SECTION IV

ABSTRACTS OF PAPERS IN PRESS

Relative Importance of Neutron and Proton Components of Nuclear Transitions and Comparative π^-/π^+ Inelastic Scattering

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Abstract

Shell model calculations for ^{18}O and ^{26}Mg yield predictions of strong state dependence of the isovector component of nuclear transition strengths, with results for ^{18}O being consistent with recent measurements of π^-/π^+ inelastic scattering ratios.

Electromagnetic multipole moments of ground states of stable odd-mass nuclei in the sd-shell

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Abstract:

Shell-model wave functions for A=17-39 nuclei are used to calculate the one-body densities upon which are based the M1, E2, M3, E4 and M5 moments of stable ground states with $J^{\pi}=3/2^+$ and $5/2^+$. Values of the moments are obtained by combining these densities with single-particle matrix elements calculated with both free-space and renormalised

LARGE SCALE SHELL MODEL CALCULATIONS

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†Research sponsored in part by U.S. National Science Foundation, Grant # PHY-7822696.

The effective M3 operator and relevant transitions in ^{24}Al, ^{24}Na, ^{34}Cl, ^{38}K and ^{38}Cl

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Calculations of Inelastic Scattering E4 Transition Probabilities in the 0d,1s Shell

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THE COLLAPSE OF THE CONVENTIONAL SHELL-MODEL ORDERING IN THE VERY-NEUTRON-RICH ISOTOPES OF Na and Mg

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ABSTRACT

Recent experimental data on the structure of the very-neutron-rich isotopes of Na and Mg show sharp departures at N=20 from the predictions of conventional $d_{5/2}$-$s_{1/2}$-$d_{3/2}$ shell-model calculations.

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The $^{48}Ca(d,n)^{49}Sc$ Reaction at $E_d = 20$ MeV; Proton Single-Particle States in ^{49}Sc

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ABSTRACT

The $^{48}Ca(d,n)^{49}Sc$ reaction has been studied at $E_d = 20$ MeV. Angular distributions of differential cross sections have been obtained for 14 transitions to states in ^{49}Sc up to an excitation energy of 7.1 MeV. A DWBA analysis has been made of the experimental data. With respect to states corresponding to the same proton single-particle orbital, relative values of derived spectroscopic factors are generally in good agreement with those obtained from (^{3}He,d) reaction data. There are remarkable differences between the results from the $^{48}Ca(d,n)^{49}Sc$ reaction and the $^{48}Ca(^{3}He,d)^{49}Sc$, however, regarding the dependence of the relative spectroscopic factors on proton single-particle orbitals.

Keyword Abstract

[NUCLEAR REACTIONS: $^{48}Ca(d,n)^{49}Sc$, E=20 MeV, neutron time-of-flight, $\Delta E = 120$ keV. Measured differential cross sections, 7.5°-50° lab. DWBA analysis, derived spectroscopic factors.]

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Possible Low-Spin Members of Stockholm Band: Excited K=0^+ Band in ^{172}Yb

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ABSTRACT

The band based on the 1043 keV K =0^+ state in ^{172}Yb has been extended to spin 14^+ following the ^{170}Er(α,2n) reaction. Extrapolation to higher spin predicts a crossing with the ground-state band at about spin 20^+.

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Elastic Scattering of ^{6}Li at 73.7 MeV

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ABSTRACT

Angular distributions for ^{6}Li elastic scattering at 73.7 MeV from targets of ^{58}Ni, ^{90}Zr, ^{124}Sn, and ^{208}Pb have been measured. Optical-model parameters for Woods-Saxon real and imaginary volume potentials have been found which describe the data well and exhibit both discrete and continuous ambiguities. For a fixed geometry, the dependence of the optical potentials on Z and A of the target and on the bombarding energy was investigated.

[NUCLEAR REACTIONS: ^{58}Ni, ^{90}Zr, ^{124}Sn, $^{208}Pb(^{6}Li,^{6}Li)$, E = 73.7 MeV; measured $\sigma(\theta)$; deduced optical-model parameters.]

