Recent activities at NSLS-II Insertion Device Magnetic Measurement Facility

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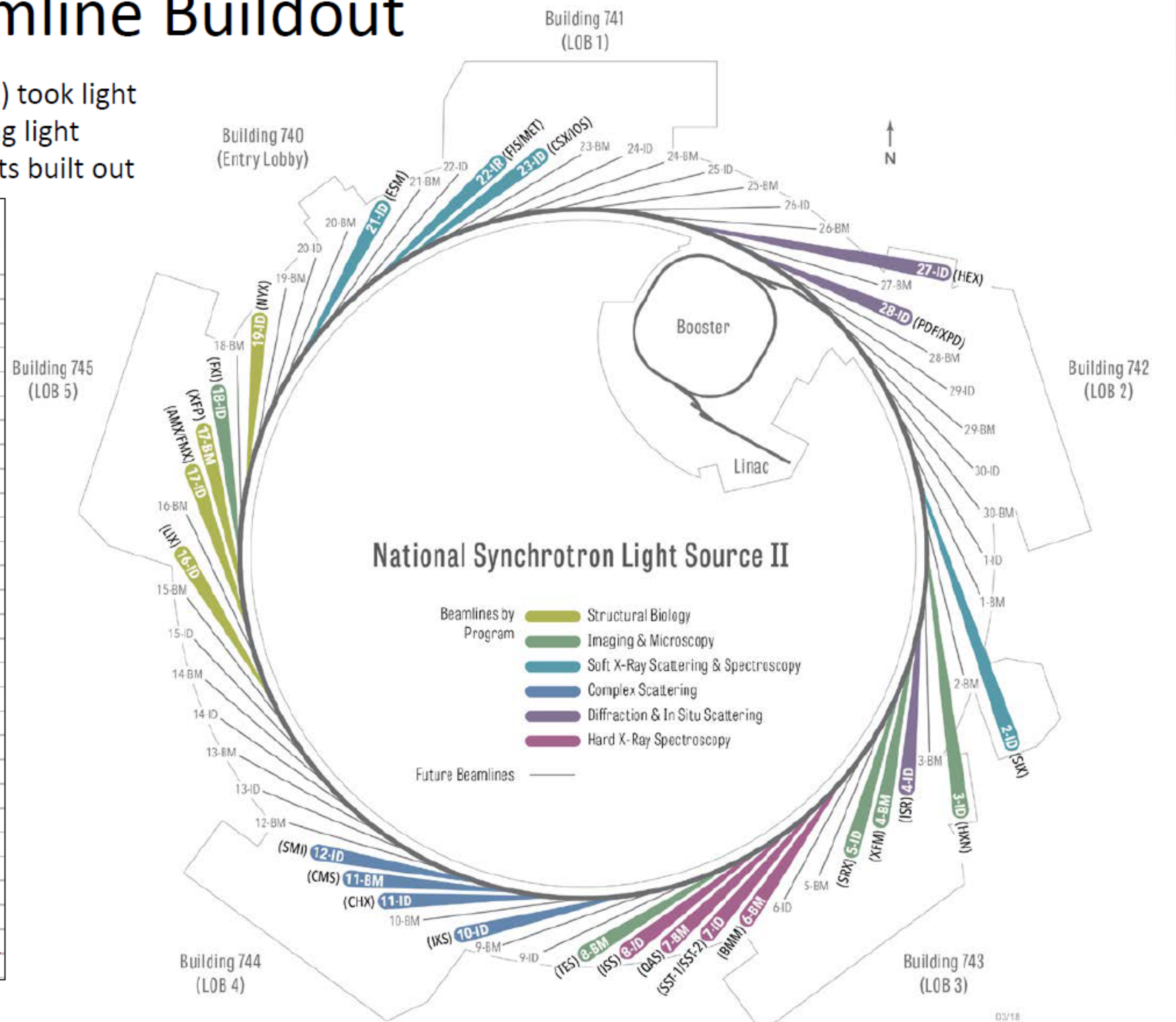
Outline

- NSLS-II Beamline Buildout
- Current Installations of NSLS-II Insertion Devices (IDs)
- Brief Introduction of NSLS-II ID-Magnetic Measurement Facility (MMF)
- HXN-IVU mechanical failure and magnetic retuning efforts
- Superconducting Wiggler (SCW) for High Energy Engineering X-ray Diffraction (HEX) Beamline
- New pulsed wire setup and MV2 Hall probe test.
- Summary

NSLS-II Beamline Buildout

- Fall 2014: First beamline (CSX) took light
- End 2018: 28 beamlines taking light
  - Nearly ½ of NSLS-II ports built out

Port: Instrument
23-ID-1: Coherent Soft X-ray Scat
23-ID-2:Coherent Soft X-ray Spectr & Pol
10-ID: Inelastic X-ray Scattering
11-ID: Coherent Hard X-ray Scattering
28-ID-2: X-ray Powder Diffraction
3-ID: Hard X-ray Nanoprobe
5-ID: Sub-micron Res X-ray Spec
16-ID: X-ray Scattering for Biology
8-ID: Inner Shell Spectroscopy
17-ID-1: Frontier Macromolecular Cryst
17-ID-2: Flexible Access Macromolecular Cryst
21-ID: Photoemission-Microscopy Facility
11-BM: Complex Materials Scattering
4-ID: In-Situ & Resonant X-Ray Studies
8-BM: Tender X-ray Absorption Spectroscopy
17-BM: X-ray Footprinting
12-ID: Soft Matter Interfaces
19-ID: Microdiffraction Beamline
2-ID: Soft Inelastic X-ray Scattering
6-BM: Beamline for Mater. Measurements
7-BM: Quick X-ray Absorption and Scattering
4-BM: X-ray Fluorescence Microscopy
18-ID: Full-field X-ray Imaging
7-ID-1: Spectroscopy Soft and Tender
7-ID-2: Spectroscopy Soft and Tender
28-ID-1: Pair Distribution Function Diffraction
22-BM-1: Frontier Synchrotron Infrared Spectroscopy
22-BM-2: MET
27-ID: High Energy Engineering X-ray Diffraction

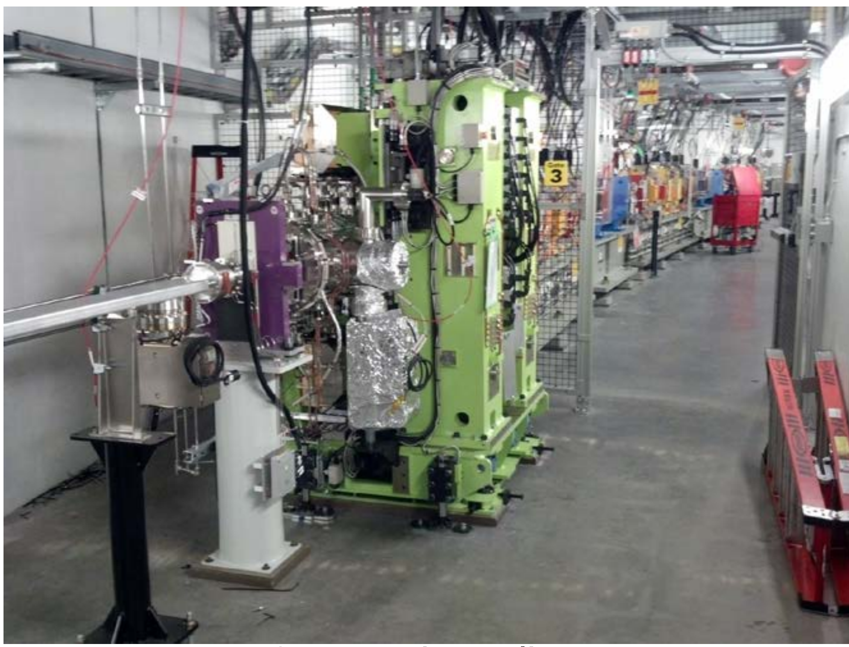


NSLS-II Insertion Devices Current Installation

- 2 x 3.0m-In-Vacuum Undulators (IVU20)
- 1 x 3.0m-IVU22 (Long Straight)
- 3 x 1.5m-IVU21s (two for canted config.)
- 2 x 2.8m-IVU23s (canted : LS)
- 1 x 2.8m-IVU23 (LS)
- 1 x 1.0m-IVU18 (canted)

- 6 x 3.4m-Damping Wigglers-DW100 (LS)
- 2 x 2.0m-Eliptically Polarizing Uundulator EPU49s
- 1 x 2.8m-EPU105 and 1 x 1.4m-EPU57 (in-line configuration)
- 1 x 3.5m-EPU57 (LS)
- 1x1.6m-U42 and 1x 1.0m-EPU60 (canted)

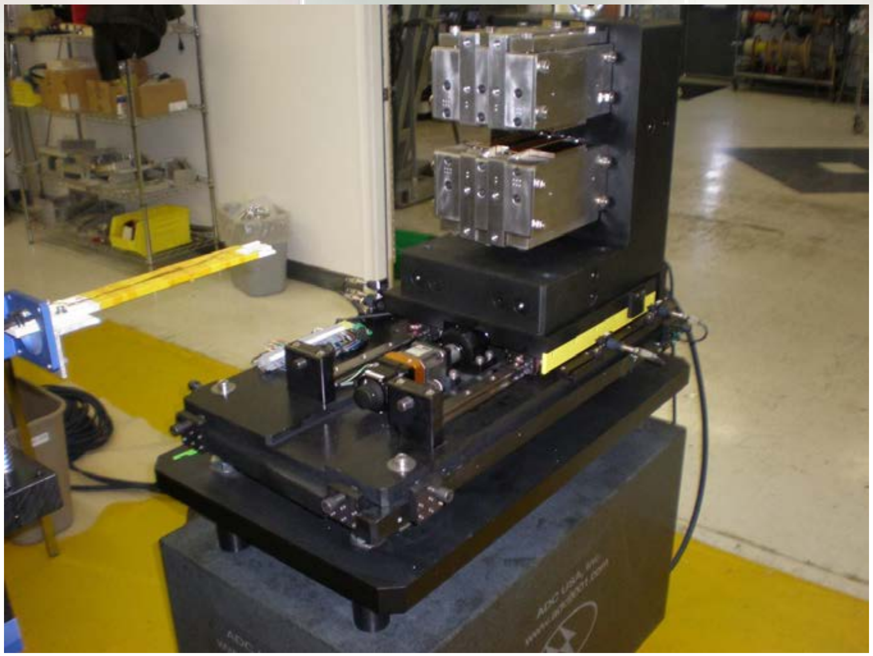
13 Different Types to Maintain!!

