Update on the impedance of stripline BPMs in the HL-LHC triplet region

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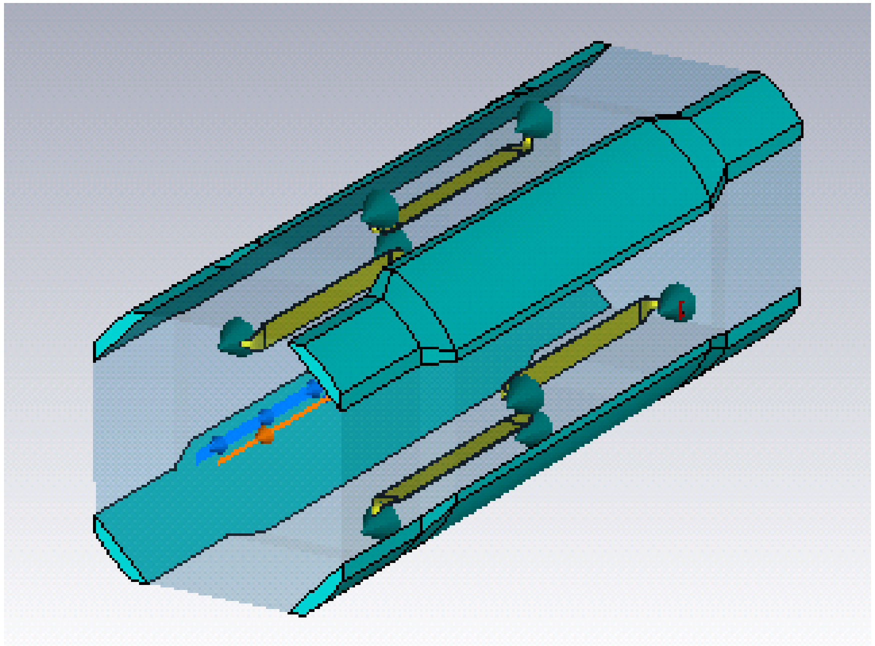
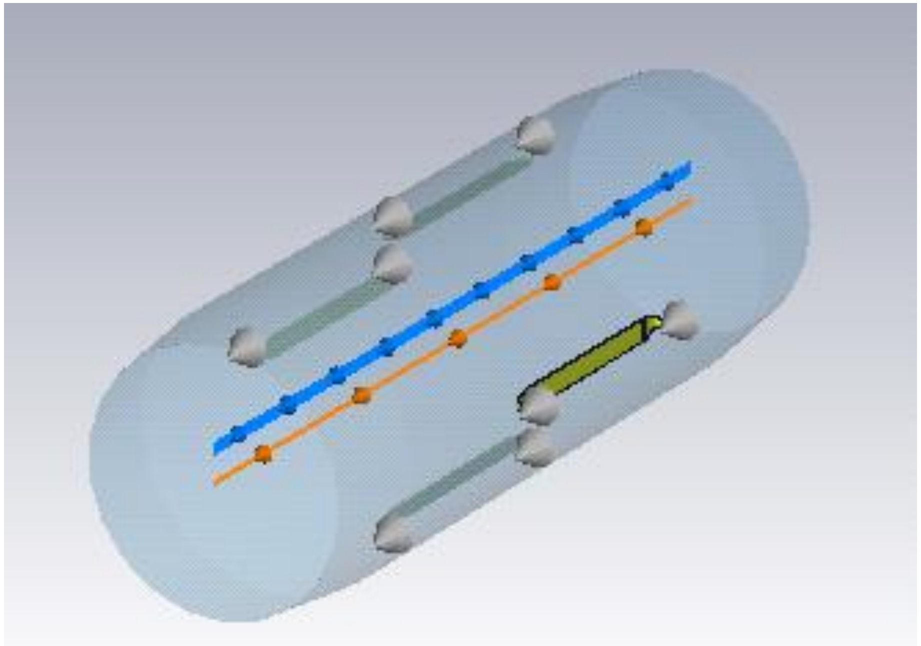
Acknowledgement: T.Lefevre, D.Draskovic

Studied models

Octagonal- with tungsten



Circular – no tungsten



Strip to strip = 112mm

Strip to strip = 123mm

PS: No inermet anymore.

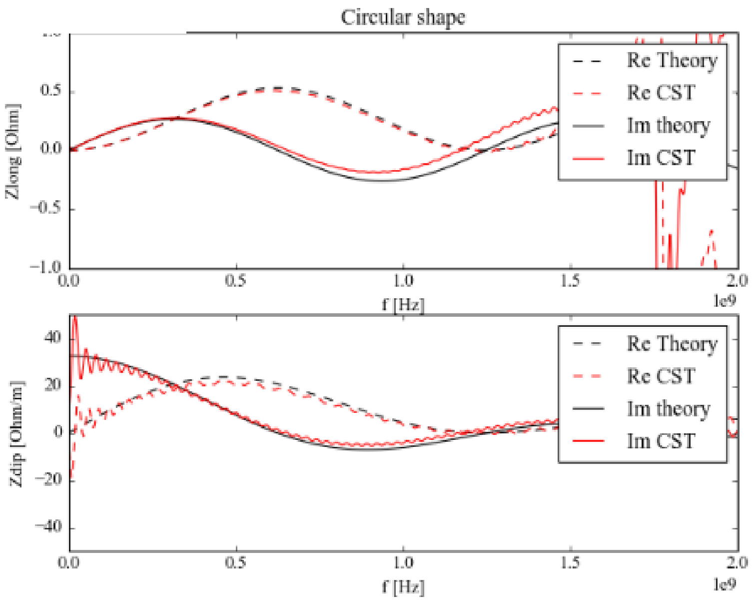
Simulations: circular shape

Re-worked out the stripline impedance calculations to account for 4 stripes. Ng's approach was for 2 stripes -> equivalence to 2-stripe case if we double the angle.

$$Z_l(\omega) = \left(\frac{2\phi_0}{\pi}\right)^2 Z_s \left(\sin^2(kl) + j\sin(kl)\cos(kl)\right) \quad \text{with} \quad k = \omega/c$$

