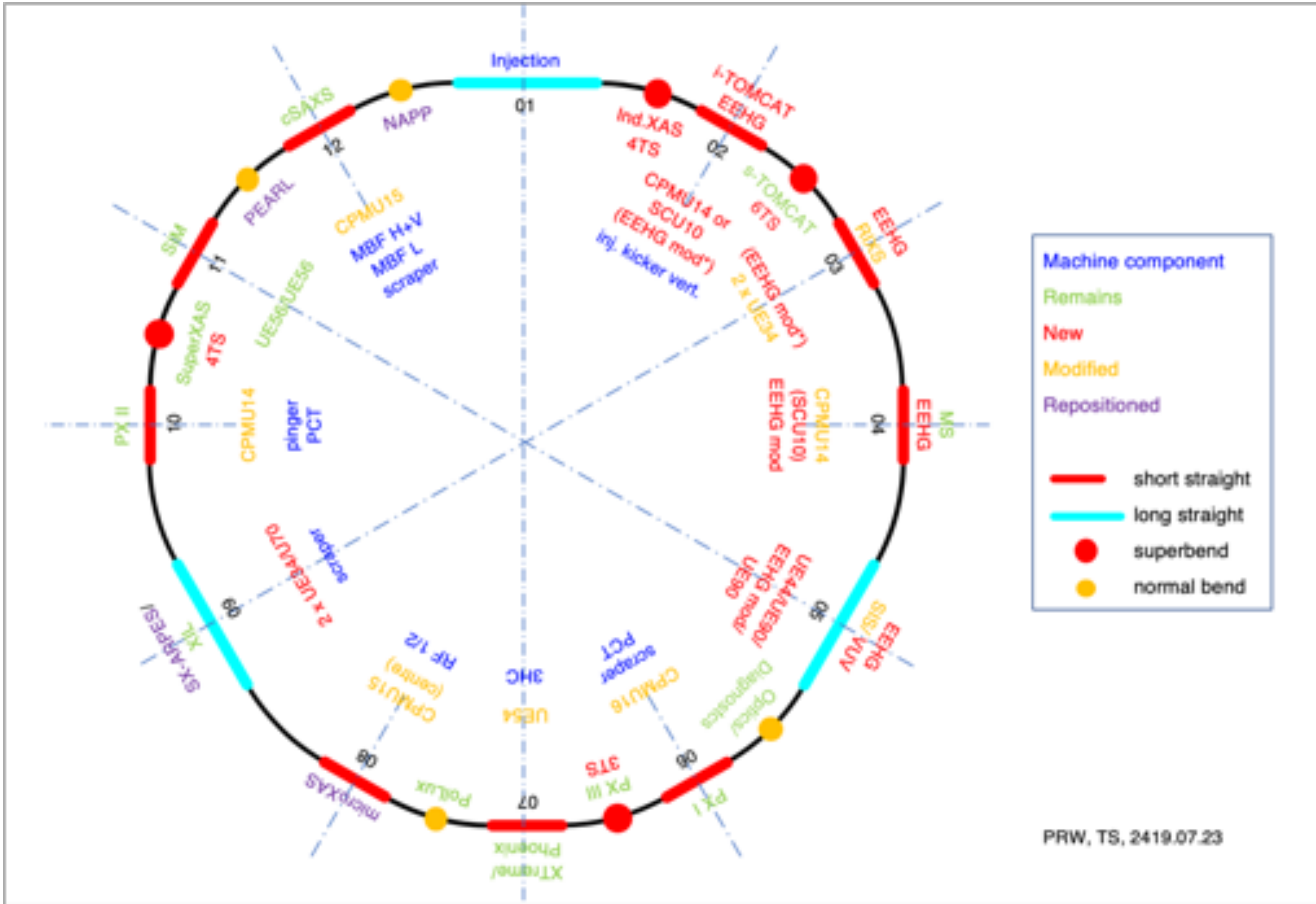
Thomas Schmidt :: Paul Scherrer Institut

Insertion Devices for SLS 2.0

SLS 2.0 Information Day, November 8, 2019, PSI

SLS 2.0 Lattice



SLS -> SLS2.0 Optimization strategies

machine

- smaller emittance (beam size) -> higher brilliance
- improved injection schemes -> smaller transverse apertures
- NEG coating and fabrication technologies for vacuum chambers
- **sc** superbends

SLS -> SLS2.0 Optimization strategies

undulators

- stronger magnet materials

  NdFeB $B_r = 1.15T \rightarrow B_r = 1.37T$ @ room temperature

- new techniques and new materials:

  cryogenic undulators PrFeB $B_r = 1.7T$ @ 77K

- new concepts:

  APPLE X making use of round vacuum chambers

  - reduced gaps for shorter period length, thus higher flux

  - field shaping for reduced on-axis heat load

- R&D:

  HTS high temperature superconductors

  to go beyond todays possibilities

- FEL concepts:

  electron beam manipulation by external Lasers

  EEHG (Femto 2.0)

SLS -> SLS2.0 Optimization strategies

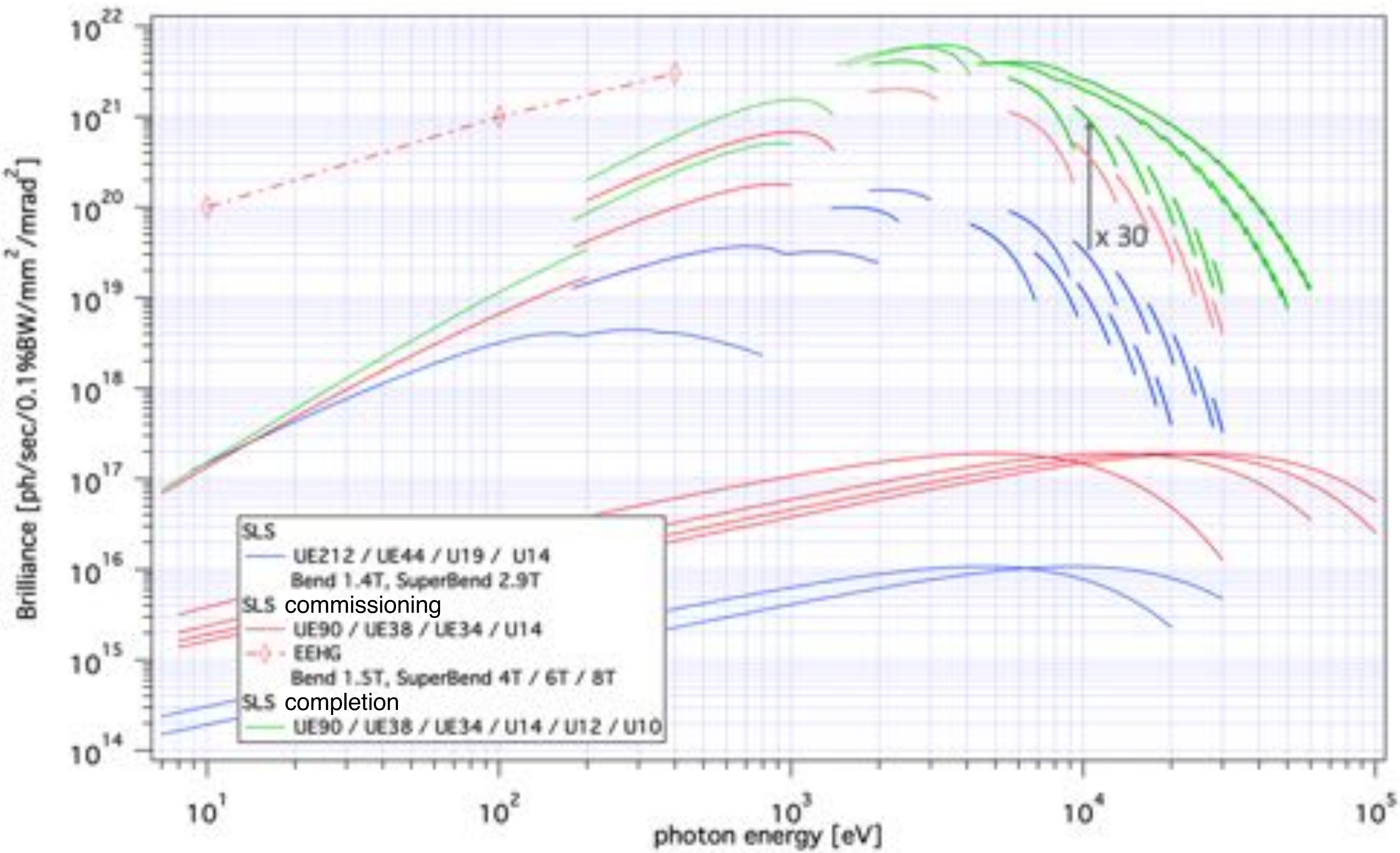
beamlines

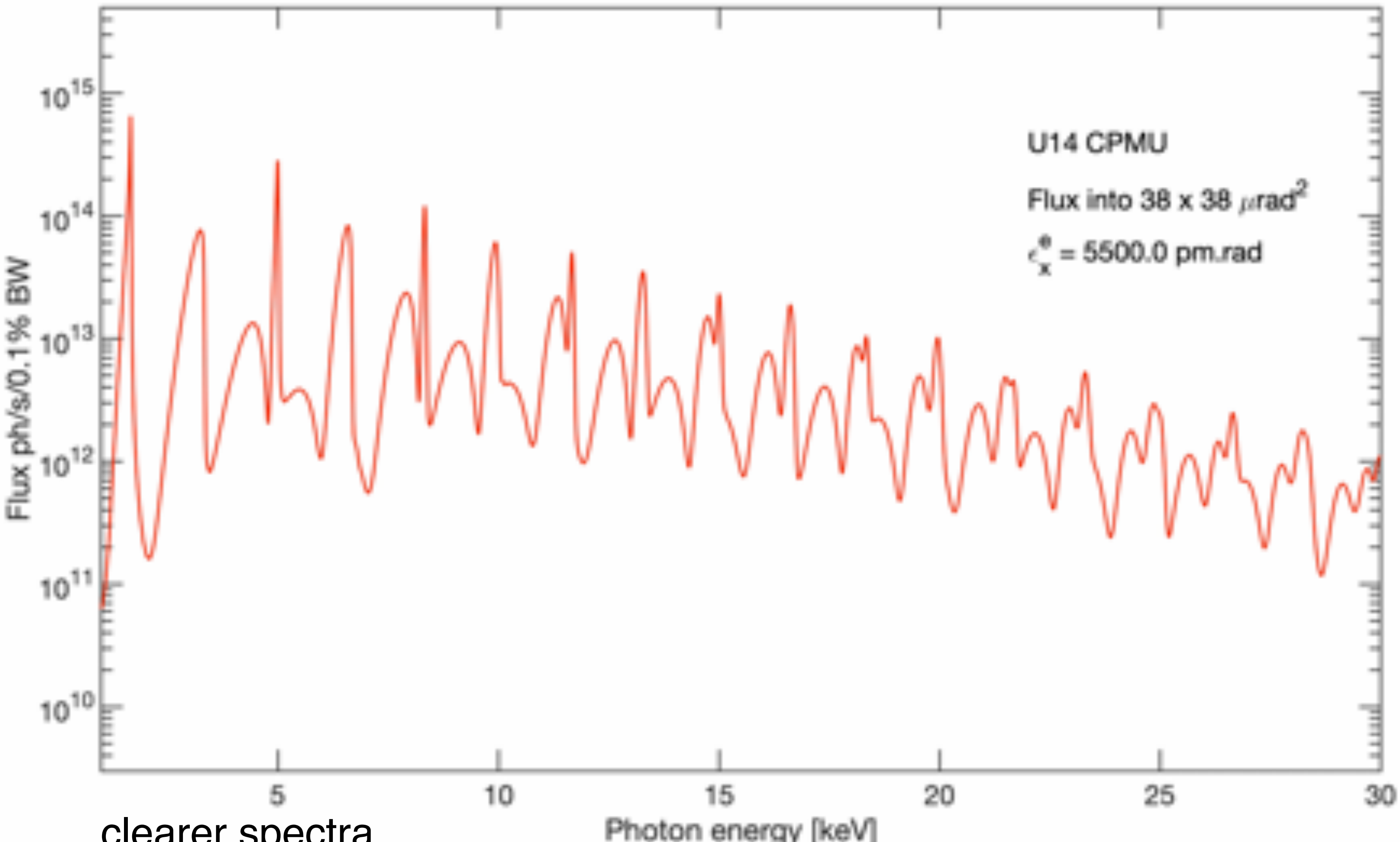
- smaller mirrors with reduced slope errors errors
- new concepts
- improved detectors

