TRIUMF

Canada's national laboratory
for particle and nuclear physics
and accelerator-based science

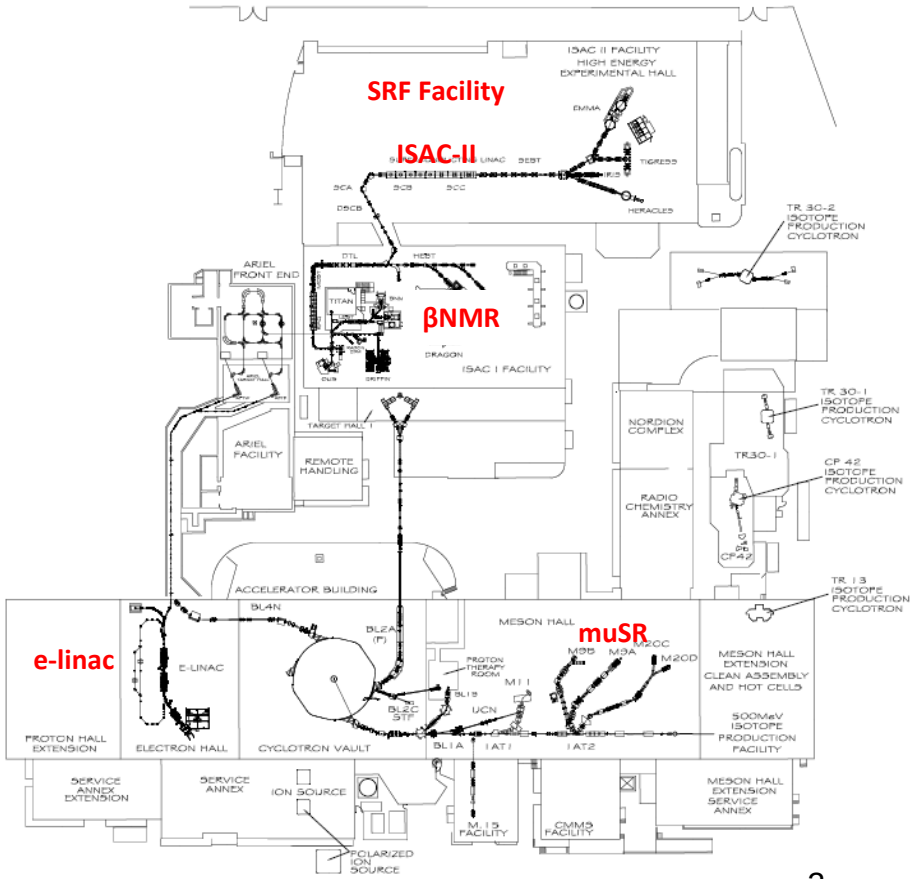
Superconducting RF research at TRIUMF

Bob Laxdal, TRIUMF

KEK Symposium, Dec. 14, 2017

Introduction

- The TRIUMF SRF program began in 2000 to support the design and development of the ISAC-II heavy ion linac with the addition of infrastructure to support SRF activities
- We now have two SC linacs in operation – the 40MV ISAC-II heavy ion linac and the 30MeV ARIEL 1.3GHz electron linac
- TRIUMF also hosts important diagnostics in material science – muSR and betaNMR
- We have an active program in student based SRF research to augment are operational capabilities

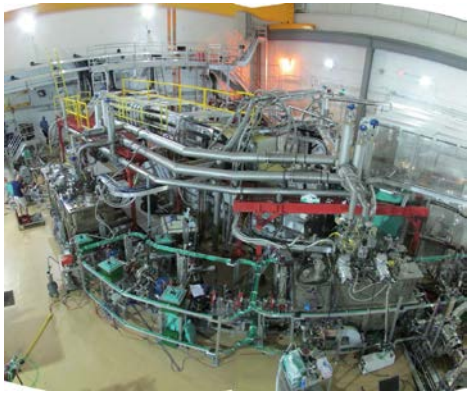


Introduction

SRF Accelerators

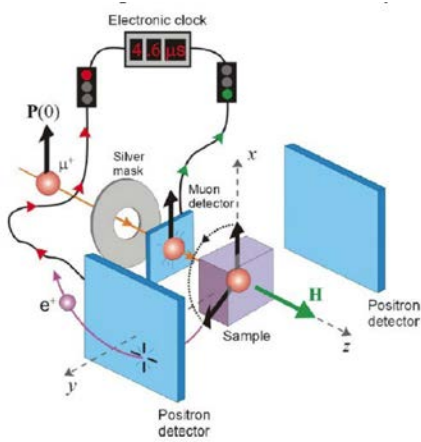
40MV ISAC-II SRF heavy ion linac @ 106MHz - operational since 2006

