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ANNUAL REPORT

NUCLEAR PHYSICS SUPPORT ACTIVITIES

1st April 2002 – 31st March 2003

Nuclear Physics Group, CCLRC Daresbury Laboratory

This document summarises the programme of work carried out by the CCLRC Daresbury Nuclear Physics Group on behalf of the EPSRC during the period 1st April 2002 to 31st March 2003. It is intended to satisfy the reporting requirement stipulated in the relevant Service Level Agreement between EPSRC and CCLRC.

1. INTRODUCTION

The Nuclear Physics Group at Daresbury Laboratory is part of the Surface and Nuclear Division of the Council for the Central Laboratory of the Research Councils (CCLRC) with access to the support staff, expertise and facilities available at both Daresbury and Rutherford Appleton Laboratories. The Group's principal role is to provide scientific, technical and engineering expertise to support and co-ordinate the programme supported by EPSRC in the field of nuclear physics. The Group will undertake design and development work for both existing programmes and new initiatives including programmes of development aimed at the generation and exploitation of new opportunities in overseas facilities. It will continue to seek out new opportunities for the UK in terms of access to such facilities. Expertise will be provided to co-ordinate these and other activities within EPSRC's overall nuclear physics programme.

2. OVERVIEW

This report covers all of the Nuclear Physics Group (NPG) activity relating to the UK nuclear physics experimental research programme in the year 2002/03. This activity has been funded through a dual support mechanism in which the funds arise from two sources:

(a) A core service level agreement (SLA)

(b) Responsive mode grants

The core SLA is intended to mimic the provision of a well found laboratory implicit in the dual funding of universities. It therefore provides for the costs of the nuclear physicists in the group,

allowing them to act as Principal Investigators on grant proposals, as well as for additional overhead charges such as accommodation costs. It also covers the general support services provided by the group which are not funded through grants as well as support for small scale ad-hoc activities.

The responsive mode grant funding is obtained in parallel with the university groups with the NPG acting as one of several institutions collaborating on a specific project. The two strands combine to fund the overall activities of the group. Since the majority of the group's ouput is related to responsive mode grants which will be the subject of peer review through specific, end-of-grant reports, the current document will restrict itself to a brief summary of the overall activities of the group in the four, broadly defined areas of technical support provided, namely, Instrumentation and Design, Software Support, Electronics Support and Target Fabrication. The final section of the report provides a year-end financial statement

The table below summaries the major EPSRC responsive mode grants which were active during the current reporting period.

Title	Known as	Grant Reference	Participating UK institutions
Exotic Nuclear States with Radioactive Beams	EXOGAM/VAMOS	(GR/M50706)	B,L,M,P,K,S,Y.
Digital Pulse Processing and Gamma Ray Tracking	TRACKING	(GR/M49489)	L,S.
Reactions of Exotic Proton-Rich Nuclei	TUDA	(GR/M76058)	E
Structures of Nuclei Far from Stability by Tagging Techniques	GREAT	(GR/M79998)	L,M,K,S,Y.
Structure and Reaction of Light Nuclei	CHARISSA/ECLAN	(GR/M97381)	Bi,S
Nucleon Transfer and Coulomb Excitation with Radioactive Beams	TIARA	(GR/N38541/01)	Bi,P,S
Isobaric Analogue States at High Spin	MIRRORS	(GR/R40081/01)	K
Study of Valance Space Limitations	HIGH SPIN	(GR/R57713/01)	L

Key: Bi = Birmingham; B = Brighton; E = Edinburgh; K = Keele; L = Liverpool; M = Manchester; P = Paisley; S = Surrey; Y = York

3. INSTRUMENTATION AND DESIGN

The NPG works in collaboration with the project engineering division at Daresbury to provide mechanical engineering and design support to the experimental UK nuclear physics community. Through the use of advanced 3D modelling techniques and FEA software, mechanical engineers and designers have been able to design highly complex structures for supporting arrays of radiation detectors for both photon and charged particle detectors. They have designed and or provided input to many projects during the current period. In many cases the design is performed by a UK design team comprised of the NPG and the Universities

of Liverpool and Manchester. This team is co-ordinated by the NPG mechanical engineer and comprises skilled and experienced 3D CAD design engineers and physicists from the institutions involved. Technical effort from Daresbury has also been used to assemble many of the complex systems before shipment to the host overseas laboratory.

