High gradient X-band accelerating structures testing under beam loading at the CTF3

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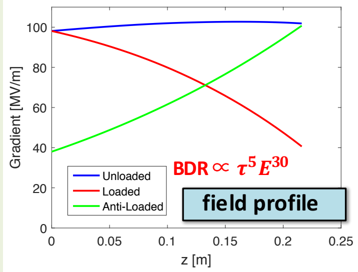
Introduction

- CLIC is based on travelling wave (TW) accelerating cavities working at an **average gradient of 100 MV/m**
- CLIC luminosity limited by RF breakdowns (BD)
- => Breakdown rate (BDR) < 3 10^{-7} BD/(pulse m)
- BD rate achievable but all tests performed without beam
- **RF beam loading significantly changes field profile** in a travelling wave accelerating structure
- Whole-structure BDR varies with the field E as ~E^{30}
- BDR along structure varies ~linearly with surface field

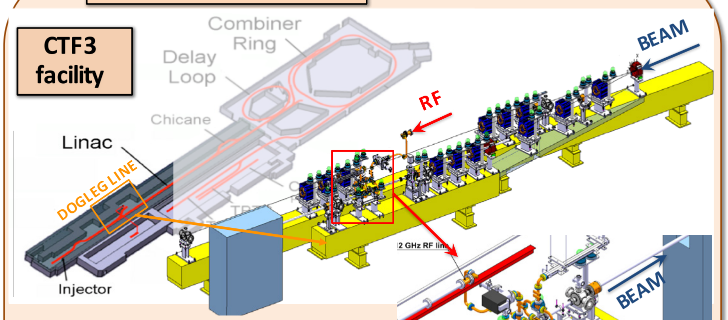
=> beam-loading effect on BDR hard to predict

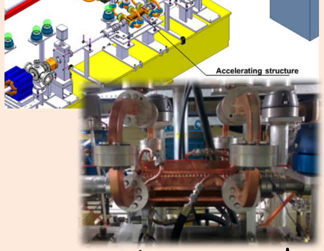
The effect of the beam loading on the breakdown rate needs to be well understood, but **has not been previously measured**



Longitudinal **accelerating gradient profile** for the CLIC structure under test unloaded (blue) at 43.3 MW input power, with 1.6 A of beam loaded (red) at 43.3 MW and anti-loaded (green) at 6.5 MW input power.

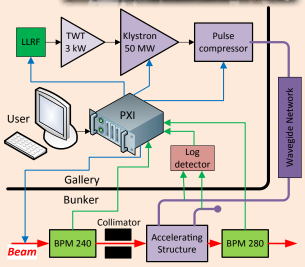
Experiment Setup

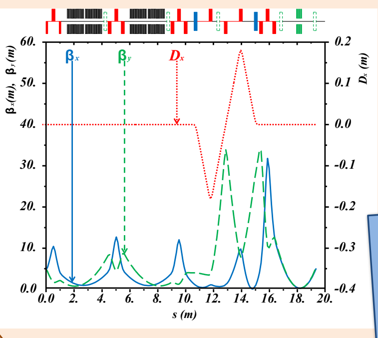




- 12 GHz TD26CC accelerating structure installed in the CTF3 at CERN
- Reused existing beam line branching off mid-linac
- Structure connected by overmoded RF line to a 12 GHz klystron with RF pulse compressor
- Transmitted and reflected input and output RF power measured
- BPMs up and downstream the structure
- pulse-to-pulse check for breakdowns (based on reflected power appearance and decrease in transmission)
- BD pulses logged with two preceding pulses

- structure was conditioned with RF
- RF breakdown rate measured without and with presence of the beam, loaded and anti-loaded (decelerating the beam)



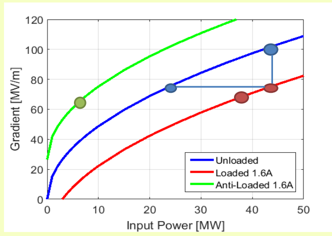


- Higher current than CLIC nominal drive beam to enhance the eventual effect on the breakdown rate
- Beam optics set to minimize the losses into the structure
- Collimator aperture at the entrance of the structure

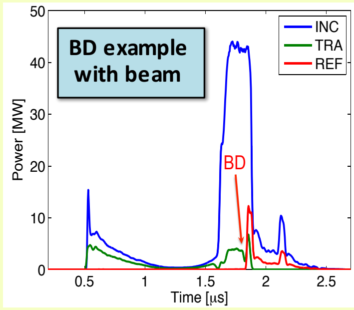
Beam properties:
- Electron beam at 120 MeV/c
- Beam current 1.6 A
- Pulse length up to 250ns (nominal CLIC pulse 180 ns)

Experimental Results

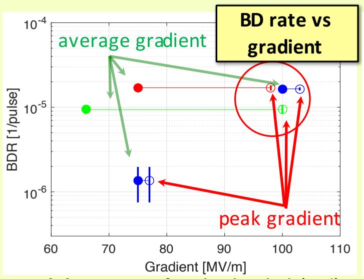
For the first time, the breakdown rate with beam-loading was measured !!!
The beam does not increase the BDR for the same input power.



Dots are the measurement points for comparison

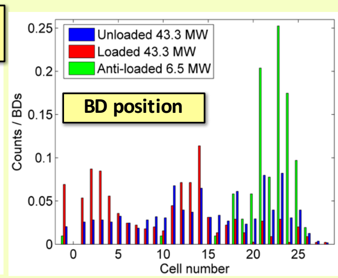


The incident (blue), transmitted (green), and reflected RF power (red). The transmitted power rises again after the BD due to the beam-loading.



Breakdown rate for the loaded (red), unloaded (blue), and anti-loaded (green) cases. The plot shows both **average gradient (filled dots)** and **peak gradient (empty dots)** for each case connected by a line.

=> Comparable BDR for similar peak gradient, not average gradient



Breakdown cell distribution along the TD26CC structure for the unloaded (blue), loaded (red) and anti-loaded (green) case.

=> BDs predominantly in the high-field region

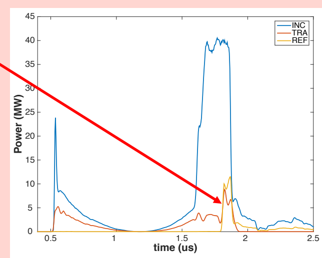
Conclusions

- 1st dedicated experiment **measured** the **breakdown rate with beam-loading**
- **BD rate dominated by** maximum **peak gradient** rather than average gradient
- **BD distribution** inside the structure **supports this conclusion**
- If confirmed => CLIC structure tapering can be optimised for loaded gradient

Follow-ups

Study the TRA power raise after BD

Idea: the transmitted power rise after the BD is induced by the beam that keeps advancing in the structure, so depends on the BD position in the structure ?



Breakdown migration

Idea: comparing the reflected power pattern with the incident and the position of the breakdown in the pulse is it possible to understand if the breakdown is moving

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