Research Group for Advanced Theoretical Physics

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The Advanced Theoretical Physics (ATP) Group was launched in 2019 in ASRC/JAEA to conduct the research of the fundamental sciences related to the atomic energy. Our missions are to support experimental researches at JAEA and to explore interdisciplinary researches with new ideas. We are also trying to form a platform to exchange new ideas, to stimulate international collaborations and to train young researchers. Core members interests cover theoretical physics on hadrons and nuclei, the strongly interacting systems. In addition, condensed matter physicists working on spintronics join the ATP.

As activities of 2019, we would like to report two achievements, a crowdfunding to encourage the young generation's interest in nuclear science, and the collaboration between theory and experiment in hadron physics.

"One Nuclear Chart for One High school" project: Crowdfunding for making nuclear chart and visiting high schools to give a lecture

From this FY, we have started an outreach project for general public and high schools in Japan. In JAEA, the Nuclear Data Center has been publishing a nuclear chart, for researchers in nuclear data and related areas since 1976. This JAEA nuclear chart includes experimental data of nuclear decays for known nuclei, and additionally theoretical decay data for unknown nuclei, which have been provided through our theoretical work. In order to popularize the use of nuclear chart to young people, we have started the "one nuclear chart for one high school" project. In the project, we try to distribute one sheet of nuclear chart to every high-school in Japan, and to give a visiting lecture with the chart (Fig. 1). For this purpose, we set a crowdfunding at the end of January in 2020 for eight weeks, which is the first attempt of crowdfunding in JAEA. The target amount of 1,500,000 yen was set, and we finally obtained 1,731,000 yen from 157 donators (Ref. [1]). This contribution will be used for the project in FY 2020.

Fig.1: Snapshot of visiting lecture with JAEA nuclear chart.

Universal features in the Roper-like resonances inspired by the recent experimental observations

As motivated by the recent observation of $\Lambda_b(6072)$ by CMS and LHCb collaborations, we have discussed it as a state analogous to the Roper resonance N(1440) [2], which is the first excited state of the nucleon of spin and parity $J^P = 1/2^+$. It remains a mysterious baryon because its properties such as decay have not been easily explained by the conventional quark model. In fact, candidates of similar nature have been reported for hyperons, $\Lambda(1600)$ and $\Sigma(1660)$, and possibly for charmed baryons, $\Lambda_c(2765)$, $\Xi_c(2970)$. The observation of $\Lambda_b(6072)$ has added another member in the list of such states, implying a universal feature in those states. LHCb reported not only the mass and life time but also the decay property of $\Lambda_b(6072) \rightarrow \Lambda_b\pi\pi$, providing useful information for theoretical studies.

In this occasion, an intern student from Osaka University, Jafar Arifi, with advice of Kiyoshi Tanida in Hadron Group performed analysis for the decay of $\Lambda_b(6072)$ assuming the heavy quark symmetry. This is particularly useful to fix the yet undetermined spin and parity of $\Lambda_b(6072)$ and give suggestions to further theoretical studies. The decay occurs through the so-called sequential processes, $\Lambda_b(6072) \rightarrow \Sigma_b^{(*)}\pi \rightarrow \Lambda_b\,\pi\pi$. The intermediate state is in fact either Σ_b of $J^P = 1/2^+$ or Σ_b^* of $J^P = 3/2^+$, both of which contribute to the decay coherently, and therefore quantum mechanical calculation with their interference is important. This has been done properly by Jafar, and the results have been compared with the data. As shown in Fig. 2, the agreement of the data and his calculation is remarkable. This agreement strongly indicates that the observed $\Lambda_b(6072)$ is a family of the Roper resonance of spin and parity 1/2+.

A further theoretical study is then to clarify the origin of such universal features in the Roper-like resonances. This will provide an important direction for hadron physics research.

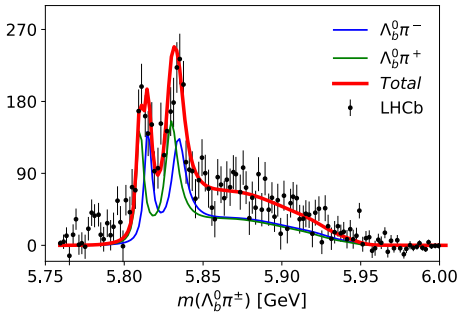

Fig. 2: Invariant mass plot of $\Lambda_b\pi$ [2].

References

[1] JAEA HP:
https://www.jaea.go.jp/news/newsbox/2020/013001/
[2] A. J. Arifi, H. Nagahiro, A. Hosaka, and K. Tanida, *Phys.Rev.D* 101 (2020) 11, 111502.