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**HOLIFIELD HEAVY ION
RESEARCH FACILITY**

Users Handbook

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MASTER

Foreword

The primary objective of this Handbook is to provide information for those who plan to carry out research programs at the Holifield Heavy Ion Research Facility (HHIRF) at Oak Ridge National Laboratory. From Chapters IV and V, potential users can determine if the beam energies and intensities and the experimental apparatus at HHIRF will meet their requirements. If they do, the user can find a description of the mechanism for obtaining accelerator time in Chapter II. It is important that users who are granted accelerator time read Chapter III which delineates their responsibilities.

Appendix A gives the names and phone numbers of ORNL personnel to call for information about specific areas. If you need information about the HHIRF but it is not clear whom to call, contact either the Liaison Officer or HHIRF Scientific Director.

The HHIRF Users Handbook was first distributed in February 1980. This revision is intended to completely replace that original document, even though some sections required only minor changes.

HHIRF Staff
January 1987

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I. General Comments on the HHIRF

The Holifield Heavy Ion Research Facility (HHIRF) is a national users facility which is located at Oak Ridge National Laboratory. The HHIRF has two accelerators, a model 25 URC tandem electrostatic accelerator and a K=100 cyclotron known as the ORIC (Oak Ridge Isochronous Cyclotron). The tandem accelerator can be used independently or in a coupled mode with the ORIC acting as a post accelerator.

The facility is available to any group having an approved experiment. Proposals for experiments are made to a Program Advisory Committee (PAC) that reviews requests for accelerator time and makes recommendations to the facility management. Final approval for experiments rests with the HHIRF Scientific Director who will generally follow the recommendations of the PAC.

As part of the national character of the HHIRF, the facility will provide heavy-ion beams, many major pieces of experimental apparatus, and computer facilities for data acquisition, without cost to those who have approved experiments. Generally, other costs will be borne by the user. Adjacent to the HHIRF is the Joint Institute for Heavy Ion Research, which provides offices and dormitory accommodations for outside users.

The users of the HHIRF are formally organized into the HHIRF Users Group. We recommend that you become a member of this group if you plan to work at the facility. Only members will receive mailings from HHIRF such as requests for proposals. However, persons who do not plan to work at HHIRF, but want information, can be placed on a mailing list for the Newsletter. Application for membership can be made by contacting the Liaison Office (Appendix A).

II. Requests for Accelerator Time

A. Procedure

To obtain time on the HHIRF accelerators, it is required that users submit a written request to the HHIRF Scientific Director. Although a request may be submitted at any time, a call for proposals will be sent to members of the HHIRF Users Group approximately twice a year and requests received before a specified date are then submitted for consideration by the Program Advisory Committee.

In general, each proposal should request time for a complete experiment rather than for individual "runs" or global programs. Thus, if measurements on several targets or with several projectiles are required to answer a question, then include all necessary targets or projectiles in the request. Ideally, each proposal should be capable of leading to a published paper. An exception would be a request for a single, exploratory measurement which could lead to a complete experiment at a later date.

A sample "Request for Beam Time" form is shown in Fig. II-1. Some specific comments on what information should be included are:

Investigators - include name, affiliation, and citizenship of each person who would be working at the HHIRF.

Spokesman - give the name, phone number, and address of one investigator who will be the contact between the research group and the HHIRF staff.

Number of 8-hr shifts - this should be a sum of "hours beam on target" and "additional hours for changes" discussed below.

Target station - beam line or experimental apparatus where experiment would be performed.

Number of runs, time between runs - use if experiment must be split into two or more "runs".

Ion Species, energy, intensity - list the desired beams (element, mass number); energies (MeV), with tolerances if critical; minimum beam current (particle nanoamp) which will allow a run to be completed in the requested time; requested values must be within the accelerator limitations given in Chap. IV.

Hours beam on target - time the beam is under the direction of the researcher. For example, "beam-on-target" hours should include time required to tune the beam through a collimation system provided by the researcher.

Additional hours for changes - time required to change beam energy or ion species; use the following estimates:

	<u>Tandem</u>	<u>Coupled</u>
small energy change	10 min	4 hr
large energy change	1 hr	4 hr
ion species change	4 hr	8 hr

Time preference - will be honored if possible, subject to the accelerator operating schedule.

Dates group cannot run - experiment will not be scheduled on these dates; do not be more restrictive than absolutely necessary.

Special equipment - list equipment required by the experiment which you expect to be provided by the HHIRF (e.g., fast oscilloscope, test/calibration instruments, detectors, radiation sources); the spokesman will be informed if requested equipment is not available.

Safety - list safety hazards associated with the experiment including electrical, chemical, flammable/explosive, and radiation hazards; indicate if "permissive entry" (i.e., access to experimental area while beam is present) will be required; failure to provide this information could result in the delay or cancellation of the experiment.

Summary of Experiment - a concise explanation of the purpose of the experiment.

A more detailed discussion of the experiment, not to exceed 4 double-spaced pages, should be included with the "request for beam time" form.

Ten (10) copies of the complete proposal should be sent to the HHIRF Scientific Director.

A copy of each approved proposal will be available for reading in the HHIRF Liaison Office.

Request for Beam Time (Send ten copies)

Title of experiment _____

HHIRF
Exp. No.

Investigators _____

Institution _____

Citizenship _____

(Continue on separate sheet if necessary)

Spokesman for Group:

Address _____

Name _____

Telephone _____

Number of 8-hr shifts for experiment _____ Target station _____

If time to be divided between more than one run, how many runs? _____

Time between runs _____

Run	Ion Species	Energy (MeV)	Min. Intensity (pnA)	Hours beam on Target
Additional hours for changes in beam energy and ion species				

Time preference _____

Dates group cannot run _____

What is the earliest date experiment could be started? _____

What special equipment is expected from HHIRF:

Aspects relating to safety: _____

Summary of Experiment (do not exceed this space):

Attach a brief description and scientific justification (no more than 4 pages) of the experiment that provides, as appropriate, the following information:

I. Physics Justification

- A. What are you trying to learn?
- B. What is relationship to theory?
- C. What is uniqueness of this experiment?

II. Details of Experiment

- A. Description of apparatus (include sketch if appropriate).
- B. What is status of apparatus at this time?
- C. What targets will be used and who will supply them?
- D. What parameters are to be measured and how are they measured?
- E. Estimates of solid angle, counting rate, etc., and assumptions used to make estimates.
- F. Details of determining time requested.
- G. How will analysis be done and where?

III. Background

- A. Status of data taken in previous studies.
- B. What is the suitability of this experiment to the HHIRF?
- C. Other considerations that are relevant to review of proposal by P.C.

B. Program Advisory Committee (PAC)

The PAC reviews the written experiment proposals and makes recommendations based primarily on the scientific merit of the proposed experiment. As part of this review the PAC may contact the spokesman for the proposal to obtain additional information or, in unusual cases, may request the spokesman to defend the proposal in person. The PAC will recommend to the HHIRF Scientific Director experiments that should be allotted accelerator time and the number of shifts that should be allocated. The PAC may also make recommendations contingent on certain conditions; e.g., the experiment should be scheduled if the experimental group can demonstrate they have available the necessary experimental equipment.

C. Appeal

What if the PAC does not recommend time for your program and you are convinced they have made a grievous error in judgment? You should first appeal your case to the HHIRF Scientific Director. If he supports the decision of the PAC, then an appeal can be made to the Director of the Physics Division of Oak Ridge National Laboratory who has the final word in disputes on the granting of accelerator time.

D. Discretionary Time

Up to fifteen percent of research time on the accelerators may be assigned at the discretion of the HHIRF Scientific Director. Example uses of this time are: 1) a new "hot" experiment which is of sufficient potential that it should not wait for the next scheduling period; 2) an approved experiment which is found to require a small amount of time more than was requested; 3) development of experimental apparatus and detectors; and 4) a positive response to an appeal.

E. Feasibility and Readiness

Proposals are reviewed by the HHIRF Technical Director to assure that requested beam species, energies, and intensities are feasible. Members of the HHIRF staff review the engineering readiness and safety aspects of the proposal. Identified deficiencies must be rectified before accelerator time will be scheduled. The proposals should clearly state the status of apparatus and detectors, and if not available or ready, when they realistically will be.

Approved experiments which cannot be made ready within one year after approval, or experiments which are inactive for a year, will be deleted from the active list. In that event, the experimental group must submit a proposal as for a new experiment.

F. Schedule

Schedules of experiments to be run are issued about a month before the beginning of a research cycle and are typically for two to four months of operation. Normally a "fixed" schedule is followed with the actual starting date occurring no earlier than one day before or any later than three days after the date given in the issued schedule. Some "buffer" time is programmed into the schedule to accommodate reasonable unscheduled maintenance. In the event of major accelerator failures, some experiments will be pulled from the schedule and rescheduled at a later time. Usually the experiments removed will be those for which the researchers have not yet done extensive experimental setup.

Sometimes an experimental group will not be able to obtain all of the shifts allocated because of unscheduled down time. In that event, only the shifts used will be charged to their total allocation and the remainder will be rescheduled at a later date.

III. Responsibilities of Users

It is important that users read and heed the policies and procedures discussed here. Some of these are for the safety of the users. More broadly, these policies and procedures are intended to provide a smooth-running operation with a minimum impact on the user.

A. Procedures for Working at HHIRF

If you are not an employee of Oak Ridge National Laboratory and you wish to work at HHIRF, there are several steps that must be taken. Which ones depend on 1) whether the time you plan to work at HHIRF for any given visit is long or short, and 2) if you are a United States citizen or not. The approximate definition of "short" is less than ten days.

1. U.S. Citizen, Short-term visit

The majority of outside users will probably fall into this classification. A relatively simple system has been developed for these persons. The procedure is as follows:

a) On your first visit to HHIRF

i) Fill out a Guest Agreement at the Liaison Office. (The Liaison Office is located next to the main entrance of the HHIRF building, as shown in Fig. VIII-3 in Chapter VIII.) A Guest Agreement is illustrated in Fig. III-1.

ii) View a slide presentation on safety procedures at the HHIRF.

iii) Follow instructions given at this office by the Liaison Secretary for obtaining a badge with your photograph. This badge permits entry into the main laboratory area of ORNL and also contains dosimeters for measuring radiation exposure.

b) For subsequent visits to HHIRF

i) Register at the Liaison Office and pick up your assigned badge.

ii) If you will arrive during hours other than the standard dayshift (8:00 a.m. - 4:30 p.m., Monday - Friday), notify the Liaison Office prior to arrival (Phone No. 615-574-4113, FTS 624-4113). This office will arrange for a badge to be obtainable from the HHIRF Operations Crew Chief upon your arrival.

III-2

iii) Upon departure, return your badge to the Liaison Office. (It will remain there until your next visit.)

2. U.S. Citizen, Long-term Visit

All long term visitors are required to have a Guest Assignment at ORNL. Contact the Physics Division Office for information.

3. Non-U.S. Citizen

A non-U.S. citizen must be approved by DOE. Request for approval is made by filling out an IA-473 Form, which can be obtained from the Liaison Office. In general this should be done when an experiment is approved by PAC. After the completed form is received at the Liaison Office, the approval procedure normally takes about one month for non-Soviet-bloc citizens and may require up to three months for Soviet-bloc citizens. Thus, it is important that the non-U.S. citizen plan well in advance for working at the HHIRF. Once DOE approval is received, the non-U.S. citizen follows the same steps outlined for the U.S. citizen in the two preceding subsections.

Soviet-bloc citizens will need to inform the HHIRF Liaison office of their visiting dates at least five days before their arrival at HHIRF.

Guest Agreement for
Users of HHIRF

A. PATENT AGREEMENT

Undersigned, as a condition to and in consideration of access to facilities and information at the Holifield Heavy Ion Research Facility ("HHIRF") of the Oak Ridge National Laboratory ("ORNL") operated by Martin Marietta Energy Systems, Inc., under its prime contract DE-AC05-84OR21400 with the United States of America as represented by the Department of Energy ("DOE"), agrees as follows:

(1) That I will promptly furnish to DOE through Martin Marietta Energy Systems, Inc., complete information concerning any and all inventions or discoveries conceived or made by me in the course of or as a result of said access to facilities and information, and waive any right or claim to pecuniary award or compensation under the provisions of the Atomic Energy Acts of 1946 and 1954 with respect to such inventions or discoveries.

(2) That DOE shall have the sole power to determine whether or not and where a patent application shall be filed, and to determine the disposition of the title to and rights under any application or patent covering such inventions or discoveries.

(3) That I will execute all documents and do all things necessary and proper to carry out this agreement; and all drawings, reports, notebooks and other scientific or technical information of every description relating to or deriving from my work in connection with this association shall be subject to inspection by Martin Marietta Energy Systems, Inc., and DOE at all reasonable times and usable by DOE for any purpose whatever without claim on the part of the undersigned for compensation.

(4) That as to any material acquired through such access which I wish to publish I will secure patent review before publication through the Director, HHIRF.

B. RULES AND REGULATIONS

I agree to observe and conform to all rules and regulations including security, health and safety rules presently in effect at ORNL or as they may be amended from time to time (see back of page for security regulations).

C. RELEASE

I agree for myself, my heirs, successors, administrators, executors and assigns to release the United States of America, including DOE and Martin Marietta Energy Systems, Inc., their officers, agents and employees from all liability for any personal injuries (including death) to me or for damage to any of my property which may arise out of my access to HHIRF and the use of its facilities unless it shall be determined that such injury or damage was caused directly by gross negligence or wilful misconduct on the part of an officer, employee or agent of Martin Marietta Energy Systems, Inc., or the United States of America, including DOE.

Guest's Name _____ Citizenship _____

Date of Birth _____ Social Security Number _____

Address _____

Parent Organization _____

Dates of Agreement, From _____ To _____

Date Signed _____ Signature _____

SECURITY GUIDELINES FOR USERS OF HHIRF

- (1) Badges must be worn at all times in the building.
- (2) No classified work will be conducted at HHIRF.
- (3) Source Nuclear Material used in experiments must be charged to and under the direction of an ORNL employee.
- (4) Firearms and cameras are not permitted in this area.
- (5) Badges must be left at Liaison Office or designated location upon completion of visit.
- (6) Unauthorized removal of property of the United States Government is a federal offense. Authorized removal must be approved by the director of HHIRF.

B. Costs Incurred by User

Generally speaking, the user must pay for materials and labor required specifically for his experiment. The HHIRF supports operation of the accelerators, major experimental apparatus, and the computer system for data acquisition, and provides technical support.

If the user expects to incur costs for materials purchased or work done, he needs to have an account to which these costs can be charged. One purpose of such a charge account is to deal with deficiencies or problems which are encountered in the process of setting up an experiment. However, the user should not plan to have major fabrication done at HHIRF. The engineering and craft group within HHIRF is not of sufficient size to handle major tasks from outside the facility.

There are two ways in which the user can have access to a charge account. One is to collaborate with a group that already has an account. The second is to open an account. The method for establishing an account depends on the type of institution from which the user's group originates. The institutions are divided into two categories: 1) private and state and local government organizations (including profit- and non-profit making, and private and state supported educational institutions), and federal government organizations other than DOE, and 2) DOE organizations and DOE cost-type contractors. The methods for arranging an account for these categories are described in the following two sub-sections. Any questions on these methods can be addressed to the Finance Officer (Appendix A).

1. Private and State and Local Government Organizations and Federal Agencies other than DOE.

Users from these organizations need to fill out a Material and Services Order Form (MSOF) ORF4300.2B. This form, when executed, is a contract between DOE-ORO and the outside party. Necessary forms can be obtained from the HHIRF Liaison Office.

An example of a partially filled in form is illustrated in Fig. III-2. A reasonable statement to be typed in item 7 of this form would be: "Furnish materials and services incidental to the use of the Holifield Heavy Ion Research Facility". Other information contained in item 7 should be:

- 1) Dollar limit of the account,
- 2) Date at which the account is to expire,
- 3) Persons authorized to charge to this account.

The amount on the order form should be at least \$1,000, although only actual cost will be billed. It is important that the user not exceed the amount stated on the MSOF. In estimating labor costs for ORNL assume about \$41 per hour. Also, ORNL materials bear overhead of about 30% of their direct cost. The expiration date must not be less than two months following the period during which costs are expected to be incurred. This form is to be mailed to the address shown in item 1 on this form.

2. Department of Energy Organizations and DOE Cost-Type Contractors

An account from these organizations can be established by sending a letter or Memorandum Purchase Order (MPO) to

J. E. Carr, Coordinator
Work for Others Office
Building 4500N
Oak Ridge National Laboratory
Oak Ridge, TN 37831.

The MPO's issued by another DOE cost-type contractor may be the contractor's normal purchase order with a statement to the following effect on the face of the purchase order:

"This is not a contract. It is a memorandum issued for services, equipment or materials to be supplied under Government contract No. DE-AC05-84OR21400 that are necessary and required in connection with Government Contract No. (DOE contract). Accounting for the cost of the services, equipment and materials will be made in accordance with and as required by Appendix 1101 of the DOE manual, unless other DOE instructions govern."

The MPO should also list the dollar limit of the account, the expiration date of the account (at least 2 months after last date account is to be used), and persons authorized to use the account.

U. S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office

MATERIAL AND SERVICES ORDER FORM

This form is for use by all persons other than Federal Agencies or DOE cost-type contractors ordering material and services from the Oak Ridge Operations Office of DOE but is not used in ordering special nuclear material (except analyzed or analytical samples), Radioisotopes, Stable Isotopes, or Cyclotron-produced Radioisotopes.

1. TO: U. S. DEPARTMENT OF ENERGY C/o J. E. Carr Work for Others Coordinator Oak Ridge National Laboratory Post Office Box X Building 4500-N Oak Ridge, TN 37831-6265	2. FROM:	3. BUYER'S ORDER NO.
		4. DATE

5. SHIP TO:	6. BILL TO:
-------------	-------------

7. MATERIAL OR SERVICE	
State amount, material, isotopic content (if applicable) and physical or chemical form. State service desired and purpose for which services and/or materials are ordered.	PURCHASE PRICE and/or SERVICE CHARGE
Furnish materials and services incidental to the use of the Holifield Heavy Ion Research Facility. The dollar limit of the account is \$ _____. The date at which the account expires is _____. Persons authorized to charge to this account are: _____ _____ <div style="text-align: right;">TOTAL</div>	

THIS ORDER IS SUBJECT TO THE ATTACHED TERMS AND CONDITIONS

8. I, the undersigned, certify that procurement and transfer of the material and/or services ordered are authorized by: (Check block and give license number and expiration date if applicable.)

- (a) ☐ NRC or ☐ _____ License No. _____ which expires _____, 19____,
or (Name of State) (Month and day)
- (b) ☐ Exemption or General License provided by U. S. Nuclear Regulatory Commission (NRC) regulations;
or
- (c) ☐ Exemption or General License provided by _____ regulations.
(Name of State)

9. ACCEPTED FOR THE U. S. DEPARTMENT OF ENERGY: J. E. Carr, Work for Others Coordinator Oak Ridge National Laboratory	10. ORDERED BY: _____ (Signature) NAME & TITLE: _____ _____
--	--

TERMS AND CONDITIONS

This order on the face hereof is placed in accordance with and subject to the following terms and conditions:

1. The term "buyer" as used herein means the person, corporation, partnership, association, firm or other entity which orders the material or services from DOE. The term DOE means the Department of Energy exercising the authority and performing the functions of the Secretary, the statutory head of that agency, and includes any duly authorized representative thereof. The term "Government" means the United States of America. The phrase "persons acting on behalf of DOE" includes employees and contractors of DOE and employees of such contractors, who fill or participate in the filling of this order pursuant to their employment or their contracts with DOE. The term "DOE Facility" means a laboratory, plant, or office operated by or on behalf of DOE.