The period started with the successful installation of the EXOGAM support at the Ganil laboratory, France. This complex structure enables a high efficiency array of γ-ray detectors to be operated in stand alone mode or in coincidence with the VAMOS recoil spectrometer. During the year ongoing effort was used to design, procure, test and ship additional items including a beam line support mechanism, a pivot for the rotation of EXOGAM with the VAMOS spectrometer, a detector manipulator to enable safe installation of the detectors in the array and two table top mounting structures, to enable the assembly and testing of the detectors. The first experiments with EXOGAM using the radioactive beams from the newly commissioned SPIRAL accelerator have been successfully performed.

The VAMOS recoil spectrometer is now fully operational. The NPG designed and constructed the ionisation chamber, the Q1/Q2 vacuum chamber and 0-45 degree target chamber for the operation of VAMOS and Exogam. In addition, the NPG designed, in collaboration with the University of Manchester the focal plane detector boxes. VAMOS has been successfully commissioned in a series of in-beam tests over the last year, which strongly involved physicist effort from the Group, to develop the ray tracking algorithms and particle identification techniques. The first experiment with VAMOS will take place in 2003 when it will be coupled to both EXOGAM and TIARA.

During the current period the NPG has completed the design of TIARA. TIARA is a state-of-the-art detector system for studying transfer reactions of exotic nuclei. It consists of Si and Ge detector arrays, coupled to the high efficiency magnetic spectrometer VAMOS. The design of the TIARA array, its support structure and integration with EXOGAM and VAMOS was performed by the Group. TIARA was successfully assembled at Daresbury, installed at Ganil and now awaits the first in-beam tests and subsequent experiments.

The design and construction of the ECLAN reaction chamber was completed during the period. ECLAN, its motion control and vacuum systems, were assembled and commissioned successfully at Daresbury by the Group.

Mechanical engineering effort in collaboration with the University of Manchester, has been used for the design of an array of Clover Ge detectors, called CLARA, for Legnaro, Italy. This work involved FEA stress analysis of the support structure for the detectors. Conceptual design work has also been used for the Rising spectrometer. Rising is an array of 15 Cluster detectors from the Euroball project that will be used for a series of experiments using the exotic radioactive beams at the GSI facility in Germany.

The NPG has the engineering responsibility for the GREAT (Gamma Recoil Electron Alpha Tagging) spectrometer. GREAT was successfully commissioned during 2002 and is currently being using in a campaign of experiments at the University of Jyvaskyla in Finland. The NPG worked closely with the designer at the University of Liverpool on the Jurogam spectrometer. Jurogam is an adaptation of the Eurogam γ-ray array, originally designed at Daresbury, and is now operation at Jyvaskyla. Mechanical design involving heat transfer calculations for the cooling system for the electronics was also performed by the Group.

The NPG has a programme to develop an Electron Cyclotron Resonance Ion Source, ECRIS, for potential use in a radioactive ion beam accelerator. The source traps an injected singly charged ion beam and by stripping electrons from the ions in the source's hot plasma, enables the ion beam to be extracted in a highly charged state for acceleration to high energy. Such a "charge

breeding" device makes the subsequent acceleration process enormously efficient reducing the cost and scale of the accelerator. A test facility was established in the tower building and the new ion source and associated equipment has been successfully tested. Charge breeding of a stable noble gas ion beam has been demonstrated with a singly charged beam of argon ions bred up to an 11+ charge state. The ECRIS and much of the associated equipment acquired for the project has now been moved to the ISOLDE facility at CERN where it is being rebuilt to enable the next stage of the programme, which is to demonstrate the process with radioactive ion beams.

