Evacuation of SR power from CLIC damping ring

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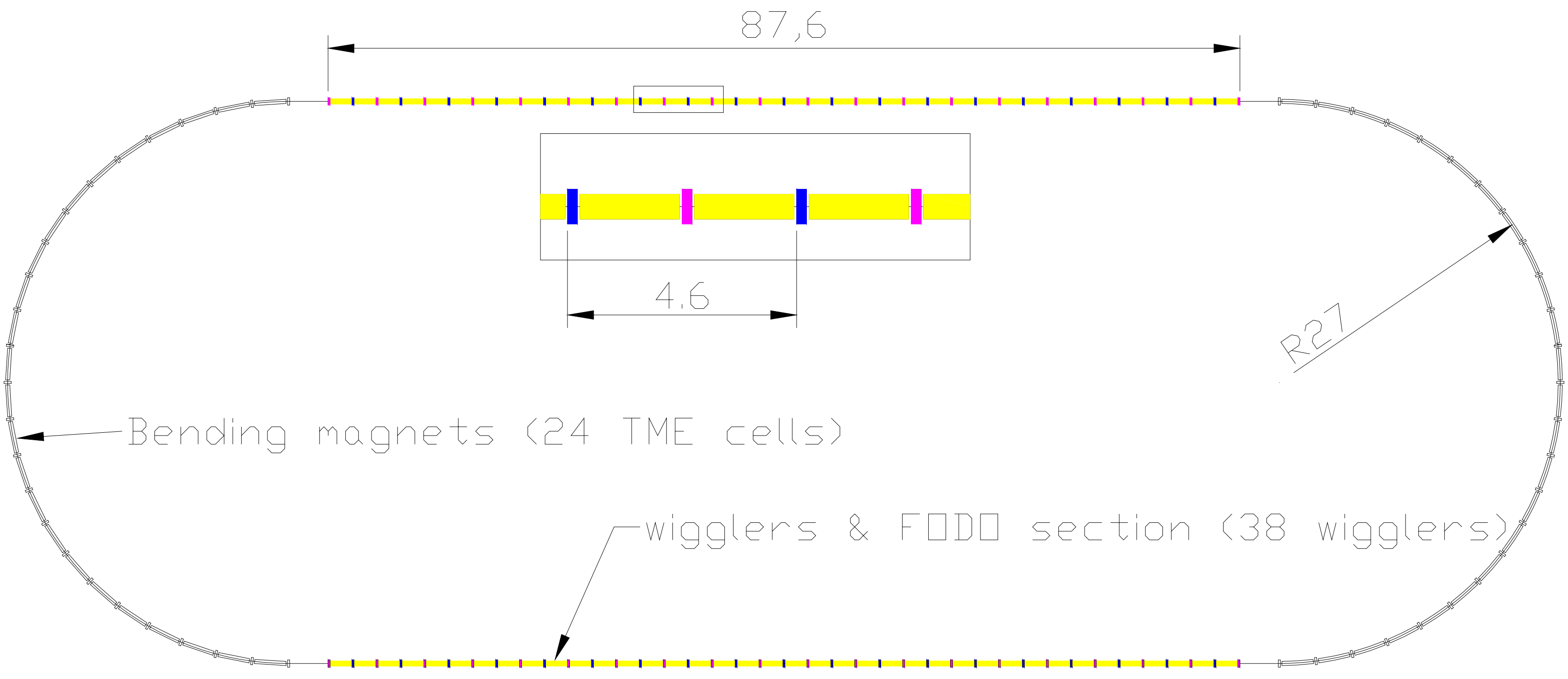
Problems Description

Layout of CLIC-DR



E = 2.424 GeV

Π = 360 m

M. Korostelev, F. Zimmermann, "Optimization of CLIC Damping Ring Design Parameters," EPAC 2002 Paris (2002).

Problems Description

Main Parameters of CLIC-DR

Parameter	*Symbol*	*CLIC-DR*
Electron energy	E_e	2.424 GeV
Maximal magnetic field in wiggler	B	1.7 T
Period of wiggler	λ	10 cm
Magnetic gap of wiggler	d	12.5 mm
Number of periods	N	20
Length of wiggler	L	2 m
Poles gap, (vacuum chamber vert. size)		12.5(8.5) mm
Number of wigglers in straight section	N_w	38
Current of beam (maximal)	I	1000 mA

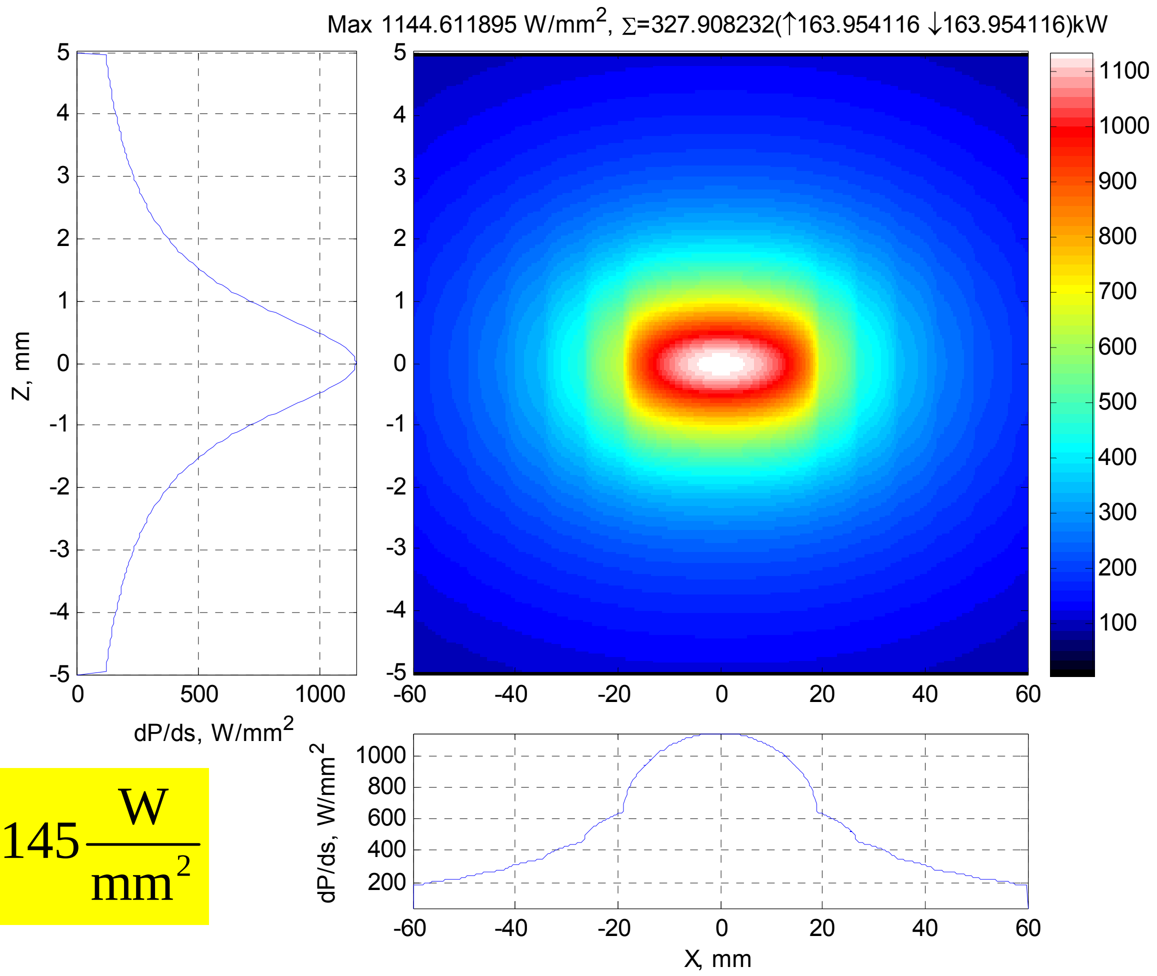
Problems Description

SR Parameters of CLIC-DR

Parameter	*Symbol, formula*	*CLIC-DR*
SR critical energy	$\varepsilon_c[\mathrm{keV}] = 0.655 \cdot E_e^2[\mathrm{GeV}] \cdot B[\mathrm{T}]$	6.541 keV
Deflection parameter K	$K = B[\mathrm{T}] \cdot \lambda[\mathrm{cm}]$	15.878
Relativistic factor	$\gamma = E_e / m_e c^2$	4743
Angular width of vertical divergence	$\theta_v = 1/\gamma$	210.8 μrad
Angular width of horizontal divergence	$\theta_h = 2K/\gamma$	6.695 mrad
Total power of radiation of one wiggler	$P_T[\mathrm{kW}] = 0.633 \cdot E_e^2[\mathrm{GeV}] \cdot B^2[\mathrm{T}] \cdot L[\mathrm{m}] \cdot I[\mathrm{A}]$	21.491 kW
Total power of radiation of all wigglers	$P_A[\mathrm{kW}] = P_T \cdot N$	**816.7 kW**

