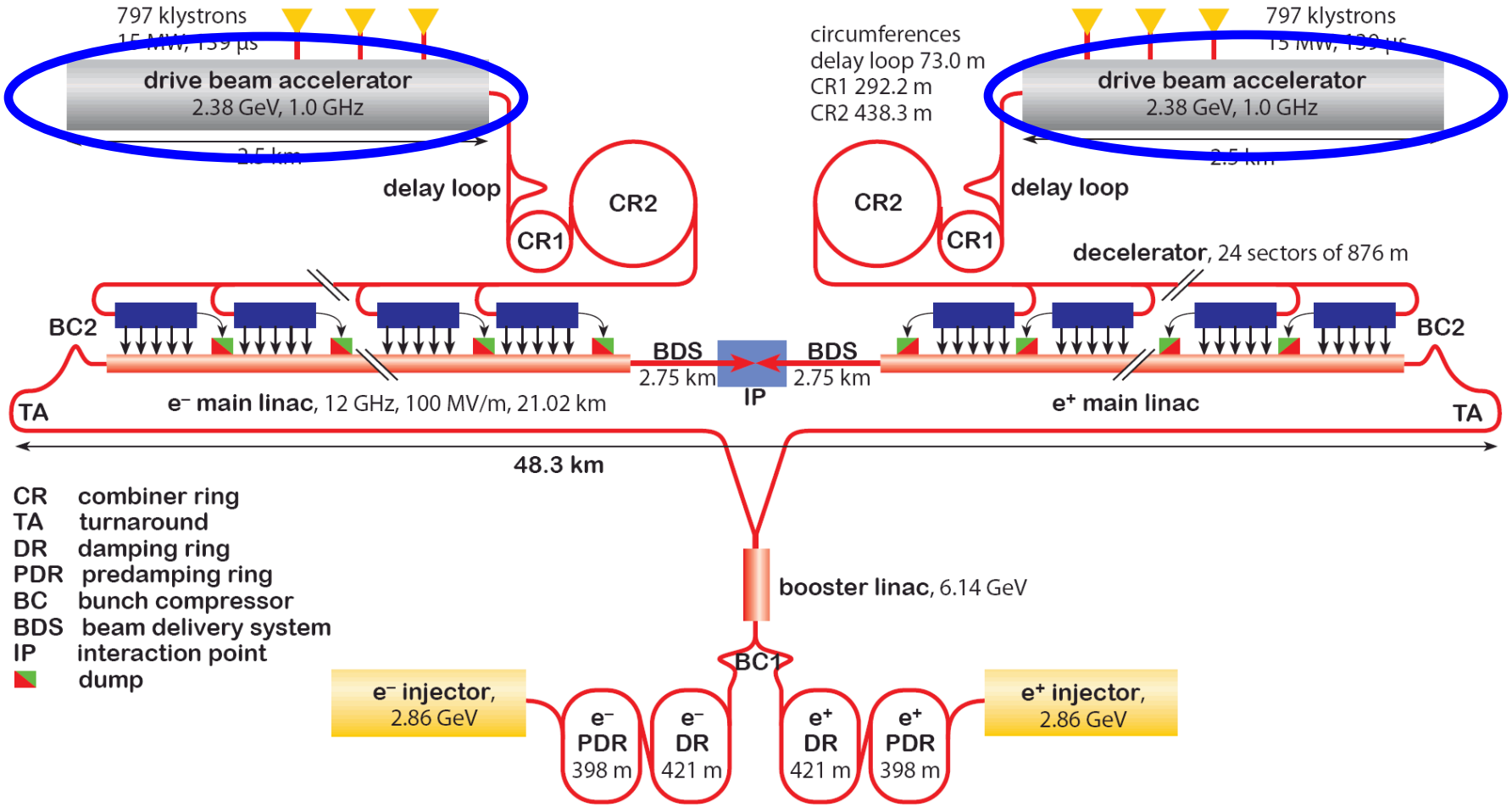
Drive Beam Accelerating Structures

Rolf Wegner

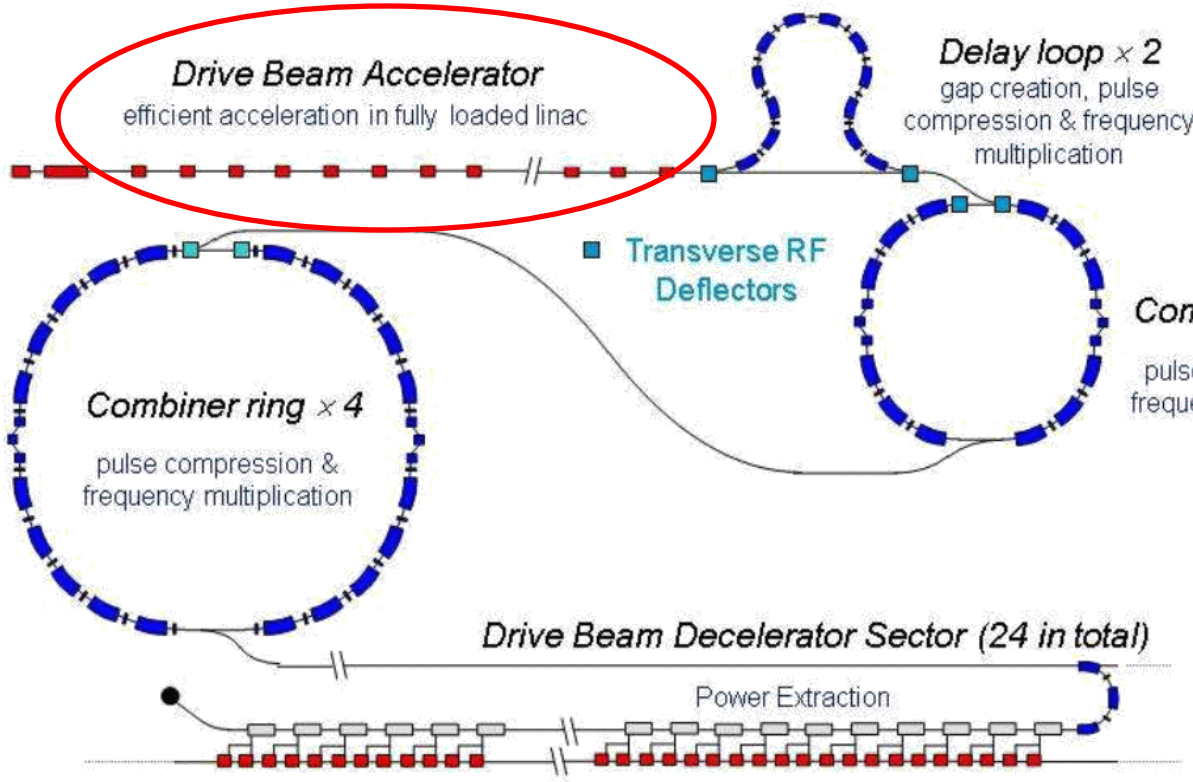
CLIC Drive Beam Accelerating Structures



Outline

- CLIC Drive Beam Complex,
  3 GHz DBA structure
- design of 1 GHz DBA structure
- optimisations for efficiency and filling time
- damping and detuning
- summary