2. The buyer understands and agrees that DOE may fulfill its obligations under this order through the operator of any of its facilities.

3. Unless otherwise provided for on the face of this order, materials and services are furnished at prices and service fees as fixed by DOE and in effect on the date of shipment of material or performance of the services or, where specific prices are not in effect, at prices and service fees computed in accordance with DOE Pricing Policy. Prices in catalogs issued by DOE or the operator of any DOE facility are subject to change without notice. Payment for materials and for services rendered will be made promptly upon receipt of billing in accordance with instructions furnished therewith. The Customer shall pay interest at the per-annum rate (365-day basis) established from time to time by DOE for general application to monies due DOE on all amounts not received by DOE on or before the due date, such interest to commence on the day immediately following the due date; except that, whenever the due date for any payment under this article falls on a Saturday, a Sunday, or a legal holiday, interest shall commence on the day immediately following the next day which is not a Saturday, a Sunday, or a legal holiday.

4. When shipment of material pursuant to this order requires the use of returnable Government-owned containers, title to such containers shall remain in the Government. If requested by DOE, the buyer will make a deposit to ensure return of the containers. The buyer will keep the containers in good condition, will not use them for any materials other than the materials shipped therein, and will, unless otherwise agreed, return them to the point of shipment, transportation prepaid, within thirty days from the date of receipt of the shipment.

5. Material covered by this order will be shipped F.O.B. the DOE facility from which the order is filled.

6. Title to property sold in accordance with this order shall pass to the buyer when such property is delivered to the buyer or to a carrier for delivery to the buyer.

7. DOE will make reasonable efforts to deliver the material and/or to perform accurately the service specified in this order, but neither the Government, DOE, nor the operator of the DOE facility filling the order will be responsible for: (a) any injury to persons or other living things or for damage to property caused by handling, shipment, use (including use based on any statement of quantity or of physical or chemical properties), storage, transfer, disposal, or reshipment of, or other act or failure to act in connection with any materials purchased or acquired from DOE hereunder, it being expressly agreed that, as between DOE and the buyer, the buyer assumes complete responsibility and liability for any injury or damage occurring; provided, however, that if such injury or damage is caused solely by the negligent packaging by DOE or the operator of the DOE facility filling the order, this assumption of liability by the buyer shall not apply; (b) any damage to, destruction or loss of, or changes in physical or chemical properties of property furnished by the buyer, either as a result of, or in the performance of any services ordered hereunder.

8. Neither the Government, DOE, nor persons acting on behalf of DOE warrant that materials delivered to the buyer under this order (i) will not result in injury or damage when used for any purpose, or (ii) are of merchantable quality, or (iii) are fit for any particular purpose.

9. Neither the Government, DOE, nor the operator of the DOE facility filling the order shall be liable under this order for damages occasioned by failure of DOE to perform its obligations hereunder if such failure arises out of causes beyond the control or without the fault or negligence of the Government, DOE, or the operator of the DOE facility filling the order or any of their officers, agents, or employees. In the event of any damages to the buyer for which DOE is liable occasioned by failure to perform its obligations hereunder, DOE's liability shall be limited to the replacement of the material in kind or, in lieu thereof, at its option, refund of any payment made by the buyer to DOE for such material. The buyer agrees to report promptly any discrepancies between the material supplied and that ordered so that replacement or other appropriate adjustment may be made.

10. DOE reserves the right to cancel this order (a) in the event the buyer's license (where applicable) is suspended, cancelled, or revoked pursuant to the Atomic Energy Act of 1954 or (b) when cancellation of this order is determined to be necessary to the national defense and security of the United States.

11. DOE shall have the right to publish and use any information or data developed or produced by DOE or persons acting on behalf of DOE in the course of or in connection with the analysis of materials or other services performed hereunder for the buyer, whether such materials are furnished by the buyer or DOE.

12. The buyer agrees to indemnify the Government, DOE, the operator of the DOE facility which supplies the material and/or services under this order, and their officers, employees, and agents against liability, including costs and expenses incurred, for infringement of any Letters Patent occurring in the course of the performance of any service for the buyer by DOE and as a result of following specific instructions of the buyer in connection therewith, or occurring in the utilization by the buyer of any item procured hereunder.

13. The buyer warrants that no person or selling agency has been employed or retained to solicit or secure this order upon an agreement or understanding for a commission, percentage, brokerage, or contingent fee, excepting bona fide employees or bona fide established commercial or selling agencies maintained by the buyer for the purpose of securing business. For breach or violation of this warranty, the Government shall have the right to annul this order without liability or in its discretion to deduct from the order price or consideration, or otherwise recover, the full amount of such commission, percentage, brokerage, or contingent fee.

14. No member of or delegate to Congress, or resident commissioner, shall be admitted to any share or part of this order, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this order if made with a corporation for its general benefit.

C. Safety

The following is an abbreviated summary of safety-related information which all users should know. More detailed information is provided in ORNL manuals on safety, health physics, and industrial hygiene which are available in the HHIRF Control Rooms.

1. Administration

The HHIRF operations staff is responsible for personnel and equipment safety at the facility. Emergency situations such as personnel injury, fires, and facility equipment malfunctions, shall be reported promptly to the operations staff (4-4720), the Laboratory Shift Supervisor (4-6606), or the ORNL Emergency Coordinator (911).

All experiments shall be subject to the scrutiny of the HHIRF operations staff and Laboratory safety offices with regard to meeting safety requirements. The operations staff will not permit any experiment to proceed where ORNL safety standards are violated.

Equipment at HHIRF is interlocked with appropriate radiation and electrical safety devices for personnel protection. Violation or intentional disablement of these safety devices is forbidden. Any facility or equipment operation which deviates from normal safety guidelines requires written approval by appropriate HHIRF administrative personnel.

2. Emergency Telephone Number

All ORNL emergency resources may be summoned by calling 911.

3. Evacuation Alarms

If Klaxon horn sounds, evacuate the building.

Two alarm systems are used at the HHIRF: a continuous alarm for fire and a pulsed alarm for oxygen deficiency. To avoid potential "low spots" personnel upon leaving the building are required to assemble either on the front lawn or on the parking lot near Building 6003. More detailed instructions on evacuation routes are posted throughout the HHIRF.

D. Care of Apparatus

Users are not to make any changes to a HHIRF experimental device without approval of the mentor of that device, nor is a user to introduce any materials which can damage or degrade the device or associated beam line. For example, the vacuum in the system should be as good after completion of an experiment as it was before the run was begun.

Upon completion of an experiment, users are to remove their own equipment from the experimental area. All material which is to be removed from the HHIRF must have a radiation survey performed by an ORNL Health Physicist. A survey can be arranged by contacting any member of the operations staff. Limited storage space is available for users apparatus if the intent is to use the equipment again within a reasonable length of time (about 1 year).

E. Publications

In order that the HHIRF management is kept aware of accomplishments of research at the HHIRF, users are requested to send a copy of each publication on research performed at the HHIRF to:

Scientific Director
Holifield Heavy Ion Research Facility
Building 6000
Oak Ridge National Laboratory
Oak Ridge, TN 37831

Publication lists will be made available to PAC members.

F. Labor Relations

Martin Marietta Energy Systems, Inc. operates the HHIRF for the Department of Energy and has a contract with the Atomic Trades and Labor Council, AFL-CIO. Consequently, fabrication, maintenance, and repair work, other than on the users' experimental apparatus, that is performed at the HHIRF will normally be done by bargaining unit personnel. The technician assigned to your experiment, or the HHIRF Liaison Officer, will assist outside users in arranging any needed craft services.

IV. Accelerator Systems

A. Tandem Accelerator

The tandem accelerator, manufactured by the National Electrostatics Corporation, has been described in detail elsewhere.¹⁻⁵ From a user's viewpoint, its most notable features are a high terminal voltage capability, provision for either gas or foil terminal strippers, charge-state selection in the terminal, and provision for a foil stripper at a position one-third of the way down the high-energy acceleration tube. A schematic view of the accelerator is shown in Fig. IV.A-1.

1. Beam Energy and Intensity

For single (terminal) stripper operation, the analyzed beam energy, E , from the tandem accelerator is given by

$$E(\text{MeV}) = \phi_T (1 + q_T) + \phi_I,$$

where ϕ_T is the terminal potential in MV, ϕ_I is the injector potential in MV and q_T is the charge state chosen in the 180° terminal magnet. (Note that because of the high charge dispersion of the terminal magnet, ions of only one charge state are accelerated in the high-energy acceleration tube.) ϕ_I is limited to about 0.5 MV with more typical values being about 0.3 MV. The design limit for ϕ_T is 25 MV, but the operating limit for regularly scheduled experiments is somewhat lower. Currently, users requiring $\phi_T > 21$ MV are requested to contact the WIRF Technical Director regarding restrictions on ϕ_T before submitting a proposal. This limit is expected to be raised in the future.

Ignoring for the moment limitations imposed by the terminal and analyzing magnets, the analyzed beam intensity, I_A , may be thought of as the product of three factors:

$$I_A = I_I f_T L,$$

where I_I is the intensity of the beam injected into the low-energy acceleration tube, f_T is the charge state fraction corresponding to the charge state q_T chosen for acceleration, and L is an anomalous loss factor.

For two stripper operation, similar formulae apply:

$$E = \phi_T (1 + 1/3 q_T + 2/3 q_2) + \phi_I,$$

Fig. IV.A-2

Fractional transmission through the tandem electrostatic accelerator for various stripper combinations and ion masses (see text).

IV.A-3

where q_2 is the charge state produced at the second stripper chosen for analysis in the analyzing magnet and

$$I_A = I_I f_T f_2 L,$$

where f_2 is the charge state fraction corresponding to charge q_2 .

The maximum value of I_I is dependent on two factors, terminal potential and ion species. For planning purposes, the limits on I_I associated with terminal potential ϕ_T are given by the following expressions.

Terminal Potential (MV)

$$\begin{array}{l} \phi_T < 18 \\ 18 < \phi_T < 20 \\ 20 < \phi_T < 21 \\ 21 < \phi_T \end{array}$$

Injected Current, I_I

$$\begin{array}{l} < 4 \text{ } \mu\text{A} \\ < [1.5 (20 - \phi_T) + 1.0] \text{ } \mu\text{A} \\ < [0.8 (21 - \phi_T) + 0.2] \text{ } \mu\text{A} \\ < 0.05 (25 - \phi_T) \mu\text{A} \end{array}$$

The limits on I_I associated with ion species will be discussed in Sect. IV.A2 below.

The maximum mass energy product, $K = AE/q^2$, of the 180° terminal magnet is 100. In this expression A is the mass of the projectile in amu, $E = \phi_I + \phi_T$ is in MeV, and $q = q_T$. This maximum K -value affects operation with ion masses greater than 150-160 in the case of terminal gas stripping. With these conditions it may be necessary to choose a charge state q_T slightly above the most probable value.

The limitation imposed by the mass energy product of the analyzing magnet ($AE/q^2 < 320$) is a more significant one. In some cases (for example, $A > 100$ for terminal gas stripping) it will be necessary to use a foil stripper near the object point of the analyzing magnet in order to produce a charge state component which can be bent by the analyzing magnet. Since only one charge state component can be analyzed, the addition of this foil stripper will reduce the analyzed beam intensity by a multiplicative factor of 0.1 to 0.2.

For planning purposes, it is convenient to introduce the parameter "fractional transmission," F , which we define as the ratio I_A/I_I in the absence of anomalous loss. Values for the fractional transmission are shown in Fig. IV.A-2 for the various possible stripper combinations. The discontinuities in the curves are due to the limitations of the terminal and analyzing magnets noted above. These curves were obtained by using the semiempirical charge state

Fig. IV.A-3

Analyzed beam energies from the tandem electrostatic accelerator for a terminal potential $\phi_T = 21$ MV and various stripper combinations.

fraction parameterization of Sayer⁶ and selecting the most probable charge state except where limited by the magnets. These curves are nearly independent of terminal potential except for $90 < A < 150$ when using GAS stripping and for $A > 200$ when using foil stripping. These are the regions where higher charge states must be selected at the terminal in order to be bent by the analyzing magnet. When using GAS stripping for $A > 150$, higher charge states must be selected for the terminal magnet plus the beam must be stripped before entering the analyzing magnet.

The anomalous loss factor, L , includes all transmission losses other than those due to charge-state selection and must be determined empirically. The following estimates are recommended for $A > 16$ (assume $L=1$ for $A < 16$):

<u>Stripper</u>	<u>L</u>
GAS	$0.8-0.0015A$
FOIL	$2.55 A^{-1/2}$
GAS-FOIL	$12/A$
FOIL-FOIL	$6.5/A$

The beam current at the exit of the analyzing magnet will then be given by

$$I_A = I_1 FL,$$

where F and L are values appropriate for the selected stripper(s). The "beam on target" will depend on the transmission between the tandem accelerator and the target station and is generally determined by the experimenters' apparatus (e.g., collimators to limit spot size or emittance).

The beam energies which can be obtained for various ion masses, at terminal potentials of 21, 23, and 25 MV, are shown in Figs. IV.A-3, 4, and 5. The discontinuities in the GAS and GAS-FOIL curves are again due to bending magnet limitations. These energies assume selection of the most probable charge state from an equilibrium charge state distribution at each stripper, except where limited by the bending magnets. For most beams, the energy can be increased or decreased by selecting a different charge state. For example, energies higher by 6-8% can be obtained at the expense of a 10-30% decrease in intensity. In practice, it may not be possible to use a stripper thick enough to obtain an equilibrium charge state distribution due to excessive energy and angular dispersion. In such cases, a lower charge state may have to be selected, resulting in lower achievable energies.

Fig. IV.A-4 Same as Fig. IV.A-3 except $\phi_T = 23$ MV.

Fig. IV.A-5 Same as Fig. IV.A-3 except $\phi_T = 25$ MV.

Fig. IV.B-1

Analyzed beam energy from coupled accelerators for tandem accelerator terminal potentials of 18- and 25-MV.

2. Available Beams

At the present time, we are using two types of negative ion sources, both developed at Oak Ridge. These are a radial geometry cesium plasma source⁷ and an axial geometry source which utilizes a solid surface ionizer.⁸ In addition, development work is in progress on a Li-cell charge exchange source.⁹ Beams available or potentially available at the present time are summarized in Table IV.A-1.

For elements having several isotopes, it may be necessary to use enriched source material. The rate of consumption of the source material is typically ~ 1 mg/day, making it economically feasible to use separated isotopes. The operations staff has available several separated isotopes, and the number will increase with time. However, users should not assume that enriched material will be available and should contact the Technical Director before requesting an ion species having a small natural abundance.

3. Beam Emittance and Spot Size

The unnormalized emittance of the beam emerging from the high-energy acceleration tube is geometrically limited to values of about 6π -mm mrad (Ref. 10). Since aberrations induced by ion optic elements following the accelerator are expected to be small, we believe this is also a good upper limit for beam on target. In practice, we find values of 1 to 2π -mm mrad to be more typical.

The typical mode of operation will give a symmetric waist in the beam at the object and image slits of the analyzing magnet. In this situation the beam spot on a target in either of the two target rooms that adjoins the tower will have an aspect ratio of 2.5 to 1. The major axis will be ~ 2 mm long.

4. Energy Dispersion

In the usual case where the injected beam is a mono-atomic ion species and where a single terminal stripper is used, energy dispersion in the analyzed beam is typically 1×10^{-4} ($\Delta E/E$, fwhm) or less. In cases where a second stripper is used, energy dispersion may be larger. In experiments where energy dispersion is an important parameter, we recommend consultation with the HHIRF operations staff.

5. Energy Calibration

A final calibration of the analyzing magnet was performed in February, 1986¹¹. The uncertainty in energies provided by the tandem accelerator is estimated to be approximately $\pm 0.1\%$. In experiments where the bombarding energy is of special importance, we recommend that the user measure the beam energy during the course of the experiment.

Table IV.A-1. Availability of various ion species

Ion*	Category	Ion*	Category	Ion*	Category	Ion*	Category
H ⁻	C	TiX ⁻	B	Ru ⁻	A	HoX ⁻	D
He ⁻	D	VX ⁻	B	Rh ⁻	A	ErX ⁻	D
Li ⁻	B	CrX ⁻	B	PdX ⁻	D	TmX ⁻	D
BeX ⁻	B	MnX ⁻	B	Ag ⁻	A	Yb ⁻	D
BX ⁻	A	FeX ⁻	B	CdX ⁻	B	YbX ⁻	D
C ⁻	A	Co ⁻	B	InX ⁻	D	LuX ⁻	D
CN ⁻	A	Ni ⁻	A	Sn ⁻	B	HfX ⁻	D
NX ⁻	B	Cu ⁻	A	Sb ⁻	B	TaX ⁻	D
O ⁻	A	ZnX ⁻	D	Te ⁻	A	WX ⁻	B
F ⁻	A	GaX ⁻	D	I ⁻	A	ReX ⁻	D
Ne	N	Ge ⁻	A	Xe	N	Os ⁻	A
Na ⁻	D	As ⁻	A	Cs ⁻	D	Ir ⁻	A
MgX ⁻	B	Se ⁻	A	BaX ⁻	D	Pt ⁻	A
AlX ⁻	B	Br ⁻	A	LaX ⁻	D	Au ⁻	A
Si ⁻	A	Kr	N	CeX ⁻	D	Hg	N
P ⁻	A	Rb ⁻	D	PrX ⁻	D	TlX ⁻	D
S ⁻	A	SrX ⁻	D	NdX ⁻	B	Pb ⁻	B
Cl ⁻	A	YX ⁻	D	SmX ⁻	D	Bi ⁻	B
Ar	N	ZrX ⁻	B	EuX ⁻	D	ThX ⁻	D
K ⁻	D	Nb ⁻ , NbX ⁻	B	GdX ⁻	D	UX ⁻	B
CaX ⁻	B	MoX ⁻	B	TbX ⁻	D		
ScX ⁻	B			DyX ⁻	D		

Category A: High yield, typically $I_I = 1$ to $4 \mu\text{A}$. For estimating I_A assume $I_I = 2 \mu\text{A}$ times the isotopic abundance.

Category B: Low yield, typically $I_I = 0.1$ to $1 \mu\text{A}$. For estimating I_A assume $I_I = 0.5 \mu\text{A}$ times the isotopic abundance.

Category C: I_A and ϕ_I are limited to 25 nA and 12.5 MV , respectively, to prevent excessive activation of accelerator.

Category D: Not yet attempted. Expected to be available if requested, but may require development.

Category N: Not available.

* "X" indicates a compound, typically a hydride, oxide or nitride, is extracted from the ion source.