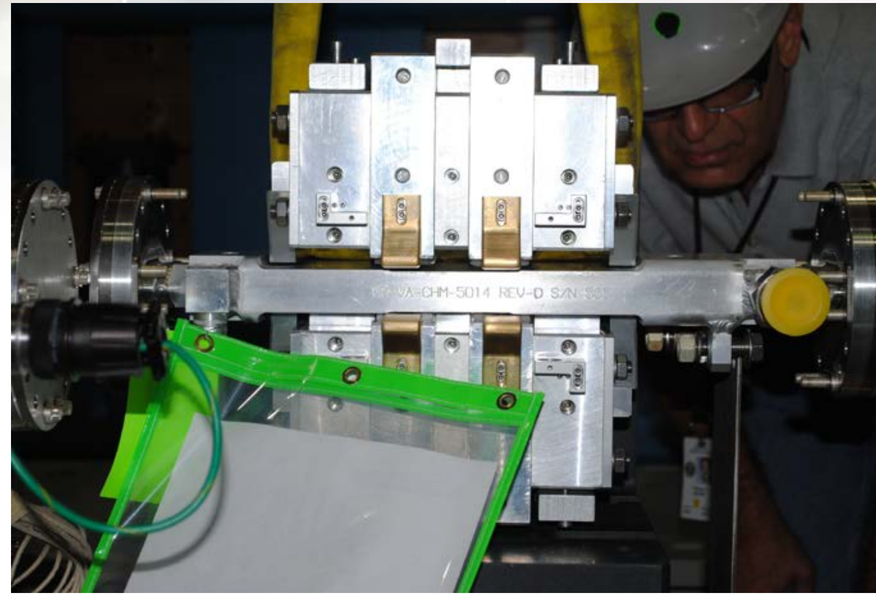


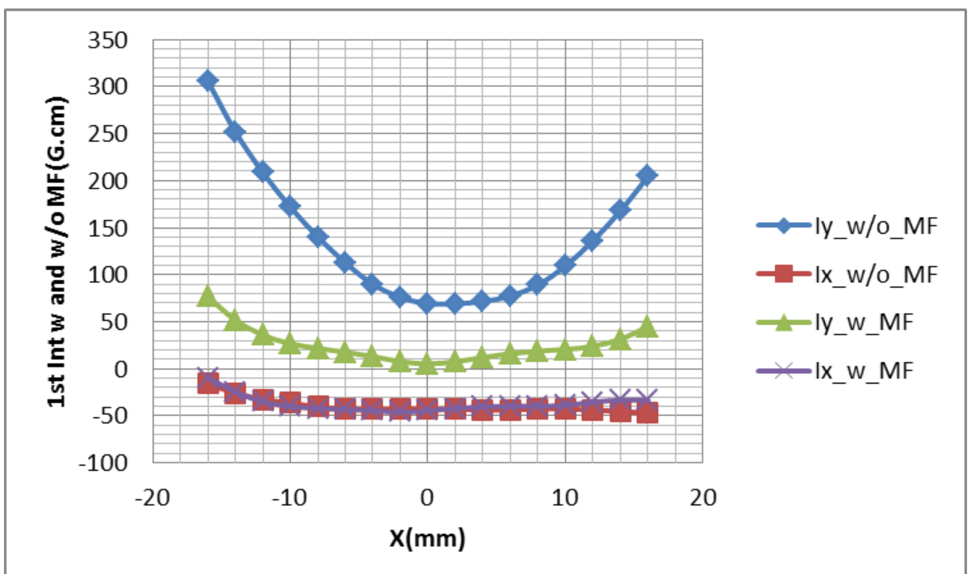
1.5m-IVU21 for SRX beamline

3.4m Damping Wigglers in tandem configuration

3PW Photos & Magnetic Measurement Results

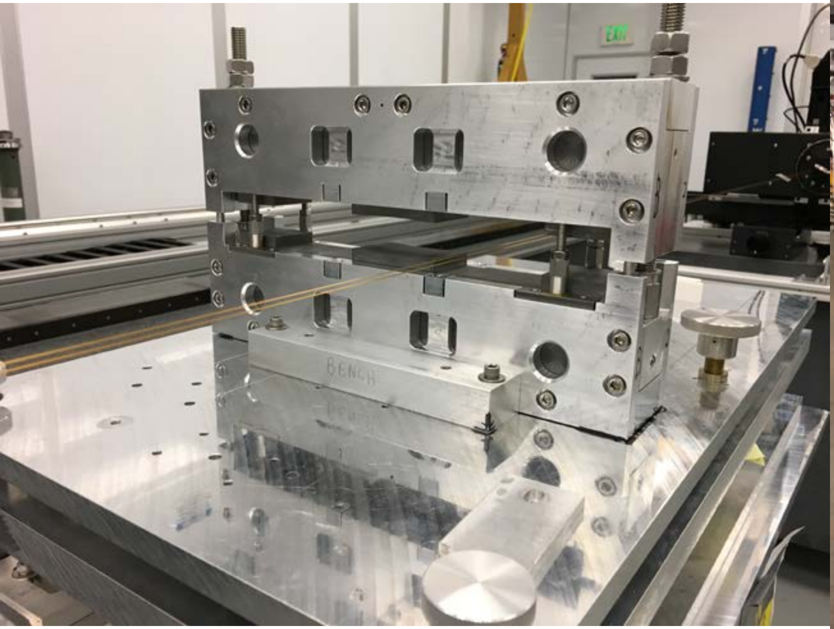






PM Canting Magnets (ESRF Design) in SST Straight

- Thanks to thinner vacuum chamber than other canted straights, PM (SmCo) canting magnets can be utilized for the SST Straight.
- Canting angles are 1mrad, -2mrad, 1mrad (same as EM canting magnets)



- NSLS-II Insertion Device (ID)-Magnetic Measurement Facility (MMF)

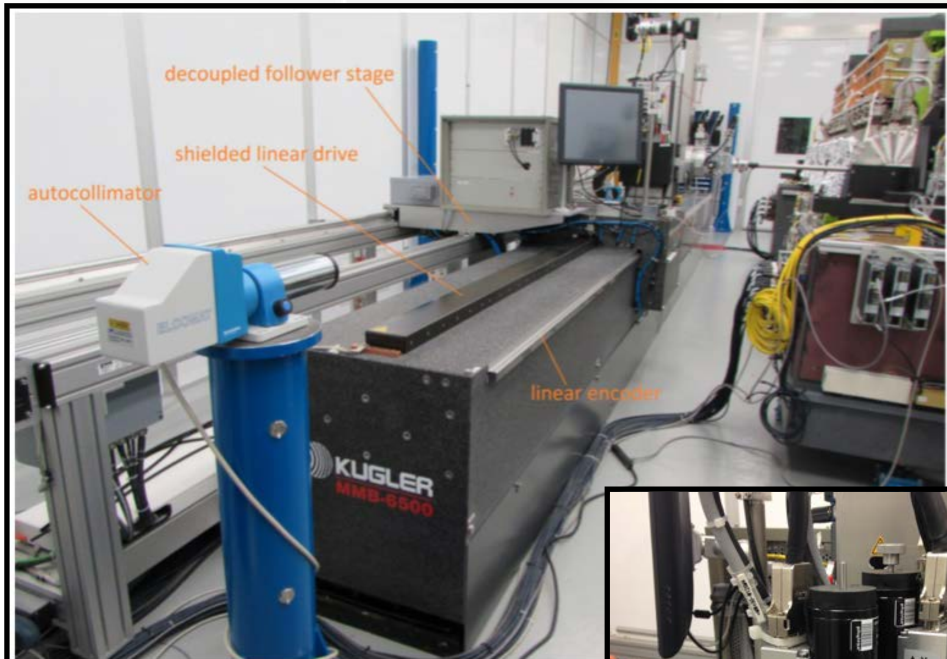
  - Hall Probe Bench
  - Flip coil / Moving Coil Bench → Improved

  - Helmholtz coil (not shown in this talk)
  - Calibration Dipole (not shown in this talk)
  - Laser Tracker and Fiducials (not shown in this talk)

Hall Probe Bench Overview (1/2)

Inside ISO Class 7 Clean Room with Temperature Regulation of 25.5C° ± 0.2C °

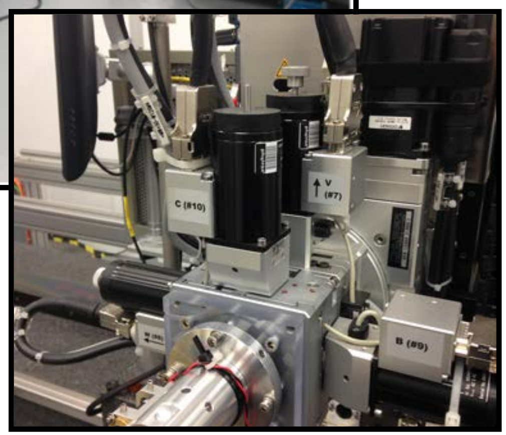
3D Hall probe-mapping bench MMB-6500 built by Kugler, GmbH



Total Z-axis travel is 6.5 m.

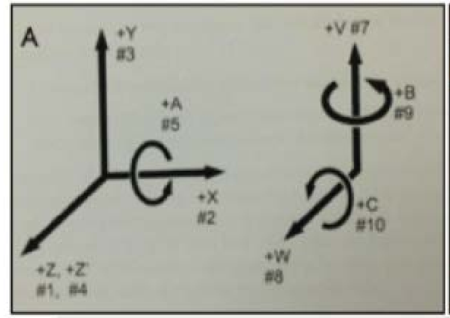
A <u>Heidenhain linear encoder</u> provides position feedback for Z-axis closed loop control.

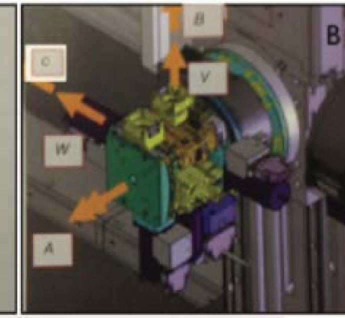
A <u>Renishaw laser linear encoder</u> is used as a trigger for on-the-fly measurements.



