GENERAL DESCRIPTION OF THE NRL SECTOR-FOCUSING CYCLOTRON FACILITY

Rollon O. Bondelid
Nucleonics Division, U. S. Naval Research Laboratory
Washington, D. C. 20390

Summary

The nuclear physics research facilities at NRL are presently being expanded by the addition of a Sector-Focusing Cyclotron Facility. The Cyclotron is essentially a copy of the Oak Ridge Isochronous Cyclotron and much of the facility concept is patterned after the Oak Ridge Installation. A beam optics system was designed that satisfied the specified criteria as to image quality, and then a building design was coupled to this beam optics system. Included in the facility are a cyclotron and beam preparation vault, and three experimental rooms which are sufficiently well shielded from each other and from the cyclotron vault, so that personnel have access to any two experimental areas while the third is utilizing the cyclotron beam. Eleven separate beam paths will permit set-up of many different experiments simultaneously. The main experimental wing of the building also includes two experimental staging areas, a control room, and a data accumulation room. A laboratory-office wing provides space for check-out of various apparatus, a target preparation room, a machine shop, a darkroom, counting rooms, a library, a conference room, and offices for the staff. The facility will be used to study nuclear interaction mechanisms, polarization phenomena, nuclear structure, heavy ion, and neutron physics, as well as various areas of applied research.

Introduction

For nearly two decades the U. S. Naval Research Laboratory has supported an active research program in low energy nuclear physics employing a number of nuclear particle accelerators. These accelerators include a 6 MeV Van de Graaff, two 2 MeV Van de Graaffs, a recently acquired 55 MeV Electron Linear Accelerator, and a 500 keV Cockcroft-Walton Set.

In order to extend their research programs to higher particle energies, the NRL scientists engaged in these research programs proposed the acquisition of a new higher energy accelerator. It was decided that higher energies with particle and energy variability were necessary features for a machine which would be the central element in the new nuclear physics research facility. An accelerator whose characteristics satisfied the description of the proposed research program is the Oak Ridge Isochronous Cyclotron (ORIC). After a review of particle accelerators operating in the energy region below 100 MeV, it was decided that the central element of the new facility would incorporate a copy of ORIC. The principal class of experiments proposed will require a beam of particles precisely controlled in energy, and with narrow energy spread. Other experiments will require that the Cyclotron be used to take full advantage of its high intensity capability, and its high energy capability. To achieve an optimum facility so as to satisfy the requirements imposed by the proposed research programs, various criteria for the design of the facility were adopted. Some of these criteria have their bases in the mathematical relationship between elements of an ion optical system; and other criteria have their bases in the experience of the individuals developing the facility.

The Cyclotron

It has been generally known for sometime that in a system of magnets used to deflect an ion beam the dispersions of all magnets should be in the same plane so as to obtain better ion optical properties of the system. Calculations were made which demonstrated that serious loss of analyzed beam intensity could occur if the dispersion of the analyzing magnet proposed for the NRL beam handling system were perpendicular to the dispersion introduced by the magnetic field of the cyclotron. Consequently, it was decided that the NRL Cyclotron would be constructed so that the median plane is horizontal, rather than vertical, as in the case of ORIC. The University of California, at Davis, is also constructing a copy of ORIC. The physical limitations imposed by the already existing building at UCD required that the UCD version of ORIC be oriented horizontally. Thus, multiple advantages were gained by both the NRL and UCD programs when it was agreed that the horizontal orientation was desirable. The result of this and other agreements was the establishment of a joint venture in which the engineering for both machines, and the procurement of components for both machines are carried out under the same contract. This engineering and procurement contract is with the firm of William M. Brobeck and Associates of Berkeley, California.

In addition to changing the plane of acceleration, various other design changes, some of which have been suggested by the ORIC Staff, have been made. A few of the changes are listed. (1) The yoke and central region have been adapted to use the axial ion source which is used on the 88 inch Cyclotron of the Lawrence Radiation Laboratory. (2) The vacuum pumping system has been modified to provide more balanced pumping between the vacuum tank and the resonator tank. (3) The vacuum tank has been re-designed so that it is completely demountable through the use of Tee joints. (4) Copper is used for the main coil conductor, rather than aluminum because of differences in the economics of electricity between Washington, D. C. (or Davis, California) and Oak Ridge. (5) The main coil power supply is a solid state device.

