WHAT'S GOING ON IN SECTOR 35?

– THE APS DIAGNOSTICS BEAMLINES

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Bingxin Yang

ASD/DIAG, Advanced Photon Source, Argonne National Laboratory

A U.S. Department of Energy laboratory
managed by The University of Chicago

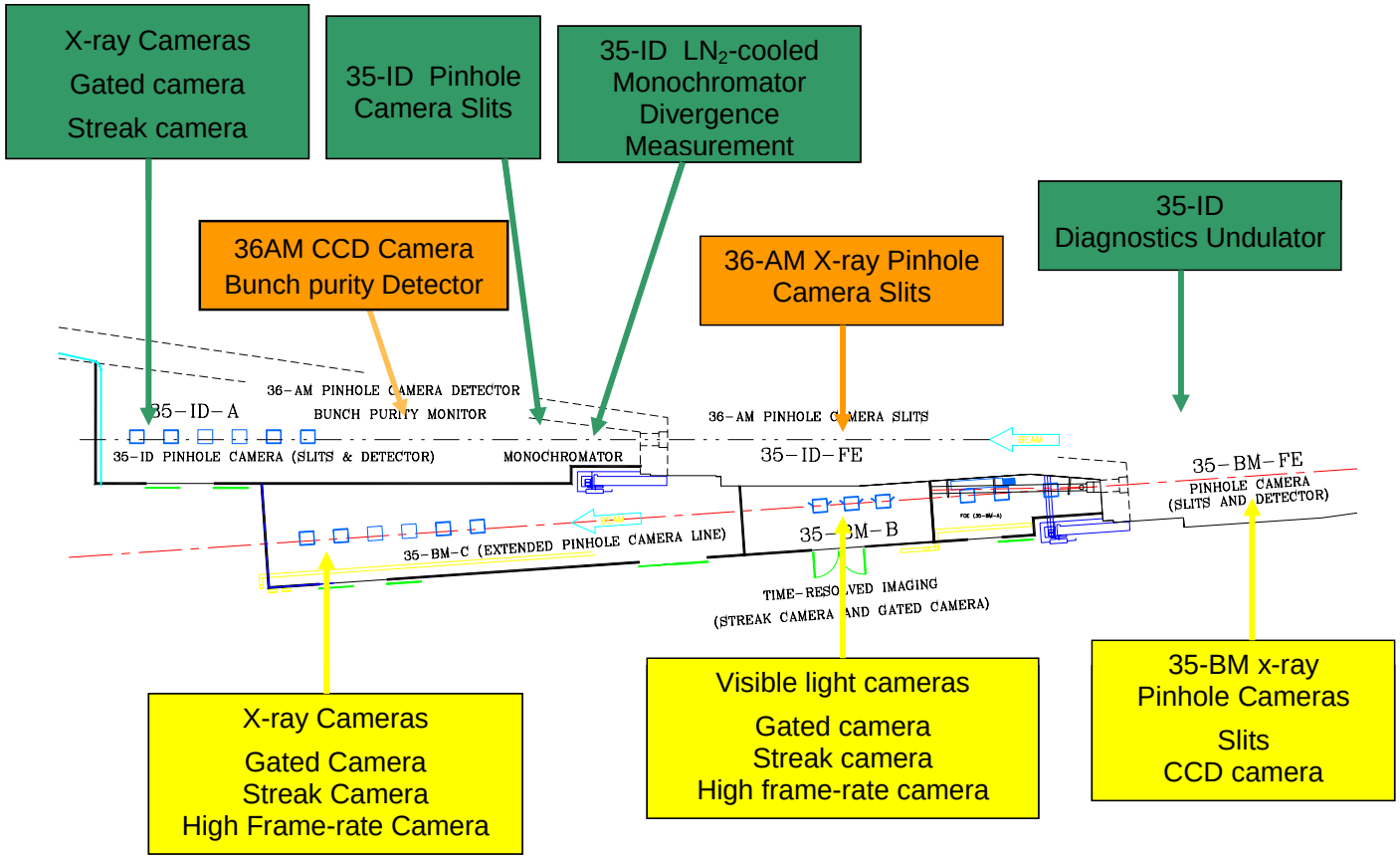
Sector 35 Beamline: E-Beam Diagnostics

Missions of the APS Diagnostics Beamlines

- **Characterize and monitor the e-beam for user operations. Help address users' concern about the electron beam.**
- **Support accelerator development for better understanding of the ring and help explore new operating parameter space**
- **Develop advanced techniques & concepts for current and future accelerators and light sources**

Floor Plan of Sector 35

35-ID: Diagnostics undulator beamlines. // 36-AM: Bunch purity monitor & x-ray pinhole camera



35-BM: (A) X-ray-based high-resolution time-resolved imaging. (B) Optical synchrotron radiation (OSR) time-resolved imaging, (C) In-tunnel X-ray pinhole camera.

Highlights of Beam Measurements

- Beam size / divergence measurements and data delivery: x-ray pinhole camera / ID monochromator.
- Bunch length measurements: streak camera
- Energy spread measurements: ID spectrum
- Transient properties measurements: time-resolved imaging with optical synchrotron radiation and undulator radiation.
- Future development

