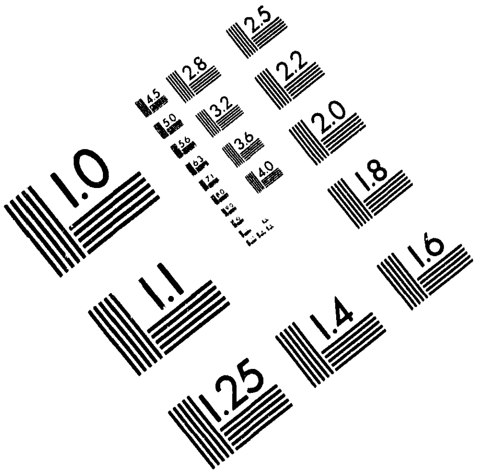

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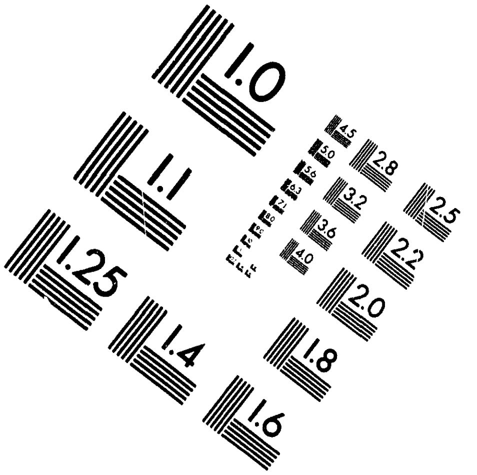

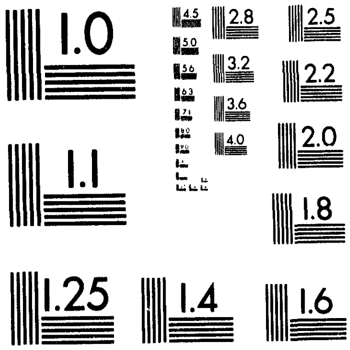

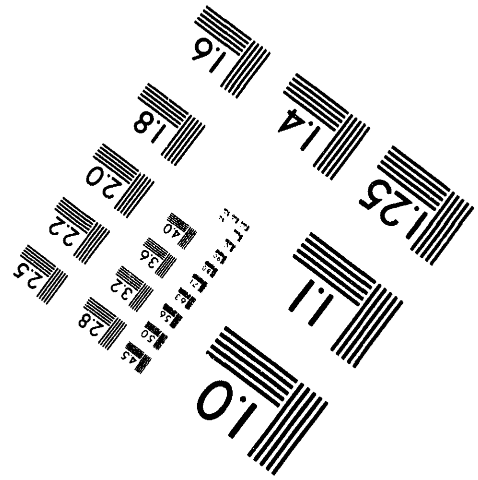

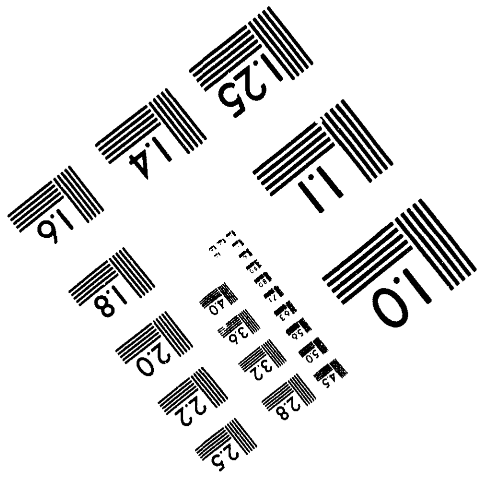

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Title:

NEUTRON-INDUCED CHARGED-PARTICLE EMISSION STUDIES BELOW 100 MeV AT WNR

Author(s):

R.C. Haight, S.M. Sterbenz, T.M. Lee, F.Bateman, LANL

S.M. Grimes, R. Pedroni, V. Mishra, N. Boukharouba,
C.E. Brient, C.C. Goeckner, Ohio University

