STATUS AND FIRST RESULTS OF THE APS-U

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APS-U Project Manager
IPAC 2024

U.S. DEPARTMENT OF ENERGY
Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

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x500

$815M

$1.5B

Assembled magnets for the upgraded storage ring

First new beamline instrument up and running

New front end systems to deliver X-ray beams to experiments

Long Beamline Building, which will house two of the nine feature beamlines

U.S. DEPARTMENT OF ENERGY
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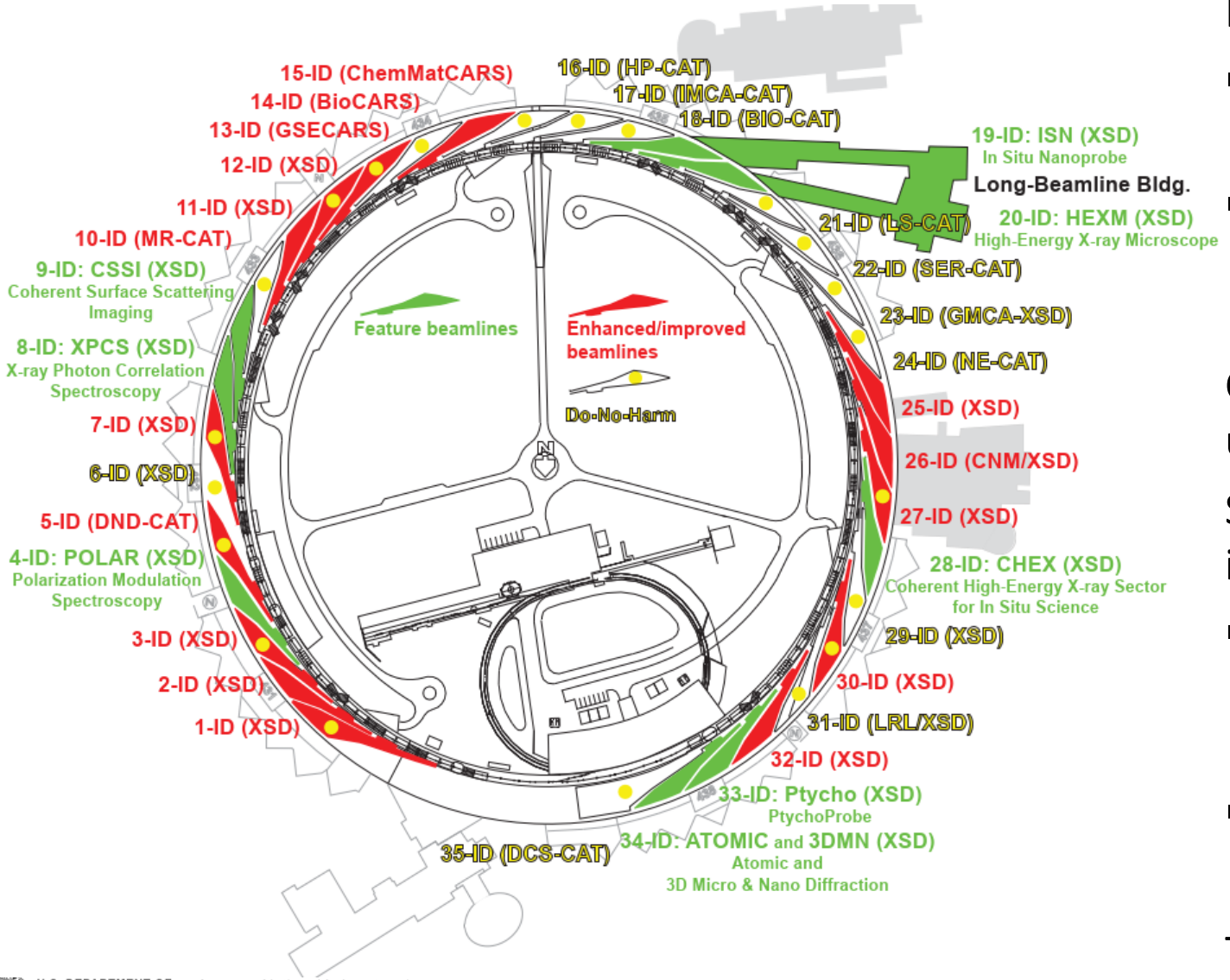
APS UPGRADE PROJECT SCOPE



Replaces / renews the whole facility

- New storage ring enabling brighter, more coherent beams at all beamlines
- New insertion devices tuned for the new storage ring energy and new bending magnet source

Combined result in brightness increases of up to 500x

Specific experimental systems scope includes

- Facilities and equipment for 9 new feature beamlines, including the Long Beamline building
- Enhanced and improved beamlines

TPC - $815M

CD-4 March 2026

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BY THE NUMBERS

Storage Ring	Insertion Devices	Front Ends	Beamlines
1,321 Magnets	11 Phase Shifters/Supports	470 Tables/Supports	36 Enclosures
4,640 Vacuum Components	48 Canted Magnets/Supports	162 Shutters	55 Mirrors
2,245 Power Supplies	33 Corrector Magnets	108 BPMs	20 Instruments
400 Power Supply Controllers	800 Vacuum Components	162 Masks	19 Monochromators
560 RF BPM Electronics	68 Power Supplies	116 Collimators	9 Transports
200 Module Assemblies	57 Insertion Devices	35 High Heat Load and Canted Front Ends	21 Compound Refractive Lens

Project is 94% complete, 97% complete by obligation
$815M TPC; $802M Estimate at Complete

PROJECT KEY PERFORMANCE PARAMETERS

Key Performance Parameter	Thresholds (Performance Deliverable)	Objectives
Storage Ring Energy	> 5.7 GeV, with systems installed for 6 GeV operation	6 GeV
Beam Current	≥ 25 mA in top-up injection mode with systems installed for 200 mA operation	200 mA in top-up injection mode
Horizontal Emittance	< 130 pm-rad at 25mA	≤ 42 pm-rad at 200mA
Brightness @ 20 keV[1]	> 1 x 10^{20}	> 1 x 10^{22}
Brightness @ 60 keV[1]	> 1 x 10^{19}	> 1 x 10^{21}
New APS-U Beamlines Transitioned to Operations	7	≥ 9