4. SOFTWARE SUPPORT

The NPG software team provides data acquisition and data analysis software solutions for all activities of the community. In many cases since all experimental facilities are outside the UK these are international collaborations and the team works closely with the hosts to ensure that the software systems are compatible with the environment and requirements of the host laboratory. It also works closely with the University of Liverpool who also provide data analysis software.

The MIDAS data acquisition system, developed by the NPG, is in use throughout the UK community as well as in many of our overseas host laboratories. It continues to be developed as needed to meet the evolving requirements of the community. The Group is always looking to adopt new technologies where these lead to more cost effective solutions. At the same time the use of common solutions within the MIDAS framework leads to extremely efficient use of resources.

There has been a continuing development and exploitation of a general purpose and modular data acquisition system that is fully integrated into the MIDAS environment. This permits to a large degree common solutions to be deployed across all of the development activities. Not only is this common solution approach highly efficient from the development and maintenance aspect but the users of the system see a familiar user interface. This development is fundamental to and used by all the project activities that follow.

A support service by email and telephone is provided to the community. This is particularly of use for the smaller university groups that may have no local source of expert advice and assistance. Site visits were also undertaken when necessary.

A data acquisition system was developed for the Gamma Ray Tracking project based on the MIDAS infrastructure. Developments were needed to handle the fully digitised signal output generated by the electronics and also to cope with the very high data rates produced which had to be written to tape. The latest generation of tape storage devices had to be used because of the volume of data acquired during a typically experimental run. The system was taken to the University of Cologne during February 2003 for a very successful test using the accelerator there. The Gamma Ray Tracking development proved the potential of fully digital analysis of the output from the detectors and led to the direct observation of effects within the detectors that had previously only been the subject of speculation or theory.

A data acquisition system was produced for the GREAT spectrometer that was installed and commissioned at Jyvaskala during September 2002. The radically new trigger-less electronics built for GREAT required a new approach to the readout and processing of the data. This enabled the detection of events at a much higher efficiency than had previously been possibly by conventional techniques.

The data acquisition system used by the MEGHA array at ANU was updated to take full advantage of the developments in the MIDAS infrastructure. The software now provides significantly better checking of the data received from the electronics in real time and filters out all bad data. This both makes the task of offline analysis easier and more efficient but also warns the users of problems with the electronics and the possible reason.

Development has continued on the data acquisition system for the EXOGAM array that is deployed at GANIL. Meetings and discussions were held with the French team working on this project to plan of the use of other detector systems such as VAMOS and TIARA with the EXOGAM array. The software to control the hardware module that will provide the co-ordination of these various detector systems was tested during November 2002. At the same time the software to control the prototype of the electronics module that handles the data from the outer contacts of the Exogam detectors was tested.

A data acquisition system was developed which handles the model 9418 ADCs purchased from Silena. These are compact low cost general purpose ADCs which can be used for a wide range of activities. Several of the University groups have purchased the systems for testing of detectors in their home laboratories. Birmingham University took a 128 channel system to IReS Strasbourg for a recent experiment using the Vivitron.

A data acquisition system was built for the TIARA detector that is now installed at GANIL. This uses a combination of electronics including the Silena 9418 ADCs and couples with the EXOGAM and VAMOS detector systems.

A data acquisition system is being built for the TUDA detector that will be installed at TRIUMF. This is a 512 channel system using the Silena 9418 ADCs.

A data acquisition system was built for use with the Euroball Cluster detectors to be used for the RISING experiments at GSI. Developments were needed in order to combine the Euroball detectors with existing GSI detector systems and to link into the existing GSI environment. A copy of this system will be used with the Euroball Clover detector array (CLARA) for experiments at Legnaro.

5. ELECTRONICS SUPPORT

The bulk of the electronics effort went into two projects in this review period: the GREAT trigger-less acquisition system called Total Data Readout (TDR) and the Gamma Ray Tracking and Digital Pulse Processing project (GRT). Other projects on which NPG electronics engineers worked were EXOGAM, TUDA, Euroball and TIARA. In addition to project work, advice was given to members of the Nuclear Physics community about the feasibility of several new ideas and discussions were undertaken about potential new grants (for which costings and manpower estimates were provided).

