GARD RF ROADMAP UPDATE - SRF

Argonne NATIONAL LABORATORY | Argonne Tandem Linac Accelerator System

SRF R&D FOR ION ACCELERATORS

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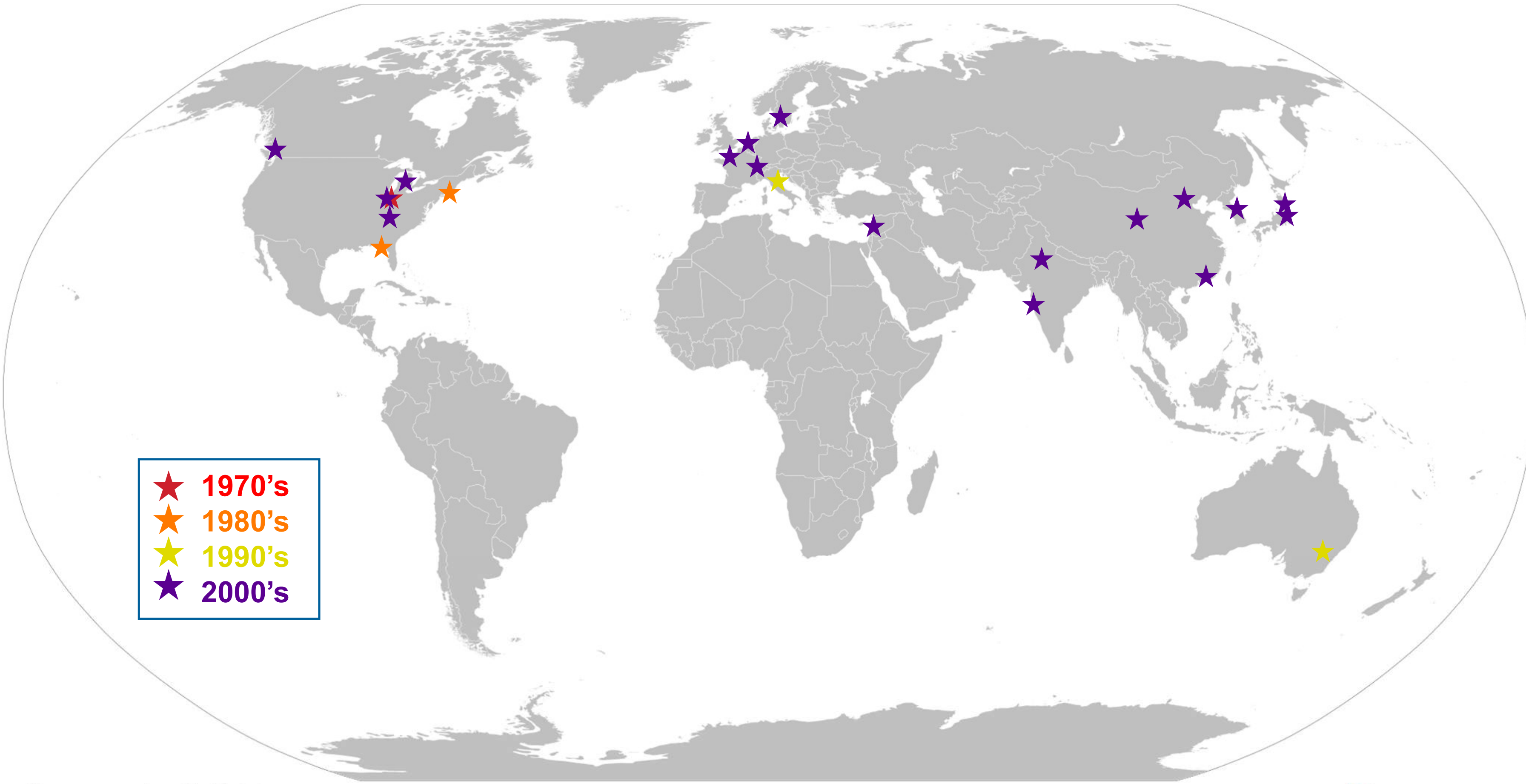
OUTLINE

- Background/motivation
- Feedback from MSU
- Three proposed topics for GARD related to ions

