Folded Tandem Ion Accelerator(FOTIA) Overview of Operational and Safety Aspects

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Plan of the talk

- Introduction of the FOTIA facility.
- Types of experiments carried out in FOTIA facility.
- Safety aspects of FOTIA facility.
- Conclusions

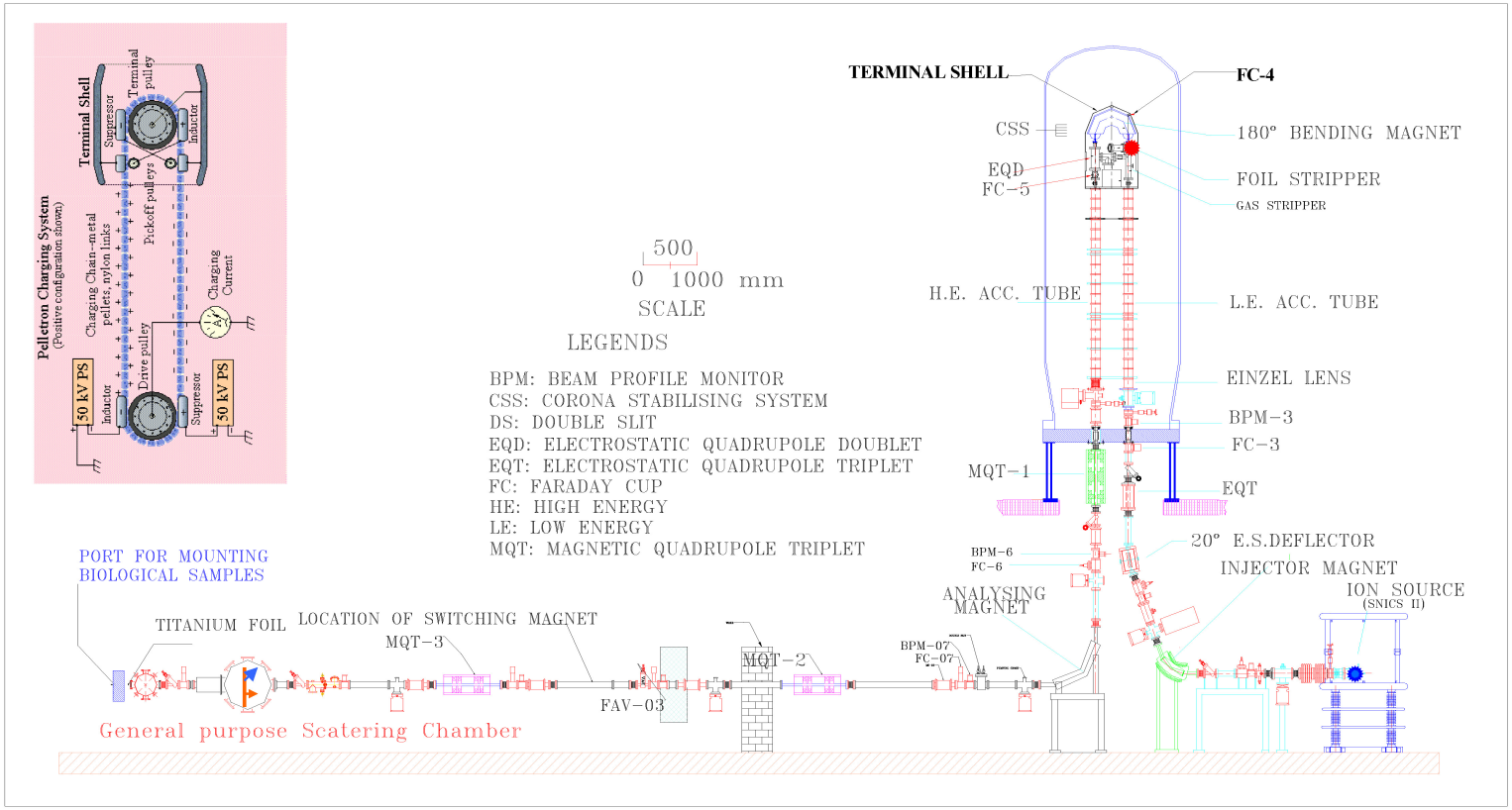
Folded Tandem Ion Accelerator(FOTIA)

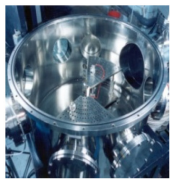
- **FOTIA** is a DC electrostatic accelerator.
- **FOTIA** is an upgraded version of old Van de Graaf accelerator.
- **FOTIA** can deliver variety of positive ion beams for experimentation into various areas of science and technology. It is extensively used by BARC and non BARC users.
- **FOTIA** is running very reliably for last ten years and contributed to various programs of DAE.

