

Instituto de Física da Universidade de São Paulo
Cidade Universitária - Caixa Postal 20516 São Paulo
Brasil

PROGRESS REPORT ON NUCLEAR DATA IN BRAZIL*

• (June 1974 - May 1975)

Compiled by

S.B.Herdade

Liasion Officer for Brazil, International Nuclear Data
Committee.

*Work supported by Comissão Nacional de Energia Nuclear
and Instituto de Física, Universidade de São Paulo.

IFUSP/P-esp.

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1. INTRODUCTION

This Progress Report has been written on the basis of:

a) published papers; b) institutes and universities annual reports; c) abstracts of papers presented at the Annual Meeting of the Brazilian Society for the Advancement of Science, Belo Horizonte, July 1975, and d) private communications.

The material has been selected having in mind the eventual interest to nuclear data compilers and evaluators. Although it was tried not to miss any appropriate institution or individual there might have been some oversight.

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2. MAIN EXPERIMENTAL FACILITIES FOR NUCLEAR PHYSICS RESEARCH.

For data on type, location, characteristics, and utilization of accelerators and research reactors in Brazil, readers should be referred to the last "Progress Report on Nuclear Data in Brazil (June 1973-May 1974)", IFUSP/P-esp. or INDC(SEC)-422, December 1974.

Progress report on new facilities :

Variable Energy Cyclotron (Instituto de Engenharia Nuclear - Rio de Janeiro).

Characteristics: Cyclotron Corporation Model CV-28; can deliver over 50 μ A of external beams of 2 to 24 MeV protons, 3 to 14 MeV deuterons, 5 to 38 MeV $^3\text{He}^{++}$, and 6 to 28 MeV $^4\text{He}^{++}$. Heavier ions can also be accelerated.

Status: operation has started in October 1974; preliminary experiments on beam alignment and energy calibration have been

carried out with 14 MeV deuteron and 28 MeV alpha particles; some excitation functions of targets of interest for radioisotope production have been measured.

The machine is going to be used for the production of neutron deficient radionuclides for medical uses, activation analysis, nuclear chemistry, radiation damage studies, nuclear reaction studies, and neutron cross-section measurements.

"Pelletron Accelerator" (Instituto de Física-Universidade de São Paulo).

A split-pole high resolution magnetic spectrometer, and a time of-flight fast-neutron spectrometer have been installed in the experimental area in addition to other equipment for nuclear reaction and spectroscopy studies. A Honeywell DDP-516 computer coupled to a IBM/360-44 is being used for automatic data collection and analysis of several experiments .

Beams of ^{16}O (36-40 MeV) ^3He (20 MeV), deuterons, and protons have been utilized in nuclear physics (see itens 6 and 7 of this report).

3. NUCLEAR SPECTROSCOPY

3.1 - Shell model calculations of the ^{40}K energy levels.

S.A.S.Vitiello and I.D.Goldman (Instituto de Física - Universidade de São Paulo).

Energies and spins of the odd parity excited states of ^{40}K have been calculated considering particle-hole configurations and a residual interaction of the type $V_{12} = V_0 (1 + \chi\sigma_1 \cdot \sigma_2) \cdot \delta(\vec{r}_1 - \vec{r}_2)$ as the one adopted by Szpikowski (Acta Physica Polonica, 25: 169, 1964). The particle-hole interaction has been treated as a perturbation of the central field where the

nucleons, move. This perturbation has been assumed to have a very short range and being represented by forces of the type $\delta(\vec{r}_1 - \vec{r}_2)$. For proton holes we used successively:

I) $d_{3/2}$ and $s_{1/2}$; II) $d_{5/2}$, $s_{1/2}$, and $d_{3/2}$; and for neutrons: I) $f_{7/2}$ and $p_{3/2}$; II) $f_{7/2}$, $p_{3/2}$, $f_{5/2}$, and $p_{1/2}$. Harmonic oscillator wave functions have been adopted in the calculations.

3.2 - Decay study of ^{178}Ta

O.A.M. Helene and I.D. Goldman (Instituto de Física - Universidade de São Paulo).

A line of 216.7 KeV has been observed in the gamma transitions of ^{178}Hf , formed by the EC decay of ^{178m}Ta (2.1 h), and has been interpreted as a transition between rotational levels in the $K = 8^-$ band. This transition would imply the formation of the 9^- state of ^{178}Hf with an intensity of approximately 0.25%. From the present result and other previous data for other transitions we can determine $\log ft$ values for the states 8^- (1148 KeV), 8^- (1480 KeV), 9^- , and 10^- , which are 4.9, 4.9, 7.0, and 7.3, respectively. Of the possible values for the spin and parity of this ^{178}Ta isomer, 7^- , 8^- and 9^- , the value 7^- is eliminated because it is incompatible with $\log ft = 7.0$ found for the 9^- state of ^{178}Hf . ^{178}Ta has been obtained from the reaction $^{181}\text{Ta}(\gamma, 3n)$ at the IF-USP LINAC.

3.3 - Measurements of mean lives of nuclear excited states and stopping power for heavy ions.

E.P. Madeira, R.V. Ribas, W.M. Roney, W.A. Seale, and T. Polga (Instituto de Física-Universidade de São Paulo).

Measurements of mean lives of nuclear excited states by the plunger method (Phys. Rev. 173:(4), 177, 1969), and of stopping power of some materials for heavy ions are being carried out. The

technique employed is the observation of the Doppler shift of the gamma-rays emitted by the recoil nucleus following Coulomb excitation caused by the bombardment with ^{16}O ions.

3.4 - Decay of an isobaric analog resonance in ^{123}Sb .

H.Miyake and A.F.R.Toledo Piza (Instituto de Física - Universidade de São Paulo).

The resonance observed at 8.60 MeV in proton inelastic scattering experiments, for 2^+ collective excited states in ^{122}Sn , is usually attributed to the state $1\ g_{7/2}$. Comparison of the calculated values for the spectroscopic amplitudes and partial widths for decay with the corresponding experimental values indicates that such resonance is due to the $2\ f_{7/2}$ state. The Toledo Piza and Kerman formalism is employed and delta, quadrupole-quadrupole and octopole-octopole interaction are included.

