Engineering and Industrializing Superconducting Particle Accelerators

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This talk will review the key technologies and design challenges for superconducting radio frequency accelerator cryomodules for large-scale production. Typical operation frequency can range from tens of MHz to a several of GHz, which gives a resonator size on the order of a 1m in size. These niobium structures, are formed using sheet metalworking, have a relatively low yield stress values, which are easily deep drawn. Manufacturing a large number of these resonators are typically limited in production time by the electron beam welding of the components which require the frequency to be within .03 % of the nominal operation frequency. Limiting the number of welds by deep drawing and minimizing components is one challenge of current resonator design. Design to ASME pressure vessel code is also an area of development which are normally made from titanium because of the similar thermal expansion coefficients. Stainless steel is being explored widely but the induced displacements upon reaching cryogenic temperatures shift the resonant frequency.

The resonators require cryogenic temperatures for super conducting operation that is typically accomplished via a liquid helium circuit and many times sub-atmospheric for greater resonator efficiency below the Lambda point of helium. To maximize thermal Carnot efficiency and simplifying the cryogenics distribution, many cryomodules produce the liquid helium inside the cryomodule using a Joule-Thompson(JT) valve to isenthalpically expand the distribution's ~5 K, 3-5 ATM helium supply. These cryogenic systems are highly specialized; require heat exchangers and industrial manufactures are limited.

The alignment of the resonators, for heavy ions, is typically required to be less than 0.5 mm from the theoretical beam axis. To facilitate mass manufacturing of the cavity string assembly, a bolt in place-machined interface from resonator to a strong back support structure is being developed. Material selection for grounded supports require low thermal conducting composites, thermal expansion stability, and tight machine tolerances. This is an area for future industrial involvement. For optimum resonator efficiency a low magnetic field environment is needed during transition to a superconducting state; a magnetic shield is used inside the cryomodule to shield earth's magnetic fields. Thermal radiation is mitigated by use of an aluminum or copper sheet metal shield to minimize overall thermal load and reduce refrigerator costs.

Design methods and technologies used for typical large production runs need to be extended to scientific apparatus. Large-scale cryomodule production using current industrial manufacture methods is going to be needed for the future accelerators and this is now just starting to happen.