Next-Generation XBPM Development

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* Heavily plagiarizing the work of Bingxin Yang

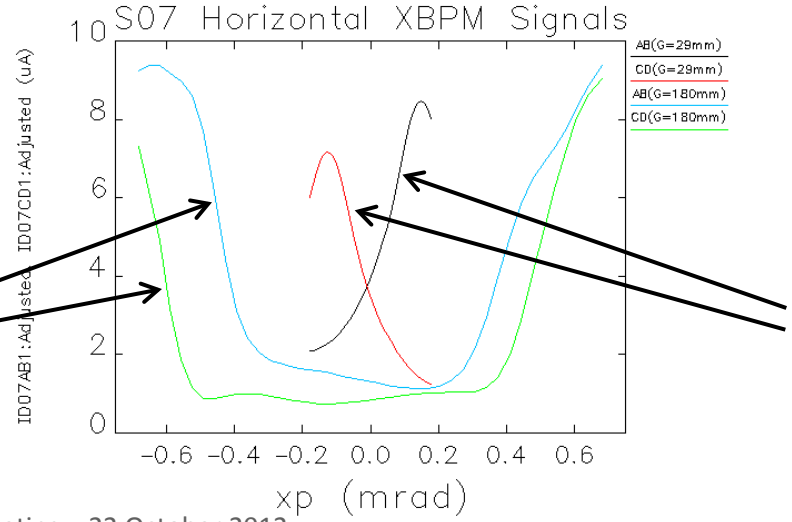
Outline

- Background and History
- Beam Stability Goals
- GRID XBPM Concept
- First Results
- Plans

X-ray Beam Position Monitors - History

- All beamlines at present are instrumented with photoemission blade xbpms
  - Two gold-coated diamond 4-blade bpms at ID beamlines
  - Two molybdenum 2-blade bpms at BM beamlines (vertical only).
- Diagnostics took over operation and maintenance of these systems c. 1996
- Variable bending magnet radiation background rendered ID xbpms useless.
- Decker Distortion successfully demonstrated at beamline 34-ID January 1999
  - Reduced stray radiation backgrounds by an order of magnitude.
  - Ring distortion / realignment completed May, 2005.
- Residual background signals compensated with ID gap feedforward.

Gap = 180 mm



Gap = 29 mm, Inboard, Outboard Blade Signals

Effects of Residual Background on Photoemission XBPMs

- Software compensation reduces the gap dependence from hundreds of μm to tens of μm residual.
- Does not meet APS-U requirements, especially for larger gaps.

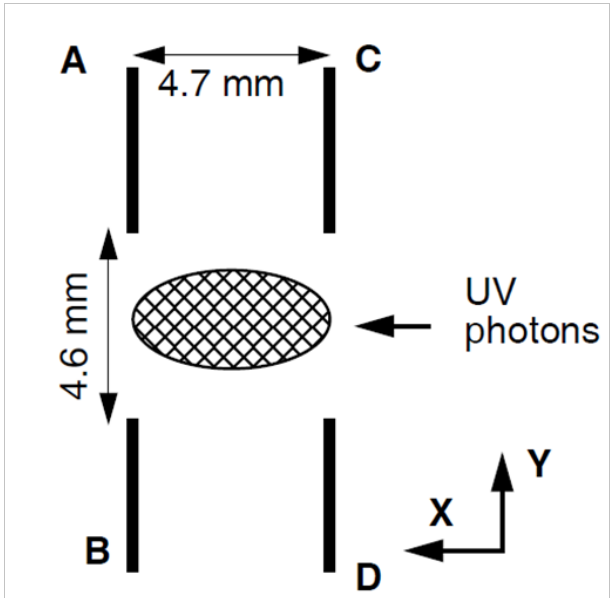
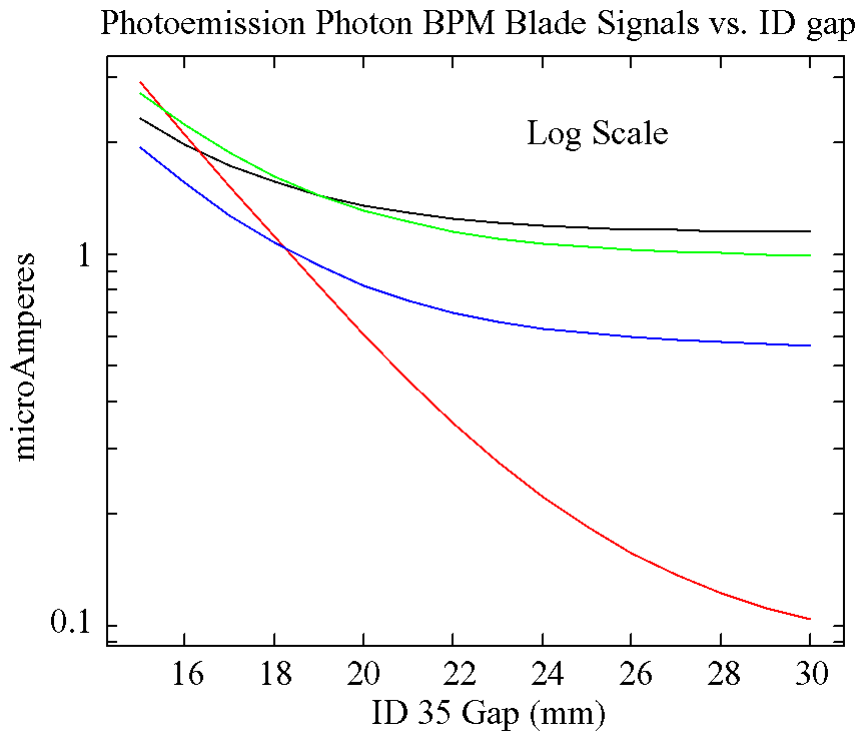


Figure 0:
P1 IDxbpm blade geometry



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.

- APS-U Beam Stability Physics Requirement Document APS_1428984
- Based on 5% of transverse beam dimensions up to 200 Hz and 10% up to 1 kHz.

XBPM requirements for APS Upgrade

Due to its long distance (18.6 m) from the source, an XBPM is most suitable for measuring the beam direction.

