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Perspective on "the future of GANIL"

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Dear valued members of the committee,

It is undisputable fact that GANIL with its state of the art instrumentation in the field of nuclear physics and large international projects such as Spiral 2 is one of the leading forces in the development of knowledge on nuclear physics as well as applications of high energy ion beams. In my perspective, however, this is not the only role that GANIL plays and may play in the future of the science in the regional as well as global context.

I would like to move your focus to one particular facility – ARIBE. ARIBE is a low energy facility of GANIL enabling collisional studies of slow highly charged ions with various targets such as molecules, ions, clusters or surfaces. The facility is hosting a large number of scientists each year and produce results qualitatively comparable to high energy facilities of GANIL. Even though, I think the potential of this facility is still not fully developed.

I will describe now my ideas in three particular fields of interest of our group. I start with most novel application of ARIBE to study processes occurring during Focused Ion Beam Induced Deposition (FIBID). FIBID technique is one of the nanofarbrication techniques that can be imagined as a 3D printing of metals on the nanoscale. Oranometallic precursor molecules are decomposed on the surface by interaction with ions, typically in keV range, which evaporate organic ligands and leave metal deposit on the surface. The technique is under development and so far several types of ion beams were proposed for applications such as He, Ne or Ga beams. The selection is based on commercially available ion sources and experiments are having applied character when trial-error is performed until the best performance is achieved concerning deposit resolution or material quality. The ARIBE facility dispose of projectile energy range relevant for FIBID and of wide range of the projectiles to be used for irradiation. ARIBE therefore provides an ideal tool for a basic research of projectile interaction with FIBID precursors in the form of molecules, clusters or deposited on the surfaces. Such fundamental studies (e.g. our pilot study [1]) may provide an important impetus for development of FIBID on the side of ion beam instrumentation as well as on the side of chemistry of the organometallic precursors.

The second field, where ARIBE provides an ideal tool for fundamental studies is radiation interaction with living tissue. While experiments at high energy beamlines of GANIL are of direct relevance and can be used e.g. for nanodosimetry, ARIBE enables detailed studies of individual processes occurring in the physico-chemical stage of the interaction. This stage in tissue practically starts with high number of charges localized in small dimensions and in laboratory it can be achieved by passing the highly charged ion in the vicinity of molecule or cluster at ARIBE facility. Well-designed experiments on individual beamlines of ARIBE then enable studies of different modes of energy transfer in this situation, total energy gained in Coulombic explosion or newly proposed processes such as interatomic and intermolecular Coulombic decay. Novel experiments are also under construction to study production of secondary electrons. These species may be important for the synergism observed for combined chemo-radiation therapy of cancer (see e.g. our study [2])

The third field, where I see a potential for contributions is the atmospheric chemistry. An important experiment was put into operation recently at Cern – CLOUD. This experiment aims to study interaction of galactic cosmic rays with atmospheric aerosol analogs prepared in highly controlled environment. Despite of state of the art analytical techniques available at CLOUD and precise control over aerosol formation parameters, interpretation of experiments

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is not trivial. Complexity of the interaction with high energy particles and complexity of the aerosol particles itself is too high. Detailed theoretical modelling is often possible only on much smaller heterogeneous molecular systems – clusters. Complementary experiments with clusters can therefore help to understand undergoing processes in CLOUD experiment and consequently in the atmosphere. Example is our recent paper in collaboration with AMO group at GANIL [3] showing an important proton transfer process in the heterogeneous clusters of pinenene and water. We are now having a beamtime granted for ARIBE facility to explore these interesting cluster species in different excited and charge states that can be very selectively prepared by interaction with slow multiply charged ions.

To conclude, ARIBE at GANIL is a versatile tool enabling very selective studies of processes relevant for many aspects of our lives. My list was focused on the studies that we are running or planning for the facility and it is far from being extensive. I thing, such interdisciplinarity is exactly what makes ARIBE an important facility with a great perspective.

As a point very specific for ARIBE, I would like to to mention that it acts as a knowledge transfer bridge between nuclear physics and physical chemistry. At ARIBE, not only the ion source and beamlines are provided by experts in nuclear physics but also the end-stations. The approach to experiment design, data acquisition or analysis is different of the techniques available in the physical chemistry laboratories and often provide new opportunities for research. This is particularly important for students and young scientists visiting GANIL, as I have seen within our small projects at ARIBE during the last years.

Sincerely yours,

Jaroslav Kočišek

Some relevant publications:

[1] Indrajith S. et al: Decomposition of Iron Pentacarbonyl Induced by Singly and Multiply Charged Ions and Implications for Focused Ion Beam-Induced Deposition, JPC C 123, 16, 2019 cover art

[2] Meissner, R. et al.:Low-energy electrons transform the nimorazole molecule into a radiosensitiser, Nat. Commun. 10, 2388 (2019)

[3] Poštulka, J. et al.:Proton transfer from pinene stabilizes water clusters, PCCP 21, 13925, 2019, back cover