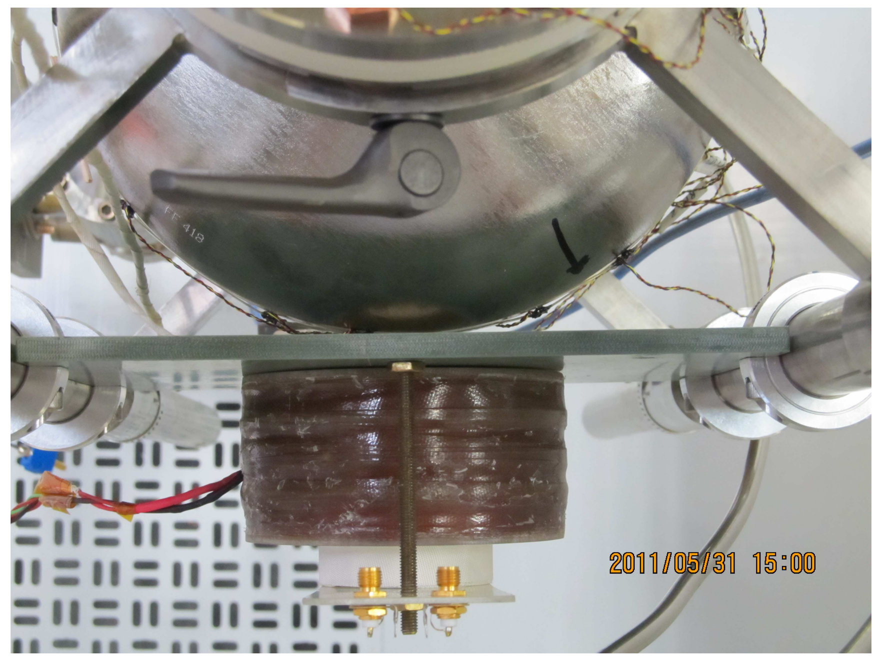
External Magnetic Fields and Operating SRF cavity

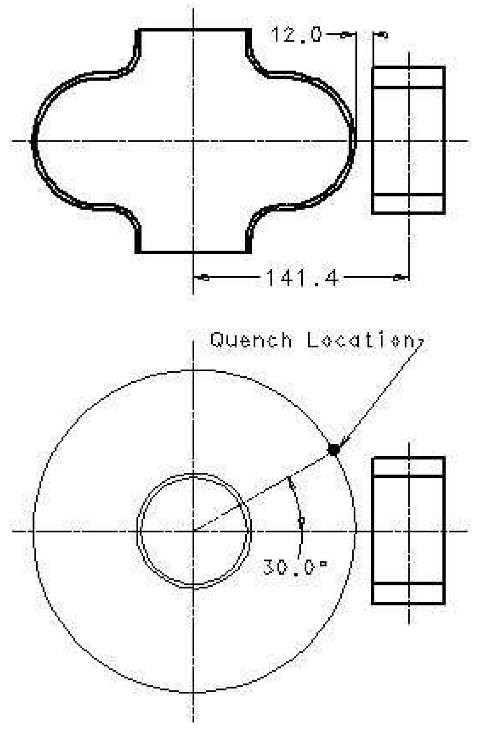
D.A. Sergatskov (das@fnal.gov), T.N. Khabiboulline, R.L. Madrak, J.P. Ozelis, I.M. Terechkine

Fermilab

When an SRF cavity is undergoing transition to superconducting state in an external magnetic field it traps some of the flux which results in an increase of surface resistance. This effect was extensively studied, is well understood by now and results in stringent requirements for an ambient magnetic field on the surface of an SRF cavity. The situation is quite different when magnetic field applied to a cavity already in superconducting state. During a normal operation the bulk of superconducting Nb should protects RF surface of the cavity from the fields on the outside. So we expect that the requirements on external magnetic field applied to an operating cavity could be significantly relaxed. One possible failure mode is when the cavity quench while the external field is applied. The magnetic field would penetrate through a normal zone formed during the quench and can get trapped during the subsequent cooling. We studied effects of external magnetic field applied to an operating SRF cavity and report the results.