CLIC Drive Beam Complex



f_{acc}= 0.99952 GHz

I_{pulse}= 4.2 A

V_{acc}= 2.37 GV

$\eta_{RF->beam} \geq$ 95%

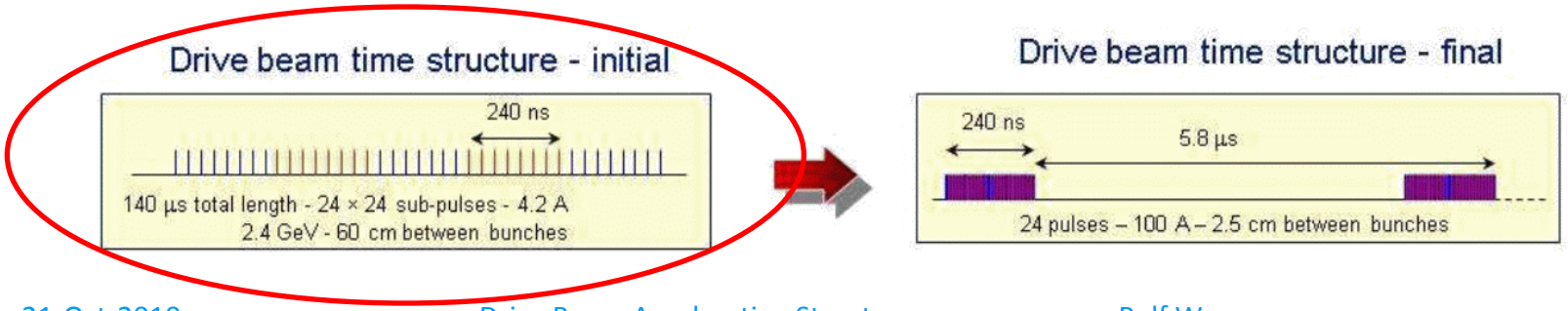
$P_{peak,RF} \approx$ 12 GW

$P_{avg,RF} \approx$ 84 MW

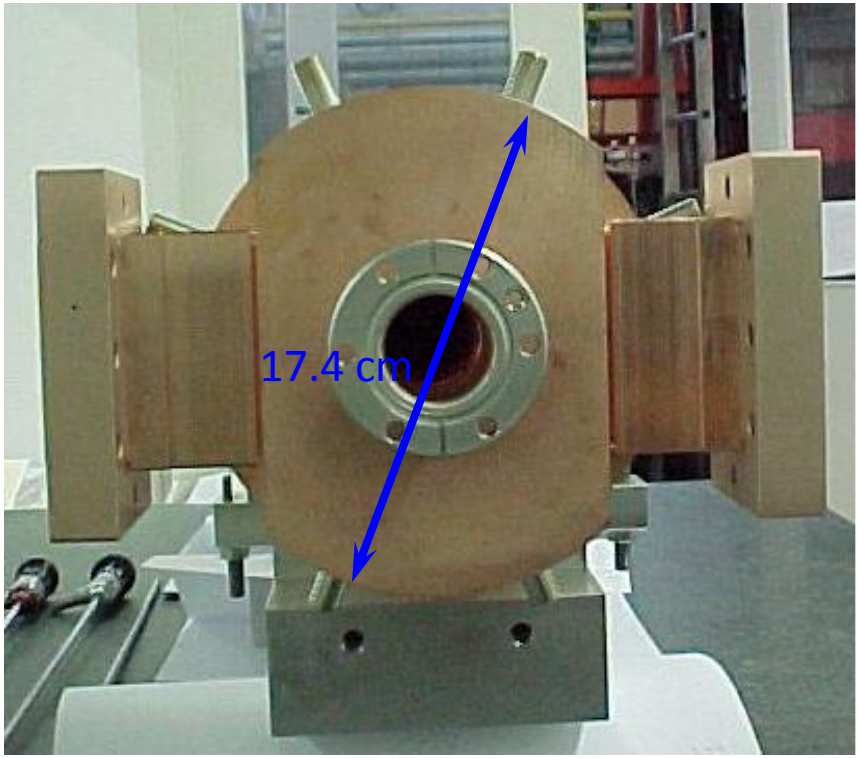
f_{bunch}= ½ f_{acc}

Q_{bunch}= 8.4 nC

ϕ_s= 19°



3 GHz DBA structure – Erk Jensen



f_{acc}= 3 GHz Length= 1.22 m

P_{in}= 33 MW $Ø_{outside}$= 17.4 cm

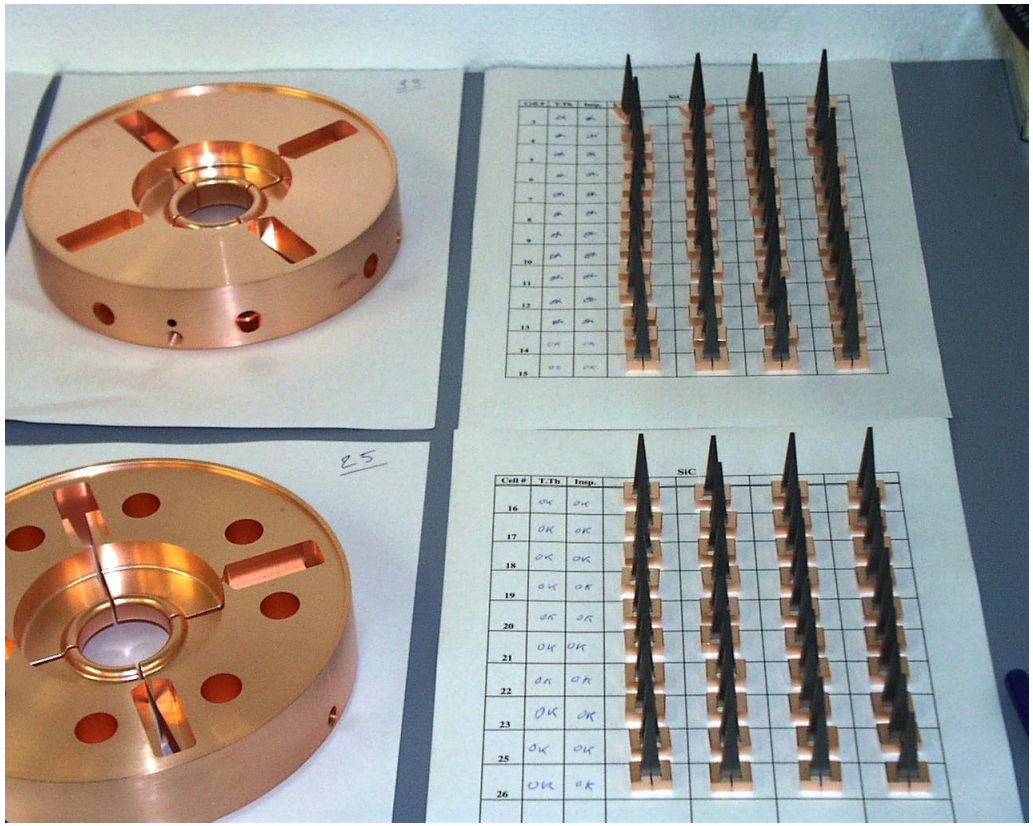
n_{cell}= 33 weight ≈ 200 kg

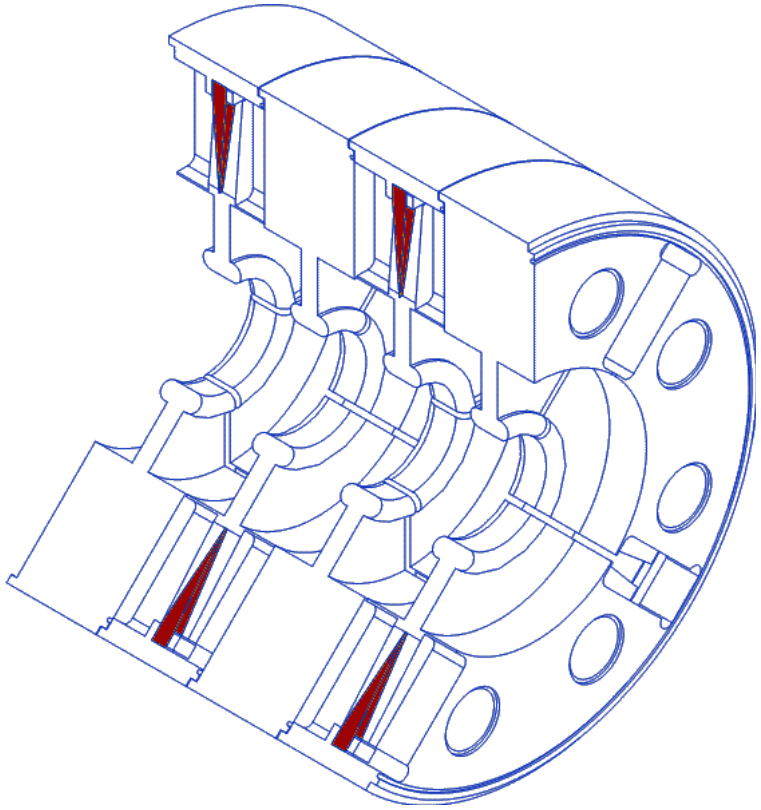
fully beam-loaded,
P_{beam} / P_{RF} = 94%

Corsini, R et al.: First Full Beam Loading Operation with the CTF3 Linac
CERN-AB-2004-057 ; SLAC-PUB-10762 ; CTF-3-NOTE-066 ; CLIC-Note-604

3 GHz DBA structure

SICA = Slotted Iris – Constant Aperture



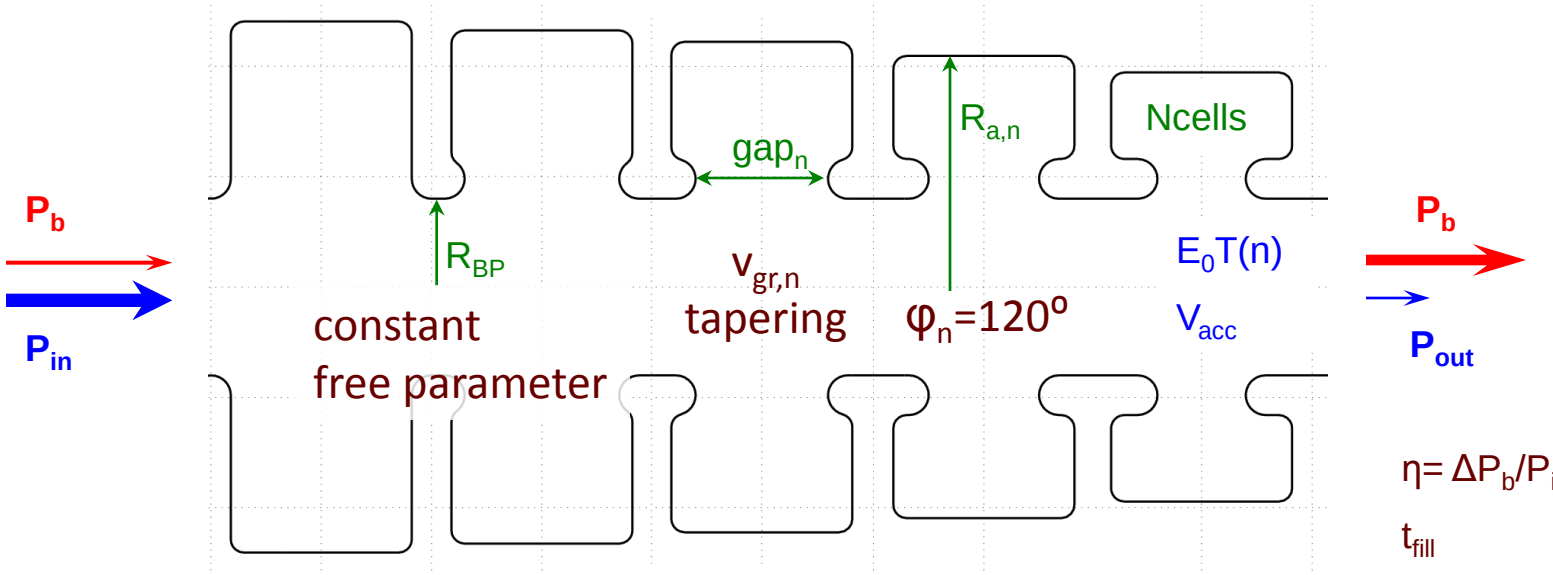


1 GHz DBA structure

- SICA principle
- but no direct scaling possible
  - 3 GHz: Ø= 17.5 cm, L= 1.2 m, weight= 200 kg
    1 GHz: Ø= 52.5 cm, L= 1.2 m, weight= 1800 kg
  - klystron P_{RF} ~ 10 to 15 MW
    (optimising klystron cost per MW and per operating hour and modulator cost)
  - noise, phase error reduction if t_{fill}= 240…250 ns
    (combination scheme => multiplication of phase noise, $t_{DL} \approx$ 240 ns, $t_{CR\ I} \approx 2*240$ ns, $t_{CR\ II} \approx 6*240$ ns)

