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Proposal for Nuclear Physics Experiment at RI Beam Factory

(RIBF NP-PAC-09, 2011)

Title of Experiment:	The E(U)RICA Spectrometer		
Category:	[] NP experiment	[] Detector RD	[X] Construction
	[] Update proposal (Experiment Program: NP -)		
Experiment Device:	[] GARIS	[] RIPS	[X] BigRIPS
	[X] ZeroDegree	[] SHARAQ	[] SAMURAI

Spokesperson:

Name	Shunji Nishimura
Institution	RIBF, RIKEN
Title of position	Researcher
Address	2-1 Hirosawa, Wako, Saitama 351-0198, Japan
Tel.	+81 (0)48 467 9475
Fax.	+81 (0)48 462 4464
Email	nishimu@riken.jp

Name	Pieter Doornenbal
Institution	RIBF, RIKEN
Title of position	Foreign postdoctoral researcher
Address	2-1 Hirosawa, Wako, Saitama 351-0198, Japan
Tel.	+81 (0)48 462 1111 ext. 4750
Fax.	+81 (0)48 462 4464
Email	pieter@ribf.riken.jp

Beam Time Request Summary:

Tuning with Beams	– DAYS
DATA RUNS	4 DAYS
TOTAL	**4 DAYS**

Primary Beam:

Particle	^{48}Ca or heavier	Energy	345 (AMeV)	Intensity	Any

RI Beams			Beam-On-Target Time for DATA RUN
Isotope	Energy (AMeV)	Intensity (/s)	Days
Any	Any	Any	4

Estimated date ready to run the experiment	Fall 2011
Date which should be excluded if any	—

Summary of Experiments:
It is proposed to construct a gamma-ray spectrometer composed of 15 already existing EUROBALL Cluster Ge detectors for experimental campaigns at the Radioactive Isotope Beam Factory (RIBF). This EUROBALL RIKEN Cluster Array (E(U)RICA) is intended for isomer and β-delayed γ-ray spectroscopy experiments of unstable nuclei and was previously employed for PreSpec campaigns, the successor of the Rare Isotope Spectroscopic INvestigation at GSI (RISING). E(U)RICA will have a full energy efficiency of 15% at 662 keV. The high granularity of E(U)RICA, each Cluster detector comprises 7 encapsulated Ge crystals, will be particularly well suited to reduce the "prompt-flash" background originating from the slowing-down of the nuclei in the active or passive stopper.

The Cluster detectors may become available for experimental campaigns at RIKEN for the year 2012, pending a final decision by the Gammapool Owners Committee, the administrators of the Cluster detectors, in July 2011. Transfer, mounting, and commissioning of E(U)RICA is planned for fall of 2011 and remounting and commissioning for PreSpec at GSI is planned for spring of 2013. In this construction proposal an outline of the physics goals, organizational structure, schedule, and the experimental configuration for the E(U)RICA spectrometer is presented.

E(U)RICA is an open project and research campaign. An international workshop is in preparation for May 23-24th at RIKEN to discuss the science, collaboration, and organizational matters. Results of this workshop may be included into the presentation at the 9$^{\text{th}}$ Program Advisory Committee (PAC) Meeting for Nuclear-Physics Experiments at the RIBF.

This construction proposal is based on a Letter of Intent (LOI), which was sent to the Gammapool Owners Committee in April 2011.

List of Collaborators:

Name	Institution	Title or position	Email
N. Aoi	Osaka University	Professor	aoi@riken.jp
H. Baba	RIKEN	RNC Scientist	baba@ribf.riken.jp
G. de Angelis	INFN Legnaro	Research Division Head	deangelis@lnl.infni.it
P. Doornenbal	RIKEN	Postdoc	pieter@ribf.riken.jp
J. Gerl	GSI	Group Leader	j.gerl@gsi.de
E. Ideguchi	CNS	Researcher	ideguchi@cns.s.u-tokyo.ac.jp
R. Krücken	TRIUMF	Science Division Head	reiner.kruecken@triumf.ca
M. Lewitowicz	GANIL	Researcher	lewitowicz@ganil.fr
Z.H. Li	RIKEN	Postdoc	zhli@ribf.riken.jp
G. Lorusso	RIKEN	Postdoc	lorusso@ribf.riken.jp
T. Motobayashi	RIKEN	Team Leader	motobaya@riken.jp
S. Nishimura	RIKEN	Researcher	nishimu@riken.jp
H. Sakurai	RIKEN	Chief Scientist	sakurai@ribf.riken.jp
H. Watanabe	RIKEN	Research Associate	hiroshi@ribf.riken.jp
H.J. Wollersheim	GSI	Researcher	h.j.wollersheim@gsi.de
K. Yoshinaga	RIKEN	PhD. Student	yoshinaga@phnp170.ph.noda.tus.ac.jp

