UA9 Goniometer Impedance Simulations - Update and Summary

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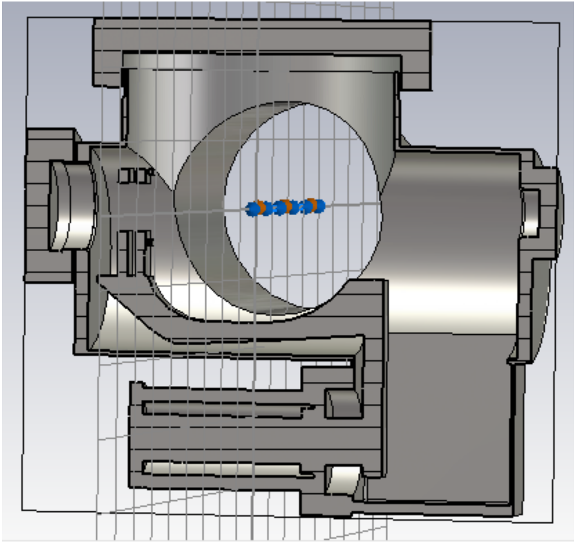
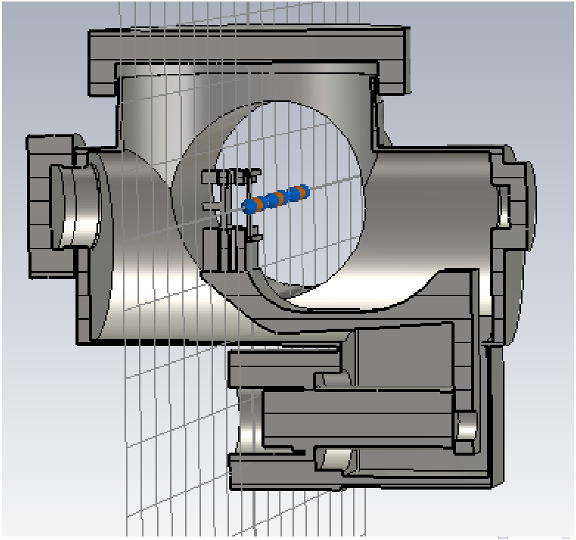
PARKED OUT



Parked In



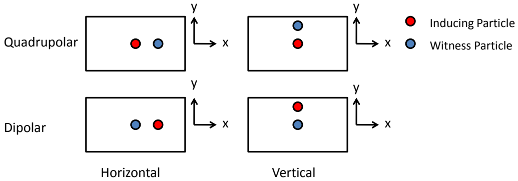
WAKEFIELDS AND IMPEDANCE

- Wakefields (EM fields generated by interactions between charged particles and their surrounding structures) are one of the many sources of instabilities in charged particle accelerators
- The impedance is simply the fourier transform of the wakefield into the frequency domain (see eq. 1)

$$W(\tau) = \int_0^{\infty} w(t)\lambda(\tau - t)dt = \int_{-\infty}^{\infty} Z(\omega)\lambda(\omega)e^{j\omega\tau}\frac{d\omega}{2\pi} \qquad (1)$$

- We often consider the frequency domain as many material/structural properties are frequency dependent (resonant frequencies of cavities, frequency dependent permitivitty/permeability etc). Also, multi-turn instabilities tend to fall of certain resonances, so convoluting with a beam spectrum is very useful

TRANSVERSE IMPEDANCES



- For a witness particle at displacement (x_2, y_2) following a source particle at (x_1, y_1), the transverse impedance are as follows

$$Z_{\perp,x} = x_1 Z_{dip,x} + x_2 Z_{quad,x} + Z_{constant,x} \tag{2}$$

where $Z_{dip,x}$ is the dipolar impedance, $Z_{quad,x}$ is the quadrupolar impedance, $Z_{constant,x}$ is the constant transverse term. Note the constant transverse term is typically zero for structures with top/bottom, left/right symmetry.