3.5 - ^{90}Zr states detected in the reaction $^{91}\text{Zn}(d,t)^{90}\text{Zr}$.

L.C.Gomes, F.C.Sampaio, O.Dietzsch, E.W.Hamburger and G. Rao (Instituto de Física - Universidade de São Paulo).

A ^{11}Zr (95% enriched) target has been bombarded by a deuteron beam at the University of Pittsburgh tandem accelerator, and the resulting tritons have been detected in nuclear emulsions after energy separation in a magnetic spectrograph. Exposures have been carried out at seven angles with an incident deuteron energy of 16 MeV. Data analysis carried out at the University of São Paulo has lead us to the identification of triton groups corresponding to 16 excited states of ^{90}Zr : 0.0, 1.761, 2.190, 2.322, 2.750, 3.077, 3.307, 3.846, 4.234, 4.460, 4.699, 4.832, 5.070, 5.080, 5.348, 5.383 MeV.

Due to the long exposure times it was possible to detect weak-

ly excited levels with a reasonable statistics. The DWBA calculations fitted to the angular distribution curves allowed the determination of the spectroscopic factors and of the relative contributions of different orbital angular momenta. In this way it is possible to describe the ^{91}Zr ground state wave function in terms of the ^{90}Zr states coupled to the single particle states of the transferred neutron.

3.6 - Study of neutron hole states in ^{123}Te .

N.A.G.Fernandes, M.N.Rao and N.Ueta (Instituto de Física - Universidade de São Paulo).

Energy levels of ^{123}Te have been studied by the $^{124}\text{Te}(^3\text{He},\alpha)^{123}\text{Te}$ reaction induced by 20 MeV ^3He particles. The obtained experimental angular distributions have been compared with the ones calculated by DWBA using the DWUCK program. The transferred angular momenta and the spectroscopic factors corresponding to several transitions are determined.

3.7 - Multipole admixture $\delta(E2/M1)$ of gamma transition in ^{71}Ga .

R.N.Saxena, A.Bairrio Nuevo Jr (Instituto de Energia Atômica - São Paulo) and F.C.Zawislak (Instituto de Física - Universidade Federal do Rio Grande do Sul).

The directional correlation of γ -transitions in ^{71}Ga have been measured from the β -decay of $^{71\text{m}}\text{Zn}$ using automated Ge(Li)-NaI(Tl) gamma spectrometer. The spin assignments to the levels at 390 ($1/2^-$), 487 ($5/2^-$), 512 ($3/2^-$), 964 ($5/2^-$), 1107 ($7/2^-$), 1494 ($9/2^+$), and 2247KeV ($7/2^+$) confirm the results of several previous studies on this nucleus. The directional correlation data have been analysed in terms of the multipole mixing ratios $\delta(E2/M1)$ for several γ -transitions. The results are: $\delta(121) = -0.2^{+0.3}_{-2.4}$, $\delta(142) = 0.04^{+0.04}$, $\delta(386) = 0.06^{+0.04}$, $\delta(487) = 0.04^{+0.03}$, $\delta(512) = -0.14^{+0.10}$, $\delta(620) = 1.3^{+0.8}_{-0.3}$, $\delta(753) = 0.0^{+0.01}$ and $\delta(964) =$

± 0.9
 ± 0.3 . The experimental results are discussed in terms of various nuclear models which are applicable for the odd-A nuclei in this mass region.

3.8 - Multipole admixture $\delta(E2/M1)$ of gamma transition in ^{69}Ga .

R.N.Saxena, A.Bairrio, Nuevo Jr (Instituto de Energia Atômica-São Paulo), F.C.Zawislak (Instituto de Física-Universidade Federal do Rio Grande do Sul) and I.D.Goldman (Instituto de Física-Universidade de São Paulo).

The directional correlation of γ -transitions in ^{69}Ga have been measured from the decay of ^{69}Ge using an automated Ge(Li)-NaI(Tl) gamma spectrometer. The measurements have been carried out for the following gamma cascades at 553-318, 787-318, 1206-318, 234-872, 1051-872, 1349-574 and 587-1336 KeV energies. Preliminary analysis of the results confirm $1/2^-$ spin assignment for the 318 KeV level in ^{69}Ga . The results are further being analysed in terms of the multipolarities of 234, 1050 and 1349 KeV γ -transitions. In addition the spin assignments to several levels in ^{69}Ga will be established.

4. PHOTONUCLEAR REACTIONS

4.1 - The (γ, n) reaction in ^{12}C and ^{14}N and $(\gamma, 2n)$ reaction in ^9Be at energies between 0.3 GeV and 1 GeV.

V.di Napoli, M.L.Terranova (Instituto di Chimica Generale ed Inorganica dell'Università, Roma) and H.G. de Carvalho, and J.B.Martins (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro, Brasil).

Cross sections per equivalent quantum of the reactions $^{12}\text{C}(\gamma, n)^{11}\text{C}$, $^{14}\text{N}(\gamma, n)^{13}\text{N}$, and $^9\text{Be}(\gamma, n)^8\text{Be}$ have been measured in the energy range 0.3 - 1.0 GeV. Average absolute cross-sections

have been calculated of (0.90 ± 0.10) mb and (0.021 ± 0.002) mb for the $^{12}\text{C}(\gamma, n)^{11}\text{C}$ and $^9\text{Be}(\gamma, n)^8\text{Be}$ reactions, respectively, over the whole energy range considered, by means of the photon difference method. As far as the $^{14}\text{N}(\gamma, n)^{13}\text{N}$ reaction is concerned, the relatively smaller values of the cross sections per equivalent quantum and the larger experimental errors did not allow to calculate any absolute cross section value.

4.2 - (γ, n) reactions in complex nuclei at intermediate energies.

V.di Napoli, F.Salvetti, M.L.Terranova (Istituto di Chimica Generale ed Inorganica dell'Università, Roma) and H.G.de Carvalho, J.B.Martins, O.A.P.Tavares (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro, Brazil).

