ACCELERATOR BASED ACTIVITIES IN INDIA

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Abstract

In India, major accelerator related programs are being pursued at BARC/TIFR-Mumbai, VECC-Calcutta, NSC-Delhi and CAT-Indore. At BARC/TIFR, research programs are being pursued with the 14 MV Pelletron accelerator and at NSC-Delhi the 15 MV pelletron accelerator is being used to carry out a variety of accelerator based research studies. At VECC-Calcutta, the existing cyclotron is being upgraded to also deliver heavy ion beams through injection by a ECR ion source. Work towards installing a K=500 superconducting cyclotron is also in progress at VECC, Calcutta. At CAT-Indore, a synchrotron radiation facility based on 450 MeV electron storage ring is being commissioned and work is also in progress to build a synchrotron source based on a 2.0 GeV storage ring in the near future. We have also the international collaboration programs, particularly involving high energy accelerator facilities abroad. This report gives an overview of the different accelerator based programs in India.

1 INTRODUCTION

India had embarked on the accelerator program with the setting up of a 1 MV Cockroft-Walton accelerator at the Tata Institute of Fundamental Research (TIFR), Mumbai and a low energy cyclotron at Saha Institute of Nuclear Physics (SINP), Calcutta in the fifties. In the early sixties, a 5.5 MV Van de Graaff accelerator was installed at the Bhabha Atomic Research Centre (BARC), Mumbai. A 2.5 MV Van de Graaff accelerator at IIT, Kanpur and a low energy (5 MeV protons) cyclotron at Punjab University, Chandigarh were also installed in the sixties. These facilities along with the APSARA and CIRUS research reactors at Trombay and available radioisotopes served as the mainstay of experimental nuclear physics research in the country for nearly two decades, till the variable energy cyclotron (K=120) became operational at Calcutta in the early 80's. Subsequently, two tandem accelerators at Mumbai (Bombay) and Delhi also got commisioned around 1990, which initiated heavy ion based experimental research programs in India.

There are, at present, a number of other low energy accelerator setups in the universities and in the various research centres, such as a 3MV tandem at CCCM, Hyderabad, a 2 MV indigeneously built tandem at IGCAR, Chennai (a similar one was earlier built at BARC), a 8 MeV electron microtron at Poona and a 12 MeV electron microtron recently setup by CAT at Mangalore University. Also, in place of the old 5.5 MV Van de Graaff accelerator, a folded 7 MV tandem accelerator is being installed at BARC. These low energy accelerators are meant for basic and applied research studies in several interdisciplinary areas. In this paper, we will not give details of these low energy accelerators as well as of other low energy accelerators set up for industrial and medical applications and will focus only on medium and higher energy accelerator facilities.

The K=120 variable energy cyclotron was indigeneously constructed and commissioned in the early 80's at Calcutta which started the medium energy accelerator based research programs in the country. A major advance was made when the 14 MV heavy ion tandem accelerator (14 UD Pelletron) facility was jointly set up by BARC and TIFR in 1989 at TIFR, Mumbai, which enabled Indian scientists to embark on research programs with the medium energy heavy ion beams. In 1991, another tandem accelerator facility with 15 MV terminal voltage (15 UD Pelletron) was set up under the auspices of the University Grants Commission at the Nuclear Science Centre (NSC), Delhi which gave a major boost to accelerator based research programs in the universities. A new centre called Centre for Advanced Technology (CAT) was started at Indore in the eighties, where at present a synchrotron radiation facility comprising of a 450 MeV electron storage ring is being commissioned and work is also in progress to build a 2.0 GeV synchrotron radiation source. Presently, upgradation of this ring to 2.5 GeV electron storage ring is under serious consideration. Discussions are also in progress on a proposal to set up a multi-Gev proton accelerator facility to provide spallation neutrons, secondary mesons and radioactive ion beams for research in several areas such as nuclear physics and condensed matter physics and for studies relating to sub-critical accelerator driven systems. Apart from the indigeneous accelerator programs, we are also having a number of international collaboration programs , particularly involving high energy accelerator facilities and photon sources abroad. As there are presentations in this conference covering more details on the accelerator facilities at NSC-Delhi, CAT-Indore and VECC-Calcutta, in this paper we will only briefly describe these and cover other programs in more detail.

