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Abstract

The Physical makeup is presented of the Weapons Neutron Research (WNR) facility at the Los Alamos National Laboratory with emphasis on the critical components. The operating experience is discussed including failure modes and their subsequent resolution. The present target-moderator configuration is given and plans for development and improvements.

I. INTRODUCTION

The Weapons Neutron Research (WNR) spallation neutron source began operation in 1978, and since has operated for over 7000 hours. There are few spallation neutron sources which have operated for this length of time. Because the WNR is one of the first high intensity facilities, our operating experience should be of considerable interest and value to those with similar facilities in the planning, construction, or commissioning phase.

We have experienced a variety of problems in the process of bringing the WNR to a fully operational facility to provide neutron beams for a diverse research program. In order to fully understand these problems, a brief description of the facility and certain system components follows.

The WNR utilizes 800-MeV protons from the Los Alamos Meson Physics (LAMPF) linear accelerator; the work described here will not deal with the operational aspects of the accelerator. As shown in Fig. 1, the major components of the WNR facility are: 1) the proton beam transport system, 2) the high-current target system (target 1) with its associated experiment areas and flight paths, 3) the low-current target and experiment area (target 2), and 4) the control building with areas for data gathering, including a system of computers for data acquisition and reduction.

There are two modes of operation which require different modes of beam structure. We obtain these modes by means of a chopper system in the injection beam transport line of LAMPF. The first (mode 1) produces narrow micropulses (~200 ps FWHM at the WNR target) spaced a minimum of 1 s apart; these micropulses occur under a macropulse envelope 600-μs long at a rate up to 12 Hz. The second (mode 2) produces a pulse up to 8-μs long; these pulses are separated by a 16μs window from the rest of the LAMPF macropulse and occur at a rate up to 120 Hz. In order to divert these beams out of the main beam line at the end of the linac, pulsed magnets are required to minimize interference with the beams for LAMPF experiments. For mode 1, a "slow" kicker is used which operates with a pulse over 1-ms long at repetition rates up to 12 Hz. This is a 32-turn, laminated-core magnet operating at 410 amperes and bends the 800 Mev proton beam 1.8°. Mode 2 requires a "fast" kicker which must produce a pulse which rises in 10μs and must remain flat within 0.1% for 8μs. This latter magnet is a single turn device operating at 6000 amperes and bends the proton beam 1.5°. Low-field (4 kG maximum) magnets with fixed fields completes the 90° bend to transport the proton beam toward WNR. The rest of the transport system consists of quadrupoles, steering magnets, beam position sensing devices, and vacuum equipment.

The two targets and their experiment rooms are shown on Fig. 2. They have been discussed in previous ICANS literature [1,2,3] and also later in the present conference.

The data acquisition and reduction system is shown schematically in Fig. 3. The hub of the system are two Modular Computer Corporation (MODCOMP) model IV/25 mini-computers. One serves as the host computer and services the major peripherals including magnetic tapes (MT), card reader (CRD RDR), Versatic printer-plotter (PPL), and the communication links to the satellite computers located in the data rooms. This host computer also supports a

CAMAC serial highway to the experiment areas for experiment control which is separate from data acquisition. Host computer #2 is primarily used for data acquisition, but by switching a few cables, it can take over all the functions of host #1. A typical satellite system is represented by Data Room 3 (See Fig.3). The experiments are interfaced through standard CAMAC hardware in CAMAC crates CC1, CC2 -- up to CC7. This interface is done through a special Differential Branch Driver (DBD)[4] at the computer via a branch highway cable to a Differential Branch Transceiver (DBT) located next to the CAMAC crates. Keyboard Terminals (KT) of either the hardcopy or visual display type are used for inputing commands to the computer. A separate graphics display (GD) is provided to display the experiment data.

A most versatile and powerful addition shown on the two hosts, but also available on the satellites, is the bulk memory (BM) which is controlled through our bulk memory processor (BMP)[5]. The memory is of the Mostek solid state type with a maximum capacity in one crate of 6 megabytes. The BMP utilizes bit slice integrated circuits and an 80 bit wide writeable control store microcode technique. It features a 24 bit wide architecture allowing direct addressing of up to 16 megawords and histrogramming of up to 16 million counts per channel without overflow. Coding for the BMP is also supported at the macro instruction level and the event analysis language "EVAL"[6] will be implemented in the near future.

In Fig. 3 we show our planned computer system expansion in dashed boxes. Procurement is underway for the purchase of the satellite systems for Data Rooms 1 and 2 plus the new data acquisition host a VAX 11/750. The Proton Storage Ring (PSR) VAX 11/750 will be delivered by July 1 and installed at the WNR. The two VAX computers will be coupled by a communications link, and the data acquisition VAX will be coupled to the MODCOMP IV's and to the Los Alamos Central Computing Facility.

Our present schedule calls for installation of the above computer modifications and the satellite system for Data Room 4 by this time next year. We are exploring the feasibility of some microprocessor-based computer systems for particular neutron scattering instruments.

