GETTING TO CD-2: AN EXAMPLE FROM THE ADVANCED PHOTON SOURCE UPGRADE

FRANK GINES
Federal Project Director
APS-Upgrade
DOE/Argonne Site Office

JIM KERBY
Principal Project Manager
APS-Upgrade
Argonne National Laboratory

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

ACKNOWLEDGMENTS

This work could not have been completed without the aid, assistance, support, ingenuity and hard work of colleagues at not just the Advanced Photon Source and Argonne, but also the Department of Energy, Basic Energy Sciences, the Argonne Site Office, BNL, SLAC, LBNL, FNAL, and multiple industries.

We have used some pictures and plots in this presentation without direct attribution to the creator/owner of that particular item, not in any way as a slight to 'owner' of that particular slide, but as an acknowledgment of the team as a whole and that the examples given are representative of the excellence of the effort overall.

BASIC ENERGY SCIENCES

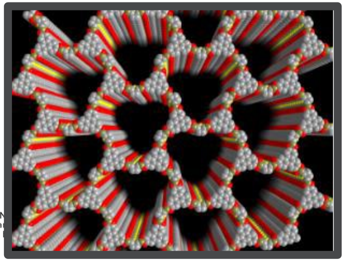
The Program:

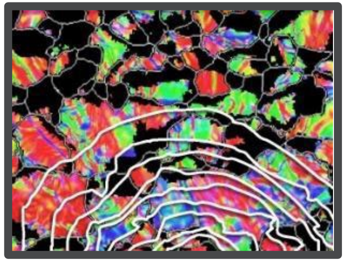
Materials sciences & engineering - exploring macroscopic and microscopic material behaviors and their connections to various energy technologies

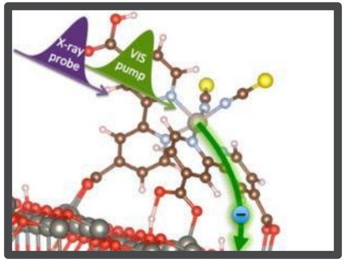
Chemical sciences, geosciences, and biosciences - exploring the fundamental aspects of chemical reactivity and energy transduction over wide ranges of scale and complexity and their applications to energy technologies

Scientific User Facilities - The largest collection of facilities for x-ray and neutron scattering and nanoscience tools in the world

Understanding, predicting, and ultimately controlling matter and energy flow at the electronic, atomic, and molecular levels







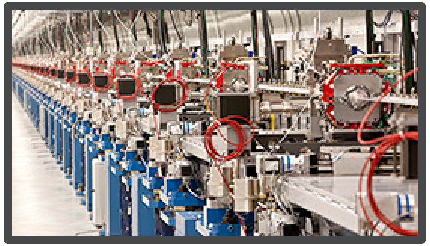
LIGHT SOURCES AROUND THE WORLD

BES X-RAY LIGHT SOURCES

Light sources are accelerators that produce exceptionally intense beams of X-rays, ultra-violet and infrared light, making possible both basic and applied research in fields ranging from physics to biology and technology, which are not possible with more conventional equipment.

BES operates five DOE light sources:

Advanced Light Source (ALS)
at Lawrence Berkeley National Laboratory



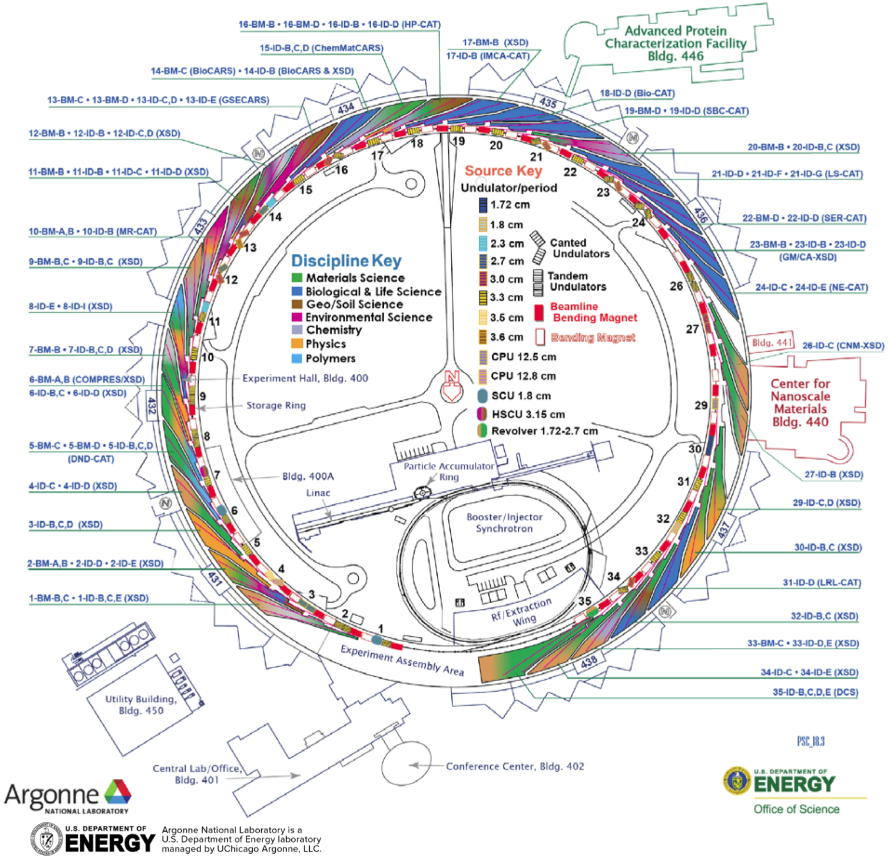
Linac Coherent Light Source (LCLS)
at SLAC National Accelerator Laboratory

Stanford Synchrotron Radiation Light Source (SSRL)
at SLAC National Accelerator Laboratory