Bingxin Yang
bxyang@aps.anl.gov

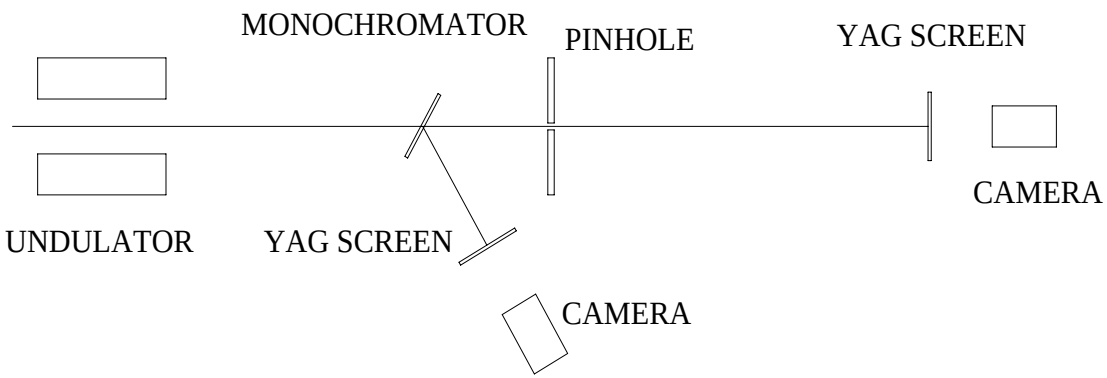
Beam size and divergence

Source size $$\sigma_x^{\,2} = \beta\varepsilon_x + (\eta\sigma_\delta)^2 + \frac{\lambda L}{8\pi^2} + \left\langle \left[x(t)\right]^2 \right\rangle_\tau + beam\_waist\_\mathrm{mod}$$

Beam divergence $$\sigma_{x'}^{\,2} = \gamma\varepsilon_x + (\eta'\sigma_\delta)^2 + \frac{\lambda}{2L} + \left\langle \left[x'(t)\right]^2 \right\rangle_\tau + beam\_waist\_\mathrm{mod}$$

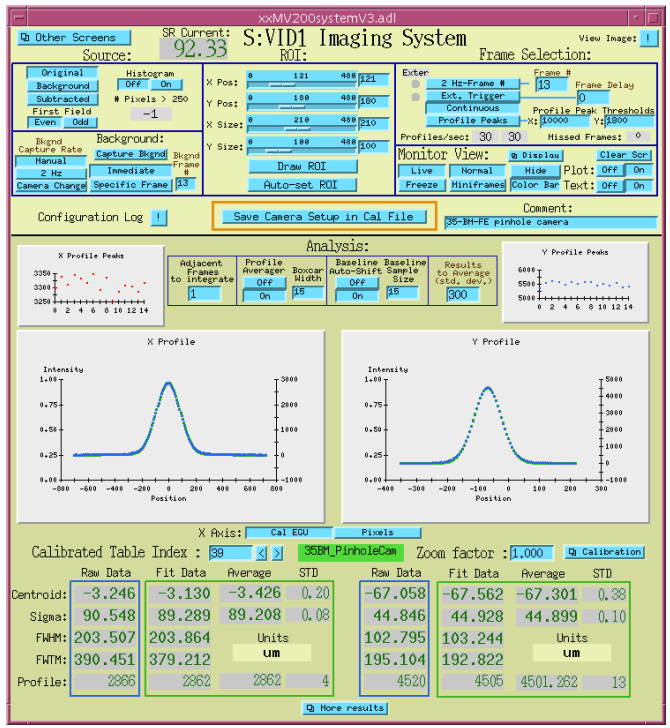
Transverse beam properties directly affects time-averaged source brilliance. They are measured with three different approaches:

- **X-ray pinhole camera for BM source sizes (35BAM and 36AM)**
- **Undulator & monochromator for ID source divergence**
- **X-ray pinhole camera for ID source horizontal size**



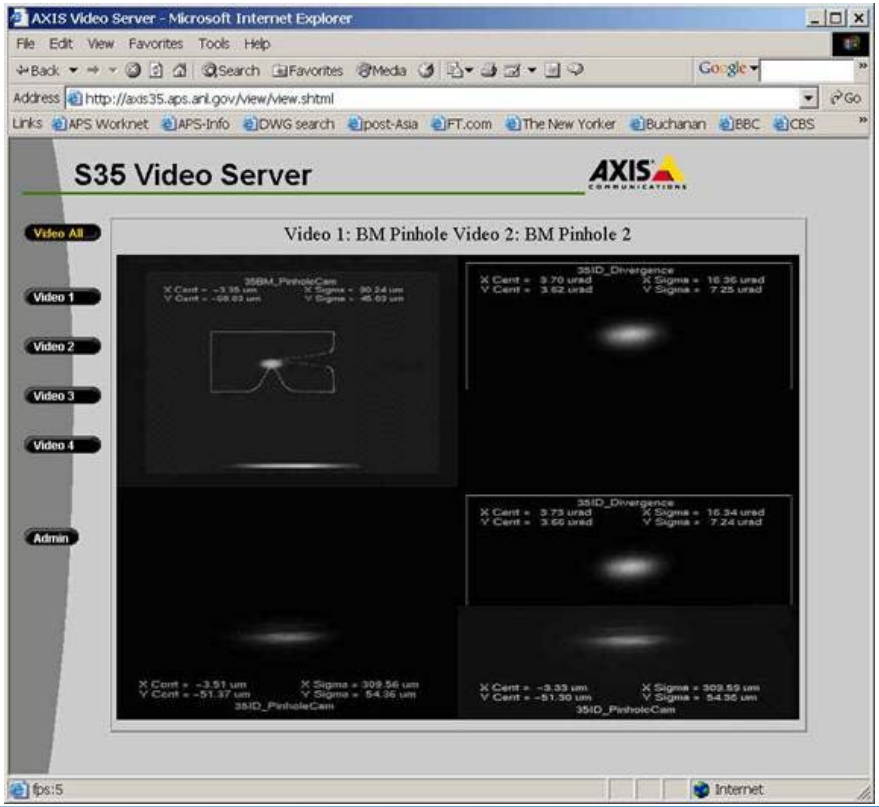
35-BM Pinhole Camera Serves All APS Users