Detailed Description of the proposed experiment

The E(U)RICA Spectrometer

Contents

1 Introduction

After several years of successful operation with stable beams at the Laboratori Nazionali di Legnaro (1997-98) and the Institut de Recherches Subatomique (1999-2003) [1], the EUROBALL Cluster Ge-detectors were moved to GSI for the first utilization with radioactive isotope beams (RIB) produced by the fragment separator FRS [2] in the Rare Isotope Spectroscopic INvestigation at GSI (RISING) collaboration [3]. A variety of techniques is necessary to illuminate different aspects of nuclear structure, i.e., obtain information on key experimental observables. Therefore, within several RISING campaigns the Cluster detectors were utilized with three experimental setups:

- In-beam γ-ray spectroscopy at relativistic energies above 100 MeV/nucleon [3],
- g-factor measurements of isomeric stopped beams [4],
- Isomer and β-delayed γ-ray spectroscopy of stopped beams [5].

Meanwhile, after a construction period of more than ten years, the Radioactive Isotope Beam Factory (RIBF) of the RIKEN Nishina Center went on-line with its first beam at 345 MeV/nucleon in 2006. The search and discovery of more than 40 new isotopes in 2007 and 2008 using an uranium primary beam at 345 MeV/nucleon and the fragment separator BigRIPS [6] demonstrated the great potential of the RIBF [7, 8]. Also with other primary beams secondary beam rates were achieved that are presently unavailable at any other facility [9, 10].
With the construction of the E(U)RICA spectrometer, i.e., bringing 15 EUROBALL Cluster Ge-detectors including the support structure and electronics to the RIBF, we hope to create unique experimental opportunities for the worldwide nuclear structure community. In this construction proposal we will describe our intentions to built the array at the focus F11 of the BigRIPS/ZeroDegree spectrometers. An international workshop has already been announced that will be held on May 23-24, 2011 at RIKEN. This workshop will help us to further clarify the goals for E(U)RICA, in particular the physics cases, and to establish and expand the collaboration.

2 Physics Case

This construction proposal for E(U)RICA at RIKEN is intended for stopped-beam experiments utilizing isomer spectroscopy and beta-delayed gamma-ray spectroscopy. Several experiments have already proposed and approved by the RIBF NP-PAC using a setup of only a few Clover Ge-detectors. The list of approved experiments is given in Tab. 2. As these experiments utilize a setup with a photo-peak efficiency of a factor three to ten less than will be available with E(U)RICA, it is expected that the spokespersons are interested in making use of E(U)RICA.
Furthermore, during the workshop in May, several ideas for new experiments will be presented that are expected lead to physics proposals for the RIBF NP-PAC meeting at the end of this year. A list of approved experiments planning to use E(U)RICA and intended physics proposals will be presented during the RIBF NP-PAC meeting in June $24/25^{\text{th}}$.

3 Experimental Configuration

The γ-ray spectroscopy experiments will be carried out with radioactive isotope beams produced after in-flight separation from the BigRIPS fragment separator. The E(U)RICA spectrometer will be located at the focus F11 of the ZeroDegree spectrometer.

