Folded Tandem Ion Accelerator Facility at BARC

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Abstract

The Folded Tandem Ion Accelerator (FOTIA) facility has been commissioned recently at BARC. Several beams (\(^1\)H, \(^3\)He, \(^12\)C, \(^16\)O, \(^19\)F) have been accelerated up to a terminal voltage of 3 MV with \(N_2+CO_2\) as insulating gas. The terminal voltage is stabilized within \(\pm 2\) kV. The beams are used for elemental analysis using the Rutherford Back Scattering (RBS) technique. After making a few measurements around this terminal voltage, \(SF_6\) will be filled in the accelerator tank in order to raise the terminal voltage to 6 MV. Some of the salient features of the FOTIA facility are discussed here.

Introduction

In the last few decades, low energy accelerators, capable of delivering light and heavy ion beams, have played an important role both in basic and applied sciences, particularly in the fields of astrophysics, material science, accelerator mass spectrometry, beam foil spectroscopy, etc.

Although there are a large number of Van-de-Graaff accelerators in different laboratories only a few of them have been converted into folded tandem accelerators [1]. A project [2] was taken up at BARC to convert the existing 5.5 MV Model CN single stage Van-de-Graaff accelerator, which was in continuous operation since 1962 at the Nuclear Physics Division, into a 6 MV Folded Tandem Ion Accelerator (FOTIA). Due to limited power available in the terminal it was possible to produce and accelerate beams of only \(H^+\) and \(He^+\) ions in the old Van-de-Graaff accelerator at BARC.

However, FOTIA can accelerate heavy ion beams of up to \(A=40\) and energy up to 60 MeV.

Description of the FOTIA Facility

The layout of the FOTIA (Fig.1) was worked out by optimizing the ion optics parameters [3] despite severe geometrical constraints.
due to the utilization of the existing infrastructure of the Van-de-Graaff accelerator. One of the novel features of the ion optics is introduction of an einzel lens at the entry of the low energy tube. With this in operation it will be possible to get good transmission even at very low terminal voltages. This has contributed to the enhancement of dynamic range of its operation. In view of the modification in the beam optics, it was found necessary to raise the high voltage column structure by 1 m to accommodate, at the exit of the high energy accelerating tube, the additional magnetic quadrupole triplet and steerer magnets which are essential for optimum transmission of the beam. A tank raising structure (1m long, 2.5 dia.) has been incorporated in the system. This was really a challenging task as this additional collar had to withstand a load of 18 tons due to pressure vessel, high voltage column section, 180° magnet, alternator, etc. Also, the structure had to be built in two halves as otherwise it was not possible to take it to the accelerator room on the first floor of the Van-de-Graaff building.

The FOTIA is an accelerator amongst a few of its kind in the world. The construction of FOTIA involved development of technologies of several important components like:
- dipole magnets,
- high voltage generator,
- electrostatic and magnetic focusing lenses
- steering devices,
- vacuum systems,
- SF6 gas handling system,
- computer control system

In FOTIA, the negative ion beams extracted from the SNICS-II source (Fig.2) are pre-accelerated up to 150 keV. Out of all the charged particles extracted from the ion source the negative ions of the desired mass are selected using a 70°-dipole magnet for injection into the low energy accelerating tube.

As can be seen in Fig. 1, three dipole magnets [2] are used in FOTIA and their parameters are given listed in Table 1. The 70°-magnet (Fig.3) is designed for a magnetic field of 14 kG in the pole gap of 4 cm and has a bending radius of 40 cm. It can bend the ions having mass-energy product \((ME/q') \leq 15\). A magnetic field of 14.5 kG was realised, with field uniformity of ± 0.1%, at a current of 180 Amp.

Several beams were extracted from the ion source and then analysed using the 70°-magnet. Analyzed beam currents of several microamperes \((H'(4.5 \mu A), Li (0.5 \mu A), C'(5\mu A)\) were measured.
μA), O⁺(24 μA), Si⁺(13 μA), Cl⁺(11 μA)) were obtained. A typical mass spectrum obtained with Fe₂O₃ cathode sample is shown in Fig. 4.