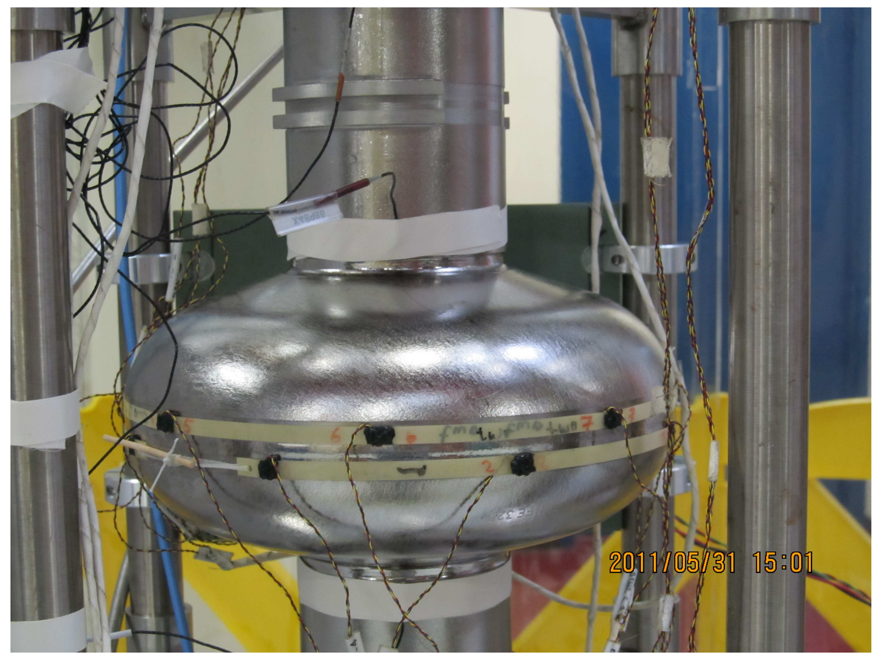
Setup: magnet





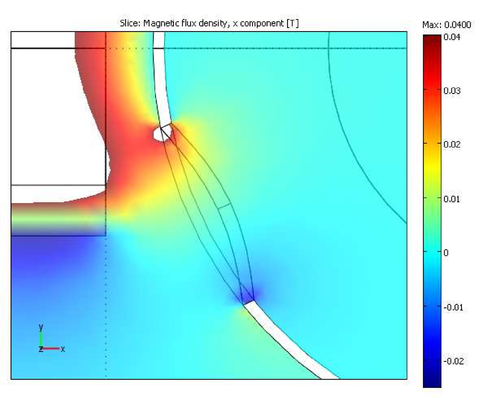
The arrow mark on the cavity points to the quench location. Field/current conversion for the magnet coil is 150 Gauss/Amp at the quench location with superconducting (te1acc002 – Tesla shape 1.3 GHz single-cell) cavity.

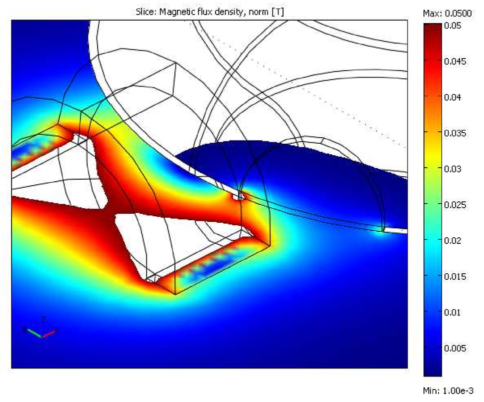
Setup: thermometers



Two bands with 8 CERNOX thermometers (~85 mm apart) each placed on the equator of the cavity. Band #1 is the bottom one. RTD#6 on the band #1 (**B1Ch6**) and RTD #2 on the band #2 (**B2Ch2**) are the nearest thermometers to the quench location.