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Core excitations in ^{63}Cu by the $^{63}Cu(p,p')^{63}Cu$ and $^{65}Cu(p,t)^{63}Cu$ reactions

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ABSTRACT

Core excitations up to $E_x = 4$ MeV in ^{63}Cu have been studied by the reactions $^{63}Cu(p,p')^{63}Cu$ and $^{65}Cu(p,t)^{63}Cu$ at 40 MeV proton energy. The transferred angular momentum L has been determined for each transition on the basis of the angular distribution shape. A quartet-plus-doublet pattern is consistently observed for the groups of states corresponding to the 2_1^+, 3_1^-, and 4_1^+ states of the core nucleus ^{62}Ni. This implies the existence of doublets arising from the coupling of collective states of the core with the $2p_{1/2}$ proton orbital, in addition to the quartets from the coupling with the $2p_{3/2}$ proton orbital considered in the conventional weak-coupling excited-core model. It is pointed out that the existence of a weak-coupling situation cannot be proved only on the basis of transfer-reaction data, and in this regard the importance of a comparative study of the inelastic-scattering and transfer-reaction data is emphasized.

NUCLEAR REACTIONS $^{65}Cu(p,t)^{63}Cu$ and $^{63}Cu(p,p')^{63}Cu$, E = 40 MeV; measured E_x and $\sigma(\theta)$, determined L. Resolution 16 keV for the (p,t), 20 keV for the (p,p'). Enriched targets. Deduced excited-core multiplets.

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MICROSCOPIC STRUCTURE OF $\Delta J^{\pi} = 1^{+}$ EXCITATIONS IN sd-SHELL NUCLEI

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INTRODUCTION

The subject of this paper is the theoretical structure of even-parity dipole excitations in light nuclei. The defining characteristics of "light" nuclei in the present context are that they have approximately equal numbers of neutrons and protons and that the "active" nucleon orbits needed to describe their structure in the conventional shell-model representation are those of a single, multiply-degenerate, level of the three-dimensional harmonic oscillator. Physical phenomena by which this class of excitations can be experimentally observed include magnetic dipole (M1) electromagnetic excitations, Gamow-Teller beta decay, radiative meson capture, and hadronically-induced charge-exchange processes such as the (p,n) reaction.

Insight into the relationships of these phenomena to each other and to the underlying microscopic structure of the nuclear states involved can be obtained from shell-model calculations as discussed in the following sections. The specific calculations to be discussed are of the matrix elements of the one-body operators which connect nuclear states of $J^{\pi} = 0^{+}$ with those of $J^{\pi} = 1^{+}$. Results are presented for examples corresponding to transitions commencing from the $J^{\pi} = 0^{+}$ ground states of the double-even nuclei $18 \leq A \leq 38$. These calculations are the common foundation for predictions about all of the various physical processes mentioned above. The present discussion will concentrate upon M1 phenomena. The presentation will treat in turn the model from which the nuclear wave functions used in the present study are derived, the special characteristics of these wave functions, the techniques by which

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Comment on Deep Hole States Observed in (p,t) Reactions*

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ABSTRACT

The (p,t) reaction on ^{120}Sn, ^{122}Sn and ^{124}Sn at a bombarding energy of 89 MeV shows a broad feature similar to the one observed at lower bombarding energy. The excitation energies and widths were consistent with those observed in the earlier expiment. Angular distributions are in good agreement with DWBA calculations in which two neutrons are assumed to have been picked up from deeply bound orbits.

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Cross Sections Relevant to Gamma-Ray Astronomy: Proton Induced Reactions

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ABSTRACT

Gamma-ray production cross sections have been measured for the gamma-ray lines most strongly excited in the proton bombardment of ^{12}C, ^{14}N, ^{16}O, ^{20}Ne, ^{24}Mg, ^{28}Si, and ^{56}Fe, for proton energies from threshold to 23 MeV. In addition, cross sections for the $^{14}N(p,n)^{14}O$ and $^{56}Fe(p,n)^{56}Co$ reactions were determined from delayed gamma-ray yields. Ge(Li) detectors were used. Tabulations of cross sections averaged over proton energy bins of 1 MeV and over power law distributions in proton energy are provided for calculations relevant to gamma-ray line astronomy. Examples are given of astrophysical information which might be extracted from spectra acquired with gamma-ray spectrometers in space, using these cross sections, e.g., parameters describing the energy distribution of incident protons.

