# Precision Spectroscopy of Kaonic Helium-4 X-rays

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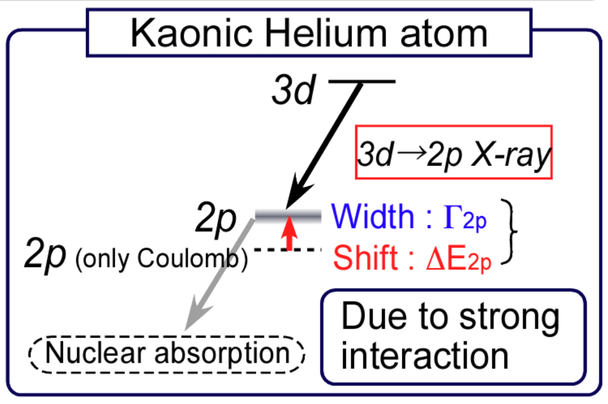
**Abstract**

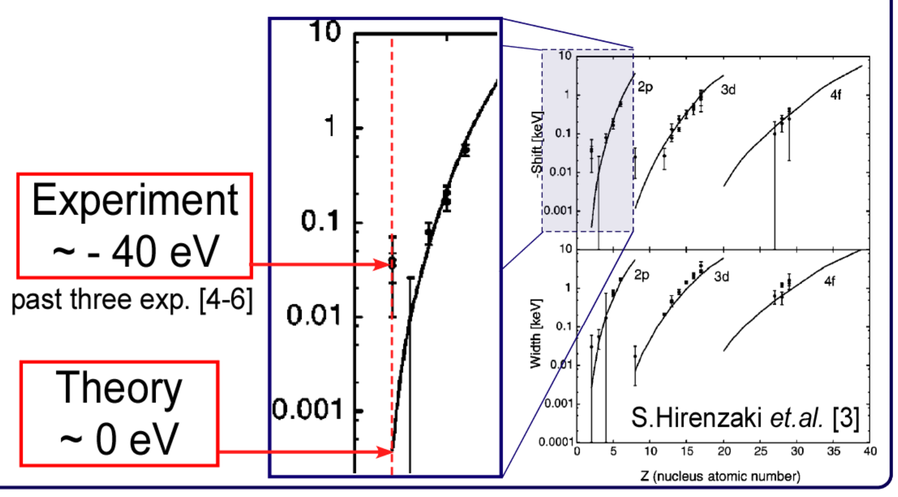
We have measured the Balmer-series x-rays of kaonic helium-4 atoms using silicon drift x-ray detectors in order to study the low-energy K-nucleus strong interaction. The energy of the *3d*→*2p* x-ray transition was determined to be 6467±3 (stat) eV (preliminary). The deduced strong-interaction energy-level shift is consistent with theoretical calculations.

## Introduction

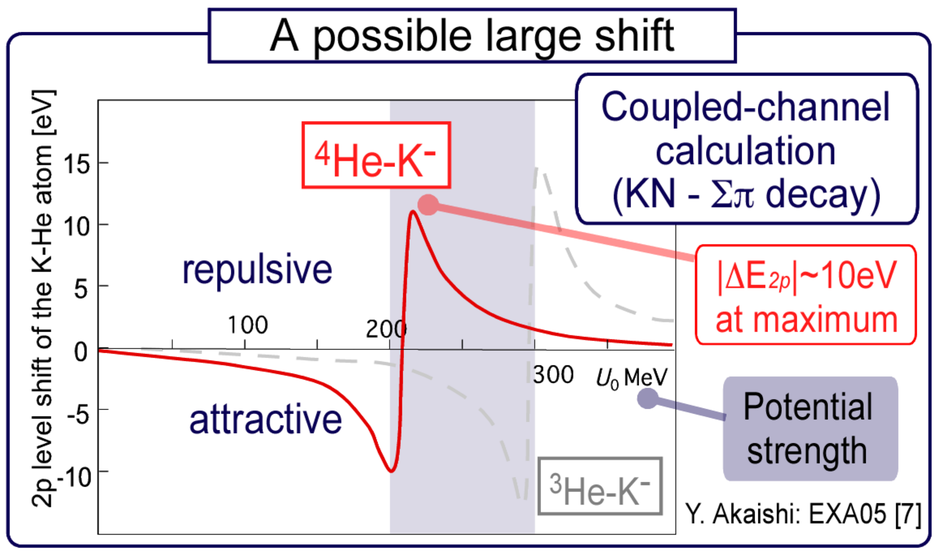
The strong-interaction energy-level shift and width of kaonic atom x-rays offer the unique possibility to precisely determine the K-nucleus strong interaction at the low energy limit. Therefore many experiments have been performed to collect data on various targets from hydrogen to uranium. It has been known that most of the available kaonic-atom data can be fitted fairly well for Z ≧ 2 by optical-potential models [1] except for kaonic helium and oxygen. The average *2p*-shift of the three kaonic helium-4 measurements reported before the present experiment (KEK-PS E570) is $\Delta E_{2p}$ = -43±8 eV [4-6], whereas the majority of theoretical calculations predict $\Delta E_{2p}$ ~ 0 eV (*e.g.* ~ -0.2 eV [2-3]). This is the so-called "kaonic helium puzzle".




