Bellow or not bellow?

CAS SCHOOL SWEDEN 2017: VACUUM FOR PARTICULE ACCELERATORS

IMPEDANCE CALCULATIONS TUTORIAL ASSIGNMENT

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HOT POTATO

CONSIDER TWO SETS OF 2 POTATOES TUBES THAT NEED TO BE CONNECTED BY A BELLOW (DIAMETER OF 7 MM AND 18 MM).

FIND FOR EACH CASE A SUITABLE TRADE-OFF BETWEEN MECHANICAL AND IMPEDANCE CONSTRAINTS

Outline

1. Reference case:
   - Continuous case
2. With 2 mm gap connection
3. Bellow connection:
   - Convolution depth effect
   - Bunch length effect
   - Effect of the radius of the pipe

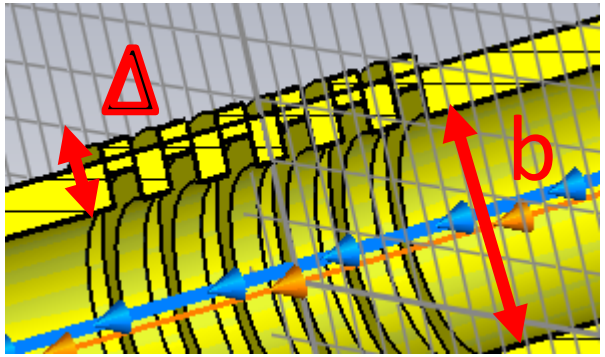
Impedance Gymnastics

Longitudinal Effective Impedance

$$\frac{Z_{\parallel}}{n} = j\frac{Z_0\beta\ell}{2\pi R}\ln\frac{b+\Delta}{b}$$

Proportional to l*Δ/b if Δ<<b

Power Losses & Longitudinal Beam Instabilities



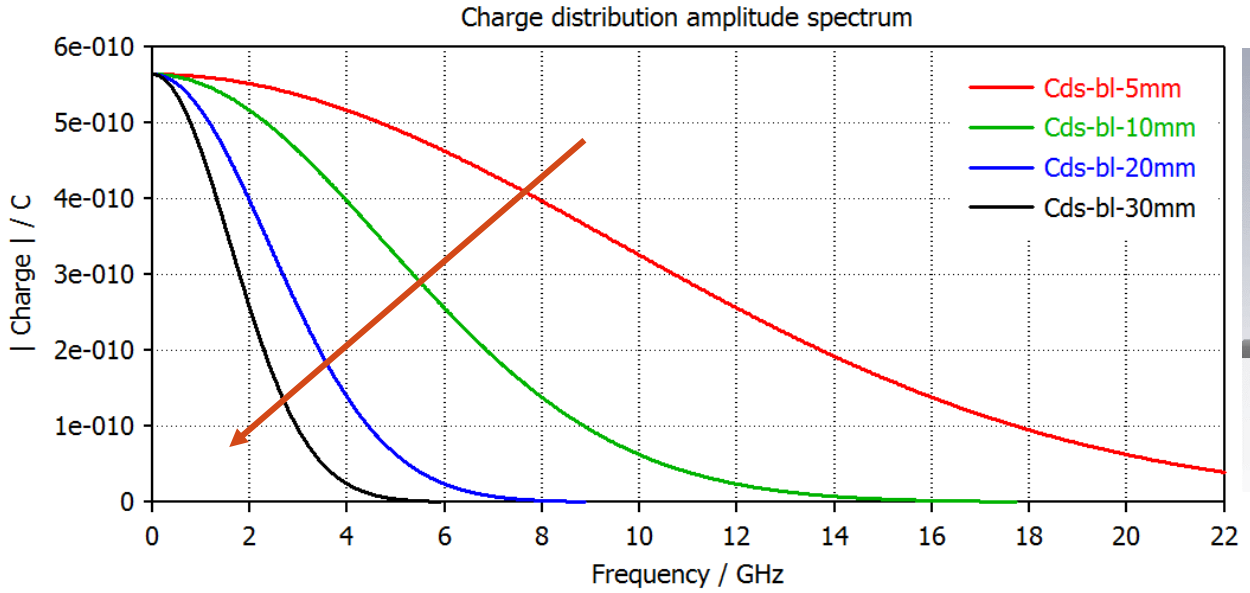
Transverse effective impedance

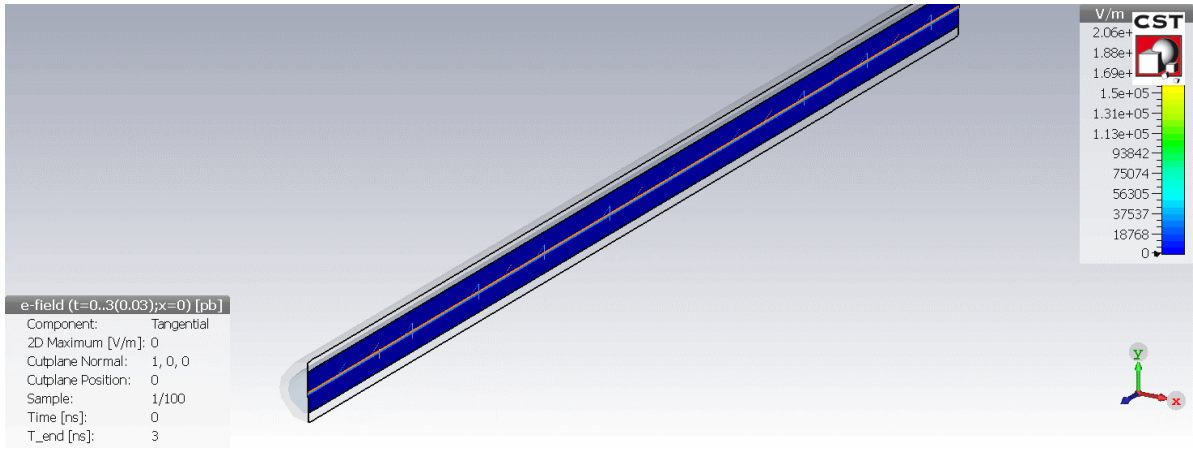
$$Z_{\perp} = j\frac{Z_0\ell}{2\pi}\left[\frac{1}{b^2} - \frac{1}{(b+\Delta)^2}\right]$$