Advanced Photon Source (APS)
at Argonne National Laboratory

National Synchrotron Light Source II (NSLS-II)
at Brookhaven National Laboratory

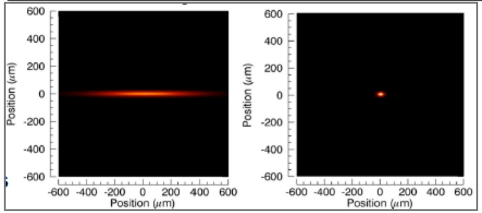
ADVANCED PHOTON SOURCE OVERVIEW



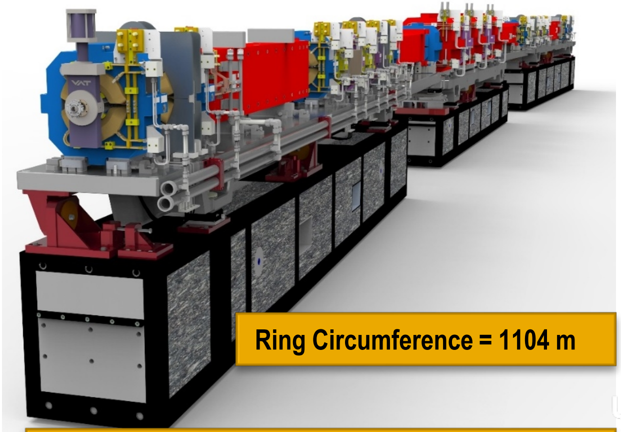
- Commissioned in 1995, first top-up operation in 1999
- 7 GeV electron storage operating at 102 mA
- In FY18, >5,700 unique onsite/offsite users from >700 institutions
- 68 simultaneously operating endstations
  - 46 undulator beamlines
  - 22 bending magnet beamlines
  - 35 APS-operated with BES funding
  - 33 partner beamlines, principally CATs
    - Funding includes NIH, NNSA and others
- Two open sectors (25,28)

ADVANCED PHOTON SOURCE UPGRADE

The project will design, build, install, commission a storage ring upgrade to the APS that will deliver a world-class high brightness, high coherence hard x-ray (>20 keV) source together with the new and upgraded scientific instruments.

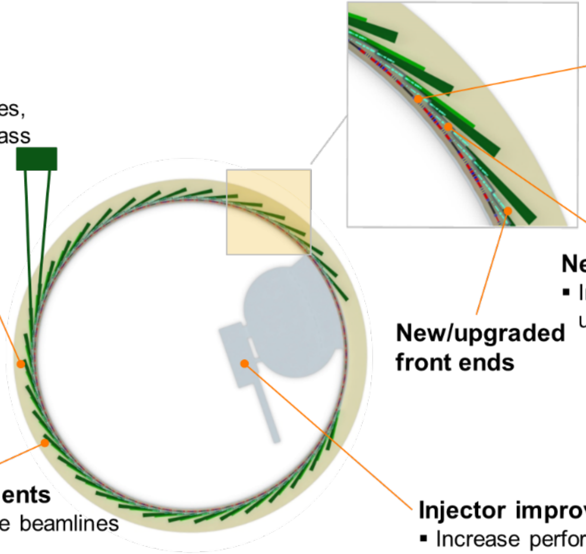


Source size reduction from MBA lattice greatly improves APS storage ring performance



Ring Circumference = 1104 m

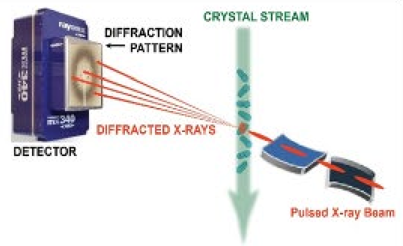
One of Forty Sectors of APS-U Arc Components
Each Sector with 33 Arc Magnets, 27.6 Meters



APS-U ENABLES PIVOTAL RESEARCH ACROSS DISCIPLINES

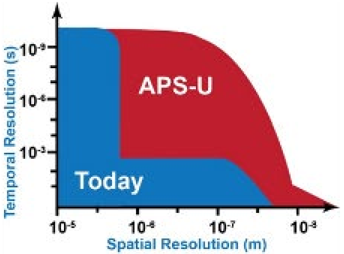
Small-Beam Scattering & Spectroscopy

- Nanometer imaging with chemical and structural contrast; few-atom sensitivity
- Room-temperature, serial, single-pulse pink beam macromolecular crystallography



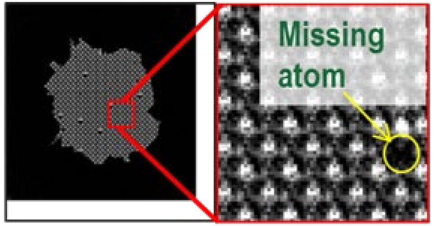
Resolution with Speed

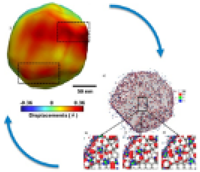
- Mapping all of the critical atoms in a cubic millimeter
- Detecting and following rare events
- Multiscale imaging: enormous fields of view with high resolution



Coherent Scattering & Imaging

- Highest possible spatial resolution: 3D visualization; imaging of defects, disordered heterogeneous materials
- XPCS to probe continuous processes from nsec onward, opening up 5 orders of magnitude in time inaccessible today,





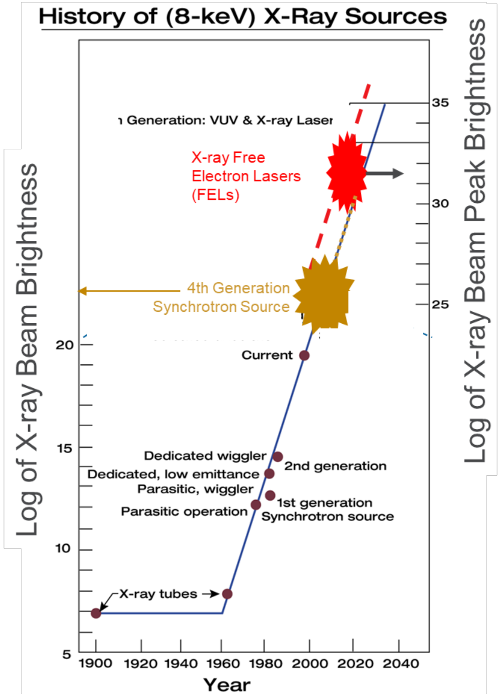
Exploit high performance computing, artificial intelligence

