中国科学院高能物理研究所
Institute of High Energy Physics, CAS

中科院高能所超导磁体组
Superconducting Magnet Group, IHEP

The recent progress of LPF3 testing

Superconducting Magnet Group, Accelerator Division

Institute of High Energy Physics, Chinese Academy of Sciences (IHEP, CAS)

2023.12.14

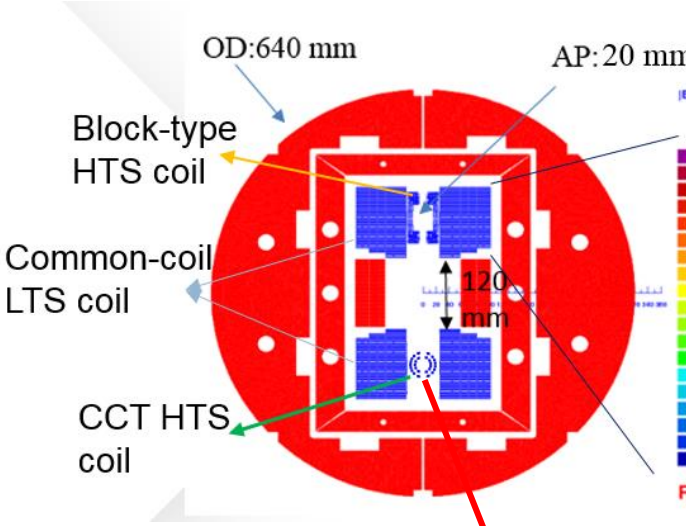
Outline

- A brief review of the design and fabrication of LPF3 magnet
- Recent test progress of LPF3 magnet
- Summary

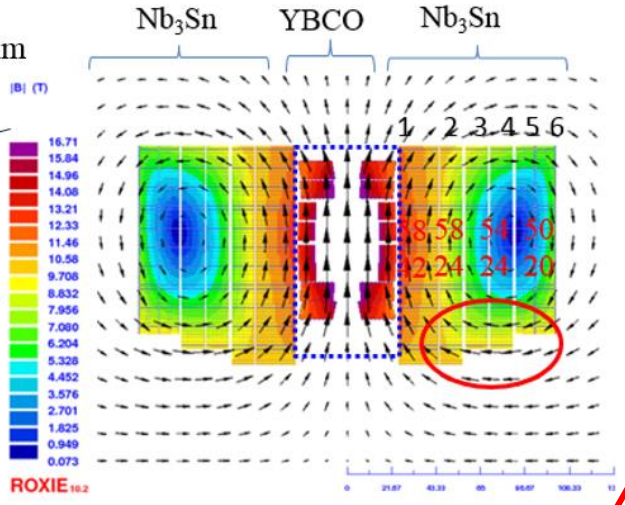
Development of LPF3- electromagnetic design

- Aiming at 16 T： 13 T (LTS) + 3 T (HTS)

