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A Variable Pulse Length Storage Ring
Manipulations of the longitudinal phase space

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1st ARD Workshop ST 3 "ps-fs electron and photon beams"

Outline

- Motivation
- Current limit of short bunches:
  measurements & scaling laws
- Bunch focusing by sc-cavities
- Double beam option
- Expected results

Motivation

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why short e^- bunches:

- time resolved, picoseconds X-ray experiments
- CSR for THz experiments

present situation:

- dedicated low-α shifts at BESSY, σ=3ps
  4 blocks of 3 days per year,
  two operation modes:
  40 mA (bursting) and 15 mA (stable)

future goal:

- simultaneously 15 ps & 1.5 ps bunch mode
  up to 100x more current in short bunches
  (→ 10000x more THz power)

BESSY II synchrotron radiation source

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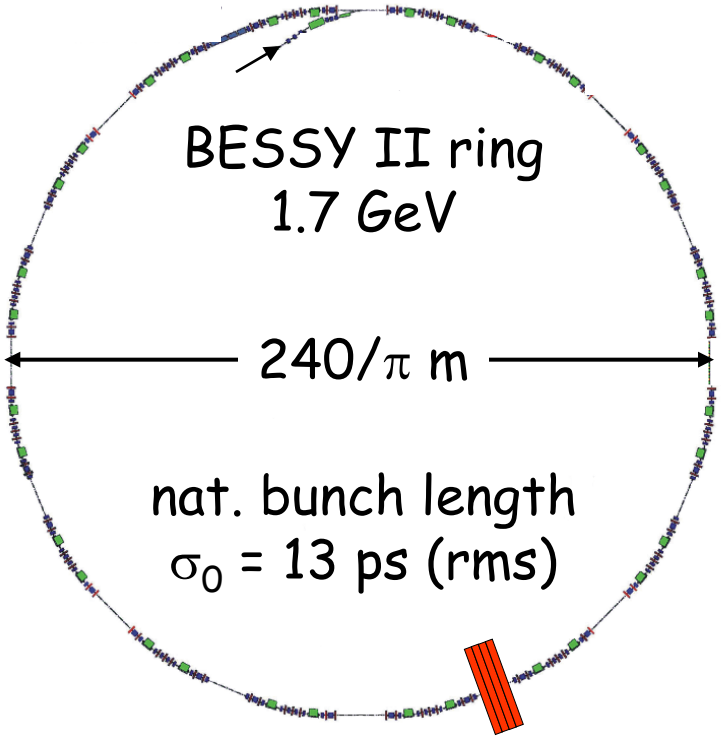
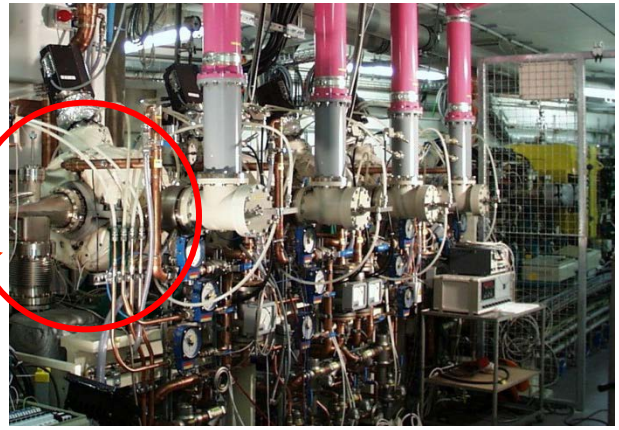


4 rf-cavities
0.5 GHz , 1.5 MV



storage ring parameters

number of cells	2x8
beam current	<300 mA
nat. emittance	6 nmrad
nat. moment. spread	0.7E-3

Low-α optics

a tool to <u>produce and study</u> short bunches

definition of α

$$L = L_0(1 + \alpha \Delta p/p_0)$$

relation σ_0 , α and V' (=dV/dt=$V_0 f_{rf}$):

$$\sigma_0 \propto \sqrt{\alpha/V'}$$

- short bunch, low current operation
  13 ps → 3 ps (rms)
  <u>700 fs are proved and analyzed</u>

- MLS – ring of PTB
  <u>improved, successful low-α optics scheme</u>
  intense, broadband THz source
  short bunch studies
  double-beam

