HZB BESSY II Light Source

HARMONIC CAVITIES @ HZB

BESSY II and MLS

11.10.2022, Markus Ries on behalf of the HZB machine group

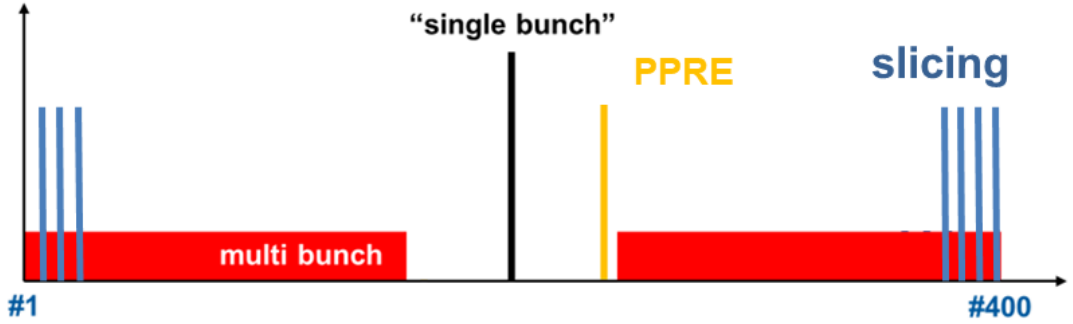
https://indico.maxiv.lu.se/event/5098/contributions/6747/

!harmagic!

HZB / Dirk Laubner

BESSY II

hybrid filling pattern operation
→ flux, brightness, timing



single bunch, few bunch → timing 100ps

low-Alpha → timing 2ps, coherent THz radiation

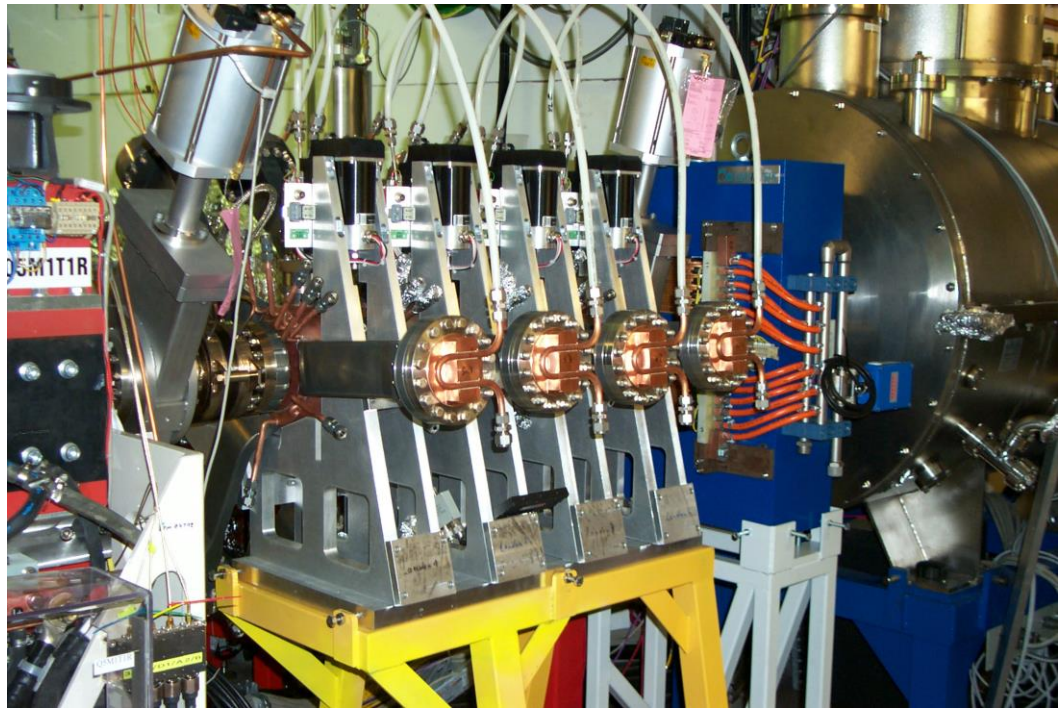
- 1988 design, 1994 ground breaking, 1998 user operation
- 1.7 GeV, 300 mA
- decay machine with TopUp upgrade
- slicing facility upgrade
- superconducting wave length shifter (x2)
- in-vacuum undulator
- 4 x 500 MHz EU cavity → 1.4MV with ~75 kW beam loading

