BESSY VSR - Upgrade for BESSY II

A Variable pulse length Storage Ring

Paul Goslawski
on behalf of the BESSY VSR project team

“Short summary of our Technical Design Study”

ARD ST3 workshop, KIT
July 15 - 17, 2015

BESSY II overview

- DBA, 240m, 1.7GeV, 300mA, $\varepsilon = 5\,\text{nm rad}$, $\sigma_0 = 15\,\text{ps}$
- Specialties: Short bunches

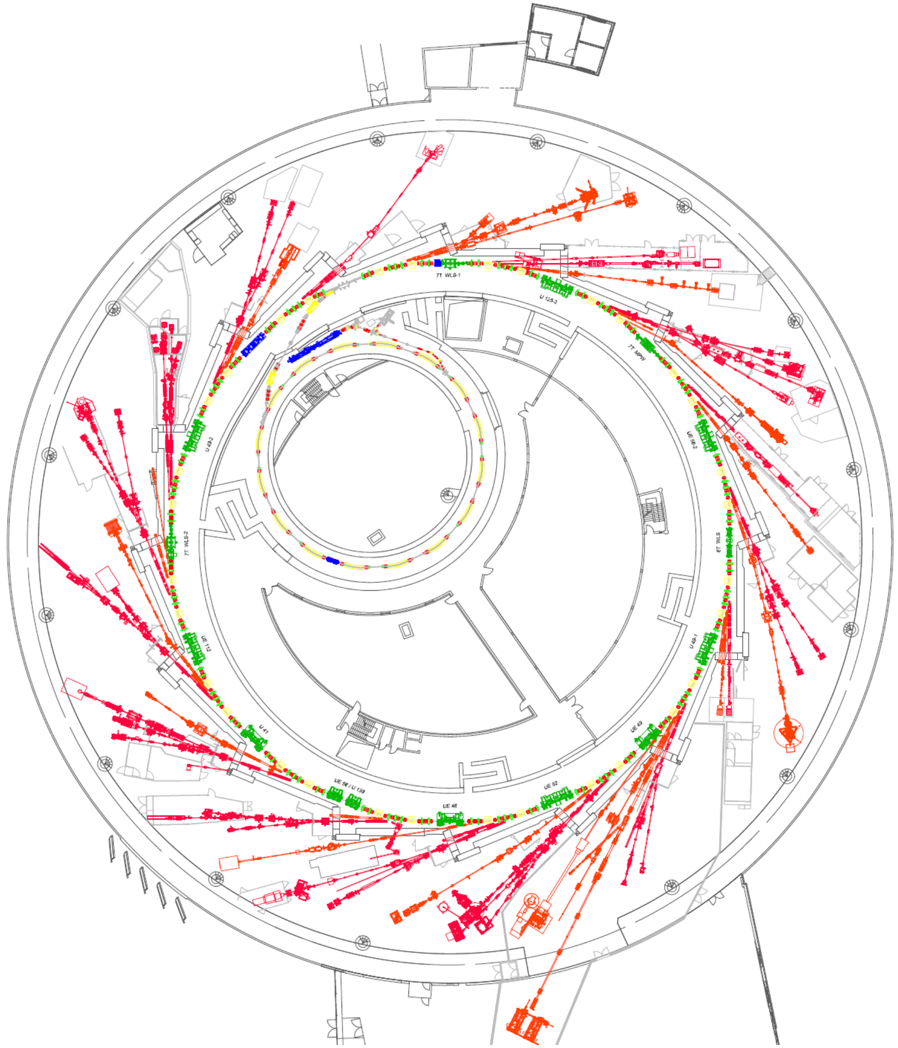
→ low α operation since 2003: ps bunches, CSR, THz

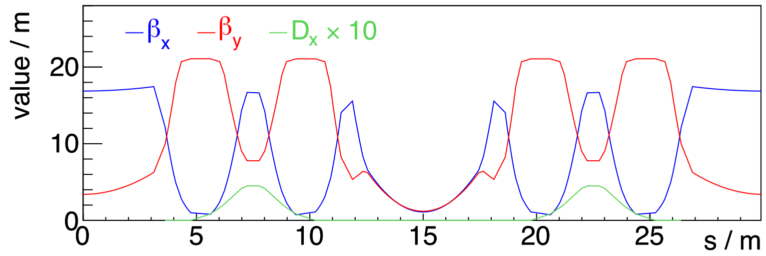
→ femto slicing: 100 fs pulses

Upgrade objectives

- Add short pulse operation at all beamlines in parallel
- Conserving photon brilliance (emittance) for all users

→ **V**ariable pulse length **S**torage **R**ing





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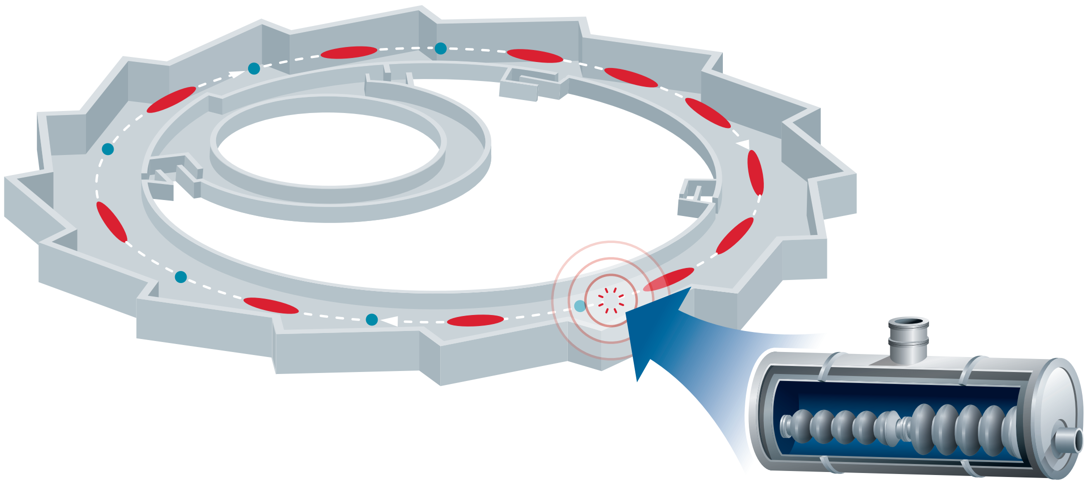

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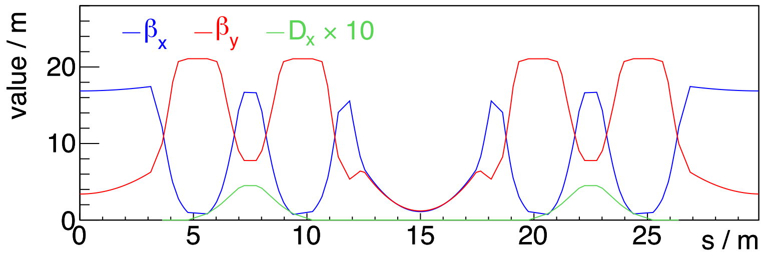


Short bunches in storage rings

Zero current bunch length σ_0

$$\sigma_0 = \frac{\alpha\, \delta_0}{2\pi\, f_s} = \delta_0 \sqrt{\frac{E_0}{f_0} \frac{\alpha}{U'}}$$

→ Today: Short pulses, low flux
Reducing α & bursting threshold
Only 2 weeks per year

→ Future: Short pulses, high flux
Increasing voltage gradient U'
sc cavities in cw operation

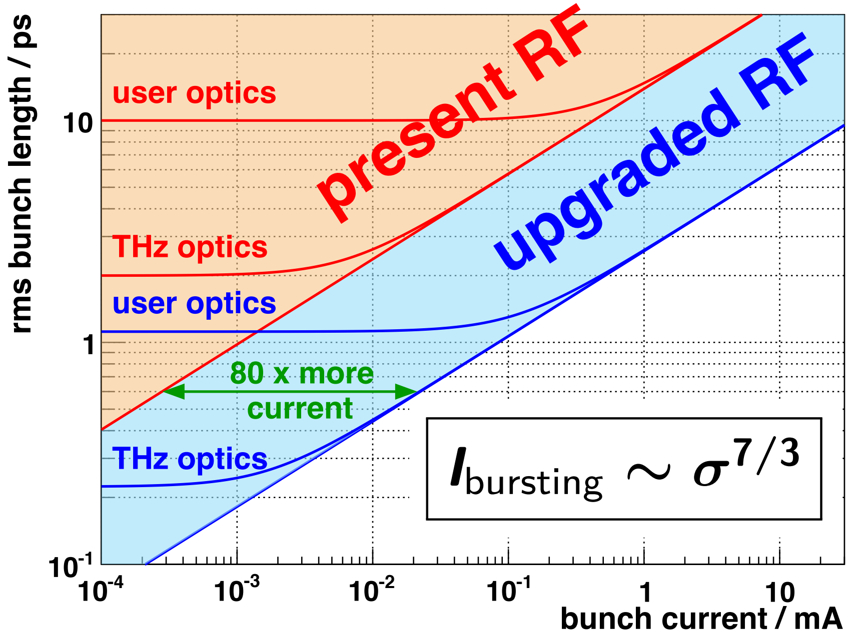
Stable operation below bursting threshold:

	Standard	Low-α
ε	5 nm rad	40 nm rad
α	$7.3 \cdot 10^{-4}$	$3.5 \cdot 10^{-5}$
σ_{0*}^{BII}	1.8 mA, 15 ps	0.04 mA, 3 ps
σ_{0*}^{VSR}	0.8 mA, 1.7 ps	0.04 mA, 0.35 ps