NUCLEAR REACTIONS: p + ^{12}C, ^{14}N, ^{16}O, ^{20}Ne, ^{24}Mg, ^{28}Si, ^{56}Fe; $^{14}N(p,n)$, $^{56}Fe(p,n)$. E = threshold to 23 MeV. Measured γ production cross sections. Applications to γ line astronomy discussed.

I. INTRODUCTION

The range of the astronomically observed electromagnetic spectrum has been extended in the last two decades to the gamma-ray region, and observations of nuclear gamma-ray lines have begun in the last decade. This new field of observational astronomy is in a period of rapid development as large, high-resolution germanium detectors are being put into space: detectors capable of distinguishing a large number of gamma-ray lines. Extensive reviews of the progress and possibilities in this area have been presented by Ramaty and collaborators[1-3] and by Chupp[4]. Accordingly, we here only briefly summarize the main features of gamma-ray line astronomy.

Gamma-ray lines provide a unique probe of the universe, as their presence is a signature of specific nuclear reactions taking place in astrophysical environments. Moreover, because of the high penetrability of gamma rays through matter, it may be possible to learn about processes such as star formation in interstellar clouds not penetrated by electromagnetic radiation from atomic or molecular line emission. Spectra of observed gamma rays can in principle be analyzed to obtain relative abundances of isotopes and energy spectra of accelerated particles at astrophysical sites. Shapes of the gamma-ray lines may provide information on the directions of accelerated particles and distinguish between gaseous matter and grains.

Possible sites of discrete gamma-ray production include solar flares, interstellar gas and dust, regions of star formation, novae, supernovae, neutron stars, and black holes. At such sites gamma rays may be produced by several distinct mechanisms. Radioactive products of nucleosynthesis from objects such as novae and supernovae can emit gamma rays. Neutron capture and positron annihilation can also produce discrete gamma rays of 2.22 and 0.511 MeV. In this work we are primarily interested in

CHARGE DISTRIBUTIONS FOR THE ^{86}Kr + ^{139}La
SYSTEM AT 505, 610, AND 710 MeV

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Nuclear charge distributions for projectile-like and fission-fragment-like reaction products were measured as a function of angle and energy loss at each of the three bombarding energies E_L = 505, 610, and 710 MeV for the ^{86}Kr + ^{139}La reaction. The charge distributions at most angles and energy losses are dominated by a peak centered close to the Z of the projectile. The variances of the Z distributions of this component exhibit a different dependence on energy loss at each of the three bombarding energies. A nucleon exchange model incorporating the effects of the Fermi motion and Pauli Principle is quite successful in accounting for the rate of energy loss per exchange deduced from the charge distribution data. This result suggests that nucleon exchange is the major mechanism for energy dissipation in these collisions. The data are also analyzed in the framework of a phenomenological model from which diffusion constants are obtained. For large energy losses a second peak appears in the charge distribution with a most probable Z equal to one-half the sum of the projectile and target Z. This component is attributed to fusion-fission. The magnitude of the fusion-fission cross section at 505 and 610 MeV is larger than TDHF predictions.

Submitted to
Particle Accelerators

Calculation of Fields in a Superconducting Cyclotron Assuming Uniform Magnetization of the Pole Tips*

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ABSTRACT

Calculation of the median plane field in a superconducting cyclotron is greatly facilitated by assuming that all pole pieces not having axial symmetry are uniformly magnetized in the vertical direction. Using this model, a detailed analysis is presented in terms of surface currents flowing in horizontal loops around the sides of each pole tip, which then leads to a field formula involving a single line integral around the closed current contour. This formula is simpler than the one previously obtained using a surface charge representation of the field sources. A straight-forward computation technique is described, and explicit formulas are presented for circular and rectangular pole geometries. The latter is used, for example, in field calculations for the focusing elements designed for the beam extraction system.