FOTIA Specifications

- **Max Voltage** 6 Million Volt.
- **Voltage Stability** $\pm 2kV$.
- **Ions** Positively charged ions with $\frac{mE}{q^2} \leqslant 42$.
- **Max Energy** 1 to 5 Mev for Proton , for heavy ions (n+1)V where n is the charge state and V is the terminal voltage.
- **Max Current**
  1. Proton : 500 nA
  2. Heavy ions(Li , $C^{3+,4+}$, O , F): tens of particle nano Amp.

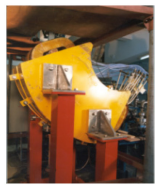
Schematic Diagram of FOTIA





Scattering chamber

Switching Magnet



90^0 Magnet

180^0 Magnet

70^0 Magnet

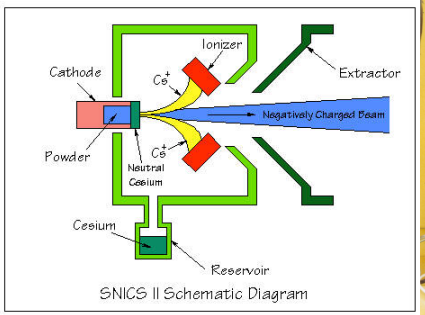
SNICS II ion Source

Slide Courtesy Dr. P Singh

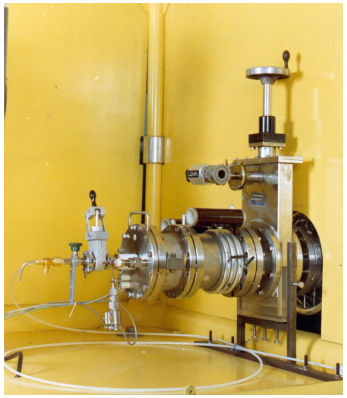
FOTIA Subsystems

- Ion Source.
- Bending and Focusing devices- electrostatic and magnetic.
- High voltage and high current power supplies.
- High Voltage generation system.
- SF_6 gas handling system.
- Vacuum system.
- Control and instrumentation system.
- Engineering Services.

FOTIA Subsystems-Ion Source



(a) Schematic

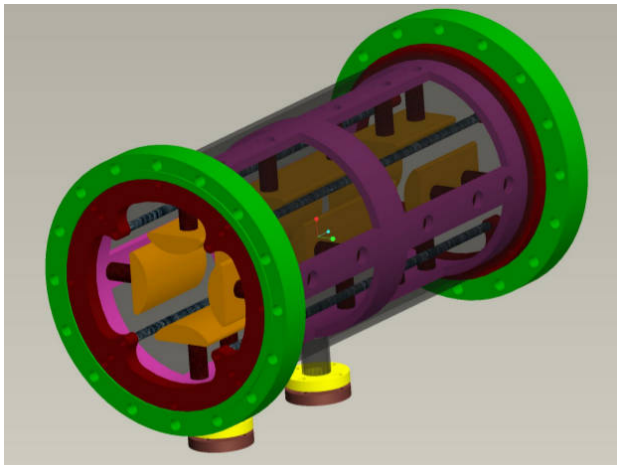


(b) SNICS

- FOTIA uses Source of Negative Ion by Caesium Sputtering **(SNICS)** as its ion source.
- **SNICS** generate negative ions by means of Caesium sputtering.Sample is put on the cathode stem.
- Positive voltage is used to extract negative ion beams.
- Beam current is function of filament current & cathode voltage.
- Must be kept under 10^{-7} mbar order of vacuum to protect Caesium.

