# in-vivo multi-probe tracker based on astrophysical gamma-ray detector technologies


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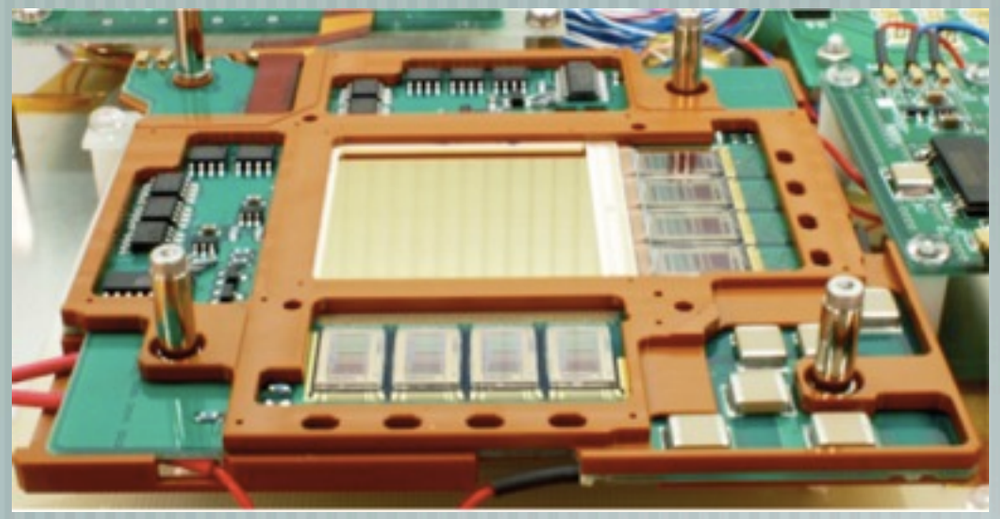
Naoki Kawachi (JAEA), Yosikatsu Kuroda (MHI)

