PHD Thesis Project proposal, 2022-2025
INFN Sezione di Firenze, Gruppo Nucleare

Frame: experimental Thesis
INFN financed experiment name: Nucl-ex (Nucl-ex national website: http://www.bo.infn.it/nucl-ex/)
Theme: nuclear fragment formation and their isotopic properties
Apparatus: FAZIA+INDRA
Involved LABS: GANIL (Caen, F)
Advisors: Advisors: Giovanni Casini casini@fi.infn.it, 0554572701 lab 0554572714
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General Physics Subject

The physics deals with the behaviour of nuclei far from stability, at conditions that can be reached on the Earth using energetic heavy-ion collisions. In particular the focus is on the Fermi energy domain (20-100 MeV/u) where NN-collisions play an important role during the nuclear reactions and very hot and deformed pieces of nuclear matter can be formed. The timescales of these systems are very short (<1zs) comparable with the interaction times. As a function of the reaction centrality, different outgoing channels can be populated, also depending on the size and the asymmetry of the incoming nuclei. Recently, the focus has been put on the formation and decay of clusters during these violent collisions because the accurate measurement of their properties can reveal details on the nuclear Equation of State (EoS) far from the equilibrium, in particular below/above the saturation density and towards the p or n drip lines. In turn, this has to do with the description of explosive and/or exotic astrophysical systems (e.g. SuperNovae explosion, NS-mergers, NS cooling process) which are currently the focus of strong interest thanks to the very recent multimessenger observation. The synergy between the information coming from terrestrial nuclear physics and astrophysical measurements is indeed welcome.

Specific proposed Physics goals

We want to address mainly this point: detect signals of neutron enrichment in the supposed diluted nuclear systems that form during the semiperipheral collisions [1,2]. Such neutron abundance in the so called midvelocity region between the phase-space regions of the fragment similar to the projectile and the fragment similar to the target could be related, within nuclear reaction models, to the symmetry energy potential. This is a part of the potential contributing to nuclear stability and whose behaviour far from saturation density is not well constrained.

Methods

Our group is since years involved in experiments aiming at precisely measuring charged particles and fragments coming from Fermi energy reactions [3,4], collecting data with well-performing detectors studied and assembled by the collaboration. Very briefly the methods consist in fixed-target experiments carried on with the FAZIA telescopes [5,6] coupled with the INDRA array at GANIL. The coupling permits to achieve large acceptance and thus to well characterize the detected events. Various reactions have been measured recently involving both symmetric and asymmetric reactions with ions of medium size (A<100). The well performing apparatus allows to to completely identify nuclei in mass and charge in the forward angular region up to Z=24-25. The event selection is very important to disentangle the various types of main sources (i.e. excited primary systems) that can break-up forming in turn smaller clusters. The experimental analysis is always guided and compared with simulated data, obtained running different reaction model codes. This allows to verify the analysis step by step and to constrain the specific model parameters when relevant.
The steps are:

- characterize the clusters in violent collisions for different selected event classes
- measure the isotopic content of fragments in the various reaction regions
- evaluate the neutron richness as function of rapidity
- study these effects for different bombading energies

The nuclear reactions that will be mainly studied are Ar+Ni at 95MeV/u Ni+Ni at 74MeV/u, with data collected in last spring 2022. Ramarkably, the last bullet can be addressed, for the Nickel system, thanks to data collected in previous experiments at Ganil on the reactions Ni+Ni at 32 and 52 MeV/u [7]. The three bombarding energies will permit to investigate the effects of neutron enrichment at midvelocity as function of the beam energy which is an unprecedented analysis.

Candidate skills and operating conditions

The candidate will work in team (both local and french subgroups) and will be engaged in the calibration and data reduction analysis of the events collected in an experiment performed at Ganil in spring 2022 with the INDRA-FAZIA set-up.

After the calibration phase the candidate will focus on the various event selection criteria, will quantify the various event classes also checking the quality of the selections adopted. The the candidate will perform various analysis to characterize the role and the nature of the various emissions of light particles and fragments.
C++ and ROOT based packages are mainly used, thus a certain software knowledge is beneficial. Reaction model simulations will be also run. Geant-4 simulations can be foreseen but are not mandatory. Since the detector electronics is fully digital many algorithms are used in the data analysis: the possibility to improve some of them in order to extract better information from the signals is not excluded. The candidate must be available to travels and to mid-long stays in the labs where experiments are performed; indeed, he/she could also participate to new experiments that will be proposed by the collaboration for the next 2023 at GANIL.
The candidate will be involved in the possible writing and publishing of papers and in the participation to Conferences where results will be presented.

References:
[1] S.Piantelli et al. Phys. Rev. C 103 034603,2021
[2] S.Barlini et al. Phys. Rev. C 87 054607, 2013
[3] S.Piantelli et al. Phys. Rev. C 101 034613,2020
[4] A.Camaiani et al. Phys. Rev. C 103 014605, 2021
[5] R. Bougault et al Eur Phys. Journal A, 50, 2014
[6] http://fazia.in2p3.fr/?lang=en
[7] C. Ciampi et al. Accepted in Phys. Rev. C, 2022