*Work supported by the U.S. National Science Foundation under Grant No. (PHY78-22696).

EVIDENCE FOR GAMMOW-TELLER STRENGTH IN BROAD BUMPS IN (p,n) AND (^{3}He,t) SPECTRA*

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INTRODUCTION

Following the discovery by Anderson and Wong of isobaric analog states[1] in (p,n) reactions (equivalent to superallowed or giant Fermi transitions in β decay) a giant Gamow-Teller (G-T), or spin-flip, transition in charge-exchange reactions was predicted.[2] Subsequently, a broad, structured peak in the ^{90}Zr(p,n)^{90}Nb reaction was interpreted as verifying the predicted transition,[3] a $0^+ \rightarrow 1^+$, $T = 5 \rightarrow T = 4$ transition from the ground state of ^{90}Zr to an excitation energy in ^{90}Nb centered at 8.4 MeV. Some of the neutron spectra of Doering, et al.[4] are shown in Fig. 1. In each spectrum the isobaric analog of the ground state (IAS) of ^{90}Zr is represented by the narrow peak at E_n = 33 MeV and the 1^+ state by the broad peak around 30 MeV. If generalized to other nuclei, concentration of G-T strength at such excitation energies could account for the generally low rates of G-T decay from the ground states of radioactive nuclei.

The same transition has been seen with the (^{3}He,t) reaction at 80 MeV at Grenoble[5] and at 130 MeV at Jülich.[6] The Grenoble work separated the 8.4-MeV peak into two groups, one at 7.2 MeV having the angular distribution of a $0^+ \rightarrow 1^+$ transition, and another of unknown multipolarity at 9.7 MeV. The Jülich work revealed another broad bump, also present in re-scrutinized (p,n) spectra,[4] at 18.5 MeV in ^{90}Nb. Before examining in detail work on Zr-that already cited plus some current unpublished data--other cases of broad bumps in (p,n) and (^{3}He,t) spectra will be briefly noted.

* This material is based upon work supported by the National Science Foundation under Grant No. Phy-7822696.

Comparison of $^{24,25,26}Mg(p,n)\ ^{24,25,26}Al$ Cross Sections with Giant M1 Strength

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Cross sections for the $^{24,25,26}Mg(p,n)\ ^{24,25,26}Al$ reaction have been measured at 35 MeV. The strengths of the larger spin-isospin flip transitions correspond surprisingly well with the matrix elements of the analogous giant M1 transitions.

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ON IMPROVING GE DETECTOR ENERGY RESOLUTION AND PEAK-TO-COMPTON RATIOS BY PULSE-SHAPE DISCRIMINATION*

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Abstract

The rise-time discrimination of pulses from Ge detectors can be used to improve the spectra on two levels: First, by discriminating against slower-rising pulses, both the energy resolution and peak-to-Compton ratios can be improved significantly, especially for detectors that have suffered neutron damage. Second, by adding a pulseheight correction to compensate for effects of varying rise-time, an improved composite spectrum can be obtained without significant loss in detector efficiency.

THE NUCLEAR DENSITY OF STATES IN THE SPACE OF NUCLEAR SHAPES

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ABSTRACT

The density of states for the nuclear shape degrees of freedom are calculated in the Fermi gas model. For quadrupole deformations, the resulting formulas agree well with the properties of the deformed excited states of ^{16}O and ^{40}Ca. Application is also made to the inertia associated with deformation coordinate. The inertia turns out to be much smaller than given by the weak coupling limit.

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COMPRESSIBILITY AND THE MONOPOLE COLLECTIVE FIELD†

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Abstract

We show the relation between conventional RPA and the collective field description of monopole vibrations by Hamamoto and Mottelson. When surface compression is properly included, the collective treatment yields the same vibrational frequency as conventional RPA, for a given compressibility.