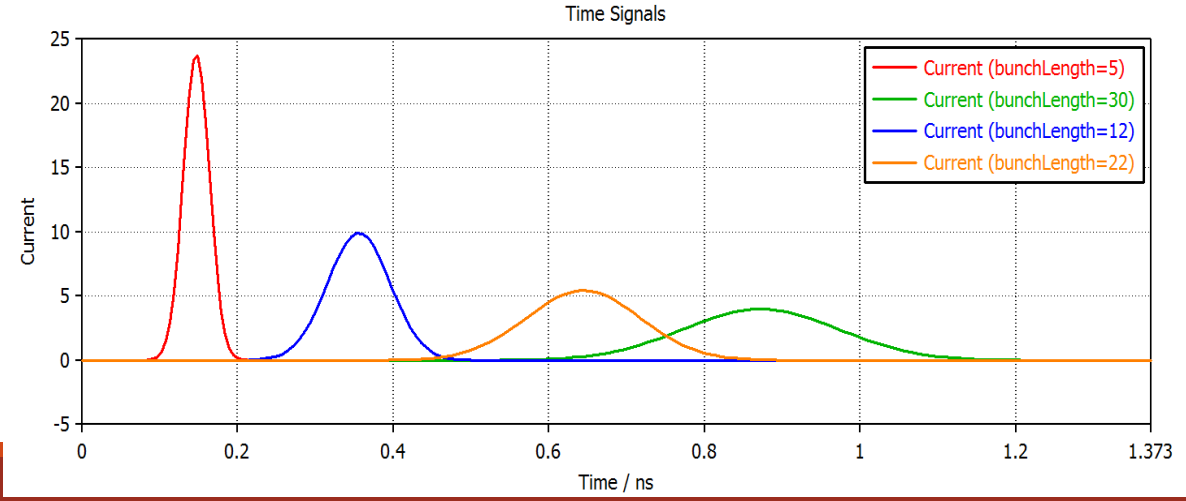
Proportional to $l*\Delta/b^3$ if Δ<<b

Transverse Beam Instabilities

Reference case: continuous perfect conducting tube



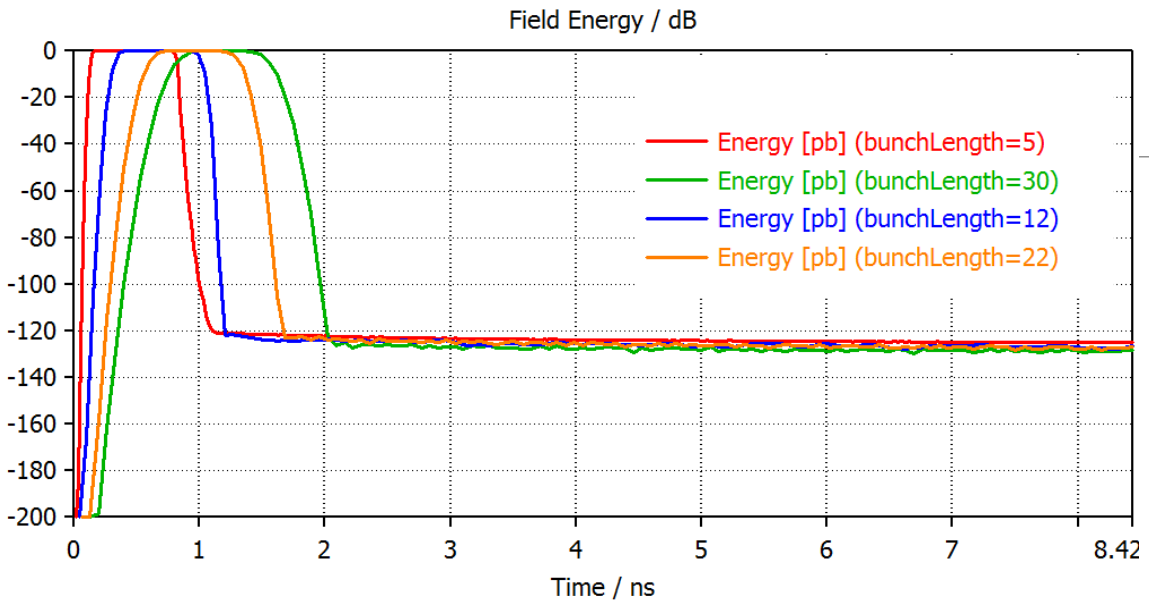




Boundary conditions:

