Lawrence Berkeley National Laboratory

Recent Work

Title

Radioactive Nuclear Beams, The First International Conference

Permalink

https://escholarship.org/uc/item/39w3x8d7

Author

Nitschke, J.M.

Publication Date

1989-09-01

eScholarship.org Powered by the California Digital Library
University of California

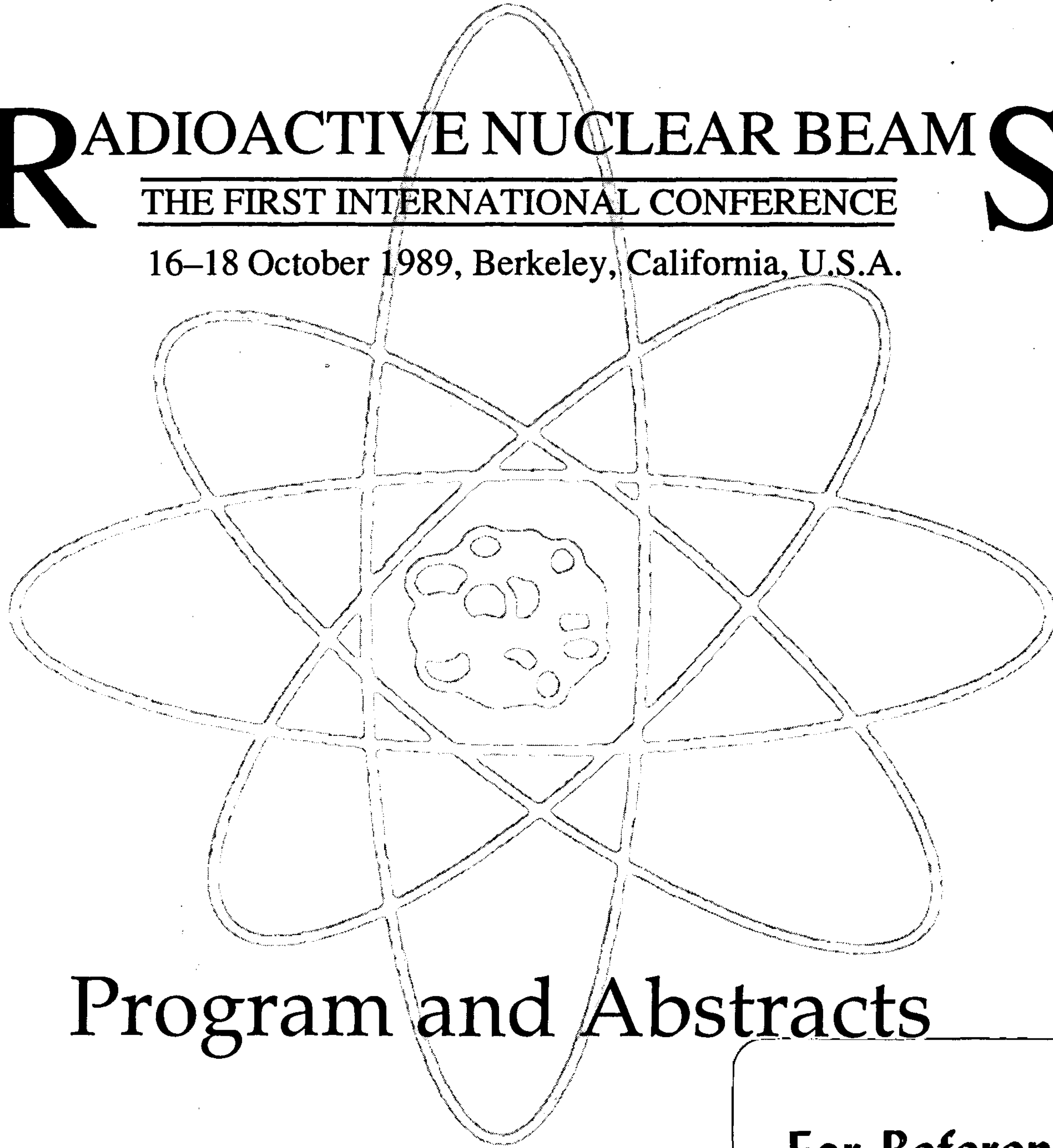
UC-413

LBL-27801
September 1989

RADIOACTIVE NUCLEAR BEAMS

THE FIRST INTERNATIONAL CONFERENCE

16–18 October 1989, Berkeley, California, U.S.A.



Program and Abstracts

For Reference

Not to be taken from this room

Lawrence Berkeley Laboratory
University of California, Berkeley

Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098

LBL-27801
Copy 1
Bldg. 50 Library.

Radioactive Nuclear Beams
Berkeley, California • October 16–18, 1989
Program Summary

8:00 | 9:00 | 10:00 | 11:00 | 12 noon | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00

Sunday									**Registration 5:00–9:00 at Shattuck Hotel and Poster Set-Up at Berkeley Conference Center**
Monday	*REGISTRATION AT BERKELEY CONFERENCE CENTER 8:00 A.M. – 5:00 P.M.*								
	WELCOME	A1...A2..	COFFEE	A3...A4..A5	LUNCH	A6...B1	COFFEE	B2...B3..B4	
Tuesday		B5...B6..B7	COFFEE	C1...C2..C3	LUNCH	D1...D2..D3	COFFEE	D4...D5..D6	**POSTER SESSION Wine & Cheese Reception**
Wednesday		D7...D8..D9	COFFEE	D10...E1..E2	LUNCH	F1...F2..F3	COFFEE	F4...F5..F6	
Thursday	**Workshop on a National High-Intensity Radioactive Beam Facility Bldg 71 (SuperHILAC) Conference Room (Rm. 264)**								

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

LBL-27801

The First International Conference on Radioactive Nuclear Beams

Program and Abstracts

16–18 October 1989
Berkeley, California

J.M. Nitschke, Conference Chairman

Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, California

This work was supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098

Preface

On behalf of the Organizing Committee it is my pleasure to welcome you to the *First International Conference on Radioactive Nuclear Beams*. Bringing together researchers from different disciplines the conference seeks to facilitate the presentation of ideas and the exchange of information in this new field. Although the number of operating radioactive beam facilities is still relatively small, several are under construction or being proposed. This expansion of experimental capabilities in the new dimension of isospin may have similar impact on our understanding of the nucleus as explorations in the domains of spin and temperature. The production of high-intensity radioactive nuclear beams needed for these studies presents many technological challenges, and a goal of the conference is to provide a scientific basis for determining the specifications of future facilities.

Close to 80 abstracts have been submitted to the conference, with subject material spanning a wide range from basic science to applications. The field of Radioactive Nuclear Beams is still in the process of defining itself and some papers presented will overlap with topics discussed at meetings focussing on nuclei far from stability. Judging from the affiliations of the over 300 authors, it is interesting to note that the emerging field of radioactive beams has already attracted scientists from fourteen different countries; with several additional countries represented among the conference participants.

The organization of a conference with participation from such diverse fields is a difficult task, and in putting together the program we have received valuable help from members of the International Advisory Committee. I wish to thank them for their contributions and hope that the meeting will be stimulating and informative.

J. Michael Nitschke
Conference Chairman

Conference Chairman

J.M. Nitschke

LBL Organizing Committee

K. Matsuta
W.D. Myers
J.M. Nitschke
E.B. Norman
J. Randrup

International Advisory Committee

P. Armbruster, FRG
J. D'Auria, Canada
W.A. Fowler, USA
P.G. Hansen, Denmark
M. Huyse, Belgium
G.J. Mathews, USA
W. Mittig, France
C. Rolfs, FRG
I. Tanihata, Japan

Session Chairmen

Session I:	I. Tanihata, RIKEN, Japan
Session II:	J. D'Auria, Simon Fraser University, Canada
Session III:	G.J. Mathews, Lawrence Livermore National Laboratory, USA
Session IV:	G. Münzenberg, GSI, FRG
Session V:	W. Mittig, GANIL, France
Session VI:	M. Huyse, Catholic University, Leuven, Belgium

Conference Host

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Conference Site

The Berkeley Conference Center
2105 Bancroft Way
Berkeley, California 94704 USA

Phone number for messages during the
Conference (8:30 a.m.–5:00 p.m.)
(415) 486-6155

Conference Secretariat

Peggy Little
Conference Coordinator
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720 USA

Phone: (415) 486-6387
FAX: (415) 486-5401
Telex: 9103662037

PROGRAM

Monday, October 16, 1989

9:00–9:10		Welcome	C.V. Shank
9:10–9:15		Opening Remarks	J.M. Nitschke

Session I. Chairman: I. Tanihata

RNB Facilities			
9:15–9:45	A1	Radioactive Ion Beams at Louvain-la-Neuve: Production, Acceleration, and Uses *(invited, 30 min.)*	J. Vervier
9:50–10:20	A2	Exotic Nuclei Arena in the Japanese Hadron Project *(invited, 30 min.)*	T. Nomura
10:25–10:45		*Coffee*	
10:45–11:15	A3	Radioactive Nuclear Beams of the Moscow Meson Facility *(invited, 30 min.)*	A.S. Iljinov
11:20–11:50	A4	The TISOL Facility at TRIUMF *(invited, 30 min.)*	J.M. D'Auria
11:55–12:15	A5	Proposals and Estimates for an Experimental Program at ISAC *(20 min.)*	L. Buchmann
12:20		*Lunch*	

Session II. Chairman: J. D'Auria

2:00–2:30 p.m.	A6	A Concept for Post-Acceleration of Radioactive Ions *(invited, 30 min.)*	H. Haas
RNB Production			
2:35–3:05	B1	The GSI Projectile-Fragment Separator—Status and Planned Experiments *(invited, 30 min.)*	G. Münzenberg
3:10 –3:30		*Coffee*	
3:30–3:50	B2	Experiments for the Isotope Separation of Secondary Beams with the Momentum-Loss Achromat *(20 min.)*	K.-H. Schmidt

3:55–4:15	B3	Radioactive Beam Production at the Bevalac *(20 min.)*	J.R. Alonso
4:20–4:40	B4	Systematics of Fragmentation Cross Sections: Empirical Descriptions and Microscopic Calculations *(20 min.)*	K. Sümmerer

Tuesday, October 17, 1989

Session III. Chairman: G. J. Mathews

9:00–9:20 a.m.	B5	LISE: A Recoil-Spectrometer at GANIL for the Production and Study of Secondary Radioactive Beams. Present Status and Future *(20 min.)*	A.C. Mueller
9:25–9:45	B6	Polarization of Radioactive Beams: First Results on Low-Energy Beams and Comparison of Methods *(20 min.)*	J. Wouters
9:50–10:10	B7	Spin-Polarized Radioactive Isotope Beams from Intermediate Energy Heavy Ion Collision *(20 min.)*	D. Mikolas
10:15–10:35		*Coffee*	
Astrophysics 10:35–11:05	C1	Radioactive Ion Beams in Astrophysics: A Discussion of Some Selected Reactions and of their Astrophysical Impact *(invited, 30 min.)*	M. Arnould
11:10–11:30	C2	Unstable Proton-Rich Nuclei Relevant to the Breakout Process from the Hot-CNO Cycle *(20 min.)*	S. Kubono
11:35–11:55	C3	Reaction Rates in the rp-Process Beyond $^{13}N(p,\gamma)^{14}O$ *(20 min.)*	M. Wiescher
12:00		*Lunch*	

Session IV. Chairman: G. Münzenberg

Nuclear Structure			
2:00–2:30 p.m.	D1	New Physics or Looking for Precursors of aNeutron Matter *(invited, 30 min.)*	W. D. Myers
2:35–2:55	D2	Dipole Vibration in Extremely Neutron-Rich Nuclei *(20 min.)*	Y. Suzuki
3:00–3:20	D3	The Possibilities of Synthesizing Heavy Elements in the Complete Fusion of Unstable Nuclei *(20 min.)*	A.S. Iljinov
3:25–3:45		*Coffee*	
3:45–4:10	D4	Deeply-Bound Pionic Atoms in Unstable Heavy Nuclei to be Formed with Radioactive Nuclear Beams *(20 min.)*	T. Yamazaki
4:10–4:30	D5	RNB Coulomb Excitation: ^{8}Li + Au *(20 min.)*	F.D. Becchetti
4:35–4:55	D6	A Test for Exchange Resonances in ^{7}Be-^{7}Li Scattering *(20 min.)*	R.N. Boyd
5:00–7:00 p.m.		**Poster Session and Wine and Cheese Reception**	

Wednesday, October 18, 1989

Session V. Chairman: W. Mittig

9:00–9:20 a.m.	D7	Nuclear Reactions and Electromagnetic Dissociation *(20 min.)*	J.P. Dufour
9:25–9:45	D8	Electromagnetic Dissociation of Exotic Projectiles at 0.8 GeV/nucleon *(20 min.)*	T. Kobayashi
9:50–10:10	D9	A Parity Violation Experiment with a Separated Beam of Tc Isomers *(20 min.)*	G. Goldring
10:15–10:30		*Coffee*	
10:35–10:55	D10	On the Production of a Beam of the Long-Lived 16+ Isomer in Hafnium-178 *(20 min.)*	W. Kutschera

RNB Applications

11:00–11:20	E1	Laser Spectroscopy of Reaction Products in a Cooled Gas Cell *(20 min.)*	G.D. Sprouse
11:25–11:45	E2	Applications of Radioactive Beams in Diagnostic Studies *(20 min.)*	A. Chatterjee
11:50		*Lunch*	

Session VI. Chairman: M. Huyse

Macroscopic Properties

2:00–2:30 p.m.	F1	A Systematics of the Nuclear Radii *(invited, 30 minutes)*	I. Tanihata
2:35–2:55	F2	Energy Dependence of Interaction Cross-Sections *(20 min.)*	S. Shimoura
3:00–3:20	F3	Radii of Radioactive Nuclei *(20 min.)*	A.C.C. Villari
3:25–3:45		*Coffee*	
3:45–4:05	F4	Magnetic Moment of Projectile Fragment ^{43}Ti *(20 min.)*	K. Matsuta
4:10–4:30	F5	Mass Measurements Using the GANIL Cyclotrons *(20 min.)*	E. Plagnol
4:35–5:05	F6	Testing Atomic Mass Models with Radioactive Beams: Motivations and Methods *(invited, 30 min.)*	P.E. Haustein

Thursday, October 19, 1989

Bldg. 71 (SuperHILAC) Conference Room (Rm. 264)
Lawrence Berkeley Laboratory

9:00 a.m.–12:30 p.m.	Workshop on a National High-Intensity Radioactive Beam Facility

TABLE OF CONTENTS *

* **Speakers are underlined**

ASTROPHYSICS

NUCLEAR STRUCTURE

Posters

Posters continued

RNB APPLICATIONS

Poster

MACROSCOPIC PROPERTIES

RNB Facilities

RADIOACTIVE ION BEAMS AT LOUVAIN-LA-NEUVE : PRODUCTION, ACCELERATION AND USES

M. Arnould[2], D. Darquennes[1], P. Decrock[3], Th. Delbar[1], W. Galster[1], M. Huyse[3], Y. Jongen[1], M. Lacroix[1], P. Leleux[1], I. Licot[1], P. Lipnik[1], M. Loiselet[1], G. Ryckewaert[1], G. Scheveneels[1], Sindano Wa Kitwanga[1], P. Van Duppen[3], J. Vanhorenbeeck[2], J. Vervier[1], S. Zaremba[1]

1) Université Catholique de Louvain
2) Université Libre de Bruxelles
3) Katholieke Universiteit Leuven
Belgium

Radioactive Ion Beams are produced and accelerated at Louvain-la-Neuve by coupling two existing cyclotrons : the first, CYCLONE 30, accelerates protons up to 30 MeV with high (~ 500 μA) intensities, and produces large quantities (~ 100 Curies) of light radioactive nuclei, for instance ^{13}N, by bombardment of suitable targets, for instance ^{13}C, using adequate reactions, for instance ^{13}C (p,n) ^{13}N ; these atoms are extracted from the target and ionized, with high efficiencies, in the 1^+ charge state, by an Electron Cyclotron Resonance ion source ; the resulting ions are then accelerated by the second cyclotron, CYCLONE, operating in the sixth-harmonic mode, to suitable energies, around 0.5 MeV/nucleon. The resulting beams are used for studying nuclear reactions of astrophysical interest, for instance ^{13}N (p,γ)^{14}O. The status of the programme, and the first results obtained as to October 1989, will be presented.

Jean Vervier
Institut de Physique Nucléaire et
Centre de Recherches du Cyclotron
Université Catholique de Louvain
Chemin du Cyclotron, 2
B-1348 Louvain-la-Neuve (Belgium)
Telephone : (10) 47.32.15 or 47.32.73
FAX : (10) 45.21.83
E-mail :

EXOTIC NUCLEI ARENA IN JAPANESE HADRON PROJECT

Toru Nomura, Institute for Nuclear Study, University of Tokyo, Tanashi-shi, Tokyo 188, Japan

A radioactive nuclear beam facility has been proposed as one of the research arenas in Japanese Hadron Project in order to promote new regions of research in nuclear physics and related fields of science. The main hardware components of the facility are a 1 GeV proton linac, an isotope separator on-line and a heavy-ion linac. A part of the proton linac beam up to 10 μA will be used to produce various exotic nuclei in spallation processes of a thick target. They are mass-separated by the ISOL and injected into the HI linac with the energy of 1 keV/u. The acceleration is made in three stages using different types of HI linacs, i.e., split-coaxial RFQ, IH and Alvarez, the maximum energy in each stage being 0.17, 1.4 and 6.5 MeV/u, respectively.
A prototype of the SCRFQ linac with the q/m value of 1/30 is now under construction. The design of the ISOL as well as the other parts of the facility is now in progress. A pilot station planned as a R&D project toward the proposed facility is also under study.

Toru Nomura
Institute for Nuclear Study
University of Tokyo
Midoricho 3-2-1
Tanashi-shi 188, Japan
Telephone: 0424-61-4131
FAX: 0424-68-5844
E-mail: NOMURA@JPNUTINS

RADIOACTIVE NUCLEAR BEAMS OF THE MOSCOW MESON FACILITY

A.S.Iljinov, V.M.Lobashev, G.N.Vialov, B.L.Zhuikov
Institute for Nuclear Research of the USSR Academy of Sciences, Moscow, USSR

An expansion of the experimental area is planned at the Moscow Meson Facility. In a new experimental hall it is proposed to place installations intended for a wide use of the residual nuclei produced in the target bombarded by the 600 MeV proton beam with a current of 0.5-1 mA. Residual nuclei extracted from two targets will be separated independently by a gas-chemical jet transport system and the mass-separator and carried to the multiply charged ions source. Multiply charged ions will be injected to a solid pole cyclotron (K=200) and then to a separated-sector (K=500) cyclotron.
The estimations based on experimental isotopic yields from pA -reactions and on the efficiency of similar installations show that the intensity of the beams of medium weight nuclides far from the β-stability line by 4-7 neutrons can be 10^{11} - 10^{9} pps. A radiochemical laboratory including hot chambers will be designed to produce radioactive targets and provide radioactive nuclear beams.

The use of radioactive beams and targets will stimulate the development of nuclear physics and related branches (new element chemistry, astrophysics, solid state physics, etc.). From the wide range of investigations the most essential one is the study of nuclei far from the line of β-stability and from the region of known nuclides. In particular, the use of cold fusion reactions can be promising for the synthesis of superheavy elements owing to structural effects that manifest themselves in neutron-rich nuclei.

