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: Prototyping new thin detectors for experiments at low bombarding energies
Apparatus: FAZIA type, alone or with GARFIELD CsI at LNL
Involved LABS: GANIL (Caen, F) for some test, LNL Padova.
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General Physics Subject
Experimental advances in the investigation of heavy-ion fusion processes at energies beyond the Coulomb Barrier (>6-10MeV/u) need the detection of rather complete events. This means that the apparatus should detect both the main nucleus (evaporation residue, ER) emitted at forward angles and the particles (charged or neutrons) emitted in broad angular regions, mainly coming from the decay of the excited compound nucleus just after the fusion. The access to rather complete events allows for balances in charge, mass, momentum; moreover, the measurments of the yield of the various emitted particles, isotopically separated as best as possible, permit accurate studies on the origin of these emissions and to separate evaporation from other mechanisms.

Specific proposed Physics goals
We mainly want to verify the presence and the persistence of the alpha cluster structure in fusion-evaporation reactions. It can be done by changing, in suitable ranges, the mass and the charge of the reactants, the beam energy, the asymmetry of the system and the neutron to proton ratios (N/Z). Our goal is to show alpha-cluster effects [1,4] in the properties of the ER and of the charge particles (LCP, neutrons are not detected); the effects appear, for instance, as differences with respect to the prediction of statistical models that interpret the evaporation contribution [3,4]. Our group has already started to address this topic [1,5] with experiments at Legnaro with Garfield-RCo apparatus [6]. The detection of the LCP is guaranteed by the large acceptance Garfield array that covers angles from 30 to 150 degrees. The proposed activity concerns the improvement of the detection of the ER, at very forward angles.

Methods
In many fusion reaction cases at the Legnaro energies, the ERs have rather low kinetic energy and so the their identification in charge is usually difficult. At present in our collaboration the detection of the ER is done with the RCo telescopes which feature a DE gas stage as a first layer: in this way the thresholds are lowered and the ER identification in charge is obtained up to Z=15 at least for rather energetic reactions.
On the other hand our group is also co-responsible of the FAZIA apparatus [7,8], now in Ganil, for experiments at higher energies (beams with E/A>20MeV) where we use a first stage made of Silicon sensors 300micron thick. Such layer is not well suited for low-E experiments as described above (DE-E threshold above 10MeV/u for Z>). Thus the proposal for this PhD is to design and develop a new first stage of Si-sensor with thickness around 20-25micron to largely decrease the threshold for Z identification at a level comparable with gas detectors.
The steps are:

- theoretical study of the phase-space regions accessible with a 20/25micron Si-stage in connection with the assumed fusion-like reactions doable at LNL
- take contacts with producer companies and follow the purchasing steps
- design, optimize the mechanics, the mounting, the back-compatibility of these new sensors with the previous telescope structure
- perform tests with source in lab with the FAZIA electronics, verifying if some modifications are needed on the analog stages of the FEE in use.
- In particular verify the Energy resolution, the effect of thickness non uniformity, the noise due to the larger capacitances.
- Since the complementary technique of E-tof can be used at low energy to help ER identification, study and verify the timing capability of the new thin stage for the E-tof technique applications. Efforts in this respect have been done in FAZIA [9]
- Perform Tests under beam of a small demonstrator with so thin Si-sensors as a first layer
- Propose an experiment to be done in LNL in order to use and benefit of the modified detection ensemble.

Candidate skills and operating conditions

The candidate will work in team (both local and other labs) and will be engaged in the various steps above.

C++ and ROOT based packages are mainly used, thus a certain software knowledge is beneficial. Reaction model simulations will be also run; some expertise in how to use MonteCarlo simulations can be important. Geant-4 toolkit for the accurate simulation of a complete telescope can be foreseen but are not mandatory. 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 and to the analyses on data collected in previous experiments at LNL

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] L. Morelli et al. J.Phys G 41, 075108 2014
[2] L. Morelli et al. J.Phys G 43, 045110 2016
[3] A. Camaiani et al. Il nuovo Cimento 42 C 2019
[4] A. Camaiani et al. Phys Rev C 97 044607, 2018
[5] X.G. Cao et al ArXiv, 01.07366v3 2018
[6] M. Bruno et al. Eur Phys. Journal A, 49, 2013
[7] R. Bougault et al Eur Phys. Journal A, 50, 2014
[8] http://fazia.in2p3.fr/?lang=en
[9] S. Valdrè et al Il nuovo Cimento C 43, 2020