2 BARC-TIFR 14 MV PELLETRON ACCELERATOR FACILITY

The 14 MV tandem Van de Graaff (Pelletron) accelerator was set up and commissioned at the TIFR campus in 1989, as a collaborative BARC-TIFR program. The main accelerator parts were supplied and installed by EII, USA. The pelletron high pressure vessel, parts of SF_6 gas handling system, five port swicthing magnet, beam lines and the pelletron control system were set up with indigeneous effort. The analysing magnet is designed to have the provision for delivering the beam into two separate beam halls A and B. This accelerator facility is described in more detail in Ref.[1]. A number of beamlines and experimental facilities have been set up in the beam hall A to pursue research programs in several areas. The experimental facilities include a general purpose scattering chamber, a large area ionisation chamber, a recoil mass spectrometer (SHRI), BaF_2 and BGO gamma detector arrays, CSHPGE detector array, and charged particle and neutron detector arrays etc. Research programs are being carried out in nuclear physics, atomic & molecular physics, condensed matter physics and accelerator physics areas. In nuclear physics, a large number of studies have been carried out in elastic and inelastic scattering, transfer, fusion and fission reactions, and in nuclear spectroscopy of a large number of nuclei at the high spins. The accelerator physics research includes work in the areas of ion source, charging system, superconducting RF resonator and lead plating developments. A beam buncher based on double harmonic bunching has been installed at the low energy section of the accelerator, which provides about one nanosecond beam bunches with about 100 nanosecond separation [2]. The beam buncher enables experiments involving the lifetime and time of flight studies and also provides the proper time structure for the superconducting LINAC booster.

The superconducting LINAC is being installed in the beam hall B, as the second phase of the accelerator development to further increase the energies of the heavy ion beams. The LINAC booster is proposed to have seven accelerating modules, each containing four quarter wave resonators (QWR), to provide an energy gain of about 14 MeV/charge. The bunched beam from the pelletron accelerator is further bunched with a superbuncher which is a 150 MHz, β=0.1 splitloop resonator of lead plated OFHC copper before entering the LINAC. The superbuncher has been tested to provide Q 1.6 x 10^8 and found suitable to compress 1-2 ns beam bunch from the pelletron accelerator obtained from the double drift harmonic buncher to a value of 200 ps needed for injection into LINAC. The accelerating elements in the LINAC are independently phased 150 MHz, β = 0.1 superconducting quarterwave resonators (QWR) made out of OFHC copper, plated with lead and housed in modular Helium cryostats. The fabrication of QWR's is being carried out at the Central Workshop, BARC and the lead plating is being done at the facility set up at TIFR. One module of four lead plated QWRs has been tested with the beam and with 90 MeV ^{28}Si beam injected into the module, an energy boost of about 5.7 MeV was measured during operation of 3 out of 4 resonators matched to a common reference frequency [3, 4]. Presently, two modules are in various stages of completion and additional 5 modules are proposed to be added. A new user beam hall will also be constructed for experiments with the higher energy beam obtained from the LINAC.

3 NUCLEAR SCIENCE CENTRE , DELHI

This is an inter-university research facility of the UGC, consisting of a 15 MV Tandem pelletron accelerator. A number of experimental facilities for research in nuclear physics, atomic physics, material and biological sciences etc. have been set up at this accelerator centre. These includes a recoil mass spectrometer (HIRA), a gamma ray detector array with CSHPGE and BGO detectors, general purpose scattering chamber etc. There is also a program to boost the beam energy through the use of superconducting RF resonators with Nb as superconducting material. In this augmentation project, each module would consist of four Niobium four gap resonators of 97 MHZ and β = .08, being designed and developed in collaboration witn the Argonne National Laboratory, USA. Further details on this program are being presented in a separate talk at this conference [5].

