

Neutron-Nucleus Collisions

A Probe of Nuclear Structure

Edited by
J. Rapaport, R. W. Finlay, S. M. Grimes
and F. S. Dietrich

AIP Conference Proceedings
Series Editor: Hugh C. Wolfe
Number 124

0572.21
R 216

Neutron-Nucleus Collisions

A Probe of Nuclear Structure

(Burr Oak State Park, Ohio, 1984)

Edited by
J. Rapaport, R. W. Finlay, S. M. Grimes
Ohio University
and
F. S. Dietrich
Lawrence Livermore National Laboratory

American Institute of Physics
New York 1985

Copying fees: The code at the bottom of the first page of each article in this volume gives the fee for each copy of the article made beyond the free copying permitted under the 1978 US Copyright Law. (See also the statement following "Copyright" below.) This fee can be paid to the American Institute of Physics through the Copyright Clearance Center, Inc., Box 765, Schenectady, N.Y. 12301.

Copyright © 1985 American Institute of Physics

Individual readers of this volume and non-profit libraries, acting for them, are permitted to make fair use of the material in it, such as copying an article for use in teaching or research. Permission is granted to quote from this volume in scientific work with the customary acknowledgment of the source. To reprint a figure, table or other excerpt requires the consent of one of the original authors and notification to AIP. Reproduction or systematic or multiple reproduction of any material in this volume is permitted only under license from AIP. Address inquiries to Series Editor, AIP Conference Proceedings, AIP, 335 E. 45th St., New York, N. Y. 10017.

L.C. Catalog Card No. 84-73216

ISBN 0-88318-323-4

DOE CONF- 840945

Neutron-Nucleus Collisions
A Probe of Nuclear Structure
(Burr Oak State Park, Ohio, 1984)



Proceedings of the
Conference on Neutron Nucleus Collisions--
A Probe of Nuclear Structure

Burr Oak State Park, Glouster, Ohio

September 5-8, 1984

PREFACE

The desire to hold this topical conference grew in part out of the success of informal workshops sponsored by Lawrence Livermore National Laboratory and held in Asilomar, California, in 1981, 1982 and 1983. The purpose was to discuss how neutrons as a probe can yield information on contemporary issues in nuclear reaction and in nuclear structure. The emphasis of the program was on reactions and scattering in the energy range up to 100 MeV, an energy range where we have or expect soon to have experimental data. However, the discussion also spanned the intermediate energy range, especially in charge exchange reactions.

The Conference was organized in six sessions including a session of Applications and Techniques and a session on Astrophysics. Another session was devoted to contributed papers. One special session was dedicated to the memory of Peter Moldauer.

The theoretical interpretation of nucleon-nucleus collision processes may be considered to be at a transition point between traditional phenomenological models and a more fundamental microscopic description. The latter has been very successful at intermediate energies where the impulse approximation may be used and the t -matrix is replaced by the free nucleon-nucleon interaction. Below 100 MeV, effects of the nuclear medium become much more important and the need of a density dependent effective interaction is clearly manifested.

Relative contributions of target neutrons and target protons to "collective" nuclear excitations has been one of the traditional problems in nuclear structure. Recent progress in this area, obtained by simultaneous analysis of nucleon inelastic scattering and from electromagnetic excitations, has been very rewarding.

In the recent years perhaps one of the most exciting results in nuclear physics has been the clear observation of spin excitations in nuclei. The most dramatic example is the observation of Gamow-Teller and M1 giant resonances in medium and heavy mass nuclei via (p,n) and (p,p') reactions at or near zero degrees with 100-200 MeV incident protons. The above data are used to obtain information on β^- strength distribution in nuclei. At present there is no information on β^+ strength distribution, which is badly needed in astrophysical problems and double beta decay.

The purpose of the Conference was to address the above questions as well as other topics in which neutron plays an important role and to elicit exchange of ideas between the participants.

One important aspect of the Conference was to review the available neutron facilities and to discuss future development plans. A workshop in experimental techniques was held to address these questions and to indicate priorities on future new facilities.

