APS Upgrade Beam Stability Enhancements

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Outline

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- Requirements
- APS-U beam stability scope
  - BPM Electronics
  - Front end x-ray alignment system
  - Realtime feedback system
  - Mechanical motion sensing system
- Summary

Beam Stability Technical Motivation

- APS orbit correction system has a lot of out-of-date hardware.
  - Many new technologies such as field-programmable gate arrays (FPGAs) increase processing speeds by orders of magnitude.
- Modernization of beam position monitoring and feedback systems will benefit the entire APS user community.
- With over 15 years of operational experience, the upgrade will be tailored to the noise spectrum and lattice specific to APS.
  - Nearly all “diseases” impacting our present systems are pretty well understood.

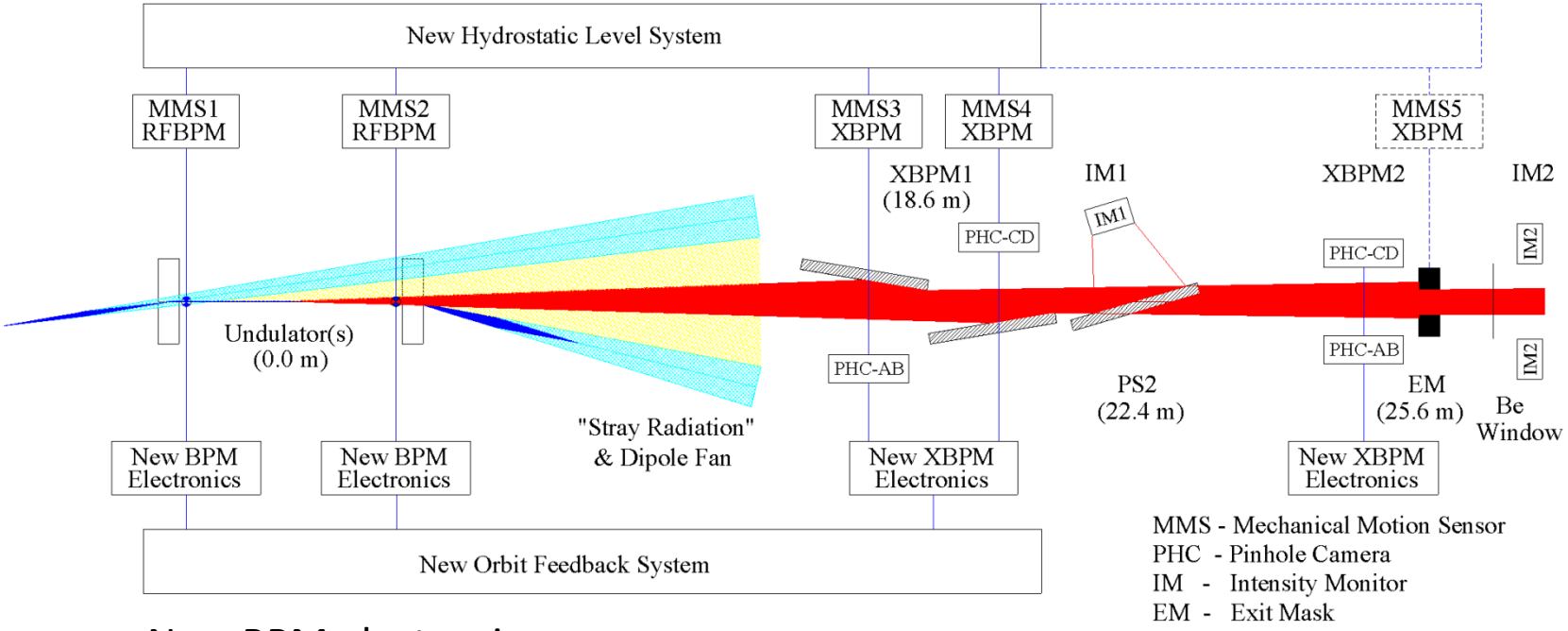
Beam Stability Requirements

		AC rms motion 0.01-200 Hz		AC rms motion 0.01-1000 Hz		Long-term drift (One Week)	
		μm rms	μrad rms	μm rms	μrad rms	μm rms	μrad rms
Horizontal	Present	5.0	0.85	5.0 - 7.0*	NA	7.0	1.4
	Upgrade	3.0	0.53	6.0	1.14	5.0	1.0
Vertical	Present	1.6	0.80	3.7*	NA	5.0	2.5
	Upgrade	0.42	0.22	0.84	0.44	1.0	0.5

* Measurement up to 767 Hz.

- Based on 5% of transverse beam dimensions up to 200 Hz and 10% up to 1 kHz.

