Internal Report
DESY M-95-13
December 1995

Wake Potentials of Short Bunches in the SBLC Accelerating Structure

Michael Drevlak

Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Wake Potentials of Short Bunches in the SBLC Accelerating Structure

by

M. Drevlak

Deutsches Elektronen-Synchrotron, DESY
Notkestraße 85, 22607 Hamburg, Germany

1 Introduction

In this paper we present the shortrange wake potentials used in the current simulations of the beam dynamics for the SBLC study. In addition, we will outline in detail how these wake potentials were obtained and which simplifications were made in their computation.

2 The Problem

The SBLC study envisages the use of short bunches. Until recently (LC 95), the value of this bunch length was $\sigma_z = 0.5$mm. In the meantime, a new parameter set has been chosen which confines the bunch length to an even smaller value of $\sigma_z = 0.3$mm. It is important to note that these bunch lengths are very small in comparison with the dimensions of the cells of the accelerating structure. The calculation of the wake potentials of such short bunches has been facilitated by the introduction of a zoom grid moving with the bunch to the time-domain field calculation programme T2 of the family of MAFIA codes ([1], [2], [3]).

Nevertheless, the calculation of the wake potentials still suffers from the fact that the accelerating structure is not strictly periodic but tapered. Furthermore, it has a great length and consists of a large number of cells (180).

3 The Structure

The SBLC accelerating structure consists of 180 cups as depicted in Fig. 1. It is to operate with a travelling wave at a frequency of 2.9979GHz in the $2\pi/3$-mode. Thus the length of each cell must be 33.33mm. For a structure consisting of 180 cells this makes for a total structure length of 6m. The profile of the cell diameters and iris diameters along the structure is tapered to make the power dissipation along the unloaded structure constant. It was assumed that the cell and iris diameters vary between the values given in table 1 [4]. As the difference in the cell diameters will be in the same order

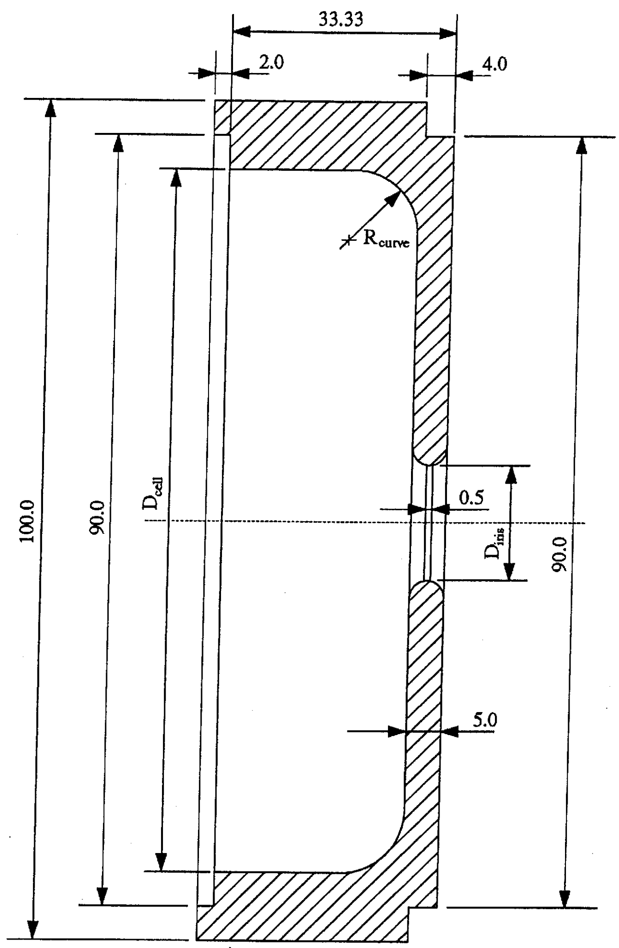

Figure 1: Schematic view of one cup of the accelerating structure. Lengths are given in mm.

as the radial grid resolution, a constant cell diameter of 81.408mm is used in the calculations presented.

