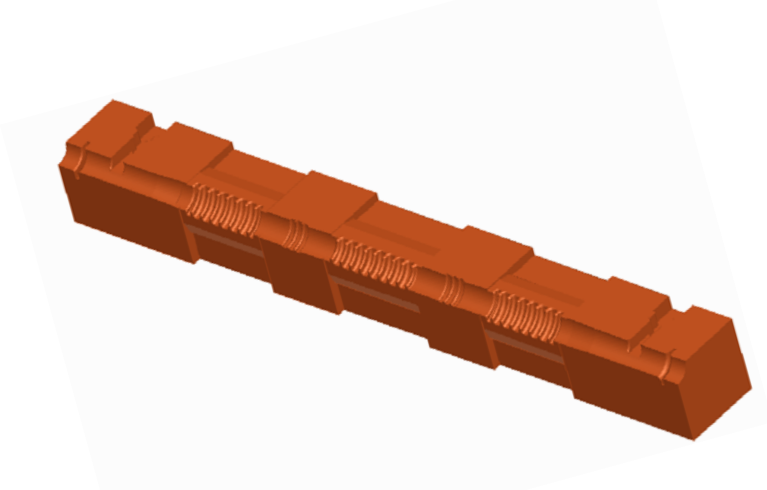
Status of PETS

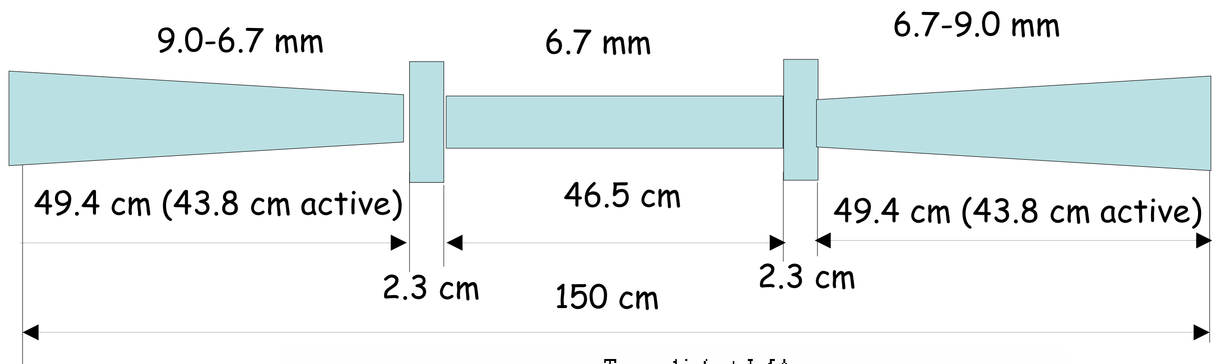
New PETS for CTF3

Motivations (not in order):

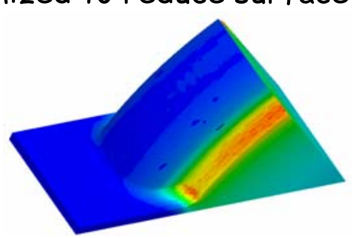
- We need a spare CTF3 PETS in a case if the existing one will show significant degradation
- We have changed the waveguide standard to increase the RF power transfer efficiency
- The CLIC PETS technology is need to be tested now, including HOM damping features
- We need to produce more power!

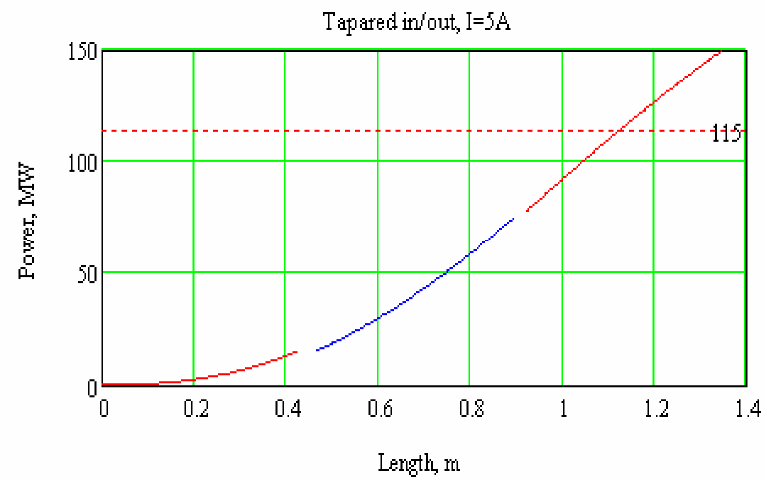
The tapering of input and output section increases the overall impedance. 150 MW rf power can be produced with 5A drive beam. Simulated beam losses are close to what we have now. The new design fits into the present layout.





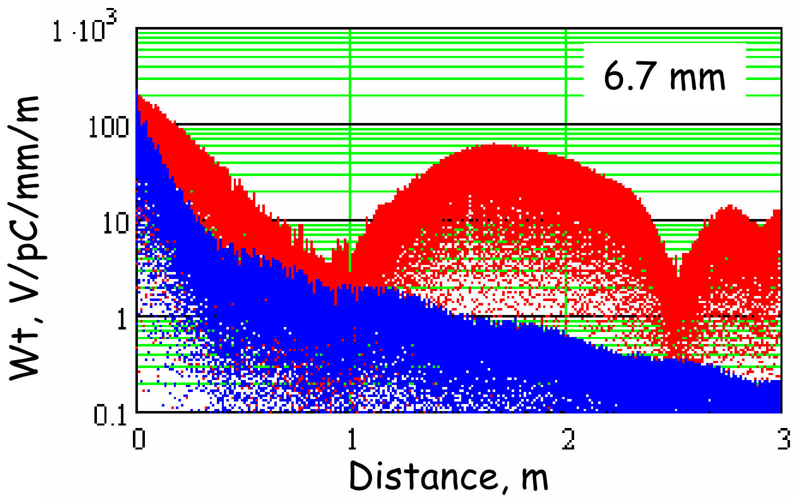
The new CTF3 PETS design follows CLIC technology. Each section consists of 4 identical racks separated with damping slots. The output coupler is integrated into the same piece and have a square waveguide output. The iris shape was optimized to reduce surface electric field.

