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High-precision X-ray spectroscopy of kaonic atoms with superconducting detector

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A high-resolution X-ray spectrometer based on an array of novel superconducting micro-calorimeters is applied to an experiment of hadron physics for the first time. The scientific campaign of the experiment was completed in 2018. The fresh result from the measurement will be presented in this symposium.

The strong interaction between an anti-kaon and a nucleon/nucleus is known to be strongly attractive in the isospin I=0 channel, which creates extensive interest in studying "kaonic nuclear states": very recently, J-PARC E15 experiment shows a clear structure which could be interpreted as the K− nuclear bound state [1]. Whereas the measurements of kaonic atom X-rays which provide unique information of the interaction at zero energy become increasingly important, the precision is still not enough to determine K− nucleus potential strength.

The experiment, J-PARC E62, aims to determine 2p-level strong interaction shifts of kaonic 3He and 4He atoms by measuring X-rays from those atoms emitted in the transition from the 3d to the 2p orbitals (6.2 keV and 6.4 keV, respectively) which is relevant to resolve the long-standing problem on the depth of the K- nucleus potential. Since the widths of the transitions are predicted to be as small as 2eV, we introduced a novel X-ray detector, namely superconducting transition-edge-sensor (TES) microcalorimeter offering unprecedented high energy resolution [2], being more than one order of magnitude better than that achieved in the past experiments using conventional semiconductor detectors.

We carried out the experiment at Japan Proton Accelerator Research Complex (J-PARC; Tokai, Japan) in June 2018 and successfully observed distinct X-ray peaks from both atoms with a 240-pixel TES array having about 23 mm2 collecting area. The achieved average energy resolution is 5 eV (FWHM) at 6 keV with the charged-particle beam off and 7 eV with the beam on. The time resolution is about 1 μs (FWHM) by merging data streams from beam-detection electronics into the TES's time-division-multiplexing DAQ system.

We give an overview of this project and report the brand-new results obtained from the scientific kaonic-atom X-ray spectroscopy campaign.

[1] J-PARC E15 collaboration, Phys. Lett. B 789 (2019) 620-625.
[2] W. B. Doriese, et al., Review of Scientific Instruments 88 (2017) 053108.

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