Summary II: Space charge and resistive-wall impedances

G. Stupakov

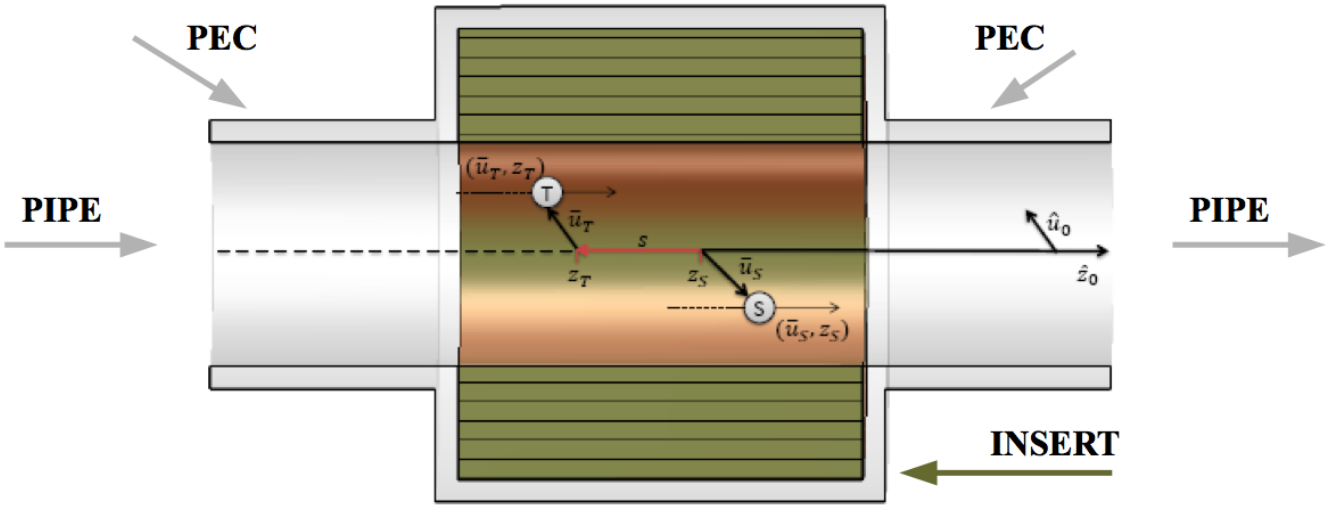
ICFA mini-Workshop on Electromagnetic wake fields and impedances in particle accelerators"
April 24–28, 2014
Erice, Sicily

Three talks

1. N. BIANCACCI (CERN), "Analytical methods for Analytical methods for inserts of finite length as benchmarkers"
2. U. NIEDERMAYER (TUD), "Impedance computation in the frequency domain"
3. M. BLASKIEWICZ (BNL) "High frequency transverse beam transfer function"

N. BIANCACCI "Analytical. . ."

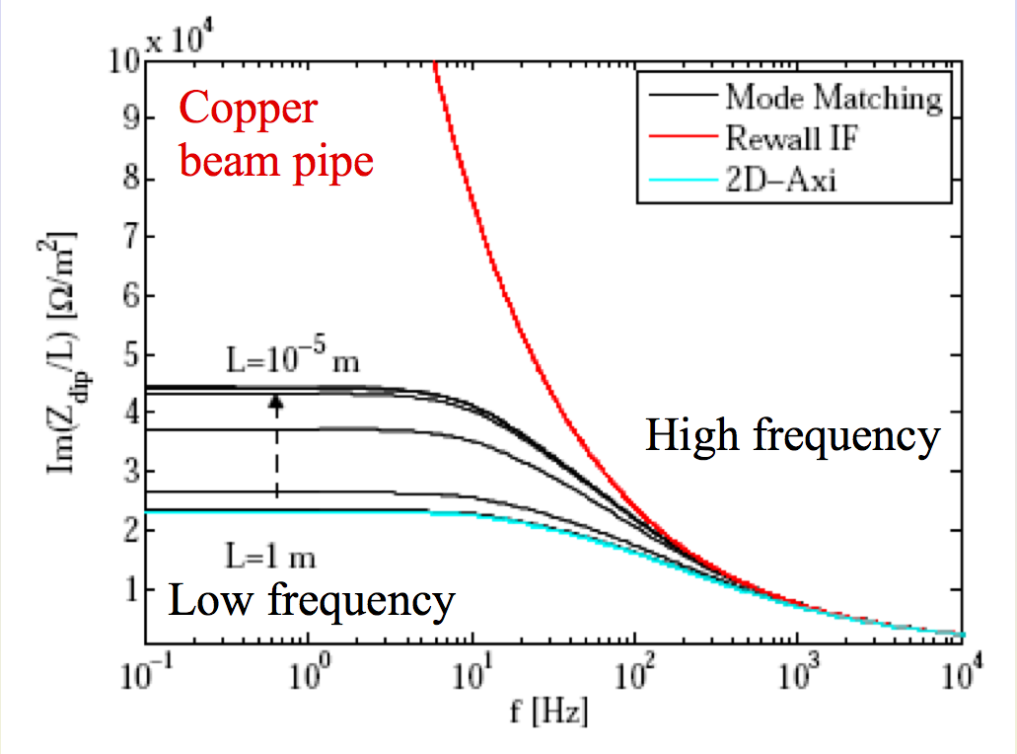
Model → Cavity loaded with a toroidal insert connected to the beam pipes.



