Vision for the Future: BESSY^{VSR}
A Variable Bunch Length Storage Ring

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presented by P. Kuske

Outline

- Motivation
- Limits 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
  (→ 10 000x more THz power)

BESSY II synchrotron radiation source

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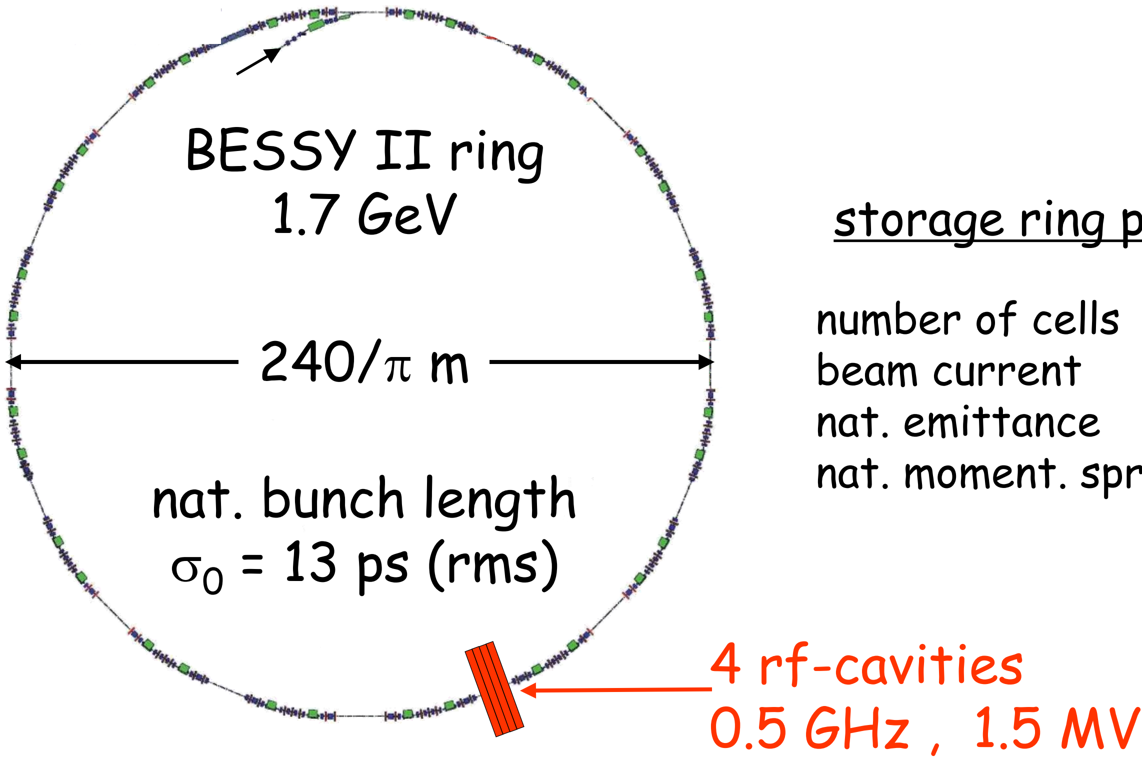

storage ring parameters

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

Low-α optics

a tool to produce and study short bunches

definition of α

$$\Delta L/L_0 = \alpha \Delta p/p_0$$

relation σ_0, α and V':

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

- pioneering work at BESSY II, since 1999

- short bunch operation, 13 ps → 3 ps (rms)
  700 fs are proved and analyzed

- MLS – ring of PTB
  first ring to control 3 orders of α

$$\alpha = \alpha_0 + \alpha_1 \Delta p/p_0 + \alpha_2 (\Delta p/p_0)^2 + \ldots$$

short bunch studies,
double-beam

"stability thresholds of short bunches" - subject of present PhD-thesis by Markus Ries, HZB

