The research objectives of the Hadron Nuclear Physics Group are 1) experimental studies of exotic hadrons and nuclei with strange and charm quarks, and hot and dense partonic/hadronic matter at J-PARC and BNL-RHIC, and 2) theoretical studies of exotic hadrons, nuclear matter, and neutron stars at low and high densities, including strangeness and charm quarks. Through these topics, we investigate many-body problems of quarks and hadrons in relation to Quantum Chromo Dynamics (QCD).

**Hadron experimental studies at J-PARC**

We made progress in the data analysis for the J-PARC E07 experiment to search for double hypernuclei and found 22 double hypernuclei, among which we uniquely identified a ΛΛ [1], as shown in Fig. 1 (Also see the research highlight of our group).

The Stage-2 request to the Program Advisory Committee (PAC) of J-PARC for the baryon spectroscopy experiment with πN→πN reactions (J-PARC E45) was officially approved in July 2018. In preparation for the Hyperon spectrometer for E42 (H-dibaryon search), E45, and E72 (search for a new Λ resonance), a high-rate beam tests up to 1 MHz at HIMAC was performed. As a result, a good efficiency, position resolution, and track reconstruction performance were achieved. We also achieved 140 ps timing resolution of a prototype TPC Hodoscope and constructed a liquid hydrogen target system. These achievements were followed by the successful performance of a 24-hour test of the superconducting dipole magnet in the summer period.

Fig.1 An event of double Λ hypernuclei (MINO event) in emulsion at J-PARC E07.

**Theoretical studies on exotic hadrons**

Throughout 2018, we performed various theoretical studies for exotic hadrons and nuclei with strangeness and charm, such as a nucleon-Ωbaryon dibaryon [2], production of η’d bound state in γd→η’d [3], properties of vector mesons in hot matter, and charmonium spectra at finite temperature [4]. As the Theoretical Physics Institute, we held 10 seminars and one of the lecture-series (by Y. Utsuno) on theoretical and experimental hadron nuclear physics. In Apr. 2019, we started a new theoretical research group in ASRC involving diverse fields, such as hadron, nuclear, and condensed matter physics.

**Other research activities**

At Belle, we were able to observe an Omega excited state for the first time [5] and two Press Releases were published on the observation. One for the discovery of the nucleus with K- meson and two protons in Jan. 2019, and the other is for the discovery of MINO event [1] in Feb. 2019.

We proposed the future heavy-ion program at J-PARC called J-PARC-HI to Japanese Nuclear Physics Community and the Reimei Workshop “Physics of dense matter and strangeness at J-PARC-HI” was held to discuss the proposal. In Nuclear Physics Committee Meeting of Dec. 2018, large nuclear physics projects including J-PARC-HI were discussed and the committee endorsed J-PARC-HI with a high priority. We submitted the proposal for Master Plan of Science Council of Japan in Mar. 2019.

**Reimei research programs**

In the Reimei research program “New Aspects of Hadron Spectroscopy and Exploration of Dense Nuclear Matter at J-PARC”, we studied baryon excited states and dense nuclear matter at J-PARC with Prof. Ken Hicks (Ohio Univ.) as principal investigator (PI). We held the workshop “Physics of dense matter and strangeness at J-PARC-HI” in Dec. 2018 as described above and “Experimental and Theoretical Hadron Physics: Recent Exciting Developments on Hadronic Resonances and Dense Nuclear Matter” in Jan. 2019. The latter had 50 participants including 12 foreign participants, where we discussed hadron physics and heavy-ion physics related to J-PARC.

In another Reimei research program “Universal physics in Many-Body Quantum Systems – From Atoms to Quarks –”, we made cross-disciplinary studies of many body quantum systems with Prof. Hans-Werner Hammer (TU Darmstadt) as PI. In addition, we held the Reimei Workshop “Universal physics in Many-Body Quantum Systems - From Atoms to Quarks -” in Dec. 2018 with 54 participants including 8 foreign participants.

**References**