$\eta \to \pi^+\pi^-\pi^0$ decay with WASA-at-COSY

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In 2008 and 2009 an experiment was carried out with WASA-at-COSY with the purpose of studying η- decays. The ηs were produced in the $pd \to {}^3He\,\eta$ reaction at beam kinetic energy 1 GeV and in total approximately $3 \cdot 10^7$ of such events were collected. This data will be used to study the not so rare η decays involving charged pions, like $\eta \to \pi^+\pi^-\pi^0$. This decay proceeds mainly via a strong isospin violating contribution, where the decay width is proportional to the quark mass difference squared, $(m_d - m_u)^2$. Preliminary results of the analysis are presented.
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Digital and analogue data acquisition system comparison in neutron-induced fission experiments

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September 9, 2010

Abstract

A comparison between modern digital data acquisition (DA) and conventional analogue data acquisition (AA) systems was performed particularly relevant in the field of neutron-induced fission and fission-fragment spectroscopy. Measurements were performed at the Institute for Reference Materials and Measurements (IRMM), in Geel, Belgium. Mono-energetic neutrons, produced with the 7MV Van De Graaff accelerator, were used to induce fission in ^{235}U and ^{234}U. The fission-fragment detection was performed with a Twin Frisch Grid Ionization Chamber (TFGIC). Parallel digital- and analogue data acquisition system were installed to compare results. The aim was to test the DA system and to verify result consistency with conventional AA systems. Digital signal processing (DSP) was established to simulate signal treatment algorithms implemented in analogue NIM modules. Results from both DA and AA in terms of angular-, energy- and mass resolution are in very good agreement for $^{235}\mathrm{U}(\mathrm{n_{thermal}},\mathrm{f})$. However, major advantages of the DA system are observed for the highly α-active ^{234}U sample. A noticeable α-particle pile-up is observed in both the analogue and digital raw data. During off-line analysis of the DA data an efficient pile-up correction was implemented via DSP, reducing the pile-up contribution without discarding the affected events. The energy resolution (peak-to-valley ratio) of the TFGIC in case of $^{234}\mathrm{U}\,(\mathrm{n},\mathrm{f})$ was significantly improved compared to the AA case. In addition, DA in conjunction with DSP expanded the flexibility in off-line analysis to achieve optimum signal treatment and reduced the number of electronic-modules drastically. DSP gave an increased stability against drifts of the electronic set-up during the experiment.

TASCA: Superheavy Elements at GSI in the 21st Century

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Studying superheavy elements (SHE), i.e. elements with a proton number larger or equal to ∼102 has become increasingly important over the past few decades. These studies aim to produce the experimental data needed to verify or discard the different theoretical models which predict magic numbers at the upper end of the nuclidic chart at very different proton and neutron numbers. One way to approach the structure of the SHE is by studying the K-isomers. If fully understood, these will provide information about the single-particle shell structure of SHE which in turn will relate to shells responsible for magic numbers at or around the anticipated 'island of stability' [1].

The "TransActinide Separator and Chemistry Apparatus" (TASCA) has been built and commissioned during the past five years at GSI, Germany. The separator [2] has been designed to optimise transmission and separation of the SHE and it was used in its first main beam experiment in 2009. The aim of this experiment was to verify the previously observed properties of element Z =114 from the Dubna Gas Filled Recoil Separator (DGFRS) [3]. For the experiment the so called high transmission mode of the separator was utilised and in the focal plane the brand new Focal Plane Detector Box (FPDB) was used [4,5]. Results from the experiment [5] involves decay properties of both ^{288,289}114.

In 2010 the separator was used in conjunction with a nuclear spectroscopy setup called TASISpec [6] (TAsca in Small Image mode Spectroscopy). This setup exploits the unique small image mode of the TASCA Separator. The produced SHE can be focused into an area of less than 3 cm in diameter providing the possibility to place composite Ge-detectors very closely around the focal plane. This results in a highly efficient detection of gamma-rays and X-rays in coincidence with implanted SHE and their decays. The TASISpec experiment aimed to disentangle the K-isomer decay scheme of ^{253}No. From previous studies [7] numerous question marks remain.