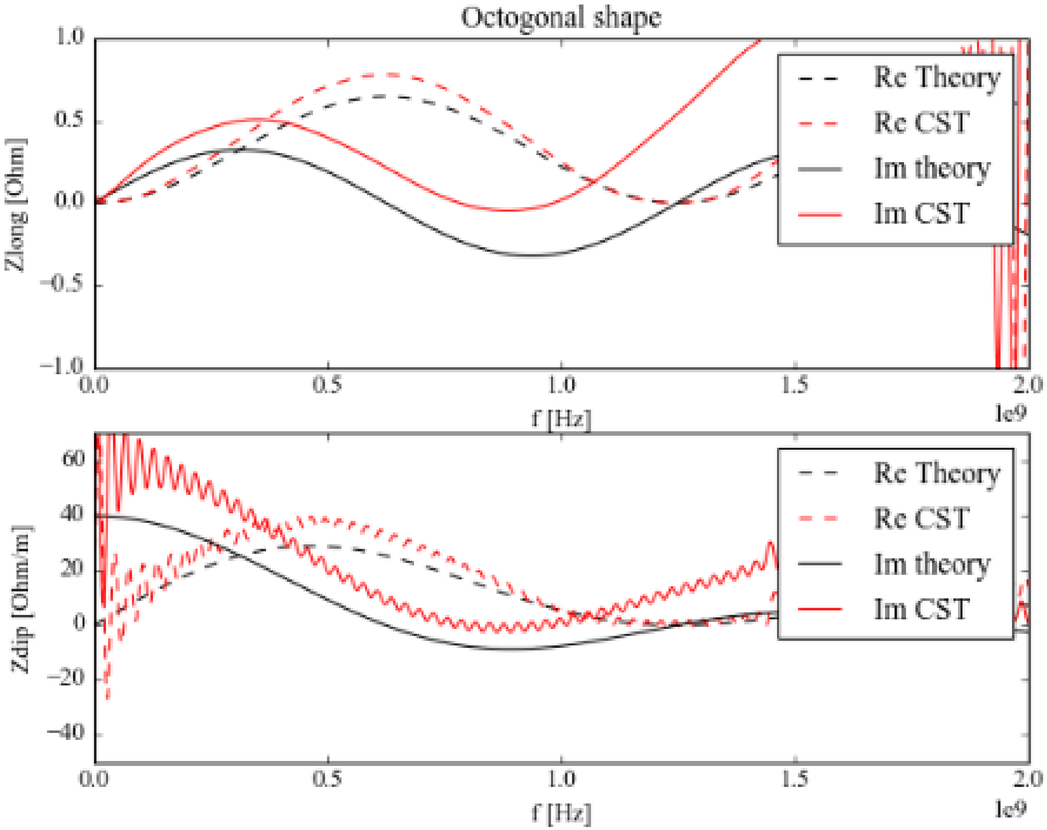
$$Z_{x,y}^{dip}(\omega) = \frac{8}{k}\frac{Z_s}{(\pi b)^2}\sin^2(\phi_0)\left(\sin^2(kl) + j\sin(kl)\cos(kl)\right)$$

Good agreement with CST simulations!

