Structure Wakefields and Tolerances

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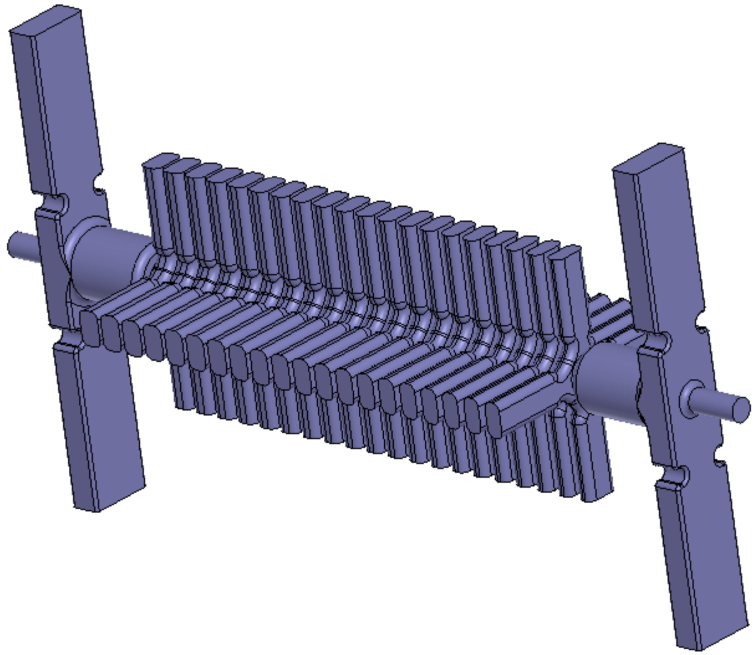
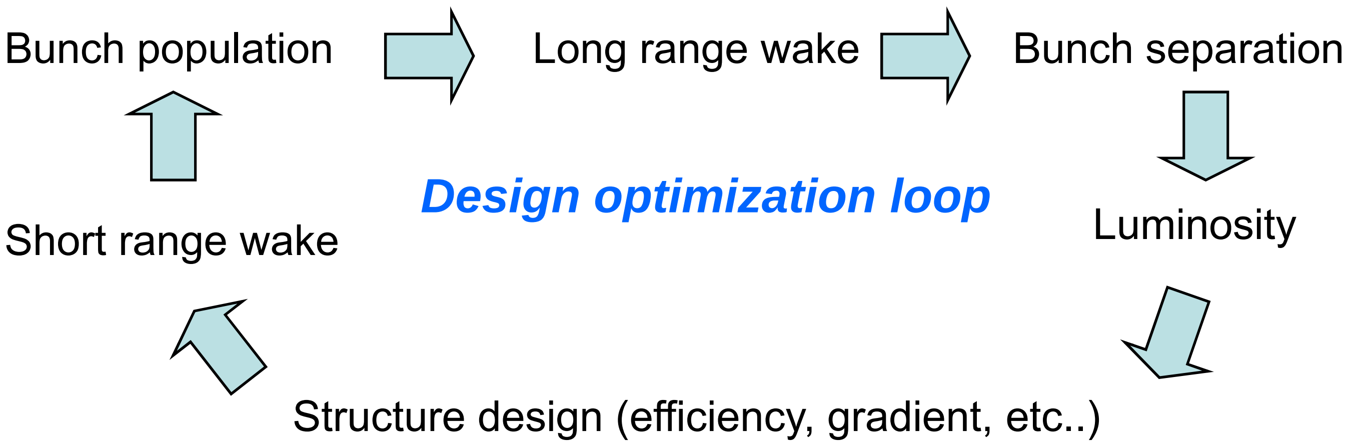
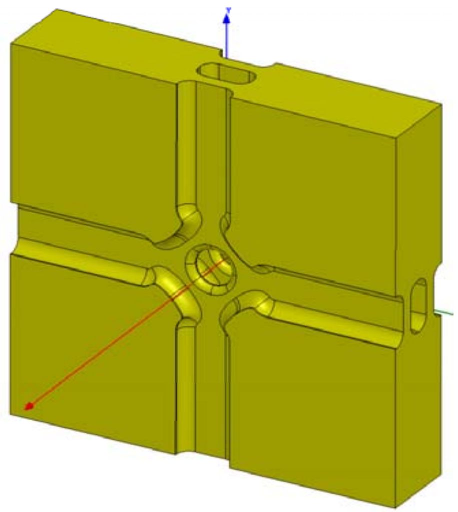
Parameters of the CLIC structure “CLIC G” (from A. Grudiev)

Structure	CLIC_G
Frequency: f [GHz]	12
Average iris radius/wavelength: $\langle a \rangle/\lambda$	0.11
Input/Output iris radii: $a_{1,2}$ [mm]	3.15, 2.35
Input/Output iris thickness: $d_{1,2}$ [mm]	1.67, 1.00
N. of reg. cells, str. length: N_c, l [mm]	24, 229
Bunch separation: N_s [rf cycles]	6
Luminosity per bunch X-ing: $L_{b\times}$ [m^{-2}]	1.22×10^{34}
Bunch population: N	3.72×10^{9}
Number of bunches in a train: N_b	312
Filling time, rise time: τ_f, τ_r [ns]	62.9, 22.4
Pulse length: τ_p [ns]	240.8