The major credit for the success of the Conference goes to all the speakers for their stimulating talks and to the participants for their lively contributions in the discussion periods. From the early planning stages of the Conference to the editing of the proceedings, Ms. Cindy White, secretary for the Ohio University Accelerator Laboratory, dedicated a sizable fraction of her time in the organization of the Conference. We certainly appreciate and commend her for her enthusiasm and competence. A large part of the Conference arrangements were done by the Ohio University Office of Workshops and Conferences. Here we acknowledge the invaluable assistance of Andrew Chonko and Steve Orth of the Workshops Office.

In these proceedings, contributions are presented as they were presented at the Conference. Photographs of the Conference here reproduced were taken by R.O. Lane who deserves all the credit and our thanks for his efforts.

Thanks are also due to the Harshaw-Filtrol and Tenulec Corporations not only for their interesting displays but also for their economic help towards the expenses of the social functions.

J. Rapaport
Athens, Ohio
November 1984

SPONSORS

U.S. National Science Foundation
Argonne Universities Association Trust Fund
Lawrence Livermore National Laboratory
Ohio University 1804 Alumni Fund
Ohio University Physics Department

ADVISORY COMMITTEE

S.M. Austin, Michigan State University, East Lansing, MI
H. Barschall, University of Wisconsin, Madison, WI
J.C. Browne, Los Alamos National Laboratory, Los Alamos, NM
G. Bertsch, University of Tennessee, Knoxville, TN
H. Feshbach, Massachusetts Institute of Technology, Cambridge, MA
H. von Geramb, Universitat Hamburg, Hamburg, West Germany
J. Harvey, Oak Ridge National Laboratory, Oak Ridge, TN
C. Mahaux, University of Liege, Liege, Belgium
A. Michaudon, Institut Laue-Langevin, France
H. Orihara, Tohoku University, Sendai, Japan
D. Seeliger, Tech. University, Dresden, East Germany
J. Speth, Inst. fur Kernphysik, KFA, Julich, West Germany
C. Zafiratos, University of Colorado, Boulder, CO

PROGRAM COMMITTEE

B. Clark, Ohio State University, Columbus, OH
P. Brady, University of California--Davis, Davis, CA
F. Dietrich, Lawrence Livermore National Laboratory, Livermore, CA
M. McEllistrem, University of Kentucky, Lexington, KY
A. Kerman, Massachusetts Institute of Technology, Cambridge, MA
F. Petrovich, Florida State University, Tallahassee, FL
J. Rapaport, Ohio University, Athens, OH
R.L. Walter, Duke University, Durham, NC

ORGANIZING COMMITTEE

F.S. Dietrich, Lawrence Livermore National Lab., Livermore, CA
R.W. Finlay, Ohio University, Athens, OH
S.M. Grimes, Ohio University, Athens, OH
C. Poppe, Lawrence Livermore National Laboratory, Livermore, CA
J. Rapaport (chair), Ohio University, Athens, OH

