BESSY Status

Peter Kuske, Helmholtz-Zentrum Berlin, Germany

XXII European Synchrotron Light Source Workshop, 24th-25th November 2014, ESRF, Grenoble, France

Content of the Talk

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I. Statistics

II. Challenges (Disaster):

- 7T-Wiggler – Melting of Components
- RF-Power Line – Fire
- Linac-Gun Sparking
- Vacuum Failure – Fatigue Vacuum Components

III. Highlights:

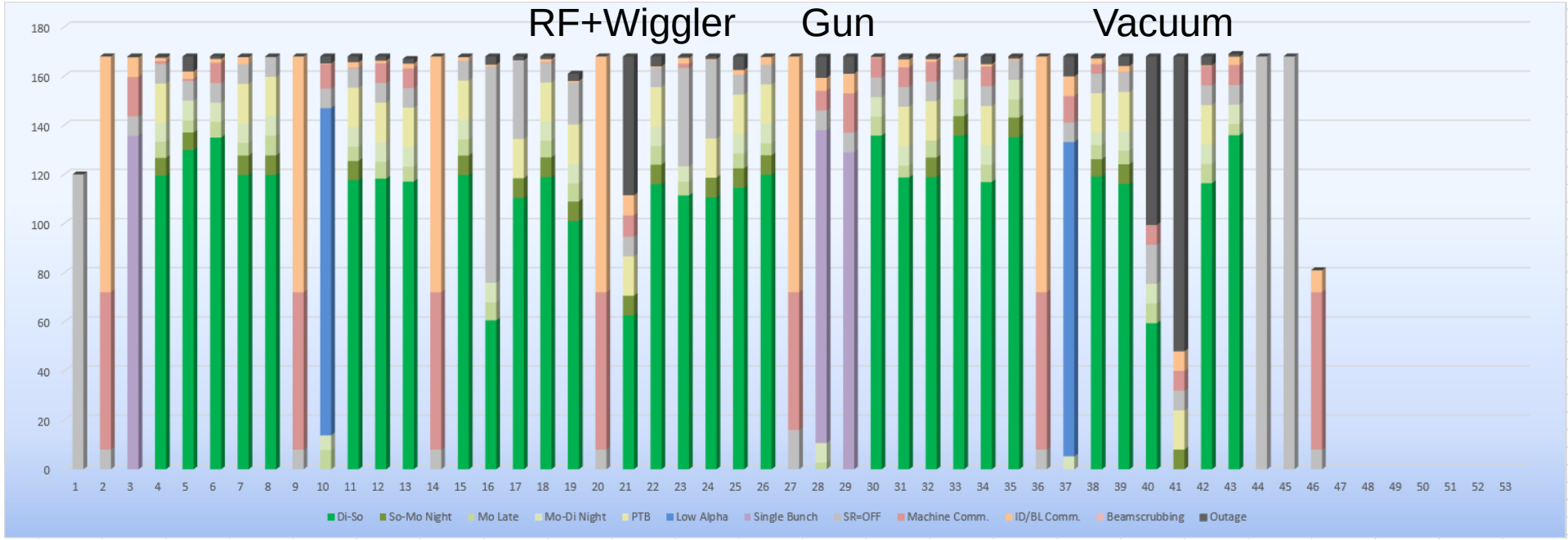
- Lifetime analysis
- Pulse Picking
- Energy Measurements
- Non-Linear Kicker

IV. Future:

- EMIL
- bERLinPro
- BESSY-VSR

V. Summary

I.1 Statistics



Year	Outage black	MTB interruption	MTTR	Availability
2012	178 h	9.8 h	0.3 h	96.3 %
2013	159 h	29.7 h	0.6 h	96.7 %
2014	324 h	30.0 h	0.8 h	93.7 %

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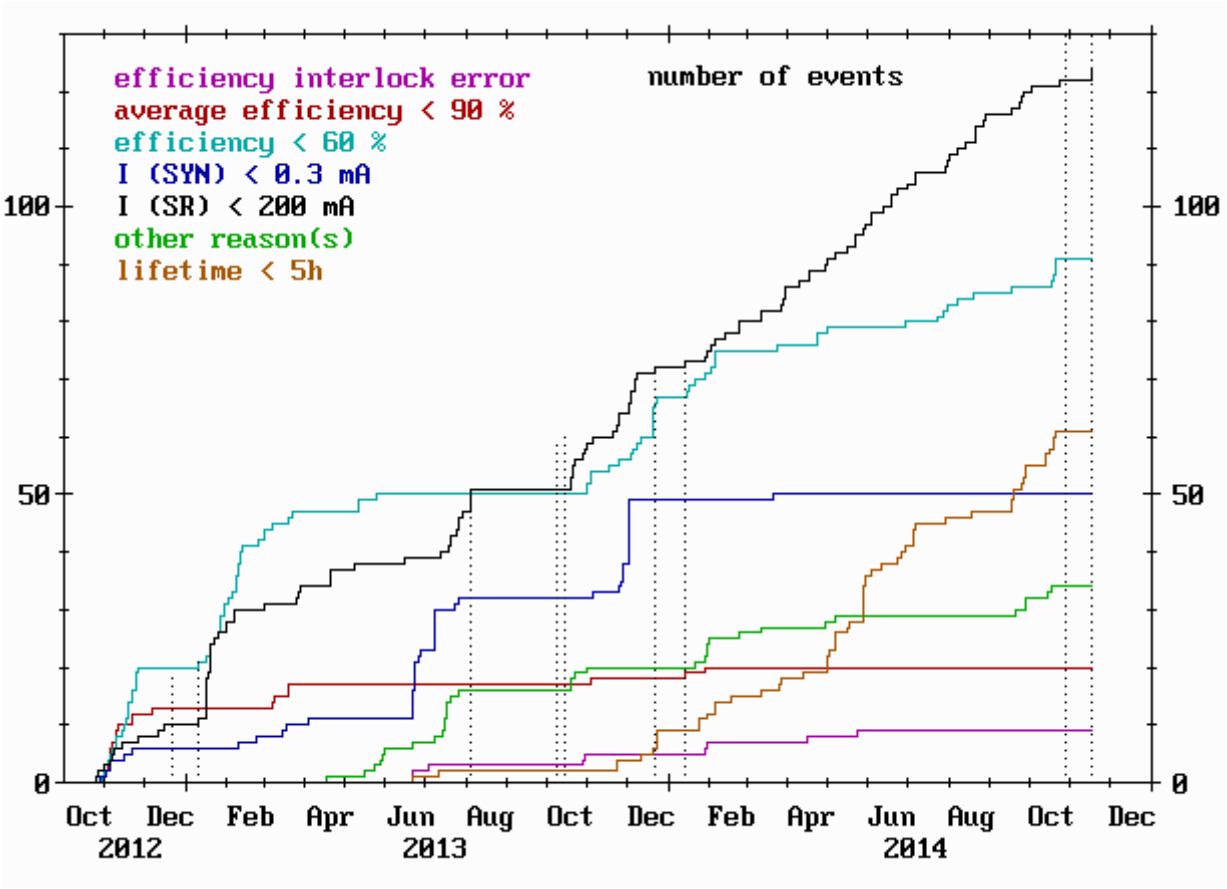
TOP-UP EVENTS:



Dominated by beam losses and lifetime violations

Lifetime interlock is new –

frequent interruptions because of poor vacuum and operational reasons

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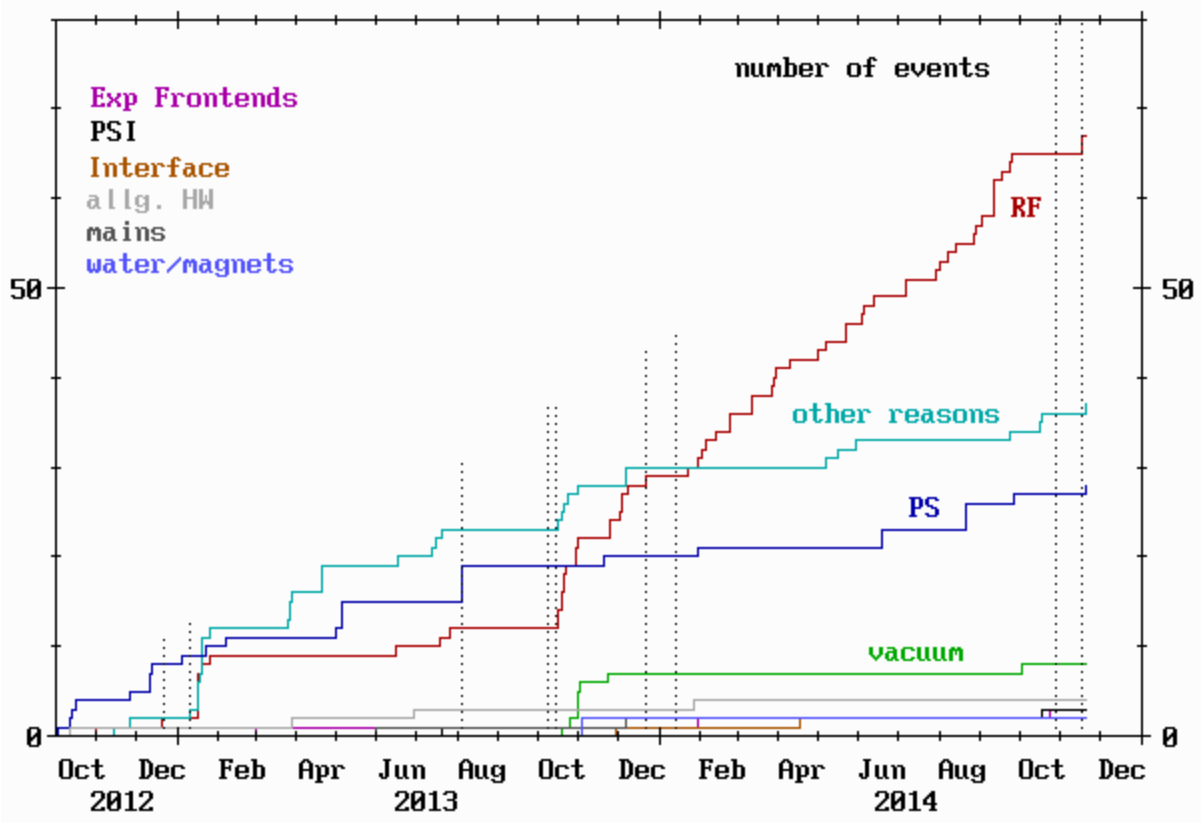
Beam Losses:



Single vacuum event can spoil the statistics (end of September)

