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Delivery of Accelerated Ion Beams from Pelletron and LINAC for Experiments in HYRA and NAND

The complete linear accelerator (LINAC) of Inter University Accelerator Centre will consist of five cryostats (figure 1), the first one acting as superbuncher (SB) consisting of a single quarter wave resonator (QWR), the next three being LINAC cryomodules housing eight QWRs each, and the last one having two QWRs used as rebuncher (RB).

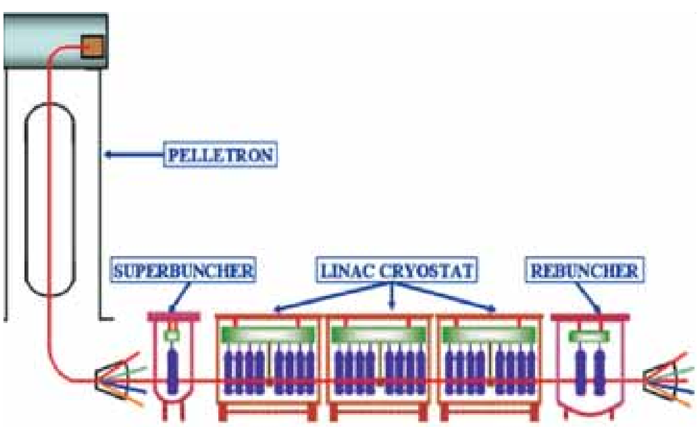


Fig. 1. The schematic of the Pelletron and the LINAC

In recent past, the remaining two LINAC cryostats were installed and aligned in the beam line as shown in figure 2. Since the initial cold tests of the resonators fabricated in-house are still going on, the indigenous QWRs are not yet installed in cryostats 2 and 3. The results achieved from the cold tests of the indigenous resonators in the test cryostat are encouraging and four resonators out of five have yielded an electric field of 4-6 MV/m at 6 watts of input power.

Fig. 2. The remaining cryostats 2 and 3 installed in the beam line

As three accelerating modules of LINAC were not ready, Pelletron beams further accelerated by the first linac module along with the Superbuncher were delivered for multiple users in the beam line of HYRA (Hybrid Recoil mass Analyzer) and NAND (National Array of Neutron Detectors). During this acceleration cycle, LINAC was operated for about two and a half months and no major problems were encountered. Three ion species were accelerated and the results, in brief, are given in Table 1. When the requirement of energy from the experimental group was less than maximal, resonators from the exit side of cryostat-1 were turned off to reduce the energy. In those cases, the last resonator of LINAC-1 was used successfully as a rebuncher cavity. During the LINAC acceleration, the superbuncher had produced a time width of ~ 150 ps at the entrance of LINAC and the maximum energy gain from all eight resonators of LINAC-1 was measured to be 3.25 MeV/charge state.

During the last LINAC operation, there was a significant progress in its automation. The drive coupler movement mechanism was made computer controlled with its position read back. During the incidents of frequency unlocking of the resonators, the complete operation was done from the Pelletron/Linac control room instead of going downstairs to lock the resonators manually. The automation of LINAC operation had helped to minimize the physical effort and was necessary for a smooth hand-over of LINAC operation to the present Pelletron operational staff.

Table 1. The beam species and their total energies delivered for experiments

Beam	Pelletron Energy (MeV)	Energy from Linac (MeV)	Total Energy (MeV)	Beam Line
$^{16}O^{+8}$	100	26 19	126 19	HYRA NAND
$^{19}F^{+9}$	115	25	140	NAND
$^{30}Si^{+11}$	126	40	166	HYRA

Hybrid Recoil mass Analyzer (HYRA) coupled with TIFR 4π Spin Spectrometer and HIGRASP setup at IUAC

