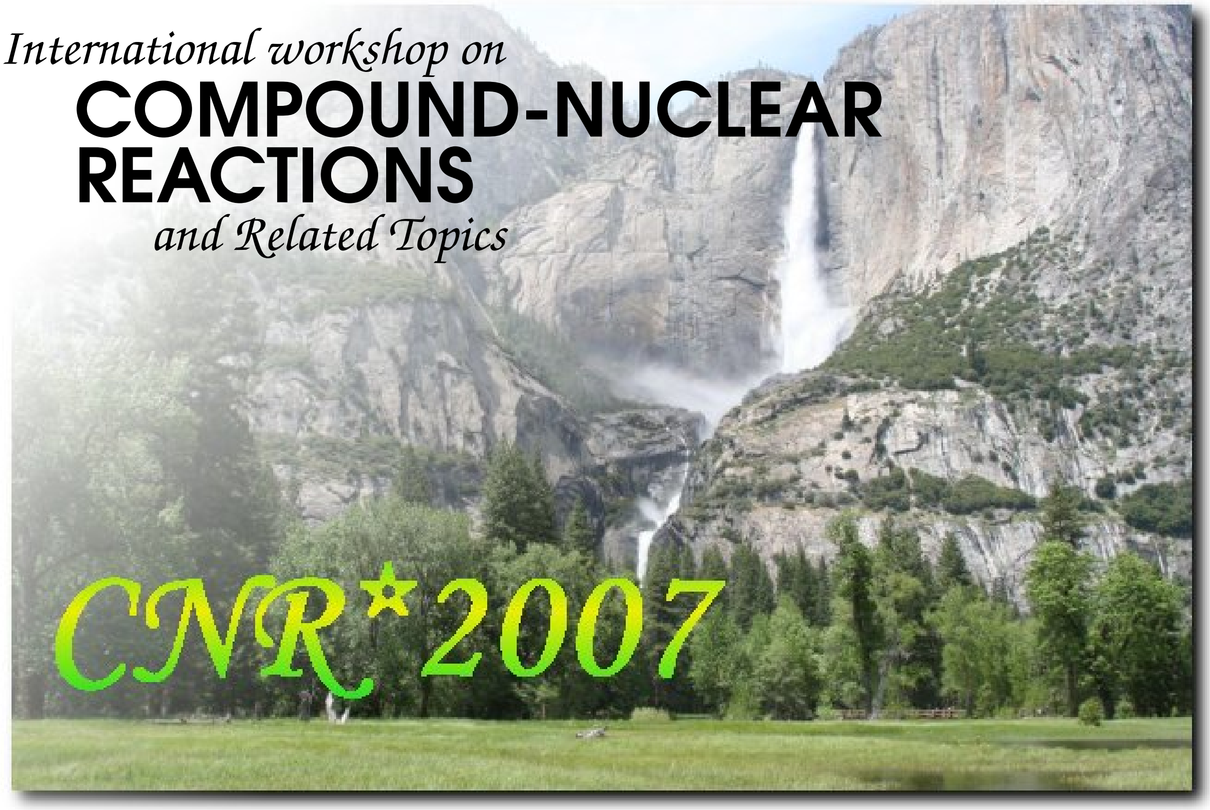

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ABSTRACTS

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The experimental study of gamma-ray decay patterns using DANCE

Undraa Agvaanluvsan

LLNL

Historically, the spectrum fitting method (where the experimental total gamma-ray energy spectrum is compared with the simulated spectrum) has been widely utilized to obtain the nuclear level density and the gamma-ray strength function. Although a great deal about the level density and the gamma-ray strength function can be learned, the difficulty is that because all multipolarities and types of gamma-emission are summed together the detailed features are obscured. The advent of the highly segmented, sophisticated calorimeter Detector for Advanced Neutron Capture Experiment (DANCE) at Los Alamos National Laboratory provides a new, experimental way to obtain the gamma-ray energy spectrum separately for each multiplicity. This is a powerful, experimental tool to test simultaneously all multiplicities as a function of gamma-ray energy. Moreover, such tests are useful for studying the excitation energy region below the neutron separation where a lack of data exists. I will present the multiplicity 2-4 spectral shapes obtained using the DANCE array for several Eu, Gd, U, Am isotopes and attempt to establish the pattern as a function of spin and deformation. I shall briefly discuss how we learn about the gamma-ray strength function from these spectra.

Level densities in the shell model Monte Carlo method: from medium-mass to heavy deformed nuclei

Yoram Alhassid

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Experimental level densities can be well described by empirical modifications of the Fermi gas model to take into account correlation and shell effects. However, such a description requires fits to the data and lacks a predictive power.

The shell model Monte Carlo (SMMC) approach is a powerful state-of-the-art method for the microscopic calculation of level densities in the presence of correlations. With this method it is possible to perform realistic calculations in model spaces that are many orders of magnitude larger than spaces that can be treated with conventional diagonalization methods. SMMC level densities of medium-mass nuclei ($A \sim 50-70$) were found to be in remarkably good agreement with experimental level densities without any adjustable parameters.

In recent years, there have been several major developments:

(i) The shell model theory of level statistics was extended to higher temperatures (including continuum effects).

(ii) Spin and parity projection methods were introduced to calculate the spin and parity distributions of level densities.

(iii) Applications to heavy nuclei have been a major challenge. On the conceptual level, an important question is whether a spherical shell model Hamiltonian (in a truncated space) is capable of describing the rotational properties of deformed nuclei. On the technical level, the low excitation energies make it necessary to perform calculations down to much lower temperatures. The SMMC level density and the moment of inertia of the ground-state rotational band were recently calculated for a well-deformed heavy nucleus (^{162}Dy) and found to be in excellent agreement with the experiments.

Kawai-Kerman-McVoy Statistical Theory of Nuclear Reactions

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Kawai-Kerman-McVoy (KKM) statistical theory of nuclear reactions is outlined. Some basic statistical assumptions and results of KKM are investigated numerically. Application of KKM to surrogate reaction method is discussed.

Determining the ^{237}Np(n,f) reaction cross section indirectly: Study of the absolute surrogate method in the 10 to 20 MeV energy range

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We have determined the ^{237}Np(n,f) cross section over an equivalent neutron energy range from 10 to 20 MeV indirectly using the surrogate reaction ^{238}U(^{3}He,t)^{238}Np. A self-supported $\sim$761 μg/cm^2 metallic ^{238}U foil was bombarded with a 42 MeV ^{3}He^{2+} beam from the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL). Outgoing charged particles and fission fragments were identified using the

Silicon Telescope Array for Reaction Studies (STARS) consisted of two 140 micro-m and one 1000 micro-m Micron S2 type silicon detectors. We have compared the results of this work with direct measurements of the ^{237}Np(n,f) cross section data, Evaluated Nuclear Data File (ENDF/B-VII.0), and Japanese Evaluated Nuclear Data Library (JENDL-3.3). The cross section data of this work follow the same trend with a maximum discrepancy of 5% higher value when compared with the ENDF/B-VII.0 dataset in the 10 to 18 MeV energy range. Starting from 18 MeV, a downward trend with respect to other datasets is observed. It appears that the downward trend is the result of additional tritons in the single triton spectrum, produced from the interaction of ^{3}He^{2+} beam with the contaminant elements, like oxygen and carbon, in the target material.