machine beamline interaction

- include x-ray bpm into feedback

SLS -> SLS2.0 Brilliance





clearer spectra

smaller (better) optics

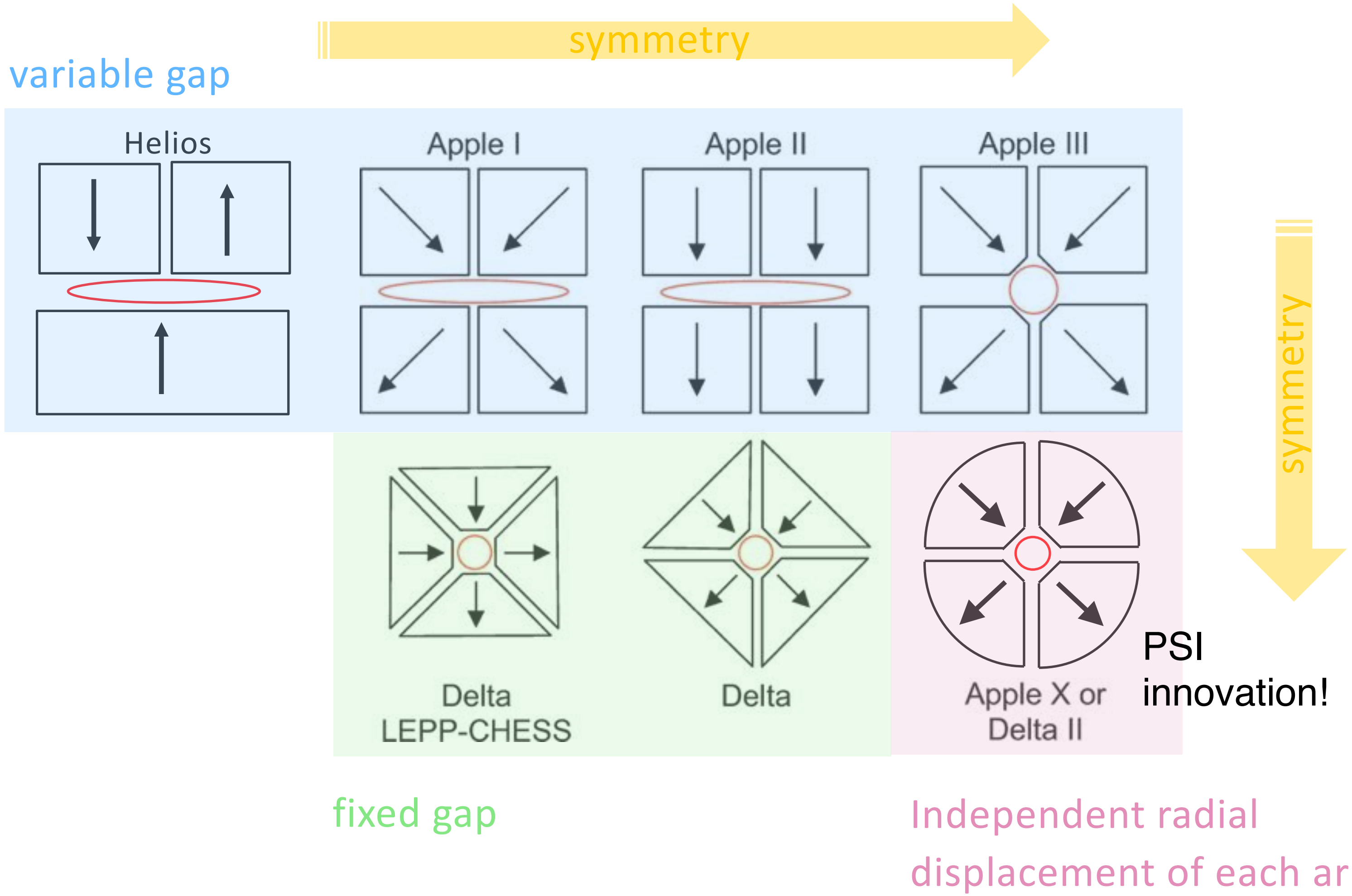
operation without monochromator

Undulators in SLS / SwissFEL @ PSI

ID	N	Gap [mm]	B_z/B_x [T]	K_z/K_x	N_{per}	Harm	E [keV]	Type	Magnets
SLS									
UE212/424	1	20	0.4/0.1	07.09.04	39	1-5	0.01-0.6	quasi-periodic ELM variable period	-
UE56	2	16	0.83/0.6	4.4/3.2	32	1-5	0.09-2	twin APPLE II	NdFeB
UE54	1	16	0.79/0.54	4.0/2.7	32	3-33	0,4-8	APPLE II	NdFeB
UE44	1	11,4	0.86/0.65	3.5/2.7	75	1-5	0,3-2	fixed gap APPLE II	NdFeB
U19	1	4,5	0,86	1,5	95	3-13	5-20	in-vac hybrid	Sm_2Co_{17}
U19	2	4,5	0,89	1,6	95	3-13	5-20	In-vac hybrid	NdFeB
U19	1	5,5	0,85	1,5	95	3-13	5-18	In-vac hybrid	NdFeB
U14	1	4	1,15	1,5	120	3-13	5-30	cryogenic in-vac	NdFeB
SwissFEL									
U15	13	3	1,28	1,8	265	1	2-12*	In-vac Dy enhanced	NdFeB
UE38	26	3	1.05/1.05	3.8/3.8	40	1	0.18-1.8	APPLE X	$SmCo_5$

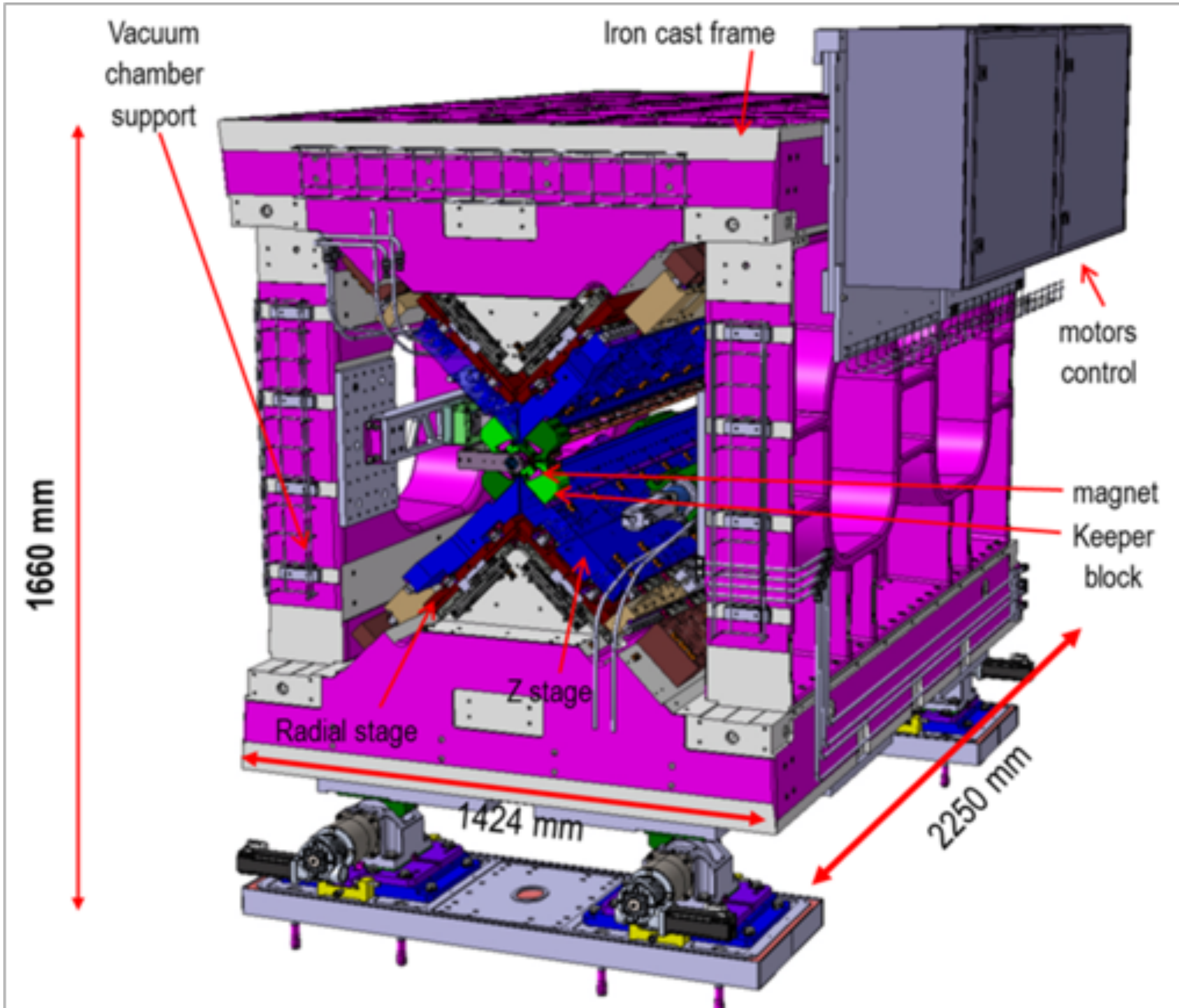
- to be replaced by APPLE X (red)
- to be checked (yellow)
- to be converted to cryogenic U14 (blue)
- preserved (green)

APPLE type undulators in a nutshell … … from Helios to APPLE X



circular → inclined → transverse gradients

SwissFEL UE38 (APPLE X)