Accelerator, Front Ends and IDs, and Experimental Systems

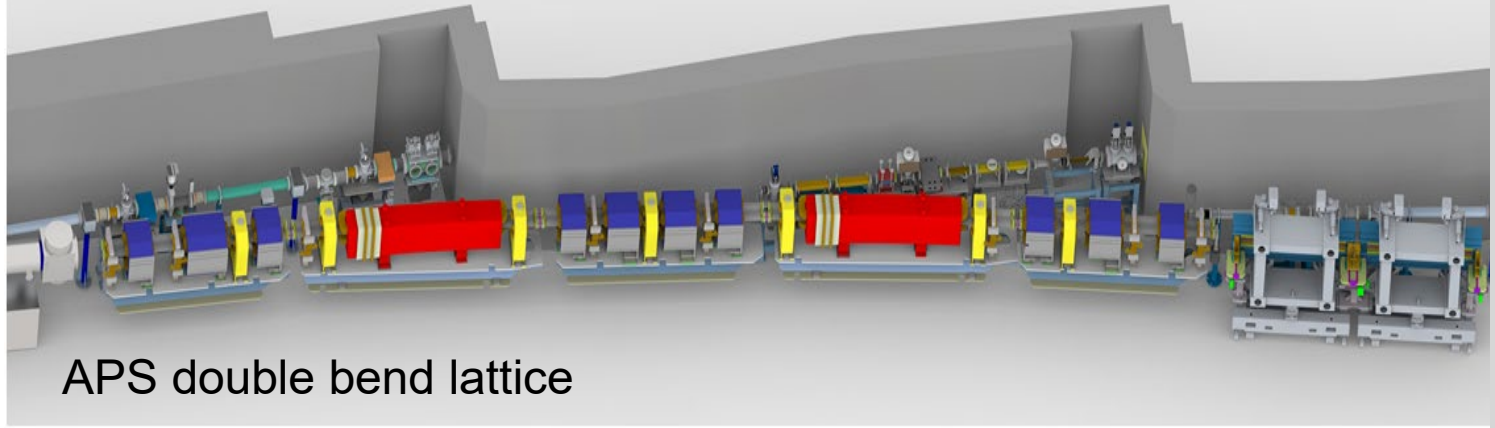
[1]photons/sec/mm^2/mrad^2/0.1%BW

The APS Upgrade systems can meet all objective KPPs

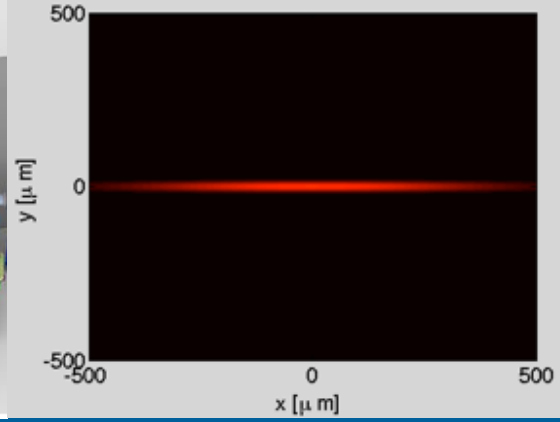
APS-U HIGH BRIGHTNESS STORAGE RING LATTICE