design of TWS

constant aperture

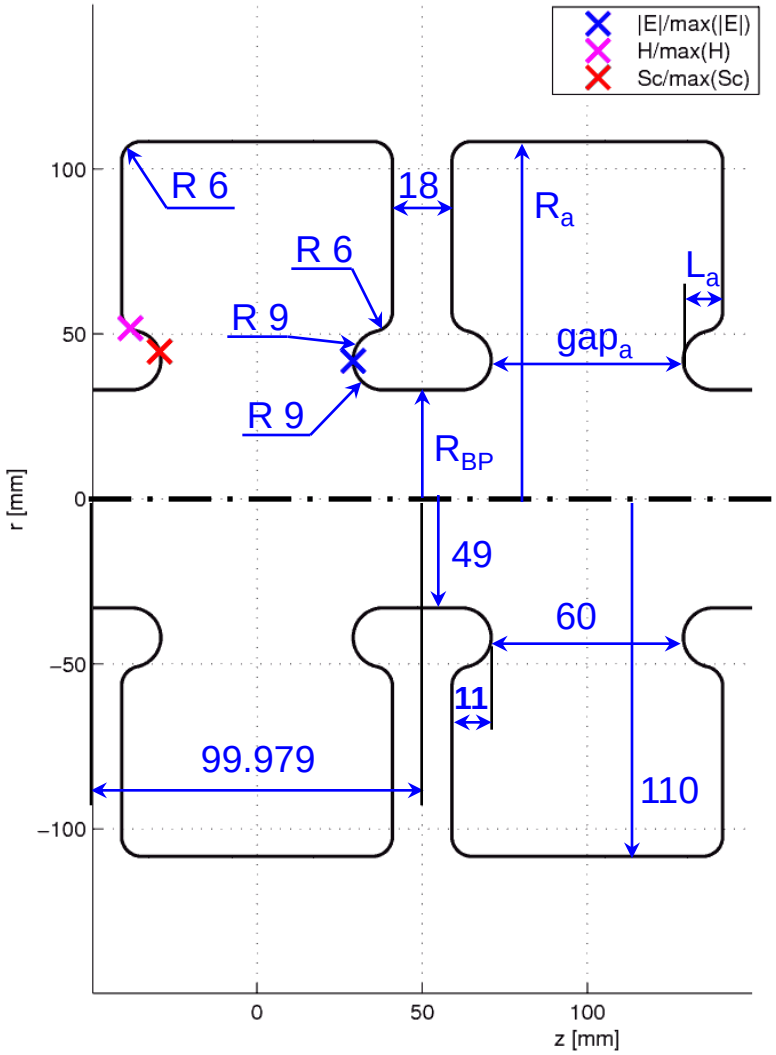


$\eta = \Delta P_b / P_{in}$

t_{fill}

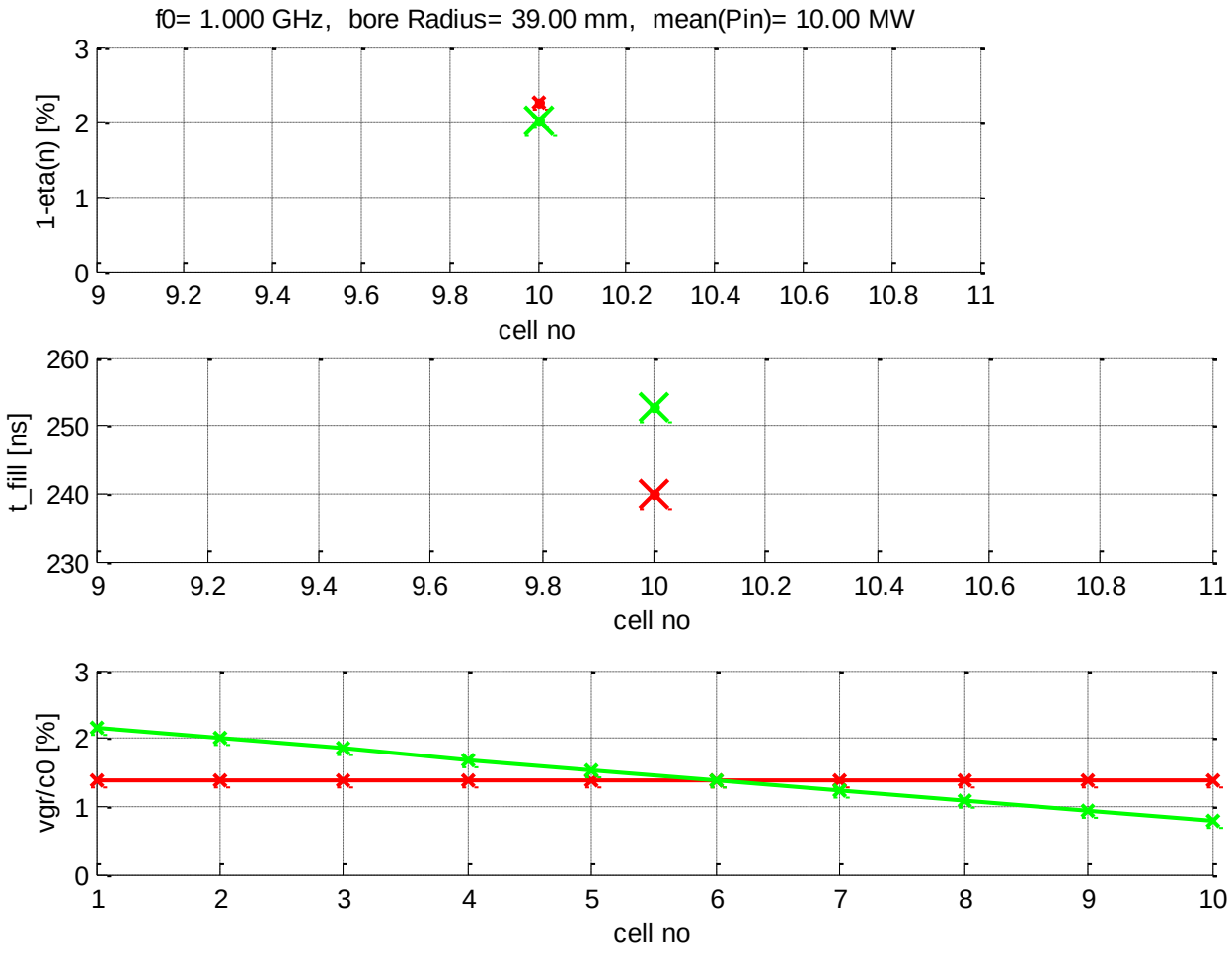
mode spectrum

basic cell geometry



typical dimensions

design of TWS



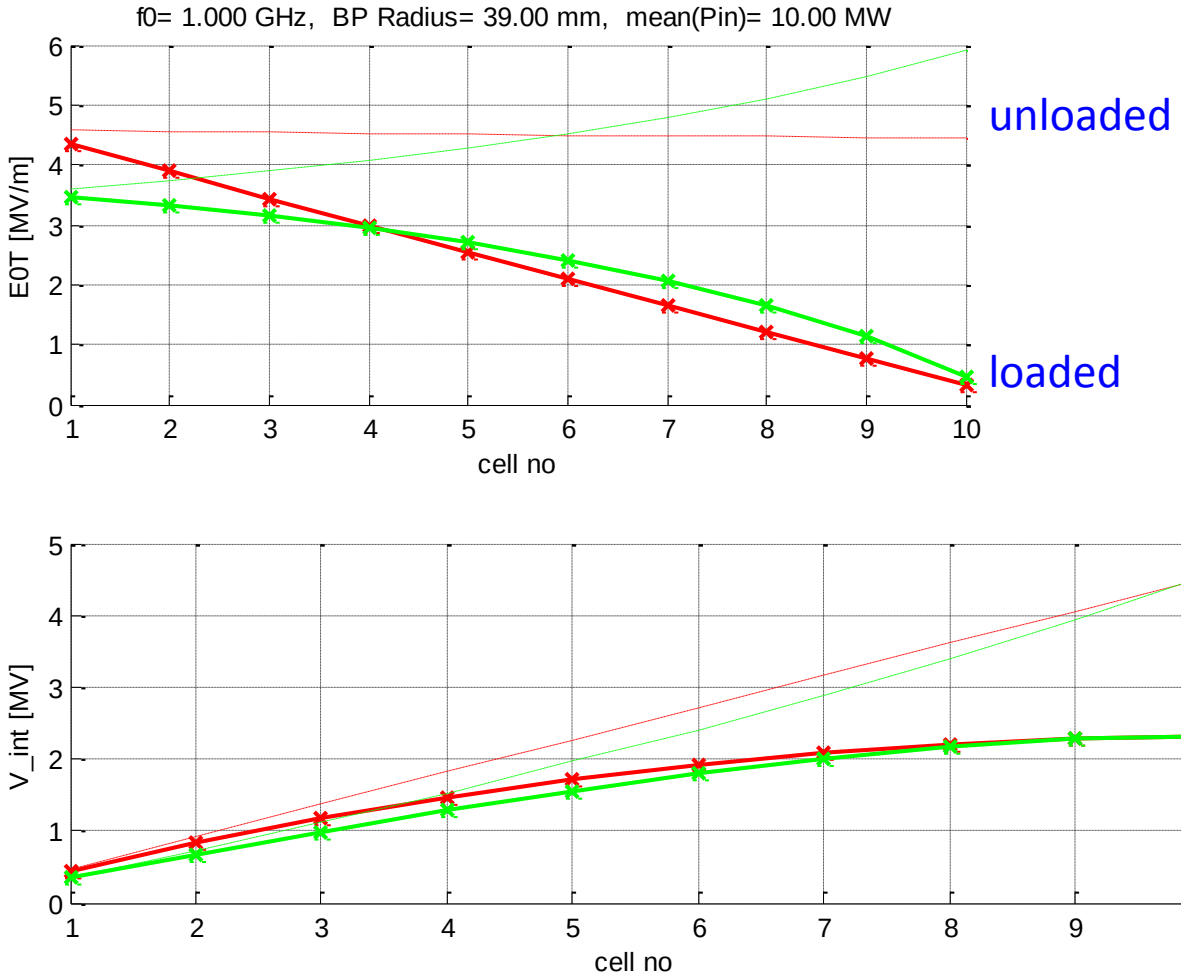
example:

P_{in}= 10 MW
I_b= 4.21 A
N_{cells}= 10
R_{BP}= 39 mm

vgr/c const. (const. impedance)
η= 97.7%
$t_{filling}$= 239.9 ns

vgr/c lin. distribution
η= 98.0%
$t_{filling}$= 252.7 ns

design of TWS



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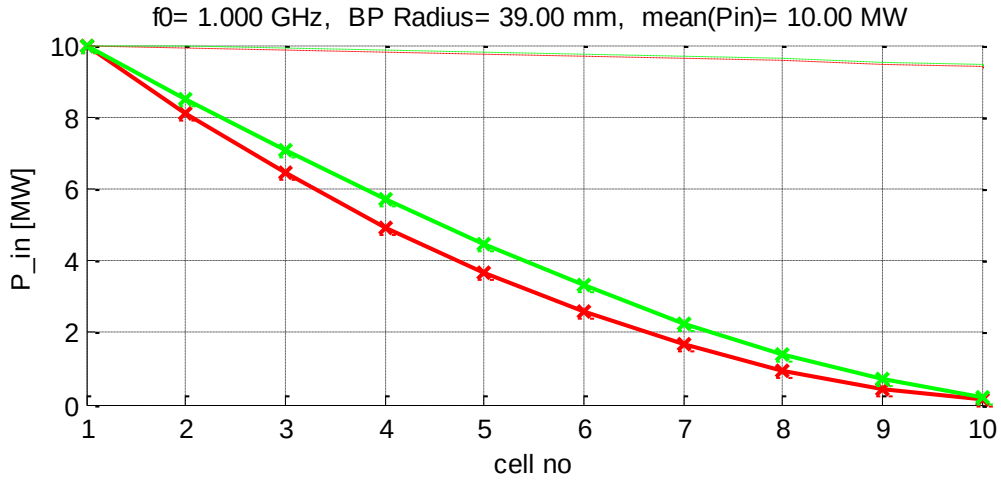
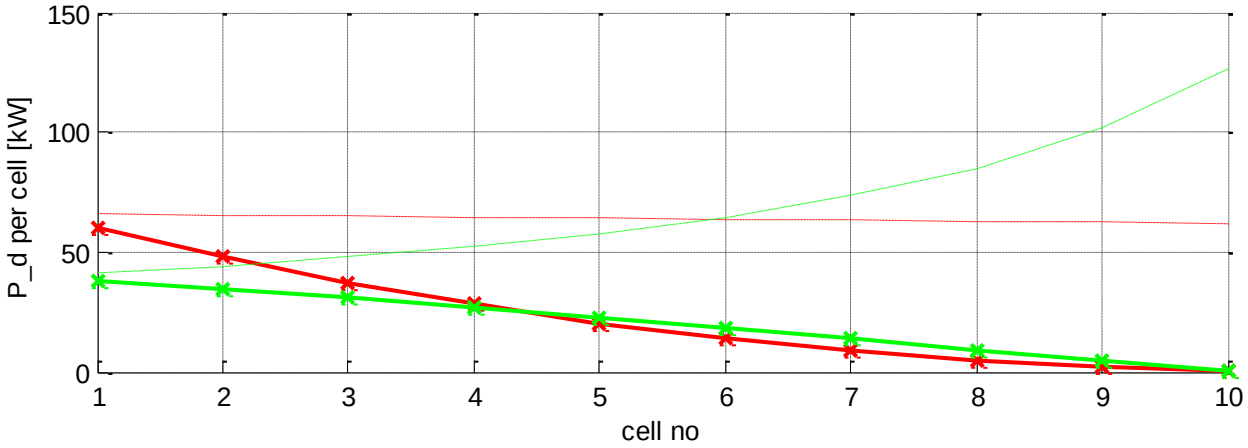