Automatic control of experiments, high volume data acquisition, analysis and reconstruction

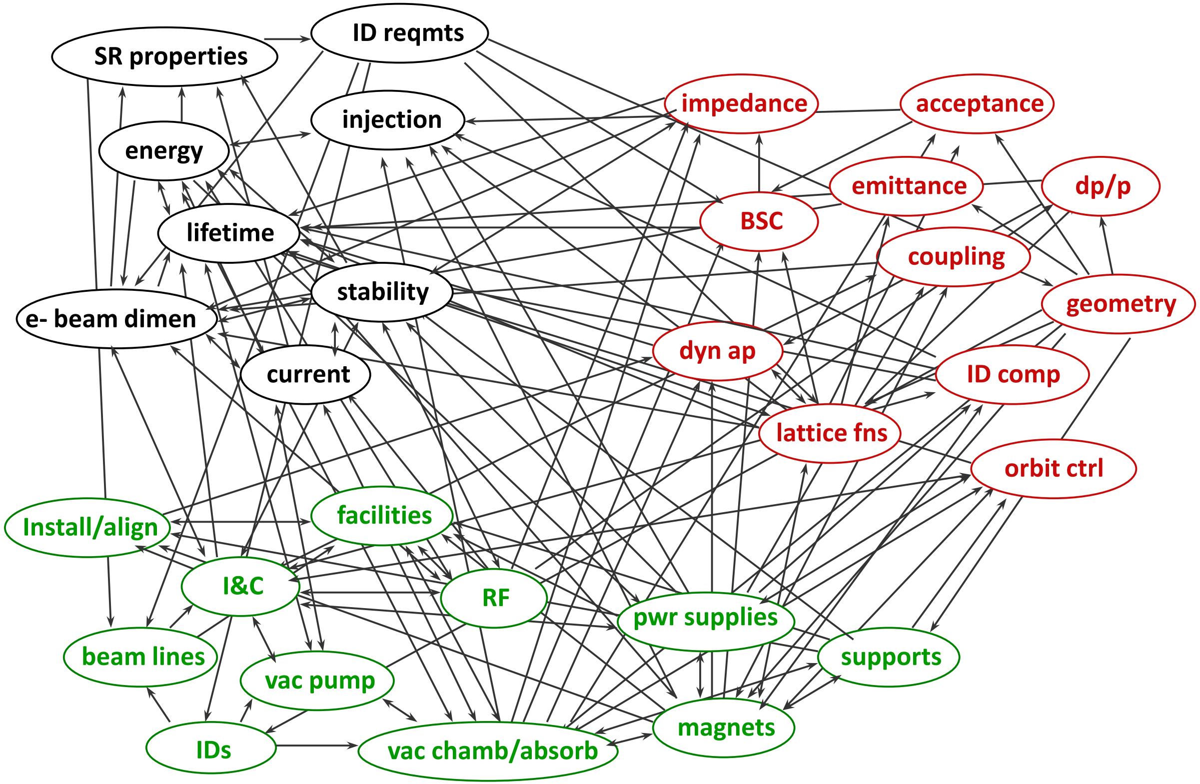
EVOLUTION OF X-RAY BRIGHTNESS

$$\frac{\textbf{Flux}}{4\pi^2\,\Sigma_h\,\Sigma_v\,\Sigma_h'\,\Sigma_v'}$$

photons/sec/0.1% BW/source area/source solid angle

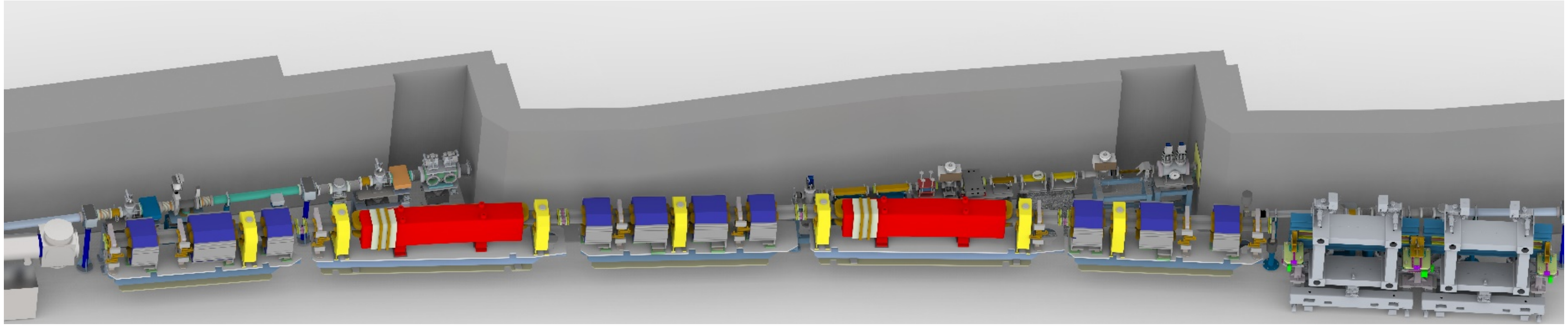