Results from the two experiments will be presented along with properties of the set-up and future plans.

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Hadron physics: an experimental overview

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The modern theory of strong interactions is Quantum Chromodynamics (QCD), the quantum field theory of quarks and gluons based on the non-abelian gauge group SU(3). It is part of the Standard Model of particle physics. QCD is well tested at high energies, where the strong coupling constant α_s becomes small and perturbation theory applies. In the low energy regime, however, QCD becomes a strongly coupled theory, many aspects of which are not understood.
One key problem of QCD is to understand its spectrum. Most observed states can be understood as conventional mesons (quark-antiquark) or baryons (three quarks). However the theory also predicts glueballs, states made entirely of the QCD gauge bosons, and also more exotic forms of matter, like multiquark states, molecules or hybrids composed of quarks and gluons. There are some indications for the existence of such states in the light quark sector, but the overall picture remains puzzling.

In this talk I will present an overview of the experimental status of hadron spectroscopy, pointing out the open questions and how they will be addressed by future experimental facilities.

Measurement of Emission of Hydrogen- and Helium-Isotopes from Iron and Bismuth Induced by Intermediate Energy Neutrons

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Abstract

We have measured double differential cross sections (DDX) for emission of hydrogen- and helium-isotopes in the interaction of 175 MeV quasi-monoenergetic neutrons with Fe and Bi using the Medley setup, a spectrometer system installed at the The Svedberg Laboratory (Uppsala, Sweden). Medley offers well defined particle identification with low-energy thresholds, over a wide dynamic range. Energy spectra were measured at eight laboratory angles. The time-of-flight was used to reduce the contribution from the low energy tail in the accepted incident neutron spectrum. The experimental data presented in this work will provide benchmark points for state-of-the-art theoretical models, helping to produce reliable evaluated data, to verify new phenomenological optical model potentials, to ensure a good link between low and high energy processes.

We compared experimental DDX with exciton model calculations and Kalbach systematics using the TALYS code; these fail to reproduce the emission of complex light ions, generally overestimating it. We show that the Kalbach phenomenological model needs to be revised for energies above 90 MeV. We have also compared our data with quantum molecular dynamics (QMD) calculations.

I will present and discuss these results.

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Memory effect reduction in radioxenon detection systems used for Nuclear-Test-Ban Treaty verification

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The Comprehensive Nuclear-Test-Ban Treaty (CTBT) bans all nuclear explosions. In order to verify its compliance a worldwide network of measurement facilities, the International Monitoring System (IMS) is currently being set up. The IMS is designed to measure the two basic phenomena caused by a nuclear explosion; energy release and radionuclide production.

A key technology used to verify the nuclear nature of an underground explosion is the detection of radioactive xenon. In an underground explosion most of the produced radioactivity will remain in the cavity. However about 15% of the fission products come in the form of noble gases (in particular xenon), which due to their inert chemical properties can reach the surface and allow for detection.

The Swedish Automatic Unit for Noble Gas Acquisition (SAUNA) is one of the radioxenon detection systems used within the IMS. SAUNA collects air, extracts a xenon sample and measures the activity of interesting radioxenon isotopes using a NaI(Tl) plastic scintillator beta-gamma coincidence detector. The main drawback with the current setup of the system is that during the measurement xenon tends to diffuse into the plastic scintillator causing an unwanted memory effect.

One approach to remove or reduce this memory effect is to coat the plastic scintillator surfaces exposed to the radioxenon sample. The coating material should be able to stop xenon diffusion without significantly impairing detector properties such as efficiency and resolution.

Two candidate materials are explored: Al2O3 deposited using Atomic Layer Deposition, and SiO2 deposited with Plasma Enhanced Chemical Vapour Deposition. These materials are deposited onto plastic scintillators and tested with respect to their ability of stopping xenon diffusion. The work is done in collaboration between Uppsala University, the Swedish Defence Research Agency (FOI) and University of Texas at Austin.

