Transition-edge-sensor microcalorimeters for mass spectrometric identification of neutral molecules

S. Okada[1], T. Azuma[1], D.A. Bennett[2], W.B. Doriese[2], J.W. Fowler[2], T. Hashimoto[3], R. Hayakawa[4], J. Hays-Wehle[2], G. Hilton[2], Y. Ichinohe[1], Y. Ishisaki[4], S. Kuma[1], T. Nakano[1], Y. Nakano[5], H. Noda[6], G.C. O'Neil[2], C.D. Reintsema[2], D.R. Schmidt[2], D.S. Swetz[2], H. Tatsuno[7], S. Ueda[8], J.N. Ullom[2], S. Yamada[4]

[1]RIKEN, [2]NIST, [3]JAEA, [4]TMU, [5]Rikkyo Univ., [6]Tohoku Univ., [7]Lund Univ., [8]JAXA

Abstract

To explore the quantum collision dynamics of the stored molecular ions by the merging experiments with a beam of the neutral atoms, we are developing a new technique of mass spectroscopy for the neutral molecular fragments from the collisions using an array of TES microcalorimeters at a brand-new cryogenic electrostatic ion storage ring in RIKEN.

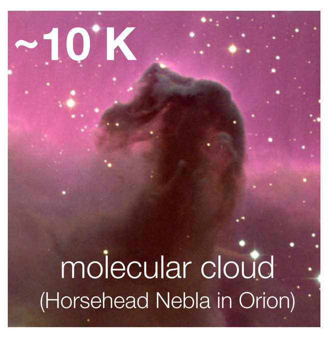
TES is operated at the superconducting critical temperature of less than 100 mK with radiation shield windows in front of the TES sensors (for each cooling stages) to avoid infrared background from heat radiation. Unlike x-rays, the low energy molecules (~10 keV) easily stop at these radiation shields even for 100-nm-thick aluminum sheet. One of key issue towards this application is how to operate TES system against the radiation background although our storage ring is at 4 K. We just started the study at RIKEN from this spring.

1. RICE-ring — Cryogenic electrostatic ion storage ring

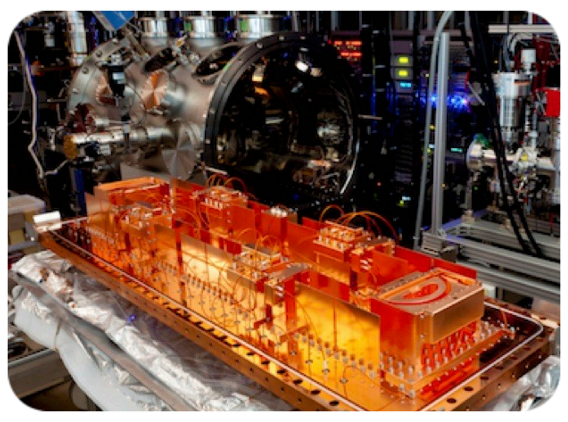
✓cold chemical reaction relevant to **universe evolution** → essential to be cooled down to 10 K

