Present Status of NSLS-II Mechanical Systems

Sushil Sharma
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Acknowledgment

Collaborators:

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and

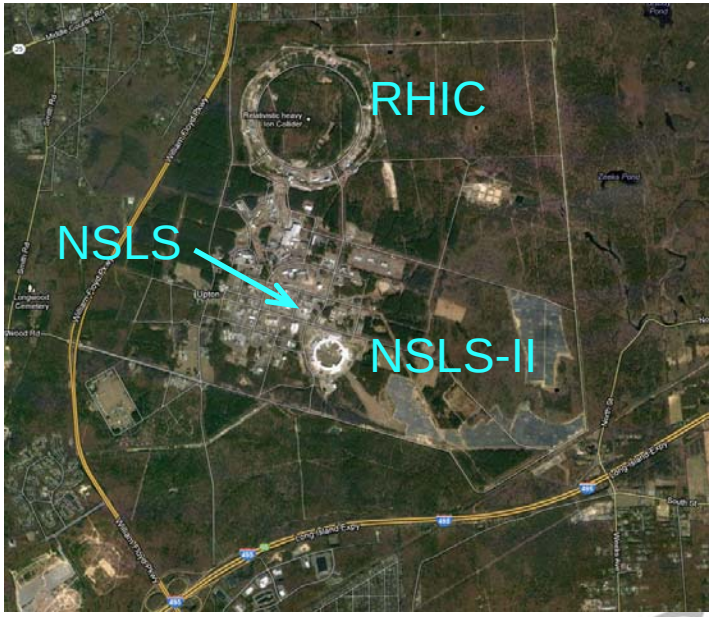
Staff of NSLS-II and Suppliers

Outline

- Introduction
- Civil Construction and Utilities
- Injector
  - *Linac, Booster, Transport Lines, Injection Straight*
- Storage Ring
  - *Magnets, Vacuum, RF, ID, Frontend*
- Beamlines

NSLS-II at BNL

- BNL is located in Long Island, 107 km from New York City.
- The site is ~ 15 km from the ocean, surrounded by two highways at 1.5 - 2 km.
- The site is a well-settled, generally uniform, 430-m of glacial-sand layer above the bed rock.



NSLS-II Project Milestones

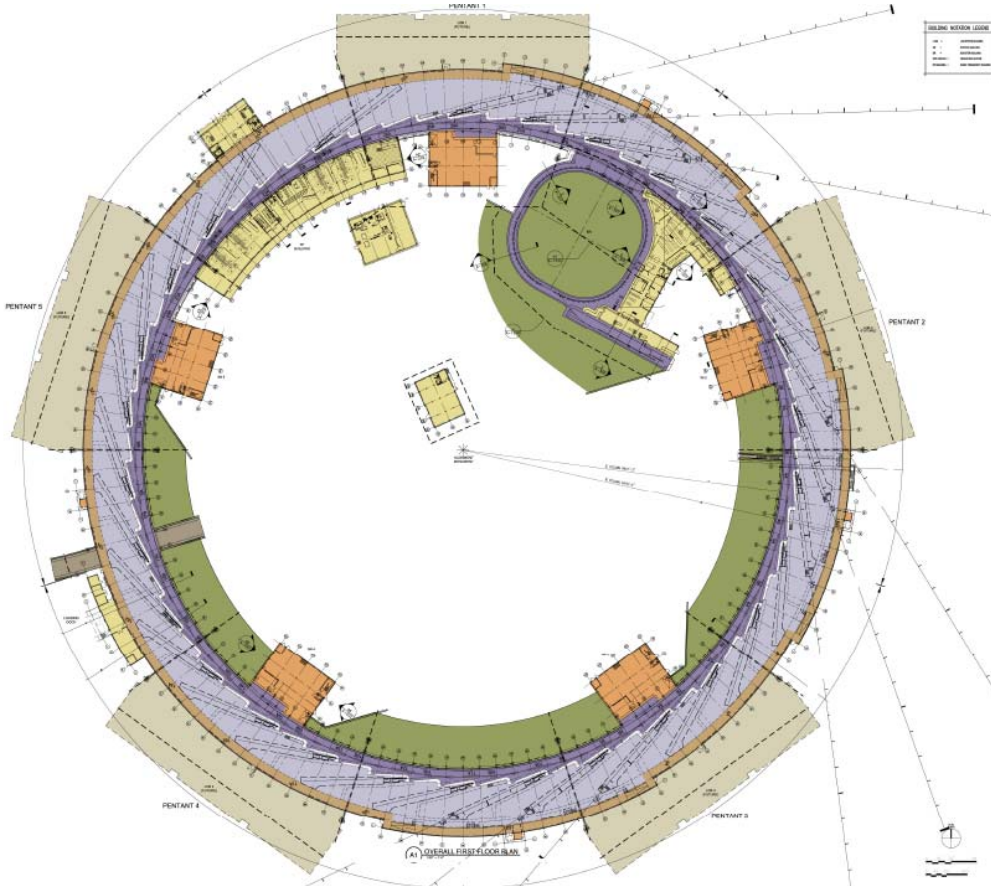
Aug 2005	**CD-0**, Approve Mission Need	**(Complete)**
Jul 2007	**CD-1**, Approve Alternative Selection and Cost Range	**(Complete)**
Jan 2008	**CD-2**, Approve Performance Baseline	**(Complete)**
Jan 2009	**CD-3**, Approve Start of Construction	**(Complete)**
Feb 2009	Contract Award for Ring Building	**(Complete)**
Aug 2009	Contract Award for Storage Ring Magnets	**(Complete)**
May 2010	Contract Award for Booster System	**(Complete)**
Feb 2011	1st Pentant Ring Building Beneficial Occupancy	**(Complete)**
Feb 2011	Begin Accelerator Installation	**(Complete)**
Feb 2012	Beneficial Occupancy of Experimental Floor	**(Complete)**
Mar 2012	Start LINAC Commissioning	**(Complete)**
Jan 2013	Start Booster Commissioning	
Fall 2013	Start Storage Ring Commissioning	
Apr 2014	Projected Early Completion; Ring Available to Beamlines	
Jun 2014	Early Project Completion; Ring Available to Beamlines	
Jun 2015	**CD-4**, Approve Start of Operations	

NSLS-II Parameters

Design Parameters

- 3 GeV, 500 mA, top-off injection
- Circumference 792 m
- 30 cells, Double Bend Achromat
- Ultra-low emittance

$\varepsilon_x, \varepsilon_y = 0.6, 0.008$ nm-rad



NSLS-II Performance Goals

- ~ 1 nm spatial resolution
- ~ 0.1 meV energy resolution
- single atom sensitivity

Construction Progress

October 2009

October, 2010

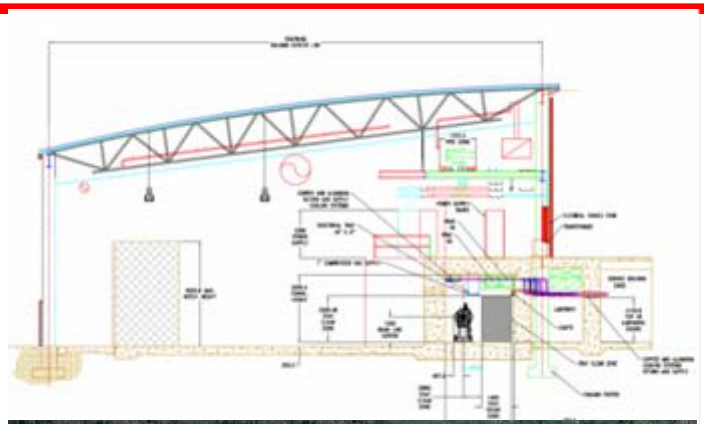
October, 2011

October, 2012

Civil Construction

Experimental Hall

SR Tunnel



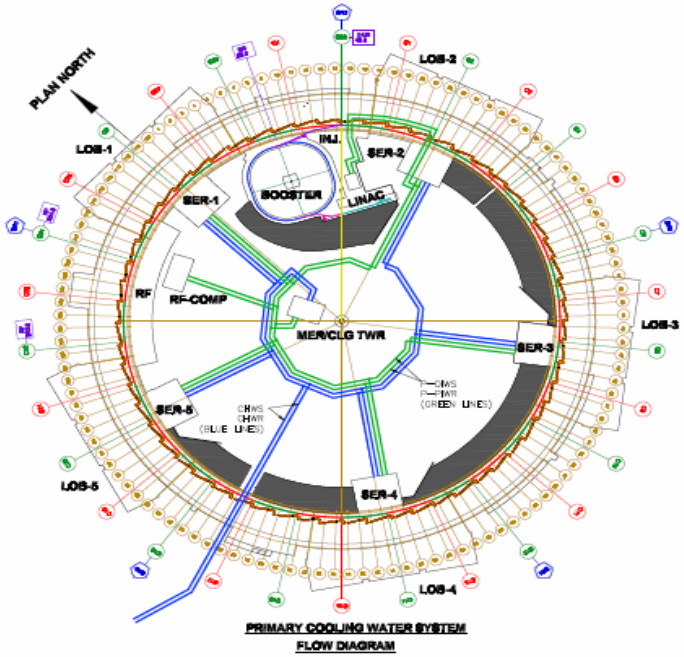
SR Roof

SR Ceiling

- The facility is built in 5 pentants.
- The SR roof is fixed. Most of the installation of the components has been done from inside the ring.
- Utilities are distributed from the Central Cooling Tower.