4 VECC, CALCUTTA

The variable energy cyclotron was commissioned in the early 80's and was the first accelerator facility in the country for advanced experimental nuclear physics research [6]. The machine provided protons and α particles for a variety of nuclear reaction and spectroscopy studies. An ISOL facility was also set up for separstion of short lived radioactive nuclei produced in α induced reactions.

Presently, two important programs are underway to augment the accelerator based research facilities at this centre. Firstly, the cyclotron is being presently upgraded to deliver heavy ion beams by setting up an ECR heavy ion source, an axial injection beamline and making required changes in the cyclotron vacuum and other sub-systems. This project is nearing completion and experimental programs with heavy ion beams should be starting soon. Other important project at this centre is to set up a K=500 superconducting cyclotron for research with intermediate energy heavy ion beams in the coming years. For more details of the augmentation programs at the VECC, Calcutta in particular, the superconducting cyclotron program, we refer to the separate paper being presented at this conference [7].

5 ELECTRON ACCELERATORS FOR SYNCHROTRON RADIATION SOURCE AT CAT, INDORE

The synchrotron radiation sources INDUS-I and INDUS-2 are being constructed at CAT, Indore. INDUS-1 is a 450 MeV electron storage ring for the production of VUV radiation. The INDUS-2 which was earlier planned to be a 2 GeV ring, is presently being considered for upgradation to 2.5 GeV ring for higher intensities in the x-ray region. The injector system, for both the rings consists of a 20 MeV microtron, and a synchrotron which can deliver upto 700 MeV electrons, suitable for injection into INDUS-2.

INDUS - 1

INDUS-1 is presently under commissioning tests and six beamlines are at various stages of construction, testing and installation for research programs. Initially, INDUS-1 was planned as a weak focussing storage ring consisting of four bending magnets each with a field index of 0.5 and a bending magnet field of 1.5 Tesla. The design of the ring was similar to that of the storage ring SIBERIA-1 of BINP, Novosibirsk. During the course of studies, it was felt that there must be adequate flexibility in the operation of the ring. The lattice design was thus modified to the present one as described in Ref. [8].

The INDUS-1 accelerator will be used to carry out spectroscopic research in atomic, molecular and solid state physics, by studying the absorption, fluorescence and photoelectron spectra. The photophysics beamline is built around a Seya-Namioka monochromator covering the spectral region of 500 - 2000 A. By exploiting the inherent time modulation of the synchrotron source, this beamline facility will provide information about excited state lifetimes in molecular systems. The photoemission spectroscopy beamline employs a 1.4 m focal length toroidal grating monochromator, terminating in an electron spectrometer, to be used for both angle integrated and angle resolved photoelectron spectroscopy. More details on the beamlines and experimental programmes using the INDUS-1 accelerator can be found in Ref.[9].

INDUS - 2

For this ring, an expanded Chasman Green type of lattice (a double bend achromat) has been selected and optimized. The ring will consist of eight unit cells each providing a 4.5 m long straight section. Each unit cell will have two 22.5 bending magnets, a triplet of quadrupoles for the control of dispersion in the achromat section and two quadrupole triplets for the adjustment of beam sizes in the long straight section(4.5 m long) and four sextupoles in the achromat section for the correction of chromaticities. An advantage of this configuration is that the two long gaps between the quadrupoles in the achromat section can be used for accommodating beam diagnostic and vacuum devices.Furthure description of the INDUS - 2 facility can be found in Ref. [10], and also in a separate paper presented at this conference [11].

