Nicolas Michel

Michigan State University - NSCL, East Lansing, MI, USA

In the frame of my collaboration with Prof. Marek Ploszajczak, his Ph.D. student Kevin Fossez, and master student Alexis Mercenne, I visited GANIL for three weeks from May 13th 2013 to May 31st 2013 in order to discuss and develop existing projects.

The first topic of my visit was to discuss proton scattering on 6He and 18Ne in the Gamow Shell Model (GSM) in the framework of the Resonating Group Method (RGM) in a core plus valence particles framework. The problem with 6He is that it is not sufficient to consider the channels associated to the ground and first excited states of 6He to treat 6He(p,p')6He proton elastic and inelastic scattering reactions. Indeed, in order to reproduce the structure of the 6He and 7Li nuclei as well as reaction channels, it has been seen necessary to include scattering states of 6He in the coupled-channel equations used in GSM+RGM. The previous calculations already done for that matter demanded to use two different Hamiltonians, one for the structure part and one for the reaction part of the 6He(p,p')6He reaction. Hence, we discussed what changes are necessary in the GSM+RGM code in order to implement this. It was seen that it is necessary to include several hundreds of reaction channels in the current codes. Although this modification will not drastically change the existing codes, it will surely be necessary to use parallel computation at the level of RGM, as coupled-channels matrices will be much larger than before. We also discussed the 18Ne(p,p')18Ne reaction, as it will be the object of a Physical Review C paper very soon. Indeed, this reaction is simpler to consider than 6He(p,p')6He, because channels involving 18Ne bound and resonant states are sufficient to obtain cross sections of good quality. This paper will present in detail the GSM+RGM method, which has not been published yet. Indeed, a new method to deal with non-local potentials was introduced therein, which is as precise as those used in the standard local reaction problem. For this, a Hamiltonian which includes partial waves of orbital angular momentum up to four has to be fitted, in order to show the good convergence properties of the GSM+RGM method. This work was seen to present neither theoretical nor practical difficulty, so that it can be handled in the short term.

The second topic of my visit was to consider the use of the No-Core Gamow Shell Model (NCGSM) with realistic interactions for light nuclei, in particular 3H, 4He and 5He. Indeed, NCGSM is a unique tool to deal with the unbound structure of 5He, which cannot be handled exactly with other methods, such as with the Coupled-Cluster method for example. In particular, I did GSM calculations of 4He and 5He, which served as benchmarks of more elaborate calculations using the Density Matrix Renormalization Group method (DMRG), which allows to diagonalize very large matrices unreachable with Lanczos or Davidson methods. We could then submit a paper related to the study of 3H, 4He and 5He ground states with GSM and DMRG to Physical Review C during my stay in GANIL. The description of proton scattering in NCGSM on 4He and 6He targets was also discussed. For this, the NCGSM+RGM method would have to be used, which will demand important numerical resources. It is in fact necessary to develop GSM+RGM in a core plus valence particles framework, as mentioned before. In particular, convergence of GSM target and reaction states must be fully attained in NCGSM+RGM, so that calculations using a core will be necessary as a testing ground for NCGSM+RGM. A Monte-Carlo method of solving GSM (MC-GSM) equations has also been discussed, as it is a project in which both Kevin Fossez and Alexis Mercenne are involved. I gave them advice on that subject while I was in GANIL, so that this project could thereby significantly progress. In particular, they could implement importance sampling in the MC-GSM method. The MC-GSM, due to its relatively low numerical cost, is of interest for NCGSM+RGM, because it could reduce GSM dimensions therein, which is the main difficulty to deal with in GSM and NCGSM.

The third topic of my visit was to implement radiative capture of proton and neutron in GSM+RGM. This project is of astrophysical interest, because radiative capture plays a significant role in the creation of elements in stars. This has been done with Kevin Fossez, who coded routines for radiative capture in GSM+RGM under my supervision. The code is now being tested by Kevin Fossez, so that we plan to have a working version this year. Possible applications have also been discussed with Marek Ploszajczak, which would involve light nuclei. NCGSM+RGM could also be applied for that matter, if we consider very light nuclei, bearing less than six particles.

I also gave a talk on GANIL entitled "Nuclear ab-initio and reaction frameworks within the Gamow Shell Model" during my visit. It was directly related to the topics of my collaboration with Prof. Marek Ploszajczak in the frame of FUSTIPEN.

As a conclusion, comprehension of the efforts to be made in the context of (NC)GSM+RGM in the long term have clearly stated, and short-term projects involving code implementation and preparation of scientific papers have been discussed and initiated.