Editor's Note: PDF version of slides from Beam Instrumentation Workshop 2010, Santa Fe, NM

Argonne NATIONAL LABORATORY

APS Beam Stability Studies at the 100-Nanoradian Level

Glenn Decker

Advanced Photon Source

Diagnostics

May 4, 2010

U.S. DEPARTMENT OF ENERGY

Overview

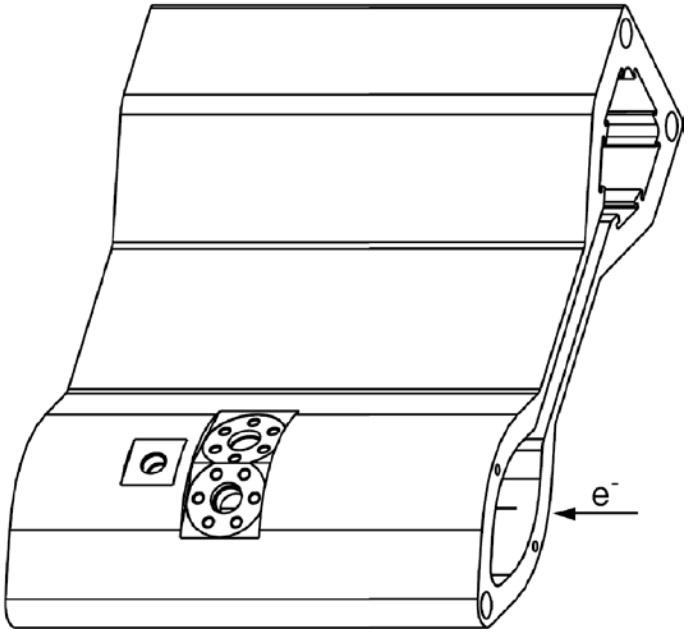
- Beam stability goals
- Hardware systems description
  - Narrowband RF beam position monitors (BPMs)
  - Broadband RF BPM data acquisition system upgrade
  - Libera boxes
  - Photoemission BPMS
  - Hard x-ray fluorescence BPMs
- Experimental arrangement
- DC Results
- AC Results

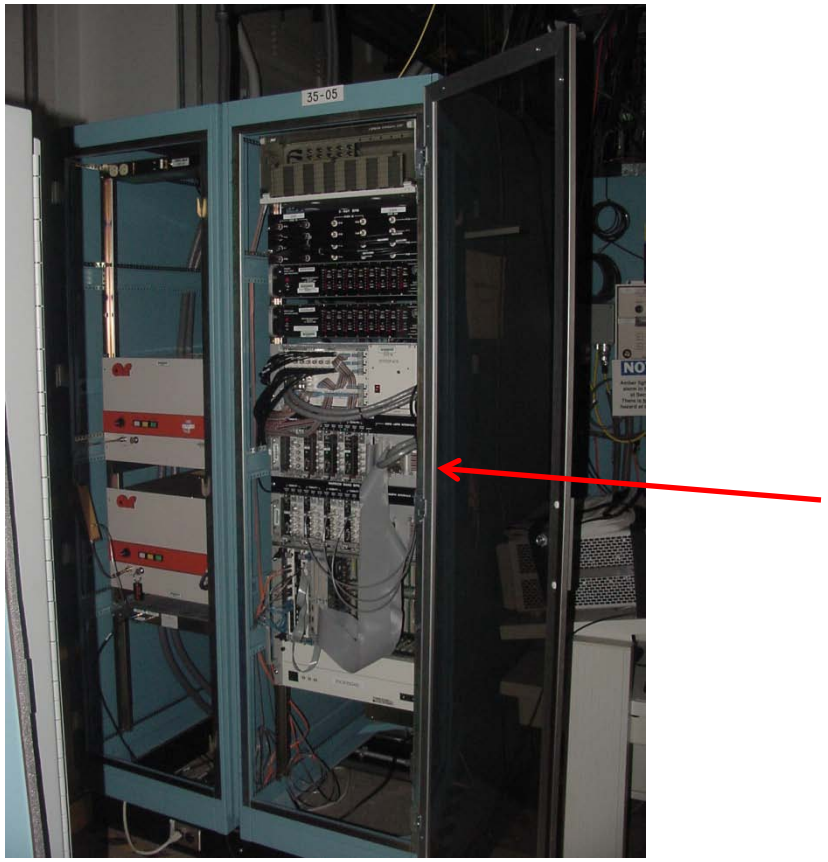
Beam Stability Performance Goals

- Typical goals for the APS Upgrade are

		AC Motion* (0.1-200 Hz)		Long term (1 week, pk-pk)	
Horizontal	Now	5.0 μm	0.85 μrad	7.0 μm	1.4 μrad
	Upgrade	3.0 μm	0.53 μrad	5.0 μm	1.0 μrad
Vertical	Now	1.6 μm	0.80 μrad	5.0 μm	2.5 μrad
	Upgrade	0.42 μm	0.22 μrad	1.0 μm	0.5 μrad

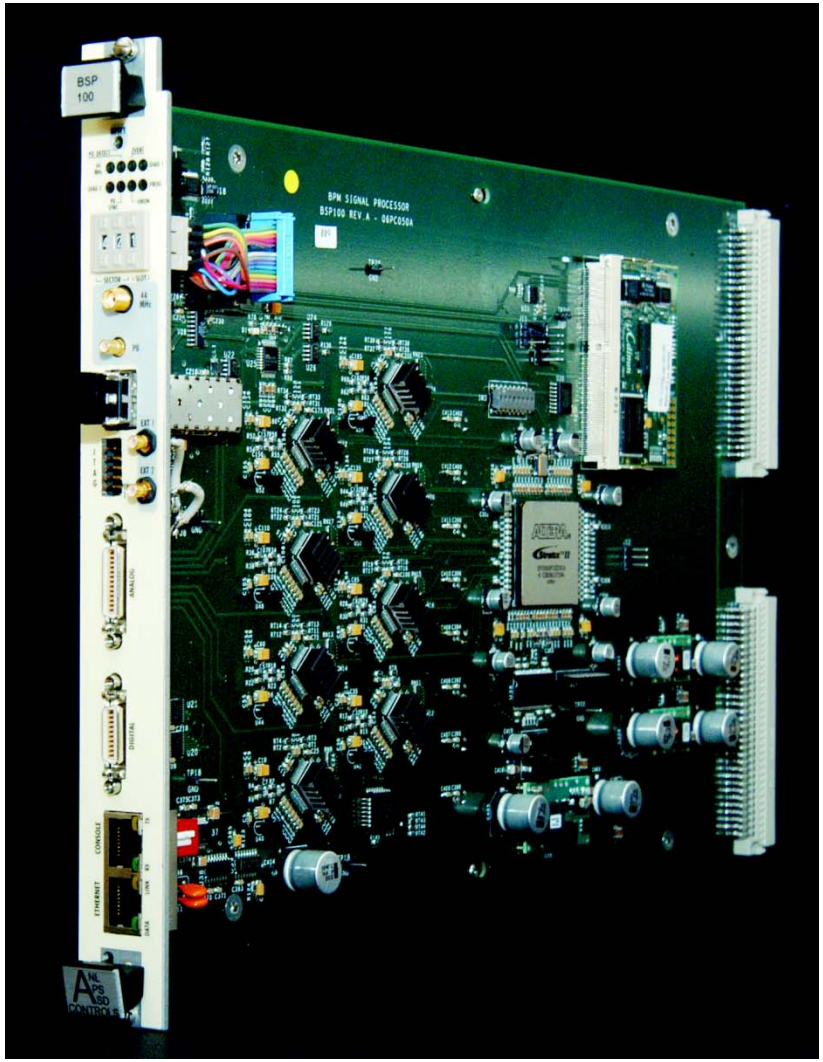
Commercial Bergoz Switched Receiver BPM





1 cm diameter capacitive buttons

APS Broadband RF BPM data acquisition upgrade



- Eight channels/board, 88 MS/sec sampling. Altera FPGA processing.
- One second (262144 samples) turn-by-turn beam history for machine studies / fault diagnosis.
- Demonstrated noise floor

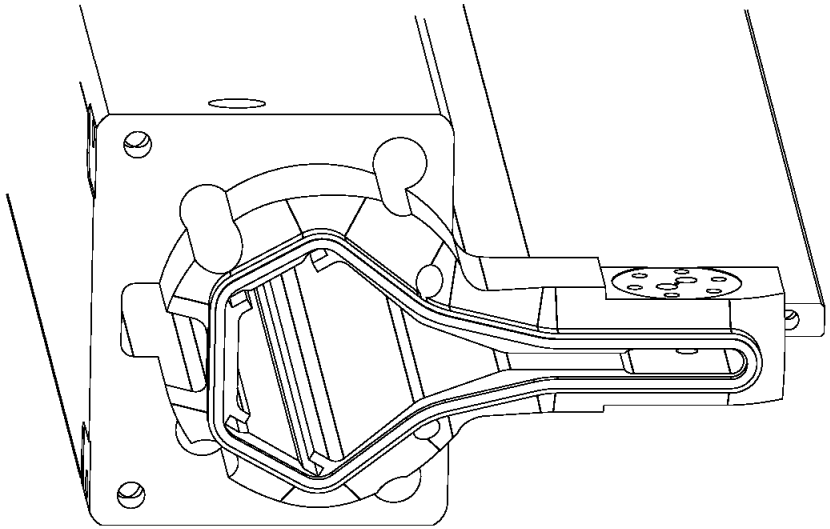
  < 5 nm / √Hz
- Five sectors instrumented, parts for 3 more sectors in hand, more on the way.

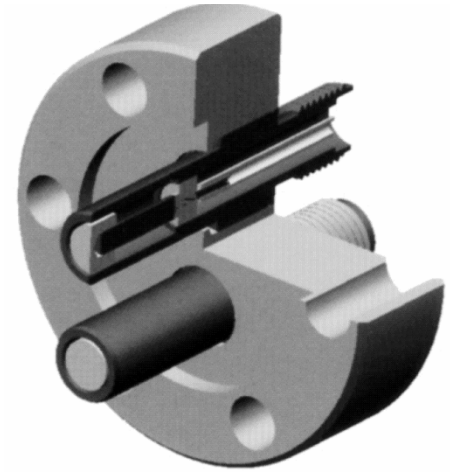
State-of-the-art Commercial Solution

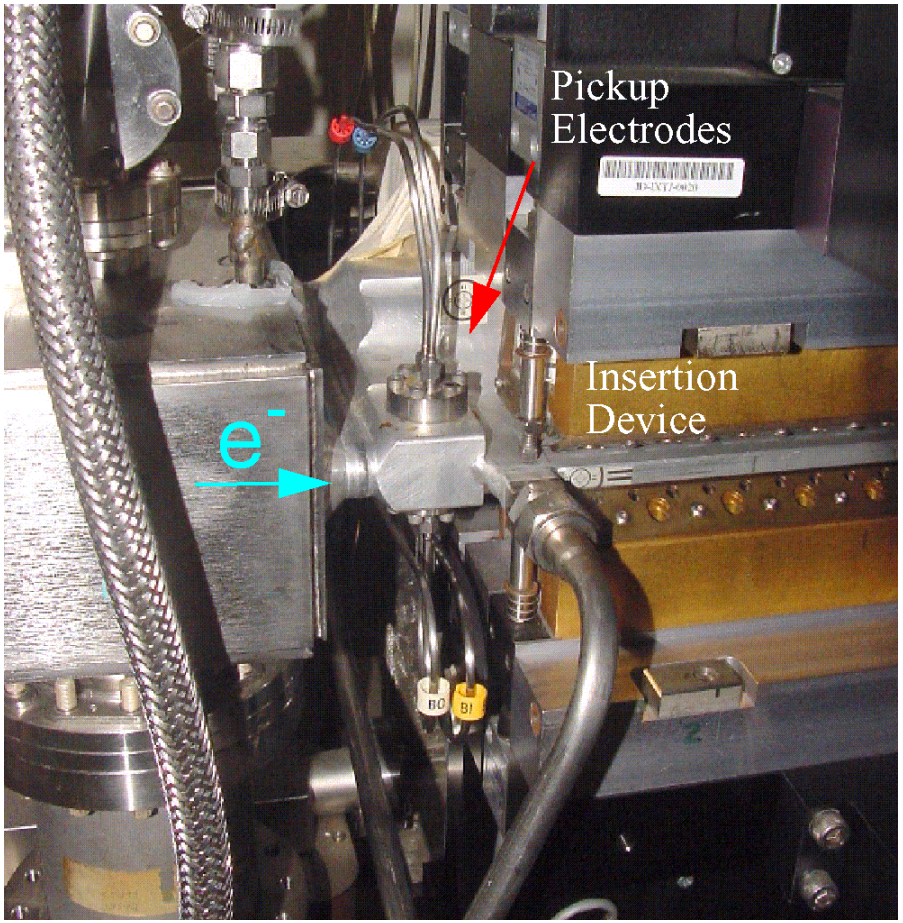
- Noise floor approaching 2 nm / √Hz.
- Long term drift 200 nm p-p / 24 hours*.
- APS has three