Bunch length – current relation for the BESSY II ring

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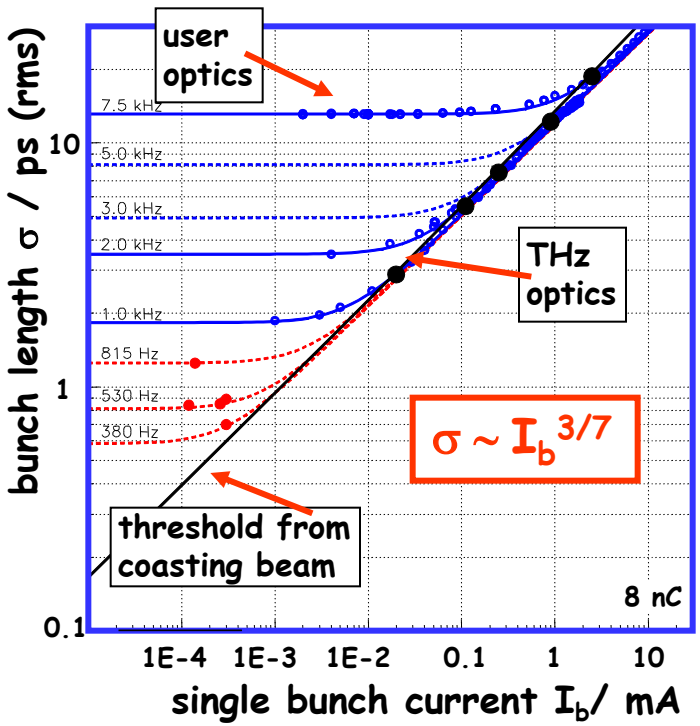
at fixed rf voltage amplitude of 1.35 MV



measurements	theory
○ streak camera	—— Stupakov & Heifets
● Fourier transform spectrometer	
● THz bursting threshold	

- beyond bursting threshold bunches blow up in energy spread
- rule of thumb: $(\sigma, I_b) \rightarrow (2\sigma, 5I_b)$

good agreement between measurement and prediction !

Are short bunches restricted to low currents ??

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<u>scaling relation</u> between α and I predicted by theory: $I \sim \alpha$

bunch length σ: $\sigma \propto \sqrt{\alpha / V'}$

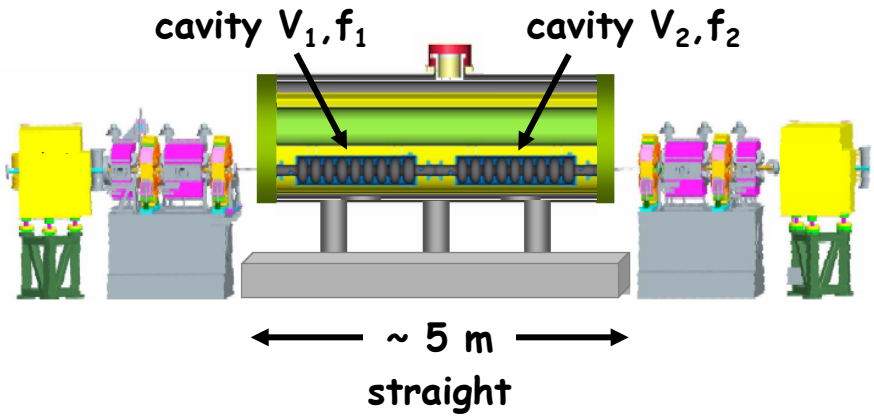
$I \sim V'$ for fixed σ

increasing the rf-gradient V' x 100
→ α needs to be increased x 100
→ I can be increased x 100