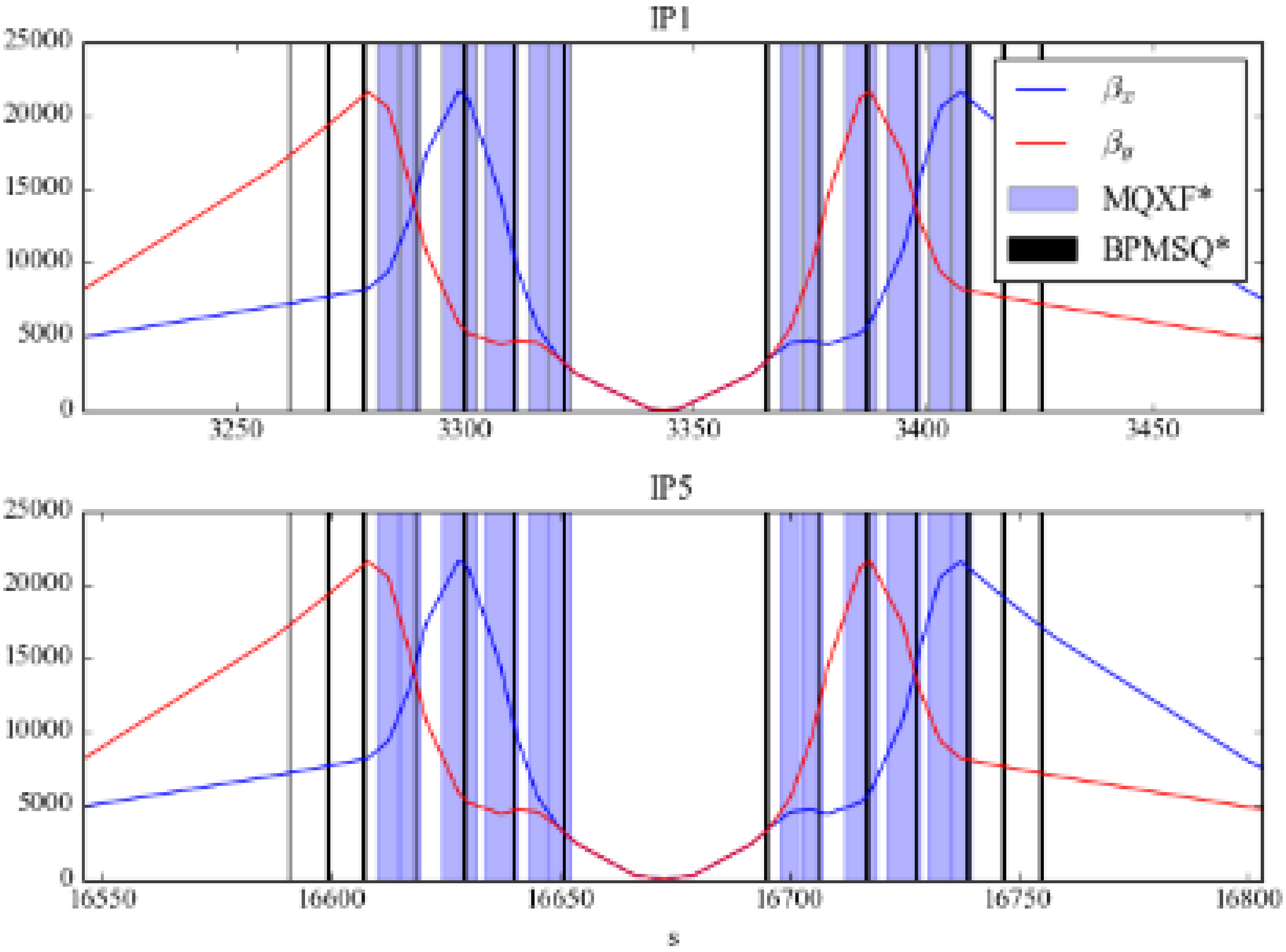


Simulations: octogonal shape

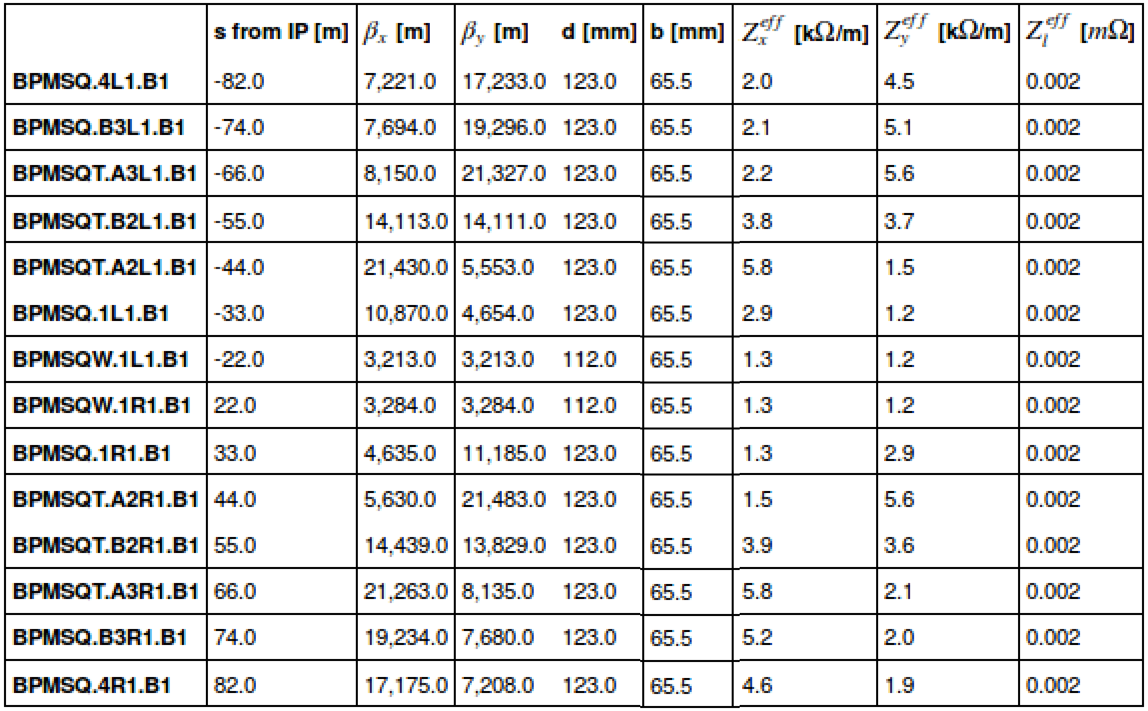
Comparing the octogonal shape simulations with theory (circular) we find an increase up to 50% in transverse, and up to a factor of 2 in longitudinal due to the change in geometry.



BPMSQ optics at 15cm beta*



IP1 impedances - circular shape



	s from IP [m]	β_x [m]	β_y [m]	d [mm]	b [mm]	Z_x^{eff} [kΩ/m]	Z_y^{eff} [kΩ/m]	Z_l^{eff} [$m\Omega$]
BPMSQ.4L1.B1	-82.0	7,221.0	17,233.0	123.0	65.5	2.0	4.5	0.002
BPMSQ.B3L1.B1	-74.0	7,694.0	19,296.0	123.0	65.5	2.1	5.1	0.002
BPMSQT.A3L1.B1	-66.0	8,150.0	21,327.0	123.0	65.5	2.2	5.6	0.002
BPMSQT.B2L1.B1	-55.0	14,113.0	14,111.0	123.0	65.5	3.8	3.7	0.002
BPMSQT.A2L1.B1	-44.0	21,430.0	5,553.0	123.0	65.5	5.8	1.5	0.002
BPMSQ.1L1.B1	-33.0	10,870.0	4,654.0	123.0	65.5	2.9	1.2	0.002
BPMSQW.1L1.B1	-22.0	3,213.0	3,213.0	112.0	65.5	1.3	1.2	0.002
BPMSQW.1R1.B1	22.0	3,284.0	3,284.0	112.0	65.5	1.3	1.2	0.002
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BPMSQT.A2R1.B1	44.0	5,630.0	21,483.0	123.0	65.5	1.5	5.6	0.002
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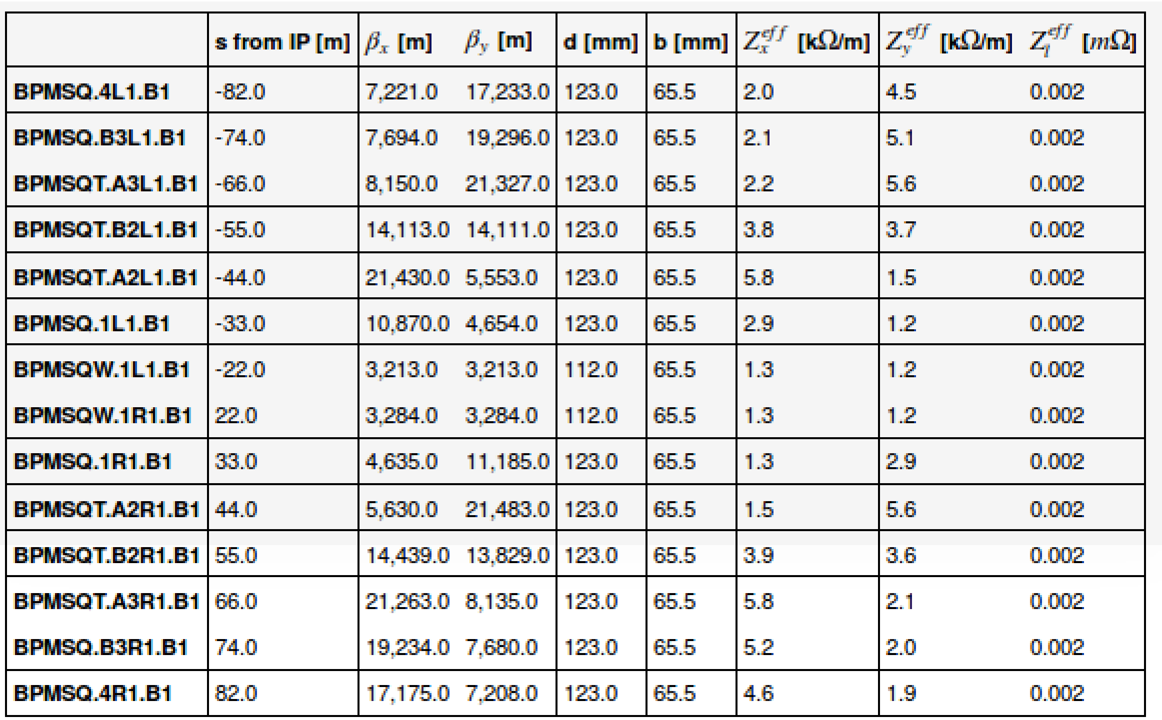
On average we have Zx,Zy = 3kOhm/m and Z/n = 0.002 mOhm per BPMSQ

