Proceedings of International Collaboration on Advanced Neutron Sources (ICANS-VII), 1983 September 13-16
Atomic Energy of Canada Limited, Report AECL-8488

STATUS REPORT ON THE WNR/PSR PULSED SPALLATION NEUTRON SOURCE AT THE LOS ALAMOS NATIONAL LABORATORY

Charles D. Bowman
Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545

INTRODUCTION

The Los Alamos National Laboratory is constructing a high intensity spallation pulsed neutron source for neutron scattering and nuclear physics research. The facility will accept beam from the Clinton P. Anderson Meson Physics Facility (LAMPF) and accumulate it in the Proton Storage Ring (PSR) now under construction. The proton beam will then be ejected in intense bursts and transported to a neutron-production target that will be an upgrade of the existing Weapons Neutron Research (WNR) target. The initial design objective for 1986 is an average neutron production rate of 1.2×10^{16} n/s over 4π with a pulse rate of 12 pps.

Fig. 1 is our most recent drawing of the WNR/PSR facility. The principal elements for the future are identified as the beam transport channel from LAMPF(6), the Proton Storage Ring(3), and the WNR target area(1). Major changes in the facility are planned that will significantly change the appearance of the facility around the target. These are described in this report.

A neutron scattering research program was begun at the WNR in 1982 at an average source intensity of 3×10^{14} n/s. Research at the WNR will continue throughout the construction period with primary emphasis on developing new fields of research that can be studied with intense pulsed neutron sources and on construction of the new class of spectrometers required for pulsed neutron scattering research. We believe that all elements necessary to complete a world class center for pulsed neutron scattering will be in place in 1986; an unsurpassed proton source, an optimally designed neutron-producing target, new space for accommodating experiments, and an array of new spectrometers specially designed for pulsed neutron scattering research. Planning is underway for neutron intensity enhancement by as much as a factor of 10 beyond the 1986 objective.

FACILITY STATUS

The WNR facility has operated well over the past year for both neutron scattering and nuclear physics experiments. About 60% of the beam time has been devoted to the 5-μsec long pulse for the neutron scattering and about 40% to the 0.2 ns microstructure mode for nuclear physics. A summary of the operation for the most recent running period is given in Table I. During this period, the WNR operation was restricted to nights and weekends because of the construction of