Due to the large requirements in core space, CPU time and computing accuracy, it is not possible to do the calculation of the wake potential for the complete accelerating structure. As the wake potential of a structure consisting of a large number of cells is not equal to the sum of the wakepotentials in the individual cells, however, it is necessary to use a sufficiently large number of cells in the calculation. We therefore chose to do the calculation of the wake potential on a structure consisting of 15 cells, having the same total taper as the actual accelerating structure. The iris diameters were assumed to vary linearly between the structure ends. The resulting taper profile is summarized in table 2. The mesh used in the computation had 66 grid lines in the z-direction for each cell and 40 grid lines in the radial direction. At the ends of the structure we added a beam pipe of 50mm length each, with the same density of gridlines in the longitudinal direction. The resulting geometry underlying the computation of the wake potentials is shown in Fig. 2.

cell number	D_{cell}/mm	D_{iris}/mm
1	82.716	30.776
⋮	⋮	⋮
180	79.984	21.786

Table 1: Cell and iris diameters of the full 180 cell accelerating structure of the SBLC.

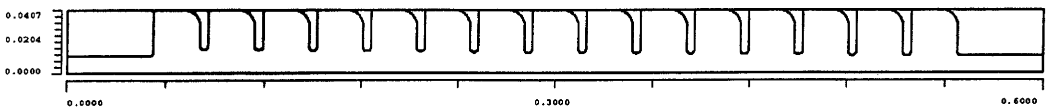

Figure 2: Structure used for the computation of the wake potentials. It consists of 15 cells and has the full taper of the complete 6m structure. Lengths are given in m.

It is instructive to compare the wake potentials of the tapered structure with the wake potentials found in a constant impedance structure. Therefore we will in addition present the wake potentials obtained for a structure with a uniform iris diameter of 26.946mm, which is the iris radius of the 90th cell in the structure [4]. For the beam pipe diameter a value of 21.786mm was used, thus equaling the beam pipe diameter of the tapered structure. The cell diameter was chosen equal to the tapered case.

The wake potentials of the full 180 cell structure were taken to be equal to the wakes of the 15 cell structure multiplied by a factor 12. The wakes to be presented in the following sections will be those of a 180-cell structure, obtained by scaling accordingly.

4 Wake Potentials for σ_z=0.5mm Bunch Length

The wake potentials were computed for a bunch with a length of $\sigma_z = 0.5$mm. Figs. 3, 4 and 6 show the longitudinal wake potentials and Fig. 5 shows the transverse dipole wake potential of the bunch in a 180 cell structure, i.e. the wakes of a 15 cell structure scaled by a factor 12.

The values of the wake potentials for a number of selected positions are summarized in tables 3 and 4.

cell number	D_{cell}/mm	D_{iris}/mm
left beam pipe		21.786
1	81.408	
		30.176
2	81.408	
		29.578
3	81.408	
		28.978
4	81.408	
		28.278
5	81.408	
		27.780
6	81.408	
		27.180
7	81.408	
		26.580
8	81.408	
		25.982
9	81.408	
		25.382
10	81.408	
		24.782
11	81.408	
		24.184
12	81.408	
		23.584
13	81.408	
		22.984
14	81.408	
		22.386
15	81.408	
right beam pipe		21.786

Table 2: Cell and iris diameters of the full 15 cell structure used in the calculation of the wake potentials. The length of the structure used in the calculation amounts to $15 \cdot 33.33\text{mm} + 2 \cdot 50\text{mm} = 0.6\text{m}$.

