Delta\ \phi_{error} = 0.01$

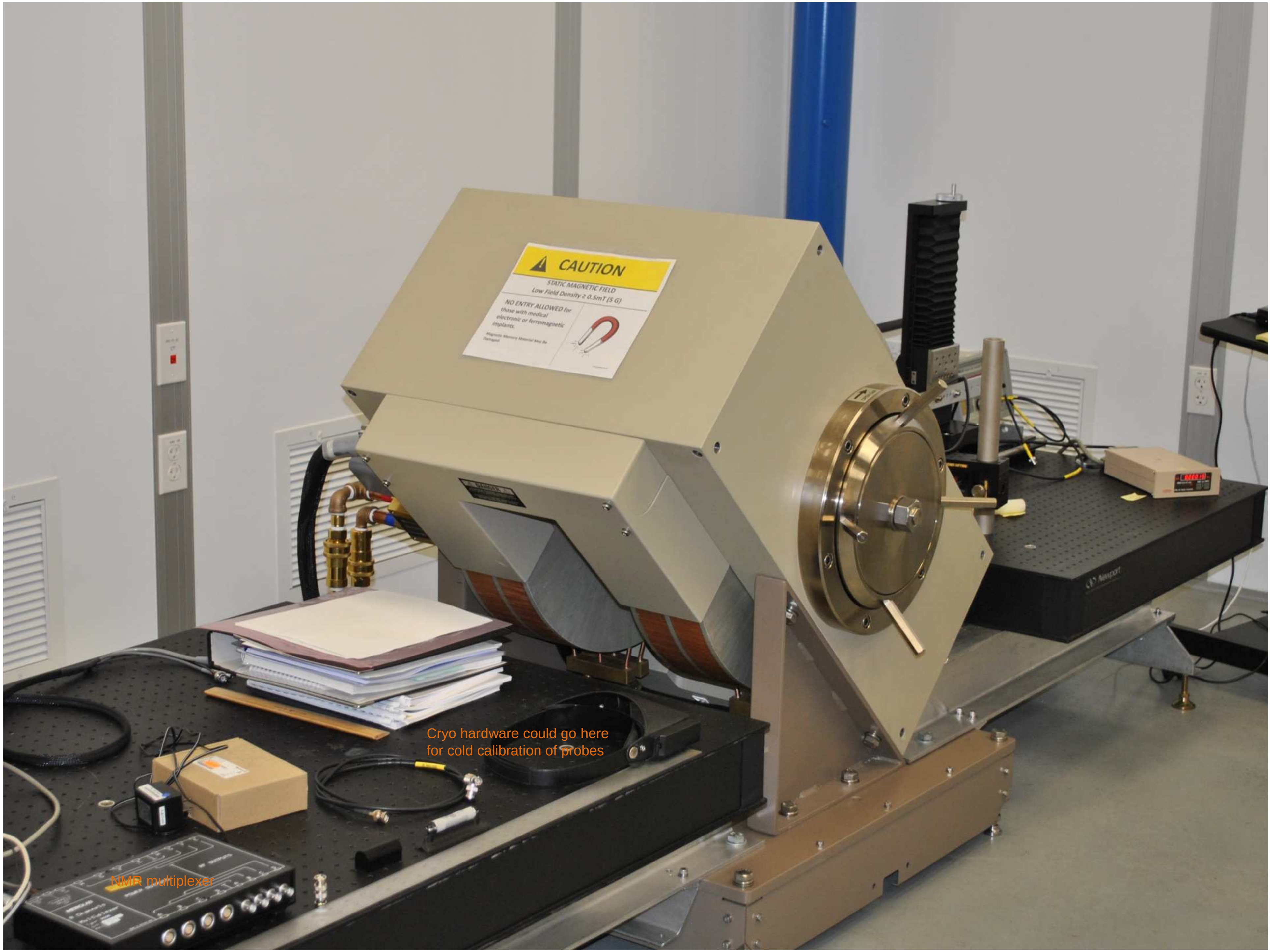
Capacitance probe for on-the-fly surface and gap measurements

