4. EXPERIMENTAL FACILITIES IN BEAM HALL

4.1 GENERAL PURPOSE SCATTERING CHAMBER (GPSC)

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

This facility has been used routinely for both Nuclear Physics and Materials Science experiments. Ten charge sensitive preamplifiers from ORTEC and CAEN have been installed this year for using with surface barrier detectors mounted inside the scattering chamber. For fast timing measurements, CANBERRA 2003 and ORTEC made VT 120 preamplifiers are used.

A detector cooling system has been installed in the GPSC beam line for improving the timing performance of silicon surface barrier detectors. The detectors can be quickly warmed up to room temperature (warm up time ~ 20 min from -4°C to 20°C) if the chamber has to be vented to atmospheric pressure. The cooling system for one detector has been tested out satisfactorily. A dedicated detector cooling arrangement for six surface barrier detectors is planned in future.

The following developments were carried out during present year:

4.1.1 Modification in Scattering Chamber

Golda K.S., A. Kothari, P. Barua and S.K. Saini

The scattering chamber of Neutron lab is equipped with a Diffusion pump backed by rotary pump with all the valves pneumatically controlled. A dedicated gas handling system has been attached to the scattering chamber for using gas detectors. Electro-polishing and ultrasonic cleaning of the chamber were carried out to get better vacuum, low 10^{-6} mbar, to carry out testing of delicate instruments like MCP. A hydraulic lifting mechanism is under construction to lift the SS lid of the chamber. A perspex lid is also provided for easy handling when the chamber is used in the range of 10^{-5} mbar vacuum.

4.1.2 Array of Neutron Detectors (AND)

R.P. Singh, Golda K.S., Rakesh Kumar, Hardev Singh[1], I.M. Govil[1] and S.K.Datta

[1]Dept. of Physics, Panjab University

As part of the DST project titled ***'Study of Nuclear Fusion-Fission time scales and level densities using neutron detectors'*** a multi detector neutron facility has been set up in Nuclear Science Centre. It consists of eight NE213 based liquid scintillators housed in Aluminium cylinders with pyrex glass window on one side and coupled to XP4512B model 5" photomultiplier tubes. Four of these detectors are 5" diameter and 5" thick (BICRON make BC501A) suitable for high efficiency neutron detection and for gamma ray tagging. The remaining four are of 5" diameter and 3" thickness (SCIONIX make LS301). These will be better for time resolution for time of flight experiments.

These detectors are operated at different High Voltages varying between 900 V to 1500 V depending on the PMT coupled to it. These PMTs are normally used at two different voltages as mentioned by the manufacturer; at a lower voltage when the detectors are used for pulse height measurements and at a higher voltage when they are used for timing measurements. BICRON detectors give dynode (positive) and anode (negative) signals from their PMTs through BNC connection. In case of SCIONIX detectors PMTs give only anode signals through BNC connection. Arrangement will be done for getting dynode signals also from these.

A dedicated electronics set up including high voltage bias supply, ADC and TDC has been provided for the array. A *pulse shape discrimination module* for neutron gamma separation has been developed indigenously. All the detectors were tested out for their pulse height as well as timing performance with source and found to be satisfactory. Time resolution is between 1 to 1.5 ns FWHM.

Provisions are made to use this array in nuclear physics experiments with heavy ion beams in GPSC and HIRA. Separate boxes and stands have been made for each detector so that they can be used at different angles at GPSC. 3 mm thick aluminium flanges have been put in the GPSC at angles of 30°, 45°, 60°, 90°, 120° on the right side of the beam direction and at 20°, 45°, 60°, 120° and 150° on the left side of the beam direction. One experiment by Punjab University has been successfully carried out in GPSC using this array.

4.1.3 Fabrication of Pulse Shape Discrimination module for Neutron-Gamma separation

Rakesh Kumar, Golda K.S., S. Venkataramanan, S.K. Datta and R.K. Bhowmik

This module works on the principle of Zero Cross Over method of pulse shape discrimination. In the zero cross over method, the anode signal from the fast photomultiplier tube coupled to the scintillator is processed through a differentiating amplifier. When pulses with different rise time go through differentiation we get bipolar pulses with different zero cross over timings. Due to the difference in the interaction mechanism in the scintillator material, neutrons and gammas give pulses with different rise times and hence can be distinguished and separated by using zero cross over method.

This is an integrated unit with two independent Constant Fraction Discriminators (CFD) and associated Pulse Shape Discriminator (PSD) circuits mounted in a single width NIM module. The input current pulse from the photomultiplier is split into two; one goes to CFD stage and the other goes to PSD stage. The PSD amplifier has an integration time of 100 ns and differentiation time of 100 ns to produce a bipolar output from the photomultiplier current pulse. The comparator and logic circuits are realised in ECL. The front panel LEMO connections give outputs like CFD, Zero Crossover, Strobe, PSD and neutron gated PSD output. Provisions for monitoring threshold settings are also provided on the front panel.

The performance of the unit is tested with a ^{252}Cf source using a 5" x 5" BC 501 organic liquid scintillator. Anode signal from the PMT is given to the PSD module. The CFD output from the module is used to start the TAC and the zero cross output is used as stop. TAC output is digitized by AD811 2k ADC. Dynode signal from PMT is amplified through EG&G 571 amplifier and given to another channel of the ADC. ADC data are collected in computer through CAMAC based data acquisition system. The Figure of Merit of the PSD is comparable with that of commercial PSD module CANBERRRA 2061A. Fig. 1 shows the 2D spectrum of TAC vs. energy showing clear separation between neutron and gamma.

Fig. 1 : Two dimensional spectrum of TOF vs. light output showing two bumps for neutron (right) and gamma (left)

4.1.4 Performance of 8 Channel Peak sensing 4K ADC-CAEN C420

Golda K.S., P. Sugathan, S.K. Datta and R.K. Bhowmik

A thorough testing of CAEN Model C420 EIGHT CHANNEL PEAK SENSING 12 bit ADC has been done. The general characteristics of the ADC in which we are mainly interested have been tested out and compared with the performances of other ADCs. There are some special features of this module that make it different from other ADCs used in our Centre. As far as linearity is concerned it is better than AD811 even though not as good as CANBERRA 8075. The dynamic range of this ADC is limited to 90% of its maximum range due to sliding scale facility. Since this is a flash type ADC it is very fast and conversion time is 1.2 μs per channel according to the manufacturer. Provision for software programming makes this ADC more flexible as far as threshold set ups and strobe width are concerned. This module can serve the purpose of a fast ADC with good linearity for nuclear physics experiments.

4.1.5 Developing extended resolution from a 12 bit ADC

K.S. Golda and R.K. Bhowmik

For high resolution Ge detectors used for γ-spectroscopy, the energy resolution typically varies from 700 eV at low energies to 1800 eV at 1.33 MeV, increasing as $\sqrt{E}$ at higher energies. A minimum of 13 bit resolution is therefore required for digitizing signals in the energy range 100 keV - 2 MeV for faithful reproduction of the peak shape at low energies.

We have explored the possibility of extending the energy range of ADCs without sacrificing the resolution at low energies by dual conversion technique. A ^{152}Eu γ–source was used for obtaining energy spectra in the range 121 keV - 1408 keV. Preamplifier signal from a Clover detector (from Eurysis) was amplified in a spectroscopy amplifier with 3 μs shaping time with gain adjusted to 4 volts/MeV, and was fed to two channels of CAEN-C420 12 bit ADC with eight independent inputs. This ADC has a dynamic range of 4 V only. To one channel of this ADC, amplifier signal of 8 V pulse height was given directly and to the second channel an attenuated pulse (with pulse height of 4 V) of the original signal was given. For the first channel, 1 mV/bit resolution was adequate to preserve the line shape at low energies. For the 2nd channel, resolution of 2 mV/bit was sufficient for the higher energies (1-2 MeV) where the detector resolution is also degraded compared to lower energies.

The digitized spectra obtained from these two sets of data were combined together in software into a single 13 bit spectrum, after software gain matching and giving adequate weight to each set of data, to get complete energy spectrum of ^{152}Eu. The combined spectrum was qualitatively similar to spectra obtained directly from a 13 bit ADC, demonstrating the application of dual conversion technique for extending the conversion range of ADCs.

4.1.6 Experiments conducted in GPSC

The list of experiments done at GPSC during 2002-2003 are given below:

Nuclear Physics Experiments

Sl. No.	P.I. & Institute / University	Title of Experiment
1.	Avinash Agarwal AMU	Study of complete & incomplete fusion reactions using heavy ions in some nuclei.
2.	BP Singh AMU, Aligarh	To study complete & incomplete fusion and pre-equilibrium emission in nuclear reactions induced by heavy ions
3.	Tilak Kr. Ghosh SINP, Kolkata	Study of heavy ion induced fission fragment angular and mass distribution at near/sub-Coulomb barrier energy
4.	K.M. Varier Calicut Univ.	Study of anomalous fusion fission reactions on deformed actinide targets in near/sub-barrier region
5.	Ajay Kr. Tyagi Panjab Uni.	Study of dynamical and entrance channel effects in fusion reaction via neutrons

Materials Science Experiments

Sl. No.	P.I. & Institute / University	Title of Experiment
1.	A.C. Pandey Allahabad University	Electronic sputtering of LiF
2.	B. Sannaki Gulbarga University	Energy loss of heavy ions in polymers / SHI in polymers : Some fundamental aspects
3.	J.K. Quamara REC, Kurukshetra	Optoelectronic processes in swift heavy ion irradiated polymers
4.	Arun Batra ISRO	Heavy ion effects in VLSI devices

Sl. No.	P.I. & Institute / University	Title of Experiment
5.	Diganta Saikia Tezpur University	Investigation of SHI irradiation effects on ionic conduction in Li based gel polymers electrolytes
6.	Naveen Acharya Univ. of Rajasthan	Development and characterization of polymeric membrane filters
7.	Pawan Kr. Diwan Kurukshetra Univ.	SHI in polymers : Some fundamental aspects / Energy loss of heavy ions in polymers
8.	J.K. Quamara REC, Kurukshetra	Conduction mechanism of ion irradiated polymers

4.2 GAMMA DETECTOR ARRAY (GDA)

Kusum Rani, Rakesh Kumar, S.Muralithar, R.P.Singh and R.K.Bhowmik

The activity in the GDA laboratory in this year was devoted in the following areas:

Experiments with GDA & Facilities

Large Gamma detector Array

Installation of Indian National Gamma Array (INGA) at NSC

Automatic Liquid Nitrogen filling System for Clover Ge system

Computer simulation of Clover performance.

