EXPERIMENTAL NUCLEAR PHYSICS

TITLE: Production and Study of Neutron-Rich Nuclei
(available for 2 students)
SUPERVISOR: Prof. Michael Thoennessen and Dr. Thomas Baumann
ABSTRACT:
During the last few years we constructed an experimental setup to measure very neutron-rich nuclei. It consists of a superconducting dipole magnet and subsequent charged particle detectors and the Modular Neutron Detector Array (MoNA) in order to measure neutrons in coincidence with the charged fragments. A collaboration between Michigan State University, Florida State University and 8 other colleges and universities are currently preparing for the first experiments which are scheduled for later in the summer. It is an ideal project for an REU student to get involved, because she/he will be involved in all of the final preparations, including scintillation and gas detectors, electronics, data acquisition and data analysis.

TITLE: Experiments with segmented Germanium Detectors for Nuclear Structure Studies
SUPERVISOR: Prof. Glasmacher
ABSTRACT:
We use liquid-nitrogen cooled high-purity Germanium detectors to detect photons emitted from nuclei in flight in order to study the structure of exotic nuclei far from stability. The Segmented Germanium Array (SeGA) is being set up for an experiment to be performed in July. We invite a student to participate in the preparation and execution of the experiment. More information on SeGA at groups.nscl.msu.edu/gamma/.

TITLE: Calibration of the S800 Spectrograph
SUPERVISOR: Prof. Alexandra Gade
ABSTRACT:
The focal-plane detector system of the NSCL's S800 magnetic spectrograph contains two position-sensitive, gas-filled particle detectors (cathode-readout drift chambers). In experiments studying the properties of exotic nuclei, the method to position-calibrate these detectors is by inserting a mask with a known pattern of holes and slits in front of the detector. The particles coming through the slits and holes mirror the pattern of the mask in the position spectrum of the detectors. We invite a student to participate in the analysis of this detector. The first part of the project would be to develop a computer code that identifies the pattern of the mask in the position spectra of the detector and relates the channel numbers in the spectrum to the actual physical position given by the known pattern of holes and slits in the mask and so calibrates the detector. Furthermore, in experiments it is very crucial that the response of this detector is approximately constant over the entire active area of the detector (roughly 30 x 60 cm). A movable alpha-source will be installed to measure the response at various positions. A second part of the project could be to take data with this calibration device and analyze the results.

TITLE: Angular Correlations in chiral, triaxial, odd-odd nucleus 134Pr
SUPERVISOR: Prof. Krzysztof Starosta
ABSTRACT:

For atomic nuclei triaxial deformation defines in the intrinsic, nucleus-fixed reference frame three mutually perpendicular directions along the principal axes of the mass distribution and three principal planes spanned by these axes. For valence nucleon in a particle or hole orbital in a triaxially deformed potential the alignment of the angular momenta with the short or long axis is favored, respectively; while the collective rotation of the nucleus aligns with the intermediate axis which is the axis of rotation preferred by a nuclear moment of inertia. In specific configurations in triaxial odd-odd nuclei the three mutually perpendicular angular momenta provided by a valence particle, valence hole and collective rotation are mutually perpendicular and can be arranged into a right-handed or a left-handed system.

As a consequence of the two possible couplings, doublet states of the same spin/parity and nearly identical excitation energy are formed for a given single particle configuration. Indeed, doublet band structures have been observed systematically in the triaxial A~130 and A~105 regions. The best examples of level degeneracy in the mass A~130 region is provided by 134Pr with levels at spin 15+ and 16+ separated by less than 60 keV as compared to ~8000 keV spanned by the bands.

For the 134Pr high quality and high statistics gamma-ray spectroscopic data are available from a Gammasphere experiment. The Gammasphere is a multi-detector system for gamma-ray studies; with 110 detectors packed around the target it looks like a big sphere of gamma-ray sensitive Ge crystals (you may have seen the detector in a recent movie "Hulk", in the movie Hulk actually has dropped the Gammasphere detector down from a hill in Berkeley, in reality, however, the detector is still up and running).

From the Gammasphere experiment on 134Pr the nuclear structure information can be extracted by investigating angular correlations between gamma-ray transitions. These correlations arise due to the preference of gamma rays to be emitted in particular directions during the decay of excited states in the nucleus of interest. The analysis of these correlations is a crucial step in establishing spins and parities for nuclear states, and consequently, for experimental proof of the doubling of states with the same spin and parity.

