US-MDP General Meeting – January 31, 2024

Results on Nb_3Sn Undulator Impregnated with TELENE and High-C_p TELENE

Emanuela Barzi, U.S. PI

Fermilab & Ohio State University

Akihiro Kikuchi, Japan PI

U.S.-Japan Science and Technology Cooperation Program in High Energy Physics

OUTLINE

- **Results obtained so far within the U.S.-Japan Science and Technology Cooperation Program in HEP for the following:**

1. **First Nb_3Sn undulator impregnated with pure TELENE, and practical implications for accelerators.**

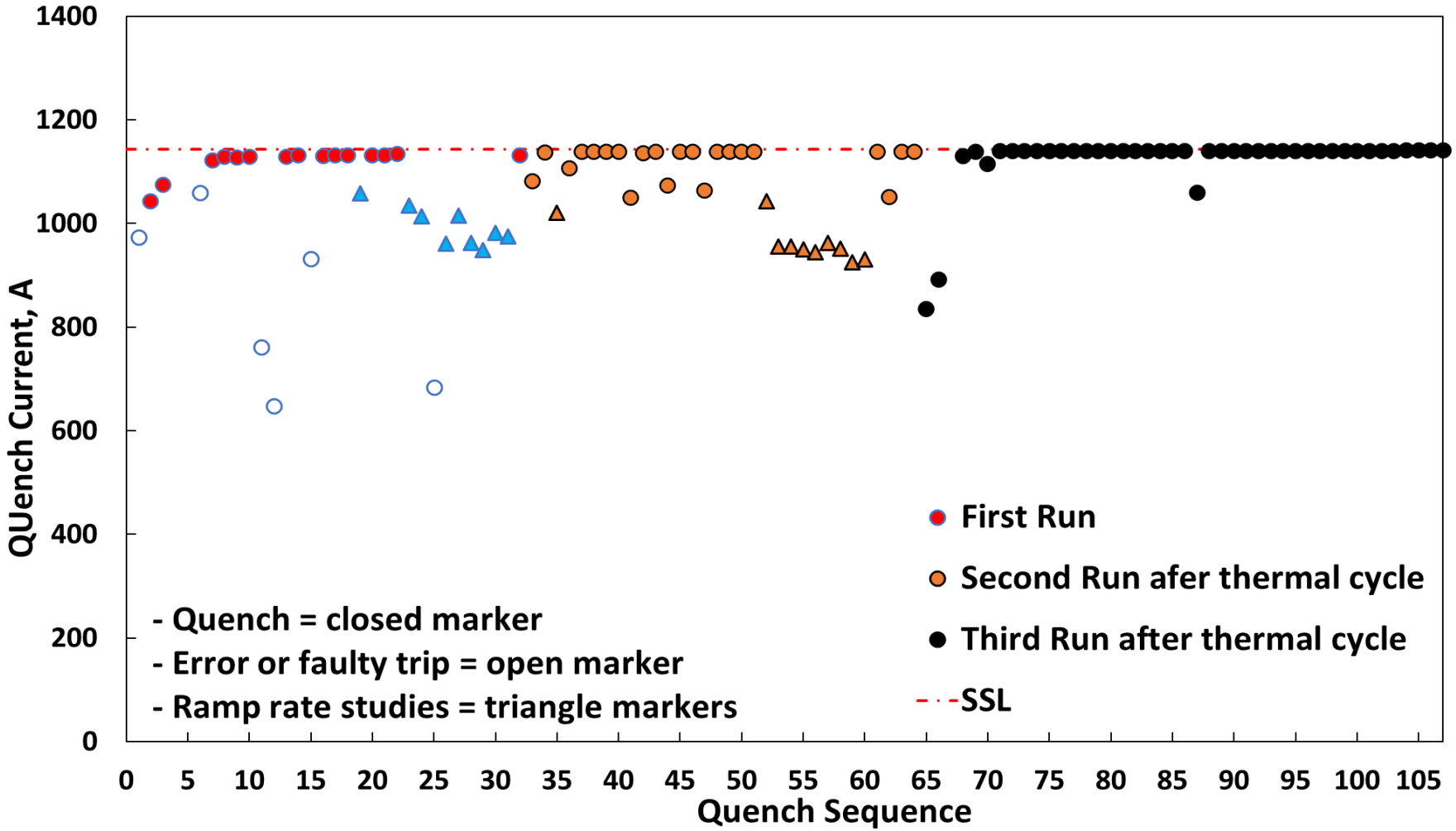
2. **Second Nb_3Sn undulator impregnated with TELENE-43wt%Gd_2O_2S and tested with advanced instrumentation.**