Original APS

ε = 3100 pm.rad

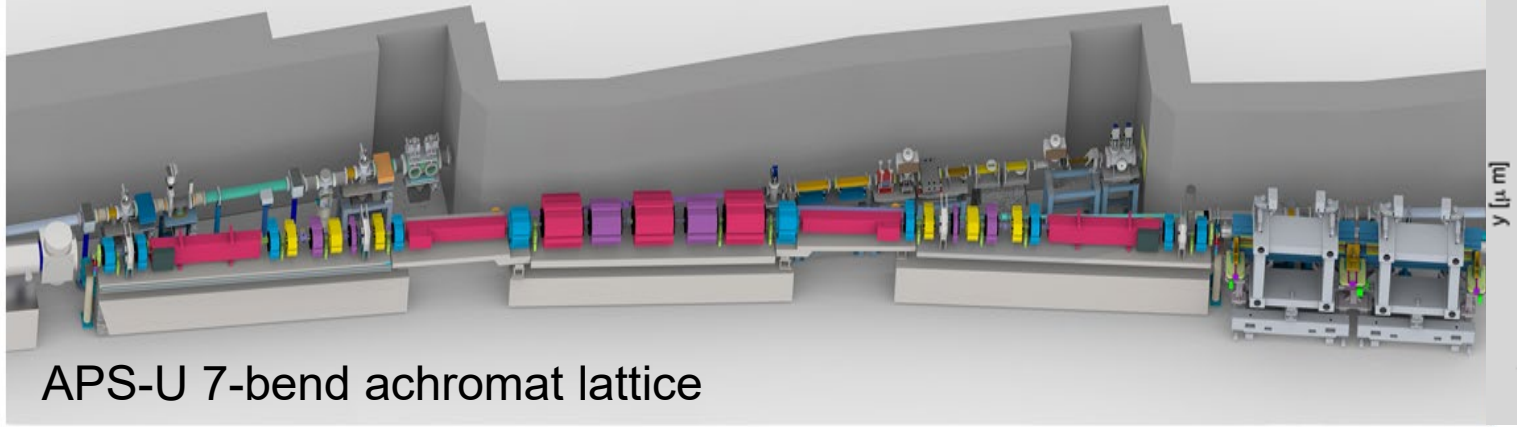


APS double bend lattice

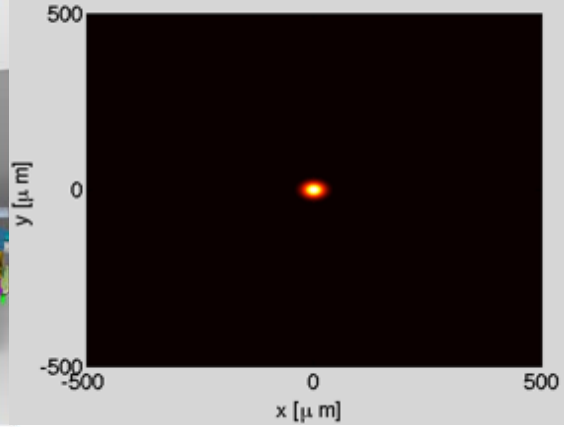


APS-U

ε = 42 pm.rad



APS-U 7-bend achromat lattice



MAY 2023 – REMOVAL STARTED

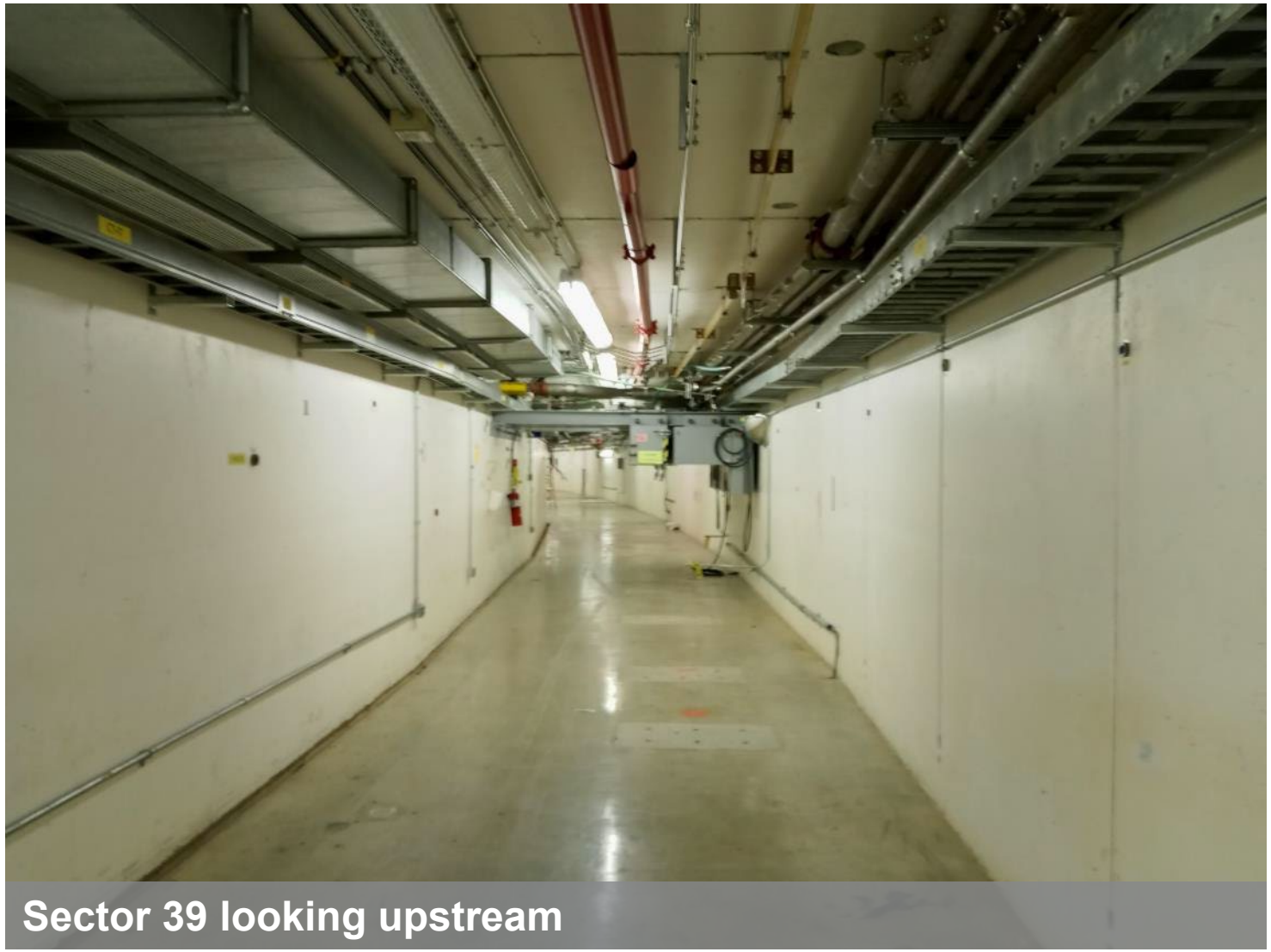
Existing insertion device & girders

Empty storage ring sector

1st item removed May 8, 2023

Front end tables

JUNE 2023 – STORAGE RING EMPTIED

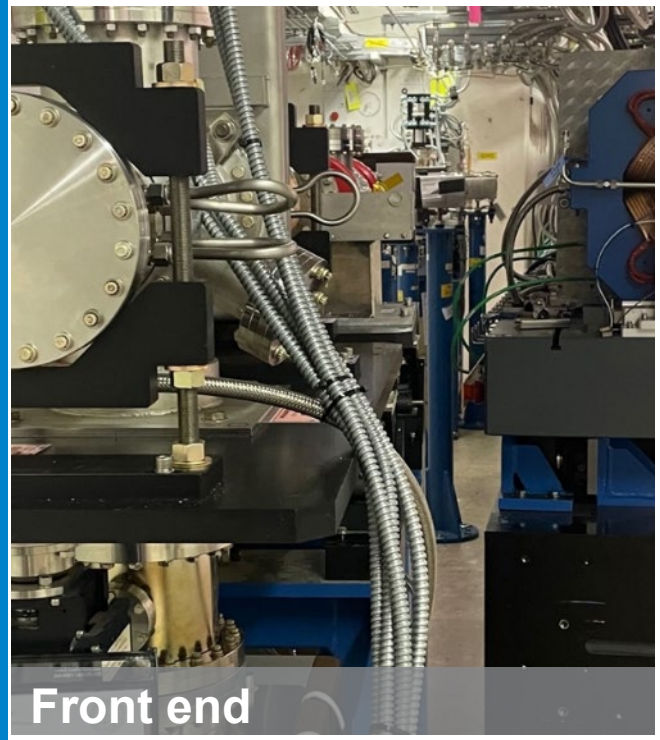


Sector 39 looking upstream

JULY 2023 – FIRST MODULE INSTALLED

1st module installed July 12, 2023

JULY 2023



Front end

Bunch lengthening system

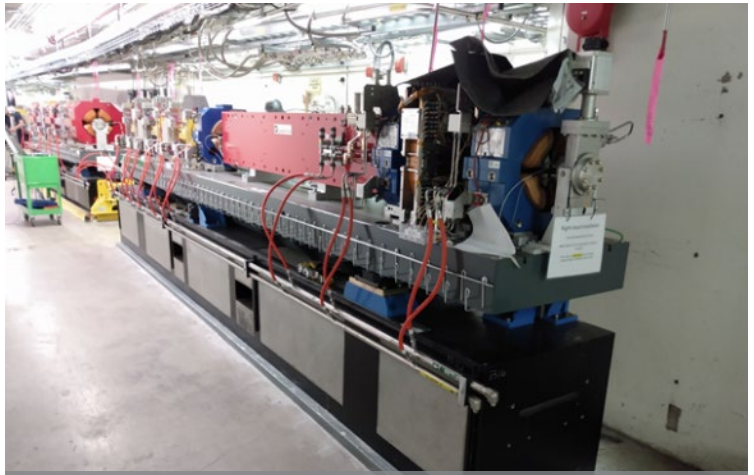
Power supply racks

Aluminum water skid

AUGUST 2023

Wall collimator

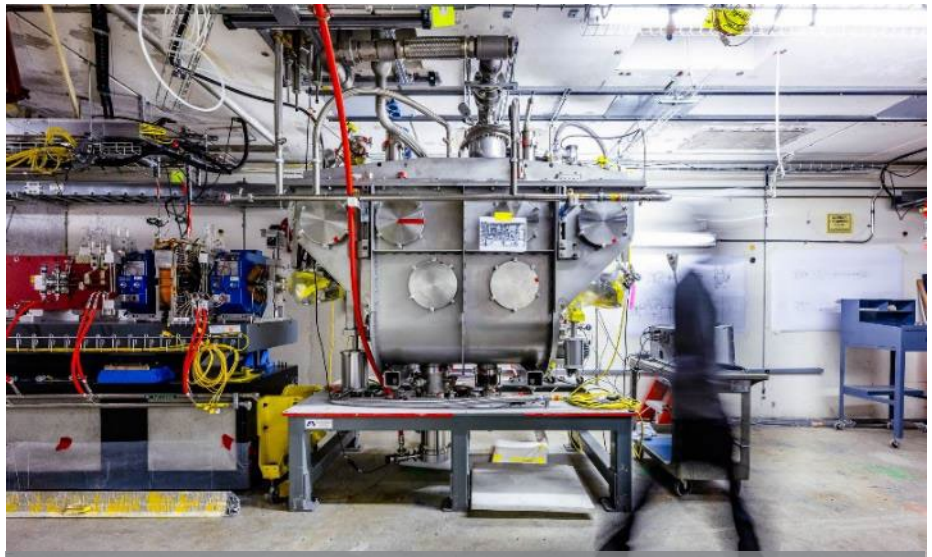
Module placement



Module grouting

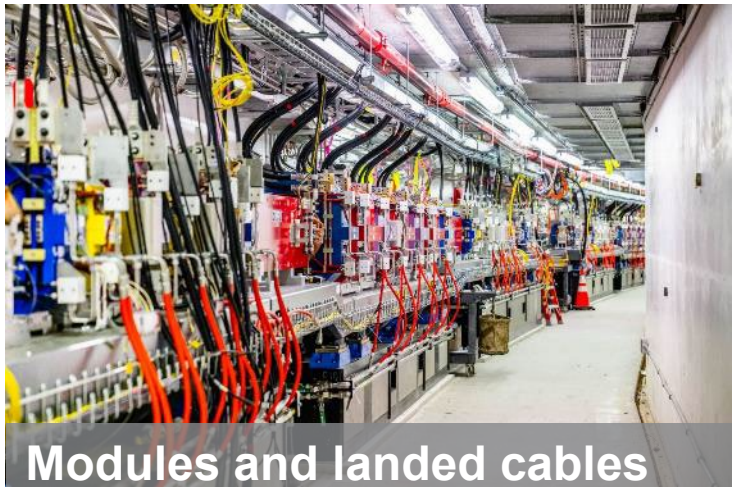
Storage Warehouse (981) before and after starting installation

