# THE STATUS OF HIRFL

Y.F. Wang, J.Y. Tang and B.W. Wei
Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China

*Abstract*

In the paper, the operation status of Heavy Ion Research Facility at Lanzhou (HIRFL) is described for the recent several years roughly. Then some improvements and developments included a super-conducting ECR ion source, a new re-buncher, a new vacuum chamber for injector SFC, two experimental devices, one is for the research of cancer therapy by heavy ion beam, another is for the research of single particle effect, and so on, are depicted in more detail. Of cause, the Cooling Storage Ring (CSR), the new project, which is under way, will be described elsewhere in the conference.

## 1 INTRODUCTION

HIRFL's operation started in the beginning of 1989, since then, it has already been run for more than 10 years. And the machine(Fig.1) is operated about 5000h each year. In 1997, the Radioactive Ion Beam Line at Lanzhou (RIBLL) was completed. In November of 1999, the project of Cooling Storage Ring (CSR) was approved by our government officially. It will accelerate, accumulate and cool the beams coming from HIRFL and do some experiments such as RIB researches, atomic physical researches, which demand for highly charged state ions (fully stripped heavy ions, or those ions with one or two electrons), application researches and so on. Both RIBLL and CSR desire strong beam intensity and full ion species from proton to Uranium. It ask us to do some upgrading in HIRFL so as to increase the beam intensity more than 1 magnitude and accelerated beam species from present carbon to xenon into full ion species.

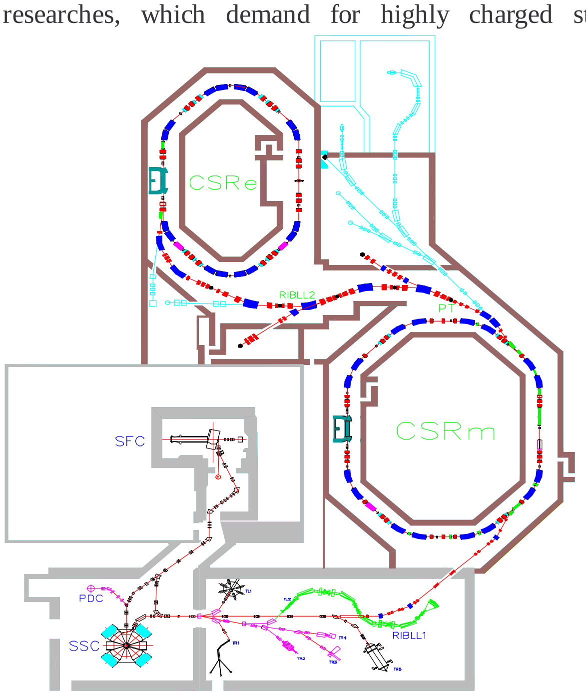


Fig.1 Layout of HIRFL-CSR

## 2 OPERATION STATUS AND IMPROVEMENT GOALS

Up to now, HIRFL has delivered more than 70 species of beam with different energies from Carbon to Xenon included metallic ions Calcium, Magnesium etc. to physicists. Started from 1998, near half of the beam time has been delivered to the Radioactive Ion Beam (RIB) physical experiments. In the last several years, the beam intensities have increased and reached 100~300eμA for the light ions and 10~50eμA for the medium heavy ions like Krypton and Xenon from SSC in the routine operation because the ECR3, a new 14.5 GHz ECR ion source was finished successfully[1)] and some improvements were completed.

According to requirements of existing RIBLL and future CSR, following three aspects should be done in a few years: The beam intensities should be increased more than one magnitude; The beam species accelerated should be extended to all of the particles from proton to uranium; The running of the machine should be more stable and reliable because of the aging of the devices and the accelerated beam should be used more effectively by the method of sharing beam time and so on. For the purpose, some improvements are in progress and some should be done.

## 3 EXISTING PROBLEMS

One of the existing main problems of HIRFL is that the transparency of beams is too low. According to the statistics, the transparency between ECR ion source after the analyzed magnet and the exit of SFC is about 4.7% in average and the transparency of main cyclotron SSC is about 7.2% only. Therefore the total transparency for HIRFL is less than 0.3%, when the transparency of the beam transport lines is considered in the same time.

