Argonne NATIONAL LABORATORY

… for a brighter future

APS Renewal – Accelerator/Facility Projects

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October 21, 2008

Accelerator/Facility Renewal - October 6, 2008

- The aim of the APS Renewal is to provide our users with the best hard x-ray source in the nation and beyond.

- Along with beamline upgrades the APS must continue to plan to keep the facility and infrastructure healthy and vibrant in order to:
  - Enhance the accelerator and infrastructure to allow the new science that is being proposed.
  - Continue to provide the reliability and availability to produce leading-edge science

- In March accelerator and facility proposals were solicited along with the request for beamline proposals

- On October 6, ~85 accelerator and facility proposals were presented to Users and APS staff

Accelerator Renewal Strategy

- The proposals are grouped into two general categories:
  - Science enablers
  - Obsolescence, upgrades, and spares; proposals directly tied to availability and reliability issues

- We made an additional distinction for R&D Proposals
  - R&D Proposals can support either Science Drivers or Obsolescence

- All proposals are available on the renewal website, http://www.aps.anl.gov/Renewal

Science Enabling Proposals in support of Renewal

- Alignment with Technical Coordinators
  - Technical Support
    - *Nanopositioning – Deming Shu*
  - Behind the Shield Wall
    - *Accelerator Operations – Michael Borland*
    - *Beam Stability – Glenn Decker*
    - *IDs – Liz Moog*
    - *Front ends – Pat Den Hartog*
  - Facility Infrastructure
    - *John Maclean (presentation yesterday)*

Accelerator Operations – Michael Borland
most of these are R&D proposals

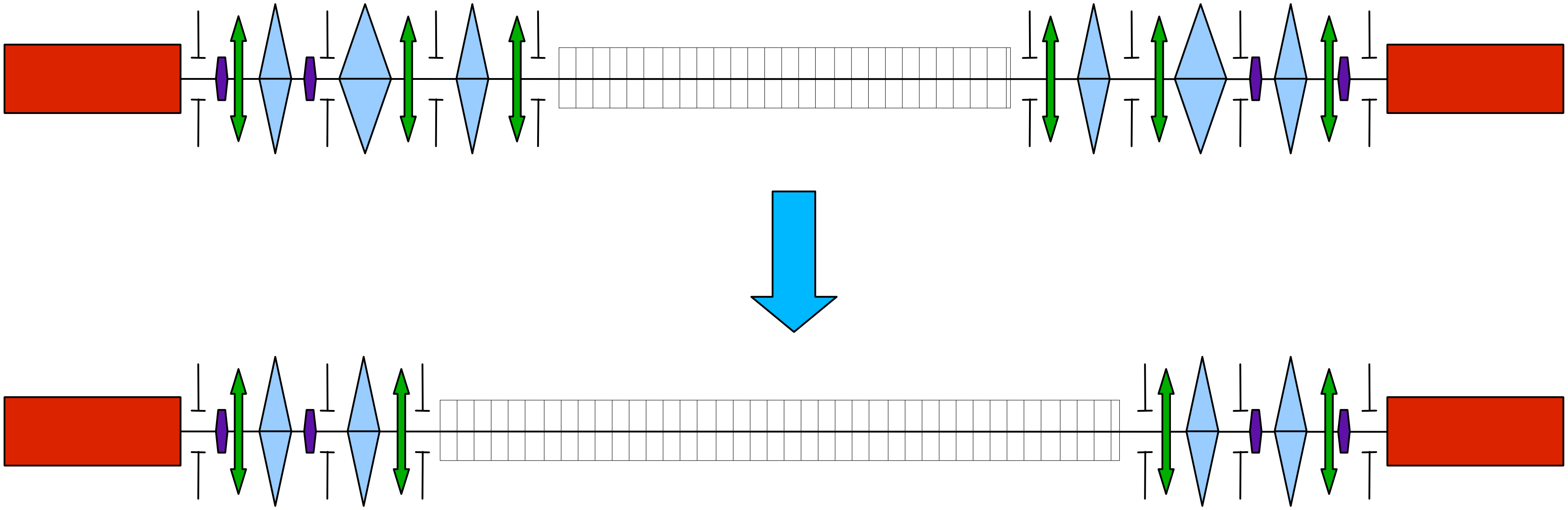
- Lattice modifications
  - Long Straight Sections
  - Reduced Horizontal Beam Size
  - Slightly lower emittance
  - Higher energy dipole radiation
  - Control of beam tilt
- Bunch pattern flexibility
  - Single Bunch Current Increase
  - Fewer than 24 bunches
  - Alternate hybrid modes
  - Higher SR current in 24 bunch mode
- Improved bunch purity
- Ultra Short x-ray pulses

Long Straight Sections (LSS)

- APS straight sections now allow 4.8 m for insertion devices
- Longer straight sections interesting for many reasons
  - Longer devices
    - *Higher brightness*
    - *Higher flux*
  - Getting more from expensive end station equipment by having several different ID designs in a single straight
  - Canted devices to increase number of simultaneous experimental stations
  - Fast polarization switching scheme
  - Space for cryostats for superconducting crab cavities
- Making many local changes may break ring symmetry
  - Injection efficiency and lifetime may suffer
  - Symmetric implementation of LSS has appeal from accelerator physics side.

