E. Status of the WNR, G. J. Russell, LASL

1. General

There are a number of stages any facility passes through before it reaches a mature state. These evolutionary phases may be broadly represented by: a) conceptual design, b) detailed design, c) construction, d) shakedown/initial operation at low-power, e) routine production at high-power, and f) development. I would categorize the present status of the Weapons Neutron Research Facility (WNR) to be that of approaching routine production operation (with an initial target and target/moderator configuration) and entering into an upgrade/development phase.

The WNR is one of several experimental facilities at the Clinton P. Anderson Meson Physics Facility (LAMPF), see Fig. I-E.1; the layout of the WNR is illustrated in Fig. I-E.2. The high-current area (target 1) is capable of accepting up to 20 μA of proton beam. The high-current target is vertical, surrounded by a cylindrical void ~2-m diam by ~2-m high, and is shielded by a laminated iron-concrete structure ~3.7-m thick. There are 12 flight paths penetrating the target 1 shield, and the moderator surface viewed by a flight path can be set at any angle to any one flight path. Eight of the 12 flight paths are aligned with the target center while the remaining 4 are offset from the target center by an average of 7.2 cm. The low-current target area (target 2) employs a horizontal target and can accept up to 0.1 μA of proton beam or be utilized for measurements with neutrons from target 1. There are 11 flight paths penetrating the target 2 shield.

Proton beam has been brought into target 1 and to the end of the WNR beam channel for use by experiments. The proton beam line into target 2 will be implemented this fall.

A summary of the (design) proton-pulse characteristics for the WNR is given in Table I. As can be seen, the width of the WNR proton pulse is variable. The WNR Proton Storage Ring (PSR) will be capable of providing additional pulse-width and repetition-rate combinations with higher instantaneous intensity. Only the extremes of the PSR operating characteristics are given in Table I.

2. Proton-Beam Line

The WNR beam line is housed in a reinforced concrete beam channel that connects LAMPF to the WNR, a distance of ~ 232 m. The beam line consists of a 10.2-cm diam evacuated beam pipe (when going through magnets the beam pipe decreases to a minimum of 5.1-cm diam), an array of magnets (used to bend, focus, and steer the proton beam), vacuum pumps, and beam-diagnostic equipment.

The WNR proton pulse is prepared for insertion into the WNR beam line by a chopper located in the main LAMPF beam line where the proton energy is 750 keV. The WNR pulse is formed by placing a known spacing (in time) between the LAMPF and WNR pulse (see Fig. I-E.3). This is accomplished by deflecting a portion of the LAMPF pulse into catcher plates at the chopper location and then allowing the protons comprising the WNR pulse to be accelerated to 800 MeV along with the primary LAMPF beam. The chopper can select individual micropulses out of the LAMPF macropulse if required.

The chopper is operated in conjunction with either of two kicker magnets (located in the LAMPF beam line) which deflect the WNR pulse into the WNR beam line. The slow kicker has the capability of deflecting entire LAMPF macropulses (500-μs duration) into the WNR beam line and can be operated from 1-12 Hz. The fast kicker operates at 120 Hz and can presently deflect 5 μs of proton beam into the WNR beam line. The combination of the chopper and kickers allows for a variety of WNR proton-pulse widths at an assortment of repetition rates. Five microsecond proton pulses containing ~ 2×10^{11} protons have been achieved at a repetition rate of 120 Hz. Single micropulse operation (proton pulse widths of 0.16 ns) is possible at an effective rate of 6,000 Hz.

3. High Current Target

The design of the WNR target and target/moderator configurations for target 1 was strongly influenced by the need to produce neutrons with energies ranging from a few meV to several hundred MeV having pulse widths as narrow as practical. A bare target is used to produce neutrons with energies $\gtrsim$ 100 keV. Neutrons with energies < 100 keV are produced by surrounding the target with a suitable moderator. The existing WNR target/moderator configuration is a tightly coupled system[1] and is shown in Fig. I-E.4.

