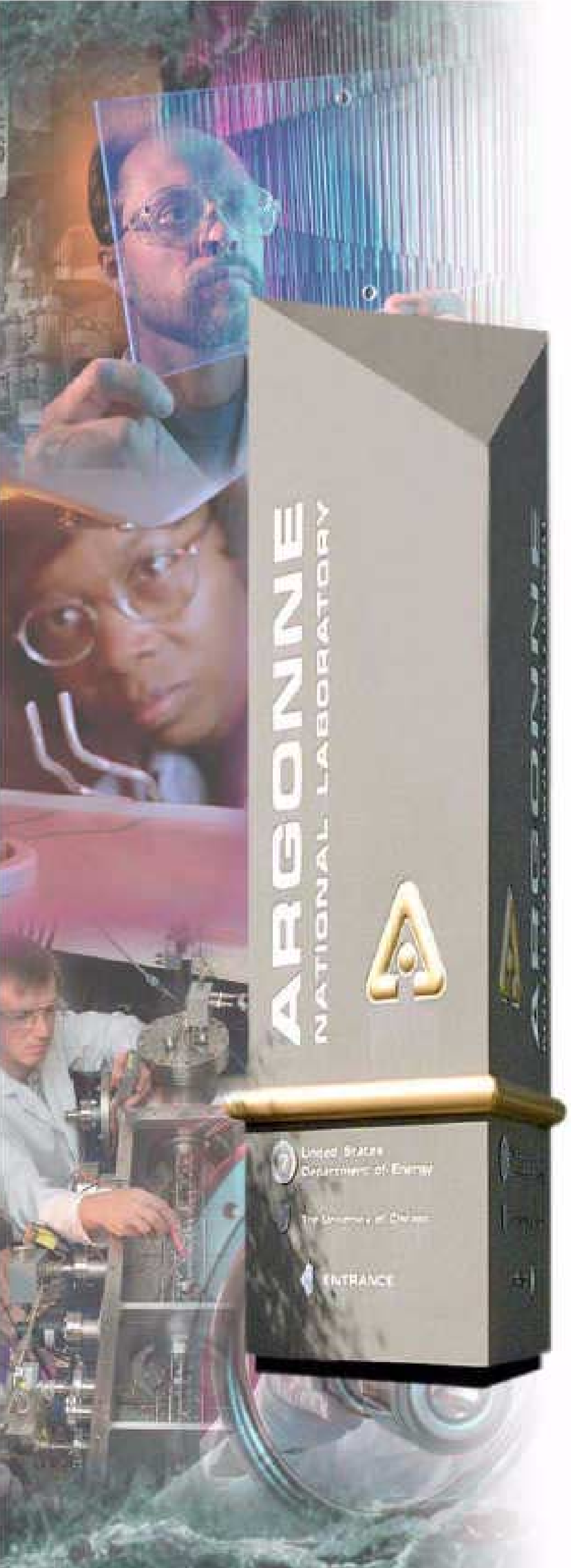


Orbit Stabilization at the Advanced Photon Source

Glenn Decker

DOE-BES Review

May 24, 2005

Beam Stability Outline

- **New beam stability specification**
- **Orbit control system overview**
- **DC Beam stability status and plans**
  - Completion of girder displacement project (“decker Distortion”)
  - “Gold standard” hard x-ray bpm project
- **AC Beam stability status and plans**
  - Monopulse rf beam position monitor data acquisition upgrade

APS AC Beam Stability Specification

Original Stability Specification
Equivalent to 5% of Particle Beam Dimensions*:

Vertical: 4.4 microns / 0.45 microradians rms
Horizontal: 16 microns / 1.2 microradians rms

Translating this 5% requirement to the present low-emittance / low coupling lattice results in**:

Vertical: 0.42 microns / **0.22*** ** microradians rms <----
Horizontal: 3.0 microns / 0.53 microradians rms

This specification gives the allowable rms beam motion of the source point in the frequency band *0.016 to 200 Hz*.

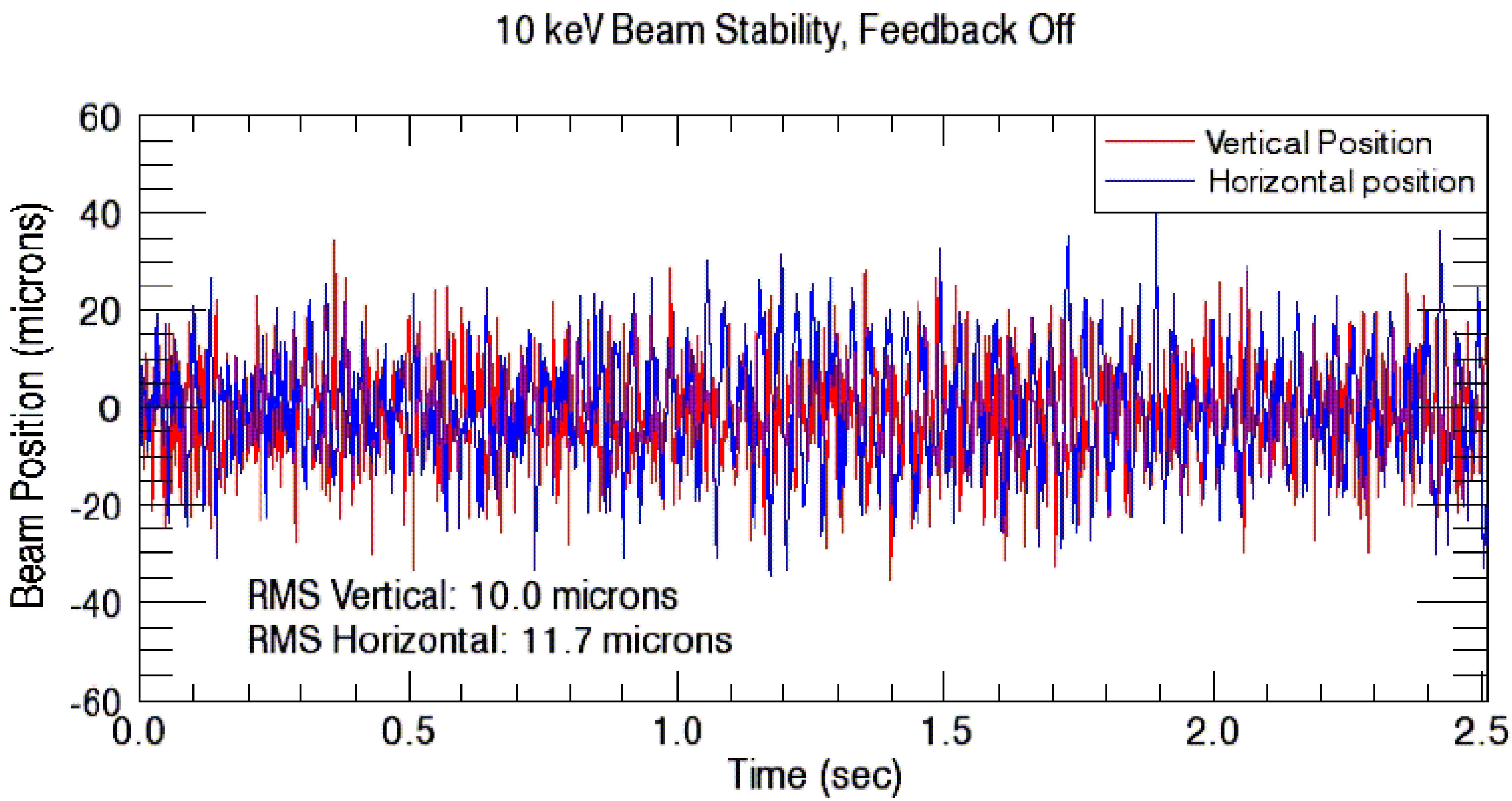
(Note: The frequency band has typically never been explicitly stated in the past.)