The presentation will describe the SAUNA system, its place in the IMS and the work in progress to reduce the memory effect.

Convergence properties of density-matrix expansions

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Present density functional theory (DFT) models of atomic nuclei are able to describe nuclear binding energies with a quite impressive accuracy of roughly 0.3 % for light and 0.1 % for heavy nuclei. However, for the description of excited states, present models appears to have a limited precision of ≈ 1 MeV which indicates a need to explore more flexible forms with better spectroscopic qualities.

In this context we have proposed a new density functional obtained as a quasi-local expansion in derivatives and restricted by the symmetries of the nuclear force [1]. The usual nuclear Skyrme DFT model is obtained as a second order expansion while we keep terms up to sixth order (see Fig. 1) allowing for a better description of the effects of the long range part of the nuclear force.

The resulting self-consistent mean-field equations as well as the linear-response equations can be derived straightforwardly in a systematic way and solved using computer codes [2]. A new and fast iterative method is used to solve the linear-response equations utilizing fields only and hence without explicitly constructing the huge RPA matrix [3].

Starting from an effective interaction all the parameters in the proposed functional can be derived by requiring it to be an approximation of the exact Hartree and Fock terms. We have performed such derivations employing different density-matrix-expansion (DME) methods starting from the effective nuclear Gogny interaction. We propose a new type of DME and demonstrate that because of the short range of the nuclear force the expansion into a quasi-local DFT functional is convergent and give good accuracy while being much faster to use than the full exchange term [4].

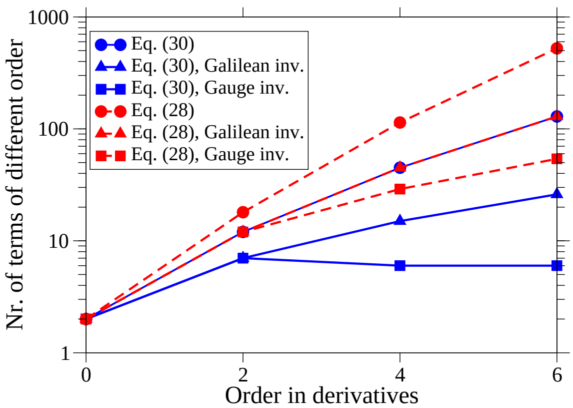

FIG. 1: Numbers of terms in the proposed DFT functional with density dependent and density independent coupling constants, Eqs. (28) and (30) of [1], respectively, plotted in logarithmic scale as a function of the order in derivatives (Figure taken from [1]).

Extending the nuclear Skyrme DFT model with more gradient terms opens up the possibility to model more physical effects such as the variation of the nucleons effective masses. Because of the speed and simplicity, these methods constitute a first step towards obtaining a universal energy density functional which is able to give accurate descriptions of low-energy observables for heavy nuclei.

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Deviations of alpha decay half-lives from the Geiger-Nuttall law as a manifestation of nuclear structure effects

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The importance of a proper treatment of α formation probability in α decay studies was attested by a recent calculation where one obtained a generalization of the Geiger-Nuttall law which holds for all isotopic chains and all cluster radioactivities [1,2]. In this universal decay law (UDL) the penetrability is still a dominant quantity. By using three free parameters only, one finds that all known ground-state to ground-state radioactive decays are explained rather well. This good agreement is a consequence of the smooth transition in the nuclear structure that is often found when going from a nucleus to its neighboring nuclei.

In this work we will show that, when a sudden transition occurs in a given chain of nuclei, departures from the UDL can be seen [3]. Perhaps even more important is that for most cases the UDL predicts the experimental values within a factor of three, except for $N = 126$, where the difference becomes about one order of magnitude. The difference is explained as a sudden hindrance of the clustering of the nucleons that eventually form the α particle. This is because the clustering induced by the pairing mode acting upon the four nucleons is inhibited if the configuration space does not allow a proper manifestation of the pairing collectivity.

