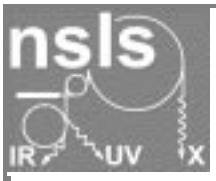

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Intermediate-Energy Light Sources

Digital Orbit Feedback Systems at NSLS

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BNL

Acknowledgements

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  John Smith (all from NSLS) and Om Singh (ANL)

Outline

- Introduction
- NSLS System Design
- NSLS System Performance
- Challenges and Future Work
- Conclusion

Relevant NSLS Ring Parameters

Parameter	UV	X-ray
Energy	800 MeV	2.8 GeV
Orbit Circumference	51 m	170 m
Horizontal/Vertical Tunes	3.1 / 1.3	9.8 / 5.7
Typical beam size, H/V	500 / 200 μm	200 / 50 μm
Lifetime	5 hrs	11-25 hrs
Nominal duration of a fill	5 hrs	12 hrs
Number of correctors H/V	16 / 16	56 / 40
Number of BPMs H/V	24 / 24	48 / 48
Typical corrector BW H/V	60/30 Hz	60 /30 Hz

Motivation and History

- Environmental noise on the beam
  (Booster, Floor Vibrations, 60 Hz Harmonics, etc.)
- Eliminate or Build a Feedback System
- NSLS efforts

  Late 80s: Analog local feedbacks in some of X-ray beamlines

  Late 80s: Analog global feedback system in UV and X-ray rings

  Mid-90s: Digital feedback test system development in X-ray ring

- "Old Digital Feedback System" at NSLS

  550 Hz sampling rate

  High gain but only ~15 Hz correction bandwidth

  Significant reduction in slow drift and 1.2 Hz booster noise

  Studies only; never put into operations

Clear advantage of going digital

Calculating Correction Values

Singular Value Decomposition of the Response Matrix

- Max # of Eigenvectors = Min(# of BPMs, # of trims)
- More Eigenvectors = Better Correction
- But as the # of Eigenvectors Increases

  Computation time grows faster than linearly

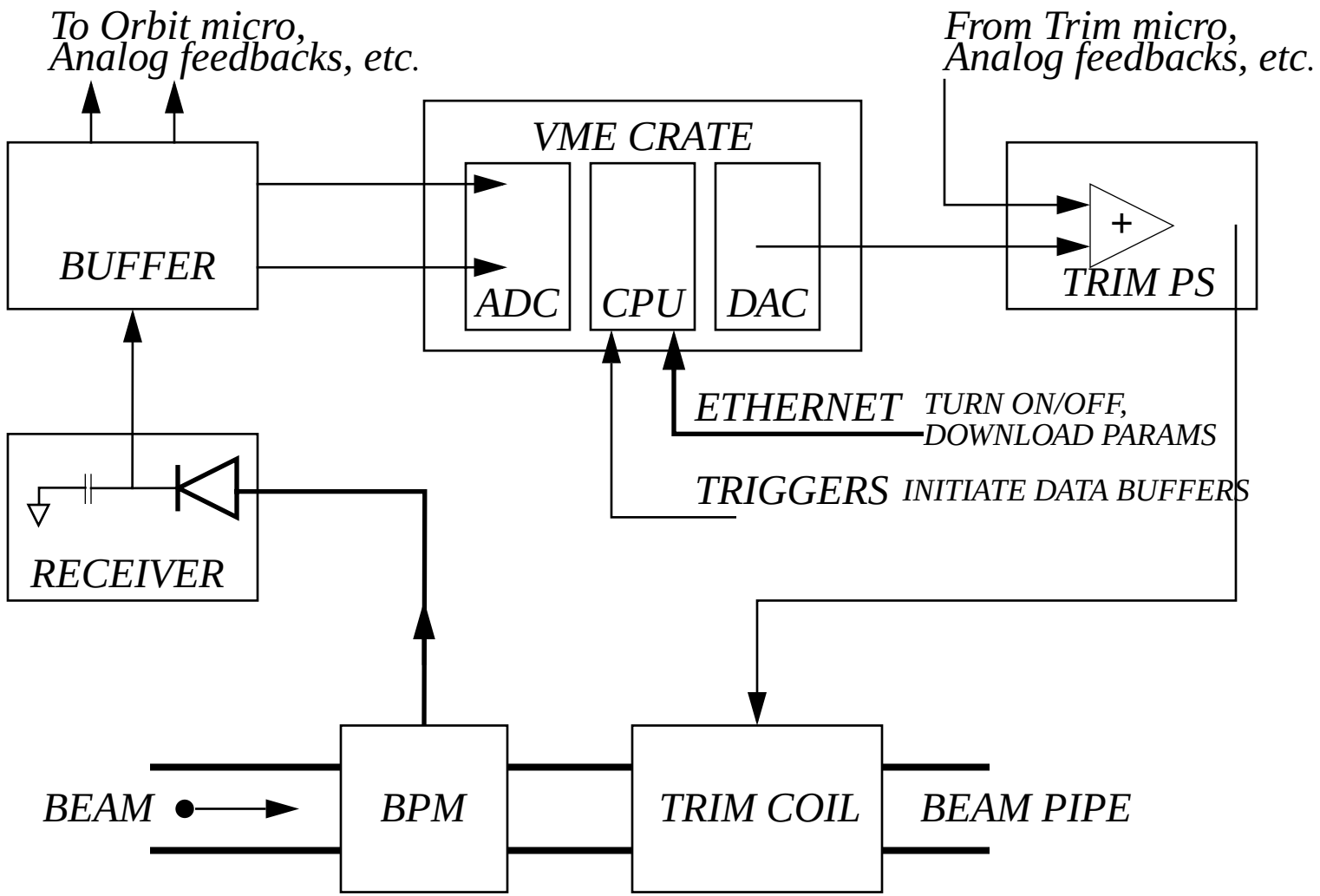
  More sensitive to errors at isolated BPMs