Lab Office Building

Utilities – Primary Systems



- Primary DIW System Capacity: 6 MW, 4000 GPM
- Resistivity: 2-6 M Ω
- Chilled Water Capacity (NSLS-II Share): ~ 2MW

DIW – Secondary Systems

Skid - RF Building

Skid – Service Building

Al – Closed Loop Skid
20 GPM, 30 kW
Temp. Stability: ± 0.05 °C

Secondary DIW (Cu) Skids:

- Load Capacity: 500 – 1600 kW
- Flow: 400 – 1100 GPM
- Supply Pressure: 110 psi
- Temperature Stability: ± 0.1°C

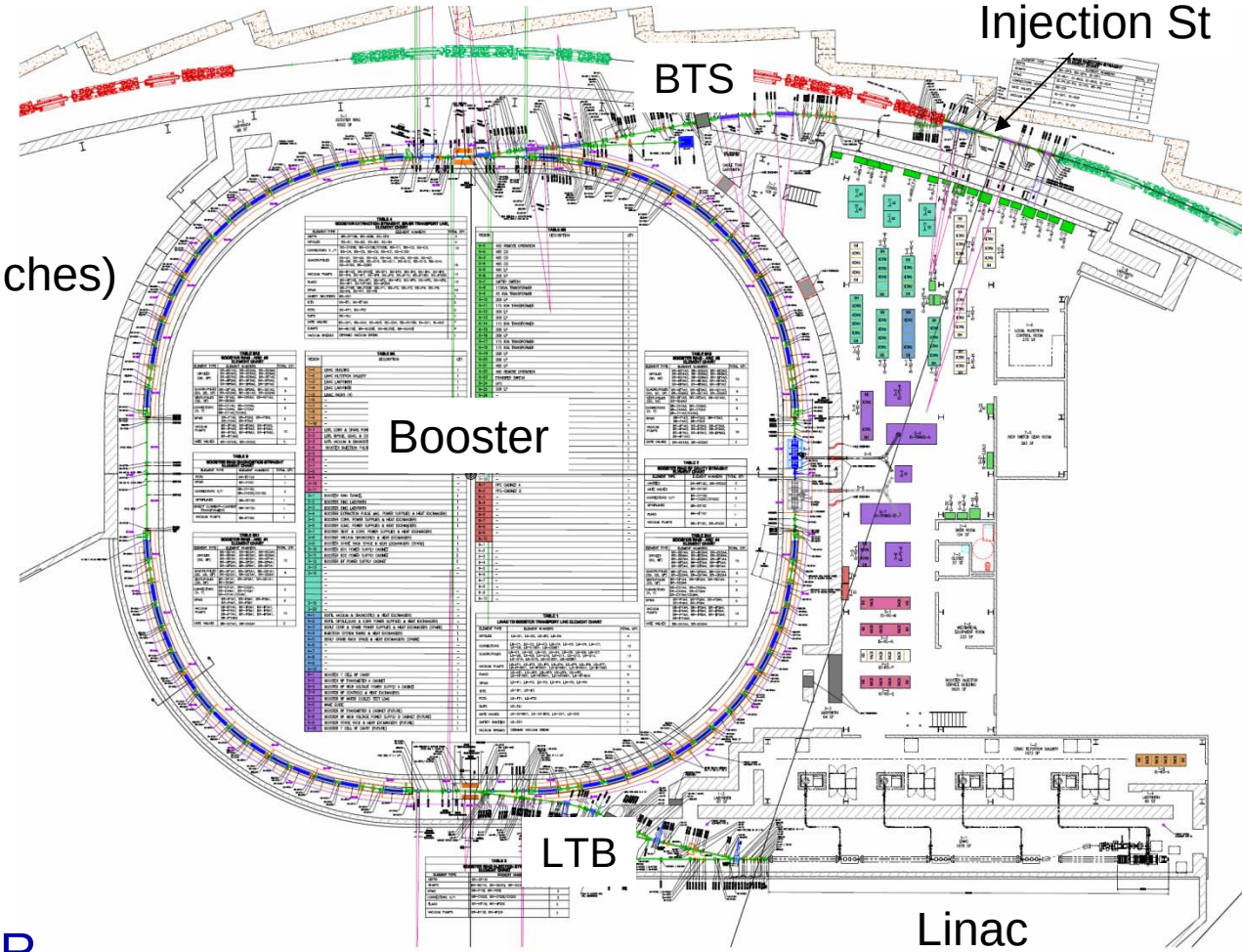
Cu Header

Al Header

Connections in the SR Tunnel

Injector System

1. Linac
   - 200 MeV, 3 GHz
   - ~ 15 nC (80 -150 bunches)
2. Booster
   - 3 GeV
   - 158 m
   - 20 mA, 1 Hz
   - 40 nm-rad
3. Transport Lines
   - Linac to Booster
   - Booster to SR
4. Injection Straight in SR



Injector System - Linac

Linac Tunnel

Accelerating Structures

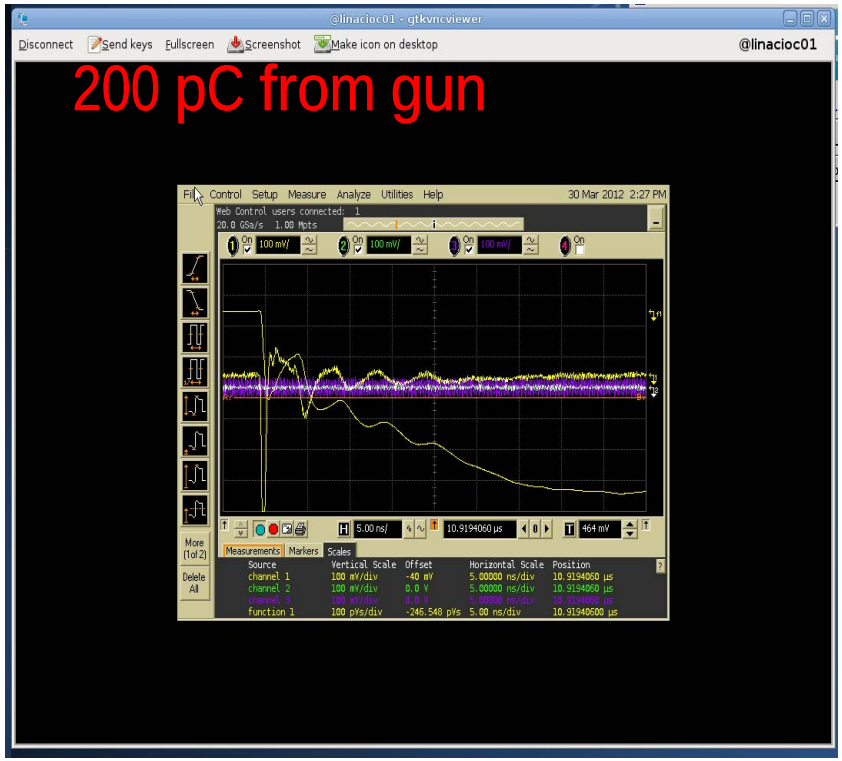
Klystron Gallery

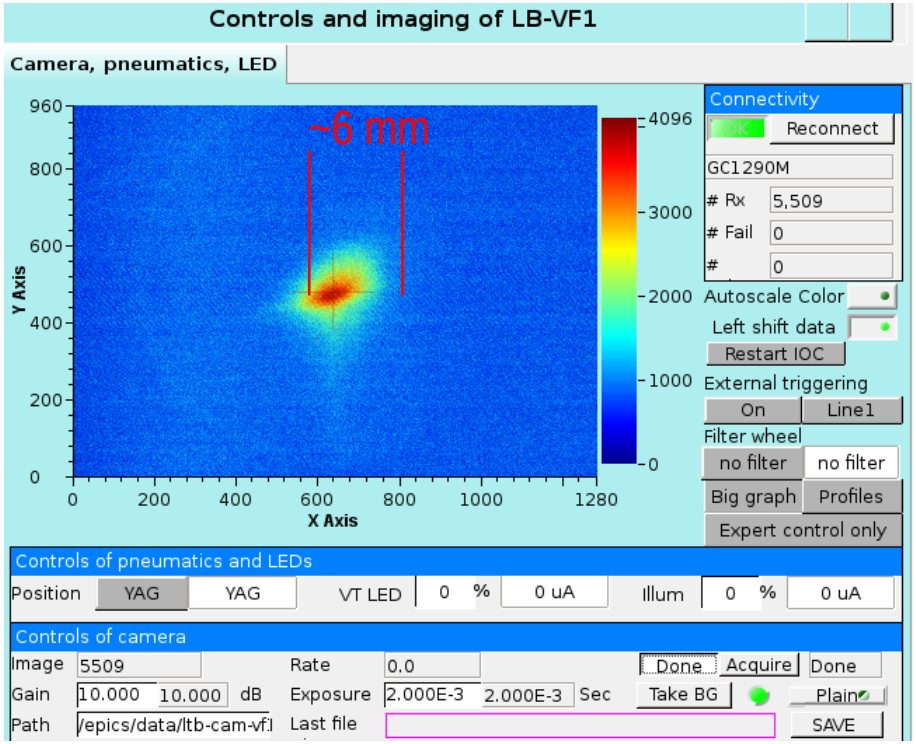
- Delivered by Research Instrument (RI), GmbH
- NSLS-II provided installation and S&A assistance.
- NSLS-II and Research Instruments commissioned the Linac jointly.

Modulator

187 MeV Beam in the Transport Line

Source: T. Shaftan, September 12, 2012





- Linac is commissioned with 13 nC per pulse.
- In both SPM and LPM modes of ops the emittance is 70 nm at 200 MeV or below
- Energy spread is below 0.5% in both modes

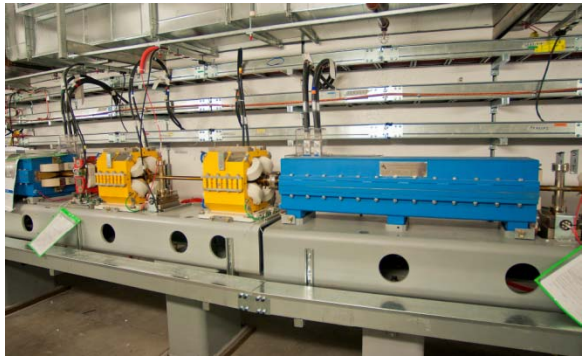
Booster Production, Assembly and Delivery

- Close collaboration between NSLS-II and BINP teams.
- All Containers (except spares) have arrived.
- Installation of booster arcs is complete.
- Installation of injection, extraction and instrumentation girders is ongoing.

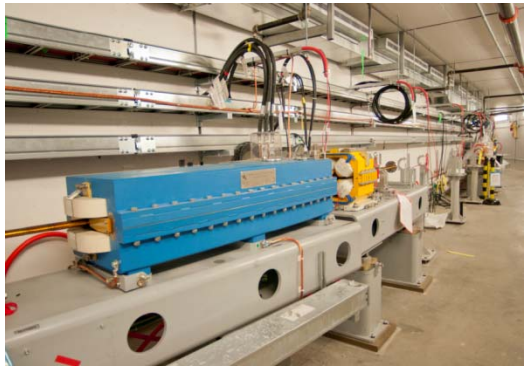
Source: S. Gurov, E. Levichev et al.