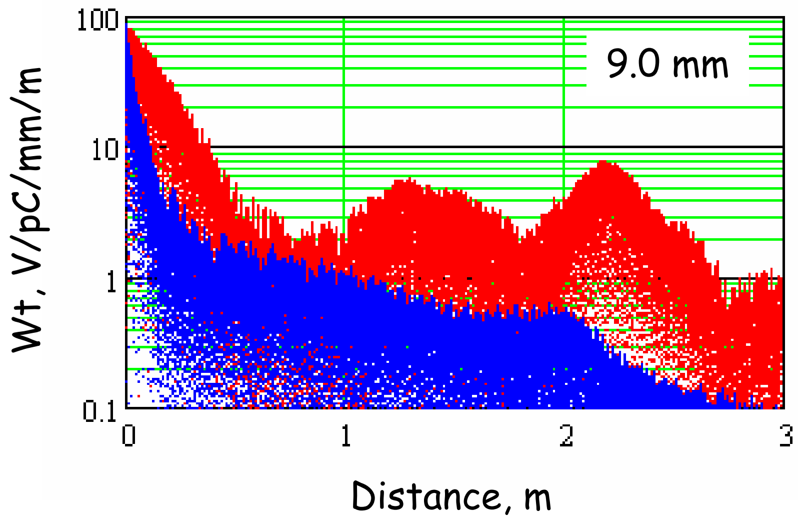




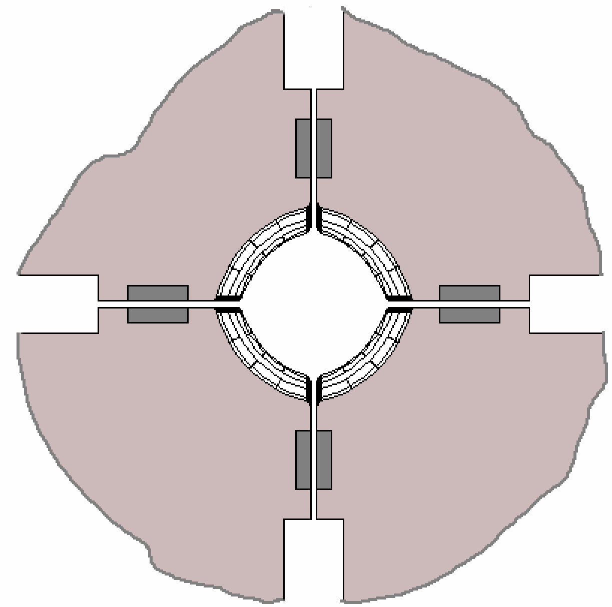
New PETS for CTF3 (continued)

Transverse wake envelopes with (blue) and without (red) damping material





HOM damping configuration



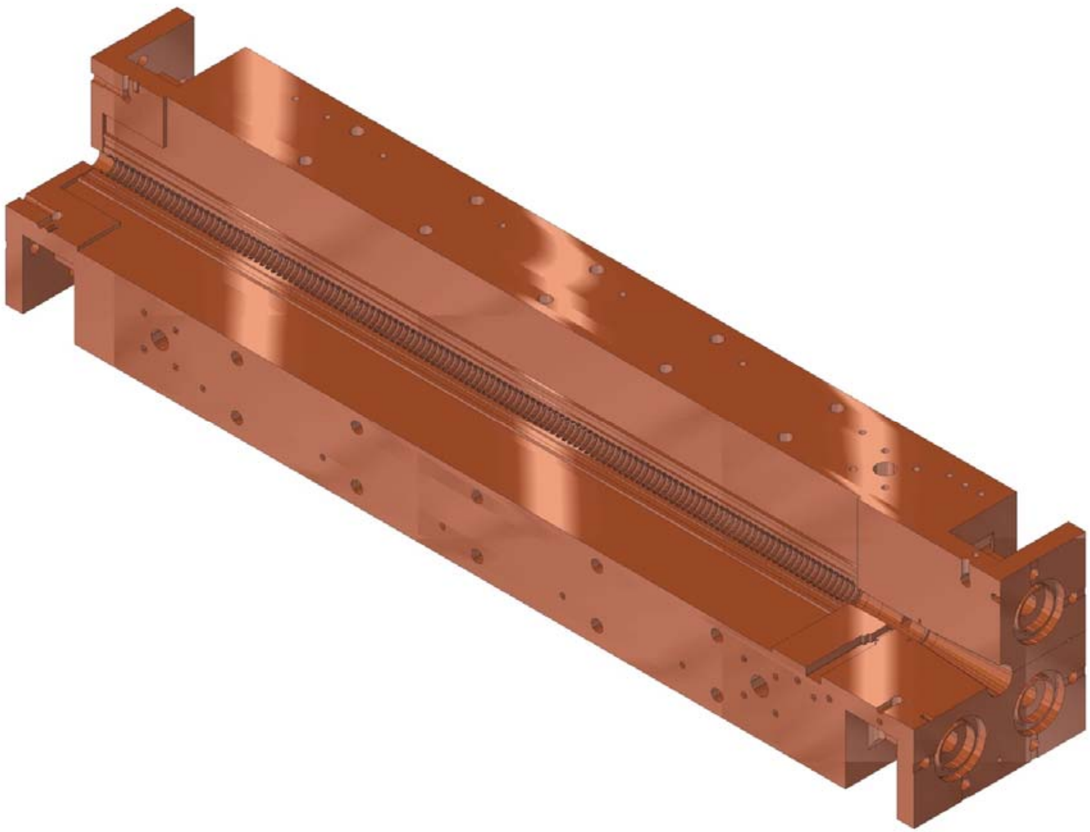
The strong HOM damping (loaded Q-factor 70-30 depending on aperture) practically cancel HOM effect on the beam losses. Confirmed with PLACET. The additional detuning via tapering will certainly help.

New PETS for CTF3 (continued)

Present status:

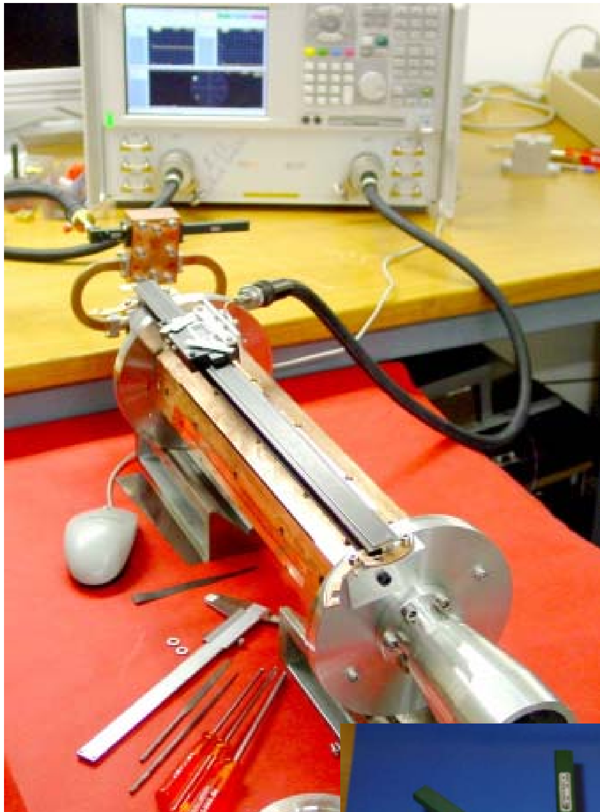
• The technical design of the CTF3 PETS is finished. Note, for the first time the CATIA files were checked with HFSS to verify RF performance. The order will be placed next month.

