HZB Facility Report

Paul Goslawski et al.
Institute for Accelerator Physics
Helmholtz-Zentrum Berlin

on behalf of
- Institute for Accelerator Physics
- Institute for SRF, Science and Technology
- Division for Accelerator Operation
- ...

26th September 2018
6th ARD ST3 Workshop, HZDR, Dresden, Germany

HZB Facilities for Synchrotron Radiation

BESSY I

E = 200 – 800 MeV
C = 60 m
EUV, soft X-ray
end of operation 1998,
now injector for Sesame

BESSY III

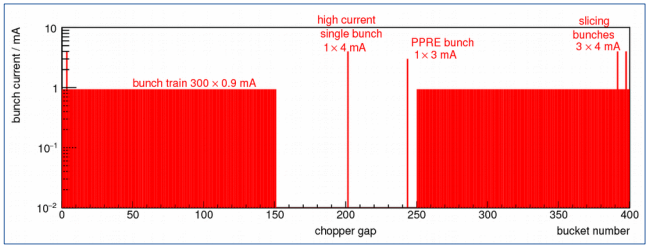
HZB and strategic partners

(PTB, FU-, TU-, HU- Berlin, MPG, FHI, ...)

- **BESSY II / VSR, MLS – syn. rad. sources**
- **bERLinPro – test facility**
- **SupraLab@HZB – Lab for SC Acc. comp.**
- Proton therapy with Charité
- Research Reactor BER II

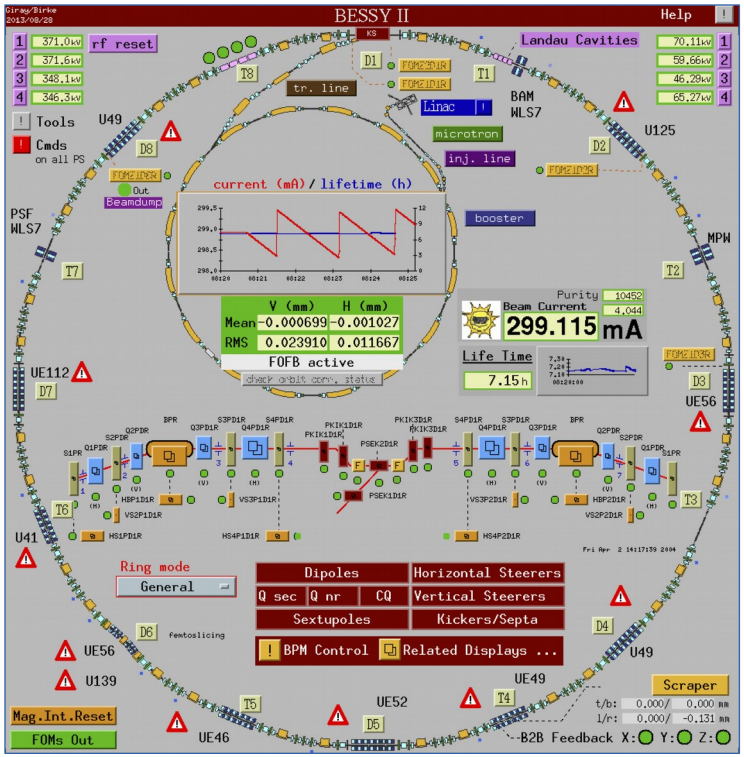
BESSY II - Synchrotron Radiation User Facility

BESSY II, 3rd generation light source, DBA lattice



- 1.7 GeV, EUV – soft X-ray, 100 eV – 1 keV – 20 keV, 240m, ε_x=5nm rad, σ_0=15ps, beamlines 22,20 (ID, Bend)
- Special features, special focus:
  - ***Spe**ctroscopy* & **Timing experiment community:** Pump-Probe, TOF, Coincidence
  - Low alpha for stable THz, FemtoSlicing, Advanced fill pattern, SB & FB mode
    (1MHz - 10 MHz)
  - Bunch separation Schemes:
    MHz Chopper, PPRE

FEMTOSPEX - Magnetism, Molecules and Surfaces, Scattering
LiquidFlexRIXS, MAXYMUS, Resonant Scattering, SPEEM, XPP
SolidFlexRIXS, THZ spectroscopy and EPR, Transmission NEXAFS



0) Maintaining & Improving BESSY II
EMIL, WLS refurbishement, TRIBs, ...

1) BESSY VSR – **V**ariable Pulse Length **S**torage **R**ing
Short and long bunches simultaneously

2) TRIBs – **T**ransverse **R**esonance **I**sland **B**uckets
Two synchrotron radiation sources in one ring

3) BESSY III - Future storage ring (DLSR) based
radiation source optimized for timing experiments (DLSR + VSR + TRIBs)

PTB's MLS - Metrology Light Source

- MLS – Machine for non-linear beam dynamic studies and more

  - **Primary Target:** Metrology in the UV - EUV range, user facility, industry cooperation
  - Highly automated operation, ramped machine
  - User mode, low-α, low-ε, single electron, ...

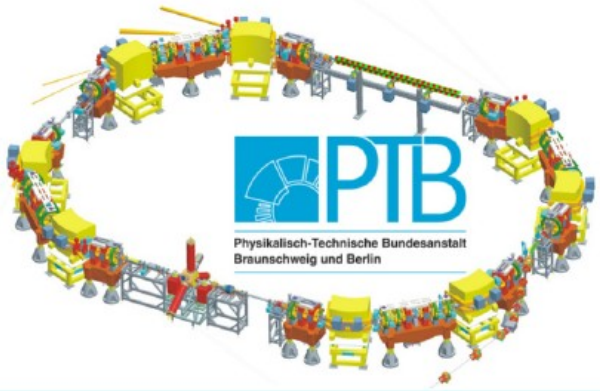
  - **Secondary Target:** optimised for non-linear beam dynamic studies in longitudinal as well as in transverse plane → test bed for Acc. Phys.
  - low-α operation, THz generation, CSR studies, α-buckets, bunch length limits, **negative low α-operation, SSMB project** with Tsinghua Univ., PTB, SLAC

60th ICFA Advanced Beam Dynamics Workshop on Future Light Sources FLS2018, Shanghai, China JACoW Publishing
ISBN: 978-3-95450-206-6 doi:10.18429/JACoW-FLS2018-THP2WB02