APS-LSS0: Quadrupole Removal

- This builds on ideas developed for the LSS investigation for IXS-CAT[1]
  - Remove the two quads on either side of the ID
  - Remove the two correctors adjacent to those quads
  - Replace next two quads with shorter quads (0.5m instead of 0.8m)
  - Replace girders and vacuum chambers
  - Increases space for ID by 3.2 m (4.8 m becomes 8.0 m)



[1]http://www.aps4.anl.gov/operations/ops_www/APSOnly/LongStraightSection/LongStraightSection.html

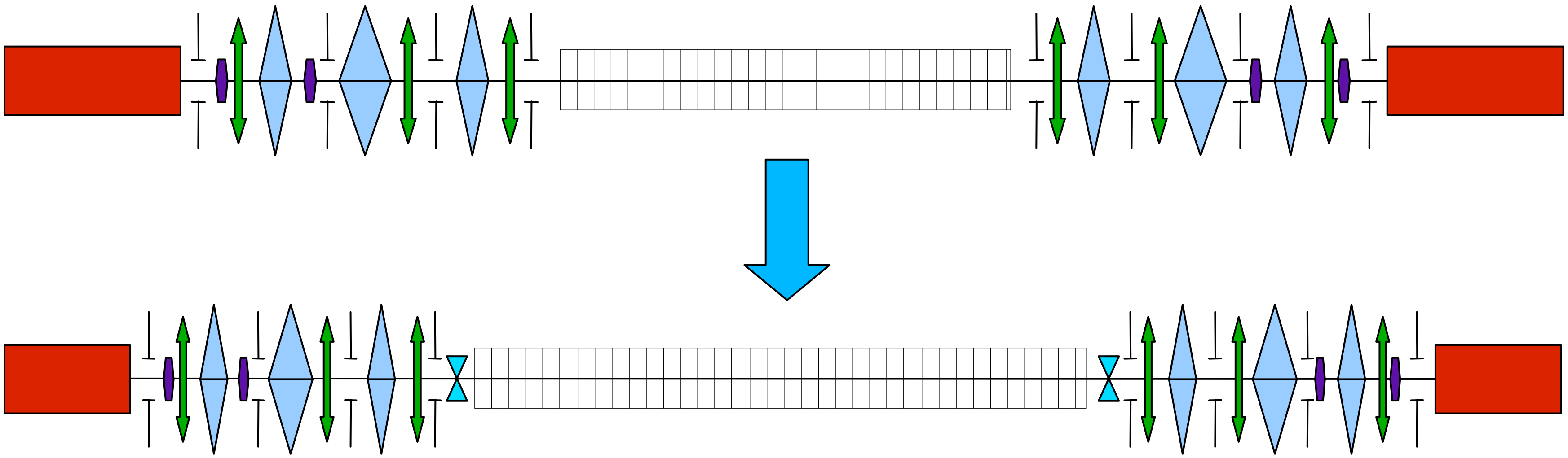
APS-LSS0: Discussion

- Preliminary modeling of a similar change[1] has been carried out
  - The emittance will increase from 3.1 to 3.4 nm (if all done)
  - More work needed to improve injection aperture, lifetime
    - *Emittance may have to be higher...*
- Advantages of this option
  - Gradual implementation optically straightforward
    - *As at ESRF, just turn off all Q1's, then gradually remove them*
    - *Lattice symmetry is approximately maintained*
  - ID straights are not displaced transversely
- Disadvantages
  - Lack of flexibility in optics
  - Decrease in single bunch current limit[2] from present 22 mA due to changes in optics, ID chamber length; however mitigating strategies are proposed (next section)

[1]V. Sajaev, ASD/APG/2007-07, September 5, 2007.
[2]K. Harkay, private communication.

APS-LSS1: Shorter Dipoles and Quads[1]

- Combines ideas from IXS-CAT LSS study[2] and APS 1nm work[3]
  - Make dipole magnets shorter (e.g,. 3m -> 2m)
  - Make quadrupole magnets shorter
  - Reduce vacuum chamber dimensions to increase magnet fields
  - Increases space for ID by 3.4 m (4.8 m becomes 8.2 m)
  - Adding skew quads around ID will take some space back



[1]M. Borland, OAG-TN-2008-022, May 2008; OAG-TN-2008-025, June 2008.
[2]http://www.aps4.anl.gov/operations/ops_www/APSOnly/LongStraightSection/LongStraightSection.html
[3]A. Xiao *et al*., Proc. PAC07, 3447-3449.

APS-LSS1: Discussion

- Modeling performed
  - The emittance will increase from 3.1 to 3.8 nm (if all done)
  - Injection efficiency probably needs work
  - Lifetime should be acceptable
- Advantages
  - Optics are in principle more flexible than APS-LSS0
    - *Must demonstrate that it can be used without deleterious effects*
  - Retention of triplets around IDs supports gradual implementation
  - Dipole radiation harder and more intense (50%)
  - Adding skew quads will give better control of beam tilts, coupling
- Disadvantages
  - Much more extensive changes than APS-LSS0
    - *New quadrupole and dipole designs*
    - *New curved and straight extrusions*
  - Current limited to 200 mA unless absorbers are improved

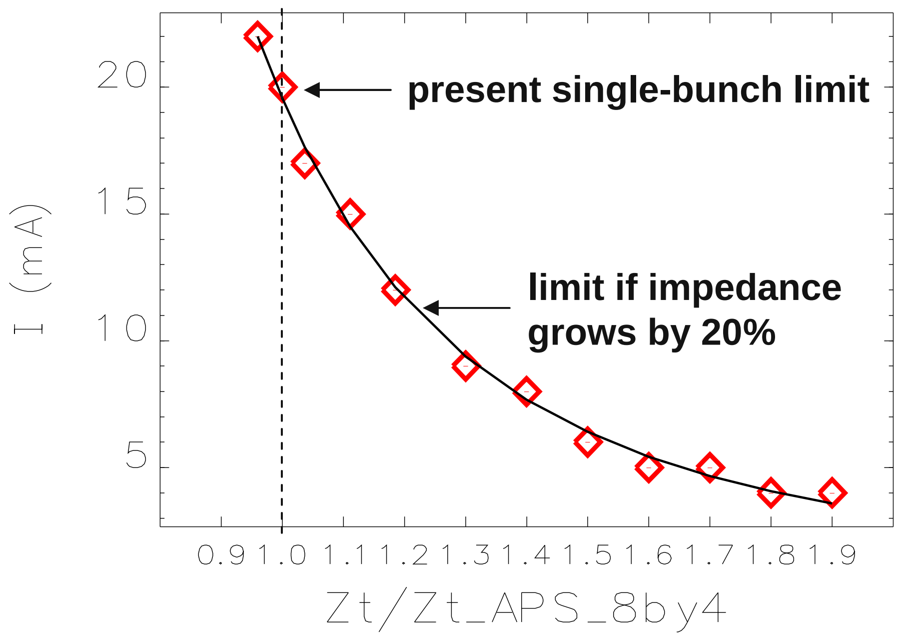
Summary of Options

Name	New girders per sector	New bends per sector	New quads per sector	New sext. per sector	ID off-set mm	Emit-tance nm	Single bunch limit mA	Total current limit mA	Injec-tion	Life-time
LSS0	3	0	0	0	0	>3.4	8~13	300	Not op-timized	Not op-timized
LSS1	5(-6)	2	6	2 sets of noses	24	3.8	~30	200	Needs work	Ade-quate

