NEGATIVE MOMENTUM COPMPACTION AT DAΦNE

M. Zobov, INFN-LNF

Workshop on
e+e- in the 1-2 GeV range: Physics and Accelerator Prospects
10-13 September 2003, Alghero, Italy

Talk Outlines

- Advantages of the negative momentum compaction factor ($\alpha_c < 0$)
- Some experimental data
- Bunch lengthening in DAΦNE with $\alpha_c < 0$
- Beam-beam effects in DAΦNE with $\alpha_c < 0$
- Conclusions

Beam Dynamics with $\alpha_c < 0$

The DAΦNE lattice is enough flexible to provide collider operation with a negative momentum compaction (P. Raimondi). There can be several advantages for beam dynamics and luminosity performance in this case:

- Bunch is shorter with a more regular shape
- Longitudinal beam-beam effects are less dangerous
- Microwave instability threshold is higher (?)
- Sextupoles are not necessary

Luminosity Scaling

- The minimum value of the vertical beta function at the IP in a collider is set by the hourglass effect and it is almost equal to the bunch length. By scaling the horizontal and vertical beta functions at the bunch length, the linear tune shift parameters remain unchanged while the luminosity scales as σ_z:

$$L \sim \frac{N^2}{\sigma_x \sigma_y} \sim \frac{N^2}{\sqrt{\beta_x \beta_y}} \sim \frac{N^2}{\sigma_z}$$

- However, since the synchrobetatron resonances are less pronounced for shorter bunches, especially in collisions with a crossing angle and with the negative momentum compaction, one can expect to achieve higher values of the tune shift parameters. This means that the maximum number of particles N per bunch can be higher, thus giving an additional factor in luminosity increase ~ N^2

Longitudinal Beam-Beam Kick

- A particle performing betatron oscillations and colliding at the IP with a counter rotating strong bunch receives a longitudinal kick

  (Y. Derbenev and A.Skrinsky, All-Union Meeting on Part. Accel., 1972, p. 386; M. Bassetti, LNT-T-105, 1978)

- This effect is equivalent to a reduction of the effective RF voltage by

$$\Delta U = \frac{NeR}{2h\beta_0^2} \qquad \text{(round beam)}$$

  for the positive momentum compaction

- The effect is stronger if we want to increase luminosity by increasing the number of particles N or by decreasing the beta function at the IP

- The incoherent motion gets unstable when $V_{RF} = |\Delta U|$

- The coherent instability can take place if $V_{RF} = 2|\Delta U|$

All this does not happen for the negative momentum compaction!

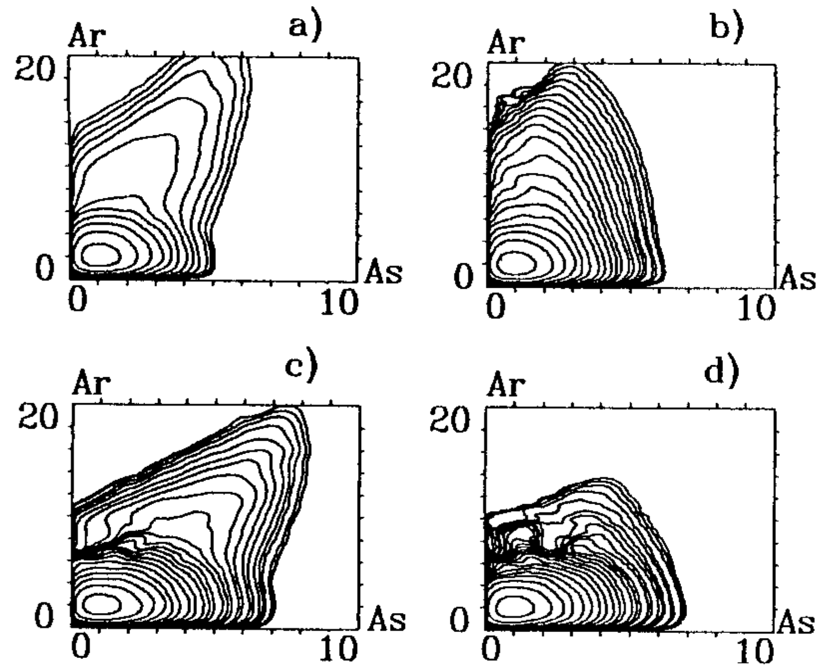
Synchro-Betatron Beam-Beam Resonances

(V. V. Danilov et al., HEACC 1992, p.1109

Analysis of the synchrobetatron motion has shown that for the synchrobetatron resonances:

- **The simultaneous growth of both betatron and synchrotron amplitudes is possible for $\alpha_c > 0$**

- **At $\alpha_c < 0$ one of the amplitudes can grow only at the expense of decrease in another one, and *vice versa***