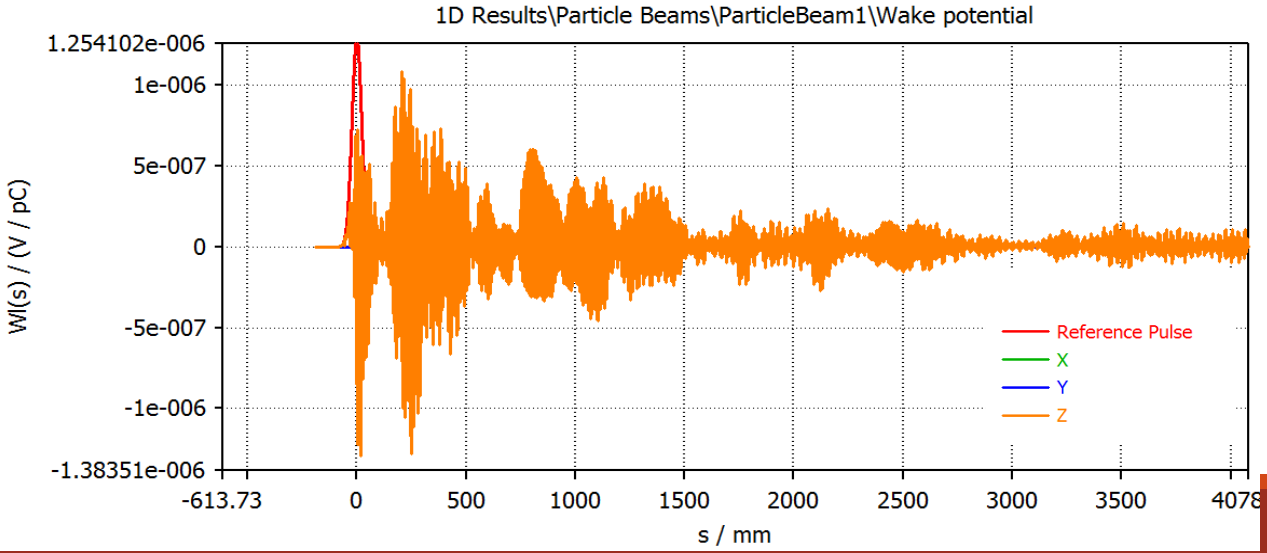
- Centred beam → Longitudinal Impedance only;
- Perfect Conducting;
- Φ = 7 mm;
- 4σ longitudinal beam length

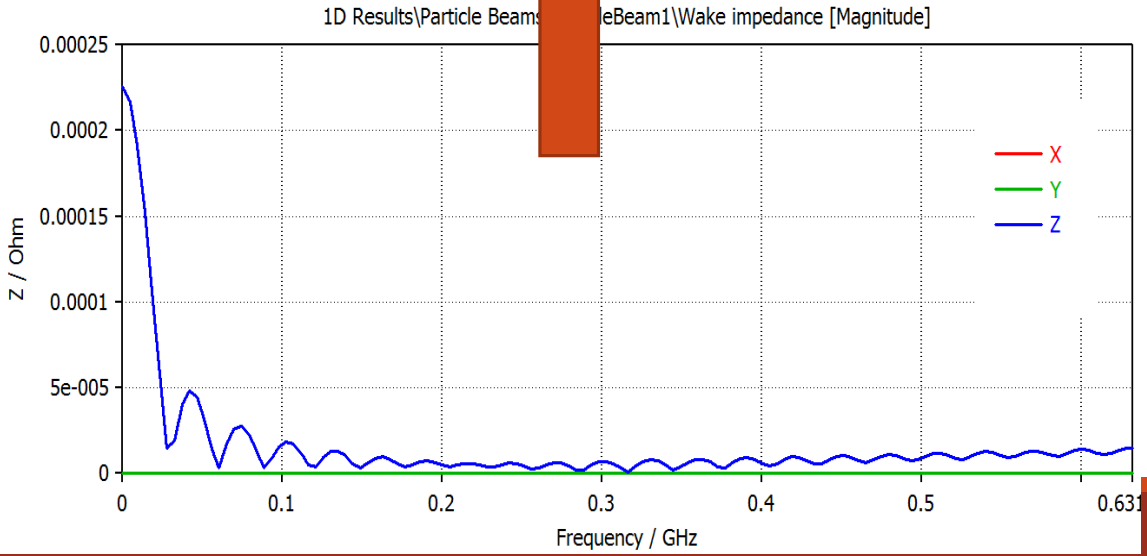
Reference case: continuous perfect conducting tube