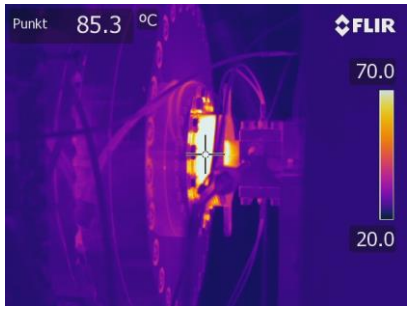
HARMONIC CAVITIES FOR BESSY II

- designed as
  - decay machine
  - without in-vacuum IDs
- harmonic cavities for bunch length control nice-to-have-technology
- high power incident
- → hardware kept alive **beyond its lifecycle, no spares**

bunch length sensitive experiments:
STXM, slicing, low-alpha (CSR)…

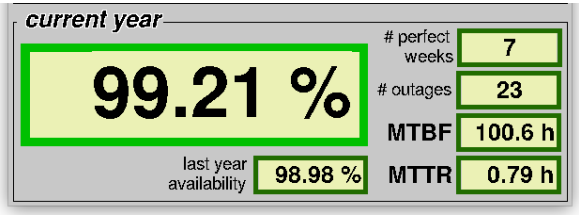
there probably will be another CPMU





Year	Scheduled	Availability
2013	4505 h	96.5 %
2014	5408 h	92.9%
2015	3896 h	97.6 %
2016	4855 h	98.7 %
2017	4299 h	94.2 %
2018	3578 h	99.2 %
2019	4058 h	98.3 %
2020	3455 h	98.5 %
2021	4960 h	98.9 %*

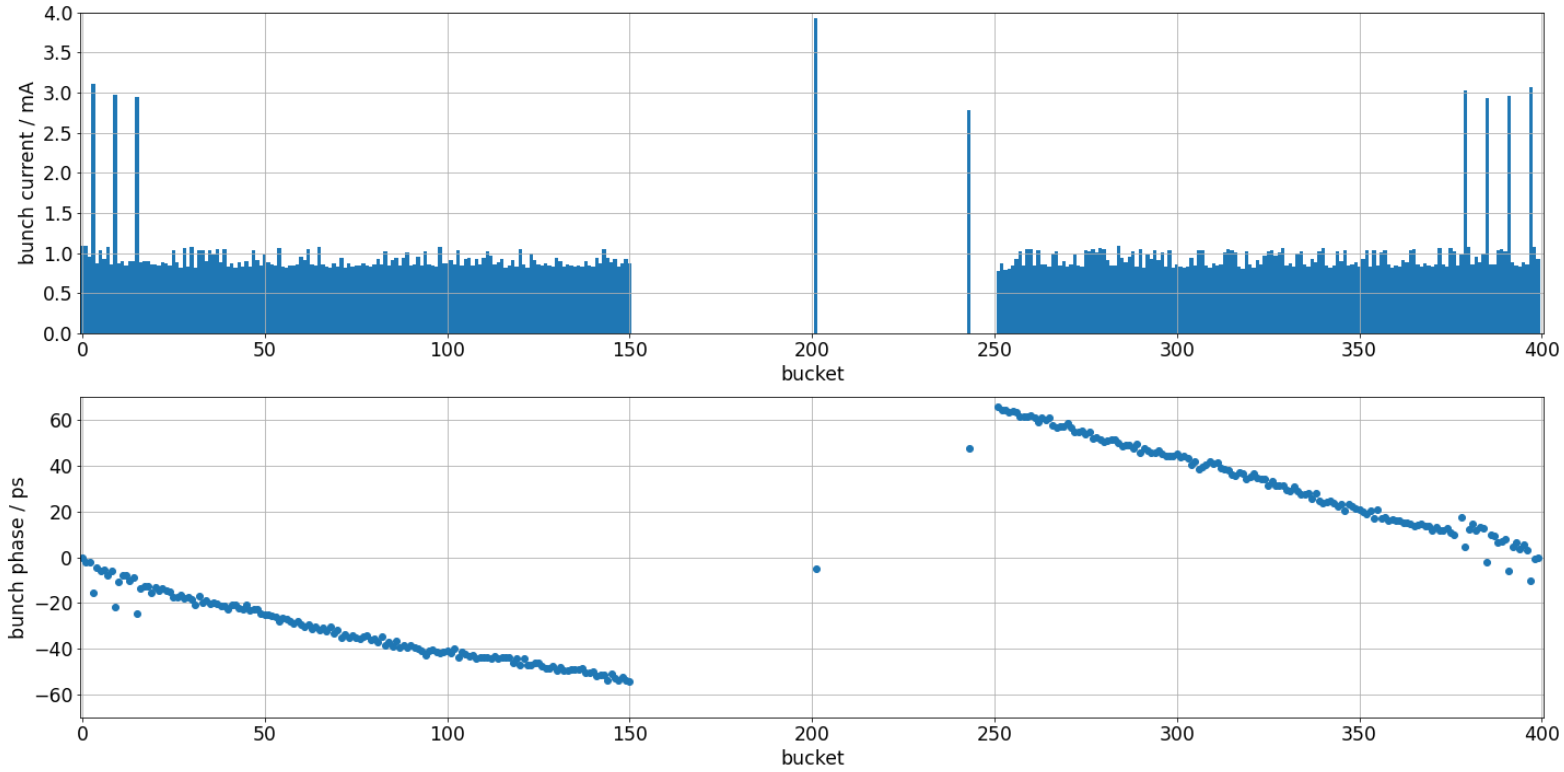
30% bunch lengthening, 25% lifetime increase