4.2.1 Experiments done using GDA beam-line

S. Muralithar, R.P. Singh, Rakesh Kumar, Kusum Rani and R.K. Bhowmik

GDA beam line was used by various users this year. The following table gives the details of the experiments completed during 2002-2003. One offline measurement of GPSC experiment with Ge detectors from the GDA set-up was done in Data room.

Description	Beam	Energy MeV	User	Facility
Breakup fusion study $^{9}Be + ^{116}Sn$, $^{10}B + ^{115}In$	$^{9}Be/^{10}B$	50 / 47.5	B.K. Yogi HPU	GPSC + Offline
Lifetime measurement in 130 region	^{19}F	93	I.M. Govil PU	RDM + GDA

Lifetime measurement ^{177}Ir	^{24}Mg	135	S. Chamoli PU	RDM + GDA
Structure of ^{73}As	^{12}C	55	B.V.T. Rao AU	GDA
Spectroscopy of ^{134}La	^{14}N	68	P. Das IITB	GDA
Magnetic moment of $9/2^-$ in ^{175}Ta	^{19}F	87	A.K. Bhati PU	PAD

4.2.2 Large Gamma Array

R.K. Bhowmik, S. Muralithar, R.P. Singh, Rakesh Kumar and Kusum Rani

During the period 2002-2003, significant progress has been made in realizing a large array of gamma detectors for γ-spectroscopic studies in India. After successful completion of the operation of an array of Clover detectors pooled from various research institutions at TIFR in 2001, the system has been reassembled at NSC during 2002-2003. This facility is described in detail in section 4.2.3.

As a long term plan for research in γ-spectroscopy in India, a proposal for the setting up of a Large Gamma Array (LGA) was submitted to DST by Nuclear Science Centre in 1998. Later this proposal was merged with the concept of a National Array with participation from all the institutions and universities and resubmitted in 1999. This proposal was accepted by DST, and funds were released in the year 2001 for the indigenous development of custom-built electronics and data-acquisition system in Phase I. Funds were also released for acquiring two Compton-suppressed Clover detectors to test the in-house developed electronics. This phase has now been completed, and the in-house developments are reported elsewhere (sections 3.5.3 and 4.2.3).

For the installation and operation of this facility in the coming years, the following work plan has been formulated:

A **Memorandum of Understanding** (MOU) has been signed among the participating institutions for establishing a world class National Experimental facility called **Indian National Gamma Array** (INGA). It is agreed upon by the participating institutions, namely, Tata Institute of Fundamental Research (Mumbai), Saha Institute of Nuclear Physics (Kolkata), Nuclear Science Centre (New Delhi), Inter-University Consortium for DAE Facilities (Kolkata Centre), Variable Energy Cyclotron Centre (Kolkata) and Bhabha Atomic Research Centre (Mumbai), to pool the resources towards this national facility.

It has been decided in the MOU that INGA would be periodically used at the three heavy ion accelerator Centres (NSC, TIFR/BARC and VECC) in the Country. It would be possible to couple the array with various auxiliary facilities in the three Centres and make them available to the users from all parts of the country. Each institution will provide the necessary infrastructure and other facilities to the INGA project, the persons working in the project and the users' community. Being a National Project, and one of its kind, it would be the endeavour of each institution to make the facility operative in the shortest period of time and ensure that it runs smoothly.

In the initial phase, the cost of local infrastructure and travel of the staff will be borne by the respective institutions. The travel for the university users will be taken care of by IUC-DAEF and NSC.

For future upgradation, project proposals would be prepared on behalf of INGA for submission to the external agencies for funding.

A proposal has now been submitted to DST jointly by NSC and other institutions for funding of the dedicated components required for installation of this facility at the new beam hall of NSC. The higher energy beam from the first module of LINAC would be shortly available in this area, and the installation of the Hybrid Recoil Separator HYRA, with which INGA would be coupled, would also start. Separate proposals would be submitted to other funding agencies for the dedicated infrastructure required at other installations. The detectors and analog/digital electronics acquired under these proposals would be available in the general pool for setting up at other accelerator centres in India.

Design of the support structure to hold up to twenty four Clover detectors and eight LEPS detectors in the HYRA beam line has been completed. As the solid angle acceptance for HYRA in the gas-filled and vacuum modes are significantly different (see section 4.3.4), it would be possible to shift the array as a whole along the beam line to change its distance from the entrance quadrupole of HYRA. A computer simulation of the structure is shown in Fig. 2. Installation work for the combined INGA-HYRA beam line would be taken up this year.

Fig. 2 : Computer simulation of the mechanical structure of INGA for HYRA beam line

4.2.3 HIRA-INGA system at NSC

K.S.Golda, Rakesh Kumar, S.Nath, R.P.Singh, N.Madhavan, J.J.Das, A.Jhingan, P.Sugathan, S. Muralithar, Kusum Rani, S. K. Saini, B.P.Ajith Kumar, S.Venkataramanan, T.Varughese, A.J. Malayadri, V.V.V.Satyanarayana, V.Patel, P.V.Madhusudhana Rao, E.T.Subramanian, R.Ahuja, A.Gupta, S.Rao and R.K.Bhowmik

BHU, DU, PU, BU, AU, CU, VBU, GU, GNDU, IITR, TIFR, SINP, IUC- DAEF-CC, VECC

INGA, the first major collaboration between the institutions in the country in the area of γ-ray spectroscopy, was initiated in 2001 at TIFR-BARC Pelletron. The detectors, electronics and data acquisition system from BARC, TIFR, SINP, VECC, IUC-DAEF and NSC were pooled together and array of nine Compton-suppressed Clover detectors with a 14-element NaI (Tl) multiplicity filter was jointly set up by the institutions in March 2001. The set up was thoroughly tested and a set of eight experiments were performed ~ 2 each by TIFR, BARC, NSC, IUC-DAEF, SINP and collaborators from the universities between April 26 to Jun 8, 2001. The performance of the Array and the Pelletron was excellent and high statistics data were collected by all participating groups.

Based on the initial success of the collaboration, it was decided to reassemble the detectors at Nuclear Science Centre in 2002. Two workshops were arranged by NSC in 2001 for utilising the accelerated beam from the LINAC. It was suggested that before the LINAC beam comes up, the power of the existing recoil separator at NSC can be fully utilised by doing recoil gated spectroscopy with INGA.

The design of a mechanical structure to hold Clover detectors at close geometry near the target plane of HIRA started in early 2002. Due to space limitations from the first quadrupole of HIRA, the front hemisphere is not available for mounting Clover detectors. The design allowed total of eight detectors to be mounted on opposite sides at nominal angles of ±80° and ±140° w.r.t. the beam direction. There are two detectors at each angle, pointing upwards and downwards respectively, at out-of-plane angles of ±18.5°. The ACS shields are mounted at a distance of 50 cm from the target so that the target to front of the heavymet collimator in front of the shield is ~ 137 mm. The distance from target to the front surface of the Clover detectors is ~ 24 cm.

The structure was fabricated by welding MS plates together in a precision jig so that the relative angle between each detector is maintained within an accuracy of ±0.5°. The two halves of the structure (Fig. 3) are mounted on the same swivel stands used in HIRA-GDA facility. These can be swung outwards during beam tuning to minimise radiation damage to the detectors.

After installation, the actual in-plane angles of the detectors have been measured to be 81.6°, 141.6°, -76.0° and -136.0° respectively. An automatic LN_2 filling system has been installed to periodically fill the detectors. In addition to the eight clovers, Four 5" diameter x 5" thick neutron detectors (BC501) were used at forward angles above and below the scattering chamber. A provision is kept for mounting a Charged particle Detector Array inside the Clover array.

The signal cables and patch-panels were made and installed so that the signals from all 8 Clover detectors and ACS (72 signals), Charged Particle Detector Array (10 signals), Neutron Array (10 signals), were sent from HIRA target site to LIBR where the elaborate electronics was set up. This enabled tuning of electronics easy with beam on target. A set of cables required for biasing the detectors (Clover, ACS, Neutron detectors) were laid from HIRA target site to nearby 19" rack. A dedicated electronics setup was made using the electronics of TIFR, SINP and NSC for the processing of the signals from Suppressed Clover Germanium Array, CPDA, Neutron and HIRA.

Ten Clover germanium detectors along with Anti-Compton shields from IUC-DAEF-CC (3), SINP (2), NSC (3) and TIFR (2) were pooled to realize the facility. Two special compact home made modules were made at NSC and installed to process the signals of two Clover Germanium detectors along with signal from respective Anti-Compton Shield. The Charged Particle Detector Array with scattering chamber and electronics was provided by TIFR for some of the experiments. For the rest of the experiments the HIRA (Aluminum) scattering chamber was used to mount the target. First few of the experiments also used two unshielded HPGe detectors at forward angles for DSAM studies. Two views of the INGA array are given in Fig. 4 and 5.

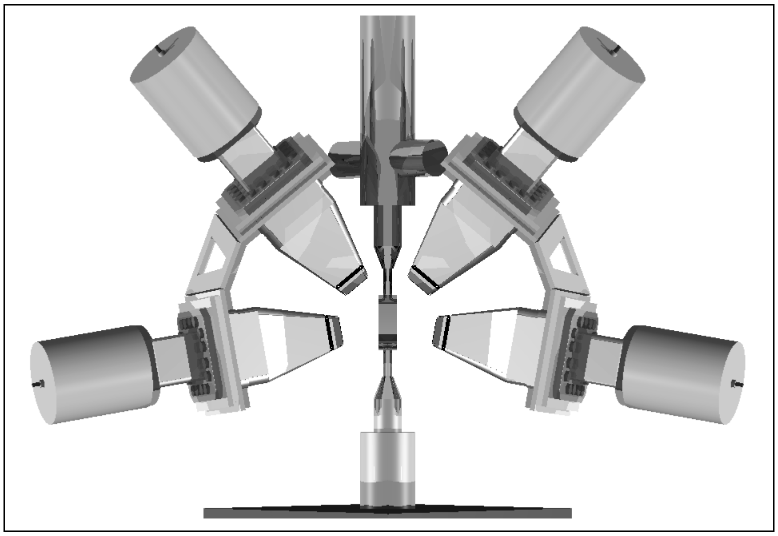


Fig. 3 : Mechanical structure for holding the Clover detectors around the target of HIRA (view from top). The front quadrupole of HIRA is shown at the bottom

The multi-crate Data Acquisition System CANDLE (*Collection & Analysis of Nuclear Data using Linux Network*) was configured to collect data from two CAMAC crates connected to two PC data servers and controlled / monitored through a 'Client' computer. A hand-shaking signal was provided between the 'Master' and 'Slave' Trigger Generators in the two CAMAC crates to ensure a common dead time for both crates.

