Poster WEPCAV013

Occurring dependency between adjustable coupling and Q_0 - finding and solving a problem during vertical cavity testing at DESY.

Poster ID, WEPCAV013
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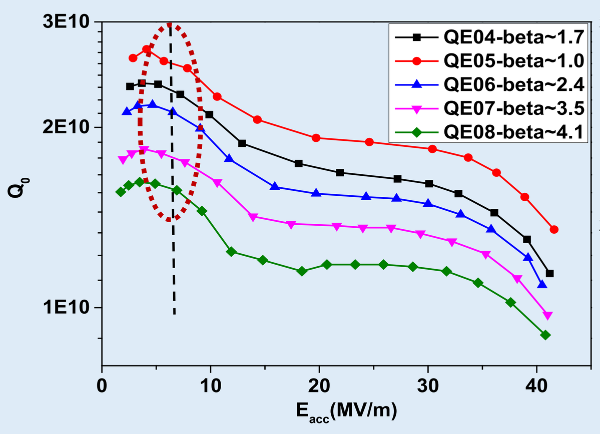
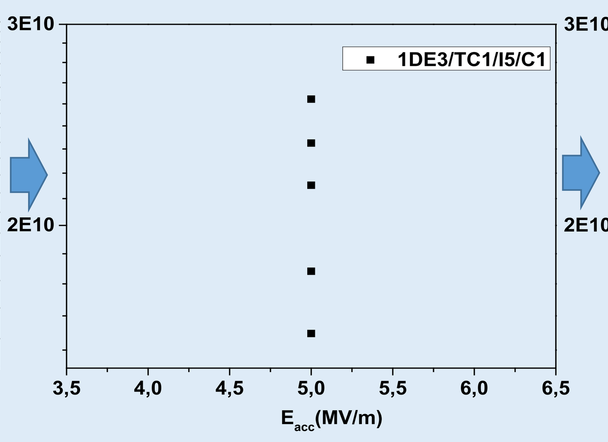
Abstract

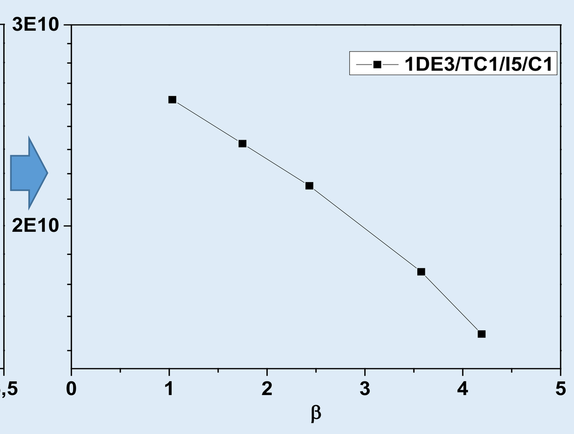
In the AMTF (Accelerator Module Test Facility) hall at DESY various types of cavities with movable input antenna have been tested during the last years. Since 2017 more than hundred vertical tests (VT) were conducted using any combination of cryostats, inserts and antennae without big troubles.

However, in the last months, an unexpected dependency between the measured quality factor and the coupling coefficient β has been observed. In order to understand the problem, several different special checks have been performed. And, in the end, the problem was identified and solved.

Introduce cross – check measurement: Q_0 vs β at 5MV/m







A special method was used to make the check measurement more clear and easy to understand. The relationship between Q_0 and β was studied with the attention being paid only on those points at 5MV/m, which means a linear curve can be drawn. A larger slope indicates a closer correlation, while it should be flat for the case of independency of β.