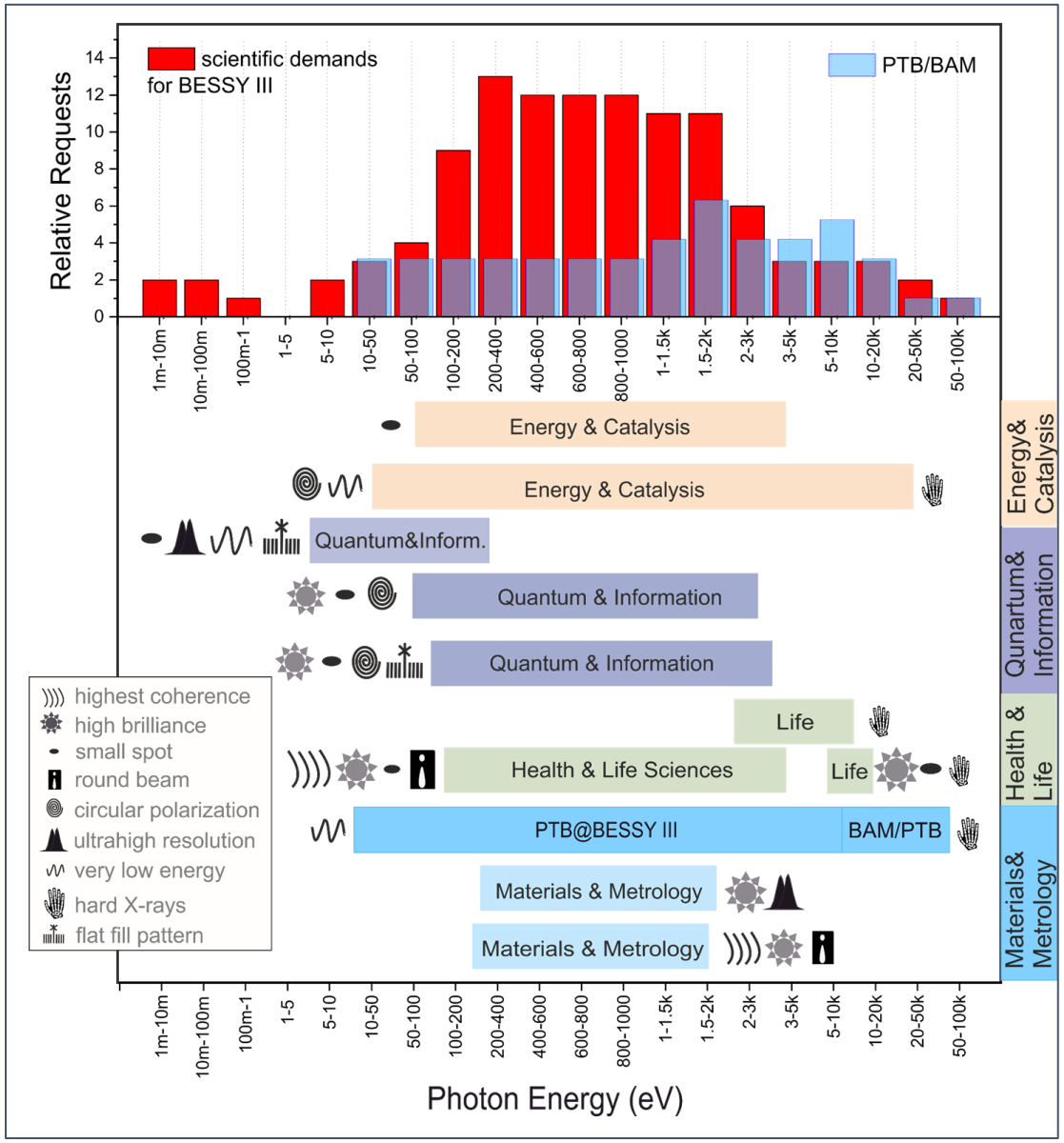
required for user operation of BESSY II *with state of the art in-vacuum insertion devices*

STABILITY & BEAM LOADING

- coupled bunch instability thresholds
  - transverse ~100mA
  - longitudinal ~ 250mA (dominated by passive cavities)
- large transient of ~120ps for standard fill pattern
- we try to convince our users to go towards shorter gap (200 ns → 60 ns)
  - hard with diverse user community
  - BESSY III perspective
- no temperature detuning for main or harmonic cavities
- “harmonic plunger” for 3rd harmonic



