Resistive Wall Wakes and Clearing Electrodes

Rainer Wanzenberg

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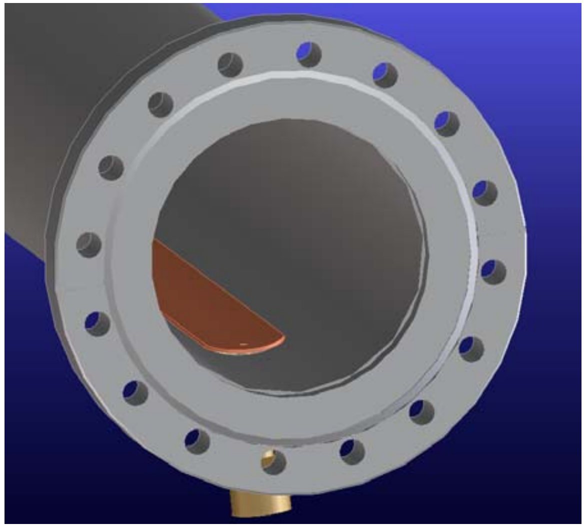
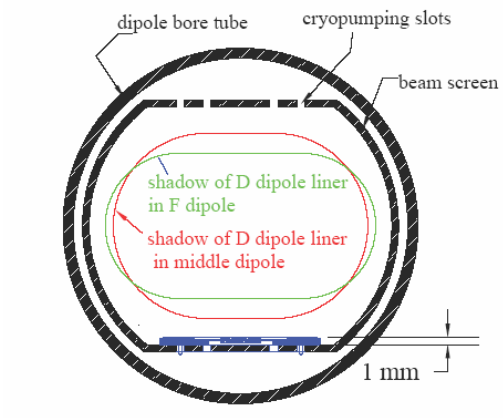
Outline

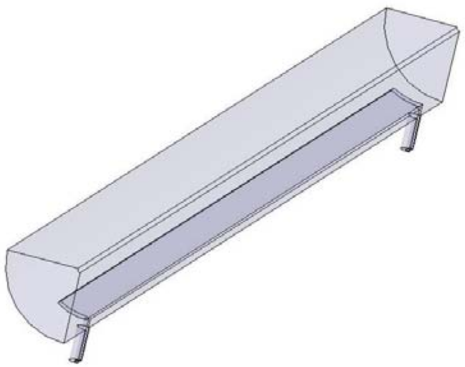
- **Clearing Electrodes**
- **Resistive Wall Wakes**
- **Coupled Bunch Instabilities**
- **Power Loss in the Clearing Electrodes**
- **Heating of the Clearing Electrodes**
- **Conclusions**

Clearing Electrodes

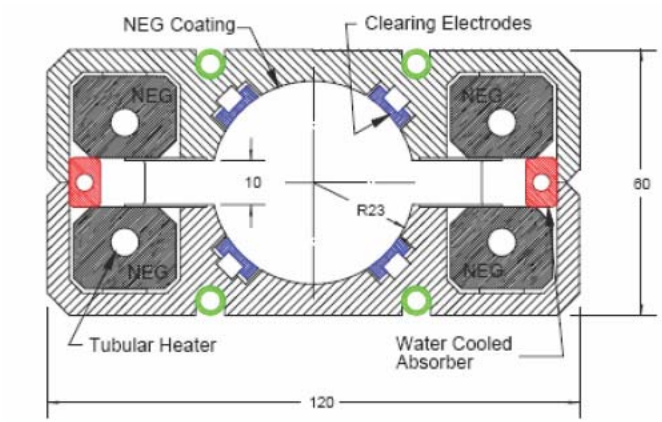




(P. McIntyre, A. Sattarov, PAC2005 Knoxville)



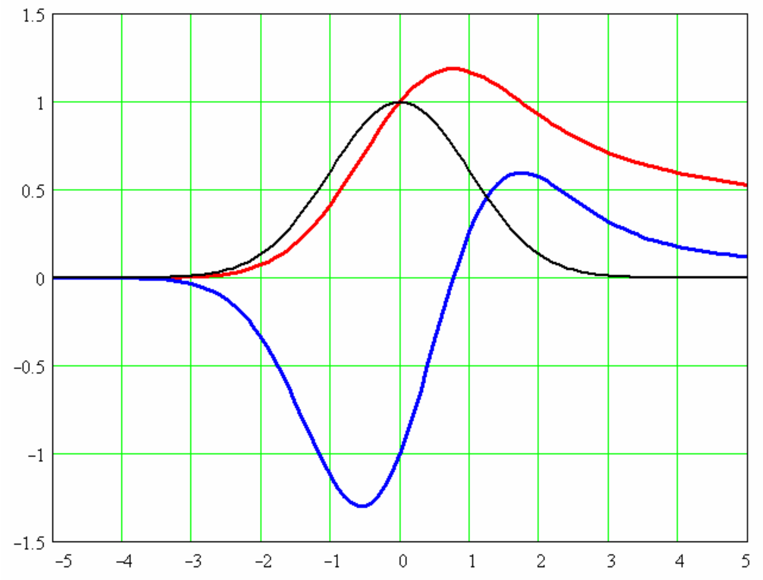
Possible design for a test at PEP-II
(Mauro Pivi, SLAC)