The target and moderators (and associated mechanical mechanisms) as well as the various cooling systems have proven to be extremely reliable over the past year of "more-or-less" routine operation. There has been essentially no loss in the WNR operation over the last year which is directly associated with target 1 not being ready to accept protons. To date, the Ta target has been subjected to approximately 2,300 μA·h of 800-MeV proton bombardment. The target system has recently been operated for a short period of time at an average proton current of 18 μA.

4. Experiments and Experimental Data

There have been some measurements made to characterize the neutronics of the high-current target and moderators, and some basic measurements made to obtain data for computer code validation. These experiments include:

- neutron-spectrum measurements at 90° to the Ta (high-current) target covering the energy range from ~ 0.5 MeV to ≈ 200 MeV
- thermal neutron spectrum measurements from an H_2O moderator
- absolute spatial distributions of thermal, epithermal, and fast-neutron surface fluxes from an H_2O moderator
- absolute measurements of thin-target neutron spectra from ~ 0.5 MeV to ~ 800 MeV as a function of angle and material
- absolute measurement of neutron production from thick targets.

Some preliminary results[2] of neutron spectra from the high-current Ta target and the H_2O moderators are shown in Figs. I.E-5 and I.E-6. Some initial results of measured spatial distributions of thermal, epithermal, and fast-neutron surface fluxes from the high-current H_2O moderator are shown in Fig. I-E.7 and I-E.8. Computations are being performed to compare with the measured distributions. Thin-target neutron spectrum measurements using Al, Cu, In, Pb, and U targets are under way to validate basic production processes incorporated in the Monte Carlo codes used in spallation neutron source design. These measurements are being done by S. D. Howe and cover the energy range from ~ 0.5 MeV to ~ 800 MeV at angles of 0°, 30°, 45°, and 112°. Some initial data at 45° are shown in Fig. I-E.9. Absolute neutron yields from targets of Pb, Th, and depleted U have been measured; preliminary results are given in Table II and compared with some earlier measurements (where possible) and initial calculations.

The arrangement of target 1 flight paths and the initial instruments being developed on them are shown in Fig. I-E.10. The instruments and flight-path location will change as target 1 is further developed.

5. Near-Term Developments at the WNR

The following facility-type developments will be undertaken within the next year:

- replace the Ta target with W, improve the H_2O moderator canister construction, and alter the method of target/moderator attachment to the target/moderator mechanisms to improve remote handling capability
- develop proton-beam diagnostics for target 1 and improve beam-spot quality
- develop a facility neutron monitor
- implement a cold moderator
- optimize the production of both high-energy and low-energy neutrons
- reduce experimental backgrounds due to γ-rays, neutrons, and protons
- increase simultaneous utilization of flight paths for target 1 and study the feasibility of incorporating a radiation damage capability into target 1 by reconfiguring the target/moderator system
- improve fast-kicker reliability and capability
- implement target 1 remote handling
- develop more long-flight paths for target 1
- develop a "universal" target 1 shutter/collimation system
- expand data acquisition/reduction capabilities
- add flexibility to chopper system to allow time-sharing of proton beams.

References

1. G. J. Russell, "Initial Target/Moderator Configuration for the Weapons Neutron Research Facility," Trans. Am. Nucl. Soc. 27, 861-862 (1977).

2. G. J. Russell, P. W. Lisowski, and N. S. P. King, "The WNR Facility - A Pulsed Neutron Source at the Los Alamos Scientific Laboratory," Int'l. Conf. on Neutron Phys. and Nucl. Data for Reactors and Other Applied Purposes, Harwell, England, September 25-29, 1978.

