# Advanced Photon Source Upgrade Status

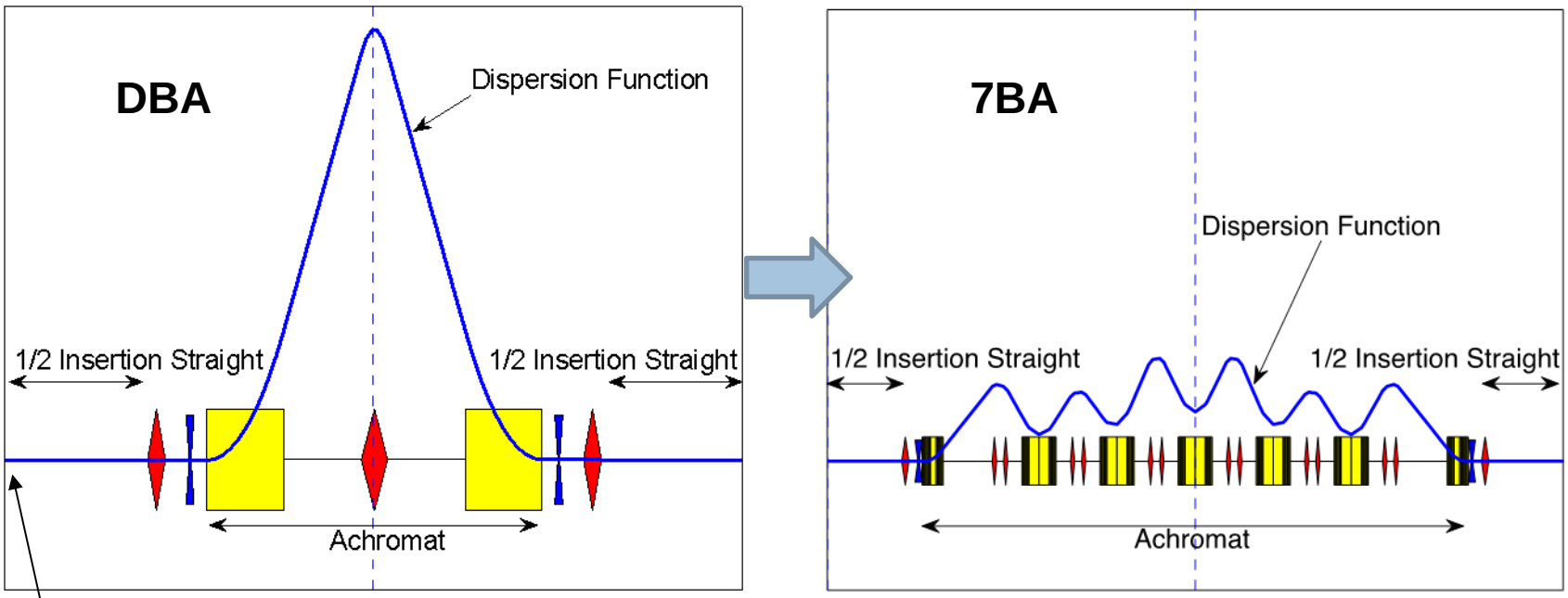
**George Srajer for the APS Upgrade Team**

**Stakeholders Meeting**
February 10, 2014

# Topics

- MBA lattice updates
- MBA Beam physics review
  - Charge and Committee
  - Other reviews
- Storage ring installation planning update

# Lattice Design Evolution from Double-Bend Achromats (DBA) to Multi-Bend Achromats




Figures: C. Steier, ALS.