## Kaonic Helium Puzzle

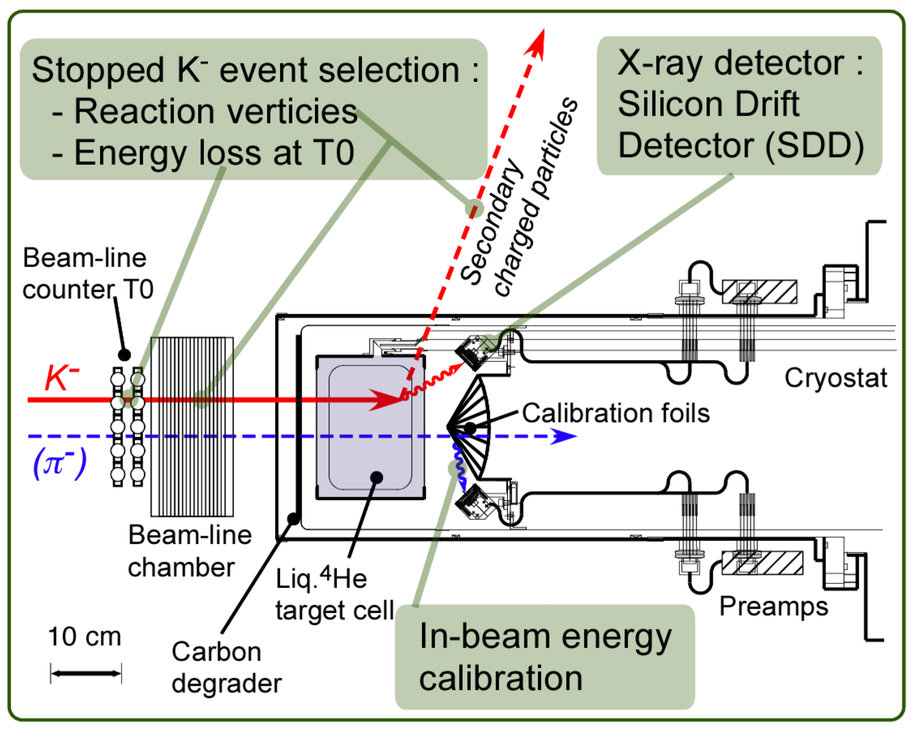



## A possible large shift

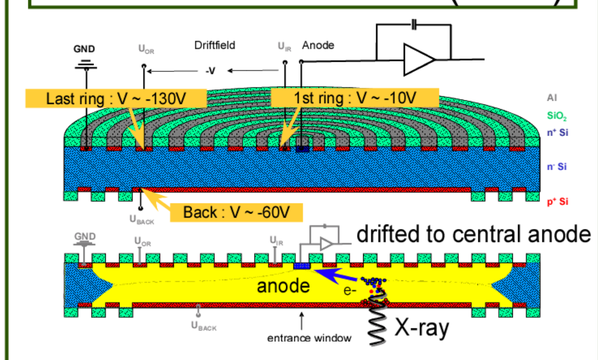



## Experiment

We have performed a measurement of Balmer-series x-rays of kaonic helium-4 atoms to an experimental precision of ~ 2 eV, thus shedding light on the kaonic helium puzzle (KEK-PS E570). To achieve such a high precision, we have employed 1) high resolution X-ray detectors (*i.e.* Silicon Drift Detector), 2) in-beam energy calibration using characteristic X-rays induced by the incident beam, and 3) an event selection which required that the reaction vertex reconstructed from an incident kaon track and an outgoing charged-particle track should be within the target fiducial volume.