Integrated Systems for Beam Stabilization

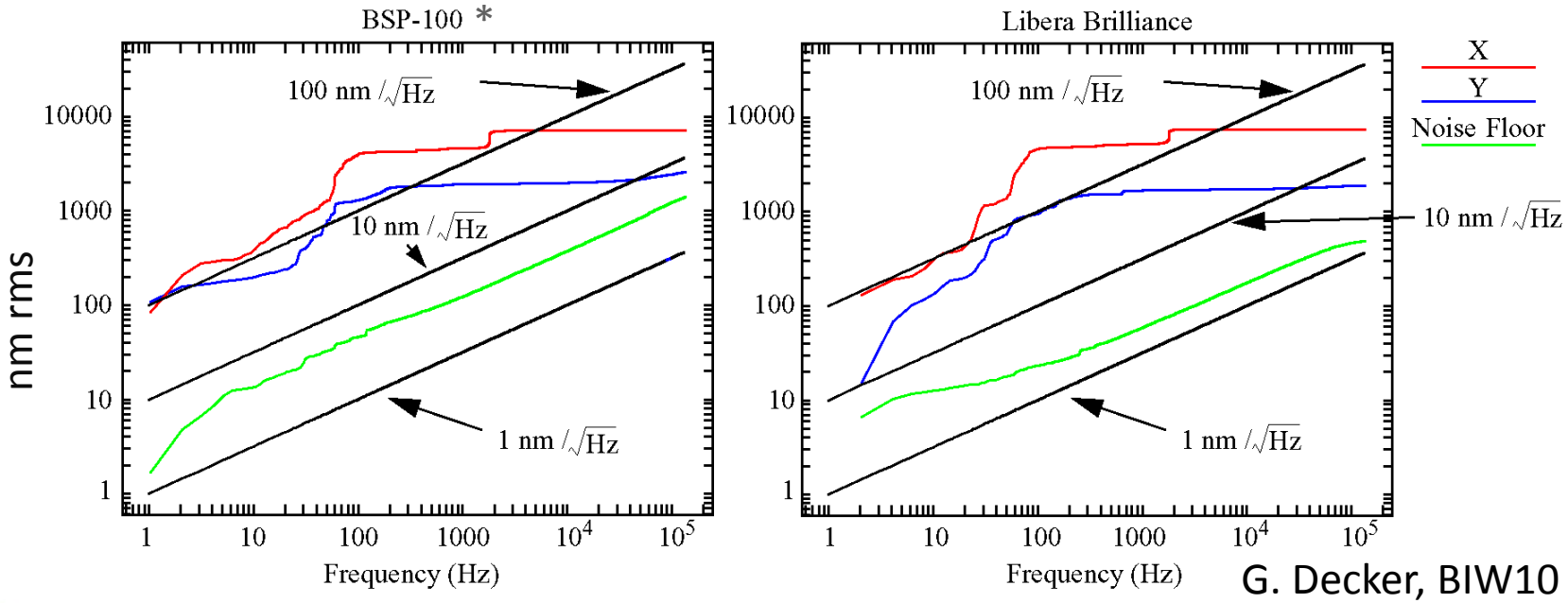


- New BPM electronics
- New front-end diagnostics
  - High-power hard x-ray BPMs
  - Intensity monitors
- New high-speed orbit feedback system
- Mechanical motion sensors
  - Capacitive proximity sensors
  - Hydrostatic level system

Beam Stability Scope

Item	Scope	Expected Improvement
New BPM electronics and data acquisition	80 high-resolution rf BPMs, 80 Bergoz rf BPMs, 70 ID photon BPMs, 70 BM photon BPMs	Factor of 2, AC noise floor.
New hard x-ray BPM systems	14 systems installed in new front ends	Factor of 2, long-term pointing stability
Real-time feedback system	Complete replacement with modern components	Extend closed-loop bandwidth from 60 to 200 Hz; reduce AC beam motion by a factor of 4.
BPM mechanical motion sensing	Install for 14 GRID XBPMs and 68 rf BPMs	Factor of 2, long-term drift

