The design of the magnet LPF3

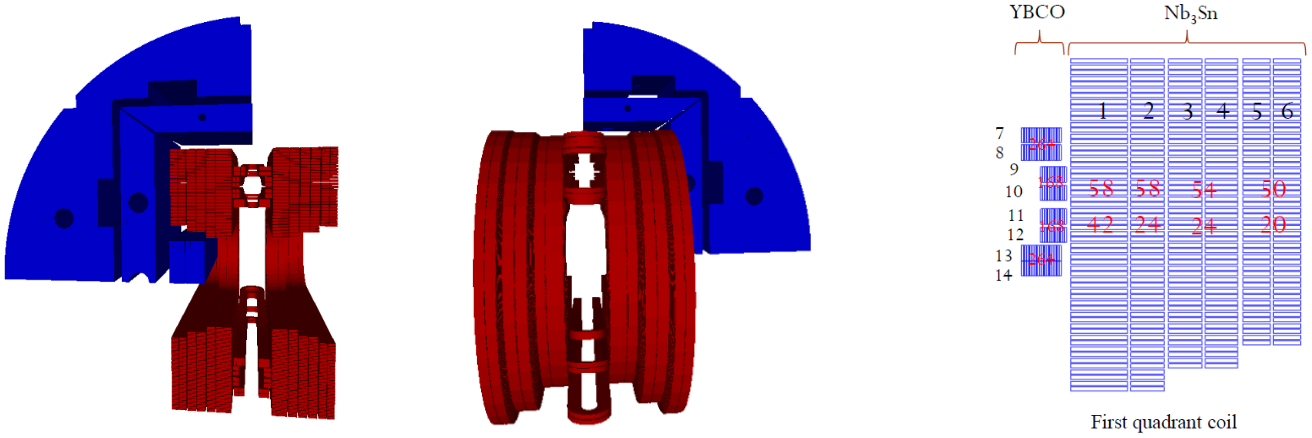

Figure 1 The design of LPF3（3D and 2D）

The main parameters of the magnet LPF3

Parameters	Unit	Value
Number of apertures		2
Aperture diameter	mm	50
Operating current	A	7580
Designed main field	T	13.01
Operating temperature	K	4.2
Inductance of magnet	mH	74

The detailed parameters of the cable that LPF3 used

	For coils	Width (mm)	Height (mm)	Numbers of strands	Cu/Sc	RRR
IHEPNS1	Inner coil block 1	19	1.45	42	1	100
IHEPNS2	Inner coil block 2 and middle coil	10.9	1.45	24	1	100
IHEPNS3	Outer coil	9.1	1.45	20	1	100

The analysis method

A 1-D adiabatic model was built in finite element software. In this model, the whole magnet is spread as a long cable. Only the thermal propagation along the cable will be taken into consideration. The heat balance equation during quench propagation can be expressed as:

$$A_i \rho_i Cp_i \frac{\partial T_i}{\partial t} - \frac{\partial}{\partial x}\left(A_i k_i \frac{\partial T_i}{\partial x}\right) + \sum_{j=1}^{N} \frac{(T_i - T_j)}{H_{ij}} = \dot{q}_{ext} + \dot{q}_{Joule}$$

where A is the crossing sectional area of cables, ρ is the density of material, Cp is the specific heat capacity of material, k is the heat conductivity coefficient, H is the thermal resistance, q_{ext} is the density of thermal disturbance energy and q_{Joule} is joule heat density.

Input

Parameters of coils: temperature, magnetic field, current, cross-sectional area of cable, length, turns, layer number; wire type, Cu/Sc, RRR;
Calculation parameters: initial disturbance length, time, energy, number of grid cells and time step.