  May run into stability problems

New System: Design Trade-Offs

- Sampling Rate = 5 KHz
  Match the analog system BW
  No anti-aliasing filters
- Independent system vs. existing micros
  Could not get 5 kHz
  Development without interfering with operations
- Where and how to digitize:
  at BPM receivers vs. off-the-shelf ADCs in a VME crate)
  Noise
  Reliability in X-ray tunnel
  Proprietary design and development time
- Single board VME CPU vs. DSPs
  Mainframe expertise at NSLS

New System Layout



NSLS UV Ring Digital Orbit Feedback System

Configuration

- VUV Ring (In Operations since the Aug. 2000)

  Both planes in one system

  24 BPMs, 8 trims, 8 eigenvectors each plane

- VUV Timing Budget

  48 μs ADC data from memory and writing to the DACs +

  88 μs kick value calculations+

  64 μs extra

  200 μs Total

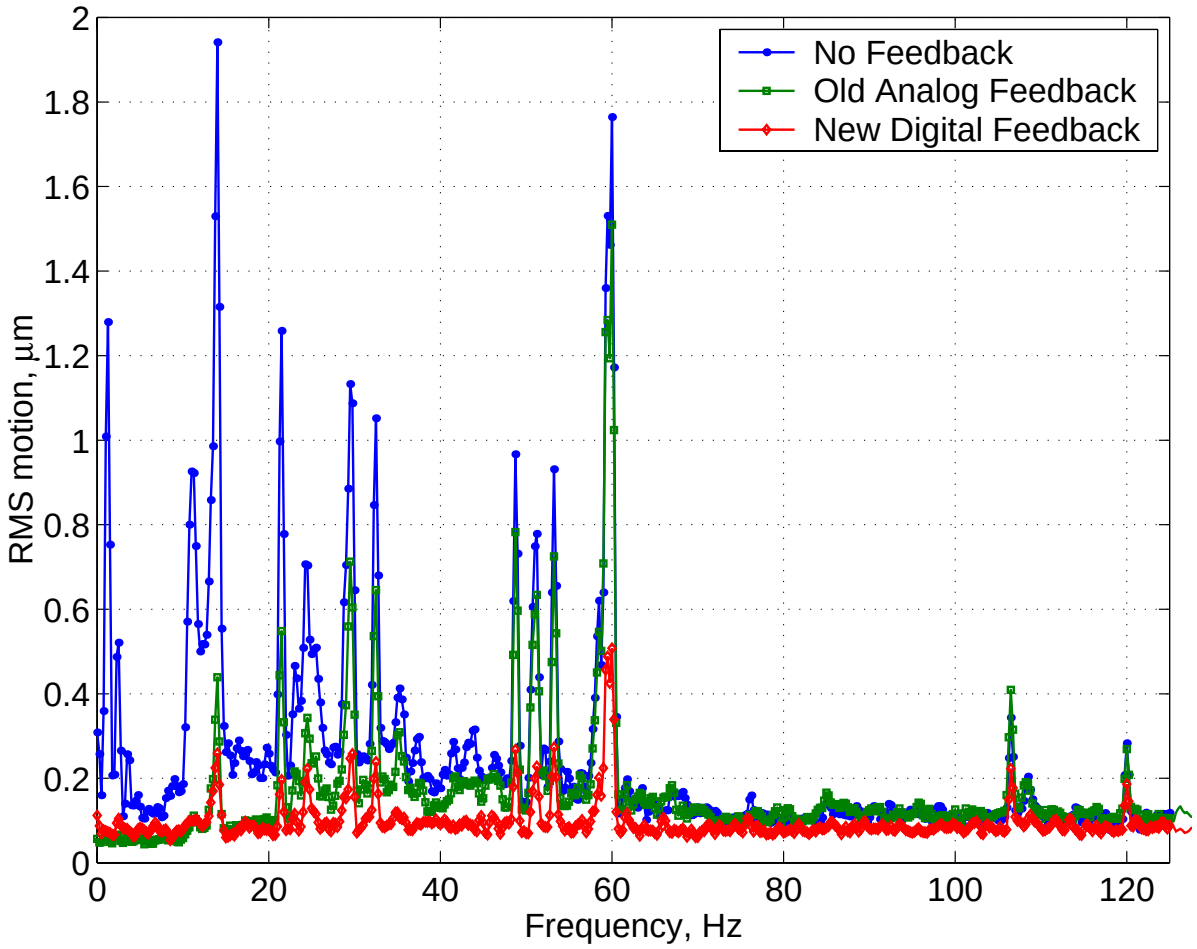
- X-ray ring Studies Configurations

