Activities on Beam Orbit Stabilization at BESSY II

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BESSY – Berlin, Germany

IWBS`02 – December 2002 – Spring 8

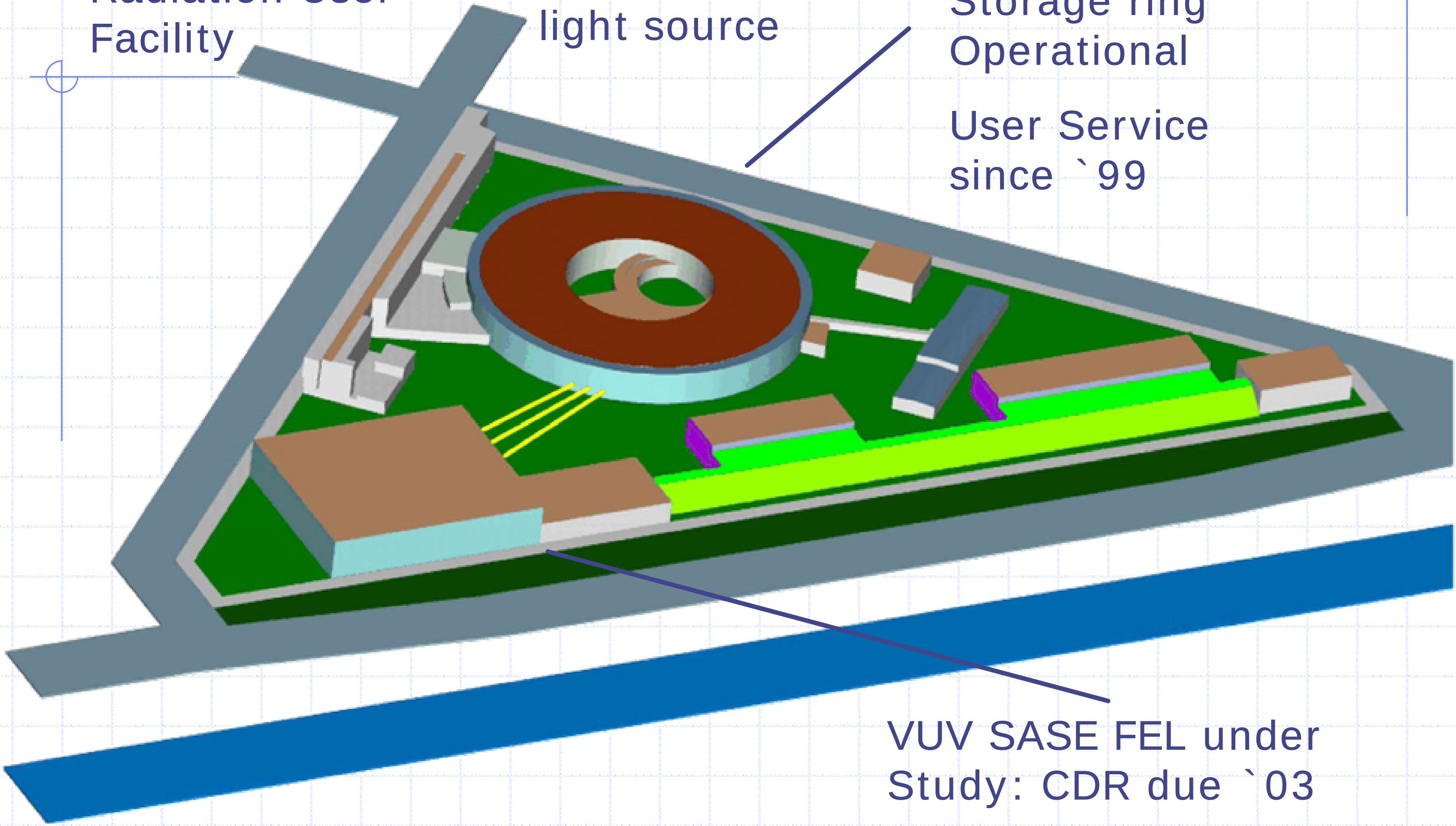
BESSY:
Synchrotron
Radiation User
Facility

BESSY II:

3rd generation
light source

1.7 GeV
Storage ring
Operational

User Service
since `99



VUV SASE FEL under
Study: CDR due `03

Outline: Status

- Components
  - Diagnostics, Correctors, Set-Up
- Performance
  - Per fill, day, week, months
- Problem Areas
  - Residuals, transients
- Conclusions

Orbit Control @ BESSY

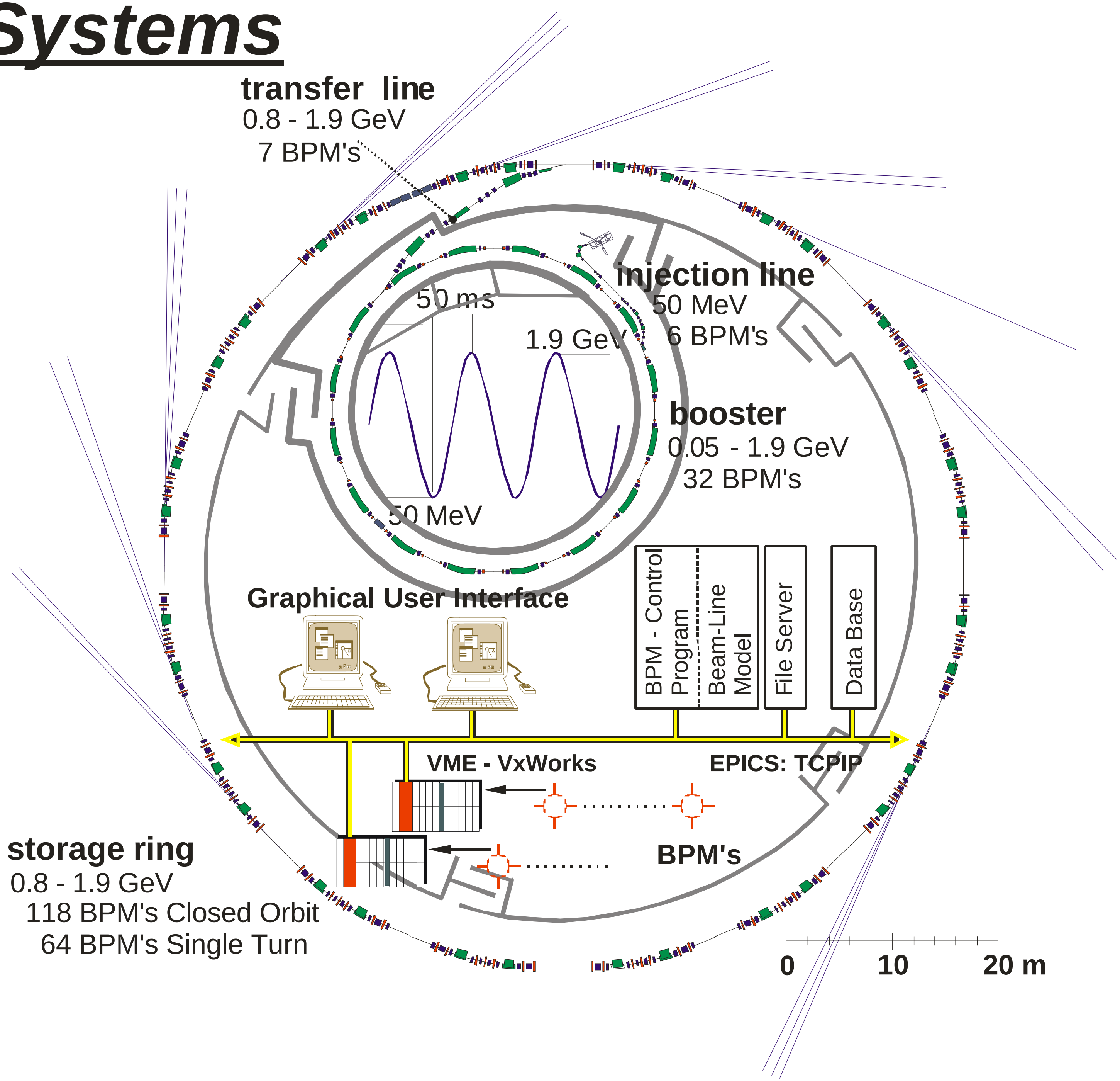
- Basic System Parameters:
  - 112 RF BPMs, 16 bit, 1µm res. (0.1s avg.)
  - 16 XBPMs, 25 SPMs, 1 TPM, 2 Pinholes
  - 64 vertical, 80+1 horizontal, 3mrad Correctors + 1Hz precision RF
  - 2 sec/orbit, 6 sec/correction cycle
  - model based response matrix
  - weighing factors 1 for RF BPM, 0 for XBPM
  - 50% significant SVD eigenvectors

The BPM Systems

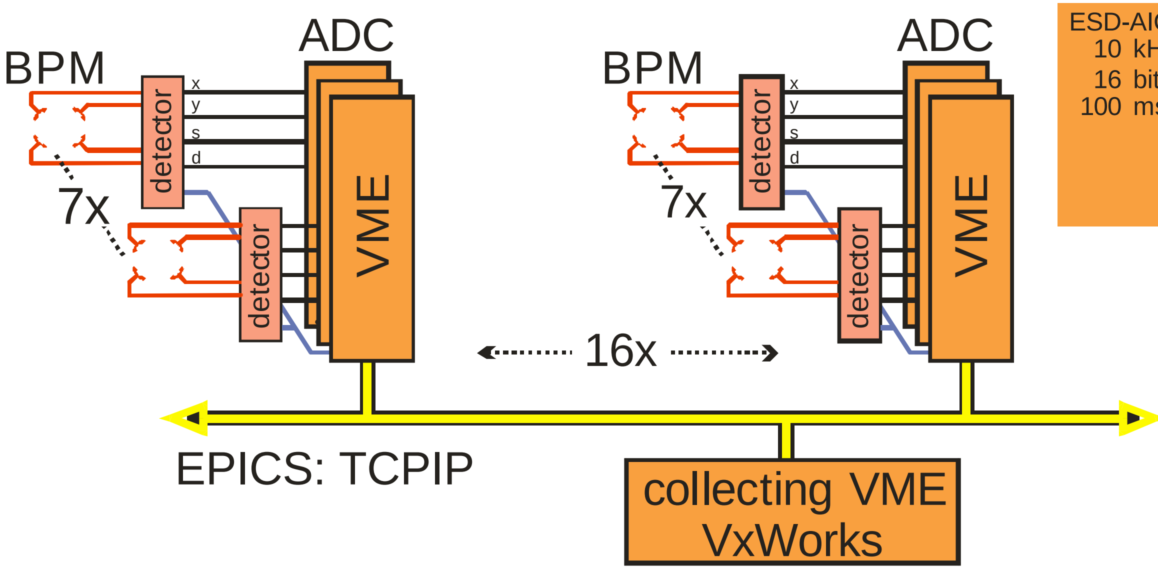
1. **Storage Ring - Closed Orbit**
   - Accurate (1 µm)
   - Reliable
   - 1 Hz Application Update Rate
2. **Storage Ring - Single Turn**
   - Fast (800 ns / turn)
3. **Injection system**
   - Fast (5 kHz sample rate)
   - Flexible

