Argonne NATIONAL LABORATORY

A Greatly Improved Storage Ring for the APS

Michael Borland and Efim Gluskin
Accelerator Systems Division
Advanced Photon Source

THE UNIVERSITY OF CHICAGO
Office of Science
U.S. DEPARTMENT OF ENERGY
A U.S. Department of Energy laboratory managed by The University of Chicago

Goals for the Ring

- Tailored to experimental requirements
- Use “crab” cavities to support experiments requiring
  - Short pulse x-rays, down to ~1ps FWHM
  - Coherent imaging with large beam size
- Long straight sections support innovative insertion devices
  - Variable-polarized high-energy (>20 keV) x-rays
  - Rapidly-variable polarization for medium-energy (<3 keV) x-rays
- Straight sections optimized for
  - Small beam size or
  - Small beam divergence
- Higher brightness.

The “Iron Law of Accelerator Physics”

- “Every useful modification makes the brightness worse.”
- Among these are
  - Longer straight sections
  - Customized source size and divergence
  - Optics modifications for crab cavities
- We are losing ground on brightness as we customize.

No Room at the Bottom

- Emittance (phase space area of the beam) is a primary determinant of brightness
- APS design was conservative but flexible
  - Original emittance of 8 nm
  - We have pushed this down to 3.1 nm
  - 15% reduction possible without heroic measures
- Any customization drives the emittance up from the minimum
- If we want these other features and no *increase* in emittance, we must replace the storage ring.

Reaching for a New Low (Emittance)

- Add damping wigglers
  - Requires significant real estate for long wigglers

How to Lower the Emittance?

- Add damping wigglers
  - Requires significant real estate for long wigglers
- Make the energy lower
  - Reduces high-energy x-ray reach
  - Increases issues with beam instabilities
  - Hard to get a large factor

$$\epsilon \propto \frac{E^2}{\nu_x^3 \rho}$$

- Increase the horizontal tune, ν_x
  - Generally requires more focusing magnets
  - Requires more, shorter dipoles so we can focus more frequently
- APS has two dipoles per sector
  - In recent years, we've explored designs with 3, 4, and 6 dipoles per sector.

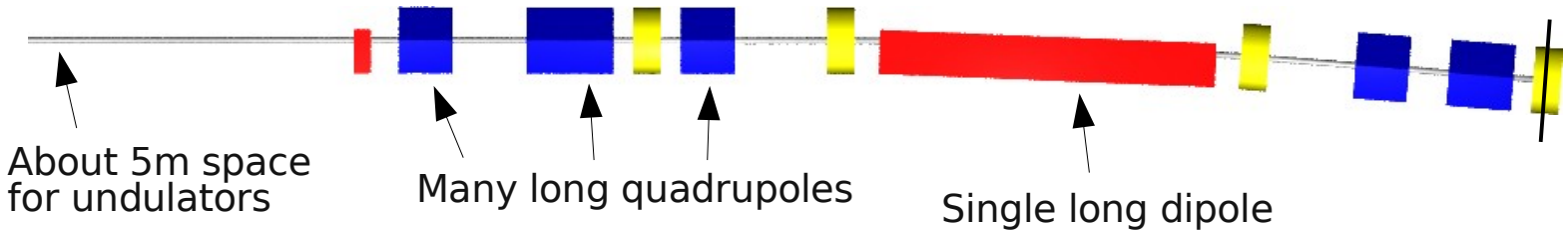
Results from Our "Next-Generation" Program

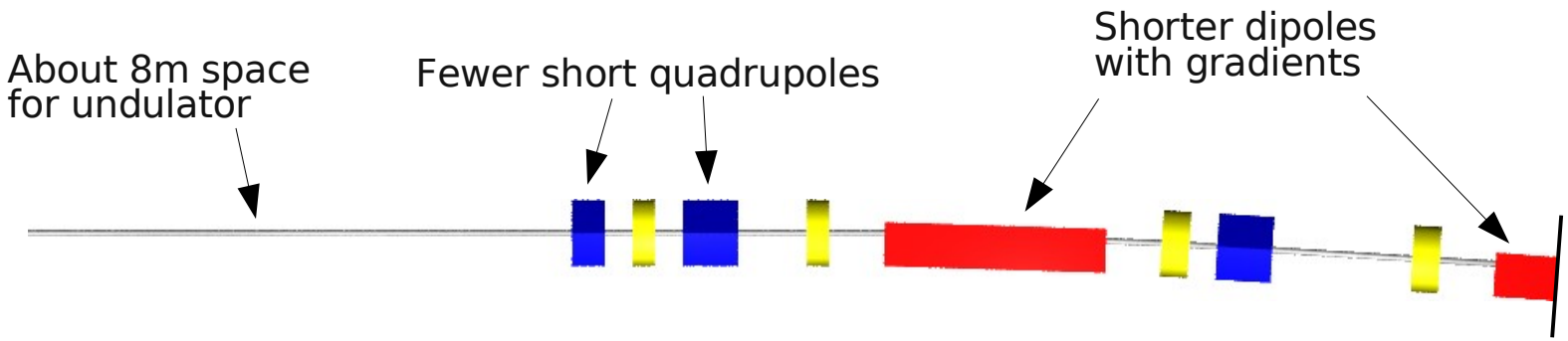
- "WAPS" wiggler-based lattice
  - 0.23 nm effective emittance
  - Only 3m for undulators in each straight
- "2xAPS" four-bend lattice
  - 0.30 nm effective emittance
  - 6.6 m for undulators in each straight
- Goals for upgrade required something different...