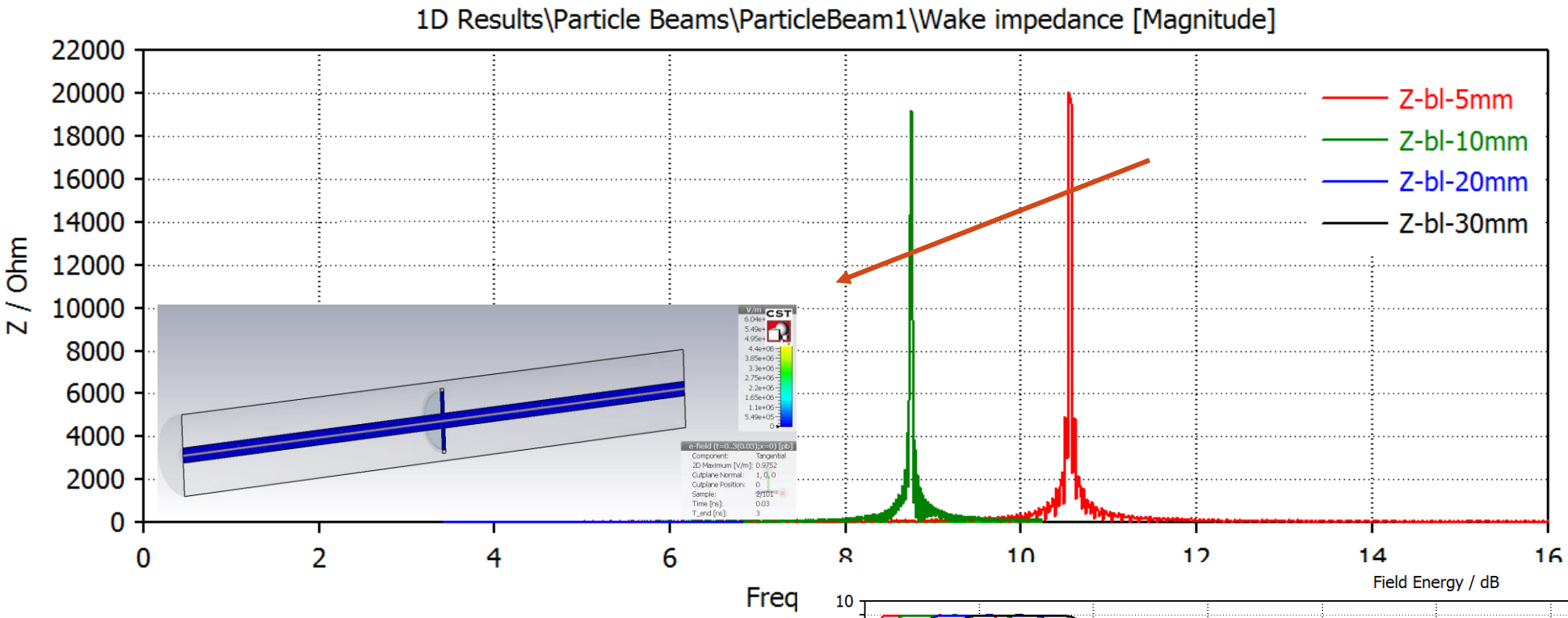
Energy stored in the tube

Simulation Instabilities



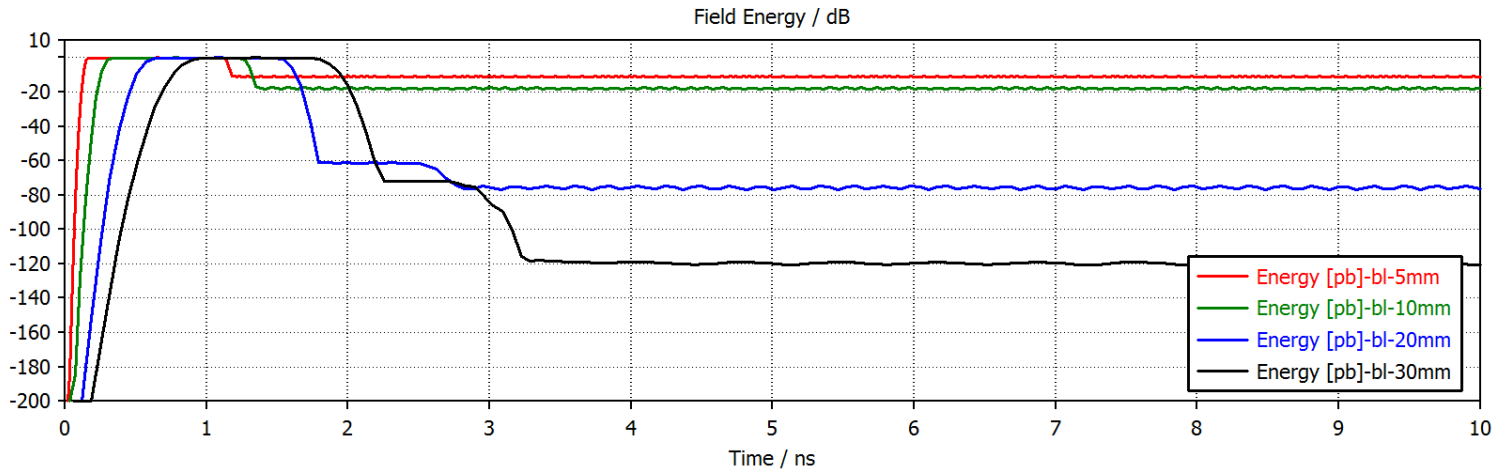


Case study : 2 mm cavity gap

