

# IMP & HIRFL

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# Annual Report



Institute of Modern Physics, the Chinese Academy of Sciences  
& Heavy Ion Research Facility in Lanzhou

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## Foreword

In 2004, the HIRFL accelerator complex was fully in operation after the shut-down for upgrading. A series measurements and tests indicate that the new rebuncher has achieved the designed requirements. The preliminary test demonstrates that the beam intensity of SSC for energy less than 30 MeV/u could be improved by a factor two with the rebuncher, but for the higher energy beam the enhancement of the beam intensity is smaller due to not enough bunching voltage. The renovation of about 300 sets of power supplies at the HIRFL has been completed. A high stability of  $5 \times 10^{-6}$  for the main power supplies of SSC was reached. To deliver a more intense pulsed beam, a chopper (pulse width 1~18 ms, pulse period 4.75~17 s) designed particularly for the CSR injection was used at the axial injection beam line of SFC. The maximum beam intensity of 13  $e\mu\text{A}$  for 7 MeV/u  $^{12}\text{C}^{+4}$  was obtained.

A considerable progress for the HIRFL-CSR project was achieved in 2004. About 98% of the total components have been completed, tested and installed. The injection beam line to CSRm has been commissioned by using the different ion species. The transmission efficiency of the injection beam line is nearly 100%. The required safe transition of the vacuum from  $10^{-7}$  Pa in the HIRFL beam line to  $10^{-9}$  Pa of CSRm has been realized. The average vacuum of CSRm is  $3.9 \times 10^{-10}$  Pa, almost one magnitude better than the expected  $3.5 \times 10^{-9}$  Pa. It is ready for the first-turn commissioning of CSRm. All the components of RIBLL II beam line and CSRc have been finished and tested also. The 350 kV electron-cooler and the cluster target of CSRc were installed and commissioned successfully. For  $\text{N}_2$  gas, the typical target density of  $10^{13}$  atoms/cm<sup>2</sup> has been obtained. Much work has been done for the internal circulating water system and the water resistance of 5  $\text{M}\Omega/\text{cm}^2$  is achieved. A new isomer state  $^{186\text{m}}\text{Ta}$  created through the (n, p) reaction by irradiation of tungsten with 14 MeV neutrons was identified by using the X- $\gamma$  coincidence measurement and the six  $\gamma$ -rays were assigned to  $^{186\text{m}}\text{Ta}$ . The half-life of  $^{186\text{m}}\text{Ta}$  was found to be  $(1.54 \pm 0.05)$  min. The production cross-section of heavy neutron-rich isotope  $^{236}\text{Th}$  in the interaction of  $^{238}\text{U}$  with 60 MeV/u  $^{18}\text{O}$  ions was precisely measured and determined to  $(250 \pm 50)$   $\mu\text{b}$ .

The test experiments of super-heavy element synthesis on the upgraded RIBLL were performed. The transmission efficiency by using the heavier ions and the reaction residues was measured. A RFQ cooler and buncher RFQ1L for the new SHE spectrometer was designed. The projectile fragmentation reaction,  $\gamma$  and neutron spectroscopy for the neutron-rich nuclei were made.

For the high-spin physics, more new results were given. The level scheme of the odd-odd nucleus  $^{146}\text{Tb}$  has been revised significantly and the level structure shows the characteristic feature of multi-particle configuration in a spherical nucleus. The high-spin states of  $^{183}\text{Au}$ ,  $^{184}\text{Au}$ ,  $^{188}\text{Au}$ ,  $^{190}\text{Tl}$  and  $^{69}\text{As}$  nuclei have been investigated. The level schemes were revised and extended, and new rotational bands were found for such nuclei. A chemical separation scheme to search for the 'missing'  $\alpha$ -decay branch in  $^{239}\text{Cm}$  was developed to establish a link for those unknown  $\alpha$ -emitters in the transuranium region to nuclides with known masses. The separation and extraction of  $^{239}\text{Pa}$  from the nuclear reactions in  $^{238}\text{U}$  target bombarded by  $^{18}\text{O}$  ions has been studied.