Bunch length – current relation for the BESSY II ring

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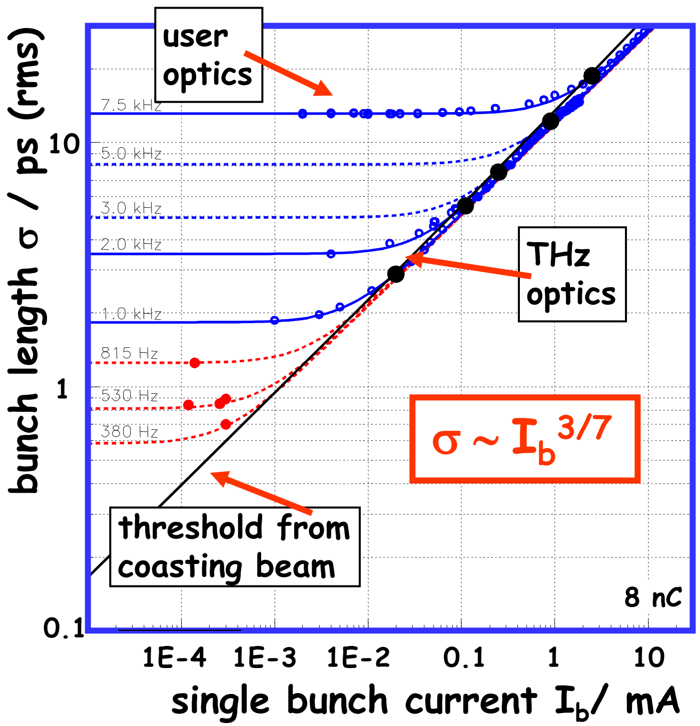
at fixed rf voltage amplitude of 1.35 MV



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

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

<u>good agreement between measurement and prediction !</u>

Are short bunches restricted to low currents ??

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scaling law between α and I predicted by:
- bunched beam theory (Sacherer)
- Vlasov-Fokker-Planck simulation
- and coasting beam (Landau Damping)

'Keil-Schnell':

$$I\,|Z_0^{||}/n| \leq F \frac{\Delta p}{p_0} \alpha \frac{\Delta p}{p_0} E_0/e \quad \rightarrow \quad I \sim \alpha$$

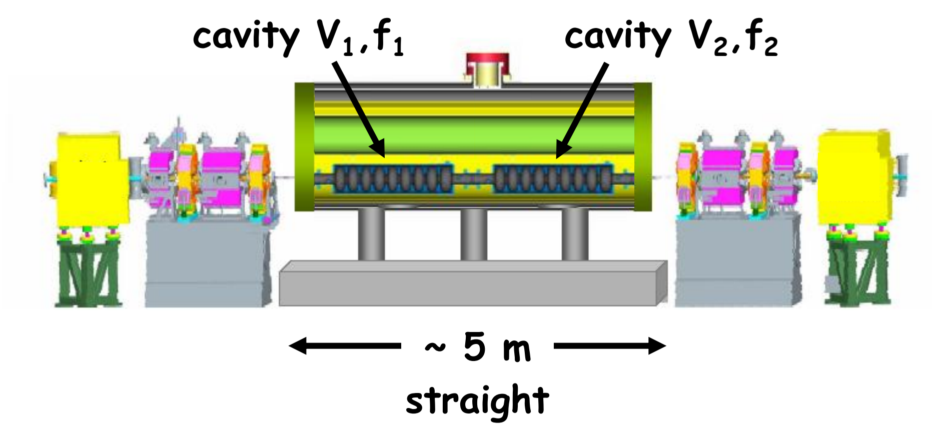
bunch length σ → $\sigma \propto \sqrt{\alpha/V'}$

→ $I \sim V'$ for fixed σ

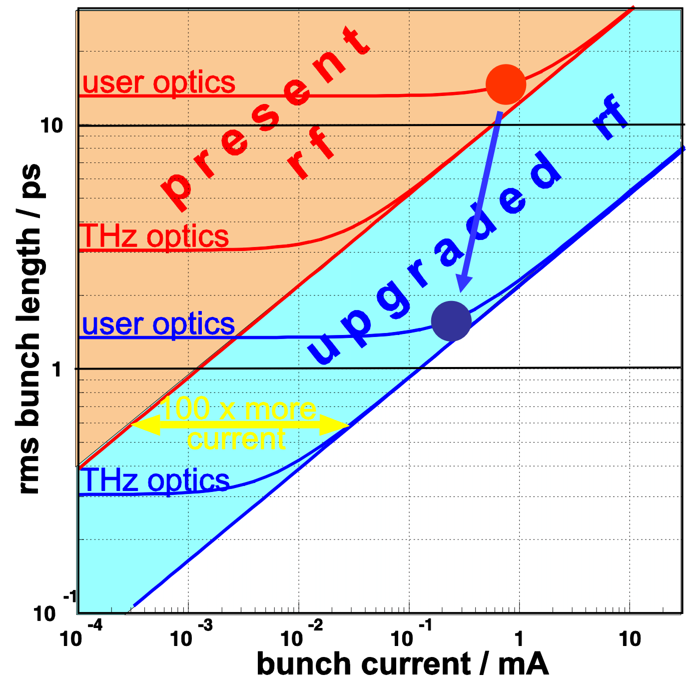
increasing the rf-gradient V' x 100
→ α needs to be increased x 100
→ I can be increased x 100