AN OVERVIEW OF THE PROGRESS ON SSMB

Chuanxiang Tang*, Xiujie Deng†, Wenhui Huang, Tenghui Rui,
Alex Chao[1], Tsinghua University, Beijing, China

  - Transverse Resonance Island Buckets, TRIBs
  - R&D project: Robinson Wiggler



parameters	
Energy	50 ... 630 MeV
Circumference	48 m
Horizontal emittance	100 nm rad
Beam current	200 mA
RF frequency	500 MHz
max. RF voltage	0.5 MV
Bunch length low-α	20 ps 1 ps
Mom. Comp. low-α	$(-3 \ldots 7) \times 10^{-2}$ 1.3×10^{-4}

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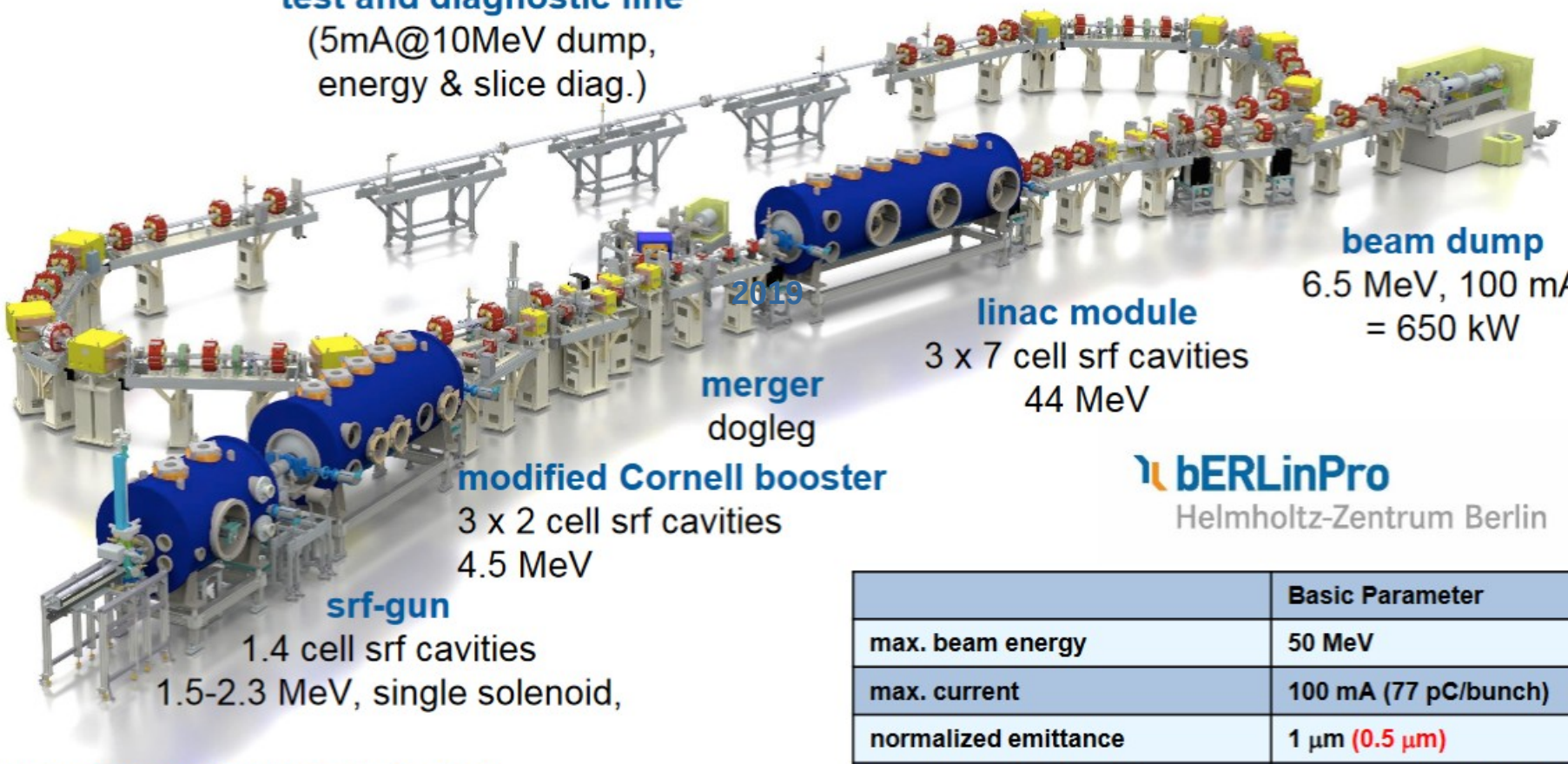
bERLinPro - R&D Test Facility

bERLinPro = Berlin Energy Recovery Linac Project

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



bERLinPro
Helmholtz-Zentrum Berlin

project started 2011, fully funded
building ready 2018
first electrons 2019
recirculation 2020+

	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}

bERLinPro – GunLab – Test Facilities

- bERLinPro, GunLab "first beams"
  - Building & most warm accelerator components ready
  - Infrastructure nearly ready
  - Next step - installation of cold SC components, GunLab with CsK_2SB
  - GunLab - First tests within HoBiCaT bunker with Cu Cathode

- First "Test Facility" Collaboration with JGU Mainz
  - "Testing XFEL cavities in CW under extreme electron beam conditions" → Verbundforschung
  - MESA Linac Module @ bERLinPro

From: P. vom Stein et al., MOPCH065, Proc. of EPAC2006, Edinburgh, Scotland, 2006