Calculation →

Output

Voltage and temperature of the magnet

The design of quench heater

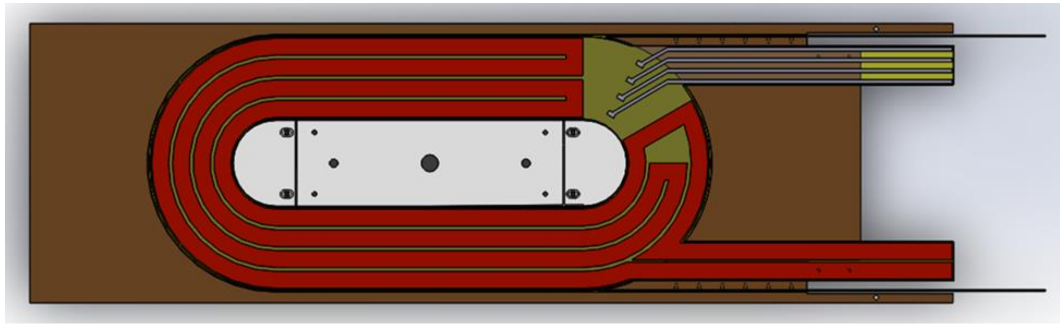

Figure 2 The design of the quench heater

The red parts are stainless steel strips used to heat the coils. The resistance of the heaters can be expressed as:

$$R = \rho \frac{l}{w * t}$$

where ρ is the resistivity of stainless steel, l, w, and t are the length, width and thickness of the strips. The lengths and width have been determined by the design shown in Fig. 2. The surface power of the heater is determined by the charging voltage U as:

$$P = \frac{U^2}{R * l * w}$$

The peak power of heaters is assumed as 50W/cm^2 in following calculation at first. Then the charging voltage can be got according to the above formula.