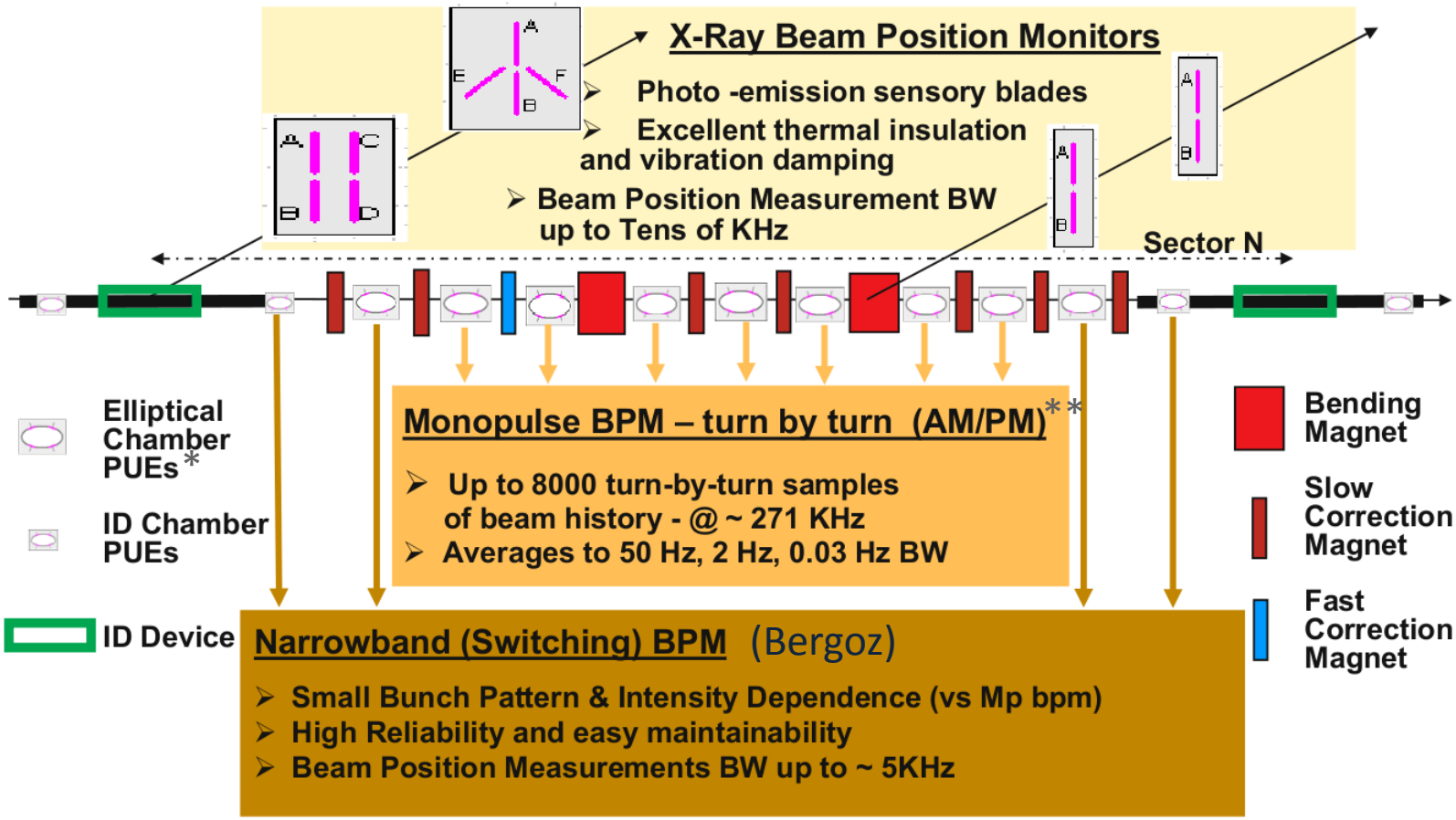
APS Upgrade beam stability goals (XBPM @ z = 18.6 m)

		RMS AC Motion (0.01 – 200 Hz)	**RMS long term drift (1 week)**
Horizontal	Angle stability goal	0.53 μrad	1.0 μrad
	X-ray beam @ 18.6 m	10.3 μm	19.3 μm
Vertical	Angle stability goal	0.22 μrad	0.5 μrad
	X-ray beam @ 18.6 m	4.1 μm	9.4 μm

Final XBPM resolution / stability goals (50% of stability goals)

	RMS Resolution (0.01 – 200 Hz)	**RMS long term drift (1 week)**
Horizontal	7.3 μm	13.6 μm
Vertical	2.9 μm	6.6 μm

Existing APS Beam Position Monitoring – One Sector

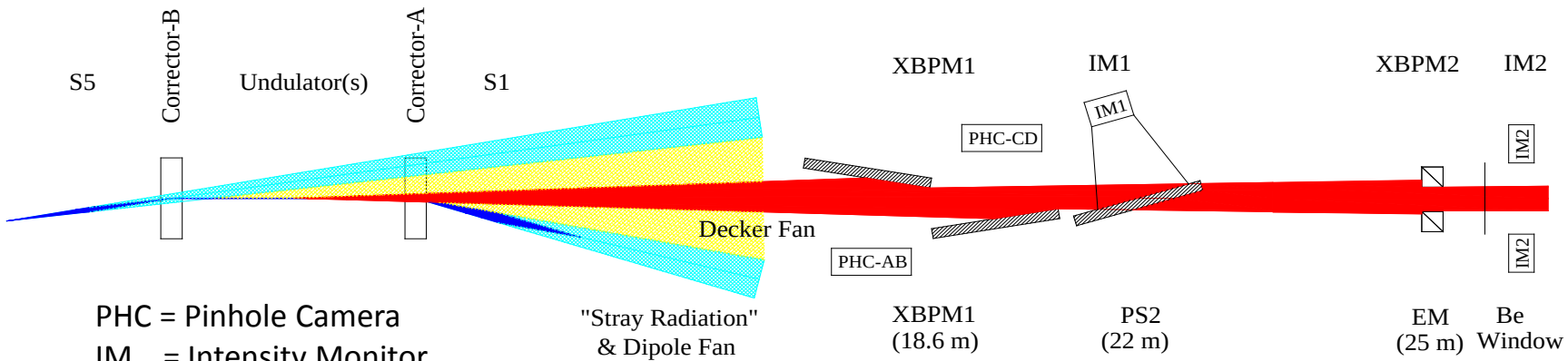


*PUE = Pickup Electrode
** AM/PM = Amplitude to Phase conversion

APS-U 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 units 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