FOTIA Subsystems-Bending & Focusing Devices:Electrostatic Devices

- Beam can be focused and bend with electrostatic devices.
- Accelerating section pre accelerate the beam after ion source.
- FOTIA has electrostatic deflector which deflects the beam by 20^0 in its path .
- FOTIA has a electrostatic quadrupole triplet to focus the beam.



- Accelerating tubes accelerate and focuses the beam.

FOTIA Subsystems-Bending and Focusing devices : Dipole Magnets

- Two types of magnets are used in FOTIA. They are dipole and quadrupole magnets.
- Dipole magnets are used to bend the ion beam. There are four dipole magnets in FOTIA.
- First dipole magnet is just after ion source. It bends ion beam 70^0 in its path. This magnet also acts as **mass selector** or **mass filter**.
- Second dipole magnet is at the terminal. This gives a bend of 180^0. This magnet acts as **charge selector**.
- Third dipole magnet is after the accelerating tube. It bens beam by 90^0. This also acts as **energy selector**.
- Fourth dipole magnet is at the experimental hall. This bends the beam to one of our three beam lines.

FOTIA Subsystems-Bending and Focusing devices:Quadrupole Magnets

- MAgnetic Quadrupole Triplet(MQT) are used to focus the ion beam.
- FOTIA has a quadrupole magnet in each beam line.
- MQT are essential to deliver right size of the beam at the target.

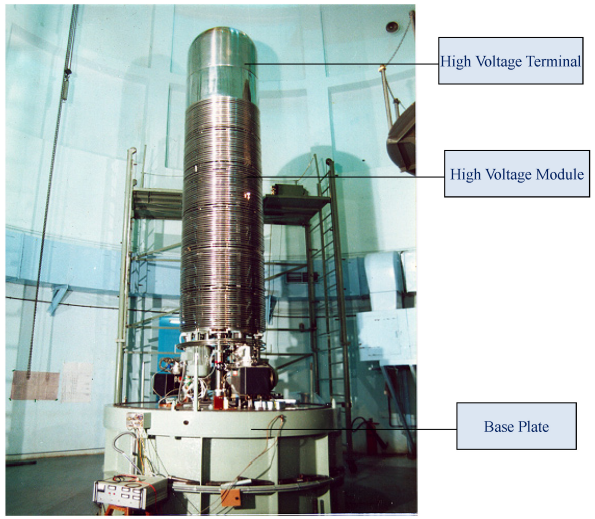
FOTIA Subsystems-High Voltage and High Current Power Supplies

- Stability of the beam is a primary requirement of experimenters.
- To maintain stability of the beam highly stable power supplies are used to create magnetic field in magnets and electric field in electrostatic equipments.
- All power supplies of the FOTIA have stability 100 ppm or better.

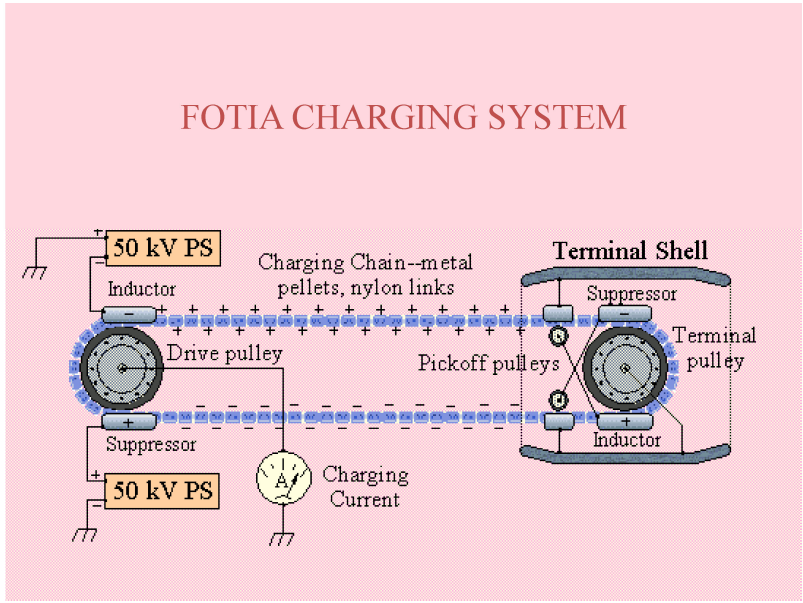
FOTIA Subsystems-Ultra High Vacuum System

- Throughout the length of beam line vacuum of the order of 10^{-8} mbar is maintained. This is a mandatory requirement for proper running of any particle accelerator.
- Distributed vacuum pumping system is employed to avoid vacuum gradient.
- FOTIA uses Turbo Molecular Pump backed by oil sealed rotary pump , diffusion pump and sputter ion pump for vacuum pumping.
- Pirani and cold cathode combination "Full Range" vacuum gauges are used for vacuum measurement at various location.

