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FCC-ee cavities RF power coupler: study on the optimal cooling strategy to boost the cryomodule energy efficiency.

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The RF fundamental power coupler (FPC) in SRF accelerating systems can have a major contribution to the cryogenic power consumption. In the framework of the FCC feasibility study, the focus on the energy saving is of primary importance given the size of the machine, with 264 cavities at 400MHz and 488 cavities at 800MHz for the collider, and 600 cavities at 800MHz for the booster, at the ttbar working point. Additionally, this early stage of the design leaves freedom in exploring and comparing alternatives within a limited number of constraints. In this paper we present the comparison between active vapor cooling and fixed temperature heat interception for the FPC, with the aim of minimizing the heat loads to the helium bath - at 4.5K and 2K for the 400MHz and 800 MHz cavities respectively –along with the overall cryogenic cost of the design solution. The choice for the FPC cooling method impacts the energy consumption, given the low efficiency of low-temperatures heat extraction, but it also affects the integration design of the coupler in the cryomodule, the cryogenic lines layout, and eventually the overall size of the cryomodule, with consequences on the tunnel space needs.
In this paper, the results - concerning the temperature field on the FPC outer conductor, and the cryogenic cooling needs - are presented for the two cooling strategies and different coupler geometries. The data are derived with a semi-analytical model, describing the different heat transfer phenomena and the selected cooling strategy. The model is parametric with respect to the geometry and the RF inputs (RF power per cavity and electro-magnetic field across the outer conductor). In this way, it is possible to maintain flexibility towards the variations, in shape and heat loads, generated by integration choices, RF design constraints, and RF operating conditions across the four FCC working points. Additionally, the model serves as a tool to guide the design of the FPC, evaluating the direct impact of a choice on the final performances of the coupler in operation.

Submitters Country

Switzerland

Authors: CANDERAN, Karin (CERN); PARMA, Vittorio (CERN)

Presenter: CANDERAN, Karin (CERN)

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