Snowmass 2021 Letter of Interest

Key Directions for Research and Development of Superconducting Radiofrequency (SRF) Cavities

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Superconducting radiofrequency (SRF) cavities are a critical technology for several frontiers of experimental high energy physics. SRF cavities make up the vast majority of the PIP-II linac, which will drive LBNF/DUNE [1]; SRF cavities provide energy to the beams of the LHC, and they will also provide crabbing at the interaction regions to boost luminosity in HL-LHC [2]; SRF cavities would provide energy for beams in the next generation of proposed Higgs factories, including ILC, FCC-ee, and CepC [3,4,5,6]; in addition, SRF cavities are being explored not for particle beam acceleration but for detection in the next generation of dark sector searches [7,8,9] as well as for quantum computing, which could be extremely beneficial for HEP applications [10,11]. To continue enabling future high energy physics experiments, research and development on SRF cavities is crucial. Continued improvements in cavity performance make new scientific applications feasible when they would have otherwise been either unachievable or too expensive. To make these performance improvements realizable, we ask Snowmass 2021 for a strong recommendation for increasing support of SRF research and technology development. In this LOI, we lay out a framework for future SRF R&D directions, which will be expanded upon in a future Snowmass 2021 contributed paper.

Figure 1 gives some examples of how SRF R&D can enable experimental physics. It plots operating gradient of large-scale SRF linear accelerators (order of hundreds of SRF cavities) versus year of first operations. It shows how as progress was made in SRF R&D to increase accelerating gradient – through years of efforts to ameliorate degradation mechanisms such as multipacting, thermal breakdown, and field emission [12,13,14] – the new capabilities would bring into reach new accelerator-based experimental programs in nuclear physics, basic energy sciences, and high energy physics.

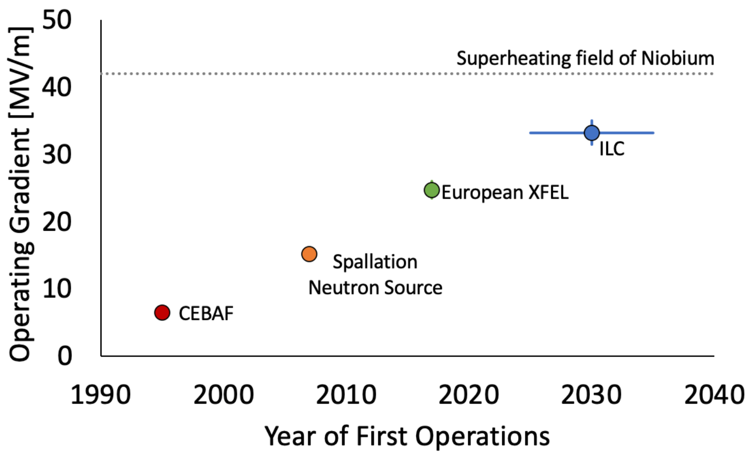

Fig. 1: *Progress with time in SRF R&D leading to higher operating gradients for large SRF accelerators.*

Fig. 1 includes ILC, based on gradient targets from the TDR. In a Snowmass 2021 submission to AF3 and AF4 [15,16], there is a discussion of how the baseline gradient could be increased, including significant increases for upgrades to ILC as R&D progress continues to be made. Figure 1 does not show other relevant ways in which R&D has improved cavity performance, such as improvements in Q_0 (e.g. the factor of ~3 improvement in Q_0 provided by N-doping has been an enabling factor in the LCLS-II X-ray FEL project [17,18]; and Q_0 values >3x10^{11} at temperatures ~1.4 K have been achieved by medium temperature baking [19]).

A roadmap for the next decade of SRF R&D was developed under the framework of the DOE GARD (General Accelerator R&D) program. The roadmap was developed by a team of leading researchers in the field from various national labs and universities, both domestic and international. The roadmap reflects the most promising research directions for advances that enable future experimental high energy physics programs. **Fig. 2** shows two summary tables from the roadmapping exercise [20].

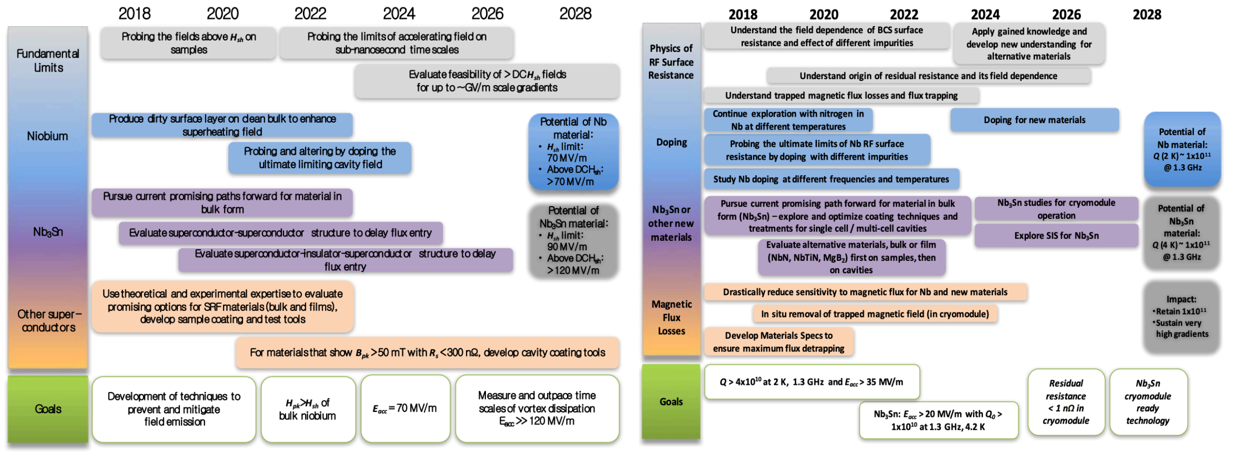

Fig. 2*: Tables showing proposed directions over a decade of research and development towards pushing the accelerating gradients (left) and Q_0 (right) of SRF cavities.*

The GARD roadmap for SRF R&D provides community-directed guidance, based on best planning from the exercise in 2017. In the contributed paper, we will outline our views on key future research directions, which largely continue to align with the roadmap from two years ago. This includes studies pushing the performance of niobium, including doping, multi-step heat treatment, flux expulsion and flux losses; it includes new materials such as Nb_3Sn as well as layered structures; it also includes fundamental studies of the physics of RF surface resistance and penetration of flux into superconductors at high fields.

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