4. EXPERIMENTAL FACILITIES IN BEAM HALL

4.1 GENERAL PURPOSE SCATTERING CHAMBER (GPSC)

M. Archunan, Golda K. S. , A. Kothari, P. Barua, P. Sugathan and R.K. Bhowmik

The GPSC facility has been used for experiments in various fields of physics viz. nuclear physics, materials science, and atomic physics. Many attachments and alternations are made in the mechanical structure and control system of this chamber as per the unique requirement of each experiment carried out. There is provision to use the part of the existing National Array of Neutron Detectors (NAND), along with GPSC for neutron measurements in nuclear physics experiments. A couple of experiments have been carried out using such facility to study the dynamics of heavy ion induced fusion-fission reactions.

Experiments carried out using GPSC

User	Experiment	Beam	No of shifts
Presidency College, Kolkata	Nuclear Track detection in polymers	S, Fe	2
Tezpur University	Development of conducting polymer based nano composites & SHI irradiation effects on them for multi functional application s	^{28}Si	2
Tezpur University	Nano material filled SHI induced ion tracks and their applications for nano devices	Cl	2
PRL, Ahmedabad	Plasmon Resonances in multiple ionization of large atoms and molecules	C O	9
MSU, Baroda	Mass asymmetry and alpha cluster effects in reactions with weakly bound nuclei	^{18}O ^{11}B	15
Anna University	Development of polymeric template assisted growth	Au Ag	2
ISRO	SHE radiation testing of electrical components	Si , Cl Ni	2
SINP, Kolkata	Coincident detection of alpha particles and identification of reaction channels in $^{6,7}Li$ + ^{64}Ni system at near barrier energies	^{6}Li	12
DAV, Jalandhar	Physico-Chemical changes of SHI irradiated N-vinyl-2-pyrrolldone grafted guar gum	C	1
Pune University	Formation of nano sized electronic devices in polymers through SHI	Si Ni	2
VECC, Kolkata	Study of fusion fission dynamics at near barrier energies	^{16}O (pulsed)	12
Punjab University	Emerging deep inelastic processes in reactions with symmetric light heavy ion systems above Coulomb energies	^{28}Si (pulsed)	15

4.1.1 Large Neutron Array: an upcoming facility

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The importance of exploring the heavy-ion reaction dynamics at bombarding energies ranging from Coulomb barrier to about tens of MeV above the Coulomb barrier is well recognized internationally. Some of the most important processes in this energy domain are Compound nucleus formation, massive transfer, deep-inelastic process, fusion-fission and quasi-fission. Due to a large transfer of energy between the projectile and target, the interaction zone gets heated to a temperature in excess of a few MeV. As a result, there is copious emission of light particles like p, n, α from the interaction zone. The systematics of light particle emission (i.e. multiplicity, angular distribution and energy distribution) has often been used to investigate the reaction dynamics. Neutrons, due to their lack of charge, provide one of the most sensitive tools for such a study. The energy spectra of neutrons, emitted during the early stages of the cooling down process, provide information about the nuclear level density at high excitation energy and spin. For the study of fission dynamics, neutron evaporation has often been used as a 'Clock' for establishing the time scale for formation-to-scission process.

There exist a few large high efficiency neutron detector arrays in the world to study the complex and exciting heavy-ion reaction processes such as fusion-fission, quasi-fission, deep-inelastic etc. Precise measurement of neutrons which are emitted at different stages (thus giving the clue about the dynamics of such reactions) of reaction between heavy ions in conjunction with the heavy fragments provide exclusive data and a unique possibility to explore such complex nuclear processes.

To be able to acquire such high precision exclusive data, a National Array of Neutron Detectors (NAND) consisting of one hundred 5″ (diameter) × 5″ (length) neutron detectors has been proposed to be set up at IUAC, New Delhi. These detectors coupled with commercially available fast PMTs can provide time resolution of about one nanosecond (elaborated in section 212) and good intrinsic detection efficiency ranging from ~ 60% to 30% for neutrons of about one MeV to 20 MeV. Such a facility would provide simultaneous information about neutron energy distribution and multiplicity distribution, and would be an internationally competitive facility.

The project for a modular neutron detector array of ~100 detectors has been conceptually accepted by the DST. A Time of flight set up with a flight path of 1 meter would be an optimum configuration for neutron multiplicity measurement for high fold distribution without appreciably compromising the energy resolution. A small number (~ 20) of detectors would be placed at a distance of 2 meters to obtain high precision data on neutron time of flight. In order to have a high fold neutron measurement in coincidence with fission fragments, the neutron array will be complimented with a high efficient fission fragment detecting system. This array with a total neutron detection efficiency of ~4% will be a unique set up which enables the measurement of second and higher order momenta of pre-scission neutron multiplicity.

The specific requirement of signal processing and data acquisition system for such a large detector array could be efficiently tackled with the indigenous development of custom made electronics. Our previous experience in in-house development of nuclear instruments [2-5] gives us the confidence in taking up the challenge of fulfilling the very specific demands of the proposed detector array.

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4.1.2 Optimization of Flight Path in Neutron TOF Spectrometers

Golda K.S. and R.K. Bhowmik

Neutron energy and angular distribution is an important information from where one can extract neutron multiplicities which reflects the time scales of fusion-fission reactions. The concept of 'neutron clock and thermometer' in fusion-fission experiments was initiated by Hinde et.al [1]. The energy measurement of fast neutrons is done either by converting the scintillation light outputs measured with the liquid scintillator into neutron energy spectra using unfolding method or by the time of flight (TOF) method. The unfolding method requires the response functions of the scintillator with good accuracy to avoid the nonphysical oscillation or distortion of the unfolded spectra. Since the detection of neutrons using scintillators depends on secondary reactions, the light output need not be proportional to the energy of the impinging neutrons and hence getting a proper response function is always not very simple. Therefore TOF is the preferred method to obtain energy of neutrons [2]. When the energy distribution of neutrons is used to extract neutron multiplicities and temperatures, the energy resolution of the system is one of the limiting parameters. A detailed computer simulation is carried out to understand the effect of resolution of the TOF setup on the uncertainty in the extracted parameters [3].