The dual mode spectrometer, HYbrid Recoil mass Analyzer (HYRA), has been operational in the gas-filled mode of its first stage to select heavy fusion-evaporation residues (ERs) in the primary beam direction. Primary beam rejection and the efficiency of HYRA in gas-filled mode have also been studied and found to be excellent. One area of fusion-fission studies in heavy nuclei that needs more attention is the study of angular momentum distribution of ERs. The moments of angular momentum distribution of ERs give a better handle to understand the onset of fission and also to critically check the various theoretical models. Exclusive measurements of Giant Dipole Resonance (GDR) in excited nuclei by spin/ER gated high energy gamma ray measurements is another field where sparse data exist. The task of coupling HYRA with 4π spin spectrometer of TIFR and the HIgh energy Gamma RAy SPectrometer (HIGRASP) of IUAC was taken up as a collaboration between IUAC and TIFR staff to facilitate both these studies. All the 32 sodium iodide detectors and the associated electronics of 4π spin spectrometer were shipped from TIFR during end of April this year. The mounting structure for the array at HYRA target site with necessary options for movement of the two halves and for alignment as well as modifications to target chamber and beam-line assemblies had been designed and fabricated at IUAC by that time. The coupling of the devices was carried out in May, followed by facility tests in June and actual experiments from July to September. Pulsed beam from Pelletron boosted by the first module of superconducting LINAC, with time period between pulses adjusted as per the flight time of ERs through HYRA, was used in the experiments. GDR measurements were carried out using HIGRASP, gated by spin/ER with four plastic scintillators suppressing the cosmic background.

Fig.1. 4π spin spectrometer at HYRA target site on specially made structure

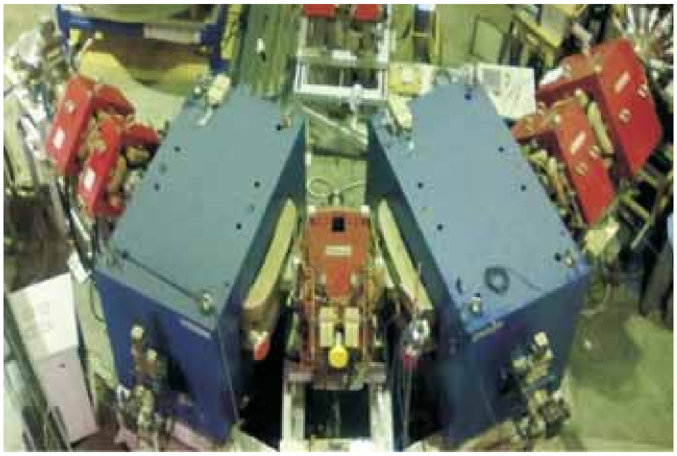


Fig. 2. First stage of HYRA coupled with 4π spin spectrometer and HIGRASP facility; Beam enters from the right and spin spectrometer

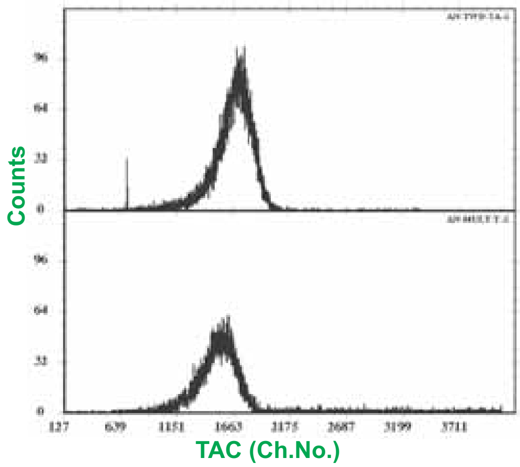


Fig. 3. TAC spectra started by focal plane signal and stopped by RF (top panel) and 'OR' signal of spin spectrometer (bottom panel); broader peak is from ERs and the sharp peak on the left in top panel is beam background