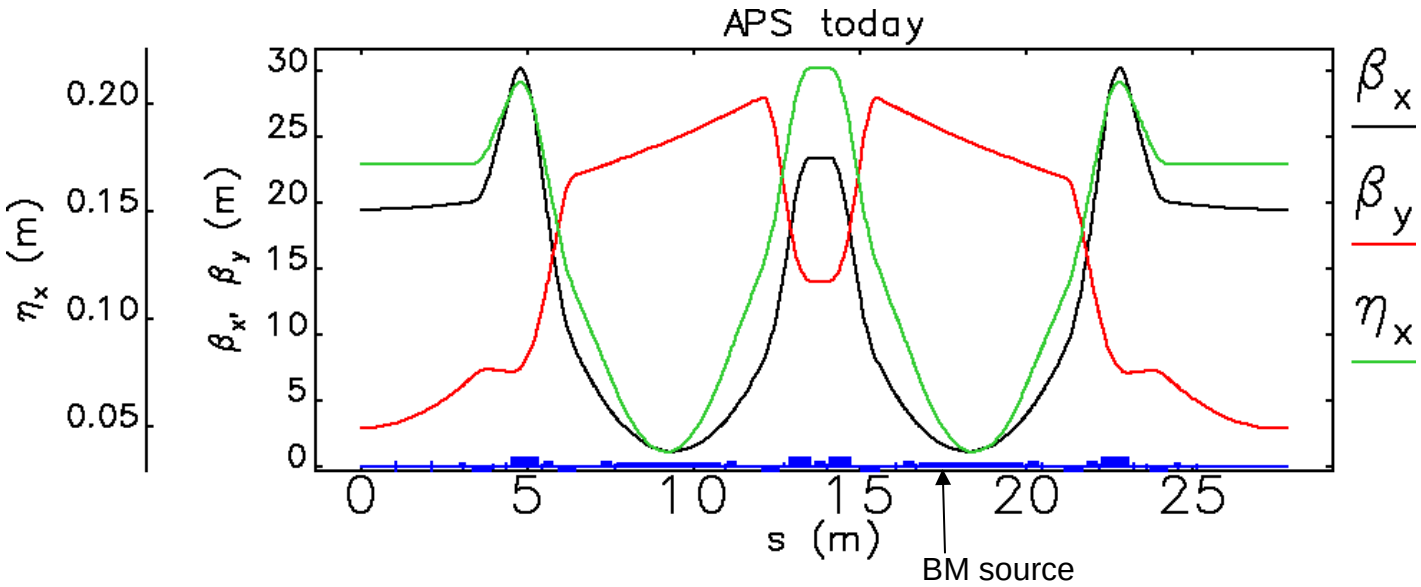
ID Source Point

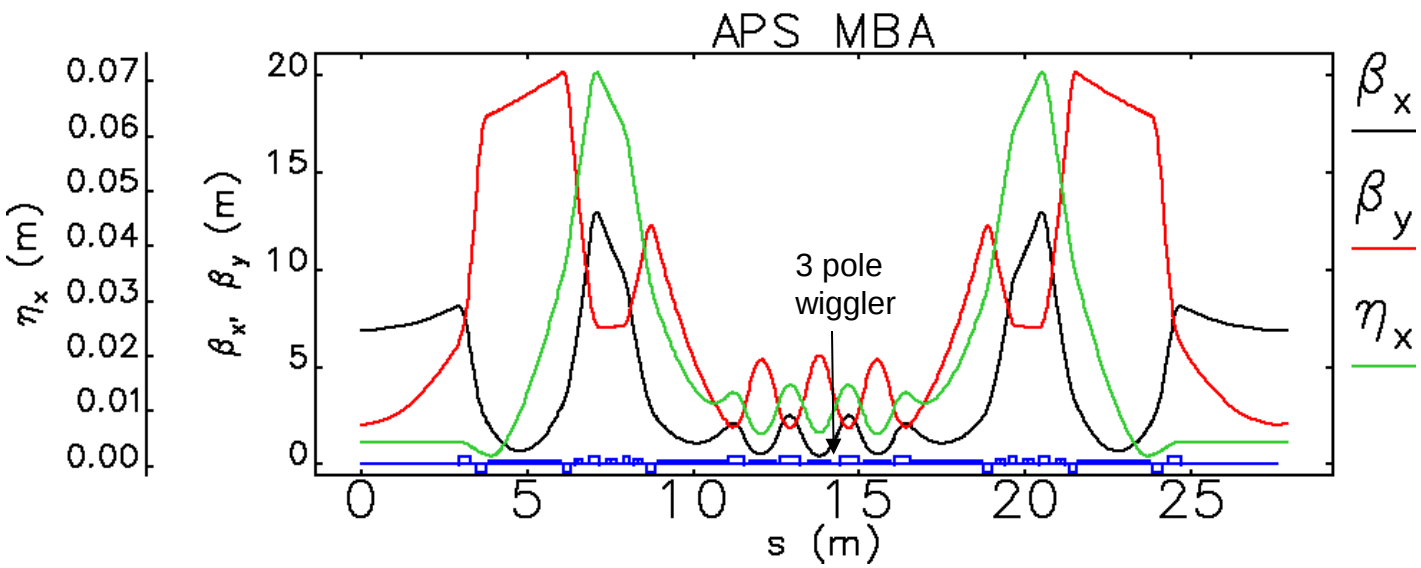
$$\varepsilon_x = C_L \frac{E^2}{N_D^3}, \quad \varepsilon_x \underbrace{\propto}_{\text{Fixed E}} \frac{1}{C^3}$$

$C_L$ = lattice constant
$N_D$ = # dipoles
$C$ = Circumference

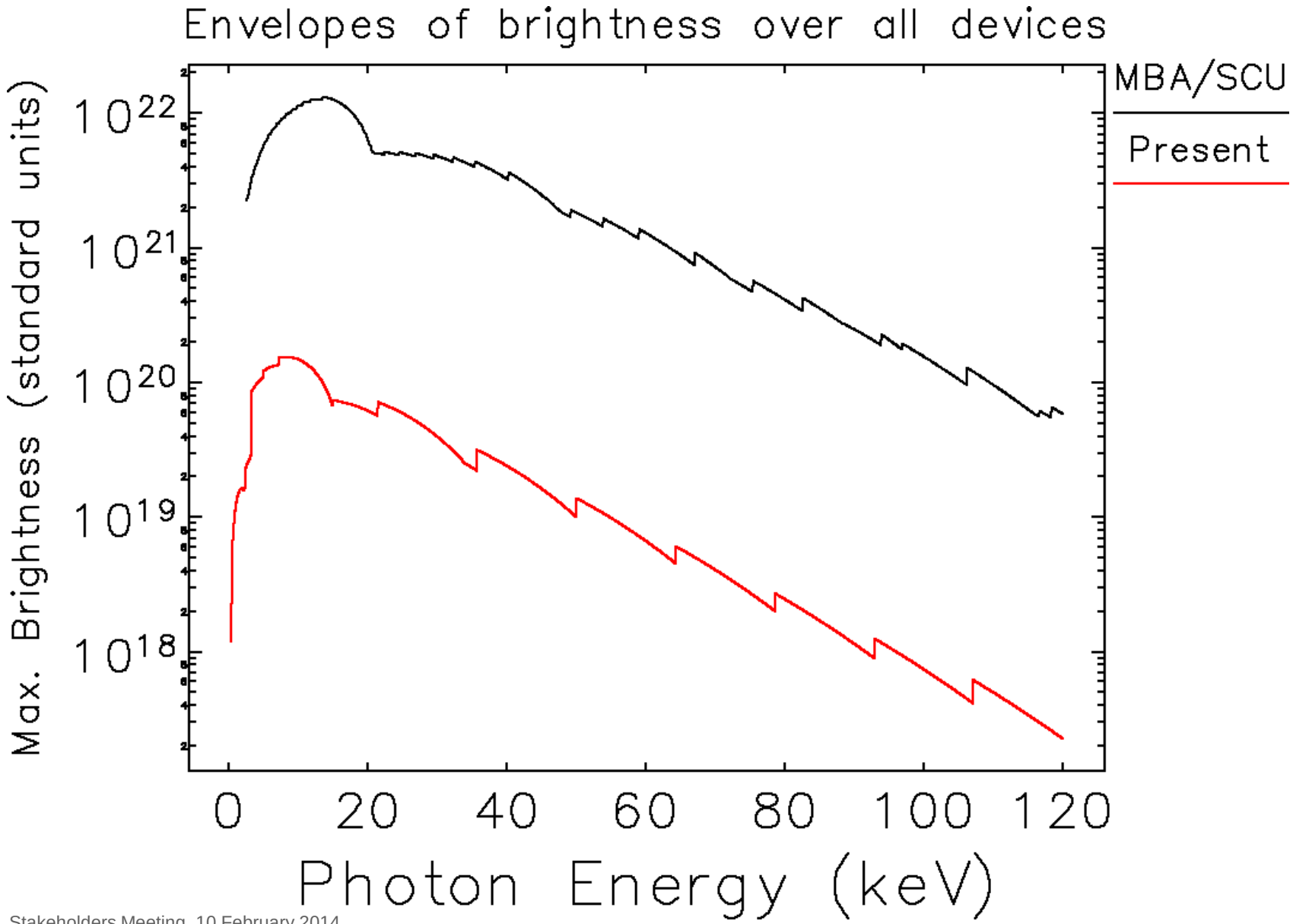
Factor of > 40 improvement in emittance from cubic scaling