30MV ARIEL SRF 10mA electron linac @ 1.3GHz – first beam 2014



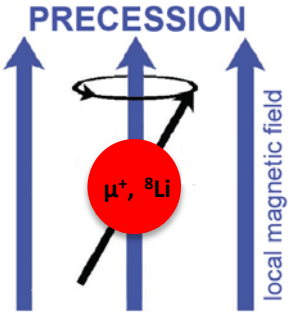
Material Science Probes at TRIUMF – muSR and β-NMR

- TRIUMF has two world class material science probes in muSR and betaNMR – utilize the beta decay of a beam of polarized muons or 8Li ions respectively as probes of local magnetism
- TRIUMF muSR samples near surface fields (100µm) and betaNMR samples surface fields (0->200nm)



Method

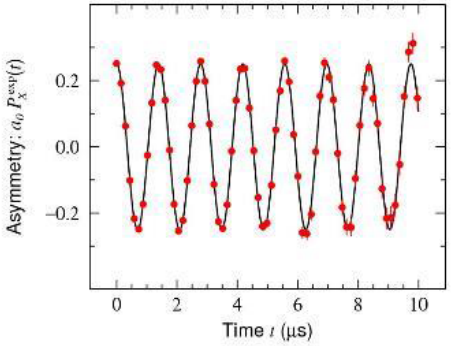
Imbedded probes decay with emitted positrons or electrons correlated with direction of spin. Spin precession dependent on the magnetic field of the imbedded probe



$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

$$^8\mathrm{Li} \rightarrow e^- + \nu_e + {}^8\mathrm{Be}$$

Atomic lighthouse



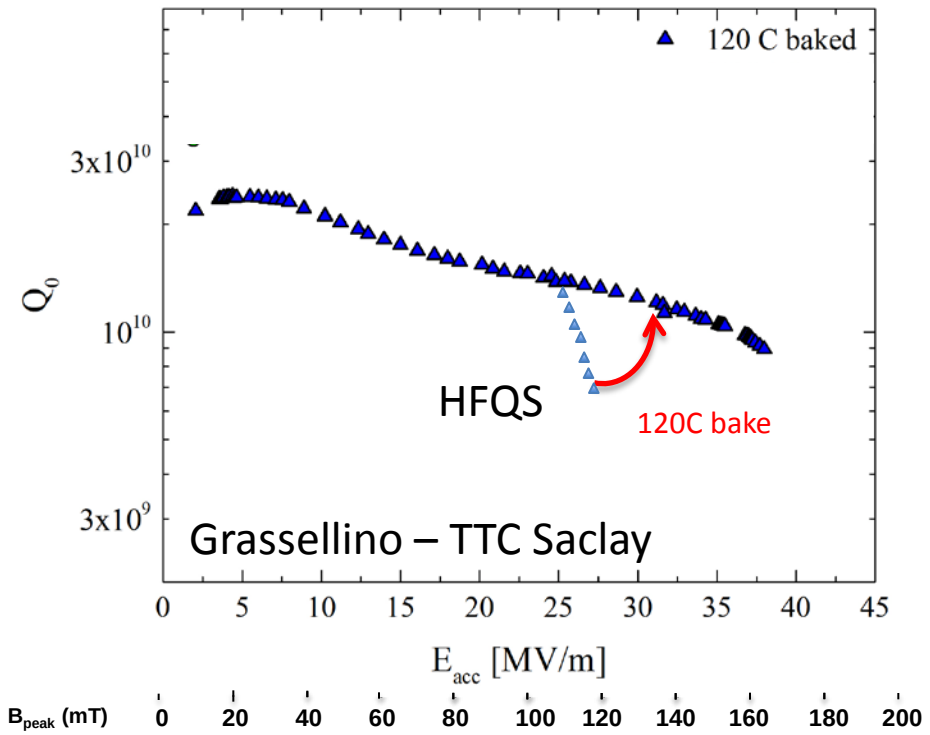
SRF Student Program

- TRIUMF offers a graduate students program in Accelerator Physics and Engineering
- One course per year taught at UBC by TRIUMF research scientists
- Five PhD students in SRF studies to date:

Problems to solve

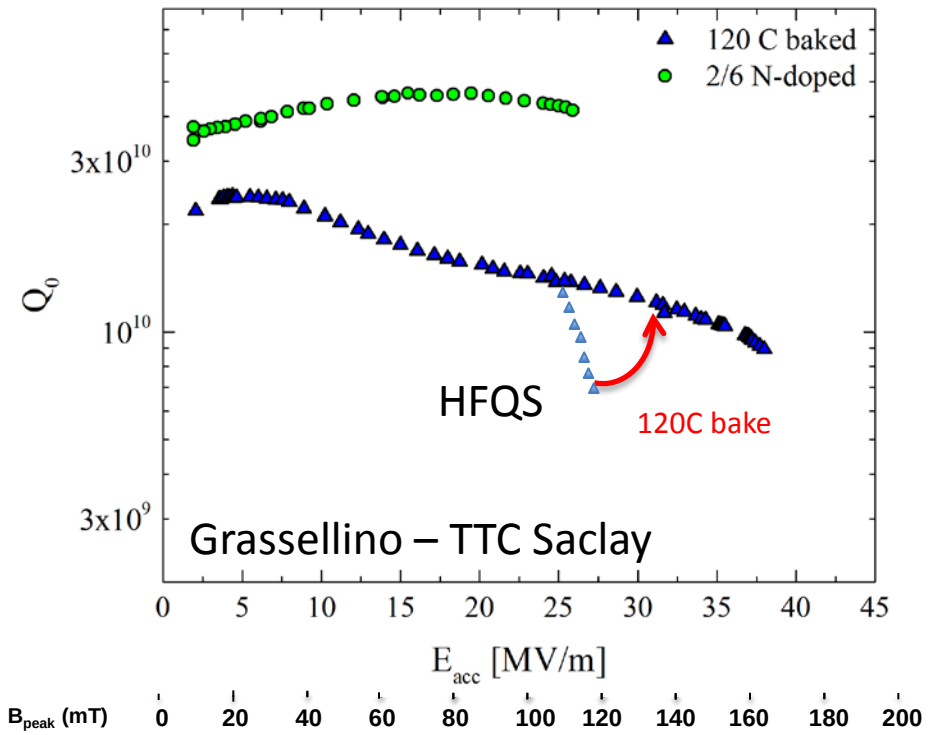
120C Bake

- The ILC baseline treatment for mitigating high field Q-slope (HFQS) is to bake in vacuum at 120C for 48 hours



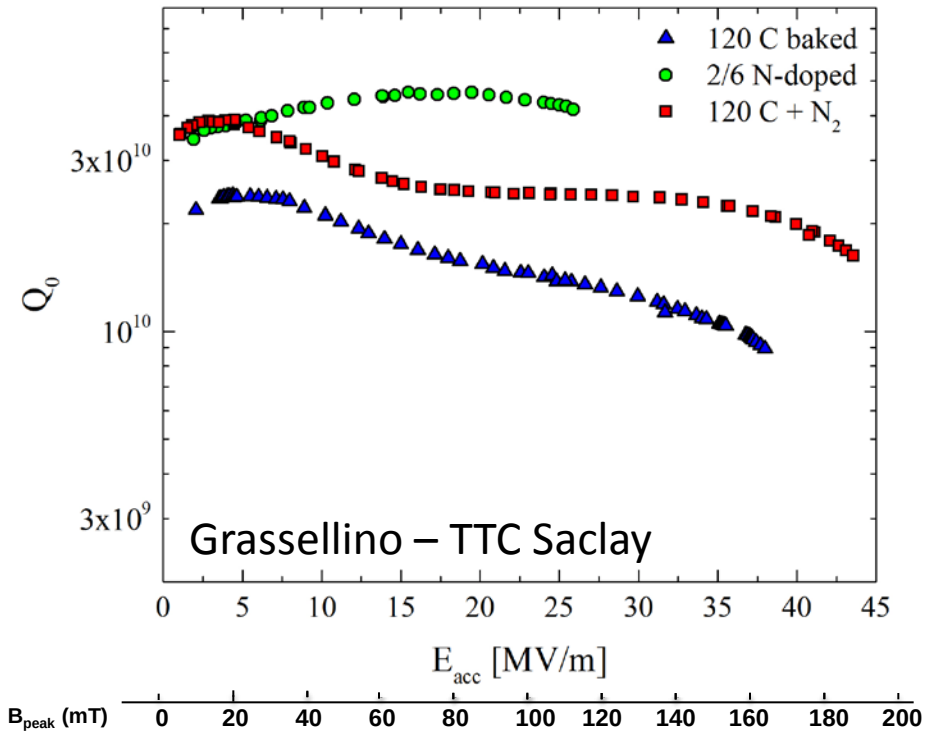
Nitrogen Doping

- The ILC baseline treatment for mitigating high field Q-slope (HFQS) is to bake in vacuum at 120C for 48 hours
- N2 doping at 800C increases Q substantially but results in a lower quench field (LCLS-II)



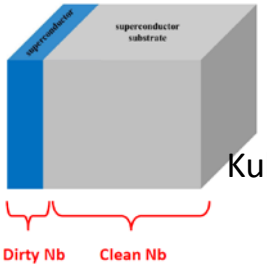
Nitrogen Infusion

- The ILC baseline treatment for mitigating high field Q-slope is to bake in vacuum at 120C for 48 hours
- N2 doping at 800C increases Q substantially but results in a lower quench field
- The new N2 infusion treatment (FNAL) raises Q (above ILC baseline) and extends the reachable field beyond B_{c1}

