On the choice of frequency and gradient for CLIC main linac accelerating structure

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Outline

- Optimization procedure
- Beam dynamics input from Daniel
- Optimization results for different sets of rf constraints
- Few examples
- Conclusions

Optimization parameter space

"real-estate" gradient: $\langle E_{acc} \rangle = \langle E_{acc} \rangle^{active} \times N_{cells} / (N_{cells}+3)$

All structure parameters are variable:

- $\langle E_{acc} \rangle$= 90 – 150 MV/m,
- f = 12 – 30 GHz,
- $\Delta\varphi$ = 50 - 130°,
- $\langle a \rangle / \lambda$= 0.09 - 0.21,
- $\Delta a / \langle a \rangle$ = 0.01 – 0.6,
- d_1/λ= 0.025 - 0.1, $d_2 > d_1$
- N_{cells} = 15 – 300.

N structures:

7
10
9
24
60
61
4

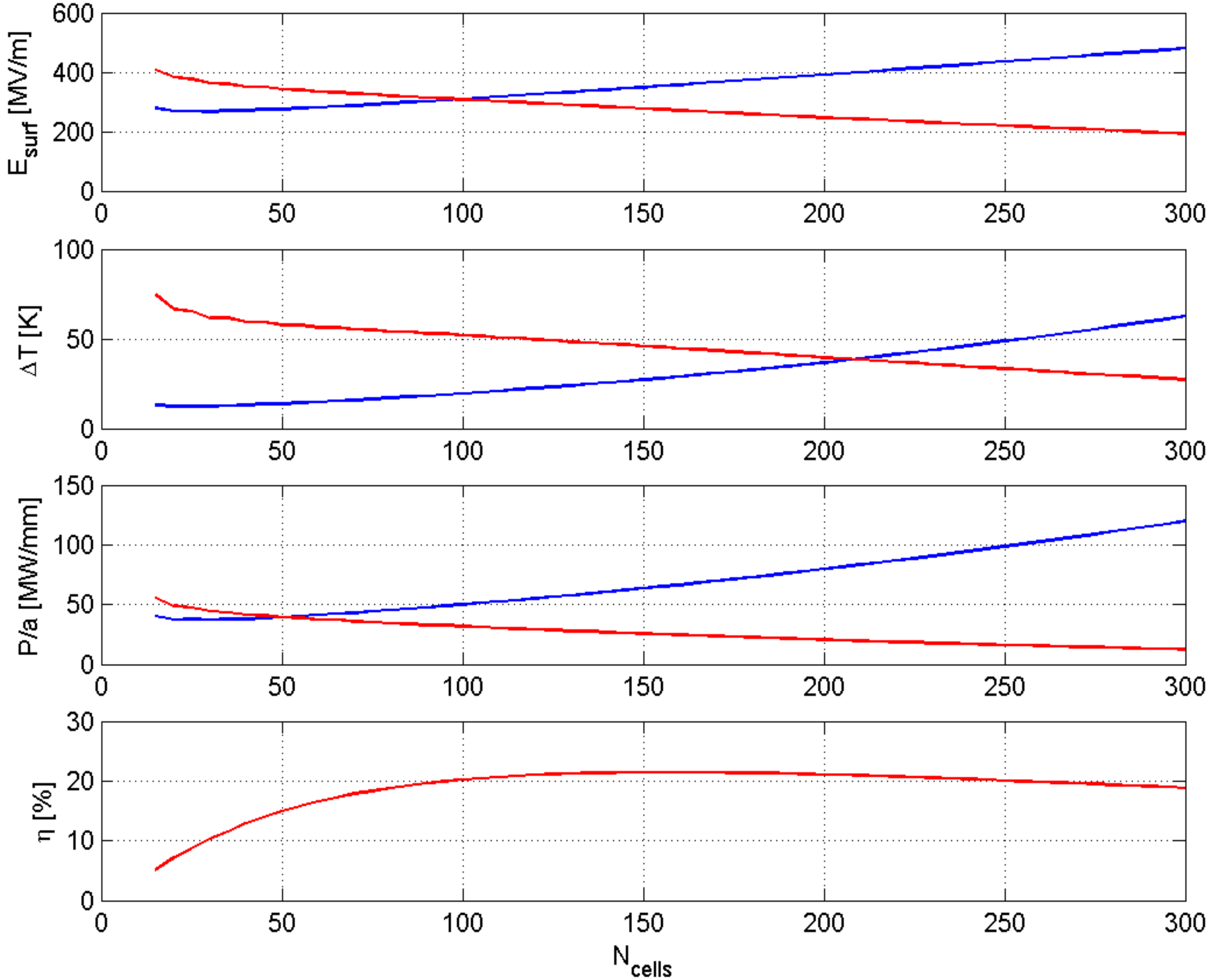
221.356.800

N.B. In this slide and in the following two ones, new features are marked in red.

Choice of N_{cells}

4 structures are chosen from 285.

first cell (blue), last cell (red)



For example:

N_{cells} = 100 – E_{surf} = const,

N_{cells} = 210 – ΔT = const,

N_{cells} = 50 – P/C = const

N_{cells} = 150 – Max(η)

Optimization constraints

Beam dynamics constraints:

N, L_{bx} depend on $\langle a \rangle/\lambda$, $\Delta a/\langle a \rangle$, f and $\langle E_{acc} \rangle$ and come from Daniel

N_{cycles} is determined by condition: $W_{t,2}$ = 10 V/pC/mm/m for N = 4×10^9

rf breakdown and pulsed surface heating (rf) constraints:

E_{surf}^{max} < 380MV/m & ΔT^{max} < 56K & $P_{in} t_p^{1/2}$ < 1200 MWns$^{1/2}$

