# Specifics of the BESSY II 0.3Hz Orbit Correction System

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# Slow Orbit Control in General

- Data Conditioning
  - BPM: Validity Check, Weighting
  - Correctors: Boundary Conditions, Resolution, Limits
- Solvers
  - Methods (Micado, SVD...)
  - Implementation, Packages
- Apply Procedures
  - Principles, Error Handling, Ramping Algorithm, Crosstalk with other Systems, Aliasing

# Orbit Control @ Light Sources

- Objectives:
  - Minimize RMS orbit deviation
  - Reproduce position/angle at any experimental station, minimal jitter
- Problem: 3rd generation sources exceed design values by 1 order :
  - Resolution of components, sources of perturbation, noise are all down to the same order of magnitude (µm, µrad)

# Outline / Topics addressed

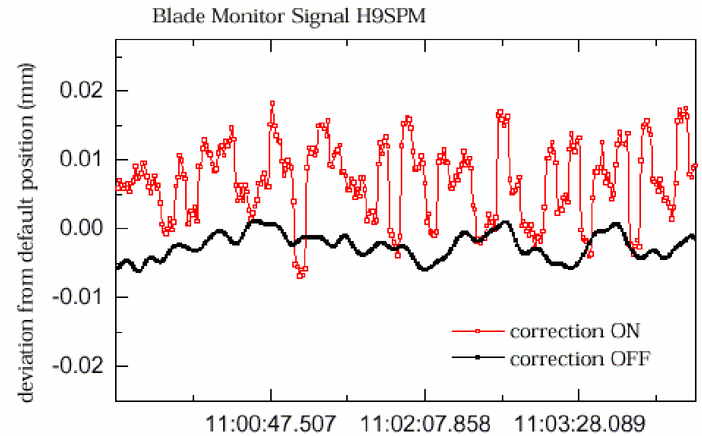
- Cure of insufficient I/O Resolution
- Path Length, Constant Beam Energy
- Second Order Phenomena
- Selection of Corrector Scheme, Target Orbit
- Role of XBPMs

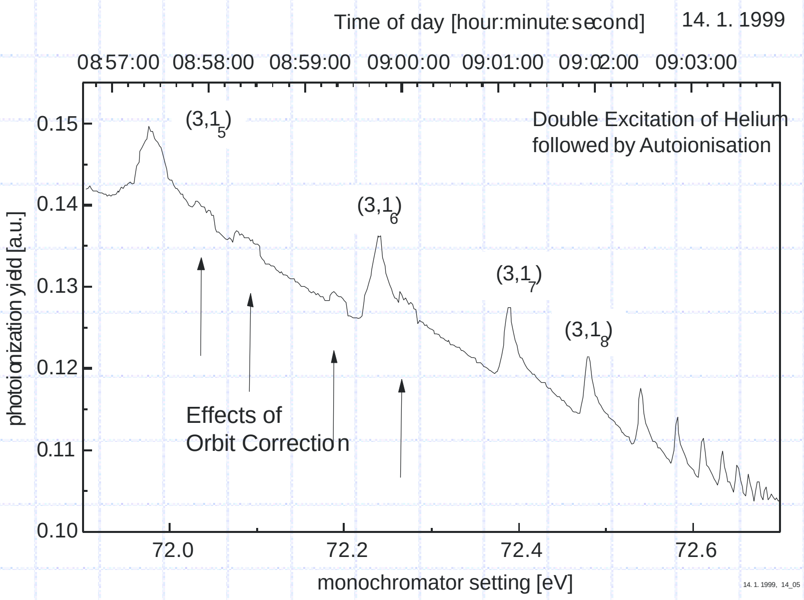
# Insufficient I/O Resolution

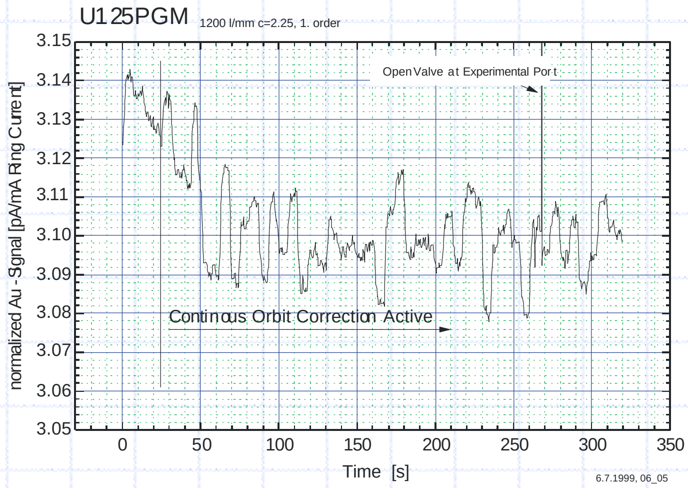
16 bit, 3 mrad correctors:

Single bit flips perturbed experiments.