Movable Input Antennae

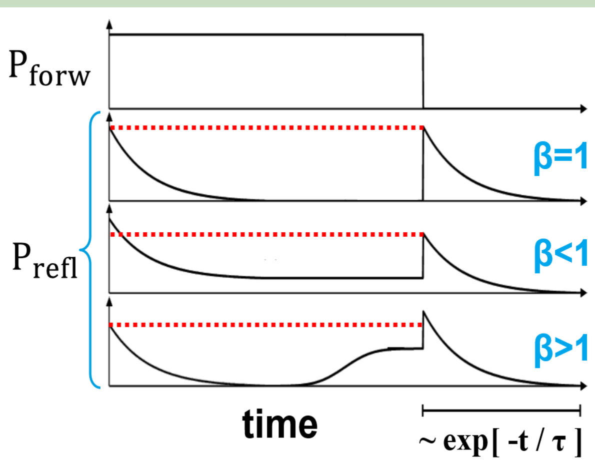
The measurement of β is done by driving the cavity with a RF pulse. The pulse length is long enough to drive the cavity near to equilibrium. The β can be calculated with values read from the oscilloscope or by usage of power measurements.

In the AMTF at DESY, a movable input antenna is used, so that the β value is adjustable [1]. During last few years, movable input antennae worked well for many cavities of different types. The general test error of Q factor should be less than 20% [2].

Determination of β value

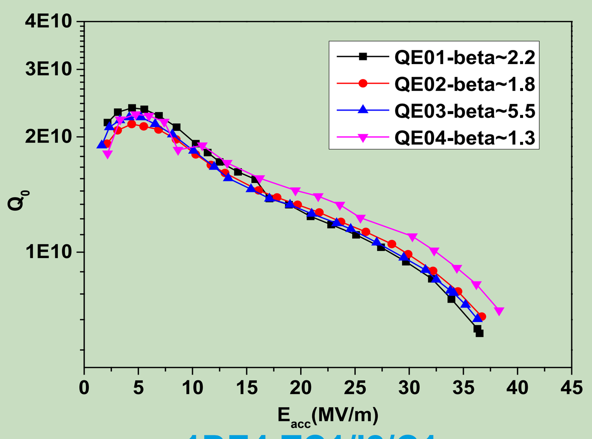
The calculation formula, which is used during CW (continuous wave) steady state is as follows [3]. For pulse mode, the coupling state can also be judged by using the power signals on the oscilloscope.

$$\beta = \frac{1 \mp \sqrt{\frac{P_{forw}}{P_{refl}}}}{1 \pm \sqrt{\frac{P_{forw}}{P_{refl}}}}$$



A dependency between Q factor and coupling value β

Normal result : the Q_0 is independent of β value

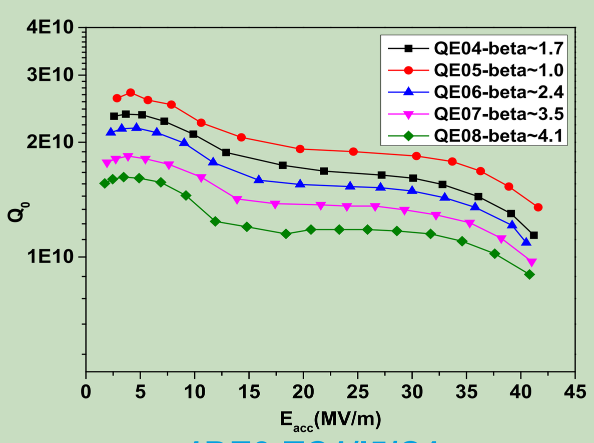


1DE4-TC1/I2/C1

In principle, the curves from the same vertical test should be the same. According to earlier research of cavity performance at DESY, the measurement error of Q_0 is around 10% (maximum less than 20%).