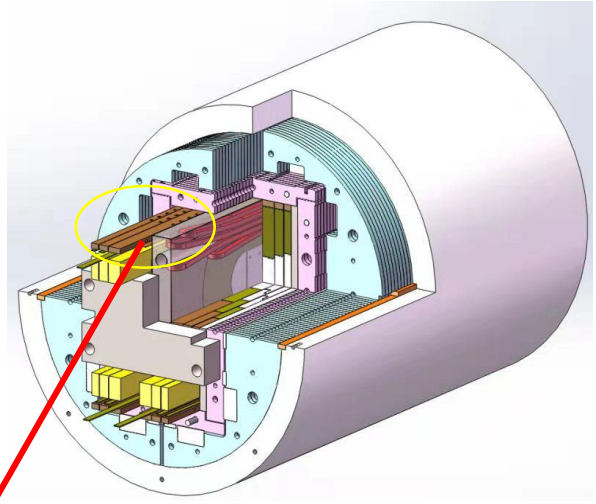
To be 16 T



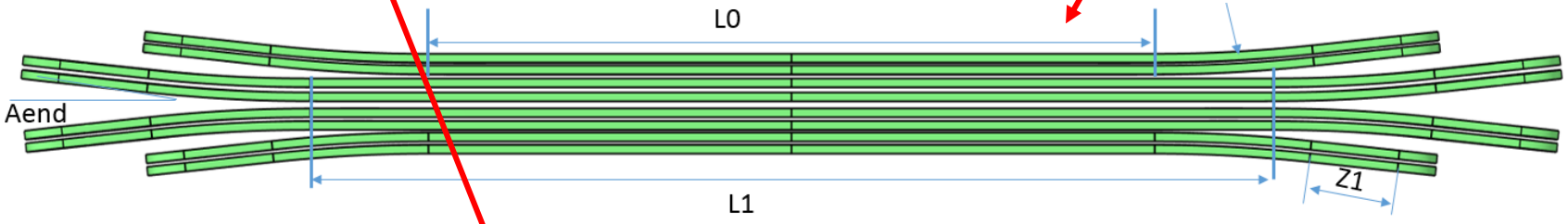
Cross-section of LPF3



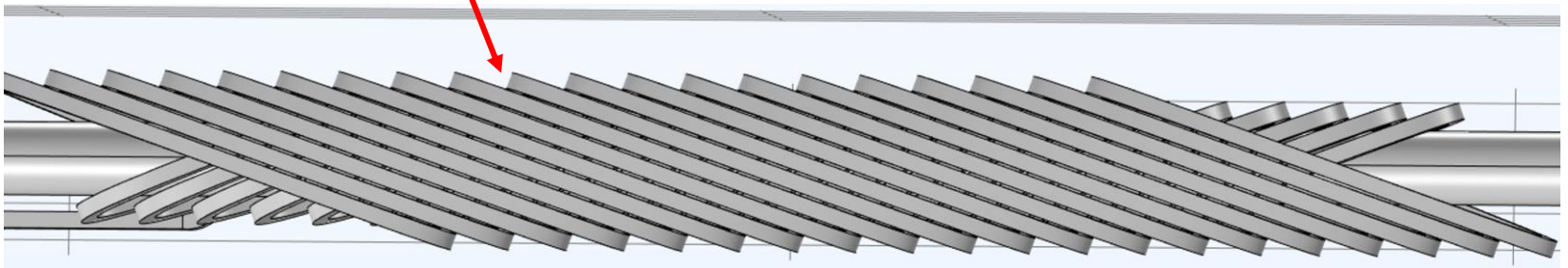
Field and flux distribution (1st and 2nd quadrant)