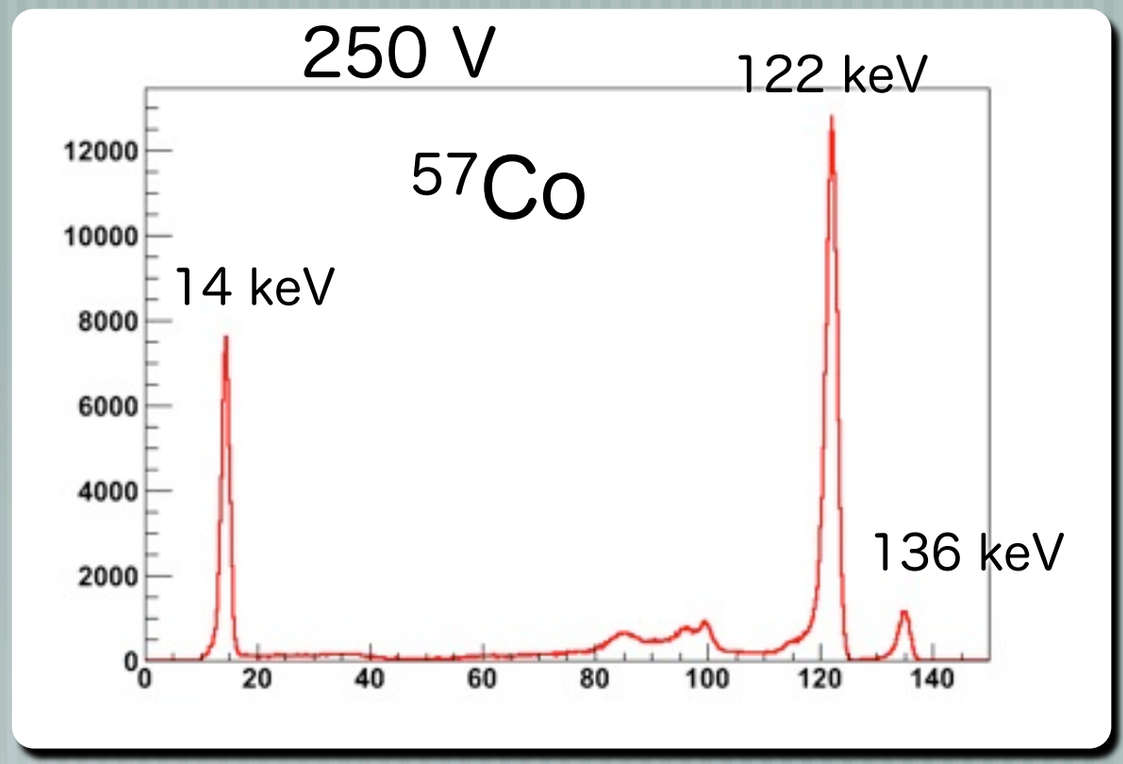

# Detector technologies for ASTRO-H

## Gamma-ray imaging systems

- Fine pitch CdTe strip imager

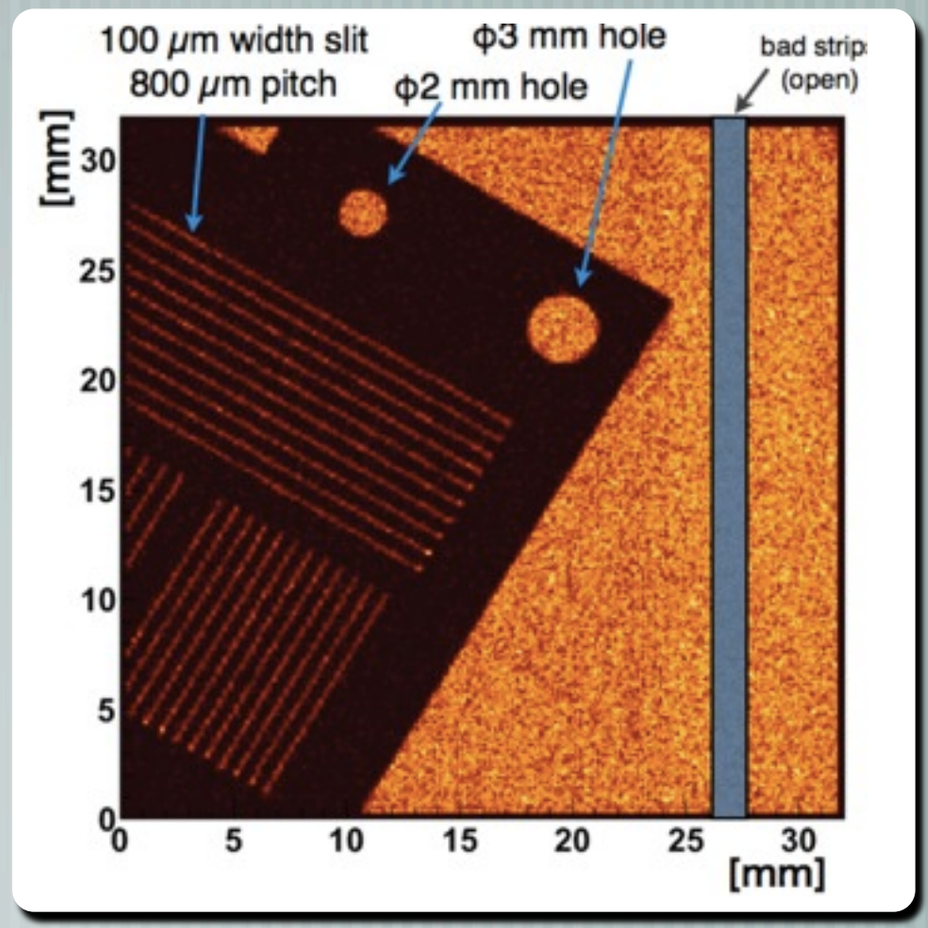


250 um pitch double-sided
CdTe strip detector
3.2 cm wide, 0.75 mm thick
ADC implemented VATAs
(-> talks by Takahashi & Watanabe)

