The E(U)RICA Project

Letter of Intent

Submitted to the Gammapool Owners Committee

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Abstract

It is proposed to utilize 15 EUROBALL Cluster detectors for experimental campaigns at the Radioactive Isotope Beam Factory (RIBF) of the RIKEN Nishina Center (RNC). The RIBF is in operation since 2007 and has shown that it is presently capable of delivering the world's most intense secondary beams from in-flight separation after fission and fragmentation reactions. The 15 Cluster detectors are currently in use for PreSpec campaigns, the successor of the Rare Isotope Spectroscopic INvestigation at GSI (RISING). The possibility has been indicated that the Cluster detectors may become available for experimental campaigns at RIKEN for the year 2012, with transfer, mounting, and commissioning in the fall of 2011 and remounting and commissioning for PreSpec at GSI in early spring of 2013. A collaboration is presently forming to explore this scientific opportunity.

With the present Letter of Intent (LoI) the RNC wants to express its interest and support for hosting the detector array for such a program. This LoI presents an outline of the physics goals, organizational structure, schedule, and the experimental configuration for the EUROBALL RIKEN Cluster Array (E(U)RICA).

E(U)RICA will be 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. A full proposal is intended to be submitted to the Gammapool Owners Committee on July 1, 2011

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 observables allowing to draw further theoretical conclusions. 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].

In this Letter of Intent we propose to connect the Cluster detectors with the BigRIPS fragment separator for experimental campaigns at the RIBF in 2012. The world's most intense secondary beam rates from in-flight separation and the high photo-peak efficiency and granularity of the Cluster detectors provide unique opportunities for nuclear structure studies. On the following pages we will describe our intentions for the EUROBALL RIKEN Cluster Array (E(U)RICA) collaboration. 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 and to establish and expand the collaboration.

2 Research

Our present intent is to operate E(U)RICA at RIKEN primarily in the stopped-beam experimental mode for isomer spectroscopy and beta-delayed gamma-ray spectroscopy. Several experimental techniques are, in principle, conceivable with the E(U)RICA spectrometer. These are:

- Fast beam experiments above 100 MeV/nucleon:
  - Coulomb excitation
  - Nucleon removal
  - Secondary fragmentation
- Slow beam experiments at energies around 4 to 20 MeV/nucleon:
  - Multiple Coulomb excitation
  - Transfer reactions
  - Fusion-evaporation
- Stopped beam experiments:
  - g-factor measurements of isomeric states
  - Isomer spectroscopy
  - β-delayed γ-ray spectroscopy

Due to the current constraints on the limited available space of BigRIPS for fast-beam experiments and the straightforwardness of stopped beam experiments we presently would like to focus our research on utilizing the techniques of isomer spectroscopy and β-delayed γ-ray spectroscopy. Experiments measuring g-factors require a dedicated setup that differs from the other two methods. However, we should perhaps point out that the collaboration may express interest during the E(U)RICA workshop in performing experiments utilizing additional techniques.

Our present limitation to stopped beam experiments nevertheless allows for the study of a wide range of important nuclear structure phenomena. In fact, several experiments addressing such questions have been 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 might become interested in making use of E(U)RICA.

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 2.1: 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.

However, as shown in the organizational diagram in Section 4 of this LoI, all proposals for experiments to be run at RIBF have to pass the RIBF NP-PAC, as will be the case for new proposals from the E(U)RICA collaboration. We anticipate that this will be also the case for reformulated (already approved) proposals that now want to use E(U)RICA. This will be addressed by the collaboration at the workshop in May and, subsequently, between NRC/RIBF management and the E(U)RICA Steering Committee. In any case though, from a science point of view the important opportunities provided by stopped-beam experiments become visible, for example, for the case of the ^{100}Sn experiment where the production yield for BigRIPS is expected to be larger by one to two orders of magnitude compared to previous experiments [11–17].

3 Experimental Configuration

The γ-ray spectroscopy experiments will be carried out with radioactive isotope beams produced after in-flight separation from the BigRIPS fragments separator at the RIBF.

3.1 General Layout

A general layout of the RIBF is shown in Fig. 3.1. 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 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.

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

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.