fully beam-loaded



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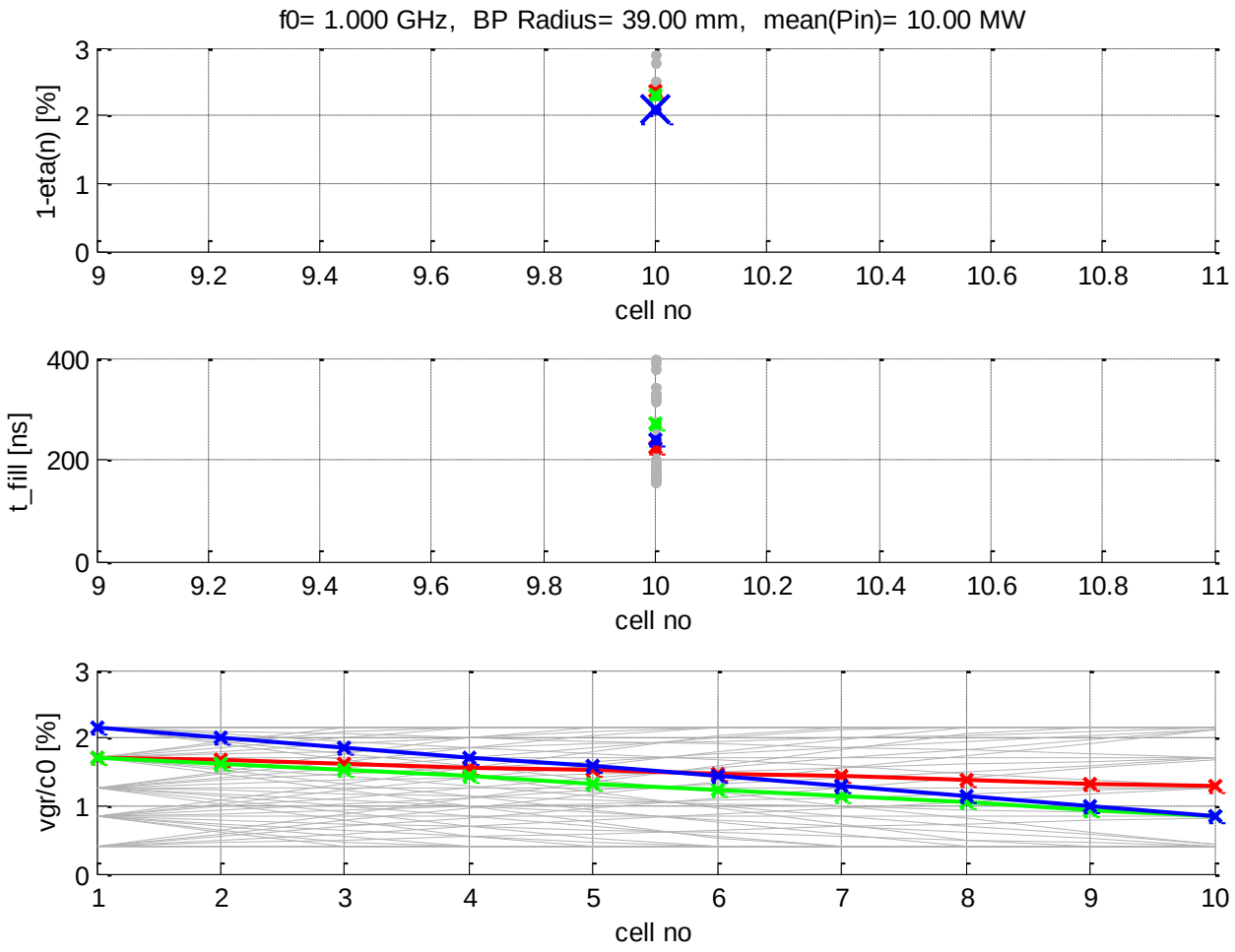
optimisations



P_{in}= 10 MW
I_b= 4.21 A
R_{BP}= 39 mm

Ncells= 10

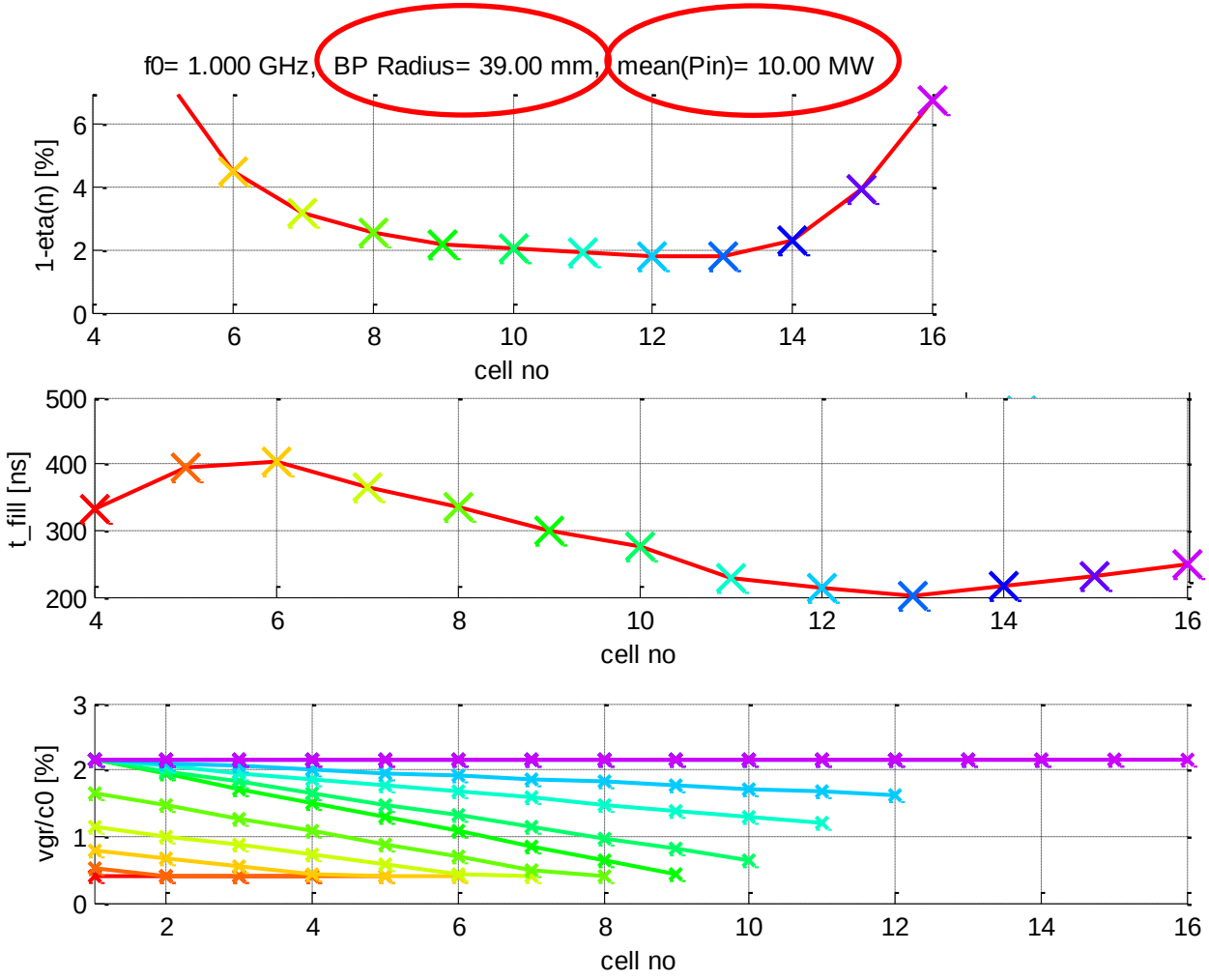
vgr/c lin. distribution

vgr/c= [2.2% to 0.86%]

vgr/c= [1.7% to 0.86%]

vgr/c= [1.7% to 1.28%]