Specialized Modes for Booster, Transfer line and Storage ring

Data collection via network handshake



BPMs Storage Ring: Closed Orbit

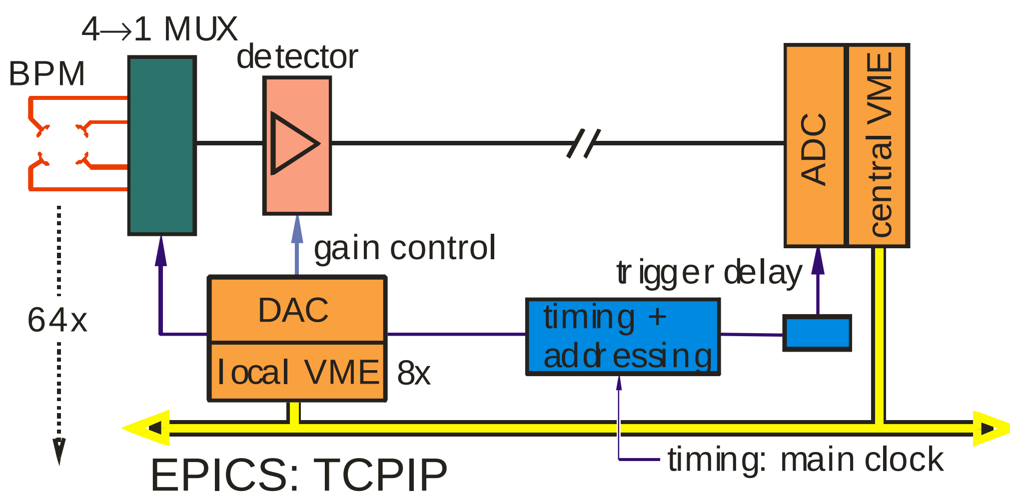


ESD-AIO16
10 kHz Sample Rate
16 bit accuracy
100 ms software averaging

Performance:

Dynamic range	±10	mm
Accuracy	~1	µm
Required current	100	µA
Update rate	1	Hz

BPMs Storage Ring: Single Turn

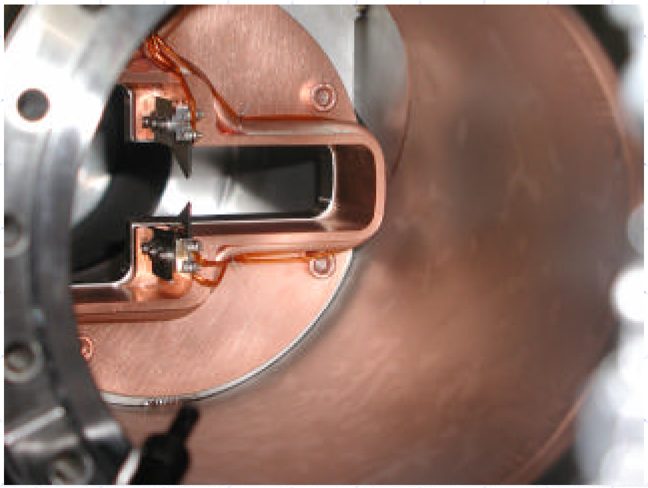


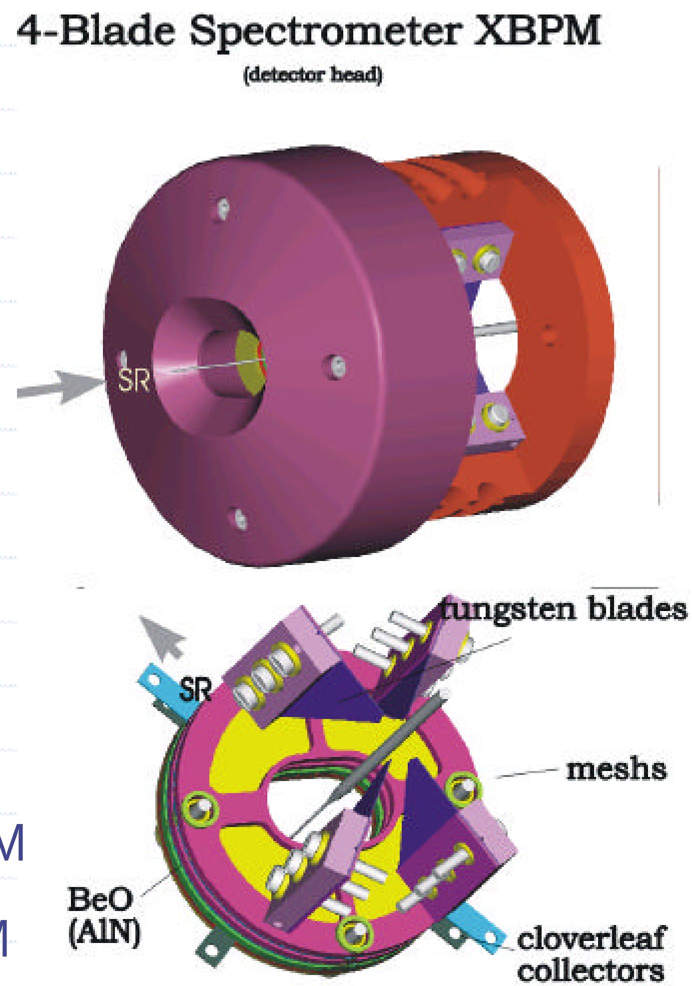
Joerger VTR1012-128
10 MHz Sample Rate
12 bit accuracy
32 k turns stored

Performance:

Dynamic range	±16	mm
Accuracy	1	mm
Required current	<100	µA
Update rate	0.2	Hz

Precise Photon BPM Systems



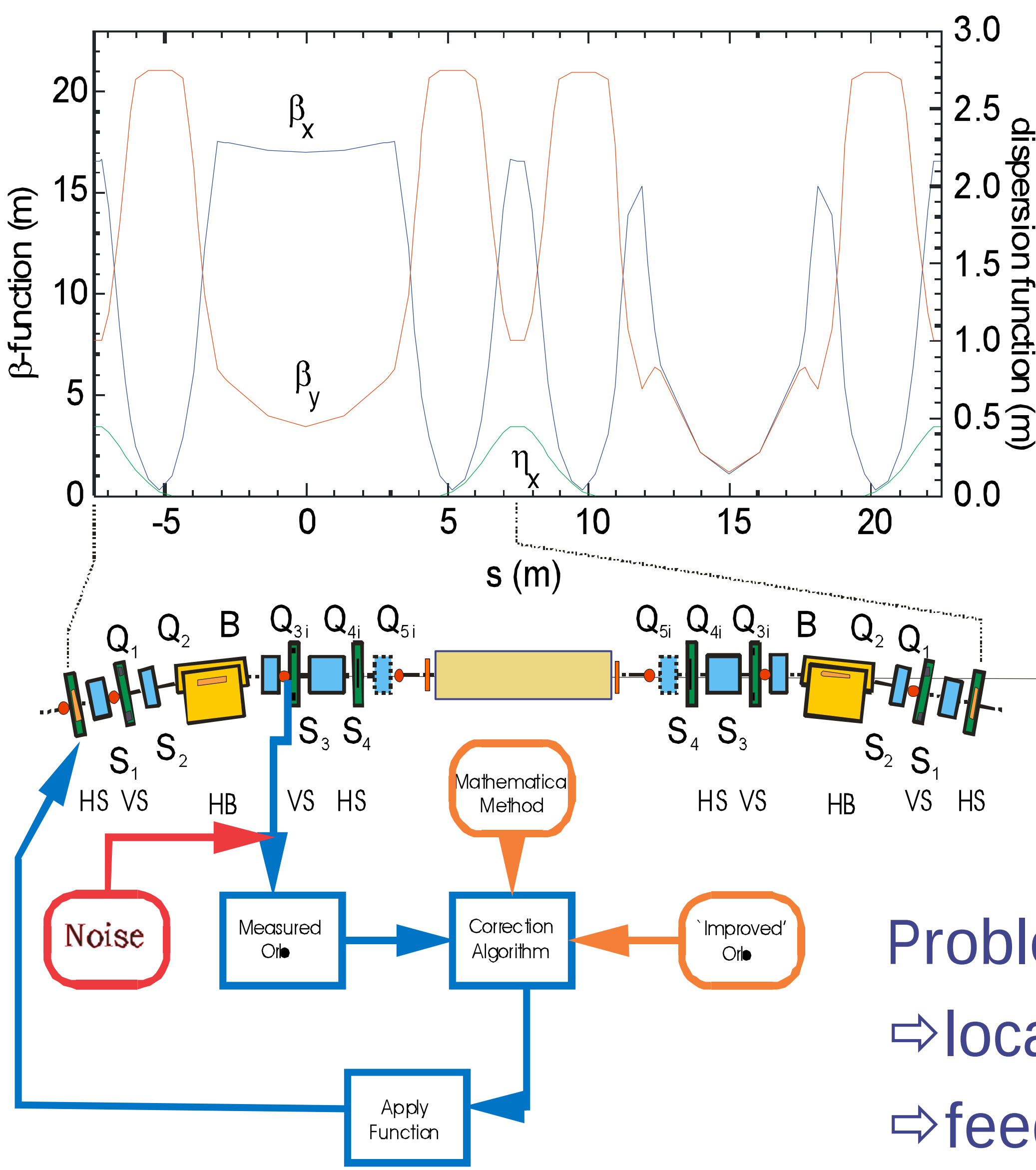


Ver.: Staggered Pair Monitors SPM

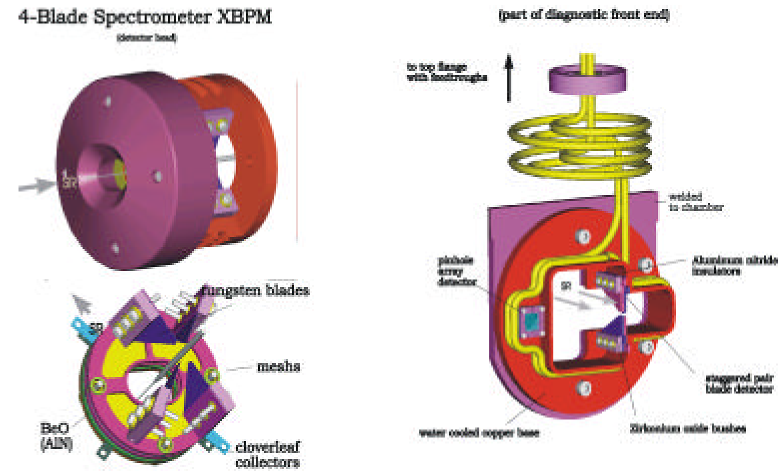
Hor.: Transversal Position Monitors TPM

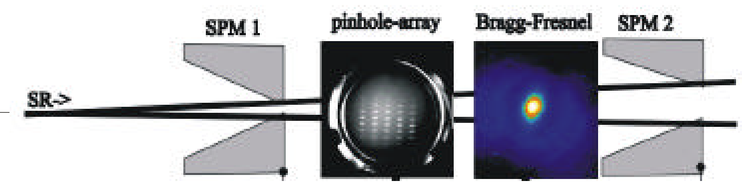
Undulator/WLS XBPM

Corrector Pattern



Diagnostic Means:Electronic + Photon BPM
Precise, Reliable, Fast, Complementary





Problem not well confined:

