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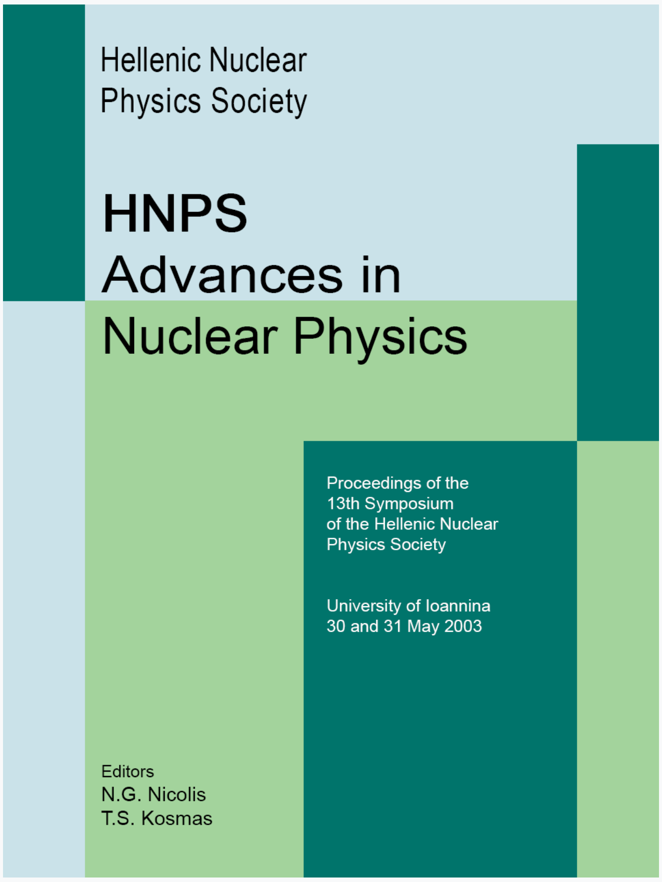

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Short-Range Correlations and Two-Body Density Matrix in Nucleon Systems

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Short-range correlations (SRC), a consequence of the strong and repulsive short-range components of a realistic nucleon-nucleon potential, continues to be an open issue in nuclear physics [1]. The last few years the two-body density matrix and its various Fourier transforms [2] are considered as key descriptors of SRC representing the next stage of complexity beyond the one-body density matrix and the single-partice momentum distribution. They appear in the analysis of recent and future experiments focusing mainly on quasielastic electron scattering ((e,e'), (e,e'N), (e,e'2N)) at rather high momentum transfer.
In this work, first I review briefly our calculations of the half-diagonal two-body density matrix $\rho_{2h}(\vec{r}_1, \vec{r}_2, \vec{r}_{1'})$ and of the generalized momentum distribution $\eta(\vec{p}, \vec{Q})$ in infinite nuclear matter [3] as well as those of $\eta(\vec{p}, \vec{Q})$ and of the two-body momentum distribution $\eta_2(\vec{p}_1, \vec{p}_2)$ in doubly-magic nuclei [4] within variational theory. Then, I am referring to our analysis in terms of ρ_{2h} of the inclusive (e,e') scattering off nuclear matter at the quasielastic regime for momentum transfer in the range 1GeV/c $< |\vec{q}| <$2GeV/c. Work is in progress to improve our calculations in finite nuclei, to extend them to other quantities both in nuclear matter and finite nuclei and to use our results in the analysis of quasi-elastic electron scattering experiments (e,e'), (e,e'N) and (e,e'2N) at large momentum transfer.

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† The work discussed here has been carried out in collaboration with O.Benhar, J.W.Clark, A.Fabrocini, S.Fantoni, T.S.Kosmas, C.C.Moustakidis, P.Papakonstantinou and M.Petraki.

SEENet: The South-East European nuclear physics Network.

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The South-East European Nuclear Physics Network (SEENet) was formed recently by 10 SEE research institutions. This report aims at presenting the status and the perspectives of SEENet.