For the nuclear theoretical physics, many calculations were done. The effect of a microscopic nuclear three-body force on the composition of the kaon-condensed phase in chemical equilibrium neutron star matter has been studied. The equation of state of neutron star matter is found to be soft considerably by the kaon-nucleon interaction in the kaon-condensed phase. In the framework of the isospin dependent Brueckner-Hartree-Fock approach, the density and momentum dependence of symmetry potential has been investigated. It is seen that the symmetry potential depends sensitively on both the momentum and density, but weakly on the isospin asymmetry. By using isospin dependent quantum molecular dynamics, it is found that the weak boose neutron-halo structure of  $^{19}\text{B}$  increases the fragmentation process in lower beam energy region due to a large neutron excess, small separation energy and an extended neutron density distribution. The effect of isospin dependent momentum interaction on the isospin fractionation ratio was investigated. It is found that the isospin momentum dependent interaction induces the significant reduction of isospin fractionation ratio as increase of beam energy. In the mean field approximation, the effective masses of baryons as different baryon percents were calculated and the EOS of hadron matter with inclusions of pentaquark  $\Theta^+$ . It is indicated that the effective masses all decrease as the baryon density increases, whether the nucleons or the  $\Theta^+$ . Isospin effect of multifragmentation for the finite nuclei  $^{112}\text{Sn}$  and  $^{123}\text{Sn}$  is studied by using a phenomenological asymmetric nuclear equation of state and an isospin dependent quantum molecular dynamics model. It is found that the isospin effect gradually vanishes with the temperature increasing. Production cross sections of superheavy nuclei Rf and Hs asymmetric and nearly symmetric projectile-target combinations are systematically studied within the framework of the

dinuclear system model. It is shown that the nearly symmetric system has higher inner fusion barrier and lower quasi-fission barrier, not favourable to form a compound nucleus.

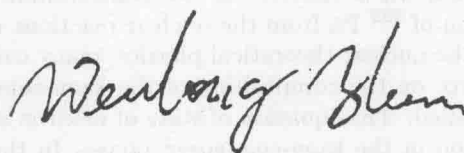
For atomic physics, several experimental setups were established. A one-stage gas-jet for recoil-ion momentum spectroscopy was constructed and the first experiment was performed at the ECR atomic beam line using  $\text{He}^{2+}$  projectile and argon target. A new 320 kV high-voltage ECR platform dedicated for atomic physics, material sciences and biological physics was installed. The dissociation and fragmentation of molecules, the transfer ionization processes in collisions between ions and molecules, and the interaction of  $\text{HCl-C}_{60}$  were investigated.

In 2004, many researches on the heavy-ion irradiation to material science were made. The significant chemical bonds such as Si-C and Si(C)-O-C bonds were formed in the C doped  $\text{SiO}_2$  films after high-energy Pb and Xe ions irradiation. An intense blue-violet light at 375~450 nm was observed from sapphire after implanted with He ions and irradiated with Pb ions. Hydrogel samples were prepared under electron irradiation and the properties of these hydrogels were investigated.

Radiosensitivity, biological effectiveness, bystander effect, cycle, repair and surviving of cells irradiated by ions and  $\gamma$ -rays were studied. Irradiation enhances on the transduction of p53 gene into human cells were found. An enhanced efficiency in cell killing around the Bragg peak of  $\beta$ -delayed radioactive  $^{12}\text{C}$  ions in comparison with the  $^{12}\text{C}$  beam was determined.

In 2004, a great progress on the control system of HIRFL-CSR was made. The all HIRFL-CSR control system has been changed into a new cluster server system consisted of seven Antium II workstations. About 12 types of modules have been developed and 680 controllers have been installed. The DSP based magnet-ramping controller with two channels of 16-bit ADC reading inputs and two channels of 16-bit DAC setting outputs was developed and tested. The optical fiber was used for connecting the controllers to the intranets. The four slots reformed VME back-plane and controller have been manufactured. The user interface and HIRFL-CSR central database programming have been finished and the central control room has been put into operation.

Finally, I acknowledge all the staff in IMP and NLHIAL as well as the colleagues from other institutions in collaboration for their all progresses and achievements obtained in the year of 2004.



Zhan Wenlong  
Director of IMP  
Vice Director of NLHIAL

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