# 4. EXPERIMENTAL FACILITIES IN BEAM HALL

## 4.1 GENERAL PURPOSE SCATTERING CHAMBER (GPSC)

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A variety of experiments were carried out using this facility in different fields such as Nuclear Physics, Materials Science and Atomic Physics. The list of experiments carried out last year using this facility is given below.

**Experiments carried out in GPSC**

| User | Experiment | Beam |
|---|---|---|
| Ranjit Karn IUAC | Lifetime measurement of levels of highly charged ions relevant to astrophysics | Fe |
| Hardev Singh Punjab University | Study of induced fusion-fission dynamics | C,F |
| A.Batra ISRO | Heavy ion induced effects in VLSL devices | Si, Ni |
| Vishal Sharma Kurukshetra Univ | Energy loss straggling for MeV heavy ions in different absorber materials | Li, O, C |
| Y.K.Vijay Rajasthan Univ. | SHI induced organization of CNT in polymer matrix and fluids | Ni |
| B.P.Singh AMUniversity | Fusion and incomplete fusion studies with heavy targets using $^{16}$O Beam | O |
| T. Ghosh VECC | Study of fusion-fission dynamics near the coulomb barrier | $^{11}$B, $^{14}$N |
| E. Prasad Calicut University | Study of entrance channel effects in fusion around the coulomb barrier | O Pulsed |
| Rahbar Ali AMU | Study of reaction mechanism in heavy ion induced reactions | O |
| Ranjeet Delhi University | Investigation of multi nucleon transfer reactions in $^{40}$Ca on $^{68,70}$Zn at & near the Coulomb Barrier | Ca Pulsed |
| Bivash Behera Punjab University | Dynamics of fusion fission process near super heavy region Punjab University | $^{18}$O, $^{16}$O |

### 4.1.1 National Array of Neutron Detectors (NAND) in beam hall II

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NAND in beam hall II at present is equipped with about thirty liquid scintillators along with the associate auxiliary detectors for the study of reaction mechanics in heavy ion induced fusion-fission. The auxiliary detectors consist mainly of fission fragment detectors. Two large area position sensitive MWPCs have been developed recently for the detection of mass and angular distribution of fission fragments. These detectors when used for time of flight measurements with reference to beam arrival time (extracted from the RF signal used for beam bunching) would give a fission fragment mass resolution of ~5amu. Fig.1 shows a full view of the array installed in the beam hall-II.

A Glycol based cooling equipment for silicon detector has been installed in the target chamber which can bring down the detector temperature to sub zero levels within half an hour. Cooled detector of fully depleted silicon surface barrier along with fast pre-amplifier is a very efficient combination for timing measurements down to ~ $10^{-10}$ second. This facility was successfully used to detect the bunch width of the LINAC beam of $^{28}$Si at ~150 MeV. The usage of rebuncher after the LINAC module could provide pulse widths down to 400 ps at the target position.

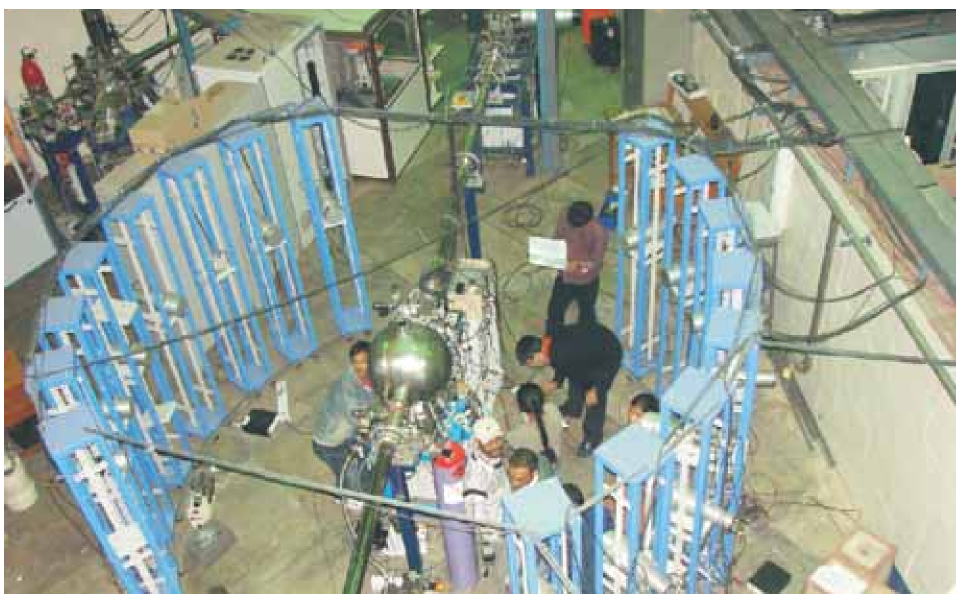

**Fig.1. Full view of the neutron array**

### 4.1.2 $BaF_2$ for timing measurements

Abhishek Rai, Golda K.S., A. Jhingan and P. Sugathan

In the NAND setup, measurement of time of flight (TOF) is used for the determination of neutron energy as well as fission fragment mass ratio. The reference time for all such measurements is normally taken from the beam arrival time. The resolution of TOF set up depends to a great extent on the width of the pulsed beam used. The accurate measurement of the width of the beam pulse becomes very crucial under such circumstances. Even though it has been well demonstrated that fully depleted silicon surface barrier detectors are the best candidates for timing measurements, there are many practical limitations such as the requirement of cooling, thin target and also radiation damage. The available literature shows that a very well tuned thin $BaF_2$ detector coupled to a fast PMT can give time resolution of the order of 100 ps. In accordance with the previous experience of other groups, we have developed a $BaF_2$ detector system by coupling a 1.5" thick 1.75" diameter crystal to a 2" diameter XP2020Q fast timing PMT. A thin Teflon cap was used to restrict the physical movement of the crystal on the PMT surface by fixing both of them tightly. It is to be emphasized that this crystal size and the coupling method we adapted are not optimized for good timing performance. However this detector assembly has been successfully used to measure the time resolution down to a limit of 400ps, as shown in Fig. 2. This is the measured FWHM obtained with this detector assembly while the actual width of the beam was about 150 ps.

The on-line monitoring of the beam width is very important to ensure the stability of the width and phase of the beam pulse for TOF measurements. The $BaF_2$ detector was placed at 30 cm distance to detect the gamma rays from tantalum beam dump. A TAC spectrum was produced between PMT anode signal and RF of beam buncher. It has been demonstrated that such a system provides a better access to the beam pulse monitoring in a non-destructive manner with less complexities.

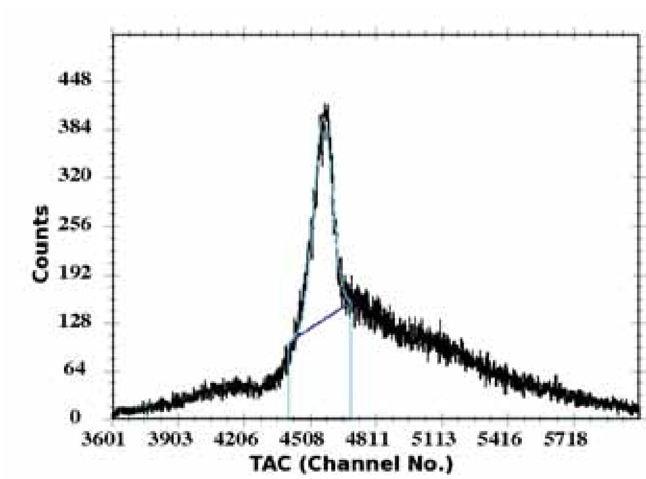


**Fig. 2. TAC between $BaF_2$ and RF**

### 4.1.3 Integrated electronics module for neutron array


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The dedicated single width NIM modules developed for neutron detector signal processing were fabricated in large numbers to fulfill the requirements of the thirty detector array. The module has been subjected to various tests with neutron source and actual experimental conditions with beam and its performance was compared with that of commercial modules (Canberra 2160A) as well as with similar electronics developed elsewhere. Most of the testing was done using a spontaneous fission neutron source (925kBq shielded $^{252}Cf$) which replicates the neutron energy spectrum from a typical low/medium energy heavy ion induced fusion-fission reaction. A 2" diameter × 0.5" thick plastic scintillator coupled to 2" diameter XP2020Q PMT was used for the time reference. To mimic the real experimental condition during the source tests, detector signals were taken through twenty meter long RG-58 coaxial cables to the electronic module.

The detector light output was calibrated with standard methods using different $\gamma$-ray sources. Compton edges of $^{22}Na$, $^{137}Cs$, and $^{60}Co$ have been used to study dynode pulse height distribution of the scintillator at a specific bias voltage. The detector bias was optimized by taking into account the best timing and pulse shape discrimination within the voltage range recommended by the manufacturer. The detector signals, both from dynode and anode, were divided with passive signal splitter and fed to home made and commercial modules simultaneously. The commercial modules were carefully tuned to match the conditions of home made module so that a direct comparison of the performance was possible. Data collection was carried out event by event mode by using CAMAC based data acquisition system to enable a critical off-line analysis. The performance of this module has been found to be comparable with the commercial ones.