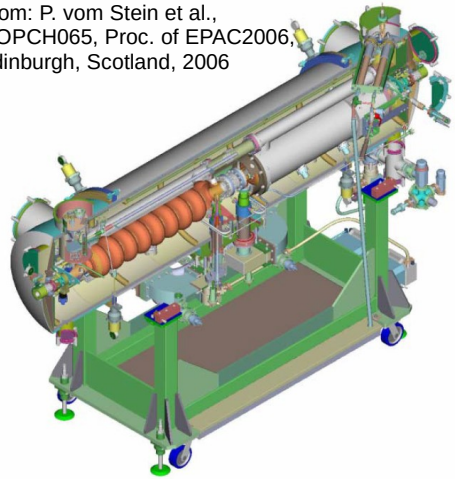


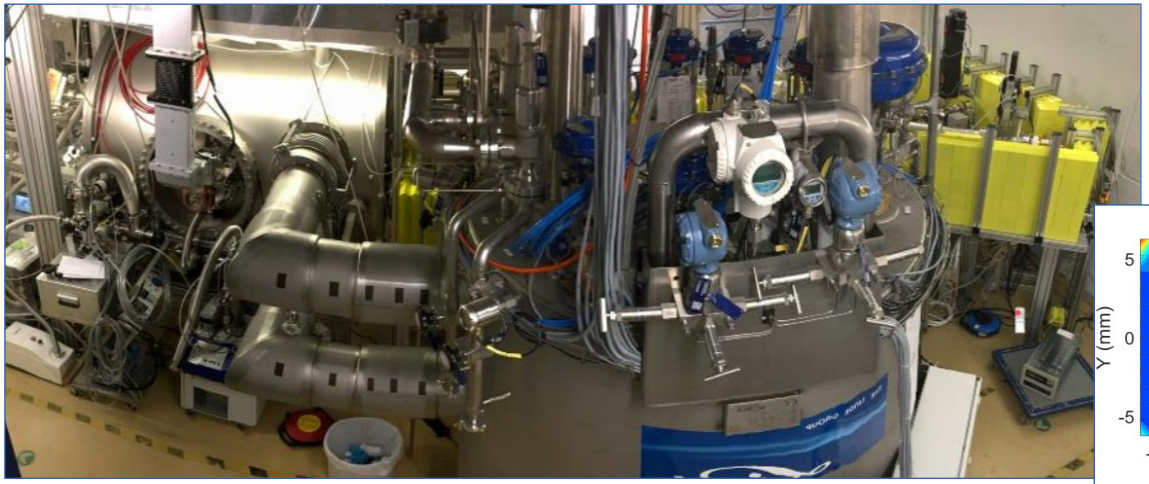
Figure 1: SRF bi-cavity module (courtesy FZ-Rossendorf)

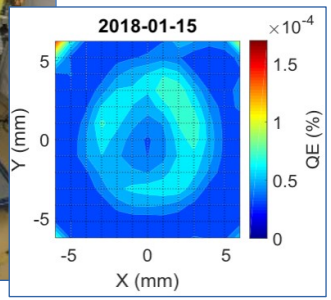
Laser
power, spot size
cathode position

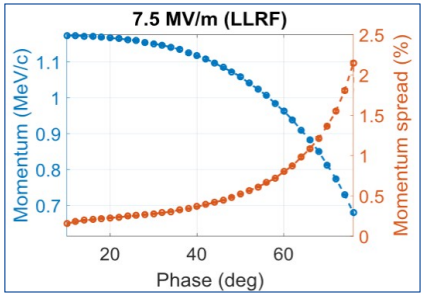
Cathode
QE scan, map

Gun
dark current
RF gradient

e- Diagnostics
phase scan, δ spread
beam size



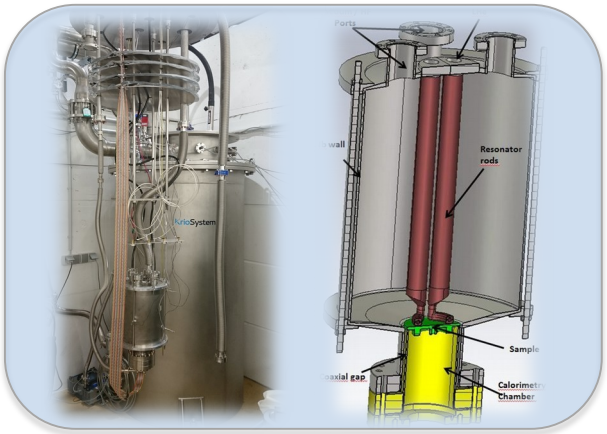


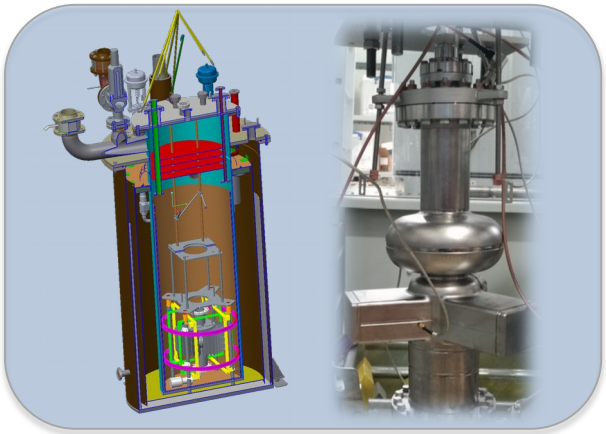


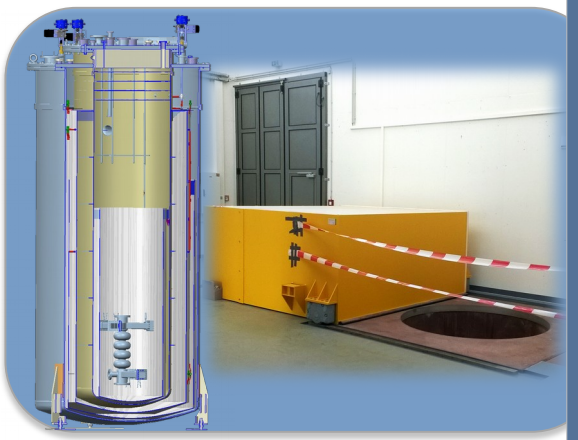
SupraLab@HZB + bERLinPro

- SupraLab with bERLinPro will offer an infrastructure for the complete SRF development chain from samples to accelerator operation with beam...