Next-Generation X-ray BPM System



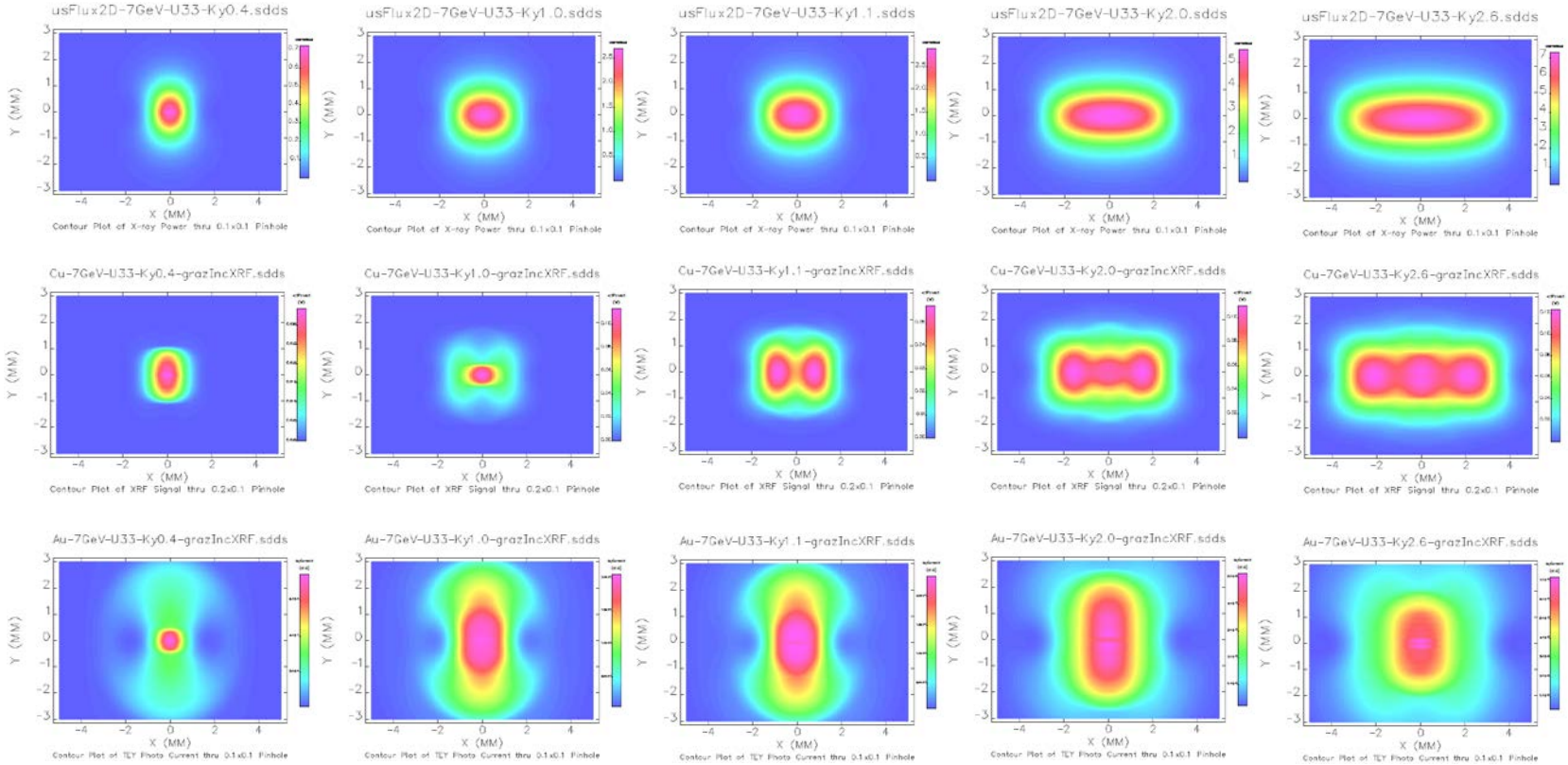
PHC = Pinhole Camera
IM = Intensity Monitor
PS = Photon Shutter
EM = Exit Mask

- Grazing incidence allows access to extremely high beam power (two U3.3 undulators at up to 150 mA).
- X-ray fluorescence reduces stray radiation background signals significantly.
- Use of two two-pixel (above, below midplane) pinhole cameras allow two independent measures of vertical x-ray beam position.
- Inboard / outboard difference provides measure of horizontal beam position.
- XBPM1 is referred to as the Grazing-Incidence Insertion Device X-ray Beam Position Monitor (GRID-XBPM).

Undulator radiation pattern depends on detector type

Example of Undulator A (3.3 cm period)

K (*Gap*)	0.4 (30 mm)	1.0 (20 mm)	1.1 (19 mm)	2.0 (15 mm)	2.6 (12 mm)
Power	usFlux2D-7GeV-U33-Ky0.4.sdds	usFlux2D-7GeV-U33-Ky1.0.sdds	usFlux2D-7GeV-U33-Ky1.1.sdds	usFlux2D-7GeV-U33-Ky2.0.sdds	usFlux2D-7GeV-U33-Ky2.6.sdds
XRF (Cu-K)	Cu-7GeV-U33-Ky0.4-grazIncXRF.sdds	Cu-7GeV-U33-Ky1.0-grazIncXRF.sdds	Cu-7GeV-U33-Ky1.1-grazIncXRF.sdds	Cu-7GeV-U33-Ky2.0-grazIncXRF.sdds	Cu-7GeV-U33-Ky2.6-grazIncXRF.sdds
TEY (Au)	Au-7GeV-U33-Ky0.4-grazIncXRF.sdds	Au-7GeV-U33-Ky1.0-grazIncXRF.sdds	Au-7GeV-U33-Ky1.1-grazIncXRF.sdds	Au-7GeV-U33-Ky2.0-grazIncXRF.sdds	Au-7GeV-U33-Ky2.6-grazIncXRF.sdds