The simulations carried out shows that when the detector distance is very large compared to the cell thickness the observed energy distribution approaches the real distribution (figure 1). However, in a realistic experimental setup having a very large flight path and a very thin detector is at a disadvantage since the efficiency of such a setup is extremely poor and background neutrons would be comparable with genuine events. A new approach of analysis of neutron TOF spectra is suggested by O. Alyakrinskiy et. al., [4] where the three dimensional (time of flight, amplitude of energy signal and neutron-gamma pulse shape discrimination) response matrix of the detector is used by allowing measurements with higher efficiency systems of large detector volumes at shorter distances. Nevertheless, this kind of analysis technique requires exact knowledge of the response matrix, which is a function of detector properties, for the energy region of interest. Hence, in practical point of view, TOF method with large flight path is the preferred technique for the energy measurement of fast neutrons. A judicious selection of parameters such as cell thickness and flight path are crucial in the design of TOF spectrometers by optimizing the energy resolution without compromising the detection efficiency of the system. The energy of neutrons emitted in a fusion-fission reaction is predominantly below 10 MeV with maximum around 2MeV. Figure 1 clearly shows that in this energy region, the deviation from the expected distribution is not substantial for 2m flight path. It is to be noticed that the yield at 10MeV is only ~1/25th of the peak value, where error in the energy measurement is about 10% due to limited resolution of the spectrometer. When the observed energy spectrum is used to extract the source parameters viz. pre- and post-scission temperatures and neutron multiplicities by chi-square minimization, the deviations in energy spectrum can cause large uncertainty in the extracted parameters. However, when a large modular neutron array is used to study the distribution of the pre- and post scission neutrons produced by different possible mechanisms involved in nucleus-nucleus collision, a shorter path length is a better option. It is to be noticed that high statistics higher order fold distribution is essential to extract shape and width of neutron multiplicities.

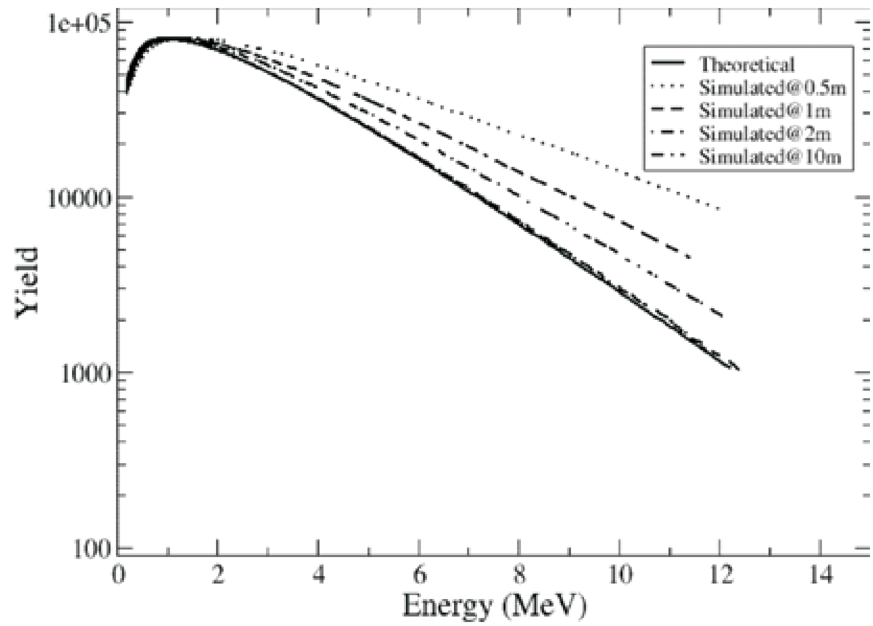

Fig. 1. De-convoluted energy spectra at different flight paths. No correction for detector time resolution has been taken into account in this analysis.

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4.2 GAMMA SPECTROSCOPY GROUP

Kusum Rani, S.K. Saini, A. J. Malyadri, Rajesh Kumar, S.K. Suman, Archunan, Ashok Kothari, P. Barua, E.T. Subramaniam, Mamta Jain, S. Venkataramanan, Arti Gupta, S. Rao, U. G. Naik, Raj Kumar, S. Muralithar, R.P. Singh, Rakesh Kumar, N. Madhavan, S. Nath, J. Gehlot, J.J. Das, P. Sugathan, A. Jhingan, T. Varughese, K.S. Golda, D. Negi, Anukul Dal, Gellanki Jnaneswari, Tarkeshwar Trivedi, Kumar Raja and R. K. Bhowmik

4.2.1 Indian National Gamma Array (INGA)

The INGA facility had first cycle of experiments of eighteen users of nuclear physics community of the nation. All the support systems of INGA (support structure with movement system, detector power supplies, LN2 'Autofill', analogue processing units, Analogue to Digital converters, and Data Acquisitions) developed in-house worked without failure throughout the cycle of experiments.

The following experiments were carried out this year using the combined GDA/INGA facility:

Date	Description	Beam	Energy MeV	User
24-3-08	High Spin Structure in ^{112}In and nearby nuclei to search for chiral bands and deformed bands.	^{16}O	75-90	R. P /TIFR
02-4-08	Magnetic dipole and Electric Quadrupole rotational structures and Chirality in A ~ ^{100}Ag isotopes	^{28}Si ^{11}B	100-130 60-70	NS/PU
10-4-08	Lifetime measurements of highly deformed band in ^{124}Ba using DSAM technique	^{34}S	135-150	AKS/ IIT, Kharagpur
18-4-08	Study of "Highly Deformed" band in of N = 80, ^{138}Ce	^{12}C	60-70	TB/ VECC
25-4-08	Spectroscopy of N ~ Z Nuclei, A=25-30 nuclei	^{16}O	25-45	AKS/UGC-DAE-CSR & LC / Raipur Univ
5-5-08	Investigation of interplay between tilted and principal axis rotation in neutron rich ^{110}Ag	^{18}O	65-70	SC/SINP & SR/ SNB-NCBS-Kolkata
13-5-08	Study of Octupole Correlations in lighter Np and Pu isotopes	^{7}Li ^{9}Be	30-55 40-60	MR/Andhra Univ.
21-5-08	Spectroscopy of Trans Lead Nuclei	^{19}F	105-120	SS/SINP
29-5-08	Different aspects of nuclear excitations at high spin in A ~ 130 region	^{16}O	75-90	AD/TIFR
6-6-08	Spectroscopy of Magnetic Bands in and around Z~ 64 & N ~ 82 shell closures	^{34}S ^{28}Si	140 130	SSG/UGC-DAE-CSR
13-6-08	Search for band termination of MR band in A~140 region	^{24}Mg	100-120	AG/SINP
23-6-08	Search for the role of proton and neutron orbits in Magnetic Rotation (A = 137 Nuclei)	^{19}F	85-100	AKJ/ IITR
30-6-08	Spectroscopy of fission fragments produced in heavy ion induced reactions using INGA set up at IUAC ;Study of neutron rich nuclei of mass 100 region using heavy-ion induced fission reaction	^{24}Mg	145	DCB/ BARC& PD/ SC (SINP)
19-9-08	Fusion-Fission dynamics A ~ 200 region	^{19}F	100	SN/IUAC

27-9-08	Study of shape changes in A= 70-80 mass region	^{28}Si	90	TT/AU
3-10-08	Study of muct-nucleon transfer & fusion around coulomb barrier	^{28}Si	103	SK/DU
16-10-08	B(E2) measurement in ^{112}Sn, ^{114}Sn	^{58}Ni	175	HJW/GSI
07-11-08	New terminating band structures in ^{155}Ho and high spin state studies of ^{154}Ho nuclei	^{35}Cl	145	LN/AU
13-11-08	High spin states in ^{107}In nucleus	^{16}O	70	DN/JNU

4.2.2 Servicing of Detectors

In this year seven clover Germanium detectors were serviced for annealing cum evacuation related problems using our dedicated vacuum station which helped in the INGA experiment's data collection. In addition one clover germanium detector each of SINP, UGC-DA-CSR, TIFR have vacuum leak problem from cryostat side requiring servicing to be done at factory.

