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This report includes contributions from the following Laboratories:

Laboratório de Física da Universidade
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LISBOA 2

Laboratório de Física e Engenharia Nucleares
SACAVÉM

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UNIVERSITY OF COIMBRA

1.1 THEORETICAL NUCLEAR PHYSICS

1.1.1 - J. DA PROVIDÊNCIA, J.N. URBANO and LIDIA S. FERREIRA - Corrections to the Gaussian Overlap Approximation: a new Boson Expansion-Nucl. Phys. A170 (1971) 129-140.

Abstract: The Gaussian overlap approximation is applied to Lipkin's solvable model, both for a weak and for a strong interaction, in order to obtain insight on the conditions for the validity of that approximation. By carrying the expansions in the generator coordinate to higher orders, corrections to the harmonic approximation are obtained and applied, also with good results, to Lipkin's model.

1.1.2 - C.M. SHAKIN* and J. DA PROVIDÊNCIA - Theorem for Energy-Weighted Averages of Spectroscopic Factors - Phys. Rev. Letters 27 (1971) 1069-1071.

Abstract: It is shown that for a system with strong correlations, the centroid of the spectroscopic amplitudes for particle removal is given by the single-particle energy (defined appropriately) times the occupation probability of the orbit.

1.1.3 - J. DA PROVIDÊNCIA and C.M. SHAKIN* - Cluster Expansions for Correlated Wave Functions of Finite Systems - Phys. Rev. C4 (1971) 1560-1563.

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* Case Western Reserve University, Cleveland, Ohio 44106

Abstract: A theory of correlated wave functions for finite systems is developed which systematically neglects the contribution from three-body cluster terms. The approximation made leads to a derivation of a Bethe-Goldstone equation for finite systems which includes modified occupation probabilities and self-consistent potentials for occupied states. The absence of potentials in unoccupied states follows from the neglect of three-body cluster terms. It is also shown that a careful treatment of the Pauli principle and occupation probabilities allows the application of variational techniques.

1.1.4 - J. DA PROVIDÊNCIA and C.M. SHAKIN[+] - Three-Body Clusters in Nuclear Matter - Phys. Rev. C5 (1972) 53-59.

Abstract: It is shown that starting with a correlated wave function for nuclear matter of a general form one may make direct correspondence to the conventional diagrammatic theory of Brueckner, Bethe and Goldstone. In particular, in this work we show that the expression for the three-body-cluster energy is the same as that obtained by Bethe. Also, it is shown that the current approximation which neglects the potencial for particle states in the diagrammatic approach corresponds to a neglect of a coupling between the two-body (Bethe-Goldstone) equation and the equation for the three-body-cluster wave function (Bethe-Faddeev). The theory presented here provides a clarification of the relation of the n-body-cluster wave functions and the structure of the wave function of the entire system.

1.1.5 - ANTÔNIO J. ALVES and ELISA M. SILVA - Addenda Correlations to the Gaussian Overlap Approximation - Nucl. Phys. A181 (1972) 669-672.

Abstract: It is observed that the validity of the Gaussian overlap approximation does not imply the validity of the harmonic approximation. A simple procedure for converting the integral eigenvalue equation of the generator coordinate method into a differential eigenvalue equation is presented. The method proposed assumes the validity of the Gaussian overlap approximation, but

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+ see note on page 4

may be applied to highly anharmonic situations. A test of the method has been made with the Lipkin model.

1.1.6 - J. DA PROVIDÊNCIA and J.N. URBANO - On the Foundation of the VMI Models for the Ground State Collective Modes of Doubly Even Nuclei - Nucl. Phys. A182 (1972) 174-182.

Abstract: The aim of the present paper is to propose a justification for the well-known VMI models of Diamond et al. and Maris - cotti et al. based upon the method of generator coordinates. On discussing their relative domains of application one concludes that, contrary to the general trend, the stretching model is to be preferred over the region of good vibrators, a result which seems to be confirmed by the scarce experimental data.

1.2 EXPERIMENTAL NUCLEAR PHYSICS

1.2.1 - J.M. DOMINGOS, G.D. SYMONS* and A.C. DOUGLAS** - Multiple Coulomb Excitation of γ- Vibrational Bands in ^{162}Dy, ^{166}Er, ^{168}Er and ^{170}Er - Nucl. Phys. A180 (1972) 600-614++.