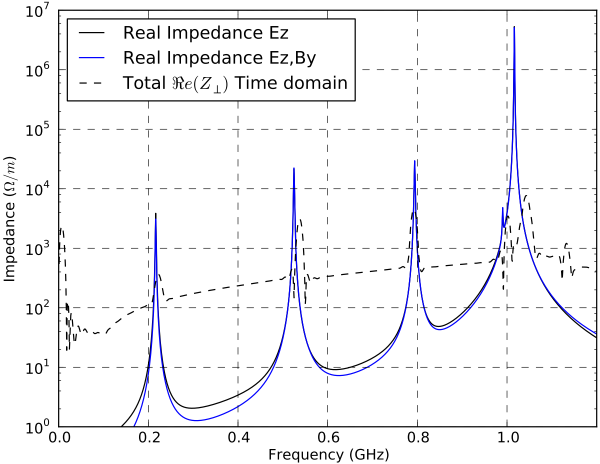


Figure 1: Horizontal transverse impedance of the goniometer in the parked out position

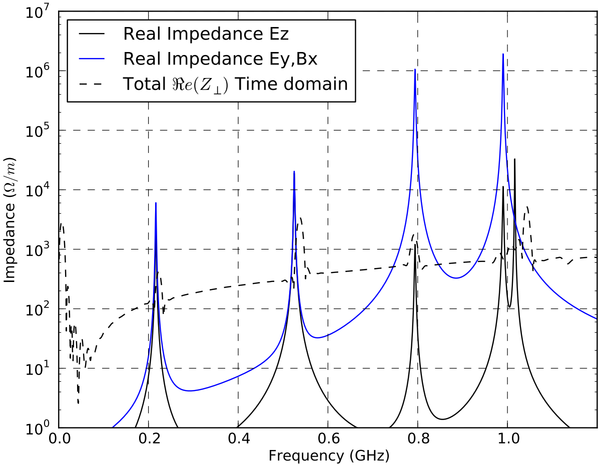


Figure 2: Vertical transverse impedance of the goniometer in the parked out position

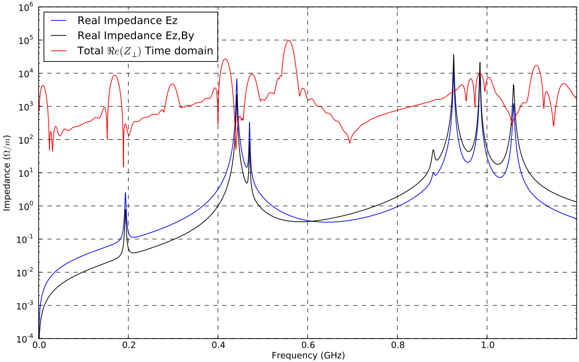


Figure 3: Horizontal transverse impedance of the goniometer in the parked in position

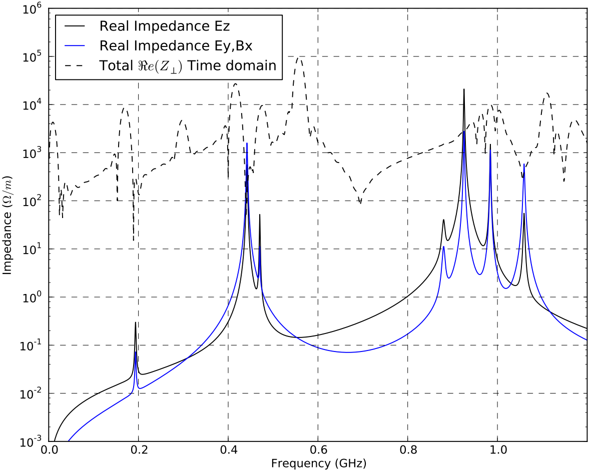


Figure 4: Vertical transverse impedance of the goniometer in the parked in position

