Progress in FRIB Energy Upgrade SRF R&D

S. Kim1†, K. McGee1,2, C. Compton1, C. Contreras1,2, K. Elliott1, A. Ganshyn1, W. Hartung1, E. Metzgar1, S. Miller1, P. Ostroumov1, A. Plastun1, L. Popielarski1, J. Popielarski1, J. Rathke1, A. Taylor1, T. Xu1, M. Martinello2, D. Bice3, G. Eremenko4, Y. Pischalnikov2, M. Kelly2, B. Guiffoyle5, T. Reid3
1Facility for Rare Isotope Beams (FRIB), Michigan State University, East Lansing, MI 48824 USA
2Fermi National Accelerator Laboratory, Batavia, IL 60510 USA
3Argonne National Laboratory, Argonne, IL 60439 USA

Abstract
As part of SRF R&D for FRIB400, the energy upgrade of the FRIB driver linac from the baseline 200 MeV/u to 400 MeV/u, two βw=0.65 5-cell elliptical cavities were built and tested with various recipes. Standard EP achieved performance higher than the design goal. $Q_x > 2e10$ at $E_b = 17.5$ MV/m, and N-doping achieved $Q_x = 3.5e10$ at 17.5 MV/m. The lever tuner assembly was built and tested in a room-temperature setup simulating an RF cavity. It showed nearly linear response with no noticeable hysteresis. We will present FRIB400 SRF R&D progress and discuss future plans.

FRIB Energy Upgrade FRIB400
FRIB400 is the energy upgrade of the FRIB driver linac from baseline 200 MeV/u to 400 MeV/u for uranium beams. This would further extend the scientific reach and discovery potential of FRIB, aligned with the overarching intellectual challenges articulated in the 2015 Nuclear Science Advisory Committee (NSAC) Long Range Plan and the National Research Council (NRC) Decadal Study. A 644 MHz $\beta_w=0.65$ 5-cell elliptical cavity was chosen for FRIB400 with the detailed design of cavity and associated ancillaries (P. Ostroumov et. al., NIMA 2018). SRF R&D began in 2018 with two 5-cell bare niobium cavities and frequency tuners.

Cavity High-Q Study
Various surface processing recipes were applied to the 5-cell cavities and tested. EP consistently (two cavities and after multiple times EP reset) showed performance meeting the design goal, $Q_x > 2e10$ at 17.5 MV/m. With 2N0 doping and 7 um cold EP, the cavity showed $Q_x = 3.5e10$ at 17.5 MV/m, an unprecedented result for a medium-β multi-cell elliptical cavity. Flux expulsion was essential to achieve such high $Q_x$ in the N-doping case. The background magnetic fields were 1 mG or smaller; cavity was then “fast-cooled” across the niobium SC transition temperature with a cell-to-cell $\Delta T$ of 4 K (bottom) to 10 K (top), and the titanium support frame was electrically isolated from the niobium cavity.

More results on various recipes, including med-T baking together with analysis on field-dependent BCS and residual resistances are presented in K. McGee, SUPCAV017, this conference. EP and N-doping were performed in collaboration with ANL and FNAL.

Conclusion and Outlook
The standard EP recipe yielded performance meeting the FRIB energy upgrade design goal and the N-doping recipe achieved 75% higher $Q_x$ than the design goal in the vertical test. Cavity high-Q R&D will be pursued with three new single-cell cavities as well as the 5-cell cavities. The R&D focus will include further $Q_x$ improvement with other recipes and effective flux expulsion in the jacketed cavity. In parallel, development of the other ancillaries such as the FPC and protoype cryomodule is in progress.