Abstract: The 2_γ and 4_γ states in ^{162}Dy, ^{166}Er, ^{168}Er and ^{170}Er have been Coulomb excited with 45-60 MeV ^{16}O ions. Values of B $(E2;0\rightarrow 2_\gamma)$ were determined and the angular correlations of the de-excitation γ-rays in coincidence with the backscattered particles have been analysed to yield E2/M1 mixing ratios for the $2_\gamma \rightarrow 2$ and $4_\gamma \rightarrow 4$ transitions. From the measured branching ratios for the decay of the 2_γ and 4_γ states, values of z_2, the spin-independent mixing parameter for the γ-vibrational band, were determined. Two additional states having spin and parity assignments 0^+ and 4^+ have been identified in ^{170}Er at energies of 889 and 1124 keV, respectively.

1.2.3 - COLLECTIVE PROPERTIES OF ^{152}Sm FROM MULTIPLE COULOMB EXCITATION++ (G.D. Symons*, J.M. Domingos, A.C. Douglas**); to be published.

The nucleus ^{152}Sm is in the transitional region between the spherical and deformed shapes. Collective states in the ground-state,

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** AWRE, Aldermaston, Berkshire.

++ Work performed at the Oxford University accelerators.

beta-band, gamma-band and octupole band have been studied with 41.0-59.1 MeV ^{16}O ions, and the results analysed with the Winther and the Boer MCE computer program. Deviations in the measured de-excitation probabilities from the calculations using the matrix elements given by the first-order band mixing theory, as well as E2/M1 mixing ratios and branching-ratios have been measured. A new approach using experimentally determined matrix elements based on recent experimental results obtained by decay studies and Doppler-shift recoil distance is still in progress.

1.2.4 - DECAY STUDIES

A general investigation of collective transitions from radioactive decay to study level properties of deformed nuclei is being started. For this purpose it is planned to use NaI-Ge(Li) and Ge(Li)-Ge(Li) detector assemblies. To supplement the existing equipment the acquisition of 2 Ge(Li) detectors and a Multichannel Analyser is planned.

1.3 INSTRUMENTATION

1.3.1 - A.J.P.L. POLICARPO, M.A.F. ALVES, M.J.T. CARVALHO and M.A.G. DA ROCHA - Improved Energy Resolution With X-Ray Gas Detectors-Nucl. Instr. Meth 96 (1971) 487-489.

Abstract: Detection of the light pulses from a xenon counter gives a resolution of 11.2% for 5.9 keV. This value can be further improved.

1.3.2 - A.J.P.L. POLICARPO, M.A.F. ALVES and M.J.T. CARVALHO - Charge and Light Peak Shifts in an X-Ray Detector - Nucl. Instr. Meth. 97 (1971) 491-496.

Abstract: A comparison is made between the peak shifts with counting rate, for the light and charge pulses from a proportional scintilation counter with a Xe-1.0% N_2 mixture, under X-ray bombardment. With ^{241}Am and ^{109}Cd sources it was found that for a suitable anode voltage no peak shift is observed for the light pulses, although the charge peak shifts (percent) are comparable

with the energy resolution. When the light peak shifts are corrected for the change of gain of the photomultiplier with counting rate, it is observed that they are only slightly smaller than those of the charge, implying that there is a compensating effect of the gas and photomultiplier gains.

1.3.3 - A.J.P.L. POLICARPO, M.A.F. ALVES, M.C.M. DOS SANTOS and M.J.T. CARVALHO - Improved Resolution for Low Energies with Gas Proportional Scintillation Counters - to be published.

Abstract: Observation of the light emitted by xenon, when the primary electrons produced by an ionizing particle are accelerated under an electric field, allows the detection of energies, in the ionization chamber region, that, with gas counters,were only previously detectable in the proportional region. For example , for 5.9 keV a full width half maximum of 500 eV was measured. The relative variance of the pulses from the gas proportional scintillation counter is $0.087\ E^{-1/2}$(E in keV) and can be slightly improved. The possibility of using the counter for fast coincidence work is considered.

1.3.4 - NEUTRON AND FISSION FRAGMENT COUNTER

A research program for the utilization of the gas proportional scintillation counter as a neutron and fission fragment detector is under way.