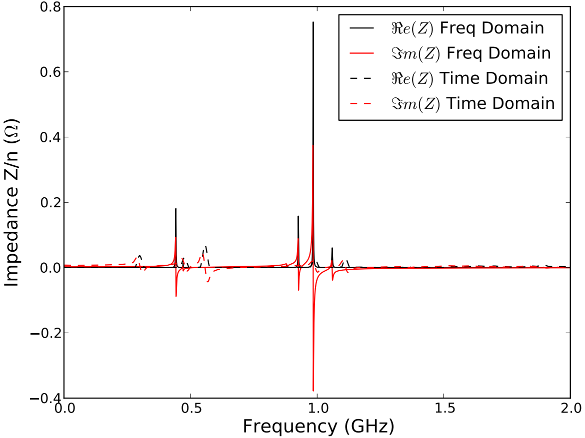


Figure 5: Normalised longitudinal impedance Z/n for the goniometer in the parked in position

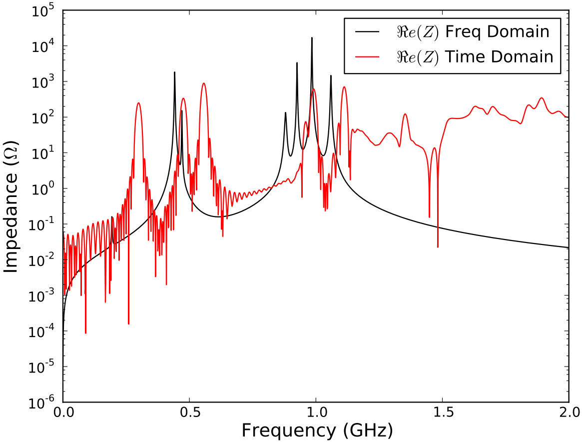


Figure 6: Real component of the longitudinal impedance for the goniometer in the parked in position. Differences in the peak values and frequencies can be attributed to surface material. See next slide

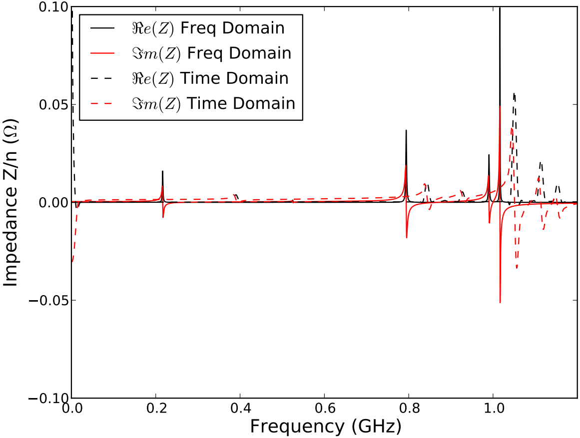


Figure 7: Normalised longitudinal impedance Z/n for the goniometer in the parked out position

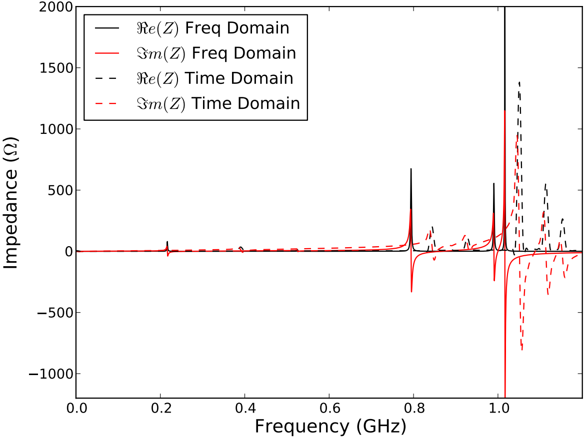
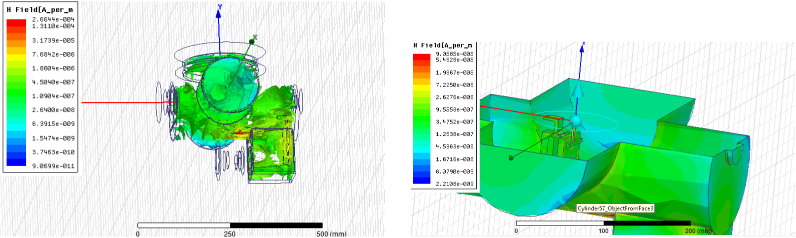