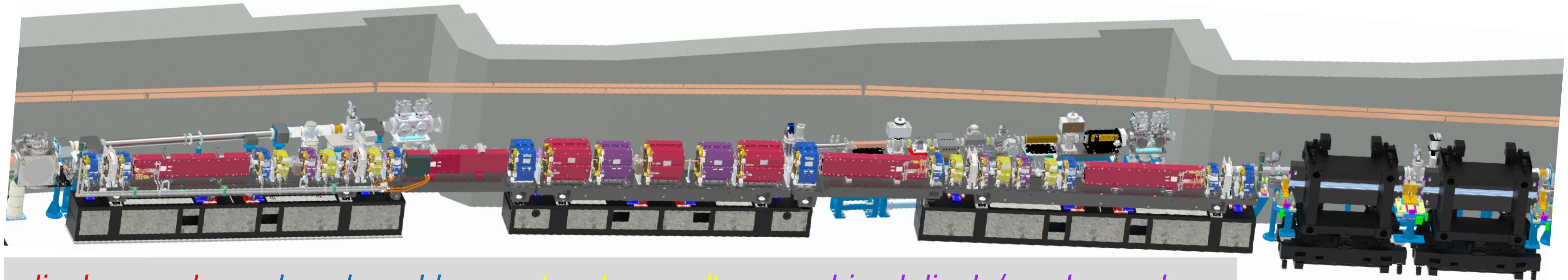
STORAGE RING DESIGN OPTIMIZATION



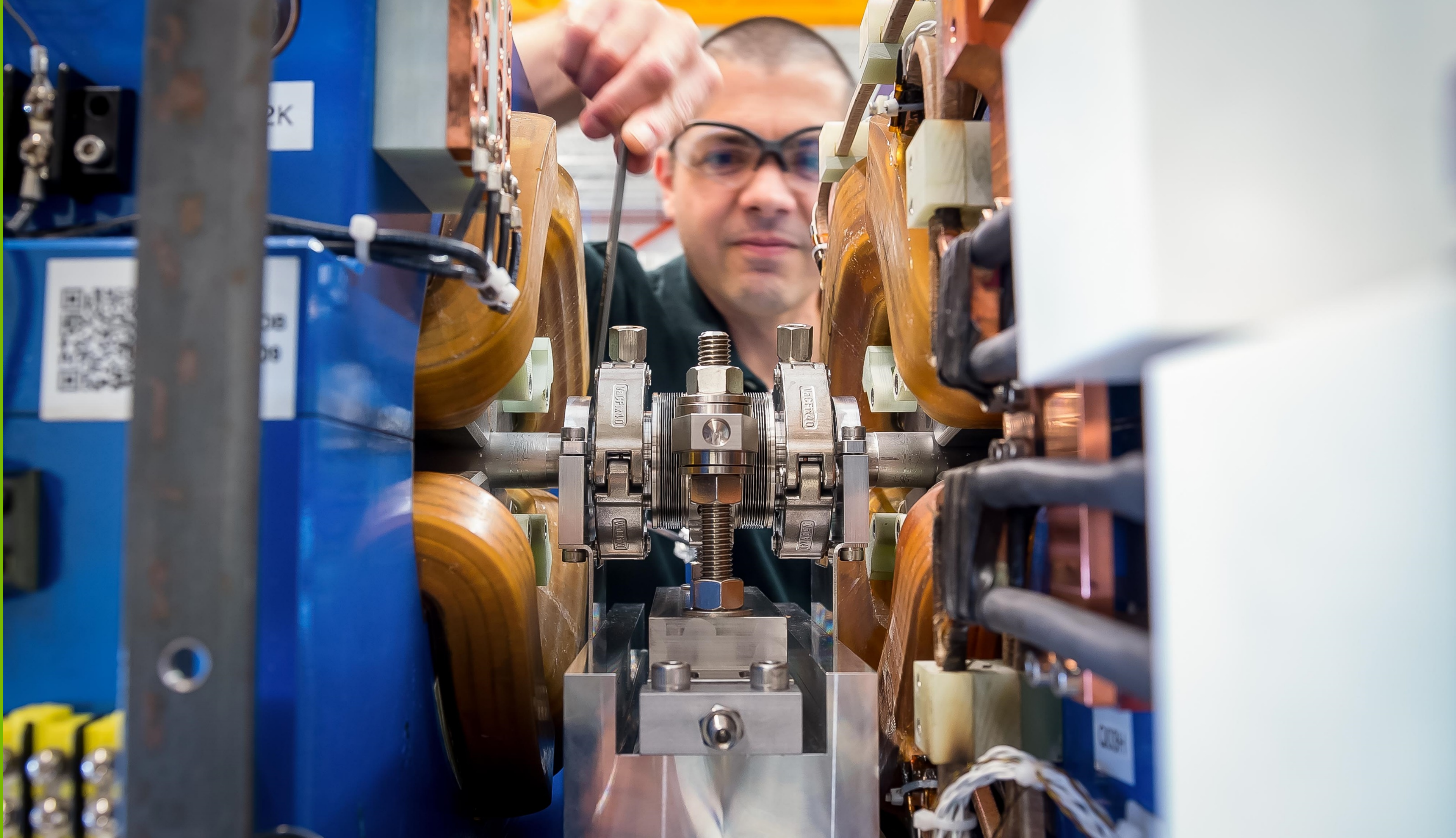
APS AND APS-U STORAGE RING LAYOUTS

Single sector, current (top) and after Upgrade (bottom)





dipoles – red, quadrupoles – blue, sextupoles – yellow, combined dipole/quad - purple