Schematic of LPF3

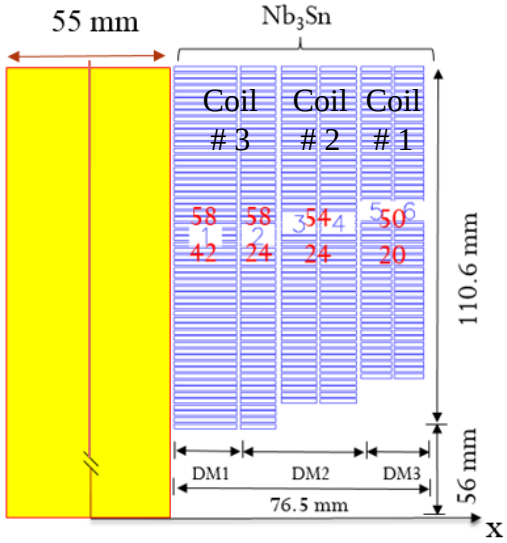


ReBCO Block-type insert coil

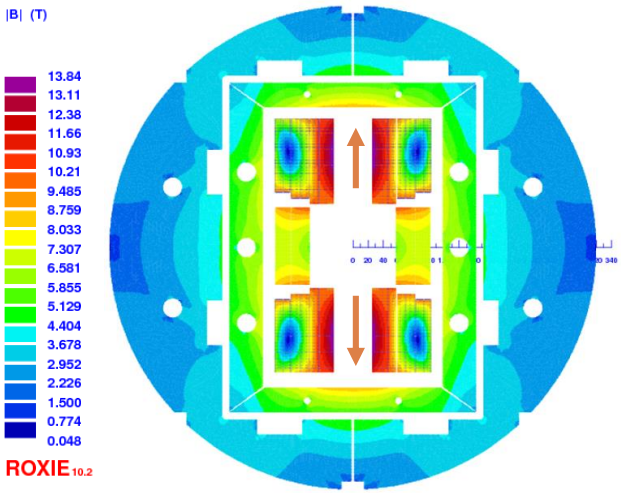


ReBCO CCT insert coil

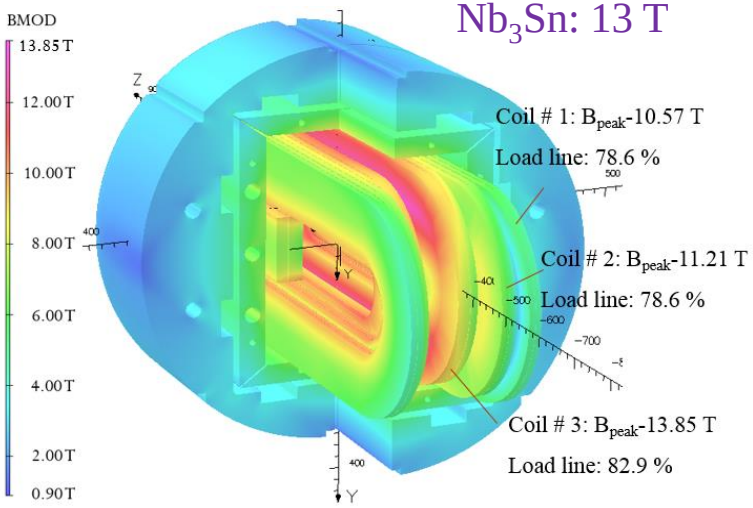
Electromagnetic design of LPF3-LTS



First quadrant coil layout



Field distribution in the cross-section (2D)



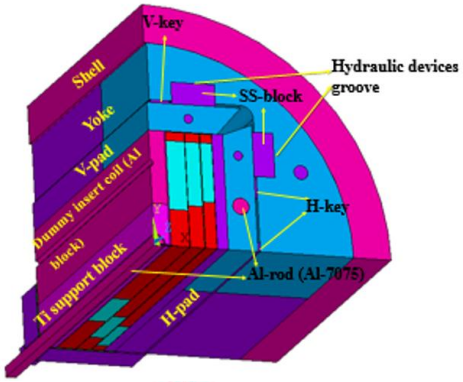
Field distribution in the magnet (3D)

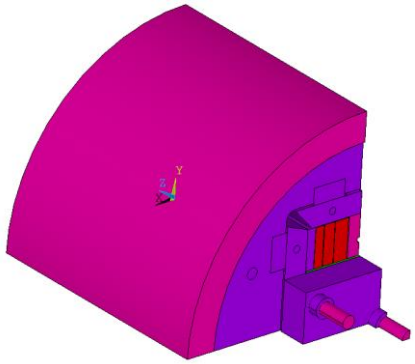
Main parameters of the magnet LPF3-LTS

Current	7580 A		Blocks	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Main field	13.02 T		Peak field (T)	13.85	11.13	10.95	11.21	10.57	10.47
			LL ratio (%)	82.91	78.16	77.18	78.6	78.63	78.09
Integral harmonics (-150-150mm); R-10	b3: 102.76		b5: -0.08	b7: -0.01	b9: 0	a2: -48.11	a4: -0.14	a6:-0.02	a8: 0
Integral harmonics (-150-150mm); R-15	b3: 231.17		b5: -0.42	b7: -0.06	b9:0.01	a2: -72.09	a4: -0.46	a6:-0.14	a8: 0.01

Parameters	Aperture Ns	Aperture diameter	Peak field	Temperature	Load line ratio	Energy	Induct-ance	LSS (coil #1,2,3)	LSS (coil #1,2,3)	Cable Ns (DM1,2,3)
Unit	-	mm	T	k	-	MJ	mH	mm	mm	-
Value	2	55	13.85	4.2	82.9	2.155	13.01	400,550,620	400,550,620	42,24,20