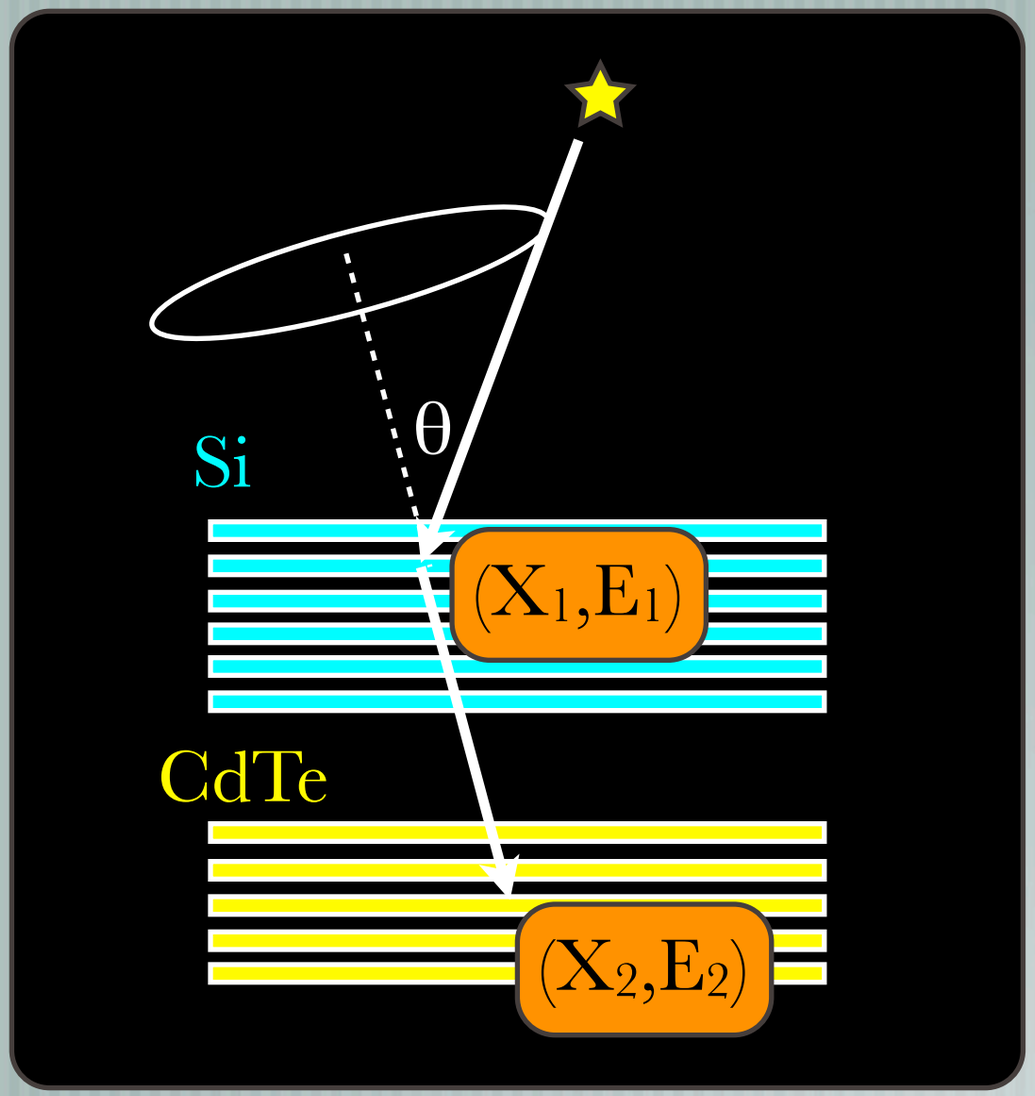



- **Si/CdTe Compton camera**

(-> this talk )