The scope of the current project is to extract the information on angular correlations of gamma-ray transitions in 134Pr from the available Gammasphere data set. The project involves state-of-the art computer manipulation of large data basis. In the process of extracting the relevant information you will have an opportunity to learn the physics underlying nuclear structure of deformed nuclei and physics of gamma-ray angular correlations. You will also apply, modify and develop software tools for the analysis of the experimental data. The project requires familiarity with basic concepts in computer programming. The analysis, which is the goal of the current project, is the necessary step in manuscript preparation for a paper on 134Pr from the Gammasphere experiment; by getting involved in this project you will become a part of the collaboration and when the project is successfully completed, a co-author of the paper.

TITLE: Lifetimes of nuclear states via time-of-flight method
SUPERVISOR: Krzysztof Starosta
ABSTRACT:
The goal of the current project is to develop a time-of-flight technique for lifetime measurements with fast beams of radioactive nuclei from nuclear fragmentation reaction. The idea behind this

method of lifetime measurements follows the Recoil Distance Method (RDM or plunger) technique, which has a long tradition of use at stable beam facilities, however, a number of modifications is needed for optimal application of the method at National Superconducting Cyclotron Laboratory (NSCL).

In the approved NSCL test experiment a beam of the Pd isotopes of interest with a velocity beta=v/c=0.33 and an energy of ~54 MeV/u will be directed on a 50 mg/cm^2 93Nb target and excited to the first excited 2+ state. Nuclei of interest will emerge from the target with velocity beta'~0.30 and decay in flight after a certain distance; the distance which corresponds to the half-life is on the order of a few millimeters. A movable 9Be reset foil with 80 mg/cm^2 thickness, positioned downstream with respect to the 93Nb target, will be used to reduce the velocity of the beam to beta"~0.26. As a consequence, the gamma-ray from the 2+ excited state will be emitted at different source velocity if the decay occurs before or after the reset foil. The velocity of the source affects the Doppler shift for the gamma ray, which can be detected experimentally, allowing identification of decays that took place in front or behind the reset foil. The ratio of these decays provides an information about the lifetime if the distance D between the 93Nb and 9Be foils and the beam velocity beta' is known.

A "plunger" device, which allows controlling the distance D between the target and the reset foil with accuracy on the order of micrometers, is currently being designed and manufactured at the NSCL for applications in the above lifetime measurements. The goal of the current project is to contribute to the development of the method by tests and calibrations of the plunger device, as well as by modeling optimal experimental conditions with application of computer codes.

TITLE: Characterization of a Position-Sensitive Neutron Detector for Use in Nuclear Equation of State Experiments
SUPERVISOR: Dr. Michael Famiano and Prof. William Lynch
ABSTRACT:
Neutron detector walls consisting of two stacked arrays of liquid scintillators were used in experiments to study the asymmetry term in the nuclear equation-of-state (EOS). It is necessary to know the energy dependent efficiency of these walls for an effective analysis. Measurements can also be affected by scattering outside and inside the detector. A simulation of these neutron walls will enable a better understanding of some the effects on measurements. This project involves assisting with the writing of a simulation using GEANT4.4.0 and analysis of the results of the simulation. Experience with C++ is necessary for this project.

TITLE: Testing and development for the LEBIT project
(available for 2 students)
SUPERVISORS: Prof. Georg Bollen and Dr. Stefan Schwarz
ABSTRACT:
The Low-Energy Beam and Ion Trap Project aims at high precision experiments on unstable isotopes available at the NSCL. In this project high-energy beams of rare isotope are converted into low-energy beams by using gas-stopping and ion trap techniques. The first type of experiments will be high-precision mass measurements of unstable isotopes. Such measurements are important since they provide information on the binding energy of a nucleus, which is one of its most fundamental properties. At LEBIT such measurements will be carried out with a Penning trap mass

spectrometer, which allows mass measurements of atoms with a relative precision better than 1 part in 10 million. Other important components of LEBIT are a high voltage ion beam transport system with a test-beam ion source and a radio frequency ion trap for beam cooling and bunching.

The installation of LEBIT is practically completed and the project is entering the important phase of testing and optimization, required prior to experiments with rare isotopes. Examples of possible REU projects are:

- Systematic study and optimization of ion beam transport parameters and comparison with ion optical calculations.
- Development and test of electronic components for the Penning trap and other LEBIT subsystems.
- Monte-Carlo simulations in ion traps.

In addition, students will participate in test-experiments of the whole LEBIT system, which are foreseen to take place this summer, and help in the installation of new components.

