Beam-Based Alignment at the KEK-ATF Damping Ring

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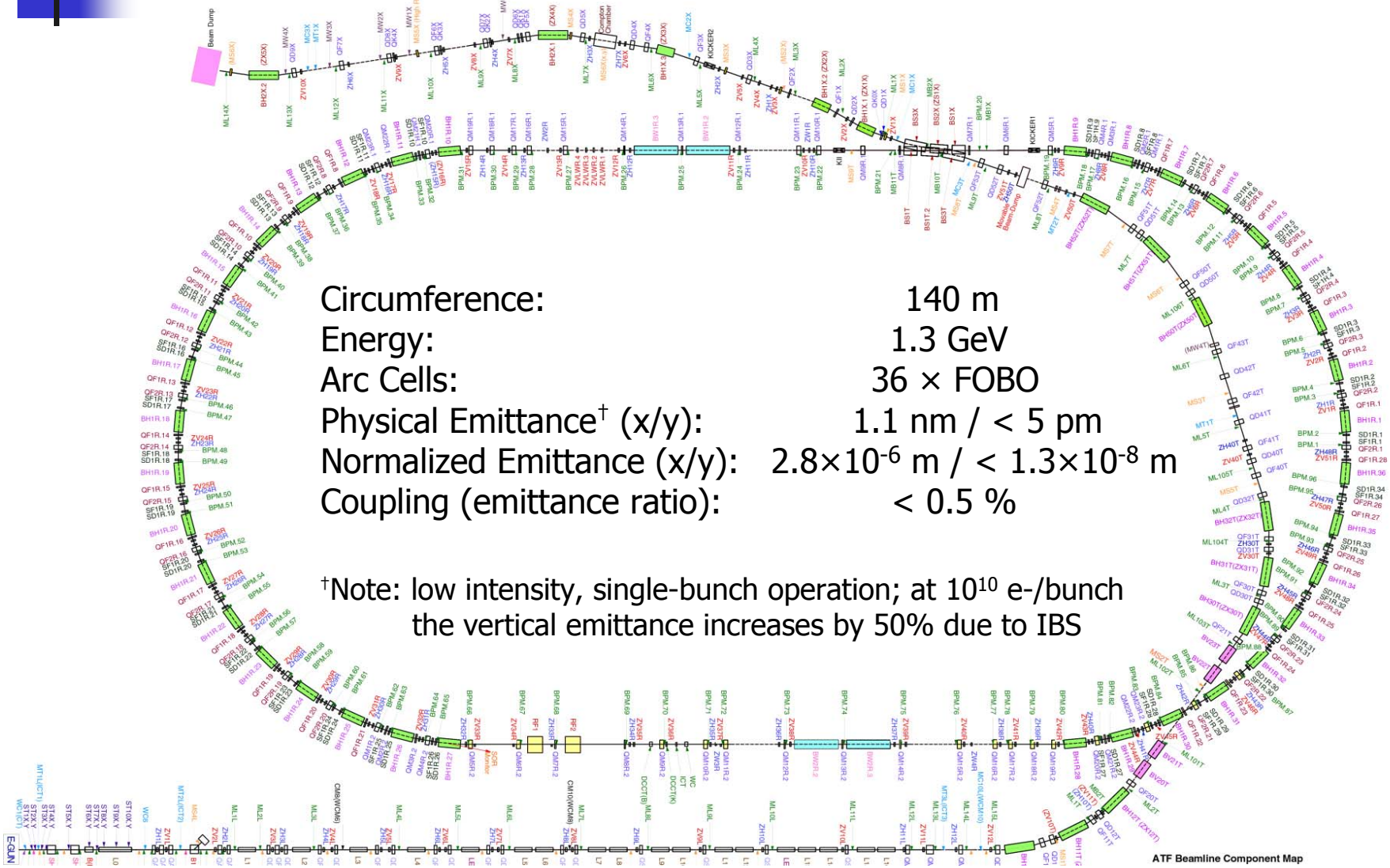
Outline

- A Brief Description of ATF
- Beam-Based Alignment (BBA) Data Acquisition and Analysis
- BBA Results
- Conclusions and Future Prospects