Problems Description

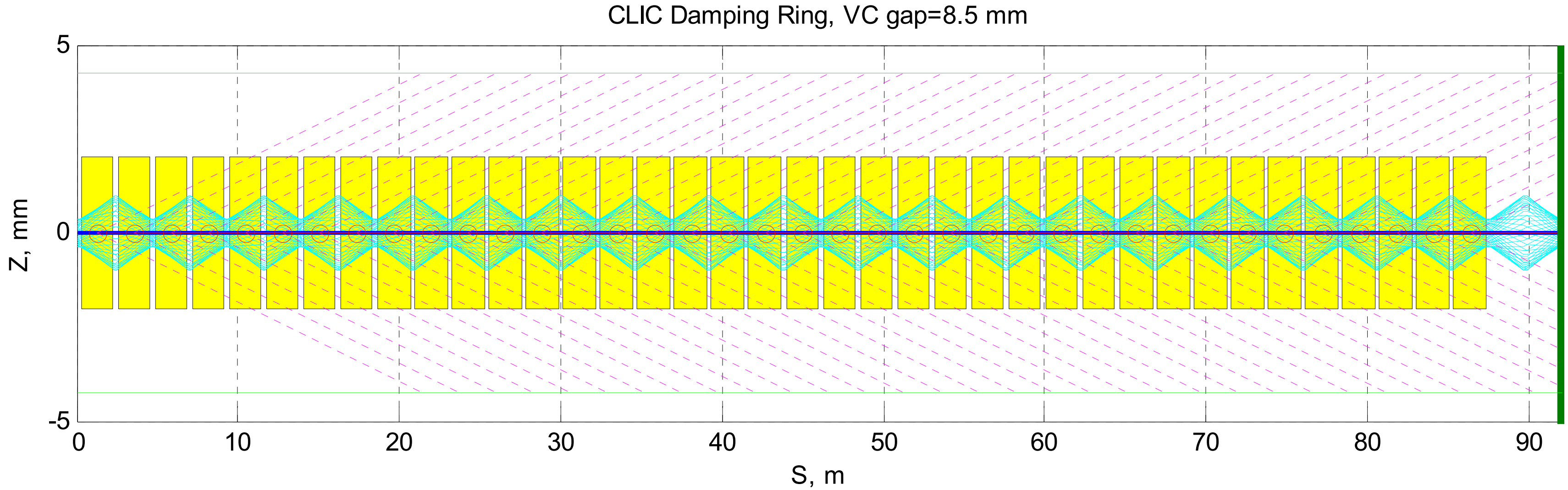
Power density at the end of straight section



$$\left(\frac{dP}{ds}\right)_{\max} = 1145 \frac{\text{W}}{\text{mm}^2}$$

Problems Description

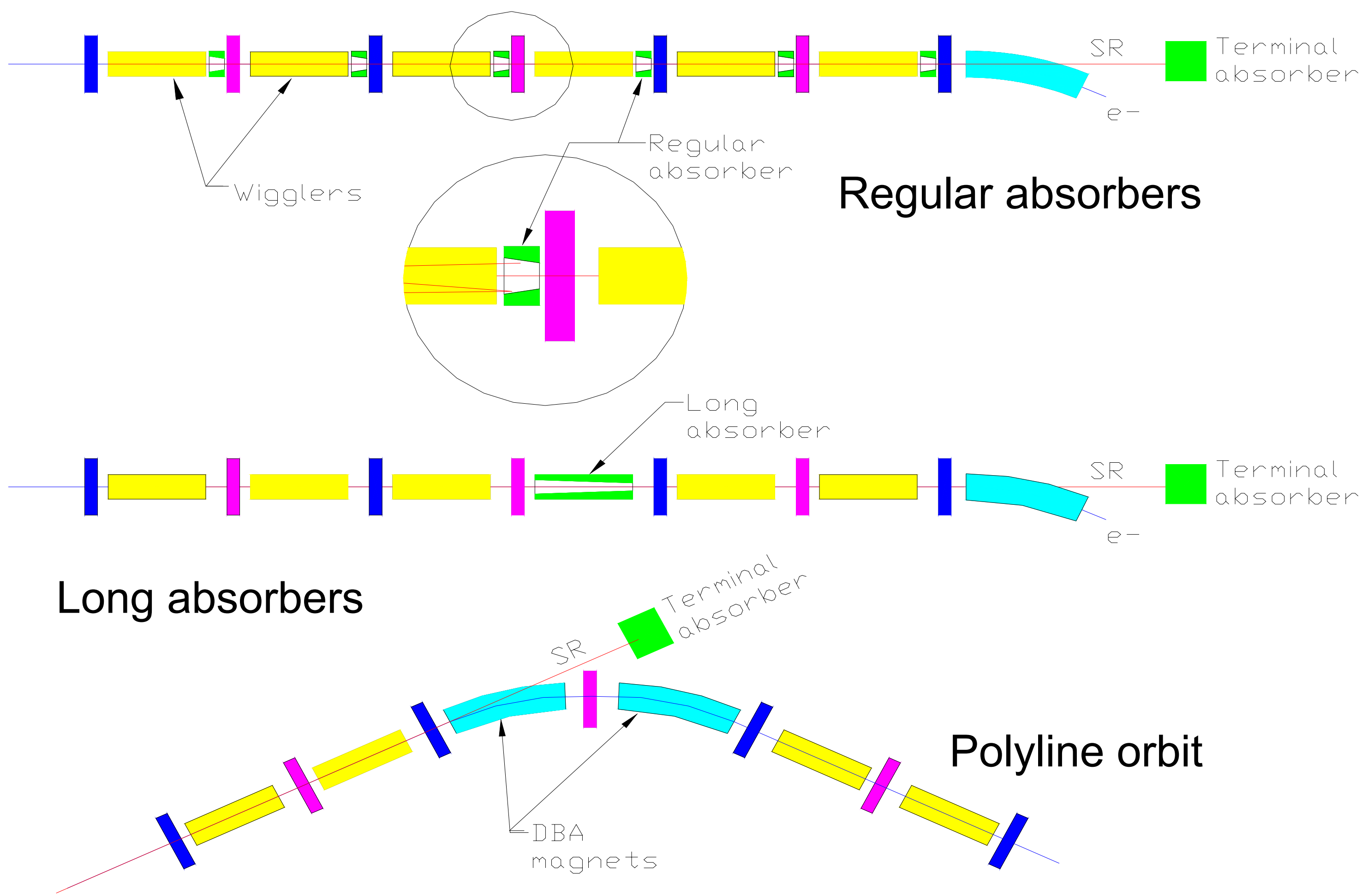
Power density at the end of straight section



Vacuum chamber overheating problems

- Mechanical instability (deformations and stresses, 0.5 mW/mm^2 is critical level for stainless steel *d*=3 mm)
- Influence to wiggler magnet (temperature gradients can create non zero wigglers integrals, 5^{o}C/m critical gradient for permanent magnet wigglers)
- Ions desorption from walls of vacuum chamber (radiational outgassing)

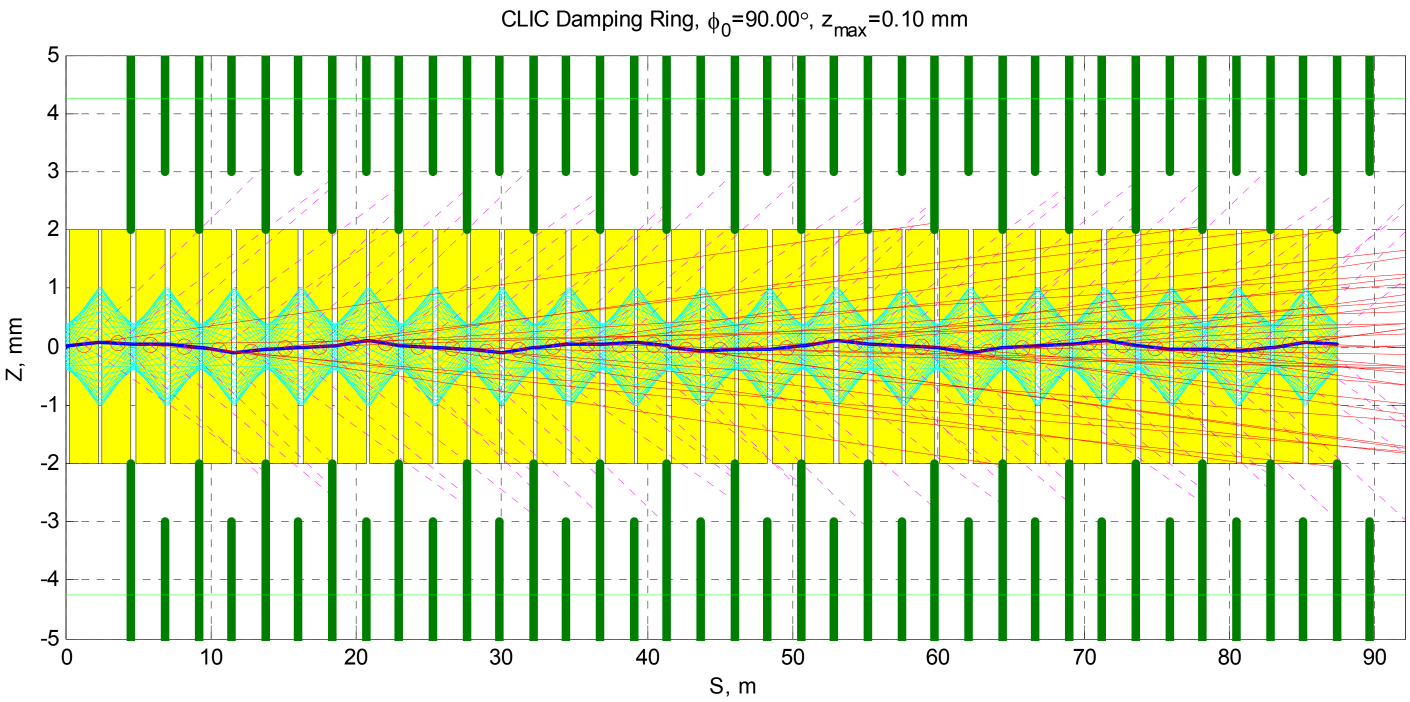
Possible solutions



Possible solutions

Way	Advantages	Disadvantages
Regular absorbers	Simplicity (not necessary modify of basis FODO structure)	Necessity of free space between wiggler and lens Big power in terminal absorber
Long absorbers		Reducing of dumping rate Big power in terminal absorber
Polyline orbit	Distributed absorption in terminal absorbers	Necessity for serious modification of ring structure