Mechanical analysis of LPF3-LTS

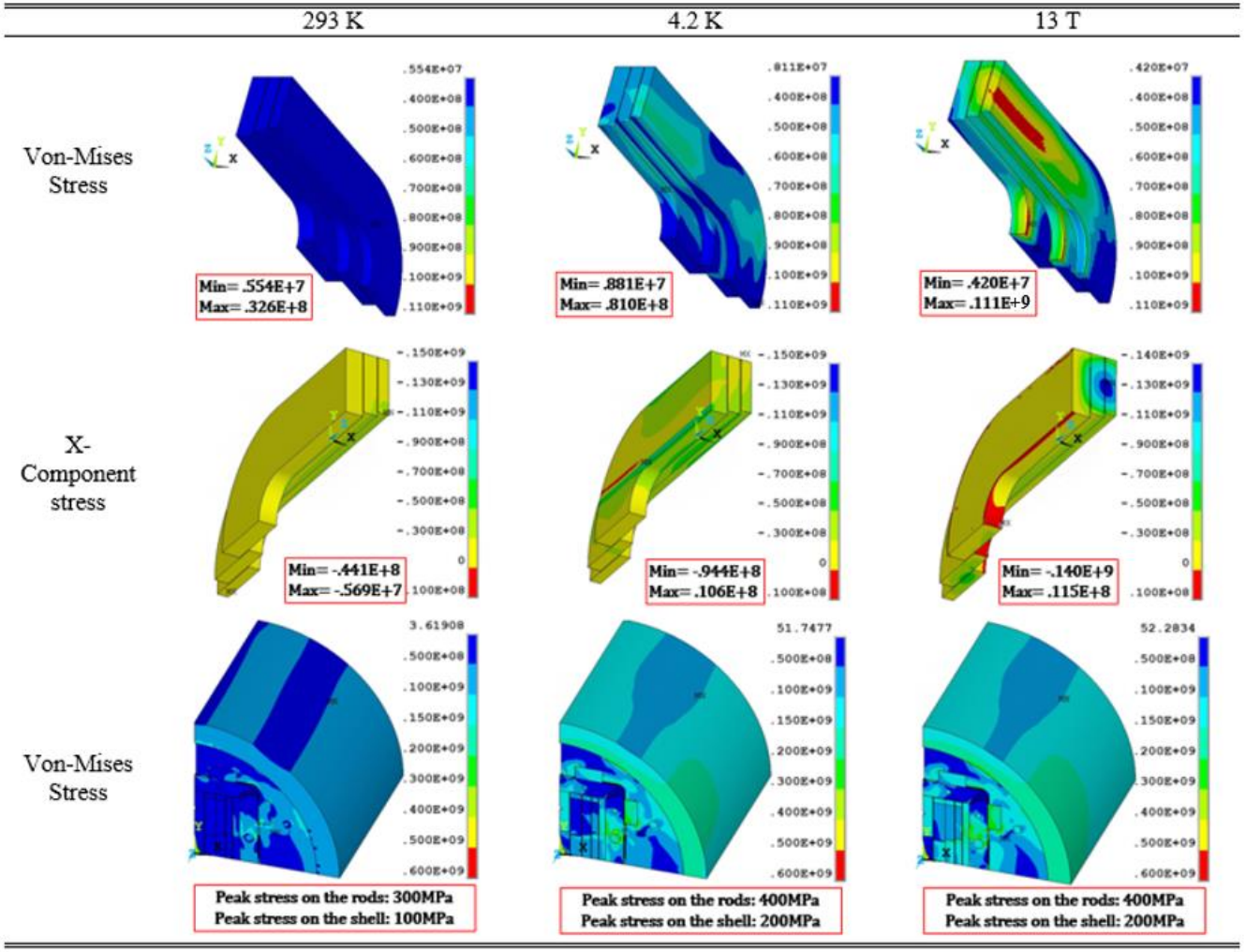




Superconducting coils
Stainless steel
Aluminum bronze
Iron
Aluminum
Titanium

1/8 mechanical FEA model

f=0.2; interference=-0.8 mm

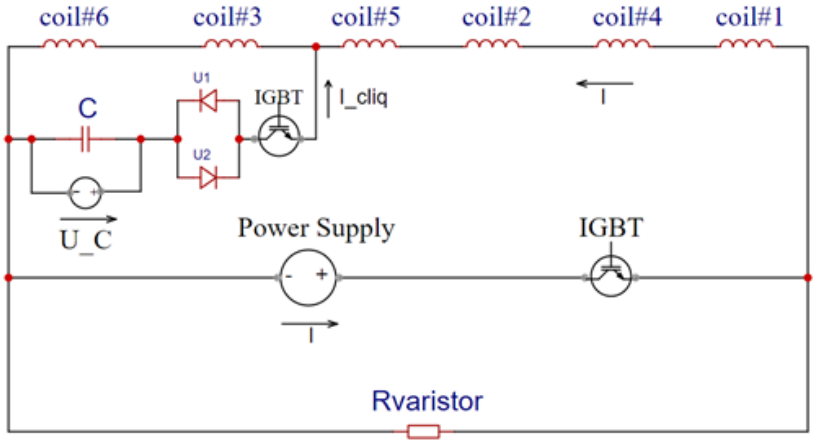


Stress variation during the three loading steps

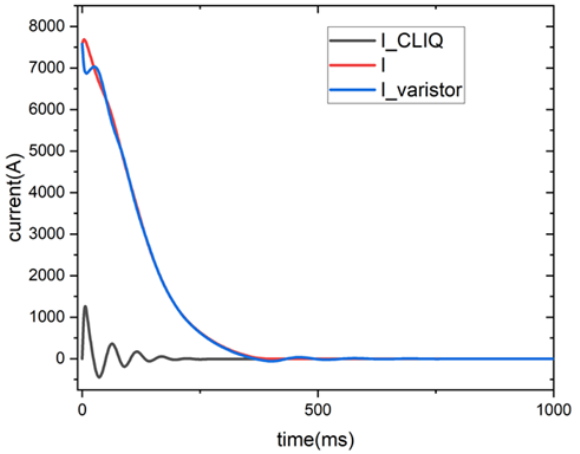
Required maximum pre-stress for bladders: 80 Mpa. Peak stress in coils during the three loading steps: 140 Mpa.

