RF Design of CLIC main linac accelerating structure

17.10.2007

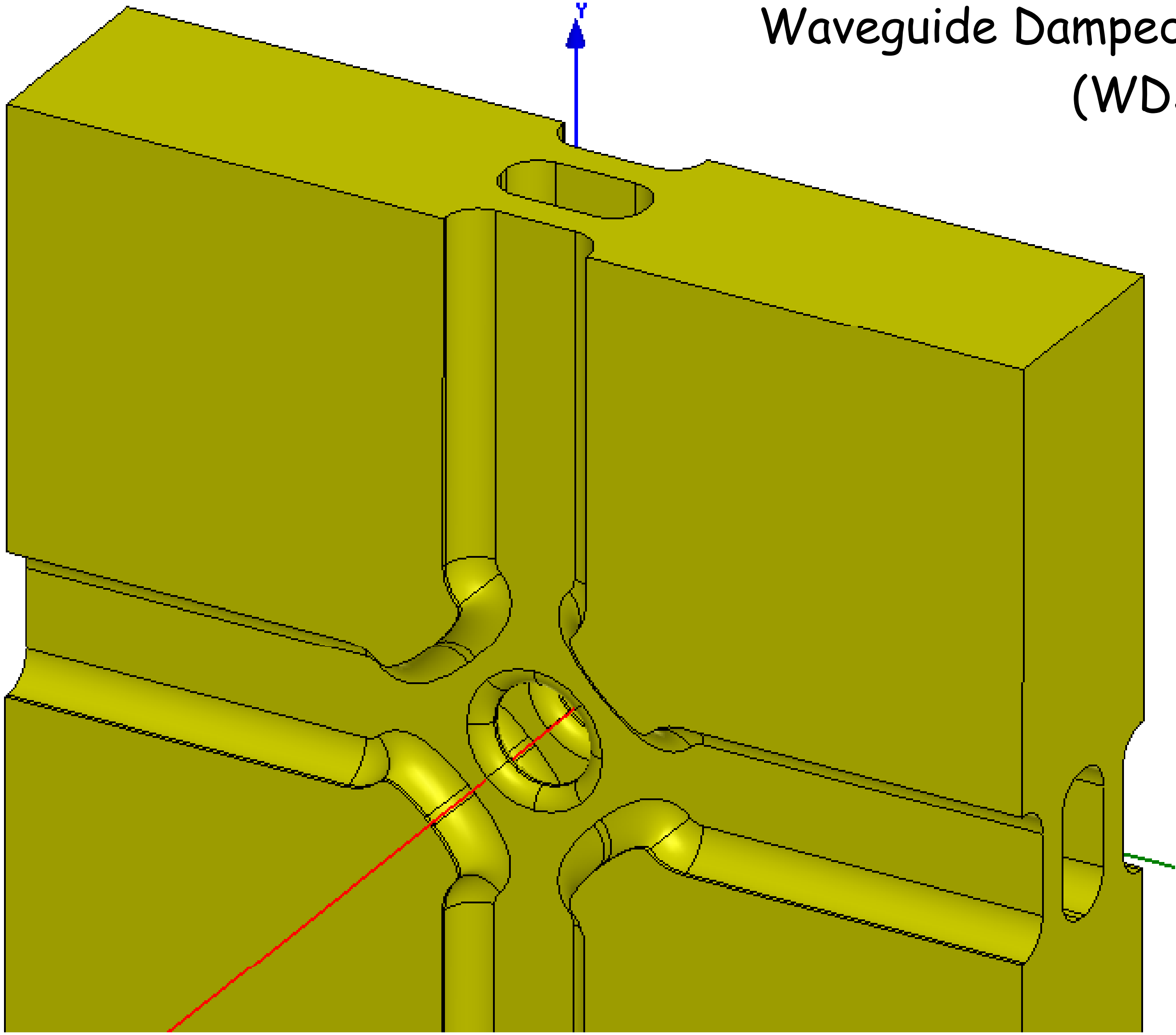
Alexej Grudiev

Outline

- Cell geometry
- Structure design
- CLIC structure parameters
  - Fundamental mode
  - Dipole modes