optimisations - efficiency

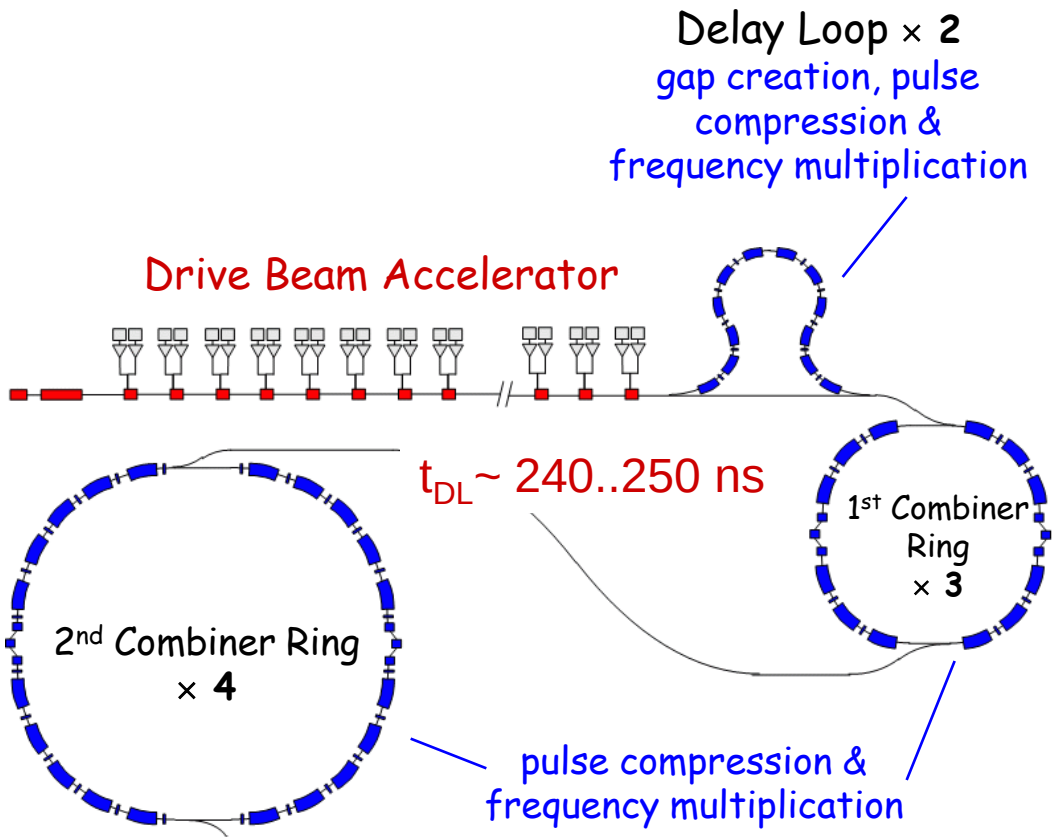


P_{in}= 10 MW
I_b= 4.21 A
R_{BP}= 39 mm

Ncells= 4 .. 16

vgr/c lin. distribution optimised for efficiency

t_{fill} - combined optimisations

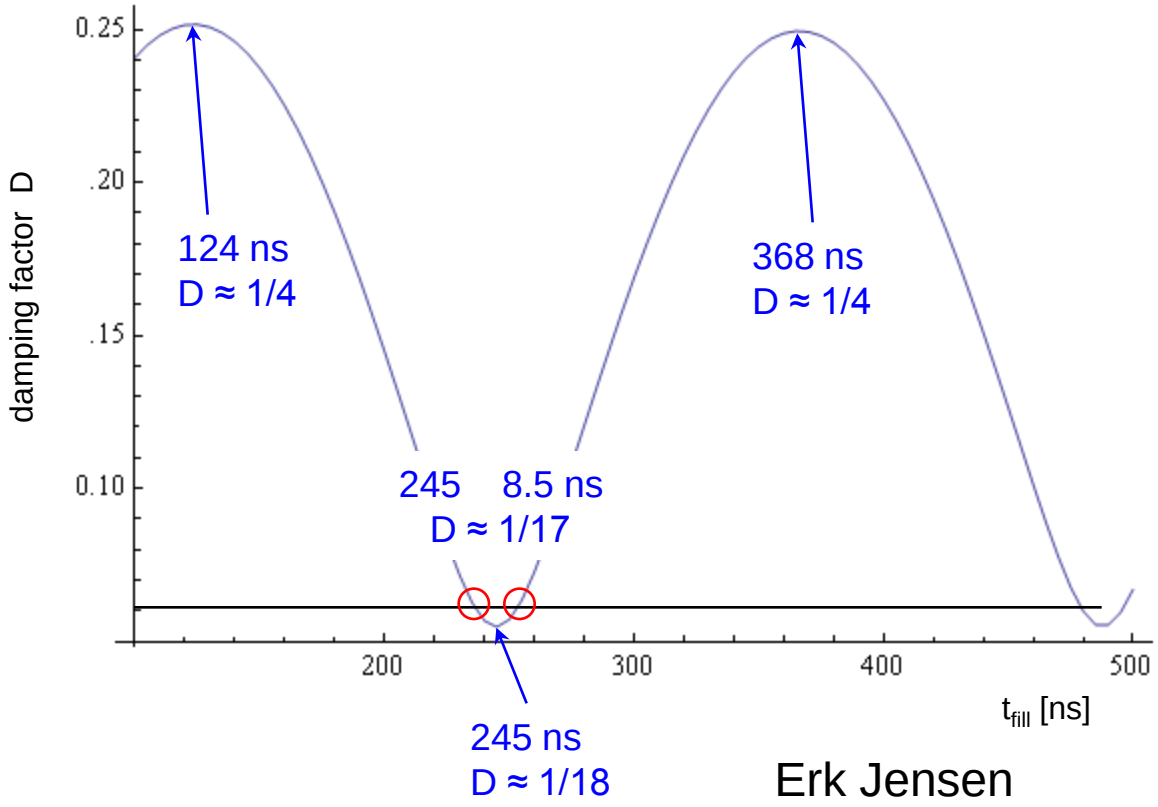


DBA structure tasks:

- acceleration => η_{RF}
- noise damping => D, t_{fill}

  appropriate t_{fill} => noise suppression at $f = 1/t_{DL}$

combined optimisations



DBA structure tasks:

- acceleration => η_{RF}
- noise damping => D, t_{fill}

  appropriate t_{fill} => noise suppression at $f = 1/t_{DL}$

combination for optimisation

$C(\eta_{RF}, t_{fill}) = f_1(\eta_{RF}) + f_2(t_{fill})$

$f_1(\eta_{RF}) = 1 - \eta_{RF}$

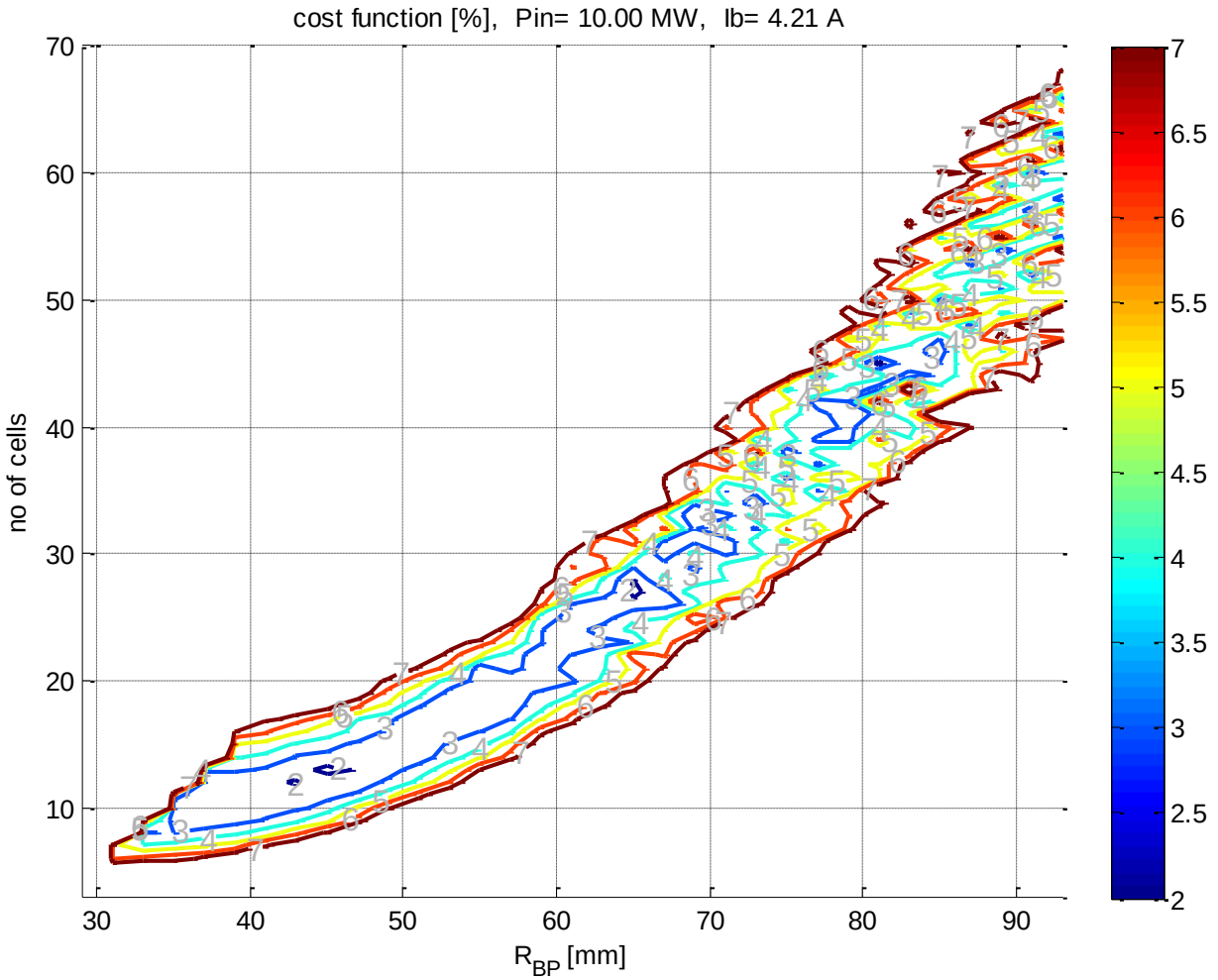
$f_2(t_{fill}) = \alpha ((t_{fill} - t_0)/\Delta t)^2$