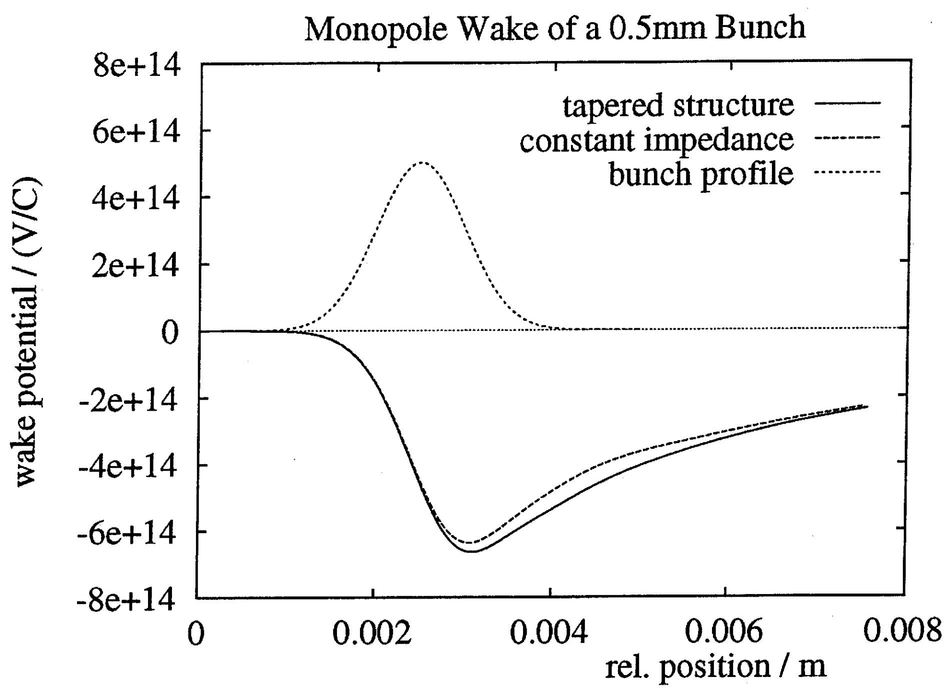

Figure 3: Longitudinal monopole wake potential in the SBLC structure (solid curve), obtained by scaling the wake of the structure shown in Fig. 2 by a factor 12. The dotted curve shows the bunch profile generating this wake potential.

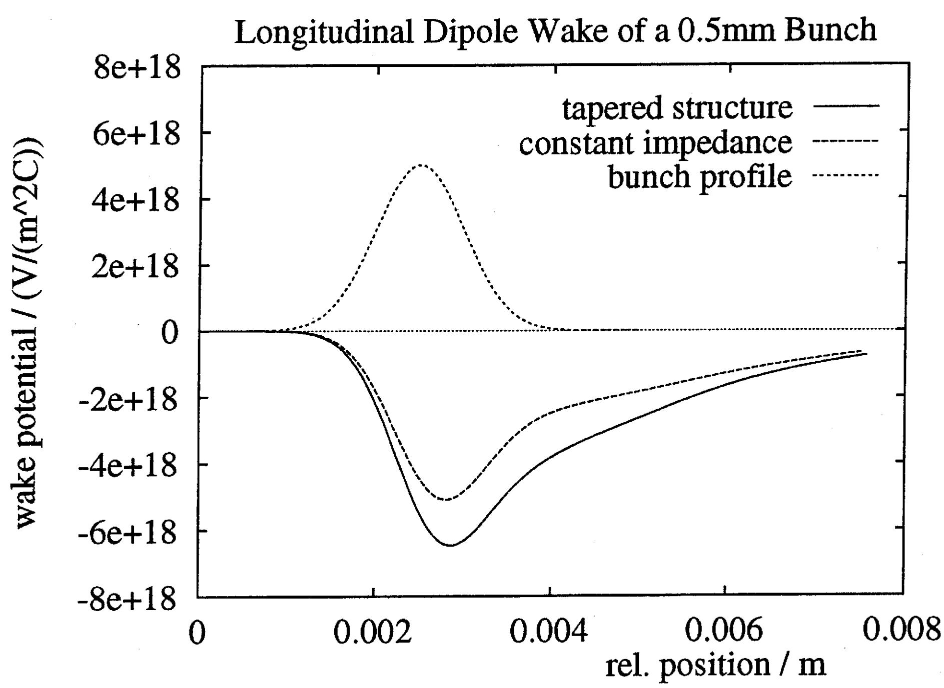

Figure 4: Longitudinal dipole wake potential in the SBLC structure normalized to the square of the bunch offset (solid curve), obtained by scaling the wake of the structure shown in Fig. 2 by a factor 12. The dotted curve shows the bunch profile generating this wake potential.

