Nuclear physics experiments using accelerators

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In this paper, we present safety aspects for nuclear physics experiments from an accelerator user’s perspective. An overview of the BARC-TIFR Pelletron and LINAC accelerators is given, followed by a description of the common experimental set-ups. In these experiments, detectors are used both online and offline to collect information. Detectors signals are processed by suitable electronics and data is gathered in data acquisition systems. Studies of nuclear reactions are often carried out in a scattering chamber. Description of the experiments and safety aspects are presented. Data acquisition systems are described. Aspects of data safety are discussed.

Keywords: Accelerator, Radiation, Safety, Data acquisition

1 Introduction

The most basic safety requirements at an accelerator laboratory are concerned with the prevention of radiation exposure to experimenters. Access to experimental beam halls is restricted. This is achieved by door interlocks with search-and-secure systems. Personal radiation dosimeters are used to monitor the radiation dose received by experimenters and ensure that these are within the specified limits of safety. At radioactive ion beam (RIB) accelerators, greater attention to safety is needed.

However, there are other, more complex, and sometimes more subtle safety concerns connected with the experiments. These issues range from the operation of cranes, handling heavy components, vacuum accidents, targets with residual activity, radioactive sources, beams with toxicity (e.g. $^9$Be), high voltages and working in congested places.

Safety is not only a precaution against human injury, but also covers monetary loss such as damage to equipment and detectors. Lastly, there is a question of data safety. Running an accelerator and performing experiments entail a substantial cost. If the data collected in the experiment is corrupted or lost, this too is a matter of concern.

2 The BARC-TIFR Pelletron at Mumbai

The 14 MV Pelletron$^1$ (supplied by NEC) was set-up in 1989 (Fig. 1). Beams from the indigenously developed LINAC booster (Fig. 2) were available from 2002 in Phase I and Phase II was completed in 2007.

3 Experimental Set-ups

In the ideal case, each experimental set-up should have its own radiation shielded cave. However in Pelletron-LINAC, we have 3 caves with 12 beam lines as partly shown in Fig. 3.

There are several major experimental set-ups such as INGA (Indian National Gamma Ray Array), Charged Particle Detector Array, High Energy Gamma Ray Array, low background HpGe offline set-up, scattering chamber, irradiation chamber etc. Each of these experimental set-ups has different

![Fig. 1 — Schematic of 14UD Pelletron](image)
safety aspects. Safety issues connected with one of the experimental set-ups is detailed below.

4 General Purpose Scattering Chamber

The scattering chamber in the 30° line in LINAC Hall 1 is used for a variety of nuclear reaction studies. The target ladder located at the centre of the chamber and the two moveable arms, where detectors can be mounted, are controlled with the help of servo motors which are remotely controlled (Fig. 4). The chamber is operated in a vacuum of 1-2×10⁻⁶ mbar.

The following are the safety issues and the working solutions:

4.1 Hydraulic lid lifting crane with vacuum interlock

The lid of the chamber (stainless steel, 400 kg) is operated by means of a hydraulic lifting crane. The hydraulic system is interlocked so that the lid cannot be lifted until the chamber is vented. After the lid is lifted, there is a manual swivel allowing the lid to be moved away. This makes it easier for the experimenters who have to work inside the chamber. In many cases two or three experimenters have to sit inside the chamber to prepare the experimental set-up. Having the lid moved away ensures additional safety. It is also necessary to test the hydraulic lift and interlock at the start of each experiment. The crane should be well maintained to ensure safety.

4.2 Vacuum (air inlet to accelerator)

The users must ensure that they do not vent the chamber before closing the isolating gate valve. An interlock for this purpose would be very useful, but has not been implemented yet.

4.3 Operation of motors

A great deal of effort has been put in the software so that operation of the moving arms is collision free. Collision of the arms would lead to mis-alignment or even damage to the arms. It is required that the users initialize the motors correctly to ensure that the software checks work correctly. Similarly the ladder height adjustment, if taken out of bounds would result in damage to the shafts of the mechanical assembly. In addition to the software checks, micro switches have been installed to ensure a second level of safety.