IP5 impedances - circular shape



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On average we have Zx,Zy = 3kOhm/m and Z/n = 0.002 mOhm per BPMSQ

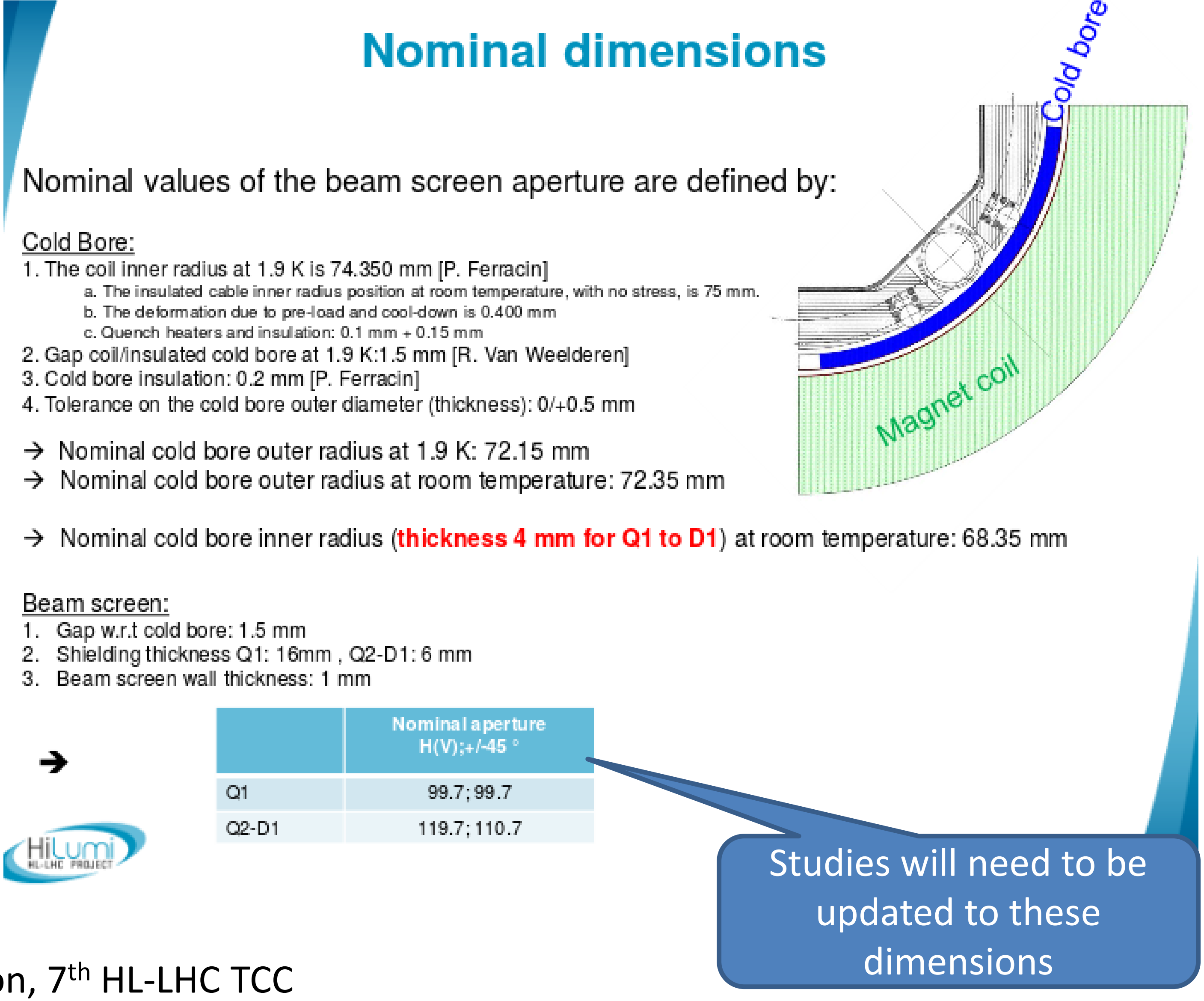
Effective impedance

- Accounting for all the BPMSQs with analytical formulas, the effective impedance is, for circular shape:

BPMQ total impedance	**HL-LHC (15cm)**
Zx = 87 kOhm/m,	Zx=20.8 MOhm/m,
Zy = 84 kOhm/m	Zy=17.8 MOhm/m
Z/n = 0.050 mOhm	Z/n=82 mOhm