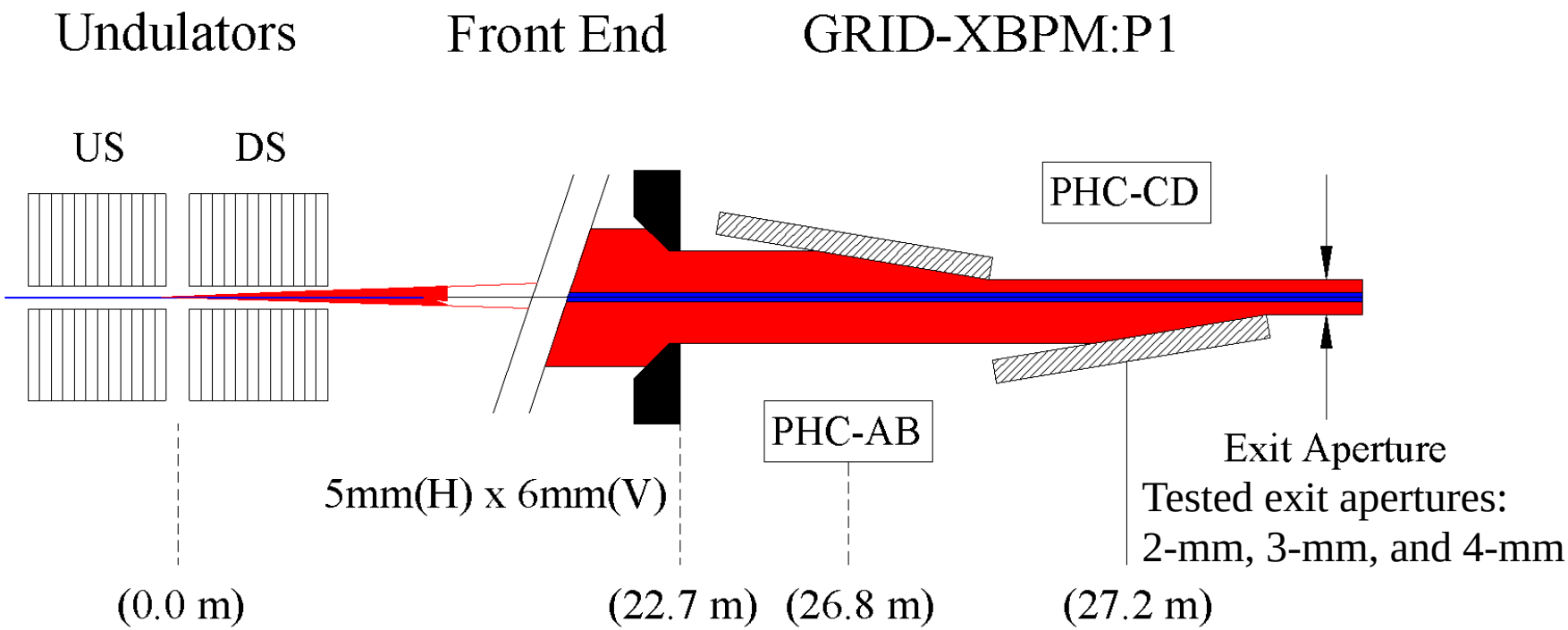


TEY (Au): Single, broader peak ➔ Easier XBPM design, dirty background

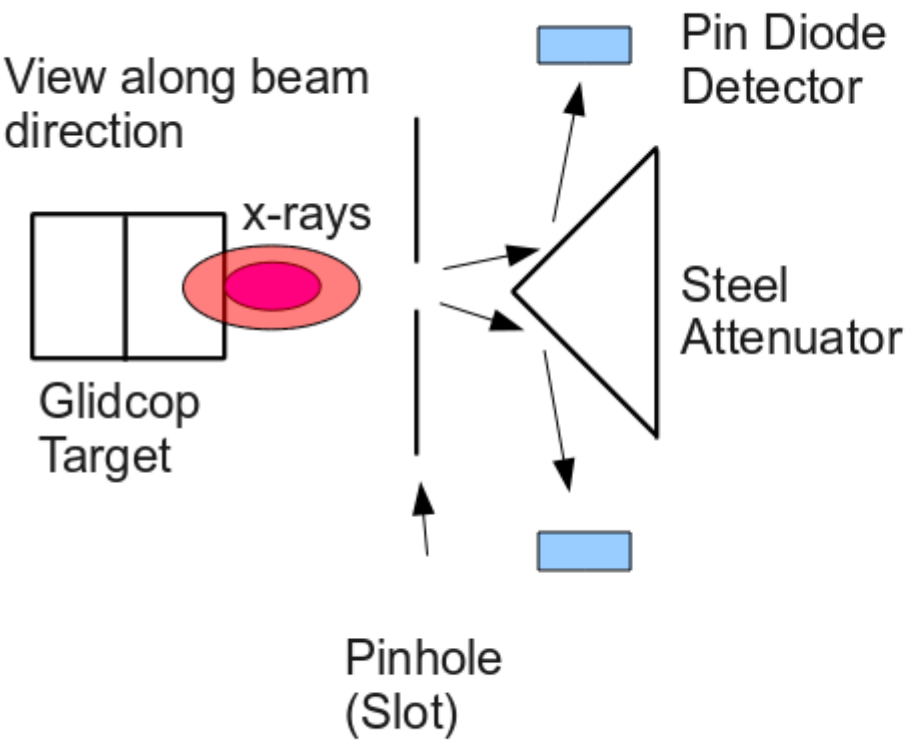
XRF (Cu GRID-XBPM): Narrow peak, lower background ➔ Harder design, clean performance

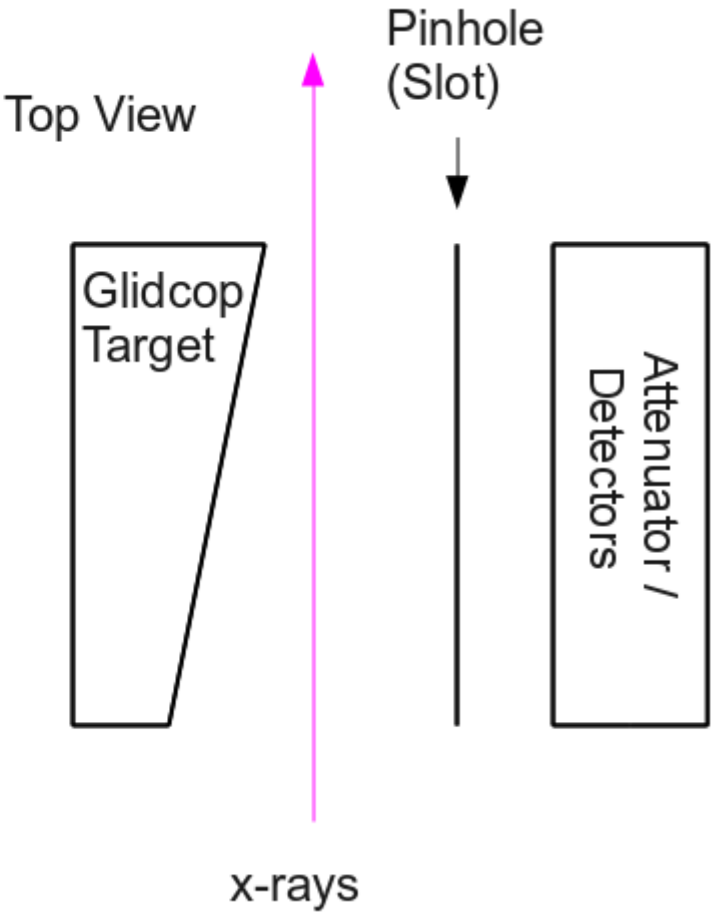
First high-power GRID-XBPM beam test in 29-IDA

- Two undulators delivered total power up to 11 kW (@100 mA)
- Absorbers on inboard and outboard sides of the beam axis. Difference in their XRF intensity gives horizontal position readout.
- Two pinhole cameras (CM-detector) measure vertical position and tilt.
- Tests ran from Jan. 26 to Apr. 3, 2012.