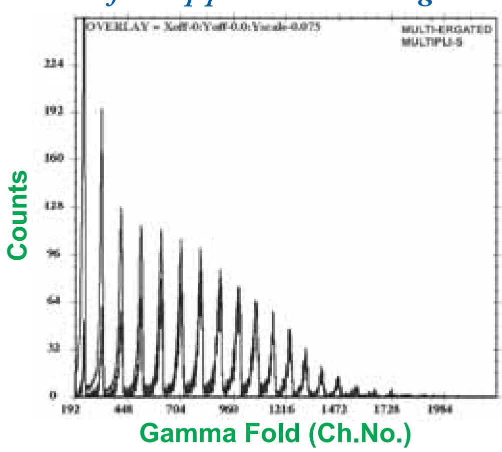


Fig. 4. Gamma fold spectrum (ER gated) superimposed with scaled down (7.5 %) singles gamma fold; Lower fold contamination is removed by ER gating; Matching of higher folds indicate ER transmission efficiency of 7.5 %

Figure 1 shows the assembly of 4π spin spectrometer at HYRA target site along with the mounting structure. Figure 2 shows the coupled system of HYRA-4π spin spectrometer-HIGRASP presently at IUAC. The photo multiplier tubes of five forward NaI detectors were wrapped with m-metal shield which could effectively suppress the effects of fringing field of the large entrance quadrupole of HYRA. This shows that the planned coupling of HYRA and Indian National Gamma Array (INGA) should pose no problem due to quadrupole fringing field as the 16 gamma detectors will be at 90o or backwards and at farther distances. Figure 3 shows the coincident timing peak with the Time to Amplitude Converter (TAC) started by ERs and, stopped by RF and delayed 'OR' signal from spin spectrometer, respectively for the fusion-evaporation reaction of 16O (120 MeV) with 180Hf. Negligible background is observed at the focal plane of HYRA with predominant detection of ERs. Figure 4 shows the comparison between singles gamma fold spectrum (scaled down to 7.5%) and ER gated gamma fold spectrum. The lowest two gamma fold events in singles spectrum are heavily contaminated by target/projectile excitation and the subsequent few gamma folds in singles spectrum are still contaminated by the fusion-evaporation reaction of the beam with entrance carbon window foil used in gas-filled operation. The ER gated spectrum cleans up these unwanted background, effectively. Higher fold events in the two spectra coincide in this projection where singles data are scaled down to 7.5 %. This value of 7.5% is the efficiency of transmission of ERs through HYRA for the settings used in this reaction. This novel method of extracting the transmission efficiency of ERs is lot easier to employ.

Experiments using Neutron Detector Array

Accelerated beams from the LINAC have been delivered to the neutron detector facility and few user experiments have been completed successfully exploring the reaction dynamics involved fusion fission reactions. The aim of the experiments was to measure the average number of neutrons emitted before (pre-scission) and after (post- scission) fission of the heavy compound nucleus produced in the reaction. It was achieved by detecting the neutrons in coincidence with the fission fragments. The neutrons were detected by an array of 24 liquid scintillators surrounding a 30 cm radius spherical chamber at a distance of 2 meter. The spherical chamber houses the targets, fission detectors and silicon detectors for beam monitoring. The fission detection system consists of two large area multi-wire proportional counters (MWPC) inside the chamber. The MWPC detectors were placed at folding angle to detect flying fragments in coincidence. The liquid scintillator is sensitive to neutrons as well as gamma rays and special custom made electronics were developed and implemented to discriminate neutrons from gamma background.

Figures showing the two MWPC fission detectors (above) and the array of neutron detectors (below)

Beams of 19F and 16,18O with energy varying from 90 MeV to 140 MeV were used on different target systems (198,196,194Pt, 204,206,208Pb). Experiments were performed in two stages, first using the tandem accelerator only and the second stage needed higher energy, which was accomplished using the tandem plus LINAC combination. A total of 86 list mode parameters were recorded using CANDLE data acquisition system developed in house at IUAC.