# MBA Lattice for APS Tunnel

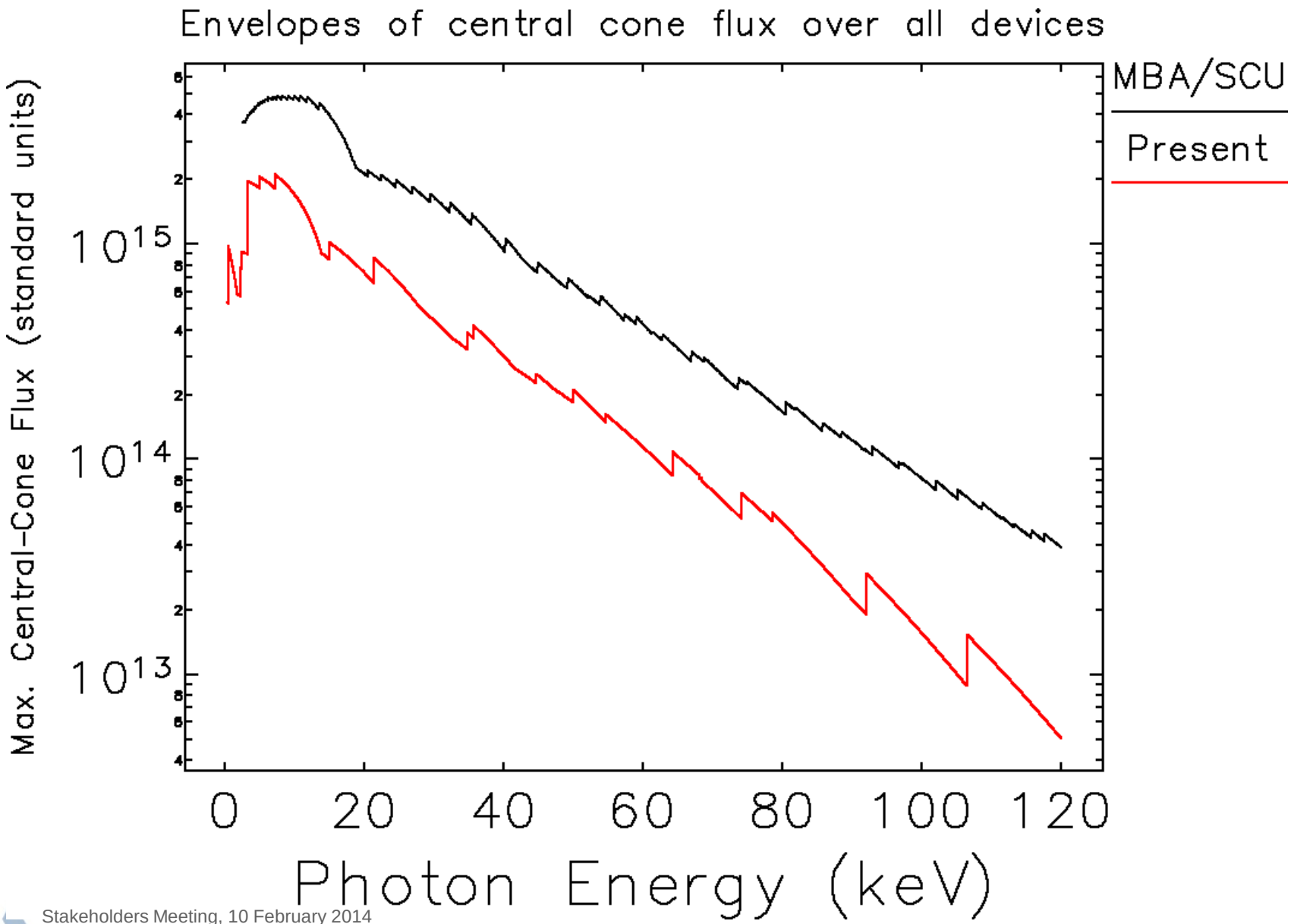


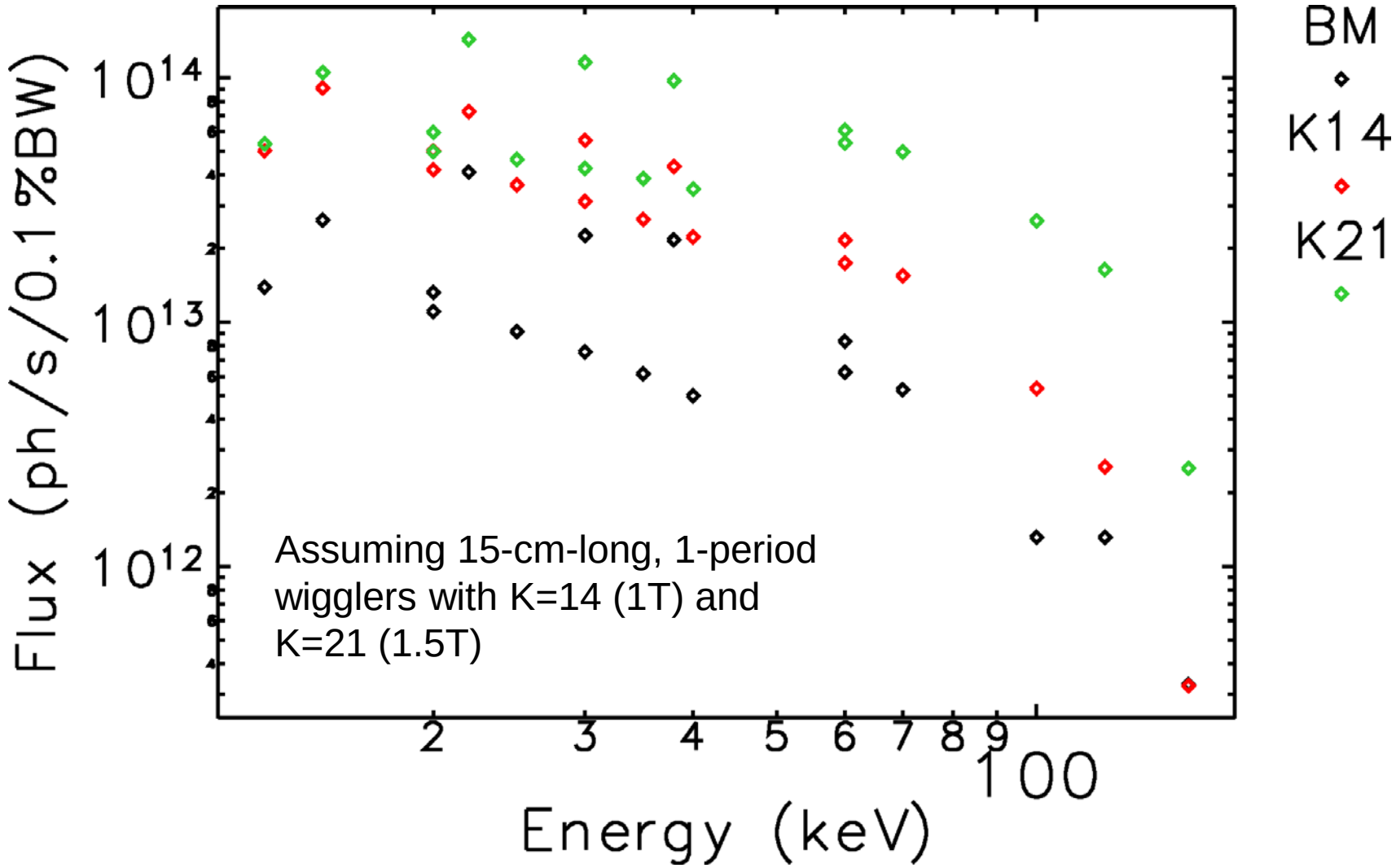
# Brightness Envelope Comparison to Present APS



# Flux Envelope Comparison to Present APS



# 3Pole Wiggler Comparison to APS BM Lines




Comparisons assume the same typical operating energy and acceptance angle for the wiggler as for the existing BM lines (data from G. Srajer).

# Comparison to Existing APS Ring

| | APS | MBA | |
|---|---|---|---|
| **Betatron Tunes** | | | |
| Horizontal | 36.204 | 95.106 | |
| Vertical | 19.272 | 36.154 | |
| **Lattice functions** | | | |
| Maximum $\beta_x$ | 30.6 | 13.0 | m |
| Maximum $\beta_y$ | 29.1 | 20.1 | m |
| Maximum $\eta_x$ | 0.216 | 0.072 | m |
| Average $\beta_x$ | 13.2 | 4.2 | m |
| Average $\beta_y$ | 16.0 | 8.4 | m |
| Average $\eta_x$ | 0.147 | 0.028 | m |
| **Radiation-integral-related quantities** | | | |
| Beam energy | 7 | 6 | GeV |
| Natural emittance | 2513.7 | 66.5 | pm |
| Energy spread | 0.096 | 0.095 | % |
| Horizontal damping time | 9.6 | 12.1 | ms |
| Vertical damping time | 9.6 | 19.4 | ms |
| Longitudinal damping time | 4.8 | 14.0 | ms |
| Energy loss per turn | 5.35 | 2.27 | MeV |
| **ID Straight Sections** | | | |
| $\beta_x$ | 19.5 | 6.9 | m |
| $\eta_x$ | 171.85 | 4.33 | mm |
| $\beta_y$ | 2.9 | 2.1 | m |
| $\epsilon_{x,eff}$ | 3129.4 | 67.7 | pm |
| **Miscellaneous parameters** | | | |
| Momentum compaction | $2.82 \times 10^{-4}$ | $5.62 \times 10^{-5}$ | |
| Damping partition $J_x$ | 1.00 | 1.61 | |
| Damping partition $J_y$ | 1.00 | 1.00 | |
| Damping partition $J_\delta$ | 2.00 | 1.39 | |