### Silicon Drift Detector (SDD)




$C = \varepsilon S / d$

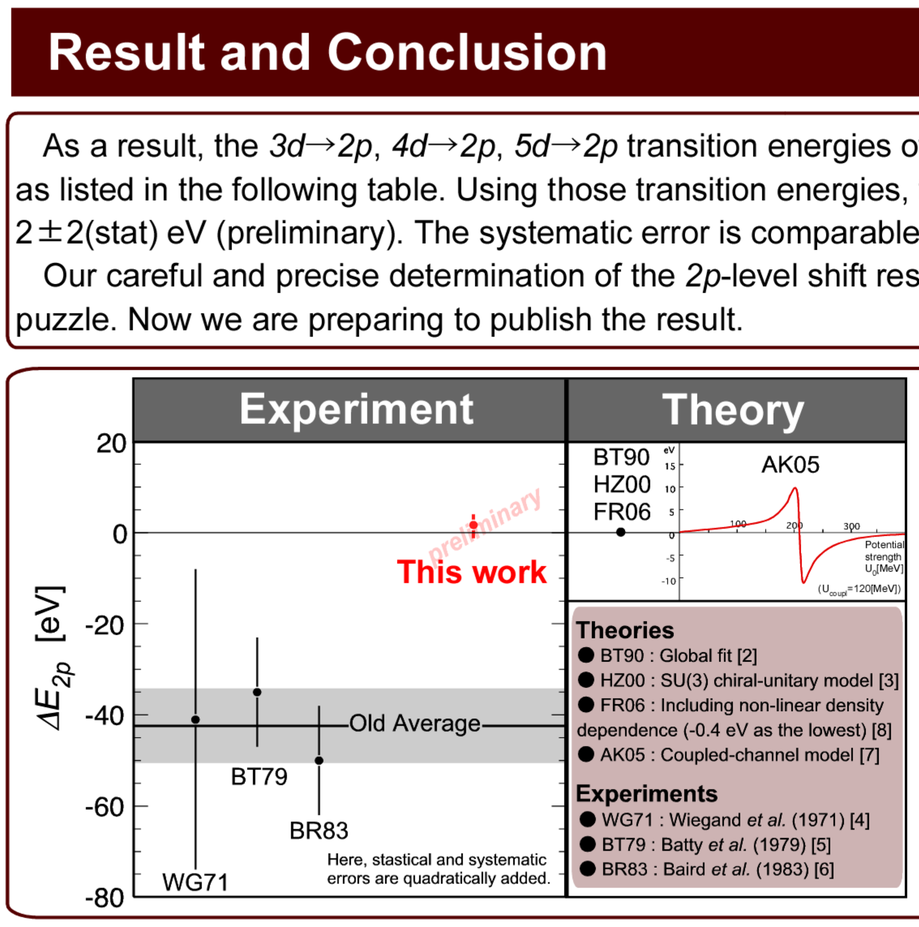

The small anode size (and hence small capacitance) is essential to realize the good energy resolution despite the large effective area.

The small anode area also makes it possible to reduce the active layer thickness, while the capacitance is still kept small. The thin active layer (less than 1/10th that of previous detectors) helps to reduce continuum background caused by the Compton scattering occurring inside the detector.

## Result and Conclusion

As a result, the *3d*→*2p*, *4d*→*2p*, *5d*→*2p* transition energies of the kaonic-helium-4 atom were determined as listed in the following table. Using those transition energies, the *2p*-level shift was deduced as $\Delta E_{2p}$ = 2±2(stat) eV (preliminary). The systematic error is comparable to the statistical error.

Our careful and precise determination of the *2p*-level shift resolved the long-standing kaonic helium puzzle. Now we are preparing to publish the result.