* Y.C. Chae, G. Decker, "APS Insertion Device Field Quality and Multipole Error Specification, PAC '95§

** http://www.aps.anl.gov/asd/oag/SRSourceParameters/sourcePointResults/

*** Includes photon angular divergence contribution, 7th harmonic, APS Undulator A

Data from Monochromatic X-ray BPM, 13ID



APS DC Beam Stability Specification

The allowable amount of peak-to-peak source point drift with period ranging from 1 minute to 1 week (168 hours) is

Vertical:	1.0	microns	/	**0.50**	microradians p-p <----
Horizontal:	5.0	microns	/	1.0	microradians p-p

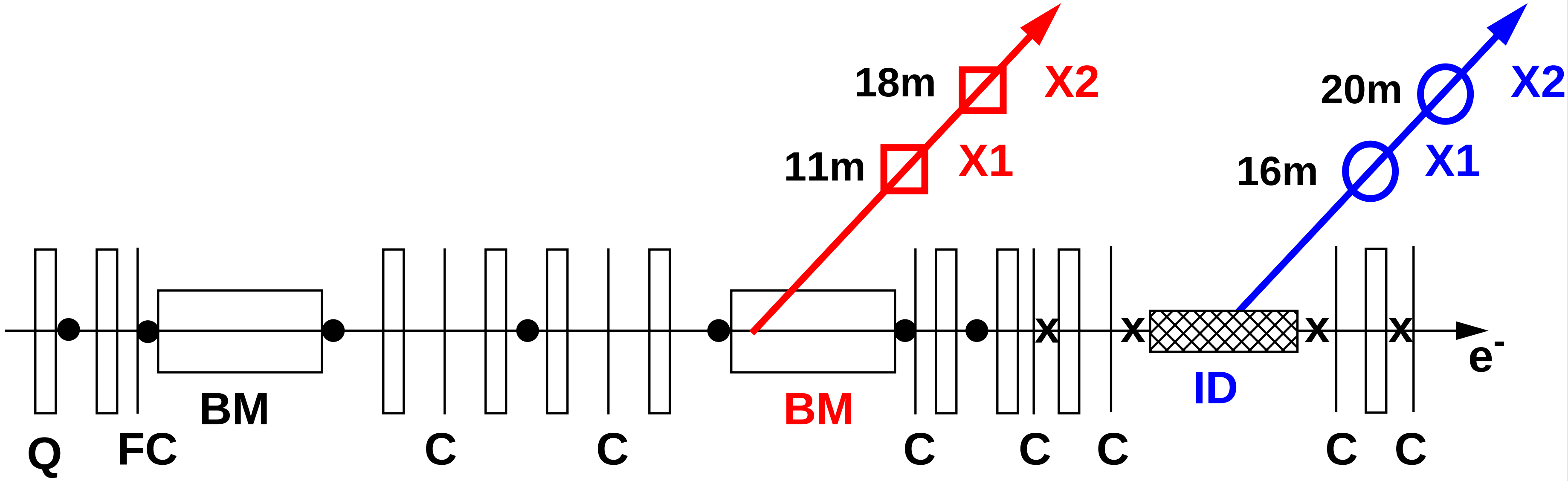
This is also to be interpretted as the week-to-week trajectory reproducibility specification, e.g. following a machine studies period.

Compare this with dc stability “goals” stated by an APS user at the 2004 user’s meeting:

- Short term:
  angular: vertical 1 μrad, horizontal 2 μrad,
  position: 5 μm
  over duration of run;

- Mid-term:
  angular: vertical 0.3 μrad, horizontal 1 μrad
  position: 3 μm
  over 1 year

Beam Position Monitors and Magnets in One Sector



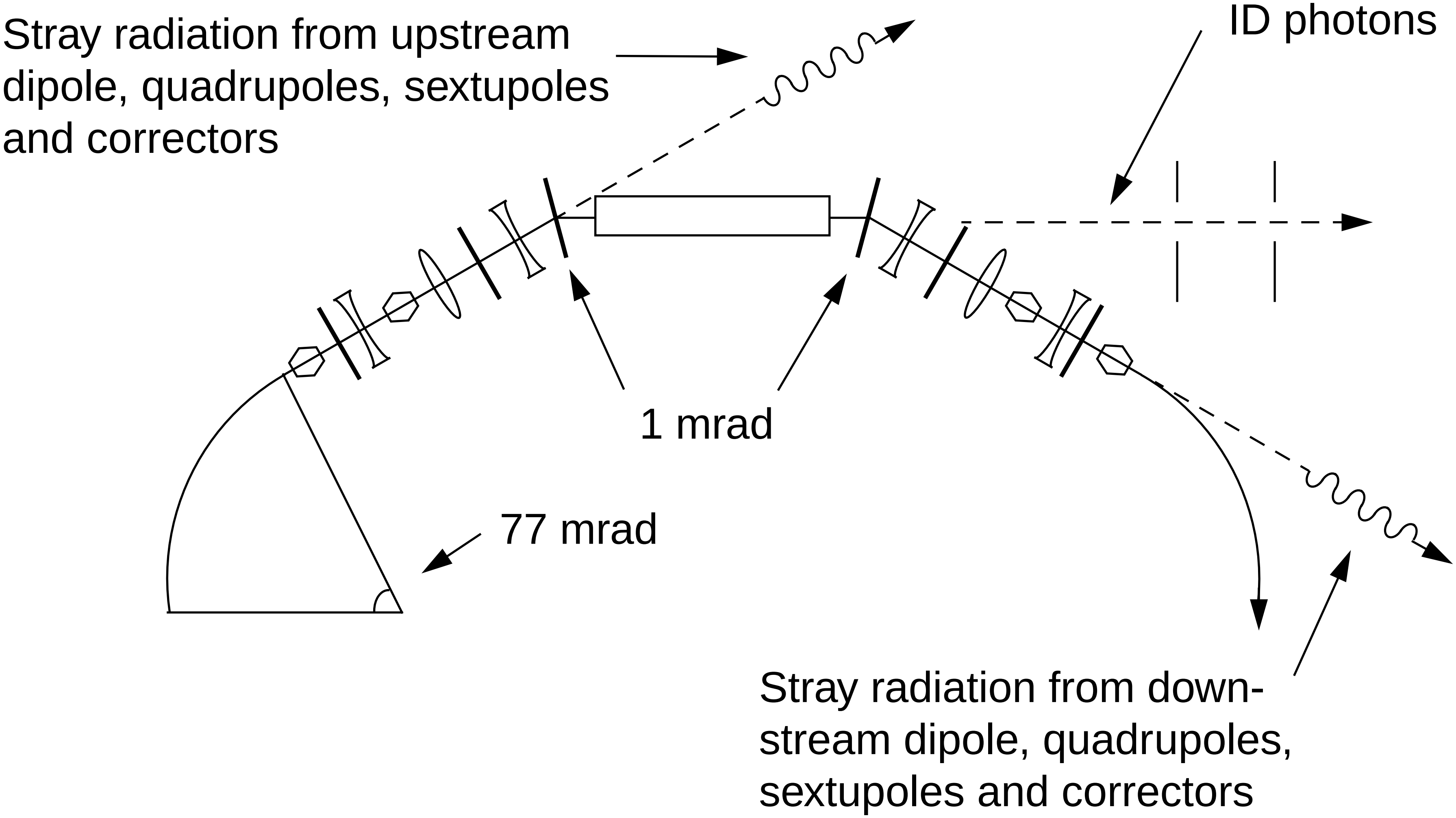
- ● : Broad-band RF Beam Position Monitors (7) (Turn-by-Turn)
- x : Narrow-band RF Beam Position Monitors (4) (~ 300 Hz)
- □ : BM X-ray Beam Position Monitors (2 - Vertical Only) (~165 Hz)
- ○ : ID X-ray Beam Position Monitors (2) (~165 Hz)
- FC : "Fast" Corrector Magnet (1) (~ 1000 Hz)
- C : "Slow" Corrector Magnets (7) (few Hz)
- Q : Quadrupole Magnets