Quench protection analysis of LPF3-LTS

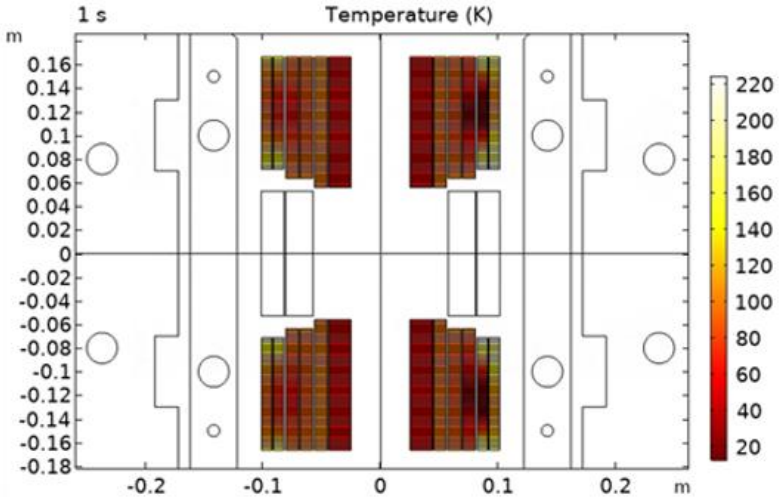
CLIQ + Varistor



The design circuit of quench protection

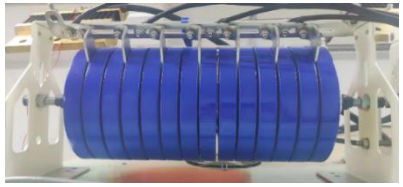


The current in the CLIQ circuit and current decay



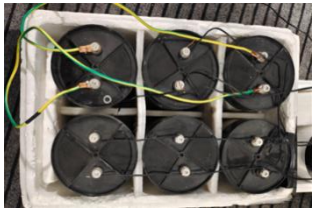
The temperature distribution of the magnet

Power supply in the CLIQ system



The varistor

The IGBT in the CLIQ system

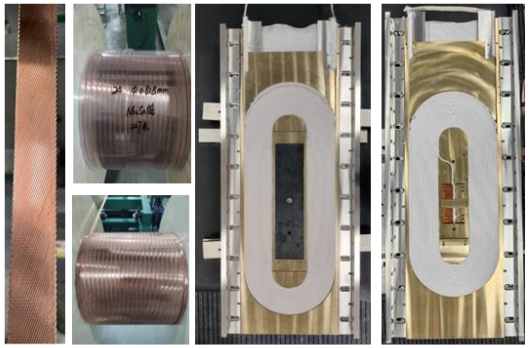
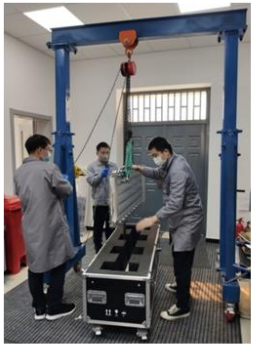


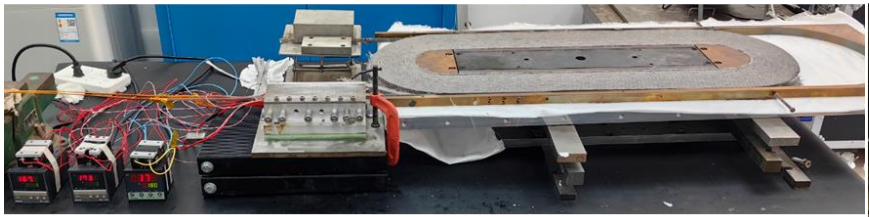
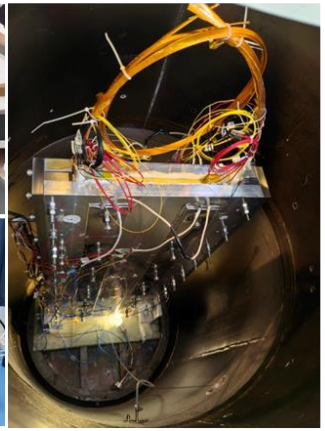
The capacitance

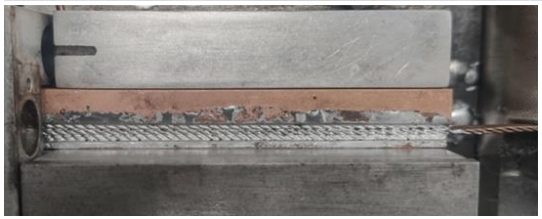
- CLIQ + varistor is adopted to accelerate the propagation of quench in the magnet.
- The capacitance: 30 mF; the charging voltage: 500 V; the hotspot temperature is about 224 K at 7850 A.

