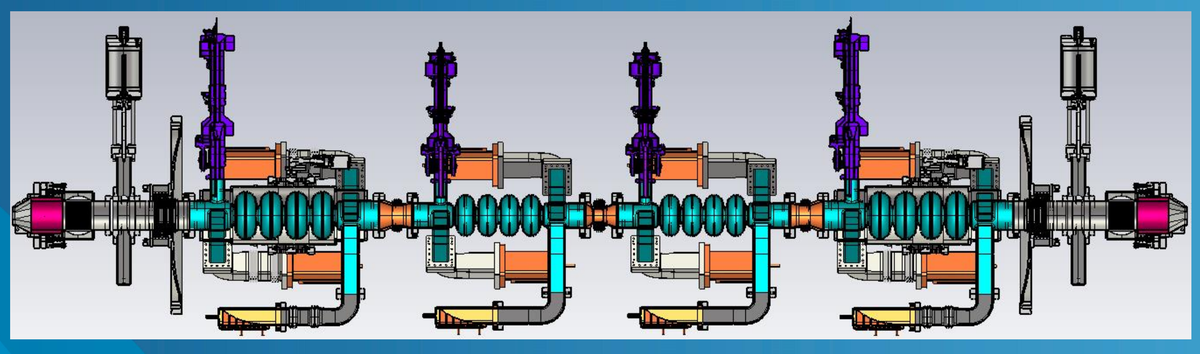


https://www.helmholtz-berlin.de/forschung/quellen/zukunft/vsr/index_en.html

BESSY VSR
Helmholtz-Zentrum Berlin

LLRF CONTROL OPERATIONAL ASPECTS OF THE BESSY-VSR UPGRADE

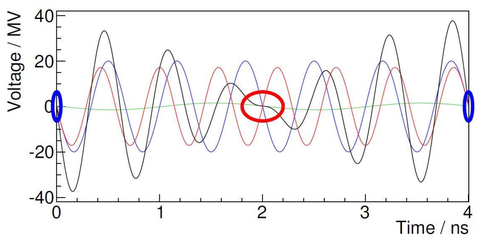
Pablo Echevarria, Axel Neumann and Andriy Ushakov

MOTIVATION

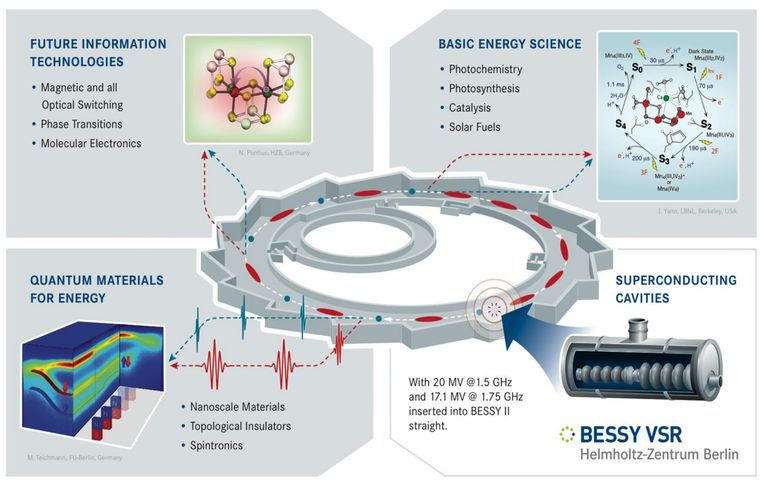
The synchrotron light source BESSY-II of the HZB will be upgraded with four superconducting cavities to allow short and long bunches in the ring at the same time without changing the optics.

The LLRF control operation of this new **user-oriented** variable pulse length storage ring (BESSY-VSR) will have to deal with:

- High Q_L (≈10^7) → Narrow bandwidth
- RF power overhead of about 12kW
- Zero crossing operation → Reactive beam loading



- Master oscillatior (MO) shifts: seasonal change of the ring size, beam dynamics studies and beam optimization, etc.
- Cold parking: in some situations SRF cavities have to be “transparent to the beam” → detuned.
- Quench detection: to shut down all cavities (NC included).
- Shorter injected bunches → New 500 MHz cavities in Booster



mTCA.4 Hardware Proposal

- **Local Oscillator:**
  - DRTM-LOG @1.5 and 1.75GHz will be developed by DESY
  - External LO for the 500MHz cavities
- **Timing board**: NAMC-psTimer
- **Down/up Conversion:**
  - DWC8VM-L2
  - DWC8VM-LF
- **Digitizer + FPGA:** SIS8300-KU
- **Tuner control:** DAMC-FMC2ZUP? +
- **Piezo control**: PZT4
- **Motor control:** MD22
- **External CPU?**

MASTER OSCILATOR DRIFTS

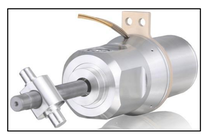
Table 1: Contributions to changes of the masterclock frequency (@500MHz)

Effect	Desviation (kHz)		Speed (Hz/s)	Beam current (mA)	Ocurrence
seasonal drifts	-5	+5	Very slow	300	During the year
thermal drifts	-1	+1	Slow	300	Day, Week
orbit bumps	-0.5	+0.5	10	300	2/day
SC WLS	-1.5	1.5	10	300	10/year
all other IDs	-0.1	0	5	300	Often
chromaticity measurement	-1.5	1.5	1000	10	100/year
momentum acceptance	-15	15	100	10	20/year

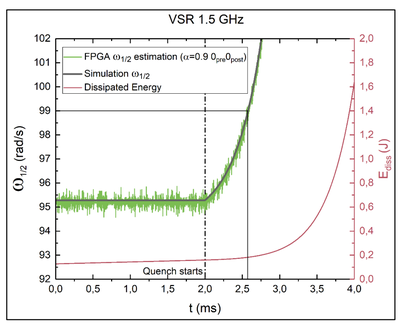
The MO frequency has to be modified to compensate the ring‘s size variation, insertion devices and beam dynamics studies.