The new critical-point symmetries E(5) and X(5) in nuclear structure:
SEARCHING FOR EMPIRICAL EVIDENCES VIA LIFETIME MEASUREMENTS

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For more then 25 years, the Interacting Boson Approximation (IBA) model has provided a very sound theoretical ground for the description of the stucture at low excitation energies of transitional nuclei. This description was realized by means of dynamic symmetries resulting from the U(6) Lie algebra. Hence, in the "elementary" formulation of IBA, i.e. IBA-1, one obtains three different chains of subalgebras from the "initial" U(6) algebraic structure. These chains are known as the U(5), SU(3) and O(6) limits that represent idealized limits of nuclear structure. Thus, U(5), SU(3) and O(6) correspond to harmonic vibrators, deformed symmetric rotors, and γ-unstable nuclei, respectively.

Recently, a new class of dynamic symmetries, the so-called E(5) and X(5) critical point symmetries, have been introduced by F. Iachello [1, 2]. These symmetries describe systems that undergo phase transitions between the two -out of the three- different structure limits of the Interacting Boson Approximation Model (IBA-1). Hence, X(5) corresponds to a phase transition when going from the rotational (SU(3)) to the vibrational limit (U(5)), whereas E(5) is the phase transition point from the vibrational to the γ-soft (O(6)) limit (see fig. 1). The excitation spectra of nuclei resembling these new symmetries can be easily obtained from simple expressions. Hence, E(5) and X(5) can provide a very pedagogical picture of nuclear structure. Based on the existing nuclear structure data, some nuclei have been proposed as the best X(5) or E(5) candidates. Following these suggestions, experimental works aiming at providing an empirical evidence of these symmetries are under progress.

This report aims at reviewing the experimental effort made so far in terms of lifetime measurements. Recent experiments are presented and further measurements are proposed and discussed.

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Proton capture reactions of medium-heavy nuclei relevant to the p-process

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Several cross section measurements mainly of proton capture reactions of nuclei in the Se-Sn region have been carried by the Demokritos Nuclear Astrophysics group in collaboration with the IfS, Stuttgart in order to contribute to a database needed for calculations that are relevant to the modeling of p-process. In this contribution, we report on the cross section measurements carried out for the reactions ^{103}Rh(p,γ)^{104}Pd, ^{113,115}In(p,γ)^{114,116}Sn and ^{121,123}Sb(p,γ)^{122,124}Te. The data are compared with the predictions of the Hauser-Feshbach theory.

Collectivity of the low-lying dipole strength in relativistic random phase approximation

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The relativistic random phase approximation is applied in the analysis of the evolution of the isovector dipole response in nuclei with a large neutron excess. The self-consistent framework of relativistic mean-field theory, which has been very successfully applied in the description of ground-state properties of nuclei far from the valley of β-stability, is extended to study the possible onset of low-energy collective isovector dipole modes in nuclei with extreme isospin values.

Neutrino-nucleus cross sections for exclusive processes

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Abstract

Exclusive neutrino-nucleus cross section, given in terms of transition matrix elements of specific multipole tensor operators, are studied for some neutrino-detection targets. The multipole decomposition of the hadronic currents, appropriate in cases where the initial and final nuclear states have well-defined spin, isospin and parity, is utilized in a unified formalism involving description of any semi-leptonic process. The relevant operators are written in terms of seven basic single-body tensor operators. At first, closed analytic expressions for the single-particle reduced matrix elements of the basic multipole tensor operators are constructed by using a harmonic oscillator basis [1, 2]. These expressions (product of a polynomial with constant coefficients, usually simple numbers, times an exponential) are functions of the momentum transfer to the nucleus. The coefficients of these polynomials can be calculated for any single-particle nuclear matrix element throughout the periodic system. As some applications we have tabulated [2, 3] the corresponding ones for the $N = 2 - 5$ major harmonic oscillator shells.

Among the methods of calculation of exclusive transition cross sections, many authors use the well known RPA method which is mainly appropriate for even-even nuclei. Since, many promising targets in neutrino-nucleus reactions are odd-A isotopes (^{37}Cl, ^{71}Ga, ^{81}Br, ^{115}In, ^{127}I, etc.),the common RPA method requires some modifications in order to calculate exclusive ν_l-nucleus cross sections . In the present work, we, first, modify the usual RPA method, so that the excited final states of odd-even nuclei may be obtained. One of the main goals of theoretical investigations, is to shed light on open problems in phenomena involving neutrinos (solar neutrino puzzle, atmospheric neutrino problem, etc.).