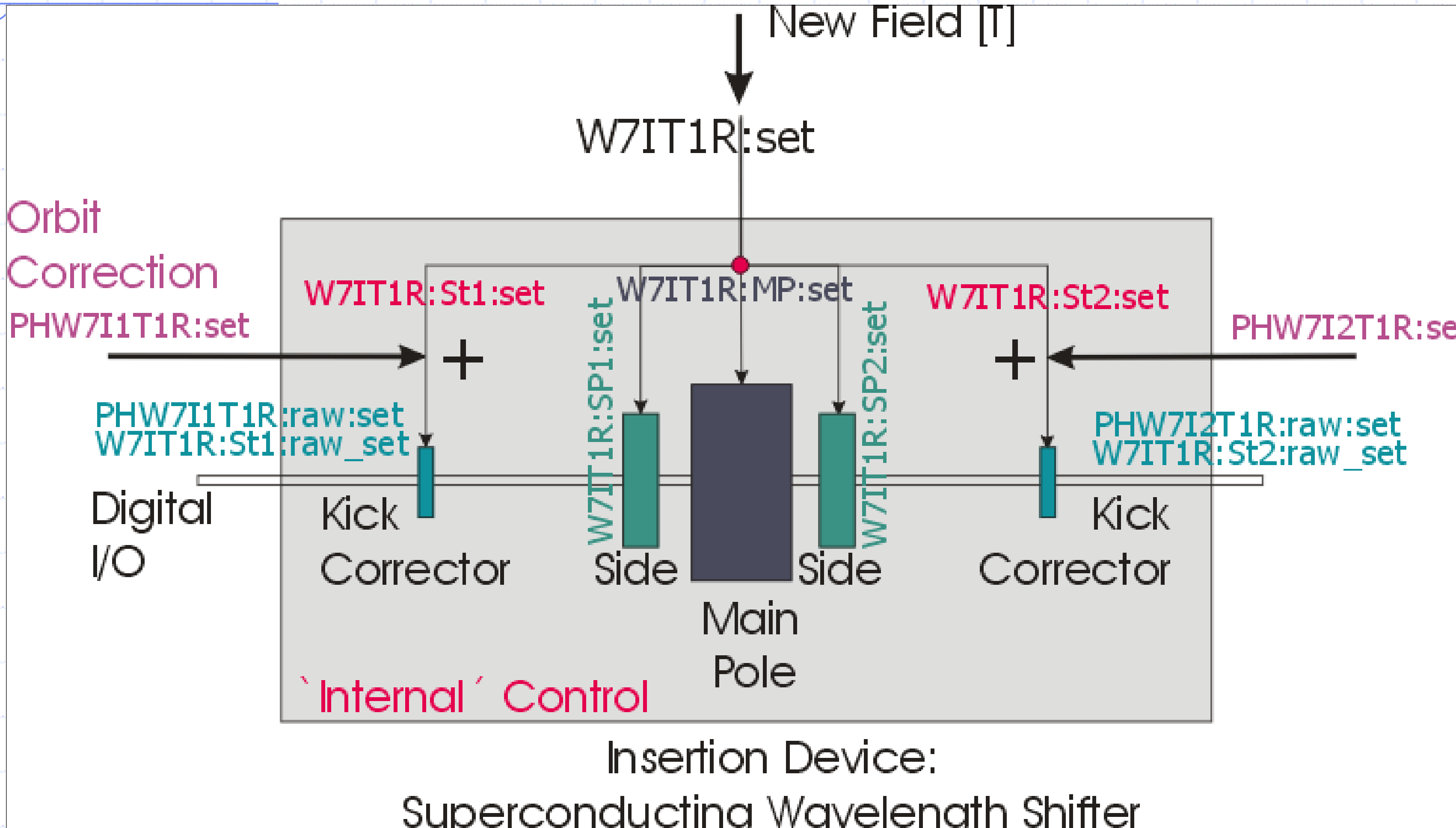
⇨local vs. global scheme

⇨feed-forward vs. drift control

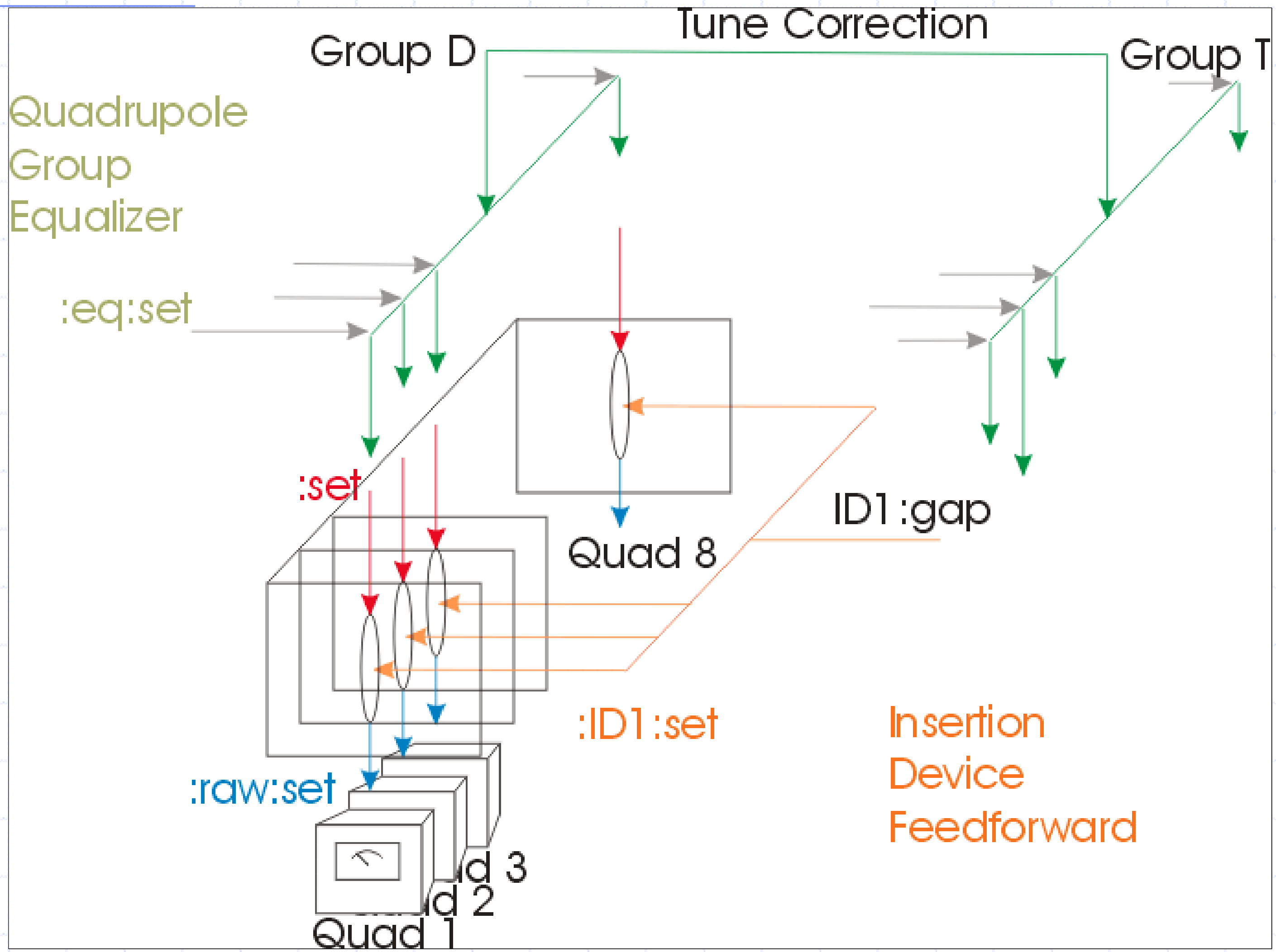
⇨orbit easier than tune/β-beat

Orbit

Orbit Kick Compensation: Feedforward-Tables (+Offset)



Tune/β-Beat Compensation: Storage Ring Quad Offset Terms



Orbit Correction Software:

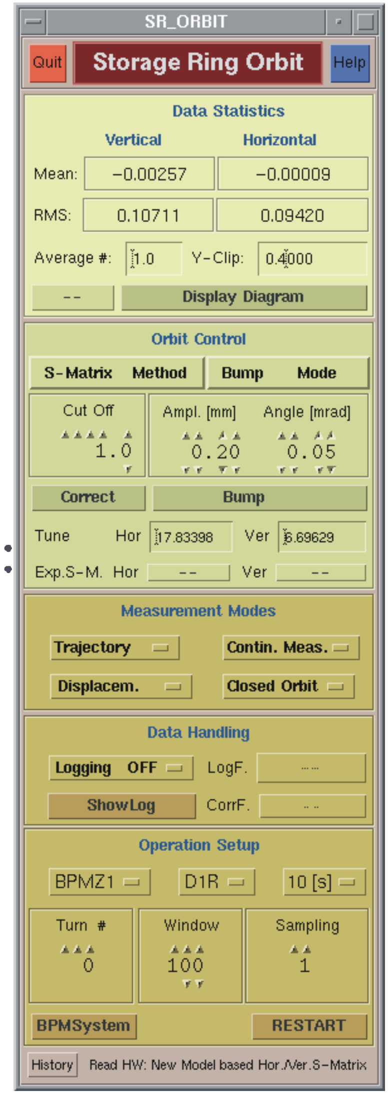
Versatile,
Accurate,
All-In-One
Working Horse

`Continous Mode':

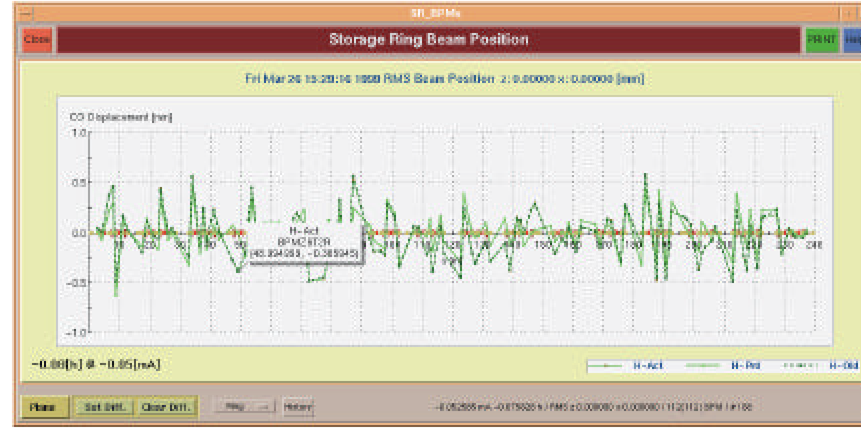
1 Orbit / 2 sec

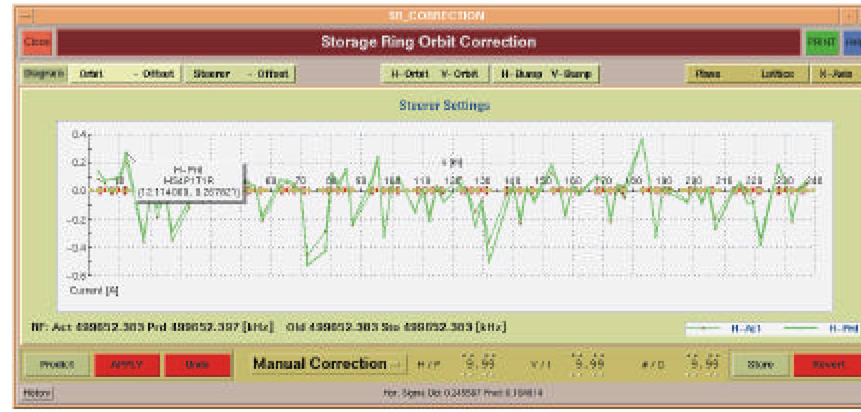
Read Orbit
Calculate/Set
Settle/Discard
Read Orbit
…