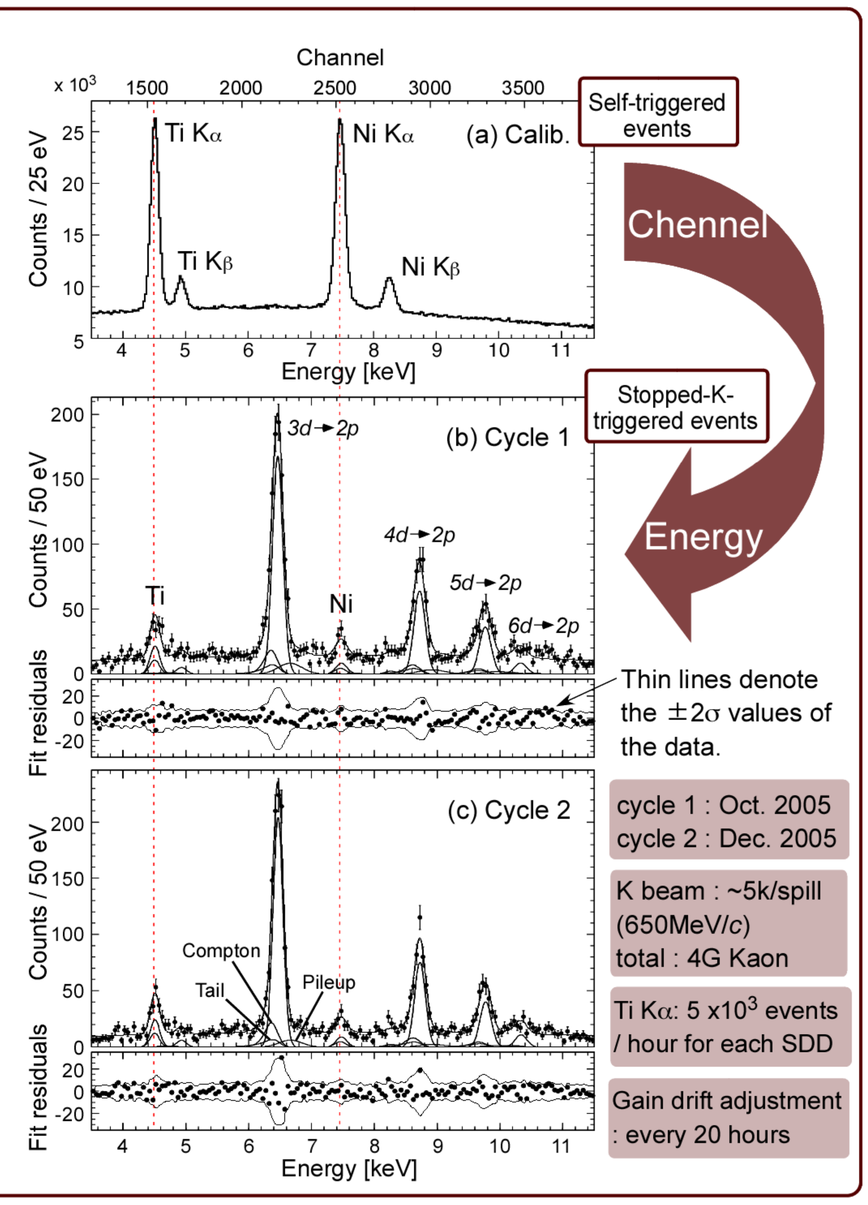

### Transition energies of K-4He atom

| | Energy [eV] | EM value |
|---|---|---|
| 3d→2p | 6467.0 ± 2.5 | 6463.5 |
| 4d→2p | 8723.5 ± 4.6 | 8721.7 |
| 5d→2p | 9761.4 ± 7.6 | 9766.8 |

preliminary

Note that the tabulated EM values were calculated by Koike [9]. These values were obtained by using the latest kaon mass given by PDG and were consistent with another recent calculation by Santos et al. [10], which differs slightly from the ones used in previous experiments [4-6].

In comparison to the previous experiment [6], we achieved
~2 times better energy resolution,
~2.5 times higher statistics, and
~10 times better signal-to-noise ratio.




**References**

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