

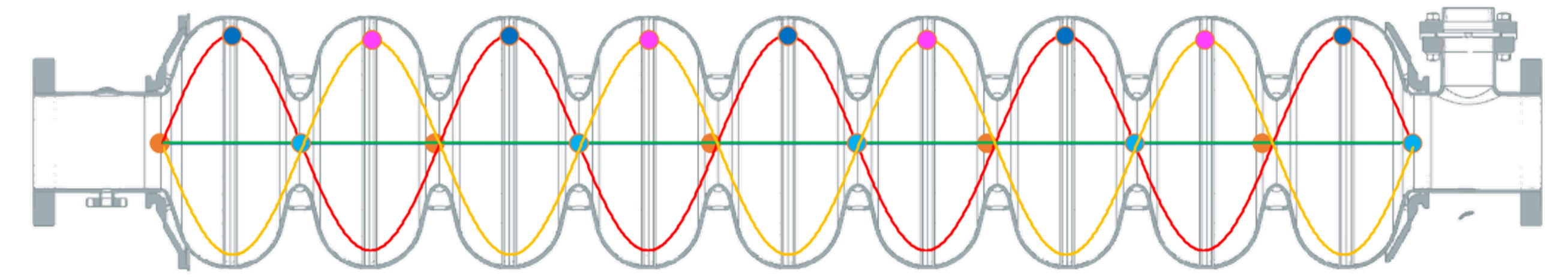
Highlight

Fermilab and Euclid Techlabs have been collaborating on Development of Traveling-Wave Superconducting RF cavity and successfully demonstrated an excitation of TW resonance in the 3-cell structure at cryogenic temperature (2K liquid helium) as the first time.

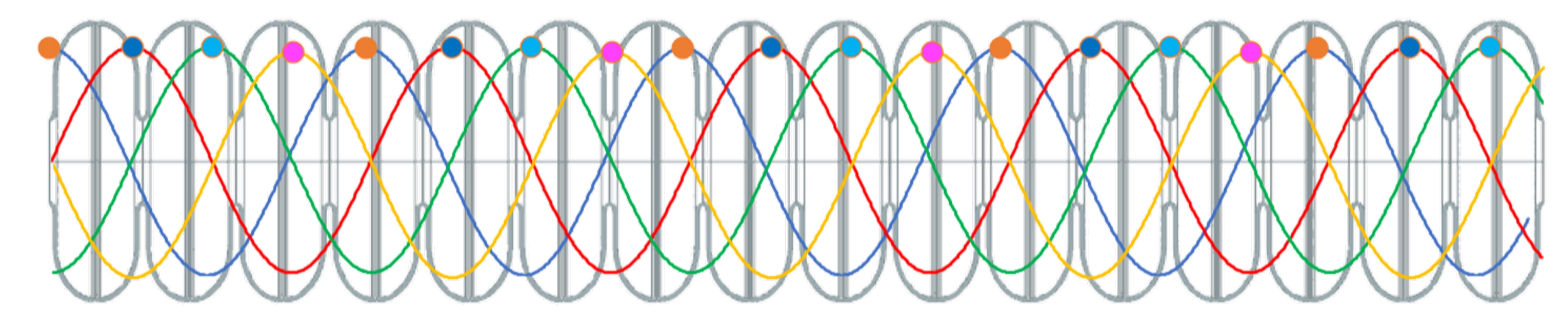
Introduction

- Presently all SRF cavities operate in a standing wave (SW) resonance field in which particles experience an accelerating force alternating from zero to peak.
- Changing to a travelling wave (TW) mode operation can improve the efficiency of acceleration per cell since a TW resonance field propagate along with a TW structure and particles in such resonance field can experience a constant acceleration force.
- The transit time factor T defined as $T=E_{acc}/E_{ave.}$, (E_{acc} ; accelerating gradient, $E_{ave.}$; average field gradient over the cell gap) can be used to evaluate such phenomena.
- A TW structure proposed in the early study showed a T of 0.9 which suggested a TW regime could effectively increase the acceleration per cell more than 20% compared with a SW regime.