Abnormal result : β value has influence on Q_0

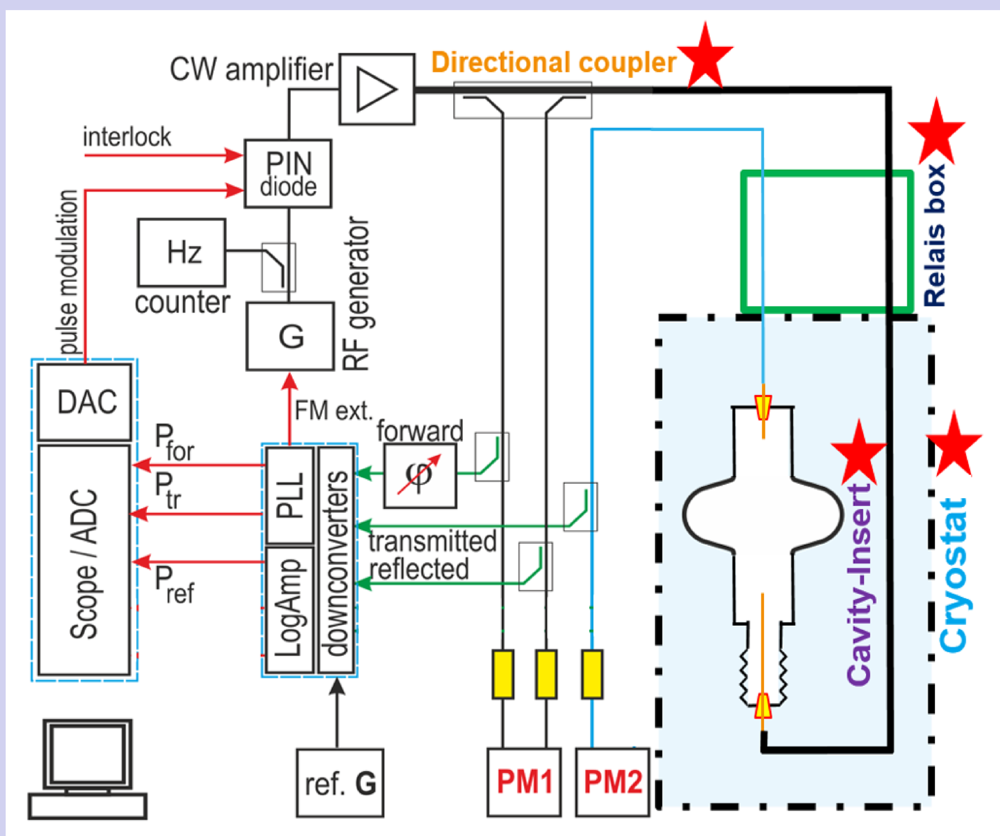
Usually, the Q factor should be independent of β value. But in this case, the change in β value can change Q_0 by about 2.5 times, which means the β value itself yields a measurement error larger than 100%.



1DE3-TC1/I5/C1

Basic status of vertical test system and the path of checking of possible error sources

Vertical test system at AMTF

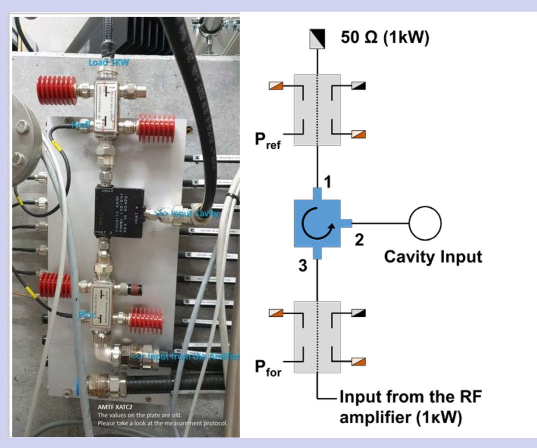


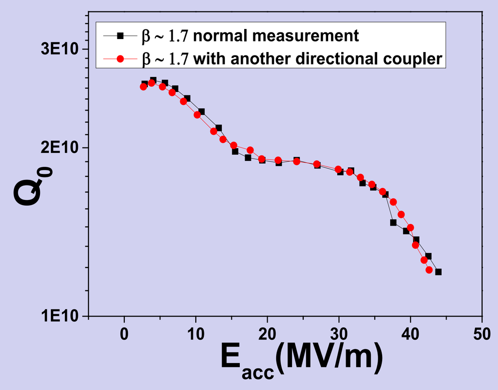
There are two vertical test stations (cryostats together with their RF system), two R&D inserts and a bunch of movable antennas in the AMTF. The possible sources can be divided into two main parts, which are marked by red stars.