BpmCorrectorInUse.adl
SR Vertical BPM Status
In Use
Not In Use
Click on BPM Status to open BPM Display
SR Horizontal BPM Status
In Use
Not In Use
Click on BPM Status to open BPM Display
Zones
F A B C D E F
A0 A1 A2 A3 A4 B5 B4 B3 B2 B1 B0 C0 D1 D2 I1 I2
NA
SR Vertical Corrector Feedback Use
Not Used
DC
RTFB
RTFB&DC
Click on PS Status to open PS Display
Mag
Sector
10 20 30 40
A:V1 A:V2 A:V3 A:V4 B:V4 B:V3 B:V2 B:V1
SR Horizontal Corrector Feedback Use
Not Used
DC
RTFB
RTFB&DC
Click on PS Status to open PS Display
Mag
Sector
10 20 30 40
A:H1 A:H2 A:H3 A:H4 B:H4 B:H3 B:H2 B:H1
LLE 05-07-04

DC Beam Stability

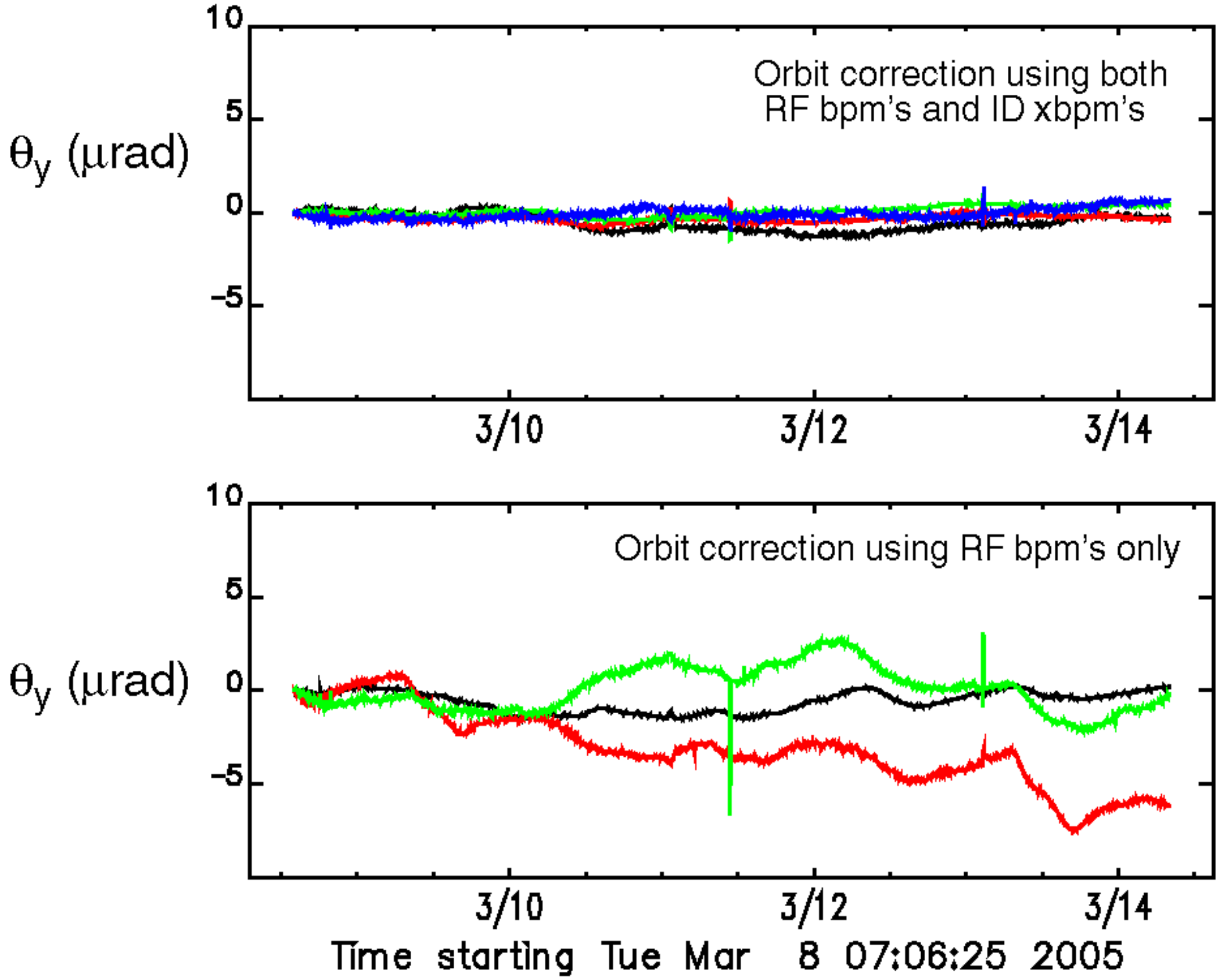
- All sectors have now been realigned to reduce id x-bpm stray radiation back-ground, completing a 7-year effort.
- Photon bpm's are used in DC feedback at all 19 bending magnet beamlines, and 17 out of 29 insertion device beamlines.
- Every insertion device straight section has 4 channels of narrowband rf bpm electronics. Two have very high resolution using pickup electrodes mounted on small aperture ID vacuum chamber, the other pair are used for the missteering interlock.