A and **C** secondary axes are particularly useful for fine angular positioning of the B_y Hall sensor

- Granite guide-beam length: 7.7 m
- Flatness deviation < ± 3 µm
- Positioning accuracy: ± 1 µm





- **9 Motion Controlled Axes**

4 Primary Axes

- **Z** master axis and **Z'** follower axis
- **Y** axis and **X** axis

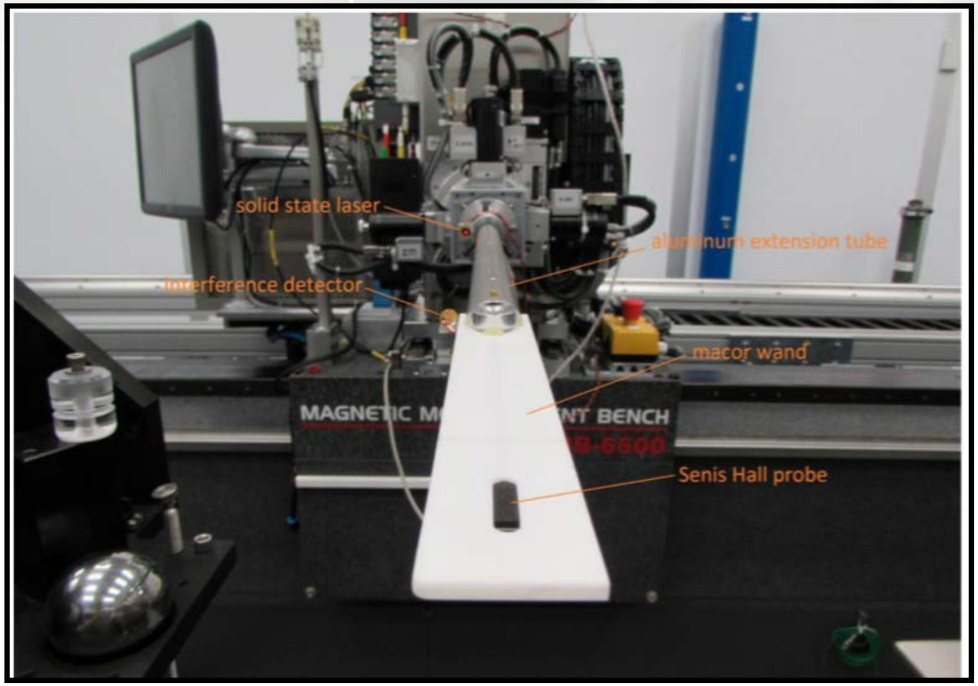
5 Secondary Axes

- **A** rotary axis
- **V** linear axis
- **W** linear axis
- **B** goniometer axis and the **C**

Courtesy of T. Tanabe

Hall Probe Bench Overview (2/2)

SENIS 3D Hall Probe



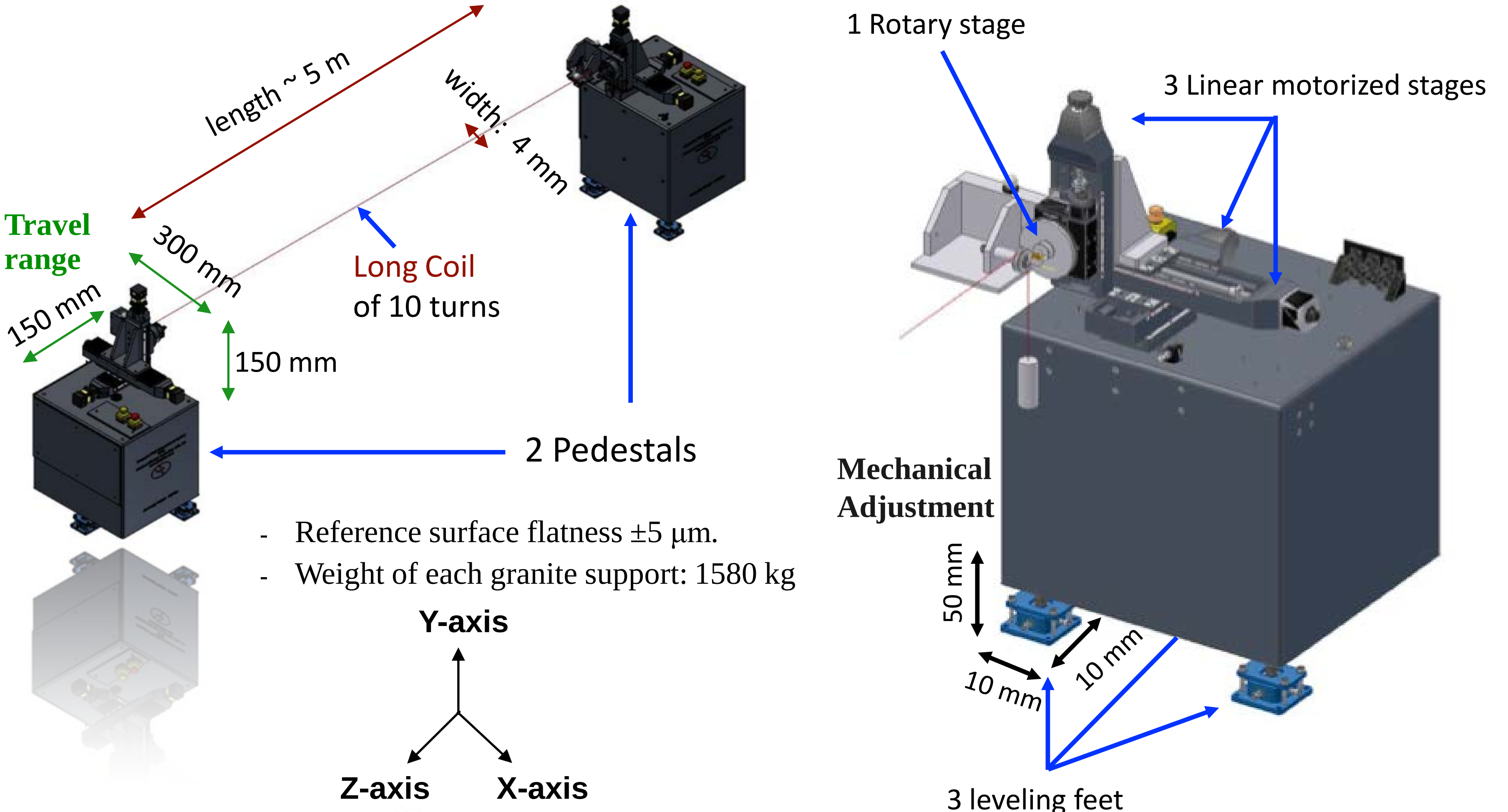
NI CompactRIO real-time Programmable Automation Controller is utilized for on-the-fly Hall probe data acquisition.

- Hall sensors X, Y and Z are arranged along longitudinal axis
- The SENIS 3D probe (H3A-03P03L) is mounted into a macor wand.
- The probe extends ~800 mm from the C stage
- Magnetic field sensitive volume of 150 x 1 x 150 μm
- Linearity error is 0.15% (up to 2 T)
- Good angular accuracy with an orthogonality error < 2°

IFMS: Integrated Field Measurement System

A set of three field integral measurement systems: a stretch wire, a moving wire and a **flip coil**

Original Manufacturer's achieved performances were marginal.
A lot of modifications have been made to improve the performance.

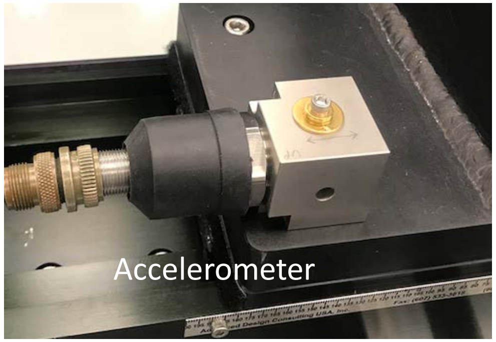


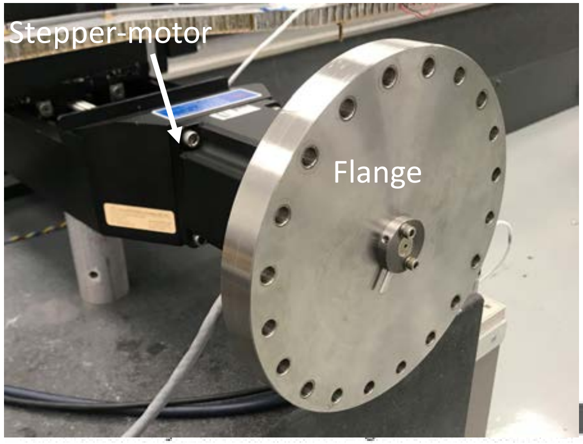
- Reference surface flatness ±5 µm.
- Weight of each granite support: 1580 kg

Courtesy of T. Tanabe

Recent IFMS Improvements Summary

- *The DeltaTau GeoBrick Turbo PMAC unit was replaced and configured.*
- *The old 2701 Keithley Voltmeter was replaced by a new 2182A Nanovoltmeter.*
- *4 Servomotors were replaced by stepper-motors.*
- *7 PLC and 14 motion programs were developed for homing of each axis, for trigger generation and for motion control.*
- *Two large flanges were used as inertial dampers to stabilize the linear axis motion in order to minimize the mechanical vibrations introduced by the motors.*
- *All stepper-motors were software configured and tuned.*
- *Developed IgorPro functions for data acquisition and analysis.*
- *Optimized measurement speed and integration time window (NPLC).*
- *Developed a new IgorPro graphical user interface.*





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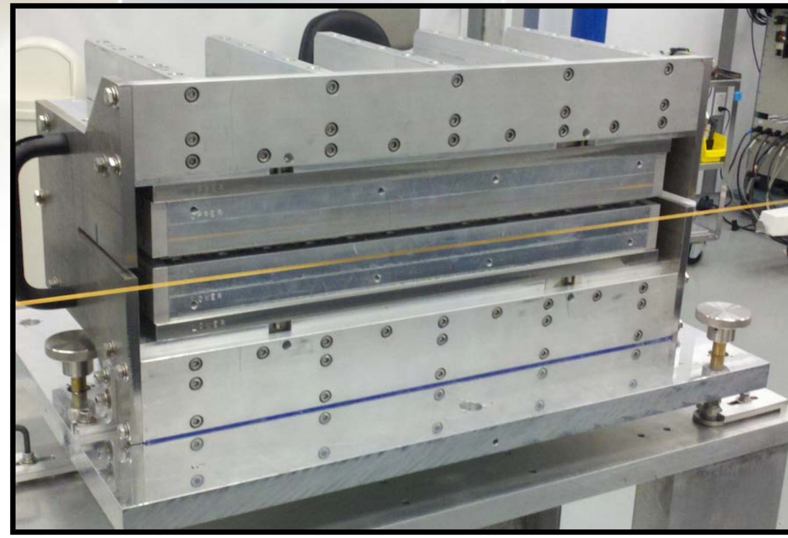
Calibration Array Scan Results (before & after)