Standing Wave in a 9-cell structure



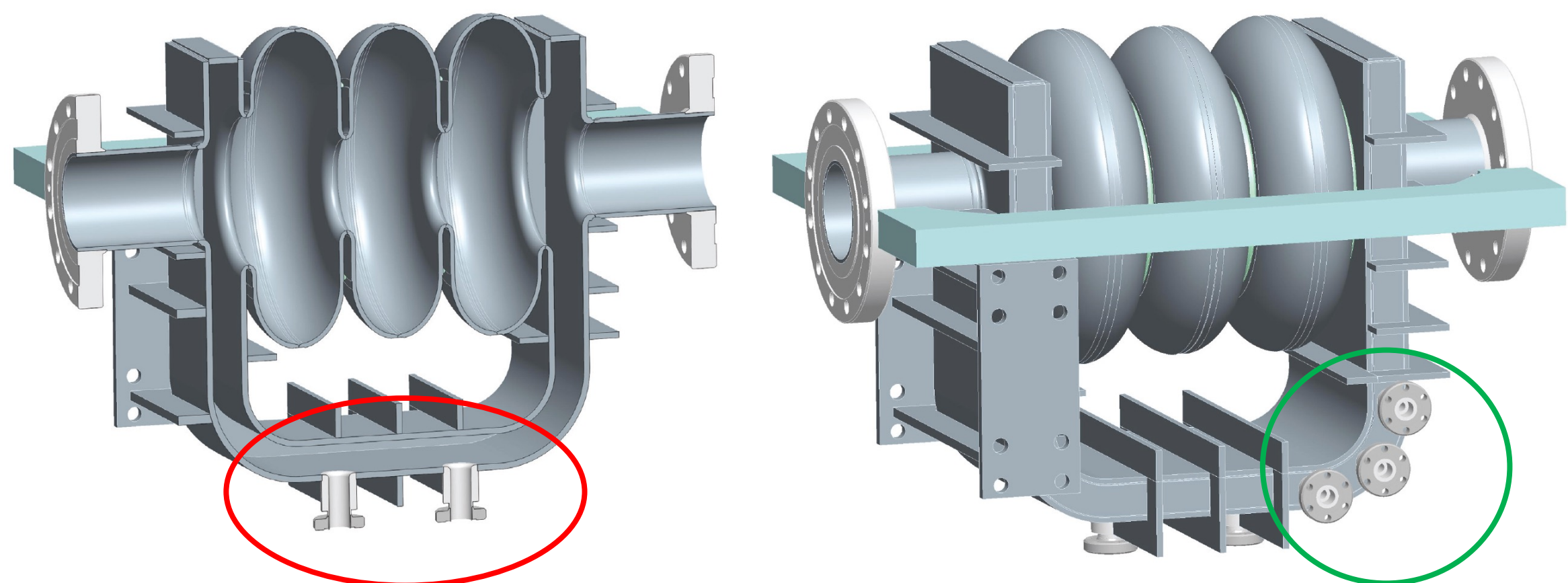
Traveling Wave in a 16-cell structure



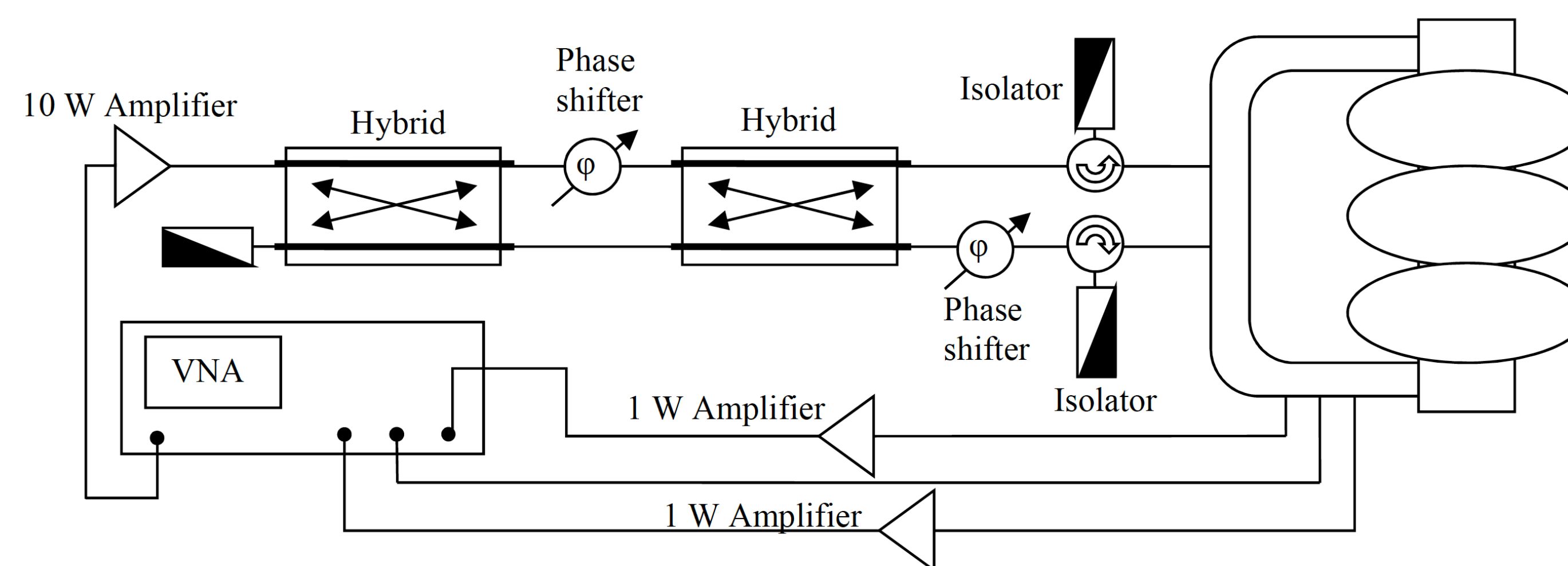
Illustrations of time-to-time accelerating field gradient profile in SW mode (Top) and TW mode (bottom). The points identify the amplitude of the field acting on the particle in sequential time-steps.

