

STUDY OF NUCLEI FAR FROM STABILITY
WITH EXOTIC NUCLEAR BEAMS

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The projectile fragmentation process has been extensively studied, since the advent of high-energy heavy-ion beams. A wide variety of stable and unstable nuclei are created as fragments in this process. The fragments sustain a velocity almost equal to that of the projectiles and their emission is limited in a narrow cone in the forward direction¹. A vast scope is now open for formation and use of such exotic beams to study basic properties of nuclei far from stability. Measurement of interaction cross section, σ_I is described here in the first half. The interaction cross section is defined as the total cross section for the process of nucleon(s) removal from the incident nucleus. Interaction and root-mean-square radii have then been deduced for stable and unstable light nuclei.

Secondary exotic nuclei were created at a creation target through the projectile fragmentation of 800 MeV/u primary beams, ranging from ¹¹B to ⁴⁰Ar. The created fragments were rigidly separated and focussed by a magnetic analyzing system of the beam transport line of Bevalac at the Lawrence Berkeley Laboratory and then led onto the reaction target². This method supplied us, together with the measurements of ionization loss and time of flight, with the clean beams of stable and unstable nuclei. The interaction cross section, σ_I was measured by a transmission-type experiment by using a large-gap magnetic spectrometer HISS³.

The measured interaction radii were converted to R_{rms} by a Glauber-type calculation. The charge radius $R_{c,rms}$ for stable nuclei agreed well with the results of nuclear radius determination by electron scattering.⁴

It is seen in Fig. 1 that the R_{rms} are well extracted to manifest the difference between those for ⁶He-⁶Li, ⁸He-⁸Li and ⁹Li-⁹Be. On the other hand, a pair of mirror nuclei ⁷Li-⁷Be show the same matter radius. The large radii of the neutron-rich isotopes ⁶He and ⁸He suggest the existence of thick neutron crusts. It is interesting to note that the nuclei ¹¹Li and ¹⁴Be show extremely inflated radii over the neighbouring nuclei, which suggests the existence of a long tail in the matter distribution partly due to the binding effect.

We now turn to another subject which may involve the use of exotic nuclear beams.

It has long been known that a positive ion, when it is introduced in liquid helium, exerts electrostriction on helium atoms surrounding it and

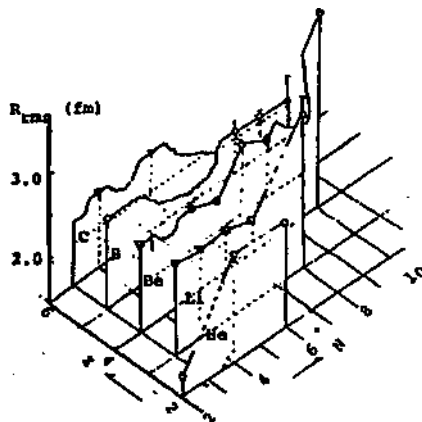


Fig. 1 Rms matter radii

forms a charged aggregate, which is referred to as "snowball". Thus the ion acquires effective mass of 50 - 100 times the He mass. Such a snowball has been a versatile probe in studying the elementary excitation in superfluid helium.⁵ Lack of proper methods for detection of snowballs has been a main obstacle for further studies in this field.

In our first experiments carried out at Research Center for Nuclear Physics, Osaka University, short-lived beta-ray emitters, ^{12}B , sustaining nuclear spin polarization were produced in the $^{232}\text{Th}(^{14}\text{N}, ^{12}\text{B})$ reaction at 135 MeV and were introduced into superfluid helium. Many of boron ions were neutralized instantaneously, but some survived to form snowballs. The charged snowballs thus formed were transported in a static electric field and were separated from the neutralized ^{12}B . The nuclear polarization of ^{12}B was then observed via measurement of beta-ray asymmetry and was compared with the known original polarization.⁶ It was found that the nuclear polarization was preserved throughout the lifetime of ^{12}B (20.3 ms). This suggests that the snowball produced around an alien ion, constitutes a suitable milieu for preserving (freezing out) the nuclear spin polarization of the core ion and that most likely the solidification takes place at the interior of the aggregate. This novel method of transportation and detection will open a new way to study nuclear moments of various unstable nuclei by using the freezing-out of polarization of exotic beams.

This method will open another new way for investigating, besides properties of nuclei far from stability, basic interactions in superfluid helium. Beams of beta-active nuclei are introduced into the superfluid helium as impurity ions and the snowballs formed around radioactive nuclei are detected by the beta-rays from the short-lived nuclei. One of the interests is the use of ^6He and ^8He and many other beta-active nuclei to study the transport phenomena related to impurity ions and thus basic interactions in liquid helium.

The author wishes to express his thanks to all the collaborators of the projects described here.

The first half of this work is supported in part by the Director, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the US Department of Energy under Contact Number DE-AC03-76SF00098, by the INS-LBL Collaboration Program and the Japan-US Joint Program for High-Energy Physics. The second half of this work is supported in part by the Grants in Aid of Scientific Research and Toray Science and Technology Grants.

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