Computer modeling



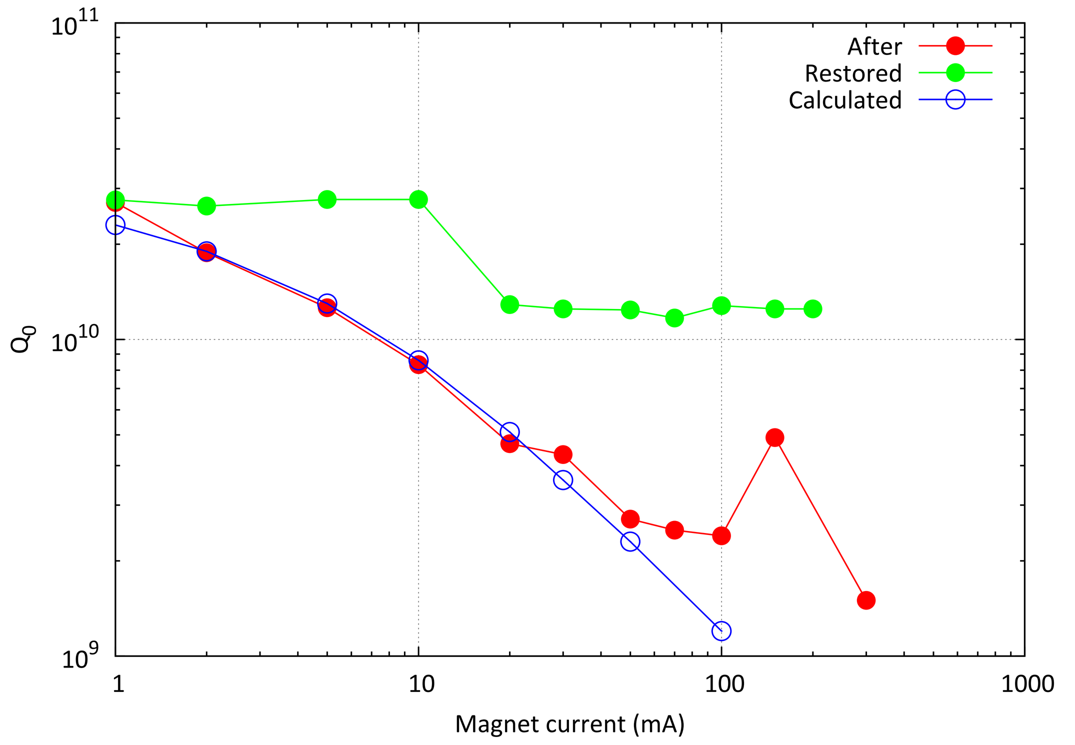


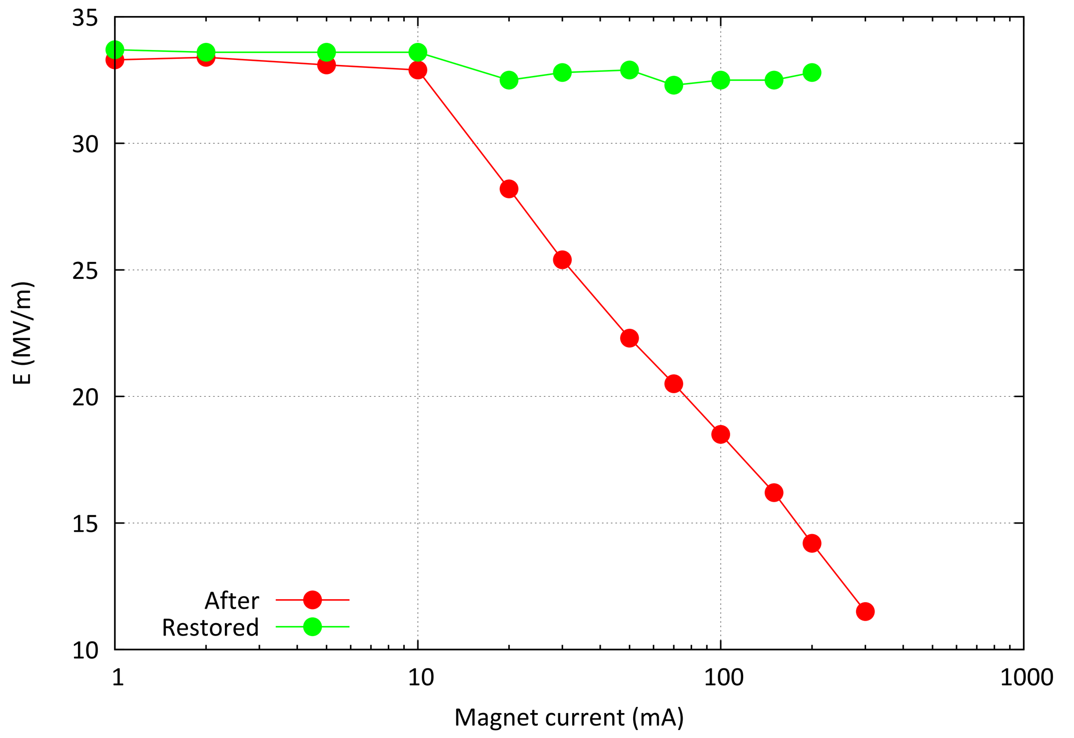
- Normal zone – 50mm dia (estimation)
- We assume 100% trapping efficiency
- We assume that all the flux is trapped in equator area

With those assumptions we can calculate the Q degradation due to trapped flux. We do not know a reliable model to calculate effects on accelerating gradient (E).

