Application of Phase Space Beam Position and Size Monitor for Synchrotron Radiation

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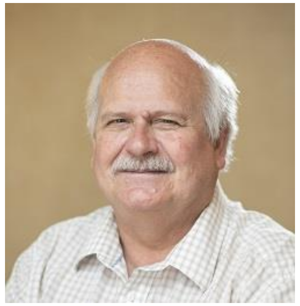
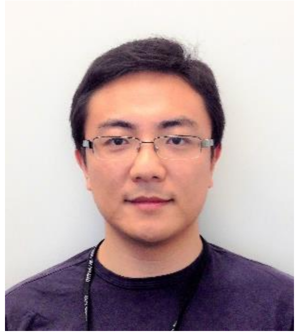


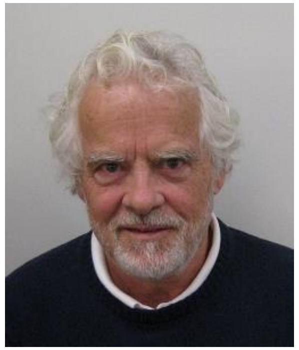
Xianbo Shi

Advanced Photon Source



Les Dallin

Canadian Light Source



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APS Machine

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APS Beamline

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Albert Macrander

Plan

- Motivation
- The system
- Results
- Optimization
  - APS-U simulations
- Conclusion
- References

Motivation: Source monitoring & Data Correction

- New generation light sources with small emittance
- MBA Lattice

$$\varepsilon \propto \frac{E^2}{(N_s N_d)^3}$$

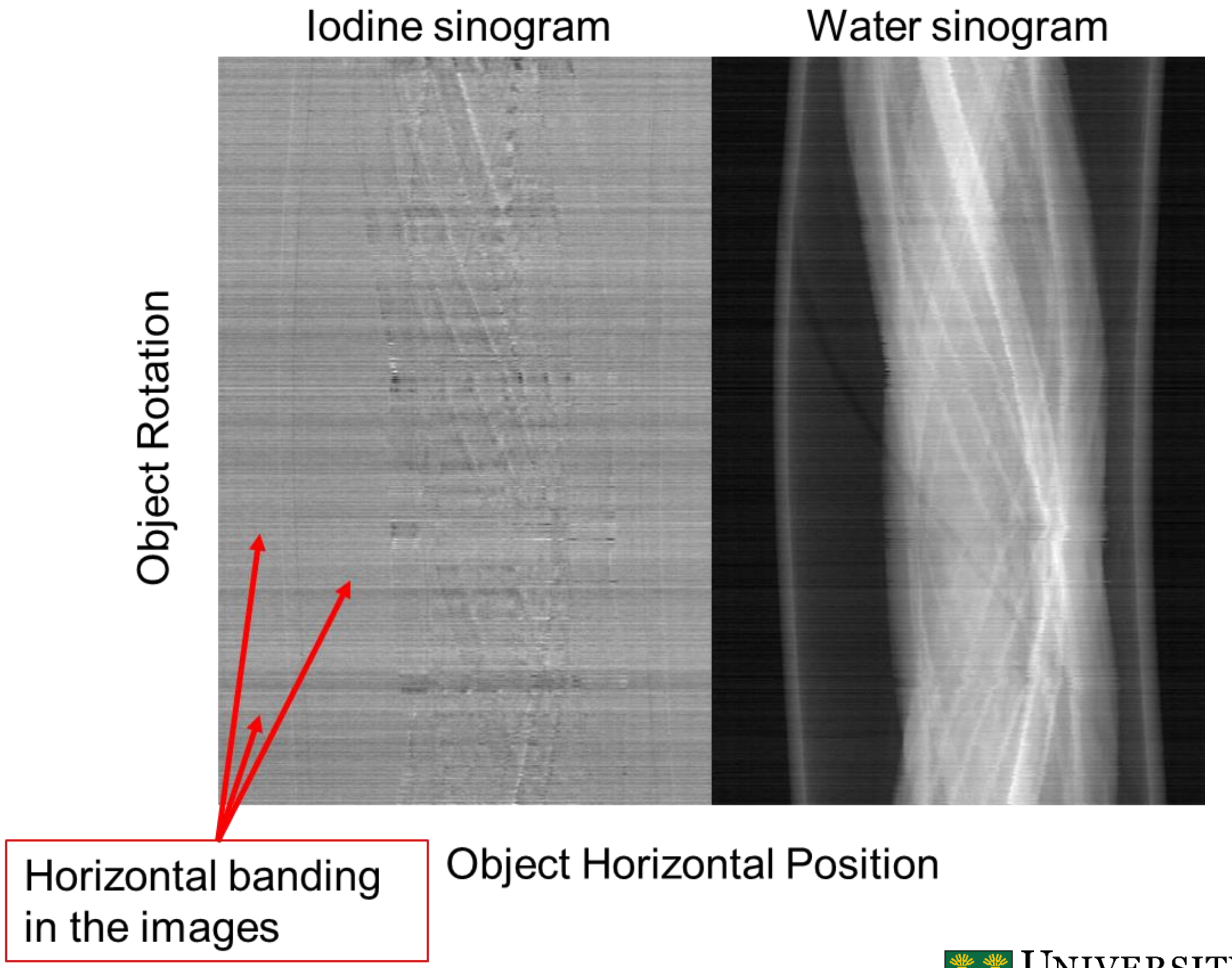
$$\varepsilon_y \propto \sigma_y \sigma_{y'}$$

Ns: # sectors in the ring

Nd: # dipoles/sector

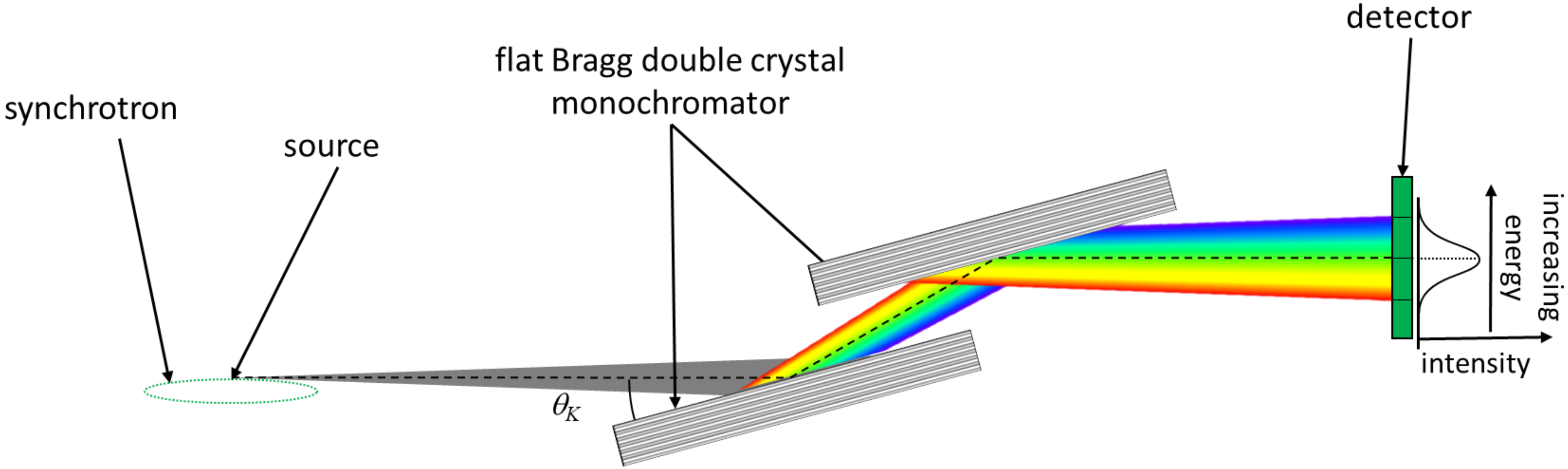
- Beam stability and source size measurements challenging and important.

What Happens When the Beam Moves?