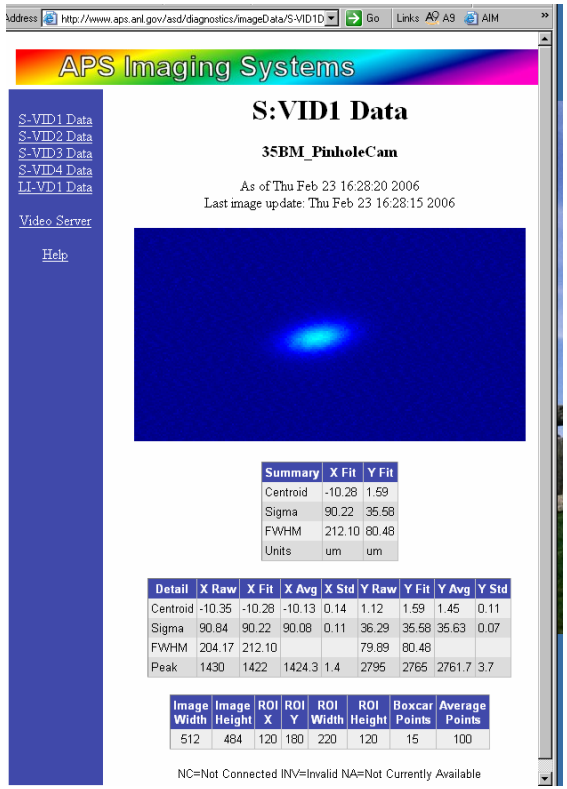
- Video image is available live in the APS CCTV network
- Video images are processed @ 30 Hz. Beam size and centroid are available as process variables
- Beam size and centroid data are archived for future use



35-BM Pinhole Camera Serves All Users

- **Web video is available at 5 frames/sec within the APS fire wall (http://axis35.aps.anl.gov)**
- **Beam image web page updated every 30 seconds outside the fire wall (http://www.aps.anl.gov/asd/diagnostics/imageData/S-VID1Data.html)**





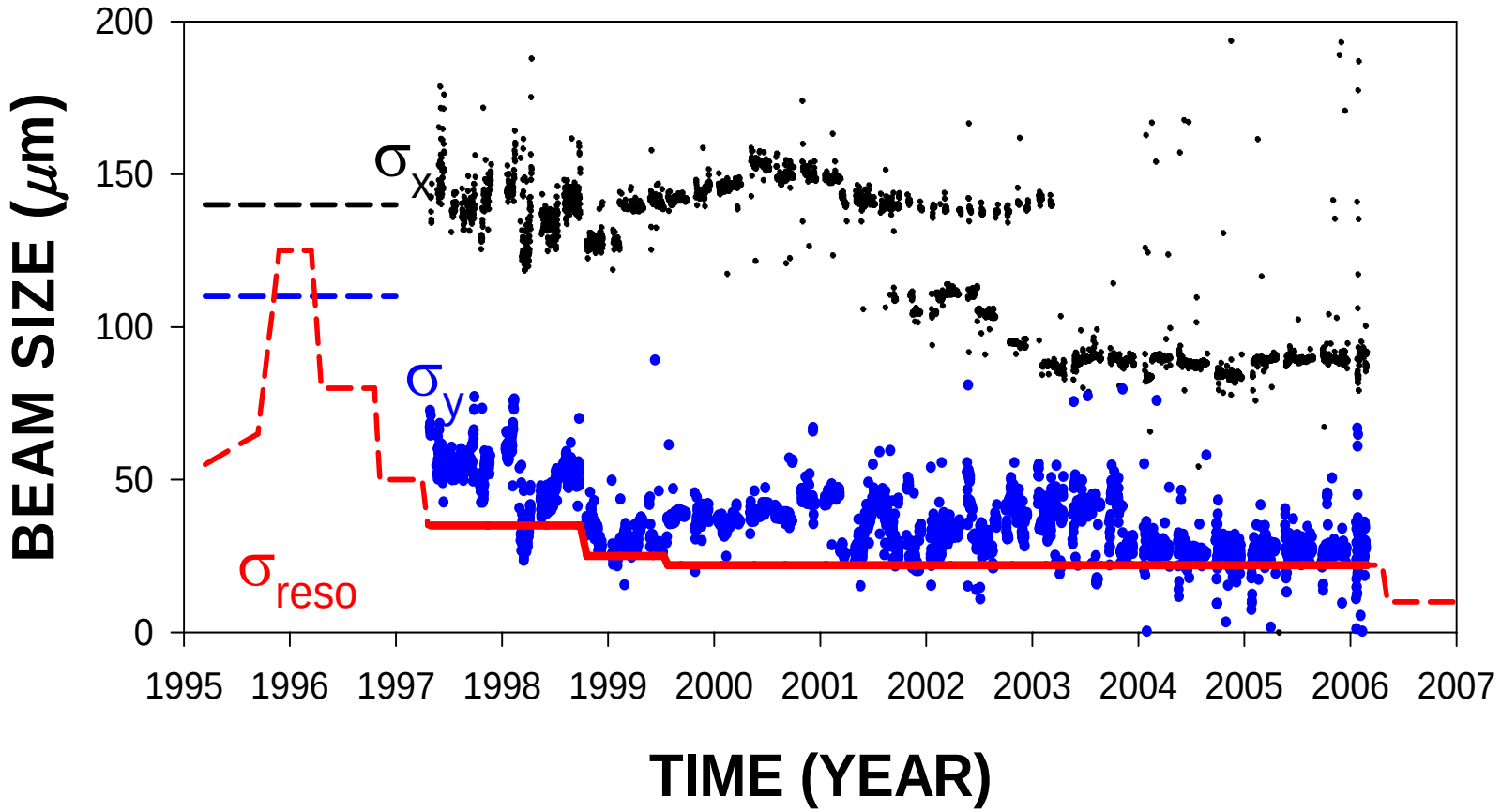
Summary	X Fit	Y Fit
Centroid	-10.28	1.59
Sigma	90.22	35.58
FWHM	212.10	80.48
Units	um	um

