

Triple-alpha studies using radioactive beam methods

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In this talk I will present results from studies of three-alpha breakup of ^{12}C using beta-decay and radioactive beam methods, and outline other nuclear astrophysics studies done in collaboration with the Chalmers group.

Superdeformation, exotic decays, and isospin symmetry in the mass A~60 region

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Largely extended experimental knowledge of a number of nuclei in the mass A~60 region, involving superdeformed structures, proton emission competing with gamma decay, and an expansion of the analysis concerning isospin breaking effects has been obtained from three experiments carried out at Oak Ridge National Laboratory and Argonne National Laboratory in the U.S.

The current work is based on fusion-evaporation reactions where the experimental set-ups comprised the Ge-array (CLARION/GAMMASPHERE) at the two laboratories. Using the mass separators (RMS/FMA) with the ionisation chambers allows for unambiguous assignments of gamma-rays to the different residual nuclei. In addition neutron and charged particle detectors around the target position were used for high-performance particle spectroscopy. The new Lund-Washington University Silicon Array (Lu-Wu-SiA), an eight telescope dE-E Si-detector segmented into 2048 pixels, aims at identifying and measuring angular distributions of discrete-energy particle decays.

New superdeformed rotational bands have been observed in ^{61}Cu and ^{61}Zn , resulting in considerably extended level schemes. In addition five excited states have been observed for the first time in the neutron-deficient isotope ^{61}Ga . This allows for an analysis of isospin symmetry via the ^{61}Ga (31 protons and 30 neutrons) and ^{61}Zn (30 protons and 31 neutrons) mirror pair in the upper fp shell. Moreover, there is indirect evidence for prompt proton decaying excited states in the ^{61}Ga nucleus.

Experimental results in the normally deformed region are compared with predictions from different sets of large-scale shell-model calculations. Isospin symmetry in the upper fp shell will be discussed. The superdeformed structures are compared with results from Cranked Nilsson Strutinsky calculations, to explore and improve the applicability of the Nilsson parameters in the A~60 region.

Sub-Barrier Coulomb Excitation of ^{110}Sn and First Results on $^{108,106}\text{Sn}$

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The advent of radioactive ion beams (RIBs) places exotic nuclei within reach of experimental study. In particular, RIBs enables a new investigation of the low energy structure of isotopes in the vicinity of the doubly magic ^{100}Sn nucleus. We present here the first results from a series of measurements of the reduced transition probability - the $B(E2)$ value - for the neutron deficient Sn-isotopes $^{110,108,106}\text{Sn}$ [1]. All three experiments were performed using sub-barrier Coulomb excitation at 2.8 MeV/u at REX-ISOLDE with the MINIBALL germanium detector array. This technique provides a measurement accuracy of $\sim 10\%$. The $B(E2)$ value can presently difficult to obtain using any other method, due to a high lying 6+ isomer present in the neutrondeficient even Sn isotopes.

Doubly-magic nuclei are of significant theoretical importance, since they provide a good testing ground for shell-model calculations. The Sn isotopic chain comprises nuclei between neutron numbers $N=82$ and $N=50$. Therefore it provides a unique opportunity to study the shell structure evolution as a function of the neutron degree of freedom. The spectroscopy of the low lying states in the even Sn isotopes have been explained within the generalized seniority scheme [2]. Large scale shell model calculations using a model space confining the neutrons to the *gds* orbitals support this picture [3]. Our recent experiments together with results from refs. [3,4] indicate a deviation from theoretical predictions manifested in a stronger than expected collectivity towards the proton dripline. This might imply that further core-polarization effects and a refined effective interaction are needed. One perhaps important effect recently discussed in refs. [5,6,7] is that of an enhanced attractive neutron-proton interaction in spin- isospin-flip vertices contained in the monopole part of the tensor force. Hence, with a decrease of neutrons in the orbital $0g_{7/2}$, the proton $0g_{9/2}$ becomes less bound, implying an increased core-excitation probability. Thus, this effect could compete with a reduction of the $B(E2)$ values originating in the decrease in neutron number. We will present the latest results and data analysis from $^{110,108,106}\text{Sn}$, and where they stand in comparison with present theoretical models.

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Discovery of the shape-isomer in ^{235}U

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The need to improve the knowledge about the double- or even triple-humped fission barrier initiated a systematic investigation of shape-isomeric decays in actinide nuclei. At present, the population and the principle decay mode in odd-A uranium isotopes is of particular interest for the improvement of nuclear reaction models. Neither of both is known today, and different half-life systematics give predictions ranging across up to five orders of magnitude. We report on the results of a recent experiment, where for the first time in odd-N nuclides a shape-isomer was discovered. The reaction $^{234}\text{U}(n, f)$ at neutron energies $E_n = 0,95$ and $1,27$ MeV was studied with the NEPTUNE (NEw Pulsed and TUneable Neutron source) isomer spectrometer of the EC-JRC IRMM. The population probability of the isomeric ground state in ^{235}U as well as the half-life for shape-isomeric fission was determined.

Studies of Light Unbound Nuclear Systems

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An experiment performed at SIS-FRS facility (GSI, Darmstadt, Germany) with relativistic beams of ^8He , ^{11}Li and ^{14}Be impinging on a liquid hydrogen target is described. The experimental setup, consisting of the neutron detector LAND, the dipole spectrometer ALADIN and different types of coordinate detectors, permits a reconstruction of momentum vectors of all reaction products in coincidence. The main goals of this experiment are twofold. First, the collected data give information on the structure of the drip-line nuclei ^8He , ^{11}Li , ^{14}Be and on the reaction mechanisms with these nuclei in the hydrogen target. The second task is studies of unbound, exotic nuclear systems, which appear via final state interactions between the different reaction products. The observed resonances are ^7He , ^9He , ^{10}He , ^{10}Li , ^{12}Li , ^{13}Li and ^{13}Be . The main focus of the talk will be devoted to a discussion of the results obtained for ^{12}Li and ^{13}Li , nuclei which were never observed in former experiments, and the physics interpretation of these data.

