Power Losses due to Button and Reentrant BPMs

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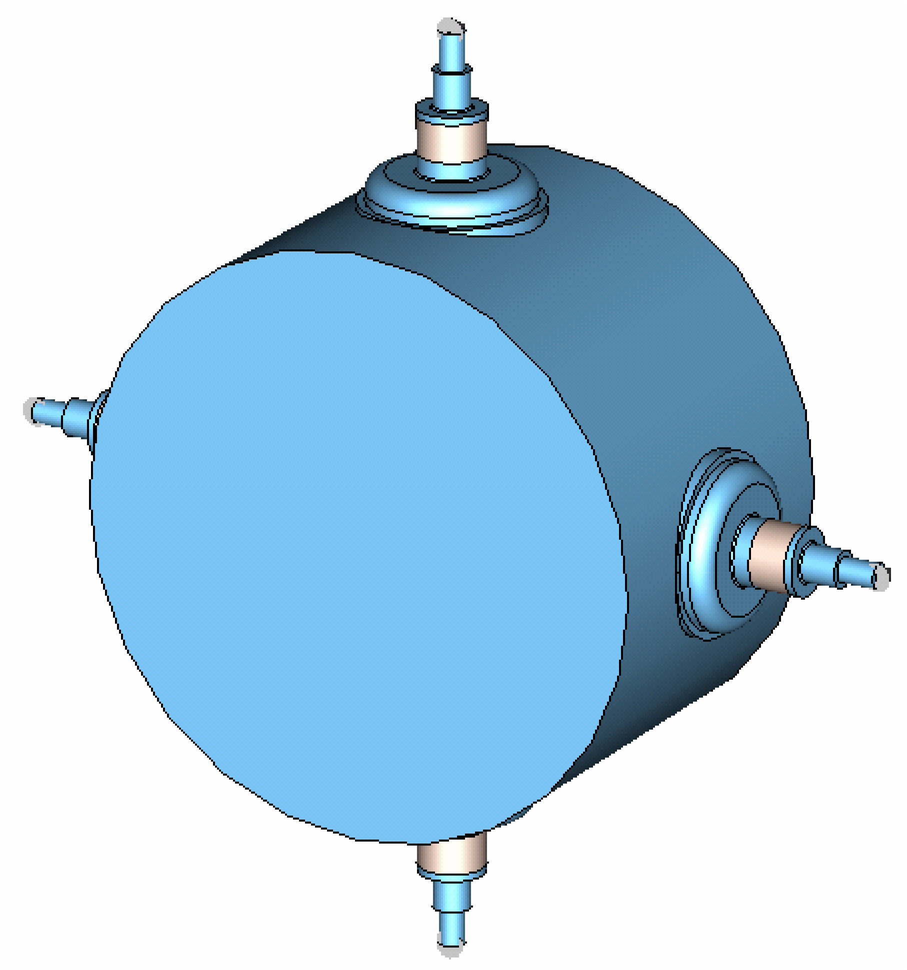
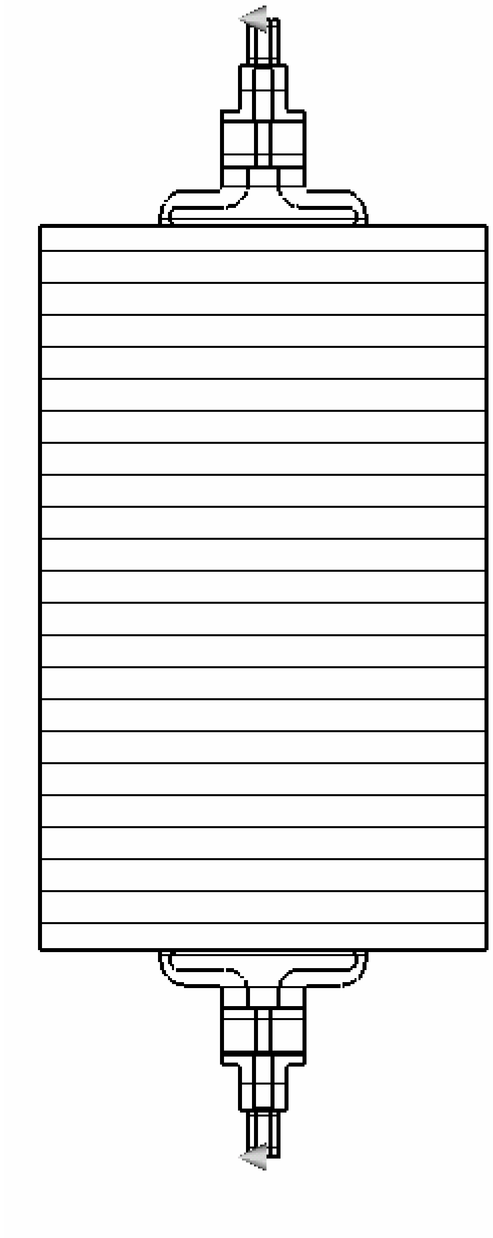
01.10.07