When operating the WNR personnel control is exercised through the Personnel Safety System (PSS), and neutron radiation monitoring devices. The PSS ensures that personnel are cleared from a given area before the proton beam is transported into that area. The PSS also provides the interlocks and barriers to prevent unauthorized entry into high radiation fields. In order to leave as much of the facility as possible open to human occupancy under operating conditions, these areas are monitored for neutron radiation levels by a system of fixed and portable neutron monitoring instruments called Albatross IV's which were developed at Los Alamos. The detection system for the Albatross is a 0.25-mm-thick Ag foil wrapped around a GM tube that is located in the center of a 25-cm-diam polyethylene pseudosphere. The neutrons thermalize in the moderator and are captured by ^{109}Ag to form ^{110}Ag plus a γ-ray. The ^{110}Ag beta decays with a half-life of 24.4μs. There is also a second GM tube wrapped with tin that is used to subtract counts due to γ-rays created in the moderator and also external γ-ray fields. The β plus the γ-ray counts from the Ag wrapped GM tube and the counts from the Sn wrapped GM tube are sent to a microcomputer where they are manipulated to give the net counts due to neutrons. This information is accumulated in bins for a predetermined time interval which can be varied between 15 sec and 8 min. This instrument was developed to respond to the pulsed nature of our source and gives a very good response over a large energy range as shown in Fig. 4. The instrument itself is shown in Fig. 5. It is a completely self contained unit with meter, an alarm level, an adjustable audible alarm, a chirping sound where the number of chirps/sec increases with increasing radiation levels, and outputs for remote monitoring and alarming. We presently utilize ten of these instruments in the main facility and outlying buildings on the long flight paths.

The control and monitoring functions for the entire facility are carried out at a single console. A computer identical to the smaller units used in the data acquisition system (MODCOMP 7830) is used for all non-safety control and monitoring. The PSS, the Albatross monitors and certain other safety related systems are hard wired independent of the computer system.

II. Operating Experience

The operating record for WNR is shown in Table I. The production time scheduled is the WNR schedule and ignores the WNR tuning time. For a facility as complicated as WNR (which relies on a sophisticated accelerator such as LAMPF) this is an excellent availability record.

The problem areas within the WNR which contributed to lost time are identified in Table II. The leading problem has been the fast kicker magnet. However, the excellent record in the most recent run cycle shows we have finally reduced the problem below the trouble threshold. The magnet itself is not the culprit, but the pulse forming network (PFN) which produces the high current pulse. The major changes we have made involve reducting or eliminating components which saw voltage or power levels close to their rated maximum. System noise in several of the timing interlock circuits also contributed to lost time by unnecessary shut downs and time spent chasing these faults. During the calendar year 1980, a lot of effort went into changing in the PFN to provide a longer pulse with better flat top characteristics (0.1%). This was very successful and led to a doubling of the pulse length to 8μs with the desired flat top.

The second item which one notices in Table II is the chopper problem we had in the early time periods. This was resolved by completely new hardware in which the chopper plates, with their helically wound copper ribbon, are better protected from melting by improperly tuned beam. The electronics feeding the chopper were also replaced. All these changes contributed to the recent excellent reliability of the chopper system.

The rest of Table II does not show any other consistent problems. The extremely good reliability of the control computer system should be noted by those planning control systems. It should also be noted that the high-current target-moderator-reflector system did not contribute at all to the WNR down time.

As mentioned earlier, because of the two target areas, the well shielded target 1, and the long flight paths (up to 200 m) with their associated experiment buildings, we try to allow human occupany in as much of the facility as we safely can during operation. When operating, there is always at least one person on duty within the WNR (there are many more some 50 m away at the LAMPF control room within radio and telephone contact). The individual at the WNR is the designated operator responsible for all aspects of the facility including safety and personnel access. The standard operating procedure (SOP) for the facility calls for certain restrictions on human occupancy during startup or if there is a gross change in the operating conditions. This has worked very well with two notable exceptions.

The main cylindrical biological shield surrounding target 1 has been found to be extremely effective holding levels at the surface to less than 0.5 mrem/h with up to 20 μA average current on the target. However, the flight paths themselves, when open for an experiment, have created large backgrounds in the experiment area which at times render the experiment hall unoccupyable. Most of the collimating is done within the bulk shield, but effective collimation against the entire energy spectrum from even a moderated target system is difficult. The neutron "get lost" pipes and beam stops are very important in preventing the higher energy neutron component from being thermalized and then finding their way back into the room experiment and also into the experiment detector system. This appears to be one of the more significant problems for all spallation sources, and we plan to study the energy spectrum and flux in our flight paths. This will then lead to a study of the proper shielding materials and collimating methods.

The second problem is largely on outgrowth of the first; namely, personnel control within the experiment area when there is restricted access to areas near particular flight paths. Experimenters are used to unlimited access to their samples and instruments. When restrictions are forced on them because of the radiation level from an adjacent flight path, there exists a potential problem from the experimenter who is rightfully concentrating on his own problems. In most cases, we erect physical barriers such as ropes (or more effectively nets) which act as a reminder. In extreme cases, we close the shutters on a group of three flight tubes in one of our corner clusters when access is needed to anyone of the three. We believe this latter problem can be eliminated by a proper solution to the first problem.

The data acquisiton system has evolved and grown as the needs of the experiments and neutron scattering instruments have become better defined. The general advice is to provide a high level computer for each instrument. We find it to be the most cost effective to standardize on some manufacturers hardware at a high enough level to support the most sophisticated software required by the most complex instrument. This may seem wasteful in that a simpler instrument doesn't need either that level of hardware or software, however the major costs are operational rather than the initial investment. The advantage of standardizing far outway the somewhat higher initial costs. In our system, we do share the expensive peripherals such as high density magnetic tapes, line printers and plotters. This means an effective and high speed data link between central processor units.