The Accelerator Test Facility at KEK



Circumference:	140 m
Energy:	1.3 GeV
Arc Cells:	36 × FOBO
Physical Emittance† (x/y):	1.1 nm / < 5 pm
Normalized Emittance (x/y):	2.8×10^{-6} m / < 1.3×10^{-8} m
Coupling (emittance ratio):	< 0.5 %

†Note: low intensity, single-bunch operation; at 10^{10} e-/bunch the vertical emittance increases by 50% due to IBS

The World's Largest Linear Collider Test Facility

BBA Data Acquisition (1)

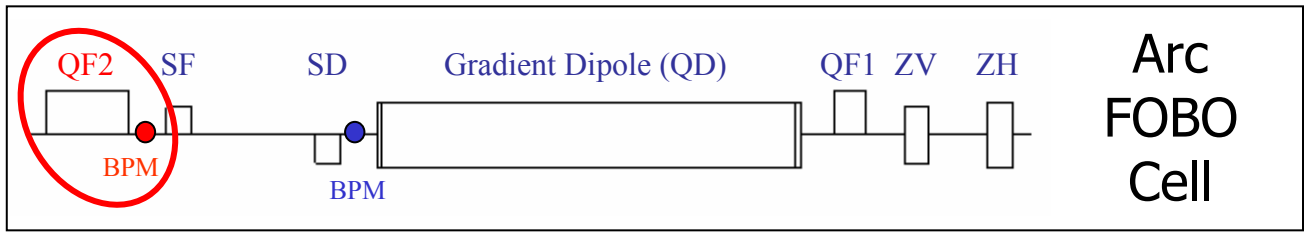
Some early challenges …

- 20 μm single-shot BPM resolution
- No multi-turn BPM data (one readout per injection/extraction cycle; each measured orbit is a new beam)
- Systematic dependence of BPM readings on bunch intensity