### 4.1.4 Project For A Large Neutron Array

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The mile stone achieved in the last year is the preparation and submission of the technical proposal for a large neutron array for the reaction dynamics studies in the heavy ion induced fusion-fission at energies near and above Coulomb barrier. This is a joint venture of IUAC and three participating universities within the country. This would be a national facility which will be used with the beam delivered by Tandem-LINAC combination at IUAC. The project is under scrutiny by the Department of Science and Technology (DST) of the govt. of India for financial approval.

Heavy ion induced fusion is an effective method to form unstable heavy nuclei which are otherwise not found in nature. The recent theoretical predictions and experimental observations suggest that there are many possible reaction mechanisms in the heavy ion induced fission near and above Coulomb barrier *viz*, fusion-fission, quasi-fission, deep quasi-fission, etc. Each of these processes has its own characteristic reaction time for developing from the contact of the colliding partners to the scission point. This was shown by Aritomo et.al.[1] using the dynamical calculation for the time development of the nuclear shape by means of the Langevin equations. The different reaction times mean that each reaction process is associated with different pre-scission neutron multiplicity. They have introduced the effect of pre-scission neutron emission into the three dimensional Langevin calculation and showed the sensitivity of model parameters such as the friction force, dissipation energy, level density parameter and neutron binding energy on pre-scission neutron multiplicity. This model is successfully applied to distinguish the pre-scission neutron multiplicity coming from fusion-fission and quasi-fission processes. It shows that the pre-scission neutron multiplicity has a strong correlation with the evolution of the composite system in the nuclear deformation space. Hence, the measurement of pre-scission neutron multiplicity in coincidence with fission fragment distribution is a powerful tool for investigating fusion-fission mechanisms.

The average value of neutron multiplicities that can be extracted from the measured neutron energy distribution and its angular correlations with fission fragments is not sufficient enough to distinguish the time scale of different dynamical processes involved in fission. It can be obtained only if one is able to extract from the experimental data, the correlation between the pre- and post-scission multiplicities and their evolutions with the parent nucleus excitation energy. Measurement of neutron fold distribution in coincidence with fission fragments is necessary to obtain the width and other higher moments of these distributions. The accuracy of the measurement of the shape of these distributions is determined by the statistical uncertainties of the higher fold distributions. The probability of the fold distribution is highly sensitive to the total detection efficiency of neutrons of the detecting system. Hence the efficiency of the neutron detecting system is the determining factor in obtaining the shape of the neutron multiplicity distributions. The recent studies carried out by L. Donadille et.al. [2] of DeMoN group have also demonstrated the same, where they have computed the correlated distributions between (i) the thermal energy available for neutron emission at the formation of composite system and the total neutron multiplicity per fission event, and (ii) between pre and post-scission neutron multiplicities, together with the individual distribution of these variables. Therefore a neutron time of flight (TOF) spectrometer with very high efficiency (overall detection efficiency >1%) and good granularity is required to carry out studies in the field of fusion-fission dynamics where co-existence of different reaction mechanisms differing by the composite system life time or the evolution path followed by the fissioning system is possible.

The neutron spectrometer required for these studies should have high granularity and also a very good time response. Since it is well established that organic liquid scintillators like NE213 or equivalent coupled to fast Photo Multiplier Tubes have good time response and excellent neutron gamma pulse shape discrimination property, they are the best candidates for the detection of neutrons having few MeV of energies. We propose to set up a modular detector array of 100 detectors of liquid scintillators of 5" thick × 5" diameter with an effective detection efficiency of ~1.25%. The neutron flight path is optimized to 2m based on the computer simulations which take into account the limitation in the energy resolution due to flight path and detector thickness and also the overall detection efficiency of the system. A fission fragment detection system consisting of position sensitive Multi Wire Proportional Counters (MWPCs) with effective solid angle coverage of ~ 68% of $4\pi$ will be made for fission fragment angular and mass distribution measurements. Along with such a high efficiency fission fragment detecting system, this neutron array would be a unique set up of this kind which can cater to the requirements for higher fold neutron measurements in coincidence with fission for studying the fission dynamics of heavy ion induced capture reactions. With the augmented energy from the

LINAC booster at IUAC, it would be possible to go to higher domains both in terms of energy and mass where such a large neutron TOF spectrometer is more relevant.

## REFERENCES

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[2] L. Donadille et al, Nucl. Phys. A 656 (1999) 259

## 4.2 GAMMA DETECTOR ARRAY (GDA)

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The users of GDA facilities have published prolifically this year contributing over twelve papers in DAE 2007 and seven communications in international journals. The primary activity in the Gamma Detector Array laboratory this year was devoted in developing the INGA facility in Beam Hall II.

### 4.2.1 Indian National Gamma Array (INGA)

The concept of a ***National facility for gamma spectroscopy*** took shape in early 2000 when a formal agreement between the various institutions (TIFR, BARC, SINP, VECC, IUC-DAEF and IUAC) was achieved for pooling the available resources. It was conceived that an Indian National Gamma Array consisting of Compton-suppressed Clover detectors with nearly $4\pi$ coverage would be set up as a national facility. This facility would be rotated among the three accelerator laboratories with a minimum stay of one year at one place. Major funding for this project has been received from the Department of Science & Technology, India.

The Clover detectors that were available with the institutions were designed to be operated at a distance of ~ 24 cm from the target with the accompanying anti-Compton shields subtending an angle of 30° at the target. As a result, a maximum of 24 Clover detectors could be accommodated in $4\pi$ geometry. The total coverage by Ge crystals is about 25% of $4\pi$, corresponding to a total photopeak efficiency of ~5%. Such a system would be optimized for collecting data at $\gamma$–$\gamma$–$\gamma$ triples or at higher fold. Three campaigns with a smaller number of Clover detectors were carried out in 2001, 2003 and 2005 at TIFR, IUAC and VECC respectively with existing infrastructure.

Fabrication of the mechanical support structure at IUAC for holding 24 Clover detectors was taken up in early 2007 and completed by mid-2007. It was decided that the first campaign with the full INGA during 2007-2008 would take place at IUAC. Installation of the mechanical structure, cabling and electronic modules started by August, 2007. The detectors and shields from all the collaborating institutions were received by Jan, 2008. The first facility test to optimize the transport of beam at INGA beam line was carried out in Feb, 2008. During March, 2008 to June, 2008, the first cycle of experiments with the INGA facility would be carried out.

### Detector Support Structure

The mechanical support structure for INGA has been designed to allow operation either in **stand alone mode** with full $4\pi$ coverage or **coupled with the recoil separator HYRA** in which case the detectors in the forward cone have to be removed. The set of 24 Anti-Compton Shields (ACS) are mounted on two movable platforms (one for forward array of eight detectors and the other for backward array having sixteen detectors) on precision guide rails [1]. The orientations of the different ACS are mounted with an accuracy of 0.5°with respect to the three axes and their positions reproducible to an accuracy of 0.5 mm with respect to the target position. The support structure was fabricated by J. J. Enterprises, New Delhi.

The platforms could be moved by dedicated electric motors either in forward or backward direction in high (10 cm/min) speed at large distances (above 5 cm) between the trolleys or at low speed (2 cm/min) when they are close together. The movement is controlled automatically by a set of limit switches. Overall views of the setup are shown in fig 1. An overview of the INGA with HYRA during installation stage is shown in fig 2. The mounting details of detectors are given in table I.

**Table I : Arrangement of detectors in the array**

| Backward Platform Ring No. | Clover Detector Position No. | $\theta$ in Degrees | $\phi$ in Degrees Ring No. | Forward Platform Position No. | Clover Detector | $\theta$ in Degrees | $\phi$ in Degrees |
|---|---|---|---|---|---|---|---|
| I | 1 | 148 | 0 | IV | 17 | 57 | 45 |
| | 2 | 148 | 90 | | 18 | 57 | 135 |
| | 3 | 148 | 180 | | 19 | 57 | 225 |
| | 4 | 148 | 270 | | 20 | 57 | 315 |
| II | 5 | 123 | 45 | V | 21 | 32 | 0 |
| | 6 | 123 | 135 | | 22 | 32 | 90 |
| | 7 | 123 | 225 | | 23 | 32 | 180 |
| | 8 | 123 | 315 | | 24 | 32 | 270 |
| III | 9 | 90 | 0 | | | | |
| | 10 | 90 | 45 | | LEPS-1 | 119 | 0 |
| | 11 | 90 | 90 | | LEPS-2 | 119 | 90 |
| | 12 | 90 | 135 | | LEPS-3 | 119 | 180 |
| | 13 | 90 | 180 | | | | |
| | 14 | 90 | 225 | | LEPS-4 | 61 | 0 |
| | 15 | 90 | 270 | | LEPS-5 | 61 | 90 |
| | 16 | 90 | 315 | | LEPS-6 | 61 | 180 |