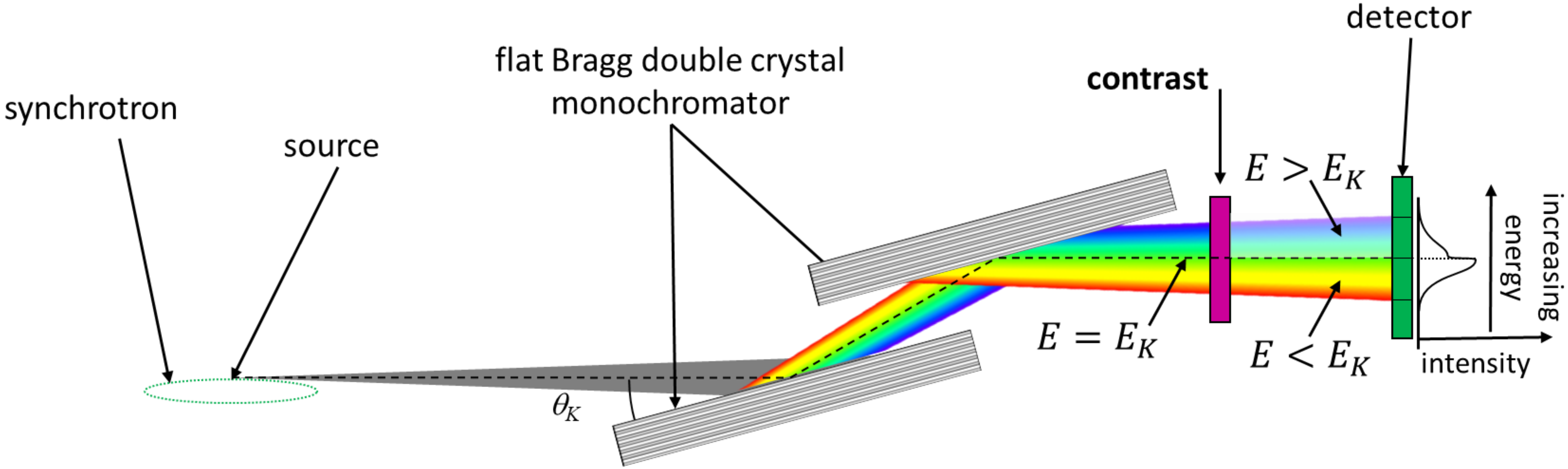
Double Crystal Monochromator

- Double Crystal Monochromator (DCM), Creates a nearly monochromatic beam

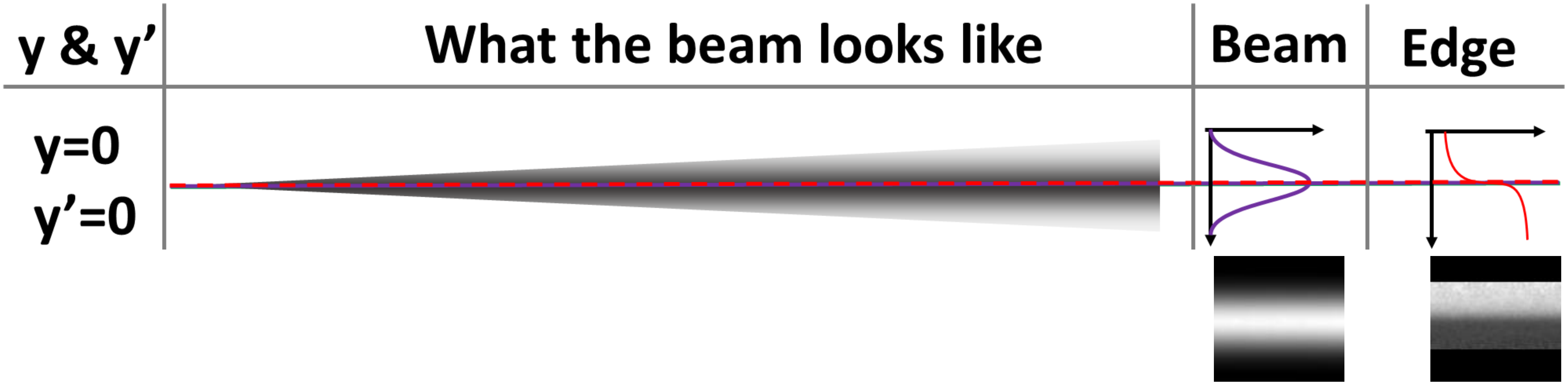


DCM @ K-edge Absorption

- Some of the beam above and some of the beam below the edge energy

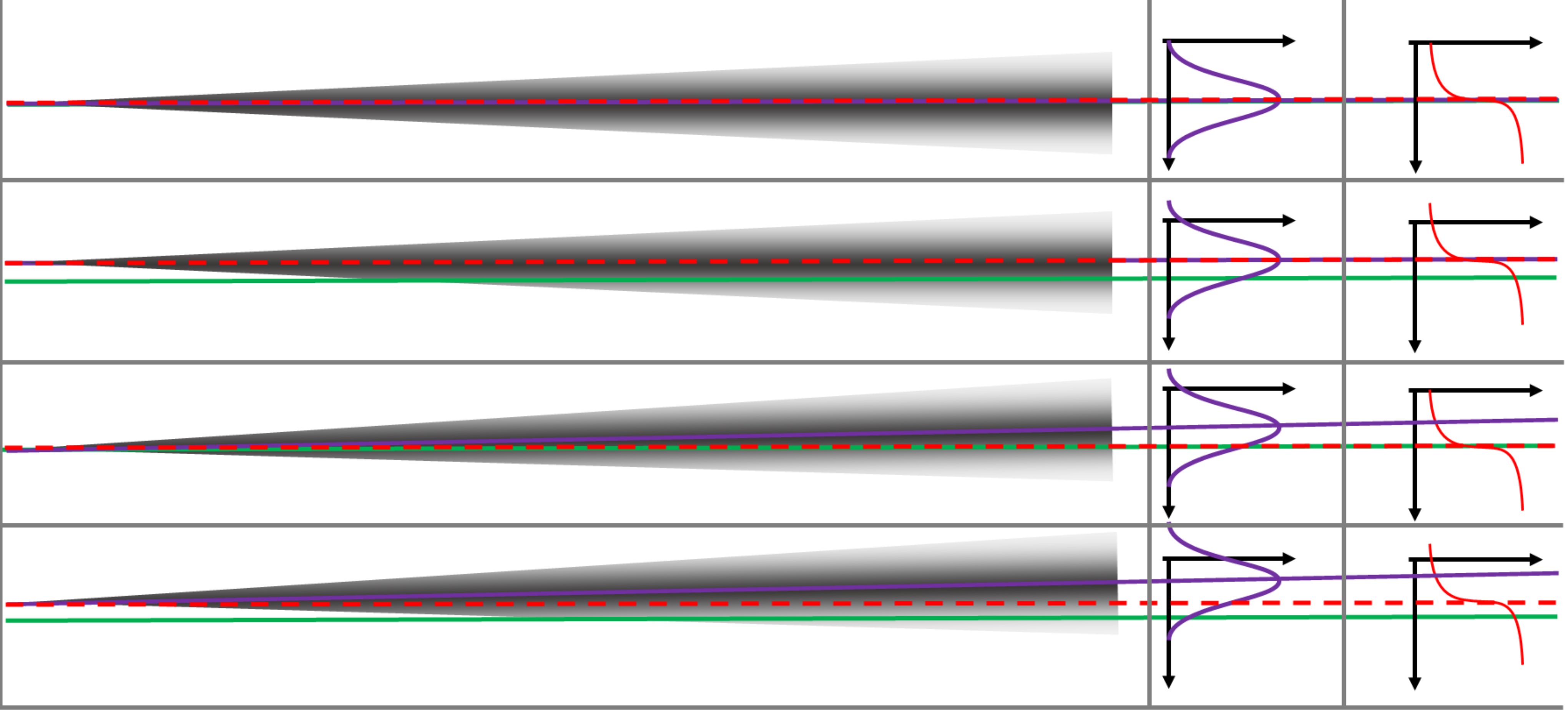


What the Beam Looks Like?