4.2.3 New Recoil Distance Device (Plunger) for INGA

The design of the new recoil distance device for lifetime measurements in the sub-nanosecond range in conjunction with the Indian National Gamma Array (INGA) was frozen. Machining of the housing of the linear actuators, support flanges, the holding and alignment mechanism with the INGA is completed. In the picture below some of these parts can be seen. There will also be provision for an independent collimator and Faraday cup to monitor the beam. The design also allows us to use the plunger device in conjunction with the mass spectrometer HYRA along with INGA. The target chamber is a glass tube with internal diameter of about 40 mm. It will be coupled to the beam line on one side and the Aluminum adapter one the other side with double 'O' ring Wilson seal. The fabrication of the cones, invar stainless steel rods and the spacers is in progress. We have also ordered a spare DC linear actuator with same specifications as the earlier ones which had been tested in our lab.

Fig.1. Picture of the components of the new plunger for INGA; figure shows the motor housing, the glass chamber, the Wilson seal adapter, teflon support flanges and the motor and the connectors from the front and from the rear side.

4.2.4 Coulomb Excitation setup in GDA

A large annular PPAC from GSI was set-up in the GDA beam line for gamma-particle coincidence to study the Coulomb excitation of Sn isotopes. In the set-up four clover detectors without the shield were used at about 135 degrees relative to the beam direction. A combination of Cu-Sn-Pb absorbers was used on the clover detectors. The PPAC covered an angular range 15 to 45 degrees. Further details about the experiment are given in the research section. A large annular PPAC was also developed by IUAC detector lab, the details of this PPAC is given in section 3.3.1.

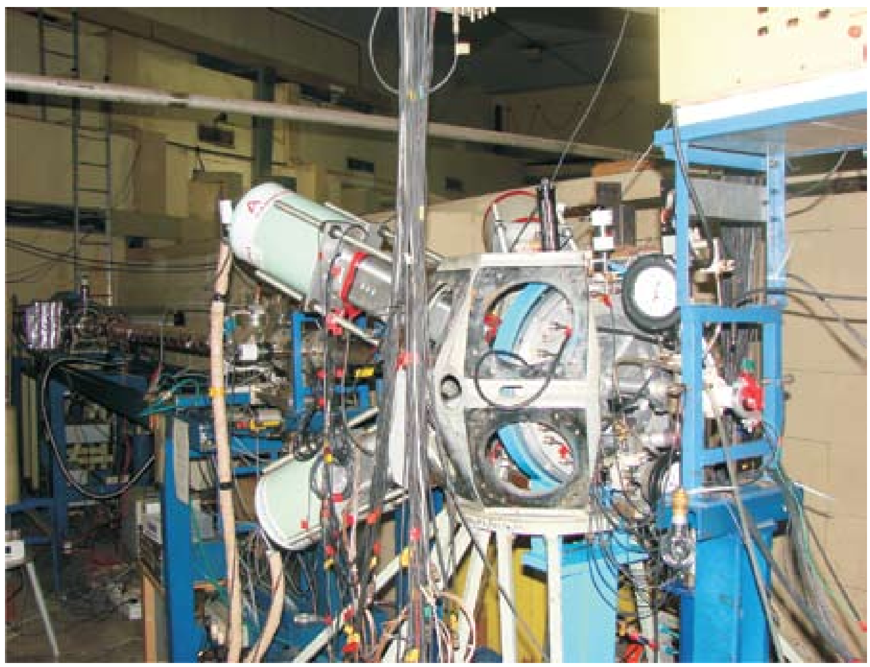

Fig. 2. Coulomb Excitation setup

4.3 RECOIL MASS SPECTROMETERS

4.3.1 Heavy Ion Reaction Analyzer (HIRA)

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HIRA [1] was used in three experiments involving stable beam and mass dispersive mode. The experiments carried out involved (i) continuation of the study of fission hindrance in $^{19}F + ^{184}W \rightarrow ^{203}Bi^*$ through evaporation residue (ER) cross section measurements, (ii) study of channel coupling effects in near barrier fusion reactions involving $^{28}Si + ^{90,94}Zr$ through ER excitation function and transfer measurements and (iii) study of ER tagged light charged particle evaporation in $^{28}Si + ^{45}Sc$ system to investigate the role of dynamical effects in modifying the energy distribution of evaporated particles.

In the first experiment, ER data were collected at higher beam energies after repeating few of the low energy data points taken earlier. HIRA transmission efficiency measurements were carried out by collecting ER-gamma coincidence data and gamma singles data using a 23% relative efficiency HPGe detector mounted at target site. This is crucial for proper cross section extraction as there are some isomers of half-life of about few tens to few hundreds nanosecond in neutron-deficient bismuth ERs which are populated in this reaction; these ions would not be charge reset by the Carbon foil at ~ 10 cm from the target. The focal plane detector used was a 50 mm x 50 mm position sensitive silicon detector. Beam rejection for this asymmetric system was excellent and pulsed beam with 4 microsecond repetition rate was used to reject the few beam-like particles that reach the focal plane.

In the second student thesis experiment, ER cross section measurements have been carried out from well above barrier to below Coulomb barrier for both systems which differ in transfer channel Q-values. Pulsed ^{28}Si beam with 2 microsecond repetition rate was used to get the TOF and also to reject scattered beam-like particles. A large, two dimensional position sensitive MWPC followed by an ionization detector was used for the detection of ERs at the focal plane. In addition to mass, charge state and energy scanning, angular distribution of ERs was carried out in 2 degree steps using 1 mSr solid angle of acceptance. These data along with theoretical calculations such as PACE [2] can be used to get the transmission efficiency of HIRA for ERs. To cross-check the transmission efficiency of HIRA for the ERs of interest, ER-gamma coincident and gamma singles data were collected as mentioned earlier. Preliminary analysis show that the transmission efficiency by the two methods agree with each other and with values obtained using simulation program [3]. A trial measurement of transfer products was attempted at higher energy using HIRA around grazing angle with reasonable success. We plan to take up the transfer measurements for the two systems in the next experimental cycle. Further details of this experiment are given by S. Kalkal et al. elsewhere in this report.