GETTING TO CD-2

Reducing uncertainty, advancing design, and controlling costs

Requires a delicate balance of

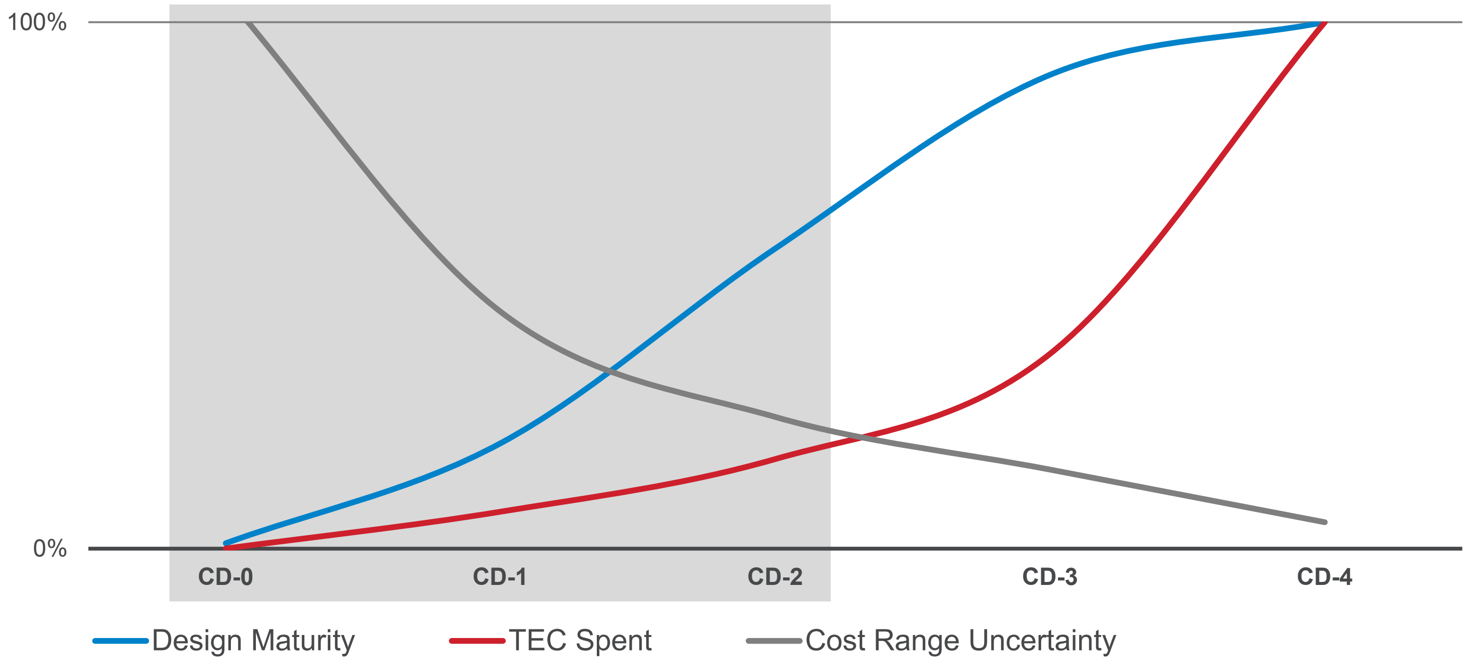
- Building on the work of others
- Choosing the concepts which need proving
- Developing the appropriate models for incorporating results
- Understanding trade-offs in technology

It is too easy to fall into the trap of building the 'best' and 'most exact' prototype, as opposed to prototyping enough to benchmark the ability to deliver key parameters.

It is also to easy to try and do this all 'in house'…relying on and building on the expertise of other is crucial.

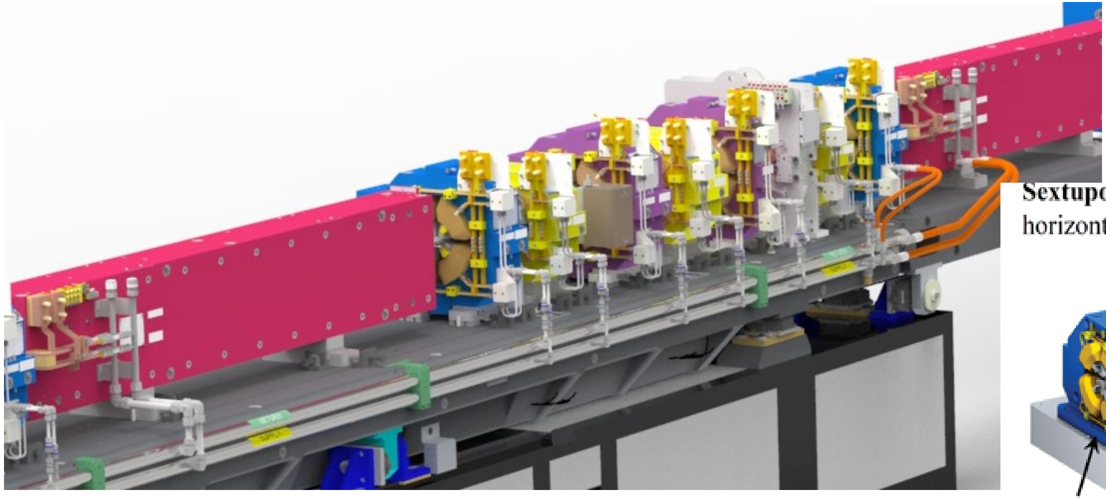
The following examples hopefully help describe our approach.

PROJECT UNCERTAINTY PLOT

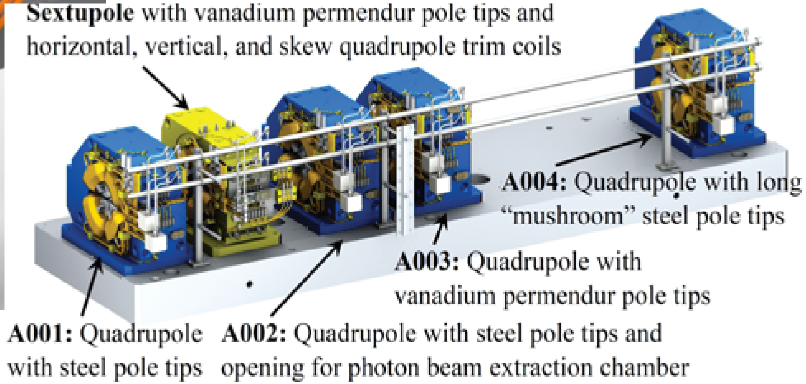


EXAMPLE 1

The need: Fiducializing a string of magnets – need to show that alignment by optical survey will meet end need positioning of magnetic axes through a series of magnets



