High-Field Studies in the Linac4 RFQ at CERN

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Introduction

The first cavity in CERN's linear accelerator 4 (Linac4) beamline is a 3m long Radio-Frequency Quadrupole (RFQ) operating at 352.2MHz. Its operational data is currently being analysed to:

- Quantify the device's RF performance.
- Complement the results from previous CERN cavity tests.
- Influence design decisions on future RFQs.

Overview of the Linac4 RFQ

While unloaded, an inter-vane voltage of approximately 78 kV and a peak surface electric field of 34 MV/m are established at an input power of ≈400kW. The cavity is equipped with a directional coupler on the input waveguide section and 16 probes, and an acquisition system has been developed to automatically log the readings during operation. The mechanical design is shown in Figure 1.

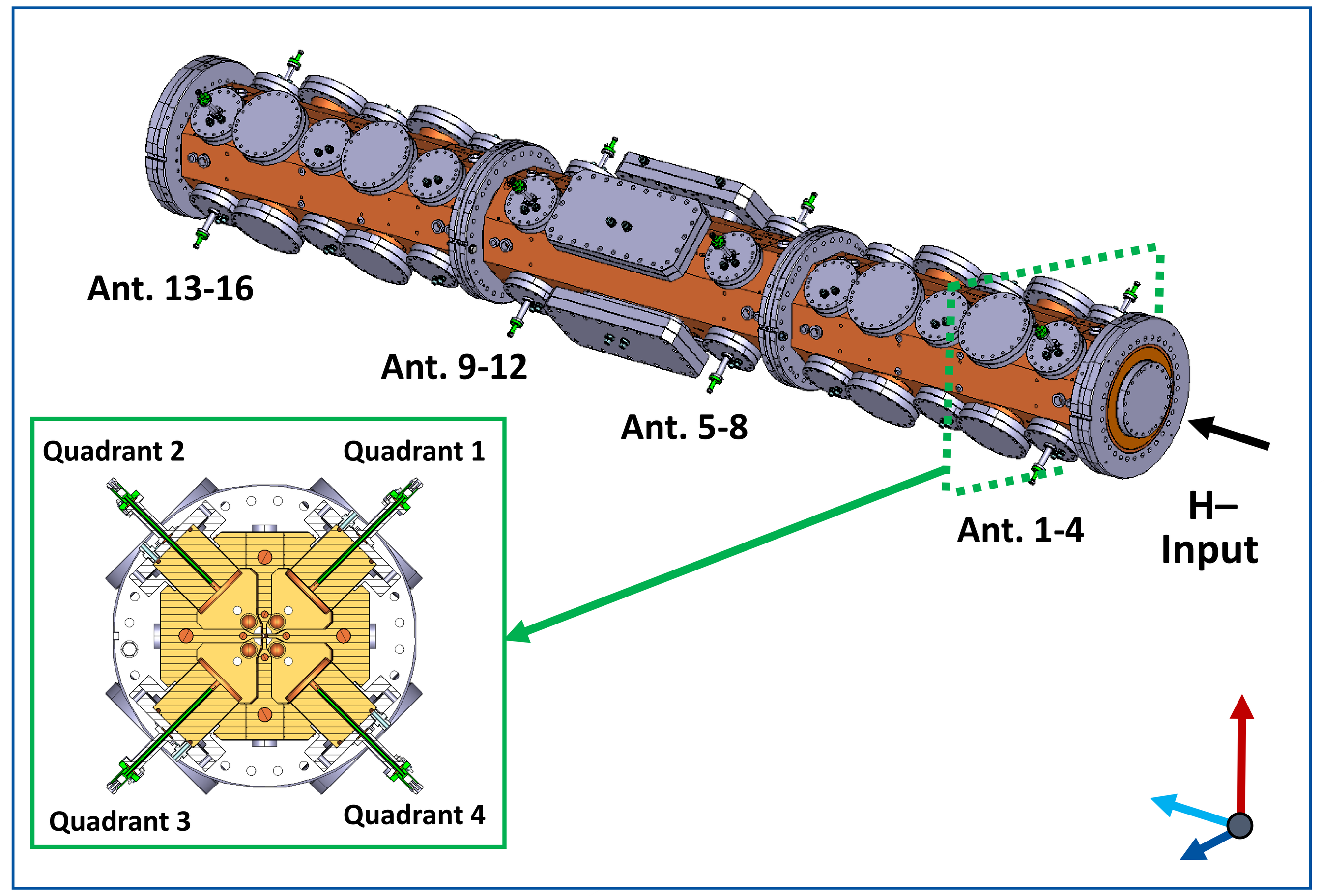

Figure 1: Mechanical design of the RFQ showing the position of the antennas and the numbering convention.

