Cryogenics for Super-FRS at FAIR

Yu Xiang, Marion Kauschke, Claus H. Schroeder, Holger Kollmus

GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Introduction

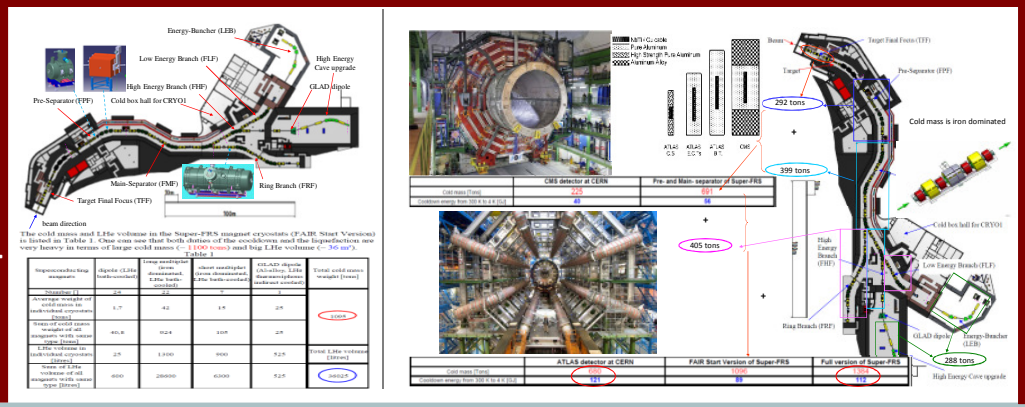
The Super-FRS at FAIR is a radioactive secondary beam fragment separator of large-acceptance, equipped with a number of superconducting dipole and multiplet (quadrupole, hexapole, octupole and steering dipole) magnets operating at 4.5 K. The total weight up to 1,400 tons of the cold mass, dominated by iron and the total LHe inventory of 47.0 m³ could be envisaged for the full version of the Super-FRS. It is a great challenge for the Super-FRS cryogenics to cooldown such large cold mass. The advantage of using LN2 precooling at 80 K is obvious in order to have a reasonable cooldown time of 3 to 4 weeks to reach 4.5 K operation temperature. The important features of the refrigerator and the cryogenic distribution system at FAIR will be presented. Most of the SC magnets of Super-FRS will be cold tested at CERN. The key issues for the cryogenic test facility planning and for the machine safety at FAIR must be clarified in terms of the limitation of cooldown / warmup rates, interface definition, the magnet cryostat protection against over-pressure under worst-case scenarios, i.e., quench and insulation vacuum sudden loss to air.

Conclusions

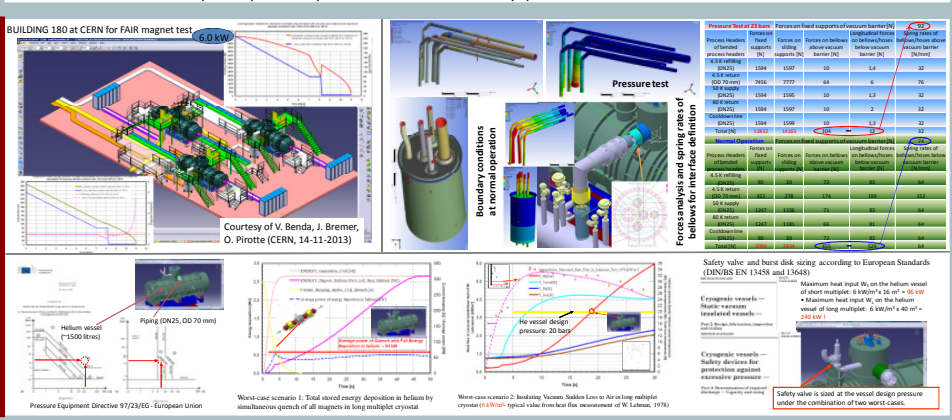
- Cooldown of the 1,400 tons cold mass down to 4.5 K has been addressed as one of the great challenges for the Super-FRS cryogenics. The capacity of the LN2 precooler at 80 K as well as the 4.5 K cooling power have been specified in order to have reasonable cooldown time of 3 to 4 weeks.
- Interface constraints between the helium distribution system and the magnet cryostats have been checked by using ANSYS 14.5 in terms of mechanical forces and deformation compensation for the test at CERN and the later tunnel installation at FAIR.
- The European Standards DIN/BS EN 13458 and 13648 are being implemented to correctly size of the safety devices based upon risk analysis under the worst-case scenarios, i.e., quench by accident with full energy deposition in helium system and the over-pressurization of helium vessel in case of insulation vacuum sudden loss to air.
- The process headers in cryogenic transfer line / feedbox units of the 4 branches for the helium distribution have been sized under the most conservative assumption upon the operation conditions of the cryoplant.