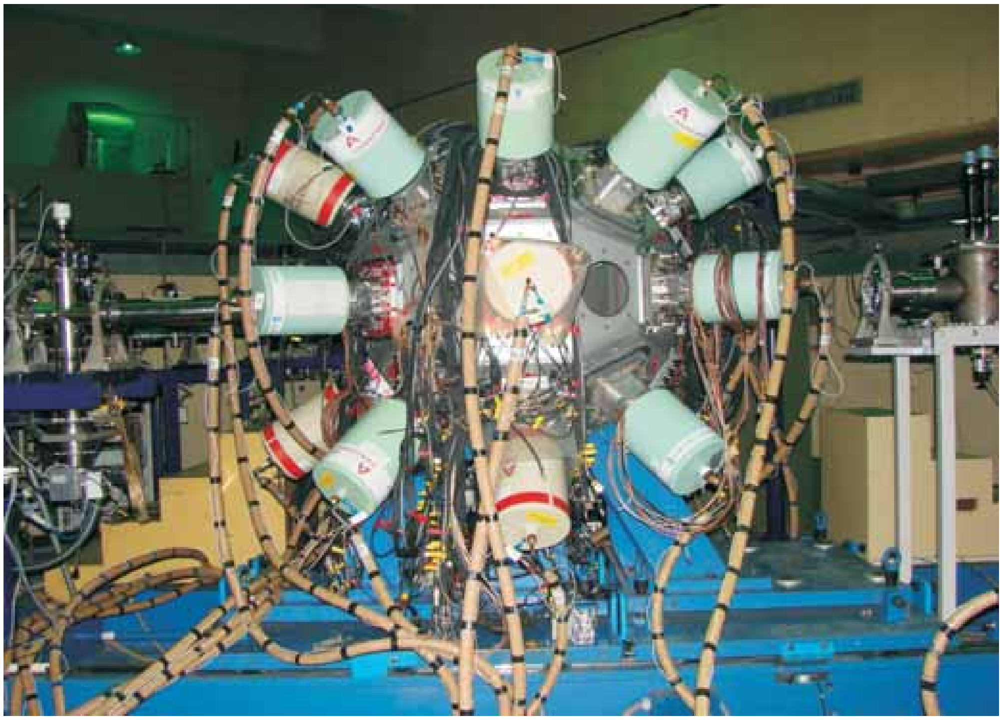

Fig. 1. View of INGA from side

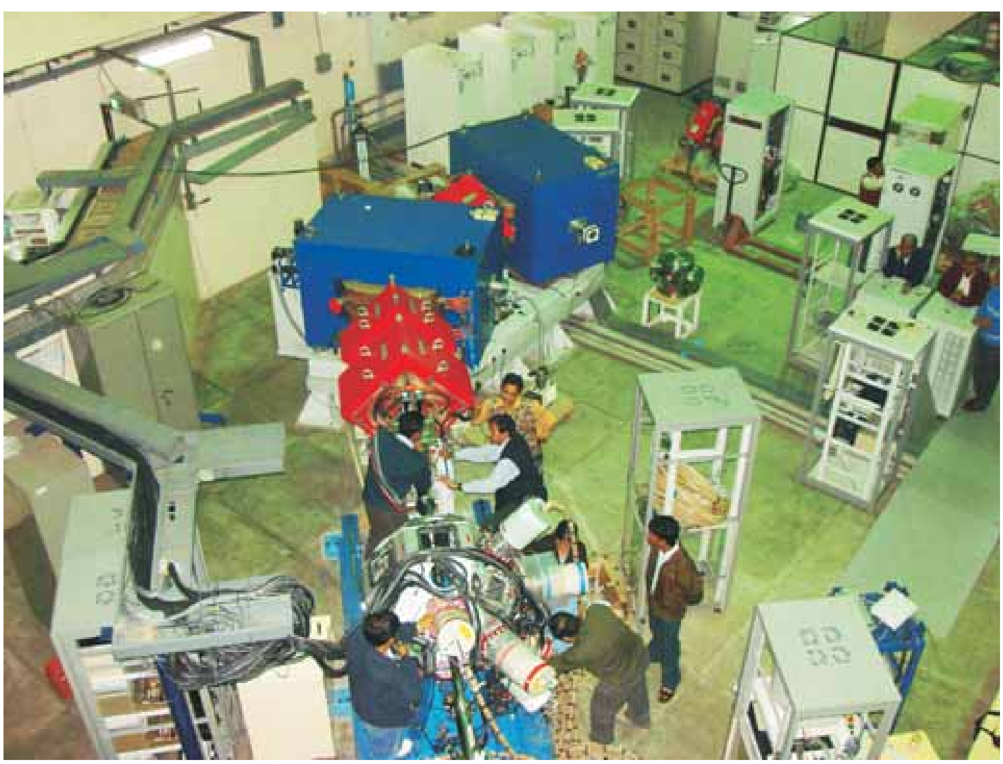

Fig. 2. INGA Array with HYRA during installation phase

## Beam line

One of the major challenges in designing the beam line was the small clearance of ~ 7.5 cm along beam axis between the collimators of the anti-Compton shields. A stainless steel beam tube of 6 cm diameter (fig 3) has been used inside the array. The backward array can slide back on its guide rails without disturbing the beam line. The scattering chamber is made of 2″ diameter glass tube (fig 4) to minimize the attenuation of γ-rays in the chamber walls. Wilson seal couplings are used between the scattering chamber and beam tubes at both ends. The target is mounted on four rods inserted along the beam tube. The beam tube downstream to the target is mounted rigidly on the mechanical structure of the forward array.

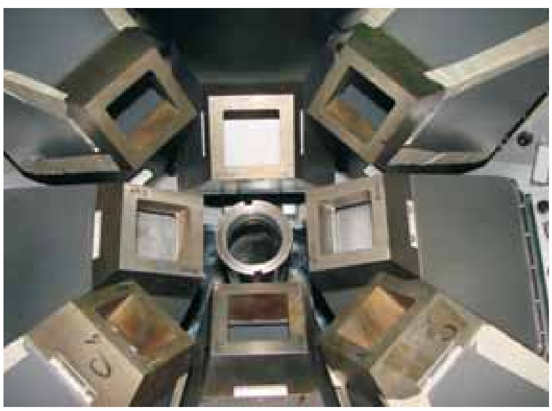

**Fig. 3. Beam tube surrounded by anti-Compton shields**

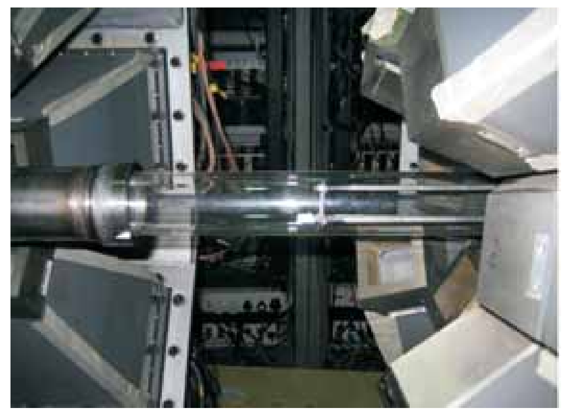

**Fig. 4. Cylindrical scattering chamber with target mounted**

The schematic diagram of the beam line is given in fig 5. Outside the array, 4″ diameter stainless steel tubes are used for transporting the beam. A Turbo-molecular pumping system backed by a rotary pump, with dedicated home-made control unit has been installed in the beam line. A removable collimator of 5 mm diameter with current readout is put at 1.5 m upstream from the target. In actual operation, the current intercepted by this collimator is minimized for centering the beam on target.

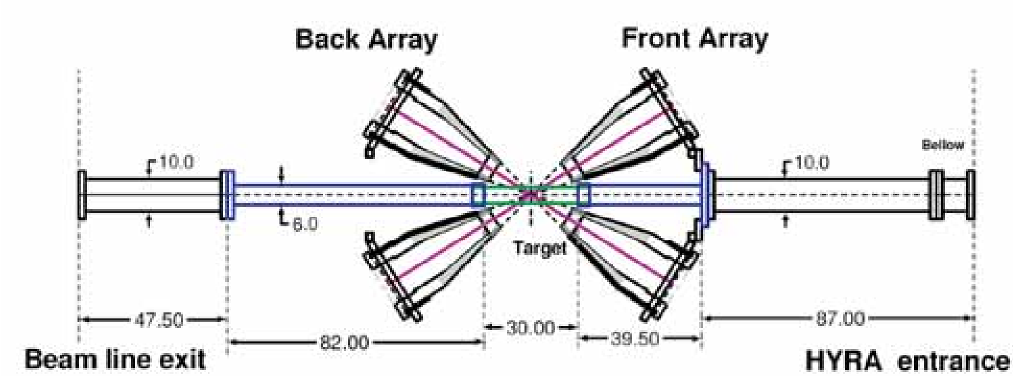


**Fig. 5. Schematic layout of the beam line for INGA (all dimensions in cm units)**

## Automatic LN2 Filling system

A dedicated home made controller with embedded PC (192.168.3.24) has been developed to provide an automatic liquid nitrogen filling system for the Clover detectors. The supply of liquid nitrogen (LN2) is from a 1000 litre Dewar (INOX make) which can be periodically (once in 2 days) filled from an outside Dewar (20,000 litre). The distribution of LN2 is done with a four column manifold catering to sixteen detectors of backward array and another two column manifold catering to eight detectors of forward array. The overall layout of the system is given in fig. 6.