For every event, the energy information from each Clover detector segment was recorded. In addition, the timing from each Clover, Charged Particle Detector signals (Multiplicity, γ-CP TAC), Neutron detector signals (energy, Pulse Shape Discrimination from 4 detectors, and γ-neutron TAC), and HIRA signals (X, Y, DE, γ-Recoil TAC) were also recorded. In total, 59 number of ADCs were readout at a typical count rate of few thousand events per second. Provision was given to take data either in singles γ- mode or γ-γ coincidence mode. The list mode data was stored in Hard disk and later archived onto CD's.

Fig. 4 : INGA facility at NSC. The aluminum scattering chamber can be seen at the centre. Two HpGe detectors are mounted at forward angles

Fig. 5 : INGA facility at NSC. The TIFR Charged Particle Detector Array can be seen at the target position. Four neutron counters are mounted at forward angles

The performance of the DAS software *CANDLE* at high count rates is shown in Fig. 6. The throughput (m) is related to the input trigger rate (n) by the equation $m = n(1 - m\tau)$ where τ is the dead time per event. The measured dead time $\tau \sim 80$ -110 μs, is primarily dictated by ~ 2 μs readout time per parameter for the List Processors used for data collection. With increasing input trigger rate, the throughput saturates at $\sim 8 .10^3$ events/sec. An FPGA based list-processing Crate Controller is currently under development to reduce the readout time by a factor of 2.

Fig. 6 : Throughput of CANDLE (solid curve) as a function of input trigger rate (y-axis). 59 parameters distributed in two CAMAC crates were read out per event. The system dead time as a function of throughput is shown by the dashed curve

The HIRA-INGA system was thoroughly checked for the functioning with two facility tests. The nuclei of M = 80 - 83 amu, populated in the reaction ^{28}Si + ^{58}Ni at 115 MeV, were dispersed in mass and transported to the focal plane of HIRA. The corresponding γ-spectra was recorded in coincidence with recoils, along with a γ-recoil time of flight TAC.

Fig 7 shows the M/q spectrum in coincidence with strong γ-lines of the nuclei ^{80}Sr, ^{82}Sr and ^{83}Y for HIRA operated at a solid angle of 10 msr. M = 80 appears twice in the spectrum corresponding to the charge states q = 16 and 15. The tailing towards higher masses arises due to θ dependent second order aberration in the spectrometer.

Fig. 7 : M/q spectra gated by known transitions in ^{80}Zr, ^{82}Zr and ^{83}Y

Fig. 8 shows γ-spectra gated by the mass groups M = 80, 82 and 83. The M = 83 spectra are dominated by the γ–transitions in ^{83}Y and ^{83}Zr, with small contamination from the transitions in the lighter isotopes ^{82}Sr and ^{82}Y.

Fig. 8 : Mass-gated γ-spectra in the Clover detectors

The Charged Particle Array and the neutron array, installed along with the INGA array, also performed satisfactorily during the experiments. Some representative spectra, obtained with charged particle and neutron gating, are reported in section 5.1.

The list of users of the INGA-HIRA facility during the period May 2002 - March 2003 are given below.

Description	Beam	Energy MeV	User	Facility
HIRA-INGA Facility test	^{28}Si	110	NSC	HIRA, Clover
HIRA-INGA Facility test	^{27}Al	95	NSC	HIRA, Clover

Shears Mechanism in A~110	^{30}Si	120	S. Tandel BU	Clover, HPGe
Nuclear Structure in A~130	^{30}Si	135, 138	N. Singh PU	Clover, HPGe
Spectroscopy of n-rich nuclei	^{34}S	150	A.K. Sinha IUC-DAEF CC	HIRA, Clover, HPGe
High spin states in ^{138}Ce	^{12}C	65	S. Chanda FC College	Clover, HPGe
Magnetic rotations in ^{137}Pr	^{19}F	80	S.S. Malik GNDU	Clover, HPGe
Spectroscopy of N=Z nuclei	^{28}Si	92	H.C. Jain TIFR	HIRA, Clover, CPDA, Neutron Det.
Chiral bands in ^{109}Ag	^{13}C	65	S. Chattopadhyay SINP	Clover, CPDA, Neutron Det.
Spectroscopy in A~40	^{28}Si	88	M.S. Sarkar SINP	HIRA, Clover, CPDA, Neutron Det.
SD bands in sd nuclei	^{12}C	60	R.P. Singh NSC	HIRA, Clover, CPDA, Neutron Det.

4.2.4 Automatic Liquid Nitrogen filling System for Clover Ge Detectors

Kusum Rani, A.J. Malyadri, S. Muralithar, Rakesh Kumar, S. K. Saini, B.P.Ajith Kumar and R.K.Bhowmik

A Liquid Nitrogen Filling System has been installed for periodically filling the Clover Germanium detector array (INGA) in HIRA beam line. The system is programmed to fill the detectors automatically every eight hours from a stationary 200 litre dewar. This storage dewar can be filled periodically from the 5000 lt dewar kept outside the beam hall.

LN_2 from the storage dewar is distributed to the clover detector dewars through two manifolds and up to sixteen electro-peumatically operated valves. Each detector has an overflow liquid nitrogen sensor (PT100). The control system monitors the resistance of each sensor through a built-in ADC and controls the opening and closing of the valves in proper sequence. Differential line driver has been used to improve noise immunity. In case of any malfunction (i.e. no liquid in storage dewar or time-out in filling of a dewar), an ALARM is sounded for manual override. By filling all the dewars in parallel, total filling time for eight dewars has been reduced to ~ 15 minutes compared to more than an hour for manual filling.

4.2.5 Simulation study of a Clover gamma ray detector

R.P. Singh, L.T. Baby and R. Bhowmik

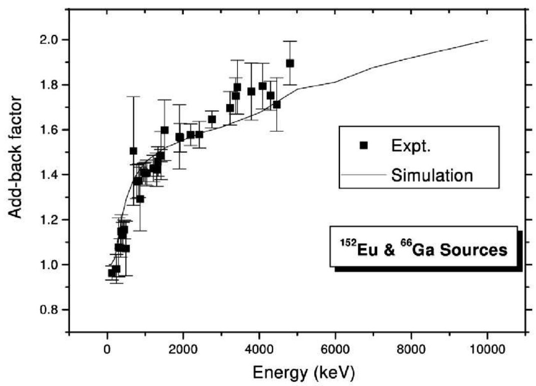
The present day gamma detector arrays employ composite Ge detectors. In the Indian National Gamma detector Array (INGA) [1] clover detectors were used. Clover detector consists of four co-axial n-type Ge detectors, arranged like the four leaf of a clover [2].

To understand the characteristics of a clover detector we have done Monte-Carlo simulations [3,4] to determine the photopeak efficiency, addback factor, peak-to-total ratio, polarisation sensitivity and Doppler broadening as a function of gamma ray energy. The simulation program follows the interaction of a flux of incident mono-energetic photons in an interacting medium consisting of four Ge crystals in a clover geometry surrounded by a BGO anti-Compton Shield (ACS) (Crismatec geometry [5]). The dimensions of each Ge crystal is cylindrical with 51 mm diameter and 71 mm length with an inactive cylindrical core (51mm length and 11 mm diameter). The front sides of the crystals are tapered to 4cm x 4cm square with a taper angle of 7.1°. The active volume of the Clover detector is about 470 cm^3. The distance from source to front face of the Clover is taken to be 25 cm.

For an incident photon the interactions of the primary and secondary photons with the medium are followed until the full energy is absorbed or part of it escapes from the interaction zone. The Ge crystals are assumed to have dead layer in front, sides and back to simulate the absorber materials. The program also stores the hit-pattern information for polarization sensitivity and Doppler broadening calculations. The energy dependence of various processes in Ge and BGO are taken from reference [6]. The Compton scattering of a photon (polarized and unpolarized) is taken from Kein-Nishina formula [7].

Fig. 9 shows the calculated addback factor as a function of photon energy. A dead layer of 0.1 mm is assumed on all sides of each crystal. The experimental data points for radioactive sources of ^{152}Eu and ^{66}Ga are taken from ref 4. The increase of the addback factor with energy is well reproduced by the calculations. Increase of the front dead layer would cause the peak of the efficiency curve to be shifted towards higher energies. The side dead layer reduces the addback factors. The back dead layer simulates the dewar material, and does not have any significant effect on the efficiency.

For energies less than 200 keV, the total spectrum consists of only single hits. The double hit probability gradually increases above 200 keV and becomes 32% of all events at 2 MeV. The experimental hit pattern distribution and total photopeak efficiency were also well reproduced in the calculations. Fig. 10 shows the Polarisation sensitivity of the Clover detector for linearly polarized photons. The experimental data are taken from ref. 8.



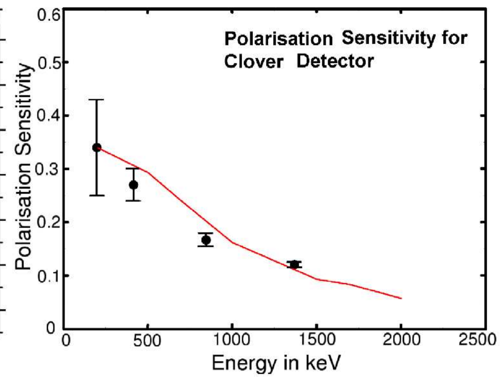


Fig. 9 : Variation of addback factor with energy for Clover detector

Fig. 10 : Variation of polarisation sensitivity with energy

Doppler Correction

In order to optimize the Doppler-correction algorithm for Clover detectors, we have studied the dependence of photopeak efficiency as a function of entrance angle of the incident photon. The energy signals deposited in the four segments of the clover are grouped into 'left' and 'right' groups by adding the energies of the corresponding segments. In Fig. 11, 'SUM' is the total photopeak efficiency of the addback signal as a function of the x-position ; 'L' and 'R' correspond to single-hit events where the total energy is deposited in the left and right crystals, respectively. The reduced efficiency at the centre of the crystals is due to the inert coaxial core.