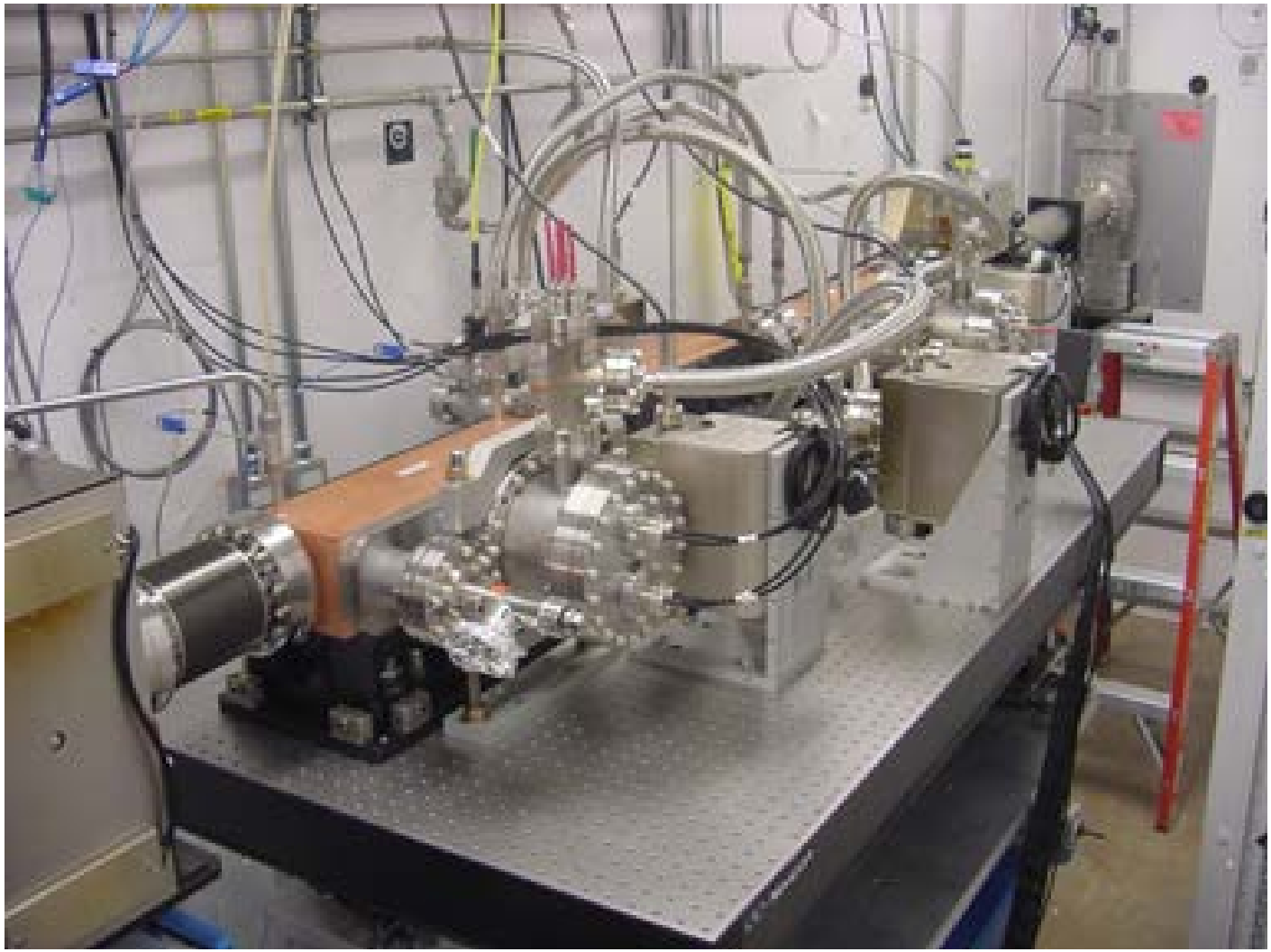


Pinhole Camera Detector Geometry



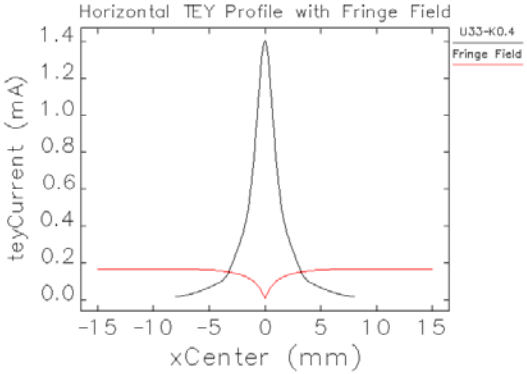


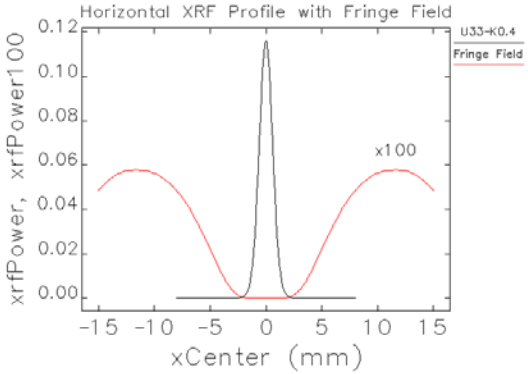
XBPM Tests at 29IDA

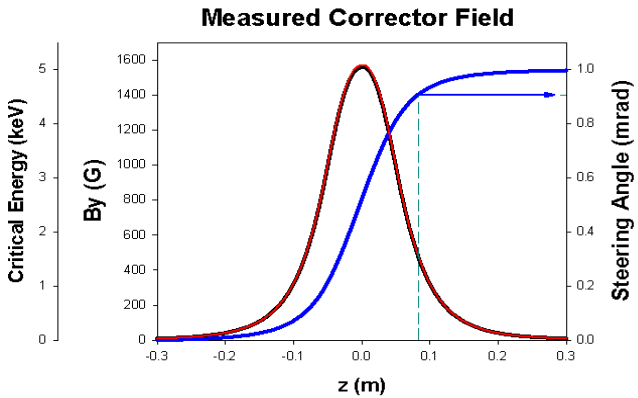


Bending Magnet Radiation Background

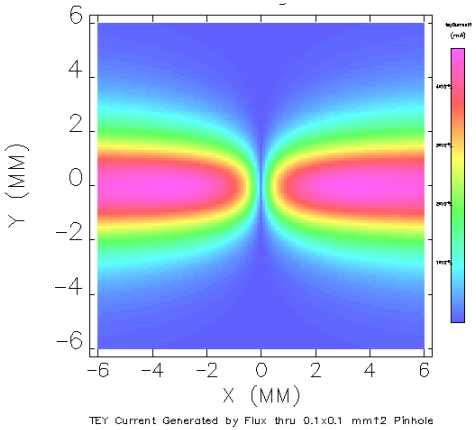
- Corrector field measurement data (C. Doose)
- Wiggler source program (R. Dejus, H. Shang)
- Compare with K = 0.4 (Gap ~ 30 mm)



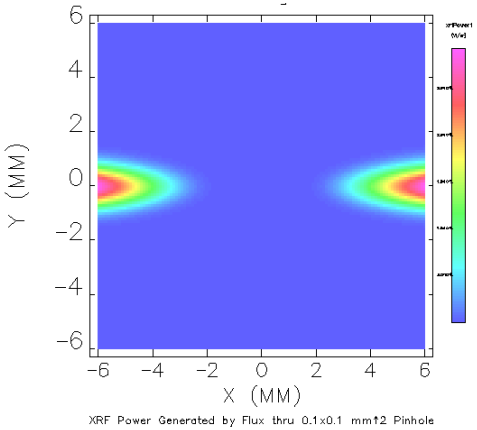




