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R&D at the APS Toward a Hard X-ray Beam Position Diagnostic

Glenn Decker
Advanced Photon Source
NSLS II XBPM Mini-workshop

U.S. Department of Energy

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U.S. DEPARTMENT OF ENERGY

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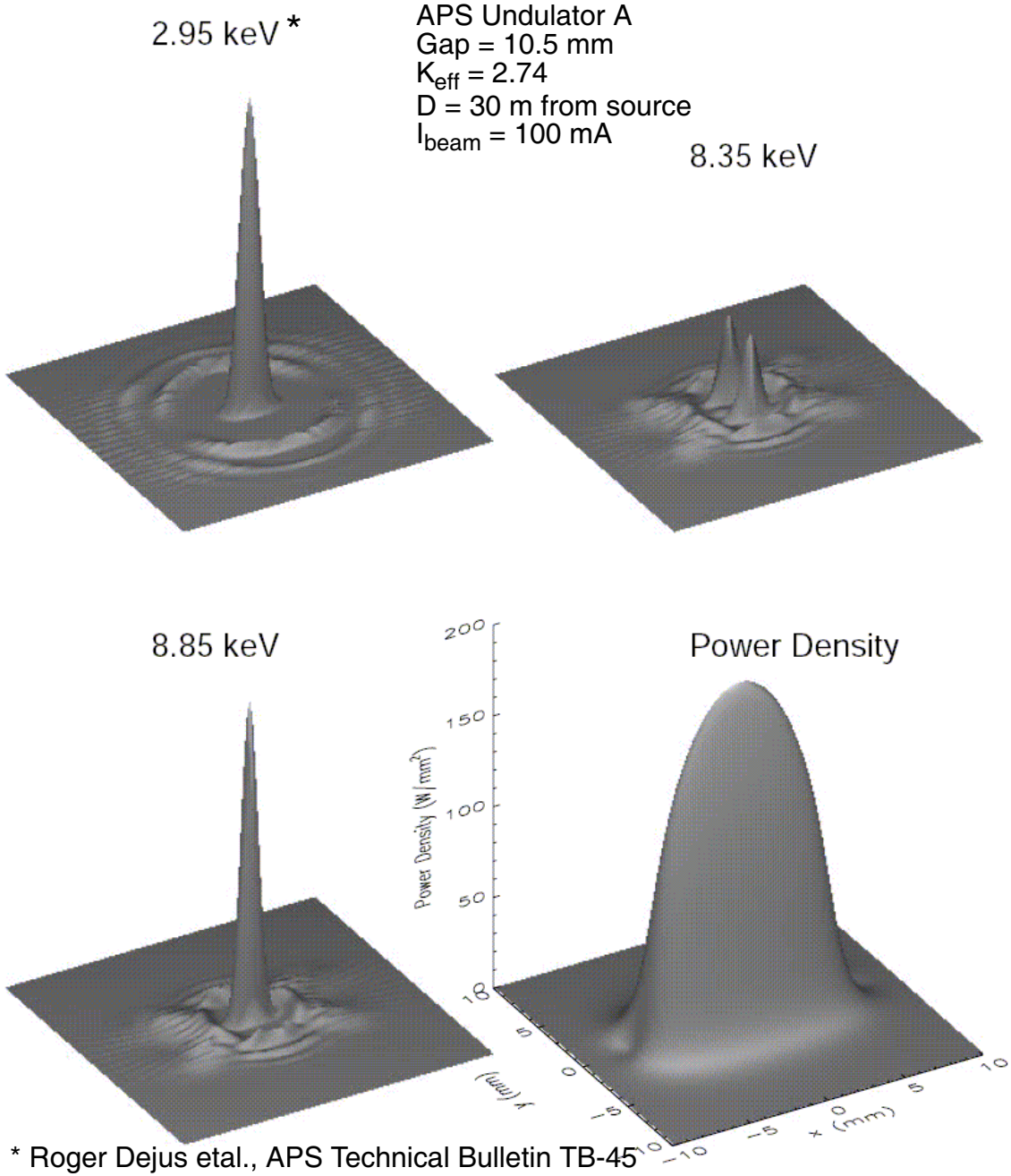
Recent Research on the Development of a Photon BPM Sensitive Only to Hard X-rays



- Ultraviolet photon bpms suffer from

  - stray radiation sources, reflections,
  - space charge effects,
  - indirect measure of the mythical hard x-ray core.

- A collaboration with a resident beam-line scientist was started in 2005 to develop a white-beam hard x-ray bpm, based on a monochromatic version developed several years ago.**

- A spare monochromator vacuum enclosure at APS beamline 19-ID was modified to allow testing of several concepts including

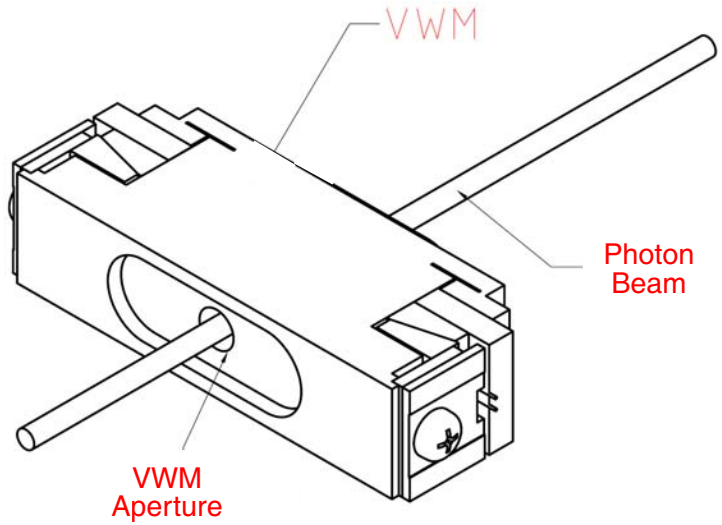
  - direct power measurement using a vibrating wire monitor (VWM) developed at the Yerevan Physics Institute.