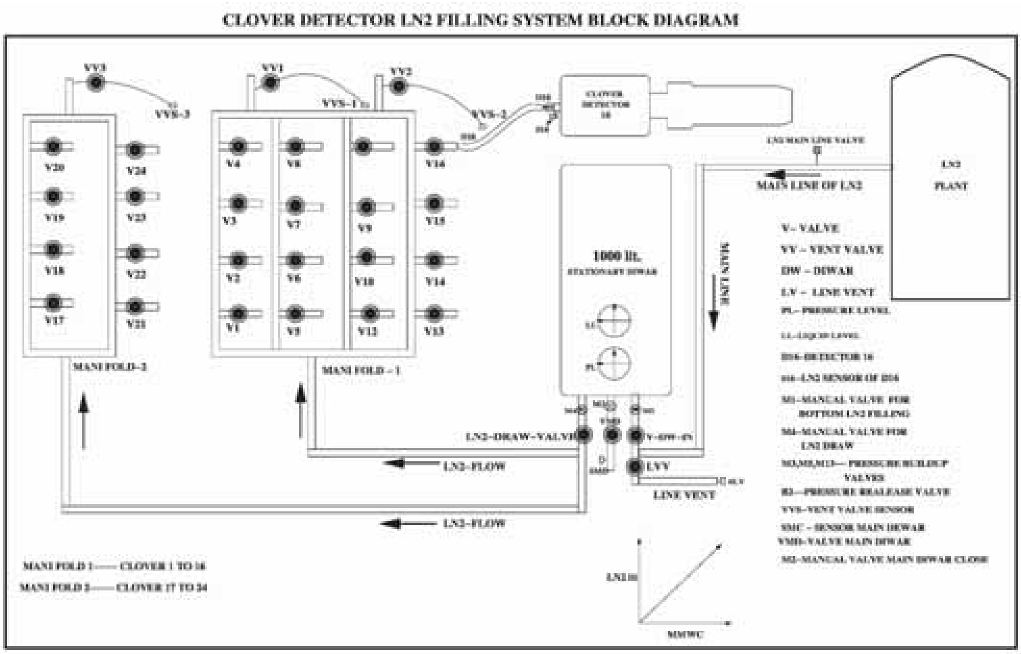


**Fig. 6. Schematic diagram for LN2 Autofill system of INGA**

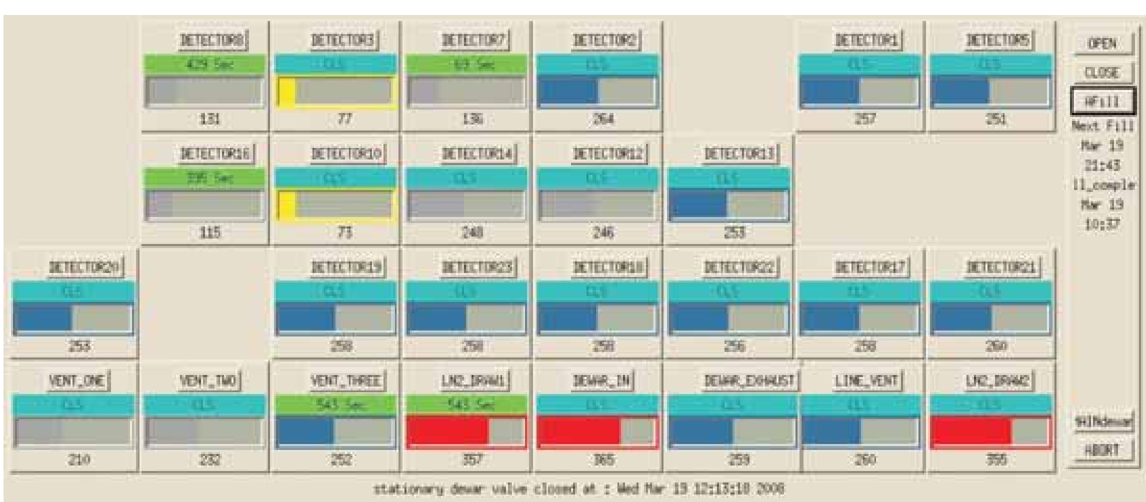


**Fig. 7. Graphical User Interface for Autofiill System**

Electrically operated cryogenic valves of Jefferson make (1/2″ diameter, normally closed), are employed for controlling the flow of LN2 to the detectors. These can be operated under software control by the program 'linserv' working under a linux operating system. The temperatures at the overflow ports of the clover detectors and the filling manifolds are measured using platinum resistance thermometers (PT100) and the valves are closed under overfill condition. A Graphics User Interface ('fill') enables the user to monitor the filling status of individual detectors. The detectors are filled automatically twice a day. Typical GUI display during 'Autofill' is shown in fig 7.

## Power and Signal cabling

The electronics for the various subsystems for INGA are mounted on Instrumentation racks powered by UPS with surge protection circuitry. Two racks are used for mounting the LN2 control valves and two for housing the high voltage supplies for Clover detectors and anti-Compton shields. The energy and timing signals from the detectors are taken to the Electronics area using RG58 signal cables. The cable ends in the Electronics area are grouped into three patch panels. RG172 cables are used for the interconnection between the patch panels and the electronic modules.

## Electronics and Data acquisition system

Home made clover modules [2] are used for processing the energy signals from Clover detectors and anti-Compton shields. The timing logic for Compton-suppression along with the generation of required strobes for data collection and pile-up rejection were also incorporated in this module. The gain setting of the shaping amplifiers of clover segments are kept at 4 MeV range. One NIM bin is used for powering four clover modules. Eight detectors are grouped into one unit for creating multiplicity of gammas and for collecting data through one CAMAC crate. The combined multiplicity from all three crates is used for event selection. The following circuits give the logic for the generation of Master trigger of an event (fig 8) and data collection (fig 9). Fig 10 shows the layout of instrumentation racks in the Electronics area.

A new home made LPCC CAMAC module has been fabricated [3] combining the role of List Processor and the Crate Controller which enables the data collection rates up to 1700 kilo bytes per second. Three CAMAC crates each having four 14 bit, 8 channel IUAC AD814 ADC's are used to collect data from all Suppressed Clover detectors. The first CAMAC crate has the Trigger generator which entertains the Event trigger and transmits it to the other two CAMAC crates via Trigger receiver modules of respective crates to maintain the synchronization of data between the three crates. The TDC's (7186) are used to create the hardware bit pattern in each CAMAC crate. The hardware Bit pattern based data collection (CNAF list changes as per the bits raised for each event in TDC's of each crate) is also enabled to have more data collection due to zero suppression in data readout. The data collection software CANDLE is run in dedicated PC (192.168.3.100) with local data archival system. All the Bias supplies [4], analogue processing [2] and Analogue to Digital converters of the detectors except TDC have been fabricated in-house.

During the installation phase, a large number students and faculty from the universities, colleges and institutes have provided help in setting up and testing of the facilities. We are grateful to them for their contribution.

