# Orbit stability at SPEAR2 and plans for SPEAR3

J. Safranek for the SSRL Accelerator Group

- **SPEAR2**
  - BPM and orbit feedback performance
  - Present orbit stability
  - Improvements in LCW and air temperature
- **SPEAR3**
  - Stability specifications
  - Mitigating sources of orbit motion
  - Orbit measurement/feedback
  - Application programs for orbit control

Beam Orbit Stabilization Workshop, Spring-8, December 4-6, 2002

# SPEAR/SSRL

- **1972 – SPEAR built (colliding beams)**
- **1974 – First beamline**
- **1982 – First fast orbit feedback**

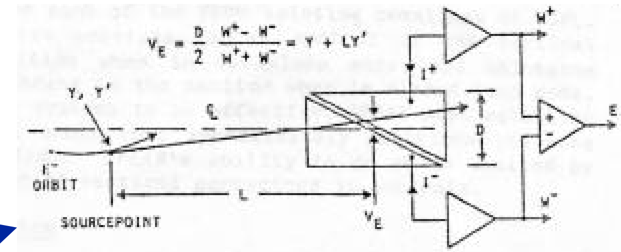



Fig. 1. Split anode vertical position monitor system. The synchrotron beam trajectory is tangential to the electron orbit at the sourcepoint.

- **1990 – SPEAR dedicated solely to S.R., with independent injector**
- **2002**
  - **11 beamlines, operations ~9 months/year**
  - **$e_x$ = 140 nm, Imax = 100 mA, E = 3 GeV**
- **2003**
  - **SPEAR3 – complete accelerator rebuild**
  - **$e_x$ = 18 nm, Imax = 500 mA, E = 3 GeV**

# SPEAR2 BPM performance

- **J.L. Pellegrin electronics, 1970's.**
- **Peak detector designed for single bunch**
  - **Requires "mondo" bucket**
  - **Significant fill pattern dependence**
  - **Low intensity dependence; AGC loop - 1 dB attenuator steps**
- **10-20 μm rms noise with 3.8 seconds/orbit**
  - **Multiplexed to single ADC**
  - **1250 reads/orbit**
- **30 BPMs ($\nu_x$ = 7.15, $\nu_y$ = 5.24)**

# SPEAR2 orbit feedback

- **Slow orbit feedback (J. Corbett et al.)**
  - **50 second cycle time**
  - **SVD orbit correction using e- BPMs only**
- **Fast feedback on photon monitors (R. Hettel)**
  - **~60 Hz bandwidth**
  - **Uses local electron orbit bumps and single photon monitors**
  - **Steering magnets – coils on quadrupoles, Al chamber (50 Hz pole)**

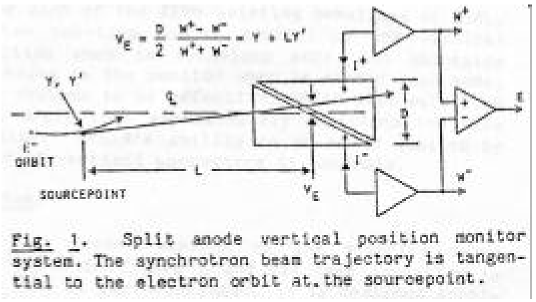
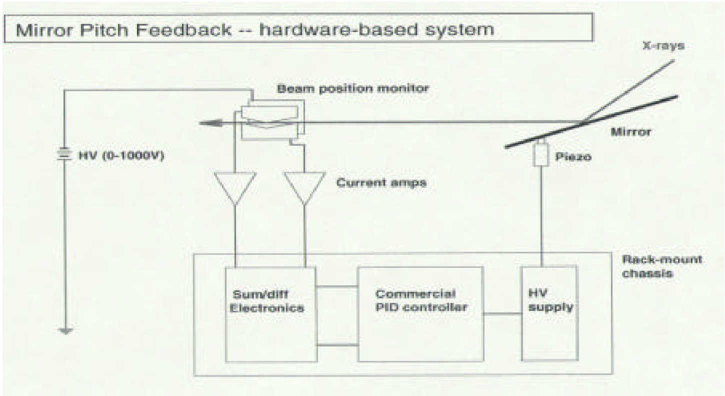
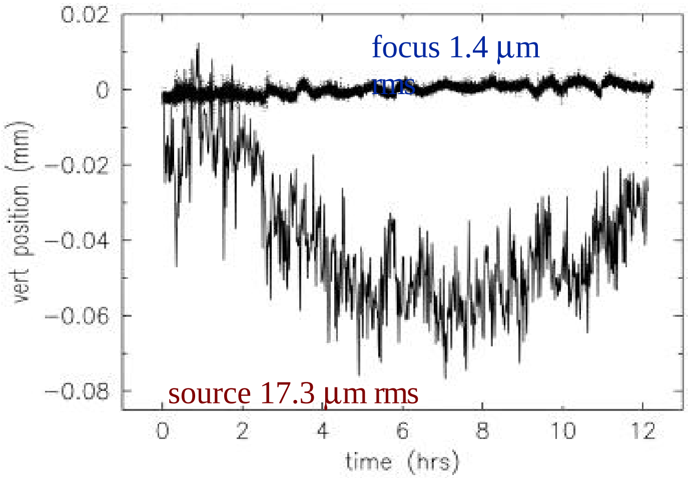


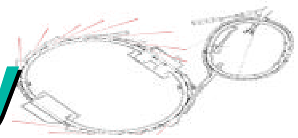
Fig. 1. Split anode vertical position monitor system. The synchrotron beam trajectory is tangential to the electron orbit at the sourcepoint.

