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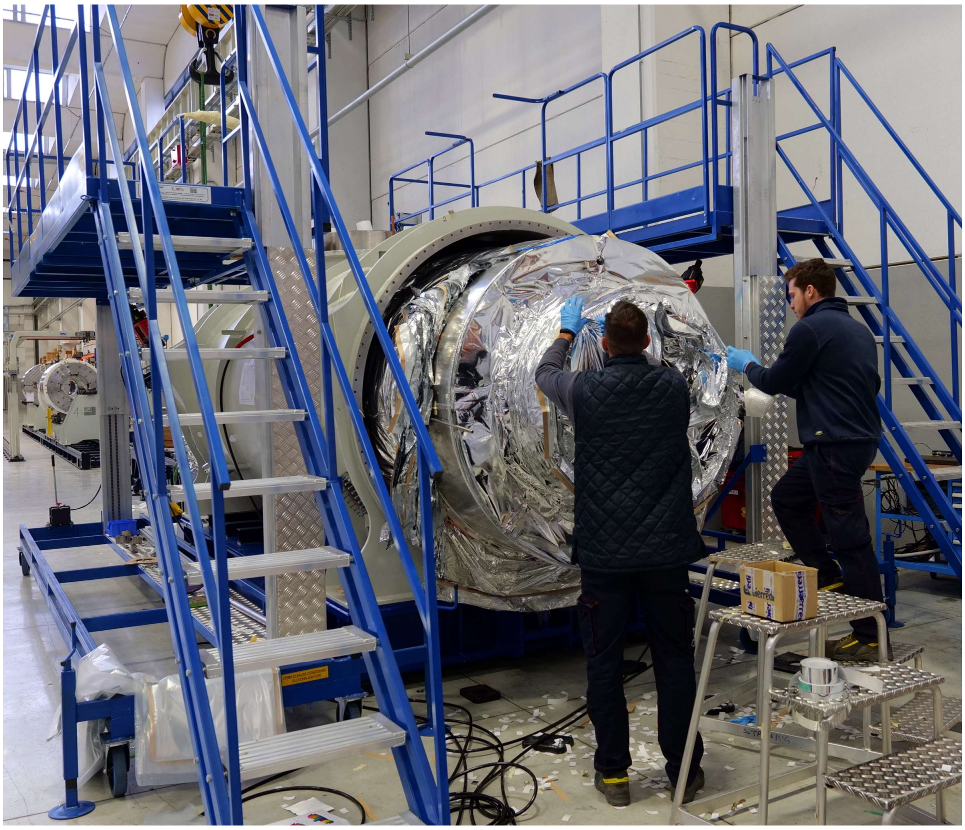
TECHNICAL ARTICLE



Super-FRS (Superconducting FRagment Separator) at GSI/FAIR in Darmstadt will be the most powerful in-flight separator for exotic nuclei up to relativistic energies

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GSI SUPER-FRS MULTIPLETS

The next future of particles separator

Roberto Repetto, Giovanni Valesi, Alice Borceto, Giovanni Drago

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Super-FRS (Superconducting FRagment Separator) at GSI/FAIR in Darmstadt will be the most powerful in-flight separator for exotic nuclei up to relativistic energies. It is composed, among other components, by multipole superconducting magnets with very large acceptance aperture combined in different Multiplets.
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Figure 1: Fist of Series Short Multiplet under test at CERN

First of series Short Multiplet has been delivered in February 2019 and the completion of its Site Acceptance Test at CERN is scheduled for March 2020 (Figure 1).

Each Multiplet houses different super-ferric magnets made by iron yoke and NbTi superconducting coils in common cryostat, filled with Liquid Helium.

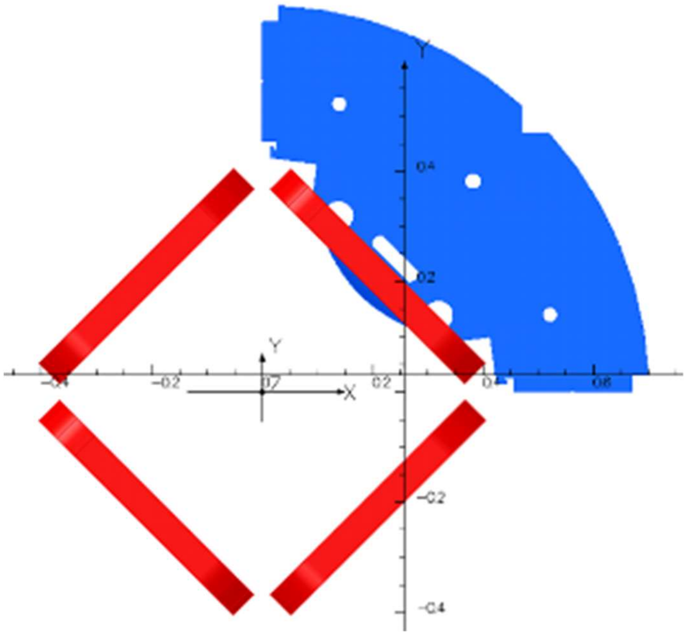

Figure 2: *Magnetic model of super-ferric quadrupole magnet*

Key design challenges are the very high field quality requirements, protection against quench, high design pressure and tight mechanical tolerances.