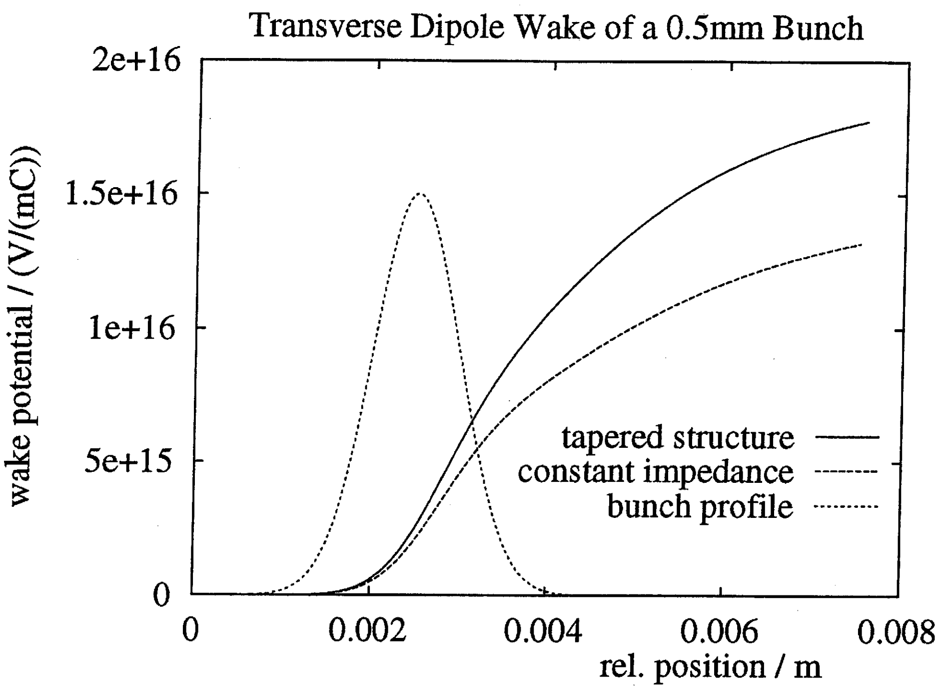

Figure 5: Transverse dipole wake potential in the SBLC structure normalized to the bunch offset (solid curve), obtained by scaling the wake of the structure shown in Fig. 2 by a factor 12. The dotted curve shows the bunch profile generating this wake potential.