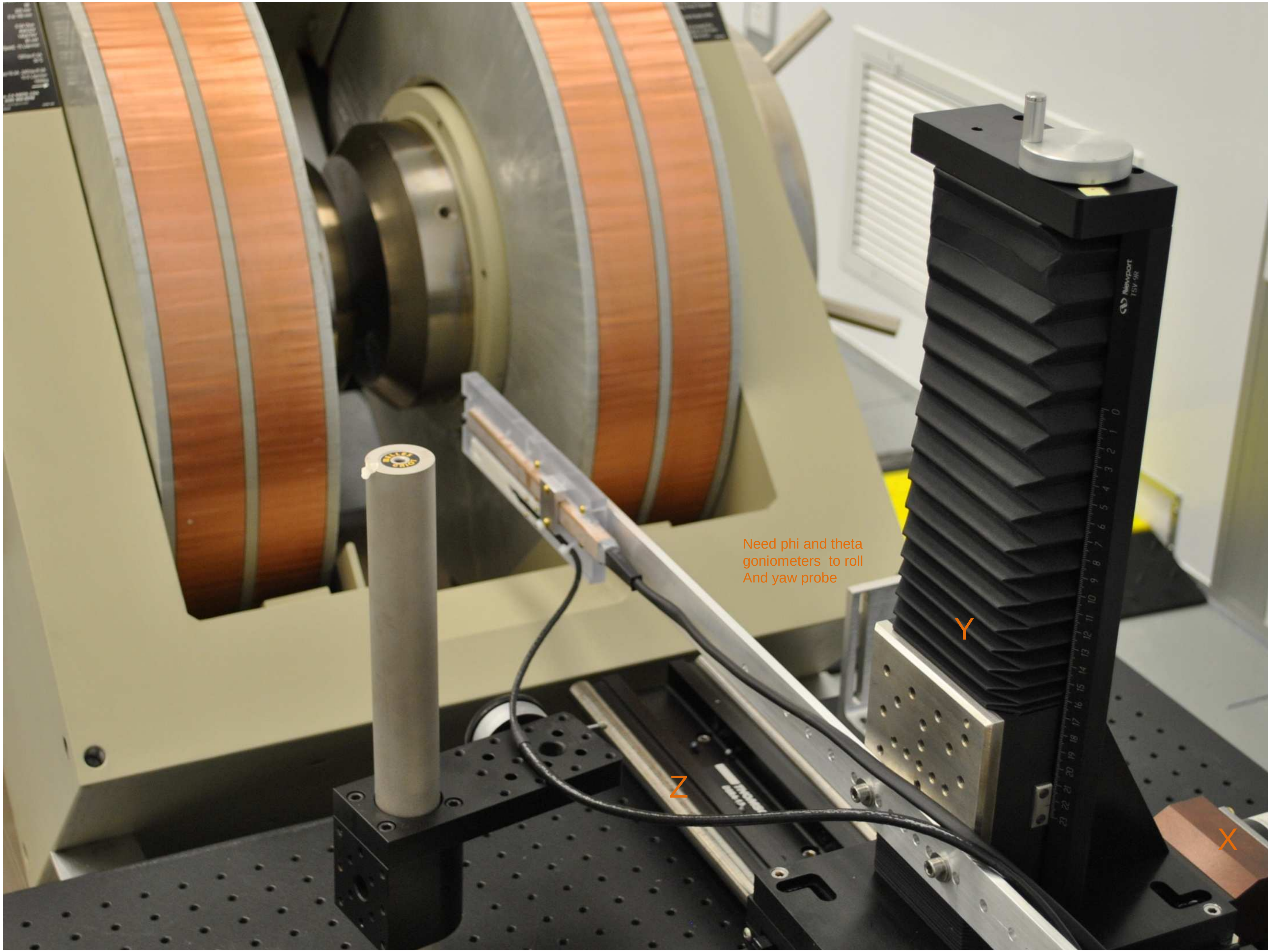


GMW 3474 dipole magnet

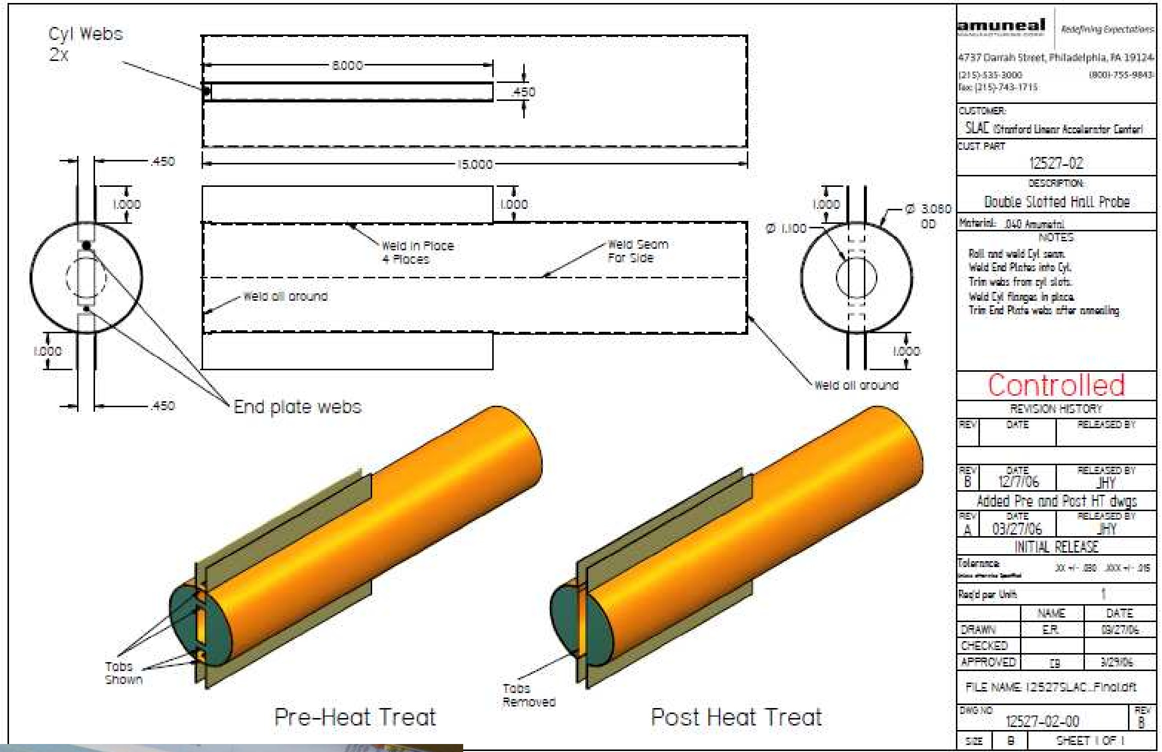
Power supply= Danfysik 853

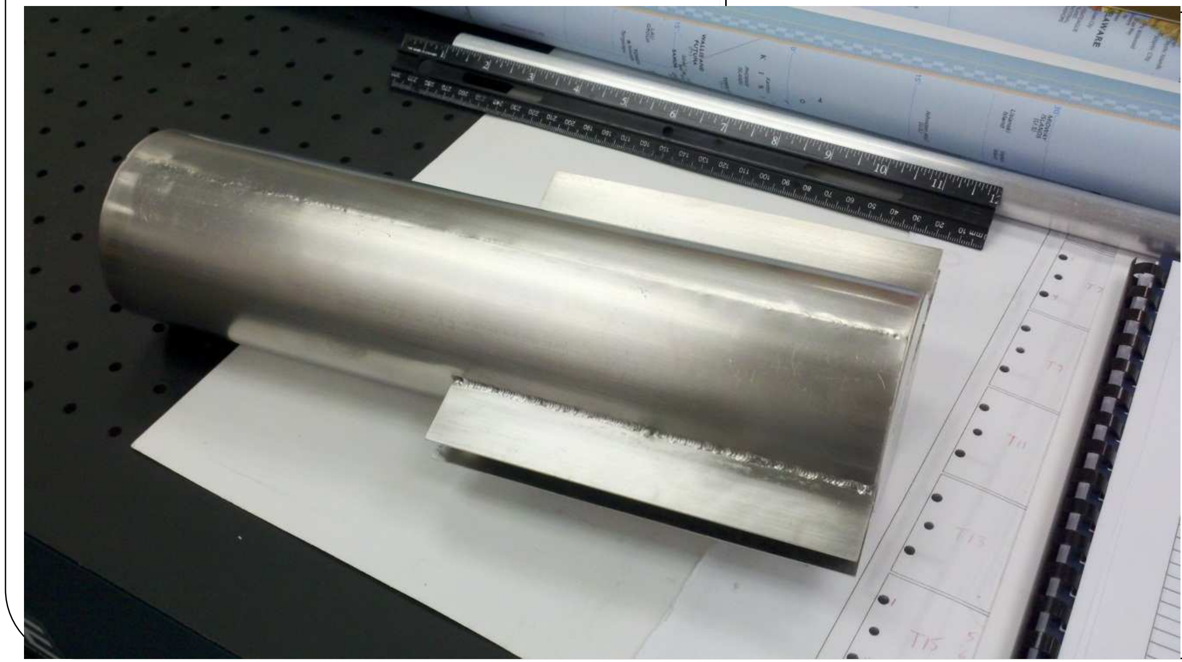
- 160 amps/80V
- Short term stability--+/- 3 PPM
- Long term stability--+/- 10 PPM
- Current reversing switch


CAUTION
STATIC MAGNETIC FIELD
Low Field Density ≥ 0.5mT (5 G)
NO ENTRY ALLOWED for those with medical electronic or ferromagnetic implants.
Cryo hardware could go here
for cold calibration of probes
NMR multiplexer


Need phi and theta
goniometers to roll
And yaw probe
Y
Z
X

Zero-Gauss chamber





Wire measurement overview

The primary tuning of the undulators shall be done by sampling the magnetic field at many points using Hall probes. However, for the calculation of the field integrals, various noise contribution from the Hall probe measurement, when integrated over the undulator length, can exceed the required field integral tolerances. Therefore, an alternative method of measuring the field integrals is desired. Field integral measurements are typically accomplished using a moving-coil and/or a flip-coil.