Assumptions →
- ✔ Any relativistic β
- ✔ Any insert length, pipe/cavity radius
- ✔ Any frequency range
- ✔ Linear, isotropic, homogeneous, dispersive material

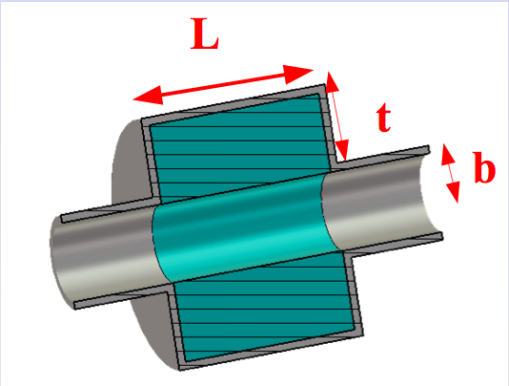
Mode matching analysis is used to solve the problem.

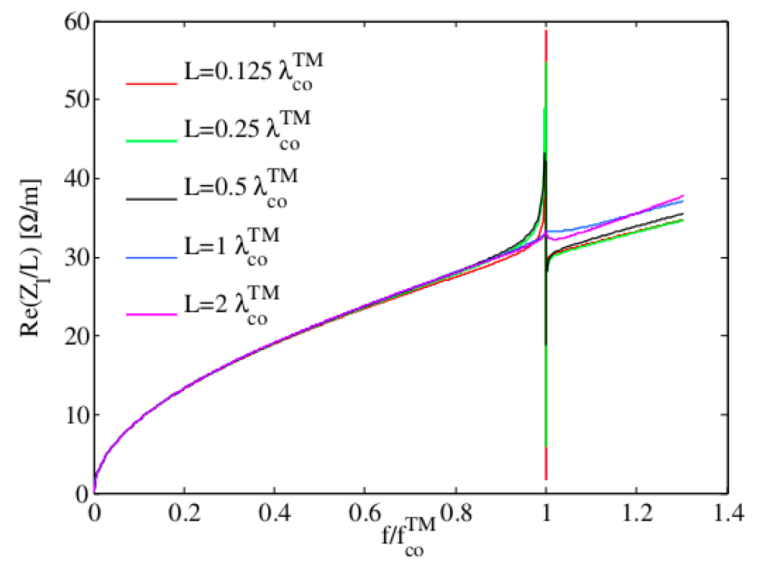
N. BIANCACCI "Analytical. . ."



Difference apparent only in the transverse impedance at low frequency, and very narrow gaps.