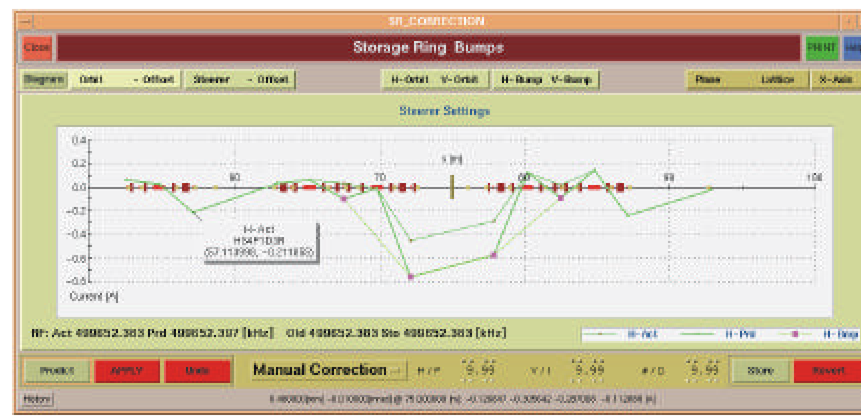
1 Corr. / 6 sec



Orbit Display and Control Interface



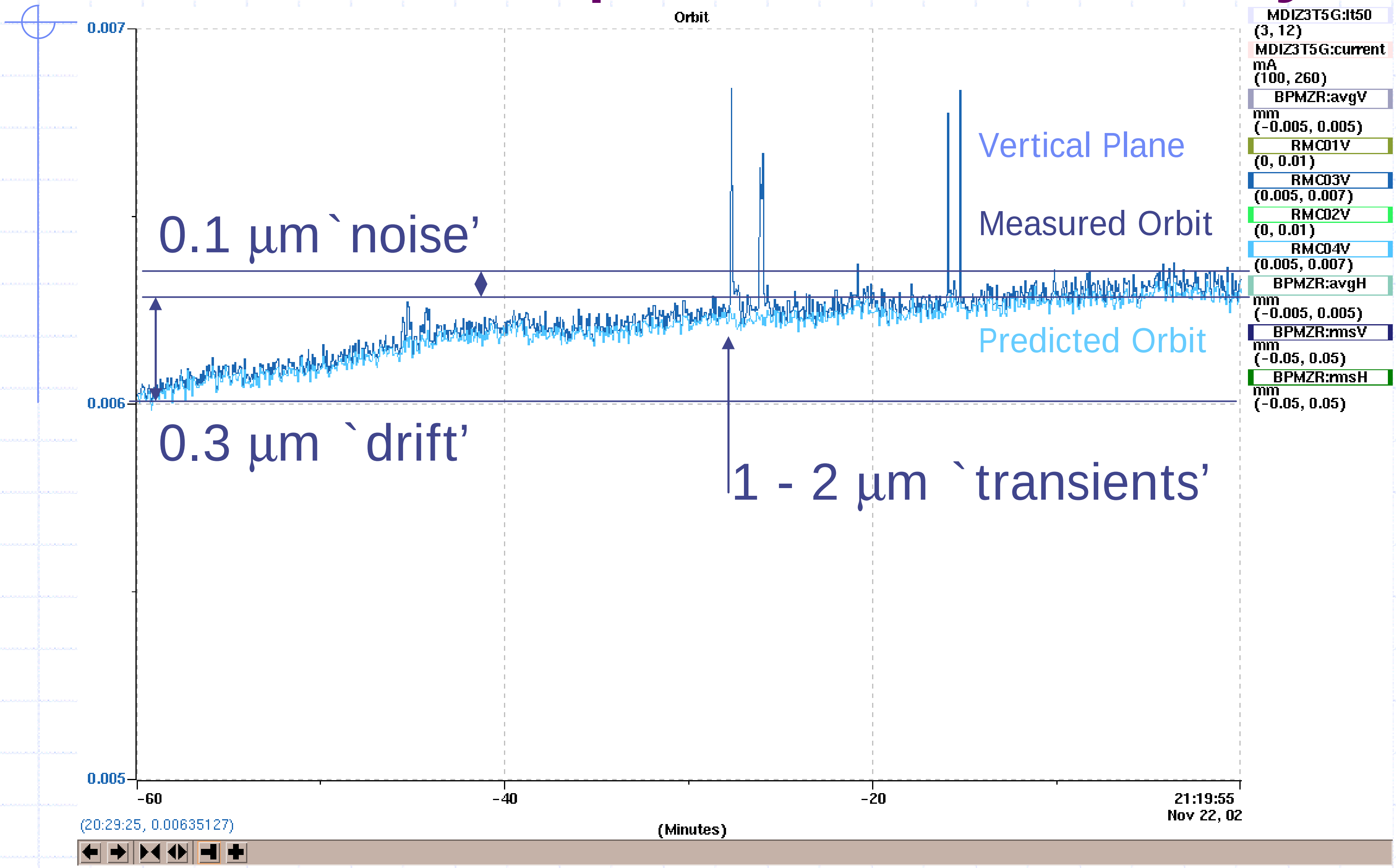




System Performance: Metrics

- Stability: per fill, weeks/months
  - orbit typically stabilized at 106/112 BPMs to better than 10µm/fill, 2µm fill to fill
- Reproducibility: spanning different user beam time slots: beam based calibration
- Reliability: MTBF, hardware faults, DAQ problems, controls failures: <0.5/month
- Human Factor: protection against faulty operation, ease of use + understanding
  - Key to problem tracking: action, data logging

1 hour example: RMS Stability

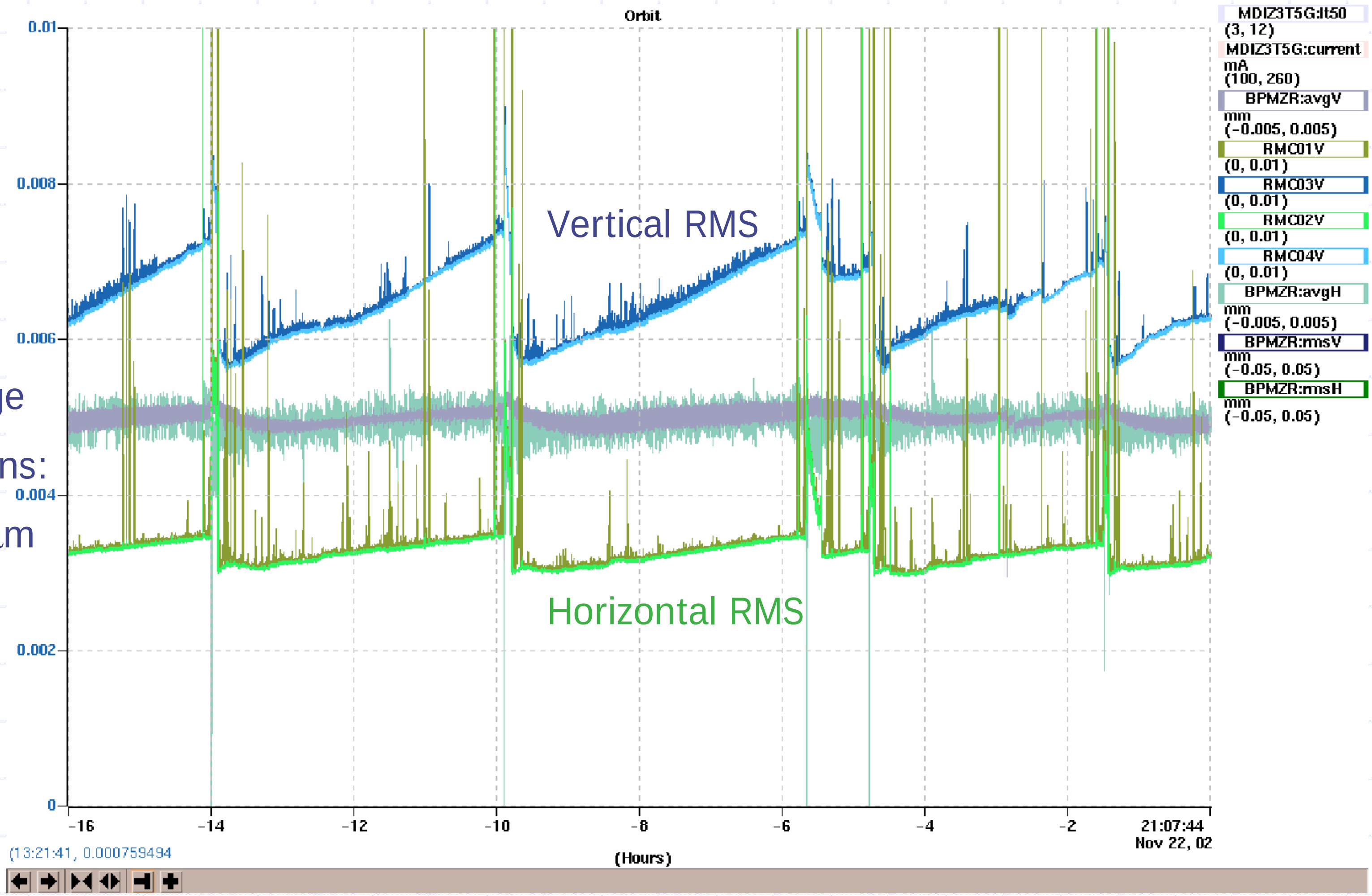


24 hours example: Avg./RMS

Average

Positions:

<0.2 µm



Stability during Start-Up Week

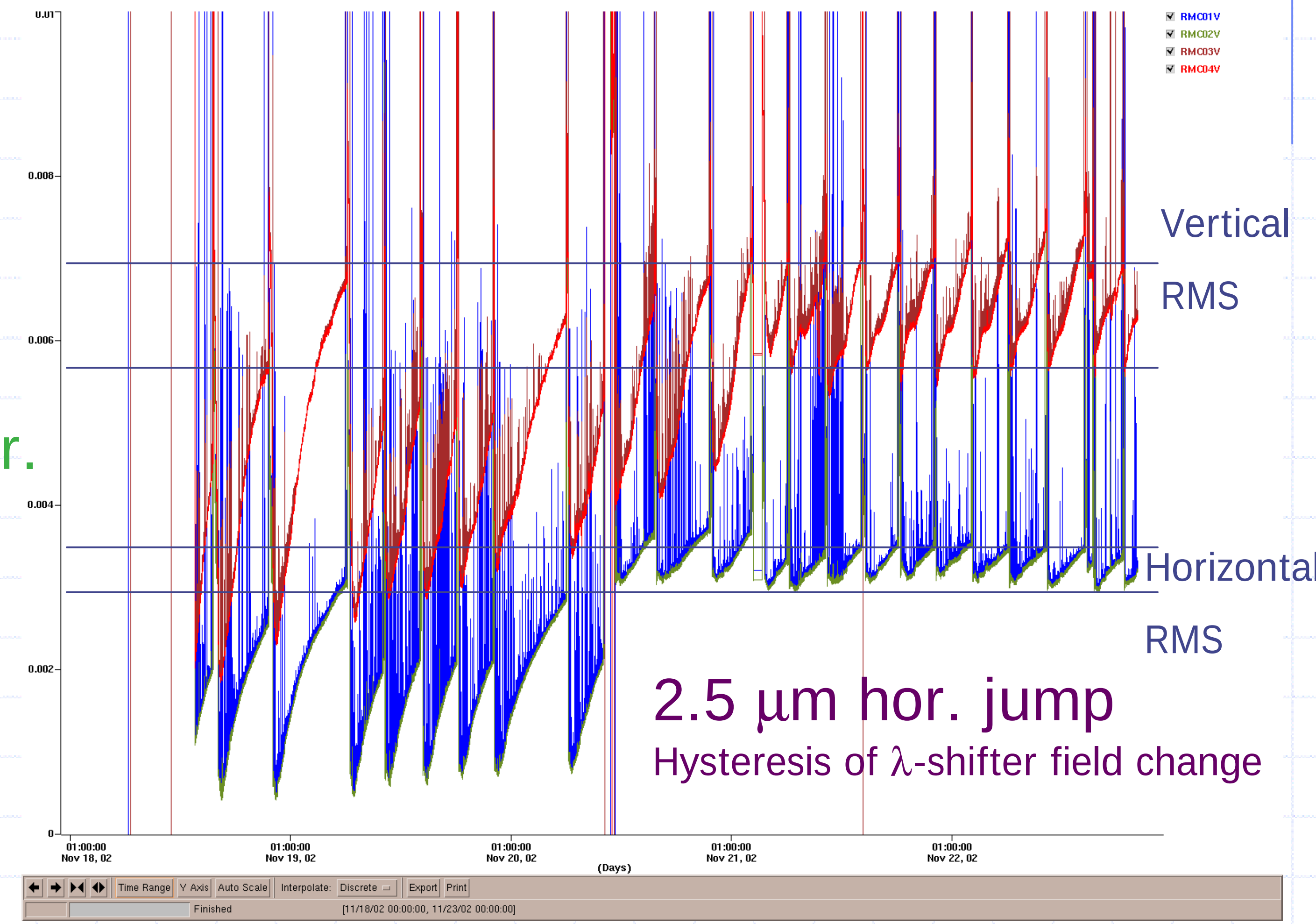
Per fill:

1.6 µm ver.

0.75 µm hor.

Fill to fill:

0.2 µm

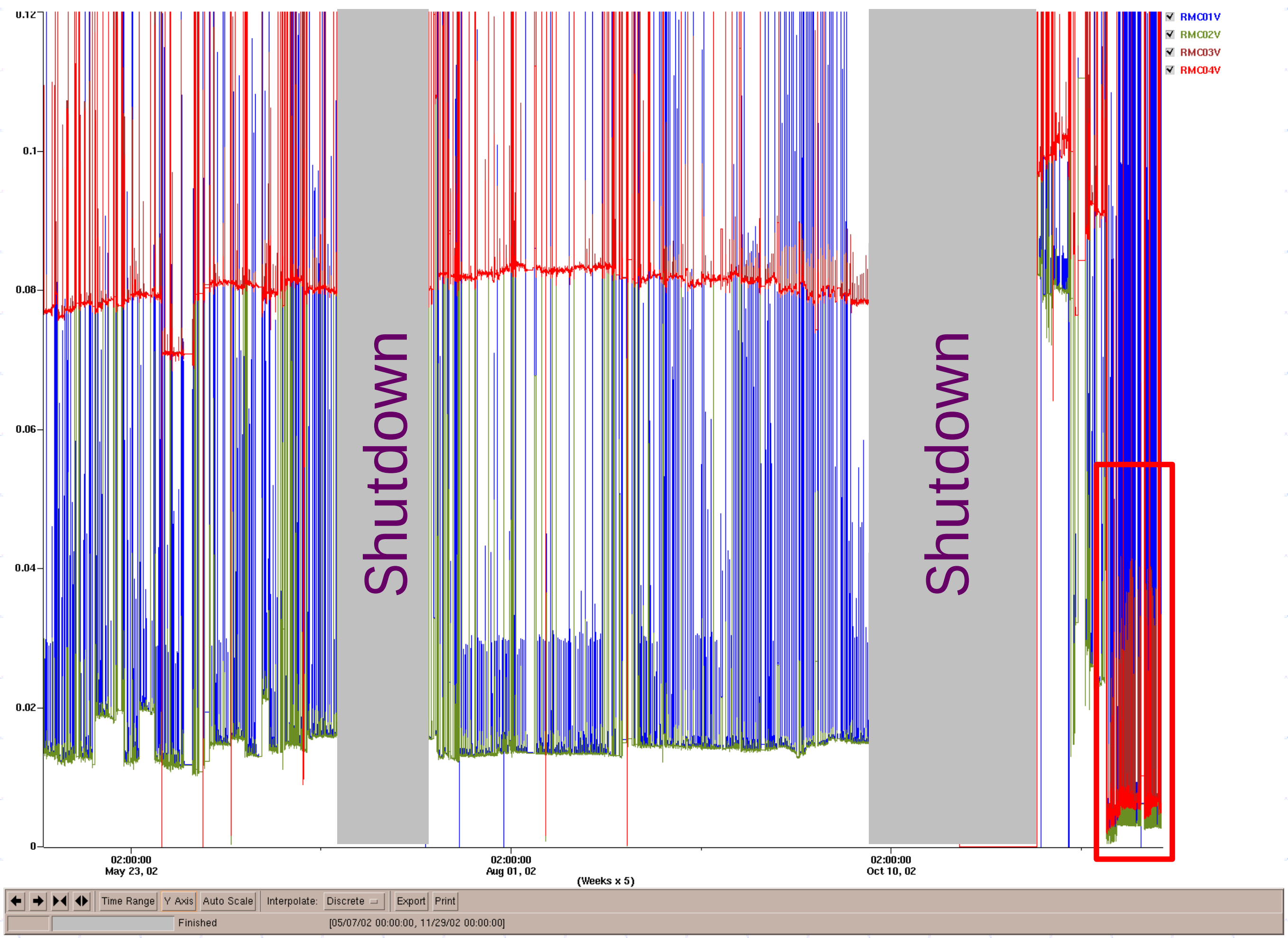


Stability 2002: 6 month raw data

Steps: e.g. Monday mainte-nance, Mistakes, Changes

User Shift:

- Recalibrated
- MD finished

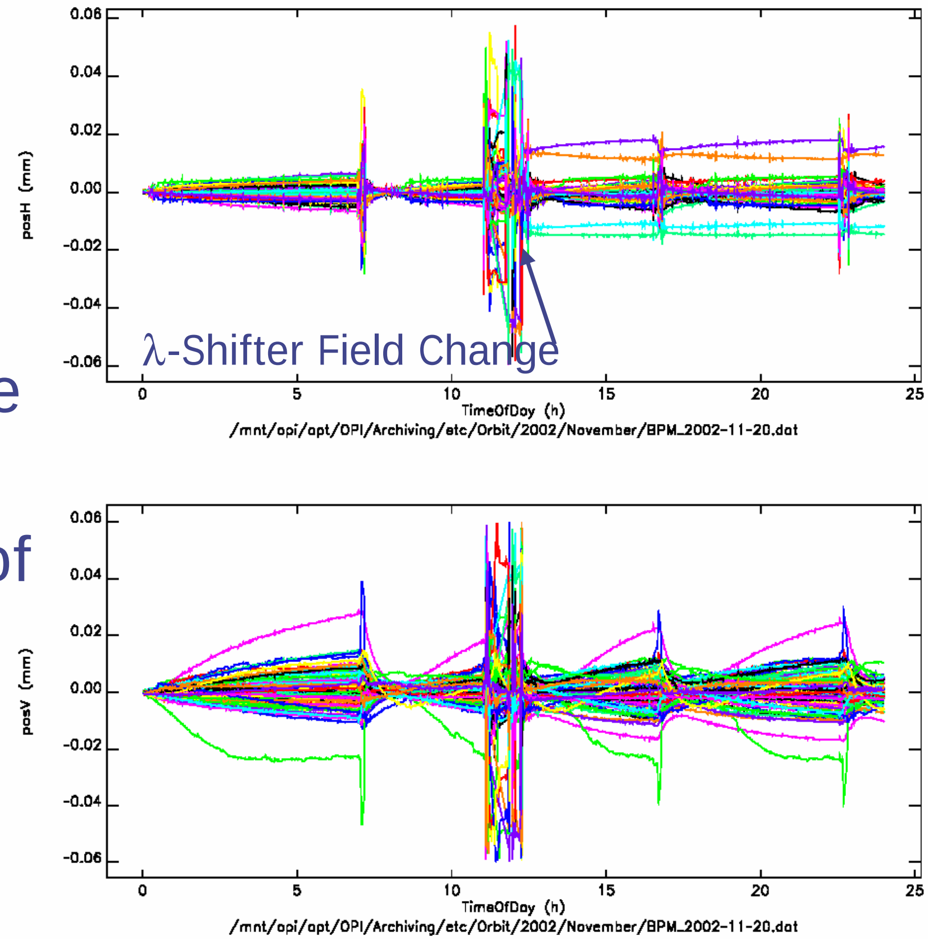


Transient Perturbations

- UE56 brakes: Magnetic drives.
- Horizontal `spikes' of 1-3 µm RMS.
- Complete compensation difficult.
- Discontinous ID-feed-forward tables similar.

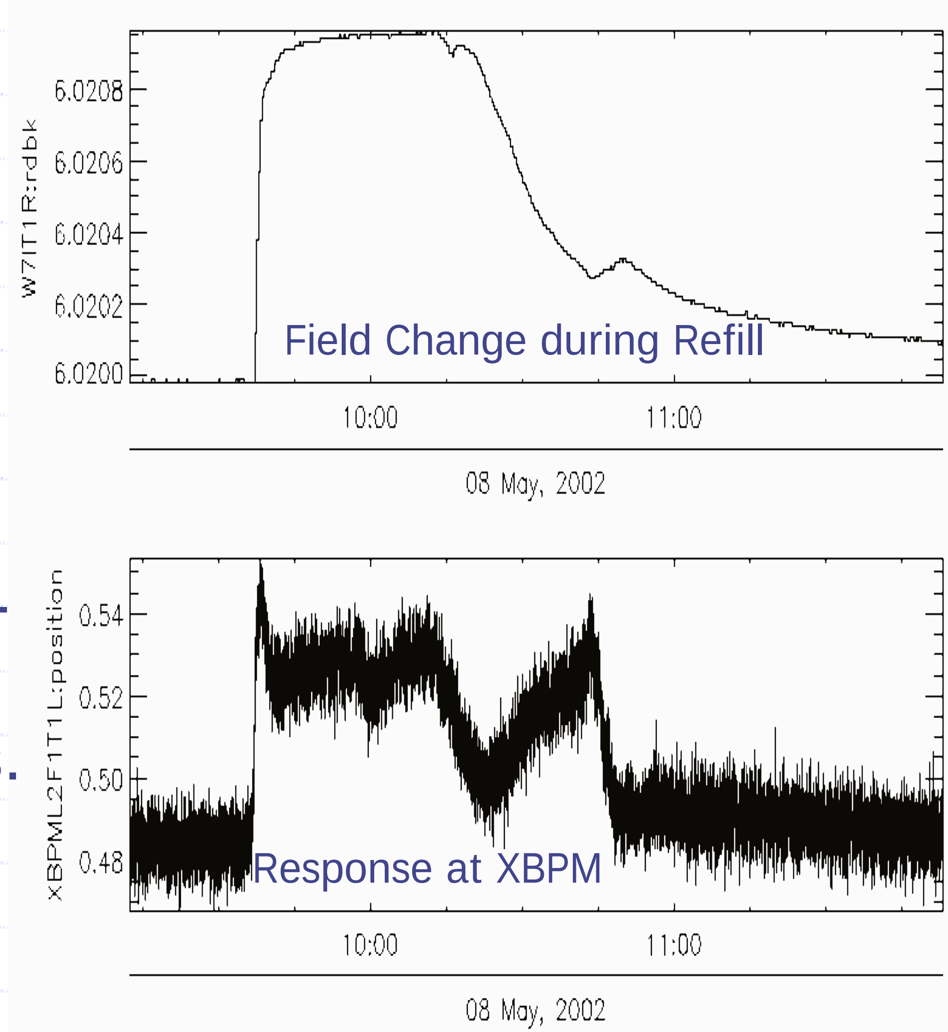
Step Function Changes

- Hardware repairs, modifications.
- Hysteresis
  - Field Cycle of λ-shifter: strong dipole kick compensators.
  - Minor adjustments of optics: ID feed-forward, tune/ chromaticity adjustment.



