Overview of Nuclear Physics Programs at RIBF
Present status and Future plan

Old facility

RIPS
~100 MeV/nucleon

GARIS
~5 MeV/nucleon

CRIB (CNS)

Phase-II
Experimental Installations
2007~2012 (plan)

New facility

350 MeV/nucleon up to U
1st beam in 2006

Phase–I  2007-
Accelerators + BigRIPS/ZeroDegree
Present Status and Future plan
GARIS
RIPS
BigRIPS/ZD
Phase-II Construction
Summary
SHE Science at RILAC

Grants-in-Aid Program by K. Morita (FY07-11)
“Search for new elements and SHE Chemistry”

~5M$ for 5 years

18GHz ECR IS

RFQ-Linac

Improvement of transmission bet. IS and RFQ
Upgrade of IS

GARIS-II dedicated for Chemistry study

Chemistry Lab.

target for high power beam

248Cm target

NP0802-AVF 44 Asai \(^{257,259}\)Lr (Z=103)

Chemistry Instrumentation
GARIS (gas-filled recoil ion separator)

More 113th elements!
Jan. 9th, 2008 -> At end of Mar., 2008

Higher rotational speed of target
3000 rpm -> 4000 rpm
Higher beam intensity
0.6 µA -> 0.9 µA
RIPS (RIKEN Projectile-fragment Separator)

Intense RI beams for light mass region
Programs fit for intermediate energy domain ~100A MeV

Operated by Ueno group

Light Exotic Nuclei such as $^8$He, $^{11}$Li:
NP0802-RRC 48 Yanlin Ye $\alpha$ knock-out
NP0802-RRC 51 Zoltan Elekes de-coupling

Polarized RI beams:
beta-NMR technique
Nuclear Moments, Application for Condensed Matter Physics

Slow RI beams:
NP0802-RRC 53 Yukari Matsuo Laser-spectroscopy w/ superfluid He

Nuclear Reactions at Low/Intermediate Energy
NP0802-RRC 49 Akira Ozawa Neutron-skin
NP0802-RRC 50 Sudhee Banerjee Hot GDR w/ stable beams
NP0802-RRC 52 Nobuaki Imai IAR
BigRIPS / ZeroDegree

Exploration into “Isospin Frontier” toward the drip-lines
Reaction study fit for high energy domain 200-300A MeV
operated by Kubo group

BigRIPS  Fragment Separator
high acceptance for fission fragments
pid for RI beams at the second section

ZeroDegree  Multi-function BT line
pid for ejectiles in inclusive- and semi-exclusive measurement
medium resolution (p/dp ~ 2000 – 4000)

RI-beam delivery line in 2007
Schedule at the new facility

2007

October  ZD construction completed
November with U beam
    ZD commissioning (5-7 days)
    Search for new isotopes (7 days)
    Several tests
December with Kr beam (2 days)
    Yield measurement for 54Ca/purity for proton-rich side

2008

Feb.-March. Shutdown
    Shielding blocks, Installation of Kappa Mag., etc.

(April-June) Experimental programs at BigRIPS/ZD
July-Sept    Shutdown
    SHARQAQ beam line construction
Achievement of Accelerators and Commissioning at BigRIPS

March, 2007

12th $^{86}$Kr$^{31+}$ beam at 345 MeV/u several pnA.
13th First Production of RI beams with $^{86}$Kr beam
23rd $^{238}$U$^{86+}$ beam at 345 MeV/u 0.002pnA
27th First production of RI beams with $^{238}$U beam

May 16th-June 3rd with $^{238}$U beam at 345 MeV/u and ~0.03 pnA max
Optics with primary beam and secondary beam
Reconstruction, Detector performances, etc
Rough yield measurements w/ Be and Pb targets
Search for New Isotopes (Kubo et al) (5days)

June 29th-July 2nd, with $^{238}$U beam
Detector tests (IC, NaI), etc
Yield survey for $^{80}$Zn, $^{130}$Cd, etc

----------------------------- PAC Sep., 2007 -----------------------------

Nov. 9th $^{86}$Kr$^{34+}$ beam at 345 MeV/u 30pnA
Data Analysis
DayOne Working Group

Aoi et al.