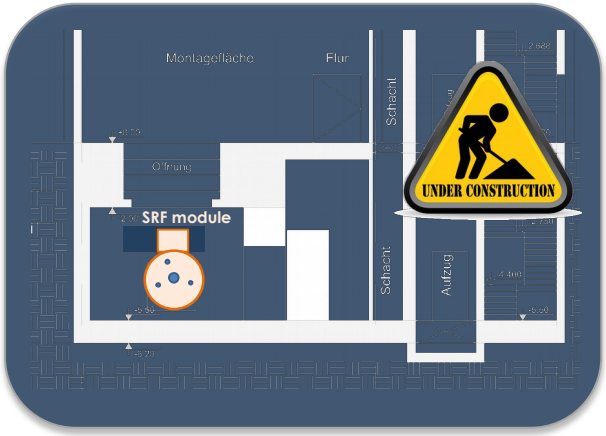
Sample testing (QPR) | **1-cell prototype testing (SVTA)** | **Full cavity testing (LVTA)**

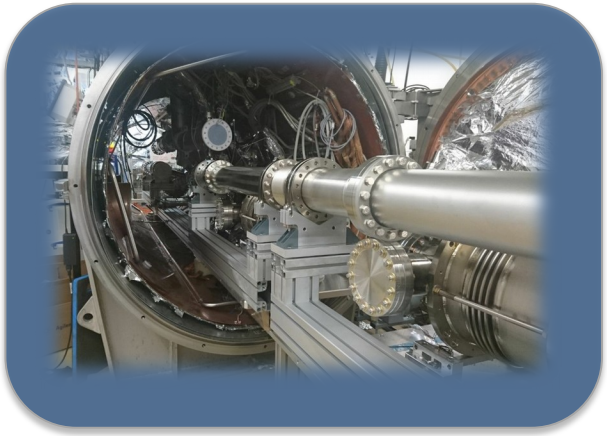






Beam ops (bERLinPro/GunLab) | **Full module tests (MTF)** | **Dressed system (HoBiCaT)**





BESSY II moves towards BESSY VSR

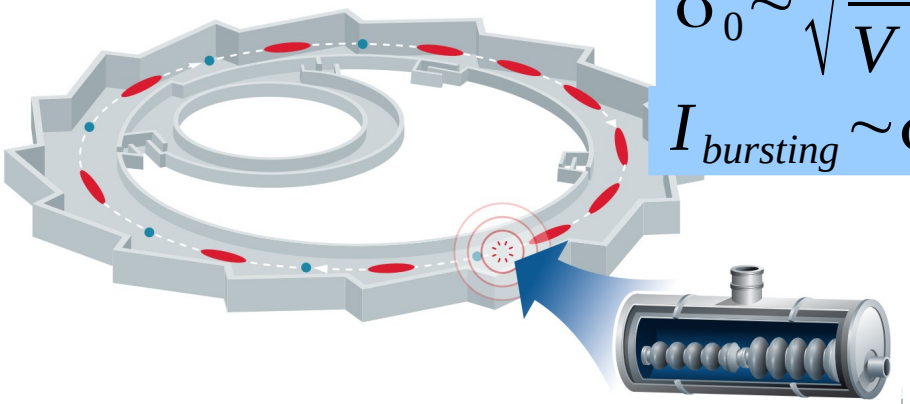
More today afternoon

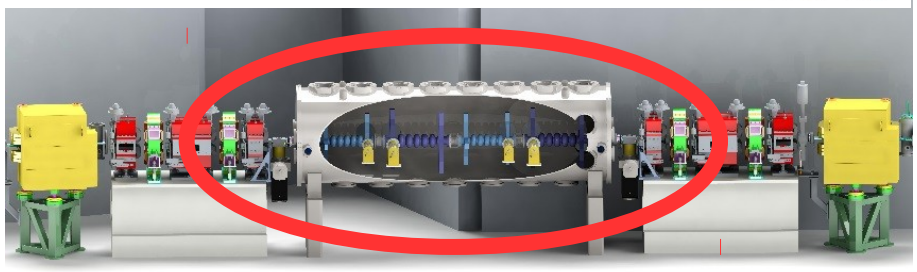
BESSY VSR objectives

- Add short pulse operation at all beam lines in parallel
- Conserving photon brilliance (emittance) for all users
- **V**ariable pulse length **S**torage **R**ing
- HOM damped CW SRF Cavities