Figure 8: Longitudinal impedance for the goniometer in the parked out position

MODE DETAILS - PARKED IN

Frequency (GHz)	Q	$R_s (\Omega)$	Power loss, 25ns (W)
0.193	176	0.3	0.01
0.442	493	3729	120
0.470	710	305	9
0.880	292	266	2
0.925	1085	6599	43
0.984	1338	33044	165
1.059	738	2982	10



(a)

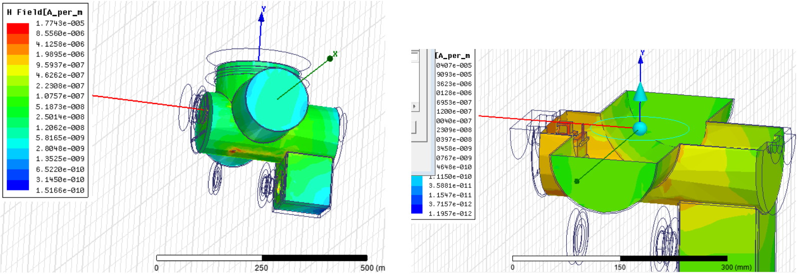
(b)

Figure 9: Magnetic field plots of 9(a) the resonance at f=880MHz and 9(b) and at f=984MHz

Note that the strong magnetic fields are located between the arm and the vacuum tank, NOT near the silicon holder.

MODE DETAILS - PARKED OUT

Frequency (GHz)	Q	$R_s(\Omega)$	Power loss (W)
0.216	259	159	8
0.524	580	27	1
0.794	741	1352	15
0.990	965	1111	5
1.016	2284	4702	20



(a) (b)

Figure 10: Magnetic field plots of 10(a) the resonance at f=794MHz and 10(b) and at f=1016MHz

Here the losses are again concentrated between the arm and tha vacuum tank, but there are larger losses on the silicon holder. What heat load can it take? Possibly need some solution (damping material on underside/back of arm?)

TOTAL ESTIMATES - PARKED OUT

- Esimates produced with full machine, 288 nominal bunches for 25ns $(N)_b = 1.15 \times 10^{11}$), and 144 nominal and high intensity bunches for 50ns ($N_b = 1.15 \times 10^{11}$ or $N_b = 1.5 \times 10^{11}$). Bunch length $\tau_b = 4ns$ at injection, $\tau_b = 1.5ns$ at extraction.

	25ns		50ns	
	1.5ns	4ns	1.5ns	4ns
Gaussian, Time	1	$\ll 1$	0.4	$\ll 1$
Parabolic, Time	1	$\ll 1$	0.5	$\ll 1$
cos^2, Time	2	$\ll 1$	3	$\ll 1$
Gaussian, Freq	0.2	$\ll 1$	0.1	$\ll 1$
Parabolic, Freq	0.2	$\ll 1$	0.15	$\ll 1$
cos^2, Freq	0.4	$\ll 1$	0.4	$\ll 1$
Gaussian on resonance, Freq	48	$\ll 1$	11	$\ll 1$