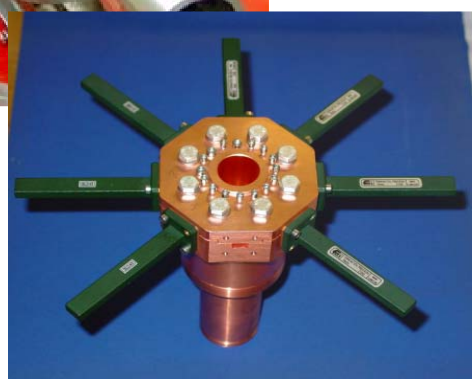
• The vacuum tank and waveguide components (overall layout) design is under way.

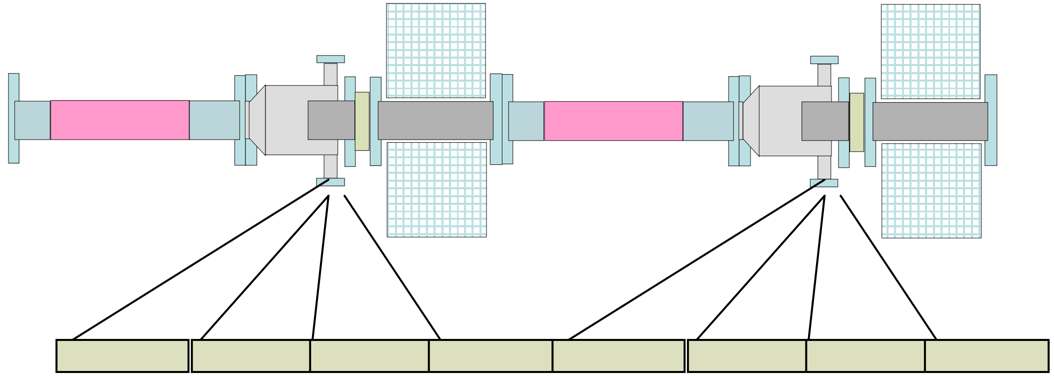


CLIC PETS 2005.

CLIC unit layout in 2005.







Length of PETS (active/overall)	L_{PETS}	0.8	0.6 / 0.8	0.6 / 0.77	m
Nominal output RF Power / PETS	P_{out}	512	556	642	MW
Transfer efficiency PETS > HDS			95	94	%
Number of accelerating structures / PETS		2	4	4	

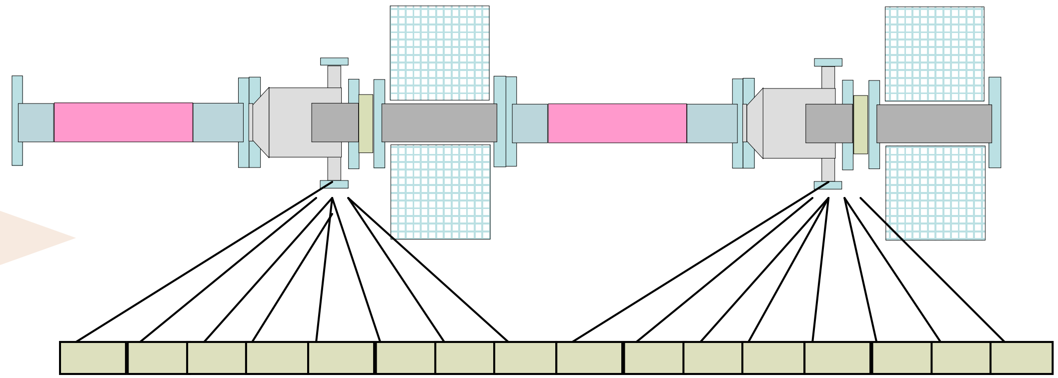
Aperture, mm	22.5
Drive beam current, A	180
Unite length, m	2.06

CLIC PETS 2006.

HDS evaluation, 30 GHz, 150 MV/m

	2005	2006
a/λ (first cell)	0.194	0.21
Power, MW	150	85
Length, mm	243	96
Pulse length, ns	58.4	14.7

Direct scaling of the CLIC unit layout.



PETS parameters direct scaling

	2005	2006
a/λ	1.125	1.125
HDS/PETS	4	8
Power, MW	642	723
Unite length, m	2.06	1.55
Active length, mm	600	345
Total length, mm	770	515
Drive beam, A	180	332
$a_{HDS}/\lambda \times N_{HDS}$	0.776	1.66

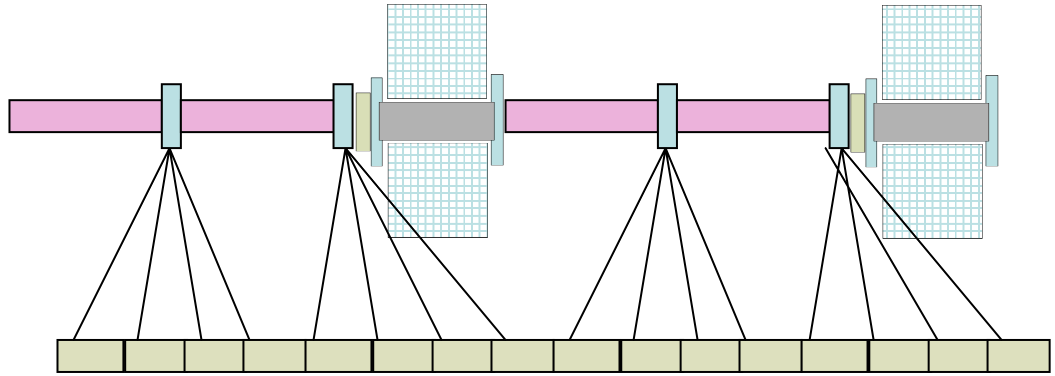
The CLIC unit length is defined by the length of the single HDS and unit layout. With a new HDS, direct application of the PETS developed in a past is not possible. The PETS design and unit layout must be revised.