BESSY III



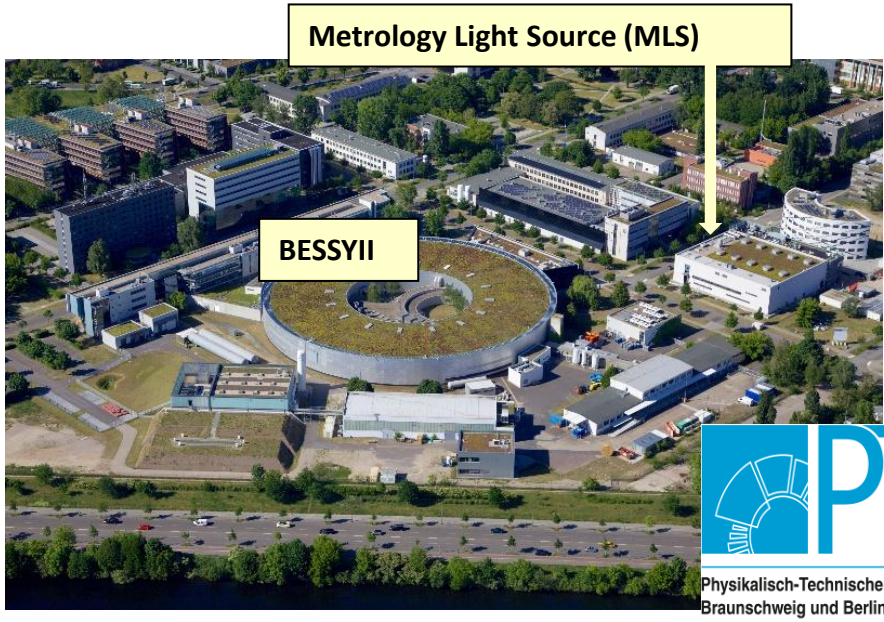
1. 1st ID harmonics polarized up to 1 keV from conventional APPLE-II undulator
2. Diffraction limited to 1 keV
3. Stay in Berlin-Adlershof with same capacity
4. Nanometer spatial res. & phase space matching
5. PTB/BAM metrology applications

1. Ring Energy **2.5 GeV** (1.7 GeV)
2. Emittance **100 pm rad** (5 nm rad)
3. Circ. **350 m**
   16 straights @ 5.6 m
   (240 m, 16 straights @ 4 m)
4. Low beta straights & Round beams
5. **Metrology – hom. bends**
6. Momentum **> 1.0e-4** compaction factor
   Bunch length **~ 10 ps**

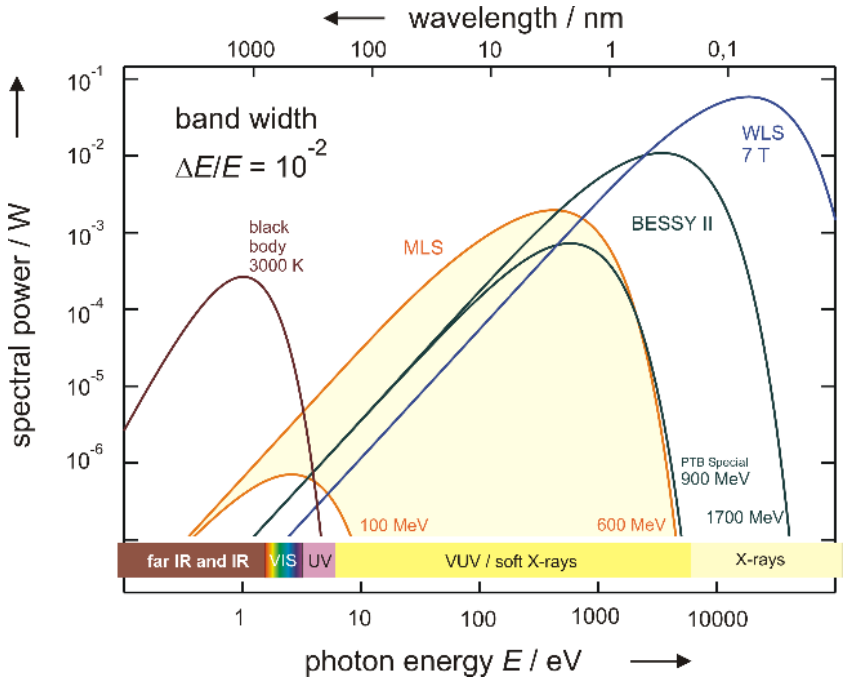
6 x 500 MHz EU cavity
6 x 1.5 GHz Harmonic EU cavity

Metrology Light Source

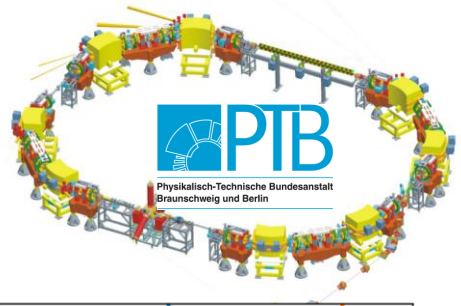
- user operation since 2008
- owned by PTB, designed & operated by HZB
- 38w/a standard operation, 8 weeks special operation