3.1 General Layout

A general layout of the RIBF is shown in Fig. 1. Stable beams are accelerated by the Superconducting Ring Cyclotron (SRC) up to energies of 345 MeV/nucleon and strike the production target of the BigRIPS fragment separator in order to produce the

Title	Spokesperson	Primary Beam	Approved/ Remaining
Search for two-proton radioactivity of ^{59}Ge, ^{63}Se, and ^{67}Kr	B. Blank	^{78}Kr	5/5
Decay Spectroscopy in the vicinity of ^{100}Sn	M. Lewitowicz, R. Krücken, S. Nishimura	^{124}Xe	10/10
Decay study for Co, Ni, Cu, and Zn near N=50 shell closure	S. Nishimura	^{238}U	7.5/7.5
β-decay study of Rb, Sr, Y, Zr isotopes on r-process path	T. Sumikama	^{238}U	4/1
Search for long-lived isomeric states in neutron-rich Cd, Ag, and Pd isotopes	H. Watanabe	^{136}Xe	6/6
Decay Spectroscopy Near ^{64}Cr (Z=24,N=40)	R. Clark	^{86}Kr	6/6
β-decay studies of Al, Si, and P isotopes near N=28	Z. Li	^{48}Ca	5/5
β-decay spectroscopy of the very neutron rich-nuclei Nb-Ag, including the rprocess waiting points ^{128}Pd	G. Lorusso	^{238}U	?/?
Gamma spectroscopy and B(E2) measurements to study shape transitions in neutron rich Mo and Tc isotopes	T. Back, E. Ideguchi	^{238}U	?/?
Search for 6^+ isomers in ^{136,138}Sn	G. Simpson	^{238}U	7/7

Table 1: List of isomer and β-delayed decay spectroscopy experiments that have been proposed and approved by the RIBF NP-PAC. The column on the right displays the number of approved and remaining days of beam time for the experiment.

radioactive isotopes of interest. Achieved and expected primary beam intensities at the RIBF are presented int Tab. 3.1. Secondary beam intensities are correspondingly high as mentioned, for example, in Refs. [9, 10] for ^{31,32}Ne.

The first stage of BigRIPS will be employed for selection and purification by the $B\rho$–ΔE–$B\rho$ method, while in the second stage the particles will be identified using $B\rho$, ΔE, and time-of-flight (TOF) information. All necessary detectors for particle identification are already available and part of the BigRIPS standard setup.

After transportation to the focus F11 the secondary beams will be slowed down by means of an aluminum degrader and stopped in either a passive plastic block for isomer spectroscopy or an active silicon detector for β-delayed γ-ray spectroscopy. The stopping position will be surrounded by the E(U)RICA spectrometer composed of 15 EUROBALL Cluster detectors.

Nucleus	Beam Intensity / pnA	
	Achieved	Expected FY 2011
^{48}Ca	230	200
^{86}Kr	30	30
^{124,136}Xe	–	10
^{238}U	0.8	5

Table 2: Examples of expected and achieved primary beam intensities at the RIBF in pnA impinging on the production target.

