Preliminary Study of an Improved Coupling Loss Induced Quench Protection (I-CLIQ) System

Talk Over View

- Introduction
- Improvements on the system
- The results of the tests on the system
- Concluding remarks

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Shanghai Superconductor Technology Co., Ltd.

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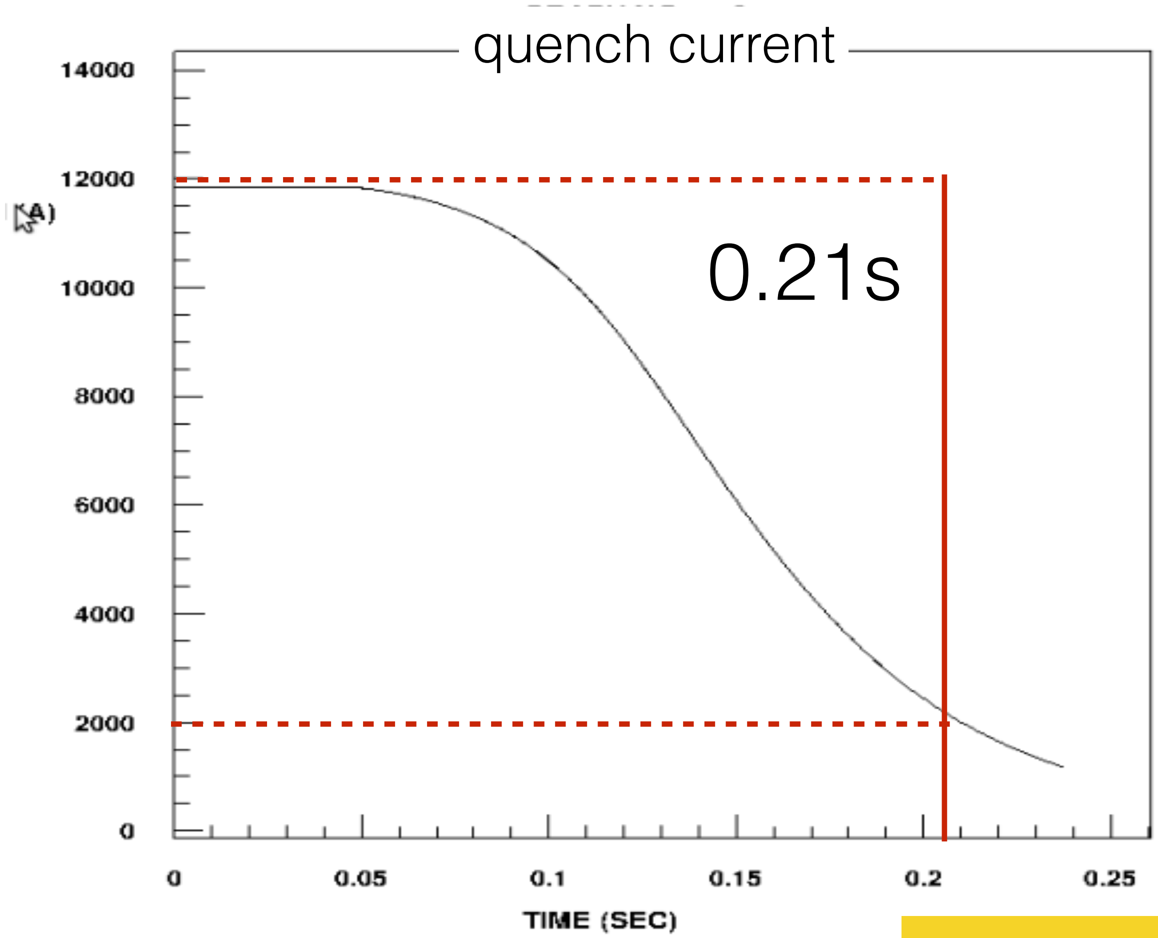
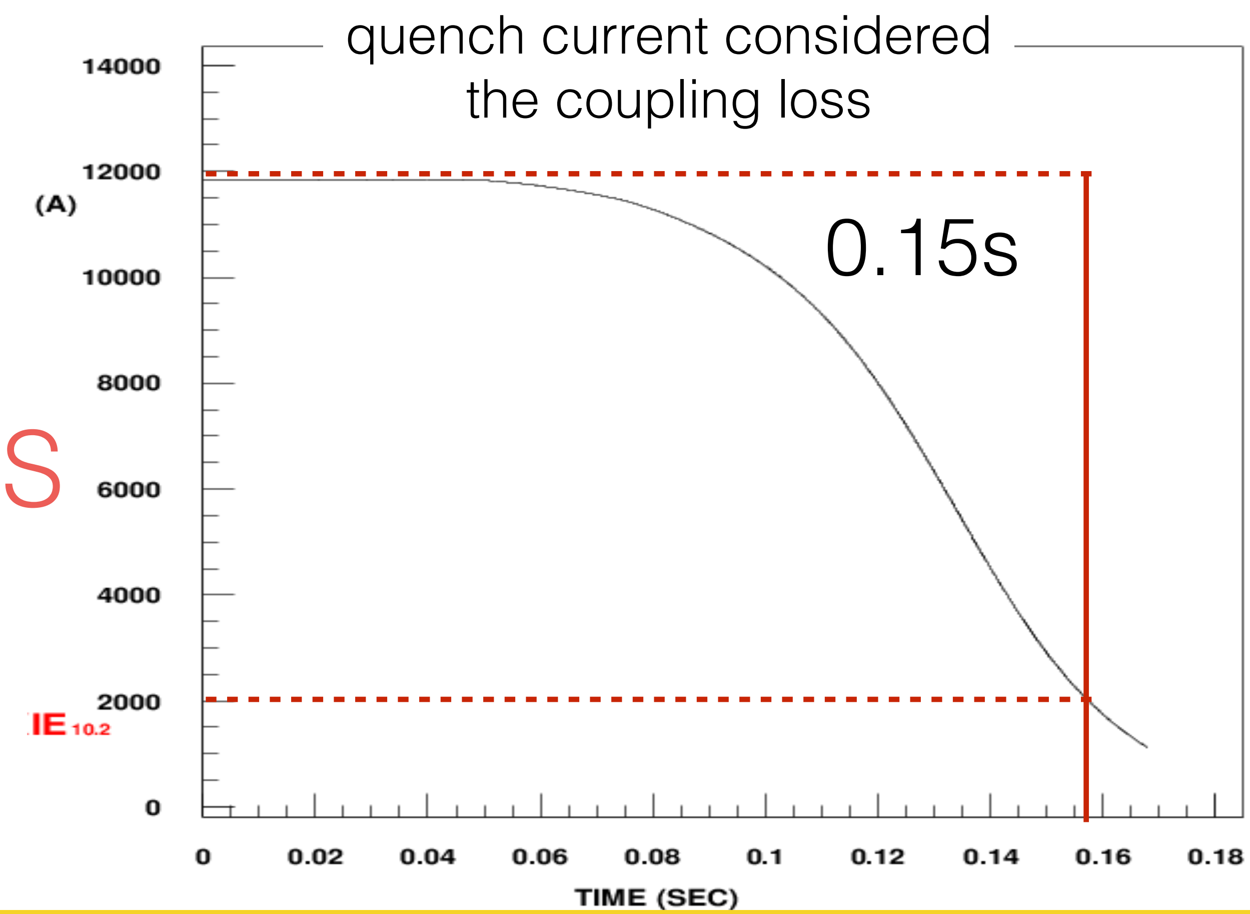
Asia/Shanghai