$$\sigma_0 \sim \sqrt{\frac{\alpha}{V'}}$$

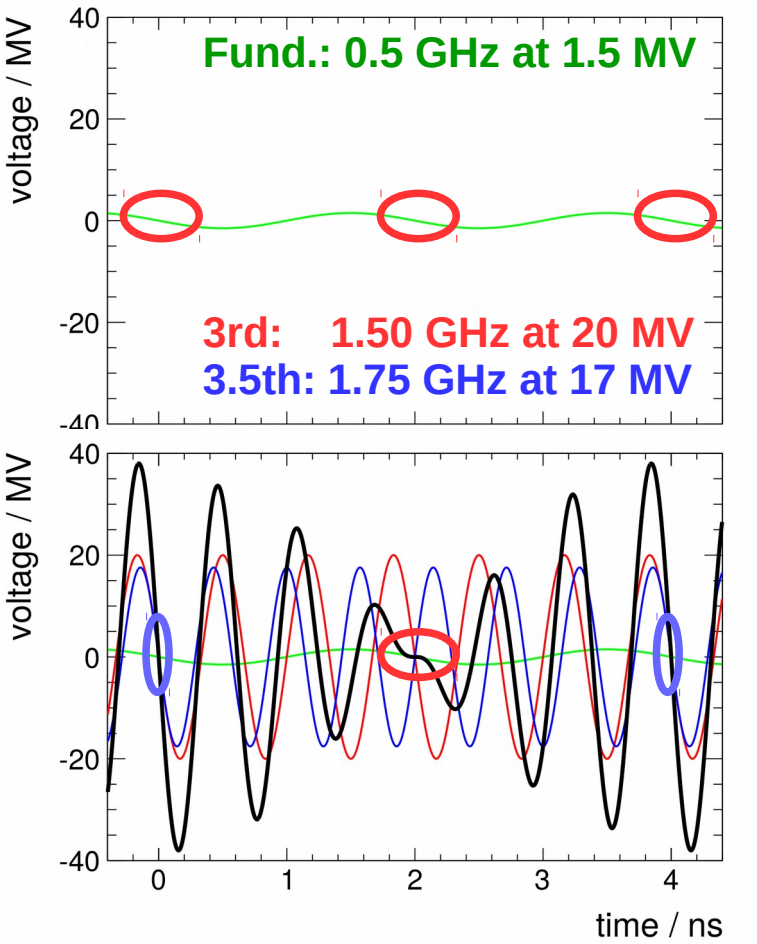
$$I_{bursting} \sim \alpha$$





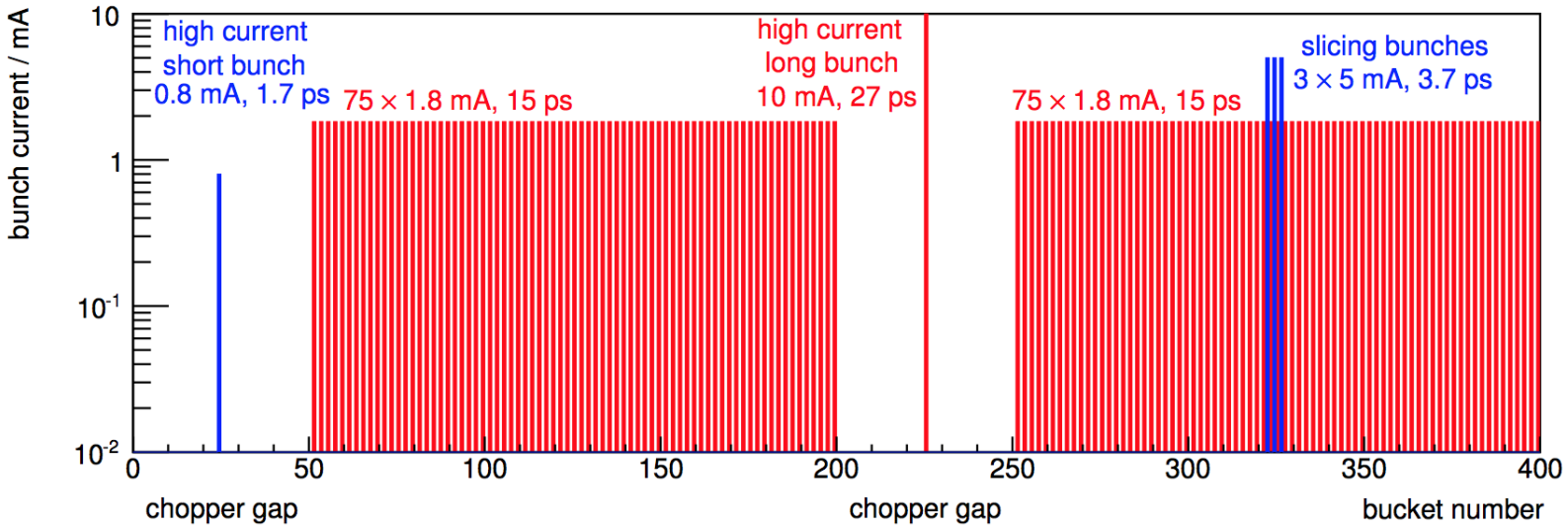
Short and Long Pulses

- Shaping the longitudinal focussing V' and phase by introducing voltage beat
- BESSY VSR cavity setup:

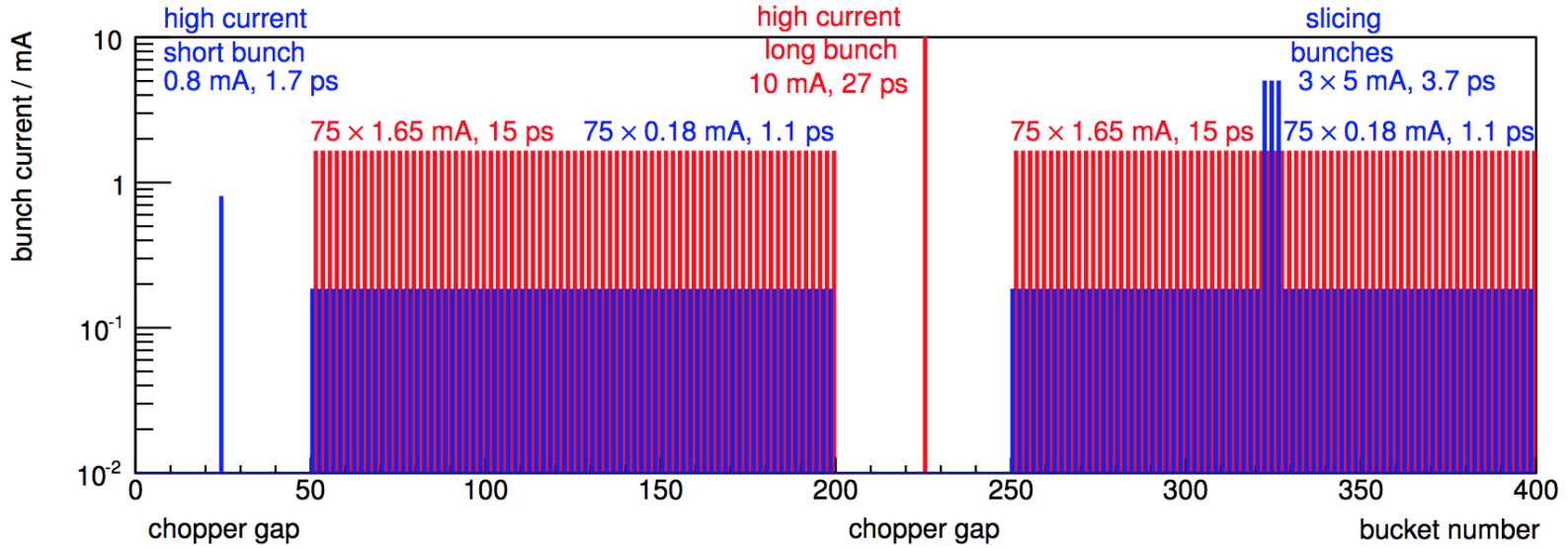


BESSY VSR - envisaged parameters and fill pattern

More today afternoon



In low α_c mode:
400 fs @ 0.04 mA / bunch

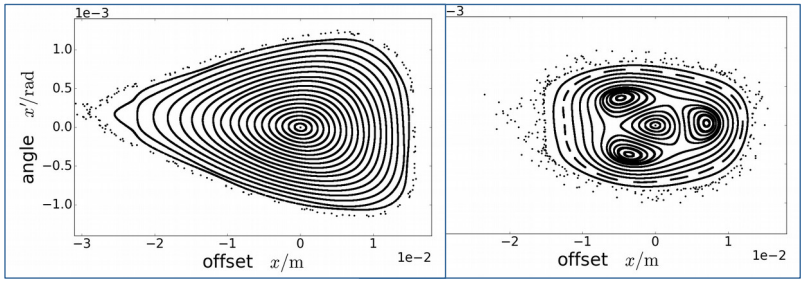


BESSY II - TRIBs, Bunch Separation Scheme

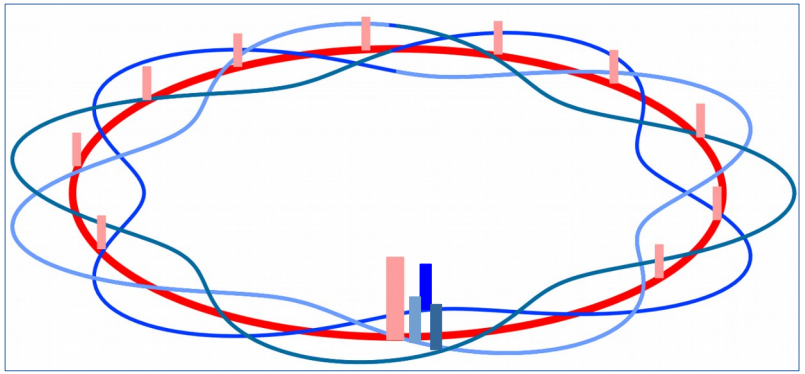
Two Synchrotron Radiation Sources with

- **TRIBs** generate 2nd stable island orbit
  - Working point on/close to resonance forms **T**ransverse **R**esonance **I**sland **B**ucket**s**
- **Goal: Two orbits / two sources in one ring**
  - Main orbit: average brightness/brilliance
  - Island orbit: timing community, repetition rate
  - **First successful "User Test Week at BESSY II in February2018, next in June2019** (beam stability with IDs, separation, TopUp injection)
- **Next steps:** (Chance for Verbundforschung/Collaborations)
  - **BESSY II: Realistic user operation mode,** TopUp injection scheme, orbit bumps, …, and
  - **Many open fundamental questions in this non-linear beam dynamics regime:** horizontal – vertical islands, transverse – longitudinal coupling, lattice design for TRIBs with 'non-linear' elements

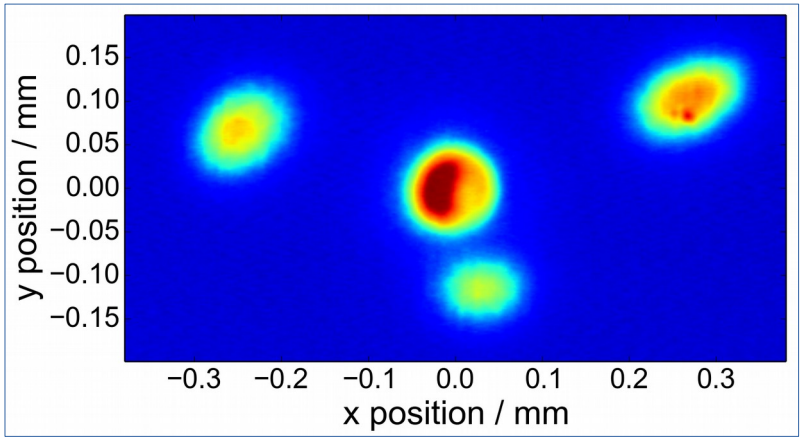
Standard BESSY II and TRIBs (x,x') phase space



TRIBs, two orbit scheme



Source point image from pinhole camera



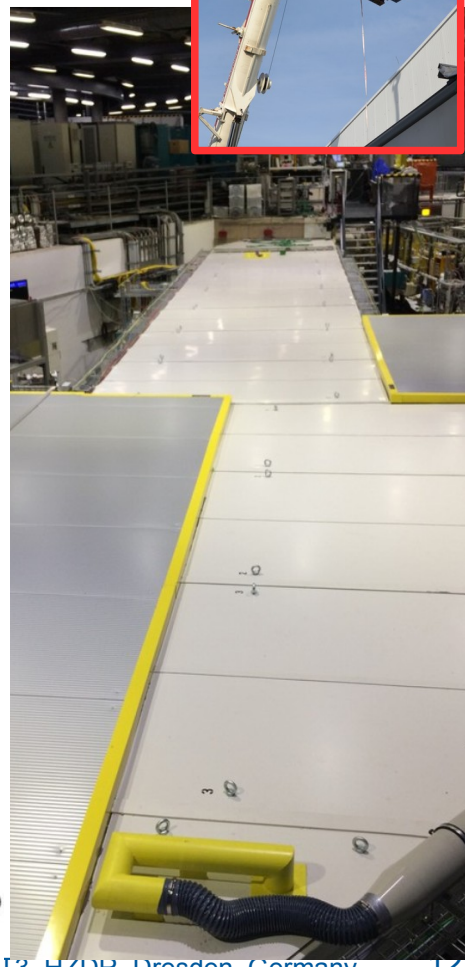
Verbundforschungsprojekt 2016 - 2019 (Uni Mainz, Uni München): PhD student: TRIBs as bunch separation scheme

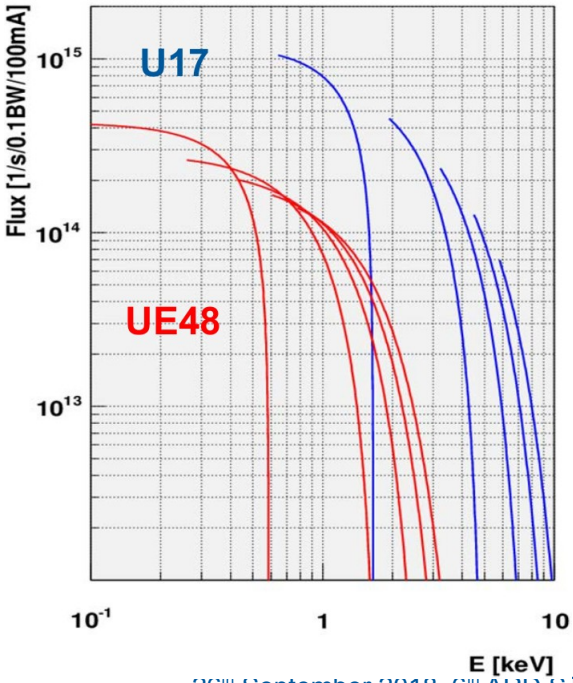
Bundesministerium für Bildung und Forschung

BESSY II - EMIL, Energy Materials In-Situ Laboratory

EMIL@BESSY II (HZB & MPG)

- Combines X-ray analysis methods and deposition tools, partially with industry related technologies
- 5 Endstations:
  SISSY (2x) - material, devices solar energy
  CAT - catalysis applications
  PEEM and PINK - inside storage ring hall
- Synchrotron radiation sources:
  Cryogenic CPMU-17 (700 eV -- 10 keV)
  APPLE II UE-48 (80 eV -- 2 keV)
- Inauguration of EMIL Laboratorys on 31.10.2016



