**TALENT Course 6: Theory for exploring nuclear reaction experiments**

**Project name:** Study of the $^{12}\mathrm{C}(d,p)^{13}\mathrm{C}$ reaction with the coupled-channel method

**Researcher(s):** A. Mercenne

**Affiliation:** GANIL

**Supervisor(s):** F. Nunes

**Project outline and aims:**

The transfers reactions are important to describe the nucleosynthesis within the stellar environment, especially throught the $p$, $s$, $r$ and $rp$ process. In this work, the $^{12}\mathrm{C}(d,p)^{13}\mathrm{C}$ reaction [1] will be studied. In the first time, by using the parameters from Ref.[2], the cross-section will be calculated taking into account the continuum with the CDCC approach (Continuum Discretized Couple-Channel) [3, 4, 5, 6, 7, 8]. In the standard coupled-channel method [9], the Hamiltonian considers the internal structure of the target, but the CDCC approach allows to consider the continuum states associated to the projectile, by using the bin wave functions. The $^{12}\mathrm{C}(d,p)^{13}\mathrm{C}$ reaction is described by considering the deuteron with a proton core, and a neutron valence. The interaction $p + {}^{12}\mathrm{C}$ and $n + {}^{12}\mathrm{C}$ will be modelised by an optical potential, and the $np$ system by a simple Gaussian interaction. These calculations will be performed using the FRESCO code [10]. In the second time, the results from CDCC approach will be compared with the R-matrix formalism.

**Methodology:**

- Find a suitable optical potential for the proton-$^{12}$C and neutron-$^{12}$C systems at 10 Mev per nucleon.
- Build the FRESCO input for this reaction.
- Calculate the cross-section, then compare with the results from the R-matrix formalism.

# References

[1] T.W. Bonner, J.T. Eisinger, A.A. Kraus, and J.B. Marion. Cross section and angular distribution of the $(d,p)$ and $(d,n)$ reactions in $^{12}$C from 1.8 to 6.1 MeV. *Phys. Rev.* ***101****, 1 (1956).*

[2] F. Delaunay, F.M. Nunes, W.G. Lynch, and M.B. Tsang. Coupling and higher-order effects in $^{12}\mathrm{C}(d,p)^{13}\mathrm{C}$ and $^{13}\mathrm{C}(p,d)^{12}\mathrm{C}$ reactions. *Phys. Rev. C* ***72****, 014610 (2005).*

[3] N. Austern, Y. Iseri, M. Kamimura, M. Kawai, G. Rawitscher, and M. Yahiro. Continuum-discretized coupled-channels calculations for three-body models of deuteron-nucleus reactions. *Phys. Rep.* ***154****, 125 (1987).*

[4] M. Kamimura, M. Yahiro, Y. Iseri, Y. Sakuragi, H. Kameyama, and M. Kawai. Chapter I: Projectile breakup processes in nuclear reactions. *Prog. Theor. Phys. Suppl.* ***89****, 1 (1986).*

[5] M. Kawai. Chapter II: Formalism of the method of coupled discretized continuum channels. *Prog. Theor. Phys. Suppl.* ***89****, 11 (1986).*

[6] M. Yahiro, Y. Iseri, H. Kameyama, M. Kamimura, and M. Kawai. Chapter III: Effects of deuteron virtual breakup on deuteron elastic and inelastic scattering. *Prog. Theor. Phys. Suppl.* ***89****, 32 (1986).*

[7] Y. Iseri, M. Yahiro, and M. Kamimura. Chapter IV: Coupled-channels approach to deuteron and $^3$He breakup reactions. *Prog. Theor. Phys. Suppl.* ***89****, 84 (1986).*

[8] M. Kawai, M. Kamimura, and K. Takesako. Chapter V: Coupled-channels variational method for nuclear breakup and rearrangement processes. *Prog. Theor. Phys. Suppl.* ***89****, 118 (1986).*

[9] I. J. Thompson. Coupled reaction channels calculations in nuclear physics. *Comput. Phys. Rep.* ***7****, 167 (1988).*

[10] X.D. Liu, M.A. Famiano, W. G. Lynch, and M. B. Tsang. Systematic extraction of spectroscopic factors from $^{12}$C$(d,p)^{13}$C and $^{13}$C$(p,d)^{12}$C reactions. *Phys. Rev. C* ***69****, 064313 (2004).*