Current in short bunches

CSR instability, bursting threshold

- Instability threshold: $I_b \sim \alpha$

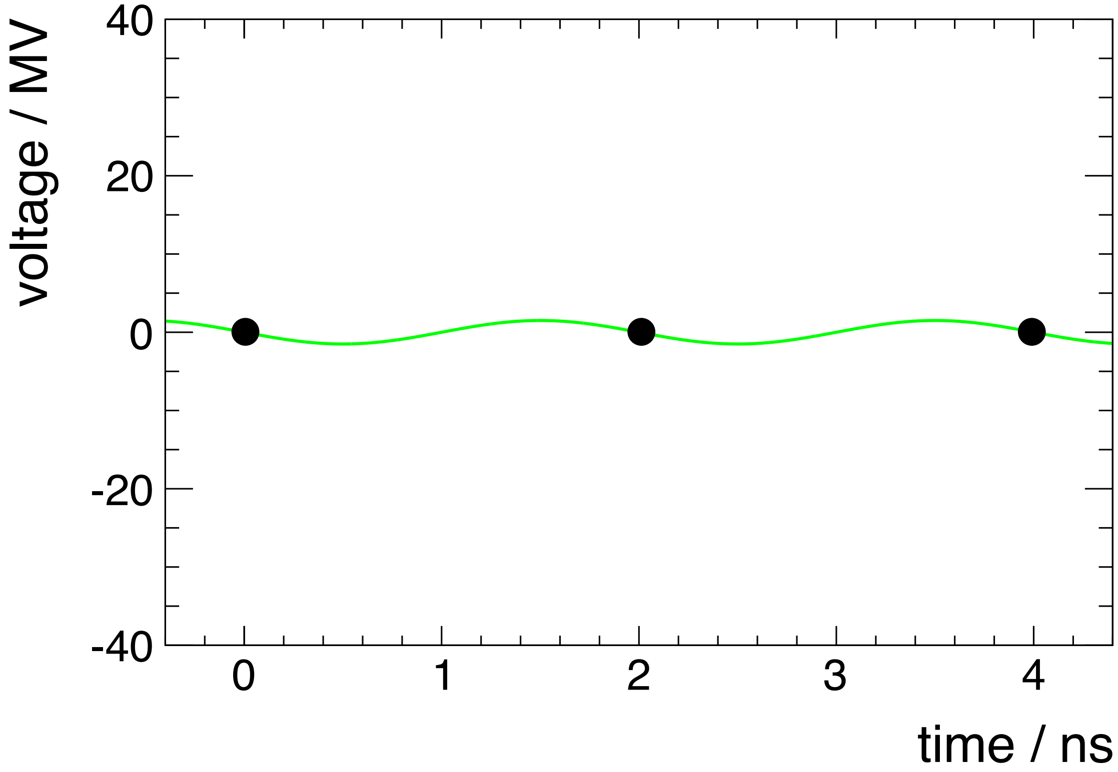


- Single bunch instability, increase of

→ bunch length and energy spread

→ spoils beam quality, but no beam loss

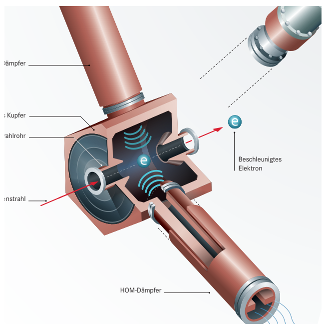
BESSY VSR - Short and long bunches simultaneously

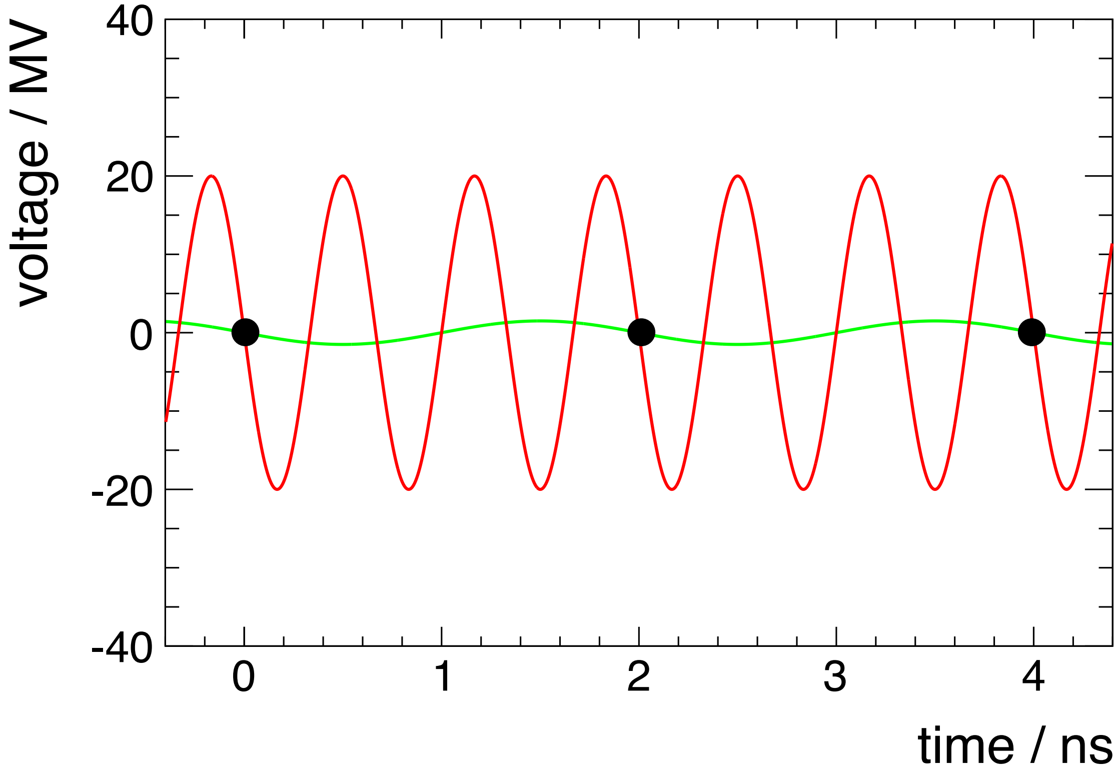


Cavity system for gradient manipulation

- Normal rf cavity

  $U' = 2\pi \; 0.5 \; 1.5\,\mathrm{GHz}\,\mathrm{MV}$





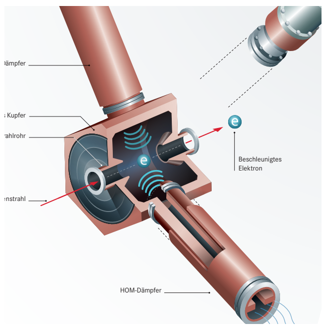
Cavity system for gradient manipulation

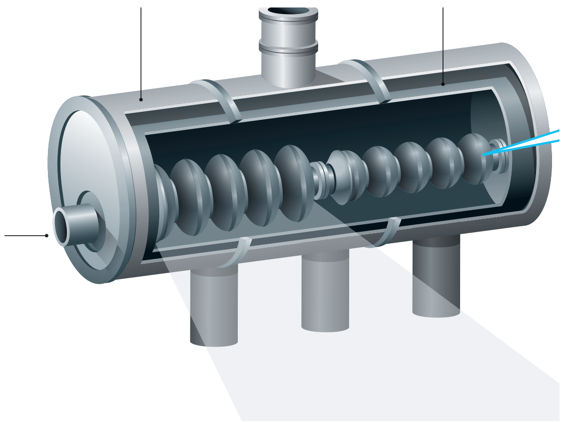
- Normal rf cavity

  $U' = 2\pi\ 0.5\ 1.5\,\mathrm{GHz}\,\mathrm{MV}$

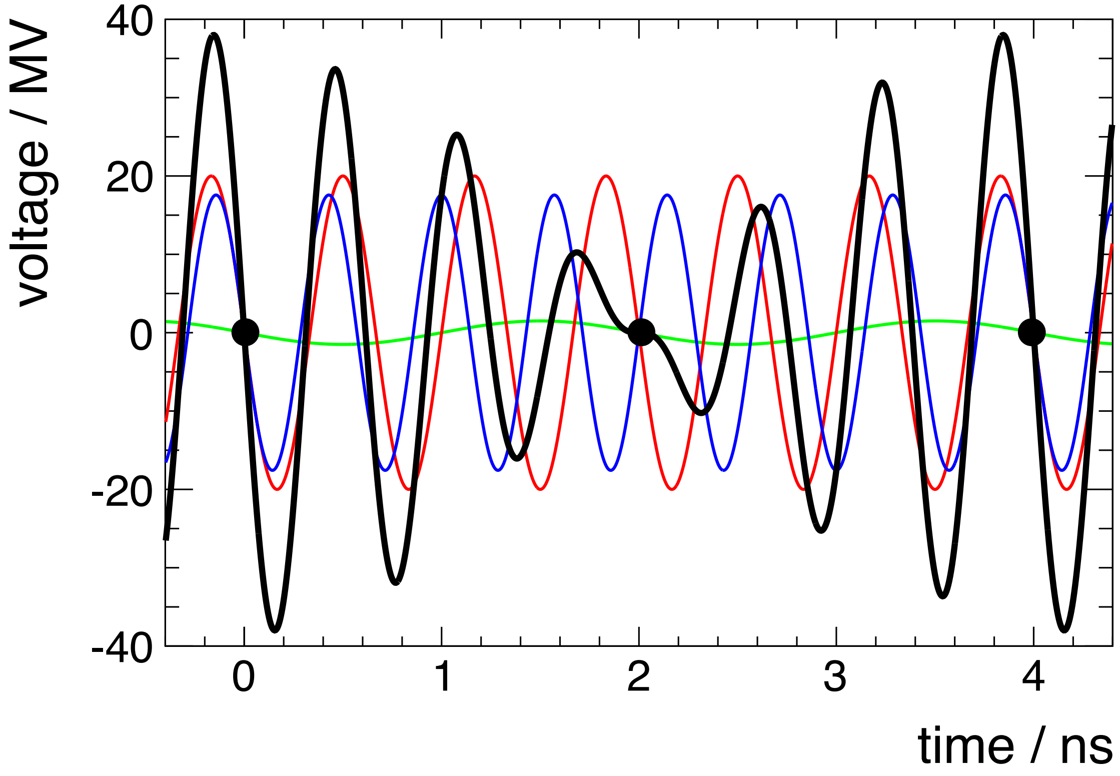
- 1$^{\mathrm{st}}$ sc cavity
  3rd harmonic