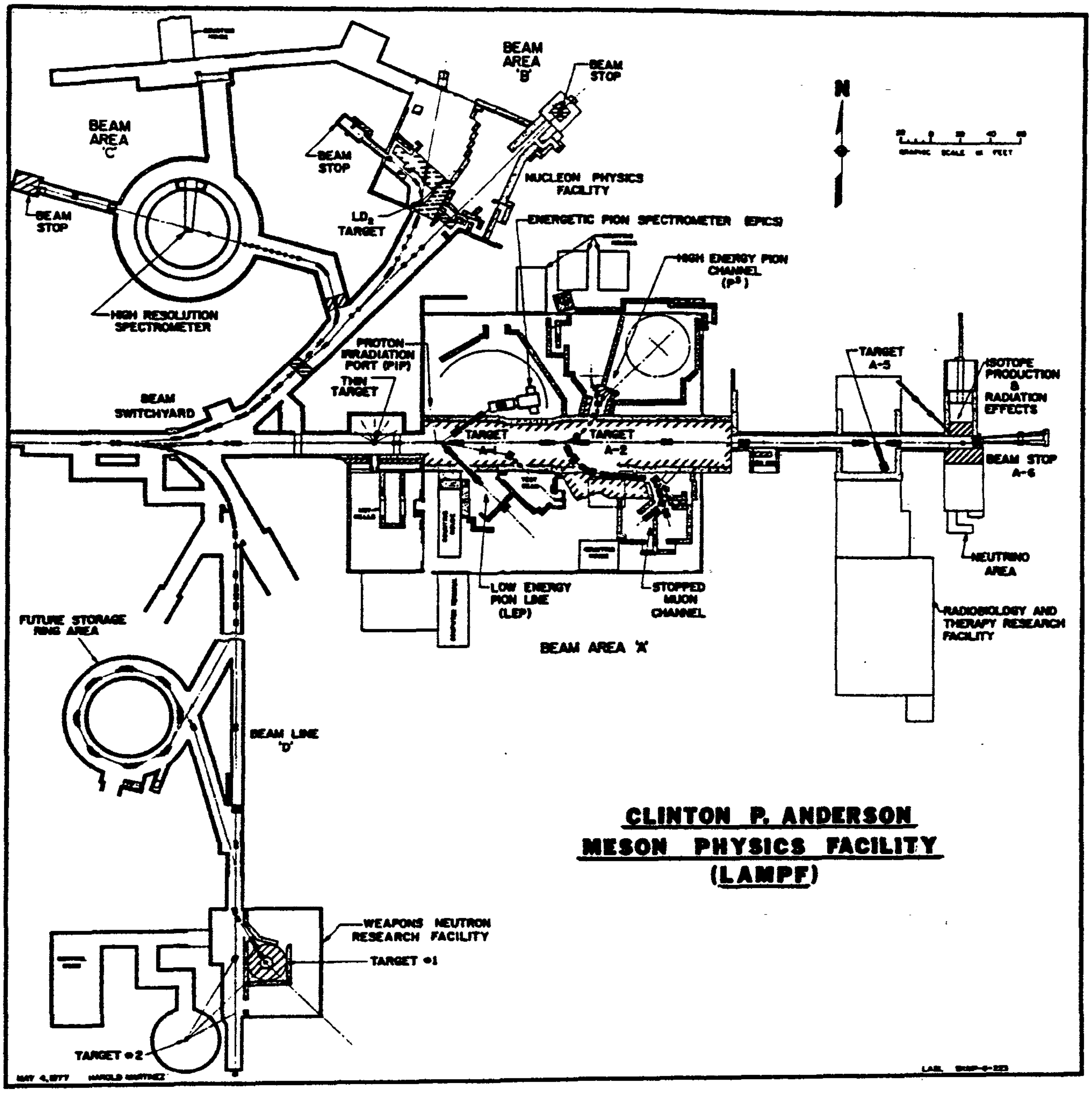

Fig. I-E.1. Experimental areas at LAMPF showing the WNR in the lower left corner.