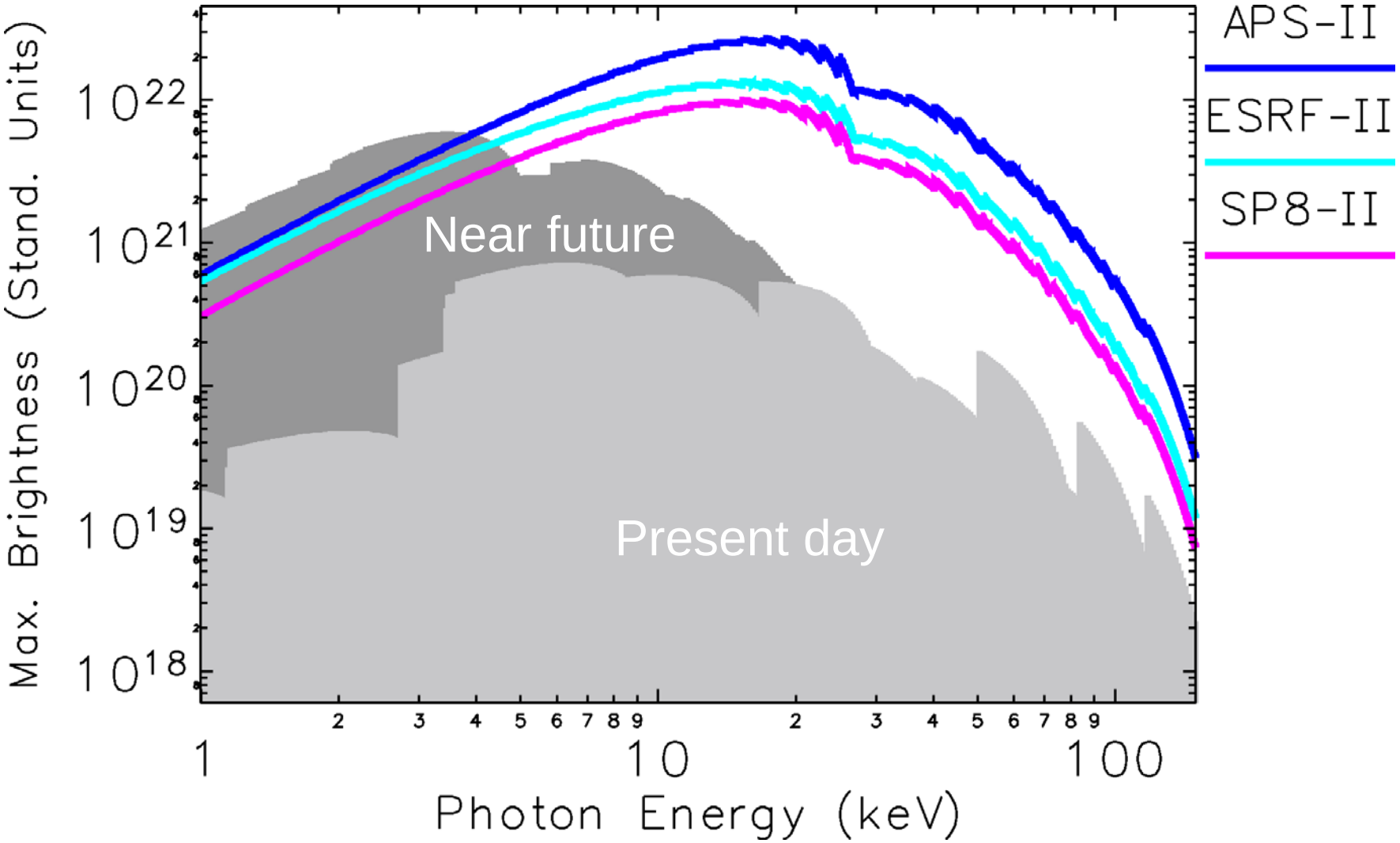
# Beam Parameters at the IDs

| $\kappa$ | $\sigma_t$ ps | $\epsilon_x$ pm | $\epsilon_y$ pm | $\beta_x$ m | $\beta_y$ m | $\sigma_x$ $\mu$m | $\sigma'_x$ $\mu$rad | $\sigma_y$ $\mu$m | $\sigma'_y$ $\mu$rad | $\sigma_\delta$ $10^{-4}$ | $\tau_{10^{th}}$ h | $\Delta T_{\mathrm{inj}}$ s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_b = 48$ | | | $f_b = 13.0\mathbf{MHz}$ | | | | | | | | | |
| 1.00 | 71 | 46.6 | 46.6 | 6.9 | 2.1 | 18.4 | 2.6 | 9.8 | 4.8 | 9.98 | 3.67 | 27.6 |
| $N_b = 81$ | | | $f_b = 22.0\mathbf{MHz}$ | | | | | | | | | |
| 1.00 | 68 | 44.5 | 44.5 | 6.9 | 2.1 | 18.0 | 2.5 | 9.6 | 4.7 | 9.80 | 5.37 | 23.9 |
| $N_b = 162$ | | | $f_b = 44.0\mathbf{MHz}$ | | | | | | | | | |
| 0.11 | 70 | 69.0 | 7.6 | 6.9 | 2.1 | 22.2 | 3.2 | 4.0 | 1.9 | 9.86 | 5.70 | 12.7 |
| $N_b = 216$ | | | $f_b = 58.7\mathbf{MHz}$ | | | | | | | | | |
| 0.10 | 67 | 68.2 | 6.8 | 6.9 | 2.1 | 22.1 | 3.1 | 3.7 | 1.8 | 9.80 | 6.61 | 11.0 |
| $N_b = 324$ | | | $f_b = 88.0\mathbf{MHz}$ | | | | | | | | | |
| 0.10 | 67 | 66.4 | 6.6 | 6.9 | 2.1 | 21.8 | 3.1 | 3.7 | 1.8 | 9.71 | 8.58 | 9.5 |

# Beam Physics Summary

- Lattice evolution continues with iteration between physics and engineering
  - Challenges of magnet engineering reinforce the tentative decision to work at 6 GeV
  - Lower emittance may be possible at lower energy, but otherwise need new, larger site
- Continue to predict brightness up to 2+ orders of magnitude above present values
  - Developing a low-βx variant that should improve brightness another 20-40%
- Flux improved by up to an order of magnitude, coherent flux by up to 2+ orders of magnitude
- Uniform fill patterns with 200 mA in 48 to 324 bunches appear possible
  - Bunch rates from 13 to 88 MHz
- Latest lattice incorporates space for three-pole wigglers
  - Appears to resolve issues with the central three dipole magnets
  - Provides significant improvement in flux compared to present BM sources
- Latest lattice has improved nonlinear dynamics, i.e.,
  - Larger injection aperture
  - Longer beam lifetime