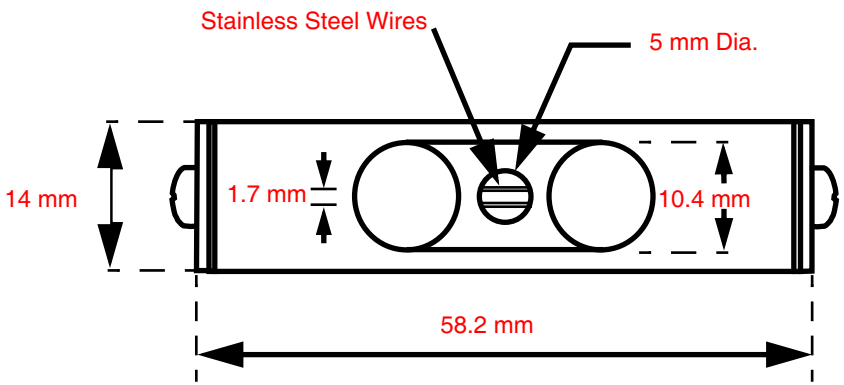
  - pin-diode detection of 9 keV copper fluorescence,

* Roger Dejus etal., APS Technical Bulletin TB-45
http://www.aps.anl.gov/Science/Publications/techbulletins/tb45.pdf

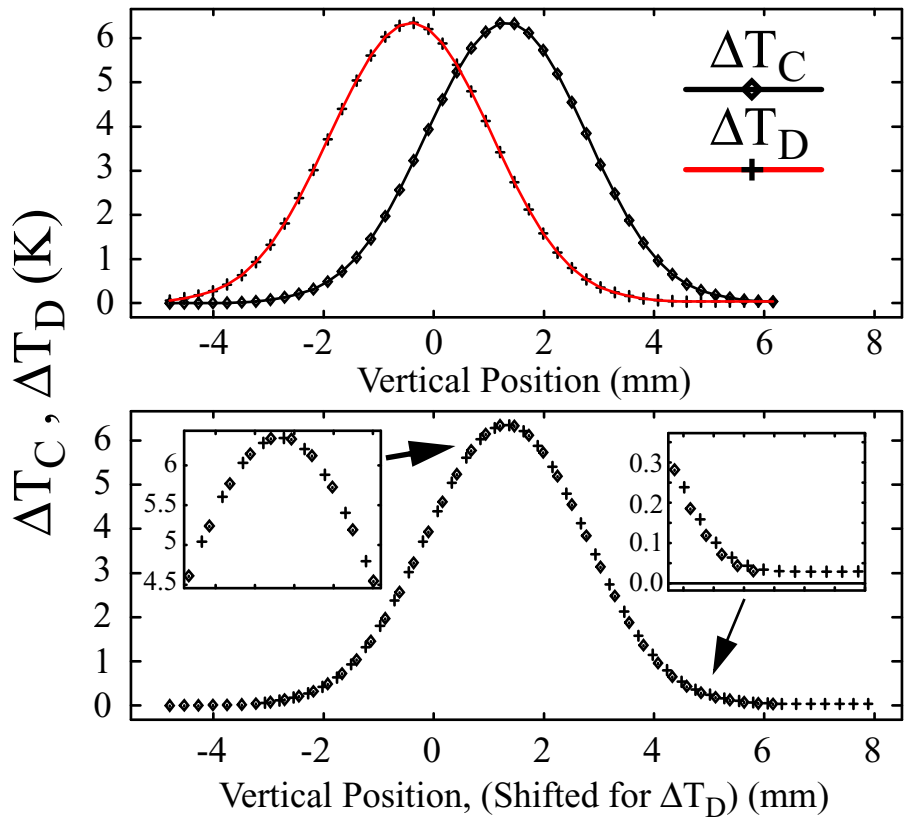
** R. Alkire, G. Rosenbaum, G. Evans, J. Synchrotron Rad. **7**, 61-68 (2000)