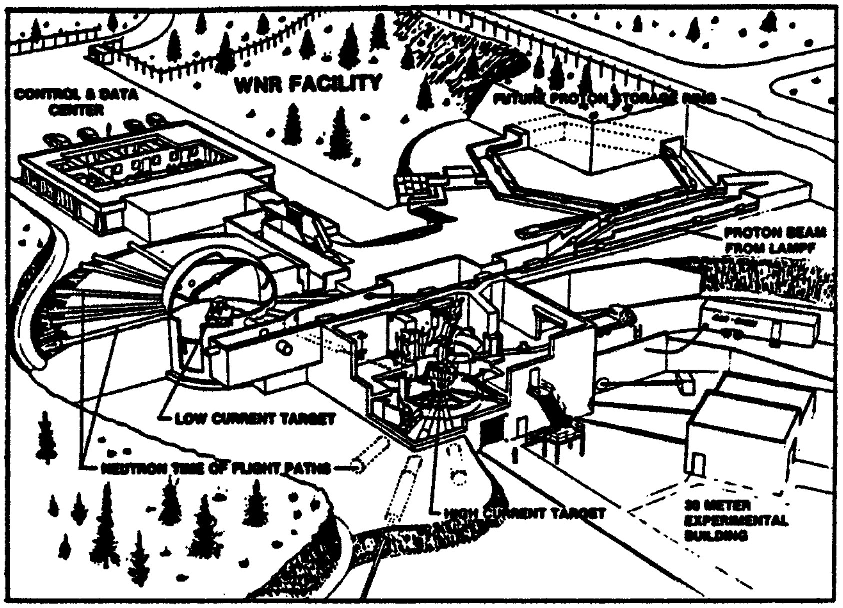

Fig. I-E.2. Illustration of the WNR.

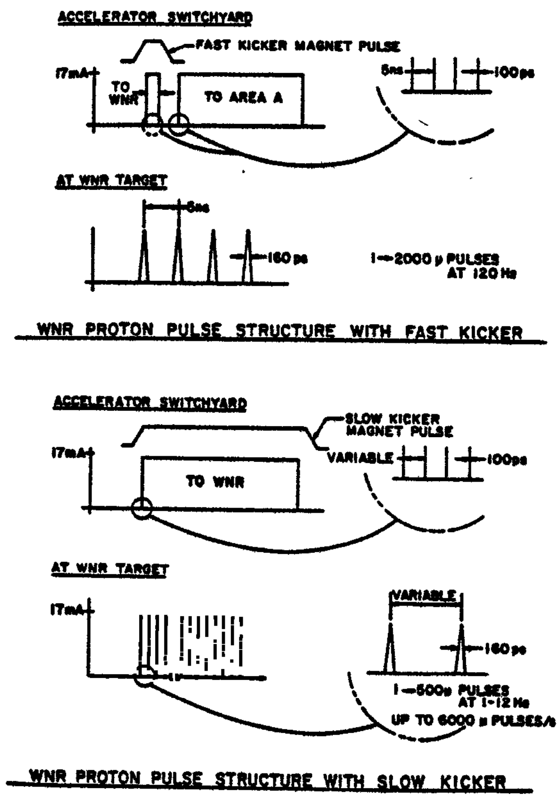

Fig. I-E.3. Illustration of the WNR proton-pulse preparation.

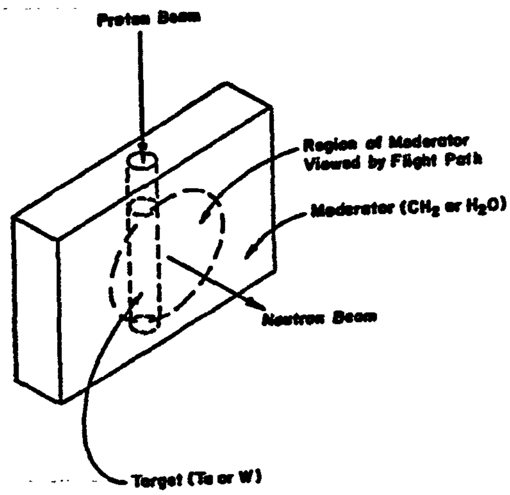

Fig. I-E.4. The initial WNR target/moderator configuration. The top of the target is below the top of the moderator.