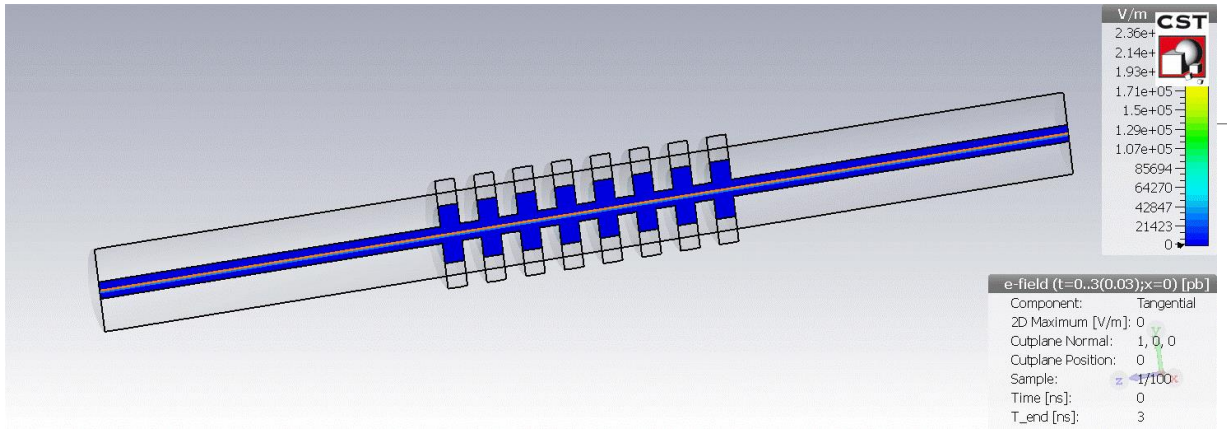


Frequency shift → different cavity diameter.

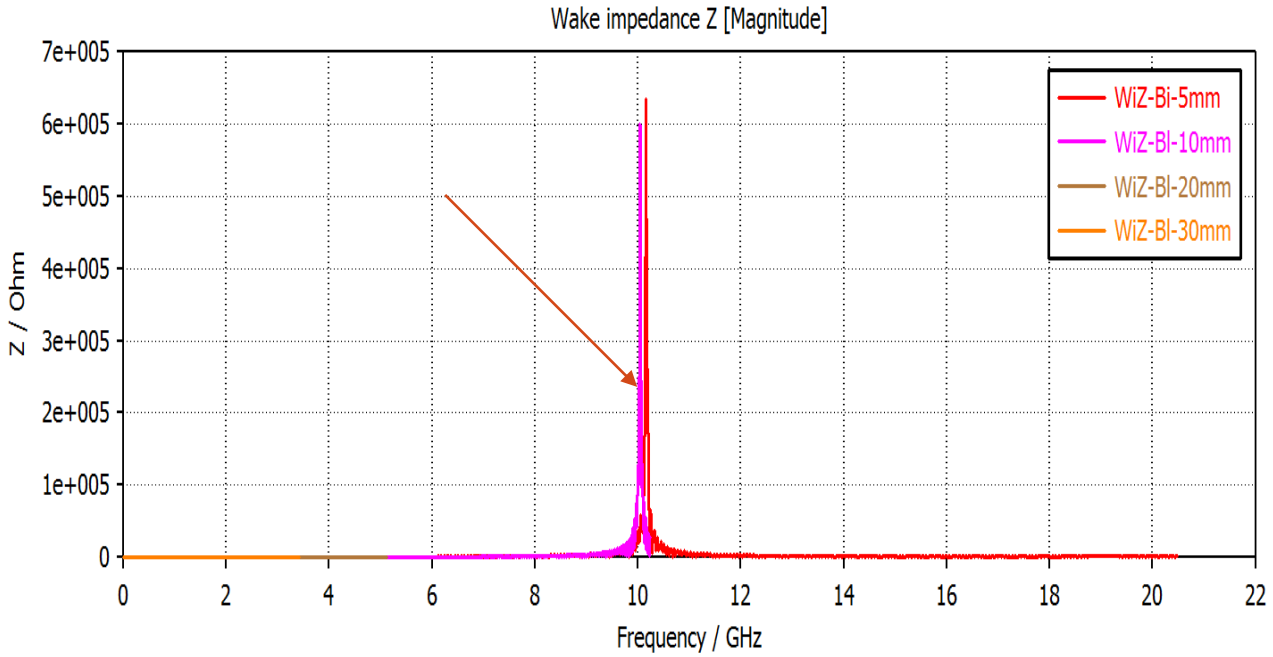
Different stored energy → beam length.