The Ion Optics System

Some of the criteria employed in the design of the ion optics system and subsequently the building layout are listed. (1) A single high resolution magnet will be used to obtain the desired low spread in energy of the beam. (2) All of the ion optics equipment will be in the same room as the cyclotron, except for final quadrupole focusing elements. It is especially important also to have slit jaws, and other bombarded surfaces in this same room so that background at the experiment is minimized. (3) There will be at least two experimental rooms fed by the high resolution beam. (4) There will be a room which can be fed by the high intensity unanalyzed beam of the cyclotron. (5) There will be multiple beam paths in all rooms. (6) All experimental rooms, including the cyclotron vault and beam preparation room will be accessible from one side of the building. The result of these and other considerations is the floor plan for the building which is shown in Fig. 1. This illustration shows some of the deviations from the ORIC design. Room 4 contains the cyclotron. The beam from the cyclotron can go straight ahead into experimental Room 1, which will be used primarly for bombardment services, or for experiments not requiring the high resolution provided by the analyzing magnet. The beam can be directed into the analyzing magnet, which is a 135°, nine foot radius magnet, described in detail in Paper II-17 of this conference. In order to reduce the space required between the object slits and the magnet, and the space between the magnet and the image slits, and for symmetry, we chose 135° as the deflection angle. The magnet will be mounted on a track and pivot arrangement so that the highly analyzed beam can be directed either into Room 2 or Room 3. Switching magnets provide for multiple paths in each of the experimental rooms. Quadrupole magnets, not shown in Fig. 1, are used to control the beam spot size along each of the beam paths. There exists a mathematical solution for each beam path such that the magnification of the object is unity. Large areas are provided outside of the experimental rooms for setting up and testing of equipment prior to installation along the beam lines.

All services for a given beam path are terminated on the wall above the point of exit of a beam path. At the time of installation of the equipment for a beam path the services will be continued in trays over the beam tube. The services for a given beam path include all the standard elements such as, control wiring, power wiring, process water, demineralized water, nitrogen, dry air, and natural gas. Portable vacuum systems are used on each beam line, and the discharge from the mechanical pumps of these portable systems is fed into a common exhaust line. All beam handling equipment is operable remotely, including the vacuum pumping stations, and the various magnetic devices which are used to focus, deflect, and analyze the beam.

There are a number of devices which have become somewhat standard in beam handling equipment. These include beam stops, beam viewers, slit collimators, scanning devices, remote vacuum joints, wall shutters, and the vacuum plumbing. Details of these devices are to be found in Paper AA-11 of this conference.

Each experimental room contains several experimental stations which terminate on the walls. Each of the eleven experimental stations has provision for 100 coaxial cables of various kinds, and for the various types of power usually used. The coaxial lines for each of the experimental stations terminate in the counting room (Fig. 1). Between each of the laboratories of the laboratory-office wing (Fig. 1) and the counting room, are a number of coaxial lines so that experimental counting set-ups can be placed in the various rooms of the laboratory wing, and connected through patch panels to the experimental stations in the experimental rooms.

The Building

It was decided that the Oak Ridge concept of fixed shielding would more nearly provide the type of facility versatility required by the proposed NRL research program. The concept of providing the electrical and mechanical services for the cyclotron and beam optics equipment in a third floor was also borrowed from the Oak Ridge facility design. Shielding calculations were made with the following results. The walls around the cyclotron vault are nine feet thick of ordinary concrete. The wall between Room 4 and Room 1 is eight feet thick, but is made of ilmenite aggregate with a density of 235 lbs. per cubic foot. The walls around Room 1 are nine feet thick, since this is the room that can receive the full beam intensity from the cyclotron. The walls around Rooms 2 and 3 are eight feet thick. The ceiling thickness over Rooms 1 and 4 is seven feet, and over Rooms 2 and 3 is six feet. (The ceiling heights are eighteen and nineteen feet respectively.) An attenuation of 10^{-5} was adopted for the transmission of neutrons through the penetrations for conduit, vacuum and gas piping, demineralized water pipes, and air ducts.

Additional facilities provided in the experimental wing of the building include a set of isotope storage wells for the storage of high intensity sources prepared by the cyclotron. There are a number of isotope storage safes, which are used for the storage of low level sources which will be used for check-out of counting equipment. A provision is made in experimental Room 3 for a large reaction particle spectrometer: a special support for the center bearing, and a 360° track have been included in the floor design. For alignment of the beam handling equipment, sight-throughs with removable plugs are provided in the shielding walls. Because the greatest neutron intensity is in the forward direction, all beam slot material is cast with ilmenite aggregate. Rabbit penetrations are also provided for rapid removable of radioactive sources prepared in Room 1. Facilities contained in the laboratory-office wing, Fig. 1, are a target preparation room, a machine shop, an electronics shop, a darkroom, various counting rooms, a library, a conference room, and offices for the staff.

