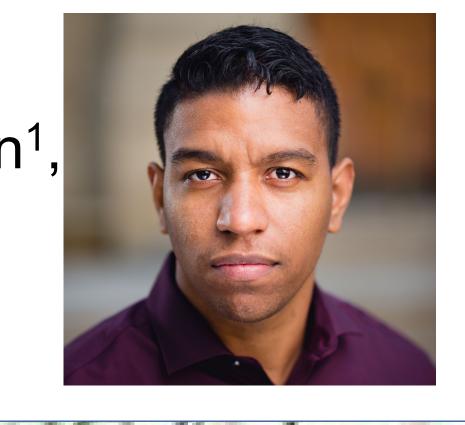
Radiation Effects of REBCO coated conductors and insulation materials for High-Radiation environments with the US-Japan HEP collaboration

BERKELEY LAB

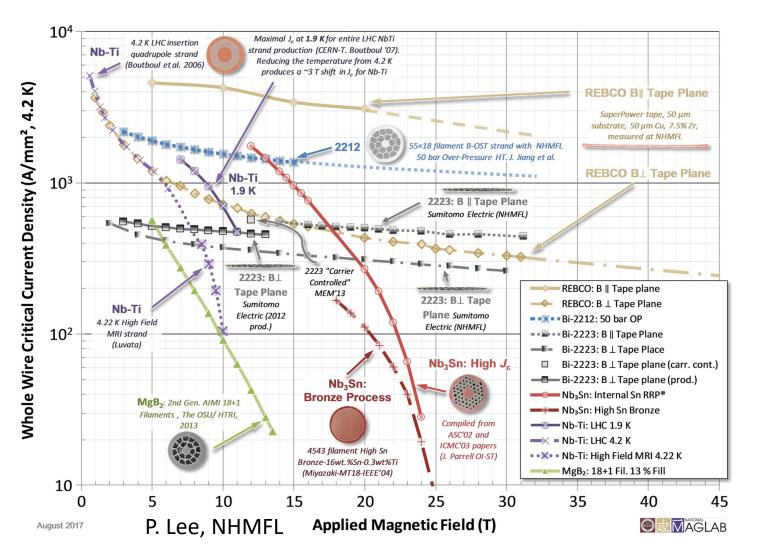
1.Lawrence Berkeley National Lab, 2. KEK, 3. University of California, Berkeley Chris Reis^{1,3}, Tengming Shen¹, Masami lio², Toru Ogitsu², Tatsushi Nakamoto², Soren Prestemon¹,

Peter Hosemann³





1 High-Temperature Superconductors opens new application space but sensitivities to radiation unknown



THE FIRM AND XHILL AND SELECTION OF THE

10-Year anticipated dose at high-lumi LHC

Ions increase then suppress J_C quadrupole location is est.~ 22.5 MGy ITER's resin-impregnated TF coils subject to a design

Neutrons too but with additional Nuclear effects

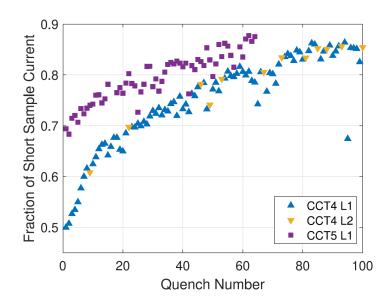
Γ_c suppressed monotonically, connected to microstructure Irradiations shown to alter Jc, Tc, Microstructure

Higher current densities and critical temperatures roughly translate to better and more capable magnets

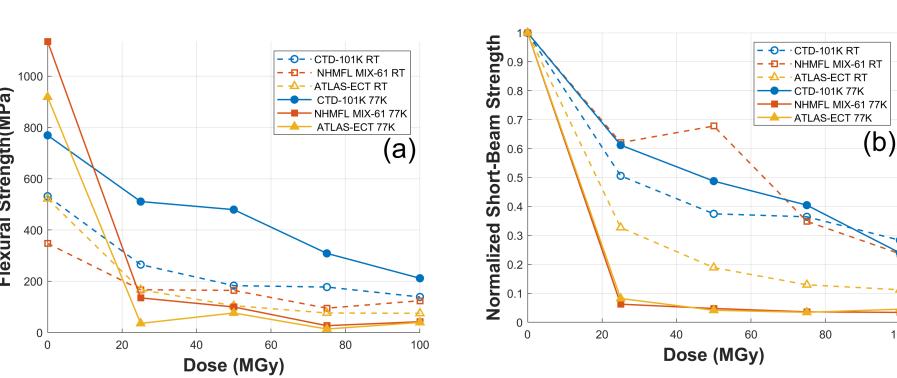
fluence of 1x10²² n/m² These factors motivate radiation aspect of this study