SEPTEMBER 2023



Bunch lengthening system in Zone F

Insertion device vacuum chamber



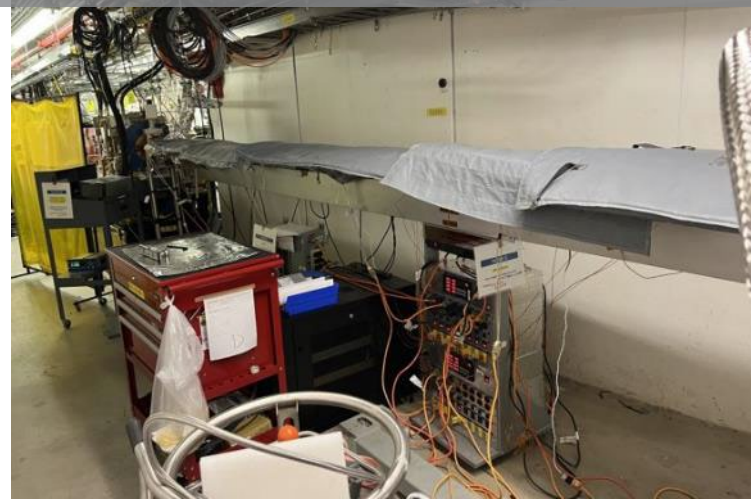
Modules and landed cables

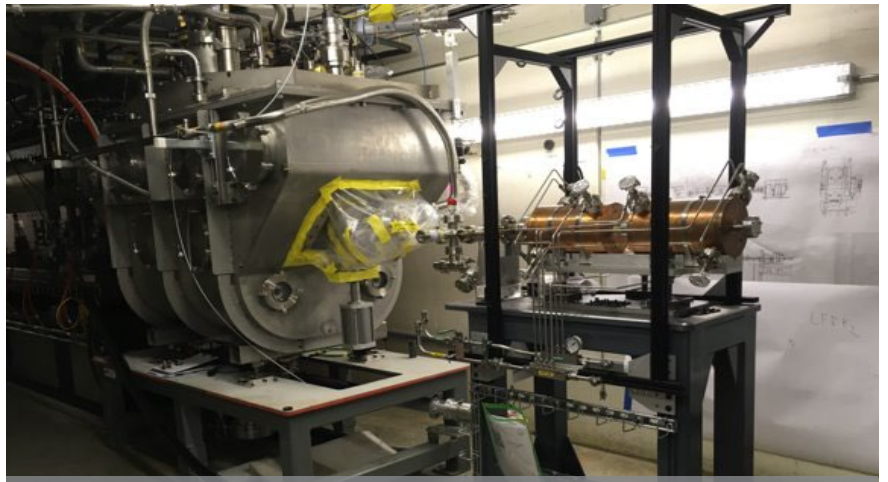
RF and kicker racks

Mezzanine installation

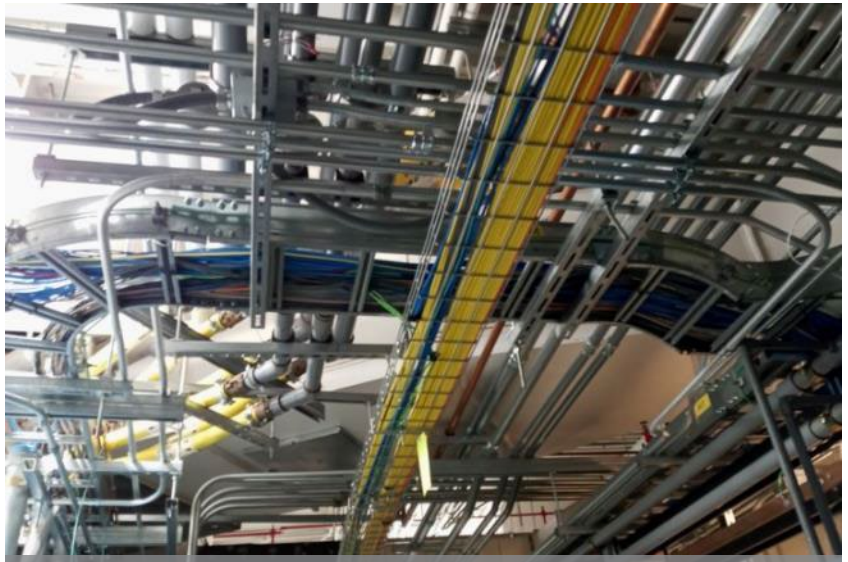
OCTOBER 2023

Insertion device vacuum chamber and module bakeout





S38 longitudinal feedback kicker pair

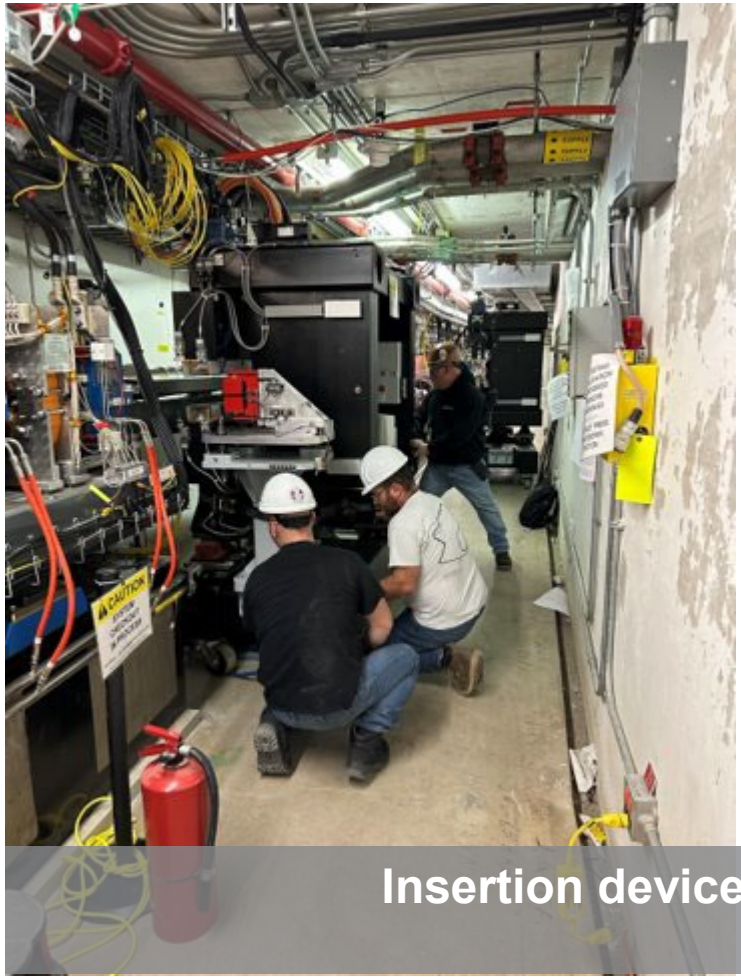


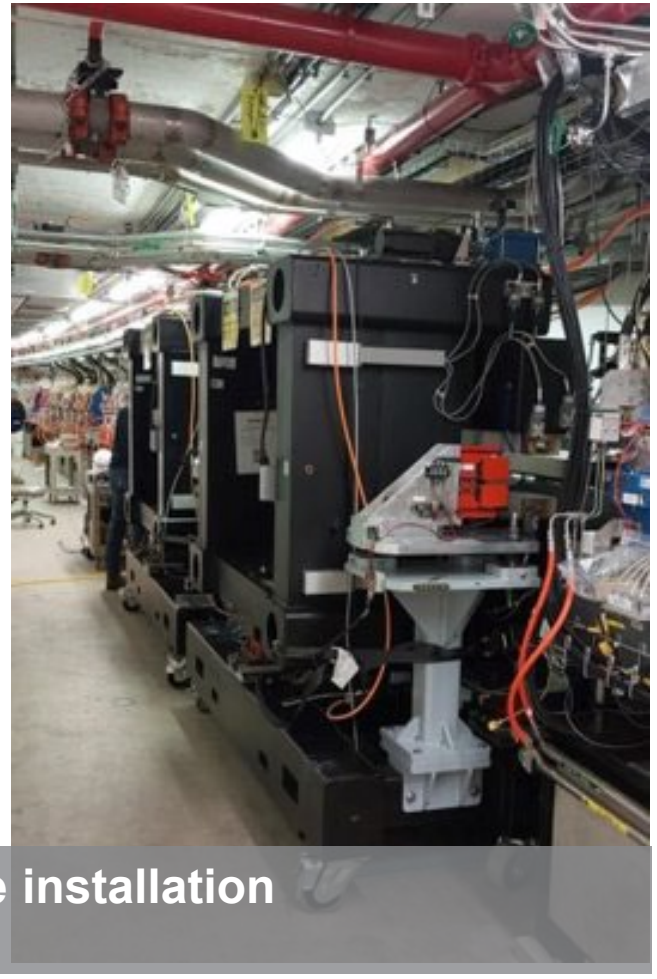
IT fiber cables

Test & Checkout

NOVEMBER 2023

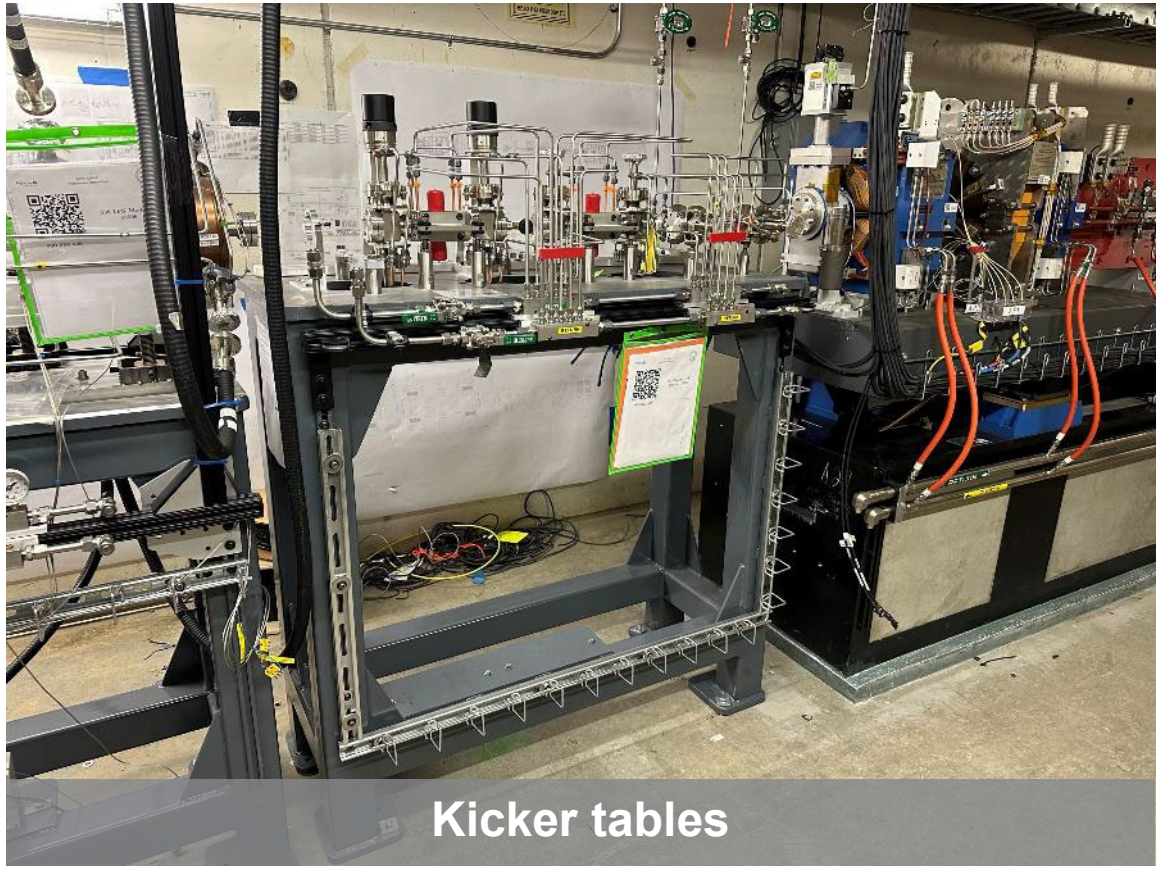
Magnet power supply test and checkout