2. DEPARTMENT OF PHYSICS

FACULTY OF SCIENCES, LISBON

Nuclear Spectroscopy and Interactions between the Nucleus and the Atomic Electrons. (Project LF1 - Director - J.G. Ferreira)

2.1 NUCLEAR SPECTROSCOPY

2.1.1 - MEASUREMENT OF ATOMIC FLUORESCENCE YIELDS BY COINCIDENCE METHODS

(A. Barroso, J. Pires Ribeiro, Amélia Maio, F. Bragança Gil and J. Gomes Ferreira)

Two papers on the atomic yields of thorium, uranium and radium have been published recently [1] by this group. Measurements of the L_{II} and L_{III} atomic yields of radon following the α decay of ^{226}Ra are now in progress, by means of coincidence experiments between $XK\alpha_1$ - XL and $XK\alpha_2$ - XL, using Ge(Li) and Si(Li) detectors.

2.1.2 - MEASUREMENT OF THE HALF LIFE OF NUCLEAR EXCITED STATES

(Maria Conceição Abreu e Silva, J. Pires Ribeiro, J.C. Soares and F. Bragança Gil)

An experimental process for the correction of half life results obtained by the "centroid shift method" using a double lens magnetic spectrometer (Gerholm) is in progress. Experiments have been done with ^{198}Au and ^{203}Hg sources, and it is hoped that half lives of the order of 200ps can be measured accurately by this method.

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(1) - J.G. Ferreira, J.C. Soares, A. Barroso and F.B. Gil
J. Phys. A, 4, 679 (1971)
F.B. Gil, A. Barroso, J.C. Soares and J.G. Ferreira
Phys. Rev. A, 5, 536 (1972)

The half life of the 81keV excited state of ^{133}Cs has been measured by γ-γ coincidence experiments [NaI (Tl) - NE 111 (plastic)]; the value obtained ($T_{1/2} = 6.42 \pm 0.10$ ns) is in good agreement with the result of Gupta et al [2] later published.

2.1.3 - ANGULAR CORRELATIONS α - X

(F. Bragança Gil, J.C. Soares and J.G. Ferreira)

This small effect, althought theoretically predicted, has not yet been observed.

An experiment in order to find the angular correlations of the cascades $\alpha - XL_\ell$, $\alpha - XL_\alpha$, $\alpha - XL_\beta$ and $\alpha - XL_\gamma$ emitted in the decay of ^{238}Pu is in course. For this purpose, a special vacuum chamber for angular correlations, with a surface barrier detector for the α-particles and Si(Li) detector for the X-ray photons has been designed. The results obtained are not yet conclusive.

2.1.4 - DECAY SCHEMES OF SOME NUCLEI

(Maria da Conceição Abreu e Silva, A. Gonçalves, Maria Juliana T. Oliveira and F. Bragança Gil)

The measurements of the relative efficiencies of the Ge(Li) and Si(Li) detectors are in course by means of computing techniques.

α-spectroscopy studies by semiconductors are in progress in order to find the accuracy of the measurements of the α-particle energies with this type of spectrometer, by comparison of the new standard values of α-particle energies which are being published by the "Bureau International des Poids et Mesures" (Sèvres, France). An analyser (Plurimat 20) with a computer (Multi-8)is being used in these experiments.

2.2 INTERACTIONS BETWEEN THE NUCLEUS AND THE ATOMIC ELECTRONS

2.2.1 - MEASUREMENTS OF L_I AND L_{II} ATOMIC FLUORESCENCE YIELDS BY THE ANALYSIS OF THE L-X RAY SPECTRUM FOLLOWING NUCLEAR DISINTEGRATIONS.

(L. Salgueiro, M.T. Ramos, M.I. Marques, M.L. Escrivão and J.G. Ferreira)

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(2) D.K. Gupta and G.N. Rao
Nucl. Phys. A, 182, 669 (1972)

Measurements of L_I and L_{II} atomic fluorescence yields by KX-LX coincidence experiments and LX-ray line intensities analysis are in course, using radioactive sources.

A curved cristal spectrometer of the Cauchois type was adapted to the use of radioactive sources, and the detection is now with a scintillation counter although the photographic recording was first employed.

Experiments started using a source of ^{198}Au and the atomic fluorescence yields of mercury will be obtained by measuring the LX-ray photons following the decay $^{198}Au \xrightarrow{\beta-} {}^{198}Hg$.

The deviation of β-particles emitted by ^{198}Au is now achieved by means of a magnetic field.

2.2.2 - MEASUREMENTS OF TRANSITION PROBABILITIES IN ^{227}Ac

(Maria Inês Macias Marques, in collaboration with Dr. Foucher Group-Orsay France).