2 Crucial Superconducting-Magnet Insulation Materials found to be Gamma-Radiation Sensitive

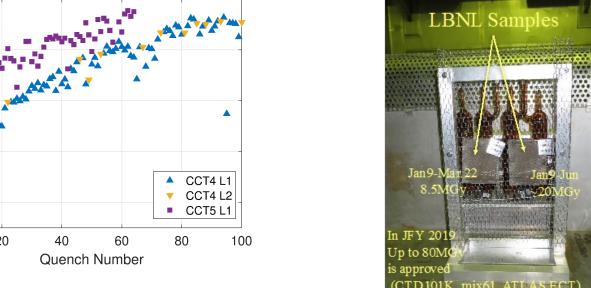




- Reducing Quenching training time crucial in future
- accelerators like the proposed FCC • CTD-101K very widely utilized
- NHMFL mix-61 magnet demonstrated greatly reduced quench training
- Reed and Evan's ATLAS Experiment's End Cap Toroid (ECT) resin also studied as an alternate epoxy to mix-61



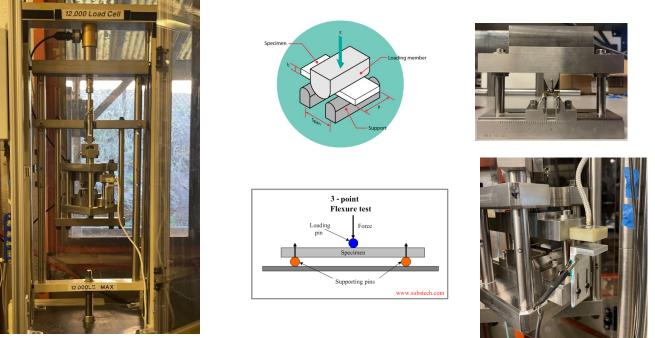
Mix-61, ECT generally show superior pristine strength but CTD-101K's radiation resistance makes it the overall outperformer

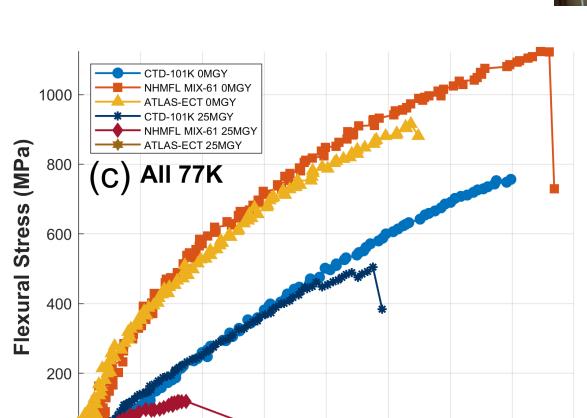


25, 50, 75, 100 MGy • Tests done at 293, 77 Kelvin ASTM Short-Beam Shear,

Gamma Irradiation done at QST

Flexural tests done Follow up Failure Mode Analysis and Microscopy also done

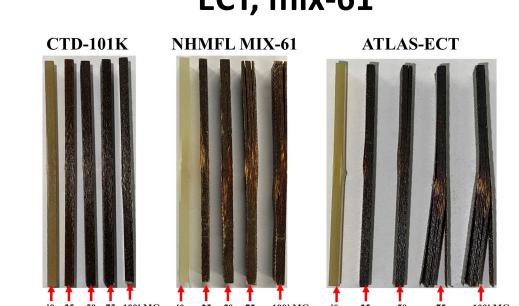




Flexural Strain (mm/mm

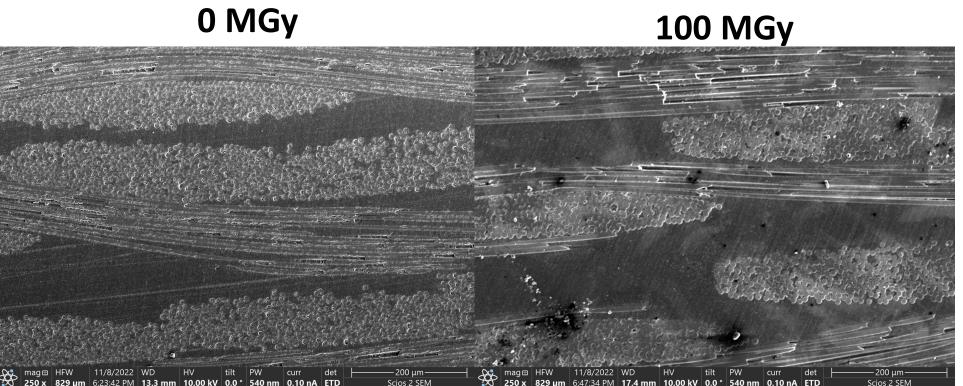
All samples darkened, changed in texture