# Si/CdTe Compton camera




Accumulation structure of high resolution (ΔE, ΔX) semiconductor detectors

The direction of incident gamma-ray ;

$$cos\theta = 1 - m_e c^2 \left( \frac{1}{E_2} - \frac{1}{E_1 + E_2} \right)$$

Advantage ;

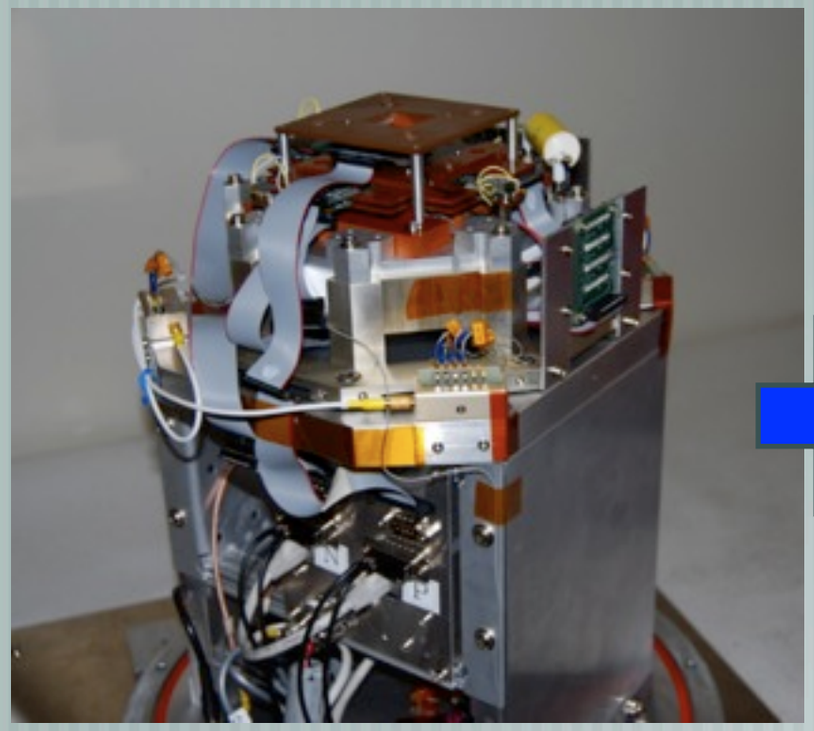
- Good angular resolution (~1° @ 500 keV )
- Good energy resolution (~1% @ 500 keV )
- Operation at around room temperature

→ ・Imaging without a mechanical collimator

Wide energy band including SPECT/PET probes

# Upgrade of a Si/CdTe Compton camera

Compton camera Mrk3
(First prototype for medical imaging)



400 um pitch Si-DSD
CdTe pixel detectors

0.23 x $10^{-6}$ @ 356 keV
10 cm

Compton camera Mrk5

250 um pitch Si-DSD
250 um pitch CdTe-DSD

3.4 x $10^{-6}$ @ 356 keV
10 cm

Soft Gamma-ray Detector
(ASTRO-H)

~ 400 x $10^{-6}$ @ 356 keV
10 cm

(cf. clinical gamma camera 100 x $10^{-6}$ )