Testing the Absolute Surrogate Method via ^{157}Gd(^{3}He,α)

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Neutron cross sections on unstable nuclei are difficult, if not impossible to measure directly. Indirect methods, such as the absolute surrogate method, may therefore be used to determine neutron cross-sections using charged particle reactions on stable nuclei. By measuring exit channel probabilities on equivalent compound nuclei, combined with calculated neutron-induced compound nucleus formation cross sections from optical models, (n,xnγ) cross sections can be determined. This study is the first attempt using STARS-LiBerACE at LBNL's 88-inch Cyclotron to test the absolute surrogate method using gamma rays to determine (n,γ) and (n,2n) cross sections.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and by Lawrence Berkeley National Laboratory under Contract No. DE-AC02-05CH11231.

Surrogate Reactions in the Actinide Region

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Over the past three years we have studied various surrogate reactions (d,p), (^{3}He,t), (α,α'), (^{18}O,^{16}O) on several uranium isotopes ^{234}U, ^{235}U, ^{236}U, and ^{238}U. In this talk I will provide an overview of the STARS/LIBERACE surrogate research program as it pertains to the actinides. A summary of results to date will be presented along with a discussion of experimental difficulties encountered in surrogate experiments. Our future experimental program plans will be outlined as well as our major upgrade to full digital electronics for our silicon and gamma ray detector systems.

Use of NIF in Nuclear Astrophysics: Examples of Experiments

Richard N. Boyd

LLNL

this talk will describe some of the basic features of the National Ignition Facility, as well as the conditions that are expected to be generated by it. It will also describe some of the general science that is to be expected from NIF. Finally, it will describe some of the needs of the nuclear astrophysical data base that might be addressed with NIF, most of which include compound nuclear states, and the unique ability of NIF to satisfy these needs.

Effect of pre-equilibrium spin distribution on neutron induced reaction cross sections

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Abstract: Cross section measurements were made of prompt gamma-ray production as a function of neutron energy using the germanium array for neutron induced excitations (GEANIE) at LANSCE. Measuring the prompt reaction gamma rays as a function of incident neutron energy provides more precise understanding of the spins populated by the pre-equilibrium

reaction. The effect of the spin distribution in pre-equilibrium reactions has been investigated using the GNASH reaction code. Widely used classical theories such as the exciton model usually assume that the spin distribution of the pre-equilibrium reaction is the same as the spin distribution of the compound nucleus reaction mechanism. In the present approach, the pre-equilibrium reaction spin distribution was calculated using the quantum mechanical theory of Feshbach, Kerman, and Koonin (FKK). This pre-equilibrium spin distribution was incorporated into the GNASH code and the gamma-ray production cross sections were calculated and compared with experimental data. Spin distributions peak at lower spin when calculated with the FKK formulation than with the Compound Nuclear theory. The measured partial gamma-ray cross sections reflect this spin difference. Realistic treatment of the spin distribution improves the accuracy of calculations of gamma-ray production cross sections.

Progress and challenges in theory of nuclei

David J. Dean

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I will discuss recent progress in theoretical and computational developments focused on understanding nuclei and their reactions. Computational capabilities are paving the way toward a quantitative and predictive understanding of nuclei where theoretical error bars can be assessed.

Compound-nucleus Formation Following Direct Interactions to Highly-excited Final States

Frank S. Dietrich

Lawrence Livermore National Laboratory

Following its formation by a direct interaction, a residual nucleus is typically excited with very few degrees of freedom. If this residual nucleus is formed at sufficiently high excitation energies, the system may evolve into a fully equilibrated compound nucleus through further interactions. Alternatively, the system may avoid this path by decaying into the continuum. The distinction between these processes is critical for the interpretation of surrogate nuclear reaction experiments, since in the analysis of these experiments it is assumed that a compound nucleus is invariably formed after the direct interaction. If this assumption fails, it is important to calculate the appropriate correction factors; i.e., the probability of compound nucleus formation as a function of spin and parity. Typical decay processes that may invalidate the compound-nucleus assumption will be described. Particular attention will be paid to the further development of a residual nucleus following a (d,p) reaction, which probably represents the worst case since the deposited neutron, which will typically be unbound, can simply leak into the continuum. To show what may be expected, we will show numerical results for the compound formation probability in a closely-related process, the (n,γ) reaction, in which the neutron is deposited into the highly-excited residual system by radiative capture. This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Detection of long fission times of super-heavy compound nuclei

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The existence of Super Heavy Elements (SHEs) is linked to the stability brought by the shell effects that increase their fission barrier. Models predict islands of stability for $N = 184$ and Z from 114 to 126. SHE are synthesized as residues of fusion-evaporation reactions with cross sections around 1 picobarn or less above $Z = 110$, making their direct study almost impossible. Nevertheless, it is possible to study the compound nucleus (CN) instead of the scarcely surviving evaporation residues: the fission time distribution of the CN is highly sensitive to the height of the fission barrier.

The fusion of the two colliding nuclei above the fusion barrier leads to the formation of an excited CN. The shell effects are expected to be washed away due to the CN temperature, but neutron evaporation can quickly cool the CN before fission and should partly restore the shell effects. It should increase the CN stability against fission and thus its lifetime. Therefore, the long fission times of the CN are a signature of strong shell effects.

The Blocking technique in single crystals is a direct method to investigate such mechanisms. With uranium and lead beams impinging on nickel and germanium single crystals, we tried to produce CNs with $Z = 114$, 120 and 124 at high excitation energy ($E^* \sim 70$ MeV). Blocking patterns for reaction products are reconstructed with position sensitive detectors at 20°. The Z and energies of all the products are measured with the ΔE-E telescopes of the 4π Indra array, so that all reaction channels are unambiguously identified. With this set-up, we can reach long fission times ($> 10^{-18}$s) that can be associated with the super-heavy CN fissions. We will discuss the results showing a significant proportion of such long fission times for Z=120 and 124, an indication of strong shell effects for these elements.