FMA showed Interlaminar shear a chief culprit and worse effects for ECT, mix-61

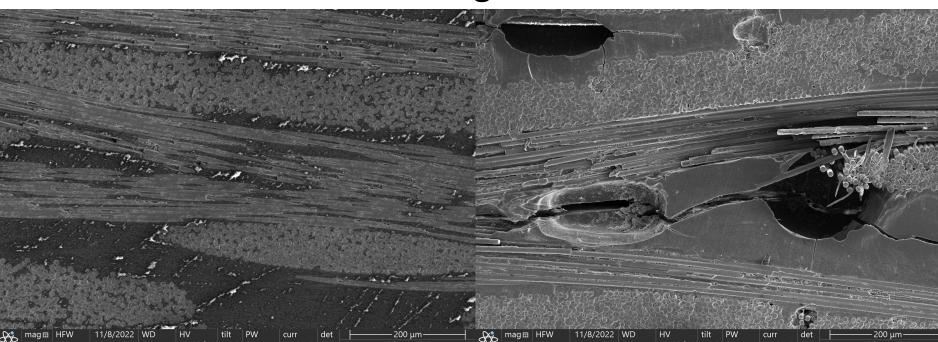


We therefore recommend NHMFL mix-61 and ATLAS-ECT for low-dose applications and CTD-101K for its strength and unparalleled radiation resistance

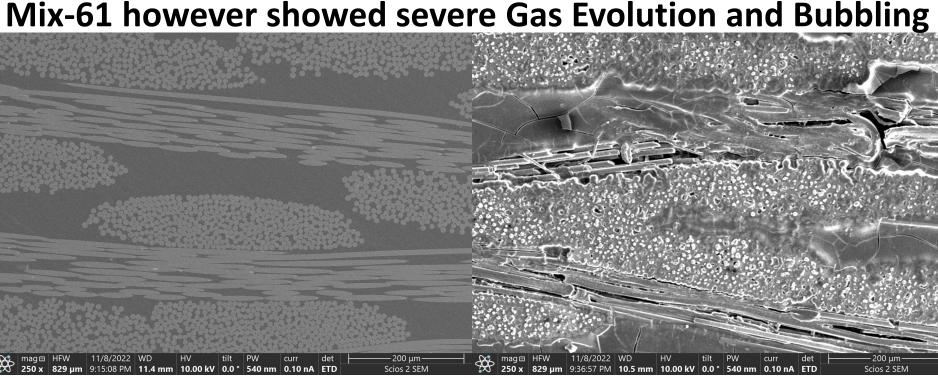
Unique PIE capabilities (15.5 T, 500 A, 4-80 K) allowed us to examine REBCO cc's themself