The work reports measurements of the cross sections per equivalent quantum of the (γ, n) reaction in ^{31}P , ^{52}Cr , ^{55}Mn , ^{59}Co , ^{75}As , ^{127}I , and ^{197}Au at bremsstrahlung energies ranging between 0.3 GeV and 1.0 GeV. Mean absolute cross sections have been calculated of (1.6 ± 0.1) mb, (2.5 ± 0.5) mb, (3.5 ± 0.5) mb, (3.0 ± 0.5) mb, (4 ± 1) mb, (5 ± 2) mb, and (8 ± 3) mb, for the above listed nuclei respectively.

4.3 - On the isomeric-yield ratio of $^{52}\text{Mn}^g$ and $^{52}\text{Mn}^m$ photoproduction from ^{55}Mn at intermediate energies.

V.di Napoli, G.Persichelli, M.L.Terranova (Istituto di Chimica Generale ed Inorganica dell'Università, Roma) and J.B.Martins (Centro Brasileiro de Pesquisas Físicas Rio de Janeiro).

Photonuclear reactions yielding, as final products, pairs of nuclear isomeric states are very useful in estimating the relative probabilities of producing each isomer. The knowledge of the

isomeric-yield ratios can provide information about the spin dependence of the nuclear-level density in the nucleus under investigation and the mechanism of the reaction. We have carried out yield measurements of the photoproduction of $^{52}\text{Mn}^g$ and $^{52}\text{Mn}^m$ from ^{55}Mn at bremsstrahlung energies from 0,3 GeV to 1,0 GeV. Previous results for rhodium isotopes are also discussed.

4.4 - On the yield ratio of ^{164}Ho isomeric states.

V.R.Vanin and I.D.Goldman (Instituto de Física - Universidade de São Paulo).

Holmium oxide targets have been irradiated by the bremsstrahlung beam of the IF/USP LINAC with energies between 14 and 28 MeV. The isomeric yield ratio has been measured by the residual activity in the samples with a Ge-Li detector. The yield ratio of the 6^- state is approximately constant and equal to 0.25 in the above mentioned energy range. This result is compatible with the predictions based on the statistical model.

4.5 - Isomeric yield ratios of ^{87}Y and ^{86}Y by (γ, xn) reactions as a function of energy.

C.M.Faria (Faculdade de Filosofia, Ciências e Letras de Rio Claro, S.Paulo) and I.D.Goldman (Instituto de Física Universidade de São Paulo).

Yttrium oxide targets have been irradiated by a bremsstrahlung beam (tantalum radiator) of the IF/USP LINAC, in the energy range 32-45 MeV. The residual activities of ^{87}Y corresponding to the metaestable state $9/2^+$ (14h) and ground state $1/2^-$ (80h) have been determined by means of the 381 KeV and 483 KeV transitions, respectively. For ^{86}Y the 208 KeV and 1078 KeV lines have been observed for the metaestable state 8^+ (48 min) and ground state 4^- (14.6 h), respectively. An increase of the yield ratio as a function of

energy have been observed in both cases: from 0.28 (32 MeV) to 0.42 (45 MeV) for ^{87}Y , and from 0.012 (36 MeV) to 0.017 (45 MeV) for ^{86}Y .

4.6 - Study of the $^{55}\text{Mn}(\gamma,3n)^{52g}\text{Mn}$ reaction up to 46 MeV.

M.Nielsen and I.D.Goldman (Instituto de Física - Universidade de São Paulo).

Mettalic manganese has been irradiated with the bremsstrahlung beam of the IF/USP LINAC, in the energy range 32-46 MeV. The yield of ^{54}Mn and ^{52g}Mn for, the reactions $^{55}\text{Mn}(\gamma,n)$ and $^{55}\text{Mn}(\gamma,3n)$, respectively, have been determined by the residual activities in the samples. The activities have been measured by a Ge-Li detector (3 KeV resolution for the ^{60}Co 1332 KeV line) following the 835 KeV transition ($T = 314$ days) of ^{54}Mn , and the 744, 935, and 1434 KeV transitions of ^{52}Mn ($T = 5,7$ days). The yield ratio, of ^{52g}Mn relatives to ^{54}Mn has been found to be 1.4×10^{-3} at 46 MeV.

4.7 - Study of the isomeric yield ratio of ^{117}In by the photo-alpha reaction in antimony.

E.A.Finotti and I.D.Goldman (Instituto de Física - Universidade de São Paulo).

The reaction $^{121}\text{Sb}(\gamma,\alpha)^{117g}\text{In}$, ^{117m}In has been studied experimentally by observing the lines 552.9 KeV ($T_{1/2} = 44$ min) from ^{117g}In , and 315 KeV ($T_{1/2} = 117$ min) from ^{117m}In , with a Ge-Li detector. To avoid the interference of the 564 KeV transition from ^{122}Sb produced by neutron capture in the target, indium has been chemically separated from the antimony sample. The isomeric yield ratio obtained was 0.8 at a bremsstrahlung energy of 35 MeV.

4.8 - Measurements of the differential gamma-ray scattering cross sections in platinum, tungsten, and silver.

P.Pitanga, S.de Barros (Instituto de Física - Universidade Federal do Rio de Janeiro) and R.Moreira (Instituto de Física - Universidade de São Paulo).

Measurements of the elastic scattering cross sections of 412 KeV gamma rays in platinum, tungsten, and silver has been carried out at angles of 40°, 60°, 90°, and 120°. The scattered radiation has been detected by a 22 cm³ Ge-Li detector with 2.5 KeV resolution, which allowed a good separation between the elastic and inelastic scattering. The experimental results in this energy, where Rayleigh and Thomson amplitudes are dominant, are compared with theoretical calculation on the basis of the form factor method.

4.9 - Electric quadrupole resonances

E.Wolynec and C.A.Botelho (Instituto de Física - Universidade de São Paulo).