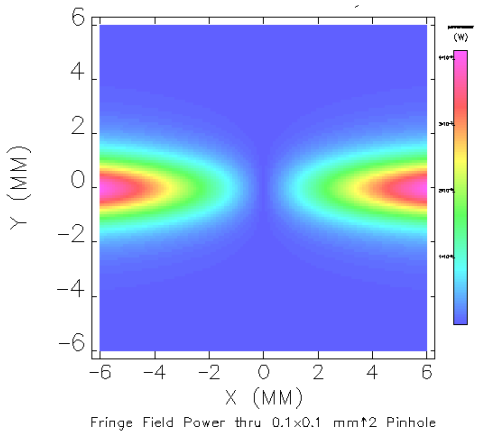
TEY (Au)



XRF (Cu-K)

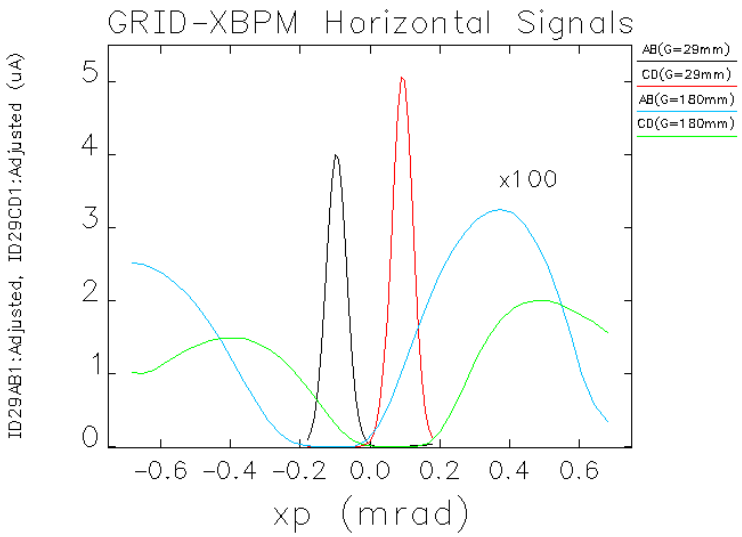


Total Power

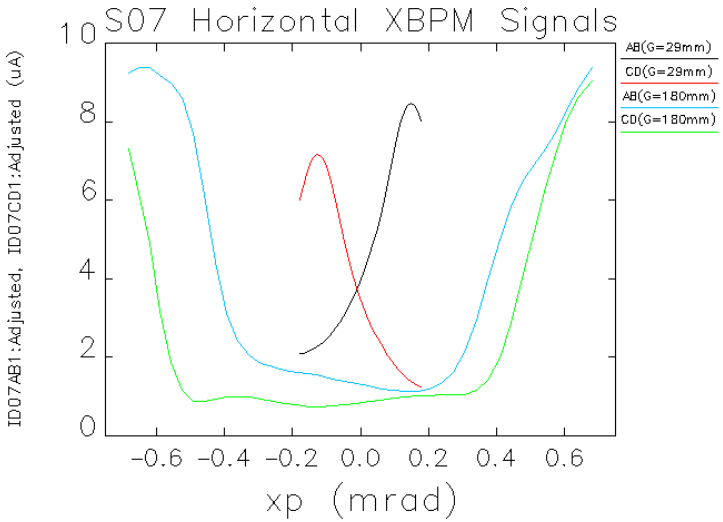


Measurements of background radiation*

- The electron beam was scanned horizontally in a wide angle range, with undulator gaps open (G_{max}=180 mm) for background, and closed (G = 29 mm, *K* ~ 0.4).



X-ray Fluorescence (Cu-K)

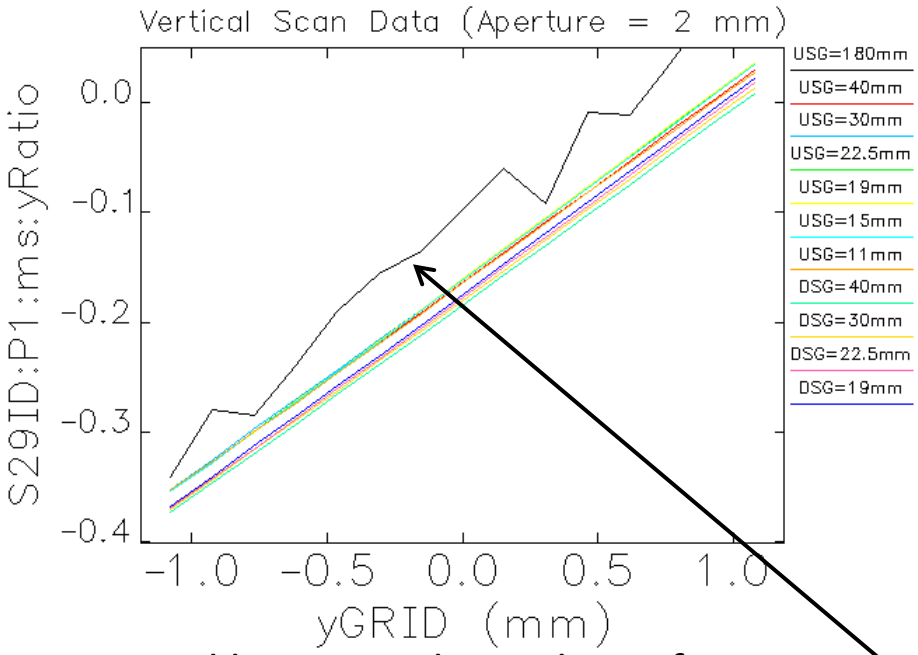


Photoemission (Au)