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

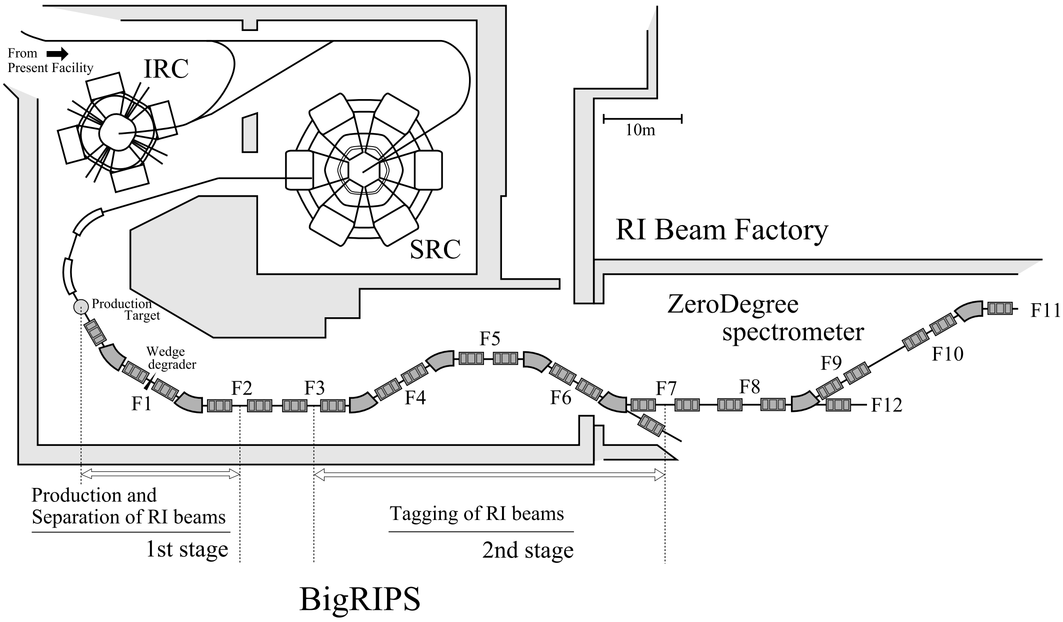

Figure 3.1: Overview of the RIBF facility. The radioactive ion beams are produced and separated with the BigRIPS fragment separator and transported to the focus F11, the location of the E(U)RICA spectrometer.

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 3.2 displays the detector configuration schematically.

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 [18]. 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

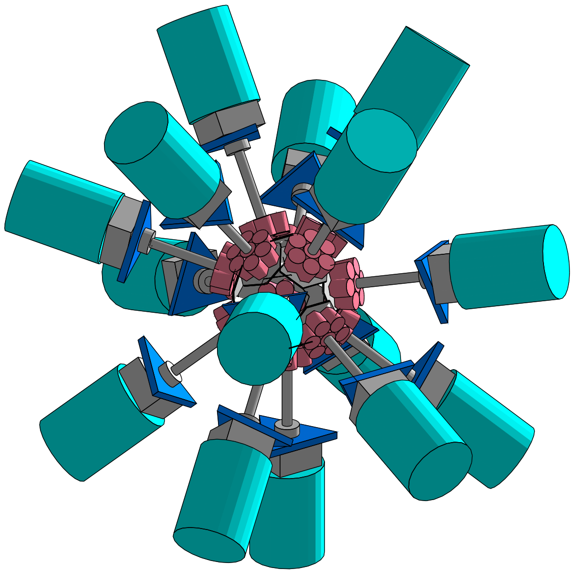

Figure 3.2: Schematic layout of the E(U)RICA spectrometer. The 15 Cluster detectors are arranged in three rings at angles of 51, 90, and 129 degrees, respectively, and distances of about 200 mm.

system (MUST2 [19]) 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 [20]. 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. 4.1. 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.