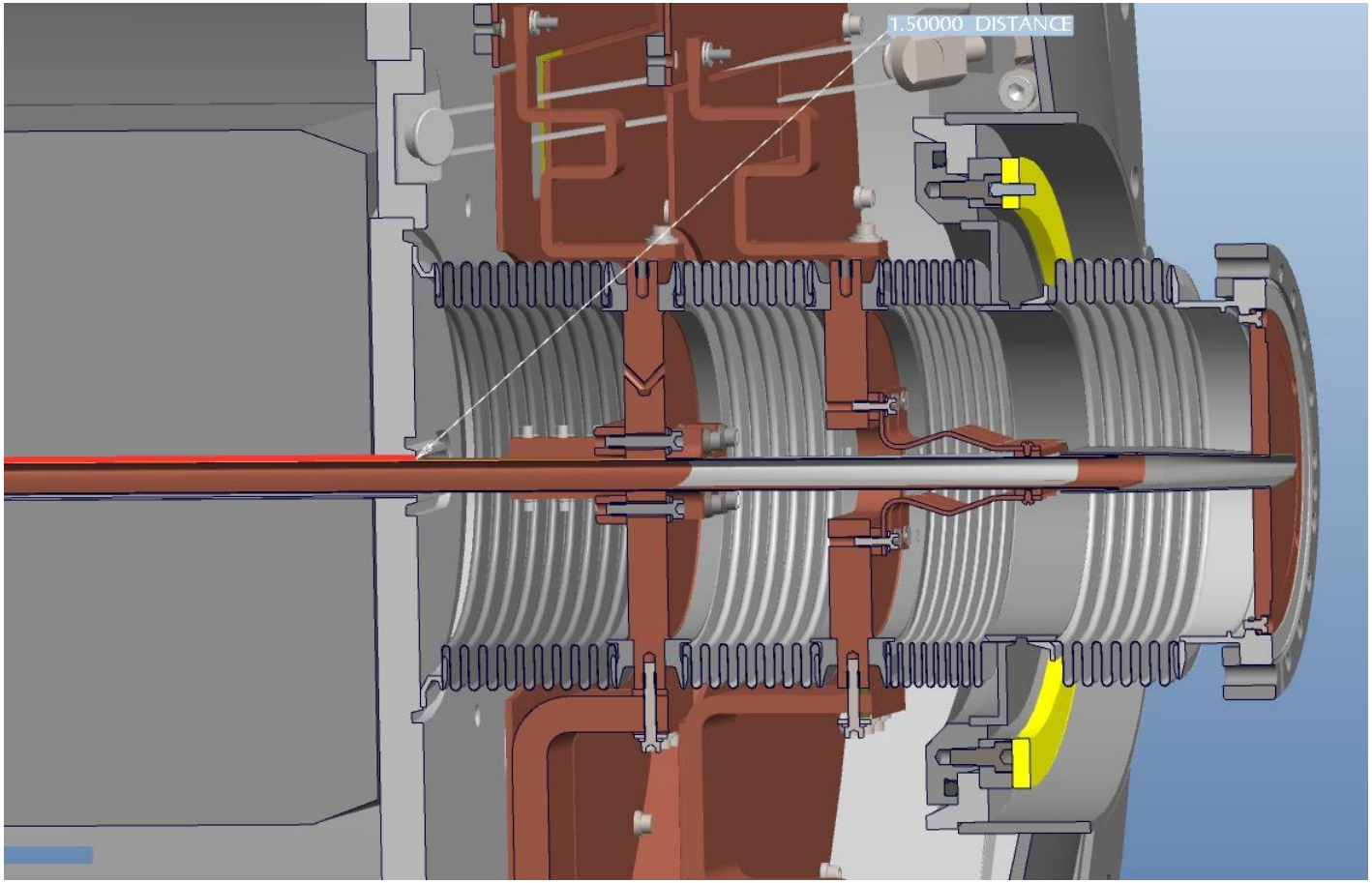
Had issues with PSs in 2012/2013, problems fixed. 2014: exchanged PSs too late.

RF failures mainly due to water flow/cooling problems in HOM-damped cavities.

II.1 7T-Wiggler

- Original wiggler showed too high LHe consumption.
- In top-up-mode, and with a few highly charged bunches the wiggler would not survive 7 days of continuous operation.
- It took ~16 months to successfully refurbish the wiggler (Budger institute) – weekly refill no longer required.
- After the installation of the wiggler (late summer 2013) transitions at the entrance and exit of the wiggler chamber became too hot – missing RF-springs, transition pieces damaged, device repaired, and reinstalled in 2014.
- Already during the commissioning we suffered from a too small vertical aperture after an electron beam steering event in the wiggler. At the time the beam position interlock was in place and active. Later, by probing the available aperture within the accepted current limits, the wiggler turned completely in-operational and had to be removed from the ring.

II.1 7T-Wiggler



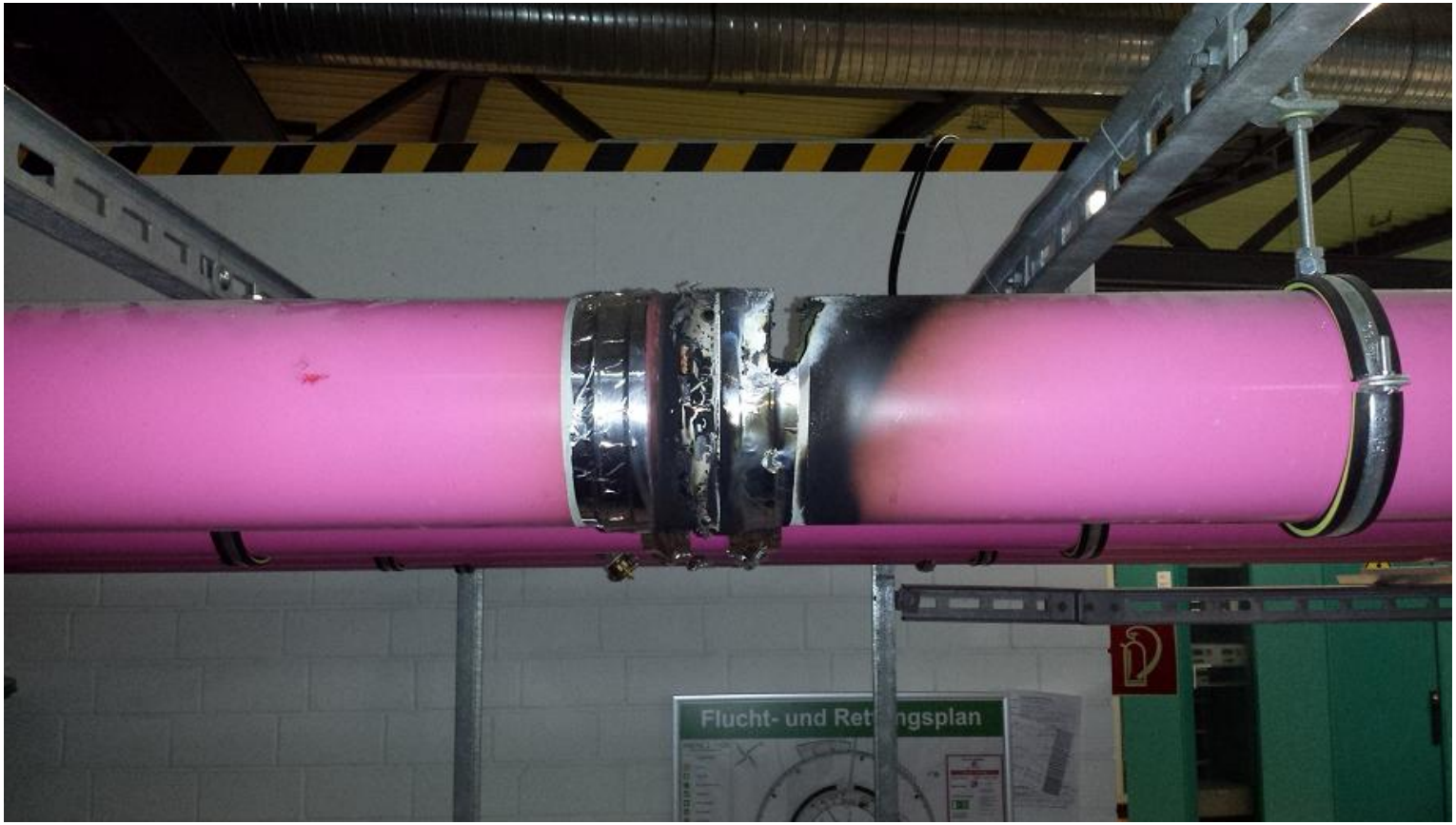
II.1 7T-Wiggler

- We have learned that the current limit (I>20mA) and the speed of our interlock was insufficient.
- Currently the wiggler is waiting for repair, the entrance and exit geometry will be vertically widened, and we will improve/sharpen the interlock.

II.2 RF-Power Line Failure

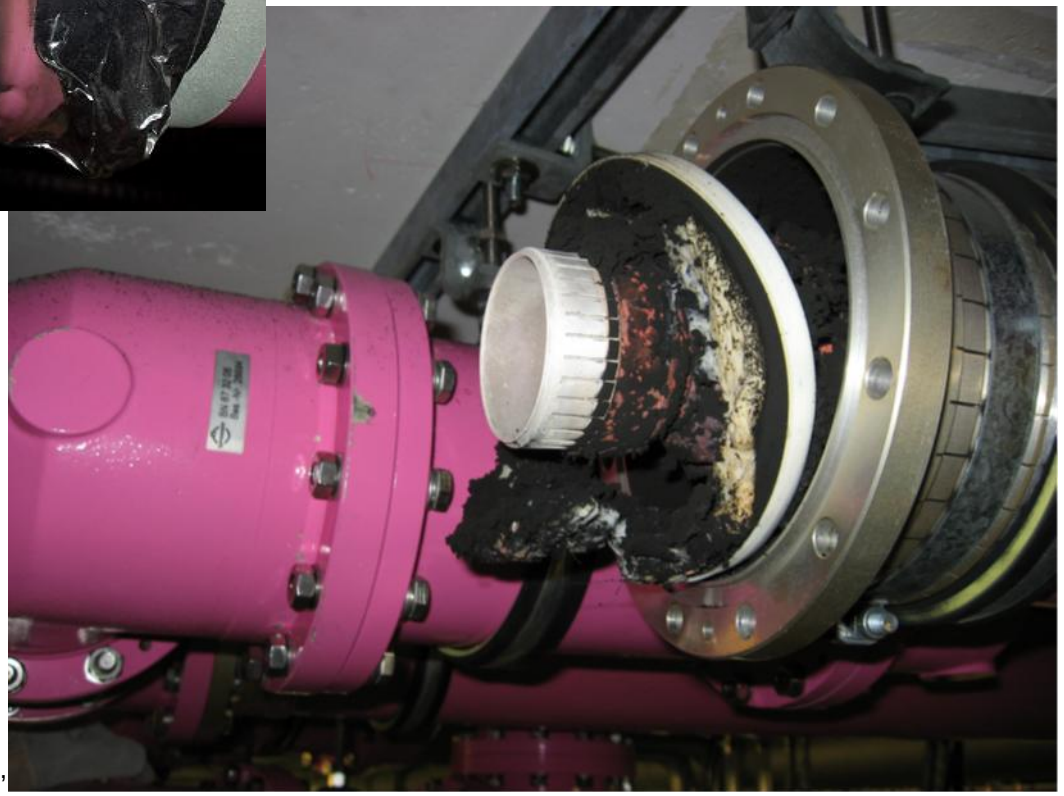
RF-modernization:

- Replace Doris-type 500MHz-cavities by HOM-damped cavities (2 out of 4)
- Replace Klystron by solid state amplifier (start with booster synchrotron RF?)
- After replacing circulator for cavity 1 and 5 days of operation: Fire alarm, and mains emergency switch-off …sudden power loss created a lot of problems



II.2 RF-Power Line Failure

Luckily, RF- and wiggler-failure occurred after a machine development week



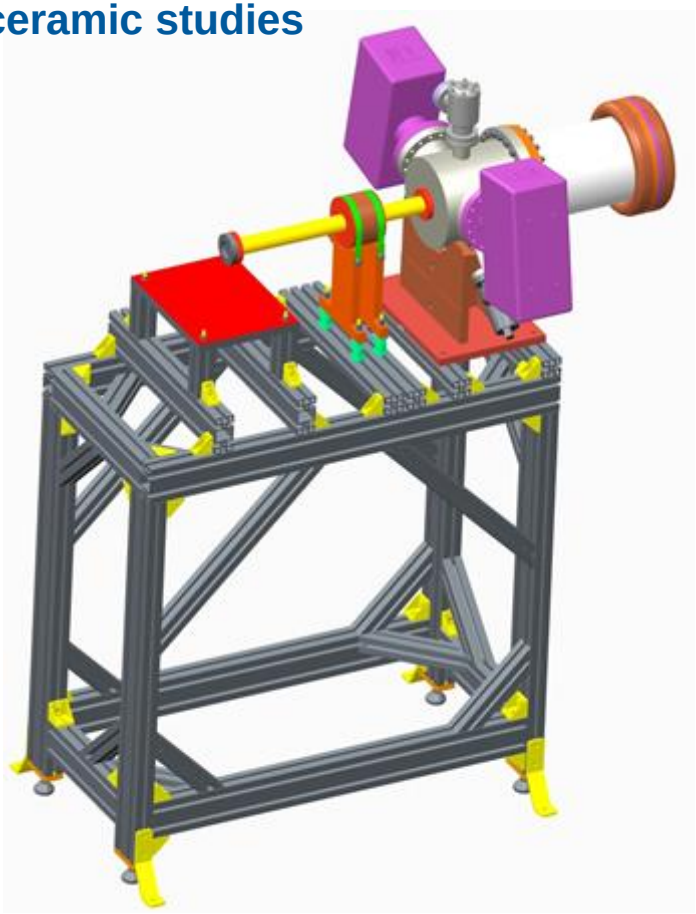
Repair of the power line and removal of the wiggler at the same time.