Quadrupole resonances have been studied by many researchers that have utilized (e,e'x) reactions at certain scattering angles in order to enhance electricquadrupole interaction relative to electric dipole. These studies have the disadvantage of using a phenomenological analysis for the form factor, which does not discriminate between E2 and E0, that have the same angular dependence, or the assumption of a nuclear model, in order to obtain the differential cross sections. We have performed computer simulation of yield measurements of the electrodisintegration of nuclei, suposing the existence of quadrupole components in the photoabsorption, and we have shown that the electrodisintegration yield is very sensitive to quadrupole transitions. It is possible

to obtain the quadrupole resonance cross-sections by analysing the electrodisintegration yield measurements on the basis of the virtual photon formalism, taking into account the Coulomb distortion in the calculation. This method has the advantage of being model independent, depending only on the validity of quantum electrodynamics.

4.10 - Spin 0 and 1 effects in deep inelastic electron-proton scattering.

A.Knoth (Instituto de Física - Universidade Federal do Rio de Janeiro)

Recent experimental measurements of the R ratio for deep inelastic electron-proton scattering, where $R = \frac{\sigma(\text{longitudinal})}{\sigma(\text{transverse})}$ and the σ 's represent the virtual photon cross section, have shown a quite rapid increase in R for small values of the variables x ($x < 0.2$). Generally, parton models for this case have been constructed using only spin 1/2 parton. We will attempt to demonstrate how the spin 0 and 1 effects can be explained while still preserving a strictly spin 1/2 parton model. Also, why do these effects only seem to appear at small x and not large x .

4.11 - Influence of Coulomb distortion in the virtual photon spectrum.

I.C.Nascimento and E.Wolynech (Instituto de Física - Universidade de São Paulo), and D.S.Onley (Ohio University, Athens, Ohio - U.S.A).

Measurements of the ratio σ^-/σ^+ between the nuclear excitation cross-sections for electrons and positrons, published in the literature, are compared with calculated ratios using photon spectra determined in DWBA. The behaviour of this ratio as a function of target atomic number Z and incident electron energy E_0

is shown to be mainly due to Coulomb distortion. These curves do not present structures corresponding to resonances in the photo-absorption cross-section, but they are very sensitive to the presence of quadrupole absorption.

4.12 - Influence of Coulomb distortion in the bremsstrahlung spectrum.

A.N.Fagundes, B.S.Bhandari and I.C.Nascimento (Instituto de Física - Universidade de São Paulo).

The bremsstrahlung spectrum, calculated in first order Born approximation is largely utilized in the study of photonuclear reactions. Nevertheless, in a recent paper Gargaro and Onley indicate that effects of Coulomb distortion may be very significant, specially in heavy nuclei. Measurements of the bremsstrahlung spectrum have not been performed in the giant resonance region, so that the precision of the formulas utilized are not known. In the present experiment the electron beam of the IF/USP LINAC has been used to bombard several different radiators with increasing atomic number Z , at the energy of 25 MeV, producing bremsstrahlung, that was detected by the activation of copper foils. Taking ^{12}C as a standard radiator for normalization purposes, the relative yields due to different radiators are compared with calculations using conventional formulas in order to have an idea of the importance of the Coulomb distortion.

5. FISSION AND NUCLEAR MODELS

5.1 - Present status of photofission of actinides near threshold.

B.S.Bhandari and I.C.Nascimento (Instituto de Física Universidade de São Paulo).

The phenomenon of photofission near threshold has received se

rious attention in the last few years due to its relative importance in studying the shape of the recently suggested "double humped fission barrier" and also mainly because of better gamma ray facilities becoming available at several laboratories. Measurements of photofission cross sections and of the angular distribution of fission fragments permit the determination of the relative contributions of the various fission channels at different excitation energies.

Presently available data on photofission cross sections, photo neutron cross section and on angular distribution of photofission fragments of actinides have been reviewed and some suggestions for additional studies have been made with the aim towards a better understanding of "threshold fission" phenomena in the framework of a double humped barrier in fission.

5.2 - Photofission of ^{238}U below threshold

B.S.Bhandari (Instituto de Física - Universidade de São Paulo) and D.S.Onley (Ohio University, Athens, Ohio, USA)

Photofission cross-sections of ^{238}U below threshold have been calculated using a double humped potential barrier parameterized by smoothly joining four parabolas and a Coulomb potential at and beyond the scission point. The primary potential well is made arbitrarily wide in order to reproduce a density of states comparable with that known to exist in the compound nucleus and which manifests itself as fine structure on the transmission resonances. A "spreading width" method is introduced by taking an average over this fine structure which results in a broadening of the transmission coefficient peaks. Relative strength in the fission channel has been calculated and an attempt has been made to reconcile the apparent resonance structures observed recently in photofission experiments and the isomeric and ground state spontaneous

fission halflives in terms of a single suitable set of parameters of a double humped barrier for ^{238}U . In addition to reproducing satisfactorily the observed resonance structure near threshold the calculation also predicts several low energy resonances in the cross-sections.

5.3 - Quadrupole component in the ^{238}U photofission at low energies.

J.D.T.Arruda Neto, S.B.Herdade, B.S.Bhandari and I.C. Nascimento (Instituto de Física - Universidade de São Paulo).

All nuclei exhibit a resonance in the photonuclear reaction cross section attributed to the E1 excitation mode. Recently, Bohr and Mottelson have made theoretical predictions of a E2 collective excitation occurring at $58A^{-1/3}$ (A = mass number). Several angular distribution experiments have evidenced the occurrence of a E2 excitation, but with a very low intensity relative to the E1 excitation, making difficult its detection. In the present work we have developed a method to obtain the quadrupole photofission cross section from the total electrofission and photofission yields, and the virtual photon spectrum calculated in DWBA on the basis of the Gargaro and Onley formalism. The sensitivity of this method is due to the fact that the ratio of the yields for E2 and E1 is much greater in electrofission than in photofission. A preliminary analysis of our data have shown the existence of a quadrupole resonance at about 9 MeV, which is consistent to the value predicted by Bohr and Mottelson (9.4 MeV).

5.4 - Electron induced fission fragment angular distribution of ^{238}U .

J.H.Vuolo, S.B.Herdade, B.S.Bhandari and I.C.Nascimento (Instituto de Física - Universidade de São Paulo).