6. Beam Time Structure

In normal dc operation, the analyzed beam intensity nominally has no time dependence. However, this should be checked by the user if it is of special importance since, in practice, the beam may be modulated in a number of ways (usually with frequencies less than 1 kHz).

Pulsed beams with a period of 250 or 1000 ns, and a pulse width of 1-3 ns, can be provided upon request. The efficiency of the buncher/chopper system used for producing this time structure is expected to be approximately 25% for a period of 250 ns and approximately 6% for a period of 1000 ns. Thus, the beam intensity estimates discussed above should be reduced accordingly.

In addition, the beam can be "macropulsed" at frequencies on the order of 10 Hz and pulse width ~ 100 μ sec. Since pulsing occurs at the source, the injected pulse current can be quite high (~ 100 μ A). Such beams may be useful in studying short-lived activities.

IV.A-12

References

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B. Oak Ridge Isochronous Cyclotron (ORIC)

1. Energy Capability

The ORIC is a variable frequency isochronous cyclotron¹ with a maximum mass-energy product of $K=100$ ($K=AE/q^2$, where A = atomic mass, E = energy in MeV, q = ion charge). It serves as an energy booster for beams injected from the tandem accelerator^{2,3,4} (coupled mode). Estimated maximum energies, in the coupled accelerators mode, for various ion masses are shown in Fig. IV.B-1, for tandem terminal potentials of 18 and 25 MV.

2. Beam Parameters

The quality of the beam obtained from the ORIC depends on many factors and can be expected to vary from run to run. The emittance is not well determined, but is estimated to be less than $6 \pi\text{-mm mrad}$ in both the horizontal and vertical planes.

The energy spread in the extracted beam is estimated to be about 0.1-0.2% (for single turn extraction). However, on beam lines C17, C18, and C20 (see Fig. V.A-1), the energy spread can be reduced by appropriate choice of entrance and exit slits on the 153° energy analyzing magnet. The 153° magnet is also used to determine the absolute beam energy to 0.2%.

The beam intensity from coupled operation will depend on the amount of beam that can be provided by the tandem accelerator (see Sect. IV.A), the charge state yield following stripping in the ORIC, and transmission losses.

For ions with $A < 28$, $Z/A = 0.5$, and $(E/A)_{\text{max}} = 25.0$ MeV/u, the maximum beam currents out of the cyclotron will depend on the ion species (e.g., $I = 100$ pA for ^{12}C , 40 pA for ^{16}O , and 6 pA for ^{28}Si). For $A > 28$, the following gives representative maximum energies (in MeV) for beam currents from the cyclotron of 10 pA and 2 pA.

<u>Isotope</u>	<u>Energy for 10 pA</u>	<u>Energy for 2 pA</u>
^{32}S	700	800
^{58}Ni	900	1000
^{79}Br	800	900
^{107}Ag	700	900
^{127}I	600	800
^{197}Au	450	580

These beam currents should be reduced by a transmission factor between the cyclotron and target. This factor depends strongly on beam collimation and on energy-resolution requirements.

Fig. IV.B-1

Analyzed beam energy from coupled accelerators for tandem accelerator terminal potentials of 18- and 25-MV.

The time structure of the extracted beam is determined by the RF-frequency and the phase angle over which acceleration occurs. The RF-frequency range is 5.79 to 20.3 MHz and the phase angle is typically <10 degrees. Nuclear physics experiments which use the cyclotron RF as a time signal can expect to achieve time resolution of approximately 2 ns.

Several of the ions which have been successfully accelerated in the coupled mode are listed in Table IV.B-1. This list is continually growing and, in principle, any ion species which can be provided by the tandem accelerator with reasonable intensity can be accelerated in the coupled mode. Users having unusual beam requirements should contact the HHIRF accelerator operations group before planning their experiment.

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Table IV.B-1

Typical Beams Provided with Coupled Operation

Ion	Energy (MeV)	Injected Ion	Injection Energy (MeV)	Tandem Voltage (MV)
$^9\text{Be}^{4+}$	158	$^9\text{Be}^{1+}$	20	9.8
$^{10}\text{B}^{5+}$	168	$^{10}\text{B}^{2+}$	40	16.0
$^{11}\text{B}^{5+}$	169	$^{11}\text{B}^{2+}$	38	15.9
$^{12}\text{C}^{6+}$	300	$^{12}\text{C}^{2+}$	54	17.8
$^{16}\text{O}^{8+}$	405	$^{16}\text{O}^{2+}$	39	12.8
$^{17}\text{O}^{8+}$	381	$^{17}\text{O}^{2+}$	44	14.6
$^{18}\text{O}^{8+}$	352	$^{18}\text{O}^{3+}$	68	16.9
$^{24}\text{Mg}^{8+}$	178	$^{24}\text{Mg}^{2+}$	20	6.6
$^{32}\text{S}^{15+}$	717	$^{32}\text{S}^{6+}$	123	17.5
$^{35}\text{Cl}^{16+}$	692	$^{35}\text{Cl}^{6+}$	124	17.7
$^{48}\text{Ti}^{17+}$	581	$^{48}\text{Ti}^{6+}$	93	13.3
$^{56}\text{Fe}^{22+}$	842	$^{56}\text{Fe}^{8+}$	170	18.9
$^{58}\text{Ni}^{23+}$	934	$^{58}\text{Ni}^{9+}$	170	17.0
$^{79}\text{Br}^{28+}$	1000	$^{79}\text{Br}^{9+}$	164	16.4
$^{109}\text{Ag}^{29+}$	733	$^{109}\text{Ag}^{8+}$	128	14.2
$^{116}\text{Cd}^{25+}$	495	$^{116}\text{Cd}^{7+}$	115	14.6
$^{116}\text{Sn}^{29+}$	684	$^{116}\text{Sn}^{7+}$	145	18.8
$^{150}\text{Nd}^{33+}$	760	$^{150}\text{Nd}^{13+}$	211	15.1

V. Experimental Apparatus

A. Nuclear Physics Apparatus

The following sections describe the major experimental devices available to users of the HHIRF. A mentor (see Chapter IX) is assigned to each device and can provide more detailed information where required. A Users Support Group is also available to assist users with equipment installation, alignment, vacuum system operation, and other tasks.

A floorplan of the experimental areas is shown in Fig. V.A-1. From this it can be seen that not all devices can receive beams from both the tandem and cyclotron (or coupled) accelerators. This will limit the range of projectile energies available on certain devices and must be taken into account when planning an experiment.

Fig. V.A-1 Floorplan of the HHIRF experimental areas.

V.A1. 1.6-m Scattering Chamber

The 1.6-m diameter scattering chamber is a general purpose device which can accommodate a wide variety of detectors. The chamber is installed on beam line C16 and can receive beams from both the tandem and coupled accelerators. Two collimators are installed on the beam line to remove beam "halo" or to limit the beam divergence if necessary.

The basic features and dimensions are shown in Fig. V.A1-1. The entire domed top is removable to provide full access to the interior. The flat bottom of the chamber is used primarily to mount the vacuum pumps, target changer mechanism, and chamber support structure.

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Fig. V.A1-1

Sketch of the 1.6-m Scattering Chamber and beam line. Dimensions of the target frames which fit the target ladder are also shown.

The target ladder will hold up to ten targets mounted on frames like that shown in Fig. V.A1-1. Targets are positioned vertically by a remotely operated linear drive which can be moved in small increments to position different parts of a target in the beam. The entire target ladder can be rotated about its vertical axis. Target holders other than this standard configuration have also been used. In particular, for experiments requiring large target-detector separation, a target wheel can be installed near the beam entrance port. This arrangement will provide flight paths up to about 1.4 m.

The upper and lower arms are removable spokes extending from a central rotating support to large gear driven rings, located near the chamber wall, which can be independently rotated through 360°. These arms provide the standard method for mounting and rotating an array of detectors and can support systems weighing up to 50 kg. Hardware is available for mounting multiple solid-state detector telescopes and a variety of other detectors. Dimensions and details of the spokes are given in Fig. V.A1-2 for users who need to design their own custom mounts. A 0.5-m diameter rotatable ring can be installed in the vertical plane for mounting out-of-plane detectors.

Access ports having 101.6 mm (4") diameter openings are located in the wall and lid of the chamber. Eight ports are equally spaced around the wall of the chamber at beam height. One is used to attach the beam line and the opposite port is generally used to install a Faraday cup. Four additional ports are located in the lid, one at the center and three equally spaced around the periphery. Two of the wall ports are normally fitted with adapters which accept large feedthrough flanges. Port dimensions are indicated in Fig. V.A1-3.

A patch panel having 48 BNC and 8 SHV connectors is located near the chamber for transporting signals to and from the ORIC counting room. The interconnecting cables are nominally 50 m long and may degrade fast, low-level signals. In such cases, it may be necessary to install part of the signal processing electronics near the chamber. Facilities for installing electronics (NIM-bins, CAMAC crates) and data acquisition computer terminals are available at both stations in the ORIC counting room.

The vacuum pumping system consists of a mechanical pump for roughing and two cryopumps for high vacuum. Pump down from atmosphere to below 10^{-5} torr requires about 1 hour. The normal operating pressure is less than 10^{-6} torr. Initial pump-down and preparation of the cryopumps will be done by the technicians. A diagram of the system is shown in Fig. V.A1-4. First time users should obtain assistance to become familiar with the various controls.

Fig. V.A1-2 Dimensions of the detector mounting arms located in the 1.6-m Scattering Chamber.

Fig. V.A1-3 Dimensions of the Access Ports and Feedthrough Adapters on the 1.6-m Scattering Chamber.

Fig. V.A1-4 Block diagram of the vacuum system for the 1.6-m Scattering Chamber.

V.A2-1

V.A2. Enge Split-Pole Spectrograph

The Enge split-pole spectrograph¹ (ESP) is installed on beam line 33 and is accessible only to tandem accelerator beams (see Fig. V.A-1 for location). Operational parameters are given in Table V.A2-1.

Table V.A2-1 Properties of the Split-Pole Spectrograph (ESP)

Mass-energy product (AE/q^2)	100
Dispersion = $\Delta s(p/\Delta p)t$	~ 160 cm
Horizontal magnification	0.34
Vertical magnification	~ 3
Maximum solid angle	~ 8 msr
Resolving power = $p/\Delta p$	~ 5000
Angular range	$0^\circ - 165^\circ$

$t\Delta s$ = change in position along focal plane.

The target chamber is 35.6 cm diam by 17.8 cm high and will accept either a four position target ladder or the HHIRF supersonic gas jet target facility². A sketch of the frames which are used for solid targets is shown in Fig. V.A2-1. Ports of 5.1 cm diameter are available in the chamber wall for mounting fixed monitor detectors. When used with the target ladder, the top of the chamber can be rotated independently of the spectrometer so that detectors mounted through two 10.2×10.2 cm² holes can be positioned. The chamber is electrically isolated so that it can be used as a Faraday cup for beam current integration.

The detector currently used at the focal plane of the ESP is a Hybrid Ray-Tracing Counter³, which is shown schematically in Fig. V.A2-2. The detector provides position, angle, E , and ΔE information which are needed to determine the ejectile mass, charge, Z , energy, and reaction angle. The active volume is 40 cm wide x 27.5 cm long x 6.5 cm high. Ray tracing allows correction for aberrations present when the full solid angle of the ESP is used. Dedicated electronics for the detector and controls for the ESP field are located in the tandem counting room.

THICKNESS ≤ 1.6 mm (TYPICALLY Ta OR Al)

Fig. V.A2-1 Dimensions of target frames used in the Split-Pole Spectrograph.

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Fig. V.A2-2 Schematic view of the focal plane detector used in the Split-Pole Spectrograph: A) position-sensitive proportional counters; B) reject proportional counter; C) ΔE -electrode; D) Frisch grid; E) E-signal grid; F) cathode strips; G) cathode; H) entrance window.

Tuning of the focal plane detector and operation of the gas jet target are sufficiently complex that users should consult the mentor of the ESP before planning an experiment.

¹J.E. Spencer and H. A. Enge, Nucl. Instr. and Meth. 49, 181 (1967).

²D. Shapira, J. L. C. Ford, Jr., R. Novotny, B. Shivakumar, R. L. Parks, and S. T. Thornton, Nucl. Instr. and Meth. in Phys. Res. 228, 259 (1985).

³D. Shapira, G. L. Bomar, J. L. C. Ford, Jr., J. Gomez del Campo, and L. C. Dennis, Nucl. Instr. and Meth. 169, 77 (1980).

V.A3. Broad Range Spectrograph

a. Introduction

The HHIRF Broad Range Spectrograph¹ (BRS) is a scaled-up version of the original Elbek design² with a quadrupole singlet (Q18-2) added between the scattering chamber and dipole to provide vertical focussing³ and, hence, larger solid angles. The BRS can be operated with or without Q18-2, depending on the experimental requirements. The mode of operation will be indicated by QUAD ON or QUAD OFF. The focal plane vacuum chamber, originally designed for photographic plates, has also been enlarged to accommodate large gas filled focal plane detector systems. The maximum particle magnetic rigidity which can be analyzed is approximately 2.2 Tm and the maximum solid angle is about 5 msr. As shown in Fig. V.A-1, the BRS can be used with either tandem accelerator or coupled accelerator beams on beamlines 51 or C18, respectively.

A technician or the mentor of the BRS will assist new users with alignment, vacuum system operation, installing computer interface modules, beam tuning, starting the gas handling systems and other tasks. Users are responsible for supplying targets, target frames, detector gas (if large quantities are consumed), magnetic tapes, monitor detectors (if needed), and any non-standard hardware required for their experiment. Users should also perform any calculations needed to determine the desired operating parameters. A program, HPRP, is installed on the data acquisition computers to assist users in calculating the various magnetic field settings and other parameters such as kinematic effects, dispersion at the focal plane, and factors contributing to the energy spread (see section f).

In the following sections, lengths are given in meters except where noted. Slit openings are normally given in inches to agree with the readout provided on these devices. The symbols Z , A , p , q , E , and $B\rho$ refer to the atomic number, mass number, momentum (MeV/c), charge state ($q \leq Z$), kinetic energy (MeV), and magnetic rigidity (Tm) of the detected particles, respectively. Several of these quantities are related by the following expressions: $B\rho = 0.0033356 p/q$; $(p/q)^2 = K(1863 + E/A)$ where $K = AE/q^2 = 48(B\rho)^2$.

b. Beam Transport

i. Beam Line C18

Beam line C18 is preceded by a beam analyzing magnet (BAM) having the following characteristics: radius = 1.829 m (72 in); bend = 153° ; $n = 0.5$; magnification = -1.0; dispersion = $(p/\Delta p)\Delta x = 288$ inches or $(E/\Delta E)\Delta x = 144$ inches. For object and image slit

openings S_1 and S_2 inches, respectively, the total energy spread in the beam after the BAM will be given by $\Delta E/E = (S_1 + S_2)/144$ or by the energy spread in the beam $(\Delta E/E)_{\text{beam}}$, whichever is smaller. If the horizontal magnification between S_2 and the target is adjusted to match the dispersion of the BAM to the reverse dispersion of the BRS, the resolution at the BRS focal plane will be essentially independent of S_2 . The beam contribution to the experimental resolution will then be primarily determined by S_1 , and will be approximately $\Delta E/E = 0.015S_1$. Values for S_1 and S_2 should be specified by the experimenter. Typical values are: $S_1 = 0.01$ to 0.04 inches and $S_2 = 0.10$ to 0.15 inches.

Two quadrupole triplets, Q3-2 and Q18-1, are used to obtain the correct horizontal magnification for dispersion matching. The desired magnification for a target in transmission geometry is given by:

$$M_H = (a + bp)E_1 \cos \theta_T / E_3 \cos(\theta - \theta_T)$$

$a=0.334, b=0.382, \text{QUAD ON}$
 $a=0.246, b=0.181, \text{QUAD OFF}$

where $E_1(E_3)$ is the incident (detected) particle energy, $\theta_T(\theta)$ is the target (scattering) angle. The approximate current settings for Q3-2 and Q18-1 to give magnification M_H and focus at the target are given by $I(A) \sim (c + dM_H^{-1})p/q$ where the constants for the various quadrupole sections predicted by first-order optics calculations are [assuming $I(A) \sim 14dB/dr(Tm^{-1})$]:

Quadrupole	c	d	Mode*
3-2A,C	0.249	0.0688	CD
3-2B	0.250	0.0582	
18-1A,C	0.359	-0.0468	DC
18-1B	0.346	-0.0385	

*CD(DC) = converging (diverging) horizontally at the entrance

When using Q18-2, the position of the intermediate focus formed by Q3-2, which determines M_H , can be fine tuned using a moveable phosphor and TV camera. Similarly, final settings for Q18-1 are determined using a phosphor placed at the target position.

Various apertures can be inserted before Q3-2 to limit the beam emittance. Dimensions of the available apertures are (horiz. x vert.): 1.5 x 1.5, 1.0 x 1.5, and 0.5 x 1.5 inches. A four-jaw collimator is also installed after Q18-1 which can be used to limit the angular divergence of the beam on target. For a total opening (horizontal or vertical) of S_{12} inches, the angular divergence will be limited to $\sim 0.33S_{12}$ degrees.

ii. Beam Line 51

Dispersion matching is not possible on this beam line; however the energy spread in the beam from the tandem accelerator is typically $\Delta E/E \sim 10^{-4}$, which is usually much smaller than the experimental resolution. Three quadrupole doublets, Q31-1, Q31-2, and Q51-1, are available, but only the first and last are normally required to obtain an acceptable beam spot on target. The optimum settings for the quadrupoles are not well established at the present time. The major beam related contribution to the experimental resolution will be determined by the width, w in cm, of the beam spot and the horizontal magnification of the BRS. For typical operating conditions, this will be equivalent to an energy spread $\Delta E/E \sim 0.002w$ (QUAD ON) or $\sim 0.003w$ (QUAD OFF).

As shown in Fig. V.A-1, the Time-of-Flight facility constitutes part of beam line 51. Care must be taken to ensure that collimators, targets, etc. are removed from the TOF chamber when transporting the beam to the BRS.

c. Spectrograph Hardware

The major components of the BRS are indicated in Fig. V.A3-1. The scattering chamber has a "sliding-band" seal on the exit side which allows the BRS to be operated over the scattering angle range $-30^\circ < \theta < +140^\circ$ on beam line C18 or $-10^\circ < \theta < 160^\circ$ on beam line 51. The scattering chamber, shown in more detail in Fig. V.A3-2, normally contains an eight-position target wheel, monitor detectors, and a Faraday cup for beam integration. Dimensions of the target frames normally used in the target wheel are given in Fig. V.A3-3. A 4-jaw slit is installed near the chamber entrance for beam clean-up and for monitoring the position of the beam. The beam line between the scattering chamber and dipole magnet contains a box for time-of-flight detectors and other accessories, a quadrupole singlet (Q18-2), vacuum (isolation) valve and a set of horizontal and vertical slits. The dipole magnet and ancillary hardware are mounted on a carriage which can be rotated about the scattering chamber on two wheels which roll on a 4.05 m radius track. The BRS is rotated by means of an air motor, the controls for which are mounted near the scattering chamber. Angle settings can be read from a scale located below the scattering chamber to an accuracy of $< 0.1^\circ$.