* Guenther Rehm, Diamond Light Source, EPAC 2008

BPM Pickup Electrodes for Libera and BSP-100



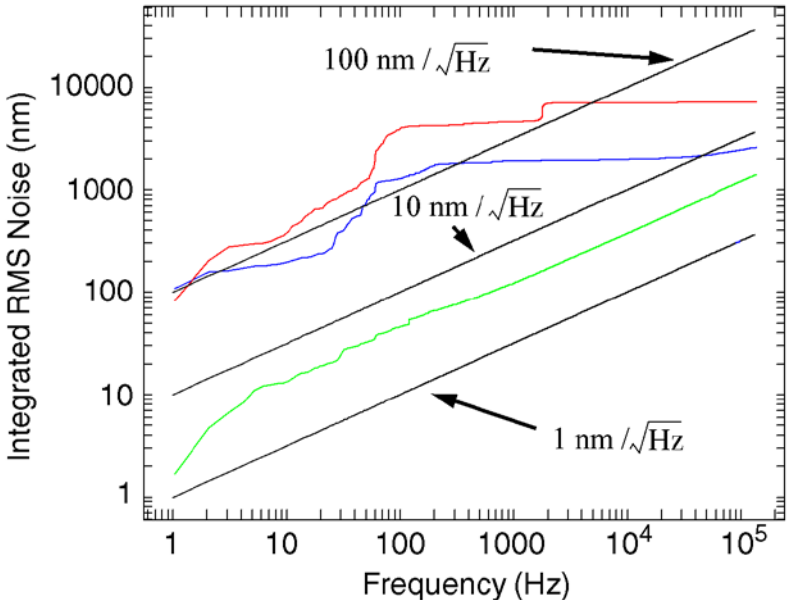




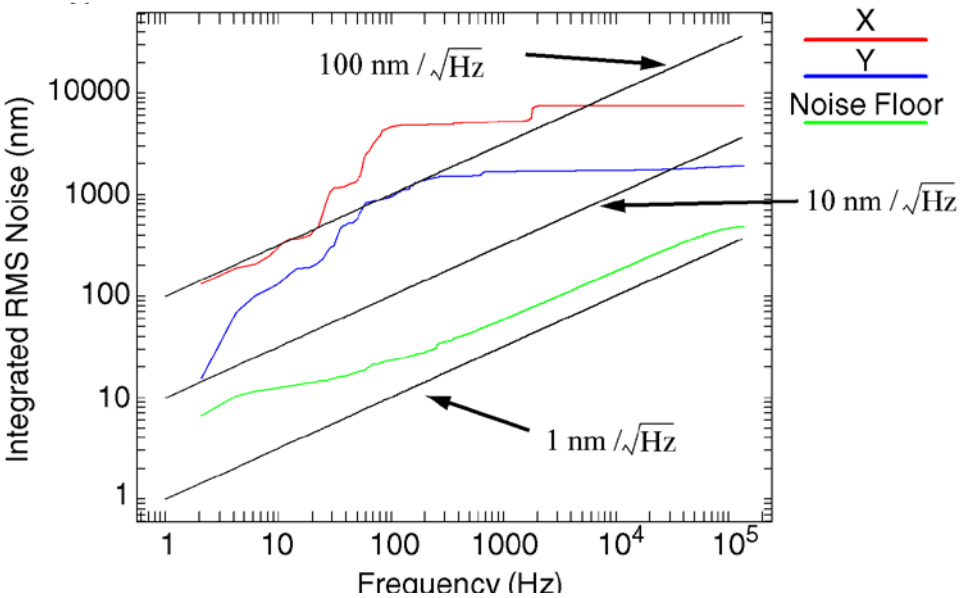
4 mm Diameter Capacitive buttons

BPM Electronics Performance

APS BSP-100 Module

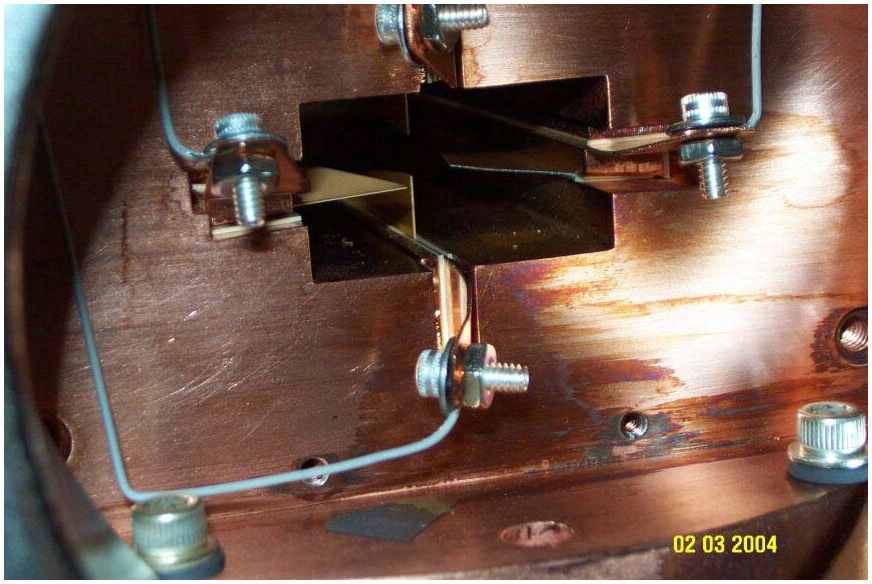


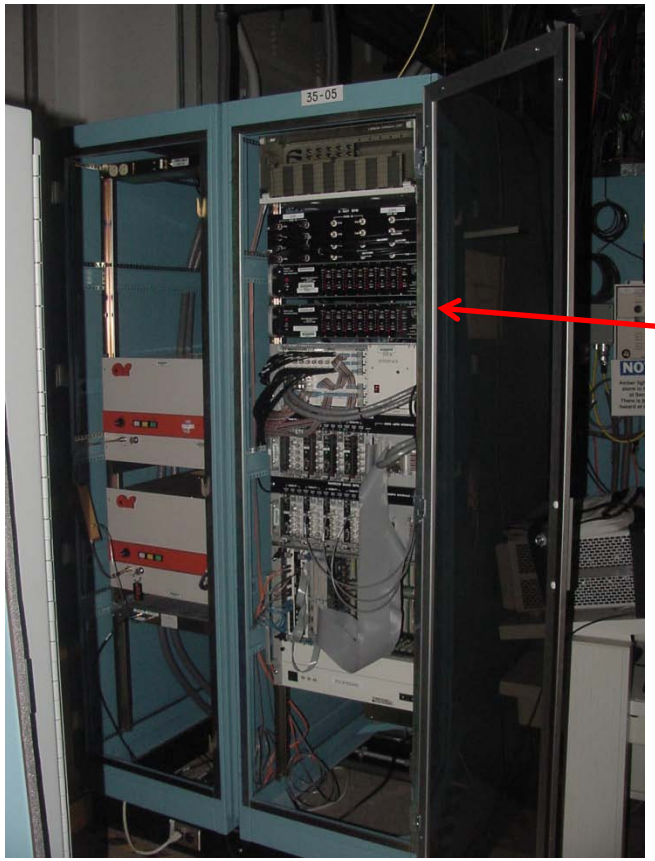
Libera Brilliance@APS

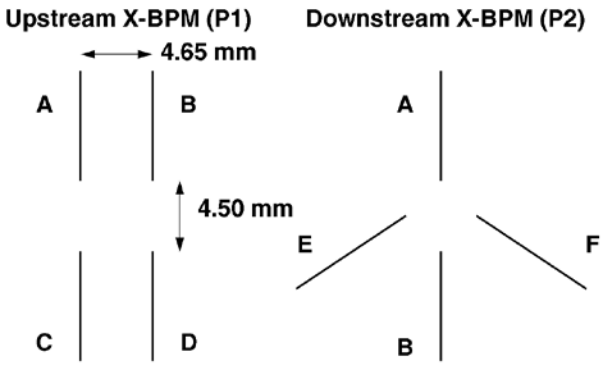


Photoemission (UV) Photon BPMS

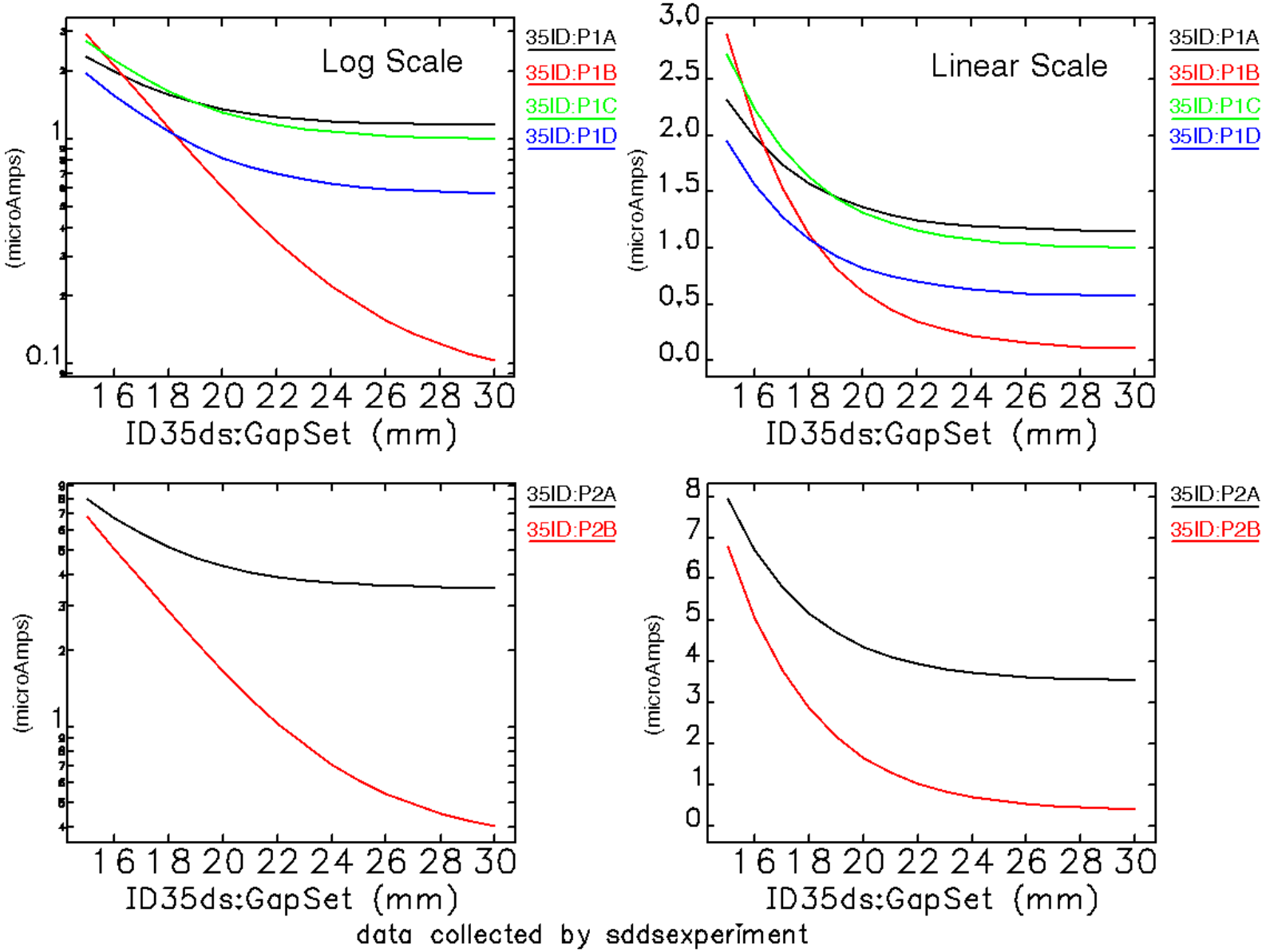
Gold-Coated Diamond Blades







Photoemission Photon Beam Position Monitor Blade Signals vs. ID gap

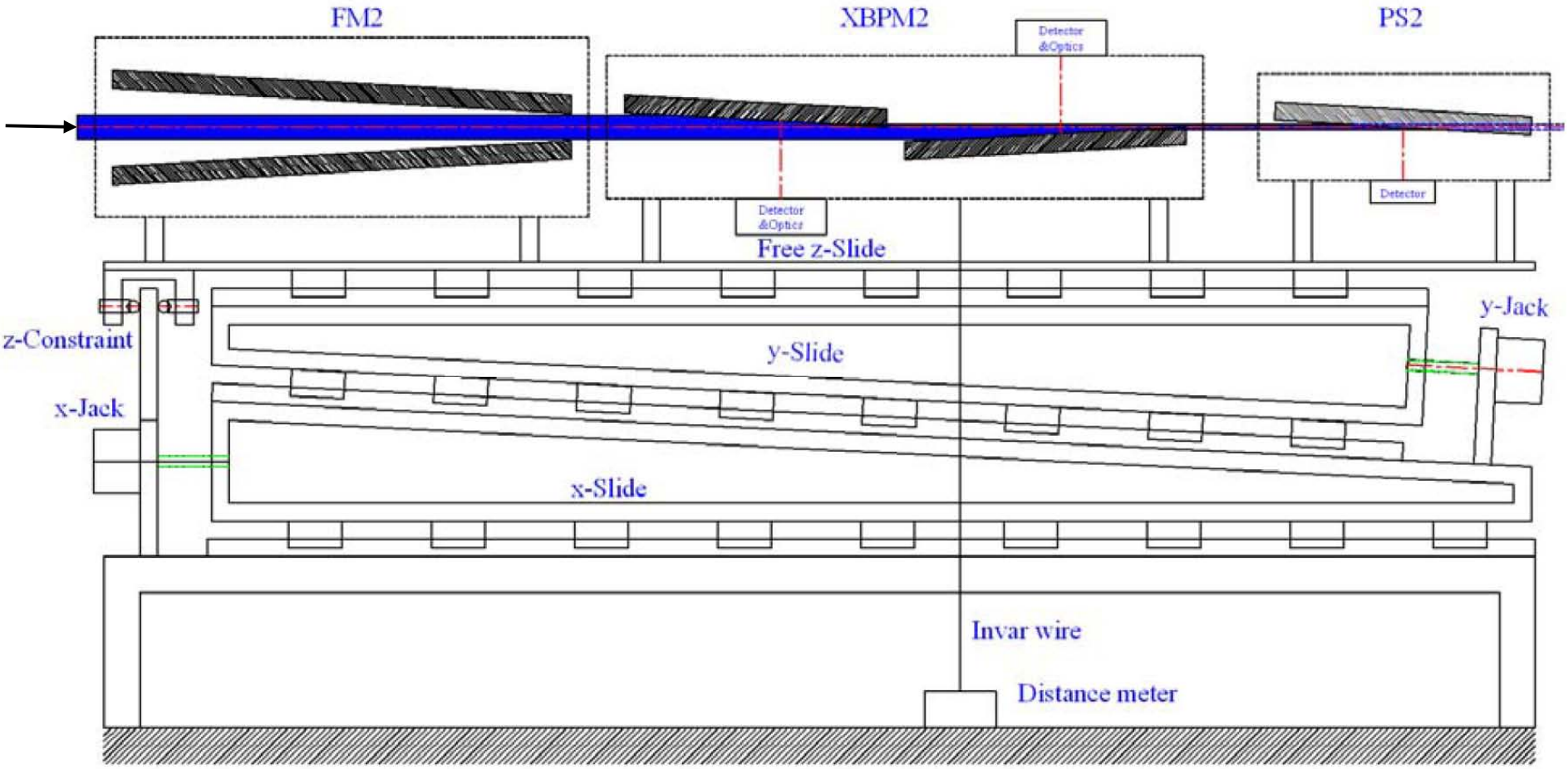


APS Front-end hard x-ray beam position monitor development

- Extensive studies have taken place at the APS investigating copper x-ray fluorescence vs. photo-emission for photon beam position monitoring.
  - Photo-emission-based bpms have residual 10-20 micron systematic errors.
  - With X-ray fluorescence, soft bending magnet radiation background is essentially eliminated.