Fig. 11 : Photopeak efficiency as a function of entrance co-ordinate of the incident 2 MeV photon. '0' corresponds to the centre of the clover front face.

Fig. 12 : Simulated energy spectrum after Doppler correction using (i) Hit-pattern (solid curve) (ii) segment energies (dashed curve)

The double-hit events has been divided into two groups, 'LR' correspond to events with $E_L > E_R$ and 'RL' corresponds to $E_R > E_L$, where E_L and E_R are the energies deposited in the left and right crystal respectively. These events are mostly localized within ± 1 cm from the boundary between two segments. For $E_\gamma > 511$ keV, most of the incident photon energy is deposited in the segment where the first interaction took place. The shapes of the response curves remain similar at higher energies where the addback component is more prominent.

Doppler correction for the single-hit events can be done by multiplying the segment energies by a corresponding scaling factor :

$E_{corr} = f_L E_L$ or $f_R E_R$ with $f_{L,R} = (1-\beta \cos \vartheta_{L,R})$ with $\vartheta_{L,R}$ corresponding to the mid-points for the left and right segments and β the velocity of the photon emitter.

For double-hit events we have tried two different algorithms:

(1) based on Hit-pattern $E_{corr} = (E_L + E_R)(f_L+f_R)/2$ ...(1)

and (2) based on segment energies $E_{corr} = (E_L f_L + E_R f_R)$ ...(2)

Both methods generate comparable spectra (Fig. 12) although the tailing is less pronounced with the 2nd algorithm. An experimental spectrum taken during INGA runs is shown in Fig. 13. The improvement in peak resolution by correcting for segment hit-pattern is clearly visible in the spectrum. First method has been incorporated in the *INGASORT* program for event-by-event Doppler correction.

Fig. 13 : Effect of Doppler correction (β = 0.03) for individual segments of the Clover using hit-pattern information (bottom curve). Top curve has been Doppler corrected for central angle of the Clover detector

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4.3 HEAVY ION REACTION ANALYZER (HIRA)

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The developments in HIRA setup last year have mainly been towards the modifications in the focal plane of HIRA and the coupling of the clover array, charged particle array and neutron detectors with HIRA.

A large focal plane chamber has been designed and fabricated in-house with appropriate provisions for mounting slits and various detector setup. In experiments with ^{7}Be beam, the secondary target and the collimator will be mounted in this chamber and the distances to the detector system were chosen keeping the required angular resolution in mind. The large bellow after Quadrupole Q4 will be replaced by a shorter one to have the focal plane detector at nearly the same distance as before. This chamber is expected to be installed in May this year soon after the HIRA-INGA experiments.

HIRA has been used in two experiments involving ^{7}Be RIB and as a tagging device in some experiments with the HIRA-INGA facility last year. The ^{7}Be(d,n)^{8}B angular distribution measurement was repeated with a modified detection system. The choice of (i) stopper for secondary beam in between the MWPC and particle identification system to facilitate online, continuous normalisation, (ii) better control of gas pressure in ΔE detector to have same gain throughout the experiment and (iii) compact, longitudinal field, energy loss detector followed by 2D position sensitive detector paved the way for minimising systematic errors. The position signals from MWPC and the 2D position sensitive SB detector were used to trace the path of the ions. The stopper drive also had position calibration mask and blank space at different levels which could be used in an interchangeable manner. The result of the analysis is reported elsewhere in this annual report.

The preliminary experiment of ^{7}Be + ^{7}Li (scattering of mirror nuclei) was carried out at HIRA focal plane with MWPC followed by two annular position sensitive Si detectors separated by compact, longitudinal ionisation detector and followed by a 2D position sensitive SB detector. The various rings in the annular SB detector were connected by resistive chain to reduce the electronics requirement without sacrificing the position or angle information. This method worked fine as we were looking for ^{7}Be and ^{7}Li and their signals were much above the noise. The detector setup worked well at close geometry and there was no count rate limitation due to delta electrons.

The in-vacuum target assembly has successfully been used for mounting ^{7}Li target in the experiment for the study of scattering of mirror nuclei (^{7}Be + ^{7}Li). A spare rotary-cum-linear motion target assembly, identical to the one developed earlier, has been made with funds from BRNS for the fabrication of mechanical assembly. Experiments with HIRA alone are expected to commence from June 2003.

As planned by the user community in the BHU workshop of September 2001, the task of combining the HIRA facility with the INGA clover array, charged particle array and neutron array was taken up. The same two swivel stands as used with HIRA + GDA (8 HPGe (with ACS) detectors) were used this time too. The stands had earlier been tested to take a load of 350 kgs each, at the time of commissioning of HIRA-GDA facility. However, as the clover detectors are of different geometry and dimension compared with HPGe detectors, appropriate mounting structures were designed, fabricated and installed. The angles chosen were 80° and 140° (in-plane) and +/- 18° (out-of-plane). The support and alignment plates for the structure and the detectors had to be designed and fabricated afresh. Welding extensions were made to the swivel stands to accommodate the bigger support/alignment plates. The neutron detectors were also accommodated on the swivel stand to have clear working space around the target chamber. Two of the four neutron detectors can be replaced by two HPGe (without ACS) detectors. The TIFR charged particle detector chamber was installed at the target site and the appropriate coupling system had been designed with TIFR group and fabricated at TIFR. A view-port and insertible quartz were incorporated upstream of target position for beam-viewing, when required. The installation and alignment procedure of the CPDA chamber and the target were worked out for reproducibility which is very crucial so as to have the beam pass through the small (6 mm dia.) opening in the target frame of CPDA. Beam tuning procedure was finalised by optimising the transmission in the beam-line, maximising the beam catcher current and simultaneously minimising the Ta X-rays from the target frame. For experiments not requiring the TIFR CPDA chamber, the small aluminium chamber was used with either a target ladder or mount for stacked targets with another upstream insertible quartz for beam viewing.

The focal plane detector consisted of a 55 mm x 55 mm 2D position sensitive MWPC with five wire planes and delay-line read-out, operated around 3.5 Torr of Isobutane. The signals used were Anode timing (for arrival of ion at focal plane and as reference signal for position extraction), X-timing (for X-position), Y-timing (for Y-position) and ΔE for separating beam-like and residues (mainly useful in normal kinematics).

HIRA was used to select the mass in several experiments. The gamma-gamma-ER TAC was clean in most of them and the FWHM was +/-10% (ie. +/- 10% velocity acceptance) consistent with +/-20% energy acceptance of HIRA. The table below shows the details of experiments where HIRA was used for ER tagging.

Experiment, PI & Institute	System	Mass Dispersion Used	Masses selected by HIRA (amu)	Status of mass defining slit	Efficiency for selected nucleus	Primary Beam Rejection Ratio	Beam current & FP count rate
Facility Test	^{28}Si + ^{58}Ni (450 μg/cm^2)	10 mm/%	80 - 84	Fully Open	~ 4.5%	10^7	

Facility Test	^{32}S + ^{27}Al (500 μg/cm^2)	10 mm/% and 5 mm/%	53 - 54 and 52 - 55	Fully Open	~ 5%	10^7	
TIFR	^{28}Si + ^{58}Ni	10 mm/%	83, 84 & 80	Fully Open	~ 4.5%		
SINP	^{28}Si + ^{12}C (100 μg/cm^2)	10 mm/%	---			Poor	
NSC	^{12}C + ^{27}Al	5 mm/%	35 -37				
Panjab Univ.	^{28}Si + ^{27}Al	10 mm/%	52	Partially open		> 5 x 10^6	5 pnA & 6 kHz
VECC	^{28}Si + ^{24}Mg	10 mm/%	44/15+ & 47/16+	Partially open		10^7	1 pnA & 600 Hz

4.3.1 New focal plane chamber of HIRA

T. Varughese, S.K. Saini, Sundar Rao, S. Nath, A. Jhingan, J.J. Das, P. Sugathan and N. Madhavan

A new focal plane chamber for HIRA (Fig. 1) has been made in NSC workshop to accommodate bigger detectors and to use it as secondary target chamber in RIB experiments. This chamber will be used in place of the existing pumping cross at the focal plane. The chamber inside diameter is 320 mm and it has a depth of 340 mm. The top and bottom lid have central port of 200 mm diameter. These ports are associated with standard CF250 bolt hole dimensions, but o-ring groove is made in place of knife edges. The plan is to mount a vacuum compatible, rotary table from the bottom lid. The beam entrance port is CF250 and exit port is ISO 300.

Rectangular pockets of 75mm x 15mm are provided on the beam entrance and exit ports. There are two such pockets from either side near entrance and exit ports. Linear motion feed-throughs can be mounted on these rectangular ports to introduce mass defining slits and/or to introduce calibration masks for detectors. The two 90^0 ports to beam direction are CF150. View ports of CF63 are made for better view of the interior of the chamber. KF25 and KF16 flanges are welded directly to the chamber body for pumping and gauge fixing.

The chamber is tested upto a vacuum of 10^{-5} torr. Installation of the chamber on HIRA platform is planned in May/June 2003.

Fig. 1 : New Focal plane chamber of HIRA

4.3.2 Development of a Large Area Telescopic Detector System for Transfer Reaction Angular Distribution Measurements

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A new telescope (ΔE-E) detector setup has been developed for the measurement of angular distribution in transfer reactions [1,2]. In this ΔE is a gas ionization detector and E-two position sensitive Si-SB detectors placed side by side (50 mm x 50 mm each) (PSSD). The design goal of the system is to have optimum Z separation (Z = 3-10 region) along with good energy resolution. They are placed symmetrically about beam axis as shown in Fig. 2. Basic design concepts are similar to [3].

To cover large angle, ΔE gas detector length should be short. So, axial field geometry is used for IC in which field distortion is minimum. The distance between the detector setup and the target has to be minimised for large solid angle acceptance so that low beam intensity experiments can be performed within reasonable time.

