Protecting a Superconducting CCT Quadrupole Magnet with a CLIQ System

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Abstract-The Superconducting Magnet Group in IHEP is developing a Canted-Cosine-Theta quadrupole magnet named SCQ-CCT (fig.1), for which a quench protection system using CLIQ method has been designed(fig.2). The design parameters of the SCQ-CCT magnet are shown in Table 1.

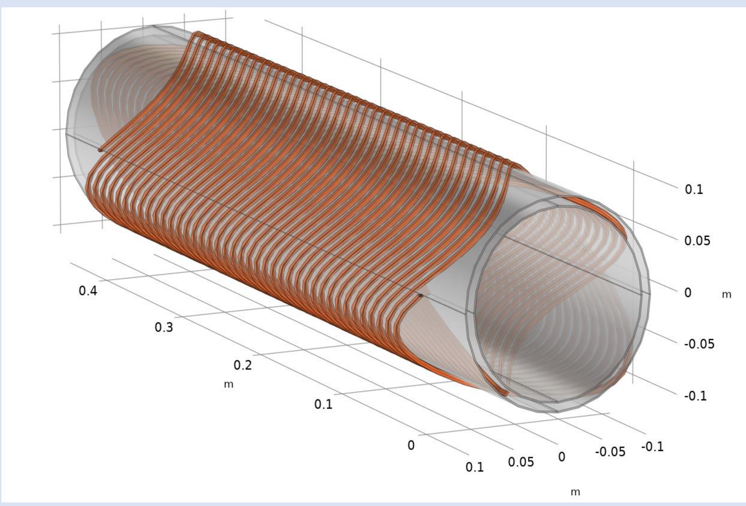


Fig.1 The SCQ-CCT magnet designed by IHEP

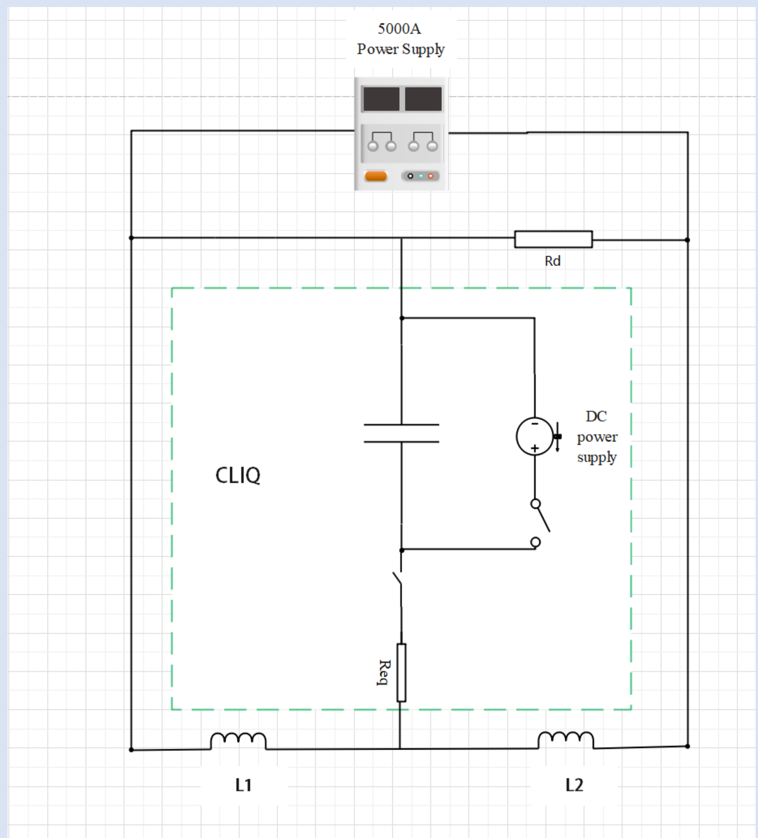


Fig.2 The CLIQ system

Table 1

Design parameters of the SCQ-CCT magnet.