Circumference	**48 m**
Revolution frequency	f_{rev} = 6.25 MHz T_{rev} = 160 ns
Operational Energy	**50 MeV to 630 MeV**
Mom. Comp. Factor	$-5x10^{-2} < \alpha < 5x10^{-2}$
emittances at 630/250 MeV	**120**(Standard User) **30 nmrad** (SSMB)
RF frequency	**500 MHz**
One Undulator	**U125** λ_u = 125 mm



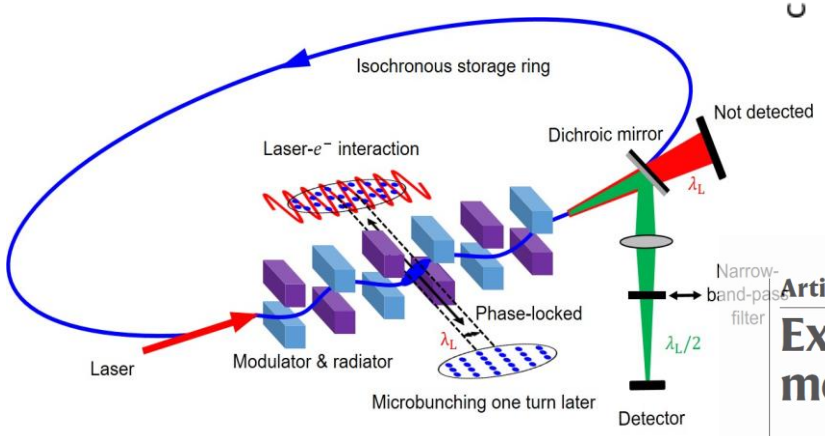
HZB BESSY II Light Source

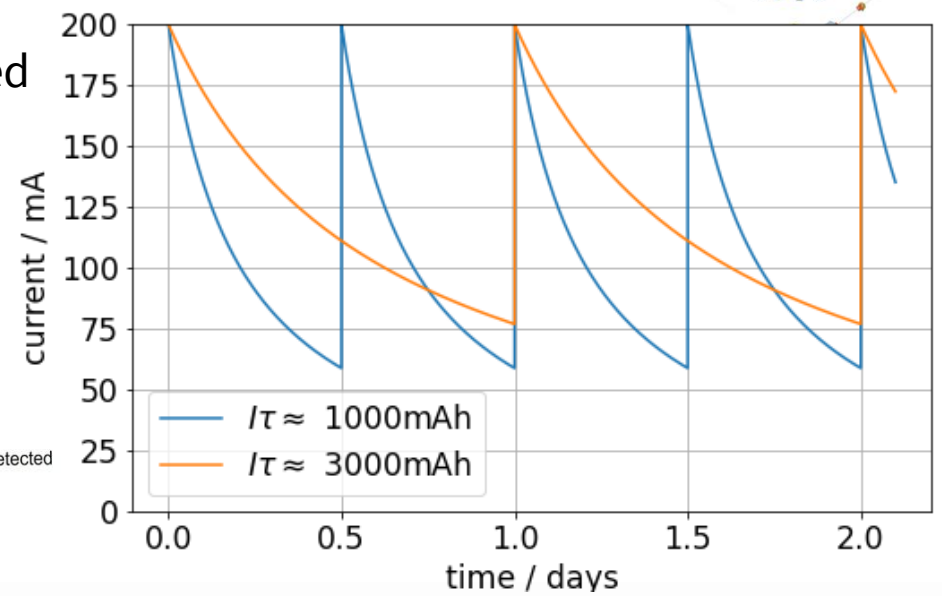


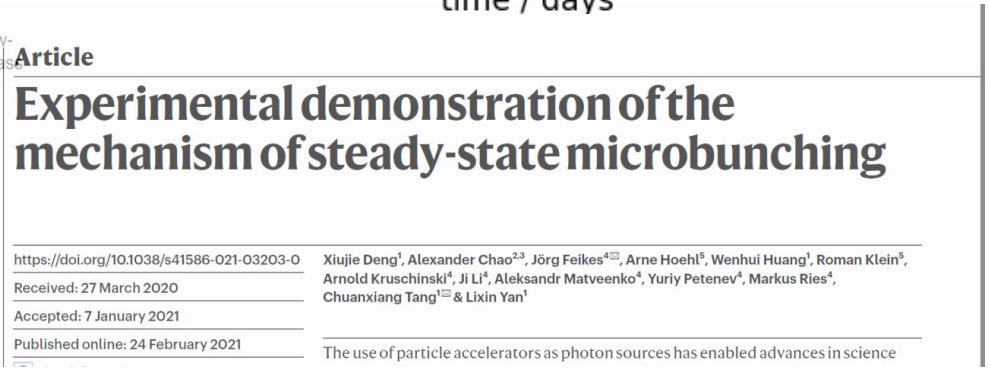
HARMONIC CAVITIES FOR MLS

- first storage ring optimized for low alpha operation by using a dedicated sextupole and octupole correction scheme
- unique conditions for experimental ARD towards steady state microbunching -> necessary condition for SSMB: $|\alpha| \leq 2 \times 10^{-5}$
- regular and frequent user operation in low-alpha (CSR)

operation conditions
- standard
  - homogeneous fill pattern, no gap
  - decaying beam
- low alpha
  - homogeneous fill pattern, no gap
  - decaying beam, 160 mA
- SSMB
  - short train, 10 µA