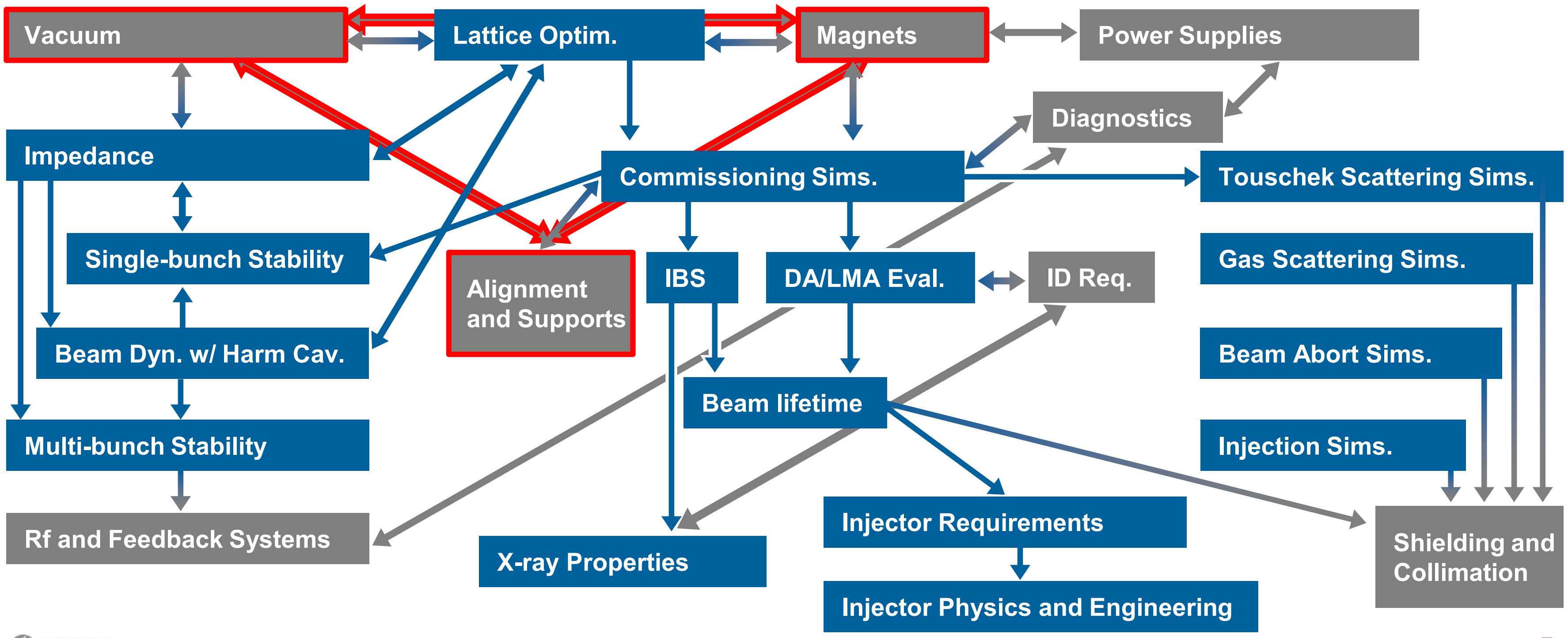
Current multiplet section design



Demonstration multiplet module (DMM) design

APS-U STORAGE RING OPTIMIZATION

(Simplified version)