# APS MBA Compared to Present and Future Machines

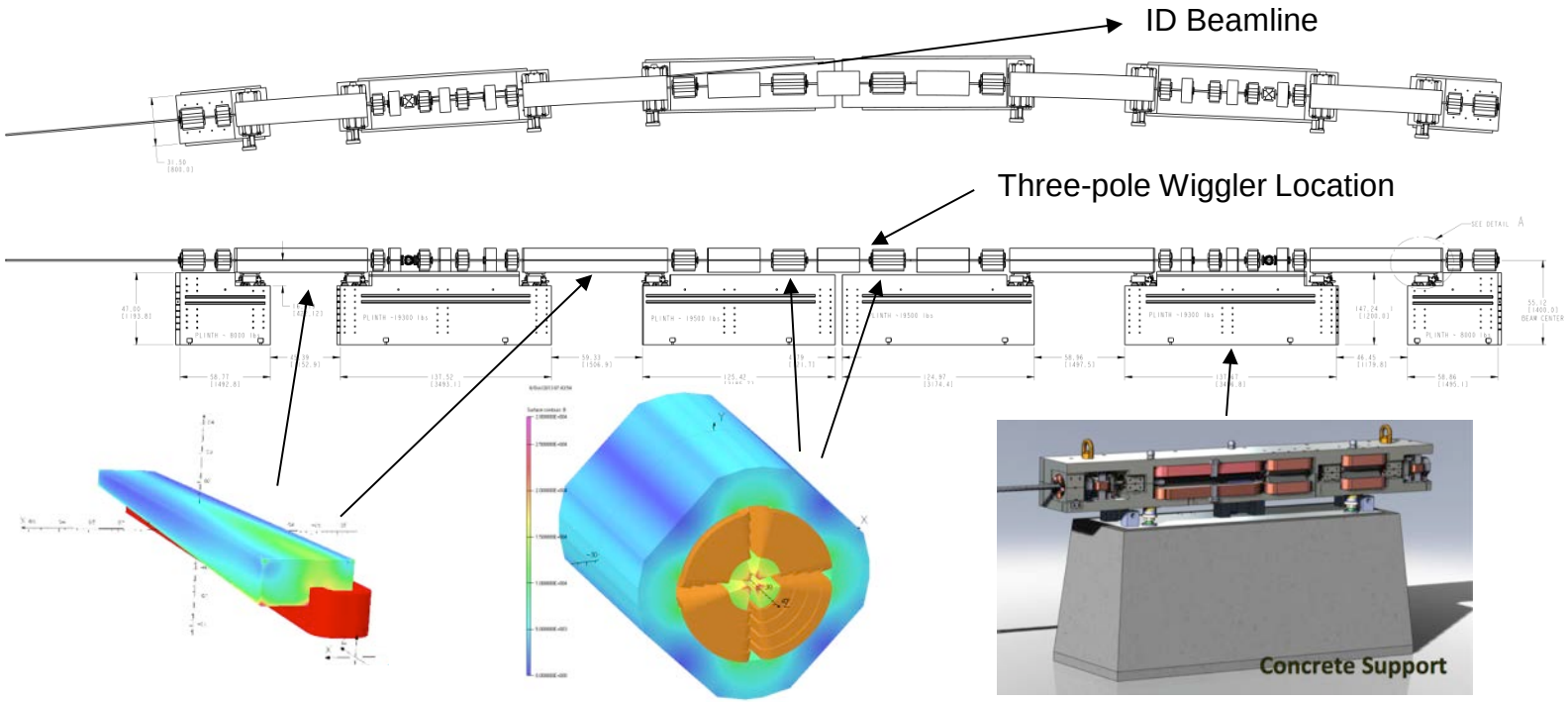


# APS MBA Accelerator Implementation

- High-Level specifications have been captured in a working assumptions document (92 pages, near completion), which will form the basis for the conceptual design.
- Working groups have been established in the areas of magnets, vacuum, support structures, power supplies, fast injection kickers, controls, diagnostics, rf systems, tolerances, mechanical systems integration, and electrical systems integration, meeting on a weekly basis.
- In addition, system engineering, decommissioning, installation, supply chain management, and infrastructure are also addressed at a high level.

# APS MBA Accelerator Implementation

- The overall lattice design has converged to a 70 pm emittance machine with an integrated three-pole wiggler servicing bending magnet beamlines. (Beam physics review February 13-14, 2014)
- Magnet strengths are high but achievable, and viable conceptual designs for each type are now feasible with this lattice.

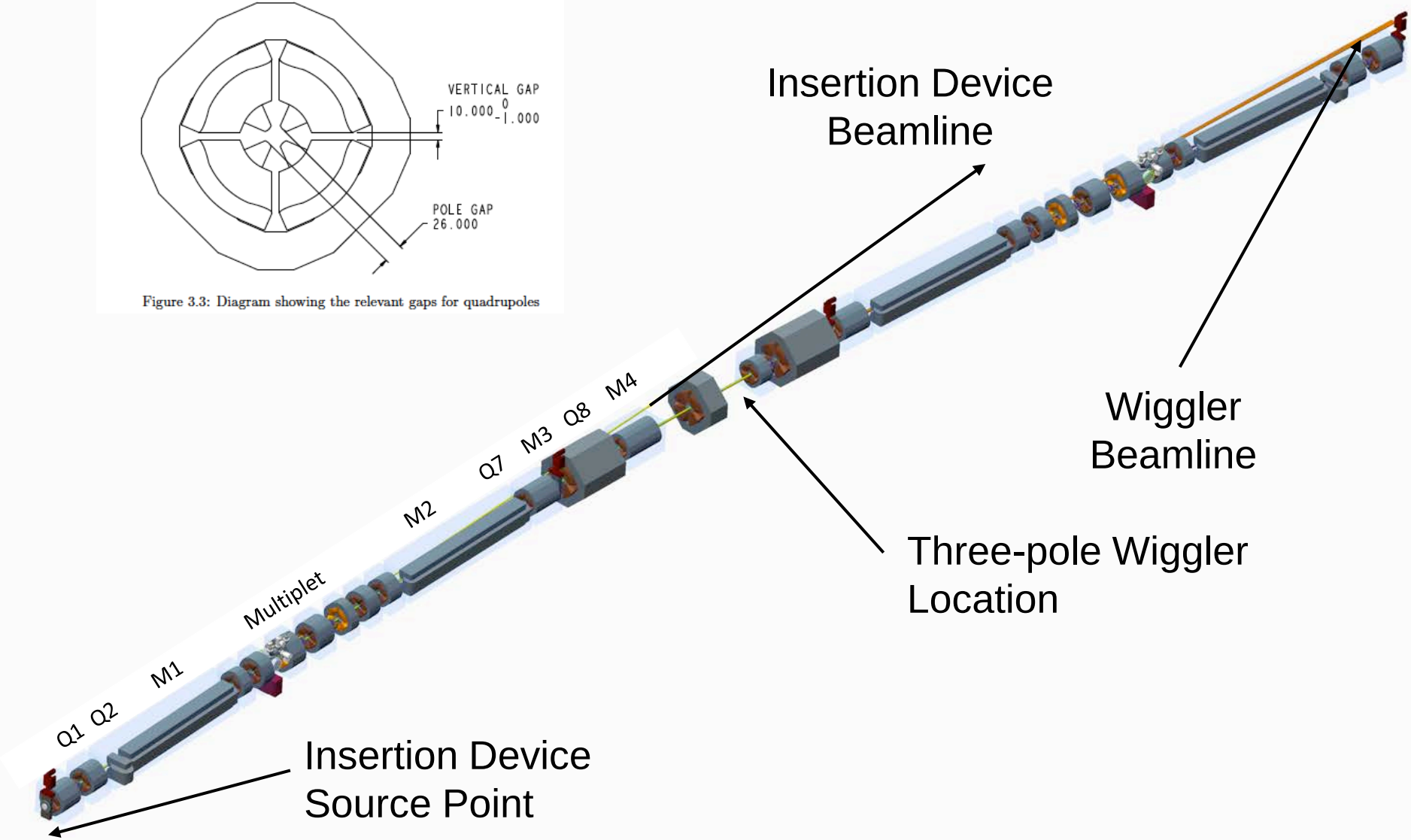



Longitudinal-gradient dipoles Quadrupoles Multi-Magnet Concept (MAX-IV)