✓dynamics of **large complex molecules**

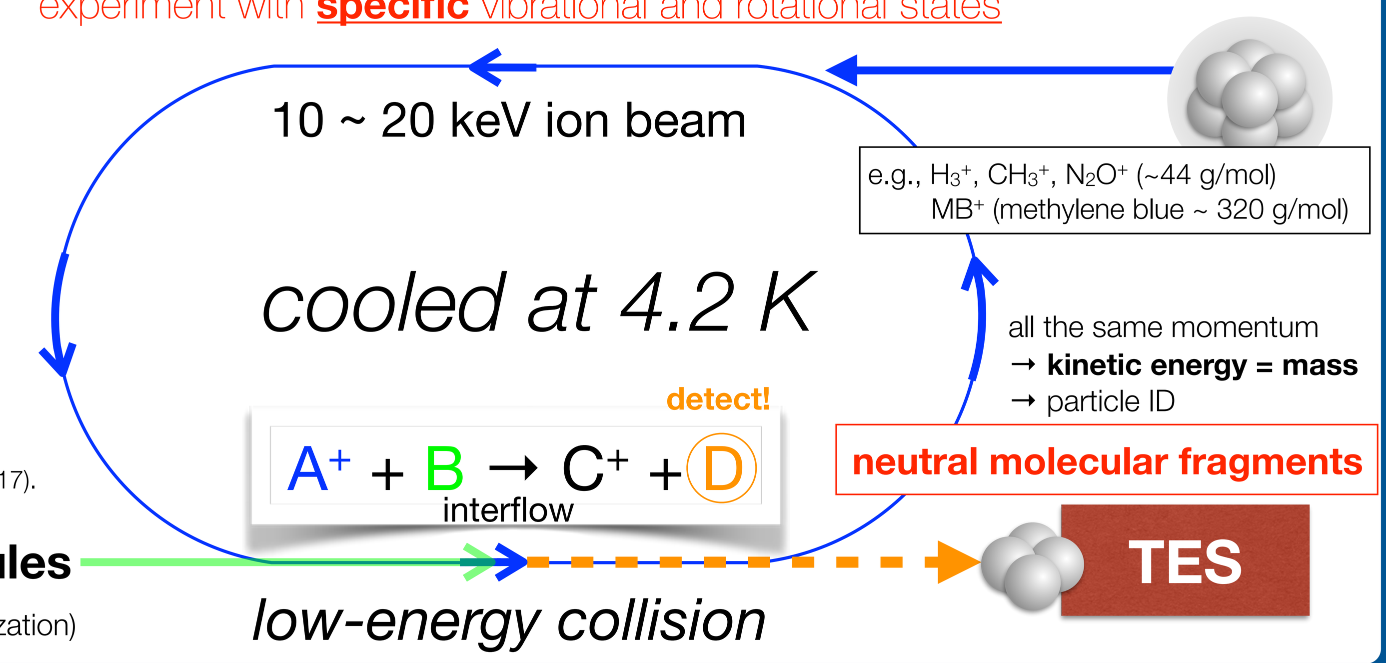
✓atom interaction with a ultra short-pulsed intense lasers



RICE-ring
(RIken Cryogenic Electrostatic ion storage ring)

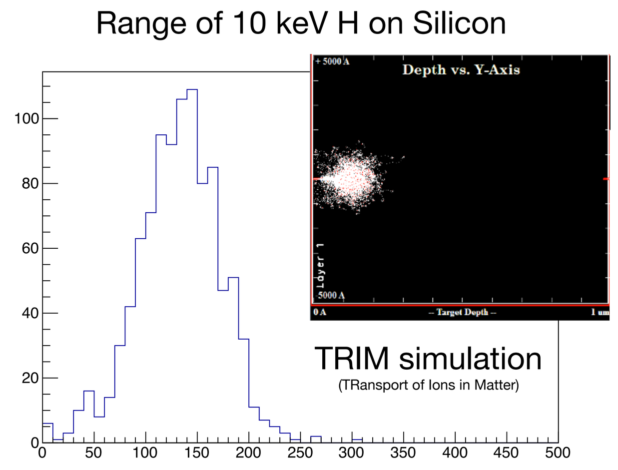


For details of this ring, refer the following paper :
Y. Nakano et al., Rev Sci. Instrum. 88, 033110 (2017).



2. Why cryogenic detector?

Why not Si detector ?