# Upgrade of a Si/CdTe Compton camera

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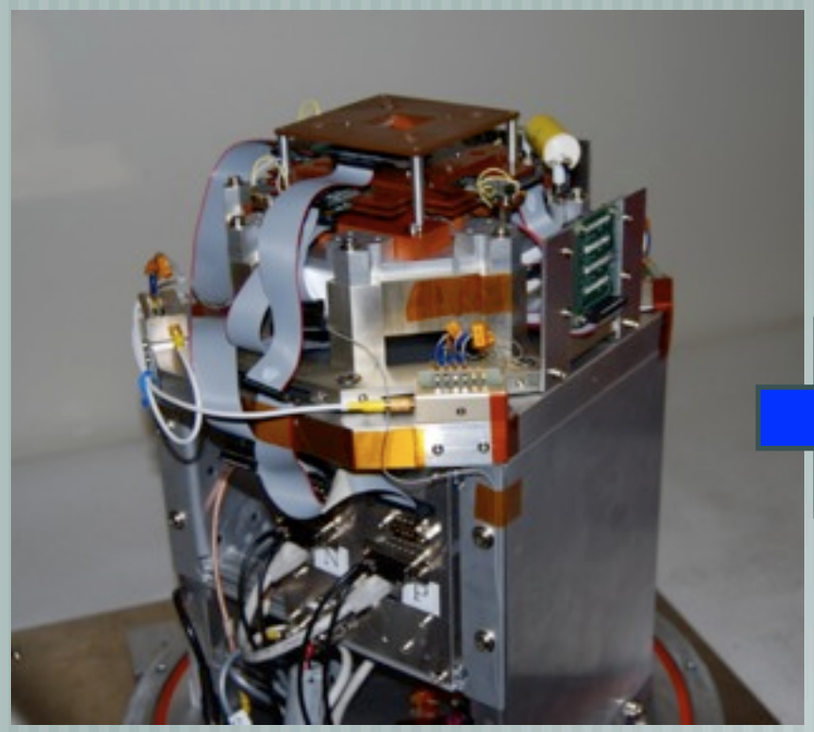

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(ASTRO-H)

~ 400 x $10^{-6}$ @ 356 keV
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(cf. clinical gamma camera 100 x $10^{-6}$ )