CONFERENCE PARTICIPANTS

M. AHMAD, OHIO UNIVERSITY, ATHENS OH 45701
R. ALARCON, OHIO UNIVERSITY, ATHENS OH 45701
S. AUSTIN, MICHIGAN STATE UNIVERSITY, E. LANSING MI 48824
N. BACK, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
H.H. BARSCHALL, UNIVERSITY OF WISCONSIN, MADISON WI 53706
S. BLOOM, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
C.D. BOWMAN, LOS ALAMOS NATIONAL LAB., LOS ALAMOS NM 87544
P. BRADY, UNIV. OF CALIFORNIA-DAVIS, DAVIS CA 95616
C. BRIENT, OHIO UNIVERSITY, ATHENS OH 45701
B.A. BROWN, MICHIGAN STATE UNIVERSITY, E. LANSING MI 48824
R. BYRD, INDIANA UNIV. CYCLOTRON FAC., BLOOMINGTON IN 47401
R.F. CARLTON, MIDDLE TENNESSEE STATE UNIV., MURFREESBORO TN 37132
J.A. CARR, FLORIDA STATE UNIVERSITY, TALLAHASSEE FL 32306
Q. CHEN, INDIANA UNIV. CYCLOTRON FAC., BLOOMINGTON IN 47405
B. CLARK, OHIO STATE UNIVERSITY, COLUMBUS OH 43210
T.B. CLEGG, UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL NC 27514
G. CODDENS, UNIVERSITY OF ANTWERPEN, ANTWERP BELGIUM
H. CONDE, UPPSALA UNIVERSITY, UPPSALA SWEDEN
J.C. DAVIS, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
J.P. DELAROCHE, SERVICE DE PHYSIQUE NUCLEAIRE, BRUYERES-LE-CHATEL FRANCE
F.S. DIETRICH, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
P. EGUN, OHIO UNIVERSITY, ATHENS OH 45701
H. FESHBACH, M.I.T., CAMBRIDGE MA 02139
R. FINLAY, OHIO UNIVERSITY, ATHENS OH 45701
T. FORD, UNIV. OF CALIFORNIA-DAVIS, DAVIS CA 95616
C.C. FOSTER, INDIANA UNIV. CYCLOTRON FAC., BLOOMINGTON IN 47405
A. FRASCA, WITTENBERG UNIVERSITY, SPRINGFIELD OH 45501
D. FRIESEL, INDIANA UNIV. CYCLOTRON FAC., BLOOMINGTON IN 47405
F. GABBARD, UNIVERSITY OF KENTUCKY, LEXINGTON KY 40553
C.D. GOODMAN, INDIANA UNIV. CYCLOTRON FAC., BLOOMINGTON IN 47405
G.C. GOSWAMI, UNIVERSITY OF LOWELL, LOWELL MA 01854
C. GOULD, NORTH CAROLINA STATE UNIV., RALEIGH NC 27695
S. GRAHAM, OHIO UNIVERSITY, ATHENS OH 45701

CONFERENCE PARTICIPANTS

S. GRIMES, OHIO UNIVERSITY, ATHENS OH 45701
R. HAIGHT, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
J.M. HANLY, UNIVERSITY OF KENTUCKY, LEXINGTON KY 40506
L.F. HANSEN, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
G. HAOUAT, CENTRE D'ETUDES B.P. 12, C.E.A. - SERVICE P2N FRANCE
J.A. HARVEY, OAK RIDGE NATIONAL LAB., OAK RIDGE TN 37831
R. HERSHBERGER, UNIVERSITY OF KENTUCKY, LEXINGTON KY 40506
S. HICKS, UNIVERSITY OF KENTUCKY, LEXINGTON KY 40506
P.E. HODGSON, OXFORD UNIVERSITY, OXFORD ENGLAND
N. HOLDEN, BROOKHAVEN NATIONAL LAB., UPTON NY 11973
G. HONORE, DUKE UNIVERSITY, DURHAM NC 27706
C. HOWELL, DUKE UNIVERSITY, DURHAM NC 27706
S. ISLAM, OHIO UNIVERSITY, ATHENS OH 45701
C. JOHNSON, OAK RIDGE NATIONAL LAB., OAK RIDGE TN 37830
C. KALBACH-WALKER DUKE UNIVERSITY, DURHAM NC 27706
H. KLAGES, KFK, KARLSRUHE W. GER D7500
H. KNOX, OHIO UNIVERSITY, ATHENS OH 45701
P. KOEHLER, OHIO UNIVERSITY, ATHENS OH 45701
R. KOHLER, CBNN GEEL, GEEL BELGIUM
CH. LAGRANCE, SERVICE DE PHYSIQUE NUCLEAIRE, BRUYERES-LE-CHATEL FRANCE
R. LANE, OHIO UNIVERSITY, ATHENS OH 45701
R. LAWSON, ARGONNE NATIONAL LAB., ARGONNE IL 60439
A. LEJEUNE, UNIVERSITY OF LIEGE, LIEGE 1 BELGIUM B4000
W.G. LOVE, UNIVERSITY OF GEORGIA, ATHENS GA 30602
J.E. LYNN, AERE HARWELL, OXFORDSHIRE ENGLAND
A.D. MacKELLAR, UNIVERSITY OF KENTUCKY, LEXINGTON KY 40506
D. MADLAND, LOS ALAMOS NATIONAL LAB., LOS ALAMOS NM 87545
V. MADSEN, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
C. MAHAUX, UNIVERSITY OF LIEGE, B-4000 LIEGE 1 BELGIUM
G. MATHEWS, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
M.T. McELLISTRETT, UNIVERSITY OF KENTUCKY, LEXINGTON KY 40506
A.S. MEIGOONI, OHIO UNIVERSITY, ATHENS OH 45701
C. MEITZLER, OHIO UNIVERSITY, ATHENS OH 45701