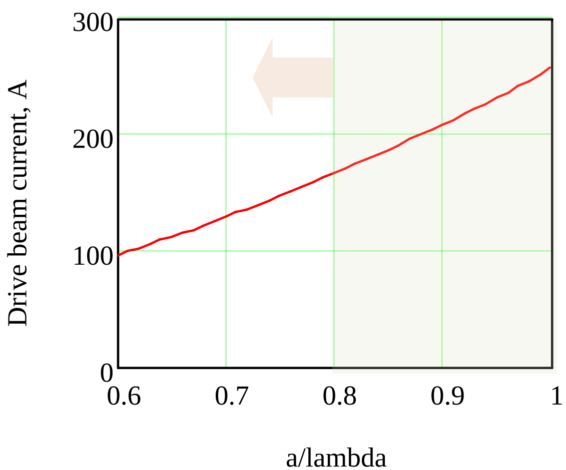
CLIC PETS 2006 layout

PETS evaluation, 30 GHz, 150 MV/m

	2005	2006
a/λ	1.125	< 0.8
HDS/PETS	4	4
Power, MW	642	360
Unite length, m	2.06	1.55
Active length, mm	600	245
Total length, mm	770	270
Drive beam, A	180	< 170
$a_{HDS}/\lambda \times N_{HDS}$	0.776	0.84

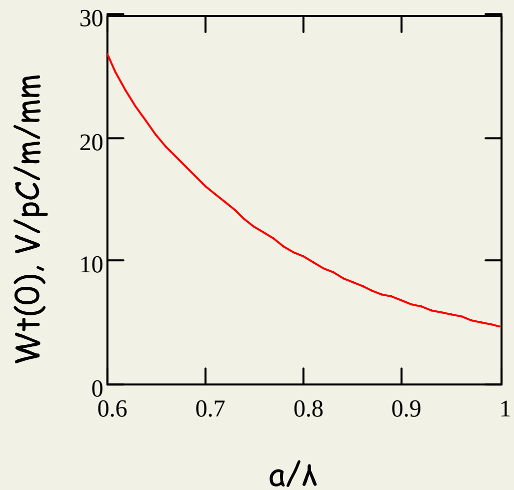
The new CLIC unit layout

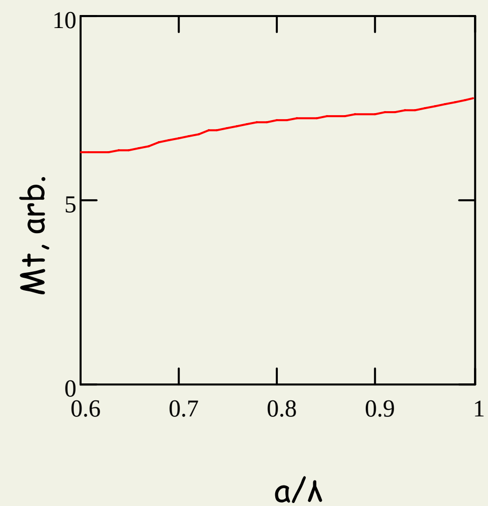




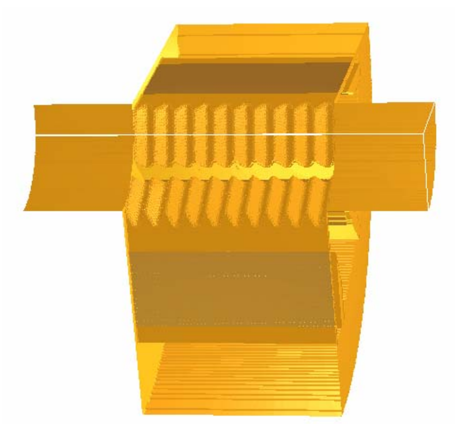
In general for the given beam power and structure length the merit factor for the short range transverse wake can be expressed as:

$$M_T = W_T(0) \times I^2$$





CLIC PETS 2006 HOM damping.

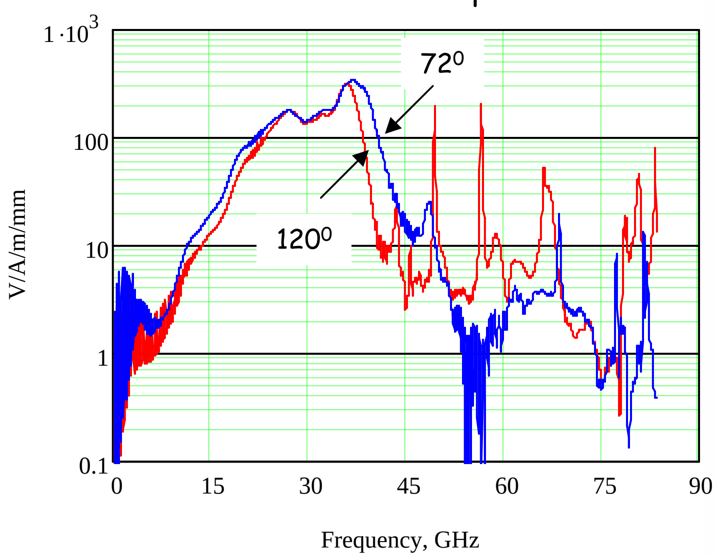


The structure with 16 mm aperture was next optimised for the HOM damping. The damping technique using damping slots and broadband loads is similar to the original design. To make simulations in more realistic environment, the external vacuum chamber was introduced connected to the PETS central part through the vacuum pumping slots.

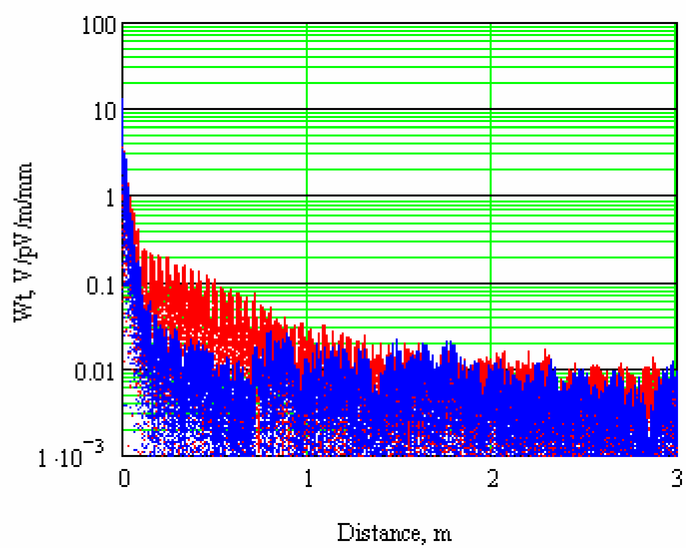
To improve the damping performance, the phase advance per cell was used for the first time as a parameter for optimization. As a criteria for optimization, the transverse wake impedance integral at a position of the bunches centers (spaced by 20 mm) was used. This parameter have a minimum for the structure with 72 degrees phase advance. In this case the HOM spectrum is tuned in a best way so that the wake zero-crossing are most close to the bunches centers.