CTD had minor changes but otherwise

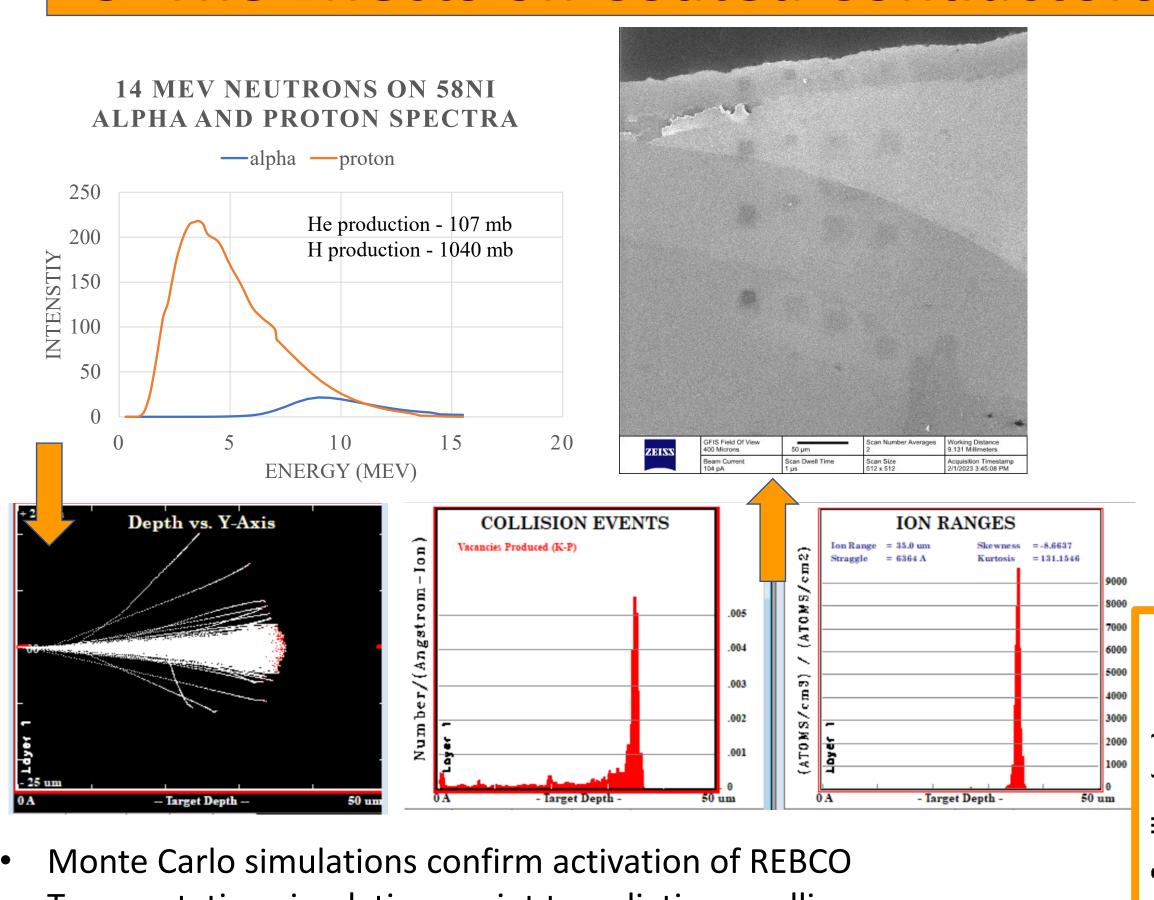


Mix-61 however showed severe Gas Evolution and Bubbling



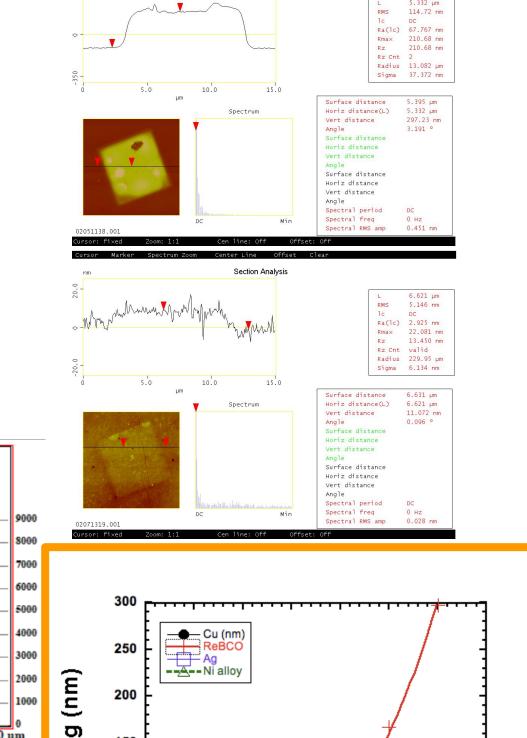
ATLAS suffered the most widespread degradation

3 The Effects on Coated Conductors Warrant Materials Science Investigation of the REBCO superconductor



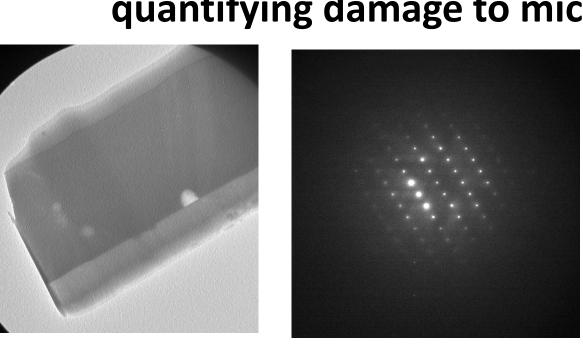
Transmutation simulations point to radiation swelling from (n, α) reactions being a potentially serious issue with fusion magnets constructed from REBCO cc's

