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Machine learning-based fault classification in superconducting cavities at Chinese ADS front-end demo SRF linac

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In 2021, the Chinese ADS Front-end demo superconducting radio-frequency (SRF) linac, known as CAFe, successfully conducted a commissioning of a 10 mA, 200 kW continuous wave proton beam. During this commissioning, it was observed that the SRF cavity fault played a predominant role, contributing to approximately 70% of total beam trips. Upon the detection of fault signals, an acquisition process recorded 8 RF waveforms using digital low-level radio-frequency systems. A meticulous study of the cavity fault mechanisms was undertaken, leading to the identification and generalization of several fault patterns through the analysis of collected time-series data. The findings revealed that the dominant causes of SRF trips were field emission-triggered cavity faults and thermal quenches. We optimized the feature extraction methods for fault signals and developed a machine learning-based fault classification model. Comparative analysis with expert identification results demonstrated an accuracy rate of over 90% for the model. This research marks a significant stride towards enhancing the availability and reliability of operational beams for the future China Initiative Accelerator-Driven System project.

Footnotes

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