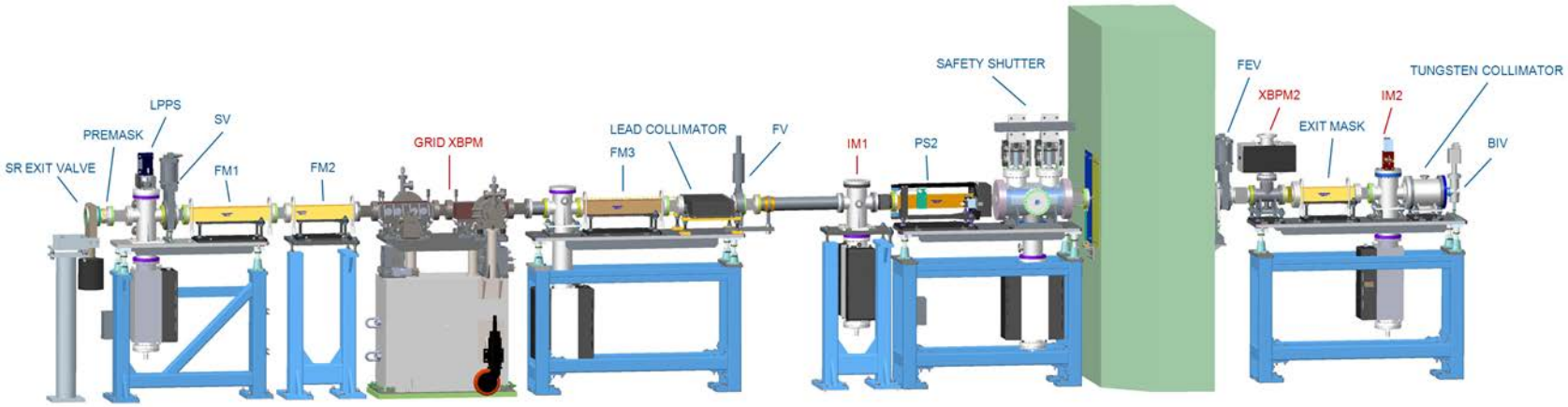
BPM Electronics



G. Decker, BIW10

* Courtesy of H. Bui, S. Farrell, R. Laird, E. Norum

Next-Generation X-ray Alignment System

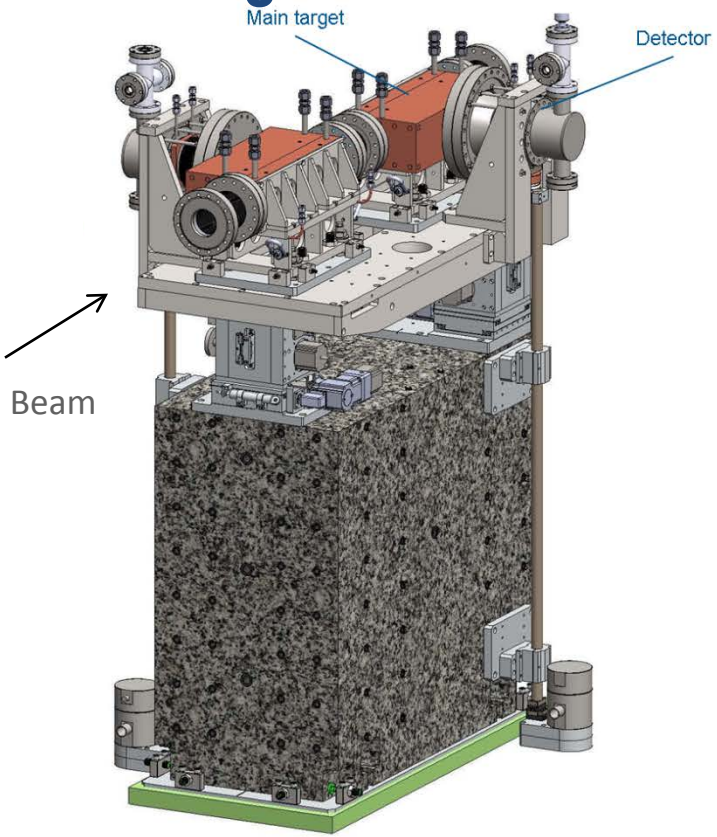


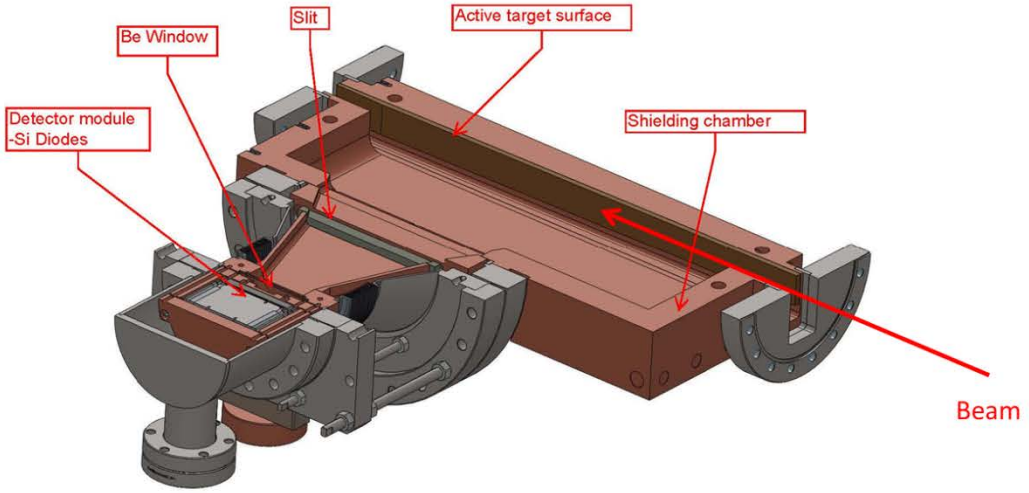
New HHL FE layout

Courtesy of Y. Jaski

- X-ray diagnostics integrated into new high heat load and canted front ends.
- Two x-ray BPMs:
  - High-power GRID xbpm upstream
  - Second xbpm uses back-fluorescence, scattering from exit mask in FOE
- Two intensity monitors
  - IM1 uses back-fluorescence from PS2 shutter, monitors flux through FM3
  - IM2 monitors flux surviving exit mask (both windowed and windowless supported)

Grazing-Incidence Insertion Device X-ray BPM (GRID)