Regular absorbers (4-6 mm × 60 mm)



Methods for power calculations

$$P_T[\mathrm{kW}] = 0.633 \cdot E_e^2[\mathrm{GeV}] \cdot B^2[\mathrm{T}] \cdot L[\mathrm{m}] \cdot I[\mathrm{A}]$$

$$\frac{dP}{d\Omega} = \frac{d^2P}{d\theta\ d\psi} = P_T \frac{21\gamma^2}{16\pi K} G(K)\, f_K(\gamma\theta, \gamma\psi)$$

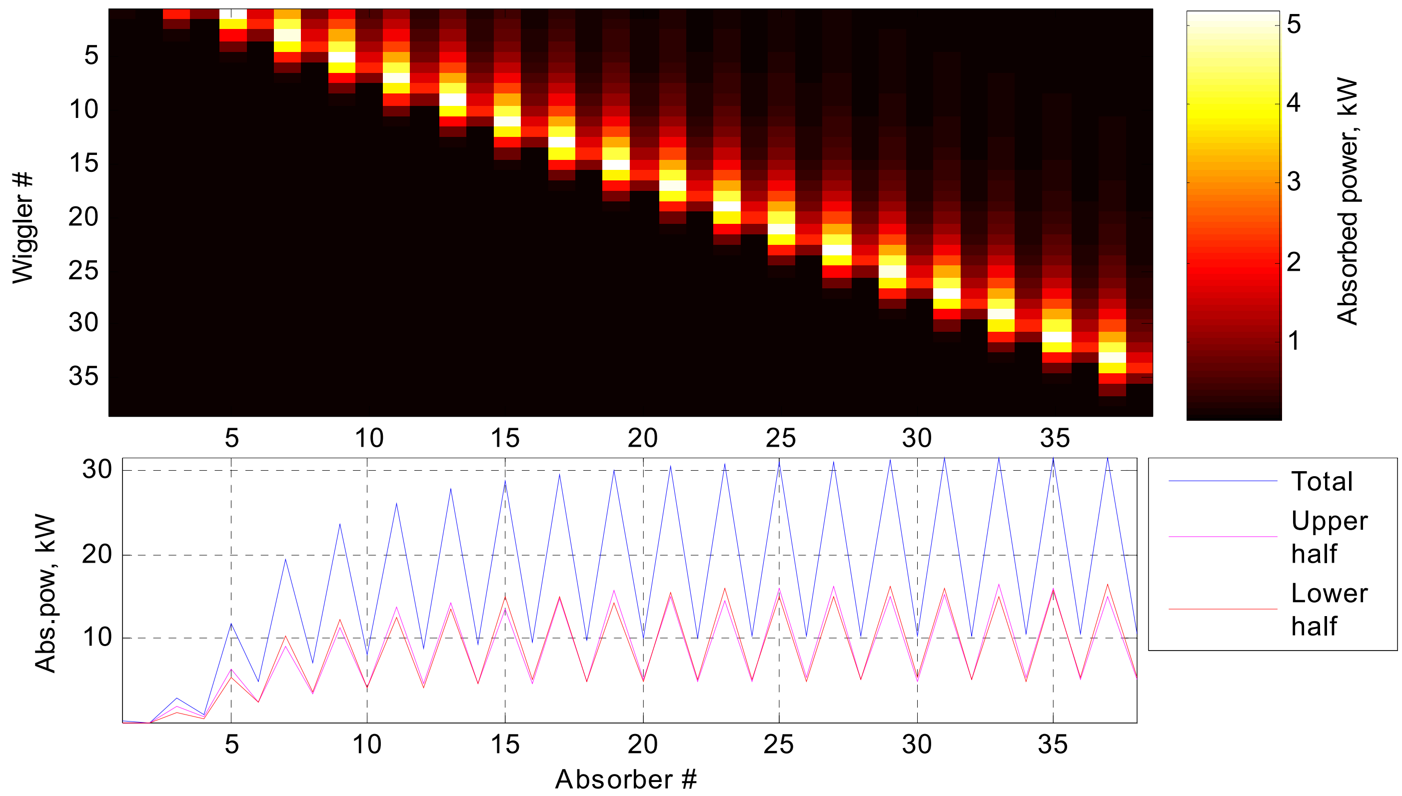
$$G(K) = K \frac{K^6 + \frac{24}{7}K^4 + 4K^2 + \frac{16}{7}}{\left(1+K^2\right)^{7/2}}$$

$$f_K(\gamma\theta,\gamma\psi) = \sqrt{1-\left(\gamma\theta/K\right)^2}\left\{\frac{1}{\left(1+(\gamma\psi)^2\right)^{5/2}} + \frac{5(\gamma\psi)^2}{7\left(1+(\gamma\psi)^2\right)^{7/2}}\right\}$$

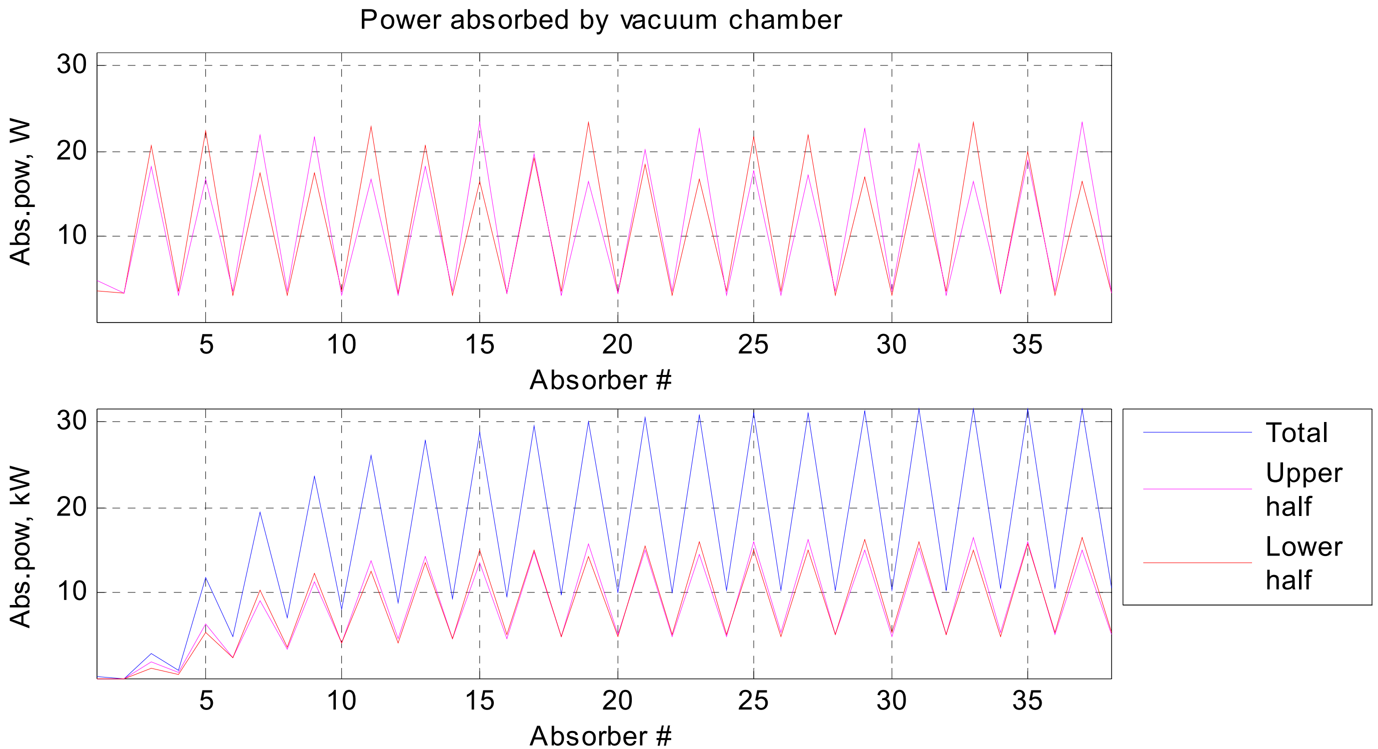
K.-J. Kim, Nucl. Instr. And Meth A246(1986)

Analysis of absorber configuration (4-6 mm × 60 mm)