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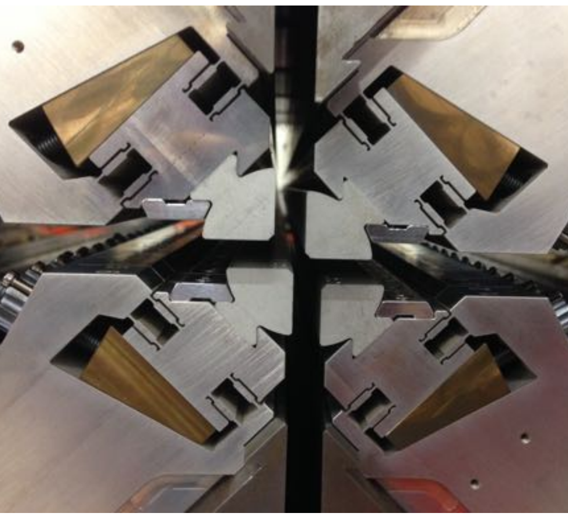
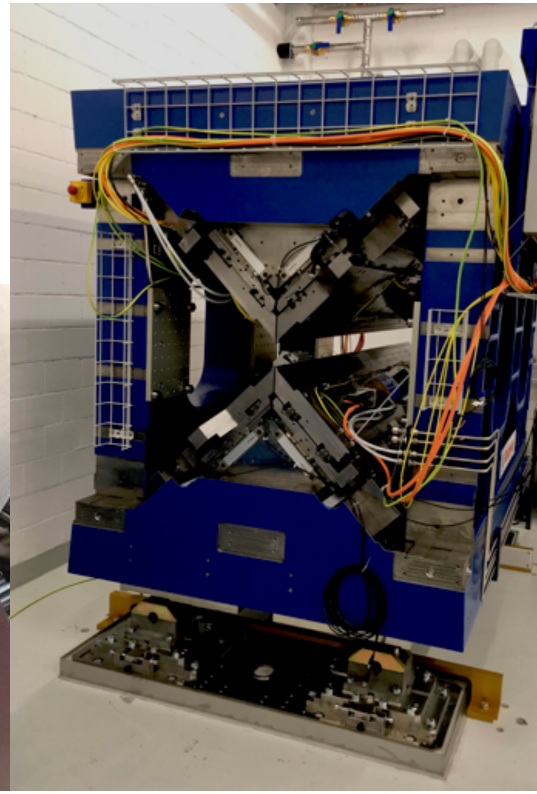
Athos prototype - Apple X