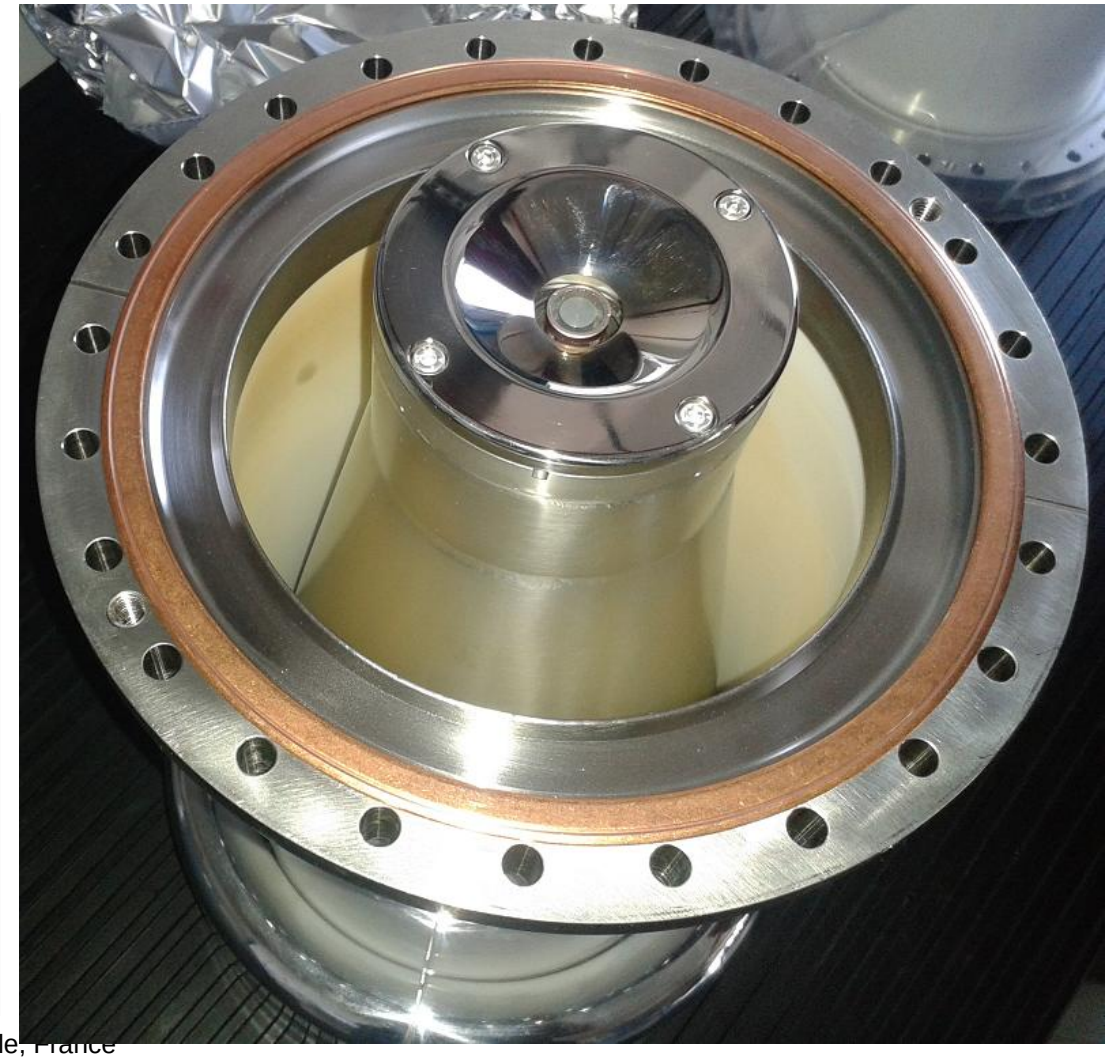
II.3 Linac-Gun Trouble

2 weeks single bunch operation without top-up because of HV-sparking in the Linac-gun
Cleaning of ceramics required – removing dirt from cathode conditioning or the pump?
Injections from the microtron every 4 h

We will build cathode test stand for:

- **cathode conditioning**
- **ceramic studies**





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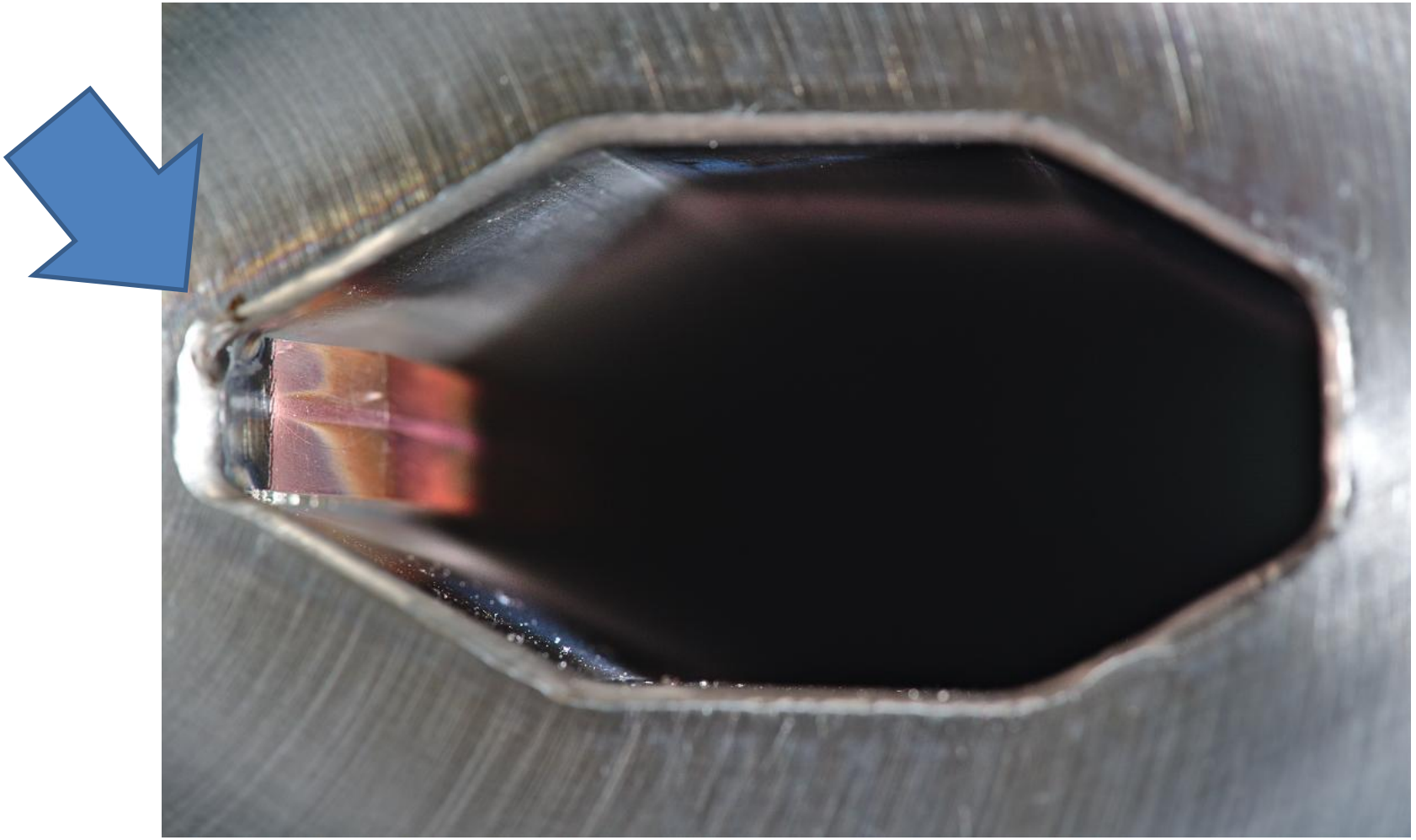
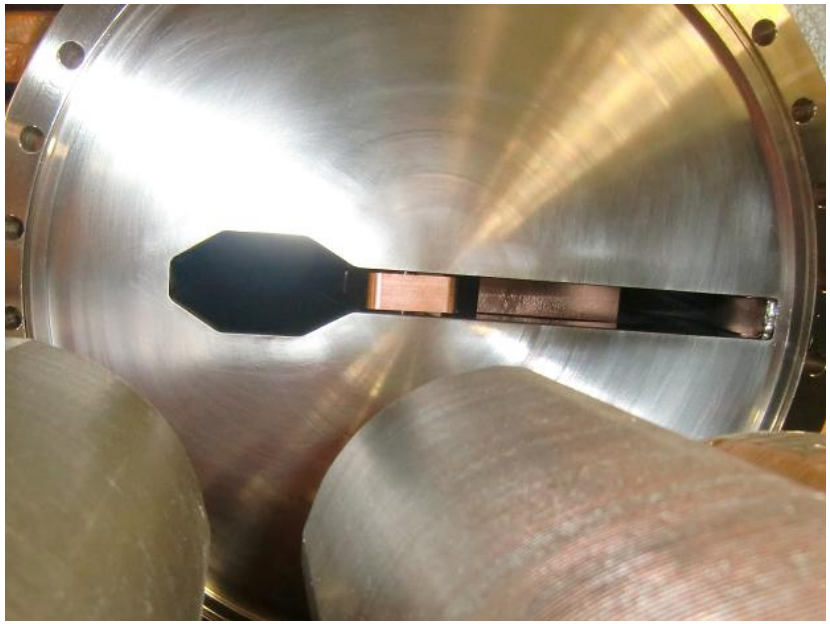
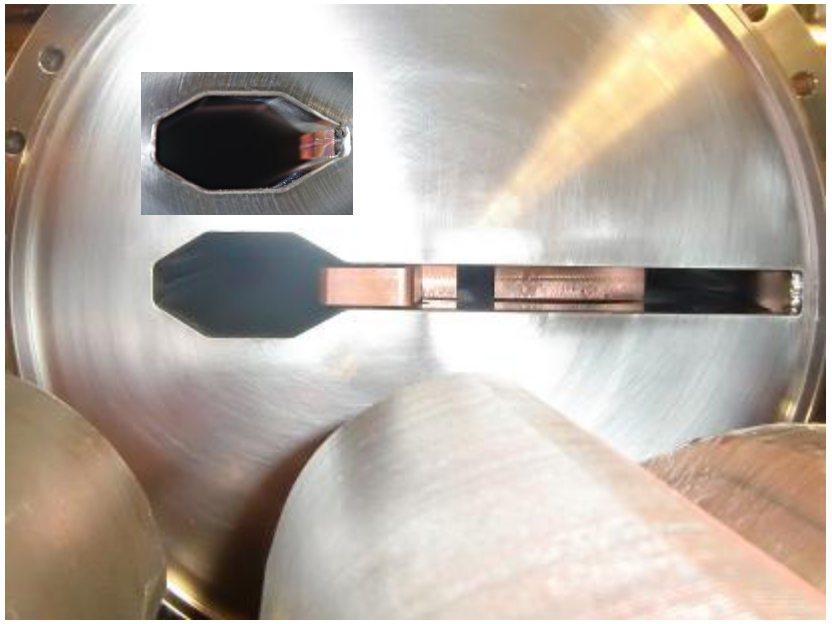
After nearly 2 years of operation in top-up-mode sudden vacuum problem after dumping beam – origin: vacuum leak at weld due to temperature shocks.