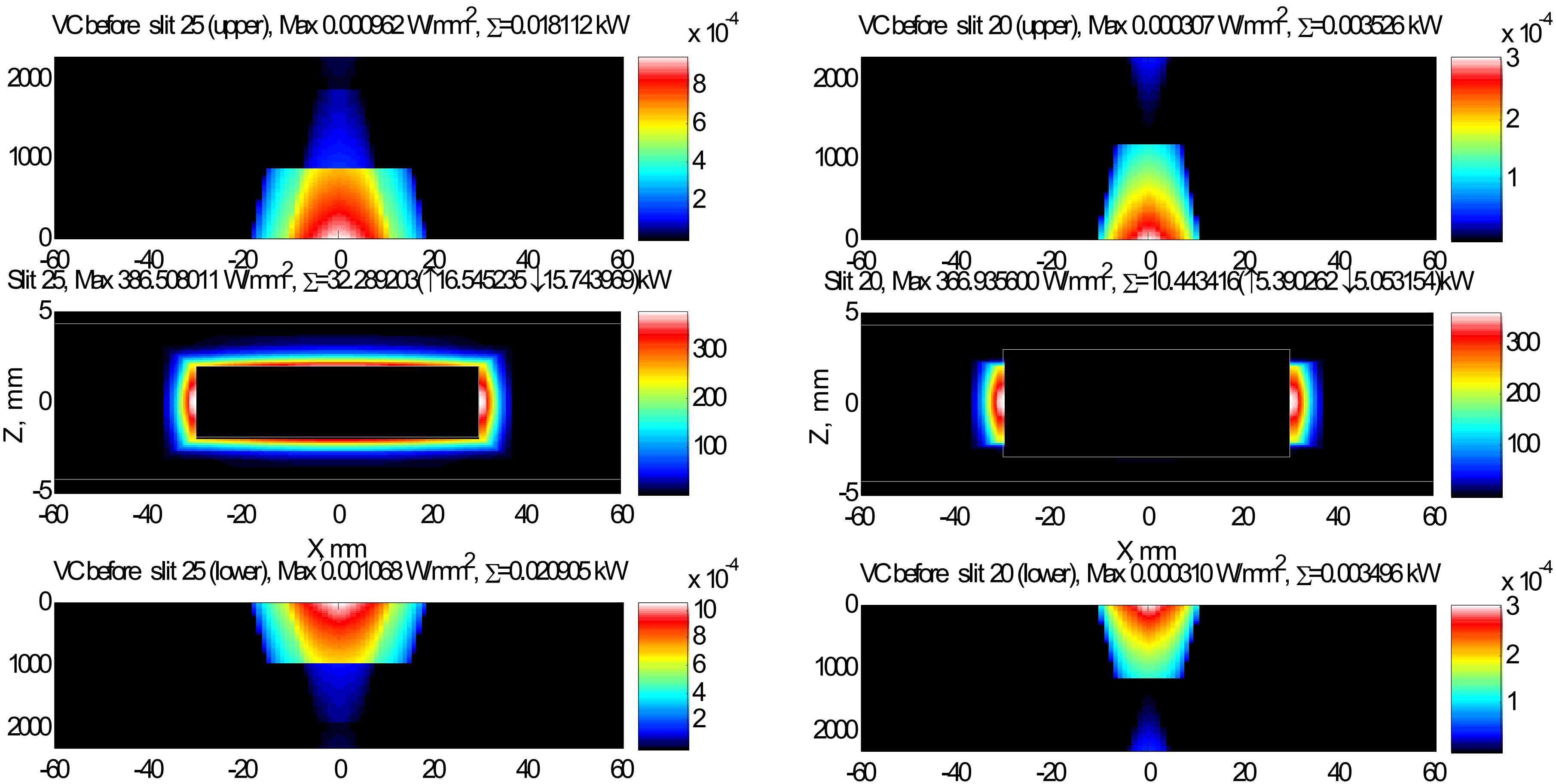
Total power 817 kW (38 wigglers), transmitted 173 kW, absorbed 644 kW



Vacuum chamber load (4-6 mm × 60 mm)

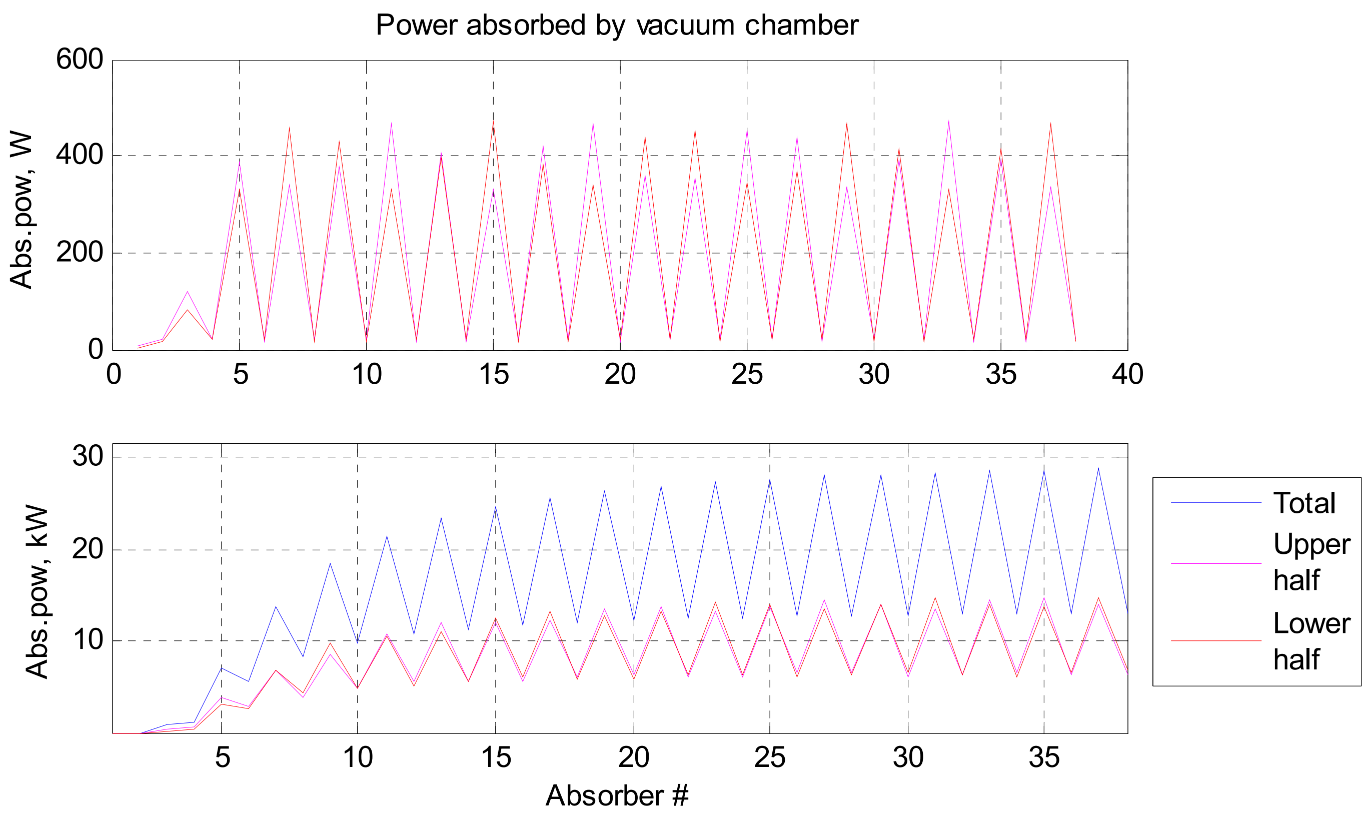


Power density analysis (4-6 mm × 60 mm)

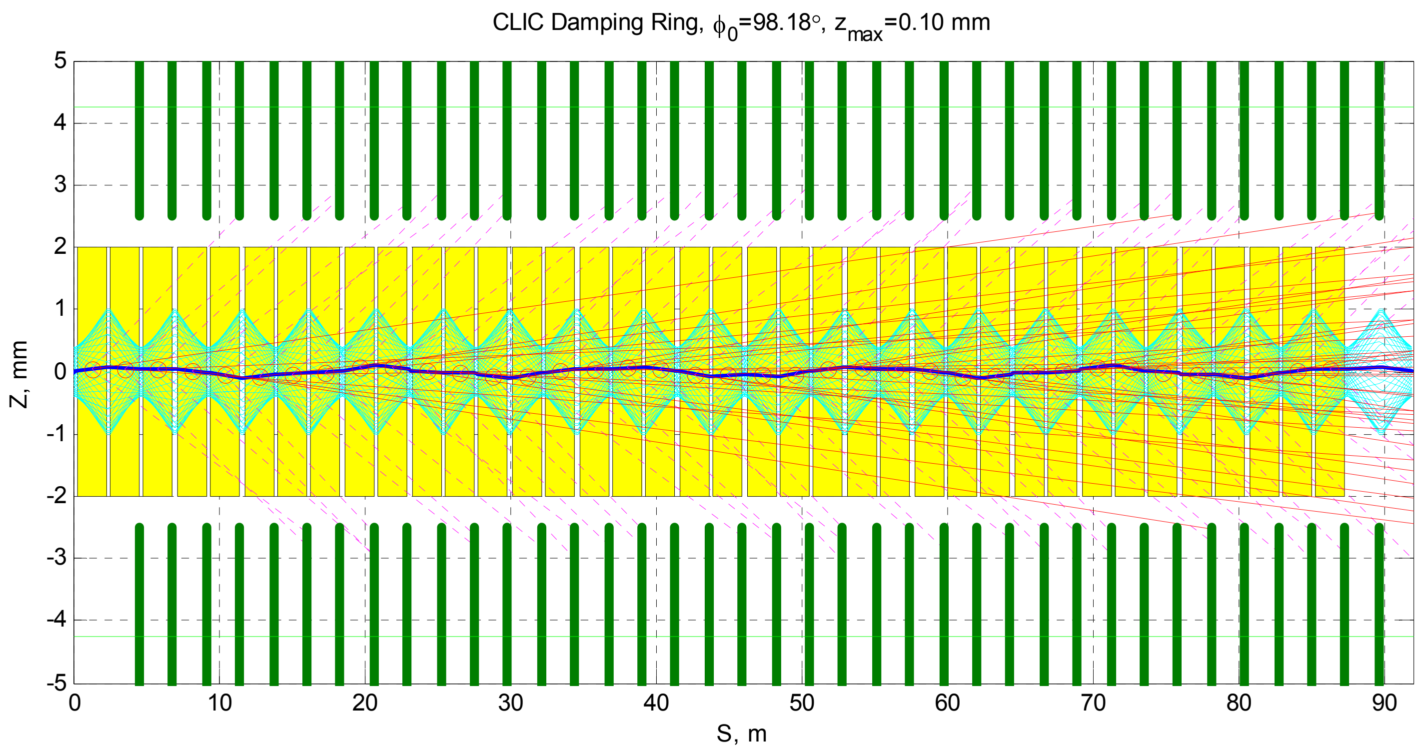


Vacuum chamber load (6-8 mm × 60 mm)