  $U' = 2\pi\ 1.5\ 20\,\mathrm{GHz}\,\mathrm{MV}$



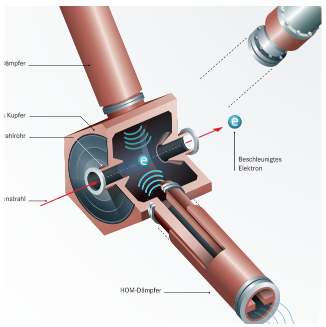


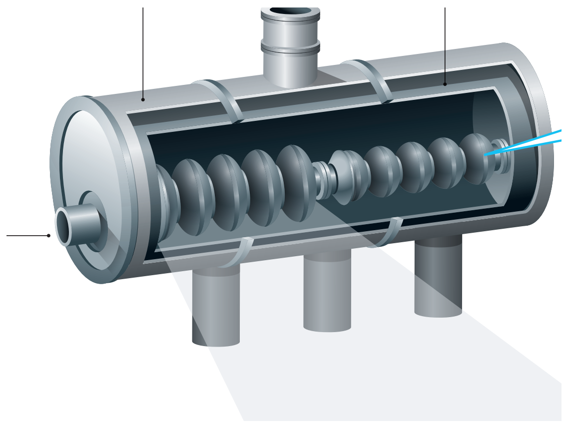
BESSY VSR - Short and long bunches simultaneously

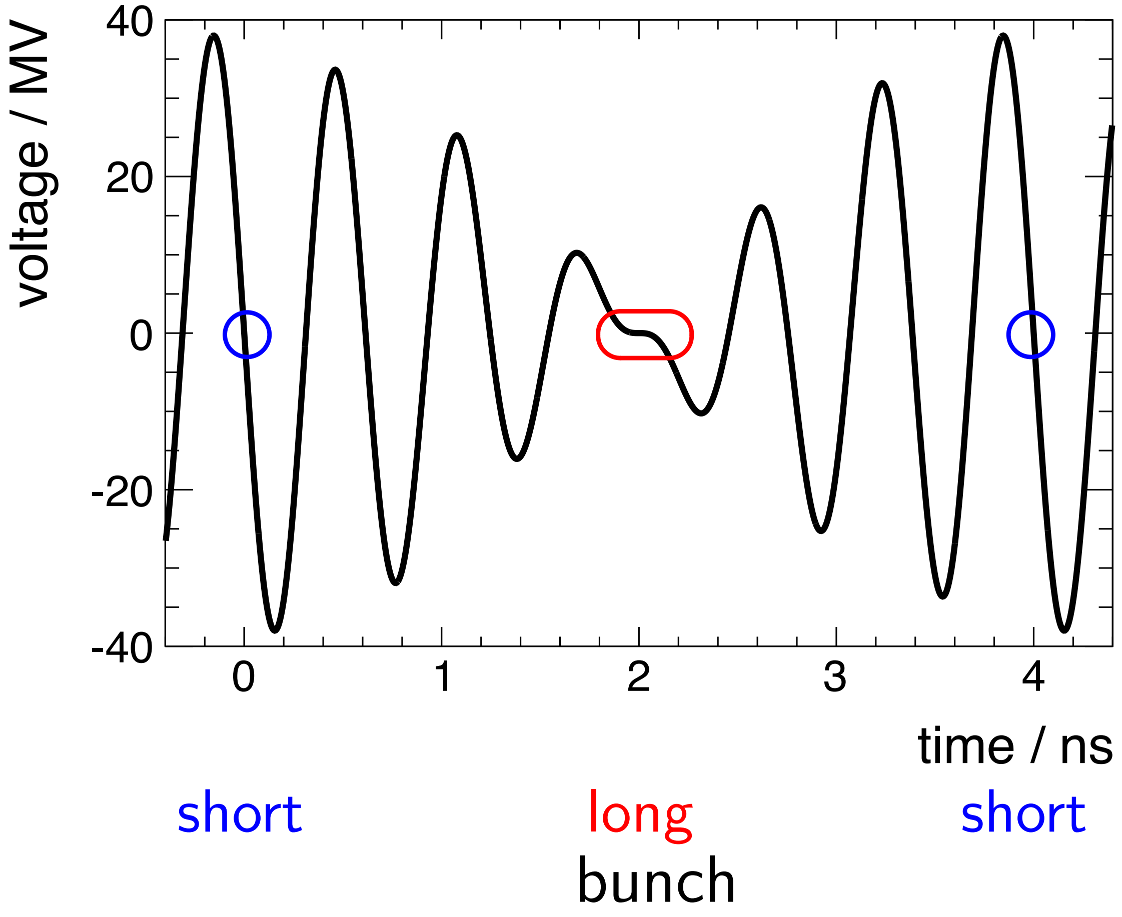


Cavity system for gradient manipulation

- Normal rf cavity
  $U' = 2\pi\ 0.5\ 1.5\,\mathrm{GHz\,MV}$
- 1st sc cavity
  3rd harmonic
  $U' = 2\pi\ 1.5\ 20\,\mathrm{GHz\,MV}$
- 2nd sc cavity
  3.5th harmonic
  $U' = 2\pi\ 1.75\ 17.1\,\mathrm{GHz\,MV}$
- Beating pattern, large and small gradient U'



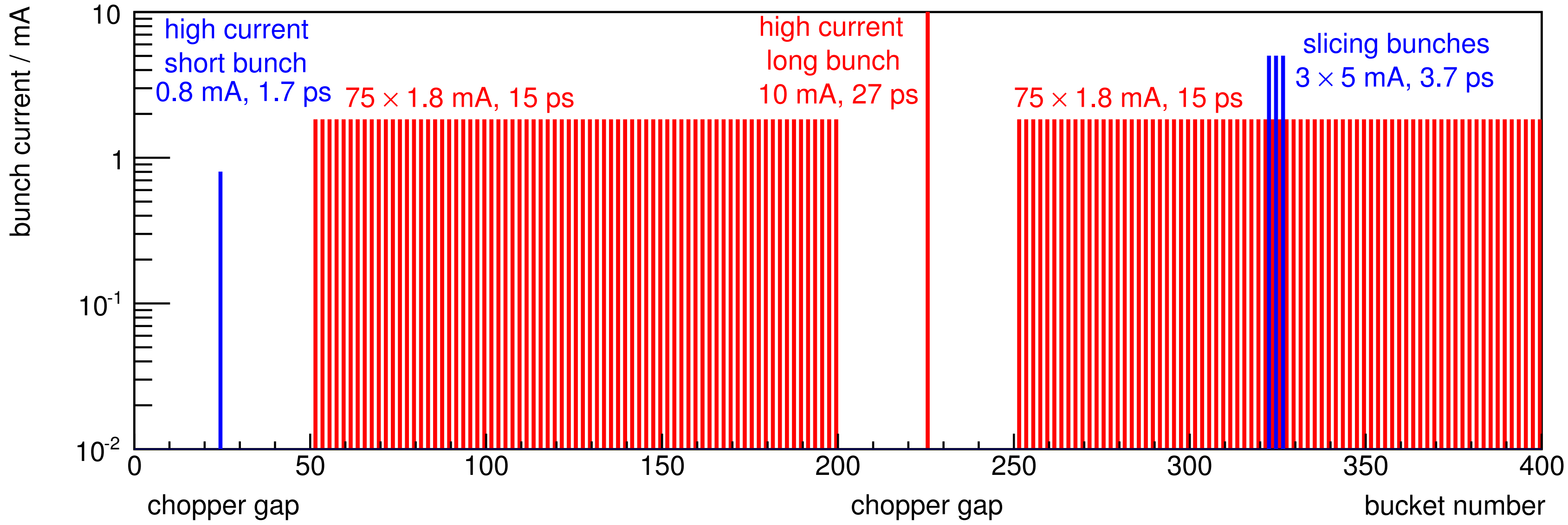




- Beating pattern, large and small gradient U'
- Short and long bunches
- Short $\sigma_{0,s} = 1.7\,\mathrm{ps}$
- Long $\sigma_{0,l} = 15\,\mathrm{ps}$

$\rightarrow$ Variable pulse length Storage Ring

BESSY VSR fill pattern / key parameters

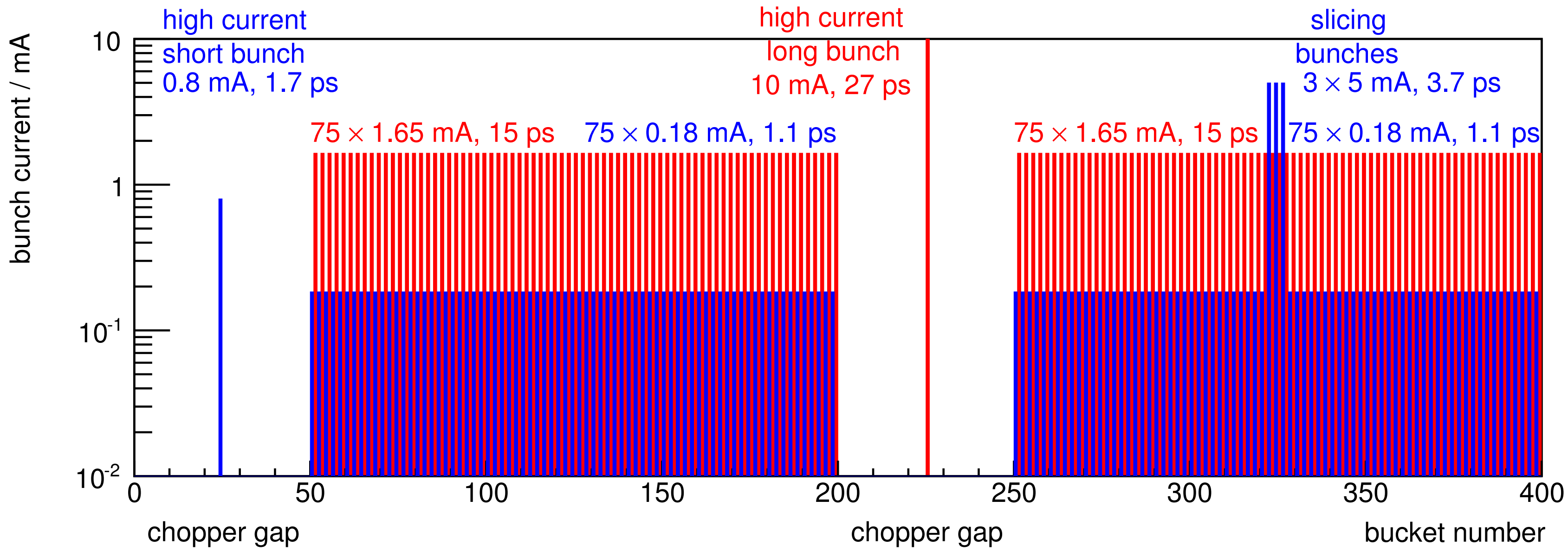


Multi functional hybrid mode

- 300 mA average current, high current single bunch and **ps short bunch**, slicing bunches,
- Low α mode: 3 ps and 0.35 ps bunches $\rightarrow$ bunch length limitation
- Mandatory: Preserving BESSY II emittance and TopUp capabilities