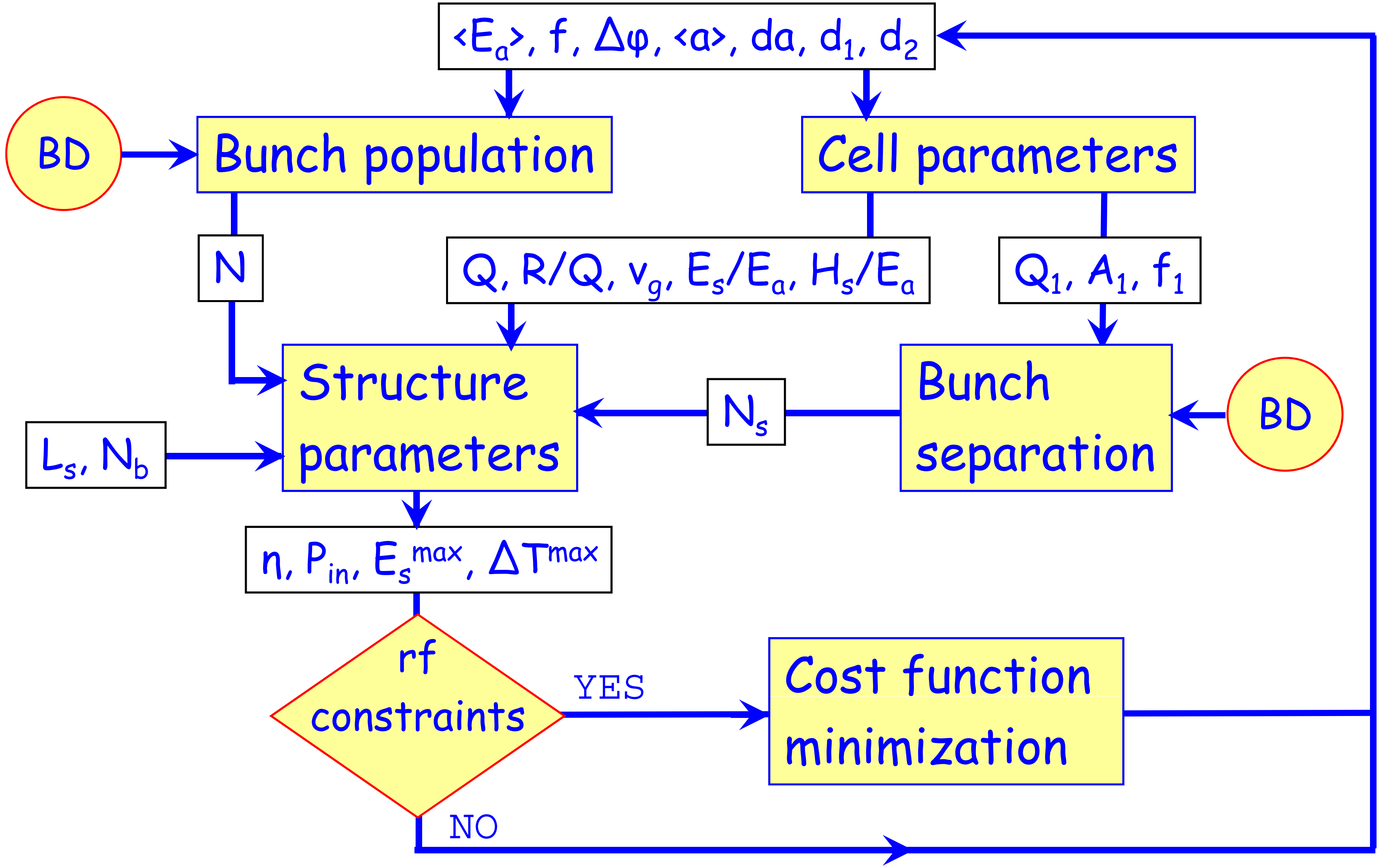
WDS cell geometry

Waveguide Damped Structure (WDS) 2 cells



- Minimize E-field
- Minimize H-field
- Provide good HOM damping
- Provide good vacuum pumping

Optimization procedure



Optimization constraints

Beam dynamics (BD) constraints based on the simulation of the main linac, BDS and beam-beam collision at the IP:

- N – bunch population depends on $\langle a \rangle / \lambda$, $\Delta a / \langle a \rangle$, f and $\langle E_a \rangle$ because of short-range wakes
- N_s – bunch separation depends on the long-range dipole wake and is determined by the condition:

$$W_{t,2} \cdot N / E_a = 10\ \text{V/pC/mm/m} \cdot 4\text{x}10^9 / 150\ \text{MV/m}$$