Booster Installation

Booster Ring

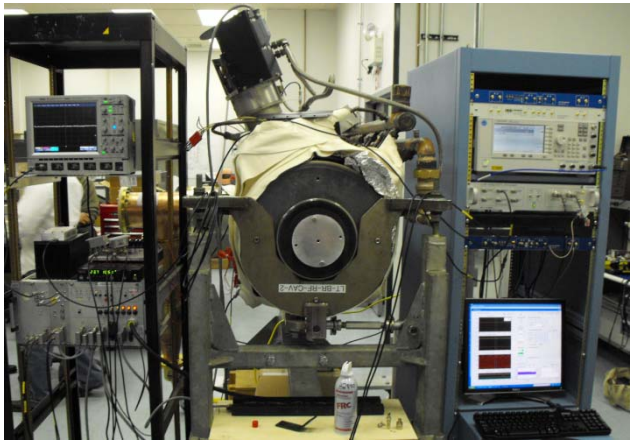


Booster Magnets

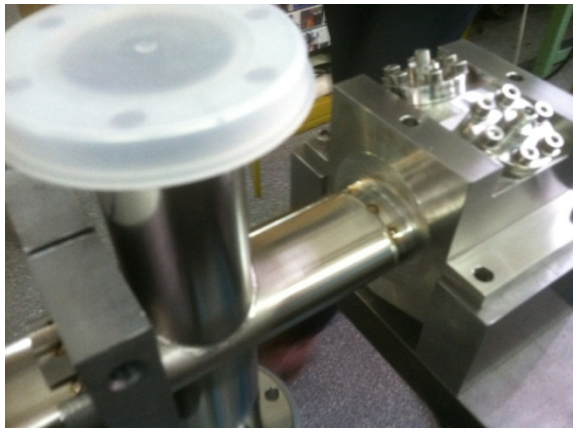


Instrumentation Section

Extraction Girder



RF Cavity



BPM Assembly

Transport Lines - Magnets

All transport line magnets (60) have been built by Stangenes (USA)

LBT magnets

- Small Correctors (10)
- Large Correctors (3)
- "Normal Quads" (18)
- "Large Quads" (2)
- Dipoles (5)

BST magnets

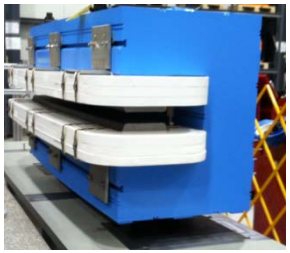
- "Long" Quads (18)
- Dipoles (4)

B. Wahl, C. Spataro, A. Jain, G. Wang, R. Fliller

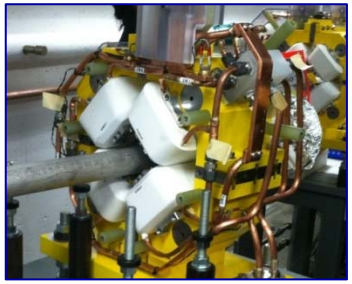
LBT 48mm Dipole

LBT 100/45mm Correctors

BST 90mm Dipole

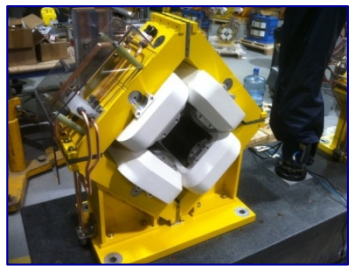


LBT 52mm Quad



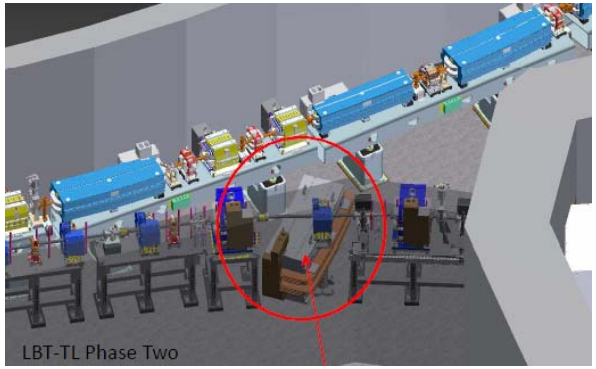
BST 52mm Quad

LBT 134mm Quad

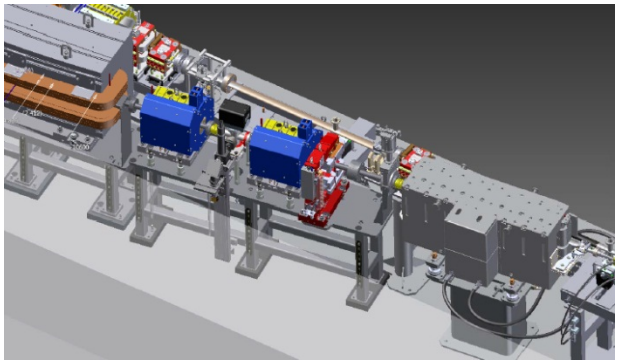


Transport Lines - Status

LTB – Phase 1



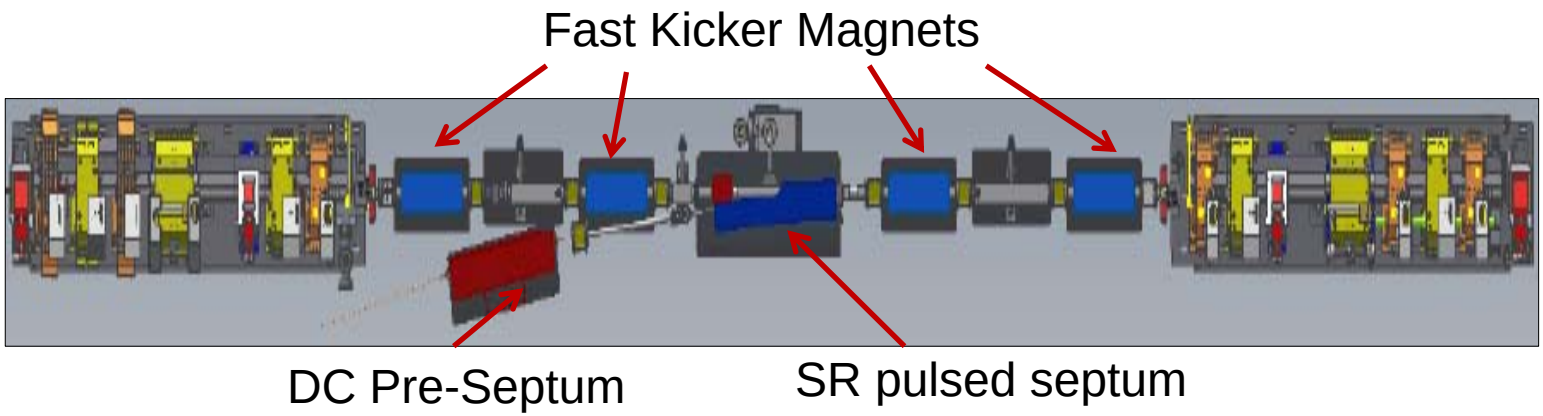
LTB – Phase 2



BTS – Phase 1

- LTB – Phase 1 is installed and commissioned.
- LTB – Phase 2 and BTS – Phase 1 are under installation.
- BTS – Phase 2 is awaiting support tables.
- Expected completion date – December-January, 2013.

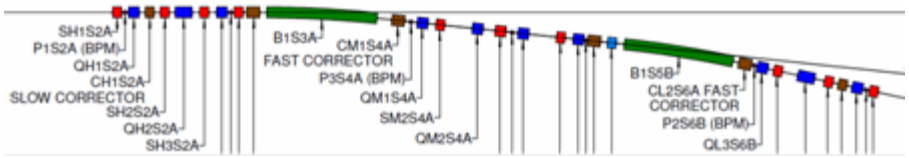
SR Injection Straight Section



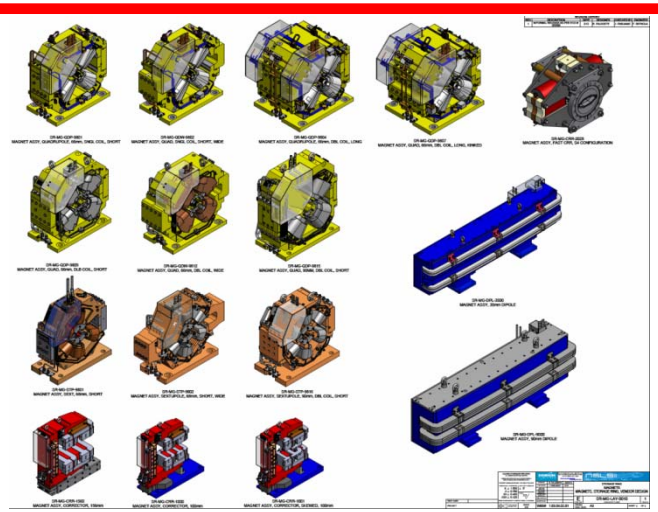
- DC pre-septum is being built by BINP
- Danfysik is building pulsed septum magnet, chamber, PS (PPT), controls.
- Fast kickers are being developed in-house
- Vacuum components are also being developed in-house.
- Expected completion date – summer of 2013.

E. Blum, P. Zuhoski, R. Heese, S. Kowalski, B. Singh

SR Magnets



NSLS-II Lattice



The SR magnets consist of 7 types of quadrupoles, 3 types of sextupoles, 2 types of dipoles and 4 types of correctors.