System Requirement

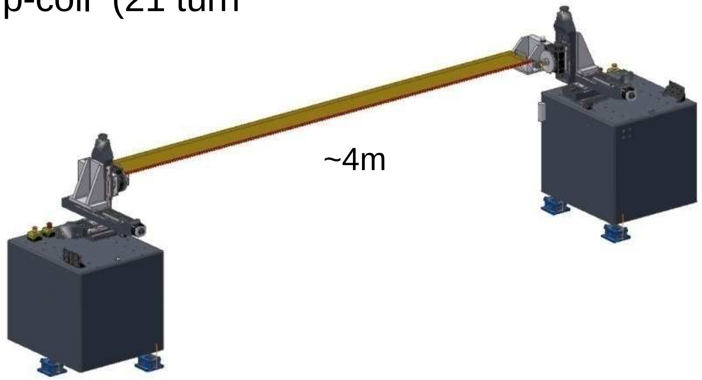
If the first field integral ($I_{1x,y}$) for an NSLS-II undulator is specified not to exceed 5G-cm, then the measurement system should be capable of accurately measuring a first field integral smaller than 0.5G-cm. Similarly, if the allowed variation of horizontal second field integrals (I_{2x}) equaling to 10% of vertical beam size in the middle of a short straight, in an NSLS-II undulator is to be below 300G-cm^2, then the measurement system must be able to measure second field integrals on the order of 30G-cm^2. → Now our Hall probe system may satisfy

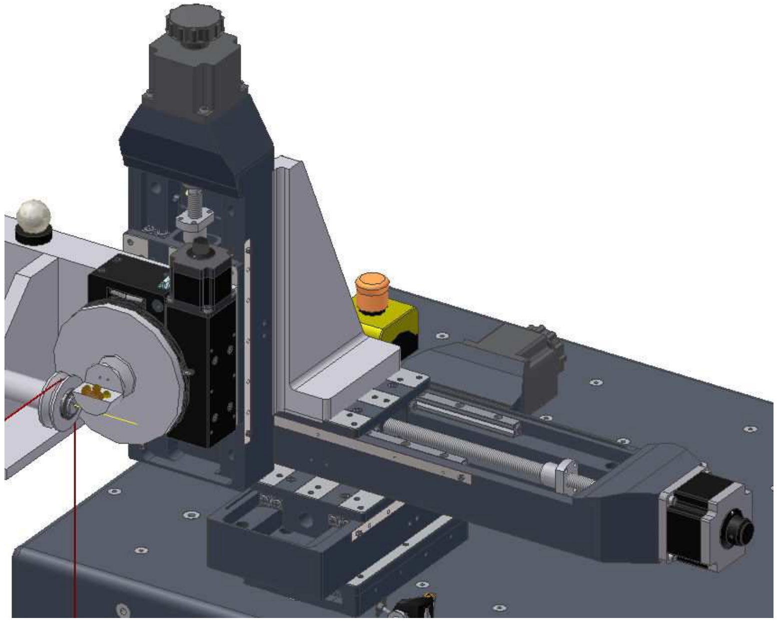
Static vs dynamic scanning

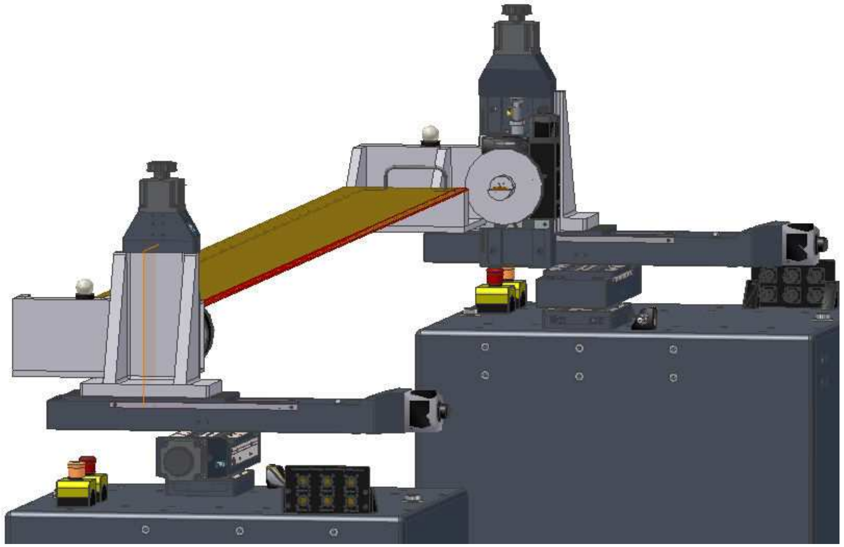
The system can be operated in two modes--static scanning with the flip-coil, and dynamic scanning with the moving-coil--each suited to high-precision and fast measurement.
The system's precision requirement is 0.5G-cm for the static scan method, and 2G-cm for the dynamic scanning 'on-the-fly' method.

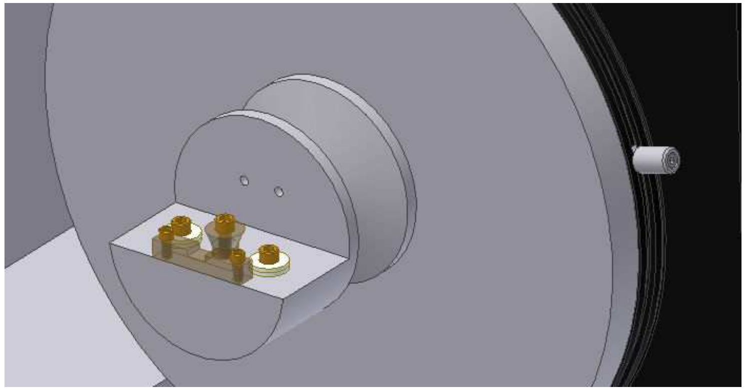
ADC Integrated Field Measurement System

- Moving-coil (150 turns for By, 10 turns for Bx)
- Stretched-wire
- Flip-coil (21 turn