RF breakdown and pulsed surface heating (rf) constraints:

- $\Delta T^{max}(H_{surf}^{max}, t_p) < 56$ K
- $E_{surf}^{max} < 250$ MV/m
- $P_{in} t_p^{1/3} / C_{in} = 18$ MW·ns$^{1/3}$/mm

Optimizing Figure of Merit

Luminosity per linac input power:

$$\frac{L}{P_l} = \frac{L_{b\times} N_b f_{rep}}{\dfrac{eE_c N N_b f_{rep}}{\eta}} = \frac{1}{eE_{cm}} \bullet \frac{L_{b\times}}{N}\eta$$

Collision energy is constant

Figure of Merit (FoM = $\eta L_{bx}/N$)
in [a.u.] = [1e34/bx/m2·%/1e9]

Cost model

Total cost = Investment cost + Electricity cost for 10 years

$$C_t = C_i + C_e$$

$$C_i = \mathrm{Excel}\{f_r;\ E_p;\ t_p;\ E_a\ ;\ L_s\ ;\ f\ ;\ \Delta\varphi\}$$

Repetition frequency;

Pulse energy;

Pulse length;

Accelerating gradient;

Structure length (couplers included);

Operating frequency;

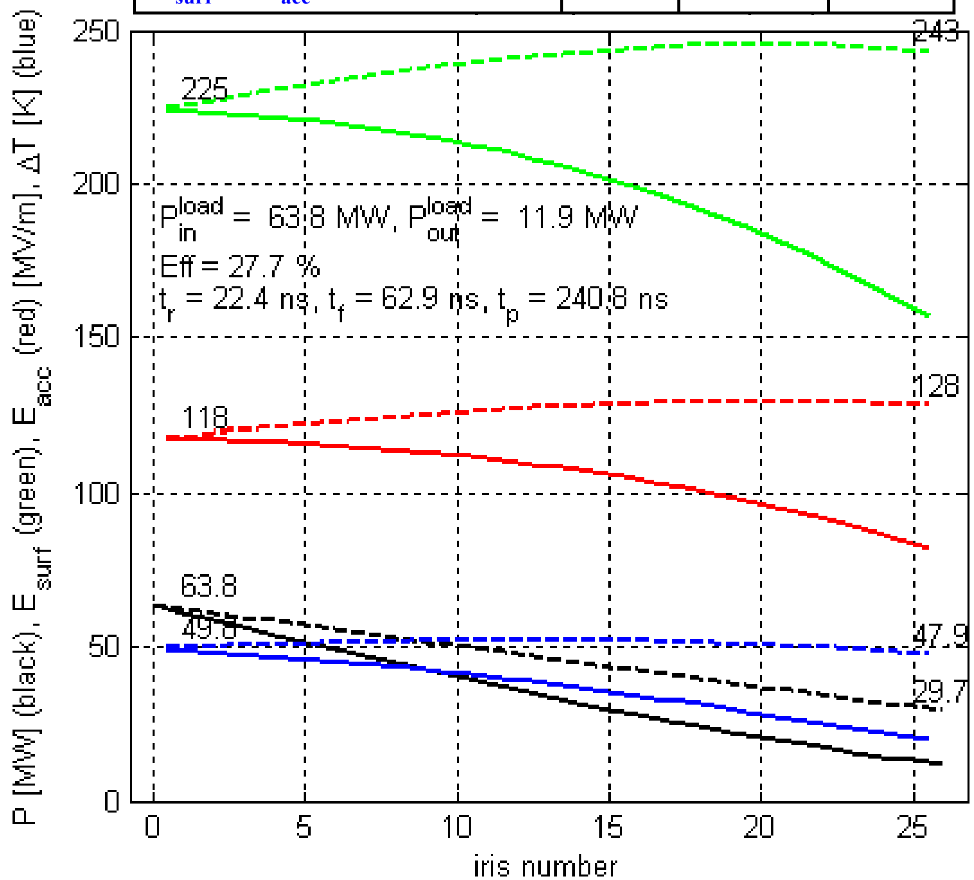
rf phase advance per cell

$$C_e = (0.032 + 2.4/\mathrm{FoM})$$

Parameters of new structure

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
Input power: P_{in} [MW]	63.8
$P_{in}/Ct_p^{P\ 1/3}$ [MW/mm ns$^{1/3}$]	18
Max. surface field: E_{surf}^{max} [MV/m]	245
Max. temperature rise: ΔT^{max} [K]	53
Efficiency: η [%]	27.7
Figure of merit: $\eta L_{b\times}/N$ [a.u.]	9.1