Re-direction of Stray Photons by Girder Alignment*

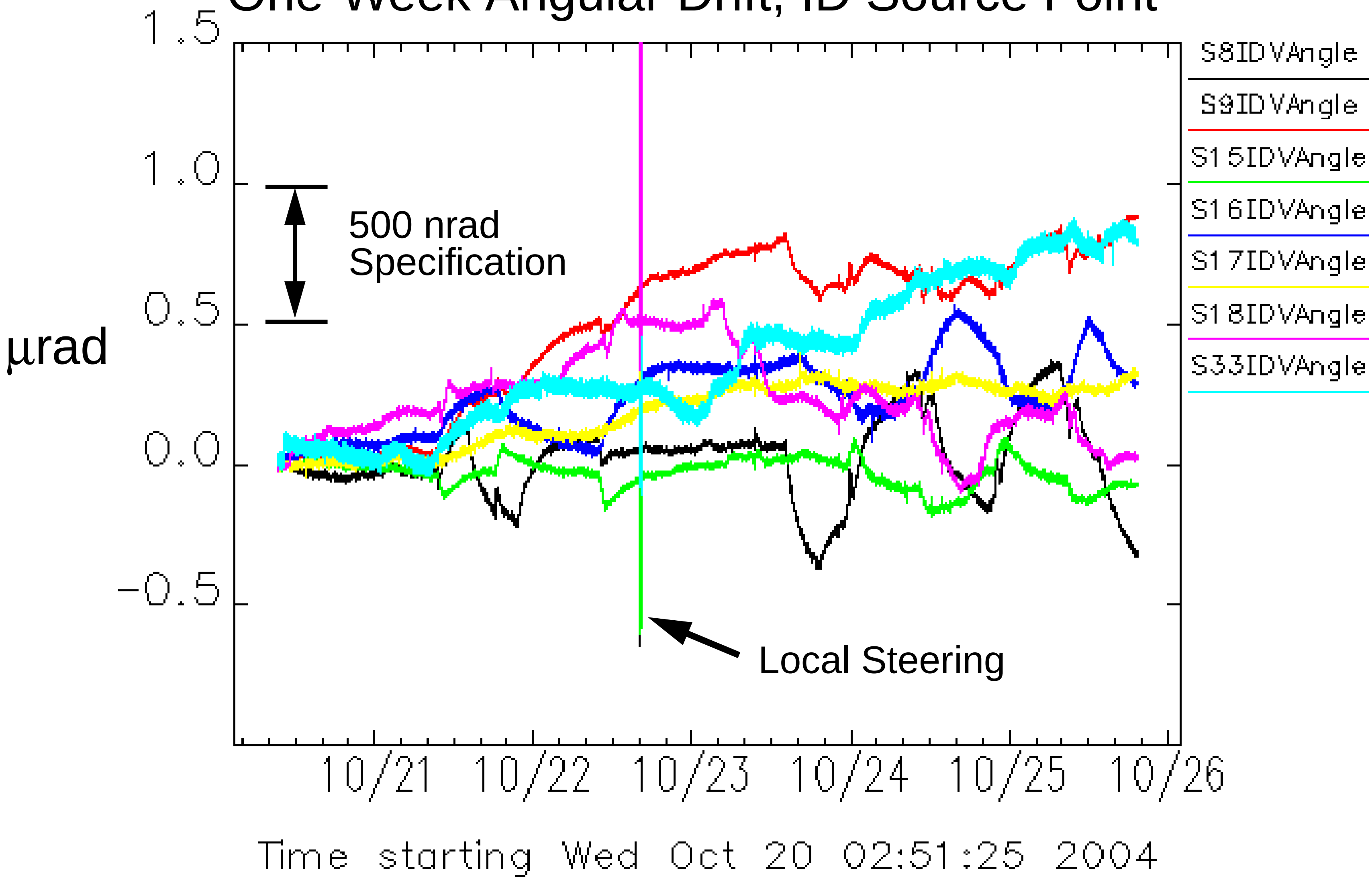


*Phys. Rev. ST Accel. Beams 2, 112801 (1999)

One-week Vertical Pointing Stability, Derived from ID Photon Beam Position Monitors

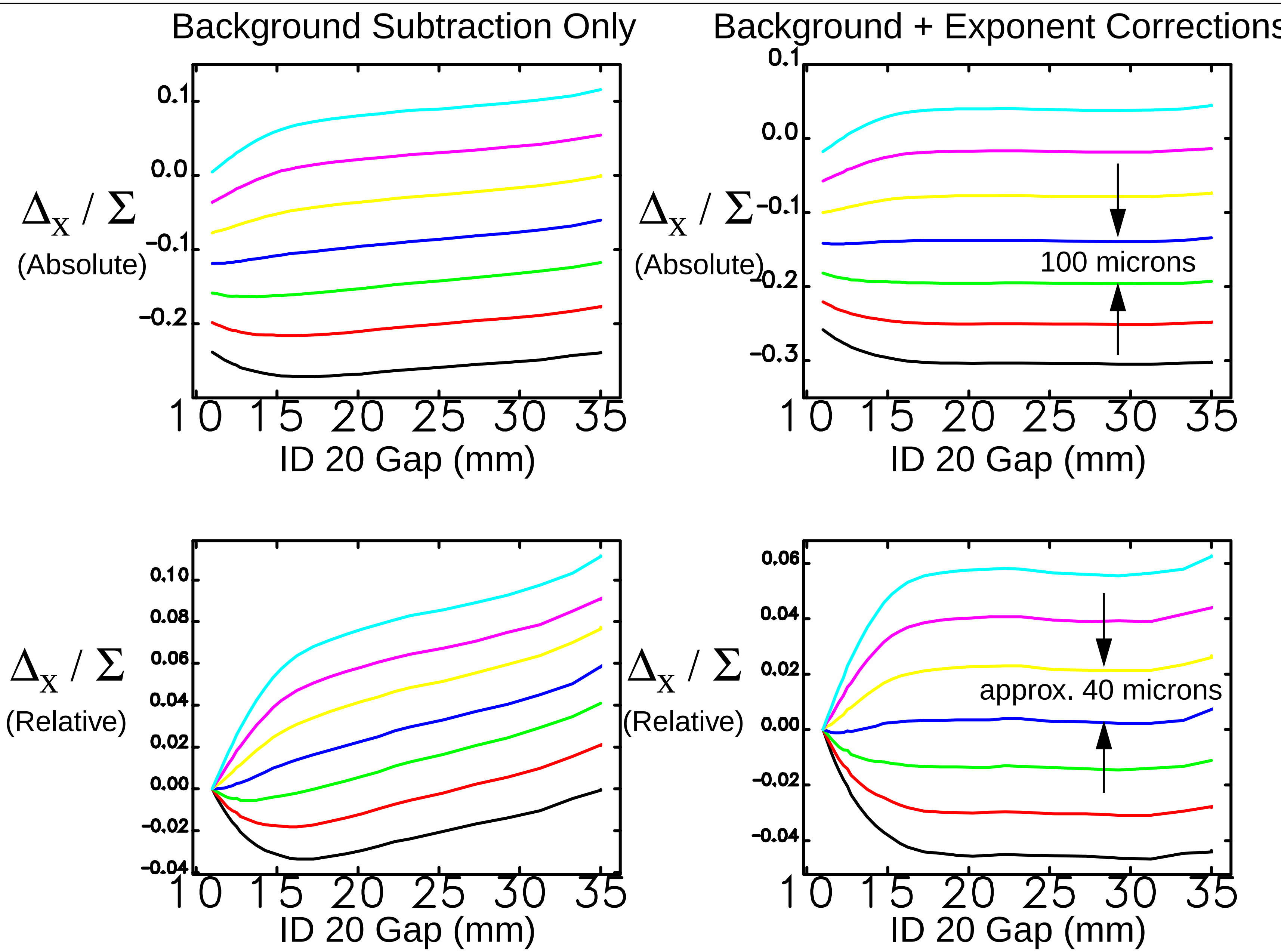


One-Week Angular Drift, ID Source Point*



* angles calculated from vertical ID xbpm readbacks, fixed gap.

Correction of Residual ID Photon BPM Gap-dependent Systematic Errors



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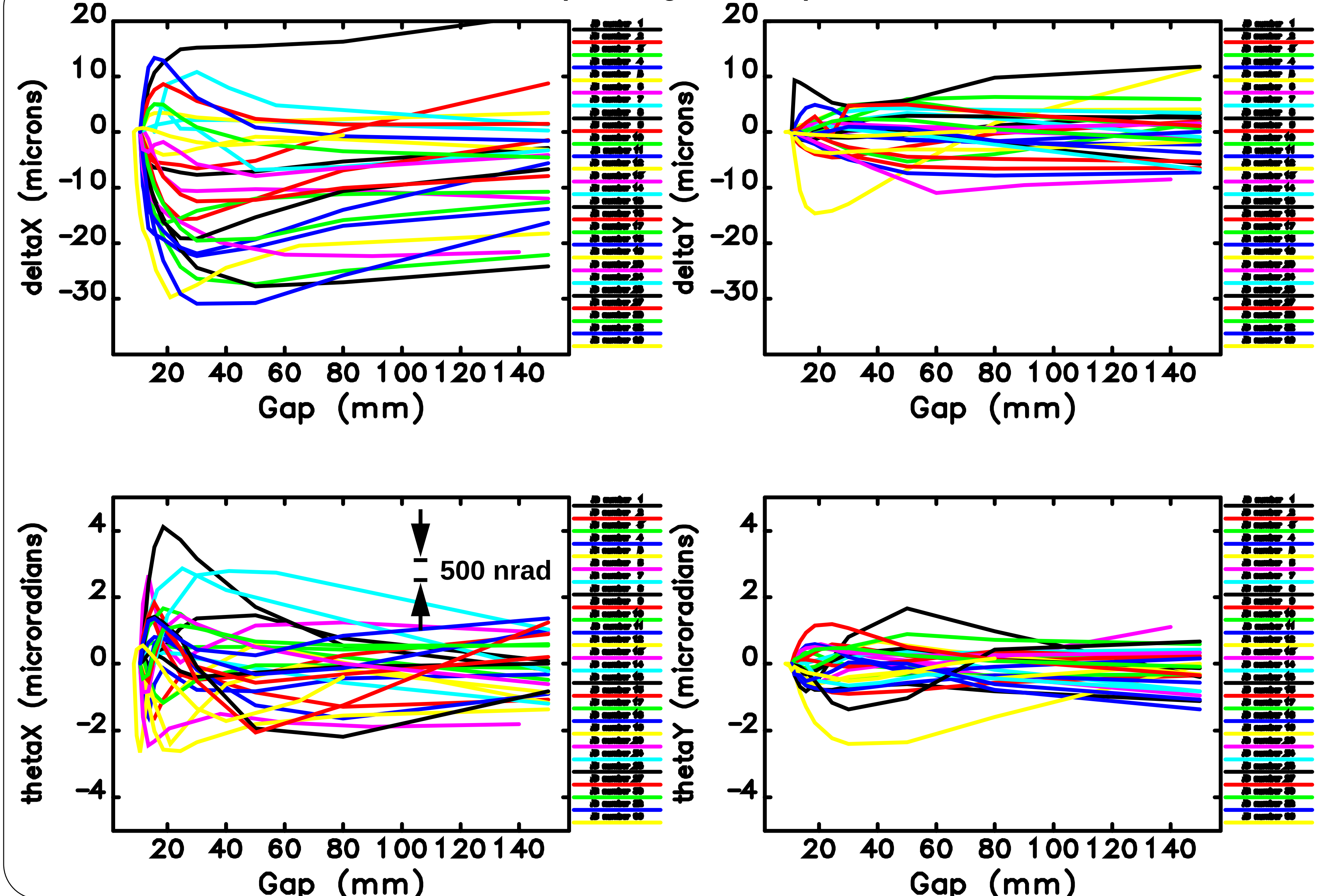
Insertion Device Field Integrals vs. Gap