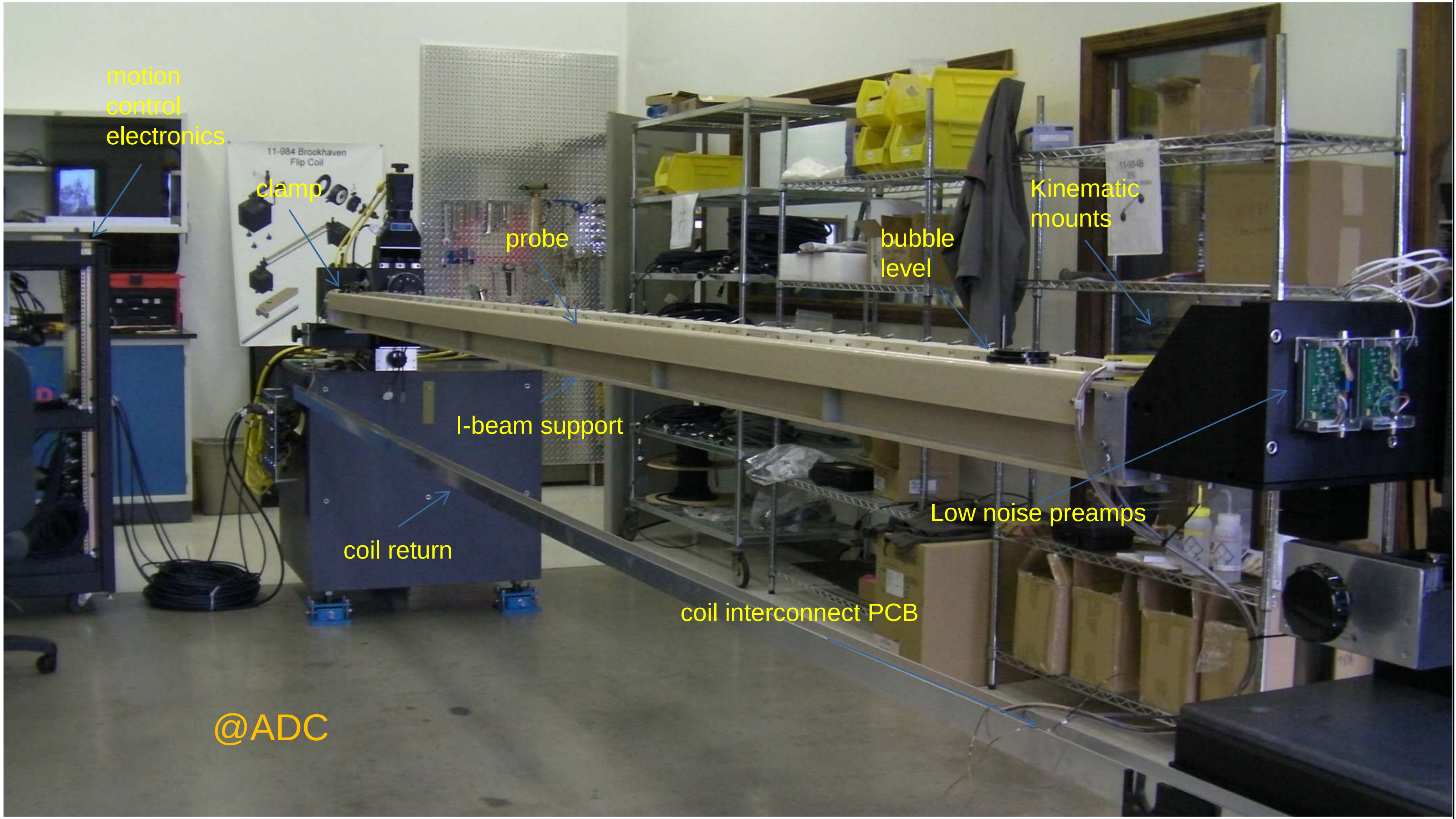




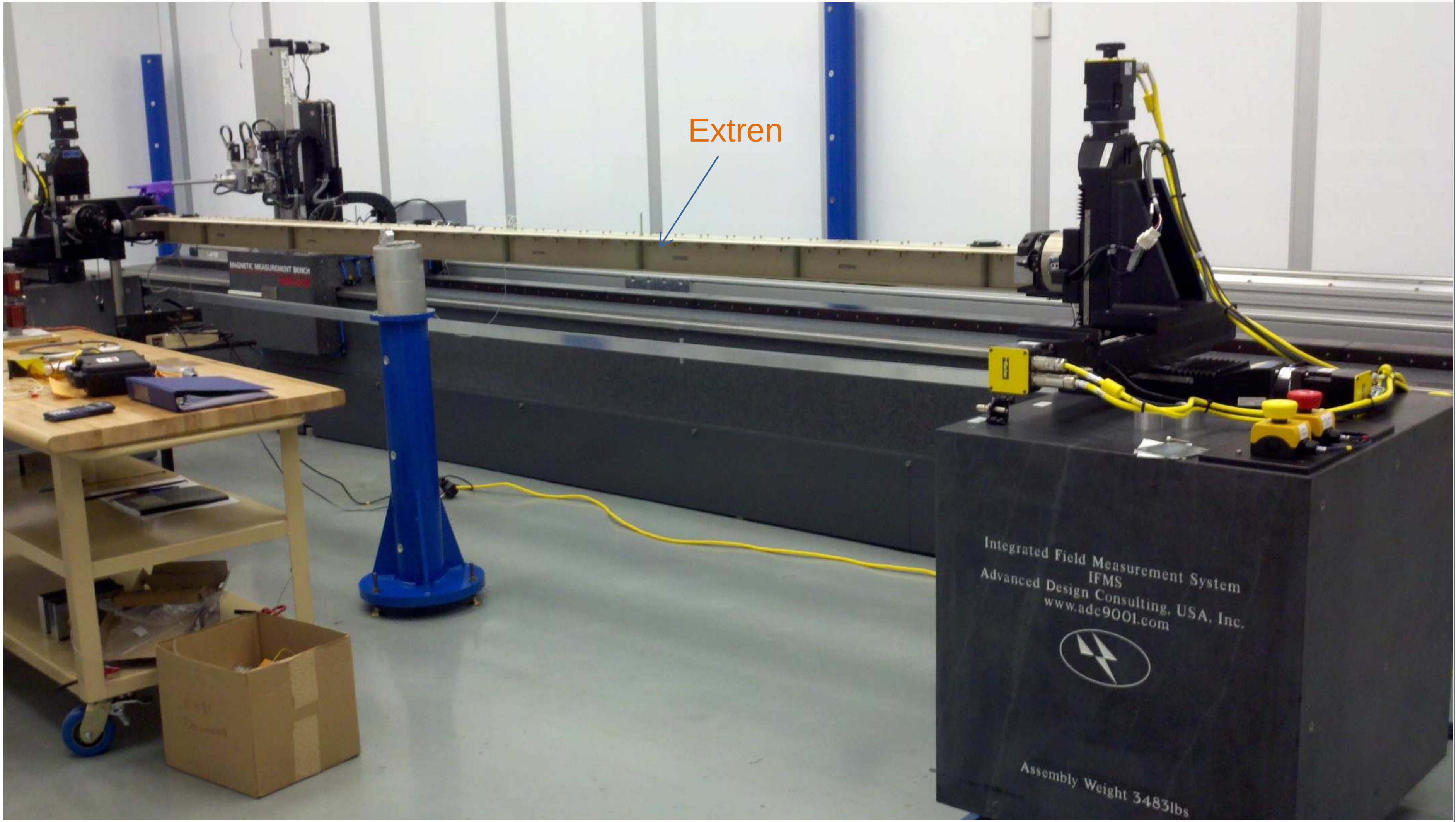




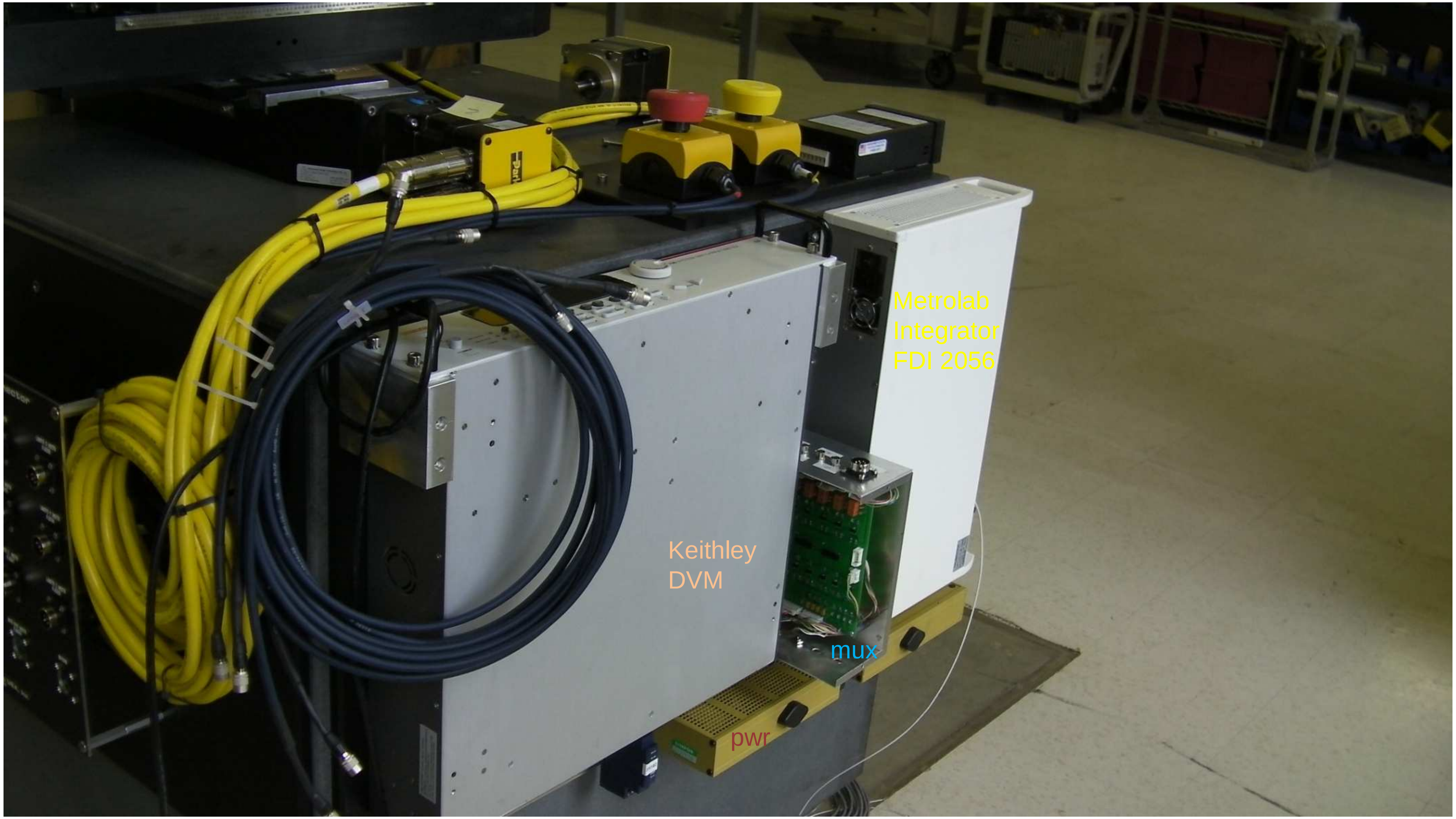
IFMS Moving Coil Probe Factory Test



IFMS Moving Coil Probe installed at BNL



IFMS Electronics



Metrolab 2056 integrator

Features:

- Low noise and low drift
- Ext triggering for on-the-fly DAQ
- Internal time-stamped buffer
- PCI express intfc via NI PXI-8360

Notes:

- PCB used for moving-coil ribbon interconnect
- Relay multiplexor used for wire probe interface to integrator
- Integrator mounted on granite monument

Delta-Tau GeoBrick controller

- 8 axis servo or stepper
- Inc and abs encoders
- RS232, USB and Ethernet
- Integrated motor amps
- Prompt output on position

❖Wire measurement system operation software is IGOR-pro, analysis software is B2E

DAQ issues for FDI 2056

Original Idea:

User Interface: Igor Pro (standard DAQ communication is only via RS232)
Motor controller: DeltaTau GeoBrick via RS232
Integrator: Metrolab FDI 2056 via XOP (C language interface module) via PXI bus

Intermittent spurious signals cannot be eliminated
Drift must be compensated
Power Integrator on first, then PC on
~~No official Metrolab support for C language routines~~

→ Official C routine support??

DAQ by Labview Vi provided by Metrolab
→ output data only in xml file
Intermittent spurious signals still cannot be eliminated

Kyma Helmholtz coil assembly

Magnet-Physik EF5 electronic fluxmeter

Magnet Characterization (used for sorting)

Equipment which can be used:

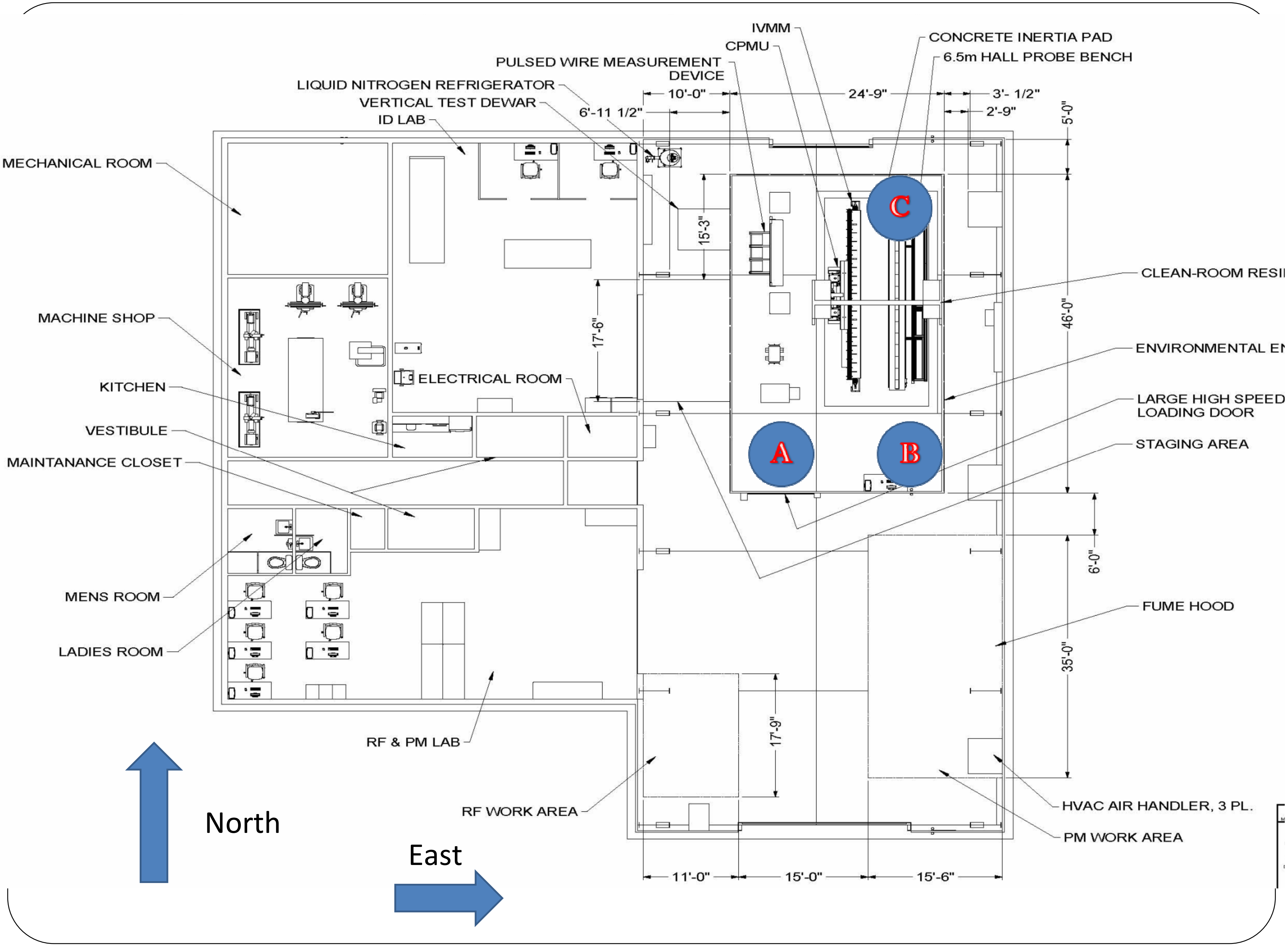
- Flip-coil + jig (ADC method)
- Fluxgate magnetometer + jig (old BNL method)
- Helmholtz with jig (new BNL method)