Inner radius [mm]	Outer radius [mm]	Spar thickness [mm]	Wire slot geometry [mm]	Tilted angle [°]	Axial Pitch [mm]	Number of wires in one slot	Operating current [A]
95.1	101.6	1.5	4.5 × 1.85	48	2.9	5 × 2	645

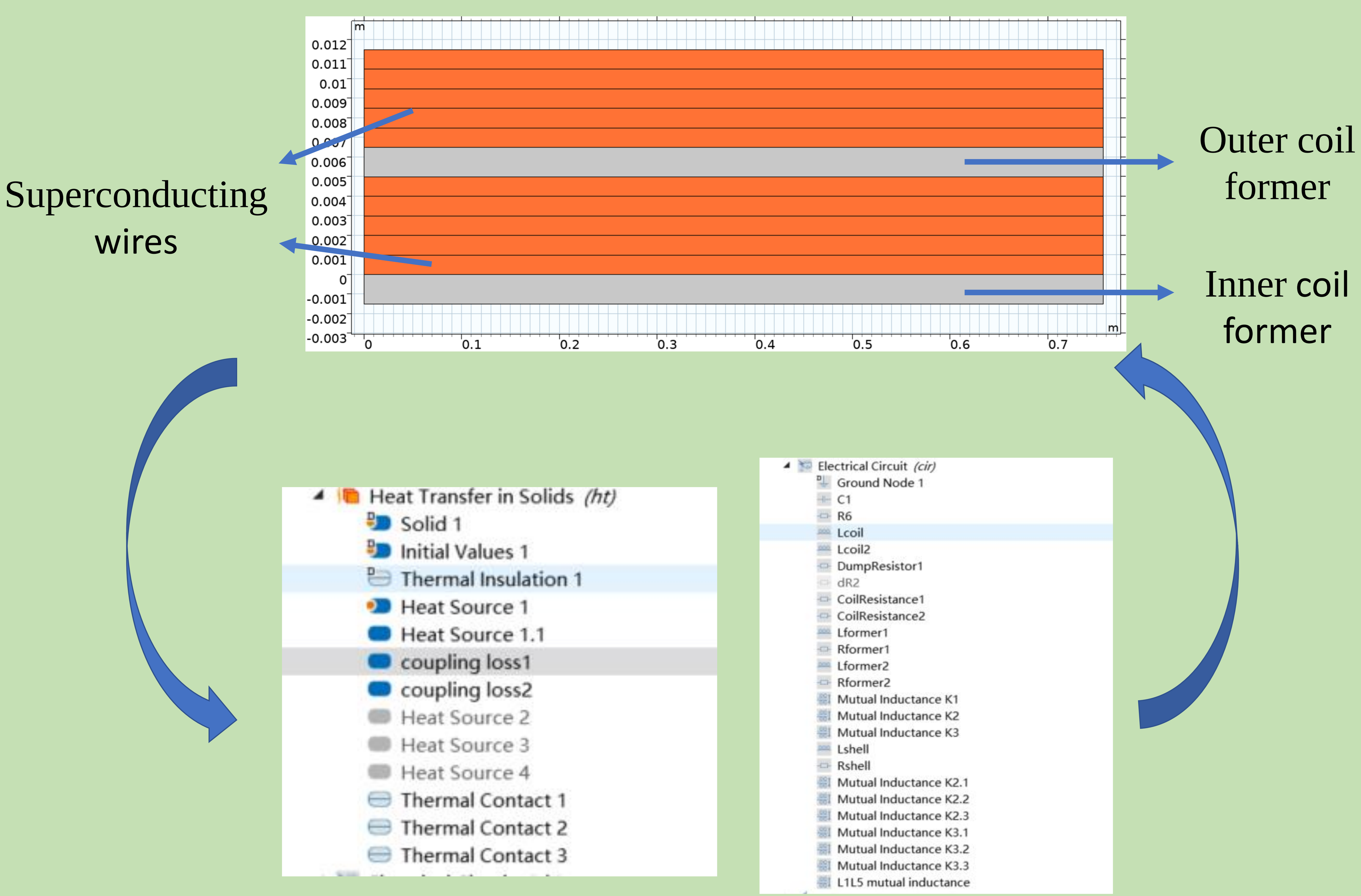
Inter-Filament Coupling Loss