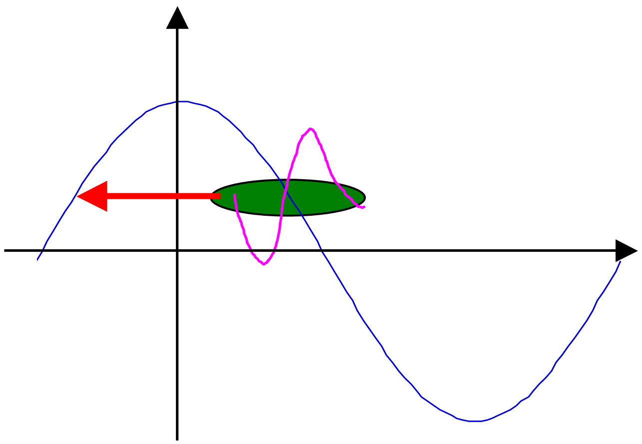
a) $\alpha = 0.04, \; \{\nu_b\} = 0.02 \;\; T_l \sim 1 \; s$

b) $\alpha = -0.04, \; \{\nu_b\} = 0.02 \;\; T_l \sim 10^5 \; s$

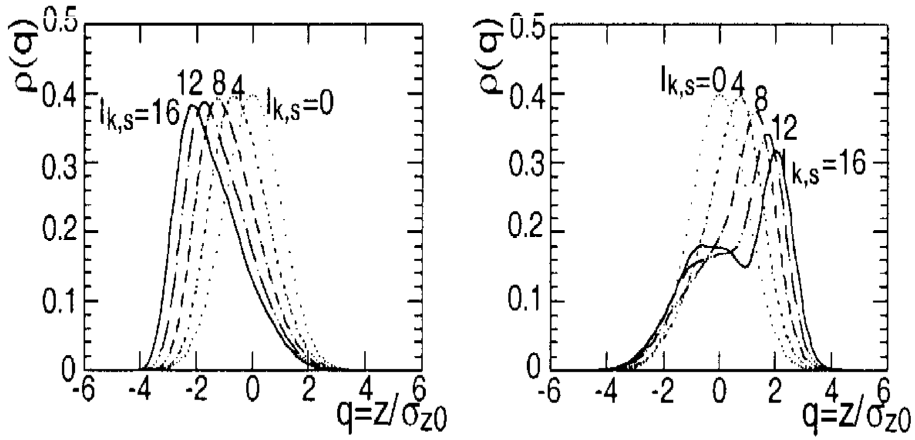
c) $\alpha = 0.04, \; \{\nu_b\} = 0.04 \;\; T_l \sim 10^5 \; s$

d) $\alpha = -0.04, \; \{\nu_b\} = 0.04 \;\; T_l \geq 10^8 \; s$

Potential Well Distortion



-The stable RF voltage slope changes while passing from a positive momentum compaction to the negative one, but the wake potential remains the same.



(a) α < 0 (b) α > 0

-In the most cases the wake lengthens bunches for the positive α_c and is focusing for the negative α_c.

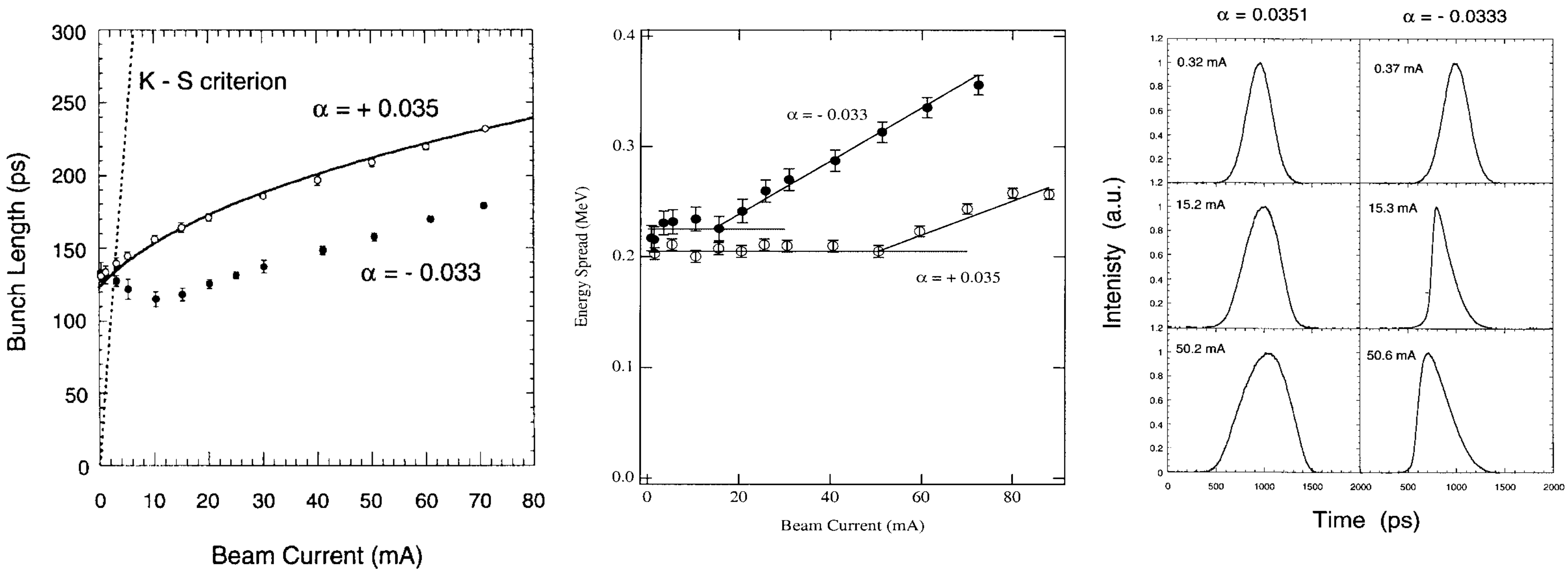
-The bunch shape is more regular at $\alpha_c < 0$ for typical wakes (for example, for the broad-band impedance model)

Microwave Instability Threshold

- It has been found that the current threshold of the instability is higher in the rings with a negative momentum compaction over a very wide range of the impedance parameters (S. X. Fang et al., KEK Preprint 94-190, 1995)
- However, the experiments on the UVSOR storage ring (H. Hama et al., Nucl.Instrum.Meth.A407, p.234) and on SUPER-ACO (A. Nadji et al., EPAC96, p. 234) have revealed that the energy spread growth was higher for the negative momentum compaction. KEKB experience (this Workshop).
- The microwave threshold depends strongly on the wake fields of a real storage ring. So, it is difficult to say a priori whether the negative or positive momentum compaction is preferable from this point of view.