Kyma system parameters

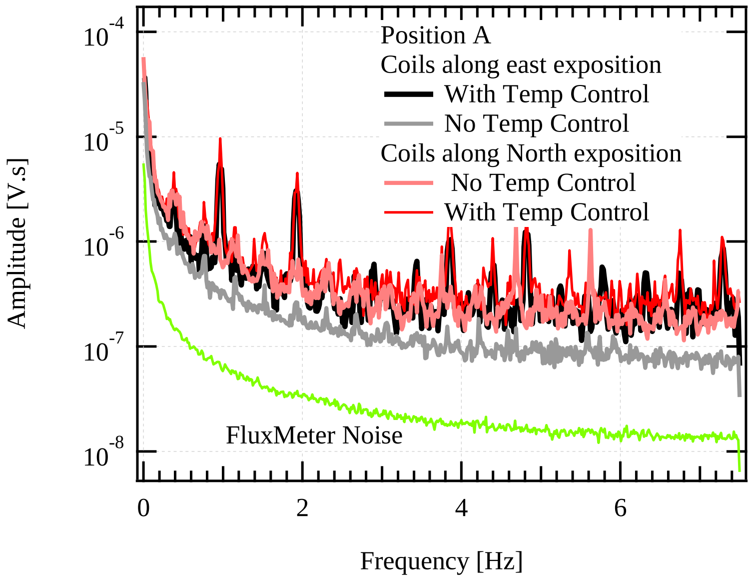
- **Coil diameter = 860 mm**
- **Number of wire turns: 3000**
- **Overall dimensions = 50 x 60 x 130 cm^3**
- **Weight = ~ 42 kg**
- **Max acceptable magnet size = 75 x 75 x 75 mm^3**
- **Flux measurement (moments) resolution = $1x10^{-6}$ Vs**
- **Flux measurement (moments) repeatability = $2x10^{-5}$ Vs**
- **Overall measurement repeatability = 0.02 %**
- **Overall accuracy (trueness + precision) for main moment = 0.5%**
- **Angle measurement resolution = 0.01 deg**
- **Angle measurement repeatability = 0.05 deg**

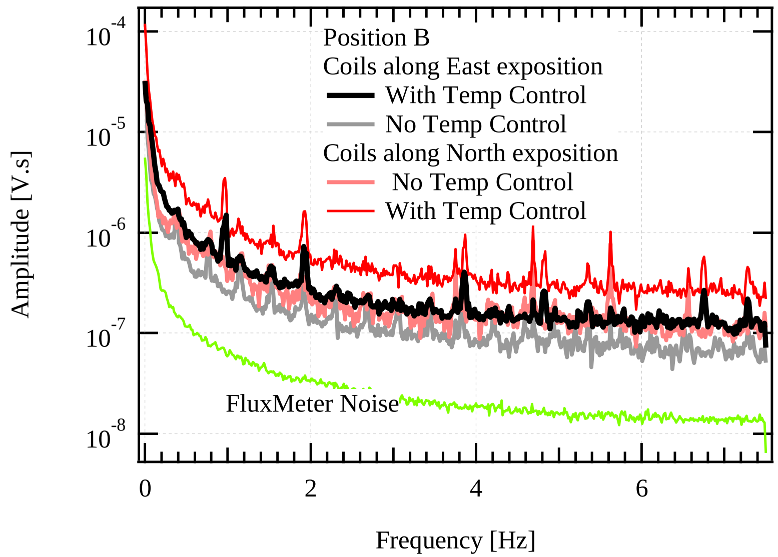
- **Automatic drift correction**
- **Self-adjusts to built-in voltage-time reference**

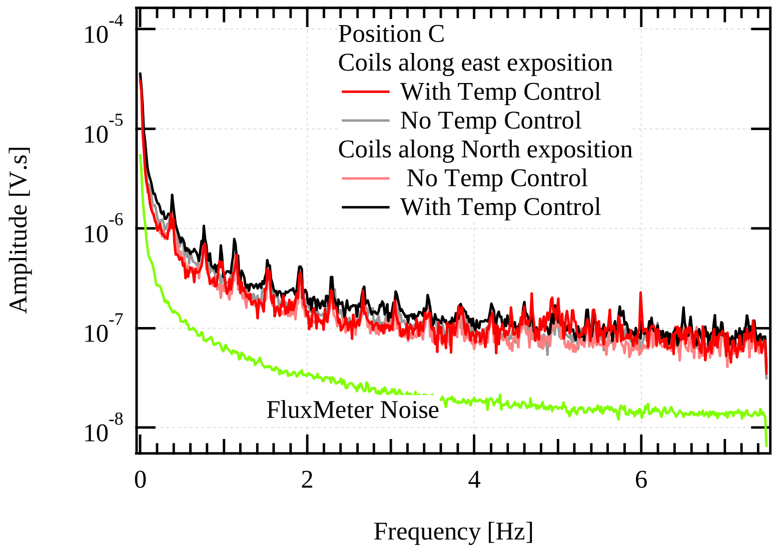
→ Does not trigger by line with 60 Hz !!!


IVMM
CPMU
CONCRETE INERTIA PAD
6.5m HALL PROBE BENCH
PULSED WIRE MEASUREMENT DEVICE
LIQUID NITROGEN REFRIGERATOR
VERTICAL TEST DEWAR
ID LAB
MECHANICAL ROOM
MACHINE SHOP
KITCHEN
VESTIBULE
MAINTANANCE CLOSET
MENS ROOM
LADIES ROOM
ELECTRICAL ROOM
RF & PM LAB
RF WORK AREA
CLEAN-ROOM RESI
ENVIRONMENTAL EN
LARGE HIGH SPEED LOADING DOOR
STAGING AREA
FUME HOOD
HVAC AIR HANDLER, 3 PL.
PM WORK AREA
10'-0"
24'-9"
3'- 1/2"
6'-11 1/2"
2'-9"
5'-0"
15'-3"
17'-6"
46'-0"
6'-0"
35'-0"
17'-9"
11'-0"
15'-0"
15'-6"
A
B
C
North
East

Amplitude spectrum







In-Vacuum Magnetic Measurement System (IVMMS)

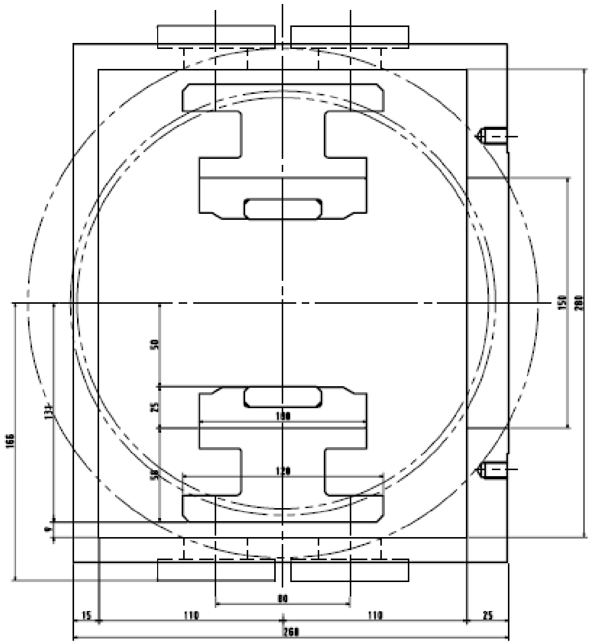
(for survey of IVUs and CPMUs)