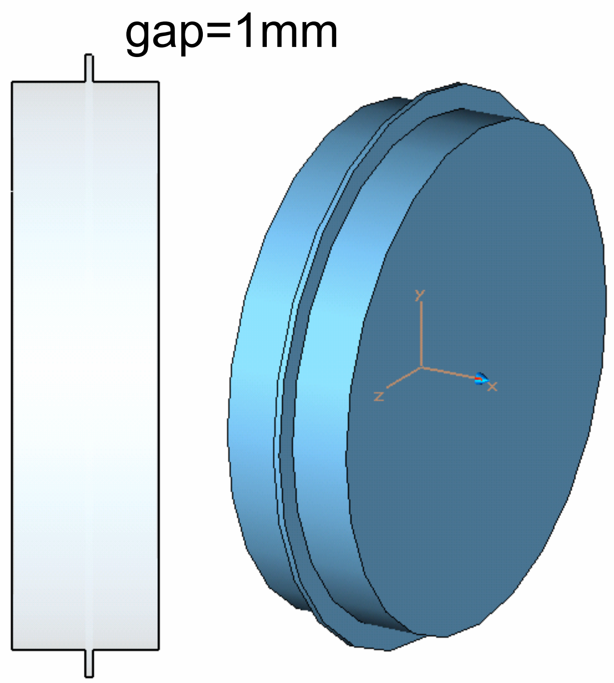
BD meeting, DESY

Button BPM





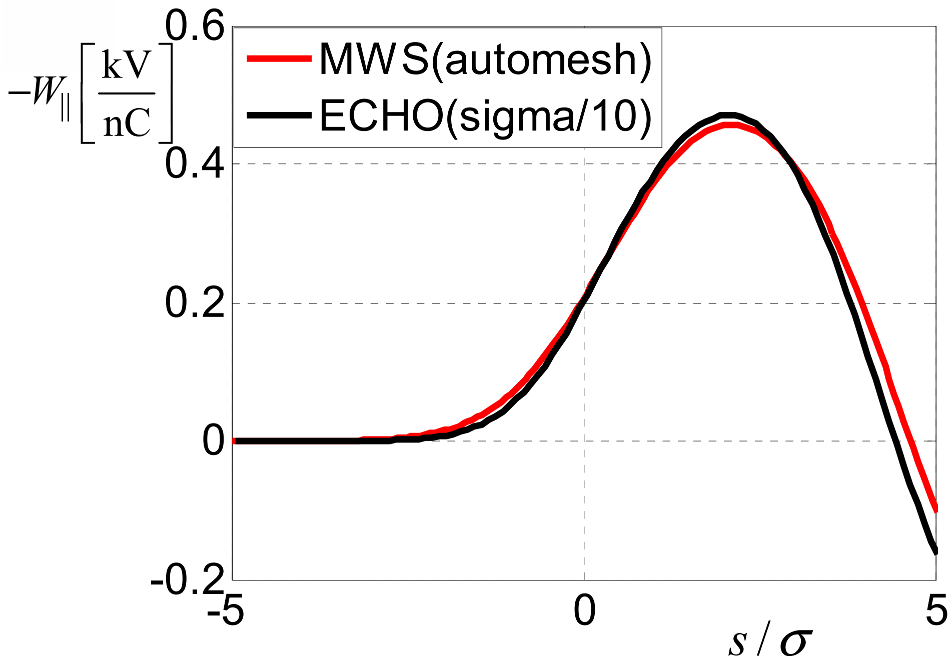
Accuracy Test of CST Microwave Studio -> OK