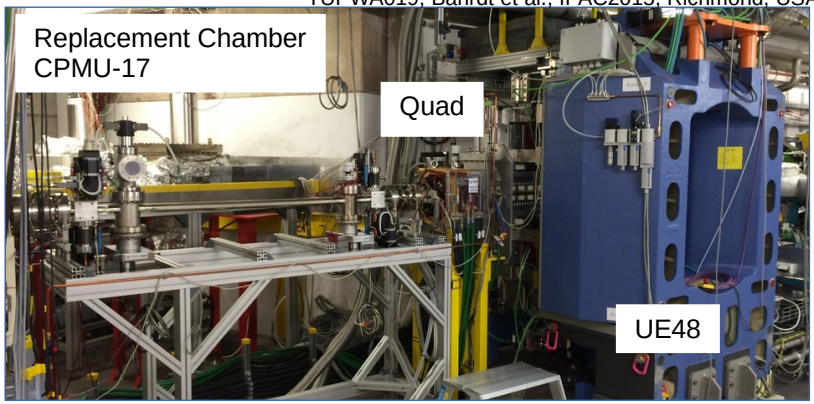


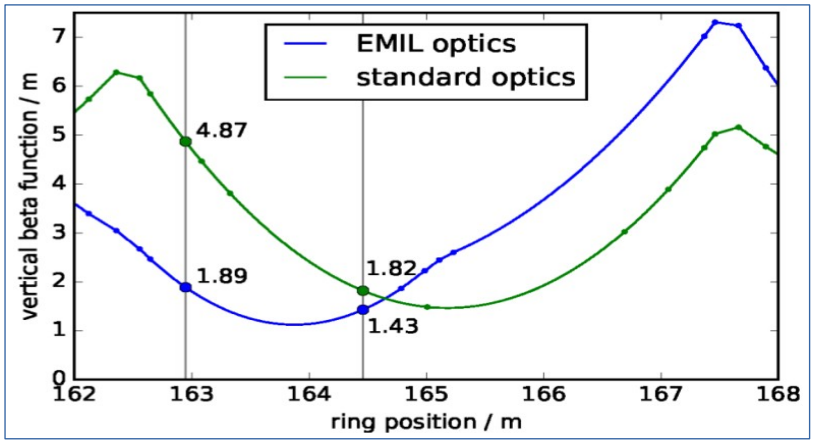
BESSY II - EMIL, Lattice & Cryogenic In-Vaccum Undulator

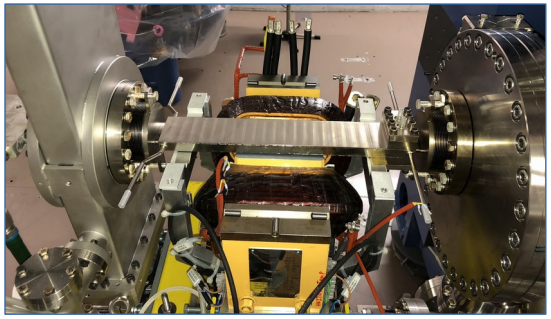
See THPOW039, Bahrdt et al., IPAC2016, Busan, Korea
TUPWA019, Bahrdt et al., IPAC2015, Richmond, USA

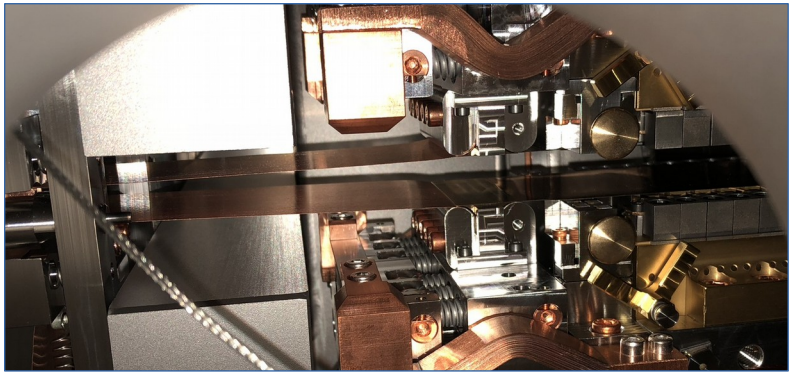
EMIL@BESSY II (HZB & MPG)

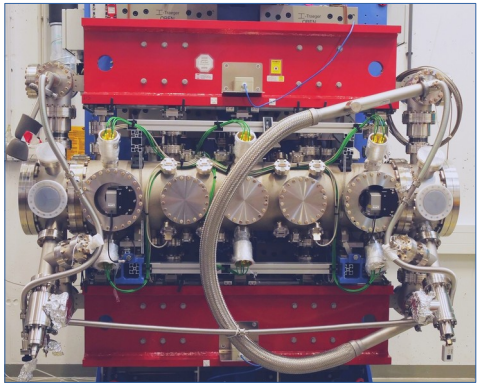
- APPLE II UE48 installed in Jan2017 and commissioned in July2017
- Cryogenic In-Vacuum undulator CMPU-17 with small gap of 5mm, installation ongoing
  –> optics adoption necessary, additional Quad moves vertical beta waist to CPMU-17



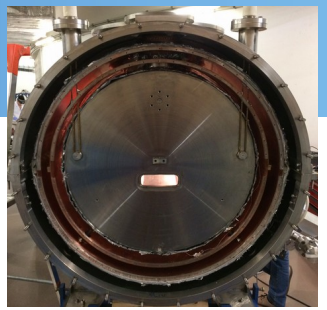




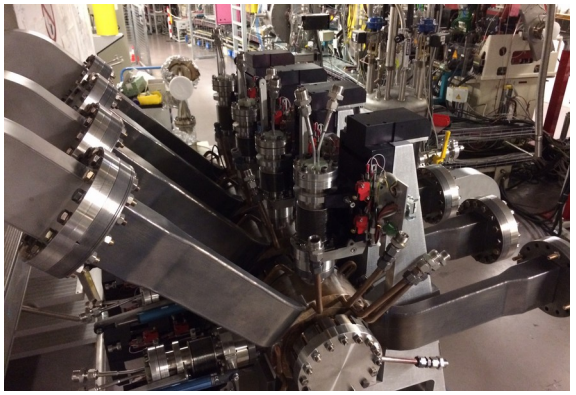




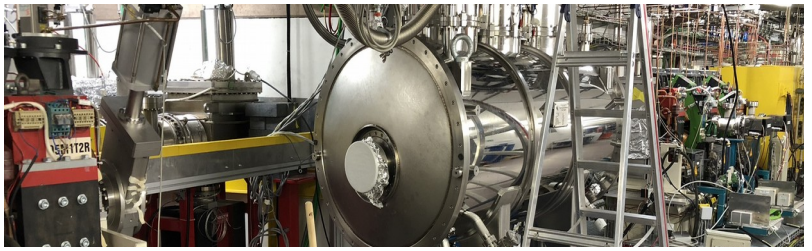
BESSY II - first ‘VSR shutdown’