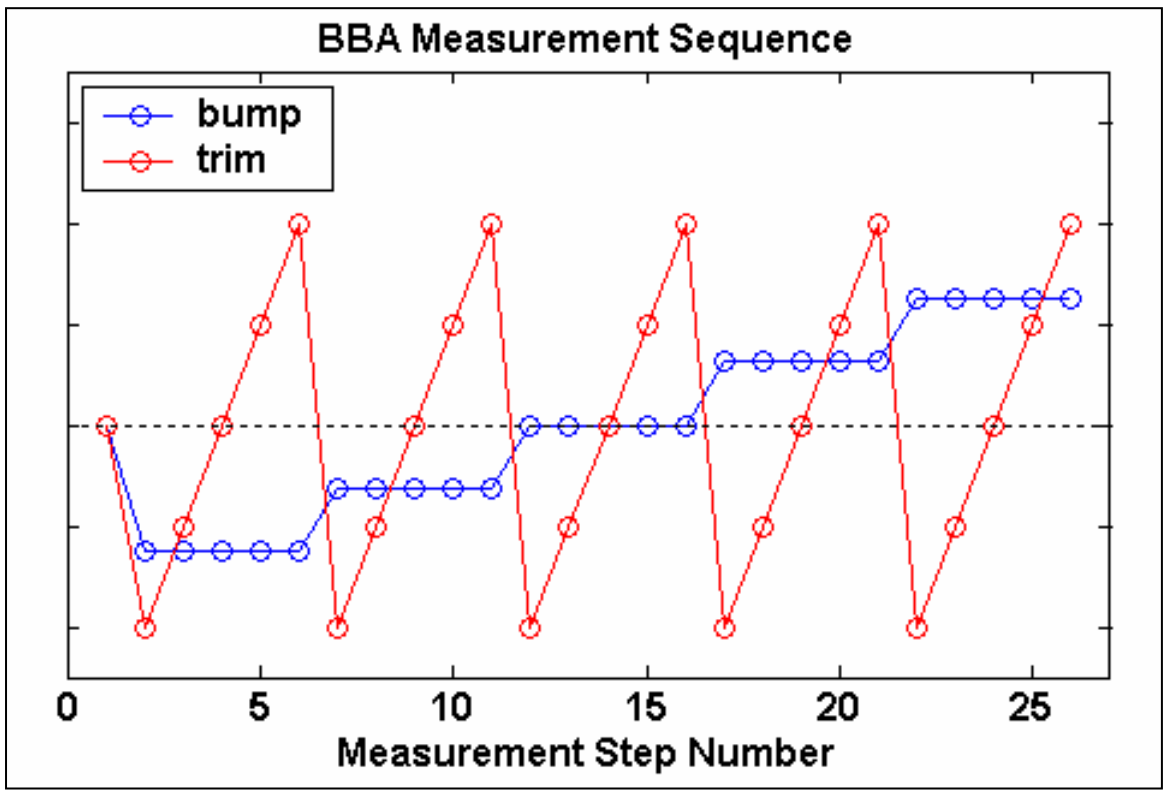
… and recent improvements

- Upgraded BPM electronics (now < 5 μm resolution)
- "Scrubbing mode" operation
- Frequent BPM calibration (suggested by MIA)

BBA Data Acquisition (2)



2D "grid" scan: closed local bump and quadrupole strength



BBA Data Analysis† (1)

Change in closed orbit (Δx_{co},Δy_{co}) due to a change in strength ($K \rightarrow K^{(1)}$) of a misaligned quadrupole (x_{bq},y_{bq}):

$$\begin{pmatrix} \Delta x_{co} \\ \Delta y_{co} \end{pmatrix}_s = \left[K^{(1)}\overline{C}^{(1)}(s;s_0) - K\overline{C}(s;s_0)\right]\left[1 + K\overline{C}(s_0;s_0)\right]^{-1}\begin{pmatrix} x_{bq} \\ y_{bq} \end{pmatrix}$$

$$C(s;s_0) = R(s;s_0)\left[1 - R(s_0;s_0)\right]^{-1}$$

$$\overline{C}(s;s_0) = \begin{cases} \begin{bmatrix} -C_{12} & C_{14} \\ -C_{32} & C_{34} \end{bmatrix}, & \text{normal quadrupole} \\ \begin{bmatrix} -C_{14} & -C_{12} \\ -C_{34} & -C_{32} \end{bmatrix}, & \text{skew quadrupole} \end{cases}$$

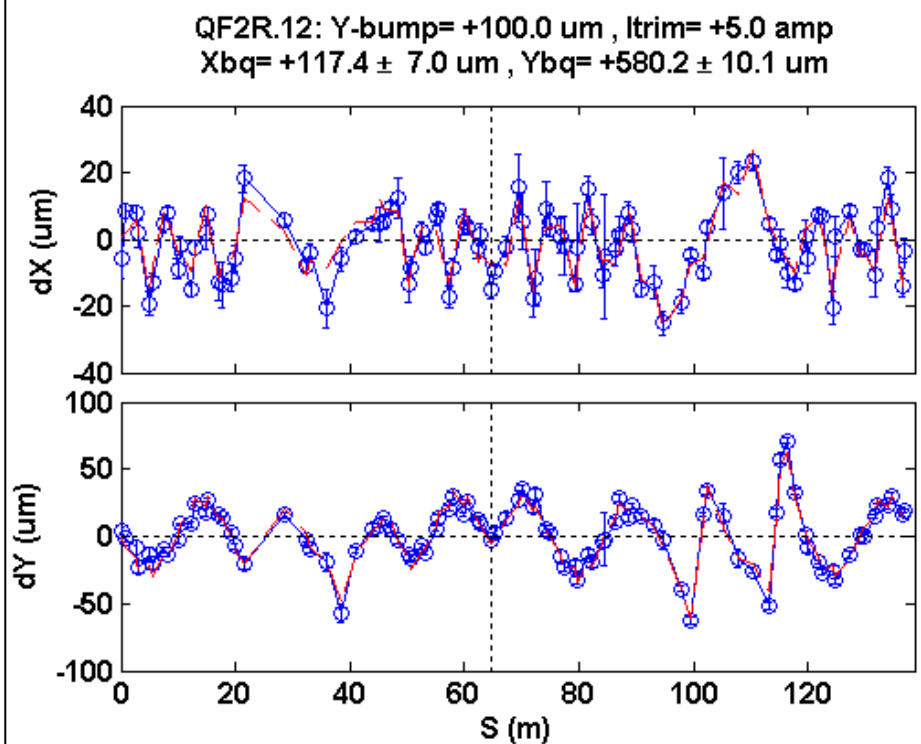
- ✓ includes closed orbit effects of ΔK (both kick and position shift)
- ✓ includes optics effects of ΔK (change in closed orbit response matrix)
- ✓ fits both planes simultaneously, including coupling