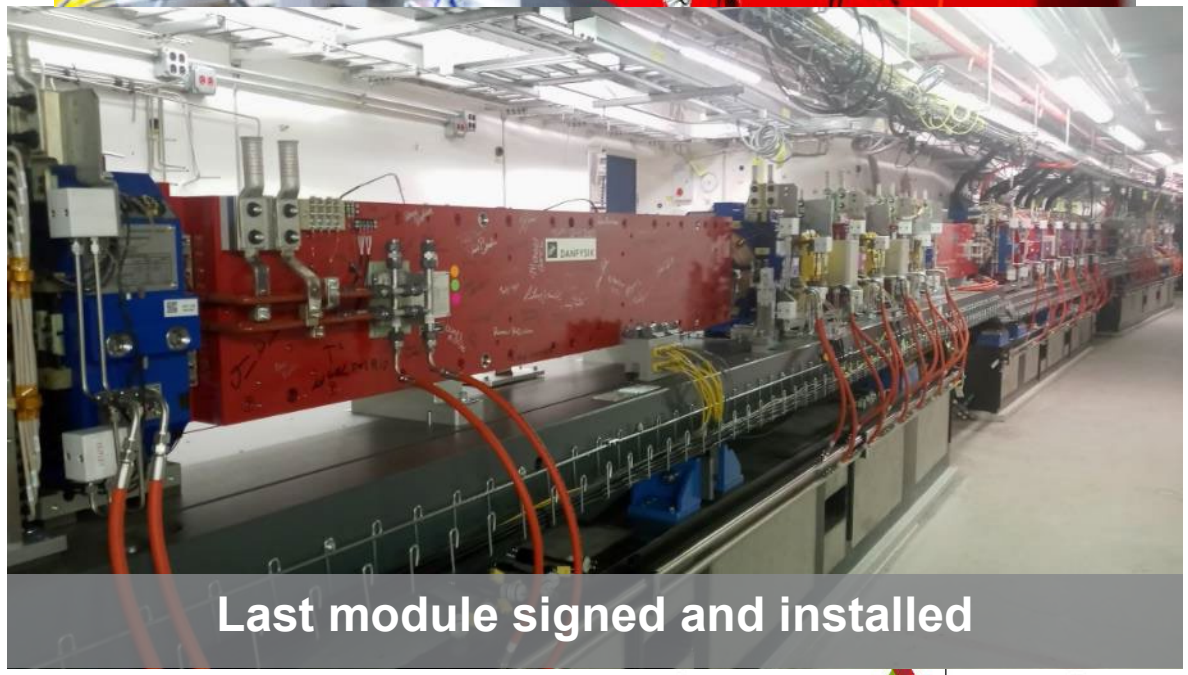


Insertion device installation

DECEMBER 2023



Kicker tables



Last module signed and installed

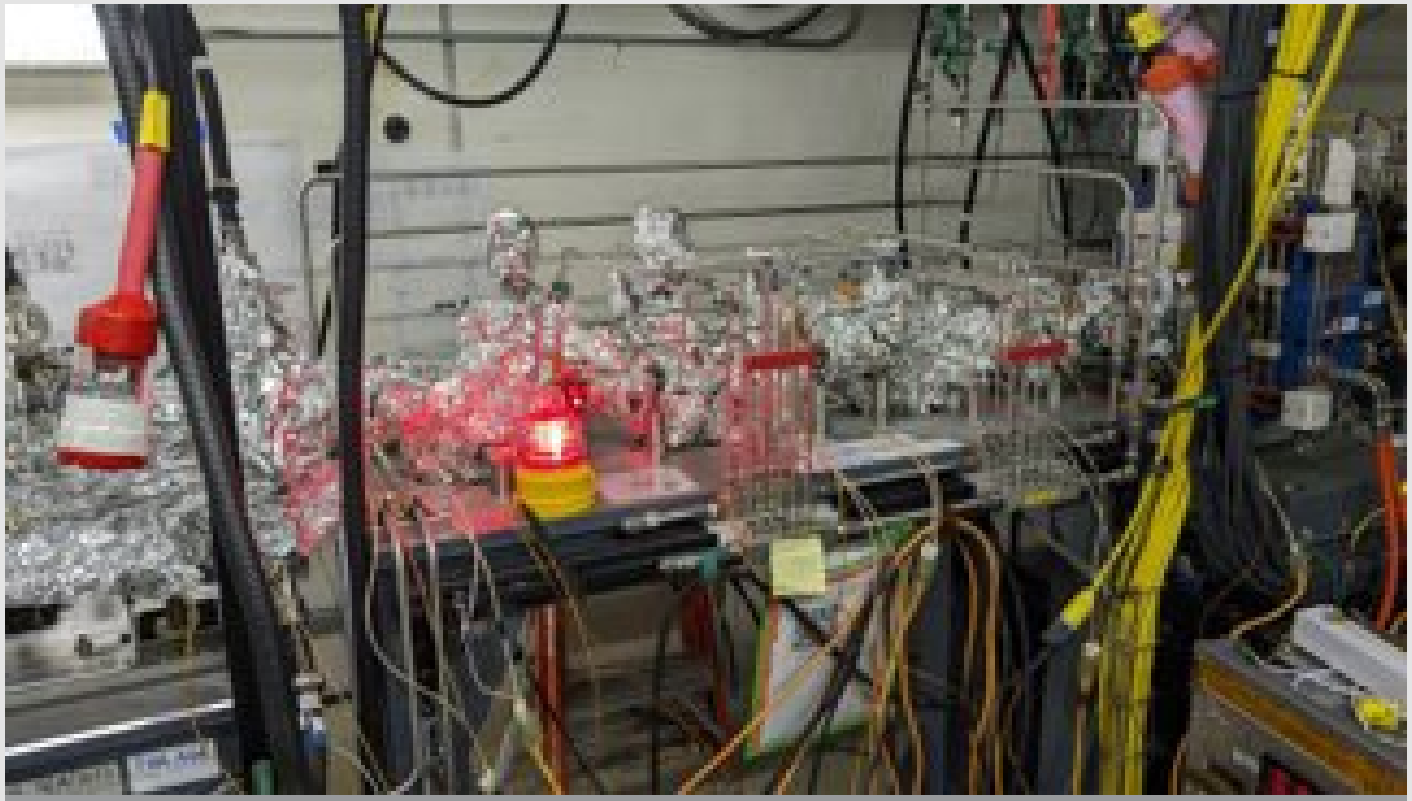
JANUARY 2024

RF Waveguide

Septum and Kicker Tables

Booster to Storage Ring (BTS) Transfer Line Tables

FEBRUARY 2024

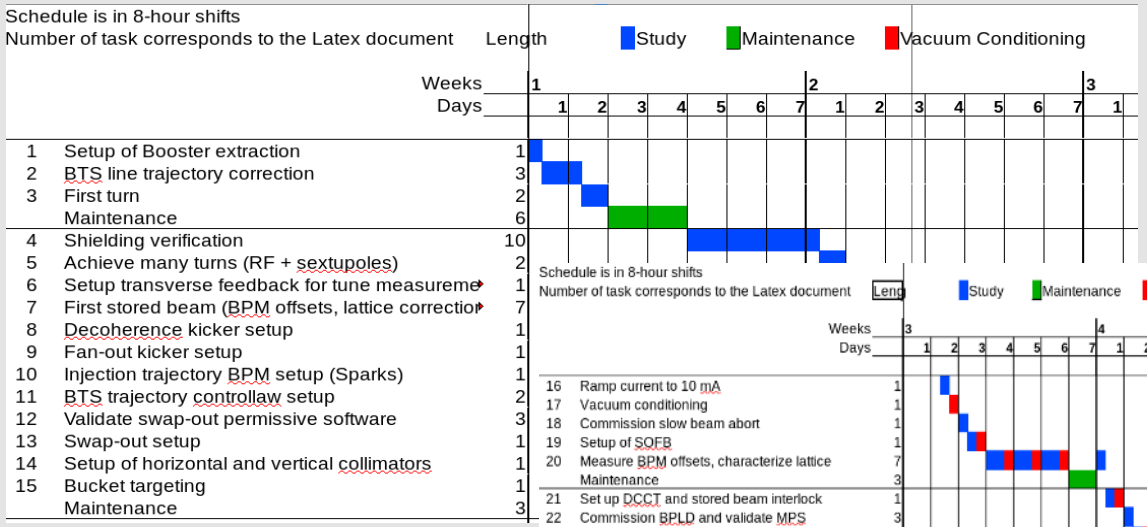


S38 Stripline Kickers Bakeout

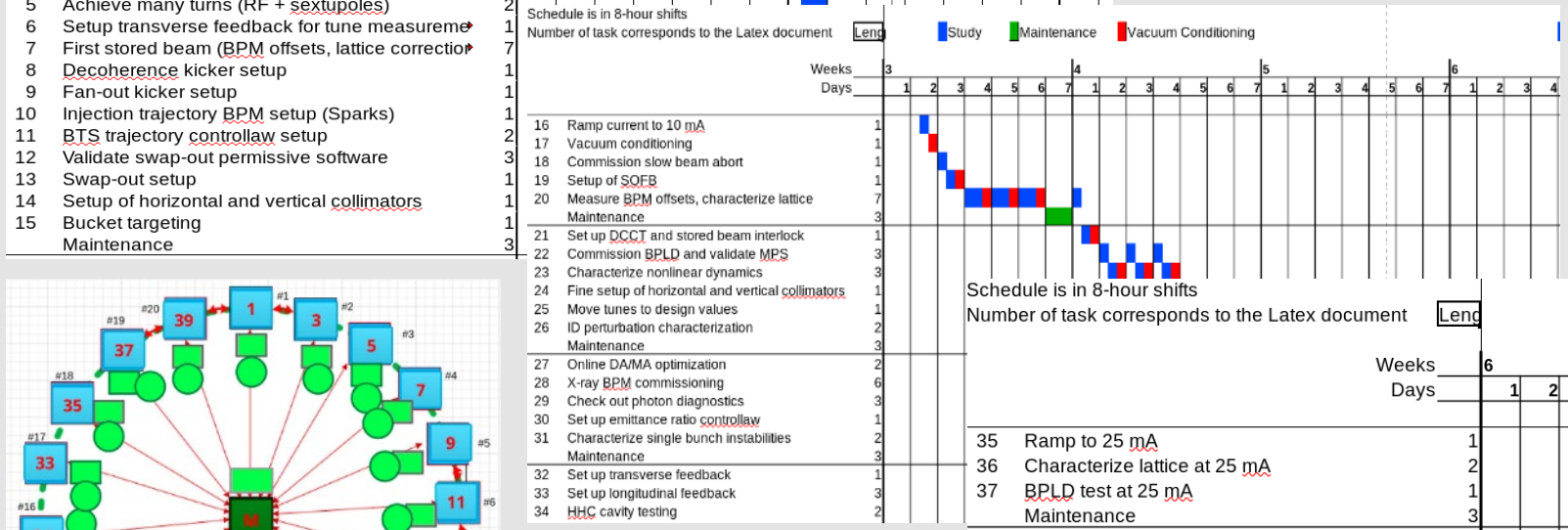
Last Storage Ring Piece

MARCH 2024

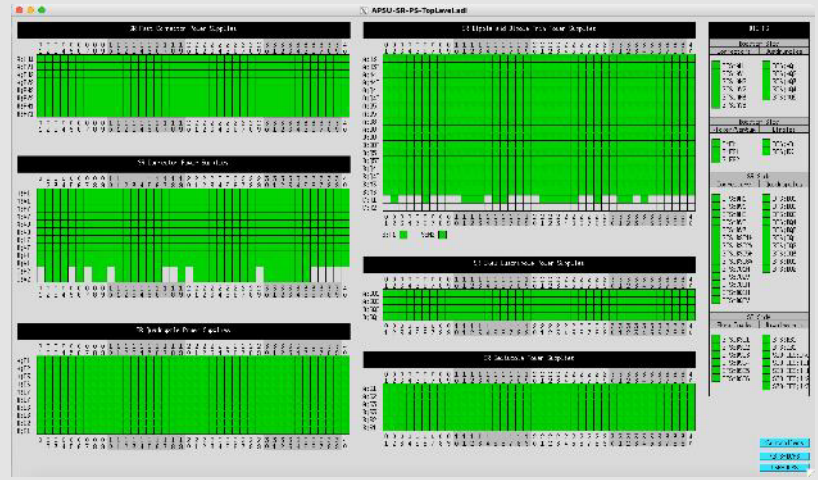
Schedule is in 8-hour shifts
Number of task corresponds to the Latex document