- If we account for only inductive impedance at max beta we get Zt_eff in the order of 280kOhm: pessimistic approach as the impedance rolls off quickly
- In case we use octogonal shape we have up to 50% increase in transverse impedance -> 130 kOhm/m
- In case we use octogonal shape we have up to 50% increase in longitudinal impedance -> 0.1 mOhm

Update on beam screen dimensions



Nominal dimensions

Nominal values of the beam screen aperture are defined by:

Cold Bore:

1. The coil inner radius at 1.9 K is 74.350 mm [P. Ferracin]
    - a. The insulated cable inner radius position at room temperature, with no stress, is 75 mm.
    - b. The deformation due to pre-load and cool-down is 0.400 mm
    - c. Quench heaters and insulation: 0.1 mm + 0.15 mm
2. Gap coil/insulated cold bore at 1.9 K:1.5 mm [R. Van Weelderen]
3. Cold bore insulation: 0.2 mm [P. Ferracin]
4. Tolerance on the cold bore outer diameter (thickness): 0/+0.5 mm

→ Nominal cold bore outer radius at 1.9 K: 72.15 mm

→ Nominal cold bore outer radius at room temperature: 72.35 mm

→ Nominal cold bore inner radius (**thickness 4 mm for Q1 to D1**) at room temperature: 68.35 mm

Beam screen:

1. Gap w.r.t cold bore: 1.5 mm
2. Shielding thickness Q1: 16mm , Q2-D1: 6 mm
3. Beam screen wall thickness: 1 mm

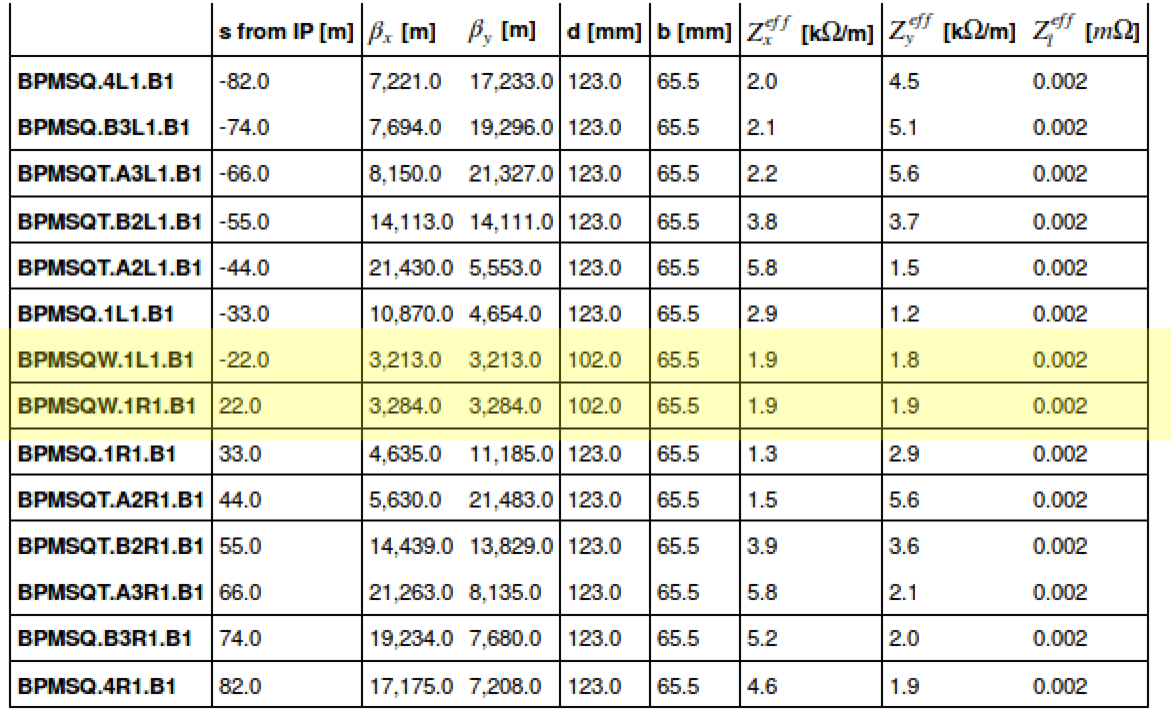
→

	Nominal aperture H(V);+/-45 °
Q1	99.7; 99.7
Q2-D1	119.7; 110.7

Studies will need to be updated to these dimensions

C.Garion, 7th HL-LHC TCC
http://indico.cern.ch/event/515629/contributions/2145081/

IP1 impedances - circular shape after screen aperture update



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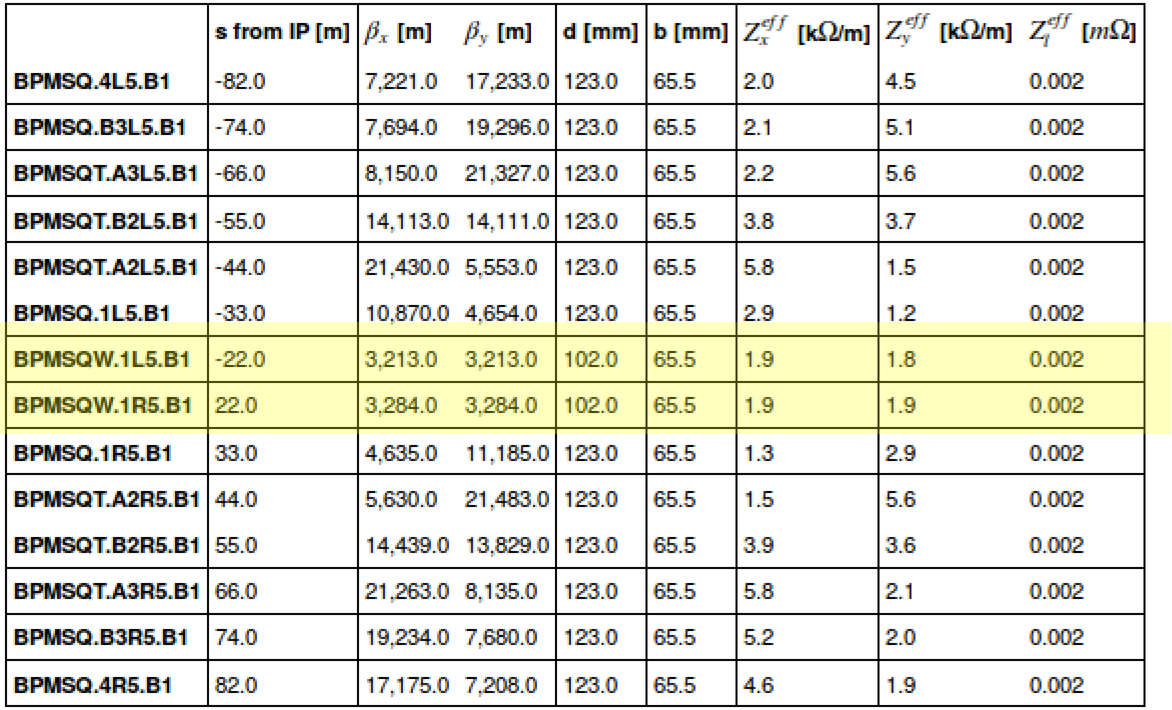
-> Negligible change in impedance