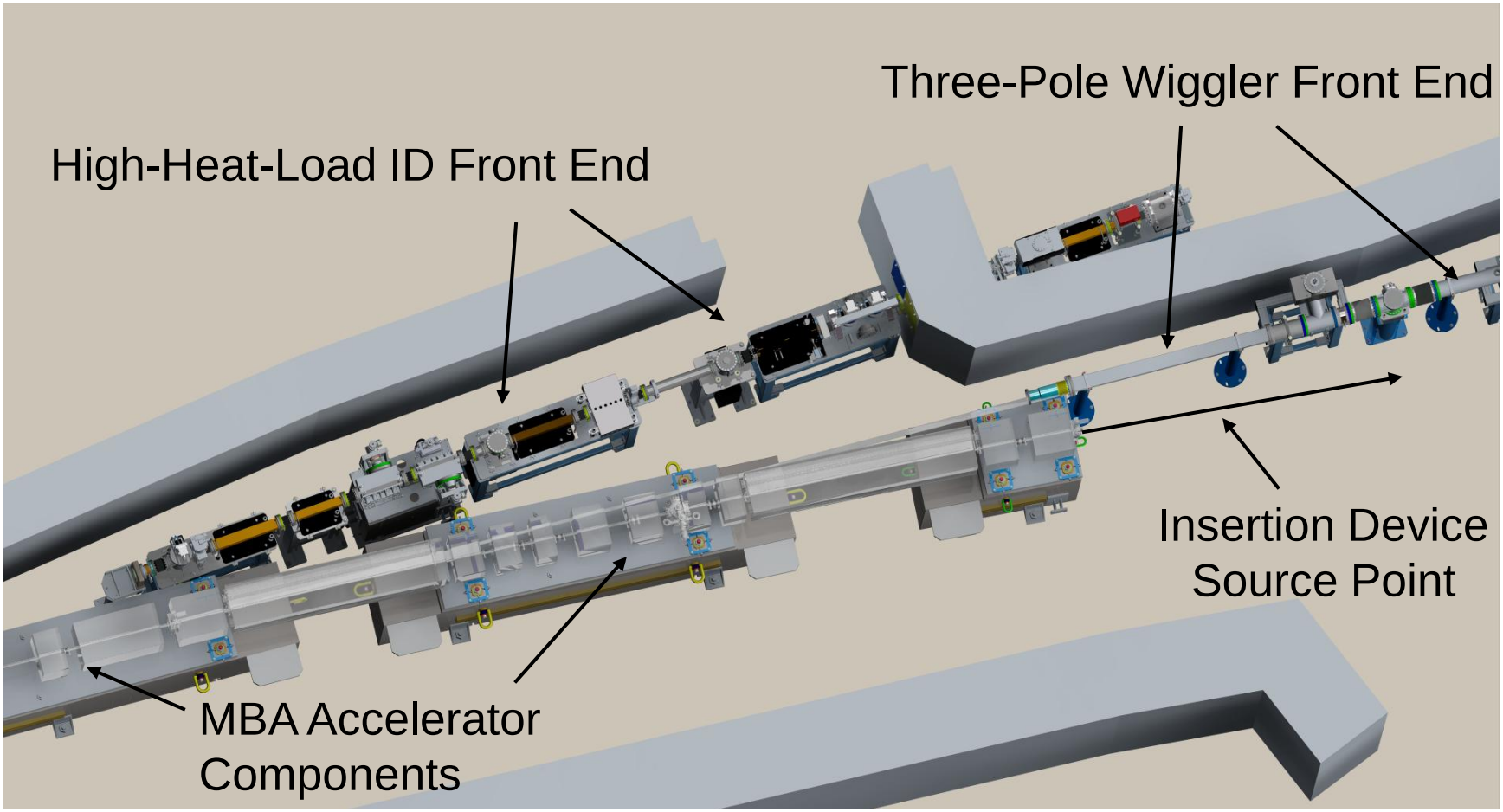
# One APS-MBA Sector with Magnets




Figure 3.3: Diagram showing the relevant gaps for quadrupoles

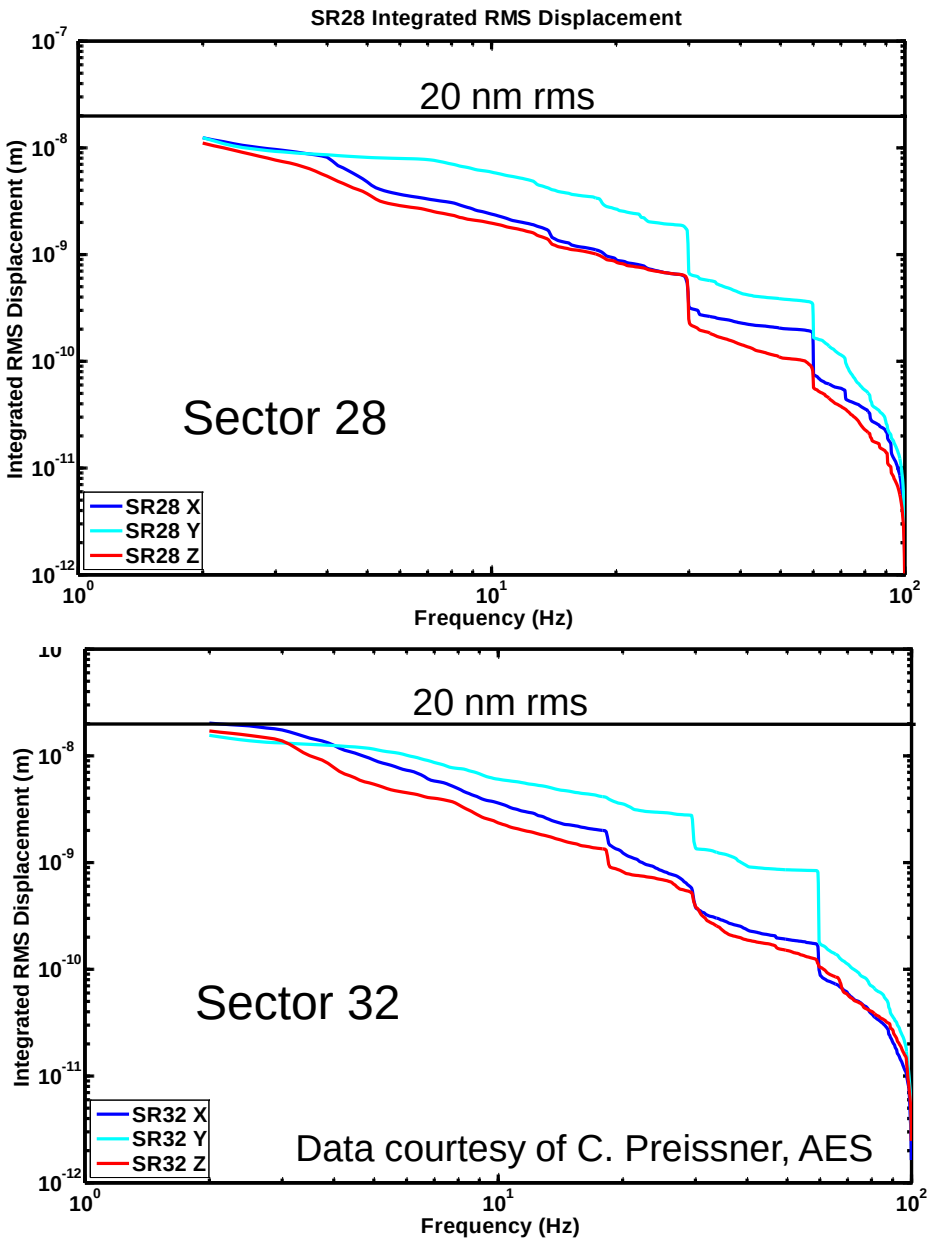


# In-Tunnel Arrangement of Components



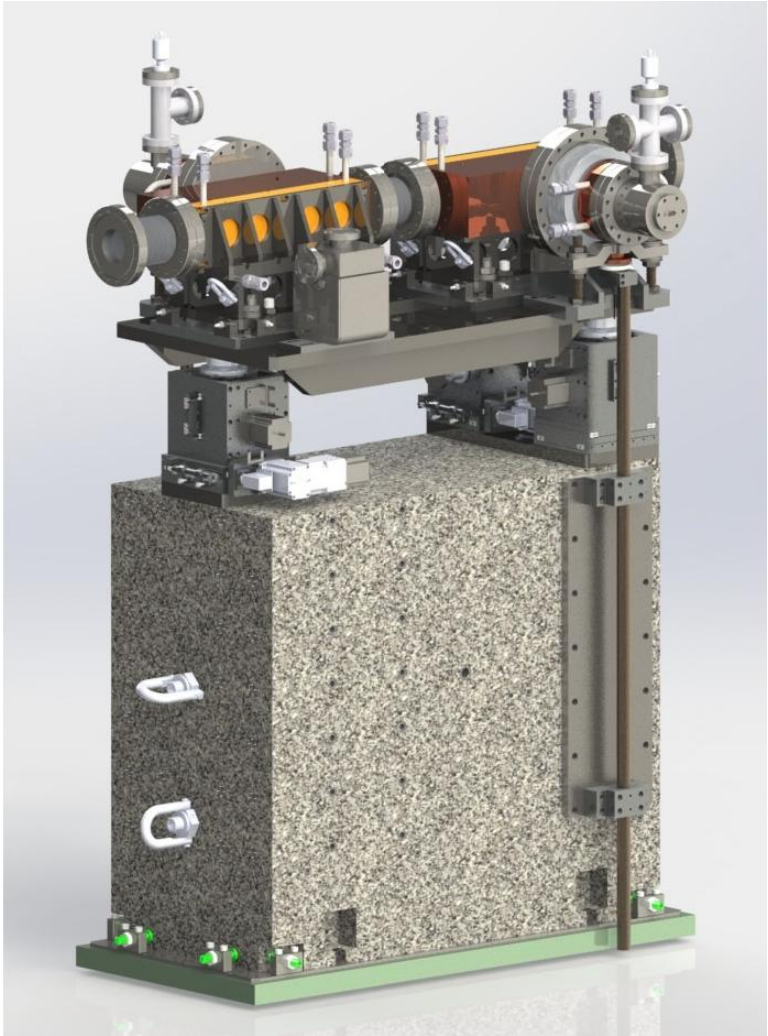
# APS Accelerator Enclosure is Extremely Quiet

- Beam stability requirements are at the level of hundreds of nm.
- Ambient ground motion is below 20 nm rms, (2-100 Hz)
- Accelerator support structure is designed to keep component vibration comparable to ground motion.
- Use of modern orbit feedback and diagnostics will assure world-dominating beam stability.



# Diagnostics, Controls and Power Supply Development

- Advanced x-ray and particle beam position monitoring will provide 200 nm / 100 nrad rms stability and control.
- High-speed steering correction coupled with modern FPGA architecture allows 1 kHz closed-loop orbit correction / control.
- DC power supplies must operate at the level of 10 ppm or better.
- Use of EPICS control system provides efficient monitoring and diagnostic capability.



High-Power Hard X-ray BPM

# R&D Activities

- Development activities are focussing on the following areas:
  - Magnet prototyping of longitudinal-gradient dipole and integrated straight multiplets (quadrupoles + sextupoles).
  - Mechanical alignment and vibration studies of integrated magnet / girder assemblies
  - Advanced power supply regulation and control
    - 10-ppm-class stability initial target
  - Investigation of advanced vacuum methodologies
    - NEG coatings for distributed pumping
    - Low-impedance vacuum joints and bellows
    - Achieving mechanical stability (especially for BPMs) under changing thermal loads
  - Diagnostics and Controls
    - Beam stability
    - Synchronization and timing
    - Data acquisition

# MBA Beam Physics Review: Charge and Committee

- Does the presented design meet the performance goals presented? Are there directions we could push to further enhance these performance parameters? Are trade-offs (energy, emittance, timing patterns, etc) properly identified? Are there alternative designs that should be explored that might be better than the presented design?