N. BIANCACCI "Analytical. . ."



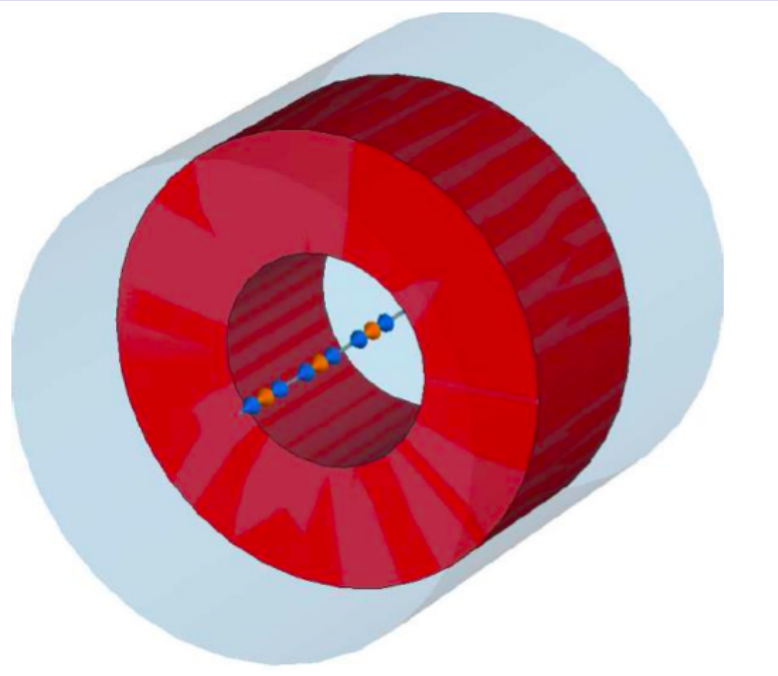


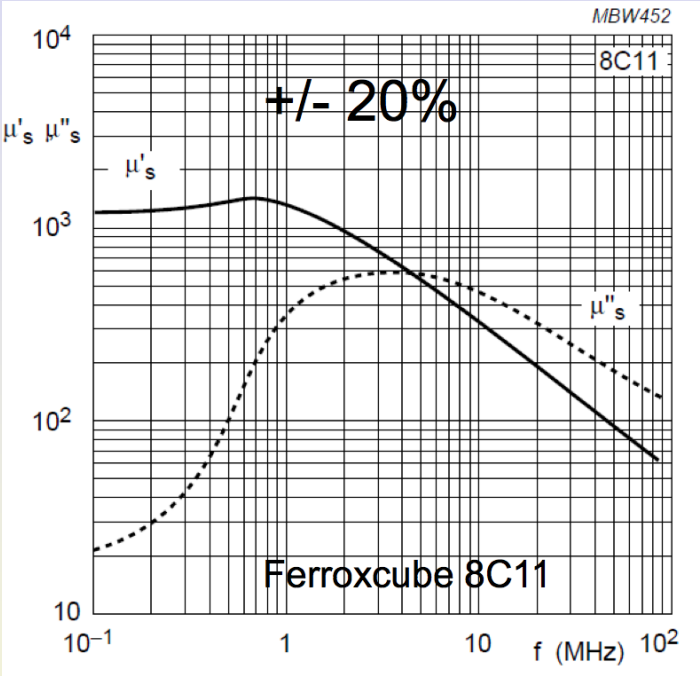
Even for very short inserts, there are trapped modes close to cut-off

G. Stupakov and S. S. Kurennoy. Phys. Rev. E (1994).

U. NIEDERMAYER "Impedance computation. . ."

Ferrite Ring in a perfectly conducting pipe





$$\nabla \times \underline{\mu}^{-1} \nabla \times \underline{\vec{E}} + i\omega\kappa\underline{\vec{E}} - \omega^2\varepsilon\underline{\vec{E}} = -i\omega\underline{\vec{J}}_{ext}$$