Triple-Bend Design

- Started with a triple-bend achromat design developed at NSLS, scaled to APS size
  - 1.8 nm emittance
  - 5.3 m for insertion devices
  - No custom source sizes
- Eliminated several magnet families to increase straight section length
  - Gradients in dipoles used to replace eliminated quadrupoles
- Optimized dipoles and optics for
  - At least 8 m for insertion devices
  - 1 nm effective emittance
  - Special straight sections with small size or divergence.

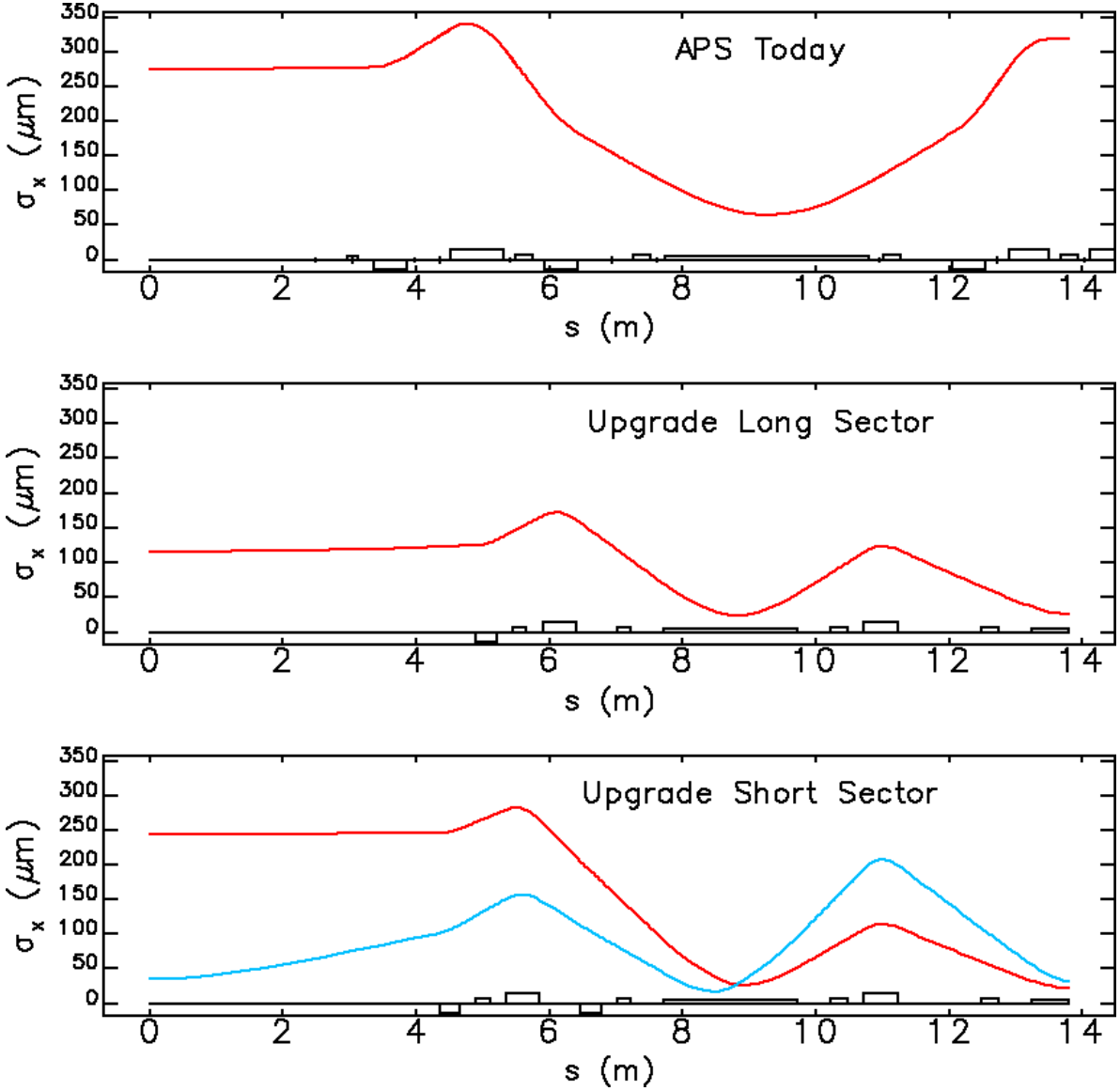
Comparison to the Present Ring



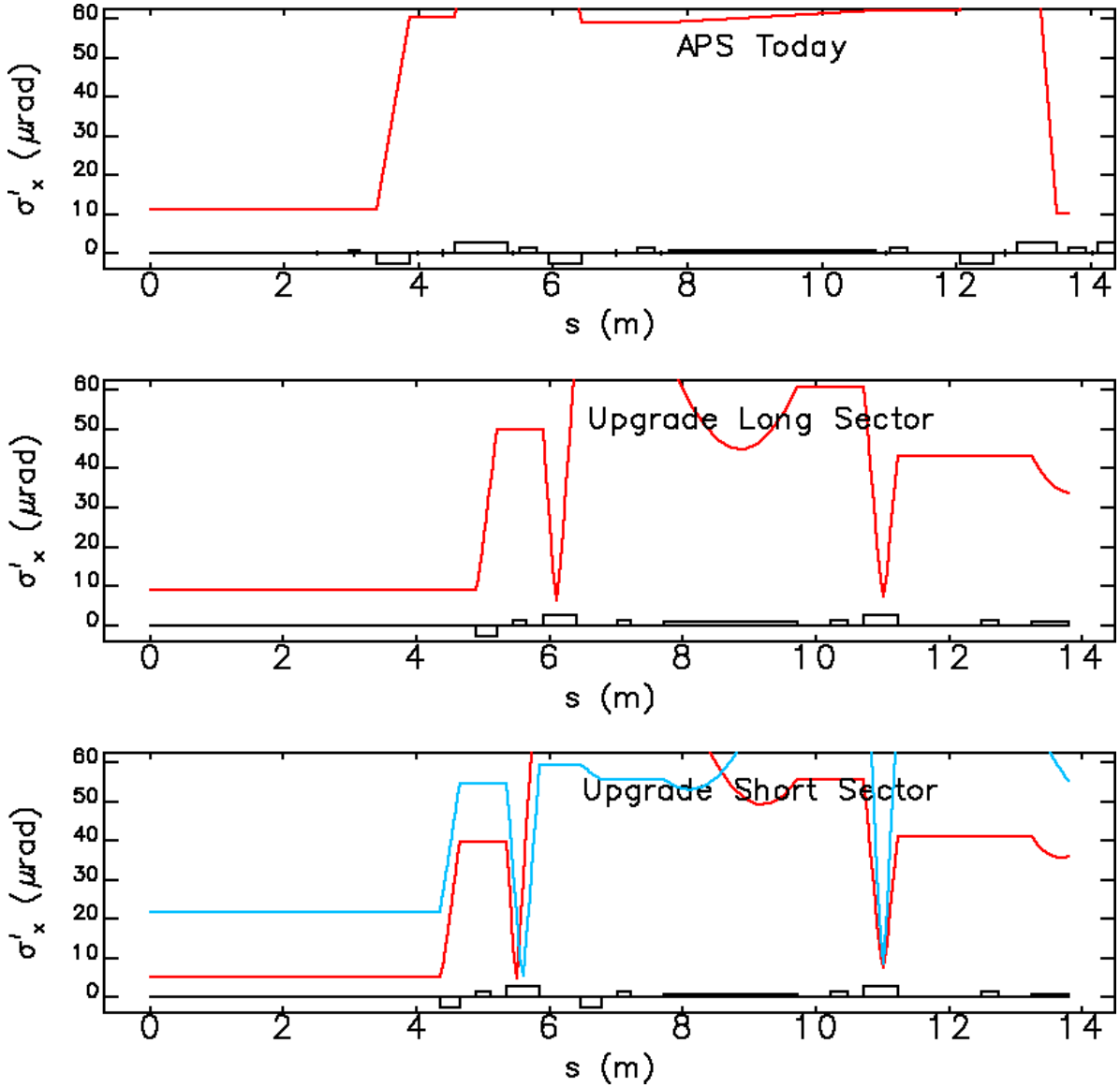


Graphics courtesy L. Emery.

