Hardware Commissioning of the RIKEN Superconducting Ring Cyclotron

TUPPRA16 Jun’ichi Ohnishi
The Magnetic Field of the Superconducting Ring Cyclotron

MOXCR01 Akira Goto
Commissioning of the RIBF at RIKEN

TUPPRA17 Nobuhisa Fukunishi (Yamada)
Present Performance and Commissioning Details of RIBF Accelerator Complex

WEPPRA02 Kazunari Yamada
Details of Beam Diagnostic System for RIKEN Superconducting Ring Cyclotron

TUPPRA15 Naruhiko Sakamoto
RF System for the RIBF Superconducting Ring Cyclotron

H. Okuno, K. Yamada, J. Ohnishi, N. Fukunishi, N. Sakamoto, O. Kamigaito, M. Fujimaki,
H. Hasebe, K. Kumagai, T. Maie, M. Nagase, S. Yokouchi, K. Ikegami, M. Kase,
A. Goto and Y. Yano, RIKEN Nishina Center
SRC: the World’s First Superconducting Ring Cyclotron

K = 2,600 MeV
Max. Field: 3.8T (235 MJ)
RF frequency: 18-38 MHz
Weight: 8,300 ton
Diameter: 19m Height: 8m

Sector Magnets: 6
RF Resonator: 4
Injection elements.
Extraction elements.

Self Magnetic Shield
Self Radiation Shield
Assembling of SRC in the vault
Cold mass assembly

Main Coil
- Solenoid winding with 396 turn
- Circumference: 10m
- Maximum Current: 5000 A
- Bath cooling

Conductor
- 15mm
- 8mm
- Rutherford type Nb-Ti SC Cable
- Stabilizer (Al-alloy with 1000ppm Ni)

# Four sets of coils
# I max = 3000 A
# The same conductor as that for the main coil
<table>
<thead>
<tr>
<th>Date</th>
<th>Phase I (Test of the S.C. Magnets)</th>
<th>Date</th>
<th>Phase II (toward the first beam)</th>
</tr>
</thead>
<tbody>
<tr>
<td>05/9/19</td>
<td>The 1st Cool-down started</td>
<td>06/6/24</td>
<td>Arrival of RF resonators</td>
</tr>
<tr>
<td>05/10/13 1:00AM</td>
<td>All the main coils transited to superconducting state.</td>
<td></td>
<td><strong>RF, Beam diagnostics, Vacuum pumping system were installed</strong></td>
</tr>
<tr>
<td>05/11/7</td>
<td>Excitation test (Imain = 5000 A, Itrim = 3000 A)</td>
<td>06/10/18</td>
<td>Vacuum for the beam &lt; 10^{-5} Pa</td>
</tr>
<tr>
<td>05/11/8</td>
<td>Trouble due to a He leak</td>
<td>06/11/~</td>
<td>RF conditioning Started.</td>
</tr>
<tr>
<td>06/4/15</td>
<td>Full excitation again</td>
<td>06/12/17</td>
<td>Beam injection to SRC</td>
</tr>
<tr>
<td>06/4/17-06/6/14</td>
<td>Magnetic field measurements</td>
<td>06/12/28</td>
<td>The first beam from SRC!</td>
</tr>
<tr>
<td>06/6/14</td>
<td>Fast shutdown test from full excitation</td>
<td>07/03/23</td>
<td>The first Uranium beam!</td>
</tr>
<tr>
<td></td>
<td></td>
<td>07/05/~</td>
<td>New isotope search</td>
</tr>
</tbody>
</table>
The First Cool-down and Excitation

Cold Mass : 142 ton

DT < 50K

T(Sup.)

Calc

23 Days

All the coils were fully excited on '05/11/07. They have never quenched so far.
Forces on the upper coil (TOSCA calculation)

In the excitations, we continuously measured the forces using the strain gauges attached to all the supports, checking whether our calculations are correct or not.
1: Quench characteristic

- Current decay: 63 s
- Temp. rise: 140 K
- Volt. Development: 1.5 kV/2

2: The main coils and S.C. Trim coils are strongly coupled together due to their relative positions.
All the coils were safely shut down even in emergency.
Field mapping over the acceleration region

- Field Mapper: 3 (60 deg./each)
- Hall Probe: 5
- Control: 2axis (Rot./Trans.)
- Mesh: about 5cm
- Meas. Time: about 3h30m/60deg.
Measured field profiles along the hill axis

- Good agreement (0.16%~0.35%)
- Small field dispersion among the sectors

Field Disturbances
- SM1 has a slightly different shape.
- Disturbance from MIC2 and MDC3

Small enough to be adjusted by the correction coils in the magnetic channels and aux. power supplies of the main and trim coils.
Installation of the parts for the SRC

- Installation of the RF resonators
- Connection with the beam chambers
- BEC (Beam chamber in the RF resonator)

**Components:**
- MDP (Main Differential Probe)
- EIC (Electric Inflection Channel)
- EDC (Electric Deflection Channel)
- Ti-alloy (cathode)
- Septum (Ground)
12/17 18:20 Al beams were injected to SRC.
12/21 16:00 Acceleration Tuning started.
   (currents of Imain, Ittrim, Injection orbits and
   phase of RF)
12/23 21:00 Acceleration up to 10cm from r_{inj}.
12/24 02:00 Acceleration up to 100cm from r_{inj}.
12/25 23:45 Something @100cm from r_{inj}.
12/26 daytime Removal of Q-mass
12/28 06:00 Beam injection re-started.
12/28 06:08 Acceleration up to the final turns
12/28 16:00 The first beam extracted!
**After the first beam**

**To the next stage**
2007/3/11 $^{86}\text{Kr}^{26+}$ 345MeV/u
(pilot for $^{238}\text{U}^{86+}$)

2007/3/23 The first Uranium beam
(TOP priority)

2007/5/ ~ New isotope search

**Improvement**
- RF resonators
- EIC/EDC (high voltage device)

**EIC/EDC**
**Specification:**
- 120kV 12mm gap

**In the first beam**
- 2mA @90kV

**Cleaning:**
- Supersonic cleaning
- Buff polishing

---

**Before**

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Dark Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>60.0</td>
<td>0.253×10^-6</td>
</tr>
<tr>
<td>0.00</td>
<td>0.253×10^-6</td>
</tr>
</tbody>
</table>

**After**

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Dark Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>60.0</td>
<td>0.214×10^-6</td>
</tr>
<tr>
<td>0.00</td>
<td>0.214×10^-6</td>
</tr>
</tbody>
</table>

**Improved!**
1. The SRC sector magnets were successfully cooled down and excited without quench.

2. Supports against magnetic forces, quench protection, cooling system, etc worked well as designed.

3. The field measurement:
   a. Field disturbances can be corrected.
   b. Data base to create isochronous fields for acceleration.

4. RF system, vacuum system and beam diagnostic system were successfully installed and tested under the stray fields arising from the sector magnets.

5. The SRC started working as an accelerator from the end of 2006.