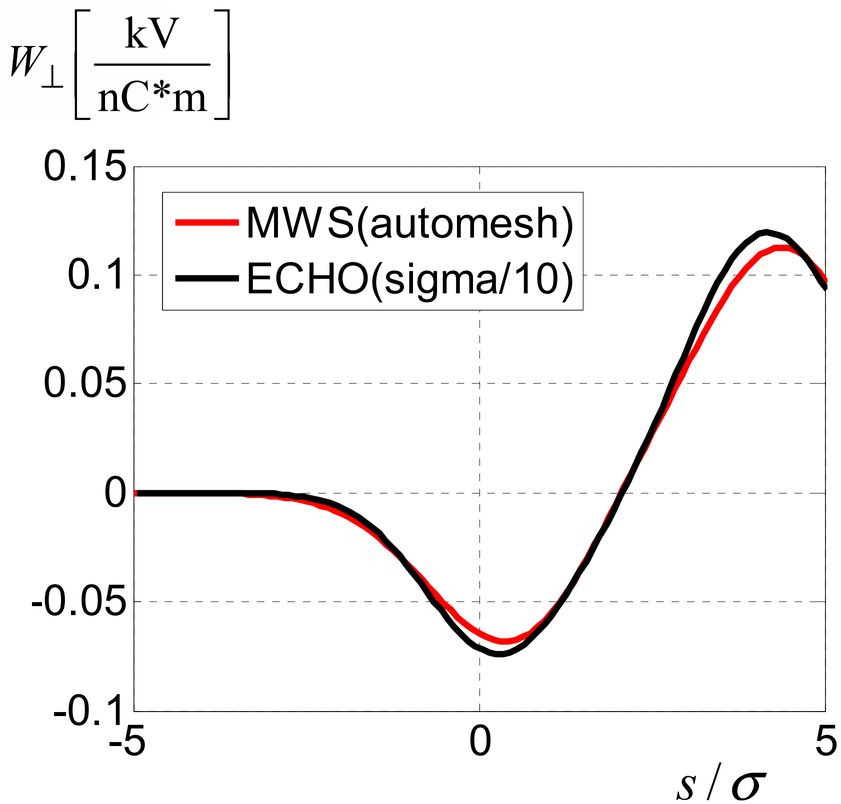


Gaussian bunch with sigma=2mm

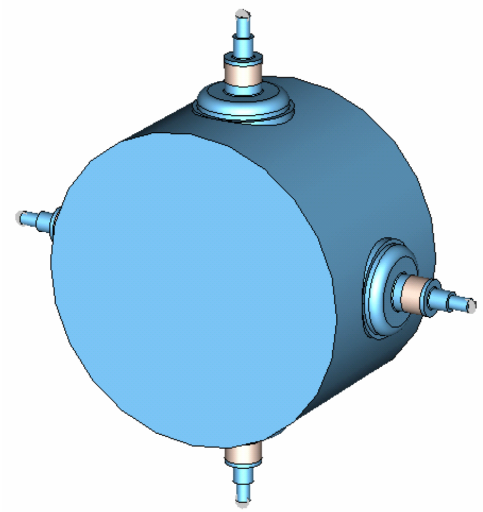
Loss = 0.05 kV/nC

Kick = 0.2 kV/nC/m





BPM with Microwave Studio



Gaussian bunch with sigma=1mm

Loss = 0.047 kV/nC

Kick = 0.13 kV/nC/m

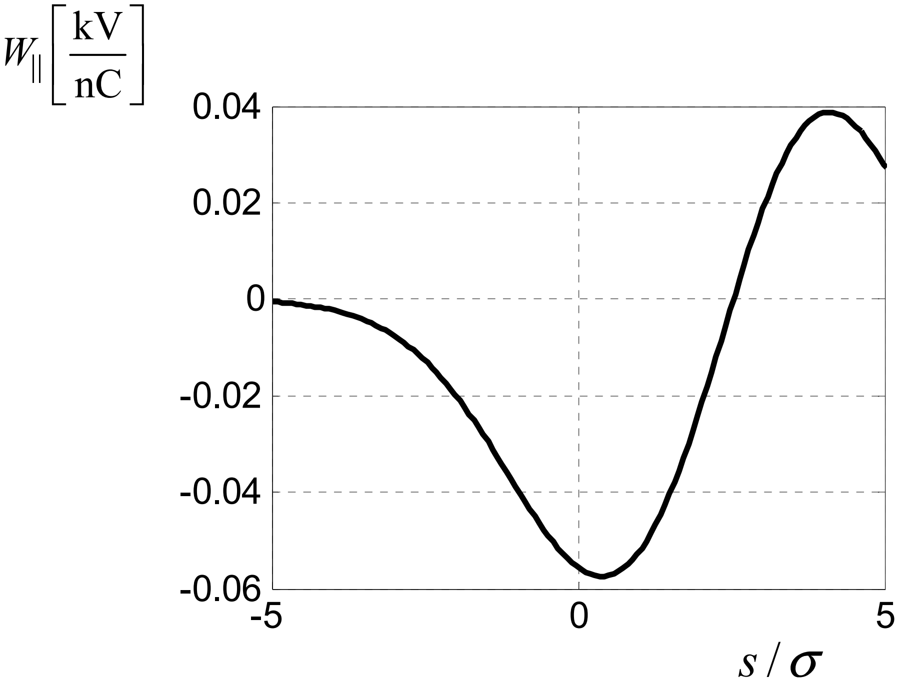
$\text{Loss} = O(\sigma^{-0.5})$

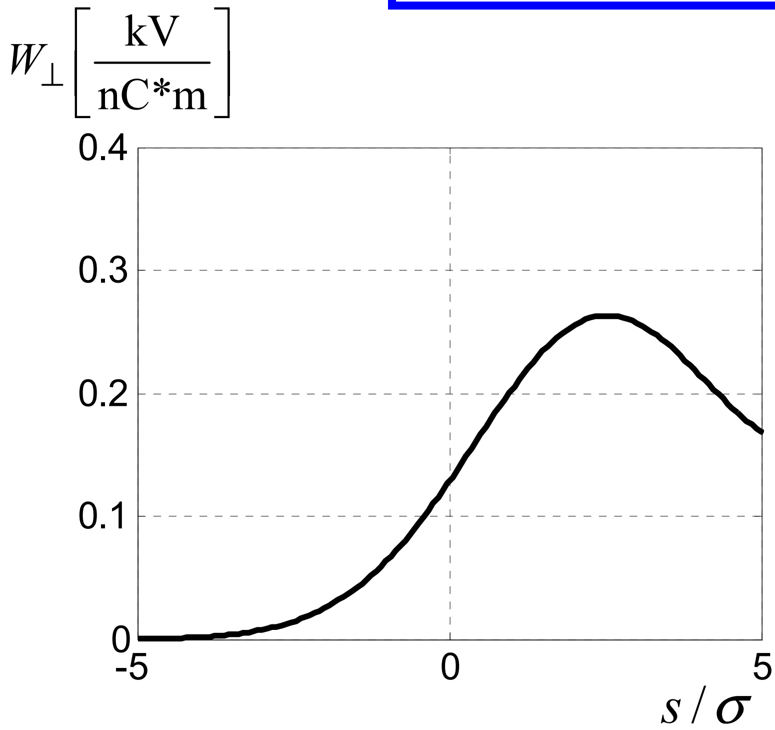
$\text{Kick} = O(\sigma^{0.5})$

Gaussian bunch with sigma=25mkm

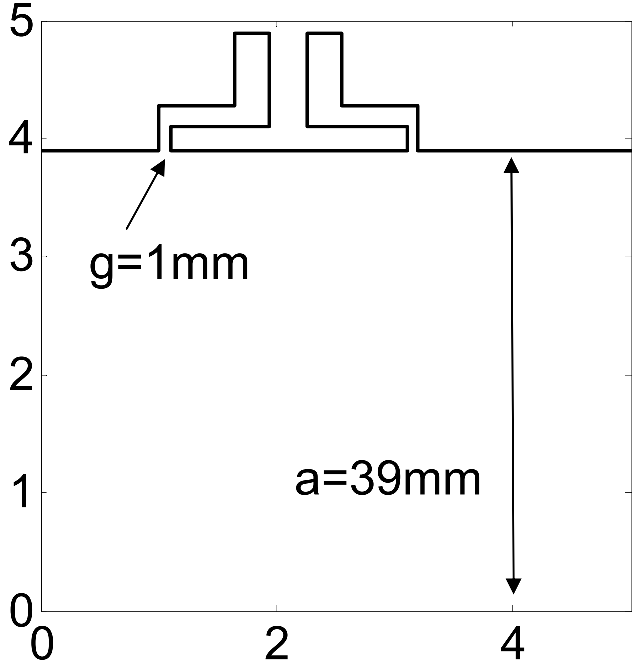
Loss = 0.3 kV/nC

Kick = 0.02 kV/nC/m





Rotationally symmetric model with ECHO (as an estimation from above)



sigma, μm	Loss, kV/nC	Kick, kV/nC/m
2000	0.11	0.44
100	0.77	0.143
25	1.68	0.076

$\text{Loss} = O(\sigma^{-0.5})$ $\text{Kick} = O(\sigma^{0.5})$

Analytical estimation (K.Bane, Sands M., SLAC-PUB-4441, 1987)

$$w_{||}^{\delta}(s) = \frac{Z_0 c}{\sqrt{2}\pi^2 a}\sqrt{\frac{g}{s}}$$

$$w_{\perp}^{\delta}(s) = \frac{2}{a^2}\frac{\sqrt{2}Z_0 c}{\pi^2 a}\sqrt{gs}$$

$$\text{Loss} = \frac{Z_0 c}{4a\pi^{2.5}}\Gamma\left(\frac{1}{4}\right)\sqrt{\frac{g}{\sigma}}$$

$$\text{Kick} = \frac{2}{a^3}\frac{Z_0 c}{\pi^{2.5}}\Gamma\left(\frac{3}{4}\right)\sqrt{g\sigma}$$