Worse than intrinsic stability

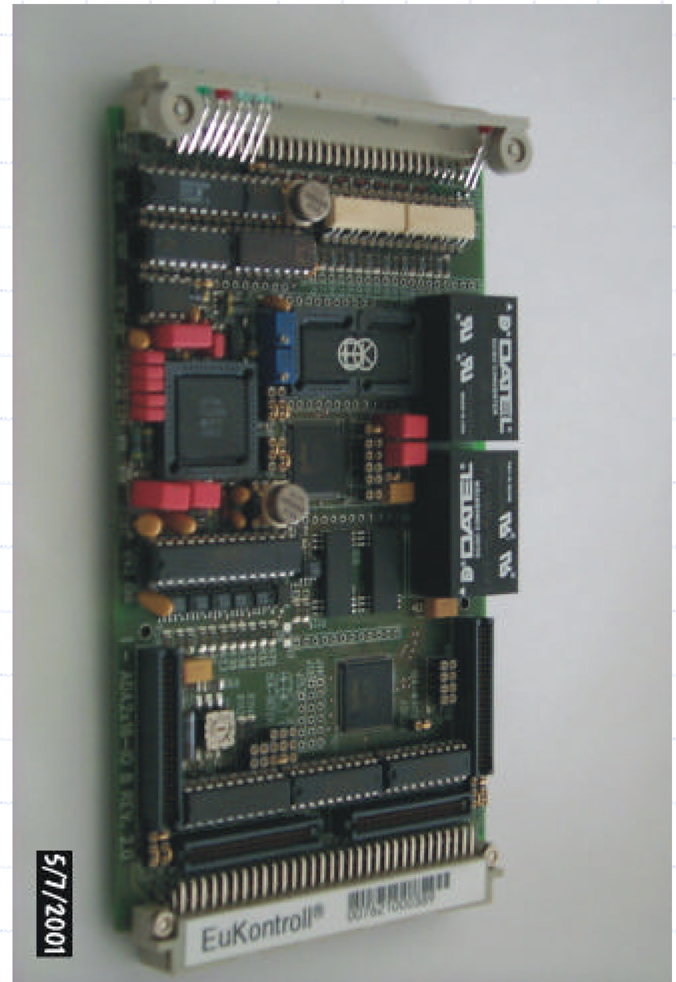


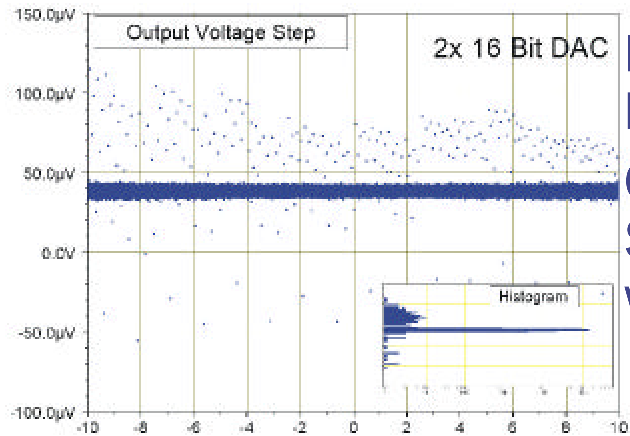



# Upgrade to Coarse/Fine Board

- Possible solutions:
  - Reduced dynamic range of correctors
  - Less corr. (SVD -> MICADO when stability reached)
  - Analyze ideal SVD result w.r.t. available set points
- Upgraded to 24 bit (PS noise ~ 19 bit)

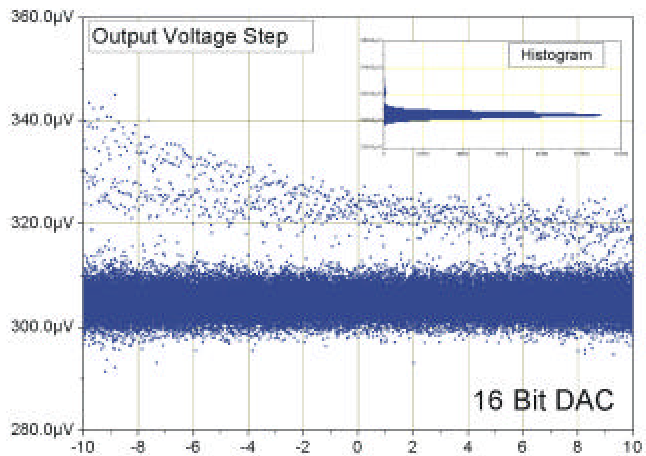


# Comparison: I/O, Beam Response




Laboratory Results:

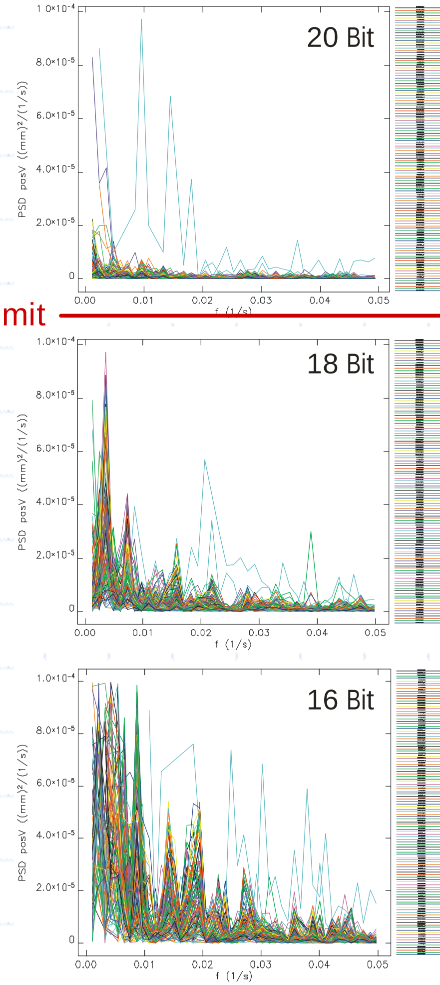
Coarse/Fine Scheme works.




PS stability limit

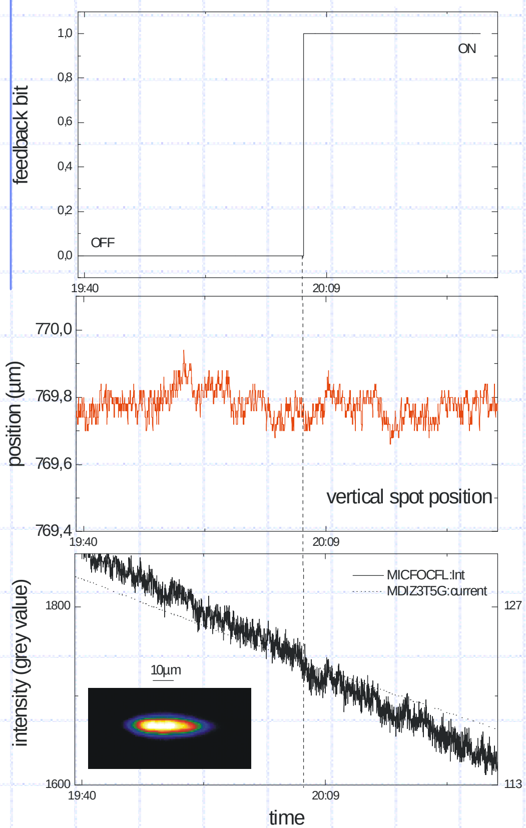
Software reduction of resolution

Beam stability improves beyond PS noise level (!)

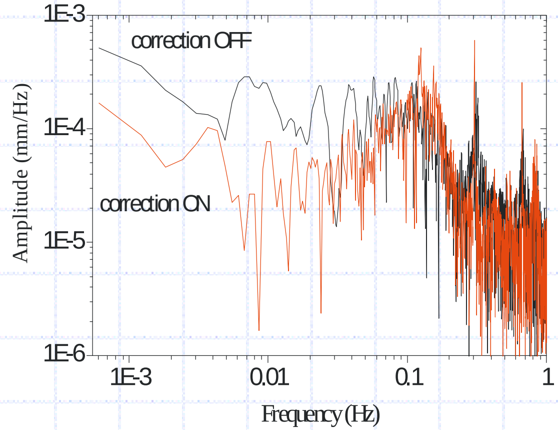


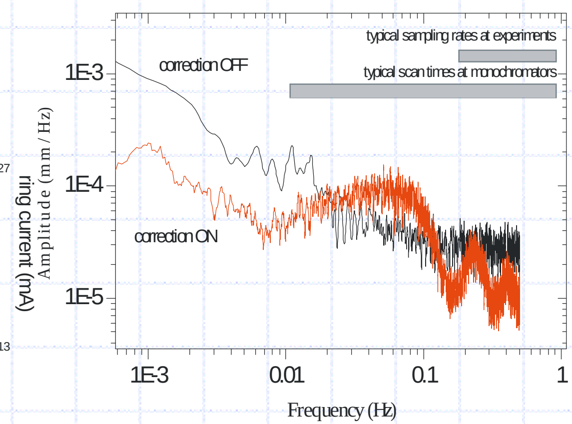
# Drastically Improved Experiment Conditions