or $P_{in} t_p^{1/3}$ < 442 MWns$^{1/3}$

or 40K or $P_{in} t_p^{1/3}/C$ < 20 MWns$^{1/3}$/mm

or $P_{in} t_p^{1/3}/C$ < 16 MWns$^{1/3}$/mm

or $P_{in} t_p^{1/2}/C$ < 42 MWns$^{1/2}$/mm

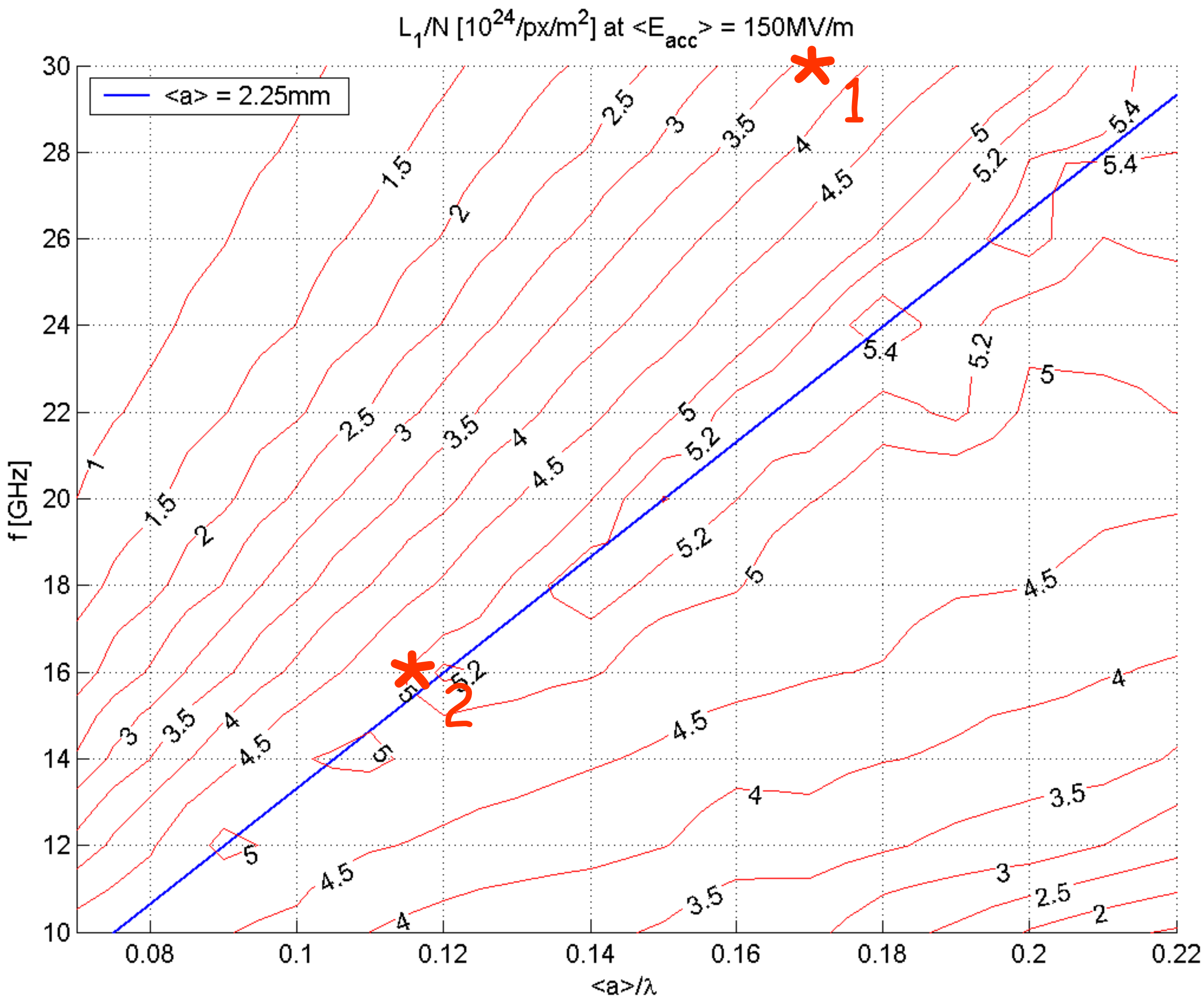
or $P_{in} t_p^{1/2}/C$ < 30 MWns$^{1/2}$/mm

Optimization figure of merit

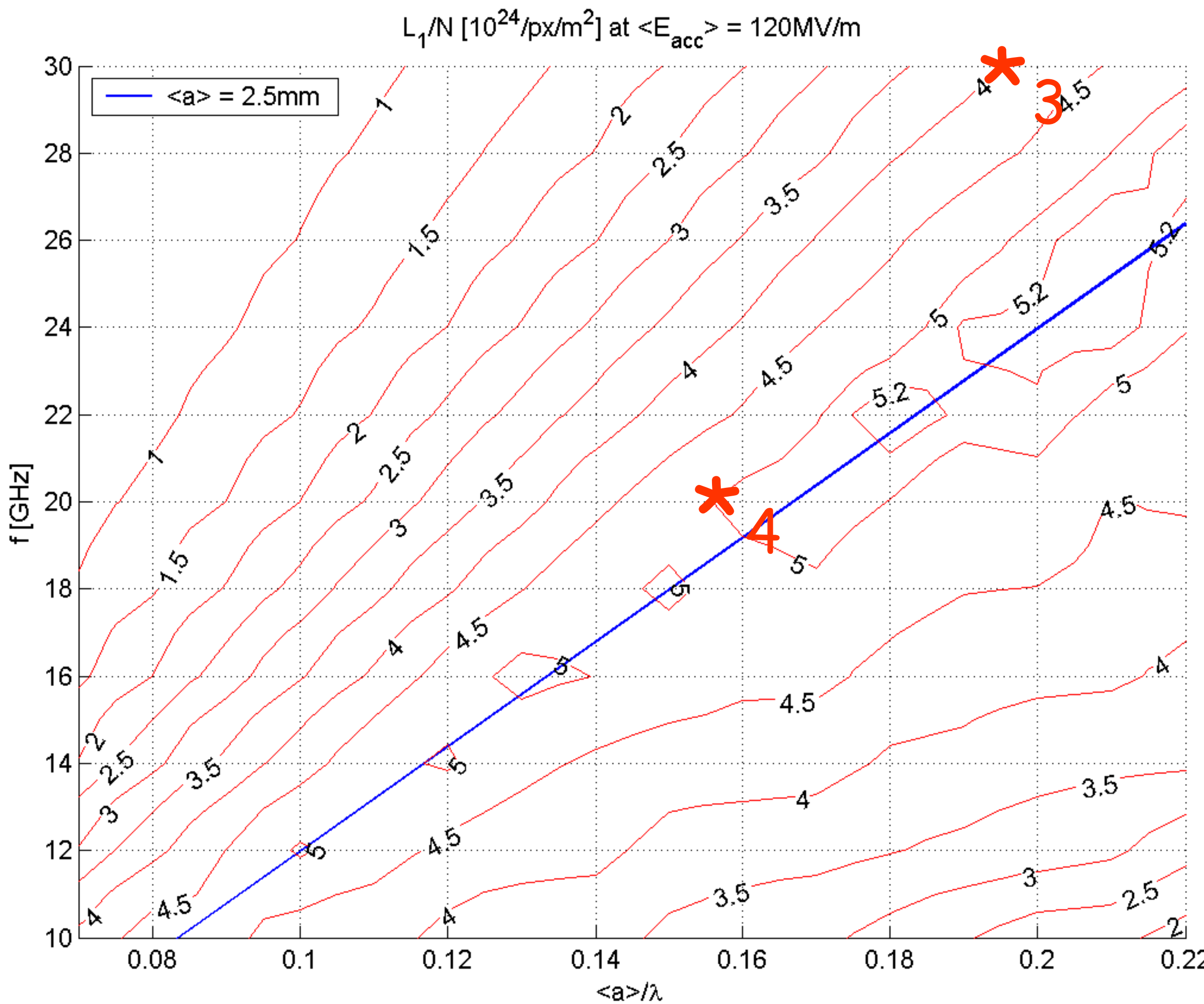
Luminosity per linac input power:

$$\int L dt / \int P dt \sim L_{b\times}/N\eta$$

Beam dynamics input from Daniel



Beam dynamics input from Daniel



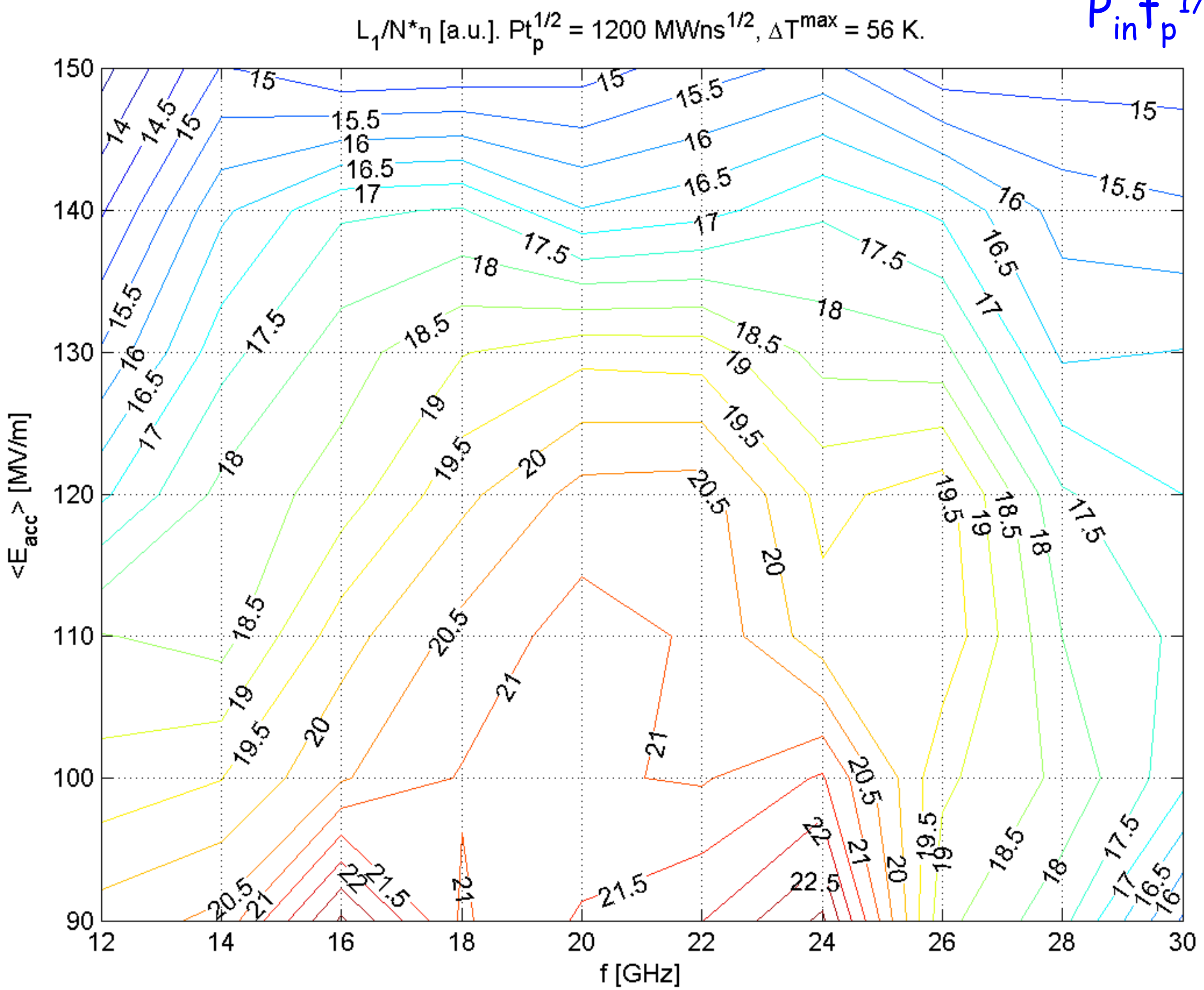
Gradient Scaling:

$N \sim \langle E_{acc} \rangle$

but

L_{bx} is simulated taking $N \sim \langle E_{acc} \rangle$

Luminosity per power optimization

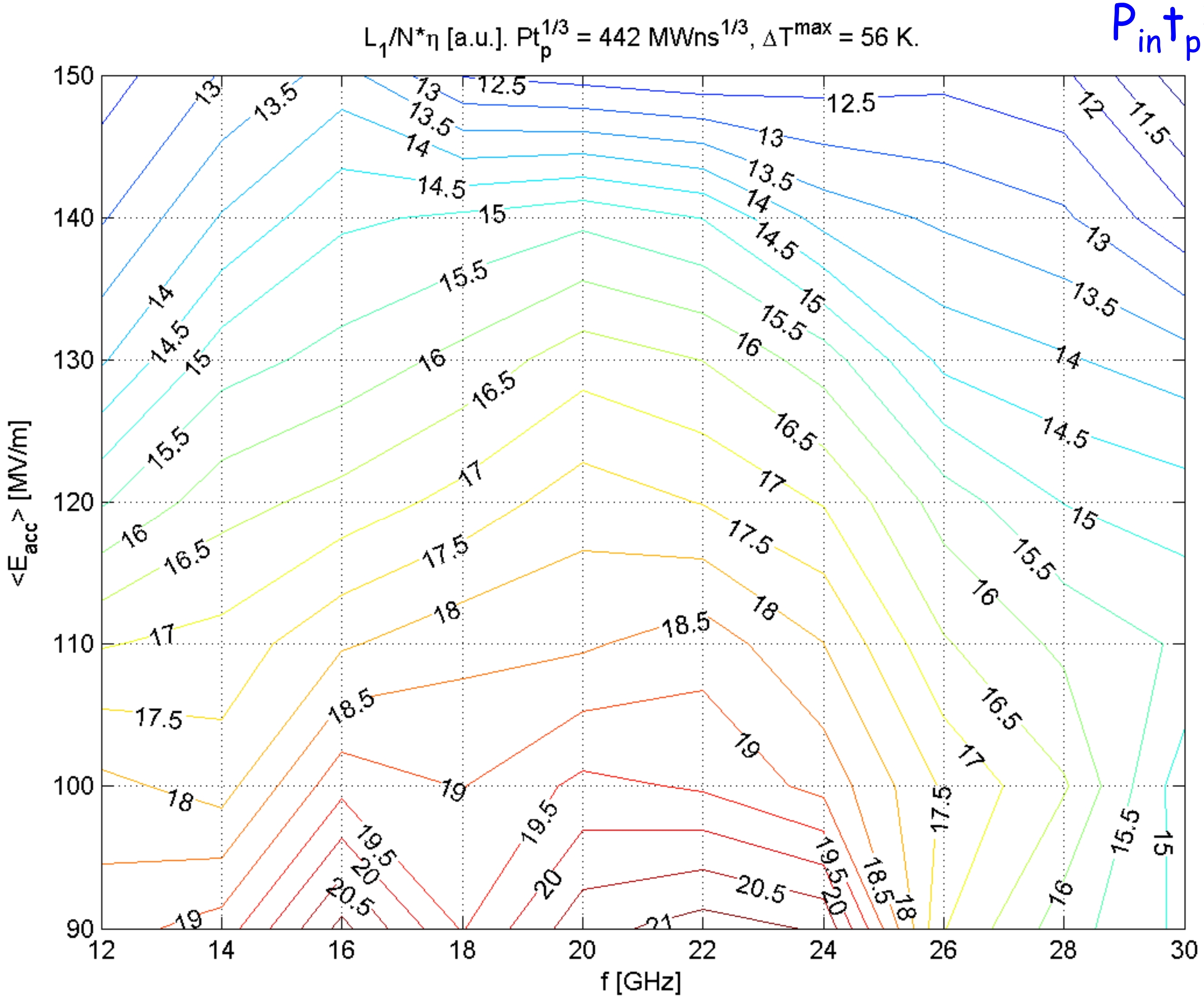


$P_{in} t_p^{1/2} < 1200$ MWns$^{1/2}$

$\Delta T^{max} < 56$K

CTF3 (7.11.2005):
~ 424 MWns$^{1/2}$

Luminosity per power optimization



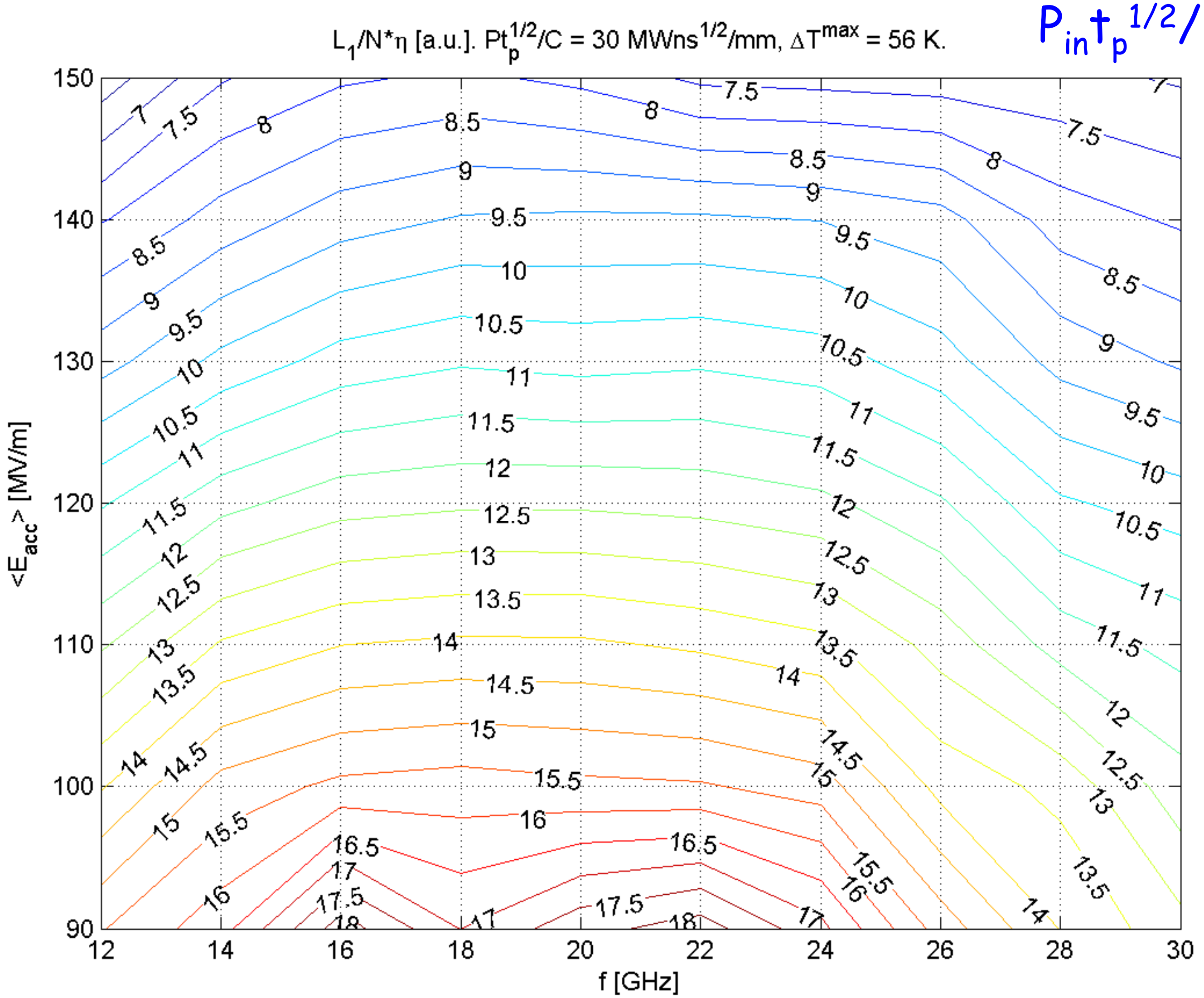
$P_{in} t_p^{1/3} < 442$ MWns$^{1/3}$

$\Delta T^{max} < 56$K

CTF3 (7.11.2005):