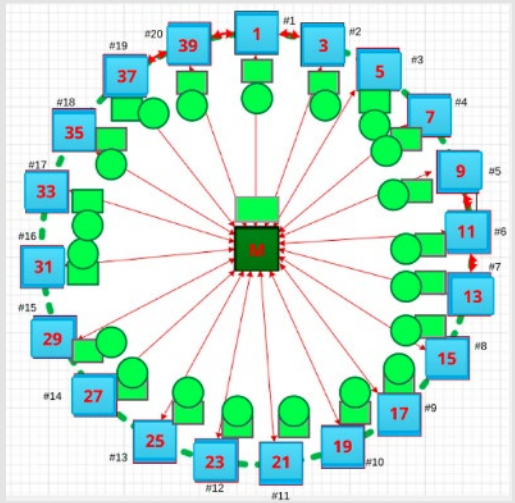


		Length
1	Setup of Booster extraction	1
2	BTS line trajectory correction	3
3	First turn	2
	Maintenance	6
4	Shielding verification	10
5	Achieve many turns (RF + sextupoles)	2
6	Setup transverse feedback for tune measureme	1
7	First stored beam (BPM offsets, lattice correctior	7
8	Decoherence kicker setup	1
9	Fan-out kicker setup	1
10	Injection trajectory BPM setup (Sparks)	1
11	BTS trajectory controllaw setup	2
12	Validate swap-out permissive software	3
13	Swap-out setup	1
14	Setup of horizontal and vertical collimators	1
15	Bucket targeting	1
	Maintenance	3