Experimental Data from UVSOR

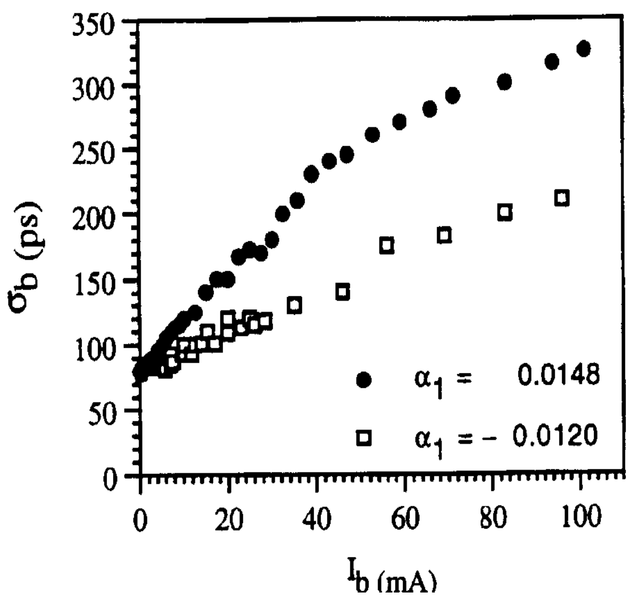
References: 1. M. Hosaka et al., Nucl.Instr.Meth. A407 (1998) 234-240
2. M. Hosaka et al., APAC98, 426-428

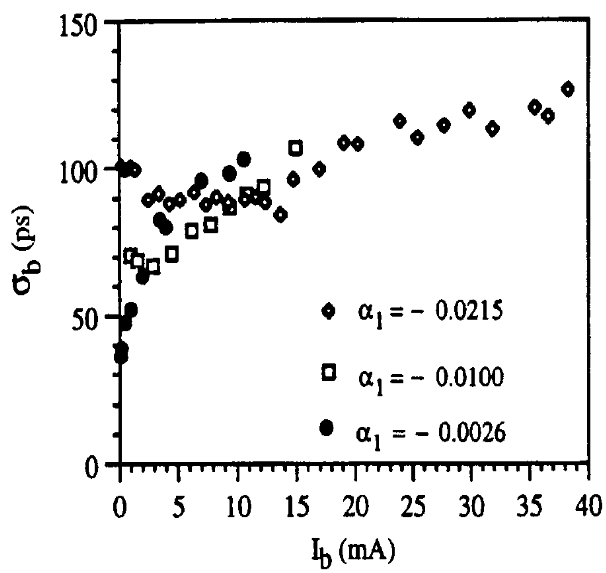


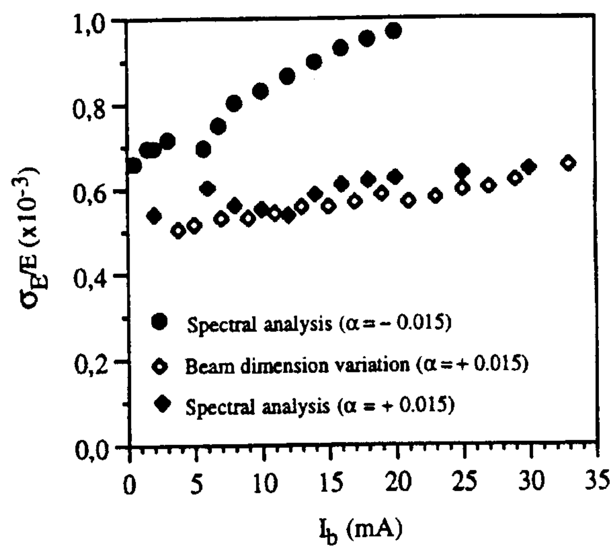
Experimental Data from SUPER-ACO

References: 1. A. Nadji et al., EPAC96, 234-240

More than 100 mA have been stored in a single bunch without sextupoles!!