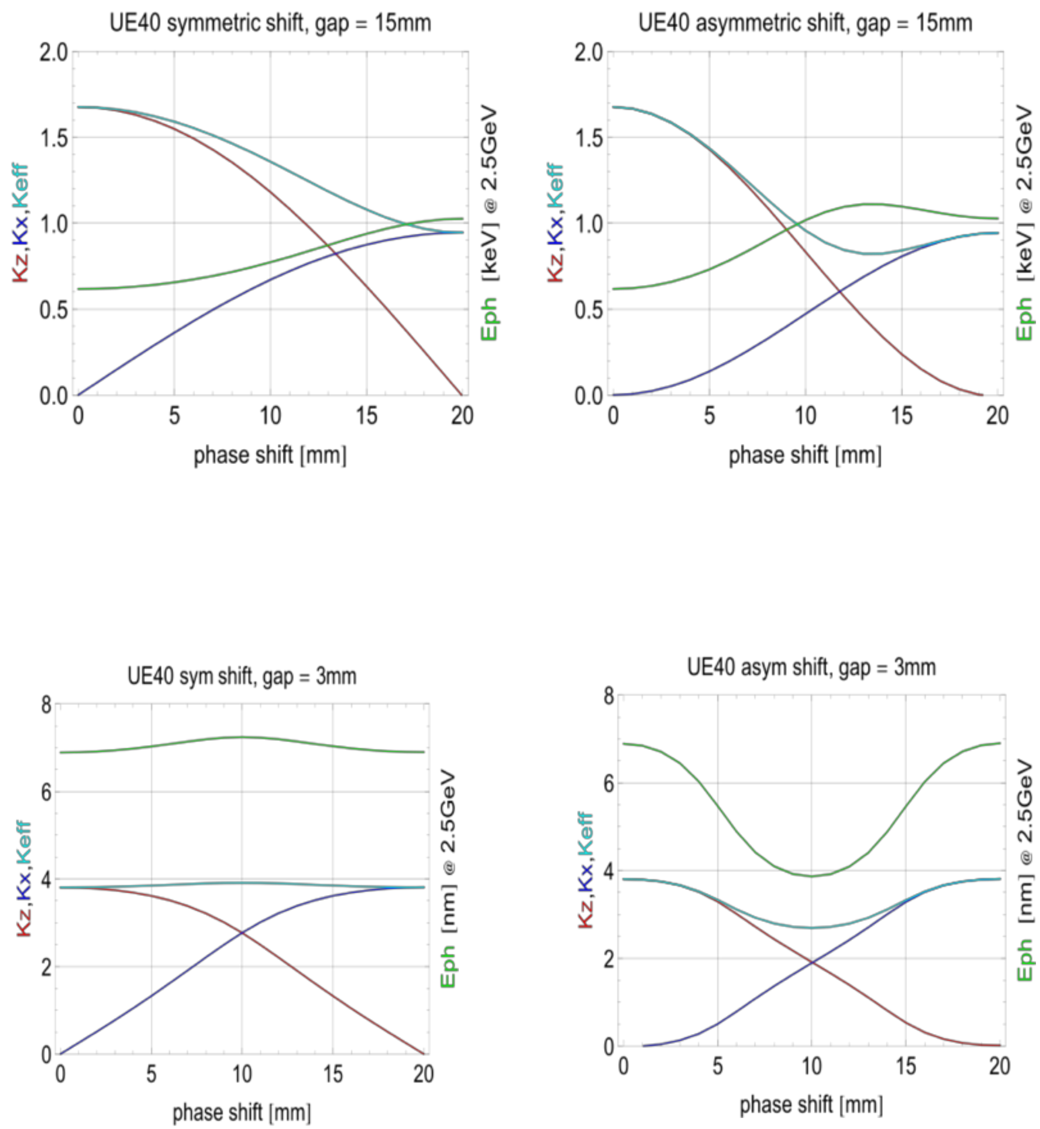
Individual radial “gap” drive

Full symmetric operation: identical photon energy range for all polarizations

Integrated vacuum chamber allows remote alignment

profit from series production of 16 modules for SwissFEL

APPLE X vs APPLE II



APPLE II

$B_z > B_{circ} > B_x$

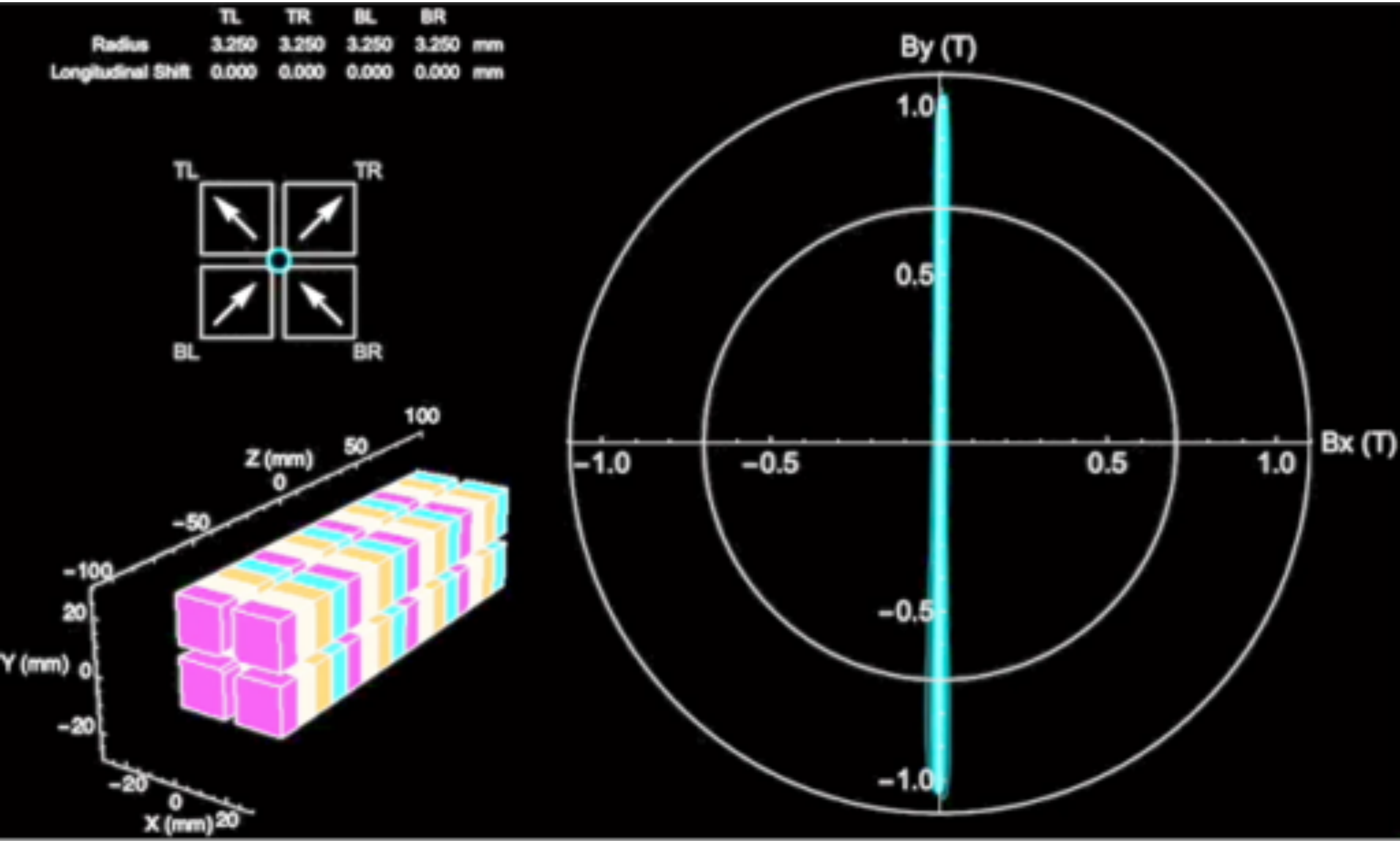
Circ shift gap dependent

APPLE X

$B_z = B_{circ} B_x$

Circ always at $\lambda_U / 4$

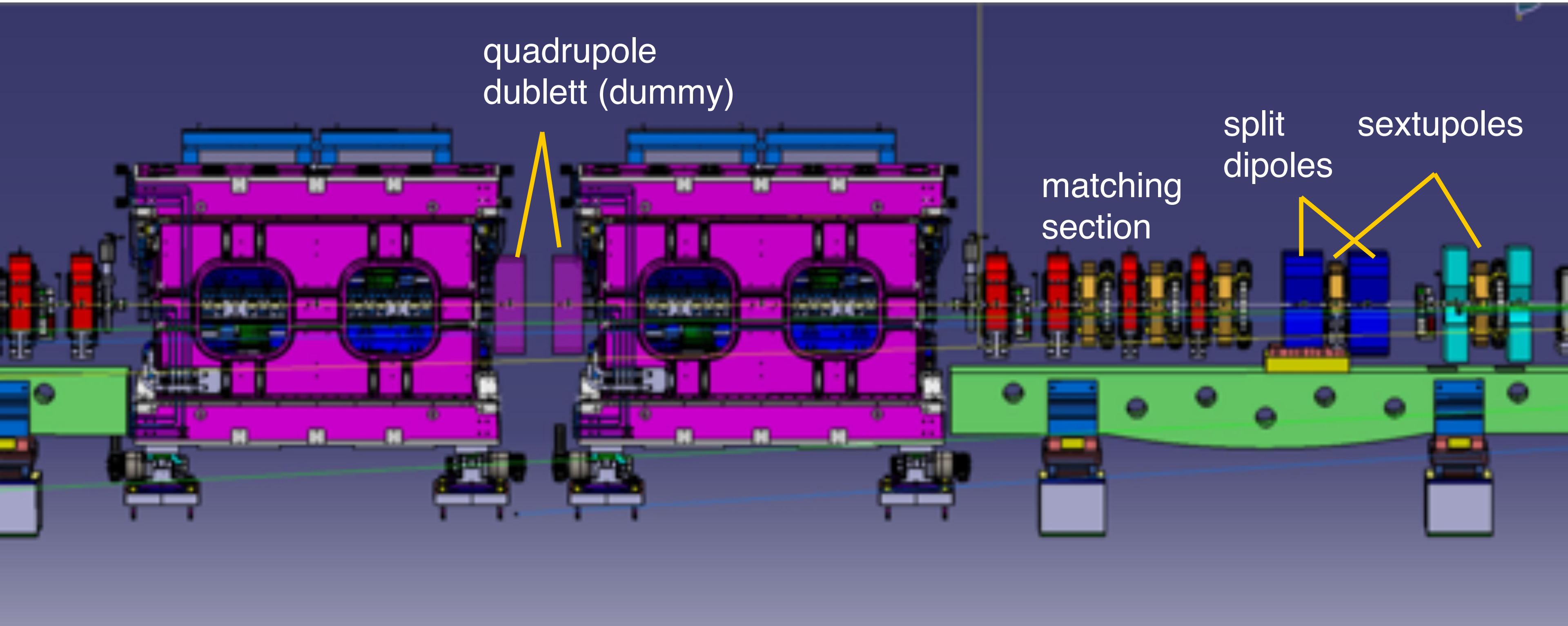
APPLE X field projections



APPLE X for VUV & soft x-ray

- carefully system integration
- outcoupling possible for soft x-ray and VUV
- tiny vacuum chambers and compact ring design

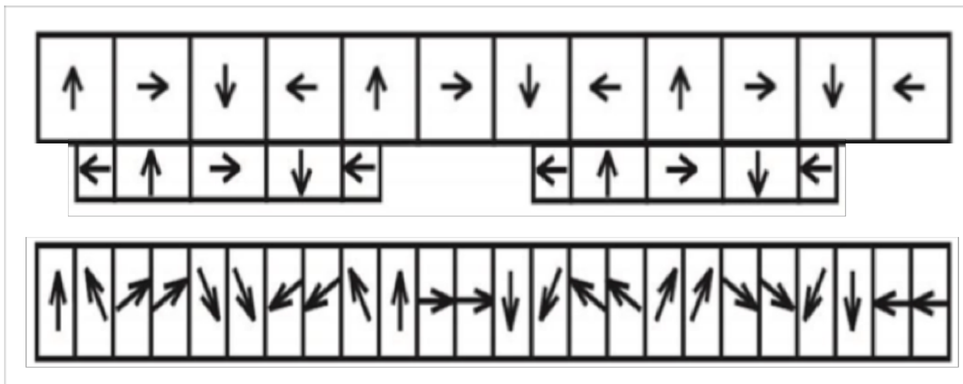
  -> careful heat load budgeting

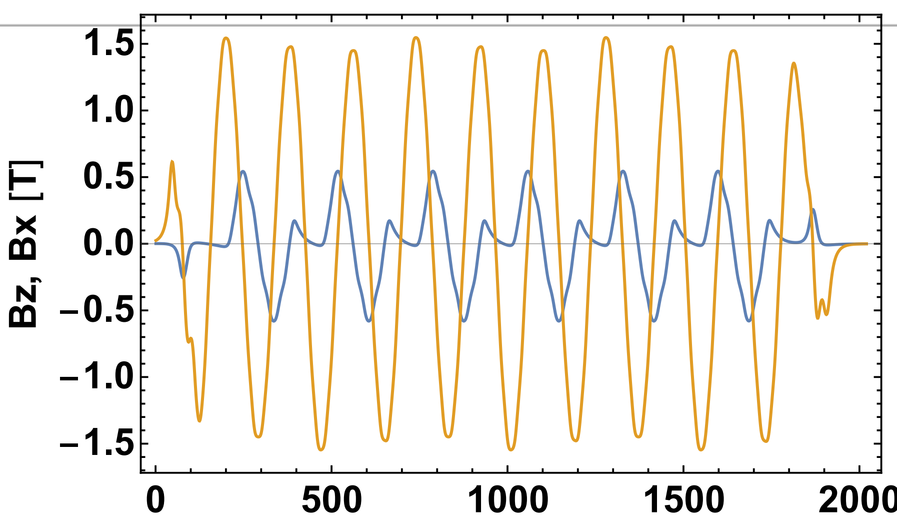


APPLE X in SLS 2.0

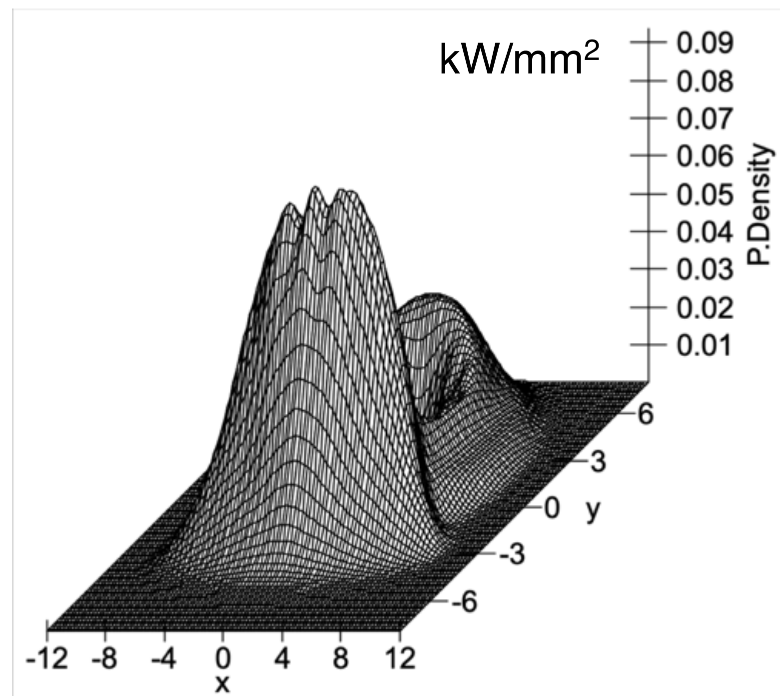
Shorter period length, more periods UE56 -> UE28