![Mass spectrum for Fe₂O₃ cathode sample](image)

The beams are injected into the low energy accelerating tube through a 20°-electrostatic deflector. An electrostatic quadrupole triplet and an einzel lens are used to focus and match the beam parameters to the

![Ion source sample Fe₂O₃](image)

Table 1: Design parameters of the dipole magnets

<table>
<thead>
<tr>
<th>Parameter</th>
<th>70°</th>
<th>180°</th>
<th>90°</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(A) CORE DETAILS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air gap (mm)</td>
<td>40</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Gap width (mm)</td>
<td>100</td>
<td>42</td>
<td>110</td>
</tr>
<tr>
<td>Bending radius (mm)</td>
<td>400</td>
<td>305</td>
<td>750</td>
</tr>
<tr>
<td>Gap field (KG)</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Field uniformity (%)</td>
<td>0.10</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>Pole geometry</td>
<td>ANAC</td>
<td>NORMAL</td>
<td>ANAC</td>
</tr>
<tr>
<td><strong>(B) COIL DETAILS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Copper</td>
<td>Copper</td>
<td>Copper</td>
</tr>
<tr>
<td>Conductor</td>
<td>Strip</td>
<td>Strip</td>
<td>Hollow Copper tubes</td>
</tr>
<tr>
<td>Size (mm x mm)</td>
<td>0.80x75</td>
<td>0.78x50</td>
<td>12x12</td>
</tr>
<tr>
<td>No. of coils</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>No. of turns per coil</td>
<td>150</td>
<td>75</td>
<td>56</td>
</tr>
<tr>
<td>Resistance per coil</td>
<td>85 mΩ</td>
<td>75 mΩ</td>
<td>40 mΩ</td>
</tr>
<tr>
<td>Current capacity</td>
<td>200 amp</td>
<td>120 amp</td>
<td>500 amp</td>
</tr>
<tr>
<td>Inter-turn insulation</td>
<td>Mylar</td>
<td>Nomex</td>
<td>Fiber glass</td>
</tr>
<tr>
<td>Max. coil temp</td>
<td>70°</td>
<td>50°</td>
<td>70°</td>
</tr>
</tbody>
</table>

Fig. 4: Mass spectrum for Fe₂O₃ cathode sample

Fig. 5: The 180° - folding magnet located inside the high voltage terminal
acceptance of the low energy tube. The electrons of these accelerated negative ions get stripped off at the stripper and a desired charge state of the positive ions thus produced is selected with the 180° magnet inside the high voltage terminal before being bent into the high energy accelerating tube where they are further accelerated.

The 180°-magnet (Fig.5) (ME/q²=10, R=30.5 cm) has been tested for its field uniformity, which was found to be ± 0.15%. A magnetic field of 10.2 kG was measured at 100 Amp.

The analysed beam is transported to the scattering chamber through the experimental beam line, which consists of MQT, switching magnet, magnetic steerer [4], beam profile monitors (BPM), Faraday cups (FC), etc. These components (MQT, the magnetic steerers (Fig.8), BPM, Faraday cups) were obtained either from local vendors or designed and fabricated in BARC.

At the exit of the 180° magnet the beam diverges. An electrostatic quadrupole doublet is used to focus the beam before it enters the high-energy tube. The beams accelerated in the high energy accelerating tube are focussed using a magnetic quadrupole triplet (MQT) before being analyzed by the 90°-magnet (Fig.6). The 90°-dipole magnet is designed for a magnetic field of 14 kG and ME/q²=50 with a radius of curvature of 75 cm. A magnetic field of 15.5 kG was obtained at 500 Amp (Fig.7).

In Table 2, final beam energies, ME/q² values and relative intensities of different charge states produced at the foil stripper in the terminal are listed. The FOTIA facility has been commissioned recently [5] and all the components (low and high energy beam lines, high voltage column section, charging assembly, SF₆ gas handling and computer...
control systems, magnets, electrostatic and magnetic lenses, steerers, scattering chamber, etc.) has been working satisfactorily [6].