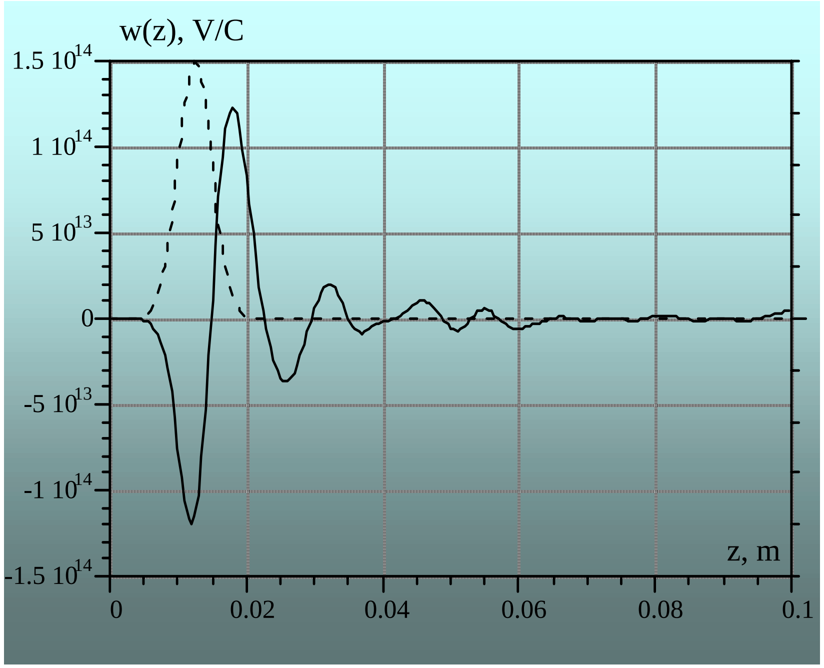


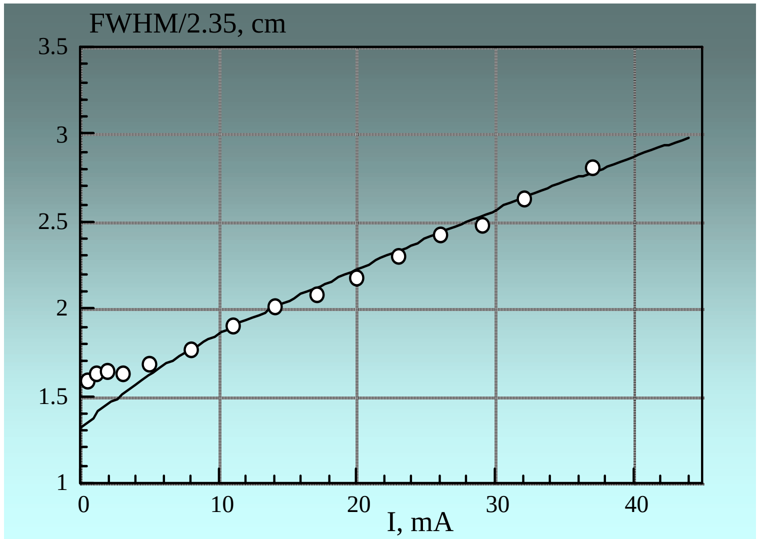
Bunch length is notably smaller for $\alpha_c < 0$

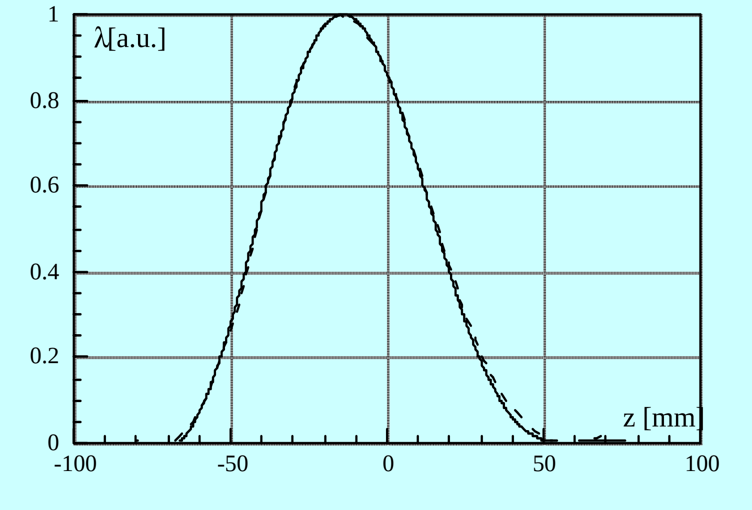
Bunch length does not depend on α_c at high currents