(Rotating Coil Data)



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Summary of Factors Limiting Long-term Pointing Stability

- Tunnel temperature +/- 0.1 degrees C is mandatory.

- ID photon bpm residual gap-dependent systematic errors

  - Internal trajectory errors cause particle / x-ray beam non-colinearity

  - RF bpm's (measuring particle beam trajectory) are used to generate lookup tables for ID photon bpm offset vs. gap

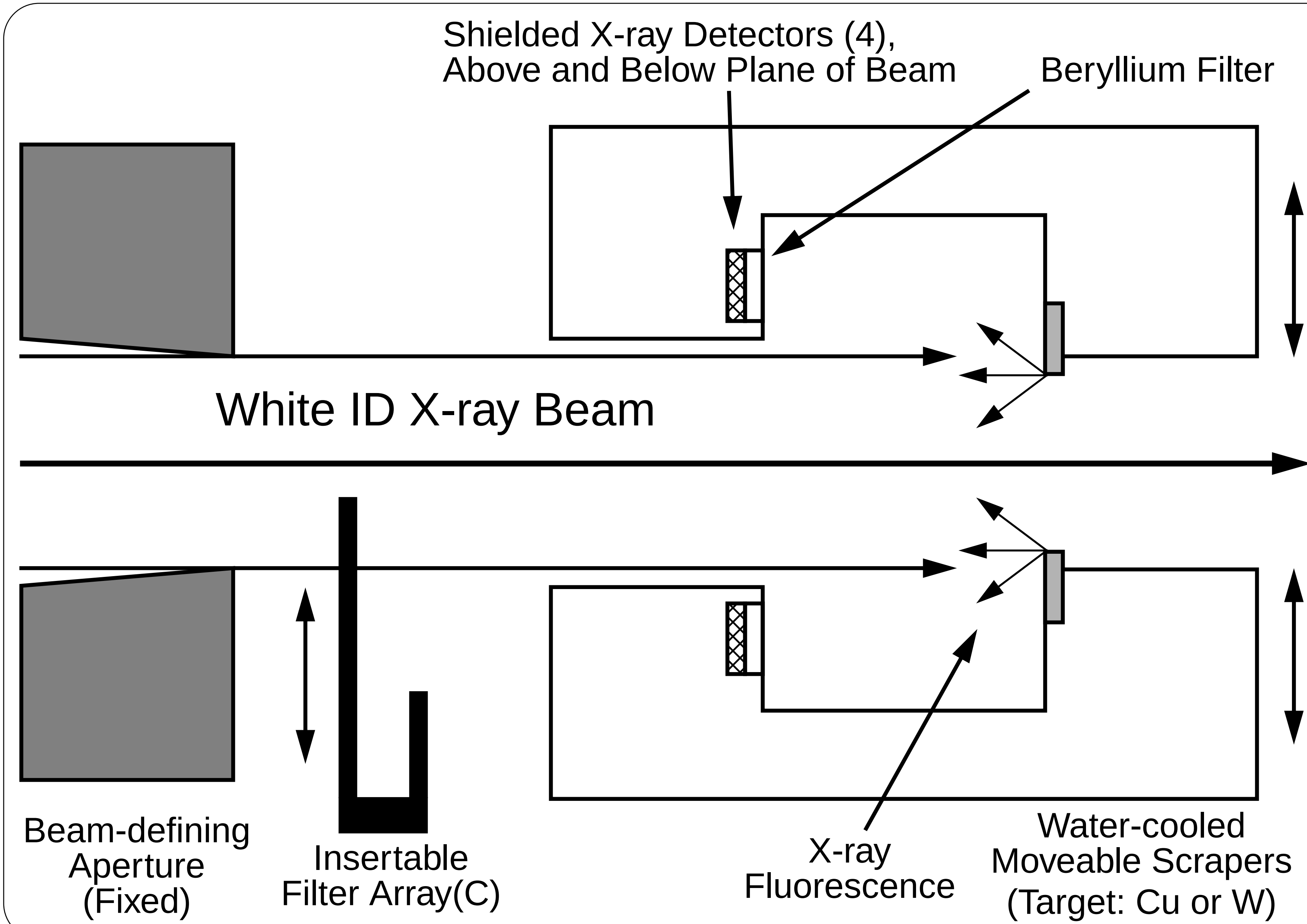
  - Photon bpm's are sensitive to bending magnet radiation, causing significant background signal, important at large ID gap.

  - Sensitivity to ultraviolet radiation halo causes other problems, e.g. electron cloud effects.

- The direction of the x-ray beam centroid relative to the particle beam is indeterminate at the few-μrad level using present technology.

  - A diagnostic sensitive only to hard x-rays is necessary to solve this problem
  - Funding has been approved to move forward on a design to be tested at 19ID in CY05, with a refined first production article to follow in 2006.