IP5 impedances - circular shape after screen aperture update



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-> Negligible change in impedance

Update on effective impedance

- Accounting for all the BPMSQs with analytical formulas, the effective impedance is, for circular shape:

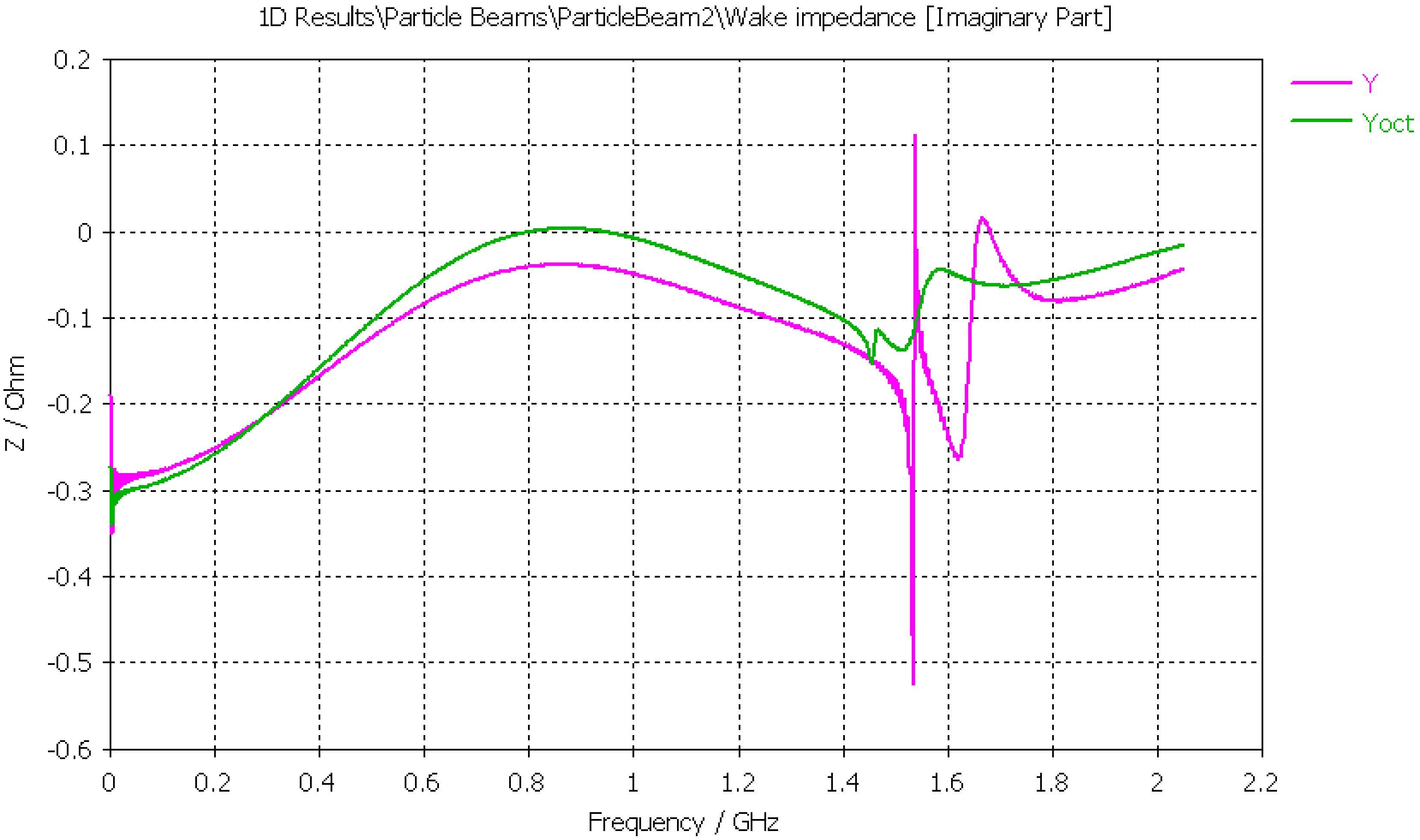
BPMQ total impedance	**HL-LHC (15cm)**
Zx = 90 kOhm/m,	Zx=20.8 MOhm/m,
Zy = 87 kOhm/m	Zy=17.8 MOhm/m
Z/n = 0.050 mOhm	Z/n=82 mOhm

