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Accelerator Enhancements for APS Renewal

APS User Meeting

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Accelerator Enhancements of APS Renewal

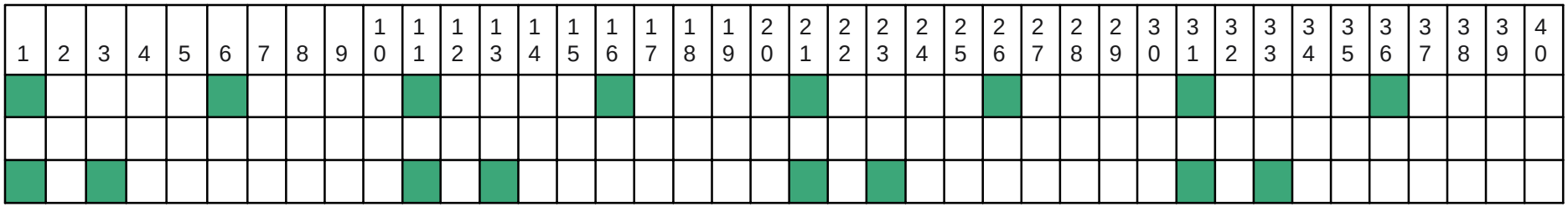
- **Long Straight Sections**
- **Higher Current**
- **Beam Stability**
- **Short Pulse Capability**
- **Tailored Insertion Device Capability**

Long Straight Sections

- Benefits
  - APS straight sections now allow 4.8 m for insertion devices
  - Longer straight sections interesting for many reasons
    - *Longer devices*
      - Higher brightness
      - Flux-starved experiments
    - *Getting more from expensive end station equipment by having several IDs*
    - *Canted devices to increase number of simultaneous experimental stations*
    - *Space for cryostats for superconducting crab cavities*

Long Straight Sections

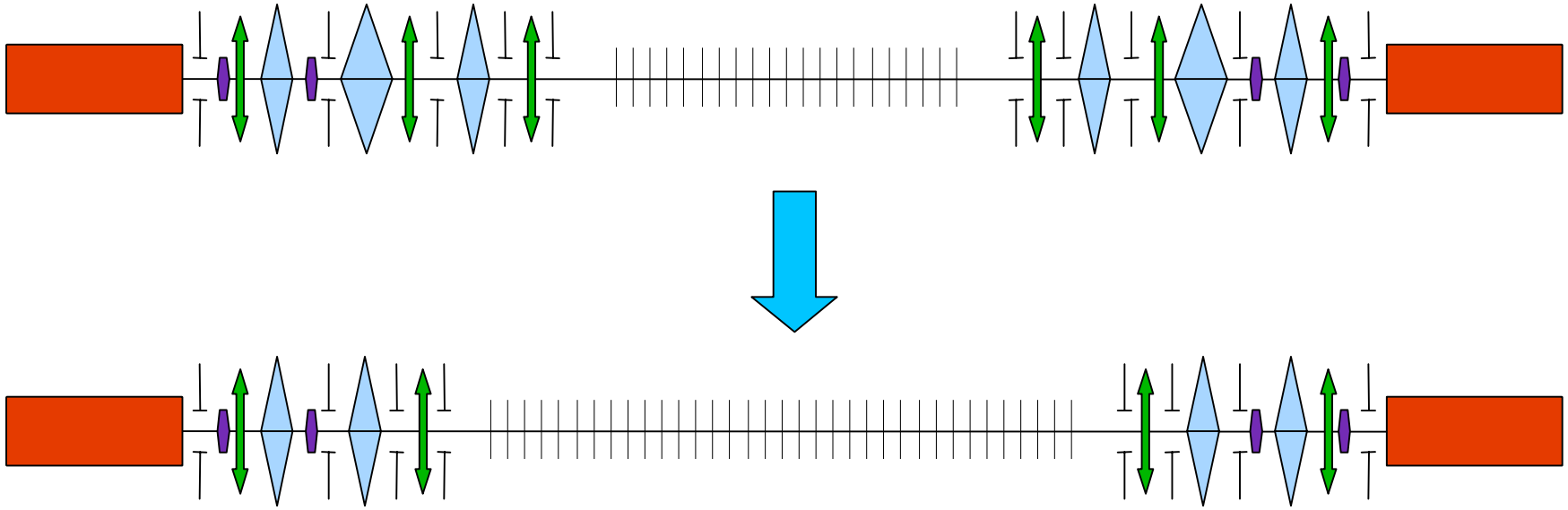
- Simulation shows random placement of LSS is unacceptable
  - Injection efficiency and lifetime will suffer
  - Must constrain LSS sectors to a symmetric arrangement
  - APS can have 2, 4, 5, 8, 10, 20, or 40 symmetrically-placed LSS
  - Studying eight-fold options most extensively



