NUCLEAR SCIENCE CENTRE

PAST, PRESENT & FUTURE

A PERSPECTIVE
Research Centres in the Universities were emphasised in the national policy on education in 1968. The proposal for accelerator centres within the family of teaching institutions was considered by UGC in early 80’s and the concept of Inter-University-Centres were accepted by the Govt in 1984. The first such Centre, NSC, came up the same year.

COMMISSIONING OF THE ACCELERATOR

Top of Accelerator tank
View from top during assembly
Accelerator tubes and equipotential rings installed
Total energy of the ion = (q+1)V where V is the terminal voltage and q is charge state after stripping at the terminal.

The charge stage and the beam energy can be enhanced by inserting a second stripper downstream to the terminal.
The Pelletron Accelerator

- **Tank ht:** 26.5 m
- **Diameter:** 5.5 m
- **Pressure:** 86 PSI of SF$_6$ gas

**Ions accelerated:**
- H to Au beams

**Ion Currents:**
- Typically 5 - 50 pnA

**Energy:** 30 - 250 MeV
Ion Energies from the Accelerator

The graph illustrates the ion energies from the accelerator, showing the dependence on mass. The different lines represent different processes:

- **Coulomb Barrier (A on A)**
- **LINAC + HCl**
- **LINAC (3 modules)**
- **Gas + Solid Stripper**
- **Solid Stripper**

The x-axis represents the mass, while the y-axis represents the energy in MeV/A.
RESEARCH PROGRAM AT NSC

Basic sciences
- Nuclear reactions near Coulomb barrier
- High spin spectroscopy
- Spectroscopy of highly charged ions
- Interaction of swift heavy ions with materials

Applied Research
- Materials characterization
- Materials Modification
- Device fabrication

Interdisciplinary areas
- Radiation Chemistry
- Radiation Biology
- Accelerator Mass spectroscopy
- Archeology, Geology, Oceanography e.t.c
EXPERIMENTAL FACILITIES FOR NUCLEAR PHYSICS

GAMMA DETECTOR ARRAY (GDA)
setup by Delhi, Punjab, Andhra, BHU, Bombay and MS (Baroda) University

High Spin spectroscopy
Life-time measurements

HEAVY ION RECOIL ANALYSER (HIRA)
setup by Calicut, Bangalore, Andhra, MSU, Punjab, NEHU, BHU, AMU, Bombay, Delhi, Saurashtra and Madras U

Heavy Ion Fusion near Coulomb Barrier
Production of low energy RIB

GENERAL PURPOSE SCATTERING CHAMBER
setup by Bangalore, Gulbarga & Mysore U

Heavy Ion Scattering and transfer reactions
Projectile Breakup
Materials Science
GAMMA DETECTOR ARRAY (GDA)

12 Compton suppressed HPGE Detectors
ANCILLARY FACILITIES WITH GDA

- BGO Multiplicity Filter: MS (Baroda)
- Charged Particle Detector Array: Delhi, Bombay
- Electromagnet for PAC studies: Panjab U
- RDM Setup for lifetime measurements: Delhi U
- Electron Spectrometer: Panjab U
List of nuclei studied using GDA facility
HEAVY ION REACTION ANALYSER (HIRA)
Research Programs with HIRA

- Nuclear Reactions around the Barrier region
- Recoil tagged gamma spectroscopy
- Focal Plane Radioactivity
- Studies with secondary beams from HIRA

Systems studied

- $^{28}\text{Si} + ^{64}\text{Ni}$
- $^{32}\text{Si} + ^{64}\text{Ni}$
- $^{28}\text{Si} + ^{144}\text{Nd}$
- $^{46}\text{Ti} + ^{64}\text{Ni}$
- $^{50}\text{Ti} + ^{60}\text{Ni}$
- $^{48}\text{Ti} + ^{58,60,64}\text{Ni}$
- $^{19}\text{F} + ^{93}\text{Nb}$
- $^{19}\text{F} + ^{175}\text{Lu}$

HIRA-GDA

BHU, Delhi, Mumbai, Andhra Pradesh
LOW ENERGY RIB FACILITY
AT NSC

HIRA facility has been used to separate out the reaction products from the direct beam using the excellent momentum resolution offered by the magnetic dipole element of HIRA. The reaction $p(^{7}\text{Li},^{7}\text{Be})n$ has been used to produce a low energy (11-22 MeV) beam of $^{7}\text{Be}$ with better than 99.99% purity and 3 mm diameter spot size (5x $10^{4}$ ions/sec intensity).