Power Loss

$$N_b = 3250\,[bunches]$$

$$f_{rep} = 30\,[Hz]$$

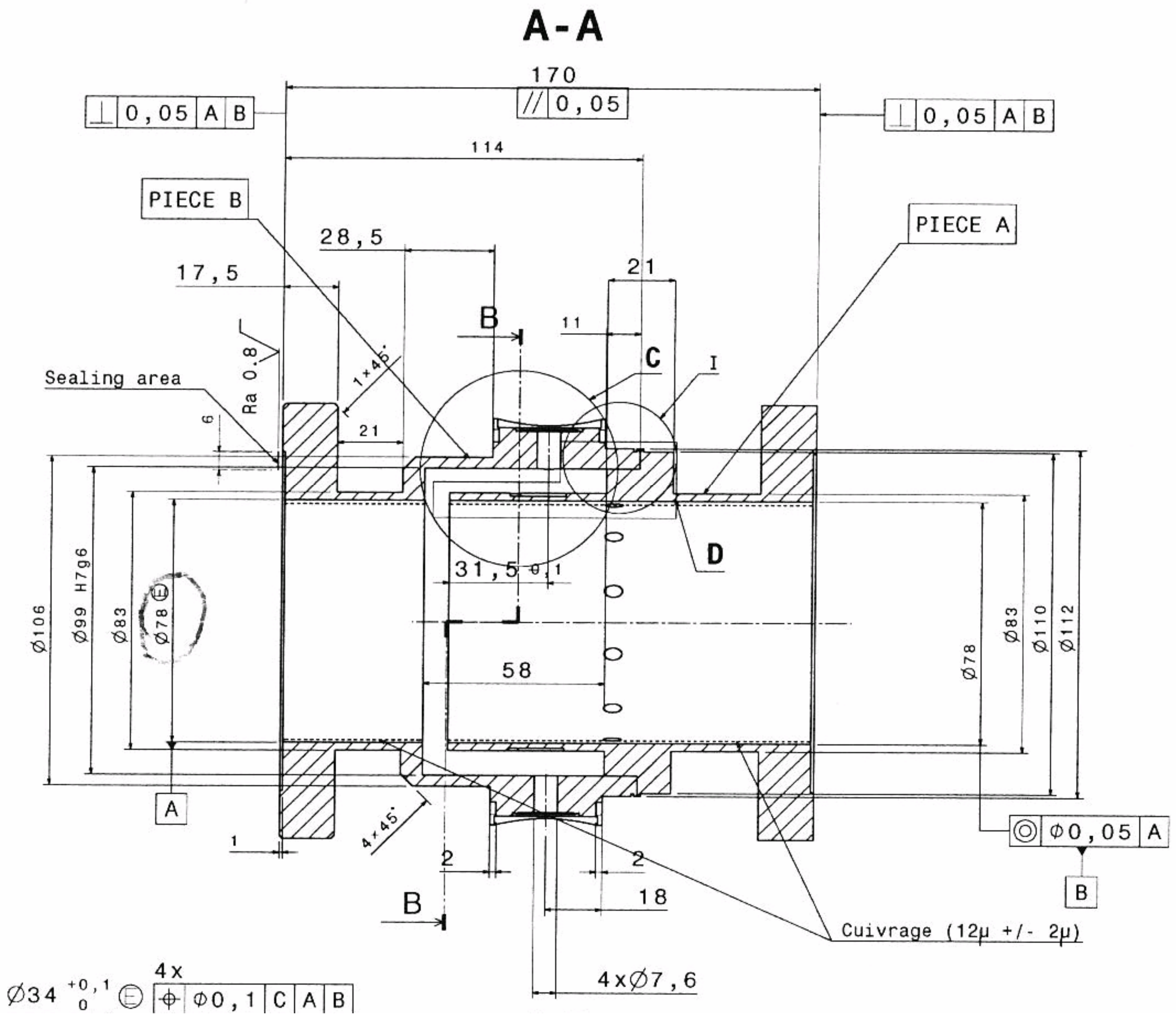
$$q = 1\,[nC]$$

$$P = N_b f_{rep} q^2 k_{loss}$$

for $k_{loss} = 1.68\,\frac{\text{kV}}{\text{nC}}$ $\quad$ $P_{geom} \le 