The angular distributions of the fragments in the electro-fission of ^{238}U have been measured in the energy range 5.78 - 14.38 MeV. The electron beam of the Universidade of São Paulo LINAC was used to irradiate a thin uranium target and the fragments were detected using makrofol. For the data analysis, theoretical angular distributions of fragments in the electron induced fission of an even-even nucleus have been calculated in terms of the usual rotation matrices and the virtual photon spectrum has been taken from the DWBA formalism given by Gargaro and Onley. Since the virtual photons are not transverse waves, they don't contain the different multipole components in equal amounts. In particular we hope to use the much stronger quadrupole intensity in virtual photon spectrum to analyse quadrupole components in the nuclear spectrum in more detail than is possible with real photons alone.

5.5 - Measurement of the delayed neutrons in the photofission of ^{238}U and ^{232}Th .

Y.Miyao, M.N.Martins, O.D.Gonçalves, L.M.Lunardi, S. de Barros, and G. Moscati (Instituto de Física - Universidade de São Paulo).

Pellets of U_3O_8 and ThO_2 , with thickness 1 to 3 g/cm^2 , have been irradiated with bremsstrahlung at the University of São Paulo LINAC in the energy range 12 to 30 MeV. The counting system was formed by a multichannel analyser operated in the multiscaler mode, which accumulated the neutron counts and the electron beam charge measured by a secondary emission monitor. The neutrons have been detected by BF3 counters immersed in a paraffin moderator. The data have been analysed by decomposing the decay curves in components of fixed half-lives, corresponding to the yields of

precursor groups. The analysis of the results shows that the yields of the different groups do not vary with energy, which limits the possible precursors to the peak regions in the fission fragment mass distribution curve.

5.6 Penetrability through a three humped barrier in quasi-classical approximation.

B.S.Bhandari (Instituto de Física -Universidade de São Paulo).

A three humped barrier has been parameterized by smoothly joining five parabolic potentials. Expression for the penetrability through such a barrier has been obtained in quasi-classical approximation and the behaviour of penetrability versus energy has been studied. In the light of recently suggested evidence for a third minimum in the potential energy surface of thorium isotopes, a plausible explanation of their sub-barrier fission characteristics is given in terms of a three humped barrier.

5.7 - Calculation of the penetrability through a two-dimensional fission barrier in the scattering formalism.

T.Kodama and R.A.M.S.Nazareth (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro).

The complete understanding of the fission process requires a dynamical description of the system. Due to the difficulty to describe the dynamics as a multidimensional process, several authors solved the problem for the unidimensional case. More recently, Hofmann introduced a two dimensional treatment. The objective of this work is to determine the penetrability for a certain fission barrier using the method proposed by Hofmann and to compare the result with the existing experimental values. In this method a bidimensional collective Hamiltonian is constructed in

which one of the coordinates (the fission coordinate) defines the fission path and the other is represented by harmonic oscillations transverse to the fission path. The frequencies of the transverse harmonic oscillations are responsible by the coupling between the two degrees of freedom of the problem and so contributing to the evaluation of the fission barrier. In our preliminary work it has been introduced a correct path for fission through the simple potential barrier given by Brack. The inertia coefficients related to the two degrees of freedom, given by Hasse, are also used.

5.8 - Exact calculation of the penetrability through a barrier for fission of heavy ions in a simple two-dimensional case.

T.Kodama (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro), R.A.M.S.Nazareth (Instituto de Física - Universidade Federal do Rio de Janeiro), and J.R.Nix (Los Alamos Scientific Laboratory - USA).

In the study of the effect of zero-point quantum oscillations of nuclei in their fusion cross-sections at low energies, we have calculated exactly the penetrability through a simple two-dimensional barrier $V(x,y)$. The coordinate x is related to the distance between the centers of mass of the two nuclei and y is related to the sum of their deformations along a common symmetry axis. The parabolic potential in x is one of the two harmonic oscillators in y , depending of the value of x relative to a critical value x_1 . Both oscillations differ by the positions of their minima and by their curvatures. This simulates the dominant characteristics in the two dimensional surface energy potential with two aligned valleys (the fission and fusion valleys) separ-

rated by a hump between them. When an incident wave which is located in the fusion valley reaches the potential barrier, it is partially transmitted and partially reflected in waves that correspond to different excited states in the transverse direction and to different energy increments in the direction of fusion. The amplitude of these waves are determined by imposing the condition of continuity to the wave functions (exactly expressed in terms of cylindric-parabolic functions) and to their derivatives in x_1 . The penetrability is then obtained from the amplitudes of the transmitted waves. The presence of the hump and of the fission valley increases the penetrability for all incident energies, but the relative increment is bigger for low energies. The penetrability is found to vary less with energy than the one calculated for the same one-dimensional barrier. This effect explain part of the anomaly that appears among the experimental values of the curvature parameter n_x obtained by analysing the low energy fusion penetrability in terms of a one-dimensional barrier and the calculated values. The experimental values are substantially smaller than the calculated ones.

5.9 - Non-lanthanide fragment yields in ^{238}U fission induced by 14 MeV neutrons.

A.V.Bellido and G.M.de Macedo Grassi (Instituto de Engenharia Nuclear, and COPPE- Universidade Federal do Rio de Janeiro).

^{238}U has been irradiated by 14 MeV neutrons, and from a nitric solution of the target, the lanthanides have been separated by precipitation with HF and the non fissioned uranium by extraction with TBP. The resulting solution has been analysed with a high resolution Ge_{Li} detector. Relative yields have been obtained of mass chains 91,92,93,101,104,105,107,128,129,131,132,133,134,135,

141 and 142, and converted to absolute yields by normalization with mass yields already published in the literature.

5.10 - The Wigner and higher order terms in the droplet mass formula.

T.Kodama (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro) and K.Takahashi (University of Koln, Germany).

The mass formula of the droplet model proposed by Myers and Swiatecki is a generalization of the one obtained from the liquid drop model, in which the concept of density distribution of the nucleons is taken into account explicitly. Several authors have obtained the droplet parameters and the resulting formulas are satisfactory at least for the masses in the ground state. Nevertheless, the experimental data are available only in a very narrow band of the N-Z plane and, besides this, perturbed by even-odd and shell effects. This makes the least square fit of the parameters very unstable. The so called Wigner terms and the high order ones are particularly very difficult to determine. These terms are carefully investigated in the present work. There are some indications that the coefficient for the higher order symmetry is much bigger than the values previously assumed.