The last experiment involved HIRA as a tagging device. The primary interest was to get the exact energy distribution of light charged particles evaporating from compound nucleus formed in fusion reactions involving asymmetric and symmetric entrance channels to study the pre-equilibrium effects. To begin with, the more symmetric combination of $^{28}Si + ^{45}Sc$ was chosen. A Si ΔE-E telescope detector combination was used in the target chamber for the detection of evaporated, light charged particles and the ERs were detected at the focal plane using the position, energy loss and TOF measurements. HIRA was rotated from 0° to about 10° and ER-alpha coincident data was collected. Analysis is in progress in this experiment initiated by user from Panjab University.

HIRA has worked well in all these experiments. Another transfer/fusion reaction experiment initiated by user from BHU has been approved this year.

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4.3.2 HYbrid Recoil mass Analyzer (HYRA)

N. Madhavan, S. Nath, T. Varughese, J. Gehlot, A. Jhingan, P. Sugathan, A. K. Sinha[1], R. Singh[2], K. M. Varier[3], M. C. Radhakrishna[4], E. Prasad[3], S. Kalkal[2], G Mohanto, J. J. Das, Rakesh Kumar, R. P. Singh, S. Muralithar, R. K. Bhowmik, P. Barua, Archunan, U. G. Naik, A. J. Malyadri, Cryogenics group, Beam transport group

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Facility tests and first experiment could be taken up in HYbrid Recoil mass Analyzer (HYRA) only after the INGA first cycle was over in early November 2008. The first stage of HYRA (Fig. 1) in the momentum-achromat configuration has subsequently been tested in vacuum mode with alpha source. The gas-filled mode operation was tested with beam at the end of November and the first user experiment (a student thesis proposal) was taken up in early December. The details of the facility used and the results obtained are summarized below.

Gas-filled mode of HYRA

The gas-filled mode of HYRA was initially tested with the calibration system ^{16}O + $^{184}W \rightarrow {}^{200}Pb^*$ that had been well studied using the existing recoil separator HIRA earlier. ^{16}O beam of ~ 100 MeV (~ 96.3 MeV on the target, beyond the pressure window Ni foil of ~ 1.3 mg/cm^2 thickness) was made to interact with ~ 210 µg/cm^2 ^{184}W target on thick carbon backing, with carbon facing the beam. Two monitor detectors were placed on either side of the beam direction for normalization purposes.The focal plane (FP) detector system, the schematic of which is shown in Fig. 2, consisted of a 0.5 micron thick polypropylene foil of size 5″ x 2.5″ followed by a two-dimensional MWPC detector of size 57 mm x 57 mm consisting of only wire frames and a two-dimensional resistive Si detector of size 50 mm x 50 mm. A removable shutter was introduced between MWPC and Si detector so as to optimize

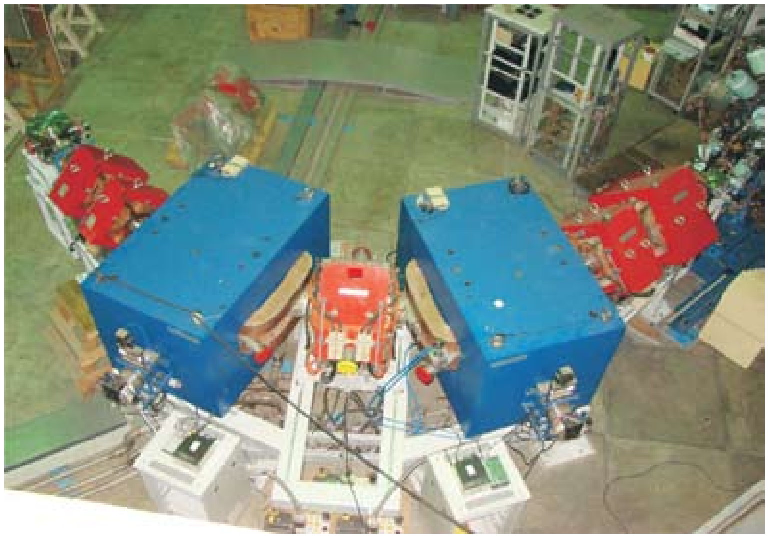

Fig.1. First stage of HYbrid Recoil mass Analyzer (HYRA)
(particles enter from the right side)

HYRA settings first looking at only MWPC signals and later, in the optimized condition, to allow the ERs to be detected in Si detector too. The focal plane detectors were maintained at ~ 1.5 mbar isobutane gas medium. The pressure of helium gas in entire HYRA was maintained constant during every run using the Baratron gauge - Solenoid valve - MKS gas pressure control unit combination.

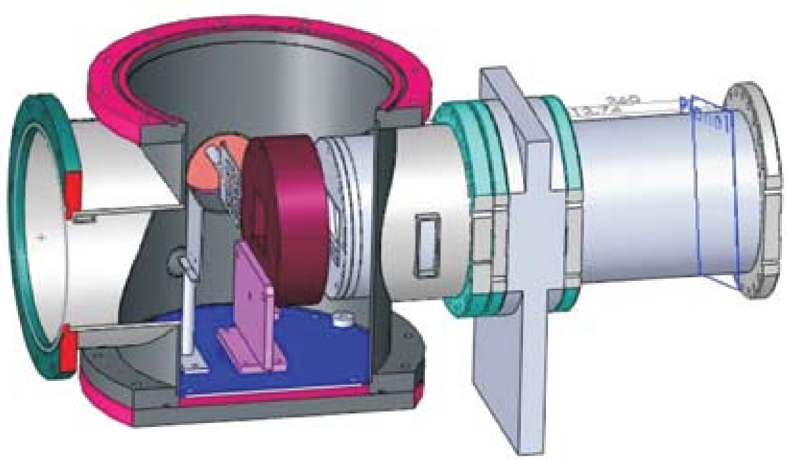

Fig. 2. Schematic of focal plane detector system of first stage of HYRA showing the window foil, cylindrical MWPC holder, removable stopper and 2D Si detector (particles arrive from the right)

