The facets of nuclear charge-exchange reactions: From nucleon-nucleon physics to the mysteries of supernova explosions and the double-beta decay.

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Charge-exchange reactions using (p,n)- and (n,p)-type probes at intermediate energies ($>$ 100 MeV/u) are widely used to study spin-isospin-flip excitations in nuclei. In the limit of vanishing momentum transfer (ΔL=0, q=0) these transitions are referred to as Gamow-Teller (GT) transitions. They are directly connected to the weak nuclear transitions with the additional advantage that they can probe excitation regions, which are inaccessible to the ordinary weak beta decay.

Transitions in the β^+ direction (GT^+) from *pf*-shell nuclei are of particular astrophysical interest as they provide important input to the modelling of the explosion dynamics of a massive star. The weak electron capture (EC) process, which predominantly populates GT^+ states in the daughter nucleus determines the rate of deleptonization and, ultimately, the explosive power of a supernova. The importance of the GT^+ strength distribution for stellar EC was first recognized by Bethe. Later, in the parameterization of Fuller, Fowler and the EC rates for nuclei in the mass range A=45-60 were systematically estimated. These tabulations are now being replaced by results of modern large-scale shell-model calculations and a detailed confrontation with experimental results is of considerable importance for the supernova physics.

The experimental studies described here employ the (d,^{2}He) reaction to obtain GT^+ strength distributions. The unbound diproton system is referred to as ^{2}He, if the two protons couple to an $^1S_0$, T=1 state. Experimentally, the $^1S_0$ state is selected by limiting the relative energy of the two-proton system to 1 MeV, which is usually guaranteed by the limited acceptance of the spectrometer. However, (d,^{2}He) reaction experiments are complicated due to the coincident detection of the two correlated protons in the presence of an overwhelming background originating from deuteron breakup. But as the reaction mechanism of (d,^{2}He) forces a spin-flip, the reaction is even more selective than (n,p), where non-spin-flip transitions compete.

The experiments were carried out as part of the ESN-collaboration at the AGOR facility at the KVI Groningen. Deuterons of 171/183 MeV were delivered by the super-conducting cyclotron. A final state energy resolution of order 110 - 150 keV was achieved which is to be compared with the 1 - 1.5 MeV resolution obtained in the early (n,p) experiments at TRIUMF.

The lecture will cover the experimental results of the (d,^{2}He) reaction on many *sd*- and *pf*-shell nuclei up to the shell closure at ^{70}Ge and including the rarest and only odd-odd *pf*-shell nucleus ^{50}V. Further, the (d,^{2}He) reaction can also be employed as a means to measure the double-β decay matrix elements, thereby giving estimates for the life-times of a number of double-β decay nuclei. It also proves to be a powerful and high resolution spectroscopic tool for giving new insights into the structure of the halo nuclei ^{6}He and ^{7}He and provides a way to measure the neutron-neutron scattering length a_{nn}, which is a fundamental quantity in nucleon-nucleon physics.

The lecture will cover all of the rich physics in quite some detail. It will also describe some of the experimental techniques, which have made these studies possible.