FOTIA Subsystems-High Voltage System



(a) FOTIA Column



(b) Pellete Charging System

Figure : Components of high voltage system

- Energy of beam is dependent on high voltage of terminal.
- Pellet charging system is used for generating very high voltage.

FOTIA Subsystems-High Voltage System (cont)

- Voltage gradient is maintained by allowing leakage current to pass through very high value (3 GΩ) resistance chain.
- Equipotential rings are used to maintain uniform electric field.

(a) Resistor Chain

Figure : Component of high voltage system

FOTIA Subsystems-SF_6 gas handling system

- High purity SF_6 gas at 90 psig pressure is used for providing very high dielectric strength to hold the terminal voltage.
- SF_6 gas is recirculated to remove breakdown products, moisture and heat.
- A separate storage tank is used to store the gas in case of tank opening.

FOTIA Subsystem-Control System

- FOTIA control system is a network based control system.
- It has two tier client server architecture.
- Computer Automated Measurement And Control(CAMAC) acts as as server.
- Operator workstation acts as client. Operator GUI is written in Qt 3 in Linux OS (Fedora 7).
- Control system deals with 128 analog inputs , 64 analog outputs , 128 digital inputs and 96 digital outputs.
- Fibre optic link is used to transmit signal to the devices floating at high voltage.

FOTIA Subsystem-Measurement and Instrumentation

- Faraday Cup is used to measure the beam current.
- Beam Profile Monitor(BPM) provide shape and size of the beam.
- Generating Volt Meter (GVM) is used to measure high voltage of the terminal.
- Hall probe is used to measure the magnetic field. Current readback of current power supply is also used to measure magnetic field.

FOTIA Beam Lines

FOTIA has five dedicated beam lines to perform five different types of experiments. They are

- Nuclear physics experiments.
- Proton Induced Positron Annihilation Spectroscopy (PIPAS) experiments.
- Trace Element Analysis (RBS, PIXE, etc.) experiments.
- Irradiation line for Material science experiments.
- Radiation biology experiments.

Nuclear Physics and Irradiation experiments

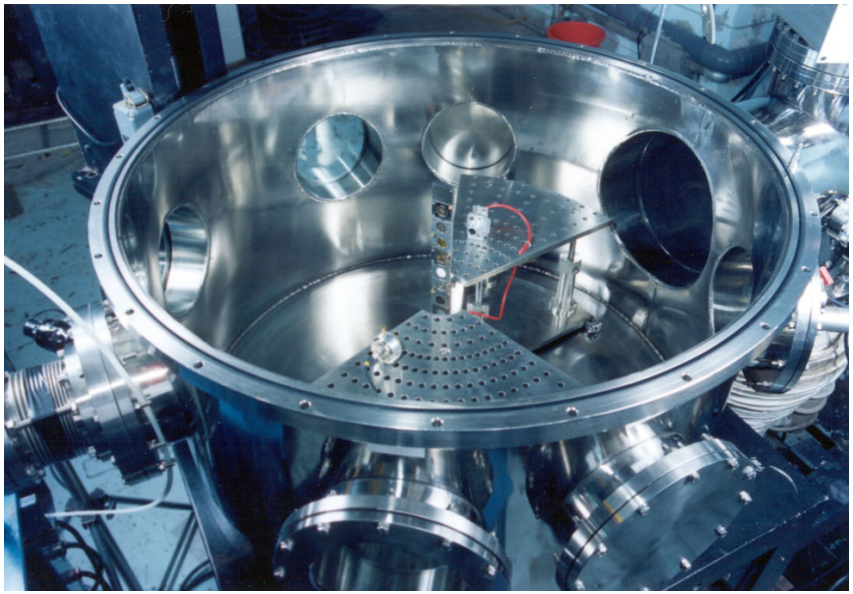


Figure : General Purpose Scattering Chamber

- Nuclear Physics and general irradiation experiments are carried out in general purpose scattering chamber .