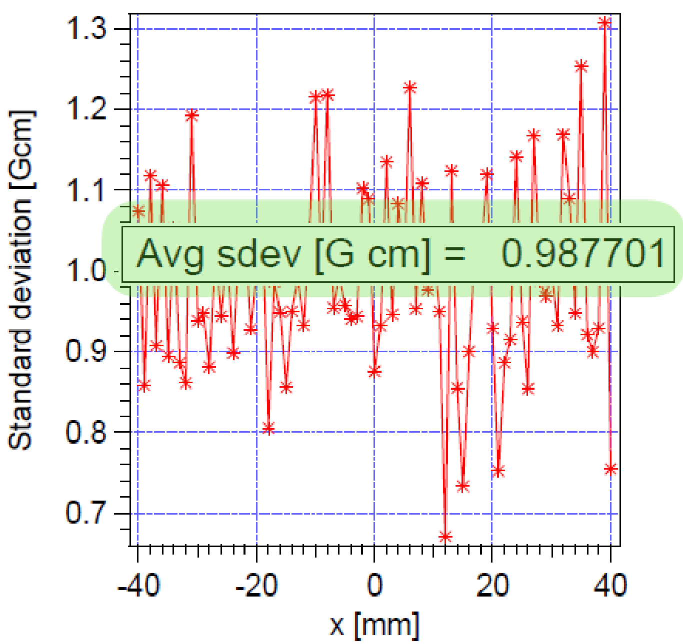
Before modifications:
Iy_sdev : 3.5 G cm
Ix_sdev : 2.5 G cm



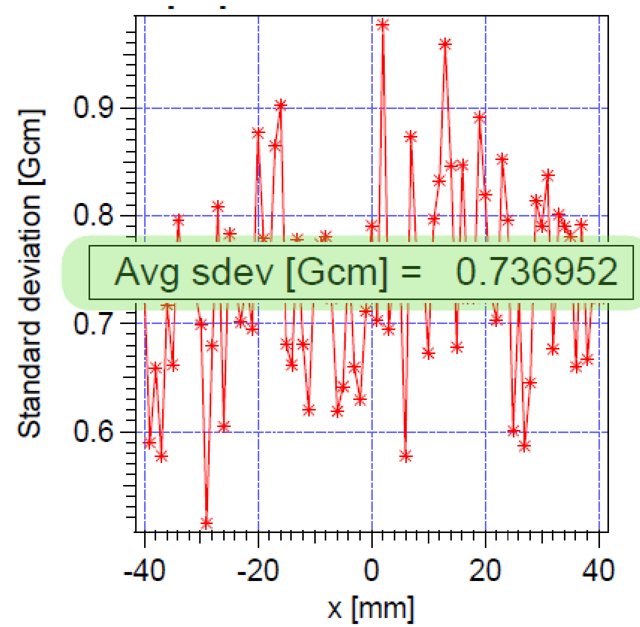
NdFeB - Fixed gap = 5.7 mm,
L = 50 cm, λ = 15 mm

After Modifications:

Vertical First Integral (Iy) 50 Scans



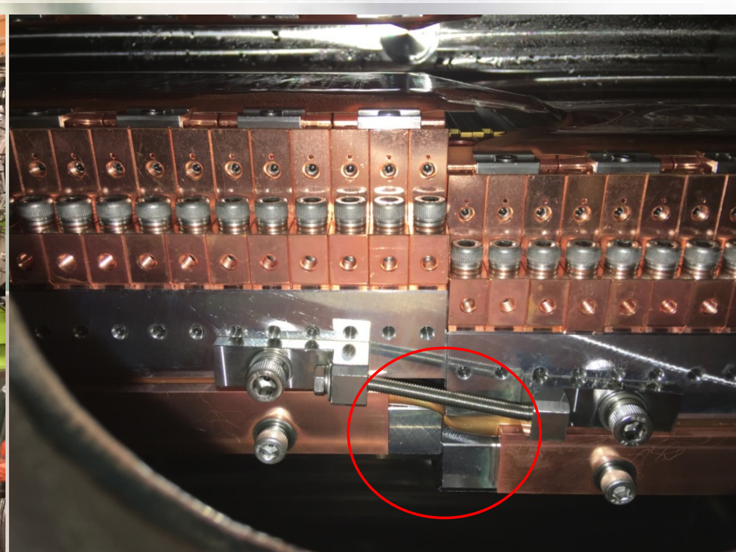
Horizontal First Integral (Ix) 50 Scans



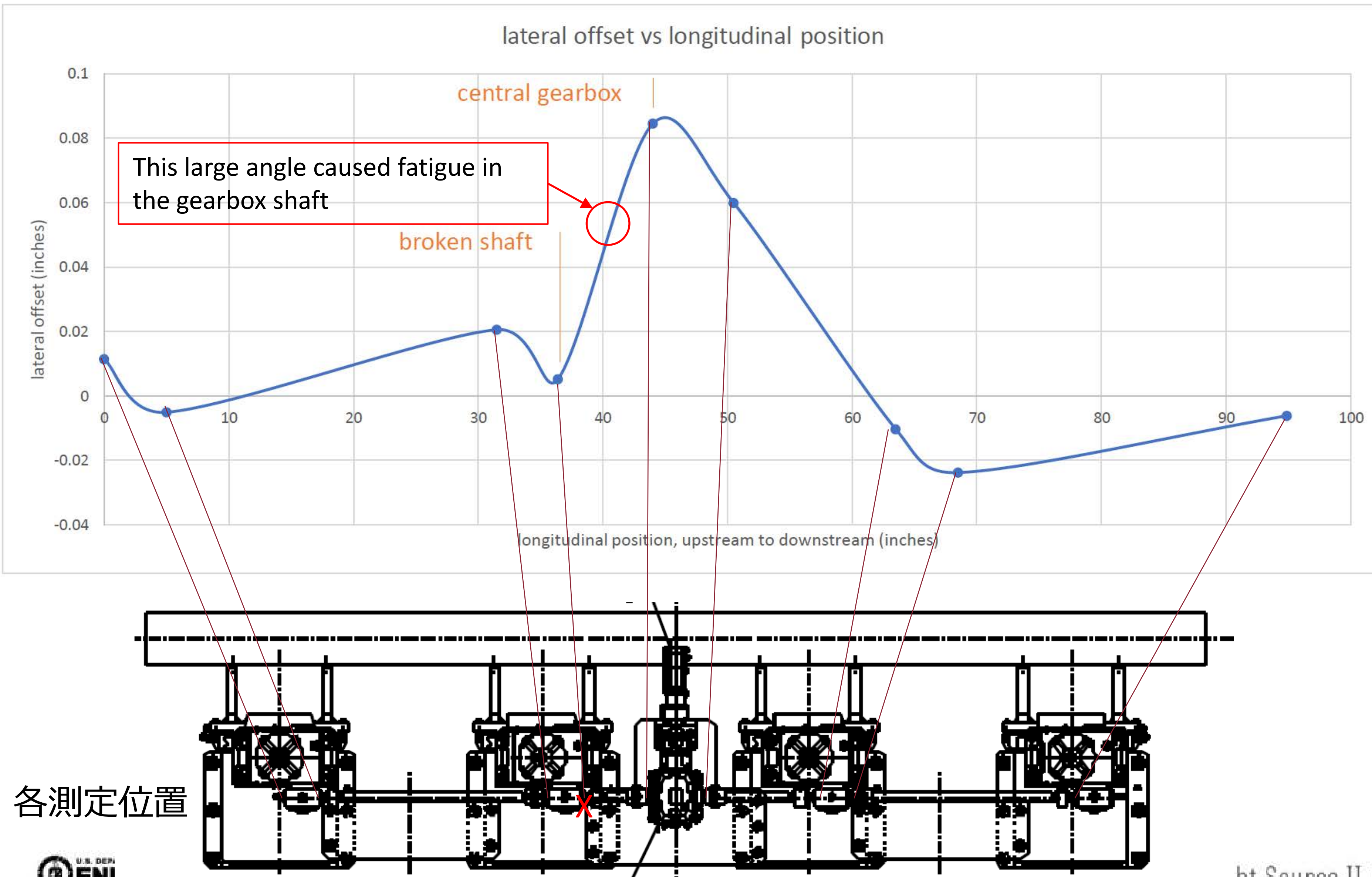
- C3-IVU Catastrophic Failure (internal water leak)
  - Cause
  - Mechanical Repair
  - Magnetic Fine Tuning

HXN (C3)-IVU Incident

- Just after midnight (0:08) on 7/1/2018, C3-IVU gap stopped responding. Soon after (0:11) gate valves around the straight closed. Operator stopped water at 2:23am.
- The device was uninstalled and the straight was back to operation with only 30 hours of loss of operation.
- The device was transported to ID-MMF (bldg. 832) for repair.
- This was the first accident of this nature by this manufacturer with more than 30 IVUs of similar design.