The control room for the Cyclotron is located adjacent to the counting room to provide for convenient communication, both visible and audible between the experimenter and the cyclotron operator. The beam optics and beam handling control system are completely integrated with the cyclotron control system. Careful liaison has been carried out between the designers of the beam optics system and the cyclotron in order that they maintain complete system integrity and maintain a unified appearance.

Space has been provided in the control room for a data acquisition system. This data acquisition system is described in detail in Paper EE-20 of this conference. Basically, the system consists of a small computer with a priority system of interrupts, together with a mulitude of input output devices. In addition to its basic application to the accumulation and prompt treatment of experimental data, this data acquisition system can be used to record and return cyclotron operational information.

The building is oriented on the site in a way such that expansion of the facility can easily be made, and long flight paths for neutrons can be established. The Cyclotron Building is located in a place such that it is easily seen from the Anacostia Freeway as one enters Washington, D. C. from the south. For this and other reasons, the architecture of the building came under the cognizance of The Commission of Fine Arts of Washington, D. C. The result of their recommendations is a building in which the concrete of the experimental wing will remain uncovered to retain the functional shielding appearance of this material; the outside walls of the experimental wing will be continued above the third floor machinery room so that the usual appendages on top of such buildings will not be visible; and the laboratory-office wing will be a glass enclosed contemporary structure. An architect's rendering of the NRL Cyclotron Building is shown in Fig. 2.

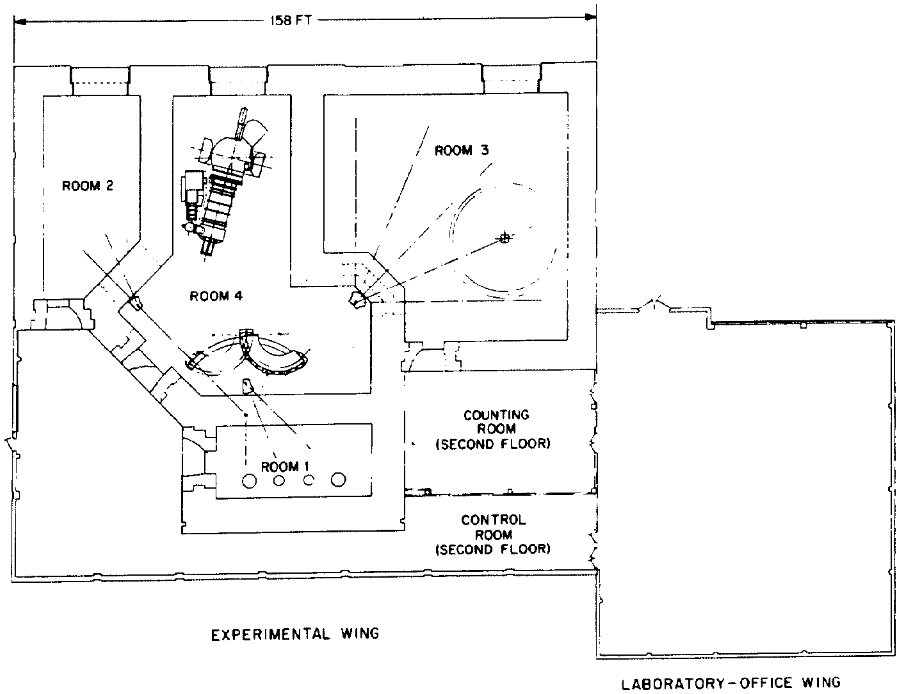

Fig. 1. Plan View of the NRL Cyclotron Building.

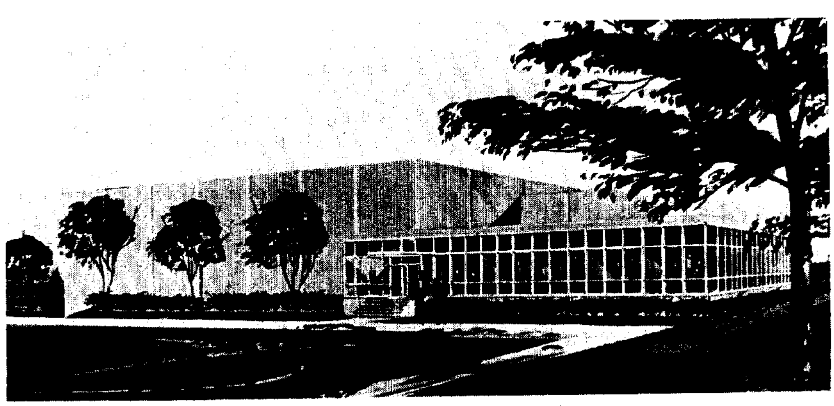

Fig. 2. Architect's Rendering of the NRL Cyclotron Building.