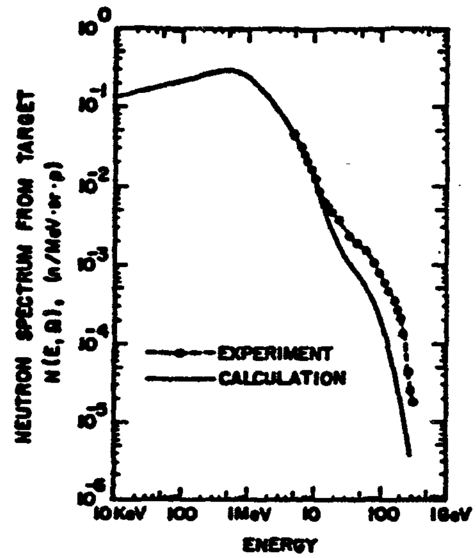

Fig. I-E.5. Fast-neutron spectrum (at 90° to the proton-beam axis) emitted from the cylindrical surface of the WNR Ta target.

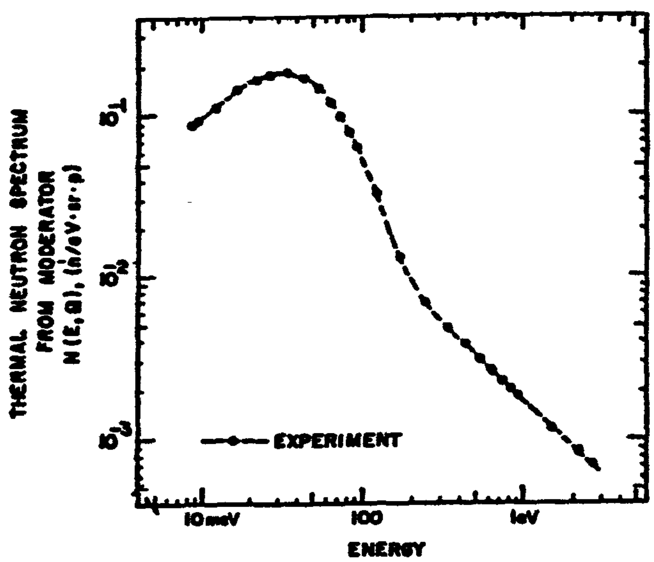

Fig. I-E.6. Thermal-neutron spectrum (at 90° to the proton-beam axis) emitted from an unpoisoned H_2O moderator.

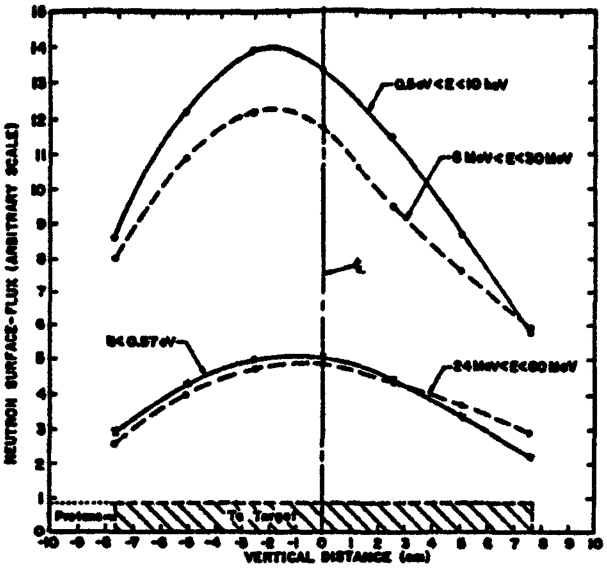

Fig. I-E.7. Measured vertical distributions of the neutron-surface flux from the 20-cm by 30-cm surface of the WNR H_2O moderator. The measurements were made along the axis of the target.