High Performance Computing Facility

The High Performance Computing facility, set up at IUAC with funding from the Department of Science and Technology, was inaugurated on the 27th of April, 2010, by Dr. V. S. Ramamurthy, Director, National Institute of Advanced Studies. The facility, one of the most powerful in the country, provides urgently needed supercomputing access to university users across the country, and also provides a boost to the ion-solid, nuclear physics and atomic physics simulation programs at IUAC. The facility is targeted at computational chemists, physicists and biologists in the university system, working in the areas of materials science, atomic and molecular physics and chemistry, radiation biology and nuclear physics.

In its first phase, the facility consists of a 400 gigaflop SMP system, a 6 teraflop distributed memory cluster, and the power and cooling infrastructure to support more than 50 teraflops of distributed memory computing. The Sun Enterprise M9000 shared memory system is configured with 20 SPARC-VII CPUs (80 cores at 2.52 GHz), 256 GB of RAM, and 3 TB of directly attached storage. The MPI cluster consists of 96 Sun Fire X2200 nodes with dual quad core Xeon CPUs, a total of 768 cores at 3.0 GHz. Each node is configured with 16 GB of RAM and 500 GB of disk, with a 20 GB/s Infiniband interconnect. In addition, 10 TB of storage is available on a PVFS2 cluster, also connected to the Infiniband. Together, the facility is configured to take on a variety of scientific HPC applications, with different requirements of CPU and memory access.

A new data centre has been set up on the first floor of the LEIB building to house the distributed cluster. With provision for 600 servers and associated network equipment in only 50 sq. m., this is one of the densest data centres anywhere. To adequately dissipate an estimated total heat load of 320 kW at 20 kW per rack, chilled water based in-rack cooling systems from Rittal have been used, the first such large scale deployment of water-based data centre cooling in the country. A system of four pumps and four 33 TR chillers supply chilled water to each rack in the data centre, through almost a kilometre of thermally insulated SS pipes. Ten modular rack-mounted UPS systems supply 500 kVA of electrical power to the data centre. Careful design and supervision of the electrical works and the piping, insulation and the hundreds of welds required has resulted in a data centre meeting all design criteria: the final installation was tested with 20 1 kW heaters in each of the 16 racks. An integrated remote monitoring system provides access to all data centre parameters such as voltage and power consumption, air and water temperatures, humidity, and water flow. The fire warning system is designed to cut off electrical power at the input end in case of a fire, and the suppression system is FM-200 based.

The utilization of the MPI cluster by the university community has been encouraging, with the 768-core system running at a steady 70-80% load. The system currently has users from Pune, Baraut, Kolkata, Delhi, Kharagpur, Tonk, Mumbai and Srinagar. Applications that have been run on the system include drug design using CPMD, DFT based electronic structure calculations (SIESTA), atomic physics calculations using GAMESS, and the nuclear shell model code being developed by Kashmir University and IUAC. While this is a good beginning, more software applications and many more users are expected to be added in the coming months.

Accelerator Mass Spectrometry

A new clean AMS chemistry laboratory for the processing of the geological samples has been set up at IUAC. The laboratory was inaugurated by Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Govt. of India on September 15, 2010. A workshop on AMS was conducted on the same day and many presentations were made by researchers in the field. The newly established chemistry laboratory will be used for the processing of geological, oceanographic etc. samples for the measurement of ^{10}Be and ^{26}Al isotopes. The laboratory is a metal free chemistry laboratory equipped with all modern facilities & has been designed to be kept at a positive pressure than the atmosphere pressure with the clean air of about 6000 class. Laminar Flow stations of 100 class air environment are being utilized for performing the column chemistry for samples processing.

IUAC AMS facility for the measurement of ^{10}Be ($T_{1/2}$= 1.34Ma) is already in operation and has been utilized by various user groups. Facility for 26Al ($T_{1/2}$=0.72Ma) measurement has also been developed and is in operation.

