STATUS OF THE SUPER FRS MAGNET DEVLOPMENT FOR FAIR

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Abstract

The Super FRS is a new 2 stage in flight separator to be built on the site of GSI, Darmstadt, Germany as part of FAIR (Facility for Anti-proton and Ion Research). It will be able to create and spatially separate rare isotopes from all elements up to Uranium. With it also very short lived nuclei will be able to be observed efficiently. The Super FRS has three branches so a wide variety of experiments can be carried out in frame of the NUSTAR collaboration. The large acceptance needed leads to large apertures of the magnets and therefore only a superconducting solution is feasible. The magnets of the Super-FRS are of so called superferric type, with superconducting coils but the field shaped by magnetic iron.

In this contribution the actual status of the designs of the dipole and multipole magnets will be presented.

INTRODUCTION

The Super-FRS is a key component of the experiments of the NUSTAR collaboration at the Facility of Antiproton and Ion Research (FAIR) which is going to be built at the site of GSI at Darmstadt, Germany [1]. It is a two stage in flight separator and the beam can be delivered to three different experimental branches [2,3]. The high- and low- energy branches and the ring branch, respectively. Due to the large acceptance required and a DC operation mode the choice was made to build the Super-FRS with superconducting magnets. Exceptions are the first few magnets after the target, where the radiation is too high and normal conducting magnets with special radiation resistant conductor will be used..

The Super-FRS will be able to accelerate all sorts of ions from protons up to Uranium up to energies of about 1.5 GeV/u and beam intensities of 10^{12}/s.

An overview of the Super-FRS is given in Fig. 1, the main design parameters of the separator are shown in Table 1.

Table 1: Design Parameters of the Super-FRS

	Value	Unit
$\varepsilon_x = \varepsilon_y$	40π	mm mrad
φ_x	± 40	mrad
φ_y	± 20	mrad
$\Delta p/p$	± 2.5	%
$B\rho_{max}$	20	Tm
R_{ion}	1500	
σ_x / σ_y	1.0 / 2.0	mm

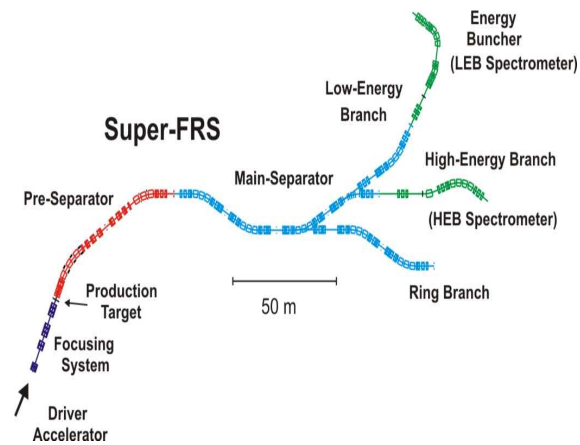

Figure 1: Layout of Super-FRS.

MAGNET DESIGN

The superconducting magnets of the Super-FRS are of so called superferric type. The magnetic field is shaped by the magnetic iron such as for a normal conducting magnet, but the coils of the magnet are wound with superconductors. The magnets have to be self-protecting, that means that they have to survive a quench without any damage even when the quench protection system fails. Nevertheless dump resistors are foreseen for machine operation. The requirement of self protectivity leads to the use of superconductors with a high Cu/SC ratio.

Furthermore the current in the magnets is limited to at maximum 300 A. This leads to coils wound of insulated wires rather than a cable. Reason for this limitation is to limit the size of the current leads for each of the magnets is powered individually and has its own pair of leads. The cooling of the magnets will be done by a liquid Helium bath. The design pressure of the Helium containers is set to 20 bar. It is foreseen to do the cool down and filling from the bottom of the He-vessel and the refill to replace evaporated He from the top. An additional requirement is a warm beam pipe.

Despite of being operated in DC mode three consecutive triangular cycles up to maximum current with a ramp up time of 120 sec have to be possible during the different operation cycles. This cycling is necessary to always have reproducible field conditions independent from the previous setting.

DIPOLES

Two types of dipoles, differing in their magnetic lengths are required in the Super FRS. From the 21 dipoles of type 3 two has to provide holes for a straight

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beam tube at the splits of the different branches. The main parameters of the dipoles are given in table 2. A prototype of a Super-FRS dipole has been built in China in a collaboration of the Institute of Electrical Engineering, Beijing, responsible for the conceptual design, the Institute of Plasma Physics, Hefei, which produced the coil and the cryostat, and the Institute of Modern Physics, Lanzhou, which produced the yoke and carried out the tests [4]. The dipole is a H-type magnet with racetrack coils, and only the coil is cooled, the iron yoke is at room temperature as for a normal conducting magnet.

Table 2: Main Parameters of Super-FRS Dipoles

	Type 2	**Type3**
Number of magnets	3	21
Dipole field [T]	0.15-1.6	0.15-1.6
Bending angle [°]	12,5	9,75
Curvature radius [m]	12,5	12,5
Effective straight length [m]	2,4	2,13
Good field region [mm]	±190	▯190d
Pole gap height [mm]	170	170
Integral field quality (relative)	±3×10-4	±3×10-4

The operation current of the prototype dipole was 232 A, the stored energy about 400 kJ and the inductance about 15 H. According to quench calculations the maximum hot spot temperature is 100 K.