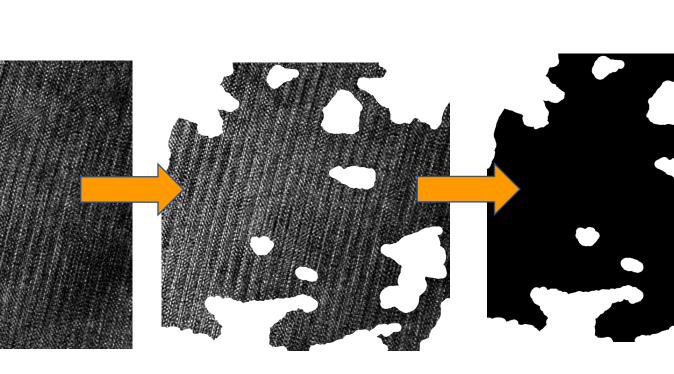
Nuclear Instruments and Methods in Physics Research. vol. 311, p. 1-4, ISSN 0168-583X



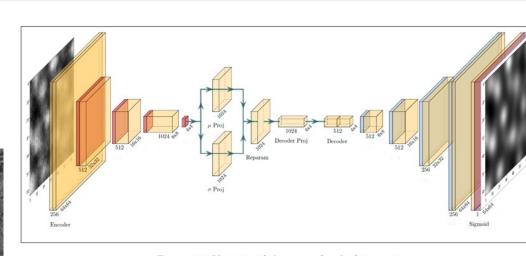
Dose (X10⁻¹⁷)

Machine Learning May be a useful tool for quantifying damage to microstructure

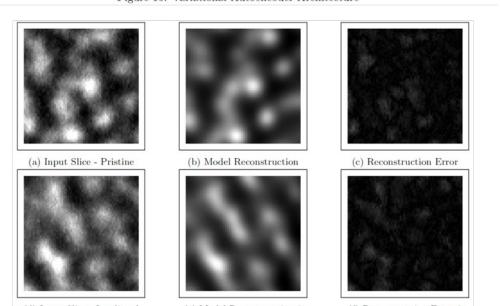




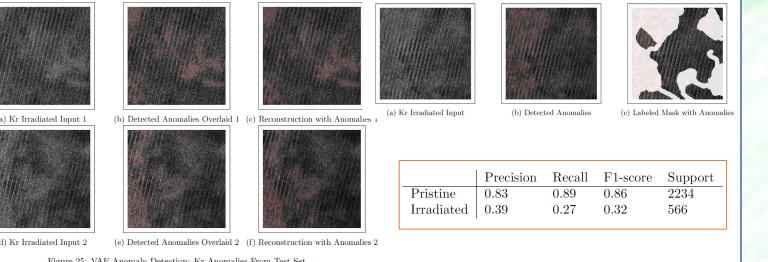
Machine Learning May be a useful tool for quantifying damage to microstructure



Variational Autoencoder Architecture code used and adjusted for this task



Code was able to take in noisy data and output 'smooth' images



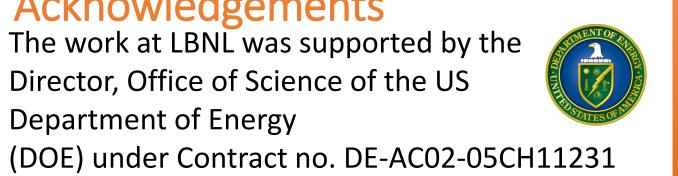
Unsupervised code made good initial run at identifying 'defects' from HRTEM images but more work to come

References

- 1. Photographer: Brice, MaximilienTaken: 16 Jun 2017Uploaded to http://cds.cern.ch/record/2272497: 16 Jun 2017 Record last updated: 22 Jun 2021. © CERN, License: http://creativecommons.org/licenses/by/4.0/
- 2. Yin et al.(2019). Epoxy Resins for Vacuum Impregnating Superconducting Magnets: A Review and Tests of Key Properties. IEEE Transactions on
- Applied Superconductivity, vol. 29, no. 5, pp. 1-5 3. [3] F. Hosni et al. (2013,) Effect of gamma-irradiation on the colorimetric properties of epoxy-resin films: Potential use in dosimetric application.

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It's an exciting time for HTS magnet technologies with several crucial studies supported by US-Japan collaboration. We appreciate your continued support!

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