Fabrication of LPF3

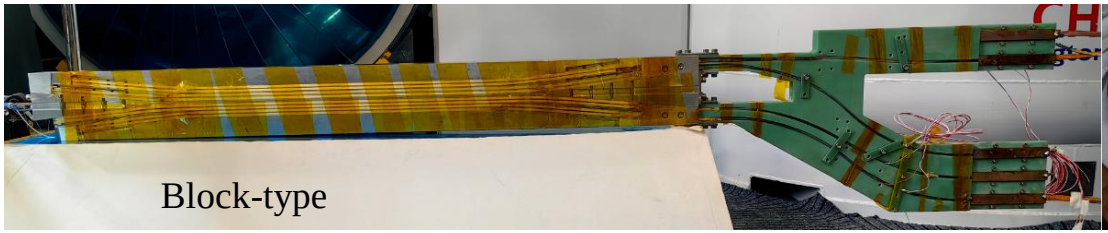
The Nb_3Sn coils for LPF3

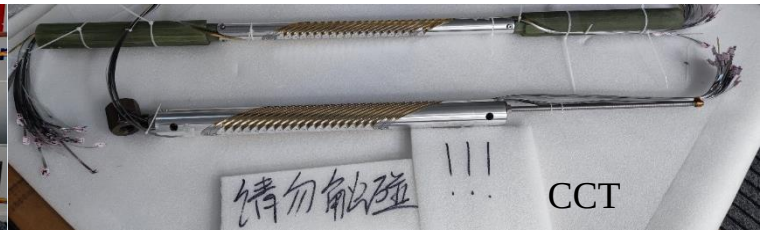






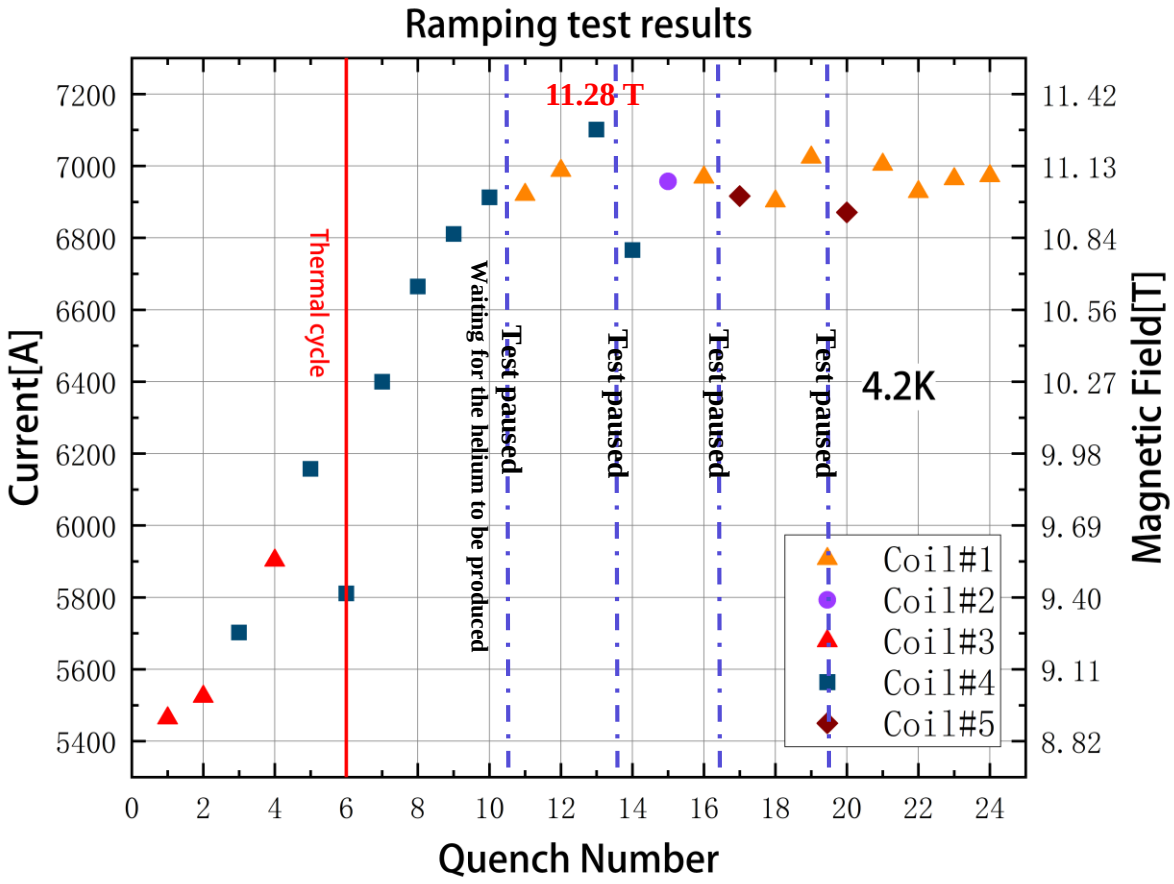

The HTS insert coils for LPF3


Block-type


CCT

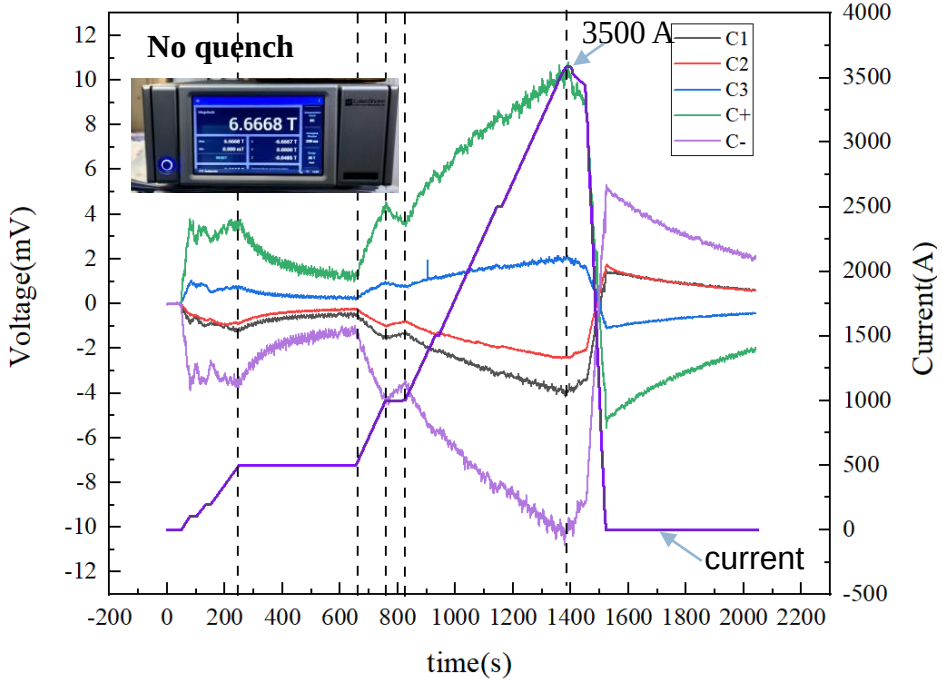
Recent test results of LPF3-LTS

- The 1st preliminary test carried out in the week Sep 3-8 2003. The six Nb_3Sn coils were firstly ramped
- 5 quenches occurred from 9 to 10 T, mainly caused by flux jump, but with an encouraging upward trend
- The performance test of LPF3 was continued in the last three weeks after the thermal cycle. A maximum field of 11.28 T has been reached within two apertures. More testing is ongoing.