$\rightarrow$ $\varepsilon_x = 5\,\mathrm{nm\,rad}$, lifetime $\geq 5\,\mathrm{h}$, average injection efficiency $\geq 90\%$

BESSY VSR fill pattern / key parameters



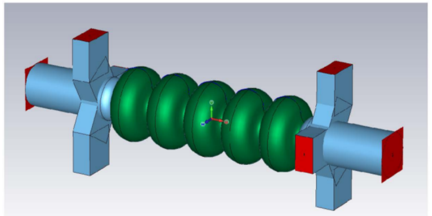
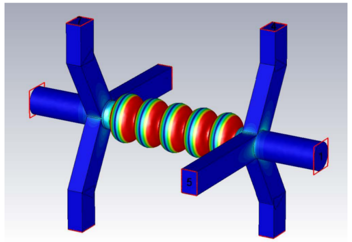
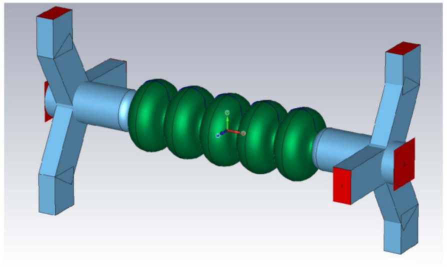
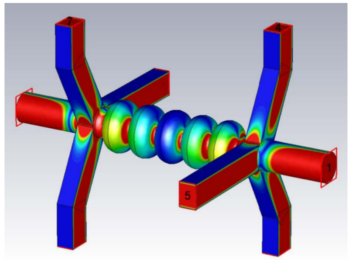
Multi functional hybrid mode

- 300 mA average current, high current single bunch and **ps short bunch**, slicing bunches, Short high repetition rate bunches
- Low α mode: 3 ps and 0.35 ps bunches $\rightarrow$ bunch length limitation
- Mandatory: Preserving BESSY II emittance and TopUp capabilities

$\rightarrow$ $\varepsilon_x = 5\,\mathrm{nm\,rad}$, lifetime $\geq 5\,\mathrm{h}$, average injection efficiency $\geq 90\%$

High-gradient SC HOM cavities in cw operation

- High frequency, high field
- Multi-cell, SC, HOM damped
- Compact, one straight 4.2 m

Parameters:

$E_{acc} = 20\,\mathrm{MV/m}$, $\frac{E_{pk}}{E_{acc}} \leq 2.3$,

$\frac{B_{pk}}{E_{acc}} \leq 5.3\,\mathrm{mT}$, $R/Q = 525\,\Omega$

CBI threshold

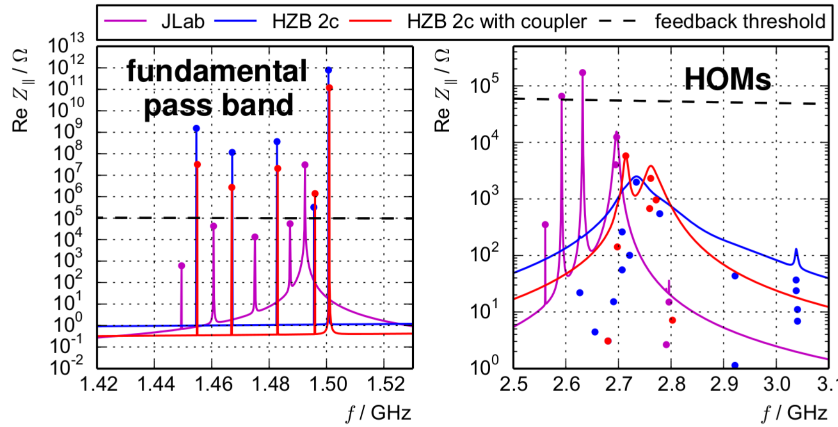
Syn.Rad. damping
$\tau_{x,y} = 16\,\mathrm{ms}, \quad \tau_z = 8\,\mathrm{ms}$

BBFB damping
$\tau_{x,y} = 0.25\,\mathrm{ms}, \quad \tau_z = 0.75\,\mathrm{ms}$

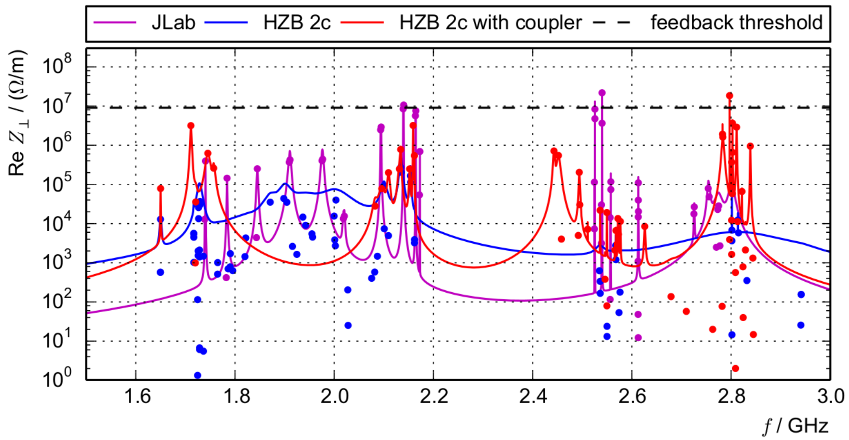
Impedance thres.:

growth rate = damping rate

Longitudinal



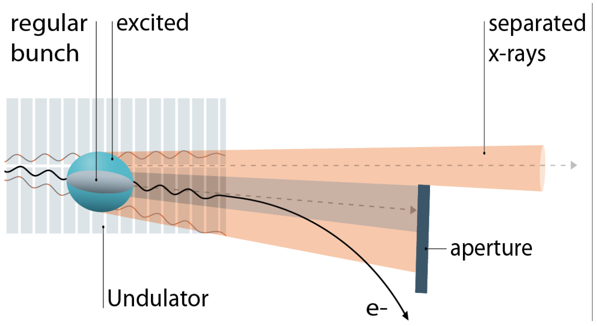
Transverse



BESSY VSR - Separation schemes

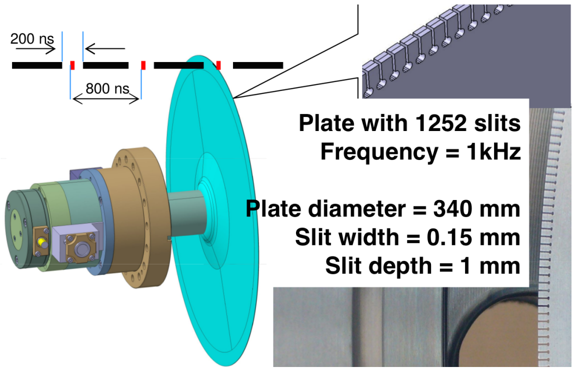
Established methods

- Resonant X-ray Pulse Picking
  ARTOF at UE52 and UE56/2



K. Holldack et.al., Nature Com. 5, 4010, 2014

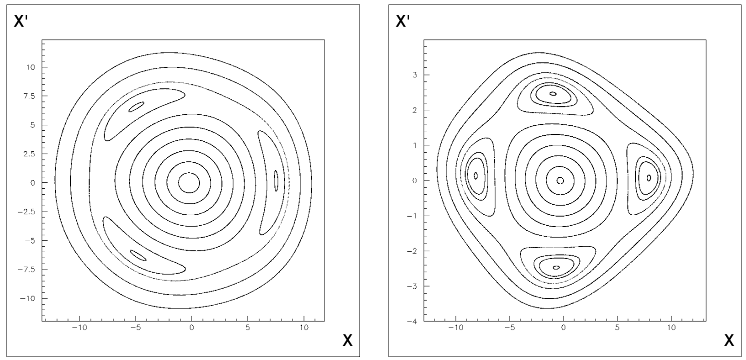
- MHz Chopper system

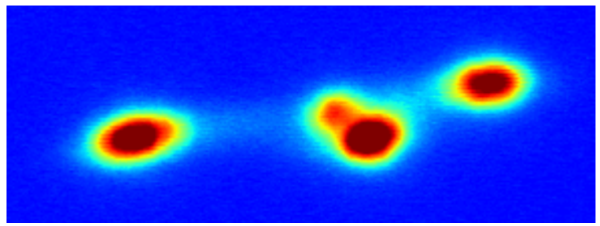


FZ Jülich and BESSY

Methods under development

- **Resonance Island Buckets**
  → Machine on resonance
  → Separate orbit for SB