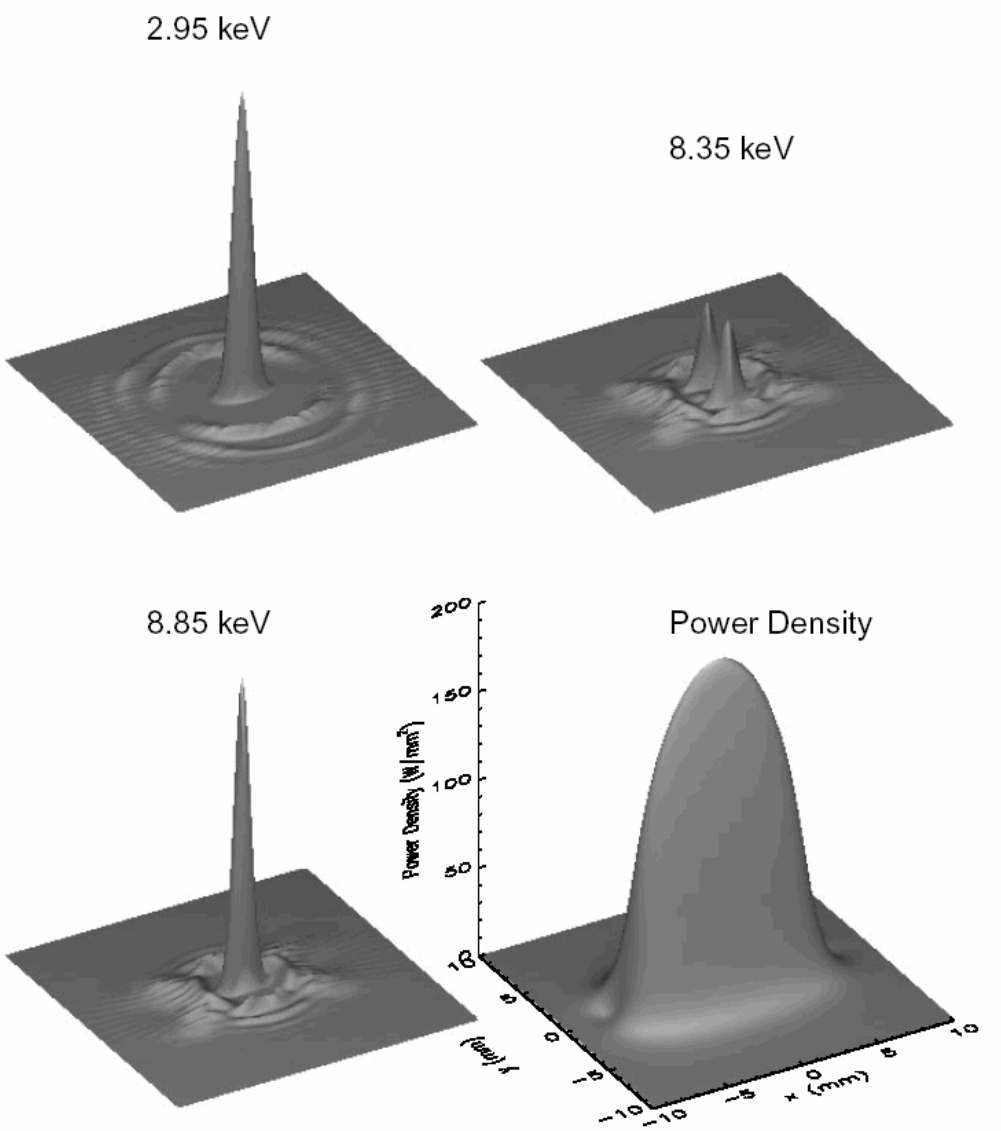
- An in-air prototype of an x-ray fluorescence-based hard x-ray bpm has been installed at APS diagnostics beamline 35-ID and is undergoing extensive testing.

Grazing-incidence Hard X-ray Fluorescence-Based Insertion Device X-ray Beam Position Monitor Conceptual Design (GRID-XBPM)



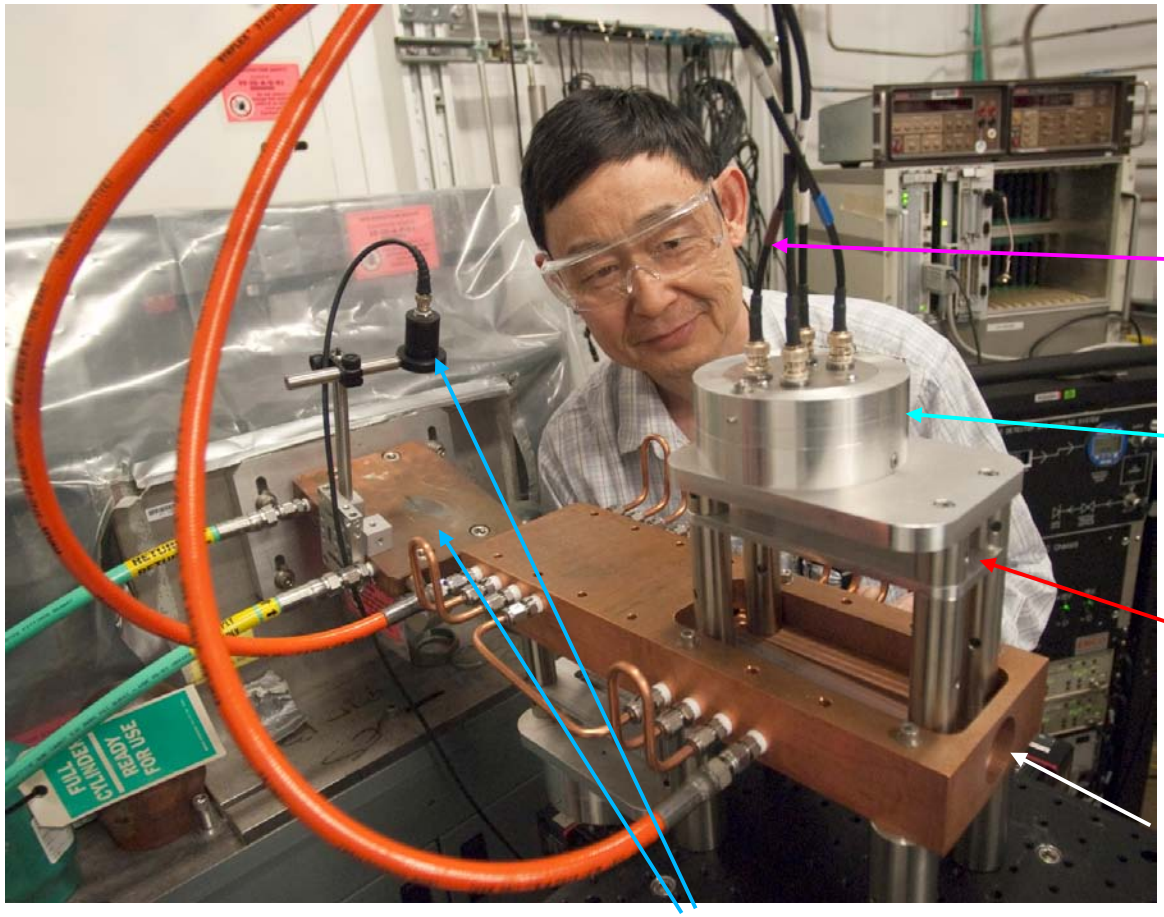
Concept courtesy of Bingxin Yang

Power Density Profiles @ 30 m, APS Undulator A, 100 mA



Courtesy of Roger Dejus

Prototype In-air GRID-XBPM @ 35-ID



Bingxin Yang

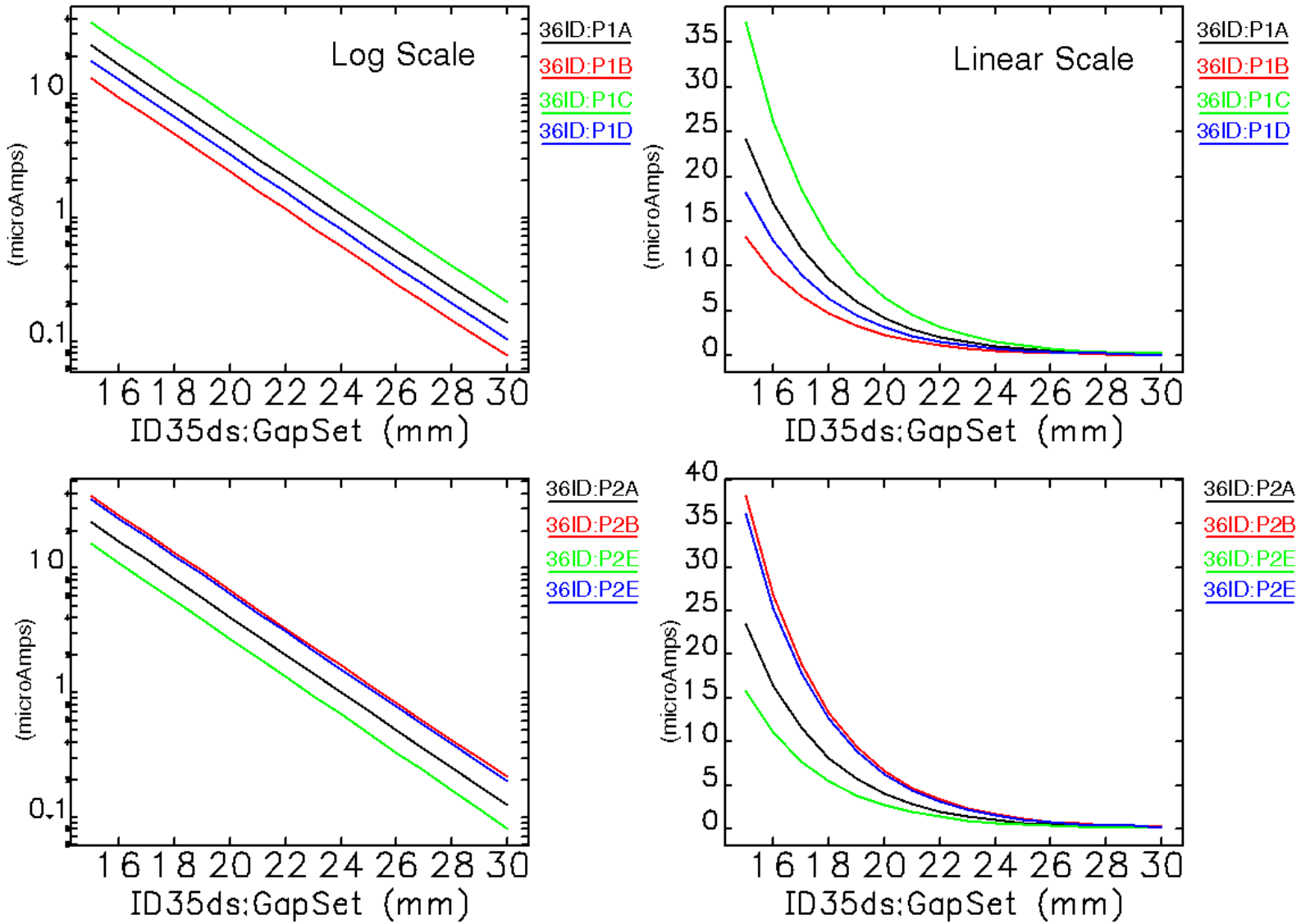
Four Pin diodes
(Two sets, top and bottom)