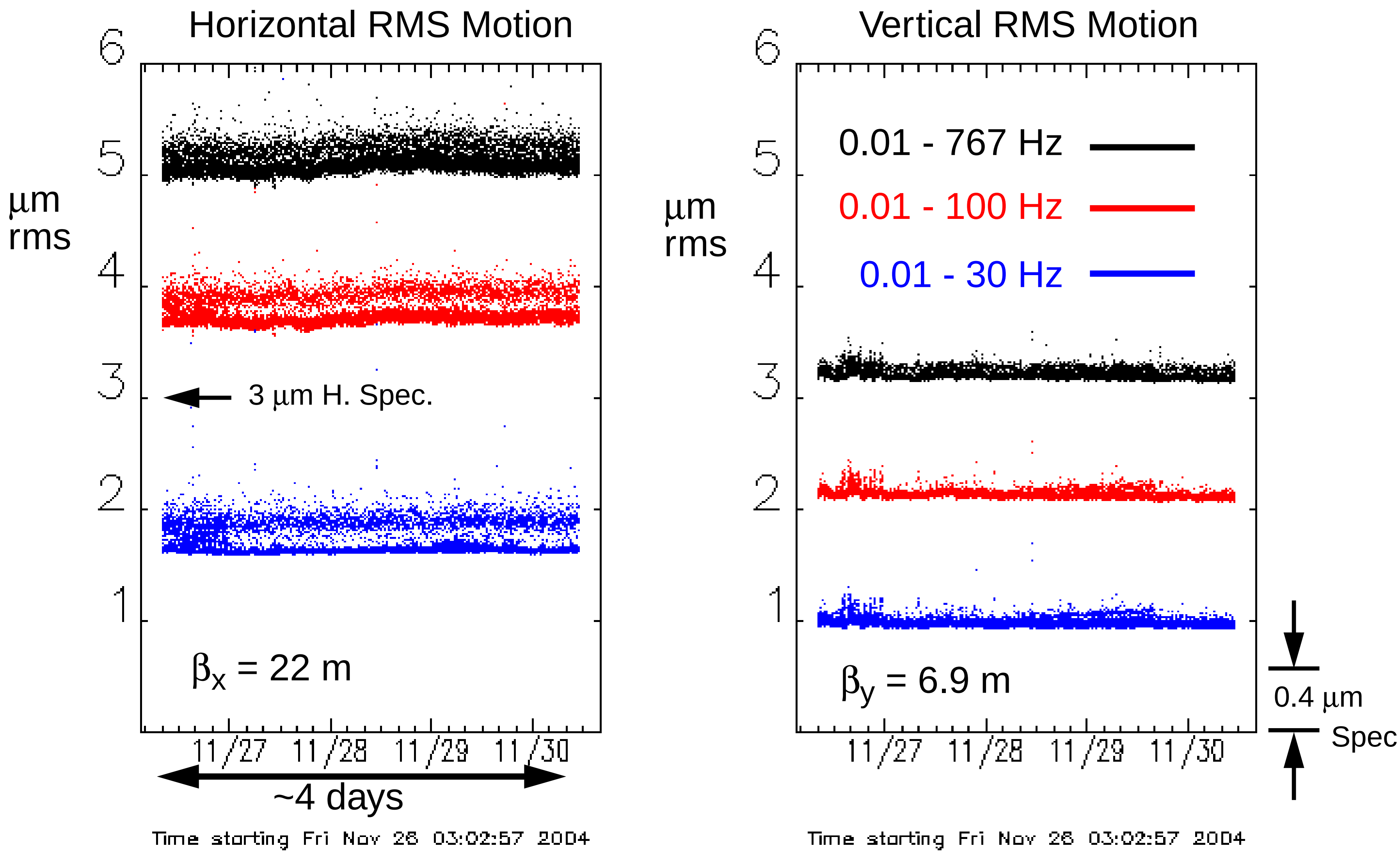
Plan View of Hard X-ray Beam Position Monitor Concept



AC Beam Stability

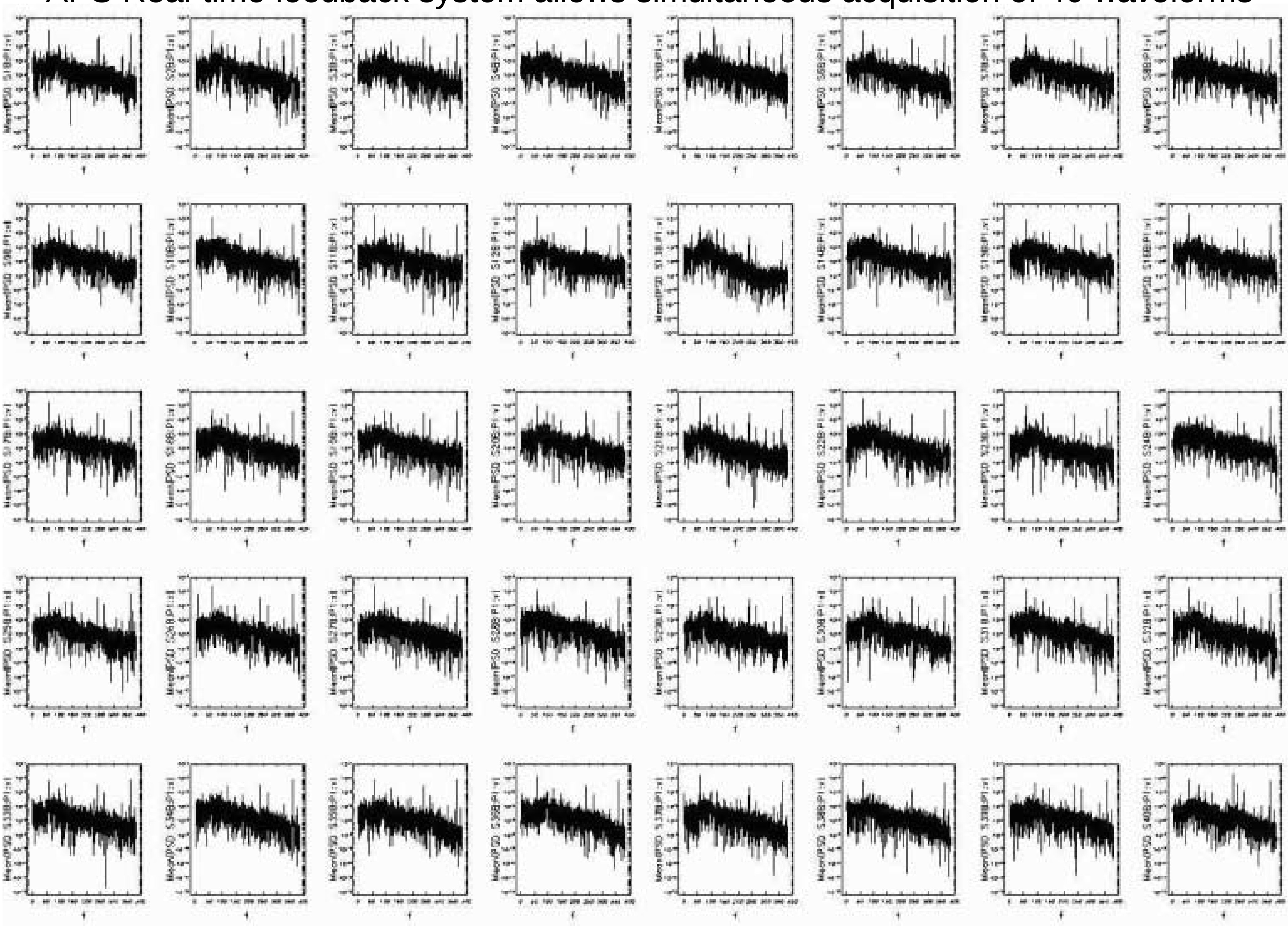
- The real time feedback system has been in operation since 1997.
- Makes use primarily of original monopulse rf bpm electronics.
- Provides powerful diagnostic of ac beam motion - 1.5 kHz sample rate, with access to virtually all beam position monitors and corrector magnet power supplies.

