February 17, 2004

PROPOSAL

for an International Workshop at the ECT* on

"Spectroscopic factors"

1. *Tentative date of the workshop:*

   Spring 2004.

   Organized by:

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2. Scientific Proposal

Correlations are at the heart of the nuclear shell model. Although this model starts from a picture based on non-interacting nucleonic orbitals in a central field, this is never a complete description. In order to understand nuclear structure at low energies it is necessary explicitly to take into account the mixing of, typically many, valence configurations brought about by the long-range part of the nuclear force. For lighter nuclei it is possible to apply a microscopic description involving the diagonalization of a large matrix representing the (effective) interactions in a restricted quantum-mechanical space made up of the orbitals available to the particles. For heavier nuclei the description typically must resort to dynamic and static shape variables. Hence, measuring the occupancies of single-particle orbitals in atomic nuclei is crucial for understanding the structure of a nucleus at the microscopic level.

A second source of correlations in the single-particle motion in a "real" nucleus is the repulsive short-range part of the nucleon-nucleon interaction. Since this force sets in strongly at distances below 0.4 fm, it follows from the uncertainty principle that it must lead to components with high momentum in the nucleon wave functions. These components are not contained in the usual descriptions of nuclear structure at low energies. They can be observed either directly or, indirectly, via their conspicuous absence at low energies. Both the long-range and the short-range correlation phenomena can be related to spectroscopic factors that represent the overlap between the many-body wave function of a state in a nucleus with mass A and the states in the nucleus with one nucleon less or more.

The purpose of the workshop will be to discuss both aspects of nuclear correlations under the joint heading of "spectroscopic factors". The motivation for bringing the two communities together lies not only in recent progress in the theory of both areas but also in the appearance of new experimental techniques in the areas of high-energy electron scattering and reactions of radioactive beams ("knockout reactions") that may lead to new and accurate information on long- and short-range correlation effects.

Spectroscopic factors represent a fundamental result of nuclear-structure theories. Their calculated values can be compared to a wealth of data obtained with transfer and knockout reactions induced by elecromagnetic and hadronic probes. Recent advances in the theory comprise the Green's function approach, Monte-Carlo based studies, correlated basis function theory, and a variety of shell-model approaches in a large basis. In all of them the basic single-particle structure of the nucleus plays a fundamental rôle, but it is modified by the complex nature of the underlying nucleon-nucleon interaction.

From the experimental point of view the (e,e'p) reaction is perhaps the most direct way to extract spectroscopic factors for proton knockout from nuclei. It is basically determined by the electromagnetic interaction and it requires as reaction theory only the knowledge of the final-state interaction of the proton with the recoiling A-1 system. Also it is sensitive to the overlap function between the A-1 system and the target nucleus at all radii. Recently, it has become clear that (e,e'p) experiments performed at high energies require a full relativistic description of both the bound and continuum state of the proton. This aspect requires further detailed theoretical attention.

Transfer reactions, such as (^{3}He,d) and (d,^{3}He), have also a long tradition. Transfer reactions like (d,p), or heavy-ion reactions, have the advantage that they can be used to study the neutron spectroscopic factors. They depend only on the surface part of the overlap function and rely on approximate reaction models such as (non-local) finite-range DWBA. As both the hadron-induced and the electron-induced reactions probe the same spectroscopic factor, a comparison between the results of the two reactions may elucidate the role of the reaction mechanism involved in each approach.

A focus of present day low-average energy nuclear physics is the study of the properties of nuclei far from stability. These include halo nuclei and other neutron-rich or proton-rich nuclei. Many experiments in this field are being performed or planned at new radioactive beam facilities. One of their aims is the use of in-beam reactions as a spectroscopic tool. In this respect new techniques have recently emerged by which spectroscopic factors for unstable nuclei are extracted from the measurements of single nucleon breakup angular distributions, parallel momentum distributions and total breakup cross sections. On the other hand there are many issues associated with weakly bound nuclei that were not present in classical spectroscopic theory applied to tightly bound nuclei. Coupling to continuum states is very important and must be treated with reliable approximations. Spectroscopy in the continuum is also a tool which has been initiated with "normal" nuclei exactly to determine the limits of validity of the single particle picture and clarify the single particle damping mechanism.

An additional aim of the workshop is to discuss how nuclear physics far from stability can be used to extend our knowledge of the nuclides toward the edges of particle stability.

Several possible semi-exclusive reactions are studied at different energies and with different projectile-target combinations. The meeting will test the accuracy of the different theoretical approaches, with special attention to the reaction models, to lead to a better understanding of the relations between existing theories and of their respective ranges of validity and finally to find the best way of extracting structure information from the experiments. We anticipate that at the workshop we will focus on the connections between available experimental observables and the relation with results of experiments on normal nuclei. As a result there will be a better understanding of the reliability of the present models and it will be clearer which improvements need to be made to enhance their predictability .

The workshop is planned to run for one week to ten days with two main topics: 1) Electron scattering. 2) Nucleon transfer and break-up from deeply bound to loosely bound nuclei.