Magnet Type	Number	Suppliers
Dipoles	60	BSL (New Zealand)
Quadrupoles	300	BINP (Russia), Tesla (England), BSL (New Zealand)
Sextupoles	270	Danfysik (Denmark), IHEP (China), BSL (New Zealand)
Correctors (slow)	180	Everson (USA)
Correctors (fast)	90	Sag Harbor (USA)

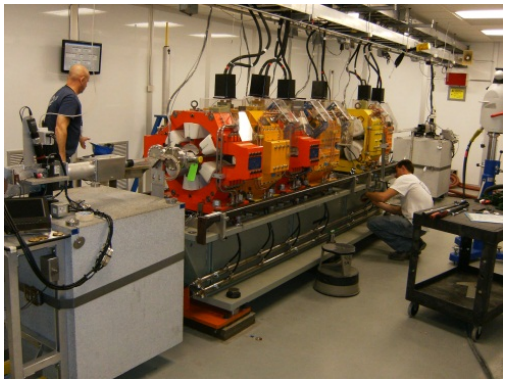
SR – Magnets and Support Status

- All girders and pads have been received
- Of the total of 842 magnets (including spares but not fast correctors), 825 magnets have been received.
- 17 magnets are in transit..

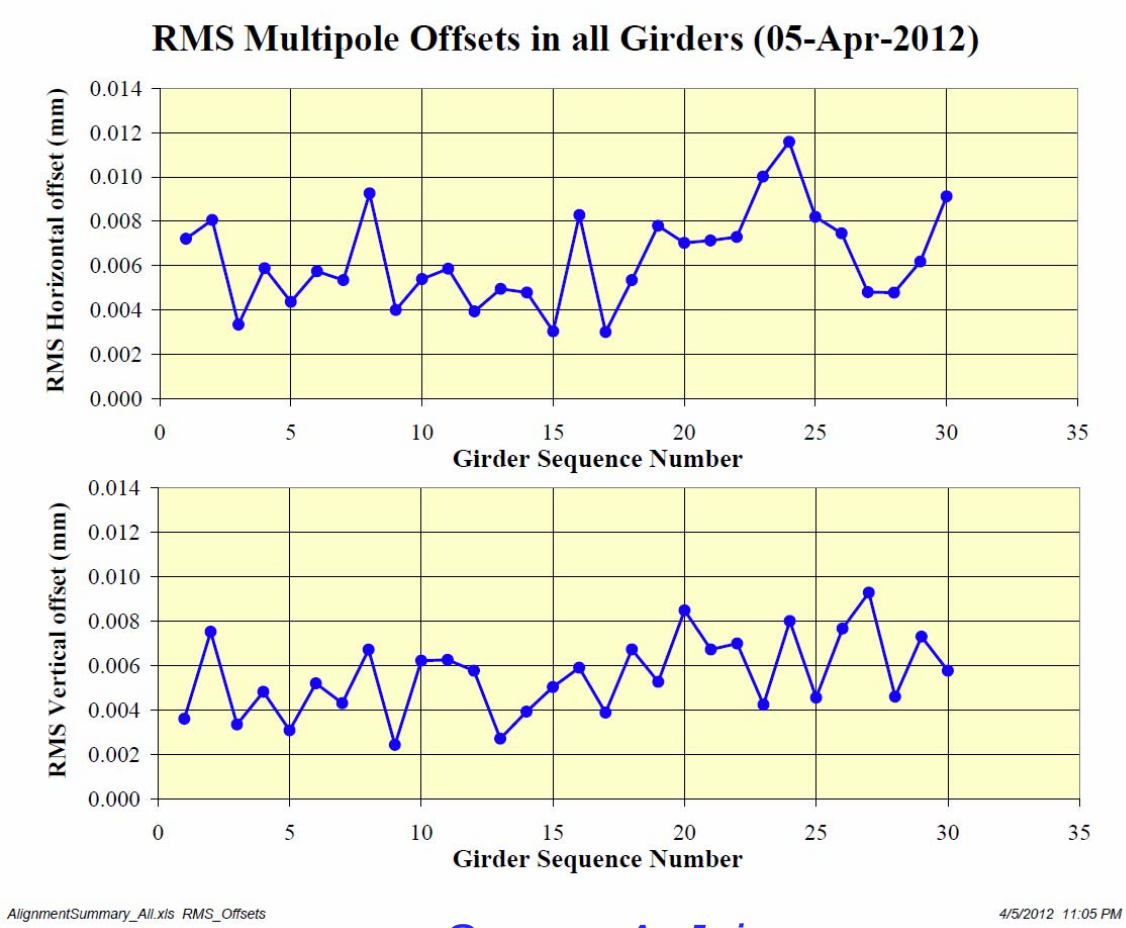
Magnet Alignment Status

75 out of 90 multipoles girder assemblies are aligned to within < ± 10 µm rms .
The aligned girders are transported to the tunnel and installed.

Magnet Pre-Alignment

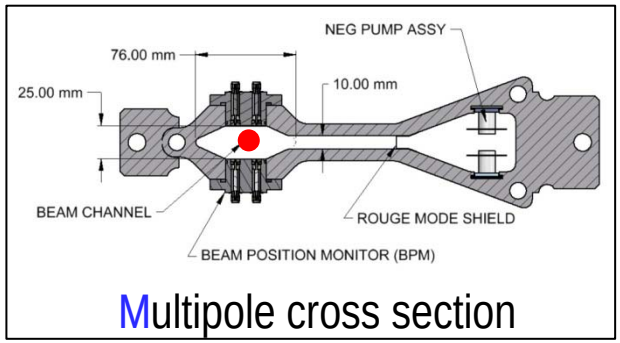


Vibrating Wire Alignment

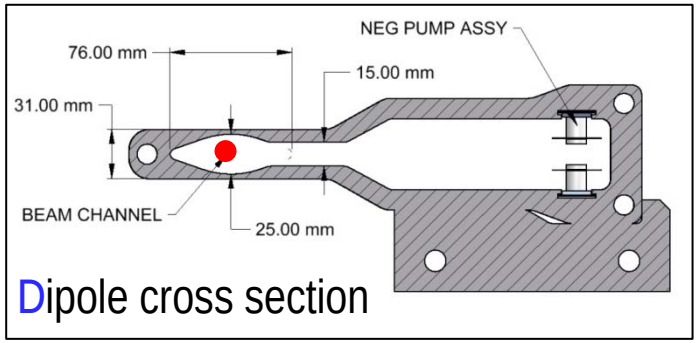


Source: A. Jain

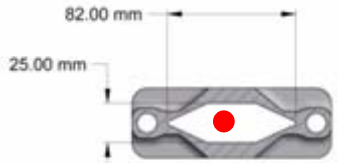
SR Vacuum System



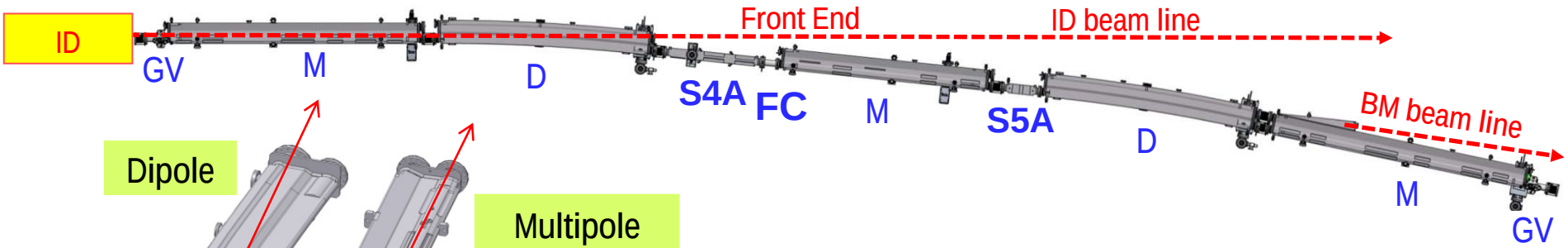
Multipole cross section

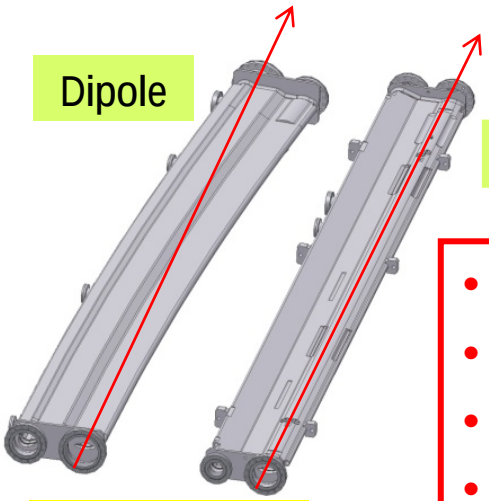


Dipole cross section



Short chamber cross section





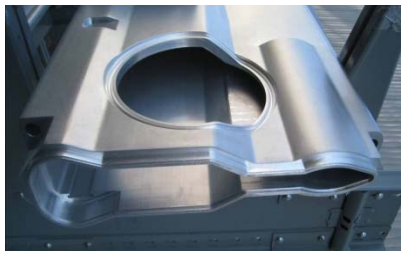
- 150 cell aluminum chambers, 3 – 4.5 m long
- 150 short/narrow cell chambers - S4A, S5A, FC (inconel)
- 38 long and 10 short chambers at straight sections
- ID chambers for DW, EPU, IVU…; exit port pipes
- Special ones at Inj., RF, and for Diag…

Cell Aluminum Chamber Fabrication

extrusion ⇛ bending ⇛ machining ⇛ cleaning ⇛ welding ⇛ assembly

V #1,2 | **BNL** | **V # 3 - 7** | **APS** | **APS** | **BNL**

Completed in Feb 11'



Machining of extrusion, adaptor, flange…

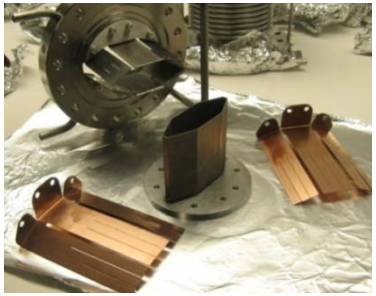
- All 150 cell vacuum chambers have been completed.
- Over 100 have been installed in the ring.