From an experimenters viewpoint, it makes little diffrence what computer is in the other room; what experimenters interact with is some sort of terminal-keyboard system. This is an area where the efficiency of the entire facility can be enhanced by a graphics interface system with well designed hardware and software.

III. Present Status

The facility operates routinely at 10 ma peak current with a 5-μs-long proton pulse at a repetition rate up to 120. This gives an average proton current of 6μA. We have tested the beam transport and target systems at higher average currents. We believe that an average current of 20 μA can be handled without significant improvements. The neutron fluxes from these proton currents will be discussed in a later talk at this conference.

The present target-moderator-reflector assembly is shown in Fig. 6. This configuration has been worked out to best fit the needs of the experiments on the various flight paths as shown in Fig. 7. The target is W, the premoderator is H_2O, the decoupler is Gd, the moderator is high density CH_2 and the reflector is Be and CH_2.

The flexibility of the target 1 crypt allows the choice of two targets and several moderator configurations. The nuclear physics program uses a bare tantalum target and sometimes surrounded with a CH_2 moderator for enhancing the resonance region. We can switch in a matter of 30 minutes to a completely different configuration for the material science neutron scattering program.

Of interest to those about to undertake operation of such a facility is the number of personnel needed. Again let me stress that I speak only of the proton beam transport system, the target-moderator system, and the data acquisition system plus responsiblity for the entire physical facility including safety. We are presently operating with 7.5 staff and 10 technicians. Our efficiency and effectiveness would be improved with the addition of 1 staff and 2 technicians.

IV. Planned WNR Improvements

A cold moderator development program is underway to provide a cold surface as shown in Fig. 8. The reflector shape, size and material will also be improved for this configuration.

The PSR is the biggest single possible improvement to the WNR and you will hear more about that shortly. The PSR is being designed to transmit an average proton current of 100μA to the WNR, and this will necessitate improvements within the WNR itself. The beam line must transmit these large currents of H^- beam to the PSR and then transport the H^+ to the targets. There is one area in the transport system between LAMPF and the PSR which will require magnets with an increased aperture to maintain beam spill and hence component activation at the present operating level.

The major improvements required are to the target-moderator support system in target 1. The shielding above the target is not adequate to protect the magnetic components in the 90° vertical bend. We propose to replace the entire turntable mechanism which holds our 2 targets, 4 moderators, and miscellaneous components. Based on our operational experience, our target-moderator development program and the stablizing of the experiment needs, we have a much clearer idea of what is needed for the target-moderator configuration. The improvements in this area will take all this into consideration while providing the additional shielding. Many components in this area presently maintained by hands on methods will have to be amenable to remote handling techniques. This will require extensive engineering.

The third area scheduled for improvement is additional shielding in the main experiment room for target 1. Some of this will be added to the biological shield and likewise to the neutron beam flight paths as they exit the shield. The character and location of this shielding is dependent on the solutions to the collimation and shielding problems discussed earlier.

These improvements are estimated to cost 2.7 million dollars with work commencing in October 1982 and completion commensurate with the commissioning of the PSR at 100μA.

References

1. G. A. Keyworth, Proceedings of the 4th Meeting of International Collaboration on Advanced Neutron Sources (ICANS IV) KEK, Tusukuba, October 20-24, 1980, Kens Report II, March 1981.

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3. J. Eckert, et al, Proceedings of the 4th Meeting of International Collaboration on Advanced Neutron Sources (ICANS IV) KEK, Tusukuba, October 20-24, 1980, Kens Report II, March 1981.

4. D. E. McMillan, et al, "High Speed Differential Branch Highway Driver", IEEE Transactions on Nuclear Science, Vol. NS-26, No. 4, August 1979.

5. R. O. Nelson, et al, "Bulk Memory Processor for Data Acquistion", Topical Conference on Computerized Data Acquisition in Particle and Nuclear Physics, Oak Ridge, Tenn. May 28-30, 1981 [to be published in IEEE Transactions on Nuclear Science].

6. R. A. Hardekopf, et al., "Event Analysis Language For High Speed Data Acquisition", Topical Conference On Computerized Data Acquisition in Particle and Nuclear Physics, Oak Ridge, Tenn. May 28-30, 1981 [to be published in IEEE Transactions on Nuclear Science].

7. R. J. Buchanan, "Neutron Radiation Detection at Pulsed Spallation Neutron Sources", International Collaboration on Advanced Neutron Sources, Los Alamos Scientific Laboratory, ICANS III, March 10-22, 1979.

Table I WNR Operating Record 8/1/78 - 5/1/81

Production Time Scheduled	9552 hrs
Beam Time Available From LAMPF	8564 hrs
WNR In Production	7282 hrs
Overall Availability	76 %
WNR Availability	85 %
Total Charge On Tungsten Target	5.38 mA hr
Total Number of Protons Striking Target	$1.2X10^{20}$

Table II. Reasons for Lost Production Time At WNR

	March 4 - May 6, 1979	May 22 - August 28, 1979	November 20, 1979 January 19, 1980	January 31 - March 28, 1980	June 27 - August 24, 1980	September 4 - November 9, 1980	March 1 - April 25, 1981
Fast Kicker	62	128	64	14	132	194	
Slow Kicker			2	4			6
Chopper	64	124	4			4	
Interlocks	2			4			
Targets	54						
Vacuum		50	6				
Control Computer		16			8		2
Magnet Power Supplies			48	26			2
Miscellaneous	12	8	2	8	22	2	18
Totals	194	326	126	56	162	200	28

Figure Captions

Fig. 1 Schematic of the LAMPF-WNR

Fig. 2 Schematic of the WNR Facility

Fig. 3 The WNR Data Acquisition Computer System

Fig. 4 Front view of Albatross IV pulsed neutron survey instrument

Fig. 5 Relative response of CH_2-moderated neutron survey instruments as a function of neutron energy.