- **Next Steps**

- **Analysis of QA data – Joe Di Marco**

1st Nb_3Sn Undulator Test Results

Impregnated with pure TELENE



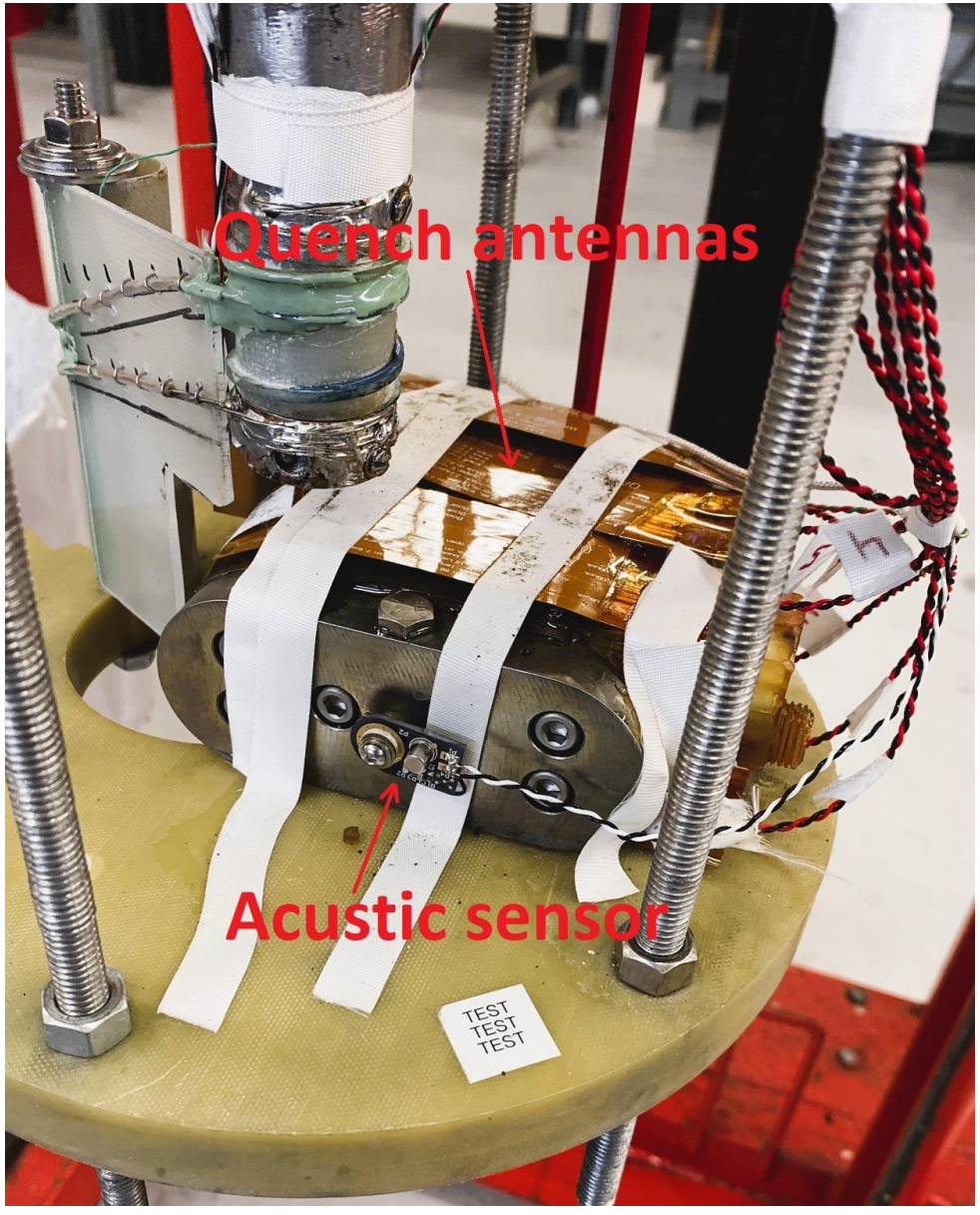
IPAC 2024 Abstract

Performance Improvement of LTS Undulators for Synchrotron Light Sources

Authors: *Akihiro Kikuchi, Ibrahim Kesgin, Daniele Turrioni, Alexander Zlobin, and Emanuela Barzi*