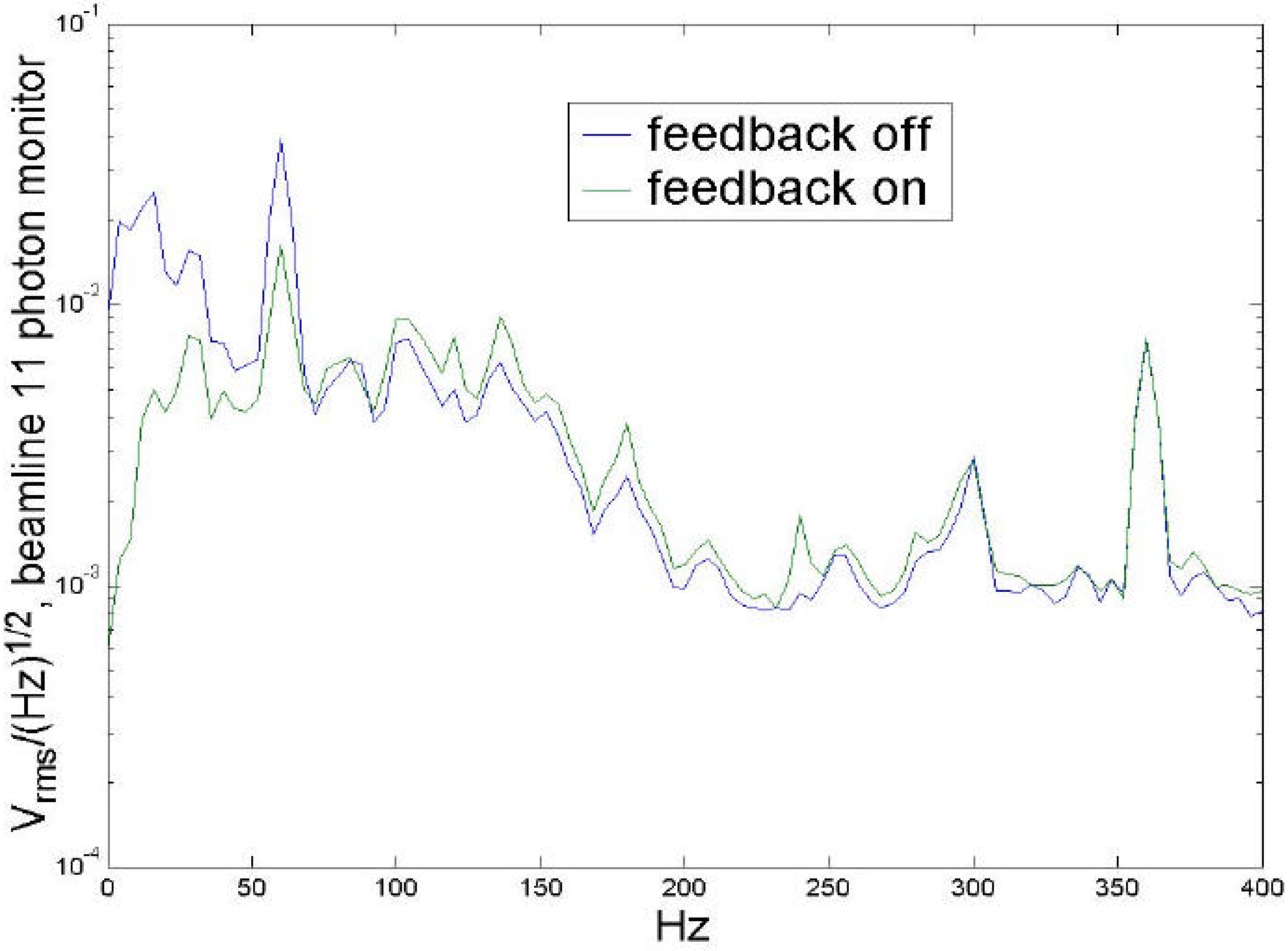
- **Mirror feedback (T. Rabedeau)**



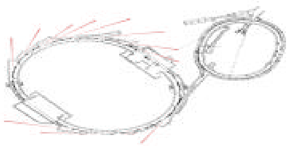



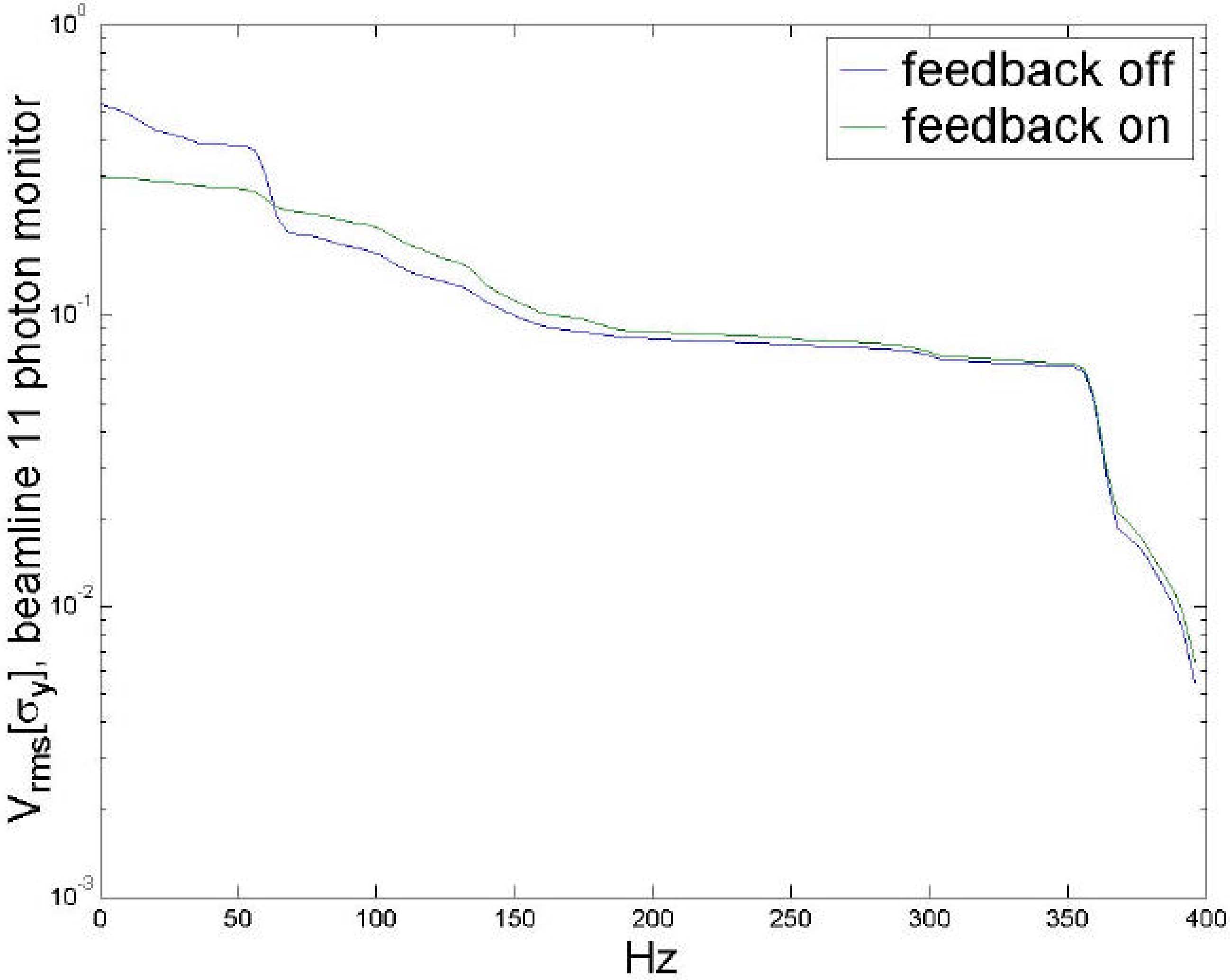
# SPEAR2 power spectral density





# SPEAR2 PSD Integral





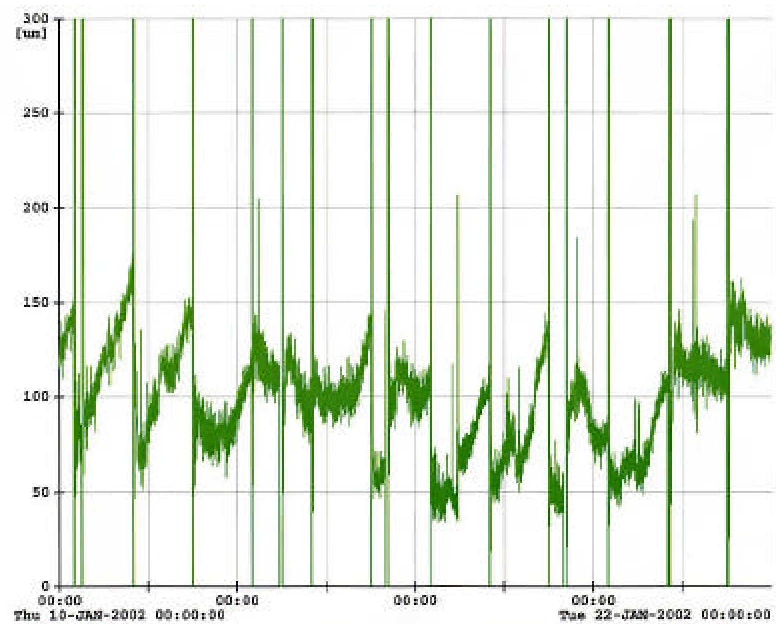
# Orbit stability over two weeks

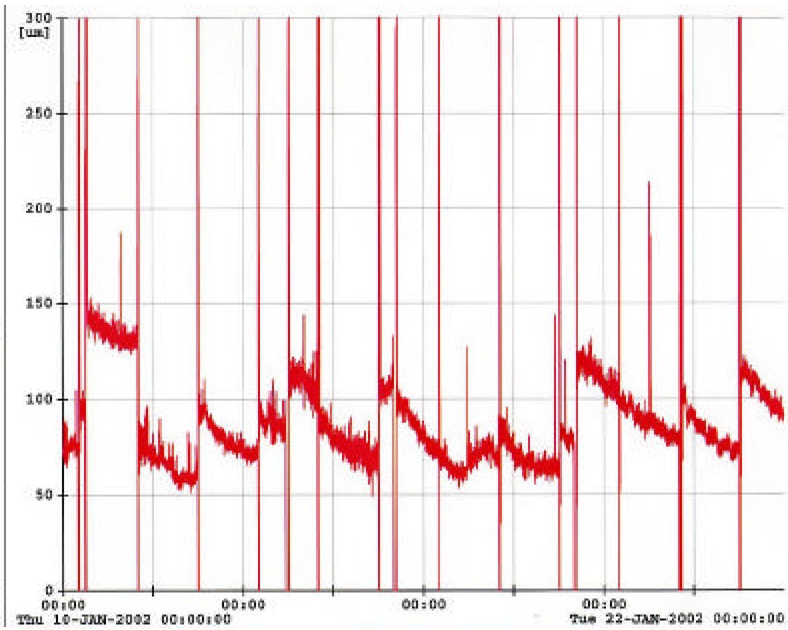
**X_rms** **Y_rms**

300 mm

150 mm

0 mm



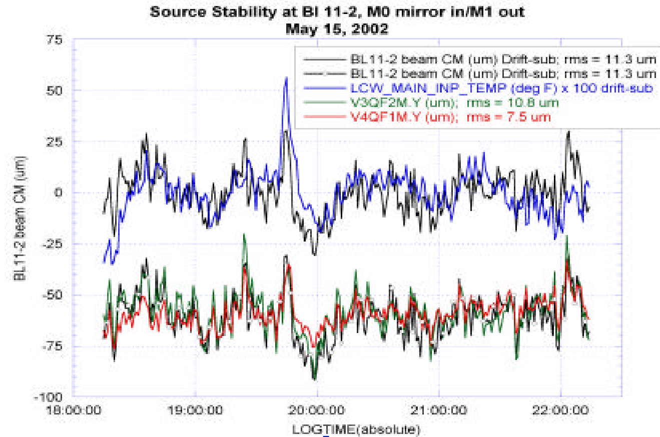



# Cooling water temperature

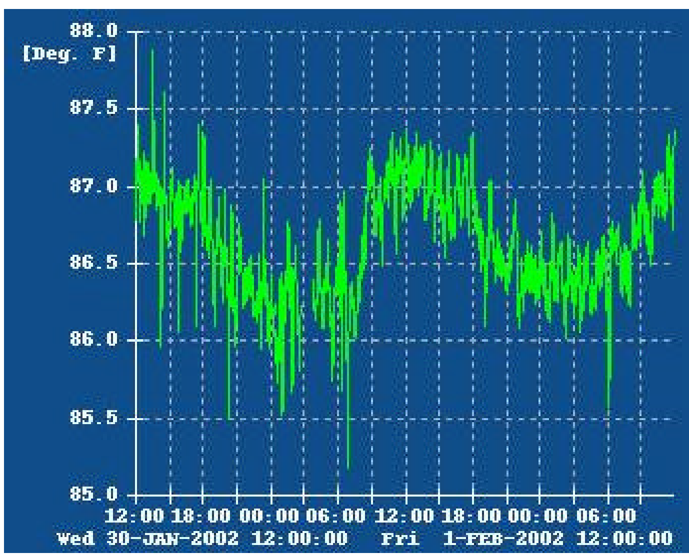
## LCW variations effect beamlines

| rms_dT,C | weekly | daily | 6 hours |
|---|---|---|---|
| 1997 | .094 | .069 | .052 |
| 1998 | .118 | .078 | .052 |
| 1999 | .138 | .068 | .057 |
| 2000 | .107 | .102 | .066 |
| 2001 | .185 | .163 | .103 |