Need not start in sector 1

Plan for Making Long Straight Sections (LSS) at APS

- We can increase the space for IDs by 3.2m as follows:
  - 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
  - Replace girders and vacuum chambers



Instead of 4.8 m for IDs, we have 8.0 m.

LSS - Maintaining Good APS Performance

- As mentioned, maintaining lattice symmetry is important
- We intend to install LSS without extended shutdowns or operational interruptions
  - Machine must continue to work well as LSS are gradually implemented
  - Installing in pairs on opposite sides of the ring is appealing
  - Can also use a combination of real LSS with mocked-up LSS to maintain approximate symmetry
- Machine performance as seen by users not greatly impacted
  - Lifetime as good, thus top-up not impacted
  - Emittance increase ~6%
  - Reduced Horizontal Beta lattice in area of LSS compromised
- Minimal R&D needed before implementation

Higher Current

- The Renewal provides the right time to upgrade the facility to accommodate higher current… always anticipated.
- The plan is to increase the capability of the facility to handle 200 mA.
- Advantage to users is increased flux and brightness.
- As part of the renewal project, all front ends and FOE optics will be upgraded to accommodate the increased power and improve the delivered x-ray beam quality.
- The accelerator can already store 200 mA with 324 bunches.
- R&D, and specific accelerator modifications are needed to store 200 mA in 24 bunches.
  - Redesigned dampers which damp longitudinal coupled bunch instabilities, known as Higher Order Mode (HOM) dampers
  - Scrapers
- May require decrease in top-up injection interval to one minute.

Renewal Accelerator Enhancement – Beam Stability

- APS Beam (orbit) stabilization system is aging
  - RMS Beam motion (.1 – 200 Hz): horizontal 4.8 μm, vertical 1.6μm
  - Long Term (one week drift) typical numbers are 10 μm and 3 μrad (h,v)

- Renewal 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**

Renewal Accelerator Enhancement – Beam Stability

- Implementation –
  - BPM Electronics Upgrade
  - Real-time Feedback System Upgrade
  - Additional Correctors used in Feedback system (factor of two)