†A. Wolski and F. Zimmerman, "Closed Orbit Response to Quadrupole Strength Variation", http://www-library.lbl.gov/docs/LBNL/543/60/PDF/LBNL-54360.pdf

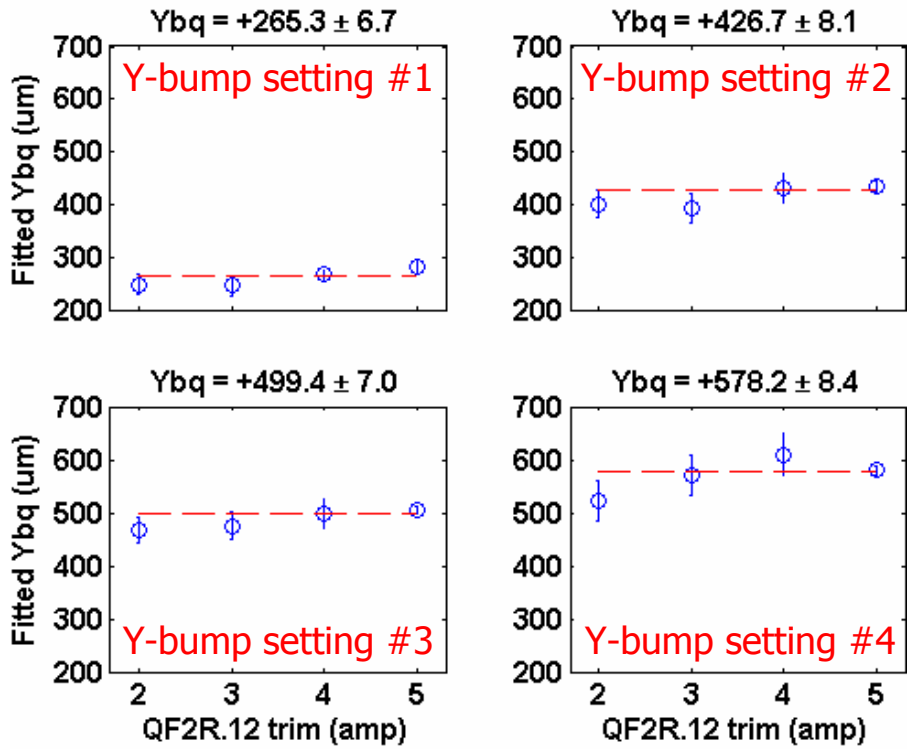
BBA Data Analysis (2)