CONFERENCE PARTICIPANTS

S. MELLEMA, UNIV. OF WISCONSIN-MADISON, MADISON WI, 53706
 K., MURPHY, DUKE UNIVERSITY, DURHAM NC 27706
 N. OLSSON, STUDSVIK SCIENCE RESEARCH LAB, 82 NYKOPING SWEDEN
 D. ONLEY, OHIO UNIVERSITY, ATHENS OH 45701
 H. ORIHARA, TOHOKU UNIVERSITY, SENDAI 980 JAPAN
 F. OSTERFELD, JKP, KFA JUELICH, JUELICH W. GER
 R. PEDRONI, DUKE UNIVERSITY, DURHAM NC 27706
 J. PETLER, OHIO UNIVERSITY, ATHENS OH 45701
 F. PETROVICH, FLORIDA STATE UNIVERSITY, TALLAHASSEE FL 32306
 H. PFUTZNER, DUKE UNIVERSITY, DURHAM NC 27706
 C.H. POPPE, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
 J. RAPAPORT, OHIO UNIVERSITY, ATHENS OH 45701
 G. RAWITSCHER, UNIVERSITY OF CONNECTICUT, STORRS CT 06268
 D. RESLER, OHIO UNIVERSITY, ATHENS OH 45701
 W. RODNEY, NATIONAL SCIENCE FOUNDATION, WASHINGTON D.C. 20550
 J.L. ROMERO, UNIV. OF CALIFORNIA-DAVIS, DAVIS CA 95616
 E. SADOWSKI, OHIO UNIVERSITY, ATHENS OH 45701
 S. SARAF, OHIO UNIVERSITY, ATHENS OH 45701
 H. SATYANARAYANA, OHIO UNIVERSITY, ATHENS OH 45701
 D. SCHRAMM, UNIVERSITY OF CHICAGO, CHICAGO IL 60637
 P. SCHWANDT, INDIANA UNIV. CYCLOTRON FAC., BLOOMINGTON IN 47405
 J.Q. SHAO, UNIVERSITY OF LOWELL, LOWELL MA 01854
 J.R. SHEPARD, UNIVERSITY OF COLORADO, BOULDER CO 80309
 A.B. SMITH, ARGONNE NATIONAL LAB., ARGONNE IL 60439
 E.R. SUGARBAKER, OHIO STATE UNIVERSITY, COLUMBUS OH 43212
 T.N. TADDEUCCI, INDIANA UNIV. CYCLOTRON FAC., BLOOMINGTON IN 47401
 N. TAMIMI, OHIO UNIVERSITY, ATHENS OH 45701
 W. TORNOW, UNIVERSITAT TUBINGEN, TUBINGEN W. GER.
 P.A. TREADO, GEORGETOWN UNIVERSITY, WASHINGTON D.C. 20057
 J. TRURAN, UNIVERSITY OF ILLINOIS, URBANA IL 61801
 I.J. VAN HEERDEN, INDIANA UNIV. CYCLOTRON FAC., BLOOMINGTON IN 47405
 R.L. VARNER JR., UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL NC 27514
 H.V. VON GERAMB, UNIVERSITAT HAMBURG. HAMBURG 2000 GERMANY

CONFERENCE PARTICIPANTS

R. WALTER, DUKE UNIVERSITY, DURHAM NC 27706
J. WAMBACH, UNIV. OF ILLINOIS AT URBANA, URBANA IL 61801
D. WANG, OHIO UNIVERSITY, ATHENS OH 45701
Y. WANG, OHIO UNIVERSITY, ATHENS OH 45701
J.L. WEIL, UNIVERSITY OF KENTUCKY, LEXINGTON KY 40506
S. WENDER, LOS ALAMOS NATIONAL LAB., LOS ALAMOS NM 87545
R. WHITE, LAWRENCE LIVERMORE NAT. LAB., LIVERMORE CA 94550
R.R. WINTERS, DENISON UNIVERSITY, GRANVILLE OH 43023
C.D. ZAFIRATOS, UNIVERSITY OF COLORADO, BOULDER CO 80309
Z. ZHOU, UNIVERSITY OF KENTUCKY, LEXINGTON KY 40506
M. ZIRNBAUER, MAX PLANCK INSTITUT, 6900 HEIDELBERG 1 W. GER.