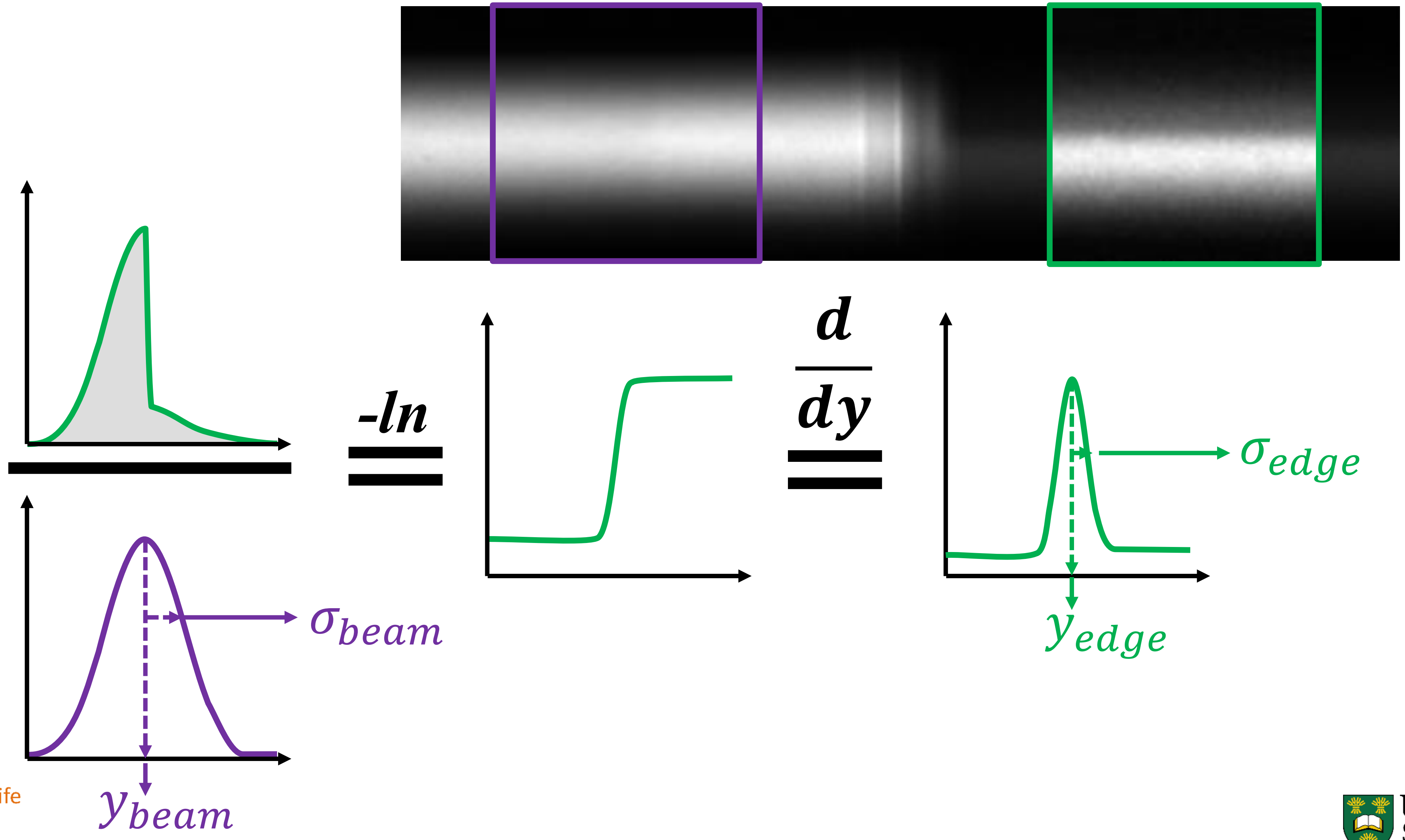


What Happens When the Beam Moves?

y & y’	What the beam looks like	Beam	Edge
y=0 y’=0			
y>0 y’=0			
y=0 y’>0			
y>0 y’>0			

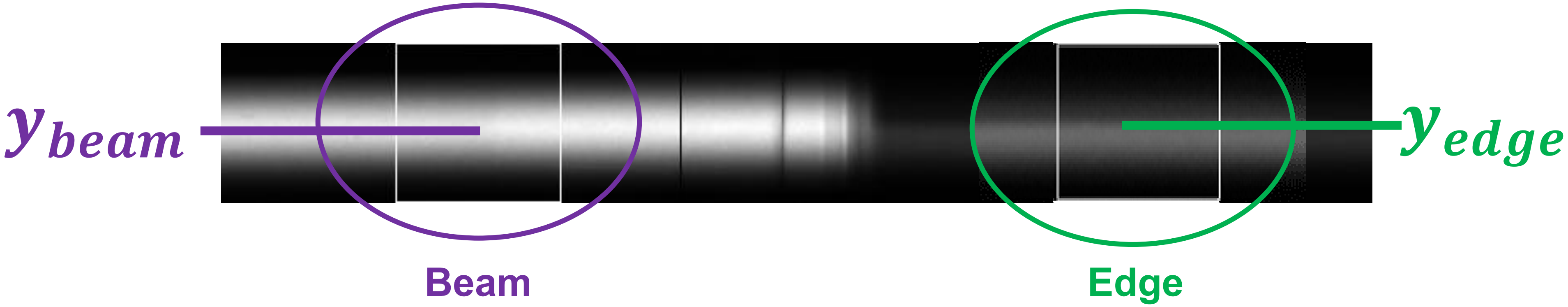


The System-Extracting Information



Source position and angle

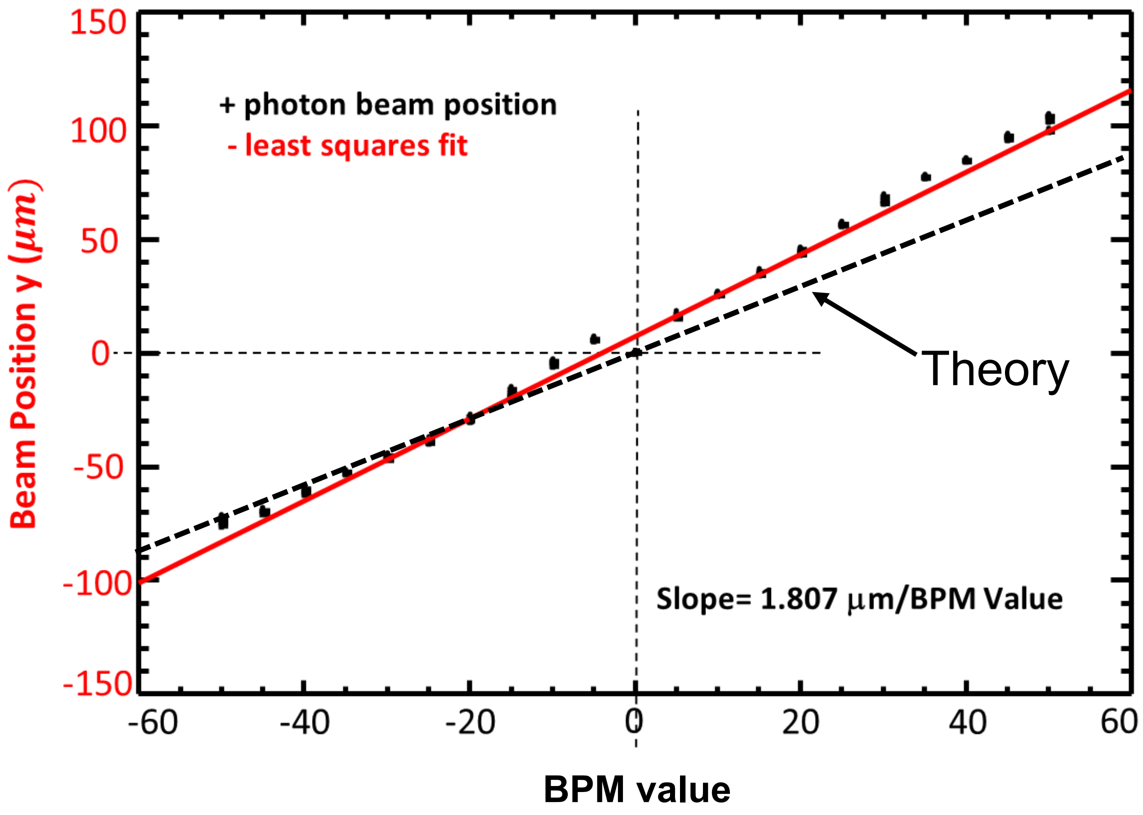
- Beam Side – no filter
  - $y_{beam} = y + Dy'$
- Edge Side – contrast filter
  - $y_{edge} = y$