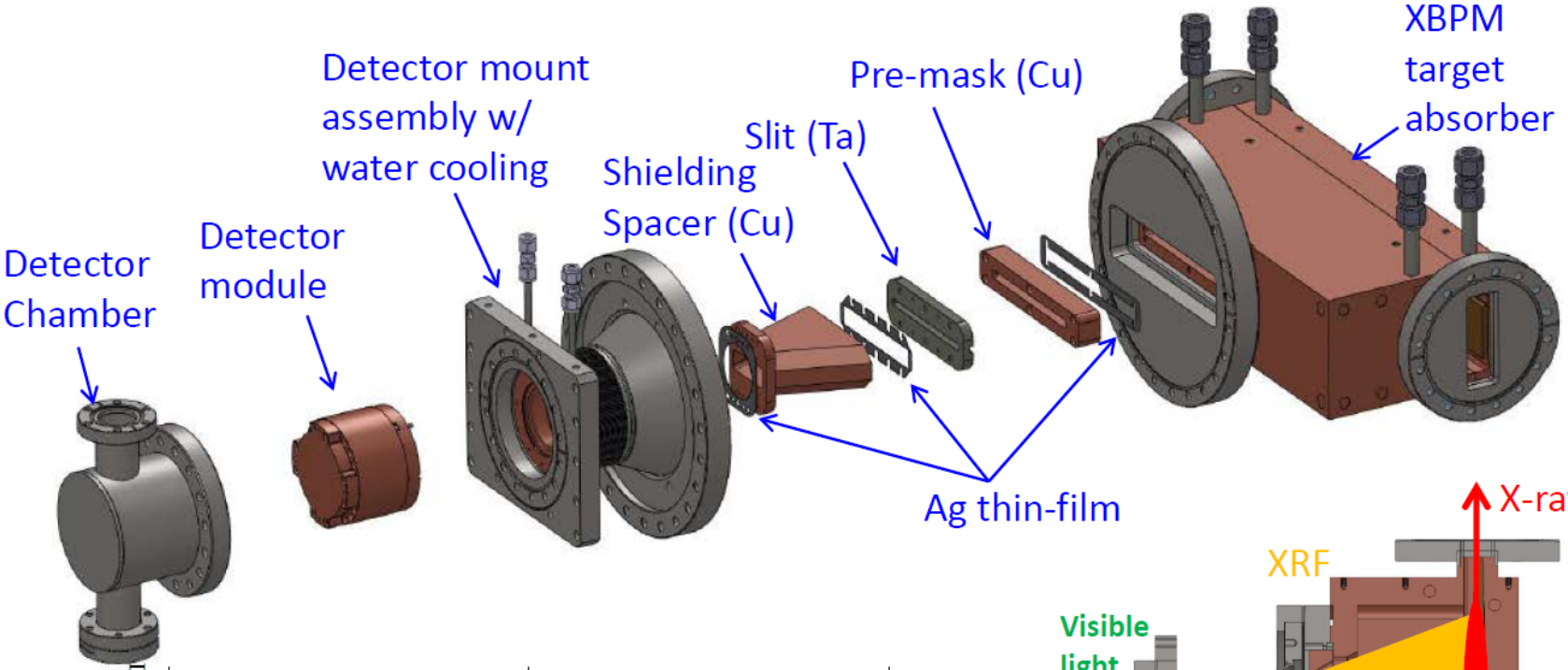


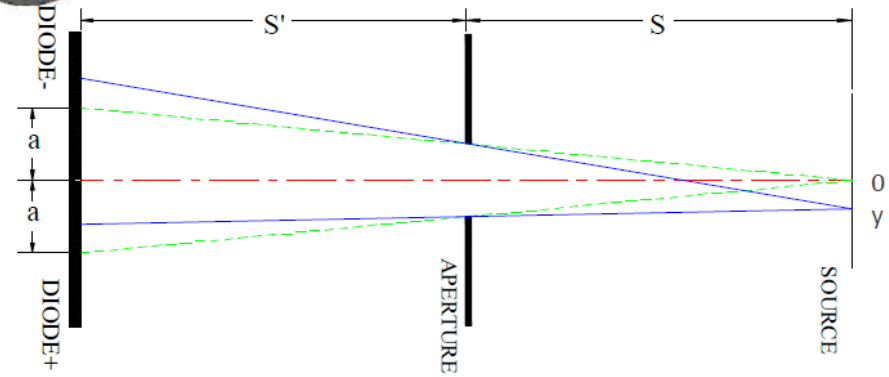
Cut out view of lower half of the target detector assembly

Courtesy of Soon-Hong Lee

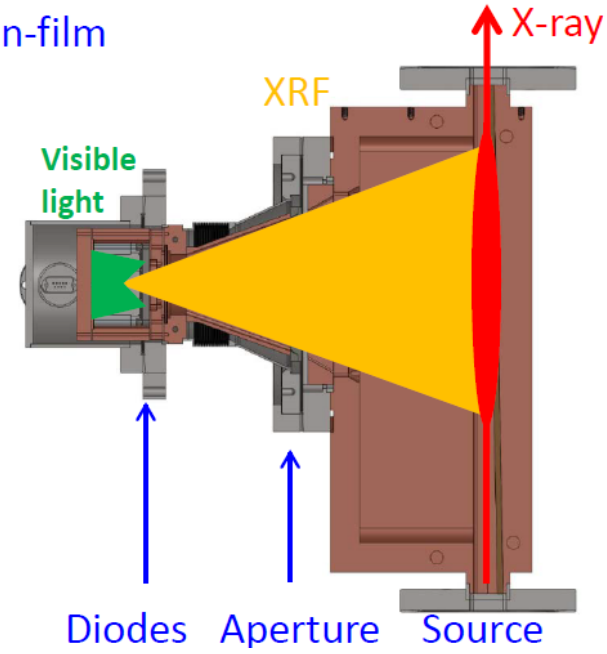
- Grazing incidence allows access to extremely high beam power (two U3.3 undulators with nominal 150 mA, safe to 180 mA).
- X-ray fluorescence reduces stray radiation background signals significantly.
- Use of two two-pixel (above, below midplane) pinhole cameras allows two independent measures of vertical x-ray beam position.
- Inboard / outboard difference provides measure of horizontal beam position.