Cooldown of large cold mass and LN2 precooler

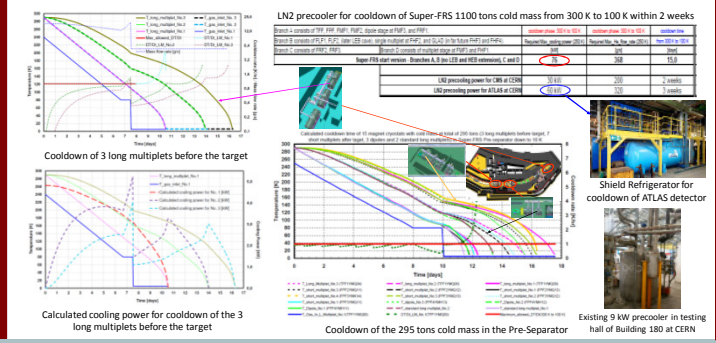
Super-FRS at FAIR



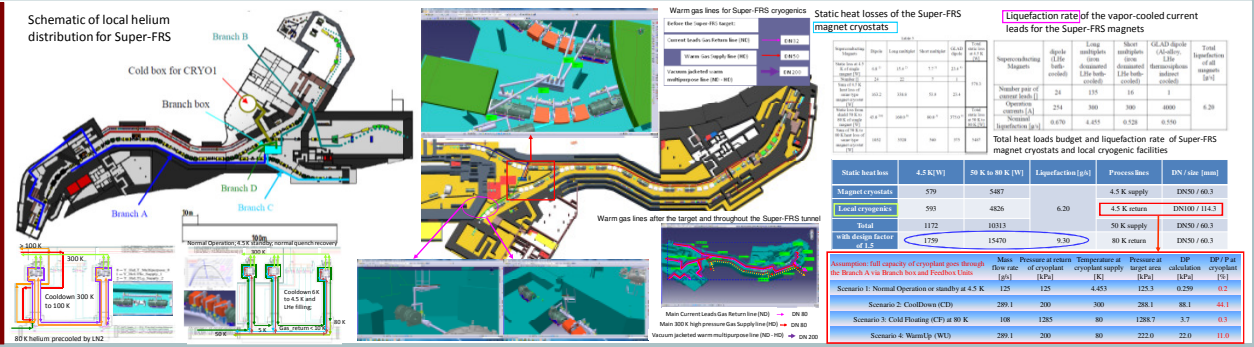
Magnet test at CERN



Cooldown calculation



Helium distribution at FAIR



Static heat loss	4.5 K [W]	50 K to 80 K [W]	Liquefaction [g/s]	Process lines	DN / size [mm]
Magnet cryostats	579	5487	6.20	4.5 K supply	DN50 / 60.3
Local cryogenics	593	4826		4.5 K return	DN100 / 114.3
Total	1172	10313		50 K supply	DN50 / 60.3
with design factor of 1.5	1759	15470	9.30	80 K return	DN50 / 60.3

Assumption: full capacity of cryoplant goes through the Branch A via Branch box and Feedbox Units	Mass flow rate [g/s]	Pressure at return of cryoplant [kPa]	Temperature at cryoplant supply [K]	Pressure at target area [kPa]	DP calculation [kPa]	DP / P at cryoplant [%]
Scenario 1: Normal Operation or standby at 4.5 K	125	125	4.453	125.3	0.259	0.2
Scenario 2: CoolDown (CD)	289.1	200	300	288.1	88.1	44.1
Scenario 3: Cold Floating (CF) at 80 K	108	1285	80	1288.7	3.7	0.3
Scenario 4: WarmUp (WU)	289.1	200	80	222.0	22.0	11.0

Presented at 25th International Cryogenic Engineering Conference and the International Cryogenic Materials Conference, 2014 July 7 – 11, University of Twente, Enschede, the Netherlands. Session: Wed-Af-Posters Session 2.4.; identifier No. 223