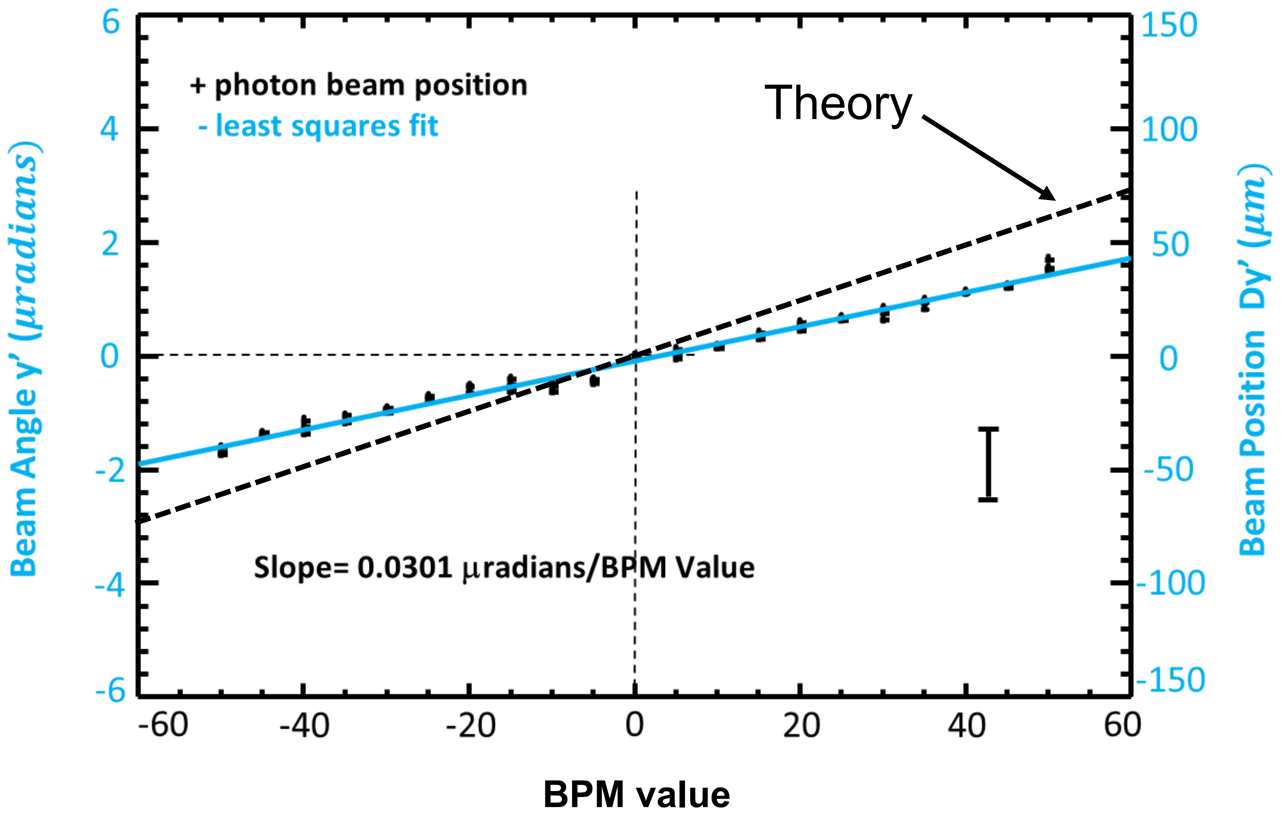
$$\boxed{y = y_{edge} \quad \& \quad y' = \frac{y_{beam} - y_{edge}}{D}}$$

Moving the Electron Beam **Position** (mostly)

Position

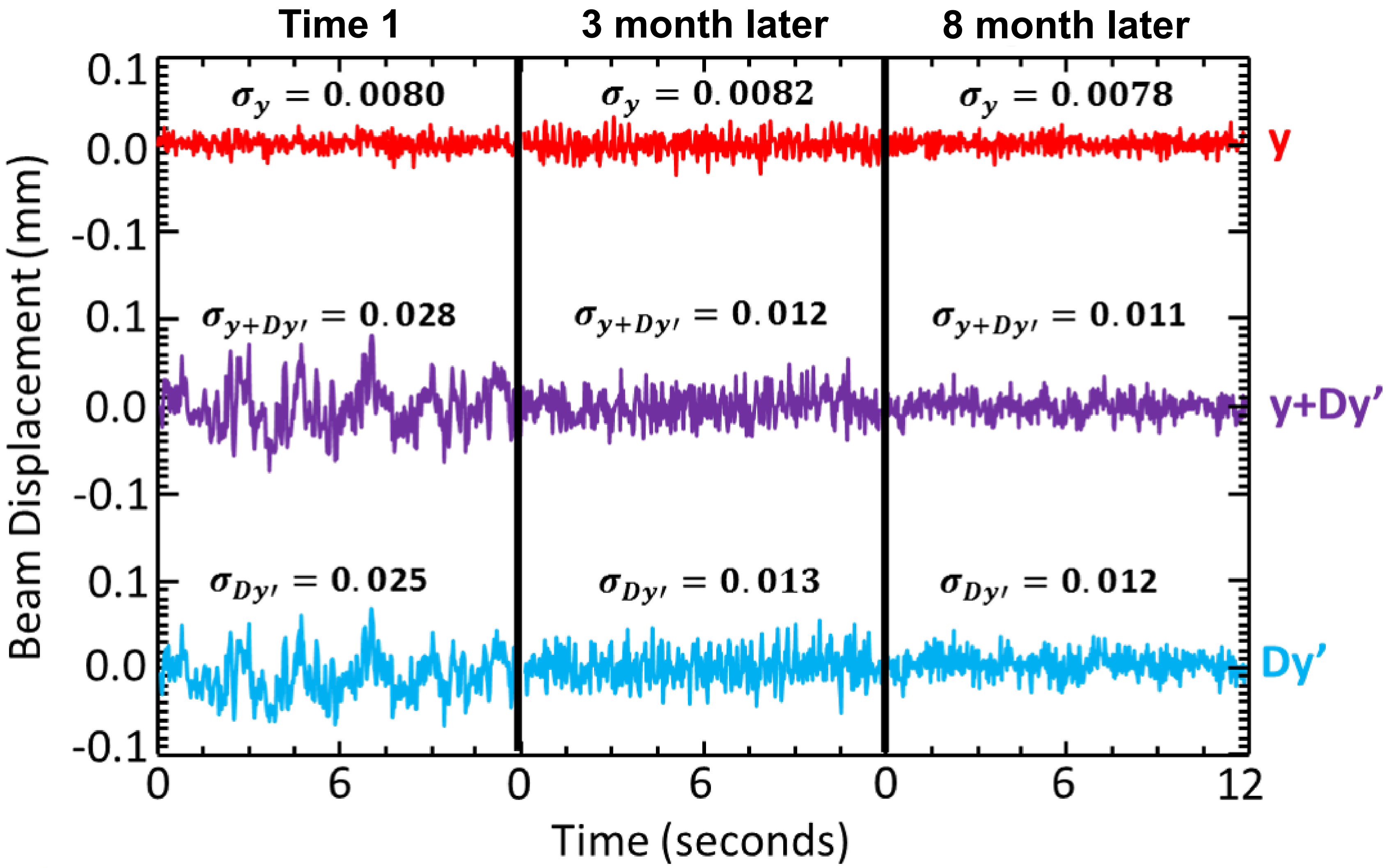


Angle



N. Samadi, *et al.*, "A phase-space beam position monitor for synchrotron radiation," *J Synchrotron Radiat,* 22, 946-55 (2015).