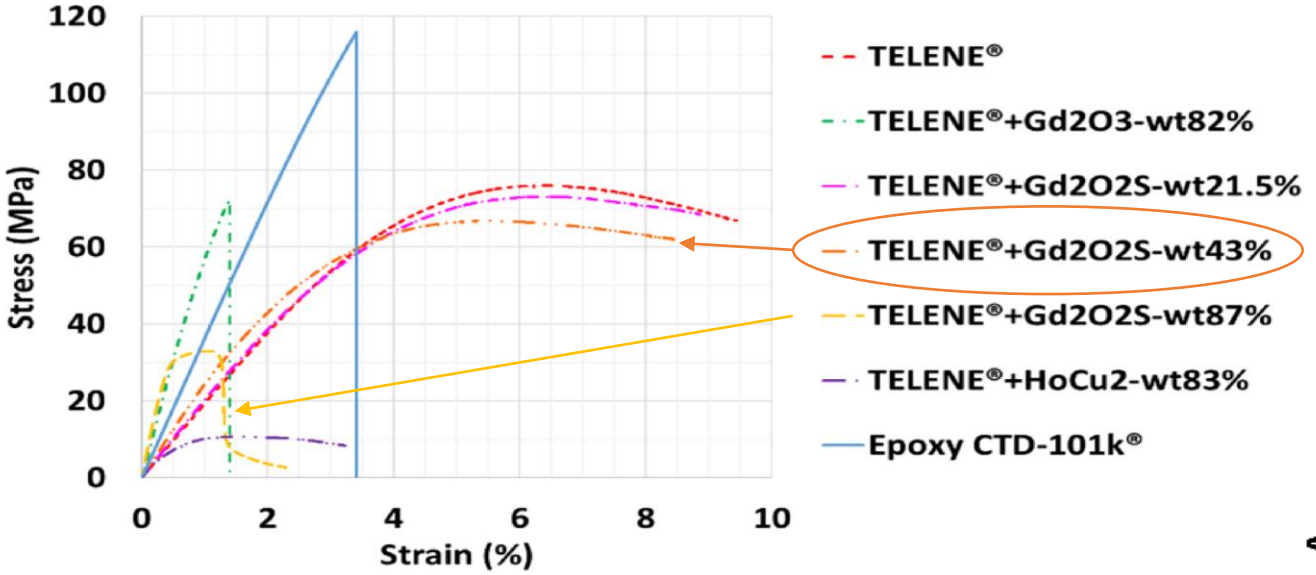
The expertise of ANL and FNAL has led to the production of Nb_3Sn undulator magnets for the ANL Advanced Photon Source (APS). These magnets showed performance reproducibility ~100% of the short sample limit, and a design field increase of 20% at 820A. However, the long training did not allow obtaining the expected 50% increase of the on-axis magnetic field with respect to the 1.1 T produced at 450 A current in the ANL NbTi undulator. To address this, 10-pole long prototypes were fabricated, and CTD-101K® was replaced as impregnation material with TELENE®, an organic olefin-based thermosetting dicyclopentadiene resin produced by RIMTEC Corporation, Japan. Training and magnet retraining after a thermal cycle were nearly eliminated, with only a couple of quenches needed before reaching short sample limit at over 1,100 A. **TELENE will enable operation of Nb_3Sn undulators much closer to their short sample limit, expanding the energy range and brightness intensity of light sources. TELENE is Co-60 gamma radiation resistant up to 7-8 MGy, and therefore already applicable to impregnate planar, helical and universal devices operating in lower radiation environments than high energy colliders.**