- All options should allow gradual implementation
  - LSS0 is the easiest in this regard
  - Working on improved solutions for LSS1,
- LSS1 more flexible but needs to be demonstrated
- Detailed studies of single bunch limits needed
- Cost estimates needed

Accelerator Operations: Single Bunch and Bunch Pattern

- **Current limit of single bunch can be reduced as transverse impedance increases; dominated by ID chambers.**
  - Each 5-m-long 8-mm chamber increases impedance by 1.5%
  - Each 5-m-long 5-mm chamber increases impedance by 6% (equivalent to four 8-mm chambers)



Symbols give simulation result (validated experimentally) and line gives polynomial fit.

Y.-C. Chae, APS Science 2007 annual report

- **R&D: single-bunch mode**
  - Optimize design of 8-m ID chamber and LSS lattice to minimize impedance
  - Analyze impact of multiple LSS on overall limit
- **R&D: 24-bunch mode**
  - Per-bunch current limits also important in 24-bunch mode
  - Evaluate effectiveness of fast bunch-by-bunch feedback system in horizontal & vertical planes
  - Redesign components overheating due to HOMs at high current (>150 mA)

Single Bunch Currents

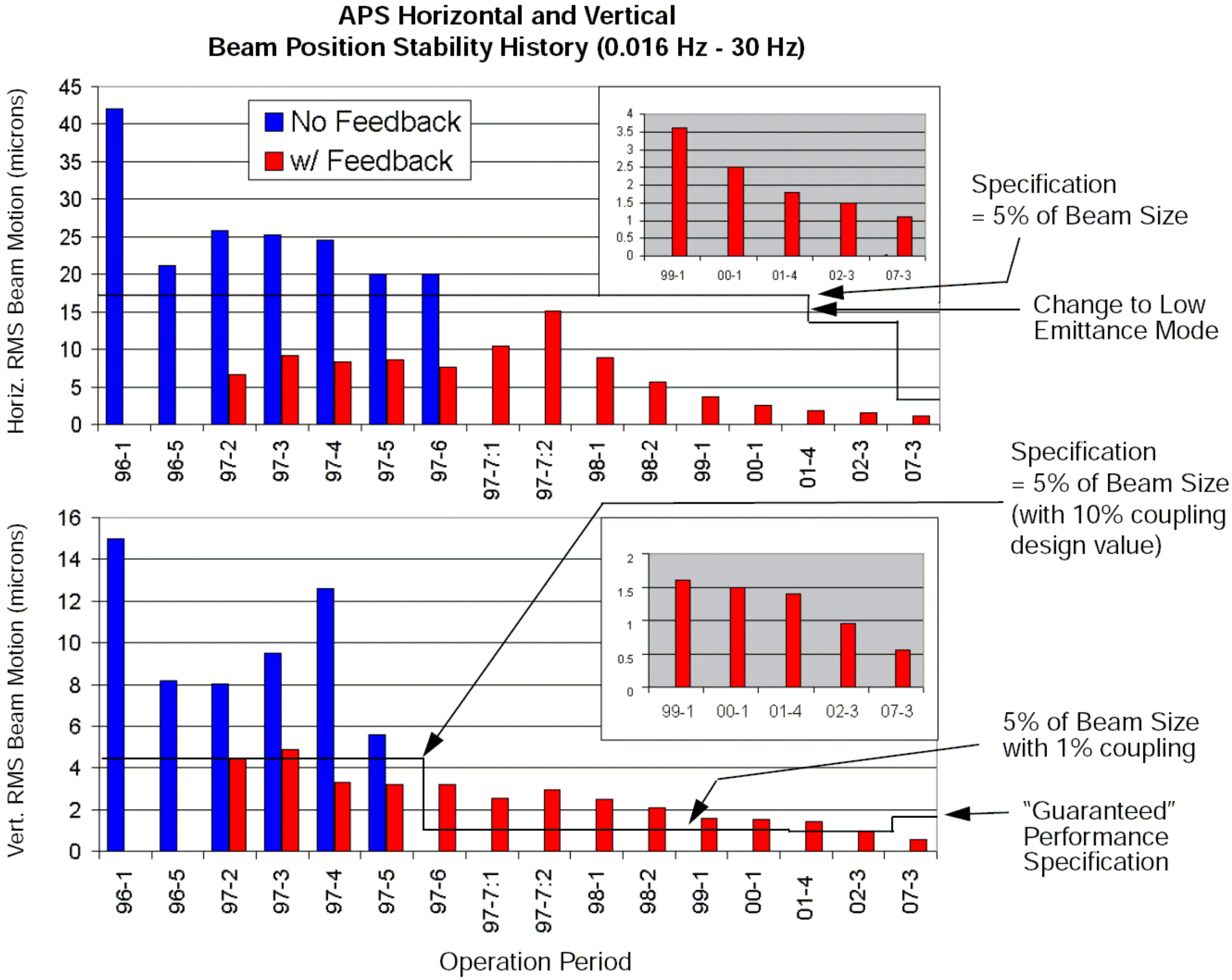
- Other proposals directed at peak bunch current
  - Bunch by bunch transverse damping system
  - Resolve chamber heating issues for high peak currents (R&D Proposal)
  - Design 3rd harmonic Landau cavity – raise single bunch threshold, longer time for topping-up, less disturbance to x-ray beam (R&D Proposal)