GRID XBPM Detector Principle of Operation





Principle of Pinhole camera



Courtesy of Soon-Hong Lee, Bingxin Yang, Peter Eng

Real-time Feedback System Upgrade

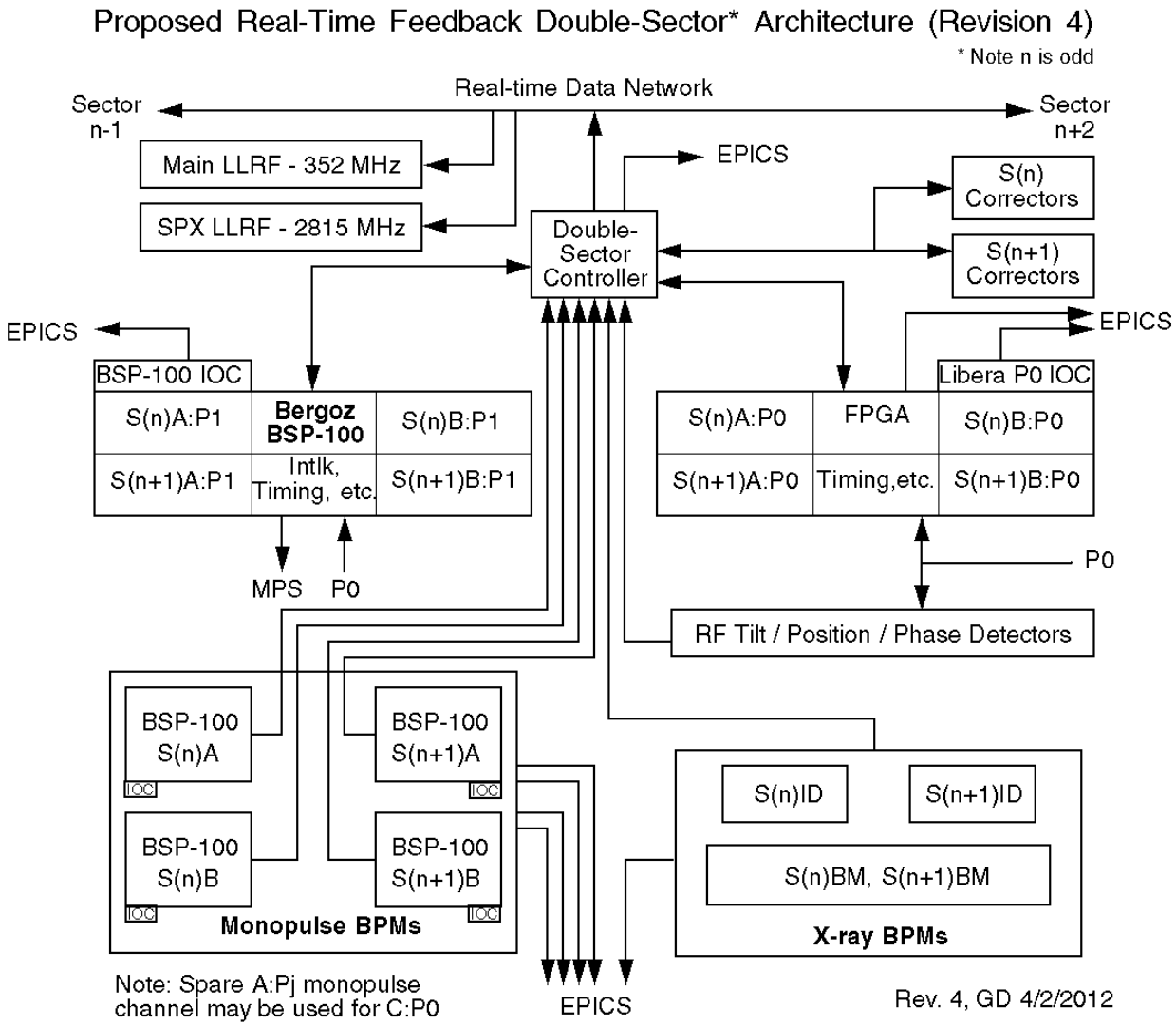
Existing System

- Maximum 160 BPMs, 38 fast correctors
- Sample rate 1.537 kHz
- Based on 15-year-old digital signal processors, reflective memory
- 3 dB BW = 60 Hz (H), 100 Hz (V)