Performance of the RFQ

The breakdown accumulation for four separate operational runs is shown in Figure 2. The probabilistic behaviour of the accrued breakdowns has been examined and is comparable to that of CERN's high-gradient X-band structures [1]. To date the cavity has shown no signs of degradation in terms of its RF performance.

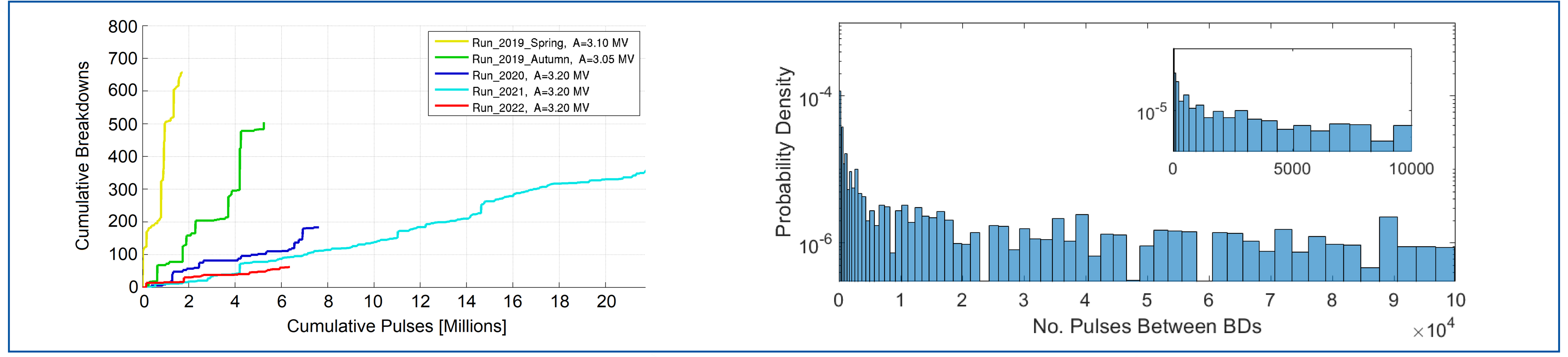

Figure 2: Cumulative breakdowns for each operational run (left) and a probability distribution showing the number of pulses between breakdowns (right).

Behaviour of the RFQ during Breakdown

During breakdowns the coupling from the RF source to the antennas is modified, with the reading from each antenna adopting a new steady state value until the cessation of the pulse. An example is shown in Figure 3. Simulations of a short circuited RFQ have been performed previously [2], and on the Linac4 RFQ the ring-down method was applied to infer the cavity Q-factor during breakdowns [3]. The results were limited by the resolution of the DAQ however, and so could not be used for localisation [3].