Results concerning transition probabilities in ^{227}Ac have been obtained by measuring the half-life of the 27.3 keV, 29.9 keV and 330.0 keV levels of ^{227}Ac (M.I. Marques, Ph. D. Thesis, University of Paris; Sept. 1971).

Good agreement was found by comparing the experimental and theoretical Nilson model values, except for E_2 transitions; new calculations have been undertaken for these transitions assuming that a Coriollis coupling (particle-rotation) is present.

3. NUCLEAR RESEARCH CENTER (L.F.E.N.)

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3.1 NEUTRON PHYSICS

3.1.1 - THERMAL NEUTRON DIFFUSION PARAMETERS

(E. Martinho and M.M. Costa Paiva)

a) Thermal neutron diffusion lengths and extrapolation lengths were measured by a static method, at room temperature, in 8 organic compounds (benzene, toluene, xylene, ethyl-benzene, benzyl-alcohol, cumene, cyclohexane, cyclohexanol). The measured diffusion length variation with Σ_{oa}, the macroscopic absorption cross-section for 2200m/s neutrons, is represented by:

$$L = (5.83 \pm 0.01) \, 10^{-2} \, \Sigma_{oa}^{-1} \quad cm \qquad (1)$$

Based on our results and on 21 L-values measured by different authors using pulsed sources we found:

$$\frac{L_{static}(\Sigma_{oa})}{L_{pulsed}(\Sigma_{oa})} = 1.070 \qquad (2)$$

Assuming $< v \, \Sigma_a > = v_o \, \Sigma_{oa}$, which is supported by the experimental pulsed results with good approximation, we can infer from (2) that in what concerns the diffusion coefficient D_o, $D_{o,pulsed}(\Sigma_{oa})$ should be 14% lower than $D_{o,static}(\Sigma_{oa})$.

b) Measurements done on other organic substances similar to those mentioned above but with a relatively more complex molecular structure, indicate that expression (1) is not valid for all organic compounds contrary to what could be expected. This problem is being investigated.

3.1.2 - NEUTRON TIME-OF-FLIGHT SPECTROMETER

(F. Carvalho, J. Salgado*, A. Henriques and A. Vallêra)

A computer code has been written to predict the performance of a curved slit chopper. The code calculates the shape of a monochromatic neutron burst generated by the chopper taking into account the actual angular distribution of velocities in the collimated beam. The chopper transmission function is determined from the area of the monochromatic pulses. A second code calculates the time-of-flight distribution from a maxwellian source, after a given flight-path and also the time channel energy distributions.

A flexible 4096-channel time-of-flight converter has been designed and built. The converter uses integrated circuity and includes a multiplexer for interfacing two such units to an on-line computer. Delay and channel width are selectable decimally by thumbwheel switches.

Measurements on a UO_2 sample have been performed. The data are being analysed.

3.2 THEORETICAL NUCLEAR PHYSICS

3.2.1 - DEUTERON BREAKUP EFFECTS IN DEUTERON ELASTIC SCATTERING

(A.S. Fonseca and F.D. Santos)

Matrix elements for an effective deuteron-nucleus interaction between the deuteron ground state and $^3S_1$ scattering states were calculated for various nuclei from ^{24}Mg to ^{120}Sn and are being used to approximate the local and non-local corrections to the Watanabe potencial.

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3.2.2 - $\pi^o \to 2\gamma$ DECAY AND ELECTRON-POSITRON ANNIHILATION INTO HADRONS

(R. Vilela Mendes)

In the framework of a previously proposed model of Schwinger terms and anomalous Ward identities the following sum rule relating the decay width and $e^+ e^-$ annihilation cross sections is obtained

$$\left[\frac{64\pi}{m_\pi^3}\ \Gamma(\pi^o)\right]^{1/2}\ \frac{f_\pi}{\sqrt{2}\,e_o^2} = \frac{1}{48\pi^3\alpha^2}\int ds\ \left\{\sigma_{tot}(e^+e^- \to I=1) + \right.$$

$$\left. + 3\sigma_{tot}(e^+e^- \to I=0)\right\}$$

Comparison with the data seems to favour $n \approx 1.5$ in the assymptotic behaviour $\sigma_{tot} \sim 1/s^n$.