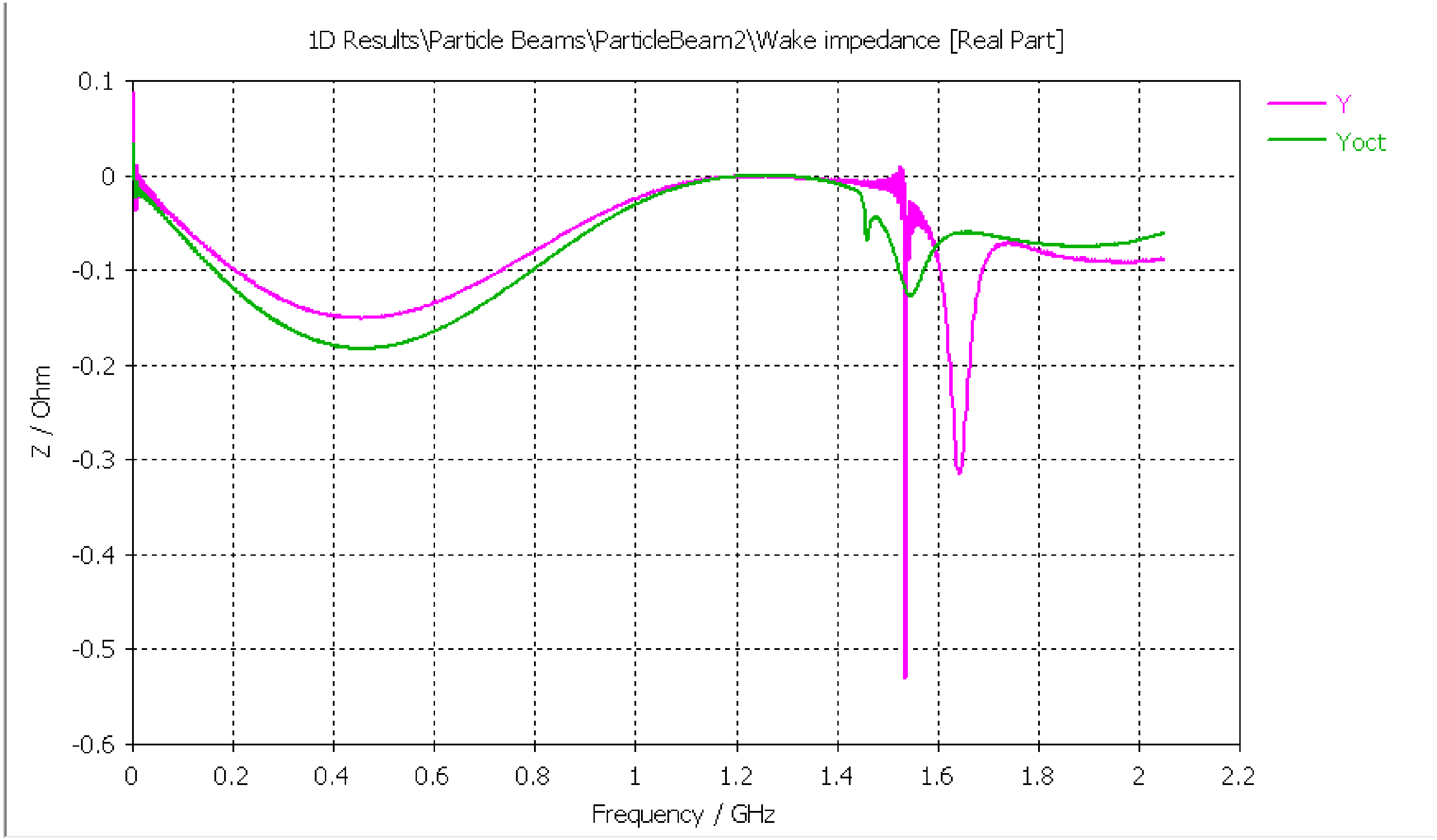
- Similar impact as before.

