Plans for the Command and Controls of PIAFE Phase 1.

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ABSTRACT

The PIAFE project proposes the production of accelerated beams of exotic ions for nuclear physics research. A fission ion source would be placed near the core of the high flux reactor of the Institut Laue Langevin. The first stages of the development of the control system for PIAFE phase 1 are described.

THE PIAFE PROJECT.

Introduction

Atomic nuclei with a large excess or deficit of neutrons with respect to stable nuclei are known as "exotic". Such nuclei are highly unstable and thus radioactive with short lifetimes. The study of exotic nuclei will be one of the main topics of research in nuclear physics in the coming years. Indeed, several projects are already being studied or are already being built around the world in order to produce accelerated beams of exotic ions.

Beams of exotic ions permit the observation of nuclear reactions which cannot be otherwise obtained. These reactions offer many new and exciting possibilities to nuclear physicists, in particular the validation of the current models of the atomic nucleus very far from the stability line.[1]

Grenoble has the chance that the SARA, the heavy ion accelerator of the Institut des Sciences Nucléaires (ISN) is adjacent to the high flux reactor of the Institut Laue Langevin (ILL). PIAFE [2] ("Production, Ionisation et Accélération de Faisceaux Exotiques") is a project which proposes the production beams of neutron rich ions with masses between 80 and 150, with a particularly high intensity, using a fission ion source placed close to the reactor core of the ILL. Phase 1 of the project should demonstrate that it is possible to produce these high intensities. The beam, accelerated to 30 keV, will be used for low energy nuclear physics. In the second phase of the project the ion beam would be transported in a few milliseconds to SARA via a 400 meter beam line, for further acceleration. Energies between 2 and 14 MeV/A could be attained.

Further information, including a copy of this article, is available at *http://isnwww.in2p3.fr/piafe/piafe.html*.

Current Status of the Project.

Preliminary studies for PIAFE began in Grenoble in 1992. The project quickly incited international interest and the PIAFE collaboration is at present composed of 11 different laboratories (5 French, 2 German, 1 Belgian, 1 Swedish, 1 Danish and 1 Russian). The scientific interest and the originality of PIAFE have been recognised by an independent committee of international experts (D, F, GB, NL, USA). They have recommended support and rapid realisation for the project.

Several R & D projects are underway, or completed. The construction of an 18m. beam line at the ISN has demonstrated the feasibility of the transfer of singly charged ions at 30 keV from the ILL.[3] Very encouraging results have been obtained also in the development of the ECR source which will capture these ions and render them multi-charged.[4] Both of these studies concern PIAFE phase 2.

At the end of 1995 the Steering Committee of the ILL accorded several man-months of effort to the project. Since that time a very efficient and fruitful technical collaboration has been established between the ILL and the ISN. The principle objective has been to establish detailed plans for ion source and the part of the beam line

close to the reactor. These plans must meet the security criteria of the French Nuclear Radioprotection Authorities, who must give their approval to the project. It has also been necessary to verify the comportment of the ion source in the event of a sudden influx of air or water in the beam tube.[5]

A new edition of the complete technical report is in preparation. This report will also include preliminary plans for the control system of PIAFE phase 1.

Figure 1 shows the general layout of PIAFE phase 1.

Zone 1 is the zone closest to the reactor where most of the radioactivity will be concentrated. It contains the ion source which is placed in the glove finger (the insert of the beam tube in the reactor). The ion source must be replaced after 3 reactor cycles (about 5 months). It is supported by a trolley and during manipulation will be towed by a tractor using a rack and pinion motor system. This zone contains the station where the tractor will be kept and the areas for the supervision and the manipulation of the source. The pre-separator at D1 will eliminate many unwanted masses, and will become extremely active. The pumping in this zone must deal with the majority of the unwanted radioactive products of the source. The glove finger itself will be pumped by a special purpose cryogenic pump. All this zone will be constructed following international norms of quality assurance.

Zone 2 contains the SFR, a low resolution spectrometer which will select the band of masses required for physics.

Zone 3 is still not completely defined. It will contain a high resolution spectrometer and the experimental areas, which may be housed in a separate building.

CONTROL AND COMMANDS OF PIAFE PHASE 1.

Requirements

Both the ILL and the ISN have experience in the use of networked PCs for control applications and so this solution was our natural choice. It is also certain that we will use a certain number of PLCs for the control of the vacuum, and also for the mechanical manipulations of the source. However the marriage of two cultures - nuclear reactors and particle accelerators, implies certain constraints of protocol and hardware. These are not yet totally defined. The system must be designed to allow easy extension to PIAFE phase 2 in the future.

In the following sections we describe the functional sub-systems of the controls, and the particularities of each one in the context of the PIAFE project.

Command and Control of the Uranium Fission Source.

When the uranium source is in place permanent surveillance will be imperative. A malfunction would be potentially dangerous. On the other hand the action which would be taken after detection of such a malfunction is of such consequence that the system must not raise false alarms. All critical controls decisions must be taken by a majority vote among three diagnostics.