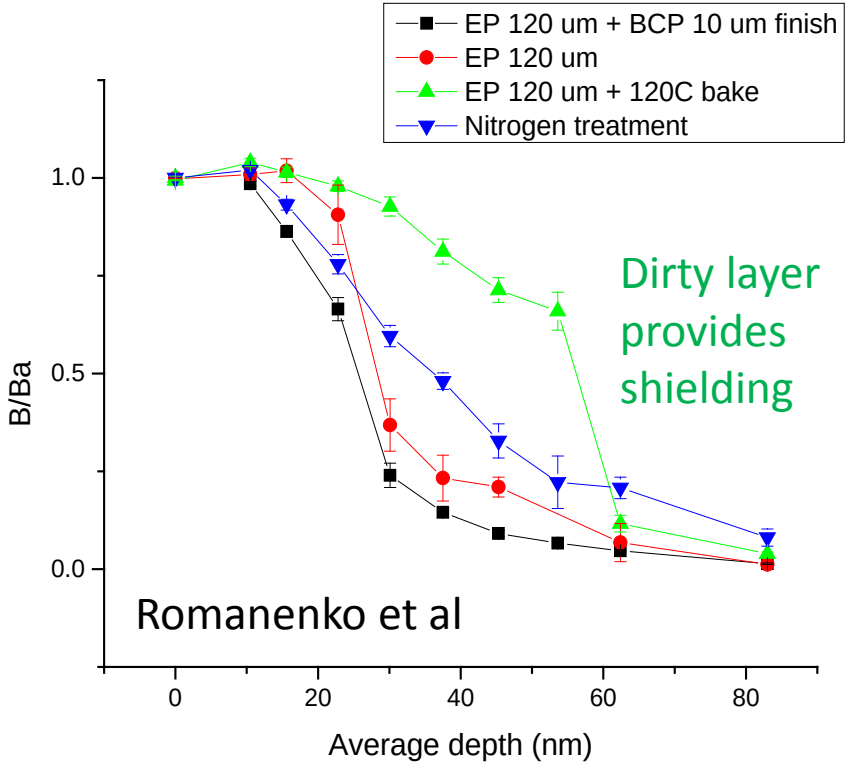


What's going on?

- 120C bake is known to manipulate mean free path at very near surface on clean bulk Nb
- A dirty layer at the surface seems beneficial in order to increase the quench field above B_{c1}
- The Nitrogen infusion is a variation of the 120C bake where N dopes the near surface without forming lossy nitrides



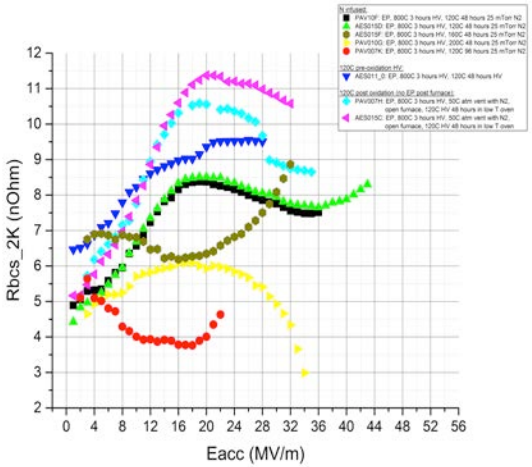
Kubo, LCWS16

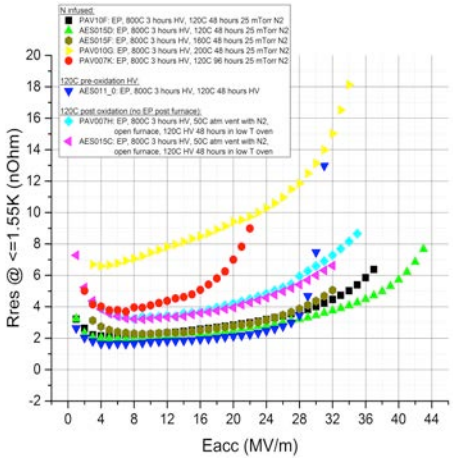


LE-muSR at PSI

Room for optimization and understanding

- Variations in the infusion process produce significant variations in the performance
- need to fine tune the duration and Temp to create right concentration and depth to reach highest fields with no Q-slope