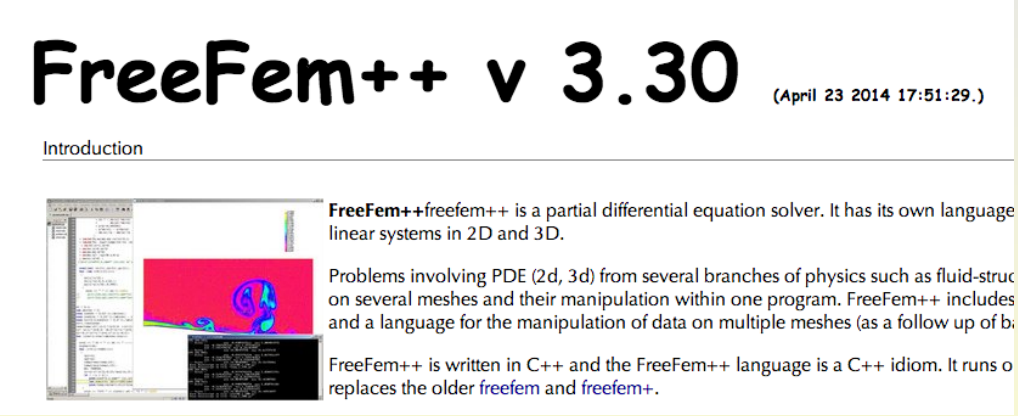
Natural approach to the problem—frequency domain analysis.

U. NIEDERMAYER "Impedance computation. . ."

Finite Integration Technique (FIT) versus Finite Element Method (FEM)
FEniCS (www.fenicsproject.org)

- Can be run by Python script
- Mesh generator→Everything free and open source
- Compiler for weak formulations of PDE

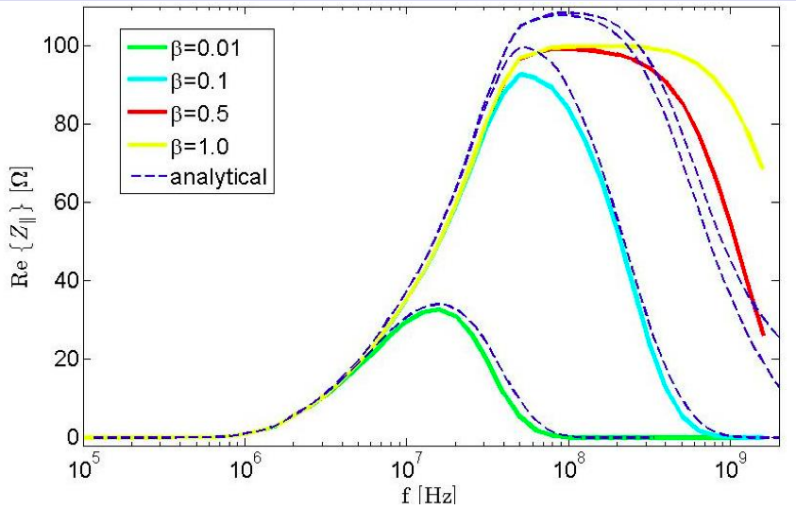
A similar tool:

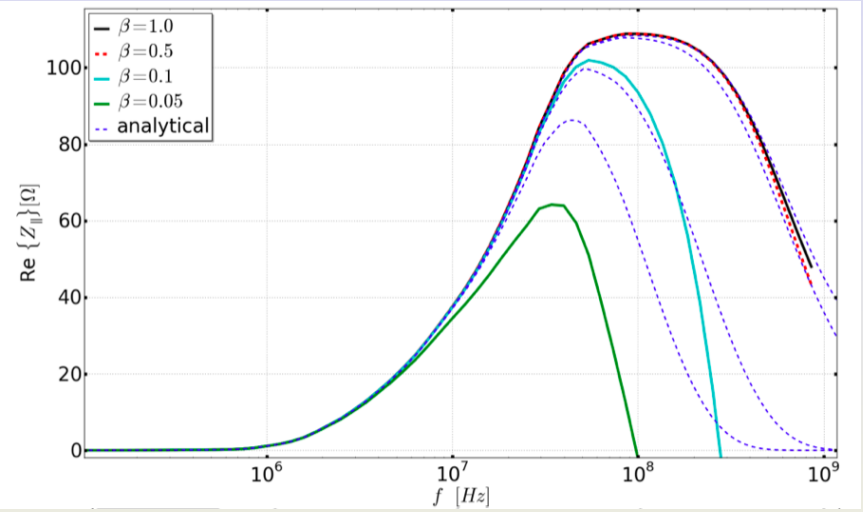


These tools can very useful for those who occasionally need to numerically solve impedance problems.