$$fcliq = \frac{\mathrm{d}B_a}{\mathrm{d}t} \Big/ \frac{\mathrm{d}I_R}{\mathrm{d}t}$$

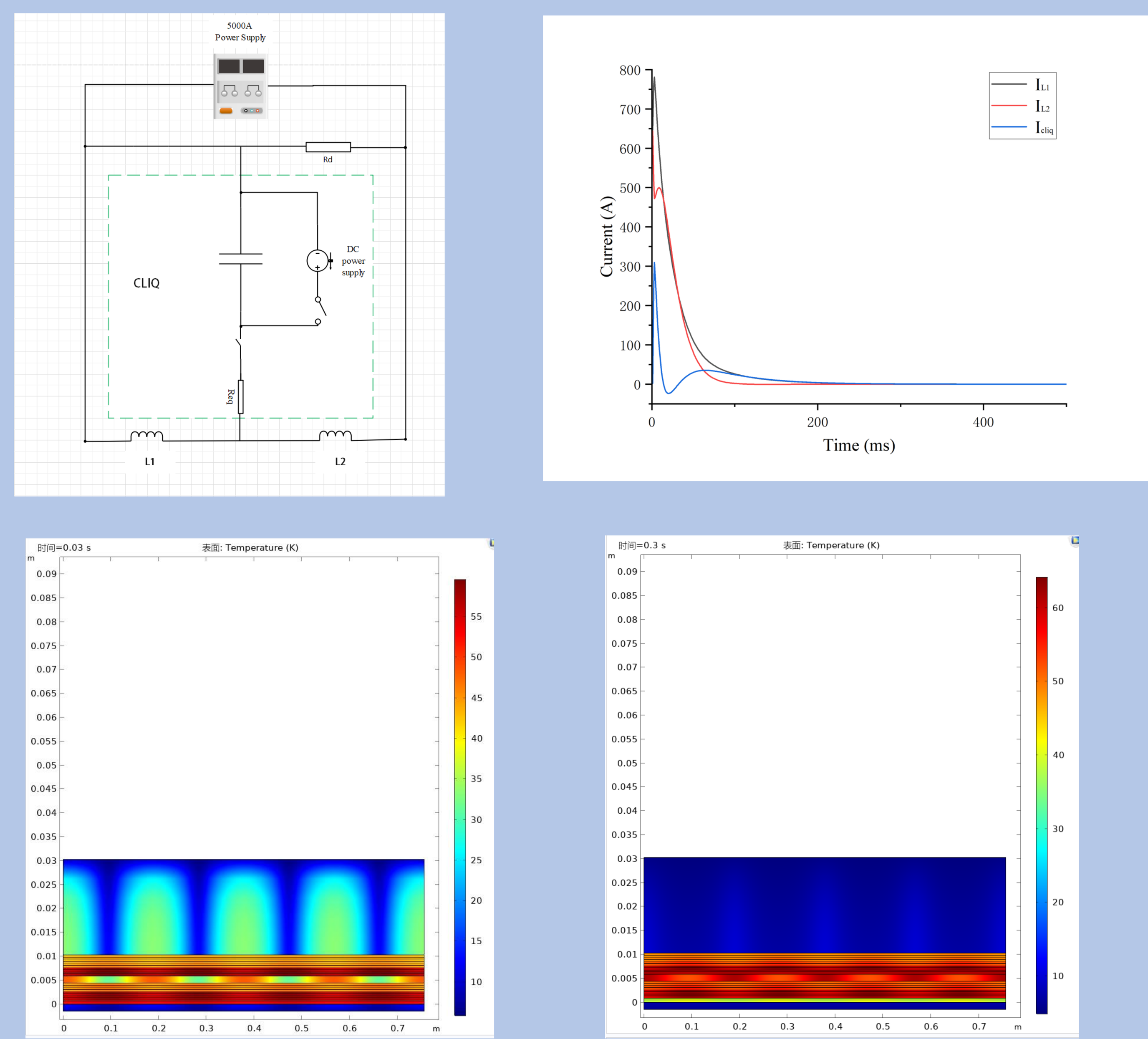
$$\frac{\mathrm{d}B_a}{\mathrm{d}t} = fcliq * CU_0 \frac{\omega^2 + \alpha^2}{w} \exp(-\partial t)[\omega\cos(wt) - \alpha\sin(wt)] \quad [\mathrm{T/s}]$$