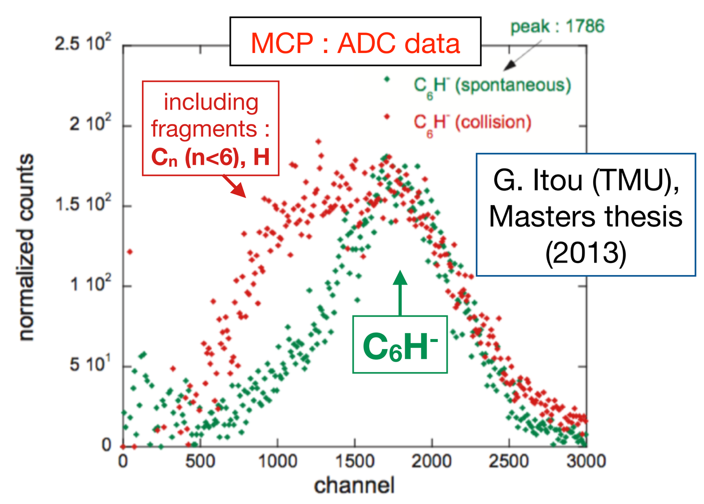
Range is only ~ 130 nm even for 10 keV hydrogen

difficult to reach the depletion layer
-> insensitive for detection of molecular fragments (keV order energy)

Why not MCP ?

MCP = Micro Channel Plate

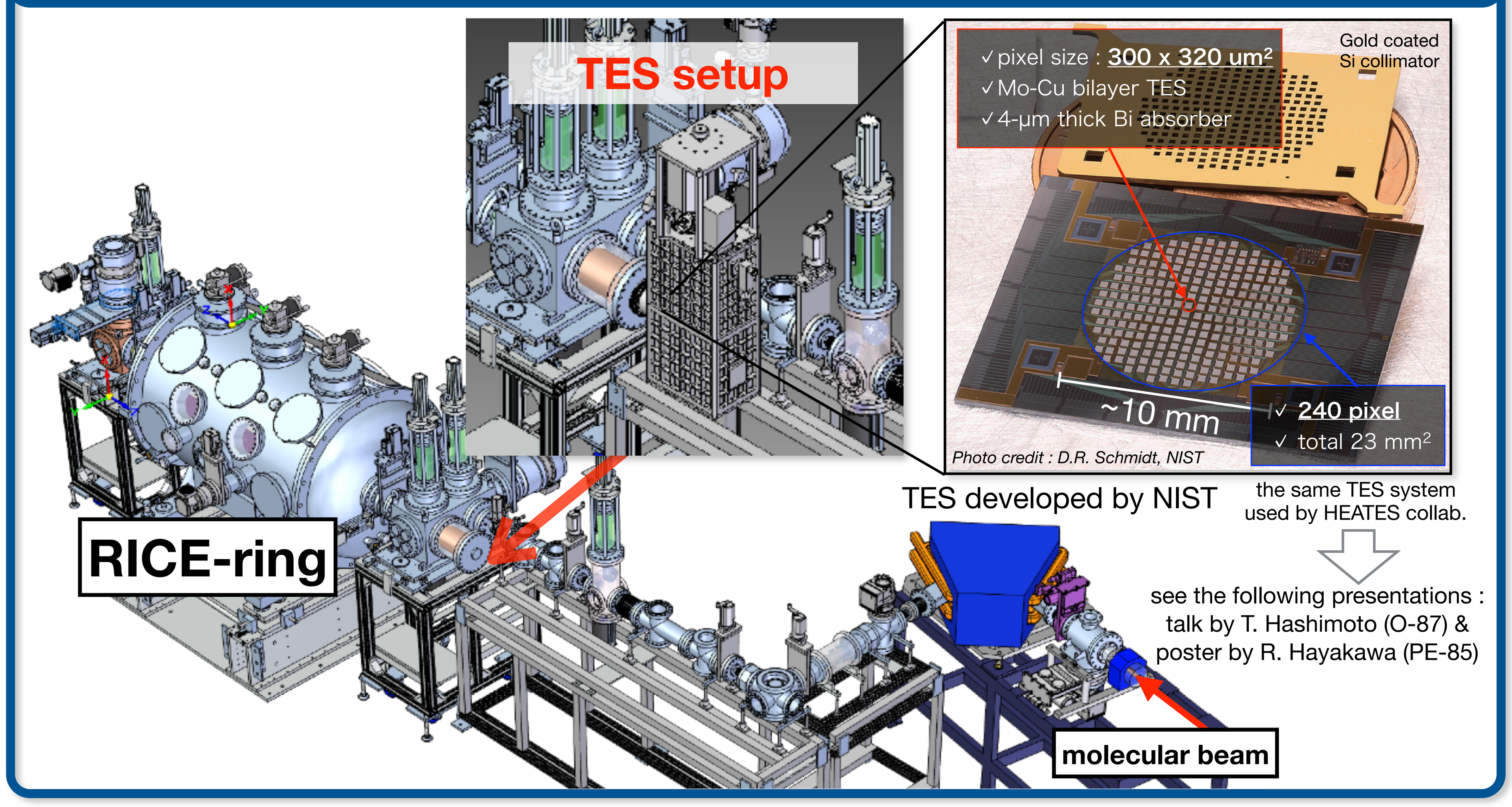
20 keV C_6H^- beam in a strage ring at TMU