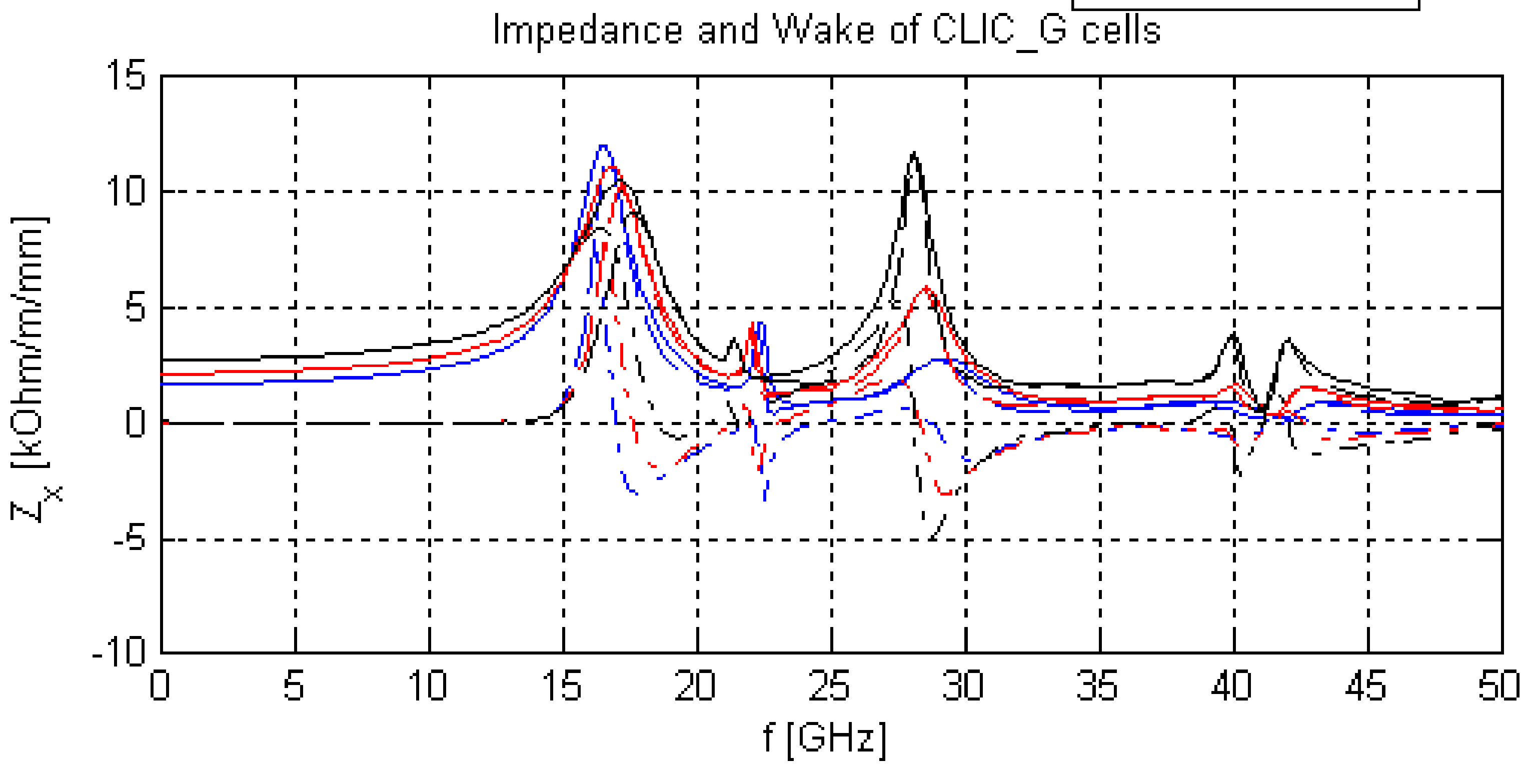
Transverse impedances and long range wakes in cells (from A. Grudiev)

cell	first	middle	last
Q_1	10	7.7	6.3
A_1 [V/pC/mm/m]	117	140	156
f_1 [GHz]	16.74	17.21	17.67