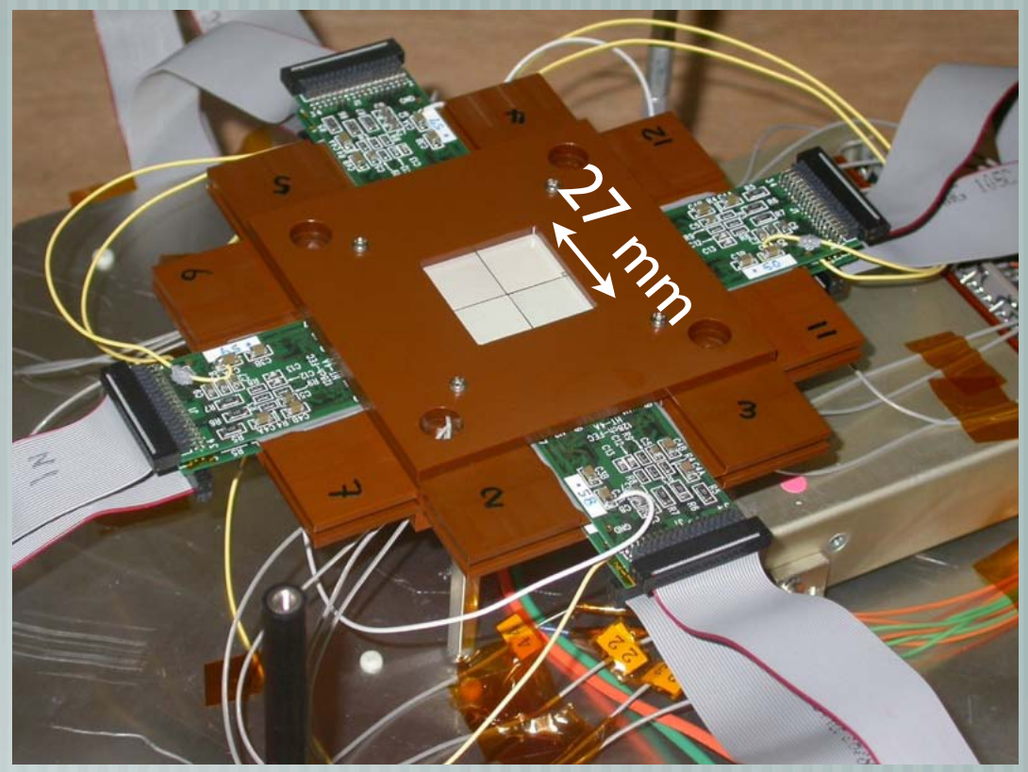
# Compton camera Mark 3

## Key elements

Double-sided Silicon strip detector


25.6 mm wide, 300 um thick,
400 um strip pitch
ΔE : 1.5 keV (FWHM) @ 60 keV

4-layer stacked CdTe pixel detector




13.5 mm wide, 500 um thick,
pixel size 1.35 mm × 4 module
ΔE / E : 1.0 % (FWHM) @ 511 keV

Low noise & low power analog ASIC, VATA (with Gamma Medica-Ideas)

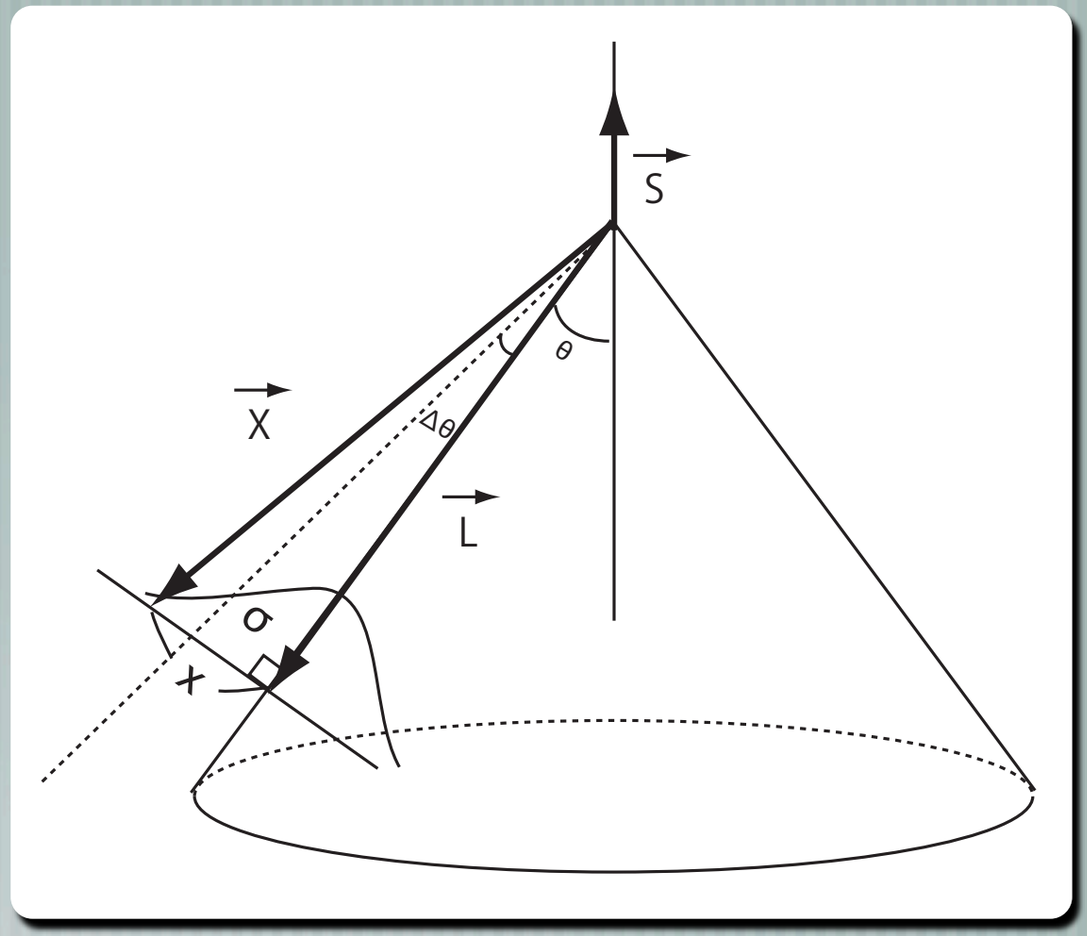
# Image reconstruction

## Back-projection

$$V(\vec{X}) = |\vec{L}|^{-w} \exp\left[-\frac{1}{2}\left(\frac{x}{\sigma}\right)^2\right]$$