0.16[W]$ $\quad$ (**upper level**, round approx.)

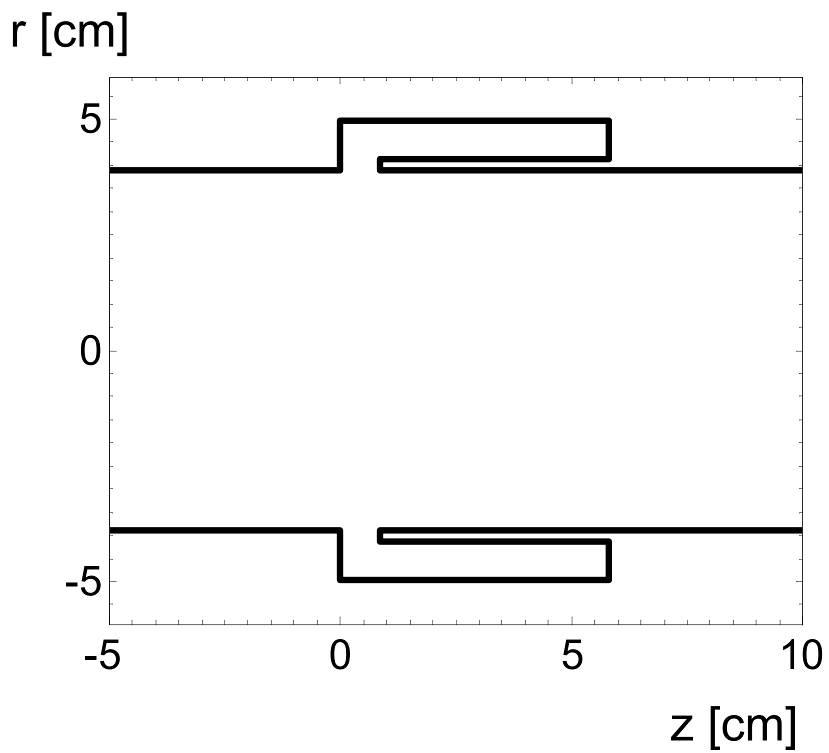
for $k_{loss} = 0.3\,\frac{\text{kV}}{\text{nC}}$ $\quad$ $P_{geom} \le 0.03[W]$ $\quad$ (**“real”**, scaled, see slide 4)