U. NIEDERMAYER "Impedance computation. . ."

Comparison of FIT and FEM solutions





Conclusions (partial)

- Both methods work well in 2D
- Convergence studies yet to be done
- Small skin depth hard to treat

M. BLASKIEWICZ, "High frequency. . ."

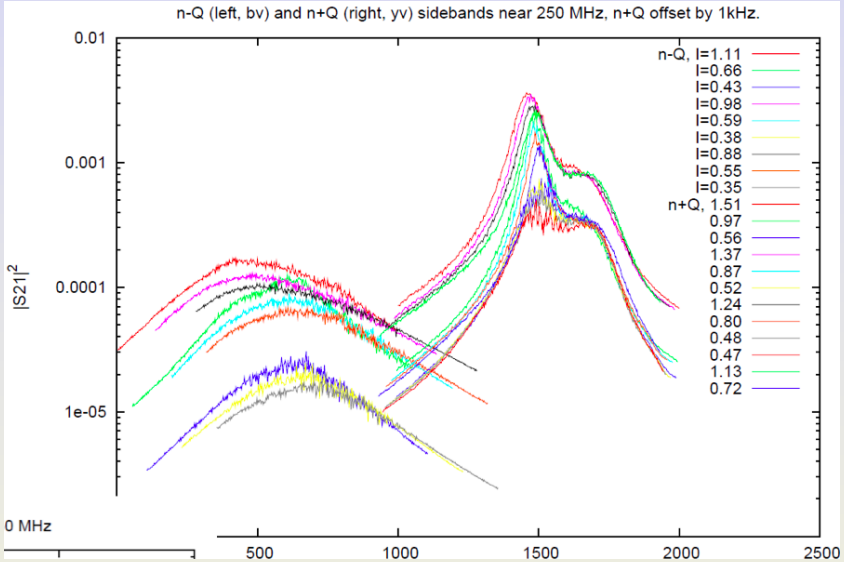
Vertical BTF data near 250 MHz were taken for RHIC at 25.5 GeV. With the FWHM bunch length ~ 20 ns, the coasting beam model is a good first approximation.
Cold coasting beam

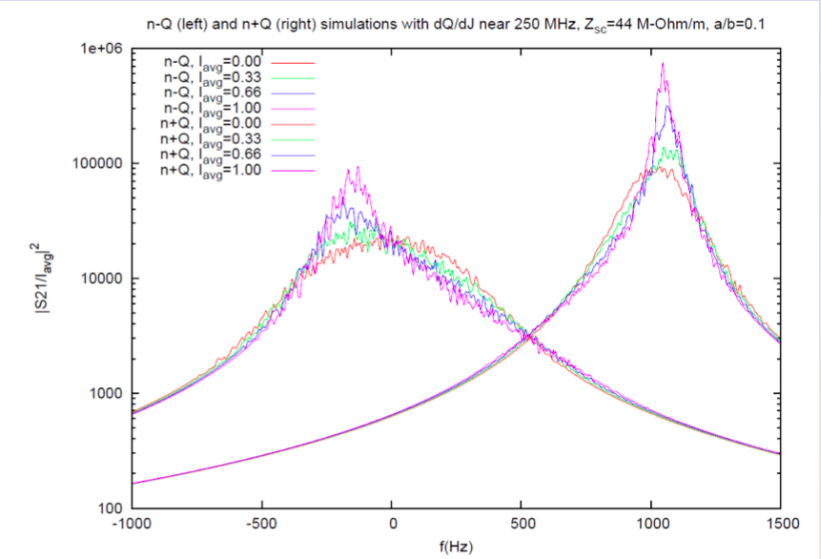
$$\left(\frac{\partial}{\partial t}+\nu_0\frac{\partial}{\partial s}\right)^2 y(s,t)+\omega_y^2 y(s,t)=-\frac{q}{2\pi R\gamma m}\int_0^\infty d\tau W_y(\tau) I_0 y(s,t-\tau)$$

An external driving term should be added to the RHS to treat BTF. More accurate treatment based on Vlasov equation which takes into account the beam energy spread is also available, as well as computer code TRANFT.

M. BLASKIEWICZ, “High frequency. . .”

Experiment (left) versus simulations (right)





- Coasting beam calculations showed much larger increase of n+Q peak
- Simulations showed less n+Q peak growth but the shift in n-Q with intensity was somewhat different
- The shoulder observed on the n+Q sidebands is not understood.