APPLE Knot for reduced on-axis heat load



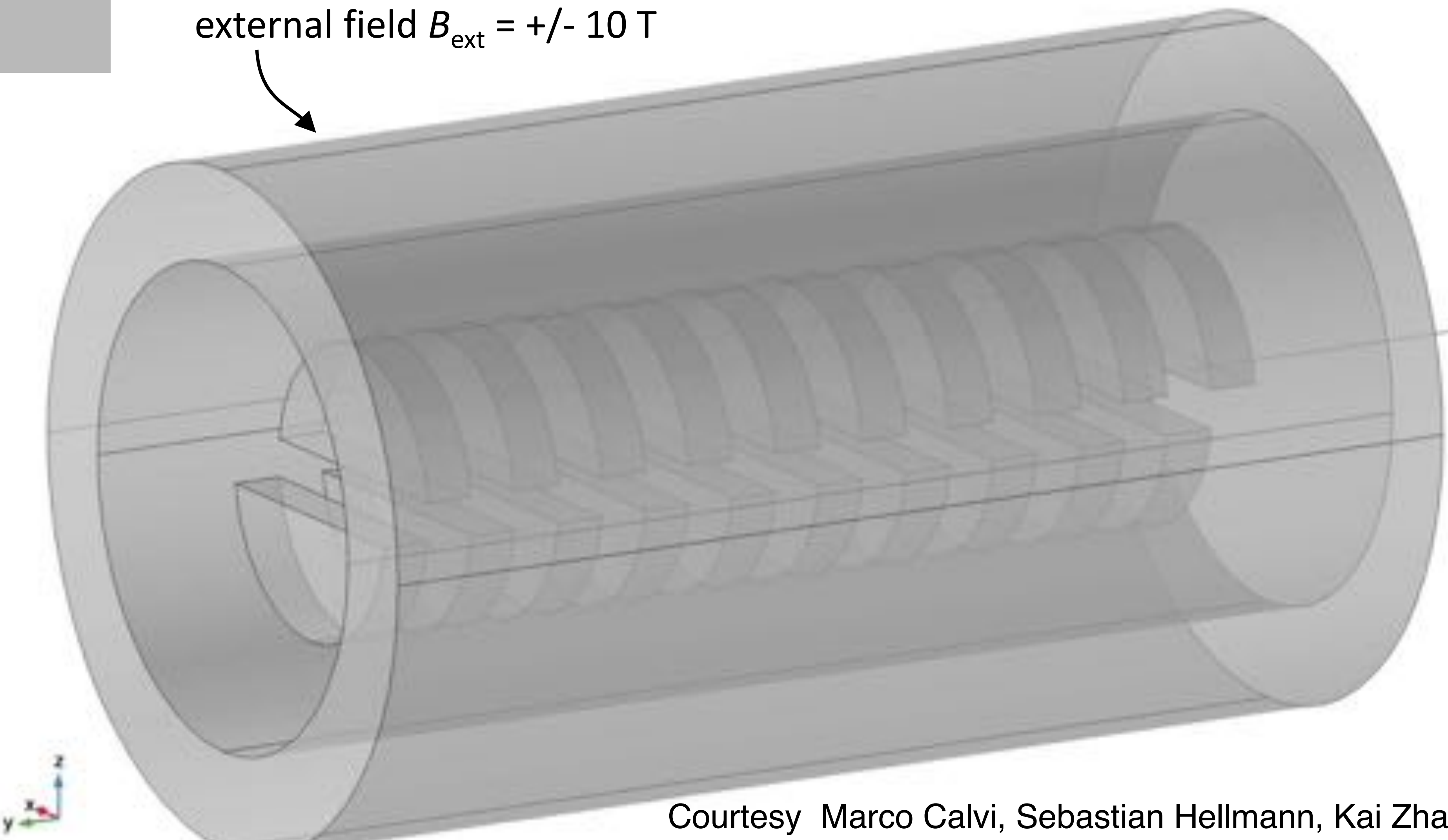


Power density at sextupole position



R&D: HTS Staggered Array

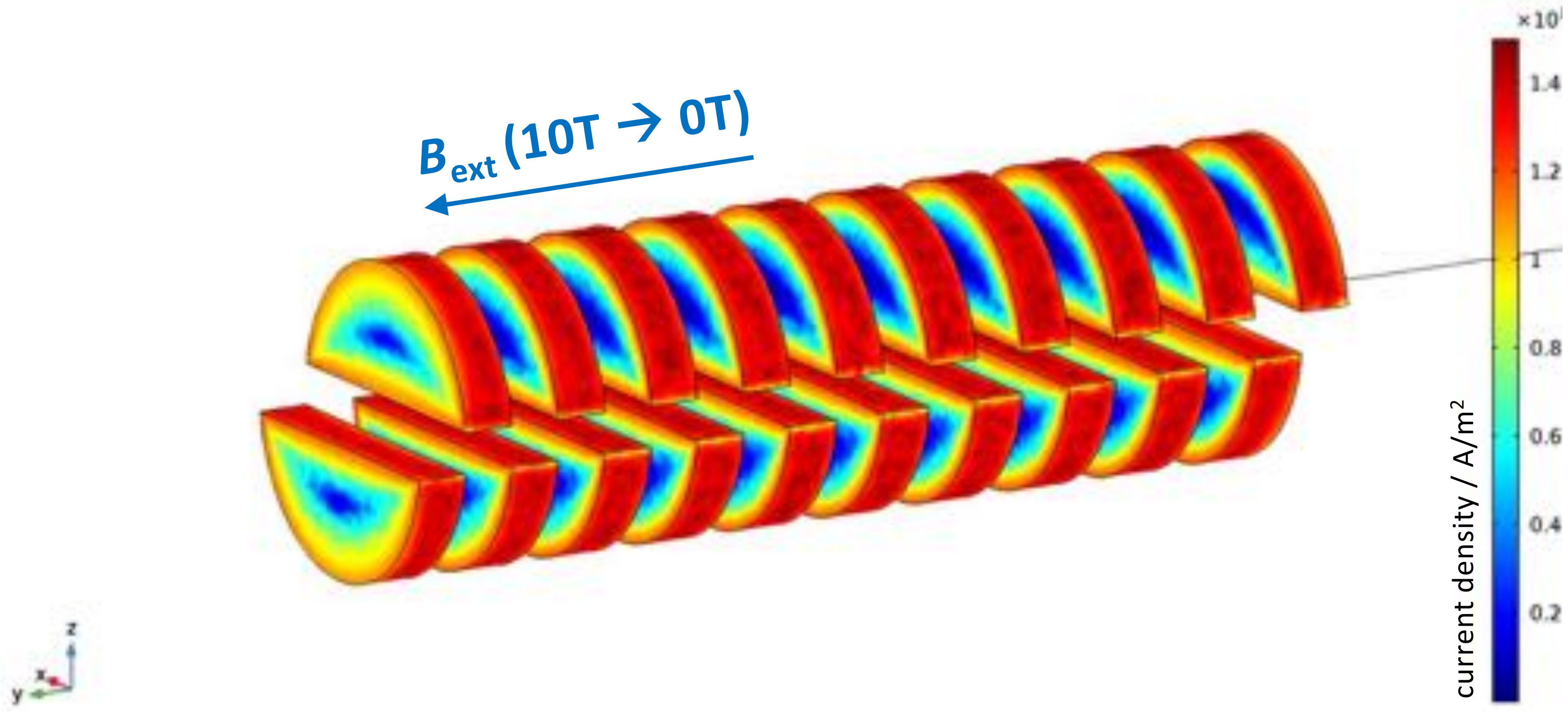
- Superconducting solenoid providing external field B_{ext} = +/- 10 T



Courtesy Marco Calvi, Sebastian Hellmann, Kai Zhang

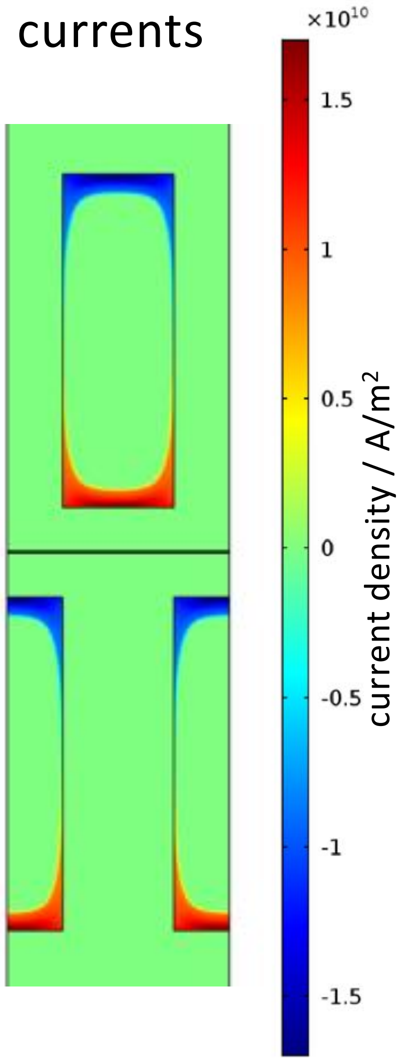
R&D: HTS Staggered Array

- Surface current density after magnetization with field 10T → 0T:



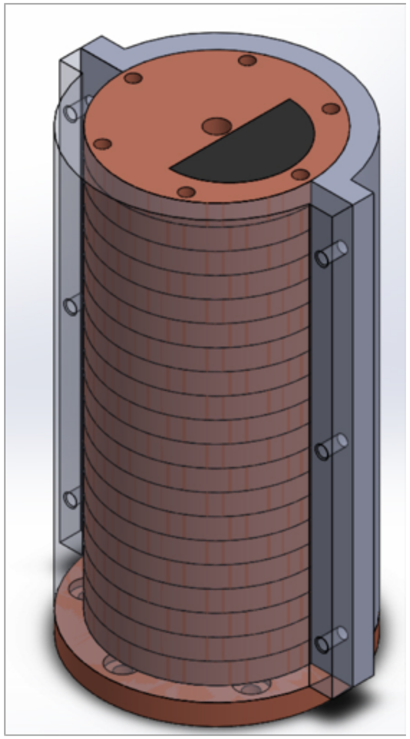
R&D: HTS Staggered Array

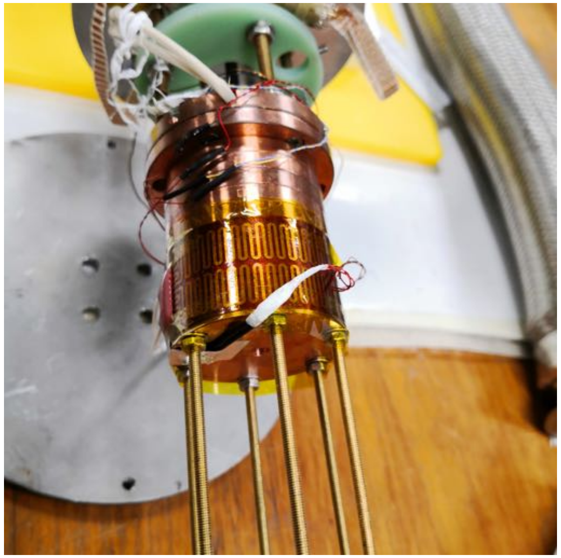
Trapped currents



First run – 23.08.2019 at Cambridge Univ.

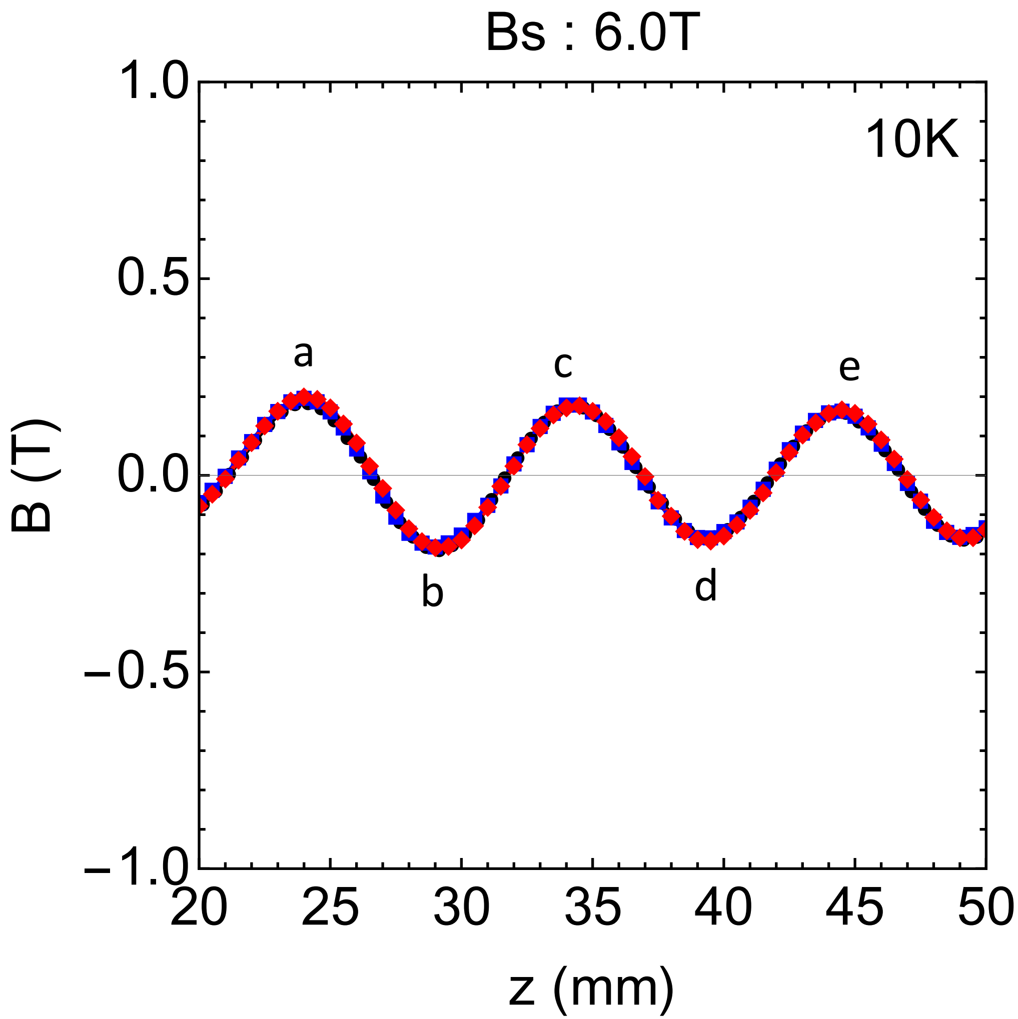
- The sample is cooled in a 7.0T solenoid
- its temperature is stabilised at 10K
- and the solenoid is ramped down in steps of 1