Alignment of slits and targets is accomplished by means of a telescope and optical target which are mounted on permanently installed alignment posts. An alignment mark, noted in Fig. V.A3-1, is scribed on the lower pole face of the dipole and provides a means for checking the zero degree setting.

Fig. V.A3-1 Schematic of the HIIRF Broad Range Spectrograph.

Fig. V.A3-2 Sketch of the lower part of the BRS scattering chamber. An upper section which supports the target changer is not shown.

Fig. V.A3-3 Dimensions of the target frames used in the standard BRS target wheel.

Separate vacuum systems, consisting of a mechanical roughing pump and a cryopump, are provided for the scattering chamber and the magnet vacuum chamber. All roughing valves are manually operated, but the high vacuum valves are air operated and controlled from a panel near the scattering chamber. Interlocks prevent opening of the high vacuum valves above 100 mTorr. Similarly, the isolation valve separating the scattering chamber and magnet cannot be opened if either is above 5 mTorr. Operation has been found to be reasonably foolproof, however, care must be taken to prevent damage to the targets or detectors. Normal operating pressure is about 3×10^{-6} Torr in both chambers. Cycling (high vacuum to air to high vacuum) will usually require about 2 hours. As a precaution, it is recommended that the isolation valve and the manual valve at the entrance to the scattering chamber be closed when rotating the BRS. No catastrophic failures of the sliding band have been experienced, but small leaks occasionally occur during rotation.

The detector box has inside dimensions 12.7 x 12.7 x 10.2 cm deep and is centered 27.9 cm from the target position. A removeable top, used to support the detector, is located 5.71 cm above the beam line. This box also contains a two-position slide mechanism which is used to insert a plate having nine vertical slots, each separated by 0.5 degrees scattering angle, for angle calibration of the focal plane detector. The other position is normally open but can be used to mount other diagnostic hardware if so desired.

The BRS can be operated with or without Q18-2. In most cases, the larger solid angle achieved with the quadrupole is desirable. However, for small angle measurements, where out-of-plane scattering may have to be reduced, operation without Q18-2 may be preferred. The aperture is 7.62 cm diam. and the maximum field gradient is approximately 20 Tm^{-1} . The current required to produce a vertical focus at the focal plane is approximately [assuming $I(A) \sim 14 \text{ dB/dr}(\text{Tm}^{-1})$]:

$$I(A) = (0.390 + 0.026p)(p/q).$$

All "QUAD ON" parameters were calculated using this focussing condition.

Horizontal and vertical slits, usually referred to as the alpha and beta slits, respectively, are located at the entrance to the dipole magnet. These are used to limit the angular acceptance and to prevent reaction products from scattering off the magnet pole faces. For full horizontal (vertical) opening $S_H(S_V)$ in inches, the angular acceptances in degrees will be (θ = in-plane, ϕ = out-of-plane):

$$\begin{aligned} \text{QUAD OFF: } \Delta\theta &= 1.776S_H; \Delta\phi = 1.749S_V \\ \text{QUAD ON: } \Delta\theta &= 1.341S_H; \Delta\phi = 2.509S_V. \end{aligned}$$

The maximum total opening for S_H is 4.0 inches, and the maximum recommended values for S_V are; $S_V = 1.3 - 0.43p$ (QUAD OFF); and $S_V = 1.8$ (QUAD ON).

The dipole magnet has a 5.08 cm gap and will accept particle trajectories having radii in the range $0.76 < \rho < 1.6$ m. The magnetic field is determined by an NMR probe and is limited to ~ 1.35 T. A zero-degree viewport, indicated in Fig. V.A3-1, is available to facilitate optical alignment. The design of the dipole magnet is described in detail in reference 2. The dipole has second-order focussing, but third-order aberrations become important for large values of $\Delta\theta$, particularly when using Q18-2. This problem can be essentially eliminated by using a ray-tracing focal plane detector and empirically determining corrections to the particle position for various values of $\Delta\theta$. If a simple position sensitive focal plane detector is to be used, $\Delta\theta$ should be limited to $\sim 5^\circ$ (QUAD OFF) or $\sim 3^\circ$ (QUAD ON).

The area of the BRS focal plane is shown schematically in Fig. V.A3-4. The various "planes" indicated are defined as follows:

REFERENCE PLANE - A plane, which lies a known distance from the edge of the dipole magnet, from which the positions of the other planes are determined.

CALIBRATION PLANE - Plane for which the relation between position, $X(\text{cm})$, and radius, $\rho(\text{m})$, has been calibrated:

$$\begin{aligned}\rho &= 0.699 + 0.004884X - 1.286 \times 10^{-6}X^2 + 1.94 \times 10^{-9}X^3 \\ X &= -142.419 + 199.06\rho + 5.95\rho^2\end{aligned}$$

Its location, relative to the REFERENCE PLANE, is given by $DR_0 = 3.298$ inches, $DL_0 = 3.194$ inches.

FOCAL PLANE - Plane having the optimum position resolution. Its location will depend on the kinematic shift, $E^{-1}(\Delta E/\Delta\theta) \text{ deg}^{-1}$, for the reaction of interest, which will shift the focus by an amount $\Delta D(\text{inches}) = E^{-1}(\Delta E/\Delta\theta) \rho (0.00637 - 0.00291\rho + 9.63 \times 10^{-4} \rho^2)^{-1}$.

DETECTOR PLANE - Plane containing the position sensitive detector. Its location is determined by DL and DR which are given by dial indicators located on top of the vacuum chamber. In most cases, the detector will be located at or near the FOCAL PLANE.

The focal plane detectors are mounted in a $2.23 \times 0.25 \times 0.38$ m deep rectangular frame supported at two points, "A" and "B" in Fig. V.A3-4, which are separated by $L_2 = 2.417$ m. The bottom of the frame contains eight rows of tapped holes (1/4-20) and seven interspersed rows of 6.35 mm locating holes, with the center row marking the normal focal plane position, spaced 5.08 cm on center for mounting detectors. A 200 cm long scale, starting at a distance $L_1 = 23.04$ cm from support A, is attached to the back of the frame for positioning the detectors. The frame can be translated perpendicular to the REFERENCE PLANE and rotated about support "A" to compensate for kinematic shifts. The desired values of DL and DR are provided by HPRP, however the detector mounting frame can only be translated by about 4 inches.

The position at which the particle trajectory crosses the CALIBRATION PLANE, X , is related to the measured position, X' , by $X = X' \text{DCOR1} + 2.54 \text{DCOR2}$ where:

$$\text{DCOR1} = 1 + \left(\frac{\tan\theta + \tan\phi}{\tan\theta_d - \tan\phi} \right) \frac{\cos\theta}{\cos\phi} \approx 1 + 0.014(DL - DR)$$

$$\text{DCOR2} = \frac{DR - DR_0}{\cos\phi(\tan\theta_d - \tan\phi)} + L_1(\text{DCOR1} - 1) + \frac{L_2}{2}(1 - \cos\theta)(\text{DCOR1} - 1)$$

$$\tan\theta = \frac{DL - DR}{L_2} ; \tan\phi = \frac{DR_0 - DL_0}{L_2} ; \theta_d = 37.5 \text{ deg}$$

$$DR_0 = 3.298 \text{ in}; DL_0 = 3.194 \text{ in}; L_1 = 9.07 \text{ in}; L_2 = 95.189 \text{ in}.$$

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Fig. V.A3-4 Schematic view of the area around the BRS focal plane.

d. Spectrograph Properties

The following relations give approximate values for several quantities which are useful in planning experiments using the BRS. For the most part, these are based on first-order optics calculations.

The solid angle when using Q18-2 will be determined by the horizontal and vertical acceptance angles, $\Delta\theta$ and $\Delta\phi$, in degrees. If Q18-2 is not used, the solid angle will be determined by $\Delta\theta$ and the height of the focal plane detector, $h(\text{cm})$, except for very small values of $\Delta\phi$.

$$\text{QUAD ON: } \Omega(\text{msr}) = 0.3046\Delta\theta\Delta\phi$$

$$\text{QUAD OFF: } \Omega(\text{msr}) = (0.00663 + 0.0521\rho^{-1})h\Delta\theta \text{ or } 0.3046\Delta\theta\Delta\phi, \text{ whichever is smaller.}$$

The horizontal angular magnification is given by:

$$\text{QUAD-OFF: } -M_\theta = 1.0 + 1.481\rho^{-1}$$

$$\text{QUAD-ON: } -M_\theta = 1.958 + 1.975\rho^{-1}.$$

The horizontal magnification along the focal plane can then be estimated from:

$$M_H = 1/M_\theta \sin 37^\circ = 1.66/M_\theta$$

where 37° is the angle between the central ray and the focal plane.

The vertical height at the focal plane is approximately:

$$\text{QUAD OFF: } Y(\text{cm}) = (0.86 + 4.36\rho)\Delta\phi = (1.5 + 7.63\rho)S_Y$$

$$\text{QUAD ON: } Y(\text{cm}) \sim -(3.475 + 3.175\rho)Y_0(\text{cm}).$$

The dispersion along the CALIBRATION PLANE can be estimated from:

$$(E/\Delta E)\Delta X(\text{cm}) = 99.5\rho + 5.95\rho^2.$$

The dispersion along the DETECTOR PLANE will be:

$$(E/\Delta E)\Delta X'(\text{cm}) \sim (E/\Delta E)\Delta X[1 + 0.014(DL-DR)]^{-1}.$$

The length of the flight path from the target to the FOCAL PLANE for a particle on axis is approximately:

$$\text{QUAD OFF: } d(\text{cm}) = 84.5 + 262.6\rho - 4.2\Delta D$$

$$\text{QUAD ON: } d(\text{cm}) = 84.5 + 267.1\rho - 4.2\Delta D$$

where ΔD is the kinematic correction in inches. The variation in path length with angle for off-axis trajectories can be estimated from:

$$\text{QUAD OFF: } \Delta d = (3.36 + 2.26\rho)\Delta\theta(\text{deg})$$

$$\text{QUAD ON: } \Delta d = (4.44 + 4.44\rho)\Delta\theta(\text{deg})$$

The effect of $\Delta\phi$ can be neglected.

e. Detectors and Electronics

As indicated in Fig. V.A3-1, the standard focal plane detection system consists of three components: 1) Vertical Drift Chamber (VDC) for ray tracing; 2) Parallel Plate Avalanche Detector (PPAD) for timing; 3) Ionization Chamber (IC) for determining Z of the particle.

Detailed reports on the operation and construction of the VDC have been published⁴⁻⁶. Briefly, the particle trajectory is determined by measuring electron drift times to several "sense" wires. The number of sense wires fired will vary between 3 and 5 (and occasionally 6) depending on the angle between the VDC and the particle trajectory. The intrinsic position and angular resolutions of the VDC have been studied under a variety of operating conditions^{5,6} and found to be typically ~0.1 mm and 10 mrad FWHM, respectively. The useable area is 5 cm high and ~37 cm long, but smaller window frames can be installed to meet experimental requirements. For example, frames with a smaller vertical opening may be required to reduce the thickness of the pressure bearing windows. All measurements performed thus far have used isobutane gas at pressures in the range of 50 to 200 torr. The optimum operating voltage should be determined at the beginning of each experiment, but a reasonable starting point is $V_c = -2800-7.3P(\text{torr})$.

The "start" signal required for the drift-time measurements is provided by a 5 cm x 41.9 cm PPAD. Signals are taken from both ends of the PPAD and combined in a mean-timer (LeCroy 624) to eliminate time shifts caused by the position dependent signal propagation time. The time resolution for coincidences between this detector and a small PPAD, using 5.8 MeV α -particles, was measured to be ~300 ps. The PPAD is operated at pressures of 5 to 10 torr of isobutane and voltages in the range of 450-600 V.

A sketch of the IC is given in Fig. V.A3-5. Three separate anode sections allow ΔE and E to be measured for a wide range of particle masses and energies. Element identification from $\Delta E \times E$ has been demonstrated for particles as heavy as nickel. The ΔE and E resolutions are typically $\sim 2\%$ and $\sim 1\%$, respectively. The usual gas fill is tetrafluoromethane CF_4 and the IC has been operated at pressures as high as 2000 torr (267 kPa). The gas pressure is normally selected to stop the particles of interest near the back of the detector. The signal from Anode 1 is also used to generate a time signal from which the vertical position of the detected particle can be determined. This feature is useful when fine tuning the vertical position of the beam spot on the target and for checking the focus of Q18-2.

The pressure bearing windows on these detectors are usually mylar films. Burst tests suggest a minimum window thickness, which provides a safety factor of ~ 2 , given by $t(\mu\text{m}) = 0.01 P(\text{torr})h(\text{cm})$, where h is the smaller dimension of the window.

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Fig. V.A3-5

Schematic of the ionization chamber (IC) used for ΔE - E measurements in the BRS.

A fourth detector, the "stop" detector for time-of-flight measurements, can be mounted in or near the scattering chamber. This detector is only required for heavier particles ($A > 30$) where the multitude of reaction product masses and charge states makes it impossible to obtain unique particle identification from the focal plane detectors alone. Originally, a small PPAD was used but the energy straggling in the $\sim 400 \text{ ug/cm}^2$ of material in this detector proved to be unacceptable. At present, two secondary electron detectors are available. The first uses an annular 2-stage micro-channel plate (MCP) designed to be mounted inside the scattering chamber. This detector has been used in several experiments and provided acceptable time resolution. However, intense background from the target and Faraday cup gives a very high counting rate which results in poor detection efficiency. A second detector, which has been tested with α -sources, will be installed in the detector box indicated in Fig. V.A3-1. This detector uses a conventional 2-stage MCP mounted out of plane at 45° . Testing is expected to be completed by mid-1987.

A "dedicated" set of electronics is mounted on the BRS to process signals from the detectors and to communicate with the data acquisition system. A simplified block diagram is shown in Fig. V.A3-6. The front-end electronics for the PPAD, MCP, and IC are conventional NIM modules consisting of linear amplifiers, constant fraction discriminators (CFD), time-to-amplitude converters (TAC), and NIM-level logic circuits. The amplifiers and leading-edge discriminators for each of the VDC sense wires are custom built cards mounted in a separate chassis⁶. The analog-to-digital converters (ADC), time-to-digital converters (TDC), input registers (LATCH), and scalers are conventional CAMAC modules. The event trigger is currently defined by signals from the PPAD, although other triggers can be added as needed. The PPAD also generates start signals for the TDC's and TAC's, gates for the ADC's, and a strobe for the LATCH, each having its own pulse width and timing requirements. On receipt of an EVENT pulse, the EVENT HANDLER executes a user supplied set of instructions for reading data, setting a BUSY signal which blocks subsequent triggers until the present event has been stored, and generating various control and output pulses such as the scaler INHIBIT and event ACCEPTED signals. Data are then transmitted to the data acquisition computers and stored on magnetic tape. A "standard" set of software has been written and is described in detail in a separate users guide. Instructions for using the data acquisition system are given in the HHIRF Computer Handbook.

Three gas handling systems are installed on the BRS to provide the different pressures required by the three focal plane detectors. A schematic of one system is shown in Fig. V.A3-7. Each system uses a capacitance type differential pressure gauge which measures the difference between the pressure in the detector, P_D , and a reference pressure, P_R , which in this case is the pressure in the surrounding vacuum chamber. The use of a differential gauge allows monitoring of

Fig. V.A3-6 Simplified block diagram of the electronics for the BRS detector system.

Fig. V.A3-7 Schematic of a gas handling system used for the standard focal plane detectors installed in the BRS.

the stress on the detector windows when roughing or backfilling the vacuum chamber. Safety features include a solenoid valve in the vacuum line to prevent backflow in the event of power failure, and automatic closure of the control valve if the pressure deviates by more than about $\pm 10\%$ from the set point. The latter feature will stop gas flow if the detector window should fail. The roughing valve allows rapid evacuation of the system, and the setup valve can be used to establish the pressure and flow rate before opening the valves to the detector. Digital display of the pressure is provided at the control panel on the BRS and also in the counting room.

f. Running HPRP

HPRP is a setup code available on the data acquisition computers which provides the user with most of the parameters needed for performing an experiment on the BRS. To run HPRP, first use the editor to construct a data file, FILENAME.EXT, containing the following:

Note	Entry	Format
1)	QUAD	A4
2)	EB,QB,S18,ZT,AT,MG/CM2,TITLE	F10,I5,F5,2I5,F10,10A4
3)	Z1,A1,Z2,A2,Z3,A3,Q3	7I5
	Blank Record	
4)	A2,Z3,A3,EX(I)	3I5,5X,6F10
	Blank Record	
5)	KG or -X,THETA,THETAT,DL,DR,ALPHA	F10,5F5

Then type: HPRP FILENAME.EXT (output to printer) or FILENAME.EXT,1 (output to console).

Notes:

1) QUAD in col's. 1-4 indicates Q18-2 is on; delete record if Q18-2 is off.

2) EB,QB = beam energy and charge state; S18 = horizontal opening of the slit at Q18-1; ZT,AT,MG/CM2 describe the main constituent of the target-only used for energy loss calculations.

3) Defines reactions of interest. Up to 5 reactions can be specified on successive records. Q3 is the charge state of the detected particle.

4) Reactions, from those which have been defined, for which spectrograph parameters are to be calculated. Up to six excitation energies EX(I) can be specified on each record and any number of records can be included. A total of at least two values of EX must be given in order to calculate DL and DR.

5) If BRS field is entered (KG), the focal plane position is calculated; if negative of focal plane position is entered (-X), required field is calculated. If the focal plane settings (DL and DR) are omitted, they will be calculated; if included they will be held fixed. THETA, THETAT, and ALPHA are the scattering angle, target angle, and BRS angular acceptance in degrees, respectively. Any number of records may be included.

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⁴W. Bertozzi, et.al., Nucl. Instr. Meth. 141 (1977) 457.

⁵M. V. Hynes, et.al., Nucl. Instr. Meth. 224 (1984) 89.

⁶T. P. Sjoreen, et.al., Nucl. Instr. Meth. 224 (1984) 421.

V.A4. Time-of-Flight Spectrometer

a. Introduction

The heavy-ion time-of-flight spectrometer is a general purpose instrument which may be used by experimentalists to classify nuclear reaction products by determining their mass and atomic number while simultaneously measuring their kinetic energy for a given angle ϕ . An advantage of this instrument is its large kinematic acceptance: products with mass greater than $A = 4$ amu and energies greater than about 0.5 MeV can be detected with good efficiency. Studies can be made of products emitted in many types of reactions such as elastic and inelastic scattering, few-nucleon transfer, deeply-inelastic reactions as well as fusion and fission reactions.

The general lay-out of the spectrometer is shown in Fig. V.A4-1. The main components include a 30.5-cm (12-in.) diam scattering chamber, two general purpose boxes which contain the timing start and stop detectors and at the end of the flight path an ionization chamber that may be used for atomic number identification and total energy determination. The spectrometer is available for coupled accelerator operation (tandem-ORIC) or tandem alone on beam lines C17 or 51, respectively.

b. The Chamber and Flight Arm

The chamber has an inside diameter of 30.5 cm (12 in.) and contains two rotating plates for mounting detectors of various kinds. The plates are moved manually from outside the chamber and may be positioned to within 0.1 deg as determined by a digital read-out. There are two target mounting devices available: 1) a five-position target ladder with manual placement, and 2) an eight-position target wheel which may be operated remotely. The standard frame which fits both target holders is 2.86 (1.125 in.) x 2.86 (1.125 in.) by 0.051 cm (0.020 in.) thick aluminum with a hole 1.91 cm (3/4 in.) in diameter.