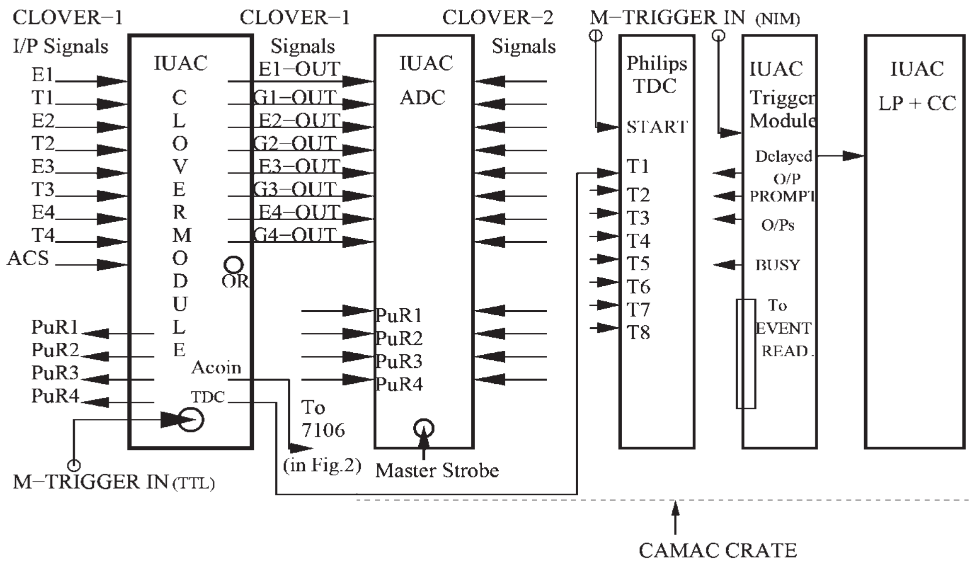


**Fig. 8. Schematic diagram for Event trigger of INGA**

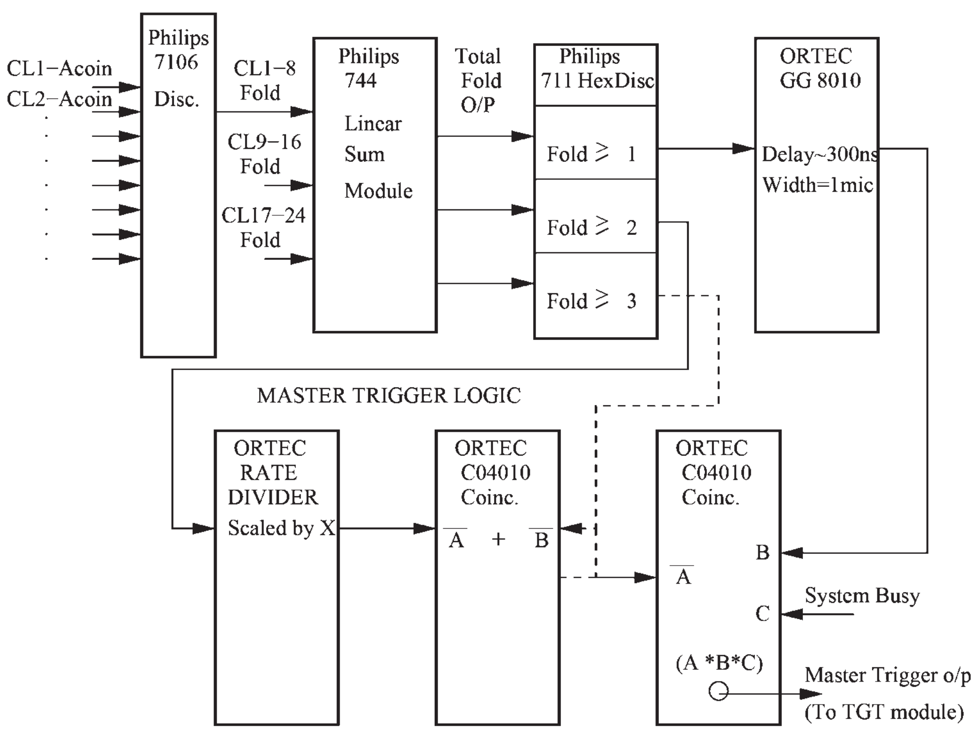


**Fig. 9. Schematic diagram Data Acquisition of INGA**

**Fig. 10. Instrumentation racks in the electronics area**

## Test Experiments

A series of test experiments were conducted for checking the beam optics for the INGA beam line. A quartz crystal was used to view the beam profile at the target position. It was found that the magnetic fields in the last quadrupole triplet had to be reduced by about 30% in order to shift the focus from the last Beam Profile Monitor (BPM) in the beam line to the target position 2 m downstream from the BPM. The position of a removable collimator in the beam line has been adjusted for centering the beam on target location. All the signal cabling, electronics and data acquisition system were checked out during the test measurements.

**Fig. 11. Multiplicity distribution**

For multi-crate readout of ~ 120 parameters, the total dead time including signal processing and readout time per event was measured to be 75 μsec. Typical coincidence count rates were ~ 12 kcs γ-γ doubles and 3-4 kcs γ-γ-γ triples for a total singles γ rate of 40-60 kcs. An oscilloscope trace of the multiplicity distribution is shown in fig 11.

## Detectors

For the operation of INGA, detectors from the collaborating institutions TIFR, SINP and IUC-DAEF were received during Dec 2007 - Jan 2008. Presently 23 anti-Compton shields and 18 Clover detectors can be used in the setup. Two detectors have developed vacuum leaks and need to be sent back to the manufacturer for servicing.

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### 4.2.2 Experiments using GDA / INGA related facilities

The GDA / INGA facilities were used in this year by various users and there were in total eight number of experiments were done (refer table).

| Date | Description | Beam | Energy MeV | User |
|---|---|---|---|---|
| 12/10/07 | Transfer & Fusion excitation function for $^{40}$Ca + $^{70,66}$Zn around Coloumb barrier | $^{40}$Ca | 106-146 | SM/DU |
| 28-12-07 | Fusion Fission dynamics in A ~ 200 | $^{19}$F | 90-110 | SN/IUAC |
| 28-1-08 | INGA facility test - Quartz | $^{28}$Si | 96 | INGA |
| 06/02/08 | INGA facility test | $^{28}$Si | 96 | INGA |
| 16-2-08 | INGA facility test | $^{16}$O | 65 | INGA |
| 20-2-08 | INGA facility test | $^{16}$O | 65 | INGA |
| 28-2-08 | Spectroscopy and lifetime measurement of $^{77}$Sr | $^{40}$Ca | 135 | DN/IUAC |
| 13-3-08 | Study of exotic shapes and nuclear structure at high spin in $^{137}$Pm | $^{32}$S | 150 | AD/BHU |

### 4.2.3 HPGe detector Service / Annealing

As the Clover and HPGe detectors have been used in-beam over the years, they need periodic annealing to minimize peak broadening due to neutron-induced damage to the crystal.

Eight HPGe detectors were evacuated and annealed to restore the FWHM of the detectors. One clover detector was serviced by replacing two FET's as part of INGA maintenance. Two Clover detectors (one each of SINP & one of UGC-DAE-CSR) have vacuum leak through the LN2 dewar side into Ge crystal chamber which will have to be serviced at factory.


**Fig 12. Annealing station for Ge detectors**

A new annealing station (fig 12) has been assembled for servicing four detectors simultaneously. This system is based on Turbo-molecular pump backed by roots pump, along with associated gauges, valves and controller with complete interlock system, providing oil free environment for annealing station.

### 4.2.4 NP - Beam Hall II 2007

One workshop on '**Nuclear Physics with Beam Hall II Facilities at IUAC**' was held in August 27-28, 2007. During the workshop, experimental proposals using Pelletron beams were invited from users. This resulted in thirty one beam experiment proposals from users across the country which was considered by the INGA – PICC and AUC. During the first cycle of INGA from February 28, 2008 to June 30, 2008, fifteen experiments have been allotted beam time.

## 4.3 RECOIL MASS SPECTROMETERS

### 4.3.1 Heavy Ion Reaction Analyzer (HIRA)

J. Gehlot, S. Nath, A. Jhingan, T. Varughese, J. J. Das, P. Sugathan, N. Madhavan, Rakesh Kumar, R. P. Singh, S. Muralithar, R. K. Bhowmik, P. Shidling[1], Ranjeet[2] and E. Prasad[3]

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[3]Department of Physics, Calicut University, Calicut, Kerala

HIRA was used in an experiment involving stable beam and mass dispersive mode. The experiment carried out involved the study of fission hindrance in $^{19}F + {}^{184}W \rightarrow {}^{203}Bi^*$ through evaporation residue (ER) cross section and spin distribution measurements, using 14 BGO detectors at the target site of HIRA. In this experiment, data for only four lower energy points could be collected and the remaining few higher energy points' data would be taken up as soon as those energies are available from the Pelletron accelerator. The details of this experiment are elaborated elsewhere (S. Nath et al.) in this report.

The earlier study of fission hindrance phenomena and entrance channel effects in $^{200}Pb^*$ compound nucleus using two systems in the entrance channel ($^{16}O + {}^{184}W$ and $^{19}F + {}^{181}Ta$) on either side of the Businaro-Gallone (BG) critical mass asymmetry, at similar excitation energy, has yielded encouraging results which have recently been communicated. We have shown that the measurement of ER cross section and spin moments are sensitive to pre-saddle dynamics and they together reveal the effect of entrance channel and indicate increased pre-equilibrium fission at higher spin values for entrance channel mass asymmetry lesser than the BG critical mass asymmetry (ie. $\alpha < \alpha_{BG}$). The research scholar (Praveen Shidling, Karnatak University, Dharwad) involved in this study has been awarded Prof. C. V. K. Baba memorial award for best Ph. D. thesis in DAE symposium on Nuclear Physics held at Sambalpur university, Orissa (December 11 – 15, 2007).

Preparations are on for two more fusion-evaporation experiments, one a thesis experiment of a Delhi university scholar and the other proposed by a Panjab university (Chandigarh) faculty, which will be scheduled in the near future.

### 4.3.2 HYbrid Recoil mass Analyzer (HYRA)

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

[1]IUC-DAE Consortium for Scientific Research, Kolkata Centre, Kolkata
[2]Department of Physics and Astrophysics, University of Delhi, Delhi

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Funds for the development and fabrication of the electrostatic dipole (ED) which is crucial to complete the second stage of HYRA have been received from DST, Govt. of India during the second half of 2007. The order has been placed and it is expected to be in IUAC, after due testing, by March 2009. The power supplies are planned to be suspended from above, inside a Faraday cage, to have more floor space available.

The first stage of HYRA has been expanded to the momentum achromat configuration Q1Q2-MD-Q3-MD-Q4Q5 (Fig. 1). The first focal plane chamber is ready and installed in the facility. The support structure for this chamber is made in modular form in order to use it in place of Q3, when required, in a reproducible manner. Electrical and water connections for the newly installed quadrupole doublet will soon be taken up.