Pinhole “camera” apertures

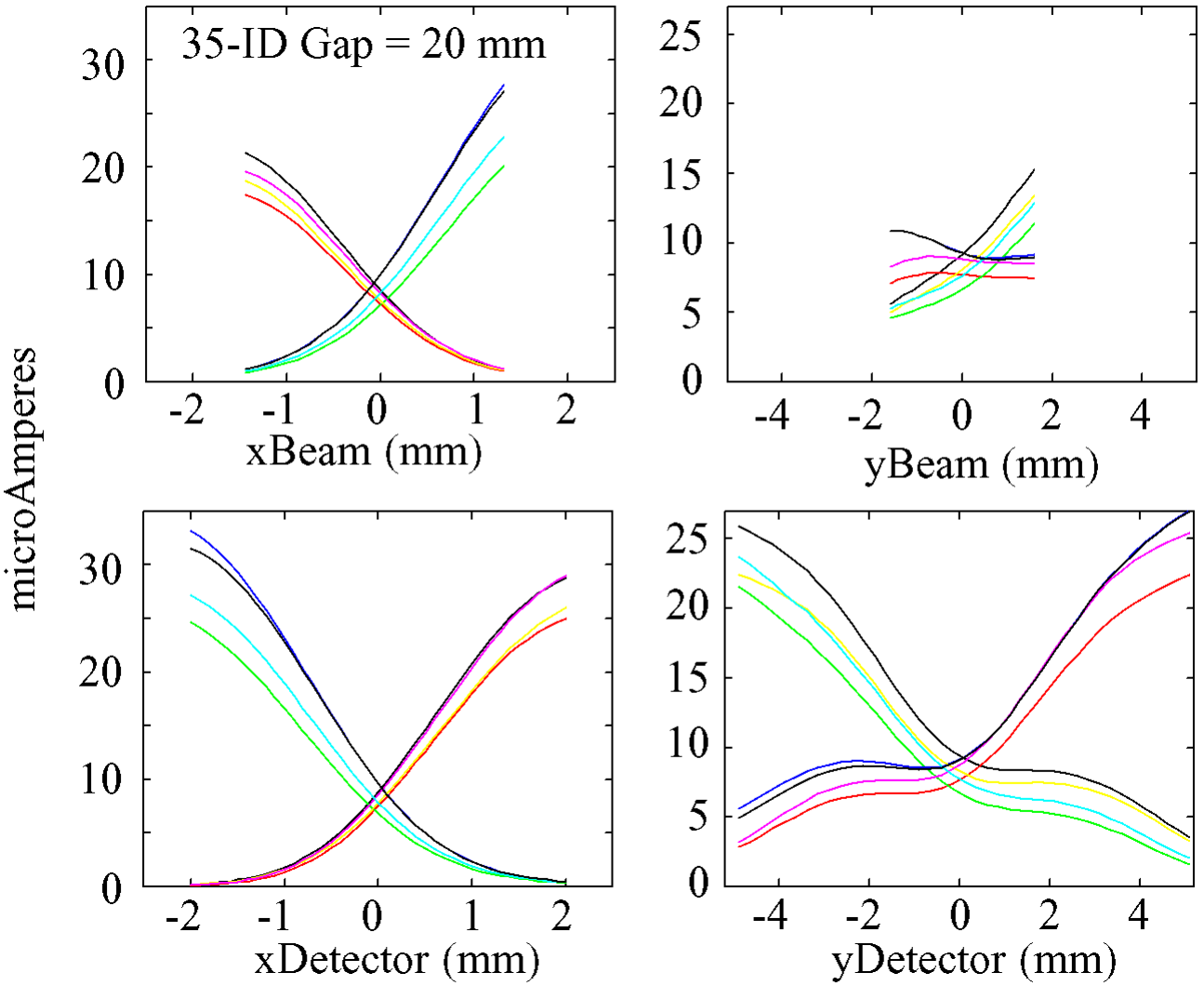
X-rays

Beam stop (PS2 surrogate)
With pin diode monitoring
X-ray transmission.

Hard X-ray Fluorescence Beam Position Monitor Photodiode Signals

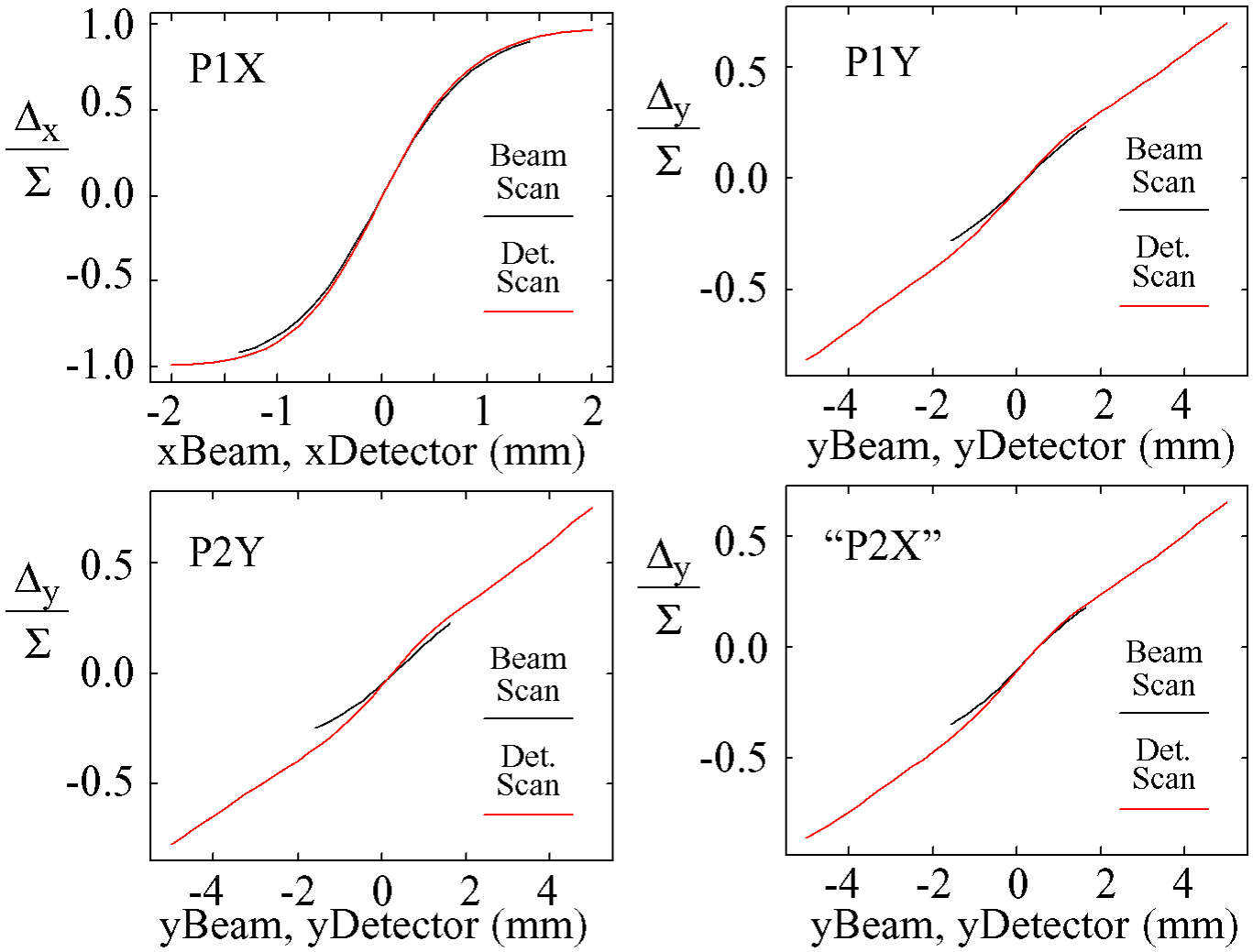


Hard X-ray BPM Calibration*



* Detector rotated 90 degrees relative to initial design

Hard X-ray BPM Calibration Cont'd

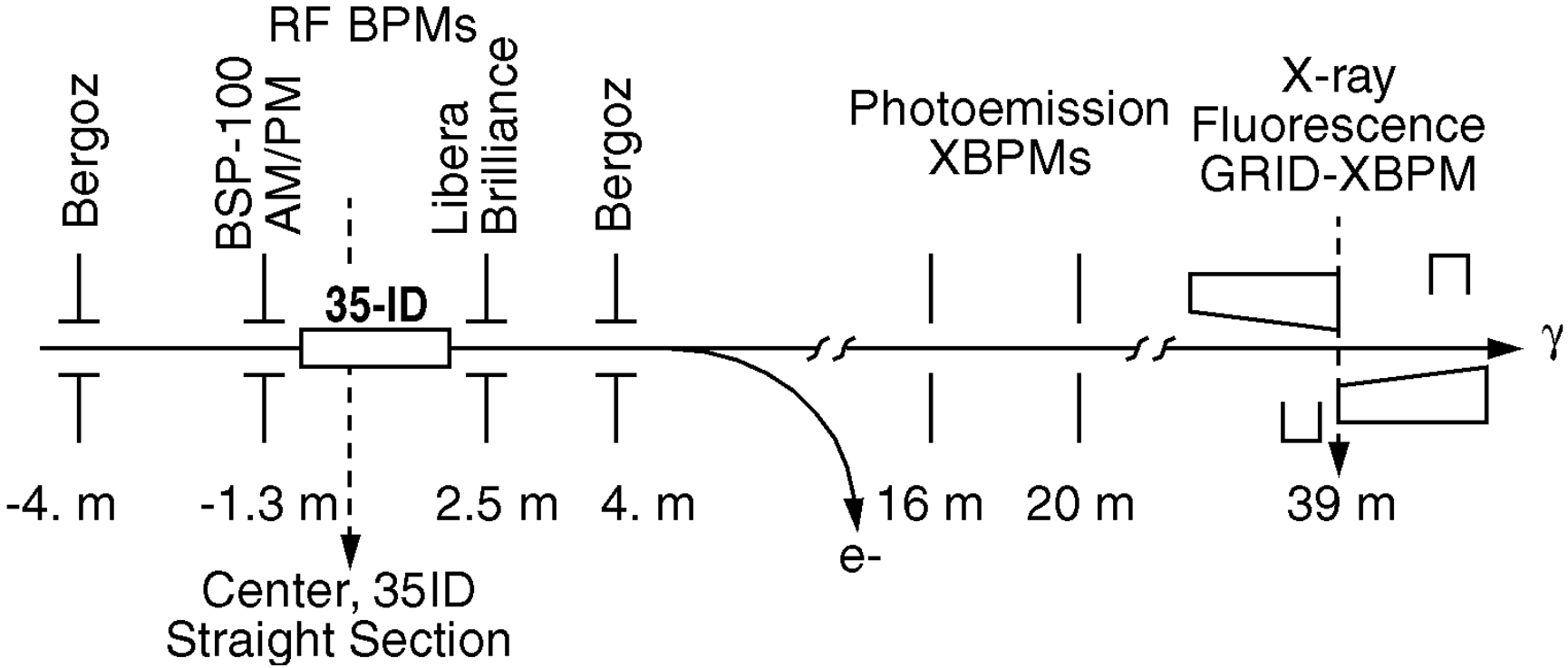


Calibration Results

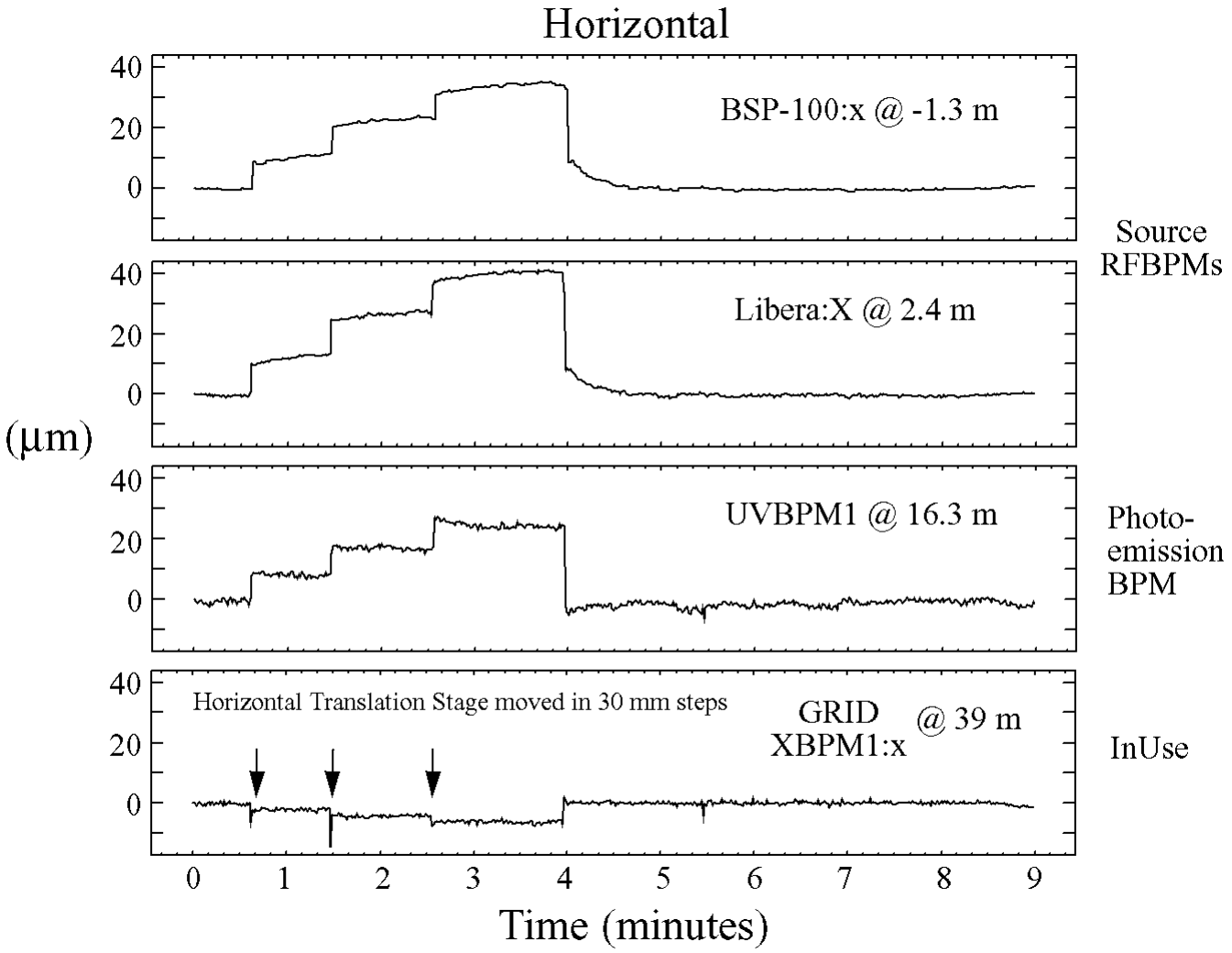
Channel	Beam Calibration Factor (mm)	Detector Calibration Factor (mm)
S36ID:P1:x	0.8842	0.8305
S36ID:P1:y	5.263	4.538
“S36ID:P2:x” (really vert)	4.987	4.506
S36ID:P2:y	5.490	4.506
S35ID:P1:x	3.682	2.963
S35ID:P1:y	1.059	0.1408*
S35ID:P2:y	0.7843	0.1348*