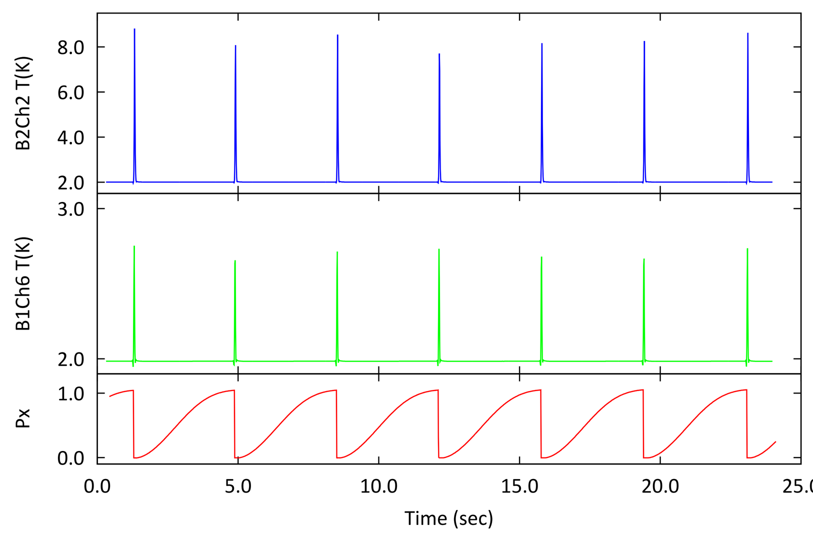
Results: degradation and recovery

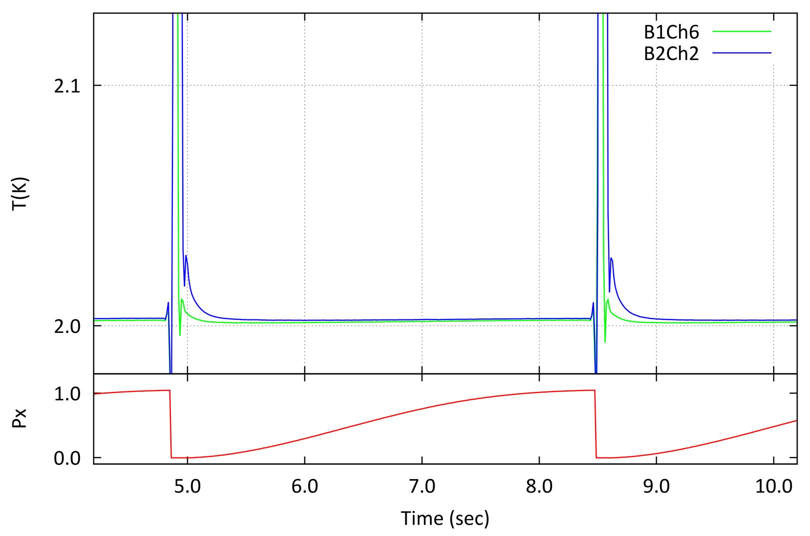
We apply some magnetic field and let the cavity quench and trap some magnetic flux. Its performance degrades in a good agreement with our calculations. We measure Q and E – those are the "After" values. Then we turn the field off and the cavity few times. E and Q measured after that are the "Restored" values. The discrepancy between calculated and measured "after" values of Q at high current may be due to:
a) flux migration violating the computer model configuration; b) flux-trapping efficiency becomes less than 100% at high flux densities.