Early achievements by Euclid Techlabs and Fermilab

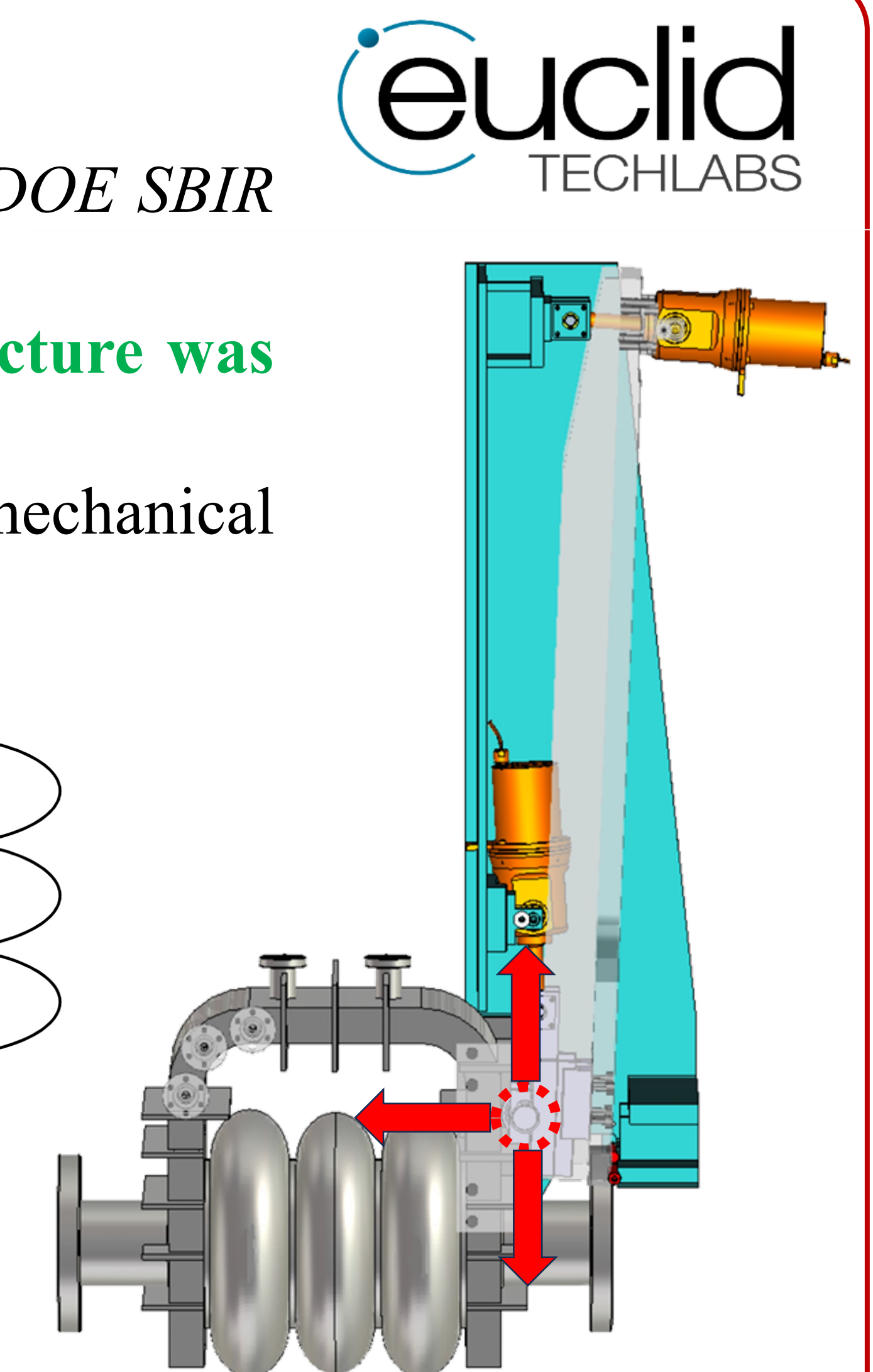
- The early stages of TW SRF cavity development have been funded by several SBIR grants to Euclid Techlabs (*DOE SBIR Grant # DE-SC0006300*) which were completed in collaboration with Fermilab.
- A 3-cell proof-of-principle TW SRF Nb cavity was fabricated and a **TW resonance excitation in a 3-cell structure was demonstrated at room temperature.**
- Special 2D tuner (the matcher) to control TW resonance in the 3-cell was also fabricated. The preliminary tuner mechanical test at room and liquid nitrogen temperatures were successful.



3D model of a 3-cell TW SRF cavity which has two Input coupler ports and three monitoring coupler ports (Forward wave, Calibration, and Backward wave signals) on waveguide power feedback loop.