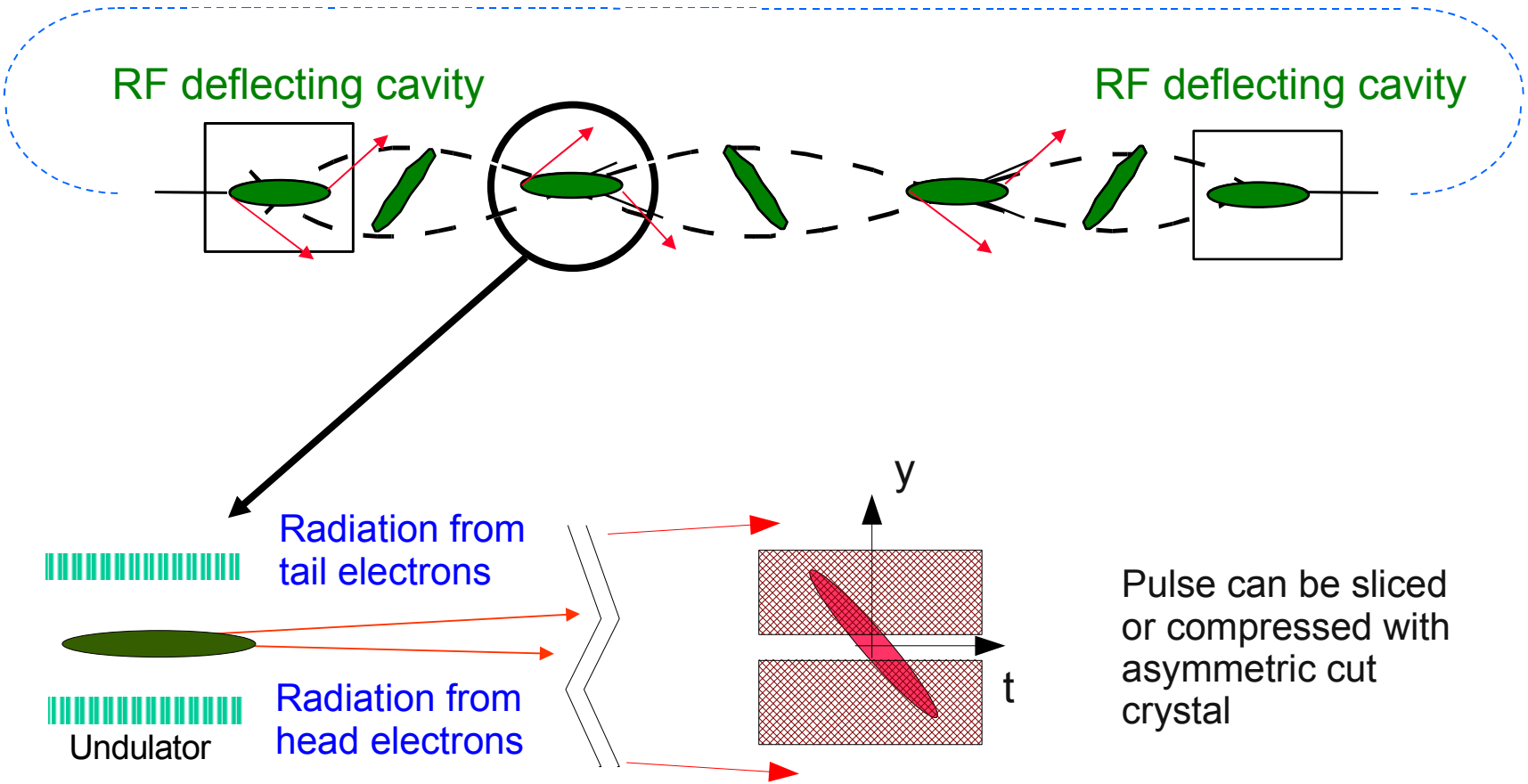
Horizontal Beam Size



Horizontal Beam Divergence



Zholents' Transverse Rf Chirp Concept



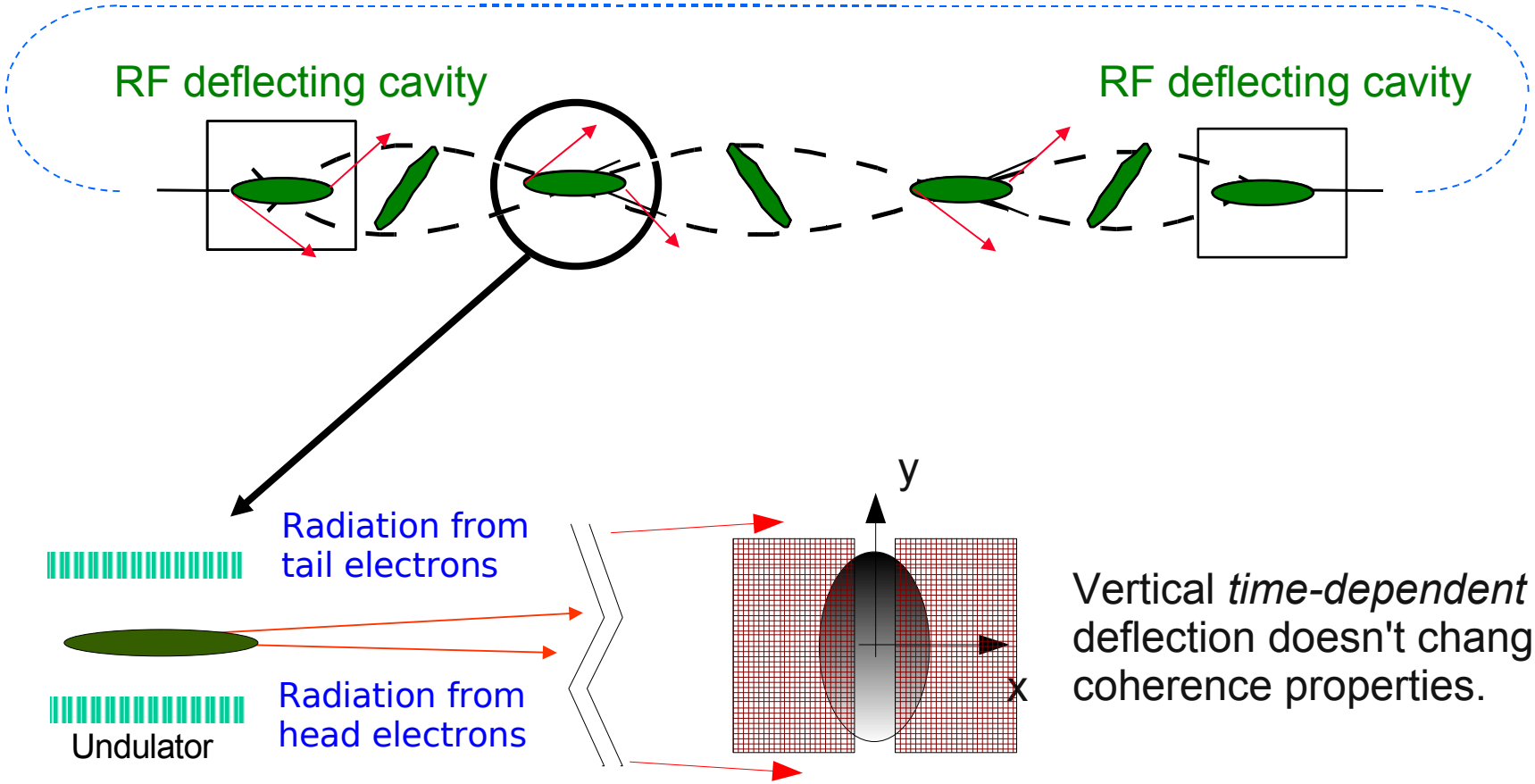
Pulse can be sliced or compressed with asymmetric cut crystal

~1ps FWHM possible for existing APS
(K. Harkay *et al.*, PAC 05, p. 668.)

(Adapted from A. Zholents' August 30, 2004 presentation at APS Strategic Planning Meeting.)

Large Area Coherent Imaging

This is another concept for using a crabbed beam.



Vertical *time-dependent* deflection doesn't change coherence properties.

Will it Work?

- Challenging physics remains
  - So far, we've looked mostly at linear optics
  - Need to develop nonlinear correction scheme
    - *Determines whether we can accumulate beam*
    - *Determines beam lifetime*
- Have not determined feasibility of crab system for this ring
- Magnets don't seem hard to build at first look
- Have to determine alignment and strength tolerances
  - Anticipate using remote movers on magnets to reduce alignment issues
  - APS has developed lattice correction techniques to deal with strength errors.

Conclusion

- APS is exploring a major upgrade
- The demanding goals require
  - New ring
  - Long straight sections
  - Customized source properties
  - Lower emittance
  - Higher current
- A promising initial concept has been developed
- Details will be systematically investigated in coming months
- APS will hold a workshop this summer to discuss upgrade
  - User input and participation needed
  - Details will be announced.