~ 221 MWns$^{1/3}$

Luminosity per power optimization

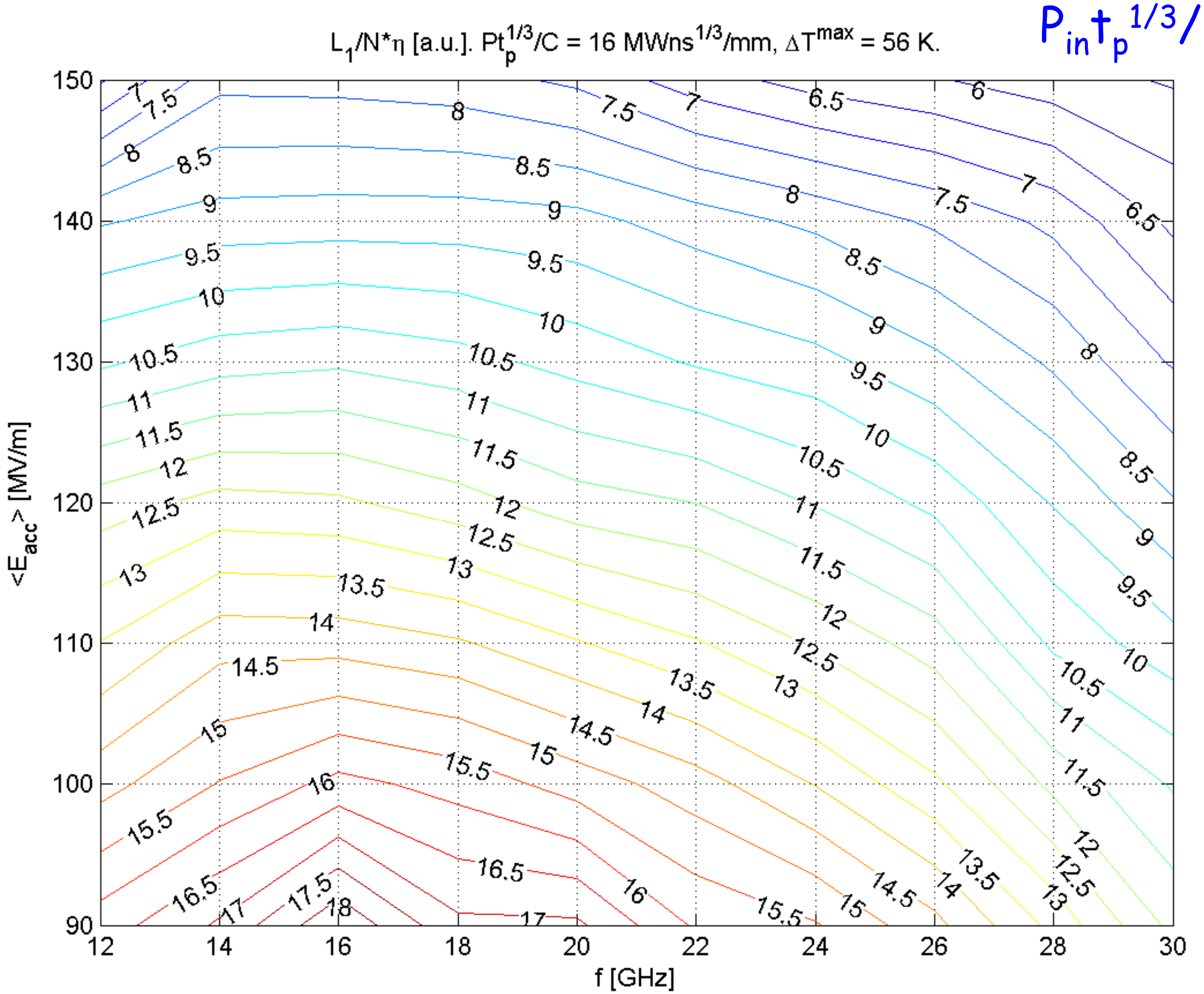


$P_{in} t_p^{1/2}/C < 30\ MWns^{1/2}/mm$

$\Delta T^{max} < 56K$

CTF3 (7.11.2005):
~ 39 $MWns^{1/2}/mm$

Luminosity per power optimization

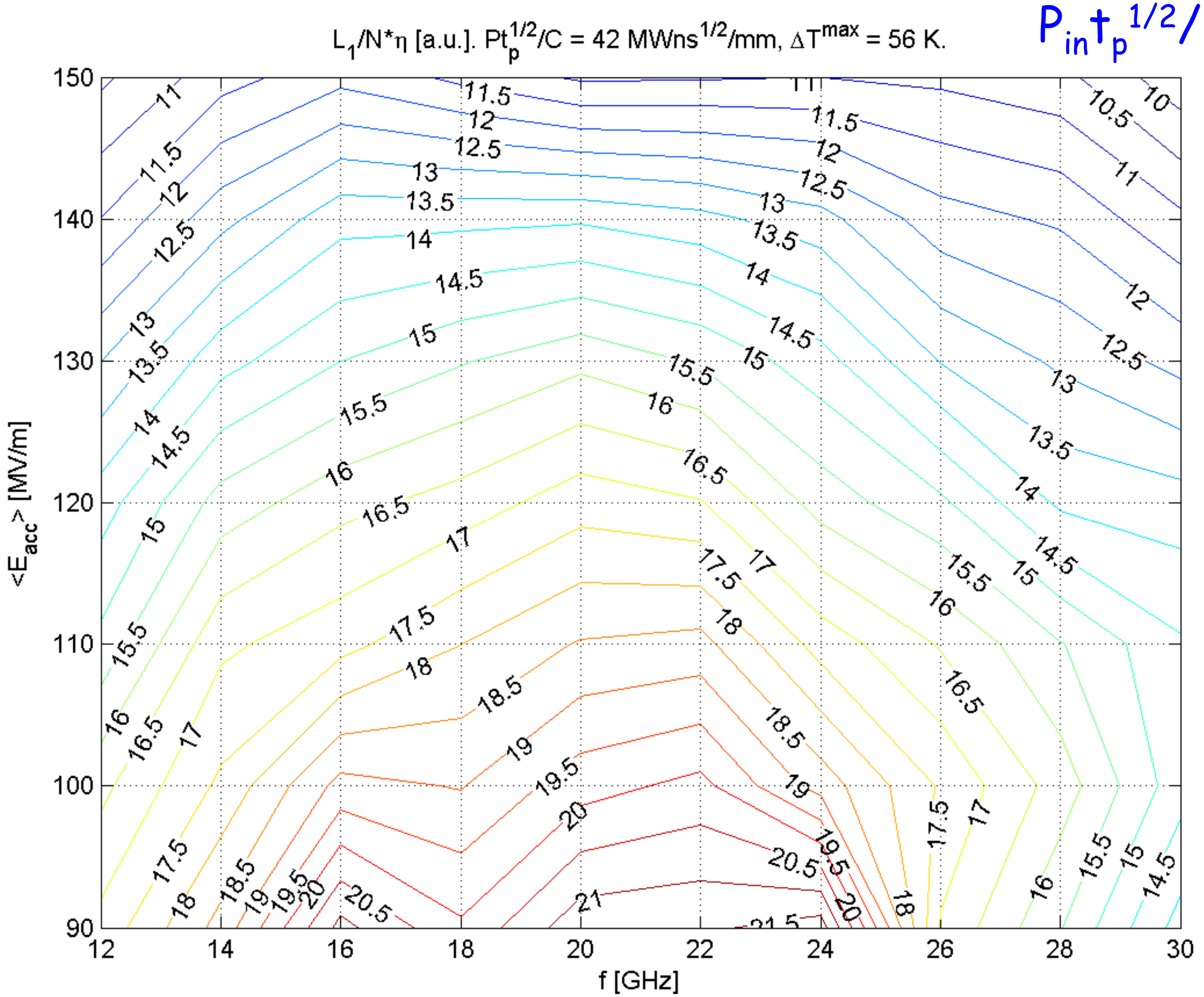


$P_{in}t_p^{1/3}/C < 16\ MWns^{1/3}/mm$