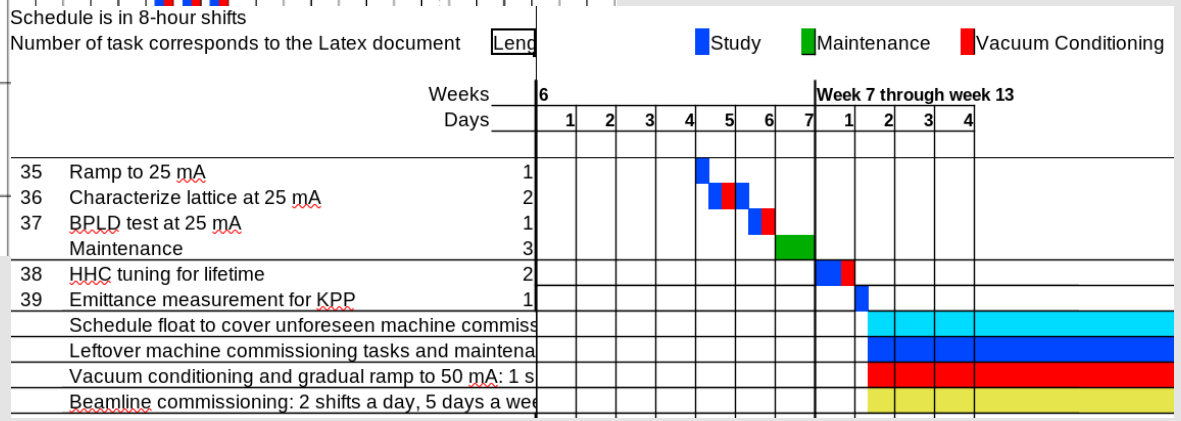


		Leng
16	Ramp current to 10 mA	1
17	Vacuum conditioning	1
18	Commission slow beam abort	1
19	Setup of SOFB	1
20	Measure BPM offsets, characterize lattice	7
	Maintenance	3
21	Set up DCCT and stored beam interlock	1
22	Commission BPLD and validate MPS	3
23	Characterize nonlinear dynamics	3
24	Fine setup of horizontal and vertical collimators	1
25	Move tunes to design values	1
26	ID perturbation characterization	2
	Maintenance	3
27	Online DA/MA optimization	2
28	X-ray BPM commissioning	6
29	Check out photon diagnostics	3
30	Set up emittance ratio controllaw	1
31	Characterize single bunch instabilities	2
	Maintenance	3
32	Set up transverse feedback	1
33	Set up longitudinal feedback	3
34	HHC cavity testing	2





Schedule is in 8-hour shifts
Number of task corresponds to the Latex document

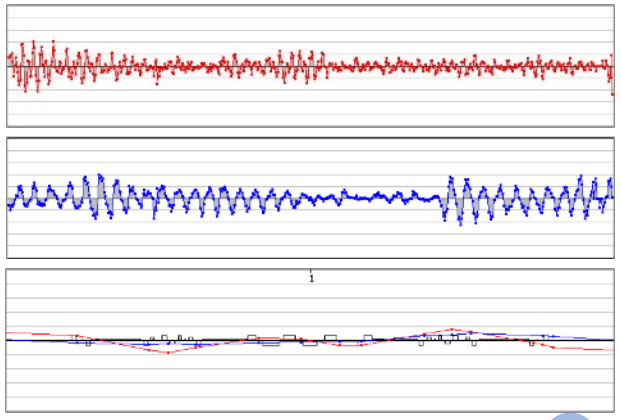


		Leng
35	Ramp to 25 mA	1
36	Characterize lattice at 25 mA	2
37	BPLD test at 25 mA	1
	Maintenance	3
38	HHC tuning for lifetime	2
39	Emittance measurement for KPP	1
	Schedule float to cover unforeseen machine commiss	
	Leftover machine commissioning tasks and maintena	
	Vacuum conditioning and gradual ramp to 50 mA: 1 s	
	Beamline commissioning: 2 shifts a day, 5 days a wee	

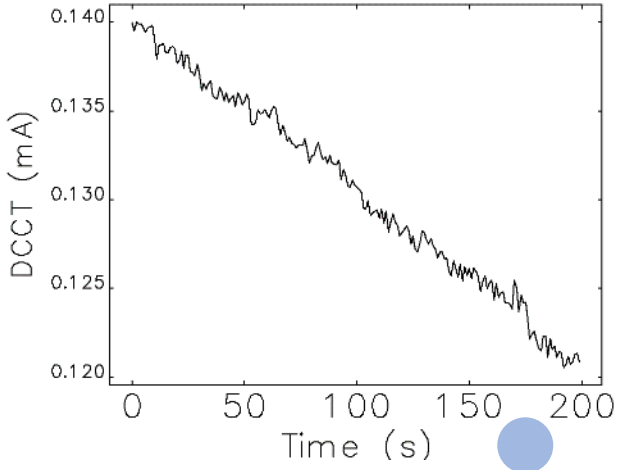
Completing Testing Without Beam & Preparing For Commissioning

APS-U COMMISSIONING –TIMELINE

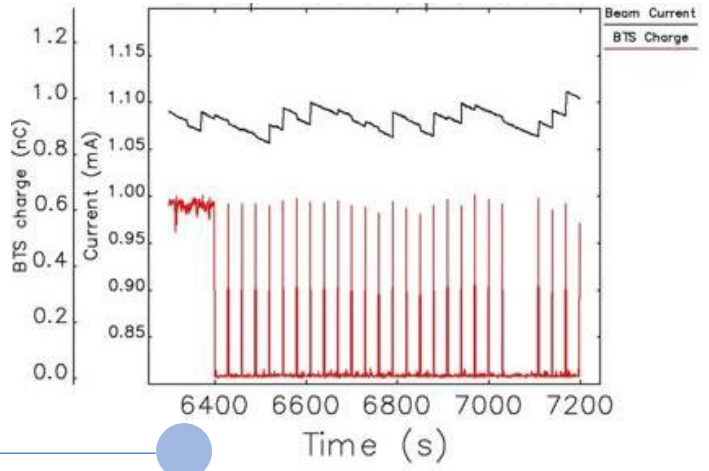
First turns



Stored beam (0.15mA)



1st Swap-Out Operation



ARR | Pre-starts | DOE review | Machine studies | Radiation studies | Machine studies | Fine tune lattice corrections, vacuum conditioning, current ramp, emittance measurements