Cell	first	middle	last
Group velocity: v_g/c [%]	1.66,	1.19	0.83
Q^{Cu}	6100	6177	6265
R'/Q [Linac kOhm/m]	14.6	16.2	17.9
E_{surf}^{max}/E_{acc}	1.9	1.9	1.9



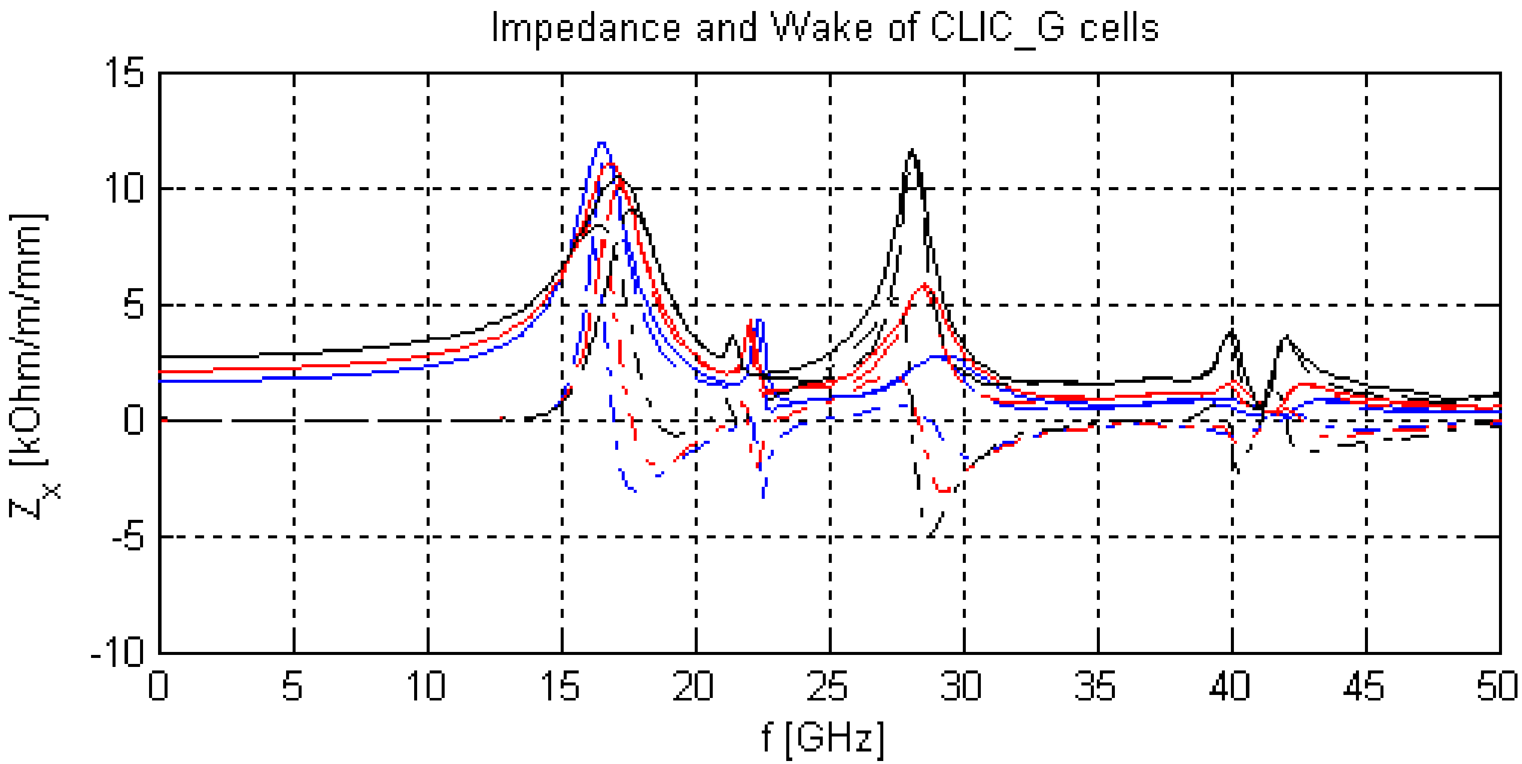
Transverse impedances and wakes in cells

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



Transverse long-range wakes in CLIC_G