Fig. 6 The present WNR target/moderator/reflector assembly for the materials science neutron scattering program

Fig. 7 WNR flight pather configuration. Fligth paths 3, 5, 6, 7, 8, 9, and 10 are used for the material science neutron scattering programs. Flight paths 11, 12, 1 and 2 are used by the nuclear physics program.

Fig. 8 Planned WNR target/moderator/reflector assembly with a cold surface.

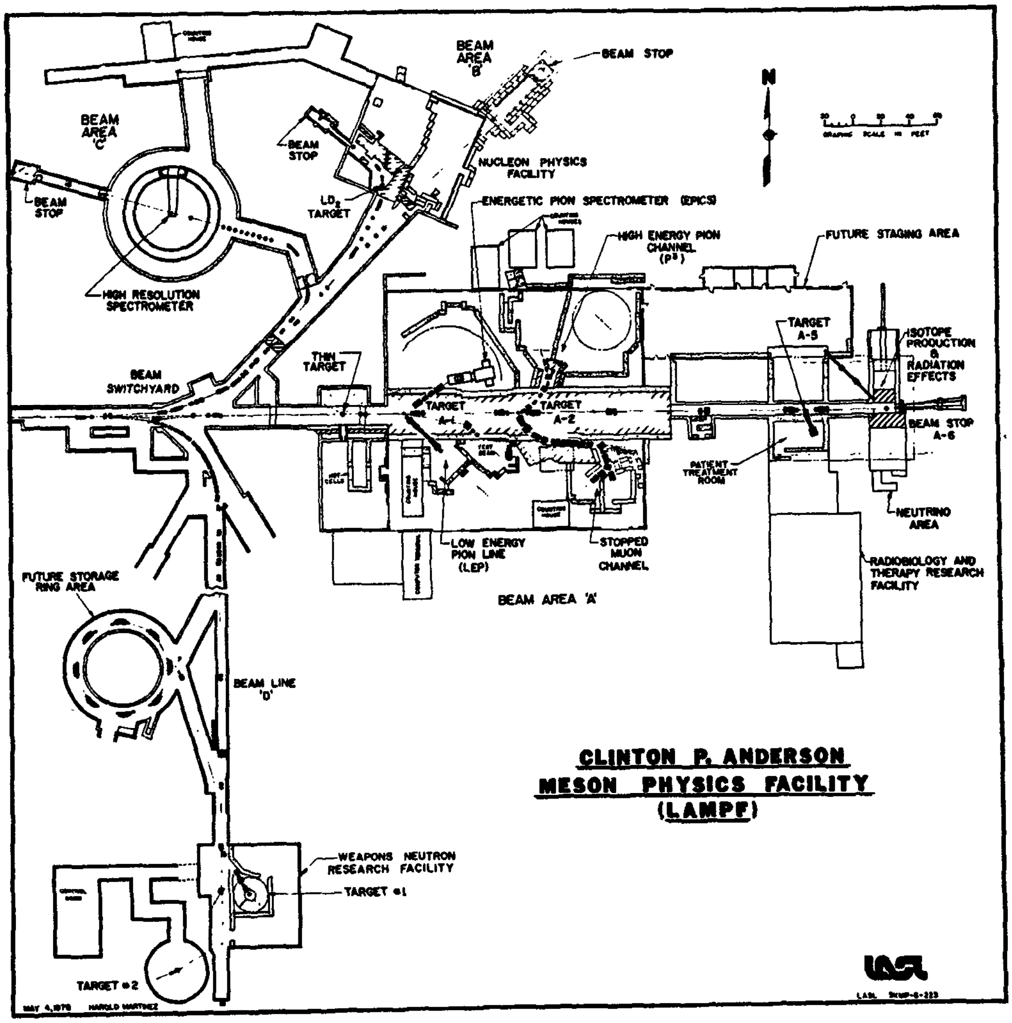
BEAM AREA 'B'
BEAM STOP
BEAM AREA 'C'
BEAM STOP
BEAM STOP
LD$_2$ TARGET
NUCLEON PHYSICS FACILITY
ENERGETIC PION SPECTROMETER (EPICS)
HIGH ENERGY PION CHANNEL (P^3)
FUTURE STAGING AREA
HIGH RESOLUTION SPECTROMETER
TARGET A-5
ISOTOPE PRODUCTION & RADIATION EFFECTS
THIN TARGET
BEAM SWITCHYARD
TARGET A-1
TARGET A-2
BEAM STOP A-6
PATIENT TREATMENT ROOM
NEUTRINO AREA
LOW ENERGY PION LINE (LEP)
STOPPED MUON CHANNEL
RADIOBIOLOGY AND THERAPY RESEARCH FACILITY
BEAM AREA 'A'
FUTURE STORAGE RING AREA
BEAM LINE 'D'
N
GRAPHIC SCALE IN FEET
CLINTON P. ANDERSON
MESON PHYSICS FACILITY
(LAMPF)
WEAPONS NEUTRON RESEARCH FACILITY
TARGET #1
TARGET #2
MAY 4,1978 HAROLD MARTINEZ
LASL