Reducing the phase advance also favor the surface electric field amplitude.

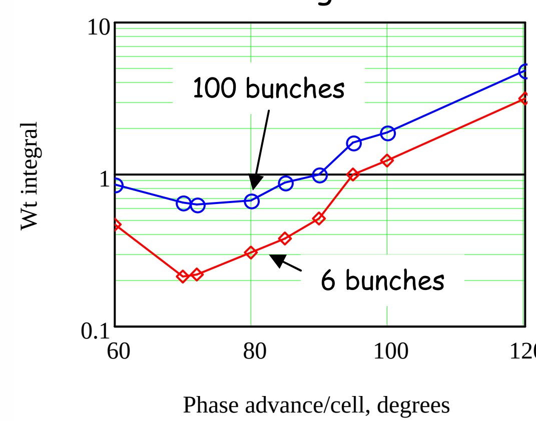
Transverse impedance



Transverse wake

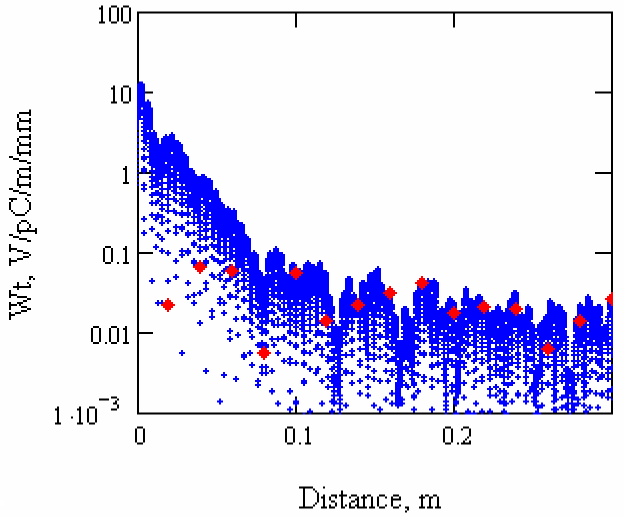


Transverse wake integral

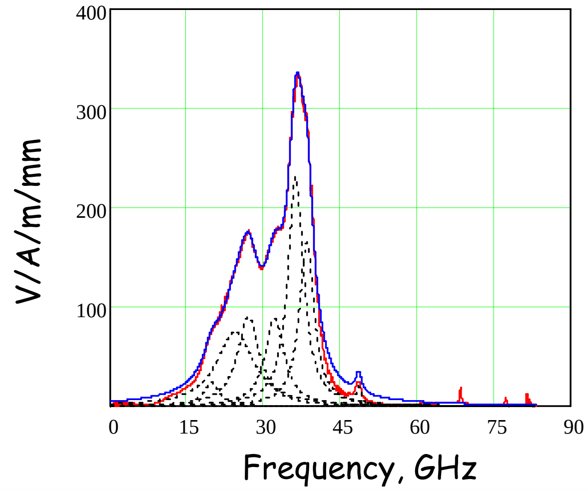


CLIC PETS 2006 HOM damping. 72 degrees/cell

Transverse wake

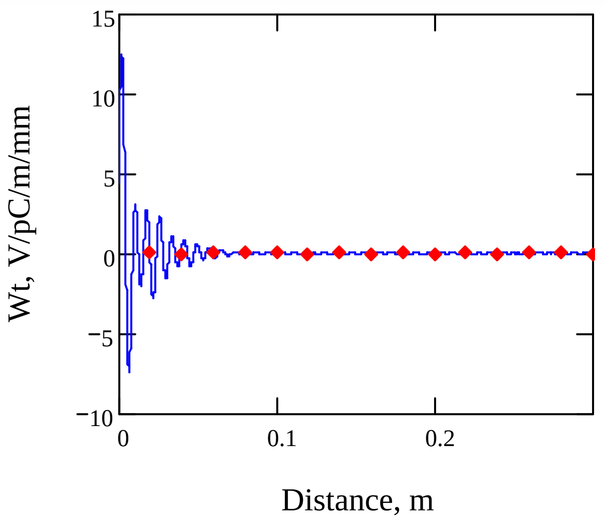


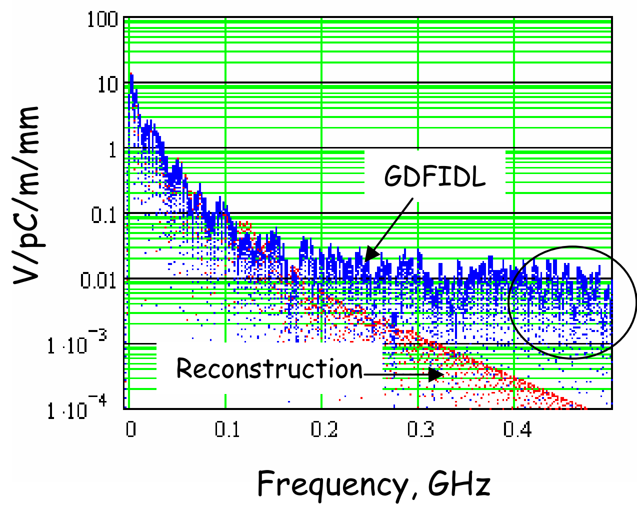
Transverse impedance



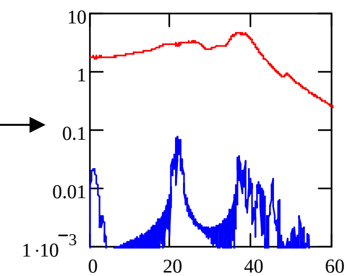
Transverse impedance representation for PLACET

	Wt	Q	F, GHz
M1	0.559	5.4	20
2	4.14	2.8	24.6
3	2.958	5.2	27.2
4	2.551	7	32.3
5	5.321	9.9	36.45
6	3.638	11	38.6
7	0.175	35	48.75



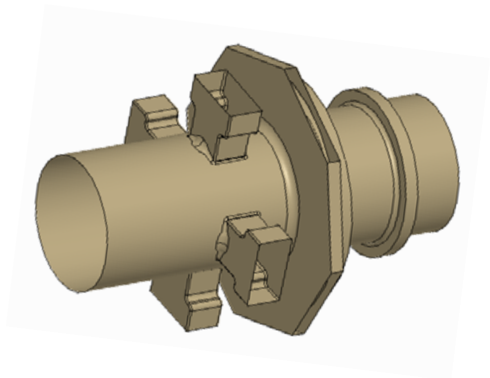


The residual wake is represented by the trapped chamber modes:

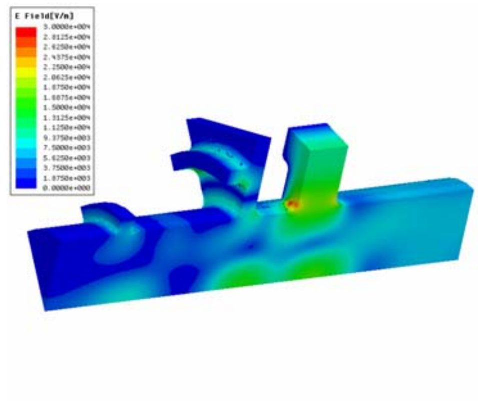


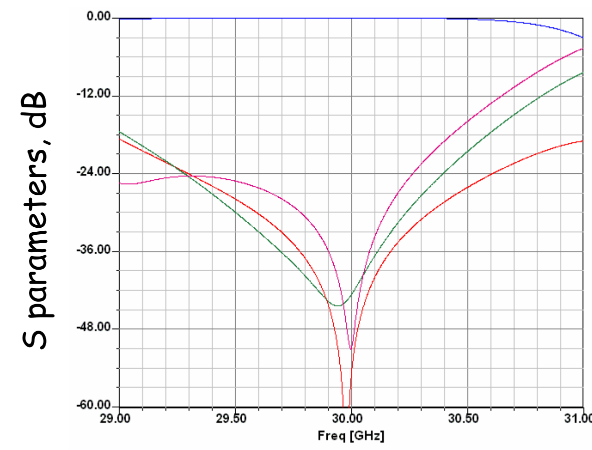
CLIC PETS 2006 extractor

The new compact "single mode" 16 mm diameter power extractor with radial HOM damping. By D. Carillo.

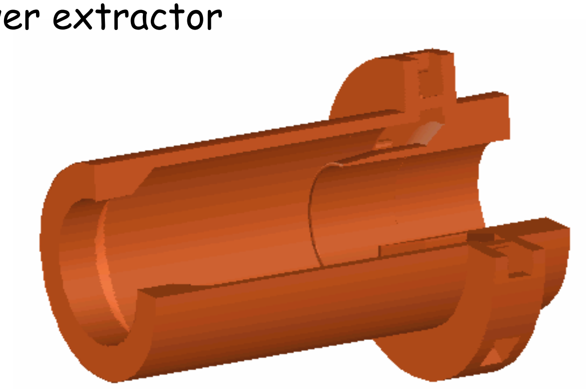


Extraction length ~ 15 mm





The old quasi-optical 22.5 mm diameter power extractor



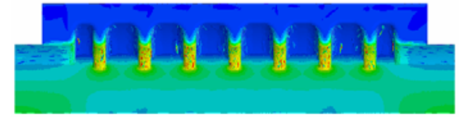
Extraction length ~ 60 mm

The term "single moded" here referred to the fact that the second symmetrical mode TM_{02} has cut-off frequency higher than a/λ=0.8 -> 0.879. However the circuit remains very overmoded – 7 other modes with different symmetry can be excited here. With the proper choice of the output waveguide number, the "simple", choke based technology can be used similar to CTF3 power production PETS, resulting in a very compact device.

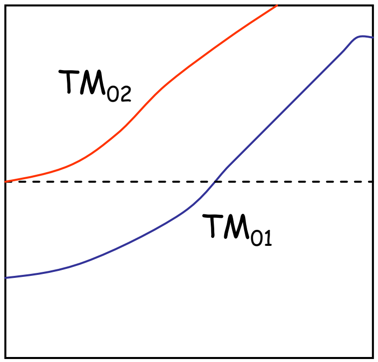
The choice of a bigger diameter (a/λ>0.8) unavoidably leads to the quasi-optical configuration.