**Commissioning of the FOTIA Facility**

The commissioning of the FOTIA basically involved: a) design, fabrication, installation and testing of its sub-systems, b) high voltage tests, c) beam trials and their characterization, and d) calibration of the 90° analyzing magnet.

**High Voltage Tests**

The high voltage system of the FOTIA consists of different components like high voltage column section, charging mechanism and measurement & control system.

The high voltage column section consists of six modules (Fig.9); each designed for one million volt. Each module has 4 ceramic insulating posts, which are ceramic to metal bonded with 18 corona gaps connected by equipotential hoops. A pellet chain charging system, made of metallic pellets and nylon links, is used for generating the voltage on the terminal. The electrical power, required in the terminal, for 180°-magnet, ion pump, foil and gas strippers, electrostatic quadrupole doublet, Faraday cup and other electronic components, is generated by the 5 KVA alternator. The maximum vibration amplitude with both Perspex shaft and pellet chain running was found to be less than 30 \( \mu \) m [7] (Fig.10), which was within the safe limit.

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**Table 2 : The final beam energies at a terminal voltage of 6 MV for ions with different charge state (q)**

<table>
<thead>
<tr>
<th>Ion</th>
<th>Z</th>
<th>q+</th>
<th>Relative %</th>
<th>( E_r ) (MeV)</th>
<th>ME/q^2</th>
<th>Ion</th>
<th>Z</th>
<th>q+</th>
<th>Relative %</th>
<th>( E_r ) (MeV)</th>
<th>ME/q^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^1)H</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>12</td>
<td>12</td>
<td>(^{28})Si</td>
<td>14</td>
<td>5</td>
<td>16</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>(^2)He</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>18</td>
<td>18</td>
<td>(^6)Li</td>
<td>6</td>
<td>16</td>
<td>34</td>
<td>42</td>
<td>33</td>
</tr>
<tr>
<td>(^{12})C</td>
<td>6</td>
<td>3</td>
<td>12</td>
<td>24</td>
<td>32</td>
<td>(^{32})S</td>
<td>16</td>
<td>6</td>
<td>28</td>
<td>42</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td>52</td>
<td>30</td>
<td>23</td>
<td>(^{35})Cl</td>
<td>17</td>
<td>6</td>
<td>34</td>
<td>48</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td>33</td>
<td>36</td>
<td>17</td>
<td>(^{40})Ca</td>
<td>20</td>
<td>7</td>
<td>31</td>
<td>48</td>
<td>39</td>
</tr>
<tr>
<td>(^{16})O</td>
<td>8</td>
<td>4</td>
<td>24</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
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<td>5</td>
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<td>47</td>
<td>36</td>
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<td>6</td>
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<td>23</td>
<td>42</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(^{24})Mg</td>
<td>12</td>
<td>4</td>
<td>24</td>
<td>30</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
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<td>48</td>
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<tr>
<td></td>
<td>8</td>
<td></td>
<td>6</td>
<td>54</td>
<td>20</td>
<td></td>
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</tr>
</tbody>
</table>
The high voltage measurement system of the FOTIA uses a generating voltmeter (GVM) mounted on the inside surface of the tank, in front of the high voltage terminal. The high voltage control system uses a corona probe mounted inside the tank opposite to the GVM. The high voltage tests were carried out using N₂+CO₂ mixture as an insulating gas. At a tank pressure of 98 psig, a sustained voltage of 3.4 MV was achieved [8].

![Fig.10: Vibration amplitude across the column section](image)

In FOTIA, SF₆ will be used as insulating gas. Since hydrocarbon free environment is required inside the accelerator tank oil free equipments are used. The new gas handling system [9] consists of an oil free compressor, a centrifugal blower, a heat exchanger, dust filters, dryers and a vacuum pump etc. The gas handling system, is used mainly: a) to transfer gas from storage tank to accelerator tank and vice versa. b) to evacuate the accelerator tank to a pressure ~0.5 Torr. This maintains purity of gas by minimizing the contamination of the gas by residual air c) to remove moisture and breakdown products by re-circulating gas in a close loop system containing activated alumina dryer, heat exchanger, blower and filters, d) to maintain the temperature, inside the accelerator tank, to its designed value.