Materials Science Activities

Thin film of Pd-Carbon nanocomposite were synthesized by atom beam co-sputtering, showed the ferromagnetic behavior, which was enhanced twenty times by swift heavy ion irradiation Appl. Phys. Lett. 96(2010)053103. The healing of CNT's was demonstrated by 55 MeV C ion irradiation Jl. of Appl. Phys. 108(2010)034102. Structural transformation in Zircon and Schelite phases of ThGeO4 under SHI irradiation at room temperature and LN2 temperature have been studied. The track radius in the irradiation at LN2 temperature is found to be 4.5 nm as compared to that in case of room temperature irradiation as 3.5 nm. Ni-silica nanocomposite thin films were synthesized by atom beam co-sputtering with metal fraction from 10 at. % to 68 at. %. The films with Ni content below 56 at.% were superparamagnetic, whereas the films with higher Ni content were metallic in nature and were ferromagnetic Jl. of Appl. Phys. 107(2010)113913.

IUAC Silver Jubilee Celebrations

Inter University Accelerator Centre celebrated its silver jubilee year (1985-2010) on March 5, 2010. The celebration started with the welcome address by the Centre Director Dr. Amit Roy followed by an excellent inaugural speech by renowned Scientist Prof Yash Pal. Other eminent personalities like Prof. G.K. Mehta, Prof. P.N. Srivastava, Prof. N. Anantaraman, Prof. Rama Ramaswamy and Prof M.G.K. Menon were present in the morning session and gave a detailed account of the birth and growth of the Centre and how it has more than fulfilled the objectives of its founders. In the afternoon session, technical talks were presented by Dr. M. Toulemonde, Dr. W.F. Henning and Dr. S.S. Kapoor, members of the Scientific Advisory Committee. In the evening, there were reminiscences by those who have seen the centre grow up since its early days and who have contributed a lot towards its development, notably among others Dr. S.K. Datta, Dr. A.K. Sinha, Prof. H.S. Hans, Prof. S.P. Pandya, Prof. Hari Gautam, Prof. A. Nigvekar, Prof. S.C. Pancholi, Prof. S.B. Patel, Prof. M.K. Pal. A large number of IUAC user community along with IUAC employees and students were present throughout the day's programme. A memento representing a small model of the Pelletron Tower was presented to all the eminent personalities who graced the occasion. A colourful cultural programme marked the end of this day long celebration with all the IUAC campus residents joining in the proceedings.

Workshops /Schools/Acquaintance Programs (April – October, 2010)

A High Performance Computing facility was inaugurated at IUAC on the 27th of April, 2010, by Dr. V. S. Ramamurthy, Director, National Institute of Advanced Studies. This was followed by a workshop which basically focused on the facility which provides urgently needed supercomputing access to university users across the country, and also provides a boost to the ion-solid, nuclear physics and atomic physics simulation programs at IUAC.

A Workshop on Heavy Ion Radiation Biology was held on 22nd April, 2010 at IUAC which was attended by around 30 participants. There were 3 invited talks and 7 oral presentations. The deliberations covered the present research scenario and the future prospects in this research area.

Another Workshop on Ion Beams in Biomaterials was held on Aug 3 at IUAC. There were 12 presentations on recent trends and future directions in this field. The workshop focused on possible experiments in this area with IUAC facilities.

A four-day conference on Swift Heavy Ions in Materials Engineering and Characterization (SHIMEC 2010) was held on 6-9 October 2010 at IUAC. The conference had 20 invited, 20 oral and 56 poster presentations. The conference was attended by nearly 140 participants including 10 from abroad. A total of 58 manuscripts were submitted and selected papers will be published in a special issue of Radiation Effects and Defects journal. During the conference, it was decided to form an international advisory committee and to make this conference a regular biennial series.