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Measurements of Fission Cross Sections of Actinides in the n_TOF Facility at CERN

The n_TOF Collaboration

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Abstract

Trans-Uranium elements (TRU) are built up in nuclear reactors based on the U/Pu nuclear fuel cycle, constituting the most important hazard for nuclear waste management. All proposals to reduce the radiotoxicity of nuclear waste containing TRU rely on neutron induced fission and capture. The response of any waste burner (e.g. criticality conditions) to the presence of TRU is directly linked to the capture and fission cross sections of TRU isotopes, such as ^{237}Np, ^{241}Am, ^{243}Am and ^{245}Cm. The fission cross sections of TRU are therefore fundamental elements in the assessment of feasibility studies of nuclear waste transmutation.
Measurements of neutron induced fission cross sections of the isotopes mentioned above are proposed for the n_TOF neutron beam. Two sets of fission detectors will be used: one based on PPAC counters and another based on a fast ionization chamber (FIC). For the entire set of measurements, a total of 5×10^{18} protons are requested.

^{234}U (n, f), ^{235}U (n, f) and ^{238}U (n, f) cross-section measurements with the FIC detector

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Abstract

The measurements which are presented here are part of the nTOF experiments, which take place at the installation of CERN in Geneva and aim the determination of cross-sections of fissions caused by neutrons in nuclei of the isotopes ^{230}Th, ^{232}Th, ^{231}Pa, ^{233}Pa, ^{232}U, ^{233}U, ^{234}U and ^{236}U. These isotopes play an important role in the Th cycle, which is used by ADS systems for the production of energy and the “incineration” of nuclear waste.

For the calculation of the ^{234}U cross-section the FIC (Fast Induction Chamber) detector was used, placed in front of the neutron beam. A ^{234}U sample was placed in the detector as well as ^{235}U and ^{238}U. The signal was digitized by means of a flash ADC and was stored in the hard disk of a computer for off- line analysis.

The data were analysed using pulse shape analysis techniques, so that fission events were separated from other channels. The number of fissions of ^{234}U nuclei per neutron energy were determined using neutron flux values calculated from ^{235}U and ^{238}U fissions, for which the cross-section is accurately known.

Κατανομή νετρονίων θρυμματισμού κατά μήκος ευρέως στόχου Pb

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Abstract

Με την βοήθεια της ανάλυσης που περιγράφεται στους επιταχυντές σωματιδίων υψηλών ενεργειών, η οποία αφορά τις αντιδράσεις θρυμματισμού, μπορούν να αναλυθούν και να εξηγηθούν τα πειραματικά δεδομένα των πειραμάτων που πραγματοποιήθηκαν στο JINR στην Dubna. Στα πειράματα αυτά στόχος Pb, ο οποίος περιβάλλεται από παραφίνη, ακτινοβολήθηκε από δέσμη πρωτονίων εύρους ενεργειών από 0.65GeV - 7.4GeV. Αποτέλεσμα αυτής της ακτινοβόλησης είναι η παραγωγή πρωτογενών και δευτερογενών σωματιδίων θρυμματισμού, κυρίως πρωτονίων και νετρονίων. Η παραγωγή αυτή μελετάται σαν συνάρτηση της ενέργειας της δέσμης. Από την γωνιακή κατανομή των πρωτογενών και δευτερογενών σωματιδίων στο χώρο, μπορεί να υπολογιστεί και η κατανομή των νετρονίων κατά μήκους του στόχου. Οι υπολογισμοί και τα πειραματικά δεδομένα είναι σε πολύ καλή συμφωνία.

Measurements of energy loss of charged particles travelling in crystalline materials along the channeling direction

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Abstract

The energy loss of charged particles channeled along a low index axis of a crystal, is only a fraction of the corresponding one along the random direction of incidence. An accurate knowledge of α, the ratio of the energy loss for channeled versus randomly incident particles for different crystals is important for both basic physics studies as well as rapidly growing applications. Most of the experiments carried out in the past in the transmission geometry for many crystals, reported values for α ranging between 0.3 and 0.7.