Accelerator Operations: Ultra Short x-ray pulses

- An R&D proposal was submitted to study both the accelerator physics issues and the rf issues for a superconducting rf (CW) implementation of the crab cavity SPX scheme. This work is presently receiving LDRD funding.
  - Study, design, and prototype the necessary accelerator system and components for the short pulse x-ray project (SPX)
    - *Unique opportunity to have 1st hard x-ray short pulse with high flux and repetition rates*
    - *1 ps time-resolution capabilities*
    - *Combined with tunability of energy, polarization, and bandwidth*

- One proposal submitted for a sub 100 fs phase noise/jitter instrument – current jitter measurement

Beam Stability – Glenn Decker



Beam Stability – Glenn Decker

- However we are falling behind
  - RMS beam motion, 0.1-200 Hz:
    (Plot on previous slide is for motion to 30 Hz)

	APS 2008	ESRF c. 2005	SPring-8 c. 2004
Horizontal (μm)	4.8	1.2 - 2.2	3 - 4
Vertical (μm)	1.6	0.8 - 1.2	1

- APS beam stability goals:

	AC Motion, 0.1 - 200 Hz		Long-term Drift, (One week)	
	microns rms	μrad rms	microns p--p	μrad p-p
Horizontal	3.0	0.53	5.0	1.0
Vertical	0.42	0.22	1.0	0.5

Beam Stability – Glenn Decker

- RF (electron) Beam Position Monitoring and Feedback Proposals
  - Monopulse rf Beam Position Monitor Upgrade: Deploy new FPGA-based monopulse rf bpm data acquisition system for improved resolution (AC), diagnostic capability, and reliability.
  - Storage Ring Real-Time Feedback System Upgrade: To increase sampling rate of storage ring real-time feedback system from 1.5 kHz to 20 kHz, suppress noise out to 200 Hz closed-loop bandwidth.
  - Fast Steering Corrector Relocation: To increase their frequency response.
  - Spurious Storage Ring Vacuum Chamber Microwave Mode Dampers: To eliminate modes impacting vertical rf beam position monitor readbacks.

Beam Stability – Glenn Decker

- X-ray Beam Position and Flux Monitoring Proposals
  - X-ray bpm System Enhancement: Hard X-ray detector development to enhance long-term pointing stability.
  - SR Portable Detector Upgrade: For absolute measurements of beamline performance at the sample location.
  - Microminiature XBPM and Flux Monitor for High-Flux Micro-focused Hard X-ray Beams: New capability exploiting CVD diamond fabrication quality.

- Storage Ring Tunnel Temperature Regulation Upgrade Proposal
  - Improve APS storage ring tunnel temperature regulation to within + / - 0.1 degrees C.

Insertion Devices – Liz Moog

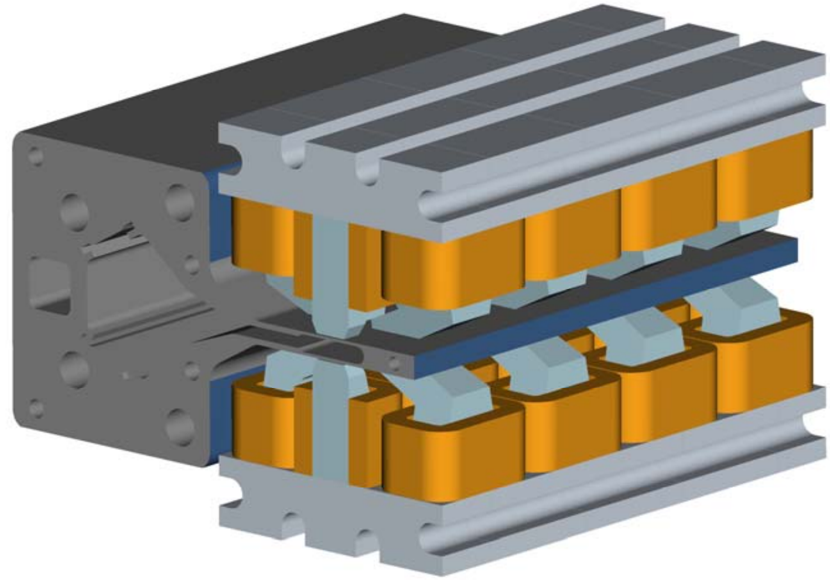
- We are aware of users desires for new insertion devices:
  – planar permanent magnet undulators (25)
  – superconducting undulators (5)
  – APPLE-style or electromagnetic polarizing IDs (5)
  – upgrade CPU strength

- There are expressions of interest for additional canting of straight sections – currently 4 are canted, 10 additional sectors seek canting of IDs

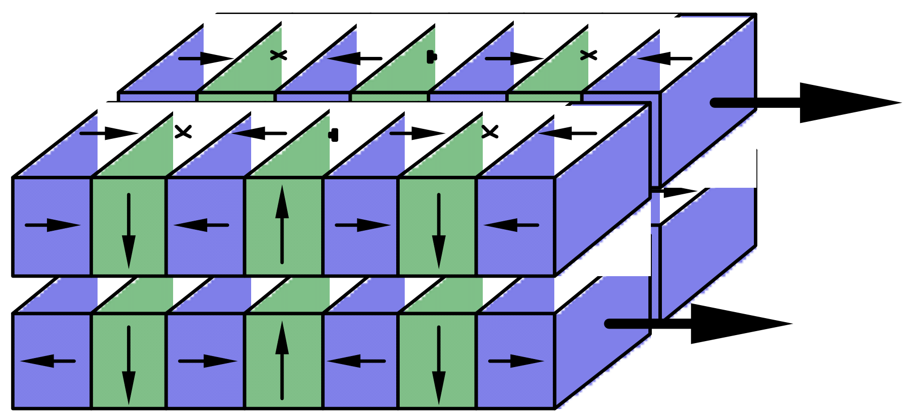
- There are R&D efforts addressing polarizing undulators and SC devices

Circular polarization gives just first-harmonic photons on axis.

(In the real world, beam emittance and an aperture result in harmonic ‘contamination’, but it is small.)



Undulators for circular and variable polarization can be electromagnetic or made from permanent magnets -- APPLE-style.