Blue – first cell

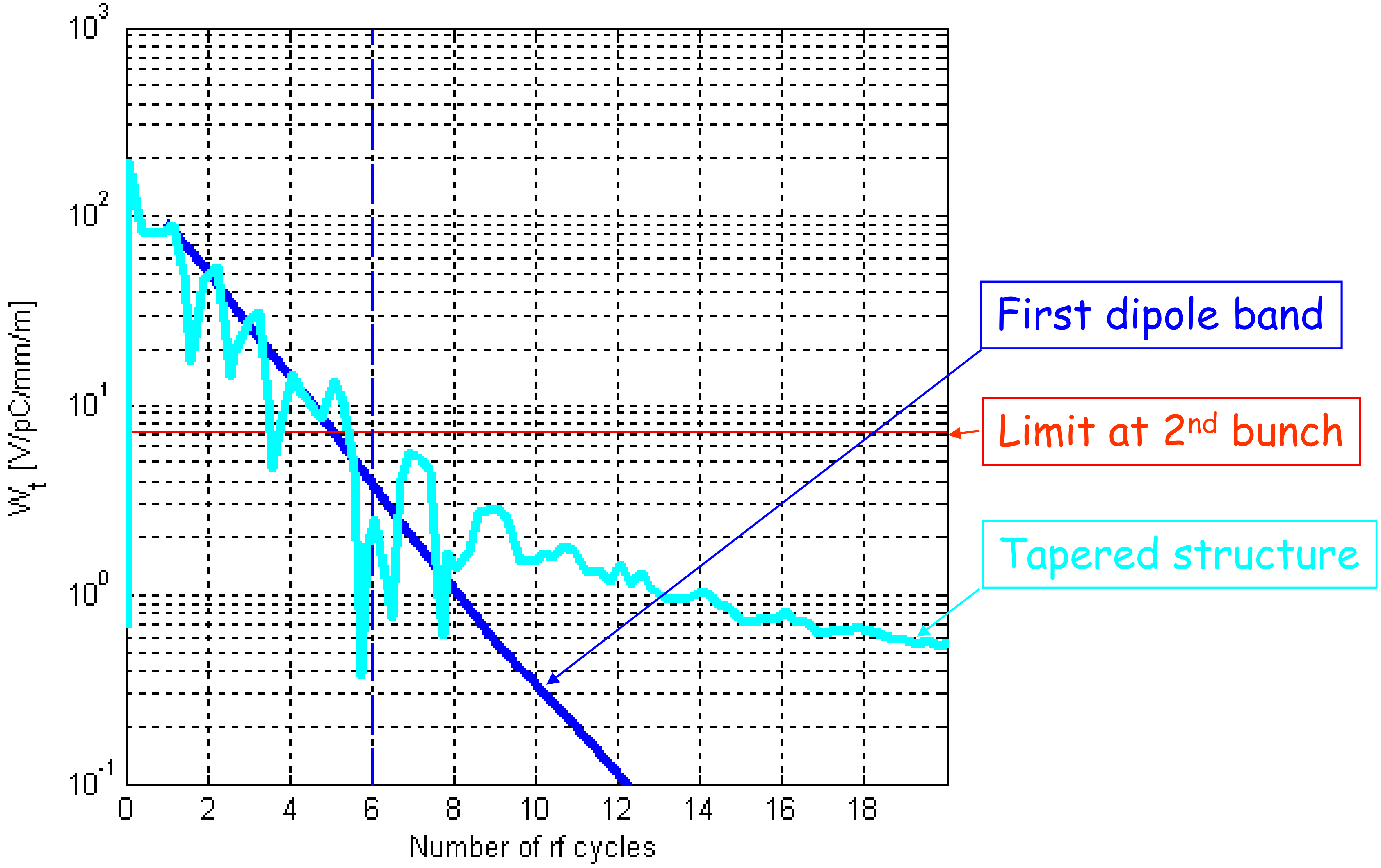
Red – middle cell

Black – last cell

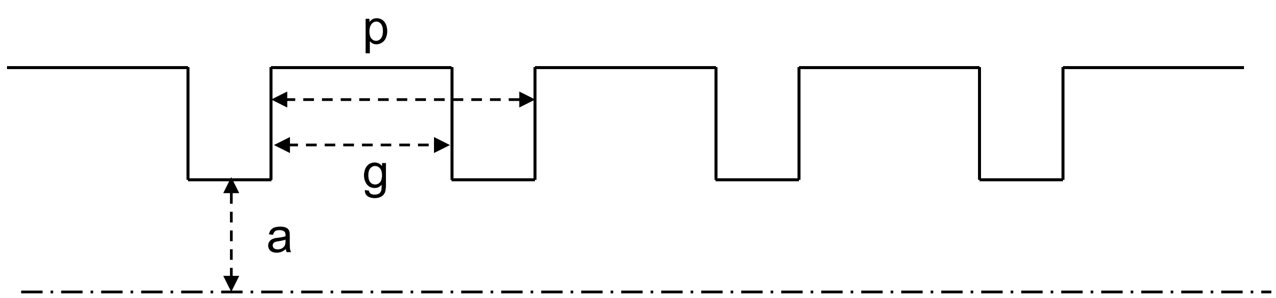


GDFDL 3D computations

Transverse long-range wakes in CLIC_G (from A. Grudiev)



Karl Bane short range wake for periodic geometric



Longitudinal wake function

$$W(s) = \frac{Z_0 c}{\pi a^2} \exp\left(-\sqrt{s/s_1}\right)$$

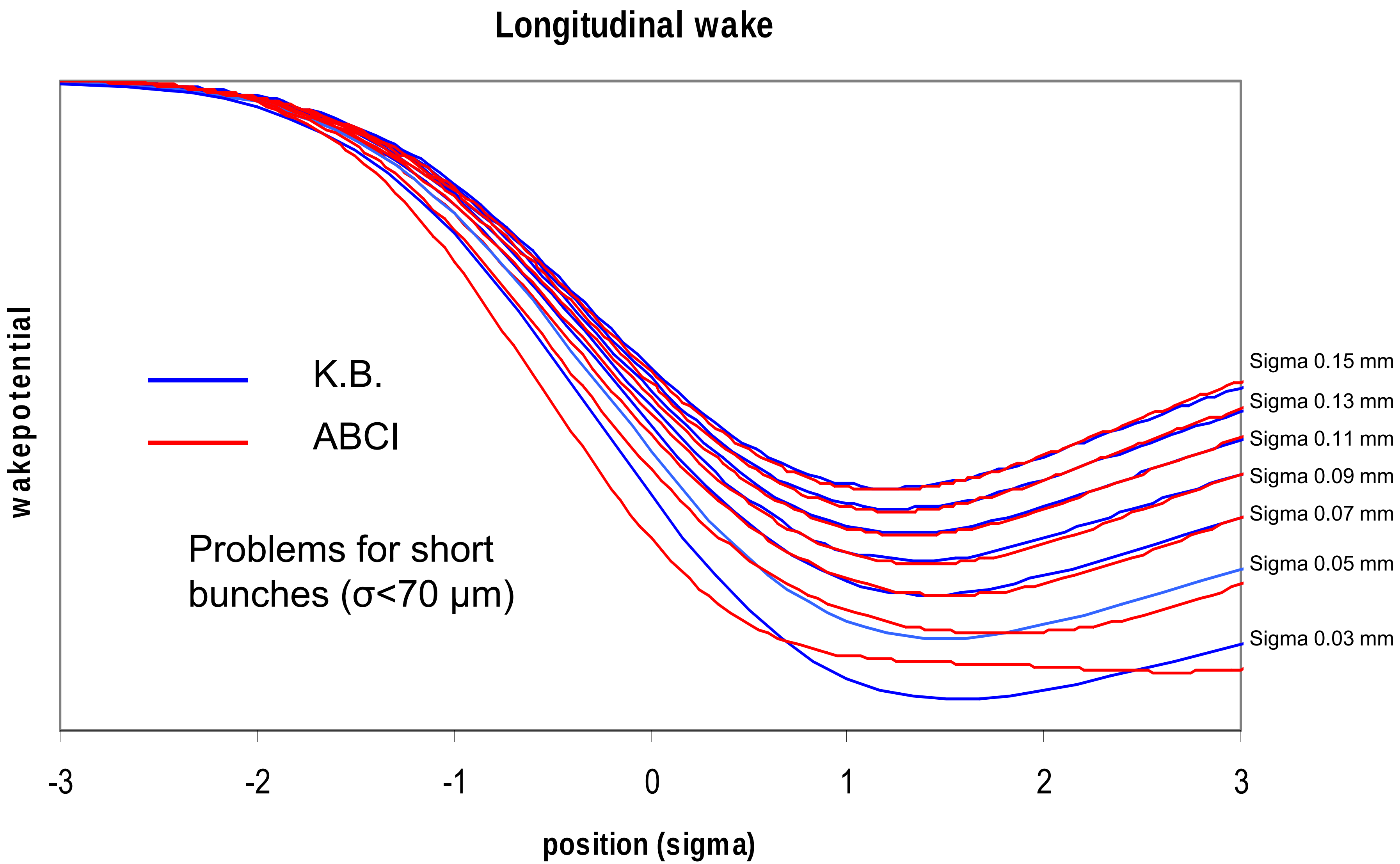
$$s_1 = 0.41 \frac{a^{1.8} g^{1.6}}{p^{2.4}}$$

