Nuclear structure studies in JUSTIPEN and EFES activities

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Place        Room 206, RIKEN RIBF building

Committee   Otsuka, Motobayashi, Shimoura, Sakurai, Nakatsukasa, Uesaka, Itagaki

Homepage    http://www.s.u-tokyo.ac.jp/torijin/index-e.html
Japan-US Theory Institute for Physics with Exotic Nuclei (JUSTIPEN)

Established in July 2006

<table>
<thead>
<tr>
<th>Year</th>
<th>number of visitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>10</td>
</tr>
<tr>
<td>2007</td>
<td>12</td>
</tr>
<tr>
<td>2008</td>
<td>25</td>
</tr>
<tr>
<td>2009</td>
<td>6</td>
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Homepage of the US side http://www.phys.utk.edu/JUSTIPEN/
JUSTIPEN Workshop in Hokkaido (summer 2008)
RIKEN RIBF building
TORIJIN office is room 206
JUSTIPEN visitors also stay there

Nishina Lodge

International house H building
International Research network for Exotic FEmto Systems
(T. Otsuka, coordinator)

• Organizing workshops with partner countries (USA, Germany, France, Italy, Finland, Norway)
• Establishing and carrying out the collaboration projects with the partner countries (both theoretical and experimental)
• Inviting students from partner countries to the CNS-EFES summer school (Japan) and sending Japanese students to summer schools of partner countries
JSPS Core-to-Core Program

From FY2003, the Japan Society for the Promotion of Science (JSPS) has conducted this program for the purpose of building and expanding a cooperative international framework in leading-edge fields of science among universities and research institutions in Japan and the following 15 western nations: The US, Canada, Austria, Belgium, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland, the UK, Australia, and New Zealand.

For more information, click here
Japanese core institutions

Apply to JSPS

Type B: Integrated Action Initiatives
Project Duration: 2 years
Budget: 20 million yen/year

Selection

Type A: Strategic Research Networks
Project Duration: 3 years
Budget: 10 - 30 million yen/year

April 2006 – March 2008

April 2008 – March 2011
International Research Network for Exotic Femto Systems (EFES)

Major Research Subjects
- Existence Limits of Matter (Drip Line)
- Magic number of Exotic Nuclei and Supernovae
  - History of Matter Synthesis
- New Elements - 21st Century Alchemy

Frontier connecting micro world and stellar processes

JSPS
University of Tokyo
Graduate School of Science
Otsuka, Shimoura

RIBF
World Biggest Cyclotron

Germany
Langanke
Support: DFG, GSI
Center: GSI
2012 FAIR

U.S.A.
Nazarewicz
Support: DOE
(JUSTIPEN program)
Centers: ORNL, MSU, ANL

Finland
Aysto
Center: JYFL

Italy
Signorini
Center: INFN

France
Gales
Support: CNRS, CEA
Center: GANIL
2013 SPIRAL2

Norway
Jensen
Center: Oslo

Japanese-German seminar
From DOE, Dr. Coon

Japanese-French seminar
2006
Second German-Japanese workshop, 4-7 October  RIKEN, Japan

2007
Joint JUSTIPEN-LACM meeting, 5-8 March, Oak Ridge National Lab, USA

Japanese-French workshop, 13-16 March, GANIL France

Tired German-Japanese workshop, 29 September – 2 October 2, Chiemsee, Germany

First FIDIPRO-JSPS workshop, 25-27 October , University of Jyvaskyla, Finland

Correlation in nuclei, 26-29 November, INT Washington University, USA
Joint LACM-EFES-JUSTIPEN Workshop, 23-25 January Oak Ridge NL, USA

Future Prospects for Spectroscopy and direct reactions, 26-28 February, MSU, USA

Hokudai-TORIJIN JUSTIPEN-EFES workshop "Perspective in Resonances and Continua on nuclei & JUSTIPEN-EFES-Hokkaido-UNEDF meeting", 21-25 July, Onuma, Hokkaido, Japan


ICHOR-EFES International Symposium on New Facet of Spin-Isospin Responses, 29-31 Oct. , Wako, RIKEN, Japan

The 6th Japan-Italy symposium on Heavy Ion Physics, 11-15 November, Tokai, Japan

Joint ANL-EFES Workshop for a Compton-Suppressed Ge Clover Array for Stopped and Energy Degraded Exotic Beams at RIKEN, 4-5 December, Argonne NL., USA
2009

First EMMI-EFES workshop on neutron-rich exotic nuclei
``Realistic effective nuclear forces for neutron-rich nuclei"
9-11 February, GSI, Germany

The 3rd LACM-EFES-JUSTIPEN workshop,
23-25 February, Oak Ridge NL, USA

First LIA-EFES workshop "Low-energy collective motion of exotic nuclei",
2-4 March, GANIL, France

Arctic FIDIPRO-EFES workshop, 16-20 April, Saariselka, Finland

• Ab initio workshop in Hawaii, 12 Oct.
Summary of this part

• **TORIJIN** is University of Tokyo – RIKEN joint program for the international activities of nuclear physics

• **JUSTIPEN and EFES** are two major missions of TORIJIN

• **EFES (Exotic FEmto Systems)** is an international network for the studies of exotic nuclei, which is selected as one of Core-to-core programs of JSPS
Workshop at the INT Fall-07 Program on Correlations in Nuclei: From Di-nucleons to Clusters

November 26-29, 2007

Notice to all participants: The workshop is constructed so as to have only four 50 to 60 minute talks per day with much time for discussion. A speaker with 75 minutes is supposed to talk for "not more" than 50 to 60 minutes and to leave the remaining time for questions and discussion. If groups of participants want to organize their own discussion groups outside of the regular lecture times, please contact the organizers about making arrangements (e.g., space) for such events.