The detection of the residual energy of such slow moving evaporation residues (mass ~ 195 amu ions of energy ~ 7 MeV immediately after target) at the end of gas-filled separator is non-trivial. Due to the large energy loss of these ERs in the helium gas of several meters length, the polypropylene foil and isobutane gas (~ 5 MeV), and a significantly large “pulse height defect” (~ 30 to 40 %) for low energy high Z ions, the measured pulse height of these ions is ~ few MeV only. The helium gas pressure in HYRA was varied to maximize the ER transmission rate through HYRA while ensuring that the beam-like particles reaching the focal plane were negligible. Figs. 3, 4 and 5 give the normalized ER detected at the focal plane for helium gas pressures of 0.5 Torr, 0.25 Torr and 0.15 Torr, respectively. The field values of the two dipole magnets were simulated and scaled around those values to get the transmission at various rigidity values. The quadrupole fields in HYRA and the last beam line steerer settings had initially been optimized at 0.25 Torr for maximum ER transmission though HYRA. For other pressure settings, the simulated magnetic dipole fields were used to scale the HYRA quadrupole fields (MD1 for Q1 and Q2, MD2 for Q4 and Q5 and average of MD1 and MD2 for Q3). The transmission of ERs was found to be maximized at 0.15 Torr pressure.

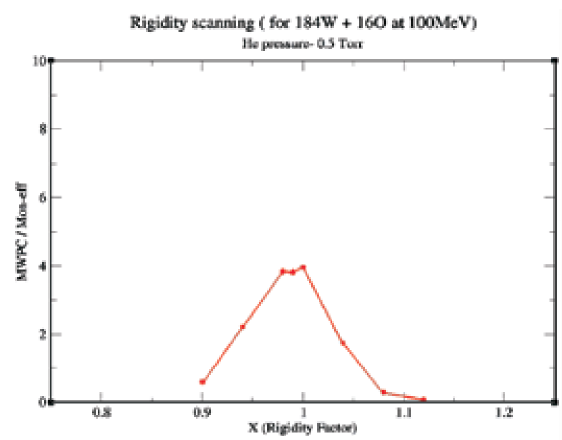

Fig. 3. Normalized ER counts at FP

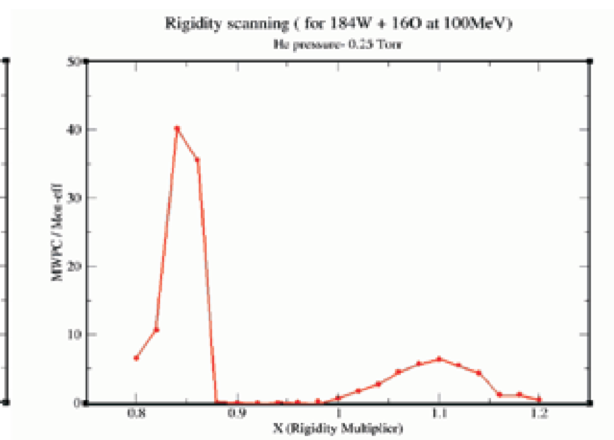

Fig. 4. Normalized ER counts at FP for 0.5 Torr of Helium gas pressure for 0.25 Torr of Helium gas pressure

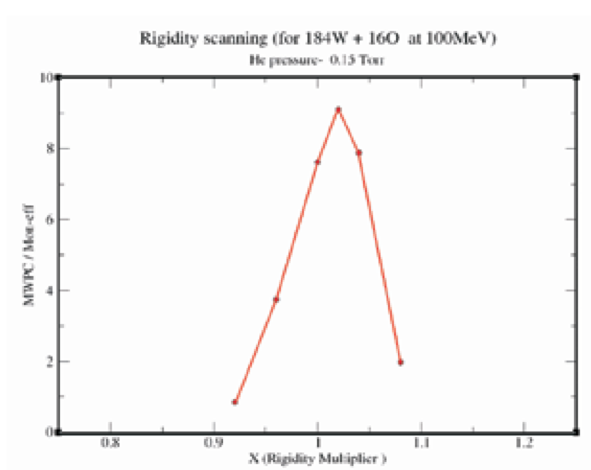

Fig. 5. Normalized ER counts at FP for 0.15 Torr of Helium gas pressure (optimized)

At 0.25 Torr pressure, the magnet settings were lowered significantly to look for contaminants reaching the focal plane. At nearly 75% of optimized field values beam-like components could be seen reaching the focal plane.

The number of ERs reaching MWPC detector was nearly 30% more than those reaching the Si detector which scales as the surface area ratio of the two detectors. This is due to the fact that the slow moving ERs undergo multiple scattering with helium atoms and can miss the relatively small focal plane detectors in spite of entering the focal plane chamber. This has encouraged us to plan for a bigger MWPC detector in future for which the work has started. The energy loss signal and the X,Y positions in MWPC detector, the energy signal and X,Y positions in Si detector and the TOF with MWPC as start and RF of the chopped beam (~ 50 ns wide and 4 microseconds between successive pulses) as stop were used to identify the ERs and decay particles at the focal plane. An aluminum target was used intermittently to check for beam-like contaminants, as such an exercise rules out heavy ERs or heavy target-like recoils. The low energy, beam-like particles at 75% of optimized field values at 0.25 Torr, mentioned earlier, was identified by this method and found to reach only the MWPC but not the Si detector implying their off-axis transmission at large scattered angle originating after multiple scattering in HYRA.

After optimization of the ER transmission for the calibration system, evaporation residue cross-section measurement in ^{16}O + ^{194}Pt was taken up. As fission is more dominant channel in this system in comparison with the calibration system of ^{16}O + ^{184}W, the optimized fields from calibration system were scaled for the new system under study. ER cross-section as a function of beam energy has been successfully carried out from well above 1D-BPM barrier (~ 25%) down to ~ 10% below barrier. The beam-like contamination was less than 5% at ~5% below barrier and could be corrected for by using aluminium target in between. The beam-like and negligible amount of target-like particles could be well separated from ERs by final energy and TOF through HYRA even at ~ 10% below barrier, where the ER cross-section had exponentially fallen down to almost 200 times of above barrier value. Further details of this experimental run are given elsewhere in this report by E. Prasad et al.

The beam rejection factor in the calibration run and experimental run was better than 10^{12}. The focal plane detector system used was effective in identifying the ERs and decay particles though all the decaying alpha particles could not be resolved among themselves by energy. Figs. 6 and 7 show the energy spectra obtained in ^{16}O + ^{184}W (where the neutron-deficient Pb ERs do not undergo alpha decay) and in ^{16}O + ^{194}Pt (where the neutron-deficient Rn ERs undergo alpha decay) systems.