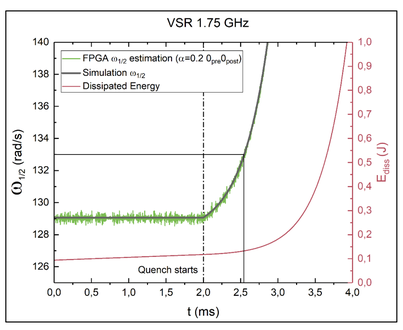
- Is the hardware bandwidth enough?
- SRF cavities will be operated at high QL → **narrow band**.
- **RF overhead** will be around 12 kW → Af=50Hz
- **Piezo range** won‘t cover some effects.
- Motor will have to be used extensively: motor exchange every year?
- Motor life time test to come at HoBiCaT: Phytron + Planetary Gear
- Moving motor at high gradients!

www.phytron.de



QUENCH DETECTION





ω1/2 estimation for a soft quench for BESSY-VSR@1.5 and 1.75 GHz with Q0=5·10⁹ and Eacc=20 MV/m.

When the SRF cavities quench, RF has to be shutdown!
Including NC cavities to avoid power transfer to SRF through the high beam current!

- Quench detection algorithm will be implemented in the mTCA.4 hardware
- A fast interlock has to be sent to NC LLRF hardware

See A. Bellandi talk

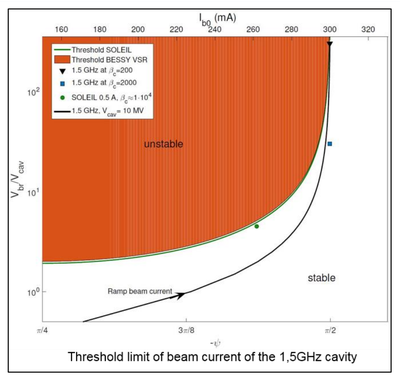
REACTIVE BEAM LOADING AND ROBINSON INESTABILITIES

$$P_f = \frac{V_{cav}^2}{\frac{R}{Q}Q_L}\frac{1}{4}\left\{1+\left(\frac{\Delta f}{f_{1/2}}+\frac{\frac{R}{Q}Q_L I_{b0}}{V_{cav}}\sin\varphi_{acc}\right)^2\right\}$$

$$\Delta f = -\frac{R}{Q}\frac{f_{rf} I_{b0}}{2V_{cav}}\sin\varphi_{acc}$$

At zero-crossing beam loading is mainly a **phase jump** of the cavity voltage.
Need to detune the cavities as beam current ramps in.

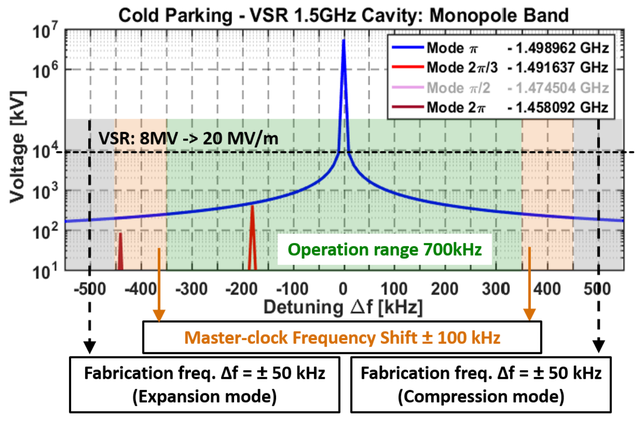
- Again! Motor will have to be used extensively → Motor life time!
- Again! Moving motor at high gradients!



Threshold limit of beam current of the 1,5GHz cavity

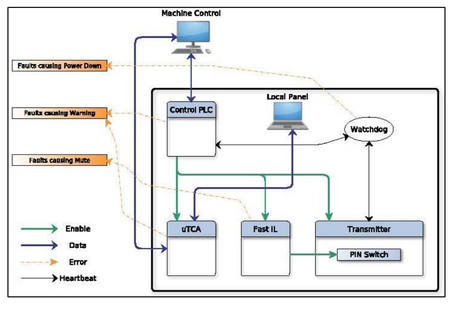
Stability regions for the 1.5GHz cavities during the current ramp-up of the storage ring

COLD PARKING



- At certain situations SRF has to be transparent to beam.
- SRF cavities need to be detuned to minimize beam loading.

NC UPGRADE TO DIGITAL



- New PETRA type cavities in booster
- New mTCA.4-based digital LLRF to be developed
- After commissioning all analogue LLRF will be replaced

KEY REFERENCES

[1] BESSY-VSR Technical Design Report.
[2] P. Schnizer *et al.*, “Status of the BESSY VSR Project”, in Proc. 9th Int. Particle Accelerator Conf. (IPAC'18), Vancouver, BC, Canada, Apr. 4,, pp. 4138-4141.
[3] P. Echevarria *et al.*, “Simulation of Quench Detection Algorithms for Helmholtz Zentrum Berlin SRF Cavities”, in Proc. 10th Int. Particle Accelerator Conf. (IPAC'19), Melbourne, Australia.

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