The angular distribution of the transfer reaction $d(^{7}\text{Be},^{8}\text{B})n$ at $E_{cm} = 4.5$ MeV, has been measured for the extraction of S17.

Other Radioactive Ion Beams ($^{6}\text{He},^{8}\text{Li},^{11}\text{C}$ & $^{17}\text{F}$) are planned in future.
EXPERIMENTAL FACILITIES
FOR MATERIALS SCIENCE

HIGH VACUUM CHAMBER
- setup by Kurukshetra, Hyderabad, JNU, Poona Universities, IIT (Delhi) and IISC, Bangalore
- Iono/photo luminescence
- Elastic Recoil Detection Analysis
- Electrical Transport
- Conduction Noise

UHV CHAMBER
- Scanning Tunneling Microscopy (STM)
- Residual Gas Analysis

GONIOMETER CHAMBER
- Ion Channeling facility
- X-ray Reflectivity
- Blocking ERDA

General Purpose Scattering Chamber
- in situ Hall Measurement
- TOF for Desorption Mass Spectrometer
**MATERIALS SCIENCE RESEARCH - AN OVERVIEW**

- **Engineering of Electronic Materials & Devices:** ion beam induced modifications in amorphous/crystalline semiconductors

- **High Tc Superconducting Materials:**
  - Flux pinning

- **Colossal Magnetic Resistance**
  - **Materials:** change of $R$ and $T_p$ in $\text{La}_x \text{Ca}_x \text{MnO}_3$

- **Modifications of surfaces & interfaces:**
  - Ion beam mixing of Ti/Si & Fe/Si, Cr on SS-304 steel

- **Diamond Like Carbon Films:** hydrogen loss

- **Swift Heavy Ions in Polymers:** Generation of micropores

- **Dynamic Studies during irradiation:** online resistivity measurements in superconductors

- **Optical Waveguide formation in Organic Crystals:** irradiation by 100 MeV Ag ions

- **Noise Measurements:** ion induced defects in semiconductors, HTC and CMR materials
**USER COMMUNITY OF NSC**

**FIELD WISE BREAK UP OF UTILIZED BEAM TIME (APRIL-OCT. 2000)**
- **NUC.PHY.** 63%
- **MAT.S.C.** 32%
- **Others** 5%

**USER WISE BREAKUP OF UTILIZED BEAM TIME (APRIL-OCT. 2000)**
- **NUC.PHY.** 28%
- **MAT.S.C.** 65%
- **Others** 7%

**Publications (-2000)**
- **Nucl. Phys.** 78
- **Mat. Sc.** 175
- **Others** 50

**Institutions**
- **58 Universities**
- **35 Colleges**
- **5 IITs**
- **28 Institutions**

**Map**
- 250 users
- 58 Universities
- 35 Colleges
- 5 IITs
- 28 Institutions
ACCELERATOR UPGRADE

- Upgradation of Buncher Electronics
- Modification in Travelling Wave Deflector
- Single Gap Multiharmonic Buncher
- Pase Locking of Pelletron Beam
- Indigenously Developed Data Acquisition & Control
- Faraday Cup at Post Acceleration Stage
- Capacitive Pick Up Loops for the Chains
- Charging System for On Line Monitoring
- Resistance Based Voltage Gradient
- Recirculating Gas Stripper System
- Conversion of Doublet to Singlet Units
- Stripper Position Readback
- Indigenously Developed 16 Core Fiber Optic Cable Connector
- Indigenous Development of Accelerator Components
Unique ECRIS based multiply charged ion beam facility having energy in the range of a few tens of keV to a few MeV

Low Energy Ion beam synthesis of SiC and formation of Nano-crystals, Ion Implantation, Ion Beam Induced epitaxial recrystallisation; atomic physics with highly charged ions
The maximum energy of ions from the Pelletron (~ 200-250 MeV) limits the research program for both nuclear physics and materials science. A superconducting LINAC booster was planned in early 90’s for future augmentation of the Pelletron.