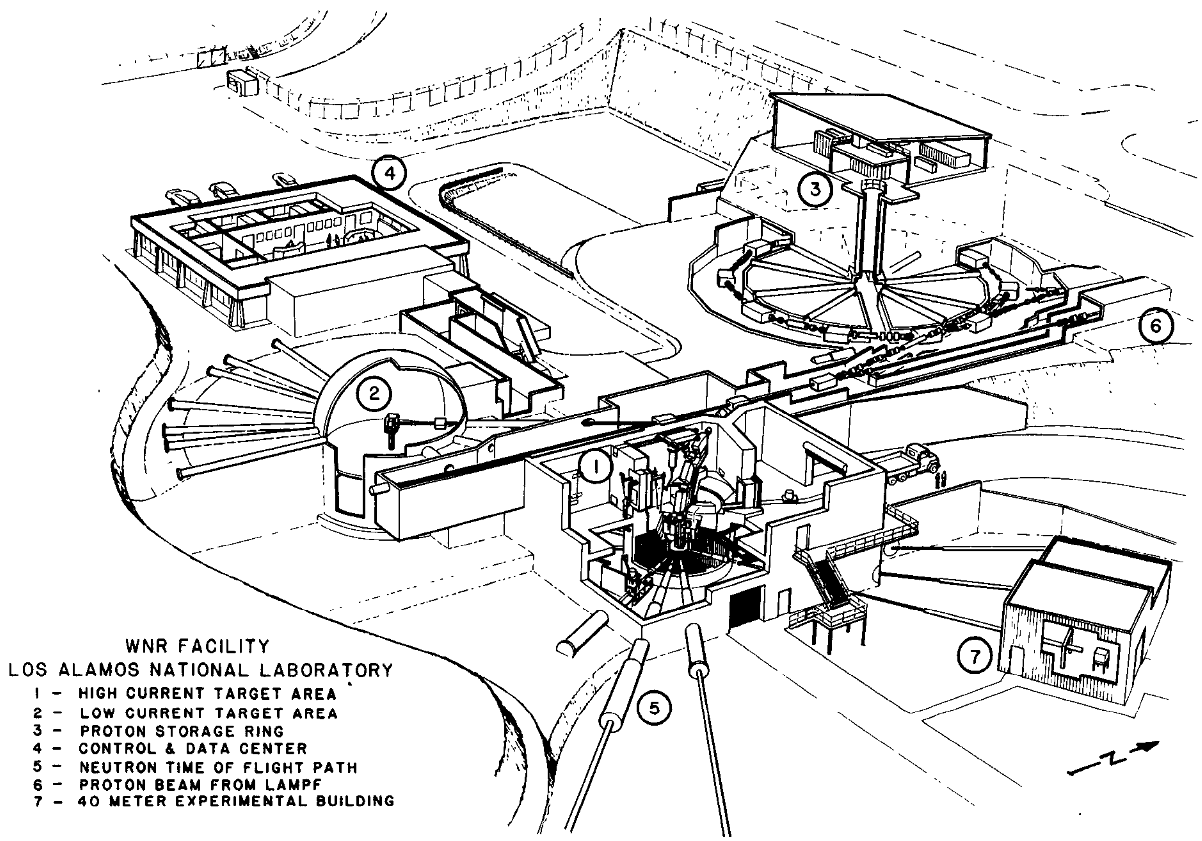

Fig. 1 Overview of the WNR/PSR Facility. With the completion of the PSR building (3), the facility presently appears very much as it is now. Major additions to the experimental area will significantly transform the appearance outside of the WNR target area (1).

Table I WNR 1982-83 Operating Summary*
(May 82-February 83)

Scheduled Operating Time	3066 Hours
Beam Available from LAMPF	2778 Hours
Beam Available for WNR Experiments	2696 Hours
Overall Availability	88%
WNR Efficiency	97%

* Daytime/Weekend-only operation due to PSR construction.

the building to house the PSR. Clearly the multiplexed magnet system, the WNR beam transport, and the target are operating excellently with only 3% down time. The construction of the building to house the PSR will be finished ahead of schedule. We received beneficial occupancy of the magnet ring hall in August.

The experimental program has been going well. Several new spectrometers operated very effectively resulting in a major improvement in research productivity. Presently operating spectrometers include a single crystal diffractometer, a constant-Q spectrometer, a beryllium difference spectrometer and an eV inelastic scattering spectrometer, the latter in collaboration with the SNS laboratory. A general purpose powder diffractometer will be brought on line in 1984.

We have begun a formal user program this year starting with two instruments--the beryllium difference spectrometer and the single crystal diffractometer. The number of instruments in the program will be increased each year. At the end of 1986, ten spectrometers should be operational and 2/3 of the neutron scattering research time will be available to outside users. Any user is eligible to apply for research time on these spectrometers. Proposals should be sent to Dr. Richard N. Silver of this laboratory. These proposals are then forwarded with comments to a joint review committee of the Los Alamos and Argonne National Laboratories, which allocates the spectrometer time among the most promising experiments. For the first running period at the WNR for the experimental program this fall, 24 proposals were received for the two spectrometers and experiental time was made available for 18 of these.

FACILITY UPGRADE PROGRAM FOR NEUTRON SCATTERING

Many changes now underway will contribute to the development of the WNR facility into an international center for neutron scattering research. These include the construction of the Proton Storage Ring, the upgrade of the target/moderator system for intense proton current and optimal neutron spectrum for several classes of experiments, a major expansion of the experimental area to allow comfortable placement of at least 15 spectrometers, a computer development program that will provide each spectrometer with a dedicated data collection system, and a formal plan for developing the spectrometer array. Each of these efforts is discussed separately below.

Proton Storage Ring

The Proton Storage Ring will enormously increase the power of the facility for both the neutron scattering and nuclear physics programs. A comparison of the two capabilities is given in Table II. Note that the pulse width will be shortened by a factor of 20 and that the intensity per burst for neutron scattering experiments will be increased by a factor of about 300. As mentioned earlier construction of the PSR is on schedule, and details are presented in a later talk in the conference by G. P. Lawrence[1]. An output current level in the long pulse mode of 20 μa is expected to be achieved at 12 pps by the fall of 1985. The full 100 μa intensity is expected in 1986 along with substantial current in 1986 in the one nanosecond mode. By 1987 full operation in both modes is expected, and work will begin on several PSR upgrade possibilities.