- Pulse excitation
  → Fast kicker
  → Transverse deflecting cavity

BESSY VSR objectives

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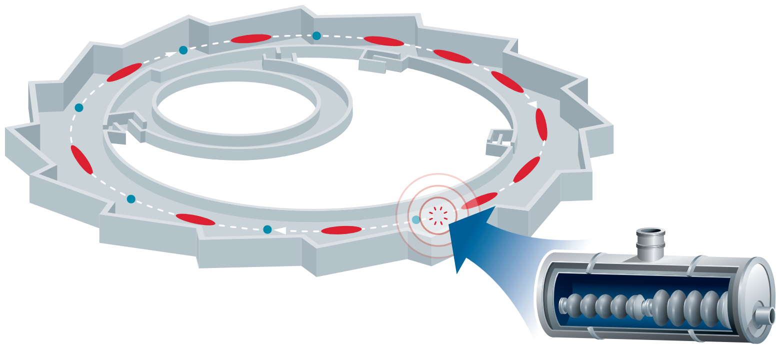
- Conserving photon brilliance (emittance) for all users

→ **V**ariable pulse length **S**torage **R**ing



Two positive reviews:

→ POF and BESSY II MAC

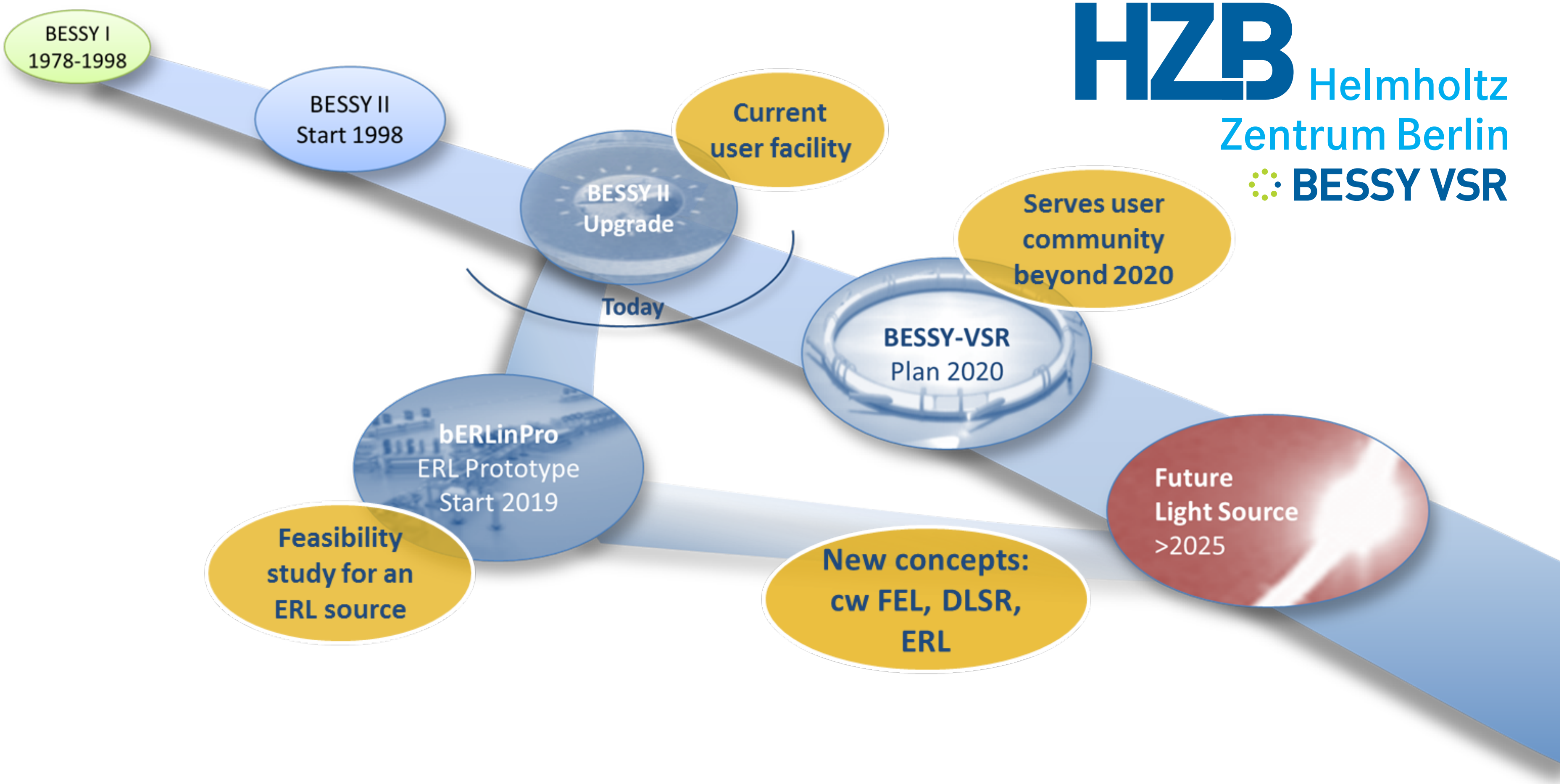
Project schedule

2011	Idea G.Wuestefeld et. al.
2014	Shown at POF → Prepare TDS
2015/03	Technical Design Study ready (http://dx.doi.org/10.5442/R0001)
2015/04	Review of TDS by BESSY II MAC
2015/06	Application to Helmholtz Association
2016/Q1	Decision about funding
2018	First money from Helmholtz

Start preparatory phase in advance (NOW) to gain as soon as possible experience with such a system

2015	Preparatory phase (MC time)
2018	First beam test of prototype module (7 weeks dark time)
2020+	Full VSR installation, start user operation (22 weeks dark time)

Thank you for your attention



HZB Helmholtz Zentrum Berlin
BESSY VSR

bERLinPro

HZB Helmholtz Zentrum Berlin

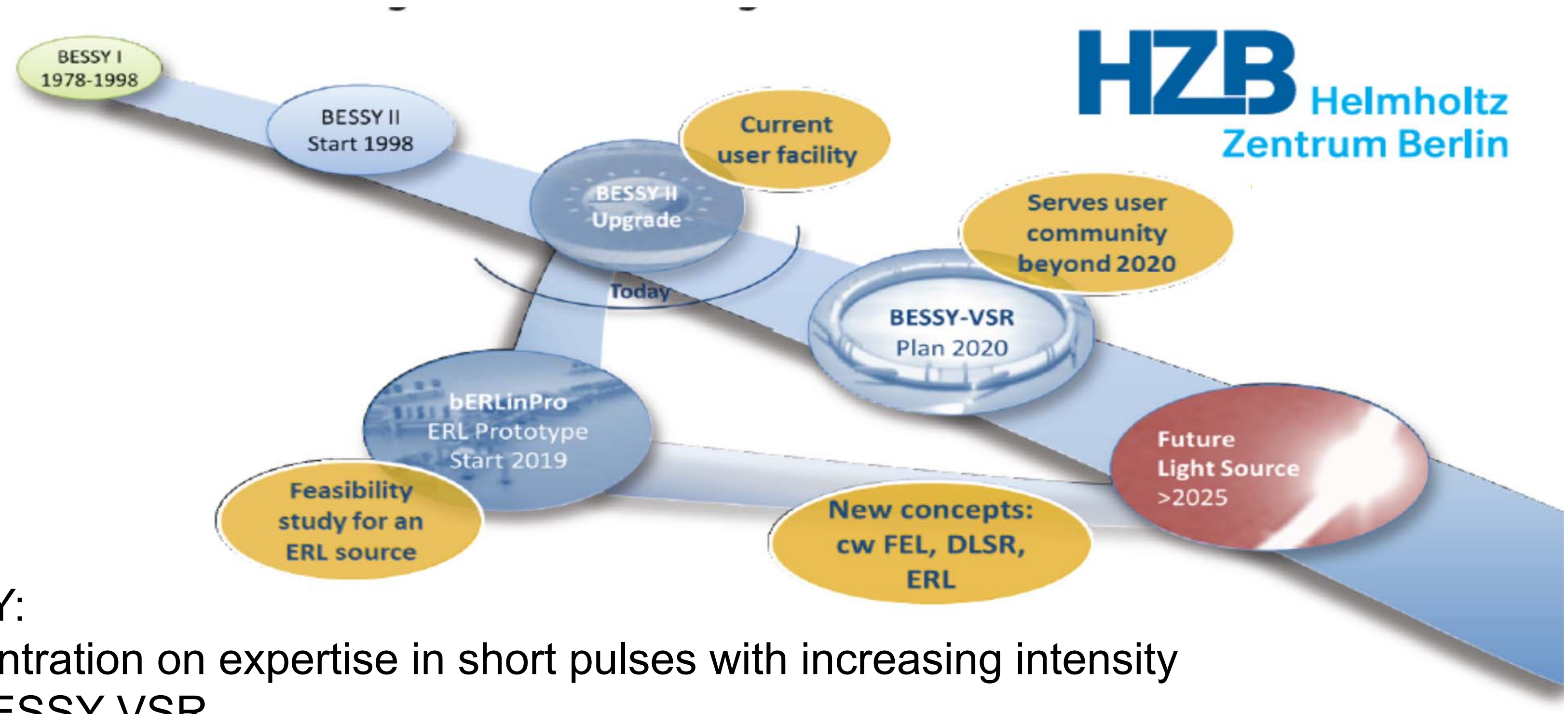
Status of bERLinPro

B. Kuske for the bERLinPro project team

The bERLinPro Team

M. Abo-Bakr, W. Anders, R. Barday, A. Bondarenko, A. Burrill, A. Büchel, K. Bürkmann-Gehrlein, V. Dürr, P. Echevarria, A. Frahm, H.-W. Glock, B. Hall, S. Heßler, A. Jankowiak, C. Kalus, T. Kamps, V. Khan, G. Klemz, J. Knobloch, J. Kolbe, J. Kühn, O. Kugeler, B. Kuske, P. Kuske, M. McAteer, A. Matveenko, R. Müller, A. Meseck, C. Metzger-Kraus, G. Meyer, A. Neumann, N. Ohm, K. Ott, E. Panofski, Y. Petenev, F. Pflocksch, D. Pflückhahn, T. Quast, J. Rahn, S. Rotterdam, J. Rudolph, M. Schmeißer, T. Schneegans, S. Schubert, O. Schüler, J. Völker, S. Wesch ... and more temporary supporters from HZB