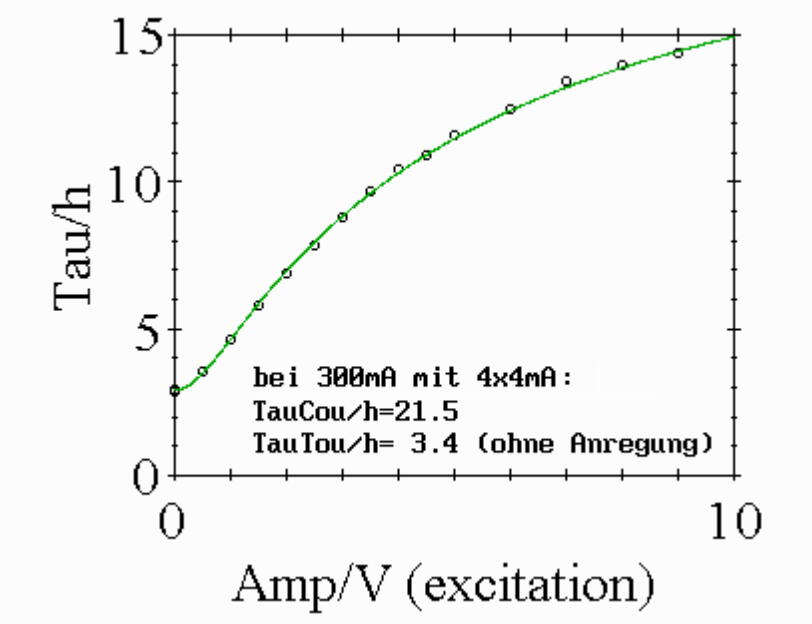
Solution:

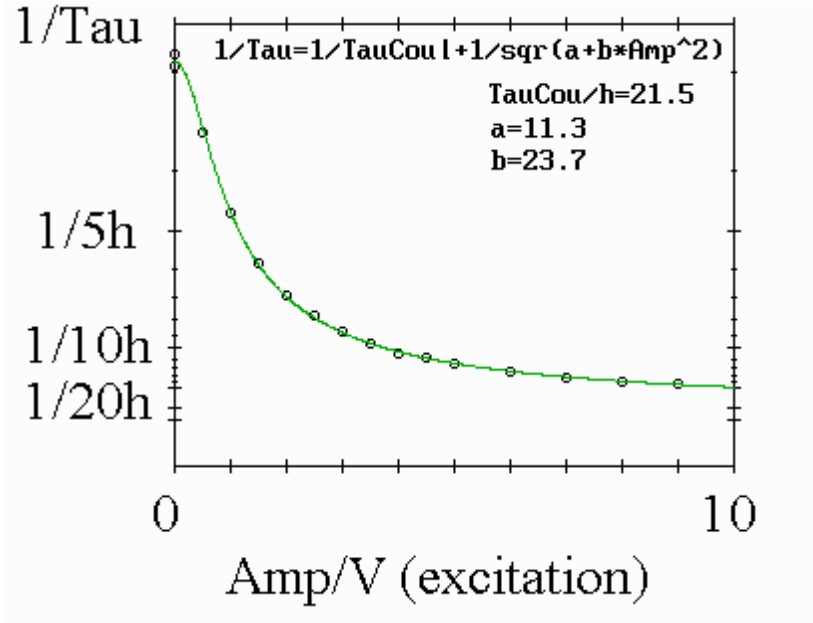
- dipole absorber moved closer to the electron beam and have less dipole radiation on critical vacuum components
- Installed PT100 at these locations which showed up to 70°C – will move and shift all absorbers





Reduced intrinsic coupling by optimizing skew quadrupole settings.
Lifetime adjusted by vertical noise excitation.
Optimization of the bunch-by-bunch transverse feedback made this excitation less efficient.
Analysis of the lifetime as a function of the noise excitation amplitude allows to distinguish between different contributions to the lifetime: 300 mA, Top-Up mode, 4x4mA



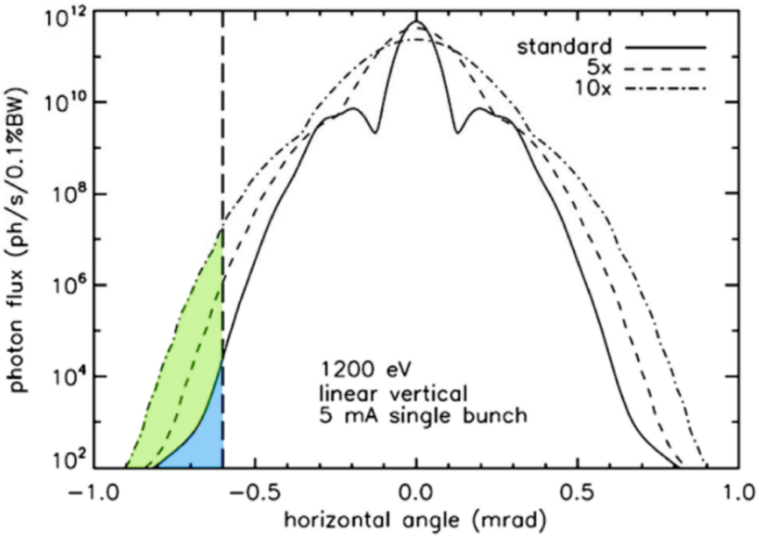


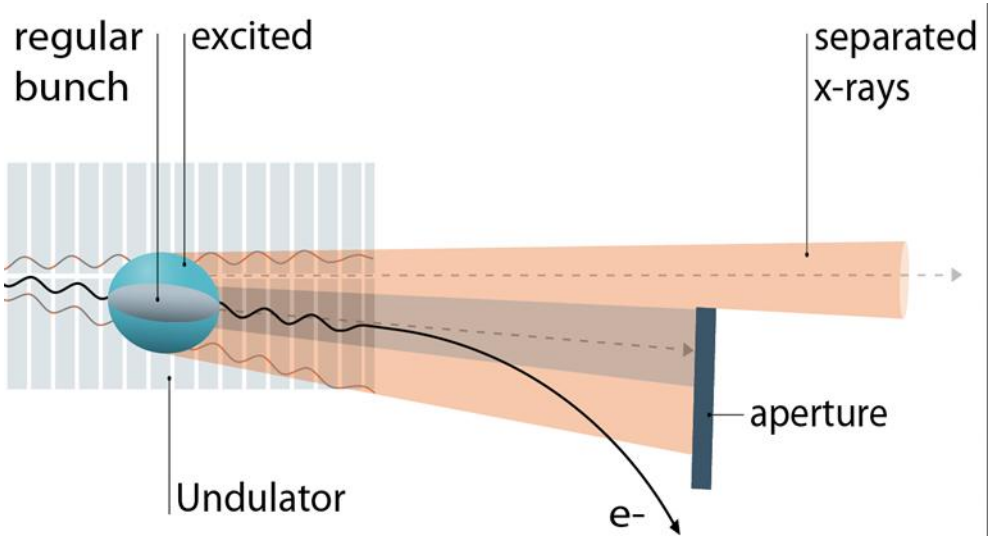
Assumption: $\sigma_y^{\,2} = \sigma_{y_0}^{\,2} + const \cdot Amp^2$

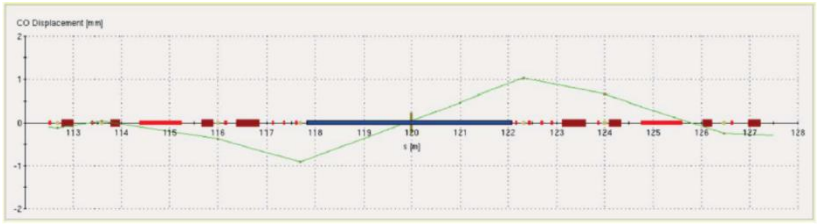
III.2 Pulse Picking

Motivation and idea:

Time resolved measurements like in single bunch mode
Like bunch separation in fs-slicing
increased emittance of one bunch – in combination with ARTOF







