Wakepotential of an Array of thin Electrodes in a Beampipe.

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Abstract

Clearing electrodes might decrease the buildup of electron clouds. The wakepotential of such electrodes is computed under simplifying conditions: The thickness of the electrodes is neglected, the electrodes are very near to the beampipe walls, the beampipe and the electrodes are assumed to be rectangular. Under such conditions, the wakepotential of electrodes without a substrate is essentially negligible. The wakepotential with substrate is significant and can be explained by the lower group velocity in the substrate.

The device under scrutiny is an array of electrodes in a beam pipe. The beampipe is assumed to be rectangular. At the bottom and top of the pipe the electrodes are attached. The electrodes are modeled as infinitely thin sheets of perfectly conducting material. If the electrodes would be located at places of constant beam-potential, and if the substrate would consist of invisible material, i.e. \( \varepsilon_r = 1 \), they would not have any wakepotential at all, as they then would not disturb the primary field of the relativistic beam. The part of the primary field which enters the space between the electrodes and the wall travels with the velocity of light towards the end of the electrode, where it recombines with the primary field of the beam above the electrode. No field scattering occurs. No wakepotential is experienced. Because the electrodes are very near to the beam pipe walls, they almost fulfill the condition of being on places of constant beam-potential.

Between the pipes wall and the electrodes is a dielectric material. The wakepotential are computed when the electrodes are lying on a dielectric with \( \varepsilon_r = 2 \), and for comparison when the dielectric material is invisible, i.e. \( \varepsilon_r = 1 \). The wakepotential of the conducting foil with dielectric is much larger. This is because the energy in the dielectric travels with a velocity much less than the velocity of light. The field which travels through the dielectric reaches the end of the foil much later than the beam reaches the end of the foil. The beam field above the foil therefore cannot recombine with the field below the foil, as it is the case if the dielectric below the foil is not present.

WAKEPOTENTIALS OF AN LHC-BEAM

The results are computed with beamparameters of the LHC. The length of the beam is \( \sigma = 8 \) cm. The width and height of the rectangular beam pipe is 4 cm.

Figure 2 shows the wakepotential of two electrodes with a length of 40 cm. The wakepotential is essentially a periodic function with a period length of 10/9 metres. This period length is twice the length of the electrodes times the refractive index of the material with \( \varepsilon_r = 2 \).

Figure 3 shows the wakepotentials of 2, 4, 8 and 16 electrodes. The shape of the wakepotentials do not differ. The amplitude grows linearly with the number of electrodes.
This period length is twice the length of the electrodes times the refractive index of the material without a supporting dielectric. The shape of the wakepotential as shown in figure 2. The period length is 10/12.5 metres. This period length is twice the length of the electrodes.

Figure 5 shows the wakepotential of 2,4,8,16 electrodes without a supporting dielectric. The shape of the wakepotentials do not differ. The amplitude grows linearly with the number of electrodes.

The permittivity of the substrate is $\varepsilon_r=2$.

The number of electrodes is 2,4,8,16. The length of a single electrode is 40 cm. The permittivity of the substrate is $\varepsilon_r=1$.

Figure 10 shows the wakepotential of two electrodes with a length of 20cm. The wakepotential is essentially a periodic function with a period length of 10/18 metres. This period length is twice the length of the electrodes times the refractive index of the material with $\varepsilon_r=2$.

Figure 11 shows the wakepotentials of 2,4,8 and 16 electrodes. The shape of the wakepotentials do not differ. The amplitude grows linearly with the number of electrodes.

Figures 6, 7, 8, 9 show the real and imaginary part of the impedance corresponding to the wakepotentials as shown in figure 4, 5. The shown results are computed by an FFT of the finite s-range of figures 4, 5 and therefore do show finite resonances, ie not dirac pulses.

Figure 12, 13 show the real part of the impedance corresponding to the wakepotentials as shown in figure 10, 11. The shown results are computed by an FFT of the finite s-range of figures 10, 11 and therefore do show finite resonances, ie not dirac pulses.