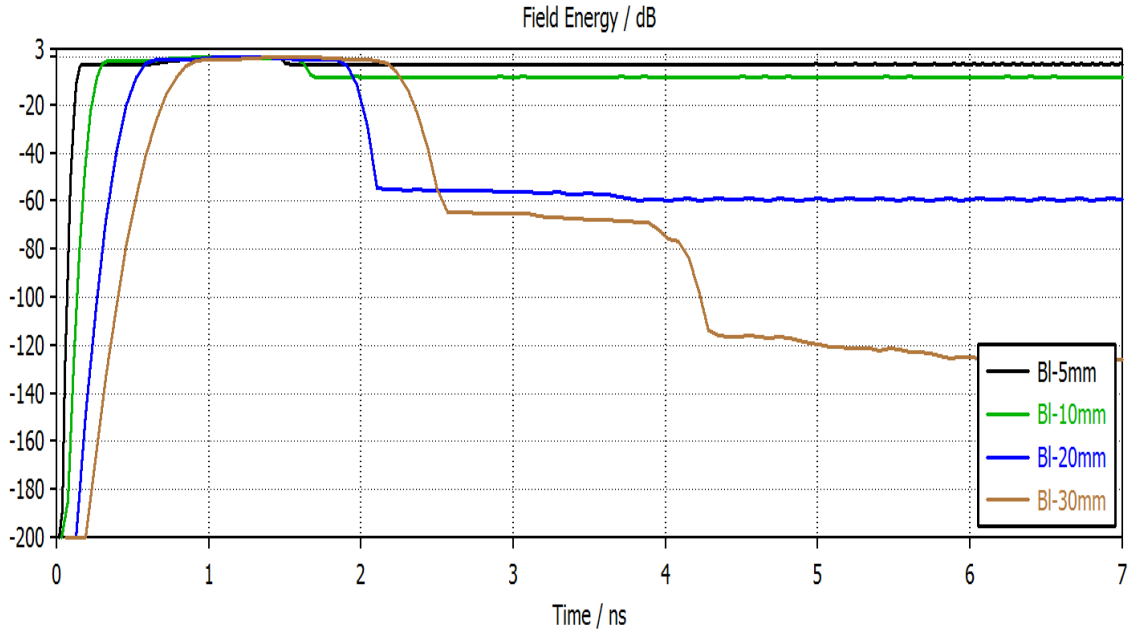


Case study : bellow, 8mm convolution depth

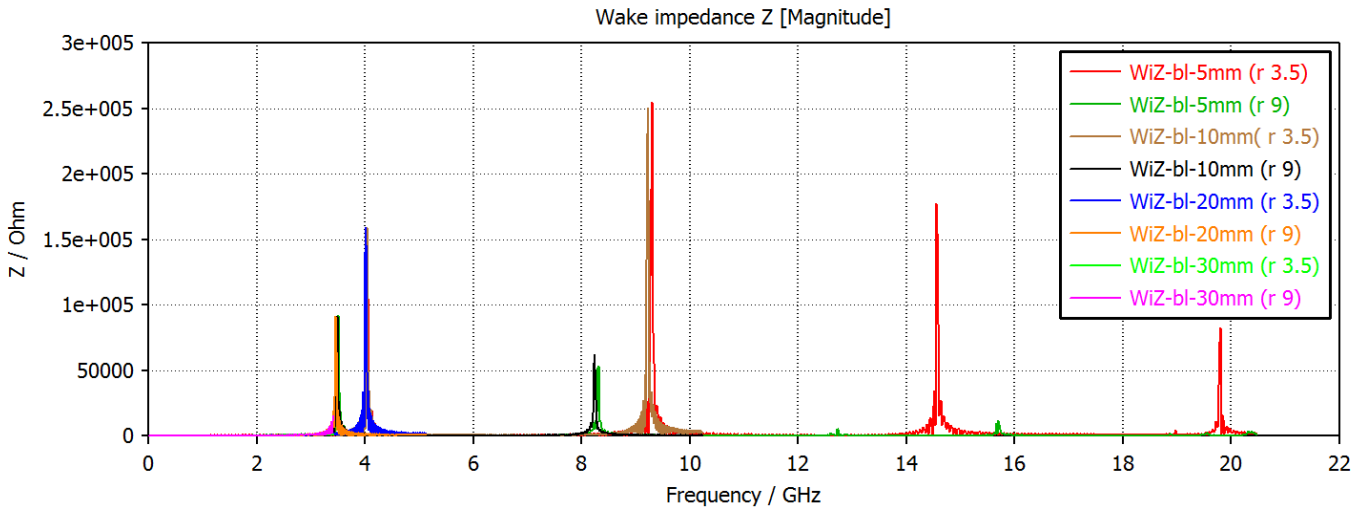


No shifts in Frequencies → constant geometry
Stored energy as function of the bunch length