Increasing of absorbers gaps to 2 mm provides 20-fold increasing of heat load on vacuum chamber

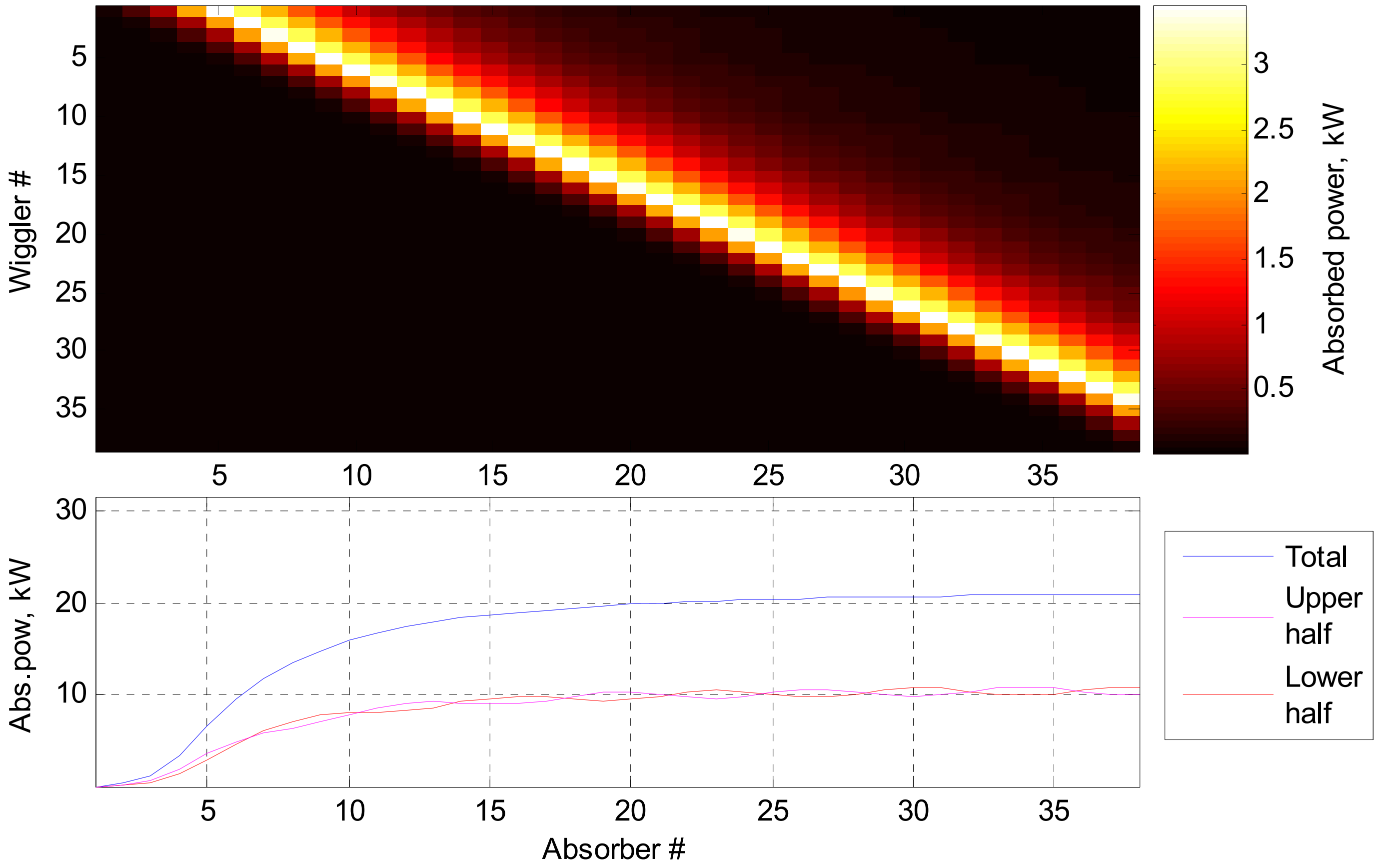


Regular absorbers (5-5 mm × 60 mm)

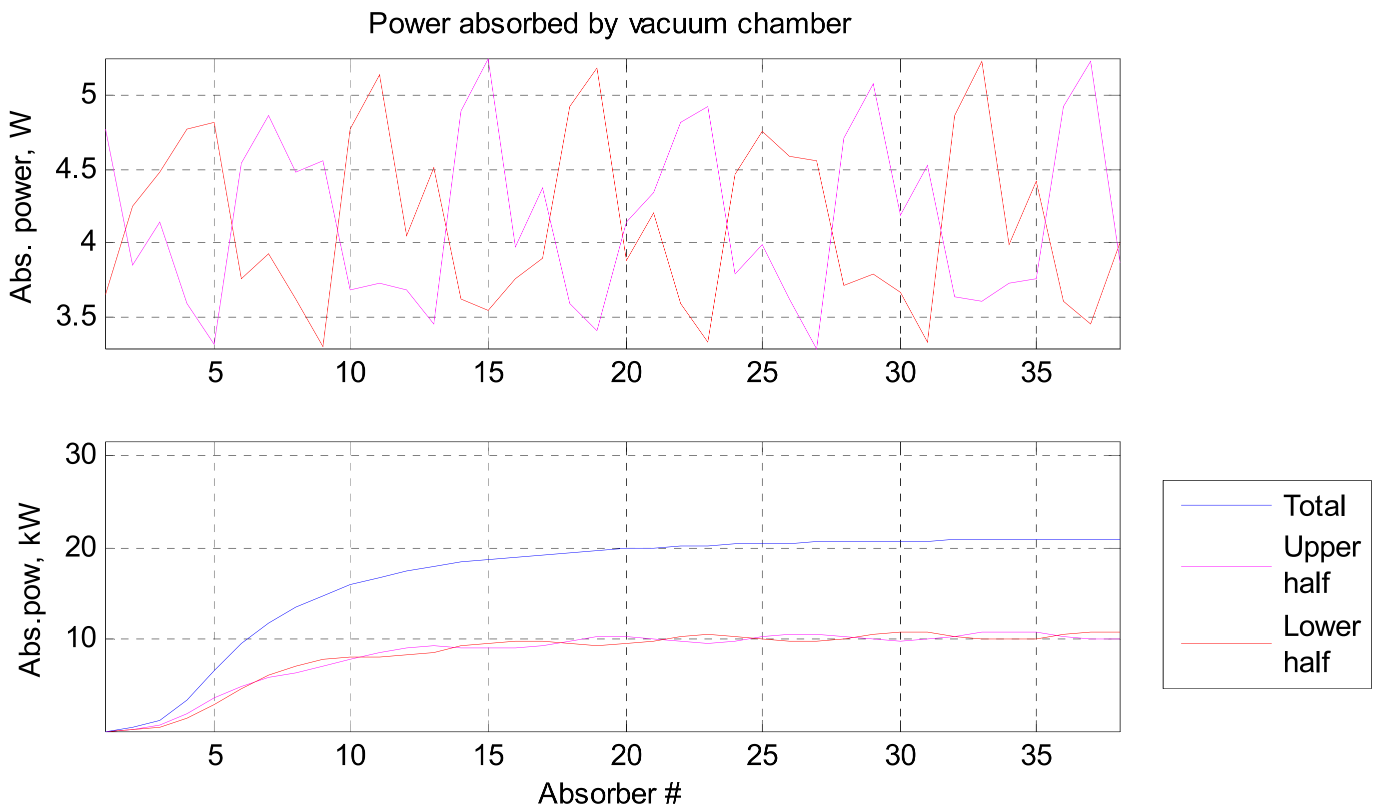


Analysis of absorber configuration (5-5 mm × 60 mm)

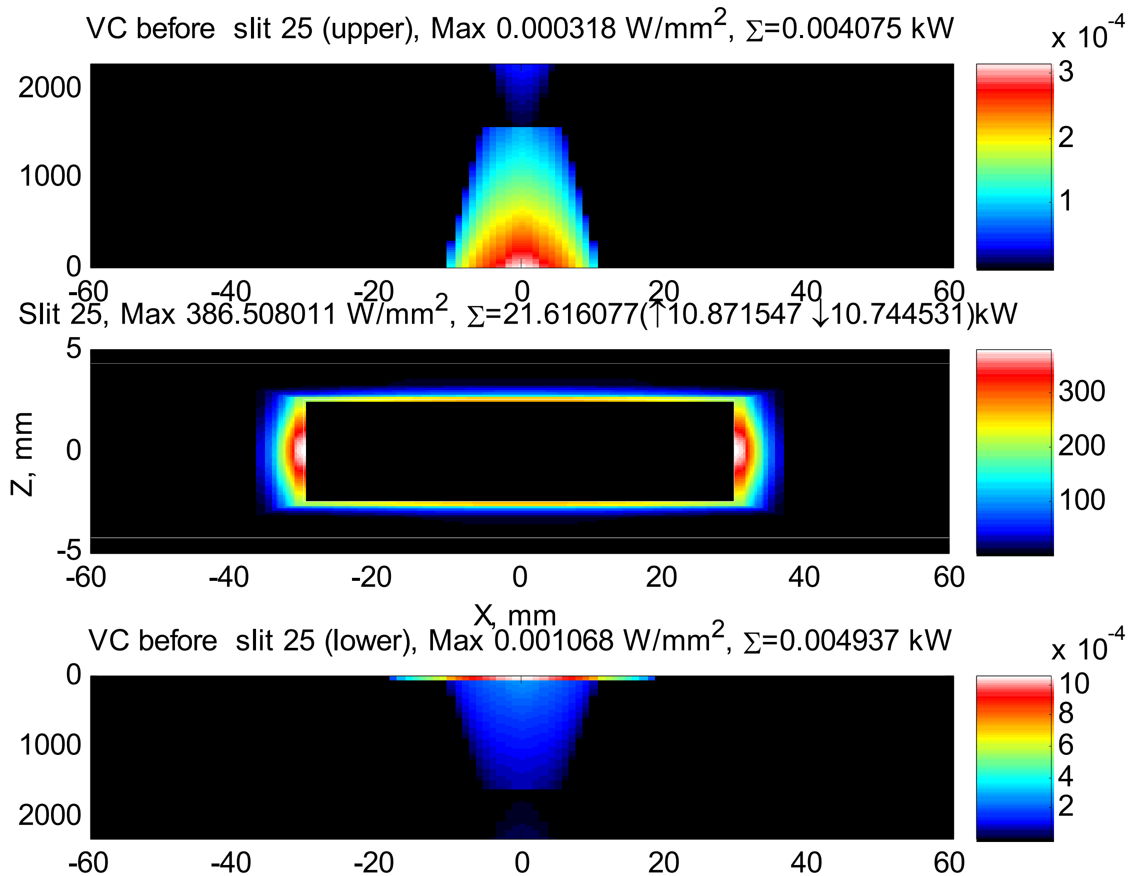
Total power 817 kW (38 wigglers), transmitted 180 kW, absorbed 637 kW