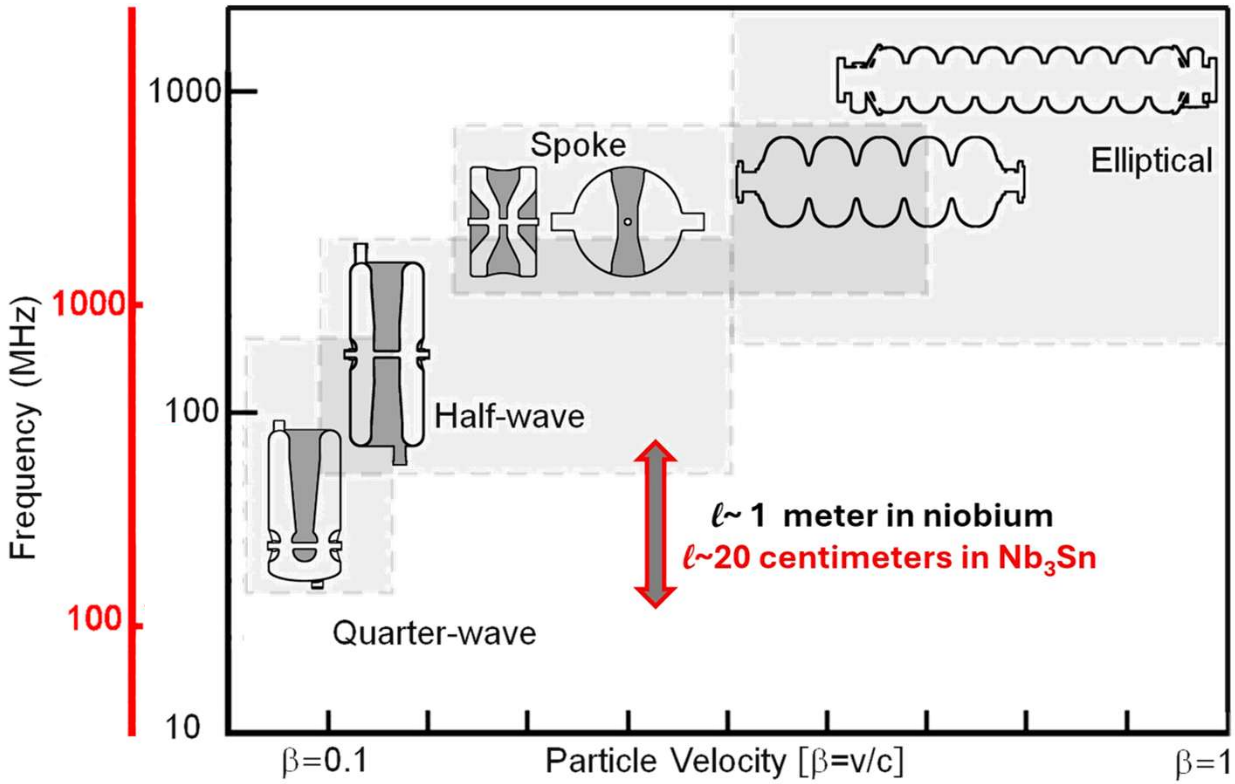
SRF ACCELERATORS FOR PROTONS AND IONS



SRF CAVITIES (NIOBIUM)

Present paradigm based on niobium established since early 2000's

Successful Nb_3Sn will impact our ability to afford future ion accelerators



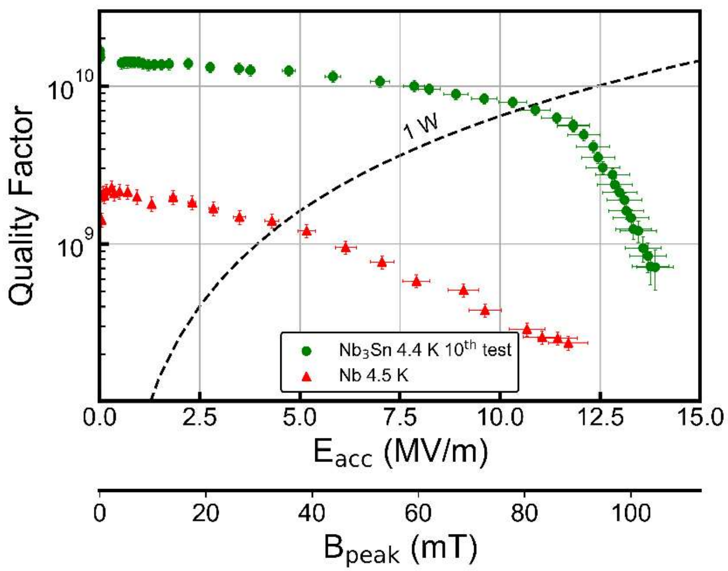
ARGONNE INTERESTS

Primary near-term motivation: new technology for cost effective ATLAS upgrades

Nb_3Sn CAVITY FOR ATLAS

Cold test – Coated vs Uncoated

- Coated cavity (green): ~10 X improvement above Nb cavity (red)
- Low field of 1.4 x 10^{10}
- B_{peak} = 105 mT field reached during testing
- T_C ~ 17.7 K measured with VNA and magnetic field probes
- High field Q slope is not FE



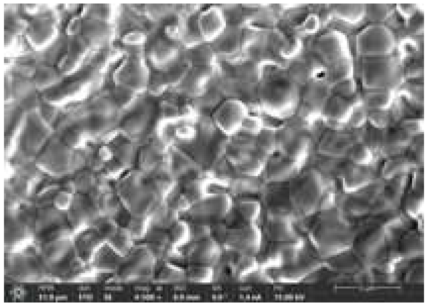
Argonne NATIONAL LABORATORY Fermilab RadiaBeam