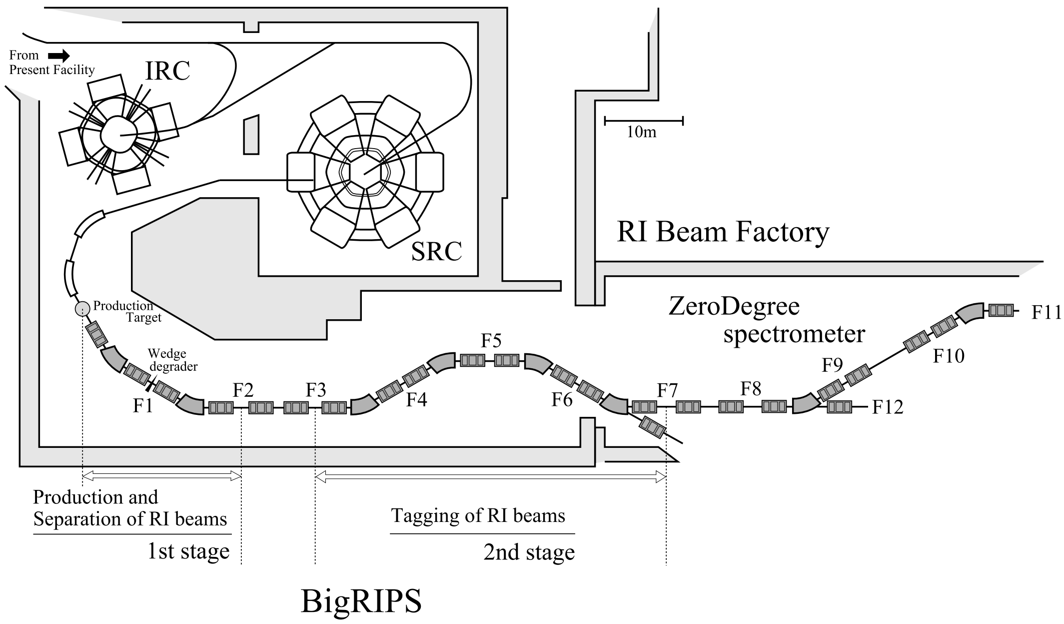
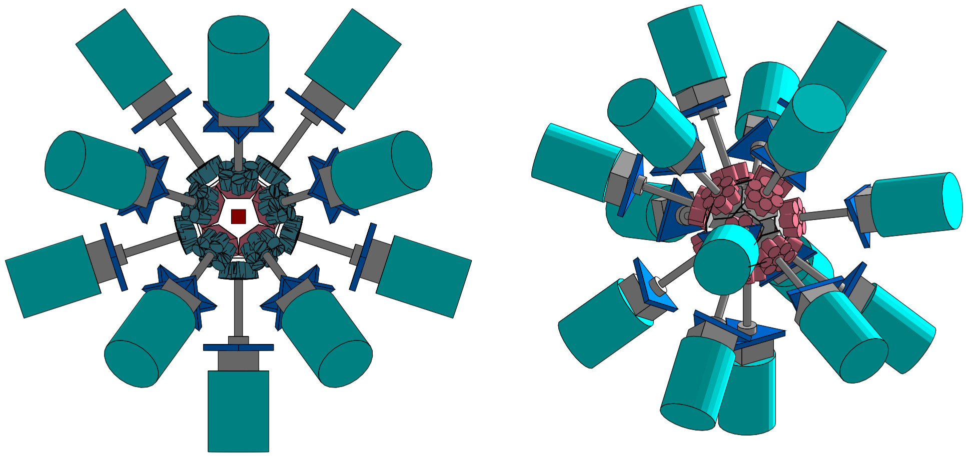


Figure 1: Overview of the RIBF facility. The radioactive ion beams are produced and separated with the BigRIPS fragment separator and transported to the focus F11, the location of the E(U)RICA spectrometer.

3.2 Support Structure and Detector Configuration

The same support structure as formerly used for the RISING stopped beam campaign at GSI [5] will be employed for the Cluster detectors, requiring a new foundation at F11.

The Cluster detectors will be arranged in 3 rings of 5 detectors at ϑ-angles of 51, 90, and 129 degrees, respectively, and distances of about 220 mm. The photo-peak efficiency at 662 keV is expected to be 15%, the same as was achieved for the RISING spectrometer [5]. Figure 2 displays the detector configuration schematically.



(a) Upstream view (b) View from 120 degrees

Figure 2: Schematic layout of the E(U)RICA spectrometer. The 15 Cluster detectors are arranged in three rings at angles of 51, 90, and 129 degrees, respectively, and distances of about 200 mm.

3.3 Electronics and DAQ

The electronics scheme will correspond to the scheme employed for RISING. The two output channels from the Cluster's preamplifiers will be sent to two individual branches for energy and timing, respectively. The energy branch will be processed by digital DGF-4C modules by XIA [11]. With these modules an energy resolution of less than 3 keV was reported at 1332.5 keV for the RISING campaigns [5]. The individual DGF channel triggers will be validated by the master trigger signal of one of the various plastic scintillators in the beam-line.

The analogue timing branch will originate from the second preamplifier output of the Cluster detectors. The readout circuit will be composed of a standard TFA-CFD-TDC branch. All digital and analogue electronic modules will be re-used from RISING.

The data acquisition systems for BigRIPS and the E(U)RICA spectrometer will run independently. Therefore, a common clock for event synchronization will be sent to both systems. This approach, which has to be worked out in detail for E(U)RICA, was already successfully implemented with the coupling of a sophisticated external detector system (MUST2 [12]) with the RIBF data acquisition.

3.4 High Voltage Supply and Cooling System

An automated high voltage supply and LN_2 cooling system will be employed for the E(U)RICA spectrometer. The cooling system corresponds to the one in use during the RISING campaigns [13]. It will be assembled and shipped to RIKEN by GSI.