Additional Experimental Space

The present experimental space at the WNR is totally inadequate for the outstanding source intensity that will be available with the PSR. A plan has been proposed for an increase in space by a factor of five in order to provide ample area for a full array of spectrometers, staging area as part of the experimental floor area, quiet rooms adjacent to the floor for assessment of progress on experiments, and space for data collection systems. In all other spallation sources the beam strikes the target in a horizontal direction with limitations in spectrometer floor space associated with beam transport to the target and with target servicing facilities. It is important in our planning to take advantage of our full circle of spectrometer locations made possible by the vertically directed proton beam. Also the arrangement should allow for a number of long (∿ 200 M) drift tubes for neutron nuclear physics.

The arrangement of the area is shown in Fig. 2. The existing experimental hall will remain essentially as is except for some outfitting that will provide a better environment for experiments. Two large halls are shown on the east and west side of the present experimental area. Each hall is spanned by a 10-ton overhead crane. Space is set aside in each hall for staging area. Support space is also provided adjacent to the experiental floor. An access channel from the northeast is provided so that a forklift can be operated on the existing experimental hall floor in

Table II WNR/PSR Performance Characteristics

	WNR		PSR	
	Neutron Scattering	Nuclear Physics	Neutron Scattering	Nuclear Physics
Proton Energy (MeV)	800	800	800	800
Pulse Width (nsec)	5000	0.2	270	1
Rep Rate (pps)	120	6000	12	720
Average Current (μamps)	3	0.2	100	12
Average Neutron Rate (n/s)	4×10^{14}	1.3×10^{13}	1.2×10^{16}	1.5×10^{15}