O.A. Wasson, A. Carlson, NIST

C.M. Bartle, Inst. of Geophysical and Nuclear Sciences
Lower Hutt, New Zealand

P. Maier-Komor, T.U. Munich, Germany

H. Vonach, IRK, Vienna, Austria

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R. C. Haight, T. M. Lee, S. M. Sterbenz, F. B. Bateman,
Los Alamos National Laboratory,
Los Alamos, NM 87545 USA
(505) 667-4415

S. M. Grimes, R. Pedroni, V. Mishra, N. Boukharouba, F. C. Goeckner, C. E. Brient
Ohio University, Athens, OH 45701 USA
(614) 593-1977

O. A. Wasson, A. D. Carlson
National Institute of Standards and Technology
Gaithersburg, MD 20899 USA
(301) 975-5567

C. M. Bartle
Institute of Geophysical and Nuclear Sciences
Lower Hutt, New Zealand
(+64) 4-570-1444

P. Maier-Komor
T. U. Munich, Germany
(+49) 89-32091

and

H. Vonach
Institut für Radiumforschung und Kernphysik
University of Vienna
Boltzmanngasse
A-1090 Vienna, Austria
(+43)1-347205

ABSTRACT

Charged-particles produced by neutron bombardment of selected targets with Z=5 through 53 have been studied for neutron energies from 1 MeV to about 100 MeV using the spallation neutron source at WNR/LAMPF. Particle detection with energy measurement and particle identification is accomplished by two-element ΔE-E counters, three-element ΔE_1-ΔE_2-E counters or with pulse-shape discrimination using scintillators directly in the neutron beam. The experimental techniques for these measurements are described and comparisons made among the different approaches. This presentation introduces five papers contributed to this conference.

I. INTRODUCTION

For several years, a program has been underway at the LAMPF/WNR spallation source of fast neutrons to study (n,charged particle) reactions in the range from 1 MeV to over 30 MeV using target foils and direct particle detection techniques. In the last year, this approach has been augmented for materials that can be constituents of scintillators by putting selected scintillating crystals in a low-intensity beam. For those scintillators that exhibit pulse shape differences for different particle types, cross sections for specific reactions can be deduced. The neutron energy range in this latter approach extends to above 100 MeV. This paper is intended to summarize these techniques and to introduce several other papers presented at this meeting.[1-4]

II. DIRECT PARTICLE SPECTROSCOPY

The approach adopted here is to place materials containing the element or isotope to be studied in a well collimated neutron beam from a spallation neutron source and then to detect the charged particles produced in the nuclear reactions. This approach is then divided into two types, where different detection schemes are used:

1. Thin targets from which the charged particles can escape and then be detected by counter telescopes.
2. Thick targets that are themselves scintillators with pulse-shape discrimination to identify the particle type.

A. Neutron Source and Flux

The neutron source chosen for these studies is the spallation neutron source at WNR/LAMPF, which is centered around the pulsed 800-MeV proton beam from LAMPF accelerator interacting with an unmoderated tungsten target.[5,6] The proton pulses each contain about 3 x 10^8 protons, have a pulse length of about 0.25 ns, and, for these experiments, are spaced 1.8 microseconds apart. The macropulses are typically 600-800 microseconds long and their repetition rate is 40Hz. Thus a typical experiment will store events detected within a macropulse and then the data are read out between macropulses.

The shape of the neutron spectrum produced in the spallation target depends somewhat on the neutron production angle. (ref. Jülich) For studies below 30 MeV or so, a 90-degree production angle gives the highest number of neutrons/sr/incident proton. Thus for our studies with thin foils (technique 1, above), this production angle is preferred. Furthermore, the neutron flux is the highest here because the flight path is the shortest (9.12 m) of any installed at WNR. Higher energy neutrons (above 100 MeV) would be a complication for these studies, and this production angle minimizes them. This approach is very inefficient in the use of neutrons because of the thin target foils necessary to allow the charged particles to escape with small energy loss and because the solid angle subtended by the detectors of about 0.1 steradians for the total of four detectors.