A liquid nitrogen pipeline is planned to lead from the storage tank outside of the RIBF building to a buffer tank on the floor B3F, one floor below the E(U)RICA spectrometer. This buffer tank will be used to fill two smaller buffer tanks for E(U)RICA that are

connected to two filling stations responsible for liquid nitrogen filling. Up to eight detectors can be attached to one station, which will be controlled by software and fill detectors automatically.
The high voltage will be applied to the individual detectors via software. Status surveillance via internet will be possible for high voltage and the filling system.
As Eastern Japan has an electrical power line voltage of 100V/50Hz, a converter unit will have to be utilized for the RISING electronics being used. Furthermore, an uninterruptible power supply will be provided for the high and low voltage of the Cluster detectors as well as the filling system.

4 Organizational Structure

The envisioned organizational structure of E(U)RICA is schematically shown in Fig. 3. It is planned to establish an international steering committee that sets the general framework for the project management. This project management, supported by the RIKEN Nishina Center, will be divided into several working sub-groups responsible for:

- Infrastructure,
- Data acquisition and analysis,
- Electronics,
- Mechanics,
- Logistics.

The level of assistance by the collaborating research community will be discussed during the E(U)RICA workshop. The collaborating research community will be closely connected to the project management in order to elaborate and structure the physics proposals, implement auxiliary detectors, carry out experiments and so on. Furthermore, the research community is expected to assist the project management in the installation of E(U)RICA at the RIBF.

4.1 Technical Support

GSI has agreed on technical expert support for mounting the E(U)RICA spectrometer, setting-up the electronics at the RIBF, and training of the technical support team for detector maintenance and operations. Further assistance is needed by the RIKEN Nishina Center Computing and Network Team for setting up and merging the independent data acquisition systems of the BigRIPS and E(U)RICA spectrometers.