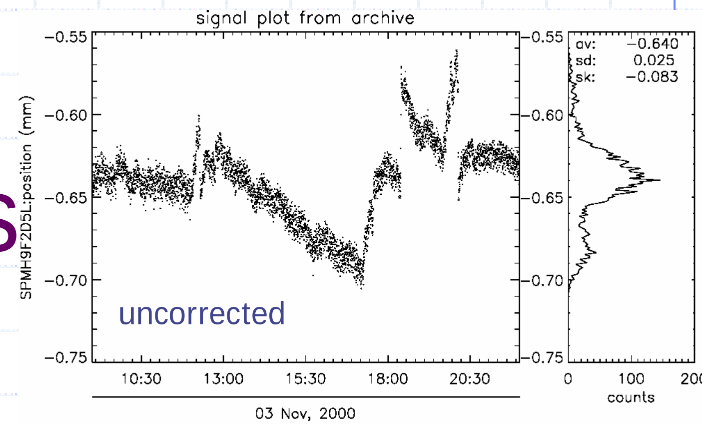
Microfocus:
unperturbed,
stabilized

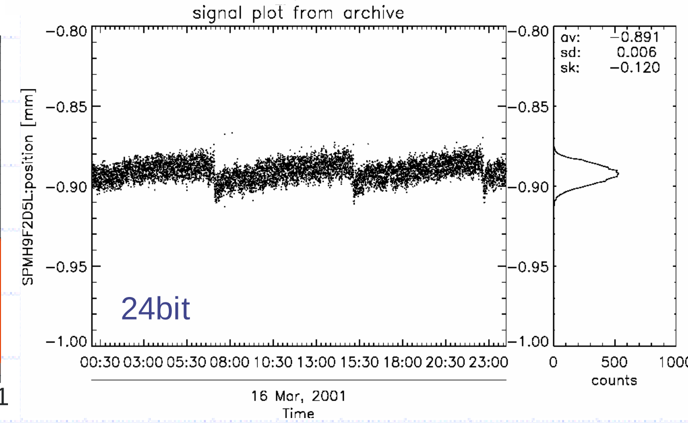


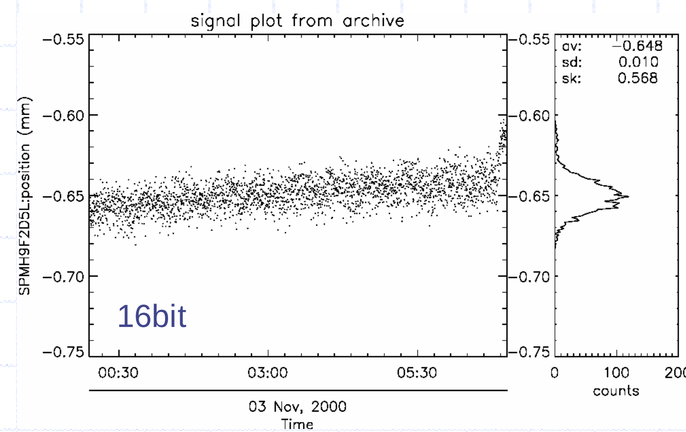

Induced noise at
0.06Hz: disappeared



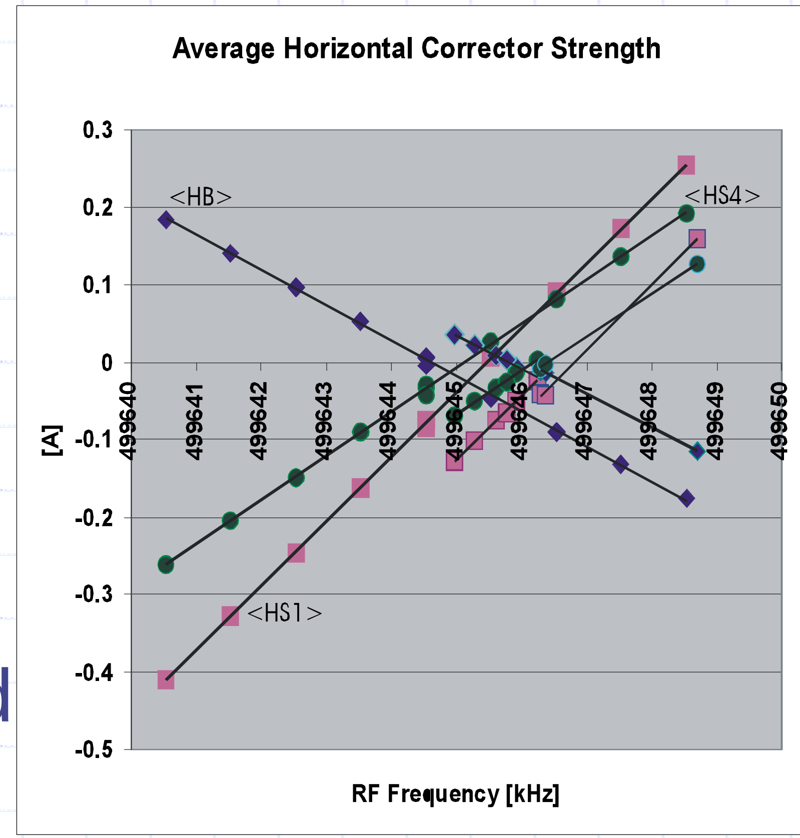



# Horizontal Orbit/Path Length

- RF change modifies energy -> undulator spectrum is shifted
- Thermal drifts change circumference -> Path length has to be adjusted with RF
- Different strategies for RF as n+1 corr:
  - iterative: dispersion (RF), SVD with n dipoles
  - extended: SVD with n+1 corr
    - boundary condition <Hcorr> =0 (in SVD terms) to preserve energy