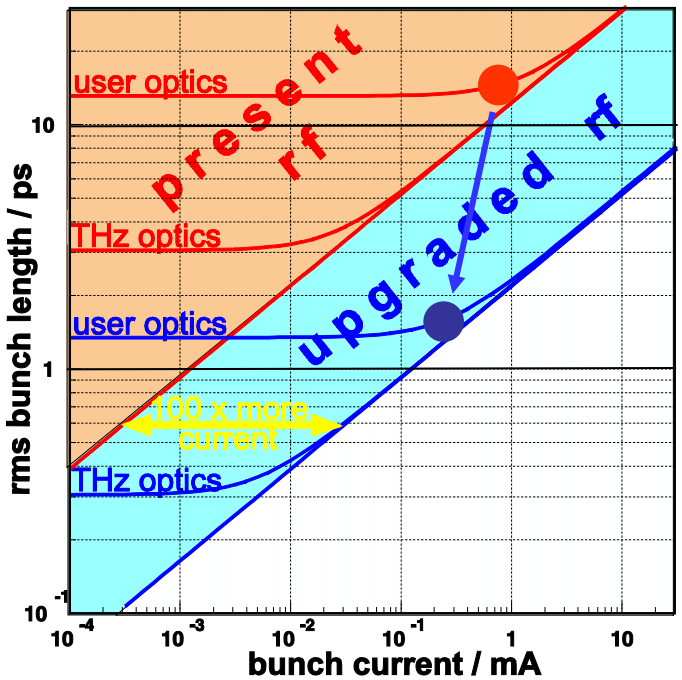
BESSY II & sc-cavities

sc-cavities for bunch shortening

sc-cavities (scheme)
100x enhanced rf-gradient



bunch length – current relation



Simultaneously long & short bunches

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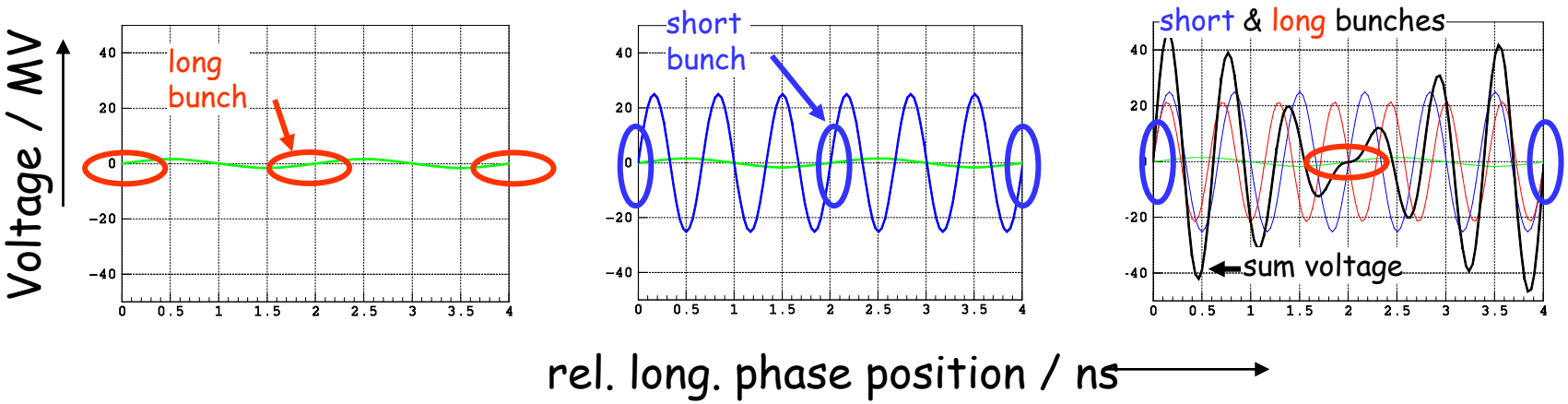
present nc-cavity (power) | sc-cavity # 1 (focusing) | sc-cavity # 1 & 2 (focusing)



0.5 GHz, 1.5 MV
$V' = V \times f_{rf} =$ 0.75 MVGHz

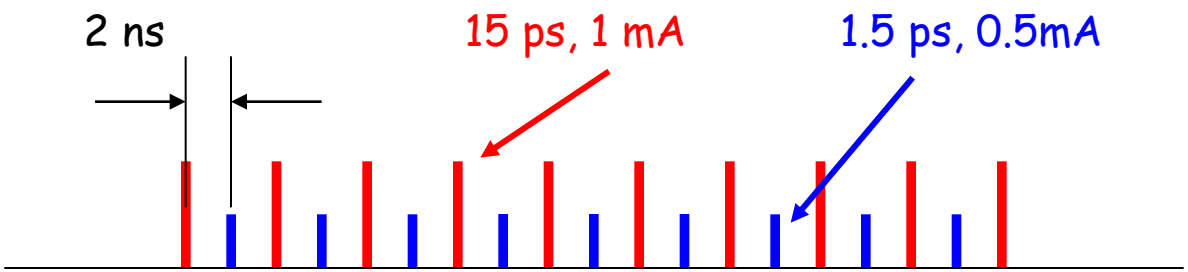
1.5 GHz, 25 MV
$V' = V \times f_{rf} =$ 37.5 MVGHz