Undulator Beam In-Vacuum Vibrating Wire Monitors (VWM) Measurements*





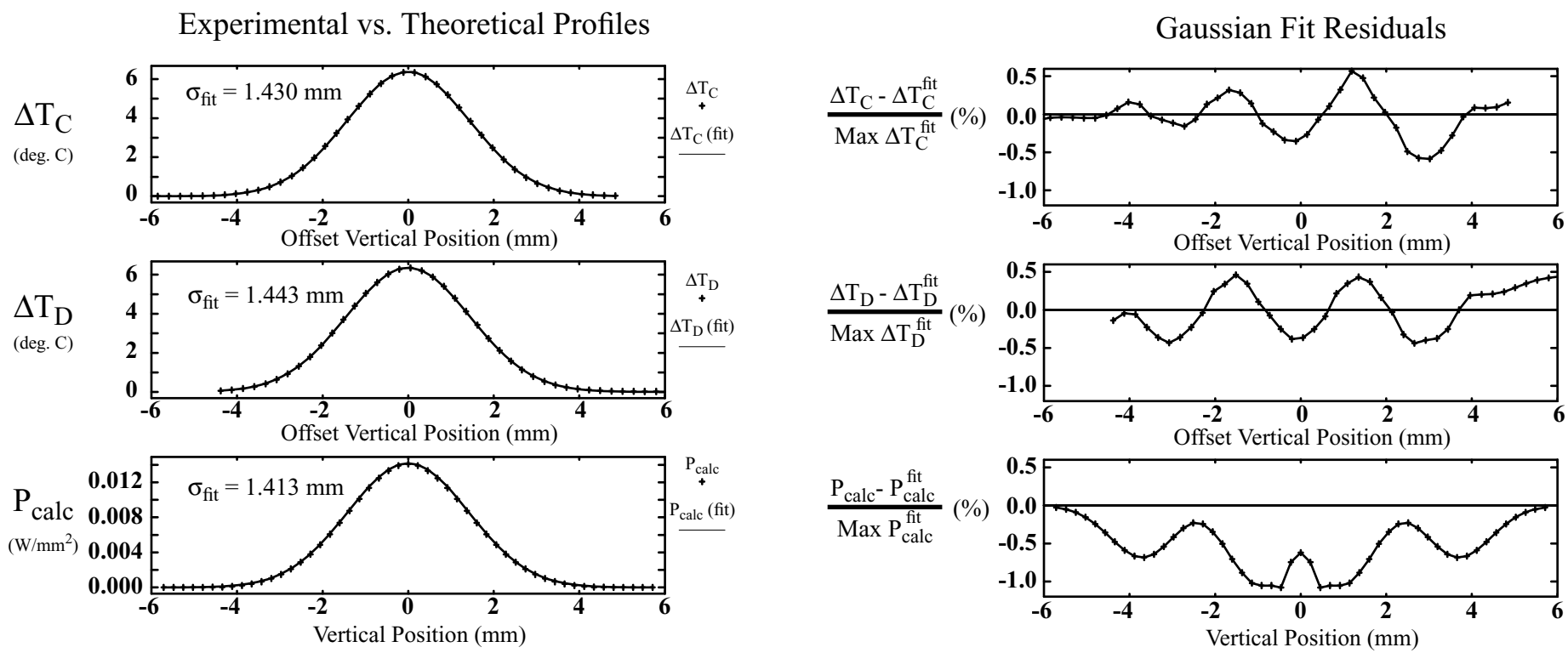
Experimental Results**



* G. Decker, S. Arutunian etal, DIPAC 2007

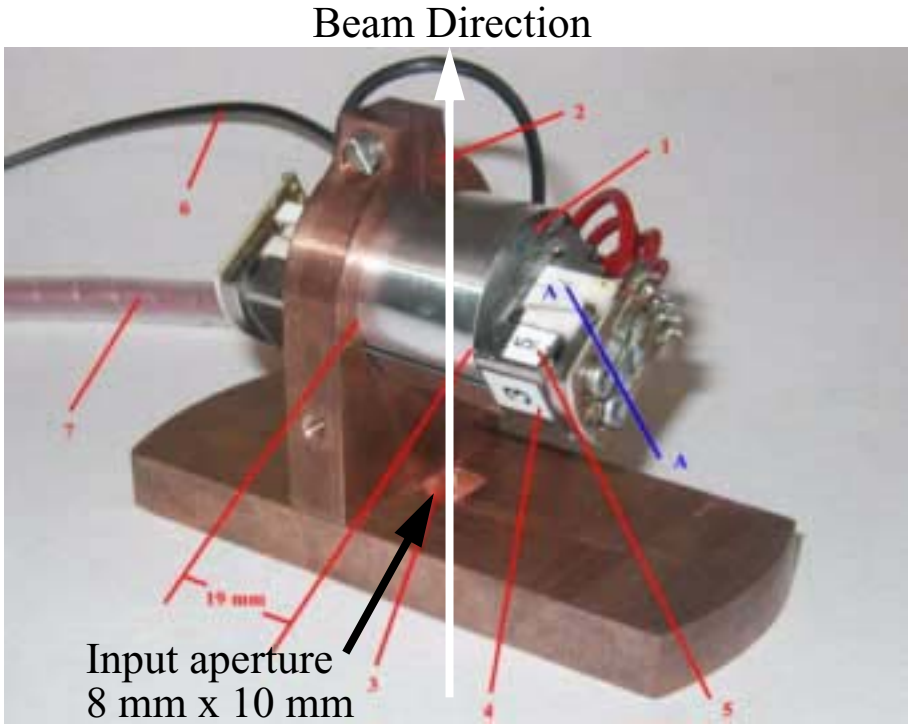
**Standard APS undulator A at 65 mm gap

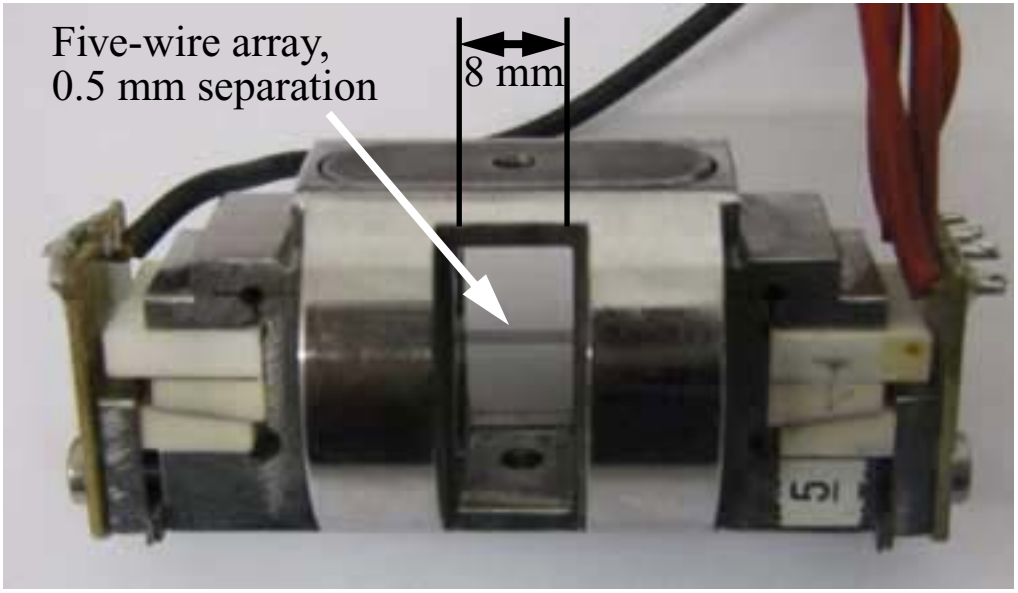
Undulator Beam Vibrating Wire Monitors (VWM) Measurements cont'd*

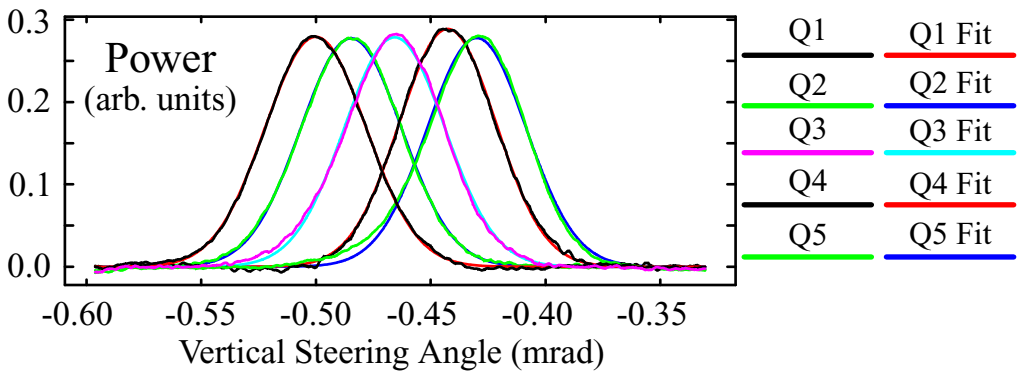


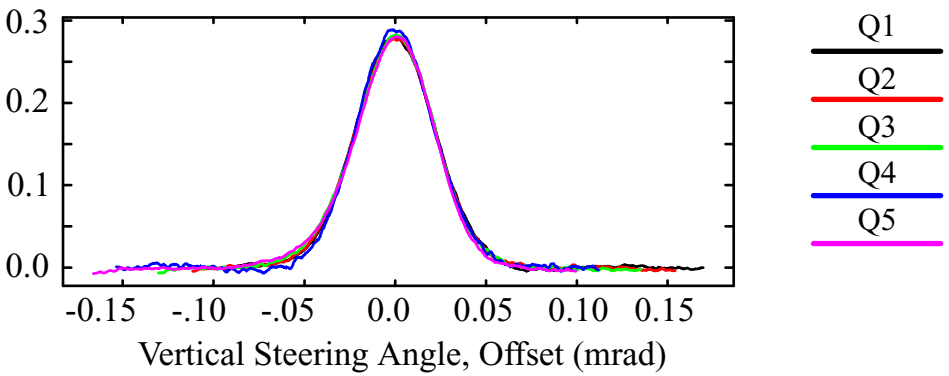
* G. Decker, S. Arutunian etal, BIW 2008