sc-cavities for bunch shortening

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

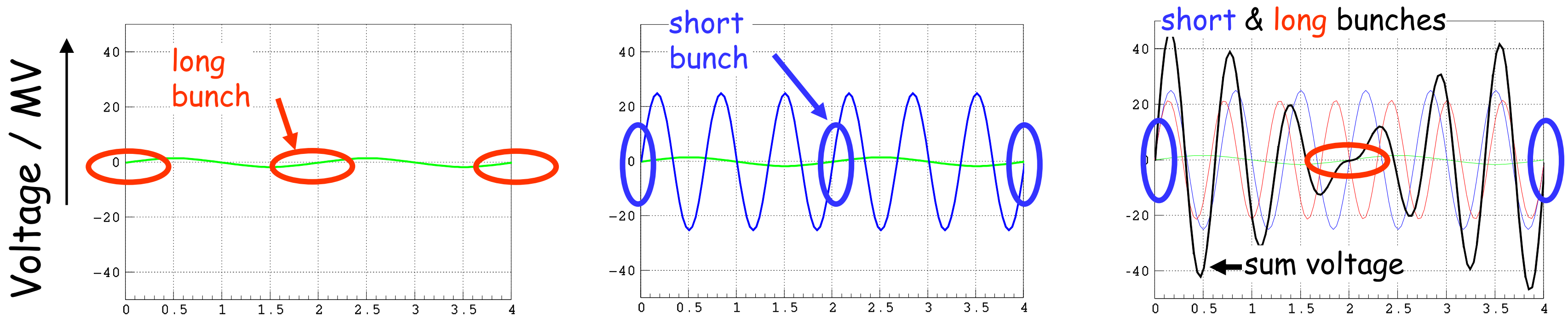


bunch length – current relation



Simultaneously long & short bunches

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



rel. long. phase position / ns →

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

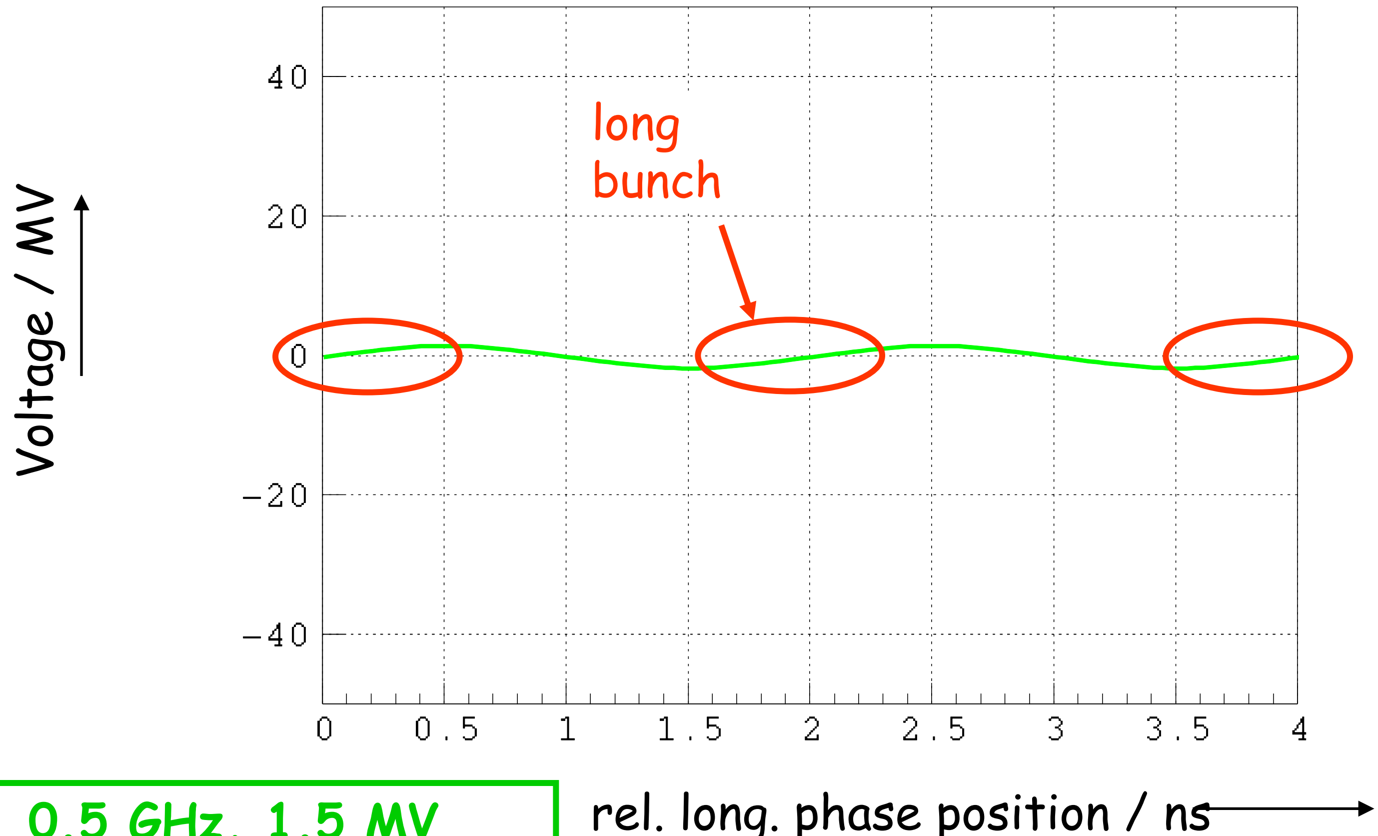
1.5 GHz, 25 MV
$V' = V \times f_{rf} =$ 37.5 MVGHz