A one day IUAC acquaintance program was held at Department of Physics, Tripura University, Agartala on Oct. 3, 2010. Lectures on Accelerators and Materials science were delivered by Dr. D. Kabiraj, IUAC. Mr. Rakesh Kumar of IUAC delivered lecture on Nuclear and Atomic Physics. Prof. A. Kumar of Tezpur University was invited to deliver lecture on their research work using IUAC ion beam facilities. Students of the University and faculty members of different Colleges participated in the program. Prof. A. Saha, Vice Chancellor of Tripura University inaugurated the program.

Two more acquaintance Programmes were held earlier this year at Visakhapatnam in March and at Mysore in June. The first one also was taken care of by Dr. D. Kabiraj and Mr. Rakesh Kumar of IUAC, while Dr. Fouran Singh was responsible for the latter one. Quite a number of participants, comprising of faculty members, research scholars and students from the neighbouring colleges and institutions, attended the programme. Possibilities of experimental research at IUAC in the fields of materials science and nuclear physics were discussed at length. The programmes ended with an open discussion with the participants. Topics related to Nuclear Physics, Materials Science and Radiation Biology were discussed which generated a lot of enthusiastic response from the participants The participants warmly interacted with the IUAC resource persons and expressed their interest on ion irradiation research work. One more such acquaintance programme is about to be held at Lucknow, on Nov.12, 2010.

Status of Teaching Laboratory

The usage of laboratory equipment developed under the Phoenix project is growing and some new ones have been added. A compact Geiger-Muller counter with USB interface and a 256 channel MCA with USB interface are now available. A new Phoenix live CD based on the popular Ubuntu GNU/Linux distribution has been made. This year we had conducted three training programmes for teachers at IUAC and a couple of "one day workshops" at other places. Python programming language is now a part of the Phoenix training program and a book titled 'Python in Education' written for this purpose can be downloaded from the Phoenix website. Phoenix based experiments are now part of the syllabus in some Universities. Those who are interested in information about training programs may join the mailing list by registering at the website www.iuac.res.in

Status of 15 UD Pelletron (April 1 to October 31, 2010)

Operation of Pelletron was quite satisfactory during this period. There was neither scheduled nor unscheduled tank opening maintenance of Pelletron in this period. A few problems were encountered which were rectified during the short maintenance period.

Switching amplifier of TWD has two banks and each of them contains six switching channels. Three channels in one bank and one channel in another bank were not working properly. The deflection voltages in these channels were not canceling out totally for the proper selection of beam particles. Tetrode valves of all these channels were replaced to solve the problem.

A leakage was observed in the bellow of pendulum valve in post acceleration section in closed condition. Therefore, the pendulum valve was kept open permanently for routine operation of accelerator. This leaky pendulum valve will be replaced during tank opening maintenance.

Sparking problem was observed in units #26 and 28, which were shorted using shorting rods. This solved the problem of unit sparking and the beam could be delivered to users at the terminal potential of 12 MV.

The MC-SNICS source was dismantled four times, twice for routine maintenance and twice for breakdown maintenance. During breakdown maintenance, the ionizer and einzel lens assembly were replaced and later the cathode contact problem was solved. Full cleaning of HV deck, GP tube cleaning and HV conditioning of GP tubes were also carried out.

The ion source could not be operated in both local and remote mode. The problem was traced to a 24 Vdc supply in local control console. Initially, in order to deliver the beam to the user in time, this power supply was replaced by a lab power supply. Later a new power supply was developed and installed in the local control console. This power supply is working satisfactorily since then. The last beam time finished on Oct. 3 and the chains were put OFF on Oct. 4.