Institute for Nuclear Research
of the Academy of Sciences of the USSR
60th October Anniversary Prospect, 7a
Moscow 117312, USR
A.S.Iljinov
Cable: Moscow MESON
Telex: 411 051 INR SU
Telephone: 334-00-66

THE TISOL FACILITY AT TRIUMF

J.M. D'Auria and M. Dombsky, Dept. of Chemistry, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6, and L. Buchmann, H. Sprenger and J. Vincent, TRIUMF, Vancouver, B.C. Canada V6T 2A3

The test on-line isotope facility (TISOL) is now operational at the intermediate energy, proton accelerator, TRIUMF. This facility is a prototype of the front end of the proposed ISAC (ISOL/post-accelerator) facility and is now available for development studies related to such an application. At present a heated surface ion source has been used with a range of targets and production yields of over 90 isotopes have been measured. An ECR (electron cyclotron resnance) ion source, specially designed for use at TISOL, has been operated successfully off-line for certain gaseous elements and is presently being installed on-line. Details of the TISOL program including observed yields, progress of the ECR installation, and the planned physics program are presented, along with the status of the proposed accelerated radioactive nuclear beams facility, ISAC.

J.M. D'Auria
Simon Fraser University
Burnaby, B.C.
Canada V5A 1S6
Telephone: (406) 291-4607
FAX: (406) 291-3765
E-mail: DAUR@SFU

PROPOSALS AND ESTIMATES FOR AN EXPERIMENTAL PROGRAM AT ISAC

L. Buchmann, TRIUMF, Vancouver, B.C., Canada V6T 2A3, J.M. D'Auria, Dept. of Chemistry, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6, and J. King, Dept. of Physics, University of Toronto, Toronto, Ontario, Canada M5S 1A7

An accelerated radioactive nuclear beams facility like that proposed for installation at TRIUMF, namely ISAC, can be used in experiments involving unstable nuclei as projectiles, studies previously not possible. Such studies range from standard low energy nuclear reactions such as Coulomb excitation and multiple nucleon transfer reactions in which levels in nuclei far from stability can be explored, to simple fusion reactions of great interest to the field of nuclear astrophysics. In this report several realistic experimental configurations are considered and estimates of expected counting rates are presented. These should help to form a foundation to develop a set of operational parameters of a final facility.

L. Buchmann
TRIUMF
4004 Wesbrook Mall
Vancouver, B.C.
Canada V6T 2A3
Telephone: (406) 222-1047
FAX: (406) 222-1074
E-mail: LOTHAR@TRIUMFCL

A CONCEPT FOR POST-ACCELERATION OF RADIOACTIVE IONS

H. Haas, H. Ravn, B.W. Allardyce, B. Jonson, C. Rolfs and the ISOLDE Collaboration

The high intensity radioactive ion beams obtained from ISOLDE (CERN) make it possible to produce beams of unstable nuclei in the MeV/nucleon range with a conventional post-accelerator. In particular the high resolution ISOLDE-3 facility, equipped with a high efficiency ECR source, in addition to the plasma and surface ion sources operating now, will allow to create the clean beams necessary for this purpose. For many isotopes of the elements from He to Al, beams with intensities in the nA range can be expected. The proposed accelerator would in its first stage produce beams of A ≤ 27 ions below 1.5 MeV/u for experiments in nuclear astrophysics, nuclear reactions and spectroscopy, for polarization studies, and for solid state applications. The post-accelerator would consist of two RFQ linacs which give the accelerations from 2.2 to 50 keV/u and 50 to 200 keV/u respective for the 1^{+} ions. Following stripping to A/q ≤ 9, four interdigital-H structures would reach a final energy of 1.2 MeV/u. With the addition of six single resonators this concept will allow continuous energy variation from 0.2 to 1.5 MeV/u. Further extensions of mass and energy range of the proposed accelerator would be possible by the addition of an electron beam ion stripper at injection and a superconducting booster linac.

Heinz Haas
EP Div./ISOLDE
CH-1211 GENEVA 23
Telephone: (41) 22 767-5825
FAX (41) 22 767-6555
E-mail: Heinz at CERNVM

The NSCL Radioactive Beam Facility

B. Sherrill, D.J. Morrissey and J.A. Nolen Jr., NSCL, East Lansing, MI 48824

A beam analysis device, the A1200, is being constructed at the National Superconducting Cyclotron Laboratory (NSCL) for routine cyclotron beam analysis. This device can also be used for the separation of radioactive beams from fragmentation. Since the A1200 forms the beginning of the K1200 cyclotron beam lines radioactive beams can be delivered to any experimental device. In order to separate fragmentation products the design makes use of the degrader/wedge concepts developed for heavy ions at GANIL and LBL. The optical design has been corrected to second order, and will allow momentum resolution of 3000 in an achromatic mode. The solid angle for collection is as high as 5 msr with low resolution. The A1200 can also be used as a dispersion matched spectrograph, where an intermediate image of the device can be used as the target position for studying interactions of radioactive ions near zero degrees with good resolution.

The details of the mechanical and optical designs will be presented. In addition some of the possible experiments with the separated radioactive beams will be discussed. With inverse kinematics it should be possible to measure masses and excited states with proton or deuteron targets at the target position of the S800 spectrograph. Radioactive beam induced transfer or elastic scattering can be studied using the A1200 in the dispersion matched mode, or with the S800. Very clean decay studies of radioactive nuclei can be made by transporting the separated beam to the RPMS and using the additional separation of the Wien filter.

B.Sherrill, NSCL
Michigan State University
East Lansing, MI 48824 USA
Telephone: (517) 353-5375
E-Mail: SHERRILL@MSUNSCL

CHARGE CARRIERS IN LIQUID HELIUM PRODUCED BY NUCLEAR BEAM

N. Takahashi, T. Shimoda, H. Miyatake, T. Itahashi and Y. Fujita
College of General Education, Osaka University, Toyonaka, Osaka, 560 Japan

Life-time of snowballs, charged aggregates of 50-100 helium atoms around an impurity ion has been estimated to be large than 800 ms. This figure is encouraging for physics of snowballs with radioactive nuclear beams.

Low-intensity pulsed beam of 135 MeV $^{14}N^{4+}$ ions from the cyclotron at the Research Center for Nuclear Physics, Osaka University was introduced into superfluid helium at 1.7 K. The pulse duration of the incoming ^{14}N beam was 10 ms and the out-beam duration was 990 ms. The ion current was measured at an electrode connected to an electrometer. The gate period for the current measurement was 100 ms and the time between the end of beam period and the beginning of gate period was varied. We observed that the collector current decreased and the half value was attained at T = 800 ms. This means that the snowballs are as long-lived as 800 ms.

Physics of charge carriers in superfluid helium has been an interesting subject for more than decades. A novel method of detection of snowballs by emitted nuclear radiation has revived an interest in this problem[1]. The long life-time of snowballs will allow spectroscopic measurements of beta unstable nuclei as cores of such aggregates.

1) N. Takahashi et al. Proc. Intl. Conf. on Nuclear Structure Trough Static and Dynamic Moments, Melbourne, 1987, p. 334

Noriaki Takahashi
College of General Education
Osaka University
Toyonaka, Osaka, 560 Japan
Telephone: (06)844-1151 ext.5237
Fax: (06)855-7621
E-mail: PCA2091 at JPNOSAKA

RNB Production

THE GSI PROJECTILE-FRAGMENT SEPARATOR - STATUS AND PLANNED EXPERIMENTS

G. Münzenberg, H. Geissel, H.-G. Clerc[1], J.P. Dufour[2], B. Franczak, E. Hanelt[1], O. Klepper, B. Langenbeck, F. Nickel, K. Poppensieker, M.S. Pravikoff[2], E. Roeckl, D. Schardt, K.-H. Schmidt, D. Schüll, Th. Schwab[4], B. Sherill[3], K. Sümmerer, and H. Wollnik[4]
GSI Darmstadt, [1]TH Darmstadt, [2]C.E.N. Bordeaux, [3]Michigan State University, [4] Universität Giessen

The Projectile Fragment Separator now being set-up at GSI is a highly versatile achromatic magnetic spectrometer. It can handle relativistic heavy ions with masses up to 250 and with energies of 0.1 GeV/u to 1 GeV/u, which corresponds to beam rigidities of 5 Tm to 18 Tm. The designed momentum resolution is $\frac{P}{\Delta P} \geq 10^3$.

The separator can be used for a great variety of atomic physics and nuclear physics experiments and offers unique possibilities in combination with the GSI experimental heavy-ion storage and cooler ring ESR. Examples of experiments are: studies of ionic charge-exchange processes, energy loss and straggling in matter, investigation of radioactive isotopes and production of secondary beams of exotic nuclei which can be used for secondary reactions as well as for the study of ^{12}C (p; γ, π^0)^{13}N, Δ -production or subthreshold production of K^- and antiprotons.

In this contribution a report on the status, the comissioning phase and first planned experiments will be given.

G. Münzenberg
Gesellschaft für Scherionenforschung mbH
Postfach 11 05 52
6100 Darmstadt 11
Tel.: 06151 / 359-733
Fax.: 06151 / 359-785
EARN: KC58@DDAGSI3

EXPERIMENTS FOR THE ISOTOPE SEPARATION OF SECONDARY BEAMS WITH THE MOMENTUM-LOSS ACHROMAT

B. Blank, J.-J. Gaimard, H. Geissel, G. Münzenberg, K.-H. Schmidt, H. Stelzer, K. Sümmerer,
GSI Darmstadt
H.-G. Clerc, E. Hanelt, B. Voss,
Inst. f. Kernphysik, TH Darmstadt
D. Bazin, R. DelMoral, J.-P. Dufour, A. Fleury, M.S. Pravikoff,
CEN Bordeaux Gradignan

The high-resolution isotope separation of projectile fragments with the two-stage achromatic magnetic spectrometer LISE in combination with a shaped energy degrader has been developed at GANIL. In addition to the magnetic rigidity of the fragments, their relative momentum reduction in the degrader is used as a selection parameter. In first experiments with the spectrometer SPES I at SATURNE this separation method was applied at relativistic energies. A high separation quality with an astonishingly low level of cross contaminants produced by secondary reactions was found.

The implications of the experimental results on the performence of the Projectile-Fragment Separator, presently under construction at GSI, are discussed.

Karl-Heinz Schmidt
GSI / KCII
Postfach 110552
D 6100 Darmstadt
Federal Republic of Germany
Telephone: FRG 6151 359739
FAX: FRG 6151 359785
E-mail: KC52@DDAGSI3

RADIOACTIVE BEAM PRODUCTION AT THE BEVALAC

J. R. Alonso, B. Feinberg, J. G. Kalnins, G. F. Krebs, M. McMahan, Lawrence Berkeley Laboratory, One Cyclotron Road, Berkeley, California 94720, U.S.A.

At the Bevalac radioactive beams can be routinely produced by the fragmentation process. The effectiveness of this process with respect to the secondary beam's emittance, intensity and energy spread depends critically on the nuclear reaction kinematics and the magnitude of the incident beam energy. When this beam energy significantly exceeds the energies of the nuclear reaction process, many of the qualities of the incident beam can be passed on to the secondary beam. Factors affecting secondary beam quality are discussed along with techniques for isolating and purifying a specific reaction product. The on-going radioactive beam program at the Bevalac is used as an example with applications, present performance and plans for the future.

Jose R. Alonso
Lawrence Berkeley Laboratory
Accelerator & Fusion Research Division
One Cyclotron Road
Berkeley, CA 94720
U.S.A.
Telephone: (415) 486-5185
FAX: (415) 486-5788
E-mail: Jose@LBL

SYSTEMATICS OF FRAGMENTATION CROSS SECTIONS: EMPIRICAL DESCRIPTIONS AND MICROSCOPIC CALCULATIONS

K.Sümmerer, Gesellschaft für Schwerionenforschung, D-6100 Darmstadt, Federal Republic of Germany

Both the intensity and the purity of radioactive beams produced by projectile fragmentation depend on the fragmentation (or "spallation") cross sections. In the past there have been various studies trying to calculate these cross sections either empirically by an approximate analytical formula[1,2] or on the basis of physical models by internuclear-cascade-plus-evaporation calculations[3]. In the present contribution, a modified empirical formula is presented together with systematic internuclear-cascade calculations. The study is concentrated on those nuclei which are of prime interest for the production of radioactive beams, i.e. products relatively close to the projectile. Multi-fragmentation or fission are not included.

Similar to previous approaches, the empirical formula consists of two terms, the mass yield, Y(A), and the distribution of isobars with mass A around the most probable charge, $f(Z_{prob}-Z)$. An important modification compared to previous approaches is a different method of incorporating the "memory effect", i.e. the influence of the projectile N/Z ratio on the fragment N/Z ratio. It can be shown that the formula describes the experimental fragmentation cross sections between ^{40}Ar and ^{197}Au with sufficient accuracy, especially with respect to the memory effect.

Since such an empirical description represents a smoothing procedure removing the scatter of the (mostly radiochemically determined) experimental cross sections, it is well suited for a comparison with model calculations. The internuclear cascade model of Yariv and Fraenkel[3] has been used to calculate systematically the fragment distributions of medium to heavy projectiles. The overall agreement between the empirical description and the model calculation is satisfactory.

1. G. Rudstam, Z. Naturforsch. *21a* (1966) 1027;
2. R. Silberberg, C.H. Tsao, Ap. J. Suppl. *25* (1973) 315, 335; *58* (1985) 873
3. Y. Yariv, Z.Fraenkel, Phys. Rev. *C20* (1979) 2227

K. Sümmerer
Gesellschaft für Schwerionenforschung
P.O. Box 11 05 52
D-6100 Darmstadt 11
Federal Republic of Germany
Telephone: (06151) 359-464
FAX: (06151) 359-785
E-mail: SUE @ DDAGSI5

LISE:
A recoil-spectrometer at GANIL for the production and study of secondary radioactive beams. Present status and future.

Alex C. Mueller, Institut de Physique Nucléaire, F-91406 ORSAY, France
and
Rémy Anne, GANIL, BP 5027, F-14021 CAEN, France

The doubly achromatic spectrometer LISE[1], installed at the intermediate-energy heavy-ion facility GANIL is now operating since five years. Essentially, it is composed by two dipole-magnets selecting (in A/Z) and refocusing (achromatically) the projectile-like fragment-beams emitted at O° from an interaction target. Isotopic purification may be obtained by Z-dependent energy-degrading[1-3] in the intermediate focal plane between the magnets. Various experimental results[4] as well with stopped beams (e.g. identification of drip-line nuclei and delayed-particle spectroscopy far off stability) as with secondary radioactive beams at about 30 MeV/nucleon (e.g. total reaction cross-section measurements and spin-alignment) will be reviewed. Now, we have started several upgradings (e.g. targets for very high primary beam intensity, beam-swinger magnets for the change of incident angle), in particular a cross-field electrostatic/electromagnetic post separator. We shall discuss these improvements which are expected to provide in the near future secondary beams of still increased intensity and isotopic purity.

1) R.Anne, D.Bazin, A.C.Mueller, M.Langevin and J.C.Jacmart
Nucl. Inst. Meth. **A257**, 215 (1987)
2) R. Bimbot, S. Della-Negra, P. Aguer, G.Bastin, H.Delagrange and F.Hubert
Z. Phys. **A322**, 443 (1985)
3) J.P. Dufour, R. DelMoral, H.Emmermann, F.Hubert, D. Jean, C. Poinot, M.S. Pravikoff, A.Fleury, H.Delagrange and K.H.Schmidt, Nucl Inst. Methods **A248**, 267 (1986)
4) Alex C. Mueller, Proceedings of the XXII. Yamada Conference on Nuclear weak processes and Nuclear Structure, Osaka, Japan, 1989 and references therein

Alex C. Mueller
Institut de Physique Nucléaire
F-91904 ORSAY (France)
Telephone: (33) 1 6 941 7314
FAX: (33) 1 6 941 6470
E-mail: MUELLER at FRCPN11

POLARIZATION OF RADIOACTIVE BEAMS : FIRST RESULTS ON LOW ENERGY BEAMS AND COMPARISON OF METHODS.

N.Severijns, W.Vanderpoorten, J.Wouters, J.Vanhaverbeke, L.Vanneste

Instituut voor Kern– en Stralingsfysika, Leuven University, B–3030 Leuven, Belgium.

In the past few years we constructed a system to polarize on line mass separated radioactive beams by reflecting them under grazing incidence angles (0.5^0 to 1.0^0) at very flat surfaces. Due to an asymmetric Coulomb interaction at the surface, the ions obtain an electronic polarization which is partially transferred to the nucleus by hyperfine interaction. When ferromagnetic surfaces are used, the polarization can still be enhanced by the capture of spin–polarized electrons from the surface. The system is ideally suited to orient short–lived light radioactive nuclei, for which it is in many cases difficult to obtain substantial orientations with low temperature nuclear orientation.
As we are dealing with beams of $10^4 - 10^6$ at/sec, a lot of effort was spent to shape the incoming beam, in order to minimize the loss of intensity. The polarized beam can be implanted either at room temperature, or at low temperatures (mK region) into a $^3He - ^4He$ dilution refrigerator.

After an extensive study of the properties of the specularly reflected beam, we recently obtained the first nuclear polarizations. In these measurements a D^+ beam was reflected at Si(100), GaAs(100) and Ni(110) single crystal surfaces. The polarization of the deuterons was detected by measuring the anisotropy of the α–particles emitted from the T(d,n)α–reaction, with four Si particle detectors. At all three surfaces, deuteron tensorpolarizations P_{zz} of 1% to 2% were obtained. It is difficult to obtain much larger orientations for deuterium, due to the presence of only one electron. On the basis of these results for deuterium, orientations of 10% to 20% can be expected for higher–Z radioactive beams.
A comparison of this method with other in–beam polarization techniques for low and for high energy beams will be given.

J. Wouters
Instituut voor Kern–en Stralingsfysika
Celestijnenlaan 200 D
B–3030 Leuven, BELGIUM
Tel. : (16) 201015
FAX : (16) 201368

SPIN-POLARIZED RADIOACTIVE ISOTOPE BEAMS FROM INTERMEDIATE ENERGY HEAVY ION COLLISION

K. Asahi, M. Ishihara, H. Takanashi[+], M. Koguchi[+], M. Adachi[+], M. Fukuda[++], N. Inabe[*], D. Mikolas[**], D. Morrissey[**], D. Beaumel[#], T. Ichihara, T. Kubo, T. Shimoda[##], H. Miyatake[##], and N. Takahashi[##]

RIKEN, Saitama 351, Japan
[+]Dept. Appl. Phys., Tokyo Inst. of Tech., Tokyo 152, Japan
[++]Dept. of Physics, Osaka Univ., Osaka 560, Japan
[*]Dept. of Physics, Kyoto Univ., Kyoto 606, Japan
[**]NSCL, Michigan State Univ., East Lansing, MI 48824, U.S.A.
[#]Inst. de Physique Nucléaire, B.P. 1, 91406 Orsay, France
[##]School of General Education, Osaka Univ., Osaka 560, Japan

Spin polarization P of projectile fragment ^{12}B in ^{14}N + Au collision at $E(^{14}N)/A$ = 40 MeV/u has been measured. The result reveals that the projectile fragments produced in this intermediate energy regime are strongly spin-polarized (P ∿ 10-20 %), implying a promising prospect of polarized radioactive isotope beams to be applied to spectroscopic studies of nuclei far from stability.