Two Faraday cups are available, one for angles less than 10° that is built into the flight arm and another that may be placed into the beam for flight arm angles larger than 10° . There are two mounting brackets on the chamber wall for monitor detectors.

The chamber entrance is equipped with two sets of adjustable slits and an anti-scattering baffle. These are necessary for beam spot definition at small detection angles.

Fig. V.A4-1 Sketch of the Time-of-Flight facility (side view).

The flight arm shown in the right-hand part of Fig. V.A4-1 has two boxes for mounting start and stop detectors. The dimension and configuration of these boxes are the same. The inside dimensions are 15.24-cm vertical and 12.7-cm width by 20.32-cm length along the beam direction. Top plates are designed with six electrical feedthroughs and two posts with sliding seals. The distance from the bottom of these plates to the reaction plane is 8.89 cm (3.5 in.).

c. Timing Detectors

The timing detectors currently in use are described below. They are not available to all users on a routine basis, but potential users are encouraged to address questions concerning their availability to the mentor for the time-of-flight spectrometer.

The time of flight of the reaction products can be determined by two microchannel plate assemblies. A side view of one of these is shown in Fig. V.A4-2. The standard converter foil is $20 \mu\text{g}/\text{cm}^2$ of carbon. The user may obtain frames from the mentor for mounting other foils of his choice. Since the carbon foils are at 45° to the flight path, the heavier products will have a significant time spread due to differences in flight path. This problem is eliminated by measuring the position of the particle path in the ionization chamber. Typical time resolution for this system is 150 psec. The flight distance is limited by the flight arm support and length of the ΔE -E detector. Arrangements for any non-standard flight distance must be made with the mentor at least 8 weeks prior to the run.

Multiwire proportional counters (MWPC) are also available under the same conditions as the microchannel plate detectors. There are two types of these detectors, one is position sensitive with 8 cm x 10 cm aperture and the other is a small, 2 cm x 2 cm aperture, fast timing detector with no position information. The small detector may be used for a start signal and the larger MWPC may be used for the stop signal as well as for position information at the entrance of the total energy detector which is described below. The time resolution with these detectors is approximately 300 psec. Details and availability of these detectors and associated electronics may be obtained from the mentor.

The mass resolution depends on the resolution of the energy detector as well as the time resolution and the system can provide individual mass identification over a wide range of products. A mass distribution for $^{20}\text{Ne} + ^{27}\text{Al}$ is shown in Fig. V.A4-3.

Fig. V.A4-2 Sketch of the fast timing detector used on the Time-of-Flight facility (side view).

Fig. V.A4-3 Illustration of the mass resolution of the Time-of-Flight facility obtained with 167-MeV Ne ions on ^{27}Al .

d. The Energy Detector

The last element of the system is a gas ionization detector. A photograph of the internal structure of this detector is shown in Fig. V.A4-4. At the entrance of the detector, a box is provided for mounting the MWPC for timing and position information. The ionization chamber is 80 cm deep and has an anode which is divided into 4 sections. This arrangement gives good total energy measurement ($\Delta E/E \sim 0.5\%$) as well as energy loss for good atomic number (Z) identification.

e. Fast Electronics

Dedicated electronic modules are available for fast timing measurements. These are noncommercial, specialized units designed to operate with the timing detectors described above. The components are fast rise-time, fixed-gain dc coupled amplifiers and constant fraction discriminators. The availability of these modules is subject to the same constraints as the timing detectors.

f. Equipment Availability

Except for the timing detectors, their associated fast electronics and solid state detectors, all items of equipment are available to all users. Special arrangements for using the timing detectors and electronics must be made with the mentor of the time-of-flight spectrometer.

Users who need to install their own detectors or require a non-standard configuration are requested to contact the mentor of the time-of-flight spectrometer or the HHIRF Liaison Officer.

Fig. V.A4-4 Photograph of the electrode assembly in the 80-cm long ionization chamber (ΔE -E detector) used on the Time-of-Flight facility.

V.A5. UNISOR Facility

The UNISOR facility, built around a Danfysik isotope separator, is designed to provide mass-separated samples, or beams, of stable and radioactive atoms. Intended primarily for studies of neutron-deficient nuclei in the region far from stability, it consists of an isotope separator installed "on-line" to the HHIRF accelerators. Operated in this mode, nuclei produced by heavy-ion reactions on targets located in the vicinity of the separator's ion source can be provided. The separator can also be operated "off-line" for mass separations of stable or long-lived material. The separator can provide a spot or line focus (at the focal plane) with a mass resolution, $\Delta A/A$ (in amu), less than $1/2000$, a dispersion (in cm) of $150/A_{\text{central}}$ with a range, $(A_{\text{max}} - A_{\text{min}})/A_{\text{min}}$, of 15%. Efficiencies vary widely, dependent upon a number of factors.

For on-line operations, the ion sources presently in use include low temperature plasma sources, high temperature plasma sources, thermal ionization sources, a helium-jet-coupled plasma source and an electron-beam-ionization source. These sources should be capable of ionizing the noble gases and most elements in groups I, II, III, IVA, VA, VIA, and VIIA, and most of the lanthanide series. All elements, however, have not been tested and there is the possibility of unknown chemical or physical effects decreasing this number. Furthermore, the target material must be relatively refractory causing additional limitation in the elements that can be produced. For those elements that can be ionized, total system efficiency will be in the range of 0.1-10%. Targets usually must be sufficiently thin (several mg/cm^2) for the reaction products to recoil out of the target into the ion source. A final limitation on the production rate, for a specific isotope, is the ion-source "hold-up time". The delay in the ion source is a statistical function of exponentially-decreasing behavior. Measured "delay half-lives" are in the range of 0.6-4 s, depending upon the element being ionized, the catcher material, the ion source in use and its mode of operation.

The facility currently has three separated-beam lines operational providing for three simultaneous, fully on-line, experiments. In addition, the separator focal plane is available for collecting long-lived material. Each beam line is equipped with a tape transport system capable of moving the collected activity from the collection-point to a shielded counting station where conventional spectroscopy can be performed using alpha, electron or gamma-ray detectors.

Two computer-based data acquisition systems are available. The first, a Tennecomp TP-5000 system, is located in the UNISOR facility. This system has 6 Nuclear Data ADC's, 1600 BPI magnetic tape drive, magnetic disk and live display. Programs are available for running standard spectroscopy experiments including spectrum multiscaling on several detectors simultaneously while acquiring multiparameter coincidence data on magnetic tape. The second is the HHIRF Perkin-Elmer system described in detail elsewhere. Special programs and hardware have been developed to adapt this system to running UNISOR experiments, including controlling the tape systems and running more than one experiment at a time.

A laser facility has been developed and placed on-line to the UNISOR separator. This facility is capable of measuring, for example, the atomic hyperfine structure of isotopes produced on-line, using the technique of collinear fast-atom/laser beams spectroscopy. Application of the system depends greatly on the atomic species. It has been used to measure the atomic hfs of light Tl isotopes at rates as low as 8×10^4 atoms/s.

A helium dilution refrigerator is being installed and is expected to be operational in 1987. This system will be placed on-line to the separator to form a nuclear orientation facility which will allow determination of gamma ray multipole mixing ratios, spins of excited nuclear states, and spins and magnetic moments of nuclei in their ground state.

V.A6. Gamma-Ray Spectrometer Systems

a. Beam line 23 (tandem beams only)

A gamma-ray spectrometer system located on beam line 23 (see Fig. V.A-1) has considerable flexibility designed into it to provide for a variety of experiments. A 1.5-m-diameter stainless steel plate is installed at floor level with a support post at the center. The top plate of the post, which rests 17.8 cm below the beam position and 116 cm above floor level, contains O-ring grooves at radii of 7.4 and 10.0 cm; this plate provides the base of cylindrical reaction chambers of similar radii. Each user is expected to supply the upper housing of the reaction chamber necessary for his experiment. Also located on this chamber base plate are positioning slots for mounting small particle detectors. The slots are positioned at every 20° on a radius of 2.5 cm and at every 10° on radii of 5.1, 5.7 and 9.0 cm.

Up to five Ge detectors in large dewars can be mounted about the center axis of the chamber. Target-to-detector distance variation of 2 to 15 cm is possible by vernier adjustment. Each dewar rests on an adjustable stand which can be attached to the support post. A larger support stand is designed for such items as an electron spectrometer or a Compton suppression spectrometer which, together with its shielding material, may weigh up to 1000 kg. This system can be moved through an angular range of about 250° .

The movement of large detector systems above the reaction chamber is easily accommodated by a support system which moves along overhead rails. This trolley arrangement permits movement of suspended detector arrays along the beam line path for a few feet on either side of the reaction chamber.

A general purpose reaction chamber, illustrated in Fig. V.A6-1, is also available. This simple chamber can be attached easily to the beam line at any experimental station and can accommodate an array of Ge detectors extending back to an angle of 30° in the horizontal plane as well as additional detectors (including large volume NaI detectors for total energy determinations) above and below the plane. Dimensional aspects of the target frames for use in this chamber are also shown in Fig. V.A6-1.

b. Beam line 7 (Coupled accelerator beams only)

An additional γ -ray experimental station, located on beam line C7, is also available. An angular correlation device, providing for two movable detectors, or a scattering chamber can be installed at this station. Since the space available is relatively small, the types of experiments that can be done are somewhat limited.

Fig. V.A6-1

Cross-section of a small, general-purpose reaction chamber used for gamma-ray studies. Dimensions of the target frames are given on the right.

V.A7. Spin Spectrometer

a. General Description

The Spin Spectrometer is a 4π array of 72 NaI detectors that approximates a hollow sphere with inner radius 17.8 cm (7.00 in.) and shell thickness 17.7 cm (6.95 in.) (Fig. V.A7-1). Each detector is a tapered prism that can be removed or inserted radially. Twelve have cross sections that are regular pentagons. Each pentagonal detector is surrounded by five detectors of irregular hexagonal cross section. The solid angle subtended by each detector is the same and close to $4\pi/72$; the useful solid angle is about $2\frac{1}{2}\%$ less because of the wall thickness of the cans and the internal packing material.

The detectors are supported by a frame made of 2.54-cm (1-in.) diameter aluminum rods based on twelve pentagons whose centers lie above the centers of the pentagonal detectors. The frame is split into two parts, each of which stands on a movable table that may be rolled on tracks perpendicular to the beam line to gain access to the reaction chamber. The overall outer diameter, including phototubes and bases, is about 1.8 m (6 ft). The center is at the normal beam height, ~ 121.5 cm (48.0 in.) above the floor.

The 72 positions in the Spin Spectrometer are designated A0-A5, B0-B5, ..., L0-L5. For each group of 6 with a given letter, the label 0 refers to the pentagonal unit and 1-5 refer to the hexagonal units surrounding it. The corresponding electronics channels are numbered from 0 through 71. Table V.A7-1 lists the angles for each position.

To accommodate the entrance and exit beam pipes, two pentagonal detectors, A0 and G0, are removed from opposite sides of the sphere. Additional units may be removed as required to accommodate other apparatus such as Ge detectors. Any pentagonal detector may be removed. This is not generally true for the hexagonal units, but about 20 or more hex units are accessible from the split between the halves of the Spectrometer. These units include all the detectors closest to the beam line and several near 90° . Experiments should be designed to use these accessible positions.

Note: Removal or insertion of NaI units is a delicate operation requiring special tools and know-how to avoid damage. Users who wish to have the configuration changed must ask a qualified person to do the job.

A set of Compton-suppressed Ge counters designed to replace NaI units of the Spin Spectrometer is available. See Section V.A8 for a full description.

Fig. V.A7-1 Photograph of the Spin Spectrometer. The two hemispheres are separated to show the spherical reaction chamber and beam line.

Table V.A7-1. Positions in the Spin Spectrometer. The angles are defined in a spherical polar coordinate system with its polar axis ($\theta = 0$) along the beam direction. The azimuthal angles are positive clockwise from the vertical ($\phi = 0$) as seen when facing the beam dump. Centroid angles are first moments taken over the face of each detector.

Detector		Centroid		Midpoint	
No.	Position	θ (deg)	ϕ (deg)	θ (deg)	ϕ (deg)
0	A0	0.00	0.00	0.00	0.00
1	A1	24.42	13.11	24.70	13.11
2	A2	24.42	85.11	24.70	85.11
3	A3	24.42	157.11	24.70	157.11
4	A4	24.42	-130.89	24.70	-130.89
5	A5	24.42	-58.89	24.70	-58.89
6	B0	63.43	180.00	63.43	180.00
7	B1	87.30	-174.61	87.58	-174.56
8	B2	67.93	-153.61	68.01	-153.32
9	B3	41.59	-165.98	41.36	-165.76
10	B4	49.51	155.73	49.38	155.41
11	B5	77.52	158.74	77.69	158.52
12	C0	63.43	108.00	63.43	108.00
13	C1	87.30	113.39	87.58	113.44
14	C2	67.93	134.39	68.01	134.68
15	C3	41.59	122.02	41.36	122.24
16	C4	49.51	83.73	49.38	83.41
17	C5	77.52	86.74	77.69	86.52
18	D0	63.43	36.00	63.43	36.00
19	D1	87.30	41.39	87.58	41.44
20	D2	67.93	62.39	68.01	62.68
21	D3	41.59	50.02	41.36	50.24
22	D4	49.51	11.73	49.38	11.41
23	D5	77.52	14.74	77.69	14.52
24	E0	63.43	-36.00	63.43	-36.00
25	E1	87.30	-30.61	87.58	-30.56
26	E2	67.93	-9.61	68.01	-9.32
27	E3	41.59	-21.98	41.36	-21.76
28	E4	49.51	-60.27	49.38	-60.59
29	E5	77.52	-57.26	77.69	-57.48
30	F0	63.43	-108.00	63.43	-108.00
31	F1	87.30	-102.61	87.58	-102.56
32	F2	67.93	-81.61	68.01	-81.32
33	F3	41.59	-93.98	41.36	-93.76
34	F4	49.51	-132.27	49.38	-132.59
35	F5	77.52	-129.26	77.69	-129.48

Table V.A7-1 (continued)

Detector		Centroid		Midpoint	
No.	Position	θ (deg)	ϕ (deg)	θ (deg)	ϕ (deg)
36	G0	180.00	180.00	180.00	180.00
37	G1	155.58	166.89	155.30	166.89
38	G2	155.58	94.89	155.30	94.89
39	G3	155.58	22.89	155.30	22.89
40	G4	155.58	-49.11	155.30	-49.11
41	G5	155.58	-121.11	155.30	-121.11
42	H0	116.57	0.00	116.57	0.00
43	H1	92.70	-5.39	92.42	-5.44
44	H2	112.07	-26.39	111.99	-26.68
45	H3	138.41	-14.02	138.64	-14.24
46	H4	130.49	24.27	130.62	24.59
47	H5	102.48	21.26	102.31	21.48
48	I0	116.57	72.00	116.57	72.00
49	I1	92.70	66.61	92.42	66.56
50	I2	112.07	45.61	111.99	45.32
51	I3	138.41	57.98	138.64	57.76
52	I4	130.49	96.27	130.62	96.59
53	I5	102.48	93.26	102.31	93.48
54	J0	116.57	144.00	116.57	144.00
55	J1	92.70	138.61	92.42	138.56
56	J2	112.07	117.61	111.99	117.32
57	J3	138.41	129.98	138.64	129.76
58	J4	130.49	168.27	130.62	168.59
59	J5	102.48	165.26	102.31	165.48
60	K0	116.57	-144.00	116.57	-144.00
61	K1	92.70	-149.39	92.42	-149.44
62	K2	112.07	-170.39	111.99	-170.68
63	K3	138.41	-158.02	138.64	-158.24
64	K4	130.49	-119.73	130.62	-119.41
65	K5	102.48	-122.74	102.31	-122.52
66	L0	116.57	-72.00	116.57	-72.00
67	L1	92.70	-77.39	92.42	-77.44
68	L2	112.07	-98.39	111.99	-98.68
69	L3	138.41	-86.02	138.64	-86.24
70	L4	130.49	-47.73	130.62	-47.41
71	L5	102.48	-50.74	102.31	-50.52

b. NaI Detectors

The NaI detectors are tapered hexagonal or pentagonal prisms sealed inside aluminum cans having a thickness of ~ 1.0 mm (0.040 in.). In some units certain areas of the side walls are thinner, but not less than 0.4 mm (0.015 in.).

Each NaI prism is viewed from its large end by an RCA-4522/12.7-cm (5-in.) phototube operating at ~ 1.9 kV negative. The original performance specifications called for pulse-height resolution $< 9\%$ FWHM for 662 keV γ rays, time spreads for ^{60}Co γ rays of < 2.5 ns FWHM and < 5.5 ns FWTM with a 100-keV threshold, and a pulse-height stability of 1% up to 50 000 counts/sec. With very few exceptions, all units met the resolution and timing specifications in early 1980. The average pulse-height resolution was then 8.6%. With the passage of time, a number of detectors have become more or less yellow and their resolution has deteriorated. In August 1984, most of the NaI crystals were found to be severely cracked at the cemented interface between the NaI and the glass window, causing some further degradation in performance. Overall, the average pulse-height resolution increased by about 25% from late 1981 to early 1985. Detectors are being replaced as part of an on-going refurbishment program and the average resolution will vary with time. Users having stringent requirements should contact the mentor of the spin spectrometer to obtain the current values.

The stability specification is met or exceeded for most of the detectors provided that the potentiometers on the tube base are set correctly. This adjustment is critical. Users must not change these settings without permission of the mentor.

c. Germanium detectors

A number of Compton-suppressed Ge detector systems, designed to fit into the Spin Spectrometer, are available (see section V.A8). In addition, the HHIRF owns a few long-necked Ge(Li) detectors that can be used at position 10 and at certain forward angles.

d. Reaction Chamber

A spherical aluminum reaction chamber with 3-mm (1/8-in.) wall thickness is available for use inside the NaI array (see Fig. V.A7-1). Its inside diameter is 33 cm (13.0 in.) and it is split into hemispheres at a angle of 65° . The entrance and exit pipes are welded to their respective hemispheres. These pipes provide a clear space of ~ 63 -mm (2 1/2-in.) inside diameter for beam transport.

Signal cables from counters within the chamber are routed through an annulus inside the entrance pipe and terminate upstream at a box with three large ports. Several cover plates are available, including two with 18 BNC vacuum feedthroughs each and one with five copper lines for gas or liquid.

Four flanged ports are provided on the sphere. Three of them (ports A, B, C of Table V.A7-2 and Fig. V.A7-2) may be fitted with a reentrant cup of 76 mm (3.00-in.) inside diameter, large enough to admit a germanium detector. The cups on hand are thin-walled and permit external Ge detectors to be placed as close to the target as 9 cm. In most experiments, however, ports A, B, and C are covered with aluminum or transparent plastic. Note: The metal cover plates must be secured with specially-shortened screws; use of standard-length screws will cause a vacuum leak. These special screws are kept in the drawer labeled "Spherical Chamber Parts."