Proton Induced X ray Emission (PIXE)

Figure : PIXE Setup

- Proton beam is allowed to fall on target material.Material emit different energy x rays according to its composition.
- Detecting X rays, composition of the material can be determined very accurately.

External PIXE & Radiation Biology

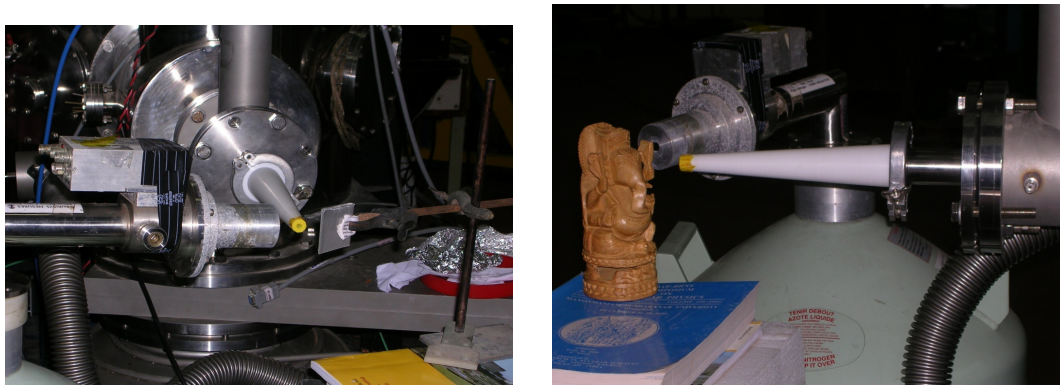


Figure : External PIXE Setup

- A thin (Ti 20 μm) or (Kapton 8 μm) window is placed at the end of beam line to take the beam.
- Proton beam of varying intensities are taken out in air.
- Radiation biology, Environment assessment and Evaluation of documents and other material for forensic application programme use beam in air.