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

Simultaneously long & short bunches

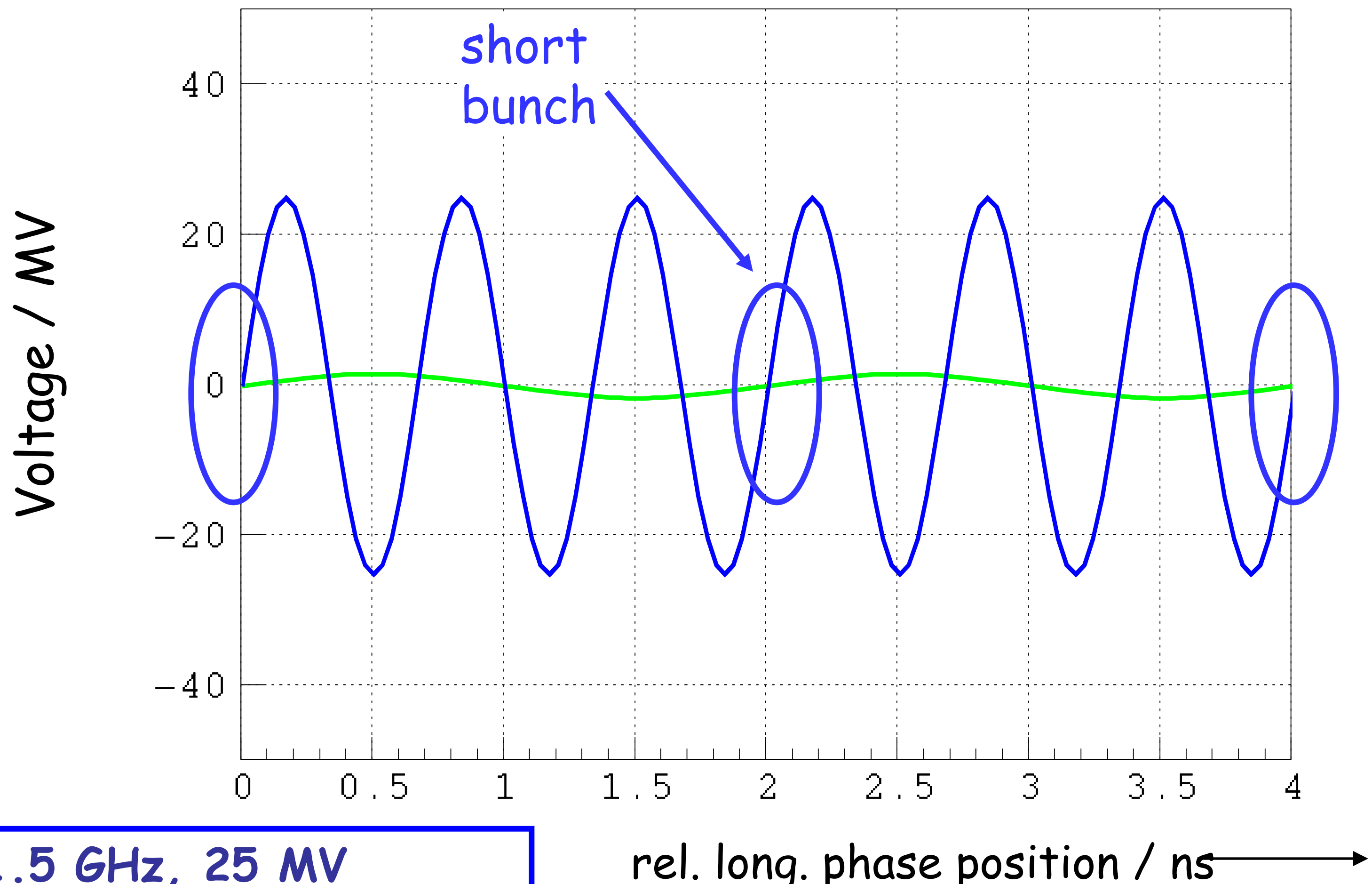
present nc-cavity (power)



