FUSTIPEN-Visit Report
Jonathan Engel, March 4–27, 2014

My FUSTIPEN-funded visit to GANIL was quite productive. Piet van Isacker was my primary collaborator; we developed a plan to add isoscalar pair bosons to the Interacting Boson Model (in a version of the "IBM-4") in order to include important physics affecting double-beta decay. Isoscalar pairing plays an important role in calculations of double-beta decay within the QRPA and shell model, but has until now been absent from those of the IBM. Kosuke Nomura, Piet's postdoc, is now coding a mapping from fermion pairs to bosons that includes $J = 1$ isoscalar bosons, and will soon examine the effects of those bosons. Eventually, we will supplement existing IBM-2 calculations of double-beta decay with this new degree of freedom. Its inclusion should shrink the double-beta matrix elements, brining them closer to shell-model results. We expect a publication in the next few months.

I also began an interesting collaboration with Danilo Gambacurta, a GANIL postdoc who moved to Catania during the summer. Danilo and Marcella Grasso (at Orsay) have developed a "second-RPA" code for use in conjunction with density-functional theory (DFT). Second RPA is supposed to improve the description of giant resonances by adding two-phonon states to the spectrum of one-phonon states produced by the ordinary RPA. But when used with modern density functionals, the two-phonon admixtures pull resonances down several MeV below experimental energies. The reason is that the two-phonon correlations are effectively included in the density functional itself. Ordinary RPA is an adiabatic limit of time-dependent DFT and though it produces resonances that are too narrow, it predicts centroids quite well. Second RPA, by contrast, has no obvious connection with DFT and leads to a double-counting of two-phonon correlations that drags centroids down.

One way out of this problem is something called the "subtraction method," a prescription for modifying the second-RPA Hamiltonian that forces the method to reduce to ordinary RPA in the adiabatic limit. The procedure has been implemented in certain models that include a subset of two-phonon states, but never in something has comprehensive and computationally difficult as second RPA. Danilo and I have figured out how to apply the procedure at successive levels of approximation within second RPA and our initial results are very promising; the resonances shift back to roughly the correct location while still allowing two-phonon admixtures to give them a realistic width. Here also, we should have a publication in a few months.

Part of the reason for my visit was to interact with Michael Bender, who came up from Bordeaux for several days to discuss the generator coordinate method (GCM). I have recently used the method to address double-beta decay and Michael has used it to add non-collective components to ground states. We both face the problem of proliferating basis states as more generator coordinates are included, and so we examined stochastic versions of the GCM. We did not decide on a definite approach, but both came to a much better understanding of the pros and cons of various Monte-Carlo-based methods. I expect we will collaborate on stochastic GCM in the near future.

Finally, I devoted some of my time at GANIL to interacting with people from outside the lab. I participated in the week-long FUSTIPEN topical meeting entitled "Understanding nuclear structure and reactions microscopically, including the continuum." The meeting facilitated conversations among people doing ab initio calculations in light and medium-mass nuclei and others applying DFT, the shell model, and other more traditional methods in heavy nuclei. I spoke about my recent work with the Oak Ridge group to derive shell-model interactions from ab initio coupled-cluster calculations. That work and other work like it in the in-medium similarity renormalization group promise to link useful and well-established techniques in heavy nuclei with ab initio calculations. The meeting produced an unusual give and take that I hope can be replicated in similar workshops over the next few years.