CONF-850912--27

LA-UR--85-3234

DE86 000770

TITLE POTENTIAL CAPABILITIES AT LAMPF TO STUDY NUCLEI FAR FROM STABILITY

AUTHOR(S) W. L. Talbert, INC-11
M. E. Bunker, INC-5

SUBMITTED TO Symposium on Recent Advance in the STudy of Nuclei off the Line of Stability, American Chemical Society,
Chicago, IL, Sept. 9-13, 1985

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

POTENTIAL CAPABILITIES AT LAMPF TO STUDY NUCLEI FAR FROM STABILITY*

W. L. Talbert, Jr. and M. E. Bunker
Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Abstract: Feasibility studies have shown that a He-jet activity transport line, with a target chamber placed in the LAMPF main beam line, will provide access to short-lived isotopes of a number of elements that cannot be extracted efficiently for study at any other type of on-line facility. The He-jet technique requires targets thin enough to allow a large fraction of the reaction products to recoil out of the target foils; hence, a very intense incident beam current, such as that uniquely available at LAMPF, is needed to produce yields of individual radioisotopes sufficient for detailed nuclear studies. We present the results of feasibility experiments on He-jet transport efficiency and timing. We also present estimates on availability of nuclei far from stability from both fission and spallation processes. Areas of interest for study of nuclear properties far from stability will be outlined.

1. Introduction

A He-jet coupled on-line mass separator, used in conjunction with a target chamber placed in the LAMPF main beam, offers an especially attractive approach for the study of nuclei far from stability. Such a facility would provide access to isotopes of a number of elements that cannot be efficiently extracted for study at any other type of on-line separator system, and the use of a long capillary transport line would allow the separator ion source to be located outside the accelerator beam-line shielding, greatly reducing the installation cost. The He-jet technique requires thin targets in order for the reaction products to escape, and to produce a sufficient yield of radioisotopes far from stability for detailed nuclear studies, a beam intensity comparable to that available at LAMPF is needed.

The mass-separated ion beams extracted from the proposed system would be directed to various experimental devices capable of determining basic nuclear properties such as half-life, spin, nuclear moments, mass, and nuclear structure. The data acquired would have broad application to theories of nuclear matter and to such related topics as nucleosynthesis of the elements. We

* Work supported by the U.S. Department of Energy.

estimate that several hundred previously unobserved nuclei, both neutron-deficient and neutron-rich, would become available for study.

This report presents a brief summary of the results of our He-jet feasibility studies, along with estimates of which nuclei would become available with our proposed facility. Specific areas for initial studies are also suggested.

2. He-jet activity transport studies

The concerns addressed in our feasibility studies of He-jet activity transport were: 1) Will the He-jet technique work at the beam intensities that exist at LAMPF?; 2) What transport efficiencies can be expected for both fission and spallation products?; 3) What is the time dependence of the activity transported?; and 4) What aerosols and/or aerosol conditions are optimum?

Using both spallation- and fission-product targets in the LAMPF H^- beam, we determined that the He-jet technique should work well at LAMPF beam intensities (~800μA). Absolute efficiencies for transport of refractory-element activities through a 22-m long capillary were found to average about 60%. Transit time measurements appear convincing that activities as short as 300 ms could be made accessible for study. We found that $PbCl_2$ aerosols provided more efficient transport than KCl or NaCl aerosols.

Optimization of the target chamber configuration resulted in a design employing two radially-directed inlets at ± 135° to a single radially-directed capillary outlet. We have chosen an inside capillary diameter of 2.4 mm as a reasonable compromise between target chamber purge rate and helium flow rate.

Two target chambers have been designed, one for fission targets and one for spallation targets. These chambers, which are designed for remote servicing, would be located at the end of a vertical shield plug near the LAMPF beam-stop. The target chambers incorporate the inlet and outlet geometries determined from our feasibility experiments and feature double containment to allow use of actinide targets.

One concern remains in our considerations. Despite the considerable experience in coupling a He-jet to a mass separator ion source [MOL81,CKA81], the reported total efficiencies are characteristically less that those achieved with normal on-line separator systems. Current efforts to improve the He-jet coupling and ionization efficiencies are, however, showing progress. An ion optical design has been made that incorporates a non-dispersive intermediate image to allow for correction of ion source fluctuations. A conceptual layout for the on-line system with this design is shown in Fig. 2.1.