One of the most challenging issues was to fulfill the field quality requirement for the quadrupole magnets. The field quality requirement is rather tight while the good field region radius, wherein the magnetic field performance has to be respected, is as large as 190 mm.
Furthermore, the magnetic field shows a non-linear behavior due to the highly saturated iron yoke. Dedicated de-saturating holes were placed in the yoke cross-section to control the iron saturation and therefore meet the required field homogeneity as depicted in Figure 2.

The second challenge was to constrain the movement of the quadrupole coils as much as possible during the excitation in order to prevent recurring quenches. It was concerned that the quadrupole coils could move due to the large electromagnetic force during the excitation up to the maximum current level of 330 A, therefore a quench could be triggered when all the work against the electromagnetic force dissipates in thermal energy.
To avoid recurring quenches special stainless-steel coil retainers have been designed by ASG. Those design solutions were confirmed during first of series Short Multiplet Site Acceptance Test at CERN, where a first quadrupole was successfully tested with satisfactory magnetic field quality and no quench.

Another innovating solution is applied during coil winding and impregnation manufacturing phases. Standard practice is epoxy Vacuum Pressure Impregnation in common tank. GSI Super-FRS coils are wound and impregnated in the same mold in order to reach required demanding geometrical tolerances. Dedicated shells were designed to accommodate racetrack coils (quadrupole and sextupole) in both phases. Once the winding phase is completed the mold is closed and filled with epoxy resin in a fully controlled vacuum pressure environment. The solution adopted also allows to minimize the amount of resin necessary for the VPI impregnation.

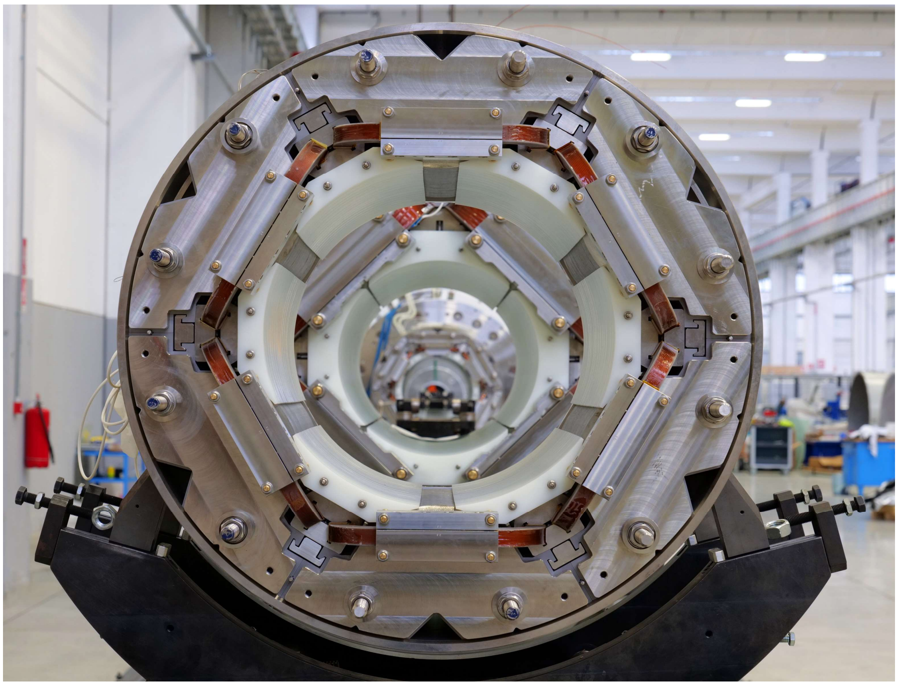

Figure 3: Magnets assembly inside LHe Vessel

Also the design of the LHe Vessel was very challenging as the chamber has to withstand a pressure of 20 bar, and for PED certification a pressure test of 22 bar. Moreover, the chamber gives structural support and guarantees alignment to the magnets.

Efforts are currently focused in the delivery of the first Long Multiplet (9 multipolar magnets, 70 tons weight and 7 meters length) and in the manufacturing of the Short Multiplets series, that was launched in late 2019.
Future work will aim to optimize and standardize the design of all components and proudly contribute to the progress of science with the new exiting insights the Super-FRS separator will bring into nuclear physics research.