$$x = |\vec{X} - \vec{L}|$$
$$\sigma = |\vec{L}| \tan(\Delta\theta).$$

$\Delta\theta$ ~1 degree




w = 2 Additional correction for the decrease of the sensitivity due to solid angle of the camera as viewed from a voxel is needed.

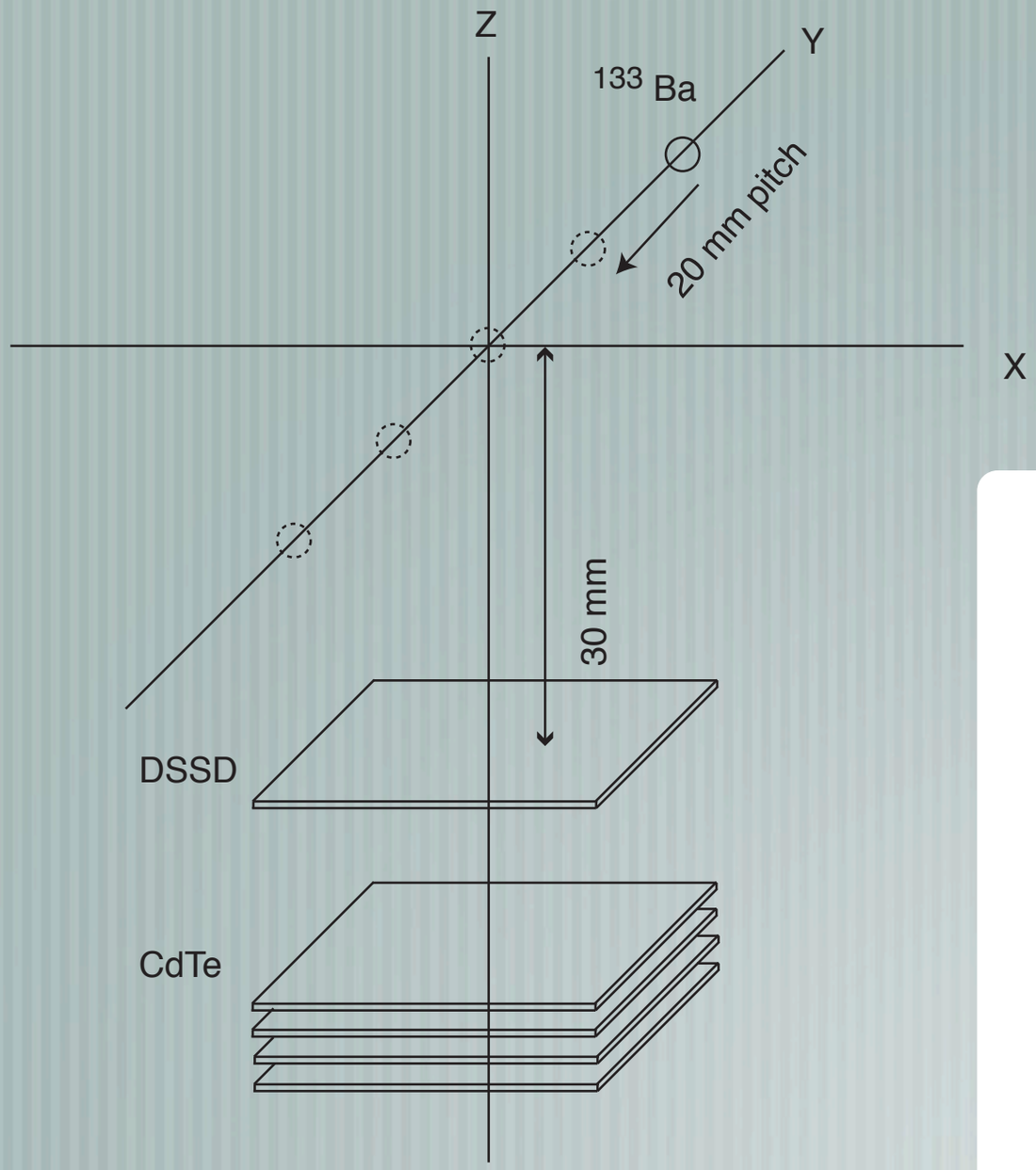
( ex. LM-ML-EM method, Takeda et al. 2009 for 2-D phantom)