$t_0 = 245$ ns

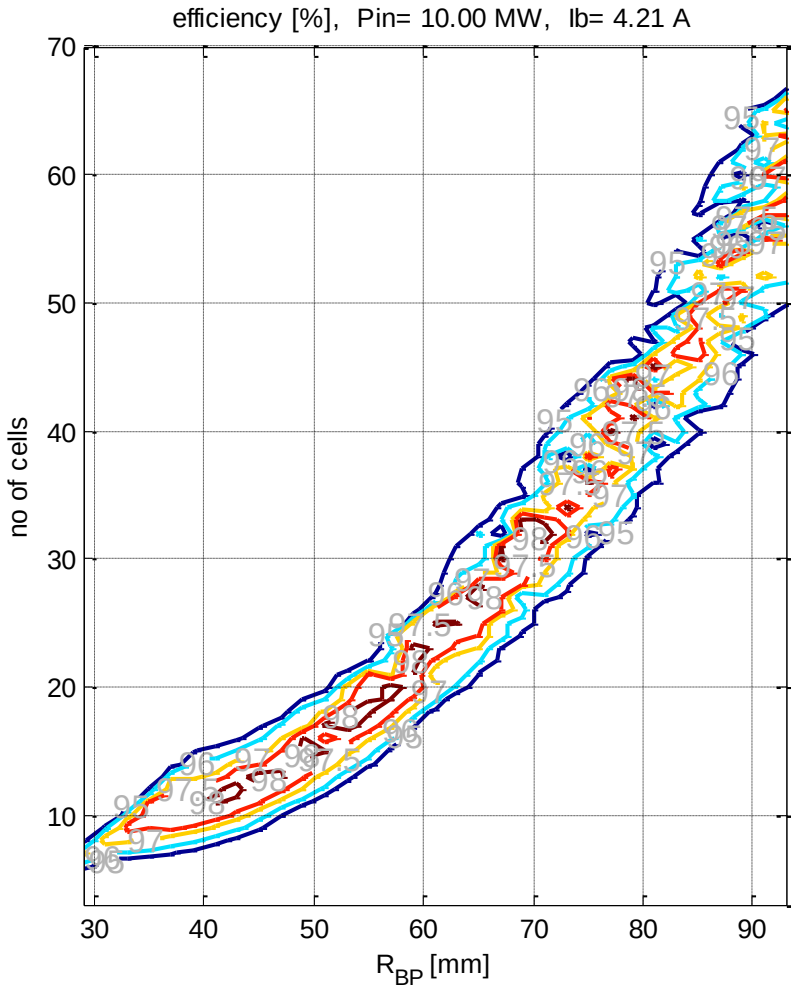
$\Delta t = 8.5$ ns

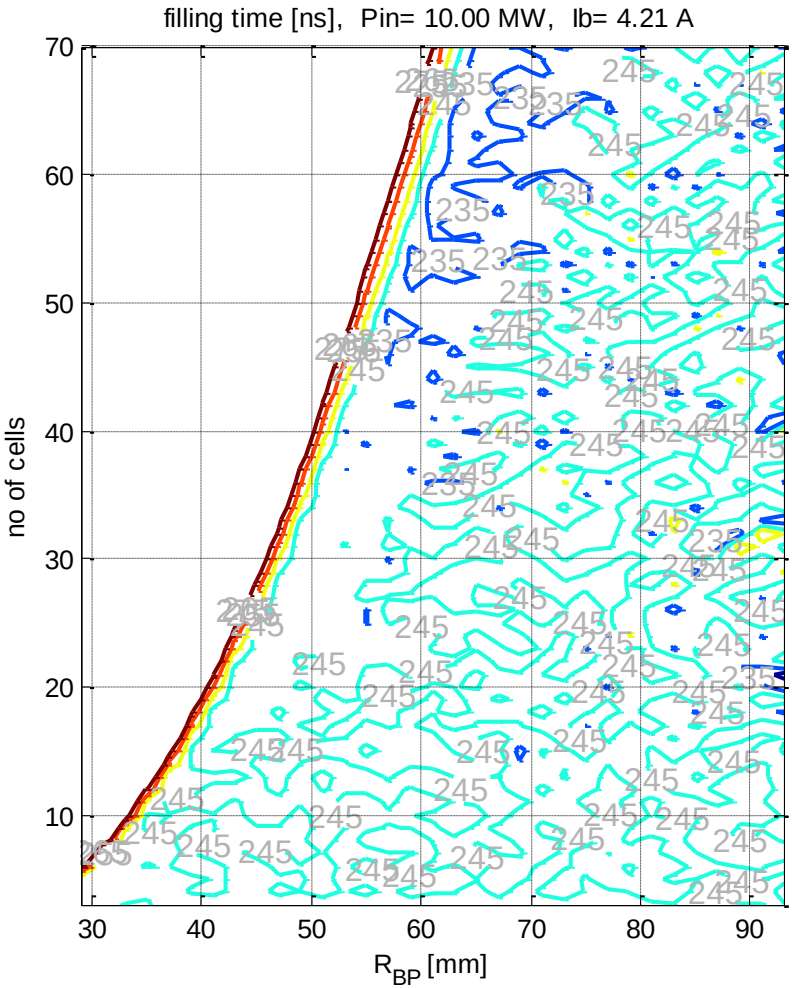
$\alpha = 2\%$

optimisations

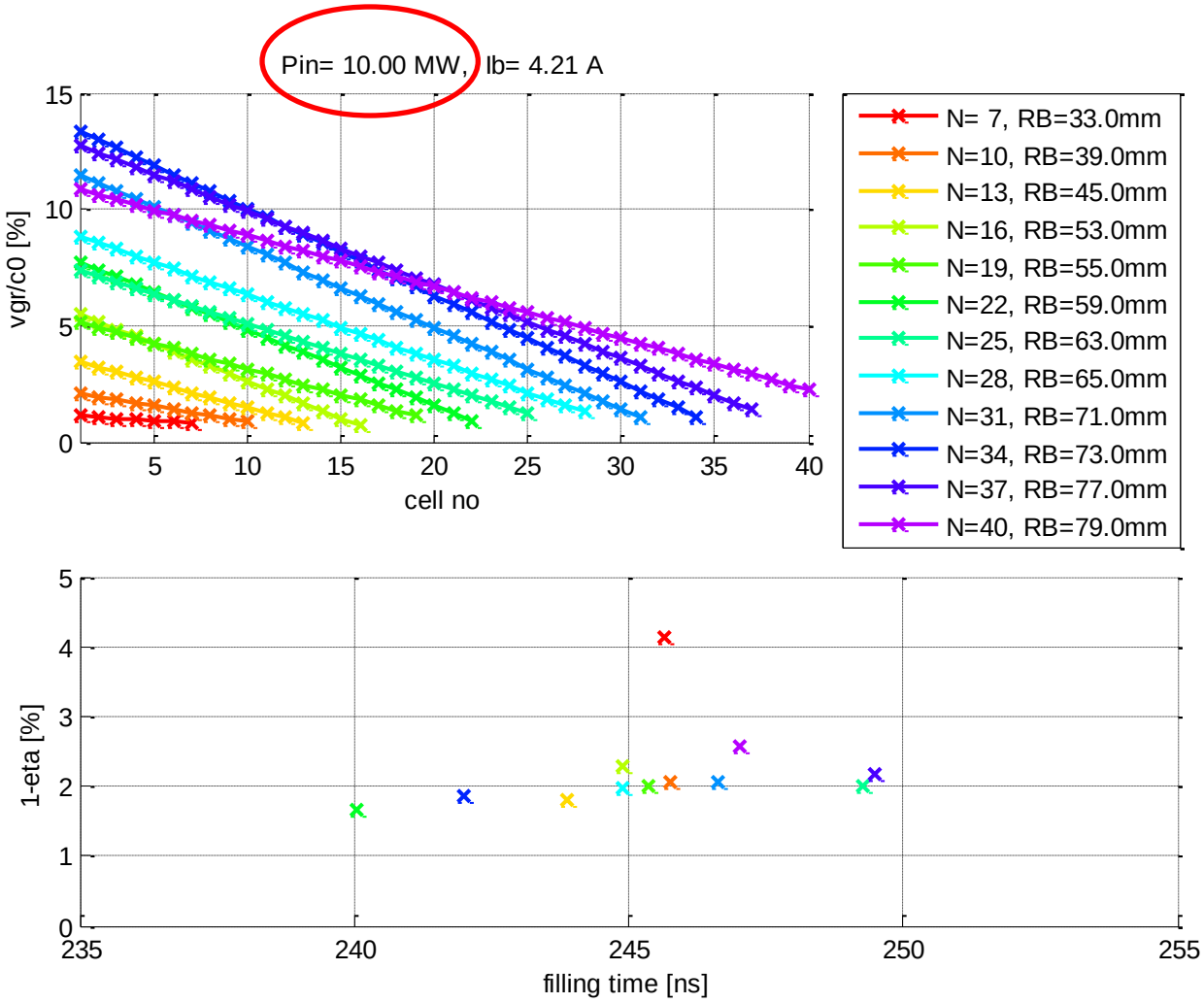


optimisations

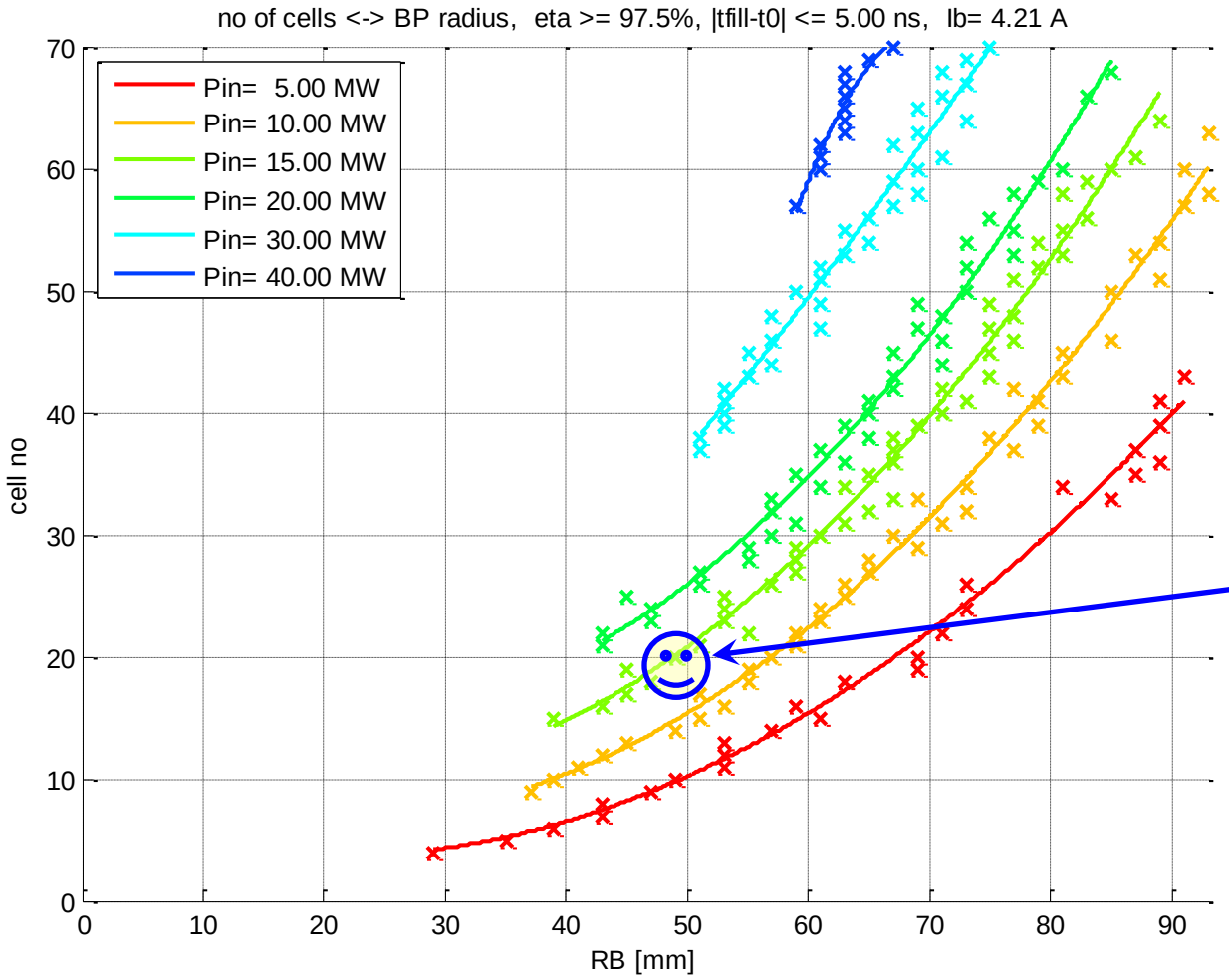




optimisations



optimisations



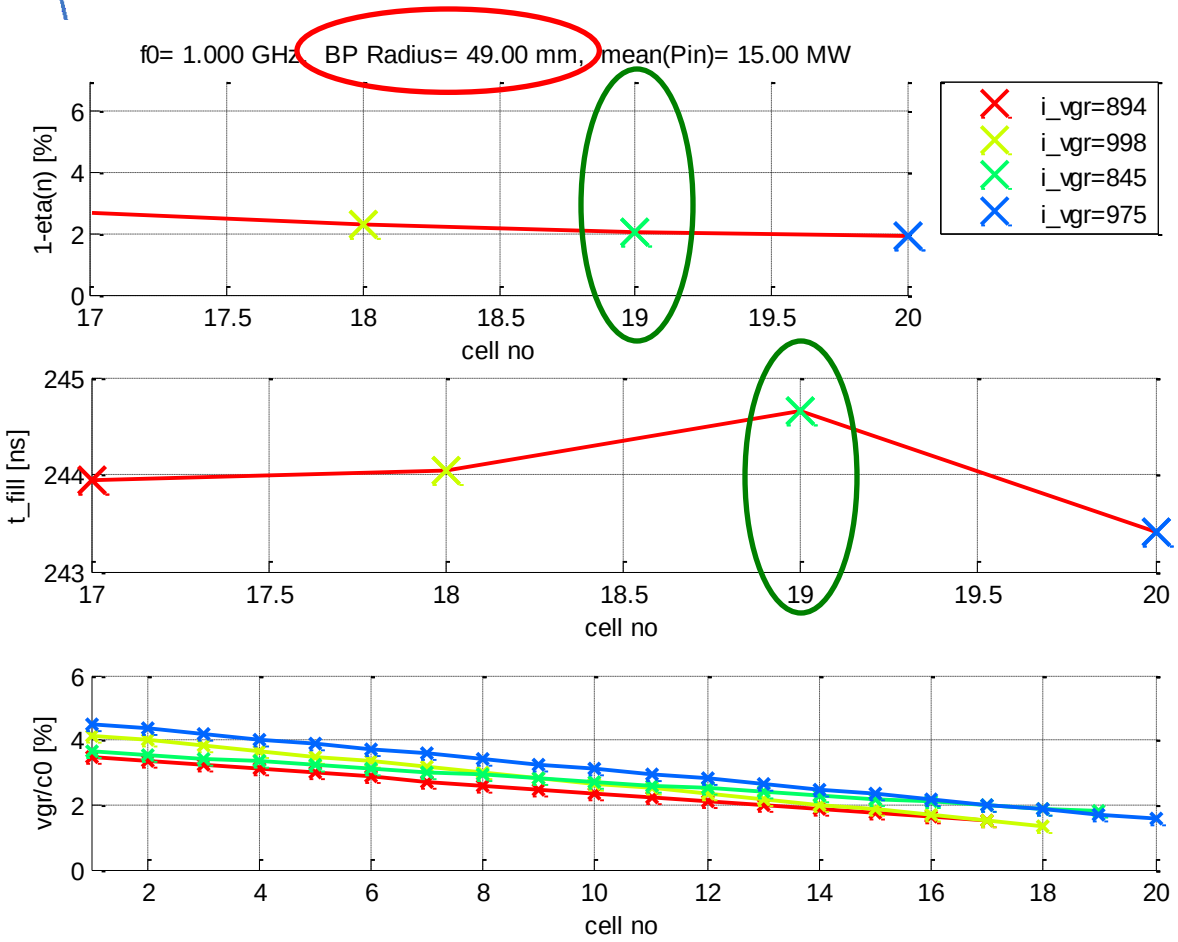
$\eta_{RF} \geq 97.5\ \%$

$|t_{fill} - 245\ ns| \leq 5\ ns$

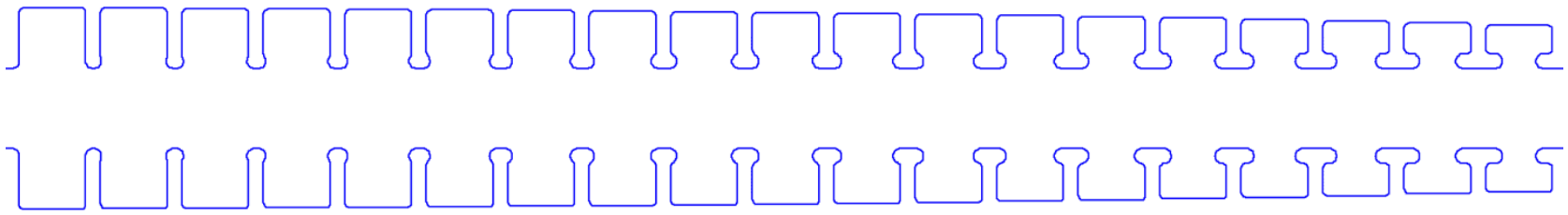
$P_{in} = 15$ MW

Beam dynamic (Avni Aksoy):
RB = 49 mm,
N = 19 cells

Baseline structure, 19 cells, RB=49 mm

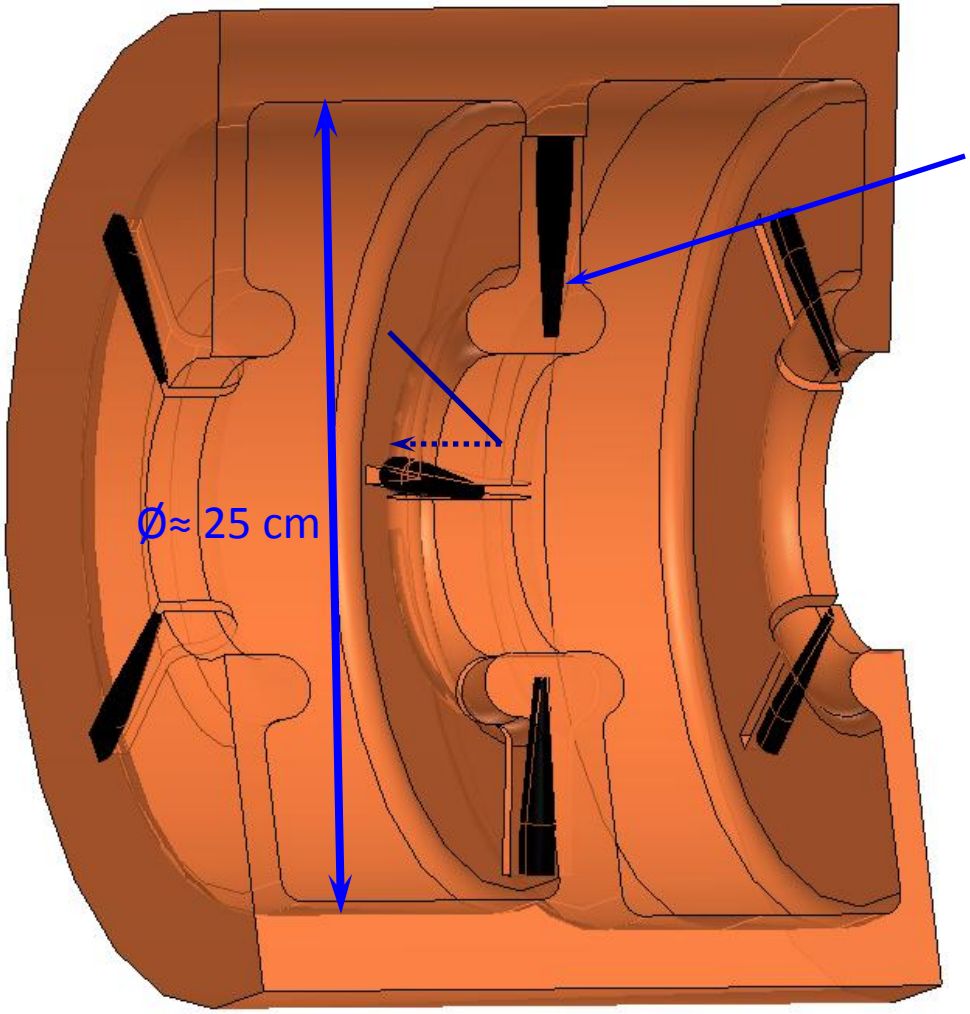


P_{in} = 15 MW
RB = 49 mm,
N = 19 cells



damping and detuning