Difference orbit fits

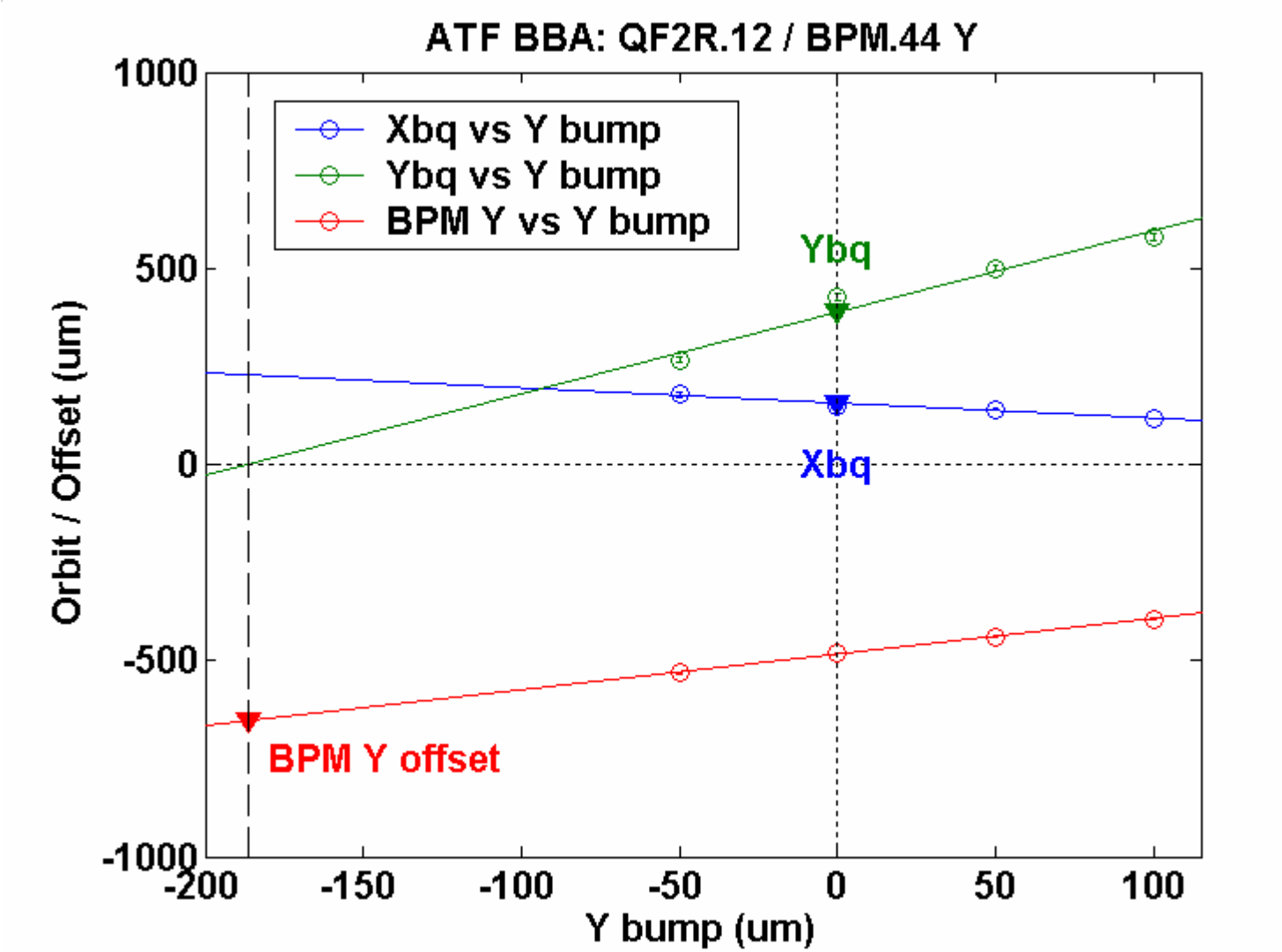
(blue = measured; red = fit)