For technique 2, where neutron energies up to at least 100 MeV are desired, more forward production angles are indicated and the 30-degree production angle is chosen. At that angle, the 41.39-meter flight path allows good energy resolution even if the time resolution of the scintillators is not extremely sharp. This approach is very efficient in the use of neutrons because the targets are thicker and the detection efficiency is close to 100% (solid angle of 4π steradians, nearly 100% detection efficiency, and only a few particles escape from the surface of the detector). The counting rate even at this relatively long flight path can therefore be very high and often the neutron flux needs to be attenuated well before the detector station. Attenuating materials (CH_2, Cu, Pb, etc.) can easily be placed in the beam both to reduce the overall flux as well as to shape the spectrum according to the experimental requirements.

Useful numbers for comparison with monoenergetic neutron sources are the neutron fluxes on target at $E_n = 10$ MeV with the proton beam parameters given above.

Production angle	Flight path (m)	Time Averaged Neutron Flux at En=10 MeV ($n\ MeV^{-1}\ cm^{-2}\ sec^{-1}$)
90^o	9.12	6×10^4
30^o	41.39	3×10^3

Although the flux at this energy is lower than can be achieved with monoenergetic neutron sources, it should be remembered that, with the spallation source, a wide range of neutron energies can be investigated simultaneously. The duty factor of this beam is about 3.2% and therefore the instantaneous neutron fluxes on target are a factor of 30 greater than those stated above. The neutron flux spectrum is monitored by a fission counter which contains deposits of both ^{235}U and ^{238}U.[7] Good agreement is obtained between these two monitors.

B. Targets

Targets are self-supporting foils (Technique 1) or scintillating materials (Technique 2). The foils are typically 10 cm in diameter and are mounted on supporting rings so that the open diameter is 8.8 cm. The large area of these foils is desired to increase the counting rate. The targets range from 0.1 to tens of mg/cm^2 in areal density. With self-supporting foils, there is a minimum of contaminating elements. The target material is also independent of the detectors so that any material that can be formed into such a foil can be investigated.

Scintillators have been used to detect charged particles produced *in situ* by neutron-induced reactions at both monoenergetic and continuous energy neutron sources (e.g. Refs. 8 and 9). For those materials that constitute scintillators, this is an extremely powerful approach because of the efficiency of particle detection and because relatively thick targets (1-2 cm) can be used. Thus, reactions can be studied on elements such as C, F, Na, K, Ca, Cs, I, and so forth, which are found in scintillators such as NaI, KI, CaF_2, and CsI. The work begun here[4] is an attempt to extend previous measurements to higher neutron energies and to new scintillating materials.

C. Detectors

Since the detectors can be completely independent of the target material in technique 1, they can be chosen to optimize parameters of interest such as energy and time resolution, energy range, sensitivity to one or more particle types, insensitivity to background radiations, and so forth. They can be shielded from the neutron beam and most of the scattered neutrons.

The detector arrangement now in use at WNR (illustrated in Figure 1) is designed to detect rather short-range particles with a lower limit in our experience being the range of 1.3 MeV alpha particles. These particles pass through the proportional counters and are stopped in the silicon detectors with enough energy loss in the silicon to give a good signal above the electronic threshold. Much more penetrating particles (up to 50 MeV protons) pass through the silicon detectors and are stopped by CsI(Tl) scintillators 1 cm thick which are coupled to 1 cm^2 solid-state photodiodes. In both cases, timing information is taken from the silicon detectors and typical time resolutions of 3 ns are obtained in short runs.

In technique 2, the scintillation detector is the target. The scintillation light is viewed by a photomultiplier in the conventional manner.