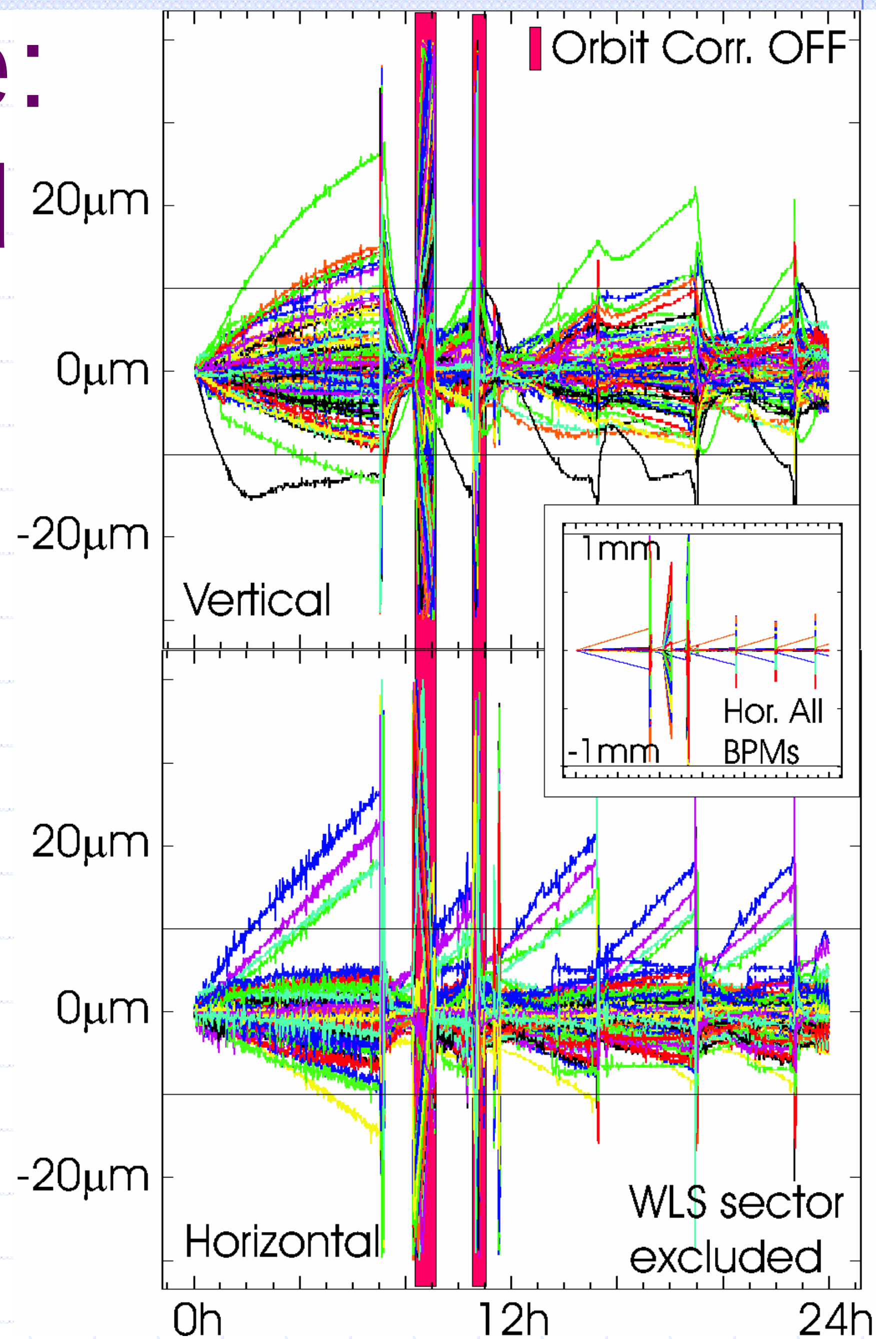
# Observations/Work-around

- Frequency drift/ corr. strength built up (weeks).
- Certain combined changes of RF / hor. correctors keep BPM pattern constant (short-cut path) but modify energy.
- Solution: all HB=0 and <HS1> small (!)