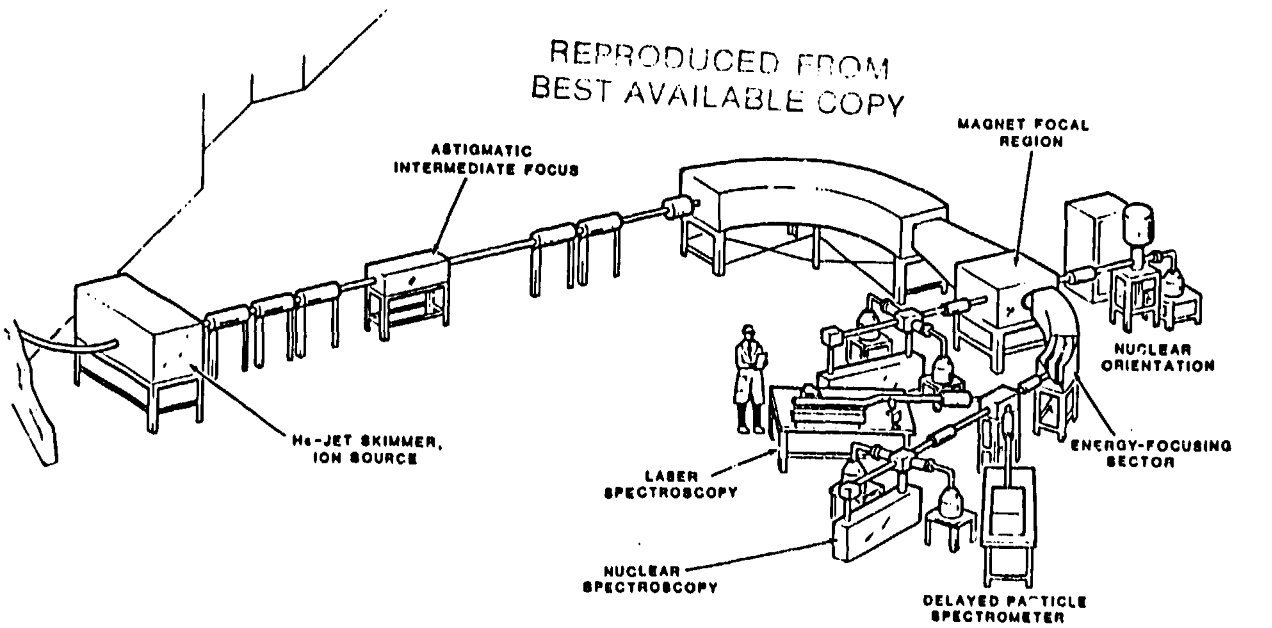

Fig. 2.1 Layout of the proposed on-line mass separator system at LAMPF, showing conceptual ion optical design for a single magnetic stage.

3. Production estimates for nuclei far from stability

To define more accurately the boundaries of the mass regions that could be accessed with the proposed He-jet coupled mass separator system, production cross sections for both neutron-deficient and neutron-rich nuclei far from stability have been estimated for 800-MeV proton reactions. The spallation-product cross sections were estimated through use of the Rudstam systematics [RUD66]. For estimation of the fission-product cross sections, however, there is no established, similar approach. Thus, an empirical approach was taken in which two overlapping Gaussian distributions were fitted to existing rubidium and cesium isotopic distributions obtained at 156 MeV, 170 MeV, and 1 GeV [TRA72,BEL80] -- one Gaussian for the neutron-rich portion of the distribution and one for the neutron-deficient portion. The parameters of the Gaussians were then varied with A and Z to account for the mass-yield variations and other differences between the rubidium and cesium data. Adjustment of the cross-section distributions to 800 MeV was accomplished by interpolation.

If we assume that 1000 atoms/s of a mass-separated radionuclide are needed for spectroscopic measurements and that the mass separator system has only a one-percent overall efficiency, a partial production cross section of about 0.7 μb is required for the nuclide in question, assuming a LAMPF beam intensity of 800 μA. According to our cross-section estimates, essentially all neutron-deficient nuclei with calculated [TAK73] half-lives >300 ms will be produced in 800-MeV spallation with a cross section of >1 μb (assuming the use of at least 10 different target materials). Interesting nuclear regions that could be reached include those near ^{76}Sr and ^{100}Sn. On the neutron-rich side of stability, most nuclei with half-lives >300 ms and mass 60-140 can be produced in high-energy fission of ^{238}U with a cross section of >1 μb. Table 3.1 summarizes the enormity of our current ignorance of nuclei far from stability accessible by high-energy spallation and fission reactions, despite over two decades of prolific on-line studies.

Table 3.1. Numbers of nuclei with unknown properties between known limits and 300-ms (according to the gross theory of beta decay[9]) or 1-μb cross-section limits; Z=10-90.

Property	Neutron-rich [$^{238}U(p,f)$]	Neutron-deficient [Spallation]
Mass	281	436
Half-life	170	198
Decay scheme	243	630
Spin-parity	300	484

Of those nuclei included in Table 3.1, we expect that unique access to about half would come from a He-jet coupled mass separator at LAMPF. We plan to use this unique access to advantage in proposed studies, to complement (rather than compete with) similar studies at other on-line facilities.