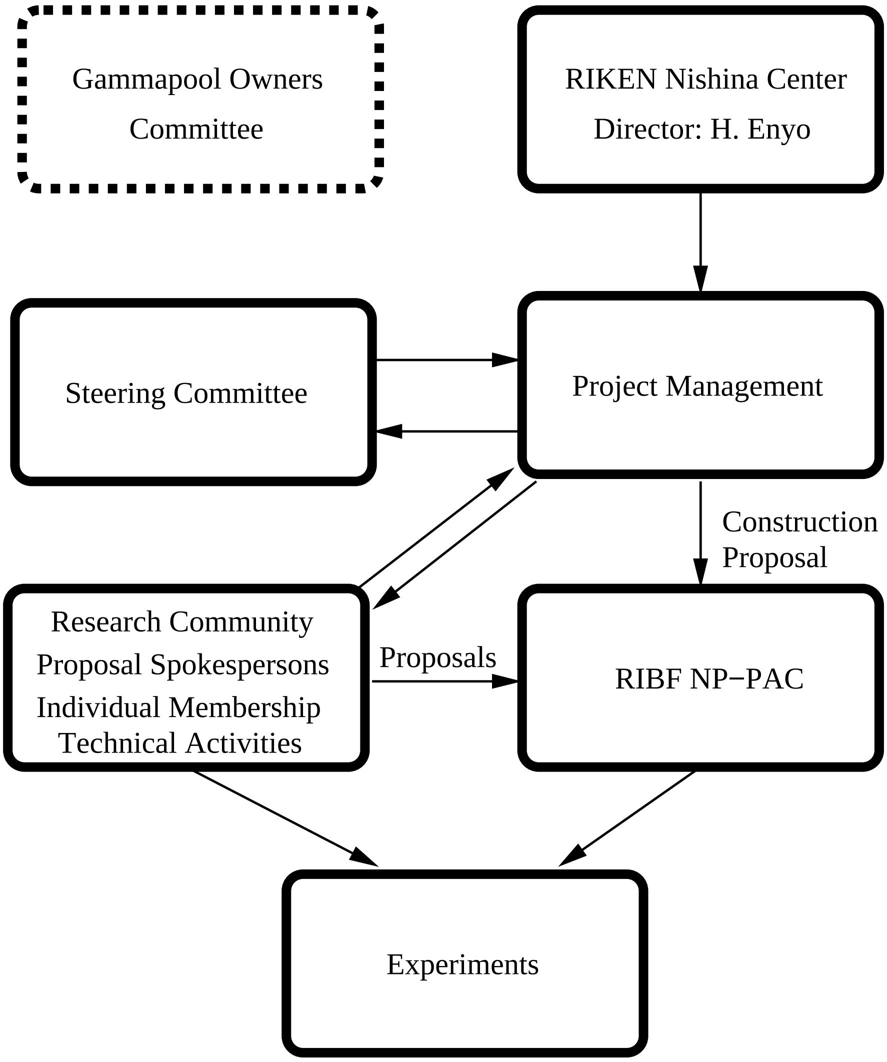


Figure 3: Tentative organizational diagram of the E(U)RICA collaboration.

4.2 Equipment Needs

Most of the electronics including the high and low voltage power supply and the holding structure (mechanical support structure and detector holders) will be re-used from RISING. Necessary equipments not yet available that need to be constructed and/or purchased for the E(U)RICA project are:

- Shipment boxes for cryostats
- BNC, SHV, and preamplifier cables for Ge detectors
- Uninterruptable power supply system
- 220/100 Volts converter for electronics

- Rail system for array movement
- Cooling system including buffer tanks, PCs, etc.
- Data acquisition PCs

5 Schedule and Beam Time Request

The planned time-line of E(U)RICA is shown in Tab. 5. The last experiments utilizing the Cluster detectors within the PreSpec Campaign at GSI have been carried out in May 2011. The RIBF beam time schedule foresees experiments using BigRIPS in the second half of 2011, which might occasionally prohibit construction and assembling works at the designated E(U)RICA location. Therefore, all construction works have to be performed considering the restrictions of the beam time schedule.
The physics cases discussed during the workshop in May will be submitted as a set of proposals to the RIBF NP-PAC to be held in December 2011 so that the first experiments with E(U)RICA can be performed from the beginning of the calendar year 2012.

Time / Task	2011									2012		
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Letter of Intent	■											
Last PreSpec Experiment		■										
E(U)RICA Workshop		■										
Construction Proposal			■									
Disassembling of PreSpec Array			■	■								
Memorandum of Understanding				■								
Shipment of Support Structure				■	■							
Shipment of Electronics				■	■							
Shipment of Detectors				■	■							
Construction of LN2 Pipeline				■	■							
Construction of Rail System				■	■							
Assembling of E(U)RICA					■	■	■					
Beam Time at RIBF							■	■	■	■	■	■
E(U)RICA Commissioning								■	■			
RIBF NP-PAC Meeting									■			
E(U)RICA Experiments										■	■	■

Table 3: Intended time-line of the E(U)RICA project in the Japanese FY 2011. The experimental program is intended to continue through FY 2012.

A commissioning of the E(U)RICA spectrometer with secondary beam is necessary to test and verify the electronics and the data acquisition system. For this, we request four days of beam time with an isomeric secondary beam that is easily stopped at the F11 focus, i.e., the primary beam should have element number of $Z \geq 20$. Furthermore, parts of the tests could be performed as parasitic users when secondary beam experiments are performed with BigRIPS only and the beam is not stopped at F7.

Regarding the E(U)RICA physics case, it is expected that the proposals concentrate on a few primary beams in order to allow for running the experiments efficiently in several blocks of beam time.

It is planned to decommission E(U)RICA in the FY2013 an ship back the equipment to GSI.

6 Collaboration

It is expected that many of the European institutions participating in RISING, more than thirty in total, will collaborate with E(U)RICA. In addition, many Japanese institutions and other institutions around the world are anticipated to join. A clear picture on the size and members of the collaboration will be obtained after the workshop in May. At present, the institutions intending to collaborate with E(U)RICA are:

- GANIL, Caen, France
- GSI, Darmstadt, Germany
- INFN, Legnaro, Italy
- Technische Universität München, Germany
- Osaka University, Japan
- Tokyo University of Science, Japan
- University of Tokyo, Japan
- TRIUMF, Vancouver, Canada
- RIKEN, Wako, Japan

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