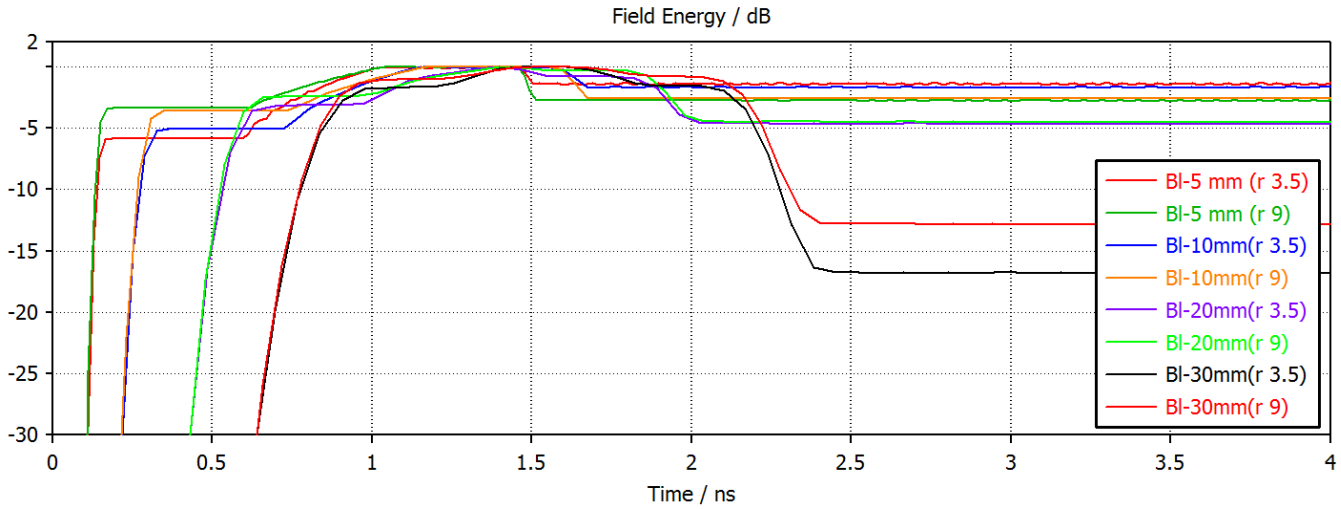


Case study : bellow, 25mm convolution depth

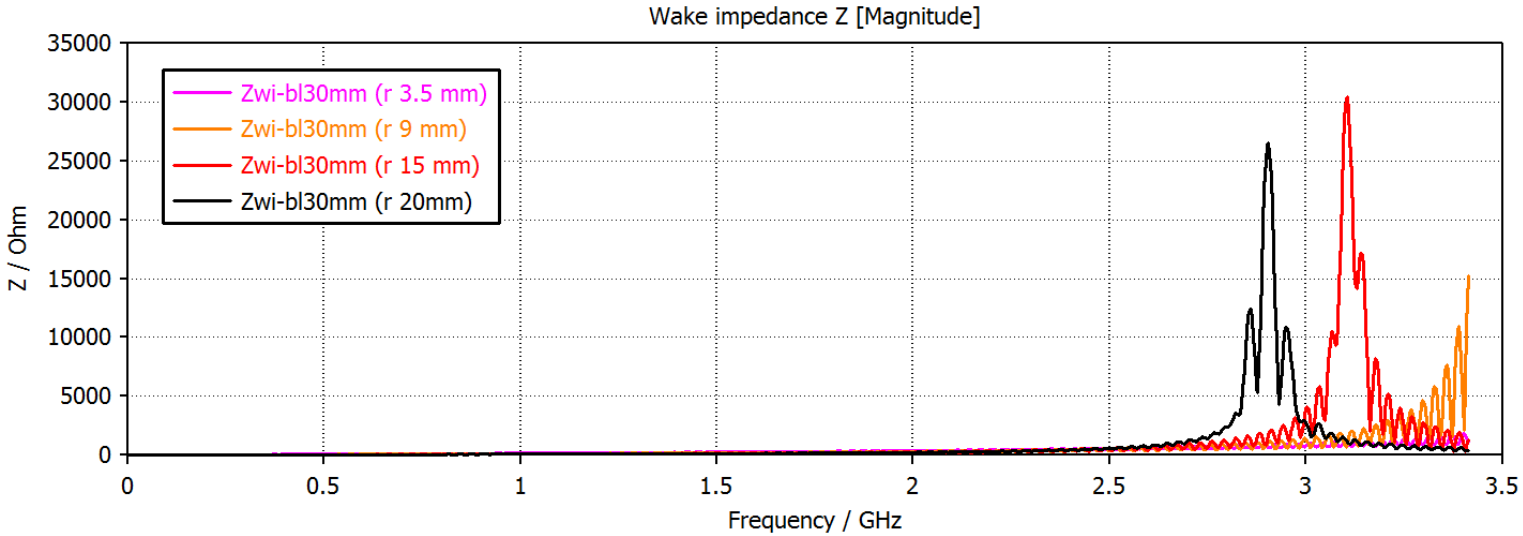


Frequency shift → different tube diameter;
Frequency spectrum → different bunch length;

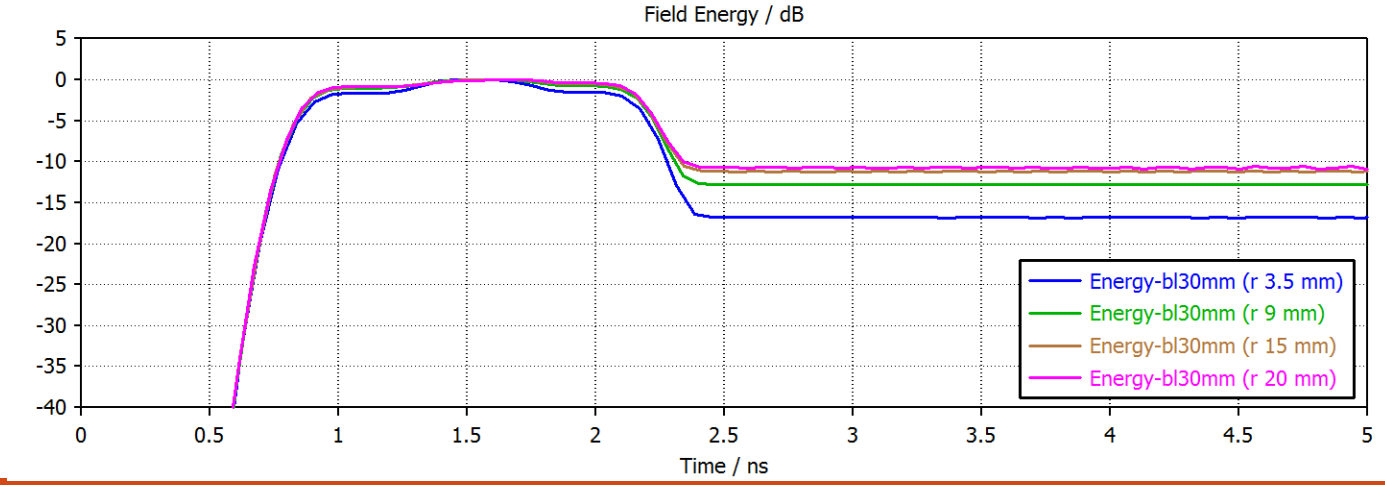
Stored energy → dependence on the diameter for longer bunch lengths



