T-A formulation

$$\nabla^2 \mathbf{A} = -\mu \mathbf{J}, \quad \text{(mf)}$$

$$\nabla \times \rho \nabla \times \mathbf{T} = -\frac{\partial \mathbf{B}}{\partial t}, \qquad \text{(PDE)}$$

The necessary boundary conditions at the edges of the 1D superconducting layer for **T** can be obtained by integrating the current density **J** over the cross-section of the layer which is equal to the transport current in the tape, as follows,

$$I = \iint_c \mathbf{J} dS = \iint_S \nabla \times \mathbf{T} dS = \oint_{\partial S} \mathbf{T} dr,$$

$$I = (T_1 - T_2)\delta,$$

The current density is multiplied by d, to obtain a surface current density $K = J_z \cdot d$. The surface current density K is impressed into the A formulation as an external surface current density by means of a boundary condition of the form

$$\boldsymbol{n} \times (\mathbf{H}_1 - \mathbf{H}_2) = \mathbf{K},$$

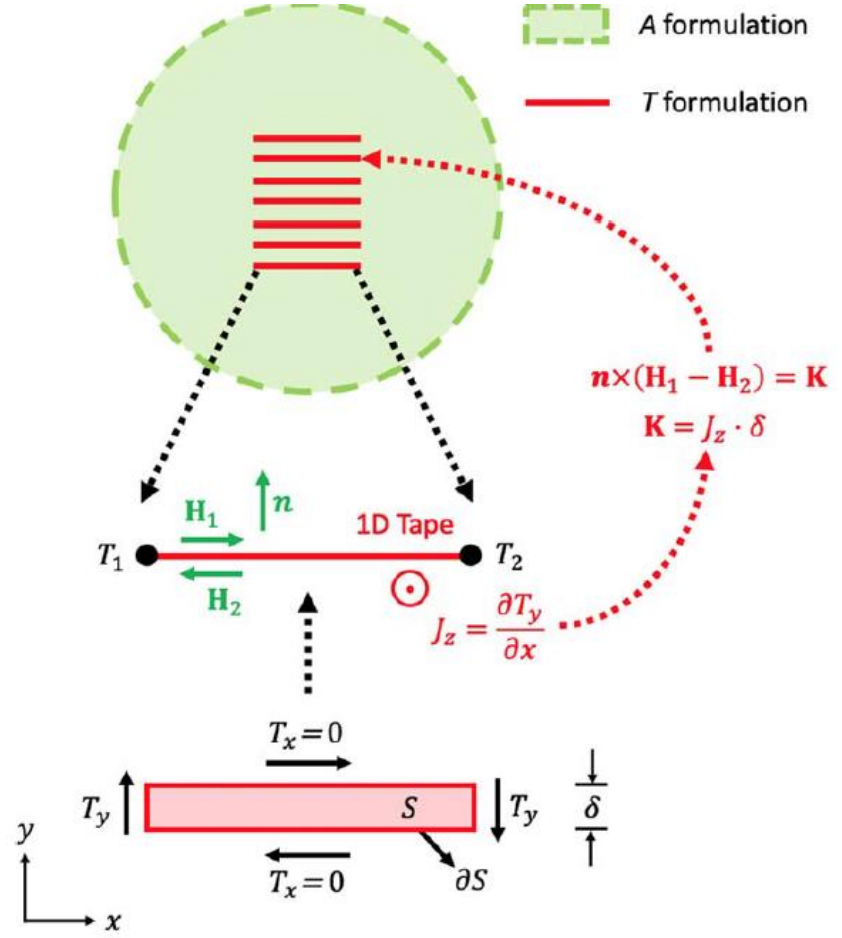
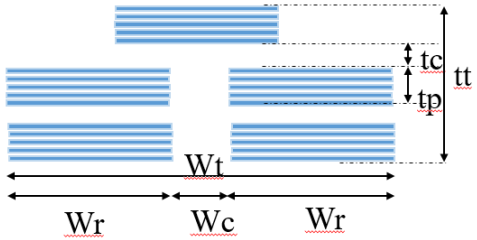
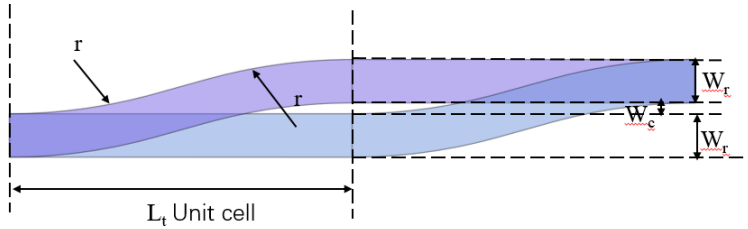
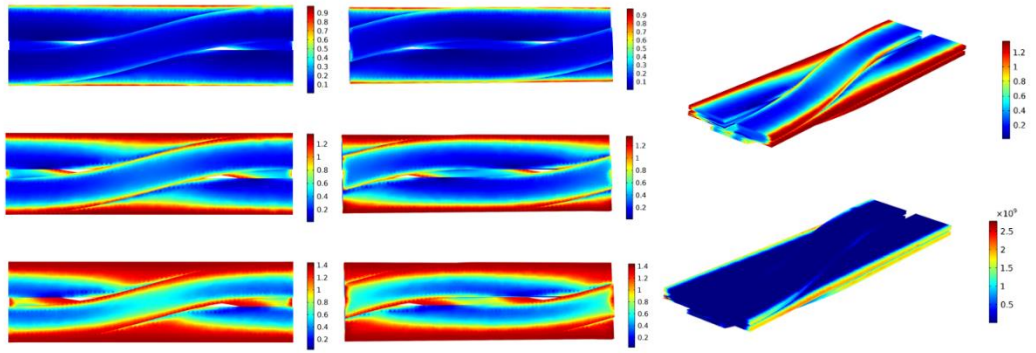