Fission fragment properties from a microscopic approach

Noël Dubray

CEA/DAM/DPTA/SPN

The constrained Hartree-Fock-Bogoliubov method is used with the Gogny interaction D1S to calculate potential energy surfaces of fissioning nuclei ^{226}Th and ^{256,258,260}Fm up to very large deformations. The constraints employed are the mass quadrupole and octupole moments. In this subspace of collective coordinates, many scission configurations are identified ranging from symmetric to highly asymmetric fragmentations. Corresponding fragment properties at scission are derived yielding fragment deformations, deformation energies, energy partitioning, neutron binding energies at scission, neutron multiplicities, charge polarization and total fragment kinetic energies.

Microscopic calculation of the multistep direct (MSD) process for nucleon scattering on deformed nuclei

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In the perspective of reducing the phenomenological input in neutron induced reaction cross-section evaluations, more microscopic and quantum mechanical calculations for the direct and pre-equilibrium processes are performed in the case of inelastic neutron scattering from deformed nuclei. This is in particular interest for actinides for which reliable input parameters are necessary to perform predictive compound reactions calculations. We will show our results for neutron inelastic scattering between 10 and 20 MeV of incident energy. Cross-section calculations are performed within a DWBA framework. The ground and excited states of the target nuclei are described with an axial Hartree-Fock and Hartree-Fock+BCS models, which use the Skm* interaction. These wave functions are projected on a spherical basis, which allows us to use the DWBA98 spherical code in a parallelized version. The transitions between the ground state and the excited states are generated by an effective two-body interaction. As we focus on parameter free calculations, we use the well-known M3Y-Paris two-body interaction which has been adjusted to reproduce NN scattering data. This interaction includes central, spin-orbit and tensor components which, as we will show, are necessary to obtain reliable prediction of the MSD cross-section. To ensure that the quality of our results does not excessively depend on the choice of the effective interaction, we have performed the same calculations with different interactions: a variant of the M3Y interaction developed recently (CDM3Yn) and the Gogny D1S interaction.

This microscopic approach allows us not only to obtain predictions for the double-differential cross-section corresponding to the MSD process but also give the excitation energy, spin and parity distributions of the residual nucleus. Since these distributions could be use as input quantities for the calculation of the evaporation process, we will be able to consider a consistent calculation of both the MSD process and the decay of the compound nucleus.

Compound-Nuclear Reaction Cross Sections from Surrogate Measurements – a Theorist's Perspective

Jutta Escher

Lawrence Livermore National Laboratory

Reaction cross sections play a crucial role in many areas of basic and applied nuclear science. In situations where it becomes difficult to impossible to produce the beam-target combination required for measuring a desired cross section directly, one has to resort to indirect approaches. The Surrogate reaction method is such an indirect approach. It allows one to determine compound-nuclear reaction cross sections via a combination of theory and experiment.

This presentation will give a brief outline of the Surrogate approach and the challenges involved in carrying out a complete Surrogate treatment. Most Surrogate experiments to date have employed approximations to determine cross sections for neutron-induced fission. The assumptions underlying the experimental work carried out so far will be detailed and calculations that test the validity of the approximations used will be presented. Prospects for employing the Surrogate method to obtain neutron-capture cross sections will be discussed.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

New Methods for the Determination of Total Radiative Thermal Neutron Capture Cross Sections

Richard B. Firestone

Lawrence Berkeley National Laboratory

Precise gamma-ray thermal neutron capture cross sections have been measured at the Budapest Reactor for all elements with Z=1-83,92 except for He and Pm. These measurements and additional data from the literature been compiled to generate the Evaluated Gamma-ray Activation File (EGAF), which is disseminated by LBNL and the IAEA. These data are nearly complete for most isotopes with Z¡20 so the total radiative thermal neutron capture cross sections can be determined directly from the decay scheme. For light isotopes agreement with the recommended values [1] is generally satisfactory although large discrepancies exist for ^{11}B, ^{12,13}C, ^{15}N, ^{28,30}Si, ^{34}S, ^{37}Cl, and ^{40,41}K. Neutron capture decay data for heavier isotopes are typically incomplete due to the contribution of unresolved continuum transitions so only partial radiative thermal neutron capture cross sections can be determined. The contribution of the continuum to the neutron capture decay scheme arises from a large number of unresolved levels and transitions and can be calculated by assuming that the fluctuations in level densities and transition probabilities are statistical. We have calculated the continuum contribution to neutron capture decay for the palladium isotopes with the Monte Carlo code DICEBOX [2]. These calculations were normalized to the experimental cross sections deexciting low excitation levels to determine the total radiative thermal neutron capture cross section. The resulting palladium cross sections values were determined with a precision comparable to the recommended values [1] even when only one gamma-ray cross section was measured. The calculated and experimental level feedings could also be compared to determine spin and parity assignments for low-lying levels.

[1] S.F. Mughabghab, Atlas of Neutron Resonances, Fifth Edition (Elsevier, New York, 2006)
[2] F. Becvar, Nucl. Instr. Meth. A417, 434 (1998)

Fusion evaporation reactions as a tool for light nuclei gamma spectroscopy

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Gamma spectroscopy of fusion evaporation residues is widely used as a tool to study nuclear structure. While fusion reactions have been studied extensively for medium mass and heavy nuclei, its use for light nuclei is no well studied and weak decay channels in (very) light nuclei can lead to the study of rather exotic species. Recent experiments at the Lawrence Berkeley National Laboratory 88" Cyclotron, based on a clean detection of the 2 protons evaporation channel, demonstrates the need of improved understanding of the reaction mechanism as well as a good prediction of the different decay channels. While many of the available fusion-evaporation codes give good results for the dominant decay channels discrepancies exist for the weaker channels. We gather here results of different experiments designed primarily to find some of these weak channels of interest and we compare them with various model calculations.

Resonance reactions with light unstable nuclei by Thick Target Inverse Kinematics method

V. Z. Goldberg

Texas A&M University, Cyclotron Institute, USA
RRC "Kurchatov Institute" Moscow, Russia

The talk will be made by the person, who pioneered the method to study compound nucleus resonances in 1990.

At present one can evidence a renaissance of the studies of resonance reactions. It is related with studies of the resonance reactions with unstable nuclei by the TTIK method. These studies are motivated by interest in the stellar processes involving interaction of radioactive nuclei with helium or hydrogen as well as by interest in the exotic structure of the drip line nuclei.

In my talk, different experiments on the resonance interactions of light radioactive nuclei with protons or α particles will be considered. Due to large available material, I'll focus on very recent or even still unpublished works, and I'll consider mainly the nuclear physics aspects. I'll also consider some experimental details to demonstrate a "poison" in the approach. In particular, I'll consider the first application of the TTIK technique to the compound reactions with three particles in the final state, and to astrophysical important case of (α,p) reactions on radioactive nuclei

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Nuclear Level Densities Off of the Stability Line

S.M. Grimes, T.N. Massey, M. Oginni, S. Shukla and A. Voinov

Ohio University

Nuclear level densities are usually interpreted in terms of the Fermi gas (Bethe) model. This model produces level densities in general which agree with data on or near the stability line.