11-2 CM, LCW



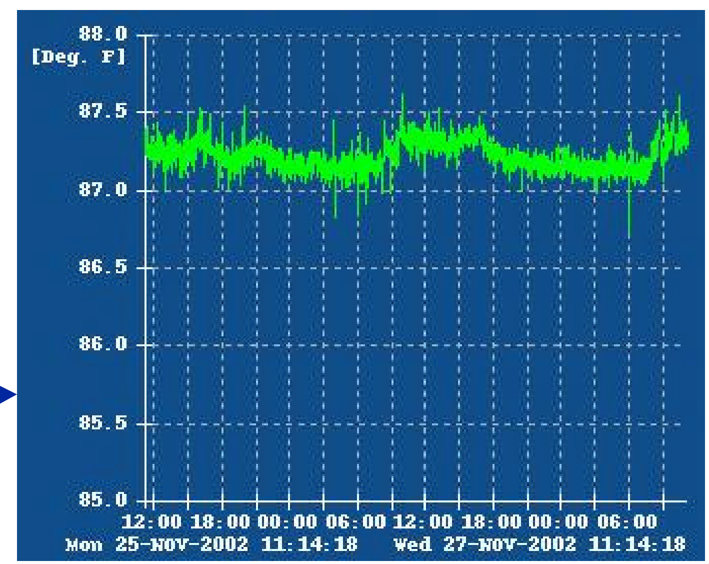

4.5 hours




LCW temperature variations reduced

Jan'02

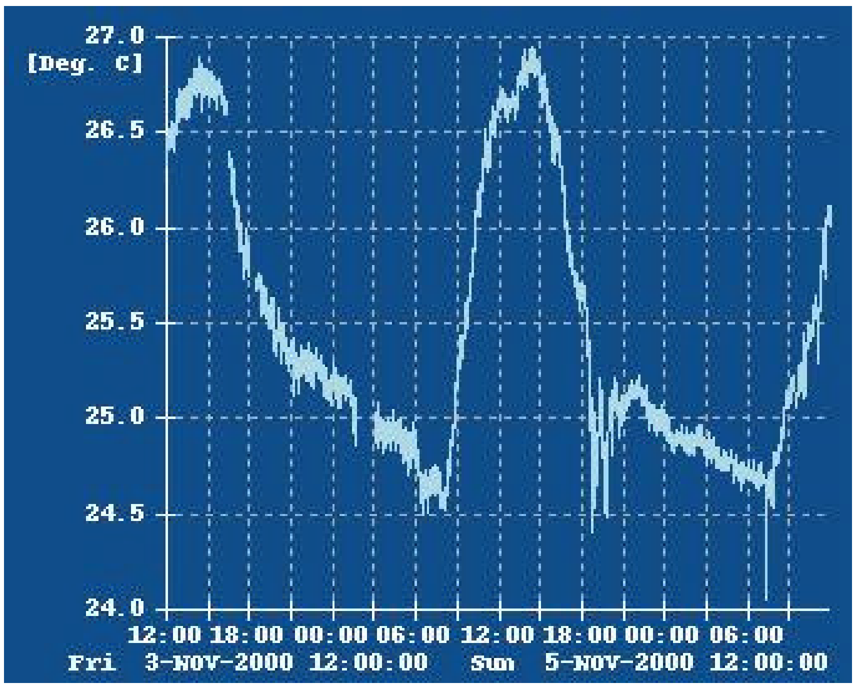
Nov'02



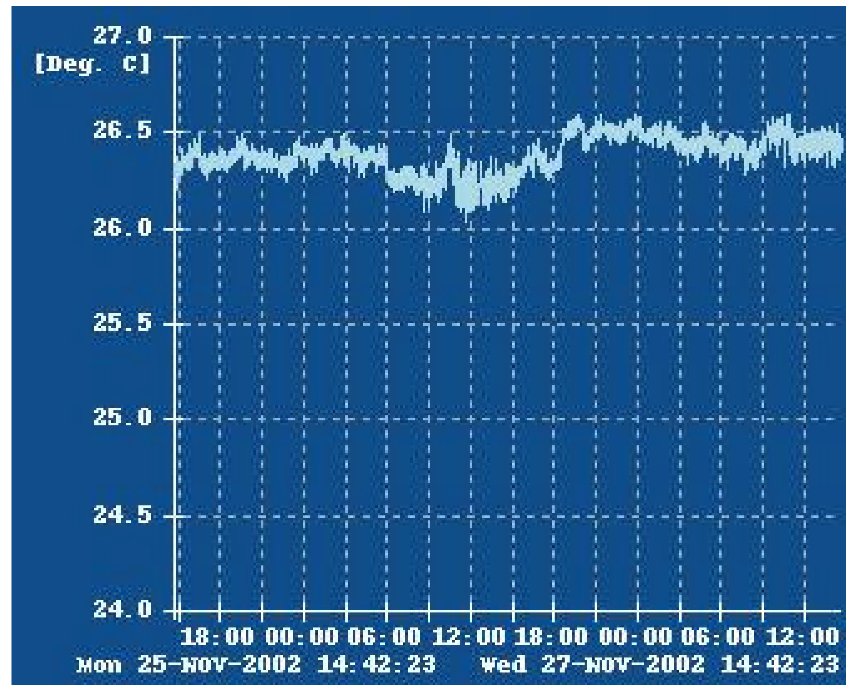
# Air temperature stability

**Extending concrete tunnel reduced air temperature variations.**

**November, 2000**




**November, 2002**



# SPEAR3 orbit stability specifications

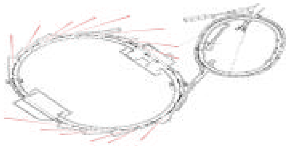


Table 3.23 RMS source point beam dimensions and stability requirements for SPEAR 3 (rms, 1% coupling).

| | | Electron | Photon | 10% |
|---|---|---|---|---|
| Dipole | $\sigma_x$ (μm) | 160 | 160 | 16 |
| | $\sigma_{x'}$ (μrad) | 236 | mrads | < mrad |
| | $\sigma_y$ (μm) | 51 | 51 | 5 |
| | $\sigma_{y'}$ (μrad) | 11 | 136 | 14 |
| ID-Wiggler | $\sigma_x$ (μm) | 435 | 435 | 43 |
| | $\sigma_{x'}$ (μrad) | 43 | 2–20 mrad | < mrad |
| | $\sigma_y$ (μm) | 30 | 30 | 3† |
| | $\sigma_{y'}$ (μrad) | 6 | 136 | 14 |
| ID-100 per und. | $\sigma_x$ (μm) | 435 | 435 | 43 |
| | $\sigma_{x'}$ (μrad) | 43 | 43 | 4 |
| | $\sigma_y$ (μm) | 30 | 30 | 3† |
| | $\sigma_{y'}$ (μrad) | 6 | 15 | 1.5 |

†. This requirement can be relaxed to 5 μm due to 50 μm minimum vertical spot size achieved from present focusing mirrors.