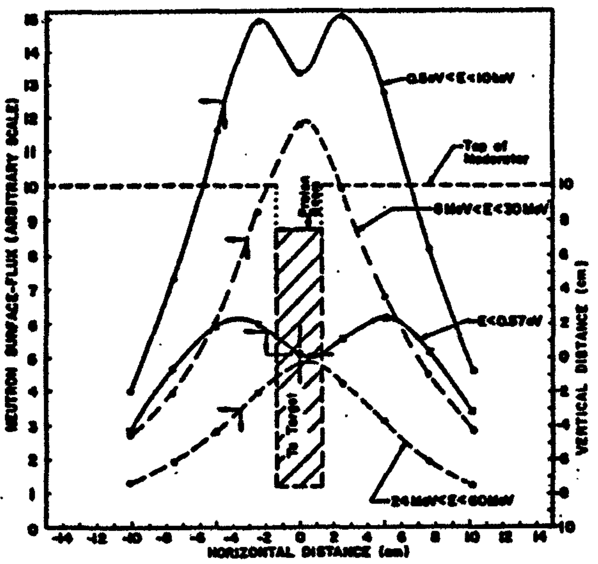

Fig. I.E-8. Measured horizontal distributions of the neutron-surface flux from the 20-cm by 30-cm surface of the WNR H_2O moderator. The measurements were made along the moderator centerline. The left axis shows the neutron surface flux and the right axis shows the vertical size of the target/moderator configuration.