Long Term Stability of AC Beam Motion

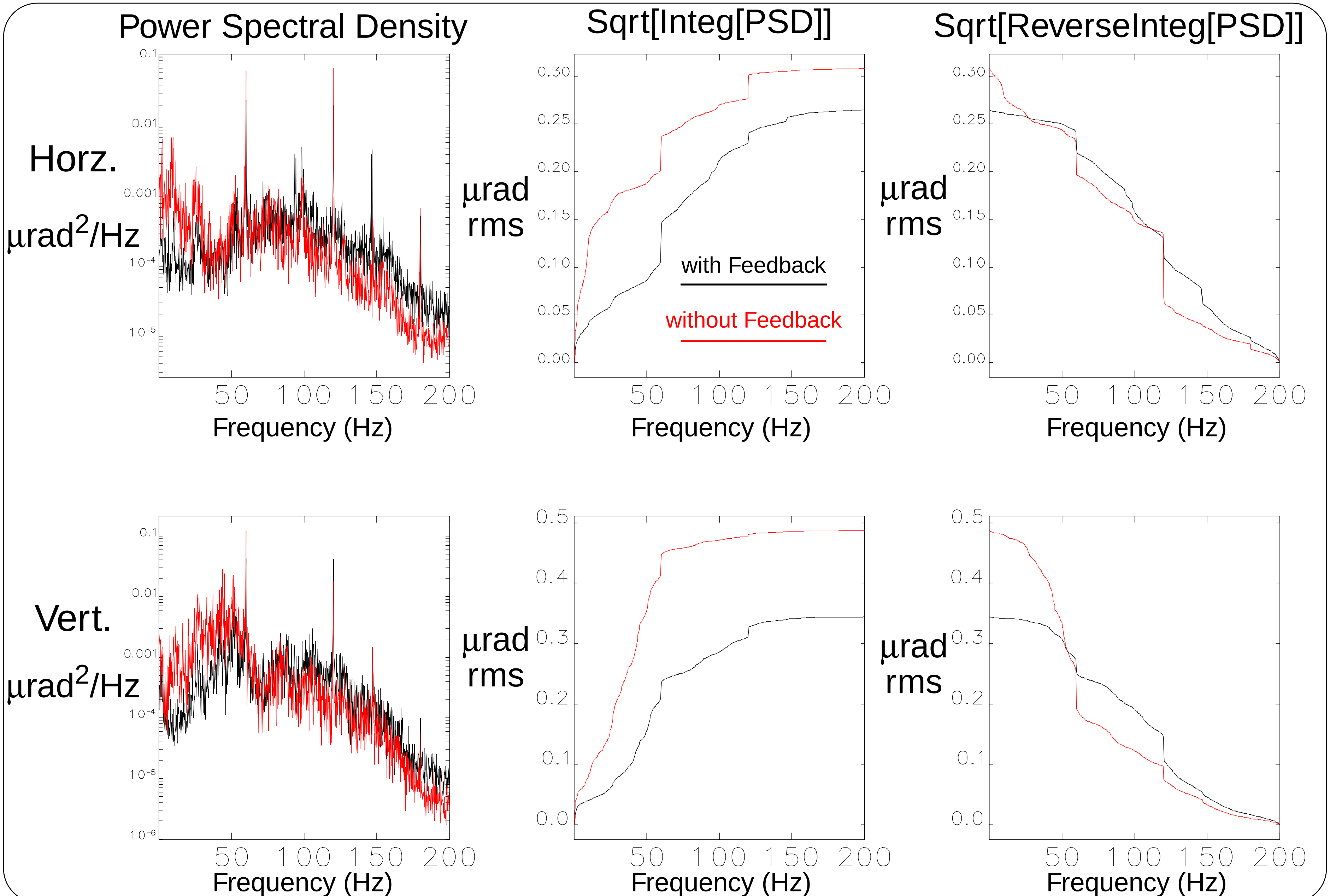


Top-up operation, 24 singlet fill pattern

APS Real-time feedback system allows simultaneous acquisition of 40 waveforms



AC Pointing Stability



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AC Beam Stability Plans

- A lot of relatively inexpensive fast network and signal processing technologies are available. This could allow a faster update rate (> 1.5 kHz), a larger response matrix, or some optimal combination.
- The addition of a second fast feedback corrector (relocation of BH4 corrector to G3 spool piece) could improve noise rejection up to a factor of two according to some older simulation results. Further investigations are ongoing.
- An over-aggressive design in the analog front end of the narrowband and photon beam position monitors (6-pole anti-aliasing filters) precludes their effective use in realtime feedback. These filters are being modified (CY05). ID photon bpm gap dependence still an issue (e.g. what to do when a user opens his gap).
- The monopulse rf bpm data acquisition and digital signal processing is archaic. Funding has been approved to upgrade one sector, to enhance functionality (e.g. fast beam history feature), and reduce electronic noise. Strategy is to retain existing monopulse receiver front ends, to be packaged separately from the new data acquisition (VXI format).

APS Beam Stability - Summary

- DC beam stability is world-class, with sub-microradian / week demonstrated, and not unusual. High-resolution narrowband rf bpm's, together with ID photon bpm's have been critical in this effort.

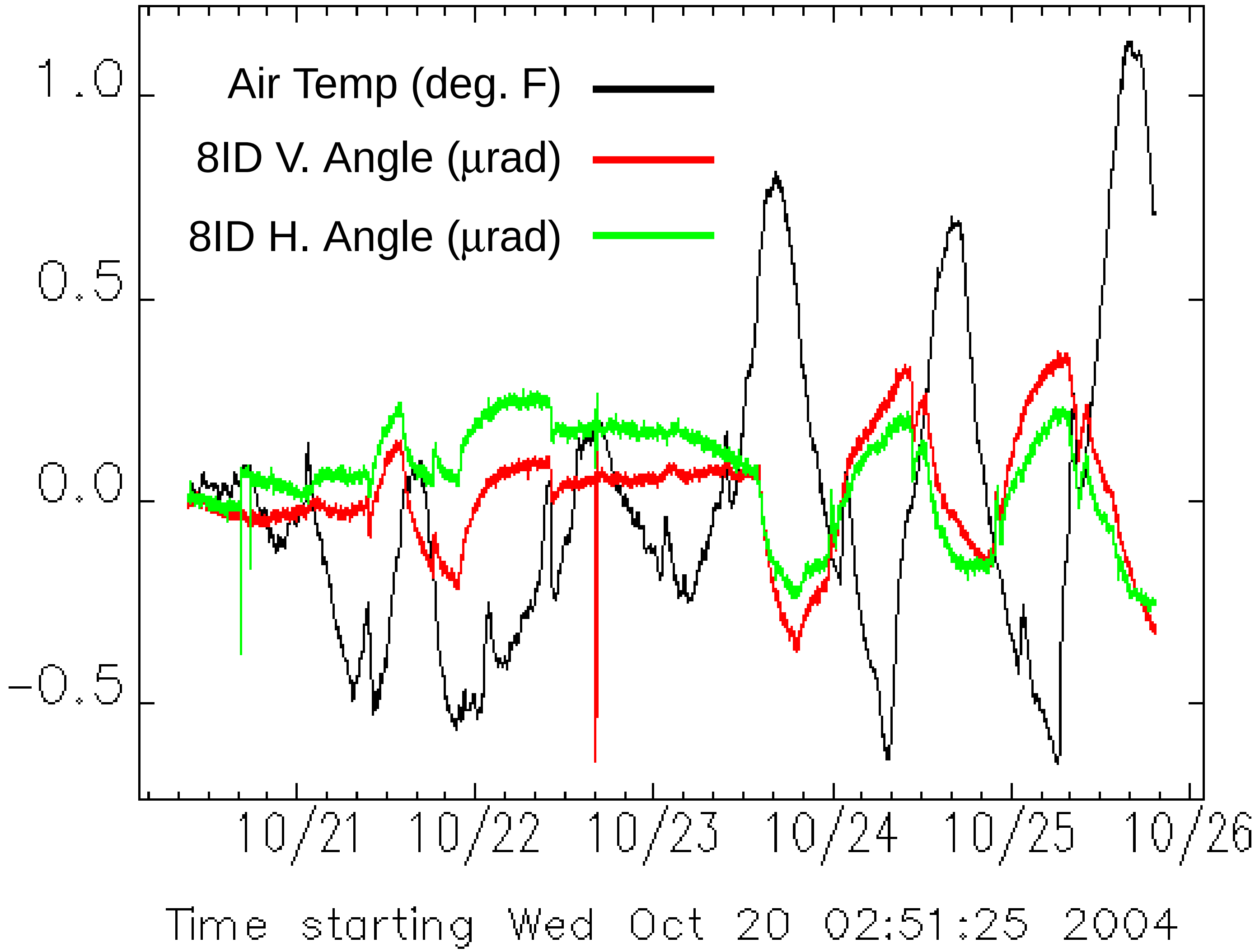
- New technology ("gold standard hard x-bpm") is needed to overcome residual gap-dependent systematic errors, to achieve true 500 nrad p-p / week goal.

- AC beam stabilization hardware is showing its age, upgrade options are under investigation, with some efforts proceeding with ARIM funds.

- Passive source identification and mitigation will continue. Tunnel temperature is becoming a limiting factor. Power supplies are no longer the dominant source of ac noise. Search for other mechanisms will continue, e.g. low-level mechanical vibration.