THEORETICAL NUCLEAR PHYSICS

TITLE: Nuclear Femtoscopy for High-Energy Collisions
SUPERVISOR: Prof. Scott Pratt
ABSTRACT:
The RHIC (Relativistic Heavy Ion Collider) at Brookhaven creates the world's ottest laboratory environment with temperatures surpassing 200 MeV. Within the esoscopic collision volume (~1.0E-14 m, the size of a gold nucleus) the ormal structure of the vacuum is expected to melt and a transition to uark-gluon degrees of freedom should take place. Unfortunately, the novel onditions only last ~1.0E-22 seconds and experiments are relegated to easuring the momenta of the ~5000 particles comprising the collision debris. pace-time information about the collision can only be gathered from wo-particle correlations. By performing numerical modeling of the collision nd some analytic calculations of correlators, we will try to improve on stimates of the collision lifetime which are crucial for understanding the quation of state of the matter. Most of the work is numerical, but the omputing techniques can be learned during the first few weeks of the program. please don't hesitate to email me (pratts@pa.msu.edu) or call me (517-355-9200 2016) if you wish to discuss the project further.

TITLE: Radiance and nuclear giant resonances
SUPERVISOR: Profs. Vladimir Zelevinsky and Alex Brown
ABSTRACT:
The phenomenon of super-radiance is known in quantum optics. If the system of many two-level atoms is placed into a volume of a size smaller than the wavelength of radiation between the two levels, the atoms are coherently coupled through their common radiation field. When the pulse of radiation travels through the system a special state of the excited atoms can be formed that radiates very fast while the remaining ("trapped") states turn out to be very long-lived. There are analogs of this phenomenon in nuclear physics and condensed matter physics.

The proposal is to study the superradiant and trapped states in simple models. In particular it is interesting to relate recently observed so-called "pigmy"-resonances in loosely bound nuclei to the physics of superradiance. This part of the giant resonance is getting clearly pronounced when the nucleus is far from the stability line and therefore strongly coupled to the decay channels. This points out to the possible link to the super-radiance phenomena. The solid-state models of periodic structures with open ends can also be studied from the same viewpoint.

Basic acquaintance with quantum mechanics is desirable. The work should be mostly analytical with simple computations in the end.

TITLE: Symmetry Energy in Nuclear Reactions
SUPERVISOR: Pawel Danielewicz
ABSTRACT:
In nuclear reactions, the matter that nuclei consist of gets compressed. From the fact that nearly all nuclei have about the same, so-called normal, density in their interior, we conclude that the nuclear energy minimizes, as a function of density, at the normal density. Beyond the minimum, the nuclear energy as a function of density is a subject of intense scrutiny. Knowing about the energy, we could make predictions on neutron stars which, collapsed under gravity, have density many times greater in their interior than nuclei. However, the nuclear energy depends not only on density, but also on the percentage difference in the neutron-proton composition of nuclear matter. Light nuclei are most often composed of 50% neutrons and 50% protons, in heavy nuclei the composition is typically 60%-40%, and, in neutron stars, the neutrons dominate. The coefficient describing the dependence of nuclear energy on composition is called symmmetry energy. The symmetry energy needs to be understood to make extrapolations to neutron stars.

In theoretical transport simulations of nuclear reactions, the adopted symmetry energy has often been of a highly simplified form, limiting the insights that could be gained from comparing simulation results to data from reactions with varying neutron-proton composition. The project consists in implementing and exploring a variety of symmetry energy forms within existing transport simulations, potentially testing the forms against data. A rainy-day part of the project would include migration of simulation outcomes and their analysis to Unix.

TITLE: Testing Excitation with a Simple Adiabatic Model
SUPERVISORS: Prof. Filomena Nunes and Dr. Neil Summers
ABSTRACT:
Light exotic nuclei are mainly probed through reactions with stable targets. Although most of the reaction models developed so far assume that the constituents of the exotic nucleus remain inert throughout the reaction process, there are indications that this assumption may not be valid. We propose to include excitation in a simple adiabatic reaction model to probe the importance of this effect. The project will involve an analytical evaluation of the problem followed by numerical computation of the resulting integrals.

ASTROPHYSICS and NUCLEAR ASTROPHYSICS

TITLE: Variable Stars in Globular Clusters and the Galactic Halo
SUPERVISOR: Horace Smith
ABSTRACT:
Pulsating variable stars change in brightness because of periodic changes in their diameters and surface temperatures. RR Lyrae stars and type II Cepheids are keys to determining distances to old

stellar populations and test cases for understanding the evolution of lower mass stars. Because they are very old, they also provide information on the processes by which the Galaxy formed. We will analyze the properties of RR Lyrae stars and type II Cepheids using (i) observations obtained with the 60-cm reflecting telescope on the MSU campus and (ii) observations obtained during the ROTSE-I project at Los Alamos National Laboratory. Part of this project will involve getting new observations of these stars and part will be based upon observations already in hand.