Figure 1. Bounded universe with superconductive layers and surrounding medium. The current vector potential **T** is computed over the HTS layers and the magnetic vector potential **A** is computed over the entire bounded universe. The surface current **K** is impressed in by means of a boundary condition. The rectangle of surface S is used in this figure to show how the boundary conditions are deduced.

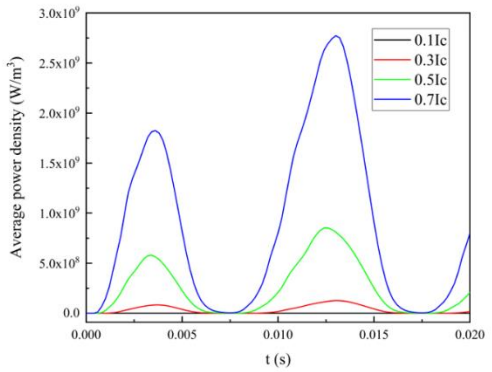
25 strands X-cables

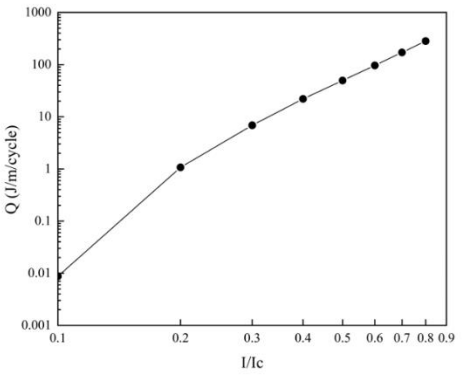






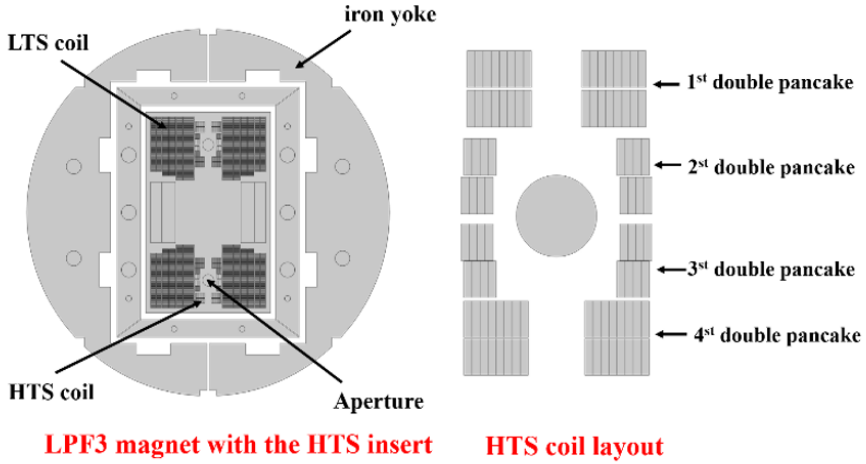
Symbol	Unit	Xcable	Description
Ns	n.a.	25	Number of tapes
ds	μm	80	Tape thickness
di	mm	0.1	Insulation thickness
Wr	mm	4	Strand width
Wc	mm	1	Channel width
Wt	mm	9	Cable width
Lt	mm		Transposition pitch
r	mm	50	radius





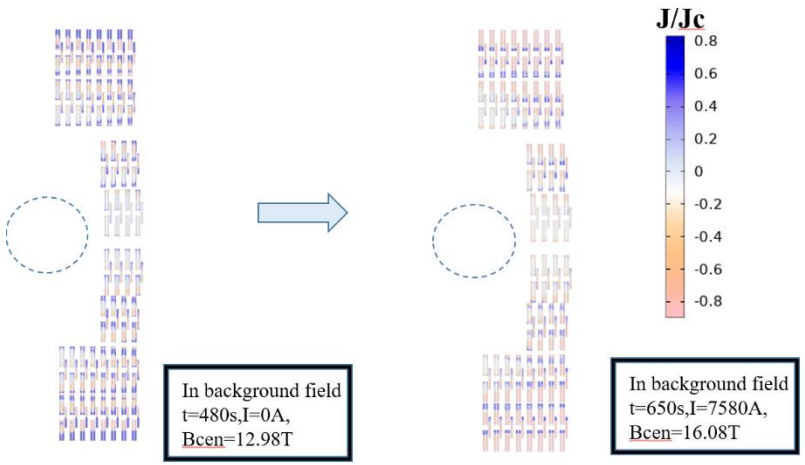
1. The X-cable was selected as a baseline for the LPF3 magnets, The X-cable is fully transposed (all tapes/strands take all positions in the cable along its length), has a high filling factor and can accommodate the tight soft-way bending radius, which is needed for making ends inside the LPF3 aperture.
2. The X-cable gives the benefits of a conductor with high current capacity and the ac loss is reduced in comparison with a wide single tape of similar capacity.