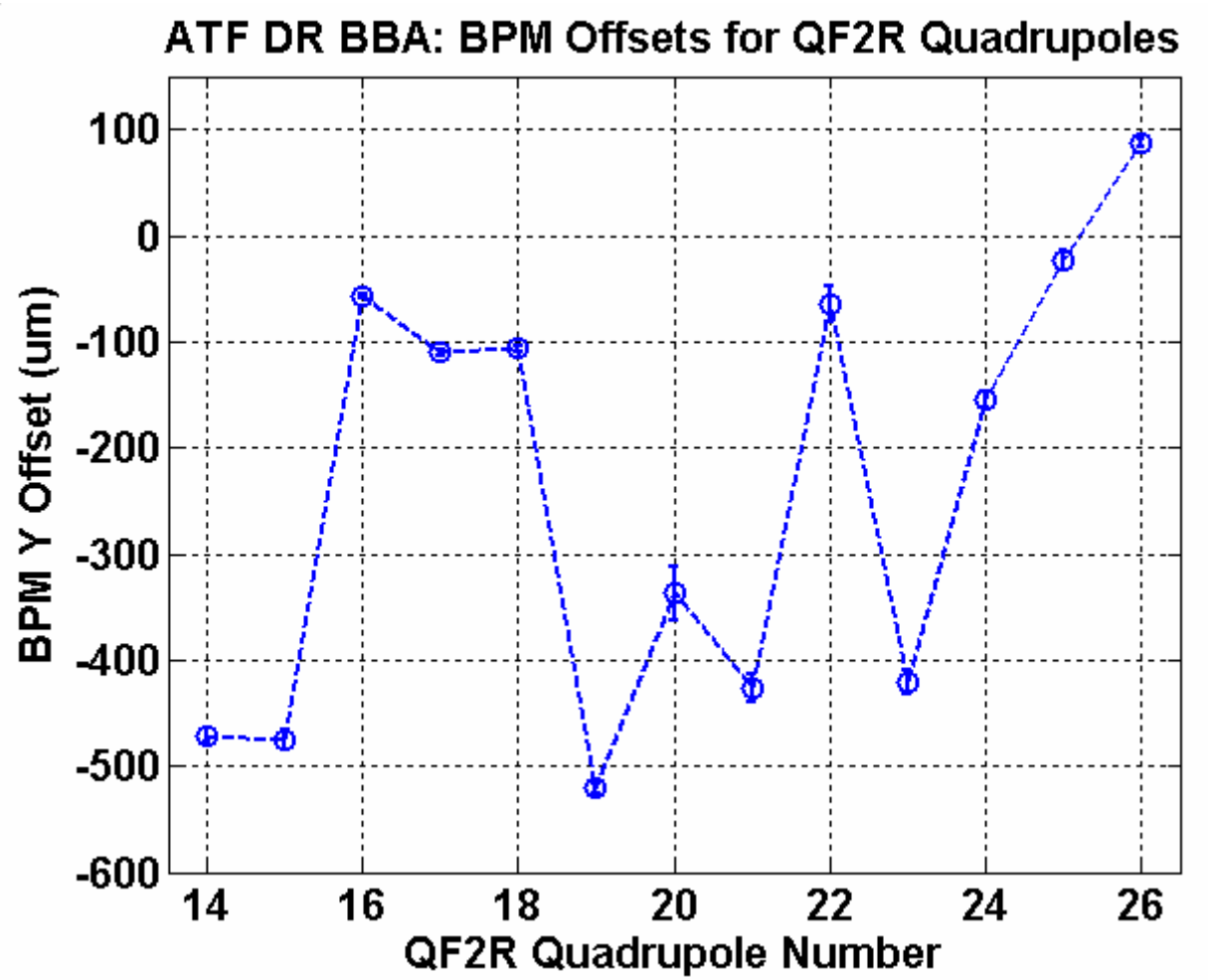
Fitted vertical beam-to-quadrupole offsets (Ybq) averaged at each bump setting



BBA Data Analysis (3)