D. Electronics

The electronics are conventional with a few exceptions. Because of the long flight paths, the locations of the beam pickoff (for timing) and the data collection areas (near the beam pickoff), and the slow signals from some of the detectors (especially the proportional counters and the solid-state photodiodes), long delay times are required for the timing pulses. Electronic delays are typically not stable over long running periods to the accuracy desired in these studies of about 1 ns. Therefore, as a developmental project, some of the timing signals are delayed by fiber optics over distances of approximately 1 km, and a significant improvement in the time-stability has been achieved for delay times of 4 microseconds.

All of the electronic signals are digitized by commercial CAMAC modules. The XSYS data acquisition, display and analysis system[10] is used throughout.

III. RESULTS

Results are reported at this conference on studies of (n,α) reactions on C, ^{56}Fe, and ^{59}Co using technique A, and on a set of three alkali iodide scintillators using technique B. Good agreement is usually found with measurements using monoenergetic neutron sources where such data are available. The strength of this approach with the continuous neutron source at WNR is that the "difficult" regions in neutron energy, that is, between 8 and 13 MeV and above 15 MeV, are easily probed. Data above 20 MeV are essential for some applications, and even for evaluations that stop at 20 MeV, it is very helpful to see the trend in the cross sections above that energy. From the continuous range of neutron energies, a different view of the landscape of (n, charged particle) reactions is now possible (see Fig. 1 of Ref. 3).

REFERENCES

1. S. M. Sterbenz, F. B. Bateman, T. M. Lee, R. C. Haight, P. G. Young, M. B. Chadwick, F. C. Goeckner, C. E. Brient, S. M. Grimes, H. Vonach, and P. Maier-Komor, "The ^{56}Fe(n,xα) Reaction from Threshold to 30 MeV," Int. Conf. on Nuclear Data for Science and Technology, Gatlinburg, TN, May, 1994 (to be published).

2. F. Goeckner, S. M. Grimes, C. E. Brient, T. M. Lee, S. M. Sterbenz, F. B. Bateman, R. C. Haight, P. G. Young, M. B. Chadwick, O. A. Wasson, and H. Vonach, "The

^{59}Co(n,α) Reaction from Threshold to 30 MeV," Int. Conf. on Nuclear Data for Science and Technology, Gatlinburg, TN, May, 1994 (to be published).

3. R. C. Haight, T. M. Lee, S. M. Sterbenz, F. B. Bateman, S. M. Grimes, R. Pedroni, V. Mishra, N. Boukharouba, F. C. Goeckner, O. A. Wasson, and H. Vonach, "Alpha-particle Emission from Carbon Bombarded with Neutrons Below 30 MeV," Int. Conf. on Nuclear Data for Science and Technology, Gatlinburg, TN, May, 1994 (to be published).

4. C. M. Bartle and R. C. Haight, "Response of Alkali Halide Scintillators to Neutrons from 5 to 100 MeV," Int. Conf. on Nuclear Data for Science and Technology, Gatlinburg, TN, May, 1994 (to be published).

5. P. W. Lisowski, C. D. Bowman, G. J. Russell, S. A. Wender, "The Los Alamos National Laboratory Spallation Neutron Sources," Nucl. Sci. Eng. **106**, 208 (1990).

6. H. Condé, R. Haight, H. Klein, and P. Lisowski, "New Neutron Facilities for Nuclear Data Measurements at $E_n > 10$ MeV," Proc. Int. Conf. Nuclear Data for Science and Technology, ed. S. M. Qaim, Jülich, Germany, 1991 (Springer-Verlag, Berlin, 1992) p. 386.

7. S. A. Wender, S. Balestrini, A. Brown, R. C. Haight, C. M. Laymon, T. M. Lee, P. W. Lisowski, W. McCorkle, R. O. Nelson, W. Parker, and N. W. Hill, "A Fission Ionization Detector for Neutron Flux Measurements at a Spallation Source," Nucl. Instr. Methods in Physics Research **A336**, 226 (1993).