The accelerating tubes are subjected to very high voltage gradient of about 2 MV/m, which requires a hydrocarbon free and clean vacuum for smooth operation of the accelerator. A distributed pumping system having eight pumping stations has been used to maintain UHV in the entire accelerator including an experimental beam line and the scattering chamber [10]. The type of the pumps installed in a particular section is based on the gas load in that section (Table 3). The vacuum chamber of the 180° magnet (Fig. 11) has been provided with a separate ion pump, as its cross section (14 mm x 24 mm) is small. The ion source section has a large gas load, which increases substantially whenever samples are changed in the ion source. A turbo-molecular pump, with the speed of 1600 litres/sec, is used to maintain ultra high vacuum in this region. The other sections are pumped by a combination of titanium sublimation and sputter ion pumps or only by sputter ion pumps. A vacuum of 8 x 10⁻⁹ Torr was achieved in the entire system.

![Fig. 11: Vacuum chamber for the 180° magnet](image)

**Voltage stabilization system**

In tandem accelerators, the energy of the beam depends on the terminal voltage \( V_T \) and charge state \( q \) of the ions. The terminal voltage stability therefore determines the energy spread of the beam. A terminal voltage stabilization (TVS) system [11] was designed and developed for the FOTIA facility, and has been used extensively during beam trials. It is a closed loop control system, which involves measurement and monitoring of terminal voltage, beam energy and their stabilization. The present control &
monitoring system consists of GVM and its amplifier, a slit amplifier and a corona probe drive controller circuit. The TVS system works in two modes namely: a) GVM control mode and b) slit control mode.

The generating voltmeter (GVM) is used to measure the terminal voltage. In GVM control mode, the TVS controller generates an error signal by comparing the terminal voltage reading from the GVM amplifier with the set reference. In FOTIA, 90° magnet is used to analyse the beam and determine its energy, which in turn is used to obtain the terminal voltage $V_T$. Any change in $V_T$ will reflect on the beam position at the exit of the analyzing magnet. A slit system located just after the analyzing magnet monitors the beam position by measuring the current pick-ups on low energy and high energy slits. In the slit control mode, the TVS compares the low and high energy slit currents and generates an error signal which is used for locking the beam position. The corona probe controller works as a shunt regulator by loading the charging system. In both the cases, corona probe controller uses the error signals for stabilizing the terminal voltage.

The TVS system regulates terminal voltage over a wide range of its operation. The TVS controller also incorporates the facility to monitor various signals like terminal voltage, corona probe current, grid voltage and slit pick-ups. The system was tested both in GVM control mode and slit control mode with a beam current as low as 2 nA and its

Table 3: Gas load estimates

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Name of the section</th>
<th>Main components</th>
<th>Volume (cm³) &amp; surface area (cm²)</th>
<th>Gas load (Torr-lit/sec)</th>
<th>Pumping speed (lit/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ion source</td>
<td>Ion source, Acc. Tube, E.S. steerer</td>
<td>47713 10822</td>
<td>1.44 x 10⁻⁵</td>
<td>1600</td>
</tr>
<tr>
<td>2</td>
<td>Injection line</td>
<td>BPM, FC, 70° Magnet Chamber, 20° Deflector, E.S. Steerer</td>
<td>51616 19287</td>
<td>6.3 x 10⁻⁵</td>
<td>820 *</td>
</tr>
<tr>
<td>3</td>
<td>Low energy accelerating tube</td>
<td>Einzel lens, Acc. Tube, E.S. Steerer</td>
<td>22407 17194</td>
<td>1.08 X 10⁻⁶</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>Terminal</td>
<td>Stripper and 180° Magnet Chambers, Pumping unit</td>
<td>9628 4473</td>
<td>9.34 X 10⁻⁷</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>High energy accelerating tube</td>
<td>Acc. Tube, Mag. Quad. Triplet, Pumping unit</td>
<td>31455 20812</td>
<td>7.5 X 10⁻⁶</td>
<td>120</td>
</tr>
<tr>
<td>6</td>
<td>Analysing magnet</td>
<td>90° Magnet chamber, BPM, FC, Slits, Pumping unit</td>
<td>40834 18393</td>
<td>1.0 X 10⁻⁵</td>
<td>1640 **</td>
</tr>
<tr>
<td>7</td>
<td>Experimental Beam line</td>
<td>Scatt. chamber, S/W magnet, Mag. Steerer, M.Q.T.</td>
<td>106306 50198</td>
<td>9.5 X 10⁻⁵</td>
<td>3000</td>
</tr>
</tbody>
</table>

Note: TSP pumps are put on only when they are required.