*Bingxin Yang, BIW12

GRID XBPM Design

- Final mechanical design for high-heat load front end GRID XBPM near completion.
- Canted design similar but rotated 90 degrees about the beam axis.

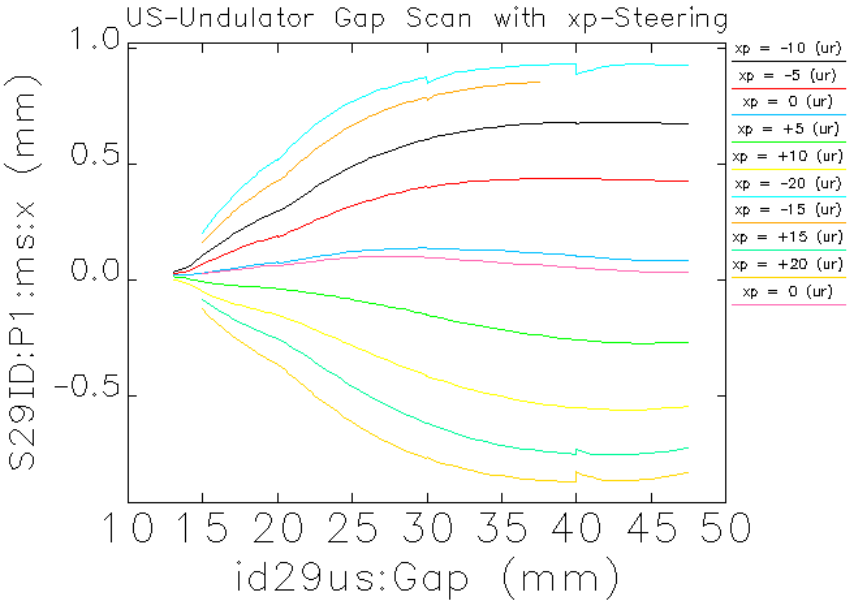


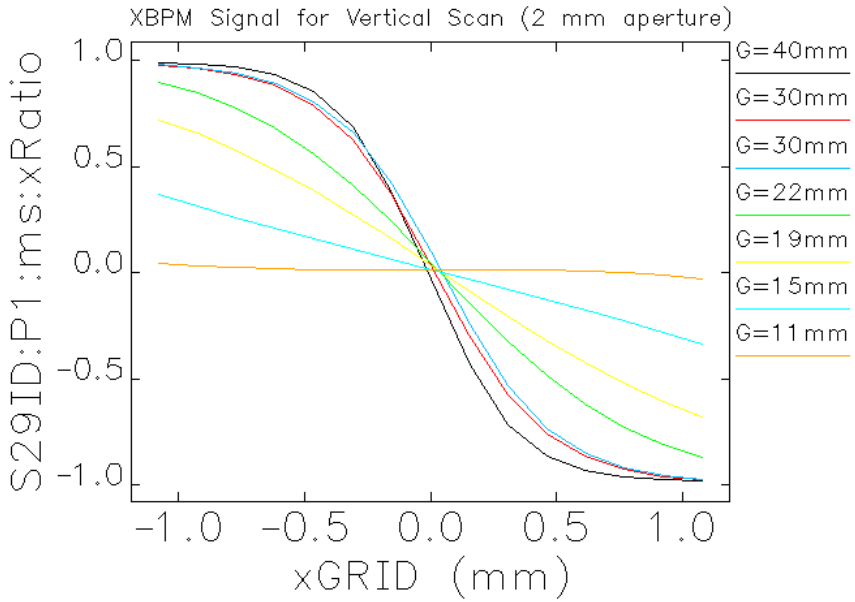
Calibration independent of gap, even with gap open(!)

Horizontal XBPM characterization

Horizontal XBPM is characterized using

- undulator gap scans at different angles (user run), or
- e-beam angle scans at different undulator gaps (machine studies).