$$P = \left(\frac{lf}{2\pi}\right)^2 \frac{1}{\rho_{eff}} \left(\frac{\mathrm{d}B_a}{\mathrm{d}t}\right)^2 \quad [\mathrm{Wm^{-3}}]$$

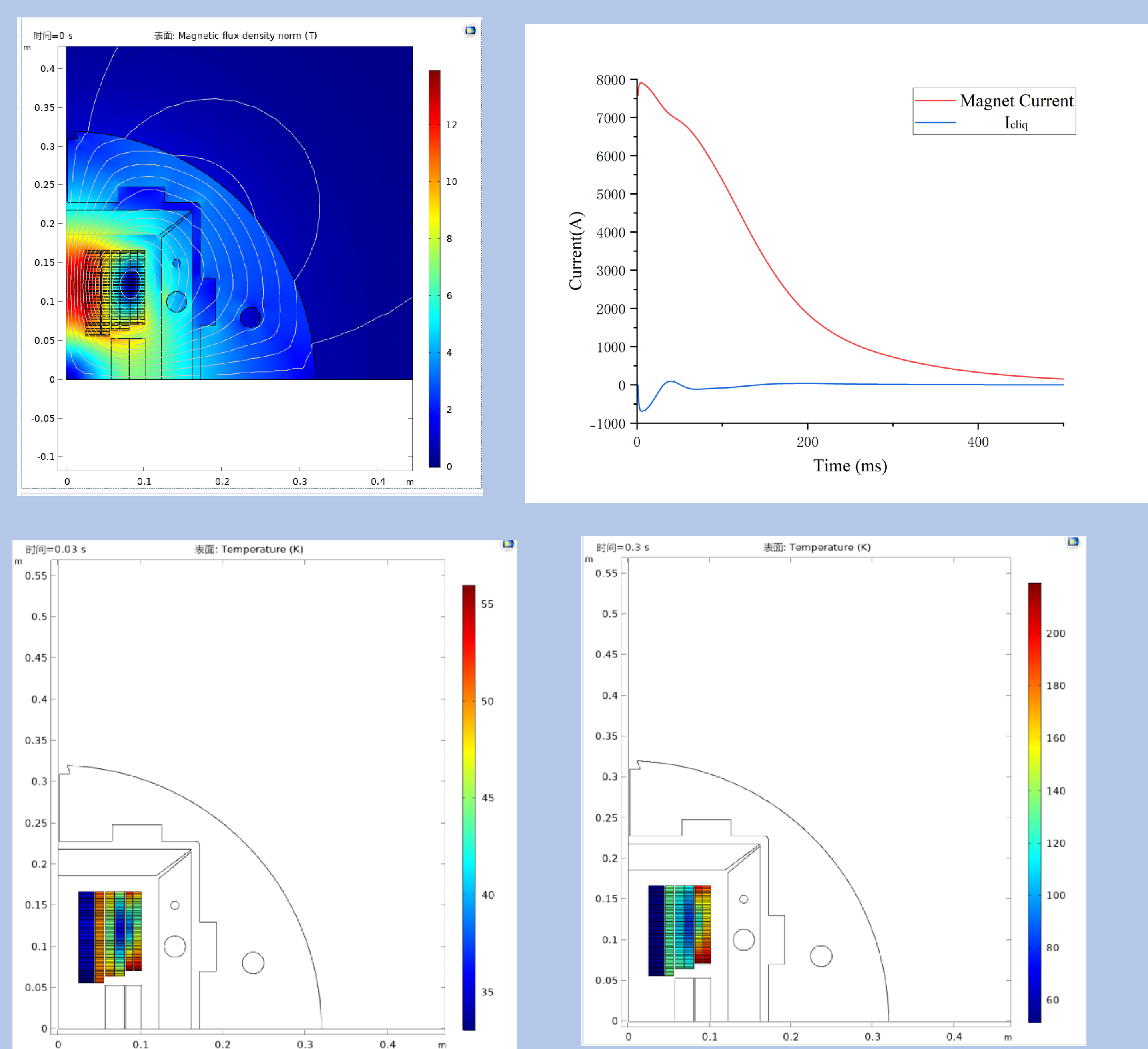
Numerical analyses



Simulation Results



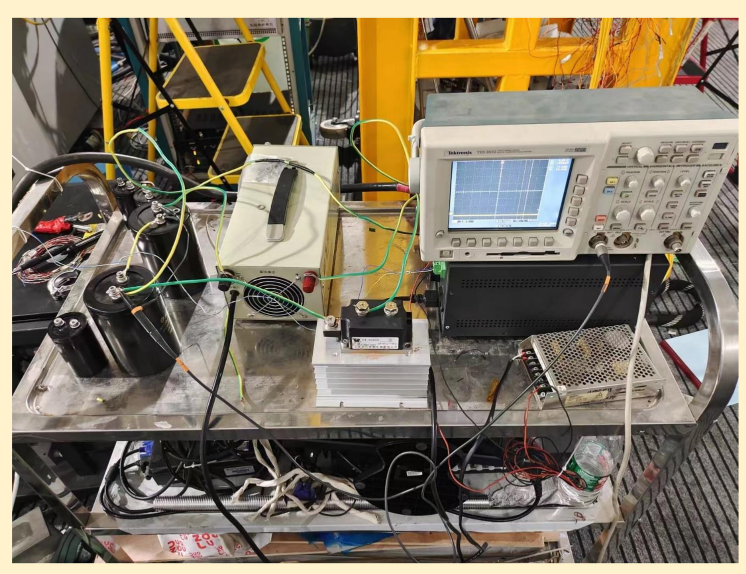
CLIQ performance on the SCQ-CCT magnet (250V 20mF)



CLIQ performance on the LPF3 magnet (500V 30mF)

Conclusion

With respect to the conventional method based on quench heaters, CLIQ system offers significant advantages in terms of electrical robustness and energy deposition velocity.
Simulation results convincingly show that the CLIQ system can work effectively that it allows a faster discharge of the magnet energy than the conventional energy-extraction resistance.



CLIQ units

[1] Rui Kang, Yingzhe Wang, Huan Yang, Jin Zhou, Xin Chen, Ao Feng, Wei Li, Rui Ma, Jinrui Shi, Menglin Wang, Zhilong Hou, Chengtao Wang, Chunyan Li, Juan Wang, Huanli Yao, ZhongXiu Liu, Ling Zhao, Qingjin Xu, A general model for simulating the quench behavior of canted-cosine-theta (CCT) quadrupole magnets, Cryogenics, Volume 128, 2022, 103574, ISSN 0011-2275, https://doi.org/10.1016/j.cryogenics.2022.103574.
[2] E. Ravaioli, "CLIQ," Ph.D. dissertation, University of Twente, Enschede, 2015. [Online]. Available: http://doc.utwente.nl/96069/