Five-wire In-Air Vibrating Wire Monitor for Vertical Profiling of Bending Magnet Radiation*



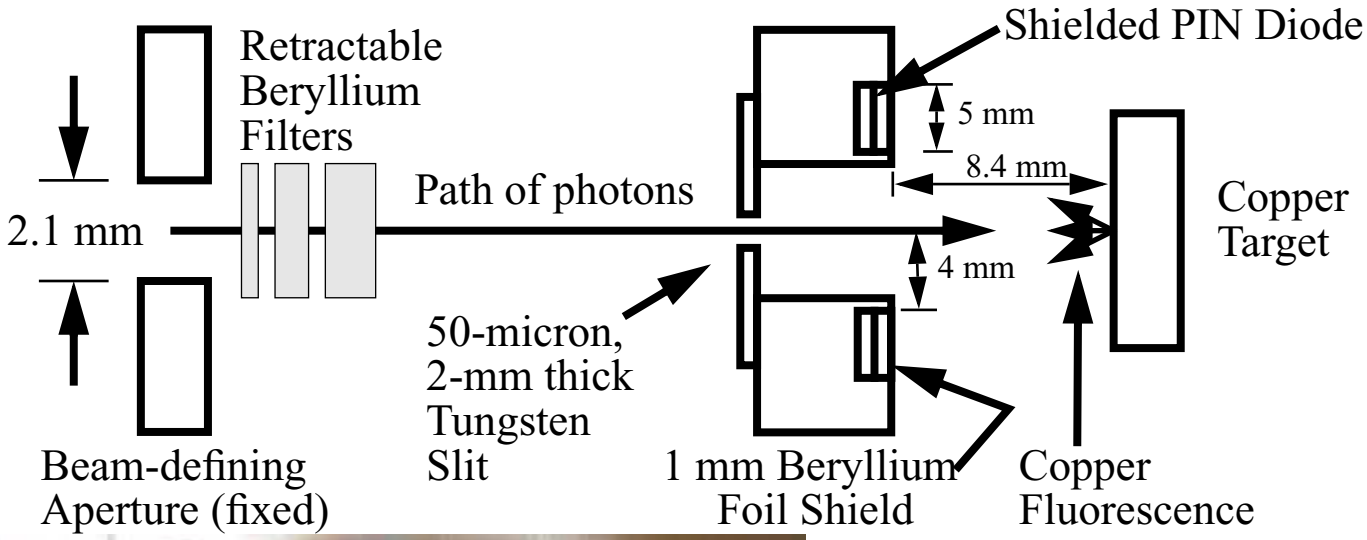


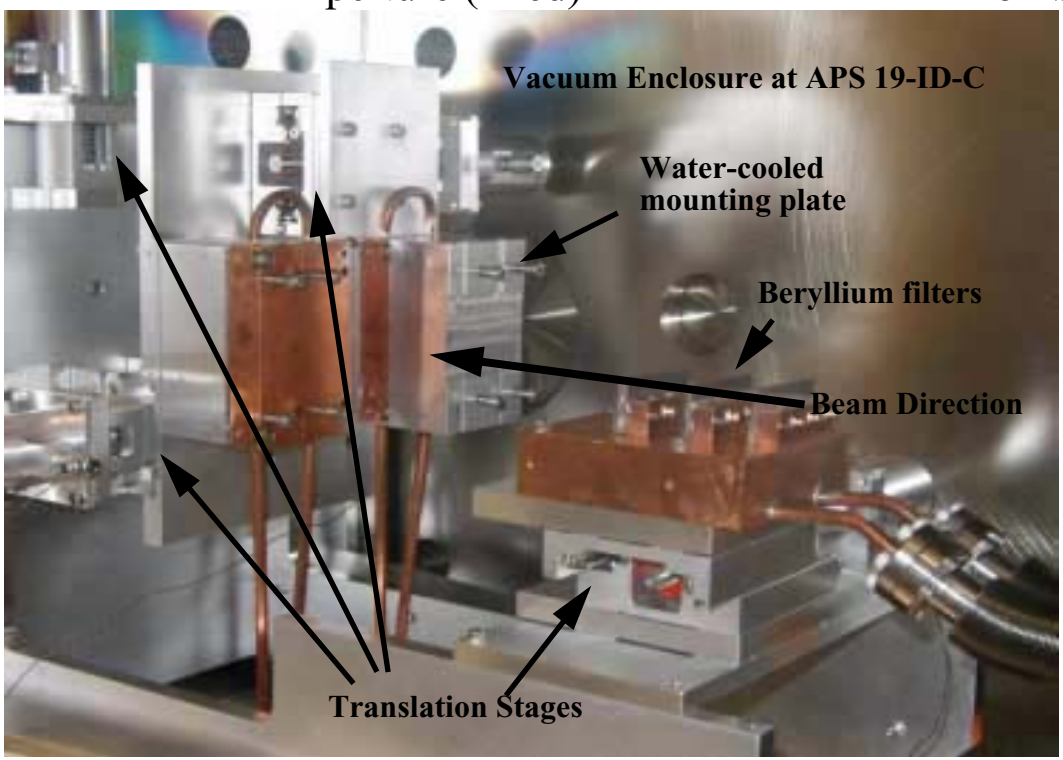


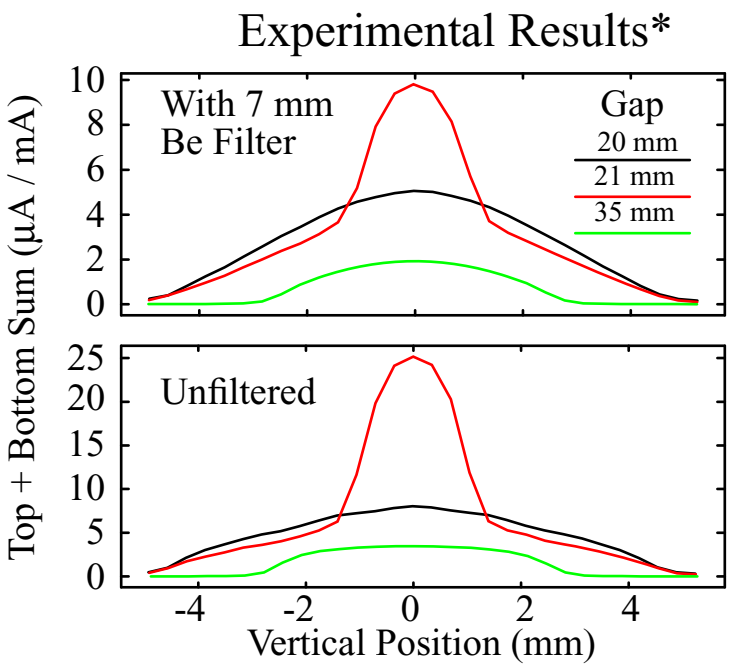


* G. Decker, S. Arutunian etal, BIW 2008

Experiment at APS 19-ID-C (c. 2006-2007)