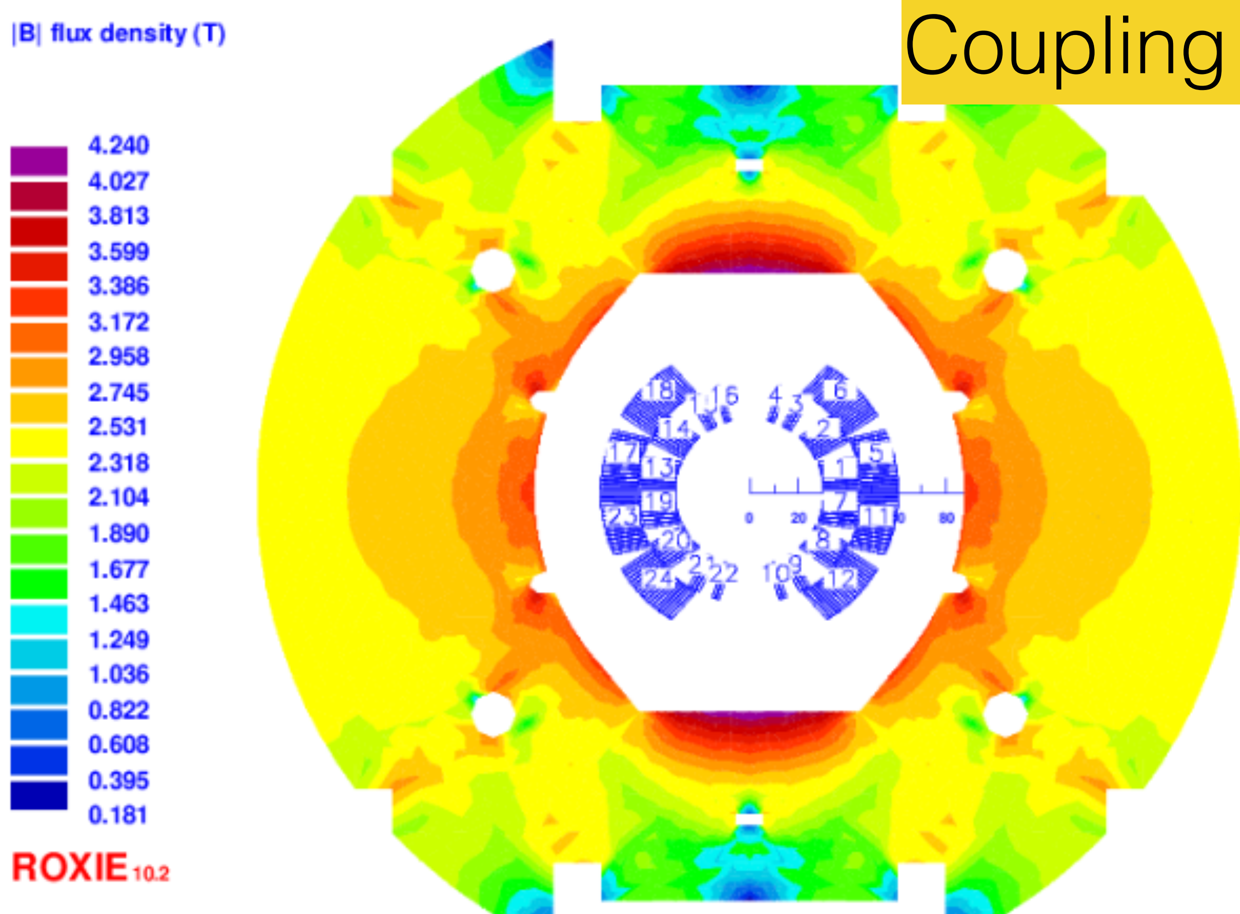
Coupling Loss Influences During Quench

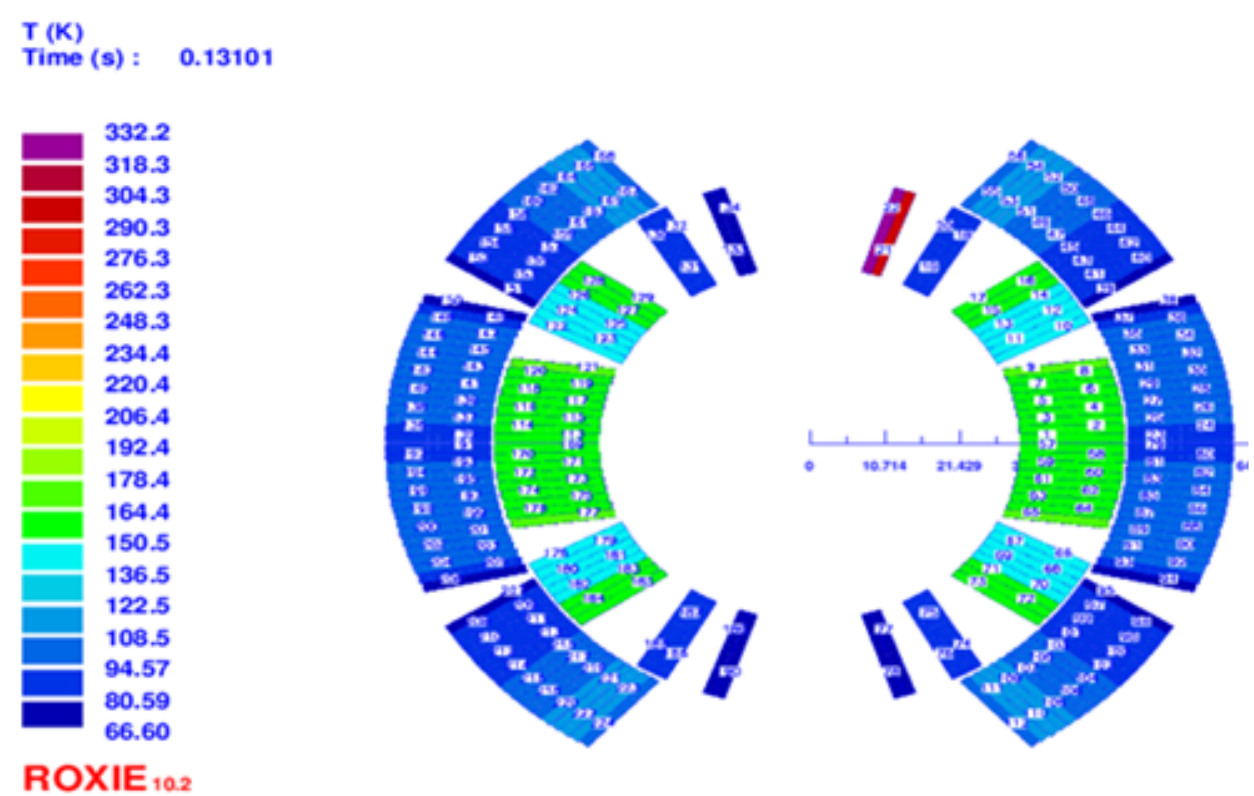


VS



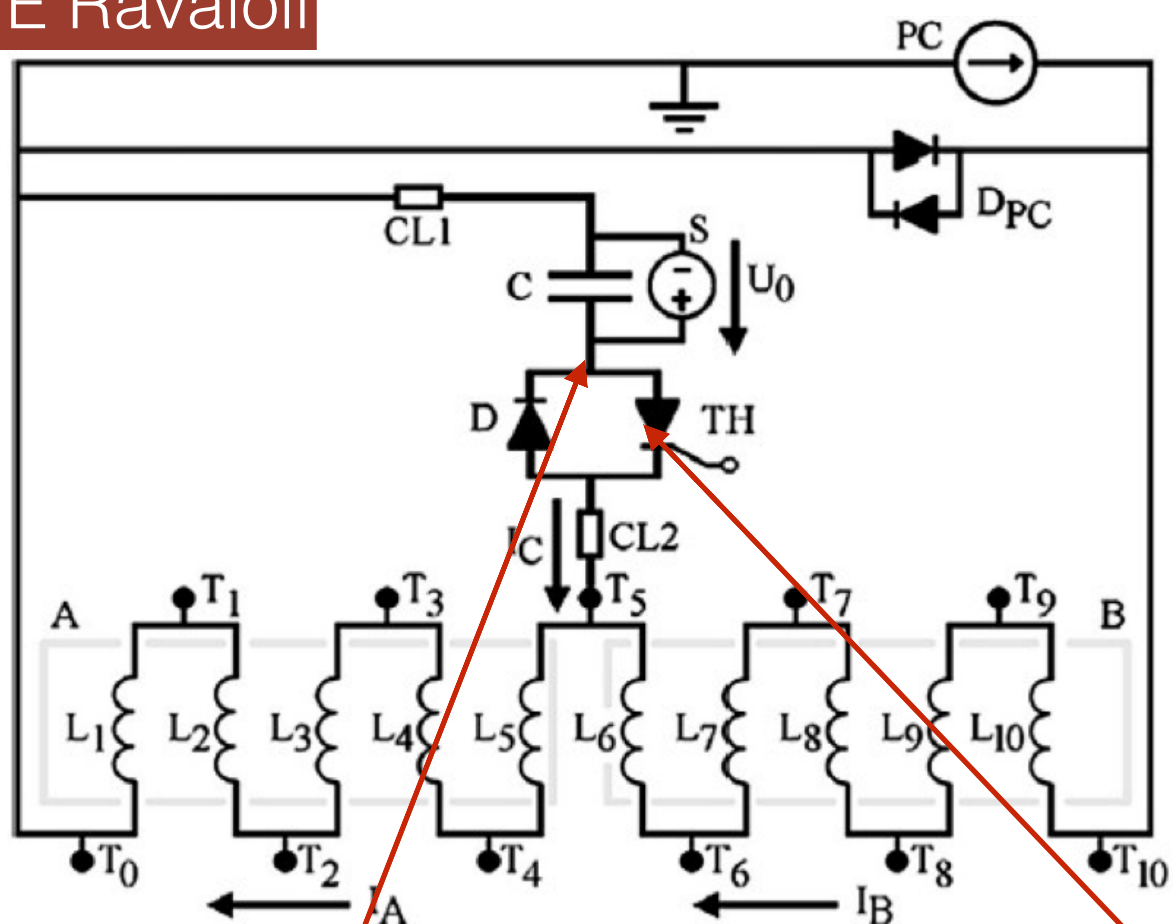
Coupling Loss can help reduce the quench time



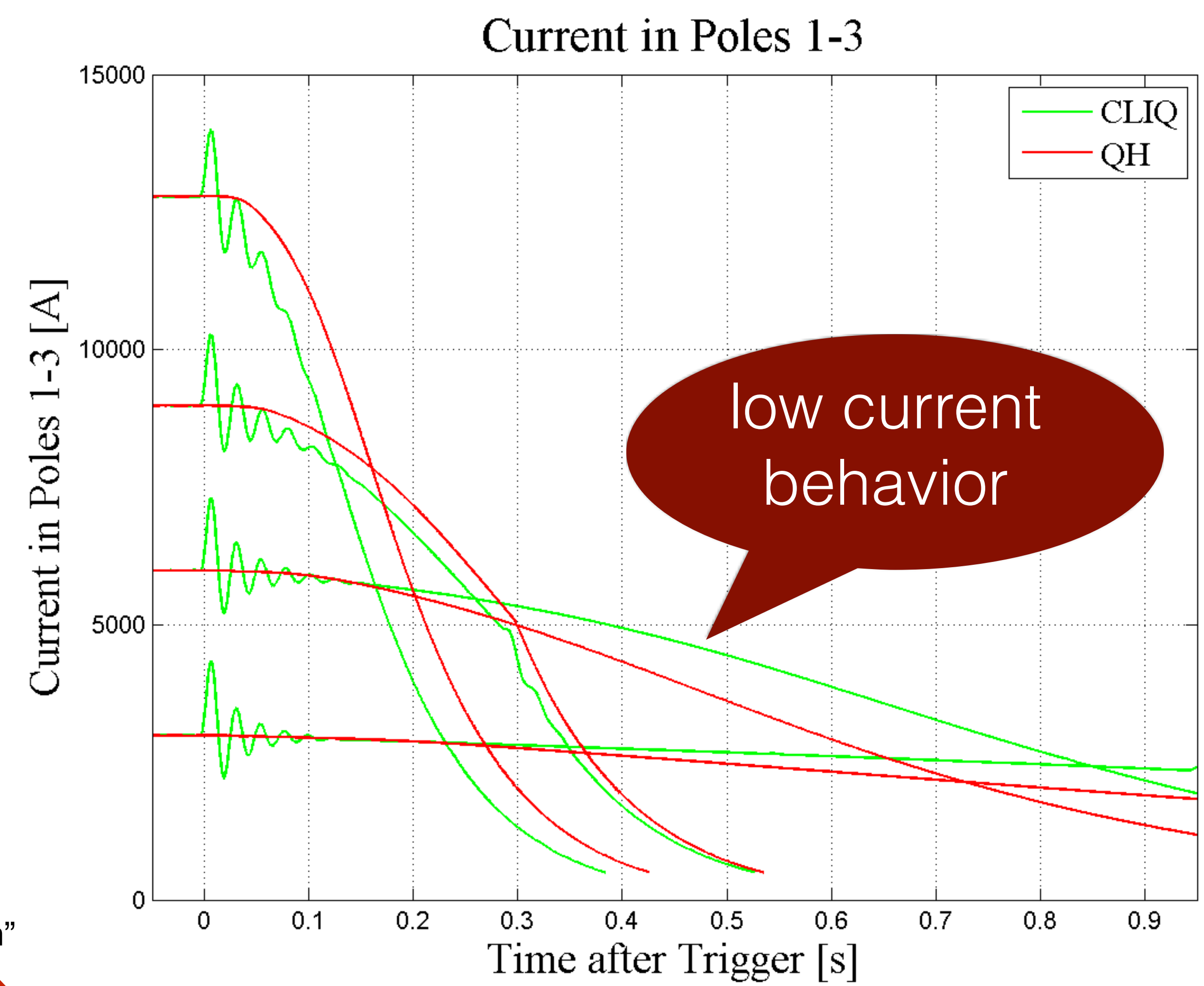


Coupling-loss Induced Quench Protection System(CLIQ)