ILC DR wiggler chamber
(RDR)

Resistive Wall Wakes

Normalized longitudinal and transverse Wake Potential



Total energy loss: $k_{loss} = \int ds\ \lambda(s)\ W_{\|}(s)$

Kick parameter: $k_{\perp} = \int ds\ \lambda(s)\, W_{\perp}(s)$

Conductivity:

Copper	$\sigma_{\mathrm{Cu}} = 58.0 \cdot 10^6 (\Omega\,\mathrm{m})^{-1}$
Steel	$\sigma_{\mathrm{Steel}} = 1.5 \cdot 10^6 (\Omega\,\mathrm{m})^{-1}$
NEG TiVrZr film	$\sigma_{\mathrm{NEG}} \approx 0.31 \cdot 10^6 (\Omega\,\mathrm{m})^{-1}$ (CERN, Sergio Calatroni)
Enamel	$\sigma_{\mathrm{Enamel}} = 9.8\ (\Omega\,\mathrm{m})^{-1} \approx 0.0 \cdot 10^6 (\Omega\,\mathrm{m})^{-1}$

$$k_{loss} = \frac{1}{4\pi^2\sqrt{2}} \Gamma(\tfrac{3}{4})\ \frac{c}{r\ (\sigma_z)^{3/2}} \sqrt{\frac{Z_0}{\sigma_{cond.}}}$$

$$k_{\perp} = \frac{1}{2\pi^2\sqrt{2}} \Gamma(\tfrac{1}{4}) \frac{c}{r^3\sqrt{\sigma_z}} \sqrt{\frac{Z_0}{\sigma_{cond}}}$$

Reference: A. Piwinski, Wake Fields and Ohmic Losses in round Vaccum Chambers, DESY HERA 92-11, 1992

Coupled Bunch Instabilities

Parameter	ILC DR
Energy / GeV	5
Circumference /m	**6695**
RF Frequency / MHz	650
RF harmonic number	14516
RF Voltage / MV	24
Momentum compaction	1.22 10^{-3}
Synchrotron tune	0.067
Total current / mA	376
Number of bunches	2625
Bunch population / 10^{10}	2.0
Bunch separation / ns	7.69
Emittance (horz.) /nm	0.51
Bunch length / mm	9
Damping time H/V/L / ms	25.7 / 25.7 / 12.9

Tune shifts

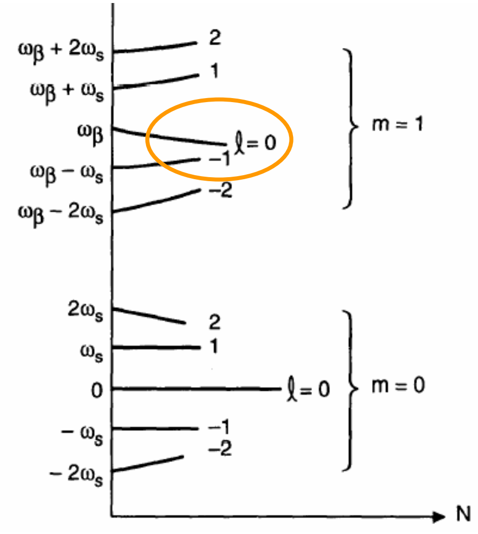
$$\frac{\Delta Q_\beta}{Q_S} = \frac{1}{Q_S}\frac{I_B \langle\beta\rangle T_0}{4\pi E/e} k_\perp$$

$$k_\perp = \frac{1}{2\pi^2\sqrt{2}}\Gamma(\tfrac{1}{4})\frac{c}{r^3\sqrt{\sigma_z}}\sqrt{\frac{Z_0}{\sigma_{cond}}}$$

$\langle\beta\rangle \approx 25$ m

$\mathrm{r} = 20$ mm

$\mathrm{I_B} = 0.143$ mA



longitudinal mode number l
transverse mode number m
mode coupling: m=0, l=1, l=2
m=1, l=0, l=-1

Material	$\Delta Q/Q_s$	$k_\perp$ (V/ pC/ m/ m)
NEG	**0.23**	1.79
Copper	**0.017**	0.13