reduction of transverse wakefields by damping and detuning



Alexej Grudiev's idea:
dampers in web (~18 mm tick)

acc. mode

$Q_0 = 2.2 \cdot 10^4$, $Q_{ext} = 3.7 \cdot 10^7$

distorted, 0.1 <=> 0.1 mm @ nose

$Q_{ext} = 1.5 \cdot 10^6$

$P_{ext,peak} = 110$ W, $P_{ext,avg} = 0.83$ W

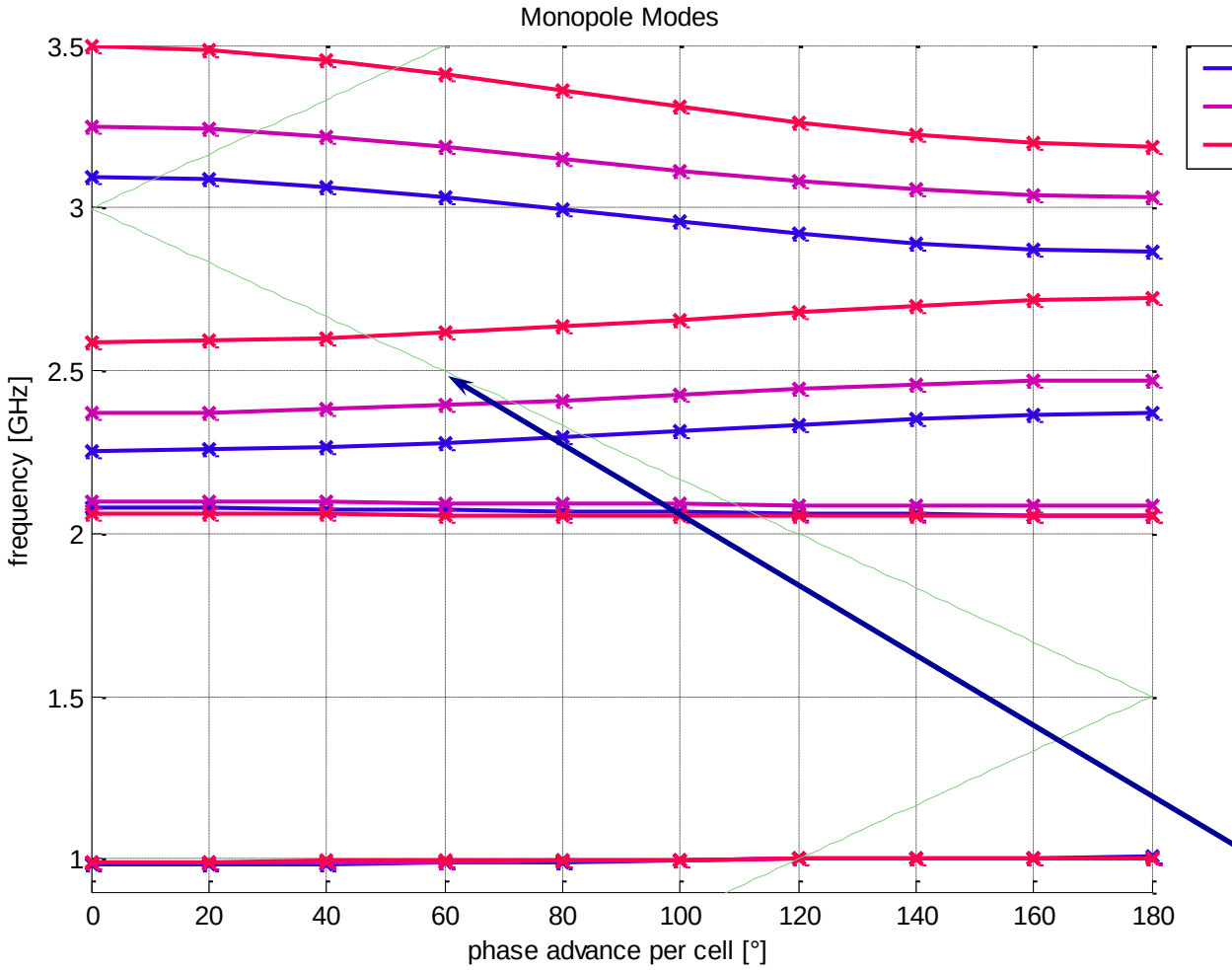
($P_{cell,peak} = 30$ kW, d.c. 0.75%)

concerns:

- **damper close to beam axis**
- **peak power in damper**

damping and detuning

reduction of transverse wakefields by damping and detuning



11 cell structure

R_{BP}= 41 mm

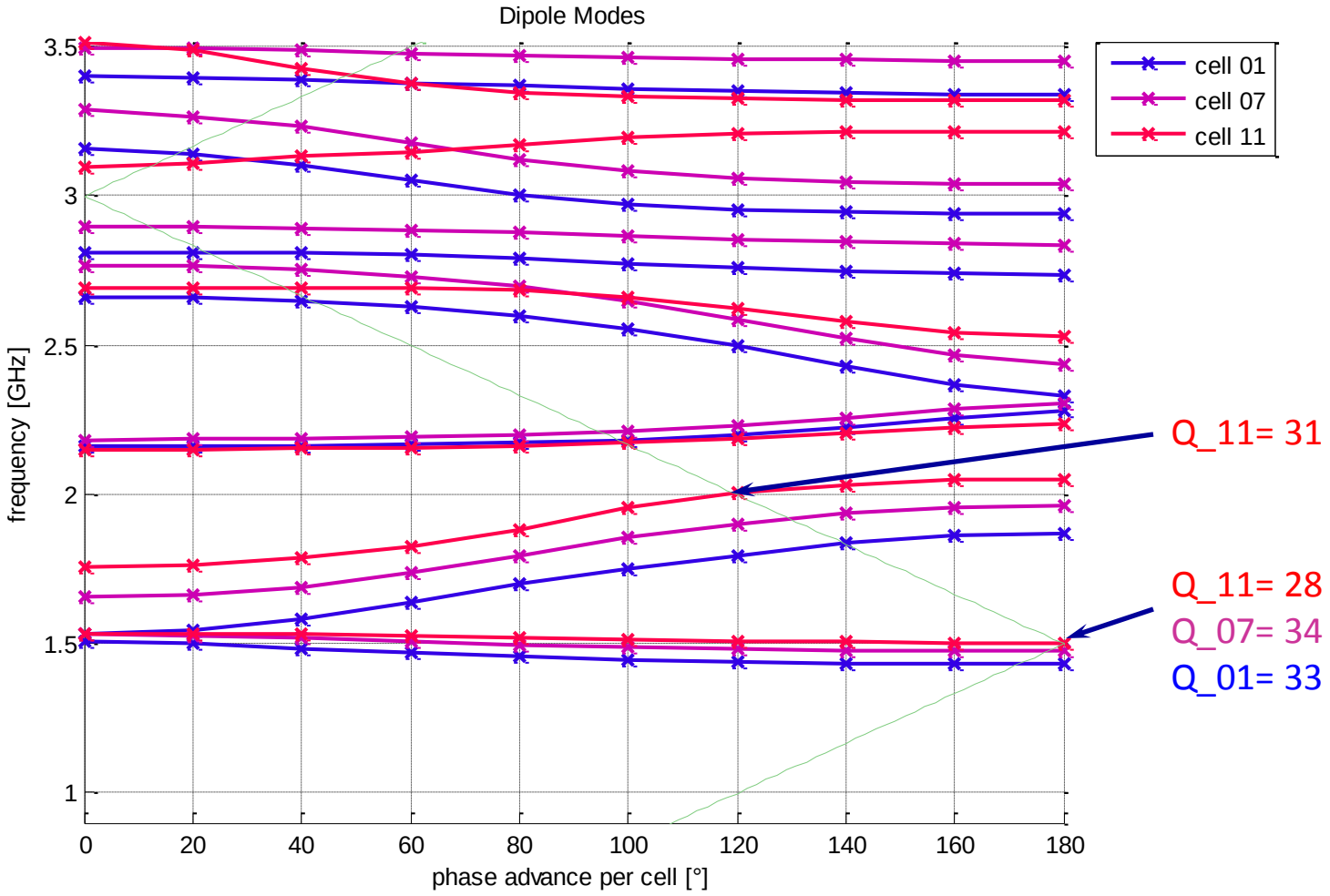
beam may excite multiples of 0.5 GHz

(only every other bucket filled)