Grassellino et al, TTC Saclay

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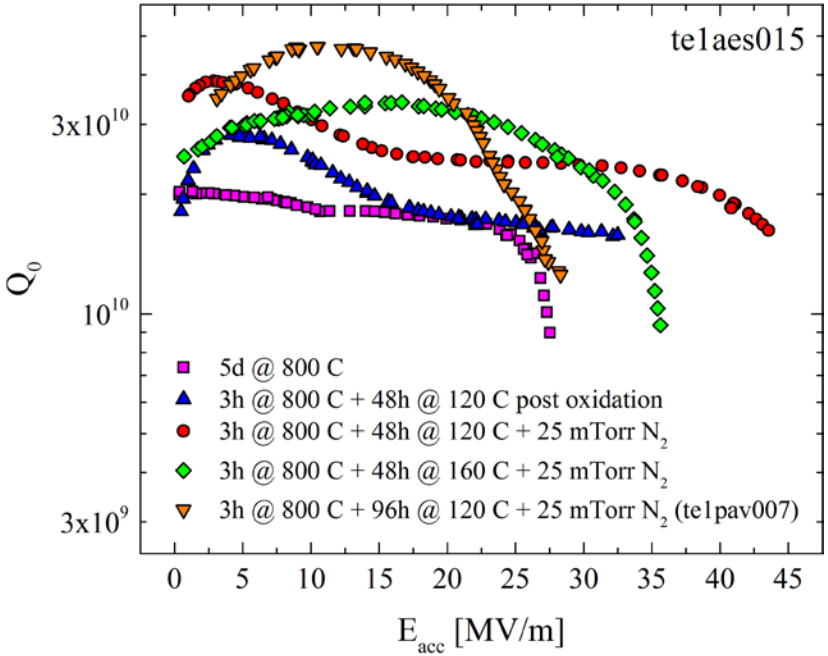
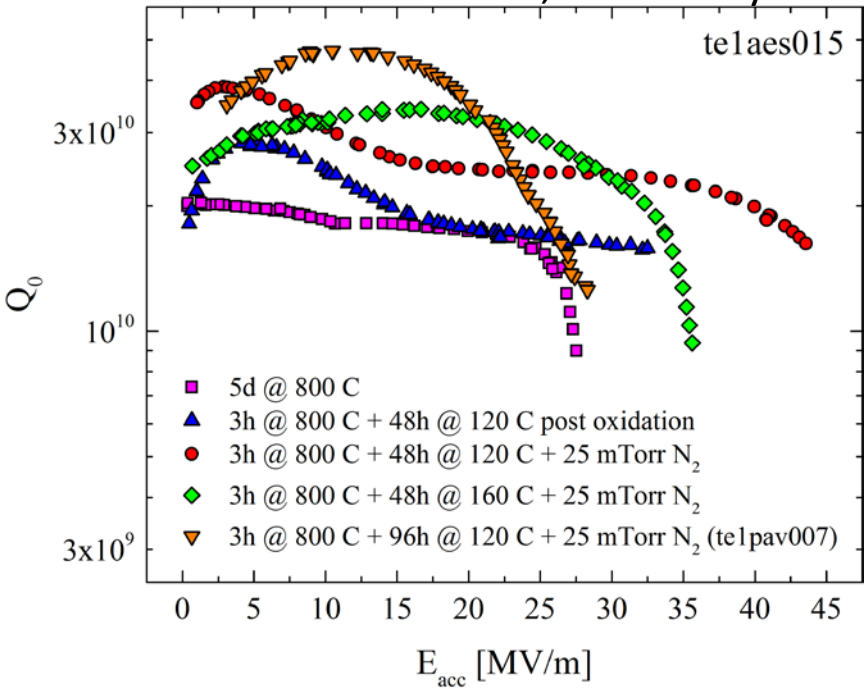


A role for TRIUMF

Nitrogen doping and baking studies

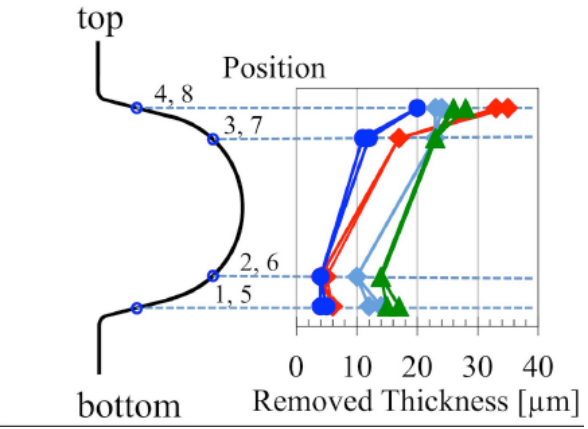
- Now commissioning a UHV rf induction oven to process single cell 1.3GHz cavities – goal is to explore various doping recipes
- Couple this program with fundamental studies using muSR and betaNMR

Grassellino et al, TTC Saclay

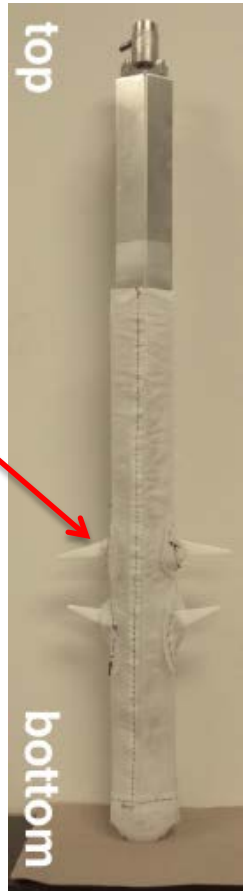


D'Sonoqua – Vertical EP Development

- TRIUMF SRF is developing vertical EP with teflon stirrers to augment doping effort – collaboration with Tamao Shishido
- Japan has the `Ninja' (Marui Galvanizing Co) – Canada has D'Sonoqua – the wild women of the woods – stealer of children yet bringer of wealth