Transverse wake function

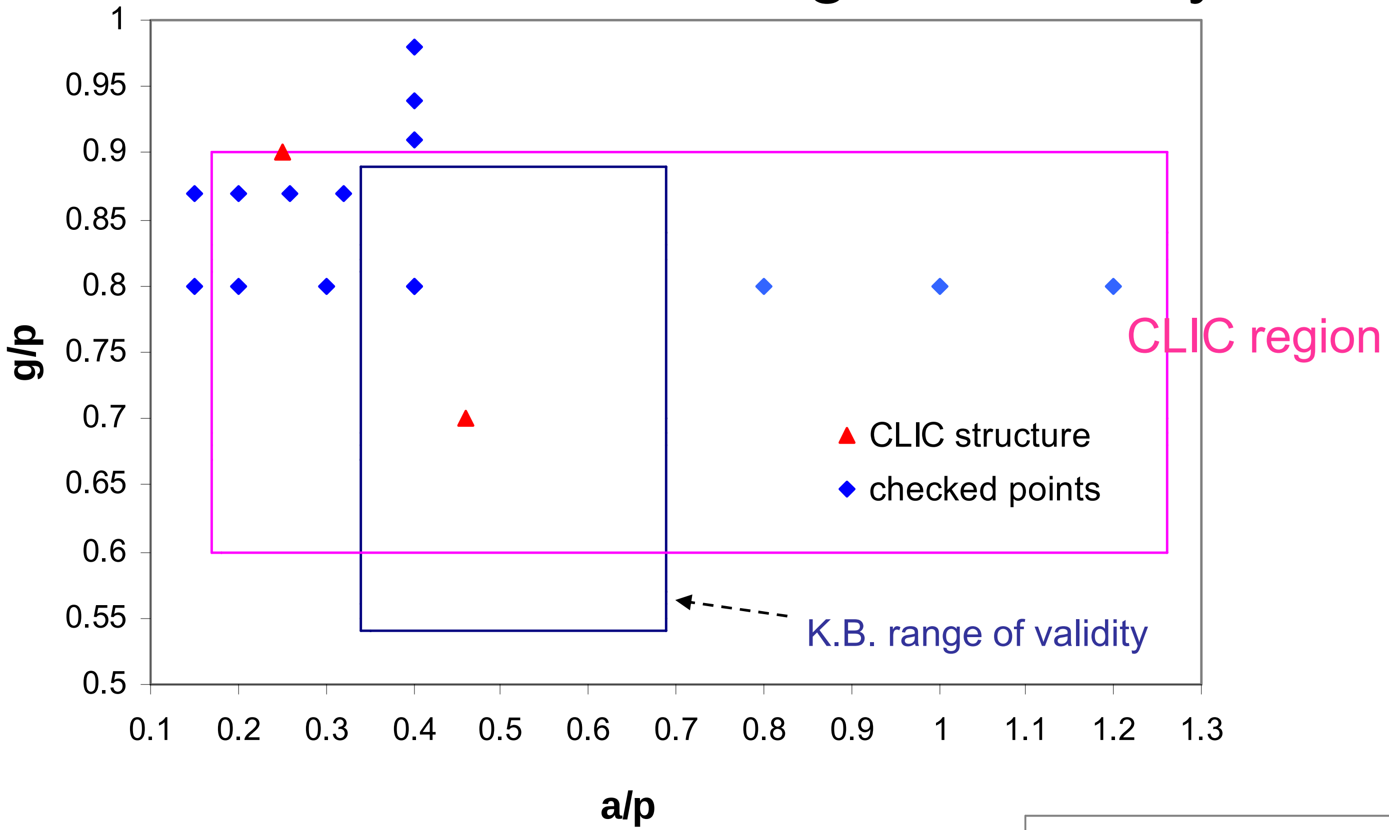
$$W_x(s) = \frac{4 Z_0 c s_0}{\pi a^4}\left[1 - \left(1 + \sqrt{\frac{s}{s_0}}\right)\exp\left(-\sqrt{\frac{s}{s_0}}\right)\right]$$

$$s_0 = 0.17 \frac{a^{1.79} g^{0.38}}{p^{1.17}}$$

2D codes: ABCI with moving mesh



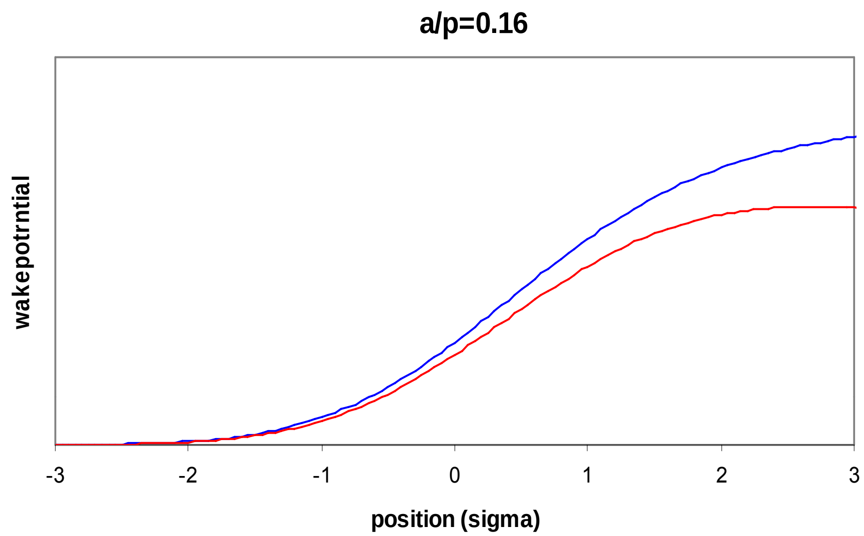
Range of validity



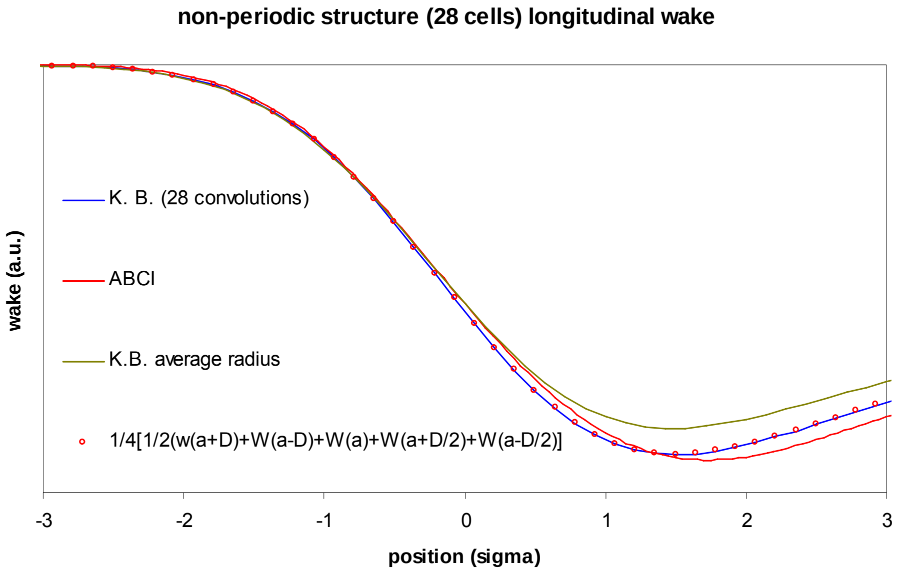
The validity of K.B. formulas has been investigated in the full CLIC region:

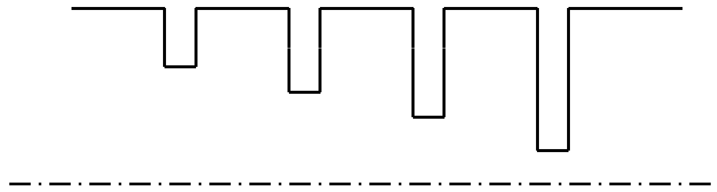
✓Good results for the longitudinal wake

✓Some discrepancies for the transverse wake for small a/p

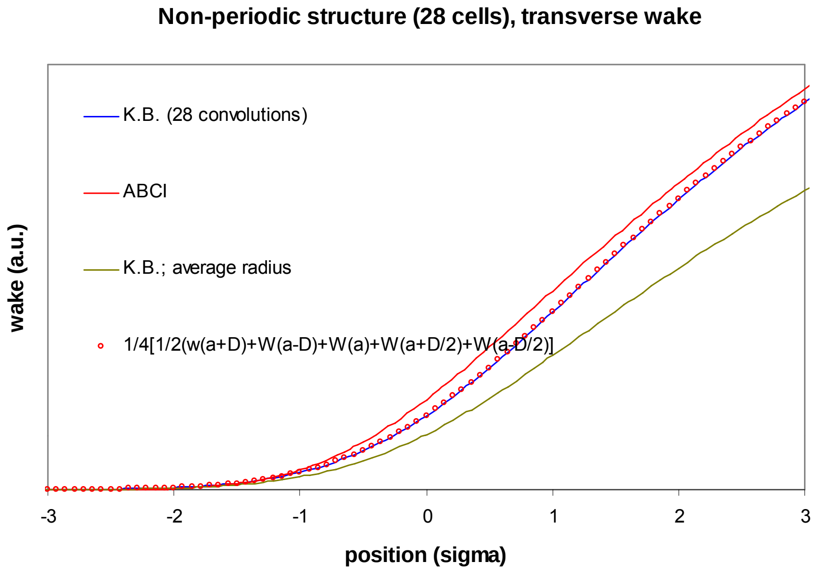


Non-periodic structures: longitudinal wake



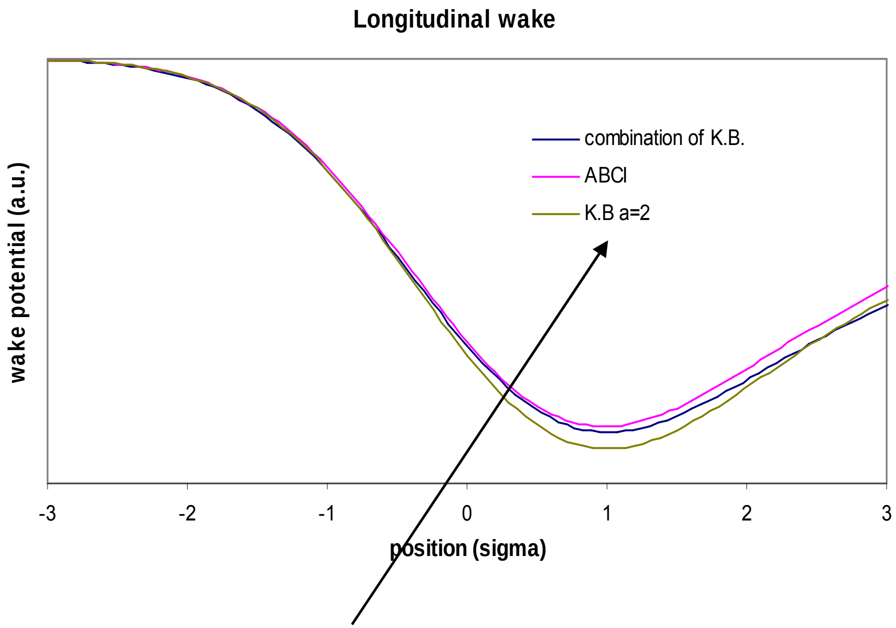


Example:0.335 < a/p < 0.603; 28 cells



K.B. provides good results also for terminated tapered structures

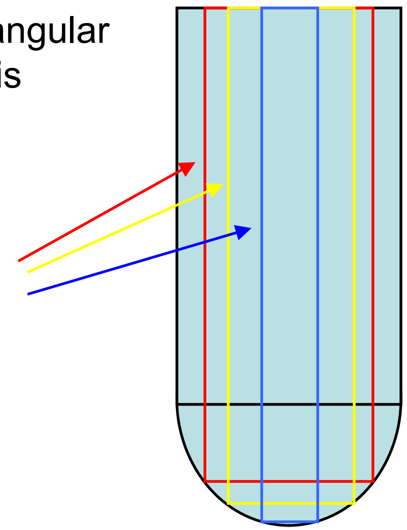
Rounded irises



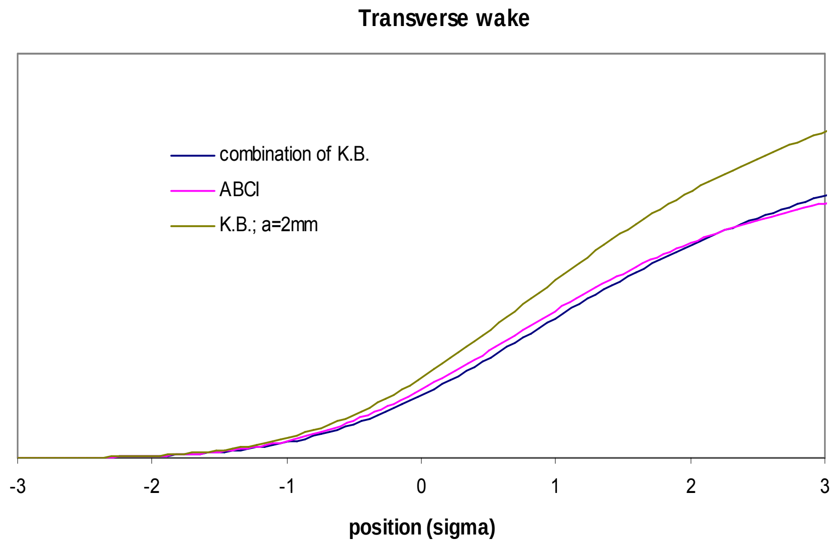
In this case a=2mm is the minimum distance to the axis

K.B. is valid for rectangular irises but the reality is different…

Let's consider the combination of different wakes originated by different geometries



The result is not bad for longitudinal wake…



The rounding of the irises seems to be the main approximation of K.B. formulas

…and better for transverse wake

Tolerances of the structures:

4 kinds of tolerances:

- *Machining (Δx, Δy, Δz)*
- *Assembly (Δx, Δy, Δz)*
- *Alignment (Δx, Δy, Δz)*
- *Operation [Cooling] (ΔT (t) water in, ΔT (z))*

Predictable: operational temperature, longitudinal elongation, transverse elongation