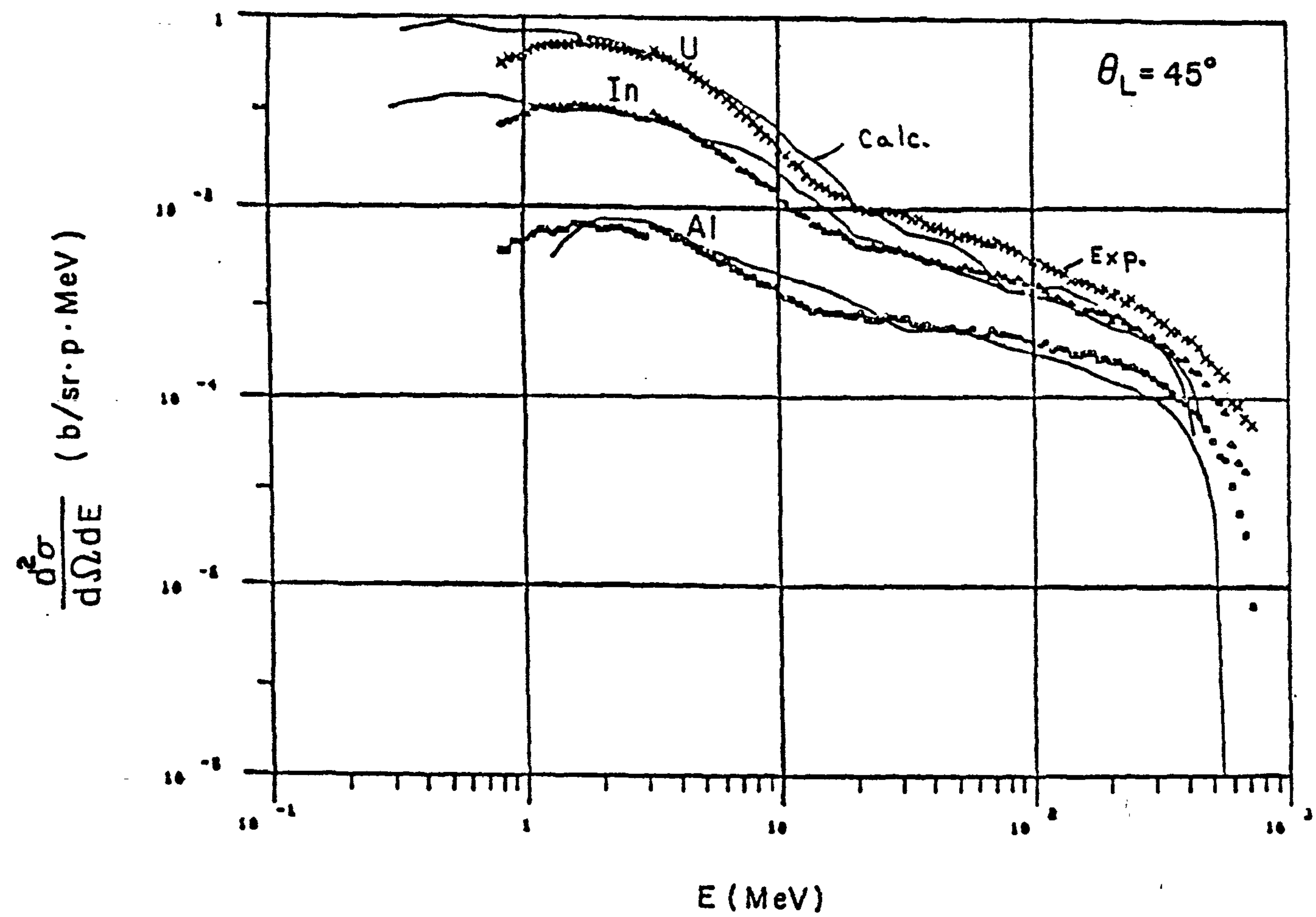

Fig. I-E.9. Neutron spectra measurements from thin targets bombarded by 800-Mev protons. The data are expressed as double differential cross sections.