The source will be observed by a mirror fixed in the beam tube (see figure 1). The image will be relayed to another mirror whose position can be micro-controlled. The image will be analysed by a pyrometer. In normal operation the source should be at 2400 °C, and of course, should not move. It is not yet clearly defined what part of this critical analysis can be entrusted to the software of the control system, and what must be hard-wired, or what will be the implication of the tripling of the diagnostic. Another problem is the surveillance of the source when not in normal operation i.e. when not at equilibrium temperature and not visible to the pyrometer. A system involving a light beam and a camera will probably be developed.

The HT feed-through to the source, and also the voltage supply to the steerers are quite delicate mechanically and electrically, given the confined space of the entry to the glove finger. For the control system a special high voltage enclosure is required and input/output data must transit via an optical fiber (see figure 2).

Beam Transport and Diagnostics. Beam Tuning.

Apart from the constraints of radioactive protection mentioned above, the beam handling and diagnostics control should be completely standard.

- Control of power supplies of the magnets and other elements (a precision better than $\pm 10^{-4}$ is required for most of the optics, and certain require $\pm 10^{-5}$ precision)
- Supervision of certain elements with an automatic action in the case of detection of abnormal incidents.
- Control and command of diagnostics for the beam tuning - movements and current acquisition.

The Vacuum Control System and the Manipulation of the Source.

The vacuum system control will resemble that of SARA. Elements will be controlled using industrial PLCs with the user interface on a PC. The PLC will supervise the system and will take action if an incident is produced, although certain securities will of necessity be hard-wired. The philosophy will be to keep the commands as flexible as possible whilst preventing forbidden manoeuvres by the pre-programmed logic.

The command of the manipulation of the source, described above, will be integrated in the vacuum control. Security regulations require that all the motor controls be doubled by a mechanical crank, which will allow the manipulation of the tractor from the exterior of the zone 1 bunker in the event of a control system failure. The manoeuvres of the source will be observed by a series of cameras.

Another particularity of the vacuum system is the series of reservoirs required to stock the pump exhaust gases which will be radioactive. Three reservoirs are planned : one will be in use, one will contain gas in course of deactivation- three months storage should be sufficient. The third will be to stock the gases from the primary pumping cycle, i.e. before the beam is present, and will also act as a back-up.

Much of the vacuum system equipment will become radioactive and must be housed in controlled zones. This means that the maintenance of the pumps (oil-changes) must be telecommanded. If a pump breaks down it will simply be replaced.

Some parts of this system must be independent from the main PIAFE controls, as they will be under the responsibility of the ILL, and not the PIAFE experiment. This will be achieved by the presence of a hard key. Also there will be a "classic" control desk which will short-circuit the control system in the event of a failure, to at least attain a secure state. The exact protocols are not yet defined.

Hardware

As mentioned above we have no reason to not choose an all PC system. Several years of experience at SARA have convinced us that with certain precautions, these machines are sufficient for our purpose[6]. We will use PLCs for the vacuum and the manipulations of the source.

At the present moment it seems that the only in-house development which may be necessary is a module to control the power supplies. We have previously developed a controller based on an industrial single board PC (PC104), and this could be adapted and improved, if no better commercial solution can be found.

Software

Although it would be prudent to produce the first version of any software using Windows 3.11, which we already use for parts of the SARA control system, at some stage in the development we will make the move to a more recent version of Windows, probably NT.

A decision about network software has not yet been taken. Several solutions are possible, it will be necessary to investigate fully the possibilities of each and execute some trials.

Part of the control system, as mentioned above, will be under the responsibility of the ILL. The software which concerns this part (the vacuum and the source manipulation of zone 1) will be sub-contracted, since this is their policy. As the vacuum of the other zones is not physically independent, it seems logical to sub-contract all the software of the complete vacuum control system- both the PLC programs and the user synoptic screens. We will define how information will be exchanged between the vacuum system and the operator consoles of the general controls.

The use of the PC environment should permit us to buy much of the software required. Probably several of the data servers could use LABVIEW. The controls machine and software could then be used independently for research and development purposes before integration into the global controls network. Indeed such work should soon start for the source surveillance pyrometer previously mentioned.

For the overall system definition, and especially for the operator console software we will try as far as possible to use formal methods of definition, following a standard software life-cycle model [7]. We hope by this means to improve the quality of the finished product, and also to increase the efficiency of our work. We are at present at the beginning of the specifications phase, and as part of this stage, have built a first prototype of the operator interface, which should be a tool to facilitate the definition of the functional specification document. In this phase we must also produce the first version of the user manual, and the first version of the validation document. This implies that we must identify the physical constraints which the system must meet, and also the user requirements.

Figure 3 shows a screen from our first prototype. This work [8] was also a comparison of two graphical application development software packages, Visual Basic and Delphi. It seems likely that we will adopt the latter for future work.

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