$\Delta T^{max} < 56K$

CTF3 (7.11.2005):
$\sim 20\ MWns^{1/3}/mm$

Luminosity per power optimization

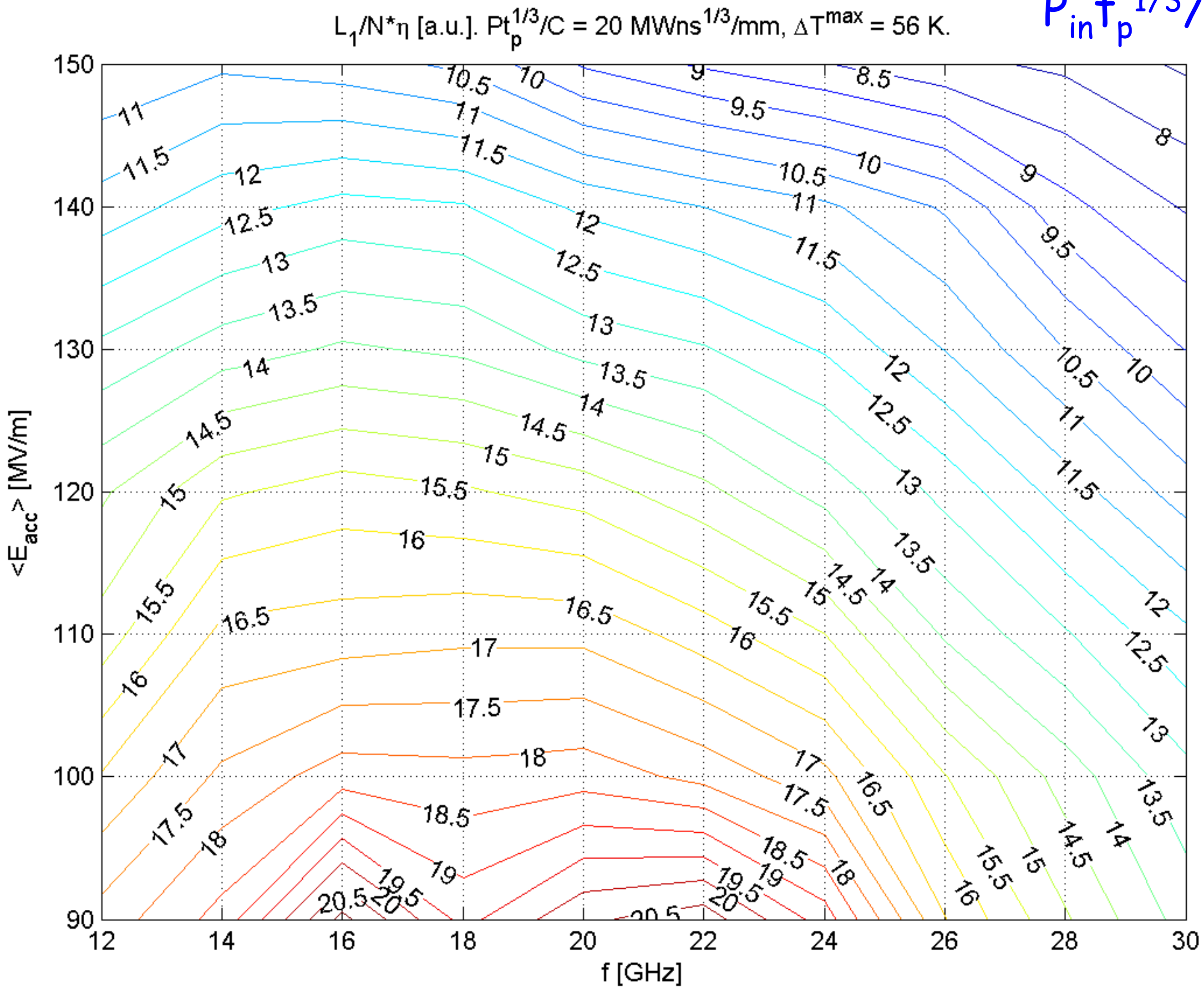


$P_{in} t_p^{1/2}/C < 42\ MWns^{1/2}/mm$

$\Delta T^{max} < 56K$

CTF3 (7.11.2005):
$\sim 39\ MWns^{1/2}/mm$

Luminosity per power optimization