* G. Decker, etal. PAC 2007, pp. 4342-4344

S35 Flux Monitor Mechanical Design

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Motivation

We aim to develop a hard x-ray beam monitor based on the work of Decker et al*. The device will be used to:

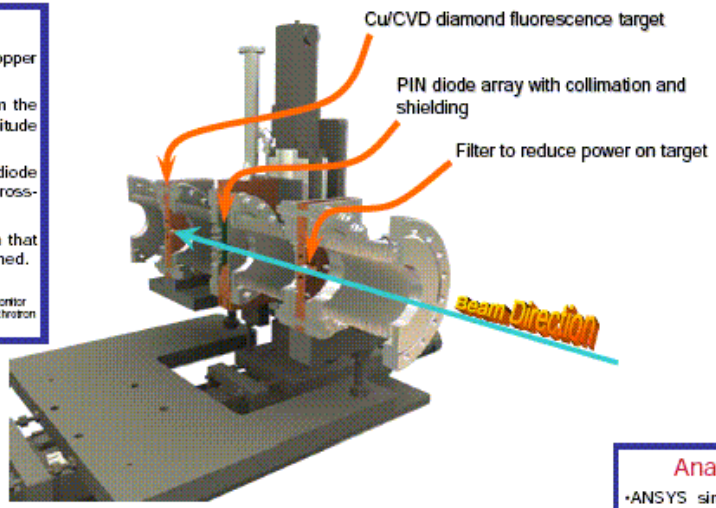
- maximize the undulator flux downstream from the exit mask on any beamline, and
- function as a position monitor upstream of the exit mask and an intensity monitor downstream of the exit mask.

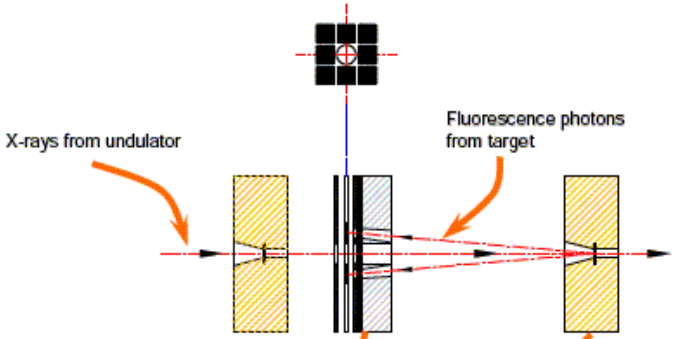
*Decker, G. A., Den Hartog, P., Singh, O., and Rosenbaum, G. (2007). "Progress toward a hard x-ray insertion device beam position monitor at the Advanced Photon Source," in *PAC07* (Albuquerque, NM).

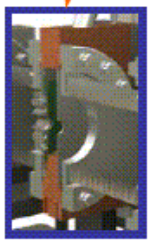
Principle of operation

- Intercept the x-ray beam with a thin copper target.
- Use the copper K-edge fluorescence from the target as an indicator of x-ray flux magnitude and position.
- Measure the fluorescence with a PIN diode array.* Collimation and shielding prevent cross-talk and keep the background noise low.
- Process the signals from the diodes such that beam intensity and position can be determined.

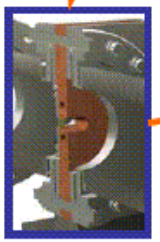
*Alkire, R. W., Rosenbaum, G., and Evans, G. (2000). "Design of a vacuum-compatible high-precision monochromatic beam-position monitor for use with synchrotron radiation from 5 to 25 keV," Journal of Synchrotron Radiation 7, 61-68.







PIN diode array



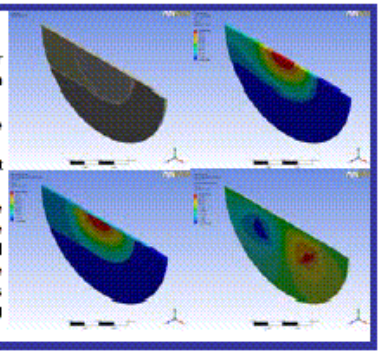
Cu/CVD diamond target.

Engineering Approach

- The physical constraints were met with a compact and modular design.
  - ✓The assembly is relatively short in length.
  - ✓The components are modular and can be reconfigured.
  - ✓The attenuation, diode array, and target are all built into vacuum flanges.
- The target was designed such that it can be moved in and out of the beam without exposing highly absorptive, normal surfaces to the beam.
- The copper target was deposited on a highly conductive, and minimally absorptive chemical vapor deposition diamond substrate.
- A filter assembly was designed to fit upstream of the PIN diode array. This will provide attenuation to keep the delivered power to the target within the design limits.

Analysis

- ANSYS simulations for the heatload from an undulator-A revealed:
  - –a maximum temperature of 195°C, and
  - –a maximum equivalent stress of 467 MPa.
- The results show while the stress level in the copper is above the yield point of 33 MPa, the temperature remains well below the melting point of 1083°C.



Engineering Challenges

- Design a compact device that could fit in a minimum amount of space for a reasonable cost.
- Design the target such that it could be moved in and out of the beam without closing the photon shutter.
- Develop a target that could provide sufficient fluorescence signal while not absorbing too much power.
- Design the target and necessary attenuation such that the device could be used with dual in-line undulators and 200mA of current.

Planned tests

Previous tests by Decker et al have proven the fluorescence beam monitor concept at low power. Currently planned tests are intended to:

- verify the survivability of the copper target at elevated temperature (not in an x-ray beam),
- verify the survivability of the copper target when exposed to an attenuated x-ray beam,
- investigate the feasibility of insertion of the monitor without closing the shutter, and
- assay the performance of the PIN diode/fluorescence monitor.