TABLE OF CONTENTS

SESSION A

THE OPTICAL MODEL POTENTIAL

The phenomenological neutron optical potential -- P.E. Hodgson	1
Implication of microscopic reaction analyses below 100 MeV -- H.V. von Geramb	14
Nuclear structure approach to the imaginary optical potential and inelastic form factor -- F. Osterfeld and V.A. Madsen	26
Contribution:	
Momentum and frequency dependence of the self-energy in nuclear matter: A path to study the effective nucleon-nucleon interaction -- A. Lejeune, V. Bernard, P. Grangé and M. Martzloff	50

SESSION B

OBSERVABLES AND EFFECTIVE INTERACTIONS

Analyzing power measurements for neutron-nucleus scattering and the spin-orbit potential -- R.L. Walter	53
Scattering of the polarized and unpolarized neutrons from ^{28}Si and ^{32}S -- C.R. Howell	72
Test of effective interactions for nucleon scattering and charge exchange below 60 MeV -- F.S. Dietrich and F. Petrovich	90
Isovector nucleon-nucleon effective interactions -- J.R. Shepard	107
Dirac phenomenology at low energies -- B.C. Clark, S. Hama, S.G. Kälbermann, E.D. Cooper and R.L. Mercer	123
Contributions:	
Interpretation of the Perey-Buck nonlocality in terms of the relativistic optical model formalism -- G.H. Rawitscher	135

Few-nucleon experiments with fast polarized neutrons -- H.O. Klages, R. Aures, F.P. Brady, P. Doll, E. Finckh, J. Hansmeyer, W. Heeringa, J.C. Hiebert, K. Hofmann, H. Krupp, Ch. Maier, W. Nitz, P. Plischke, J. Wilczynski. H. Zankel and B. Zeitnitz	137
--	-----

Isovector " $\Delta J^\pi = 0^-$ " transitions observed in the charge-exchange (p,n) reactions on $^{13,14}\text{C}$ and ^{16}O -- H. Orihara	139
--	-----

The (n,p) reaction at zero degrees from ^{12}C , ^{13}C , ^{90}Zr and ^{209}Bi at 65 MeV -- T.D. Ford, F.P. Brady, C.M. Castaneda, J.L. Romero, J.R. Drummond B. McEachern, M.L. Webb, N.S.P. King, J. Martoff and K. Wang	141
--	-----

The analog of the ^{40}Ca G.D.R. through the (n,p) reaction at 65.5 MeV -- C.M. Castaneda, J.L. Romero, F.P. Brady, J.R. Drummond, T.D. Ford and B. McEachern	143
---	-----

SESSION C

NUCLEAR STRUCTURE WITH NEUTRONS

Isovector vibrational modes in heavy nuclei -- J. Wambach	146
--	-----

Isospin effects in nuclear vibrations -- V.A. Madsen and V.R. Brown	171
--	-----

New aspects of nuclear structure from the viewpoint of neutron induced reactions -- B.A. Brown	183
---	-----

Sensitivity of neutron scattering to low energy collective excitations -- M.T. McEllistrem	208
---	-----

Determination of nuclear transition densities with various probes -- J.A. Carr, F. Petrovich and J.J. Kelly	230
---	-----

Contribution:

Nucleon scattering from ^{34}S -- R. Alarcon, J. Rapaport, R.T. Kouzes, W.H. Moore and B.A. Brown	256
---	-----

SESSION DA

APPLICATIONS AND TECHNIQUES

Nuclear physics in the 10-300 MeV energy range using a pulsed white neutron source -- C.D. Bowman, S.A. Wender and G.F. Auchampaugh	259
Neutron scattering above 25 MeV with monoenergetic neutrons -- R.W. Finlay	274
Neutron measurements for biomedical and fusion technology applications -- H.H. Barschall	286
Contributions:	
Can an atomic beam polarized source be improved for neutron emission experiments by using an ECR ionizer? -- T.B. Clegg	297
On performing (p,n), (d,n) and (n,n) measurements with a rotating magnet beam swinger -- F.S. Dietrich and T.B. Clegg	299