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IDENTIFICATION OF EXCITED STATES IN THE N = Z NUCLEUS ^{92}Pd: EVIDENCE FOR A SPIN-ALIGNED NEUTRON-PROTON COUPLING SCHEME

F. Ghazi Moradi

Gamma-ray transitions have been identified for the first time in the N=Z nucleus ^{92}Pd and the energies of the lowest excited states have been deduced. The experiment was performed at the Grand Accelerateur National d'Ions Lourds (GANIL) using the ^{58}Ni(^{36}Ar,2n)^{92}Pd heavy-ion fusion-evaporation reaction at a beam energy of 111 MeV. Charged particles, neutrons and gamma rays emitted in the reactions were detected by the DIAMANT CsI charged particle detector system, the NEUTRON WALL liquid scintillator detector array and the EXOGAM Ge detector array. The results are in agreement with theoretical predictions of a "phase transition" from the normal isovector pairing and seniority scheme to a spin-aligned neutron-proton coupling scheme at N = Z.

MACRO – a methodology for handling nuclear data uncertainties

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ABSTRACT

MACRO— massive computation methodology for reactor operation – is a newly started project at the department of physics and astronomy at Uppsala University. It addresses the problem that uncertainties from nuclear data are not handled in a consistent manner in the nuclear data libraries. Since the nuclear data libraries are input to various application codes, the output from these codes have unknown uncertainties, and so do macroscopic parameters which are calculated from the codes.

A method called TMC – total Monte Carlo – has been proposed by Koning and Rochman [1] to investigate the propagation of nuclear data uncertainties into reactor physics codes and macroscopic parameters. In this method, the uncertainties in nuclear model parameters will be derived from theoretical considerations and comparisons of nuclear model results with experimental cross-section data. Given the probability distribution in the model parameters, a large set of random, complete ENDF-formatted nuclear data libraries will be created using the TALYS code. The generated nuclear data libraries will then be used in neutron transport codes to obtain macroscopic reactor parameters with correct uncertainties.

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Fission of Relativistic Radioactive Beams

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While nuclear fission is a very well-studied reaction, the advent of radioactive beams and the experimental opportunities of current and future experimental facilities open the way to new and exciting studies aiming at the dynamics of nuclear matter over a wide range of energies. Fully-identified projectile fragments at relativistic energies allow, for the first time, to study the impact of the isospin degree of freedom in a systematic way. For fission at low excitation energies this is important in order to understand the influence of the underlying nuclear shell structure on the reaction dynamics. At high excitation energies diffusion and friction-like processes have a strong impact on the time scale of nuclear fission. The advantages and disadvantages of first experiments using this approach will be discussed and results are compared to experimental approaches from literature. Future fission studies will benefit from the exclusive experiments that the new R^3B set-up and FAIR will provide. It will be discussed how future experiments can yield results which are not only relevant for the understanding of nuclear fission at different energies but also for fields ranging from nuclear astrophysics, the formation of super-heavy nuclei and production rates of neutron-rich radioactive beams.

This work has been supported by HIC for FAIR.

Confessions of a Nuclear Data Junkie

Mattias Lantz
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This is a complete confession of my abuse related to collecting experimental nuclear data of total reaction cross sections and related observables. The status of my abuse, and positive and negative effects from it, will be discussed. Furthermore, the program that I am following in order to become free from my abuse will be discussed.

Towards an Effective Field Theory for Vector Mesons

Stefan Leupold
Department of Physics and Astronomy, Uppsala University

I will start with a brief introduction to QCD and to the concept of effective field theories. Recently such an effective field theory has been proposed for systems where light vector and pseudoscalar mesons are the active degrees of freedom. I will mainly focus on the results of this scheme for leading-order calculations of various vector-meson decays.

Tardigrades – small, slow and survive radiation

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Abstract

Most people know that we, humans, are rather radiation-sensitive (the lethal dose for humans is a few Gy) and some of us may share the common belief that cockroaches, or perhaps fruit flies, would inherit the Earth after a nuclear war. We are, however, surrounded by a species that is far more radiation tolerant than cockroaches as well as fruit flies.