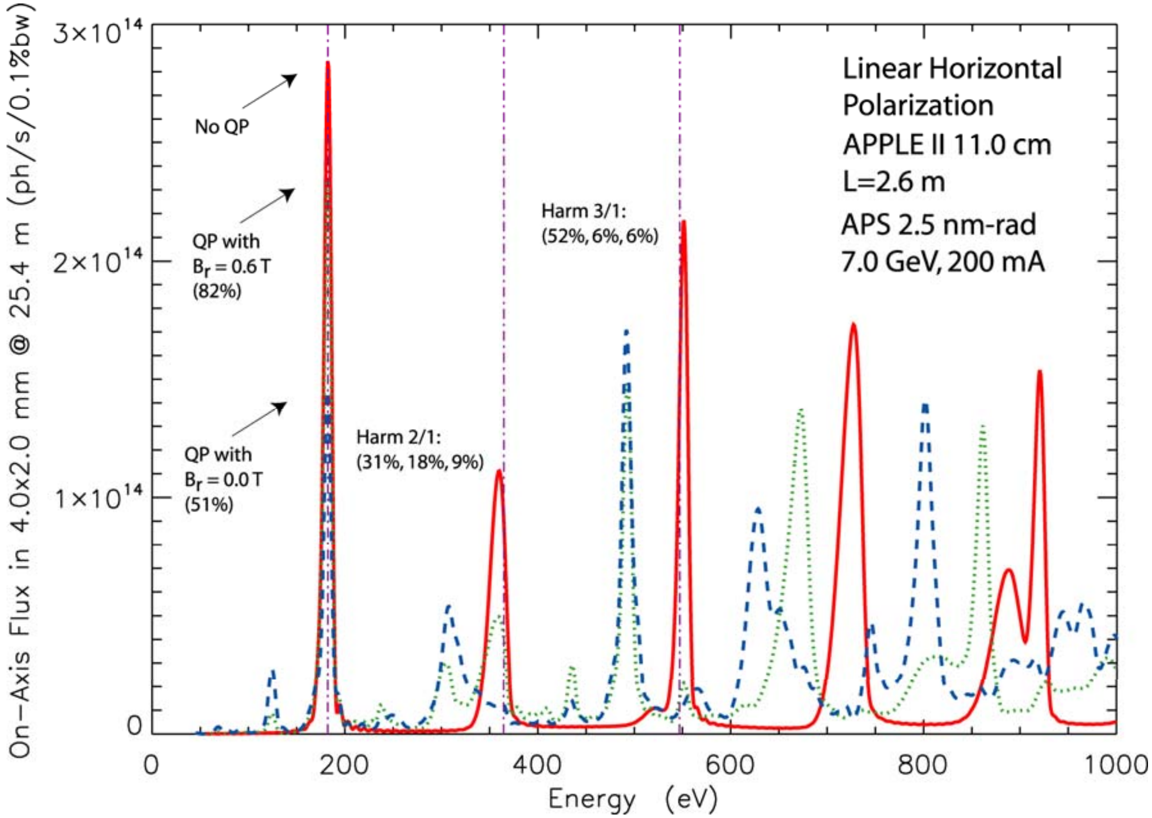
The choice between permanent or electromagnet depends on the needs of the particular beamline.

At ~11 cm period, permanent magnets give a higher field strength.

Electromagnets allow for more rapid changes in the polarization.

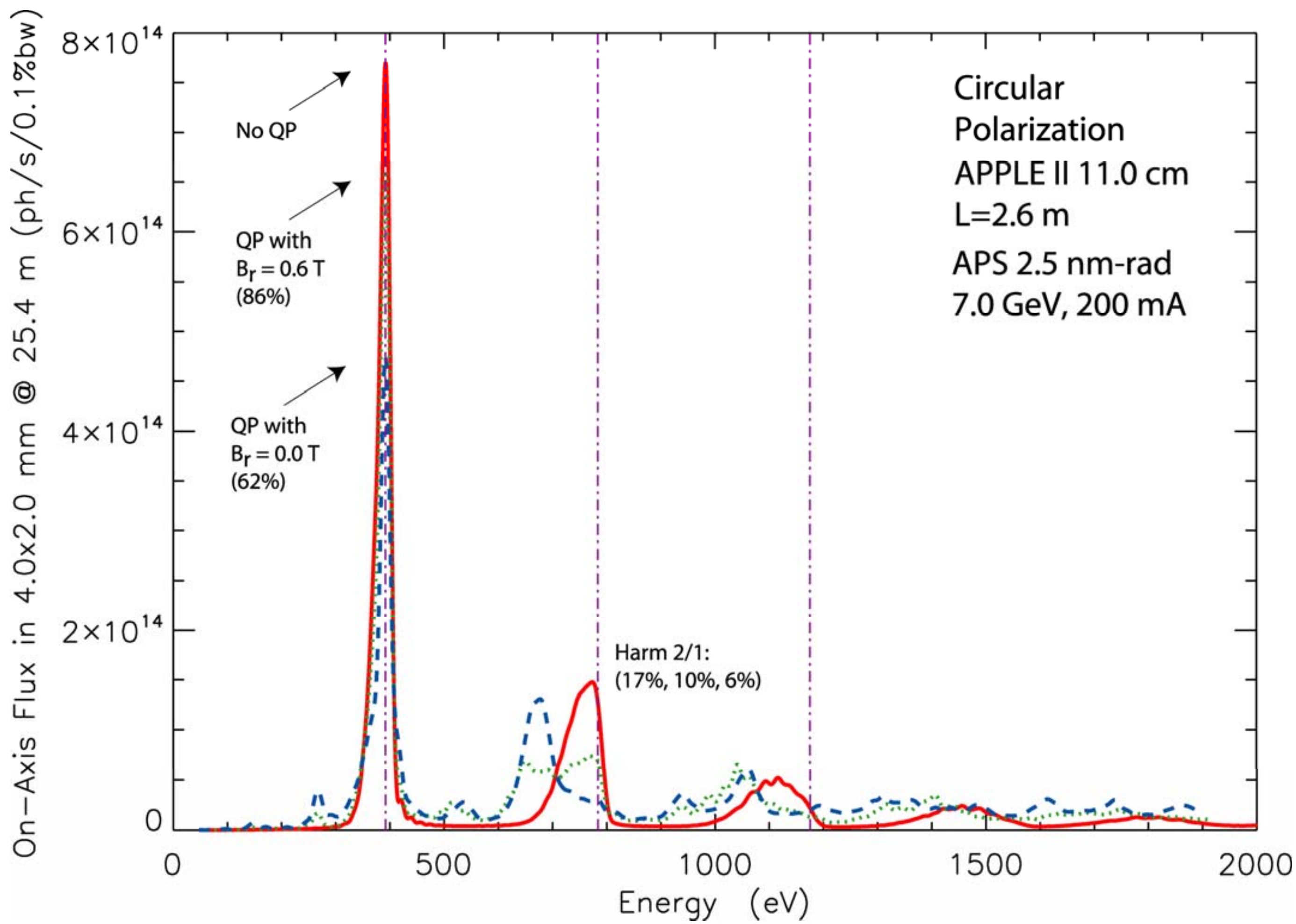
Quasiperiodicity is another means of decreasing high harmonics