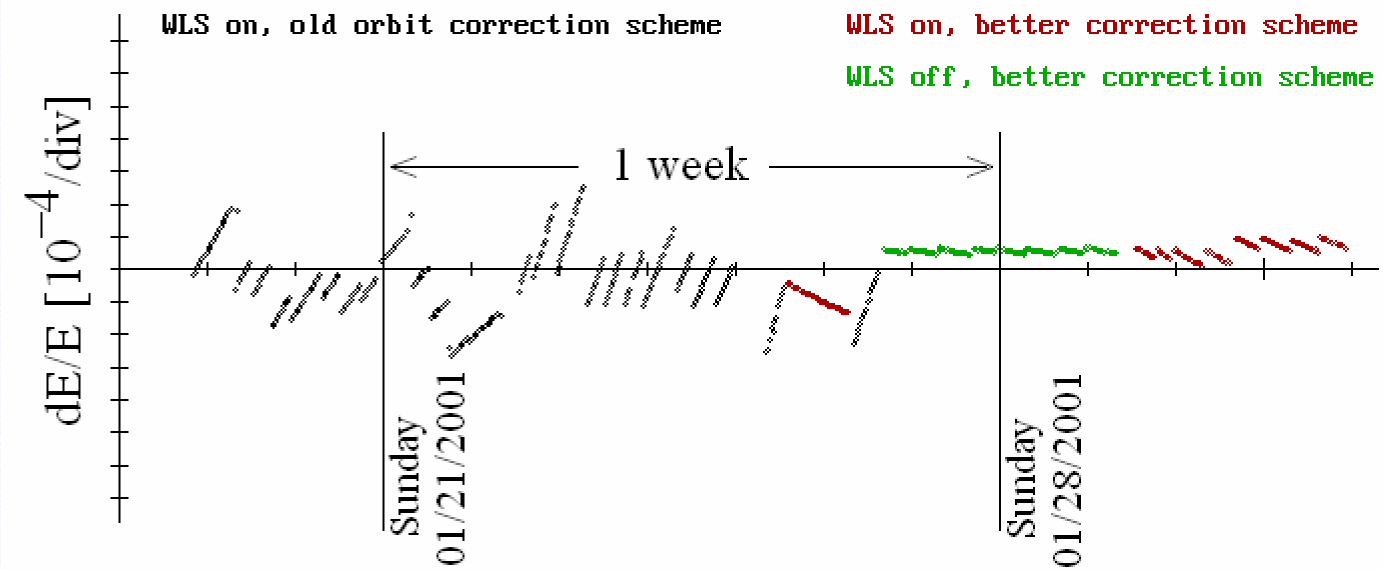
# Localized Source: Lessons Learned

- Super-conducting wavelength shifter
  - Initially persistent current mode
  - no internal correction
- SVD correction
  - Field decay builds up proper compensating hor. local 4 bump
  - mainly adjacent HS4



# Second Order Effects + Cure

- Growing values of neighboring HS4 correctors.
- Boundary condition <HSx>=0 distributes large <HS4PxT1R> values to finite <HS1>: energy shift.
- Solution: HS4 of sector T1 excluded from `low mean value' condition, $\Delta E/E < 10^{-4}$ restored for ON and OFF.



# Consequences / Questions:

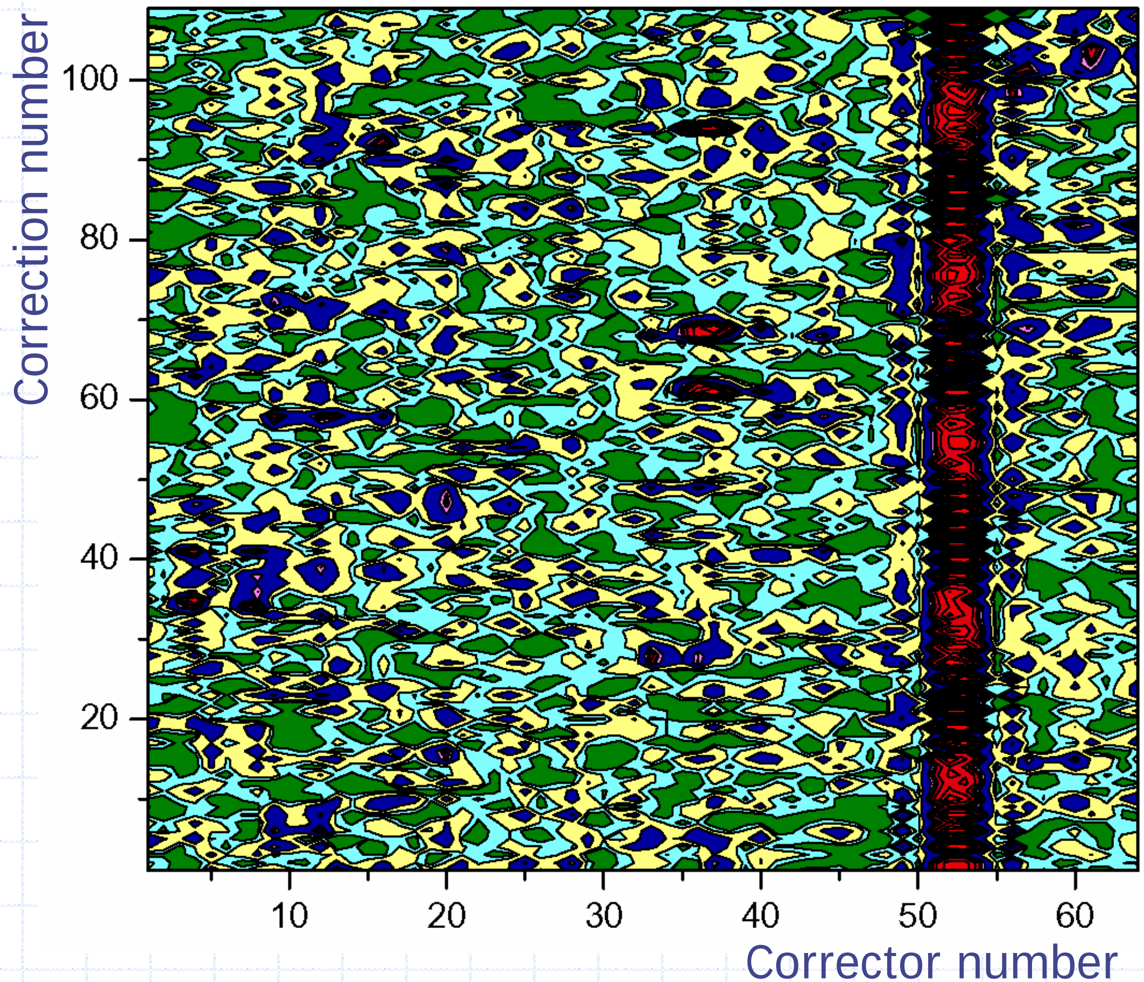
- No Choice of hor. SVD Cut Off Factor
  - Soft SVD (50% eigenvectors) distribute residual perturbation around the ring within a few days.
  - Cure: full inversion (all eigenvectors)
- How to Evaluate/Compare:
  - empirical `multi-patched' global system
  - Scaling with number of exceptions?
  - Hard to test/analyze: user shifts are the only realistic, long-term experiments.
- Problem of all local `DC' drift sources

