# Towards Understanding the Origins of the Strain Irreversibility Cliff in RRP® $Nb_3Sn$ Wires

N. Cheggour[1,2], K. Osamura[3], S. Machiya[4], P. J. Lee[1],
T. Kawasaki[5], and S. Harjo[5]

[1]*Applied Superconductivity Center, NHMFL, Florida State University, Tallahassee, FL 32310, USA*

[2]*Department of Physics, University of Colorado, Boulder, CO 80309, USA*

[3]*Applied Superconducting Division, Research Institute for Applied Sciences, Tanaka, Kyoto 6068202, Japan*

[4]*Department of Mechanical Engineering, Daido University, Takiharu, Minami-ku, Nagoya, Aichi 457-8530, Japan*

[5]Neutron Science Section, *J-PARC Center, JAEA, 2-4 Shirakata, Tokai-mura, Naka-gun, Ibaraki 319-1195, Japan*

$Nb_3Sn$ superconducting wires made by the restacked-rod process (RRP®) exhibit a precipitous change in the intrinsic irreversible strain limit $\varepsilon_{irr,0}$ with heat-treatment temperature $\theta$, called the *strain irreversibility cliff* (SIC). The main part of SIC occurs over a very narrow range of $\theta$. This can pose a real challenge for choosing suitable heat-treatment conditions that can optimize the wire's transport, strain, and thermal properties all at once, especially for large, wind and react, magnet systems. To gain a better understanding of SIC origin(s), we conducted neutron-diffraction experiments at the Japan Proton Accelerator Research Complex (J-PARC) on three RRP® $Nb_3Sn$ wires, doped either with Ta or Ti, and having either a standard or reduced Sn content. Samples were reacted at different values of $\theta$, ranging from 600 to 700 °C. We also studied the samples' microstructure by use of optical and scanning-electron microscopy. We will depict the evolution of the crystal structures of $Nb_3Sn$ and the other wire constituents, lattice parameters, and sharpness of the diffraction peaks as a function of $\theta$. We will also present the evolution of Sn content in both $Nb_3Sn$ and in the Cu-Sn adjacent phases. Correlations of the samples' nanostructure and microstructure with their electromechanical behavior will be discussed to shed light into the origin(s) of SIC.

**Acknowledgements**: This work was supported by U.S. Department of Energy, Office of High Energy Physics, Grants DE-SC0017657, DE-SC0010690, the State of Florida, and by a grant-in-aid of the Ministry of Education, Culture, Sports, Science and Technology, Japan (26420669). $Nb_3Sn$ RRP® wires were provided by the U.S. Conductor Development Program (CDP). We are grateful to J-PARC for allowing us to conduct experiments at the MLF Takumi BL19 (proposals No. 2015A0130 and No. 2017A0205).