The fourth port (port T of Table V.A7-2 and Fig. V.A7-2) is smaller and is normally used for the target rod. One target at a time may be mounted on the rod. A target frame that will fit this mount is sketched in Fig. V.A7-3.

The chamber may be rotated about the beam axis through any angle. In the standard position of the reaction chamber, with port T on top, ports A, B, and C are centered exactly below the detectors at positions I0, L3, and F1, respectively. Rotation in increments of 72° will position these ports directly below four other sets of detectors.

A five-position target holder is available for mounting on any of the three large ports. Target frames that will fit this holder are shown in Fig. V.A7-4. These are a standard design of the Niels Bohr Institute Tandem Accelerator Laboratory.

The entrance hemisphere accepts curved aluminum bars (inside radius 5-15/16 inches, cross section $\frac{1}{2} \times \frac{1}{2}$ inch square) to support detectors or telescopes mounted on 6.3-mm (0.250-in.) diameter rods or tubes. These bars have radial holes at intervals of 5° to accept the mounting rods.

Note: All the mounting hardware is delicate, having been made of thin plastic or aluminum to minimize interactions with γ rays.

Users with special requirements not met by the spherical chamber may remove it and install their own chamber, subject to approval of the mentor.

Table V.A7-2. Ports in the spherical reaction chamber.

Port	Standard position	Diameter ^a cm (in.)	θ^b (deg)	ϕ^b (deg)	Opening ^c cm (in.)
A	I0	7.9 (3.125)	116.57	+72.00	8.8 (3.48)
B	L3	"	138.65	-86.25	7.6 (2.98)
C	F1	"	87.58	-102.56	"
T	Top	3.8 (1.500)	110.00	0.00	-

a) Inside diameter of the open port. See Fig. V.A7-2.

b) See Table V.A7-1 for definition.

c) Minimum diameter of opening in NaI array when NaI unit is removed.

4 HOLES EQUALLY SPACED ON $3\frac{7}{8}$ DIA BOLT CIRCLE
DRILL AND TAP 6-32 $\times$ 1/4 DEEP

(c)
SCRIBE LINES EVERY 10°

3 HOLES EQUALLY SPACED ON $2\frac{1}{4}$ DIA BOLT CIRCLE
DRILL AND TAP 6-32 $\times$ 1/4 DEEP
O-RING GROOVE: $1\frac{3}{8}$ ID, 5/32 WIDE, 0.115 DEEP

4 HOLES EQUALLY SPACED $3\frac{7}{8}$ DIA BOLT
CIRCLE CLEARANCE FOR 6-32

GROOVE: $3\frac{1}{4}$ ID, 5/32 CIRCLE, 0.115 DEEP
MAXIMUM THICKNESS ALLOWABLE WITH
STANDARD 6-32 SOCKET HEAD SCREW

Fig. V.A7-2

a) Sketch of ports A, B, C. b) Sketch of covers for ports A, B, C. The four holes should be counterbored 3/32 inch deep for 6-32 socket-head screws. c) Sketch of port T. Dimensions are given in inches.

Fig. V.A7-3

Sketch of a target frame for use with the single-target mounting rod inserted in port T. The dimensions are given in inches. The material is normally aluminum. Since port T is at 110° , the beam will not be normal to the target. For normal incidence, the frame should be bent 20° along a line about 1 cm below the center of the hole and the frame mounted on the off-center side of the target holder.

Fig. V.A7-4

Sketch of a target frame for use in the five-position target holder. The material is normally aluminum.

THICKNESS: 0.5 mm
ALL DIMENSIONS ARE IN mm

e. Beam Line

The Spin Spectrometer is on beam line C15 which can receive beam both from the tandem or from ORIC. The normal method for beam transport requires intermediate foci within or near certain beam-switching magnets to cancel the energy dispersion and thereby minimize the spot size. Spot diameters of 2 mm or less from the tandem alone or coupled to ORIC have been obtained without use of collimators. Focusing and positioning of the beam spot in the center of the reaction chamber are checked with a phosphor in place of the target.

The beam dump is shielded and as far as possible from the Spin Spectrometer. Radiation from the beam dump has not been significant in any experiment carried out thus far. Beam stoppers of Ta, C or Al are available. The beam stopper can be changed by opening the far end of the Faraday cup.

f. Data Acquisition

The dedicated electronics include custom-made constant-fraction discriminators, fast analog circuits for multiplicity and sum-energy selection, and the microprocessor-like Event Handler, plus commercially-built wide band amplifiers (LeCroy 612A), CAMAC ADC's (LeCroy 2249A), and TDC's (LeCroy 2228A). All modules are located in the south counting room, near the Spin Spectrometer. Digital information from the CAMAC-based equipment is transmitted via a branch highway to one of the Perkin-Elmer computers. The high voltage power supplies (LeCroy 4032 and 4032A) are also interfaced with the computer via a LeCroy 2132 controller and a serial highway.

The Event Handler is programmable. It may be used to select which events meet the experimenter's criteria and which parameters of such events should be transmitted to the computer. The computer may be used to make further selections and modify the data stream before the events are permanently recorded. The computer can also provide on-line sampling for checking the validity of the data being recorded. Data from supplementary detectors may be processed by additional CAMAC units and interfaced via the same Event Handler.

The time required for digitization and transmission to the computer limits the data acquisition rate to ~ 2000 to 4000/sec, depending on the average multiplicity. In some experiments the rate is governed by the allowable singles rates or by the rate at which magnetic tape can be written.

g. Set Up, Record Keeping, and Data Analysis

A large body of software and documentation has been written for the Spin Spectrometer. At ORNL, this is resident on the Perkin-Elmer computer in account 200 (password SS) and is documented extensively in loose-leaf books labeled SPINSPEC.DOC kept in the Perkin-Elmer computer room and the counting rooms.

Information on detector serial number, HV, position, CAMAC addresses, etc., together with detector performance (gain, resolution, etc.) is kept in a disk file called SPINSPEC.USR. This file is unique for each experiment. It is referenced and updated automatically by a number of programs. The user should be sure that a valid userfile exists in the account under which he is running his experiment.

Software for the analysis of Spectrometer data (gain corrections, neutron-gamma separation by time of flight, etc.) exists on the Perkin-Elmer computers and is described in the above-mentioned documentation. Parallel programs and documentation exist on the Nuclear Chemistry VAX 11/780 at Washington University.

Calibration methods and examples of data are given in Ref. 1.

h. General Information

The concept of the Spin Spectrometer was developed by D. G. Sarantites, Professor of Chemistry at Washington University, St. Louis, and most aspects have been under his general supervision.¹⁻³ Most of the mechanical components including the NaI cans were designed by John T. Hood, engineer at Washington University, and constructed in their cyclotron shop under a contract with Oak Ridge National Laboratory. Some of the fittings for the reaction chamber were designed by J. H. Barker, then at St. Louis University, and built in his shop. Harshaw Chemical Company supplied the NaI and packaged the detectors. Testing the NaI detectors was done by M. Jääskeläinen at Washington University. The special electronic components, computer linkages, and data acquisition programs were designed by D. C. Hensley of ORNL. M. L. Halbert (ORNL) worked out the beam transport system and the computer programs for set up and operation of the Spin Spectrometer.

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V.A8. Compton-Suppression Spectrometer System

To accommodate a new generation of high efficiency γ - γ coincidence experiments, we have acquired a large array of Compton-suppressed Ge detectors. Each of these detectors can be inserted into a Spin Spectrometer location, replacing an existing solid hexagonal or pentagonal NaI detector. An illustration of a pentagonal unit is shown in Fig. V.A8-1. A 2.5-inch axial penetration in the outer Compton suppression shield permits insertion of the large-volume N-type Ge detector. The cooling arm of the Ge detector is 0.75 inches in diameter and can accommodate a split annular Compton suppressor which intercepts the forward-scattered photons from the Ge detector.

Tests have been performed on a prototype system consisting of a pentagonal BGO suppressor shield, an n-type Ge detector with an efficiency of 24% (standard notation), and a small split annular BGO detector located behind the Ge detector. The results for a ^{60}Co source are summarized in Fig. V.A8-2 where the full energy peaks at 1.17 and 1.33 MeV are off scale. For this measurement the Ge detector was pulled back 2 cm behind the front lip of the suppression shield. Note that the front lip of this prototype shield was 0.39-inch thick NaI and the front opening was 1.89 inches in diameter. To capture more effectively the photons back-scattered from the Ge detector, the front lip in the final design of the BGO suppressors is 0.79 inch thick, with a 1.65-inch diameter front opening. This results in a Compton-suppressed spectrum having a reduced level of counts in the region of channels ~550 to ~750.

There are presently 22 Compton suppression shields available. These include 12 BGO shields (3 hexagonal, 9 pentagonal) and 10 NaI shields (4 hexagonal and 6 pentagonal). The BGO shields provide a suppression factor of about 5-6, which is about twice that for the NaI shields. Experiments have been completed with as many as 18 Compton suppressed Ge detectors installed in the spin spectrometer. However, the Ge detectors are relatively fragile and the number of operational systems may vary with time. Dedicated electronics, including high resolution 14-bit ADC's, have been purchased for use with the Compton suppression system.

When used in the Spin Spectrometer ball, the Compton suppression array can take advantage of the total energy and γ -ray multiplicity selection. In fact, there exists the capability to add back into the ball, most of the energy and multiplicity information from the suppression devices. In addition to spectroscopy experiments, the Compton suppression system is very useful for reaction studies because of the large central cavity in the ball where it is possible to locate a complex array of particle detectors.

Fig. V.A8-1

Cross-sectional view of a pentagonal Compton-suppression shield for use in the Spin Spectrometer. Also shown is the small split-annular detector mounted on the cooling arm of the Ge-detector.

Fig. V.A8-2 Illustration of the suppression achieved with the BGO-shield. The source was ^{60}Co .

As noted in Sect. V.A7, not all spin spectrometer positions can be used for installing Compton suppression units. The following table lists spin spectrometer locations which can be used for suppression units. Other locations may be possible, but the user should consult the mentor of the spin spectrometer before planning to use locations other than those listed.

Hexagonal detector locations:

<u>Angle</u>	<u>Spin Spectrometer Position (see table V.A7-1)</u>
~24°	A2, A3, A4, A5
~155°	G2, G4, G5
~90°	D1, E1, F1

Pentagonal detector locations:

0°	A0
~63°	C0, D0, E0, F0
~117°	I0, J0, K0, L0

Although the Compton suppression system was designed so it can be used in the spin spectrometer, there may be times when the relatively large target-to-detector distance (~20 cm) is undesirable, such as in the study of triple or higher-order coincidences. For such cases, a support stand is being designed which will allow the Compton suppression units to be mounted in close geometry and operated in a "stand-alone" configuration.

Due to the complex nature of the Compton suppression system, there exists the possibility of extensive and costly damages in all aspects of an experiment from the setting up to the removal of equipment following the completion of measurements. Thus, it is necessary that experimenters carry out all such operations under the supervision of the mentor and technician in charge of these facilities. It is probably advisable that this consultation process begin prior to the submittal of a written proposal for beam time.

V.A9. 80-cm Spherical Chamber

A thin-walled, spherical, aluminum chamber has been made available for use at the HIRF. An all aluminum beam line, including a "feedthrough box," two cryopumps, and a reconfigurable beam dump, has also been installed on beam line C9 to accompany the chamber. A schematic of the chamber and beam line is shown in Fig. V.A9-1. Full mechanical drawings for all chamber and beam line ports and assemblies are available on request.

The chamber consists of two hemispheres of 40-cm radius spun from 3.4-mm-thick type 6061T aluminum alloy plates. The wall thickness is typically 10% thinner than this due to the effects of spinning, with thickness variations of ~ 10% going from pole to equator of a given hemisphere. The hemispheres are joined on a plane by 0.95 cm x 2.22 cm aluminum flanges, one of which contains a Viton O-ring. Handles are provided for lifting off the upper hemisphere, to which is attached only a 60-cm-long piece of the 7.62-cm diameter downstream beam pipe. The plane joining the hemispheres is inclined at 45° to the beam axis and intersects a horizontal (reaction) plane at $\theta = \pm 90^\circ$ with respect to the beam axis.

A target ladder, shown in Fig. V.A9-2, is mounted to the lowest point of the lower hemisphere. It will hold four targets (or phosphors, etc.) mounted on 1.125 in. square x ≤ 0.032 in. thick Al frames. The ladder can be moved up and down with its vertical position fixed by a pin and a series of holes drilled in the portion of the ladder outside the chamber. Mounted concentric to the target ladder mechanical feedthrough are two other mechanical feedthroughs, to which are mounted inner and outer detector support rings, dimensions of which are shown in Fig. V.A9-3. Both have mounting surfaces located 6.35 cm below the beam axis and have mounting slots spaced around their circumference. The slots are also marked in degrees. The two rings can be rotated independently, as can the target ladder. A set of three angle position markers for the detector rings and the target is located below the chamber. The user may also choose to remove the rings and their supports and attach his own devices to the internal mounting plates for the rings.

A set of 14 BNC feedthroughs is provided on the lower hemisphere, 7 each on 2 insulated black Delrin flanges. Thirty-eight other BNC feedthroughs, 3 sets of gas feedthroughs, and vacuum gauges are located on a "feedthrough box" located 100 cm upstream of the chamber center. These are reached by cables and gas lines placed in the upstream beam line; a 5.5-cm diam sleeve inside the 9.5-cm diam beam line keeps these cables and gas lines from intercepting the beam. Spare flanges exist for this feedthrough box to be tailored to the users' needs.

Fig. V.A9-1

Schematic of the 80-cm Spherical Chamber and typical associated hardware. Dimensions are in inches.

TARGET LADDER, 6061 T6 ALUMINUM
80 cm NEUTRON CHAMBER

Fig. V.A9-2 Target ladder used with the 80-cm Spherical Chamber. Dimensions are in inches.

	DIA C	DIA B	DIA A
OUTER RING	30.500	26.500	14.125
INTER RING	24.500	20.500	11.125

MATERIAL: 6061 T6 Al

INNER, OUTER DETECTOR SUPPORT RINGS 80 cm NEUTRON CHAMBER

Fig. 7.A9-3

Sketch and dimensions of the rotatable detector mounting rings installed in the 80-cm Spherical Chamber. Dimensions are in inches.

A Faraday cup with guard ring is provided. The entire chamber and beam line are electrically insulated, while the BNC feedthroughs are insulated from the chamber. Two patch panels containing a total of 90 RG-58 cables with BNC feedthroughs and 50 RG-59 cables with SHV feedthroughs have been installed near beam line C9 for use with the chamber. These patch panels are marked "C111-S" and connect to the ORIC counting room.

A viewing port at 135° in the horizontal plane is provided together with an internal light to aid in viewing the chamber's contents while it is under vacuum. A second viewport located just above the beam axis upstream of the chamber is provided for viewing phosphors with a TV camera during beam tuneup.

A 1/8 in. thick steel plate has been attached to the floor to allow use of magnetic clamps on the base of portable neutron detector stands. Ten such all-aluminum stands exist.

Beam line C9 is only accessible to coupled-accelerator beams. Two quadrupole doublets and an x-y steerer pair comprise the beam optics. Usually, no slits or collimators are provided in order to minimize neutron background. It is possible to provide collimators just inside the cyclotron vault wall. Two cryopumps are provided on beam line C9, one just upstream of the "feedthrough box" and the other just upstream of the Faraday cup. The latter pump may be removed at the experimenters' request. Pressures below 1×10^{-6} torr have been obtained in the sphere. The sphere can be moved to other beam lines at the experimenters' request, although some expense for craft work will be incurred in doing so.

For coupled operation of the tandem and cyclotron, time resolutions of better than 1.5 ns FWHM have been observed for the beam arrival at the target relative to the cyclotron RF signal. These have been measured both by observing elastically scattered projectiles in silicon surface barrier detectors and by observing gamma rays in NE213 scintillators and Pb-glass Cerenkov counters. In all cases, the detector had a time resolution of 1 ns FWHM. These time resolutions have been observed for beams of 400-MeV ^{16}O , 600-MeV ^{24}Mg , and 705-MeV ^{32}S .

A photograph of the chamber, as used in an experiment measuring neutron-fission fragment coincidences, is shown in Fig. V.A9-4. Two parallel plate avalanche counters, mounted on a bar supported by the outer ring, can be seen. Also visible are the ten NE213 neutron counters with veto paddies and a 1-meter-long quartz tank containing NE213, thus forming a position-sensitive neutron counter. The protective light cover of the latter has been removed, as has the upper hemisphere of the chamber.

The upper hemisphere can be replaced by a suitable device of the experimenter's design, such as a hemisphere with penetrations to attach large external ion chambers. Suitable engineering design of a proposed replacement must be demonstrated before its installation, as the atmospheric pressure acting to collapse an 80-cm-diameter sphere is 22.9 English tons.

ORNL-PHOTO 6011-84

Fig. V.A9-4 Photograph of the 80-cm Spherical Chamber with internal and external detectors in place. The upper hemisphere has been removed to show the inside of the chamber.

V.A10. Velocity Filter

The velocity filter was developed through the combined efforts of ORNL and MIT. The device, which was designed by H. Enge, was fabricated at MIT and subsequently installed at HHIRF in 1982. A side view of the velocity filter is shown schematically in Fig. V.A10-1. The separated electrostatic and magnetic deflecting elements allow the desired particles to be transported through the device, while undesired particles are stopped by baffles. The selected particles are then focussed at the detector using a quadrupole doublet. Design features include built-in voltage multipliers for the electrostatic deflectors, which eliminate the need for high voltage cables, and microprocessor control of the various power supplies to facilitate tuning.

The velocity filter is installed on beam line 21 and is therefore only accessible to beams from the tandem accelerator. The maximum rigidity of the selected particles which can be fully deflected by the electrostatic elements is $E/q = 9.6$ MeV. Higher rigidity particles could be accommodated by reducing the amount of deflection. The maximum acceptance solid angle is 2.4 msr, and adjustable slits located at the entrance to the velocity filter can be used to reduce the acceptance if required. The velocity acceptance, $\Delta v/v$, is $\pm 5\%$. The entire device can be rotated about the target over the angular range -5° to $+22^\circ$. However, the useable range is presently limited to angles near 0° by the bellows attachment to the scattering chamber. A new chamber, having a sliding seal which will allow full angular coverage, is being designed and will be available by late 1987.

Fig. V.A10-1 Sketch of the Velocity Filter (side view).

Several detectors are available including a thin Breskin-type detector, which can be used to measure time-of-flight, and an ion-chamber plus silicon detector telescope for ΔE -E measurements. Any special detector requirements should be discussed with the mentor of the velocity filter before planning an experiment.

The compact structure of the velocity filter is shown in the photograph in Fig. V.A10-2. Also shown are the present spherical scattering chamber and associated beam line components.

ORNL-PHOTO 5570-83

Fig. V.A10-2 Photograph of the velocity filter (left), scattering chamber (center), and beam line 22 (right).

V.A11-1

V.A11. HILI Detector (available mid-1987)

A Heavy-Ion Light-Ion (HILI) detector system is being developed which will be able to detect multiple heavy- and light-ejectiles. The HILI detector will be located on beam line C20 and will, therefore, only have access to coupled-accelerator beams.