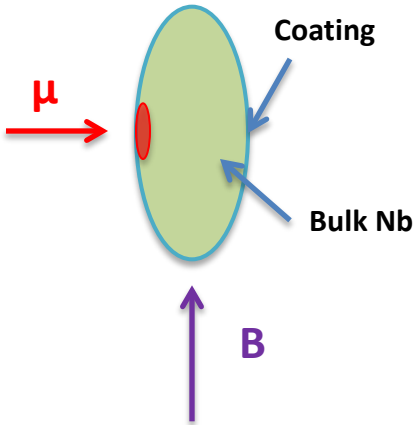
paddles

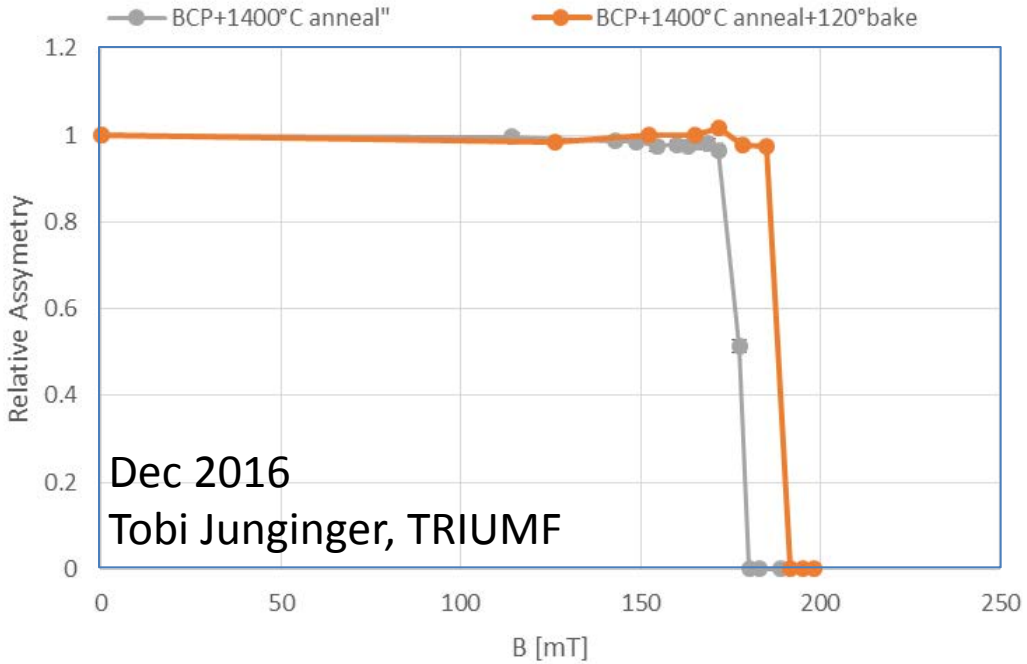


Fundamental studies - field of first flux entry with muSR

Findings: Baking at 120C in vacuum can enhance the field of first flux entry

- Bake at 120C moved field of first flux entry in annealed sample from 174mT to 188mT
- consistent with `dirty layer' hypothesis