  One system per plane

  48 BPMs, 55 trims, up to 16 eigenvectors horizontal

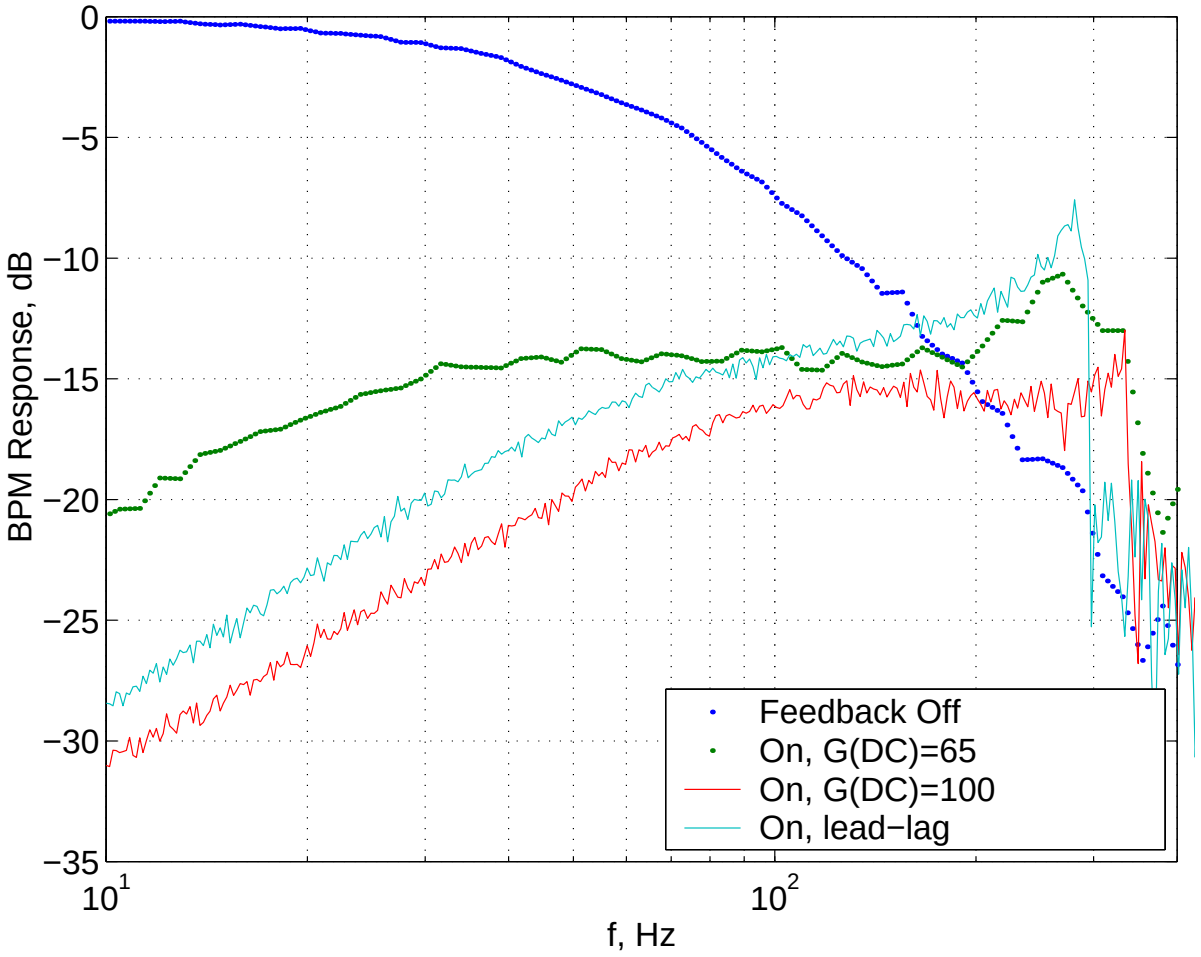
  48 BPMs, 39 trims, up to 16 eigenvectors vertical

Orbit Noise Reduction



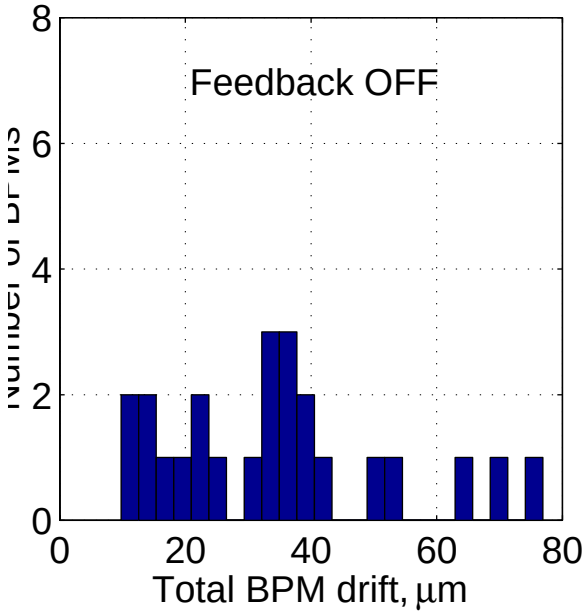
Frequency Response Measurements

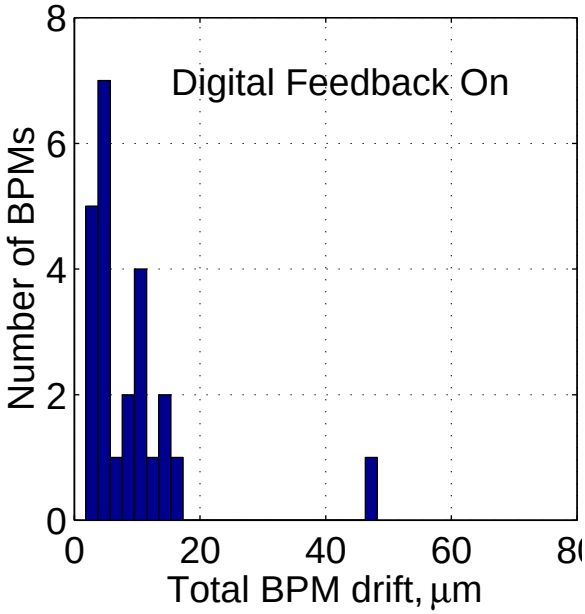
<u>Setup</u>: Use a network analyzer; excite a vertical trim not used in the feedback; measure the response at a vertical BPM