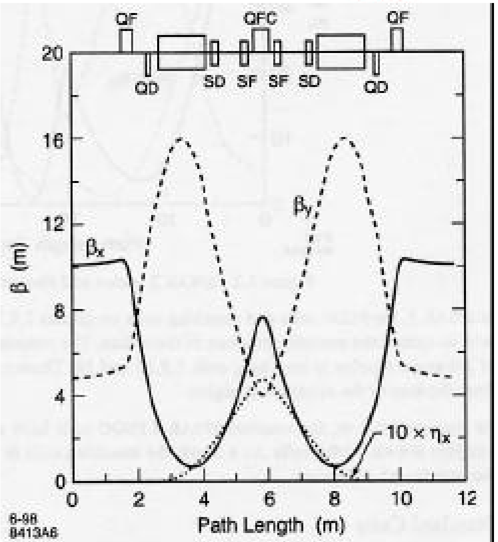



Figure 3.3 SPEAR 3 cell optics.

| | |
|---|---|
| E | 3 GeV |
| I | 500 mA |
| $e_x$ | 18 nm |
| $n_x$ | 14.19 |
| $n_y$ | 5.23 |
| $n_s$ | .008 |
| $s_E$ | .097% |
| $V_{rf}$ | 3.2 MV |
| $a_c$ | .0011 |

# SPEAR3 alignment

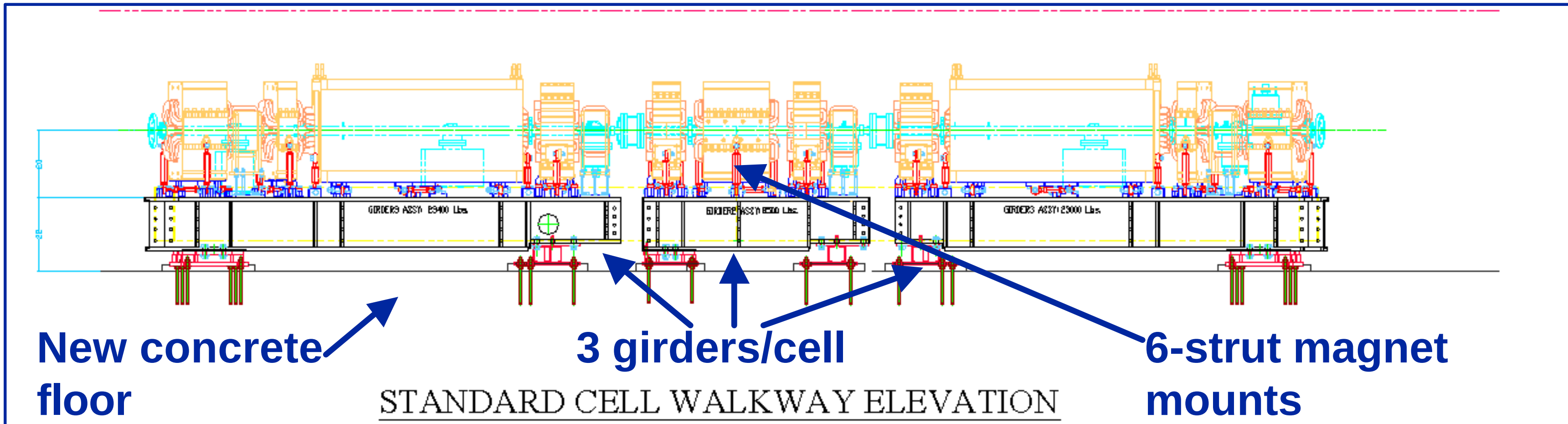
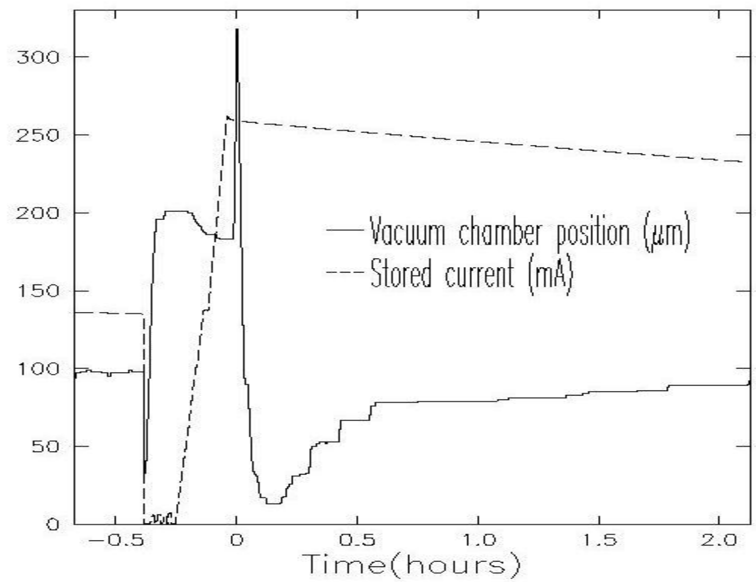



**Table 4.28** Tolerances for lattice-component alignment

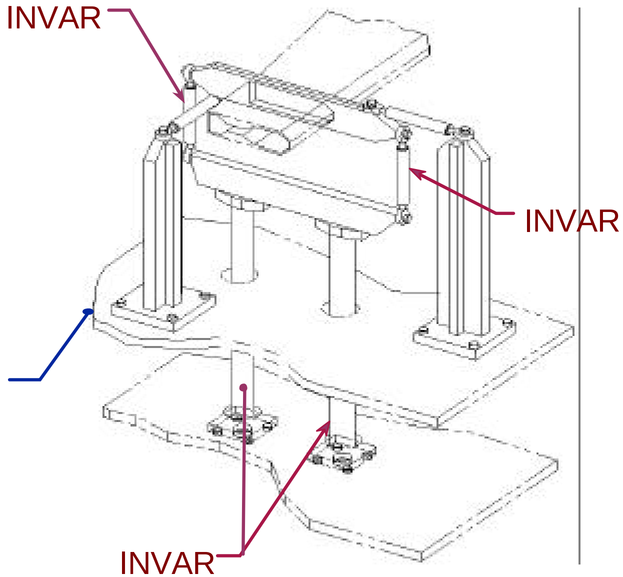
| Component | Rotation rms error (mrad) | | | Displacement rms error (mm) | | |
|---|---|---|---|---|---|---|
| | ΘZ roll | ΘX pitch | ΘY yaw | ΔX Dx | ΔY Dy | ΔZ Ds |
| Bend magnets | 0.50 | 0.30 | 0.50 | 0.20 | 0.20 | 1.50 |
| Quadrupoles | 0.50 | 0.50 | 0.50 | 0.20 | 0.20 | 1.50 |
| Sextupoles | 0.50 | 0.20 | 1.00 | 0.20 | 0.20 | 1.50 |
| RF cavity | 1.00 | 0.50 | 0.50 | 0.20 | 0.20 | 1.50 |
| bpm | 1.00 | 0.50 | 0.50 | 0.25 | 0.25 | 1.50 |
| Vacuum Chamber | -- | -- | -- | 0.25 | 0.25 | 0.50 |
| Kicker | 1.00 | 0.25 | 0.25 | 0.50 | 0.50 | 1.50 |
| Insertion Device | 0.50 | -- | -- | 0.25 | 0.25 | 1.50 |

# SPEAR3 vacuum chamber, BPM stability

- All synchrotron radiation hits $H_2O$-cooled masks.
- BPM mechanical motion constrained by Invar struts.




**NSLS chamber motion**

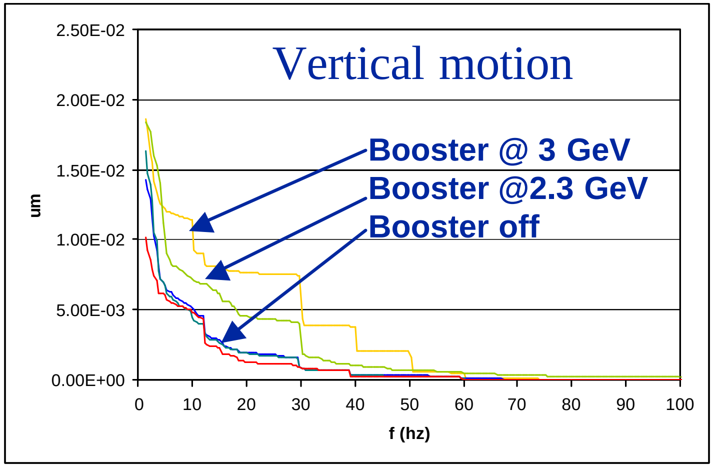


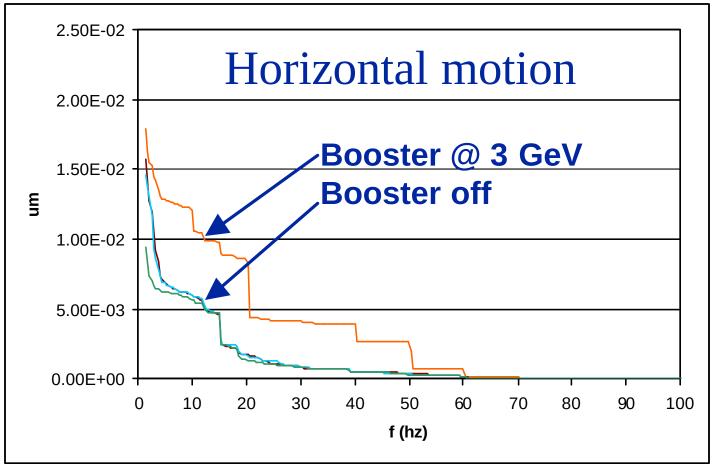

**SPEAR 3 chamber/BPM supports**

3 μm/°C vert, 15 μm/°C hor

# Magnet vibrations

- Allowable uncorrelated magnet motion (10% beam size)
  - Specification: 33 nm vertical, 250 nm horizontal
  - Measured in SPEAR2: 70 nm vertical, 700 nm horizontal
- Lowest vibration mode
  - SPEAR2: 4.5 Hz
  - SPEAR3: 17 Hz
- Ground motion measurements (A. Seryi)



# SPEAR3 power supply stability

- **Pulse width modulation (20-40 kHz)**
- **Dipole and quad supply bandwidth > 100 Hz (suppression of line voltage transcients)**
- **24-hour stability specs (supplies exceed specs):**
  - **Dipole: 50 PPM**
  - **Quadrupoles: 100 PPM**
  - **Sextupoles: 500 PPM**
  - **Correctors: 500 PPM**

