HITRI plus
Heavy Ion Therapy Research Integration

www.hitriplus.eu

MAGNET SYSTEM DESIGN

FOR THE NEXT-GEN CARBON-ION THERAPY FACILITIES

DECADES OF EXPERIENCE IN ACCELERATOR DESIGN, CONSTRUCTION AND OPERATION. EXPERTISE AND KNOW-HOW OF MAGNET SYSTEM DESIGN

DESCRIPTION

Various magnet design options were evaluated for the demonstration, with the CCT magnet based on Nb-Ti emerging as the most promising choice for the synchrotron and gantry. This selection, optimized for both applications, outperformed the Cos-Theta alternative.

Additionally, advancements in septum magnet concepts and wax impregnation techniques, influenced by research on the Future Circular Collider (FCC), have impacted HITRI*plus* activities.

Collaborating with the I.FAST and TERA-NIMMS-SIGRUM projects, key parameters are finalized for the demonstrator, focusing on a curved CCT design with specific magnetic rigidity, bending radius, and magnetic field strength.

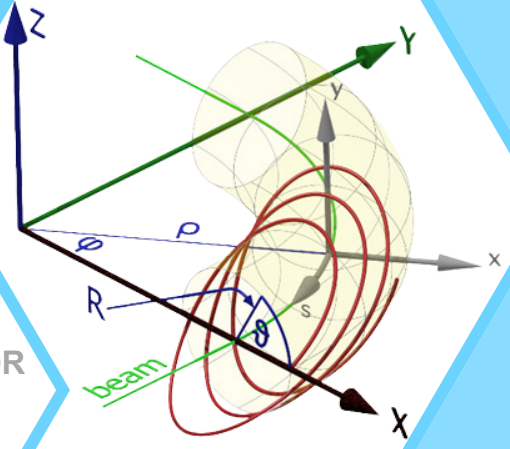
Financially, the conductor cost is significantly lower than Rutherford cabling, with expectations of cost-effective mechanics. Operating at a cryocooler temperature of 4.7 K to 5 K, power supply requirements are manageable, supporting maximum current and ramp rates.

CHALLENGE

CCT magnets integrate magnetic fields from interleaved and tilted solenoids, ensuring structural integrity by intercepting Lorentz forces. While established in straight designs, curved CCT magnets present a challenge.
They provide a cost-effective alternative to Cos-Theta magnets, reducing construction costs with fewer components.
Their flexibility enables compact, energy-efficient accelerators. Currently, successful curved prototypes are yet to be achieved.

SOLUTION

HITRI*plus* plans to construct and test an innovative curved CCT demonstrator magnet. The superconducting Nb-Ti winding, twisted in six strands around copper, will be encased in an iron yoke with braided polyester insulation. The support structure, a hollow curved tube, will be made from pre-prep material.
The curved mandrel and windings are likely to be of Aluminium - Bronze. This pioneering magnet aims to demonstrate the feasibility of a curved CCT design with a central field of 4 T, a ramp rate of 0.4 T/s, and a compact bore diameter of 80 mm.



GEOMETRY FOR CURVED CCT MAGNET

VALUE

The demonstrator will confirm the feasibility of constructing a curved CCT applicable in both an accelerator ring and a gantry.
CCT magnets show promise for bending and focusing particle beams, reducing facility size and treatment costs.Unlike Cos-Theta, CCT coils are robust and easily configured.
Cryo-cooled gantry magnets simplify installation and daily operation, tested initially in a cryostat bath.
Curved CCT magnets offer opportunities for more compact machinery in industrial applications.

WAX IMPREGNATION METHOD FOR CCT MAGNETS

Impregnating CCT magnets with epoxy or wax boosts their performance and durability.
The wax-impregnated CCT magnets offer superior performance compared to epoxy-coated ones, showing solid consistency even under stress.
Tests conducted by the Paul Scherrer Institute confirm that wax-impregnated Nb_3Sn cables can reach their short-sample limit without experiencing any quench.
Similarly, in the SuShi septum project for the Future Circular Collider, a wax-impregnated CCT magnet reached nominal current without any quench.
This technique effectively manages wax contraction and void formation, ensuring consistent performance.
The HITRI*plus* magnet's test coil, utilizing this method, showcased remarkable consistency without the need for overpressure.
Furthermore, the polyester braid serves as a crucial component, preventing large voids in case of refill failure during freeze-out.

CHALLENGE

CCT magnets typically require impregnation with wax or epoxy resin for insulation and mechanical support. Superconducting coils impregnated with epoxy resins need multiple quenches to reach full capacity.
The intricate geometry of CCT magnets poses impregnation challenges. Circular grooves can trap liquid wax, leading to voids.
Careful temperature control is necessary during wax impregnation to maintain an open refilling channel and prevent blockages.

SOLUTION

By employing wax impregnation, void formation during freeze-out was successfully prevented, with zero quenches observed during testing.
This method allows coils to reach desired limits without quenching, providing superior mechanical support compared to epoxies in stress-managed coils.

VALUE

Wax emerges as a superior alternative to epoxy for impregnating CCTs, particularly in stress-managed coils such as those in the HITRI*plus* CCT demonstrator.
Cost-effective at 50 CHF for 10 kg, wax outperforms epoxy, priced at 2300 CHF for a 5-gallon kit.
Reversible wax mitigates risks, allowing coil rewinding without mandrel damage. Impregnation takes 4-5 hours, posing fewer health risks and ensuring immediate magnet operation.