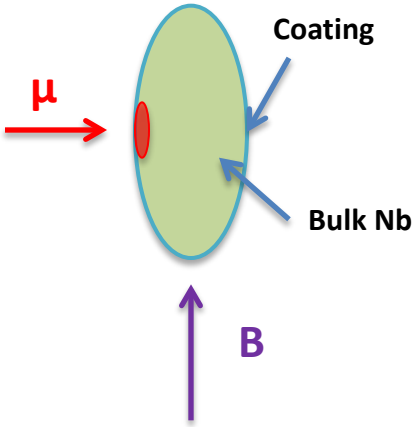


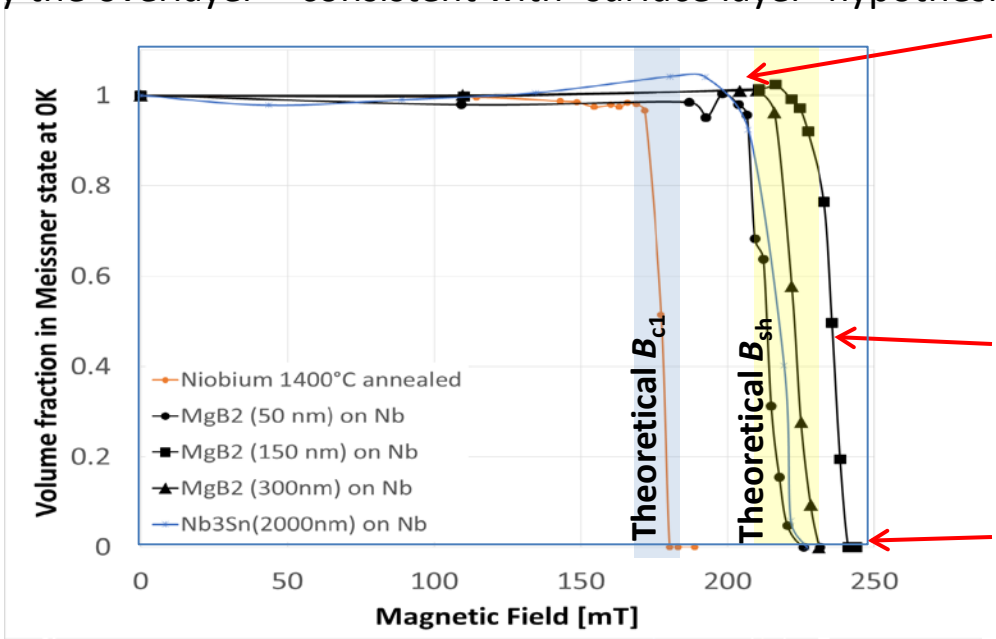


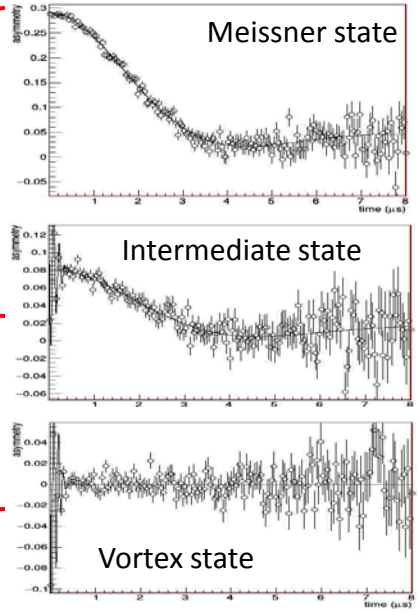
Fundamental studies - field of first flux entry with muSR

Findings: A layer of a higher T_c material on niobium can enhance the field of first entry by about 40% from a field consistent with H_{c1} to a field consistent with H_{sh}.

This enhancement does not depend on material or thickness suggesting that superheating is indeed induced in niobium by the overlayer - consistent with `surface layer' hypothesis



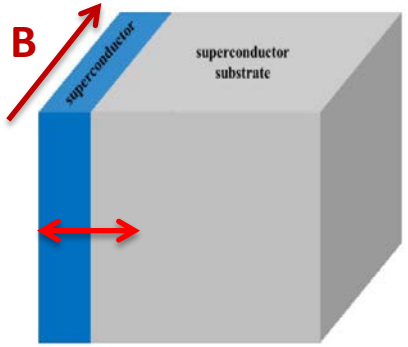


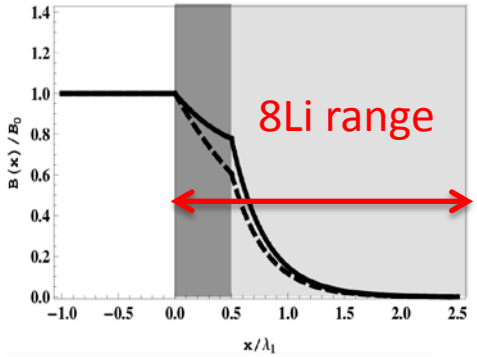


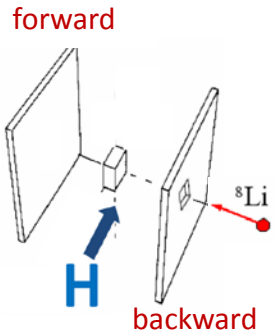
T. Junginger, R. Laxdal, W. Wasserman, *Superheating in coated niobium*, SUST, DOI: 10.1088/1361-6668/aa8e3a, 2017

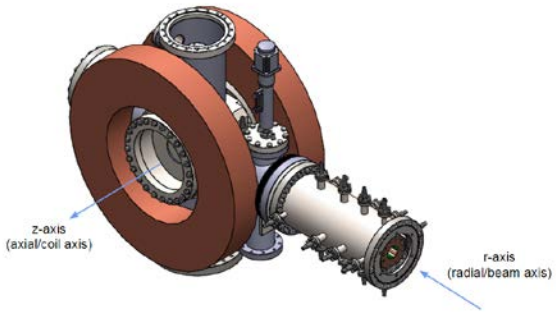
Fundamental studies – details of surface layer with beta-NMR