A SS vacuum chamber has been fabricated to mount the electrodes as well as the Si-SB detectors. To minimise dead space, a step has been provided on the entrance side where ΔE electrodes fit in. To take out electrical connections feedthroughs are provided through KF 16 port. For gas handling, two gas in/out ports are also provided with KF 16 coupling. The vacuum chamber is fabricated in such a way that it can be easily installed in new focal plane chamber of HIRA. For mounting of PSSDs, a mounting arrangement is made which preserves alignment. This is specially required for reproducibility in angular distribution measurement. A gas handling flange (CF 150) has been developed for the new chamber to get gas feed from external cylinder to the detector. This flange also has provision for vacuum by-pass of the detector chamber to the focal plane chamber. For taking electrical connections from the detector a new connector flange has also been made. The detector chamber has been tested for vacuum up to 6 x 10^{-5} mbar.

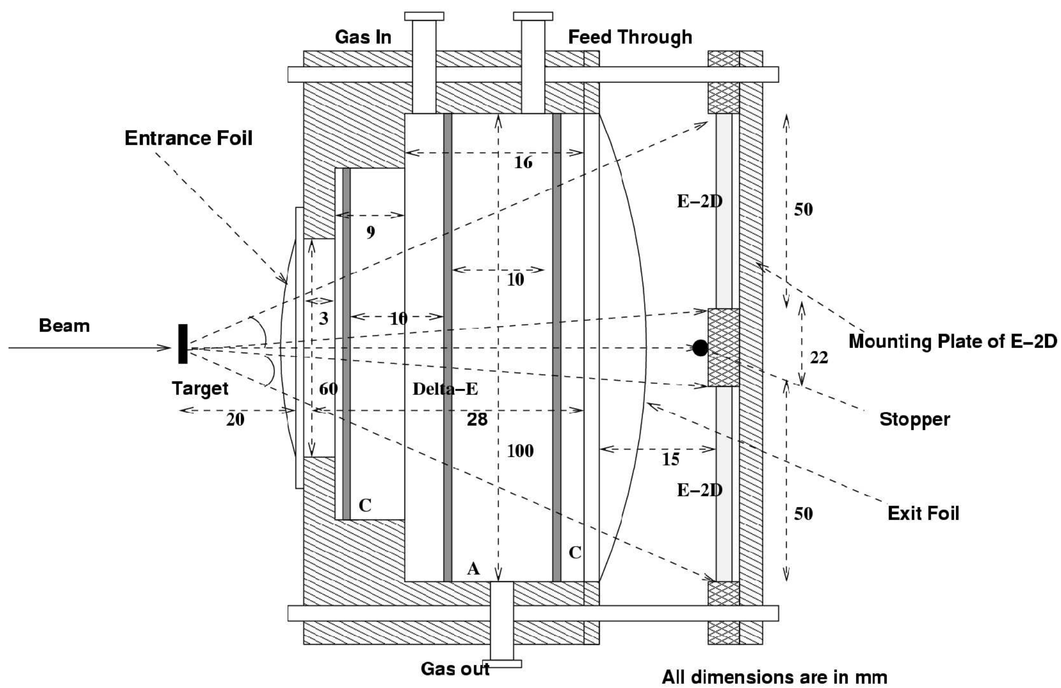

Fig. 2 : Schematic Diagram of the Telescope Detector System

The entrance window of the detector is a 1.5 micron polypropylene foil in order that scattered particles lose minimum energy, followed by an ionization chamber of ID=100 mm and active area ≥ 7500 mm^2. The electrode frames (circular) are made by parallel 20 micron diameter gold plated tungsten wires separated by 1.5 mm. The wire planes were made using the inhouse wire winding machine. The separation between electrodes are 10 mm each with the total active length of ΔE-gas as 20 mm. The dead space at the entrance/exit is about 5 mm. The exit foil of the gas detector will be 1.5 micron polypropylene. Sufficient gap between the target -entrance foil and PSSDs -exit foil is kept so that even if the foils bulge by 5-10 mm under pressure, they will not be damaged.

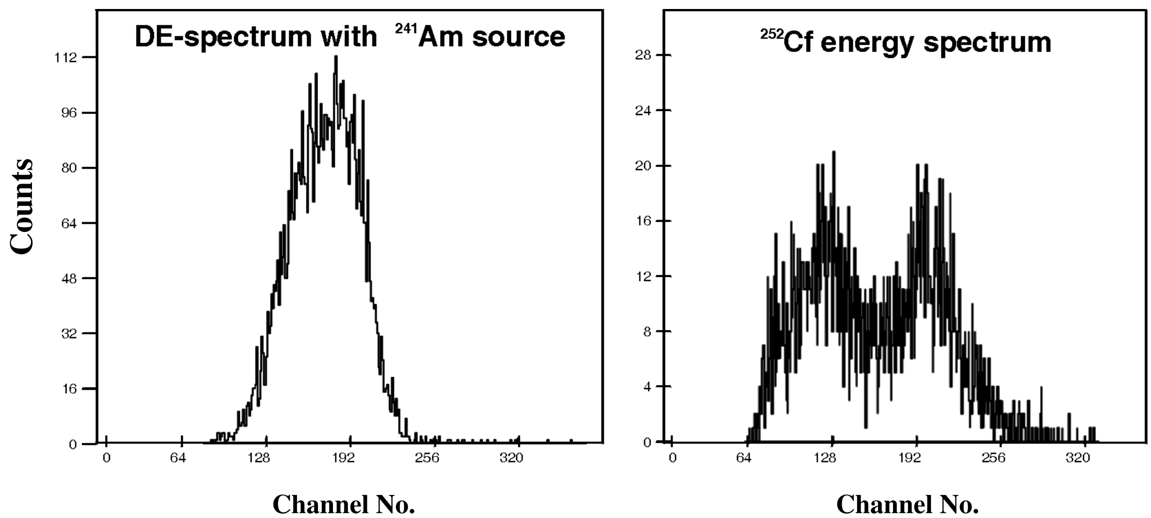

Fig. 3 : ΔE-energy signal from (a) α-particles from ^{241}Am
(b) fission fragments from ^{252}Cf

We have tested the gas detector using ^{241}Am source with isobutane gas at 80 mbar and the detector resolution came out to be about 140 keV. The α-spectrum obtained with ^{241}Am-source is shown in Fig. 3(a). The detector was also tested with ^{252}Cf -fission source at 40 mbar, the fission fragment-energy spectrum is shown in Fig. 3 (b).

While designing the detector we have taken the one proton stripping reaction ^{28}Si(^{7}Be, ^{6}Li)^{29}P (Q=-2.86 MeV) at about 16-21 MeV as a possible target projectile combination [2]. Using TRIM programme [4] we have seen that ^{7}Be, ^{6}Li will lose enough energy in ΔE-gas (with isobutane) for proper Z identification and the rest part of the energy will be detected in the E detector. We intend to separate the projectile like particles resulting from ^{7}Be+^{28}Si elastic scattering from the ones arising from various possible transfer channels according to their Z-values (like ^{6,7}Li,^{7}Be and ^{8}B, etc.). With this detector setup entire angular distribution approximately 10^0-45^0 (in Lab) can be measured simultaneously. The efficiency of the setup as a function of θ_{cm} for this reaction is shown in Fig. 4. Here efficiency at a given angular bin is defined as the ratio of solid angle covered by our detector to the total solid angle in which particles are scattered in this angular bin.

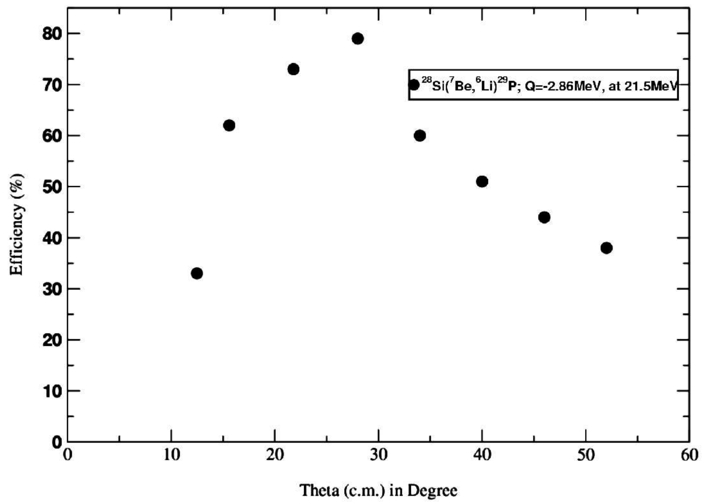

Fig. 4 : Detection efficiency as a function of angle (see text)

One important aspect of this new detector is the possibility of moving it along an axis perpendicular to the beam axis. This will help in covering larger angle on one side depending upon the experimental requirements. For this purpose, a new precision movement assembly has been developed where the detector will be mounted. This will allow movement of the detector up to ± 20 mm on either side of the beam axis. Provisions are also made so that the distance between the target and detectors can be varied. As increasing angular coverage in annular detector can be achieved only through reduction of target -detector distance, this will work as a complimentary setup to [3] for reactions where angular distributions are much broader (i.e $M_{proj} << M_{target}$) in direct kinematic reaction.

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4.3.3 In Vacuum Transfer System for $^{7}Be+^{7}Li$ Scattering Experiment

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In many nuclear physics experiments the purity of the target element is crucial. Specially when one deals with the target material which is hygroscopic in nature (such as Li, Ca) i.e., forms hydroxides by capturing moisture from air or which is easily oxidisable(for eg., Mg, Fe), one has to take some special care such that the target should not come in contact with air or water molecule [1]. For strongly reactive target materials, an in-vacuum target transfer system is needed from the target evaporation chamber to the scattering or reaction chamber.

At Nuclear Science Centre, New Delhi, we have done a quasi-elastic scattering experiment with ^{7}Be on ^{7}Li recently using the existing radioactive ion beam (RIB) facility [2] here which produces a high purity ^{7}Be beam. For that we need a high purity ^{7}Li as target as the quasi-elastic effect that we want to study is a small effect and should not be masked by the presence of impurity in the target. The details of the in-vacuum target transfer system fabricated for this purpose is described as follows.