# SPEAR3 BPM Processors

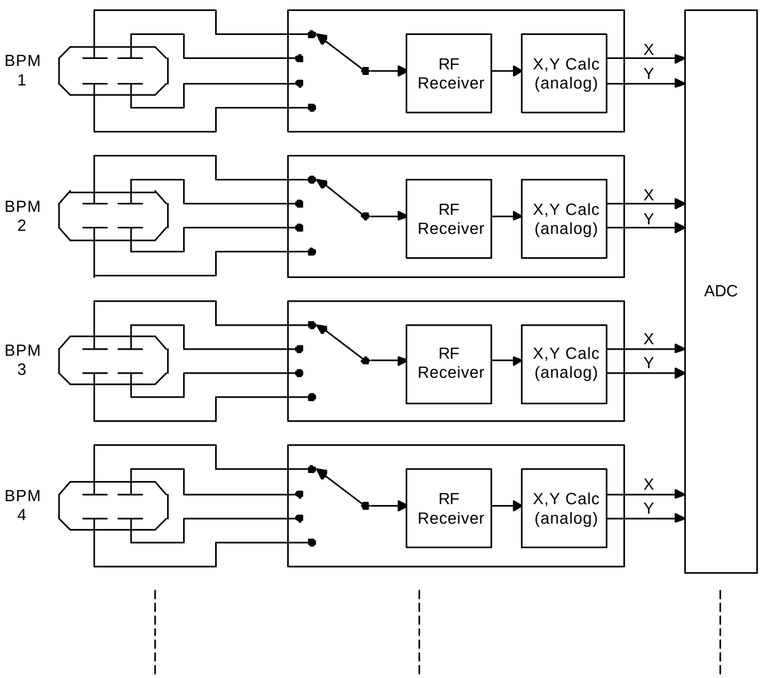
## 4:1 button MUX (Bergoz) analog receiver

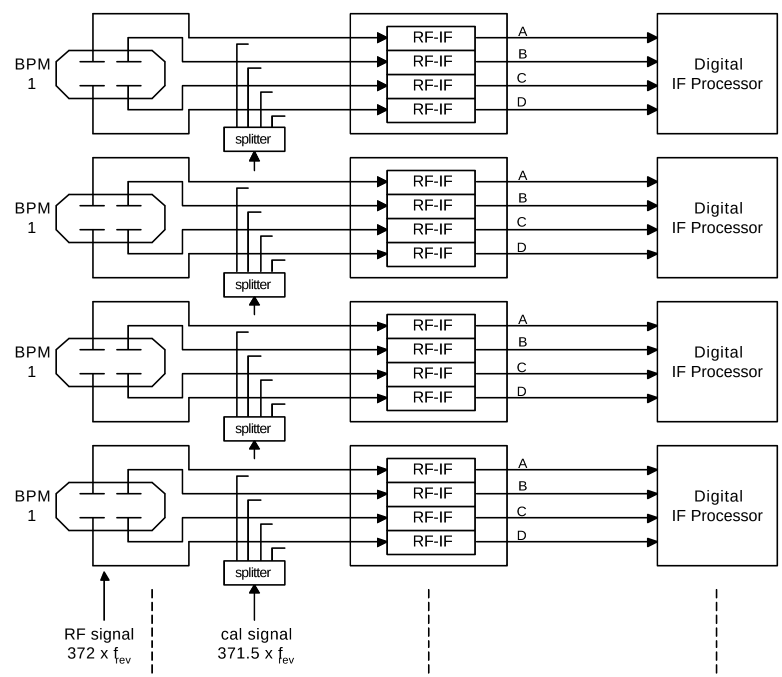
multi-turn BPM measurement
~100-200 Hz BW

## parallel processing digital receiver (Echotek)

1st turn/single-turn/multi-turn BPM measurement

~1 µm at 4 kHz

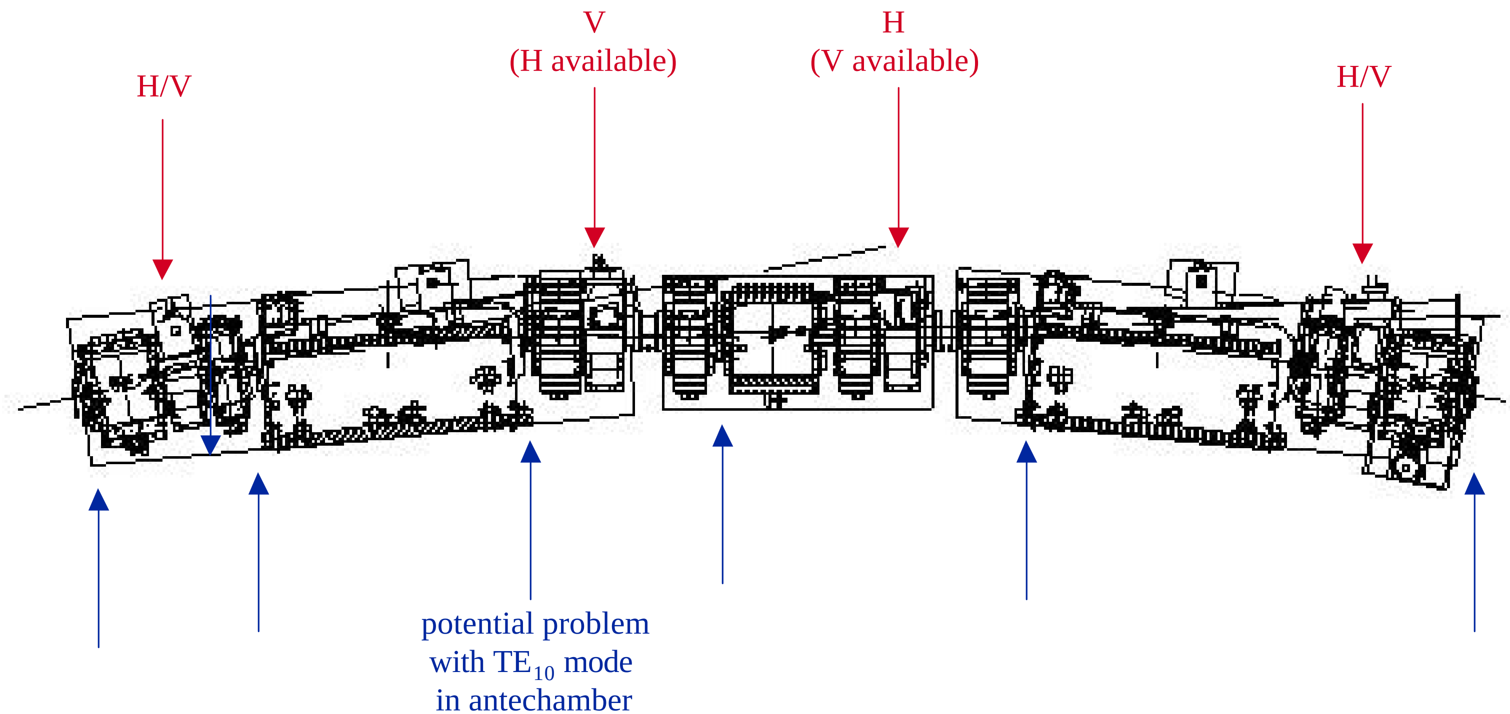


# SPEAR3 BPM/Corrector locations

## Corrector locations

(72 total; 54 H and 54 V correctors used for orbit feedback )