3.2.3 - REAL AND VIRTUAL THREE-PION STATES IN THE $K_L \to \mu^+\mu^-$ DECAY

(R. Vilela Mendes)

A vector meson dominance model is being used to compute the amplitudes $3\pi \to$ two real or virtual photons. Preliminary results are larger than those previously obtained by soft meson techniques. A model of virtual dissociation in 3-pion states is being used to test the relative phase of the 2γ and 3π intermediate state contributions.

3.3 EXPERIMENTAL NUCLEAR PHYSICS

3.3.1 - LOW LYING STATES OF ^{29}Si

(M.C. Vouga and M.F. da Silva)

The levels of ^{29}Si below 3.7 MeV have been studied with the ^{28}Si (d,p γ)^{29}Si reaction at 1.87 MeV. Angular correlation measurements for levels at 2.032, 2.427, 3.069 and 3.623 MeV are in fair agreement with published data [1]. Additional information is obtained on mixing ratios. The data for the .554 MeV transition between

(1) I.G. Main et al., Nucl. Phys. A 158 (1970) 364

the 5th and 4th excited states is compatible with $\delta = 0.33^{+0.15}_{-0.26}$ and $1.69^{+0.46}_{-0.26}$. Although both values are accepted at the 0.1% confidence level, the data favour the higher value by a factor of 18.

3.3.2 - (p,γ) RESONANCES IN Al^{27}

(P.M. Correia, J.M. Cunha and L.A. Cunha)

Single resonances at 1262, 1457 and 1588 keV and doublets at 1364, 1662 and 1968 keV were studied using a Ge(Li) spectrometer. Singlet data is in good agreement with data from various authors [1,2]. The study of the doublets shows transitions not previously reported. The observed decay of the 1364 keV doublet is in strong disagreement with published NaI(Tl) data [3]; decays of the upper member to ground and 9382 keV states are found to be much weaker than reported and instead a strong transition to the 6276 keV state is observed.

3.4 INSTRUMENTATION

3.4.1 - INSTRUMENTATION FOR THE HANDLING OF EXPERIMENTAL DATA

- Several interfaces have been completed which allow the simultaneous use of 3 ADC's on the PDP 15 computer. The interfaces cover the add-to-memory, data channel, and program controled modes of transfer. (J. Vicente and C.M. da Silva)
- An incremental plotter has also been interfaced to the PDP 15 computer and can now be used with data acquisition and manipulation as well as with FORTRAN or FOCAL programs. (J. Vicente and C.M. da Silva).
- A multiplexer is under design to allow a flexible way of connecting an ADC or a similar device to the computer through any of the transfer modes and at the same time allow for multiple units in the same

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(1) E.F. Gibson et al. Phys. Rev. 172 (1968) 1004

(2) M.A. Meyer et al. Nucl. Phys. A 144 (1970) 261

(3) R. Nordhagen and A. Tveter, Nucl. Phys. 56 (1964) 337.

or different modes.
(J. Vicente and M.C. da Silva)

- The Data Handling and Acquisition Program version-I has been completed. An improved version II with modified program philosophy is underway. This version will allow subroutine reentry and task queues.
(M.G.F. Dias and C.M. da Silva)

3.4.2 - VAN DE GRAAFF ACCELERATOR

3.4.2.1 The beam line for (p,γ) reactions has been completed and successfully used in the study of ^{27}Al resonances. Beam energy resolution obtained was 0.85 keV FWHM. Beam spot at the target can be smaller than 1 milimeter square.
(P.M. Correia and J.M. Cunha)

3.4.2.2 A sine-wave beam energy modulator has been constructed which provides a 14 keV window. This enormously facilitates the determination of resonance shapes and of machine energy setting, allowing for such factors as target deterioration and carbon buildup.
(L.A. Cunha)

3.4.2.3 A pick-up-capacitor has been mounted inside the accelerator tank, in order to monitor the high voltage terminal ripple. This allows a direct (CRT) observation of the energy stabilization as well as the accelerator tube condition. In the future, it is planned to use this device to provide a better corona stabilization of the accelerator energy.
(P.M. Correia and J.M. Cunha)

3.4.3 - RPI REACTOR

On Sept. 1st the reactor will be shut down for a period of about 6 weeks in order to perform the substitution of the original reactor control equipment by a new fully transistorized system which has been built locally. When the test and calibration work of the new equipment is performed, for the first time the reactor will be operated normally in a three shift round-the-clock schedule, 5 days per week.