Part one is the RF measurement system consisting of the cryostat itself and the directional coupler. Part two is built by the cavity insert, in which the cavity is mounted, and the relay box on top of the insert.

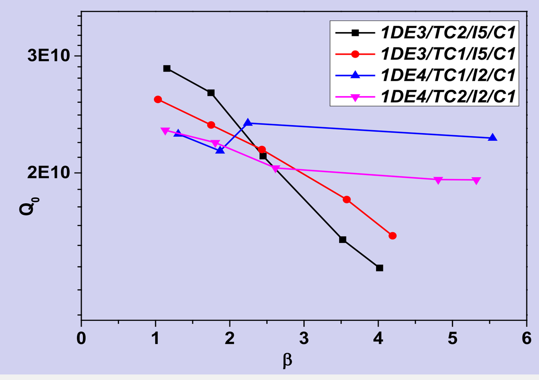
Directional coupler : independent of β

The formula for the β value is using the amplitudes of both forward and reflected signal, which are taken from the directional coupler. This check was performed immediately after the awareness of the unwanted dependency. Another directional coupler was connected into the system while all the other parts were kept the same. The Q vs. E curves from those two different directional coupler measurement are identical, which indicated that the error is not produced by the RF hardware.





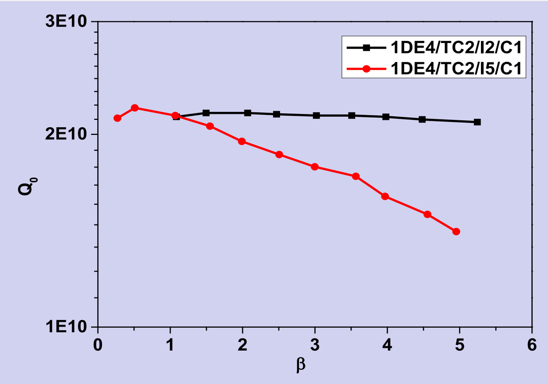
Check of cryostat: same results on different cryostats



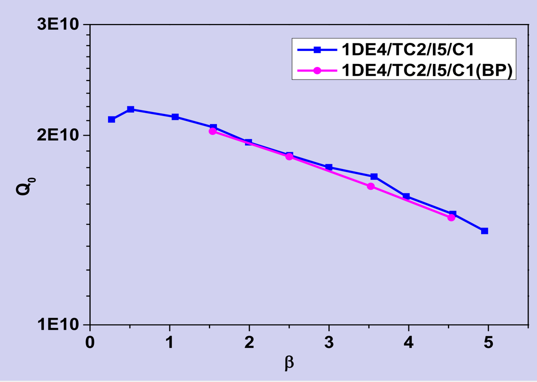
For both cryostat, the results were that 1DE3 with Insert 5 shows a dependency of β (black and red) while 1DE4 in Insert 2 (blue and pink) shows an independency, which means both RF and cryostat systems are working well.

Check of insert: different results on different inserts

The same cavity (1DE4) was assembled into different cavity-inserts. And the result was that Insert 2 (black) shows independency of β while Insert 5 (red) yields a dependency, which suggests that the Insert-5 is the possible error source.