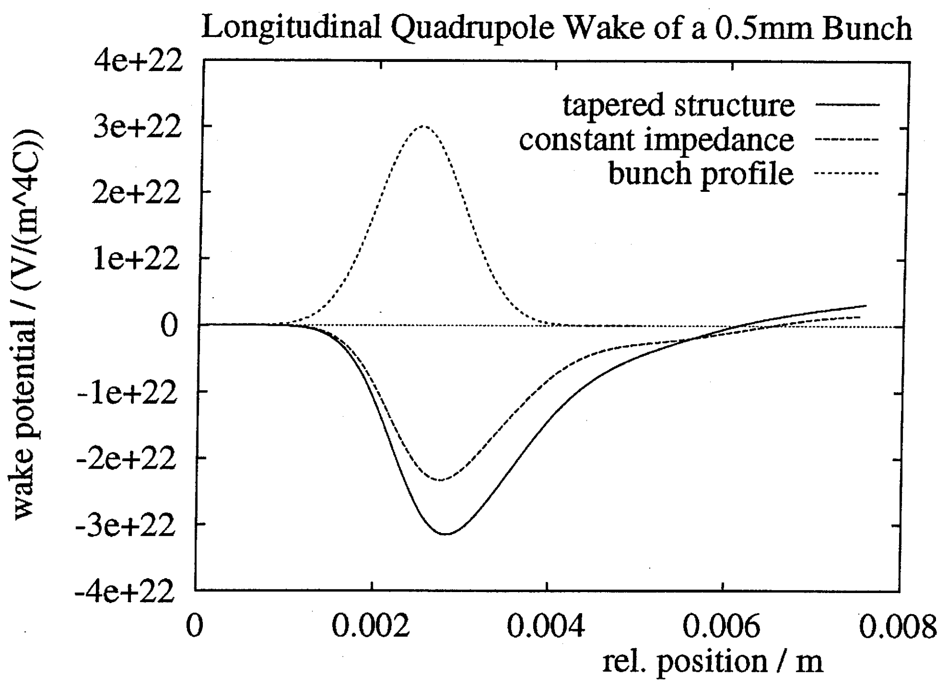

Figure 6: Longitudinal quadrupole wake potential in the SBLC structure normalized to the 4-th power of the bunch offset (solid curve), obtained by scaling the wake of the structure shown in Fig. 2 by a factor 12. The dotted curve shows the bunch profile generating this wake potential.

position	$\mathcal{W}_{\parallel}^{m}$ / (10^{12}V/C)	$\mathcal{W}_{\parallel}^{d}$ / (10^{15}V/m^{2}C)	$\mathcal{W}_{\parallel}^{q}$ / (10^{21}V/m^{4}C)
$-3\sigma_z$	-2.848	-16.19	-0.0977
$-2\sigma_z$	-27.64	-336.71	-1.806
$-1\sigma_z$	-160.20	-2199.48	-11.64
0	-459.04	-5499.53	-27.68
$1\sigma_z$	-659.96	-6371.73	-30.77
$2\sigma_z$	-618.64	-4942.27	-22.97
$3\sigma_z$	-537.67	-3826.61	-14.12
$4\sigma_z$	-463.18	-3171.07	-8.00
$5\sigma_z$	-405.56	-2638.37	-4.70

Table 3: Numerical values of the wake potentials at selected longitudinal positions within the bunch with respect to the bunch center. The bunch length is $\sigma_z = 0.5$mm. The wakes were obtained by scaling the wakes of the structure shown in Fig. 2 by a factor 12. The indices m, d and q refer to the monopole, dipole and quadrupole wake. For the dipole case, both the longitudinal and the transverse wakes are shown. The position 0 in the tables corresponds to the abscissa 2.5mm in the plots of the wake potentials.

position	$\mathcal{W}_{\perp}^{d}$ / (10^{15}V/mC)
$-3\sigma_z$	0.0022
$-2\sigma_z$	0.0608
$-1\sigma_z$	0.6053
0	2.5616
$1\sigma_z$	5.547
$2\sigma_z$	8.4302
$3\sigma_z$	10.615
$4\sigma_z$	12.371
$5\sigma_z$	13.837

Table 4: Numerical values of the transverse dipole wake potential at selected longitudinal positions within the bunch with respect to the bunch center. The bunch length is $\sigma_z = 0.5$mm. The wake was obtained by scaling the wake in the structure from Fig. 2 by a factor 12. The position 0 in the tables corresponds to the abscissa 2.5mm in the plots of the wake potentials.

5 Wake Potentials for σ_z=0.3mm Bunch Length

The wake potentials in this section were computed for a bunch with a length of $\sigma_z = 0.3$mm. The results are illustrated in Figs. 7 and 8. The structure geometry was again chosen as outlined in section 3, consisting of 15 cells with the same total taper as the full structure of 180 cells. In addition to the wakes obtained from the direct computation, we have shown the wakes obtained by scaling the wakes of the 0.5mm bunch. There, the ordinate underlying the wake potential was scaled proportionally with the bunch length and the amplitude of the wake potential was scaled inversely with the square root of the wake potential. Wake potentials of a constant impedance structure are no longer considered.