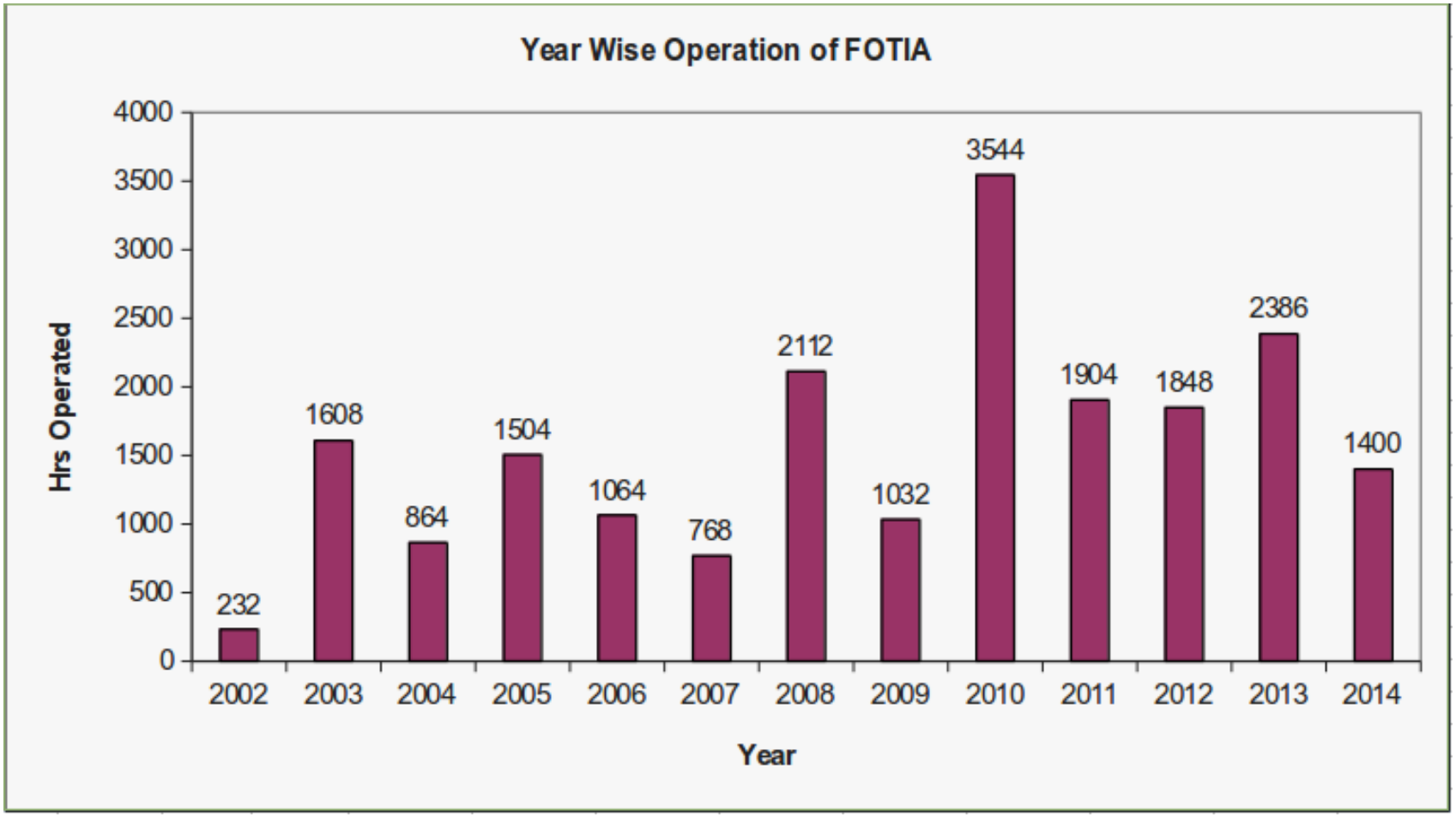
Some notable experiments

- Simulation of neutron damage of stainless steel in reactor by proton beam.
- PIXE studies of Gall bladder stones .
- Determination of material composition for Archaeological sample.
- Quadrupole testing for the project X of Fermi lab , USA.
- Characterisation and calibration of various equipements to be used in upcoming Low Energy High Intensity Proton Accelerator(LEHIPA).
- Nuclear detector calibration.

Non DAE users of FOTIA

- Indian Institue of Technology(IIT) Powai.
- Mumbai University.
- North Easternal University.
- Annamalai University.
- Punjab University.
- SAMEER.
- ISRO.
- DRDO has propsed some experiments. Discussion is going on.

FOTIA Operational Statistics



Safety aspects in FOTIA

Figure : Wining Safety Shield

- FOTIA is one of the safest accelerator in operation. It won safety shield for three consecutive years(2011 to 2013).
- FOTIA is regulated by Unit Level Safety Committee-Particle Accelerator (ULSC-PA). Many of FOTIA practices are recommended to other accelerator facilities by ULSC-PA.

Safety in FOTIA

Safety aspects of FOTIA can be classified as

- Human Safety.
- Equipment Safety.

Human Safety in FOTIA

Human safety is of utmost importance because it can't be compensated.

Human safety involves the safe working condition for

- Electrical Systems
- Mechanical Systems
- Radiation
- General Industrial Safety.

To ensure human safety following strategies are taken:

- Training of the personnel.
- Audio Visual alarm and deterrent notices such as "No Entry" etc .
- Different guiding notices such as "Exit" , "Emergency Exit" , "Fire Exit" , "Assembly point" etc
- Emergency response procedure (such as "Actions to be taken in case of electric shock") posters.
- Automatic interlock protection in case of human mistakes.

Human Safety in Electrical System

- All the high voltage areas are properly marked and DANGER notice is put up to prevent a person to approach nearby.
- High voltage area of deck power supply is enclosed by the protective cage and cage door is interlocked with the high voltage power supply in such a way that if, the cage door is open then power supply can't be switched ON.
- If the power supply is ON and cage door is opened, then immediately power supply will automatically get switched off.
- An earthing rod is provided to discharge the deck, after entry, the cage should be grounded, which ensures that if by mistake power supply remained ON, still it will be at ground potential, thereby ensuring safety of working personnel.
- All the electrical equipments are ISI certified.
- High voltage and high current cables are marked and laid properly as per Indian Electricity rule.
- Earthing resistances are ensured to be below allowed values and checked regularly.