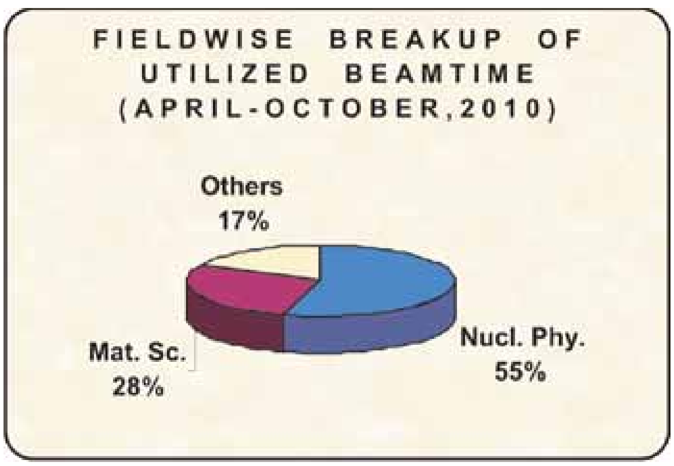
Pneumatic high pressure testing of SF6 storage tank is mandatory and it has to be done once in every five years. This testing for all five SF6 storage tanks was started after the beam runs were over. Few other minor maintenance works were also carried out during this period.

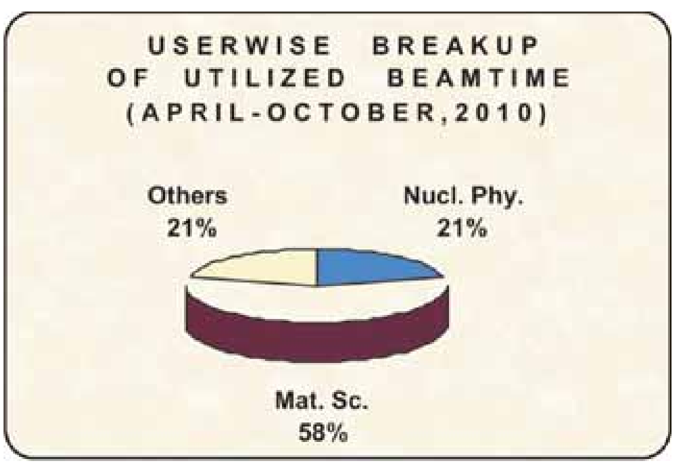
Maximum terminal voltage achieved during high voltage conditioning was 13.2 MV. 16O pulsed beam (89.3 MeV) was delivered to user at maximum terminal potential of 12.77 MV and 28Si beam (84 MeV) was delivered to user at minimum terminal potential of 9.34 MV. Out of total beam time of 2448 hours, 1314 hours of beam time was used for pulsed beam runs using multi harmonic buncher (MHB) along with low energy chopper and traveling wave deflector. 68 hours of total pulsed beam time was utilized by LINAC group for facility testing and 683 hours of remaining pulsed beam was delivered to users, after boosting beam energies using LINAC. Energies of 16O, 19F and 30Si beam were boosted using LINAC. 16O, 18O and 19F beams were bunched for different experiments for remaining 563 hours of pulsed beam. All the pulsed beam runs were quite stable.

The uptime of machine for this period was 97.66%. The beam utilization time was 55.56%

Statistical Summary

Total Chain Hours	=	4406 Hrs.
Beam utilization time	=	2448 Hrs.
Beam change time	=	8 Hrs.
Machine Breakdown time	=	103 Hrs.
Machine scheduled maintenance	=	0 Hrs.
Accelerator conditioning	=	1273 Hrs.
Beam tuning time	=	309 Hrs.
Experimental setup time	=	375 Hrs.





User List: April to October, 2010

University / Institute / College	Shifts utilized
Allahabad University	03
BH University, Varanasi	03
Calicut University	08
Dayalbagh Institute, Agra	04
Delhi University	51
GGSIP University, New Delhi	04
GND University, Amritsar	04
IIT, Delhi	02
IIT, Roorkee	03
ISRO,Bangalore	04
IUAC, New Delhi	52
Kalyani University, WB	02
Karnataka University	09
MS University, Vadodara	07
Mumbai University	02
Mysore University	02
NIT, Raukela	02
North Orissa University	03
Periyar University	02
PRL, Ahmedabad	02
Punjab University	49
Rajasthan University	02
Tezpur University	04
TIFR, Mumbai	18
Utkal University	03