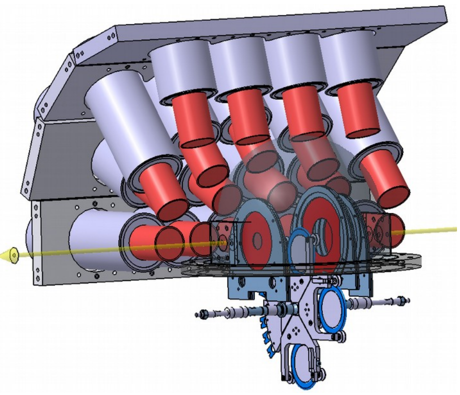
Gamma Gates & Particle Acceptance in $^{12}C+^{12}C$

PROJECT SUPERVISION :
DIRECTEUR DE THESE :PROF SANDRINE COURTIN
CO-ENCARDEMENT : MARCEL HEINE
INSTITUT PLURIDISCIPLINAIRE HUBERT CURIEN (IPHC –CNRS, UMR 7178)
23 RUE DU LŒSS, 67037 STRASBOURG
TEL : 03 88 10 10 68 87; E-MAIL : SANDRINE.COURTIN@IPHC.CNRS.FR

Context :

Fusion of two nuclei is one of the principal mechanisms of stellar nucleosynthesis of the elements. At the temperature present at the stellar site, *fusion hindrance* and *resonances* play a crucial role defining the reaction rate of element production as well as the thermodynamics conditions influencing *e.g.* the life time of the star. This demonstrates the fundamental influence of nuclear structure on astrophysics. Hindrance was evidenced in the 2000s for heavy ions. For lighter systems, such studies are even more challenging, because a significant background hampers the conventional approach at deep sub-barrier energies. Hence, to diminish the background, coincidence measurements of several characteristic particles must be done (see STELLA apparatus image).



Project Details :

This work comprises the analysis of experimental $^{12}C+^{12}C$ fusion data from measurements with STELLA (STELlar LAboratory) at Andromede, IJCLab, Orsay, the comparison with simulations of the detector response to characteristic particle emission and cross checking using geometric studies. The subject covers all aspects of coincidence measurements. On one side, the gamma-energy selection with conventional full-energy-deposition gating will be compared to extending cuts reaching into the Compton spectrum. The efficiency and uncertainties of both approaches will be determined in the comparison with simulations. On the other side, the effect of kinematic widening on the effective particle-detector energy-resolution from an extended beam spot, taking into account the compact geometry inside the chamber, is to be investigated. Therefore, several beam settings are to be analyzed and to be compared to simulations and geometric acceptance estimations.

During the analysis of coincidence data of STELLA, (full)-energy gates on charged particles are applied resulting in a seemingly pure gamma spectrum exhibiting the full-energy peak and Compton plateau suggesting to extend the energy gating to the entire spectrum. The impact of possible sources of remaining backgrounds events will be evaluated by analyzing the associated particle spectrum. The efficiency and uncertainties will be defined by comparing to Geant4 simulations. For investigating the energy resolution during charged particle detection, results from source runs will be extrapolated to measurements of the angular dependency of evaporated particles with ^{12}C beam. The effect of the beam spot size is to be analyzed by comparing measurements with different slit settings defining the beam-spot extension to analytic calculations of the reaction kinematics as well as simulations from Geant4 simulations. This allows to define an effective energy resolution and the effects of kinematics widening on the measurements of $^{12}C+^{12}C$ fusion measurements.

The student will be introduced in automated calibration routines for gamma and particle detection as well as basic data compliance checks. The analysis carried out with ROOT as well as Geant4 serves to obtain the coincidence efficiency, the associated uncertainty and to calculate $^{12}C+^{12}C$ reaction cross-sections. The experiment at Andromede is currently in the setup phase and the student is offered the opportunity to join data taking in early 2022. The subject has the potential to be followed up by a PhD in the STELLA team of DNE.

TEAM : Sandrine Courtin, Dominique Curien, Marcel Heine, Emma Monpribat, Jean Nippert