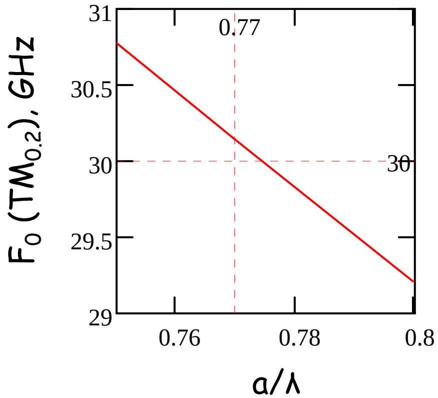
CLIC PETS 2006 matching section

9 mm CTF3 PETS,
one matching cell

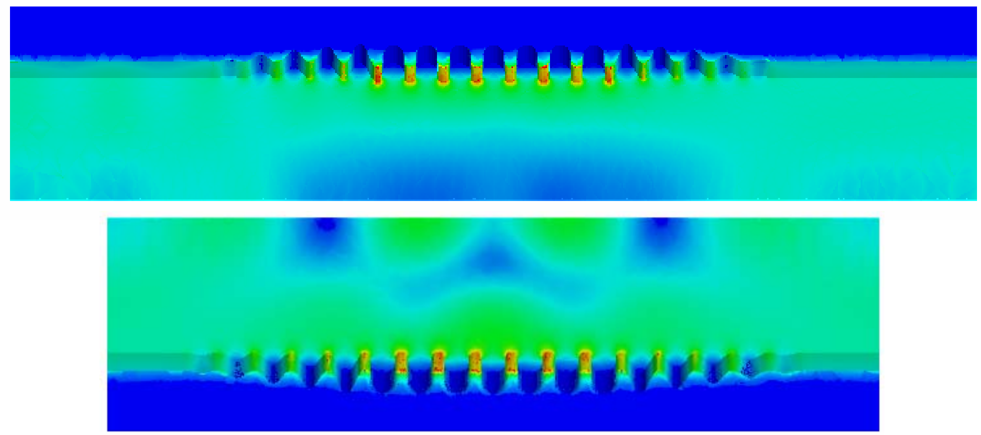


Dispersion curves for the structure
with aperture close to a/λ = 0.8

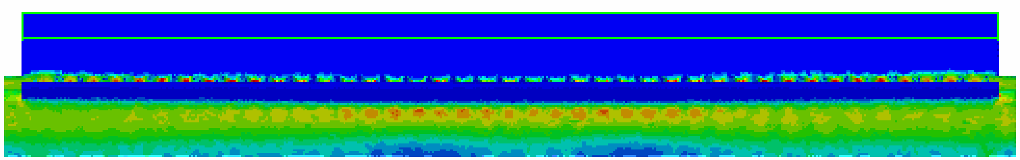




PETS 2006 a/λ = 0.77, 5 matching cells,
Matching length ~ 10 mm

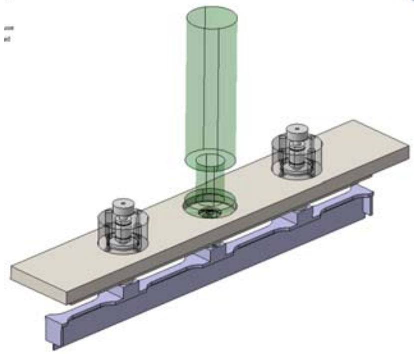


a/λ = 0.8

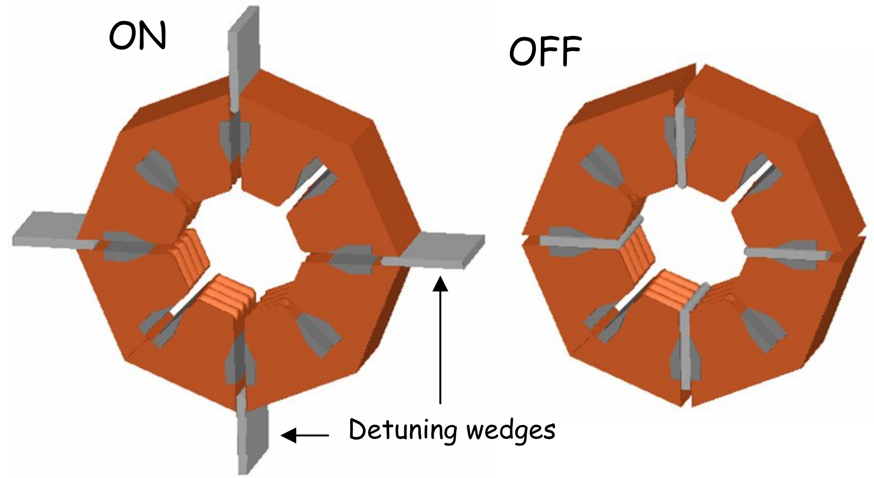


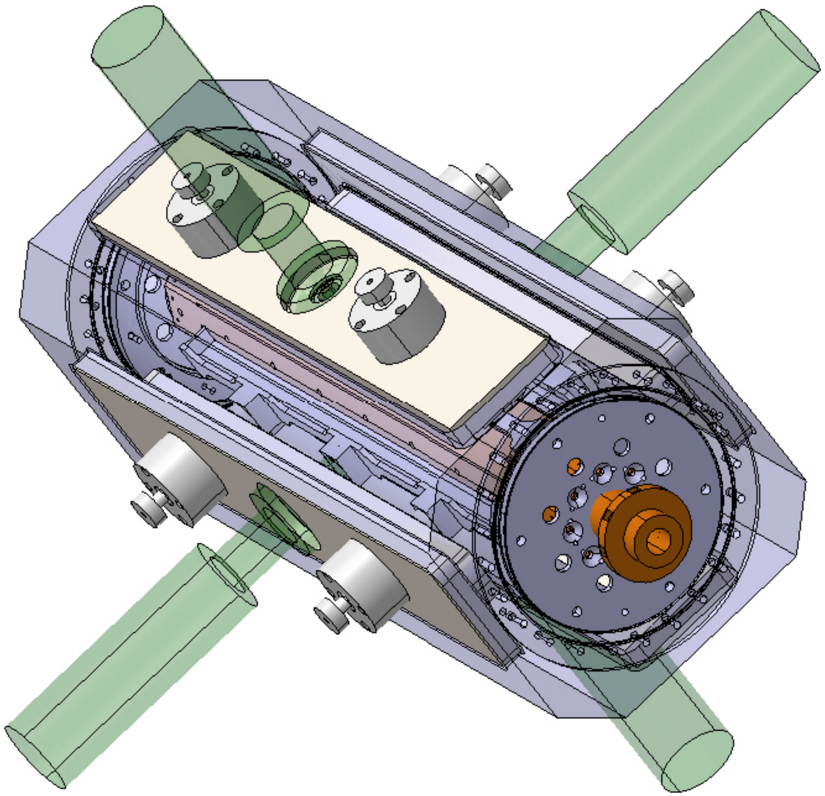
PETS 2005, 15 matching cells,
Matching length ~ 60 mm

CLIC PETS 2006 On/Off mechanism



The ON/OFF mechanical design was done in TS, CERN. It allows fast – 50 ms linear movement of the detuning wedge. The mechanical prototype fabrication and the first tests are planned for this year.



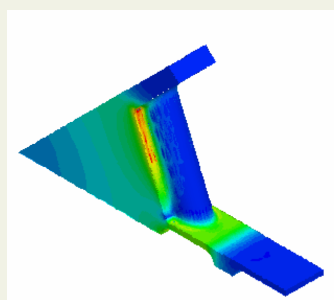


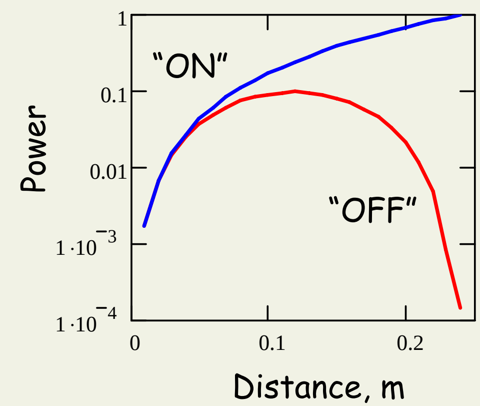
If we need to avoid power build-up at the end of the structure, then the detuning should be introduced:

$$F_D = F_0 \pm \frac{\beta \times C}{(1-\beta) \times L}$$

Where F_D is a new detuned synchronous frequency, L – length of the structure and β - group velocity. In our case for the full deployment of the wedges:

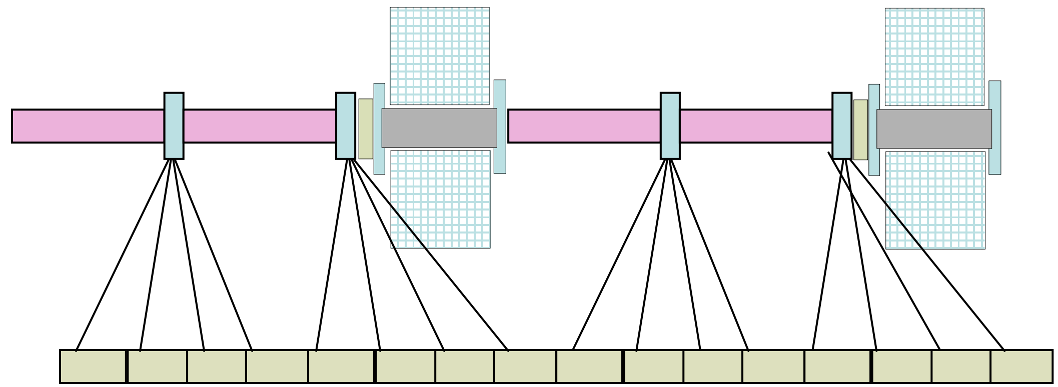
F_D= 34.52 GHz
Beta/C = 0.782
L = 0.245 m