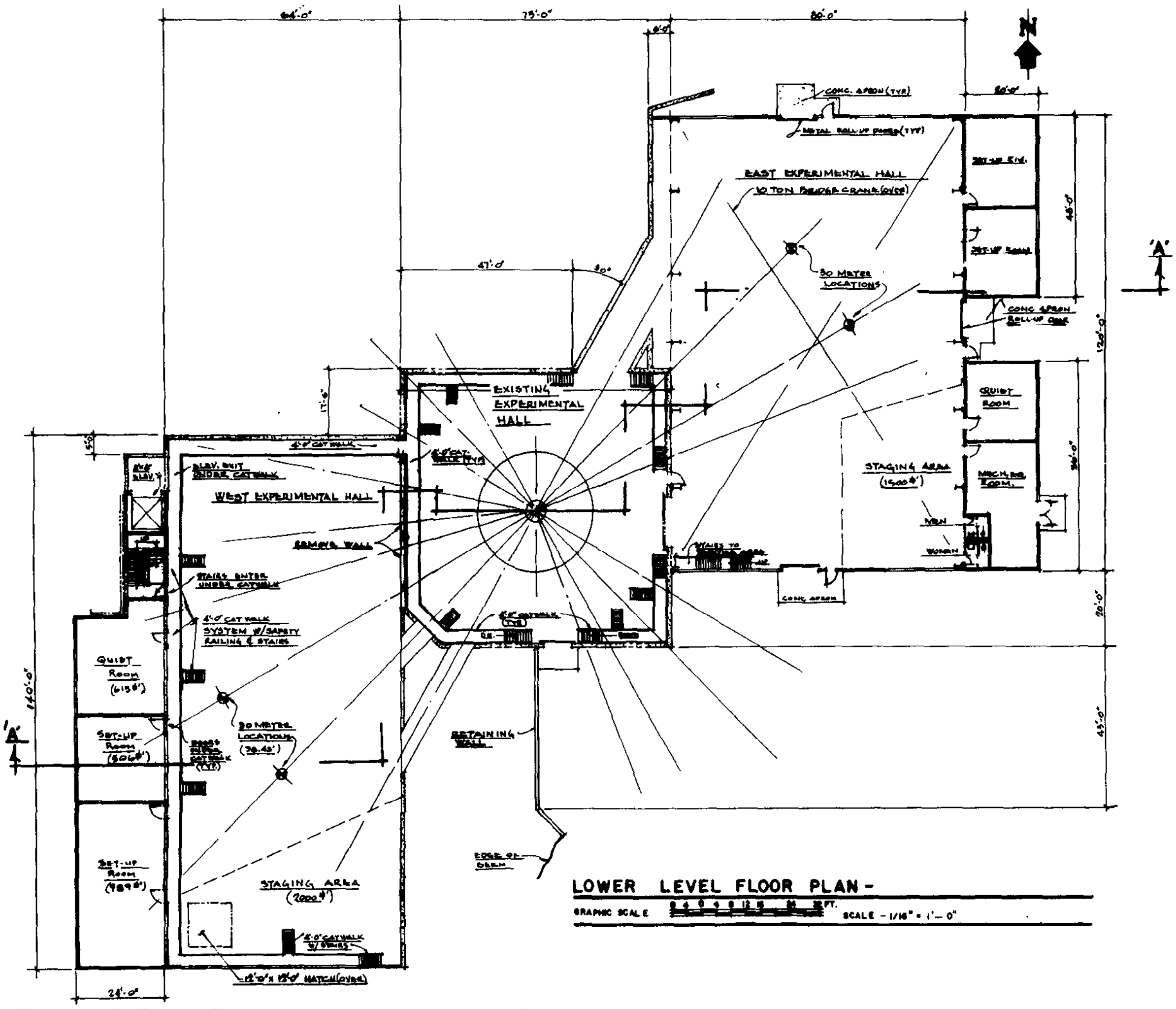

Fig. 2 Ground Floor Plan for Augmentation of WNR/PSR Experimental Area. The existing WNR target area at the center of the figure will be expanded with the addition of two large halls. New drift tubes to be drilled will increase the total for neutron scattering to 15. The four drift tubes in the southeast quadrant will be used for neutron nuclear physics research.

the north, east, and south sectors. Generally the experiments requiring the highest neutron intensity will be located in the northwest quadrant of the existing experimental hall, and the higher resolution systems and more bulky experiments in the two outer halls. Note that the low current target area identified as (2) in Fig. 1, where we now conduct moderator studies, etc., will be replaced by the west hall.

Fig. 2 shows 19 drift tubes, which are required to fully use the present and proposed experimental space. However, the biological shield was originally constructed with only 12 drift tubes. It will be necessary therefore to drill several new drift tubes through the 15-ft thick 80% iron-20% concrete shield. A new drift tube was drilled this past year to demonstrate that installing new drift tubes is practical. The four drift tubes pointing in the southeasterly direction will be devoted to long flight path nuclear physics experiments. This leaves 15 flight paths for neutron scattering research. Taking into account the possibility of two spectrometers on some of the beam lines, it is expected that space will be available for 20 or more spectrometers.

Target, Moderators, and Shielding

The intense PSR beam currents will require a complete redesign of our present target-moderator system. We must accommodate the needs of nuclear physics for 0.25 to 10,000 eV neutrons, cold moderators for both neutron scattering and nuclear physics, and tailored moderators for particular neutron scattering spectrometers. A large variety of moderators is therefore required. A target-moderator geometry under consideration now is shown in Fig. 3.

A key element of this concept is a split target arranged so that equal neutron intensity is produced in the upper and lower segment and a relatively large volume of uniform flux density is created that is relatively free of target cooling paraphenalia. Several moderator types therefore can be placed in this region to service different spectrometers. Isolation from background associated with high energy neutrons should also be optimized in this geometry. A through-tube geometry is possible, which might be valuable for some experiments. It also will be possible to use wing geometry if additional moderator types are required.