The GREAT project work centred on the ADC cards which collect and timestamp the data from the detectors and the Metronome card which ensures that the timestamps are consistent throughout the system. As well as designing the ADC card and a prototype Metronome card, protocols for system error detection and recovery were worked out, even to the point of recovering from a power failure. 16 ADC cards were tested and delivered and 2 prototype Metronome cards were constructed and used prior to the delivery of the full specification production Metronome card from the University of Liverpool. VXI crate control and interface

cards were designed, built and tested to allow the use of a commercial C-sized resource manager for physics applications in a larger, D-sized, VXI crate. All these items were completed on time and on budget. During the course of the project a need was identified to test the full electronics and data acquisition in UK before delivery to Finland where the detectors were installed. To meet this need a pattern generator card was designed and built. These cards comprised 16 channels of pulsers with programmable pulse height and pulse separation, controlled on a per channel basis. Four such cards (64 channels) were used successfully to debug the GREAT TDR system at rates up to 10kHz/channel using pseudo-random data, resolving many problems prior to delivery.

The GRT project work centred on building and testing 20 GRT4 cards (each with 4 channels of 80MHZ 14 bit Flash ADCs with digital processing in each channel) to instrument the two segmented Germanium detectors purchased by the project. The cards were put together into a 64 channel system which was used initially in the University of Liverpool for characterisation scans of the 2 detectors. Afterwards the system was moved to the University of Cologne where a highly successful in-beam experiment was performed. The experiment demonstrated the effectiveness of the pulse shape analysis by correcting an energy peak which had been Doppler broadened. The efficacy of the Doppler correction depends strongly on knowing the energy and exact position where the gamma ray first interacted in the crystal. The same position information is key to the success of gamma ray track reconstruction towards which the GRT project was working. (The pulse shape analysis work was undertaken in partnership with the University of Liverpool.) The whole CCLRC part of the project, which was largely electronics, was completed on time and to budget. The GRT work has shown that a gamma ray tracking array is feasible, so NPG group members have taken leading roles in technical discussions about electronics systems for the European AGATA gamma tracking project.

Support was provided for the trigger systems in both EXOGAM and Euroball. Other system support was provided for the Neutron wall in Euroball and for readout in EXOGAM. Problems were solved by telephone, email and by on-site visits, eg to GANIL for EXOGAM.

The TUDA system is the main user of the relatively new Silena 9418 VME peak sensing ADC card (32 channels, 12 bit resolution) which has also been purchased in smaller quantities by most UK university Nuclear Physics groups. Support for setting up these ADCs with the commercial Fairbus control/readout system was provided. A FERA version of a 48 bit register was designed, built and tested by the NPG. Other groups used the VME bus for control and readout. For this a Silena ADC control card was designed, built and tested. One card was supplied to each UK university group who had bought the Silena 9418 ADCs including the TIARA and VAMOS experiments.

6. TARGET LABORATORY

Thin film targets and foils are required for low-energy nuclear physics experiments. In order to meet current demands of UK physicists engaged in nuclear structure experiments around the world, a large variety of targets are required from elements throughout the periodic table. The target preparation laboratory (TPL) at Daresbury Laboratory has provided this service to the UK community and is the only facility of this kind available in the UK.

The TPL has been in operation since the early days of the Nuclear Structure Facility at Daresbury and target preparation has been performed by a specialist technician. Prior to this reporting period this experienced target maker retired and in March 2002 the NPG employed a replacement. The current period has therefore been dominated by the training of the new technician which has been extremely successful.

The laboratory is now equipped with two sputtering units, an electron beam gun, and three coating rigs, all for target preparation. In addition, several items essential for efficient operation of such a facility, such as an accurate balance and vacuum storage system, are available. The new technician has rapidly become familiar with this equipment and is in the process of learning the diverse techniques of target preparation. Towards the end of the period new targets of lead, tin, gold and nickel have been delivered to the UK community. New fabrication techniques for different target species are under investigation continually and the laboratory is fully operational.