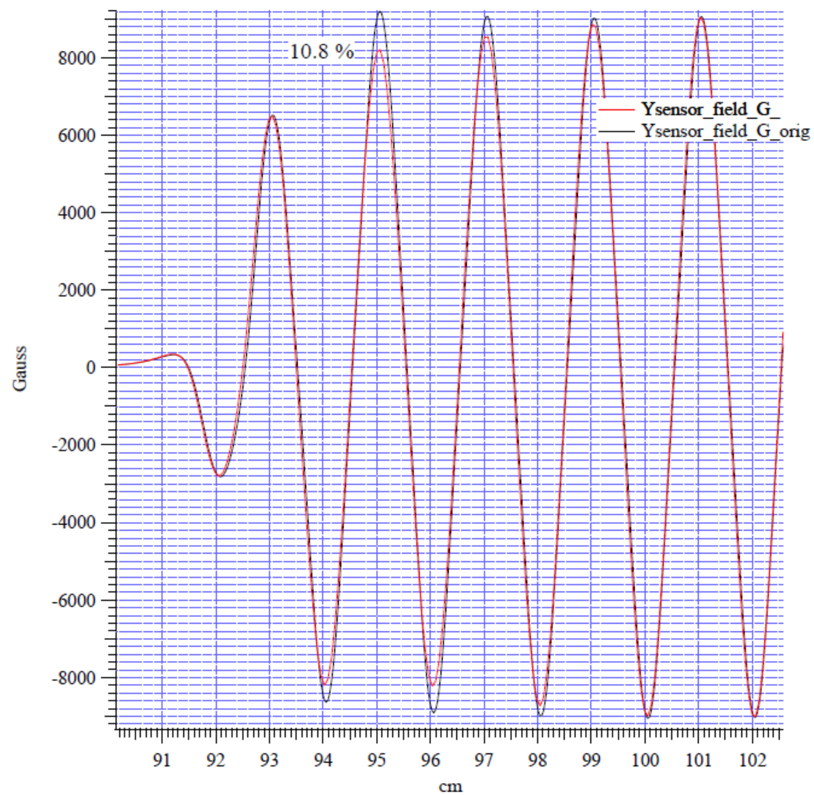


It was determined that the primary root cause of the gearbox shaft failure at Cell 3 is misalignment of the drivetrain. It was likely to be created during transportation.



Recovery Efforts

- While waiting for a spare gear box to arrive, the damaged gear box was moved to the right most position to reconnect the drive train.
- Realign the drive train with a faro arm.
- Magnetic measurement found that the first six modules had been slightly demagnetized. They were replaced with spare modules.
- The following preventive measures have been implemented:
  - PLC in DeltaTau software which monitors the difference between US and DS linear encoder's reading even during the gap motion. If the discrepancy is greater than 100 microns, the motion will be stopped.
  - Switches which can detect slight shift between girders. Once detected, send signal to kill the motor.



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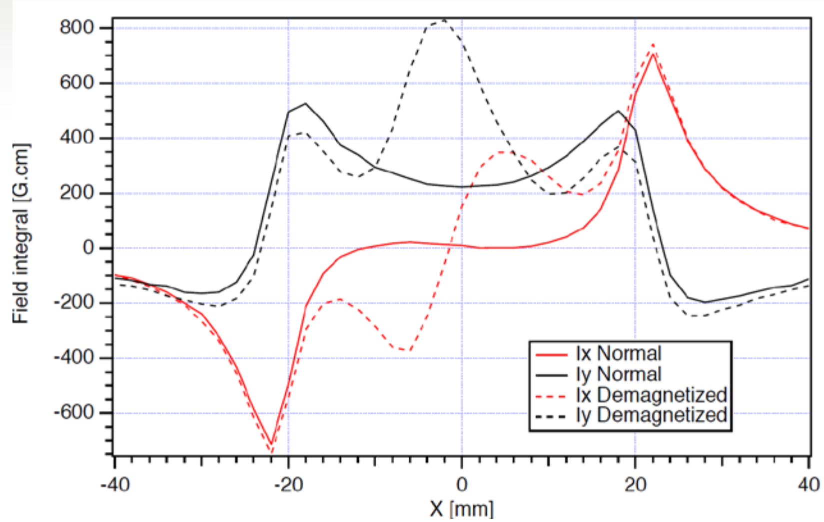
Field Change in Demagnetized Magnet Modules

- **Field Integral Measurement 5mm above**

Normal

Demagnetized (one example)



- **Hall probe scan along Z at X=0**

Normal

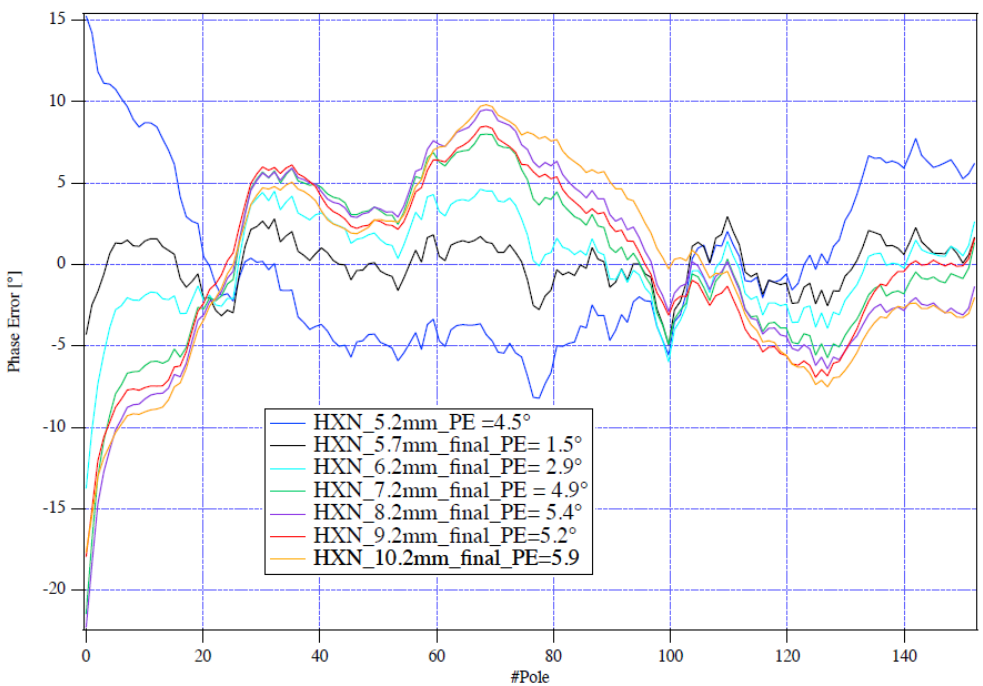
Demagnetized (several units)

HXN-IVU Magnetic Performance

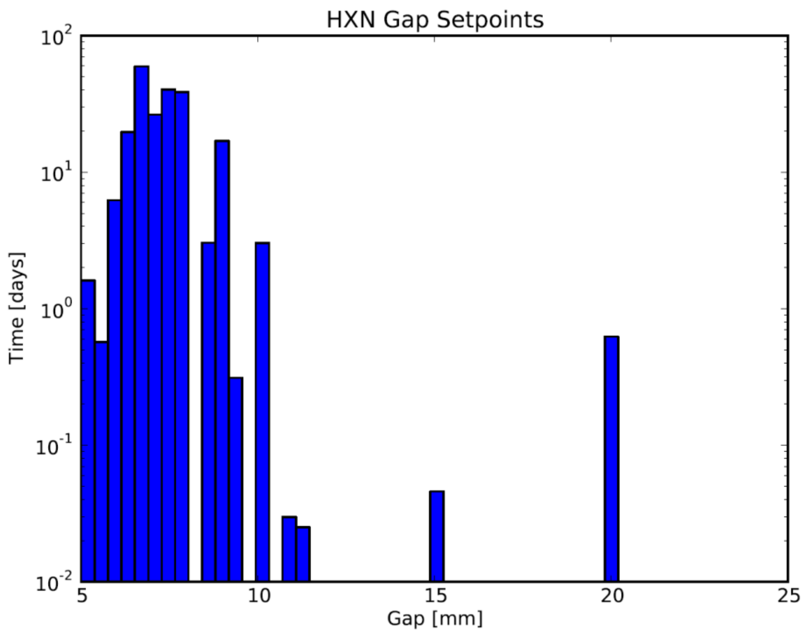
HXN - Multipole

Gap [mm]	5.2	5.7	6.2	7.2	8.2	9.2	10.2
ND [G cm]	-147	-163	-167	-174	-168	-170	-159
SD [G cm]	25	21	17	8	4	-0.2	-2.3
NQ [G]	53	10	-13	-69	-82	-28	-34
SQ [G]	-38	-65	-11	-3	38	11	38
NS [G/cm]	2	33	14	83	66	142	96
SS [G/cm]	-181	-159	-128	-34	-35	-94	-81

Phase Error vs Gap



PE optimized for most used gap range



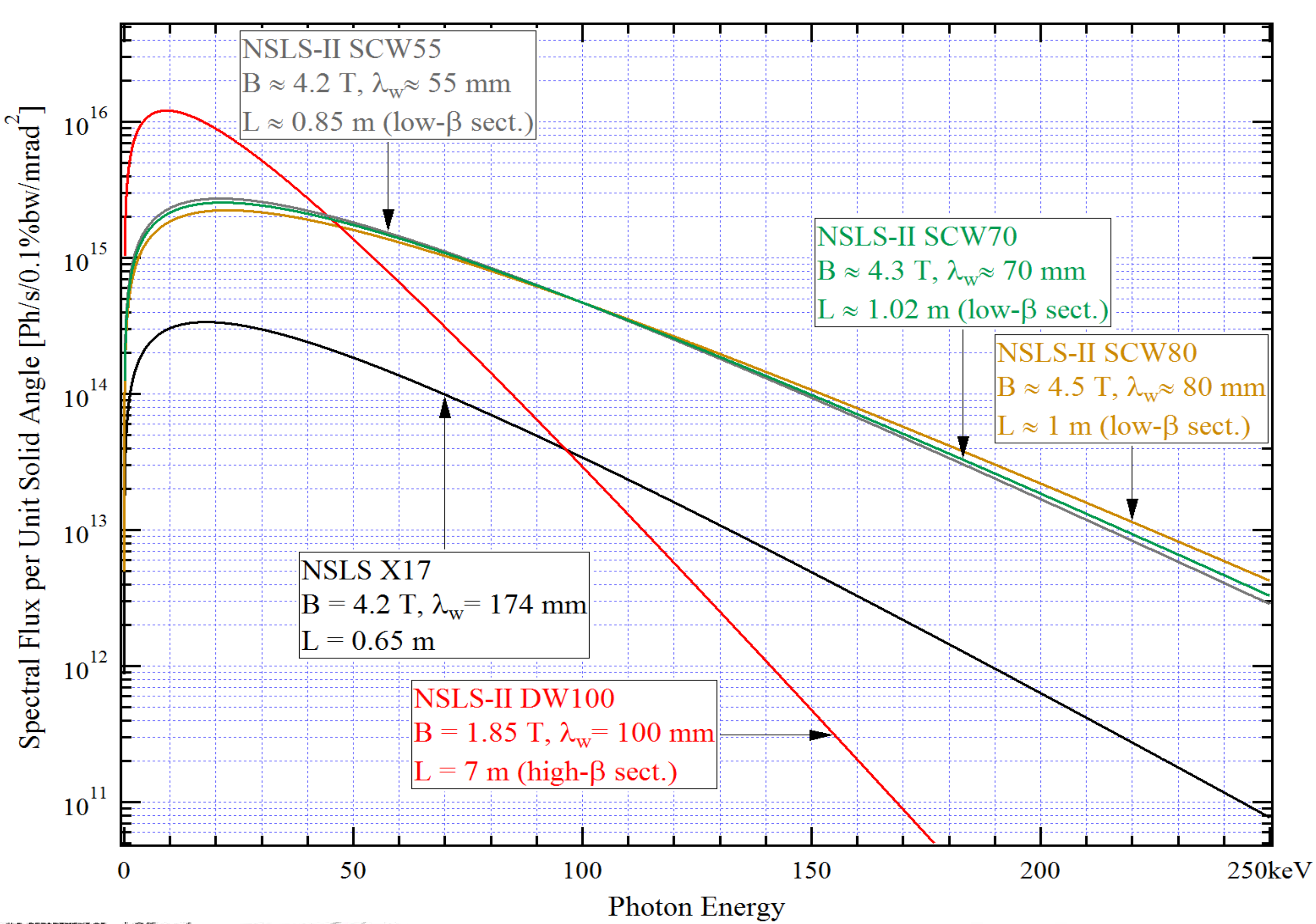
- High Energy Engineering X-ray (HEX) Beamline-Super-Conducting Wiggler (SCW)
  - Specs
  - Straight Section Layout
  - Tosca Model
  - Magnetic Measurement Plan