For proton- or neutron-rich nuclei, relatively little experimental data is available. At least one recent paper has found evidence that for nuclei with fixed A, there is a reduction in a for nuclei off of the stability line.

Currently, an effort is underway to provide further information on this question at Ohio University. An experimental investigation of reactions proceeding through compound nuclei of ^{82}Kr, ^{82}Sr and ^{82}Zr has been started. These represent nuclei which are on the stability line two units off the stability line on the proton-rich side and four units off the stability line on the proton-rich side. A model which has a drop for proton-rich nuclei relative to those on the valley of stability will produce more protons relative to neutrons than a conventional model. Results from this study should be available in a few months.

A parallel theoretical study is also underway. A mechanism for producing such reduction in level density would be the exclusion from the level density of levels which are too wide to be compound states. The widths could be large if single particle states which are very unbound rather than bound or quasi-bound are populated. A code has been written which calculates level densities including widths. By excluding levels with > 250 KeV, one can produce reduced level densities off of the stability line. Calculations will be compared with previous results.

Work supported by the U.S. Department of Energy.

Electron Capture-delayed neutron emissions in Neutron Star Crust simulations using a Hauser-Feshbach model

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Recently Electron Captures (EC) into excited states of neutron-rich nuclei were shown by the LANL-MichiganState-Mainz collaboration to result in Neutron Star (NS) Crust heating which was 5 times that of previous calculations. That result also highlighted the importance of a spread in X-ray burst abundances over several mass chains which could contribute to substantial heating through large shell and sub-shell gaps showing up in the excitation energy spectrum of the EC daughter. Such effects did not dominate when a single beta-stable species was evolved in an accreted parcel of matter in earlier calculations. We are now exploring the nucleosynthesis and heating from neutron processes deeper in the NS Crust beyond about 10^{11} g/cc. Electron captures into excited states of neutron-rich nuclei above neutron separation energies requires a Hauser-Feshbach code to calculate the branchings between 1-, 2-,3-,...neutron emission rates in the stellar environment. Since the evolving composition has a free neutron fraction at a very high density, the equilibrium composition at a given depth requires readjustments with respect to both the electron chemical potential and the neutron chemical potential, thus the emitted neutrons can be captured into other mass chains with a net release of heat. From a nucleosynthesis perspective, we have a very interesting and hitherto unexplored pattern of weak interactions and neutron processes similar to the r-process, with the exception that the weak processes are primarily density-driven in the rather cold crust (T_9 =0.4–0.6)and in the β^+ direction, that is, toward increasing neutron richness.

Is $(d, p\gamma)$ a surrogate for neutron capture?

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[3] *Lawrence Berkeley National Laboratory*

The surrogate reaction technique is an indirect way to determine cross sections by measuring a reaction that proceeds through the same compound nucleus. Neutron capture cross sections on unstable nuclei are difficult to measure due to target activity and relative low intensity of neutron beams. A neutron transfer reaction, such as (d, p) has the advantage over a direct (n, γ) measurement since it can be measured in inverse kinematics. To benchmark the validity of using the $(d, p\gamma)$ reaction as a surrogate for (n, γ), the ^{171,173}Yb$(d, p\gamma)$ reactions were measured and

compared with the neutron capture cross sections measured by Wisshak et al. The $(d, p\gamma)$ ratios were measured using an 18.5 MeV deuteron beam from the 88-Inch Cyclotron at LBNL. The reaction protons were measured using the Si detector array STARS and coincident γ-rays were detected using 6 Ge Clover detectors (LiBerACE). Results comparing the surrogate ratios with the known (n, γ) cross sections will be presented.

Work supported in part by the U.S. Department of Energy and National Science Foundation.

A Time Projection Chamber (TPC) for precision ^{239}Pu(n,f) cross section measurement

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High precision measurements of the ^{239}Pu(n,f) cross section have been identified as important for the Global Nuclear Energy Partnership (GNEP) and other programs. Currently the uncertainty on this cross section is of the order 2–3% for neutron energies below 14 MeV and the goal is to reduce this to less than 1%. The TPC has been identified as a possible tool to make this high precision measurement. In this talk I will present the work that has been done to motivate the TPC as a solution, and show the status of the design.

Nucleosynthesis in Early neutrino Driven Winds

R.D. Hoffman

LLNL

One of the outstanding unsolved riddles of nuclear astrophysics is the origin of the so called “p-process” nuclei from $A = 92$ to 126. Both the lighter and heavier p-process nuclei are adequately produced in the neon and oxygen shells of ordinary Type II supernovae, but the origin of these intermediate isotopes, especially ^{92,94}Mo and ^{96,98}Ru, has long been mysterious. Here we explore the production of these nuclei in the neutrino-driven wind from a young neutron star. We consider such early times that the wind still contains a proton excess because the rates for electron neutrino and positron captures on neutrons are faster than those for the inverse captures on protons. In addition to the protons, alpha-particles, and heavy seed, a small flux of neutrons is maintained by electron anti-neutrinos capture on protons. This flux of neutrons is critical in bridging the long waiting points along the path of the rp-process by (n,p) and (n, γ) reactions. Using the unmodified ejecta histories from a recent two-dimensional supernova model by Janka et al., we find synthesis of p-rich nuclei up to ^{102}Pd. However, if the entropy of these ejecta is increased by a factor of two, the synthesis extends to ^{120}Te. Still larger increases in entropy, that might reflect the role of magnetic fields or vibrational energy input neglected in the hydrodynamical model, result in the production of numerous r-, s-, and p-process nuclei up to $A \sim 170$, even in winds that are proton-rich.

Absorption-Fluctuation Theorem for Nuclear Reactions

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In nuclear reaction theory one uses average amplitudes to calculate optical or coherent cross sections. Unitarity dictates that one must take into account a statistical or fluctuation cross section and add it incoherently to the optical one to obtain the average cross section to be compared to the data. There are three types of fluctuations that must be considered in different types of reactions:

- Initial state fluctuations: These occur in low energy reactions that involve the formation of the compound nucleus. The fluctuation cross section is commonly referred to as the Hauser-Feshbach cross section.
- Final state fluctuations: These arise in reactions populating resonances in the final channel. The reactions are hybrid in the sense that the initial channel may not involve the formation of the compound nucleus.
- Intermediate state fluctuations: these fluctuations occur in multi-step reactions, where the green function describing the propagation in the intermediate channels has a non-vanishing fluctuation conribution, arising from, e.g. the Brink-Axel mechanism.

We discuss the above hierarchy of fluctuations and how they are intimately related to the presence of absorption (non-Hermitian channel Hamiltonian). We also discuss the issue of convergence of multi-step reactions, such as FKK, in view of the intermediate state fluctuations.