A schematic drawing giving the approximate angular range covered by the detector is shown in Fig. V.A11-1. The front sections are 30-cm deep ionization chambers which will provide E , ΔE , and position information for heavy particles. The upper and lower chambers are physically separated and can therefore be operated at different gas pressures. In addition, each chamber has a split anode structure to allow simultaneous detection of two heavy particles. Position sensitive parallel plate avalanche detectors, not shown, are located in front of the ion chambers to provide additional timing and position information for the heavy fragments.

The back sections will each contain 96 plastic scintillator telescopes arranged in a 6×16 array for measuring E , ΔE , and position of light charged particles. These detectors are designed to identify protons up to 140 MeV. Time-of-flight will also be determined to provide a crude measurement of neutron energies.

Initially, only the upper detectors will be completely instrumented, but implementation of the lower section is in the planning stage. More details will be provided following installation and in-beam testing of the detector.

ORNL-DWG 84-44393

Fig. V.A11-1 Sketch of the Heavy-Ion Light-Ion (HILI) detector.

V.B. Atomic Physics Apparatus

Apparatus for atomic physics research available to users are listed in Table V.B-1. These normally reside at the EN tandem site at ORNL, but they are all portable and can be brought to a beam line from the 25-MV tandem or ORIC when needed. Details on these devices can be obtained from the Atomic Physics Apparatus Mentor.

Table V.B-1. Atomic physics apparatus available for experiments at HHIRF.

Si and Ge X-ray spectrometers

Two curved crystal X-ray spectrometers; 10.2-cm Rowland circle

VUV grazing incidence spectrometer

Cylindrical mirror electron spectrometer

Parallel plate electron spectrometer

Beam foil target traverse apparatus

Electrostatic charge-state analyzer with magnetic quadrupole selective focusing

High resolution magnetic spectrometer for precision beam particle energy measurement

Merged electron-ion beam apparatus

Two precision goniometers for crystal channeling studies

Electrostatic beam particle charge state selector

C. Electronics

A general pool of electronics, listed in Appendix B, is available to all users. However, because there will be more than one research group set up at any given time, it does not necessarily follow that all modules are available to one particular group. To help us best meet your electronic needs, let us know well in advance what HHIRF modules are desired for your experiment. A large number of various types of signal cables are also available.

In addition to this electronics pool, several of the experimental devices (e.g., time-of-flight, magnetic spectrographs, spin spectrometer) have dedicated electronic systems.

With the exception of a few oscilloscopes, the HHIRF does not routinely calibrate electronic equipment. However, there are calibrated current sources available for researchers who wish to calibrate current integrators, and other instruments can be calibrated if required to meet the experimenters needs.

D. Equipment Not Provided by HHIRF

Sects. V.A., V.B., and V.C list experimental equipment which is provided by HHIRF. We wish to emphasize that some items will not be provided by the facility. These include Si detectors, targets, separated isotopes, expensive gases, and magnetic tapes.

E. Apparatus Provided by Users

Beam lines can be made available for portable apparatus brought by the user. The distance between the floor and the beam line in the two experimental rooms adjoining the tandem tower is 133.0 ± 1.3 cm (52.3 ± 0.5 in.). For the other beam lines it is 123.0 ± 1.3 cm (48.5 ± 0.5 in.). Each component must be able to pass through the ~ 1.2 m wide x 2 m high doors to the experimental areas.

All radioactive sources, and any equipment which has been exposed to radiation, must be checked by an ORNL health physicist before installation or use at the HHIRF. A radiation survey can be arranged by notifying any member of the operations staff upon your arrival.

V.E-2

Apparatus brought by users will be given an engineering and safety review and must meet certain criteria before its use will be permitted at HHIRF. It must be established that it will have no long-term detrimental effect on vacuum systems of HHIRF. New beam lines are being designed for an average pressure of $<10^{-7}$ Torr.

Figure V.E-1 shows the standard flange on the ORIC beam line. It is necessary for the portable apparatus brought in by the user to couple to this. The tandem beam lines will end with a standard hollow section, i.e. Ultek Model No. 267-4400, having a standard Varian type Conflat 15.24-cm (6.00-in.) flange.

Fig. V.E-1 Standard flange on the end of the ORIC beam lines. Dimensions are in mm (inches).

V.F-1

V.F. Signal Transport

Because the HHIRF has developed over several years, the signal cables between the experimental devices and counting rooms are not all the same. Table V.F-1 summarizes what is available. See Fig. V.A-1 for the locations of the various counting rooms.

Table V.F-1. Cables between different areas.

Between areas		Signal						HV
		RG8	RG8	RG58	RG62	RG62	RG114	RG22
		50Ω	50Ω	50Ω	93Ω	93Ω	185Ω	
Counting Room	- Device (Station)	BNC		BNC	BNC	UHF	UHF	Twin SHV
Tandem	- Velocity filter (21)			10	2			2
Tandem	- Gamma ray (23)	38						2 4
Tandem	- H.I. Applications (31)	24						2 4
Tandem	- Split pole (33)	24						2 4
Tandem	- Atomic physics (35)	24						2 4
ORIC	- Gamma ray (C7)		8			9	9	
ORIC	- Neutron (C8-10)	18	8	90		18	9	50
ORIC	- Spin Spec. (C15)	10				20		
ORIC	- Time of flight (C17)		18			9		
ORIC	- TOF, BRS, HILI (C17-20)	10		60	10			20
ORIC	- BRS (C18)		8			9	9	
ORIC	- HILI (C20)		8			9	9	
ORIC	- 1.6-m chamber (C16)	16		32				8
South	- Spin Spec. (C15)			40	18			20

VI. Computer Facility

a. Introduction

This Handbook section presents an overview of the data acquisition and analysis hardware and software available to HHIRF users. Detailed descriptions are provided in a separate Computer Handbook. Although continual growth is required to keep pace with ever-increasing user demands, the systems are fully developed and user-disorienting changes are not expected.

It is the policy of the HHIRF to furnish the facilities associated with one CPU, without cost to the user, during each scheduled experiment. Additional capabilities will be provided on an "as-available" basis; however, users of large amounts of computer time may be charged a prorated fraction of the operational cost of the system. The capital cost of the system is borne fully by the HHIRF.

The system is heavily loaded -- around the clock CPU utilization averages about 40% and tape drive utilization is somewhat higher. Whether this load constitutes saturation is a subjective judgement -- those forced to work nights and weekends probably vote in the affirmative. The priorities for use of the facilities continue to be:

1. data acquisition, including a reasonable amount of setup and calibration time,
2. data reduction by research personnel full-time at HHIRF or employed by ORNL,
3. data reduction by personnel not covered in 2.

b. General Description of the System

The HHIRF contains two major counting rooms, one associated with the older experimental areas (ORIC counting room) and one with the newer areas supporting "tandem-only" beams (tandem counting room). These areas are served by CAMAC branch and serial highways from one or more computers. Additional counting areas such as UNISOR and the south counting room are served by CAMAC serial highways and high-speed data links back to the major counting rooms (see Fig. V.A-1). Fig. VI-1 is a reasonable approximation of the computer configuration that supports these data acquisition areas. Typically, CPU-A serves the ORIC counting room, CPU-B serves the tandem counting room, and CPU-C has branches to both rooms to handle setup and low data-rate applications; this configuration is often changed to better match anticipated work loads.

Fig. VI-1 Block diagram of the HHIRF data acquisition system.

All input to the data acquisition system comes from CAMAC modules -- ADC's, TDC's, gated latches, counters, interfaces to non-CAMAC equipment, etc. The data are collected and built into an event-by-event data stream containing event delimiters and parameter ID tags by a programmable controller called the "Event Handler¹". The Event Handler executes a user-supplied procedure which describes the experiment's hardware configuration, tests to be used in selecting data, and the structure of the data stream. A "MACRO"-like language and program paradigms are available for use in programming this device.

The data stream is derandomized in time by a FIFO buffer and further blocked into large buffers in the host computer. In most experiments these buffers are written on 6250 bpi, 125 ips magnetic tape drives for subsequent processing and as large a sample as time permits is simultaneously processed, generating histograms for use in monitoring the quality of the data being taken. In simple experiments the event-by-event tapes may not be required and the real-time histograms may provide a complete description of the experiment.

Procedures are available for logging scalers and inserting scaler readings into the data stream and for CAMAC output to experimental apparatus.

c. Data Processing

Both real-time and post-acquisition data processing are performed using the HHIRF high level Comprehensive Histogramming Language² (CHIL). This FORTRAN-like Language generates instructions for histogramming data or (in the off-line environment) selecting interesting events for further analysis. It provides simple gates, free-form-gates (2-D regions of arbitrary shape), condition tests and branch statements, and "do-loops". Up to three user-supplied (FORTRAN) subroutines may be called anywhere in the CHIL procedure to perform user-specific calculations. These subroutines receive the current event in expanded form (an array containing $P(N)$ = parameter #N and non-existent parameters set to -1) and may alter parameters and generate new parameters before passing the event back to the CHIL procedure. This type of user customization has proved to be a very effective means of meeting special requirements while maintaining a high degree of generality, standardization and reliability.

CHIL can generate any combination of 1, 2, 3, or 4-D histograms to a maximum of 32 megabytes (the limit for present real-time programs is 8 megabytes of which 2 megabytes are in CPU memory). Histograms may be recorded at 16 or 32 bits/channel.

d. Data Display

A general purpose interactive computer program for display and analysis of data is available³. This program provides means for generating color displays of 1- and 2-D histograms. Analysis capabilities include (1-D) peak searching and fitting to a polynomial background plus a sum of Gaussian peaks and (2-D) interactive input of simple and free-form-gates and projection of counts in the region of interest on any axis. Gates generated by this program may be saved for reuse and for use by CHIL in subsequent analysis.

e. User Interaction and Support

The primary mechanism for interaction between users and the computer system is the computer "Nanny." The Nanny is a person approved by the HHIRF who has assumed the following responsibilities:

1. To provide help to new researchers (including visitors) in learning how to use the HHIRF computer system.
2. To serve as a bi-directional communications channel between the computer staff and research group members (identify and report problems, distribute real-time verbal information, etc.).
3. To prevent and correct abuses of the system by those in his charge (hogging of CPU's or disk space or tape drives, poor housekeeping habits, and other anti-social behavior).

Each of the HHIRF resident research groups has a designated Nanny. The HHIRF liaison officer or some member of the computer group will serve as Nanny for outside users who have no resident collaborator. It is important for you to know your Nanny and establish rapport.

Technicians are available (see Appendix A) to assist users. They will be able to answer most of your questions and can direct you to the person best suited to help you with more complex problems. Administrative questions should be referred to the Computer Systems Manager (Appendix A).

A Computer Handbook is available which, together with Perkin-Elmer documentation, provides all the information you should require to successfully use the data acquisition system. HHIRF policy is to maintain up-to-date copies of this document in the computer and counting rooms and to furnish copies to major users whenever a complete reprinting is performed (approximately biennially). No distribution of interim update materials is attempted but such materials can be obtained through your Nanny or other knowledgeable friend.

f. Off-site Data Processing

CHIL and related scanning and utility programs are available in a "VAXPAK" for use in off-site data processing on VAX computers. Although these programs were originally designed to make effective use of Perkin-Elmer microcoded procedures and assembly language, the VAXPAK versions, written entirely in FORTRAN, are reasonably efficient and offer significant advantages in reliability, flexibility, and HHIRF compatibility. Users who wish to analyze HHIRF-data at their home institutions should contact W. T. Milner (Appendix A) for further information about VAXPAK.

¹D.C. Hensley, "The Event Handler II", IEEE Trans. Nucl. Sci. NS-26, No. 4, 4454-58 (1979).

²W. T. Milner and J. A. Biggerstaff, "CHIL - A Comprehensive Histogramming Language", IEEE Trans. Nucl. Sci. NS-32, No. 1, 277-281 (1985).

³R. O. Sayer, "RIP - A General Purpose Interactive Display at HHIRF," IEEE Trans. Nucl. Sci. NS-30 No. 5, 3833-37 (1983).

VII. Support to Users

A. Accelerator Operations Managers (TOM/COM)

Each scheduled experiment will be assigned a Tandem-accelerator Operations Manager (TOM) or Coupled-accelerators Operations Manager (COM), depending on the mode of accelerator operation. Users will be informed of the TOM or COM assigned to their experiment soon after it is placed into the run-schedule. It is the responsibility of the experiment spokesman to contact the assigned TOM/COM two weeks before the scheduled time for the experiment to be certain that the operations staff clearly knows what beam parameters (energy, intensity, resolution, etc.) are required.

The TOM/COM will determine the compatibility of the users beam requirements and the capabilities of the HHIRF accelerators, and inform the experiment spokesman of any problem areas.

B. Users Support Group

The primary function of the Users Support Group is to assist users in the setup of experimental apparatus and in the implementation of their experiment. This group currently includes two laboratory technicians and one electronics technician. A mechanical engineer is also available to assist with more complex problems. Names and telephone numbers are listed in Appendix A.

A laboratory technician is assigned to each experiment and will assist in setting up and aligning experimental apparatus, establishing vacuum-tight systems, locating components, and in general help with the mechanical aspects of the experiment. The electronics technician will assist in location of electronic modules and components and in setting up of electronics, will take responsibility for repair of malfunctioning modules, and in general will provide assistance with the detector and electronic systems.

Members of the Users Support Group are the ones who will answer the majority of questions of the users and provide the most assistance. As part of this, they are qualified to answer many questions about the operation of the experimental devices. More detailed questions on the performance of experimental apparatus should be addressed to the appropriate mentor. The mentors of the major experimental devices are listed in Appendix A.

If the installation, modification or repair of an experimental device or ancillary equipment furnished by a user requires personnel beyond those in the Users Support Group, the charges for labor and materials must be borne by the user (Sect. III).

B. The Joint Institute for Heavy Ion Research

The Joint Institute for Heavy Ion Research (JIHIR) is a collaborative endeavor of Oak Ridge National Laboratory, the University of Tennessee, and Vanderbilt University. It is housed in two buildings adjacent to the HHIRF (see map in Fig. VIII-3).

The mission of the Institute is:

"to promote and support heavy-ion research at the HHIRF by providing an intellectual center and physical support for researchers who work at the HHIRF to the mutual benefit of all sponsors and participants in the field of heavy-ion research."

One way in which the JIHIR is fulfilling this mission is by providing dormitory accommodations for non-resident users of the HHIRF. The dormitory, located in Bldg. 6007 (see Fig. VIII-3), has kitchen facilities and lodging accommodations for up to ten HHIRF users. Information on reserving dormitory rooms is discussed in Chapter VIII.

There are also offices in the JIHIR which can be assigned to outside users who, for example, are here for extended periods or who are frequent intermittent visitors. Requests for offices should be directed to the Liaison Office (see Appendix A).

Another means by which the JIHIR fulfills its mission is through sponsorship of conferences and workshops held at the JIHIR. HHIRF users will be kept aware of conferences and workshops which are in their field of interest.

VIII-1

VIII. Travel and Lodging

Air travel to the Oak Ridge area is through the McGhee-Tyson Airport which is approximately 19 km (12 miles) south of Knoxville. There is limousine service between the airport and the motels in the city of Oak Ridge. The phone number for the limousine is (615) 482-5417. However, there is no public transportation between the motels in Oak Ridge and HHIRF. Thus the users need to provide their own local transportation. The most common solution is to obtain a rental car at the airport. Assistance for travel can be obtained at the Liaison Office. Figure VIII-1 shows some of the major roads in the Oak Ridge-Knoxville area. The usual route between the airport and Oak Ridge is marked.

If you drive to Oak Ridge from the north via Interstate 75, turn off at the Clinton exit. Follow State Highway 61 through Clinton and continue on it until near Oak Ridge. Very near Oak Ridge, State Highway 61 veers off to the right. Do not follow it but rather continue straight ahead. This road becomes shortly Oak Ridge Turnpike which is the major east-west street in Oak Ridge.

When arriving from the west via Interstate 40, turn north onto State Highway 58 (Oak Ridge exit). This highway will run into State Highway 95 which becomes a little later Oak Ridge Turnpike. When arriving from the south via Interstate 75, turn off at State Highway 95. When arriving from the east via Interstate 40, follow the blue-marked roads in Fig. VIII-1.

Figure VIII-2 shows some of the major streets in downtown Oak Ridge. It also shows the roads between Oak Ridge and the HHIRF. The HHIRF is approximately 16 km (10 miles) from Oak Ridge. The HHIRF is easy to find at ORNL. As you approach the laboratory from Oak Ridge, the tandem accelerator tower will be clearly visible on the south side of the road.

There are adequate parking facilities at HHIRF in a lot behind the building. There are also a few parking spaces near the entrance for visitors (see Fig. VIII-3). The Liaison Office is located on the north side of the building next to the main entrance.

VIII-2

Lodging can be obtained at motels in Oak Ridge, several of which are marked on the map in Fig. VIII-2 and listed below (rates as of mid-1986 are listed):

- a) Holiday Inn Motel, 420 S. Illinois Avenue, Phone 615-483-4371
\$41.00 single, \$44.00 double
- b) Diplomat Motel, 206 S. Illinois Avenue, Phone 615-483-5615
\$36.00 single, \$41.00 double
- c) Ridge Inn Motel, 1590 Oak Ridge Turnpike, Phone 615-483-1385
\$30.00 single, \$35.00 double
- d) Alexander Hotel, 210 E. Madison Road, Phone 615-483-3555
\$35.00 single
- e) Garden Plaza Hotel, 251 S. Illinois Ave., Phone 615-481-2468
\$54.00 single, \$61.00 double, Friday - Sunday nights \$40.00

There are also limited dormitory accommodations in Bldg. 6007 of the Joint Institute for Heavy Ion Research (JIHIR) which is adjacent to the HHIRF (see Fig. VIII-3). The dormitory rooms are available to those involved in Holifield Facility programs where highest priority for room assignments is for researchers participating in the current experimental run or in a setup for the next experiment. There are also kitchen facilities in the Joint Institute. There is a cafeteria and canteen at Oak Ridge National Laboratory that serves lunch 11:00 a.m. - 1:15 p.m., Monday through Friday.

The maximum assignable time for dormitory rooms at the JIHIR is two weeks. Reservations can be made up to one month before arrival date and visitors are expected to cancel their reservations if their plans are changed.

Reservations for lodging at the Joint Institute can be made by calling the Liaison Office.

The temperature at Oak Ridge ranges from a mean summer temperature of 24.2°C (75.6°F) to a mean winter temperature of 5.3°C (41.6°F). The average relative humidity is 70%, the average rainfall is 140 cm (55 in.), and the average snow fall is 10.7 cm (4.2 in.).

Oak Ridge - Knoxville Route Map

Fig. VIII-1

Map of the Knoxville-Oak Ridge area and airport location.

OAK RIDGE - ORNL MAP ON REVERSE SIDE

City of Oak Ridge

Fig. VIII-2 Map of the Oak Ridge-ORNL area.

Fig. VIII-3 Map of the HHIRF and JIHIR area.