- Reduce the strength of a pair of poles, at intervals along the undulator.
- Quasiperiodicity shifts the higher harmonics in energy so they don't go through the monochromator. All harmonics are decreased, but the higher ones drop more. The heat load is still there, though.
- Quasiperiodicity could be turned on & off in an electromagnetic ID.

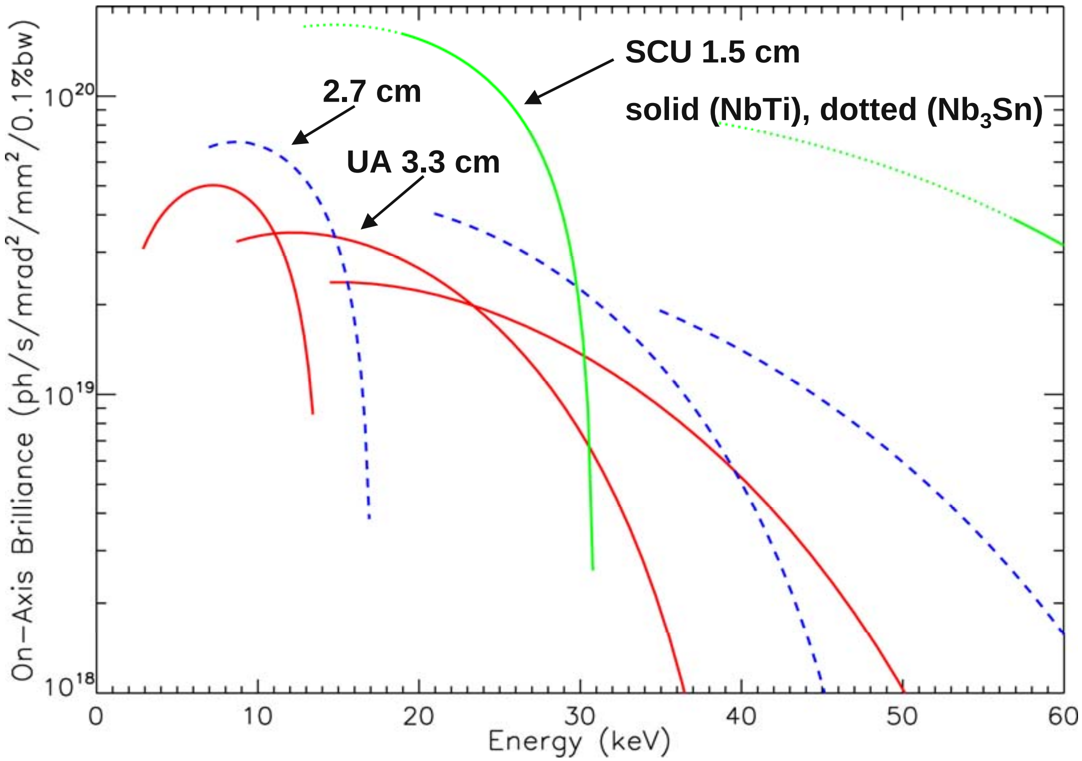


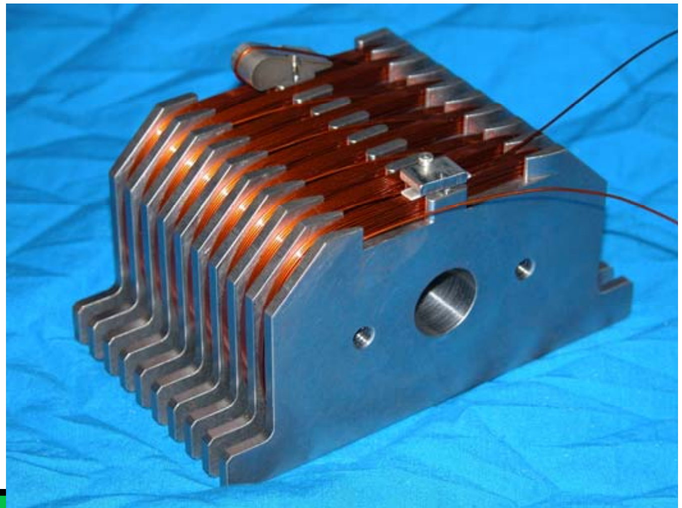
Quasiperiodicity can even help with circular polarization

The small higher harmonic 'contamination' that remains in circular polarization can be decreased by quasiperiodicity.



A short-period superconducting undulator can give more flux at higher photon energies





A magnetic design has been finalized. Short prototypes are in production. Longer ones are planned for testing in early spring.