0.5 GHz, 1.5 MV
$V' = V x f_{rf}$ = <u>0.75 MVGHz</u>

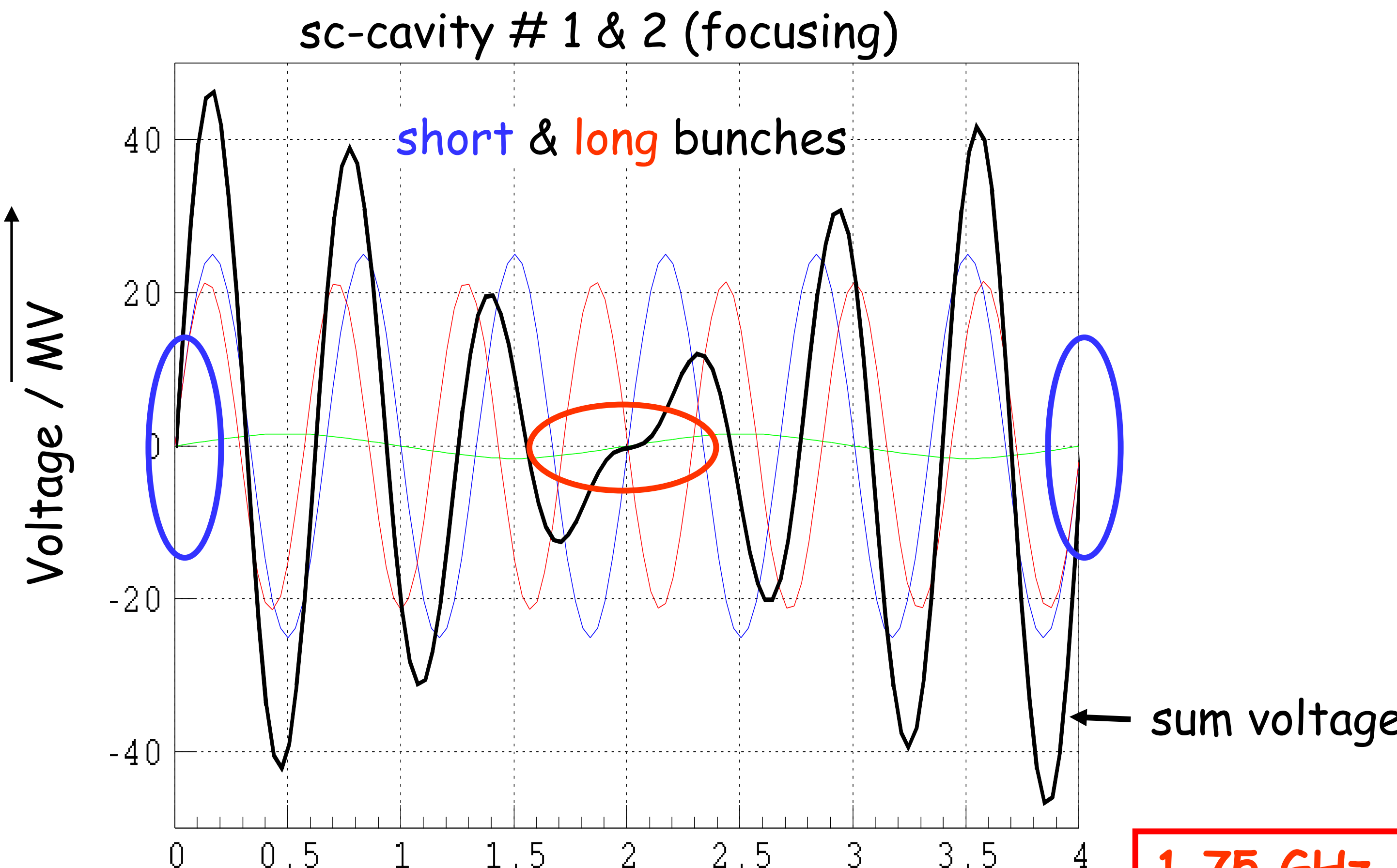
Simultaneously long & short bunches

sc-cavity # 1 (focusing)



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

Simultaneously long & short bunches



- flexible fill pattern, I<300 mA
- <u>15 ps & 1.5</u> ps pulses simultaneous at all beam ports
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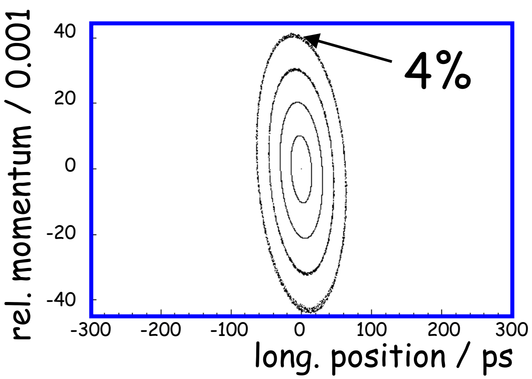
1.75 GHz, 21.4 MV
$V' = V \times f_{rf} =$ <u>75 MVGHz</u>