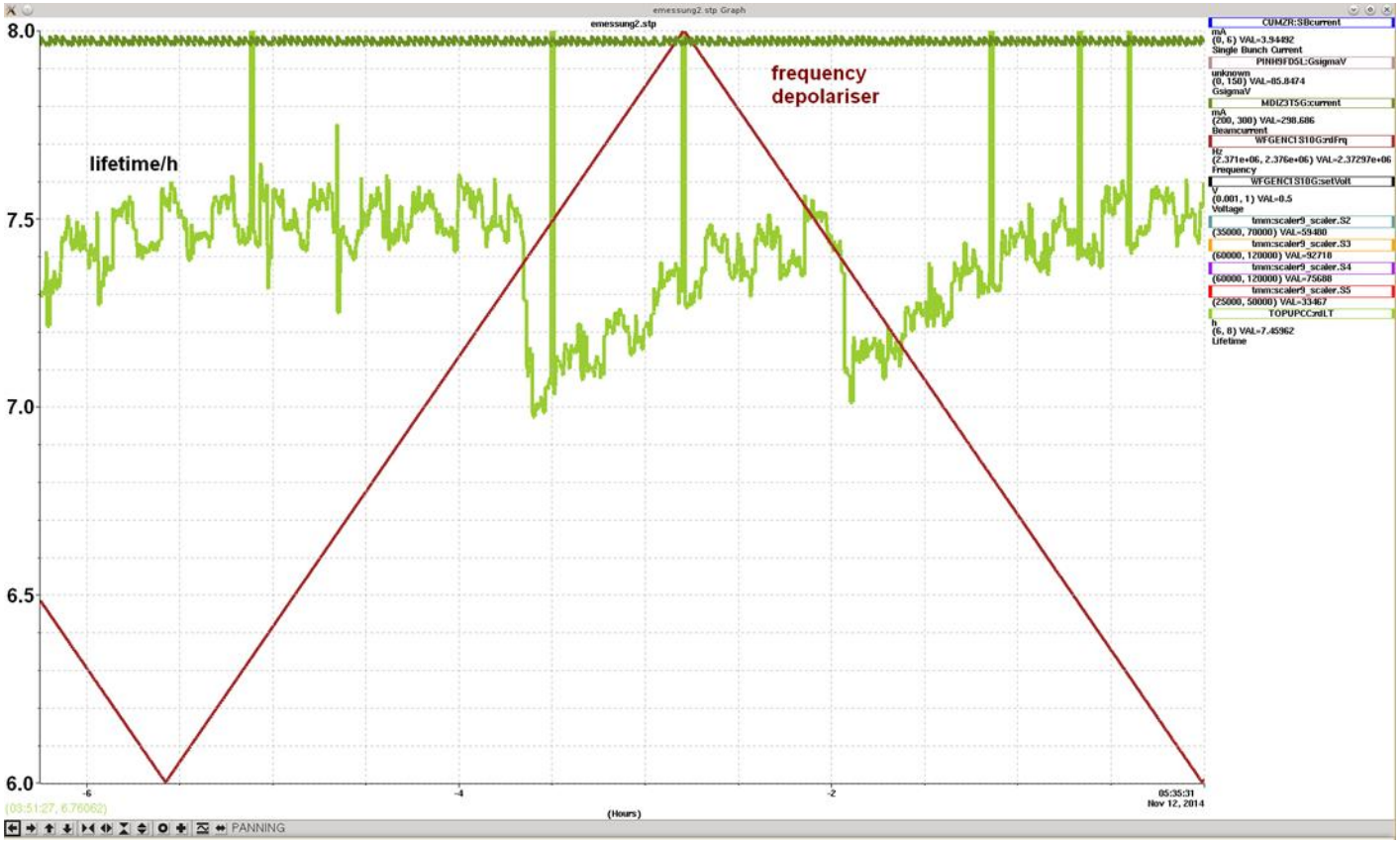
Bunch separation with a chopper wheel delivers full intensity.

Established on a couple of beam lines
Digital bunch-by-bunch feedback very helpful

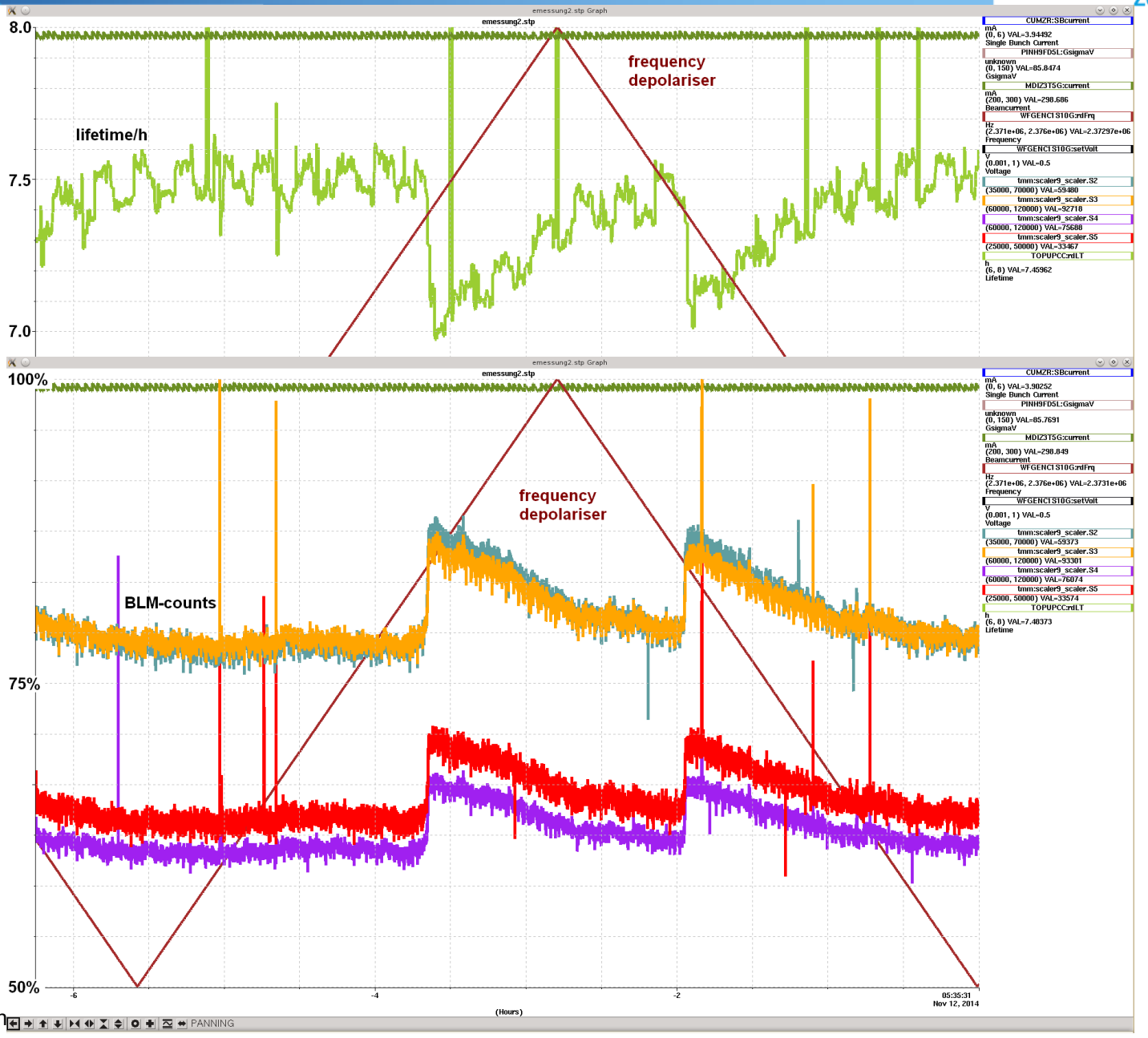
nature COMMUNICATIONS

Single bunch X-ray pulses on demand from a multi-bunch SR source
K. Holldack et al.
Nature Communications 5, 4010, doi: 10.1038/ncomms5010, 30.05.2014

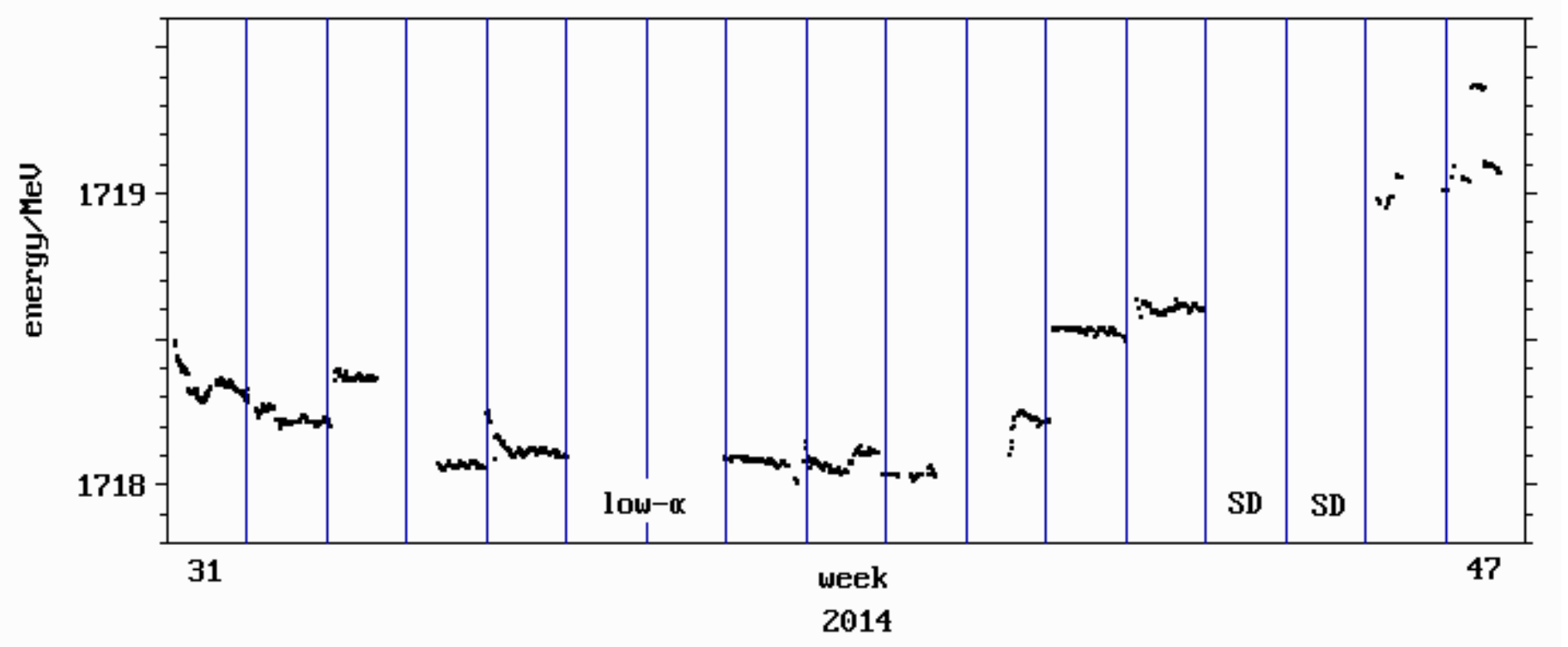
- Will there be polarization build-up? With 300 mA, injection every ~60s, permanent vertical excitation for vertical emittance increase
- Can we depolarize the beam with the stripline-kicker of the vertical transverse bunch-by-bunch feedback (in the future we will loose our dedicated long striplines)
- How stable is the energy of the beam – in view of the recently introduced fast-orbit-feedback and different handling of the RF-steering



III.3 Energy Measurements



Last 3.5 months:



Surprisingly large variations – horizontal orbit correction algorithm violates boundary conditions: orbit length and $\oint B_y ds \neq const$

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In-vacuum stripline-type design