In-beam spectroscopy of ^{110}Xe : Structure of A~100 nuclei near the proton dripline.

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Gamma-ray transitions have been identified for the first time in the extremely neutron-deficient ($N = Z + 2$) nucleus ^{110}Xe and the energies of the three lowest excited states in the ground-state band have been deduced. The results establish a breaking of the normal trend of increasing first excited 2+ and 4+ level energies as a function of decreasing neutron number as the $N = 50$ major shell gap is approached for the neutron-deficient Xe isotopes. This unusual feature is suggested to be an effect of enhanced collectivity, possibly arising from isoscalar n-p interactions becoming increasingly important close to the $N = Z$ line.

Different approaches to nuclear wobbling motion

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Wobbling excitations was observed a few years ago in triaxial Lu isotopes at high spin. In the body-fixed reference frame of the nucleus this collective motion is associated with small amplitude fluctuations of the direction of the total spin. This type of motion will be described using two different models. The coupling of several particles to a triaxially deformed rotor core is used for a basic description which is compared with the use of the generator coordinate method (GCM). In the GCM approach the tilting angles in the tilted axis cranking model is used as generator coordinates.

η -production in proton-proton collisions at $Q=72$ MeV excess energy

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While it is generally agreed that the near-threshold production of η mesons in NN collisions is dominated by the $N^*(1535)$, there are different one-boson exchange models (e.g [1]) for how the N^* is excited. In order to discriminate between models, differential cross sections and polarization observables are needed. It is also unclear up to what excess energies s-wave production suffices to explain data. Although it has been shown that an isotropic angular distribution for the produced η mesons does not necessarily rule out higher partial waves, finding deviations from isotropy does imply that higher waves are involved in the production. Early measurements of $pp \rightarrow pp\eta$ at CELSIUS [2] found such an anisotropy in the η polar angle distribution, while the more recent data from COSY [3] do not. It would be interesting to find the reason for the discrepancy.

The reaction $pp \rightarrow pp\eta$ has been studied at $Q=74$ MeV excess energy with the WASA detector at CELSIUS [5]. The η meson was identified through its decay into two photons and all final state particles were detected. I will present preliminary results for the differential cross sections, including the pp and $p\eta$ invariant mass distributions, based on about $100 \cdot 10^3$ events. The $\cos \theta_{\eta}^*$ -distribution is found to be anisotropic, indicating the presence of higher partial waves.

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Rotating Bose condensates

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A rotating gas of ultra-cold bosons exhibits many fascinating phenomena due to superfluidity. Here we give a short introduction to quantized vortices in Bose systems, and then show some diagonalisation results for a repulsive two-component Bose gas. As this system acquires angular momentum, it will go through a number of interesting vortex phases. Furthermore, in the weakly-interacting limit, a number of quantities are given exactly by simple, analytical expressions, which is quite remarkable for a many-body quantum system.

Radon - A health hazard

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The Swedish Radiation Protection Authority (SSI) estimates that the yearly number of deaths, caused by radon, amounts to about 400 i.e. a number equally high as that of mortal casualties in the traffic. Presence of radon and radon decay products in homes, in schools and at work could cause lung cancer. It constitutes one of the greatest risks from ionizing radiation and is thus a serious health hazard.

The Subatomic physics group at Chalmers initiates a plan to establish a radon center in order to develop technology for and provide education and information to actors within the construction and housing markets, the public sector and all residents in flats and dwellings. The radon center should be based on two legs - a center of competence and a center for measurements - concentrating on the indoor environment in general and radon problems in particular.

The goal is to create a multidisciplinary cooperation for research, education, consultant and information activities related to health hazardous presence of radon in dwellings, schools, work places, public places and water. The plan is that the central part of the center should be a research school focusing on the indoor environment, especially the radon problem, and include about 5 research students and one professor. The research will be focused on methods for mapping presence of radon, health threats of radon, sanitation of radon in buildings and construction of radon free buildings. The research school should represent a broad interdisciplinary activity and should comprise disciplines like techniques for nuclear measurements, environmental medicine, geology, physics and techniques of construction of buildings, material techniques, legislation and economy issues related to indoor environment.

Status of the Cell Irradiation Facility at the Lund Nuclear Probe

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The CELLION project is directed towards the studies on cellular response to targeted single ions. Several institutions among Europe, within the CELLION network, are dedicated to develop single ion hit facilities (SIHF).

The sub-micron beam line at the Lund Nuclear Probe has been modified in order to create a Single Ion Hit Facility for biological applications. The system is a horizontal facility using a post cell detection system. A silicon detector is used during the irradiation procedure to detect the ions that have passed through the cells and to control the applied dose. The detector can be substituted, by an offline transmission microscope which, in addition to specialised software, is used to locate the cell position.

Currently, the Lund Nuclear Probe is under development in order to achieve cell target irradiation. However, non-targeted proton irradiation is performed routinely in living cells. The first biological results have been obtained in collaboration with the Bio Medical Centre in Lund, using proton irradiation to study oxidative effects in hepatoma cell line. A report of the system status and results will be presented.

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