TOTAL ESTIMATES - PARKED IN

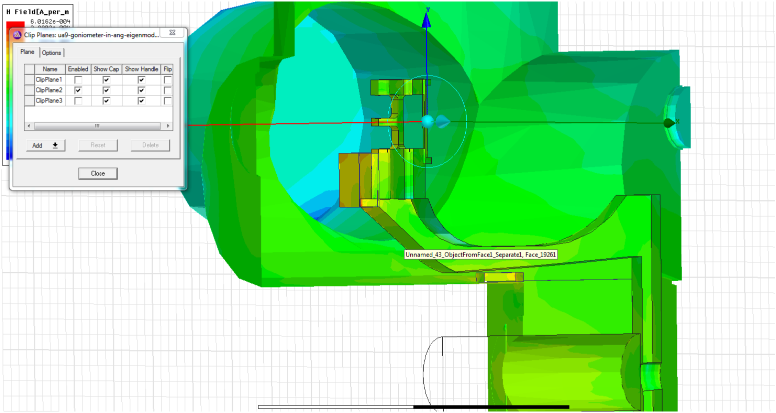
- Esimates produced with a machine of 4 trains of 48 nominal bunches, nominal bunch intensity for 25ns $(N)_b = 1.15 \times 10^{11}$), and a single high intensity bunch ($N_b = 1.45 \times 10^{11}$). Bunch length $\tau_b = 4ns$ at injection, $\tau_b = 1.5ns$ at extraction.

	25ns		1 bunch	
	1.5ns	4ns	1.5ns	4ns
Gaussian, Time	10	0.1	0	0
Parabolic, Time	13	0.1	0	0
cos^2, Time	23	0.1	0	0
Gaussian, Freq	7	0	0	0
Parabolic, Freq	9	0.1	0	0
cos^2, Freq	13	0.1	0	0
Gaussian on resonance, Freq	349	$\ll 1$	$\ll 1$	$\ll 1$

NOTES ON BEAM-INDUCED HEATING

- Assuming we fall on a resonance is the worst case scenario
- We always plan for the worst case scenario. Better to be pessimistic and surprised than to have a very expensive pile of scrap
- Similarly, estimates from the frequency domain and much more realistic - Time domain uses PEC for most material - Qs of resonances are unphysically high - discrepency between time and frequency domain plots
- This is also likely the reason for the discrepencies between the time domain and frequency domain simulations - Simulations to be done to confirm this

- Using ferrite as a damping material - R_s/Q of a resonance is a function of the geometry - fixed. Q we can change by clever use of materials. If we add a lossy material, like ferrite, in regions of high magnetic (magnetic lossy material) or high electric (electrically lossy laterials), we decrease the Q of the resonance and get smaller power loss as a result.



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	ClipPlane1	☐	☑	☑	☐
	ClipPlane2	☑	☑	☑	☐
	ClipPlane3	☐	☑	☑	☐

Figure 11: Placement of ferrite blocks within the structure

MODE DETAILS - PARKED IN

f (GHz)	0.442	0.984
Q (No Ferrite)	493	1338
P_{loss} (W, No Ferrite)	120	165
Q (TT2-111R)	50	
P_{loss} (W, TT2-111R)	8	
Q (8C11)	28	39
P_{loss} (W, 8C11)	5	0.2

SUMMARY

- We have carried out time domain and frequency domain simulations for the beam impedance of the UA9 goniometer
    - Parked Out - Agreement between the two is quite good - Time domain simulations using a realistic material would help reaffirm results.
    - Parked In - Longitudinal impedance agreement is quite good. Agreement in the transverse plane is more dubious - Again simulations with a realistic material needed to confirm results.
- Heating estimates for both operational and worst case scenario situations have been carried out. For both parked in and parked out with short bunches at 25ns - could be a serious problem!
- Field maps seem to indicate the use of ferrite as a damping material would be effective. Simulations in some possible locations seem to confirm this would be the case.

OPEN QUESTIONS

- Check the effects of the use of damping ferrites on the transverse modes and for modes in the parked out position. The magnetic fields in the parked out position are concentrated near the crystal holder so should be effective also.
- Comparison between time domain/frequency domain transverse impedances - In time domain we may individually identify dipolar, quadrupolar and constant transverse terms. In frequency we only identify a transverse kick factor for each mode - How to identify with dipolar, quadrupolar and constant terms?
- Heating estimates - Worst case scenario and realistic estimates can vary drastically. Do we take worst case in all cases? Can mean the difference between work to find a solution to a non-existent problem. Then again, it could be the actual case and some device goes caput.