Particle ID of C_6H^- and other fragments is difficult

Energy resolution is not enough

3. Setup with TES microcalorimeter

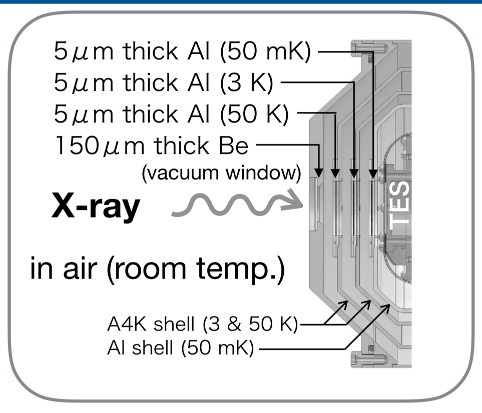


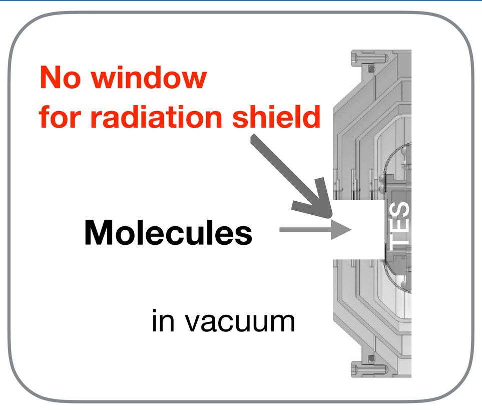
TES developed by NIST

the same TES system used by HEATES collab.

see the following presentations : talk by T. Hashimoto (O-87) & poster by R. Hayakawa (PE-85)

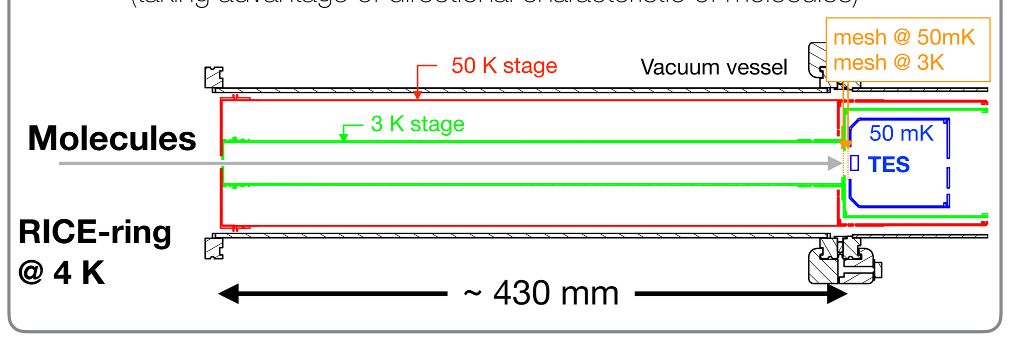
4. Radiation shield — X-ray vs. molecule

