RCNP EXPERIMENT E189

# PROPOSAL FOR EXPERIMENT AT RCNP

15/01/2002

**TITLE:**

Search for Alpha Cluster Condensation in $^{16}$O

**SPOKESPERSON:**

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**EXPERIMENTAL GROUP:**



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| G. P. Berg | RCNP | COE | H. Yoshida | RCNP | D |
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| M. Uchida | Kyoto Univ. | D | Y. Yasuda | Kyoto Univ. | D |



**RUNNING TIME:**

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|---|---|
| Test running time for experiment | 4 days |
| Data runs | 2 days |

**BEAM LINE:** WS (WS beam line + Grand Raiden)

**BEAM REQUIREMENTS:**

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|---|---|
| Type of particle | $^{4}$He and $^{6}$Li |
| Beam energy | 50–100 MeV/u |
| Beam intensity | 5 enA on target |
| Energy resolution | $<$ 200 keV (FWHM) |
| Injection mode | High Resolution Mode |
| WS transport mode | Dispersive/Achromatic Modes |

**BUDGET:**

| | |
|---|---|
| Summary of budget request | 2,500,000 |
| Experimental expenses | 2,000,000 |
| Travel plan | 500,000 |

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## SUMMARY OF THE PROPOSAL

Recent theoretical investigations show a possibility of $\alpha$-particle condensation in low density nuclear matter with $\rho \leq 0.03$ fm$^{-3}$. Röpke *et al.* [**?**] made a variational ansatz for the solution of the in-medium four-body equation. Beyer *et al.* [**?**] solved the Faddeev-Yakubovsky four-body equation for an $\alpha$-like cluster in nuclear matter. These studies indicate that such $\alpha$ condensation can occur only in the low-density region below a fifth of the saturation density. At higher densities rather a state of ordinary $p$-$n$, $n$-$n$, or $p$-$p$ Cooper paring will prevail.

Tohsaki, Horiuchi *et al.* [**?**] proposed a new $\alpha$ cluster wave function in order to investigate $\alpha$-particle Bose condensed states in finite nuclei. Their wave function was applied to $^{12}$C and $^{16}$O. The calculation confirmed that the second $0^+$ state at $E_x$=7.65 MeV in $^{12}$C is the 3$\alpha$-cluster condensed state. Furthermore they pointed out that the fifth $0^+$ state at $E_x$=14.0 MeV in $^{16}$O could be considered as the 4$\alpha$-cluster condensed state. These $\alpha$-cluster condensed states have large root-mean-square (rms) radii of 4.29 and 3.97 fm compared with 2.65 and 2.73 fm for ground states in $^{12}$C and $^{16}$O, respectively. Large rms values indicate that these $0^+$ states correspond to very dilute systems which are only about a fifth of the experimental ground state densities. The fact that $\alpha$-cluster condensed $0^+$ states are of dilute densities is in agreement with nuclear matter calculations where it was shown that a condensate of $\alpha$-like particles is possible only in matter with $\rho \leq 0.03$ fm$^{-3}$.

It should be noted that the fifth $0^+$ state in $^{16}$O has been observed experimentally only as a $^{12}$C+$\alpha$ resonance formed via the $^{12}$C$(\alpha,\gamma)^{16}$O reaction [**?**]. This state has not been observed via other reactions, therefore, it is not yet clear whether this $0^+$ state really exists or not.

In this Proposal, we propose to search for the 4$\alpha$-cluster condensed state in $^{16}$O via the $^{16}$O$(\alpha,\alpha')$ or $^{16}$O$(^6\mathrm{Li},^6\mathrm{Li}')$ reaction. After optimizing the probe ($(\alpha,\alpha')$ or $(^6\mathrm{Li},^6\mathrm{Li}')$) and the beam energy (50 MeV/u or 100 MeV/u), we will measure the angular distribution in the angular range of $0^\circ \leq \theta_{\mathrm{lab}} \leq 7^\circ$ in $1^\circ$ steps for the 4$\alpha$-cluster condensed state at $E_x$=14.0 MeV in $^{16}$O. The measurement at forward angles will allow a distinct monopole $0^+$ assignment.