4.4 Use of radioactive sources inside the chamber

In most experiments, calibration sources (usually Pu-Am or ²³³Th alpha) are employed to calibrate the detectors before, after and even during the experiment. The source is mounted on the target ladder in one of the target positions. The usual precautions for source handling are required and special care is needed to avoid contaminating the
chamber. Indeed it would be quite catastrophic to have the accelerator beam impinging on a radioactive source.

5 Data Acquisition Systems

Ultimately, the purpose of any experiment is to gather data.

We have 4 different types of data acquisition systems in our laboratory. We started with CAMAC systems (1 μs readout time) and these are still in use in many of the simpler experiments. We upgraded this to FERA (Fast Encoding and Readout) in 2005 (Fig. 5).

We are now gradually changing to VME systems. In addition, we are using a digital data acquisition system (prepared by XIA) for the clover array experiments.

5.1 Data acquisition in a radiation zone

There are two possible configurations. In smaller experiments (typically up to 30 parameters), the detector signals from the pre-amplifiers are cabled to the counting room outside the radiation zone and the major electronics and data acquisition are located in the counting room. This requires sufficient number of cables from beam hall to counting room. For experiments with more parameters (50-500), we locate all the electronics and data acquisition inside the beam hall and use a remote PC as terminal to acquisition.

Safety of the acquired data is a major concern. Accidental data loss or data corruption would mean that the cost associated with accelerator operation during beam time is lost.

We are concerned with the following issues.

5.2 Media failure

In the early days (1980s and early 1990s) magnetic tapes were used for data archiving (in the earliest times, tapes were used as the primary medium). Magnetic tapes were prone to failure and it was necessary to maintain 2-3 copies of the data. In our laboratory, we relied more on disk storage and less on tape backup in that era. With the advent of more reliable, low cost and large capacity hard disks, the problems of media failure is much less in modern times.

5.3 Human failure

During data archiving, it is common for users to delete unwanted data, rearrange disk directories etc. We have seen a few cases of inadvertent data loss during this process (an extreme case would be for the user entering the Linux command "rm *").

5.4 Data overwriting

Although the acquisition system warns against starting a run for which files already exist, when there are many experimenters working together, confusion can result in overwritten files.

5.5 Missing reference data

Data acquisition is often incomplete without the proper noting in the log book (whether electronic or hand written). In many cases, the users have not bothered to set-up a scaler and are manually noting the integrated beam charge. In cross-section measurements, if the beam charge is unavailable the data are of no value.

5.5 Data Safety Solutions

The first and foremost point is user awareness. Users need to be aware of the problems that can arise and be mentally alert when dealing with data. The second point is to ensure that a second (or third) copy of the data is generated as a matter of routine during the experiment soon after the primary file is acquired. Most often, users are performing offline analysis of prior runs during the course of the experiment. If this is done on a secondary copy of the data, we achieve a level of safety.

For experiments with the clover array, data volumes are large and offline analysis is many times limited. In this case it is absolutely necessary to perform data back-ups periodically on 1 TB fireware or USB external hard disks. These back-ups could be
taken during liquid nitrogen fills or during temporary beam outages. It is, generally, not recommended to copy files from earlier runs from the main PC while a run is currently acquiring. We are planning to set-up a RAID (redundant disk array) which would be very helpful and provide a failsafe way to ensure that data is not lost.

6 Conclusions

Safety issues at an accelerator laboratory are a concern for the experimenters. Radiation safety is achieved by shielding and radiation monitoring. Other issues, connected with experiments require more careful attention: crane operation, handling heavy equipment, vacuum accidents, residual radioactivity, radioactive sources, toxic materials, high voltages and so on. The concept of safety is extended to cover the important area of data safety.

References
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4 http://www.tifr.res.in/~pell/lampshtml