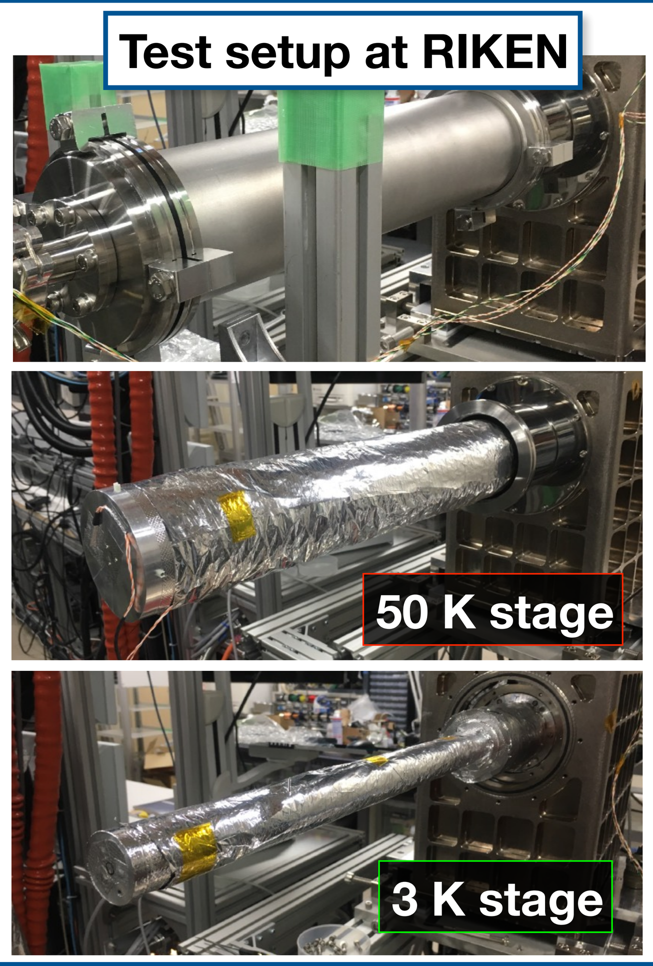




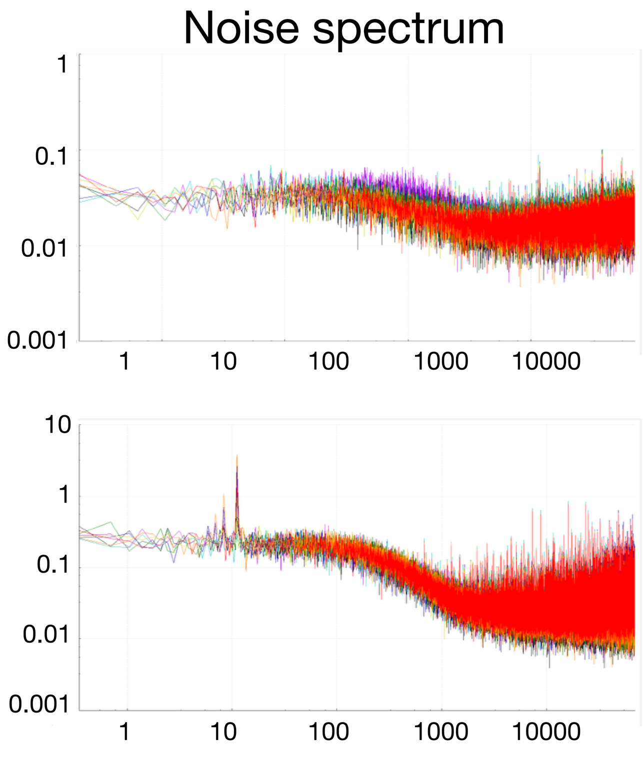
IR affects not only cooling capacity but also TES energy resolution

