BEIJING RADIOACTIVE NUCLEAR BEAM FACILITY(BRNBF)

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1. INTRODUCTION

It is well recognized that the radioactive nuclear beam (RNB) promises a bright future in significant areas of nuclear physics and related sciences[1] . Proposals for RNB facilities have been put forward in many countries, that are in various stages of completion.

In order to promote the fundamental and applied research of nuclear physics in the foremost frontier, China Institute of Atomic Energy (CIAE) has proposed the Beijing Radioactive Nuclear Beam Facility (BRNBF), which is an extension of the existing HI-13 tandem accelerator. The proposed BRNBF is an ISOL type radioactive nuclear beam facility.

The plan view of the Beijing Radioactive Nuclear Beam Facility is shown in Fig.1.

A new intensity proton cyclotron accelerator will be built to provide proton beam with 70 MeV 200μA. A thicktarget/ion--source system will produce the interesting exotic radioactive nuclear beam which will then be isotopically separated by an on-line mass separator. The beam then pass through a charge exchange canal to inject its charge state to negative ion and to inject into the HI-3 tandem.

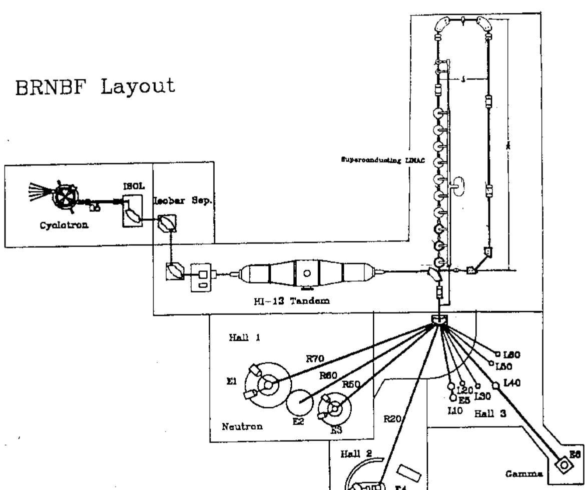

Fig.1. plan view of the BRNBF

A super conducting heavy ion linac accelerator will be built as a post accelerator, which can give the energy gain of 17MeV/q. By this facility an intensity of more than 10^9 pps, 5MeV/u radioactive exotic ion beam for mass up to A=140 will be expected. Investigation has shown that the BRNBF is technologically feasible in China. The BRNBF will be an advanced and competitive facility on the world in the first decade of next century[2]. It will be a major tool for searching for new nuclides and studying the nuclear structure physics, nuclear astro-physics, nuclear reaction mechanism, atomic physics, material science, life science as well as other application of nuclear physics.

The three accelerators of BRNBF can be operated in five different modes.

a) Single cyclotron operation.
b) Single tandem operation.
c) Combination of tandem and linear .
d) Combination of cyclotron and tandem.
e) Combination of three accelerators.

II. PRE-ACCELERATOR CYCIAE 70

As the pre-accelerator, a new proton cyclotron will be built on the west to pre-existing HI-13 tandem accelerator, and will provide 70MeV, 200μA proton beam, which will be used to bombard thick targets for producing radioactive nuclei.

The new cyclotron machine which called CYCIAE 70 combines the advantages of solid-pole and separator sector cyclotrons of three system: external negative hydrogen ion source and injection system; magnet and RF system; stripping foil and beam transportation system.

Since 1995, some R & D programs for CYCIAE 70 have been carrying out. For example, the beam dynamics, the magnet computation and test of Dee and RF cavity model have been carried out. In addition, 3.5 mA negative hydrogen ion source has been developed in CIAE.

III ISOL SYSTEM

The mass separator is composed of the target/ion source system, match lenses, 90^o magnet with ρ=1.3m and charge exchange canal. Whole equipment of the spectrometer are located on a high-voltage platform with potential up to 300kV. The platform connect the primary proton beam line and the isobar separator system beam line by two accelerator tubes. The layout of the ISOL system is shown in Fig. 2.

Production rates for various exotic elements such as C, O, F, Na, Si, P, Cl, K, Cu. As, Nb, Tc, Rh, up to In using (p,xn), (d,xn) reactions by proton, or deuteron beam at 50-70 MeV are the region of 10^8--10^{11} atoms/pμA/s. In general, the production efficiency of primary beam to exotic nuclei is about 0.1%. The conversion efficiency of exotic atoms to charged ion inside the ion source can be estimated as 30%. The efficiency of beam transportation from ion source, through on-line isotope separator, to the entrance of tandem accelerator is about 50%. In addition, most elements which have lower electron affinities are difficult to be ionized into negative ions directly. They have to pass through the charge exchange canal to convert

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the charge state from positive to negative. The conversion efficiency is about 30%.

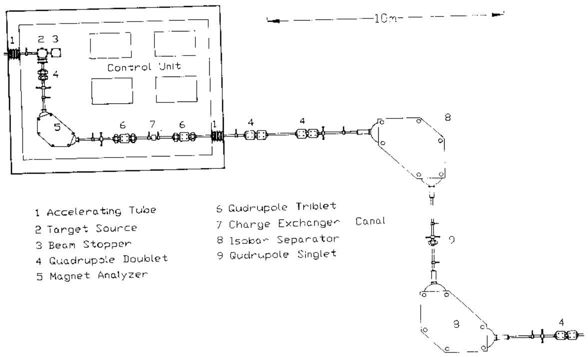

Fig.2.: The layout of the ISOL system

A modified version of the ISOLDE type electron beam plasma source will be chosen as the main source at BRNBF, which has been selected and redesigned for ORRIBF facility at Oak Ridge National Laboratory [3],[4] .Desirable properties of the target materials are fast diffusion and effusion release of RIB species, such as, high production cross section; high melting point; low vapor pressures at high temperatures and large diffusion coefficients. In order to achieve a high performance isobar separator, the second high resolving mass separator at ground potential has been designed with two 90^o ρ=2.5m opposite bending magnets. The mass resolving power is about 20,000 at the image slit of the second magnet.