Energy spread is higher for $\alpha_c < 0$

DAΦNE Wake Field

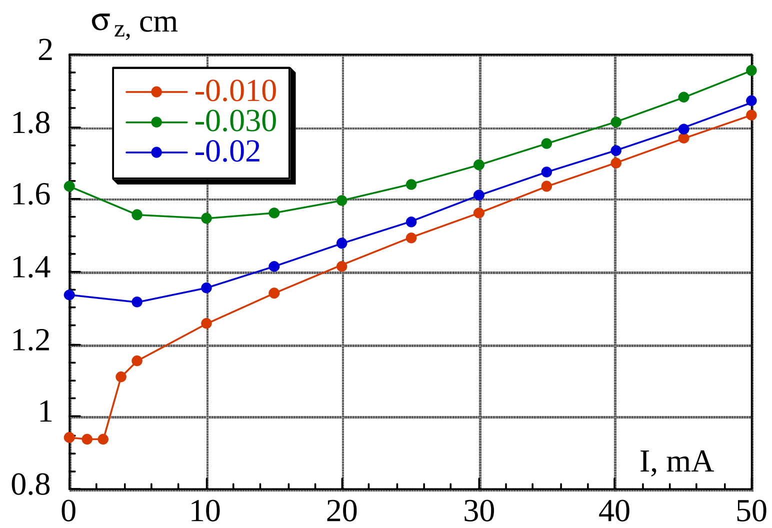


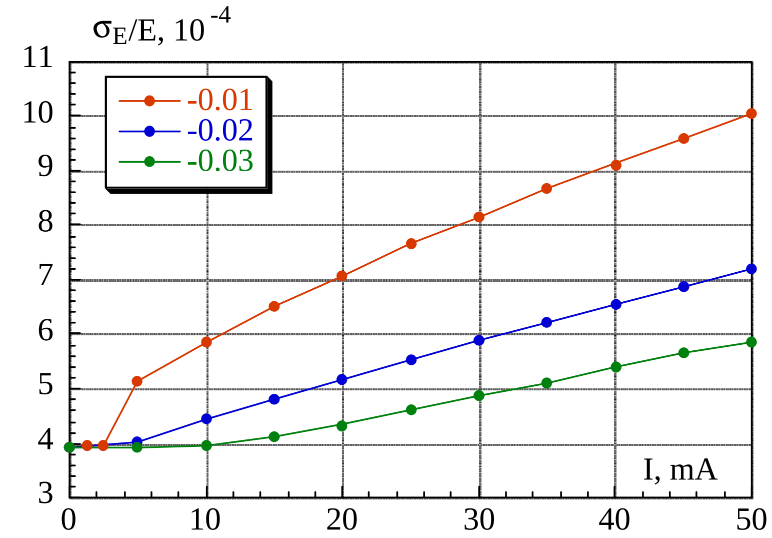




Calculated DAΦNE wake potential has been successfully applied for bunch lengthening and microwave threshold predictions