Monday, November 26, 2007

8:00-13:00: Arrival/Check-in/Registration/Finding Office at INT

13:00: Start of Workshop in Conference Room C520: Official welcome/announcements/introductions

Session 1: Shell evolution/tensor correlations (Session Chair: Bruce Barrett)

14:30-15:00: Coffee Break

15:00-16:15: Takayuki Myo (Osaka University): "Role of the tensor correlation in neutron halo nuclei"

16:15-18:00: Group meetings/Discussions/Special Seminars

Dinner on your own
Many-body correlation in neutron-rich systems

- Neutron-neutron (di-neutron) correlation
Di-neutron correlation in $^8$He?

- $^8$He is well-bound compared with $^6$He and $^{11}$Li
- Sub-closed configuration of spin-orbit-favored shell

Di-neutron $\rightarrow$ spin zero $\rightarrow$ no spin-orbit

Example of the cluster-shell competition governed by the spin-orbit interaction
$^4\text{He}+4\text{n}$ model space (AMD)

N. Itagaki, M. Ito, K. Arai, S. Aoyama and Tz. Kokalova
Tohsaki-Horiuchi-Schuck-Roepke wave function for the study of gas-like states of alpha clusters

\[ \Phi = \int d\vec{R}_1 d\vec{R}_2 \cdots d\vec{R}_n \]
\[ \mathcal{A} \, G_1(\vec{R}_1)G_2(\vec{R}_2)G_3(\vec{R}_3) \cdots G_n(\vec{R}_n) \]
\[ \times \exp\left[-(\vec{R}_1^2 + \vec{R}_2^2 + \vec{R}_3^2 \cdots + \vec{R}_n^2)/\sigma^2\right] \]
\[ = \mathcal{A} \prod_{i=1}^{n} \int d\vec{R}_i \, G_i(\vec{R}_i) \exp\left[-\vec{R}_i^2/\sigma^2\right], \]

Applying THSR wave function to $^{8}\text{He}$

$$\Phi_{\text{THSR}}^{\sigma}(^{8}\text{He}) = A[\Phi(\alpha)\Phi_{1}^{\sigma}(2n)\Phi_{2}^{\sigma}(2n)],$$
$$\Phi(\alpha) = G_{\alpha}(R_{0})\chi^{p\uparrow p\downarrow n\uparrow n\downarrow},$$
$$\Phi_{k}^{\sigma}(2n) = \int dR_{k}G_{2n}(R_{k})\exp\left(-\frac{R_{k}^{2}}{\sigma^{2}}\right)\chi^{n\uparrow n\downarrow}$$

$\chi$ : Spin-isospin wave function

Integral is replaced by the sum of randomly generated wave functions with Gaussian weight (Monte Carlo Integral)
Overlap between the obtained states of $^8\text{He}$ and THSR wave function

<table>
<thead>
<tr>
<th>$\sigma$ (fm)</th>
<th>$0_1^+(\Psi_{\text{AMD}})$</th>
<th>$0_2^+(\Psi_{\text{AMD}})$</th>
<th>$0_3^+(\Psi_{\text{AMD}})$</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.43</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>2</td>
<td>0.53</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>0.61</td>
<td>0.08</td>
<td>0.03</td>
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<tr>
<td>4</td>
<td>0.45</td>
<td>0.36</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>0.24</td>
<td>0.48</td>
<td>0.07</td>
</tr>
</tbody>
</table>

In $^7\text{H}$, the distribution of the di-neutron clusters is much more spatially extended

Many-body correlation in neutron-rich systems

- Alpha-like correlation in heavier systems
- Glue-effect of the neutrons

Stabilization of “geometric shape” by adding valence neutrons in $^{14}\text{C}$
$^{20}\text{C}$ Chain States

in collaboration with J.A. Maruhn
Stability of linear chain against the bending motion

Solid \( {}^{20}\text{C} \, (\pi^4 \sigma^2 \delta^2) \)
Dotted \( {}^{16}\text{C} \, (\pi^4) \)
FIG. 1: The energy convergence of the $0^+$ states of $^{18}O$. From 1 to 100 on the horizontal axis are states with various $^{16}O+n+n$ configurations, and tetrahedron configuration of four $\alpha$-clusters with $s^2$ neutrons are superposed (from 101 to 105). The basis states with $^{14}C+\alpha$ configuration are introduced afterwards (106-150).

Excitation energy

- cluster-threshold
- cluster structure with geometric shape (solid)
- mean-field, shell structure (liquid)
- gas-like structure

- Cluster structure with geometric shape (solid)
- Mean-field, shell structure (liquid)

- Exotic nuclei (HO, WS, WS+LS)
Interaction $\rightarrow$ Gaussian 3 range Softcore potential (G3RS)
Tamagaki et al.

Just between the threshold and Coulomb barrier top energies

$^{40}\text{Ca}+\alpha+\alpha+\alpha+\alpha$

THSR with $\sigma = 4$ fm
Summary

• Many-body correlation becomes important in weakly bound systems

• Although $^8$He corresponds to the sub-closed shell configuration of spin-orbit favored shell for the neutrons, the ground state contains components of di-neutrons with spatially extended distribution

• Alpha cluster states are stabilized with geometrical shape when neutrons are added, and “geometric cluster states” appear below the threshold energies

• Gas like states of 3 alpha around $^{40}$Ca can be investigated starting with a softcore potential

• JUSTIPEN and EFES activities played essential role for such studies

• We hope many nuclear scientists in the USA visit Japan as JUSTIPEN visitors and extend the collaboration network