* Yes, really

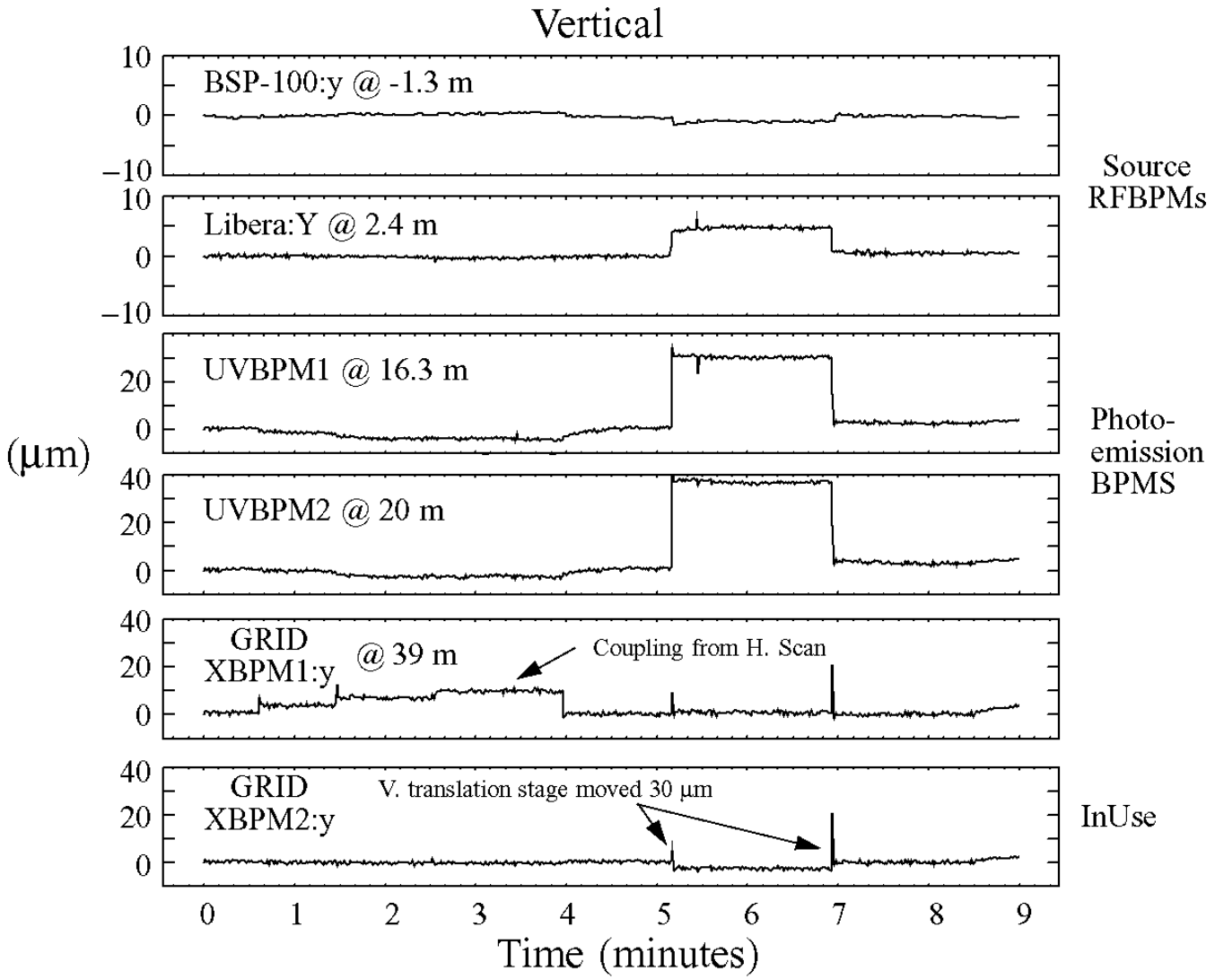
APS 35-ID Undulator Beamline Experimental Arrangement



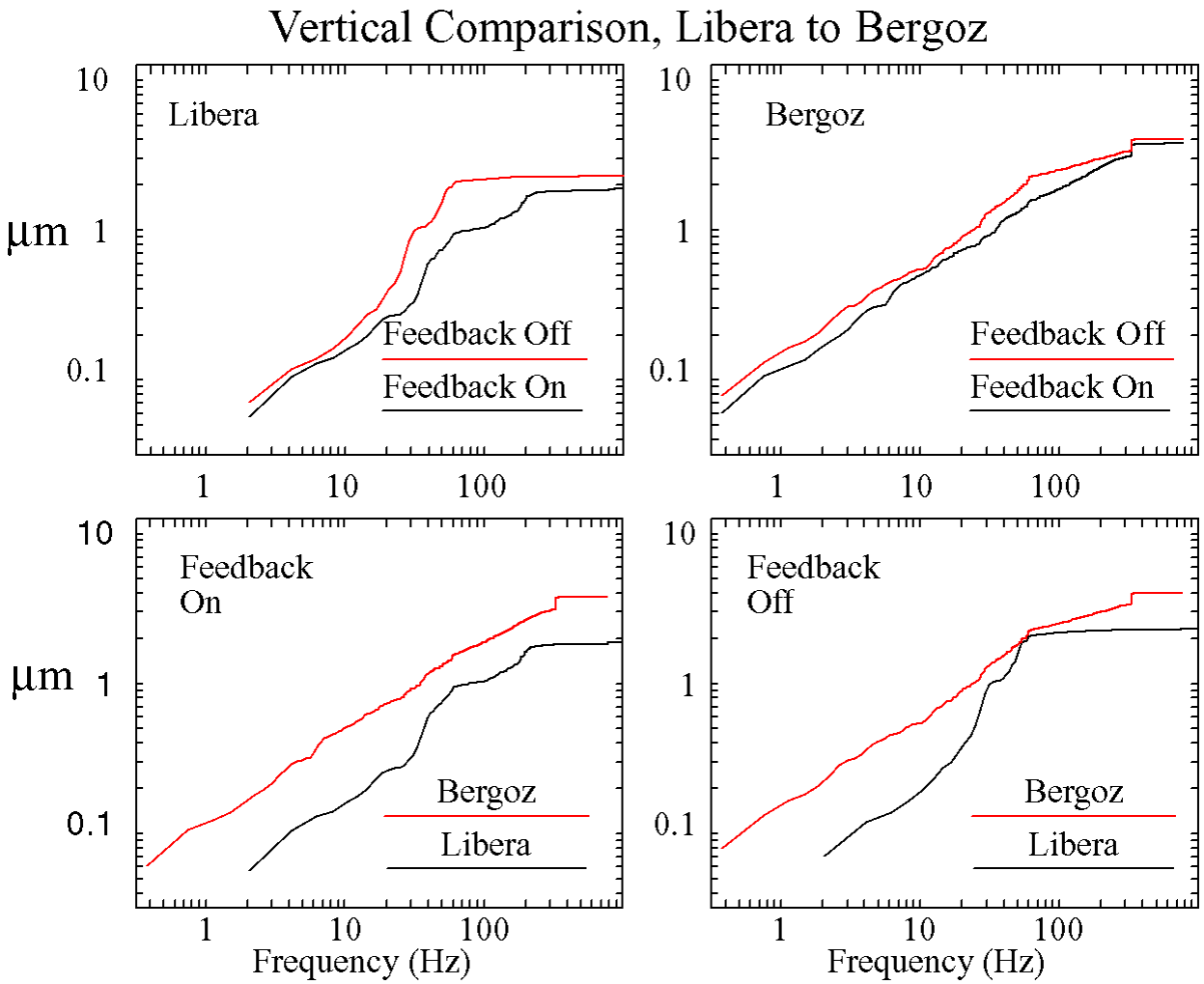
DC Performance



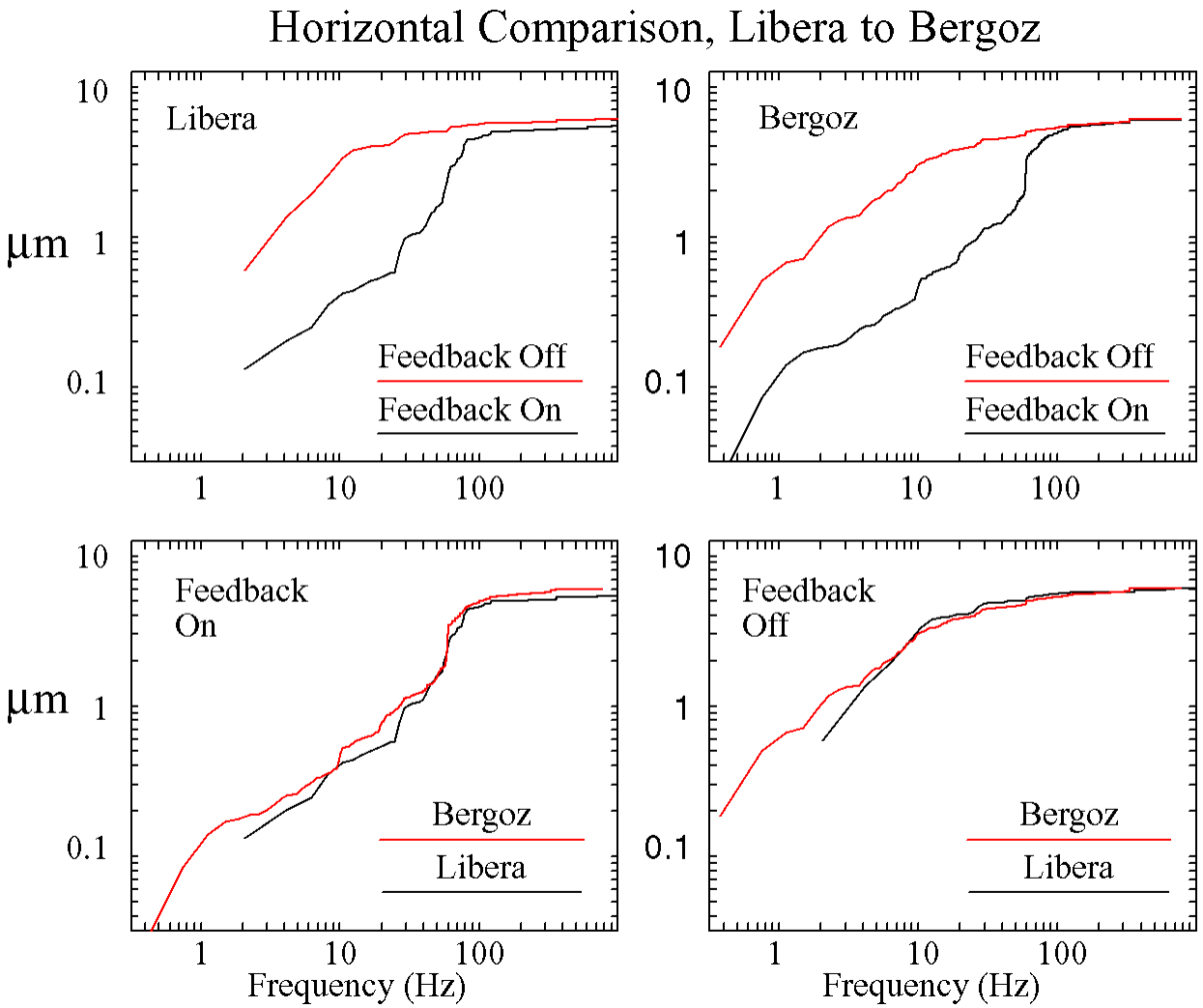
DC Performance Cont'd



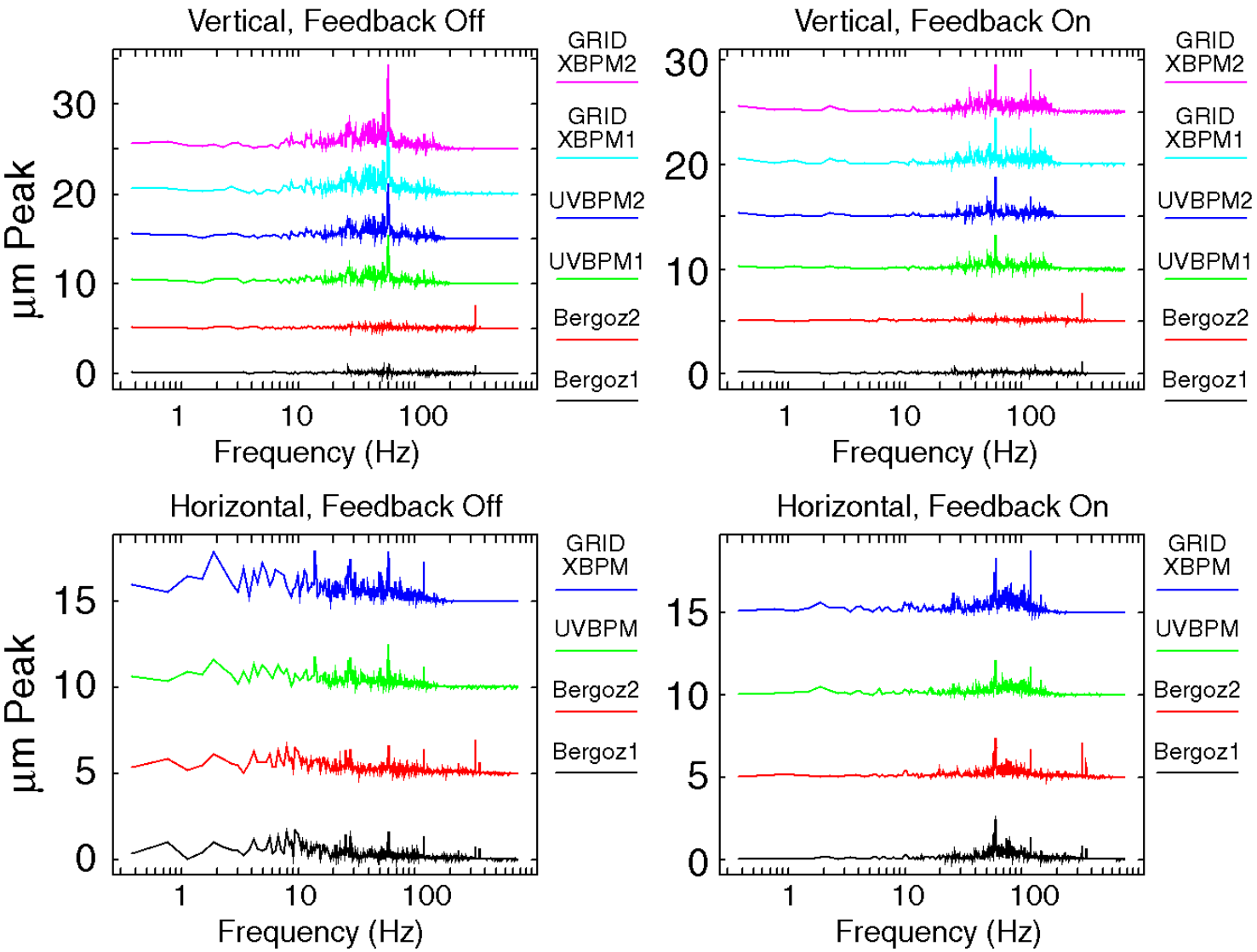
AC Performance- Libera vs. Bergoz: Unfair Comparison



