Contribution ID: **41** Type: **Poster Presentation**

Review of μSR and β-NMR Studies on Superconductors for Radiofrequency Accelerator Technology

The performance of superconducting cavities in particle accelerators is limited by magnetic flux behavior in the near-surface region, where radiofrequency currents flow. Muon spin rotation (μSR) and beta-detected nuclear magnetic resonance (β-NMR) are uniquely suited to investigate this regime, offering access to local magnetic properties with depth resolution on the nanometer scale. This contribution reviews how these techniques have been applied to study the field of first vortex penetration, magnetic pinning, Meissner screening, and magnetic impurities in materials such as niobium, Nb_3Sn, MgB_2, and NbTiN-based heterostructures. Surface μSR enables characterization of bulk flux entry and pinning strength, while low-energy μSR and β-NMR reveal detailed screening profiles, impurity effects, and interface phenomena. These measurements provide microscopic insight into how surface treatments and material layering influence the stability of the superconducting state under high parallel magnetic fields. The results help inform material development strategies aimed at achieving higher accelerating gradients and reduced losses in next-generation particle accelerators.

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NSERC

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Session Classification: Poster Session 1

Track Classification: Superconductivity