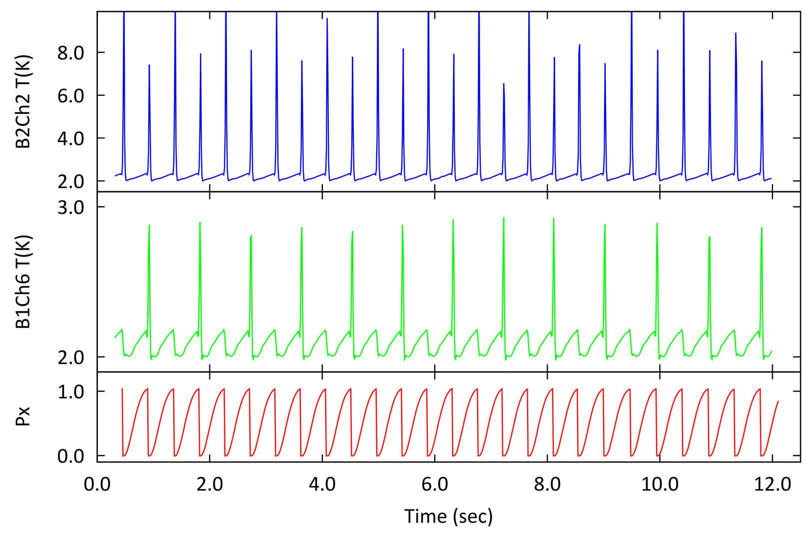


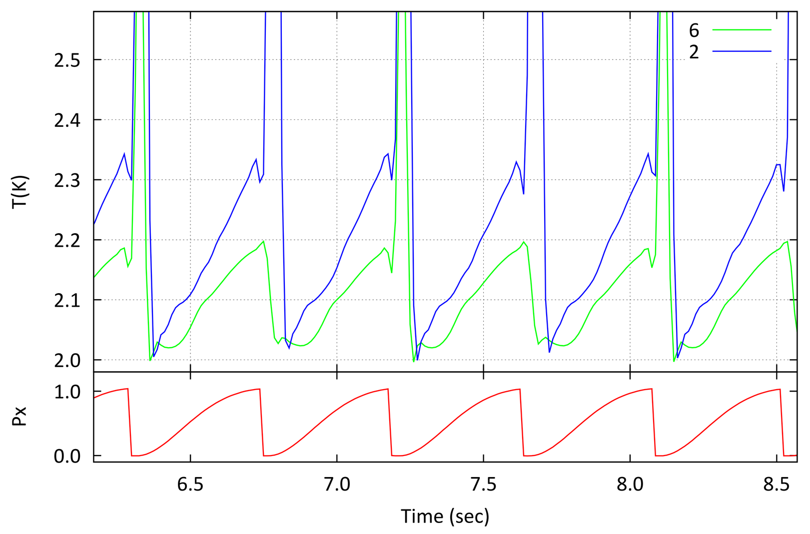
Results: quench migration



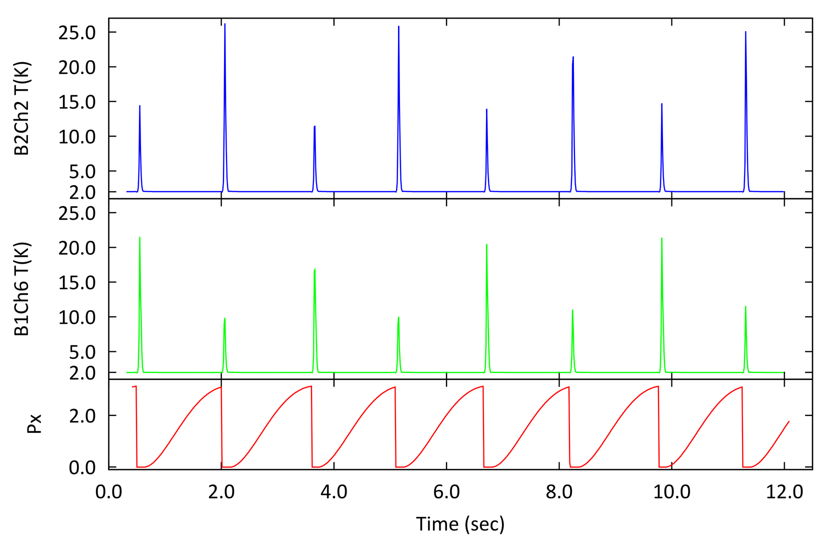


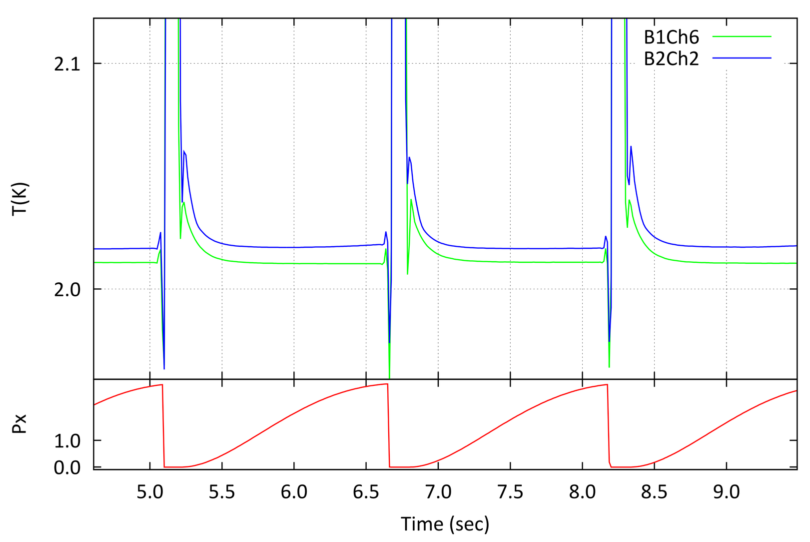
Cavity quenches before any field has been applied. Note the absence of pre-heating signature.





Cavity quenches w/ 100mA in the coil. A large pre-heating signature on both RTDs. B1Ch6 does not show quench signature every other time! Quench originates at two distinct locations.





After a series of "annealing" quenches (w/ no external field applied), the quench signature looks almost like the original.

Conclusion

It appears that an SRF cavity, once in SC state, can tolerate much higher magnetic field than it is usually assumed. If the cavity quenches and traps some magnetic flux, its performance degrades as expected. Yet, it is possible to (almost) recover the original performance (in terms of E and Q) by letting the cavity quench with no external field applied.