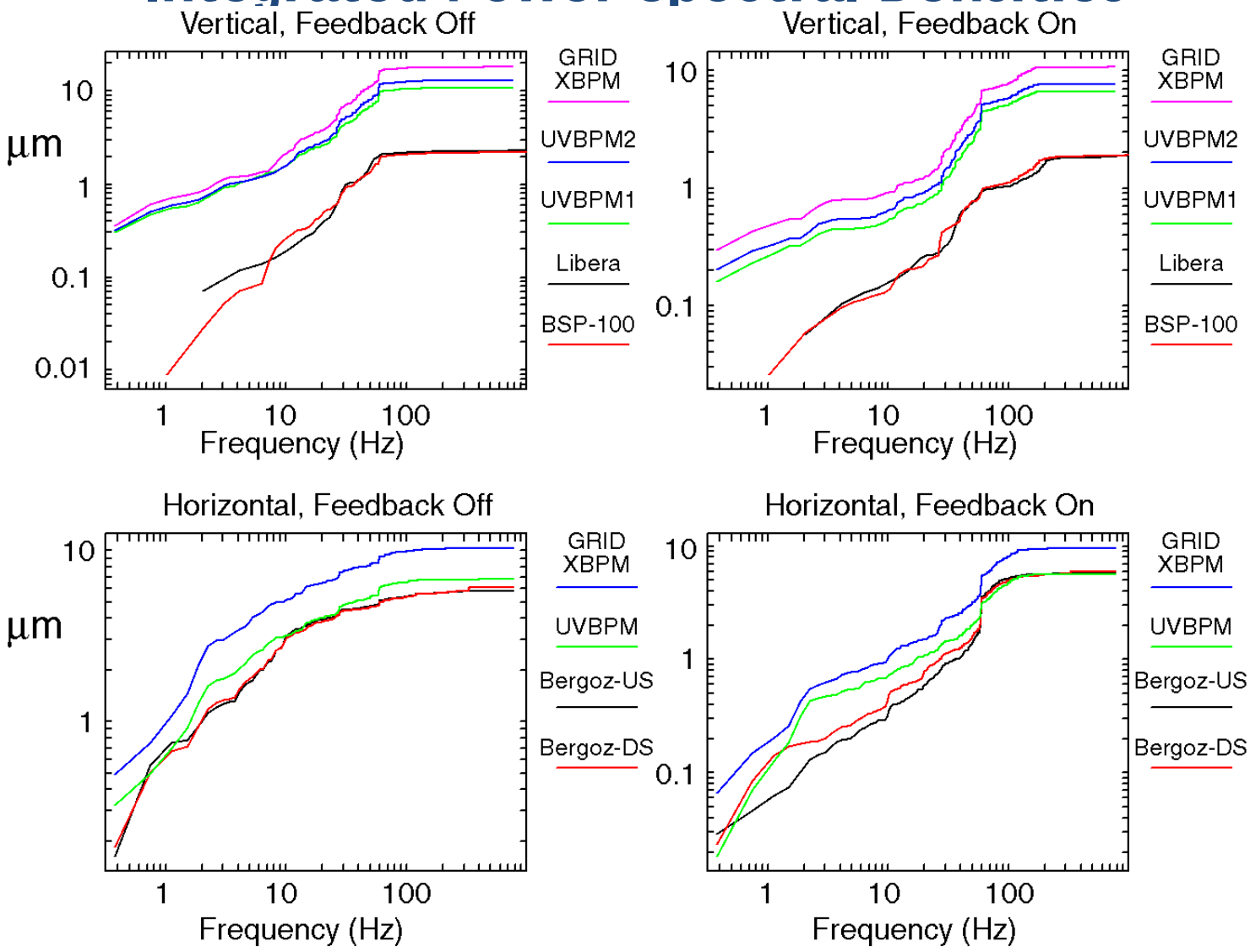
Libera vs. Bergoz: Less Unfair Comparison



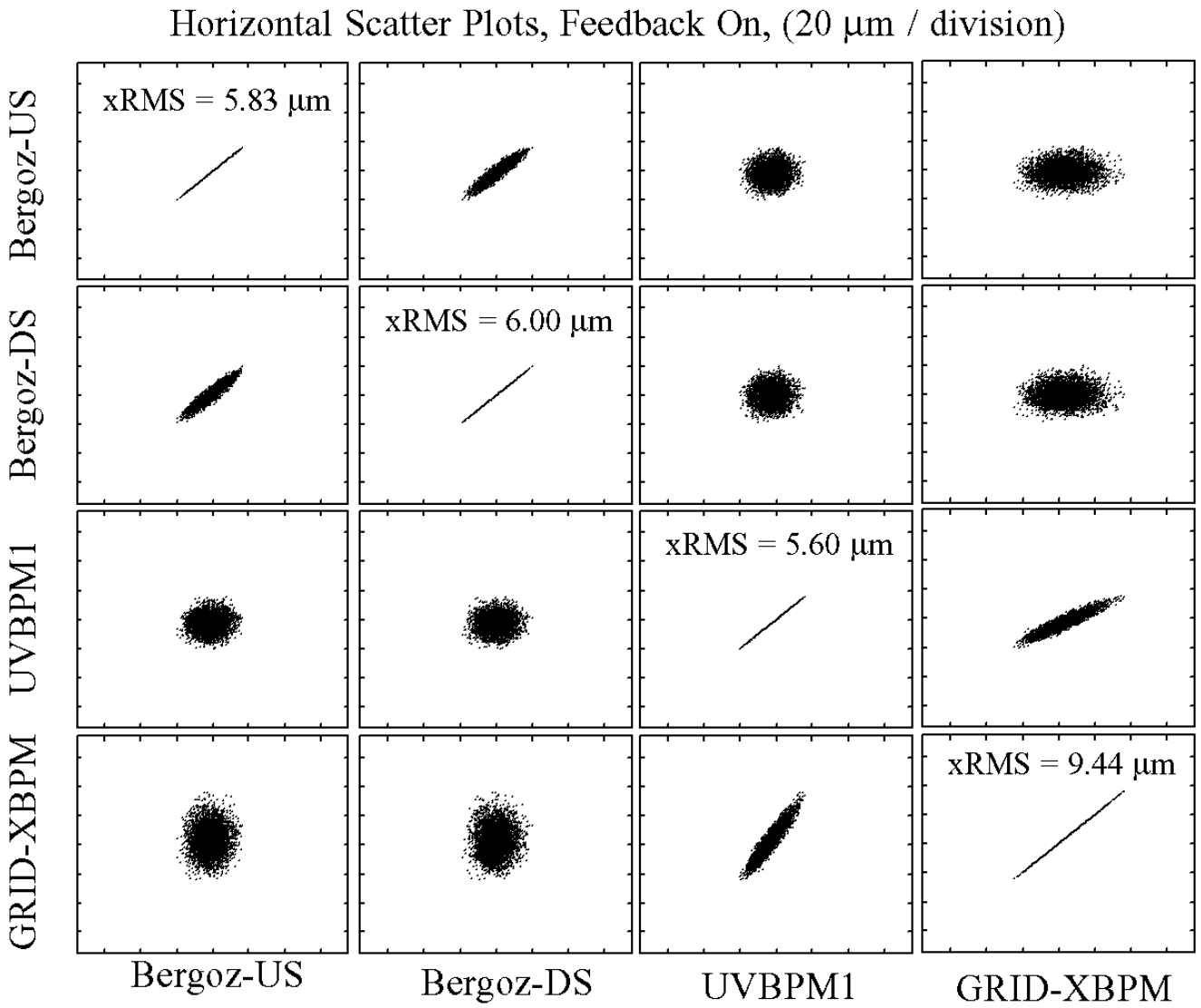
FFTs


Vertical, Feedback Off
μm Peak
30
20
10
0
1
10
100
Frequency (Hz)
GRID XBPM2
GRID XBPM1
UVBPM2
UVBPM1
Bergoz2
Bergoz1
Vertical, Feedback On
30
20
10
0
1
10
100
Frequency (Hz)
GRID XBPM2
GRID XBPM1
UVBPM2
UVBPM1
Bergoz2
Bergoz1
Horizontal, Feedback Off
μm Peak
15
10
5
0
1
10
100
Frequency (Hz)
GRID XBPM
UVBPM
Bergoz2
Bergoz1
Horizontal, Feedback On
15
10
5
0
1
10
100
Frequency (Hz)
GRID XBPM
UVBPM
Bergoz2
Bergoz1