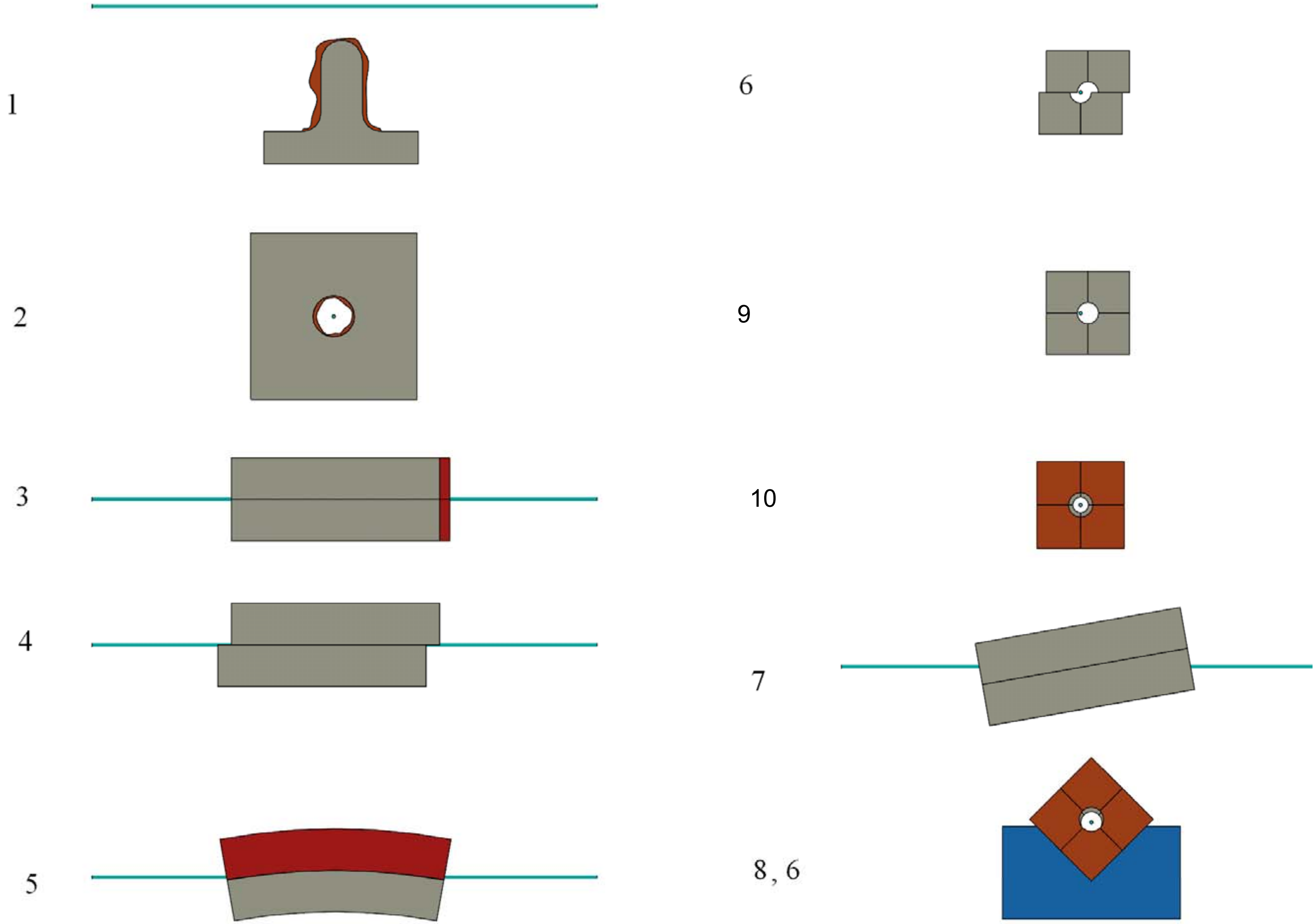
Unpredictable: water temperature instability, RF power variation

3 kinds of problems

- *Alignment (wakefield effects)*
- *Bookshelf (transverse kick)*
- *RF matching (reflected power, phase errors)*

- Assumptions:
- *Structures in quadrants*

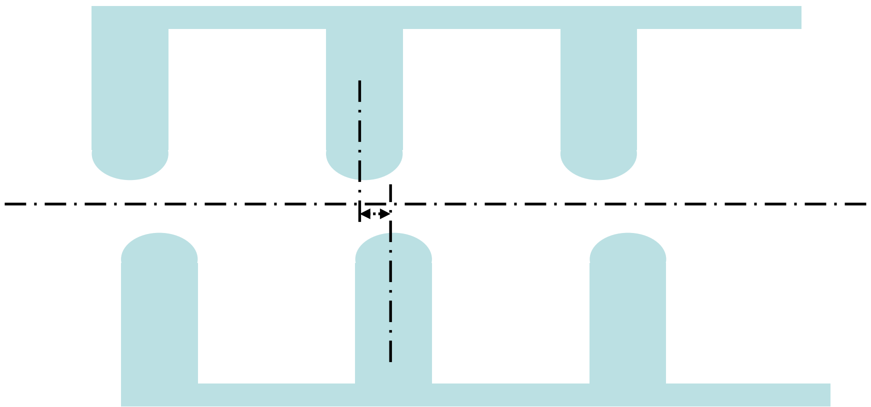
Item	Effect of the item	Performance	Cause				Solution	Magnitude of tollerance (mm)	Criticality	Comments	Scheme
			Machining	Ass.	Alignm.	Oper.					
SHAPE											
Shape of an Iris	dephasing	lower efficiency	x				-Tuning	±0.001	high	local	1
Shape of the matching Iris	mismatching	lower efficiency	x				-Tuning	±0.001	high	local	2
LONGITUDINAL											
Expansion of the structure due to the heat dissipation	dephasing	lower efficiency				x	-Thermal elongnation compensated (isotropic)	±0.005 mm	low	thermal elongation	3
Relative position of the quadrant or the tilt of the discs.	transverse kick	RF induced transverse kick	x	x			-Disk tecnology (?) - Average shape assembly	±0.001 mm	high	bookshelf	4
TRANSVERSE											
Relative position of the quadrant	***wakefield***	beam induced transverse kick	x	x			- Average shape assembly	±0.005 mm	low	allignement problem	6
Expansion of the structure due to unsymmetric heat dissipation	***wakefield***	beam induced transverse kick				x	-Symmetric deformation design	±0.005 mm	high	bending	5
Thermal isotropic expansion	dephasing	lower efficiency				x	-Very accurate water temperature control	±0.1 C°	high	variation of the structures	10
Supporting of the accelerating structure	***wakefield***	beam induced transverse kick	x	x	x		-Accurate Reference interfaces in structures	±0.005 mm	low	structure axis wrto beam axis	9
TILT											
Tilt of the full structure	transverse kick	RF induced transverse kick			x		-Reference points in the structures	±0.03 mrad	low	tilt of full structure	7
Deformation of support	transverse kick	RF induced transverse kick				x	Active cooling system	±0.03 mrad	low	Support interference	8