Long Term Orbit Drift

Conditions: Standard VUV Ops, 5 hour fill, 830 mA>I>350 mA

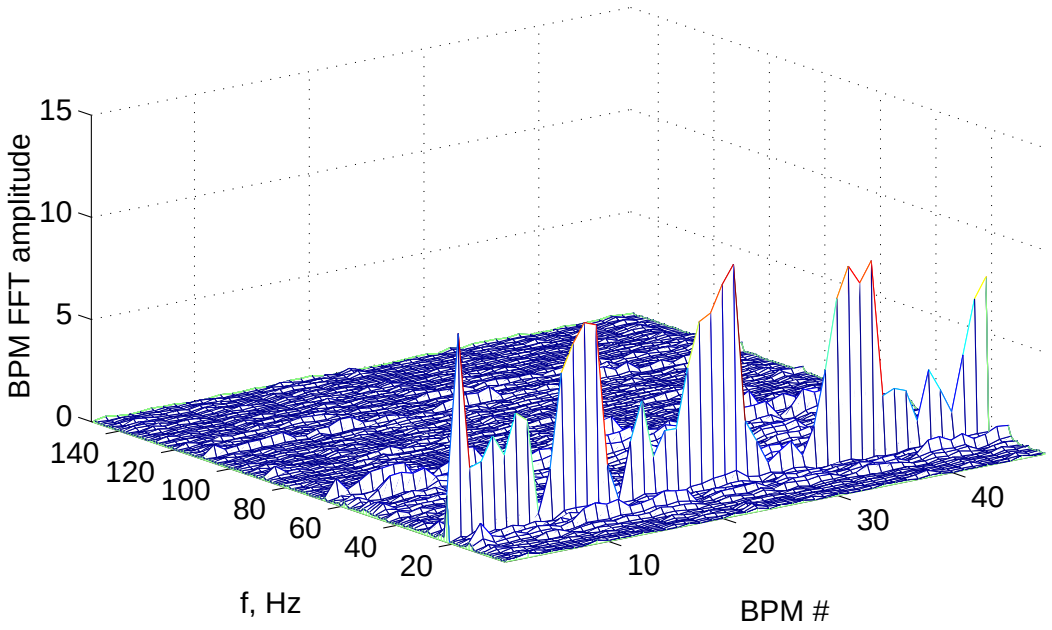




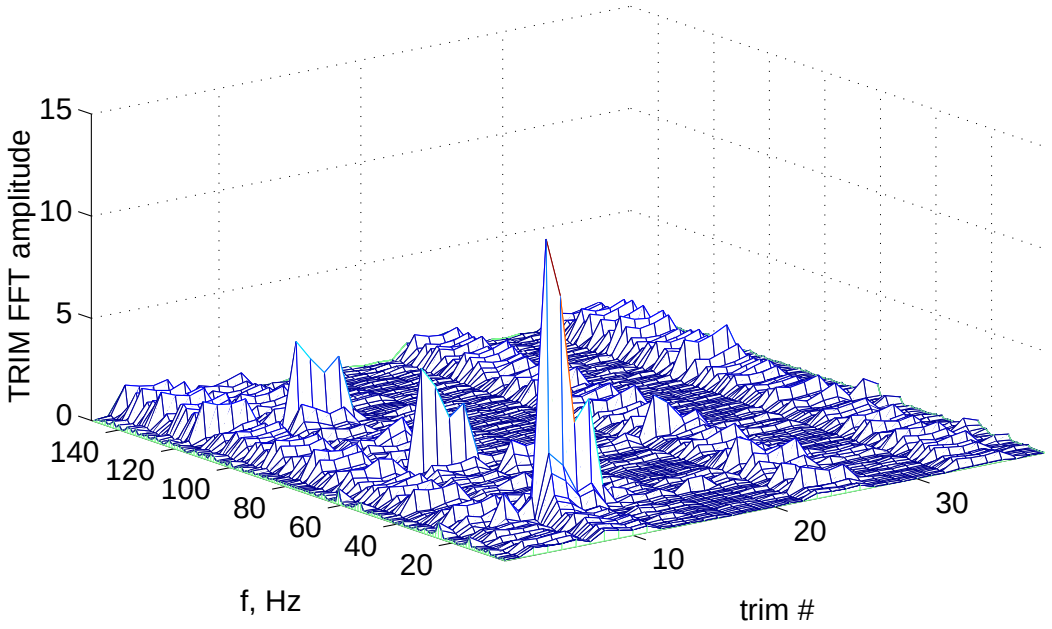
- Average drift reduced from 35 μm to 6 μm (<3% FWHM vertical size)
- Same in horizontal
- X-ray ring: vertical O.K., horizontal - systematic BPM errors