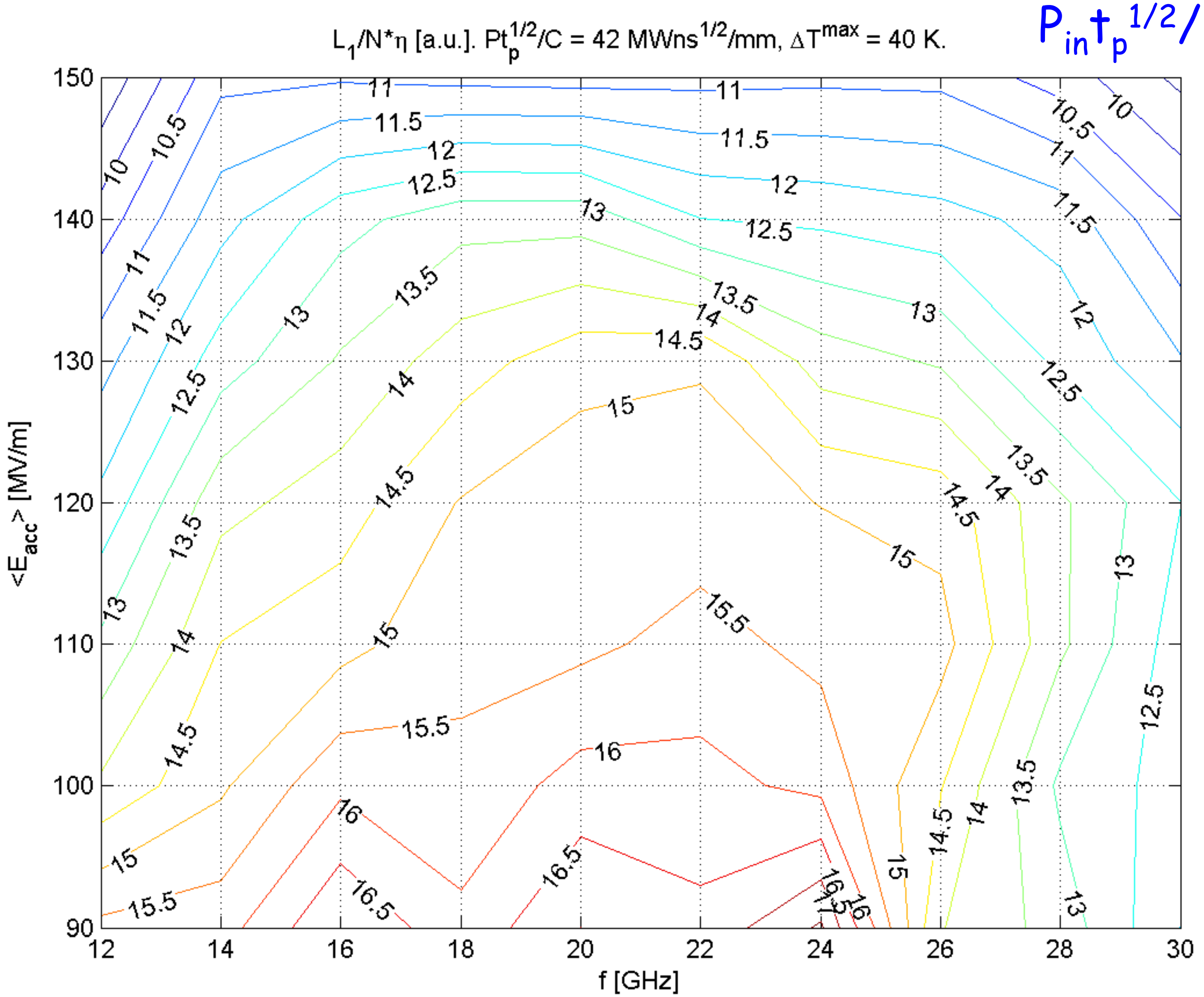
$P_{in}t_p^{1/3}/C$ < 20 $MWns^{1/3}$/mm

ΔT^{max} < 56K

CTF3 (7.11.2005):

~ 20 $MWns^{1/3}$/mm

Luminosity per power optimization



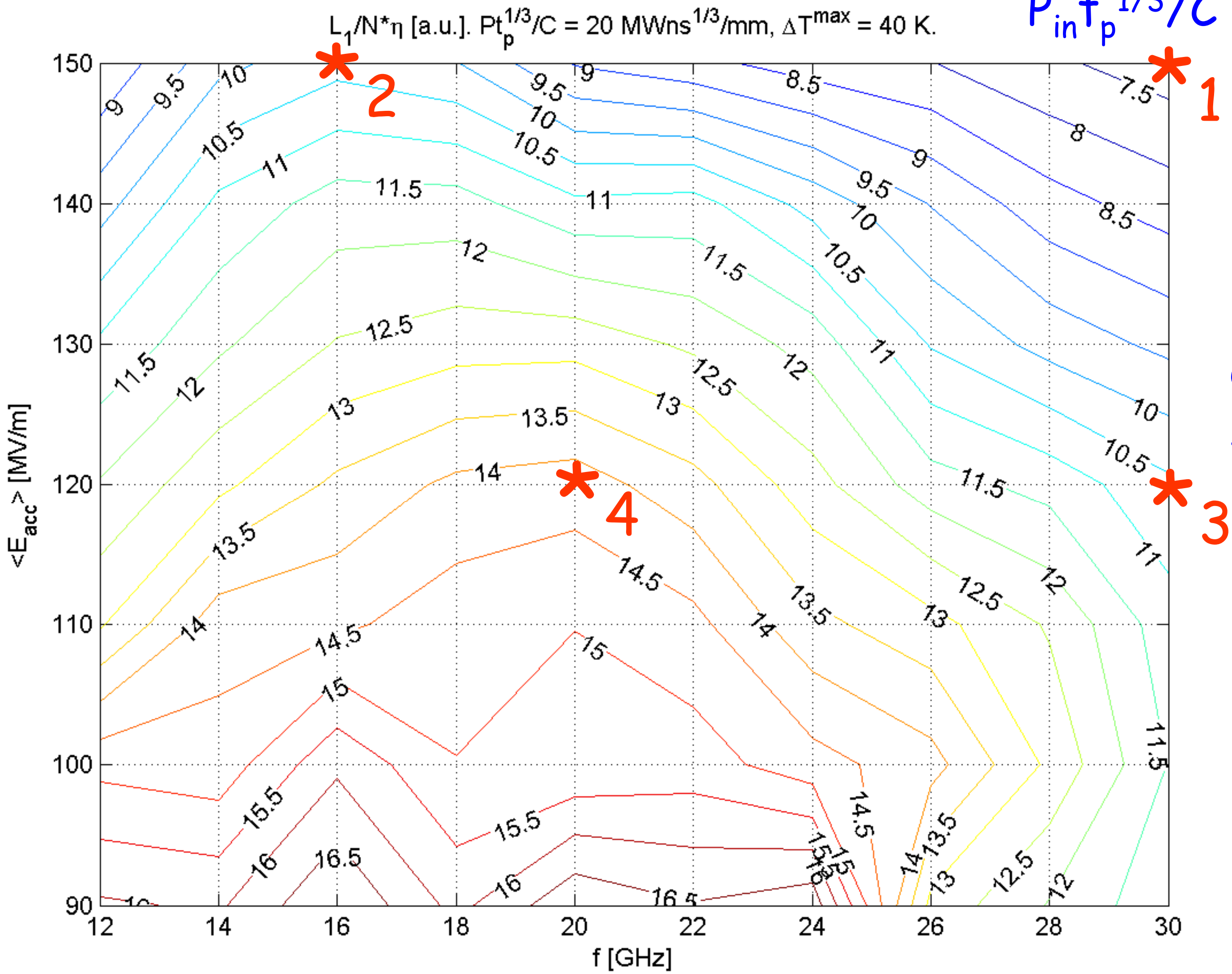
$P_{in} t_p^{1/2}/C$ < 42 $MWns^{1/2}/mm$

ΔT^{max} < 40K

CTF3 (7.11.2005):