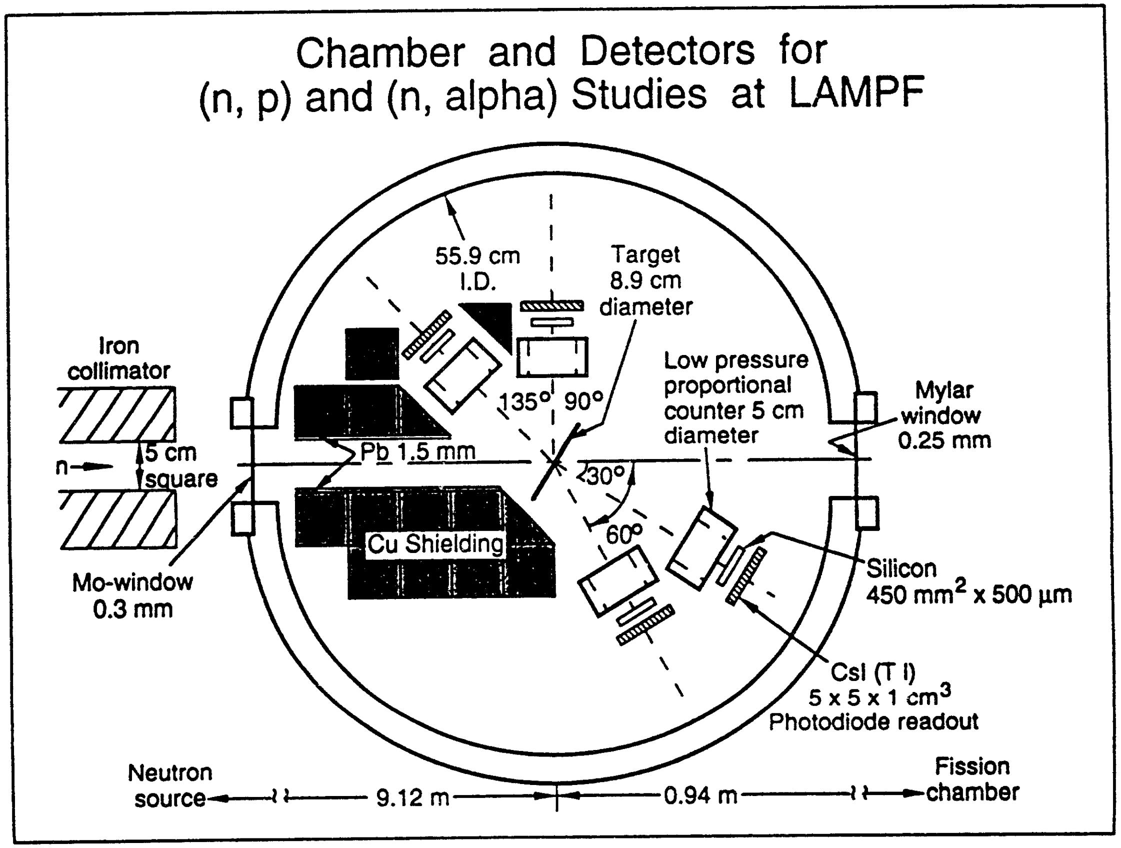
8. H. Weigmann, G. F. Auchampaugh, P. W. Lisowski, M. S. Moore, and G. L. Morgan, "Neutron-Induced Charged-Particle Reactions on ^{23}Na," Proc. Int. Conf. Nuclear Data for Science and Technology, ed. K. H. Böckhoff (D. Reidel, Antwerp, Belgium, 1983) p. 814.

9. C. M. Bartle, "A study of (n,p) and (n,α) reactions in NaI(Tl) using a PSD method," Nucl. Instr. Meth. **124**, 547 (1975).

10. N. R. Yoder, "XSYS, IUCF Data Acquisition Software," Indiana University Cyclotron Facility internal report (1991).

Figure Captions:

Figure 1. Experimental setup of detectors for (n,charged particle) reactions for neutrons in the range 1-50 MeV at WNR/LAMPF.



Chamber and Detectors for (n, p) and (n, alpha) Studies at LAMPF

Figure 1

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