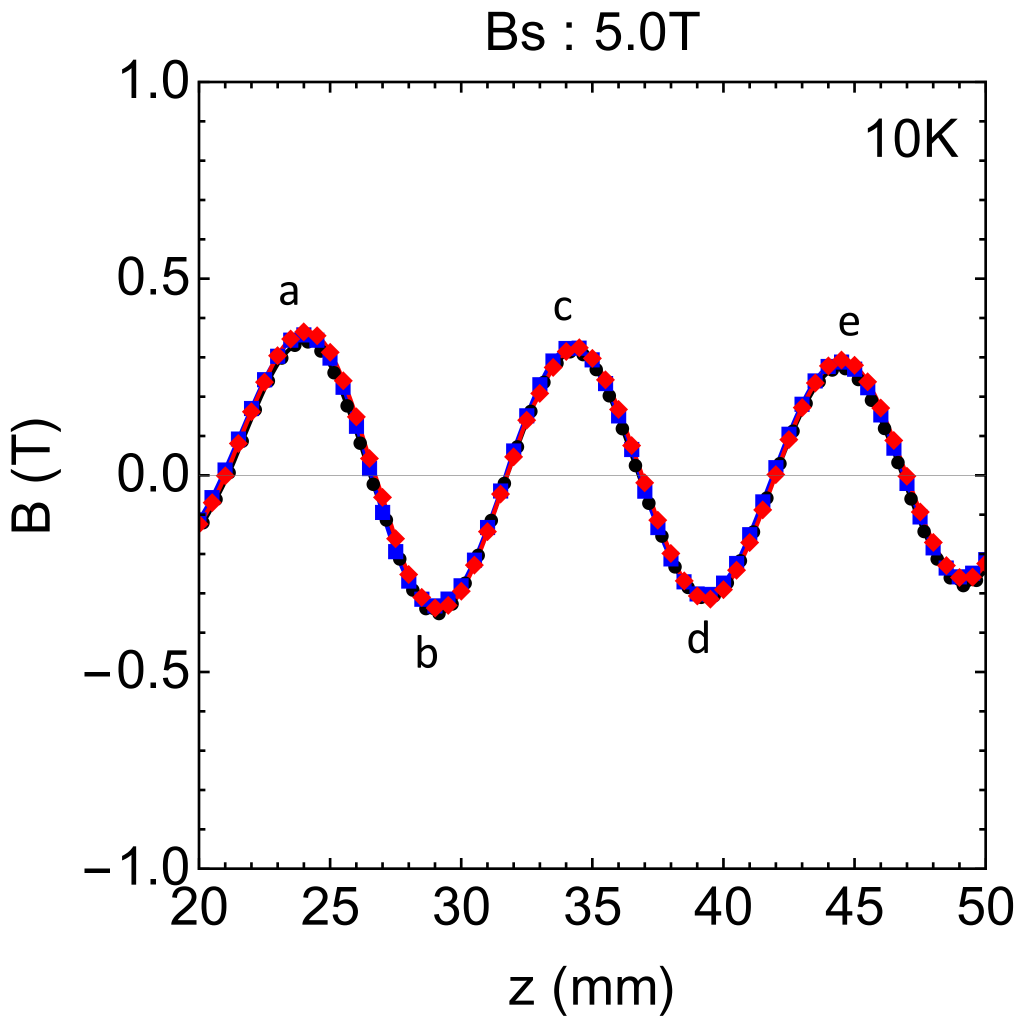
P

First run – 23.08.2019 center periods



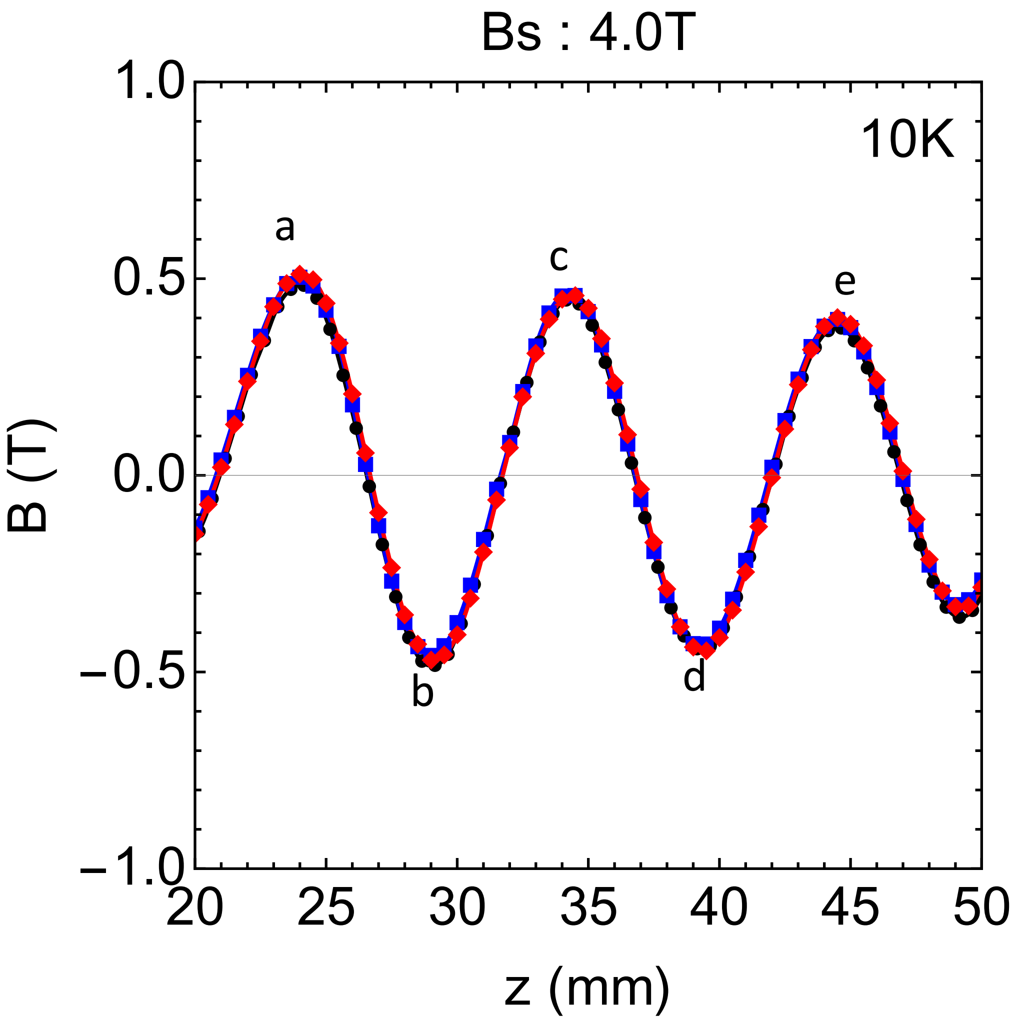
*B: By1, By2, By3

First run – 23.08.2019



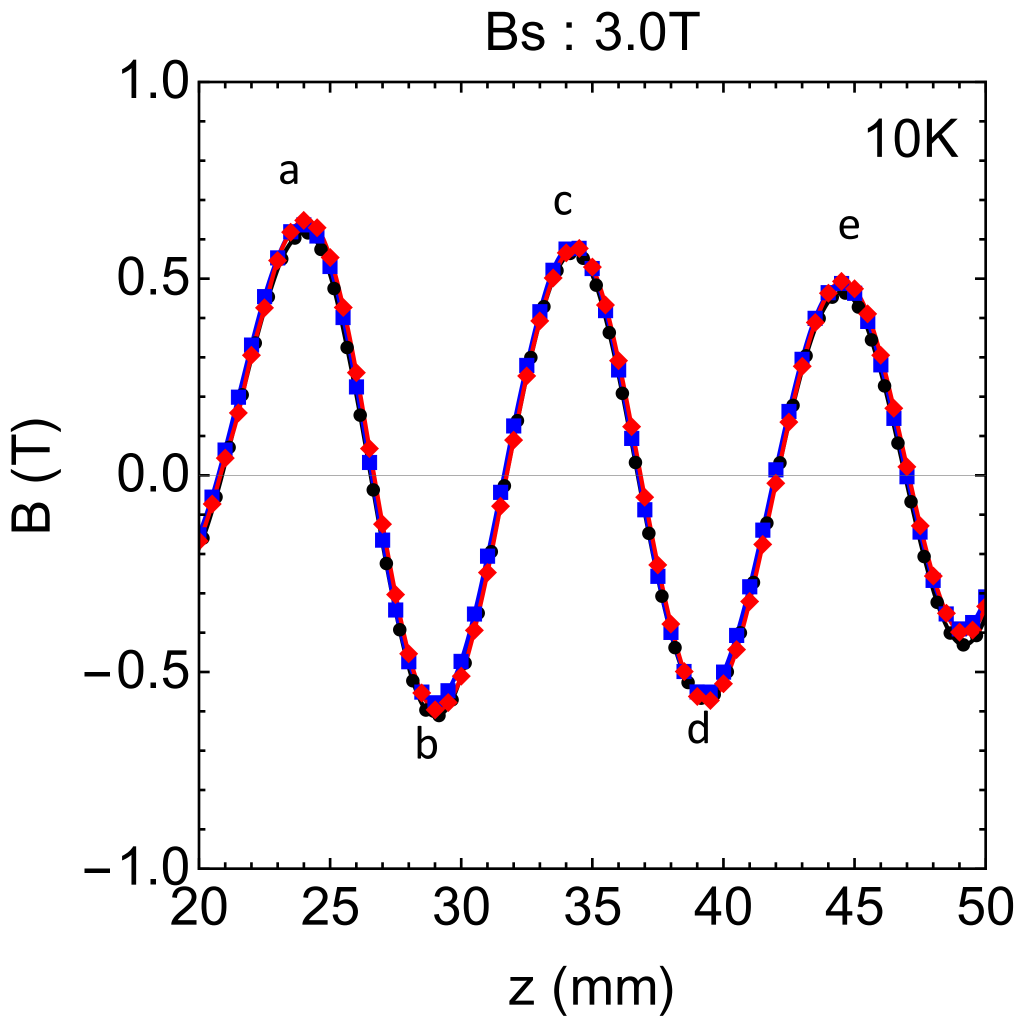
*B: By1, By2, By3

First run – 23.08.2019



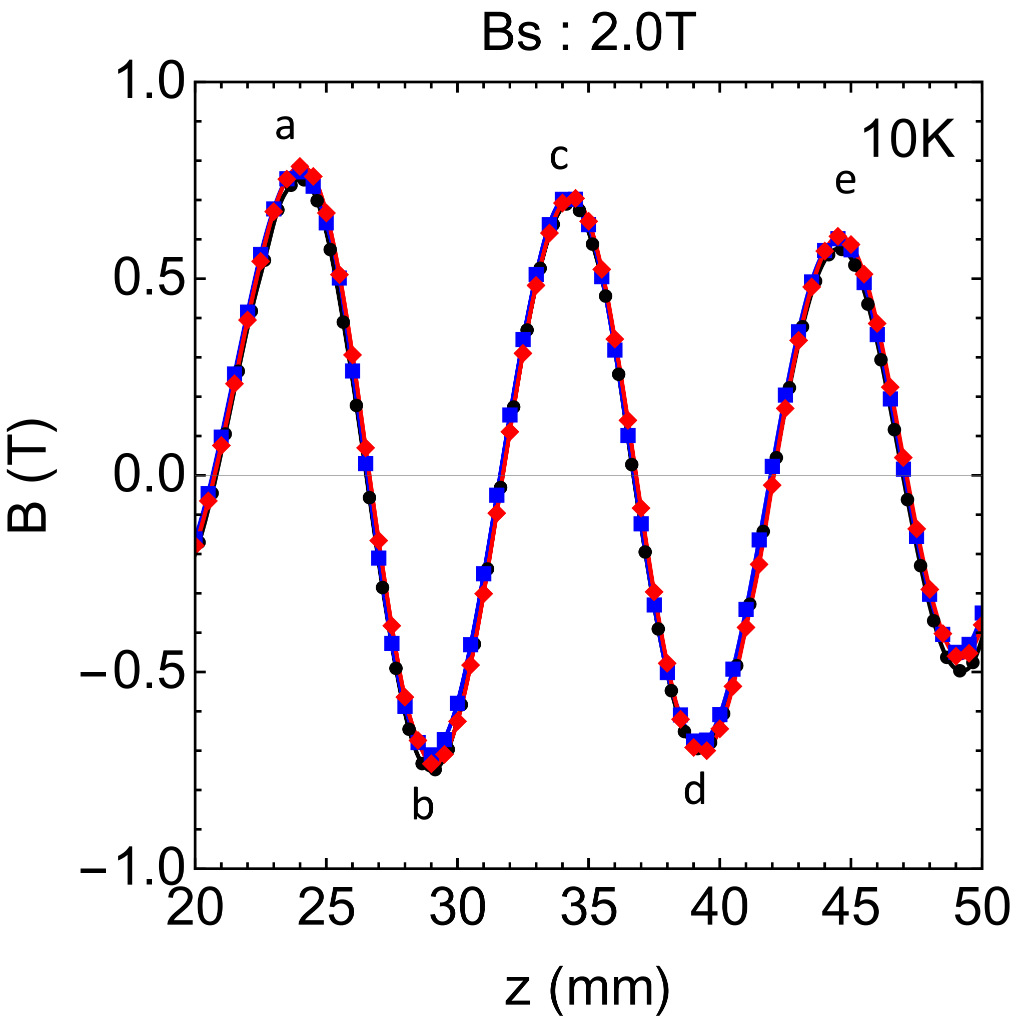
*B: By1, By2, By3

First run – 23.08.2019



*B: By1, By2, By3

First run – 23.08.2019



*B: By1, By2, By3