Machine Diagnostics

X−ray Ring Buffer Orbit Dump 04/01/01 ~19:15; All Feedbacks Off



X−ray Ring Buffer Trim Dump 04/01/01; Digital Feeback ON



Challenges and Future Work

- How to implement global and local correction together?

  SVD + BPM weights

- How to add photon blade monitors to the system?

  trivial except RM with IDs closed

- Which combination of trims/BPMs to use?

  simulations

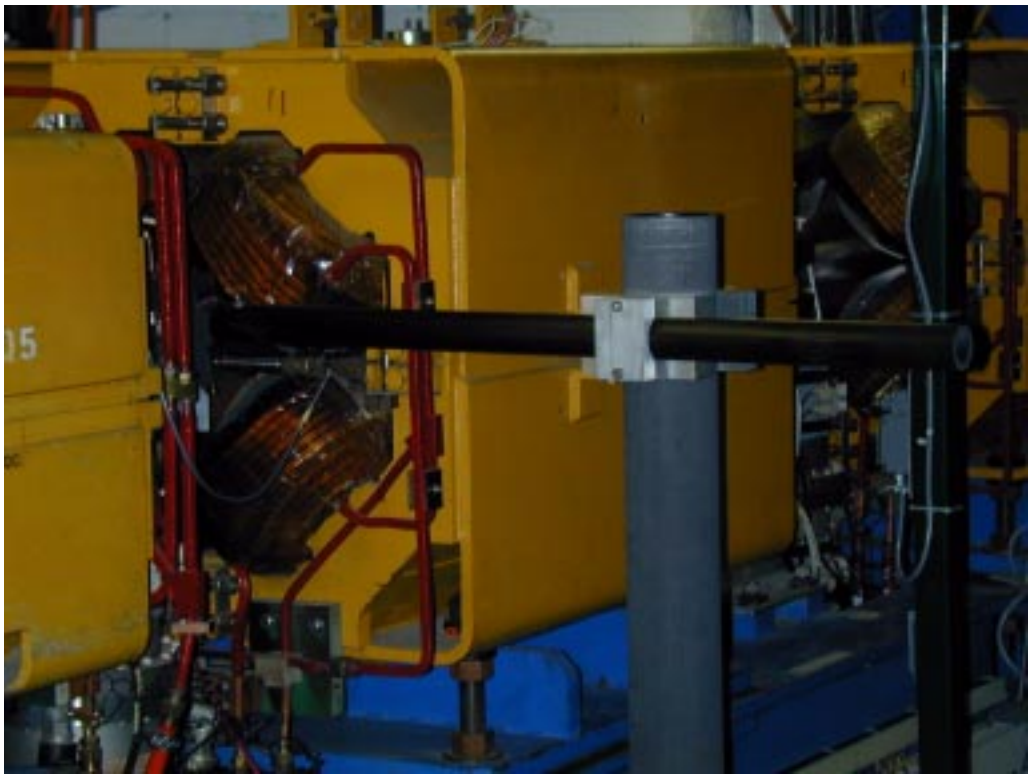
- Optimal algorithm?

  simulations

- How to account for BPM errors due to mechanical motion?