Fig. 1

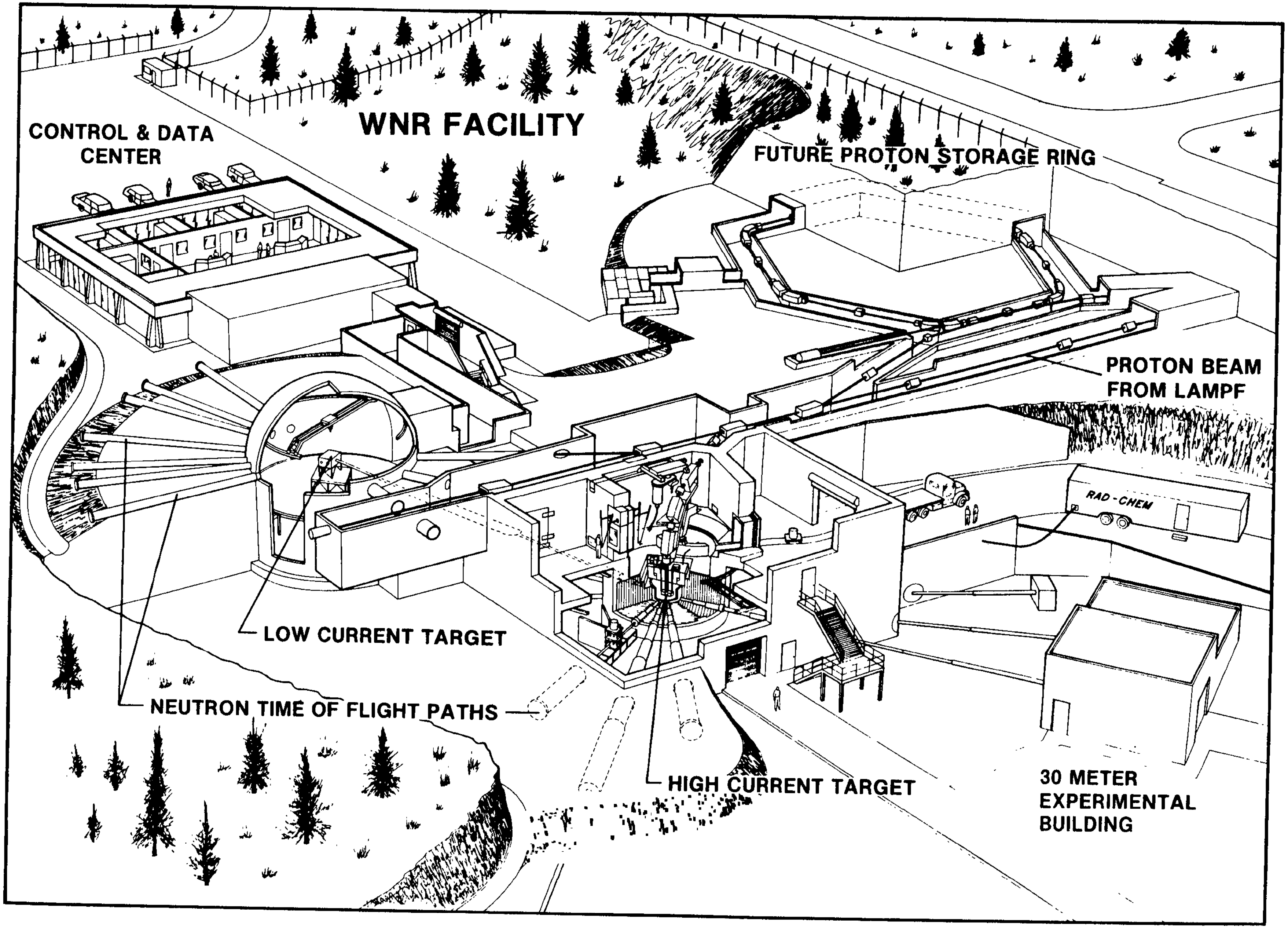
WNR FACILITY
CONTROL & DATA CENTER
FUTURE PROTON STORAGE RING
PROTON BEAM FROM LAMPF
RAD-CHEM
LOW CURRENT TARGET
NEUTRON TIME OF FLIGHT PATHS
HIGH CURRENT TARGET
30 METER EXPERIMENTAL BUILDING

Fig. 2

WNR COMPUTER SYSTEMS - PRESENT AND PROPOSED (DEM4-81)