Detail	X Raw	X Fit	X Avg	X Std	Y Raw	Y Fit	Y Avg	Y Std
Centroid	-10.35	-10.28	-10.13	0.14	1.12	1.59	1.45	0.11
Sigma	90.84	90.22	90.08	0.11	36.29	35.58	35.63	0.07
FWHM	204.17	212.10			79.89	80.48		
Peak	1430	1422	1424.3	1.4	2795	2765	2761.7	3.7

Image Width	Image Height	ROI X	ROI Y	ROI Width	ROI Height	Boxcar Points	Average Points
512	484	120	180	220	120	15	100

Bingxin Yang
bxyang@aps.anl.gov

35-BM X-ray Pinhole Camera Data Archive

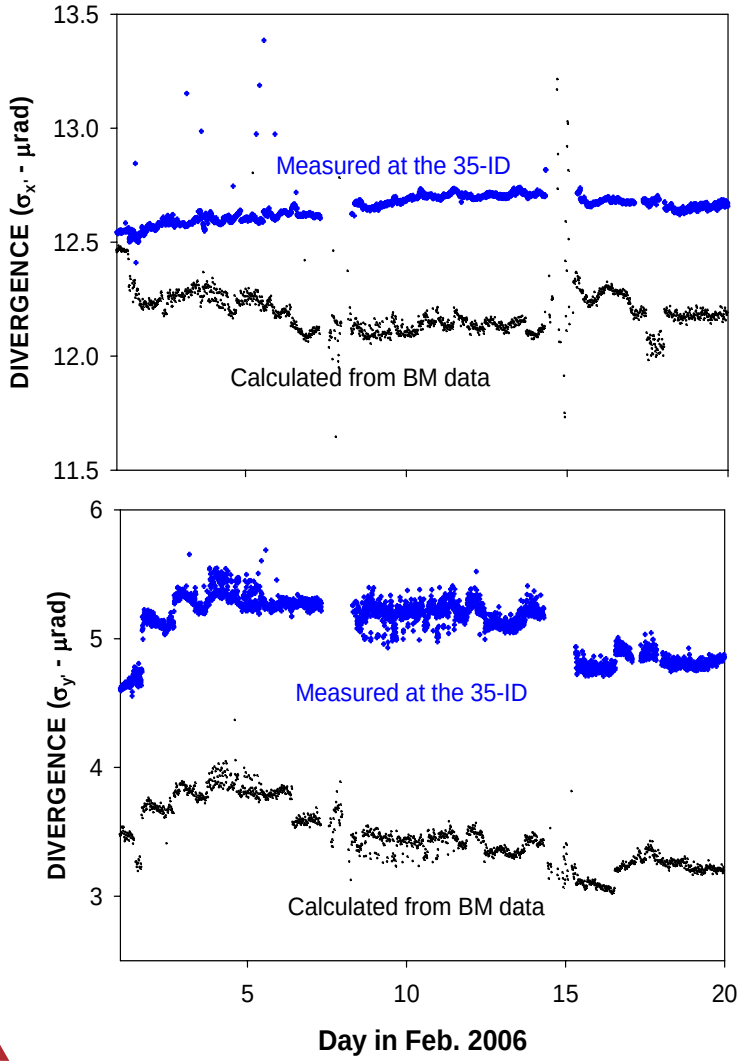


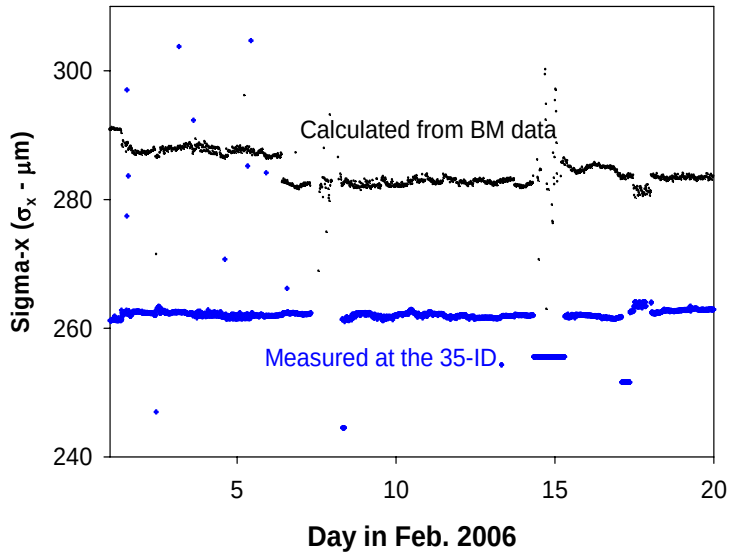
Vertical beam size steadily decreases…

Current state: $\sigma_x = 90\ \mu\text{m},\ \sigma_y = 17-25\ \mu\text{m},\ \sigma_{reso} = 22\ \mu\text{m}$

