International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Exploring nuclear structure with deep-inelastic heavy-ion collisions

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Deep-inelastic processes between complex nuclei were first observed in the sixties [1], but it was not until the early 1970s that the importance of the new damped-reaction mechanism was recognized by experimental groups and that theoretical concepts were developed (e.g., [2]). A specific goal early on was to discover the collective phenomena and relaxation processes occurring within a small quantum system that is initially far from equilibrium. The usefulness of deep-inelastic reactions for discrete gamma-ray spectroscopic studies came into focus only in 1990's, when it was demonstrated that they are amenable to populating excited structures at relatively high spin in nuclei far off the valley of beta stability [3]. This initial work triggered a series of experimental investigations aimed at exploring high-spin structures in neutron-rich nuclei hard to reach by other methods. The technique relies on using processes which occur at incident energies roughly 20% above the Coulomb barrier where the production of neutron-rich species results from a tendency towards N/Z equilibration of the di-nuclear system formed during the collisions. Characteristic gamma rays from those products can in principle be measured, but, since the total reaction yield is spread over many nuclei, the spectra are quite challenging. The development of efficient Compton-suppressed germanium arrays (GASP, GAMMASPHERE, EUROBALL) enabled fruitful studies of discrete gamma rays from those reaction products, especially in measurements carried out with a thick target. Here, the presence of known gamma rays is combined with the gamma-gamma coincidence technique to provide an accurate identification of the product nuclei. In thin target experiments, on the other hand, the gamma rays need to be detected in coincidence with reaction products identified, for example, in a magnetic spectrometer (CLARA+PRISMA, EXOGAM+VAMOS), as this is the only way to properly correct for Doppler effects while simultaneously providing the identification of the fragments.

By using both thick and thin targets with deep-inelastic collisions, yrast and near-yrast structures have been located in many nuclei that were previously inaccessible. The results include: the discovery of the doubly-magic character of ^{68}Ni [4], the identification of a sub-shell closure at N=32 in neutron-rich nuclei [5], the location of high-spin yrast isomers in neutron-rich nuclei in the neighborhood of the doubly- magic ^{208}Pb (e.g., [6]), etc.

With the advent of high-intensity, neutron-rich radioactive beams at energies close to the Coulomb barrier, there is much optimism about the potential of deep-inelastic processes as a unique tool to access yrast structures in exotic nuclei located close to the radioactive projectile.

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