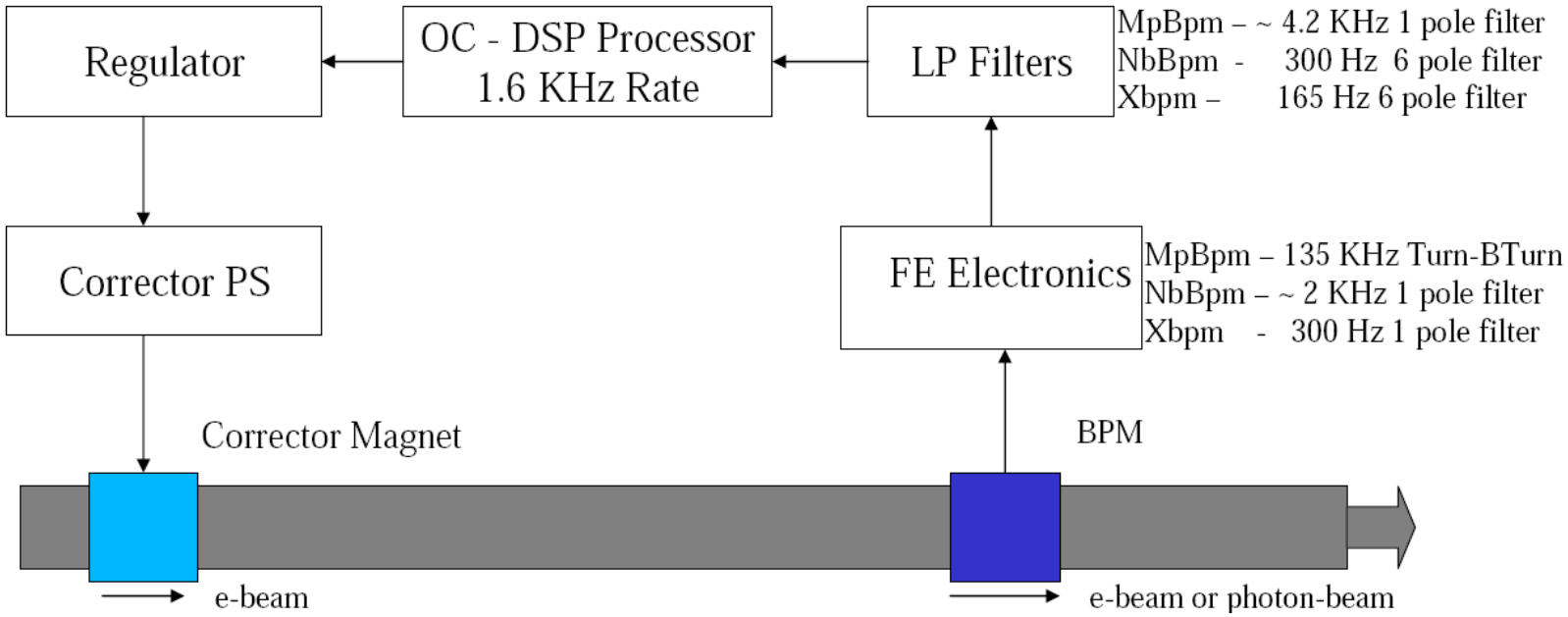
Integrated Power Spectral Densities



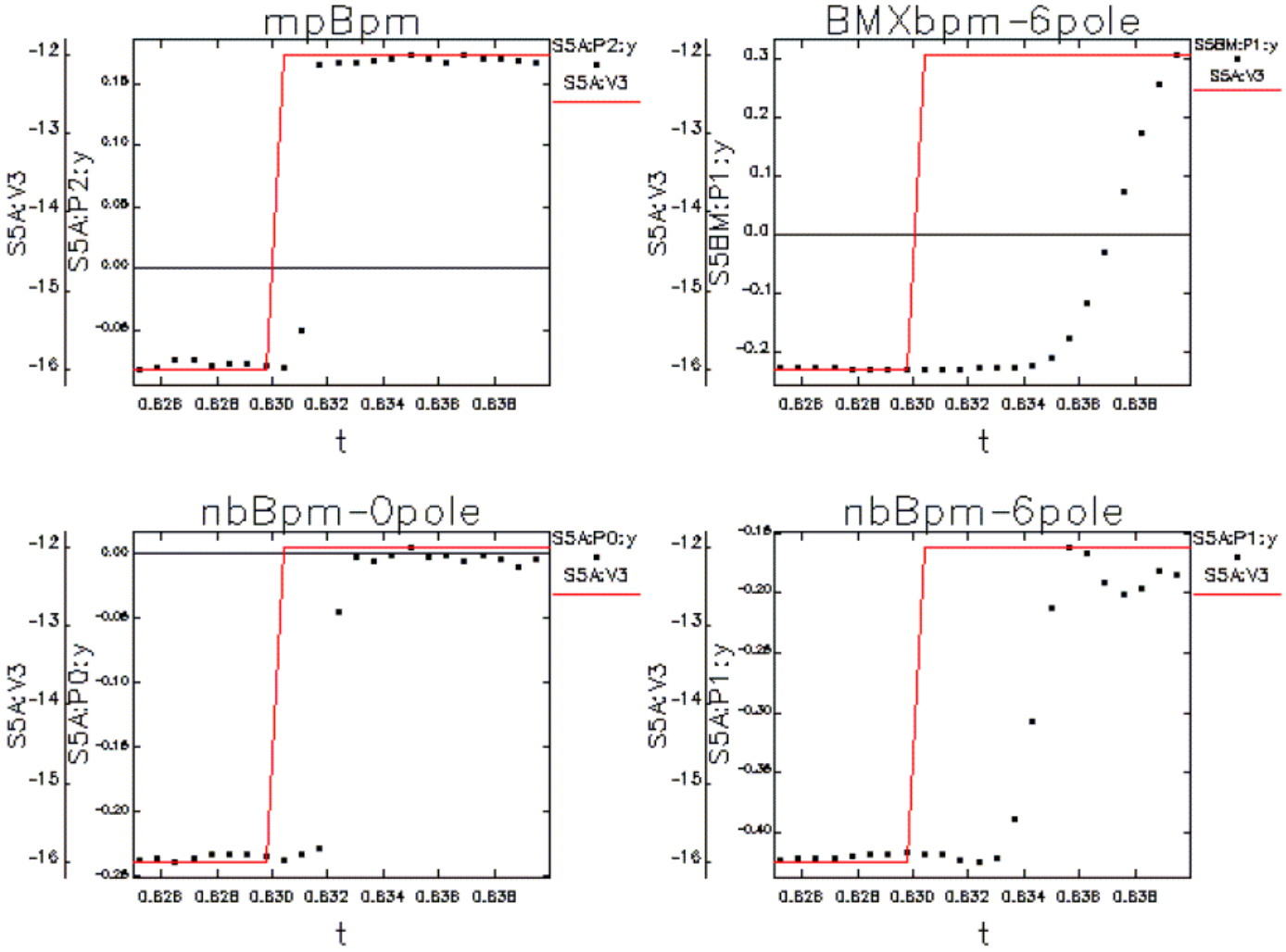
Correlations



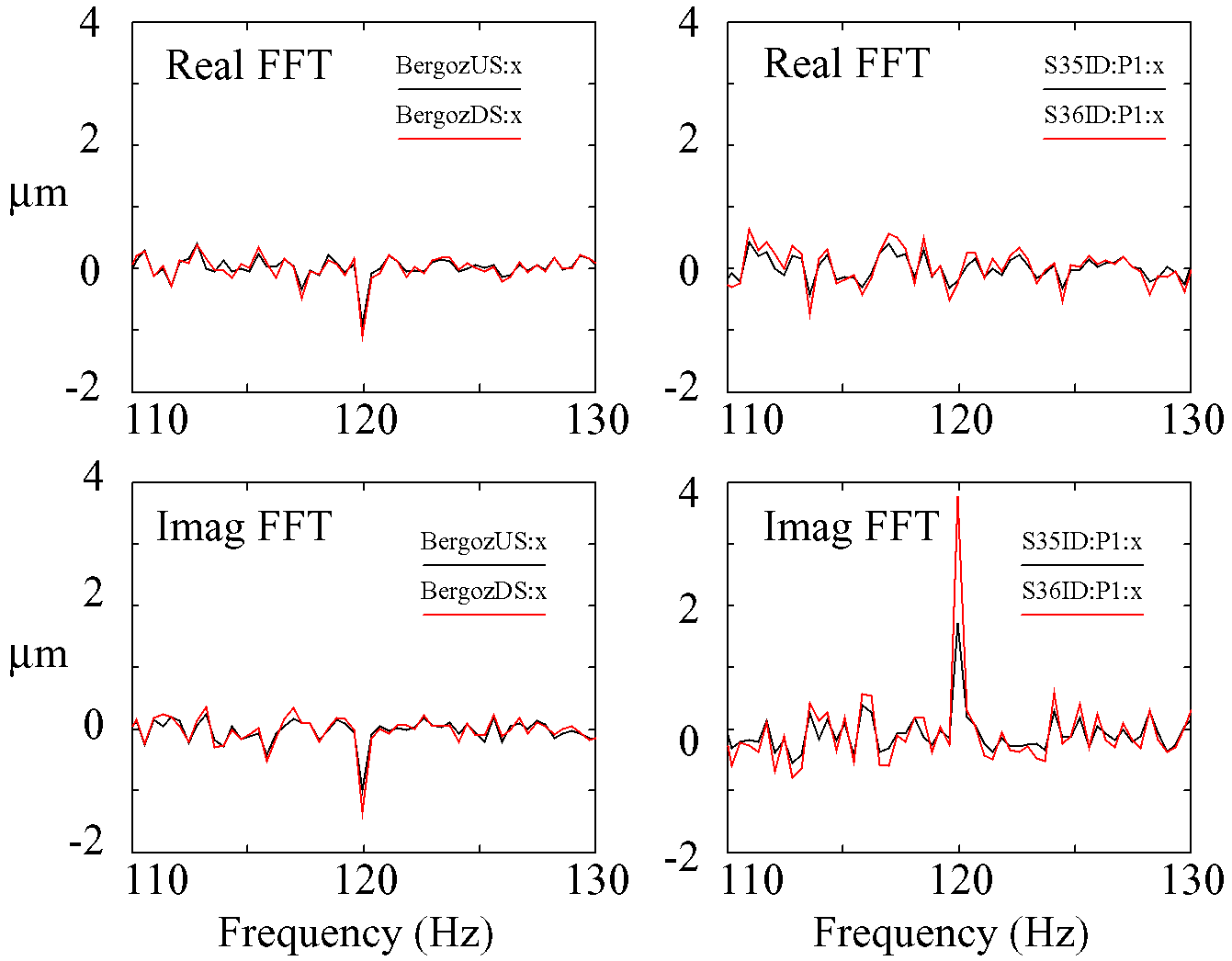
Filtering


Regulator
OC - DSP Processor
1.6 KHz Rate
LP Filters
MpBpm – ~ 4.2 KHz 1 pole filter
NbBpm - 300 Hz 6 pole filter
Xbpm – 165 Hz 6 pole filter
Corrector PS
FE Electronics
MpBpm – 135 KHz Turn-BTurn
NbBpm – ~ 2 KHz 1 pole filter
Xbpm - 300 Hz 1 pole filter
Corrector Magnet
BPM
e-beam
e-beam or photon-beam