- Are there errors or omissions in our simulations that should be addressed? Are there unnecessary or incorrect boundary conditions or assumptions such that we are being driven to a particular, less-than-optimal solution? Are there any reasons why the presented design would not work?
- Do our calculations (lattice, nonlinear dynamics, injection, impedance, collective effects) appear to be valid? Are they integrated sufficiently such that the design as presented is consistent with conceptual design status and forms a solid basis for continued development in the future?
- Beyond the above questions, the committee is encouraged to comment on any other aspects of the design that in your experience are relevant or interesting, or should be further investigated in more detail.

| REVIEW COMMITTEE |
| --- |
| **Weiming Guo – BNL** |
| **Simon Leeman – MAX IV, Sweden** |
| **Ryutaro Nagaoka – SOLEIL, France** |
| **Panteleo Raimondi – ESRF, France** |
| **Christoph Steier – Chair, LBNL** |
| **Richard Walker – Diamond, UK** |

# MBA Beam Physics Review: First Day

Thursday, February 13, 2014

| 8:45 | Welcome (Srajer / Kerby) |
|---|---|
| 9:00 | Introduction / Overview (G. Decker, 45 +15 min), |
| 10:00 | Nominal lattice and performance (M. Borland 45 +15 min) |
| 11:00 | Break (15 min) |
| 11:15 | Alternate lattice and performance (Y. Sun 45+15 min) |
| 12:00 | Lunch (45 min) |
| 13:00 | Tolerances and stability (V. Sajaev 30 + 10 min) |
| 13:40 | Injection (A. Xiao 40 + 10 min) |
| 14:30 | Break (15 min) |
| 14:45 | Single-bunch collective instabilities (Y. Chae 40 + 10 min) |
| 15:35 | Multi-bunch collective instabilities (L. Emery 20 + 10 min) |
| 16:05 | Injector capabilities (C. Yao 20 + 10 min) |
| 16:35 | Discussion / Executive session |

# MBA Beam Physics Review: Second Day

Friday, February 14, 2014

| | |
|---|---|
| 8:45-12:00 | Executive Session / Discussion |
| 12:00 | Lunch |
| 13:00 | Closeout |