Introduction



BESSY:

Concentration on expertise in short pulses with increasing intensity

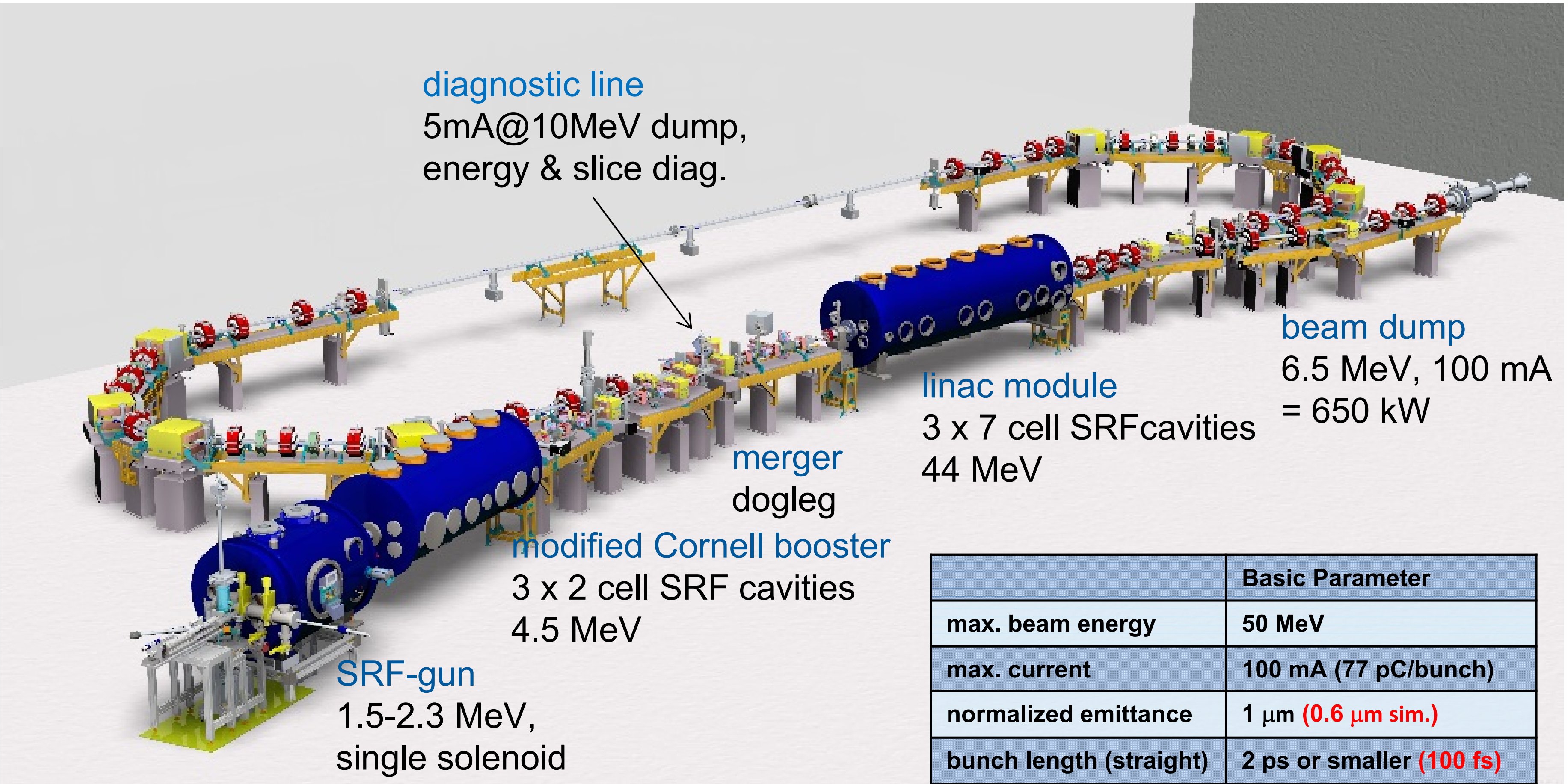
=> BESSY VSR

=> Energy Recovery Linacs

- ✓ Single pass devices – supreme properties of new injectors can be preserved
- ✓ Enabling technology increasingly accessible
  High current injectors, SRF technology, modern photocathodes
- ✓ Compatibility with SR: 100mA, <1mm mrad emittance (normalized), few GeV, multi-user operation
- \- ERLs in operation: low energy, low current, large emittance, not multi-user

bERLinPro – Berlin Energy Recovery Linac Project

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



	Basic Parameter
max. beam energy	50 MeV
max. current	100 mA (77 pC/bunch)
normalized emittance	1 μm (0.6 μm sim.)
bunch length (straight)	2 ps or smaller (100 fs)
rep. rate	1.3 GHz
losses	< 10^{-5}

Main Challenge

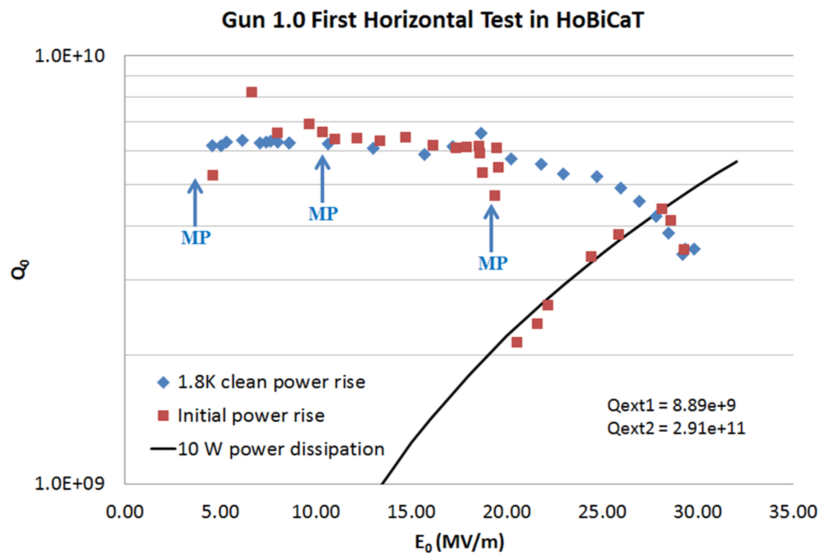
bERLinPro

SRF photoinjector, 1.4cell gun cavity, with SC solenoid, 1.5 – 2.3 MeV

Jefferson Lab : cavity production

Challenge:

- Performance not demonstrated to date
- 30 MV/m CW operation
- CsK2Sb nc cathode =>100 mA
- Dark current/halo control
- Emittance preservation



Horizontal test @ HZB confirms vertikal results @ JLab

Status:

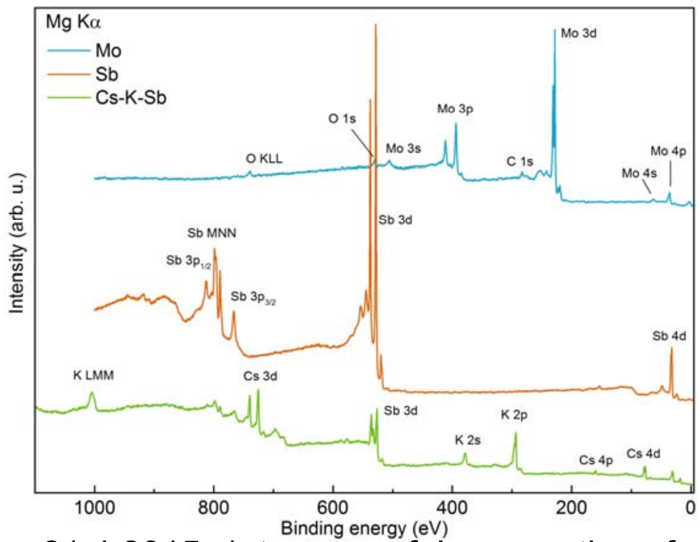
- 1.4 cell cavity produced at Jlab with some difficulty also due to tight 0.4 cell – close to specs
- Cavity@ HZB and quality confirmed in horizontal test
- Module tank is in house
- Cold string assembly Mid-August 15

Main Challenge

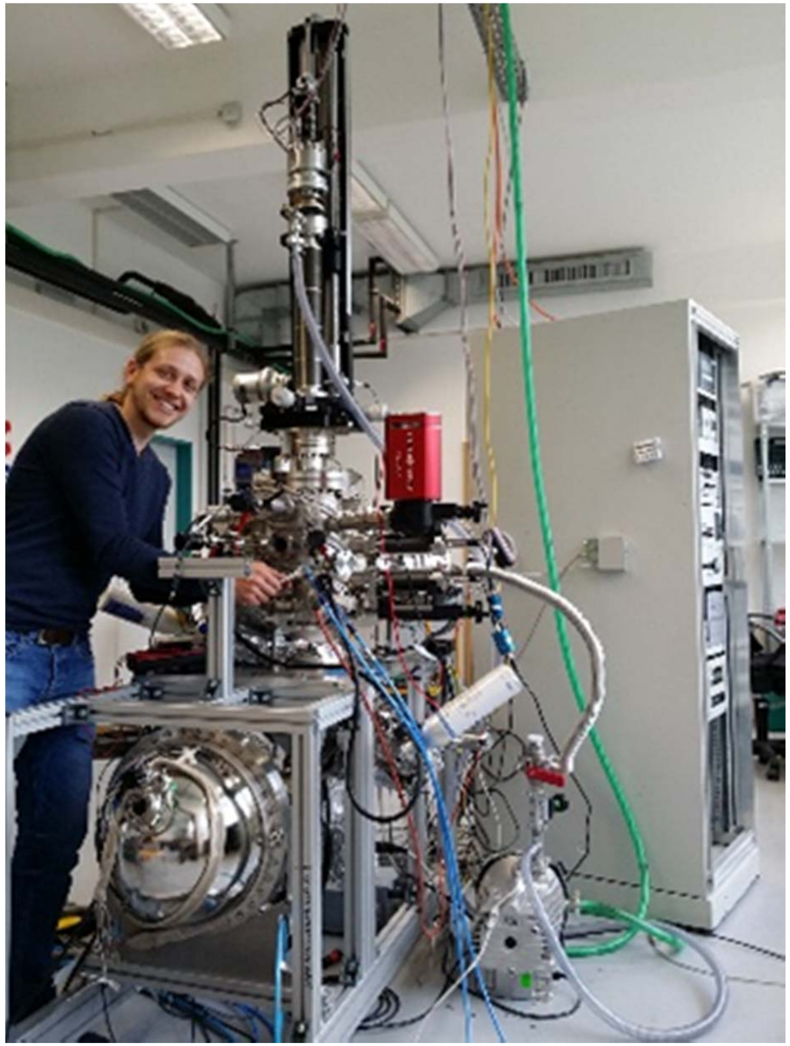
Photocathode production and analysis teststand

