β-SRF – β-NMR Beamline Extension for SRF Studies Commissioning and First Results

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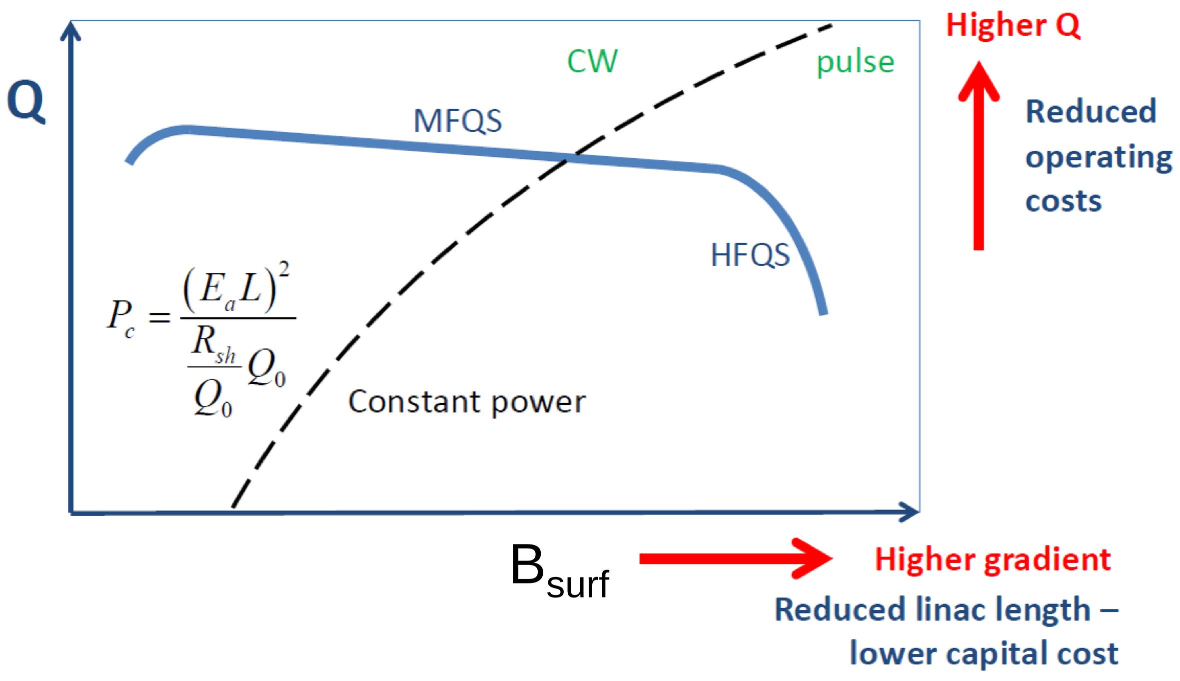
Abstract

TRIUMF β-NMR facility has been upgraded with a new spectrometer capable of surface-parallel fields up to 200 mT. This new spectrometer allows for, at the nanometer-scale, depth-resolved studies of the local electromagnetic fields near the surface of superconducting RF (SRF) materials, including conditions close to niobium's critical field. The β-NMR technique is first introduced, and the first results on SRF samples are shown. The new spectrometer has been successfully built, installed, and used for the first high-fields measurements on SRF samples.



Background & Motivation

- Nb SRF cavities → high power/energy accelerators. SRF performance → **"Q vs B$_{surf}$" curve.**
- Accelerating fields ↑, the surface magnetic fields (**B$_{surf}$**)↑, and Q ↓. **B$_{surf}$ > 150 mT, the SRF cavity quenches** → normal conducting.
- **Modifying the nm-scale near surface** (heat treatment, impurity doping) → enhance SRF performance: higher Q & quench limit > 150 mT.
- Ideal SRF probe: **depth-resolved & local fields sensitive + a high-parallel magnetic field (~200 mT).**