Power Loss in the Clearing Electrodes

Power loss:

$$P_{loss} = N_{bunches}\ f_0\ q_b^{\ 2}\ k_{loss}$$

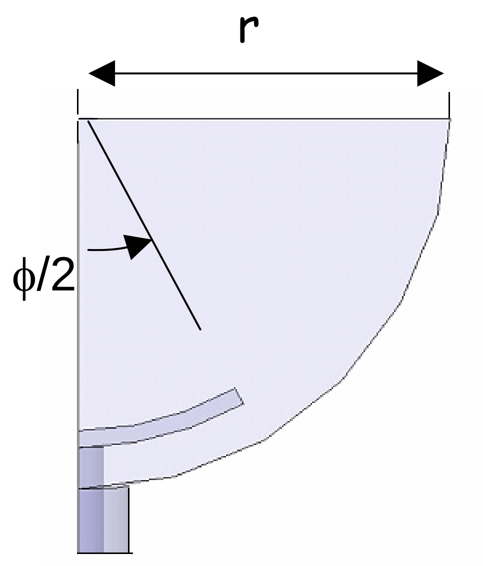
$$k_{loss} = \frac{1}{4\pi^2\sqrt{2}}\Gamma(\tfrac{3}{4})\ \frac{c}{r\ (\sigma_z)^{3/2}}\sqrt{\frac{Z_0}{\sigma_{cond.}}}$$

Material	P_{loss}(W / m)	k_{loss} (V/ nC/ m)	δ / μm
NEG	**16.2**	13.4	12.4
Copper	**1.18**	0.98	0.9

(r = 20 mm, $\phi=2\pi$, σ_z = 9 mm, $c/\sigma_z = 2\pi$ 5.3 GHz)

$$Z_{\|}(\omega) = \frac{1 \mp i}{2\pi\ \phi} L \sqrt{\frac{|\omega|\mu_0}{2\sigma_{cond.}}} = \frac{1 \mp i}{2\pi\ \phi} \frac{L}{\delta(\sigma_{cond.},\omega)} \frac{1}{\sigma_{cond.}}$$

$$\delta(\sigma_{cond.},\omega) = \sqrt{\frac{2}{\mu_0\ \sigma_{cond.}|\omega|}}$$



Heating of Clearing Electrodes

Power loss:

$$P_{loss} = 1.225 \; \frac{\sigma_z}{c} \frac{N_{bunches}}{T_0} \;\; \hat{I}^2 \;\; \mathrm{Re}(Z_{\|}(\omega = \tfrac{c}{\sigma_z}))$$

$$\hat{I} = \frac{c q_b}{\sigma_z \sqrt{2\pi}} = 42.5\,\mathrm{A}, \quad \Gamma(\tfrac{3}{4}) = 1.225, \quad \frac{c}{\sigma_z} = 2\pi \cdot 5.3 \cdot \mathrm{GHz}$$

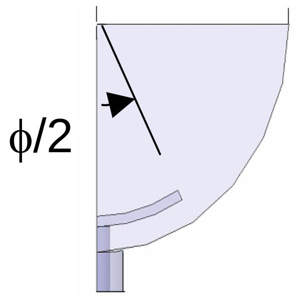
Material	P_{loss}(W / m)
NEG	**16.2**
Copper	**1.18**

(r = 20 mm, $\phi = 2\pi$)

Heating:
Black Body Radiation (isolated Electrode), T_E = temperture of the pipe (Environment)

$$T = \sqrt[4]{\frac{P_{loss}}{\phi \, r \; L \; c_{StB}} + {T_E}^4}, \quad \Delta T = T - T_E$$

$$c_{StB} = 5.67 \cdot 10^{-8} \, \frac{\mathrm{W}}{\mathrm{m}^2 \, \mathrm{K}^4}$$



Material	ΔT / K
NEG	**17.5**
Copper	**1.4**

(r = 20 mm, T_E=310 K)

T does not depend on ϕ,
since $I \sim \phi^2$, $Z \sim 1/\phi$, $P \sim \phi$

Conclusions

- **Loss and Kick parameter for a resistive wall have been calculated for the ILC DR for different materials.**

- **The betatron tune shift seems to be tolerable even if the whole chamber is coated with NEG material.**

- **The dissipated power in the chamber wall is 1 W/m …16 W/m depending on the material.**

- **The Heating of isolated clearing electrodes is small if the electrodes are made from copper.**

- **There are different measurements for the resistivity of NEG material:**

$$\sigma_{\mathrm{NEG,\,CERN}} \approx 0.31 \cdot 10^{6} (\Omega\,\mathrm{m})^{-1}$$ CERN,

$$\sigma_{\mathrm{NEG,\,ESRF}} \approx 0.06 \cdot 10^{6} (\Omega\,\mathrm{m})^{-1}$$ ESRF (E. Plouviez), SOLEIL,

R. Nagaoka: Study of Resistive-Wall Effects on SOLEIL, EPAC 2004