Dr. E Ravaioli

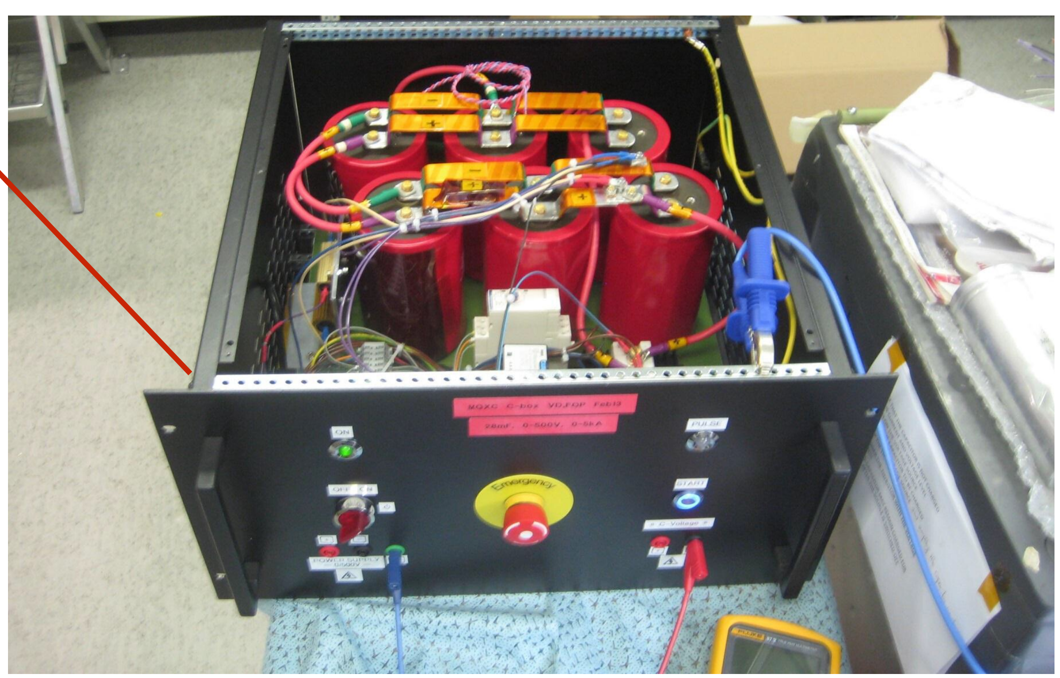


E.Ravaioli “First experience with the new Coupling Loss Induced Quench system” Cryogenics60(2014)33-43



$$U_c(t) = U_0 \cdot e^{(-at)} \cdot \left[\cos(\omega t) + \frac{\alpha}{\omega}\sin(\omega t)\right]$$

A promising method, however, there is still room for improvement



CLIQ-Coupling-Loss Induced Quench System for Protecting Superconducting Magnets carried out by E.Ravaioli, V.I.Datskov at CERN 02.04.2014

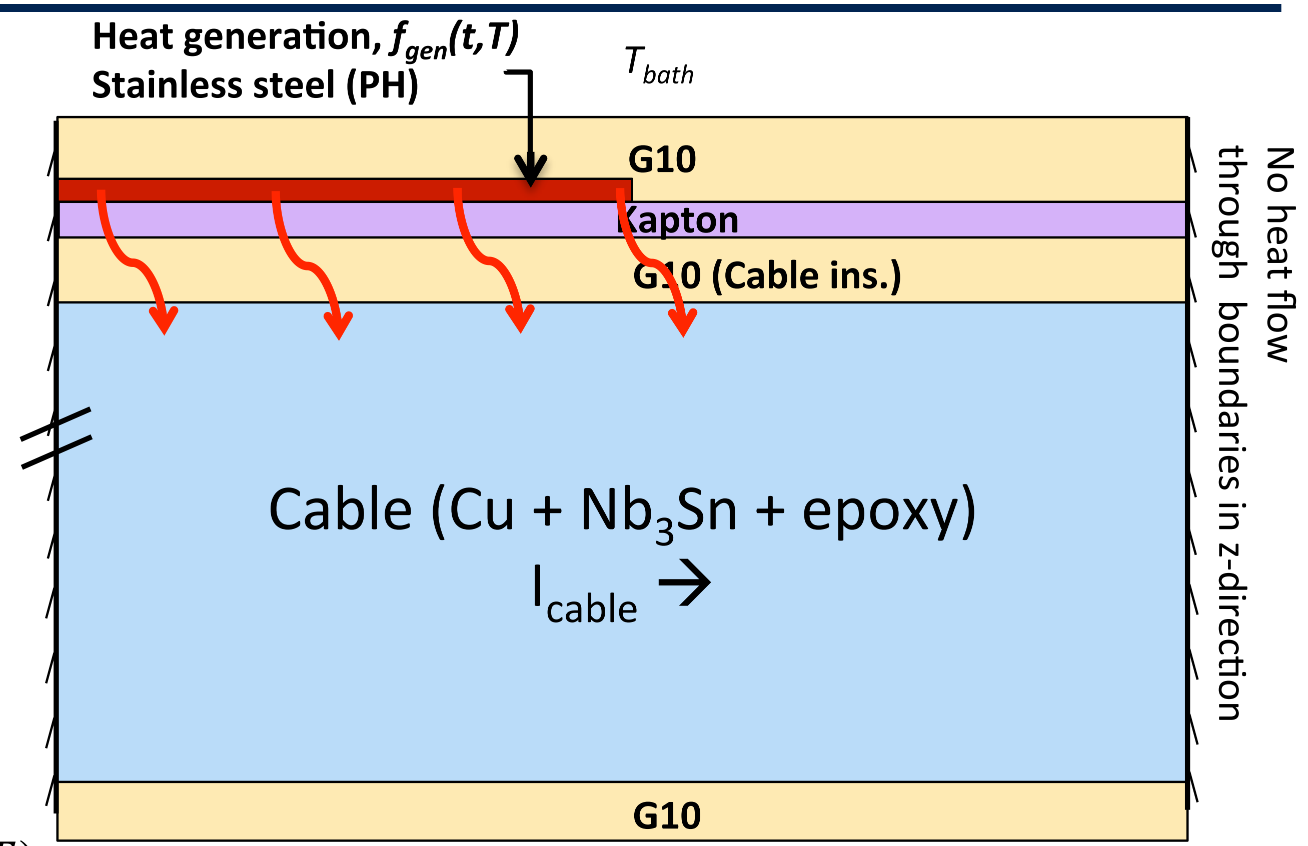
Conventional Heaters Quench Protection System(QHs)

Given the high energy density, high J and minimum coil thickness / mass, the coil must be switched to normal state in typically 30-50 ms in order not to overheat the coils after quench.

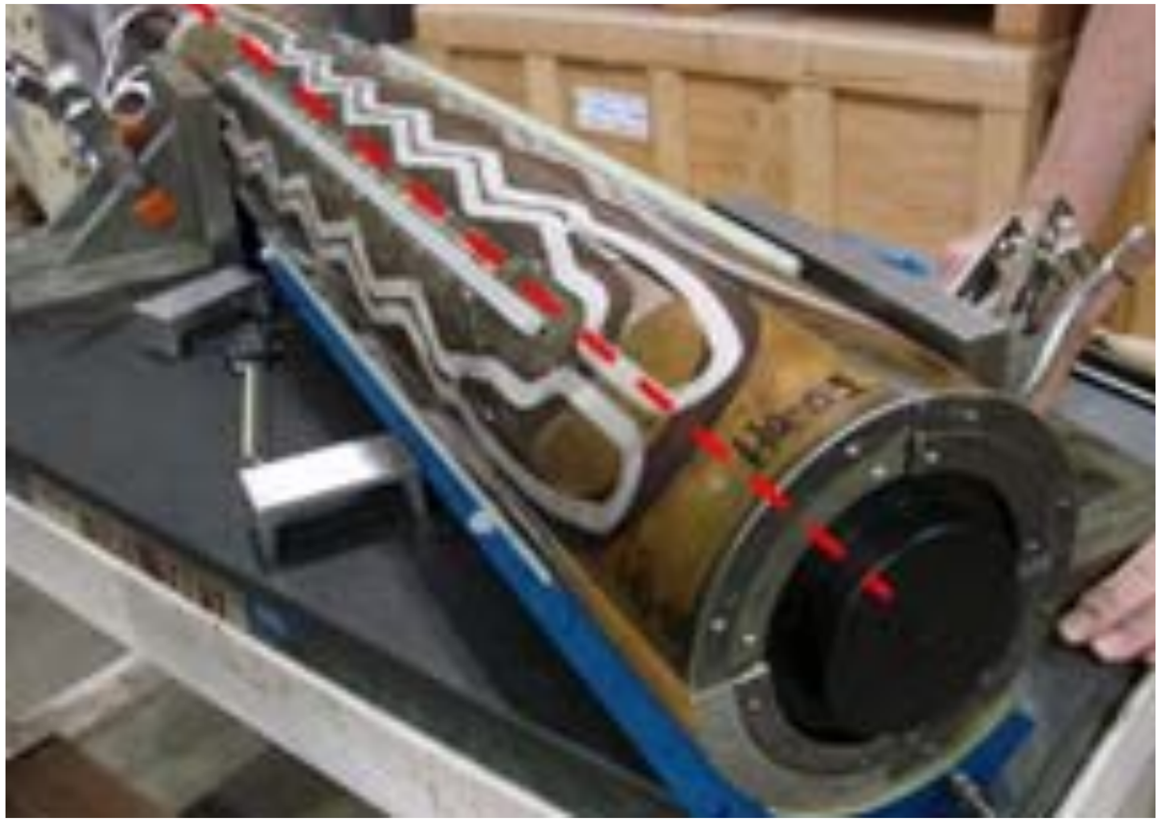
Inherently slow process

$$\gamma_m c_{p,m}(B,T)\frac{\partial T}{\partial t} = \frac{\partial}{\partial y}\left(k_m(B,T)\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k_m(B,T)\frac{\partial T}{\partial z}\right) + f_{gen,m}(t,T)$$

Minimize detection time (~10 ms), heater delay time (5-10ms) and adopt many heaters to heat the coil uniformly(10-30ms).



"MQXF Quench Protection" carried out byG.Ambrosio, M.Sorbi at LARP/CM20 HiLumi meeting Napa Valley,CA,USA 8-10 April,2013



G.A.Kirby, B.Auchmann IR Upgrade Nb-Ti, 120mm Aperture Model Quadrupole Test Results at 1.8K