1.75 GHz, 21.4 MV
$V' = V \times f_{rf} =$ 75 MVGHz

- flexible fill pattern, I<300 mA
- 15 ps & 1.5 ps pulses simultaneous at all beam ports
- all IDs available

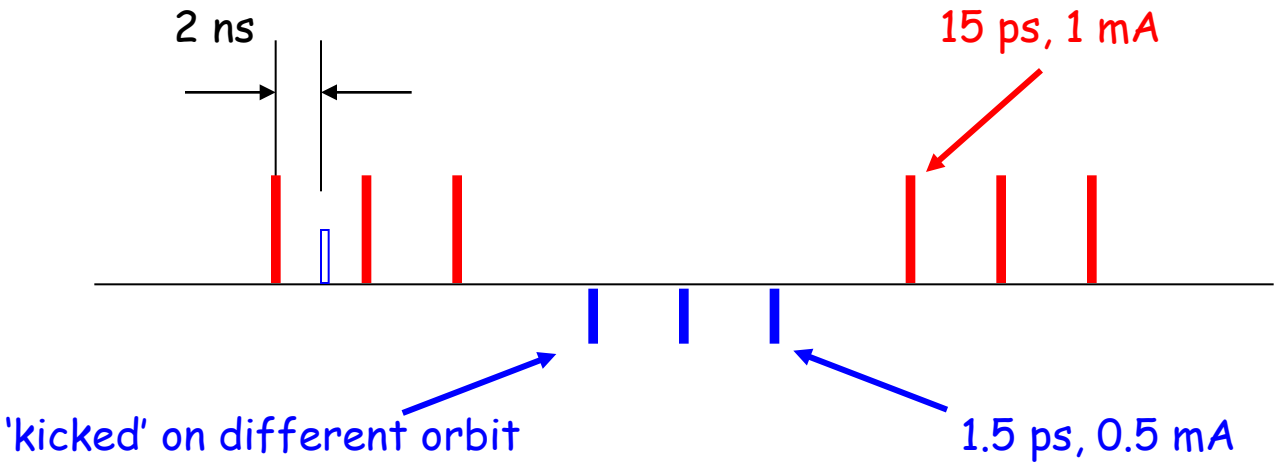
Long & short bunches, fill pattern

Example #1



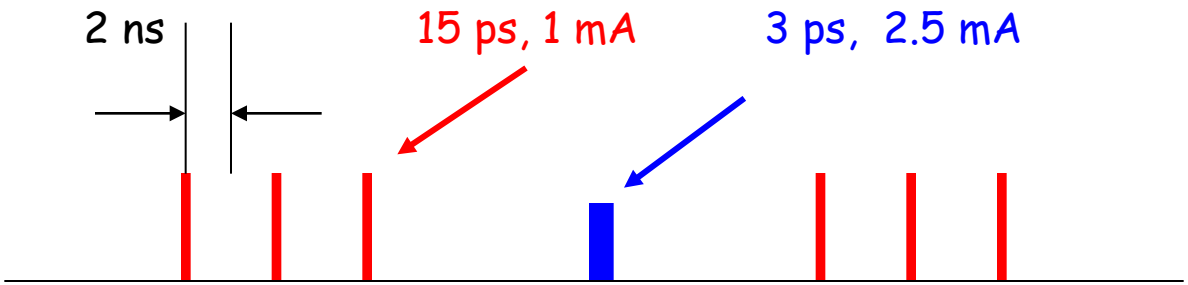
Long & short bunches, fill pattern

Example #2



Long & short bunches, fill pattern

Example #3



More advanced scheme: double beam

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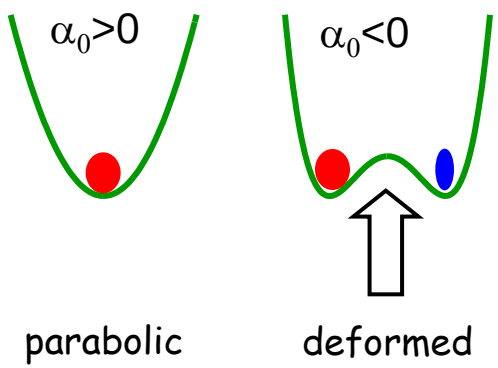
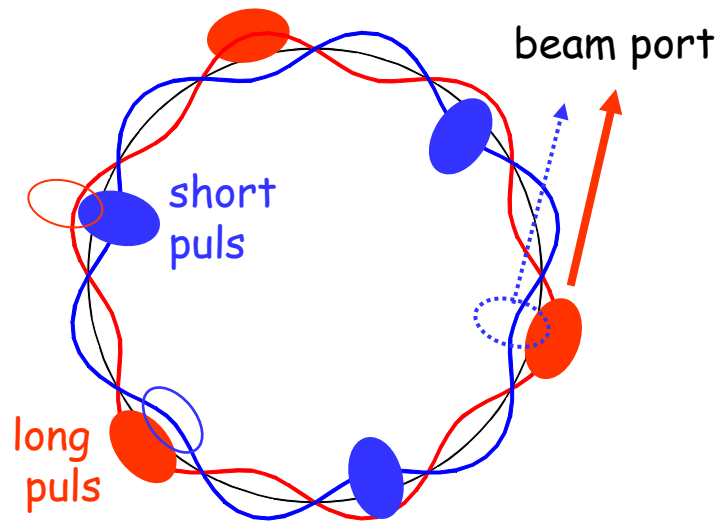
2 sc-rf cavities & low α optics

longitudinal potential well



double beam scheme



→ long and short bunches: longitudinally and transversely separated

More advanced scheme: double beam

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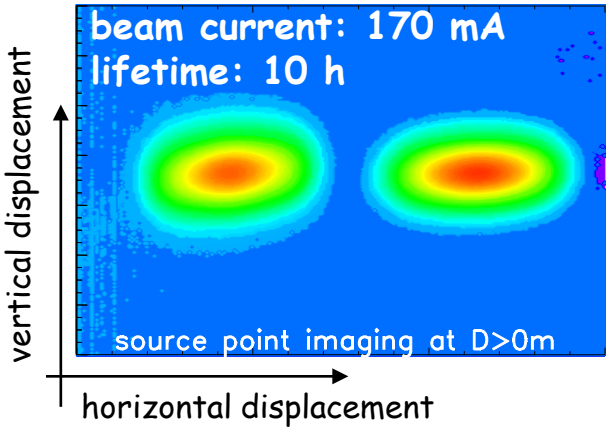
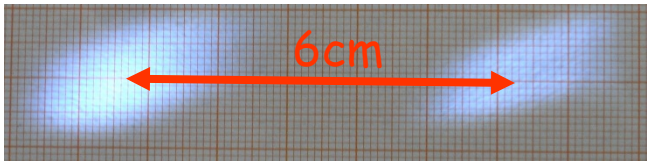
measurements at MLS

e^- beam source point image



photon beam image (beam port exit)



transverse separation of photon beams