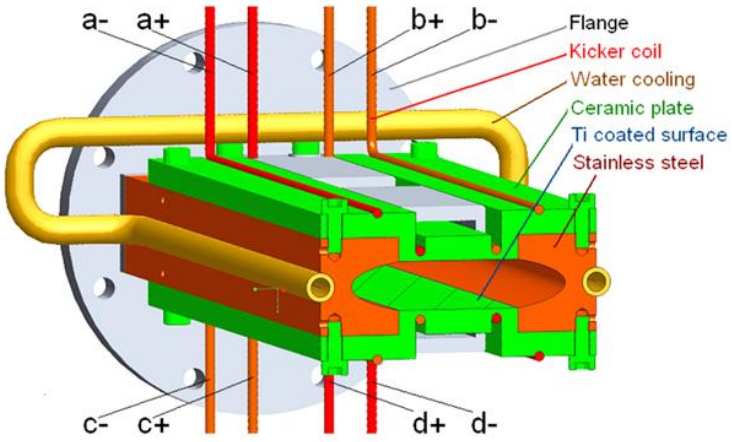
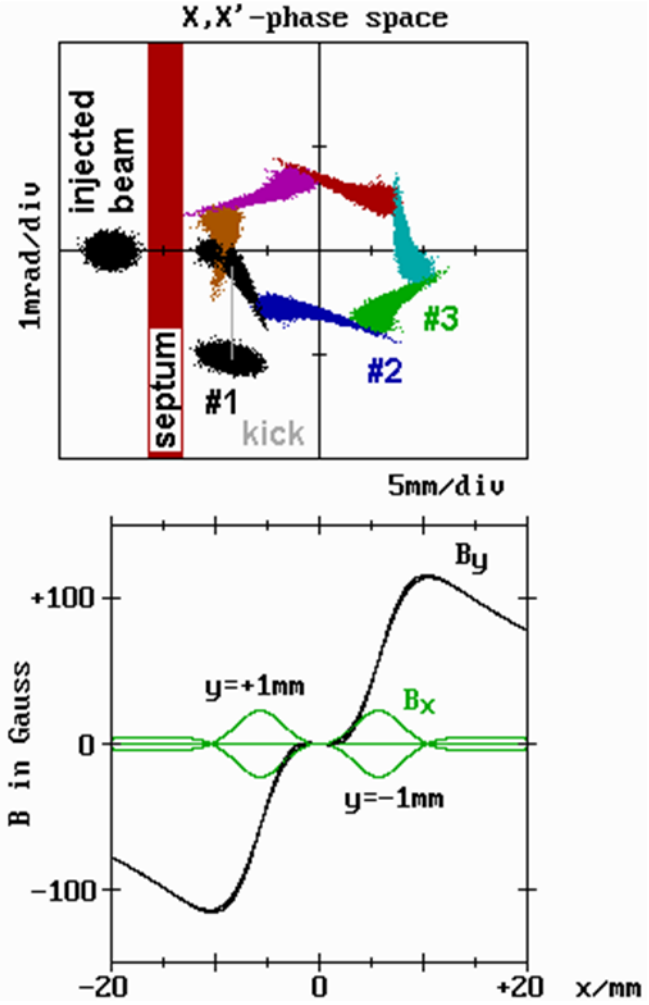


Figure 3: Sectional view of kicker magnet structure, second magnet design.



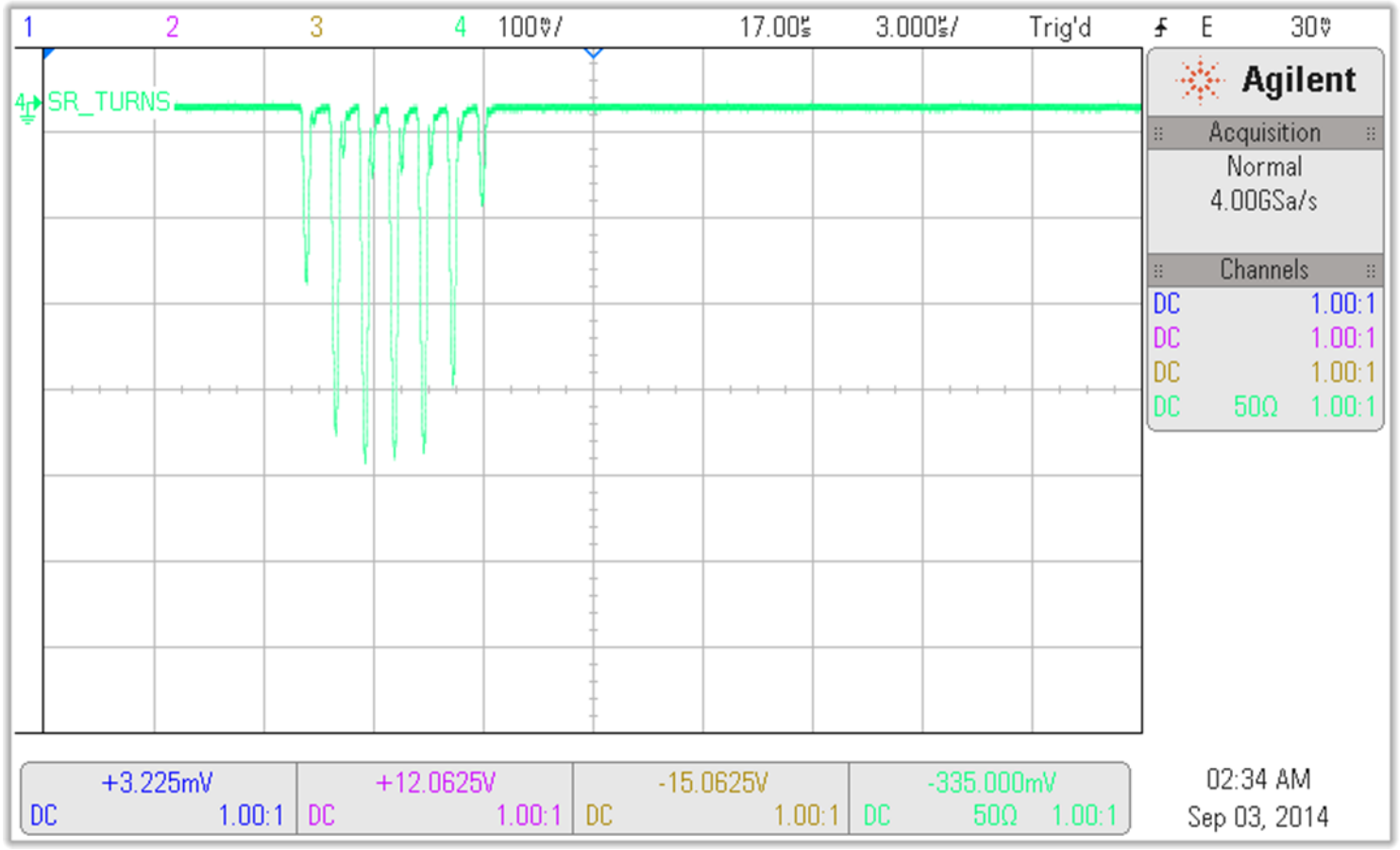
Orbit perturbations: < 1 µm vertically and ~3 µm horizontally

SOLEIL SYNCHROTRON

MAX IV

P. Kuske, et al, XX1 ESLS Workshop, Karlsruhe, 21-22, November 2013

Beam injected into the BESSY II ring without any injection kicker – 7 turns before beam gets lost at the injection septum:



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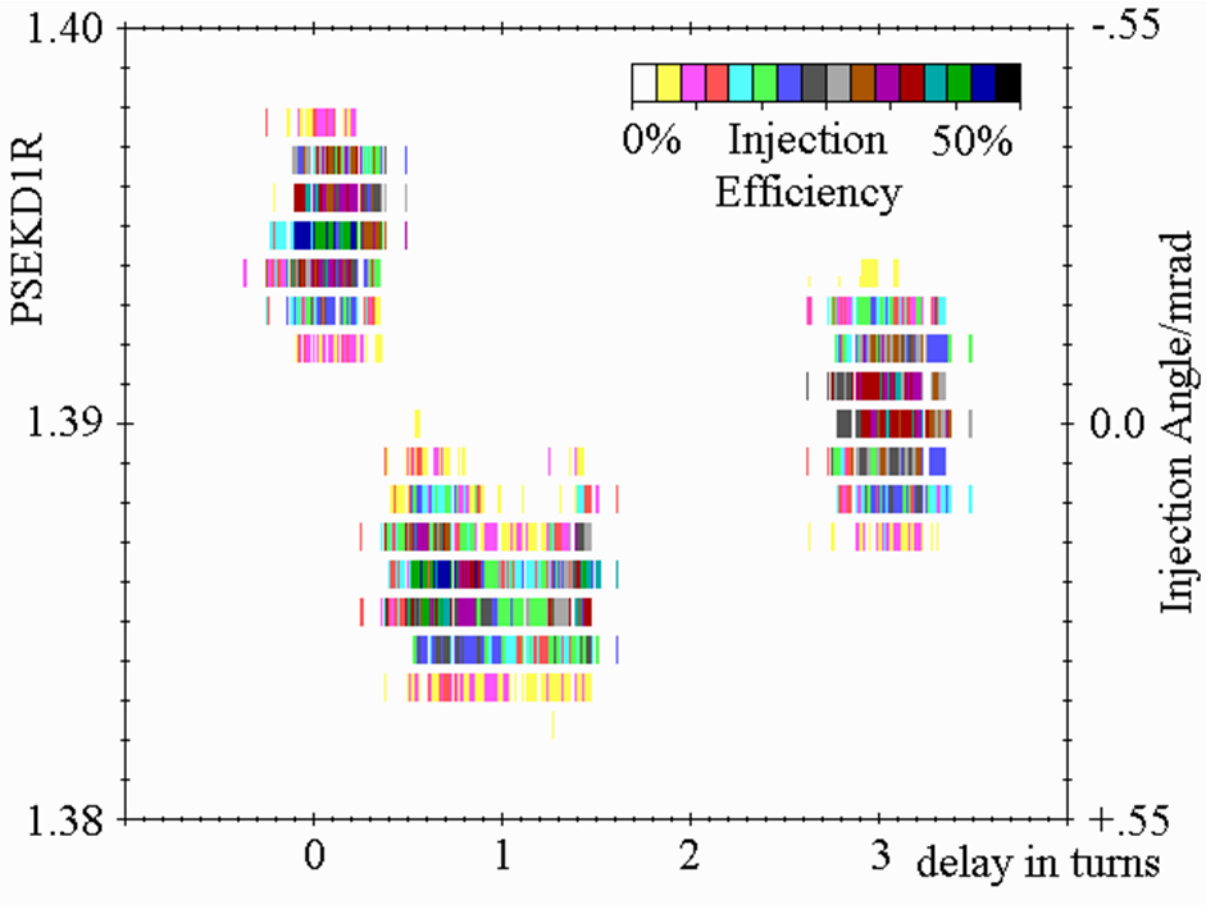
VARIATION OF THE HORIZONTAL INJECTION ANGLE AND KICKER DELAY



Efficiency up to 60% and kicking the injected beam at later turns

Magnet works as expected

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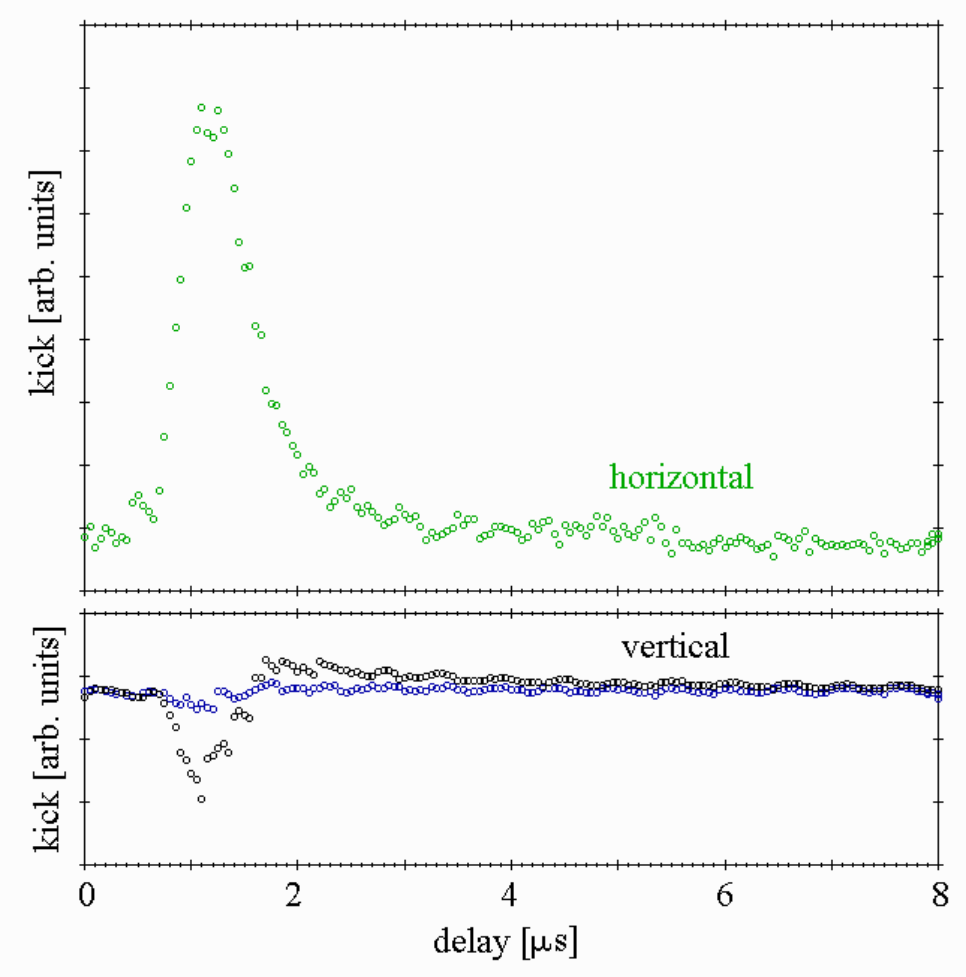
Temporal variation of the field at about dX~-11 mm and dY~2mm