Front ends – Pat Den Hartog

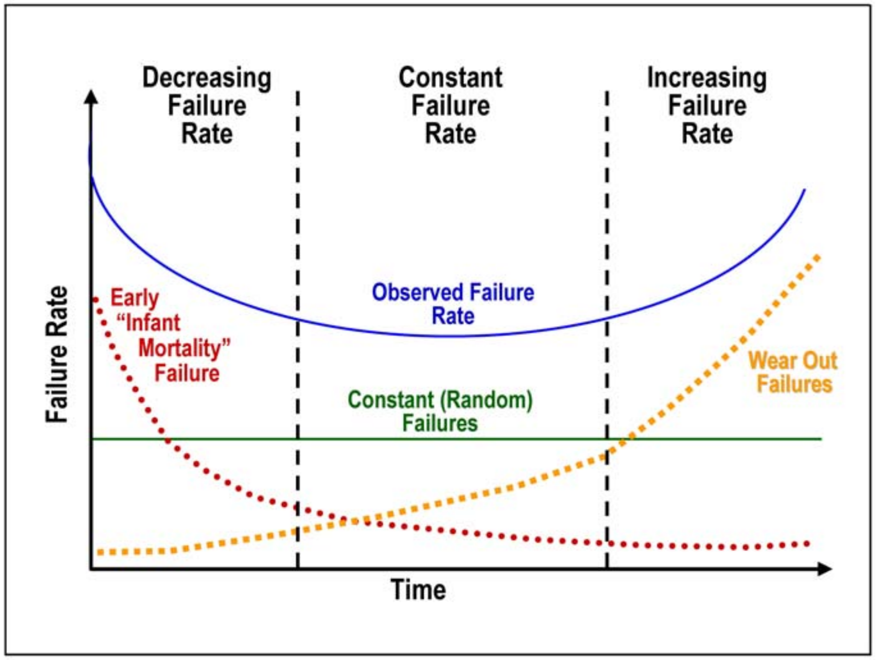
- Support for long straights, new insertion devices
  - Insertion Device Vacuum Chamber – smaller gap, lower impedance (R&D Proposal)
  - Prototype Long Straight Section (R&D)
- New Front Ends
  - Canted front ends
  - IEX FE
  - SPX FE
  - Finish currently undeveloped FE infrastructure
- Front End Upgrades to allow higher current or higher power IDs
  - Upgrades to all version 1.2 and 1.5 front ends
  - New, higher heat load design,
  - High heat load components (R&D)

Nanopositioning – Deming Shu

- Several proposals were submitted in support of High precision positioning and motion metrology system (non-contact sub-nanometer)
- Some solutions (tens of nanometers) available now, however this is primarily an R&D effort:
  - Successful design of nanopositioning systems to exploit 1 nm resolution x-ray optics– both refractive and reflective, requires collaboration across engineering disciplines (mechanics, controls, electronic hardware) from the start.
  - In addition, a concerted R&D engineering effort is necessary to develop nanotomography stages that have runout/wobble small enough to obtain tomographic resolution on par with state of the art scanning probes.
- A *Nanopositioning Working Group* (chaired by John Quintana) has been formed that will:
  - articulate a 5 to10 year plan for development of the positioning systems necessary to support nanometer level optics and
  - coordinate the necessary engineering R&D efforts.

Obsolescence, Spares, and Upgrades – John Quintana

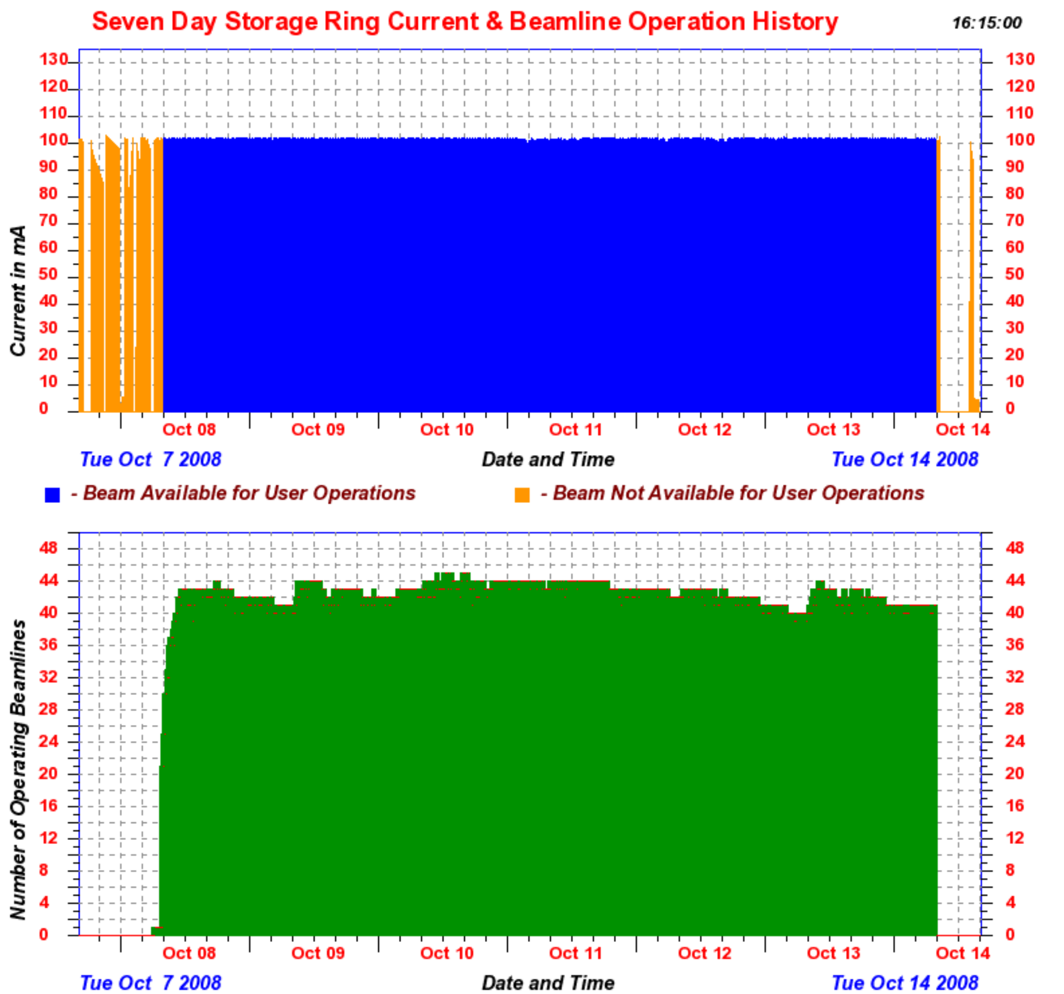
- Many APS systems are more than 12 years old.
- Due to budget constraints, recapitalization into accelerator systems has slowed over the last several years.
- APS is beginning to experience failures in systems which have experienced few failures over last several years.
  - RF coupler failures
  - Storage ring current monitor failures.
- Many APS systems have inherent redundancy, but this only “hides” the decay.
- Certain APS systems require upgrade simply because parts are no longer available.
- “Upgrades” are driven by obsolescence concerns.