double beams can be easily produced at the MLS low-α optics
→ <u>good life time</u>, → <u>high currents</u>

HZB expertise

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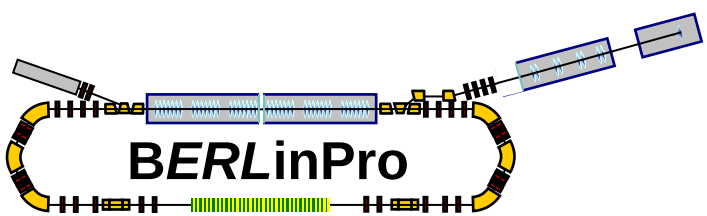
BERLinPro and BESSY^{VSR}:

- BERLinPro cavities close to the BESSY^{VSR} , 1.3 GHz to be scaled to 1.0 GHz and 1.25 GHz
- high current beam interaction with sc cavities



Summary

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simultaneously long & short bunches:

- 175 long bunches, 15 ps < 300 mA
- 175 short bunches, 1.5 ps (rms)
- all beam ports supplied
- all IDs available
- present transverse user optics applied

expected results:

beam parameter	present 350 bunch filling THz optics	BESSY^{VSR} 175 bunch filling user optics	BESSY^{VSR} 175 bunch filling THz optics	
bunch length (rms) / ps	3	1.5	0.7	0.3
current (sb) / mA	0.04 (0.03 nC)	0.8	0.14	0.02
current (mb) / mA <300	14	(140)	24	3.5

Acknowledgment

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