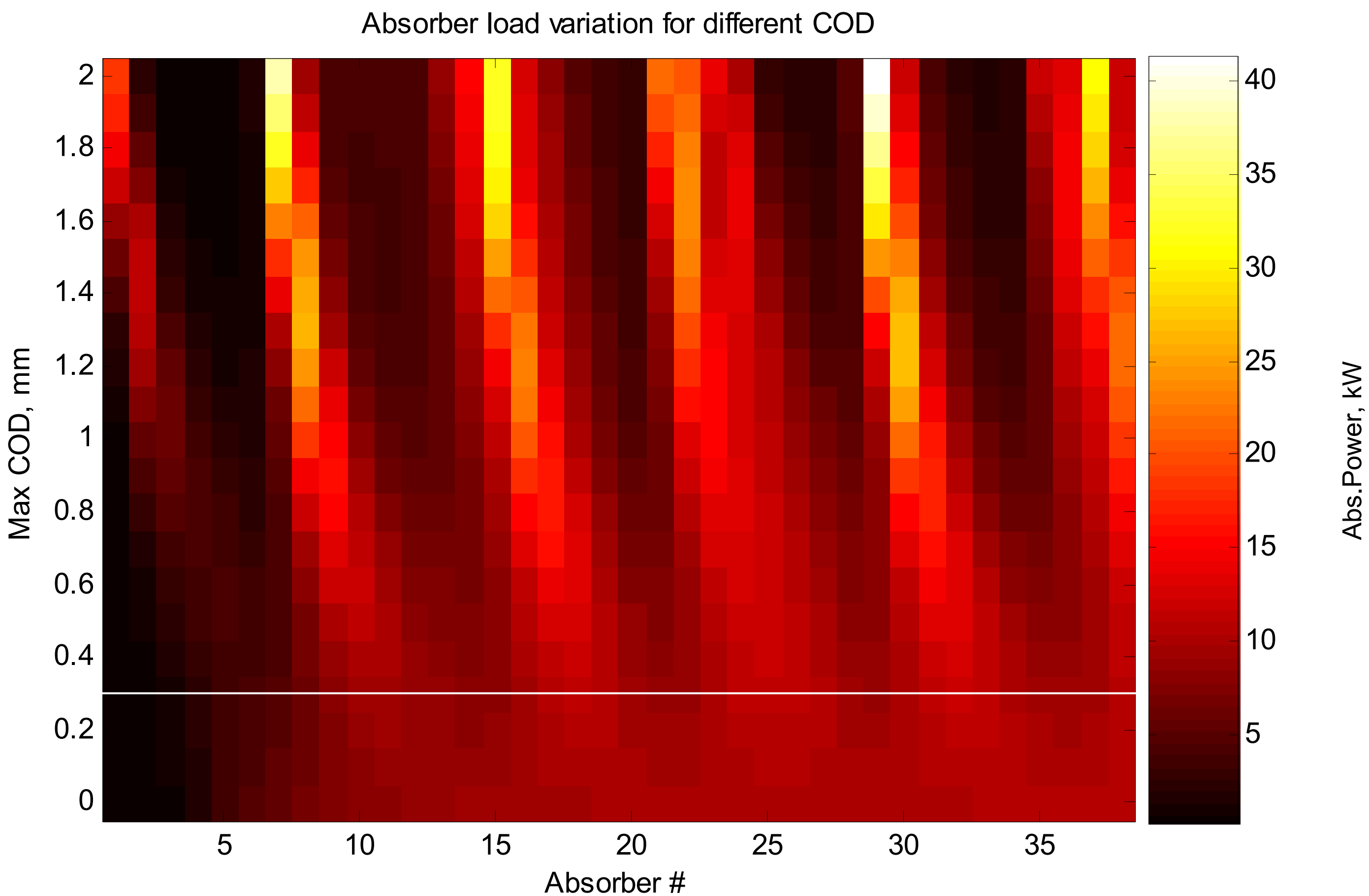
Vacuum chamber load (5-5 mm × 60 mm)



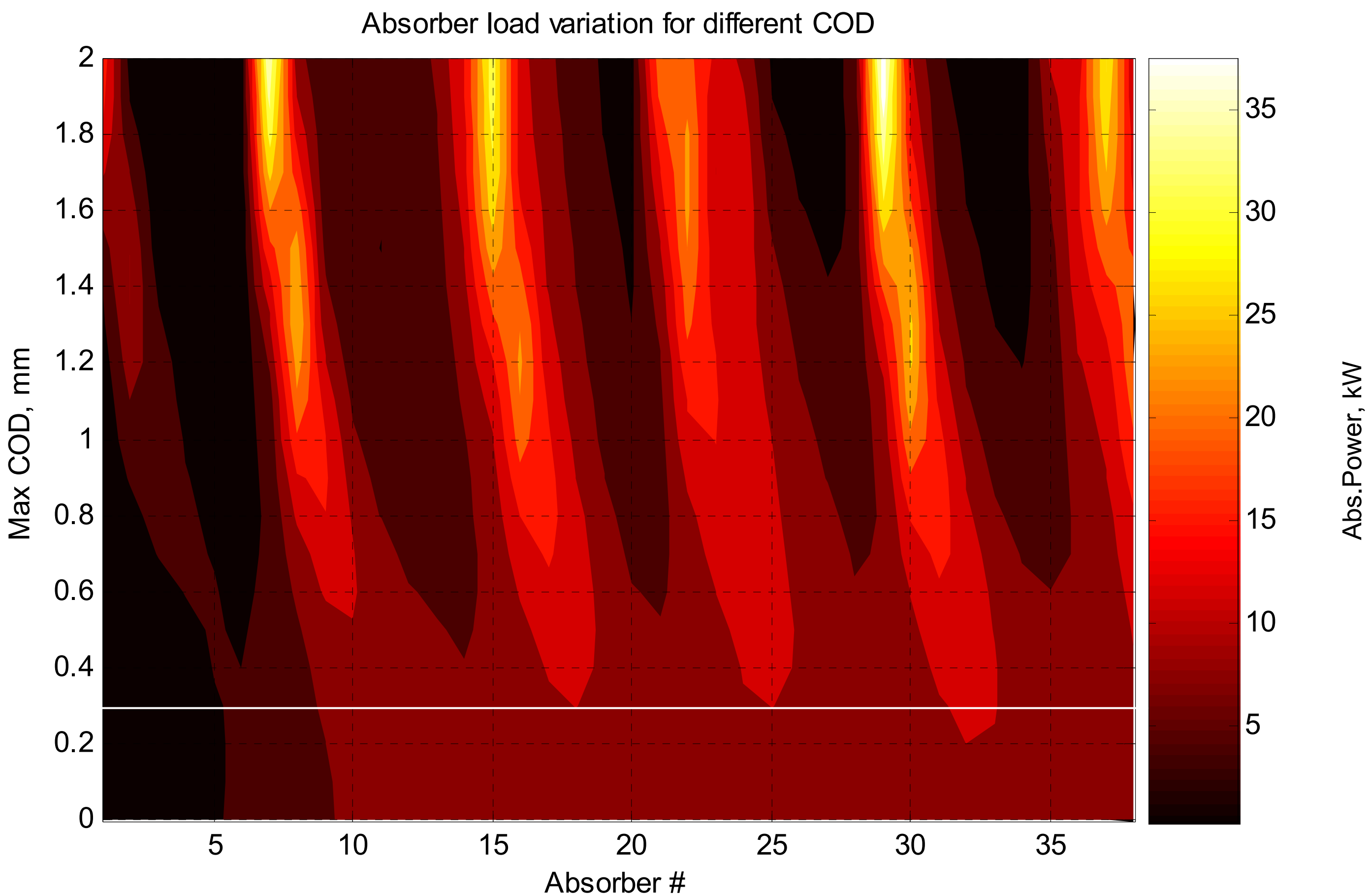
Power density analysis (5-5 mm × 60 mm)