Attempt to measure the transmission efficiency of HYRA for ERs using the ER-gamma coincident measurement was not successful due to the proximity of the thick Ni window foil to the target which swamped the singles gamma spectrum. However, the ER-gamma TAC peak was clean and prominent (Fig. 8) with FWHM of ~ 300 ns. A short re-run has been

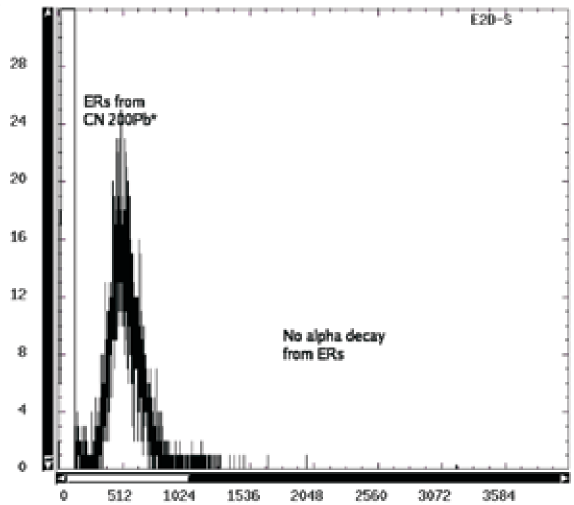

Fig. 6. Energy spectrum at FP Si detector for $^{16}O + ^{184}W \rightarrow ^{200}Pb^*$ system; ERs detected (no alpha decay channel)

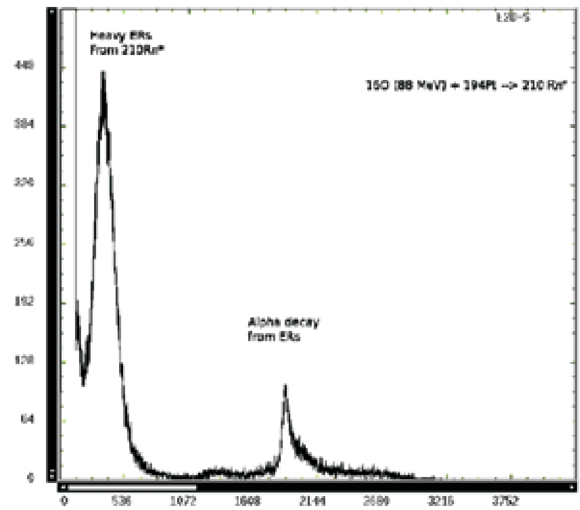

Fig. 7. Energy spectrum at FP Si detector for $^{16}O + ^{194}Pt \rightarrow ^{210}Rn^*$ system; only ERs and alpha decay from them detected

taken up recently moving the Ni window foil 25 cm further upstream so as to enable proper lead shielding of gamma detector from the gamma rays originating from the Ni foil. Detailed analysis is in progress.

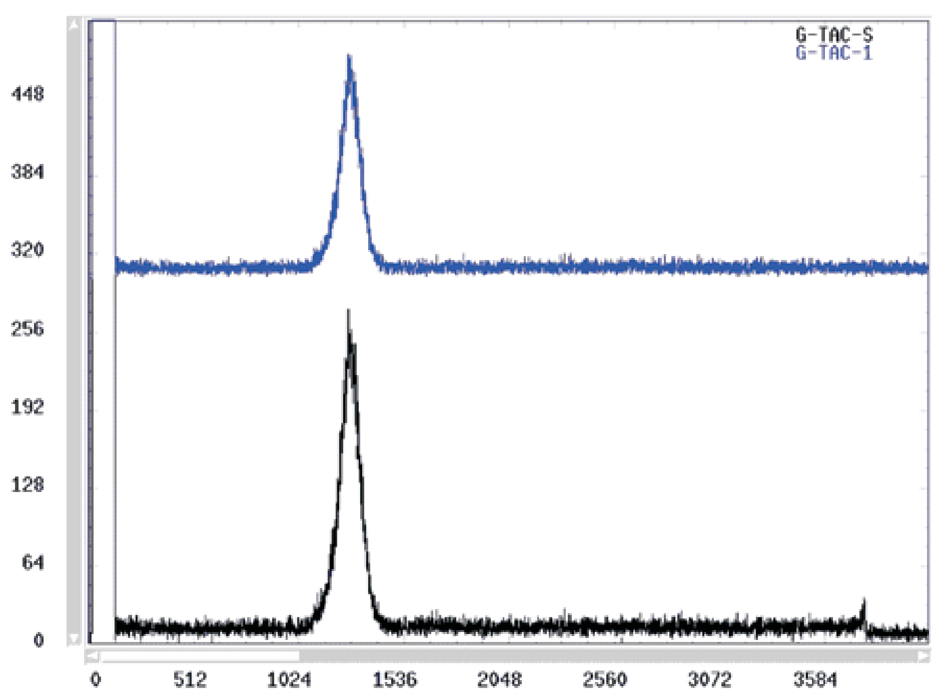

Fig. 8. ER-gamma TAC peak with MWPC signal as start and gamma detector signal as stop; ungated (below) and gated by energy in Si detector (above)

Momentum achromat (vacuum) mode of HYRA

The vacuum, momentum-achromat mode of first stage of HYRA has been tested using alpha source. Solid angle of acceptance of 28 mSr has been experimentally measured which agrees with the GIOS simulation values. A fixed slit system (Fig. 9) has been designed and fabricated for use at Q3 centre to transport secondary radioactive particles and to reject primary beam in inverse kinematics. The slit system is made in a modular fashion so that the width and position of slit openings can be easily chosen for any experiment. This mode is useful in producing low intensity, secondary RIBs. A new gas cell has been fabricated to act as primary target for this purpose and the spare rotary/linear motion target foil assembly developed for HIRA has ben adapted to the existing HYRA target chamber, which can also be used as primary target in secondary RIB production. We plan to take up ^{6}He secondary beam production, initially.

Fig. 9. Fixed slit system, used at Q3 centre in momentum achromat (vacuum) mode, for secondary RIB selection

The transmission of alpha particles through this slit system for a slit opening of 20 mm (in X) and 50 mm (in Y) has been experimentally measured to be ~ 64% which agrees with GIOS simulation and corroborates the X and Y magnification and size (Fig. 10) at the centre of Q3 for alpha source of size 12 mm diameter.