Reentrant BPM



gap=8.5 mm

Reentrant BPM



Gaussian bunch with sigma=25 mkm

g=8.5 mm, a=39 mm

$$\text{Loss} = \frac{Z_0 c}{4 a \pi^{2.5}} \Gamma\left(\frac{1}{4}\right)\sqrt{\frac{g}{\sigma}}$$

Loss (analytical) = **2.77** kV/nC

Loss (ECHO) = **2.68** kV/nC

Reentrant BPM

Long range wake

Up to 3 m for sigma =2.5 mm

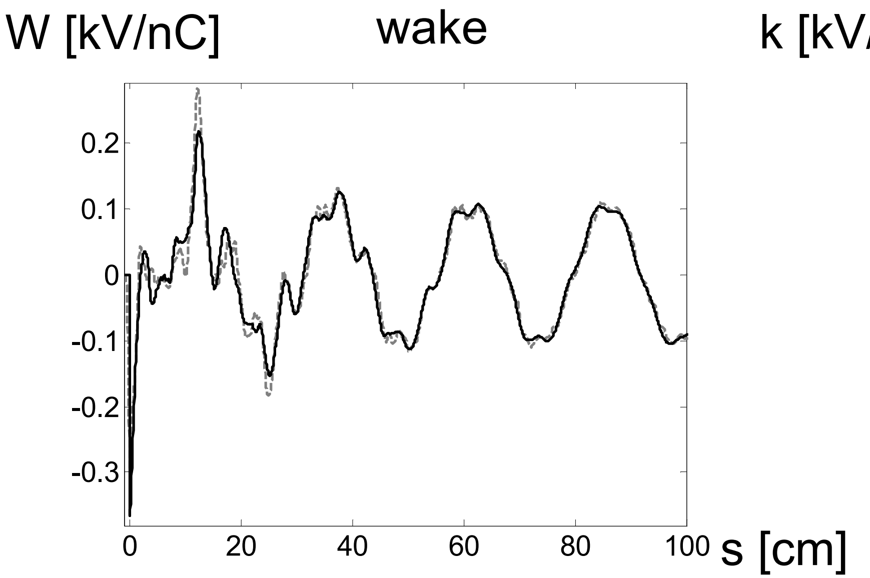
$$W(s) = \sum_{i=0}^{N} 2k_i \cos\left(2\pi f_i \frac{s}{c}\right) e^{-\alpha_i \frac{s}{c} - \left(\frac{\pi f_i}{2c}\right)^2 \sigma^2}$$

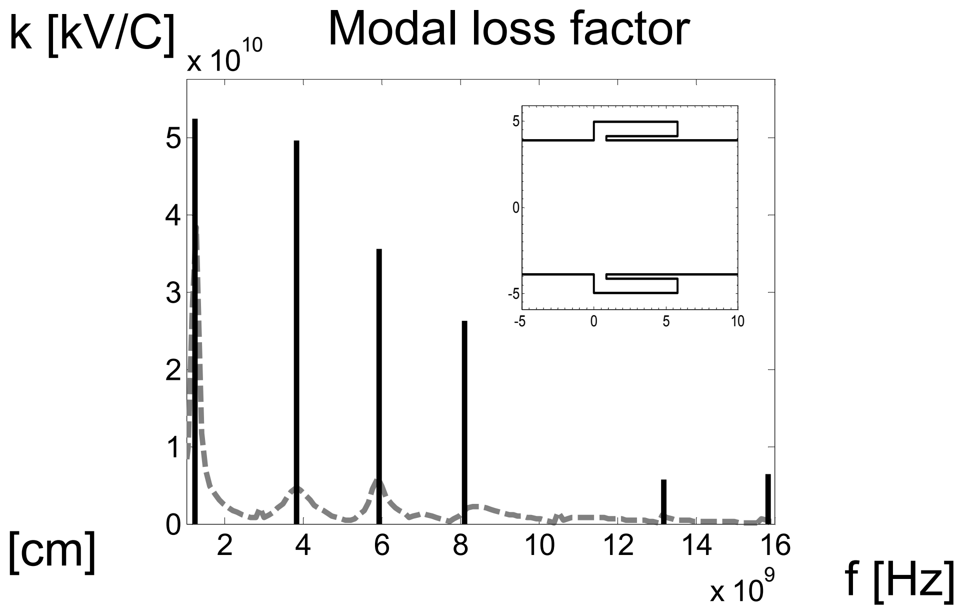
$$Loss \approx \sum_{i=0}^{N} 2k_i e^{-\left(\frac{\pi f_i}{2c}\right)^2 \sigma^2}$$