* 820 = 700 (TSP) + 120(SIP), ** 1640 = 1400 (TSP) + 120(SIP)
performance was satisfactory. The voltage stability was found to be about ± 2 kV.

**Control and monitoring system**

A PC based system [12] developed in BARC has been used in FOTIA for controlling and monitoring parameters of beam handling components located both at the high voltage and ground potentials. The ion source parameters are controlled using a fibre-optic data telemetry system [13]. The control and monitoring system has a network of PCs with a front-end interface using CAMAC instrumentation and uses QNX real time operating system.

**Beam Characterization and Energy Calibration**

The first beam ($^{12}$C) on target was delivered on April 21, 2000. The beam was characterised [5] by measuring the Rutherford Back Scattering (RBS) from the self-supporting targets of $^{197}$Au, $^{120}$Sn and $^{56}$Fe. The targets were mounted inside the 80 cm diameter scattering chamber (Fig.12).

![Fig 12: Scattering chamber used for RBS measurements](image)

The elastically scattered particles were detected using a surface barrier detector mounted at $\theta_{lab}=160^\circ$. The experimental set up is shown in Fig.13. To calibrate the pulse height of the detector, an alpha source was mounted on one of the target holders.

Using kinematics, the incident energy ($E_i$) was calculated from the scattered particle energy ($E_s$) for each of the targets using the following relation:

$$E_s = \left( \frac{m_1}{m_2} \right) \frac{m_1}{m_2} \cos 2\theta + m_i \cos \theta \sqrt{m_1(m_1 \cos^2 \theta - 1) + m_i^2}$$

Here $m_1$ and $m_2$ are masses of the projectile and target. The $\theta$ is scattering angle in the lab system.

The terminal voltage $V_T$ was calculated from this $E_s$ using the relation $E_s = E_{in} + (q+1)V_T$, where $E_{in}$ is the energy of the beam from the ion source and $q$ is the charge state of the analysed $^{12}$C beam. In the present experiment charge state of $4^+$ was selected. The average terminal voltage calculated using above RBS data, after correcting for energy loss in the gold (dead) layer of the detector and kinematic broadening etc. was found to be 2.54 ±0.020 MV, which was consistent with the generating voltmeter reading of 2.54 MV. Subsequently, stabilization system has been modified and terminal voltage stability has been improved to ± 2 kV [14].

For the magnetic field $B$ (in Tesla), generated by the 90° magnet, the energy $E$ (in MeV) of the beam is given by the relation,

$$B = \frac{(K/q)}{\sqrt{\left(A \{1+(E/2A\mu c^2)\}\right)^{1/2}}}$$

where $A$, $\mu$, and $q$ are the mass number, mass of the projectile in amu and the charge state of the particle, respectively. The $K$-value of the magnet can be obtained once the energy of the beam is known. Both back scattering (BS) and resonance scattering techniques were used to obtain the $K$-value [15].

In the BS measurements, proton, Lithium, Carbon and Fluorine beams were used. In the case of BS with proton beam, the energy was calibrated by measuring the backscattered protons from Tantalum ($^{181}$Ta), Niobium ($^{92}$Nb) and Carbon ($^{12}$C)
targets. The back scattered protons were measured by a silicon surface barrier detector placed at $\theta_{abs}=160^\circ$ using the setup discussed above. In the spectrum of the thick target, center of the falling edge at the highest energy is taken as the scattered energy of BS from the front surface. The incident beam energy ($E_{inc}$) was calculated from the energy of the scattered ions for each of the targets for different terminal voltages. In these measurements, the terminal voltage was varied between 2.1 - 2.5 MV. The BS of $^7$Li, $^{12}$C and $^{19}$F beams (with different charge states) were done from gold targets. The BS spectrum of $^7$Li from $^{197}$Au measured for calibration of the 90°-analyzing magnet is shown in Fig. 14. The alpha peaks from Am-Pu source mounted on one of the target holder positions are also seen in the figure.