5.11 - Monopole and dipole resonances and the droplet model mass formula.

T.Kodama (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro) and E.R.Hill (Th, Darmstadt, Germany)

By calculating the change in potential energy in the droplet formula due to the change in the density distribution parameters, we can investigate the giant resonance phenomenon more satisfactorily than by the utilization of the usual mass formula.

The kinetic energy for the droplet parameter can be also calculated. The resonance energy is obtained by diagonalising the total hamiltonian with respect to these parameters. Comparison with the experimental value gives information about the droplet parameters which cannot be obtained from the nuclear masses in the ground state. It is also discussed the pulsing mode of the nucleus in this model.

6. LIGHT AND HEAVY ION REACTIONS

6.1 - Distortion effects in (p,2p) quasi-free scattering

P.M.Mors (Instituto de Física - Universidade do Rio Grande do Sul).

Results of (p,2p) experiments have been presented, in general, in the form of energy spectrum and angular correlation curves. In this work, the presentation of part of these results in the form of momentum distribution contour diagrams in momenta space, as suggested by Jacob and Maris, has been investigated. The contour diagrams drawn from a theoretical calculation for the ^{16}O (p,2p) ^{15}N reaction, for the 1s and 1p states, at bombarding energies 200 MeV and 378 MeV, are very sensitive to the distortion caused by the optical potential on the incident and emergent protons, presenting deformations and dislocations, as compared to the circular forms centered in the origin that they should have without distortion. The dislocation and deformation of each diagram are attributed, respectively, to the real and imaginary parts of the optical potential that actuates on the protons involved in the reaction.

6.2 - On the inversion of the potential scattering problem on the basis of the harmonic oscillator.

A.F.R. de Toledo Piza and M.M.Watanabe (Instituto de

Física - Universidade de São Paulo).

The representation of a nucleon-nucleon potential on the basis of the harmonic oscillators from scattering (phase shifts) informations only, following the procedure utilized by the University of Sussex group (Elliott et al, Nucl.Phys. A121: 241,1968) is analysed for the case of phase shifts produced by known potentials. The adequacy of the method is proved for regular potentials. Nevertheless, the introduction of repulsive cores leads to serious problems in the interpretation of the results in the procedure suggest in Sussex. The effects of possible contributions outside the energy surface are studied through the potential short range unitarian transformations, that maintain the phase shifts invariant.

6.3 - Study of the reaction ${}^7\text{Li}(p,n){}^7\text{Be}$ with a time-of-flight system.

W.R.Wylie, E.W.Cybulska, R.A.Douglas, and E.F.Pessoa
(Instituto de Física - Universidade de São Paulo).

A three-stage beam pulsing system has been designed and build at the University of São Paulo Pelletron accelerator. The obtained pulse width was less than 2nsec, and the compression factor more than 10. Neutron angular distributions for the reaction ${}^7\text{Li}(p,n){}^7\text{Be}$, with 8.5 MeV incident protons, have been measured.

6.4 - Study of the ${}^{91}\text{Zr}(d,p){}^{92}\text{Zr}$ reactions.

T.Borello-Lewin, L.B.Horodyski Matsushigue, C.M. Oliveira, and F.Sampaio (Instituto de Física - Universidade de São Paulo)

The study of the ${}^{91}\text{Zr}(d,p){}^{92}\text{Zr}$ reaction relates to a program for obtaining detailed experimental informations on nuclei with number of protons or neutrons near closed shells (Rev.Bras.

Fis., 2:157,1972). A self-sustained target, enriched to 89% in ^{91}Zr , of $540 \mu\text{g}/\text{cm}^2$ thickness, has been bombarded by 12 MeV deuterons at the University of Pittsburg tandem. The resulting protons have been analysed by a magnetic spectrograph and detected in nuclear emulsions, located at 9 scattering angles, between 89° and 55° , with a resolution of 12 KeV. The decomposition of the experimental angular distributions in contributions corresponding to the compatible angular momenta will be made using DWBA calculations and least square fits. It is expected that that the results will contribute to the description of collective aspects of the even nucleus ^{92}Zr .

6.5 - Collective model analysis of deuteron inelastic scattering in ^{91}Zr .

L.B.Horodynski-Matsushigue, T.Borello-Lewin, O.Dietzsch, E.Hamburger and H.Miyake (Instituto de Física-Universidade de São Paulo).

Nuclear emulsions plates have been exposed in the University of Pittsburg tandem magnetic spectrometer for the study of the $^{91}\text{Zr}(d,d')$ reaction, as part of a program on detailed spectroscopic studies of nuclei near magic numbers. About 50 levels have been detected and 27 angular distributions obtained. These distributions may be classified by a visual analysis, in three main groups. The situation of ^{91}Zr , with only one neutron besides the magic nucleus ^{90}Zr , is adequate to the de-Shalit simple model, which consider the coupling of each collective state of the even nucleus with the extra particle. The description of the excitation process of these even nucleus levels is usually made within the DWBA formalism. Extensive calculation have been carried out with the DWUCK program, and macroscopic interaction (R.H.Bassel

et al, Phys.Rev. 128: 2693,1962). The inclusion of the imaginary part in the interaction has a pronounced effect on the angular distributions. For deuterons of 17 MeV incident energy, consideration of Coulomb excitation was important, specially for low multipolarity states. These calculations have shown that the three above mentioned groups correspond to transferred angular momenta $L = 2, 3, \text{ and } 5$, in accordance with the more strongly excited states in the neighbour nuclei ^{90}Zr and ^{92}Zr . The obtained average deformation parameter β_L are, for the case of $L=2$, closer to the values for ^{92}Zr . We are engaged in a more fundamental description of the ^{91}Zr levels, using the BCS + RPA approximations for describing the even nucleus states and constructing the odd nucleus states assuming contributions of more than one configuration.