Off-axis beam experiences fields dominated by eddy currents at later times

O. Dressler, P. Kuske
Advanced Low Emittance Rings Technology Workshop, Valencia, Spain, 5 - 6 May 2014

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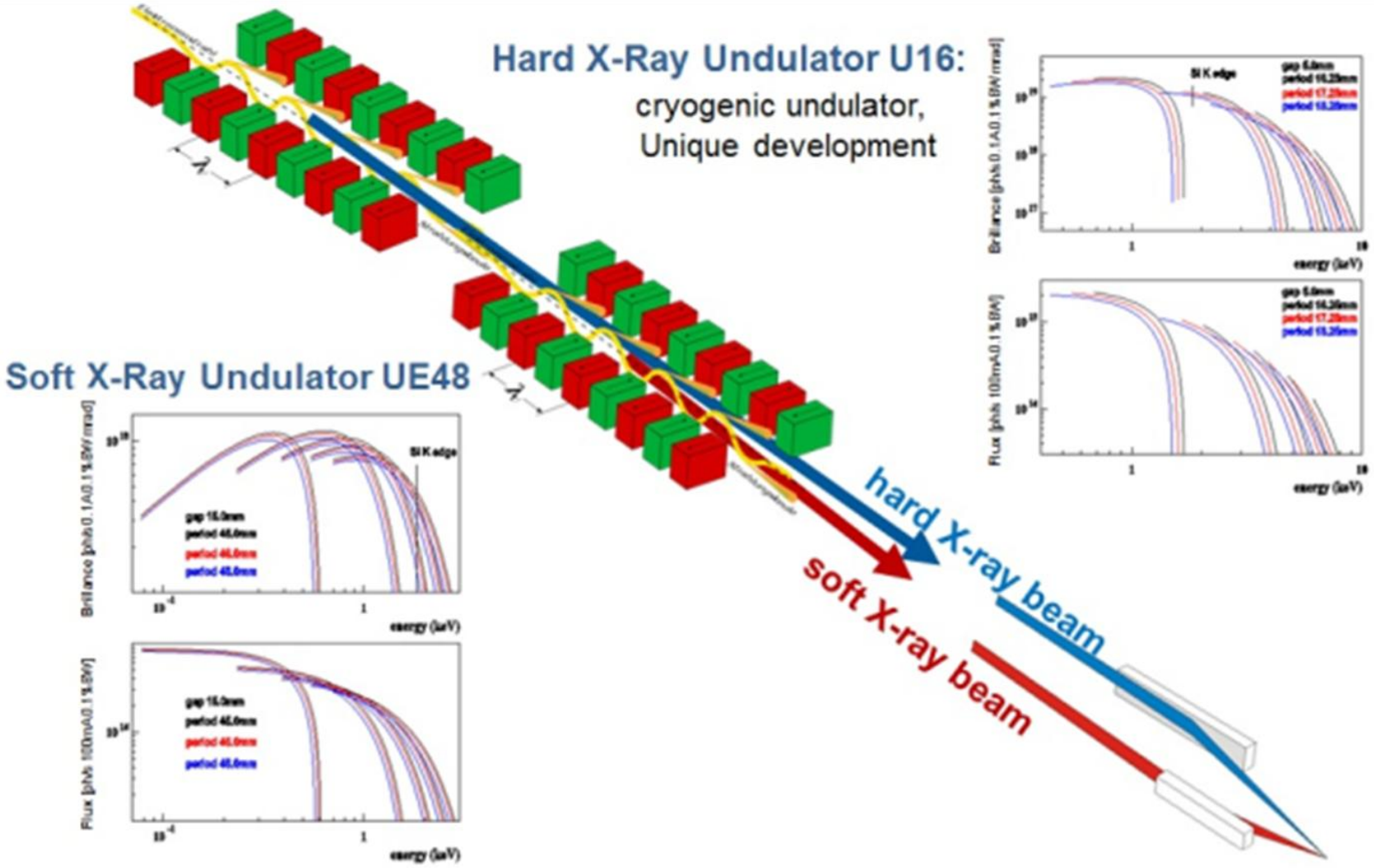
ENERGY MATERIALS IN-SITU LAB BERLIN (EMIL)



see the HZB homepage for more detailed information

IV.1 Future: EMIL

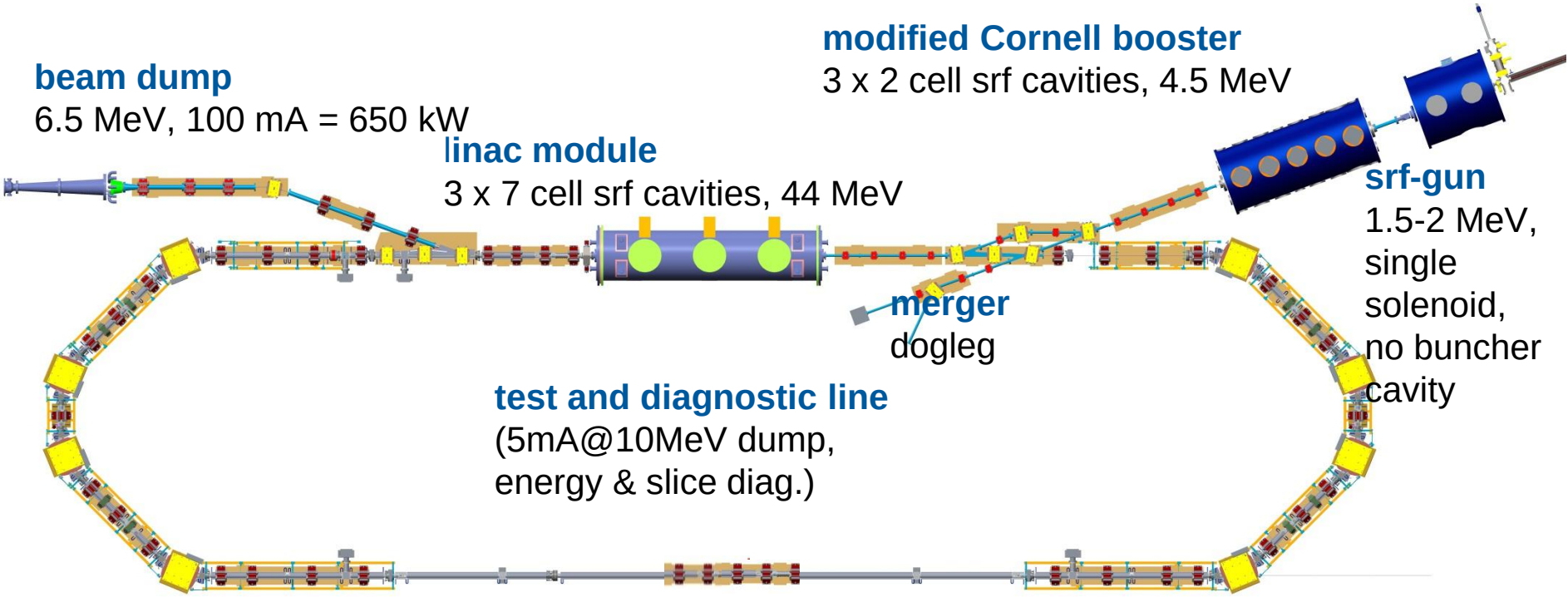
Next steps:

- Installation of vacuum chambers with two pairs of scrapers to mimic the small gap of the cryogenic undulator.
- Installation of the additional quadrupole magnet in the middle of the straight section to bend the beam with a shifted focus. Quadrupole and sextupole magnets adjacent to the straight have been modified already.
- Performance tests in view of top-up operation and higher particle losses with the smaller vertical gap.
- APPLE II undulator ready in 2016
- Cryogenic undulator installed at the end of 2015

IV.2 bERLinPro - Status

bERLinPro = Berlin Energy Recovery Linac Project

100 mA / low emittance technology demonstrator (covering key aspects of large scale ERL)



- developing cw srf technology for injectors and linacs
- explore parameter space of ERLs
- be ready for future large scale facilities
- educate and train accelerator physicists + engineers + technicians

	Basic Parameter
max. beam energy	50 MeV
max. current	100 mA (77 pC/bunch)
normalized emittance	1 μm (0.5 μm)
bunch length (straight)	2 ps or smaller (100 fs)
rep. rate	1.3 GHz
losses	< 10^{-5}

IV.2 Future: bERLinPro

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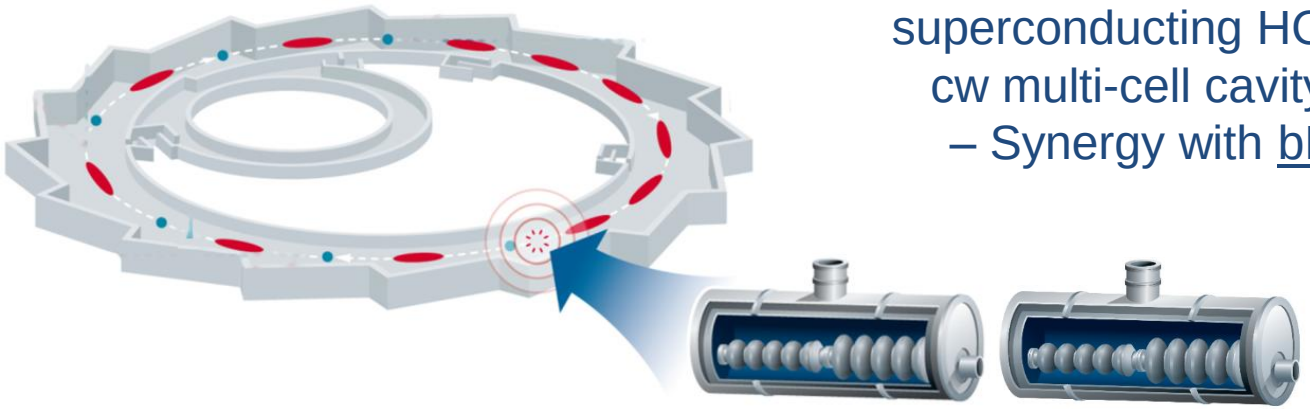
- Full funding since 2011
- Ground breaking in April 2015, severely delayed
- 2 buildings: underground for accelerator (radiation safety)
- + technical hall above ground
- First gun-cryo-module in the process of being assembled, first beam expected in Gun Lab November 2015
- Second and final gun module will be build based on experience with the first
- Installation of all components 1Q/2017
- „Banana“ without Linac cavity strings (<10mA, 6.5 MeV) 4Q/2017
- Recirculation in 1Q/2019