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:

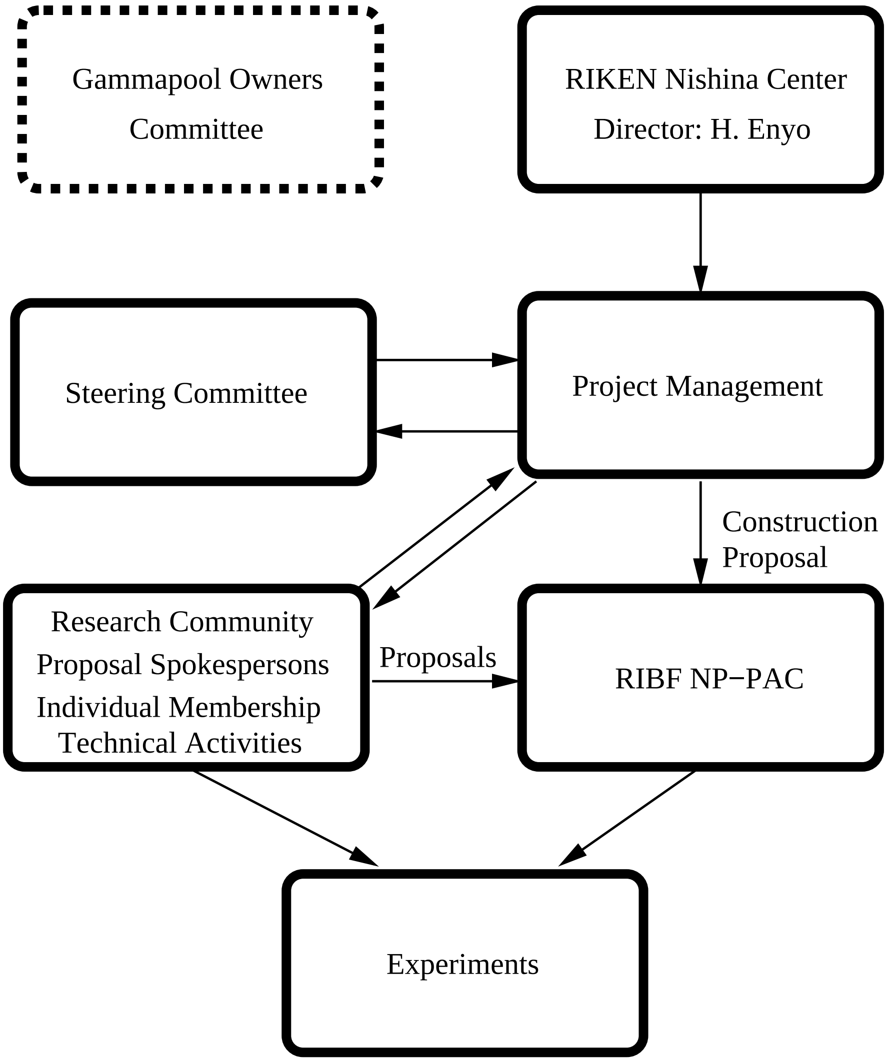

Figure 4.1: Tentative organizational diagram of the E(U)RICA collaboration.

- Shipment boxes for cryostats
- BNC, SHV, and preamplifier cables for Ge detectors
- Uninterruptable power supply system
- 220/100 Volts converter for electronics
- Rails for array movement
- Cooling system including buffer tanks, PCs, etc.
- Data acquisition PCs

4.3 Costs

In addition to the costs accruing from the equipment above further expenses will be incurred for travel expenses of the technical expert support from GSI and the project management. The costs for the equipment needs and the travel expenses will be covered by the RIKEN Nishina Center. The operating costs for E(U)RICA (mainly liquid nitrogen and equipment maintenance) are expected to be comparable to RISING.

5 Schedule

The planned time-line of E(U)RICA is shown in Tab. 5. Following the workshop, the E(U)RICA construction proposal will be submitted to the RIBF NP-PAC, which will be held June 24-25th, 2011. The proposal will include a request for commissioning beam time towards the end of 2011.

The last experiments utilizing the Cluster detectors within the PreSpec Campaign at GSI will be carried out in May 2011. The RIBF beam time schedule foresees experiments using BigRIPS from October 2011, which might occasionally prohibit construction and assembling works at the designated E(U)RICA location. Therefore, all construction work should be performed in the months between June and September.

In addition to the usual call for proposals announced by the RIBF in the summer, 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			■	■								
Shipment of Holding Structure			■	■								
Shipment of Electronics			■	■								
Memorandum of Understanding				■								
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 5.1: Intended time-line of the E(U)RICA project in the Japanese FY 2011. The experimental program is intended to continue through FY 2012.

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. 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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