Normal Operations Measurements

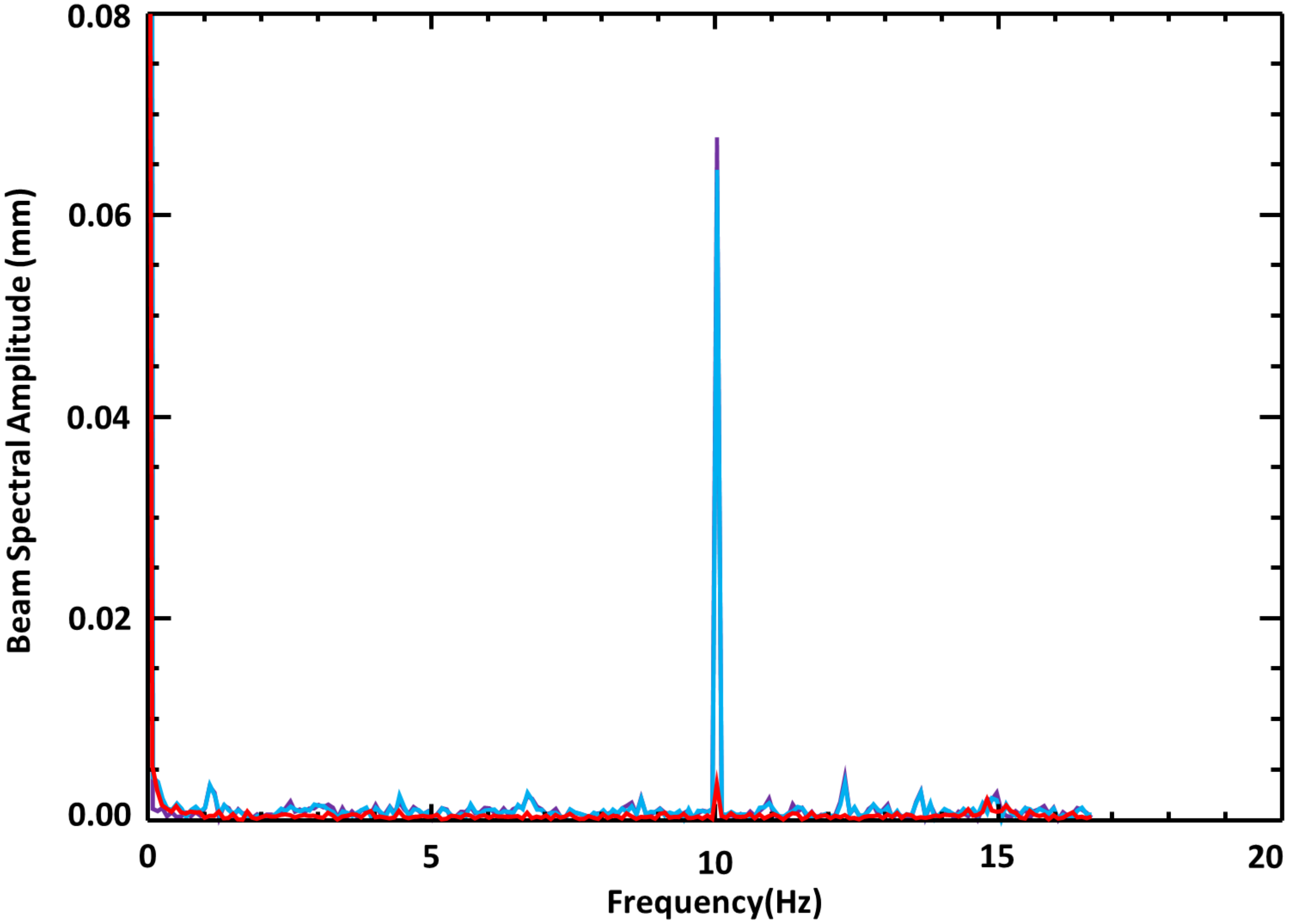


- Measurements made while the beam stability was improved

N. Samadi, *et al.*, "A phase-space beam position monitor for synchrotron radiation," *J Synchrotron Radiat,* vol. 22, pp. 946-55, Jul 2015.

Correcting Experimental Data

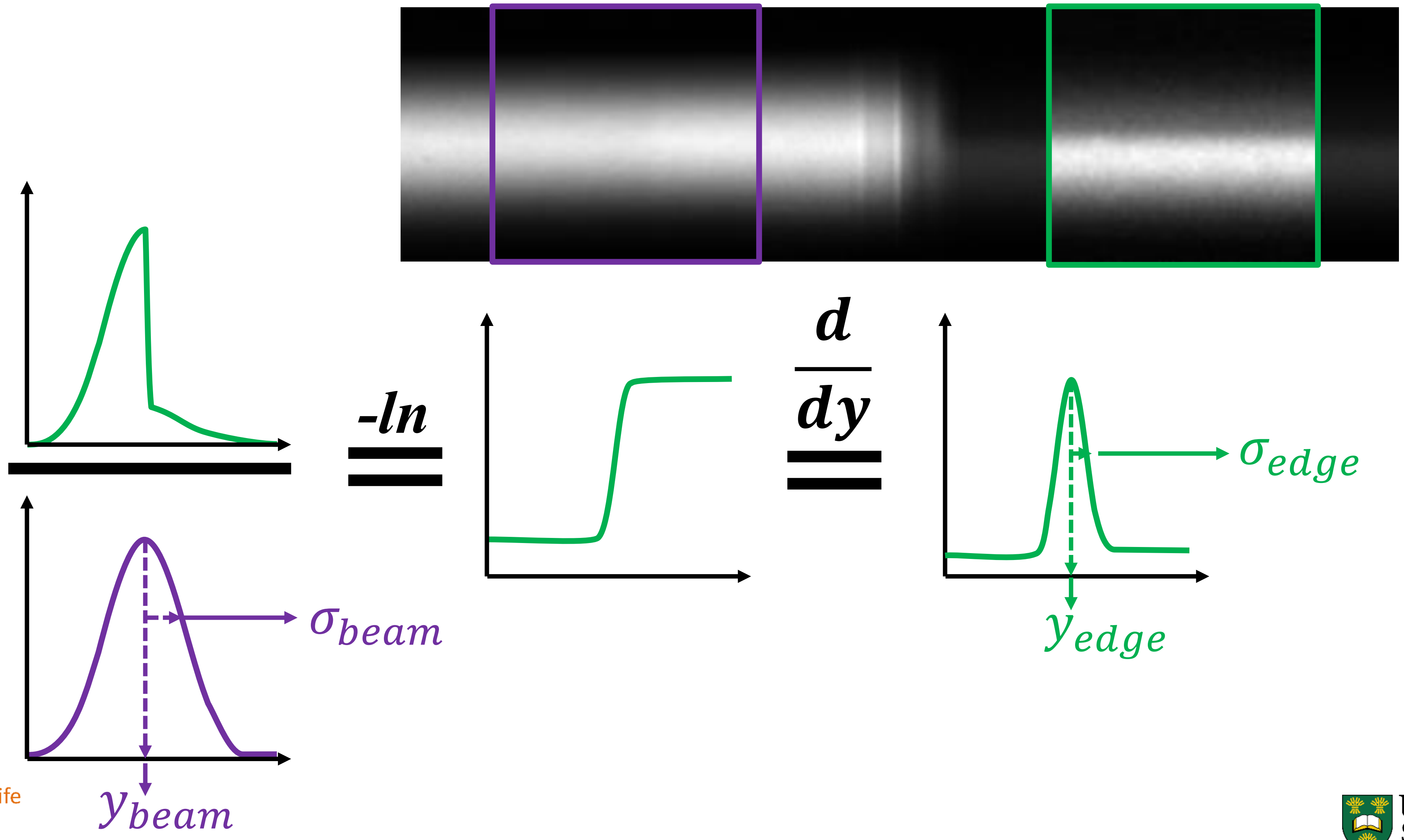
- Measurements made while a beam motion with 10 Hz frequency and different amplitudes was put in the ring



The Dashed line show the predicted value based on a machine optics simulation

N. Samadi, *et al.*, "A Vertical Phase Space Beam Position and Emittance Monitor for Synchrotron Radiation," *Proc. IBIC2018*. 186–189 (2018).

The System-Extracting Size Information



Beam size and Divergence - Emittance

The Vertical Emittance Comes from the Widths

What we want

- Contributions to the K-Edge Width

$$-\frac{d}{dy} \quad \sigma^2_{edge} = \sigma^2_{y_{esource}} + \left(D\sigma_{y'_{edge}}\right)^2 + \left(D\sigma_{y'_{mono}}\right)^2$$

$$= \otimes \otimes$$

- Contributions to the Unfiltered Beam Width

$$\sigma^2_{beam} = \left(D\sigma_{y'_{esource}}\right)^2 + \sigma^2_{y_{esource}} + \left(D\sigma_{y'_{ph}}\right)^2$$