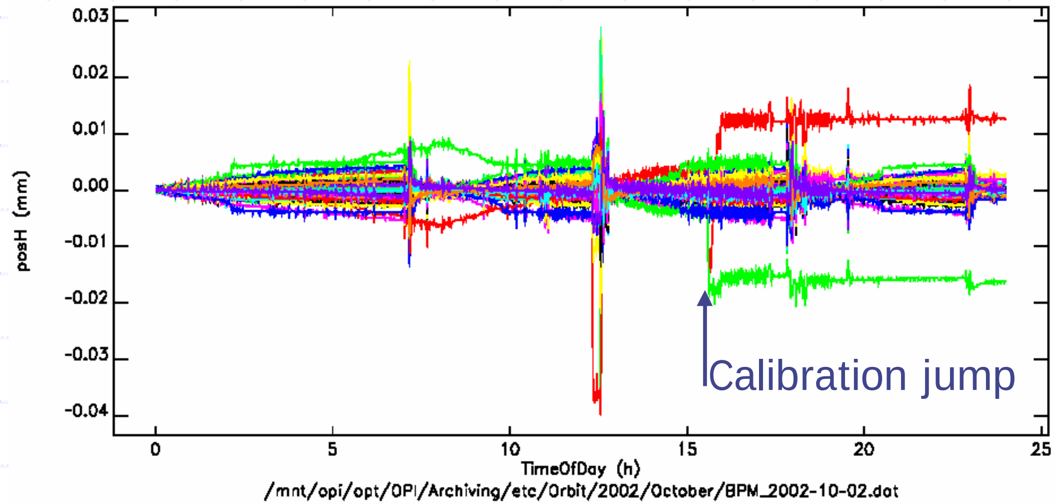
Other Uncorrected Residuals

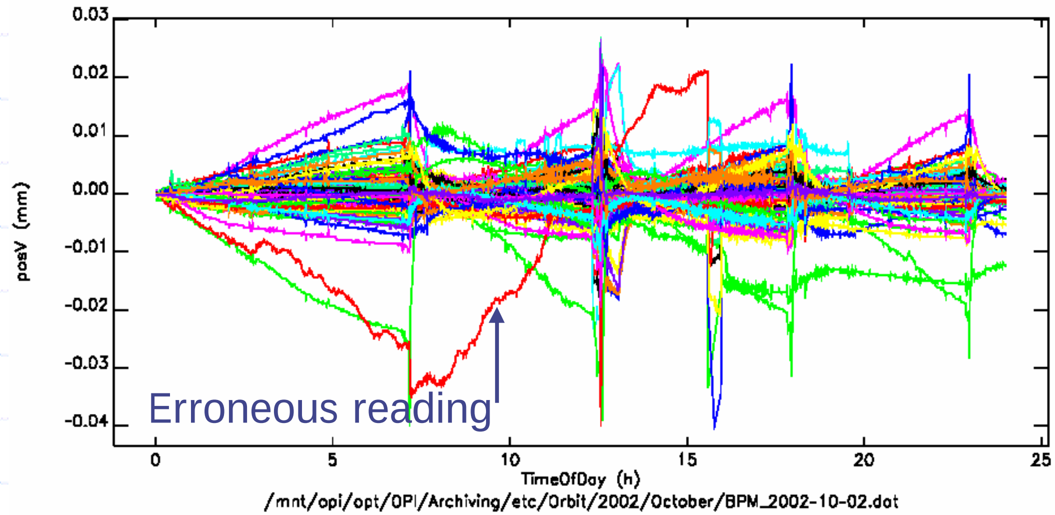
- LHe refill of super-conducting λ-shifter modifies field.
- Decay of SC eddy currents (~1h).
- Uncalibrated path length correction of λ-shifter cycles: slight beam energy changes.
- …..



BPM Failure Detection/Repair

- MTBF: ~2 month
- Remaining malfunction hard to detect
  - E.g. exotic oscillator output level causes erroneous readings
- Beam-Based auto-calibration not yet implemented





Problem Tracking Facilities

- Comprehensive signal archive (~8000 channels): time, source-effect correlations
- Operator/Program action logging: irregularities, misunderstandings, malfunctions

File Options Preferences Help

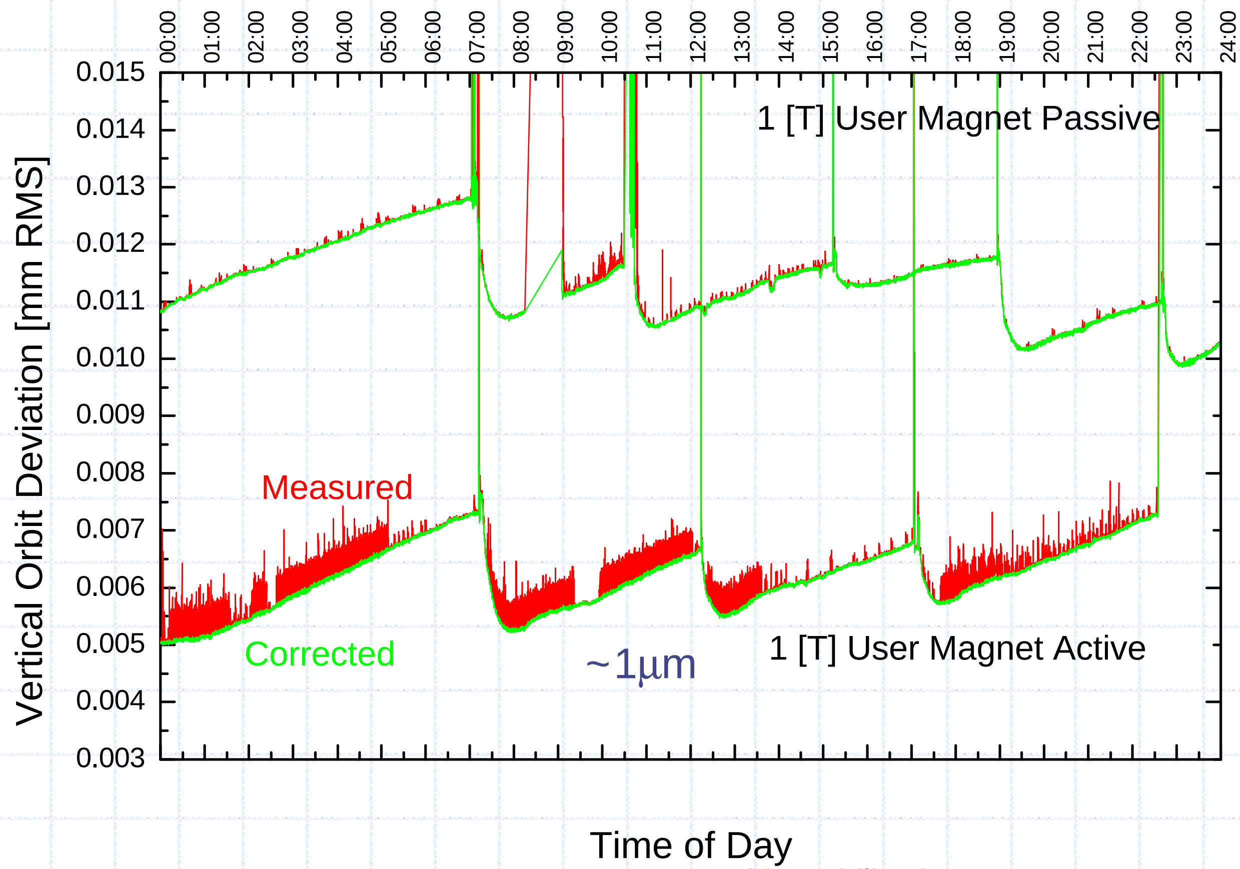
Facility	Device	Host	Process	PID	User	Time	Status	Severity	Verbosity	Valu	Erro	Text	Messa
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:46:37 200	CORR	Info	Note	N/A	0	# 858 (100) 48.167575 mA −0.033841 h: H# 48/−48 O 0.006999/−854382451 P 0.00677	PROGRAM RESULT,CALC
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:52:26 200	CORR	Warn	Note	N/A	0	*** @Correction # 182: 2 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:52:35 200	CORR	Warn	Note	N/A	0	*** @Correction # 184: 2 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:52:39 200	CORR	Warn	Note	N/A	0	*** @Correction # 185: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:53:33 200	CORR	Warn	Note	N/A	0	*** @Correction # 197: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:53:46 200	CORR	Info	Note	N/A	0	# 1066 (200) 192.290943 mA −0.113091 h: H# 48/−48 O 0.006890/−917262023 P 0.006	PROGRAM RESULT,CALC
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:56:57 200	CORR	Warn	Note	N/A	0	*** @Correction # 244: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:58:28 200	CORR	Warn	Note	N/A	0	*** @Correction # 266: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 11:59:13 200	CORR	Warn	Note	N/A	0	*** @Correction # 277: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:00:50 200	CORR	Info	Note	N/A	0	# 1272 (300) 245.717424 mA 3.754377 h: H# 48/−48 O 0.002781/−375578597 P 0.0026	PROGRAM RESULT,CALC
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:07:51 200	CORR	Info	Note	N/A	0	# 1476 (400) 238.219165 mA 3.833817 h: H# 48/−48 O 0.002651/490312062 P 0.00263	PROGRAM RESULT,CALC
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:20:38 200	CORR	Warn	Note	N/A	0	*** @Correction # 464: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic7c:0.0	opic7c	N/A	18535	opi	Mon Nov 25 12:21:56 200	Meas	Err	Warn	N/A	0	Persistent AGC Error at BPMZ4D2R (# 290901)	PROGRAM RESULT,CALC
Orbit	opic7c:0.0	opic7c	N/A	18535	opi	Mon Nov 25 12:21:56 200	Meas	Warn	Note	N/A	0	BPMZ4D2R at 27.264000 m disapp.(# 12 x=32.736000 <nxt 32.736000 m>)	PROGRAM NOTIFICATIOI
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:22:01 200	Meas	Err	Warn	N/A	0	Persistent AGC Error at BPMZ4D2R (# 1887)	PROGRAM RESULT,CALC
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:23:07 200	CORR	Info	Note	N/A	0	# 1919 (500) 24.534314 mA −0.015123 h: H# 48/−48 O 0.017755/347849652 P 0.01771	PROGRAM RESULT,CALC
Orbit	opic7c:0.0	opic7c	N/A	18535	opi	Mon Nov 25 12:23:49 200	Meas	Warn	Note	N/A	0	BPMZ4D2R at 27.264000 m reapp.(# 12 s=32.736000 <prv 26.005000 m>)	PROGRAM NOTIFICATIOI
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:24:00 200	CORR	Warn	Note	N/A	0	*** @Correction # 513: 2 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:24:04 200	CORR	Warn	Note	N/A	0	*** @Correction # 514: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:28:28 200	CORR	Warn	Note	N/A	0	*** @Correction # 576: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:30:08 200	CORR	Info	Note	N/A	0	# 2123 (600) 100.124077 mA 7.918975 h: H# 48/−48 O 0.003079/−786256207 P 0.0030	PROGRAM RESULT,CALC
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:36:02 200	CORR	Warn	Note	N/A	0	*** @Correction # 631: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:40:51 200	CORR	Info	Note	N/A	0	# 2435 (700) 108.108340 mA −0.072203 h: H# 48/−48 O 0.008520/−1639597794 P 0.0	PROGRAM RESULT,CALC
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:45:43 200	CORR	Warn	Note	N/A	0	*** @Correction # 767: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 12:48:00 200	CORR	Info	Note	N/A	0	# 2643 (800) 253.268979 mA 3.813557 h: H# 48/−48 O 0.002822/−1720145895 P 0.002	PROGRAM RESULT,CALC
Orbit	opic3c:0.0	opic3c	N/A	2015	opi	Mon Nov 25 13:13:50 200	CORR	Warn	Note	N/A	0	*** @Correction # 872: 1 with BAD efficiency ***	PROGRAM BRANCH/FLOV