Following the pioneer works of the last decade [1, 2], a new approach has been proposed recently, based on the use of a nuclear resonance as a marker for the range, and on the assumption of an exponential rate of dechanneling of the incoming particles.The experiments were performed using the 5.5 MV Tandem Accelerator at N.C.S.R. 'Demokritos', Athens, Greece and the 3 MV TANDETRON Accelerator at Forschungszentrum, Rossendorf, Dresden, Germany. Protons and alphas were accelerated to energies 1.7-2.5 and 3.0-3.5 MeV, respectively and were lead to high accuracy goniometer chambers.

This method led to the successful simulation of backscattering spectra in the systems $p+^{28}Si$ <100> [3], $p+^{28}Si$ <111> [4], p+SiC, $p+SiO_2$ [5] and $\alpha+SiO_2$, α+MgO, $\alpha+Al_2O_3$ [6]. In this approach, the dechanneling process is defined by only two parameters, the average ratio, α, of stopping powers in the channeling and random directions (over the energy range in which the particle travels inside the channel) and the mean channeling distance, λ. This technique allows *in situ* measurements and can be applied to several bulk single crystals (simple or compound) without any particular sample preparation, combining NRA and channeling.

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Nuclear structure calculations for ^{72}Ge using deformed Hartree-Fock

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Abstract

We calculated the low-lying spectrum of $^{72}_{32}$Ge nucleus using a deformed configuration mixing shell model approach which is based on Hartree-Fock (HF) states. The deformed orbits $|\lambda\rangle$ entering the HF single particle equations in our axially symmetric system are eigenstates of the $\hat{J}_z$ operator and are expanded to basis states $|j\rangle$ with a projection k_λ along the symmetry axis as

$$|\lambda\rangle = \sum_j c_{jk_\lambda} |jk_\lambda \tau_\lambda\rangle \tag{1}$$

(j denotes the single particle angular momentum). The expansion coefficients $c_{j\lambda}$ are determined via the iterational procedure. Since, the two-body interaction matrix elements are available in the shell model representation, for the radial part of the basis states $|j\rangle$ we used (spherical) harmonic oscillator states, $|j\rangle \equiv |(nl)jk\tau\rangle$. In Eq. (1) the intex τ_λ distinguishes proton and neutron orbits and can be dropped for charge-preserving process.

The model space employed for the calculations comprises as active orbits the $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$ and $0g_{9/2}$ single particle levels (^{56}Ni is assumed as inert core). We used as two-body interaction the modified Kuo effective-interaction for the $f_{5/2}pg_{9/2}$ valence space. The spherical single particle energies of these orbitals relative to ^{56}Ni are taken to be the same for protons and neutrons. The ground state of $^{72}_{32}$Ge in this method corresponds to the lowest 0^+ level obtained from the lowest $K = 0^+$ intrinsic state.

We considered the following bands for ^{72}Ge: (i) The lowest $K = 0^+$ band, which gives on angular momentum projection the lowest J = 0^+, 2^+, 4^+, etc. levels. (ii) The first excited $K = 0^+$ intrinsic band, which gives also the excited levels J = 0^+, 2^+, 4^+, etc. (iii) Two $K = 2^+$ intrinsic bands obtained respectively by neutron and proton excitation. These intrinsic bands give the excited J = 2^+, 3^+, 4^+, etc. levels of the gamma band. (iv) The $K = 1^+$ intrinsic band, which gives the levels J = 1^+, 2^+, 3^+, etc. They appear at about 1 MeV but none of them has been observed. (v) One $K = 1^-$ negative parity band, which gives the levels J = 1^-, 2^-, 3^-, ... This band is obtained by exciting a valence neutron from $p - f$ orbit to $g_{9/2}$ orbit (they lie at about 2.2 MeV). Experimentally a negative parity band has not been observed for ^{72}Ge. However some negative parity levels have been identified (at around 2.5 MeV).

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