SESSION DB

CONTRIBUTED PAPERS

Contributions:	
Neutron, alpha and total widths and spin assignments for resonances in $^{33}\text{S}+\text{n}$ from 10-400 keV -- G.P. Coddens, M. Salah, J.A. Harvey and N.W. Hill	302
$d_{5/2}$ -single particle strength in $^{48}\text{Ca}+\text{n}$ -- J.A. Harvey, C.H. Johnson, R.F. Carlton and B. Castel	304
High resolution neutron resonance spectroscopy -- R. Köhler, L. Mewissen, F. Poortmans, I. Van Parys and H. Weigmann	306
Optical model scattering functions for low energy neutrons on ^{86}Kr -- R.F. Carlton, J.A. Harvey and C.H. Johnson	308
Energy dependence of the local optical potential for neutron-nucleus scattering -- J.P. Delaroche, P.P. Guss, G.M. Honore, C.R. Howell and R.L. Walter	310

The imaginary part of the spin-orbit interaction for neutron-nucleus scattering -- R.L. Walter, W. Tornow and P.F. Guss	312
Neutron scattering on deformed nuclei -- L.F. Hansen, R.C. Haight, B.A. Pohl, C. Wong and Ch. Lagrange	314
Semi-microscopic calculations of elastic, inelastic and total neutron scattering by ^{239}Pu -- Ch. Lagrange, D.G. Madland and M. Girod	318
Semi-microscopic interpretation of fast neutron scattering from ^{208}Pb -- G. Haouat, Ch. Lagrange, J.C. Brient, Y. Patin, R. de Swiniarski and F. Dietrich	320
Phenomenological mapping of the Fermi-surface anomaly with neutron-nucleus collisions -- R.W. Finlay, J.R.M. Annand, J.S. Petler and F.S. Dietrich	322
Nucleon induced excitation of $K^\pi = 0^+, 0_2^+, 1^-$ and 3^- bands in ^{12}C -- A.S. Meigooni, R.W. Finlay, J.S. Petler and J.P. Delaroche	324

SESSION DC

WORKSHOP IN EXPERIMENTAL TECHNIQUES

Summary of facilities for experimental studies of neutron- induced reactions -- C.D. Zafiratos	327
An accelerator system for the production of an intense neutron beam for research -- D.L. Friesel	361
A beam swinger for neutron scattering -- C.D. Goodman	375
Facilities for neutron induced reactions -- F.P. Brady	382
Neutron spin transfer measurements: Why and how -- T.N. Taddeucci	394
A facility for neutron scattering measurements at 22 MeV -- N. Olsson and B. Trostell	401
Planning of neutron physics at the rebuilt cyclotron of the Gustaf Werner Institute, Uppsala University -- H. Condé	403

SESSION E

IN MEMORY OF PETER MOLDAUER

Contribution:

Peter Arnold Moldauer: Memorial Session Introductory Remarks -- A.B. Smith	410
Some comments on the theory of nuclear reactions -- H. Feshbach	412
Statistical theories of neutron cross sections of the actinides -- J.E. Lynn	427
Optical models for low-energy s-, p- and d-wave cross sections -- C.H. Johnson	446
Level density calculations: Past, present and future -- S.M. Grimes	463

Contribution:

Complete solution of a model in statistical nuclear reaction theory -- M.R. Zirnbauer	481
--	-----

SESSION FA

ASTROPHYSICS

r and s-processes: Chronometers, thermometers and neutron dosimeters -- R.R. Winters	484
Neutron capture processes of heavy element synthesis -- J.W. Truran	504

Contribution:

A parametric study of dynamic process neutron-capture nucleosyntheses: Nuclear data needs -- G.J. Mathews, W.M. Howard, K. Takahashi and R.A. Ward	511
Neutron capture processes in astrophysics -- B.S. Meyer and D.N. Schramm	515