EXAMPLE: Nb_3Sn R&D FOR LOW BETA

Fermilab

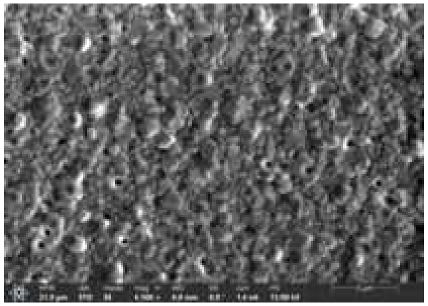
Material studies closely coupled to cavity development

Baseline
1.3 GHz
single cell



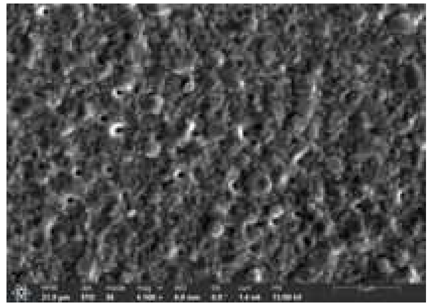
QWR 145 → Tin source end

Diameter: 0.83 um
Thickness: 1.53 um



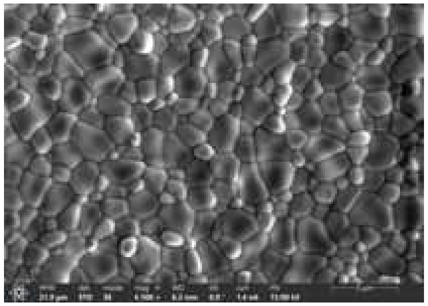
QWR 145→open end

Diameter: 0.68 um
Thickness: 1.56 um



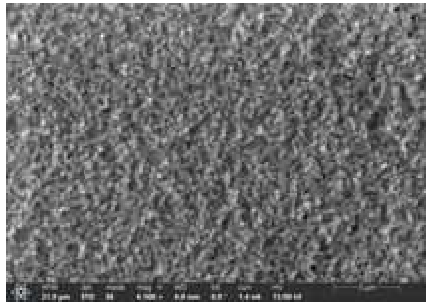
QWR 218 → Tin source end

Diameter: 1.56 um
Thickness: 2.72 um



QWR 218→open end

Diameter: 0.50 um
Thickness: 1.31 um



N. Tagdulanga, "Analysis of vapor diffusion Nb3Sn coating at Fermilab: Minimizing impurities using TOF-SIMS," in Proc. North American Particle Accelerator Conf. (NA-PAC'25), 2025, paper WEP011.

FUTURE ION ACCELERATORS (Nb_3Sn SRF)

(Non exhaustive) ion linac applications that could benefit Nb_3Sn

- Proton and heavy-ion facilities for science: ATLAS, (PIP-II, FRIB, EIC?)
  - Our 10-year strategic plan for a high intensity ATLAS upgrade using all modern SRF structures probably only possible with cost reductions enabled by Nb_3Sn
- Accelerator Driven Systems (ADS): 600 MeV to 1 GeV proton accelerators for waste transmutation, neutrons for nuclear engineering studies, energy production
  - Cost >$2B (niobium-based)
  - Cost reduction by factors with Nb_3Sn?…
- Isotopes for medicine
  - Dedicated dual 40 MV electron and light-ion SRF linacs
- Low intensity heavy-ion linacs: post accelerator for RIB's, Single Event Effect facility
  - Candidates for higher frequency (small aperture) SRF structures

INPUT FROM MSU/FRIB

Degradation in SRF cavities from ion beams

- FRIB is based on a large heavy-ion SRF driver linac / light and heavy-ions to 200 MeV/u
- Observe field emission degradation in SRF cavities related to heavy ion beam losses
- Evidence suggests that it is not due to particulate or residual gas migration from warm sections
- Proposal for GARD:
  - R&D to study the effect of heavy ion beam exposure to surface contaminants (hydrocarbons, chemical residues) for other known sources for FE
  - Niobium coupons or cavities to study the effect of heavy ion beam exposure
  - Timescale ~1-2 years

R&D OPPORTUNITIES AND THE GARD ROADMAP

Proposals for GARD in the context of present Nb_3Sn R&D for ions

1. New diagnostics supporting Nb_3Sn coating / e.g. “coating monitor concept (FNAL)” could be used broadly to study and compare coatings on different cavities and from different facilities
   - Timescale ~ 2 years
2. Lattice/beam physics/cavity EM design/preliminary layout studies for future ‘green field’ proton and heavy-ion linacs that make best use of Nb_3Sn
   - This could include higher frequencies and potentially different β ranges than existing structures.
   - Examples with cross cutting interest: a 10 MeV/u heavy-ion linac; a 1 GeV proton linac
   - Timescale 2-3 years
3. Development and demonstration of new Nb_3Sn SRF structures for ions
   - Protons and heavy ion linacs from Nb_3Sn will likely use similar cavities even if the overall linac designs differ
   - Timescale 3-5 years

Closing remark: GARD roadmap activities that align closely or are fully integrated with accelerator R&D in other areas can increase the impact of those efforts