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Cluster productions in intermediate-energy proton-nucleus reactions

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We propose a model to describe cluster productions within the framework of the intranuclear cascade (INC) model. In our model, both a combination of surface coalescence process and knockout process has been introduced into the INC model. Results of our new model were compared with experimental data at intermediate energies. It is found that our new INC plus GEM model gives a good overall agreement with the experimental data. The influence of the introduction of the cluster production mechanisms is investigated.

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^{241}Am(n,γ) cross sections measured with DANCE in the neutron energy range between 0.02 eV and 300 keV

Marian Jandel

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The Detector for Advanced Neutron Capture Experiments (DANCE) at Los Alamos National Laboratory (LANL) was used for neutron capture cross section measurement on ^{241}Am. The high granularity of DANCE (160 BaF_2 detectors in a 4π geometry) enables the efficient detection of prompt gamma-rays following a neutron capture. DANCE is located on the 20.26 m neutron flight path 14(FP14) at the Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE). The absolute ^{241}Am(n,γ) cross sections were obtained in the range of neutron energies from 0.02 eV to 320 keV. Resonance parameters for $E_n < 20$ eV were obtained using SAMMY7 fit. The results will be compared to existing evaluations in detail.

Fission cross sections measurements via the surrogate reaction technique

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The determination of neutron-induced fission cross sections of neutron-rich actinides in the energy range from 1 to 10 MeV is of considerable interest for reactor physics as well as for the determination of not yet well known fundamental quantities such as transition states, level densities and fission barrier parameters. However, the great specific activity of many of the actinides targets extremely complicates the direct measurement of these cross sections. The surrogate method is a powerful tool to infer neutron-induced cross sections of short-lived nuclei. After an overview on the experimental techniques employed in different surrogate experiments we will concentrate in a recent measurement preformed by the CENBG to determine the neutron-induced fission cross sections and the fission-fragment mass distributions of ^{242,243}Cm and ^{241}Am.

Nuclear Reaction Data for Nuclear Technologies and Applications

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We discuss how nuclear reaction theories and experimental data are utilized in many different application fields, such as nuclear energy production (fission and fusion), radiation shielding, and nuclear astrophysics. The neutron-induced compound nuclear reactions, which take place from in the sub-eV energy range up to tens of MeV, are the most important mechanism; (1) to analyze the experimental data, (2) to predict unknown reaction cross-sections, (3) to evaluate the nuclear data for databases such as ENDF (Evaluated Nuclear Data File), JENDL (Japanese Evaluated Nuclear Data Library), and JEFF (Joint Evaluated Fission and Fusion), and (4) to reduce the uncertainties.

To improve the predictive-power of nuclear reaction theories in future, further development of compound nuclear reaction theories for fission and radiative capture processes is crucial, since these reaction cross sections are especially important for nuclear technologies. An acceptable accuracy of these cross-sections has been achieved only if they were experimentally confirmed. However, the compound reaction theory is getting more important nowadays as many rare nuclides, such as americium, are involved in applications. We outline future challenges of nuclear reaction modeling in the GNASH/McGNASH code, which may yield great improvements in prediction of nuclear reaction cross-sections.

Recent Experiments at ORELA and LANSCE, and Their Impact on Compound Nuclear Models

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I will describe results from recent experiments at the Oak Ridge Electron Linear Accelerator (ORELA) and the Los Alamos Neutron Science Center (LANSCE) facilities. Although the main motivation was nuclear astrophysics, data from these measurements are used routinely to test and improve compound nuclear models. At ORELA, we have made high-resolution neutron capture and total cross section measurements on ^{192,194,195,196}Pt and used the R-matrix code SAMMY to extract parameters for 1262 resonances. Such a large number of resonances over four isotopes allows detailed comparisons to theory. This should lead to better predictions for (n,γ) reaction rates for nuclides (e.g. ^{192}Ir) beyond the reach of current measurement techniques. At LANSCE, we have developed a new technique for using the Detector for Advanced Neutron Capture Experiments (DANCE) to determine spins for resonances in odd-A nuclides. Although there have been previous experiments of this type, the combination of the high flux at LANSCE, high efficiency and granularity of the DANCE detector, and our new data-analysis technique yielded substantial improvements. First measurements on ^{147}Sm have made it possible to determine spins for 41 resonances with previously unknown or only tentative assignments. These new spins allowed us to reliably extract separate neutron strength functions and average level spacings for each of the two s-wave spins. These average resonance parameters are in good agreement with theory. However, the distribution of reduced neutron widths changes shape near E_n=350 eV; from being consistent with the expected Porter-Thomas (PT) distribution below this energy to being inconsistent with PT for resonances over the next 350 eV. This work was supported in part by the U.S. DOE under contract No. DE-AC05-00OR22725 with UT-Battelle, LLC.

Moment methods and nuclear level densities

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Nuclear level densities are a key input for calculations of statistical reaction rates. One microscopic approach to modeling the level density is through moment methods, based upon averages of nuclear matrix elements. Contrary to common belief, third moments (asymmetries) are often large and important. We propose a modified Breit-Wigner as a useful model for the secular behavior of partial densities.

New Evaluation of Neutron Induced Reactions for ^{182,183,184,186}W

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The availability of accurate nuclear data for tungsten directly affects the reliability of a simulation carried out in a fusion reactor, because tungsten is considered as a prime candidate of plasma facing materials (PFM) which have to withstand heat and particle fluxes from the plasma in the environment of a fusion reactor. As a nuclear data file for a fusion neutronics calculation, the FENDL-2.1 which was taken from the ENDF/B-VI.8 for tungsten, is recommended. However, the data from this library failed to reproduced the measured data such as the total cross sections measured by Dietrich *et al.* and the energy and/or angle dependent neutron spectra measured by Marcinkowski *et al.*. Moreover, the calculation of leakage neutron based on these data showed a large discrepancy with the measured data by the pulsed sphere experiments at the D-T neutron source facility of Osaka University, OKTAVIAN. Similar poor results have appeared in the available libraries such as ENDF/B-VII.0, JENDL-3.3 and JEFF-3.1.

In response to this situation, neutron cross sections for ^{182,183,184,186}W were evaluated in the neutron-incident energy range from 0.1 MeV to 20 MeV, using the nuclear reaction model code EMPIRE-2.19 with a consistent set of input parameters for all tungsten isotopes. Our results were converted into ENDF-6 formatted files, checked by a set of the checking codes, and validated through fusion neutronics shielding experiments in SINBAD. Consequently, we constructed the data files which reproduced not only the measured data for each reaction but also integrated the measured data for a neutronics problems. We note that the latter as well as the former are very useful for adopting nuclear models and model parameters, especially in the case of insufficient measurements.