Goal: Develop a more systematic approach to cathode preparation by situ analysis during production

- XPS => electronic structure
- LEIS => composition
- QE v. wavelength
- "Momentatron" => therm. emittance



21.4.2015: 1st successful preparation of a Cs-K-Sb layer and characterization by XPS



Cathode growth and analysis chamber at HZB

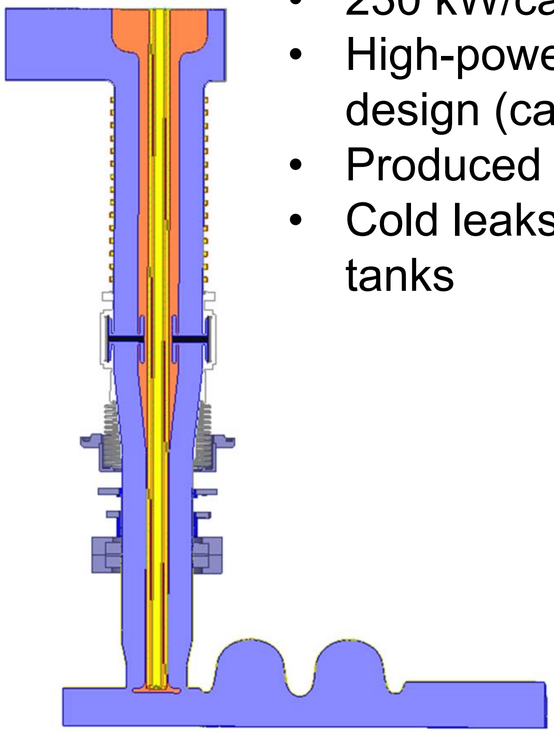
bERLinPro

Booster, 3 x 2 cell SRF cavities, 4.5 MeV

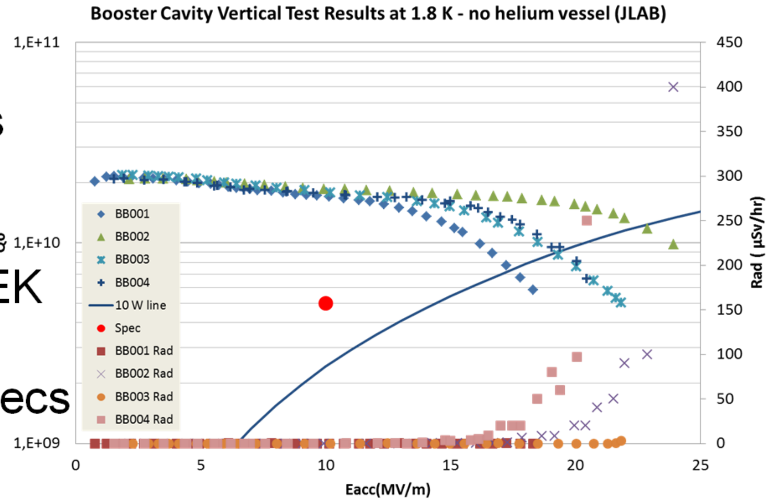
Jefferson Lab : cavity production

Challenges:

- 3 acc. cavities ⇔ 5 acc. cavities (Cornell)
- 230 kW/cavity beam loading!
- High-power coupler modified KEK design (call for tender)
- Produced cavities exceeding specs
- Cold leaks after welding of HE-tanks



Work by Vasim Khan



Vertical test of booster cavities exceeds specs.

SRF auxiliaries:

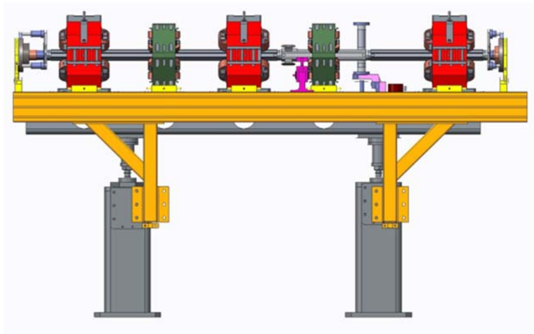
- Vertical test stand in operation (2 cell cavities)
- Cleanroom in operation
- 270kW klystron based transmitter in house
- 15kW solid state transmitter prototype in operation
- Cryogenic plant call for tender ongoing

Warm Systems - Status

Magnet and Girder Production and Installation

- Contract awarded Q1 2014
- Final design review Q4 2014
- Delivery Q3 2016

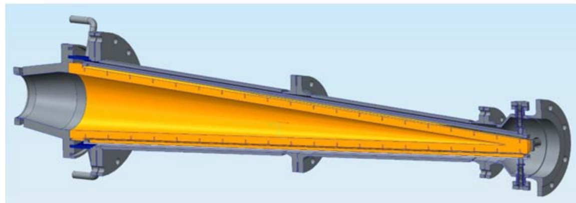
Budker Institute of Nuclear Physics



High Power Beam Dump (650kW)

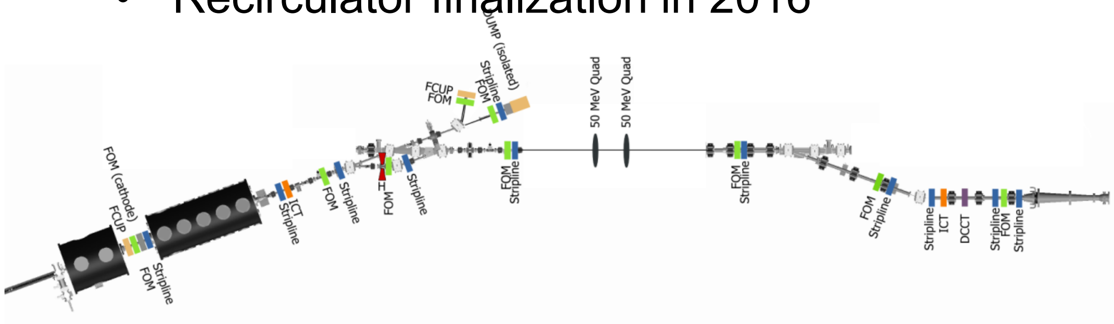
- Delivery Q3 2015
- Temperature and out gassing tests
- Local lead shielding: 21t of lead to prevent air activation

research instruments



Vacuum System

- “Banana” (low energy part of the machine) constructed and ready to place the call for tender
- Recirculator finalization in 2016