Q ~ 20000

damping and detuning

reduction of transverse wakefields by damping and detuning



next steps

- coupler design, matching
- wakefield calculation (trans., long.)
- optimisation of damping
  - RF design
  - beam dynamics
  - mechanical design
- PIC simulation (RF + beam)

summary

travelling wave structure for CLIC DBA

- efficiency ≥ 97% (fully beam-loaded)
- filling time 245 ns ± 5 ns
- 1st degree of freedom: input RF power
- 2nd degree of freedom: no of cells <=> BP radius
- choice: 15 MW, 19 cells <=> BP= 49 mm
- wakefield reduction by detuning and damping
  transverse have been estimated (A. Aksoy)
  longitudinal will be studied
- compact damping solution, validation of principle

CERN

CLIC

beam parameters – A. Aksoy

Introduction

The aim of the study is finding best linac optics in order to transport the beam through Drive Beam Linac (DBL) in required tolerances.

Lattice and structure design has been studied with considering transverse instabilities. (Structure design by Rolf Wegner)

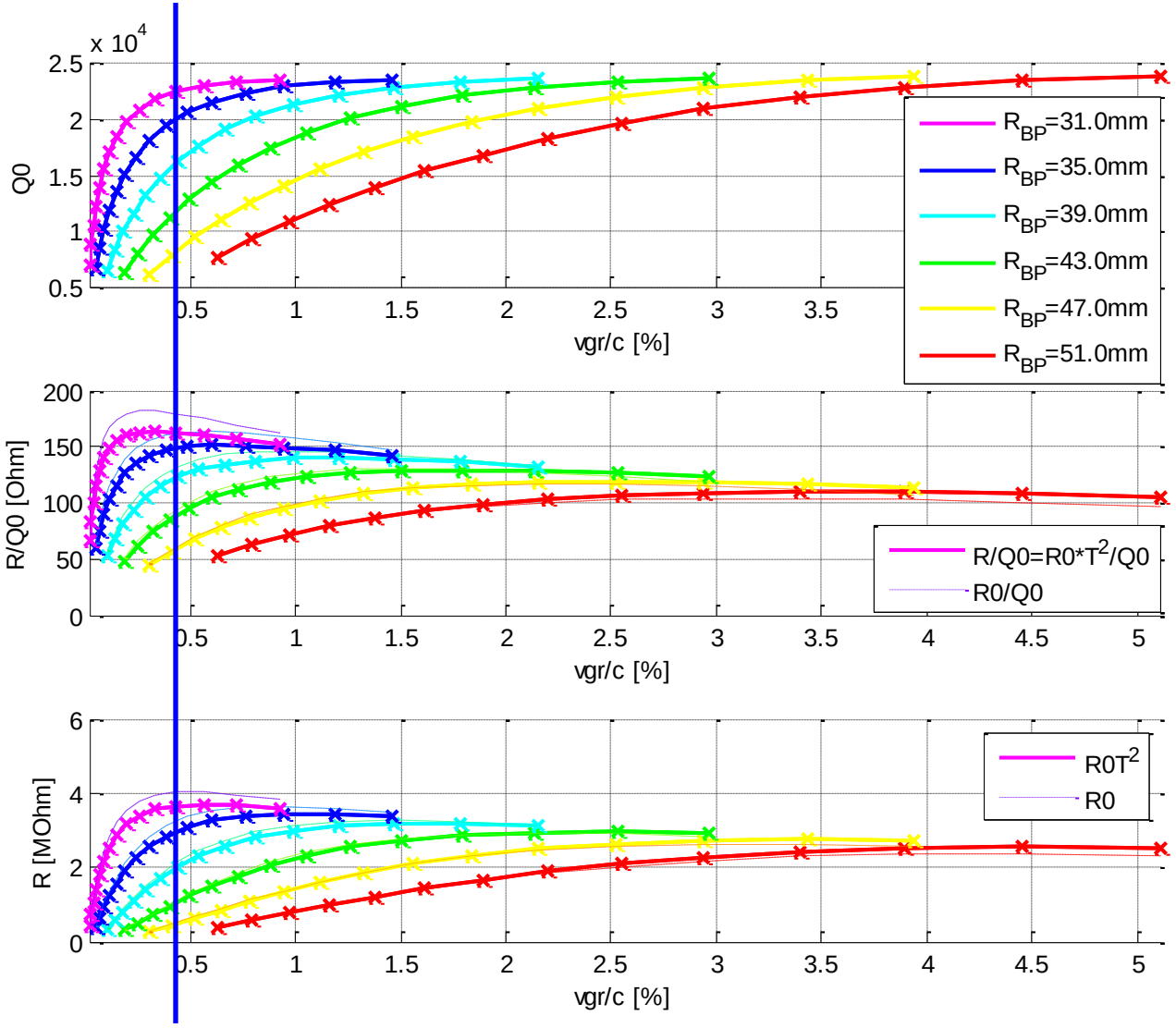
Bunch compressor and its position on DBL is studied with longitudinal tolerances.

PLACET and analytical calculations have been used for calculations.

Parameter	**Value**	Unit
Initial Energy	50	MeV
Final Energy	2400	MeV
Energy Spread	< 0.35	%
Pulse current	4.2	A
Bunch charge	8.4	nC
Bunch Length	1.0	mm
Emittance Growth	<10	%
Pulse Length	140	μs
Bunch separation	60	cm
No of bunches per pulse	70128	
Bunch length error tolerance	1	%
Phase error tolerance of bunch	0.2 (175)	deg(μm)

A.AKSOY 3

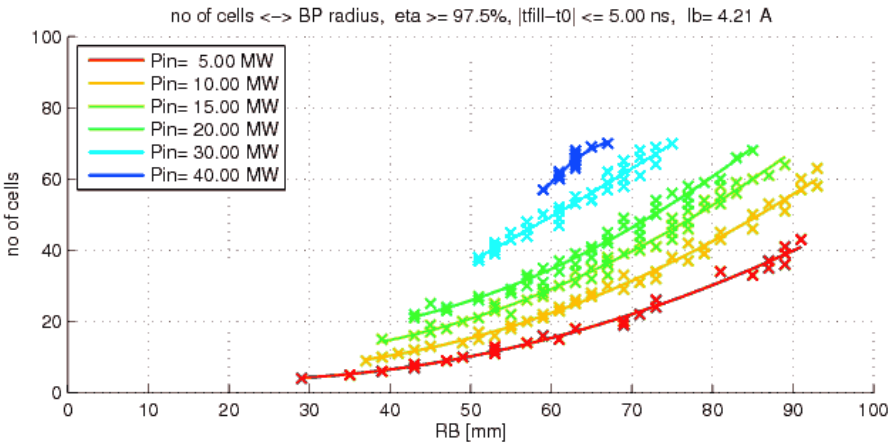
simulations of basic cells

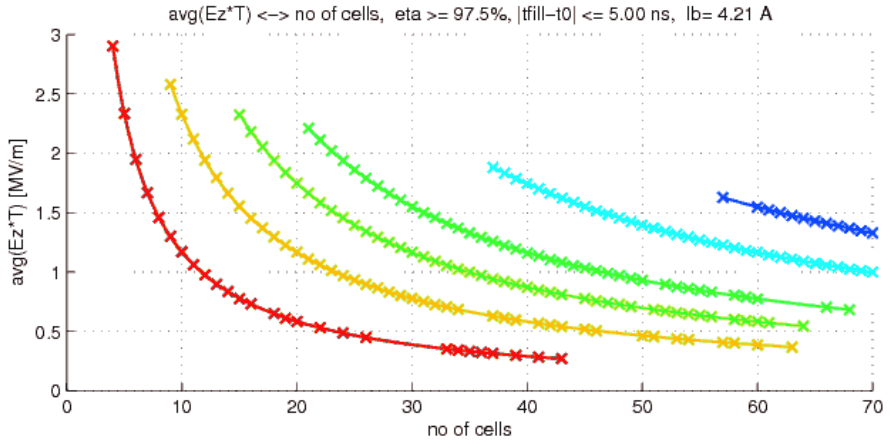


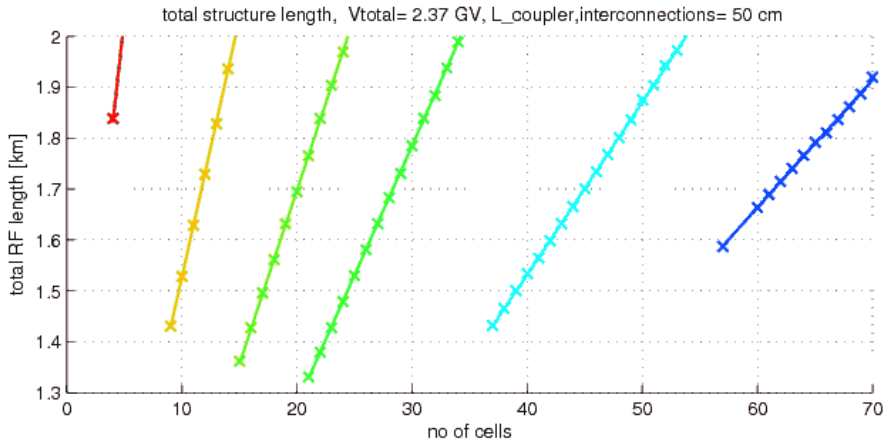
variations:
R_{BP}
gap <=> vgr/c

tuning R_a => f_0=1GHz

vgr/c range:
min ~ 0.4% to 0.5%


no of cells <–> BP radius, eta >= 97.5%, |tfill–t0| <= 5.00 ns, Ib= 4.21 A
Pin= 5.00 MW
Pin= 10.00 MW
Pin= 15.00 MW
Pin= 20.00 MW
Pin= 30.00 MW
Pin= 40.00 MW
no of cells
RB [mm]


avg(Ez*T) <–> no of cells, eta >= 97.5%, |tfill–t0| <= 5.00 ns, Ib= 4.21 A
avg(Ez*T) [MV/m]
no of cells


total structure length, Vtotal= 2.37 GV, L_coupler,interconnections= 50 cm
total RF length [km]
no of cells