March 25-29

April 8

April 10

April 13

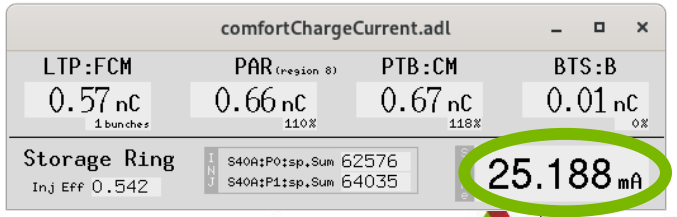
April 18

April 20

April 29

May 18

25mA @ 6GeV

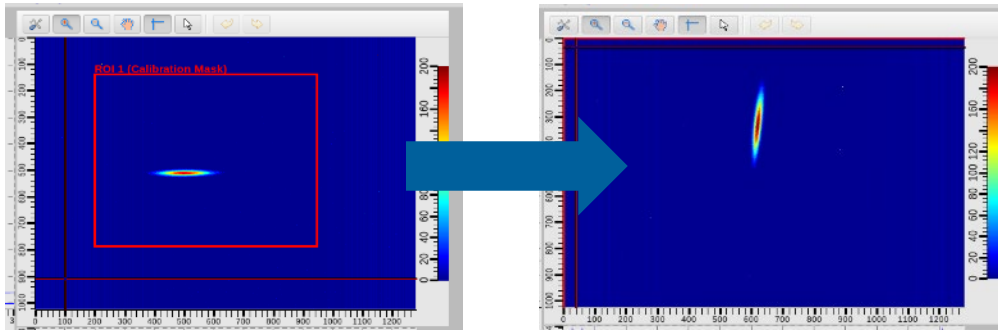


DOE Authorizes Start of Commissioning

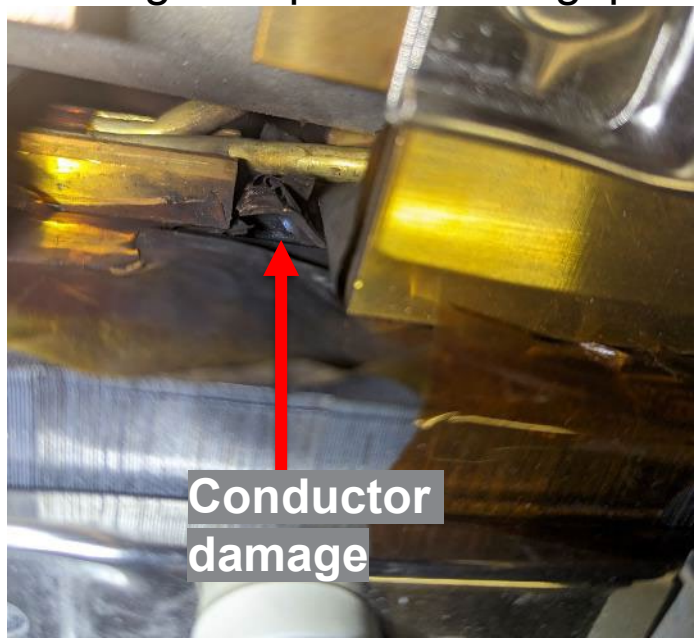
CLEARING HURDLES

- **Small 2.8-mm wide storage ring beam entrance**
  - Use horizontal and vertical emittance exchange
- **5 original BTS quadrupoles designed for positrons connected the 'positron way' to new power supplies**
  - Reverse magnet connections
- **Septum failure due to 16-mm gap along the current carrying conductor of the magnet**
  - Modified spare septum with longer copper piece to constrain and cool 16-mm gap

Emittance exchange in BTS transfer line



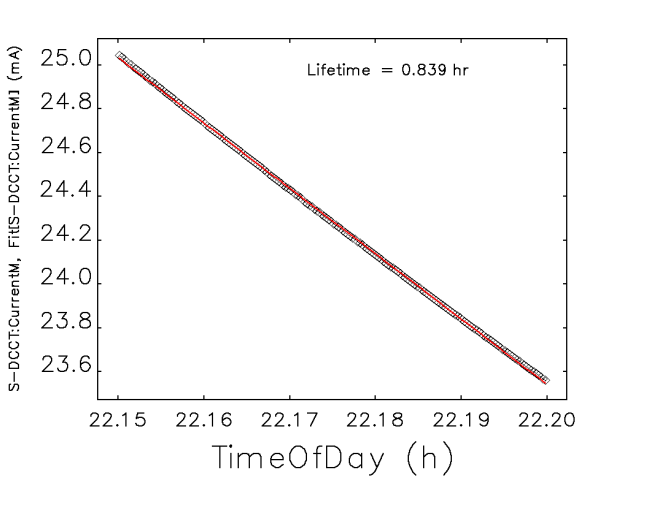
Damaged septum 16mm gap



AMAZING WORK…MORE TO DO

ACCOMPLISHMENTS

- Completed commissioning phase 1
  - 1st use of emittance exchange
  - Demonstrated 1st turn and stored beam with new storage ring
  - 1st swap-out operation
  - Achieved 25 mA @ 6 GeV



FUTURE WORK

- Complete commissioning plan
  - Vacuum conditioning
  - Emittance measurements
  - Characterize lattice at 25 mA
- Complete accelerator KPPs
- Finish installation and alignment/ realignment of beamlines to prepare for beamline commissioning
- Commission feature beamlines

BEAMLINES

BEAMLINE STARTUP (CURRENT STATUS)

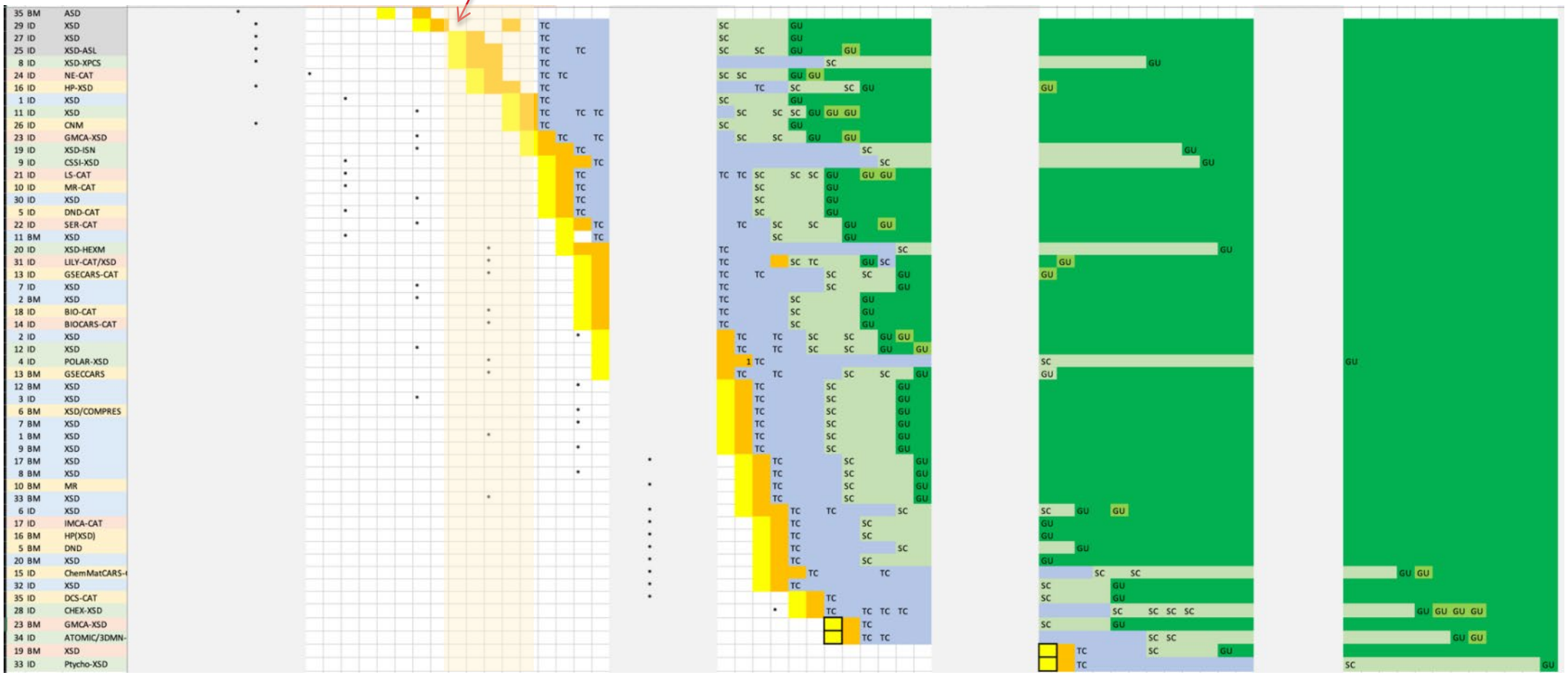
Time increments in weeks

Shielding Verification
Technical Commissioning
Scientific Commissioning
Accepting General Users

Week starting 6/2/24

2024 2025

Feb. March April May June July Aug Sept Oct. Nov. Dec. Jan. Feb. March April May June July Aug



Component Delivery Limited

SUMMARY

- Early commissioning results point to a well aligned and assembled storage ring
- Team efficiently and effectively addressing complications arising with such a complex machine
- Quickly approaching demonstrating accelerator KPPs and transitioning to beamline commissioning

- **Incredible team performing exemplary work with an incredible safety record**

ACKNOWLEDGMENTS

Special thanks to the Advanced Photon Source (APS) Upgrade team as well as the multitude of divisions that assisted the project and contributed to its success: Advanced Photon Source, Infrastructure Services, Financial Management and Procurement Services, and the Office of the Director.