Thu Nov 28 16:36:19 2002 From Mon Nov 25 03:31:14 2002 To Wed Nov 27 16:31:14 2002

Unexpected Events

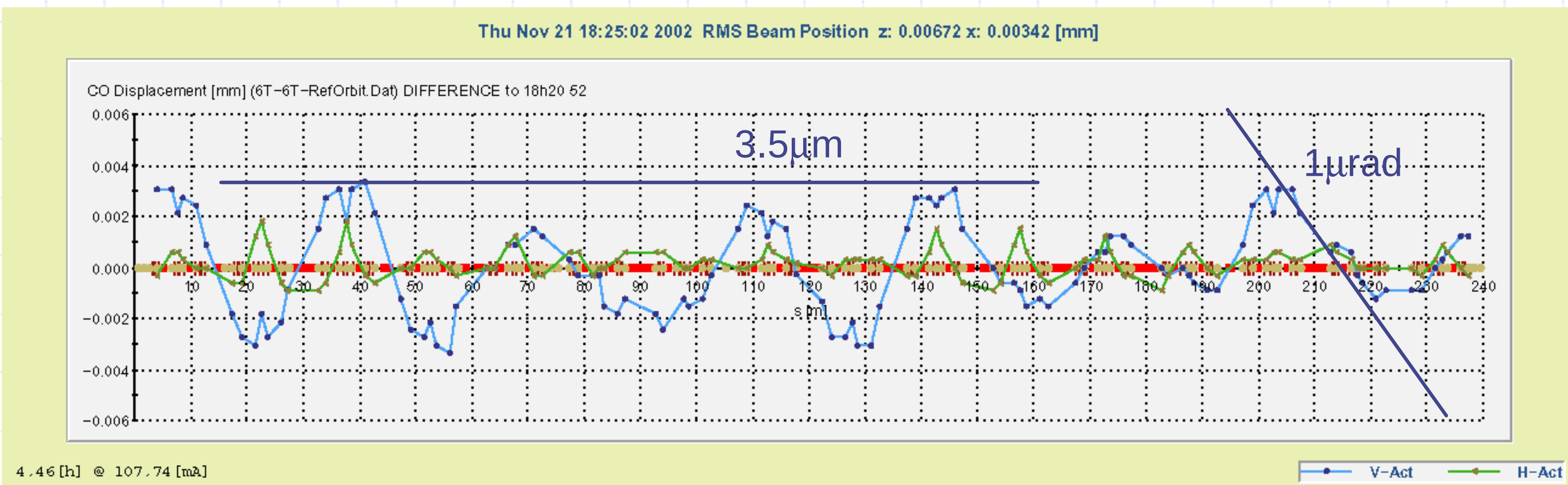
- New, unexplainable orbit jumps appear: Phase analysis points to a ring segment with NO active element
- Pattern of perturbation corresponds to users time slots.

1 μm Orbit perturbation due to 1[T] user magnet switched outside (!) storage ring tunnel (3m from beam pipe).

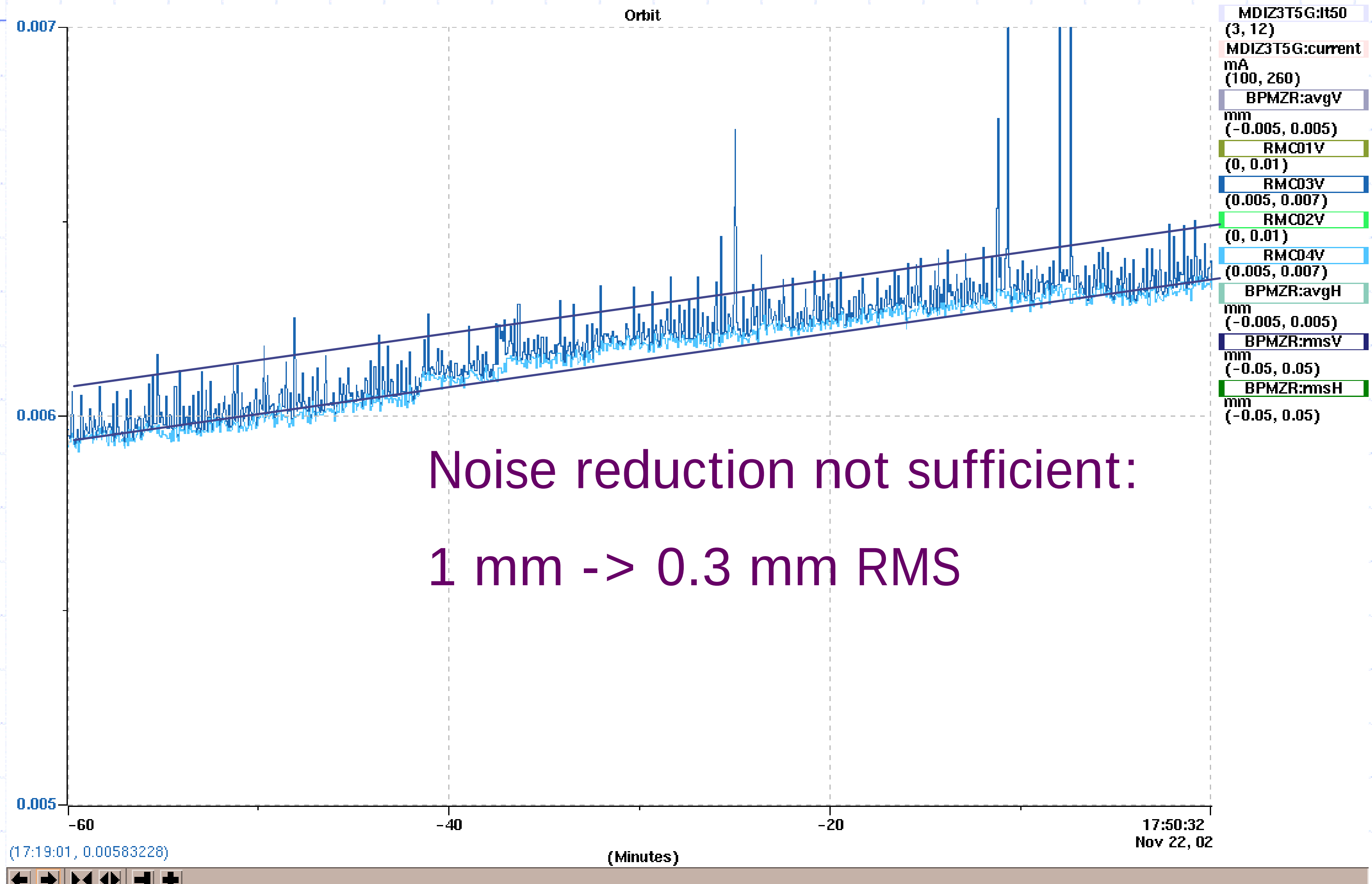


Behind RMS: Deviations/Angles

- User magnet causes 4 µm, 1µrad peak perturbation
  - Corrected within 2 cycles.
- Obvious required counter-measures:
  - Distance, shielding, local feed-forward.
  - Inadequate: fast local ID source point feed-back.



Present Choice: New Location

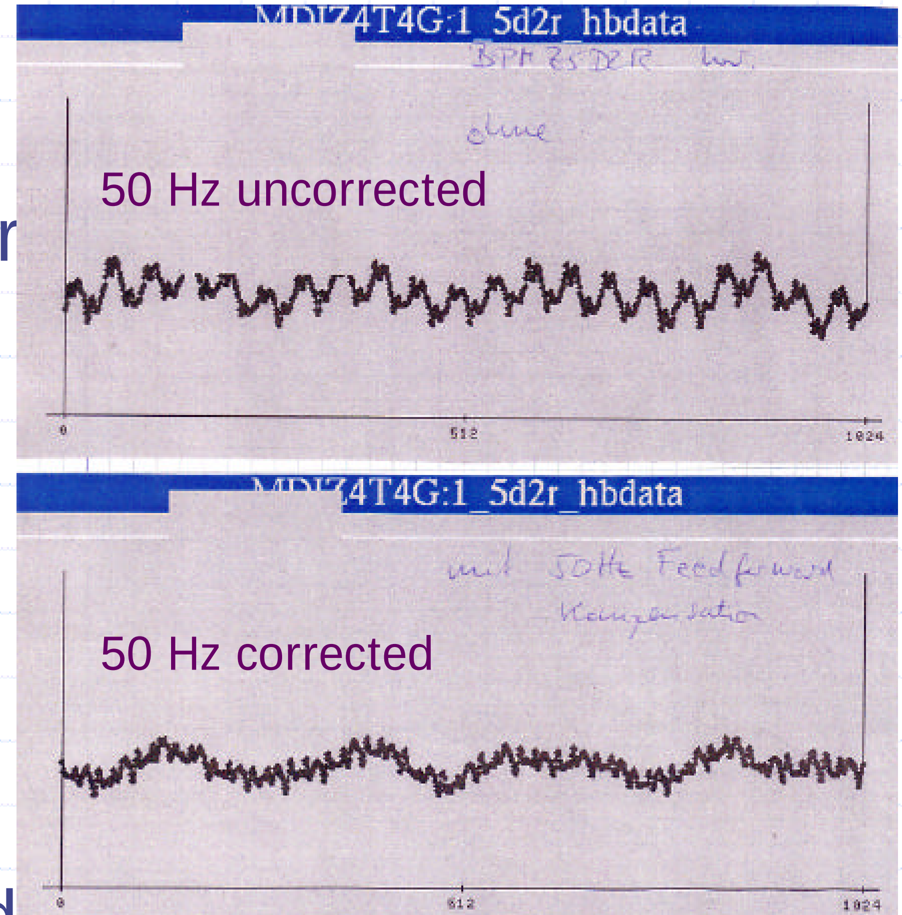


Noise reduction not sufficient:

1 mm -> 0.3 mm RMS

50 Hz Mains Suppression

- Fast BPM signal analysed.
- Put air coil corrector at optimal position.
- Feed-forward compensation proves feasibility.
- Users don't suffer, most detectors average with same frequency: not used