Hybrid Quench Protection System

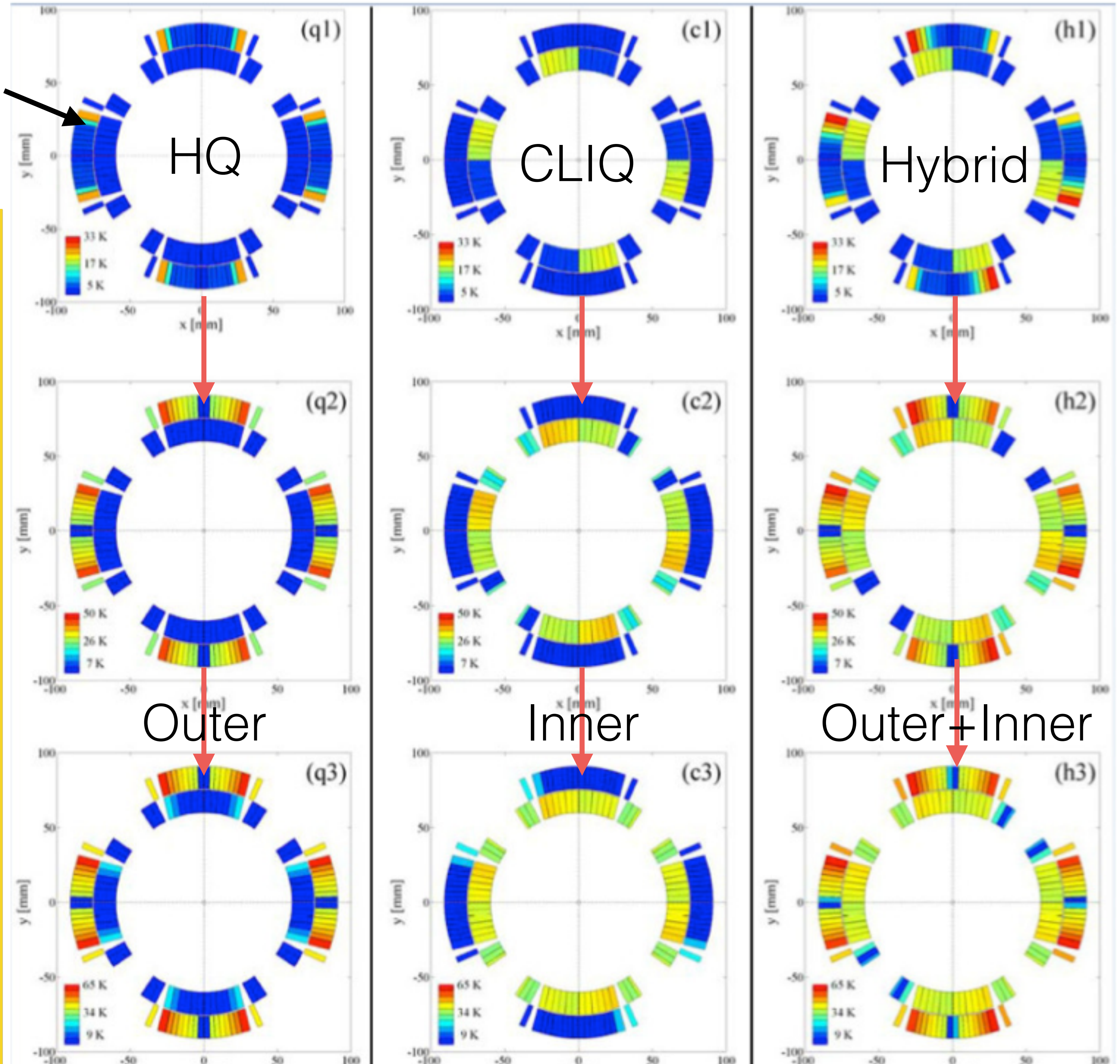
Temperature distribution after quench corresponding to three different methods

global transition

much faster current decay

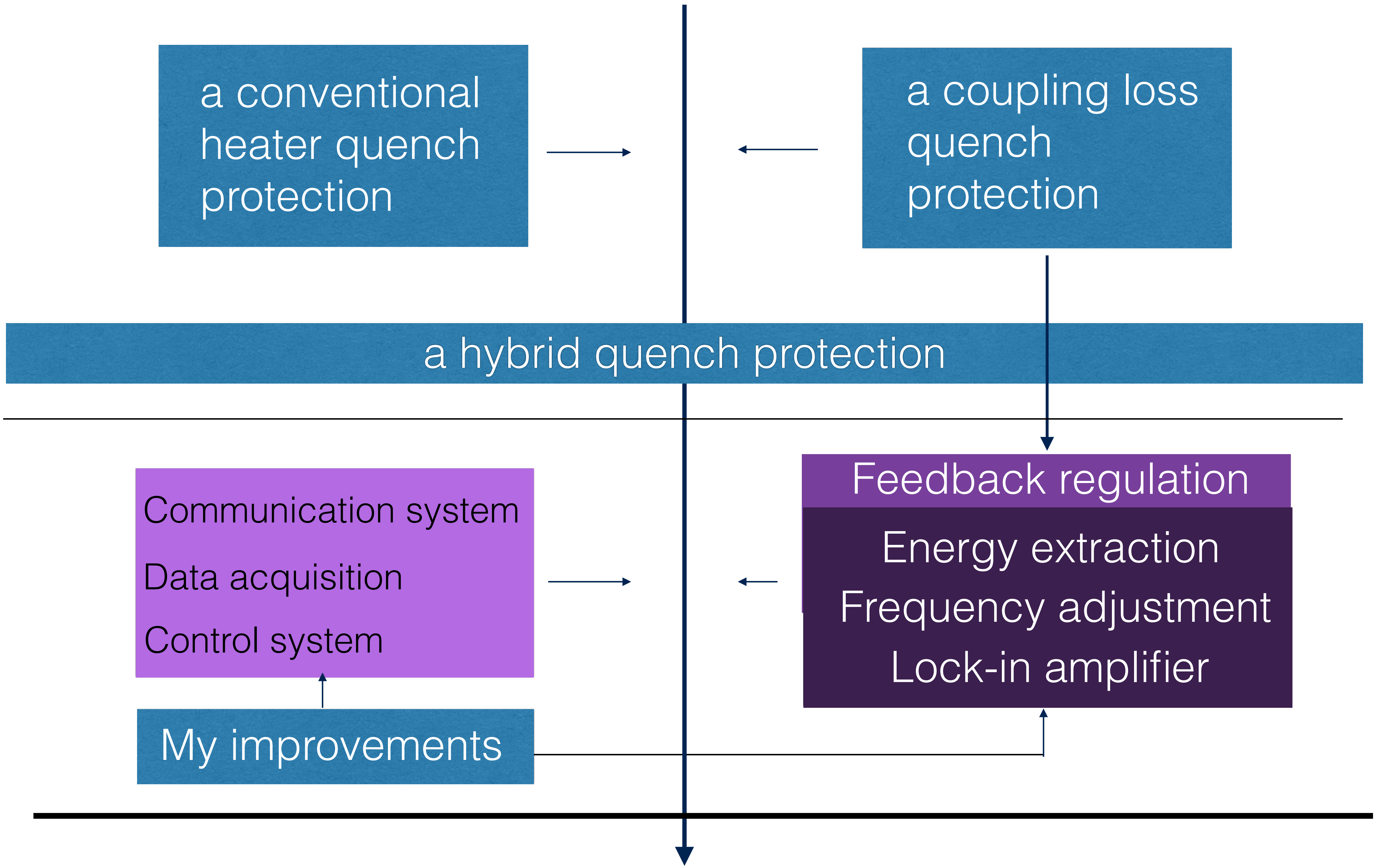
significantly lower hot-spot

more homogeneous temperature distribution in the coil



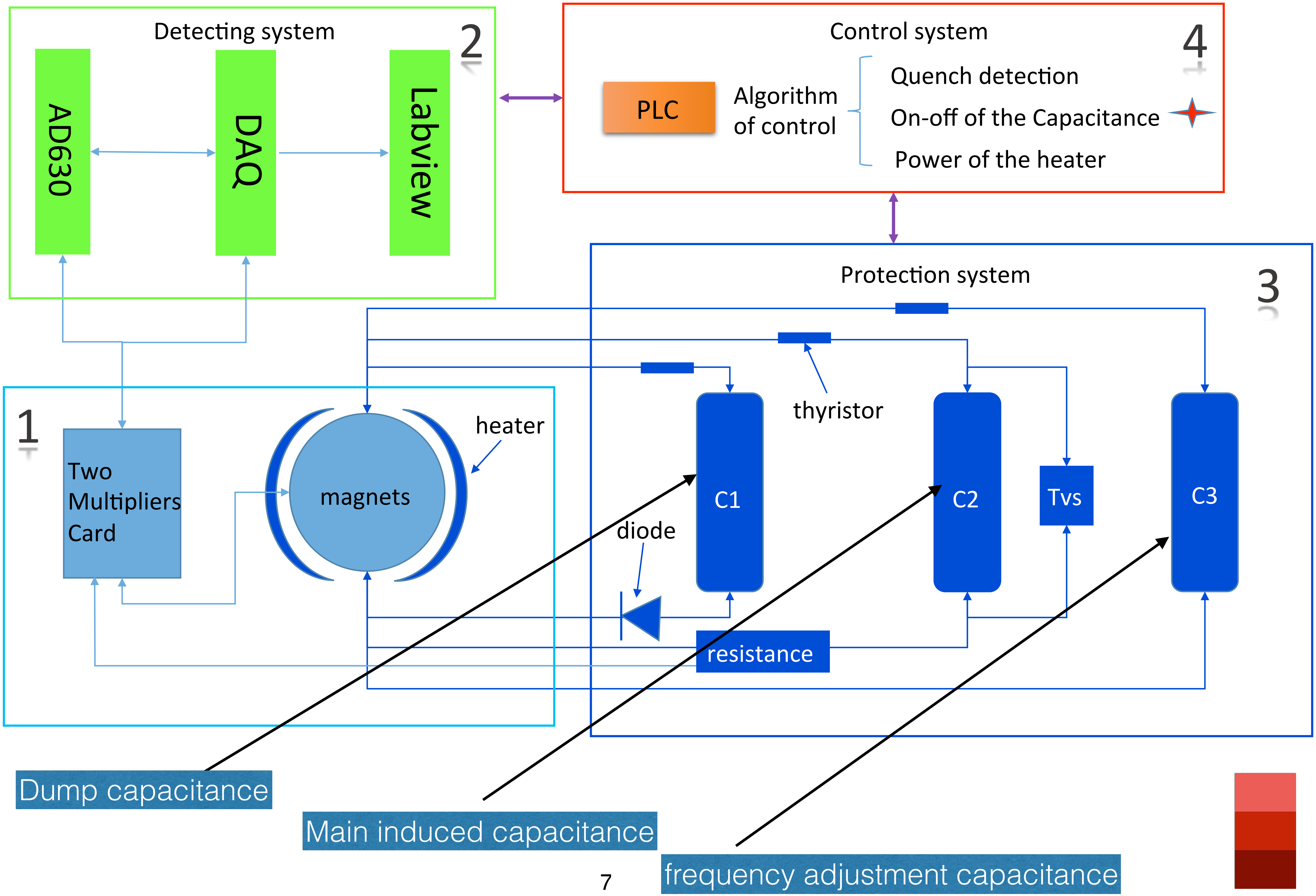
E Ravaioli,V I Datskov "A new hybrid protection system for high-field superconducting magnets"ESAS SUPERCONDUCTIVITY NEWS FORUM(global edition),October2013