1
2
3
4
5
6
9
10
7
8, 6

Bookshelf effect

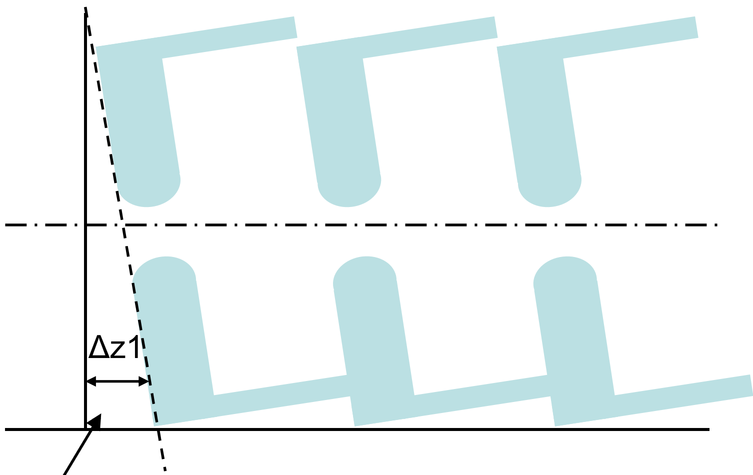
(transverse kick due to Ex,y)

$\Delta z \approx$ 1 microns from computations (Daniel)



Structure in quadrants

(problem mainly for the **machining** and **assembly**)

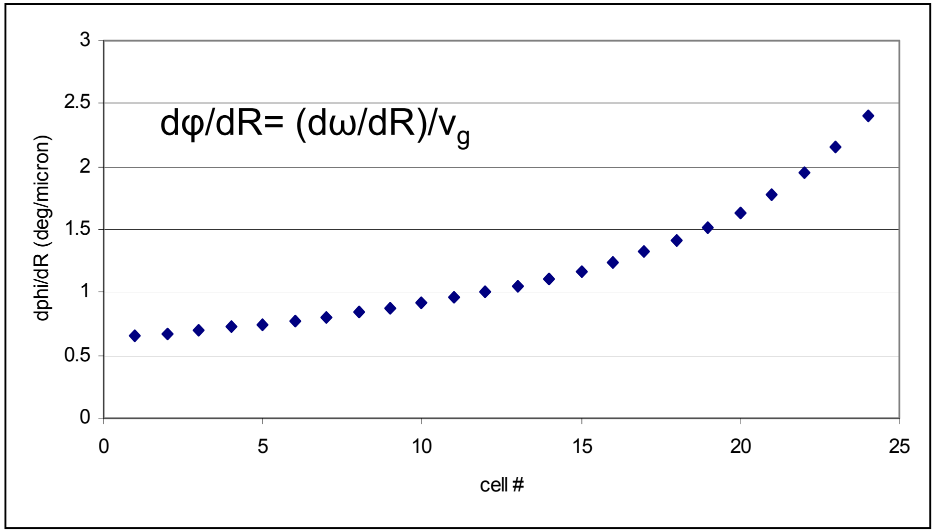


$\Delta z1 \approx D/a^* \, \Delta z$ (1 micron)

Structure in disks

(problem mainly for the **brazing**; probably easier to achieve)

