Progress of the FAIR Cryogenic System

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Outline

• Introduction
• Cryogenic topology
• FAIR machines
  • SIS 100
  • SuperFRS
  • Experiments
• Refrigerator
• Summary & Outlook
FAIR – machines and experiments

- APPA
- HEDgeHOB
- SIS 100
- SIS1
- HESR (FZJ)
- CR (BINP)
- Super-FRS
- CBM
- NuSTAR

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Cryogenic topology

CRYO plant: CRYO2
common compressor station

Cool down/
Warm up Unit

CWU

SIS 100
(SIS 300)

CBM

SuperFRS

(Panda)

APPA

R3B

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FAIR – SIS100- Magnets

Iron dominated magnet design:
- Dipole: 1.9 T, 4 T/s @ 1 Hz; 109 pcs.
- Quadrupole module: 27 T/m; 84 pcs.

Single cable (13 kA)
- Helium
- CuNi tube
- Superconductor
- NiCr wire
- Kapton foil
- Glass fiber tape
- Bus bars
- Supply return

For more information:
Dr. Christian Roux:
9-O-3A-2:
The optimized sc dipole of SIS100 for series production

Details: FAIR – Technical Design Report, July 08

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Cycle A
Proton cycle
Intensity: $2 \times 10^{13}$
Repetition rate: 5s
$Q_{\text{dyn, dipole}} = 1300$ W
$Q_{\text{dyn, quadrupole}} = 1000$ W
$Q_{\text{dyn, total}} = 4600$ W

Cycle B
RIB cycle U$^{28+}$
Intensity: $5 \times 10^{11}$
Repetition rate: 4s
$Q_{\text{dyn, dipole}} = 1080$ W
$Q_{\text{dyn, quadrupole}} = 740$ W
$Q_{\text{dyn, total}} = 4040$ W

Cycle C
triangular cycle U$^{28+}$
Intensity: $1.2 \times 10^{11}$
Repetition rate: 1.029 s
$Q_{\text{dyn, dipole}} = 7000$ W
$Q_{\text{dyn, quadrupole}} = 4900$ W
$Q_{\text{dyn, total}} = 13500$ W

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- all magnets supplied by parallel channels
- heat load in the magnets depends on the machine cycle
- static load = 2 W to maximum cycle = 50W
- adaptation of the mass flow through the magnets by variation of the supply pressure

<table>
<thead>
<tr>
<th></th>
<th>No ramp</th>
<th>Cycle A</th>
<th>Cycle B</th>
<th>Cycle C</th>
<th>4 K hold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored mass in sectants</td>
<td>900 kg</td>
<td>800 kg</td>
<td>800 kg</td>
<td>650 kg</td>
<td>460 kg</td>
</tr>
</tbody>
</table>
iron dominated magnet design:
dipole: 0.15 - 1.6 T; 27 pcs.
quadrupole: 1-10 T/m; 80 pcs.

multiplet:
Total mass: > 60t
cold mass: ~ 45t
current: ~250 A
Helium inventory: ~ 1500 l
heat load budget: ~ 30 W
no ramping

35 pcs.

For more information:
Dr. Yu Xiang:
10-P3-206 : Cryogenic supply for Super-FRS at FAIR

Details: FAIR – Technical Design Report, July 08
Today

HADES:
- LN$_2$ cooled shield
- Dedicated helium plant (100W@4.5K)

FAIR

HADES:
- Helium cooling also for the shield
- Refurbishment of the old feed box

Common branch box for both magnet systems
Summary of heat loads for the cryogenic plant

SIS 100

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Equivalent Heat Load @ 4.4 K [kW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>33</td>
</tr>
</tbody>
</table>

SIS100  SuperFRS

- Cold mass [t]: 400  1300
- Helium inventory [t]: 1.3  5.9

including a safety margin of 50%
For the part load operation different modes are possible:

- heaters within the users substituted immediately the heat load
- the valves of the turbines are partly closed => the energy consumption will near to maximum load; adaptation time to load changes very short
- reduction of the compressor flow => the energy consumption will be reduced; adaptation time to changes > 1h
Summary & Outlook

1. Start version:
   1. Single plant to cover low ramp duty (approx. 90% of experimental requests)
   2. CWU: for cool-down, warm-up and short time coverage of peak loads

2. Future options:
   1. Second plant to cover full dynamic load (known precisely after first run)
   2. Dedicated cryo plant for SuperFRS
   3. Replacement of the open LN$_2$ cycle by a Brayton machine
FAIR – SIS100- supply system

Supply line 4.4 K
Return line 4.3 K 300 K
shield cooling 50-80 K
Helium transfer lines
Cold electrical connection
warm electrical connection

Feed box 3

Current lead box
Damp resistor

Power supply

Compressor
Refrigerator Cryo 2
Distribution box 3

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