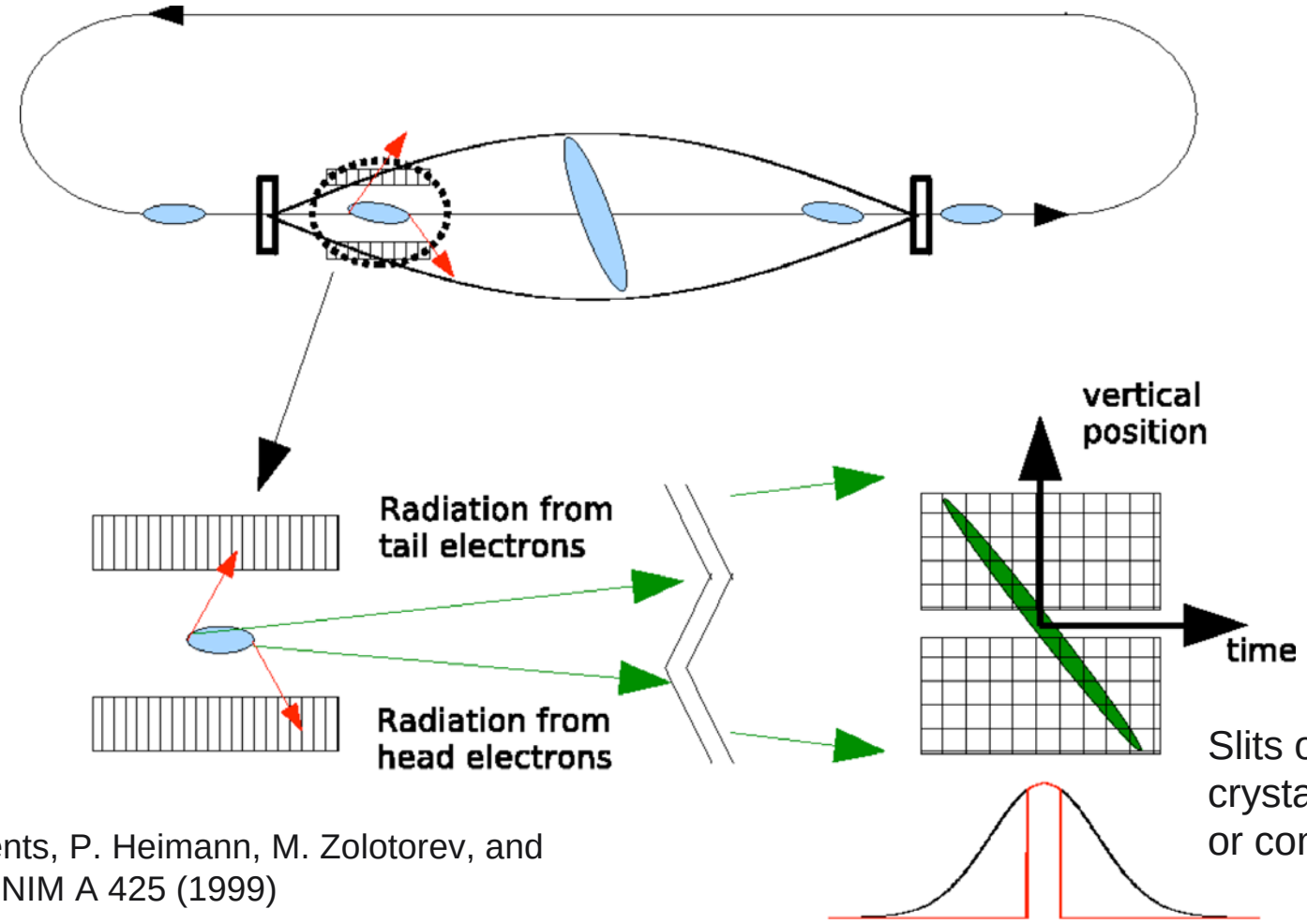
  - X-bpm system Enhancements
    - *Long term pointing stability and repeatability*
  - Portable Beamline Detector Suite
    - *Troubleshooting individual beamline performance*

  - Thermal and vibrational stabilization of accelerator and beamline components

  - Improvements to injection orbit transient expected

Renewal Accelerator Enhancement - SPX

- Provision of ultra short x-ray pulses at a few APS beamlines
  - Goal is 2 ps FWHM with 1% photons; all bunches

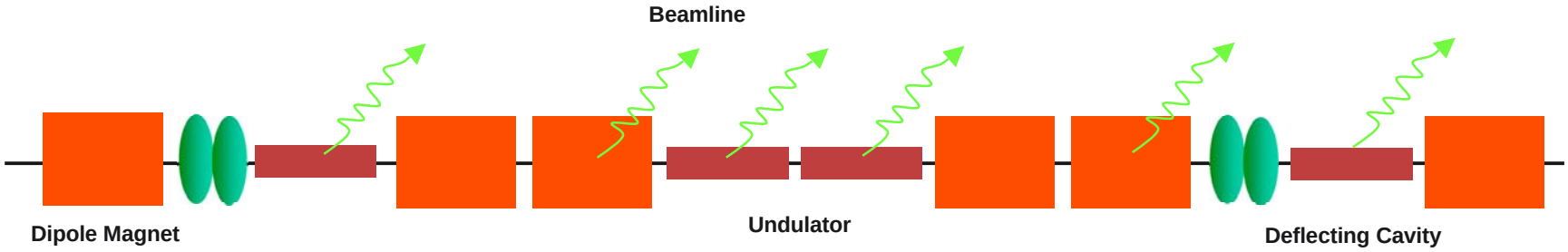


Slits or asymmetric crystals used to clip or compress pulse

A. Zholents, P. Heimann, M. Zolotorev, and J. Byrd, NIM A 425 (1999)

SPX Potential Layout

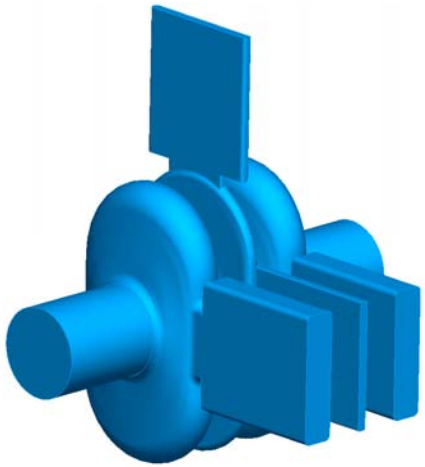
- The APS has explored a number of layout scenarios. The example below would allow two ID beamlines to receive the short pulses