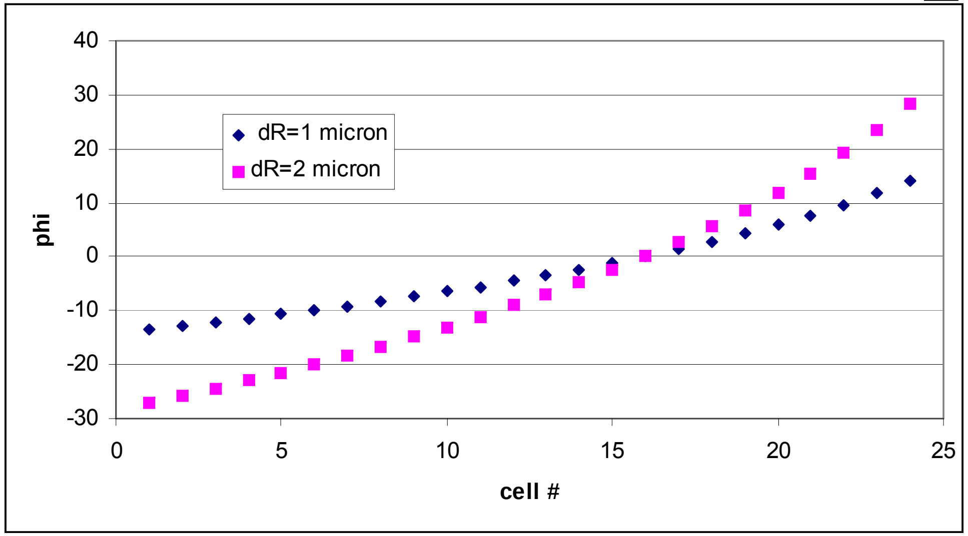
Dephasing due to cell shape errors

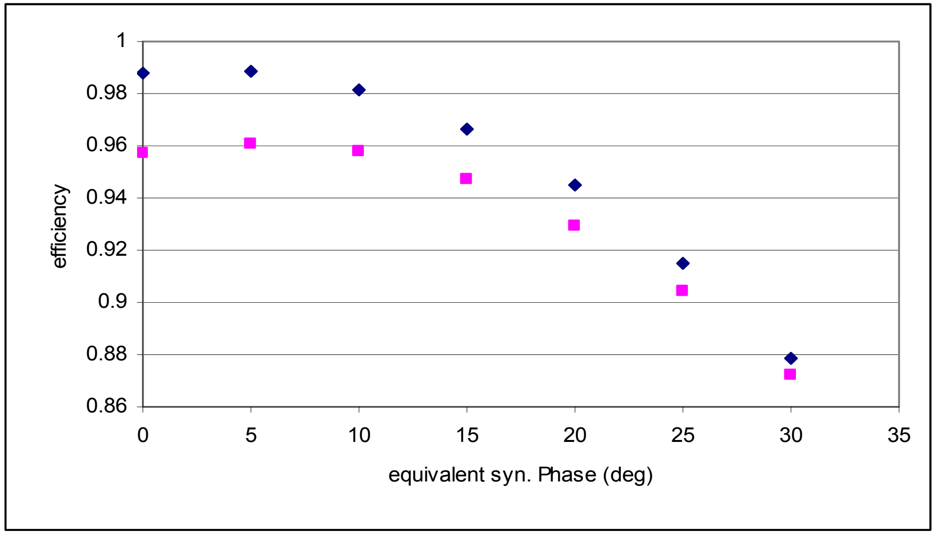


More sensitive parameter: cell radius

Computed for the CLIC_C structure

In the case of no tuning features and systematic error on all the cells



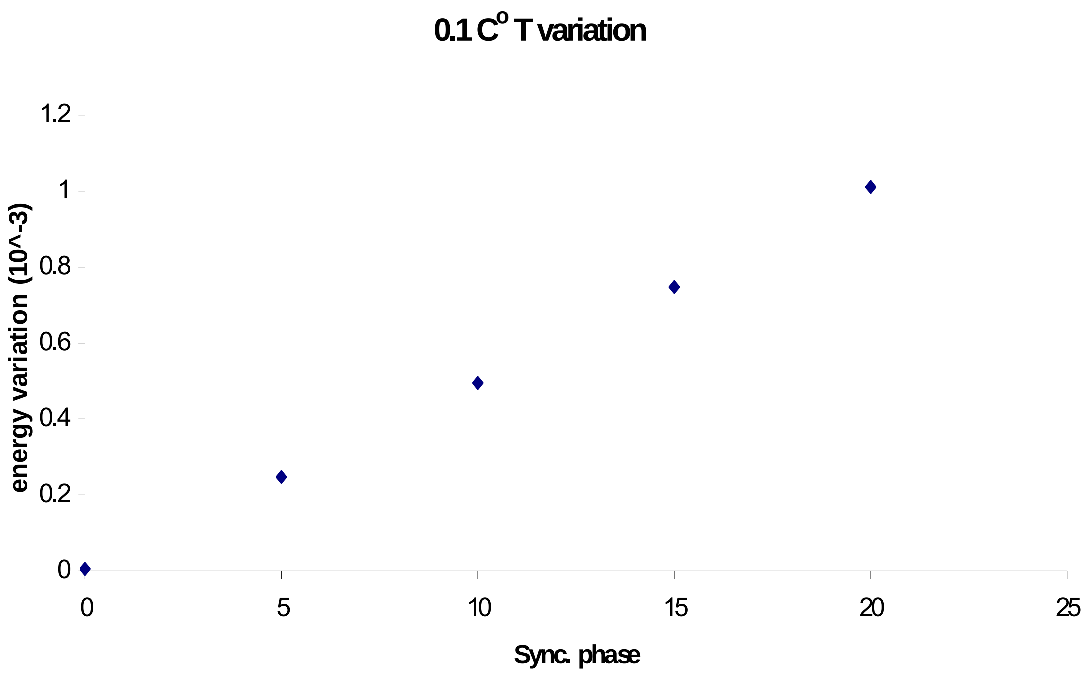


Dephasing due to temperature variation (dynamic effect)

Assumption: isotropic dilatation

Dilatation has two effects on phase:

1) Elongation of the structure; 1D problem, negligible effect
2) Detuning and consequent dephasing of each cell; 3D problem, dominant effect

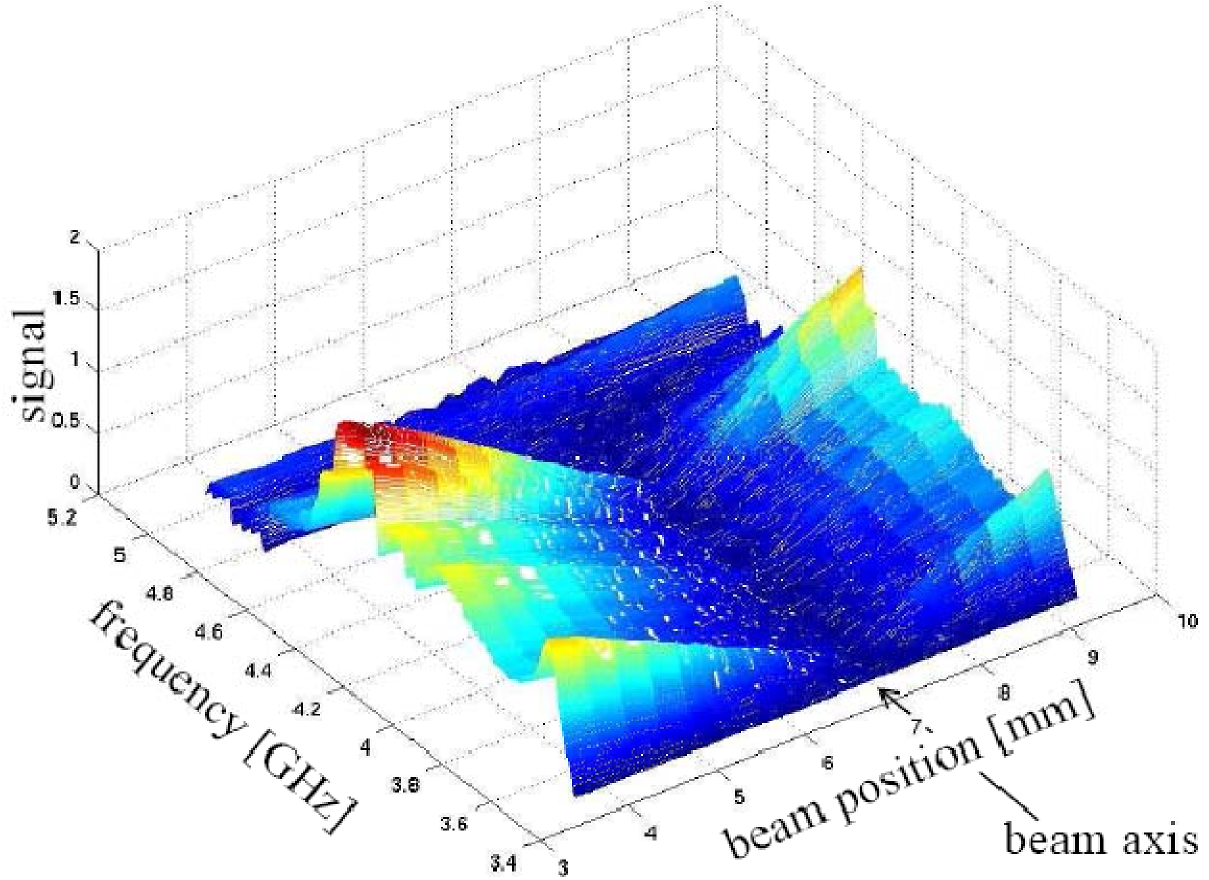


Conservative approach: same T variation for the full linac

The average gradient variation is “equivalent” to 0.15 deg phase variation *(drive beam-main beam phase)*

Wakefield for beam position monitoring

Long range wake could offer the possibility for a beam position monitor which detect the wakefield propagating in one of the damping waveguides



From J.E. Prochnow "Beam Position Monitoring at CLIC"

Conclusion

- Long range wakefields determine the bunch separation, reliable software exists (GDFDL)
- Short range wakefield determine the bunch population,
- 2D computations with moving mesh are relatively fast and precise (ABCI)
- K.B. range of validity is larger than predicted but not enough to cover CLIC region
- K.B. does not consider rounded irises, a possible correction based on a new fitting of S_0 is under study
- Wakefield have an impact on structures tollerances
- RF mismatching, dephasing and bookshelf are critical for structure tollerances
- Variation of the cooling water temperature could origin beam energy variations