Experimental nuclear level densities and γ-ray strength functions in Sc and V isotopes

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The nuclear physics group at the Oslo Cyclotron Laboratory (OCL) has developed the so-called Oslo method, which enables the extraction of the nuclear level density and γ-ray strength function simultaneously from primary γ-ray spectra.

We report on experiments recently performed on ^{44,45}Sc and ^{50,51}V at the OCL. The Oslo method will briefly be discussed, and the experimental level densities and γ-ray strength functions will be presented. Also, the results will be compared with theoretical predictions from phenomenological models and microscopic calculations.

Benchmarking the External Surrogate Ratio Method

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The Surrogate Ratio Method is a new technique that can be used to obtain neutron induced reaction cross sections on unstable nuclei. The first experiment using the ratio method demonstrated that the fission probabilities for ^{237}U vs. ^{239}U were the same over a wide range of equivalent neutron energy regardless of whether the nuclei were formed using neutron-capture or the (d,p) reaction. However, this result had significant (>20%) uncertainty. In order to benchmark the ratio method with greater precision a new experiment was performed at the 88-Inch Cyclotron at LBNL using the Silicon Telescope Array for Reaction Studies (STARS). In this experiment, excited ^{234}U and ^{236}U nuclei were formed via inelastic α-particle scattering and the ratio of their fission probabilities was compared to the known ^{233}U(n,f)/^{235}U(n,f) cross section ratio. For this experiment, ^{234}U and ^{236}U targets were bombarded with a 55 MeV α-beam and the fission fragments in coincidence with outgoing α-particles were measured. We will show the status of the experiment and future work needed.

This work is a University of Richmond, Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory and Yale University collaboration and was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and LBNL, DE-AC03-76SF0098, and Grant Nos. DE-FG-05NA25929, DE-FG52-06NA26206, and DE-FG02-05ER41379.

Experimental Overview of Compound Nuclear Resonance Reactions

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The study of compound nuclear reactions is a vast and diverse field — here we focus on resonance reactions. We briefly summarize efforts at addressing the ma jor issues: A — How to measure the resonances, B — How to categorize resonances (spin, parity, resonance energy and strength), C — How to describe the distribution of resonances strengths and spacings, D — How to assess data quality. Sample illustrative examples are provided for each of these topics.

Nuclear reaction data on titanium isotopes

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We describe the nuclear reaction modeling on titanium isotopes, $^{46-50}$Ti. We used the Hauser-Feshbach reaction code, GNASH, for the threshold reactions and CoH for the total and capture cross sections. As one of the inputs for GNASH, we calculated the optical transmission coefficients using the Koning and Delaroche global optical potentials for neutrons and protons, and Avrigeanu, Hodgson, and Avrigeanu potentials for alpha-particles. In adjusting the level density and the pre-equilibrium parameters for the GNASH calculation, we referred to the LANSCE/GEANIE experiment on ^{48}Ti reaction cross sections as well as other experiments available for (n,p), (n,α), etc. We also took into account the direct inelastic scattering by using the coupled-channel calculation and the DWBA method. We assumed that the coupled-channels potential is similar to the spherical potential of Koning and Delaroche with proper deformation parameters.

On the other hand, we also investigated the resonance parameters in the energy region below several hundreds keV. We basically adopted the parameters from the Mughabghab's 2006 compilation, and made some adjustments mainly to reproduce the reference thermal cross sections.

This new evaluation was validated with the MCNP calculations of k-eff's on several hard-spectrum criticality experiments that involve Ti as a reflector or moderator.

The Fission Barrier Landscape

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A fissioning nucleus allows for the study of the most deformed nuclear objects found in nature. In the Pb region a fissioning nucleus is deformed beyond the superdeformed or even hyperdeformed state. Because the fission saddle configuration represents a stationary point at which the probability to fission is determined, it is able to sustain its own spectroscopy. Consequently, the physics describing the saddle point masses should be similar to that of the ground state. The zeroth order spectroscopic information is the fission barrier which is directly related to the mass of the saddle- point shape. In principle, one should also be able to explore the shape dependence of pairing, the shell effects at the saddle, the single particle level density at the saddle, the collective enhancements to the saddle level density, fission delay times, etc. We present a new method for determining fission barriers with nearly spectroscopic accuracy. With the improved accuracy achieved from the work described in this talk, it may be possible to achieve a future detailed exploration of the saddle mass surface and its spectroscopy at a future radioactive beam facility.

New Results on Nuclear Fission — Data and Interpretation

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The installations of GSI, Darmstadt, offer the possibility to perform experiments on nuclear fission in inverse kinematics at beam energies around 1 A GeV. By using secondary projectiles, this approach overcomes the limitations of conventional experiments on stable or long-lived target material. Moreover, the fission products can be fully identified in A and Z due to their high velocities in the laboratory frame. Different excitation mechanisms can be distinguished, e.g. nuclear interactions and electromagnetic excitations. In a series of experiments, the characteristics of multi-modal fission of neutron-deficient actinides and pre-actinides have systematically been mapped. More recently, the complete nuclide production in fission of ^{238}U projectiles induced by protons, deuterons and lead has been determined. These experiments gave a new global insight into the nuclide production in fission reactions, which is particularly relevant for applications in nuclear technology, e.g. for accelerator-driven systems, and for secondary-beam facilities.

Combined with previous results, the large body of data gave reason for intensive work on their theoretical understanding and on the development of codes. An attempt was made to interpret the data on the basis of a few well-established concepts and well-known features of the microscopic properties along the fission path. In particular, the statistical model was used to deduce the decisive properties of the mass-asymmetric potential on the fission path from the measured nuclide yields. According to the two-centre shell model, the macroscopic-microscopic approach proves to be particularly powerful when applied to the fission process, because the relevant microscopic properties can already be related to the shells in the separated fragments. Thus, they are determined by the number of neutrons and protons in the two nascent fragments, while they are independent from the fissioning system. The result of Langevin calculations were used to include the main features of the fission dynamics.

Determining the (n, γ) cross section of ^{153}Gd using surrogate reactions

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The astrophysical s-process is responsible for the synthesis of many of the nuclei heavier than iron. These isotopes are created through a series of low-energy (n, γ) reactions and subsequent beta decays of the generated radioactive nuclei. At *s*-process branch nuclei, the neutron capture and beta-decay rates are comparable. The branching ratio between these competing processes determines the path nucleosynthesis follows and is therefore crucial for tests of s-process models.

Direct measurements of (n,γ) cross sections for branch nuclei are extremely challenging due to the inherent difficulties associated with radioactive targets and the low intensity of available neutron beams. The surrogate reaction technique can be used to circumvent these difficulties by creating the same compound nucleus through light-ion reactions on a stable target. The cross section can be determined by combining optical model calculations for the formation of the compound nucleus with the measured exit channel probability for γ-ray emission.