BPM Errors due to Beam Pipe Motion I

- “Old digital system” used to give smaller horizontal orbit drift with increased # of eigenvectors
- Users observed the opposite...
- This was traced to the beam pipe motion
- Ceramic stands to measure this motion were built



BPM Errors due to Beam Pipe Motion II

- Observations

- Ultimate Fix

  Real time measurement of BPM motion

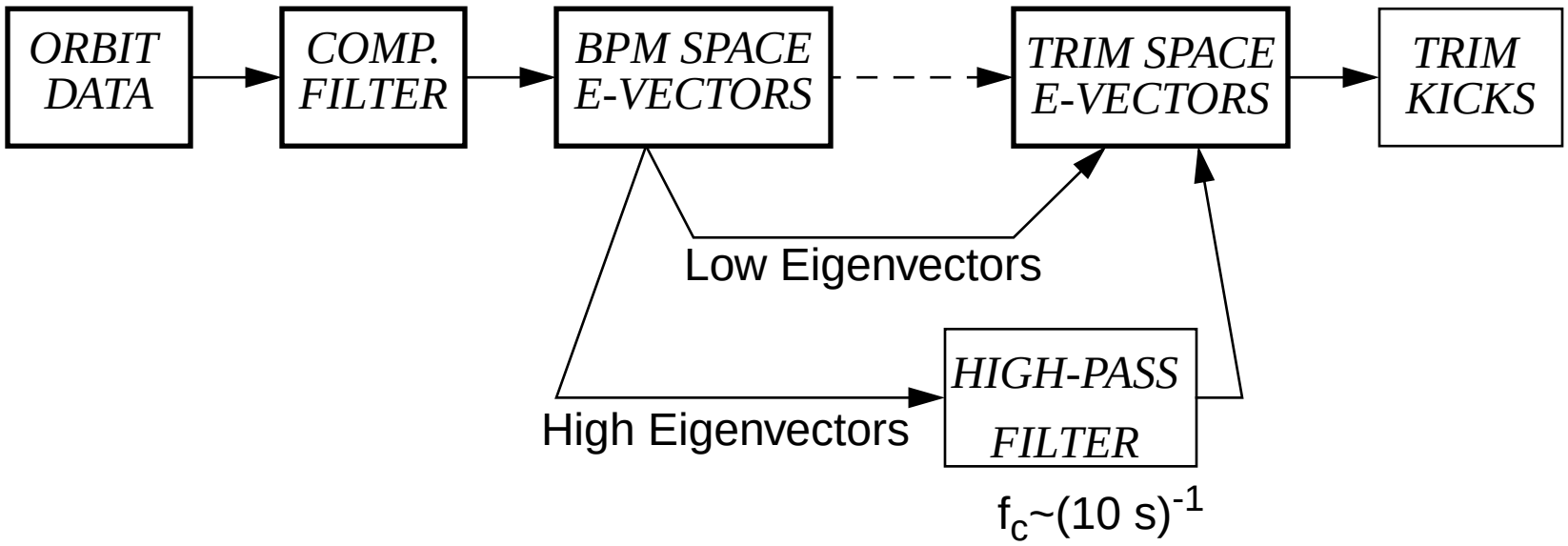
  Account for the error before feedback correction

- Simpler solution

  Use a look-up table based on beam current, beam pipe temperature etc.

BPM Errors due to Beam Pipe Motion III

- Short Term Fix Based on Timescale Separation



Slow drift -> fewer eigenvectors

High frequency noise -> more eigenvectors

Summary and Outlook

- We have built a 5 kHz digital orbit feedback system

- Significant improvement over the existing analog system
  - Orbit Noise Correction
  - Slow Drift Reduction
  - Use for Machine Diagnostics

- VUV ring status:
  - The system is used in regular operations

- X-ray ring status:
  - Global Correction Works
  - Local Correction is Being Incorporated in Digital
  - Will be in Operations Soon

- Further development (algorithms, modelling, etc.)