A ^{14}N beam from the RIKEN Ring Cyclotron was used. Fragments ^{12}B emitted from the target in the direction $\theta_L = 5°$ were transmitted through a dipole magnet and implanted in a stopper placed at a focul point. Spin polarization P was deduced from the observed up/down asymmetry of beta ray emission in the decay of $^{12}B_{g.s.}$ ($I^{\pi} = 1^+$, $T_{1/2}$ = 20.2 ms).

The polarization P observed as a function of momentum of the ^{12}B fragment shows positive values in the higher momentum side whereas it becomes negative for the lower momentum side. The sign change occurs around the peak of the yield spectrum. This behavior well conforms with prediction[1]) from a model of projectile fragmentation.

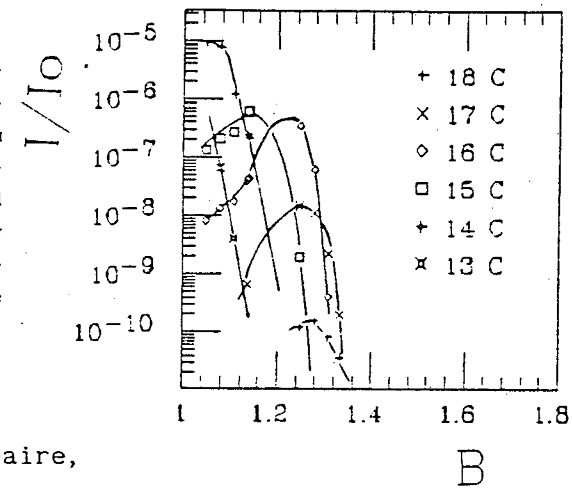
Koichiro Asahi
The Institute of Physical and Chemical Research (RIKEN)
2-1 Hirosawa, Wako-shi, Saitama 351-01, Japan
Telephone: 0484-62-1111
FAX: (484)-62-1449
E-mail: RIK835::ASAHI

RADIOACTIVE BEAM PRODUCTION AT 50-80 MeV/u

R. BIMBOT, F. CLAPIER, B. KUBICA, IPN Orsay, France, P. AGUER, CSNSM, Orsay, France, R. ANNE, Y. SCHUTZ, GANIL, Caen, France, G. ARDISSON, A. HACHEM, Université de Nice, France, J. CHAPMAN, J. LISLE, University of Manchester, U.K., Y. GONO, Riken, Japan

Radioactive heavy ion beams have been produced at GANIL through interaction of ^{18}O, ^{22}Ne and ^{40}Ar projectiles with light targets. These secondary beams are selected, transported, and focused using the LISE spectrometer which is composed of two dipoles and 10 quadrupoles. The influence of various parameters (primary target nature - Li, Be, Al - and thickness, incident beam energy) on the secondary beam yields have been studied, particularly for incident ^{18}O (Fig. 1). Secondary beams can thus be produced with intensities ranging from a few ions to 10^8 ions/s, the more exotic beams being the less intense. The outgoing beams can be purified using a wedge degrader placed between the two dipoles. Almost pure beams of ^{16}C and ^{17}N have thus been obtained. Moreover, the LISE spectrometer is being modified (addition of a velocity filter) in order to increase its selectivity in secondary beam transmission.

Production yields for beams of C isotopes produced through 45 MeV/u ^{18}O+187 mg/cm^2 Be reactions. The symbols I and I_o stand for the secondary and primary beam intensities, B is the dipole magnetic field in LISE.



René BIMBOT
Institut de Physique Nucléaire,
91406 - Orsay Cedex
Tel: (33)1.69.41.51.96
Fax: (33)1.69.41.64.70

CYCLOTRONS FOR THE PRODUCTION OF RADIOACTIVE BEAMS

D. J. Clark, Nuclear Science Division, Lawrence Berkeley Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, U.S.A.

The modern sector-focused cyclotron accelerates beam at 100% macroscopic duty factor, giving a large time acceptance from the injection system and thus high intensity. It also is capable of producing energies up to 500 MeV/u or more for light and heavy ions. Cyclotrons can be used in several ways to produce radioactive beams.

They can accelerate heavy ions, which then fragment when hitting a target, producing many species of radioactive beams at approximately beam velocity. Fragmentation work has been done at the GANIL ring cyclotron in France, which is designed for up to 100 MeV/u for the lighter heavy ions. For higher energies, superconducting cyclotrons are more economical, and designs have been proposed up to 400 MeV/u for the lighter heavy ions. The cyclotron can either stand alone with its own ion source, or can be injected by a higher intensity low charge state accelerator, such as a linac or cyclotron.

Cyclotrons can also be used to accelerate protons of high intensity, which can hit a spallation target and produce many radioactive isotopes at near zero energy. These radioactive species can then be fed into an ion source and injected into a mass separator or into another accelerator, such as a cyclotron or linac, to accelerate them to energies needed for atomic or nuclear physics. A good example of a high intensity proton cyclotron is the PSI ring cyclotron in Switzerland with a 590 MeV proton beam of over 300 μA, and a planned upgrade to 1 mA.

In this paper a review will be given of the radioactive beam production capabilities of present cyclotrons. Future possible designs will also be discussed.

David J. Clark
Lawrence Berkeley Laboratory, Bldg. 88
1 Cyclotron Road
Berkeley, CA 94720
Telephone: (415) 486-5088
FAX: (415) 486-5401

RADIOACTIVE NUCLEAR BEAMS FROM THE ARGONNE FRAGMENT MASS ANALYZER*

Cary N. Davids, Physics Division, Argonne National Laboratory, Argonne, IL 60439, USA

The Fragment Mass Analyzer (FMA) is a recoil mass spectrometer currently under construction at the ATLAS facility. It uses a QQEMEQQ combination of quadrupole (Q), electric dipole (E), and magnetic dipole (M) elements to separate nuclear reaction recoils from the primary beam and to disperse the recoils at the focal plane by M/Q (mass/unit charge). It has a solid angle of 8 msr, an energy acceptance $\Delta E/E$ of ± 15%, and a M/Q acceptance of ± 6% around a central energy and M/Q. The support structure of the FMA allows rotation about the target over an angular range of -5 to +45°, and has an additional radial degree of freedom to accommodate large detector arrays at the target position.

The FMA will be used in a number of different types of experiments. In one such class of experiments, an array of gamma detectors will be placed around the target, and events in this array will be tagged by the detection of the associated ion at the focal plane. In another mode, decay studies on nuclei far from stability will be conducted on a selected M/Q range using a fast tape transport system placed behind a mask at the FMA focal plane.

Radioactive nuclear beams can be produced at the FMA exit. This is done by tuning the ion optics to provide a parallel beam out of the last quadrupole, either with or without M/Q dispersion. Calculated properties of these radioactive beams will be presented, along with a discussion of the kinds of experiments that are being planned in this area.

*Work supported by the U. S. Department of Energy, Nuclear Physics Division, under Contract W-31-109-ENG-38

Cary N. Davids
Argonne National Laboratory
Building 203
9700 S. Cass Avenue
Argonne, IL 60439
Telephone: (312) 972-4062
FAX: (312) 972-3903
Bitnet: DAVIDS@ANLPHY

A FISSION SOURCE OF RADIOACTIVE HEAVY IONS

W.D. Hamilton, Joint Institute for Heavy Ion Research, ORNL, Oak Ridge, TN 37831 and Vanderbilt University, Nashville, TN 37235, USA

Fission products formed following neutron capture in a high flux reactor may be mass separated to provide intense beams of radioactive nuclei. These will span a broad mass range whose form will depend on the target and on the presence of epithermal neutrons. Shorter lived activities may be used for beams and those with a longer half-life may be collected to form radioactive targets.

Neutron fluxes as high as 10^{14}neutrons cm^{-2}s^{-1}may be obtained at present in the moderator and in a future reactor designed to accommodate such a source this flux could be greatly exceeded.

An advantage of a neutron induced fission source is that a thick target may be used; its size being limited by heating, and its physical form and structure. Fission products, because of their high recoil energy, may be relatively easily and efficiently extracted. A further advantage of a reactor based source is that the reactor power may be maintained at a constant level for long periods and consequently the fission rate is relatively stable.

Work supported by the Joint Institute for Heavy Ion Research, Holifield Heavy Ion Research Facility, Oak Ridge, TN 37831 through Contract No. DE-FG05-87ER40361 and Vanderbilt University, Nashville, TN 37235 under Contract No. DE-AS05-76ER05034.

W.D. Hamilton
Joint Institute for Heavy Ion Research, ORNL
PO Box 2008, Building 6008
Oak Ridge, Tennessee 37831-6374
Telephone: (615) 576-7656, FAX: (615) 574-1268

PRESERVATION OF ALIGNMENT IN MAGIC-ATOMS IONS

M. Hass, M. Satteson, C.Y. Wu, and N. Benczer-Koller
NSRL, U. of Rochester, Rochester, New York 14627

When recoiling ions from a typical fusion-evaporation reaction are brought to the focal plane of a Recoil Mass Separator (RMS) device, the nuclear alignment which was produced by the reaction is generally destroyed due to the random interaction of the atomic spin with the magnetic elements of the beam-transport and separating system. Measurements of, for example, magnetic moments of isomeric levels are thus impossible under these conditions.

This alignment can be preserved, however, for charge states which correspond to magic atomic numbers[1-3]. We have carried out an experiment for the 10^+ isomer in ^{54}Fe, using the $^{27}Al(^{31}P,2p2n)^{54}Fe$ action at $E(^{31}P)$=110 MeV which produces ^{54}Fe nuclei in the 16^+, Ne-like charge state. Two Ge detectors were used to measure the ratio of singles counts, $N(0^0)/N(90^0)$. The double ratio $R=[N(0^0)/N90^0)]^{16}/[N(0^0)/N(90^0)]^{17}$ is a direct measure of the alignment carried by the separated beam in the Ne-like state. Our experimental result of R=1.10(1) yields a value of a_2=0.1, corresponding to 40%-50% of alignment preservation. The Pb stopper was placed then in an external magnetic field of 0.1 T and the time-differential precession of the aligned 10^+ level was measured. A Larmor precession pattern, in agreement with the singles results described above, was obtained.

These results represent significant preservations of the original alignment and opens up many new possibilities in the field of electromagnetic moments of isomers and far-from-stability nuclei

Michael Hass
NSRL, U. of Rochester
Rochester, NY 14627 USA
Bitnet: HASS@UORNSRL
Tel: 716-275-4937
FAX: 716-473-5384

1) J. Bendahan et al., Z. Physik A331,343(1988)
2) E. Dafni and M. Satteson, Phys. Rev. C38,2949(1988)
3) H.J. Jansch and D. Fick, Z. Physik D9,117(1988)

EFFECIENT PRODUCTION OF ^{7}Be USING THE RESONANT ^{10}B(p,α) REACTION AT E(^{10}B) $\doteq$ 22 MeV.

J.J. Kolata, K. Lamkin, and A. Morsad, Physics Department, University of Notre Dame, Notre Dame, IN 46556, USA
F.D. Becchetti, J. Brown, W.Z. Liu, J.W. Jänecke, and D.A. Roberts, Physics Department, University of Michigan, Ann Arbor, MI 48109, USA
R.E. Warner, Physics Department, Oberlin College, Oberlin, OH 44074, USA

Reactions involving ^{7}Be e.g. ^{7}Be(p,γ) are of considerable interest in nuclear astrophysics. ^{7}Be also has many industrial applications as an implanted tracer element. We have devised and demonstrated a method for producing a clean, intense (>10^6/sec) low-energy (ca. 22 MeV) ^{7}Be beam. This method uses the resonant capture of a ^{10}B beam on a proton target via the ^{10}B(p,α) reaction ($d\sigma/d\Omega \doteq 100$ mb/sr). A test run using the UM-UND RNB facility [NIM B40/41 (1989) 503] has confirmed the feasibility of the method for producing a relatively clean ^{7}Be beam. The limitation on intensity is presently the proton target (CH_2 or TiH_2). A rotating, plated production target has been designed for use in a planned ^{7}Be(p,γ) measurement.

J.J. Kolata
Physics Department
University of Notre Dame
Notre Dame, IN 46556 USA
Telephone: (219) 239-7716
FAX: (219) 239-5952
E-mail:

Astrophysics

RADIOACTIVE ION BEAMS IN ASTROPHYSICS: A DISCUSSION OF SOME SELECTED REACTIONS AND OF THEIR ASTROPHYSICAL IMPACT

M. Arnould, Institut d'Astronomie, d'Astrophysique et de Géophysique, Université Libre de Bruxelles, Belgium

At all times and at all astrophysical scales, nuclear reactions involving unstable nuclei have played, and continue to play a key role. Some selected reactions of that type are discussed in order to make clear the astrophysical consequences of the often very large uncertainties still affecting their predicted rates.

Special emphasis is put on (i) the so-called hot pp-chain, which could have developed in massive, very massive, or supermassive very low-metallicity stars. Those objects could have played an important role during a possible pregalactic stellar era, or very early in the galactic history; (ii) the hot CNO chain, which is namely considered to power nova explosions, (iii) the hot NeNa-MgAl chains, which could develop during central hydrogen burning in massive non-exploding stars, or during the explosive burning of hydrogen, namely in novae. Those chains of reactions might be responsible for the production of the especially interesting nuclides ^{22}Na and ^{26}Al. The implications of such a synthesis for cosmochemistry, for the modeling of the early solar system, as well as for gamma-ray line astronomy are outlined.

Finally, the need for more information on nuclear reaction rates involving radioactive nuclides heavier than iron is stressed, in particular on grounds of some recent calculations of the p-process, which is aimed at explaining the synthesis of the stable A>70 neutron-deficient species.

M. Arnould
Institut d'Astronomie, d'Astrophysique et de Géophysique
Université Libre de Bruxelles C.P. 165
Av. F. Roosevelt, 50 Tel.: (322) 642.2864
B-1050 Bruxelles Fax: (322) 642.3595
Belgium E-mail(BITNET):R00901@BBRBFU01

UNSTABLE PROTON RICH NUCLEI RELEVANT TO THE BREAKOUT PROCESS FROM THE HOT-CNO CYCLE

S. Kubono, Y. Funatsu, N. Ikeda, M. Yasue, T. Nomura, Y. Fuchi, H. Kawashima, S. Kato[1)], H. Orihara[2)], H. Miyatake[3)], and T. Kajino[4)]

Institute for Nuclear Study, University of Tokyo, Tanashi, Tokyo, 188 Japan, 1) Yamagata University, Yamagata, 990 Japan, 2) Tohoku University, Sendai, 980 Japan, 3) Osaka University, Toyonaka, Osaka, 560 Japan, 4) Tokyo Metropolitan University, Setagaya, Tokyo, 158 Japan

Unstable proton-rich nuclei in light mass region should be important in the explosive hydrogen-burning process in stellar sites. One of the current problems is the onset process and the temperature of the rapid-proton (rp) process[1)] from the HCNO cycle.

A series of experimental works have been performed to investigate the nuclear structures of proton rich, unstable nuclei, specifically the states near and above the proton thresholds of ^{20}Na and ^{21}Mg, which could be crucial for this problem.

^{20}Na nucleus should be one of the most critical nuclei for the breakout problem. We have studied ^{20}Na with the (^{3}He,t) and (p,n) reactions on ^{20}Ne[2,3)]. Several new states have been identified together with spin-parity assignments. Specifically, the first excited state above the proton threshold in ^{20}Na has been identified to be the 1^+ state at 2.637 MeV, which may be the s-wave resonant state with a large amplitude in the ^{19}Ne + p scattering. The stellar reaction rate estimated shows a much stronger enhancement than the previous predictions[1,4)].

^{21}Mg is also important for this problem as the main flow will go through this nucleus after reaching ^{20}Na in the rp-burning stage. About 15 new states have been identified by using the ^{24}Mg(^{3}He,^{6}He)^{21}Mg reaction at 73 MeV. An interesting observation is that the most states near the proton threshold show large Coulomb shifts, and thus one of the possible s-wave resonant states expected from the mirror nucleus ^{21}F is found to be a bound state. The stellar reaction rate of the ^{20}Na(p,γ)^{21}Mg process will be also discussed.

References:
1) R. Wallace and S. E. Woosley, Astrophys. J. Suppl. 45 (1981) 389.
2) S. Kubono, et al., Z. Phys. A331 (1988) 359.
3) S. Kubono, et al., Astrophys. J. (1989) in press.
4) K. H. Langanke, et al., Astrophys. J. 301 (1986) 629.

Shigeru KUBONO
Institute for Nuclear Study, Univ. of Tokyo
3-2-1 Midori-cho, Tanashi, Tokyo, 188 Japan
Phone 0424-61-4131, FAX 0424-68-5844
E-mail KUBONO@JPNUTINS

Reaction Rates in the rp-Process Beyond $^{13}N(p, \gamma)^{14}O$

M. Wiescher, J. Görres, Department of Physics, University of Notre Dame, Notre Dame, IN 46556, USA.

The hydrogen burning reaction sequences in explosive nucleosynthesis events (novae, x-ray burst, supernovae) are described by the r(apid)p(roton capture) process. The reaction path of the rp-process is, depending upon temperature and density conditions, between the line of stability and the proton drip line and is determined by the reaction rates of the nuclear reactions involved.

To determine the reaction flow path the rates of several key reactions of the rp-process (bottlenecks and waiting points) have been indirectly investigated by measuring the structure of the particular compound nucleus above the proton threshold. In the measurement of transfer reactions populating these nuclei, level density, level energies and decay channels above the proton threshold have been studied to extract the necessary information for calculating (p, γ)- reaction rates. These studies have been performed at the Cyclotron Laboratory at Michigan State University and at the FN-Tandem at the University of Notre Dame. reactions on stable or long-lived nuclei along the process path have been investigated directly at low energy accelerators at CalTech and the university of Toronto.

Based on the results of these measurement reaction flow studies have been performed to determine more accurately the temperature and density of the re-process reaction path and its endpoint.

Michael Wiescher
Department of Physics
University of Notre Dame
Notre Dame, IN 46556
Telephone: (219) 239-6788
FAX: (219) 239-5952
E-mail: FMYBA3@IRISHMVS

Use of the GANIL radioactive beams for astrophysical purposes

P. Aguer[1], F. Azaïez[2], S. Barhoumi[1], R. Bimbot[3], G. Bogaert[1], F. Clapier[3], D. Disdier[4], S. Fortier[3], H.J. Gils[5], J. Kiener[5], M. Kious[1], L. Kraus[4], A. Lefebvre[1], I. Linck[4], T. Motobayashi[7], H. Rebel[5], C. Stephan[3], L. Tassan-Got[3], J.P. Thibaud[1], A. Villari[6].

Stellar evolution models need fusion reaction cross sections for masses lighter than about 30. The reactions are of the type (p,γ) or (p,α), with the proton energy in the range of several tens of keV. At the high temperatures and densities in explosive stellar environments, proton and alpha capture by radioactive nuclei can compete with β decay. Then, the cross sections required for stellar models concern radioactive nuclei, and are difficult to determine due to the experimental problems. A key reaction in the *hot CNO cycle* is the $^{13}N(p,\gamma)^{14}O$ reaction. A determination of that cross section at stellar energies ($E_{cm} \approx 500$ keV) with a ten minute half life gas target is impossible. A radioactive beam facility is currently being built to produce a ^{13}N beam at Louvain la Neuve.

Alternatively, the production of radioactive beams at Ganil has been studied. Such beams are produced at rather high energies (several tens of MeV/amu), and the ratio of the radioactive beam intensity to the primary one is about 10^{-6} for a radioactive material lighter (or heavier) than the primary beam mass by two units of mass.

