SCIENTIFIC REPORT OF THE VISIT

Reference Number: 3959
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Project: "Neutrino mean free path in isospin asymmetric nuclear matter"

Purpose of the visit

The final scope of this project is the determination from a microscopic many-body approach of the neutrino mean free path inside hot isospin asymmetric nuclear matter. To such end, we need first to characterize asymmetric matter as a Fermi liquid by computing the quasi-particle interaction and the Landau parameters that then will be used in the evaluation of the response function including RPA correlations, and after from it, the neutrino mean free path.

The purpose of this visit has been the microscopic determination of the quasi-particle interaction directly obtained from the nucleon-nucleon G-matrix including the contribution of the correlation and the rearrangement terms in the evaluation of the quasi-particle energy.

Description of the work carried out during the visit

From the Landau theory of Fermi liquids, the quasi-particle interaction can be obtained as the functional derivative of the quasi-particle energy with respect to the occupation number.

$$f(\vec{k},\vec{k}') = \frac{\delta\varepsilon(\vec{k})}{\delta n(\vec{k}')} . \qquad (1)$$

During this visit, we have computed the quasi-particle energy from the Brueckner G-matrix including the contribution of the correlation, M_1, and the rearrangement, M_2, terms in the expansion of the mass operator, i.e,,

$$\varepsilon(\vec{k}) \approx \frac{\hbar^2 k^2}{2m} + M_1(\vec{k},\omega) + M_2(\vec{k},\omega), \qquad (2)$$

where we have calculated M_1 and M_2 in terms of the G-matrix

$$M_1(\vec{k},\omega) = \sum_{\vec{h}} n(\vec{h}) \left\langle \vec{k}\vec{h} \right| G(\Omega = \omega + e_1(\vec{h})) \left| \vec{k}\vec{h} \right\rangle_A \qquad (3)$$

and

$$M_2(\vec{k},\omega) = \sum_{\vec{h}\vec{h}'\vec{p}} \frac{\left|\left\langle \vec{h}\vec{h}'\right| G(\Omega = e_1(\vec{h}) + e_1(\vec{h}'))\left|\vec{k}\vec{p}\right\rangle\right|^2}{\omega + e_1(\vec{p}) - e_1(\vec{h}) - e_1(\vec{h}')} n(\vec{h})n(\vec{h}')(1 - n(\vec{p})). \quad (4)$$

The G-matrix G have been obtained by solving the Bethe-Goldstone equation

$$G(\Omega) = V + \sum_{\vec{k}\vec{k}'} V\left|\vec{k}\vec{k}'\right\rangle \frac{(1 - n(\vec{k}))(1 - n(\vec{k}'))}{\Omega - e_1(\vec{k}) - e_1(\vec{k}') + i\eta}\left\langle \vec{k}\vec{k}'\right| G(\omega), \quad (5)$$

using the realistic Argonne Av18 bare nucleon-nucleon force supplemented by a three-body force of the Urbana type to reproduce properly the saturation properties of symmetric matter. The auxiliary field e_1 has been taken

$$e_1(\vec{k}) = \frac{\hbar^2 k^2}{2m} + \mathrm{Re}\left(M_1(\vec{k},\omega = e_1(\vec{k}))\right). \quad (6)$$

During this visit we have prepared the code that computes the quasi-particle energy including the contributions of M_1 and M_2 for the case of symmetric matter at zero temperature.

Description of the main results obtained

Our results are still preliminary, and for the moment our formalism is only ready for the symmetric nuclear matter case at zero temperature. We are at this moment making different checks and tests of the code. These checks and tests will be hopefully finished in a few weeks, allowing us to obtain the first definite results for the symmetric matter case at zero temperature.

Future collaboration

The present project is still at its earlier stages. As we said, our results for the are still preliminary. Once our formalism is ready for the symmetric matter case at zero temperature, we will extend it, first to the finite temperature case, and then to asymmetric matter case both at zero and finite temperature.

Our final objective, however, is to compute the neutrino mean free path in dense and hot hadronic matter. To such end, we will need to extend our formalism to the case of hot β-stable matter including other degrees of freedom, such as e.g., hyperons, in addition to the nucleonic ones. This task will still require some time to be fully completed. Several visits in both ways (Coimbra-Orsay, Orsay-Coimbra) will be needed.

Projected publications

We expect that all this work will generate several publications. The formalism itself will be presented in one publication. A second publication will be devoted to the Landau parameters and neutrino mean free path in hot isospin asymmetric nuclear matter. Finally, the results for the Landau parameters and the neutrino mean free path in hyperonic matter both at zero and finite temperature will be presented in a third and a fourth publication, respectively.