Welding at APS

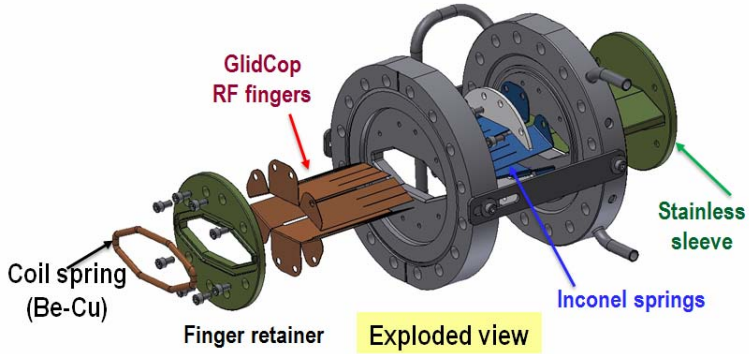
Vacuum certification
(150°C x 24hr)

Completed chambers

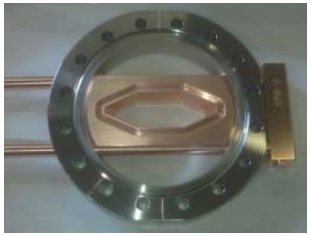
SR Vacuum Components



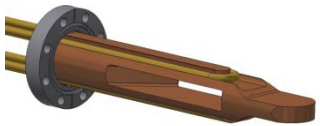
Bellows Liner



Bellows Assembly

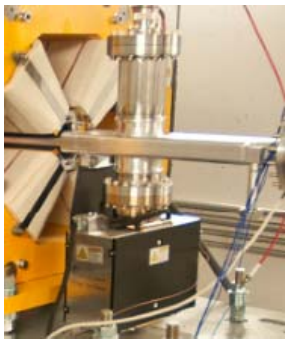


Flange Absorber



Crotch and Stick Absorbers

- All RF Bellows have been fabricated.
- All ion pumps and gate valves are available
- Absorbers, made from Glidcop, are under fabrication, keeping pace with installation and bakeout.



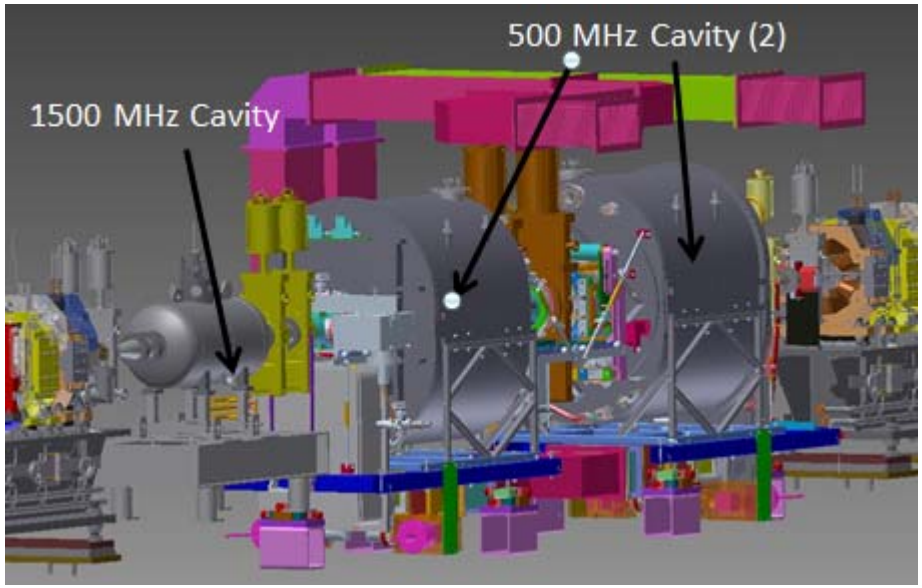
Ion Pump

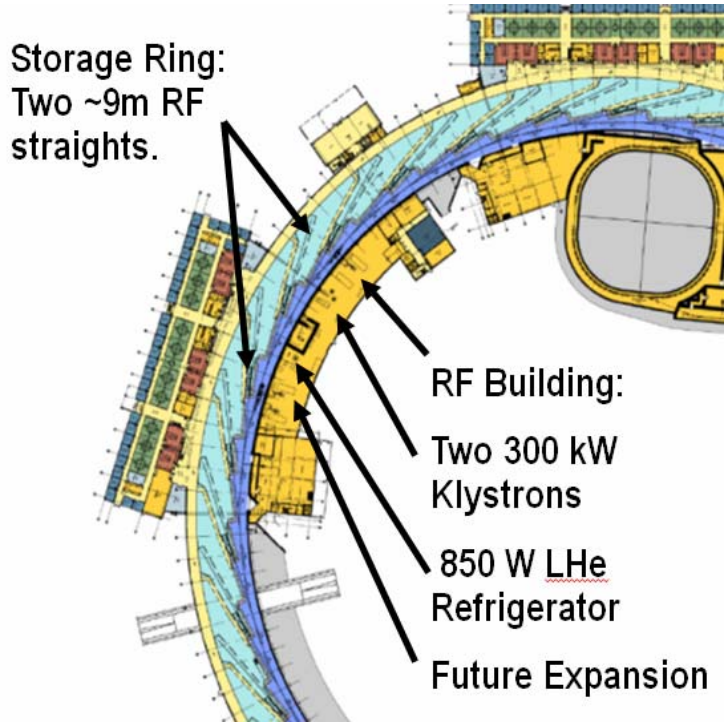
Gate Valve

SR RF System

500 MHz - SCRF Parameters

Parameter	Value
Frequency [MHz]	500
Electric field (normalized to 0.3m) [MV/m]	>8 MV/m
Accelerating Voltage (beam energy gain) [MV]	>2.4 MV
Unloaded Q (at 8MV/m)	$>7*10^8$
Static heat losses [W]	<30 W
Dynamic heat losses (at 4.5k and 8MV/m) [W]	<120 W
Maximum power transferred to beam [kW]	>250 kW
Loaded Q	2×10^5



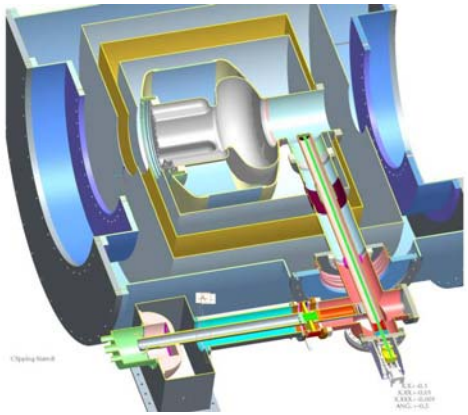


- Initial commissioning will be done with only one 500 MHz SCRF.
- Final configuration will consist of 2 straights each with two 500 MHz and one 1500 MHz SCRF cavities.

SCRF Cavities Status

Helium Vessel
(Myer Tool, USA)

500 MHz SCRF



Conceptual Design

Cavity

(AES, USA)

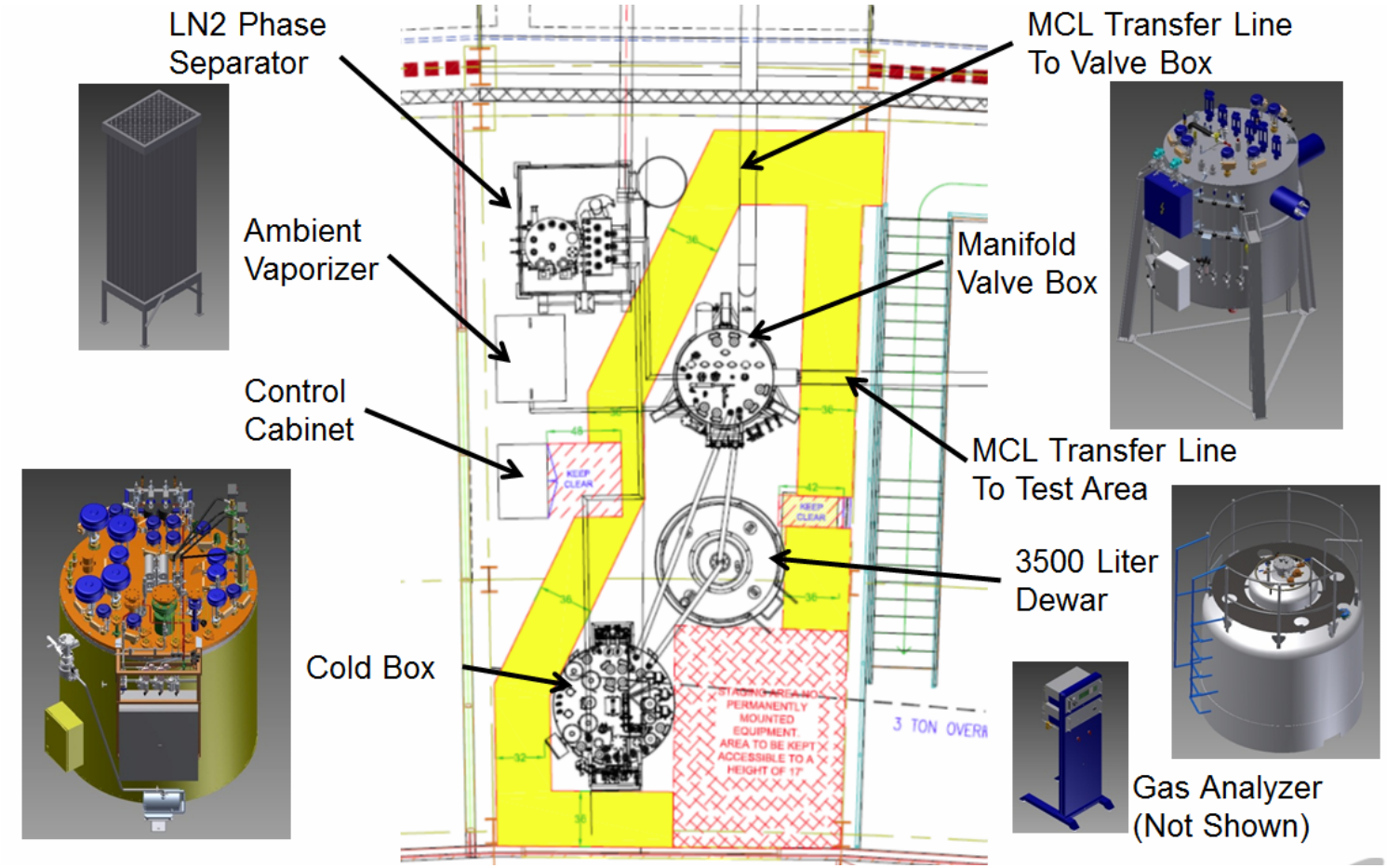
Fluted Pipe

- Delivery of the first 500 MHz SCRF is in May 2013. Commissioning will be completed during the summer of 2013.
- The second cavity will be delivered in the fall of 2013.
- The Installation of the 1500 MHz cavity is scheduled in 2015.