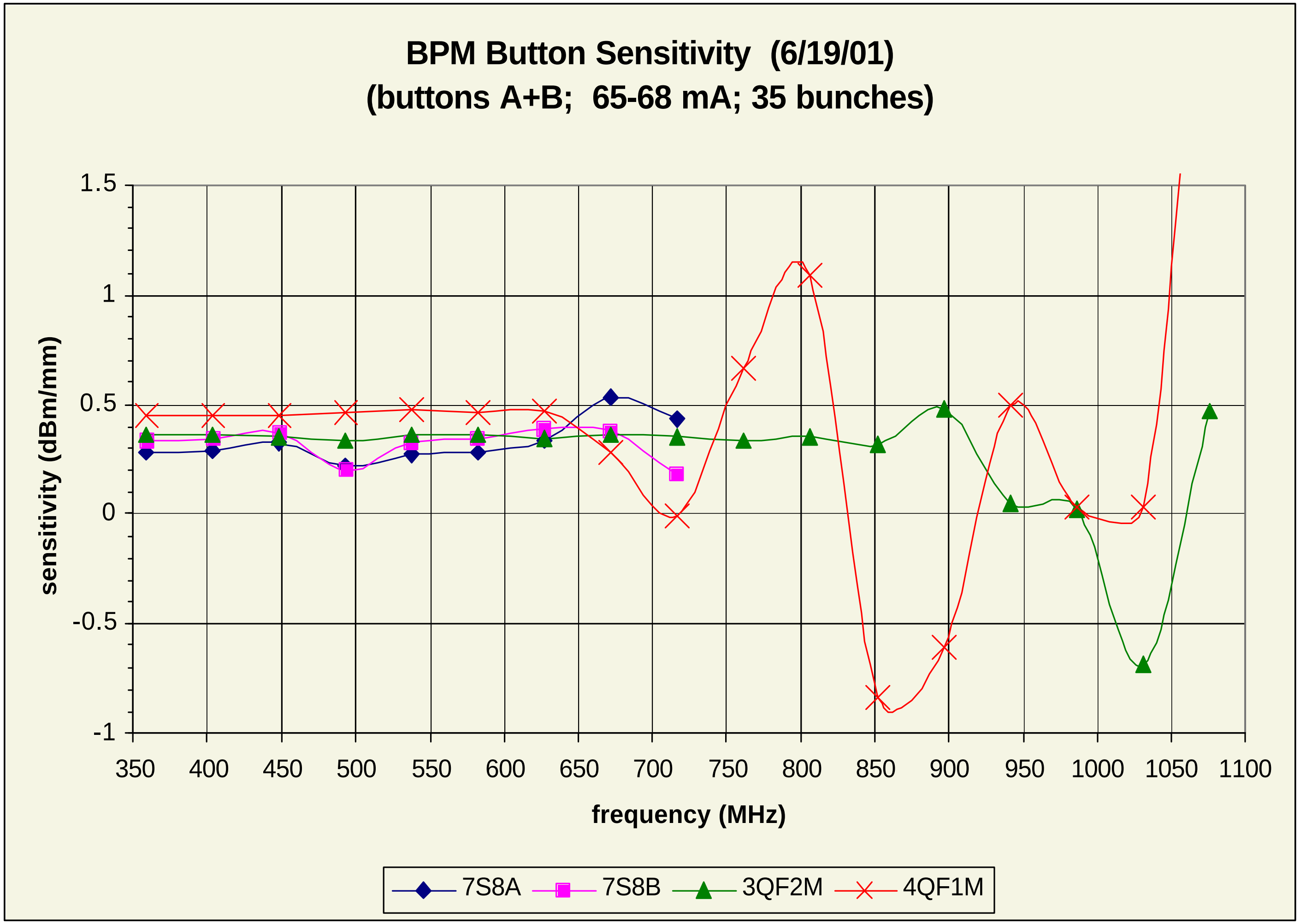


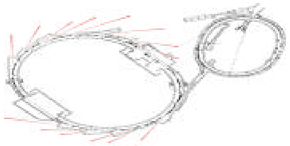

## BPM locations

(104 total; 90 used for orbit feedback)

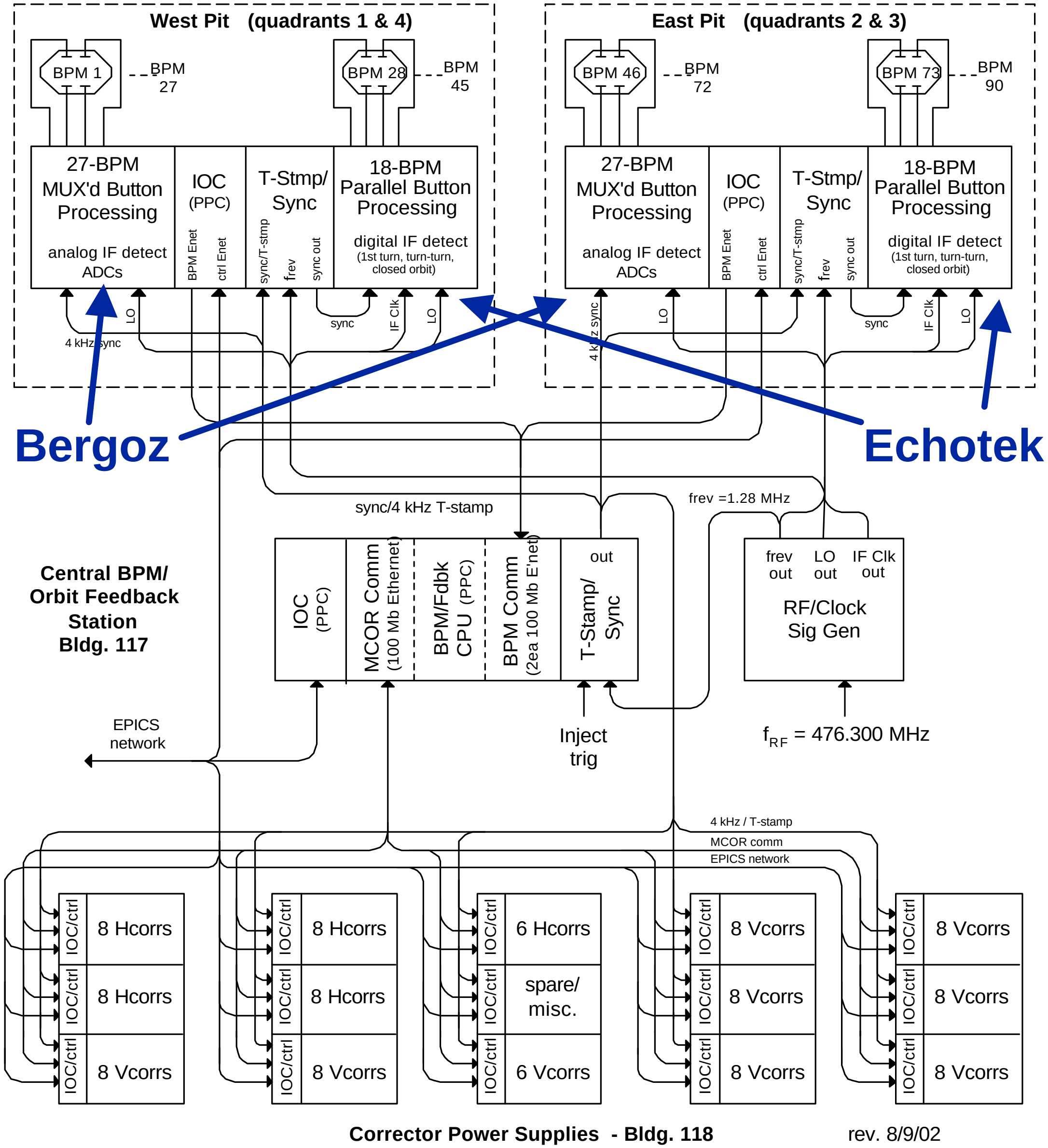
# RF modes in SPEAR ID vacuum chambers

BPM gain vs. frequency



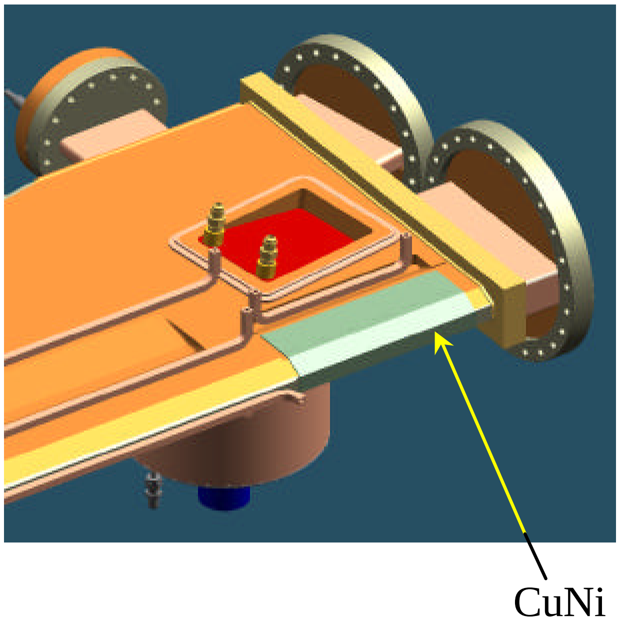


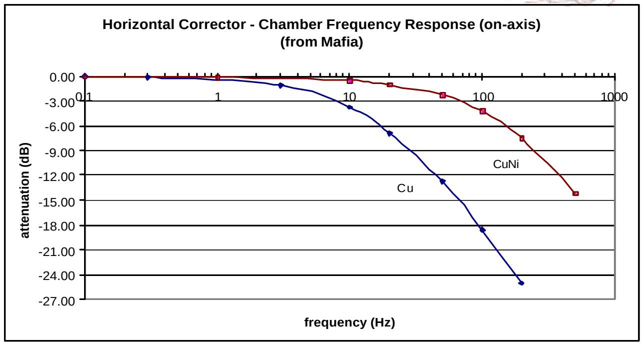
# Digital orbit feedback

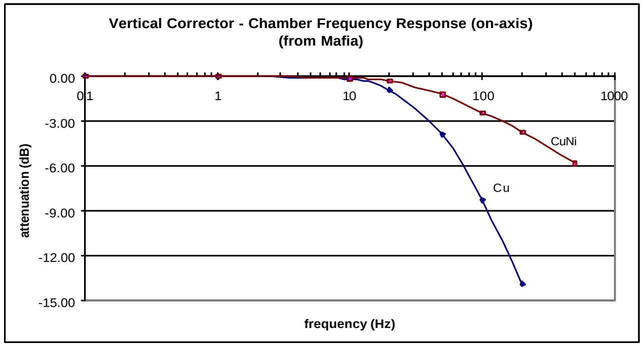


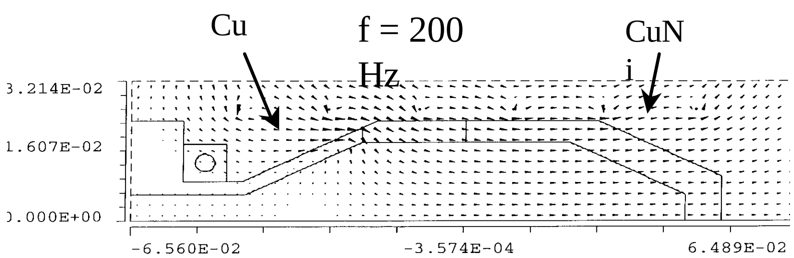

- **100 Hz bandwidth**
- **4 kHz cycle time**
- **Electron + photon monitors**
- **~18 effective bit steering magnets**