$$= \otimes \otimes$$

What we measure

What we need to figure out

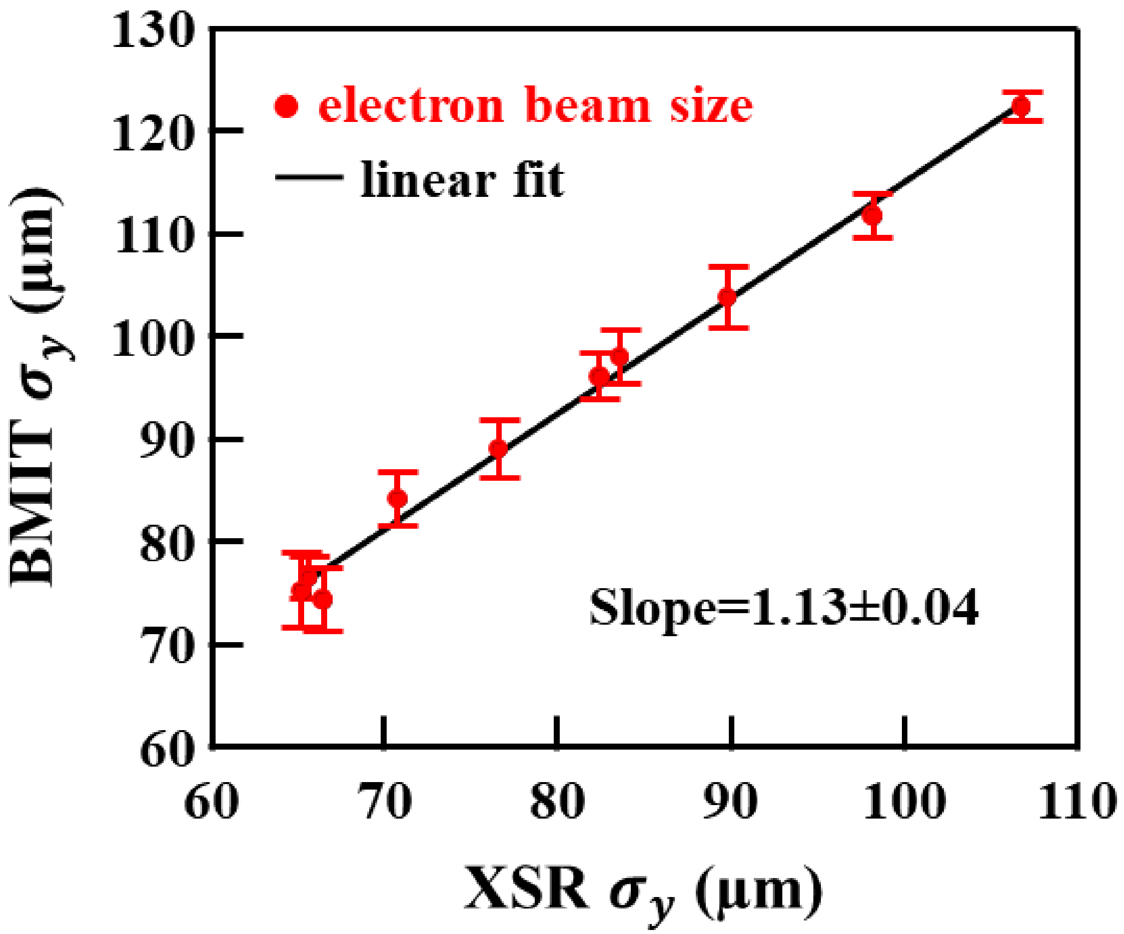
Measurements of Emittance

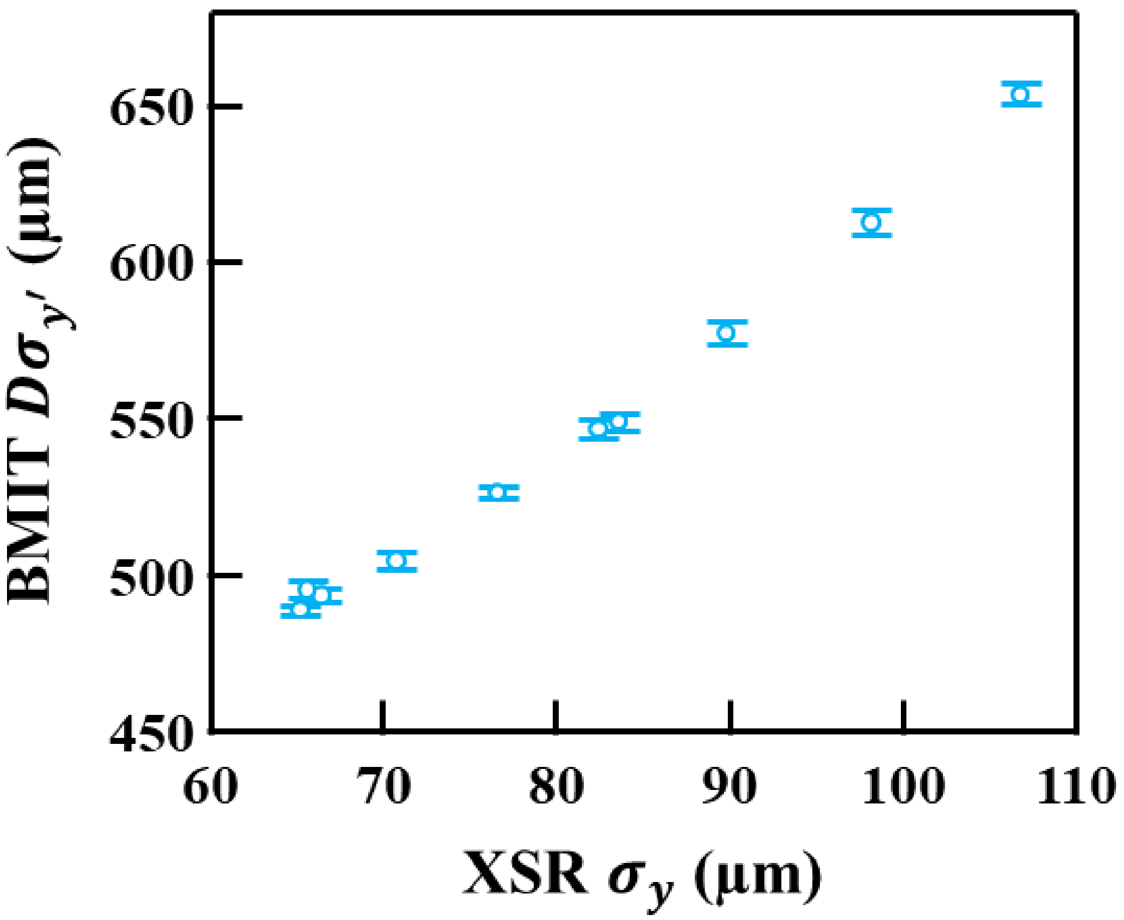
- $\sigma_y = \sqrt{\sigma_{edge}^2 - (D\sigma_{y'_{K-edge}})^2 - (D\sigma_{y'_{mono}})^2}$

$$\varepsilon_y \propto \sigma_y \sigma_{y'}$$

- $\sigma_{y'} = \frac{1}{D}\sqrt{\sigma_{beam}^2 - \sigma_y^2 - (D\sigma_{y'_{Ph}})^2}$

Changing the Electron beam Size (mostly)





N. Samadi, *et al.*, "A Real Time Phase-Space Beam Emittance Monitoring System," *J Synchrotron Radiat,* Accepted, April 2019.

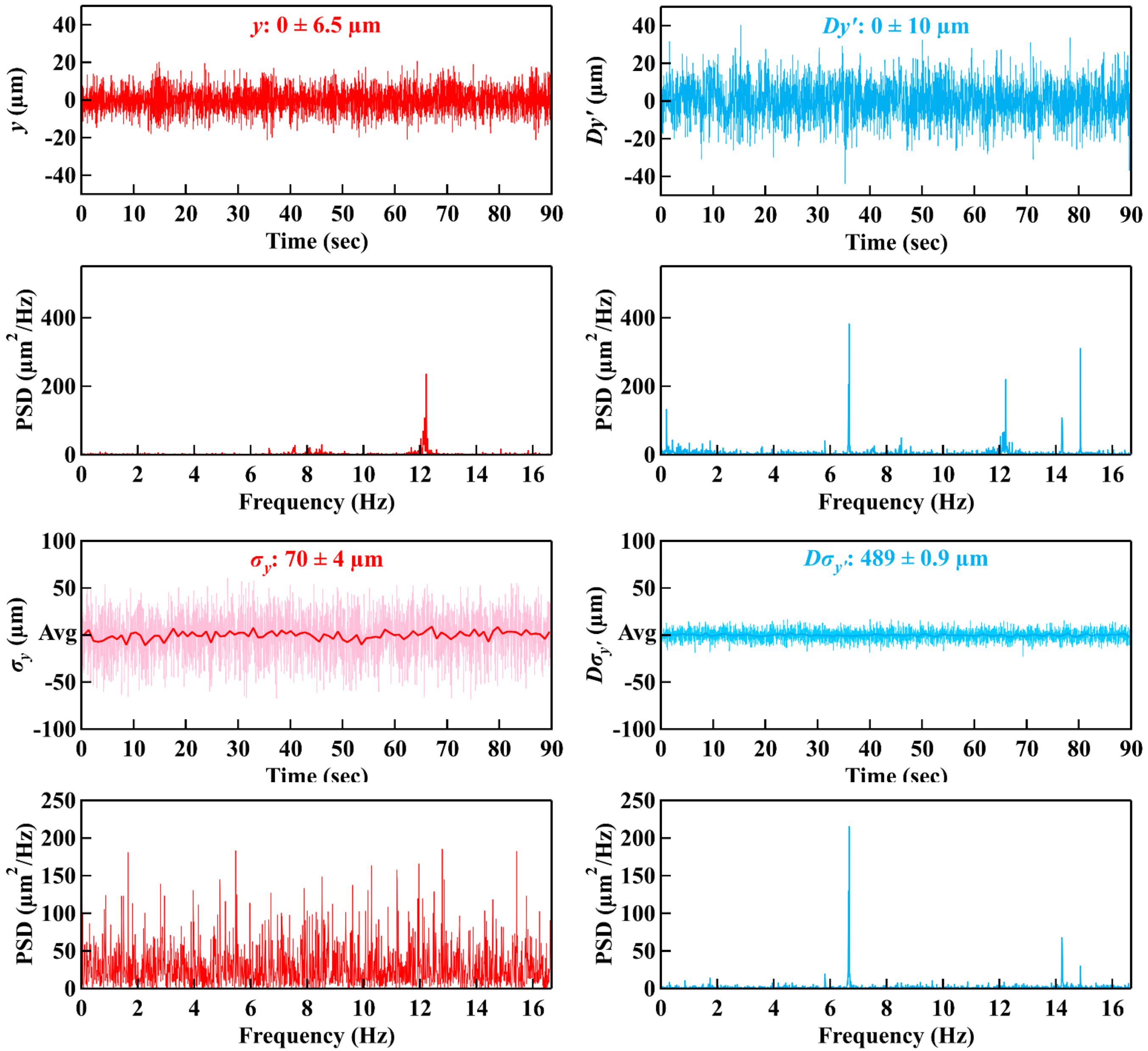
ps-BPM Outputs

y | Dy'