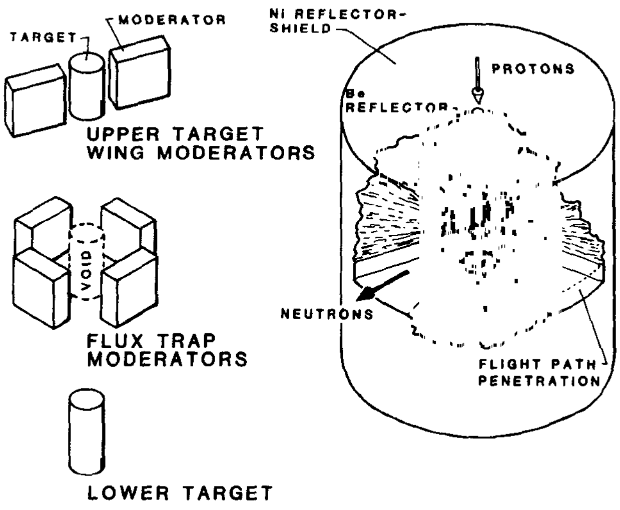

Fig. 3 Prospective WNR Target-Moderator-Reflector Assembly. The target consists of a split target surrounded by an inner Be reflector and an outer Ni reflector. The beam enters from the top. The facility can accommodate several moderators and also a through-tube flight path geometry.

The inner region of the target assembly is surrounded by a Be reflector that in turn is surrounded by a Ni annular cylinder serving as a second neutron reflector and as additional biological shielding. The complete assembly is about one meter in diameter and one meter high. We have addressed the question of broadening of the neutron pulse by the reflector. Calculations by Russell[2] show that the neutron pulse is not broadened by the reflector beyond the 270 ns width of the proton pulse from the PSR except at lower energies where moderation time in hydrogen dominates.

The clear separation between the moderator and the neutron producing target is expected to be beneficial if the facility intensity is upgraded via additional beam current, by emphasizing a ^{238}U target, or by means of a fission booster. For a possible future fission booster the reflector also could serve as a large heat sink for afterheat in case the target cooling system malfunctions. In summary this geometry allows 360° access to moderators, separates moderator and target cooling apparatus, reduces streaming of high energy background-producing neutrons down the drift tubes, creates a region of uniform flux for placement of moderators, and substantially increases the effectiveness of the biological shield. The target-moderator system is discussed in greater detail in another contribution to this meeting by Russell[2].

Spectrometer and Data Collection Development

Neutron scattering research began in 1982 with several exploratory spectrometers that performed successfully. Two of these, the filter difference spectrometer and the single crystal diffractometer were brought into operation in 1983 as fully engineered spectrometers. Adequate resources are expected to allow two additional fully engineered spectrometers to be brought on line in 1984 and 1985 and perhaps three or four in 1986. Therefore at the close of 1986 ten fully engineered spectrometers are expected to be operational. Approximately one spectrometer per year will be added after 1986. User input on the priority of instrument construction and user participation in spectrometer design and construction will be solicited for spectrometers to be installed after 1984.

The high average neutron intensity of the WNR/PSR and the low 12-hertz repetition rate will require the handling of very high instantaneous data rates from the spectrometers. A computer system to handle these rates is under construction. The system provides a data collection computer for each spectrometer and a central computer at the WNR/PSR for data reduction and analysis. A coaxial cable link to the Los Alamos National Laboratory central computing facilities was completed in 1983 that will make accessible to WNR/PSR scientists and users world forefront space in data processing and the most advanced data storage facilities.

In summary, a fully equipped world class neutron scattering facility should be operational in 1986 with 100 μa of 800-MeV average proton current at a repetition rate of 12 pps. Ten fully engineered spectrometers with a separate data collection computer for each should be operational in the newly completed and greatly enlarged experimental space. At least three separate moderators should be operational each optimized for different neutron spectral capabilities. A ^{238}U target probably also will be operational at that time. The WNR will be conducting a full experimental program throughout the '83 to '86 construction period including an active user program.

OTHER PSR-RELATED PROGRAMS

The PSR is being constructed with components that should allow rapid upgrading to 200 μa at 24 hertz; with redesign of several of the critical power components it is hoped that 400 μa will be achievable at 48 hertz. The PSR will also produce 1-nanosecond bursts at the rate of 720 hertz and at an average current of 12 μa. This latter capability is particularly powerful for MeV neutron time-of-flight experiments. Initially the PSR will run in either the long pulse or short pulse mode, but upgrading to allow multiplexing of the two modes is under consideration. The PSR has very attractive capabilities for a broad spectrum of experiments and it will be used for experiments other than neutron scattering although neutron scattering will carry the highest priority. Presently the most prominently discussed additional programs include neutron nuclear physics, neutrino research, and muon condensed matter and nuclear physics research. Such programs for spallation sources are reviewed in detail in a paper by Dombeck[3] submitted to this meeting. A brief summary of plans for the WNR/PSR is given here.