IV.3 BESSY-VSR – Basics

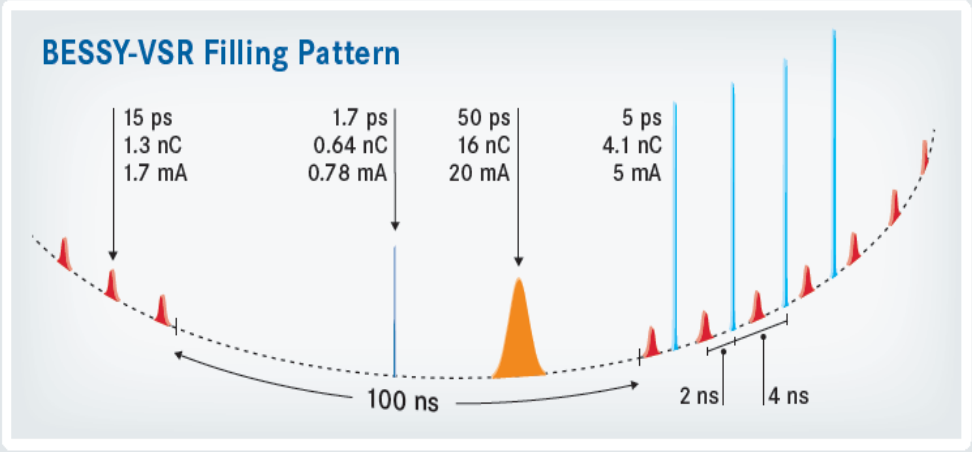


superconducting HOM damped
cw multi-cell cavity systems
– Synergy with bERLinPro

Operation of hybrid filling pattern with few single bunches within a 100ns gap interlaced to the multibunch buckets

- one short (sub-ps to ps) and one long bunch that can be pulse picked by mechanical choppers or resonant excitation of a single bunch
- additional compressed short bunches filled between the long bunches

- Preservation of source size (emittance) at 5nm mrad level
- Preservation of high average brilliance

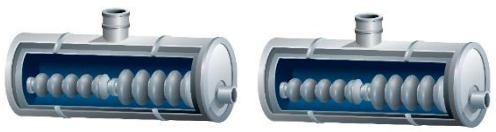


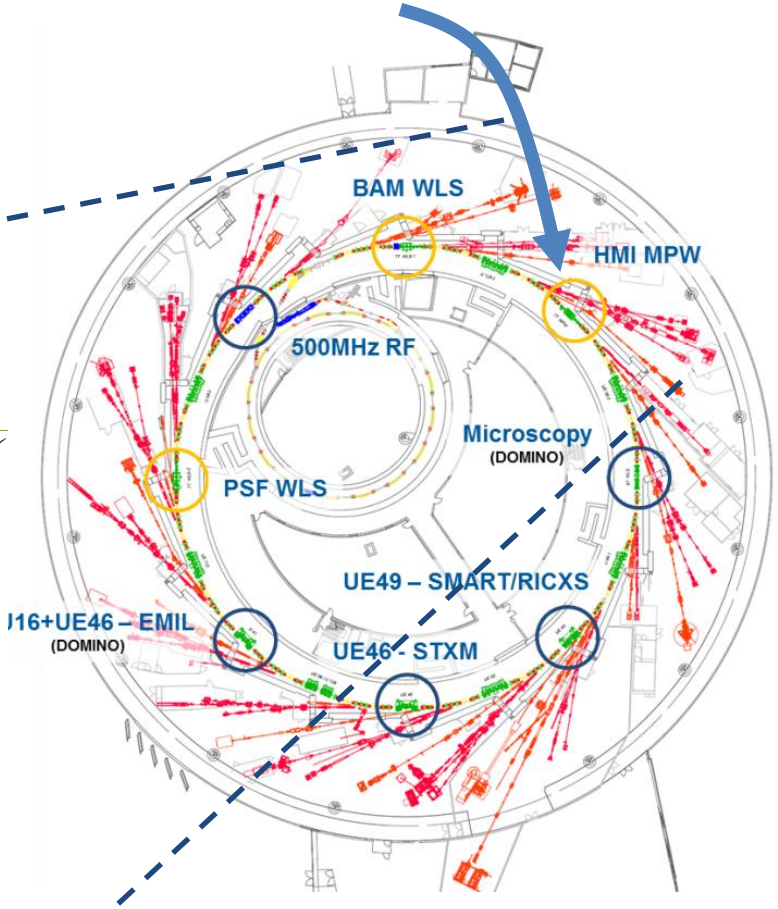
IV.3 BESSY-VSR – technical realisation

Two cryo-modules with each:
1 x 5 cell @ 1.5 GHz & 1 x 5 cell @ 1.75 GHz
operating at **1.8 K LHe** temperature
active length: **0.93 m** with **20 MV/m**
gradient: **30 MV•GHz**
total gradient: **60 MV•GHz (x 80)**

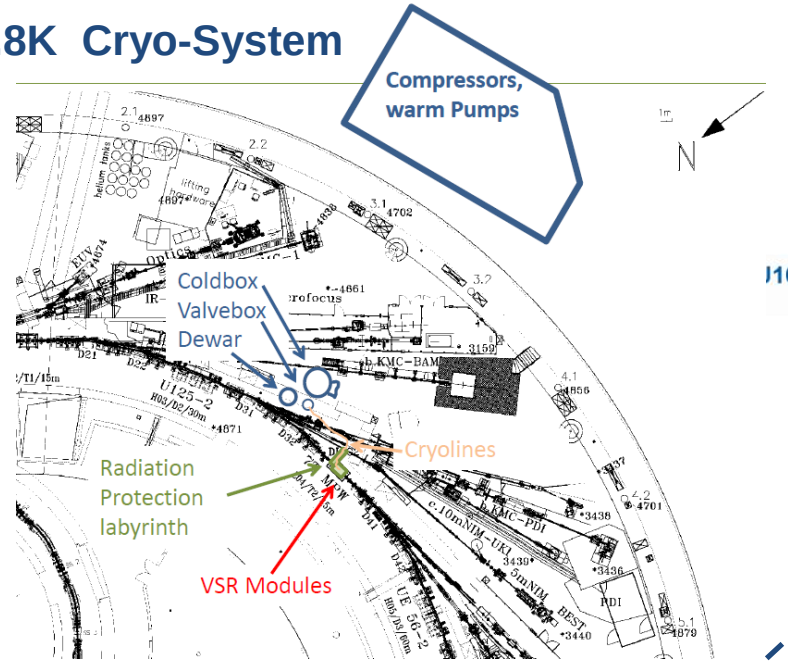
shortest bunchlength = 1.7 ps
(340 fs in low alpha)

sacrificing one straight

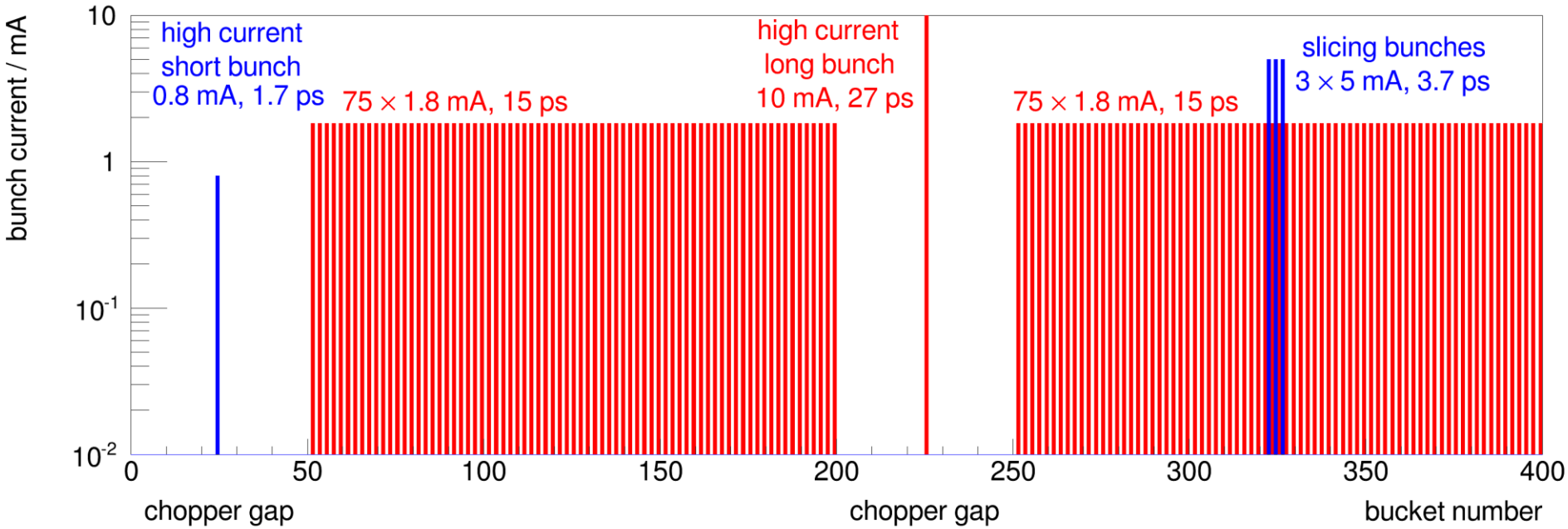




Installation of 1.8K Cryo-System



IV.3 BESSY-VSR – project parameters



- 300 mA average current
- MHz Chopper usable for single bunch separation
- ion clearing provided through gaps

in low alpha mode
340fs @ 0.02mA/bunch
(part of TDS)

multi functional hybrid mode

ps short single bunch, high current single bunch, slicing bunches, high average brilliance

mandatory: preserving BESSY II emittance and TopUp capabilities
→ 5 nm rad, lifetime > 5h, average inj. eff. > 90%

IV.3 Future: BESSY-VSR

Finishing „Technical Design Study“, TDS, has highest priority
Expect funding in 2018 and short bunches >2020

Work on the following beam dynamics issues:

- bunch separation: chopper wheel, pulse picking by quasi resonant excitation, or transverse resonance islands (see Paul Goslawski‘s contribution)
- scaling law: stability of the compressed bunches – simple scaling no longer valid
- cavity development + CBI simulations – longitudinal plane requires HOM optimized cavities + strong bunch-by-bunch feedback
- transient beam loading and phase transients – gap for ion-clearing and chopper wheel required, impact on Touschek lifetime
- topping up short bunches – ramping sc cavities in the ring and/or shorter bunches from the injector

V.1 Summary

- Top-Up operation runs very smooth and in combination with the fast orbit feedback has improved the beam stability for all users.
- We mastered a couple of challenges in the operation of BESSY.
- Other activities not mentioned: digital bunch-by-bunch feedbacks, fast orbit correction + suppression of the 10Hz-component from the booster synchrotron, Linac and gun development
- Build up operations team and hired personal for our future projects.
- Building for bERLinPro is the bottleneck and causing delays.
- Right now the “Technical Design Study”, TDS, for BESSY-VSR has the highest priority.
- Competition between bERLinPro and BESSY-VSR for human resources related to cryogenics – nearly impossible to hire adequate personal
- Jörg Feikes will report on the status of the MLS which is operated and maintained by the same HZB staff