NO FACILITY AVAILABLE WORLDWIDE

→ WE BUILD ONE

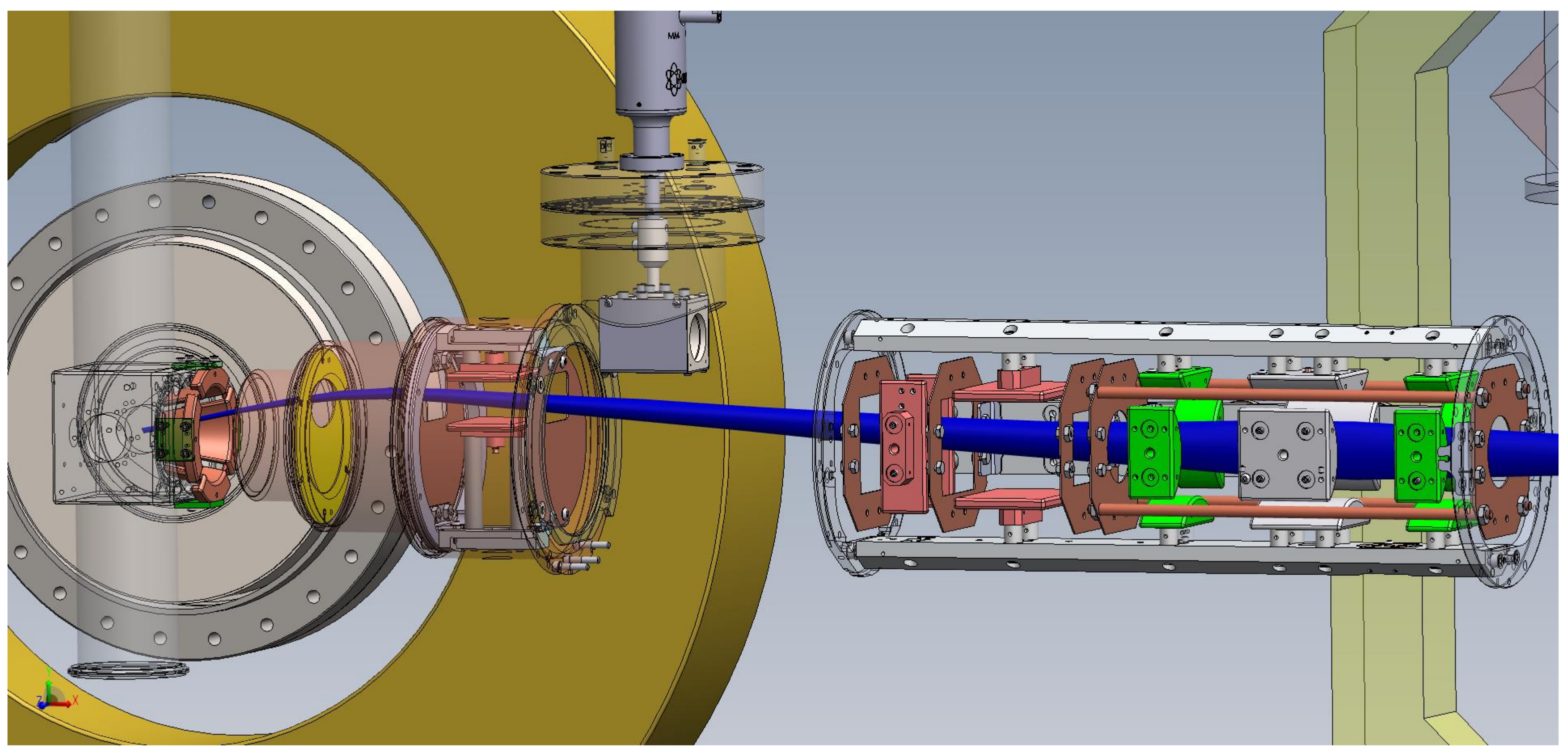
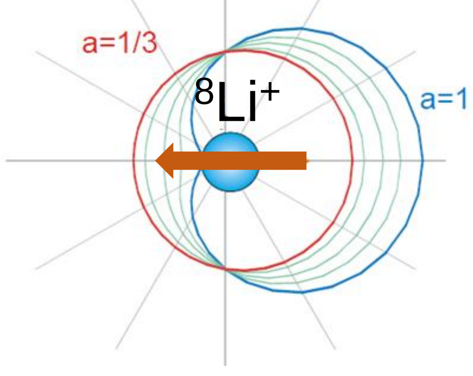


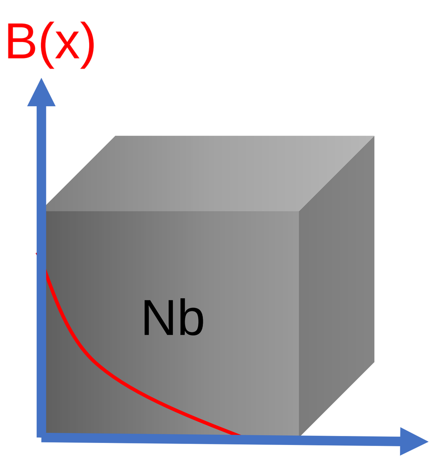
Figure 1: Radioactive ion trajectory (in blue) at the new high-parallel-field beamline. Off-axis steering is required to compensate for high transverse magnetic fields and through the radiation shields (for a future He-3 cryostat).

β-NMR Facility & Technique

- TRIUMF unique facilities: high-energy muons (μSR) and low-energy radioactive ions (β-NMR) → **detect local fields via asymmetric emission of β-particles**



- Only β-NMR → **nm-scale depth-resolution**. Requires: **radioactive beam** (TRIUMF ISAC), **laser facility** (polarize nuclear spins), and **spectrometer** (deceleration/depth-control & measurements).
- Two spectrometers: low/parallel (0-24 mT) & high/perpendicular fields (0.5-9 T). Both → **down to ~ 4K**.
- **First measurements of SRF samples with β-NMR** (24 mT): **variations of local magnetic field** at the surface layer w/ different heat-treatment.