TITLE: Globular Clusters and Low-Mass X-ray Binaries
SUPERVISOR: Prof. Stephen Zepf
ABSTRACT:
Globular clusters are one of the few places in the universe where the density of stars is high enough that they interact closely. One of the results of these gravitational interactions is the formation of very close binary star systems in material from a normal star is pulled onto a companion neutron star or black hole. This heats up the infalling material so that it radiates at X-ray wavelengths. There are a handful of such systems known in the Milky Way, but the combination of Hubble Space Telescope imaging of globular clusters and X-ray imaging from the Chandra Telescope allow the study of this process in much larger numbers in nearby galaxies. The project will be to combine Hubble and Chandra data to learn more about how these low-mass X-ray binary systems form and evolve.

TITLE: Southern Astrophysical Research (SOAR) Telescope
SUPERVISOR: Prof. Jack Baldwin
ABSTRACT:
The SOAR telescope was just dedicated, and will begin observations this summer. The astronomy group will have LOTS of work over the next year involving SOAR. We can use computer-adept undergraduate students in several ways during that time:

- occasionally observing remotely on SOAR for engineering tests and/or scientific programs.
- helping to analyze engineering data.
- helping to write/test remote observing software.
- creating web sites.

We are looking for undergrads who already have the computer background so that they could jump very quickly into actually being helpful at these tasks. Either Linux or Windows knowledge would be of interest.
This project could take two students for the summer.

TITLE: Reaction Networks for Thermonuclear (type Ia) Supernovae
SUPERVISOR: Prof. Edward Brown
ABSTRACT:
Hydrodynamical simulations of thermonuclear (type Ia) supernovae require as input the energy release from nuclear reactions, the rate of electron captures and the rate of neutrino emission. These quantities are computed using a network of equations to describe the nuclear burning. It is not feasible to include all relevant isotopes, however, and so these codes must employ an approximate set of equations that reproduces the burning rate and tracks the evolution of the mean nuclear mass and electron to nucleon ratio. In this project, the REU student will design, test and implement a network for use in simulations of type Ia supernovae. Recent studies suggest that the

concentration of Ne22 in the white dwarf plays an important role in setting the peak brightness of the supernova, and the network must account for this. The student will learn how to analyze the reaction network, and about stellar explosions in general. During this project, the student will interact with members of the nuclear astrophysics research group at the Joint Institute for Nuclear Astrophysics at the National Superconducting Cyclotron Laboratory. Knowledge of programming is useful.

TITLE: Nuclear reaction rates in stellar explosions
SUPERVISOR: Prof. Hendrik Schatz
ABSTRACT
Explosions on the surface of neutron stars are powered by nuclear reactions and are frequently observed as bright X-ray outbursts. In fact, these outbursts occuring on an hourly basis in many sources are among the brightest objects in the sky. However, as X-rays do not penetrate the atmosphere, they can only be observed by X-ray telescopes in orbit.

Recently, a number of theoretical and experimental results have allowed to determine the nuclear reaction rates in X-ray bursts much more reliable. The project consists of extracting the relevant data from publications and bringing them into a form that can be used in X-ray burst models. This invloves some basic mathematics and curve fitting. The results are then plugged into an X-ray burst model to see, whether the predicted light curve of the explosion changes due to the new data. Some basic experience with computer programming would be helpful for this project.

CONDENSED MATTER PHYSICS

TITLE: Giant Magnetoresistance in Magnetic Multilayers (experimental)
SUPERVISORS: Profs. Jack Bass and William Pratt
ABSTRACT:
Giant Magnetoresistance (GMR) in Magnetic Multilayers is of interest both for the underlying physics and for technology--the read heads in modern computer hard drives are now GMR multilayers. The MSU group pioneered measurements of Giant Magnetoresistance in Metallic Magnetic Multilayers with Current Flow Perpendicular to the Layer Planes, a geometry that usually gives more direct access to the physics underlying GMR. A specific project will be chosen after discussion with the REU student. The project will involve sample preparation (using a state-of-the-art sputtering system), sample characterization, and measurement of magnetoresistance. The project might also involve optical and electron-beam lithography in collaboration with a Ph.D. student or Postdoc.