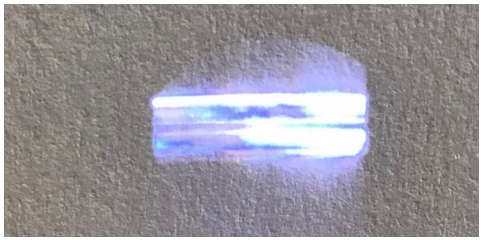
- Extensive shutdown to maintain BESSY II and prepare for VSR
  - Refurbishment of BAM- and PSF-WLS (Wave Length Shifter) Colleagues from Budker Institute
  - Re-Installation of Landau Cavities, after failure in HOM loads
  - Cryogenic In-Vaccum Undulator CPMU-17 for EMIL hard x-Ray branch



  - Removal of Multipole Wiggler in T2 straight for BESSY VSR cryomodule (MPW, 5keV - 100 keV) ; MPW will be shipped to SOLARIS



  - T2 straight equipped with scrappers
  - New diagnostics beam line for BESSY VSR, **VSR diagnostics**, first light



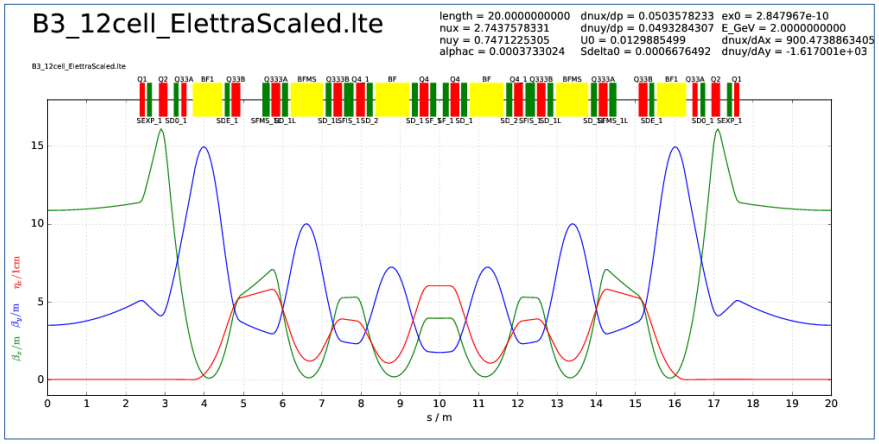
  - Infrastructure for BESSY VSR (Cryoplant, Booster PETRA Cav., etc.)

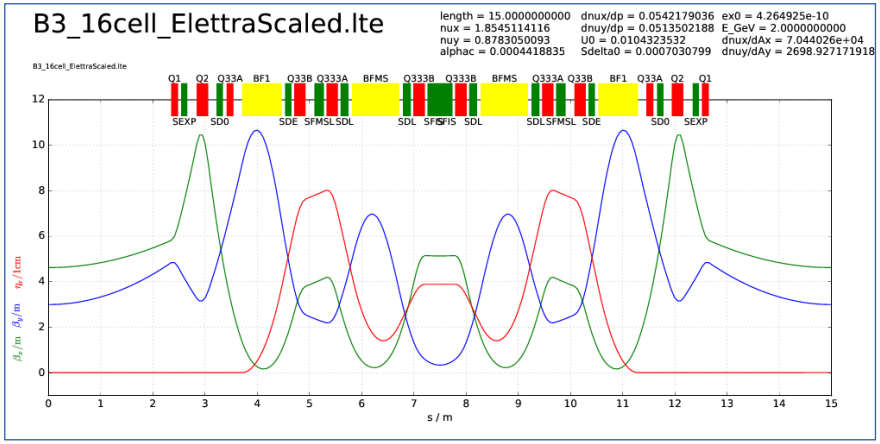
First thoughts towards BESSY III

- Next-generation low emittance storage ring light sources will operate with long bunches and homogeneous fill to fight bad lifetime
  - **(Simultaneous) Timing Experiments become unfeasible at these facilities!**
  - Study EUV soft X-ray source pushing transverse and **longitudinal** bunch properties towards practical (not necessarily ultimate) limits

Study lattice (MBA) solutions optimized for timing experiments

- **MBA combined with VSR, TRIBs** (+ low alpha, FemtoSlicing, CHG, EEHG, …)
- Shortest bunches in storage rings; bunch length limitations from CSR, intra-beam-scattering and from single particle beam dynamics
- Coupled bunch instabilities (CBI) and cavity impedance studies, transient beam loading





Summary & Outlook for HZB accelerators/facilities

- **Test Facilities: SupraLab & bERLinPro**
  - **SupraLab:** QPR, SVTA, LVTA, HoBiaCat, MTF + bERLinPro
    → Full testing of design and development chain for SC RF devices
  - **berLinPro:** building, magnets, infrastructure ready,
    installation of SC components,
    with Gun & Booster 5 MeV beam possible, MESA Linac collaboration
    GunLab: first test with CU cathode, next test with CsK2SB in bERLinPro
- **MLS:** negative-α studies & SSMB project with Tsinghua Uni., SLAC
- **BESSY II / VSR / III**
  - **BESSY II:** EMIL with cryogenic small gap in-vaccum undulator CPMU-17
    TRIBs as bunch separation scheme, two syn.rad. sources from one ring
  - **BESSY VSR:** procurements ongoing, first hardware and first tests at HZB, full cold string design nearly ready, pushing towards preparatory phase (2020+), (see afternoon talk)

Thank you for your attention !

A BIG THANKs to all Colleagues who make all this possible!
electrons + warm and SC heartware, photons + beamline scientists hardware, IDs, user groups, operation, IT, communication, administration