RF feed and measurement scheme for the 3-Cell TW



3D model of the cavity with 2D tuner on WG

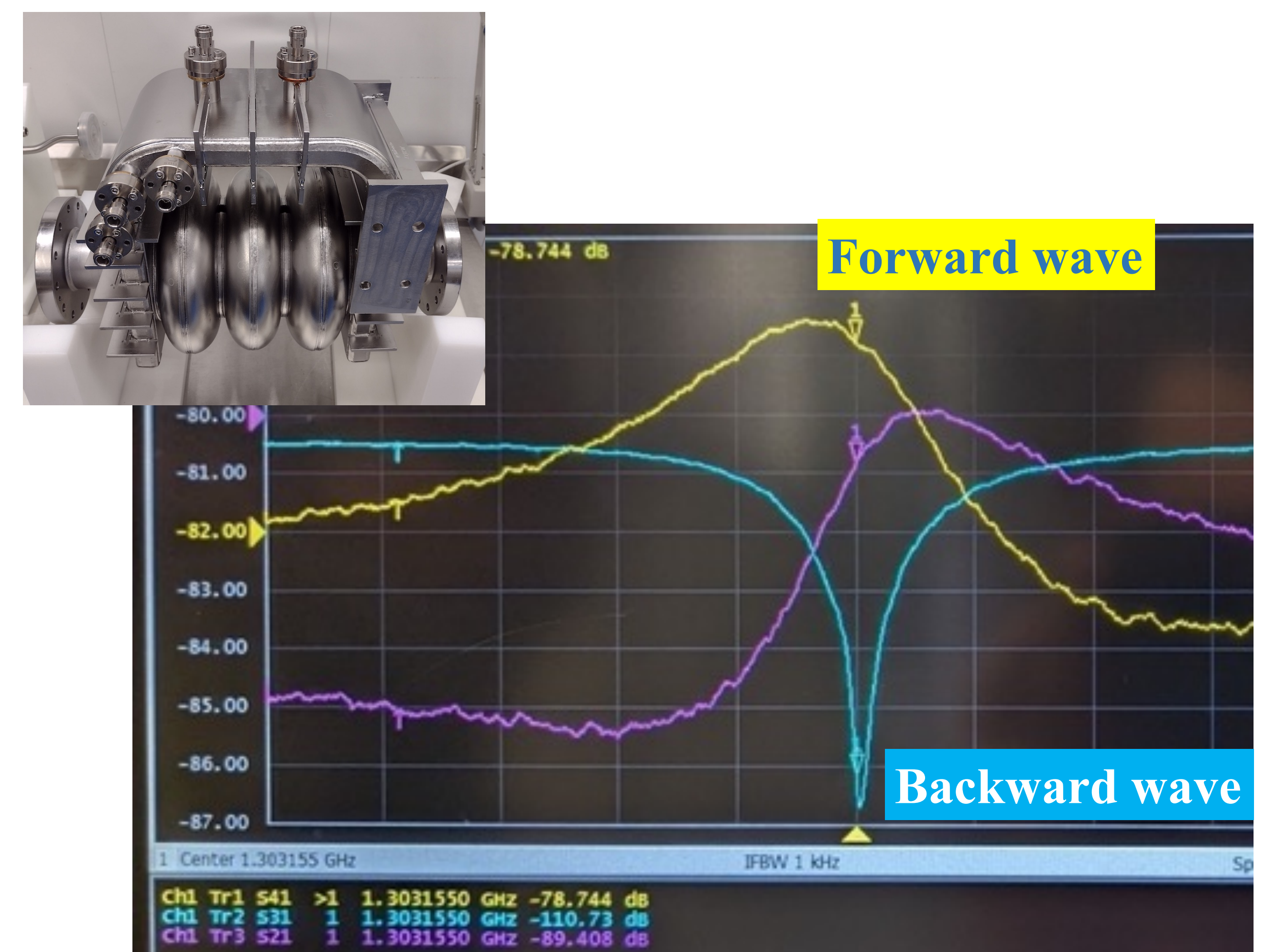
Ref. R. Kostin et al. "Progress towards 3-cell super-conducting traveling wave cavity cryogenic test," Journal of Physics: Conf. Series 941 (2017) 012100

Recent progresses

1. Cavity preparation for a cryogenic testing
 - The 3-cell cavity had been processed for the first cryogenic testing. Bulk BCP, degas, and final light BCP were applied.
 - After final BCP, the cavity also had a field profile tuning in SW mode to the simulated field distributions from CST for 3 cell TW mode.
 - The detail of cavity preparation was reported at SRF2023, please see the paper on <https://accelconf.web.cern.ch/srf2023/papers/tuptb043.pdf>

2. Demonstration of TW resonance excitation at cryogenic temperature

- A cryogenic testing to demonstrate a TW resonance excitation in 2K liquid was carried out at Fermilab using the same RF configurations with a room temp test and successfully accomplished as the very first time.
- An example of TW profiles at 1303.155 MHz in 2K He was shown in the right chart with processed signals.
 - Yellow; a forward wave signal
 - Blue; a suppressed backward wave signal (>30dB less than forward)
 - Purple; a signal from the calibration pick up.
- A purity of tuned TW wave in the 3-cell structure estimated from the monitoring signals was more than 99%.



A high-power test of the 3-cell cavity in TW regime at cryogenic temperature is under preparation.