Single particle transfer and pairing in dripline nuclei

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Transfer reactions and Coulomb excitation reactions have provided much of the basic nuclear structure information for nuclei close to the valley of stability. The availability of radioactive nuclear beams makes it possible to apply the same powerful technique to unstable nuclei: physics issues that can be addressed are for example, single particle structure, shell evolution and shell quenching phenomena, neutron skin, evolution of shapes and new forms of pairing.

Transfer reaction with unstable beams in inverse kinematics will allow measurements of the following key properties of exotic nuclei:

- Single-particle shell model energies.
- Nucleon occupancies of single-particle levels in individual nuclear states.
- Radial densities for neutrons in specific orbitals, contributing to neutron haloes or skins in ground and excited states.
- Spin-orbit splitting in neutron rich nuclei.

As an example transfer reactions around ^{132}Sn and ^{78}Ni can provide valuable information about the spin-orbit interaction at large isospin values.

For N=Z nuclei the stripping of one proton and one neutron leads to levels in mirror nuclei. The measurements, under identical conditions, of the very similar reactions (as (d,n) (d,p) (d,t) and (d,^{3}He)) should provide valuable information on isospin symmetry via the excitation energies and spectroscopic factors for states in the heaviest mirror pair studied in this way to date.

Complementary information in this field will be determined by comparing the electromagnetic transition amplitudes involving analogue states in the isobaric spin doublets and triplets, whose members with Z ≥ N can only be studied with radioactive beams and inverse kinematics reactions. The study of isospin symmetry and isospin violation mechanisms in the nuclei with Z~N will be extended using RISING to a region of much heavier nuclei.

Here a unique situation arises, in which pairing between neutrons and protons (*pn*) becomes a dominant feature in the nuclear structure. Enhancement of the *pn* pairing correlations [1,2] may led to a new collective phase, the *pn* pair condensate, and to a variety of new phenomena associated with possible mixing/coexistence of isovector and isoscalar pairing phases. The isovector pairing correlations have been studied extensively and the resulting odd-even mass staggering, the reduction of the moment of inertia as well as the backbending phenomenon are key signs of isovector superfluidity in atomic nuclei. In contrast, the *np* pairing (collective) correlations are still to be investigated. Due to the absence of a clear signature, it appears difficult to quantify the effect precisely from experimental data and a systematic investigation is required. At the moment the most direct experimental signature, besides mass measurements, of the existence of such a collective phase has been found in the high spin behavior of medium mass N=Z nuclei. Here the four quasi-particle alignment is observed to be significantly delayed in rotational frequency with respect to the heavier N>Z isotopes. This delay contradicts the extended pairing and deformation self-consistent TRS calculations and may reflect an additional binding due to the neutron-proton pairing correlations in the T=0 channel [3].

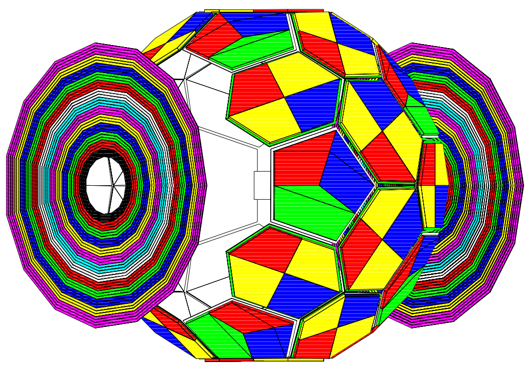
Multinucleon transfer reactions have been extensively used to investigate isovector pairing correlations. Of particular interest in this respect are also the collisions between heavy ions since they offer the possibility of observing multiple transfer of pairs and thus to measure the pair-density in the nuclear medium [4].

Similarly, a direct signature of the coherent isoscalar state can be provided by the enhanced transition rates in the transfer of two nucleons, namely a deuteron transfer reaction from an even-

even to an odd-odd nucleus. Here the value of the proton-neutron pair transfer amplitude should measure whether or not the two nucleons form a correlated pair. Examples are deuteron pick-up reactions on the N=Z nuclei ^{64}Ge, ^{68}Se or ^{72}Kr [4].

We propose here to use a segmented Si detector array combined with the RISING Ge detectors to measure gamma-particle coincidences in the transfer process. Combining particle and gamma detection strongly releases the requirements on the energy resolution for the scattered particles allowing an increase of about one order of magnitude in the target thickness. The gamma-ray detection will allow the selection of individual excited states in the final nucleus.

The proposed set-up will make use of the Si-ball Euclides, used as an ancillary detector in Euroball, improved with Si-strip detectors at forward and backward angles to provide the necessary angular resolution (TRACE).



Schematic side view of TRACE using Si strip detectors of 0.9 mm (0.1mm gap), 300 μm thickness corresponding to an angular resolution of 1.2^0 at forward angles. Using the existing Euclides segmentation at backward angles one can estimate an angular resolution of 2.8^0.

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[3] G. de Angelis et al. Phys. Lett. B 415 217 (1997)
[4] L. Corradi et al. Phys. Rev. C 63 02160(R) (2001)
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