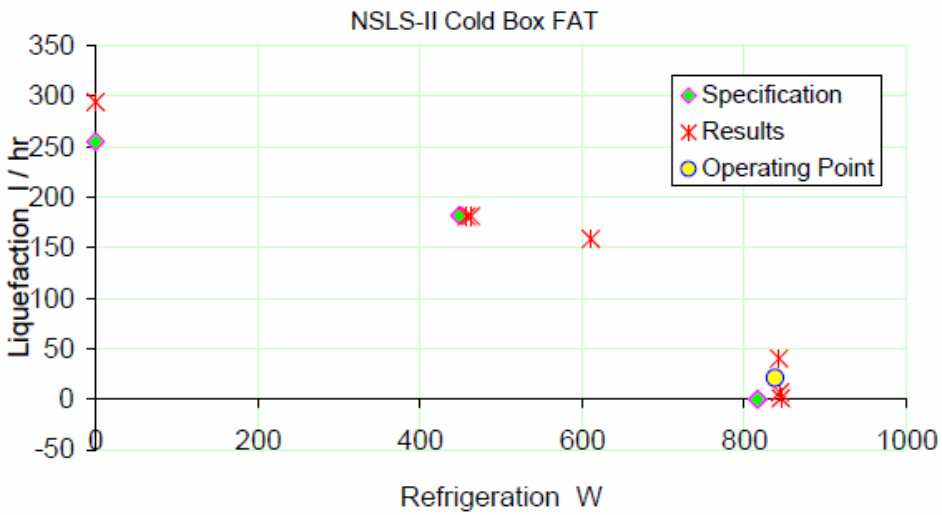
1500 MHz SCRF
(Niowave, USA)

NSLS-II Cryo-System

The 816 W cryo-system is built by Linde with Kaeser, Cryofab, PHPK and Trinity as subcontractors. The system delivery is to be completed in January 2013.



Cryo-System Acceptance Testing

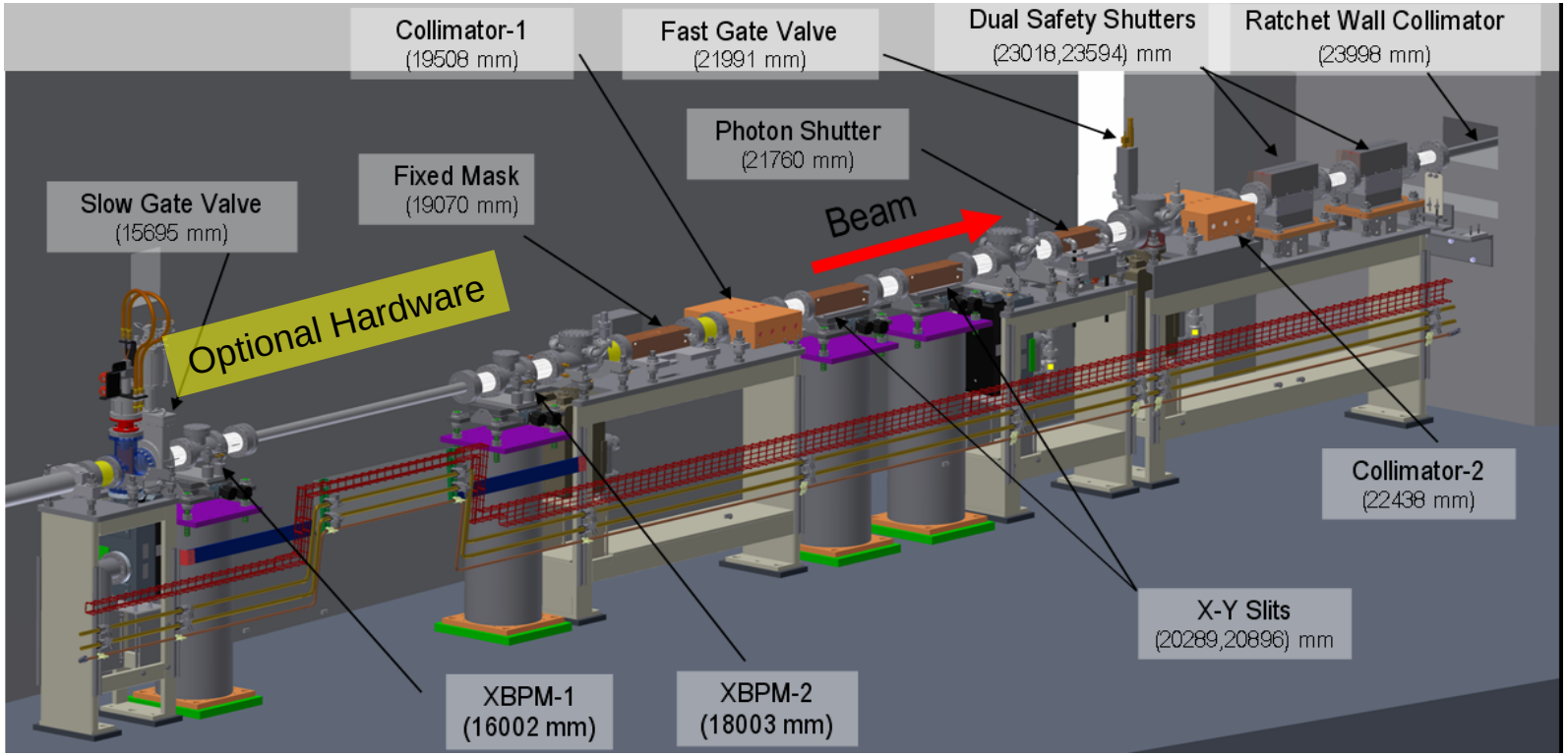


	Specification	Measurements
Refrigeration duty	816 W & 0 L/hr	845 W & 1 L/hr
Mixed duty	449 W & 182 L/hr	458 W & 181 L/hr
Liquefaction	0 W & 255 L/hr	0 W & 295 L/hr

Commissioning of the cryo-system at NSLS-II will begin in February 2013.

Typical IVU Frontend Assembly

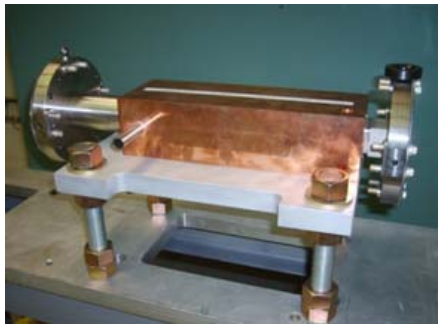
Number of Frontends: Project (6), ABBIX (2), NEXT (6)



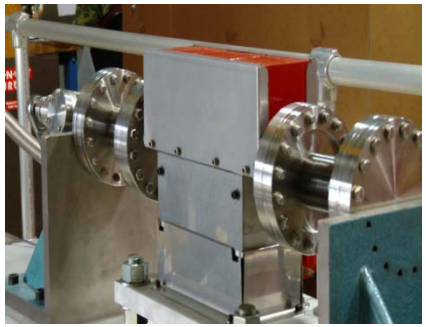
- A pair of X-Y Slits downstream of the fixed mask.
- Out-of-vacuum dual safety shutters.
- The mask, slits and photon shutter are made from Glidcop.
- Thermally stable Invar stands.
- Space for optional hardware between two XBPMs.

Frontends Components

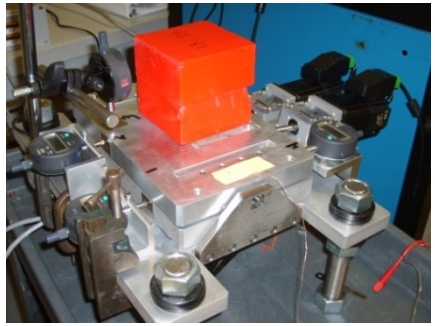
Fixed Mask



Safety Shutter



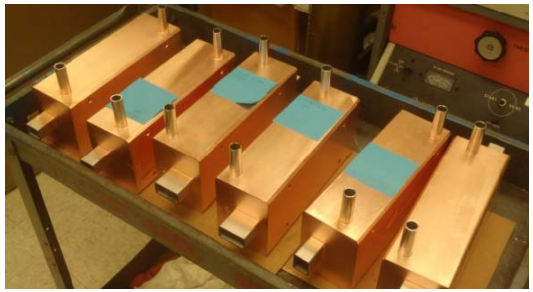
X-Y Stages



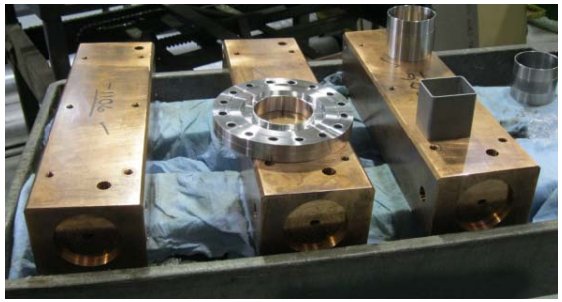
Lead Collimator

- Prototypes were made and tested for performance and fatigue life.

Fabrication of Components:



Photon Shutters



Fixed Masks

Collimators

Frontend Assembly and Installation

- Frontend assembly has started.
- 6 frontends without slits and XBPMs will be installed in March 2013.
- Slits and XBPs will be installed in May-June 2013.
- Integrated tested will be completed iby July 2013.