Bingxin Yang
bxyang@aps.anl.gov

Undulator Beam Divergence: Measured vs. Calculated





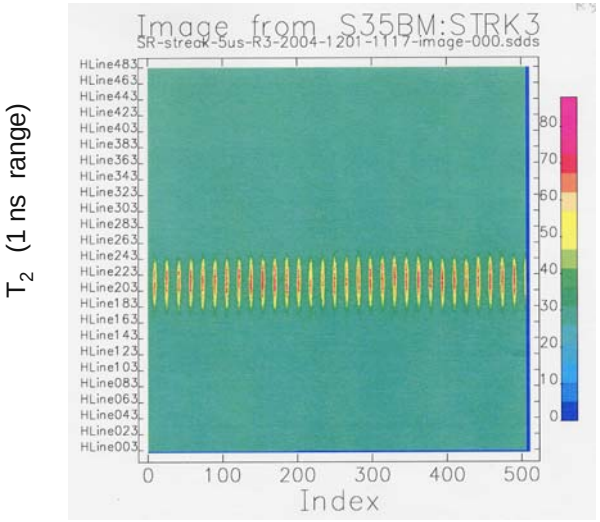
Compare calculated source parameters with measured ones (resolution subtracted)

- Good agreement in horizontal divergence
- ~ 8% off in horizontal beam size
- Not so good agreement in vertical divergence
- Vertical size not shown (resolution-limited)

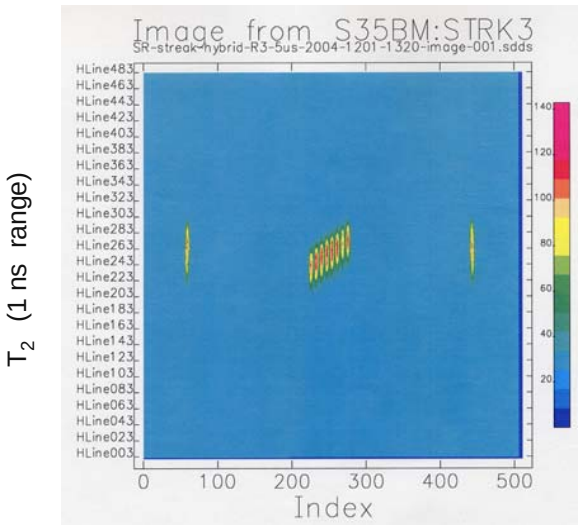
Work in progress.

Bingxin Yang
bxyang@aps.anl.gov

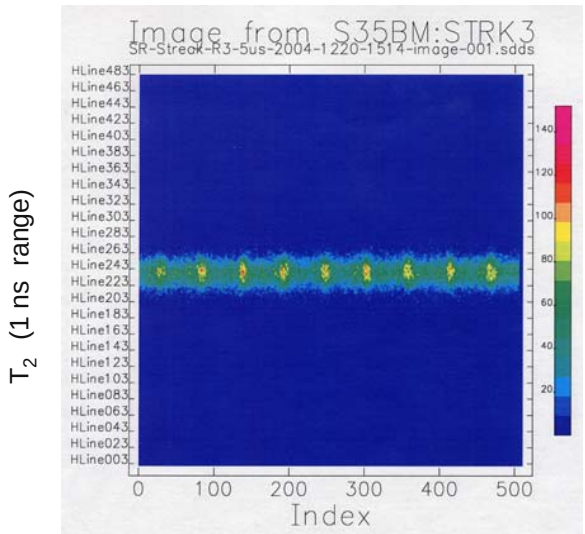
Bunch length measurements: OSR Imaging
Streak Imagefor Different APS Storage Ring Fill Patterns



24-singlets



1+8*7



324-singlets

	24-singlets	Hybrid: 1+8*7	324-singlets
Bunch length (rms)	**40 ps**	**Singlet (8 mA): 50 ps** **Septuplet: 32 ps**	**25 ps**

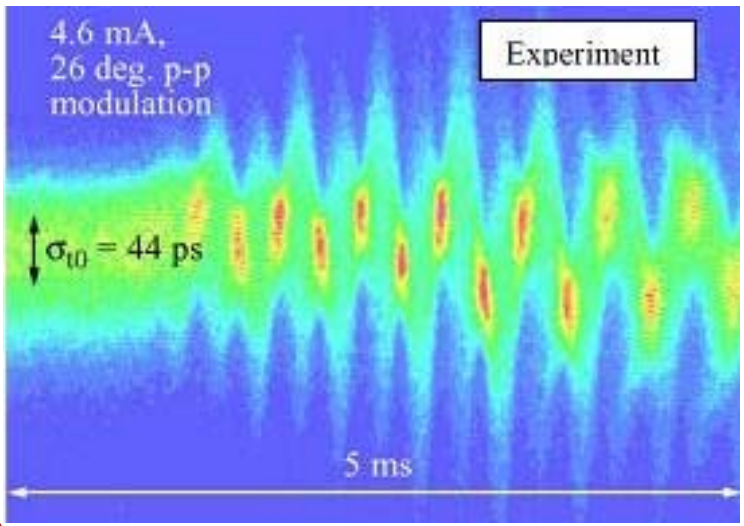
* Synchroscan streak camera was critical for reliable phase information