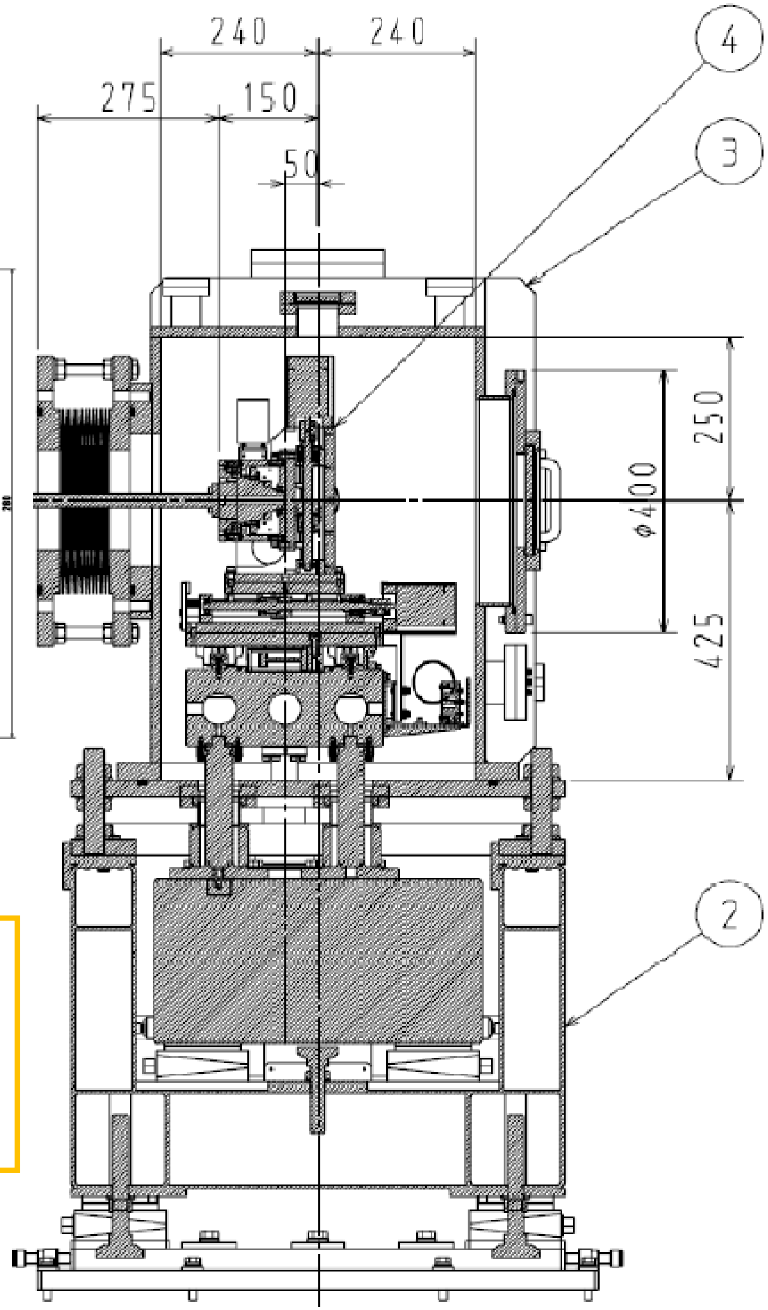
Toyama has been awarded the contract. We are approaching the PDR

- We provide specs and 'conceptual' design approaches—vendor selects design
- Z-axis travel—1.75 m, with the design scalable to 4.5 m
- Operational vacuum—10^-5 torr
- Low temperature operation to 40 *K—CPMU survey
- X,Y,Z and R axis control—maybe additional stages for probe orientation
- Smooth, precise Hall probe translation—minimize roll, pitch and yaw
- With or without probe trajectory compensation—pre-mapped or on-the-fly
- Thermal shielding of motion controlled assembly
- Compensation of the vacuum load
- Cable management

Toyama is designing

NSLS-II IVMMS





Issues:

- Thermal load for cryogenic meas.
- Vacuum compatible lubricant
  (Dicronite, Defric coating, etc.)