Article

Experimental demonstration of the mechanism of steady-state microbunching

https://doi.org/10.1038/s41586-021-03203-0
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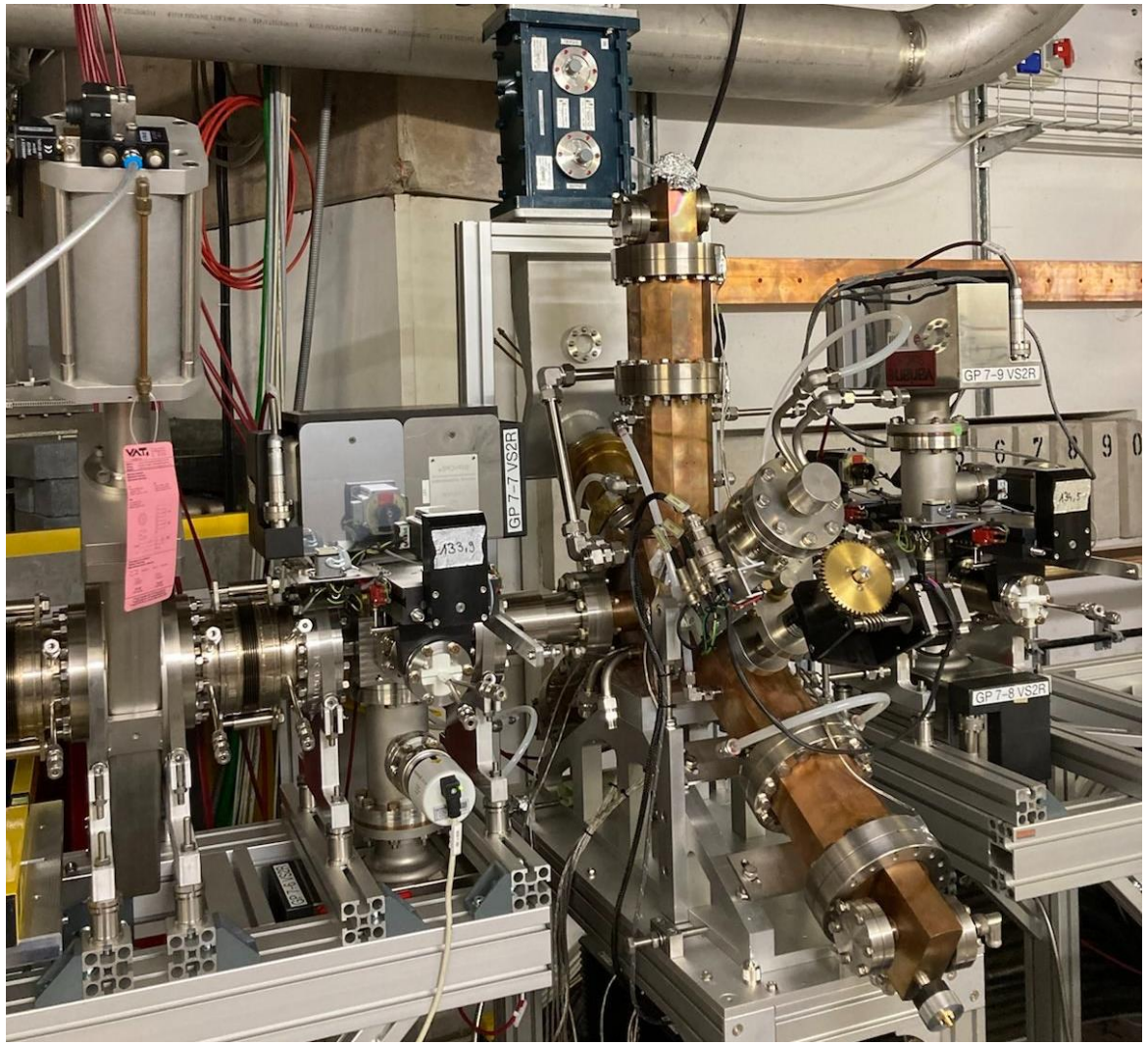
Xiujie Deng[1], Alexander Chao[2,3], Jörg Feikes[4]✉, Arne Hoehl[5], Wenhui Huang[1], Roman Klein[5], Arnold Kruschinski[4], Ji Li[4], Aleksandr Matveenko[4], Yuriy Petenev[4], Markus Ries[4], Chuanxiang Tang[1]✉ & Lixin Yan[1]

The use of particle accelerators as photon sources has enabled advances in science

