6 - 1 Operation Status of HIRFL in 2014

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Since beginning of 2014, HIRFL has been operated about 7 272 machine hours, including 626 h for the machine preparation, 998.5 h for the machine commissioning, 158.5 h for equipment failure period, 4 964.5 h for experiment target time and 235 h for the machine study. Several different operation modes were included: 1 321.5 h for the independent operation of SFC; 2 631 h for operation of the combination of SFC+SSC; 1 422 h for operation of the combination of SFC+CSRm, 1 897.5 h for the operation of the combination of SFC+CSRm+CSRe, and 289.5 h is the others.

In 2014, HIRFL provided 25 different species of heavy ion beams for various experiments. Especially 11 kinds of heavy ion beams with different energy were firstly provided for experiments. The typical ion beams provided by HIRFL in 2014 are listed in Table 1.

Table 1 The tupical ions beam provided by HIRFL in 2014.

Index	Ion	(SFC)		(SSC)		(CSRm)		(CSRe)
		Energy /(MeV/u)	Current /μA	Energy /MeV/u	Current /μA	Energy /(MeV/u)	Current /μA	Current /μA
1	$^{78}Kr^{19+/28+}$	4.0	4.2	—	—	432.5/487	600	Secondary beam
2	H_2^+	10.0	4.0	—	—	250	30-50	—
3*	$^{40}Ar^{11+}$	4.8	3.2	—	—	—	—	—
4*	$^{16}O^{6+/8+}$	7	8.5	—	—	265/360	600-100	—
5	$^{12}C^{4+/6+}$	7	2.3	80.55	0.17	—	—	—
6	$^{40}Ar^{12+/17+}$	6.17	5.0	70	0.45	—	—	—
7	$^{16}O^{6+/8+}$	6.17	5.9	70	0.45	—	—	—
8*	$^{12}C^{4+/6+}$	5.361	2.8	60	0.24	—	—	—
9	$^{209}Bi^{31+}$	0.911	0.6	9.5	0.04	—	—	—
10	$^{58}Ni^{19+/25+}$	6.17	1.2	70	0.07	—	—	—
11*	$^{32}S^{9+}$	3.9	1.7	—	—	—	—	—
12*	$^{40}Ar^{9+/15+}$	2.794	3	30	0.05	—	—	—
13	$^{20}Ne^{7+}$	6.17	3.8	—	—	—	—	—
14*	$^{16}O^{6+}$	7.5	2	—	—	—	—	—
15*	$^{22}Ne^{8+}$	7.5	2.2	—	—	—	—	—
16	$^{86}Kr^{17+/26+}$	2.345	4.5	25	0.13	—	—	—
17	$^{12}C^{4+/6+}$	4.906	5	54.5	0.35	—	—	—
18*	$^{36}Ar^{15+}$	8.5	1.9	—	—	8.5	300	—
19*	$^{14}N^{4+}$	4.5	2.8	—	—	—	—	—
20*	$^{40}Ca^{12+}$	5	2	—	—	—	—	—
21	$^{12}C^{3+}$	4.2	5	—	—	122.375	270	200
22	$^{12}C^{4+}$	7	10	—	—	165/300	1 500	—
23*	$^{40}Ca^{12+}$	4.825	2	—	—	—	—	—
24	$^{209}Bi^{31+}$	0.911	0.3	9.5	0.01	—	—	—
25	$^{58}Ni^{19+}$	6.3	1.2	—	—	467	280	Secondary beam

Several experiments were carried out on HIRFL facility in 2014, including 3 749 h of beam time for physical experiments, 332 h for biological experiment and beam test, 883.5 h for research of material irradiation and single event effect, 235 h of beam application for the machine study. The summary of the HIRFL operation time

distribution is shown in Table 2.

Table 2 Distribution of the HIRFL operation time in 2014.

Operation time distribution	Time/h	Percentage/ %
Total operation time	7 272	100
Failure time	158.5	2.2
Preparation of beam	1 624.5	22.3
Other time	289.5	4.0
Experimental beam time	5 199.5	71.5
Nuclear physics	3 749	72.1
Irradiation	883.5	17.0
Biophysics	332	6.4
Machine study	235	4.5

The highlights of the operation work are listed as follows:

1. The molecular ion H_2^+ was extracted from CSRm at the energy of 250 MeV/u, and then delivered to the external target for experiments.
2. The process of the SSC operation is very quick and efficient. For example, the $^{18}O^{6+/8+}$ ion beams provided by SSC was delivered to the experimental terminal without any machine failure. It would be the first time in the HIRFL operation history.
3. Two nuclei mass measurements were done at CSRe successfully. Many achievements have been made through these measurements
4. The $^{58}Ni^{28+}$ ion beam at the energy of 301 MeV/u was cooled with the electron cooler at CSRe firstly.
5. The ^{86}Kr and ^{209}Bi ion beams were delivered to the experimental terminal TR5 more than 800 h.

Several issues in the accelerator machine study were finished:

1. Slow extraction study on CSRm. The slow extraction experiment was performed with the ion beam at the top energy when a sinusoidal RF voltage is applied. It has increased the efficiency about 20%.
2. SSC injection study on the influence of the elements' position. The injection efficiency can be improved 10% by optimizing the position of MSi3 and MSi4, but in the same time the extraction efficiency was decreased more than 50%. This study should be done in the coming year.
3. SFC extraction study on the influence of the solenoids in the SFC beam line. By changing the polarity of the three solenoids, a good extraction efficiency of SFC was achieved.
4. SFC extraction study on the influence of the buncher B02 voltage. The experimental results show that the voltage of B02 is high enough for the heavier ions, but it is still not in sufficient range to satisfy the requirement of the light ions.
5. Study on the transverse coupling of ion beams extracted from superconducting ECR ion source.
6. The beam position measurement and the closed orbit correction study on CSRm. The stored ion beam orbit was measured through 15 BPMs around the CSRm storage ring. The measurement showed that displacements as large as 20 mm were happened in the second and forth sections. The displacements can be decreased within 10 mm by a local orbit correction.
7. Study on the electron cooling effect. The cooling effect was optimized by the electron and ion beam position monitors in the cooling section. The cooling force was measured with the aid of RF-buncher in the CSRe storage ring.