[NUCLEAR STRUCTURE Giant monopole vibrations, surface effects, relation to compressibility.]

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Pionic Atoms and Low Energy Elastic Scattering

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Abstract

A fit to pionic atom data is used to determine four of the parameters of the low energy pion-nucleus optical potential, while the other parameters are taken from theory. The resulting potential is used to predict elastic scattering for 30 - 50 MeV pions. The effects of extrapolating the parameters to 50 MeV with a simple energy dependence are examined.

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KEYWORDS:

NUCLEAR REACTIONS Optical potential, fit to pi-mesic atoms. Calculated elastic scattering with extrapolated potential at 30, 40, 50 MeV on individual targets.

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THE REPULSION IN THE S-WAVE PION NUCLEUS OPTICAL POTENTIAL†

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Abstract

It is shown that the medium enhancement of the second order correction to the real part of the S-wave pion-nucleus optical potential explains most of the repulsion needed in fits of the level shifts in pionic atoms. The dispersive part of the absorptive contribution is of far smaller significance.

† Research supported in part by the National Science Foundation

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THE EFFECTIVE S-WAVE πNN INTERACTION IN NUCLEI*

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Abstract

We show that virtual pion rescattering in a nuclear medium gives rise to an effective S-wave πNN interaction Hamiltonian. The first few terms in the density expansion of the strength parameter are estimated and shown to be appreciable in nuclear matter.

*Research supported in part by the National Science Foundation

INTERPRETATION OF π-NUCLEUS SCATTERING†

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ABSTRACT

A brief account is given of work done at Michigan State on π-nucleus scattering. Emphasis is on estimating the general behavior of cross sections, elastic, quasielastic and true absorption, when most of the basic microscopic physics is used in at least a minimal way.

INTRODUCTION

I will not talk about the interpretation of π-nucleus scattering, for the same reasons given by Eisenstein in his talk, i.e. that the more subtle effects are still obscure. I will talk instead about the work done at Michigan State on pion nucleus scattering. This work was done by G. Bertsch, J. Chai, J. Carr, C. Ko, H. McManus, G. Richter, D. Riska and K. Stricker. I will not go into any calculational details but will try to make the motivation and method clear. The approach is via multiple scattering and the optical potential. As has been pointed out by many speakers at this conference, pion nucleus scattering differs from pion nucleon scattering in that an additional process, true absorption occurs. This proceeds mainly via a two body mechanism, s- and p-wave rescattering on one nucleon and absorption by another. The basic microscopic data is then free π nucleon scattering, and the amplitude for π+D→NN and the inverse N+N→π+N+N. In addition we introduce phenomenology, i.e. from pionic atoms where the effect of true absorption is marked. We start from pionic atoms and extrapolate to higher energies.

The form adapted for the optical potential is, ignoring isovector terms and some kinematic factors which are given by K. Stricker, et al.[1],

$$2\omega\, U_{opt} = -4\pi\bar{b}_0\,\rho(r) + 4\pi c_0\,\vec{\nabla}\,\frac{\rho(r)}{1+\frac{4\pi}{3}\lambda c_0\,\rho(r)}\,\vec{\nabla} \qquad \text{(multiple scattering) (1a)}$$

$$-4\pi B_0\,\rho^2(r) + 4\pi C_0\,\vec{\nabla}\rho^2\vec{\nabla} \qquad \text{(true absorption)(1b)}$$

$$-4\pi c_0\,\frac{\omega}{2m}\nabla^2\rho - 4\pi C_0\,\frac{\omega}{4m}\,\nabla^2\rho^2 \qquad \text{(angle transformation) (1c)}$$

$$+2\omega\, V_c(r). \qquad \text{(Coulomb potential) (1d)}$$

This is a natural extension of the form introduced originally by Kisslinger and extended first by Ericson and Ericson[2] and more recently by Thies[3] and by Brown, Jennings and Rostokin[4]. Let us

†Invited talk at "Second International Conference on Meson-Nuclear Physics", Houston, Texas, March 1979.