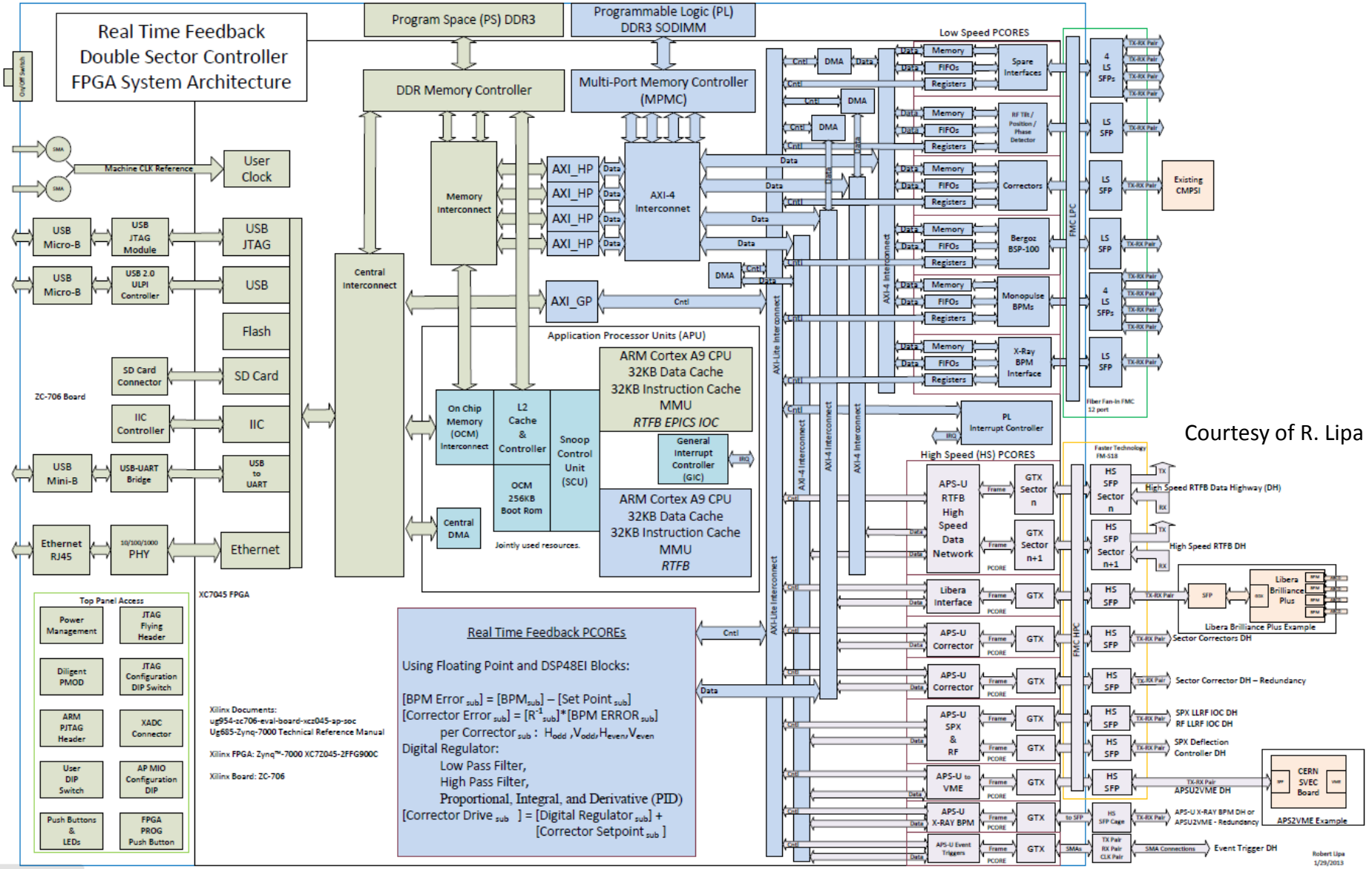
Upgraded System

- Maximum approx. 500 BPMs, 70 fast correctors, 250 slow correctors
- Sample rate Frev / 12 = 22.6 kHz
- Based on extremely high-speed FPGA data protocols
- Access to phase detectors, beam tilt monitors supporting SPX
- Interfaced to main and SPX low-level rf (LLRF) systems
- 3 dB BW > 200 Hz (correctors only), 1 kHz (w/ llrf feedback)
- Full-time FPGA expert (R. Lipa) hired into Diagnostics Group April 2012