Copy from runbook

Vibrations

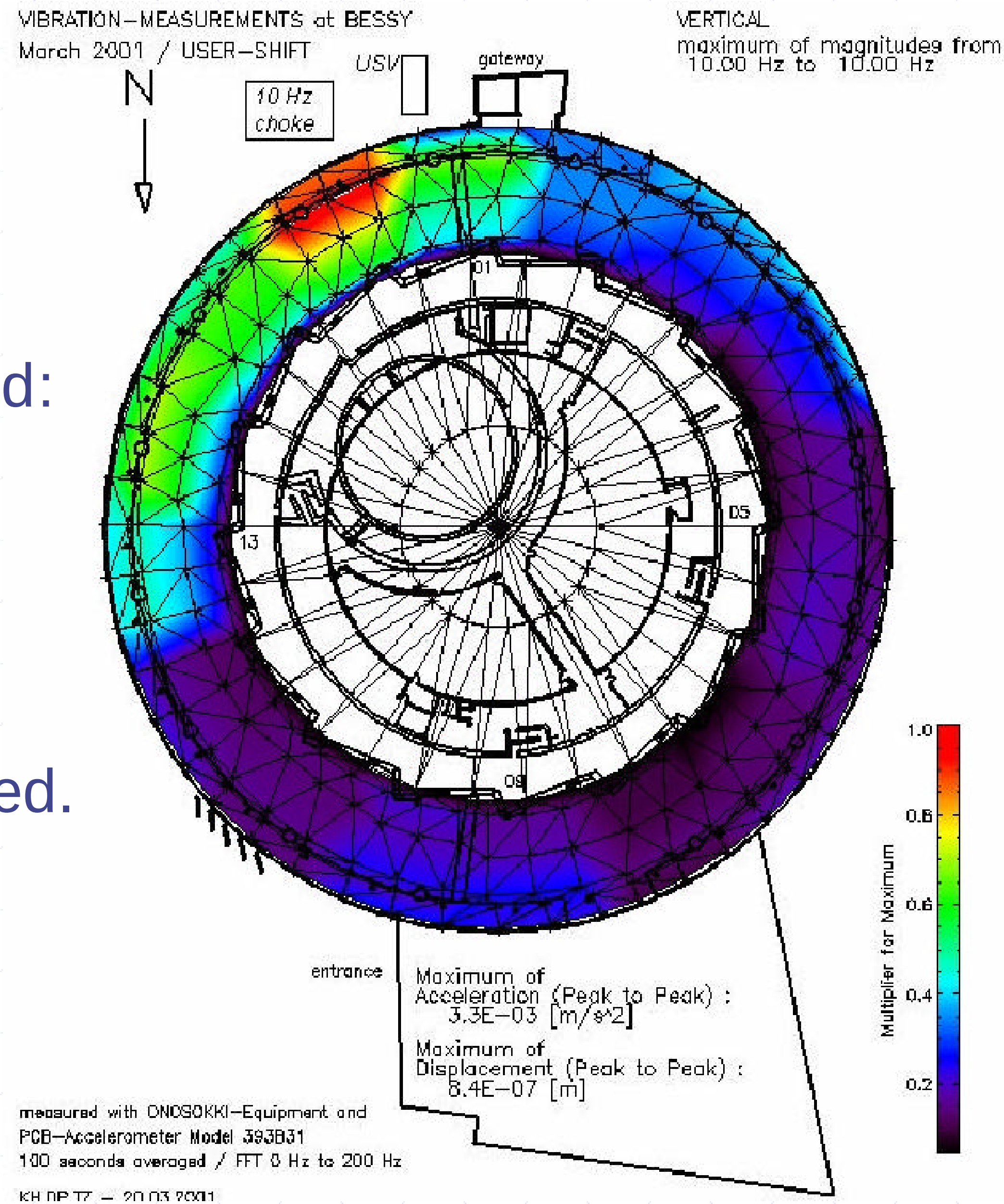
Tunnel, experimental floor well characterized:

•Frequency

•Magnitude

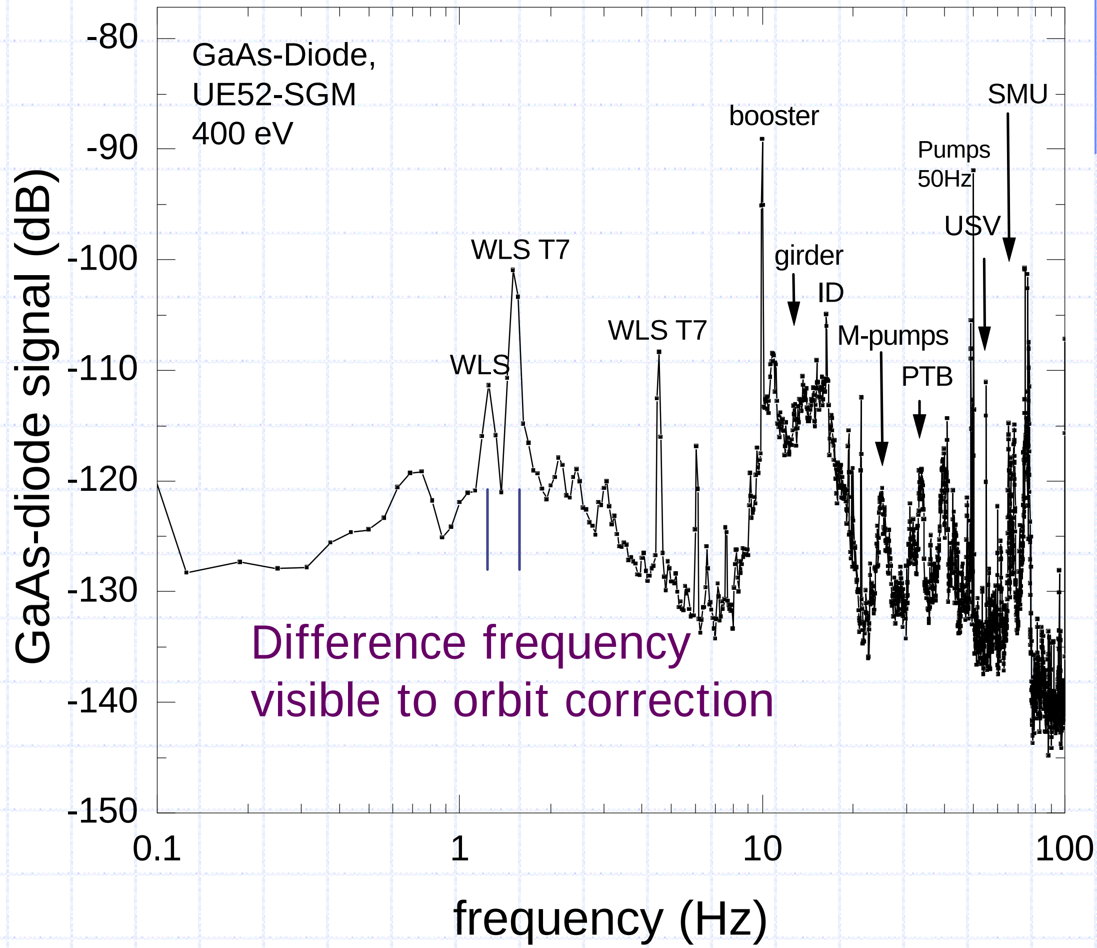
•Critical components, major sources identified.

•Consequences for beam-line design: vibration damped BL elements.



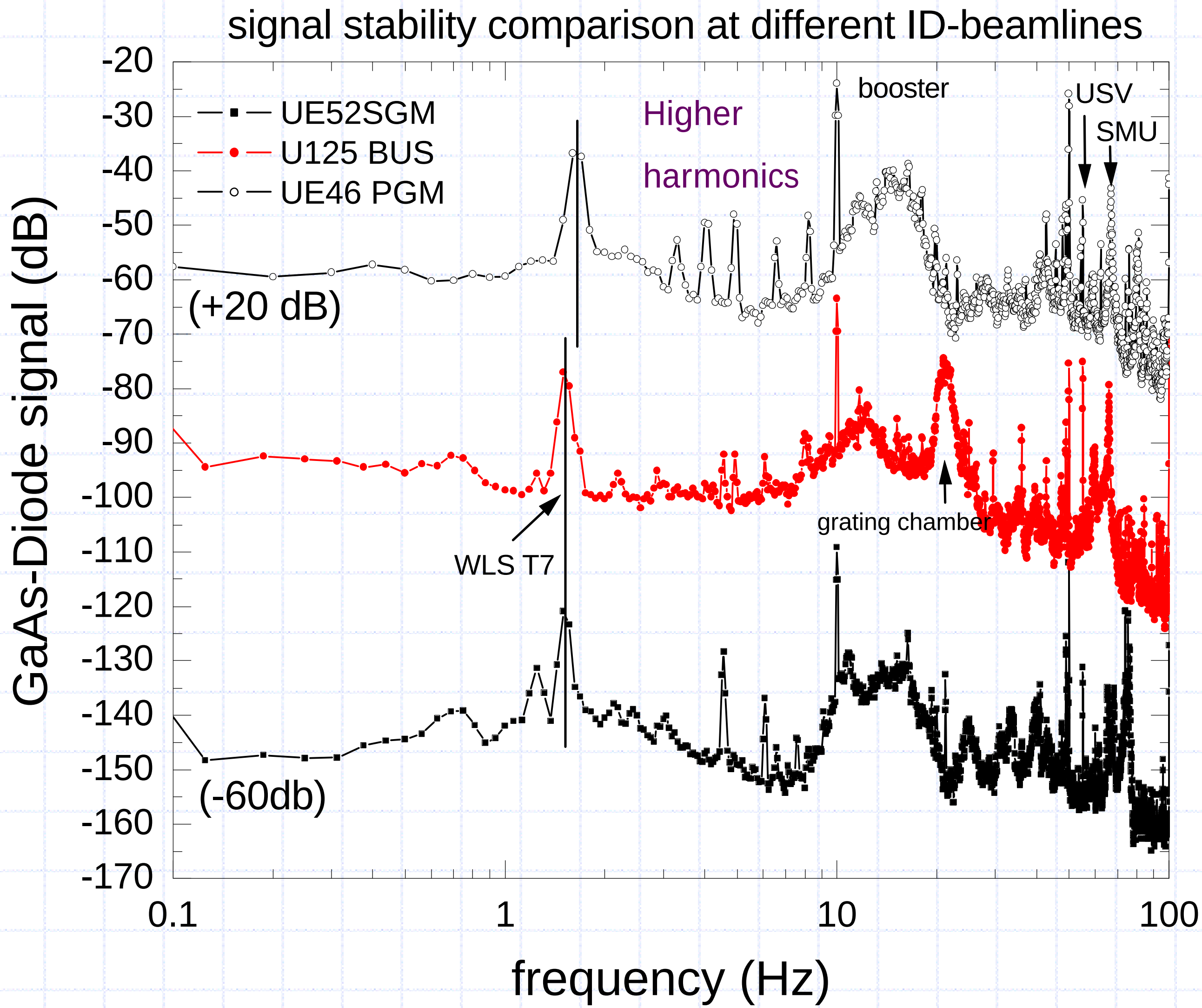
Stability: Spectral Overview

- Diode @ experiment position
- Metric: achievable signal/noise ratio
- Dominant:
  - LHe recondensor
  - White circuit
  - Gyro mains



Comparison of Sensitivities

Help to distinct accelerator beam orbit dominated effects from beam line specifics.



Conclusions

- RF-BPM and XBPM diagnostic: precise, consistent, complementary.
- Growing understanding of sources and feasible countermeasures.
- Effect on experiments widely varying.
  - IR beam-line most sensitive.
- Perturbations tied to beam-line and beam orbit are of similar order.
- Improvement attempts have to consider both areas.