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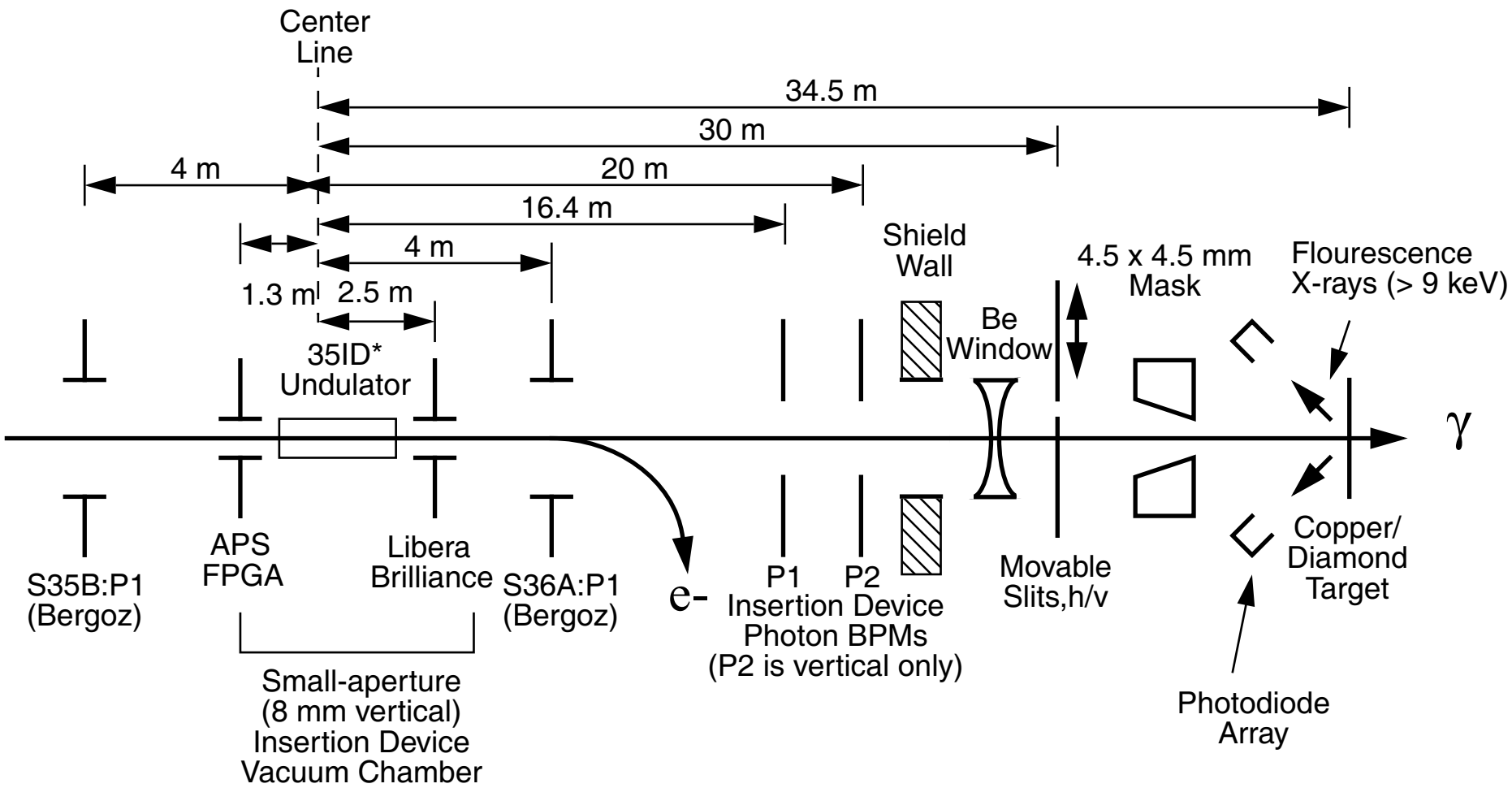
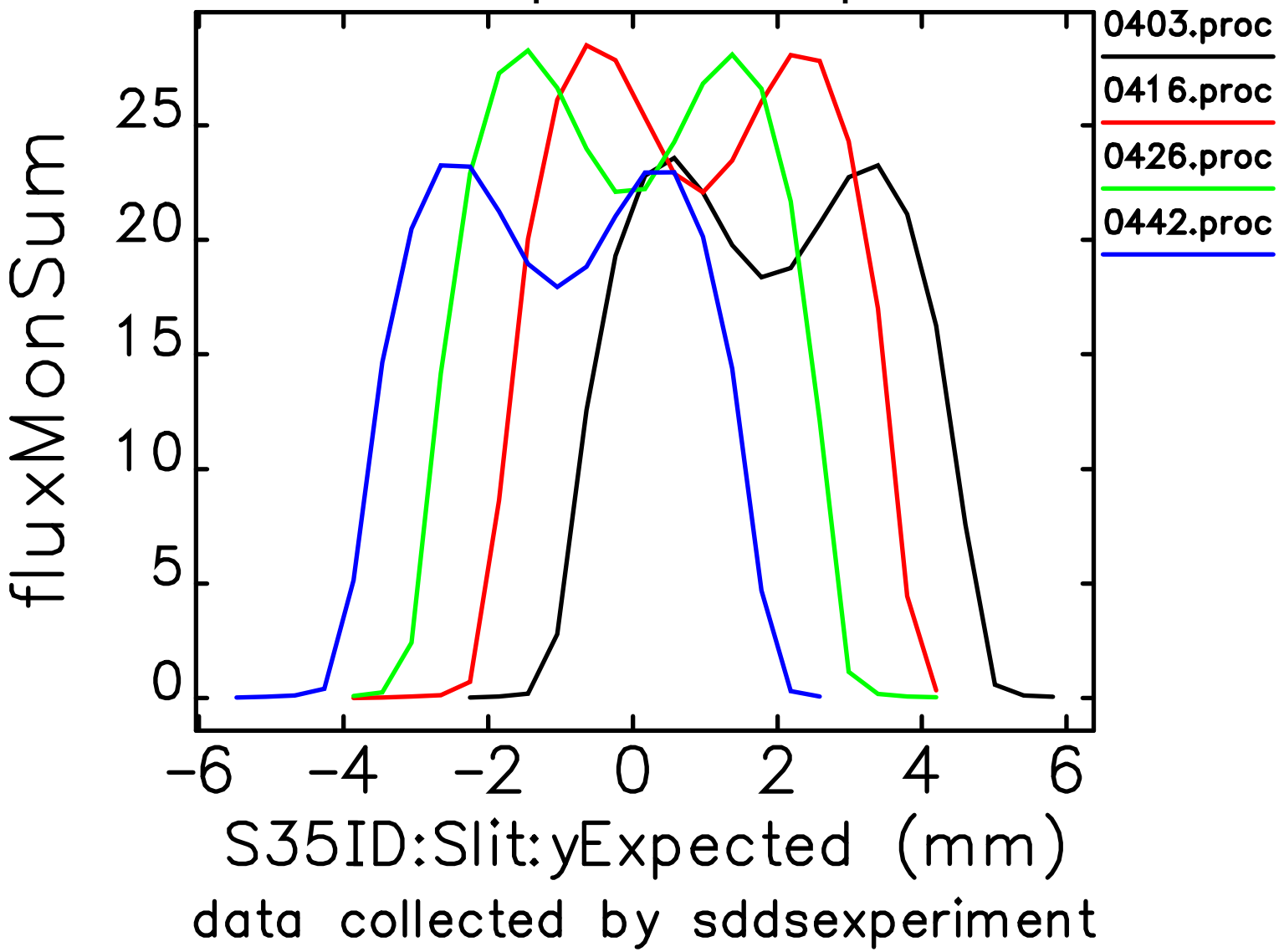
*This work is supported by The U.S. Department of Energy, Office of Basic Energy Sciences, under contract No. DE-AC02-06CH11357