6.6 - Relative Q-values for (d,t) reactions in Zr stable isotopes.

L.C.Gomes and O.Dietzsch (Instituto de Física - Universidade de São Paulo).

Relative Q-values for (d,t) reactions induced in zirconium isotopes ($A=90,91,92,94, \text{ and } 96$) have been determined by a simultaneous observation of triton groups corresponding to transitions to the ground states. The target contained all the mentioned isotopes, and the tritons have been detected by nuclear emulsion plates located in the focal plane of the University of Pittsburg magnetic spectrometer. The Q-values have been normalized, for the one of ^{92}Zr obtained from the mass excess table of Wapstra and Gove (Nuclear Data, A9:303,1971). The $Q(d,t)$ results obtained in this experiment for the mass 90 and 91 isotopes are in good agreement with the ones of the above mentioned table. Nevertheless,

our results indicate discrepancies in the $Q(d,t)$ values of the mass 94 and 96 Zr isotopes (27,5 KeV and 22,1 KeV, respectively) and, therefore, a disagreement in the masses of the isotopes 93 and/or 94, and 95 and/or 96.

6.7 - Inelastic scattering of ^3He and α in ^{124}Sn and ^{124}Te

C.A.Appoloni, S.Salém, M.N.Rao, and N.Ueta (Instituto de Física -Universidade de São Paulo).

Angular distributions have been determined for the elastic and inelastic scattering of alpha and ^3He particles, of approximately 20 MeV, in ^{124}Sn and ^{124}Te targets. The inelastic scattering angular distributions corresponding to one phonon (2^+ and 3^-) levels have been analysed by DWBA, using the optical parameters obtained in the analysis of the elastic scattering. Results of this analysis and the deformation parameters of ^{124}Sn and ^{124}Te are presented.

6.8 - Optical model parameters for ^3He and alpha particle beams in $Z \approx 50$ nuclei.

A.T.M.Mendes, N.Ueta and M.N.Rao (Instituto de Física Universidade de São Paulo)

Angular distributions have been measured for the elastic scattering of ^3He and alpha particles in ^{124}Sn , ^{124}Te and ^{123}Sb targets, in energies of approximately 20 MeV. The experimental results have been analysed in order to determine optical model parameters. These parameters will be utilized in DWBA analysis of transfer reactions induced by alpha and ^3He particles.

6.9 - Study of one proton transfer reactions in tellurium isotopes.

A.S.Toledo, M.N.Rao, N.Ueta and O.Sala (Instituto de Física - Universidade de São Paulo)

Levels of ^{125}I have been studied by the reaction $^{124}\text{Te} (^3\text{He},d)^{125}\text{I}$ with an incident energy of 19,5 MeV. The deuteron angular distributions have been measured by utilizing surface barrier telescopes and particle analog identification. The transferred angular momenta (lp) and the spectroscopic factors for several transitions have been obtained by DWBA calculations. The studies will be extended to the reactions $(^3\text{He},d)$ and (α,t) in ^{122}Te and ^{124}Te .

6.10 - Preliminary results for reactions induced by ^{16}O in ^{27}Al .

J.C.Acquadro, D.Pereira, O.Sala, and N.D.Vieira Jr
(Instituto de Física - Universidade de São Paulo).

Reactions induced by ^{16}O in ^{27}Al are studied by identifying the resulting particles with a proportional counter coupled to a semiconductor detector. Preliminary results indicate the possibility of determining cross sections for the transfer of a few particles, as well as for the formation of a compound nucleus or partial fusion.

6.11 - Study of the reaction $^{10}\text{B} (^{16}\text{O},\alpha)^{22}\text{Na}$

J.Hirata, M.J.Bechara, T.Borello-Lewin, E.R.Cruz,
L.C.Gomes, A.I.Hamburger, L.B.Horodynski-Matsushige,
K.Koide, F.Sampaio, E.M.Takagui, N.Marquardt,
and O.Dietzsch (Instituto de Física - Universidade de São Paulo).

Excitation functions of several α particle groups, corresponding to low excitation levels of ^{22}Na , populated in the interaction $^{10}\text{B} + ^{16}\text{O}$, have been determined at $\theta_{\text{LAB}} = 0^\circ$, in steps of 250 KeV, in the bombarding energy range 36.0 - 39.5 MeV. A surface barrier semiconductor detector, protected by Ni and Al

foils with thickness sufficient to stop the incident ^{16}O beam and other heavy ions, has been used to detect the alpha particles. The ^{16}O beam has been produced in the University of São Paulo Pelletron accelerator. Any structure has been observed corresponding to the states 0.58 and 1.9 MeV in ^{22}Na , contrarily to the observations of other authors in the energy range 40-46 MeV (Campo et al, Phys.Rev.C, 9:1258,1974). However, our results suggests structures of 400 KeV width at $E_{\text{LAB}} = \quad \text{MeV}$ for the transition corresponding to the ground state and at $E_{\text{LAB}} = 37 \text{ MeV}$ for the state of $E_x = 1.53 \text{ MeV}$.

6.12 - Threshold energies for $D(^{16}\text{O},n)^{17}\text{F}$ reactions

V.H.Rotberg (Instituto de Física - Universidade de São Paulo).

Threshold energies for $D(^{16}\text{O},n)^{17}\text{F}$ reactions, in the charge states 4^+ and 3^+ of the ^{16}O ion, have been utilized for the energy calibration of the University of São Paulo Pelletron accelerator. The neutrons have been detected by a long counter and the threshold energies utilized to determine the calibration constant of the 90° analysing magnet coupled to the accelerator. These energies have been re-calculated in the present work and the results presented discrepancies when compared to the values adopted in other laboratories as calibration references. These discrepancies are due to approximations that are usually valid for kinematic calculations of endoergic reactions induced by light particles in heavier targets, but that are not applied to the present situation.

6.13 - Excitation of ^{24}Mg by the interaction $^{10}\text{B} + ^{14}\text{N}$

K.Koide, A.Ceballos, N.Marquardt, and O.Dietzsch
(Instituto de Física - Universidade de São Paulo).