As demonstrated by Baur *et al* [Nucl. Phys. A458(1986)188], Coulomb dissociation can be a source of information on radiative capture processes of astrophysical interest. Instead of studying the reaction $A + b \rightarrow B + \gamma$, one can determine the cross section of the inverse reaction $B + \gamma \rightarrow A + b$. The virtual gamma is provided by the Coulomb field of a heavy target (Pb or U) and the element B is the beam, with an energy of a few tens of MeV. In particular, B could be radioactive material provided by a secondary beam at Ganil. With the B element being ^{14}O or ^{19}Ne, such a method has potential astrophysical interest.

P. Aguer
[1]C.S.N.S.M. Bat 104 - 108
91405 ORSAY FRANCE
FAX: (0)1 69 41 52 68
Bitnet: AGUER@FRCPN11

[2]*C.E.N.B.G.*
[3]*I.P.N. Orsay*
[4]*C.R.N. Strasbourg*
[5]*KfK Karlsruhe*
[6]*GANIL,* [7] *U. RIKKYO*

THE ROLE OF $^{13}N(p,\gamma)^{14}O$ FOR HEAVY ELEMENT SYNTHESIS IN STARS

A. Jorissen, M. Arnould, Institut d'Astronomie, d'Astrophysique et de Géophysique, Université Libre de Bruxelles, Belgium

The $^{13}N(p,\gamma)^{14}O$ reaction, which is currently under experimental scrutiny at very low energy at the Cyclotron of Louvain-la-Neuve (Belgium), is known to govern the operation of the hot CNO cycle. In addition, it could also determine the efficiency of the heavy element synthesis in a variety of stellar environments where the necessary neutrons are provided by $^{13}C(\alpha,n)^{16}O$. That source operates through the $^{12}C(p,\gamma)^{13}N(\beta^+)^{13}C(\alpha,n)^{16}O$ chain when protons are mixed into He- and C-rich layers. Various branchings to that path may, however, hinder more or less drastically the liberation of neutrons. We delineate the physical conditions in which $^{13}N(p,\gamma)^{14}O$ can play such a role, and we evaluate the impact of the uncertainties in the rate of that reaction on the efficiency of the heavy element synthesis. In particular, we identify situations in which the adoption of Caughlan and Fowler's (1988) rate for $^{13}N(p,\gamma)^{14}O$ allows the neutron capture process to go all the way from Fe to Os, while a tenfold increase in that rate would imply a stop in the heavy element buildup already at Cu.

A. Jorissen, M. Arnould
Institut d'Astronomie, d'Astrophysique et de Géophysique
Université Libre de Bruxelles C.P. 165
Av. F. Roosevelt, 50 — Tel.: (322) 642.2864
B-1050 Bruxelles — Fax: (322) 642.3595
Belgium — E-mail(BITNET):R00901@BBRBFU01

C6

NEUTRON CAPTURES ON ^{18}F AND ^{19}F PRODUCTION

S. Goriely, A. Jorissen, M. Arnould, Institut d'Astronomie, d'Astrophysique et de Géophysique, Université Libre de Bruxelles, Belgium

The origin of the cosmic ^{19}F is still very uncertain and debated. We propose a new stellar environment for its production. It relies on the possibility for protons to be injected into He- and C-rich layers of various (single or double) stars at different stages of their evolution. In such conditions, the $^{12}C(p,\gamma)^{13}N(\beta^+)^{13}C(p,\gamma)^{14}N(\alpha,\gamma)^{18}F(n,\alpha)^{15}N(\alpha,\gamma)^{19}F$ and $^{12}C(p,\gamma)^{13}N(\beta^+)^{13}C(p,\gamma)^{14}N(\alpha,\gamma)^{18}F(n,p)^{18}O(p,\alpha)^{15}N(\alpha,\gamma)^{19}F$ chains can develop, the neutrons being produced by $^{12}C(p,\gamma)^{13}N(\beta^+)^{13}C(\alpha,n)^{16}O$. The efficiency of the proposed ^{19}F nucleosynthesis mechanism depends heavily in particular on the key reactions $^{18}F(n,p)^{18}O$ and $^{18}F(n,\alpha)^{15}N$. We emphasize the interest of a detailed experimental and theoretical analysis of those two reactions, as well as of a careful evaluation of the uncertainties still affecting their rates.

Some numerical experiments are performed in order to test the sensitivity of the predicted ^{19}F yields to variations in the adopted rates of those two reactions.

S. Goriely, A. Jorissen, M. Arnould
Institut d'Astronomie, d'Astrophysique et de Géophysique
Université Libre de Bruxelles C.P. 165
Av. F. Roosevelt, 50 Tel.: (322) 642.2864
B-1050 Bruxelles Fax: (322) 642.3595
Belgium E-mail(BITNET):R00901@BBRBFU01

NUCLEAR SPECTROSCOPY AND RADIOACTIVE BEAMS IN NUCLEAR ASTROPHYSICS

A.E. Champagne, Dept. of Physics,
Princeton University, Princeton, NJ 08544, USA

Rates for reactions on short-lived targets that are now "measured" via indirect, nuclear spectroscopy, could be obtained directly with radioactive-beams. However, since traditional "resonance hunting" is not the most efficient use for such a facility, nuclear spectroscopy, involving both stable targets and radioactive beams can be a powerful complement to direct radioactive-beam measurements: In the best case, the spectroscopic approach can provide the reaction rate itself and thereby determine which reactions warrant further scrutiny. At worst, a direct measurement could be undertaken with prior knowledge of which states could be important resonances and with some idea of their properties. These techniques need not be limited to stable targets and beams. For example, analyses of direct reactions produced with radioactive beams could be crucial to an understanding of cases where a cross-section measurement alone would not provide unambiguous information. Such a situation could arise when interference effects or direct-capture contributions are important. In these circumstances, nuclear spectroscopy and direct measurements together can provide information that would not be obtainable by either method alone.

A.E. Champagne
Department of Physics
Princeton University
Jadwin Hall
P.O. Box 708
Princeton, NJ 08544 USA
Telephone: (609) 452-4425
E-mail: AEC@PUPCYC

UNSTABLE NUCLEI AND PRODUCTION OF THE LIGHT ELEMENTS IN PRIMORDIAL NUCLEOSYNTHESIS[1,2]

T. Kajino, Department of Physics, Tokyo Metropolitan University, Setagaya, Tokyo 158, Japan

R. N. Boyd, Department of Physics and Department of Astronomy, The Ohio State University, Columbus, OH 43210

The abundances of the light nuclides ^{9}Be, ^{10}B, and ^{11}B are studied in the standard model of primordial nucleosynthesis, in which the density of the universe is assumed to be uniform, and of the nonuniform density model, in which density fluctuations are allowed. In these calculations, two reactions not usually included in primordial nucleosynthesis models are included: the ^{7}Li(^{3}H,n)^{9}Be and ^{9}Be(^{3}H,n)^{11}B reactions. Considerably higher abundances of ^{9}Be, ^{10}B, and ^{11}B are found to be produced in the nonuniform density model. Furthermore, the relative abundances of those niclides differ considerably from those produced in any other production mechanisms. Thus consideration of their abundances, together with that of ^{7}Li, might resolve the controversy surrounding the ^{7}Li abundance, and provide a test of primordial nucleosynthesis models. In our study galactic chemical evolution of ^{9}Be, ^{10}B, and ^{11}B since the time of primordial nucleosynthesis also is considered by taking account of spallation production of those nuclides in galactic cosmic rays, and explicit note is made of the factors which have the largest uncertainties. Although observational limits of these nuclides are still too high to allow a test of the predictions of the two primordial nucleosynthesis models, present measurements are approaching the level needed. Experimental determination of the nuclear reaction rates on Li-Be-B species, particularly of (^{3}H,n), (^{3}H,p), (^{2}H,n), and (^{2}H,p) reactions on unstable nuclei, are highly desirable in order to theoretically predict the primordial abundances of ^{9}Be, ^{10}B, and ^{11}B with high precision.

References

1. Boyd, R. N., and Kajino, T., Astrophys. J. 336 (1989) L55.
2. Kajino, T., and Boyd, R. N., in preparation.

Toshitaka Kajino
Department of Physics
Tokyo Metropolitan University
Setagaya, Tokyo 158 Japan
Telephone: (3) 717-0111 (ex. 3351)
FAX: (3) 725-8101

Production of Radioactive ^{22}Na-Target and the Measurement of the ^{22}Na(p,γ)^{23}Mg Reaction

H.P. Trautvetter*

Institut für Kernphysik, Universität Münster

West Germany

A ^{22}Na-target will be produced by means of the implantation technique at the ISOLDE-CERN facility. It has been demonstrated that the surface ionisation source has a 100 % efficiency for Na-ion extraction of Na included in Al-material. Using a ^{24}Na-source material it has also been demonstrated that 56 % of the total ^{24}Na-content can be deposited on a target substrate. It should therefore be possible to produce 2 targets with about 5 x 10^{16} ^{22}Na-atoms from the available 35 mCi ^{22}Na.

For the subsequent experimental nculear physics studies facing such high target background activity one needs a threshold detector which is insensitive to this activity. The photodisintegration of deuterium with subsequent neutron counting has been used to construct a detector for high energy γ-rays but which is blind for $E_\gamma < 2.225$ MeV.

*In collaboration with R.W. Kavanagh, H. Ravn, C. Rolfs, H. Schulte, S. Seuthe, and F.B. Waanders.

Nuclear Structure

NEW PHYSICS
or
LOOKING FOR PRECURSORS OF NEUTRON MATTER EXOTICA

W.D. Myers, Lawrence Berkeley Laboratory, University of California
Berkeley, CA 94720, USA

If neutron matter were bound, nuclear physics would be enriched by amazing structures. These structures, with lifetimes limited only by beta decay, would include neutron balls of arbitrary size (no fission or alpha decay to limit the mass number!). They might contain clusters of protons, with topologies not necessarily those of a single sphere, e.g. two or more fragments held apart by their coulomb repulsion, or a hollow proton bubble. Unfortunately, neutron matter is probably not bound (or only slightly so, making it difficult to find experimentally). But how far is one from such an exotic generalization of nuclear physics?

Even if neutron matter is slightly unbound we might expect to see precursors of exotic neutron matter effects in phenomena that are observable at the neutron drip lines. The best way to proceed is to study nuclei with the largest possible neutron excess, both light and heavy nuclei, since even if neutron matter were bound, small neutron balls would tend to be destabilized by their surface energy. If neutron matter is unbound the maximum neutron excess for a given Z is limited by neutron drip. Otherwise, (for a sufficiently large system) the neutron excess could grow indefinitely. What does this drastic difference look like if neutron matter is only slightly unbound?

W.D. Myers
Lawrence Berkeley Laboratory
Bldg. 70A, Rm. 3307
University of California
Berkeley, CA 94720 USA
Telephone: (415) 486-5626
E-mail: myers@lbl.bitnet

DIPOLE VIBRATION IN EXTREMELY NEUTRON-RICH NUCLEI

Y. Suzuki, Physics Department, University of Michigan, Ann Arbor, MI 48109, USA and Physics Department, Niigata University, Niigata 950-21, Japan
K. Ikeda, Physics Department, Niigata University, Niigata 950-21, Japan
H. Sato, Radiation Laboratory, Institute of Physical and Chemical Research, Wako, Saitama 351-01, Japan

Excess neutrons in extremely neutron-rich nuclei are expected to play a distinctive role because of loose coupling to the core. The possible existence of a new type of dipole oscillation in these nuclei has been studied in both macroscopic and microscopic terms.

In macroscopic terms we use a hydrodynamical model of Steinwedel and Jensen type to examine the energy and dipole strength of a unique dipole mode in which the core and excess parts vibrate against each other. It is shown that this dipole mode appears at a low excitation energy and takes up a sizable amount of the classical electric dipole sume rule; e.g., in ^{61}Ca this mode reaches the excitation energy of 8 Mev and occupies 15% of the sum rule strength.

In microscopic terms we use the single particle wave functions generated by density-dependent Hartree-Fock calculations to calculate the distribution of dipole strength in a Tamm-Dancoff approximation. The calculation has been performed for He, O and Ca isotopes. It is found that extremely neutron-rich light nuclei exhibit a fragmented dipole strength at low excitation energies in consistency with the macroscopic prediction. It will be interesting to explore the consequence of the appearance of the low energy dipole oscillation in relation to the enhancement of the electromagnetic dissociation cross section in extremely neutron-rich nuclei.

Y. Suzuki
Physics Department
Bldg. Dennison, Rm 722
University of Michigan
Ann Arbor, MI 48109 USA
Telephone: (313) 763-1161
FAX: (313) 763-9694
E-mail: SUZUKI@UMIPHYS

THE POSSIBILITIES OF SYNTHESIZING HEAVY ELEMENTS IN THE COMPLETE FUSION OF UNSTABLE NUCLEI

E.A.Cherepanov, Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna 141980, USSR
A.S.Iljinov and M.V.Mebel, Institute for Nuclear Research of the USSR Academy of Sciences, Moscow USSR

The beams of neutron-rich radioactive nuclei offer a unique possibility for synthesizing the superheavy nuclei lying around the magic neutron and proton numbers N=184 and Z=114. The radioactive beams can also be used to produce heavy isotopes (N>160) of new elements with life-times longer than 1 min. In order to predict the most suitable radioactive beams for solving these problems we have calculated a great number of production cross sections for heavy isotopes of the transfermium elements formed in complete-fusion reactions between unstable nuclei, and selected the most promising ones. For example, as a result of shell structure effects, the isotopes of the element with Z=110 could be produced either in cold fusion of the doubly magic nuclei $^{208}Pb(^{78}Ni,n)^{285}110$ or in "warm"fusion $^{244}Pu(^{44}S,3n)^{285}110$ while the heavy isotopes of element 104 might be obtained in the reaction $^{244}Pu(^{25}Ne,4n)$ $^{265}104$.

In the calculations we used the empirical systematics of the ratio Γ_n/Γ_f, the interaction barrier B_{int} and the fusion barrier B_{fus} and their extrapolation to the neutron-rich region. The influence of the shell structure on the values of Γ_n/Γ_f is considered as a function of the temperature. In the calculations we take into account the hindrance of the fusion process (extra-push), the enhancement of subbarrier fusion with growing N of the interacting nuclei and the influence of the structure properties of the interacting nuclei.

Institute for Nuclear Research
of the Academy of Sciences of the USSR
60-th October Anniversary Prospect, 7a
Moscow 117312, USSR
A.S.Iljinov
Cable: Moscow MESON
Telex: 411 051 INR SU
Telephone: 334-00-66

Deeply Bound Pionic Atoms In Unstable Heavy Nuclei to be Formed With Radioactive Nuclear Beams

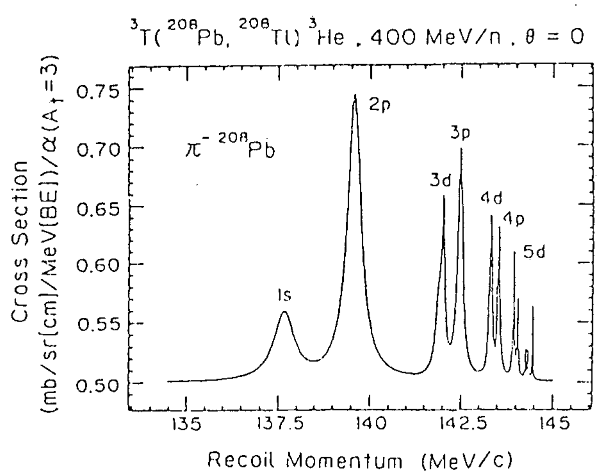
T. Yamazaki [a], R.S. Hayano[b], H. Toki [c], and P. Kienle[d]

a) Institute of Nuclear Study, University of Tokyo, Japan
b) Department of Physics, University of Tokyo, Japan
c) Department of Physics, Tokyo Metropolitan University
d) GSI, Darmstadt, F.R. Germany

Recently, Toki and Yamazaki [1] have shown that deeply bound π^- states in heavy nuclei may exist with narrow widths due to strong repulsion, which pushes out pions saved from being absorbed. Since the standard method of measuring the x-ray cascades does not reach the inner bound states due to pion absorption, the use of pion transfer reactions such as (n,p) and d, ^{2}He) has been proposed and the first trial (n,p) experiment with the TRIUMF-CHARGEX facility has been performed [2]. A (d, ^{2}He) experiment on ^{208}Pb is being planned at Saturne.

In order to obtain a better mass resolution (say, 100keV FWHM at 140MeV excitation), we propose to use the inverse kinematics in heavy ion reacitons; i.e., a heavy projectile such as ^{208}Pb at energy ~400MeV/A hits a light nucleus like d or t and the recoil nucleus as ^{2}He or ^{3}He after the charge exchange reaction is detected. The recoil nucleus carries momemtum of about 140MeV/c. The formation of pionic atoms signals in the energy spectra of the recoil nucleus, as shown below. We can achieve the energy resolution of less than 0.1MeV with a careful experimental set-up of a magnet for detection of recoil nucleus and a cooled heavy ion beam. An expected spectrum t(^{208}Pb, ^{208}Tl) ^{3}He at 400MeV/AS is depicted in Fig. 1. The radioactive nuclear beam would also provide spectroscopy of pionic atoms in unstable nuclei.

1. H. Toki and T. Yamazaki, Phys. Lett. 213B(1988) 129
   H. Toki et al., to appear in Nucl. Phys. (1989)
2. M. Iwasaki et al., to be published.



RNB COULOMB EXCITATION: ^{8}Li + Au

F.D. Becchetti, J. Brown, J.W. Jänecke, W.Z. Liu, and D.A. Roberts, Physics Department, University of Michigan, Ann Arbor, MI 48109, USA
J.J. Kolata and A. Morsad, Physics Department, University of Notre Dame, Notre Dame, IN 46556, USA
R.E. Warner, Physics Department, Oberlin College, Oberlin, OH 44074, USA

We have observed the Coulomb excitation of the particle-stable first excited state of ^{8}Li (E_x=0.98 MeV, J^{π}=1^{+}) from the reaction ^{8}Li + Au at E(^{8}Li) $\doteq$ 14 MeV. COULEX probabilities have been measured out to $\theta_{cm} \doteq 90°$ and compared with COULEX theory using the known moments of ^{8}Li. Relevance to newly predicted "halo" giant resonances in RNB projectiles is considered (Y. Suzuki, private communication).
This work was supported by NSF grants PHY-8605907, PHY-8421302, and PHY-8521042.

F. Becchetti
Physics Department
Randall Laboratory
University of Michigan
Ann Arbor, MI 48109 USA
Telephone: (313) 764-1598
FAX: (313) 763-9694
E-mail: BECCHETTI@UMIPHYS

A TEST FOR EXCHANGE RESONANCES IN ^{7}BE-^{7}LI SCATTERING

R.N. Boyd, M.S. Islam, G. Kolnicki, and M. Farrell, Ohio State University, Columbus, OH 43210 USA; and T-K. Wang, K.E. Sale, and G.J. Mathews, Lawrence Livermore National Laboratory, Livermore, CA 94550, USA

It has been suggested, by Vary and Nagarajan, that a resonance mechanism might exist in scattering between analog nuclei at energies near their coulomb barrier. We have designed an experiment to test that theoretical assertion.

The OSU-LLNL radioactive beam facility produced beams of ^{7}Be at energies from 7.0 to 12.6 MeV, with energy definition of about 0.5 MeV, by impinging beams of ^{7}Li on a H_2 gas cell. The double-triplet quadrupole spectrometer was used to select the ^{7}Be beam. Because tight collimation at the cross over between the two triplets was used to restrict the ^{7}Be beam energy spread, the intensity was 2×10^4 ions per sec. The ^{7}Be beam was scattered from a 0.20 mg/cm^2 thick ^{7}LiF target.