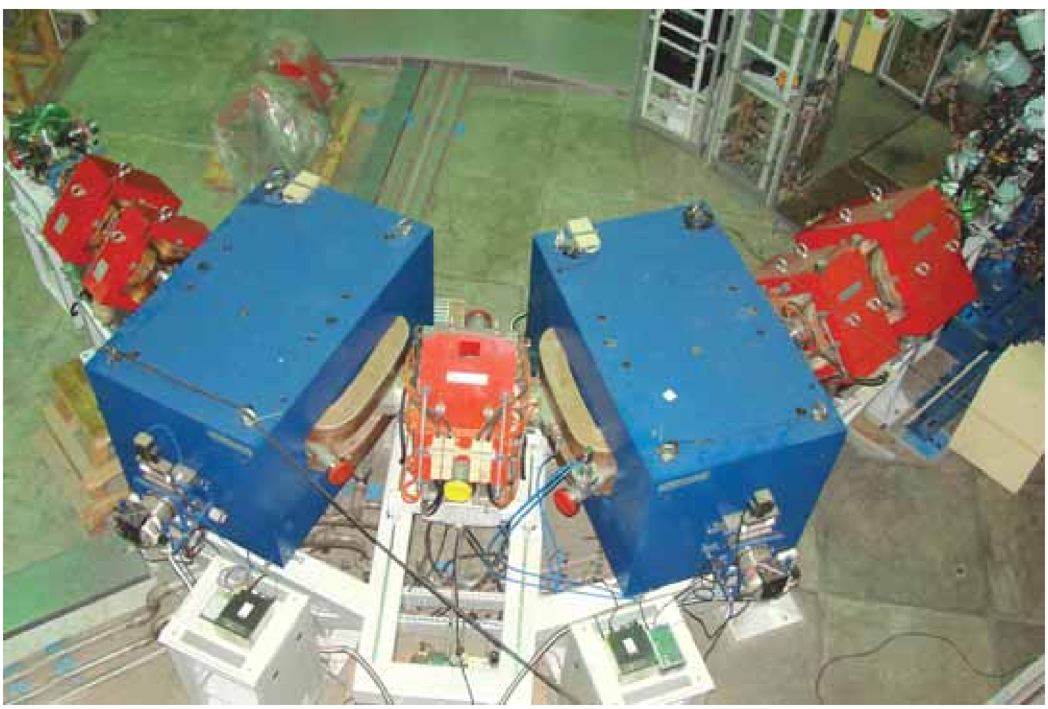

**Fig. 1. HYRA first stage momentum achromat coupled with INGA facility**

Beam tests of the momentum achromat for secondary unstable beam production and further tests/experiments using gas-filled mode are planned to be taken up after the stand-alone INGA campaign that is currently underway. Ion optical trajectories for the momentum achromat, in dispesive plane (bottom) and in non-dispersive plane (top), are shown in Fig. 2. The separation between primary stable beam and secondary radioactive beam, achieved using the momentum achromat at Q3 centre, are shown for few cases in Fig. 3 (a and b).

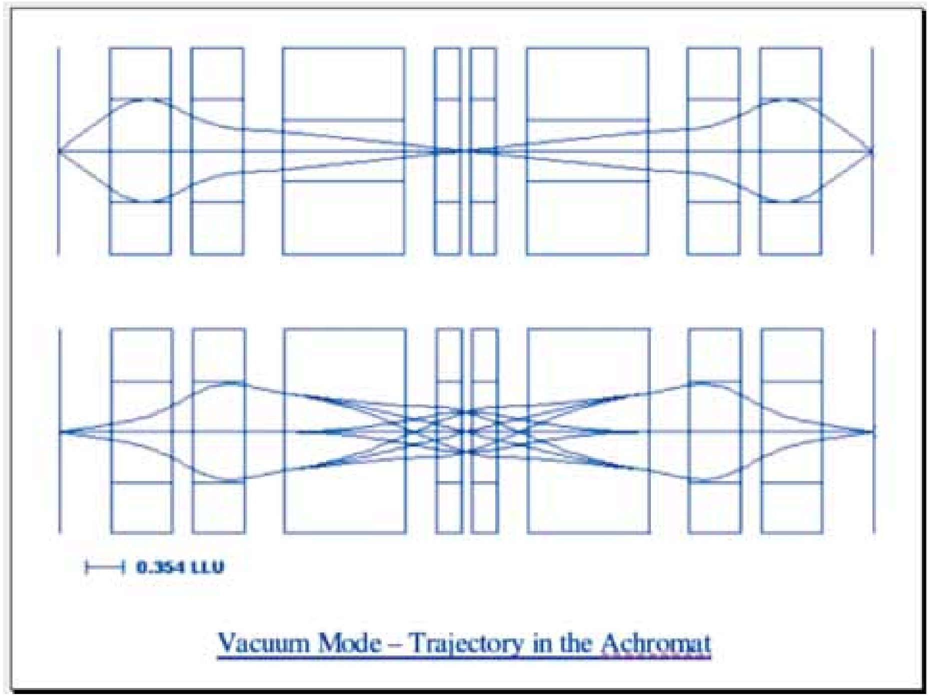


**Fig. 2. Trajectories of particles in momentum achromat mode of HYRA (first stage)**

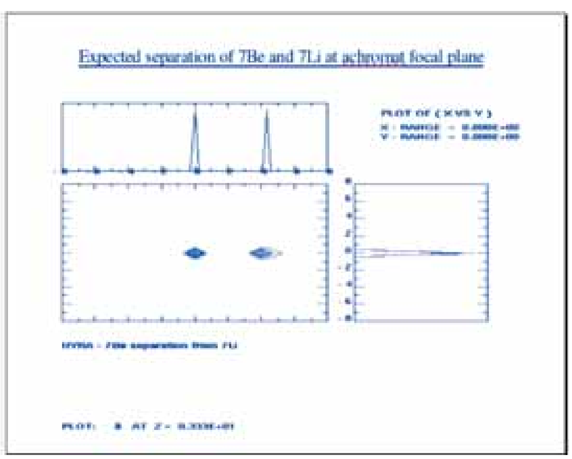


**Fig. 3 (a)**

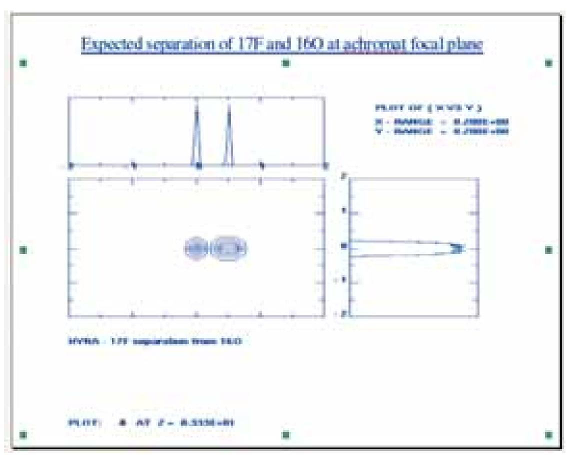


**Fig. 3(b)**

**Fig. 3. Separation between stable primary beam and radioactive secondary beam at Q3 centre of HYRA in momentum achromat mode, simulated using GIOS program (a) for $^{7}$Li and $^{7}$Be combination and (b) for $^{17}$O and $^{17}$F combination**

IGOR modules, being developed indigenously for remote control/read-back of power supply settings, are expected to be ready in a month's time. There was a delay in getting these ready last year as the same group was involved in the design and fabrication of INGA clover and BGO detector power supplies and pre-amplifier power supplies.

Most part of last year was devoted to setting up the INGA facility in HYRA-INGA beamline. The 4" beamline was dismantled in July 2007 in order to pave the way for setting up of INGA support structure and the array. After the completion of the array installation, the modified beamline, designed taking into account the constraints of INGA and HYRA, was installed and connected to HYRA in January 2008. In the stand-alone INGA campaign too, the beam is taken to the MD1 beam catcher in order to reduce the gamma background and the current measured in the beam catcher helps in beam tuning.

In the case of first trial winding for superconducting Q1-Q2 using copper wire, it was noticed that the coil was not uniformly taut and the epoxy coating was not sufficiently thick. The wire winding machine has been improvised by including an additional braking mechanism for the wire spool and better epoxy dispenser (Fig. 4). One more trial copper winding has been carried out which is much better in epoxy coating and uniformity. Winding of superconducting wire will be taken up after couple of copper windings. The cryostat development, which was not taken up due to the LINAC second and third cryostat related work, is planned to be pursued so that the cryostat will be ready by this year end.