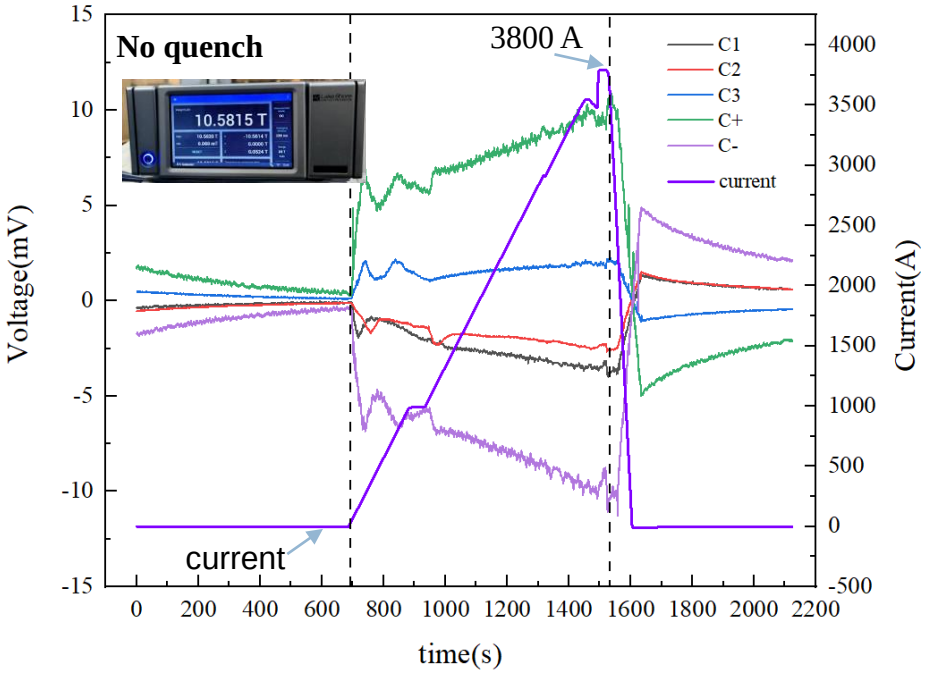


Recent test results of LPF3-HTS

- **The preliminary test of Block-type insert coil was carried out under self-field, 5 T and 9 T. The coil has been subjected to a maximum current of over 3790 A (the designed current), with no quenches observed.**
- **As commonly observed in NI coils, a charging delay between the power supply current and generated magnetic field has also been found in this insert coil.**
- **Due to the significant heat generated by the current leads, the test had to be stopped as soon as the current reached ~3800 A. The field provided by the HTS insert coil is 1.91 T @ self-field, 1.67 T @ 5 T and 1.58 T @ 9 T, respectively.**



Test result of Block-type insert coil under 5 T



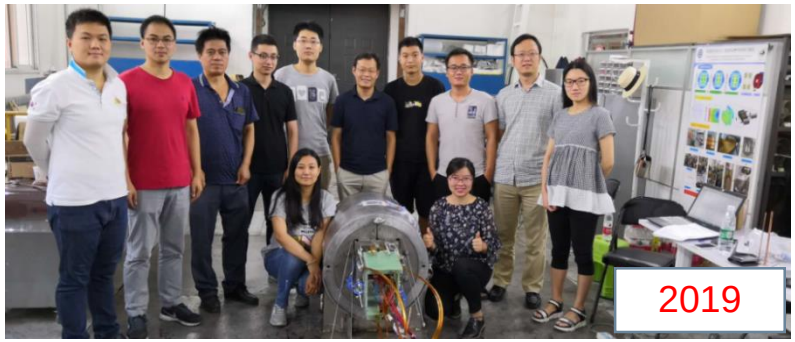
Test result of Block-type insert coil under 9 T

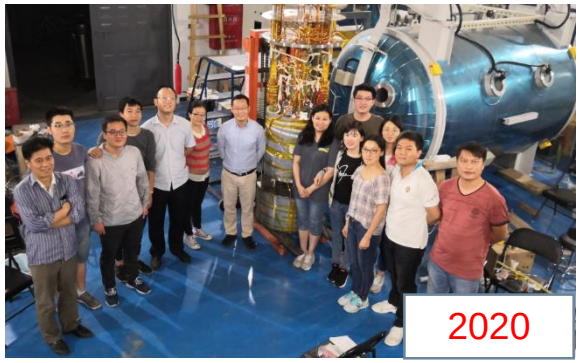
Summary

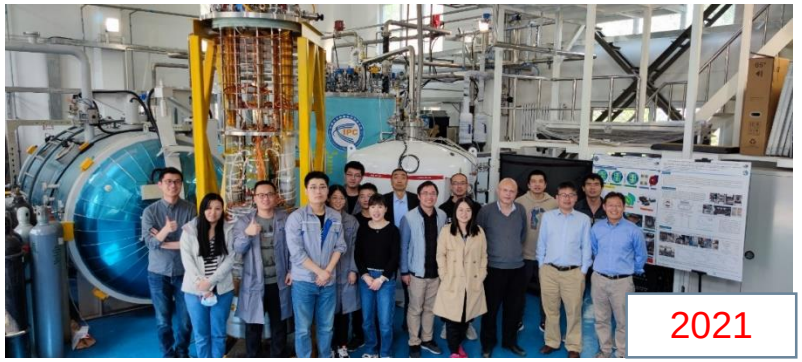
1. Based on the experiences mastered in the LPF1 series magnets, a 16-T high field dipole magnet named LPF3 has been designed, fabricated and is in the performance test process.

2. The preliminary test of Nb_3Sn coils showed promising results, with a maximum field of 11.28 T @ 7101 A & 4.2 K reached within two apertures. Futher training tests will be carried out soon.

3. The preliminary test of Block-type insert coil was carried out under self-field, 5 T and 9 T, respectively. The coil has been subjected to a maximum current of 3800 A, with no quenches observed. A charging delay between the power supply current and generated magnetic field was found during the ramping test. More tests would also be performed to investigate the electrical-magnetic behavior of this coil soon.







10.23 T	→	10.71 T	→	12.47 T	→	To be beyond 16 T
Year:2018		2019		2020-2021		2022-2023

Welcome to visit Qingjin's lab!

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Thanks !