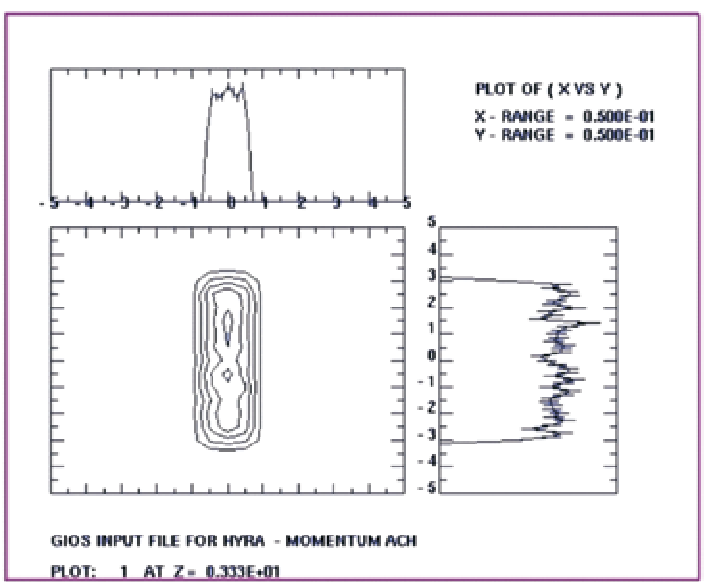

Fig. 10. Horizontal and vertical size of alpha particles at the centre of Q3 in momentum achromat mode

Other Developments

IGOR modules, developed indigenously for remote control/read-back of power supply settings, have been installed. They, along with indigenous quadrupole power supplies, have worked well during the initial tests/experiment.

The electrostatic dipole (ED) for the second stage of HYRA is being fabricated and is now expected to be shipped by end of May, after acceptance tests of vacuum/high voltage. Setting up of the second stage of HYRA is expected to start in late June on receiving the ED and accessories.

The cryostat for superconducting quadrupole doublet (SCQ1Q2) has been designed and ordered by the cryogenics group at IUAC and it is expected to be ready by July this year. The winding of superconducting coils and their low temperature tests are planned to be completed by cryogenics group by June this year so that the final welding, at site, with the magnet and coil assembly can be completed in Jully.

4.4 MATERIALS SCIENCE FACILITY

A. Tripathi, Ravi Kumar, V.V. Shivkumar, F. Singh, S.A. Khan, P. K. Kulriya, I. Sulania, P. Barua, A. Kothari and D.K. Avasthi

The materials science facilities continue to support the research programmes of a large number of users from different universities and institutions from India and abroad. The swift heavy ion irradiation and related experiments are performed in the two materials science beamlines in beamhall I and beamhall II, and in general purpose scattering chamber (GPSC) in beamhall I. Many users are also using the off-line facilities for preparing and characterizing samples. A total of 67 user experiments were performed this year, without any beam time loss due to major facility break down. Experiments are being done in different areas of swift heavy ion induced materials modification and characterization and the details of the research programmes are given in section 5.2.

The irradiation chamber in materials science beamline is used in most of the irradiation experiments and ERD studies. A new set of o-rings is now being used in this chamber for improved operation. The irradiation chamber and in-situ XRD facility in beamhall II were used in three user experiments this year.

Many materials science users are also using FTIR, PL, XRD, AFM and UV-Vis systems. The RF sputtering system, ball milling system, box furnace and tubular furnaces are being extensively used by users for preparing samples. The development of microwave plasma based deposition system is also progressing. The components for the integration of in-situ Renishaw InVia micro-Raman set up in the beam line are fabricated and its installation is underway.

There were five beam-times in which on-line ERDA facility was used. The objectives of these investigations were (i) Hydrogen content measurement in Niobium used in LINAC resonator cavities, (ii) Loss of oxygen in Indium oxide due to SHI irradiation, (iii) Loss of oxygen in zinc oxide having different grain size, (iv) Composition analysis of pristine and 1 MeV Au irradiated glass and (v) Online detection of nitrogen loss in iron nitride, aluminum nitride and nickel nitride.

4.4.1 Fabrication of new sample ladder for irradiation chamber

P. K. Kulriya, R. Ahuja

There is only one four-side target ladder for mounting the samples for SHI irradiation experiments in materials science beam line in Beam hall-I. Many user experiments such as the ones involving polymer samples require irradiation at low fluences. Such low fluence irradiation experiments require very small irradiation time and most of the time of the user is consumed in mounting the sample on the target ladder. By using an alternate ladder, we can save at least two hour of beam time per shift in the low fluence study. Hence it was felt necessary to fabricate a new ladder to save the beam time of the accelerator as well as the user.

Fig.1. Target ladder for irradiation chamber

A new target ladder has been fabricated and leak testing was done at room temperature and at liquid nitrogen temperature. At present, the new ladder is being used by many users for their experiment.

4.4.2 Plasma based synthesis of thin films

V.V. Siva Kumar

For plasma-based synthesis of thin films at IUAC, an rf sputtering system is available and a microwave CVD system is developed. The RF sputtering system is being used for the growth of thin films for the users. Study of growth of thin films of Carbon nanostructure is planned with the microwave CVD system.

The RF sputtering system was operational for thin film deposition. Thin film depositions of Boron Carbon Nitride (GND University), Hydroxyapatite (Anna University) and Polyimide composite (MSU, Baroda) were done. A problem in the vacuum system was encountered and corrective measures were taken up. Upgradation of the vacuum system by incorporating a Turbo Pump/Dry pump for depositing thin films in clean vacuum is also being done.

4.4.3 Development of microwave CVD system

V.V. Siva Kumar, P. Barua, R. Ahuja. S.K. Saini, S. Rao, Y. Mathur, U.K Rao and D. K. Avasthi

The assembling and testing of the microwave CVD system was completed after carrying out various works. The microwave components were assembled and connected to the plasma chamber having a quartz window for passing the microwaves. Arrangements for passing Argon and Ethylene gases into the plasma chamber, water connections to the microwave source and Dummy load, grounding of the system, electropolishing of the plasma chamber, interfacing of the micorwave power supply with the microwave source and its testing, substrate holder with dc bias, electrical connections etc. were done and the assembling of the system was completed. The microwave plasma system was tested by producing Argon plasma with 50 watts of forward power. The reflected power was minimized to < 10 %. Thin film deposition on glass substrate was performed by using Ethylene and Argon gas mixture.

4.4.4 Ball milling system for synthesis of nanopowders

V. V. Siva Kumar

The Ball Milling system was in operational condition and was used to synthesize nanocrystalline powders of SrS:Ce and BaS:Bi for users(KU Kurukshetra). The powder samples were milled for durations ranging from 1 hr to 6 hrs. with a ball to powder ratio of 2:1. Synthesis of Boron Carbon Nitride nanopowder was done by using Boron Nitride and Graphite powders for user (GND University). The ball milling was done for 20hrs. and 50 hrs. with a ball to powder ratio of 10:1.