ALIGNMENT TRADE-OFF BUDGET

Total Motion and Position Budget
P

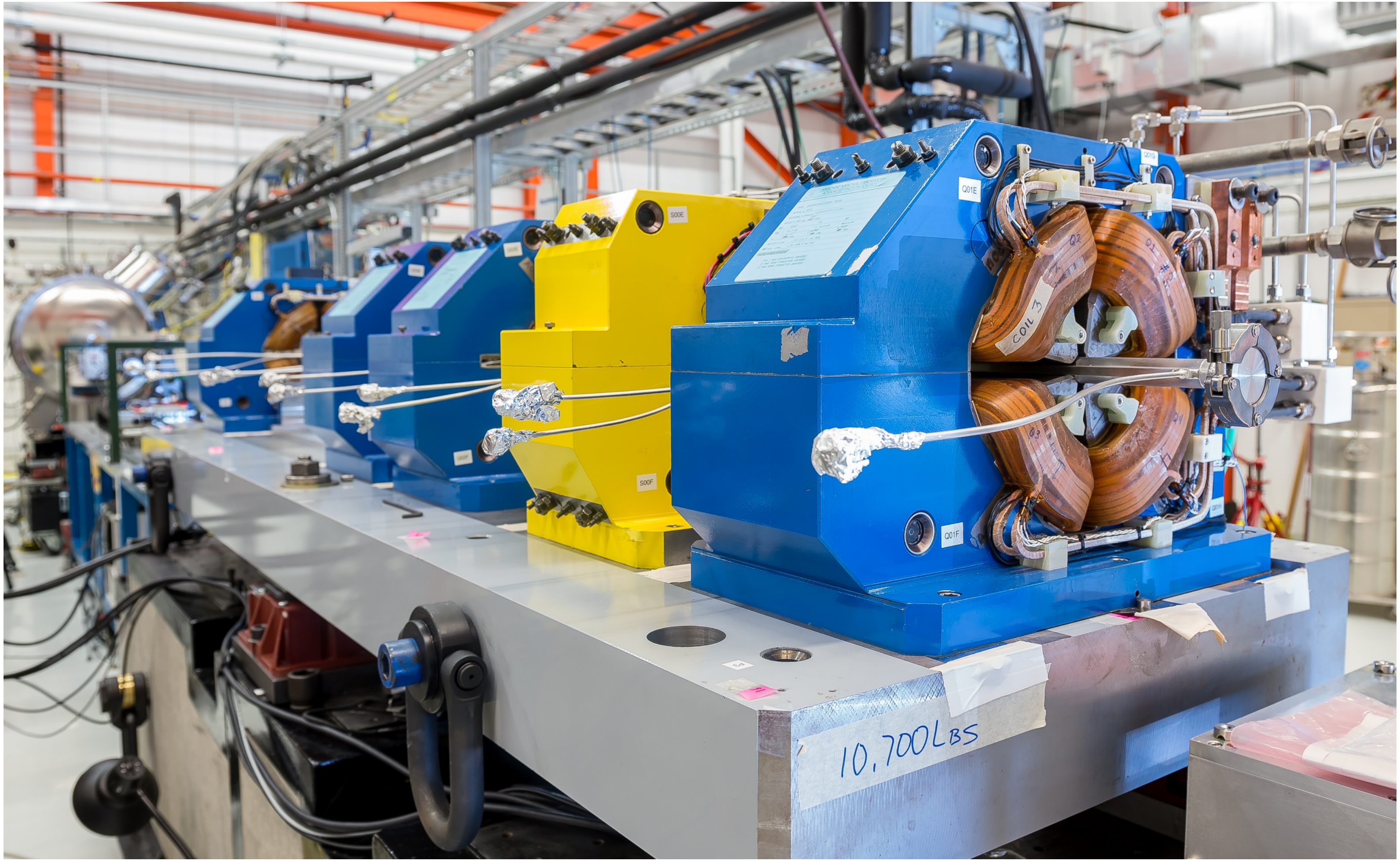
Rating / Noise of Power Supplies
P_e

- Dipoles P_{dip}
- Quads P_{quad}
- Correctors P_{corr}

BPM Alignment / Vibration
P_{BPM}

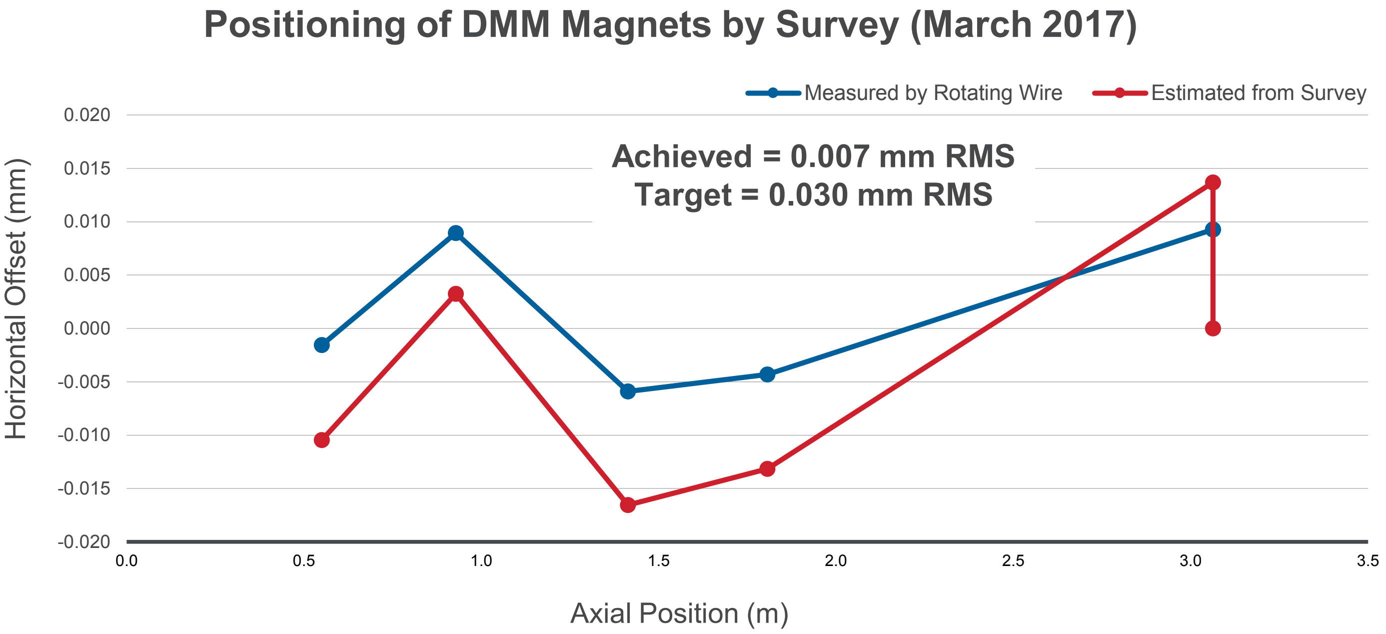
Magnet Alignment / Vibration
P_m

- Girder displacements + pitch/yaw P_{girder}
- Displacement of magnets on girders $P_{magnets}$
- Dipole rolls P_{drolls}