Contracted to Toyama, Inc., Japan

Survey


Laser Tracker
www.faro.com
FARO


FARO Arm

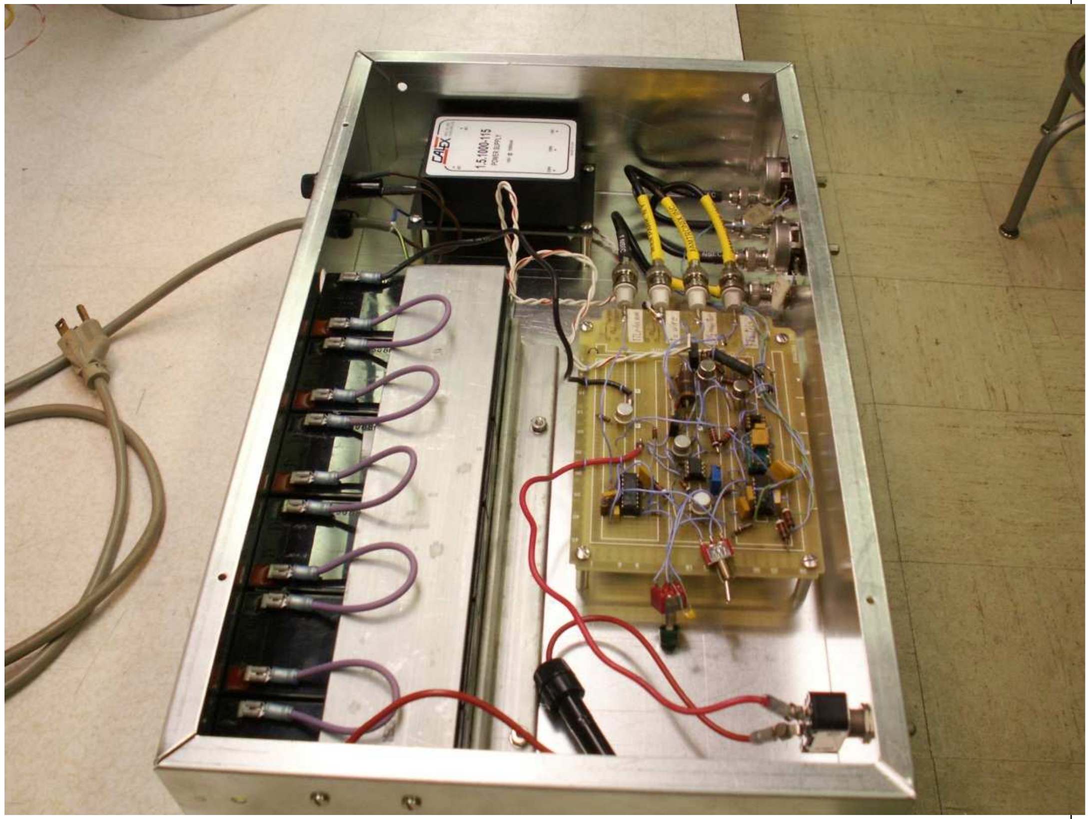

Spherically Mounted Reflector

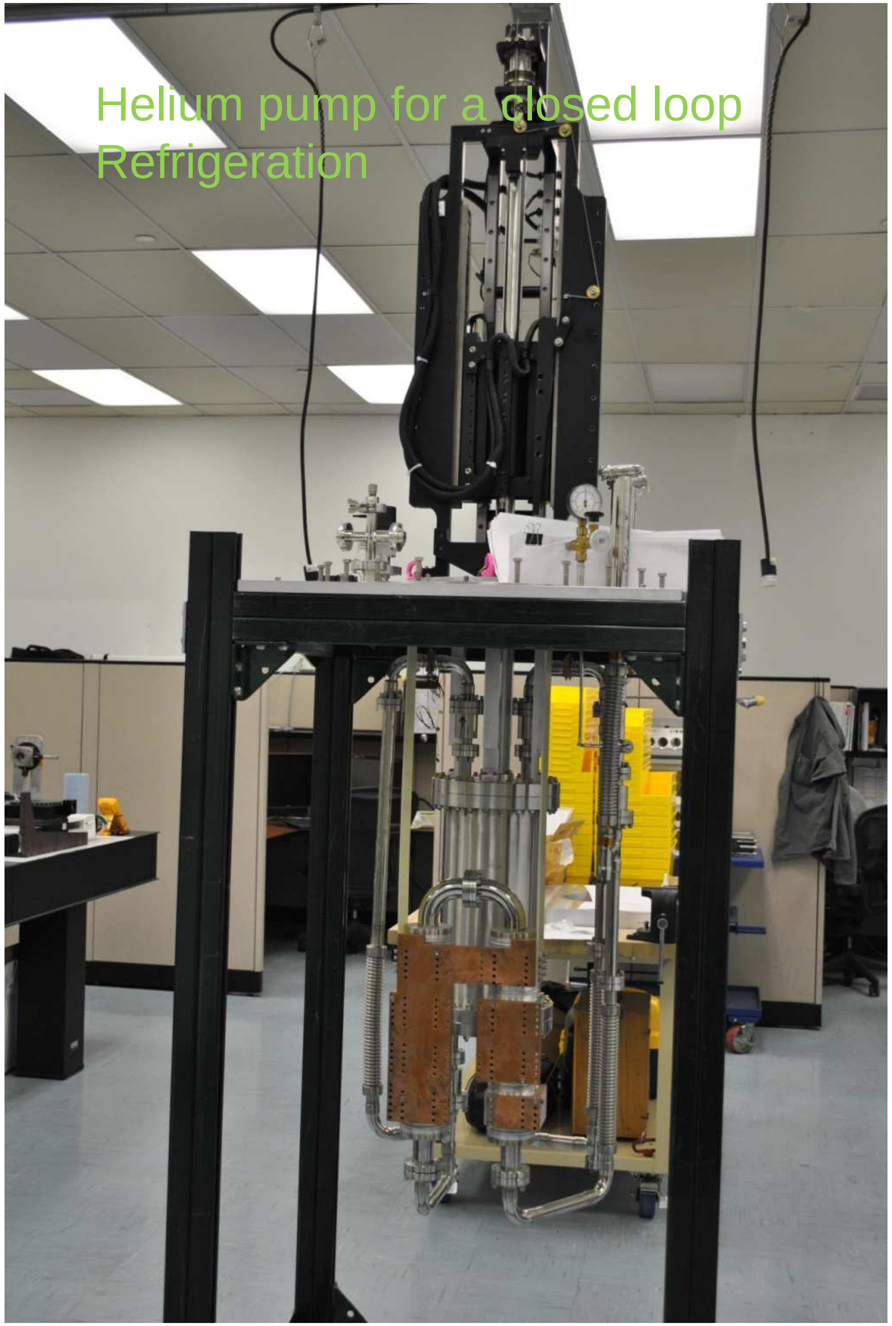

Tracker and Arm


UISHER

Novel HV Pulser

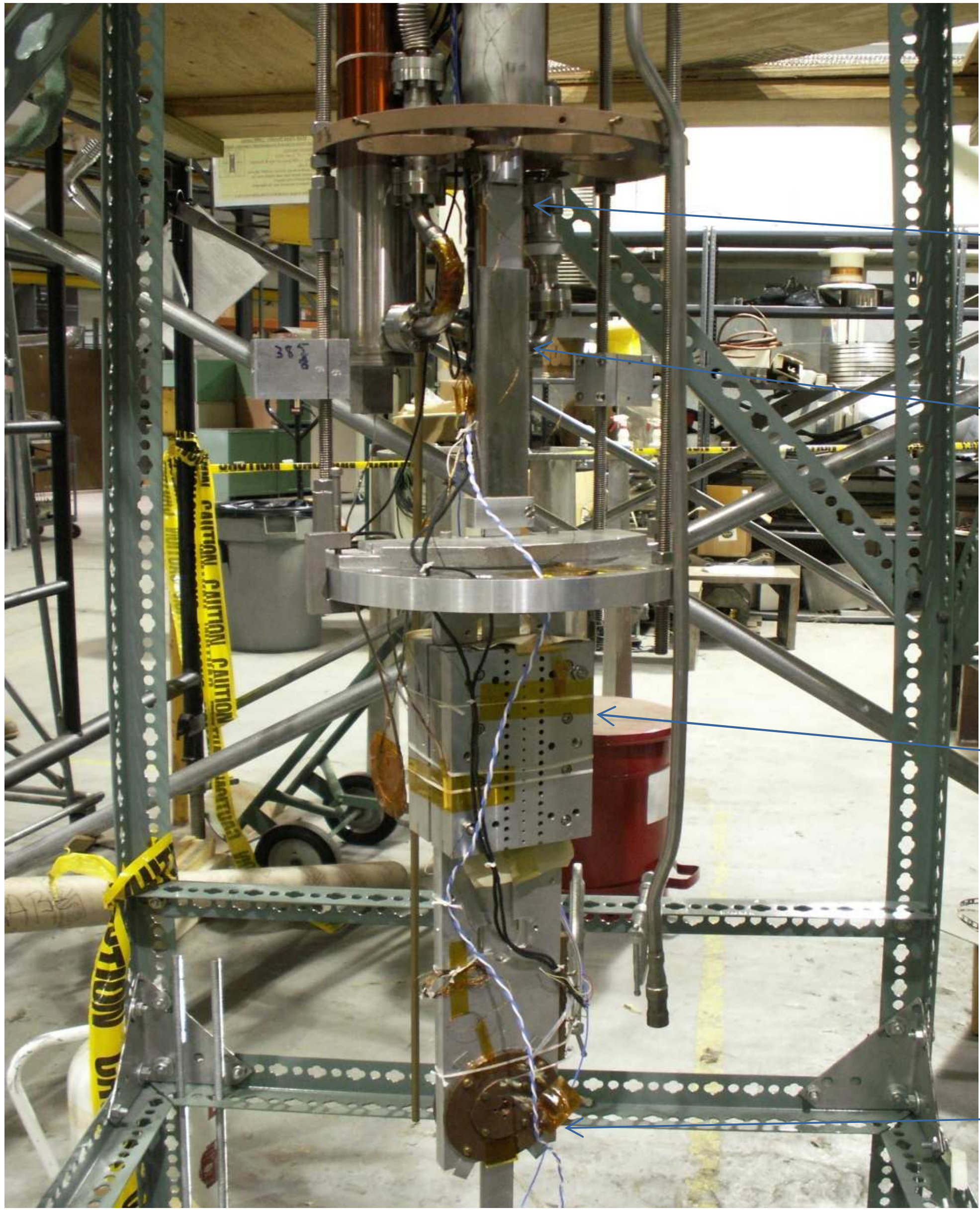
- Commercial pulse generator incapable to meet our requirement (50V-2A, 20ms flat-top)
- The unit can provide a pulse repetition range of 1 pulse every 12 seconds to 5 pulses per second and a pulse width range of 250 μs to 25 ms.
- 16, small, 12 V, 1.2 amp-hour, lead-acid batteries
- The unit is housed in a 17” long by 10” wide by 4” deep enclosure which is mountable in a 19” rack.
- Improved unit (200V) is being designed.




Helium pump for a closed loop
Refrigeration


Vertical Test Facility (VTF)

Vertical Test Facility (VTF)—originanally designed for SCU survey



❖May use closed-loop He-vapor cooling for future HTC SC designs

Summary

- ACS Environmental Enclosure—
  operational bugs rectified. Soon to be purified for class 10000 operation.

- Kugler Hall Probe Bench—
  installed and tested. Motion control and data ACQ interface via LabVIEW VI have been completed.
  Must integrate autocollimator and capacitance probe into the system.

- Calibration dipole and NMR are operational—
  probe holder and motion controlled assembly must be upgraded for automated calibration.

- Integrated Field Measurement System (IFMS)—
  Modification for integrator software is needed. Keithley voltmeter option is considered as a back-up.
  Refine the tuning of rotating motors.

- Helmholtz coil system—Kyma must fix “Magnet Physik” integrator problem.

- In Vacuum Magnetic Measurement System (IVMMS)—upcoming FDR with Toyama.

- Vertical Test Facility (VTF) & Closed circuit He refrigerator system—
  Top hat assembly has been placed on new stand, modifications to the refrigerator to be made.