Improvements

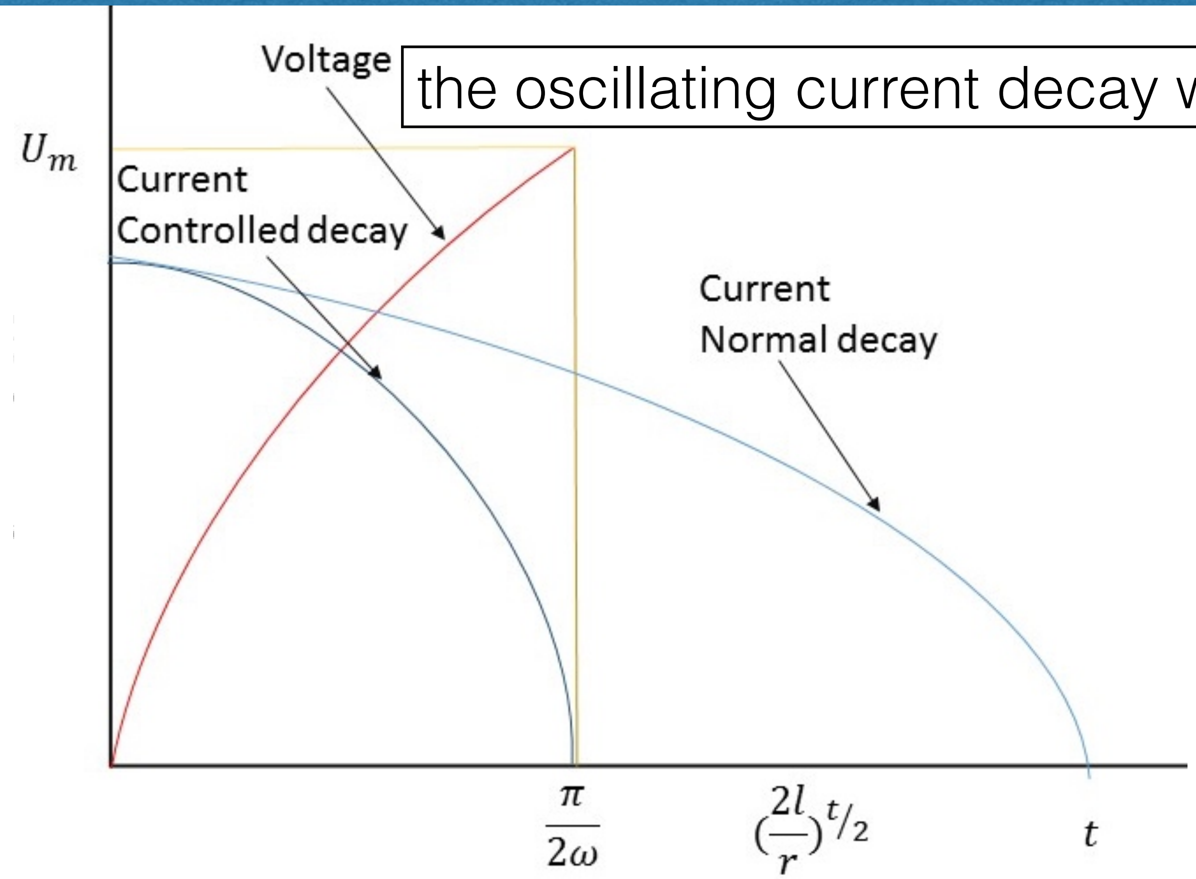


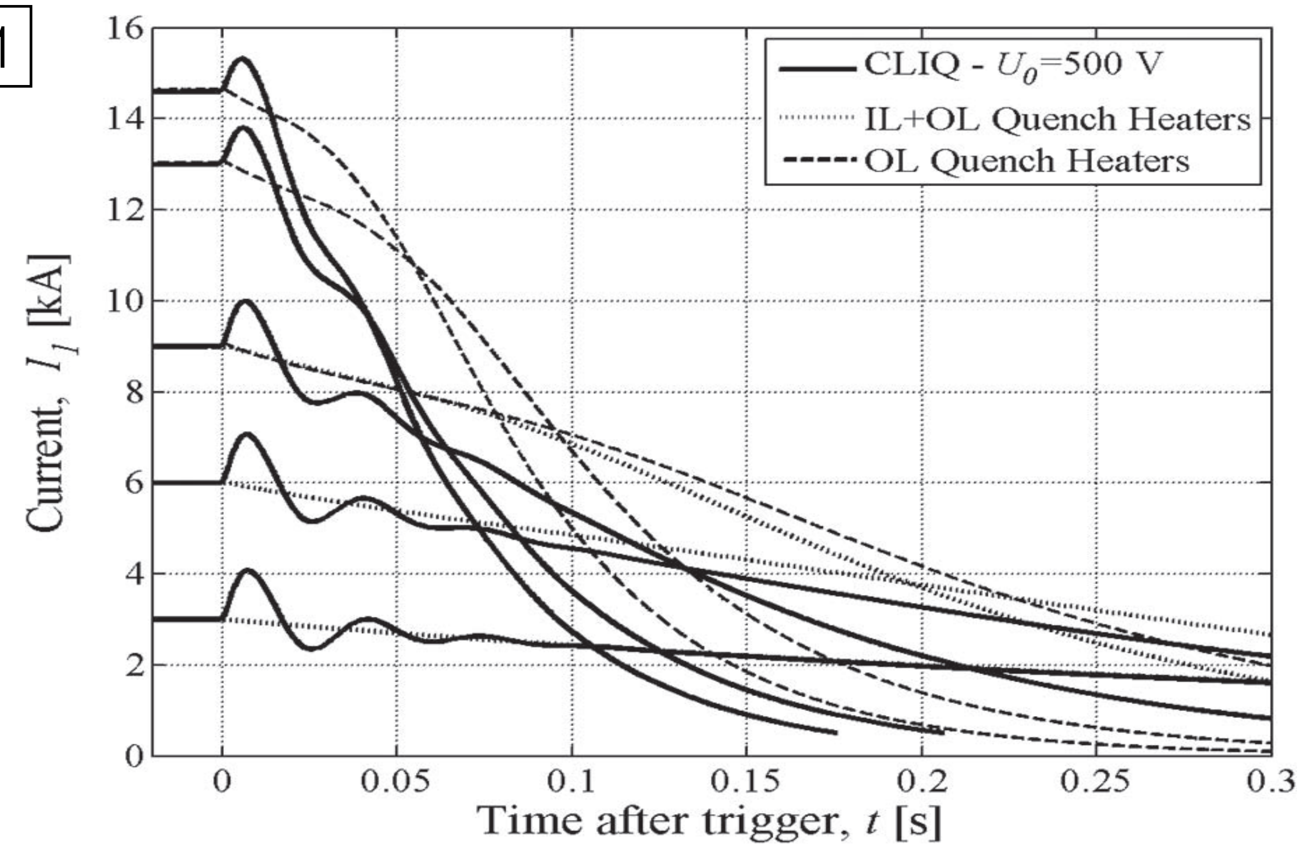
An Improved Coupling Loss Quench Protection(I-CLIQ)

Improved Coupling Loss Quench Protection(I-CLIQ)



Working Process of the System





E.Ravaioli,H.Bajas "Protecting a Full-Scale Nb3Sn Magnet With CLIQ,the New Coupling-loss Induced Quench System" TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY,VOL.25,NO.3,JUNE 2015

Quench before	Quench detection
Self-preparation	Quench signal
Input the Parameters of protected magnets	C1 start to work

10ms

Negative protection

possitive quench protection

C2 start to work → Heater start to work → C3 start to work → C1 C2 C3 start to work together

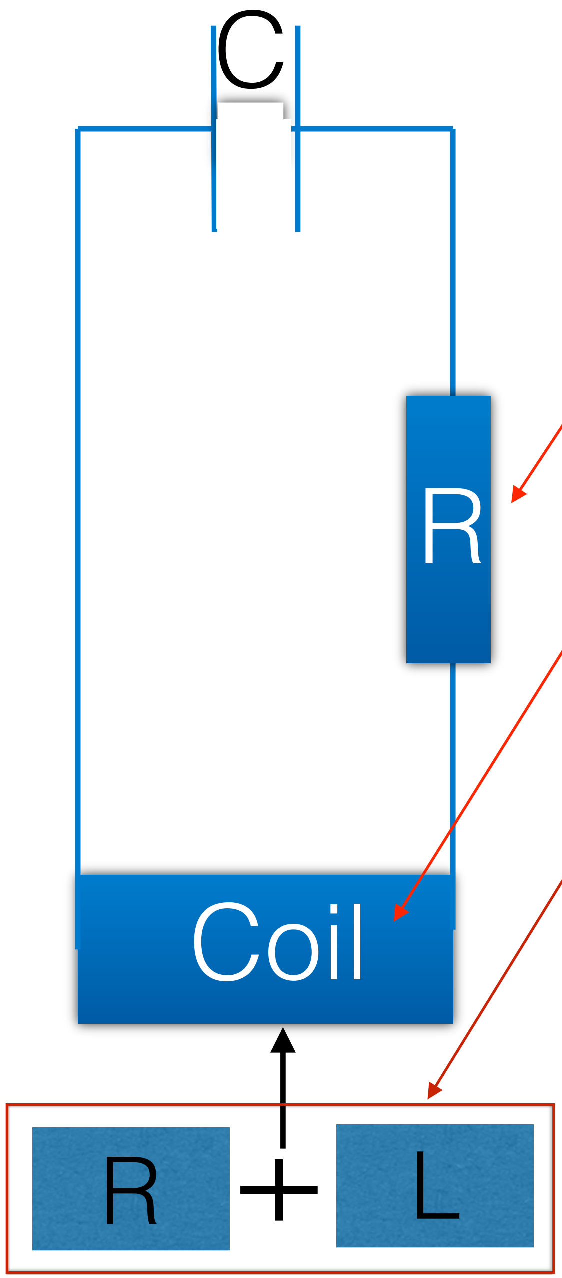
Induced — heat — adjustment — extraction

500ms

Quench start → Quench fierce → Quench end

Measurement of Induced Energy

Basic theory: We assumed that the coil consists of a resistance and a pure inductor, the voltage of them have a 90 phase difference.



Lock-in amplify

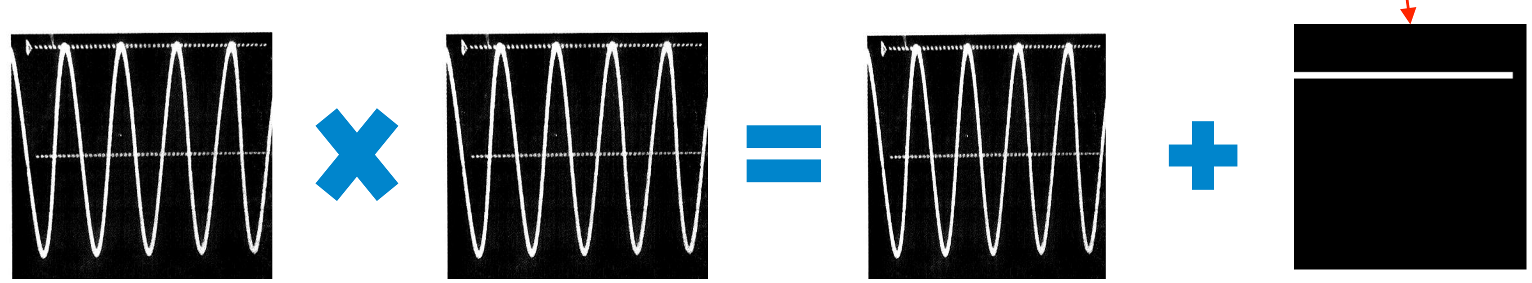
Mathematical Principles: Fourier series+ the conversion of trigonometric function