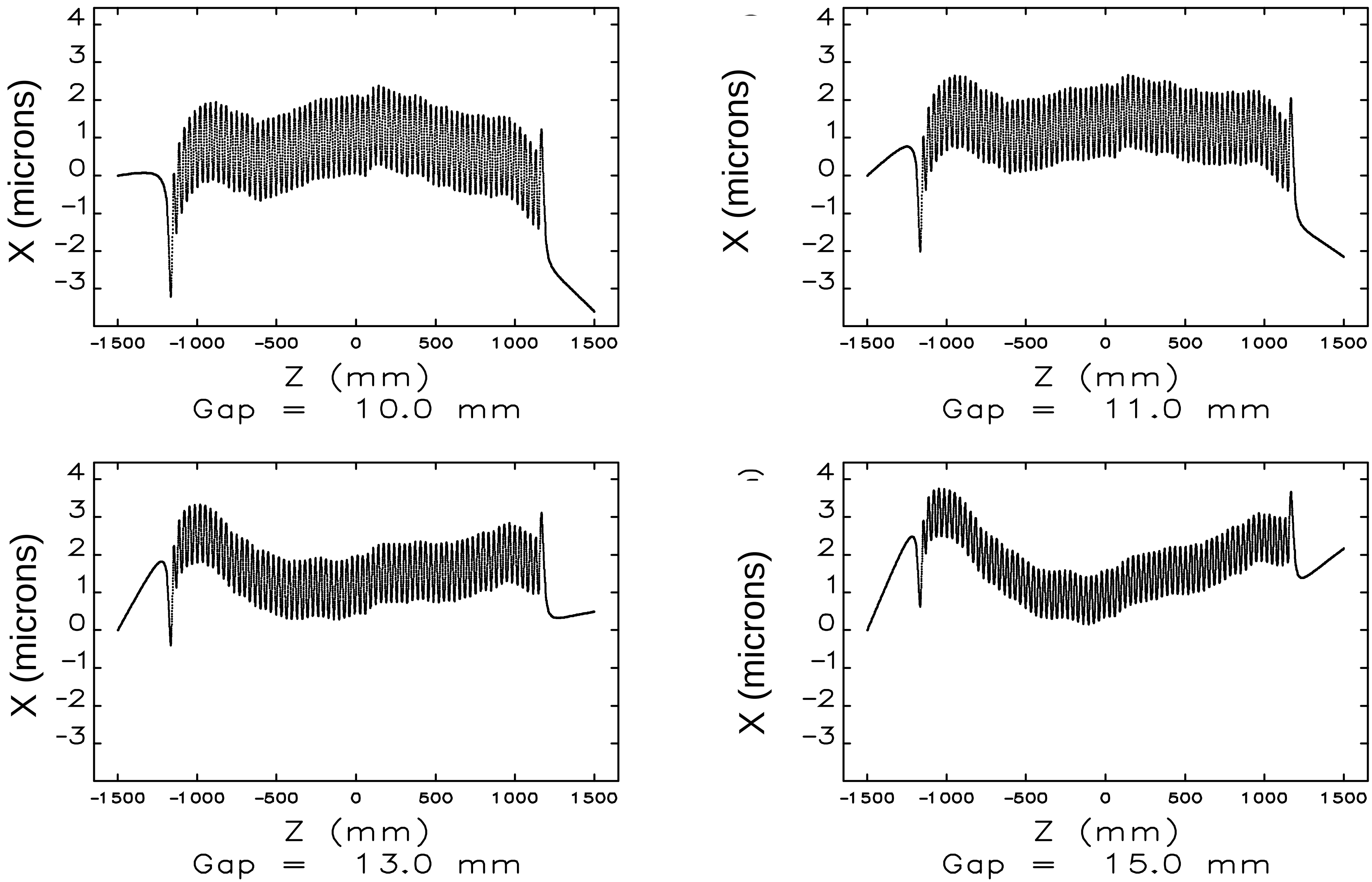
Backup Viewgraphs

Local Tunnel Air Temperature Impacts Pointing Stability

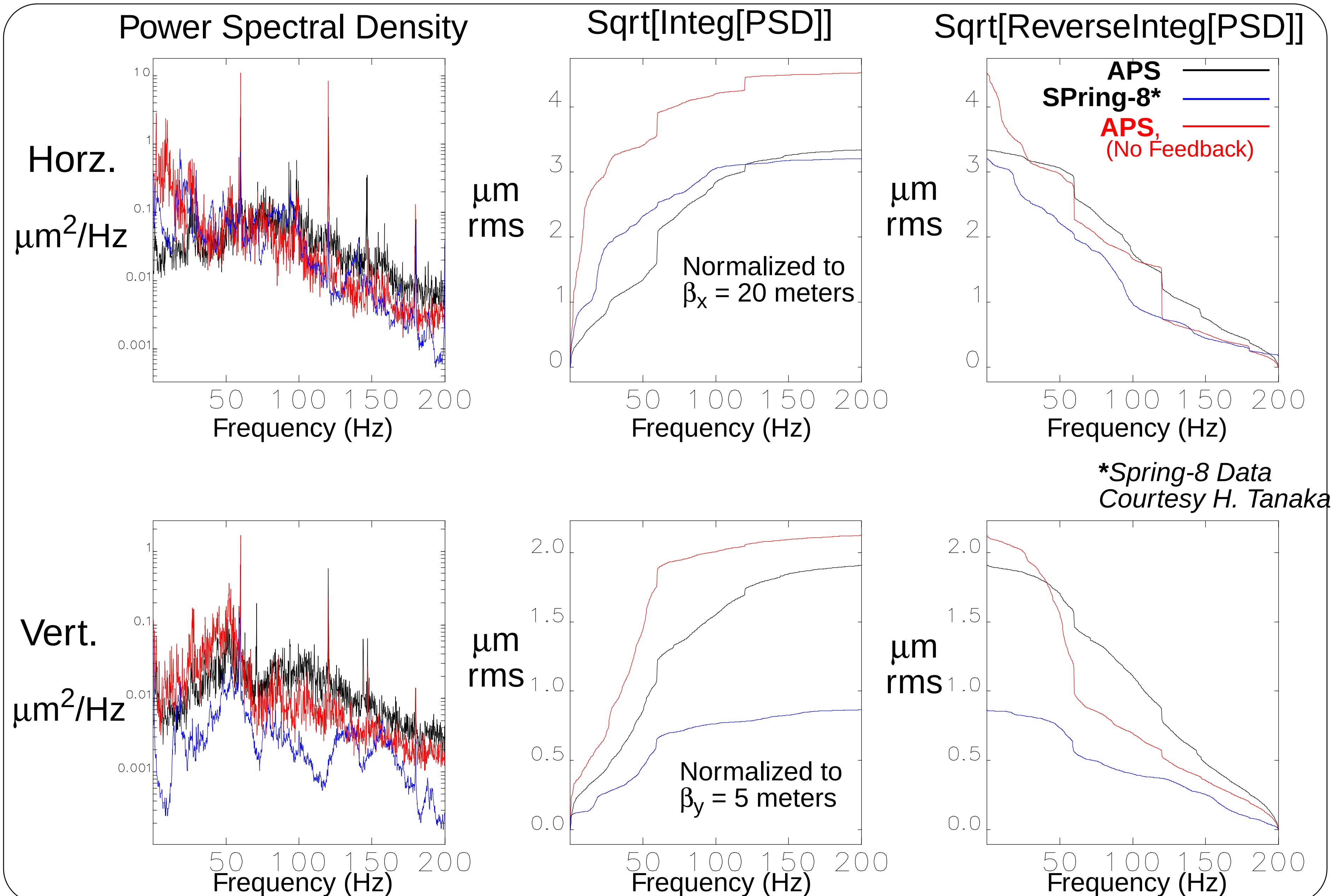


Variation of Particle Trajectory Through Insertion Device vs Gap

(Derived from Second Field Integral of Magnetic Measurement Data)



AC Beam Stability



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