Real-time Feedback System Upgrade cont'd

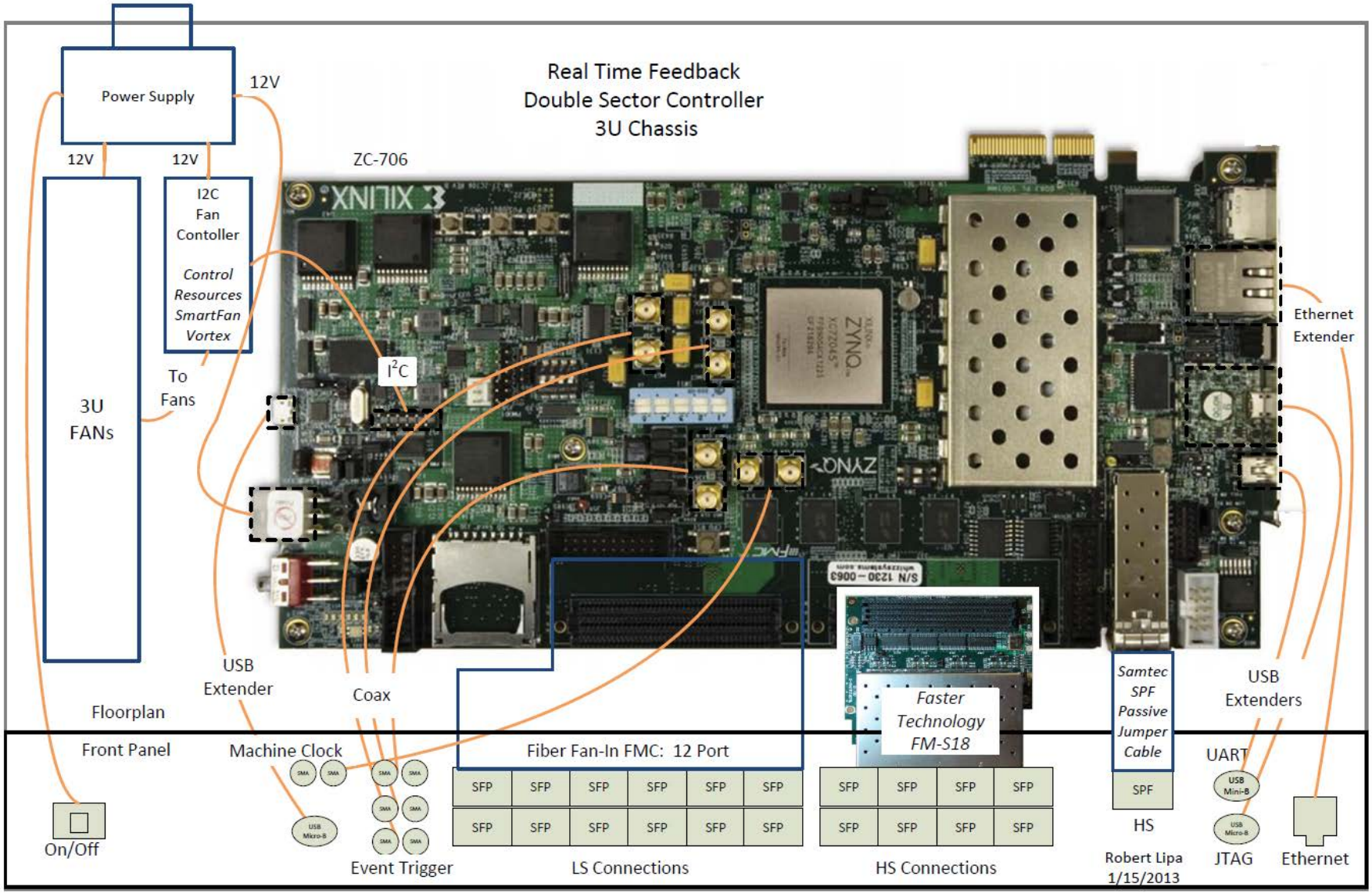


RTFB DSC FPGA System Architecture



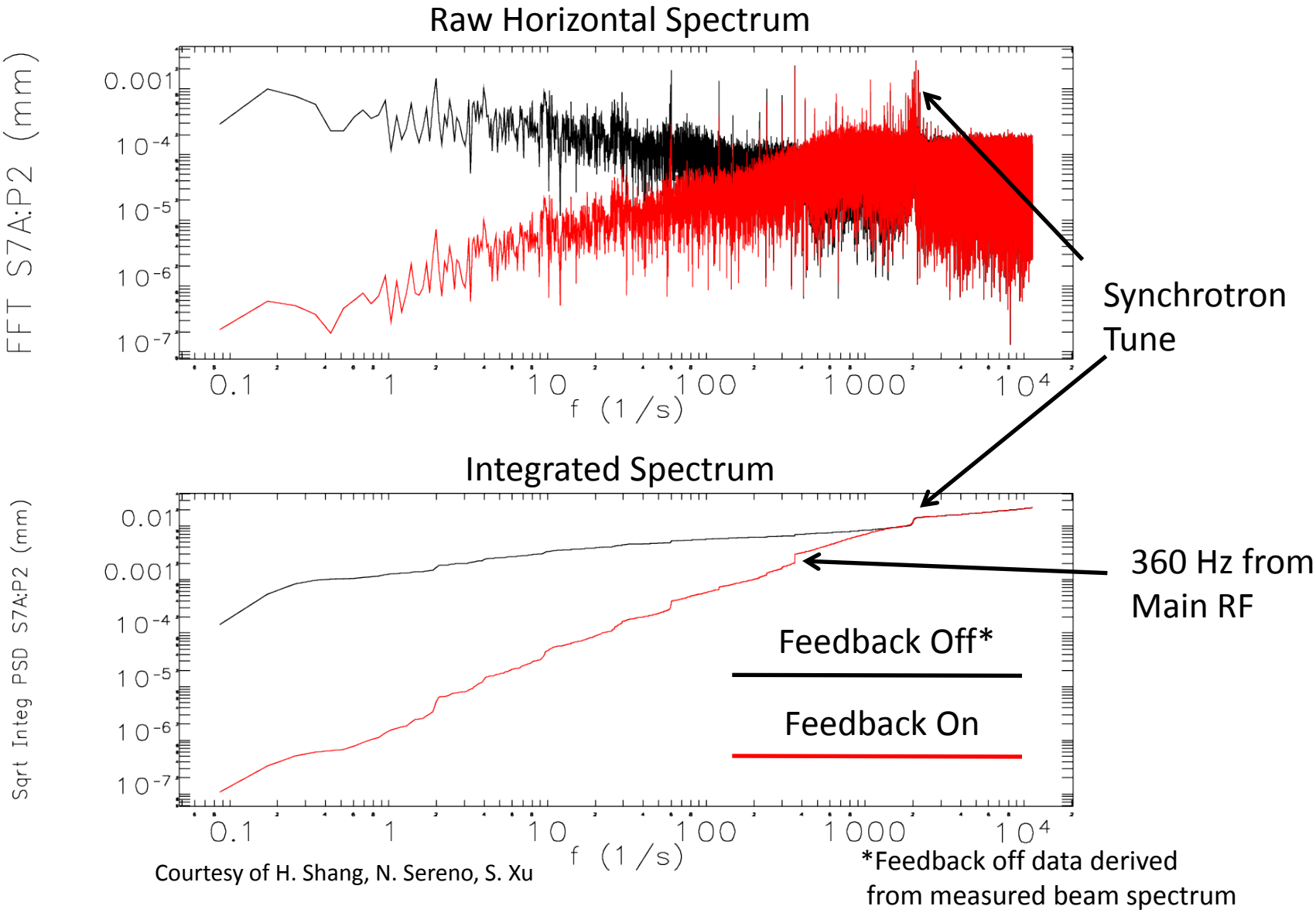
Courtesy of R. Lipa

RTFB DSC 3U Chassis



Courtesy of R. Lipa

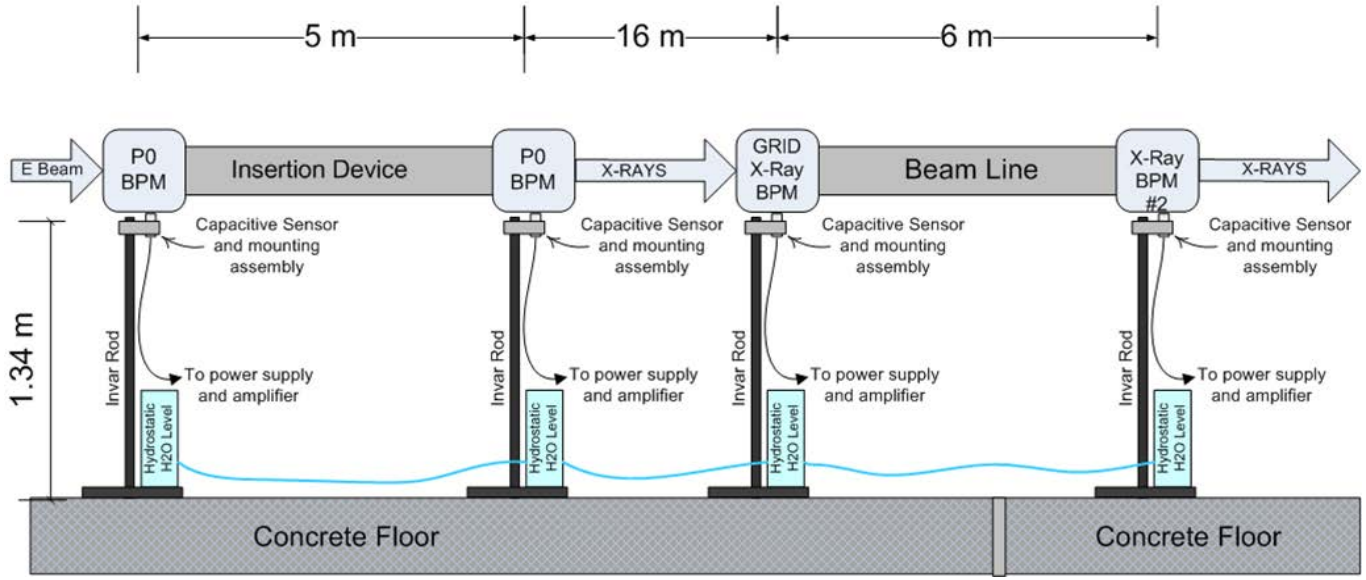
First Fast Feedback Simulation Results

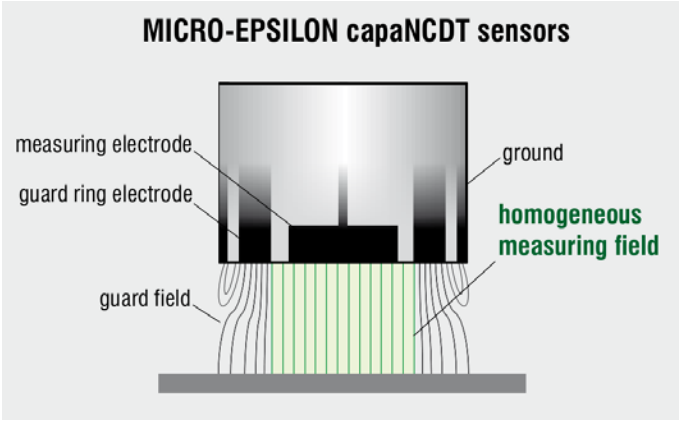


Courtesy of H. Shang, N. Sereno, S. Xu

*Feedback off data derived from measured beam spectrum

BPM Mechanical Motion Sensing

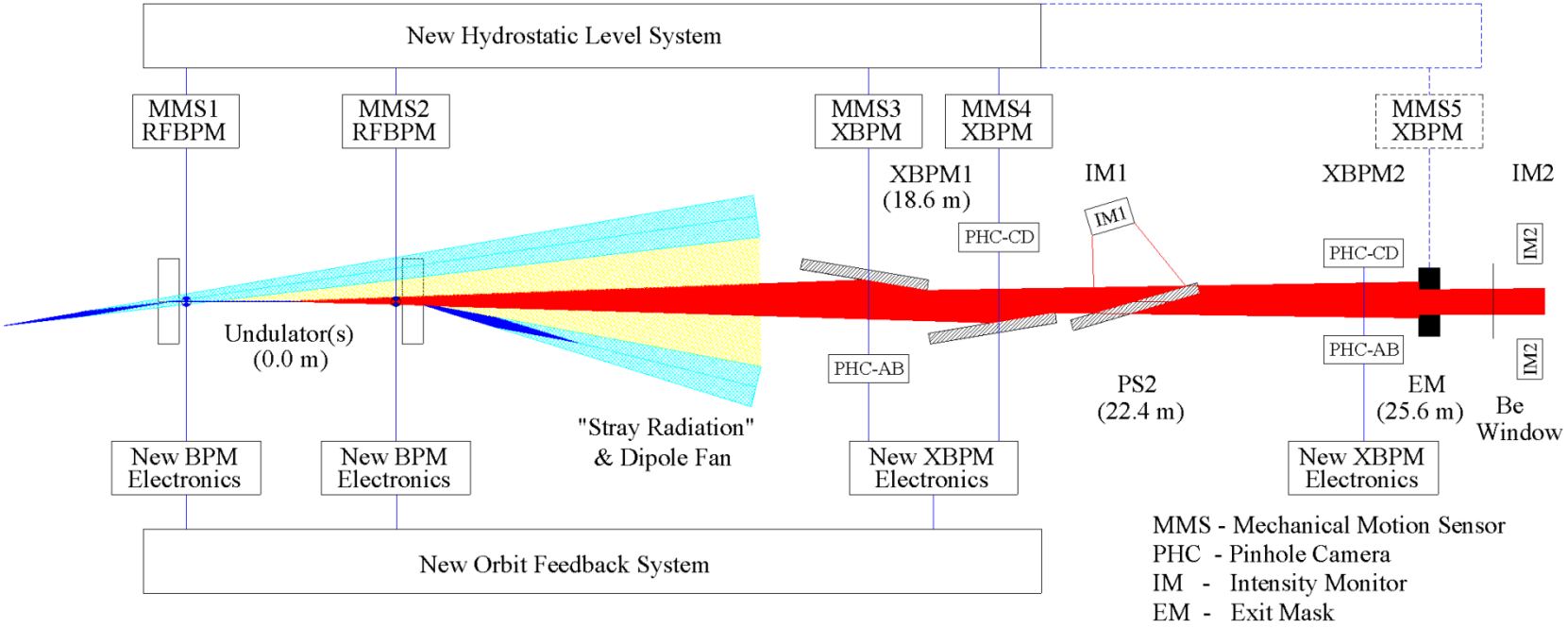




- Commercially-available capacitive motion sensors have sub-nm resolution.
- Local hydrostatic level network provides vertical datum.

Courtesy of B. Lill

Hardware Demonstration at 27-ID RIXS



- First production articles and many prototypes of these systems will be available for testing by May 2014, coinciding with front end installation.
- A full dress rehearsal is being planned for most systems for Summer, 2014.
- Results will be used to refine final system design.
- Rinse, repeat until completion FY17 / FY18.

APS-U Beam Stability Summary

- Beam Stability upgrade preliminary design is complete; final design is underway.
- Global improvements are planned for all beamlines:
  - BPM electronics
  - Mechanical motion sensors
  - Fast orbit feedback upgrade
- New beamlines will have additional performance enhancements:
  - X-ray fluoresence-based high-power xbpms
  - Intensity monitors to track flux through mask apertures
- First integrated system tests planned for summer 2014