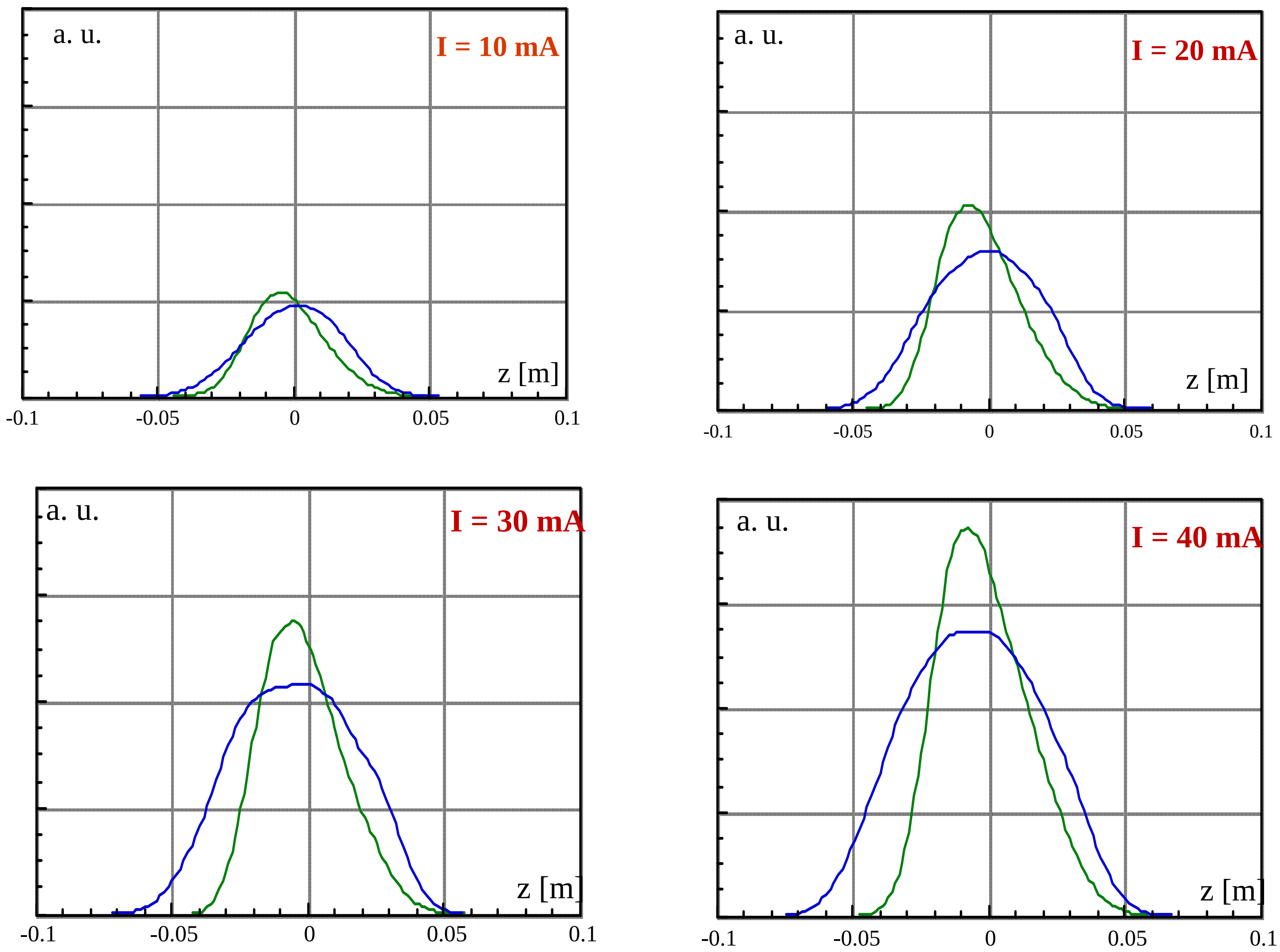
Typical Bunch Lengthening



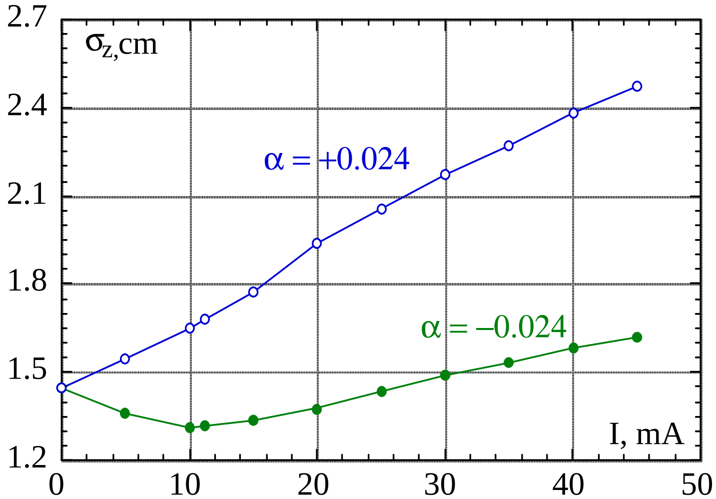


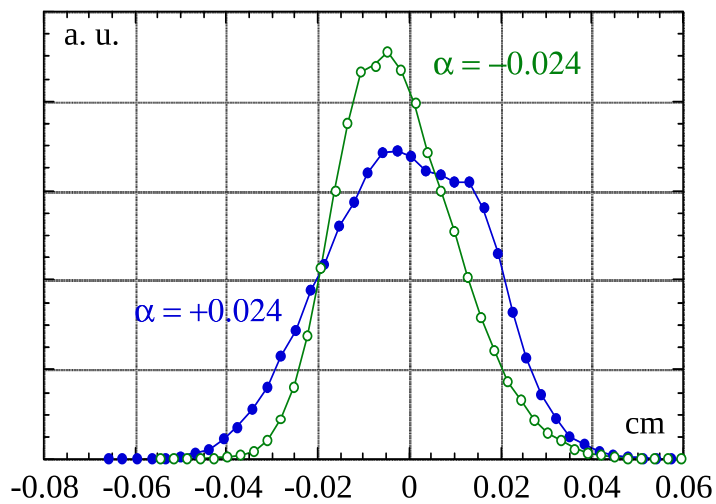
- Below the microwave threshold bunch shortens
- Above the threshold the energy spread starts growing and bunch passes into lengthening regime
  (There is a minimum of the bunch length at the threshold)
- The threshold depends on the momentum compaction value.
  Usually, the lower the momentum compaction the lower the threshold
- For bunch currents much higher than the threshold bunch length does not depend on α_c.

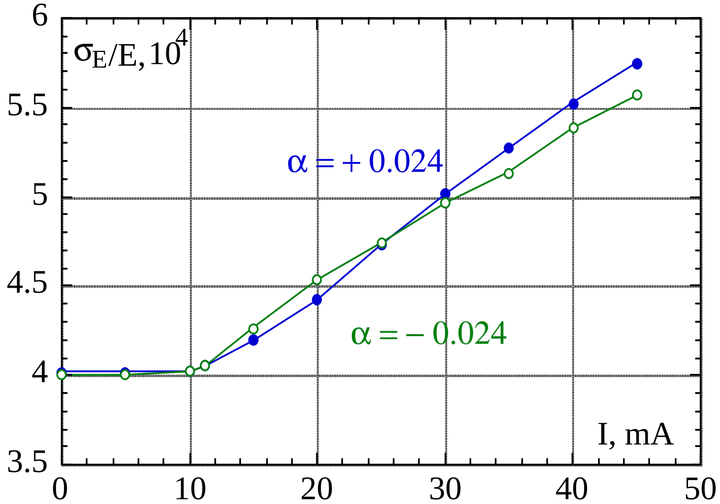
Bunch Charge Distribution



Bunch Length and Energy Spread







α_c = - 0.024 seems to be an optimum considering given DAΦNE wake:

- microwave threshold is equal for the positive and the negative momentum compaction (~10-12 mA)