Instrumentation Added



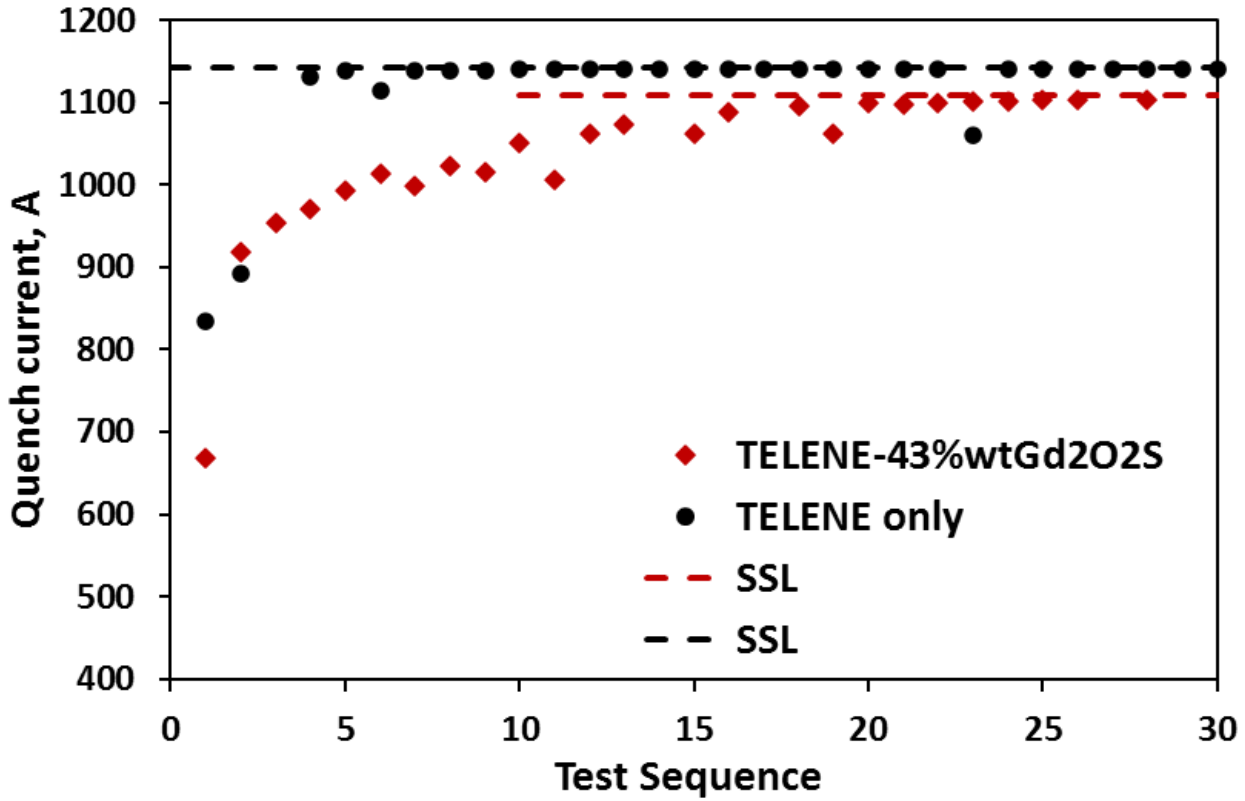
- 2 acoustic sensors (provided by S. Krave) were added, i.e. bolted on the magnet end plates, one on each side.
- 5 quench antennae (QA) wrapped the coil.
- The NI Compact Rio (25 Khz sampling rate, circular buffer of 1000 samples) was used to acquire voltage taps, QAs, and current. Data acquisition and quench detection are triggered when the bucked voltage signal is above threshold.
- A 20 MHz, 8-channel picoscope was used for the acoustic signals. Their data acquisition is triggered when the voltage of one of the signals is above 0.3 V.
- For synchronization of the two DAQ systems, the current channel was a shared channel.