IX. Organization

Figure IX-1 illustrates the organizational relationship of the HHIRF with Oak Ridge National Laboratory. Figure IX-2 gives the major elements which are relevant to the users. The HHIRF Users Group as of December 1986 had 447 members. The group is represented by a 6-person Executive Committee whose members are elected by the constituents of the Users Group. The policies and procedures of the HHIRF Users Group are stated in the Users Group Charter which is given in Appendix C.

Any concerns or comments of any member of the HHIRF Users Group should be brought to the attention of the Executive Committee. The formal link between this Committee and the HHIRF is provided by the Liaison Officer who is an ex-officio member of the Executive Committee. The Program Advisory Committee, PAC, which provides recommendations to the HHIRF director, was discussed in Chapter II.

Several members of the HHIRF research staff serve as "mentors" of the major experimental devices at HHIRF. The functions (where appropriate) of the mentors are:

- 1) To assure that the beam line and experimental apparatus available to users-at-large are in good condition.
- 2) To direct or coordinate or be cognizant of design, development, fabrication, relocation, and modification of experimental apparatus to be used on his beam line.
- 3) To approve any modification to the beam line and experimental devices on the beam line.
- 4) To assist as liaison between the users of the experimental system and the resources and services available at HHIRF.

The user in seeking the assistance of mentors should take into consideration they are scientists whose primary responsibility is to carry out their own research programs at HHIRF. The time required to act in the capacity of mentors should not exceed 20% of their total time.

The personnel in the organization given by Figs. IX-1 and IX-2 are given in Table IX-1.

Fig. IX-1 Organization of the HHIRF with the Oak Ridge National Laboratory.

Fig. IX-2 Organization of the HHIRF.

Table IX-1. Personnel (December 1986)

ORNL Director - Herman Postma

ORNL Associate Director for Physical Sciences - Alex Zucker

Physics Division Director - James Ball

HHIRF Scientific Director - Russell Robinson

HHIRF Technical Director - Charles Jones

Physics Research Section Leaders - Fred Bertrand, Franz Plasil

Users Group Executive Committee - Rotating Membership

Program Advisory Committee (PAC) - Rotating Membership

(Contact the Liaison Office for Current Members)

Liaison Officer - Ron Auble

Appendix A

HHIRF Assistance Directory

FTS Dial 52+
Comm. Dial (615) 57+

Physics Division Office	Ms. Kay Thacker	4-4772
Finance Officer	Ms. Cindy Milner	6-6854
Scientific Director	Russell Robinson	4-4109
Technical Director	Charles Jones	4-4753
Liaison Office	Ms. Regina Webber	4-4113
Liaison Officer	Ron Auble	4-4689
Safety Officer	Hee Kim	4-4708
Accelerator Operations	Control Room	4-4720
Computer Systems		
Manager	John Biggerstaff	4-4754
Technicians	Charles Thomas	6-7390
	David Galbraith	4-4795
Software Support	Bill Atkins	4-4728
	Bill Milner	4-4762
Mechanical Engineer	Jim Johnson	4-4738
Laboratory Technicians		
Vacuum, Mechanical	Bob Miles	4-4760
	Charles Reed	6-0059
Electronics, Detectors	Mark Whitley	4-7802
Experimental Device Mentors		
1.6-m Scattering Chamber	Ron Auble	4-4689
80-cm Spherical Chamber	Glenn Young	6-2770
Time-of-Flight Spectrometer	Felix Obenshain	4-4712
Broad Range Spectrograph	Ron Auble	4-4689
γ-Ray Spectrometers	Noah Johnson	4-4739
Velocity Filter	Hee Kim	4-4708
Split-Pole Spectrograph	Dan Shapira	6-2648
Spin Spectrometer	Mel Halbert	4-4723
UNISOR	Ken Carter	6-2642
Atomic Physics Apparatus	Phil Miller	4-4781
HILI Detector	Dan Shapira	6-2648

HHIRF ELECTRONICS POOL (DECEMBER 1986)

DESCRIPTION	NUMBER
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AMPLIFIER, LINEAR, SPECTROSCOPY	
MODEL: ORTEC 485	4
MODEL: ORTEC 408, BIASED AMP.	2
MODEL: ORTEC 410	11
MODEL: ORTEC 450	2
MODEL: ORTEC 571	27
MODEL: ORTEC 572	10
MODEL: ORTEC 570	2
MODEL: ORTEC 472A	2
MODEL: ORTEC 451	1
MODEL: ORTEC 452	3
MODEL: ORTEC 460	2
MODEL: ORTEC 575	2
MODEL: TENNELEC TC202BLR	7
MODEL: TENNELEC TC203	2
MODEL: TENNELEC TC205A	6
AMPLIFIER, LINEAR	
MODEL: BERKELEY 71X216, 700 MHZ	5
MODEL: BERKELEY 71X214	4
MODEL: CANBERRA 2020	2
MODEL: ELSCINT CAU-N-3, MAIN AMP.	1
MODEL: LECROY 134	3
MODEL: LECROY 133B, 2 CHAN	4
MODEL: LECROY 612A, 12 CHAN, X10	4
MODEL: PHILLIPS 776, 16 CHAN, X10	3
AMPLIFIER, TIMING	
MODEL: ORTEC 454	10
MODEL: ORTEC 474, TIMING FILTER	15
MODEL: ORTEC 574, 4 CHAN, X4.5	10
MODEL: CANBERRA 2110	2
AMPLIFIER, DELAY	
MODEL: TENNELEC TC215	8
MODEL: ORTEC 425, DELAY AMP.	2
MODEL: ORTEC 427, DELAY AMP.	5
AMPLIFIER, SUMMING	
MODEL: ORTEC 415 SUM AND DELAY	3
MODEL: ORTEC 433 SUM AND INVERT	5
MODEL: TENNELEC TC212 DUAL SUM AND INVERT	11
COINCIDENCE	
MODEL: LECROY 465, 3 FOLD	1
MODEL: LECROY 622, QUAD	6
MODEL: ORTEC 414A FAST COINC.	1
MODEL: ORTEC 418, UNIVERSAL	2
MODEL: ORTEC 418A, UNIVERSAL	2
MODEL: EG&G C212, COINC. BUFFER	1
DISCRIMINATOR	
MODEL: EG&G/ESN CF8000, OCTAL CF DISC.	1
MODEL: ORTEC 436, 100MHZ DISC.	1
MODEL: ORTEC 473, CFD	1

MODEL: ORTEC 473A, CFD	5
MODEL: ORTEC 463, CFD	2
MODEL: ORTEC 583, CFD	3
MODEL: ORTEC 934, QUAD CFD	15
MODEL: TENNELEC TC454, QUAD CFD	5
MODEL: TENNELEC TC455, QUAD CFD	2
MODEL: CANBERRA 1428A, CFD	3
MODEL: LECROY 523, OCTAL	2
MODEL: LECROY 623B, OCTAL	9
MODEL: PHILLIPS 706, 16 CHAN	3
MODEL: PHILLIPS 715, 5 CH. CFD	3
MODEL: PHILLIPS 7106, 16 CH., CAMAC	1
MODEL: LECROY 620L, OCTAL	1
MODEL: ORTEC 421, INTEGRAL	1
MODEL: EG&G T101/N	1
MODEL: EG&G T105/N, 2 CH.	2
GATE & DELAY GENERATORS	
MODEL: EG&G/ESN GG8000, OCTAL GATE GENERATOR	1
MODEL: ORTEC 416A	5
MODEL: ORTEC 416	1
MODEL: JOERGER GG, DUAL	4
MODEL: LECROY 222, DUAL GATE	6
ANALOG TO DIGITAL CONVERTERS	
MODEL: CANBERRA 8060	4
MODEL: LECROY 2249W, CAMAC, 12 CHAN, 11 BIT	10
MODEL: LECROY 2259, 12 CH, CAMAC	1
MODEL: LECROY 2259A, CAMAC, 12 CHAN, 11 BIT	5
MODEL: LECROY 3511, CAMAC, 13 BIT	8
MODEL: ORTEC 811, CAMAC, 11 BIT, 8 VOLT INPUT	8
MODEL: NUCLEAR DATA ND581	1
TIMING SINGLE CHANNEL ANALYZERS	
MODEL: ORTEC 455, TIMING SCA	1
MODEL: ORTEC 551, CONSTANT FRACTION	2
MODEL: ORTEC 420	5
MODEL: ORTEC 420A	3
MODEL: ORTEC 406A	1
MODEL: CANBERRA 2037A	2
MODEL: ORTEC 550, SCA	1
MODEL: ORTEC 555	1
MODEL: TENNELEC 440	1
MODEL: H.P. 5583A	3
TIME-TO-PULSE HEIGHT CONVERTERS	
MODEL: ORTEC 437	8
MODEL: ORTEC 437A	2
MODEL: ORTEC 457	3
MODEL: ORTEC 467	2
MODEL: TENNELEC 861	2
TIME-TO-DIGITAL CONVERTERS	
MODEL: LECROY 2228A, 8 CHAN, 11 BIT	13
MODEL: LECROY 2229, CAMAC 8X TDC, ECL	5
MODEL: LECROY 4202 TDC	1

LOGIC MODULES AND LEVEL CONVERTERS

MODEL: LECROY 688AL, NIM-TTL-NIM	4
MODEL: LECROY 364AL, DUAL 4-FOLD LOGIC	2
MODEL: LECROY 365AL, DUAL MAJORITY LOGIC	13
MODEL: LECROY 428F, QUAD LINEAR FAN IN/OUT	1
MODEL: LECROY 429A, 4 CHAN FAN-IN/OUT	14
MODEL: LECROY 430, OCTAL, LOGIC-FAN OUT	1
MODEL: LECROY 380, 32-FOLD MULTIPLICITY	2
MODEL: LECROY 380A, 32-FOLD MULTIPLICITY	1
MODEL: LECROY 441B, ECL, 16 CHAN DELAY/FAN OUT	2
MODEL: LECROY 450B, ECL, PROGRAMMABLE LOGIC UNIT	1
MODEL: LECROY 4532, ECL, 32-INPUT MAJORITY LOGIC	2
MODEL: LECROY 4616, ECL-NIM-ECL	3
MODEL: PHILLIPS 740, QUAD LINEAR FAN IN/ FAN OUT	2
MODEL: PHILLIPS 752, QUAD 2-FOLD AND/OR	3

LINEAR GATE

MODEL: ORTEC 409	5
MODEL: ORTEC 426	8
MODEL: ORTEC 442	2
MODEL: ORTEC GI 200/N GATE INTERFACE	4
MODEL: CANBERRA 1452	2
MODEL: PHILLIPS 7145, LINEAR GATE/MUX	1

PULSERS

MODEL: BNC RP2, TAIL	2
MODEL: BNC PB-3	1
MODEL: BNC PB-4	1
MODEL: ORTEC 448	1
MODEL: ORTEC 480	1
MODEL: BNC BH-1, TAIL	3
MODEL: ORTEC 419, PRECISION	1

SCALERS

MODEL: LASL 804B SCALER MIXER	2
MODEL: ORTEC 776, COUNTER/TIMER	1
MODEL: ORTEC 778, DUAL SCALER	3
MODEL: ORTEC 430	2
MODEL: ORTEC 431, TIMER/SCALER	1
MODEL: ORTEC 462, TIME CALIBRATOR	2
MODEL: ORTEC 719, TIMER	1
MODEL: ORTEC 875, COUNTER	1
MODEL: ORTEC 484	3
MODEL: LECROY 2551, CAMAC, 12 CH.. 24 BIT	12
MODEL: KINETIC SYSTEMS 3640, CAMAC, UP/DOWN COUNTER	1
MODEL: JORWAY 85A, QUAD	3

INPUT/OUTPUT REGISTER, CAMAC

MODEL: JOERGER QIR, QUAD INPUT	2
MODEL: JOERGER QOR, QUAD OUTPUT	1
MODEL: JORWAY 40X, OUTPUT	1
MODEL: JORWAY 65, NIM INPUT	3
MODEL: JORWAY 71B, CRATE CONTROLLER	1
MODEL: JORWAY 41, OUTPUT	3
MODEL: JORWAY 92, COMM. INTERFACE	2
MODEL: KINETIC SYS. 3472, INPUT GATE	1
MODEL: LECROY 2341A, 16 FOLD	2

CURRENT DIGITIZER	
MODEL: RED NUN RN8111	1
MODEL: ORTEC 439	5
DELAY BOX	
MODEL: ORTEC DB463	1
MODEL: SCIENCE ACCESS. 032	1
POWER SUPPLY, HIGH VOLTAGE AND BIAS	
MODEL: ORTEC 459, 0-5KV	8
MODEL: ORTEC 456, 0-3KV, 10MA	7
MODEL: TENNELEC TC940A, 0-3KV, 10MA	3
MODEL: ORTEC 210, QUAD BIAS	15
MODEL: BERTAN 1792X, 10KV	2
MODEL: TENNELEC TC950, 0-5KV BIAS	4
MODEL: TENNELEC TC952, 0-3KV	4
MODEL: WENZEL N-1130-4, 6KV QUAD	1
MODEL: LECROY 2132, INTERFACE FOR HV4032	1
POWER SUPPLY, PRE-AMP	
MODEL: TENNELEC TC930, DUAL	5
MODEL: ORTEC 114, DUAL	3
RATE METERS	
MODEL: ORTEC 441	1
MODEL: TENNELEC TC526	2
MODEL: TENNELEC TC590	2
MISCELLANEOUS NIM MODULES	
MODEL: CANBERRA 8200, STABILIZER	1
MODEL: CANBERRA 8220A, MIXER/ROUTER	1
MODEL: EGG AN102/N, DC MIXER	2
MODEL: ORTEC 404, PILEUP INSPECTOR	3
MODEL: ORTEC 464, PSD ANALYZER	2
MODEL: TENNELEC TC601, STROBED PULSE STRETCHER	1
MODEL: CANBERRA 1426, EXTRAPOLATED ZERO STROBE	2
MODEL: TENNELEC TC529, ALARM CONTROL	1
MODEL: TENNELEC TC599, HOWLER	1
PREAMPLIFIER	
MODEL: ORTEC 109PC	7
MODEL: ORTEC 113	3
MODEL: ORTEC 124	3
MODEL: ORTEC 125	3
MODEL: ORTEC 142A	5
MODEL: TENNELEC TC130	3
MODEL: TENNELEC TC133	3
MODEL: TENNELEC TC135	2
MODEL: TENNELEC TC145	2
MODEL: TENNELEC TC161D	2
MODEL: CANBERRA 2004	19
OSCILLOSCOPE	
MODEL: TEKTRONICS 475	1
MODEL: TEKTRONICS 454	1
MODEL: TEKTRONICS 7904	2
MODEL: TEKTRONICS 2213	1
MODEL: TEKTRONICS 2215	1
MODEL: HEWLETT PACKARD 1722A	1
MODEL: HEWLETT PACKARD 1740A	1
NIM BINS	62
CAMAC CRATES	16

Appendix C
Users Group Charter
for

Holifield Heavy Ion Research Facility
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831

The Holifield Heavy Ion Research Facility (HHIRF) Users Group is an organization of scientists interested in the accelerator facility and in the research program at the HHIRF. The purposes of this group are as follows:

- a) To provide a formal channel for the exchange of information between the HHIRF administration and the scientists who utilize this facility for research.
- b) To provide a means for the inclusion of its members in specific projects connected with the development and operation of the facility and in the program of research.

Through a wide representation of scientists, the group will make known to the HHIRF administration the needs and desires of those scientists actively engaged in research projects. As one example of the relationship between the users community and the HHIRF administration, it is expected that some members of the Proposal Review Committee and the Policy Committee will be selected from candidates proposed by the Users Group.

1. Membership. The membership of the Users Group is open to scientists interested in the HHIRF. Users will be practicing experimental and theoretical scientists working in any field of research for which the capabilities of the HHIRF are appropriate. Following the completion of an original membership list, new members will be added by action of the Executive Committee of the Users Group upon receipt of a written request. Each member will need to renew in writing his membership every third year beginning with the year 1979.

2. Officers and Executive Committee. The officers of the Users Group shall consist of a Chairperson, Chairperson-elect, Liaison Officer, and four other elected members. The Chairperson, Chairperson-elect, and four elected members will constitute the Executive Committee of the HHIRF Users Group. The Liaison Officer will be an ex officio member of the Executive Committee.

a. Two new members of the Executive Committee shall be elected annually by members of the Users Group by written ballot, distributed prior to October 1 to the membership as of September 1, and shall take office on January 1 of the following year. A plurality of votes cast is sufficient for election. In case of a tie vote the elected member will be selected from the candidates of said tie vote, by vote of the Executive Committee. The term of office is three years. After the election, the then current members of the committee shall choose one of the current first-year or newly elected members to be Chairperson-elect.

b. The Chairperson-elect will succeed to the office of Chairperson at the end of one year.

c. The term of Chairperson of the Users Group is for a period of one year.

d. Current members of the Executive Committee may not be nominated for re-election. No more than two of the elected members of the Executive Committee may be from one institution.

e. A Liaison Officer of the Users Group is appointed by the HHIRF Director in consultation with the Chairperson and Chairperson-elect of the Users Group. It will be the duty of the Liaison Officer to act as secretary of the meetings, keep the minutes, maintain the membership list, request nominations, send and tally mail ballots, and generally serve as secretary to the Users Group. It is further the duty of the Liaison Officer to keep the Users Group informed of new developments at the HHIRF and other matters of interest to the Users by means of frequent newsletters. The Liaison Officer shall serve for a period of two years and can be reappointed.

3. Meetings. The HHIRF Users Group shall meet at least once each calendar year at a time and place designated by the Chairperson, upon advice of the Executive Committee. Notice of the meeting should be sent to the members of the Users Group at least a month in advance and shall include the agenda for the meeting. The Secretary-Liaison Officer will prepare summaries of all meetings, which will be mailed to all members, arrange details of meetings and other necessary work of the Committee.

4. Procedures

a. The Executive Committee may, on its own initiative, and shall, upon instruction of a majority of the members attending a general meeting, submit questions for consideration to the full membership. Results of the deliberations of the Users Group shall be communicated to the Director of the HHIRF.

b. The Executive Committee shall be responsible for forwarding to the HHIRF administration names of scientists recommended for selection as members of the Proposal Review Committee, the Policy Committee and other committees as requested.

c. The Executive Committee shall appoint a Nominating Committee consisting of five members of the Users Group, but not including any officers, who are charged with the duty of nominating a slate of candidates each year for two positions on the Executive Committee. The Nominating Committee may meet in person if it wishes or may transact its business by mail or by telephone. The Chairperson of the Nominating Committee will be designated by the Chairperson of the User Group. Direct nominations from the membership can be made by a petition from at least ten members, sent to the Chairperson of the Executive Committee prior to September 15. It is expected that the membership of the Executive Committee will reflect the diverse areas of research conducted at the HHIRF.

d. In the event that a position on the Executive Committee be vacated prematurely, the Committee shall appoint a member of the Users Group to fill the unexpired term. If the vacated post should be that of Chairperson-elect, the Executive Committee shall appoint a new committee member; the newly completed Executive Committee will then elect a new Chairperson-elect from among the committee members serving in their first or second year.

5. This Charter may be amended by a written vote of the members. A proposed amendment shall be introduced at a general meeting. A two-thirds majority of the members voting is required for passage of the amendment. The vote must be taken within a month of the time the amendment was introduced.