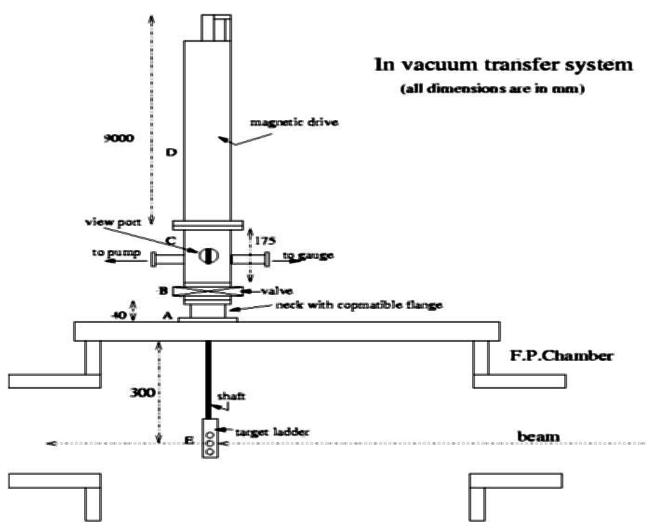

Fig. 5 : In-vacuum target transfer system

The schematic drawing of the in-vacuum target-transfer system is shown in Fig. 5. A is the neck with compatible flange to the target evaporation chamber as well to the HIRA focal plane chamber. A is connected to the valve B whose other end is connected to the T-chamber C. The T-chamber has the provision for pump port and port for gauge and a view port to see the target. The T-chamber is coupled to the magnetically driven shaft bought from MDC for in vacuum transportation. This magnetic drive allows the vacuum tight transportation of the target by pulling or pushing the target ladder which is attached to the shaft. This special magnetically coupled drive had the driving length of 600mm which is required to push the target in to the beam height in the reaction chamber of HIRA and pulling out the same into the T-chamber when required and a provision to rotate the target to put it in the required direction.

Thin targets of ^{7}Li (~ 500 μg/cm^{2} thickness) have been made by evaporating [4] ^{7}Li at a very low rate 0.1 nm/sec on a Carbon backing of 10 μg/cm^{2} thickness after taking all the necessary steps to avoid any contamination. We could achieve the desired thickness of ^{7}Li without any peeling off of the target.

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4.3.4 Hybrid Recoil Mass Analyser (HYRA)

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Recoil Mass Separators have been built as devices which are optimised for nuclear physics studies using heavy ion beams. Over the years, development in this field has resulted in larger solid angle, better beam rejection and improved mass resolution [1]. Concurrently there has been gas filled spectrometers developed mostly for the search of heavy nuclei produced with sub nano barn cross section [2]. A combination of these two types of spectrometers will provide a step towards the ultimate machine for the purpose of nuclear reaction studies around the barrier for heavy ions. The proposed Hybrid Recoil Mass Analyser (HYRA) is designed with this idea in mind and combines the power of a modern recoil mass spectrometer and a gas filled spectrometer.

The electromagnetic configuration for HYRA (Fig. 6) is QQ-MD-Q-F1-Q-MD-QQ-F2-QQ-ED-MD-QQ-F3. The entire spectrometer can be operated in vacuum mode, simlilar to ORNL [3] to get an energy dispersion-less, variable mass dispersion at focal plane F3. The initial part till focal plane F2 is a momentum achromat which helps to separate primary beam-like particles at the intermediate focal plane F1 with the help of moveable stoppers and to transport the products of interest. Forward moving reaction products (A < 100 amu) produced in inverse kinematics can be selected and mass analysed at F3.

In the gas-filled mode, part of the momentum achromat can be used as gas-filled separator to access very heavy nuclei (A > 200 amu). The velocity and charge state focusing effects increase the efficiency to select the sparsely produced evaporation residues amidst the overwhelming fission process. The momentum achromat can also be used to select light RIBs produced in (*p,n*), (*d,n*) type of reactions in inverse kinematics, carry out secondary reaction at F2 and study it using the downstream spectrometer. The project has been approved and accorded financial sanction by Department of Science and Technology (DST), Government of India.

Fig. 6 : Electromagnetic Configuration for HYRA

In a meeting of all the investigators of this project at NSC, the maximum magnetic rigidity of the gas-filled portion of HYRA was frozen at 2.25 T-m. As we are planning to use helium gas, this rigidity is sufficient to access very heavy nuclei (A ~ 250 amu and beyond). The independent focal plane option for the gas-filled portion which required special (dual bending direction) dipole magnet [4] was removed so that the higher rigidity could be achieved within the overall budget. Fine tuning of the ion-optics has subsequently been done to incorporate these changes. The longer path length in our gas-filled separator will be compensated by operating it at lower gas pressure so that the ratio of the number of collisions inside the magnetic dipole field to the total number of collisions remains similar to other operating gas-filled separators. The option of removing the initial quadrupole to move the target closer to the dipole MD1 is considered for increasing the acceptance in the gas-filled mode. The electromagnetic components beyond the gas-filled separator (or the momentum achromat) will have magnetic rigidity of 1.5 T-m and electric rigidity of 20 MV to handle reaction products produced in inverse kinematics.

The lengths of the quadrupoles and the maximum pole-tip fields have been independently frozen keeping the overall weight and cost in mind. Special quadrupole chambers are planned to increase the angular acceptances in both planes. The current plan to have the corridor outside the Phase II beam hall has helped in getting more space and the overall space available is taken into account in freezing the lengths of individual components.

HYRA will be made stationary as rotation of such huge electromagnetic setup gets extremely complicated for the amount of extra information that may be available. In inverse kinematics, the kinematic forward focusing helps to collect more residues in the forward direction. In the gas-filled separator mode, limited amount of angular distribution information, if necessary, can be obtained by using a moveable slit at the entrance.

With the initial seed money, indigenous development of prototype 300A, 90V power supply for quadrupole has begun. The large amount of power involved requires a variable transformer to protect the transistor banks while operating at lower currents/output power. One such transformer has been designed and fabricated indigenously. The variable transformer is shown in Fig. 7. The control electronics which had earlier been tested on a 200 A prototype power supply will be integrated in the new supply. The fabrication of the cabinet is to be taken up. Active controller for precise gas pressure regulation along with accessories for the gas-filled separator has been ordered.

Fig. 7 : Transformer for HYRA magnet power supply

DST has released first year's break-up this January and we have requested for the release of one more instalment to take up the ordering of most of electromagnetic elements together which is expected to reduce the fabrication time and also the cost. Tendering for the initial electromagnetic components will be done by August 2003.

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4.4 MATERIALS SCIENCE FACILITY

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The materials science facilities continue to be used by 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 78 user experiments comprising 268 shifts were performed in this year, without any beam time loss due to facility break down. Special emphasis is being given to research programs in thrust areas where group experiments are being conducted. Special attention is also given to research scholars' Ph. D. related experiments which comprised 31 experiments (92 shifts) this year. Experiments are being done in different areas of swift heavy ion induced materials modification and characterization and the details of the research programs are given in Section 5.2.

The materials science facility has three experimental chambers. The first: high vacuum chamber is used in most of the experiments. It is used for irradiation, photo-luminescence/ iono-luminescence and in-situ transport measurements. It has a base pressure in low 10^{-6} torr range and is pumped by a diffusion pump. As the overall vacuum in the chamber had been deteriorating over the time, the diffusion pump was overhauled this year. All the parts including the liquid nitrogen trap were removed and were cleaned with chemicals. The DP was assembled again after replacing the DP oil. A modification was also added to avoid overspilling of LN_2, which was found responsible for DP heater damage. A double slit which is mounted before the chamber and is very useful for ERDA experiments, was modified for larger movement in X direction. This chamber is also used for iono-luminiscence/ photo-luminiscence studies. The set up of collector outside the chamber was completed and and the facility was used for in-situ and off-line experiments. In-situ studies of resistivity variation and facility for irradiation at elevated temperatures (up to 400°C) is also operational in this chamber.

The second chamber: ultrahigh vacuum chamber has a base pressure in 10^{-9} torr range. A chamber with scanning tunneling microscope is attached to this chamber. This STM was used in one user experiment this year. Efforts are on to optimize utilization of this facility. The chamber was also equipped with a residual gas analyzer which has been sent for repairing.

The third chamber: goniometer chamber is pumped by a 450 l/s turbo pump and is equipped with a triple axis goniometer for channeling studies. The facility was used for channeling and blocking experiments this year. A larger area position sensitivity detector, developed by Hyderabad university group was used in this experiment. This detector has provided an energy resolution of 3% with the provision of kinematic correction during the data analysis. The double slit before the goniometer chamber, crucial for channeling experiments was also modified for larger movement in X direction. The software for synchronised movement of detector and goniometer along with data acquisition for XRR facility is under development. The damaged Cu X ray tube was replaced by a Mo tube for testing the set up. In-situ X ray reflectivity set up did not make any progress this year due to space limitations.

The problems with time of flight (TOF) set-up were sorted out. A faulty grid was replaced and sample mounting arrangement was modified. The system will be tested in a facility test run being awaited.

Apart from beamline facilities, the off line facilities consist of RF sputtering system to prepare thin films of oxide materials, high temperature furnace to synthesize the ceramic materials and target for RF sputtering system, transport measurement system (R-T, I-V, C-V, 1/f noise, dielectric constant, permeability). The facility for magneto resistance measurements at low temperature (1.5 to 300 K) in the presence of high magnetic field up to 8 Tesla has been tested and experiments are being performed on CMR and HTSC materials. The ball milling system has been installed and is used for preparing nano-particles of ferrite and ZnO. Many users from all over the country are using these off line facilities to study their materials before and after irradiation.

4.4.1 Synthesis of semiconductor nanocrystalline powders and thin films

V.V. Siva Kumar

In this year we have continued the work to establish facilities for synthesizing nanomaterials and used these facilities to synthesize nanocrystalline powders. A ball milling system (SPEX 8000 D) was procured and installed. ZnO and SiO_2 powders were milled using hardened steel vials and balls for 2, 5, 10, 15, 24, 36, 50 and 75 hours with different ball to powder ratios. The X-ray diffraction measurements of the ZnO powder milled for 36 hours with ball to powder ratio of 10 shows broad peaks and the average crystallite size of the nanocrystals obtained using Scherrer's formula is about 8 nm. The inverse microemulsion technique was used for making Eu doped Y_2O_3 nanoparticles. The phase was confirmed by X-ray diffraction technique. Detailed studies on these powders are in progress.

The design of plasma based sputtering system for synthesizing nanocrystalline thin films on LN_2 cooled substrates is almost complete and the components are being procured. The development of the new system will be undertaken in the next year. With the existing rf sputtering system, thin films of ZnO nanocrystals embedded in SiO_2 matrix were deposited by reactive co-sputtering.