Obsolescence, Spares, and Upgrades

When balancing priorities we need to remember:

"If the accelerator goes down so do all of the beamlines."



Obsolescence, Spares, and Upgrades - Power Supplies (Wang)

- Replacements and upgrades are needed to:
  - Replace aging power supply systems to maintain high reliability
  - Avoid long downtimes in case of failure
  - Reduce maintenance/repair time
  - Improve performance/reliability
- Proposals:
  - Storage ring converter replacement (1334 converters with digital, high-resolution converters and eliminate 220 obsolete units)
  - Build storage ring dipole magnet power supply spares
  - Build new booster ramping power supplies
  - Upgrade PAR/booster kicker and corrector power supplies and magnets
  - Booster FPGA-based ramp correction

Obsolescence, Spares, and Upgrades - RF (Nassiri)

- Develop solid state RF amplifier
  - Eliminates reliance on high power CW klystrons
  - Questionable long-term production commitment of klystron manufacturer
- Replacement of UVC power supplies – higher noise and jitter specs
- Replacement of linac rf components

Obsolescence, Spares, and Upgrades - Diagnostics & Controls

- Diagnostics (Decker)
  - Storage ring and injector flag upgrade – “The system is very old, cameras are dying from radiation damage, and cannot be purchased anywhere. We are essentially out of spares.”
  - Upgrade storage ring loss, photon, and injector synchrotron light monitors
  - Emittance measurement for PAR bypass and BTS booster bunch cleaning – allowing bunch purity to be brought to levels achieved ar ESRF and SPring-8
  - Booster and PAR BPM upgrades

- Controls (Arnold)
  - Upgrade accelerator controls hardware and software infrastructure
  - Replace ID controls

Obsolescence, Spares, and Upgrades – Mechanical Systems

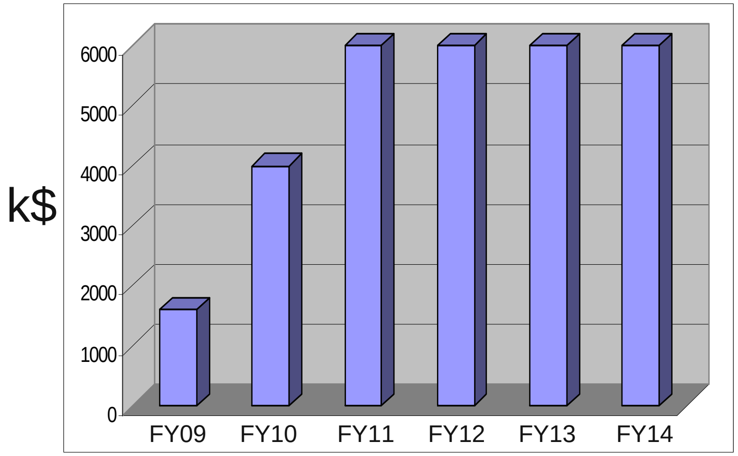
- Mechanical Operations & Maintenance (Goeppner)
  - Replacement of water and vacuum system controllers and other aging components
  - Build stock of spares for cryopumps and other facility mechanical systems

- Safety Interlocks Group (Markovich)
  - Upgrade 44 Generation 1 PSS Systems

Planning Has Begun to Address Obsolescence …

- Funding for these proposals is anticipated to come from operating and Accelerator Improvement Projects (AIP) funds
- Additional effort will be needed
- We anticipate implementing the approved proposals over a 5-6 year period (FY09 – FY14)
- Prioritization has begun by APS management
- For planning purposes - accelerator renewal proposals potential start dates and project durations being mapped onto funding profile

AIP Funding Profile



APS Renewal Projects: Accelerator AIP Funding

Project	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Total
Informations Systems Infrastructure	0	0	0	0	0	0	0	0
Information Systems Infrastructure	0	0	675	156	0	0	0	831
Upgrades to APS Central Computing and Networks	380	800	925	1000	1000	0	0	4105
Upgrades to Accelerator Control System	150	350	425	425	400	0	0	1750
Insertion Device Control - Maintenance & Upgrade	50	150	150	150	150	0	0	650
Accelerator Controls Infrastructure Upgrades	110	270	521	480	330	0	0	1711
SR beam loss monitor upgrade	0	0	135	135	135	135	0	540
SR photon monitor upgrade	70	140	140	210	0	0	0	560
Injector synchrotron light monitor upgrade	0	0	0	50	50	50	0	150
Three-screen emittance measurement for PAR (bypass) and Booster (BTS)	0	0	0	0	100	0	0	100
SR and Injector Flag Upgrade	50	50	100	100	100	0	0	400
Booster Bunch Cleaning	0	50	50	50.5	0	0	0	150.5
Booster BPM Upgrade	0	0	20	150	0	0	0	170

Accelerator Renewal Proposal Contacts

- Feedback is invited.
- Points of contact for feedback & comments:
  - Science Enablers: Michael Borland / Denny Mills
  - Beam Stability: Glenn Decker
  - Insertion Devices: Liz Moog
  - Front Ends: Pat Den Hartog
  - Nanopositioning – Deming Shu

  - Obsolescence / Spares / Upgrades: John Quintana
  - Infrastructure and IT: John Maclean

  - General: Rod Gerig
- All proposals are available on the renewal website, http://www.aps.anl.gov/Renewal