@1. Update of RF-System
   for stable operation of the Cyclotron

@2. Charge-Exchanging Beam Extraction.
   to Providing High-Intensity Beam for R.I. Production.

@3. Accel-Decel System for ECR-IS.
   to Obtain more Ion-current extracted from ECR-IS.

@4. New Inflector for Beam Injection.
   for Quick-operation of the Cyclotron.

and Operation status of the Cyclotron.
NRS Cyclotrons

HM-18

NRS-930
Update of RF-system

@ Q-value of the resonator having the range of around 4000 to 7000 at the frequency range between 21.2 to 11 MHz.
@ The maximum proton energy of 90 MeV has been successfully extracted.
@ Stable operation.

SPECIFICATION of RF-System

* Resonater : Moving-Short, Span of 1025mm.
* Frequency : 11.47 ~ 21.14MHz.
* Freq. Comp. : ~ 400kHz, with Capacitance drive.
* Q-value : 7000 @ 11MHz, 4000 @ 21MHz.
* Power-Amp : 4CW50000E.
* Dee-Voltage : ~ 43 kV @ 21MHz.
* Dee-Angle : Two of 86-deg.
• Extraction beam energy: 10 ∼ 80 MeV for H⁺.

• Extraction beam current: up to 30-micro amperes would be expected.

• Dispersion at Extraction: 
  R16 = -1.32 m
  R26 = -6.32 mrad.

• Beam-line: under designing.
Decelerator: (Accel-Decel System)

Relation: \( I_{ext} \propto V_{ext}^{3/2} \)

Example of Beam Increasing at Injection-Line

- P-18MeV \((V_i = 5.8 \text{ kV})\): \( \frac{290}{180} \mu\text{A at } V_{dec} = -10 \text{ kV} \), 1.6 times
- P-40MeV \((V_i = 8.13 \text{ kV})\): \( \frac{300}{170} \mu\text{A at } V_{dec} = -8.13 \text{ kV} \), 1.8 times
Emittance Change in Decelerator

Results of the numerical calculation for $^{12}$C$^{4+}$-beam

Initial Emittance

$\varepsilon = 175\pi$ mm-mrad

Parameter of the simulation:
Injection Voltage : $V_a = +10$ kV,
Add. Negative Voltage : $V_b = -10$ kV
Einzellens Voltage : $V_c = +3.8$ kV.

Emittance change by the beam intensity
b) Non space-charge : $\varepsilon = 245\pi$ mm-mrad,
c) $I = 200$ e\(\mu\)A : $\varepsilon = 256\pi$ mm-mrad,
d) $I = 400$ e\(\mu\)A : $\varepsilon = 273\pi$ mm-mrad.

The results predicted that the distortion on the beam profile affected by deceleration is negligibly small, however, the emittance increase and/or a distortion of their shapes causes by the space-charge effect is clearly indicated if the beam size is less than 10 mm and its current is greater than 400 e\(\mu\)A.
Forth: New H12-Inflector

Projection of Ion-orbits on X-Y plane for each H1, H2, and New H12 inflectors

Inflector--Parameters of NIRS--930

<table>
<thead>
<tr>
<th>Type</th>
<th>Re [cm]</th>
<th>Rm [cm]</th>
<th>Energy--Range (Actual) [MeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>2.2</td>
<td>1.3</td>
<td>40 – 90</td>
</tr>
<tr>
<td>H2</td>
<td>2.85</td>
<td>1.6</td>
<td>6 – 50</td>
</tr>
<tr>
<td>H12</td>
<td>2.52</td>
<td>1.45</td>
<td>14 – 80</td>
</tr>
</tbody>
</table>
Better transmission efficiencies have been obtained in the beam acceleration and extraction. It covered a wide range of beam energies and allows quick changes of different acceleration modes.

<table>
<thead>
<tr>
<th>Extracted Beam &amp; Energy [MeV]</th>
<th>18</th>
<th>30</th>
<th>40</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Inflector</td>
<td>H1</td>
<td>H2</td>
<td>H12</td>
<td>H1</td>
</tr>
<tr>
<td>Transmission Efficiency [%]</td>
<td>37.4</td>
<td>57.5</td>
<td>47.8</td>
<td>51.7</td>
</tr>
<tr>
<td>Buncher Efficiency [Times]</td>
<td>1.7</td>
<td>1.63</td>
<td>3.4</td>
<td>3.65</td>
</tr>
<tr>
<td>Refference Beam Current [uA]</td>
<td>23</td>
<td>23</td>
<td>21.5</td>
<td>22</td>
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</table>

*Note: The table represents the result of new H12-inflector.*
<table>
<thead>
<tr>
<th>Beam</th>
<th>Energy [MeV]</th>
<th>Rf-Freq. [MHz]</th>
<th>Injection V_I [kV]</th>
<th>FC2</th>
<th>FC4</th>
<th>R = 45 mm</th>
<th>R = 925 mm</th>
<th>BSO</th>
<th>Buncher efficiency</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>18</td>
<td>20</td>
<td>5.9</td>
<td>280</td>
<td>177</td>
<td>40</td>
<td>35.5</td>
<td>23</td>
<td>63.2 %</td>
<td>2008.1.17</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>12.83</td>
<td>8.65</td>
<td>305</td>
<td>205</td>
<td>44.5</td>
<td>44.5</td>
<td>23</td>
<td>58.6 %</td>
<td>2007.12.20</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>14.85</td>
<td>8.2</td>
<td>230</td>
<td>150</td>
<td>19.2</td>
<td>17.5</td>
<td>11.3</td>
<td>65.2 %</td>
<td>2008.2.20</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>14.85</td>
<td>8.2</td>
<td>94</td>
<td>42</td>
<td>14.6</td>
<td>10.2</td>
<td>4.3</td>
<td>44.7 %</td>
<td>2007.12.4</td>
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<tr>
<td>H2+</td>
<td>28</td>
<td>17.75</td>
<td>8.19</td>
<td>258</td>
<td>175</td>
<td>41.6</td>
<td>35</td>
<td>19</td>
<td>67.8 %</td>
<td>2008.1.17</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>12.83</td>
<td>8.65</td>
<td>228</td>
<td>146</td>
<td>30</td>
<td>22</td>
<td>16.5</td>
<td>64 %</td>
<td>2007.12.20</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>15</td>
<td>6.25</td>
<td>100</td>
<td>61</td>
<td>14</td>
<td>9.4</td>
<td>6</td>
<td>61 %</td>
<td>2008.1.17</td>
</tr>
<tr>
<td>He2+</td>
<td>72</td>
<td>11.74</td>
<td>5.65</td>
<td>40</td>
<td>24</td>
<td>6.15</td>
<td>4.1</td>
<td>1.65</td>
<td>60 %</td>
<td>2008.1.17</td>
</tr>
</tbody>
</table>

Note: The table provides transmission and efficiency data for different beams at NIRS-930.
Beam Current Change as a Function of Extraction Voltage: \( I \propto V^{3/2} \)

\( I \) : Extraction beam current from ECR-IS

\( V \) : Voltage difference between Source and Extractor

**Result of beam current increase as a function of additional negative voltage**

- **Injection Line**
- **Extracted from Cyclotron**

Beam: \(^{12}\text{C}^{4+}\) of 7.2 [MeV], Extracted from Cyclotron
Injection Voltage: 5.6 [kV],
\((Br)_{inj} = 18.41 \; [kg\cdotcm]\)