Frontend Assembly

Ratchet Door

Partially Assembled Tables

NSLS-II Project Baseline Insertion Devices

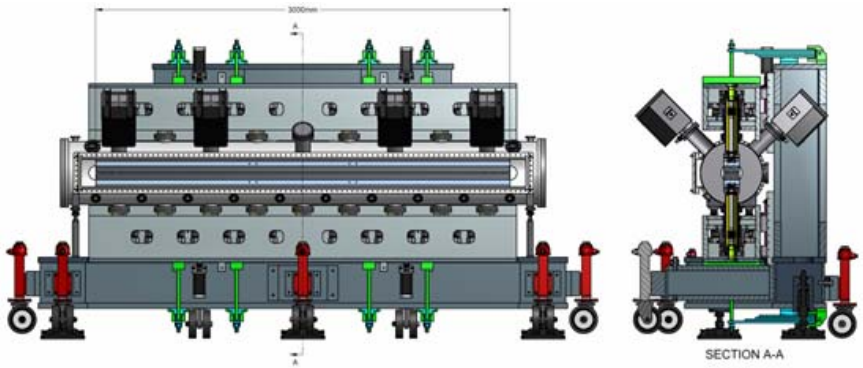
Name	U20	U22(IXS)	EU49	U21(SRX)	DW-1.8T	3PW
Type	IVU	IVU	EPU	IVU	PMW	PMW
Photon energy range	Hard x-ray (1.9-20keV)	Hard x-ray (9.1keV)	Soft x-ray (250eV-1.7keV)	Hard x-ray (1.9-20keV)	Broad band (<10eV-100keV)	Broad band (<10eV-100keV)
Type of straight section	Short	Long	Short (canted)	Short (canted)	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	36 x 2	69	34 x 2	0.5
Magnetic gap (mm)	5	7.4	11.5	6.2	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

Source: T. Tanabe, June 2012

Project Insertion Devices

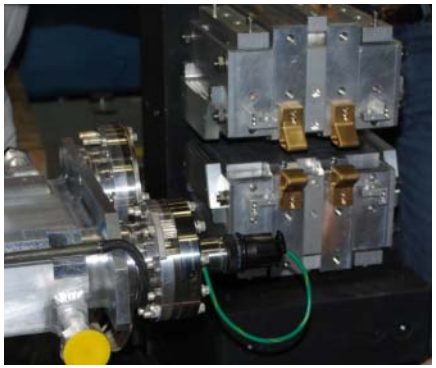
Damping Wiggler

EPU Frame



IVU Model

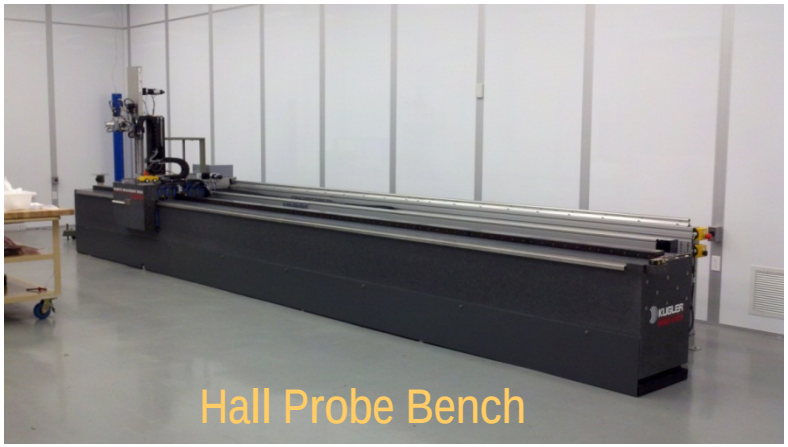
- All ID types are under construction (Danfysik, Kyma, Hitachi, ADC): (6) DW, (5) IVU, (2) EPU, (1) 3-PW
- First DW and a 3-PW have been delivered.
- First EPU is expected in January 2013, and the first IVU is expected May-June 2013.
- Contracts for additional IDs are being placed for non-project (NEXT, ABBIX) beamlines

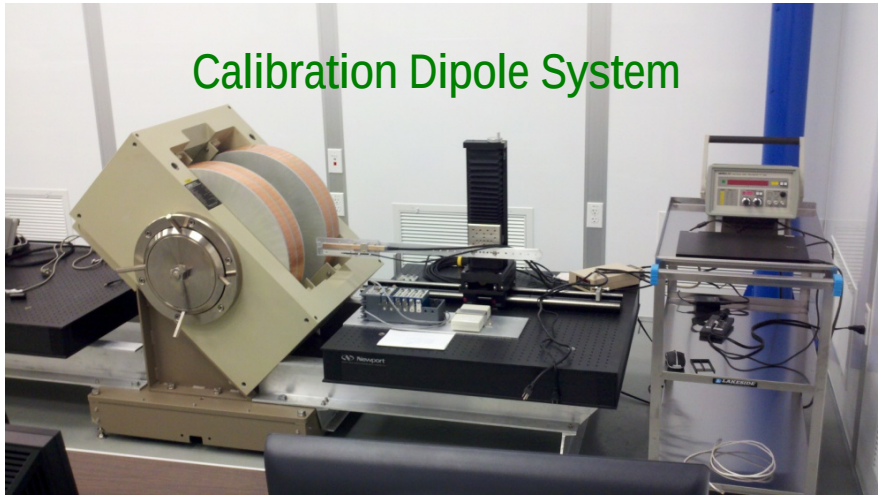


3-Pole Wiggler

ID-Magnetic Measurement Facility (MMF)

- Clean Room has been completed
- Hall probe bench is in operation
- Calibration Dipole is in operation
- Flip/long coil system (IFMS) is to be delivered soon



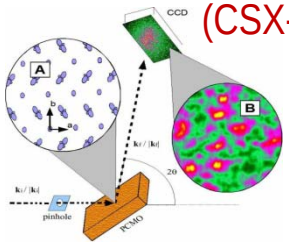


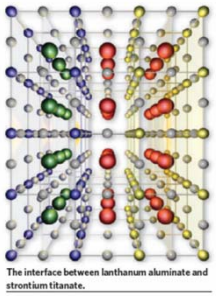
Source: T. Tanabe

NSLS-II 6 Project Beamlines

Source: P. Zschack, June 2012

Coherent Soft X-ray Scattering (CSX-1)



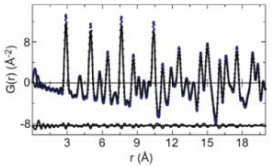


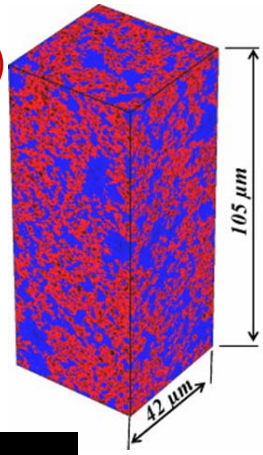
Fast switching polarization

(CSX-2)

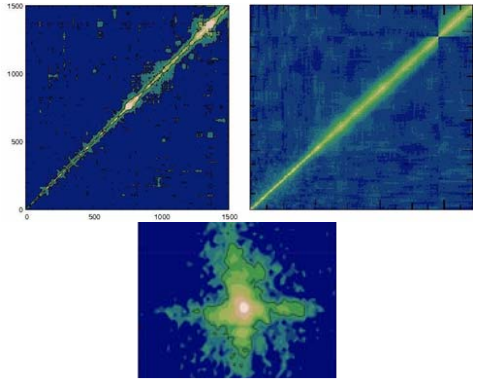
X-ray Powder Diffraction (XPD-1)

PDF studies (XPD-2)

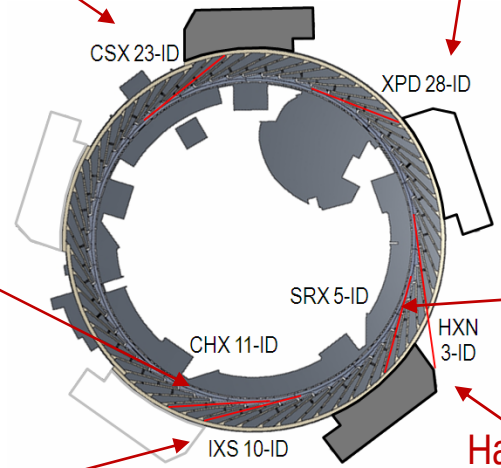


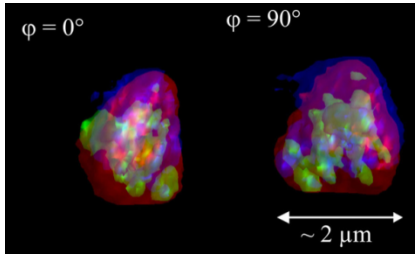


Coherent Hard X-ray Scattering (CHX)



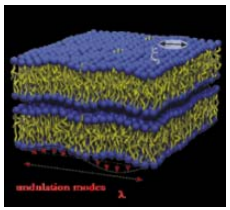
L. Li, LW, AF

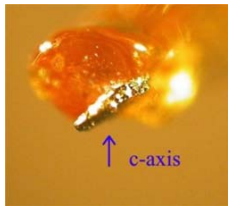


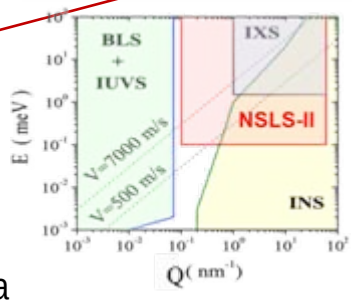


Sub-um Resolution X-ray Spectroscopy (SRX)

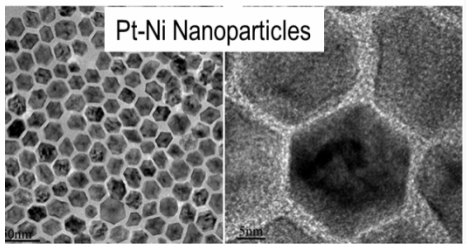
Inelastic X-ray Scattering

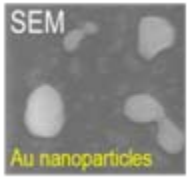


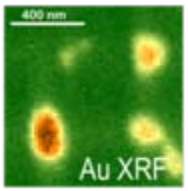




Hard X-ray Nanoprobe (HXN)