Scattered ^{7}Be ions were detected by a detector telescope at 15°, and by a single detector at 20°. The telescope also provided identification of reaction products such as ^{10}B or ^{12}C. Peak fitting yielded the ^{7}Be elastic scattering peaks resulting from F and Li from the target. The data thus derived provide a limit on resonance strength and width, both unspecified in the theory as it has been developed thus far.

This work was supported by the US DOE through LLNL under contract number W-7405-ENG-48, and by NSF grant PHY86-00749.

Richard N. Boyd
Department of Physics, The Ohio State University
174 W. 18th Avenue
Columbus, OH 43210 USA
Telephone: 614-292-2875
FAX: 614-292-2928
E-mail: BOYD@OHSTPY

NUCLEAR REACTIONS AND ELECTROMAGNETIC DISSOCIATION OF ^{11}Li AT 100 MeV/n

J.P. Dufour[1)], D. Bazin[1)], B. Blank[2)], H.G. Clerc[3)], R. Del Moral[1)], A. Fleury[1)], J.J. Gaimard[2)], H. Geissel[2)], F. Hubert[1)], K.-H. Schmidt[2)], M. Steiner[2)], K. Sümmerer[2)].

1 - CEN Bordeaux-IN2P3 2 - GSI Darmstadt 3 - TH Darmstadt.

In the past few years, nuclear reaction studies of ^{11}Li aroused much interest due to the observation of large reaction cross-sections. It has been conjectured that a single hypothesis, namely the existence of a neutron halo, would explain both the large radius of ^{11}Li as obtained with low-Z targets and the high electromagnetic dissociation cross-section with high-Z targets. According to this picture a significant rise of the electromagnetic dissociation cross-section should be observed when the beam energy is lowered from 800 MeV/n down to 100 MeV/n. An experiment to observe this effect has been carried out at SATURNE (Saclay, France) a few weeks ago. First results will be presented at the conference.

The principle of the measurement is to detect nuclear fragments of the secondary reaction through ΔE, range and characteristic beta radioactivity. In order to have an unambiguous beta-decay activity it is necessary to physically separate the desired secondary beam (^{11}Li, ^{9}Li, ^{8}Li in our case). The high resolution spectrometer SPES1 was used for this purpose. The primary target was placed before the first analyzing magnet and an achromatic degrader having a wedge shape was placed at the usual target position. This degrader provides the required Projectile-Fragment Isotopic Separation.

Secondary targets of C, scintillator, Cu, Sn, and Pb have been used. At the exit of the target the projectile-fragments were slowed-down in a stack of five scintillators (thickness=1 cm) with two electronic chains for each detector in order to obtain Z measurements as well as beta detection. A close geometry allowed to cover scattering angles up to 120 mrad.

J.P. Dufour
CEN - Bordeaux - IN2P3
F - 33170 GRADIGNAN FRANCE
Tel: (33) 56 89 18 00
Fax: (33) 56 75 11 80

Electromagnetic Dissociation of Exotic Projectiles at 0.8 GeV/nucleon

T.Kobayashi[1], S.Shimoura[2], I.Tanihata[3], T.Suzuki[3], K.Sugimoto[4], K.Matsuta[4], H.H.Wieman[5], D.L.Olson[5], W.F.J.Müller[5,6], and T.J.M.Symons[5]

[1]KEK, [2]Univ. of Tokyo, [3]RIKEN, [4]Osaka Univ., [5]LBL, [6]GSI

Electromagnetic dissociation cross sections of exotic projectiles, $^{6,8}He$, $^{9,11}Li$, $^{11,12,14}Be$, have been deduced from the target mass dependences of interaction cross sections and one (two)-nucleon-removal cross sections at 0.8 GeV/nucleon incident energy. Experiment was performed at LBL Bevalac using B42 line as a fragment separator and the HISS detectors.

The EMD cross sections of the exotic nuclei on high-Z targets were found to be much larger than those of the stable projectiles : $\sigma^{EMD}(^{11}Li+Pb)$ and $\sigma^{EMD}(^{11}Be+Pb)$ are 40 and 80 times larger respectively than $\sigma^{EMD}(^{12}C+Pb)$ after scaling the cross section by Z_{proj}^2. Following the interpretation of the EMD process at a few GeV/nucleon as being the excitation and decay of a Giant dipole resonance (GDR) by virtual photons, the EMD cross section can be related to the energy of the GDR. If the GDR is described with one Lorentzian function, the estimated GDR energies, $E_{GDR}(^{11}Li) \approx 5$ MeV and $E_{GDR}(^{11}Be) \approx 7$ MeV, are much lower than expected from the systematics of the stable nuclei.

It has been suggested that a nucleus with a long tail in the density distribution might have an additional soft GDR component corresponding to the oscillation of the core against the tail neutrons. The energy of the soft GDR of ^{11}Li nucleus was also estimated from the EMD cross section to be 0.9 MeV. The energy of the soft GDR turned out to be really low. This is the first experimental evidence which supports the idea of the soft GDR.

Toshio Kobayashi
Physics. Div., National Laboratory for High Energy Physics (KEK)
Oho, Tsukuba-shi, Ibaraki-ken, 305, Japan
Phone : 0298-64-1171
E-mail : KOBAYASH@JPNKEKVX

A PARITY VIOLATION EXPERIMENT WITH A SEPARATED BEAM OF Tc ISOMERS

C. Broude, G. Goldring, M. Hass and N. Takahashi, The Weizmann Institute of Science, Rehovot, Israel
S. Hofmann, F.P. Hessberger and V. Ninov, Gesellschaft für Schwere Ionen, Darmstadt, Germany

A separated isomer beam of $^{93}Tc, \tau = 15\mu s$, was prepared at the SHIP facility at GSI using the $^{45}Sc(^{52}Cr, 2p2n)^{93}Tc$ reaction at $E(^{52}Cr)$= 70 MeV and was used in a parity violation experiment. The experiment consists of polarizing the isomer beam with a stack of tilted foils and measuring the forward/backward asymmetry along the axis of polarization which would be the consequence of an M2/E2 mixture. Previous attempts were carried out at the Pelletron accelerator at the Weizmann Institute and led to a limit for the parity violating matrix element: Hpv<8 meV (Hyp. Int. 34, 139 (1987)). In the GSI experiment the foils were made of a plastic material and covered on the stopper side by an evaporated layer of carbon. The isomer beam was stopped in a foil of lead and the decay gammas observed in two germanium detectors, along and opposite to the polarization vector. The foil stack was flipped periodically by 180°. The asymmetry of the 750 KeV transition was compared to other isomeric decays which should exhibit no asymmetry. An indication of an asymmetry was found: A_γ=0.00125(50), implying a parity violating matrix elements: Hpv=1.4(7) meV.

This measurement is considered as a model for future work with beams of isomers and radioactive nuclei with polarization introduced to the nuclear system after separation, beam handling and acceleration.

Gvirol Goldring
The Weizmann Institute of Science
76100 Rehovot, Israel
Telephone: 8-482651
FAX: 8-466 966
E-mail: FNGOLDRI@WEIZMANN

D10

ON THE PRODUCTION OF A BEAM OF THE LONG-LIVED 16+ ISOMER IN HAFNIUM-178*

W. Kutschera, I. Ahmad, R. V. F. Janssens and R. C. Pardo, Argonne National Laboratory, Argonne, IL 60349 and
L. Mausner, Brookhaven National Laboratory, Upton, NY 11973

The 16+ isomer in Hafnium-178 (E_x = 2.447 MeV) is a very rare high spin species which has a long half-life of 31 years. This encourages one to consider the production of a rather unusual heavy ion beam, where the projectiles would carry a spin of 16 $\hbar$. Such a beam would allow one to perform heavy ion experiments not possible by any other means, e.g. Coulomb excitation (of the projectile) to very high spin and highly selective heavy-ion transfer reactions. The beam may also provide an interesting tool for hyperfine interaction studies.

We discuss here the feasibility of producing a low-intensity ^{178m}Hf beam at a heavy ion facility equipped with an ECR source, such as the new ATLAS injection system at Argonne. A source material containing 3 μg of ^{178m}Hf will have a rather modest activity of 0.2 mCi. Assuming a total efficiency of 10^{-3} to convert this material into a highly charged ion beam, one would be able to provide a beam of about 2 ppA (10^7 ions/s) for 10 days. To investigate the production of ^{178m}Hf with a medium-energy proton beam, we have irradiated 0.8 mm thick Ta plates at the Brookhaven Linac Isotope Producer (BLIP) with 50 μAh of protons in the energy range from 50 to 190 MeV. Production cross section of ^{178m}Hf measured via the dexcitation gamma rays of the isomer will be presented at the meeting.

The main technical challenge is the production of a ^{178m}Hf beam with a low admixture of ground state nuclei (different experiments may require different levels of isomeric purity). Since it is expected that any source material will contain an appreciable fraction of nuclei in the ground state, an efficient technique to separate ^{178m}Hf from ^{178g}Hf will have to be developed. We will discuss first ideas how such a difficult separation may be achieved with the help of laser beam interactions.

*This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract W-31-109-ENG-38.

Walter Kutschera
Argonne National Laboratory
Physics Division, Bldg. 203
Argonne, IL 60439 USA
Telephone: (312) 972-4026
FAX: (312) 972-3903
E-mail: KUTSCHERA@ANLPHY

NUCLEAR STRUCTURE USING RADIOACTIVE BEAMS

K. HEYDE

Institute for Nuclear Physics,
Proeftuinstraat, 86 B-9000 Gent (Belgium)

The possible impact that radioactive beams might have by inducing nuclear reactions in order to reach new zones of exotic nuclei further out of the present studied nuclei will be discussed.

This promising technique might lead to the discovery of new nuclei that can serve as a good testing ground for our present day understanding of nuclear structure. More in particular, implications relating to the observation of regions of intruder states and nuclear coexistence will form the central part of the discussion.

ONE AND TWO-NEUTRON TRANSFER REACTIONS WITH VERY HEAVY IONS

X. T. Liu, M. W. Guidry, S. P. Sorensen, X. L. Han, R. W. Kincaid, Department of Physics, University of Tennessee, Knoxville, TN 37996, USA, C. Y. Wu, D. Cline, W. J. Kernan, E. Vogt, A. E. Kavka, T. Czosnyka, Nuclear Structure Research Laboratory, University of Rochester, Rochester, NY 14627, USA, M. L. Halbert, I. Y. Lee, and C. Baktash, Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA

One and two-neutron transfer reaction with ^{116}Sn and ^{58}Ni beam on ^{161}Dy and ^{162}Dy targets, and ^{112}Sn beams on the spherical nuclei ^{117}Sn and ^{118}Sn, were studied. These measurements were performed at Oak Ridge National Laboratory using the Tandem, Cyclotron, and the Spin Spectrometer. The particle-particle-γ coincidence method was employed to identify the reaction exit channels. The Spin Spectrometer provided γ-ray total energy and multiplicity which was used to identify reaction entry channels. By gating on total γ-ray energy, the population of the ground-state band was approximately separated from others.

The transfer probabilities, and two-neutron transfer enhancement factors were determined as a function of scattering angle. Rotational signatures were measured for directly populating the ^{160}Dy yrast band up 18^+ states. Nuclear structures effects on one and two-neutron transfer reactions, for instance pairing effects and spatial orientation of deformed nuclei effects, are discussed.

Xin-Tao Liu
Department of Physics
University of Tennessee
Knoxville, TN 37996-1200 USA
Telephone: (615) 974-7812
FAX: (615) 974-7843
Bitnet mail: XTLIU@UTKVX

LIFETIME MEASUREMENTS FOR BETA-EMITTING PROJECTILE FRAGMENTS

K. Takeyama, M. Izumi, Y. Nojiri, T. Minamisono, A. Kitagawa, A. Ozawa, S. Momota, Y. Matsuo, T. Ohtsubo, K. Sugimoto, I. Tanihata[1], K. Omata[2], Y. Shida[2], S. Shimoura[3], K. Ekuni[4], T. Kobayashi[5], K. Matsuta[6], J.R. Alonso[6], G.F. Krebs[6], and T.J.M. Symons[6]
Osaka Univ., [1]RIKEN, [2]INS, [3]Univ. of Tokyo, [4]Kyoto Univ., [5]KEK, [6]LBL

Half lives of five light β emitters including a $f_{7/2}$-shell mirror nucleus have been measured using a projectile fragment separator built in Beam 44 at the Bevalac of LBL. The nuclei studied were $^{20,21}F$, $^{37,39}Ca$ and ^{43}Ti. These nuclei were produced through projectile fragmentations of ^{22}Ne, ^{40}Ca, and ^{46}Ti primary beams using a thick Be target at the energies around 200 MeV/ nucleon. Produced nuclei were separated by rigidity- and energy loss-analyses using the separator. Only the desired isotopes were transported down to the final focus and implanted in a thin catcher. Beta rays emitted from the stopped nuclei were detected by two sets of plastic scintillation counter telescopes covering a large solid angle. Counting periods were separated from beam bombarding periods to reject background countings, and time spectra of β rays were observed to deduce the lifetimes.

The observed time spectra of β rays were analyzed by the χ^2-minimizing method using functions composed of decaying components and a long life background. From the analyses, the half lives were deduced to be $T_{1/2}$= (11.03±0.05) sec, (4.21±0.03) sec, (169.9±9.4) msec, (864±7) msec,and (503 ± 8) msec for $^{20,21}F$, $^{37,39}Ca$ and ^{43}Ti, respectively. Thus, this established technique to get short-lived β emitters with high productivity and separability will be applied for precise measurements of the half lives and the branching ratios for the $f_{7/2}$-shell mirror nuclei.

Yoichi Nojiri
Faculty of Science, Osaka University
Toyonaka, Osaka 560, Japan
Telephone: (06) 845-0371
FAX: (06) 855-6664
E-mail: OSAVAX::MITSU

ELASTIC AND INELASTIC SCATTERING OF ^{8}Li AND ^{6}He IONS.

J. Brown, K. Ashktorab, F.D. Becchetti, W.Z. Liu, J.W. Jänecke, and
D.A. Roberts , Physics Department, University of Michigan, Ann Arbor, MI 48109, USA
J.J. Kolata and A. Morsad, Physics Department, University of Notre Dame, Notre Dame, IN 46556, USA
R.E. Warner, Physics Department, Oberlin College, Oberlin, OH 44074, USA

Elastic, and in selected cases (targets ^{12}C and ^{14}N) inelastic scattering of ^{8}Li and ^{6}He beams, E = 10 to 14 MeV, have been observed on targets $2 \leq A \leq 27$ using the UM-UND RNB facility [NIM B40/41 (1989) 503]. Large inelastic scattering probabilities are often observed, e.g. $^{12}C_{g.s} \rightarrow {}^{12}C_{2+}$, which can be attributed to the peculiar properties of ^{8}Li (deformation, T and J^{π}). Inelastic excitation of the RNB projectile can also be significant and thus *both* target and projectile excitation are major components of the total reaction cross sections. Analysis of the data in terms of a deformed ^{8}Li optical model are compared to analyses done for (stable) ^{6}Li and ^{7}Li projectiles.
This work was supported by NSF grants PHY-8605907, PHY-8421302, and PHY-8521042.

F. Becchetti
Physics Department
Randall Laboratory
University of Michigan
Ann Arbor, MI 48109 USA
Telephone: (313) 764-1598
FAX: (313) 763-9694
E-mail: BECCHETTI@UMIPHYS

BARYON EVAPORATION FROM COSMIC QUARK-GLUON PLASMA[1]

K. Sumiyoshi, K. Kusaka and T. Kajino, Department of Physics, Tokyo Metropolitan University, Setagaya, Tokyo 158, Japan

Baryon evaporation from cosmic quark-gluon plasma is studied in the chromoelectric flux tube model, which is a phenomenological model of the confinement in QCD and well explains high energy jet phenomena. Probability for baryons to penetrate through the phase boundaries of the plasma is found to be very small compared with that of mesons at the temperatures of cosmic QCD phase transition. This result confirms us that large baryon number density fluctuation remained after the phase transition due to the concentration of excess quarks in the shrinking quark-gluon bubbles. This baryon inhomogeneity drastically changes the nucleosynthesis from that of the standard big-bang model and even suggest a baryonic dark matter. Although we might get the baryon fluctuation, detail informations of this fluctuation; density, volume fraction, size and shape of high density region, are not yet obtained definitely. These quantities largely affect the abundances of elements in the nucleosynthesis and provide criteria for the formation of quark nuggets. Though we still have several uncertainties; nucleation rate of hadron phase, percolation of both phases and hadronization of high density region, which should be answered from theoretical studies of the QCD phase transition, we can calculate the evolution of quark-gluon bubbles during the coexistence epoch and get an amplitude and a shape of fluctuation at the end of phase transition using the baryonization rate we obtained. These problems are now under investigation.

Reference

1. K. Sumiyoshi, K. Kusaka, T. Kamio, and T. Kajino, Phys. Lett. B to be published.

Kohsuke Sumiyoshi
Department of Physics
Tokyo Metropolitan University
Setagaya, Tokyo 158, Japan
Telephone: (3)717-0111(ex. 3327)
FAX: (3)725-8101

D16

STRUCTURE OF ^{11}Li IN A MICROSCOPIC ^{9}Li + n + n MODEL

Y. Tosaka, Graduate School of Science and Technology, Niigata University, Niigata 950-21, Japan
Y. Suzuki † and T. Tamura, Physics Department, Niigata University, Niigata 950-21, Japan and †Physics Department, University of Michigan, Ann Arbor, MI 48109, USA

A Glauber-type analysis of the interaction cross section has shown that some of the neutron-rich nuclei in the vicinity of the neutron drip line have anomalously large radii. One of the most striking examples is the nucleus ^{11}Li. The ^{11}Li nucleus is also known to be a very weakly coupled system: The two-neutron separation energy is only 200 keV. Some interesting questions which naturally arise include: What is the structure of ^{11}Li? How can a bound system be formed from the three particle-system, ^{9}Li, n and n, in which no pairwise bound states exist?

We have studied the properties of ^{11}Li including the energy, root mean square radius and density distribution in a microscopic ^{9}Li + n + n model. The ^{9}Li - n potential was constructed by a folding procedure. The needed effective two-nucleon potentials are chosen to be consistent with the binding energy of ^{10}Li and the low energy n - n scattering data. The calculation included many configurations of $p_{1/2}, s_{1/2}, d_{5/2}, d_{3/2}, p_{3/2}, f_{7/2}, f_{5/2}$ single particle orbits.

The wave function obtained shows a density distribution more extended than that of ^{9}Li and reproduces successfully the matter root mean square radius. However, the binding energy of ^{11}Li is found to be still deficient by 1.0 - 1.5 MeV. Possible improvements in insufficient binding are discussed from the viewpoint of dineutron clustering and continuum spectrum.