Figure 14 shows the wakepotential of two electrodes with a length of 10cm. The wakepotential is essentially a periodic function with a period length of 10/37 metres. This period length is twice the length of the electrodes times the refractive index of the material with $\varepsilon_r=2$.

Figure 15 shows the wakepotentials of 2,4,8 and 16 electrodes. The shape of the wakepotentials do not differ. The amplitude grows linearly with the number of electrodes.
The fact that the energy owing below the electrodes cannot recombine with the energy flowing above. From that model one would expect that the wakepotential only depends on the number of the electrodes, not on their length. It might be, that the wakepotential has this dependence on the length of the electrodes, because the length of the exciting bunch is comparable with the length of the electrodes. To investigate this, the wakepotential of a shorter bunch is computed. Figures 18, 19, 20 show the wakepotentials of a gaussian line charge with sigma=8cm. Total charge 1pC. The number of electrodes is 2. The length of a single electrode is 20 cm. The permittivity of the substrate is epsr=2.

**DISCUSSION AND CONCLUSION**

Figures 3, 11, 15 show that the amplitude of the wakepotentials grow linearly with the number of electrodes.

The amplitude of the wakepotential of two electrodes with a length of 40cm, 2, is 0.01 V/pC. The wakepotential of two electrodes of half length, 20cm, 10, is 0.004 V/pC. The wakepotential of two electrodes of quarter length, 10cm, 14, is 0.001 V/pC. This suggests that the wakepotential grows with the length of the electrodes. This is not expected from the model that the wakepotential comes from the fact that the energy flowing below the electrodes cannot
Figure 11: The computed longitudinal wakepotential for a gaussian line charge with sigma=8cm. Total charge 1pC. The number of electrodes is 2,4,8,16. The length of a single electrode is 20 cm. The permittivity of the substrate is epsr=2.

Figure 12: Real part of the computed longitudinal impedance. The number of electrodes is 2. The length of a single electrode is 20 cm. The permittivity of the substrate is epsr=2.

Figure 13: Real part of the computed longitudinal impedance. The number of electrodes is 2,4,8,16. The length of a single electrode is 20 cm. The permittivity of the substrate is epsr=2.

Figure 14: The computed longitudinal wakepotential for a gaussian line charge with sigma=8cm. Total charge 1pC. The number of electrodes is 2. The length of a single electrode is 10 cm. The permittivity of the substrate is epsr=2.

Figure 15: The computed longitudinal wakepotential for a gaussian line charge with sigma=8cm. Total charge 1pC. The number of electrodes is 2,4,8,16. The length of a single electrode is 10 cm. The permittivity of the substrate is epsr=2.

Figure 16: Real part of the computed longitudinal impedance. The number of electrodes is 2. The length of a single electrode is 10 cm. The permittivity of the substrate is epsr=2.
Figure 17: Real part of the computed longitudinal impedance. The number of electrodes is 2, 4, 8, 16. The length of a single electrode is 10 cm. The permittivity of the substrate is $\varepsilon_r=2$.

Figure 18: The computed longitudinal wakepotential for a gaussian line charge with $\sigma=1\text{cm}$. Total charge $1\text{pC}$. The number of electrodes is 2. The length of a single electrode is 10 cm. The permittivity of the substrate is $\varepsilon_r=2$.

Figure 19: The computed longitudinal wakepotential for a gaussian line charge with $\sigma=1\text{cm}$. Total charge $1\text{pC}$. The number of electrodes is 2. The length of a single electrode is 10 cm. The permittivity of the substrate is $\varepsilon_r=2$.

Figure 20: The computed longitudinal wakepotential for a gaussian line charge with $\sigma=1\text{cm}$. Total charge $1\text{pC}$. The number of electrodes is 2. The length of a single electrode is 40 cm. The permittivity of the substrate is $\varepsilon_r=2$. 