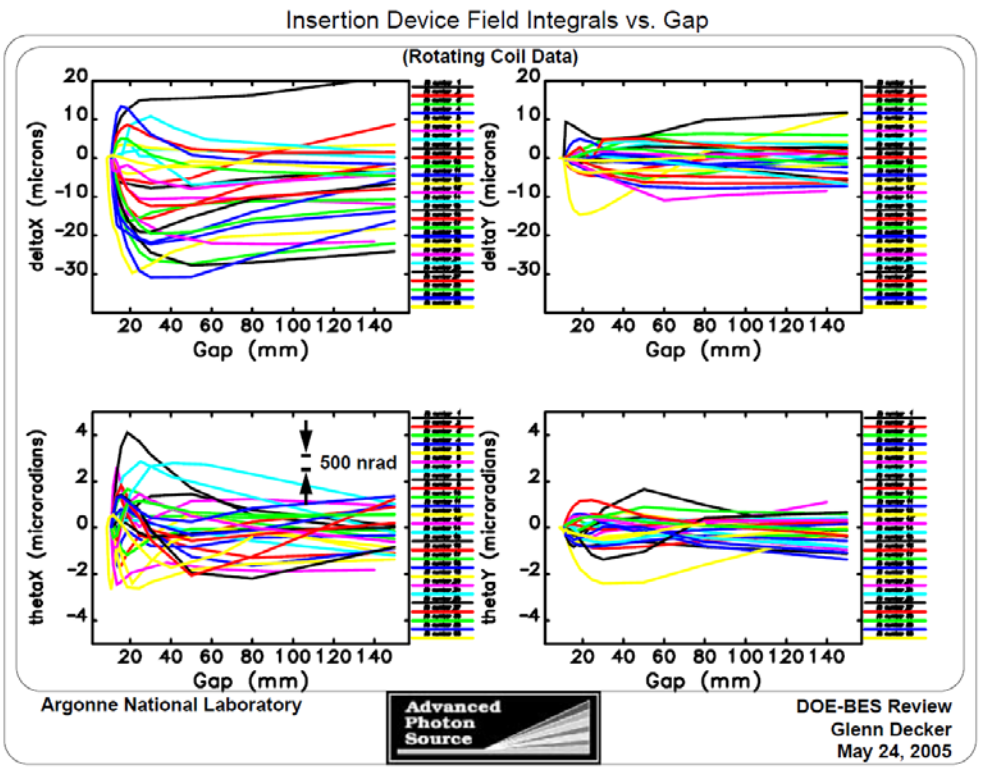


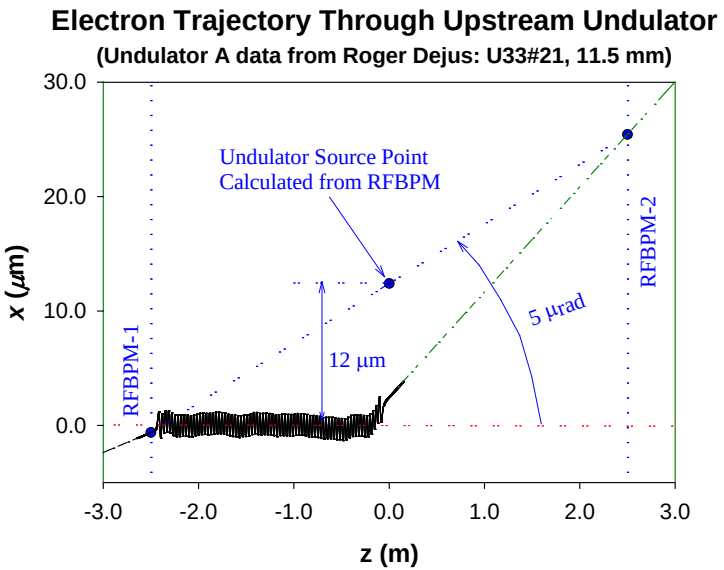


Loss of sensitivity at small gap a result of upstream limiting aperture

Internal Insertion Device Steering

- For a typical undulator: effective source point may shift by > 10 μm; effective beam angle may differ by more than 5 μrad.
- The shift depends on undulator gap (field).

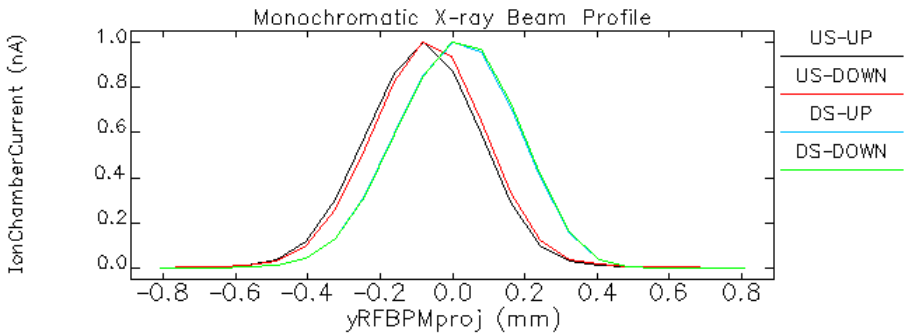


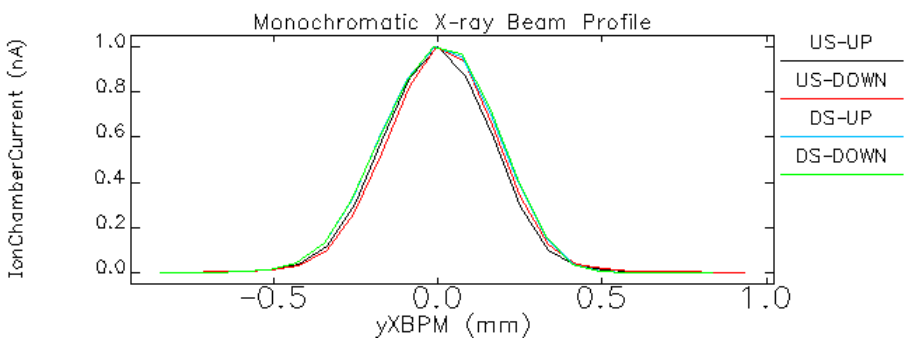


Undulator steering is ten times larger than APS-U Physics Requirements. We need a direct measurement of x-ray beam position.

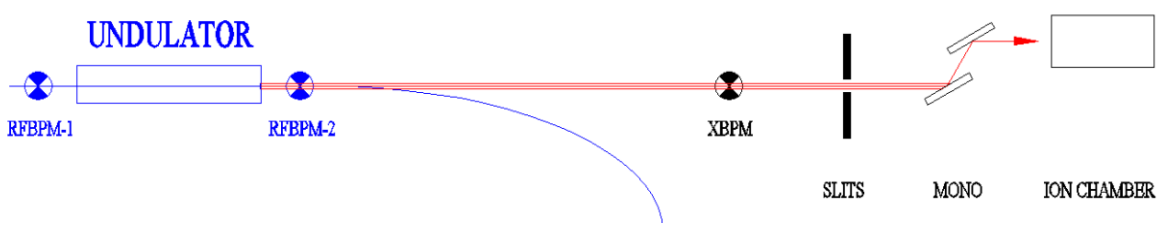
Mono beam profile measurements

- Use two RFBPMs to control electron orbit / scan e-beam angle
- Only one undulator (upstream OR downstream) is used at a time.
- A 90 micron shift between upstream and downstream undulators is seen.
- GRID-XBPM correctly reads the x-ray beam position.





Parameter	Value
Gap, G	25 mm
Energy, E_1	11.89 keV
Slits openings	1.0 mm (H) × 0.3mm (V)



Future Plans

- Final design of GRID XBPM for APS-U High Heat Load (HHL) front ends nearing completion. Long lead procurements to start in early November.
- First full high-power tests at 27-ID RIXS in 2014.
- Canted Undulator front end XBPM design is the primary activity in 2013.
  - Base design is essentially HHL-XBPM rotated 90 degrees about the beam axis, with 4 top + 4 bottom detectors vs. 2+2 for HHL.
- Alternate design using Compton scattering from Beryllium target being pursued with operations funding.

Summary

- First GRID XBPM high-power tests completed, extremely promising.
- Procurement for 27-ID RIXS imminent.
- Design / Development efforts in FY13 will focus on the canted undulator xbpm design.