10,700LBS

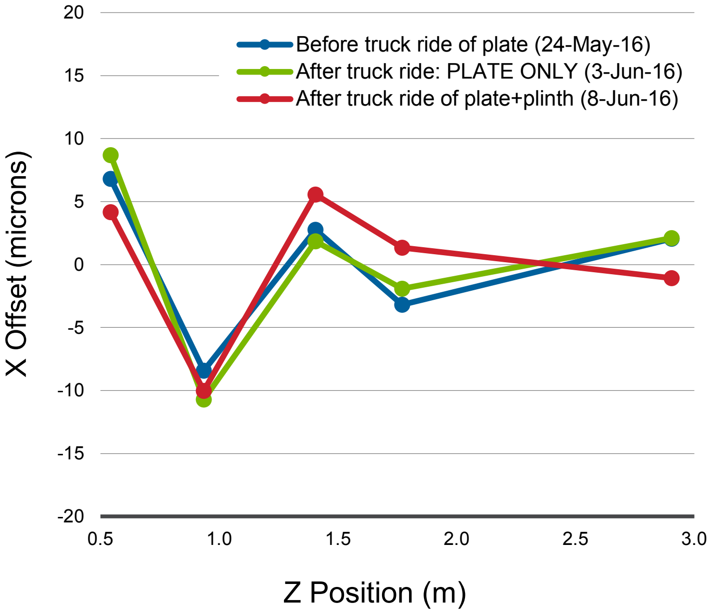
DMM ASSEMBLY: ALIGNMENT METHOD TESTS

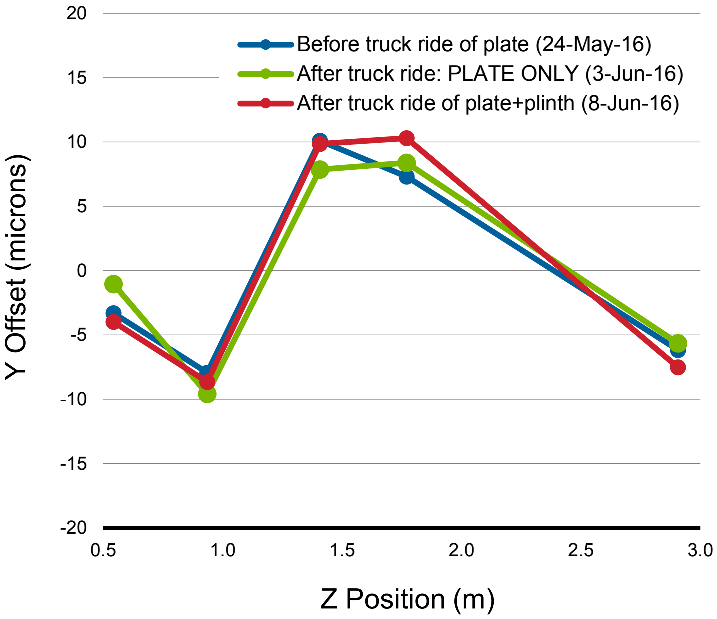
Magnetic centers derived from fiducialization and survey agree with direct magnetic measurements



DMM ASSEMBLY: TRANSPORTATION TESTS

Based on magnetic measurements using a long rotating wire in a straight DMM assembly





DMM FIDUCIALIZATION SUMMARY

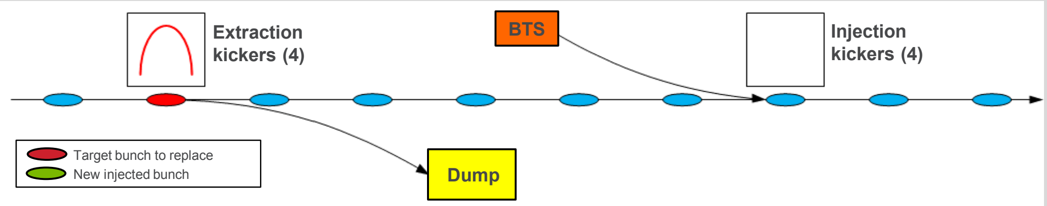
- Starts with the experience of NSLS-II at BNL
- Uses models of allowable errors / error budgets to estimate targets for needed result
- Introduces complication due to geometry of new machine, making old measurement technique – direct measurement of magnetic axes-- invalid
- Uses early design of APS-U MBA lattice, and individual prototype magnets—but fewer than the full complement in the final design. None of the magnets, nor the layout of the magnets, is exactly consistent with the current final design
- Includes possible shipping induced motions

Results confirm alignment of magnetic axes, well within targets, possible by combination of individual magnetic measurements and mechanical / optical steps.

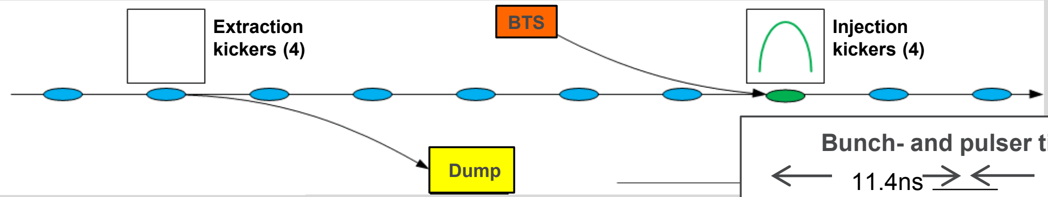
EXAMPLE 2

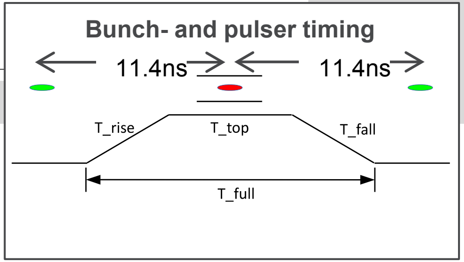
The need: development of a fast pulser for injection / extraction that will support 324 bunch operation

Target bucket is emptied by the extraction kickers in Sector 38



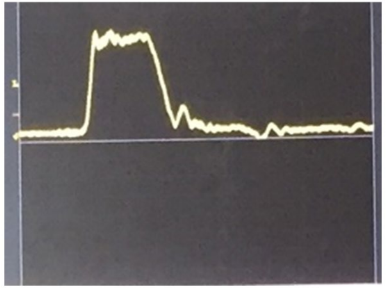
On the same turn, the septum and injection kickers in Sector 39 deflect the incoming bunch into the target bucket and kick it on axis



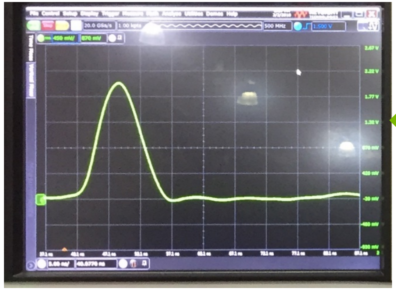


20KV PULSERS UNDER TEST AT APS

Multiple year effort to evaluate and confirm performance and reliability of supplies



50 ns full scale



FAST PULSER SUMMARY

- Builds on industrial work used by ILC which meets initial pulse shape requirements
- In parallel, evaluate technologies from two vendors – however results different pulse shapes
- Fed new pulse shape back to beam physics / injector studies – acceptable
- Both systems now under test for >1 year without failure
- Expect competitive bidding situation

SUMMARY

Advancing design, while reducing uncertainty and controlling costs is a challenge for any project, and requires:

- Building on the most recently available experience and data – technical, cost, and schedule
- Creating models that can evaluate trade-offs and options
- Focus on key parameters and technologies needing benchmarking – not exact prototypes of the final product including every detail
- Understanding of those needs by incorporating lessons learned, skills, and experience of experts from all backgrounds
- Avoiding sense of (fake) security brought on by false precision in any parameter (including cost)
- Accept that the process can be very non-linear

THANKS FOR YOUR ATTENTION!