Strategy to produce outputs efficiently and effectively
man-powers, budget, information exchange among groups

Program sequence for approved experiments
Step-by-step Policy : “Simple” to “Complicated”
Setup and Analysis
PID, decay-properties, energy of excited state,
precise measurement, cross section

Scientific impacts = First measurements
Request of primary beam intensity to Accelerator Div.
> 100 pnA for Ca, Kr   > 0.2 pnA for U
-> Acceleration commissioning in 2008
for not only U, Kr but also Ca
beta- and in-beam spectroscopy ready to go!
Achievement of Accelerators and Commissioning at BigRIPS

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Nov. 9th $^{86}$Kr$^{34+}$ beam at 345 MeV/u 30 pnA

Data Analysis

PAC Sep., 2007
Example: F3-F5 Matrix

**OPTICS**

U + Be 2mm

B $\rho$ 01 7.25 Tm

**F3&F5 Focus**

F3

- $Y$
- $X$

F5

- $A$
- $B$

$(x | \delta)$

- F3X
- F5X

$(a | \delta)$

- F5A
- F3Agate

- F5X
- F3Agate

- F5A
- F5X
Optics Analysis : comparison with COSY

EMIS07 Ohnishi

${^{119}}\text{Pd}^{45+}$ 2.6444(2.6495) 118 counts
${^{122}}\text{Pd}$ 2.6521(2.6577) 850 counts
${^{120}}\text{Pd}^{45+}$ 2.6666(2.6722) 157 counts
${^{123}}\text{Pd}$ 2.6739(2.6800) 580 counts
${^{121}}\text{Pd}^{45+}$ 2.6888(2.6943) 59 counts
${^{124}}\text{Pd}$ 2.6956(2.7026) 187 counts
${^{122}}\text{Pd}^{45+}$ 2.7111(2.7177) 33 counts
${^{125}}\text{Pd}$ 2.7174(2.7255) 26 counts
${^{123}}\text{Pd}^{45+}$ 2.7333(2.7392) 7 counts
${^{126}}\text{Pd}$ 2.739() 

Total dose: $2 \times 10^{12}$

Cf. ${^{124}}\text{Pd}$ 19 counts, ${^{125}}\text{Pd}(\text{cand.})$ 1 count
at GSI, 1997 PLB 415, 111 (97)
total dose $\sim 1 \times 10^{12}$
$Z=46$

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<thead>
<tr>
<th>Isotope</th>
<th>Energy (MeV)</th>
<th>Counts</th>
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<tbody>
<tr>
<td>$^{119}$Pd$^{45+}$</td>
<td>2.6442 (2.6486)</td>
<td>95 counts</td>
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<tr>
<td>$^{122}$Pd</td>
<td>2.6520 (2.6566)</td>
<td>841 counts</td>
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<tr>
<td>$^{120}$Pd$^{45+}$</td>
<td>2.6662 (2.6710)</td>
<td>143 counts</td>
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<tr>
<td>$^{123}$Pd</td>
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<td>2.6885 (2.6936)</td>
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<td>$^{124}$Pd</td>
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<td>$^{121}$Pd</td>
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<td>$^{125}$Pd</td>
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<td>$^{123}$Pd$^{45+}$</td>
<td>2.7340 (2.7392)</td>
<td>9 counts</td>
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<tr>
<td>$^{126}$Pd</td>
<td>2.744 (2.74756)</td>
<td>3 counts</td>
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</table>

A/Q resolution (r.m.s.): 0.05% at $Z=46$

Bp res. $\sim 0.045\%$ (r.m.s.)

$\rightarrow 0.016\%$ (limit due to pos. res.)

Tof res. $\sim 0.0125\%$ (r.m.s.)

A/Q $\rightarrow 0.028\%$ (limit)
Yield Rate Comparison
experimental values versus predicted by LISE

350\textit{A} MeV U + Be

Preliminary

Ohnishi et al.
ZeroDegree Spectrometer

Ohnishi et al.

STQ16-STQ23, D7, D8: Final adjustment in this month.
Layout of detectors at ZDS

Focal plane chambers completed
Detectors will be installed in this spring
Proposed programs at BigRIPS+ZD

NP0802-RIBF 54 Itahashi (d,³He)
NP0802-RIBF 55 Nakamura Inclusive Coulomb DIS.
NP0802-RIBF 56 Baba GDR
NP0802-RIBF 57 Gillbert/Lapoux/Otsu MUST-2
NP0802-RIBF 58 Sohler/Elekes Knock-out reactions
NP0802-RIBF 59 Famiano Mass measurement
NP0802-RIBF 60 Watanabe Isomers
Phase-II construction 2007-2012

To maximize the potentials of intense RI beams available at RIBF

http://rarfaxp.riken.go.jp/RIBF-TAC05/

SAMURAI - large acceptance
Kobayashi et al.

SCRIT - e-RI collision
Wakasugi, Suda et al.

Rare RI Ring – mass
Ozawa et al.

SHARAQ - high resolution
Shimoura et al.

SLOWRI- slow beams
Wada et al.

RI Spin Lab. at RIPS – pol. RI beam
Ueno et al.
Phase-II
Construction budget has been approved for

SHARAQ BT  2M$ in FY2008
SAMURAI      15M$ in FY2008-2011

1$ = 100JYen
SHARAQ Spectrometer

Spectroscopy with High-resolution Analyzer and Radio Active Quantum beams

Sakai, Shimoura et al.