y power spectrum | Dy' Power spectrum

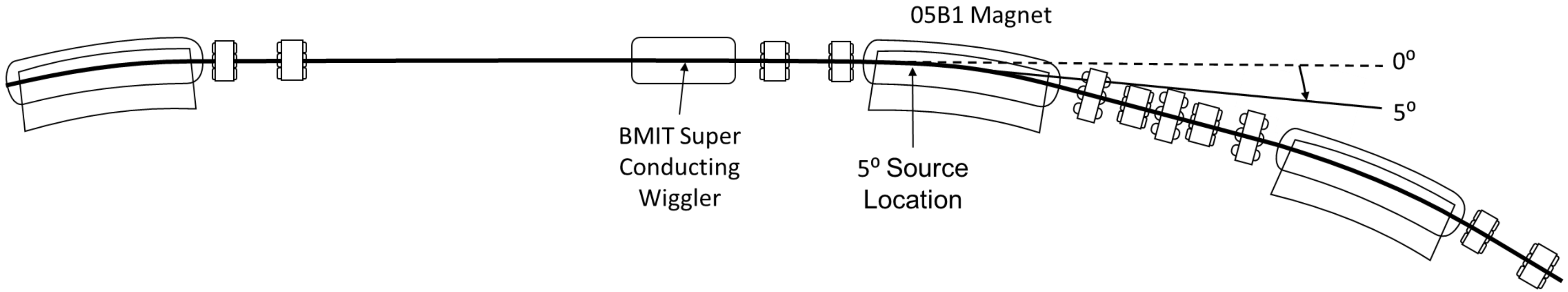
σ_y | $\sigma_{y'}$

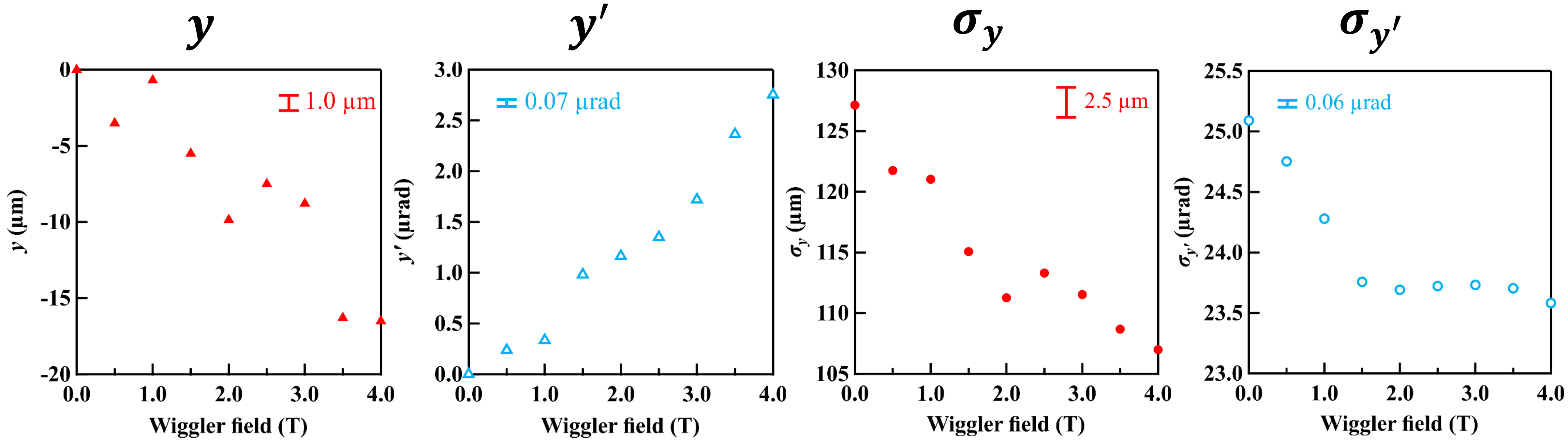
σ_y power spectrum | $\sigma_{y'}$ power spectrum



Samadi, N., Shi, X., Dallin, L. & Chapman, D., *Phys. Rev. Accel. Beams*. To be submitted (2019).

BMIT wiggler field change study





Samadi, N., Shi, X., Dallin, L. & Chapman, D., *Phys. Rev. Accel. Beams*. To be submitted (2019).

Optimization Process

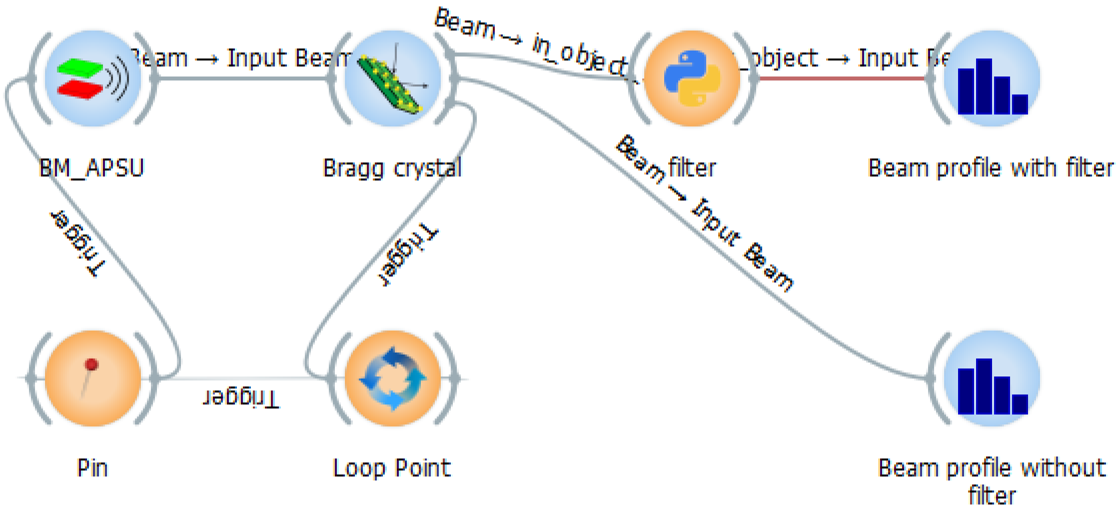
- The monochromator
  - crystal material
  - reflection geometry
  - choice of lattice planes
- The K-edge filter
  - sets the energy
  - the K-edge width
  - the concentration and thickness of the filter element
- The system geometry and
  - the only relevant distance is the source to the detector distance.
- The detector
  - pixel size in the diffraction plane

Samadi, N., Shi, X., & Chapman, D., *J. Synchrotron Rad.* To be submitted (2019).

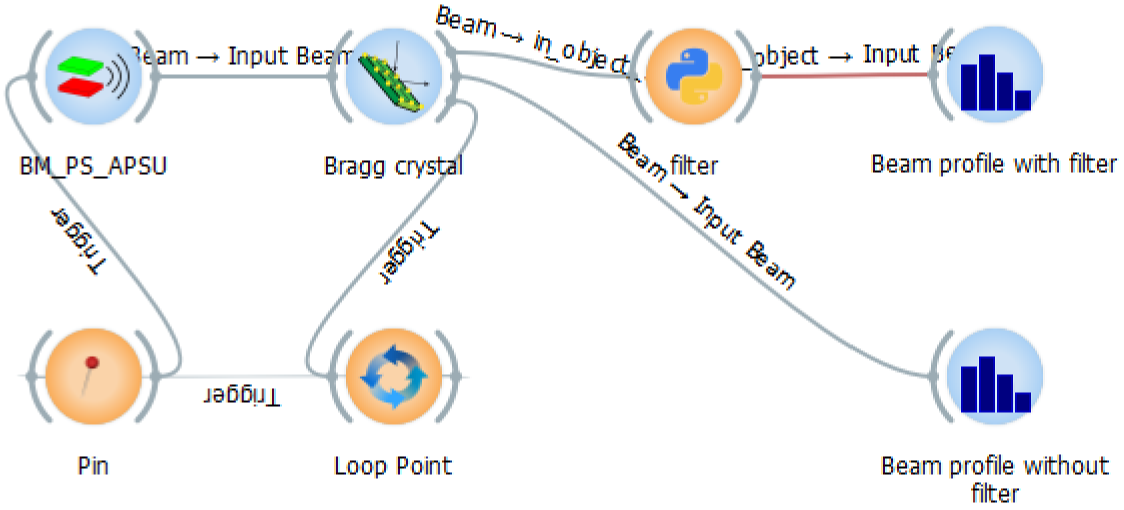
Ray-Tracing and Modelling

- Simulations done in ShadowOui package in the OASYS environment
  - The nominal electron beam size: σ_{source} = 4.9 μm and σ'_{source} = 2.8 μrad.