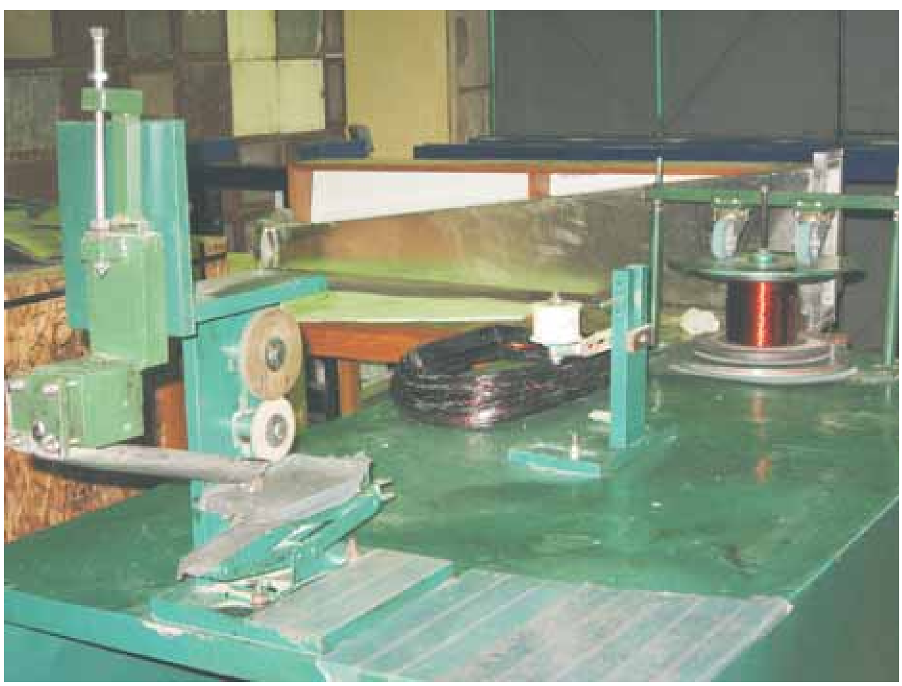

**Fig. 4. Improvements in wire winding mechanism**

## 4.4 MATERIALS SCIENCE FACILITY

A. Tripathi, Ravi Kumar, V.V. Shivkumar, F. Singh, S.A. Khan, P. K. Kulriya, I. Sulania, D. Kabiraj, R.N. Dutt, 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 related experiments are performed in the three chambers in the beamline as well as in the general purpose scattering chamber. Besides this the off-line facilities are also being used by many users for preparing and characterizing samples. A total of 115 user experiments comprising 334 shifts 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 high vacuum chamber in materials science beamline is used in most of the experiments for irradiation and ERD studies. A new arrangement for mounting the o-ring in this chamber was made this year for smoother operation. The goniometer mounted on UHV chamber for channeling studies had developed a problem and the problem was rectified this year. The irradiation chamber in beamhall II was used in 2 user experiments this year. The in-situ XRD facility was also used in user experiments this year.

FTIR and PL systems are also being used regularly. The UV-Vis spectrophotometer in radio-biology lab is used by many materials science users. The D/W lamps of the system were replaced this year to improve its performance. The materials synthesis lab has many synthesis techniques and 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.

### 4.4.1 Scanning Probe Microscope

A. Tripathi, I. Sulania

Multi Mode SPM with Nanoscope IIIa controller acquired from Digital/Veeco Instruments Inc. was extensively used in user experiments. The calibration and performance in AFM/MFM mode was tested using standard grid and magnetic tapes respectively. The operating software had developed a problem which was rectified. The system in 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. PSD studies for surface growth on InP surface were performed this year. This year more than 700 samples from 50 users have been studied in AFM/MFM mode.

### 4.4.2 Micro-Raman set up

F. Singh, A. Tripathi, J. Zacharias, D.K. Avasthi

The installation and offline testing of the Renishaw InVia micro-Raman set up was completed last year and the facility is regularly being used. To protect the system a cabin in beam hall II designed and fabricated. The chamber for in-situ study has been designed and fabricated and is under testing. A vibration free table and 4 axis sample movement system have also been acquired for integrating the system with beam line.

**Fig. 1. Renishaw Invia Micro-Raman Setup in beamhall II**

### 4.4.3 D8 Advance XRD Diffractometer

P. Kulriya, F. Singh and A. Tripathi

The Bruker D8 advance system from Bruker has been used in characterization of more than 1000 samples from nearly 100 users this year. Out of these GIXRD mode has been used in 490samples and Bragg-Brentano Geometry was used in study of 574 samples. The low temperature insitu XRD set up was used in 3 user experiments.

The XRD set up had a breakdown due to a problem in cooling tube of X-ray generator and the problem was rectified by replacing the cooling fan and modifying its mounting arrangement. The replacement of Cu X-ray tube was also undertaken to improve the performance of the XRD facility. There was a problem in glancing angle measurements which necessitated refurbishment of Göbel Mirror and it has been sent to the company for polishing.

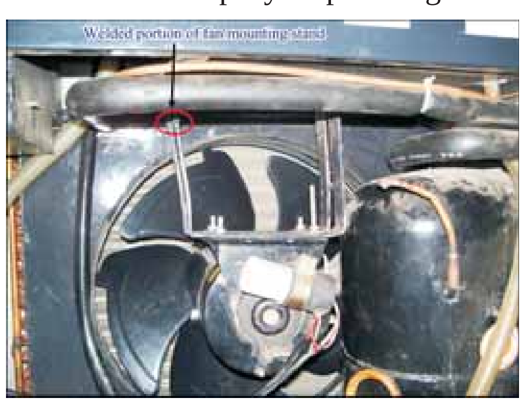


**Fig. 2. Photograph of the fan mounting stand with arrow showing the portion which was broken.**

### 4.4.4 Testing of sample cooling unit with beam


P. Kulriya, A. Tripathi, D.K. Avasthi and D. Pandey[1]

[1]Banaras Hindu University, Varanasi


The indigenously fabricated sample cooling unit cooled with liquid nitrogen ($LN_2$) was installed with insitu X-ray diffractometer in the last academic year. A minimum temperature of 88K was achieved. Recently, the test experiment with swift heavy ion beam was performed when target was kept at low temperature. The polycrystalline sample of $BaTiO_3$ has been irradiated at the materials science beamline, phase-II of the Pelletron accelerator at the IUAC, New Delhi. The irradiation was done using $^{108}Ag^{+9}$ ions with kinetic energy of 120 MeV. This energy corresponds to electronic stopping power of 8.0 keV/nm as calculated using SRIM. The ion fluences were varying from $1x10^{11}$ to $3x10^{13}$ ions/cm$^2$.The XRD spectra was recorded with scattering angle varying from $10^0$ to $90^0$ with a scan speed of $0.1^0$/min.  Spectrum is recorded using position sensitive Vantec detector with detection step of $0.02^0$ in Bragg -Brentano geometry. Figure 1(a) shows the XRD spectra of pristine and irradiated $BaTiO_3$ at 300K. Pure $BaTiO_3$ exits in a tetragonal structure with lattice constants a=0.3994nm and c=0.4033nm at the room temperature and pressure. It transforms to the rhomb-centered structure with lattice constants a=0.4004nm at low temperature (less than 200 K).

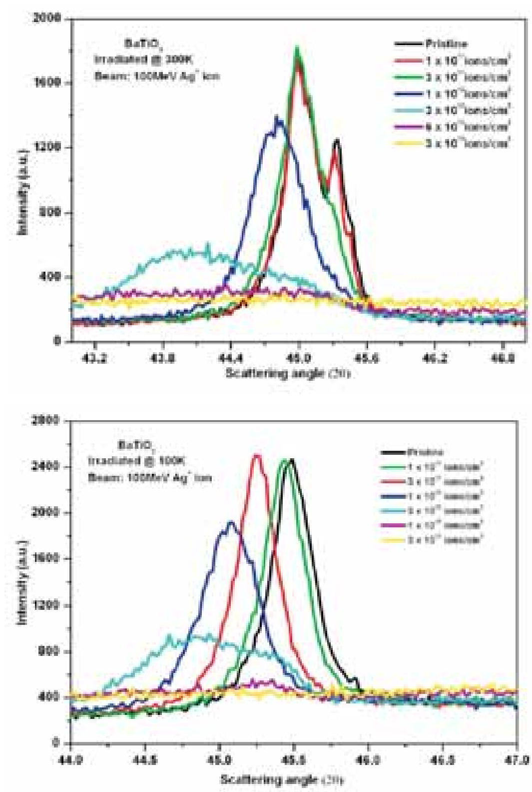


**Fig.1. In-situ X-ray diffractometer spectra of pristine and irradiated ($BaTiO_3$ samples) with $^{108}Ag^{+9}$ ions at (a) 300K and (b) 100K with ion fluence varying from $1x10^{11}$ to $3x10^{13}$ ions/cm$^2$**

It is clearly revealed that at the lower fluence, scattering angle shifted toward low angle and the intensity of the peak is decreased with increase in the ion fluence. The possible reason for this lattice expansion is the strain induced by ion irradiation. But when fluence is further increased then the sample becomes completely amorphous at the $6x10^{12}$ ions/cm$^2$ fluence. It will remain amorphous up to very high fluence in the range of $3x10^{13}$ ions/cm$^2$. Figure 1(b) shows the XRD spectra of pristine and irradiated $BaTiO_3$ at 100K. It also shows similar behavior as the room temperature irradiated sample except that it became amorphous at a higher fluence (~ $1\ x10^{13}$ ions/cm$^2$).