Deng, X., Chao, A., Feikes, J. *et al.* Experimental demonstration of the mechanism of steady-state microbunching. *Nature* **590,** 576–579 (2021)

HARMONIC EU CAVITY

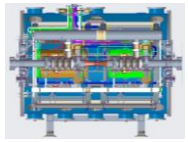
- ALBA Active Design
- collaboration ALBA/HZB/DESY
- under commissioning
- in operation at BESSY II at this very moment (parked at -4.5 rev. harmonic, transmitter off)

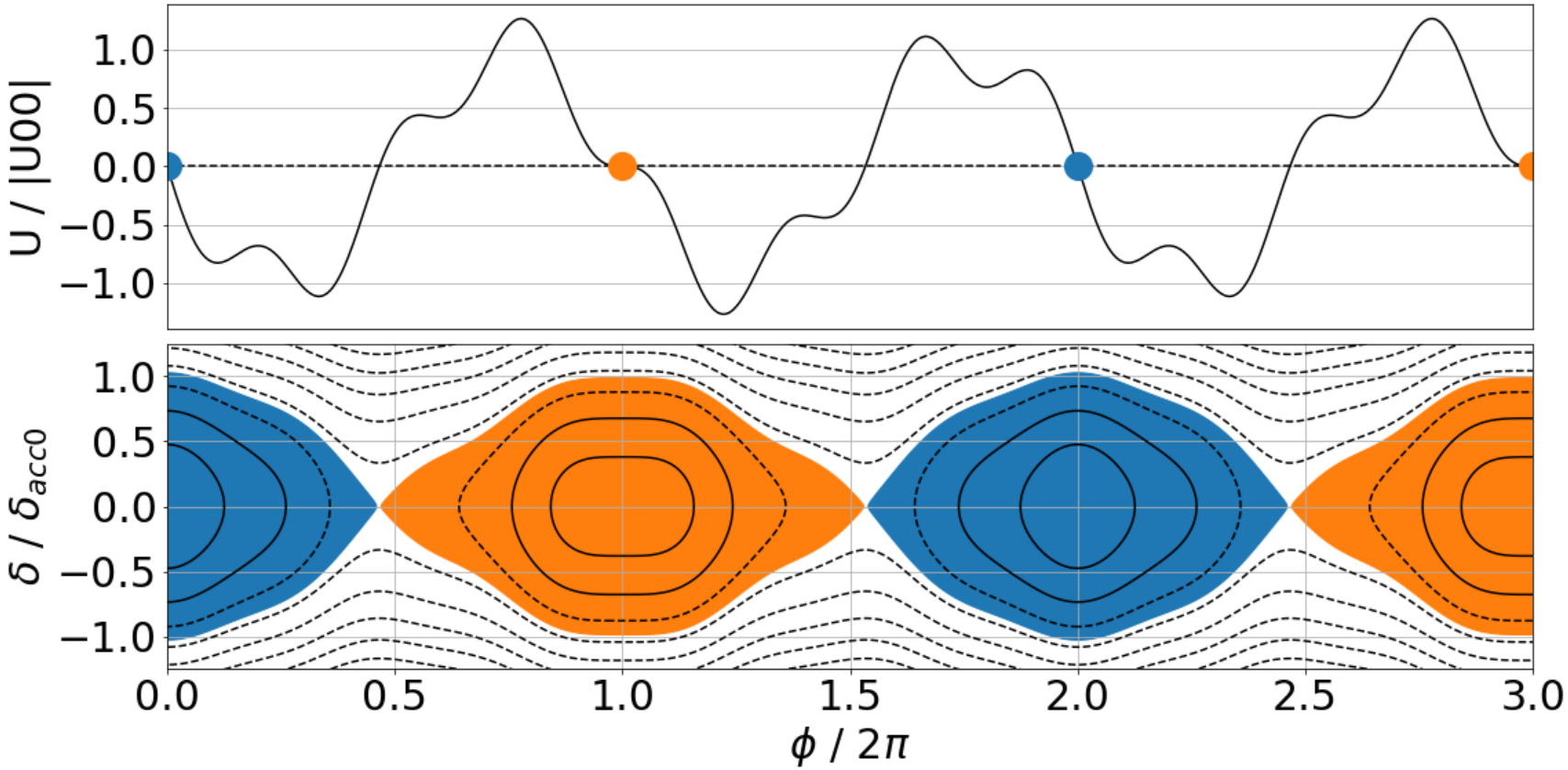


→ talk of Alexander Matveenko today 15:55

3.5TH HARMONIC CAVITY @ 1.75 GHZ

- VSR “light”
  instead of shorten every 2nd bunch
  → lengthen every 2nd bunch
- voltages of 3rd and 3.5th harmonic defined by main RF gradient, momentum acceptance, bunch length
- see the talk of Adolfo Velez
  Wed. 12, 10:10





R&D with potential relevance for BESSY III

WHERE DO WE GO NOW WITH HARMONIC CAVITIES?