Y. Suzuki
Physics Department
Bldg. Dennison, Rm 722
University of Michigan
Ann Arbor, MI 48109 USA
Telephone: (313) 763-1161
FAX: (313) 763-9694
E-mail: SUZUKI@UMIPHYS

FRAGMENTATION OF SECONDARY BEAMS OF 200 GeV/N NUCLIDES

W.T. Williams, He Yudong, Ren Guoxiao, and P.B. Price
Physics Department, University of California, Berkeley, CA 94720

Others have found that charge-changing cross sections for secondary fragments produced at Bevalac energies are generally consistent with the semi-empirical expression $\sigma_{\Delta Z} = \pi r_0^2[A_T^{1/3} + A_P^{1/3} - b]^2$ fitted to data for primary beams. [Exceptions apply to separated beams of very neutron-rich nuclides such as ^{11}Li.] We have measured the total charge changing cross sections and one-proton-removal cross sections of secondary beams of nuclides produced by nuclear and electromagnetic spallation of 200 GeV/N ^{32}S in Cu targets and 14.5 GeV/N ^{28}Si projectiles in Cu and Pb targets. For several secondary nuclei (resolved in charge but not in mass) the total and lp-removal cross sections are larger than those for primary beams with similar charge. The high cross sections are explainable if the secondary beams are enriched in unstable isotopes, especially neutron-poor nuclides which have low binding energies for proton removal.

NEW DECAY DATA NORTH-EAST OF ^{100}SN USING MICROSECOND MASS SEPARATED BEAMS

P.J. Woods, Physics Dept., University of Edinburgh, Edinburgh, EH9 3JZ, U.K.
R.D. Page, S.J. Bennett, M. Freer and B.R. Fulton, Physics Dept., University of Birmingham, Birmingham, B15 2TT, U.K.
A.N. James, Physics Dept., University of Liverpool, Liverpool, L63 3BX, U.K.
M.A.C. Hotchkis, Physics Dept., University of Manchester, Manchester, M13 9PL, U.K.
R.A. Cunningham, Daresbury Lab., Warrington, WA4 4AD, U.K.

The Daresbury Recoil Mass Separator is routinely capable of providing 1 part in 300 mass resolution. The sub-microsecond in-flight separation of evaporation residues makes it an ideal tool for the study of short-lived proton and alpha emitters residing along the proton drip-line. Analysed evaporation residues are implanted into a 2-dimensionally position sensitive silicon detector. Positional information is used to identify the parent masses of subsequent decays and to facilitate the determination of branching ratios and half-lives.

The principal objective of our first experiment using the above technique was to detect the ground-state proton decay of ^{108}I. A previous search by other workers using a catcher foil technique at GSI failed to observe this decay, though the search was insensitive to cross-sections < 5 μb. Since ^{109}I is a known proton emitter it was anticipated that ^{108}I would also decay by proton emission, though its half-life may be too short for direct observation.

260 MeV ^{58}Ni beams were used to bombard an ^{54}Fe target in order to produce ^{108}I ions via the 3n 1p evaporation channel. No evidence was found for the proton decay of ^{108}I. However, a previously unobserved decay line is present at a higher energy. We tentatively assign this line to the α-decay of ^{108}I though a possibility remains that the line is due to beta-delayed proton emission. Subsequent experiments are planned to resolve this uncertainty.

Phil Woods
Physics Dept., The King's Buildings
Edinburgh. EH9 3JZ
Telephone: (0044) 31 667 1081 Ext. 2741
FAX: (0044) 31 662 4712
E-MAIL: PJW@UK.AC.EDINBURGH.EDGA

Fermion Dynamical Symmetry and Nuclear Spectroscopy in Exotic Regimes

C.L. Wu

The Fermion Dynamical Symmetry Model (FDSM) is a symmetry-dictated truncation of the spherical shell model [1]. The FDSM has recently been applied to a variety of nuclear structure problems with striking success; for example, analytical FDSM calculations of quantities such as B(E2) values [2], or ground-state masses of the heavy nuclei [3], rival the best large-scale numerical calculations in accuracy, even though the FDSM calculations could have been done on a hand calculator. In addition, the FDSM provides a microscopic link between the common semi-phenomenological approaches to the structure of strongly collective nuclei and the spherical shell model: the FDSM yields the Particle-Rotor Model and the Cranked Shell Model in the limit of large particle number, the Interacting Boson Model in the limit of large shell degeneracy (neglect of Pauli Principle), and Hartree-Fock Bogoliubov theory in the coherent state approximation.

The success of the FDSM in these applications suggests that it may be the best microscopic theory currently available to predict the ground and excited-state properties of nuclei far from stability. Such predictions are of considerable importance in guiding proposed experiments for a radioactive beam facility. I will introduce the FDSM, and concentrate on applications of the FDSM to nuclei far from stability: microscopic predictions of masses and other ground-state properties, global properties dictated by dynamical fermion symmetries, spectra and moments of excited states, and implications for the r-process in astrophysics.

1. C.L. Wu, X.G. Chen, J.Q. Chen, D.H. Feng, and M.W. Guidry, Phys. Rev. C36, 1157 (1987).

2. D. H. Feng, C.L. Wu, M.W. Guidry, and Z.P. Li, Phys. Lett. 205B, 156 (1988).

3. C.L. Wu, X.L. Han, Z.P. Li, M.W. Guidry, and D.H. Feng, Phys. Lett. 194B, 447 (1987).

C. L. Wu
Dept. of Physics and Astronomy
The University of Tennessee
Knoxville, TN 37996-1200

RNB Applications

LASER SPECTROSCOPY OF REACTION PRODUCTS IN A COOLED GAS CELL

G.D. Sprouse, A. Berger, J. Billowes†, S. Dutta§, J. Das, C. H. Holbrow‡, T. Kühl§, T. Lauritsen, J. Schecker, and F. Xu. Physics Department, State University of New York, Stony Brook, NY 11974-3800, USA

The study of properties of nuclei far from stability with laser spectroscopy requires sensitive methods in order to be able to work with small production rates. We have shown that by directly recoil-implanting reaction products into a liquid nitrogen cooled gas cell and observing laser resonance fluorescence, that measurements of isotope shifts and hyperfine structure of Yb can be performed with production rates of less than 10^3 sec^{-1}. This method complements the collinear laser spectroscopy method, and has a lower production threshold for some elements as it avoids the restriction of a secondary ion source. The gas cell method is generally applicable to other species, and has been tested successfully with Ba, Bi and Hf.
Yb isotopes produced in heavy-ion fusion reactions were slowed down and stopped in 10 Torr of argon gas cooled to about 100K. Resonance fluorescence was then observed for these cooled atoms before they diffused to the walls of the cell. The isotope shifts were measured for ^{152,154,156,158,166}Yb and the charge radii were extracted with standard methods. The transition from the spherical N=82 nucleus to the strongly deformed isotopes occurs between N=82 and N=86, unlike in Er and Dy where there is a large increase in $\langle r^2 \rangle$ from N=88 to N=90.

† Manchester University, Manchester, England.
§ GSI, Darmstadt, W. Germany.
‡ Colgate University, Hamilton, New York.

Gene D. Sprouse
Physics Department, State University of New York
Stony Brook, New York 11794-3800
Telephone 516-632-8118
E-mail: SPROUSE@SUNYSBNP

APPLICATIONS OF RADIOACTIVE BEAMS IN DIAGNOSTIC STUDIES

Aloke Chatterjee and Jorge Llacer, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720, USA

This Bragg peak therapy of cancer patients with heavy charged particles requires precise localization of the Bragg peak on a tumor volume. A slight error can cause severe underdosing of the tumor region and overdosing of the nearby critical organs. For precise localization of the Bragg peak, one requires an experimentally measured value of the water equivalent thickness between the point of entry and the target volume. Between these two end points there can be unknown amounts of bone, tissue, sinus, air, etc. Presently used CT techniques may not be as reliable as desired, especially when there is a large amount of thick bone or air path. We have a technique which uses high energy radioactive beam and a sensitive positron camera, which, we expect, will achieve the desired accuracy. In this technique, radioactive particles such as ^{19}Ne or ^{11}C are used. These isotopes decay by emitting positrons, which then annihilate with the medium electrons to produce two gamma rays, separated by 180°. These gamma rays can then be detected in coincidence mode by a positron camera to locate their origin in space. Through adjustment of the energy of the radioactive particles (mostly ^{19}Ne will be used), they will be stopped on the location of the tumor, verifiable by the positron camera. This method provides a direct measure of the required water equivalent thickness. This technique will be applied in the treatment position (on-line) and just before the actual therapy. Unlike X-rays (used in CT), radioactive particles have penetration properties that are very similar to those of the heavy charged particles used in Bragg peak therapy. The value of the water equivalent thickness measured by a radioactive beam is then directly applicable for treatment planning with heavy charged particles. Precise delivery of Bragg peak dose on a tumor volume, while sparing the normal cells and nearby critical organs, constitutes an extremely important component of the evaluation of heavy particle treatment modality.

Aloke Chatterjee
Lawrence Berkeley Laboratory
Bldg. 29, Rm. 216
University of California
Berkeley, CA 94720 USA
Telephone: (415) 486-5415
FAX: (415) 486-4122 or 7000

OPTIMIZATION OF THE PRODUCTION OF A ^{7}Be RADIOACTIVE BEAM FOR TRIBOLOGY STUDIES

M.L. Mallory, National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824-1321, USA

We have produced a ^{7}Be radioactive ion beam from the fragmentation of an accelerated heavy ion beam on the K500 superconducting heavy ion cyclotron at Michigan State University. This beam has been implanted into a ceramic disk, which is currently being used in tribology studies. This implanted ^{7}Be beam has made it possible to study in situ the wear of ceramics, plastics, aluminum and other light mass materials by using extremely sensitive radioactive techniques as previously used by the surface layer activation method (10's of nm/hr sensitivity).

The desired sample requirements, 1) no radiation damage, 2) no target heating, 3) depth-dose distribution maximized at the sample surface, 4) reasonable bombardment time, 5) no interfering radiation background, can all be achieved by the ^{7}Be method.

Our present program at MSU has focused on optimizing the heavy ion accelerator conditions for producing the ^{7}Be beam. This has led to a series of experiments and calculations which clearly illustrate the unique character of ^{7}Be, (it is the lightest mass radioactive species having a half live >20 days and a detectable γ-ray in the decay). We shall report the results of our studies. The implantation of this radioactive ion beam into light mass materials opens a new area in wear studies.

Merrit Mallory
NSCL/MSU
South Shaw Lane
East Lansing, Michigan 48824-1321 USA
Telephone: (517)353-3246
FAX: (517)355-2246
Bitnet: MALLORY@MSUNSCL

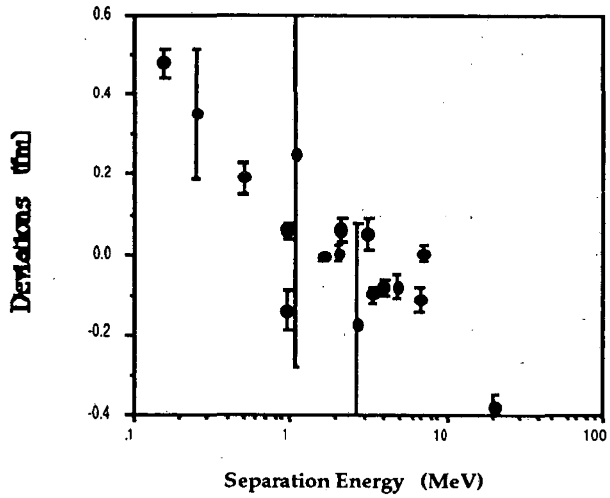
Macroscopic Properties

A SYSTEMATICS OF THE NUCLEAR RADII

Isao Tanihata[1], T. Kobayashi[2], S. Shimoura[3], K. Sugimoto[4], and T. Minamisono[4]

Secondary radioactive beams of 800 MeV/nucleon have been used to determine the nuclear radii of unstable isotopes of He, Li, Be, B, and C.[5] In these experiments secondary beams of radioactive nuclei at ~800 MeV/nucleon were produced by the magnetic separation of projectile fragments. The interaction nuclear radii R_I were determined from the interaction cross sections σ_I. Increase of the radii were observed in neutron dripline nuclei. In particular an existence of a giant neutron halo was discovered from the anomalously large size in combination with other additional informations.[6]

Recent calculations by Chang and Myers using the Thomas-Fermi model reproduces the general tendency of the R_I .[7] Deviations from the observed values are, however, seen in nuclei near the neutron dripline as well as ^{4}He. The figure shows a plot of R_I^{exp} - R_I^{theory} against the minimum separation energy of neutron or neutrons. It is seen that the deviation is strongly correlated with the separation energy. It suggest that the model of nuclear radii has to include the binding energy effects properly. Also it may suggest that the neutron halo exist in general for nuclei with small neutron separation energy.



Isao Tanihata
RIKEN
2-1 Hirosawa, Wako, Saitama 351-01
JAPAN

---

[1]RIKEN, 2-1 Hirosawa, Wako, Saitama 351-01, Japan
[2]KEK, Tsukuba, Ibaraki 305, Japan
[3]Dept. of Physics, University of Tokyo, Hongo, Tokyo113, Japan
[4]Faculty of Science, Osaka University, Toyonaka, Osaka 560, Japan
[5]I. Tanihata et al. , Phys. Letters **160B** (1985) 380, & **B206** (1988) 592, and Phys. Rev. Letters **55** (1985) 2676.
[6]T. Kobayashi et al., Phys. Rev. Letters **60** (1988) 2599.
[7]H. S. Chung and W. D. Myers, Private communications

Energy Dependence of Interaction Cross Sections

S.Shimoura[1], I.Tanihata[2], T.Kobayashi[3], K.Matsuta[4], K.Katori[4], K.Sugimoto[4], D.L.Olson[5], W.F.J.Müller[5,6], and H.H.Wieman[5]

[1]Univ. of Tokyo, [2]RIKEN, [3]KEK, [4]Osaka Univ., [5]LBL, [6]GSI

In a past several years, we have been measuring interaction cross sections (σ_I) of various nuclei at 0.8 GeV/nucleon[1)] and calculate nuclear matter radii of unstable nuclei by fitting σ_I with Glauber-type optical model[2)]. This model predicts experimental value of σ_I very well (about 1 % accuracy) for stable nuclei of which matter distributions are obtained form electron scattering data. To check the accuracy of the model in another way, we have measured interaction cross sections of stable and exotic nuclei, ^{12}C and ^{11}Li (^{8}He,^{14}Be) on Be, C and Al targets at 0.4 (0.6) GeV/nucleon, where nucleon-nucleon cross sections are different from those at 0.8 GeV (σ_{NN} [0.4 GeV] $\approx$ 0.7 σ_{NN} [0.8 GeV]). Experiment was performed at LBL Bevalac using the separated secondary nuclear beams from B42 line and the HISS detectors.

The interaction cross sections at 0.4 GeV/nucleon are found to be about 90 % of those at 0.8 GeV/nucleon. For the ^{12}C projectile, the Glauber-type calculation with the same matter distributions as 0.8 GeV/nucleon case is able to predict this reduction factor. This is a strong support to obtain matter distributions of unstable nuclei quantitatively from interaction cross section measurements in this energy region.

1) I.Tanihata et al., Phys. Lett. **B206**, 592 (1988)
2) P.J. Karol, Phys. Rev. **C11**, 1203 (1975)

Susumu Shimoura
Department of Physics, Faculty of Science, University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan
Phone: 03-812-2111 ext 4234
E-mail: SHIMOURA@TKYVAX.HEPNET

RADII OF RADIOACTIVE NUCLEI

W. Mittig, E. Plagnol, Y. Schutz, M. Lewitowicz, GANIL, B.P. 5027, 14021 - Caen/Cedex, France.
A.C.C. Villari, IFUSP and CNPq, C.P. 20516, 01498 - São Paulo, S.P., Brasil.
L. Bianchi, A. Gillibert, CENS - DPhN/BE, 91191 Gif-Sur-Yvette, France.
C. Stephan, L. Tassan-Got, IPN, B.P. 1, 91406 - Orsay/Cedex, France.
G. Audi, CSNSM, bat. 108, 91405 - Orsay Campus, France.
Zhan Wenlong, IMP, Lanzhou, China.
A. Cunsolo, A. Foti, Dipartimento di Fisica and INFN, Corso Italia 57, 95129 - Catania, Italia.
A. Belezyorov, S. Lukyanov and Y. Penionzhkevich, LNP - INR, P.O. Box 79, Moscow, URSS.

Studies of the nuclear radius of radioactive nuclei at intermediate energies have become possible with measurements of the total reaction cross section (σ_r) using the associated-γ technique. Although results using the associated-γ technique agrees with σ_r obtained by attenuation method or elastic scattering for stable nuclei, it could fail for very exotic neutron rich nuclei due to break-up reactions leading to a nucleus in the ground state or at low exitation energy plus one or several neutrons.

We present in this contribution, new GANIL σ_r measurements for radioactive nuclei using a new simple direct technique. As in our preceeding work, σ_r is an energy-integrated quantity. The secondary exotic beam is stopped in the high-resolution double function Si(Li) surface-barrier detector/target. Integrated reaction cross section is directly deduced from the energy spectrum of the detector/target, as reaction events do not have the same energy as elastic scattering.

The reduced nuclear radius r_0 is deduced for all isotopes in the frame of Kox parametrization. We observe an important effect of r_0 enhancement as function of the isospin for a given atomic mass. This result agree with Tanihata's result for $A = 12$. This effect is observed for masses from $A = 10$ up to $A = 18$. For heavier nuclei, the effect is strongly reduced, at least in the isospin range measured.

A.C.C. Villari
DFN - IFUSP, C.P. 20516
01498 - São Paulo, S.P., Brasil.
telephone : (11)211-2742
fax : (11)815-4272
mail : VILLARI%47551.HEPNET@LBL

F4

MAGNETIC MOMENT OF PROJECTILE FRAGMENT ^{43}Ti

M. Izumi, Y. Nojiri, T. Minamisono, A. Kitagawa, A. Ozawa, S. Momota, Y. Matsuo, T. Ohtsubo, K. Sugimoto, I. Tanihata[1], K. Omata[2], Y. Shida[2], S. Shimoura[3], T. Kobayashi[4], K. Matsuta[5], J.R. Alonso[5], G.F. Krebs[5], and T.J.M. Symons[5]
Osaka Univ., [1]RIKEN, [2]INS, [3]Univ. of Tokyo, [4]KEK, [5]LBL

The magnetic moment of the $f_{7/2}$-shell mirror nucleus $^{43}Ti(I^{\pi}=7/2^{-}$, $T_{1/2}$=0.50 sec) has been measured using a projectile fragment separator built in Beam 44 at the Bevalac of LBL. The ^{43}Ti nuclei were produced through projectile fragmentation using a ^{46}Ti primary beam at 240 MeV/A. The produced fragments in a Be target were separated by rigidity- and energy loss-analyses. Polarization was created in the nuclei by means of the tilted foil technique. Passing through ten tilted thin films of Au deposited Mylar, the ^{43}Ti nuclei were polarized through asymmetric beam-foil interactions. For the proper utilization of the technique, the energy spread in ^{43}Ti was reduced by a wedge-shaped absorber installed at a dispersive focus of the beam line. By controlling their ranges with a thickness controllable double-wedge absorber, the ^{43}Ti nuclei were implanted into a polycrystalline sample of TiC to maintain the polarization during the lifetime of the nuclei. Beta rays emitted from the stopped ^{43}Ti nuclei were detected by two sets of plastic scintillation counters placed above and below the TiC catcher relative to the polarization. NMR measurements on ^{43}Ti were made by means of asymmetric β decays. An appreciable NMR effect was found at an rf frequency $f=730 \pm 70$ kHz for an external magnetic field H_0= 4.8 kOe.

From the data, the magnetic moment of ^{43}Ti was deduced to be $|\mu|$= (0.70±0.07) nm. The obtained magnetic moment is in good agreement with the predicted values from the shell model calculations. Since it has been shown that the combined technique is quite suitable to study magnetic moments of the $f_{7/2}$-shell mirror nuclei, the technique will be applied on other mirror moments.