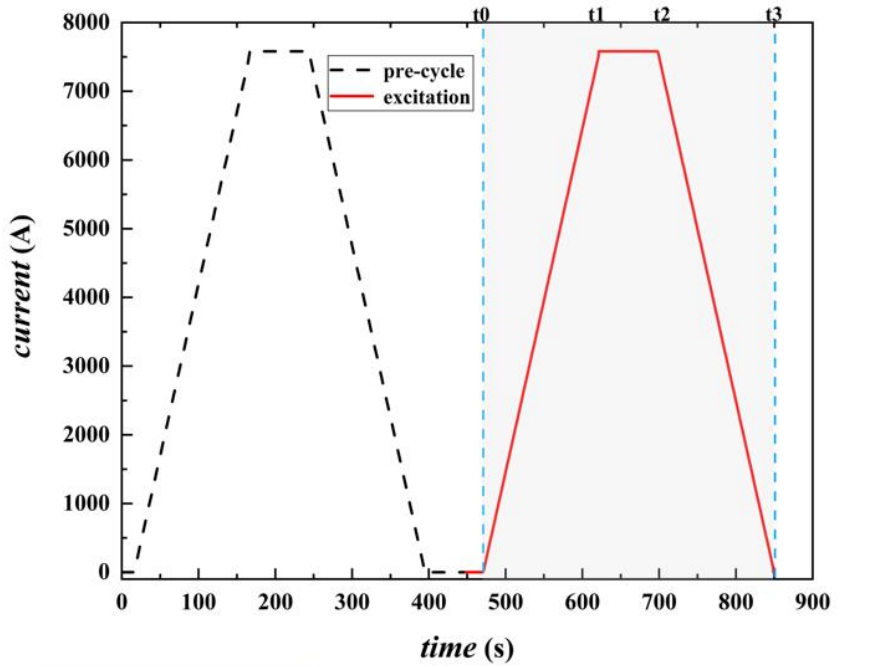
25 strands X-cables

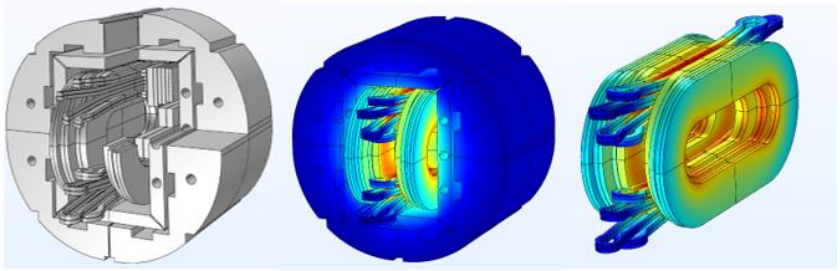


LPF3 magnet with the HTS insert

HTS coil layout

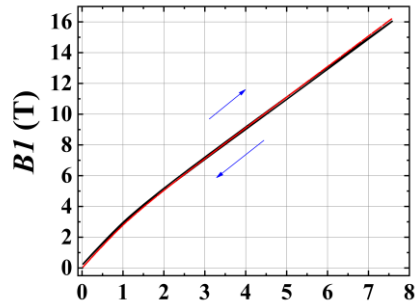
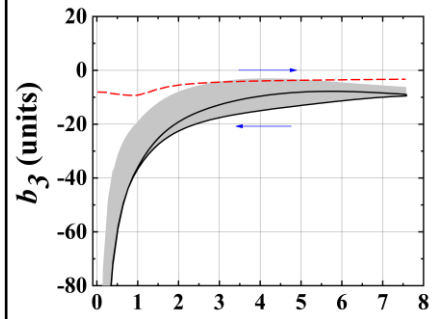
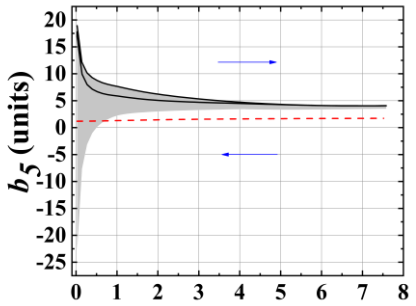
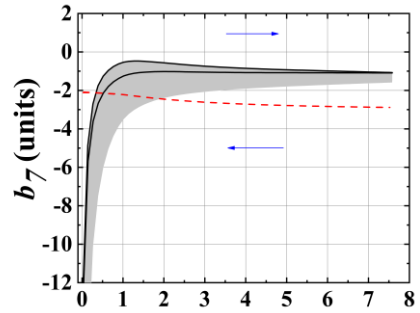
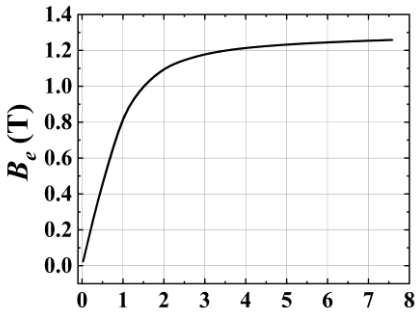
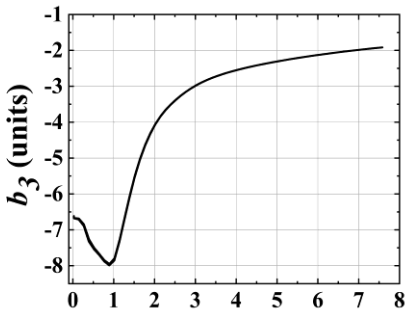
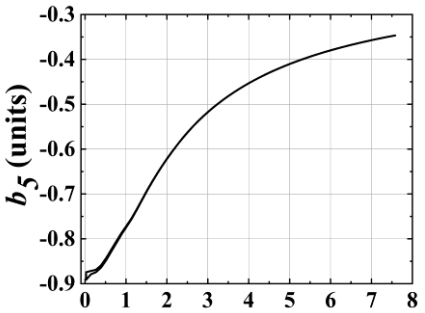
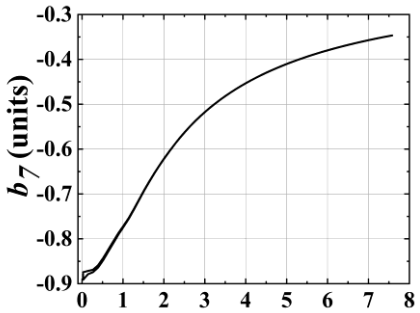
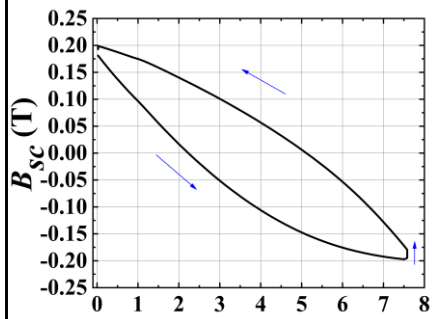
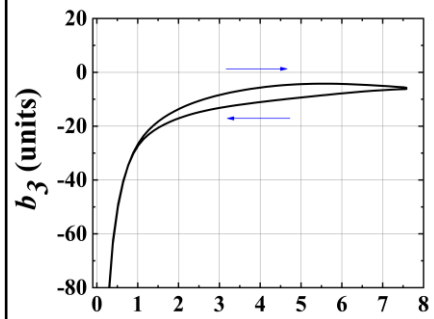