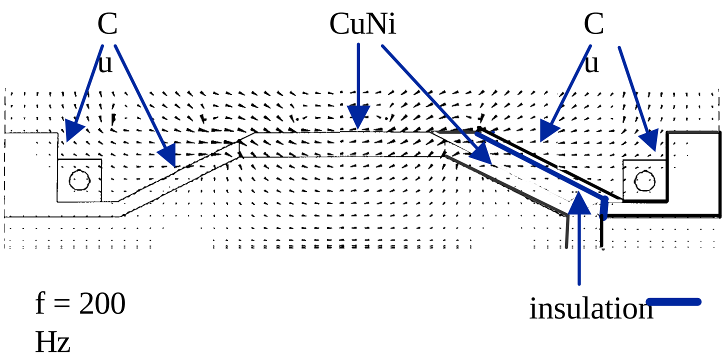
# SPEAR3 Cu chamber eddy current break



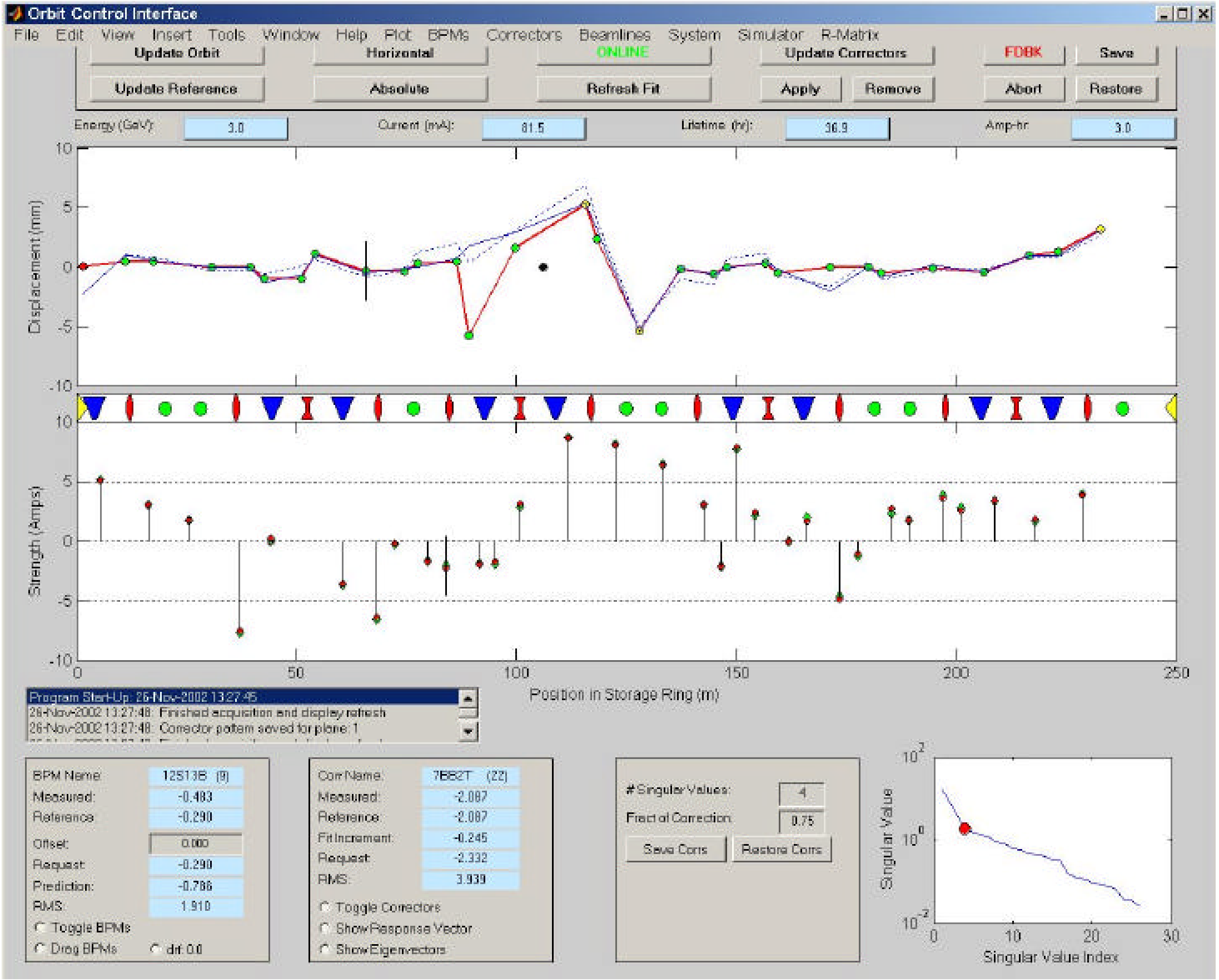



# MATLAB-based orbit control



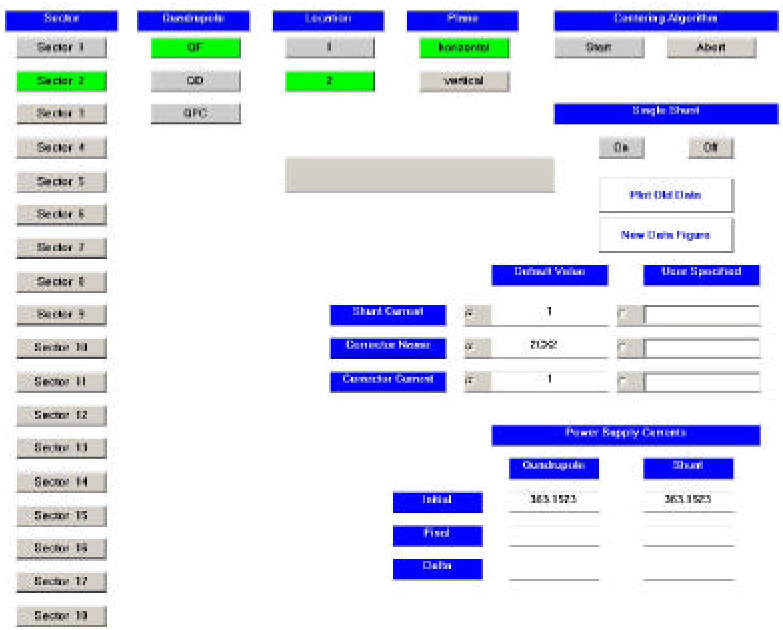

**J. Corbett**

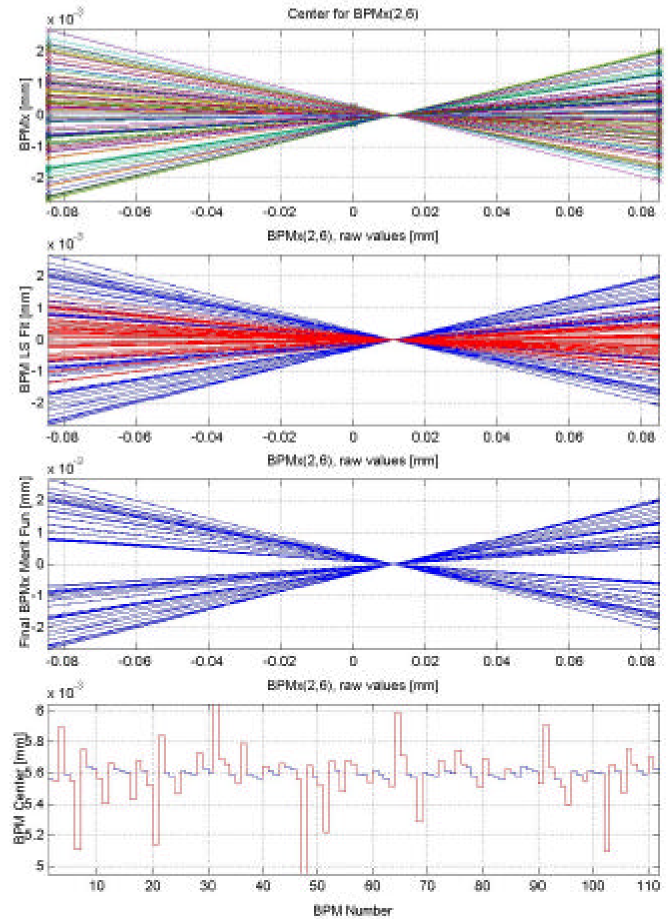
**A. Terebilo**

# Beam-based alignment algorithm from ALS

## Quadrupole modulation:

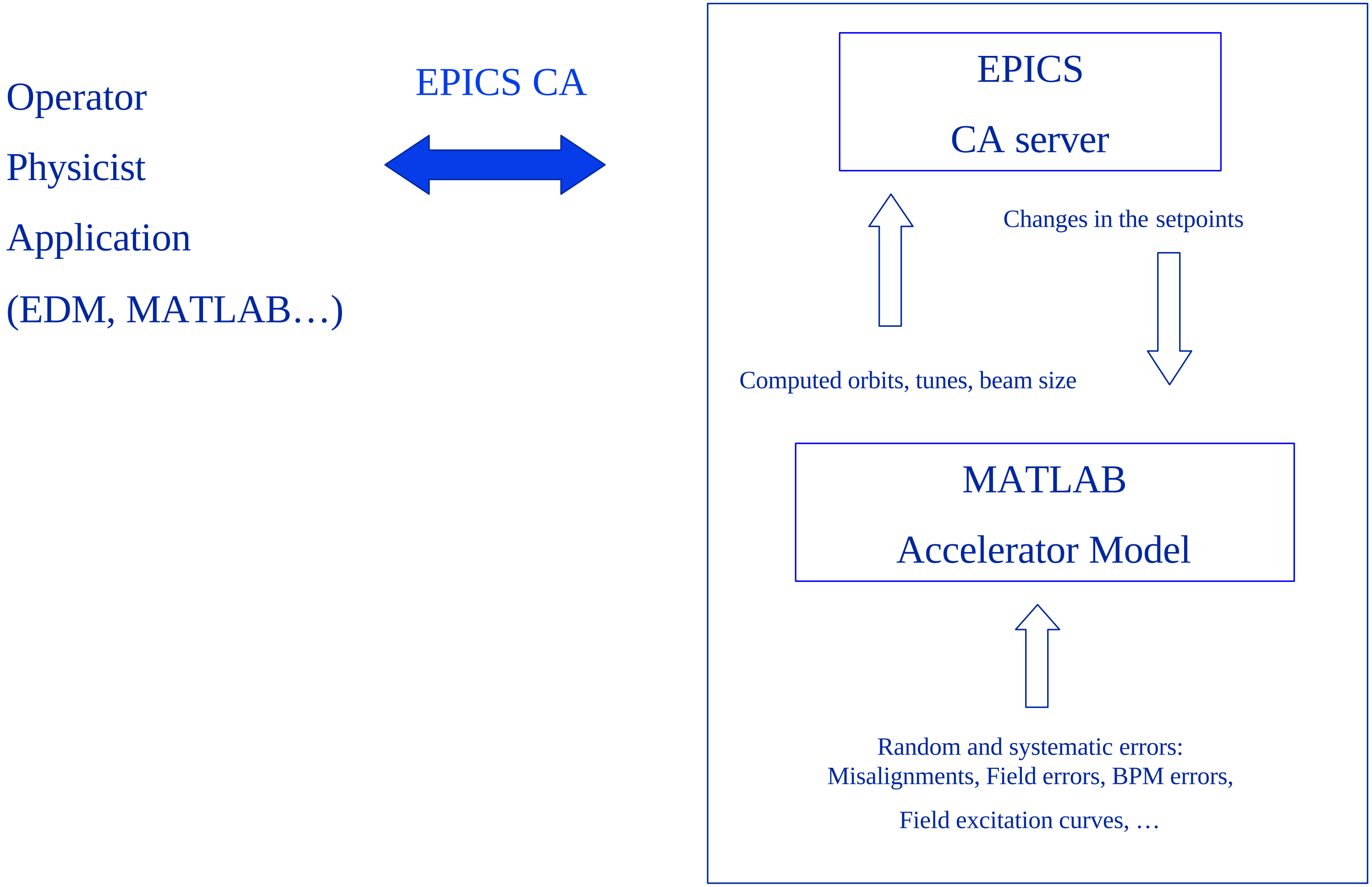
**GUI** **Simulation results**



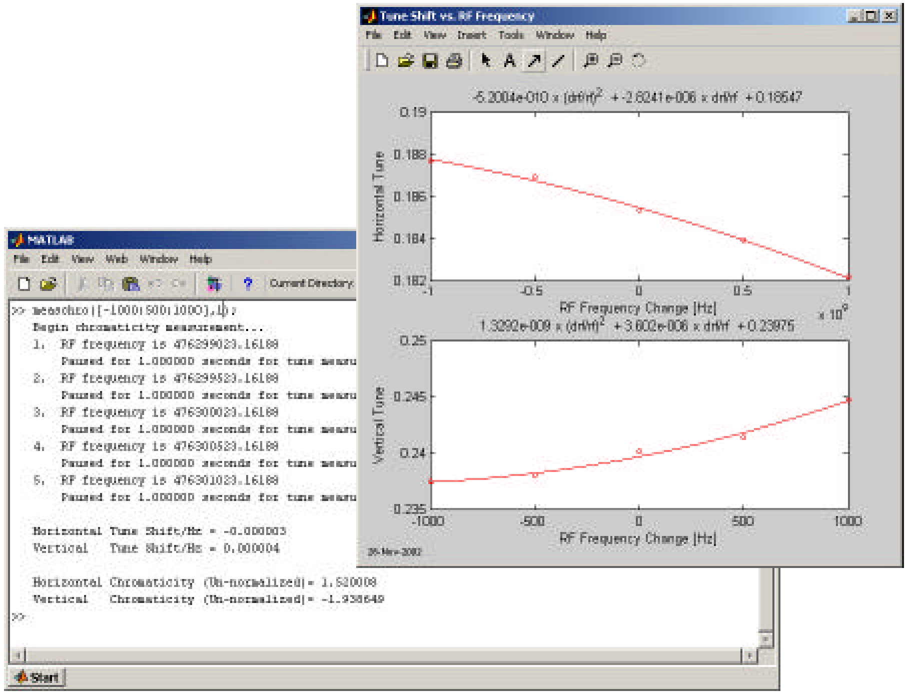

**Greg Portmann**

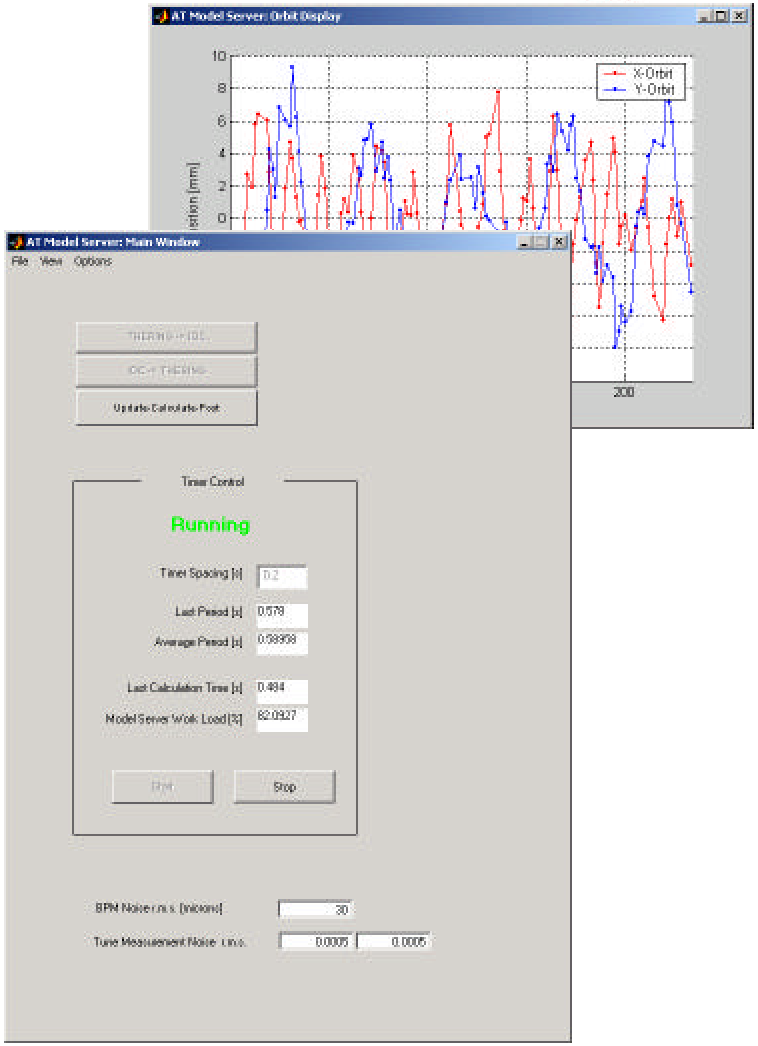
# SPEAR3 simulated commissioning of application algorithms




**A. Terebilo, J. Corbett**

# SPEAR3 simulated commissioning




**G. Portmann**

Chromaticity measurement application (left) running on an operators PC

tested against a

simulated SPEAR3 (right) running on a dedicated PC

**A. Terebilo**

# Acknowledgements

I would like to express my appreciation to the SSRL accelerator physics and engineering staff who helped me prepare this presentation - in particular Jeff Corbett, Tom Dao, Domenico Dell’Orco, Bob Hettel, Jim Sebek, and Andrei Terebilo.