The tardigrade (also known as water bear or moss piglet) is a millimeter-sized, eight-legged creature with sensational survival skills which populates practically all habitats on Earth and can be revived after many years of playing dead. Very little is known about why tardigrades are so tolerant to hostile environments in general and to ionizing radiation (the lethal dose for tardigrades is a few thousand Gy) in particular.

In this talk will be presented a number of radiation studies, including a spectacular space odyssey, conducted on tardigrades. In addition, possible explanations to their extreme radiation tolerance and what we can learn from them will be discussed.

Effective Field Theories for Few- and Many-Body Systems

Lucas Platter
INT Seattle, USA

Effective field theories (EFTs) should in principle provide a systematic way to improve the description of systems that display a separation of scales. In nuclear systems this scale separation is set by the inverse scattering length, the pion mass and the natural scale set by quantum chromodynamics. The EFT approach is then to form ratios of these separated scales and to exploit them as small expansion parameters. I will discuss recent progress in the application of the EFT approach to few- and many-body physics. I will give examples from the so-called pionless and chiral EFTs, will address the relation to system of ultracold atoms and will briefly lay out how density functional theory might be used to extend the current reach of the EFT approach.

GENIUS –Generation IV research in the Universities of Sweden

Many developed countries today see nuclear power as an important part of their future energy mix. To improve fuel supply and waste management, the so called Generation IV systems are under development. These systems would offer sustainability in terms of breeding fissile fuel from ^{238}U or ^{232}Th, hence increasing fuel resources by two orders of magnitude. They would also be able to reuse plutonium and minor actinides from spent nuclear fuel, in this case reducing the long-term radiotoxic inventory directed to geological disposal by two orders of magnitude.

While safe design and operation of such reactors is a prerequisite for licensing, their economical competitiveness will, to a large extent, depend on development of new structural and fuel materials and the associated recycling technology. In addition, more refined methods for monitoring and prediction of performance during nominal as well as transient conditions will allow operating them with safety margins that even exceeds those of today's reactor technology.

In the GENIUS project, a national research programme is defined which will contribute significantly to advance the science and technology relevant for the Generation IV systems planned to be demonstrated in Europe.

Measurement of fragment mass yields in neutron-induced fission of ^{232}Th and ^{238}U at 33, 45 and 60 MeV

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J.P. Meulders, R. Prieels

Incineration of spent nuclear fuel in Accelerator-Driven Systems requires nuclear data on neutron-induced fission of actinides at energies above 20 MeV – the upper limit of conventional evaluated nuclear data files. Over the past years, a significant effort has been devoted to measurements of neutron-induced fission cross-sections at intermediate energies but there is a lack of experimental data on fission yields. Here we describe recent measurements of pre-neutron emission fragment mass distributions from intermediate energy neutron-induced fission of ^{232}Th and ^{238}U.

The measurements have been carried out at the neutron beam of the Louvain-la-Neuve neutron beam cyclotron facility CYCLONE. Quasi-monoenergetic neutrons with the peak energies 32.8, 45.3 and 59.9 MeV were produced by protons impinging on a thin lithium target. A multi-section Frisch-gridded ionization chamber was used as a fission fragment detector. The measurement results are compared with available experimental data as well as with predictions of the multi-modal random neck-rupture model implemented into the TALYS code. Some modifications of the TALYS code to reduce deviations from the experimental data on both neutron-induced fission cross sections and fragment mass yields are discussed.

Electromagnetic transition form factors for light vector and pseudoscalar mesons

CARLA TERSCHLUESEN AND STEFAN LEUPOLD, Department of Physics and Astronomy, Uppsala University

In [1,2], an effective field theory was proposed in which light pseudoscalar and vector mesons are treated on equal footing. Within the framework of that theory, we calculate Dalitz decays of ω-, ϕ-, π^0-, η- and η'-mesons and the corresponding form factors in leading order. For the $\omega \to \pi^0$ form factor, data were taken by the NA60 collaboration [3]. Our approach describes these data much better than the standard-vector-meson-dominance model. Furthermore, the decay widths for the processes ω-meson into dilepton and pion, ϕ-meson into dielectron and η-meson and pseudoscalar meson into dilepton and real photon agree well with the experimental data. Besides, decay widths and form factors for the decays of ω-meson into dilepton and η-meson and of ϕ-meson into dimuon and η-meson are predicted [4].