Progress is being made on Superconducting SPX R&D

- Transition from LDRD to R&D phase
- Our goal for the R&D phase is to validate the design performance of a SRF deflecting cavities system and assess its operational utility, performance with beam and its impact on the storage ring operation
  - Passive cavity
  - Powered cavity
- Considerable progress has been made in modeling, simulation, analysis, initial prototyping and cold test during LDRD phase
  - Single-cell SRF structure
  - Multi-cell SRF structure

Niobium Single-cell prototype cavity



A 3-cell cavity with horizontal cavity-mounted dampers on each cell. A vertical damper is located on the central cell to damp vertical dipole modes.

Niobium Single-cell prototype cavity with on-cell waveguide damping – a new concept

Insertion Devices

- Tailored to users requests
- All existing APS designs are available

Period length	Number	Length (periods)	K_{eff}
33-mm (Undulator A)	24	72	2.74
33-mm	5	62	2.74
18-mm	1	198	0.46
23-mm	3	103	1.17 [a]
27-mm	3	88	1.78
30-mm	2	79	2.20
30-mm	3	69	2.20
35-mm (SmCo)	1	67.5	3.08 [b]
55-mm	1	43	6.57
128-mm (Circularly Polarized Und.)	1	16	$K_{x,y}<2.8$

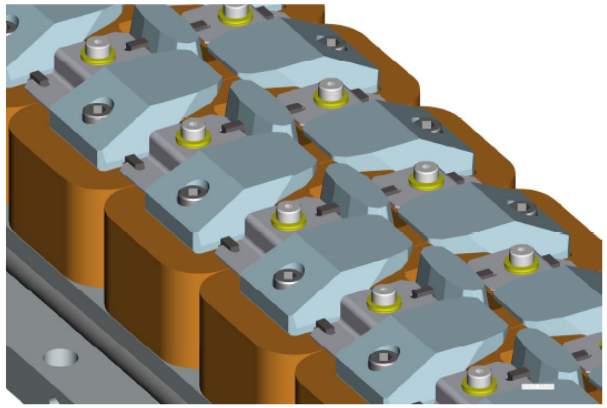
Device length includes the ends - approx. one period at each end is less than full field strength.
K value is at 10.5 mm gap unless stated otherwise. CPU is all-electromagnetic.

[a] at 10.6 mm gap.

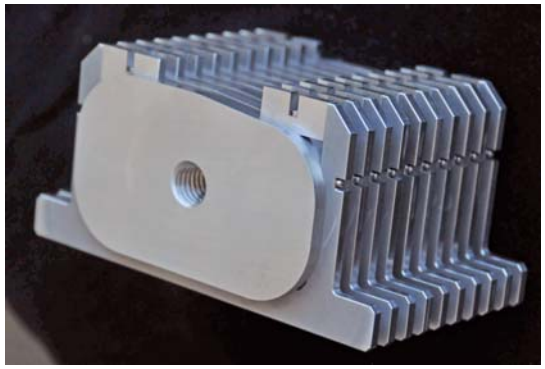
[b] at 9.5 mm gap.

Insertion Devices

- R&D work continues on two new designs
  - IEX: Electromagnetic quasi-periodic undulator for low energy x-rays (200 eV to 2.5 keV photon energy) Variable polarization (left- and right-handed circular, horizontal and vertical lin
    - *0.4m long prototype being developed*
    - *Not rapid switching*



  - Super Conducting Undulator: 20-25 keV in first harmonic
    - Undulator period of 16 mm; beam stay-clear of 7 mm.
    - 42-pole magnetic structures have been successfully produced and tested, reaching the expected critical current and showing good magnetic field quality.



Summary of Renewal Accelerator Enhancements

- The accelerator portion of the renewal is a package of improvements that provides greater performance in terms of:
  - beam stability
  - Increased brightness and/or flux
  - flexibility to beamlines
  - individual requirements provided to the extent possible
- Minimal R&D required for a project of this scope
- Implemented during existing shutdowns, therefore minimal impact on operations