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The Effect of the Nuclear Medium on S-wave Pion Absorption†

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Abstract

It is shown that the effects of the nuclear medium on the pion propagator and the renormalization of the πNN interaction, described in terms of excitation of virtual isobar-hole pairs can enhance the predicted absorption rates for pions at threshold to values close to the empirical ones.

†Research supported in part by the National Science Foundation

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The Magnetic Form Factor of $^3He^{\dagger}$

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Abstract

The behavior of the magnetic form factor of ^3He for momentum transfers $q^2 < 30\ fm^{-2}$ is studied with simple wavefunction models and with account of pion and ρ-meson exchange current effects. The single nucleon current contribution to the form factor depends strongly on the D-state probability. The exchange current contributions dominate the form factor for $q^2 > 5\ fm^{-2}$. The sensitivity of the exchange current contributions to wavefunction details--short range correlations and D-state percentage--and hadronic form factors in the exchange operators is investigated in some detail. With inclusion of the ρ-meson exchange effect the predicted position of the form factor minimum is in reasonable agreement with the most recent data.

†Research supported in part by the National Science Foundation

MSU Nuclear Theory Preprint

POLE TERMS AND ABSORPTION IN THE P-WAVE PION-DEUTERON INTERACTION†

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Abstract

We investigate how well the P-wave pion-nucleon interaction in a nucleus is approximated by a local interaction operator which neglects the spatial extent of the inelastic intermediate state. By comparing the matrix elements of the approximate and complete reaction amplitude for ealstic pion-deuteron scattering we find that the local approximation is accurate to within 10% for the P_{11} state and to within 25% for the P_{33} state.

†Research supported in part by the National Science Foundation

MSU Theoretical Nuclear Physics
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ELASTICITY AND QUADRUPOLE VIBRATIONS

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Abstract

Coherent quadrupole vibrations are shown to obey the classical equations for an elastic medium. The motion is predominantly a transverse wave.

FIRST STUDY OF THE (^{14}C, ^{12}C) REACTION.
SELECTIVITY OF THIS REACTION AND THE ENERGY LEVELS OF ^{28}Mg AND ^{30}Si

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The first measurements are reported for (^{14}C, ^{12}C) two-neutron stripping reactions. Energy spectra up to an excitation energy of 12 MeV have been measured at 69 MeV for the ^{26}Mg (^{14}C, ^{12}C) and ^{28}Si (^{14}C, ^{12}C) reactions. A strong selectivity of this reaction is observed. Using this selectivity, the comparison of the spectra suggests J^{π} assignments for several ^{30}Si and ^{28}Mg states. The results from other two neutron stripping reactions, (t,p) and (^{18}O, ^{16}O) are compared with those of the (^{14}C, ^{12}C) reaction.

[NUCLEAR REACTIONS $^{26}Mg(^{14}C,^{12}C)^{28}Mg$; $^{28}Si(^{14}C,^{12}C)^{30}Si$; E = 69 MeV ; measured $\sigma(\theta)$; ^{28}Mg and ^{30}Si deduced levels, J, π. Enriched targets.]

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THEORIES OF HEAVY ION COLLISIONS

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Abstract

The various theories of heavy ion collisions are reviewed, emphasizing their soundness in terms of the fundamental dynamics, their practicality for actual calculations and their success in explaining the existing data.

Introduction

In this lecture I shall review the various theories that have been developed to describe heavy ion collisions, and discuss their relative merits both on practical grounds and in comparison to experiment. In classifying the theories, we first examine which dynamic variables in the theory have been explicitly singled out in the equations of motion. The fewer and simpler the variables, necessarily the more phenomenological will be the theory. The theory is a good one if it correlates a large body of experimental data, and particularly if the parameters can be derived from more fundamental considerations. The simplest possible treatment, seen in the friction model of Gross and Kalinowski [1], uses only the ~~cm~~ coordinates of the nuclei as dynamic variables. At an intermediate level of detail, there are theories which consider the shapes of the nuclei as well as their positions. This description has been exploited by Broglia and collaborators [2 - 4]. At the next level of detail we may consider the time evolution of individual

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