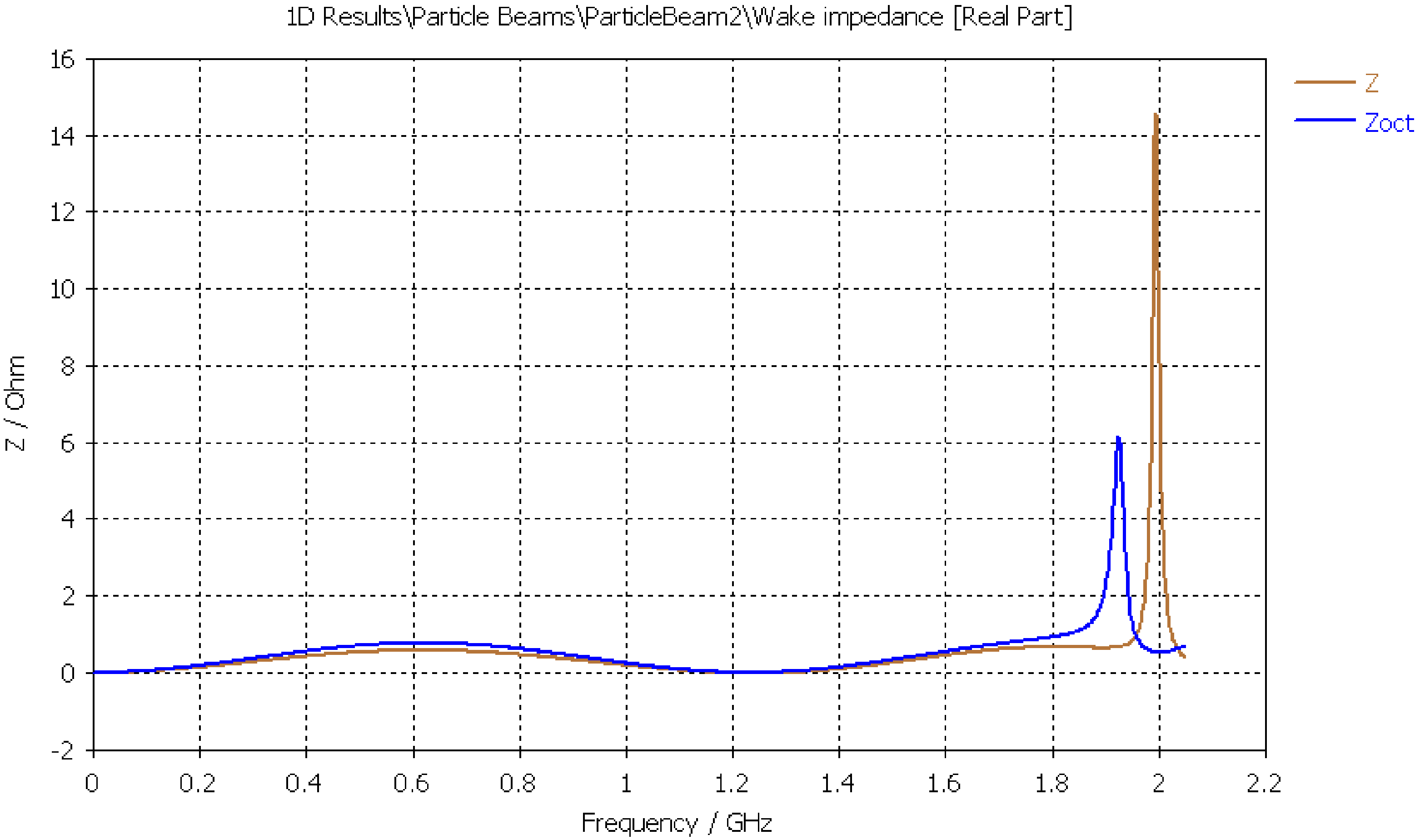
Conclusions and outlook

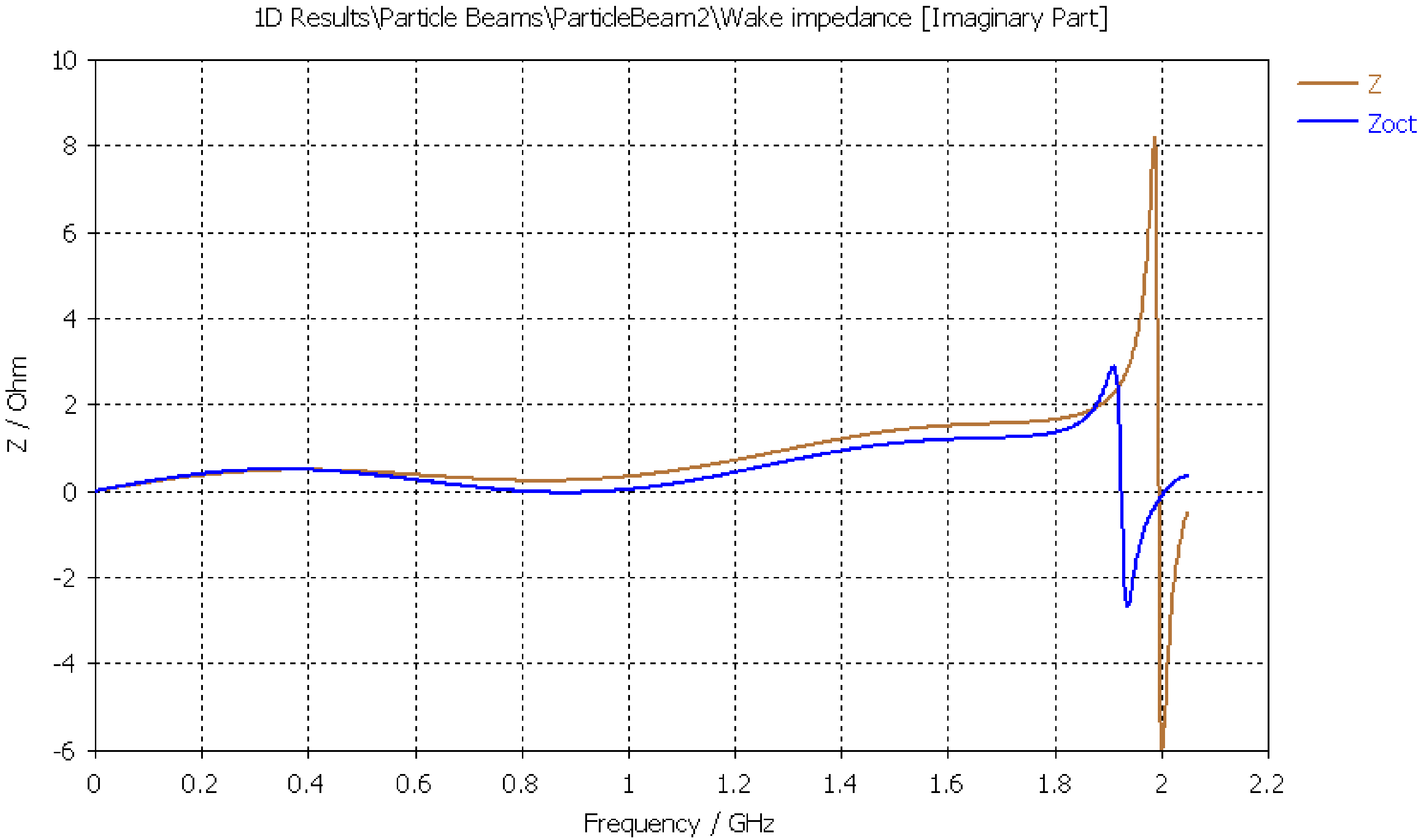
- The triplet stripline BPMs impedance look negligible in both configurations, octogonal and circular, wr.t. the full HLLHC impedance model.
- The longitudinal impedance is < 0.1%
- CST simulations have been investigated w.r.t. analytical formulas extended to the 4-stripes case for both shapes.
- Analytical estimates predict a very small impact of the aperture reduction in Q1’s BPMSQ: nevertheless the CAD model should be updated to the new beam screen specs and new simulations should be performed.

Appendix


1D Results\Particle Beams\ParticleBeam2\Wake impedance [Imaginary Part]
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Z / Ohm
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
Frequency / GHz
Y
Yoct


1D Results\Particle Beams\ParticleBeam2\Wake impedance [Real Part]
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Z / Ohm
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
Frequency / GHz
Y
Yoct


1D Results\Particle Beams\ParticleBeam2\Wake impedance [Real Part]
Z
Zoct
Z / Ohm
16
14
12
10
8
6
4
2
0
-2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
Frequency / GHz


1D Results\Particle Beams\ParticleBeam2\Wake impedance [Imaginary Part]
Z / Ohm
10
8
6
4
2
0
-2
-4
-6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
Frequency / GHz
Z
Zoct