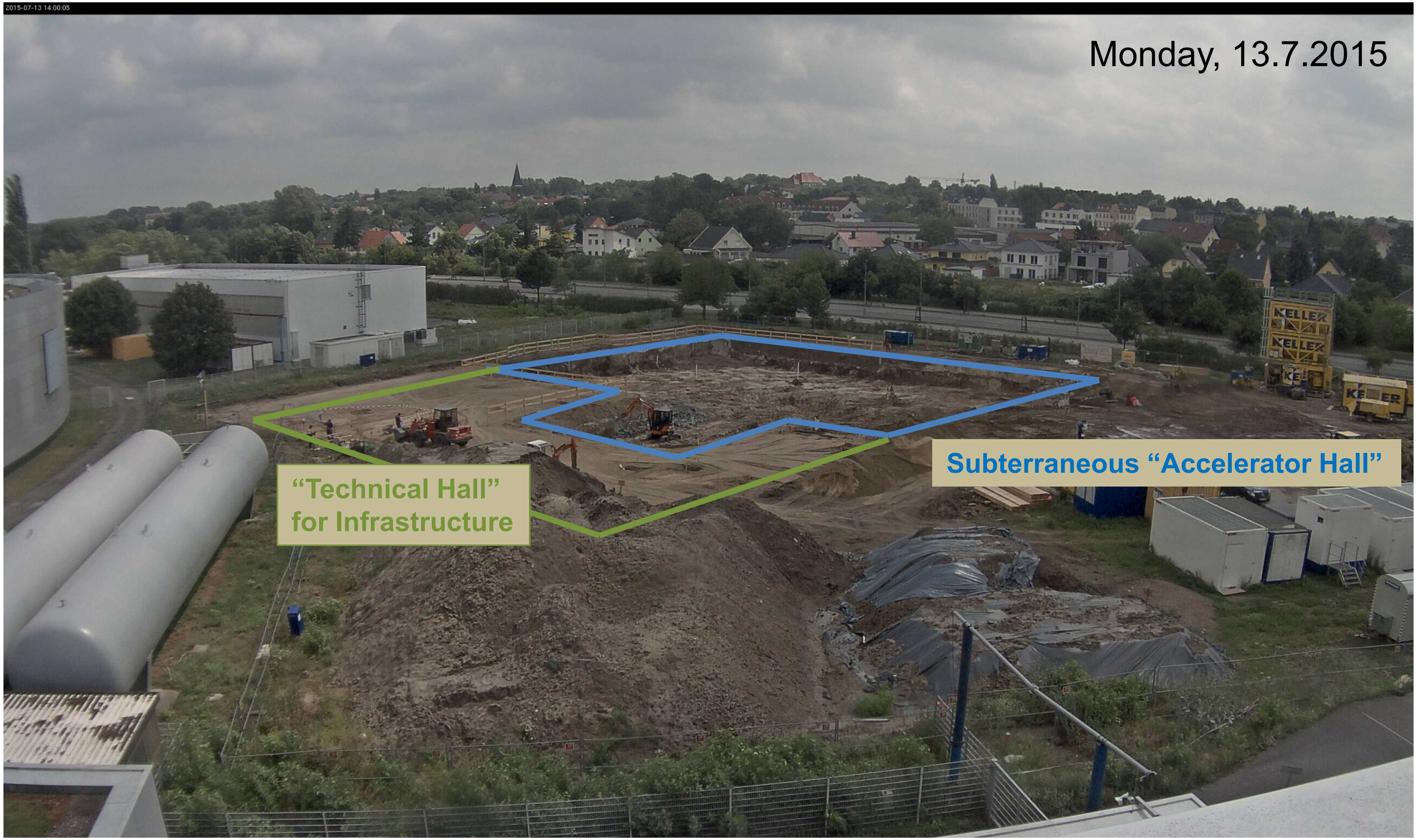


Diagnostics

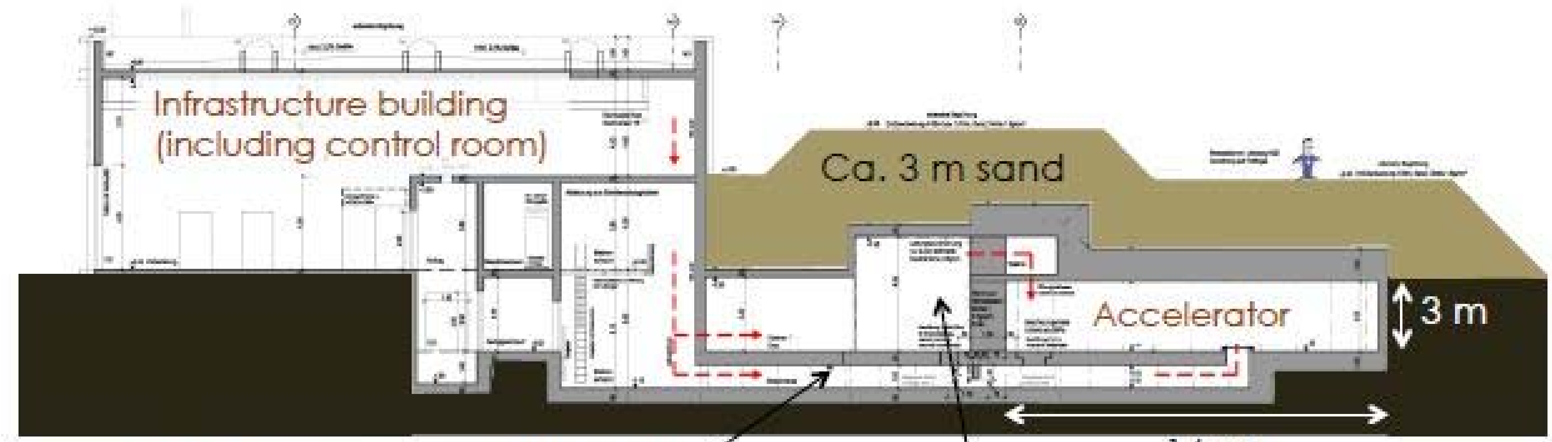
- Concept developed
- “Banana” test bed
- Components partly ordered / in development

Construction Site

bERLinPro



Time Table



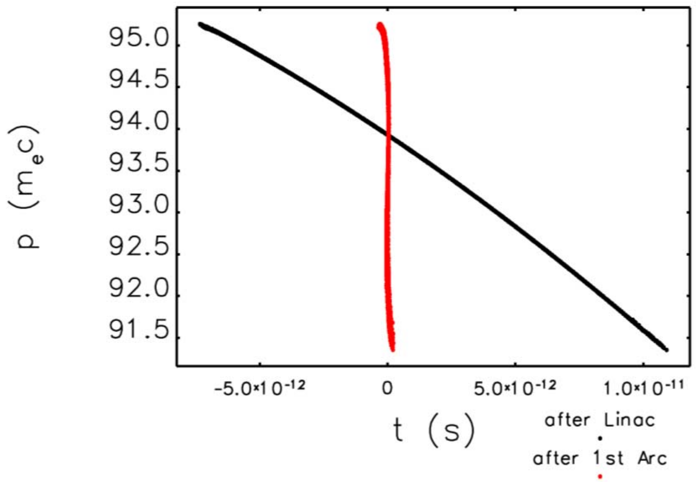
Time table:

- HGF application 10/2008
- Funding received 10/2010
- Complete redesign necessary mainly due to underestimation of radiation shielding/construction costs
- 2 years delay in construction due to change in personal, insolvency of planning team and law suit between construction companies. Start of trough construction 3/2015, official “ground breaking” 10.9.2015
- Building ready for bERLinPro occupancy Dec. 2016 / First electrons gun-to-dump May 2018.
- Recirculation September 2019.

bERLinPro

Even shorter pulses in bERLinPro
(work by A. Ginter)

- Single pass device / no extended equilibria
- 2ps pulse length in standard mode / 100mA
- Compression in injector or arc
- Limit of compression @ 77pC is CSR
- Flexible injection:
  - different repetition rates or charge



Example for arc-compression of 77pC bunch. Result: 100fs

	Bunch length [ps]	Bunch charge [pC]	Emittance [π mm mrad]
Standard mode	2	77	0.6 /0.6
Short pulse mode *	0.1	77	2.4/1.4

*: using standard arc settings

Recent Publications (2015)

bERLinPro

2015

Reviewed journals:

G. Pöplau, U. van Rienen, A. Meseck, Numerical Studies of the Behaviour Of Ionized Risidual Gas in an Energy Recovery Linac, PRST-AB 18, 044401 (2015)

S. Lagotzky, R. Barday, A. Jankowiak, T. Kamps, C. Klimm, J. Knobloch, G. Mueller, B. Senkovskiy, and F. Siewert, Prevention of electron field emission from molybdenum substrates for photocathodes by the native oxide layer, Eur. Phys. J. Appl. Phys. (2015) 70: 21301

Conferences, talks, poster:

Matter and Technologies Kickoff Meeting:

J. Kühn, New Light on Photocathodes for High Brightness Electron Sources, Matter and Technologies Kickoff Meeting, ST1 Superconducting SRF Technology, WP2 Cathode Development, DESY, Hamburg, 26.02.2015

DPG-Frühjahrstagung 2015, Arbeitskreis Beschleunigerphysik, Wuppertal, 09. - 13. März 2015

M. A. H. Schmeißer, J. Kühn, T. Kamps, A. Jankowiak, Photocathode development and spectral response measurements at HZB

J. Völker, T. Kamps, A. Jankowiak, Aufbau eines optischen Messsystems zur Untersuchung von Halo- und Dunkelstrom in GunLab

T. Beutler, J. Völker, T. Kamps, A. Jankowiak, Vermessung eines supraleitenden Solenoids,

H. Vennekate, A. Arnold, T. Kamps, P. Kneisel, P. Lu, P. Murcek, T. Jochen, R. Xian, Transverse Emittance Compensation

IPAC2015, Richmond, VG, USA

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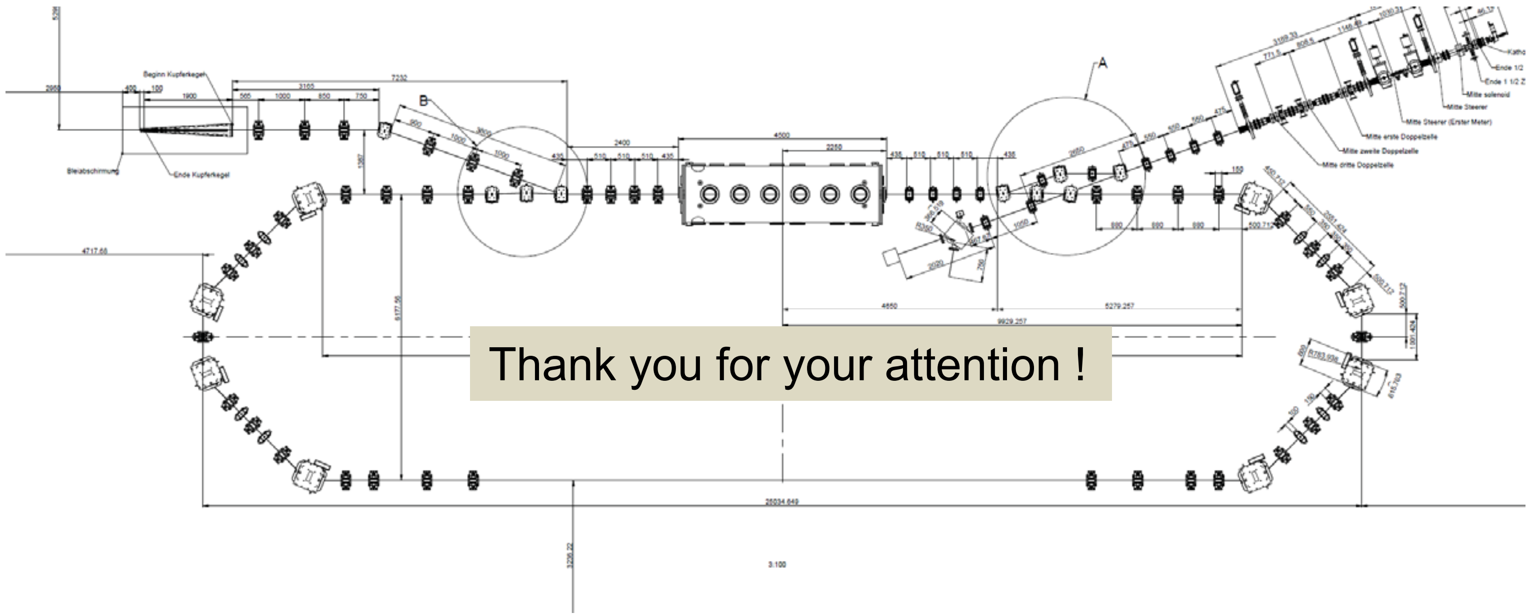

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