Contribution aux exercices de prospective nationale 2020-2030

Accélérateurs et instrumentation associée

NEXT GENERATION OF TARGETS

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Informations générales

Titre : Next generation of targets
Acronyme : *(optionnel)*

Résumé *(max. 600 caractères espaces compris)*
Irradiation targets and thin foils in general (used as strippers, converters or material for nuclear reactions) are essential ingredients in accelerators and nuclear experiments. Up to now, these objects are mainly in solid form but with ever higher intensities and the need for heaviest, high-Z nuclei to be accelerated, their integrity and lifetime can become a major concern. We propose to investigate the limitations of present material, to explore the manufacturing and use of gaseous or liquid targets and to consider alternative methods for solid material (e.g. actinides). These suggestions are made on the basis of some developments currently being considered or in use in facilities worldwide.

Préciser le domaine de recherche *(plusieurs choix possibles)*

- o *Sources de particules (ions lourds stables, ions radioactifs…) et cibles associées*
- o *Développement durable de la discipline (infrastructures technologiques, fiabilité…)*
- o *Autre R&D spécifique : (préciser)*

Préciser la motivation principale visée par la contribution :

- o *Accélérateurs pour la physique nucléaire*
- o *Accélérateurs pour les applications sociétales (santé, énergie, industrie…)*

1. Description des objectifs scientifiques et techniques

To meet the demands of various specific applications in nuclear physics, research and development to improve target production are major issues. There is a need to develop new methods of fabrication and search for alternative solutions compared to the present ones.

(1) Thin targets for nuclear physics experiments

In the coming years, with unprecedented high intensity beams from the superconducting linear accelerator of the SPIRAL2 infrastructure rare exotic nuclei for fundamental physics or for direct application, i.e. radioisotopes, will be accessible in larger amount. However, the limited lifetime of targets can become a principal bottleneck for the intensity upgrade due to their large heat deposit inducing increase of radiation damage, i.e. weakening of the material by modifying the solid lattice. Then, in order to keep the structural integrity of the target, the dissipation of the high power deposited into them by the primary beam is a major challenge. Although targets stations are designed for targets to sustain such intensities (up to 10 pµA at S^3) in terms of heating, up-to-date development on target preparation can be envisaged in order to go beyond present technologies.
With the « Super Separator Spectrometer S3 », the observation of very exotic nuclei in the Super Heavy Element region (Z>104, SHE) or at the drip line will become possible. Such nuclei are produced by fusion-evaporation reaction of heavy ions at the Coulomb barrier with nuclei of thin (≈300µg/cm²) isotopically enriched targets, made either of stable material (Pb, Bi, Ni,

…) to be used at short term or then of actinides (Cm, Pu, Am….). In addition, LINAC beams are efficient tools to investigate radioisotopes for medical application where bismuth targets are essential.
In a vacuum spectrometer an additional solid thin foil of carbon placed, few centimeters downstream of the targets, aims at equilibrating the charge state of the produced nucleus.

a. From solid to liquid state

As an alternative to stable material, developing liquid or gaseous targets would be a pathway. It would help in preventing to deal with the radiation damage. Moreover, it allows ignoring backing material, necessary for solid target or the presence of other elements in the chemical composition (compounds such as oxides) which can induce background by interfering with the "good" events of the nuclei of interest.
A "metallic" liquid target was designed within the project LIEBE (Liquid Eutectic Lead Bismuth Loop Target for EURISOL) (1) and looks promising. Within the recent accepted ANR, REPARE, aiming at the study of radioisotopes, specifically ^{211}At, the workpackage "High Power Liquid Target" considers the design of such liquid Bi targets taking into account the issues on safety and confinement. A further development based on this concept could be conducted by taking into account specific requirements of targets used in fusion-evaporation reaction (S^3 and radioisotopes).
For neutron production, presently solid Be and Li converters are envisaged to solve the problem of withstanding currents of 20-30 µA for light beams of 30MeV, depositing 1MeV within a thickness of 1mm. In order to accept higher beam power, a compact liquid-lithium target was built and tested at the SOREQ Nuclear Research Center for neutron production (2), (3) and is under test at FRIB (4). It is known that the use of liquid lithium is problematic in terms of safety. Therefore, a precise study of its interest in our community should be conducted.

