Superconducting RF for CW Synchrotrons and ERLs

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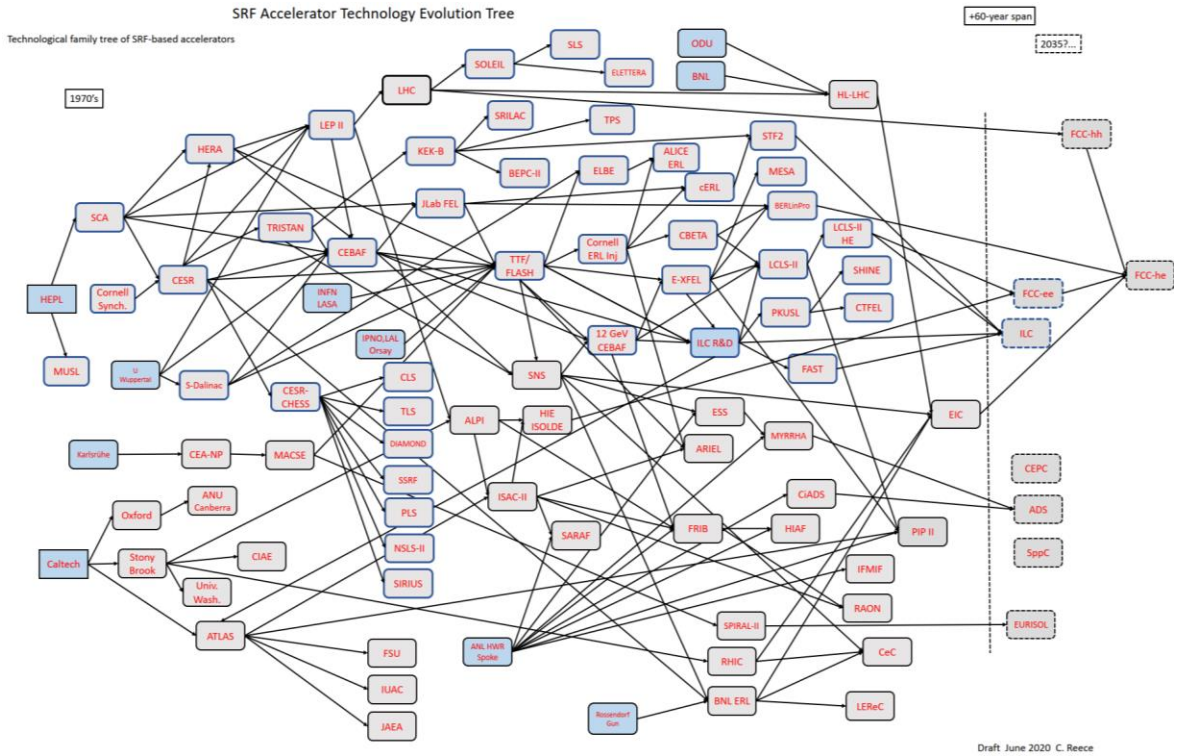
Superconducting RF technology has made significant progress over the last decades, as illustrated in the "technology family tree" shown below, produced by Charles Reece. This R&D focused primarily on high gradient acceleration as needed for linear accelerators such as TESLA and the ILC – the primary figure of merit was thus the reachable accelerating gradient. For recirculating accelerators however, like in particular synchrotrons and – in lesser degree – energy-recovery linacs, small cavity losses and small cryogenic consumption as well as high beam power and higher-order-mode (HOM) suppression are of higher importance than accelerating gradient. This latter approach addresses the needs of machines like the FCC and the EIC.



Building on the experience gained from the large-scale LEP RF system (288 superconducting cavities) and the LHC RF system, which both use superconducting cavities based on copper substrate coated with a thin Nb inside layer, CERN is investigating further in this technology for the FCC in the future. This technology is complementary to the sheet-Nb technology mostly used for high gradient applications. We see the following advantages of this technology: Copper serves as a heat sink and thus has a temperature-stabilizing effect. Copper is cheaper than niobium and easy to machine. Cu-Nb technology allows operation at 4.5 K, while sheet Nb calls for operation at lower temperature. Also, Cu-Nb cavities behave more controllably under extreme conditions (quench, warm-up). These benefits are most pronounced for lower frequency cavities typically used in storage rings. On the downside, Cu cavities with a Nb thin-film have in the past suffered from the so-called "Q-slope", i.e. a steady decrease of the quality factor with larger field gradient. This is why these cavities are typically used at moderate gradient. Results of recent R&D however, performed jointly by CERN and JLAB, are very encouraging to tackle this weakness with improved coating techniques.
In this letter, JLAB, BNL, FNAL, Cornell University and CERN wish to highlight a common interest to continue and expand their well-established and fruitful R&D in international collaboration. These institutions are recognized as world leading in the field of SRF. CERN is interested in the optimization of superconducting cavities and cryomodules for the operation in recirculating accelerators like rings and energy-recovery linacs operating in CW.
CERN operates its present accelerators SPS and LHC at 200.4 MHz, 400.8 MHz and 801.6 MHz. To maximize synergies, CERN has opted for the same frequencies for studies of possible future accelerators (FCC-ee, FCC-hh, FCC-he and LHeC).
Areas of R&D (for an overview see e.g. https://indico.cern.ch/event/832933):

- Improved cavity fabrication techniques (EHF, electroforming, spinning, hydroforming, Additive machining, electropolishing, micro-mechanical polishing…),
- Improved coating techniques (HiPIMS, Energetic Condensation, positive pulse…),
- Investigation of thin film techniques for A15 superconductors like Nb_3Sn or V_3Si, applicable to cavities,
- Optimization of cryomodule design,
- Design and optimization of fundamental power couplers (FPC) and HOM couplers to handle 500 kW+ in CW.

In many of these areas of R&D, a strong synergy between FCC and the EIC is clearly visible. Fruitful collaborations between the US Labs and Universities and CERN on several of the above subjects already exist.