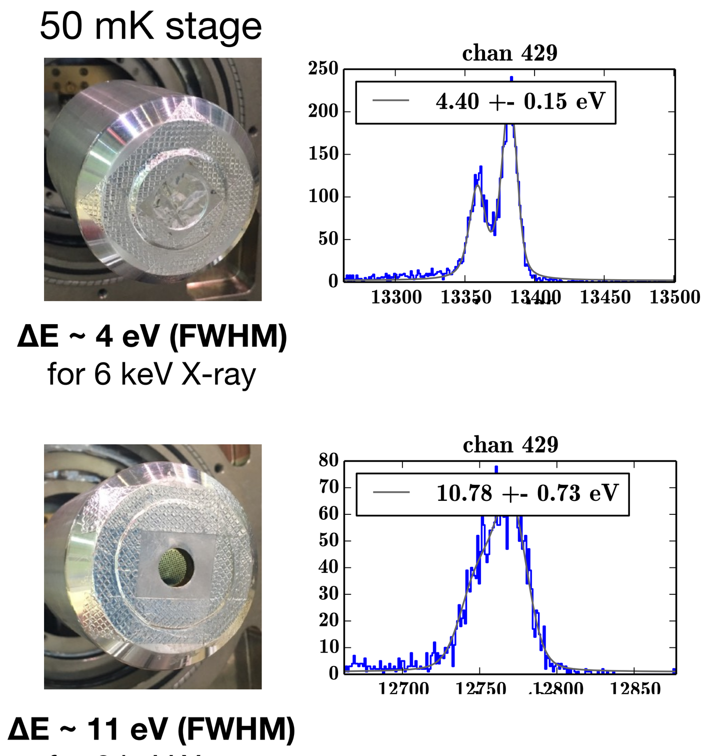
extend cylinder for radiation shield
(taking advantage of directional characteristic of molecules)