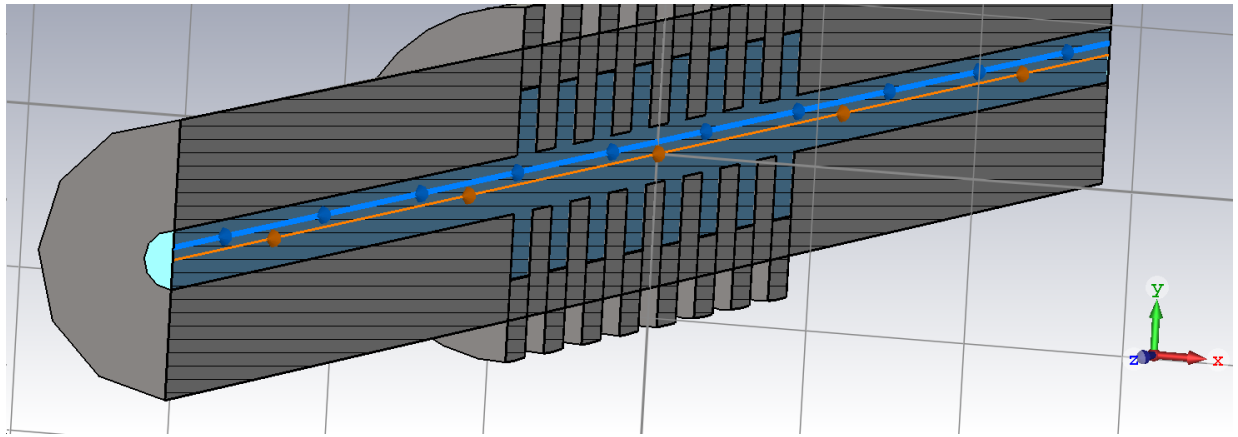
Case study : bellow, 25mm convolution depth



Stored energy → dependence on the diameter for longer bunch lengths;
Frequency spectrum for larger diameter → coupling with longer bunch length?



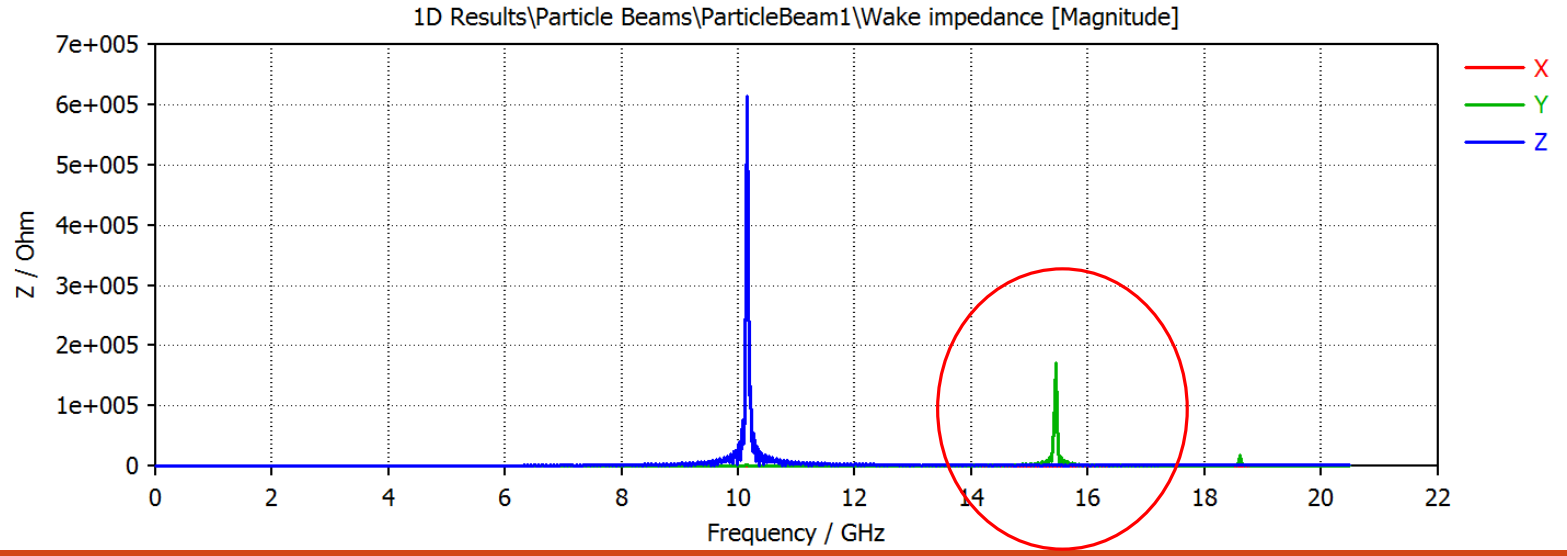
What about transverse Impedance?



Boundary conditions:

- 8mm convolution depth;
- Φ = 7 mm;
- y beam offset = 1.5 mm;

Off axes beam induces resonant frequencies that could induce beam instabilities.



Conclusions

Impedance gymnastics :

we played with the different parameters to understand the effect of cavities on the longitudinal stability of the beam;

A final optimal configuration depends on many factors:

1. Beam characteristics;
2. Geometry of the cavity;
3. Mechanical feasibility of the configuration and ease in installation.