Due to the interactions of the intense primary proton beam in the target activate the target itself and the second neutrons activate the source structural materials, the platform room should be shielded by a heavy concrete and a remote handling system for the routine maintenance of the target-ion source has to be needed.

IV. SUPER CONDUCTING LINAC.

In order to extend the region of stable and the radioactive ion species with energy higher than relative Coulomb barrier, a superconducting linac as a booster following the tandem accelerator has to be planned to build. The sketch of the booster linac is shown in Fig. 3 A new post stripper accepts the high energy beam coming from the tandem. Two 45^o magnets form a L-bending transport line with one single quadrupole lens being inserted in between, to preserve isochronism and achromatism of the symmetric beam line. Two quadrupole triplets focus the beam to the object slit of the second isochronism and achromatism system to be composed of two 90^o magnets and a single quadrupole lens in between. The mode of the resonator for linac sections is the cylindrical coaxial quarter wave resonator (QWR) which was very successful developed at Weizimann Institute[5] , University of Washington [6] , Stony Brock[7], Legnaro Laboratory[8] and JAERI[9]. Their experience shows that the excellent frequency stability, the simple structure for manufacture and balance electrically, the broad curve of the transit time factor, the low peak surface field values and wide energy per nucleon range together with the low cost constitute are the important advances in technology of superconducting resonators for heavy ion linac.

In the proposal facility, the QWR resonators should cover the β_i values from 0.05 to 0.10 and β_0 values from 0.10 to 0.16. We choose 20 cavities of the optimum low β section with β_1=0.07 for frequency of 108 MHz and 20 cavities of the optimum high β section with β_h=0.10 for frequency of 144 MHz.

The concept design of the RF system, the control system, the vacuum system and the beam optics for the superconducting Linac accelerator have finished. The R & D of the mechanical and electrochemical preparation of the substrate of the cavity, the technology of the Niobium-sputtered copper QWR resonators have been testing in Peking University.

V. CONCLUSION

The proposal for radioactive nuclear beam is anextension project of the present tandem accelerator. The pre-accelerator provides the primary beam and the radioactive beam. The post-accelerator increase the energy, not only for the radioactive ion but also for the stable ion. The existing tandem accelerator, switch magnet, experimental area and the date acquisition system are used to perform the radioactive nuclear experiments.

In order to reach the internationally advanced level in the area of radioactive nuclear beams in a period as short as possible, the existing technology, both home and abroad, will be adopted in the proposal.

a) A 30 MeV, 350µA high intensity proton cyclotron constructed by CIAE delivered beams in October, 1994. The proposed 70 MeV, 200µA cyclotron will used the similar technology.

b) The existing tandem has been in good operating condition since it put into operation in 1987. The main fragile spare parts are home made. The expertise of the technical staff is compatible to the BRNBF operation and maintenance.

c) The proposed superconducting LINAC is the same type as being built in the United States, Japan, Italy, and Israel. The Know-how would help our project. Peking University has accumulated rich experience in the R & D of superconducting cavity. Collaboration of CIAE and Peking University is important in constructing the LINAC.

d) On-line isotope separators have been build in both CIAE and Institute of Modern Physics (IMP) in China. The target/ion source technology can be learnt from CERN and ORNL.

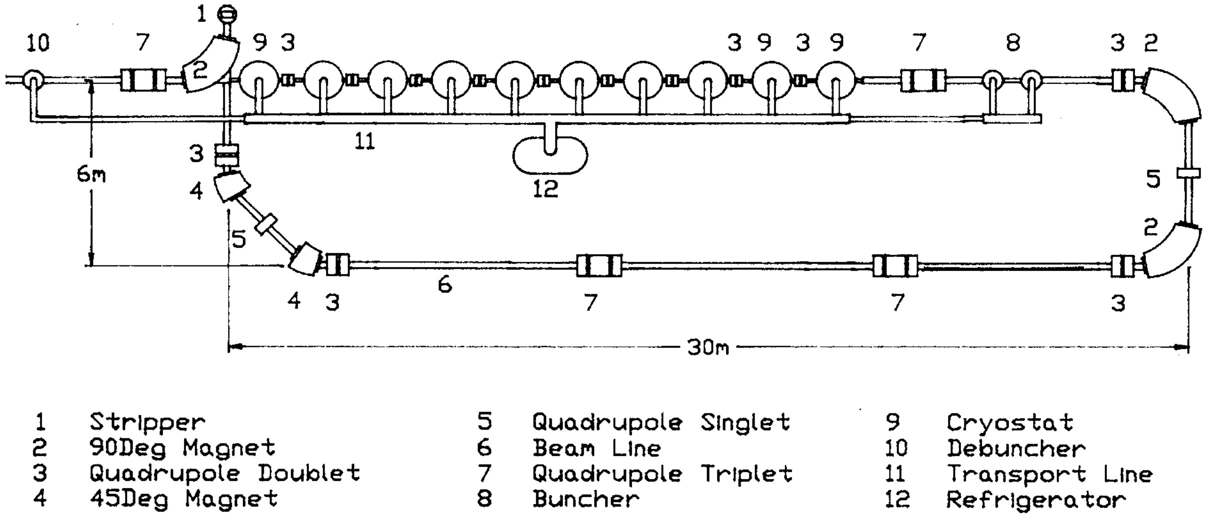

Fig. 3 sketch of the booster linac

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