4.4.5 Scanning Probe Microscope

A. Tripathi and I. Sulania

Multi Mode SPM with Nanoscope IIIa controller acquired from Digital/Veeco Instruments Inc. was extensively used in user experiments. The regular calibration and performance testing in AFM/MFM mode using standard grid and magnetic tapes was conducted. The system was used in the following areas of research: Ion induced surface morphology, SHI induced changes in size and its distribution of nanoparticles, SHI induced modification in magnetic domains, SHI induced plastic flow of material and characterization of ion tracks in terms of size and number density. This year more than 760 samples from 75 users have been studied in AFM/MFM/CAFM (620/90/50) mode.

4.4.6 In-situ X-ray Diffractometer setup

P. Kulriya

The Bruker D8 advance *insitu* X-ray diffractometer setup has been used extensively for offline studies of phase identification of the thin films as well as for the powder samples. The setup was used for the characterization of more than 700 samples from nearly 110 users this year. The total number of samples characterized by the user in glancing angle and Bragg -Brentano geometry are 375 and 355 respectively.

The glancing angle mode of the diffractometer setup had a breakdown due to decrease in the reflectivity of the Gobble mirror. Due to decrease in the reflectivity, it was not possible to record the good quality diffraction pattern of thin film samples. To solve the problem, the mirror was dissembled and sent for refurbishment to the supplier. The supplier has repolished it and the same has been installed with the XRD system. After reinstallation, system has been heavily used and working fine. The other maintenance problems undertaken were (a) problem in the shutter of the X-ray tube, (b) interfacing problem in the controller of the Vantac detector, (c) cooling water problem in the X-ray tube and (d) replacement of the Miniature Circuit Breakers (MCB) of the cooling unit.

4.5 RADIATION BIOLOGY

4.5.1 Status of the Radiation Biology Beam line

A. Sarma, P. Barua, A. Kothari, E.T. Subramaniyam and M. Archunan

The specially designed beam line can deliver beams of ^{7}Li, ^{11}B, ^{12}C, ^{14}N and ^{16}O. The flux can be controlled from 10^2 particles/sec/cm^2 to 10^6 particles/sec/cm^2. The exit window is having 40 mm diameter with active area for cell irradiation defined by the standard 35 mm petri-dish. The uniformity is about 95% over 35 mm diameter. The flux control is done by adjusting a double slit through CAMAC from control room. A pre-set controller for Faraday cup ensures the exposure repetition as per user requirement.

The Automatic Sample Irradiation system for Radiation Biology Experiment, Aspire, has been installed and being used by the user community. This system takes care of the remote handling of petri dishes in an enclosed sanitised environment during irradiation, multiple irradiations of one sample after another without losing time and keeping the petri dishes in the medium when they are not being irradiated. The system is controlled by Linux based software. Further works are going on towards more efficient electronics for dosimetry.

Fig.1. Multi axis positioning system Aspire in the beam line

4.5.2 Status of the Molecular Radiation Biology Laboratory

A. Sarma

The laboratory is designed to extend user support to the best possible way during experiments. The experiments that are undertaken recently require suitable inhouse facilities for relevant protocols. Apart from the equipments of the Cell Culture facility like autoclave, biosafety cabinet, CO_2 incubator, and other normal equipment like microbalance, oven, refrigerated centrifuge, PCR machine, Gel Doc, FIGE system and Semi dry transblotter etc., we have installed a -80 C Ultra Freezer [Heto] and a -20 C Deep Freezer [Vest Frost] and a large capacity 4 C freezer.

In addition, we also have a fluorescent microscope [Carl Zeiss] to facilitate the experiments based on FISH and immunofluorescent assays.

For accurate cell counting, a Coulter Cell Counter [Beckman Coulter] is installed in the laboratory. This equipment would drastically enhance the speed and accuracy of post irradiation cell plating during the beam time and thus would save a lot of time.

Initial works with HeLa cells have been started and in order to provide exposure to research scholars to real life experiments, initial cell survival studies using gamma ray and C and O beam have been carried out. In addition to that preparation of cDNA for studying gene expression and the microscopic evaluation of apoptosis using fluorescent dye like Hoechst 33258 has also been carried out. Apart from HeLa, cell culture works with breast cancer cell line MCF-7 has also been started

Some works have been initiated to study the interaction of gold nano particles with HeLa cells.

4.6 ATOMIC PHYSICS

4.6.1 Status of the Atomic Physics Beam line

B.P. Mahanty[1], Mumtaz Oswal, S.K. Saini, and T. Nandi

[1]Department of Physics, Punjabi University, Patiala

Dedicated atomic physics beam line has been extended further in the beam hall-II to include a versatile set up for charge state fraction measurement of post-collisional projectile ions. It includes a retractable Faraday cage, a gate valve, two beam collimating slit systems, an inclined and straight electrostatic analyzer (ISESA), a trapper drift tube chamber, a position sensitive proportional counter (PSPC) and another retractable Faraday cage at the beam dump position. Retractable Faraday cage will allow one to check the beam line alignment whenever necessary. Trapper drift tube chamber of 1.25 M long provides opportunity to place a 200 mm long PSPC. It can also be used as position sensitive parallel plate avalanche counter. Further, charge state fraction measurement set up can be used as a new electron spectrometer. This electron spectrometer will be used to detect the range of binary encounter electrons and cusp electrons produced in the collision of MeV ions with the C-foils. These electrons are in the keV energy range and will hardly be affected by earth's magnetic field. Further, due to good position resolution in the electron counter, this electron spectrometer is expected to be high resolution one. The physics problem in mind is to study a rare three-electron-Auger process. Cross section of this process is very small and hence no problem in handling the electron counting rates. The facility will be tested in this year.

Doppler tuned spectrometer (DTS) has been tested successfully off line as well as on line in general-purpose scattering chamber (GPSC). Nowadays, high resolution x-ray spectroscopy experiments using Doppler tuned spectrometer are being regularly carried out at GPSC. Another DTS has been duplicated in order to cover wider spectral range simultaneously. Foil translation system as well as absorber foil changing mechanism without breaking the vacuum have been improved. Further, a Faraday cage has been made so that beam particle normalization will correctly be done.

We are going to carry out multi nucleon transfer reactions in GPSC. For this purpose a new detector mounting assembly has been already fabricated and a new x-ray detector has been ordered which can be placed quite close to the target at GPSC chamber. The purpose of these nuclear studies is to make use of secondary beam-foil source as a new method of investigating H-like heavy ions. In this source ion-beams are replaced by projectile like ions produced from nuclear transfer reactions.

1 M normal incidence Spectrometer had been made ready for optical spectroscopy experiments in the PKDELIS laboratory a few years ago. Now a beam line has been designed to couple the PKDELIS with this spectrometer. Fabrication of beam line and procurement of the beam line components have been started. We hope to make the program ready in a year time. Measurements will start with l-dependent level population studies relevant to cometary physics.