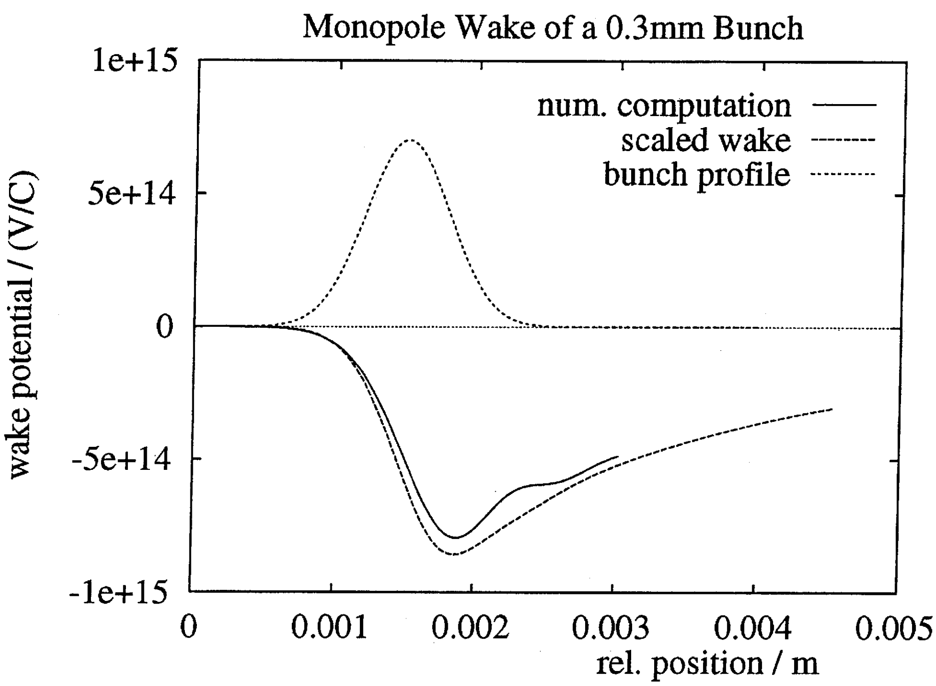

Figure 7: Longitudinal monopole wake potential in the SBLC structure as obtained directly from the numerical computation (solid curve). The dashed curve indicates the wake obtained by scaling the amplitude and abscissa of the wake of a 0.5mm bunch. The dotted curve shows the bunch profile generating this wake potential. Both wakes were obtained by scaling the wake of a structure as shown in Fig. 2 by a factor 12.