# Contrast: Local Perturbation

Difference frequency of vertically acting LHe recondensor is seen by orbit correction.

Despite soft SVD (50% EV): perturbation stays local.

Small, AC?



# Number/Partitioning of Correctors

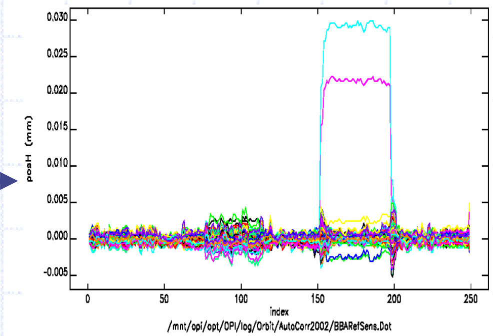
- Pro small number:
  - noise induced by corr. increases as sqrt(n).
  - correctors mostly at identical phase positions.
- Pro large number:
  - local perturbations not distributed around ring.
- Partitioning:
  - ID-feed-forward table creation:
    - MD shift: change gap, correct via internal coil offset, transfer results to improved set-point table, repeat...
    - User mode: gap changes drive internal coils, orbit correction uses only ring dipoles, ID corrector offset = 0
    - Including ID coil offset values into the orbit correction would give a better RMS, but ... we don't do it.

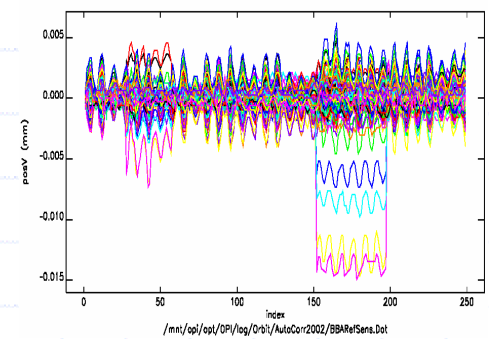
# Optimal Target Orbit

- Beam-Based Alignment reference orbit is the (unreachable) physical optimum.
- Golden orbit is the best achievable: New reference, RMS deviation ~0
  - Initially more noise: sign reversal of eigenvector phases randomly achieves better RMS, but slightly larger local variation.
  - Residual perturbations move to a finite RMS: when should a golden orbit be redefined?
  - Less sensitive against HW failure (no orbit jump due to new sum composition)

# Optimal Target Orbit

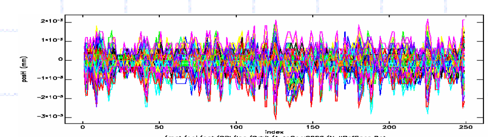
- Verification of malfunction sensitivity
  - Hor., Ver. Corrector, BPM excluded.
- How to start:
  - Full inversion after shutdown (100% eigenvectors)?
  - Improved reproducibility?
  - How fast does this orbit relax? We don't dare to test!