Diagnostic Instrumentation Arrangement at APS Sector 35 ID Line (12/2008 - 2/2009)



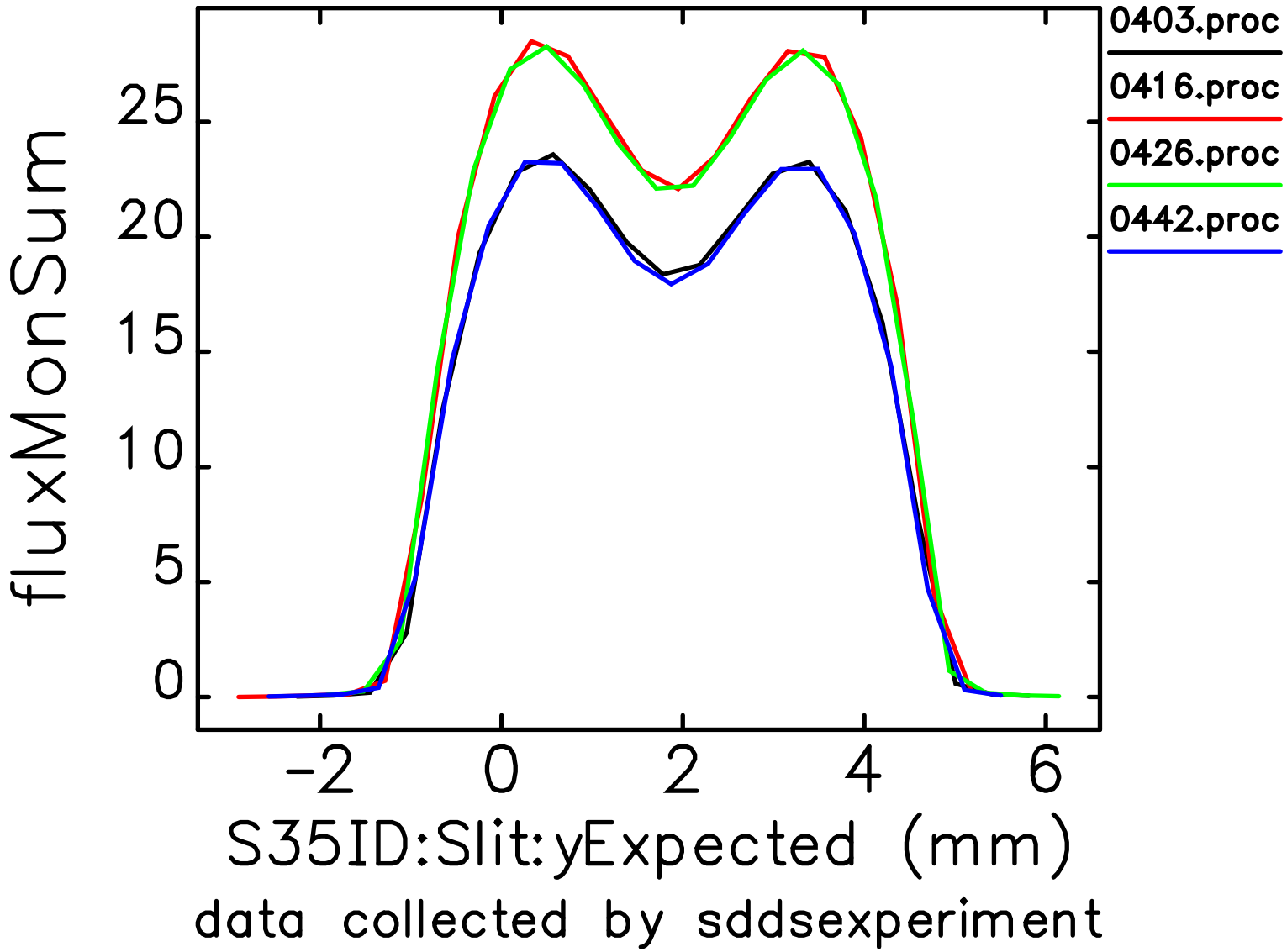
* 1.8 cm period hybrid undulator

Data Collected by Scanning the Beam Across a 250-micron Horizontal Slit, for Four Vertical Slit Locations Displaced in Steps of 1.0 mm*