4.4.2 Studies on nc-ZnO/SiO_2 films

V.V.Siva Kumar, F.Singh and D.K.Avasthi

Thin films of ZnO nanocrystals embedded in SiO_2 matrix were deposited on uncooled Si substrates by reactive co-sputtering of a ZnO-Si target using an oxygen plasma. The deposited films were annealed for 4 hours in air at 500°C, 750°C and 1000°C. The ZnO and SiO_2 phases in the films are confirmed by X-ray diffraction. The average crystallite size of the ZnO nanocrystals in the deposited film which was obtained using Scherrer's formula is about 11 nm. The as deposited and the films annealed at 500°C show strong stable PL emission in the green region which can be due to large number of oxygen vacancies in the ZnO nanocrystals. Films annealed above 500°C showed weak PL emission which can be due to decrease of the oxygen vacancies in the nanocrystals. These films will be used for studying the effect of low energy ion beam irradiation on their optical properties.

4.4.3 Structural And Magnetic Studies of $NiMn_{0.05}Ti_xMg_xFe_{1.95-2x}O_4$

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Approach of the present work is to investigate the structural and magnetic properties of Nickel ferrite system, with successive increase of concentration of Mg^{2+} and Ti^{4+}. The variation in the structural and magnetic properties such as Curie temperature T_c, Saturation magnetization M_s and Initial Permeability μ_i as a function of concentration of the Mg and Ti are studied.

A series of samples of $NiMn_{0.05}Ti_xMg_xFe_{1.95-2x}O_4$ for x= 0.0, 0.1, 0.2, 0.3, 0.4, 0.5 were prepared by conventional ceramic technique. For structural confirm ation powder x-ray diffraction measurements have been performed. The X-ray patterns ensure that the samples of all compositions have a single-phase cubic spinel structure. The lattice parameter obtained from X-ray diffraction increases with concentration (see Fig. 1), which was expected since the ionic radii of Mg^{2+}(0.66A°) and Ti^{4+}(0.68A°), is larger than the ionic radii of Fe^{3+}(0.64A°). From Fig. (2) it is seen that the Curie temperature decreases with the increase in the concentration of the dopants. This decrease can be explained on the basis of exchange interaction.

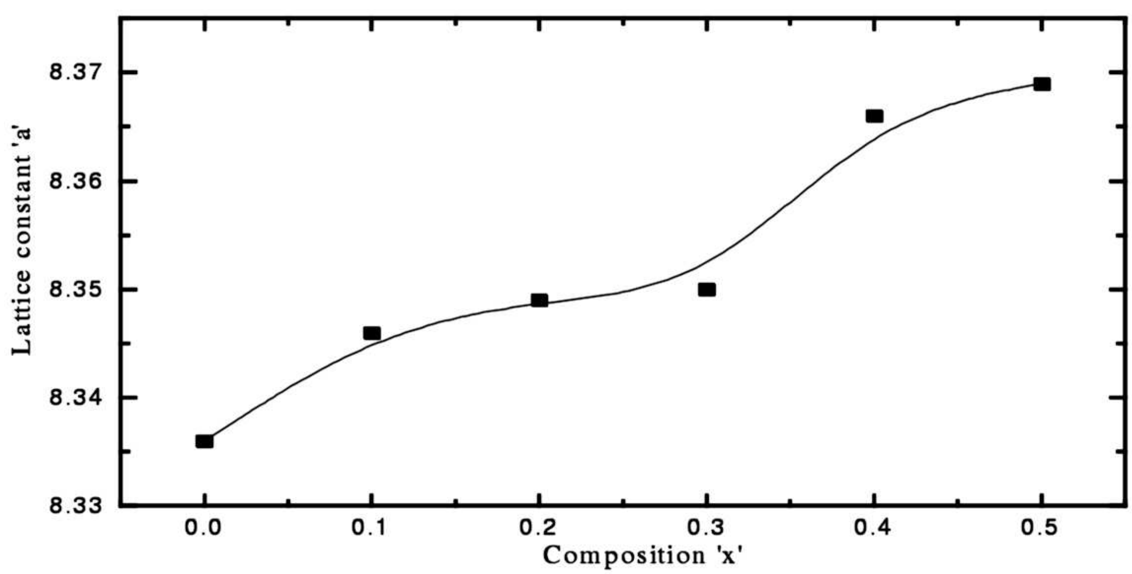

Fig. 1 : Variation of lattice constant 'a' with concentration 'x' in $NiMn_{0.05}Ti_xMg_xFe_{1.95-2x}O_4$

The saturation magnetization M_s was performed using Vibrating Sample Magnetometer. M_s decreases with increase in concentration of the substituents as shown in Fig.2, which can be explained on the basis of Neel's Molecular field model.

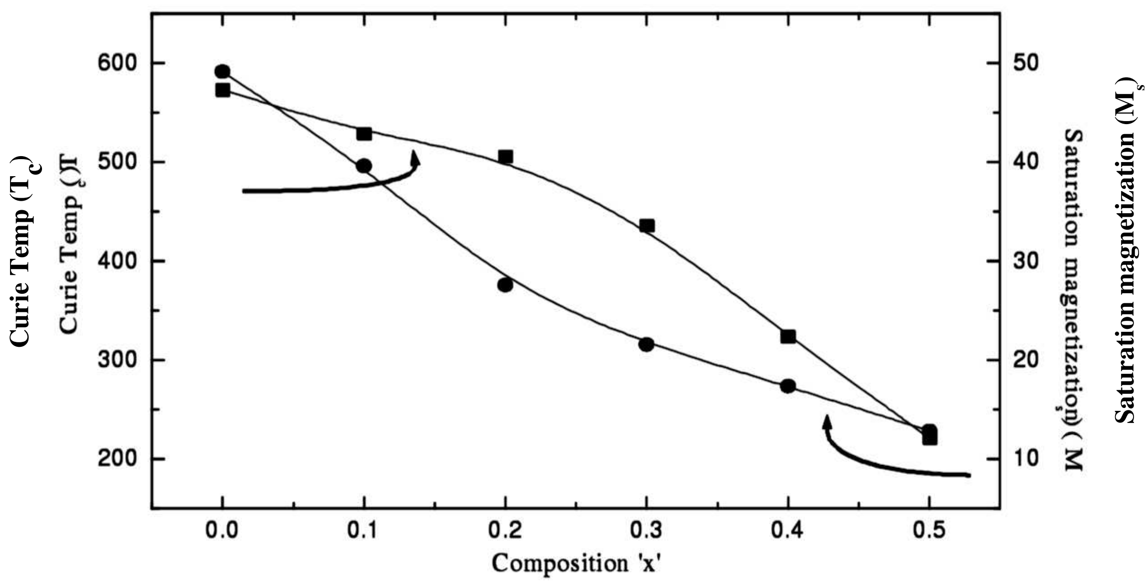

Fig. 2 : Variation of Curie temp (T_c) and M_s with 'x' in $NiMn_{0.05}Ti_xMg_xFe_{1.95-2x}O_4$ ferrite

Fig. 3 : Variation of initial permeability μ_i with frequency for x = 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5 in $NiMn_{0.05}Ti_xMg_xFe_{1.95-2x}O_4$ ferrite

Fig. 3 shows the variation of initial-permeability as a of function frequency for x = 0 to 0.5. A high permeability is observed for the samples but it decreases with the concentration of the substituents. The variation in permeability can be explained using Globus model. The resonance peak is likely to be observed at higher frequency, which we were not able to measure due the limitation of the instrument used.

4.4.4 Performance of the Large Area two dimensional Position Sensitive Detector Telescope (LAPSDT) developed for Material Analysis at NSC

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Energetic Ag ions delivered from 15MV Pelletron accelerator at NSC have been used to perform LAPSDT based ERDA experiments at NSC. Here we present some of these recent results to show the detector performance. These experiments have been performed using 200 MeV Ag with a recoil angle of 55° in Goniometer chamber with the Backgammon structure on the ΔE_2 anode.

Z-identification

Fig. 4 shows measured ΔE-E_{res} spectra on the calibration sample. The inset of Fig. 4 shows the structure of the calibration sample prepared for the LAPSDT based ERDA experiments. This sample was grown by electron gun evaporation technique in the high vacuum chamber at the target laboratory of NSC. Elements in the different layers were chosen so as to have reference ΔE-E bands in different mass regions (From Li to Ni). Clear separation between different constituent elements could be observed from these spectra and bands are in agreement with the simulation spectra obtained from SERDA program for the same experimental conditions.

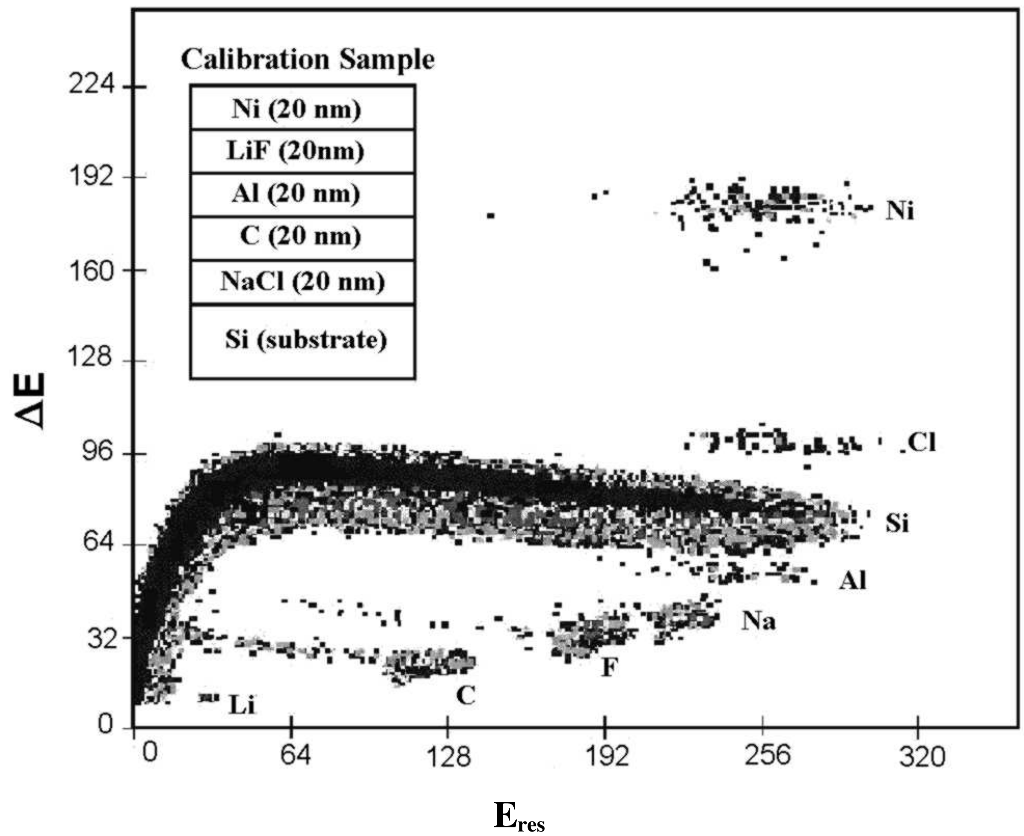

Fig. 4 : ΔE-E_{res} spectrum obtained from calibration sample (Inset : sample structure)

Kinematic corrections

Two dimensional position sensitivity and the effect of field homogenization have been shown in our earlier report [1]. Here we show the utilization of the position information in scattering plane for kinematic corrections that have been performed for the first time in India.