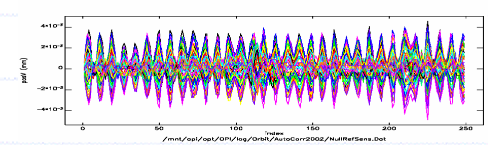



Reference:

BBA orbit



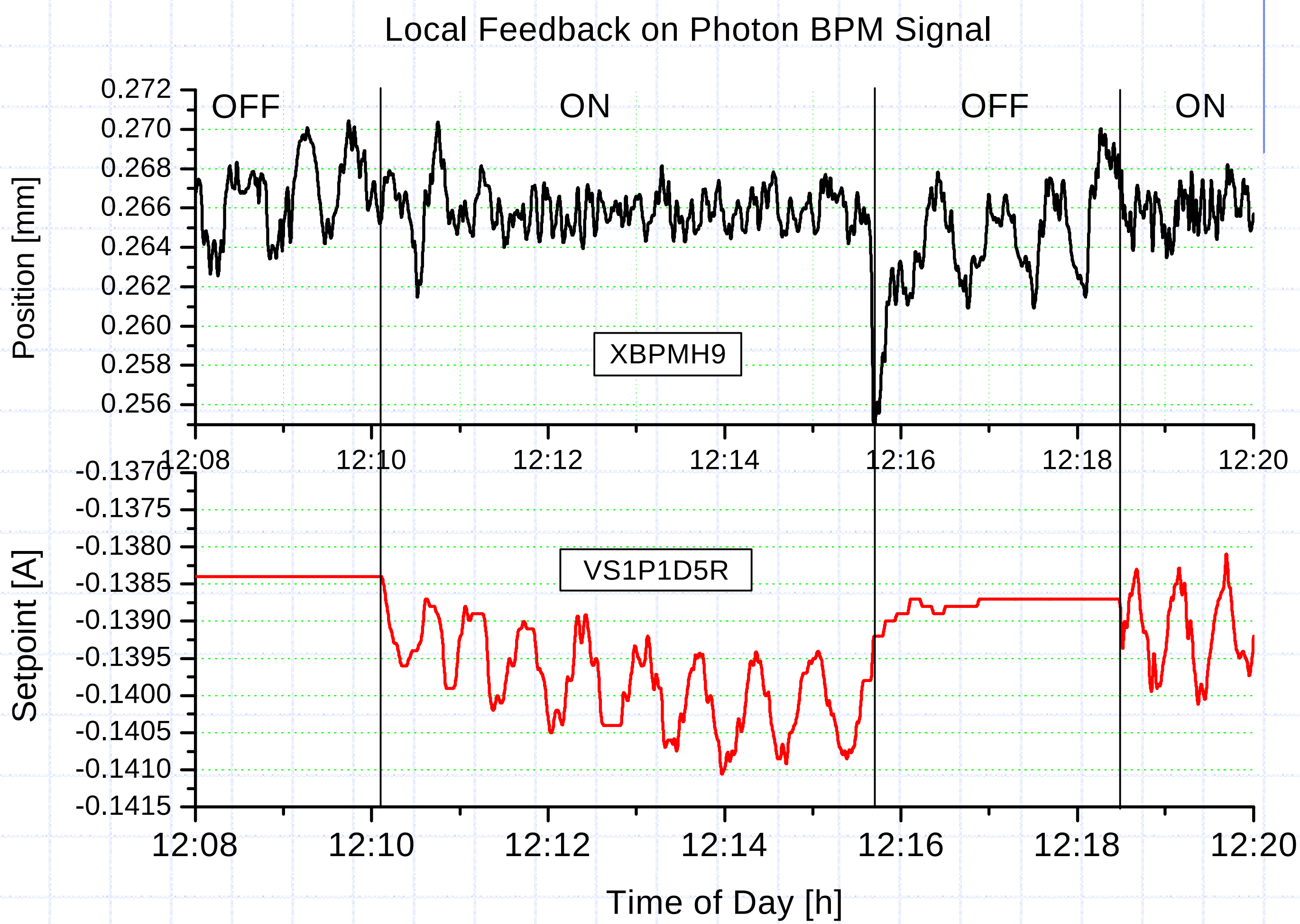


Reference:

Golden orbit

# XBPM Target: Pilot Experiment

- Corrector resolution now 24 bit
- 1µm BPM new limit
- XBPM signals allow to take advantage of steerer resolution



# Future: XBPM-aware methods

- XBPM signal in principle more sensitive
- XBPM signals depend on RF-BPM pre-conditioning and ID parameters
- Possible scenario:
  - correct with RF-BPM to the resolution limit
  - switch to XBPM when ready, supervised by RF-BPM signals
  - On `degradation' RF-BPM based correction is resumed, XBPM consistency supervisor

# Conclusion

- Methods commonly used do not properly match all detailed needs.
- Tailored localized corrections required.
- Empirical procedures cured our recent problems.
- No metric to quantify improvement against trade off, alternative approaches.
- Long term behavior of ad hoc patchwork unclear/hard to predict
- Effects on experiment vary: beam lines, operation mode, detector...
- Option: weighted global system