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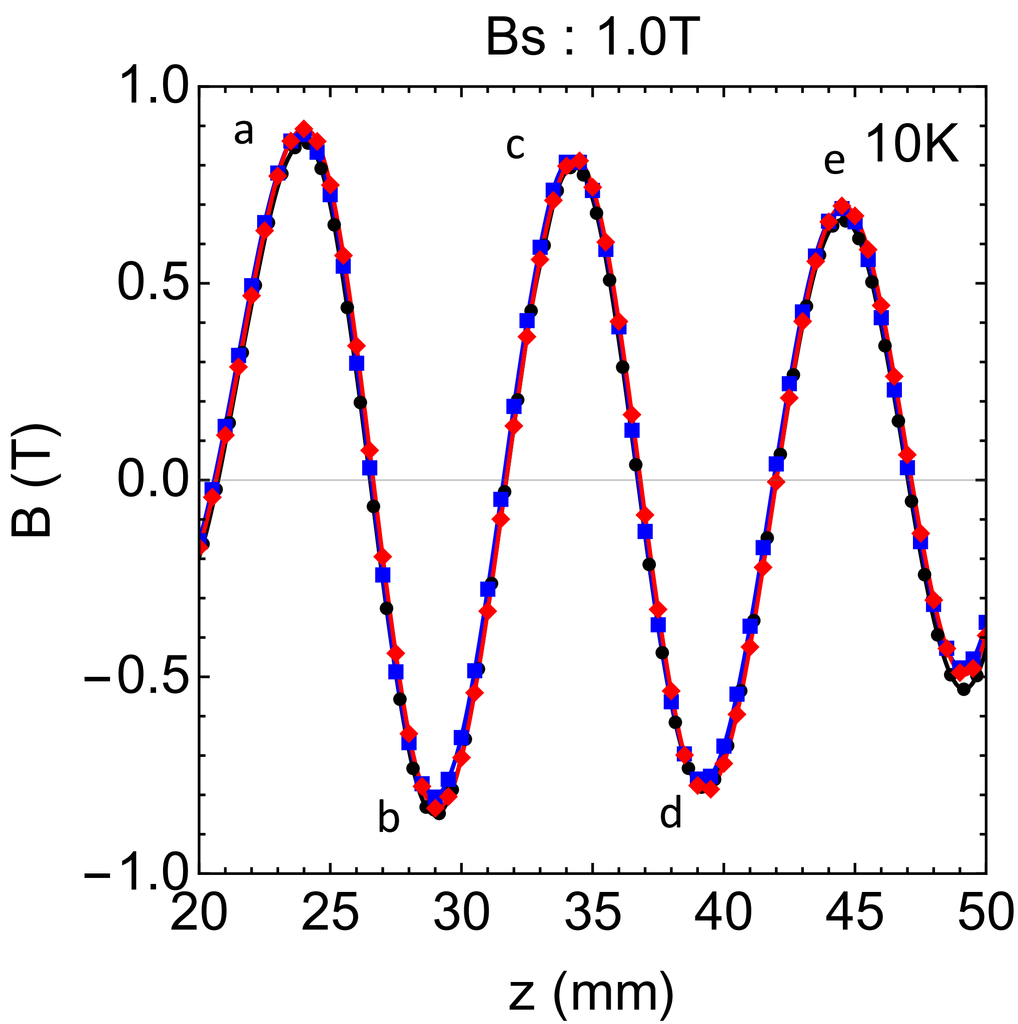
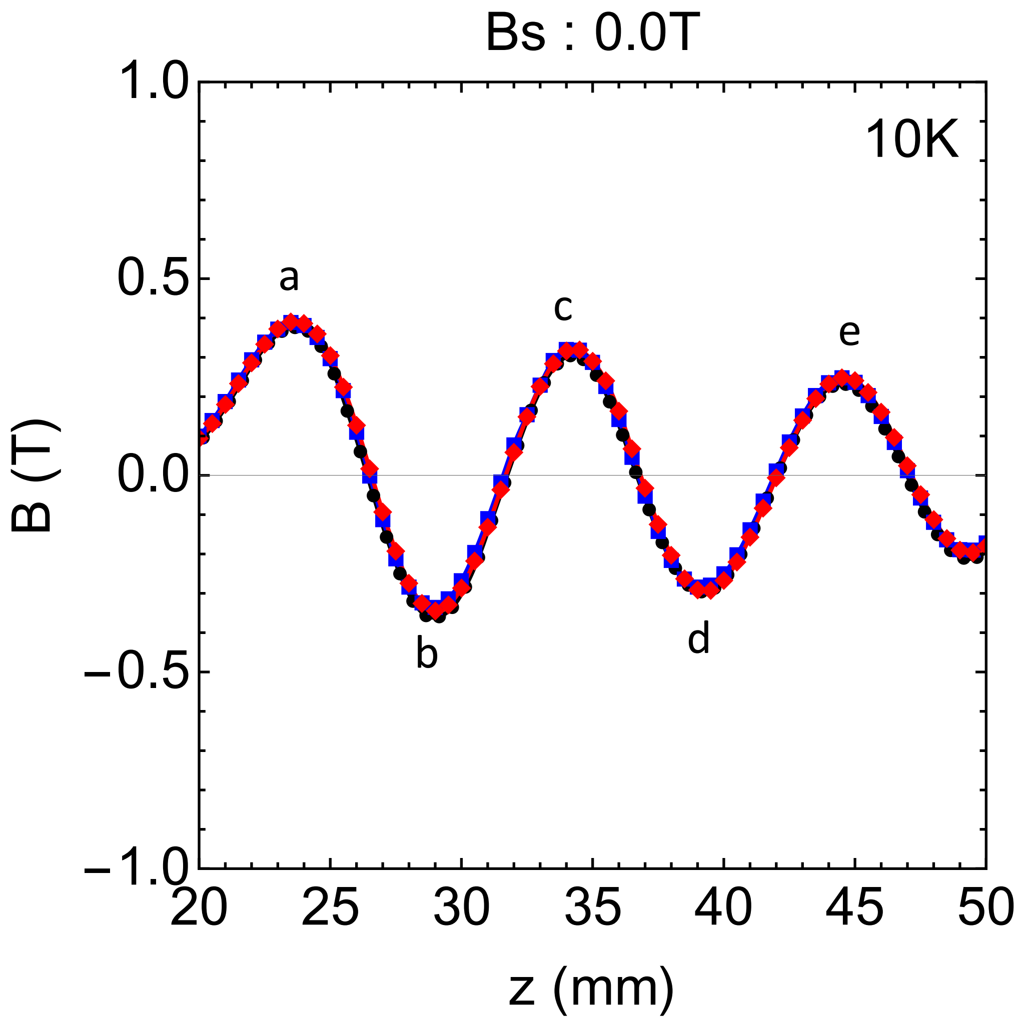
First run – 23.08.2019



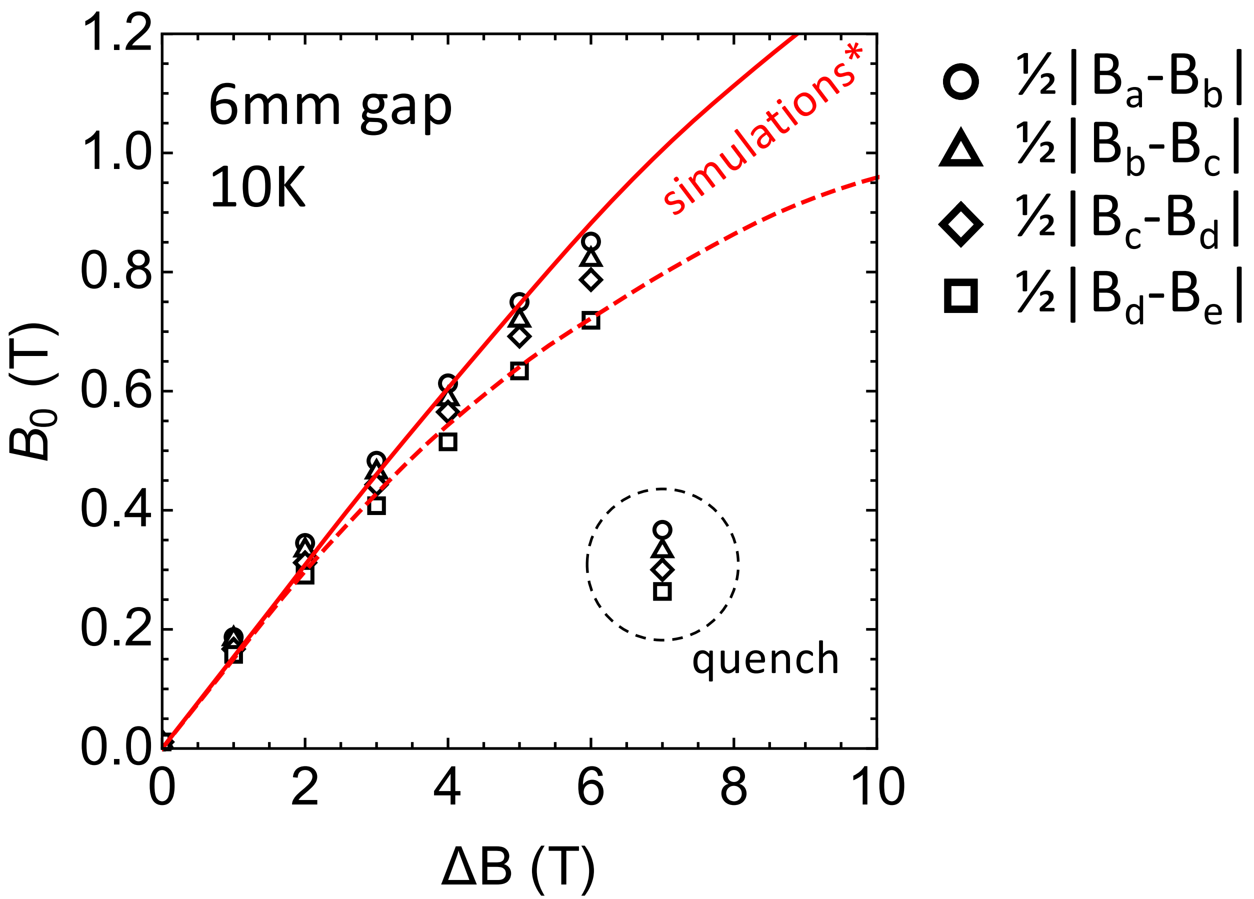
*B: By1, By2, By3

First run – 23.08.2019 - quench



*B: By1, By2, By3

Summary first run



*simulations: the solid redline results from the scaling laws provided by the company ATZ, the dashed line is from measurements done in Cambridge @ 40K and scaled to 10K (x2.5)