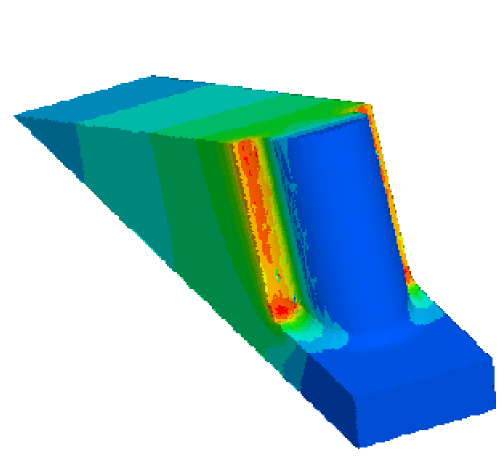
CLIC PETS 2006 Parameters

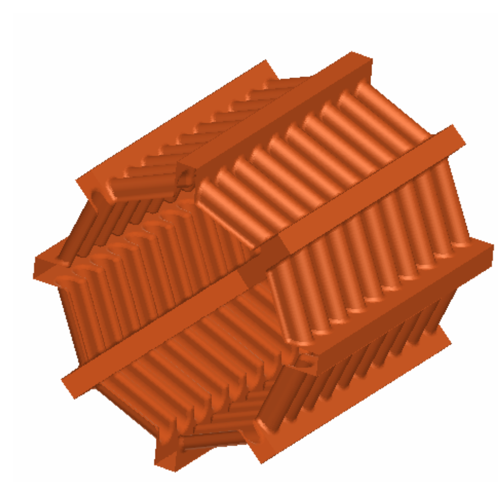
The CLIC unit layout



PETS 2006,
30 GHz, 150 MV/m

a/λ	0.77
2a, mm	15.4
φ/cell degrees	72
Cell length, mm	2
Iris thickness	0.7
R/Q, Ohm	1300
Vg/C	0.728
Q-factor	7500
PETS/Quad.	2
HDS/PETS	4
Power, MW	360
E max, MV/m	122
Unite length, m	1.55
Active length, mm	246
Extraction length, mm	25
N cells	123
Total length, mm	270
Drive beam, A	151
$a_{HDS}/\lambda \times N_{HDS}$	0.84





PETS in CLEX

Two Beam Test Stand

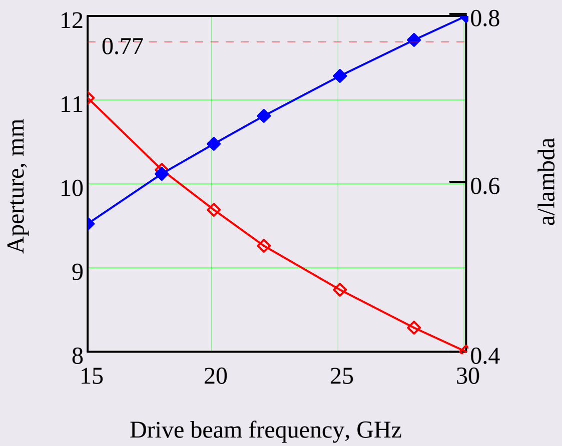
To produce 360 MW from 35A drive beam, the new CLIC PETS design can be used directly. The only modification is a structure length:

$$L_{TBTS} = L_{CLIC} \times \frac{I_{CLIC}}{I_{CTF3}} = 1.06\ m$$

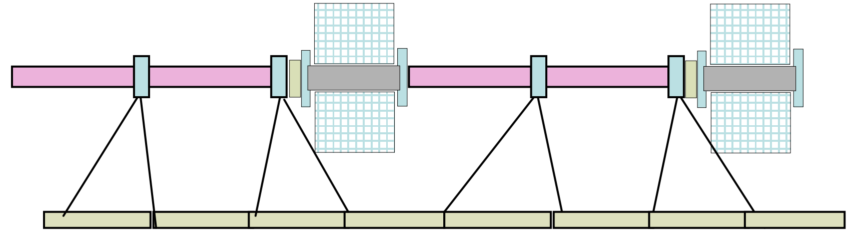
Test Beam Line

In a tests beam line single PETS should decelerate the drive beam by about 5 MeV, which corresponds to 165 MW produced power. The 72 cm long new CLIC PETS will do that.

Different frequencies. Assuming similar deceleration, current and TBL layout, the PETS aperture will be scaled as:



CLIC - other frequency and gradient (example)



Frequency 18 GHz, Accelerating gradient 100 MeV/m, 3 TeV					
Frequency, GHz	18			Drive beam energy, GeV	**1.57038674**
Gradient, MeV/m	100			Number of PETS/sector	1171.529359
HDS length (active), m	0.167	72	5	Number of HDS/sector	2343.058717
HDS length, m	0.178597222	(Ncells + extra cells)		Sector Length, m	418.4637784
HDS/PETS	2			Energy gain/sector, GeV	30.6122449
PETS/Quadrupole	2			Number of Sectors	49
Unite length, m	0.714388889			CLIC accelerator length, m	20504.72514
Quad+BPM, m	0.25			sing. Beam Energy, MW x sec	0.41657714
PETS length	0.232194444			Combination factor	32
Coupler length, m		0.05		Wt, V/pC/m/mm	9.265279576
PETS active length,m	0.182194444			MT	**0.190747046**
PETS aperture, mm	19	5.7		HDS apperture	6.06
PETS R/Q, Ohm/m	1694.251625			Power/circ. Norm. to HDS	**0.682689198**
PETS Vgroup, V/C	0.5331188			Pulse length, ns	43.6
PETS /OFF detuning, GHz	1.880198648			LF pulse lenght 1 ,Combination	136.7296
Power/ HDS, MW	70	100.3		LF pulse lenght 2, Linac	136.6981676
Power/ PETS, MW	**149.8311277**			Drive Linac fr., GHz	1.125
DB current, A	**124.1955673**	*Single complex: T=2 x 32 x Nsector x Pulse length*			
Electrons/bunch	31100000000			*Drive/main efficiency*	*0.180966243*
Bunch spacing, sec	2.77778E-10				
Beam current, A	1.79136			*Klystron-modulator efficiency*	*0.7*
N bunches	102			*DB accelerator efficiency*	*0.93*
T bunches, sec	2.80556E-08			*Wall plug to main efficiency*	*0.117809024*
Beam energy, MW x sec	0.0753864			Repetition rate, Hz	243
Beam power, MW	18.3188952			*Wall plug power, MW*	*310.9930724*