### 4.4.5 Development of a low cost Electric Field versus Polarization (E-P) Measurement Setup

Shailendra Kumar[1], Rajesh Kumar[2], S. K. Suman[2] and Ravi Kumar[2]

[1]Department of Applied Physics, Aligarh Muslim University, Aligarh

Ferroelectric and multiferroic materials are usually defined as irreversibility of the spontaneous polarization by an applied electric field, the observation of the hysteresis is fundamental for the research on ferroelectrics and multiferroic materials. There are number of experimental setup aimed for measuring these loops, among these setups the Sawyer-Tower circuit is one of the most traditional, which consists of a oscilloscope and a large integrating capacitor in series with the specimen. In the Sawyer-Tower circuit, a sinusoidal or triangular voltage is applied to one of the electrodes of the sample, and the charge Q generated in the sample is detected. The loop obtained using the simple Sawyer-Tower circuit is often distorted because of conduction current and heat dissipation as well. The significance of this measurement can be easily understood by examining the P-E loops for some simple linear devices. It is well known that there are two charge measurement modes for the system, Sawyer-Tower and virtual ground amplifier mode. In an original Sawyer-Tower circuit there was no provision to eliminate or compensate the different contributions coming from non linear conductivity, capacitance of the samples under study and signal phase difference etc. These contributions deform the shape of the real hysteresis loops to some extent and in some case, may lead to misinterpretation of the ferroelectric character of the materials. Therefore, some modifications in the original Sawyer-Tower circuit are needed. Here, we have developed electric field versus polarization measurement setup, where we have added some new features to compensate the insulating resistance and linear capacitance of the ferroelectric material. This setup is simpler and less expensive than earlier reported, capable to extract quantitative information of coercive field ($E_c$), remanent polarization ($P_r$) and saturation polarization ($P_s$). These parameters are most likely to be of interest to the materials manufacturer and will give a better understanding of the material behavior too.

Fig. 1 shows the block diagram of the modified ferroelectric hysteresis loop tracer. A transformer is used to generate high voltage (5 kV (pp), 50 Hz). The applied voltage (V) can be adjusted using the variac transformer. The output of the transformer i.e. high voltage is applied to three different points: (i) to one electrode of the ferroelectric sample (ii) to the network designed for compensating both insulating resistance and linear capacitance of the sample and (iii) to the amplifier /attenuator whose output is directly connected to the X axis of an oscilloscope. The other electrode of the ferroelectric capacitor is connected to an operational amplifier, which is at zero volt potential (virtual ground). $V_S$ denotes the voltage across the ferroelectric sample. If $C_S$ is the capacitance of the ferroelectric samples, the charge developed across the ferroelectric sample will be $C_S V_S$.

Since the operational amplifier has infinite input impedance, charge for the ferroelectric sample should come from $C_B$ i.e. capacitor connected between the amplifier's output and non-inverted terminal. The charge from $C_S$ goes into $C_B$ thus producing a voltage which is equal to $q/C_B$, so that the Op-Amp voltage is $-V_B$. Since the charge should be same on both the capacitors, therefore, $V_B = -(C_S/C_B)\, V_S$. This voltage is proportional to the polarization of the ferroelectric sample and is inverted by an amplifier and than applied to the Y axis of the oscilloscope. Compensation of the linear conductivity of the ferroelectric sample is realized in this circuit by injecting a charge of the opposite sign to that produced by the $V_S$ across the ferroelectric sample. This current is generated by inverting $V_S$ and by applying it across $R_C$. Similarly, the current through the linear capacitance of the sample is cancelled by applying a voltage to $C_C$. In our circuit $R_C$ and $C_C$ have values of 10 k ohm and 10 nF. Fig. 2 (a - d) shows the ferroelectric hysteresis loop of BaTiO3, PNN and TGS. Fig. 2 (c, d) shows the hysteresis loop before and after the compensation at room temperature. The observed value of the ferroelectric parameters i.e. spontaneous polarization and coercive field are in the good agreement with values in the literature.

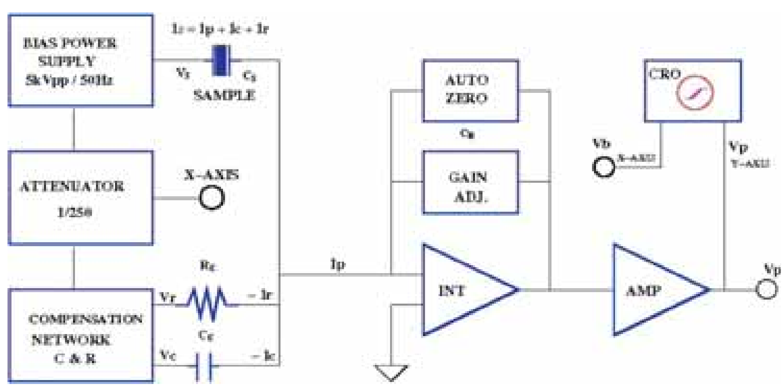


**Fig.1. Block diagram of electric field (E) versus polarization (P) measurement setup**

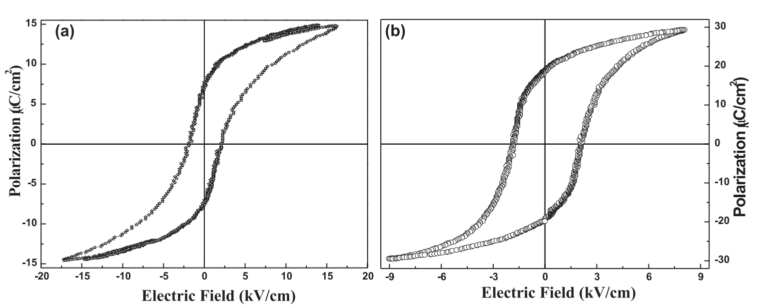


**Fig.2. Hysteresis loop at room temperature for (a) $BaTiO_3$ and (b) $(PbNi_{1/3}Nb_{2/3}$-$PbZr_{0.34}Ti_{0.66})O_3$**

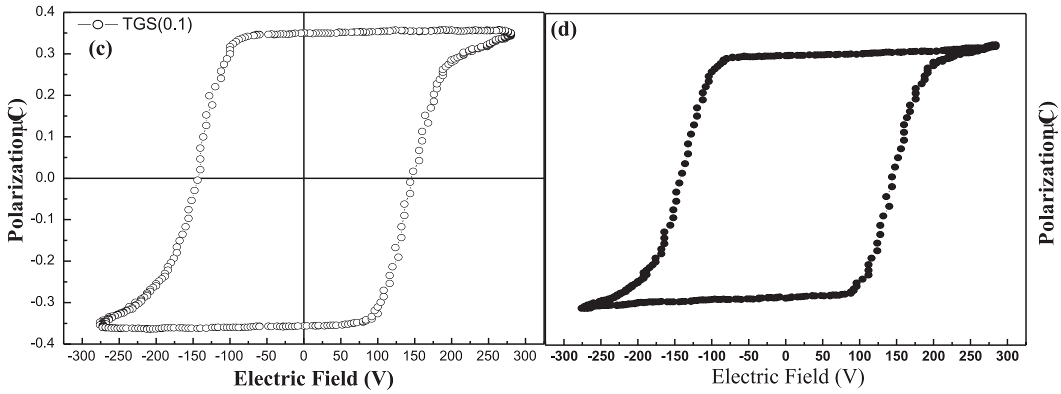


**Fig.3. Hysteresis loop of TGS single crystal for (c) Uncompensated and (d) Compensated one**

## 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 proton, $^{7}Li$, $^{11}B$, $^{12}C$, $^{14}N$ 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 are. The uniformity is better than 97%. The flux control is done by adjusting a double slit through CAMAC from control room. A preset controller for faraday cup ensures the exposure repetition as per user requirement.

A major redesigning of the irradiation system is currently going on, which would take 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 dosimetry system would also be improvised along with that. The renovation would facilitate better experimental condition from the biological point of view.

**Fig.1. Multi axis positioning system during the laboratory testing**

The installation and testing of the servo motors and pneumatic system using the computer has been done and the components have been mounted on the locally fabricated base plate and stand. The magazines for keeping the petri dishes have been made with precision machining and the entire system is expected to be operational by April 2008.

### 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]. This year we have augmented the storage facility by procuring a large capacity freezer.

In addition, a fluorescent microscope [Carl Zeiss] has been installed 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 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, cell survival studies using radio mimic reagent like $H_2O_2$ has bee 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, projects involving MCF-7, CHO and lung carcinoma cells would also be taken up in due course.

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 Atomic Phyics Beam Line

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

[1]Department of Physics, Punjabi University, Patiala

Dedicated atomic physics beam line has been installed in the beam hall II with many new features. They include a beam collimator, changed geometry of x-ray detectors, monitoring ion-beam flux by silicon surface barrier detectors as well as a Faraday cage, a triple axes target mounting system containing three target ladders, a viewing camera, lighting arrangement, etc. This beam line is planned to carry out various experiments such as beam-foil, inner-shell ionization, and electron spectroscopy in the vacuum chamber and at the back charge state fraction (CSF) analysis of the beam on passage of the solid foil as well as gas jet/cell. CSF measurements using electrostatic analyzer and position sensitive proportional counter (PSPC) will be realized soon. The beam line is designed in such a way that one experimental set up does not disturb the other.

In this vacuum chamber we have installed a precision foil thickness, required for collision-induced intra shell transition experiments, measuring set up also using cooled silicon surface barrier detector at $-20^{o}$ C.

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 is being 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. Besides, we are shortly going to carry out multi nucleon transfer reactions in GPSC. Such nuclear studies are required to make use of secondary beam-foil source as a new method of investigating H-like heavy ions (see article 5.4.3). In this source ion-beams are replaced by projectile like ions produced from nuclear transfer reactions.

1 M normal incidence Spectrometer has been made ready for optical spectroscopy experiments in the PKDELIS laboratory. We are planning to make a program for carrying out measurements relevant to astrophysics.