**PROPOSAL FOR EXPERIMENT AT RCNP**

**TITLE:**
**Pionic atom spectroscopy with the $^{136}$Xe(p,$^{2}$He) reaction toward a systematic study with N=82 isotones**

**SPOKESPERSON:**


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| Yuni N. Watanabe | Department of Physics, University of Tokyo | Graduate Student (D3) |
| Atsushi Tamii | RCNP, Osaka University | Associate Professor |
| Nobuyuki Kobayashi | RCNP, Osaka University | Specially Appointed Assistant Professor |
| Satoshi Adachi | RCNP, Osaka University | Research Assistant |
| Agnieszka Czeszumska Anna | RCNP, Osaka University | Research Assistant |
| Azusa Inoue | RCNP, Osaka University | Graduate Student (D2) |
| Shoken Nakamura | RCNP, Osaka University | Graduate Student (M1) |
| Kenta Itahashi | RIKEN Nishina Center | Senior Research Scientist |
| Takahiro Nishi | RIKEN Nishina Center | PostDoc |
| Hans Geissel | GSI | Professor |
| Yoshiki K. Tanaka | GSI | PostDoc |

**RUNNING TIME:**

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| Test experiment: | |
| – Installation time without beam | 4 days |
| – Starting up the detectors | 1 day |
| – Data runs | 1 day |
| Main expeiment: | |
| – Installation time without beam | 4 days |
| – Starting up the detectors | 1 day |
| – Beam commissioning | 1 day |
| – Calibration measurements | 2 days |
| – Data runs | 9 days |

**BEAM LINE:** Ring : WS course

**BEAM REQUIREMENTS:**

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| Type of particle | p |
| Beam energy | 350 MeV |
| Beam intensity | $\leq$ 30 nA |
| Other requirements | energy resolution $\leq$ 150 keV<br>halo-free, small emittance |

**BUDGET:**

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| Isotopically enriched $^{136}$Xe gas | 1,000,000 yen |
| Other experimental expenses | 500,000 yen |
| Travel expenses | 200,000 yen |

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**SPOKESPERSON:** Akane Sakaue, Hiroyuki Fujioka, Takahiro Kawabata

## SUMMARY OF THE PROPOSAL

The study of partial restoration of chiral symmetry through deeply bound pionic atoms is carried out actively from both theoretical and experimental sides. The proposed experiment aims at being the starting point for revealing the density dependence of the quark condensate, which is an order parameter for chiral symmetry breaking. For this purpose, we would like to investigate deeply bound pionic states in Xe isotopes (Z=54) and N=82 isotones, among which the nuclear densities probed by orbiting pions are different. To start with, we would like to perform an experiment with a $^{136}$Xe target in the gas form. The pionic atom spectroscopy with Xe gas target is possible only at RCNP, where many nuclear experiments using gas targets have been realized.

A measurement of the $^{136}$Xe(p,$^{2}$He) reaction using a 350 MeV proton beam with high intensity will be performed at the RCNP WSF course. Two protons, which are decay particles of $^{2}$He, will be momentum-analyzed by Grand Raiden. The experimental feasibility has been verified in the E483 experiment with a solid $^{124}$Sn target carried out in October–November 2017.

The target needs to be cooled in order to obtain a sufficient yield without deteriorating the resolution. Since the existing cooling system with liquid nitrogen is not available because of the boiling point of Xe (161 K at 1 atm), we would like to develop a new cooling system for the gas target. This newly developed system may be useful for other experiments.