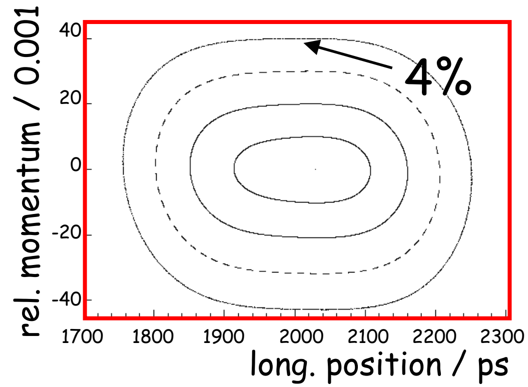
MAD tracking

single particle tracking, BESSY II user optics & two sc-cavities

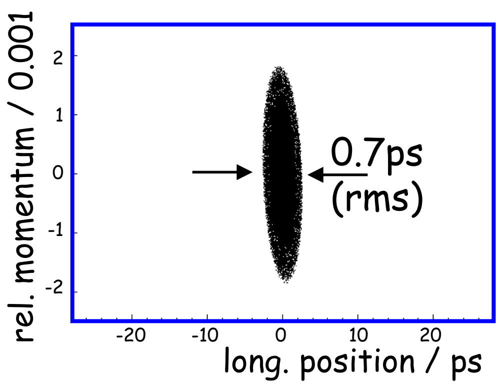
short

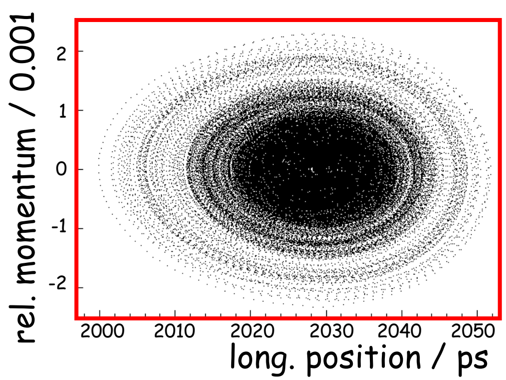


long



short & long bunch momentum $\Delta p/p_0$ acceptance +/- 4%





short & long bunch quantum excitation & damping
10 damping times

More advanced scheme: double beam

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chromatic orbit length:

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

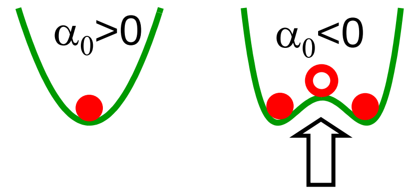
orbits of equal length $L=L_0$:

I) $\Delta p/p_0 = 0$ II) $\alpha = 0$

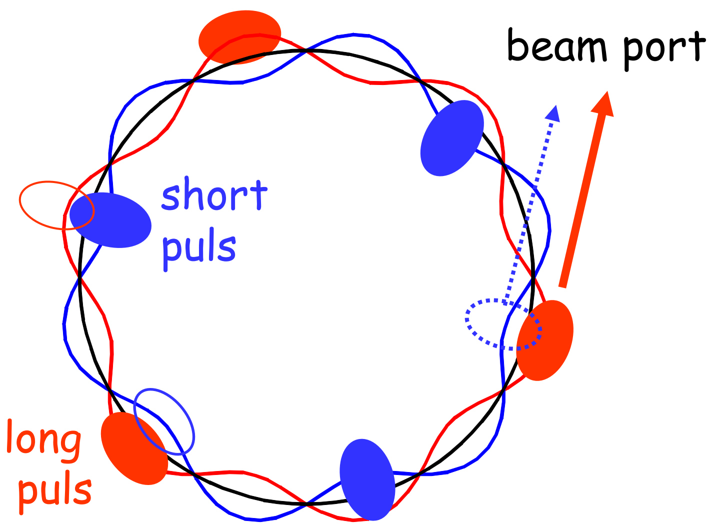
2 solutions if $\alpha = \mathbf{0}$

$$\alpha = \alpha_0 + \alpha_2 (\Delta p/p_0)^2$$

$$(\Delta p/p_0)_F = \pm\sqrt{-\alpha_0/\alpha_2}$$



double beam scheme



2 sc-rf cavities & low α optics

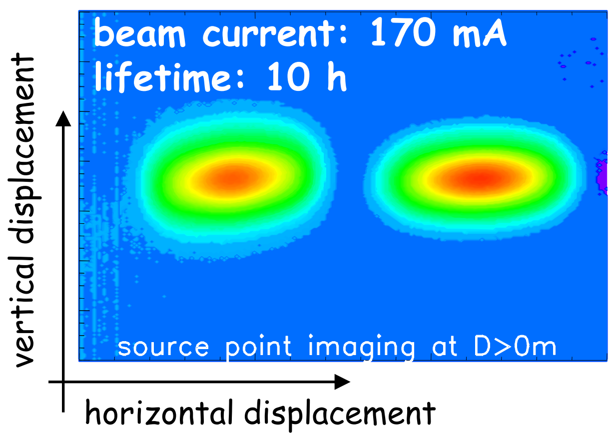
- double beam scheme combined with two sc-rf cavities

→long and short bunches longitudinally and transversely separated

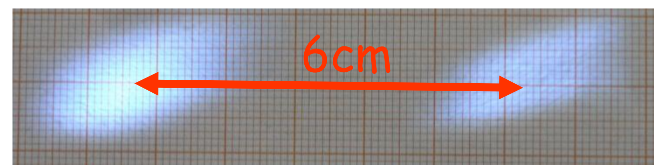
More advanced scheme: double beam

measurements at MLS

e^- beam source point image



photon beam image (beam port exit)



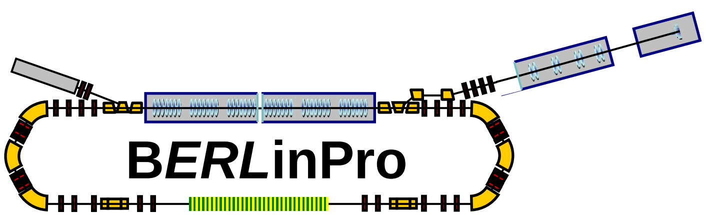
transverse separation of photon beams

double beams can be easily produced at the MLS low-α optics

→ <u>good life time</u>, → <u>high currents</u>

BERLinPro and BESSY^{VSR}:

- BERLinPro cavities close to the BESSY^{VSR} , 1.3 GHz to be scaled to 1.5 GHz and 1.75 GHz
- high current beam interaction with sc cavities



Summary

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