2nd Nb_3Sn Undulator Test Results
Impregnated with TELENE-43wt%Gd_2O_2S

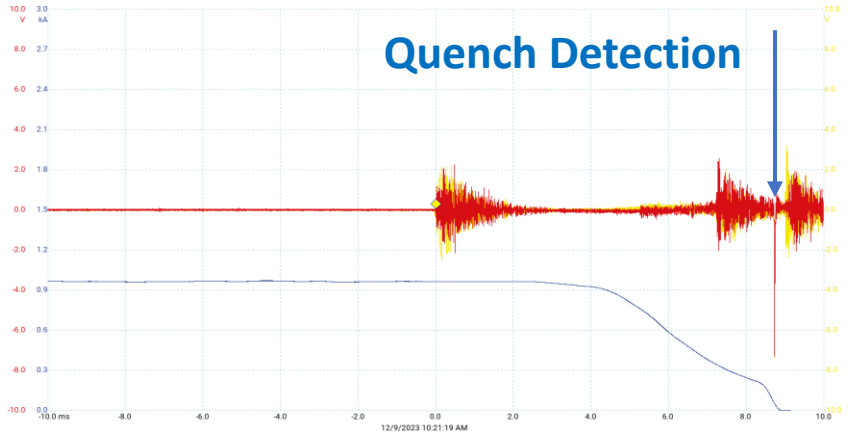


- **A reason for the TELENE-43wt%Gd_2O_2S to be less effective than pure TELENE in eliminating training is its much lower thermal diffusivity D = $k/(\rho C_p)$ than for pure TELENE, due to its larger C_p.**

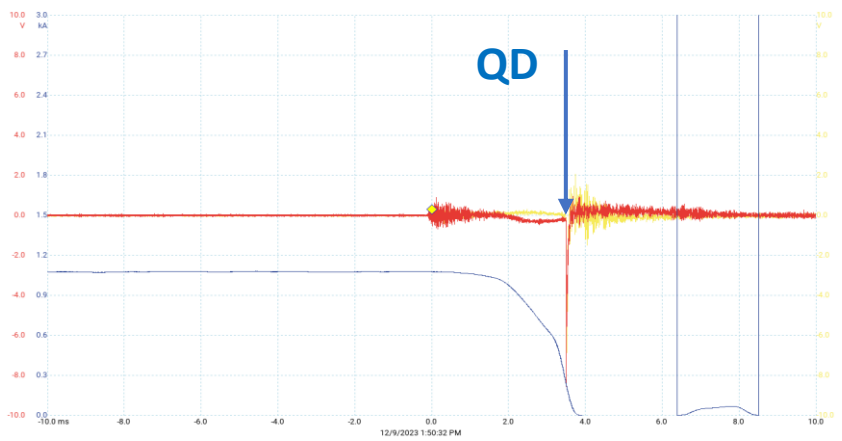
- **Thermal conductivity of these resins needs to be increased through materials engineering.**