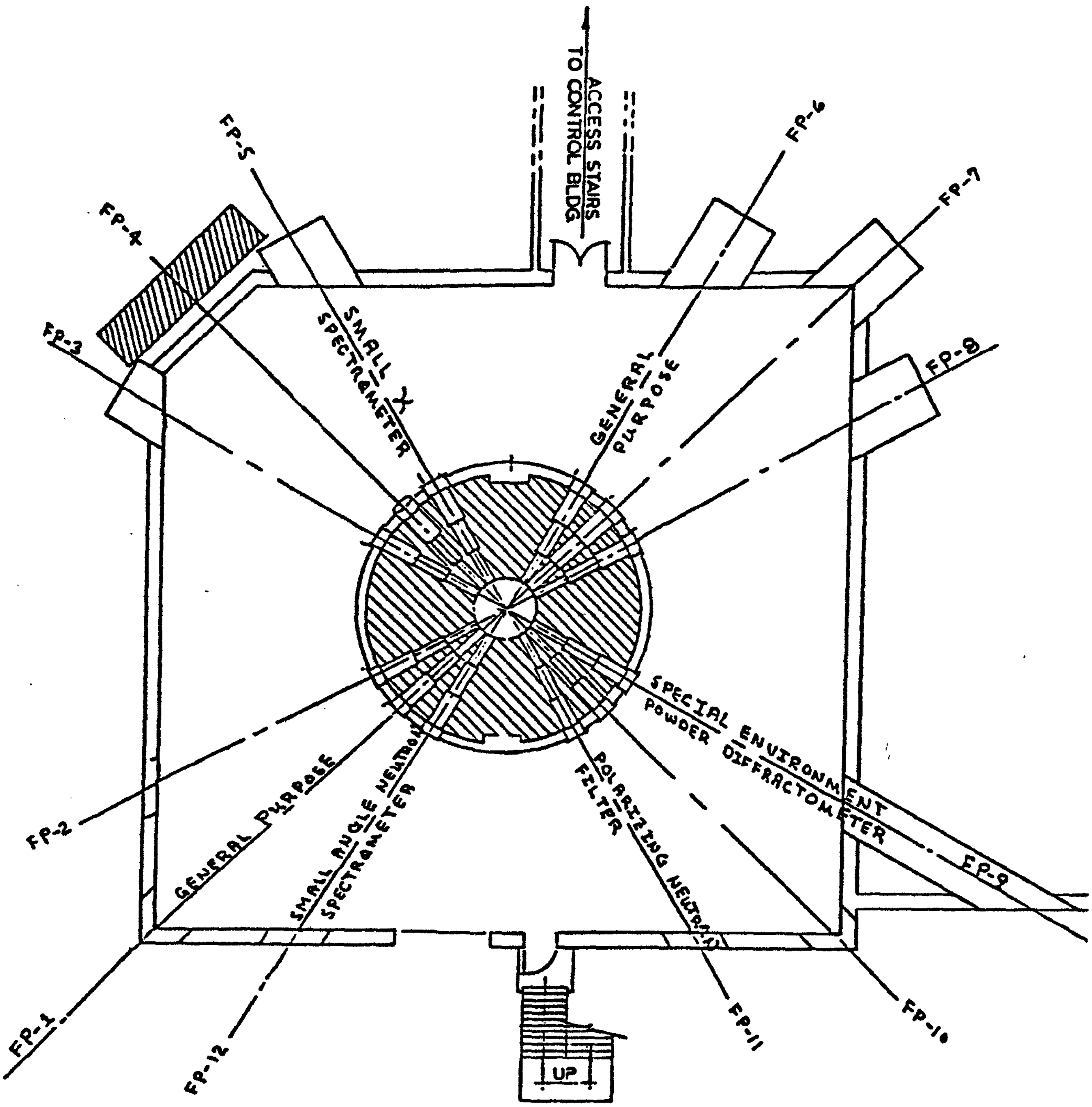

Fig. I-E.10. Initial flight-path utilization for target 1 at the WNR.

TABLE I

LAMPF AND WNR PROTON BEAM DESIGN CHARACTERISTICS

	LAMPF[a]	WNR		WNR + PSR	
		Micropulse[b] Mode	Macropulse[c] Mode	Low Repetition Rate Mode	High Repetition Rate Mode
Pulse Width	500 μs	160 ps	10 μs	200 ns	1 ns
Protons/pulse	5×10^{13}	5×10^{8}	1×10^{12}	5×10^{13}	1×10^{11}
Repetition Rate	120 Hz	1-6000 Hz	120 Hz	2.4 Hz	720 Hz
Protons/s av	6×10^{15}	$5 \times 10^{8} - 3 \times 10^{12}$	1.2×10^{14}	1.2×10^{14}	7.2×10^{13}
Average Current	1 mA	0.08 nA - 0.5 μA	20 μA	20 μA	12 μA

a The LAMPF beam structure contains micropulses separated by 5 ns intervals and grouped in 500-μs-long macropulses at 120 Hz for a 6% duty factor.

b Individual LAMPF micropulses form the WNR pulse.

c Multiple LAMPF micropulses comprise the WNR pulse. In the macropulse mode, a variety of pulse width and repetition rate combinations are possible; only the longest pulse width at the highest repetition rate is illustrated.

TABLE II

PRELIMINARY LASL FERFICON[a] RESULTS
COMPARED TO EXTRAPOLATED BNL COSMOTRON DATA

Proton Energy (MeV)	Target Material	LASL Target Size diam x length (cm x cm)	LASL FERFICON		BNL COSMOTRON H_2O Captures/Proton		BNL COSMOTRON Target Size diam x length (cm x cm)
			Calculated Neutron Leakage[c] (n/p)	Measured Thermal Neutron Captures/Proton	Calculated	Measured	
800	Pb	9.85 x 40.7	17.1	13.0	15.8	13.4	10.2 x 61.0
800	U	10.0 x 40.7	26.9	25.3	23.2	26.1	10.2 x 61.0
800	Th	18.3[b] x 40.7	21.9	17.1	----	----	-----
800	U	19.3[b] x 40.7	30.2	28.8	----	----	-----

[a]FERFICON stands for Fertile-to-Fissile Conversion.
[b]Effective target diameter.
[c]Includes neutrons of all energies leaking from a bare target.