APS-U BM source



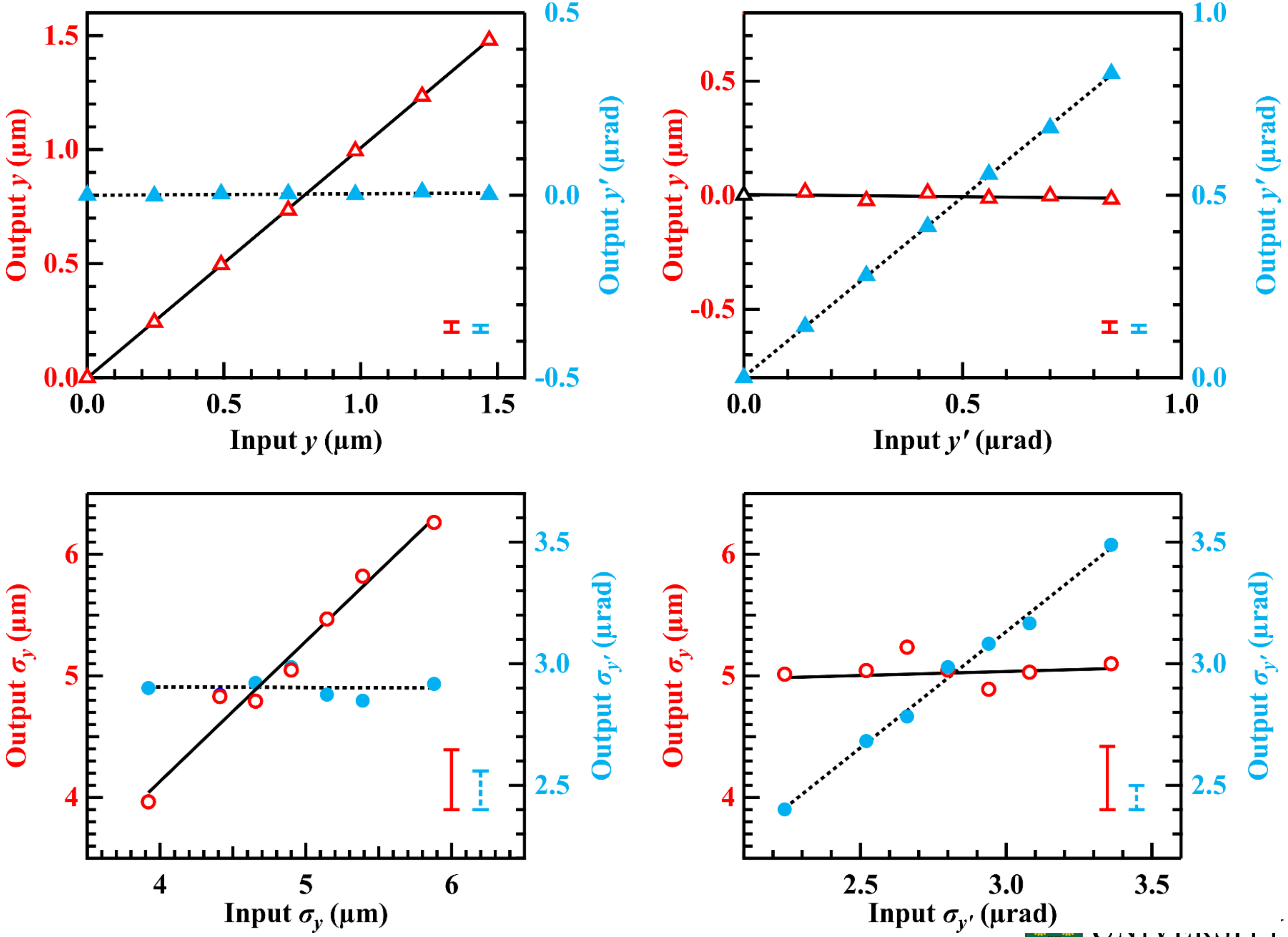
APS-U source with zero-emittance



Samadi, N., Shi, X., & Chapman, D., *J. Synchrotron Rad.* To be submitted (2019).

Example of ps-BPM for APS-U Source

- APS-U
- Si (111)
- Single Bragg
- Barium K-edge
- 37.441 keV
- 10 m from the source
- 10 µm detector



Samadi, N., Shi, X., & Chapman, D., *J. Synchrotron Rad.* To be submitted (2019).

Conclusion

- Beamline
  - BPM
  - Correcting Experimental Data
- Machine
  - BPM
  - Control and Feedback System
  - Emittance Measurements

- real-time capability of beam position and size monitoring
- the data can be used for both source and beamline diagnostics
- the system has the sensitivity to be used at small-emittance sources.

Reference

1. Samadi, N., Bassey, B., Martinson, M., Belev, G., Dallin, L., De Jong, M. & Chapman, D. "A phase-space beam position monitor for synchrotron radiation," *J. Synchrotron Radiat.* **22**, 946–955 (2015).
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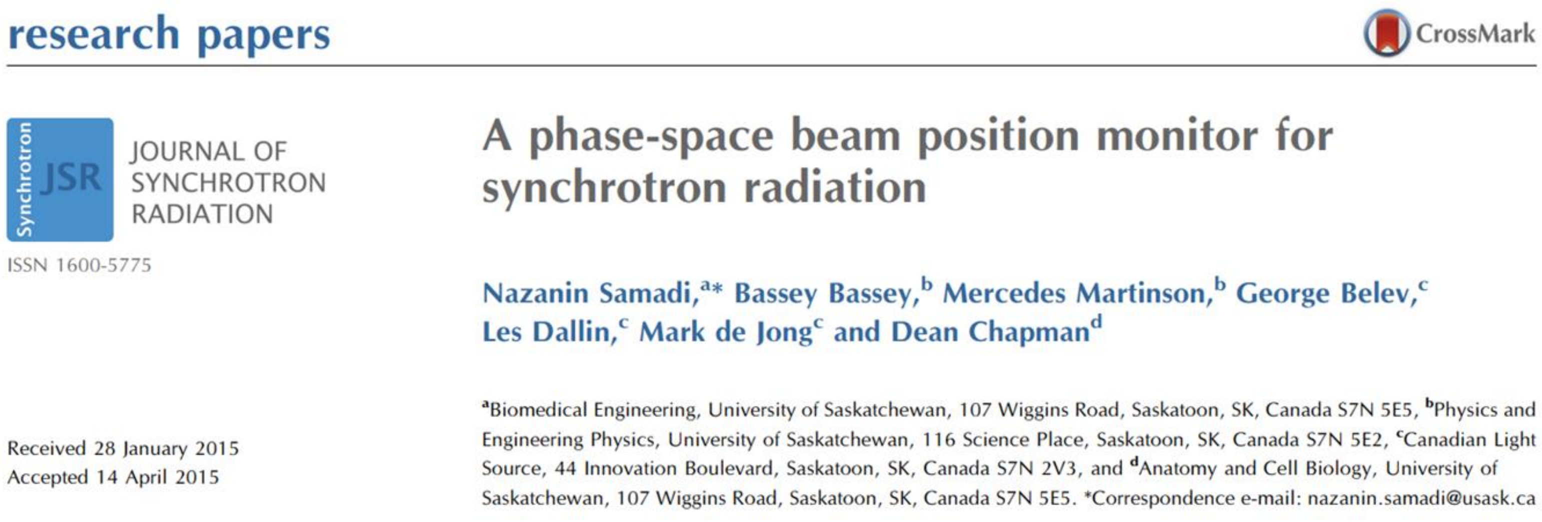

research papers

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A phase-space beam position monitor for synchrotron radiation

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Thank you!

Questions?