4. Possible Specific Studies

Given the large variety of new nuclei that would become available with the proposed on-line separator system, a focus is needed for possible initial studies. On the other hand, the importance of making systematic studies of nuclear properties over sizeable regions must be recognized. For example, the novel feature of shape coexistence was established only through detailed, systematic studies of nuclear decays. A notable feature of the proposed on-line mass separator system is the capability to make unique nuclear structure studies in several interesting regions.

One such region is that around N=Z=38, postulated to be a region of strong deformation [MÖL81]. Although this prediction has some experimental support [LIS82,PRI83,HEY84], other theories predict nuclei in this region to be spherical, with some softness toward deformation [ÅBE82,BUC79]. Recent work in this region suggests an apparent quenching of pairing correlations in ^{84}Zr, resulting in moments of inertia at about rigid-body values [PRI83].

The neutron-rich nuclei near ^{100}Zr comprise another recently established deformed region [KHA77,WOL77,SCH80,AZU79]. Here, the onset of deformation is especially abrupt, and strong quenching of pairing correlations seems indicated [PEK85]. The He-jet technique offers the capability of mapping the extent of this unusual deformed region in the refractory-element area above A=100 -- a region presently inaccessible at other on-line facilities.

The region around ^{100}Sn also offers exciting possibilities. Studies of nearby nuclei have been unable to determine the applicable coupling scheme or the interplay of the nearly symmetric neutron-proton configurations. Furthermore, heavy-ion reaction cross sections pose a severe limit in extending the previous studies in this region.

Last, but not least, it is important to search for other regions besides the Pt region in which the nuclear structure can be described in terms of supersymmetric boson-fermion theory. The proven existence of several such regions would bring us one step closer to a comprehensive theory of all nuclei.

References

[ÅBE82] S. Åberg, Phys. Scr. 25, 23 (1982).

[AZU79] R. E. Azuma, G. L. Borchert, L. C. Carraz, P. G. Hansen, B. Jonson, S. Mattsson, O. B. Nielsen, G. Nyman, I. Ragnarsson, and H. L. Ravn, Phys. Lett. 86B, 5 (1979).

[BEL80] B. N. Belyaev, V. D. Domkin, Yu. G. Korbulin, L. N. Androneko, and G. E. Solyakin, Nucl. Phys. A348, 479 (1980).

[BUC79] D. Bucurescu, G. Constantinescu, and M. Ivascu, Rev. Roum. Phys. 24, 971 (1979).

[HEY84] K. Heyde, J. Moreau, and M. Waroquier, Phys. Rev. C 29, 1859 (1984).

[KHA77] T. A. Khan, W. D. Lauppe, K. Sistemich, H. Lawin, G. Sadler, and H. A. Selic, Z. Phys. A283, 105 (1977).

[LIS82] C. J. Lister, B. J. Varley, H. G. Price, and J. W. Olness, Phys. Rev. Lett. 49, 308 (1982).

[MÖL81] P. Möller and J. R. Nix, At. Data Nucl. Data Tables 26, 165 (1981).

[MOL81] D. M. Moltz, Nucl. Instr. and Meth. 186, 135 (1981) and references therein.

[OKA81] K. Okano, Y. Kawase, K. Kawade, H. Yamamoto, M. Hanada, and T. Katoh, Nucl. Instr. and Meth. 186, 115 (1981).

[PEK85] L. K. Peker, F. K. Wohn, J. C. Hill, and R. F. Petry, to be published.

[PRI83] H. G. Price, C. J. Lister, B. J. Varley, W. Gelletly, and J. W. Olness, Phys. Rev. Lett. 51, 1842 (1983).

[RUD66] G. Rudstam, Z. Naturforsch. 21a, 1027 (1966).

[SCH80] F. Schussler, J. A. Pinston, E. Monnand, A. Moussa, G. Jung, E. Koglin, B. Pfeiffer, R. V. F. Janssens, and J. van Klinken, Nucl. Phys. A339, 415 (1980).

[TAK73] K. Takahashi, M. Yamada, and T. Kondoh, At. Data and Nucl. Data Tables 12, 101 (1973).

[TRA72] B. L. Tracy, J. Chaumont, R. Klapisch, J. M. Nitschke, A. M. Poskanzer, E. Roeckl, and C. Thibault, Phys. Rev. C 5, 222 (1972); J. Chaumont, Ph.D. thesis, Faculté des Sciences Orsay, 1970 (unpublished).

[WOL77] H. Wollnik, F. K. Wohn, K. D. Wunsch, and G. Jung, Nucl. Phys. A291, 355 (1977).