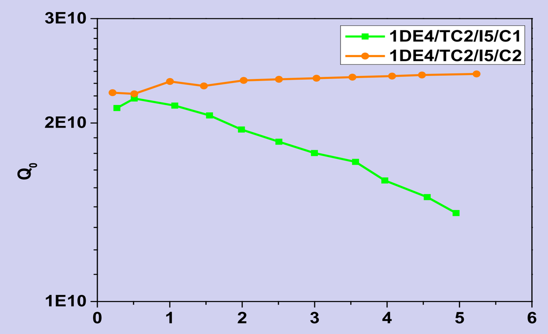
Check of relay box : independent of β



All inserts at AMTF have an additional relay box, which is used to select the RF loops during cable calibration. Both of the curves with normal (blue) and bypass (pink) setting act in the same way, hence the relay box can be excluded as error source.

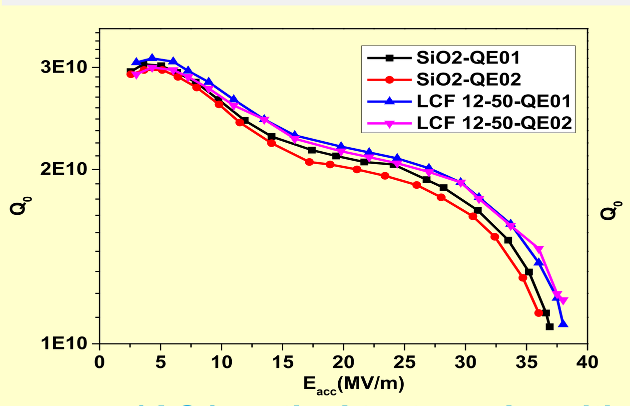
Check of insert INPUT cable: error source

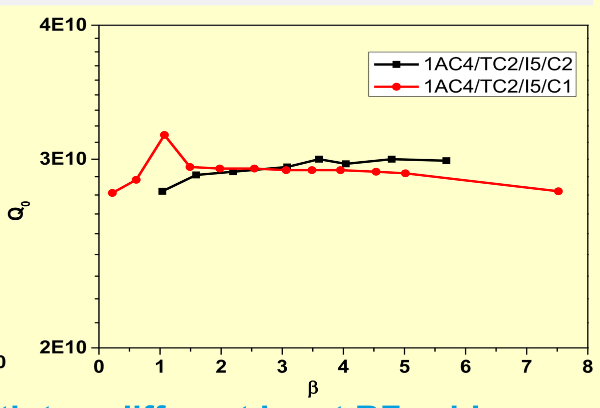
The results of these check indicated an unexpected uncertainty of RF cable. After exchanging the input RF cable (new one: SiO2), the curve did show independency of β as it should be (gold) compared with the old LCF 12-50 cable (green).



Cavity	Cryo & RF	Insert & Cavity-Antenna: Insert	Insert & Cavity-Antenna: Cable	In short	Results	
1DE3	XATC1	No.5	LCF 12-50	TC1/I5/C1	✗	Dependency
	XATC2	No.5	LCF 12-50	TC2/I5/C1	✗	Dependency
1DE4	XATC1	No.2	LCF 12-50	TC1/I2/C1	✓	Independency
	XATC2	No.2	LCF 12-50	TC2/I2/C1	✓	Independency
	XACT2	No.5	LCF 12-50	TC2/I5/C1	✗	Dependency
				TC2/I5/C1(BP)	✗	Independency
	XATC2	No.5	SiO2	TC2/I5/C2	✓	Independency

After solving the problem





1AC4 vertical test results with two different input RF cables

The repaired input cable of LCF 12-50 also shows the awaited indepence of β again.

Summary

In principle, the input RF cable should be independent of the coupling coefficient. But a damaged input RF cable has introduced a resonance that strongly depends on the coupling coefficient β.

Reference

[1] https://tesla.desy.de/srf_infrastructures/srf_infrastructure_at_desy/,
[2] Y. Yamamoto et al., "ERROR ESTIMATION IN CAVITY PERFORMANCE TEST FOR THE EUROPEAN XFEL AT DESY" WEPMB007 Proceedings of IPAC2016, Busan, Korea
[3] RF Superconductivity for Accelerators (H. Padamsee, J. Knobloch, T. Hays) [page 154]

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