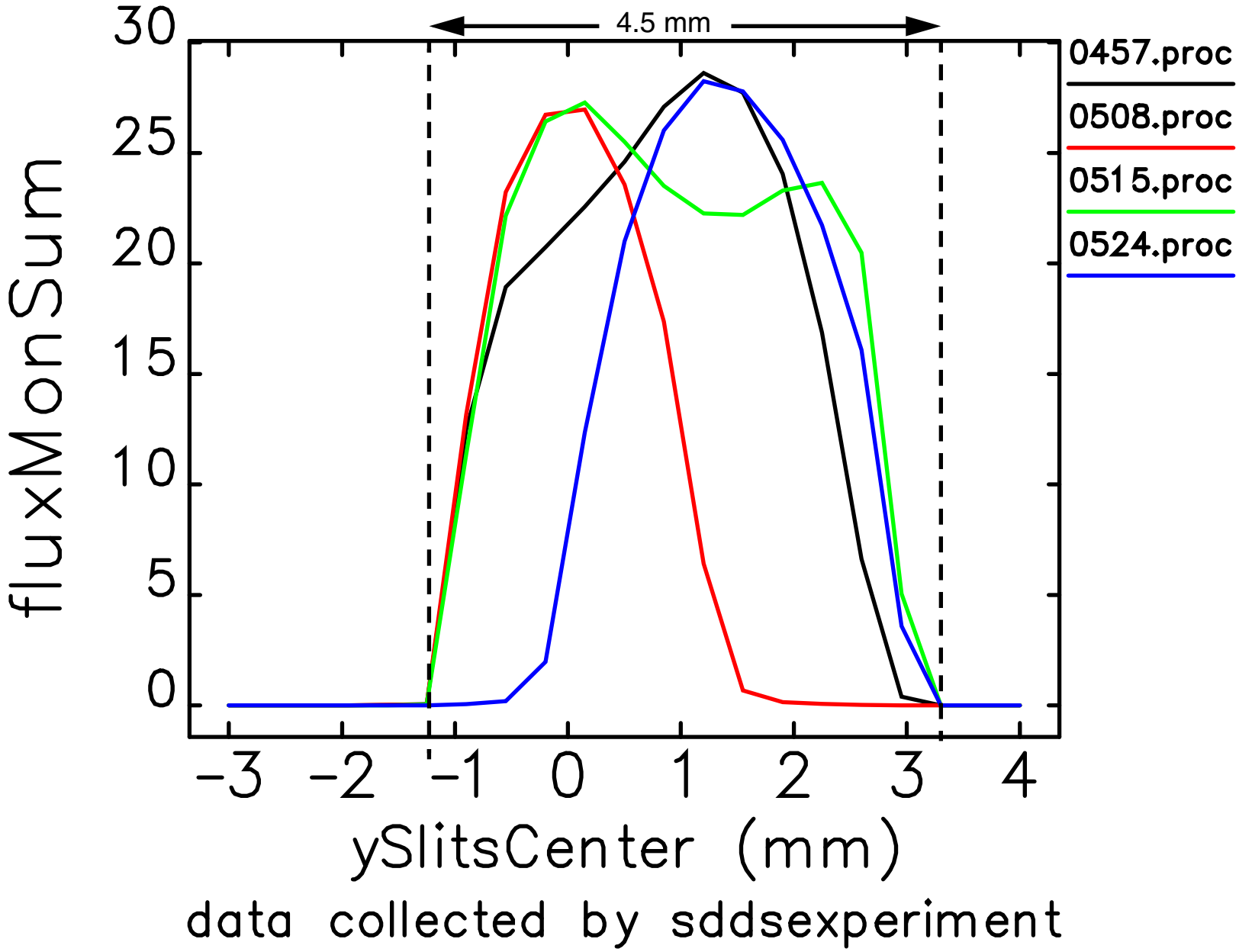
*As determined from dial indicator

Beam Scan Data, Shifted by Increments of 0.9725 mm*

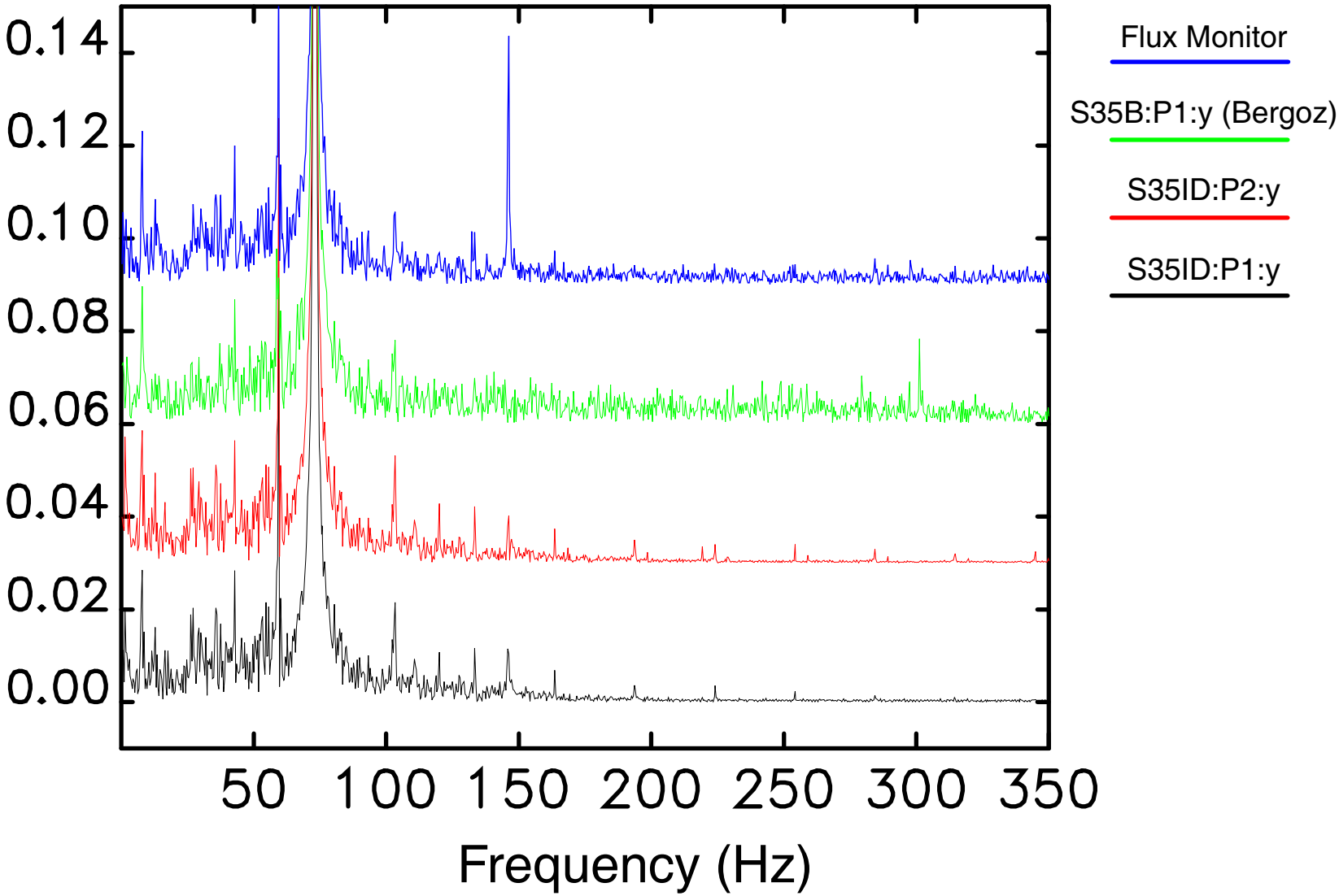


* As determined by lattice model, extrapolated to slit position

Result of Scanning Slit Across Beam, for Four Different Beam Steering Settings



Simultaneously Acquired Spectra, Normalized to Common 73 Hz Drive Source



Conclusions

- Direct access to photon beam position monitor data from the accelerator control system is critical to providing 100 nanoradian-scale pointing stability.
- Ultraviolet-sensitive detectors have many problems.
- Upstream of the monochromator, the beam size is of scale $1/\gamma$ vert, K/γ horz. , while what gets through the monochromator is much smaller - most of the photons are available for position monitoring and control.
- Moving the detector is almost never the equivalent of moving the beam. If beam motion sensitivity is desired, the only way to measure it is by moving the beam, not the detector. This is a result of upstream apertures primarily, but also may result from in-line windows with funny shapes.
- APS has developed two reasonably new technologies for beam position detection of hard x-rays :

  - Copper back fluorescence
  - Vibrating Wire Monitor

- The diagnostics beamline at APS 35-ID provides a powerful tool to quantify multiple independent beam position monitoring technologies - 6 and counting.