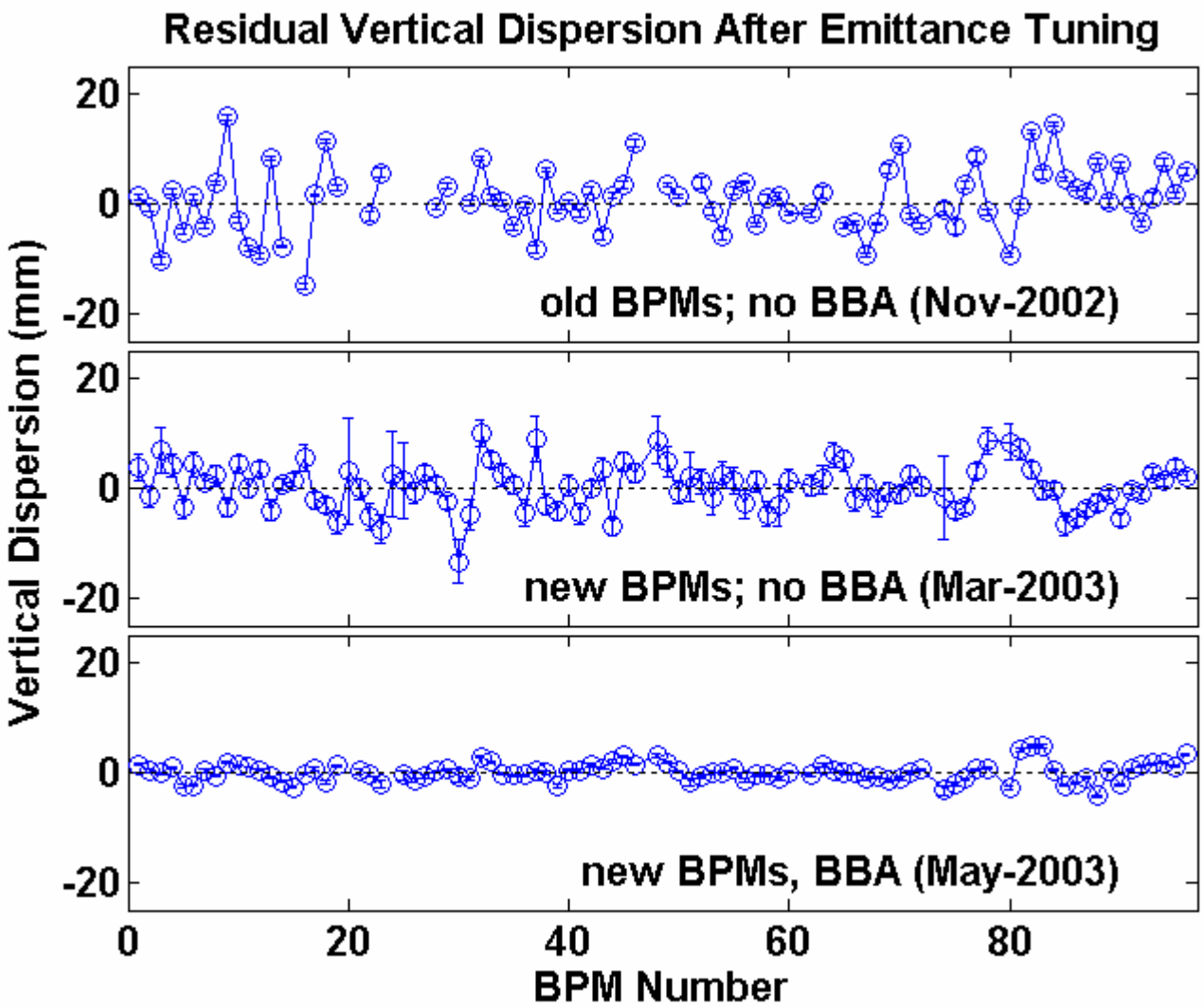


BBA Results (1)



- Measured offsets are large (» 100 μm) compared to survey alignment (< 100 μm)
- Average error on measured offsets is small (< 10 μm) … offsets are stable
- Separate tests have shown that offsets come from the BPM electronics

BBA Results (2)



$\eta_y^{rms} = 5.8$ mm

$\varepsilon_y > 10.5$ pm

$\eta_y^{rms} = 4.2$ mm

$\varepsilon_y = 6 - 10$ pm

$\eta_y^{rms} = 1.7$ mm

$\varepsilon_y = 3.5 - 5$ pm

Conclusions and Future Prospects

- BBA has been successfully used at the KEK-ATF Damping Ring to determine BPM offsets.
- Use of these BPM offsets has contributed to the achievement of < 5 pm vertical emittance, which is better than needed for the present GLC/NLC Damping Ring design.
- This BBA analysis allows us to use the quadrupoles themselves as BPMs, determining the actual beam offsets w.r.t. the magnetic center of each quadrupole; in the proposed GLC/NLC Damping Rings, magnet movers will be used to center the quadrupoles on the closed orbit.
- The analysis developed at the ATF has also been used successfully at PEP-II and will continue to be used.
- We hope next to demonstrate high resolution BBA of the ATF sextupoles, with the aim of further reducing the vertical emittance.

Acknowledgements

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- Kiyoshi Kubo (ATF)

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