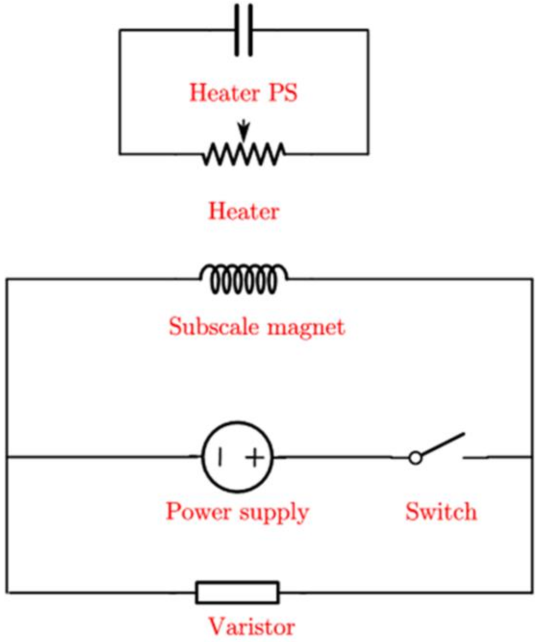

Figure 3 The designed quench protection circuit

Simulation results

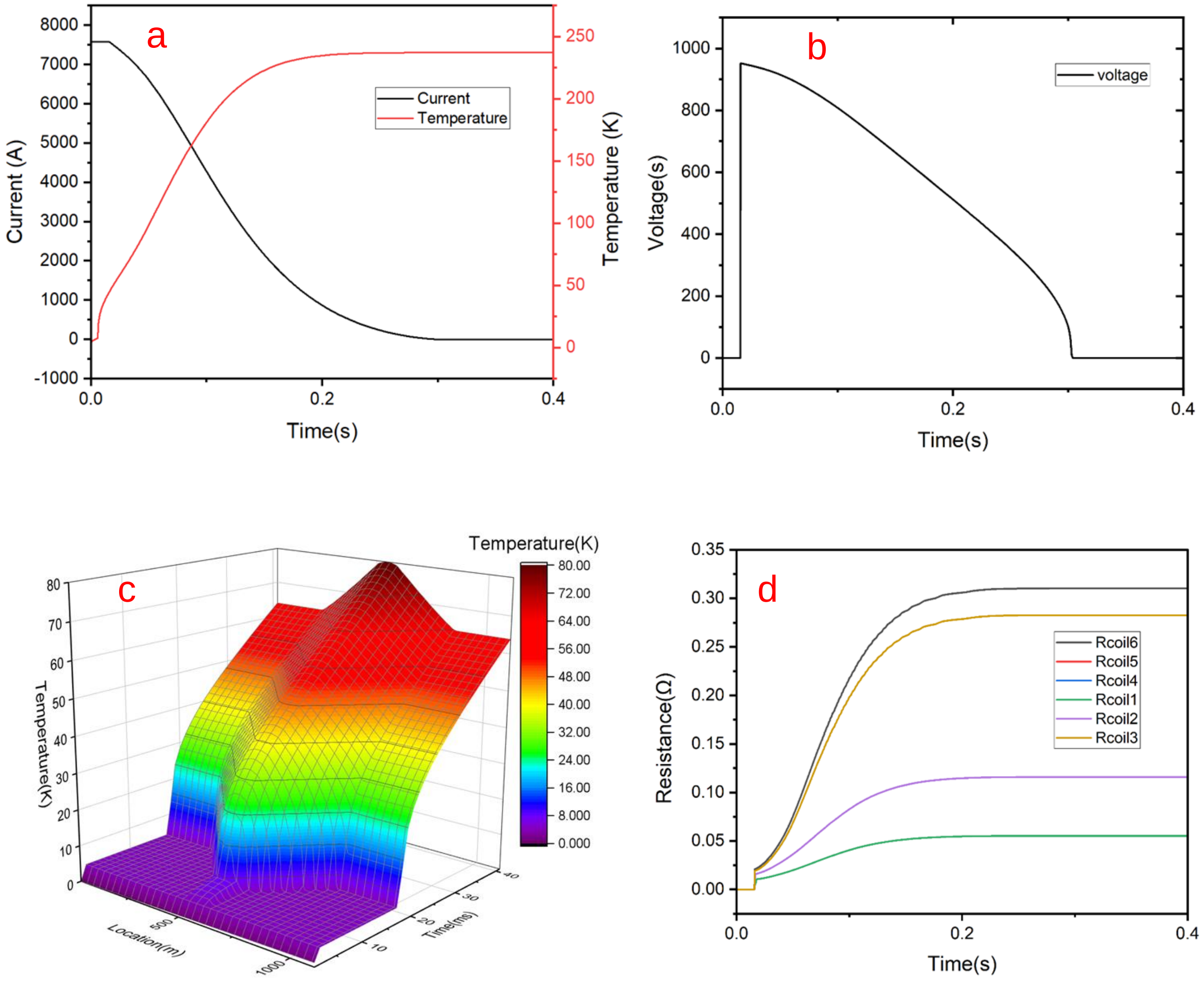

Figure 4:(a) The current decay and hotspot temperature during the quench process with varistor and quench heater; (b) The terminal voltage of the varistor; (c) The temperature nearby the hotspot in first 40 ms.; (d) The resistance of each coil

Figure 4 show the simulation results with varistor and quench heater when the voltage threshold and validation time are set as 100 mV and 10 ms.

The model has also been calculated with different delay time and voltage thresholds. The simulation results are shown in figure 5. Considering that the simulation is under adiabatic condition, the standard of detection can be relaxed in real test campaign on the premise of ensuring the safety of the magnet.

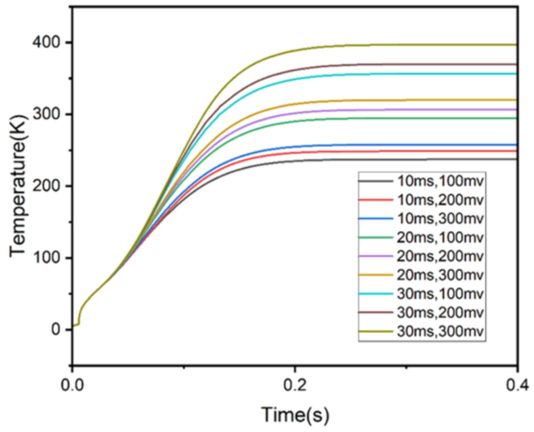

Figure 5 The hotspot temperature with different protection parameters