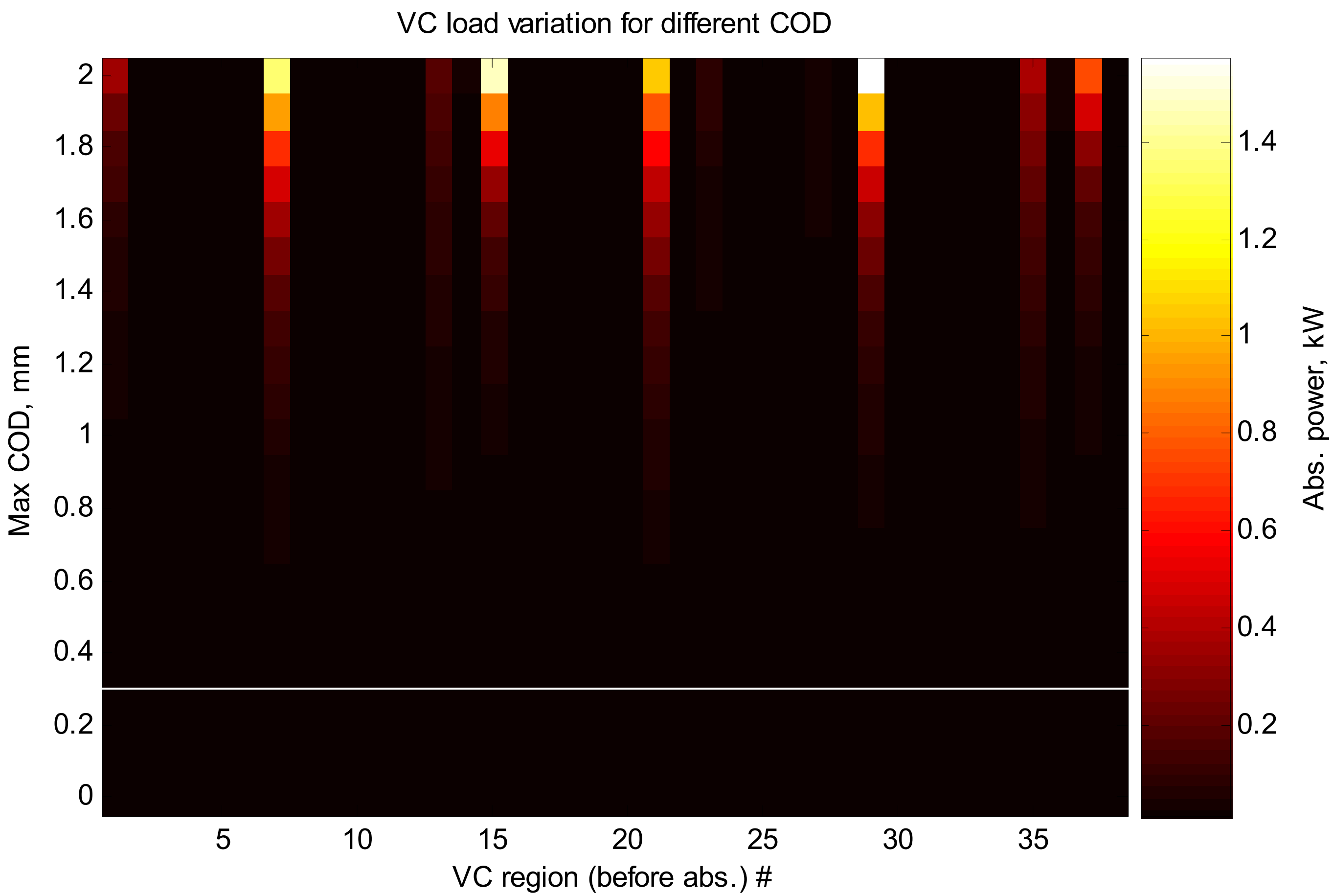
COD influence on the power redistribution



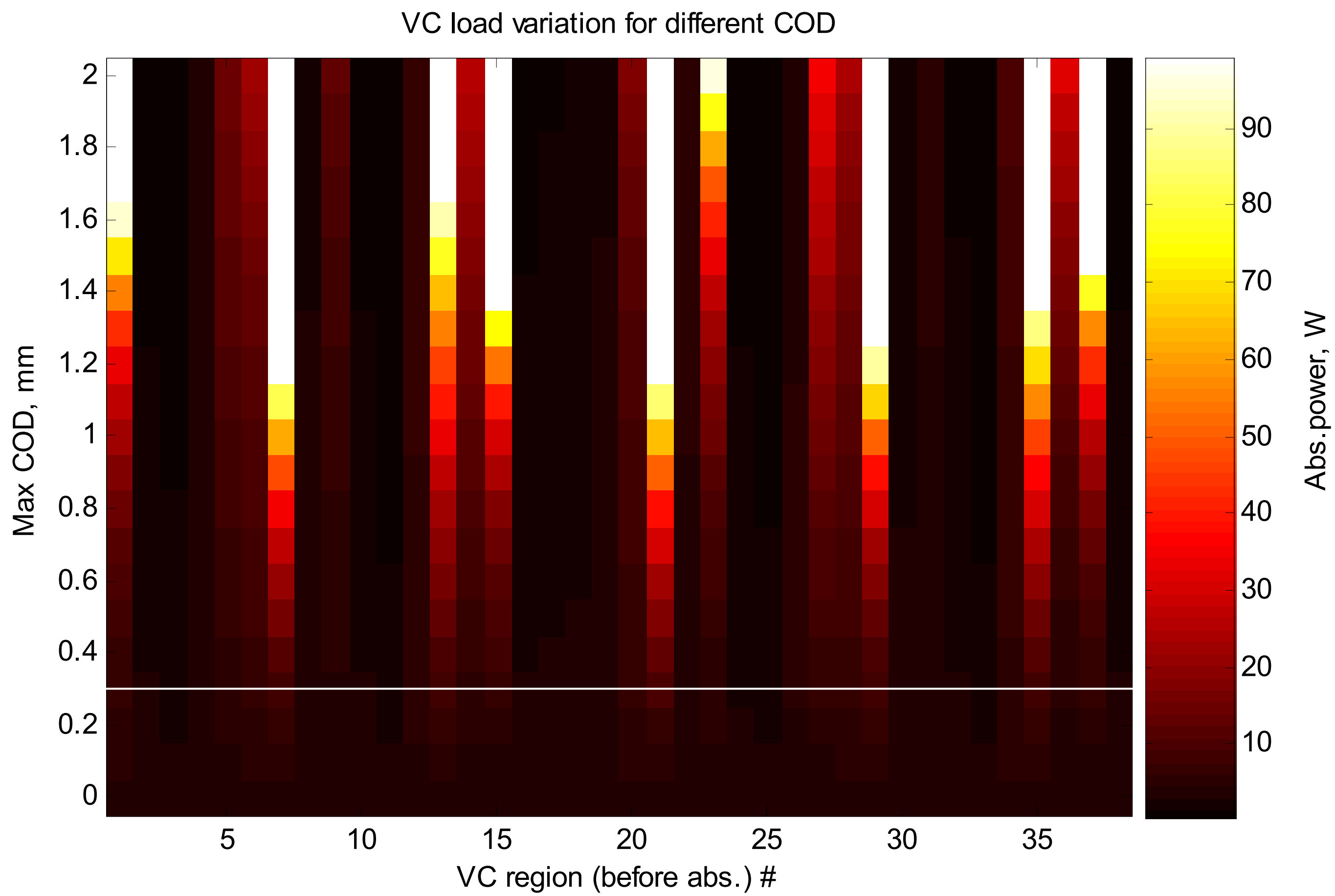
COD influence on the power redistribution



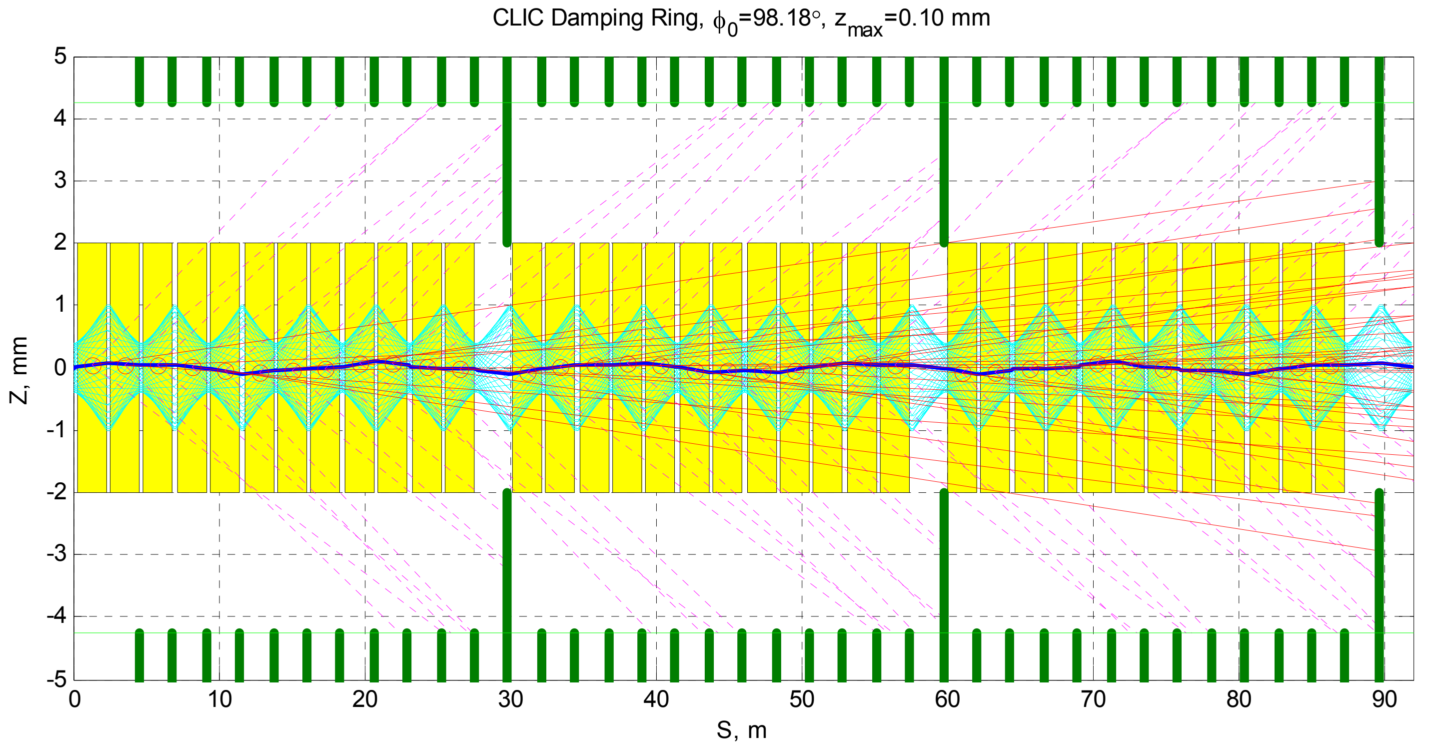
COD influence on the vacuum chamber load