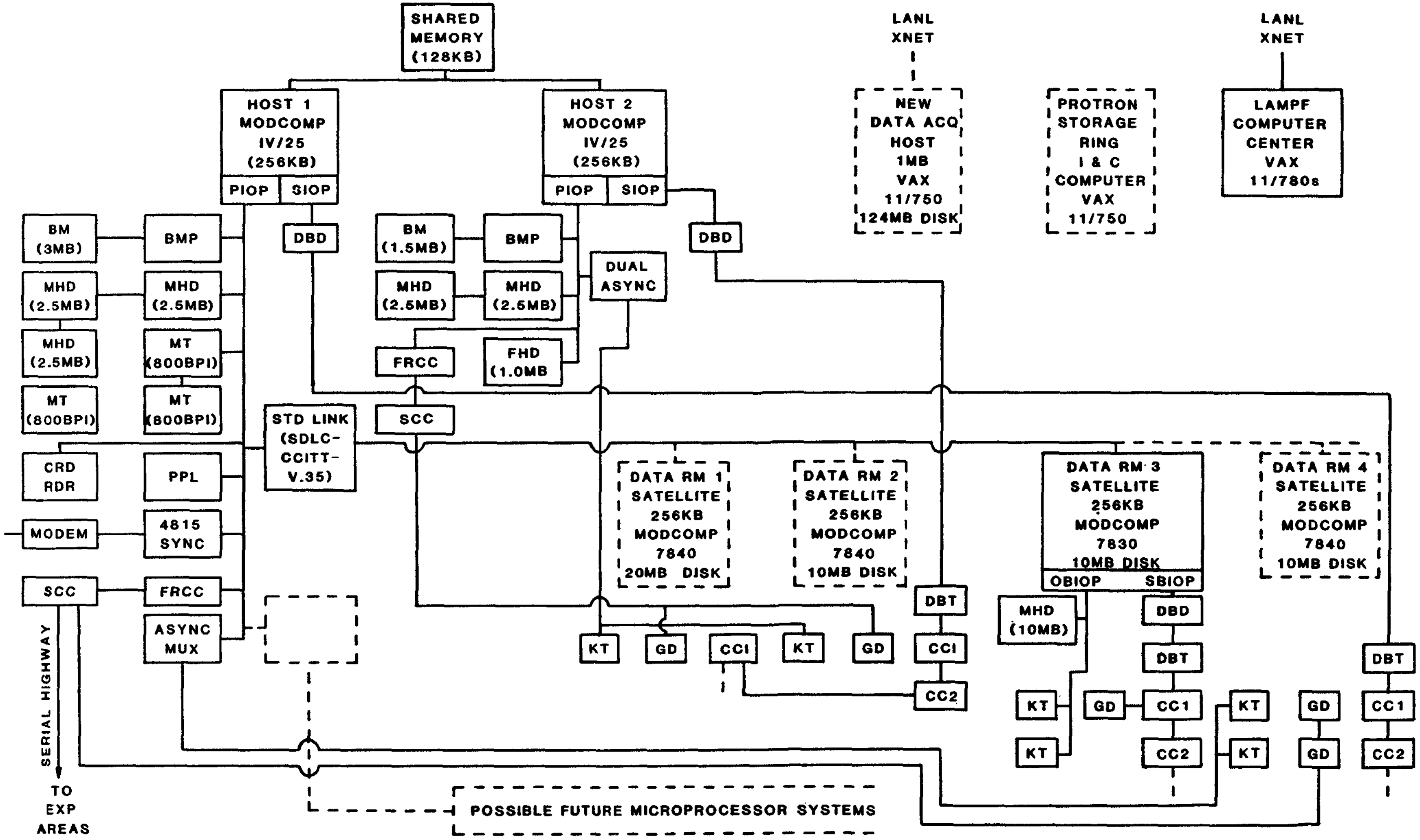

Fig. 3

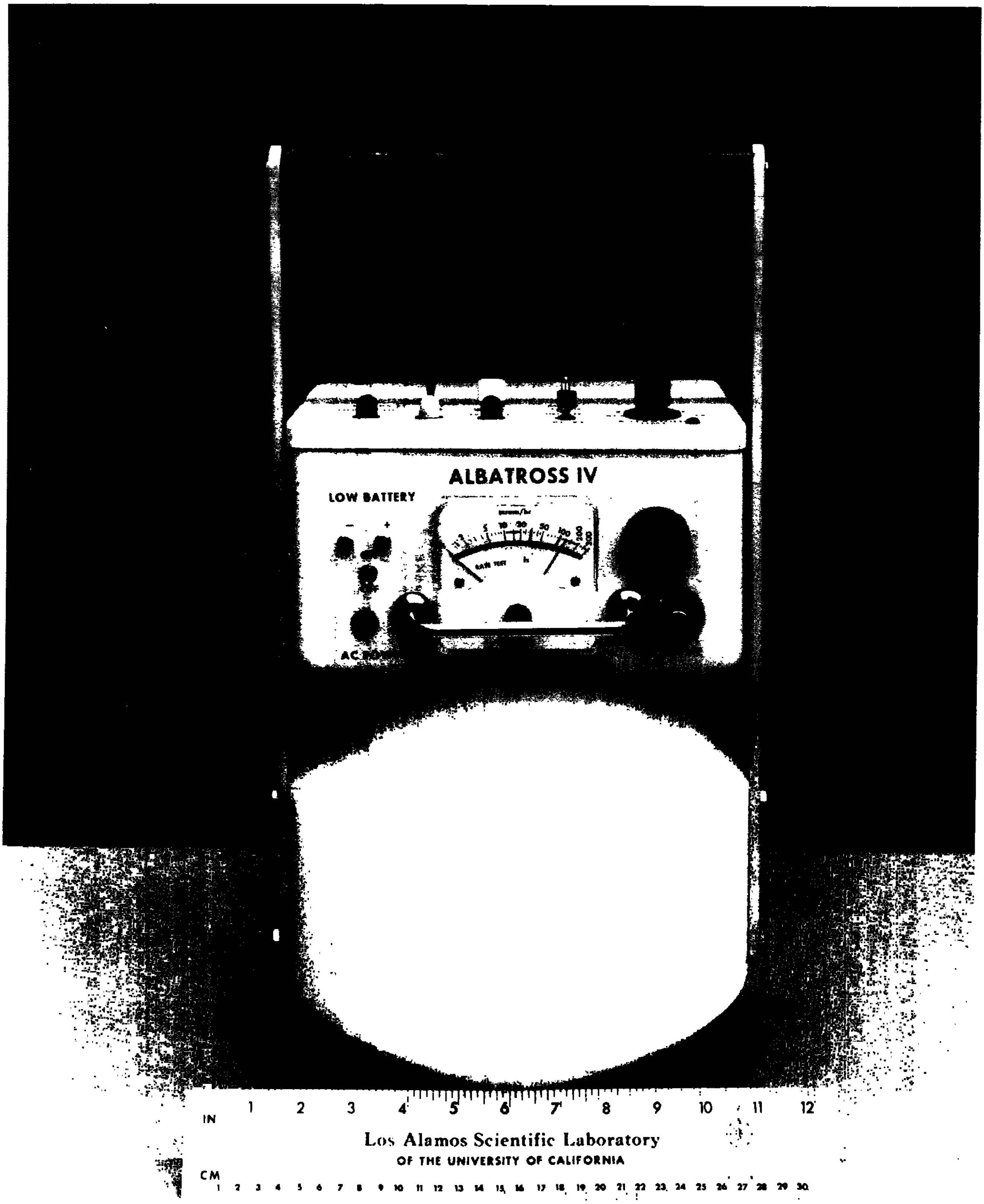
ALBATROSS IV
LOW BATTERY
AC
IN 1 2 3 4 5 6 7 8 9 10 11 12
Los Alamos Scientific Laboratory
OF THE UNIVERSITY OF CALIFORNIA
CM 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