a. From solid to gaseous state

Carbon foils, often used as strippers as well as charge state equilibrium system in vacuum spectrometers, are not considered as critical issues in general because of their high melting point. Nevertheless, it was observed that with heaviest beams (U beams) at low energy their lifetime decreased dramatically.
That is why facilities as GSI, MSU/ANL and RIKEN have extensively studied alternatives to carbon foils (5), (6): FAIR and RIBF use N_2 (7) or He gas (8), (9) strippers respectively and FRIB a liquid lithium stripper (4). A review comparing the performance of solid strippers to gas and liquid ones is given on (10).
At first glance, the main constraints for gas material are the pressure regulation and the length necessary to achieve the desired thickness (30 µg/cm² = 0.7 m at 10 mbar). A detailed study on the drawbacks and advantages of such gas system for replacing carbon foils in spectrometers such as S^3 is worthwhile to be conducted.

b. Actinide targets

Actinide targets will open new opportunities in SHE or fission and nuclear data studies. Nevertheless, due to their scarcity and radiochemical constraints, efficient methods of production and specific, dedicated facilities are needed to manufacture them. Currently, the most widely applied process for the production of thin Actinide layers is molecular plating. This method is known to quickly produce deposits of acceptable uniformity and adherence with rather high yields. But this method requires “thick and conductive” backings, limiting their choice.

- To pursue this common production method, radiochemists at IPNO conduct detailed studies on the deposition mechanism, coupled with precise characterization of the layers at each step of the process.
- We propose also to reduce the thickness of the backing and the study of alternative material to limit the heating of the target and to favor the adhesion of the layers.
- A novel method, called Drop-on-Demand (DoD) inkjet printing technique (11), has been developed recently. It enables the production of targets of varying size and geometry on different substrates.

These latter studies were proposed in collaboration with radiochemists from IPN Orsay and the University of Mainz, the members of the target laboratories at GSI and GANIL responding to recent calls of ANR (PRCI). Despite the positive and favorable reports of the reviewers, the proposal was rejected by the funding agencies.
Another efficient and novel approach was conducted at Dubna in collaboration with PSI considering intermetallic targets (12).
The continuation of these latter studies in collaboration with our international colleagues would be of great interest for our community. In the European framework, this initiative is described in the SANDA EU-project (h2020-nfrp2018) which aims at maintaining and developing European facilities for actinide targets production and fostering their network.

(2) Targets for SPIRAL1

Presently, only carbon targets are used for SPIRAL1 facility, but other materials as Niobium, Al_2O_3, SiC, MgO, CaO can be envisaged. Indeed, Nb, already used in (13), can be irradiated with a ^{12}C beam to produce nuclei up to Z=41 with higher intensities as present ones. This channel would be of interest for following exotic beams: ^{60}Zn, ^{64}Ge, ^{63}Ga, ^{67}As, $^{72,74,76}Kr$, ^{79}Se. Other materials, Al_2O_3, SiC, MgO, CaO… (14), (15) can be found as a porous ceramic or impregnated in carbon foam (RVCF). Their exploitation on SPIRAL1 would give access to $^{21\text{-}22}Mg$, ^{25}Al, $^{10\text{-}11\text{-}15\text{-}16}C$, ^{28}Mg, ^{30}P, $^{32\text{-}33}P$… beams.
These new targets have to be tested off-line beforehand in order to prove their stability under high temperature. Moreover, irradiation of samples has to be conducted to study their release efficiency for radioactive atoms.

2. Développements associés, calendrier et budget indicatifs

The developments associated to each of the cases described above are different and have to be evaluated one by one. For some cases, the interest to use gaseous or liquid material is not straightforward. A detailed balance between pros and cons has to be evaluated.

3. Impact

Such proposed technical development will directly have an added value for nuclear physics and a societal impact due to the radioisotopes made available for the benefit of the whole society.

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