By the analysis, the main reasons why the transparency is so low for injector SFC are as follows:

stray magnetic field for SFC and vacuum pressure for SFC.

For SSC, the reasons are as follows: mismatching between two cyclotrons and energy mismatching between two cyclotrons.

## 4 SOME IMPROVEMENTS

In the past several years, some improvements were made such as improvement of the source beam line located between ECR ion source and injector SFC, designing and constructing of a new ECR ion source[1], control system converted from central mode to distributed mode, the improvement of cooling water system and so on.

In order to solve the problems and accomplish the expected goals mentioned above. Some improvements are being made and some prepare to be made.

### *4.1 Manufacture of a New Rebuncher B1*

A new rebuncher B1 including a cavity, a generator and so on is manufacturing in Shanghai and in Nanjing respectively. The rebuncher was redesigned with new structure and new parameters. It will be finished by the end of the year. The construction of new rebuncher B2 will be started next year after the new B1 is tuning successfully. Use of the new B1 and B2 will improve the longitudinal property of beam and enhance the transparency of beam in SSC obviously.

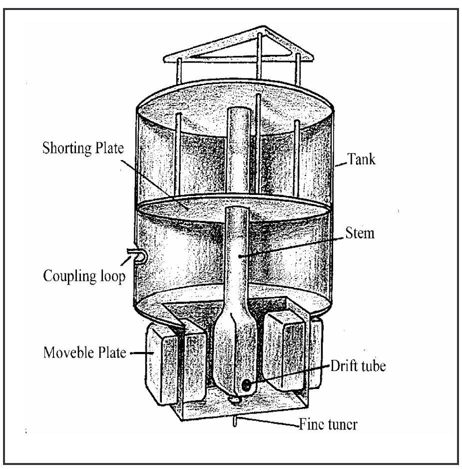


Fig.2 Schematic drawing of the new B1 cavity

### *4.2 Manufacture of The New Vacuum Chamber for SFC*

In order to improve the vacuum performance of SFC, a new vacuum chamber with two layer walls is in construction now. It divides into two parts. The first one is in the center of the machine that will keep the vacuum pressure better than $1\times10^{-7}$ Torr for beam running[2]. The second one divides two parts too located between the first part and upper magnetic pole and between the first part and down magnetic pole, respectively to keep poor vacuum pressure. All of the trim coils, harmonic coils and so on are put in the second part. The advantage of improvement of vacuum pressure is not only to increase the intensity of heavy ion beams but also make the very heavy ions like lead, uranium and so on to be accelerated possible. The fabrication of this vacuum chamber will be finished in the end of the year. And it will be installed late soon.

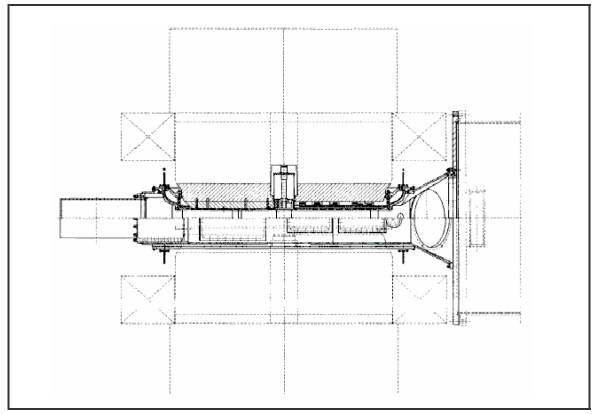

Fig.3 Schematic drawing of the new SFC vacuum chamber

### *4.3 Decreasing of Stray Field of SFC*

In the meantime of constructing the new vacuum chamber mentioned above, the problem of stray magnetic field around SFC is considered. According to the possibility of space, on the two sides of the old magnetic yoke, the iron plat with thickness of 15 cm is installed respectively to decrease the magnetic saturation in yoke. And under the SFC and on the ceiling of the underground in which the ECR ion source and the successive transport beam line are fixed, a piece of iron with thickness of 2 cm will installed to shield the stray field. According to the computation by using MAFIA, the strength of the stray magnetic field will be decreased to the one third of original one. So the magnetic mapping of SFC should be made again next year.

