Contribution ID: **280** Type: **Oral Presentation**

TES-based X-ray spectroscopy of kaonic atoms

Friday, 26 July 2019 10:45 (15 minutes)

We applied a transition-edge-sensor(TES)-based X-ray spectrometer to a hadron-physics experiment at a charged-particle beam line for the first time.

An anti-kaon is the lightest meson containing a strange quark, and known to be strongly attractive to a nucleon. Therefore, anti-kaonic nuclear states have been proposed and are attracting great interest as a new form of matter and a possible unique testing ground of this high-density material. Along with direct searches of such a nuclear bound state, X-ray spectroscopy of kaonic atoms are of great importance. A kaonic atom is a Colomub-bound state of a negatively-charged kaon and an atomic nucleus. At most inner obitals, the strong interaction induces a shift and broadening of the atomic energy levels from their purely electromagnetic values. Thus, precise measurements of the X-ray-emission lines of kaonic atoms can reveal the anti-kaon-nucleus strong interaction at zero kinetic energy.

In 2018, we performed a scientific campaign to measure the 3d→2p X-ray lines of kaonic helium-3 and helium-4 (6.2 keV and 6.4 keV, respectively) at the Japan Proton Accelerator Research Complex (J-PARC; Tokai, Japan). Our goal is to determine the strong-force shift in the helium 2p orbital to a precision well below 1 eV using a 240-pixel TES array of about 23 mm^2 collecting area with 4 mum thick Bi absorbers. We stably operated the TES spectrometer during nearly one-month machine time and successfully observed X-ray lines of kaonic atoms.

Here we will describe the details of our experimental methods and present the overview of the data analysis. Especially, we will focus on how we dealt with challenges unique in our TES application: 1) energy resolution is deteriorated by charged-particle passages; 2) a continuum background in the X-ray spectrum is generated by charged particles; 3) the science X-ray yield is very low.

Less than 5 years of experience since completion of Ph.D

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Session Classification: Orals LM 004

Track Classification: Low Temperature Detector Applications