Reference signals $S(t) = A_1 \sin(\omega_1 t + \varphi_1)$

Under test signals $R(t) = A_2 \sin(\omega_2 t + \varphi_2)$

multiplication

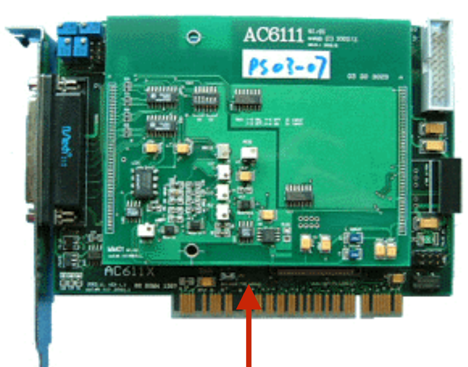
$$S(t) \cdot R(t) = \frac{A_1 A_2}{2} \cos[(\omega_1 - \omega_2)t + (\varphi_1 - \varphi_2)] - \frac{A_1 A_2}{2} \cos[(\omega_1 + \omega_2)t + (\varphi_1 + \varphi_2)]$$



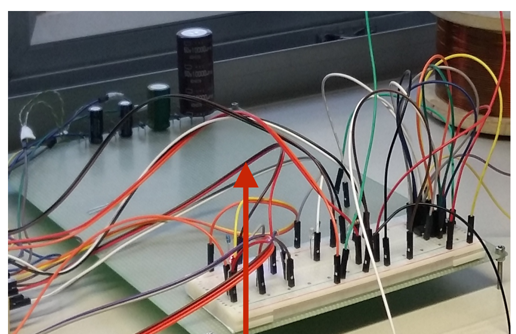
I-CLIQ Protection System

Lock-in amplifier based on Labview

Two Multipliers card with AD630



DAQ