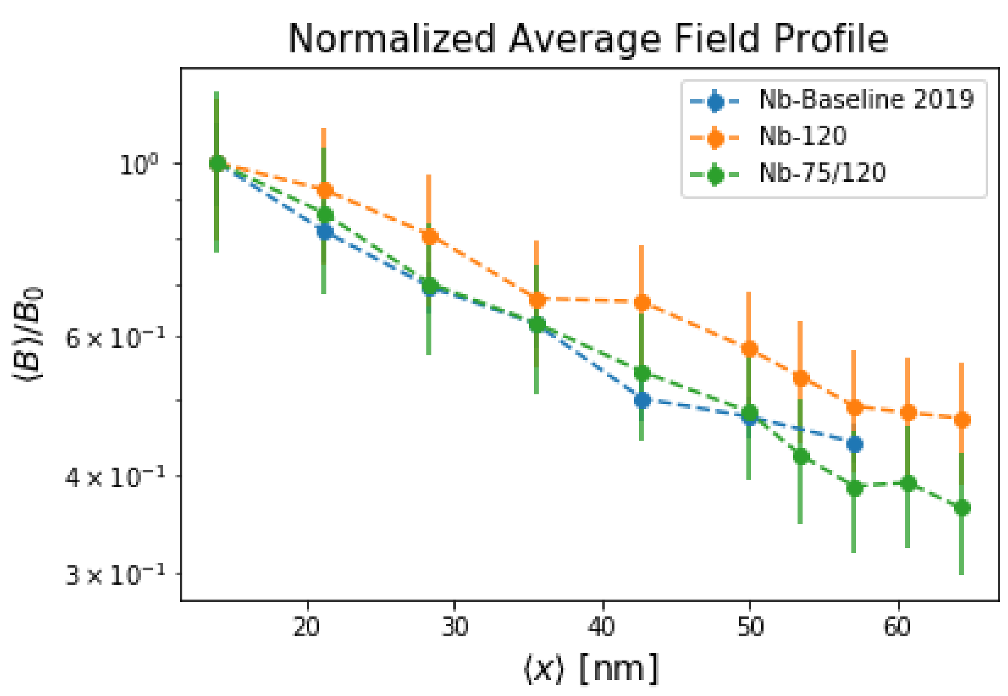


Figure 2: Semi-log plot of the (normalized) mean local magnetic field vs. the mean depth for Nb samples with different heat treatments at 24 mT.

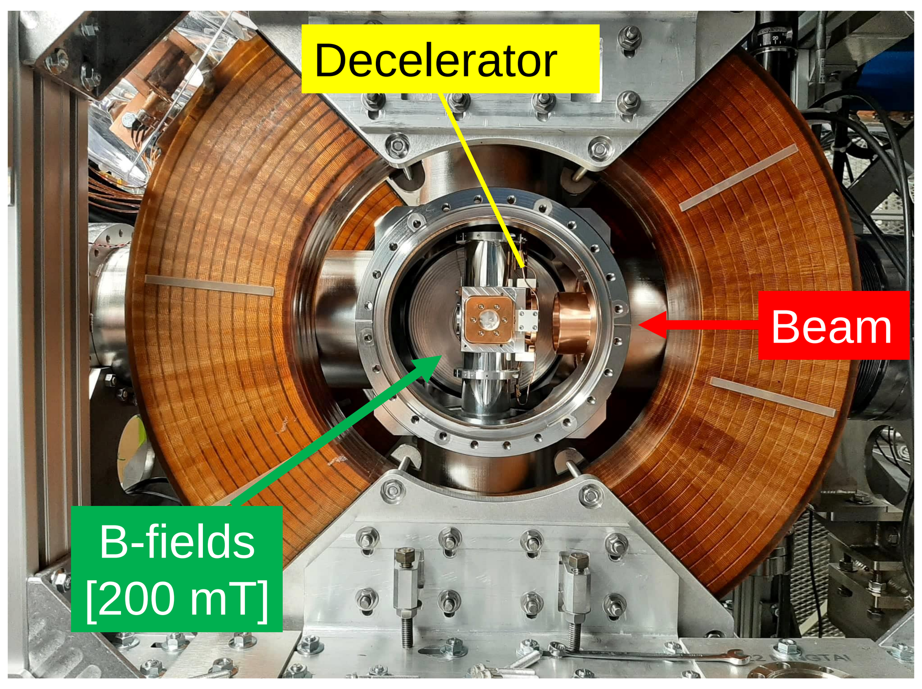


Figure 3: The new high/parallel field spectrometer configuration post installation on the beamline extension (ca. July 2021).

β-SRF Beamline Extension

- No facility exists for a nm-scale depth-resolved local probe with fields > 30 mT (cf. LE- μSR, PSI, Switzerland). **Compensating severe transverse deflection is much easier with heavier ions.**
- The low/parallel spectrometer is extended with a new ~1 m **high/parallel (up to 200 mT)** beamline. Complex steering (**compensate for high transverse *B*-fields) & future He-3 cryostat** → new & improved ion-optics + diagnostics.
- Successfully **commissioned in August 2021**. **First experiments at high-fields (~50 mT) for SRF samples done in October 2021.**

Acknowledgement

Funding for this project was provided by the NSERC Research Grant. E.T. acknowledges financial support from NSERC IsoSiM program.

Discovery, accelerated