Figure 2: Prototype Super-FRS dipole during testing in Lanzhou.

Test Results

The prototype magnet has been tested in Lanzhou in 2009. Figure 2 shows the magnet at the test stand. The magnet reached the desired field level and also the field quality was within the specified limits (see Figure 3). Also the triangular cycling was possible without quenching. The measured heat loads were 6.8 W and 8.1 W for zero and maximum current, respectively.

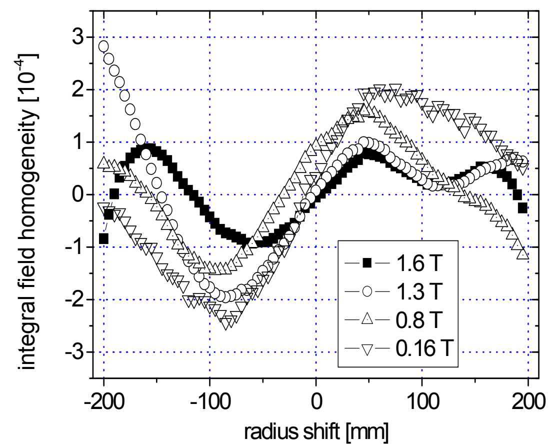

Figure 3: Measured field quality of Super-FRS dipole at various field levels.

MULTIPLETS

Quadrupole, sextupole and steerer magnets are arranged in so called multiplets where several magnets are grouped in one common cryostat. Depending on the position of the multiplet within the Super-FRS it contains from 2 up to 9 mulriplets (including octupole coils, which are embedded in part of the quadrupoles). Table 3 gives an overview of the main parameters of these multiplet magnets. A sketch of the biggest multiplet needed is given in Figure 4. Altogether 33 multiplets are needed for the Super-FRS (including two spare multiplets).

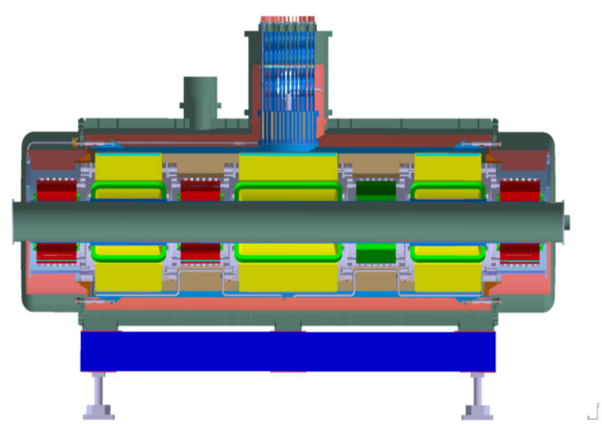

Figure 4: Cross section of biggest multiplet. Yellow and Green are the three quadrupoles (the bigger type 4 in the center), red are the sextupole magnet and green is a steerer magnet. Together with the two octupole coils embedded in the shorter quadrupoles and not shown here, the multiplet contains 9 magnets, which are all powered individually.

Table 3: Main Parameters of Super-FRS Multiplet Magnets

	Quadrupole Type 3	**Quadrupole Type4**	**Sextupole**	**Steerer**	**Octupole (embedded in Quadrupole 3)**
Number of magnets	46	34	41	14 (13v/1h)	
Field/Gradient range	1-10 T/m	1-10 T/m	4-40 T/m²	0-0,2 T	105 T/m³
Effective length [m]	2,4	2,13	0,5	0,5	
Radius of usable aperture [mm]	±190	±190	±190	±190	
Field quality	$\pm 8 \cdot 10^{-4}$	$\pm 8 \cdot 10^{-4}$	$\pm 5 \cdot 10^{-3}$		

In contrast to the dipoles for the multiplets also the iron is at 4.2 K. The Helium inventory needed for the big multiplet is about 1200 l (in contrast to the dipole where the He volume was about 20 l). At the moment only preliminary designs exist. According to these studies the stored energy of the type 4 quadrupole is about 1.2 MJ and the inductance of this magnet is about 27 H. Studies of the quench behaviour of the magnets show that for the quench of a single magnet the pressure rise in the vessel is below the design pressure of 20 bar even in the case of failure if activation of the dump resistor, so all the Helium can be kept inside the vessel. This is also the case if all the magnets of the biggest multiplets quenches and the dump resistors are activated as foreseen.

STATUS AND OUTLOOK

The Super.FRS dipoles will be tendered by FAIR whereas the multiplets are a German in-kind contribution and therefore will be purchased by GSI. The tendering procedure for the multiplets has started already, for the dipoles it will start in summer. It is expected that the first magnets will be ready in the first half of 2015.The cold test of all magnets is foreseen at CERN, the preparation of the test facility has started, too. After successful intensive tests of the first items of dipole, short and long multiplet the rest of the series production can be started. According to the actual time scale all magnets shall be produced, tested and installed at FAIR by 2019.the rest of the series production can be started. According to the actual time scale all magnets shall be produced, tested and installed at FAIR by 2019.

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