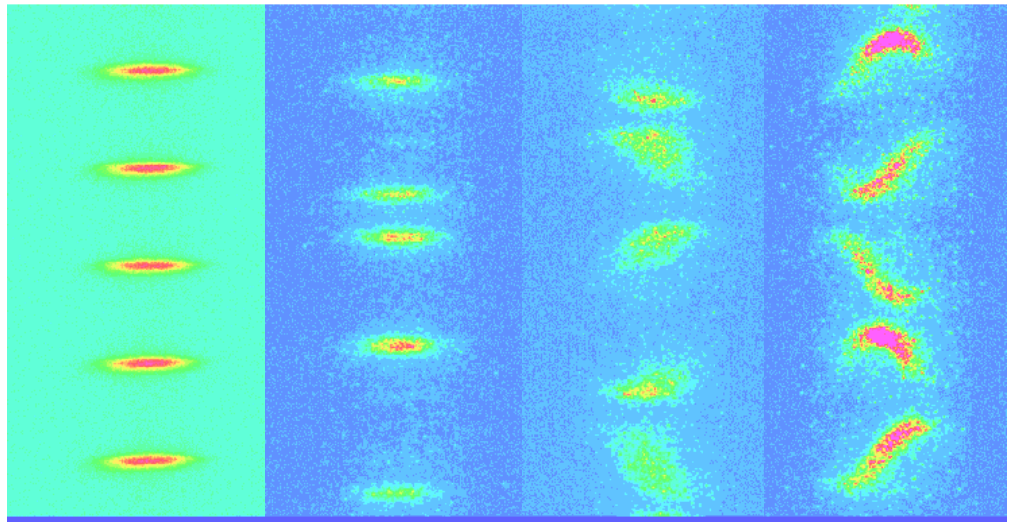
Courtesy of A. Lumpkin and B. Yang

Studies with potential user applications

ps x-ray source related studies

- RF phase modulation induced beam shortening (Glenn Decker)
  - Every bunch for several micro-seconds
- Synchro-betatron coupled motion (Weiming Guo, B. Yang, K. Harkay)
  - Tilted bunch in a single turn.
- These studies help us to understand and develop ps x-ray sources.





E-Beam Energy Measurements

Standard e-beam energy measurements techniques

- **Lattice dispersion function:** BPM readings vs energy change (rf frequency)
- **Beam energy spread:** Beam sizes at difference dispersion function

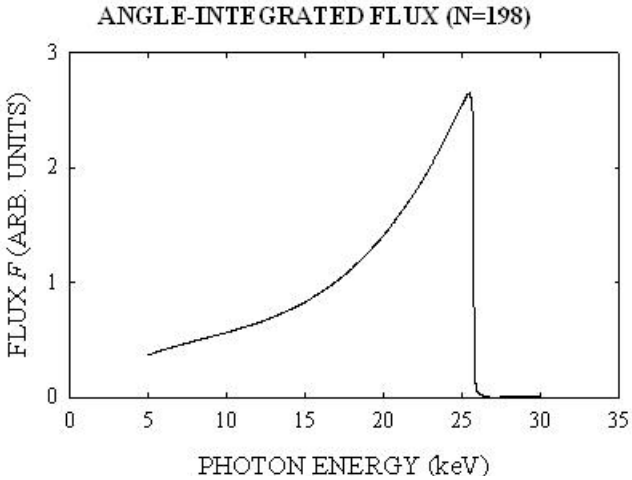
$$\begin{pmatrix} \beta_{xA} & \eta_{xA}^2 \\ \beta_{xB} & \eta_{xB}^2 \end{pmatrix} \begin{pmatrix} \varepsilon_x \\ \sigma_\delta{}^2 \end{pmatrix} = \begin{pmatrix} \sigma_{xA}{}^2 \\ \sigma_{xB}{}^2 \end{pmatrix}$$

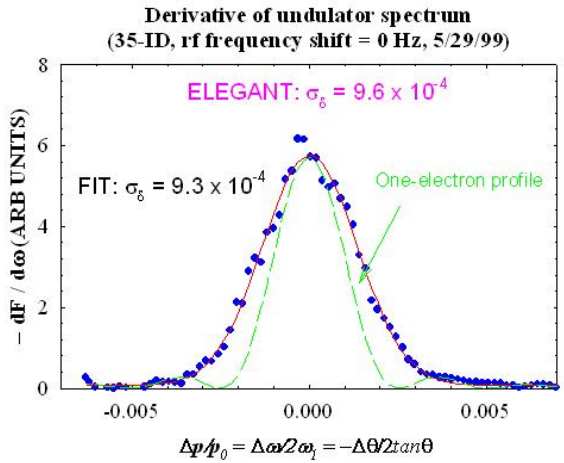
This is the original plan for sector 35. With development of the low-emittance lattice, the determinant of this 2 x 2 matrix continues to decrease, and error bar of this technique continues to increase.

Undulator Diagnostics: Energy Measurements

Undulator Angle Integrated Spectra

- Sharp drop-off at odd harmonics (aperture radius ~ 1/γ.)
- Fit the edge (~ Error function) or derivative (~ Gaussian)
- **Clean**: independent of beam emittance and lattice functions.
- **Accurate**: only monochromator angle needs good calibration.
- **Simple** data collection and treatment.
- **Efficient**: do not lose photons in apertures, good S/N ratio.





Developed as an R&D project. Need to become bread-butter technique now.