### *4.4 Promote of the RF Voltage for SSC*

The voltage amplitude of rf cavities for SSC should be increased. Up to now the RF voltage amplitude afforded to be applied is less than 120 kV. It is lower than expected ones. This summer, in the period of machine shut down, after some improvements, the results seem better. The voltage of 180 kV could be achieved for the RF of 13.5 MHz. When the machine starts to be operation, we will check how large the beam will be.

### 4.5 Super-conducting ECR Ion Source

A new super-conducting ECR ion source is in designing and producing now. The goal of researching this ECR ion source is to enhance the beam intensity of ultra-heavy with ultra-high charged states. Two micro-wave powers of 14.5 GHz and 18 GHz are used to heat the plasma in the same time. The maximal axial magnetic field in the plasma cavity is 3 T. The expecting results for the ECR ion source are shown in Table1. It is very helpful to enhance the species, energy and intensity of accelerated beam.

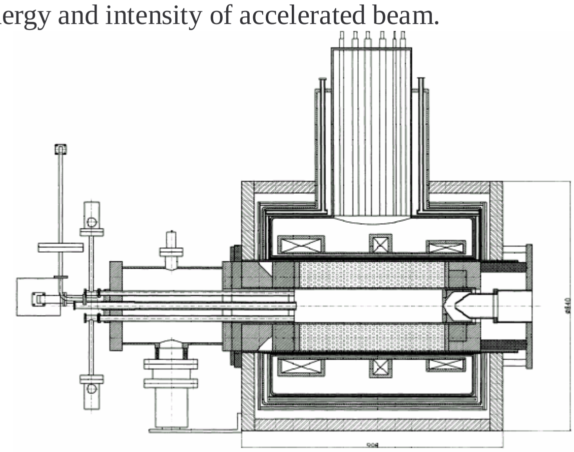

Fig.4 Super-conducting ECR ion source

### 4.6 Decreasing of Perturbation Field in SSC

We prepare to put a “C” type of the iron in the position of a small radius of the valley where Mi2 magnet is located to trim the first harmonic field. In the case the magnetic field mapping should be made again. It is useful to increase the beam transparency in SSC.

### 4.7 Improvement of Power Supplies

In order to ensure the stability and the reliability of operation for the machine, and according to the aging of some devices, some devices should be changed and improved. For example, the cooling pips, relays, and so on, especially, for the power supplies. There are more than 300 power supplies in HIRFL and the performance of most of them are poorer due to the long term operation. Now the technology of silicon controlled rectifier and soft switch is used for the power supplies instead of transistor method. This work is under way.

### 4.8 Enhance the Beam Using Effect

Considering the operation of HIRFL with higher utilization efficiency and construction of some new experimental devices, such as “single particle effect” device, “cancer therapy research” device and so on, the distribution of devices and corresponding transport lines are rearranged. All of the devices will be shielded each other. By using pulsed bending magnets and quadrupoles, it is possible to transfer the beams both from SFC and SSC to the different devices or share same beam for different devices in the same time. Both of heavy ion beam from SFC and proton beam from SSC which connects with the second injector cyclotron PDC(Proton Dedicated Cyclotron, a 10 MeV fixed energy cyclotron, is under construction) to offer 125 MeV proton beam to the different devices too in the same time. In the future, the sharing time method will be taken when CSR starts to be operation, in which only 7seconds are needed for the beam injection in the period of 17seconds.

## 5 SUMMARY

HIRFL has already run more than 10 years. To meet the requirement of physicists and new project-CSR as its injector, many improvements must be done although it is very difficult. It is expected that the machine could be running more reliable and all of the goals mentioned above could be accomplished.

## REFERENCES

[1] Zhao H Y, Liu Z W, Zhang W et al. A New Working Model and a New Magnet Field Configuration Tested on HIRFL ECRIS. In: Donald P M, Judith E R ed. Proc. of 13th Inter. Workshop on ECRIS. Chicago(USA),1997.34

[2] Wang Y F, Tang J Y, Lei W. Consideration of HIRFL Vacuum Pressure. Proc. of the 15th Inter. Conference. Caen, France,1998.301