HEX-SCW Current Specs for Users (RSI ver.10)

Beamline	HEX and MRE
Type	SCW
Device envelope length	~1.8 m
Magnetic Length	1.2m nominal (29 main and 4 partial poles)
Canted	No
Period: nominal	70 mm
Nominal (minimum) gap of vacuum bore tube	10 mm TBC
Peak field nominal	4.3 T
Keff: nominal	28.1
Energy Range:	8 keV –200 keV
Power total: nominal	55.7 kW
Max.power per unit solid angle: nominal	28.4 kW/mr^2
Straight	Low beta
Device center	May be offset in the straight towards the downstream end.
Power density distribution angle *1 (mrad H) : nominal (maximum)	9.87 (10.15)
Power density distribution angle *1 (mrad V) : nominal (maximum)	0.88 (1.47)
Gap scanning and other requirements	Current adjustment 0 – 100%

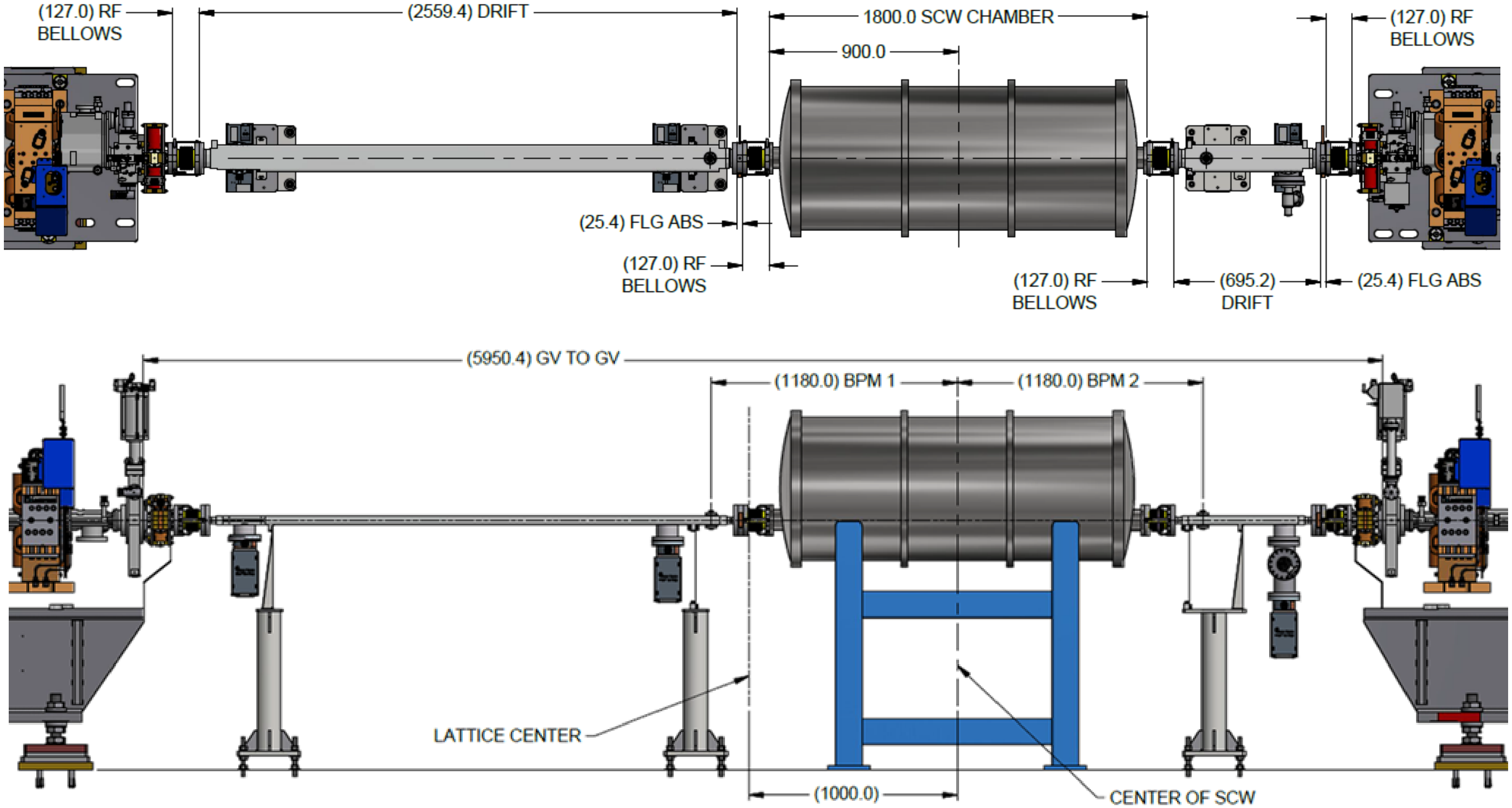
Note 1: The fan angles of the radiation quoted here are as seen at 16m from the source, and take into account the effects of source length; the worst case fan size is taken. The two values quoted are for the points where the power density falls to values that are 1% and 0.1% of the central value. Designs of the fixed mask entrance shall take into account these fringe power loads.

Spectra


NSLS-II SCW55
B ≈ 4.2 T, λw≈ 55 mm
L ≈ 0.85 m (low-β sect.)
NSLS-II SCW70
B ≈ 4.3 T, λw≈ 70 mm
L ≈ 1.02 m (low-β sect.)
NSLS-II SCW80
B ≈ 4.5 T, λw≈ 80 mm
L ≈ 1 m (low-β sect.)
NSLS X17
B = 4.2 T, λw= 174 mm
L = 0.65 m
NSLS-II DW100
B = 1.85 T, λw= 100 mm
L = 7 m (high-β sect.)
Spectral Flux per Unit Solid Angle [Ph/s/0.1%bw/mrad2]
10^16
10^15
10^14
10^13
10^12
10^11
0
50
100
150
200
250keV
Photon Energy

Straight Section

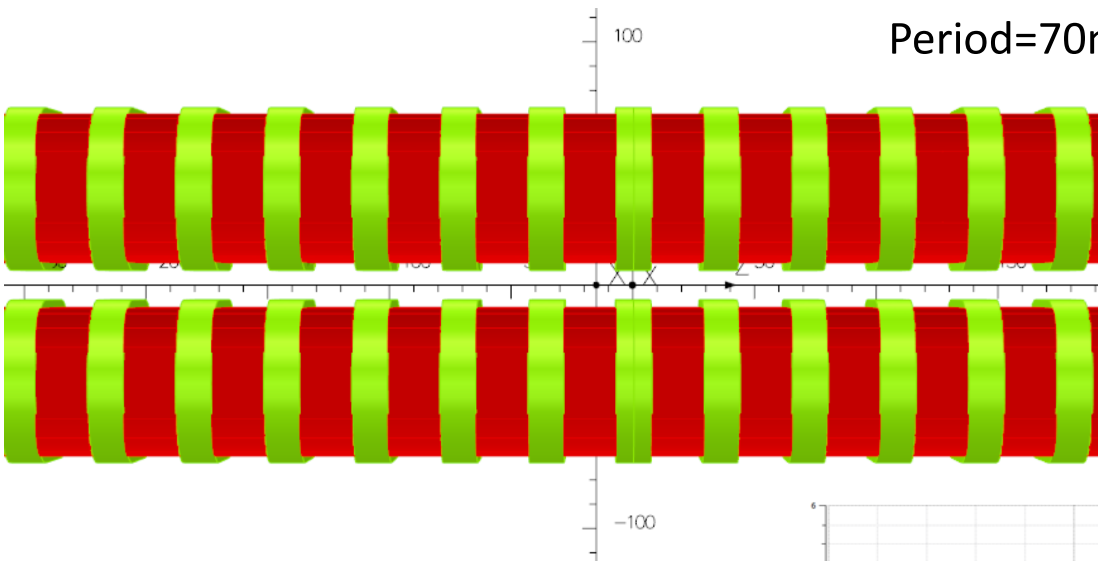
- Device will be shifted downstream by 1m. Approved by accelerator physics group.
- BPMs installed on adjacent chambers
- Valves will be installed on both ends of the device to allow baking of surrounding components



Selected Vendor’s Proposed Coil Design

Advantages: Can use the same winding mechanism as SCU
Fewer splices than horizontally wound coil design