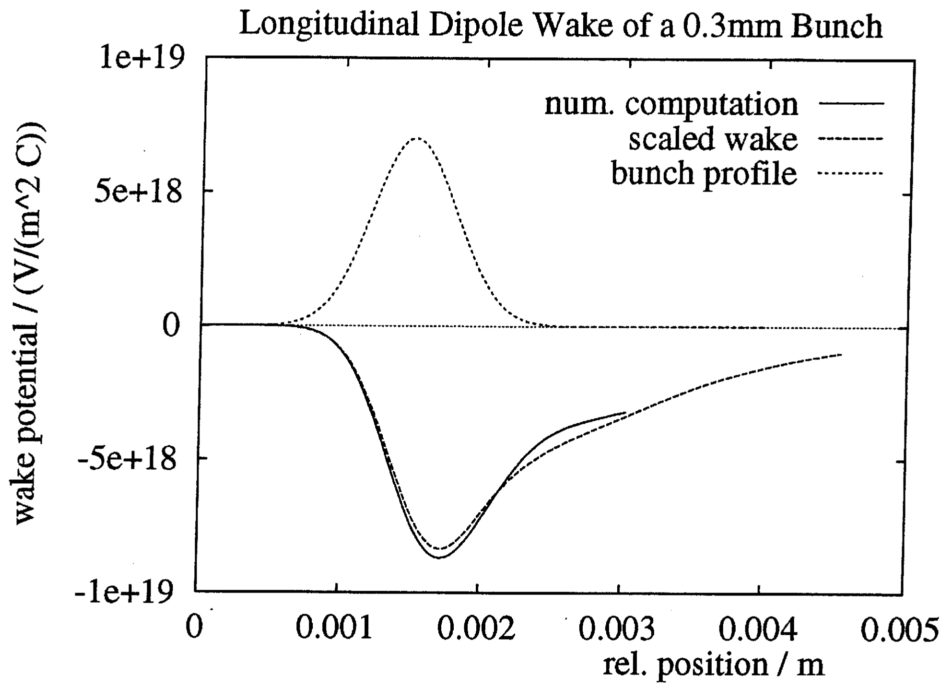

Figure 8: Longitudinal dipole wake potential in the SBLC structure normalized to the square of the bunch offset (solid curve). The dashed curve indicates the wake obtained by scaling the amplitude and abscissa of the wake of a 0.5mm bunch. The dotted curve shows the bunch profile generating this wake potential. Both wakes were obtained by scaling the wake of a structure as shown in Fig. 2 by a factor 12.

position	$\mathcal{W}_{\parallel}^{m}$ / (10^{12}V/C)	$\mathcal{W}_{\parallel}^{d}$ / (10^{15}V/m^{2}C)
$-3\sigma_z$	-4.751	-10.874
$-2\sigma_z$	-36.668	-427.40
$-1\sigma_z$	-179.926	-3011.04
0	-507.528	-7431.41
$1\sigma_z$	-777.049	-8509.53
$2\sigma_z$	-711.341	-6324.86
$3\sigma_z$	-597.993	-4454.67
$4\sigma_z$	-565.072	-3619.94
$5\sigma_z$	-488.859	-3215.12

Table 5: Numerical values of the wake potentials at selected longitudinal positions within the bunch with respect to the bunch center. The indices m and d refer to the monopole, dipole and quadrupole wake. The wakes were obtained by scaling the wake of a structure as shown in Fig. 2 by a factor 12. The position 0 in the tables corresponds to the abscissa 1.5mm in the plots of the wake potentials.

6 Loss Parameters

In order to facilitate the quantitative comparison of the various wakepotentials, we give a table containing the longitudinal and transverse loss parameters of the monopole, dipole and quadrupole wakes.

Calculation	$k_{\parallel}^{mono}/(\mathrm{V/C})$	$k_{\parallel}^{dipole}/(\mathrm{V/Cm^2})$	$k_{\perp}^{dipole}/(\mathrm{V/Cm})$	$k_{\parallel}^{quad}/(\mathrm{V/Cm^4})$
500μm bunch, direct computation, tapered structure	$4.14 \cdot 10^{14}$	$4.53 \cdot 10^{18}$	$3.0 \cdot 10^{15}$	$2.25 \cdot 10^{22}$
500μm bunch, direct computation, constant structure	$4.01 \cdot 10^{14}$	$3.58 \cdot 10^{18}$	$2.42 \cdot 10^{15}$	$1.68 \cdot 10^{15}$
300μm bunch, direct computation, tapered structure	$4.74 \cdot 10^{14}$	$6.11 \cdot 10^{18}$	$2.43 \cdot 10^{15}$	$3.87 \cdot 10^{22}$
300μm bunch, computation by scaling, tapered structure	$5.35 \cdot 10^{14}$	$5.84 \cdot 10^{18}$	$2.32 \cdot 10^{15}$	$2.91 \cdot 10^{22}$

Table 6: Longitudinal and transverse loss parameters of the monopole, dipole and quadrupole wakes obtained from the different calculation methods. The values were obtained from the wakes of the structure shown in Fig. 2 scaled by a factor 12.

Acknowledgements

The author wants to thank D. Kelly and R. Wanzenberg for reading the manuscript.

References

[1] M. Dehler: "Numerische Lösung der Maxwellschen Gleichungen auf Kreiszylindrischen Gittern", Dissertation, Technische Hochschule Darmstadt, 1993

[2] T. Weiland: "Transverse Beam Cavity Interaction", Nucl. Instr. Meth. 212, 1983, pp. 13-21

[3] T. Weiland: "Comment on Wake Field Computation in Time Domain", Nucl. Instr. Meth. 216, 1983, pp. 31-34

[4] N. Holtkamp: private communication