Capacitance

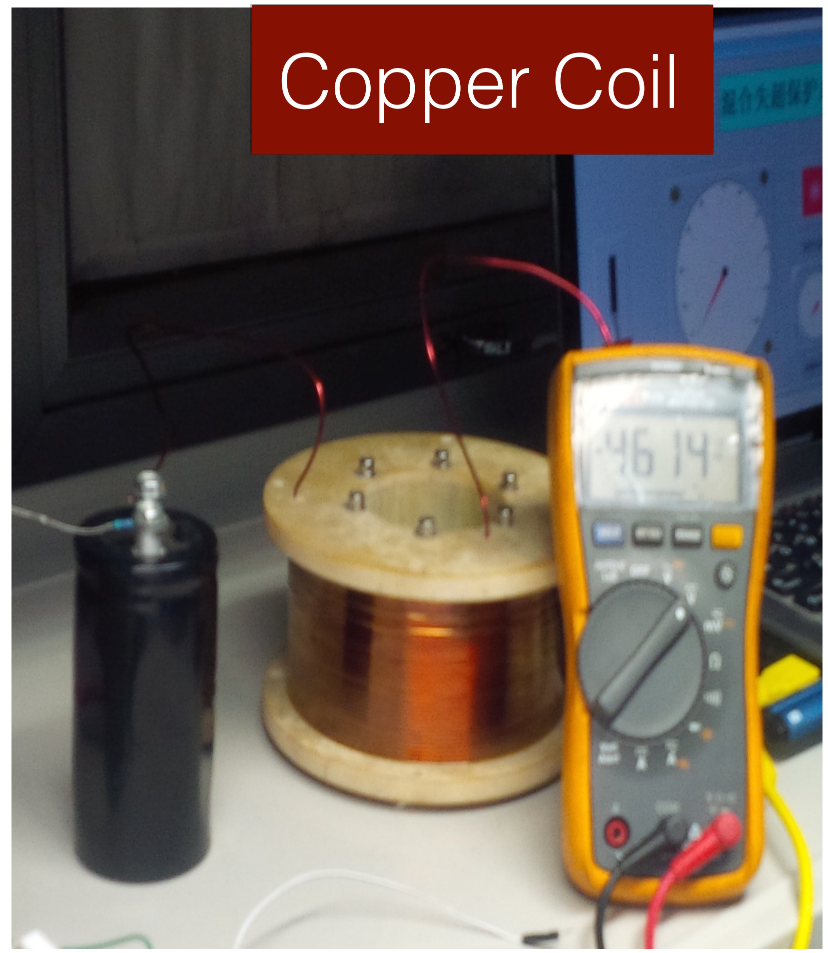
PLC

Electromagnetic relay

Direct-current main

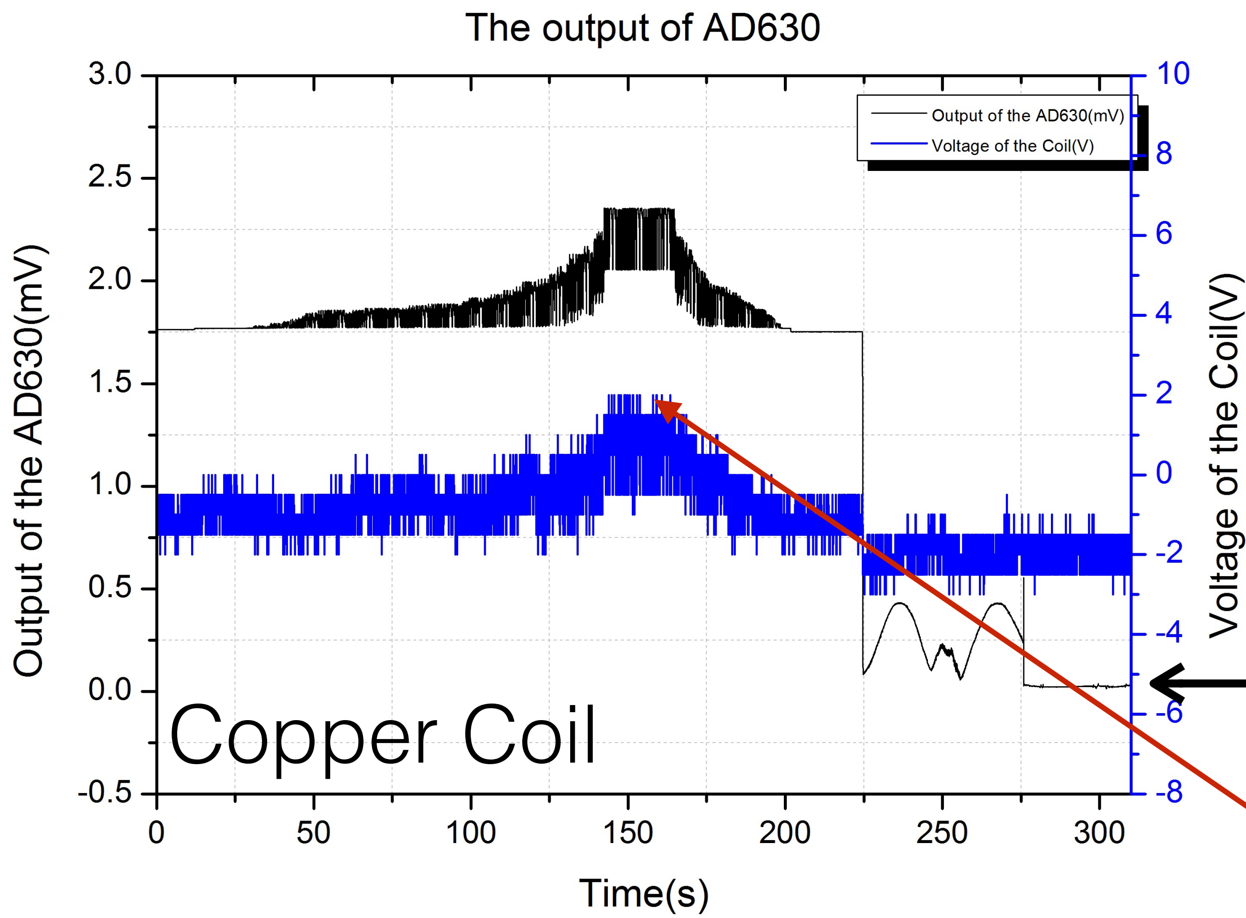
Data recorder

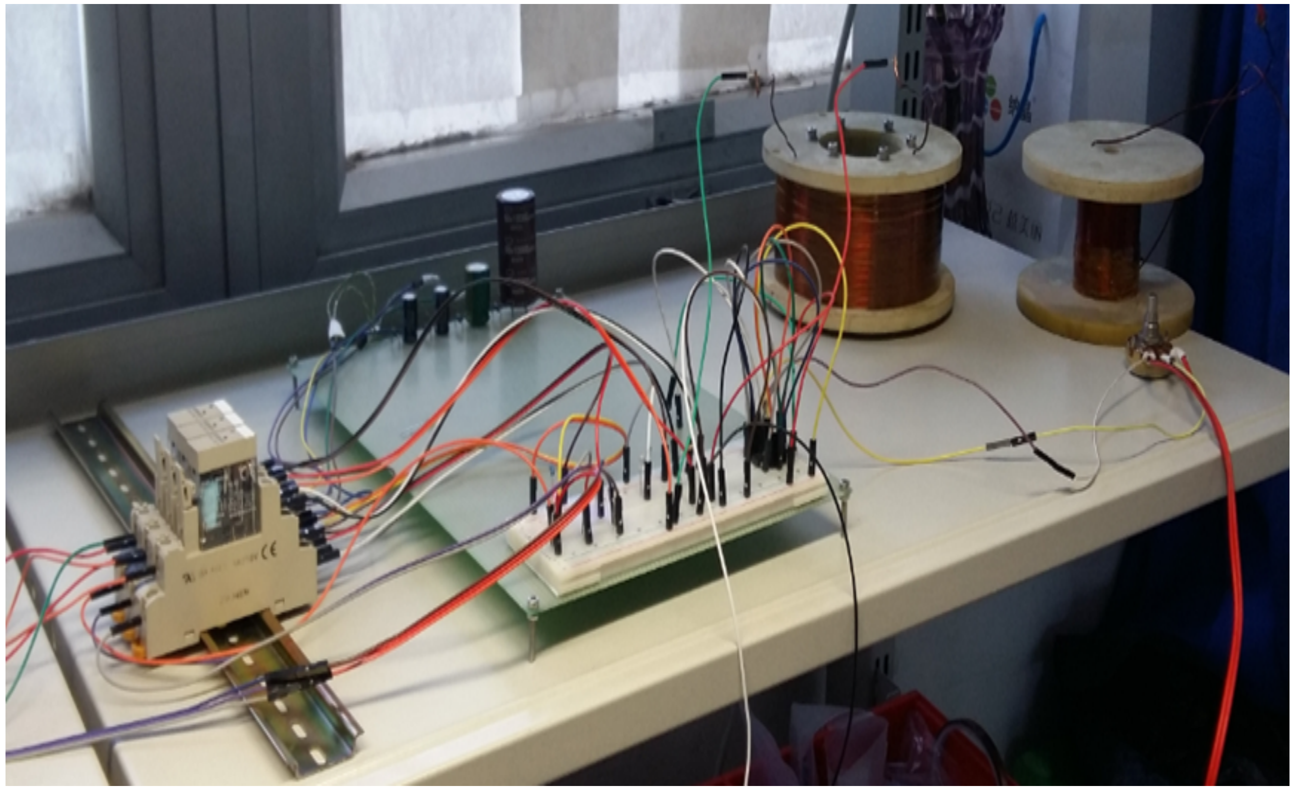
Tested Coils

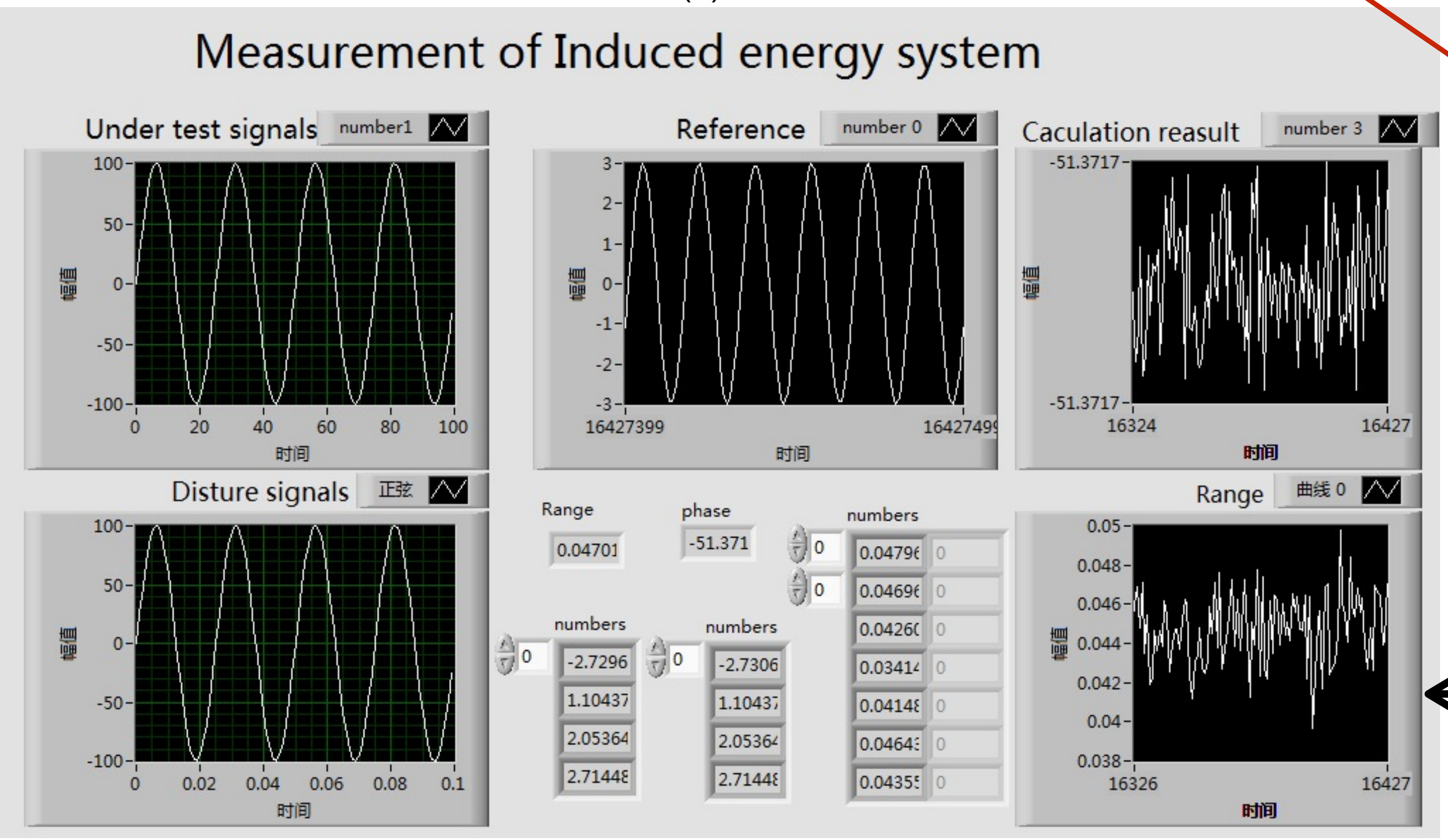


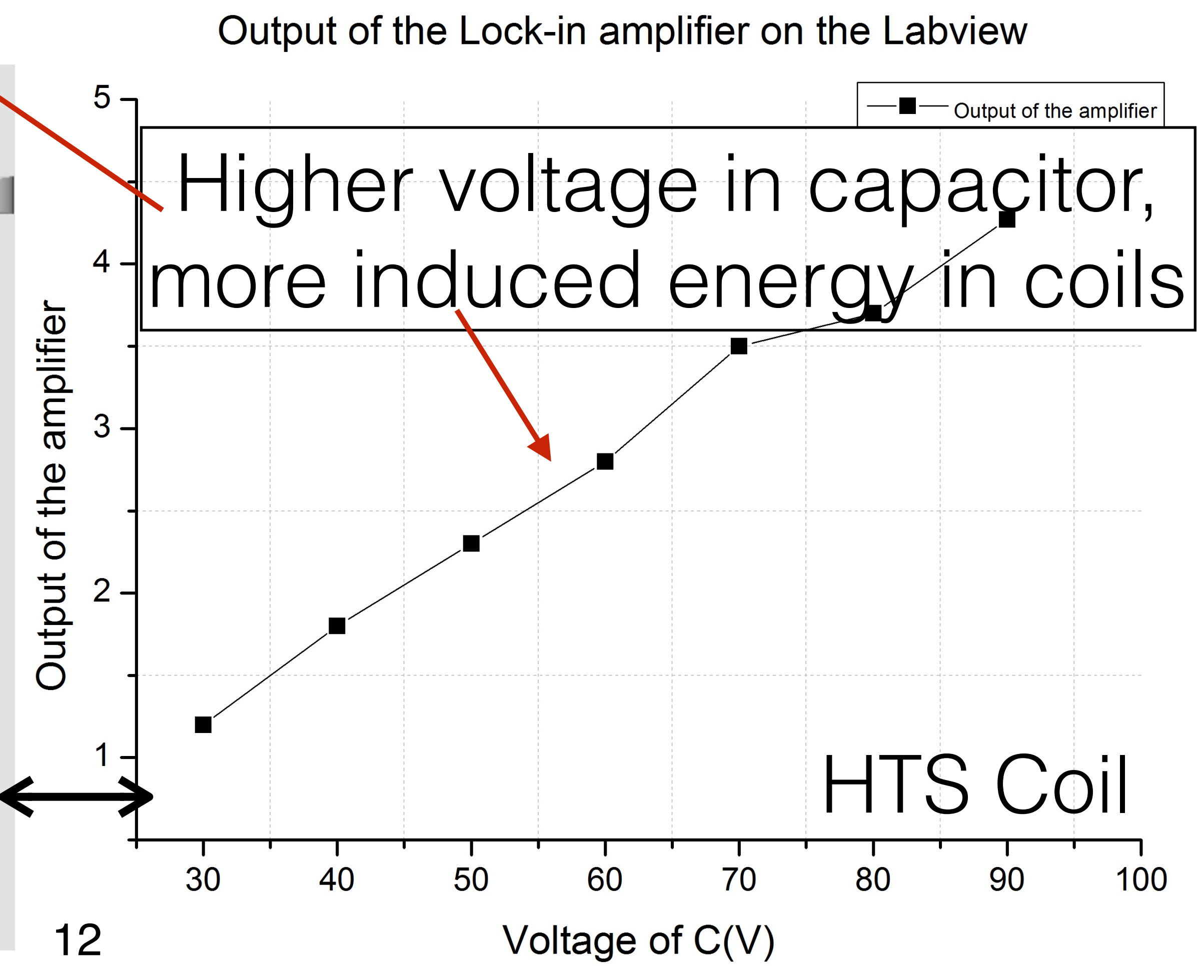
Tested Coil	Type of Wire	Inner diameter（mm）	Outer diameter（mm）	turns	electrical inductance
HTS Coil	2GS YBCO	70	98.22	34*2	0.5mH
Copper Coil	red copper	70	120	1600	40mH
LTS Coil	NbTi	100	180	5000	3000mH