5. Shield effect @ 50 mK

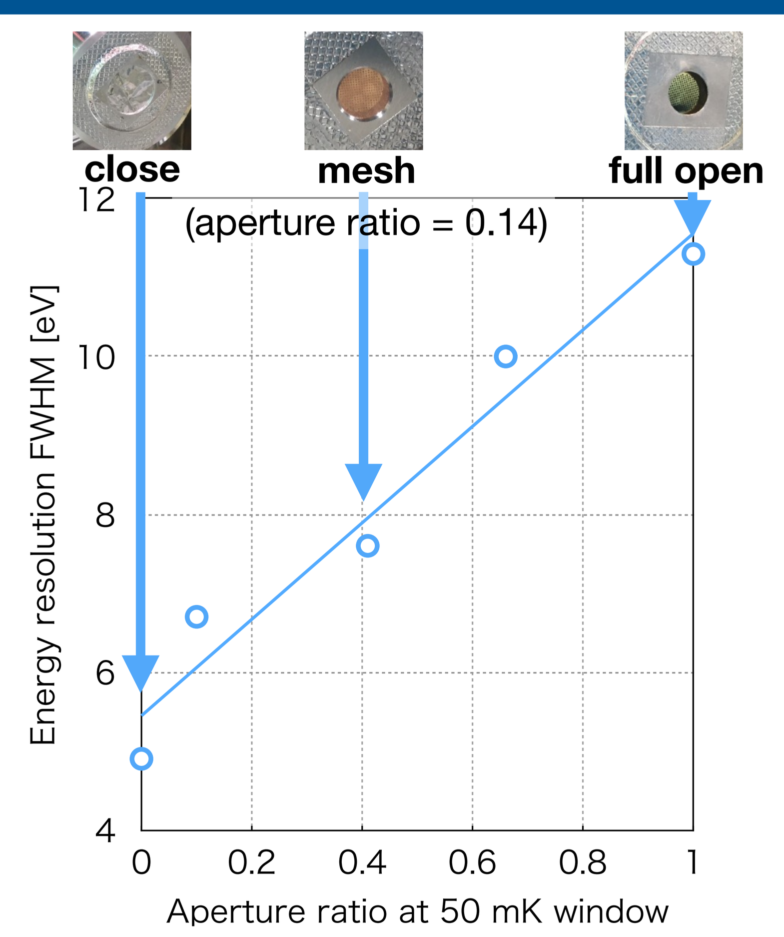


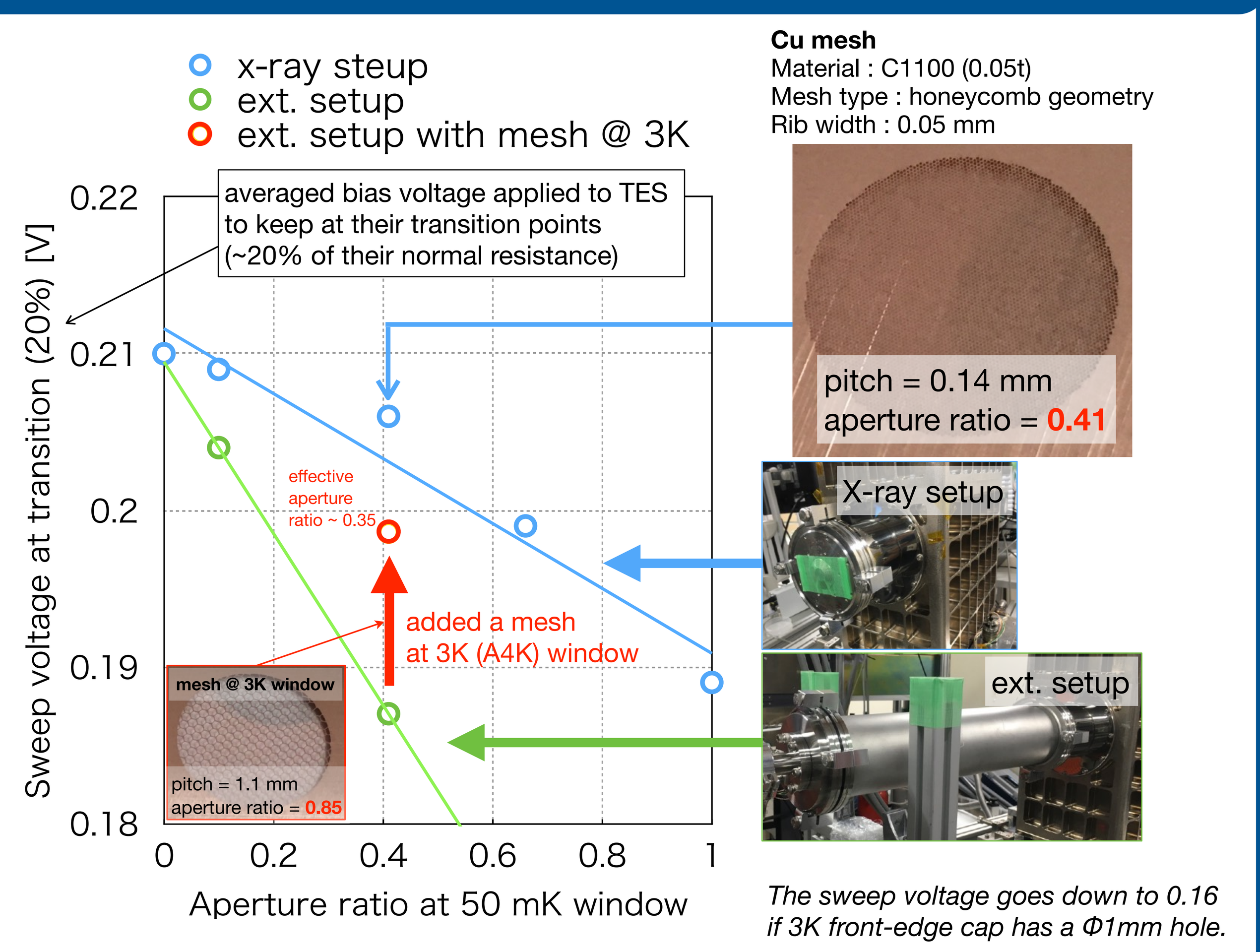


ΔE ~ 4 eV (FWHM) for 6 keV X-ray

ΔE ~ 11 eV (FWHM) for 6 keV X-ray

6. Mesh at 50 mK (and 3 K) window





The sweep voltage goes down to 0.16 if 3K front-edge cap has a Φ1mm hole.