RI beam as new probe to control $\Delta q$, $\Delta S$, $\Delta T$
Missing mass spectroscopy with standard kinematics
Spin-isospin response probed by fast RI beams:
transparent at 300$A$ MeV
Double charge exchange: double GTR, IVSMR
Multi-neutron system, etc.

External investment by CNS, Univ. of Tokyo
High resolution spectrometer for fast RI beams
$p/\Delta p \sim 15,000$, $\Delta q < 1 \text{ mrad}$, $B\rho = 6.8 \text{Tm}$

SHARAQ spectrometer

Recycle from SMART
Super Conducting doublet Q
Focal Plane detector (collaboration with GANIL)

Energy resolution $\Delta E/E = 1/7500$
Total weight $\sim 500$ ton
SHARAQ Beam line
Dispersion matching to achieve high res.

Completed in March 2009

SHARAQ Commissioning in March, 2009

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<tr>
<td>Infrastructure</td>
<td>hard-wiring/piping installation</td>
<td>Connection of the component</td>
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BigRIPS

SHARAQ beamline

10 m
SAMURAI
(Superconducting Analyser for MUUtli-particles with Radio-Isotope beams)

Versatile superconducting spectrometer with a large acceptance for exclusive measurements

Invariant/missing mass spectroscopy for unbound states
giant resonances,
(p,2p) etc

EOS in asymmetric nuclear matter

Particle correlations in a few-body system

Coulomb breakup for radiative capture c.s.
(p,γ), (n,γ)

Kobayashi et al.

Bending Magnet
Superconducting
Large B\cdot L (7Tm)
Large pole gap (80cm)
Weight ~ 600 ton

Neutron

Proton

Heavy Ion

TPC
(not shown in picture)
Current Status

• Budget approved – ~15M$ in FY2008 – 2011
  \(1\$ = 100\text{JPY}\)

• Specifications to be fixed soon ...
  \(\rightarrow\) Open bidding in the first half of FY2008

• All the contracts must be made in FY 2008
  -- all the specifications are (basically) fixed
  including magnets, detectors,…

• Core-collaboration in Japan
  RIKEN – Tohoku Univ. – Tokyo Tech – Kyoto Univ.
Construction Schedule

…still under discussion, very tentative, hope to be ready in summer 2011!

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</tbody>
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Participants
Tohoku Univ.
Kobayashi (Leader), Iwasa
TiTech
Nakamura*, Satou
Kyoto Univ.
Murakami*
RIKEN
Yoneda*, Otsu, Sekiguchi
Kubo, Okuno
Yano, Motobayashi, Sakurai

International workshop will be held in this year.

external investment is definitely welcome.
Measurement of the momentum distributions of the inner-shell protons via He, Li, C\((p,2p)\) reactions (RIBF-017)

The Kappa spectrometer (Little-SAMURAI)

Oct. 2008~ Ready for experiment

Kappa magnet
40 cm gap
Bmax = 1.2T
BL = 2.2 Tm
w =60t
PID A< 30
SCRIT (Self-Confining Radioactive Isotope Target)

Wakasugi and Suda et al.

Self-confining Radioactive Ion Target system realized in an electron-ring for e-RI collisions

Charge form factor measurement

R&D Study at KSR

We succeeded in
i) Cs ion trapping in SCRIT
ii) Measurement of elastic scattered electrons from trapped Cs ions
Plan of Electron Scattering Experimental System using SCRIT at RIBF

Re-use of AURORA2 (Sumitomo Co.)
150~700 MeV
500mA
Summary

**BigRIPS/ZD :**
Data analysis is in progress to obtain basic performances of BigRIPS. Acceleration test for Ca is MUST to formulate programs. About one year delay from an original plan made at Feb., 2007.

**2nd-Phase :**
SHARQ-BT and SAMURAI have been funded. Test of SCRIT at KSR has been in great success.

**GARIS :**
The SHE experiment for 113 is running up to the end of this Mar.

**RIPS :**
RIPS is in good shape to accept specific programs at intermediate energy as well as in a light mass region.
Schedule in 2008-2009 for the new facility

2008

Mar.
Construction of ZeroDegree completed.

Apr. – June
Commissioning of BigRIPS / ZeroDegree ($^{238}\text{U}$)
Development of primary beams ($^{238}\text{U}$, $^{48}\text{Ca}$ or $^{86}\text{Kr}$)

$^{238}\text{U}$ 0.03 pnA -> >0.2 pnA
Experiments (new isotope search+test) ($^{238}\text{U}$)

Oct. - Nov.
Development of primary beam development ($^{48}\text{Ca}$ or $^{86}\text{Kr}$)
A few experiments with $^{48}\text{Ca}$ or $^{86}\text{Kr}$ beams
The Kappa system will be ready.

2009

Mar.
Commissioning of SHARAOQ