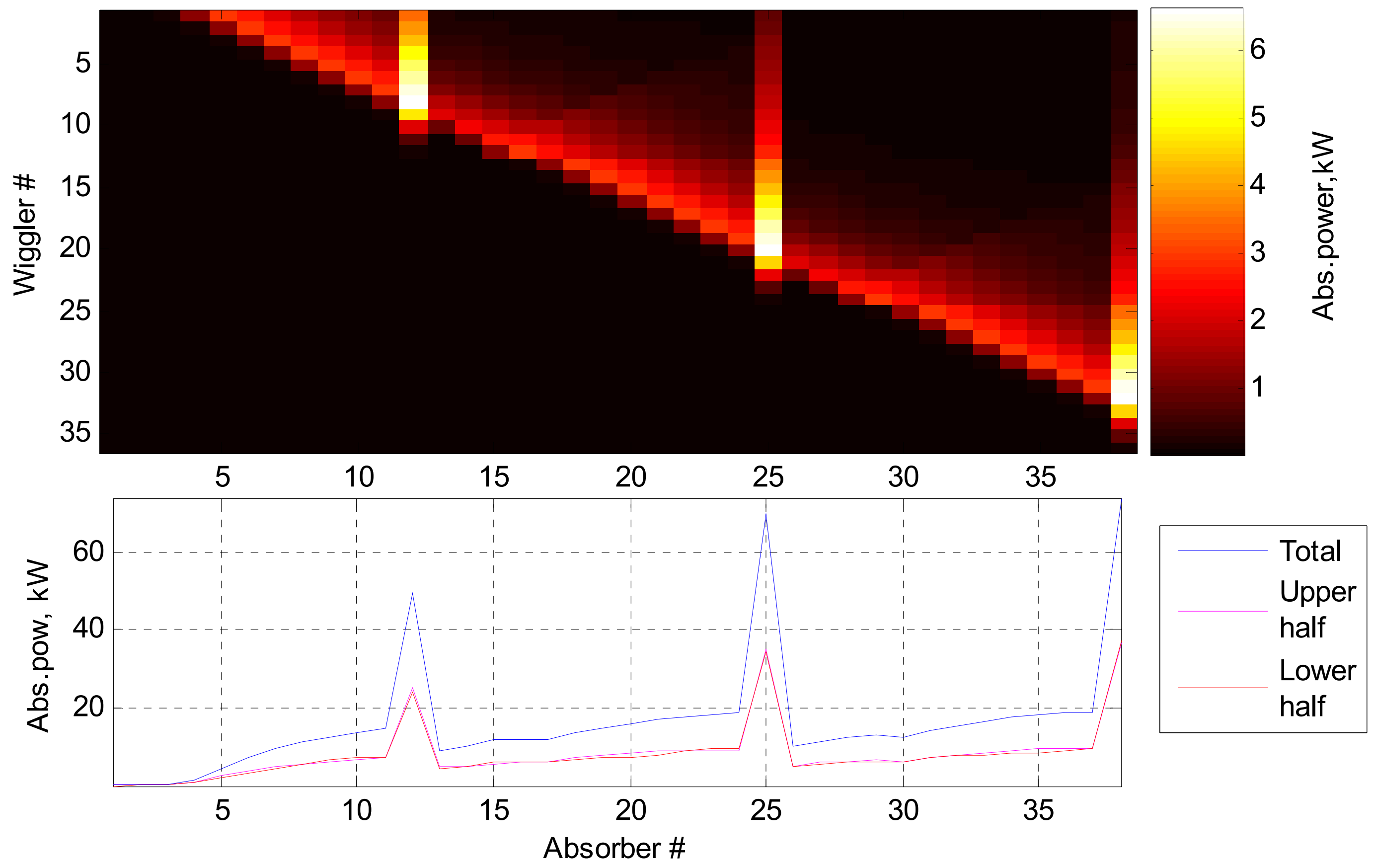
COD influence on the vacuum chamber load



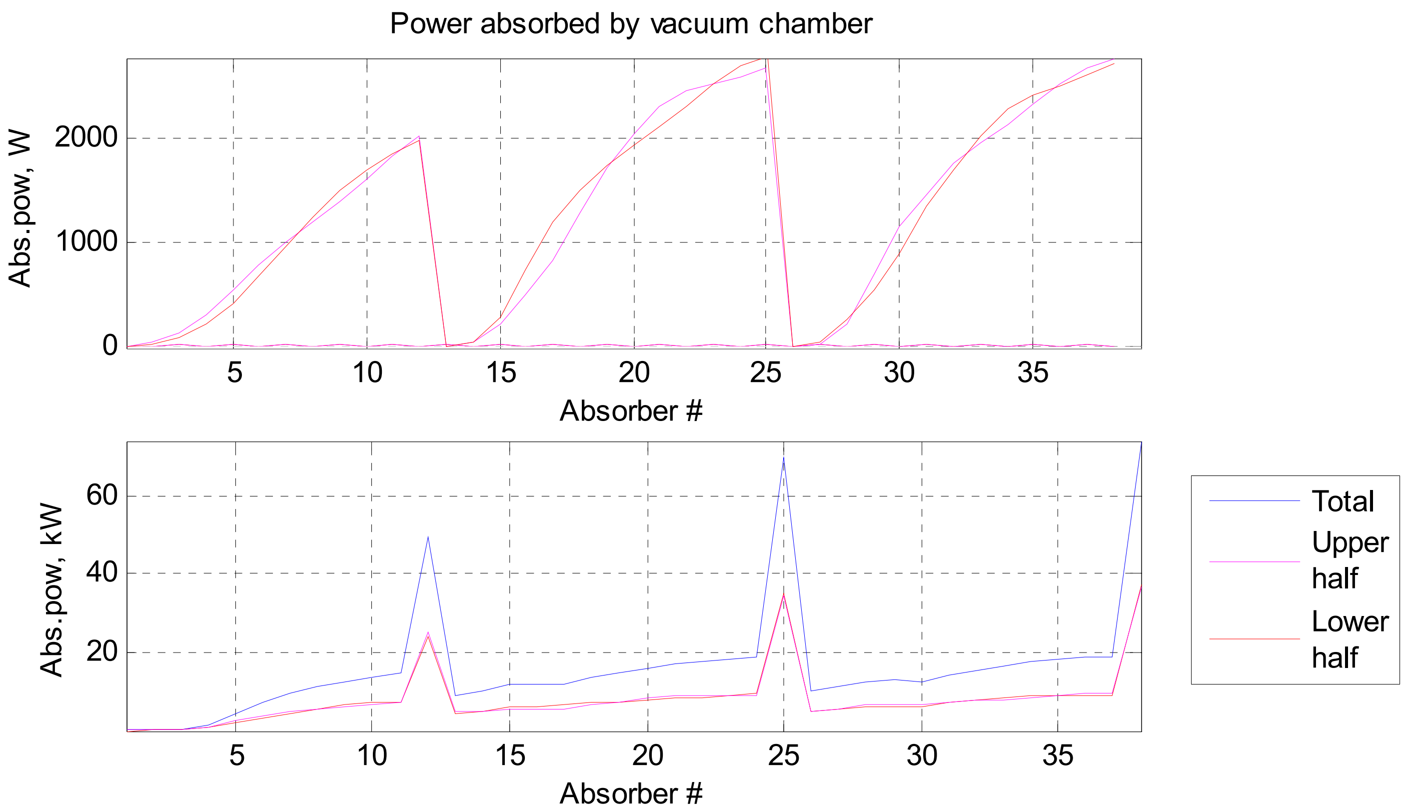
Long absorbers layout



Analysis of absorber configuration (long absorbers)



Vacuum chamber load (long absorbers)



Conclusions

- The most suitable configuration of SR absorbers for CLIC-DR is regular absorbers with 4-6 mm (or 5-5 mm) gaps, in these cases the vacuum chamber heat loads not exceed 20 W, SR transmitted trough absorbers system has a power lower than 200 kW and can be absorbed without big problems in long final absorber
- A lack of free space (between a rear end of wiggler and quadrupole lens) for installing absorbers can be compensated by small reducing length of wigglers (remove 2 periods). This way can reduce a dumping efficiency (10%), but solves many problems of mechanical design of absorbers
- A tolerances for mechanical misalignments (and deviation of close orbit from straight line) should not exceed 0.3 mm over whole straight sections
- Detailed design of absorbers can be performed with taking into account of many related questions (material of chamber, vacuum chamber and antechamber geometry, getter deposition, precise geometry of wiggler pole etc). So this work should be continued with intensive collaboration with experts (mechanical designers, getter and wiggler specialists)

Related problems

- Research and estimation of secondary effects of high power absorption (fluorescence reemission, photoelectons yield, electrons clouds density etc)
- Development of system for active protection, choice of different types sensors (intensity monitors, BPM, X-ray position sensitive monitors, heat sensors), development of strategy for critical situation treating (fast beam shout system etc)