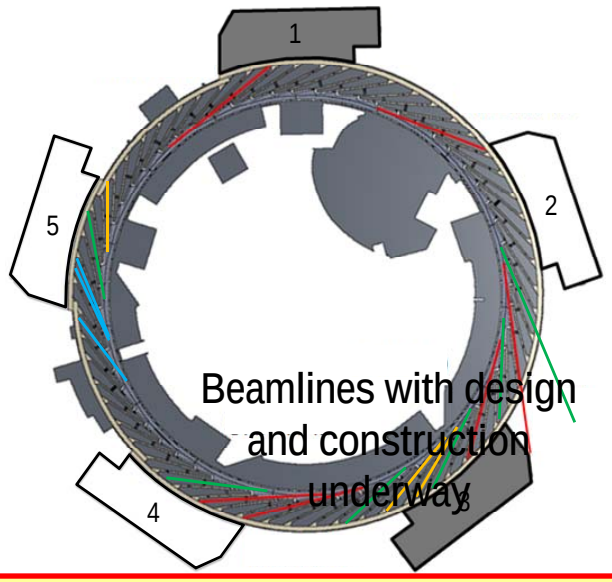






NSLS-II Beamlines Underway

18 Beamline Construction Projects Underway
21 Simultaneous Endstations (SE)
28 Total Endstations (TE)



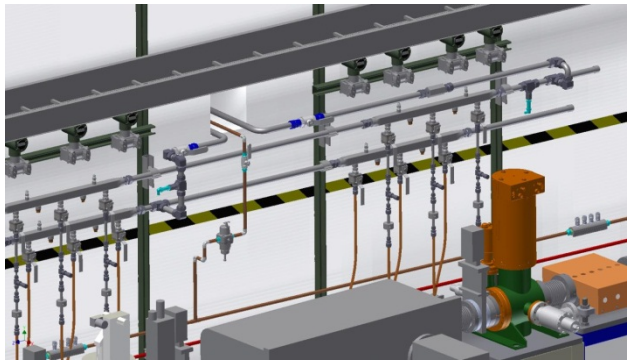
22 additional beamlines (25 SE) have been proposed by the user community and approved by the SAC and NSLS-II but are not yet funded.

Source: S. Dierker, DOE Review, April 2012

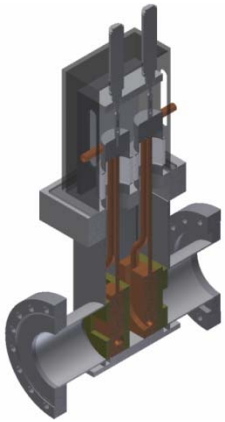
Beamline ConstructionProjects	SE	TE
NSLS-II Project Beamlines		
•Inelastic X-ray Scattering (IXS)	1	1
•Hard X-ray Nanoprobe (HXN)	1	1
•Coherent Hard X-ray Scattering (CHX)	1	1
•Coherent Soft X-ray Scat & Pol (CSX)	2	2
•Sub-micron Res X-ray Spec (SRX)	1	1
•X-ray Powder Diffraction (XPD)	1	1
NEXT MIE Beamlines		
•Photoemission-Microscopy Facility (ESM)	2	3
•Full-field X-ray Imaging (FXI)	1	1
•In-Situ & Resonant X-Ray Studies (ISR)	1	2
•Inner Shell Spectroscopy (ISS)	1	1
•Soft Inelastic X-ray Scattering (SIX)	1	1
•Soft Matter Interfaces (SMI)	1	2
NIH Beamlines		
•Frontier Macromolecular Cryst (FMX)	1	1
•Flexible Access Macromolecular Cryst (AMX)	1	1
•X-ray Scattering for Biology (LIX)	1	1
Type II Beamlines		
•Spectroscopy Soft and Tender (NIST)	2	6
•Beamline for Materials Measurements (NIST)	1	1
•Microdiffraction Beamline (NYSBC)	1	1
	TOTAL 21	28

Beamlines - Common Components

Hutch



Utilities

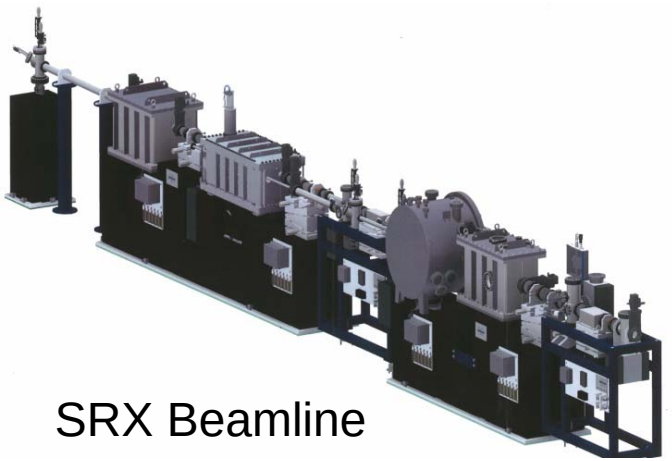


Safety Shutters

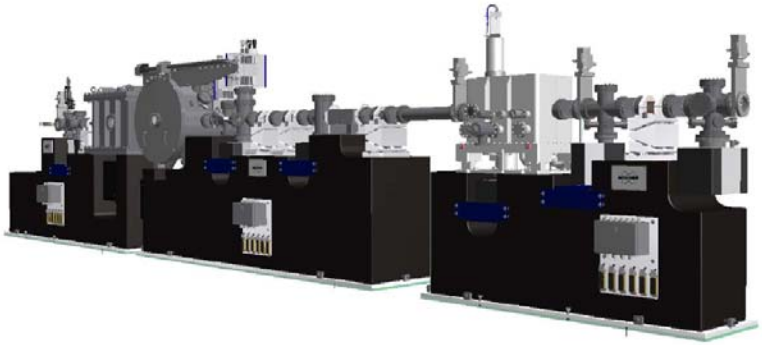
- Construction of the hutches is ongoing.
- Some common designs have been completed – (utilities, safety shutters)
- Phased installation of the beamlines has started.

Hutch under Construction

Beamlines design, Fabrication and Installation

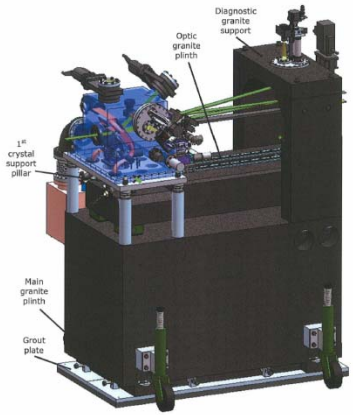


SRX Beamline



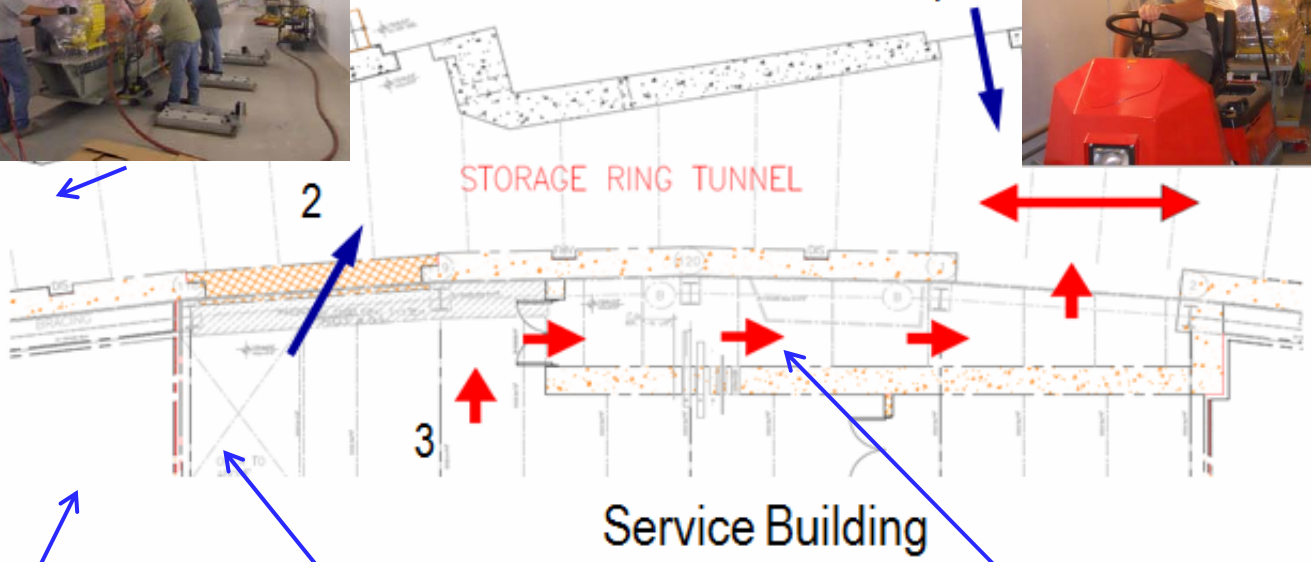
CHX Beamline

- Final design of all beamlines are nearly complete.
- Long lead procurement has started.
- Installation of all beamlines is expected to be completed in the 4th quarter of 2013
- Beamlines are expected to be ready for beam by June 2014.



XPD Monochromator

Girder Installation

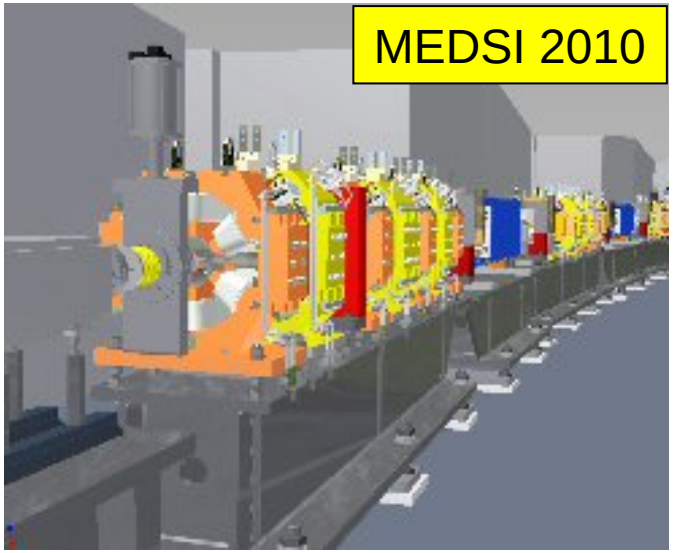


Bldg 902

Flatbed

- 102 out of 150 girders have been installed.
- Average installation time is ~ 2 hours.

Summary



3D Model (April, 2010)

Installed Systems (October, 2012)

- A substantial progress has been made in the design, construction and installation of the NSLS-II Mechanical Systems.
- Almost all accelerator systems will be ready several months before the start of commissioning.