~ 39 $MWns^{1/2}/mm$

Luminosity per power optimization



$P_{in} t_p^{1/3}/C < 20$ MWns$^{1/3}$/mm

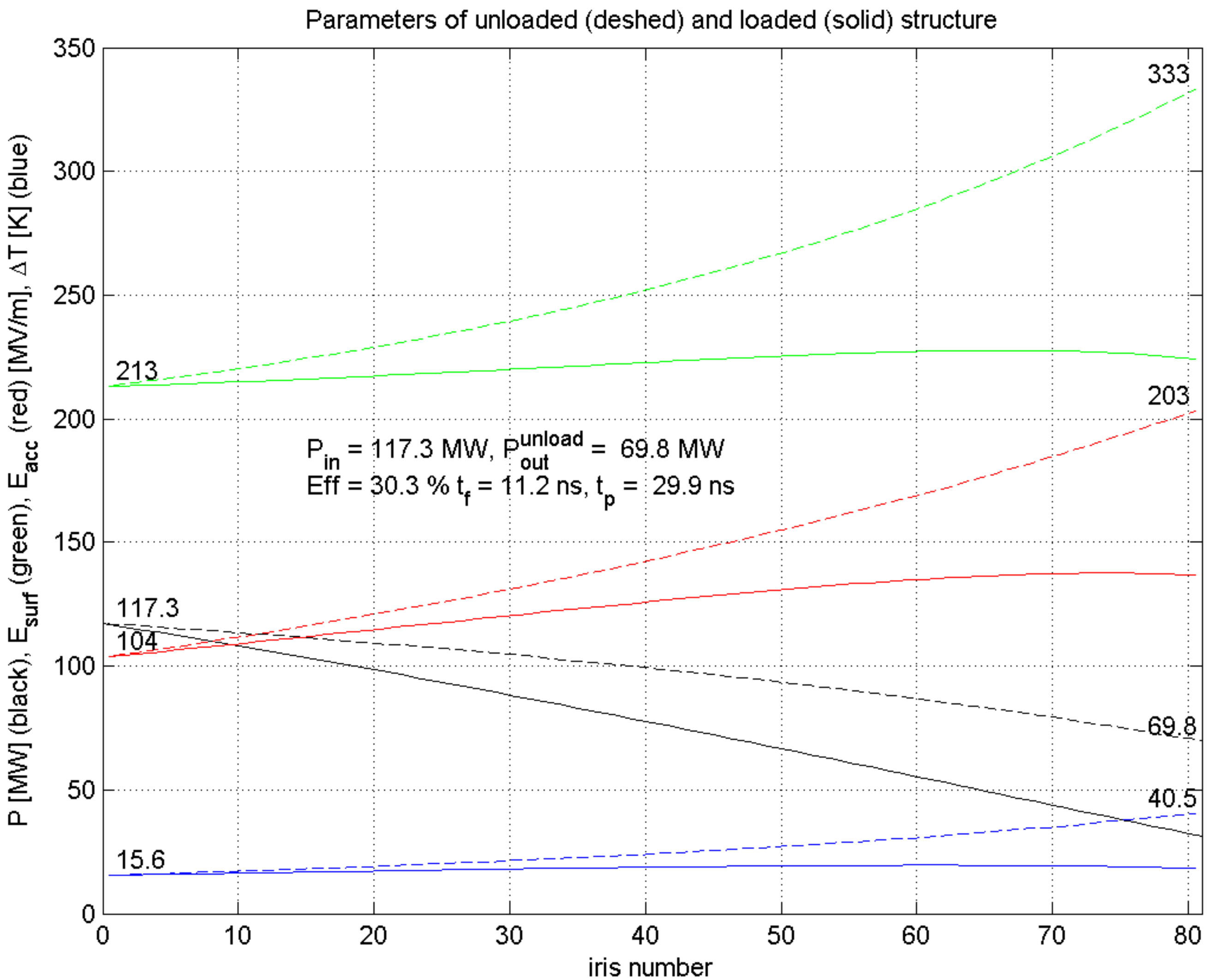
$\Delta T^{max} < 40$K

CTF3 (7.11.2005):
~ 20 MWns$^{1/3}$/mm

Parameter list of structures: 1-4

$<E_{acc}>$ [MV/m]	150	150	120	120
f [GHz]	30	16	30	20
$\Delta\varphi$ [º]	50	50	50	50
$a_{1,2}$ [mm]	2.1, 1.3	2.73, 1.58	2.37, 1.53	2.92, 1.73
$d_{1,2}$ [mm]	0.25, 0.3	0.47, 0.47	0.25, 0.25	0.25, 0.25
$L_{b\times} /N^* \eta$ [a.u.]	7.24	10.3	10.6	14.26
E_{surf}^{max} [MV/m]	376	379	321	331
ΔT^{max} [K]	37.4	38	39.9	40
$<a>/\lambda$	0.17	0.115	0.195	0.155
$L_{b\times}$ [m^{-2}]	0.78×10^{34}	1.9×10^{34}	1.01×10^{34}	1.85×10^{34}
N	2.22×10^{9}	3.82×10^{9}	2.55×10^{9}	3.78×10^{9}
N_c, l [mm]	76, 106	39, 102	107, 149	81, 169
N_s	6	5	6	5
N_b	64	88	79	76
τ_p [ns]	18.1	43.5	20.9	30.0
P_{in} [MW]	99	96	106	116
η [%]	20.5	20.7	26.9	29.1

Parameters of structure 4



$\langle E_{acc} \rangle$ = 120 MV/m

f = 20 GHz

N.B. Parameters are slightly different from the table because of interpolation.

Main linac parameter list

For $L_1 = 3.3\times10^{34} cm^{-2}s^{-1}$

<E_{acc}> [MV/m]	150	150	120	120
f [GHz]	30	16	30	20
f_{rep} [Hz]	657	197	415	234
L_{tot} [$cm^{-2}s^{-1}$]	5.5×10^{34}	7.4×10^{34}	5.8×10^{34}	7.4×10^{34}
P_b [MW/beam]	22.4	15.9	20.1	16.1
P_l [MW/linac]	109.4	76.8	74.7	55.6

Conclusions

- Optimum frequency is in the region of 16-20 GHz
- Optimum gradient is in the region of 100 MV/m or lower
- Reduction of frequency from 30 to 16 GHz at fixed gradient of 150 MV/m increases luminosity per power by ~50%
- Reduction of gradient from 150 to 120 MV/m at fixed frequency of 30 GHz increases luminosity per power by ~50%
- Reduction of gradient from 150 to 120 MV/m and taking frequency of 20 GHz which is the optimum one at this gradient increases luminosity per power by factor 2