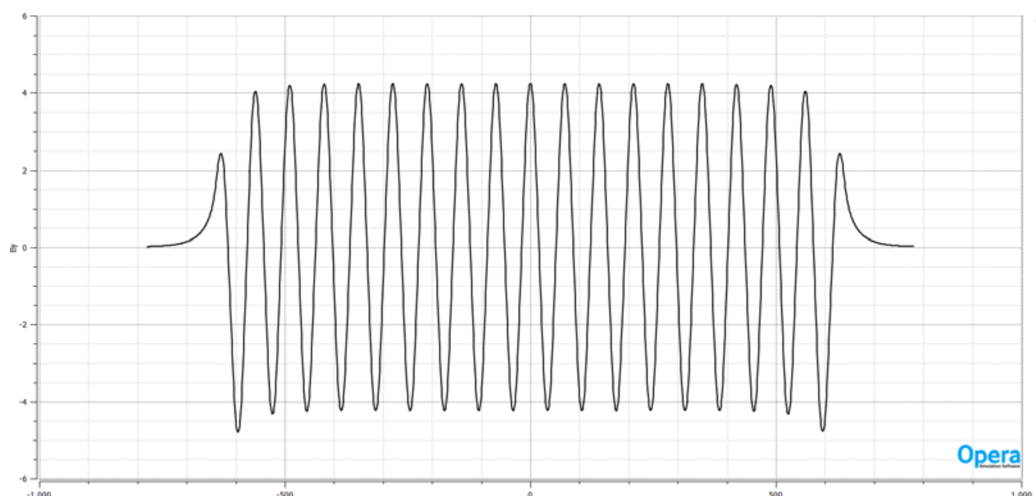
Disadvantages: Requires longer wires which results in larger stored energy
No external mechanism to counteract magnetic force on coils



Period=70mm

Pole Gap=12mm

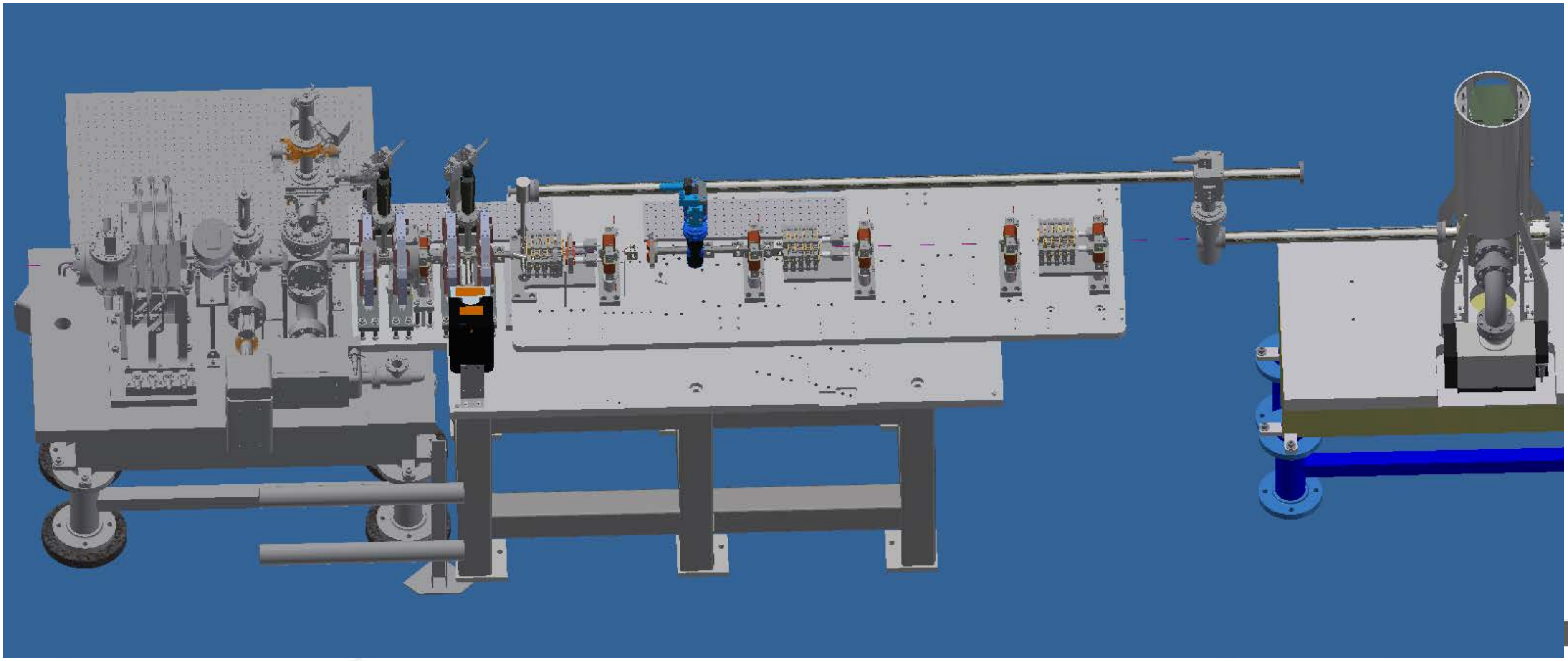
Iron core: 1010 steel
I= 431 A x 300 T
NI=129300
J=647.6 A/mm^2
Stored Energy=43kJ



- New Pulsed Wire Setup for
  - SCW
  - Small aperture PM quad for UEM

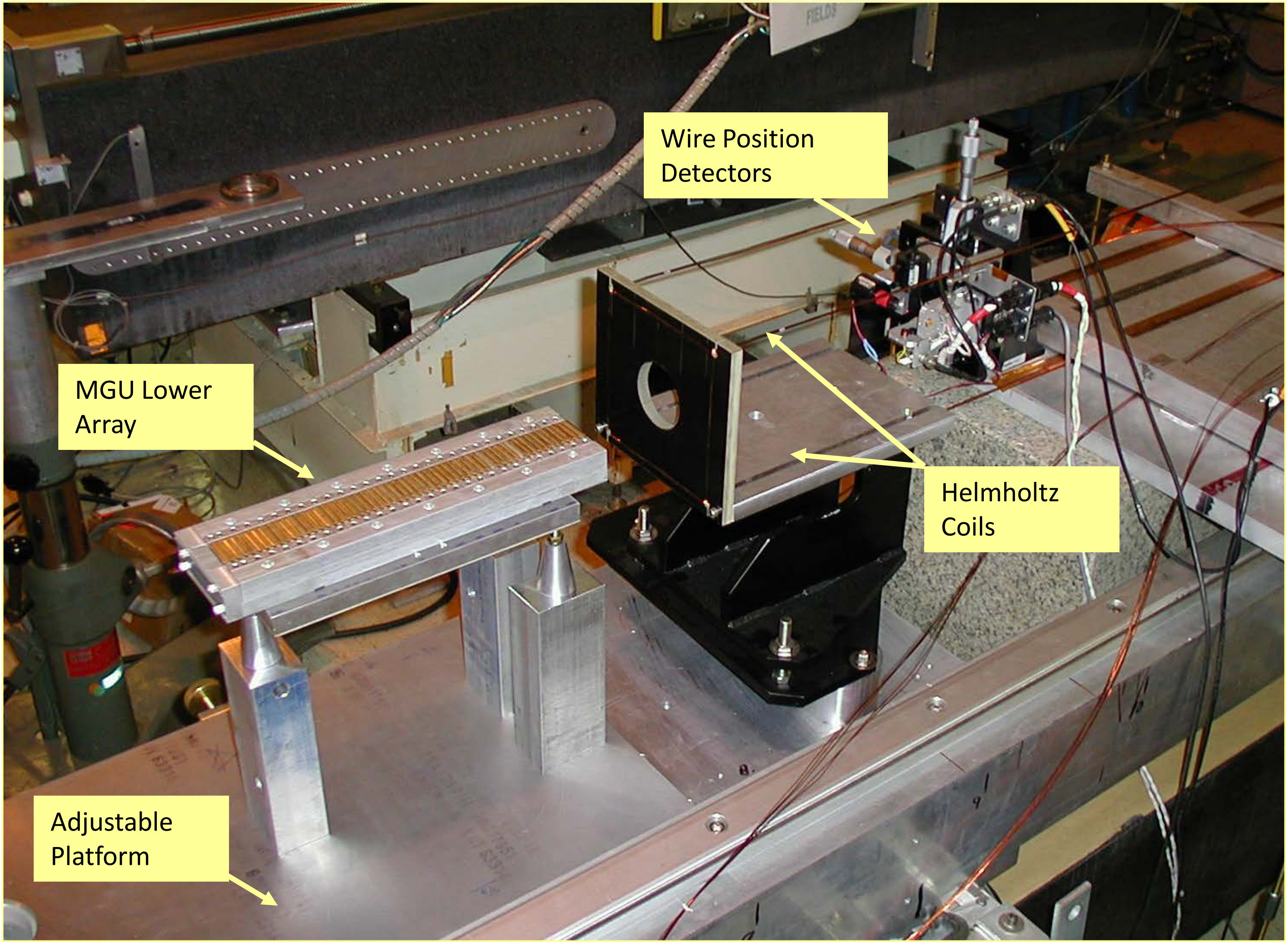
Ultra-fast Electron Microscope (UEM)

- <1pC in a single shot with 3.3MeV electron beam at Accelerator Test Facility at BNL (Cf. 13pC for UED)
- Magnification: 2000:1
- Resolution: <100 nanometer
- Remove Diagnostics chamber and stage assembly from the former Ultra-fast Electron Diffraction (UED) system. The rest of the UED system will remain as is.
- Small aperture quadrupoles are required for shorter focusing length.



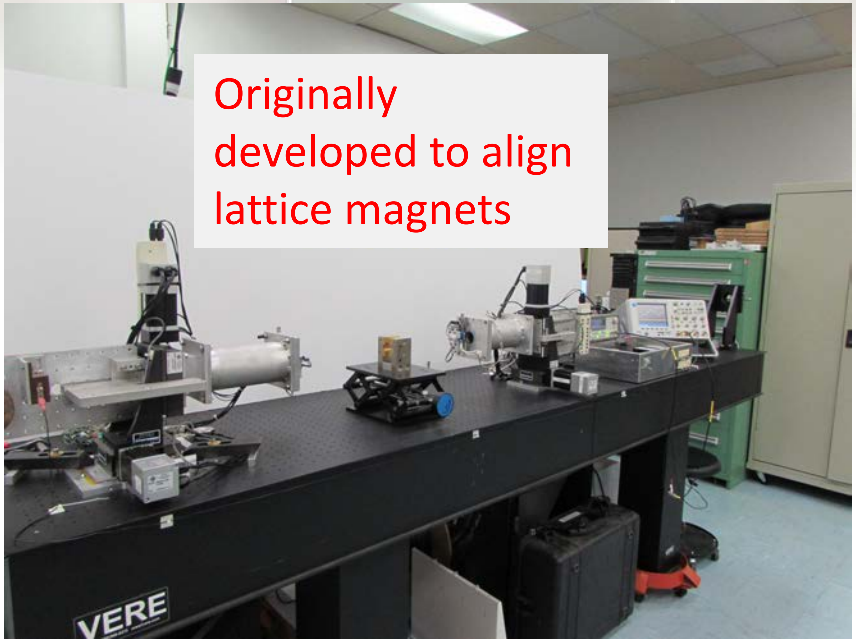
NSLS Pulsed Wire Bench (1998 – 2007)