The ion energies from the LINAC can be further enhanced by replacing the Pelletron by a high intensity high charged state ion source like ECR.
NUCLEAR SCIENCE CENTRE
ACCELERATOR AUGMENTATION SCHEMATIC

Beam Hall I

Beam Hall II

INJECTOR
BUNCHER
SNICSS ION SOURCE
16 MV PELLETRON
ANALYSING MAGNET
SWEEPER
SWITCHING MAGNET
SC BUNCHER
LINAC MODULES 15 - 20 MV/q
SC REBUNCHER
SWITCHING MAGNET
Nuclear Science Centre in collaboration with Argonne National Laboratory, U.S.A., has developed RF superconducting Niobium quarter wave coaxial line resonators for accelerating ions from our Pelletron accelerator up to mass $A=100$. The resonators will operate at 97 MHz and are optimized for particle velocity $(v/c)=0.08$. Resonators are formed entirely of niobium and are jacketed in stainless steel vessels which contain the liquid helium. A stainless steel to Niobium explosively bonded flange provides the welding transition between niobium and stainless steel. A novel pneumatic slow tuner in the form of a niobium bellow provides a tuning range of approximately 100 kHz, substantially larger than any working QWCL resonator. First beam test of the cavity to be used as Superbuncher is planned in March, 2001.
The Cryogenic distribution system for LINAC is one of the largest such facilities in India. It has a Helium refrigeration system with 600 W capacity and a closed loop liquid Nitrogen plant of capacity 5000 W.
ECR based High Current Injector for LINAC

FROM PELLETRON

SUPERCONDUCTING RFQ

MAGNET

1 MeV/A

SUPER BUNCHER

LOW β MODULE

2 MeV/A

LINAC MODULES

5 MeV/A

ECR SOURCE

q/A ~ 1/7
350 kV
ΔT ~ 1 ns
<table>
<thead>
<tr>
<th>LANDMARK</th>
<th>DATES</th>
</tr>
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<tbody>
<tr>
<td>NSC established</td>
<td>Nov, 1984</td>
</tr>
<tr>
<td>Construction</td>
<td>Dec, 1986</td>
</tr>
<tr>
<td>Pelletron</td>
<td>Dec, 1990</td>
</tr>
<tr>
<td>GPSC installed</td>
<td>Apr, 1990</td>
</tr>
<tr>
<td>1st user beam</td>
<td>July, 1991</td>
</tr>
<tr>
<td>GDA commissioned</td>
<td>Aug, 1991</td>
</tr>
<tr>
<td>HIRA commissioned</td>
<td>Dec, 1991</td>
</tr>
<tr>
<td>ANL project</td>
<td>Mar, 1992</td>
</tr>
<tr>
<td>Materials</td>
<td>Mar, 1993</td>
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<tr>
<td>LEIBF commissioned</td>
<td>July, 2000</td>
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<tr>
<th>FUTURE PROJECTIONS</th>
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<tr>
<td>Resonators from ANL</td>
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<tr>
<td>In-beam test of Superbuncher</td>
</tr>
<tr>
<td>1st LINAC Module</td>
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<tr>
<td>Beam in Phase II area</td>
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<tr>
<td>3 LINAC modules</td>
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<tr>
<td>High current Injector Project</td>
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One of the major objectives of increasing the beam energy is to make new areas to be accessible to the user. As can be seen from the accompanying figure, the mass regions $A > 200$ and $A < 60$ in inverse kinematics would become available after LINAC installation. Two major projects (LGA & HYRA) for studying these mass regions for nuclear spectroscopy and reaction dynamics were submitted to DST.

We are glad to inform the user community that these two projects have been approved by DST. LGA would now be implemented as part of the Indian National Gamma Array (INGA) composed of 24 Compton-suppressed Clover detectors. DST would initially provide funding for six detectors, and the rest would be obtained by pooling from other research institutions in the country (TIFR, BARC, IUC-DAEF, SINP and VECC.
NSC is augmenting the ion-beam facilities to provide the user community with ions of energies ranging from a few keV to hundreds of MeV and mass ranging from 1 to 200. To exploit the various online/ *in-situ* facilities, the following thrust areas of research in materials science have been identified:

- Ion beam induced crystallization
- Transient-enhanced diffusion
- Ion-beam mixing in multi-layers
- Electronic sputtering
- Nano materials: synthesis by ion beam

Users are requested to contact Dr. N.C. Mishra for further details.

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**Experimental facilities for Nuclear Physics**

All the experimental facilities in Beam hall I were installed in collaboration with various university groups. We plan to use the same modus-operandi for the facilities in Beam hall II area.

The users are requested to come forward and participate in the various workshops planned this year for forming working groups in various facilities.

- June 19: Workshop on RIB
- June 20-21: Nucl. Phys. Facilities
- Sept 20-21: Physics with Large Gamma Array coupled with HYRA
FUTURE POSSIBILITIES

FROM PELLETRON

SUPER BUNCHER

MAGNET

1 MeV/A

LOW β MODULE

SUPERCONDUCTING RFQ

2 MeV/A

LINAC MODULES

MAGNET

50 keV/A

ECR CHARGE BOOSTER

Mass Analyzer

DRIVER ACCELERATOR FOR RIB

ISOL SOURCE