Neutron Nuclear Physics

The WNR/PSR will provide outstanding characteristics for neutron nuclear physics studies from the ultra-cold neutron energy range up to 250 MeV. This is well illustrated in Figs. 4 and 5 prepared by Auchampaugh[4] where the average neutron flux on a sample is shown as a function of neutron energy. The optimum flight path has been chosen to allow a resolution of approximately 0.1%. The pairs of numbers in parenthesis are the repetition rate and the flight path respectively. The numbers in parenthesis after the facility acronym are the pulse width. The curves for WNR show the capability with and without the PSR. The facilities referred to by acronyms are located as follows: ORELA (ORNL), Gelina (CBNM), KFK (Karlsruhe), and HELIOS (Harwell).

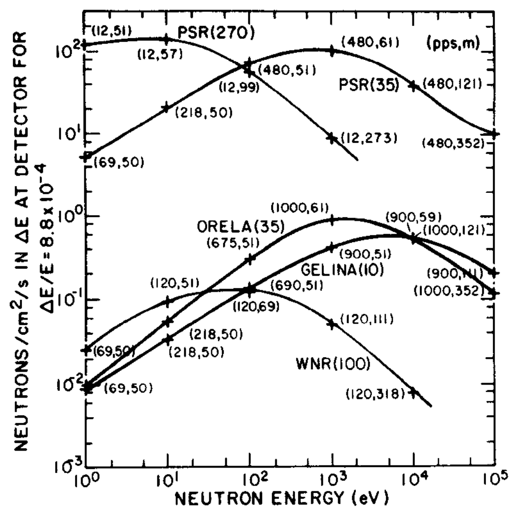

Fig. 4 Comparison of Neutron Facilities for the Low Energy Region. The two quantities in parenthesis represent pulse rate and flight path to achieve maximum neutron flux in the energy internal ΔE for the given resolution. The quantity in parenthesis by the facility name represents pulse width in nanoseconds. There are presently no plans for operating the PSR in the 35 nanosecond mode.

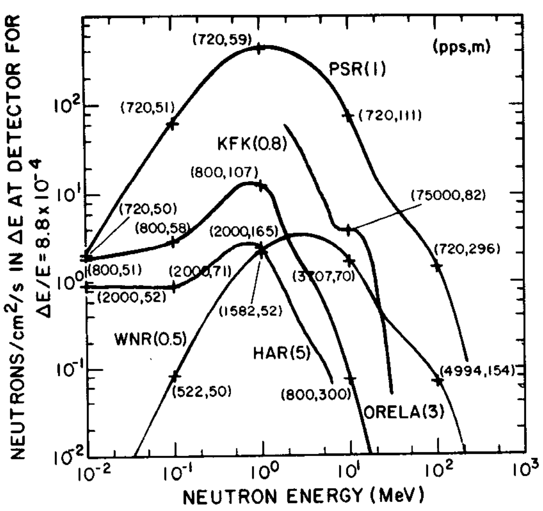

Fig. 5 Comparison of Neutron Facilities for the High Energy Region presented as in Fig. 4.

Note the enormous gain of the WNR/PSR over the WNR and the performance of the WNR/PSR relative to facilites elsewhere. Its greatest potential relative to other sources is for experiments above and below the 10-1000 keV range. At the lowest end of the range the combination of a cold moderator and a mechanical doppler system for neutron velocity reduction into the ultra-cold range (about 7 m/s) will allow collection of densities of ultra-cold neutrons that might reach 250/cm^3. A collaboration between Los Alamos National Laboratory and Argonne National Laboratory is underway to develop this for possible use in a high sensitivity attempt at measurement of a neutron electric dipole moment.

Neutron nuclear physics in the region below 1 keV has been relatively inactive in the recent years, but the factor of 1000 advantage made possible by the PSR should be a strong stimulus to this field. Studies such as doppler-free resonance neutron spectrocopy, resonance total reflection, studies with polarized beams, etc., which have not been performed thus far, should be possible. There is much in this energy range of interest at the interface of nuclear and condensed matter physics, and these two fields might well mesh here with mutual benefits to both. Since the WNR/PSR will operate 80% of the time in the long pulse mode, which is suitable for eV neutron nuclear physics, an aggressive program in this field would be possible.