Fig. 4

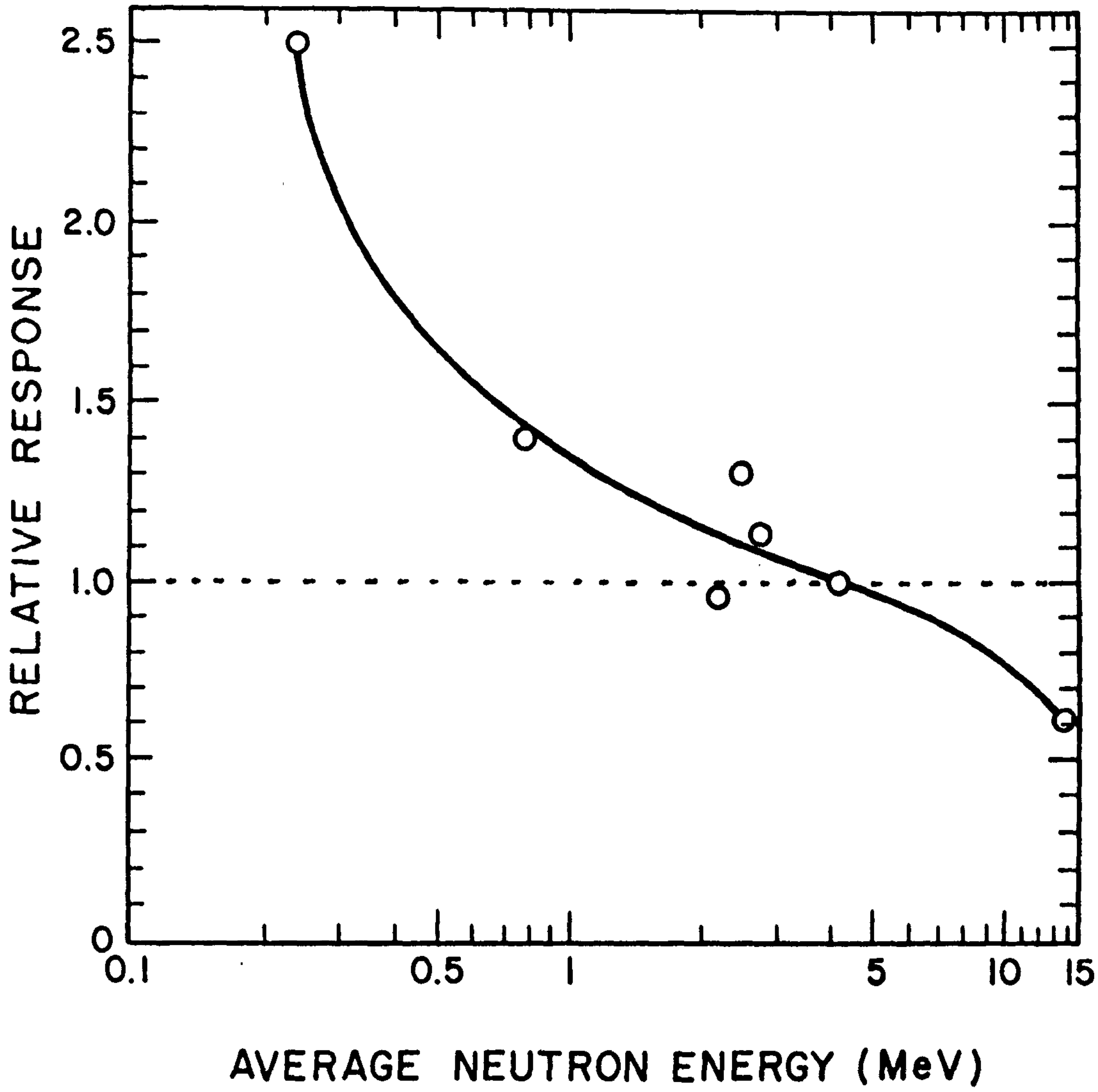

Fig. 5

Relative response of Albatross IV as a function of average neutron energy. The neutron sources used were; PuLi, PuF, ^{252}Cf, D-D, PuB, PuBe, and D-T, with average