- Beta-NMR is a unique facility to characterize magnetic properties of materials at surfaces and film interfaces
- Perfect for SRF characterization of doping and new materials since it can probe the superconductor through the London layer
- New high field spectrometer has been designed and will be installed in 2017
- **Will be a unique facility in the world for diagnosing new treatments (doping), new materials (Nb3Sn) and new structures (SIS layers)**





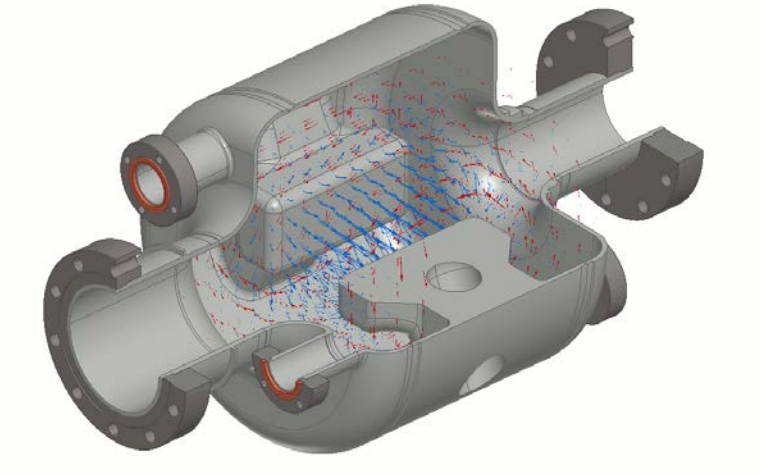


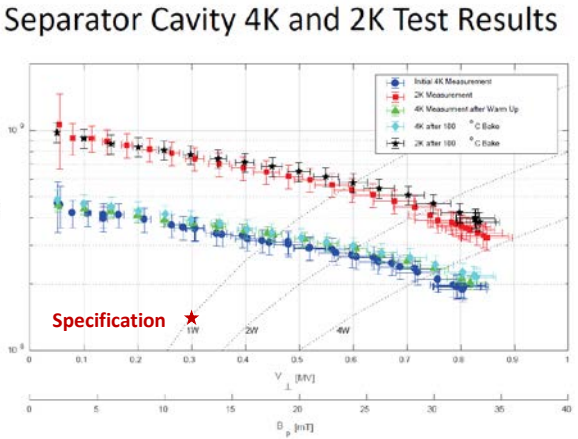


New beta-NMR line will allow surface studies up to 200mT

SRF Dipole Cavity – Doug Storey (U.Victoria)*

- 650MHz rf deflecting mode cavity has been fabricated from reactor grade Niobium with TIG welding
- First superconducting rf cavity fabricated at TRIUMF
- Cavity recently tested and meets design specification

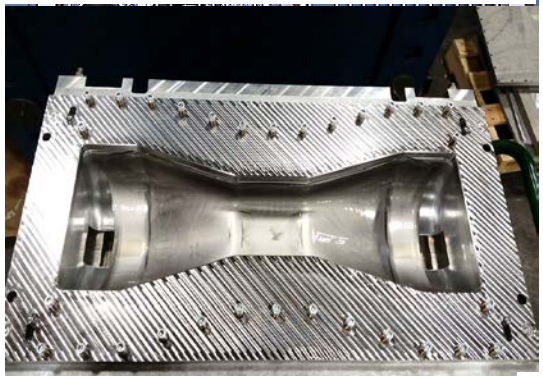


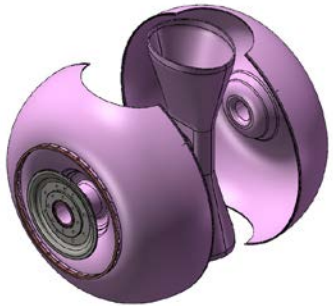


SRF/RF Work for Others

- Design and fabrication of two single spoke resonators (SSRs) – 325MHz β=0.3 – for RISP (Korea)
- Cavity is designed to suppress high field multipacting - early tests confirm this – we are now degassing the cavity before the next cold test
- TRIUMF Machine Shop and SRF team successfully formed Nb parts - developed local fabricators for brazing and spinning
- Also designing SSR tuner and coupler for RISP

SSR1 spokes + fixture





SSR1 cavity - RISP

SRF at TRIUMF

- SRF at TRIUMF began in 2000 with cavity and infrastructure development in support of the ISAC-II heavy ion linac.

- SRF department supports
  - Internal projects
    - ISAC-II heavy ion linac, ARIEL e-Linac,
  - Student education
    - Fundamental and technical SRF
  - External collaborations (FRIB, KEK, IMP, CERN, RISP, FNAL, VECC, Cornell)

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Thank you!
Merci!

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