6 INTERNATIONAL COLLABORATIONS

India is also collaborating with major international accelerator facilities in Europe, USA and Japan. The contributions have been mainly in the areas of accelerator technology, software development, detector fabrication and experimental programs. Under the CERN-India agreement, India is making in-kind contributions, by way of hardware, software and manpower to the Large Hadron Collider (LHC), being built at CERN. As a part of this activity, CAT, Indore has taken up work towards supply of some of the accelerator parts such as the corrector hexadecupole magnets and vacuum components for the LHC at CERN in very large numbers. Earlier, the groups from BARC and VECC had contributed to the development of the control software for acceleration of Pb ions at the SPS, and now BARC teams are getting involved with software activities related to LHC at CERN.

On the experimental front, the high energy groups from TIFR have been collaborating with CERN for a number of years in many of the pioneering high energy physics experiments performed at the LEP collider. For carrying out these experiments, the TIFR groups have also participated in the development of gas and scintillation detectors for the L3 detector set up. The scientists from TIFR and Delhi/Chandigarh universities have also participated in the D0 experiments at the FERMILAB, USA, which led to the discovery of the top quark. They are also involved in contributing to the upgradation of the D0 experimental setup. In the last few years the VECC group, in association with Jammu, Chandigarh and Jaipur universities and Institute of Physics, Bhubaneswar have participated in the WA98 experiment at SPS, CERN. These groups have built a Photon Multiplicity Detector, consisting of several thousands of scintillators with fibre optic readout [12], which were used in the experiments in relativisitic heavy ion collision studies with the WA98 detector setup. More recently, the groups from BARC and Benaras Hindu Univeriesty have joined the PHENIX collaboration for relativistic heavy ion collision experiments to be performed using the BNL relativisitic heavy ion collider (RHIC) [13]. In the PHENIX collaboration, the Indian groups are involved in computer simulation studies [14], of the PHENIX detector and also in the work of fabrication of the tracking stations of the muon arm of the PHENIX detector. Many Indian teams from the national laboratories and universities are also making contributions towards construction of the CMS and ALICE detector set ups for the experiments with the upcoming LHC at CERN. BARC scientists are also collaborating in the experimental programs with COSY, Julich. For many years the groups from BARC have also been performing experiments at the spallation neutron facility at the Rutherford Appleton Laboratory in UK, having contributed a versatile neutron spectrometer for neutron inelastic scattering studies for experiments at one of the beam lines.

At KEK and RIKEN in Japan, many collaborative experiments involving scientists from different institutions in India are being pursued. A group from Utkal University, Bhubaneswar is involved in the BELLE experiment at KEK to study the CP violation in K decay. Scientists from VECC are participating in the radioactive ion beam (RIB) facilities at RIKEN. Indian scientists are also participating in the utilization of the 8 GeV SPRING-8 synchrotron source. Recently, a workshop was held in Mumbai to identify areas of further collaboration in the context of the upcoming facilities at KEK such as the Japan Hadron Facility (JHF). In the coming years, further areas of collaborations with Japan will be identified and strengthened.

7 PROPOSAL FOR BUILDING A MULTI-GEV HADRON FACILITY

There is a proposal to build a 3 GeV proton synchrotron in India, to cater to the research interests in many areas such as nuclear physics, condensed matter physics , radioactive beam physics and pion physics and also for R&D relating to accelerator driven sub-critical reactor systems. The proposed scheme is to start with a 2 MeV proton beam from a RFQ accelerator and boost the energy to 100 MeV using a LINAC. This in turn will be injected into the synchrotron ring to attain the maximum energy of 3 GeV,with fairly good intensity for secondary beam experiments. Based on these ideas, a detailed proposal is presently being worked out.

8 CONCLUDING REMARKS

Over the years India has achieved the capability to design, build and operate accelerators and carry out accelerator based research programs in the various frontier areas of nuclear science. India is now ready to expand its activities and base for setting up more advanced accelerator facilities by way of technologies and skilled manpower. We attach great value to cooperation amongst countriesin the field of accelerator activities and India is keen to play a significant role in international endeavours in this area.

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