neutron energies of 0.25, 0.79, 2.2, 2.5, 2,8, 4.2, and 14 MeV, respectively.

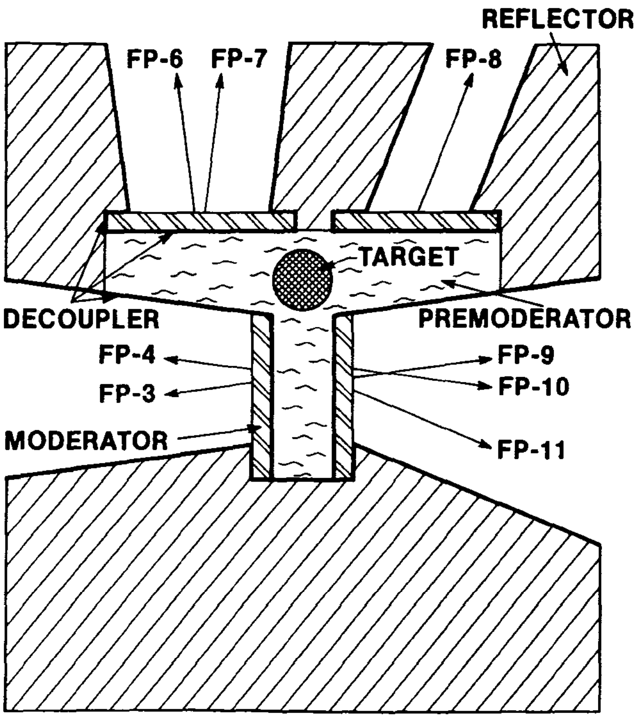

Fig. 6

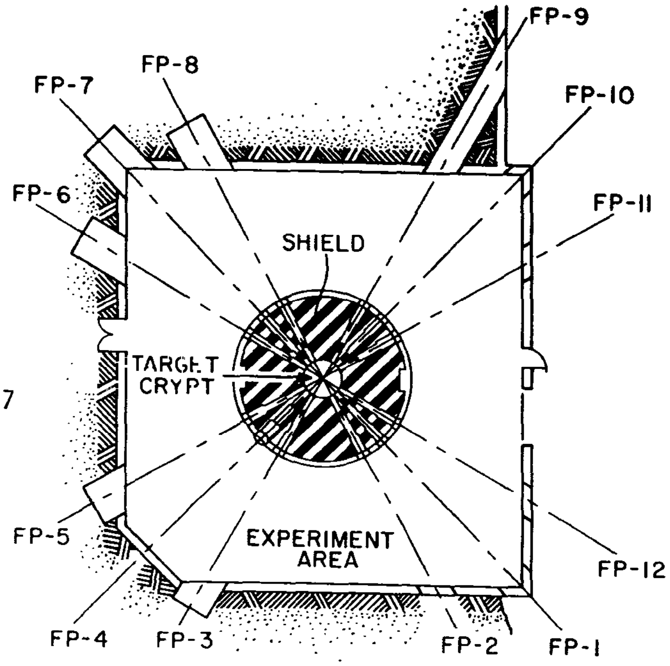

Fig. 7

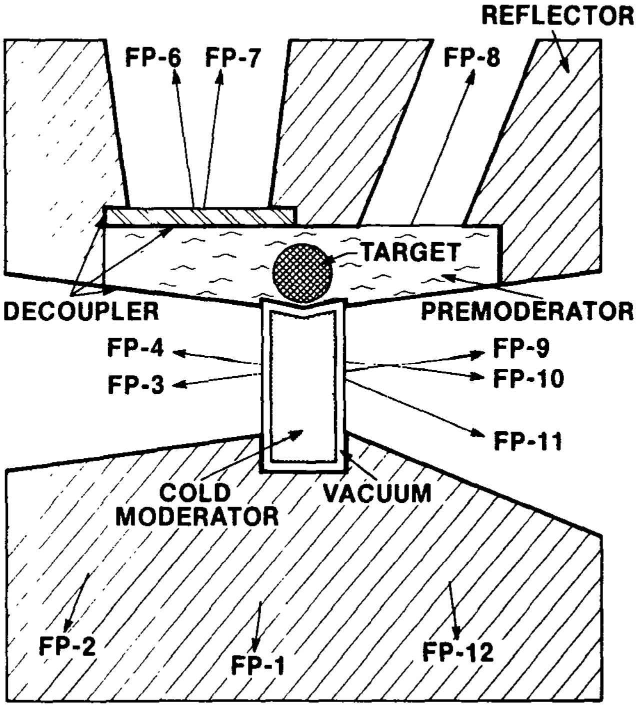

Fig. 8