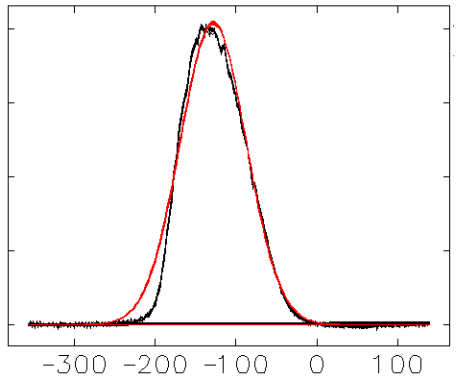
Bingxin Yang
bxyang@aps.anl.gov

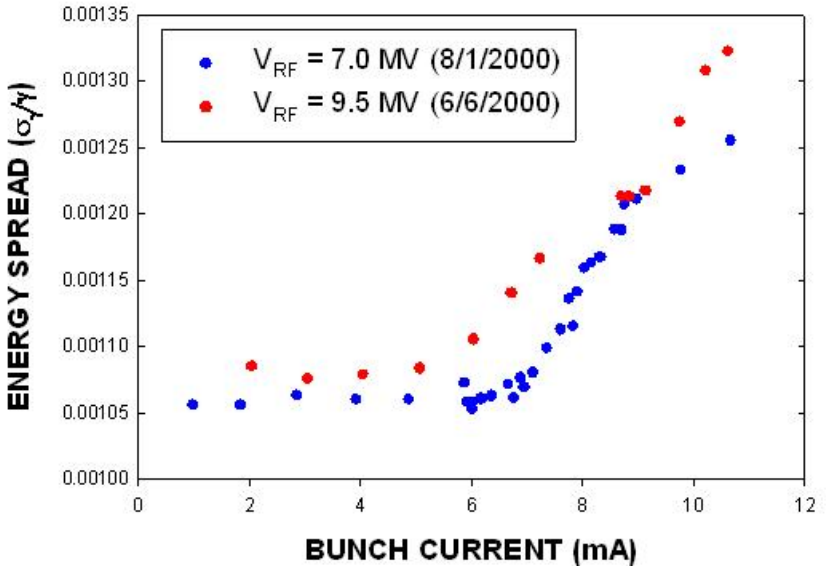
Bunch Length and Energy Spread vs. Bunch Current

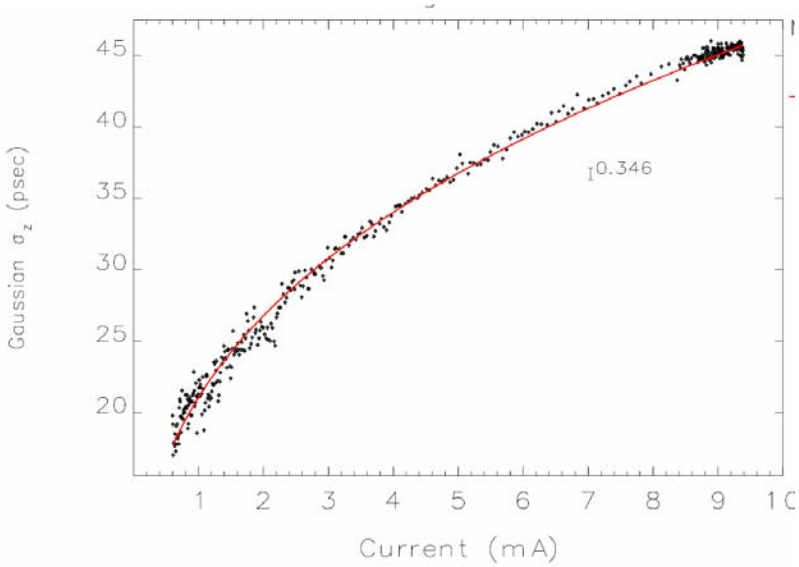
Bunch current dependence

- Longitudinal wakefield causes charge distribution deviating from Gaussian.
- Average energy spread increases above thresholds.

➔ **For timing experiments using a single-bunch in the hybrid fill, the bunch length and size are different from the average values.**



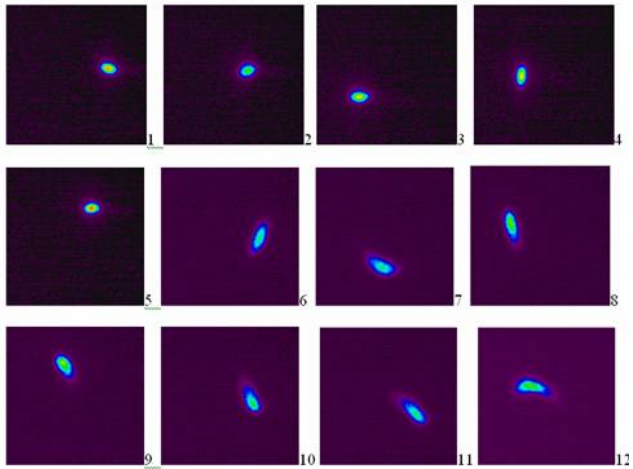


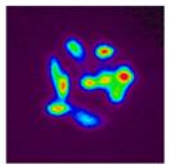


Bingxin Yang
bxyang@aps.anl.gov

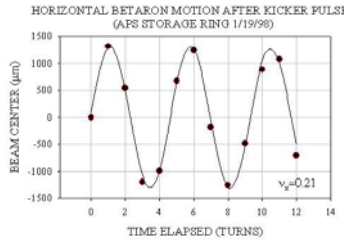
Time-resolved Imaging: OSR Gated Camera

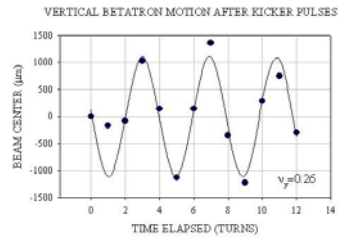
- Capture beam motion / damping, understand top-up operation
- Measure horizontal damping constants
- Limited spatial resolution