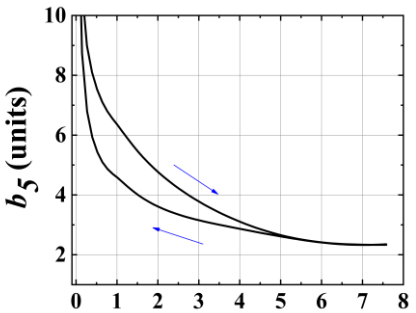
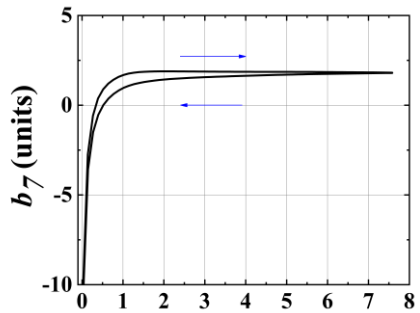






1.The iron yoke is saturated in the 13T external magnetic field, so it does not have a dynamic effect on the field quality of the LPF3 magnet.
2.The hysteresis effect of the external low temperature magnet is ignored and its current is uniform .
3.The influence of parallel field on the critical current of ReBCO is ignored.

LPF3 magnet field quality

	B1	b_3	b_5	b_7
Magnetic field				
yoke				
SCIF				
	current（kA）	current（kA）	current（kA）	current（kA）