Excitations curves have been determined by the reaction $^{10}\text{B}(^{14}\text{N},\alpha)^{20}\text{Ne}$ at $\theta_{\text{LAB}} = 0^\circ$, and for the reaction $^{10}\text{B}(^{14}\text{N},p)^{23}\text{Na}$ at $\theta_{\text{LAB}} = 165^\circ$, in the bombarding energy range 9,5 to 13 MeV. The experimental data have been obtained in the Laboratory of Nuclear Physics of the University of Montreal by utilizing a high intensity ion beam at a tandem Van de Graaff. In both reactions no evidence has been found for the strong resonance (corresponding to a excitation energy of 33.2 MeV in ^{24}Mg) observed by other authors in the interaction $^{12}\text{C} + ^{12}\text{C}$. Our data gives a direct evidence that the formation of this resonant state in ^{24}Mg depends strongly on the entrance channel.

7. NEUTRON PHYSICS

7.1 - Slow Neutron Cross Section of Deoxyribonucleic Acid, ex-Thymus.

R.Fulfaro, V.S.Walder, L.A.Vinhas and L.Q.Amaral*
(Instituto de Energia Atômica - São Paulo).

In order to study the dynamics of water in biological molecules and the freedom of motion of the hydrogen atoms, the neutron transmission through a DNA sample was measured in the neutron wave-length interval 4.0 to 6.5 Å using a crystal spectrometer. The knowledgement of the bounding state of the water present in DNA is very useful to study the structures and the function of biological macromolecules. NMR studies suggest some form of ice-like coordination for H_2O in biological molecules, where as results obtained from neutron inelastic scattering in polyglutamic acid suggest a behaviour similar to liquid water. In the present work, measurements were performed at room temperature for a dry sample and for a wet sample with 7.8% moisture. The total cross sections, σ , and the scattering cross sections per hydro-

* Presently at the Instituto de Física-Universidade de São Paulo

gen atom, $\sigma_{S/H}$, were determined in each case, thus obtaining the cross section of H_2O present in DNA. This cross section shows that the water in DNA presents a behaviour similar to that of liquid water. By analysing the $\sigma_{S/H}$ curve for dry DNA it is observed that the hydrogen atoms have not much freedom of motion in this biological molecule. Also, the cold neutron inelastic scattering for DNA samples were measured; the results are being analysed.

7.2 - Liquid-Solid Transition in Cyclohexanol by Neutron Transmission.

R.Fulfaro and L.A.Vinhas (Instituto de Energia Atômica -São Paulo).

The total cross section of the cyclohexanol was measured for 6.13\AA wavelength neutrons, varying the sample temperature in a range that includes the melting point. From these experimental results and by comparison with theoretical calculations it was possible to obtain the Debye temperatures for both states. These temperatures were used to calculate the disorder entropy variation near the fusion point.

7.3 - Multiple Neutron Diffraction Experiment with Temperature Variation.

C.B.R.Parente and R.S.da Costa

Multiple neutron diffraction patterns have been obtained with an aluminum single crystal at different temperatures. For a temperature change of 70°C the patterns show a distinct variation in the angular position of the peaks ranging from about 0.02° to 0.2° . To perform the experiment so that it could be used for the determination of the cell parameter in each temperature, a careful crystal mounting and alignment were done. The mechanical precision of all movable parts of the 2θ and θ axes of the neu-

tron diffractometer allows an angular positioning with an error within 0.01°. The goniometer used to set the scattering vector of the primary reflection along the proper direction as well as to turn the crystal around it has an angular precision of the same order. The counting time was 6 minutes which gave an statistical fluctuation of the order 0.5% and the angular steps were taken as 0.05° for narrow peaks and 0.10 for the broad peaks. The cell parameter values determined by the angular positions of the peaks presented calculated errors of the order of $3 \times 10^{-3} \text{ \AA}$.

7.4 - Hydrogen Concentration Determined by the Neutron Transmission Method.

L.A.Vinhas, R.Fulfaro, V.S.Walder and C.B.R.Parente.

It has been developed the techniques for determining the hydrogen content of hydrogenous compounds by neutron transmission. The method is based in the large slow neutron scattering cross section of hydrogen compared to carbon and other elements. Using the crystal spectrometer of IEA, selecting neutrons of energy 0.145 eV, the experimental transmission of 14 standard compounds have been measured. The precision and accuracy of the method were studied.

7.5 - Measurement of the relative cross-section for the reaction $^{103}\text{Rh}(n,n')^{103m}\text{Rh}$ by activation.

S.B.Herdade, E.W.Cybulska, R.A.Douglas, E.F.Pessoa, and W.R.Wylie (Instituto de Física - Universidade de São Paulo)

Following the recommendation contained in INDC(NDS) - 47/L (1972), the relative cross-section for the reaction $^{103}\text{Rh}(n,n')$ ^{103}Rh has been measured in the energy range 4.0 - 8.0 MeV. The reaction $^7\text{Li}(p,n)^7\text{Be}$ produced at the University of São Paulo Pel-

letron accelerator has been utilized as neutron source. The neutron spectra of this reaction, for 8,5 MeV incident protons, has been determined at several angles by the time-of-flight method. The activation of the rhodium foils has been detected by means of the X-rays following internal conversion of the 40 KeV transition, with a NaI(Tl) detector through a thin Be window. Preliminary results are in agreement with previous measurements by Santry and Buttler (Can.J.Phys. 52:1421,1974).

Addresses of Institutions mentioned in this Progress Report

Instituto de Física - Universidade de São Paulo
Caixa Postal 20516 - São Paulo, S.P.-Brasil

Instituto de Energia Atômica
Caixa Postal 11049 - Pinheiros
São Paulo, S.P.-Brasil

Centro Brasileiro de Pesquisas Físicas
Av. Wenceslau Brás, 71
Rio de Janeiro - RJ, Brasil

Instituto de Engenharia Nuclear
Caixa Postal 2186 - ZC-00
20000 Rio de Janeiro-RJ- Brasil

Instituto de Física
Universidade Federal do Rio Grande do Sul
Av. Luiz Englert s/n
91000 Porto Alegre- R.S.- Brasil