TITLE: Development of an image-plate x-ray camera for studying of the structure nano-materials
SUPERVISOR: Prof. Simon Billinge
ABSTRACT:
Nanoscience and nanotechnology are two current "buzz-words" in physics that refer to the development of materials that take advantage of special properties associated with their small size, where small here refers to the nanometer length-scale. A major stumbling block in this endeavor is to study the atomic-scale structure of materials of this dimension since conventional approaches to

structure solution fail for these materials. In my group we are developing novel methods using advanced x-ray and neutron scattering to do this. The REU project will be to develop and commission an x-ray camera for collecting data using recent image-plate technology. The camera has been designed and built by us, but has to be configured and tested and then data from the camera have to be extracted and analyzed. The project will be a mixture of hands-on work to configure and commission the camera, experimental work in the form of data collection, and computer analysis, including some code writing, to extract and process the data. No specific experience is needed except some experimental aptitude and interest and basic confidence in using computers. Some straightforward programming skills will also get you going more quickly with that aspect of the project.

TITLE: Quantum Cryptography and Entanglement
SUPERVISOR: Prof. Carlo Piermarocchi
ABSTRACT:
On 21 April 2004 an Austrian scientist has used for the first time a quantum cryptography protocol in a $3500 bank transaction (see Nature Apr. 29 2004 p 883). The protocol is based on sharing a pair of entangled photons to create the encoding key. Upon arrival, both photons are measured by their respective owners. This act of measurement determines the state of the photons, and thus the state of the key. One important issue for the success of quantum cryptography is related to the availability of efficient devices to generate entangled pairs. Quantum dots are man-made semiconductor nanostructures that are very promising in this direction. The project consists of two parts: (i) introduction to quantum cryptography protocols, in particular the ones based on sharing EPR pairs. (ii) Investigation of semiconductor quantum dots as a source of entangled photons and single photon emitters.

BIOLOGICAL PHYSICS

TITLE: Projects in Molecular Biophysics
(available for up to 3 students)
SUPERVISOR: Prof. William Wedemeyer
ABSTRACT:
First Project. In this REU project, we seek to develop fast techniques for detecting when biological molecules stick together. We will exploit the basic principle that the random tumbling of molecules in solution becomes slower when the moment of inertia is increased. We will measure the tumbling rate principally by dielectric dispersion, but will cross-check our results using fluorescence depolarization and non-Newtonian viscosity measurements. Applications include rapid detection of bacterial/viral DNA and the discovery of novel pharmaceuticals.

Second Project. In this REU project, we will seek to develop new techniques for measuring the structure of biological molecules from X-ray solution scattering. Specifically, we will measure the difference in X-ray scattering from a protein and from a homolog in which a single chemical group has been eliminated. The difference spectrum should give the distribution of distances between the eliminated group to all other atoms in the protein. By repeating such experiments with different eliminated groups, a low-resolution picture of the entire protein should be obtainable. The proteins have been prepared; the student need only take the X-ray spectra and interpret the results.

Third Project. In this REU project, we will study the energies of interaction between rigid protein molecules and the surrounding solvent. We will carry out a systematic study of the solubility, heats of solution, molecular volume, orientational correlation time and dipole moment of twenty proteins that differ in a single position. The experimental data will be compared to computational simulations and used to make improved energy functions for proteins. The proteins have been prepared; the student will carry out the measurements and interpret the results.

HIGH-ENERGY PHYSICS

TITLE: Parton Distribution Functions
SUPERVISOR: Profs. Wu-Ki Tung and Dan Stump
ABSTRACT:
The Parton Model describes the quark structure of the nucleons (protons and neutrons). One project would be to study different models and their agreement with data from high-energy scattering experiments. Another model would be to study predictions of future experiments based on current parton model parameters, and the uncertainties of the predictions. One definite project is to study and compare examples from the new LHAP compendium of parton distribution models.

PHYSICS EDUCATION

TITLE: LON-CAPA Platform Development
SUPERVISOR: Profs. Gerd Kortemeyer, Ed Kashy and Wolfgang Bauer
ABSTRACT:
LON-CAPA is an award-winning program for teaching physics and other subjects. The LON-CAPA development team offers two projects to REU students for this summer.
Platform Development: This project will require solid existing programming experience, preferably in Perl and in the development of web applications. The students will be members of the LON-CAPA development team over the summer, and work to implement new functionality within the LON-CAPA system.

TITLE: LON-CAPA Physics Problems Development
SUPERVISOR: Profs. Gerd Kortemeyer, Ed Kashy and Wolfgang Bauer
ABSTRACT:
LON-CAPA is an award-winning program for teaching physics and other subjects. The LON-CAPA development team offers two projects to REU students for this summer.
Physics Problem Development: In this project, students will work with faculty in the LON-CAPA project to development new homework problems for introductory physics with a focus on real world conceptual problems.

ACOUSTICS

TITLE: (may be available if a student is especially interested in this field)
SUPERVISOR: Prof. William Hartmann