Safety Issues-Radiation Shielding and Interlocking System

In order to get an idea about expected radiation level around the high voltage terminal of the FOTIA, radiation measurements were made, using proton, carbon and oxygen beams, at various locations including high voltage terminal of the 14 UD pelletron accelerator by simulating FOTIA conditions [16]. The x-ray radiation level was found to be negligible and well below the permissible limit. The radiation level was also very small when beam was stopped on a thick SS stopper mounted in one of the holes of the stripper foils. In both the cases neutron intensity was found to be consistent with the NCRP values. This data was a very useful input to the shielding calculations for the FOTIA project.

Radiations measurements were made both with heavy ion and proton beams up to a terminal voltage of 3 MeV. With heavy ion beams dose rates both for gamma and neutron were negligible. In the case of proton beams the gamma dose rate were very small at all the energies. However, for a
current of 10 nA the neutron dose rate were measured to be 0.06 and 0.8 mR/hr at 2.5 and 3.0 MV terminal voltage, respectively. Therefore interlocking of beam hall door is essential whenever proton beams are accelerated at higher terminal voltages.

A PLC based safety interlocking system has been implemented in FOTIA. This system takes care of different abnormal conditions and generates suitable audio/visual alarms and brings the malfunctioning units to safe shutdown condition. The components related to charging, vacuum systems, SF₆ leakage and radiation, etc have been connected to this system for status display and safety interlocking purpose. The system has been tested and working satisfactorily.

Summary and Conclusions

The folded tandem ion accelerator facility has been commissioned recently. Several sub-systems involving state-of-the-art technologies were developed. Beams from \(^1\text{H}\) to \(^{19}\text{F}\) have been accelerated up to a terminal voltage of 3 MeV. The terminal voltage is stabilized to ± 2 kV. Progressively the terminal voltage will be raised to 6 MV and other beams up to \(^{40}\text{Ca}\) will be accelerated. This facility will be widely used for multi-disciplinary research of interest & relevance to BARC. Recently, experiments were done [17], in collaboration with Radiochemistry Division, to investigate the effect of hydrophobicity of membrane matrix on the selectivity towards cations. The membranes were prepared by physical inclusion of hydrophobic cation-exchanger in the matrix formed by polymer chains of cellulose triacetate with a plasticizer. The 4 MeV proton beams were used for depth profiling using Rutherford Back Scattering technique.

In order to carry out experiments in different fields like nuclear physics, astrophysics, atomic physics, AMS, etc, a new hall has been constructed and five beam lines are being set up.

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References


Dr Pitamber Singh was conferred the BARC Technical Excellence Award for the year 2000 for his exemplary contributions to Accelerator Physics and Technology.

About the author ...

Dr Pitamber Singh joined the Nuclear Physics Division in 1976 after graduating from 19th batch of the BARC Training School. He received his Ph.D. degree in physics from Mumbai University in 1983. Dr Singh spent more than one year at the Max-Planck Institute fuer Kernphysik, Heidelberg, Germany, and has worked in several accelerator labs. In addition to designing and building the first 2 MV Tandem Accelerator at BARC, he has made an outstanding contribution in setting up the 6 MV Folded Tandem Ion Accelerator (FOTIA) facility at BARC. Recently, he has also been selected as a member of the "National Academy of Sciences, India" for his excellent contribution towards indigenous development of the accelerator technology in the country and nuclear reaction studies using heavy ion beams from charged particle accelerators. Presently, he is working on the development of high Intensity Proton Accelerators. Dr Singh is a co-author of about 175 scientific publications. Presently, he is head of FOTIA Section of the Nuclear Physics Division.