Prony-Pisarenko fit

P. Thoma, Berechnung der Güten einiger Resonanzen
eines verlustfreien Resonators mit angekoppeltem verlustfreien Wellenleiter.
(1992, Darmstadt, Diplomarbeit betreut bei Martin Dohlus)

Long range wake





	Freq, GHz	2*K_n, kV/nC	alpha	Q
1	1.22	**0.105**	0	Inf
2	3.81	**0.099**	0.22	5.3634
3	5.91	**0.071**	0.08	24.3639
4	8.1	**0.052**	0.17	14.8516
5	13.2	**0.012**	0.1	42.3142

$$Q_i = \frac{\pi f_i}{\alpha_i}$$

$$f_{cutoff} = 2.4048 \frac{c}{2\pi a} = 2.94\text{GHz}$$

$$Loss(5) = \sum_{i=0}^{4} 2k_i e^{-\left(\frac{\pi f_i}{2c}\right)^2 \sigma^2} = \mathbf{0.33}\,\frac{\text{kV}}{\text{nC}}$$

Loss for sigma = 25mkm (ECHO) = **2.68** kV/nC

Button BPM vs. Reentrant BPM

for sigma = 25mkm

$N_b = 3250\,[bunches]$

$f_{rep} = 30\,[Hz]$

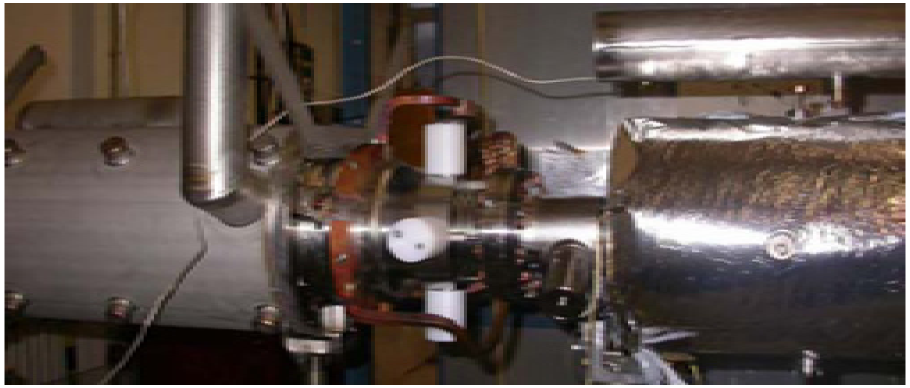
$q = 1\,[nC]$

	Loss factor, kV/nC	Power loss, Watt
Button BPM	0.3	0.03
Button BPM (optimized for signal)	0.8	0.08
Reentrant BPM	2.7	0.26

BPM vs. others

for sigma = 25mkm $N_b = 3250\,[bunches]$ $f_{rep} = 30\,[Hz]$ $q = 1\,[nC]$

	Loss factor, kV/nC	Power loss, Watt
Button BPM (optimized for signal)	0.8	0.08
Reentrant BPM	2.7	0.26
10 flange gaps (0.6 mm)	0.66*10=6.6	0.64
TESLA Cryomodule (including belows)	148	14.4



superconductive normal conductivity

Acknowledgements

- *to Martin Dohlus for useful discussions*

- *to Rolf Schuhmann for “Prony-Pisarenko” Matlab script*

- *to CST GmbH for the new wakefield solver*