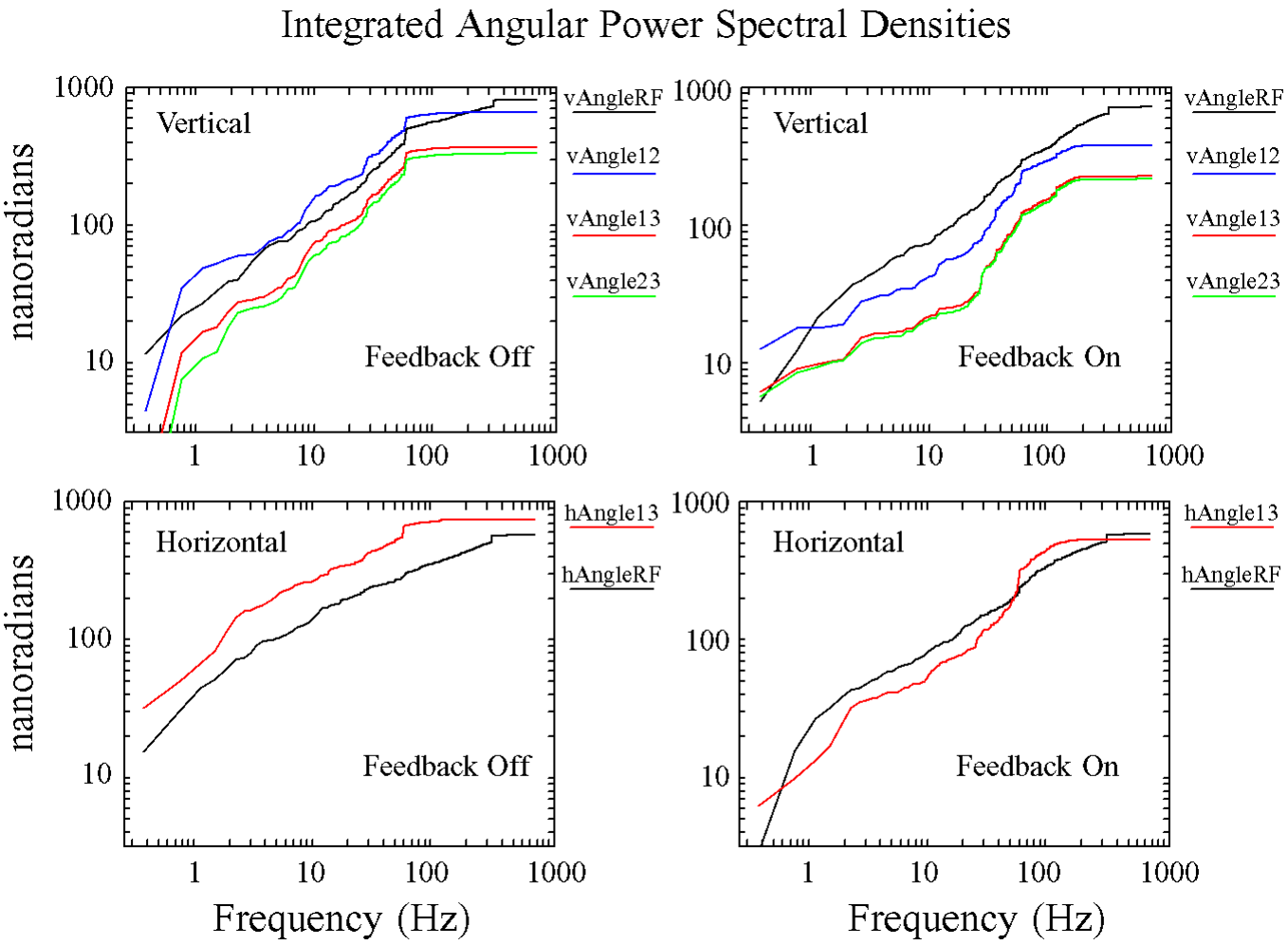
Filtering cont'd



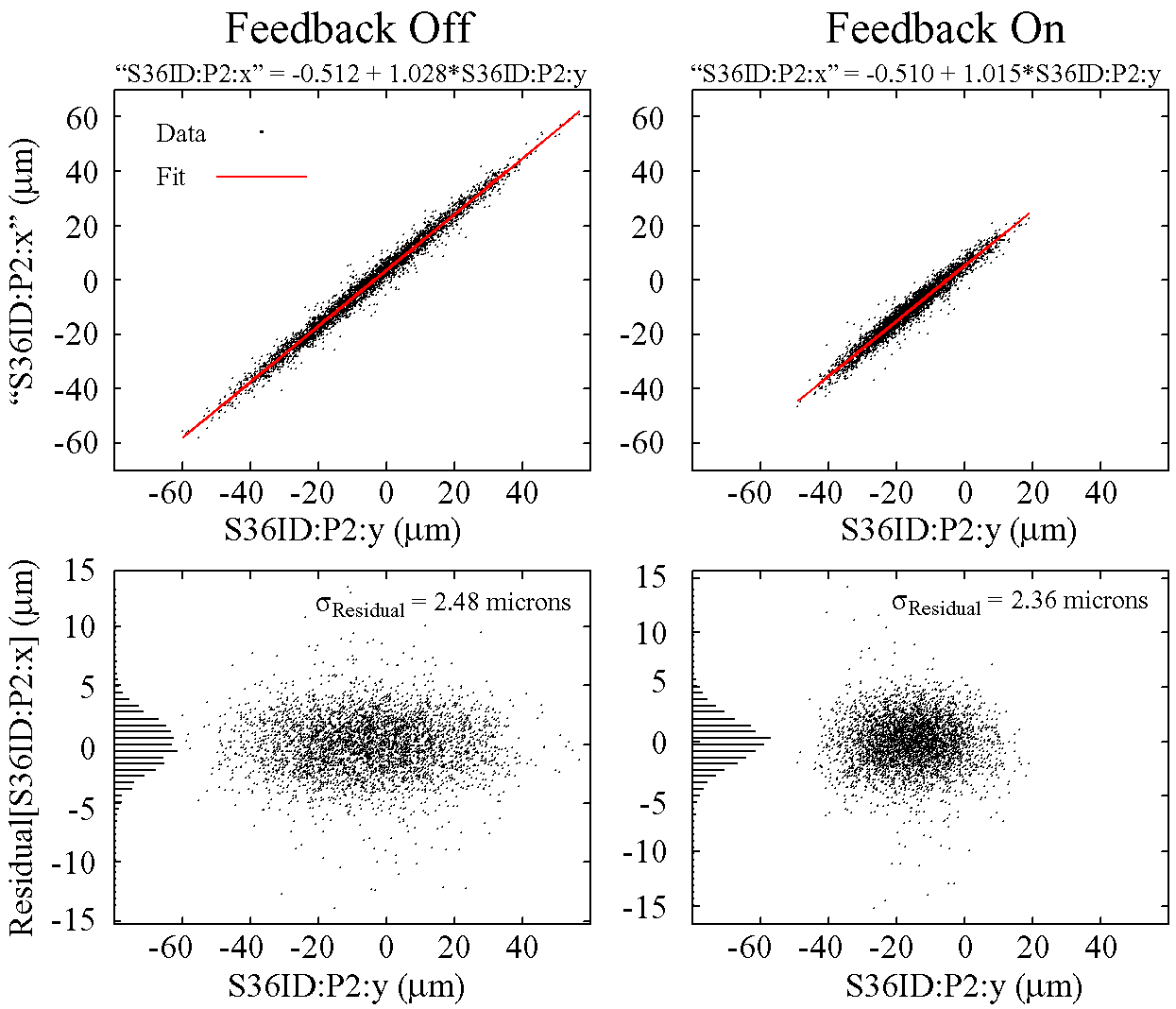
Filtering cont'd cont'd



Angle Power Spectral Densities



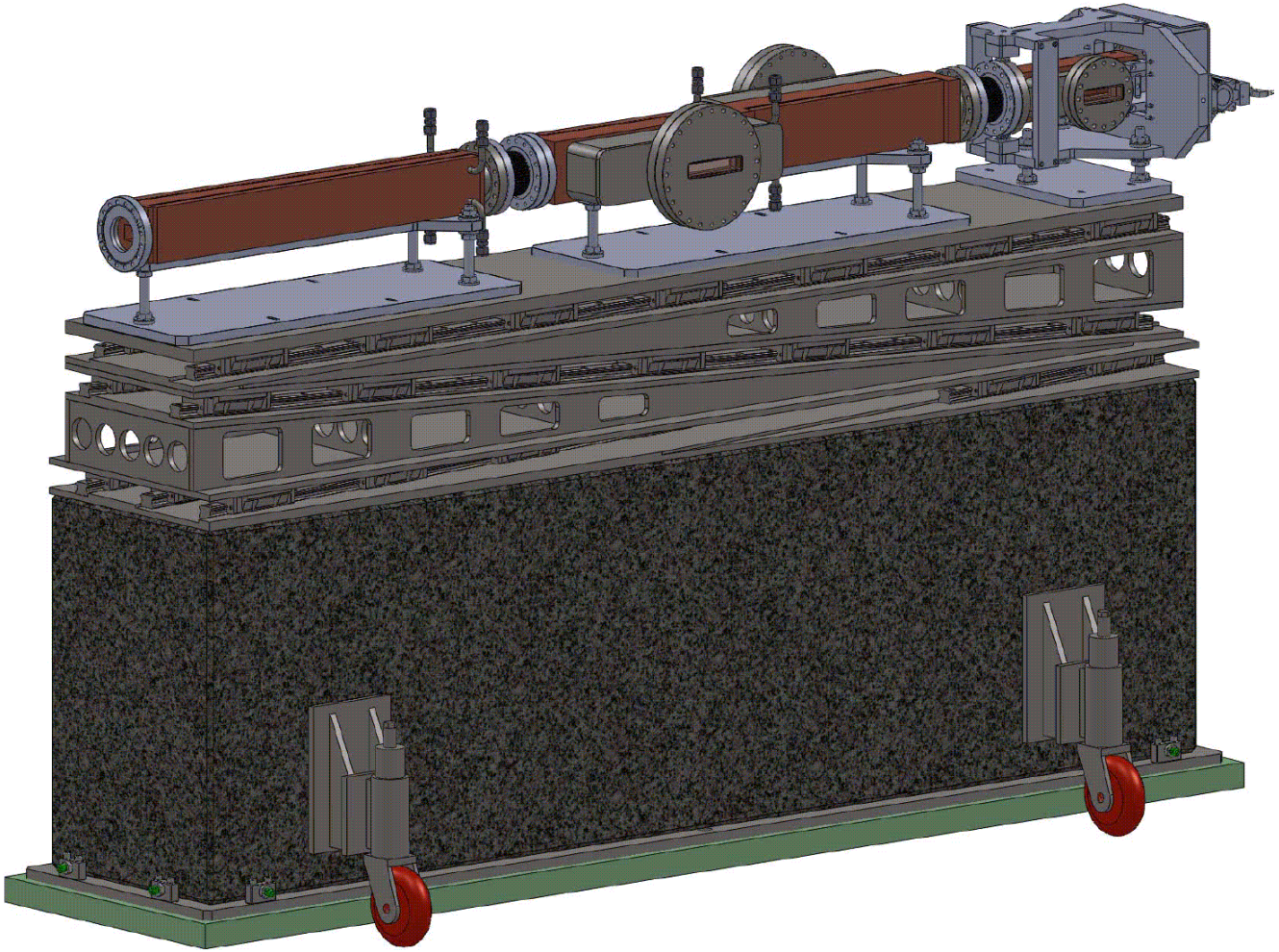
Angular Resolution



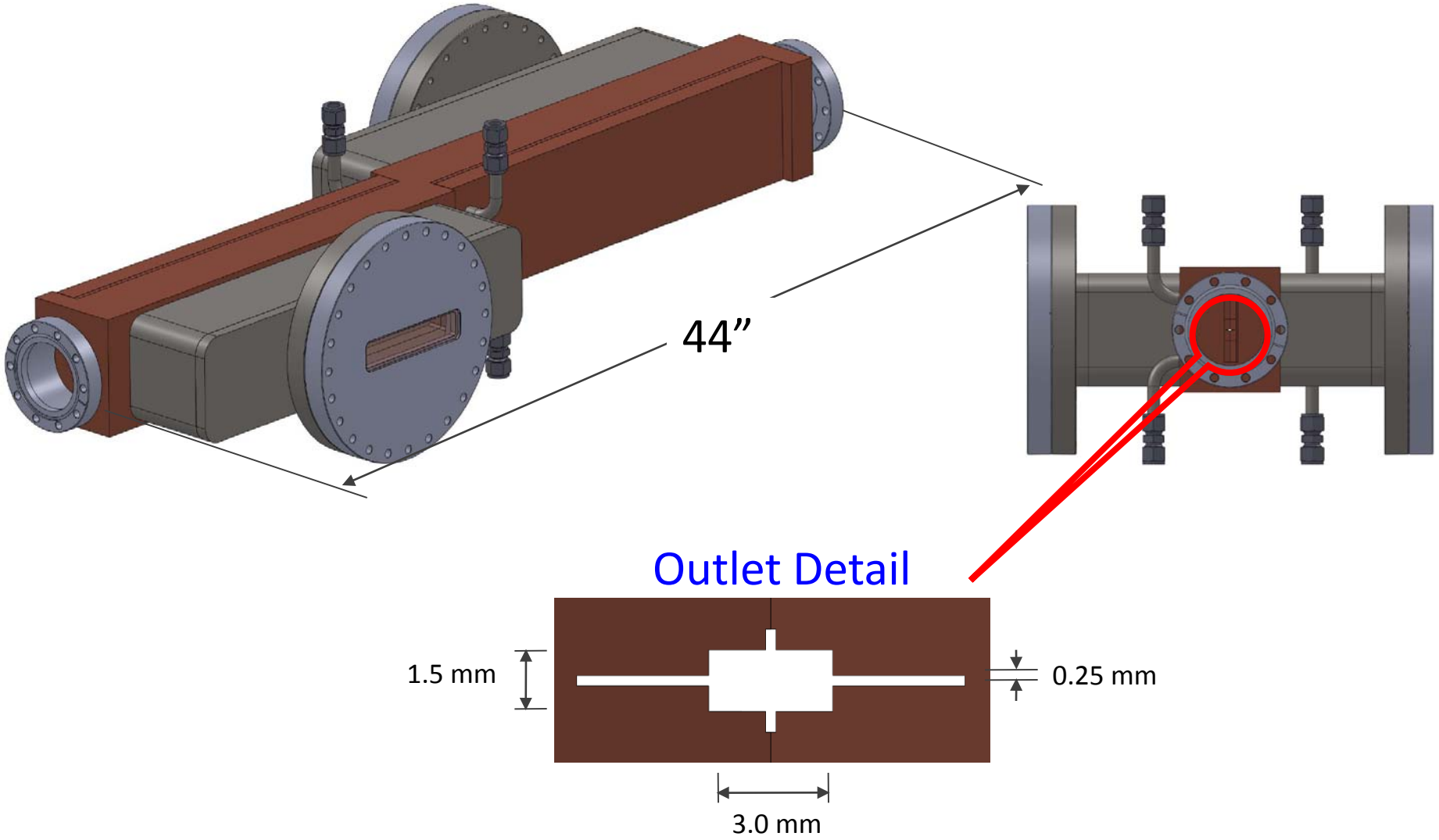
Summary

- An array of diagnostics have been deployed at APS beamline 35-ID allowing studies of angular motion with unprecedented resolution: 60 nanorad rms in a frequency band from 0.4 to 200 Hz.
- The development of a hard x-ray fluorescence-based BPM has played a pivotal role in this work and forms an important element of the APS Upgrade.
- This detector has been included in DC orbit correction for the first time, allowing very high resolution (and accuracy) steering based on stepping motors.

GRID-XBPM Assembly Drawing

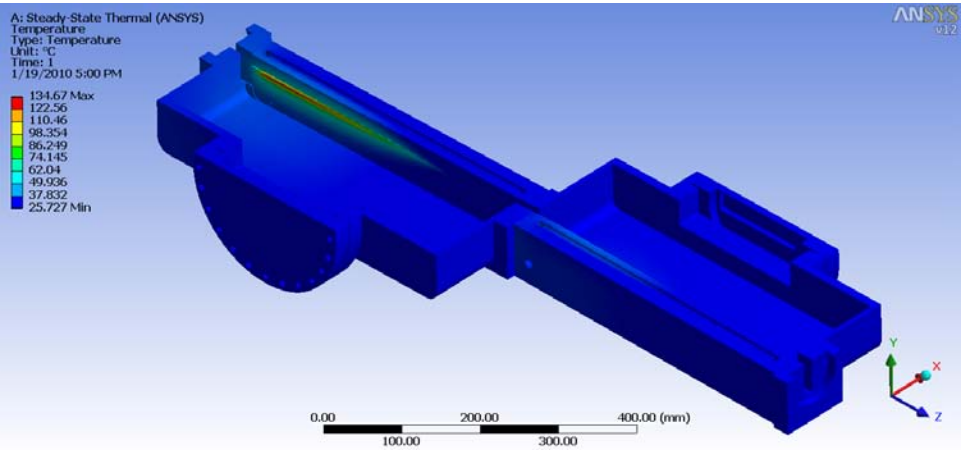


Conceptual Design of the first article GRIDXBPM

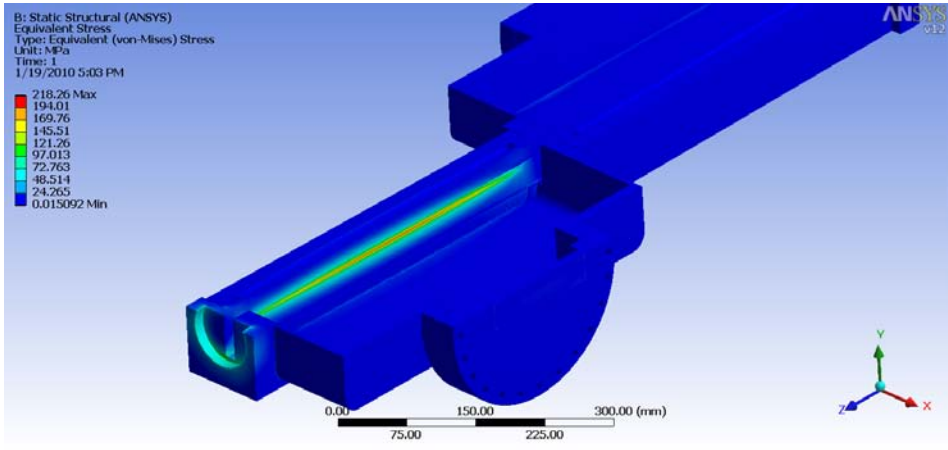


Courtesy of Soon-Hong Lee, AES-MED

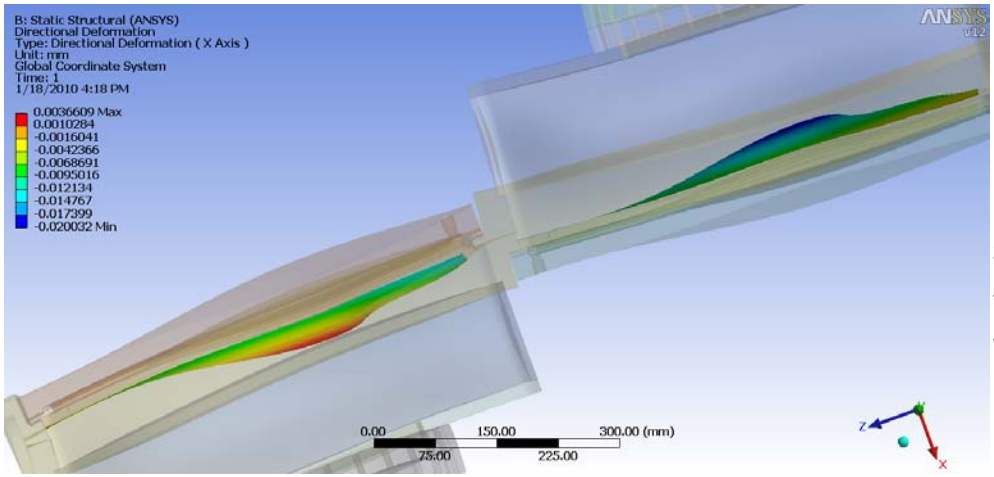
Simulation Result (Preliminary) - Vertical



Temperature Distribution @ Case 4 (Max. 134.7 °C)



Stress Distribution @ Case 3 (Max. 218.3 MPa)



~ 11.3 µm bump

Surface deflection @ Case 1
(Horizontal direction only, 2100x)

Beam stability specification (<200Hz)
- Vertical : 0.3 µm rms
- Horizontal: 3.0 µm rms

Note: 10 kW =
5 m Undulator A
@ 100 mA

Courtesy of Soon-Hong Lee, AES-MED

Libera Brilliance / GRID-XBPM Comparison

Vertical Comparison, Source to End of Beamline