We have collected data to determine the low-energy (n, γ) cross section for the unstable nucleus ^{153}Gd ($t_{1/2}$ =240 days) by bombarding a stable ^{154}Gd target with protons from the 88-Inch Cyclotron at the Lawrence Berkeley National Laboratory to create the desired 154Gd* compound nucleus. The STARS/LiBerACE silicon and clover germanium detector arrays were used to detect γ-rays in coincidence with the scattered protons. Additional cross section measurements using 156Gd and 158Gd targets are compared to direct measurements of the (n,γ) cross sections for ^{155}Gd and ^{157}Gd to check the technique. The current status of the analysis will be discussed.

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Experimental Level Density and gamma-Strength Functions in rare earth nuclei

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The Oslo group has developed a technique to simultaneously measure the level density and gamma-ray strength function. After establishing the level density as a function of excitation energy, the entropy is known and we can explore various thermodynamical parameters of the nucleus. The temperature, derived within the framework of the micro-canonical ensemble, shows structures, which we associate with the break up of nucleon pairs. And the nuclear heat capacity deduced within the framework of the canonical ensemble exhibits an S-shape as function of temperature, indicating a phase transition. Nuclear level densities and gamma strength functions are input parameters in large network calculations of stellar evolution. A pygmy resonance at around 3 MeV has been observed in several deformed rare earth nuclei and vanishes for the spherical nuclei. This is as expected for a scissors mode pygmy resonance. Results from Oslo combined with a thermal neutron capture experiment analysing two-step cascades finally establish the M1 multipolarity of this pygmy resonance. The width of the pygmy resonance observed in Dy isotopes in the Oslo experiments are generally wider than what the Prague group observe when analyzing two-step cascades from neutron capture experiments. So we performed an experiment on the same nucleus, namely ^{163}Dy, as the Prague group had analyzed and preliminary results will be presented. Preliminary result for ^{143,144,146,147}Sm will also be shown and a discussion of what happens to the level density and the radiative strength function as one approaches and crosses the $N = 82$ closed shell.

A measurement of ^{40}Ca$(\alpha, \gamma)^{44}$Ti in the regime relevant for supernova nucleosynthesis

Steven Sheets

LLNL

The ^{40}Ca$(\alpha, \gamma)^{44}$Ti reaction is the main production reaction for the radioactive nuclide ^{44}Ti, which serves as an important diagnostic for understanding explosive nucleosynthesis. A new self-consistent measurement of this reaction is proposed using the Tandem Van de Graaf at the Center for Experimental Nuclear Physics and Astrophysics at the University of Washington . A report is given on the current status of ^{40}Ca$(\alpha, \gamma)^{44}$Ti measurement.

Is there a low energy enhancement in the Photon Strength Function in molybdenum ?

Steven Sheets

LLNL

Recent claims of a low energy enhancement in the photon strength function of ^{96}Mo are investigated. Using the DANCE detector the gamma-ray spectra following resonance neutron capture was measured. The spectrum fitting method was used to indirectly extract a photon strength function from the gamma-ray spectra. No strong low energy enhancement in the photon strength function was found.

Improved Neutron Capture Data and Evaluation with Statistical Nuclear Structure Models for Transport Libraries

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The Evaluated Gamma-ray Activation file (EGAF) is a new thermal neutron capture database of discrete line spectra and cross sections for over 260 isotopes. It is part of an IAEA coordinated research project. This database is used to improve the capture gamma production in ENDF libraries. For medium to heavy nuclei the unresolved quasi continuum part of the gamma cascades are not experimentally available. This continuum can contain up to 90% of all the decay energy, and in this work is modeled with the statistical nuclear structure code Dicebox. This code is also used as a consistency check to improve the level scheme evaluation. Other predictive capabilities are shown with respect to the population of capture state resonances. Accordingly, the resulting unresolved continuum is deemed reasonably accurate for inclusion in the ENDF libraries. For the capture of higher energy neutrons there is little experimental data available making evaluation of modeling codes problematic. Dicebox is also being analyzed as a quasi continuum model along with the Empire Hauser-Feshbach code. Both codes approach the problem as a Monte Carlo sampling of many cascades through a given level scheme. The new library sections are inserted into ENDF libraries and evaluated using MCNP5.

Nuclear Reactions used for Superheavy Element Research

Mark A. Stoyer

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Some of the most fascinating questions about the limits of nuclear stability are confronted in the heaviest nuclei. How many more new elements can be synthesized? What are the nuclear and chemical properties of these exotic nuclei? Does the "Island of Stability" exist and can we ever explore the isotopes inhabiting that nuclear region? This talk will focus on the current experimental research on the synthesis and characterization of superheavy nuclei with $Z > 112$ from the Dubna/Livermore collaboration. Reactions using ^{48}Ca projectiles from the U400 cyclotron and actinide targets (^{233,238}U, ^{237}Np, ^{242,244}Pu, ^{243}Am, ^{245,248}Cm, ^{249}Cf) have been investigated using the Dubna Gas Filled Recoil Separator in Dubna over the last 8 years. In addition, several experiments have been performed to investigate the chemical properties of some of the observed longer-lived isotopes produced in these reactions. Some comments will be made on nuclear reactions used for the production of the heaviest elements. A summary of the current status of the upper end of the chart of nuclides will be presented.

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Breakup Reactions on Deformed Nuclei

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Compound nuclear reaction calculations of deformed nuclei require input from direct reactions. The amount of compound nucleus formed in the reaction is determined from the direct reaction component, i.e. the imaginary part of the optical potential. Also the transition matrix elments from direct reactions are required inputs into the Hauser-Feshbach calculation. Inelastic excitations of the deformed target are coupled via rotational/vibration couplings. The transition potentials are obtained by calculating the scattering of nucleons from the deformed target via a coupled channels code. This is limited to rotational/vibrational bands. Other states are included via a weak coupling DWBA model or by the weak coupling model for odd-A nuclei.

The coupled channels model employed in typical Hauser-Feshbach calculations can only couple the ground state rotational or vibrational bands. Other levels are then included uncoupled only to first order. A more complete description of the direct reactions would involve including the other levels on the same footing as rotational bands. This involves calculating the transition potentials of inelastic states from particle-hole excitations. The scattering of nucleons from the deformed target can then be calculated using coupled channels where more complete set of channels is included in the calculation.

Here we consider the breakup of deformed projectile, which consists of a deformed core+particle. The breakup of this deformed core+particle from the scatting off a nucleon is a similar problem as the scattering of nucleons from deformed targets. We consider the elastic scattering and breakup of 11Be from a proton target using an extended coupled channels model, which can include deformation of one of the fragments.