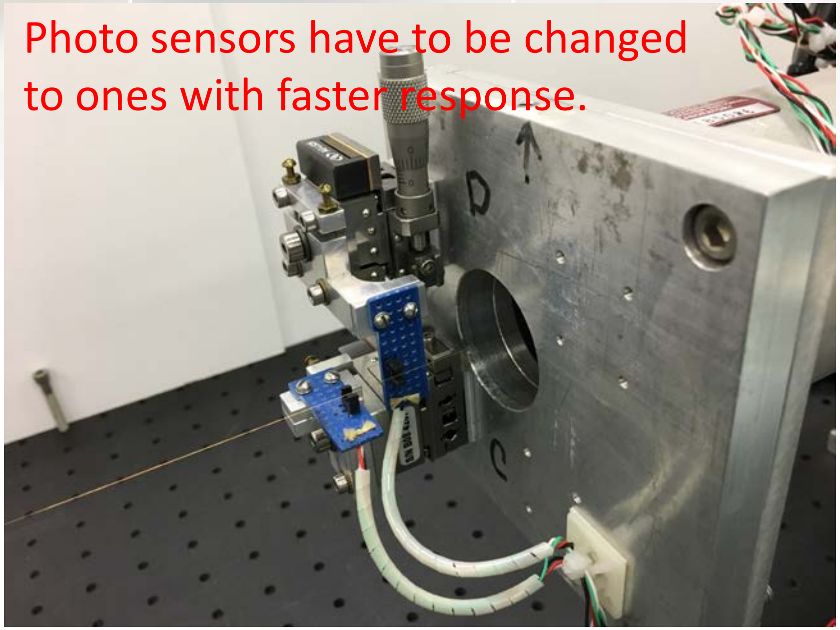
PULSER: 100V, 2 A, 10 ms. Viscous damper at the end. Tensioning by weight

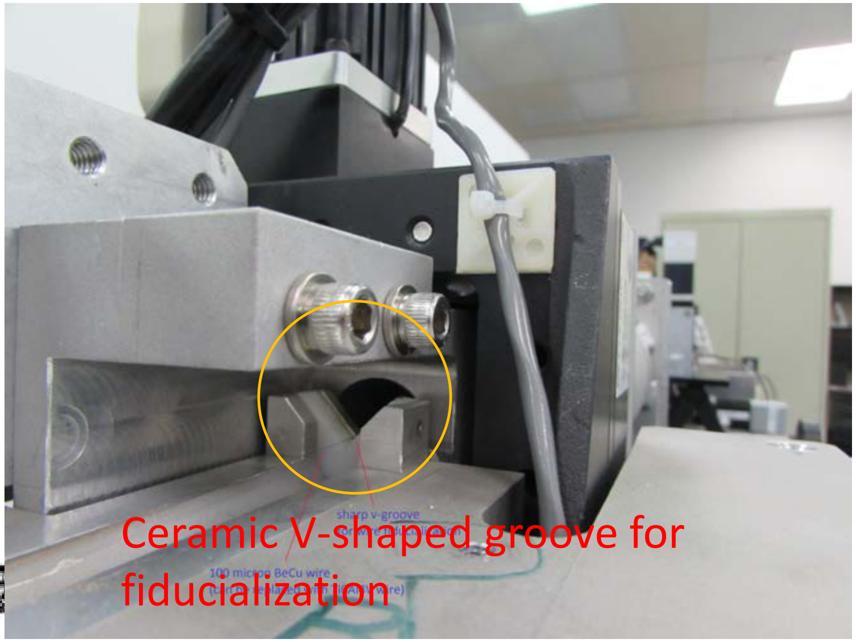


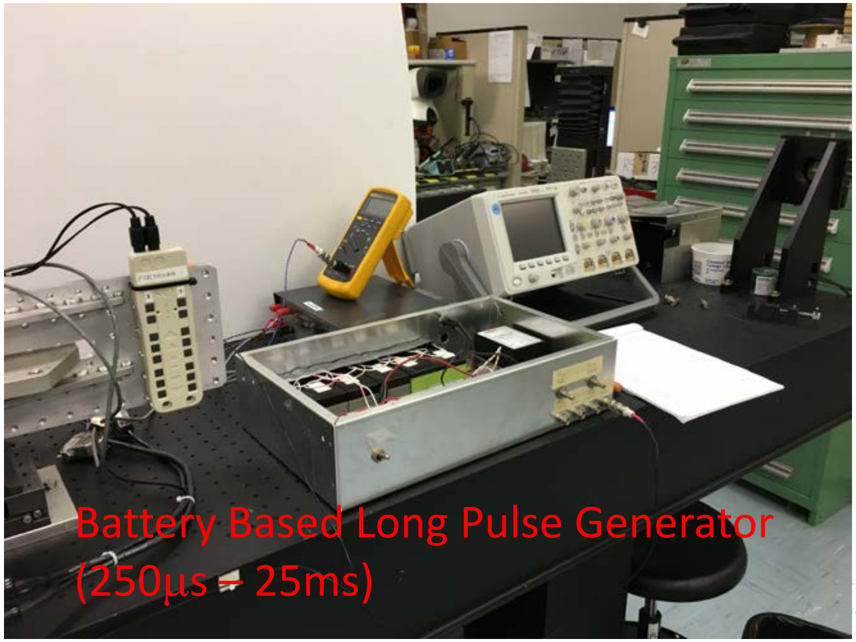
Original work: [1] R.W. Warren, NIM A272 (1985) 257;

- New pulsed wire bench which has been repurposed from NSLS-II vibrating wire bench



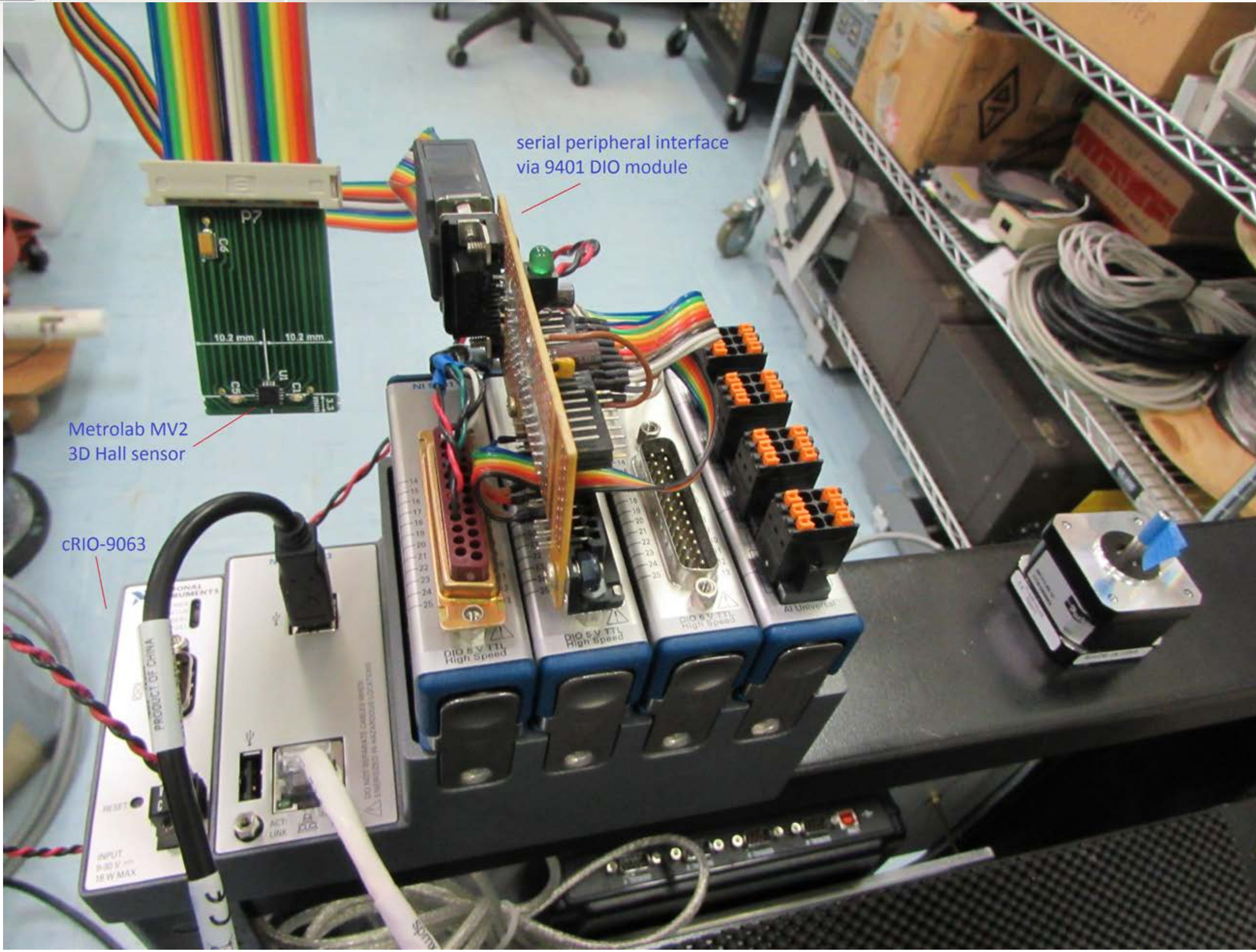






MV2 Chip Test

3D sensor by Metrolab
Good up to 30T
Evaluation kit costs $1870 in the US.



Summary

- Incremental improvement of flip coil bench has improved the repeatability of the 1st integral measurement by a factor of ~four from the original design and it is less than 1 G.cm.
- After four years of operation, slight demanetization appeared in the first few period in an IVU even though magnets with very high Hcj (33kOe) are used.
- The vibrating wire system used for NSLS-II magnet alignment is repurposed to be converted to a new pulsed wire bench. It is expected to be used to measure small aperture (R=2.5mm) PM Quads for UEM and for 1.2m-long SCW. With the help from APS, the software to remove dispersion effects is expected to be implemented.
- For the measurement of field mapping for the SCW, MV2 hall element is being tested.

battery pulser

This unit can accommodate 16, small 12V, 1.2 amp-hour, lead acid batteries.

~2A with 100 micron BeCu wire
Less with Ti6Al4V wire