Akira Ozawa
Faculty of Science, Osaka University
Toyonaka, Osaka 560, Japan
Telephone: (06) 845-0371
FAX: (06) 855-6664
E-mail: OSAVAX::MITSU

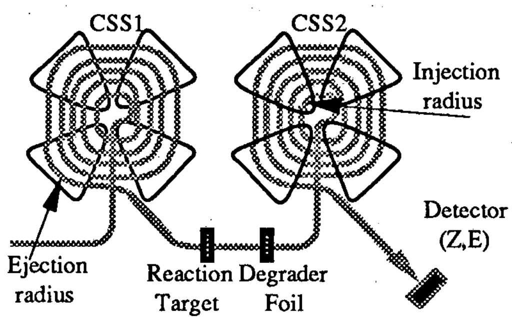
MASS MEASUREMENTS USING THE GANIL CYCLOTRONS

E.Baron, P.Bricault, A.Chabert, A. Gillibert[1],S.Groult, R.Lacey,W.Mittig, N.Orr,
E.Plagnol, C.Ricaud, Y.Schutz, A.C.C.Villari[2]
GANIL, BP5027, 14021 Caen Cedex

A standard method for mesuring masses is to use the time of flight technique coupled to a measurement of the energy. However to obtain high quality measurements ($\Delta M/M \approx 10^{-6}$) the necessary flight path becomes considerable and the method becomes inapropriate.

The ganil facility operates by a coupling of three successive cyclotron (C_0, CSS1 and CSS2) with a stripper foil between CSS1 and CSS2. After acceleration by the first two cyclotron, energies typically attained are of the order of 5-15 A.MeV. At these energies, close or above the Coulomb barrier, it is possible to use compound nucleus reaction mecanisms to produce exotic nuclei with high beam intensities by replacing the stripper foil with an appropriate target. The nuclei produced will then be injected into the CSS2, accelerated, extracted and identified by nuclear charge and energy. Because of the selectivity of this cyclotron and the very long flight path, typically 5 km, mass measurements with a resolution of 5.10^{-6} can be expected.

A particular difficulty is expected to occur due to the high frequency coupling between CSS1 and CSS2. Because of this, the velocity of the secondary beam has to be a given fraction of the velocity extracted from the CSS1. To take this into account, a velocity degrading foil will be placed between the reaction target and the injection into the CSS2.



E.Plagnol
GANIL
B.P. N°5027
14021 Caen Cedex 21, France
Telephone (33) 31 45 47 09
Fax (33) 31 45 46 65
E-Mail : PLAGNOL@FRIPN51

1) CENS -DPhN/BE
91191 Gif-sur-Yvette, France

2) DFN - IFUSP
C.P.20516
01498 - São Paulo, S.P., Brasil

F6

TESTING ATOMIC MASS MODELS WITH RADIOACTIVE BEAMS: MOTIVATIONS AND METHODS*

Peter E. Haustein, Chemistry Department, Brookhaven National Laboratory, Upton, NY 11973, USA

Radioactive beams (and/or radioactive targets) will be highly effective in increasing the yields of isotopes that lie far from beta-decay stability. An important goal to pursue with these species is a broad program of nuclidic mass measurements. This is motivated by the observation that mass models generally diverge from one another[1] in regions far from beta-decay stability where well measured masses are sparse or nonexistant. Stringent tests of mass models are therefore possible and these can highlight important features in the mass models that affect their extrapolation properties.

Several candidate nuclear reaction systems can be considered. Their selection is based on the use of radioactive beams to access mass regions where yields of new isotopic species can be optimized and in which distinctions among mass models (based on their predictions) are most apparent. Future opportunities in this area will be highlighted by several examples.

*Research performed under the auspices of the U. S. Department of Energy under Contract DE-AC02-76CH00016.

[1]P. E. Haustein, At. Data Nuc. Data Tbls. 39, 185 (1988).

Peter E. Haustein
Chemistry Department
Brookhaven National Laboratory
Upton, NY 11973, USA
Telephone: (516) 282-4340
FAX: (516) 282-5815
E-mail: HAUSTEIN@BNLDAG.BITNET

MEASUREMENT OF REACTION CROSS SECTIONS USING ^{11}Be BEAM

M.Fukuda, N.Inabe, M.Adachi, K.Asahi, T.Ichihara, M.Ishihara, M.Koguchi, T.Kubo, H.Kumagai, T.Nakagawa, H.Sagawa, S.Shimoura, and I.Tanihata

RIKEN(The Institute of Physical and Chemical Research),Wako,Saitama 351-01,Japan

Interaction cross sections(σ_I) and fragmentation cross sections were measured using ^{11}Be radioisotope beam by the transmission method using Si counter telescope in the intermediate energy ranges.(20 - 40 MeV/u) There are two advantages in using intermediate energy beam. One is that at intermediate energies, σ_I is expected to become more sensitive to such effects as an increase of the surface defuseness or neutron halo, because the nucleon-nucleon cross sections are much larger. Another point is that an information on the shape of the nucleon distribution in the nucleus can be aquired by using different energy beams from that used at LBL.

Our result shows a large enhancement of σ_I by 20 - 30 % compared with systematics of total reaction cross sections for the stable region. The main ingredient of this large enhancement was found to be the extremely large cross section of 11Be -> 10Be + n channel. The cross section of the channel is about five times larger than the calculated value by simple geometrical model for standard nuclei.

Both these results and the 800 MeV/u data can be reproduced by a simplified Glauber model using a nucleon distribution which is deduced by a Hartree-Fock calculation with a consideration of binding energy. This calculation shows a large spread of the wave function of the last neutron to the outer region of the nucleus.

Mitsunori Fukuda
Department of Physics, Osaka Univ. ,
Toyonaka, Osaka 560, Japan
Telephone: (06)845-0371
E-mail: FUKUDAMI@JPNOSKFM.BITNET

F8

LASER-INDUCED FLUORESCENCE OF WEAK RADIO-ACTIVE BEAMS

S.A. Wells, D.E. Evans, J.A.R. Griffith,
Department of Physics, University of Birmingham,
Birmingham B15 2IT, U.K.
D.A. Eastham, J. Groves, D.W.L. Tolfree,
SERC Daresbury Laboratory, Daresbury, Warrington WA4 4AD, U.K.
J. Billowes, I.S. Grant and M.P. Dancy,
Schuster Laboratories, University of Manchester,
Manchester M13 9PL, U.K.
P.M. Walker
Department of Physics, University of Surrey,
Guildford GU2 5XH, U.K.

Heavy ion accelerators such as the NSF at the Daresbury Laboratory are capable of producing a wide variety of radio-active beams. The intensities of the beams of atoms or ions are always modest, and ultra-sensitive methods are needed to observe laser-induced fluorescence. The fast atom-photon coincidence technique has been applied to neutron-deficient barium atoms down to ^{120}Ba. Nuclear moments and isotopes shifts have been determined from the measured hyperfine splittings and isotope shifts. An abrupt increase in the mean square radius is observed at ^{121}Ba, large enough to disrupt the systematic staggering seen for the isotopic series. The hyperfine structure has also been observed for an isomeric state of ^{127}Ba which has a lifetime of about 2 seconds. The measurements lead to an unambiguous assignment of the spin of the isomer. Another technique has been tested with stable krypton atoms. Fluorescence photons in the VUV wavelength region are detected with high efficiency using a channel plate detector. The background is small enough that it should be possible to measure hyperfine spectra on beams with fewer than 10^3 atoms per second.

I.S. Grant
Department of Physics
Manchester University
Manchester M13 9PL UK
Telephone: (061) 275 4158
FAX: (061) 273 5867
E-mail: MZI@UK.AC.MAN.PH.G2

DIRECT MASS MEASUREMENTS WITH RADIOACTIVE NUCLEAR BEAMS

E. Hagberg*, K.S. Sharma**, G. Dyck**, V.T. Koslowsky*, H. Schmeing*, J.C. Hardy* and R.C. Barber**.

* Atomic Energy of Canada Limited, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada K0J 1J0

** University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

A novel technique has been developed to measure the atomic mass differences between radioactive isotopes directly with an on-line isotope separator. Mass doublets or triplets are peak matched as in a conventional mass spectrometer but the new technique does not rely on ion detection but on observation of the specific radioactive signatures of the isotopes under study. Consequently, centroids can be determined, free of interfering stable contaminants. Furthermore, ground state decays can be distinguished from unwanted isobars and even isomers, to the extent that they have different radioactive signatures; the fact that the corresponding radioactive beams overlap does not generally pose a problem.

Our technique has been verified with beams of radioactive nuclides whose masses are well known. New masses have been measured for neutron-deficient In, Br and Ga nuclides. Precisions of 1 ppm have been reached. The new technique is versatile and we expect to be able to measure the masses of a broad range of radioactive nuclides.

E. Hagberg
Atomic Energy of Canada Limited
Chalk River Nuclear Laboratories
Chalk River, Ontario, Canada K0J 1J0
Telephone: (613) 584-3311
FAX: (613) 584-2039
E-mail: 02373@AECLCR

F10

SYSTEMATICS OF 14 MeV ^{8}Li-INDUCED SINGLE-NUCLEON TRANSFER REACTIONS ON LIGHT NUCLEI

W.Z. Liu, F.D. Becchetti, J. Brown, J.W. Jänecke, and D.A. Roberts, Physics Department, University of Michigan, Ann Arbor, MI 48109, USA
J.J. Kolata, A. Morsad, and X.J. Kong, Physics Department, University of Notre Dame, Notre Dame, IN 46556, USA
R.E. Warner, Physics Department, Oberlin College, Oberlin, OH 44074, USA

One-neutron transfers, mostly (^{8}Li,^{7}Li), and one proton transfers, mostly (^{8}Li,^{9}Be) have been studied on targets $2 \leq A \leq 27$ at E(^{8}Li) $\approx$ 14 MeV using the UM-UND RNB facility [NIM B40/41 (1989) 503]. Installation and operation of a high intensity cesium sputter source (NEC-SNICSII) now yields $\sim 10^6$ ^{8}Li/s thus permitting measurements to discrete nuclear levels with cross sections down to 1 mb/sr (i.e. typically out to 60° cm). Unlike low-energy ^{7}Li-induced reactions (which often have $Q \leq 0$), the ^{8}Li-induced reactions ($Q>0$, often $Q \gg 0$) can be "direct" transfers even as E(^{8}Li)$\rightarrow$ 0. However, like other HI reactions "Q-windowing" can be significant for reactions where $Q \neq Q_{opt}$. Recent data includes measurements on ^{7}Li, ^{14}N and ^{13}C targets and improved measurements for ^{2}H, ^{9}Be, ^{12}C and ^{27}Al.
This work was supported by NSF grants PHY-8605907, PHY-8421302, and PHY-8521042.

F.D. Becchetti
Physics Department
Randall Laboratory
University of Michigan
Ann Arbor, MI 48109 USA
Telephone: (313) 764-1598
FAX: (313) 763-9694
E-mail: BECCHETTI@UMIPHYS

MAGNETIC MOMENT OF SHORT-LIVED β-EMITTING $^{41}Sc(I^{\pi}=7/2^{-})$

T. Minamisono, Y. Nojiri, K. Matsuta, K. Takeyama, A. Kitagawa,
T. Ohtsubo, and A. Ozawa
Faculty of Science, Osaka University, Toyonaka, Osaka 560, Japan

In the isoscalar magnetic moments of the LS doubly closed shell ±1 nucleon nuclei around A= 16 and 40, large quenching of expectation values of spin were disclosed that provided best evidence for the tensor correlation. Also the enhancement of the isovector orbital g_l-factor disclosed the role of meson exchange currents. In the present experimental studies, the magnetic moment of ^{41}Sc was determined with better precision by means of the asymmetric β-decay distribution and NMR detection. The difficulty to evaluate the crystalline internal fields, in the catcher in which the polarized ^{41}Sc were held with the polarization maintained was solved by selecting an ionic crystal, CaO, instead of a Pt metal. From the present measurements the majority of the implanted nuclei in the crystal were disclosed to be lcated in substitutional sites of Ca atoms, and the magnetic moment was determined to be $|\mu(^{41}Sc{:}I^{\pi}=7/2^{-})| = (5.4305\pm0.0018)$ nm.

From the new isoscalar magnetic moment, the spin expectation value was extracted. In terms of the spin matrix element derived from the new isoscalar moment, the deviation of the experimental one from the single particle value was -(11.64±0.48) % of the single particle value, while the configuration mixing correction (c.m.) was -27.57 %. This large c.m. that was more than twice of the experimental deviation may suggest that a large correction due to the meson and other causes than c.m. is necessary. This deviation is analyzed in terms of the effective g-factors of the nucleon in the nucleus.

Tadanori Minamisono
Faculty of Science, Osaka University
Toyonaka, Osaka 560, Japan
Telephone: (06) 845-0371
FAX: (06) 855-6664
E-mail: OSAVAX::MITSU

F12

QUADRUPOLE MOMENT OF SHORT-LIVED β-EMITTING $^{41}Sc(I^{\pi}=7/2^{-})$

T. Minamisono, Y. Yasui, T. Ohtsubo, A. Kitagawa, Y. Matsuo,
Y. Nojiri, K. Matsuta, and S. Takeda
Faculty of Science, Osaka University, Toyonaka, Osaka 560, Japan

Nuclear quadrupole effects in the NMR spectra of ^{41}Sc in TiO_2 crystals were detected by use of the β-NMR detection in order to study effective electric charges of a single valence nucleon in an averaged nuclear potential. The method and technique employed in the measurements were the NMR for polarized β-emitter, i.e., the production of the unstable ^{41}Sc beam, creation of the spin polarization, and the following recoil implantation of ^{41}Sc in a TiO_2. The electric field gradients, were obtained in the tetragonal TiO_2 crystal(rutile). As the first step, an NMR spectrum was detected as a function of magnetic field with a frequency modulated rf (FM= 2 MHz), the center frequency (7.000 MHz) of which was fixed constant. Knowing the $|eqQ/h|$ is about 6.5 MHz, two transitions $\pm 7/2 - \pm 5/2$ in the magnetic substates were separately detected. The electric quadrupole coupling constant for the ^{41}Sc in TiO_2 was determined to be $|eqQ(^{41}Sc:7/2^{-})|=$ (6.54±0.08) MHz.

The field gradient effective to the Sc atoms at the substitutional site of Ti atoms in the crystal was measured by means of a high field (47 kOe) NMR detection on the stable isotope ^{45}Sc in a TiO_2, 0.5 % in atom-number. Two NMR transitions, i.e., $\pm 1/2 - \mp 1/2$ transitions, were detected as a function of rotation angle around a fixed axis that was set perpendicular to the high magnetic field. The coupling constant, $|eqQ(^{45}Sc:7/2^{-})|=$ (11.99±0.12) MHz, and the asymmetry parameter $\eta=$ (0.54±0.02) were determined. By use of the known quadrupole moment $Q(^{45}Sc:7/2-)=$ -(0.22±0.01) b, we obtained $|Q(^{41}Sc:7/2-)|=$ (0.120±0.006) b. Rather larger enhancement in the effective charge for neutron than that for proton was concluded from the systematic data on the LS doubly closed shell ±1 nucleon nuclei, ^{41}Sc, ^{41}Ca, ^{17}F and ^{39}K.

Tadanori Minamisono
Faculty of Science, Osaka University
Toyonaka, Osaka 560, Japan
Telephone: (06) 845-0371
FAX: (06) 855-6664
E-mail: OSAVAX::MITSU

PREDICTIONS OF GROUND-STATE DEFORMATIONS OF EVEN-EVEN NUCLEI*

S. Raman, Oak Ridge National Laboratory, Oak Ridge, Tennessee

The quadrupole mode is the lowest-order mode describing the nuclear surface that is of interest to nuclear structure. Nuclei with permanent quadrupole deformations are generally axially symmetric and prolate. A measure of their deformation is provided by the B(E2)↑ value for the first-excited 2^+ state of even-even nuclei. These measured values have been recently tabulated.[1] It has now become possible to fully understand B(E2)↑ systematics[2] in terms of global empirical and regional semiempirical models. These systematics can also be compared with more basic models that, however, require extensive numerical calculations. A simple ansatz that "Nuclei, not too near closed shells, are as deformed as they can be within a single major shell" appears to quantitatively reproduce the variations of the quadrupole moments and hence the deformations of nuclei. This ansatz can be employed, in turn, to make predictions for nuclei for which experimental B(E2)↑ values are not known. Such predictions have also been recently published.[3]

*Work done in collaboration with coauthors who are listed below. This research was sponsored by the U.S. Department of Energy under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy systems, Inc.

[1]S. Raman, C. H. Malarkey, W. T. Milner, C. W. Nestor, Jr., and P. H. Stelson, Atomic Data and Nuclear Data Tables 36, 1 (1987).
[2]S. Raman, C. W. Nestor, Jr., and K. H. Bhatt, Phys. Rev. C 37, 805 (1988).
[3]S. Raman, C. W. Nestor, Jr., S. Kahane, and K. H. Bhatt, Atomic Data and Nuclear Data Tables 42, 1 (1989).

S. Raman
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6354
Telephone: (615) 574-4496
FAX: (615) 576-1319
BITNET: RAMANS@CESARVAX

F14

Projectile Fragmentation of Exotic Nuclei at 0.8 GeV/nucleon

T.Kobayashi[1], S.Shimoura[2], K.Sugimoto[3], K.Matsuta[3], I.Tanihata[4], T.Suzuki[4], H.H.Wieman[5], D.L.Olson[5], W.F.J.Müller[5,6], and T.J.M.Symons[5]

[1]KEK, [2]Univ. of Tokyo, [3]Osaka Univ., [4]RIKEN, [5]LBL, [6]GSI

Momentum distributions and production cross sections of projectile fragments from the breakup of exotic projectiles, $^{6,8}He$, ^{11}Li, and ^{14}Be, on a carbon target have been measured at 0.8 (and 0.4) GeV/nucleon incident energies. Experiment was performed at LBL Bevalac using the separated secondary nuclear beams from B42 line and the HISS detectors.

The momentum distributions (MD) of projectile fragments from few-nucleon-removal process showed very different distribution compared with those from the stable projectiles. The MD of ^{9}Li fragments from ^{11}Li on a carbon target showed very narrow ($\sigma_0 \approx 17$ MeV/c) component in addition to the component ($\sigma_0 \approx 70$ MeV/c) which was observed commonly in the fragmentation of stable projectiles. The same phenomenon was also observed in the MD of ^{10}Be fragment from ^{11}Be.

Since the MD of the projectile fragment, hence that of the removed nucleon(s), is a Fourier transform of the spacial wave function of the removed nucleon(s), observed component with the narrow momentum width corresponds to the wave function with very long tail in the density distribution. Several observations for ^{11}Li and ^{11}Be nuclei : (1) the large RMS radii deduced from the interaction cross section measurement, (2) small two (one)-neutron-separation energies, and (3) the narrow momentum distributions observed in the present experiment, suggest the existence of a large neutron halo around these neutron-rich nuclei.

Kenzo Sugimoto
2-13-29 Minami-Kasugaoka, Ibaraki-shi, 567 Japan
Phone : 0726-23-0698
E-mail : KOBAYASH@JPNKEKVX

Technical Developments

DESIGN OF A 7T SOLENOID MAGNETIC LENS SYSTEM FOR RADIOACTIVE BEAM PRODUCTION, 10 MEV/u < E/A < 50 MEV/u.