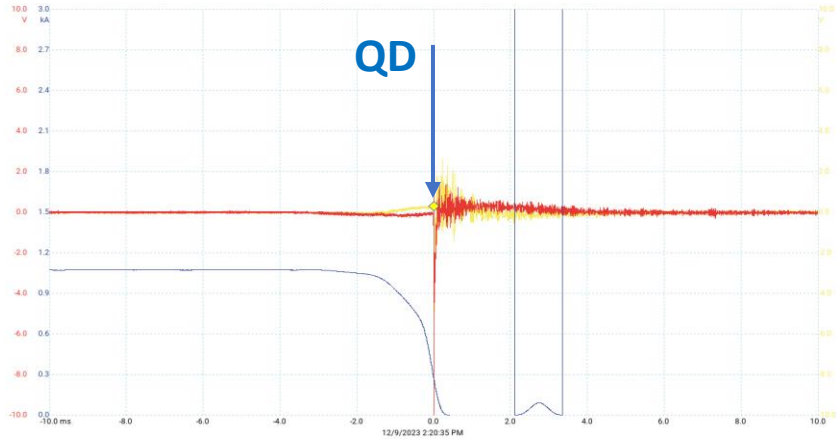
Identified Acoustic Patterns



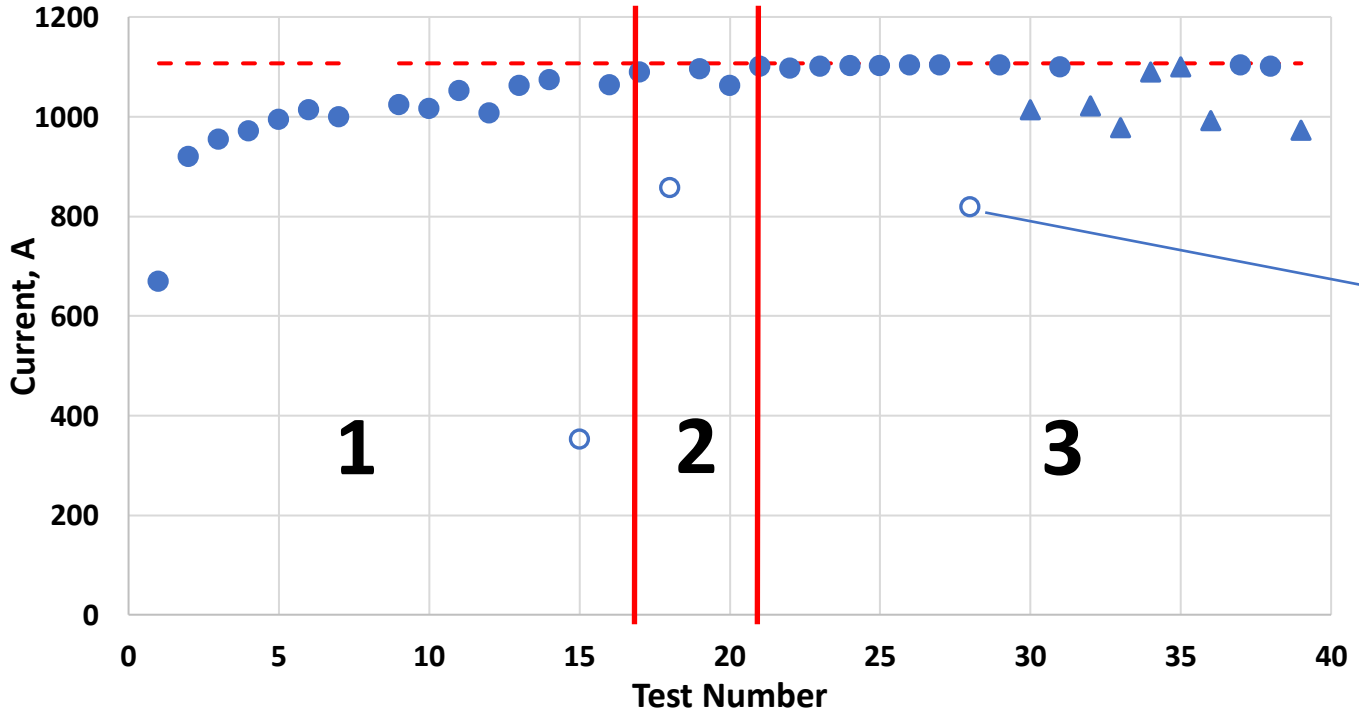
Zone 1

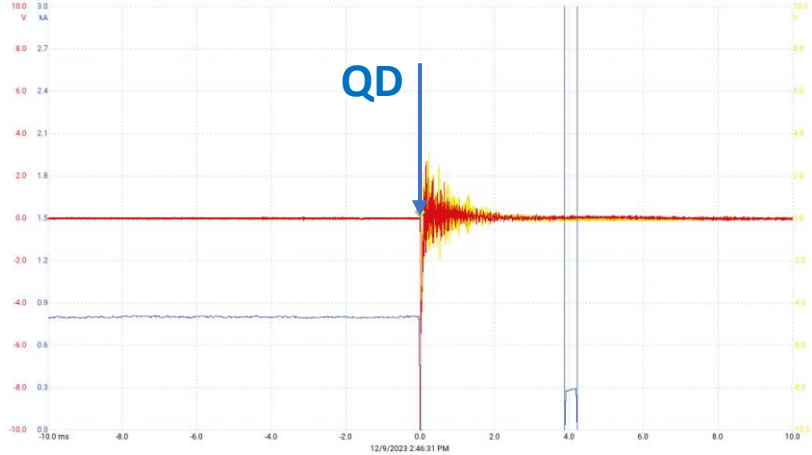


Zone 2



Zone 3





False trip

Next Steps

- **TELENE was successful to prevent training in the Nb_3Sn ANL undulator, which produces a maximum magnetic field of about 5 T and maximum equivalent stress on the conductor of less than 100 MPa. The next necessary step is to check whether the developed resins can lead also to a reduction in training in stress managed magnets, which is the current core design in the US Magnet Development Program (US-MDP).**
- **High-C_p ceramic powders mixed in TELENE have proven to be exceptionally radiation resistant to Co-60 gamma irradiation. When combined with the ductility and toughness properties of TELENE, these resins have already shown superior training performance with respect to CTD-101K. To fully exploit their characteristics, the last necessary step is that of increasing their thermal diffusivity D by adding high-thermal conductivity components in these resins.**
- **A 2-year extension was proposed for this grant, with FNAL, ANL, LBNL and BNL on the US side.**