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Prompt Fission Neutrons as Probes to Nuclear Configurations at Scission

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Prompt neutrons and gamma-rays emitted at or following the scission point can be used to constrain nuclear configurations at scission as predicted by theoretical mass models such as microscopic-macroscopic or mean-field approaches, and test model hypotheses on the partitioning of the total excitation energy available at scission among the two fragments. We have implemented Monte Carlo simulations of the evaporation process following the acceleration of the excited primary fission fragments, and obtained detailed distributions of prompt neutrons and gamma-rays characteristics, e.g., $\overline{\nu}$(A,TKE). Only this level of detail can lead to meaningful constrains on the models and their parameters. Numerical results will be presented in the case of neutron-induced fission of ^{235}U, for incident neutron energies ranging from 0.5 up to 6 MeV.

Compound Nucleus Contributions to the Optical Potential

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The optical potential for elastic scattering of nucleons on a nucleus has, in addition to the monopole folding potential, contributions from all kinds of nonelastic reactions. Direct reactions, such as populate collective inelastic states or pickup reactions, all remove flux from the elastic channel, and so their effect on elastic scattering can be represented as an imaginary contribution to the optical potential.

There is also a multitude of compound nucleus states, each of which is a long-lived resonance and is therefore a narrow peak in an incident-energy spectrum. These compound resonances also remove flux from the elastic channel, and this flux is emitted some long time later: either back to the elastic channel, or by γ-ray or particle emissions. We define the optical potential to include the effects of all 'fast' absorption from the elastic channel when averaged over some interval $I \gg D$, where D is the level spacing. We must thus treat separately the 'compound elastic' that only much later feeds back to the elastic channel. Hauser-Feshbach models may be used to calculate the relative probabilities of all these decay processes, whether compound elastic or emissions, provided optical potentials are available for the outgoing channels.

A full *ab-initio* calculation of the optical potential therefore requires us to explicitly couple the elastic channel not only to the direct reactions list above, but also to all the particle-hole excitation states in the target. These p-h states may be regarded as *doorway states* through which the flux flows to more complicated and to (in the end) long-lived compound nucleus resonances. The random-phase approximation (RPA) calculates the linear combinations of p-h states that include the residual interactions within the target, and I show preliminary results for elastic flux loss using both p-h and RPA descriptions of target excitations.

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An Overview of Fission Measurements at LANSCE

John Ullmann

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Measurements of nuclear fission are central to the experimental program at the Los Alamos Neutron Science Center (LANSCE). These measurements can be made from thermal energies (and below) up to hundreds of MeV. Several detector systems are used, including a parallel-plate ion chamber for high-precision fission cross section measurements, an array of neutron and gamma-ray detectors (FIGARO) for multiplicity and emission-spectrum measurements, an array of HP Ge detectors (GEANIE) for gamma and x-ray output measurements and fission-fragment identification, a 4π array of BaF_2 detectors (DANCE) for gamma output and capture-to-fission ratio measurements, and a lead slowing-down spectrometer for cross section measurements on very small (nanogram) quantities of material. Some current results and future plans will be discussed.

Event-by-Event Simulation of Induced Fission

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We are developing a novel code that treats induced fission by statistical (or Monte-Carlo) simulation of individual decay chains. After its initial excitation, the fissionable compound nucleus may either deexcite by evaporation or undergo binary fission into a large number of fission channels each with different energetics involving both energy dissipation and deformed scission prefragments. After separation and Coulomb acceleration, each fission fragment undergoes a succession of individual (neutron) evaporations, leading to two bound but still excited fission products (that may further decay electromagnetically and, ultimately, weakly), as well as typically several neutrons. (The inclusion of other possible ejectiles is planned.)

This kind of approach makes it possible to study more detailed observables than could be addressed with previous treatments which have tended to focus on average quantities. In particular, any type of correlation observable can readily be extracted from a generated set of events, as will be illustrated. With a view towards making the code practically useful in a variety of applications, emphasis is being put on making it numerically efficient so that large event samples can be generated quickly. In its present form, the code can generate one million full events in about 12 seconds on a MacBook laptop computer.

The development of this qualitatively new tool is still at an early stage and quantitative reproduction of existing data should not be expected until a number of detailed refinement have been implemented.

Experimental study of level density and gamma-strength function from compound nuclear reactions

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The nuclear level density and gamma-strength function are the most uncertain inputs in Hauser-Feshbach model calculations. Traditionally, the main information about the nuclear level density comes from experimental data on neutron resonance spacing available at the neutron separation energy. To interpolate the level density function to different energy regions and to calculate a total level density, the Fermi-gas model function and spin cut-off factor are usually used. However, both spin cut-off parameter and interpolation procedure have uncertainties which are difficult to estimate. In this work we will show experimental data on level densities obtained from particle evaporation spectra at the Edwards Accelerator Laboratory of Ohio University. Deuteron, ^{3}He and light ion projectiles have been utilized. These data are compared to level densities based on Fermi- gas model and neutron resonance spacings.

The gamma-strength function is very difficult to measure below the particle separation energy. One of experimental methods is based on a measurement of two-step gamma-cascades following a compound nuclear reaction. The method will be discussed and first results obtained at the Edwards Laboratory from ^{59}Co(p,2γ)^{60}Ni reaction will be presented.

Statistical Theory of Compound-Nucleus Reactions

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An overview over theoretical developments since the 1950s is given. Bohr's idea of independence of formation and decay of the compound nucleus, the Hauser-Feshbach formula and Ericson's proposal of statistical fluctuations of the compound nucleus cross section show the need for a statistical theory. Random-matrix theory (RMT) is identified as suitable dynamical tool. The scattering matrix S is written as sum of a smooth background and of resonance contributions. The latter are modelled in terms of a RMT Hamiltonian. S can also be written as sum of the average and of the fluctuating S-matrix. The average S-matrix is determined by optical-model and direct-reaction reaction theories and serves as input for the statistical model which in turn aims at calculating average cross sections and cross-section fluctuations. A unitary transformation reduces the case with direct reactions to the one without (diagonal average S-matrix). For the latter case, the extant theoretical approaches are reviewed. Results and open problems are discussed.

Microscopic theory of fission

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The quantitative description of fission is arguably the most daunting challenge in contemporary nuclear physics. Since its official discovery in 1939, a predictive theory of this phenomenon has remained elusive, until now. Recent advances in formalism, coupled with the advent of parallel computing have finally made the microscopic treatment of fission within the framework of quantum many-body theory feasible.

In this talk, we will present Hartree-Fock-Bogoliubov calculations of induced ^{240}Pu fission using a finite-range effective interaction. This approach represents a fully microscopic, fully quantum-mechanical treatment of fission, where the only phenomenological input is the effective interaction between the nucleons, which has been successfully applied to a variety of nuclear-physics problems. In particular, we will examine the behavior of the fissioning nucleus near scission, and discuss the properties (e.g., excitation and kinetic energies) of the fission fragments deduced within this formalism.

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