Human Safety- Mechanical System

- Personnel are required to wear helmet and safety shoes when they are working in the accelerator room.
- Personnel are required to wear ear plug in high noise area such as compressor room.
- Personnel are required to wear eye protection and gloves when dealing with liquid nitrogen.
- All high pressure area are marked with DANGER notice. Pressure value of accelerator and storage tank are always monitored.
- Pressure Release Safety valve of compressors are set at 10% above the working pressure and well below the design limit.
- Heavy objects, such as gas cylinders etc. are tied securely with the chain.

Human Safety- Radiation

Though radiation level in FOTIA is minimal but no lapses are allowed dealing with radiation related issues.

- Radiation areas are marked and DANGER notices are displayed.
- Gamma monitors and Neutron detectors continously monitor the radiation level.An audio visual alarm is automatically generated if radiation detectors pick up radiation above the permissible limit.
- During accelerator operation, the radiation level is monitored periodically by health physicist and logged in logbook.
- Personnel must wear the TLD and fast neutron badges.
- FOTIA employs search and secure interlock system to ensure that no person can be trapped in the accelerator room or beam hall during accelerator operation and receive high radiation dose.

General Industrial Human Safety

1. **Fire and Chemical safety:** Adequate smoke detectors are installed throughout the building. In case of smoke or fire audio alarm is generated and visual indication at fire alarm pane identify the troubled zone.
2. **Safety against Inflammable material:** During sample change or Caesium loading, inert atmosphere of Argon gas is maintained and personnel are required to wear the proper safety gadgets such as hand glove and safety goggle while handling Caesium.
3. SF_6 **leakage:** SF_6 monitors and Oxygen deficiency monitors are provided. In case of SF_6 leak audio-visual alarm is generated.
   If oxygen level falls below 19.0 %, emergengy evacuation from building alarm is generated.
4. **General industrial safety:** Protective helmets, Protective gloves, safety belts and safety shoes are available for use if required.

Equipment Safety

Safety Interlocks are provided to ensure automatic operation during fault condition in fail safe mode. Two levels of interlocking arrangement have been provided

1. **PLC based:**
   - Charging chain motor, Rotating shaft motor
   - SF_6 Compressor, Blower, Rotary pump.
   - SF_6 Monitors, Oxygen deficiency Monitors, Radiation Monitors
   - Rouging pumps, Ion pumps, Isolation valves
2. **Hard-wired:**
   - Cage door with the pre-acceleration voltage.
   - Cathode cooling pump with isolation transformer.
   - GVM with TRV
   - Turbo pump valve with Ion Gauge Controller.
   - Fast acting valve with Ion Gauge Controller-1 & Ion Gauge Controller-2.

Safety motto of FOTIA

FOTIA team believes in following two dictums

- Know safety, no injury.
  No safety, know injury.
  – Author Unknown
- **Safety is a mission not an intermission.**

FOTIA staff know safety. As a result FOTIA,till today, has never faced pain of any injury or equipment damage.
Since safety is a mission

- All the sensors, safety equipments, interlock systems are periodically tested and maintained.
- We are always open to the suggestions which can improve our facility's safety.

Conclusions

- **FOTIA** is running very reliably for last ten years and contributed to various program of DAE.
- **FOTIA** follows stringent safety norms to ensure human and equipment safety.
- **FOTIA** design, installation and operational experience are being utilized to design and commission next generation bigger and more complex accelerators.
- **FOTIA** has a smaller cousin known as **Low Energy Accelerator Facility(LEAF)** . This is a Low energy(upto 50 keV) high current(order of hundreds of nano ampere) *negative* ion accelerator. This accelerator is also running very successfully and produced very high quality international papers. Three PhD students of IIT Bombay have extensively used this facility for their research work.

Invitation

The FOTIA team invite all possible users from BARC and outside research community to make use of both the facilities which is delivering variety of ion beams for research within BARC premises.

Acknowledgements

My sincere thanks to

- Dr P Singh , Head IADD
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- All FOTIA staffs.


Thank
You!