Echo-Enabled Harmonics Generation in a nutshell

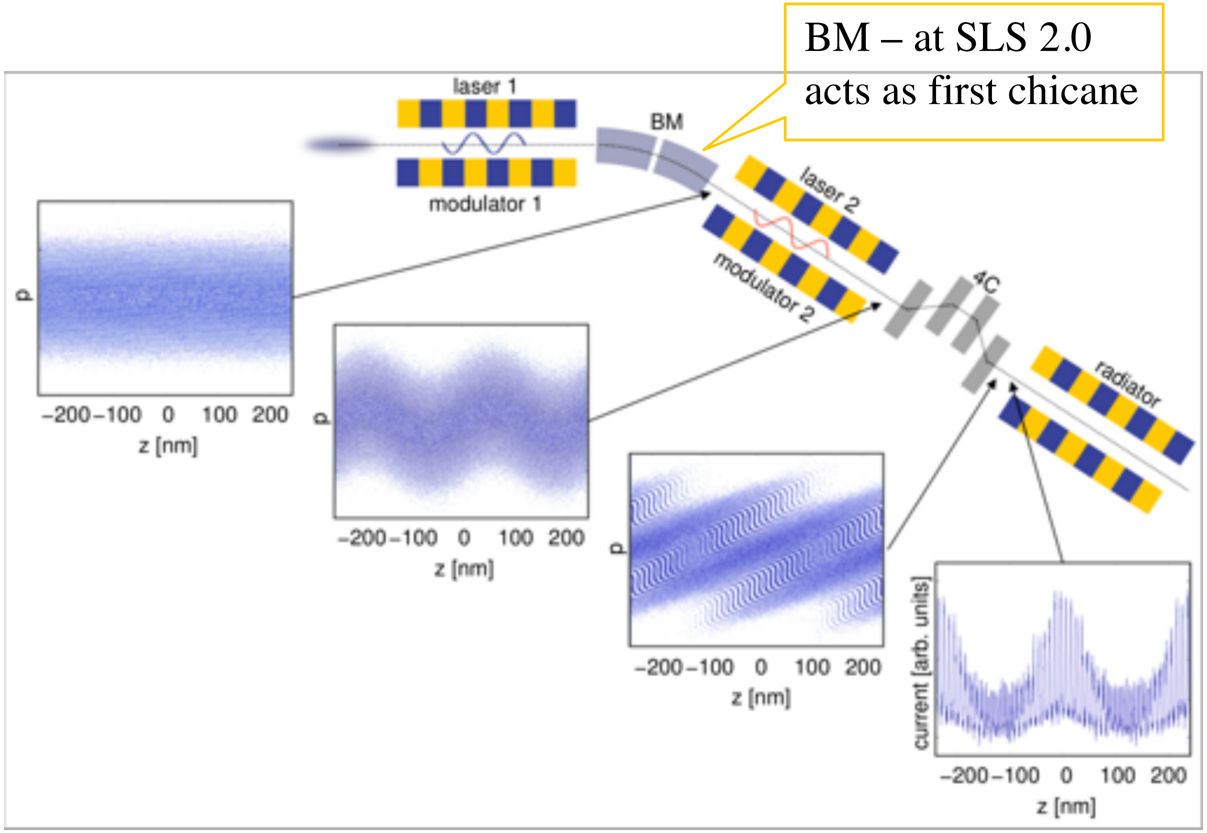
EEHG:

Modulation of electron bunches with external laser

Energy modulation turns into current spikes

Large fraction of coherently radiating electrons

Extreme increase in generated photons, source in between s.r. and FELs.



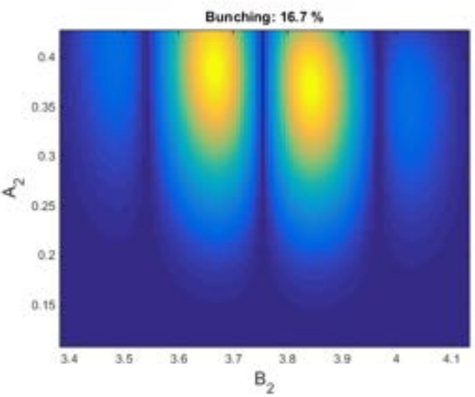
- Initially developed for FEL but applicable to storage ring (Xiang, Stupakov, Phys. Rev. ST: Acc. Beams 12, 03072 (2009))
- Precursors of coherent harmonic generation (CHG) demonstrated at Elettra (Ninno et al. PRL 101, 053902 (2008))
- EEHG demonstrated in UV at Delta (Khan et al., Synchrotron Radiation News 26, 25 (2013)

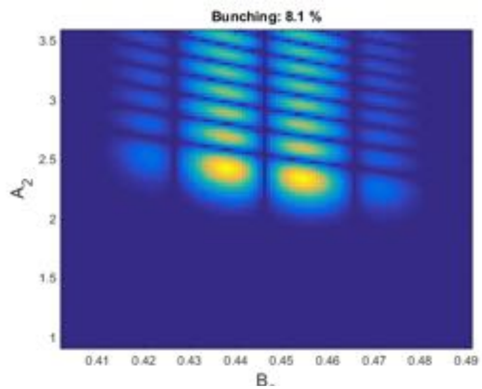
EEHG Echo Enabled Harmonic Generation

Beamlines: VUV, SIS?

Bunching factors at

7eV (left) 100eV (right)



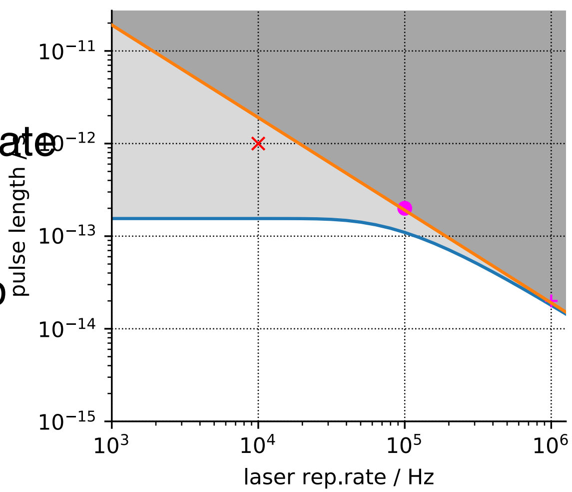


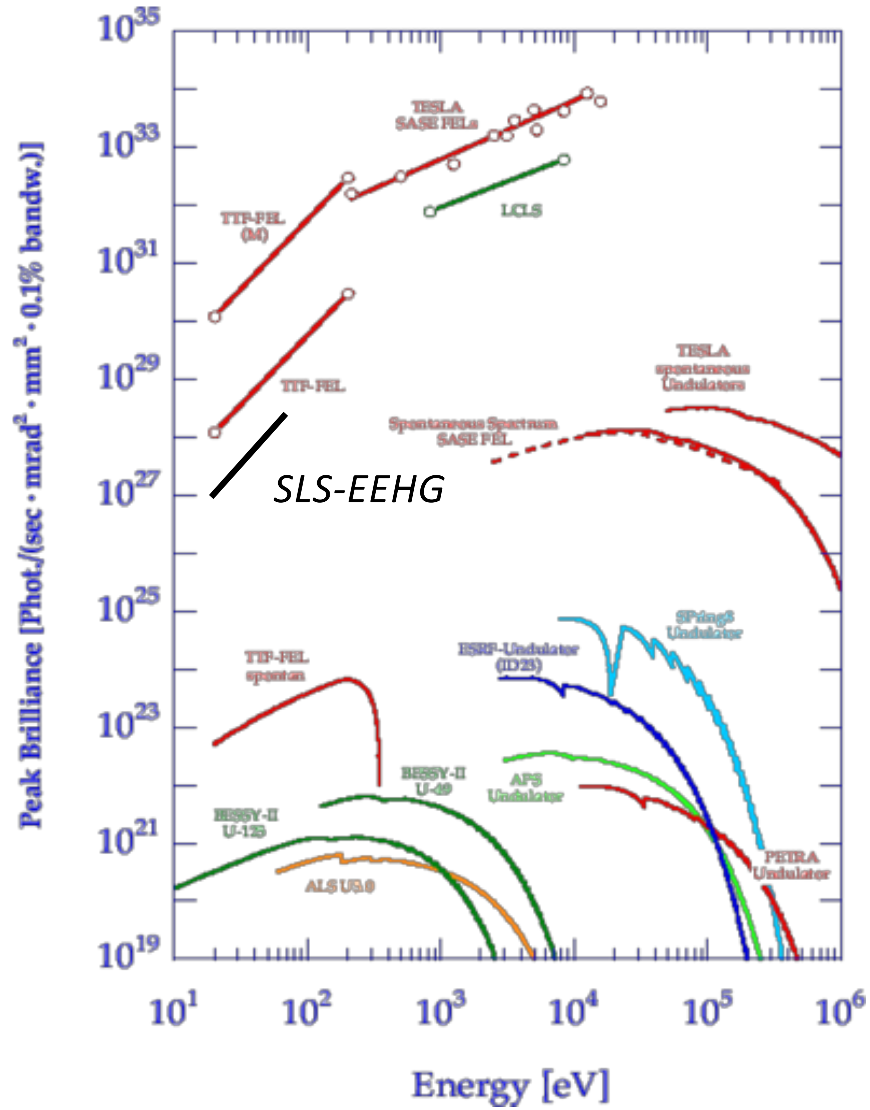
Trade off:

Bunch length vs rep rate

for 5% dE/E increase

No emittance blow-up





Courtesy: S. Reiche, E. Ferrario, B. Riemann

SLS & SwissFEL: concept

SLS 2.4 GeV

soft x-ray variable polarization

APPLE II

twin UE56 (<- BESSY II)

UE54 soft & tender x-ray

fixed gap UE44

quasi-periodic elm

hard x-ray

in - vacuum (<- SPring-8)

work horses: U19 -> 20keV

CPMU U14 -> 30keV

gap min = 4mm, 2m long

2.9 - 3.4 GeV **SwissFEL** 2 – 5.8 (7) GeV

soft x-ray variable polarization

APPLE-X

UE38, Chic Modes

in - vacuum

U15 3mm, 4m long -> 12keV

U10 sc ?! (2025 ff) -> 36keV

SwissFEL & SLS-2: concept

SLS 2.0 2.4 GeV

soft x-ray variable polarization

APPLE II / APPLE X

gap min = 4mm, 2m long

hard x-ray

in - vacuum

U19 -> CPMU14 / 12

U10 sc ?!

gap min = 4mm, 2m long

2.9 - 3.4 GeV **SwissFEL** 2 - 8 GeV

soft x-ray variable polarization

APPLE-X (DELTA II)

UE38, Chic Modes

in - vacuum

U15 3mm, 4m long -> 12keV

U10 sc ?! (2025 ff) -> 36keV

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Wir schaffen Wissen – heute für morgen

Thanks
to
many
many
people
from

PSD and GFA