Measurement of Induced Energy

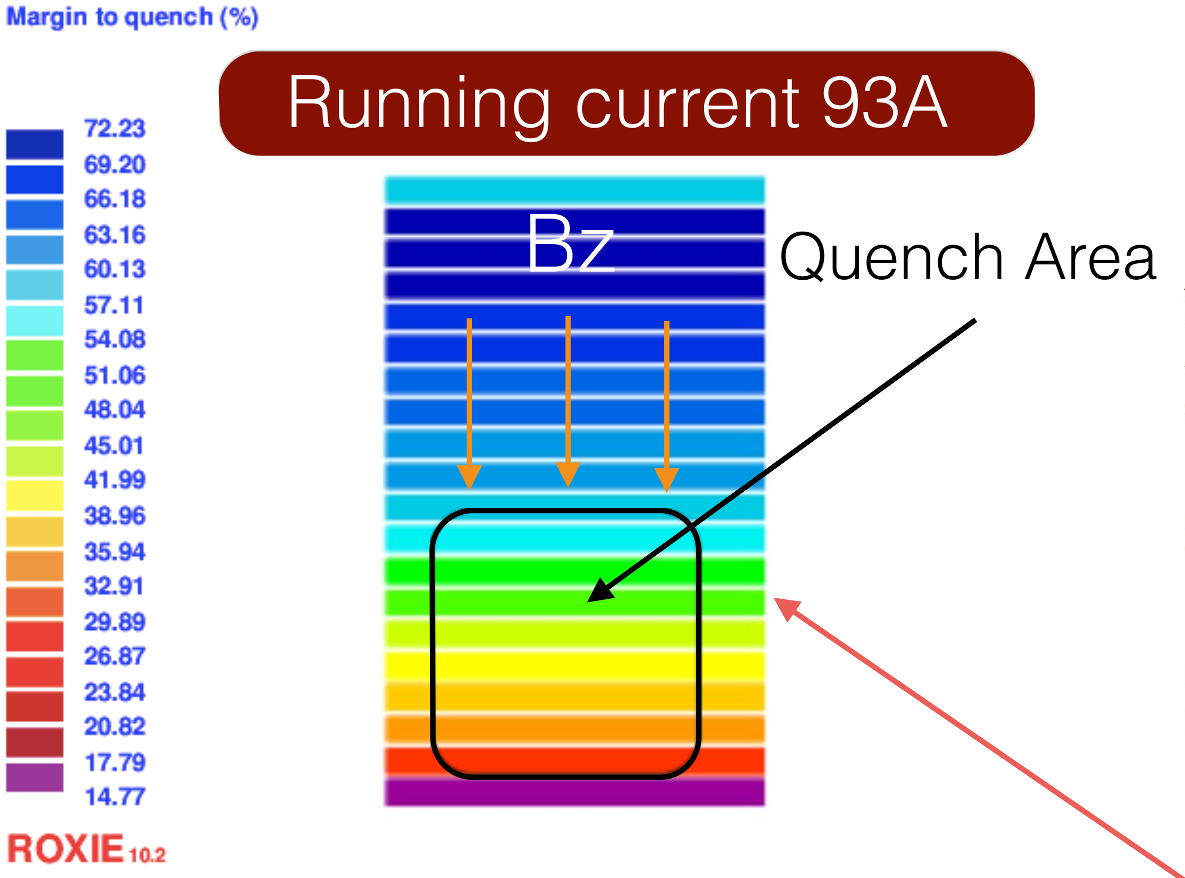


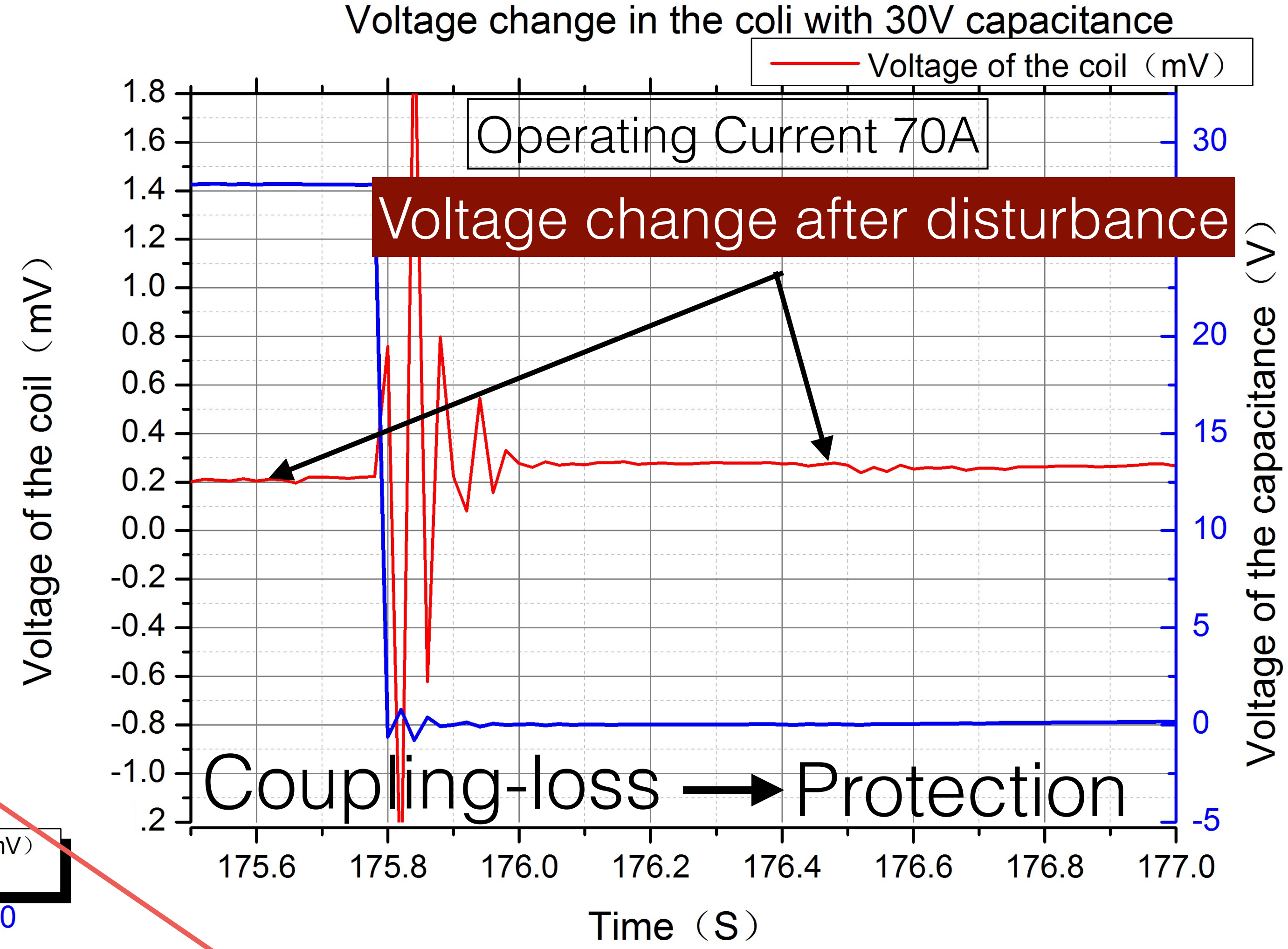


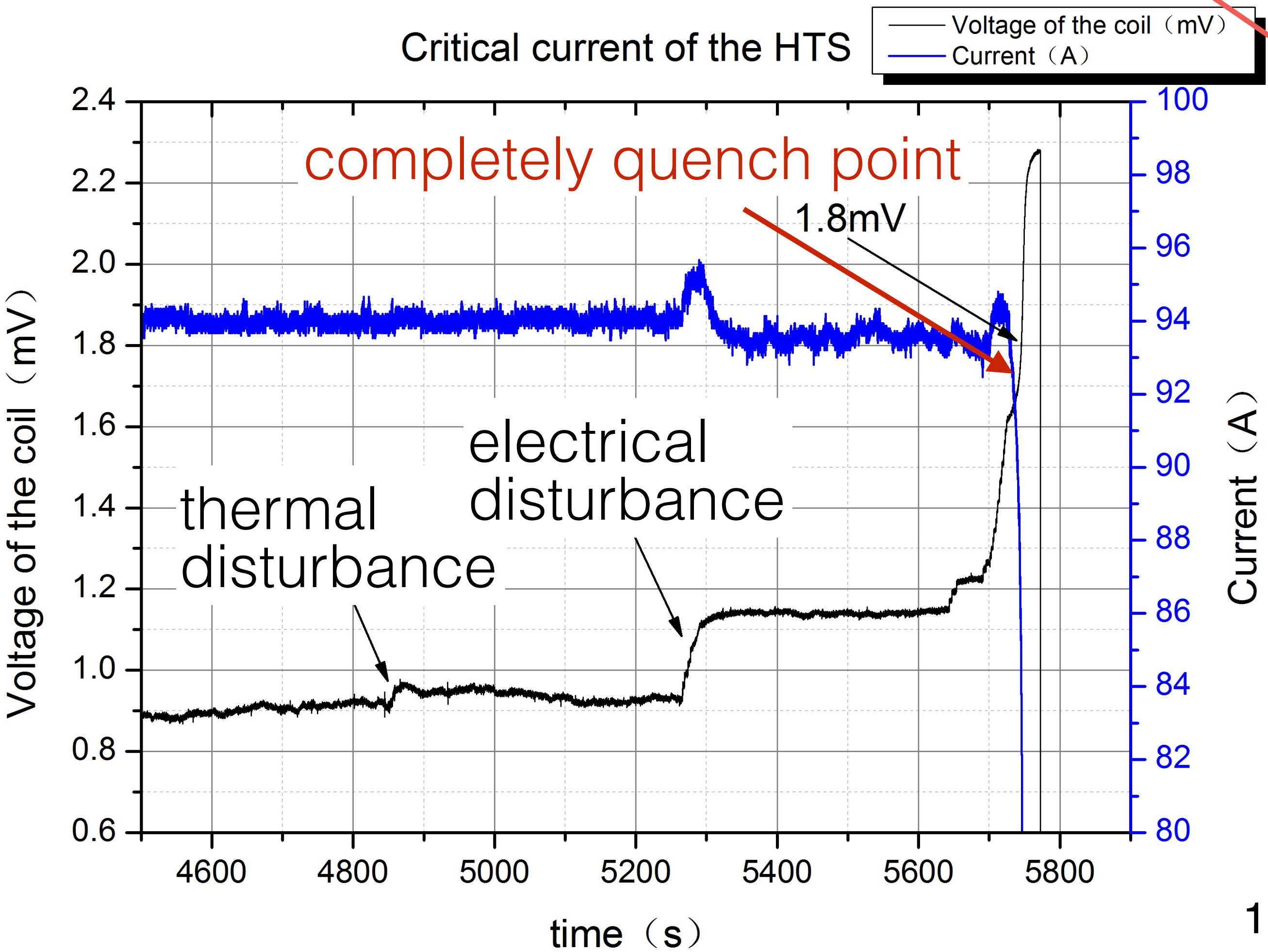


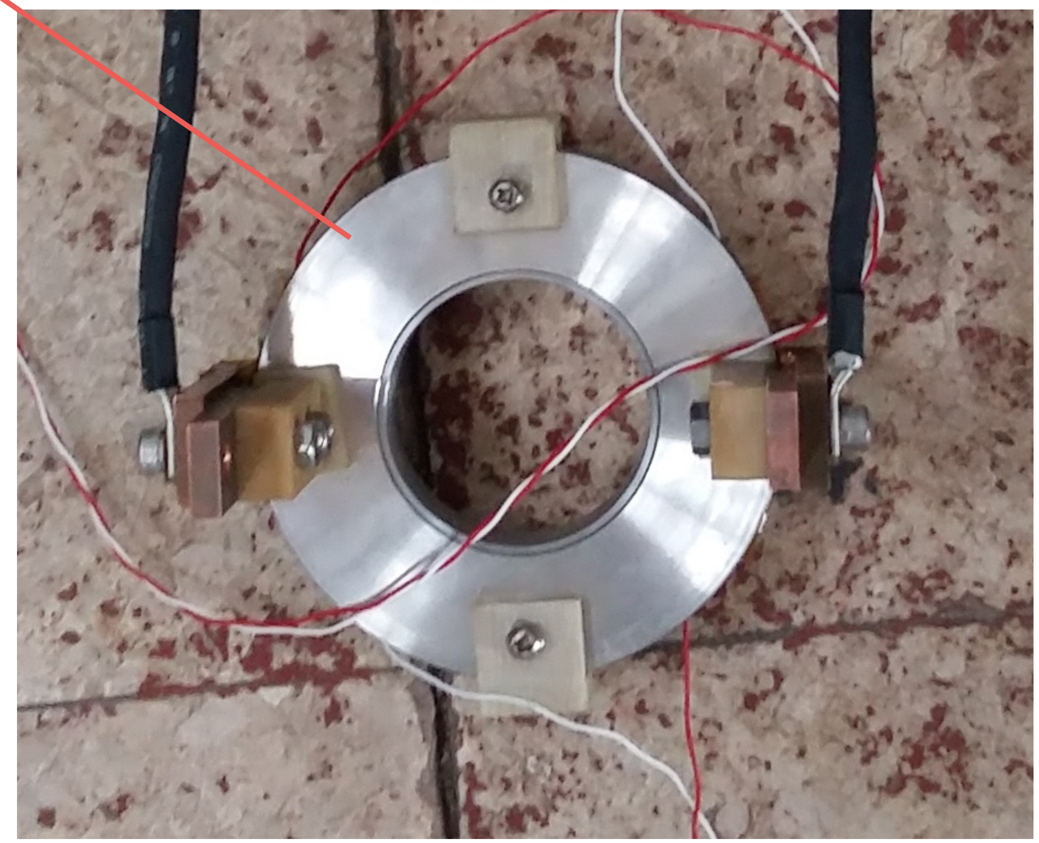


The Effect of CLIQ on the HTS Coil









Concluding Remarks

- The coupling loss induced quench protection system can work well on HTS coil
  - For HTS coils, it may induce more coupling loss, therefore, the quench protection effect could be better
- To apply the I-CLIQ to the high-field superconducting magnets , the following challenges remain to be solved.
  - The reliability
  - High voltage breakdown
  - Responding speed of the system
- The I-CLIQ system is going to test on a larger HTS(Bi2223) coil at the Institute of High Energy Physics(IHEP)

Thanks

Q&A