-bunch length does not exceed 1.5 cm up to the bunch current of 30 mA

Initial Data for Simulations

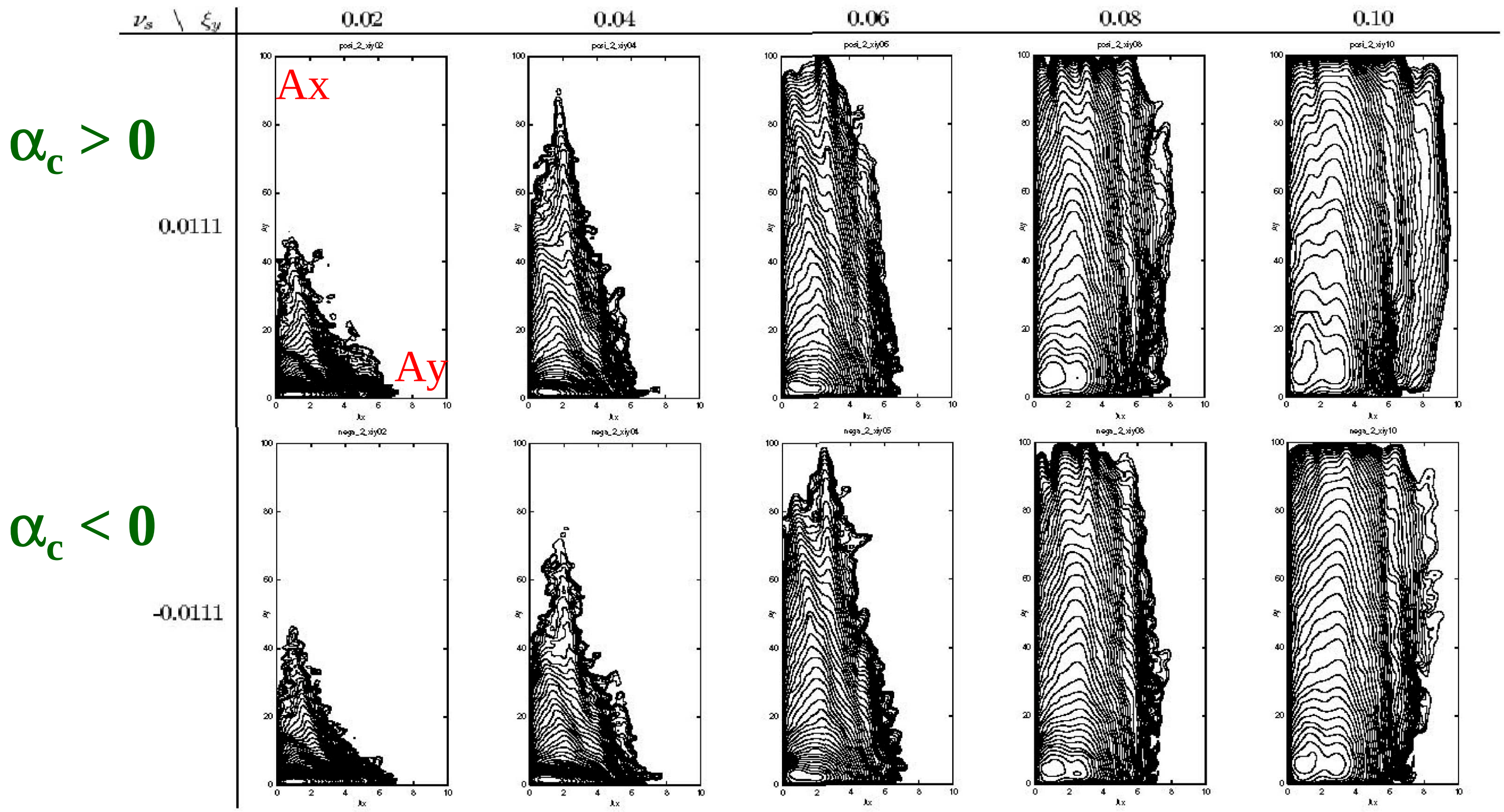
β_x = 1.5 m; β_y = 1.5 cm; k = 0.2%; ε_x = 0.5x10^{-6}; ε_y = 10^{-9}

I, mA (bunch)	ξ_x	ξ_y	σ_z, cm	L, 10^{30} (expected)
5	0.009	0.020	**1.359,1.545**	0.728
10	0.018	0.040	**1.314,1.651**	2.889
15	0.027	0.060	**1.337,1.773**	6.550
20	***0.036***	***0.080***	**1.376,1.939**	***11.64***
25	0.045	0.100	**1.436,2.056**	1.819
30	0.054	0.120	**1.489,2.171**	2.620

$>10^{33}$ in 100 bunches

Equilibrium Density Contour Plots

(Working Point (0.154;0.212)



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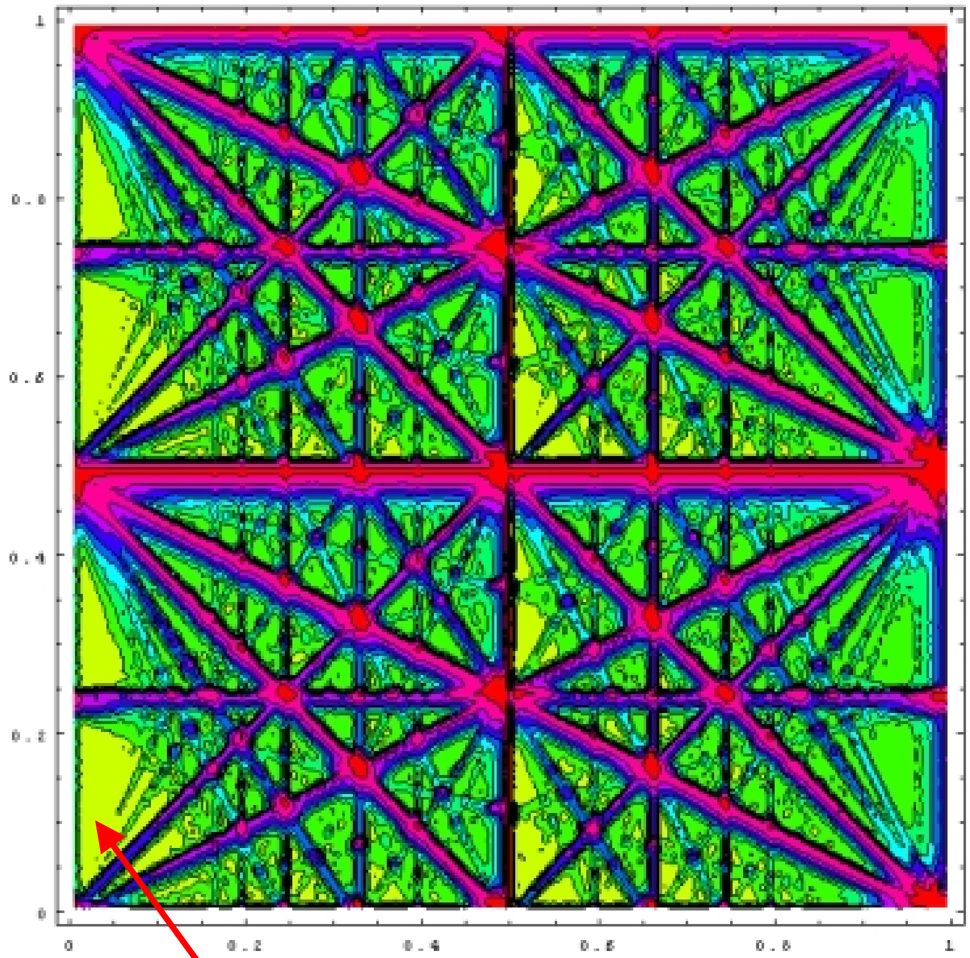
Change of the Working Point