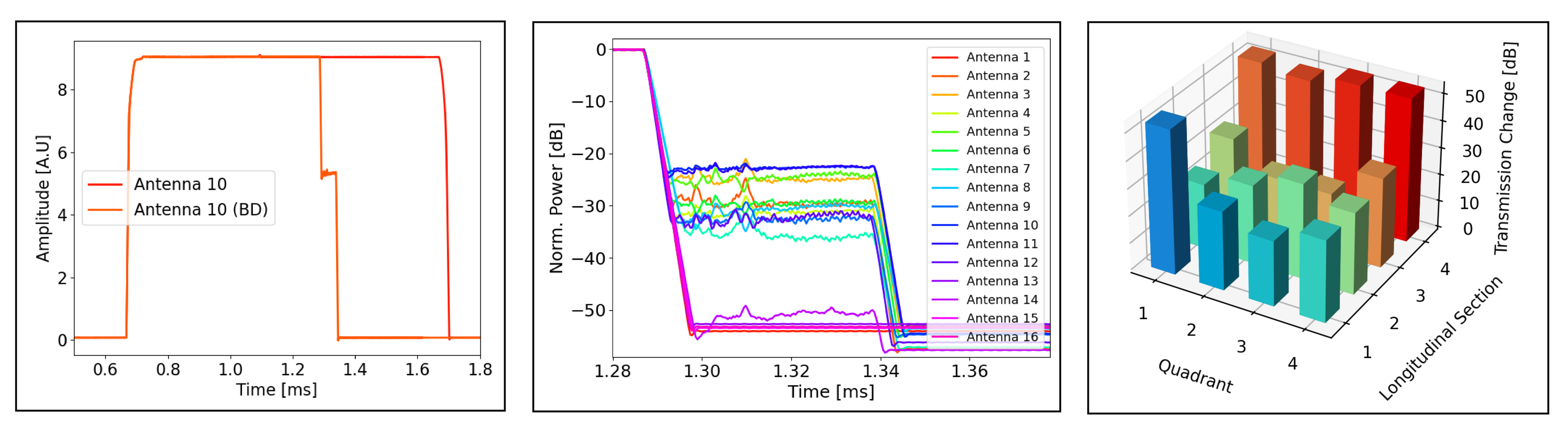

Figure 3: Signal from antenna 10 during a BD and non-BD pulse (left), all the antenna signals when a breakdown occurs (centre), and the change in transmission during the breakdown in dB calculated for the entire array of antennas (right).

Breakdown Localisation Studies

An investigation is now underway to determine whether the change in antenna S-parameters can be used to reliably infer the longitudinal and radial position of the breakdowns during operation. In simulation, the breakdown is modelled as a short between the peak electric field regions on the chosen vanes at a given longitudinal position. A frequency domain simulation is then performed and the resulting S-parameters are algorithmically compared with operational data. An illustration of the simulation setup is provided in Figure 4.

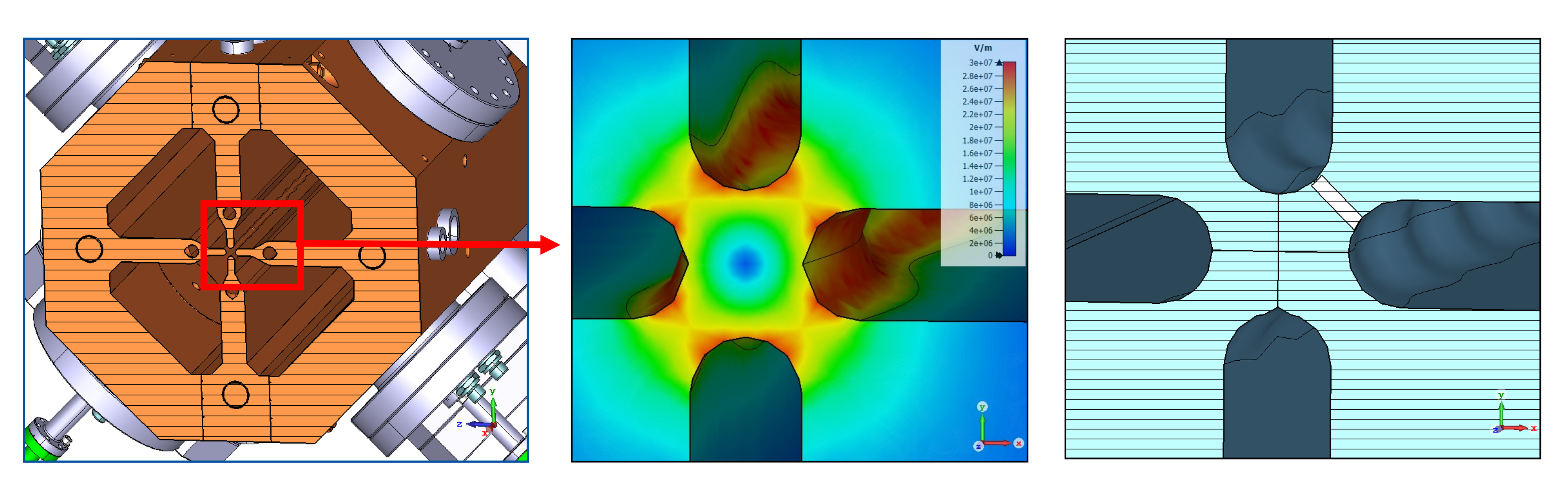

Figure 4: Cross-section of the RFQ (left), the nominal E-field distribution around the vane tips (centre), and the PEC short used in simulation (right).

Conclusion and Future Work

The breakdown rate of the Linac4 RFQ is currently <1E-5 bpp and to thus far no degradation of its RF performance has been observed. Novel simulations to determine whether it is possible to localise the breakdowns longitudinally and radially are currently underway. The results may then complement existing theories on breakdown and influence future cavity design decisions.

References

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International Workshop on Breakdown Science and High Gradient Technology (HG2022), Tuesday 17th May 2022