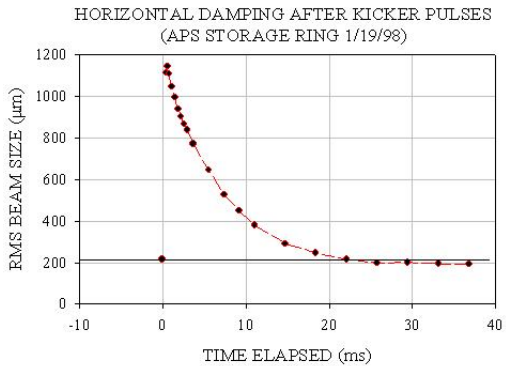


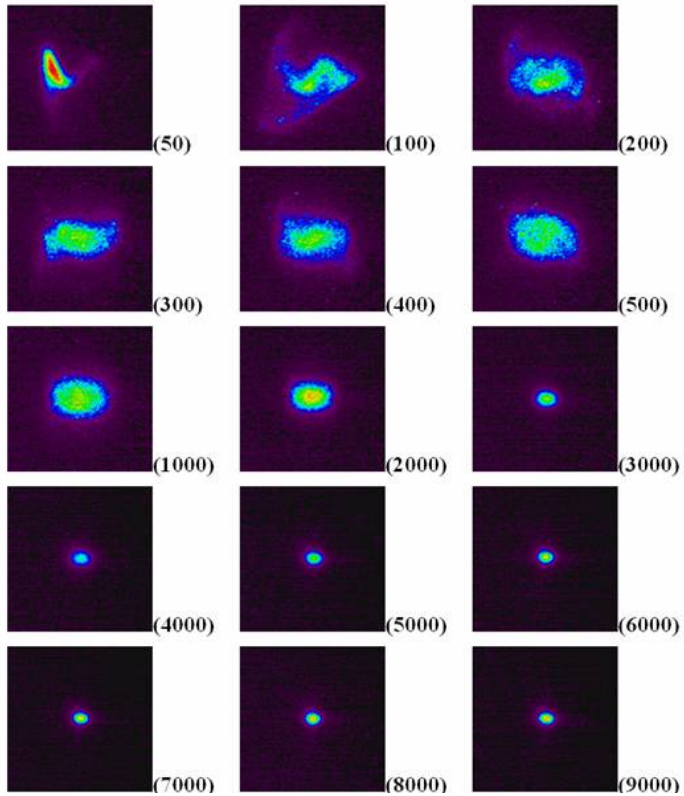


COMBINED IMAGES 0→9







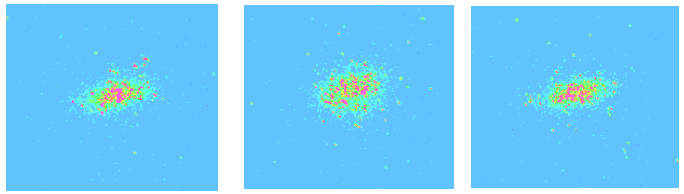


Bingxin Yang
bxyang@aps.anl.gov

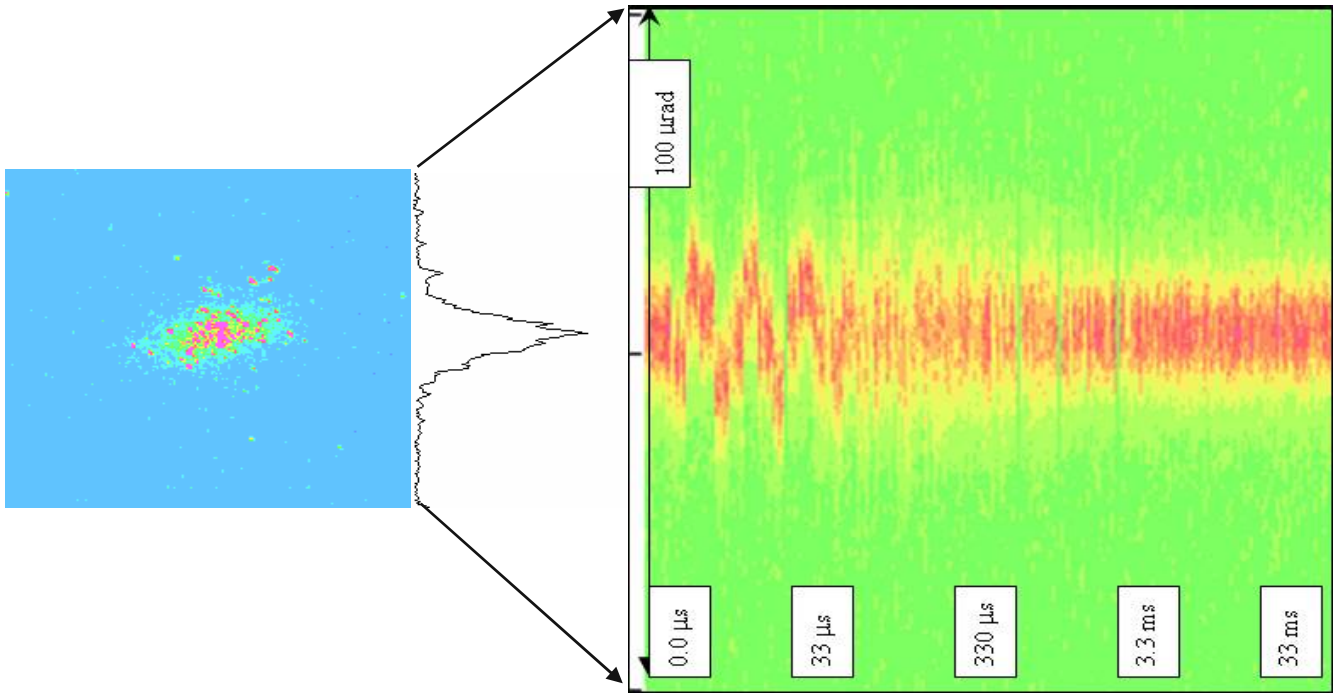
Time-Resolved Imaging: Undulator Gated Camera

Time-resolved Imaging with Undulator

- Higher flux and larger field of view than BM pinholes
- Better resolution than OSR imaging



-3 TURNS +80 TURNS
8000 TURNS



Summary and Future Development

- We have built a powerful suite of photon diagnostics tools at Sector 35. We need to communicate the beam data to users in a timely fashion. We will start a Sector 35 Website in near future
  - Links to real-time beam images.
  - Longitudinal bunch profile, updated once several weeks depending on fill pattern.
  - **User suggestions welcome!**
- We are given a task to build a portable detector to benchmark the APS beamlines:
  - Average x-ray beam properties: flux, size, etc.
  - Beam fluctuations and correlation with S35 data.

Acknowledgment

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DISCUSSION

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