For the MeV region, the WNR/PSR will be operated in the short pulse mode for approximately 20% of the time. Although this fraction is small, the very high intensity can be used to pursue experiments that cannot be done now, or experiments can be done in less time with associated increases in productivity. Experiments now underway at the WNR in fission fragment angular distribution studies and neutron-induced γ-ray emission will be greatly improved. Nuclear data measurements, particularly those of interest to the fusion programs, will be greatly facilitated by the enhanced intensity. Depending on the degree of future program development in MeV neutron nuclear physics studies, it might be appropriate to provide another target cell downstream from the PSR and WNR where such measurements could be pursued 100% of the time. Preliminary studies indicate that it should be possible to multiplex the short and long pulse modes of the PSR so that both classes or experiments could run simultaneously with separate targets.

Neutrino Physics

The attractiveness of neutrino physics using the intense proton pulses and associated low duty cycle of the PSR has been well documented[5], and facilities for a neutrino physics program are under development that would eventually use PSR beam. A neutrino experiment is being constructed at the end of the long channel that transports beam between LAMPF and the WNR. An additional beam transport line is being built into this channel that will allow LAMPF beam to be multiplexed past the PSR and the WNR and onto a target for production of muon neutrinos. The first experiments are planned for 1984. An extensive neutrino research program can be pursued for several years with the LAMPF beam while the PSR is brought on line and upgraded.

After meeting the first PSR design objectives of 100 μa in the long pulse and 12 μa in the short pulse, the long pulse capability will next be upgraded to 200 μa at which point 100 μa of beam would become available for neutrino research. Further increases in PSR current to as much as 400 μa would be allocated either to neutron scattering, to neutrino physics, or to both in accordance with relative priorities and support levels.

Muon Physics

The facilities for production of muon neutrinos for neutrino research naturally produce copious intensities of pulsed muons. A low duty cycle high intensity source of muons is highly attractive for use in condensed matter, atomic physics, and nuclear physics research. Studies by Heffner[6] indicate that muons can be collected and transported effectively from the same target used for muon neutrino production so that studies using both neutrinos and muons can be conducted simultaneously. It also appears that muon research and neutron nuclear physics research could share the same target provided that a separate target cell for this purpose were available downstream from the WNR/PSR.

SUMMARY

Much progress has been made in WNR/PSR facility development and in planning and implementing a full research program since the last ICANS meeting. Construction of the PSR continues on schedule, a significant neutron scattering research program is under way at the WNR that can continue through the construction period, and a formal neutron scattering user program was begun this year. The problem of bothersome backgrounds at the WNR has been solved, and a versatile and effective target-moderator design has been developed. Plans are being implemented for spectrometer construction, data collection and analyses facilities, and a major augmentation in experimental space.

Other areas of research besides neutron scattering made possible by the PSR have been thoroughly examined for the purpose of strengthening the Los Alamos National Laboratory research base. Promising programs include neutron nuclear physics, neutron nuclear data, neutrino physics, and muon nuclear and condensed matter physics. It also can provide forefront capability for several branches of nuclear physics research. Development of the PSR research facilities in these directions will be pursued, with highest priority continuing for neutron scattering research.

REFERENCES

1. G. P. Lawrence, Los Alamos Proton Storage Ring, ICANS VII Proceedings, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada (1983).

2. G. J. Russell, "WNR Targets and Moderators," Ibid.

3. T. W. Dombeck, "Nuclear and Particle Physics with High Intensity Pulsed Neutron Sources," Ibid.

4. G. F. Auchampaugh, Reproduced from the paper: "Status and Comparison of New, Planned, and Upgraded Pulsed White Neutron Source Facilities Since 1970," Nuclear Cross Sections for Technology, NBS Special Publication 594, pp. 920-928 (1980).

5. G. J. Stephenson, Jr., "A National Facility to Provide a High Intensity Neutrino Source," Los Alamos National Laboratory, Los Alamos, New Mexico (1982).

6. R. H. Heffner, "Proceedings of a Workshop on Muon Science and Facilities at Los Alamos," Report LA-9582-C, Los Alamos, New Mexico, March 15-18, 1982.