F.D. Becchetti, J. Brown, W.Z. Liu, and D.A. Roberts, Physics Department, University of Michigan, Ann Arbor, MI 48109, USA

A 40 cm bore, 100 cm long, ca. 7T multi-coil superconducting solenoid has been designed and is under construction (Cryomagnetics, Inc.) for use as a RNB lens at the MSU-NSCL heavy-ion facility. This magnet is essentially a scaled-up version of a smaller device (20 cm bore, 3.5T) used successfully at the UM-UND RNB facility [NIM B40/41 (1989) 503]. Provisions have been made for inclusion of radial electric-field lenses, corrective solenoid lenses and mid-plane energy-loss absorbers to provide improved optics and/or mass separation. The good optical properties of solenoid lenses and the large solid angle available with a large-bore s.c. magnet (50 - 2000 msr) result in a system well-suited for production of high-intensity (10^6 - 10^8/sec), well-focused RNB's with $E/A \leq 50$ MeV/u. A number of experiments involving RNBs, A≤40 are planned, in particular study of ^{6}He-induced reactions.
This work was supported in part by the NSF Nuclear Physics Division and DoE University Instrumentation program.

F. Becchetti
Physics Department
Randall Laboratory
University of Michigan
Ann Arbor, MI 48109 USA
Telephone: (313) 764-1598
FAX: (313) 763-9694
E-mail: BECCHETTI@UMIPHYS

A RECOIL MASS SPECTROMETER FOR THE HHIRF FACILITY

J. D. Cole, Idaho National Engineering Laboratory
T. M. Cormier, Texas A&M University
J. H. Hamilton, Vanderbilt University

A Recoil Mass Spectrometer (RMS) is to be built that will carry out a broad research program in heavy ion science. The RMS will make possible the study of otherwise inaccessible exotic nuclei. Careful attention has been given to match the RMS to all the beams available from the HHIRF accelerators, including those beams with the highest energy as well as massive particles for use in inverse reactions. With the use of inverse reactions, the production of secondary radioactive beams is possible. This is due to the design of the spectrometer. The RMS is to be a momentum achromat followed by a split electric dipole mass spectrometer of the type operating at NSRL at the University of Rochester. The RMS is essential for many of the proposed experiments on short lived and/or low cross section products. The spectrometer design will be discussed, with examples and comparisons with other spectrometers given. Attention will be given to the production of secondary radioactive beams. Detector arrays to be used with the RMS will also be discussed.
This work was supported in part by the U. S. Department of Energy under contract No.DE-AC07-76ID01570.

J. D. Cole
Idaho National Engineering Laboratory
IF-603 Rm 311
MS 2211
Idaho Falls, Id 83415
Telephone: (208) 526-4091
FAX: (208) 526-2814
BITNET: jdc@inelegg

AN ELECTROSTATIC TRANSPORT SYSTEM FOR FISSION ISOMERS

H. Backe, Th. Blönnigen, M. Dahlinger, D. Habs[‡], W. Lauth, A. Scherrer, P. Schwamb, Institut für Physik, Universität Mainz, D-6500 Mainz, Fed. Rep. of Germany
[‡] MPI für Kernphysik, D-6900 Heidelberg, Fed. Rep. of Germany

We are preparing an experiment to measure the spin and the electromagnetic moments of the 14 ms fission isomeric state in ^{242}Am with a new ultra-sensitive laser-spectroscopic method. It is based on fission fragment detected resonance ionization spectroscopy in an buffer gas filled optical cell. The fission isomers are produced via the ^{242}Pu(d, 2n)^{242m}Am reaction ($\sigma = (8 \pm 3)$ μb) using a 12 MeV deuteron beam from the MP tandem accelerator of the MPI für Kernphysik at Heidelberg.

The fission isomers are transported from the target to the off-axis positioned optical cell via an electrostatic beam transport system. It consists in the target region of a 6 cm long 100 kV extraction for the highly charged fission isomers (charge state $\bar{q} = 20^+$, energy $E \leq 100$ keV) and a 12 cm long deflector between accelerator and optical cell. The axis between the projectile beam and the extraction direction amounts to 45° and, therefore, the fission isomers are already separated from the primary beam. However, in order to avoid direct view from the entrance foil of the optical cell to the target, the fission isomer beam has to be displaced parallely by 6 cm. This is performed by a doubly focussing cylindrical deflector. Its inner electrode consists of a wire grid the fission isomers pass through.

A beam spot size of 1.2 cm^2 and a rate of 1 fission isomer per μC deuteron beam charge impinging the PuF_3 target of saturation thickness was measured using a x-y position sensitive surface barrier detector at the position of the optical cell 30 cm behind the target.

Michael Dahlinger
Institut für Physik
Universität Mainz
Postfach 3980
D-6500 Mainz
Germany
Telephone: 0049-6151-39-3128
FAX: (6131) 392964
E-Mail: X114@DDAGSI3

G4

BEAM DYNAMICS OF HEAVY ION BEAMS IN A SUPERCONDUCTING INTERDIGITAL STRUCTURE FOR TRIUMF'S ISAC

J.S. Fraser, H.P. Schneider, and L. Buchmann, TRIUMF, Vancouver, B.C., Canada V6T 2A3, and J.M. D'Auria, Dept. of Chemistry, Simon Fraser University, Burnaby, B.C., Canada, V5A 1S6

In 1985, a linac was proposed for the accelerated radioactive beams facility (ISAC) at TRIUMF. The linac was comprised of a low frequency (23 MHz) radiofrequency quadrupole (RFQ) structure followed by a conventional room temperature drift-tube linac (DTL). The rationale for the choice of a linac is reviewed and the use of an alternative to the room temperature DTL, a superconducting, interdigital structure (1,2) is described. Detailed beam dynamics calculations, using a modified version of the time-dependent PARMELA code are discussed. Linac configurations for achieving final energies from 0.3 MeV/u to 10 MeV/u are presented.

1. J.R. Delayen and J.E. Mercereau, "A Superconducting Half-Wave Resonator for Accelerating High Velocity Ions", IEEE Trans. Nucl. Sci. NS-32, No. 5, 3590 (1985).

2. K.W. Shepard, "A Superconducting Heavy Ion Injector Linac", IEEE Trans. Nucl. Sci., NS-32, No. 5, 3574 (1985).

J.S. Fraser
TRIUMF
4004 Wesbrook Mall
Vancouver, B.C.
Canada V6T 2A3
Telephone: (406) 222-1047
FAX: (406) 222-1074
E-mail: FRASER@TRIUMFCL

PROJECTILE FRAGMENT SEPARATOR FOR RIKEN RING CYCLOTRON

Toshiyuki Kubo, M. Ishihara and I. Tanihata, RIKEN, Hirosawa 2-1, Wako-shi, Saitama 351-01, Japan

A projectile fragment separator (RIPS: RIKEN Projectile-fragment Separator) has been constructed at RIKEN Ring Cyclotron facility (K=540 MeV), in order to provide intermediate-energy (E<135MeV/A) radioactive nuclear beams. The fragment separator has been designed to be an achromatic beam line with an intermediate dispersive focus. It consists of Q-Q-Q-SX-D-SX-Q-F-Q-Q-SX-D-SX-Q-Q-Q-F-Q-Q-Q-F configuration, where Q, D and SX represent quadrupole, dipole and sextupole magnets, respectively, and F represents focuses. The method of isotopic separation is based on a combination of magnetic rigidity analysis and energy loss differences of fragments. The achromatic energy degrader, which does not affect first-order optics, is used at the dispersive focus (first focus) to generate the energy loss differences. The isotopic separation is made at the second focus. Experimental devices are set at the third focus.

The fragment separator has been designed to have large acceptance (80 mr in angle and 8% in momentum) and to have magnetic rigidity about 65% larger than that of the cyclotron. These features enable efficient production and collection of fragments, especially for neutron rich nuclei. In the ion-optical design of the separator, optical aberrations have been minimized by introducing the sextupole magnets, in order to achieve mass resolution greater than 100. An ion-optical treatment of the degrader has been made in optics calculation to take account of its effects on the aberrations.

The fragment separator has been designed to have a swinger magnet for primary beams, which enables the production of polarized fragments.

The detail of the separator will be described.

Toshiyuki Kubo
RIKEN, Hirosawa 2-1,
Wako-shi, Saitama 351-01, Japan
Telephone: 0484-62-1111 ex. 4114
Fax: 0484-61-5301
E-mail: RIK835::KUBO (hepnet)

NaI DETECTORS IN A HIGH BACKGROUND COUNTING

L. Bonnet, M. Frédéric, P. Leleux, I. Licot, P. Lipnik
Institut de Physique Nucléaire, Catholic University of Louvain, Louvain-la-Neuve, BELGIUM

With a view to measure a (p,γ) reaction induced by a radioactive beam on a hydrogen-rich target, the γ-rays detectors (in our case, NaI crystals) would be able to a face a high annihilation γ-ray background.

We have realised a new photomultiplier voltage divider in order to maintain operational the resolution and stability of the detectors versus couting rate. A CAMAC-based data acquisition system for a multidetector was also developed; for each NaI, the time-of-flight relative to the cyclotron RF and the total pulse charge integrated in an analog-to-digital converter were registered. As an example spectra of 8 Mev γ-rays from the $^{13}C(p,\gamma)$ reaction were recorded.

The intrinsic pile-up of γ-rays in the detectors was studied both by calculations and measurements using positron sources.

Pierre Leleux
Institut de Physique Nucléaire
Catholic University of Louvain
Chemin du Cyclotron, 2
1348 - Louvain-la-Neuve
BELGIUM
Telephone : (32) 10-47.32.29
FAX : (32) 10.45.21.83

SEPARATION OF PROJECTILE FRAGMENTS BY MEANS OF RIGIDITY AND RANGE ANALYSES

K. Matsuta, J.R. Alonso, G.F. Krebs, T.J.M. Symons, M. Izumi[1], Y. Nojiri[1], T. Minamisono[1], A. Kitagawa[1], A. Ozawa[1], S. Momota[1], Y. Matsuo[1], T. Ohtsubo[1], K. Sugimoto[1], I. Tanihata[2], K. Omata[3], Y. Shida[3], S. Shimoura[4], and T. Kobayashi[5]
LBL, [1]Osaka Univ., [2]RIKEN, [3]INS, [4]Univ. of Tokyo, [5]KEK

A projectile fragment separator has been built in Beam 44 at the Bevalac of LBL for the systematic study of the magnetic moments for the $f_{7/2}$-shell mirror nuclei. Separation of a single isotope from various fragments produced at a thick target has been successfully demonstrated using a ^{43}Ti secondary beam produced through projectile fragmentation of a ^{46}Ti primary beam. The ^{43}Ti nuclei were produced by bombarding a Be target 1.27 cm thick at 240 MeV/nucleon. The energy of the fragments was around 100 MeV/nucleon after the target. The first analysis was made in terms of rigidities of the fragments. Since the velocities of the projectile fragments were very close to those of the primary beam, A/Z of the fragments can be separated by the rigidity analysis. In order to select a single isotope, a range analysis was used as the second analysis. Since the range of isotope beams with the same rigidity are proportional to Z^{2s-2}/A^{2s-1}, another type of analysis can be provided. For our case, parameter (s) was very close to 1.74.

In order to carry out the range analysis effectively and to use the tilted foil technique for polarizing the beam, energy spread in the beam was reduced by a wedge-shaped absorber installed at a dispersive focus. In order to control their ranges, a thickness controllable double-wedge absorber was installed at the final focus. Using a Au foil as the final absorber as well, the resultant energy of the secondary beam was successfully degraded down to 1.5±1.0 MeV/nucleon. The obtained range distributions indicate that the separation of the isotopes was good enough to get the single isotope to be stopped in a thin catcher.

Kensaku Matsuta
Lawrence Berkeley Laboratory
Bldg. 50 Room 208
Berkeley, CA 94720, USA
Telephone: (415) 486-4145
FAX: (415) 486-4565
E-mail: LBL::INSLBL

OPTIMIZATION OF THE CONDITIONS OF USE OF HIGH EMITTANCE SECONDARY BEAMS

W. Mittig, GANIL, B.P. 5027, 14021 Caen-Cedex, France.

Secondary beams as obtained for example by a fragmentation-like process have a very high emittance in θ, ϕ, δ space. Hence serious problems for the transportation and use of these beams arise, because the difficulty and cost of construction of optical devices increases with the emittance. The project SISSI at GANIL, a superconducting solenoid doublet, will be used to show how one can trick out the Liouville theorem in this context. With such a type of optics, beams of an angular emittance reduced by one order of magnitude are expected. Different ways of getting solutions for the measurement of high resolution angular distributions and energy spectra independent of the emittance of the beam will be shown and illustrated by exemples. The possibilities and limitations of the use of high speed detectors to define the beam-properties before a reaction in order to reduce the effective emittance will be discussed.

W. MITTIG
GANIL
BP 5027
14021 CAEN-CEDEX
TEL : (33) 31.45.46.47
Fax : (33) 31.45.46.65
Mail : MITTIG @FRCPN11

AN ION-GUIDE ISOL COUPLED WITH A GAS-FILLED RECOIL SEPARATOR

K. Morita and T. Inamura
Cyclotron Laboratory, Institute of Physical and Chemical Research, Wako-shi, Saitama, 351 Japan
T. Nomura and J. Tanaka
Institute for Nuclear Study, University of Tokyo, Tanashi, Tokyo, 188 Japan
Y. Nagai and A. Yoshida
Department of Applied Physics, Tokyo Institue of Technology, Meguro, Tokyo, 152 Japan
T. Shinozuka and M. Fujioka
Chyclotron and Radioisotope Center, Tohoku Univeristy, Sendai, 980 Japan

A tandem-type ion-guide isotope separator on-line has been installed at the RIKEN Ring Cyclotron facility. Nuclear reaction products recoiling out of a target are separated from the primary beam by a gas-filled recoil separator and are quided into the ion-guide system placed in the second stage. Due to non-existence of an ion-source and plasma formed by the primary beam as is the case in the usual ion-guide separator, a clean mass-spectrum is obtained without backgrounds, making it possible to apply a new technique of measurements like coincidences between arrival and decay of the rare events.

Toru Nomura
Institute for Nuclear Study
University of Tokyo
Tanashi, 188 Japan
Telephone:(0424)61-4131
FAX:(0424)68-5844
E-mail:NOMURA JPNUTINS

ION-OPTICAL DESIGN OF A PILOT SEPARATOR FOR THE JHP-ISOL

M. Fujioka and T. Shinozuka, Cyclotron and Radioisotope Center, Tohoku University, Sendai, Japan

T. Nomura and H. Kawakami, Institute for Nuclear Study, University of Tokyo, Tanashi, Japan

H. Wollnik and S. Meuser, Institute of Physics II, University of Giessen, Giessen, West Germany

Construction of a pilot separator of the JHP-ISOL for accelerated radioisotope beams is proposed at the Sector-Focusing Cyclotron of INS. The former will be virtually one half of the magnetic part of the latter, and is expected to achieve a mass dispersion and resolving power of 5 m and 10000, respectively. The ion optics of this pilot separator is designed and described. The separator consists of a 68-degree bending part of mean radius of $\rho = 0.6$ m after the extraction electrode and an einzel lens, a pair of analyser magnets of 45-degree deflection of $\rho = 2.5$ m for mass analysis, and a final bending magnet after the slit to send the mass-analysed beam into the initial stage of the following heavy-ion accelerator having an acceptance energy as low as 60 keV/u, as well as of multipole elements.

This pilot separator will not only be used for actual researches of nuclei far from stability using the cyclotron beams on-line, but also it (especially, the mass-analysing pair of magnets) will finally be transferred and constitute part of the later planned JHP-ISOL.

M. Fujioka
Cyclotron and Radioisotope Center
Tohoku University
Aramaki-Aoba, Sendai 980 JAPAN
Telephone: 022-263-5360
FAX: 022-263-5358
E-mail: FUJIOKA@JPNTOHOK

AN ELECTRON CYCLOTRON RESONANCE ION SOURCE FOR EFFICIENT PRODUCTION OF RADIOACTIVE NUCLEAR BEAMS.

P. Van Duppen, P. Decrock, M. Huyse, G. Reusen; L.I.S.O.L., K.U.Leuven, 3030 Heverlee, Belgium
C. Dom, F. Baeten; I.R.E., 6220 Fleurus, Belgium
Y. Jongen; C.R.C., U.C.L., 1348 Louvain–la–Neuve, Belgium

A single stage E.C.R. ion source was constructed for the Radioactive Ion Beam project [1] in Louvain–la–Neuve. The magnetic structure of the source consists out of a permanent magnetic hexapole and an axial solenoidal field. The microwave power (6.4 Ghz) was coupled to the copper body of the source that acts as a multimode cavity. Off–line tests with a calibrated Ne leak show a maximum ionization efficiency of 52 %, 15 % and 3 % for the Ne^{1+}, Ne^{2+}, Ne^{3+} respectively. Measurements have been performed varying microwave power, support gas flow and gas nature.

In a first test where the two cyclotrons were coupled producing a ^{13}N ($T_{\frac{1}{2}}$=9.96m) beam of 8.4 MeV, an ionization efficiency of 0.5 % was obtained. This low number is partially due to sticking of the N atoms to the wall. In order to solve this problem, installation of a quartz tube in the source is foreseen and the possibility in using alternative wall coatings will be investigated.

In this contribution, we will present the layout of the source in detail and present the first results. The possibilities to couple an E.C.R. source with different target systems (high temperature diffusion based targets and a He–jet system) will be discussed.

[1] The RIB–project is a collaboration between the universities of Louvain–la–Neuve, Bruxelles and Leuven.
Th. Delbar, J. Vanhorenbeek and M. Huyse ed. RIB–n°1

P. Van Duppen
L.I.S.O.L., K.U.Leuven,
Celestijnenlaan, 200 D
B 3030 Leuven Belgium
Telephone: 32/16/201015
FAX: 32/16/201368

EXPECTED PERFORMANCE OF THE PROPOSED JHP-ISOL

H. Wollnik and S. Meuser, Institute of Physics 2, University of Giessen, Giessen, West Germany

M. Fujioka and T. Shinozuka, Cyclotron and Radioisotope Center, Tohoku University, Sendai, Japan

T. Nomura and H. Kawakami, Institute for Nuclear Study, University of Tokyo, Tanashi, Japan

An ion-optical design was recently proposed for the JHP-ISOL, the isotope separator on-line for accelerated radioisotope beams, which together with a heavy-ion accelerator of ultra-low acceptance energy, constitute the main facility of the E (Exotic Nuclei) Arena of the JHP (Japanese Hadron Project). The optical design of this separator system has been elaborated to include higher-order aberrations as well as ray-tracing simulations considering space-charge effects. Part of the previous design is changed, especially, that of the injection beam line and the electrostatic analysers. Also the problem of beam rotation has been studied in some detail.

It is shown that it is possible to attain the design aim of a mass resolving power of 20000 at a transmission near 100 % for a plasma ion source of reasonable emittance as far as the ion optical calculations are concerned.

H. Wollnik
II Physikalishes Institut, Universitaet Giessen
Heinrich-Buff-Ring 16,
6300 Giessen, West Germany
Telephone: 0641-7022760
FAX: 49-641-7022099
E-mail: HERMANN WOLLNIK@DGIPIG5

Author Index

AUTHOR INDEX

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. Neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or The Regents of the University of California and shall not be used for advertising or product endorsement purposes.

Lawrence Berkeley Laboratory is an equal opportunity employer.

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
1 CYCLOTRON ROAD
BERKELEY, CALIFORNIA 94720