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Tilted foils polarization at REX-ISOLDE

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ISOLDE, CERN

Spin polarized nuclei can be used as sensitive probes to explore nuclear and atomic structures. Methods commonly used for achieving nuclear spin polarization, such as optical pumping and low temperature orientation, typically provide high degrees of polarization but impose severe restrictions in the type of nuclei that can be polarized. Tilted foils are a relatively non invasive device in a beam line and can be used to polarize the spin of a wide range of nuclei even with very short life times. Experiments using this technique were carried out in the 80s and 90s at various institutes over the world, even at REX ISOLDE with physics results. The aim of this project is to evaluate the possibilities of systematically producing polarized beams of various exotic nuclei for the nuclear and solid state research communities in affiliation with ISOLDE. This includes not only the production of polarization but also the equipment and methods required for reliable measurements. The project is a work in progress.

Stroke asymmetry of tilted superhydrophobic ion track textures

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Abstract: The stroke asymmetry of contact angles of water drops on tilted hydrophobic textures is demonstrated, obtained by ion track etching followed by a hydrophobic treatment. Preliminary trends concerning the advancing and receding contact angles are established, each with and against stroke direction. In rough agreement with Cassie-Baxter theory, the cosines of these four contact angles depend linearly on the wetted area fraction. The etched tracks are randomly distributed on the surface of polycarbonate disks and inclined by 30° with respect to the surface, whereby the aspect ratio of individual etched cones is larger than 10. The morphology of the resulting surface is characterized by randomly shaped flat tops overhanging on one side and gradually falling off on the other side. The area fraction of the supporting tops can be calculated from the number of impinging ions per unit area and the cross section of the etched ion tracks. The top layer of the texture consists of flat, horizontal, irregularly shaped tops supporting water drops in the Cassie-Baxter state. With increasing etching time, the texture becomes increasingly clefted. To fabricate the textures, we irradiated polycarbonate with 5×10^7 $^{80}Br^{7+}$ions/cm^2 of 30 MeV total energy, having a range of about 20 µm in polycarbonate at a tilt angle of 30° with respect to the sample surface and etched the latent ion tracks selectively. See fig. 1. The textured surface is made hydrophobic by carbondifluoride radicals (CF_2) resulting from the decay of octafluoro- cyclobutane, C_4F_8, in a plasma reactor. The goal of the report is to show that the tilt orientation of a superhy- drophobic surface leads to advancing and receding contact angles depending on the orientation with and against the stroke direction.

Keywords: Ion tracks, etching, superhydrophobic surface, surface texture, tilted microtexture.

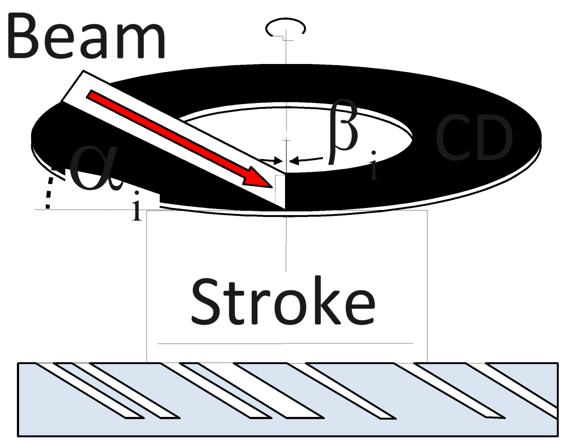

Fig. 1. Definition of irradiation angle α_i and stroke direction of the texture resulting from selective ion track etching. For α_i < 90° the stroke direction of the etched shingle structure will be clockwise, i.e. generate less friction when sweeping with a soft tissue or brush clockwise over its surface. The beam hits the sector β_i of the rotating CD.