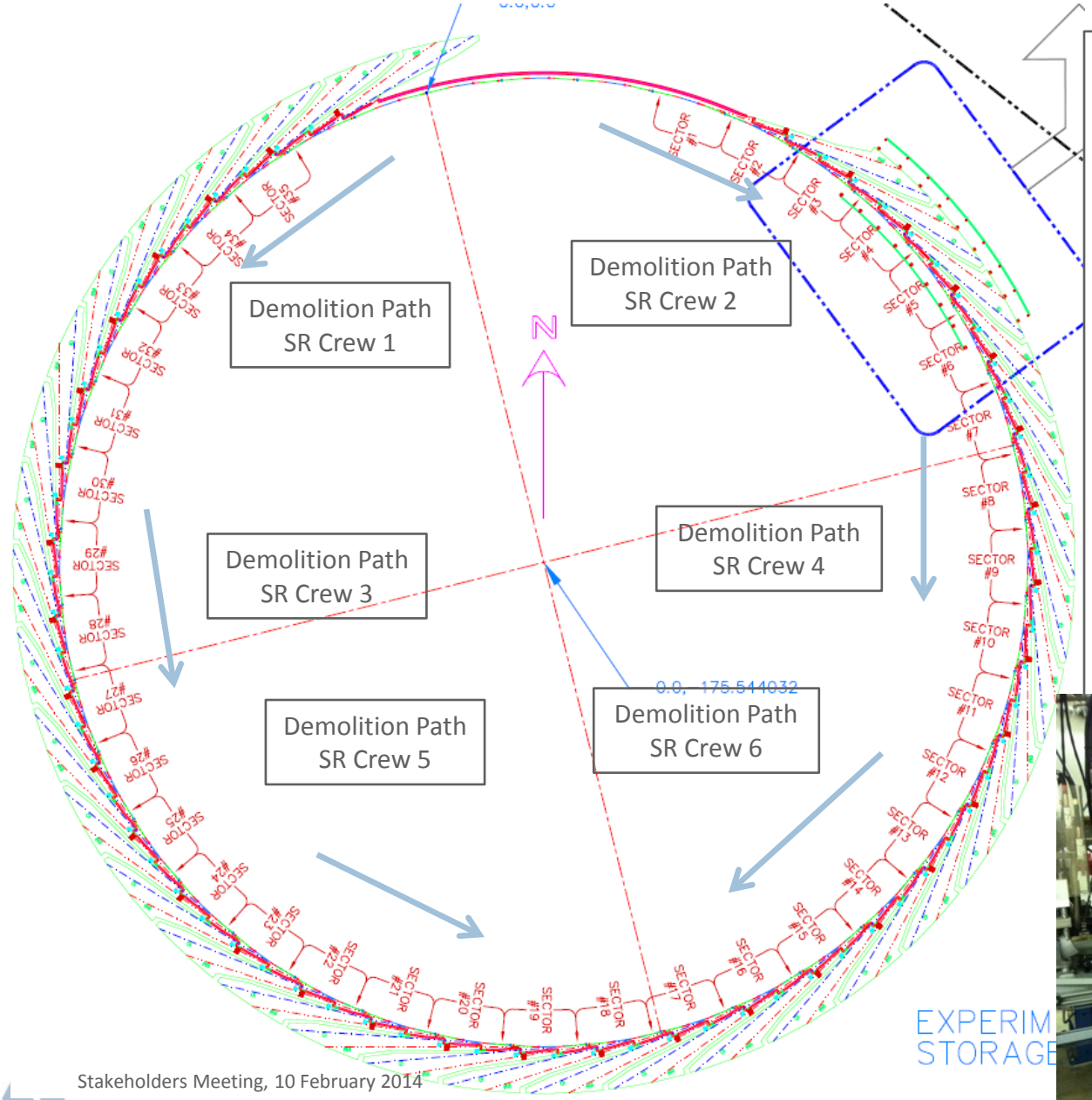
# Design Reviews

- CD-1 Review Plan is being developed:

| APS-U Design Review Plan - Accelerator Systems | | | | | | | |
|---|---|---|---|---|---|---|---|
| WBS | Subsystem | Review Type | Review Title | Target Date | Actual Date | Responsible Person | Comments |
| | | Pre-CDR R&D | Longitudinal Gradient Dipole Review | November 26, 2013 | November 26, 2013 | | |
| | | CDR | MBA Beam Physics Review | February 13-14 2014 | February 13-14 2014 | M. Borland | |
| | | CDR | Magnet and Mechanical Support Review | March 13-14, 2014 | | M. Jaski | |
| | | CDR | Kickers/Injection & Extraction | March 19, 2014 | | F. Lenkszus | |
| | | CDR | Power Supplies | March 20, 2014 | | J. Wang | |
| | | CDR | Diagnostics/Controls | March 21, 2014 | | B. Lill/R. Farnsworth | |
| | | CDR | Vacuum System Review | March 26, 2014 | | H. Cease | |
| | | Conc Plan Rev | Decommissioning/Installation | March 28, 2014 | | C. Prokuski/T. Fornek | |
| | | CDR | Injector System | TBD | | | |
| | | CDR | Infrastructure Review | TBD | | | |
| | | | | | | | |

- Conceptual Design Report completion: May 2014
- Director's CD-1 review: June/July 2014 (TBD)
- DOE CD-1 Review ready: August 2014 (TBD)

# Initial Planning on Replacement of Storage Ring Components




Techs disconnect & store vacuum components, RF, utilities, etc. during day shift.

Contract demolition crew removes and stores girders and supports, cuts and caps cables during second shift and removes and stores supports, removes grout, strips walls & floor, modifies HVAC, water systems

Typical girder

# APS-U Staging and Processing Facilities Needed

Working with Argonne in planning; NOT part of the APS-U

- Preparation facilities
  - Magnet/girder receiving, staging, inspection and alignment – 17,000 sq. ft
  - Vacuum cleaning and processing area – Facilities exist at Bldg 382
  - Completed girder staging – 24,000 sq. ft temperature controlled

- Facilities needed during shutdown
  - Insertion Device Reprocessing and staging – 10,000 sq ft temperature controlled (some IDs re-used, magnets replaced on some IDs)

- Facilities needed long-term after shutdown for disassembly, processing for re-cycle and staging for shipment to disposal or re-cycle sites
  - 5000 sq ft covered
  - 5000 sq ft storage yard

# Options for Staging and Processing Facilities

Working with Argonne in planning; NOT part of the APS-U

| | Magnet/Girder Receiving, Assembly, Test and Staging (41,000 sq ft) | Insertion Device Temporary Storage & Modification (10,000 sq ft) | Recycle, Temporary Storage & Disassembly Area (10,000 sq ft) |
|---|---|---|---|
| 1 | New Bldg (41000 sq ft) | Use 400A/314 for staging and temporary storage | Consider Bldg 367 7000 sq ft internal, 7000 sq ft external |
| 2 | Offsite Rental (41000 sq ft) | Use 400A/314 for staging and temporary storage | Bldg 367 as above |
| 3 | Displace other operating ANL divisions from existing high bays | Use 400A/314 for staging and temporary storage | Bldg 367 as above |
| 4 | Supplement 400A/314 with new 25000 sq ft bldg | Build long beamline end station bldg and use for ID rework (5000 sq ft) | Bldg 367 as above |
| 5 | Explore FermiLab space | Use 400A/314 for staging and temporary storage | Bldg 367 as above |

# Option for Disposal/Re-cycle Processing Facilities

The 367 area includes a high bay with crane and several other attached buildings for a total of ~ 7000 sq. ft. Another ~ 7000 sq. ft. in the fenced in yard. This area is currently occupied by WMO. They anticipate no longer needing the buildings after FY 2015

# APS Upgrade Summary

- Excellent progress continues to be made incorporating the MBA
  - Lattice design:
    - Lattice evolution continues with iteration between physics and engineering
    - Continue to predict brightness more than two orders of magnitude above present values
  - Hardware/technology: Magnets, Vacuum, Electrical systems, etc.
- Technical reviews planning in progress
  - Beam Physics review scheduled for February 13-14, 2014
- Project goal: ready for DOE CD-1 review in August 2014