<u>Example 1</u> (Calibration sample):

Fig. 5 shows the projections of three different bands (corrected and uncorrected Cu, Si & C) on the E_{total} axis. These results confirm the improvements in the separation of bands / depth resolution obtained after implementing the kinematic corrections.

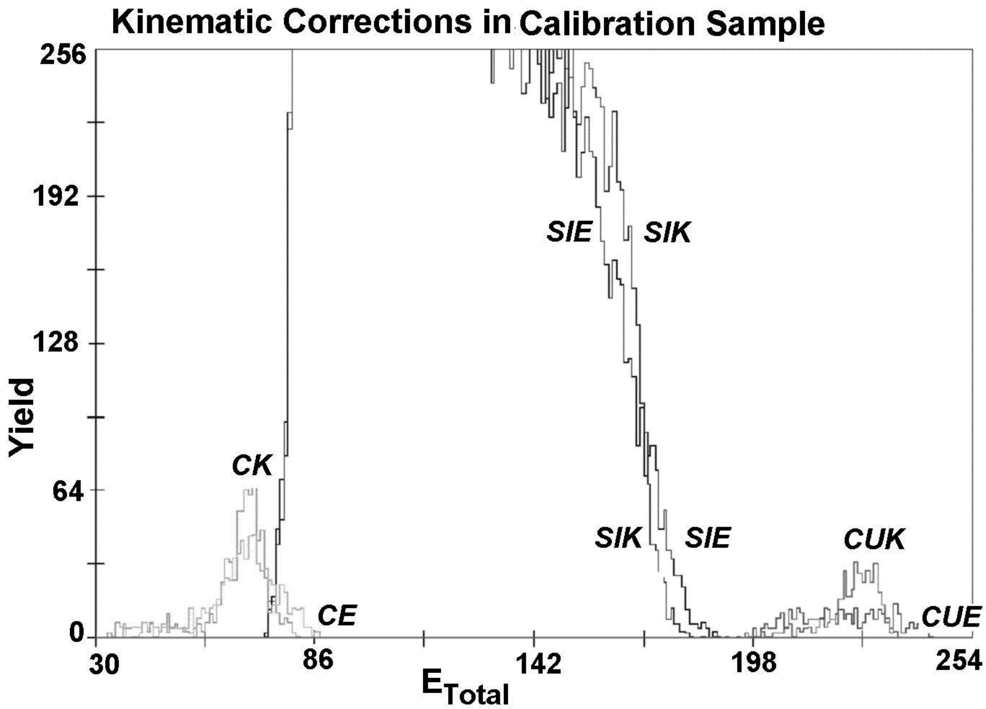

Fig. 5 : Projections of uncorrected and corrected (CE & CK), Cu (CUE & CUK) and Si (SIE & SIK) bands obtained from Calibration sample.(axes X: E_{total}, Y: Yield)

<u>Example 2</u> InGaAs/GaAs sample:

This is a single $In_{0.1}Ga_{0.9}As$ (400A°) layer grown in GaAs substrate. Ga and As bands could not be separated because these elements are coming from depth also. "*In*" band could be separated in ΔE_1- E_{total}. The depth resolution has been improved to 3.4% from 14% after implementing the kinematic corrections.

[1] Annual Report 2001-2002, Nuclear Science Centre

4.5 LIBR BEAM LINE

4.5.1 Status of LIBR Beam Line for Beam-Foil Experiments

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The general purpose scattering chamber, shown in Fig. 1, was installed last year. This year many subsystems for the beam -foil experiment using single as well as two-foil were installed. The present facility has longer flight path (100 mm) unlike the earlier one developed at GDA beam line which was having only 12 mm.

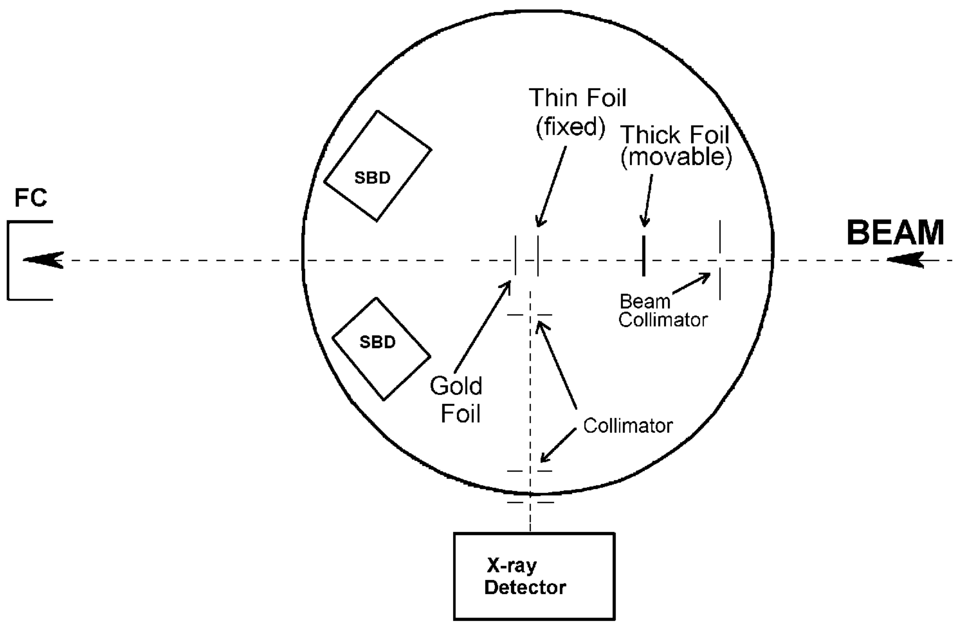

Fig. 1 : LIBR Scattering chamber

Except the longer flight, all other features are similar to the earlier one. Plunger setup is equipped now with a micro stepping motorized linear motion feed through (Model MFL-275-4) and a programmable motor logic controller (Model MLC-1) procured from Huntington Laboratories Inc., CA94043. A computer program was written at NSC to control and read out its movement using a remotely placed PC. The most special feature of the present set up is to load five thin foils in place of second target while two-foil geometry is used as shown in Fig. 2.

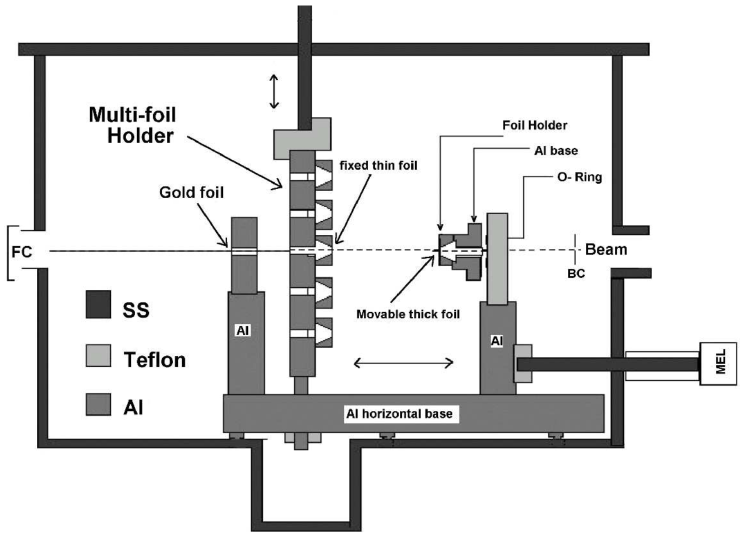

Fig. 2 : Experimental setup for two-foil geometry

Couple of experiments of users from different universities were successfully carried out. Facility has option of carrying out inner shell ionization experiments. Present set up has kept option for post foil charge state analysis unlike the earlier one. An electrostatic charge state analyzer for emergent beam from the foil have already been designed and fabricated. This analyzer is having one plate inclined and other parallel with respect to the beam axis. A parallel plate avalanche detector (PPAD) is under development. Analyzer will be used in the forthcoming experiment.

We have developed an indirect method of separating the contribution of satellite line from the main line in the lifetime determination [see section 5.4.1.]. However, we have planned to employ a direct method of a high-resolution x-ray spectroscopy using multi channel Doppler tuned spectroscopy. It has also been designed and is under fabrication in our work shop.

4.6 RADIATION BIOLOGY BEAM LINE

4.6.1 Status of the Radiation Biology Beam Line

A. Sarma, P. Barua, A. Kothari

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 radiation field is having 30 mm diameter with better than 97% uniformity. 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. The beam line area which is presently being used by the Indian National Gamma Array experiments is expected to be available for Radiation Biology experiment from June 03 onwards.

4.6.2 Status of the Molecular Radiation Biology Laboratory

A. Sarma

The laboratory is designed to provide user support in the best possible way during experiments. The experiments that are undertaken recently require suitable inhouse facilities for relevant protocols. Apart from the normal equipment like microbalance, autoclave, biosafety cabinet, oven, refrigerated centrifuge etc., we have installed PCR machine, Gel Doc, AFIGE system and Semi dry transblotter. It is planned to procure a fluorescent microscope to facilitate the experiments based on FISH and immunofluorescent assays.