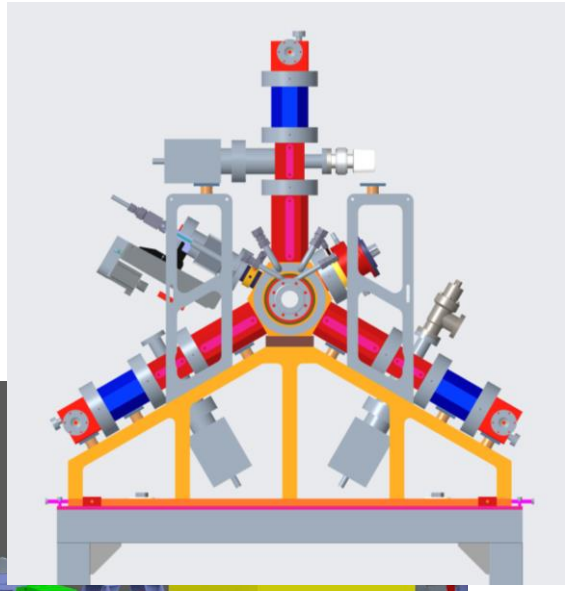
- BESSY II
  - ensure reliability
  - explore beating
- MLS
  - improve user operation
  - high potential for SSMB research
- upgrade to dLLRF (20 units including fund. RF)
- design ingredient for BESSY III and MLS2
- contribute to a common / standardized design
- timescale
  - 6 x 1.5 GHz cavities @ 2025
  - 4 x 1.75 GHz cavities @ 2026

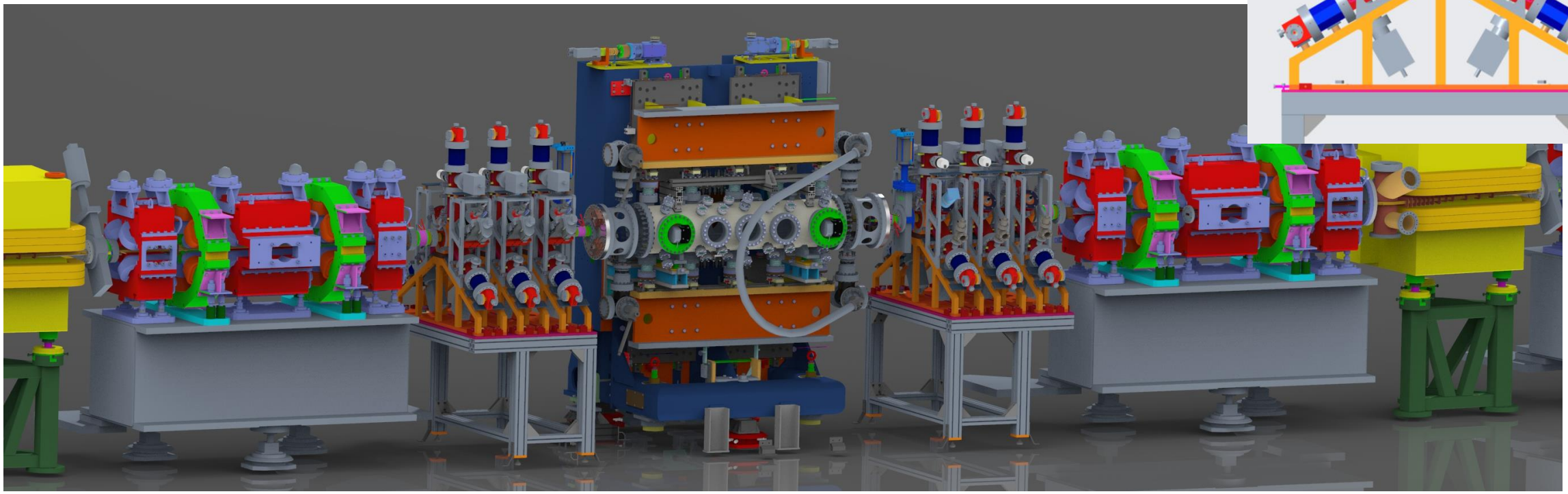
Item	Machine	Frequency	Requested
Cavity	BESSY II	1.5 GHz	4
	BESSY II	1.75 GHz	4
	MLS	1.5 GHz	2
Transmitter	BESSY II	1.5 GHz	3x15kW (1 existing)
	BESSY II	1.75 GHz	3x15kW (3 existing)
	MLS	1.5 GHz	1x15kW
dLLRF	BESSY II	1.5 GHz	3+1
	BESSY II	1.75 GHz	3+1
	MLS	1.5 GHz	1+1

quite some work to do…

see talk of Andranik Tsakanian tomorrow

MID TERM FUTURE AT BESSY II





many thanks

to all HZB and PTB staff contributing to operation and development activities,
to the colleagues from ALBA and DESY for their collaboration,

and all contributors to this workshop

and

for your attention