- Modification of the DAΦNE wigglers

(M. Preger, C. Sanelli, to be published)

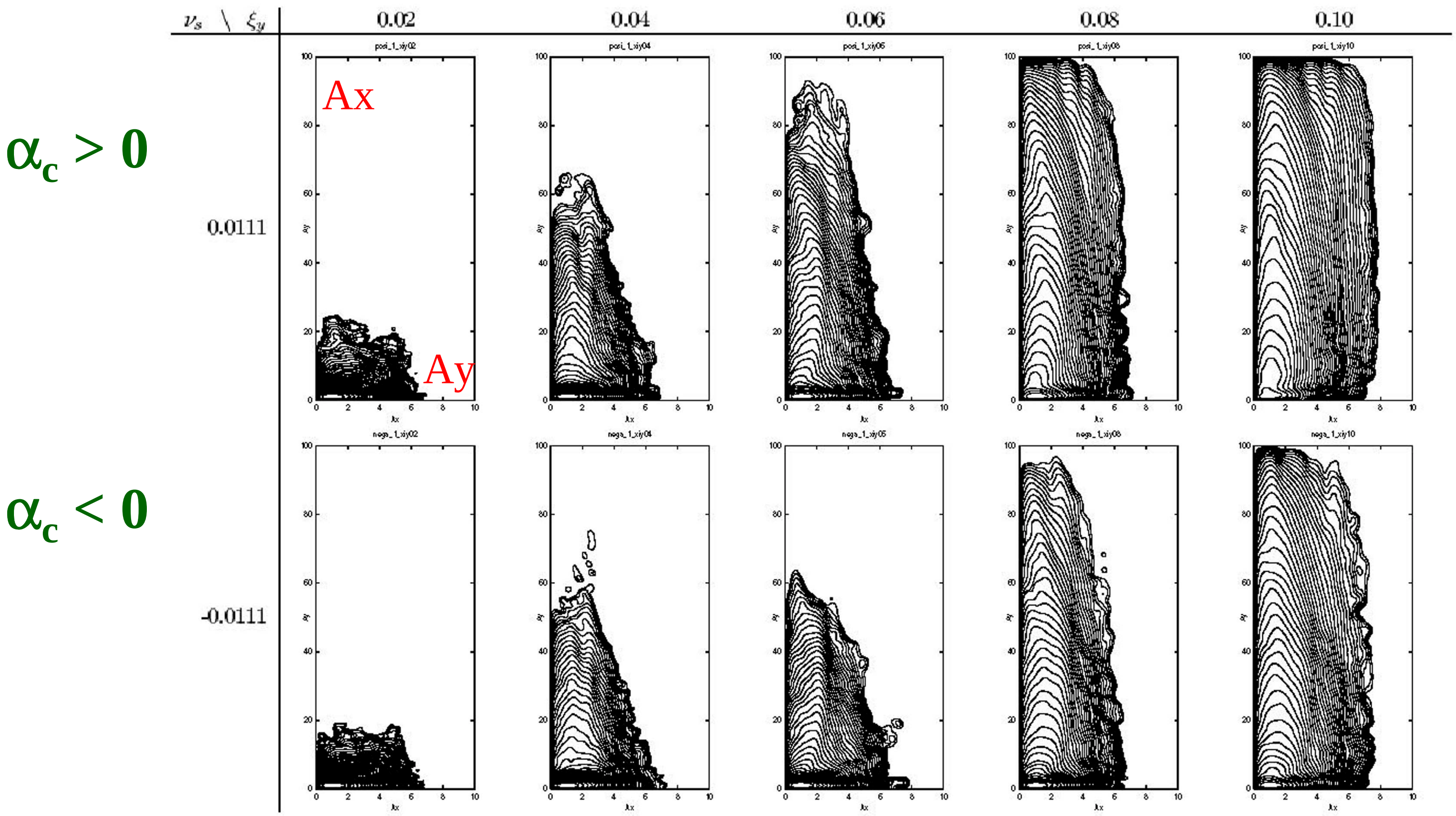
- Dynamics aperture is larger

(P. Raimondi)

- Possibility to shift the working point closer to the integers

Equilibrium Density Contour Plots

(Working Point (0.057;0.097)



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Conclusions

- It is worthwhile to try a collider operation with a negative momentum compaction factor since this can provide several advantages in beam dynamics

- Simulations indicate that by shifting the working point close to the integers and applying a lattice with the negative momentum compaction we have a possibility to push DAΦNE luminosity to 10^{33} $cm^{-2}s^{-1}$ level