w = 0 No L-dependance, meaning that the correction for solid angle is done during back-projection process.

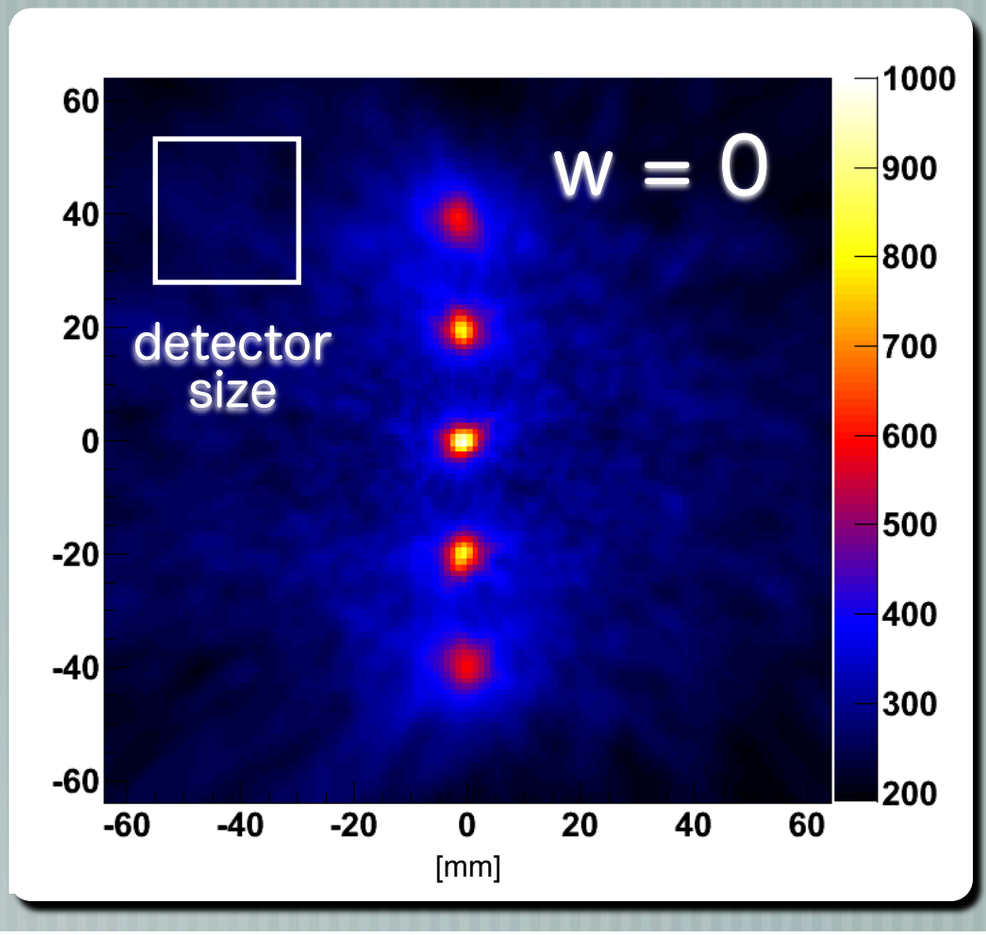
(Takeda et al. IEEE TNS submitted )

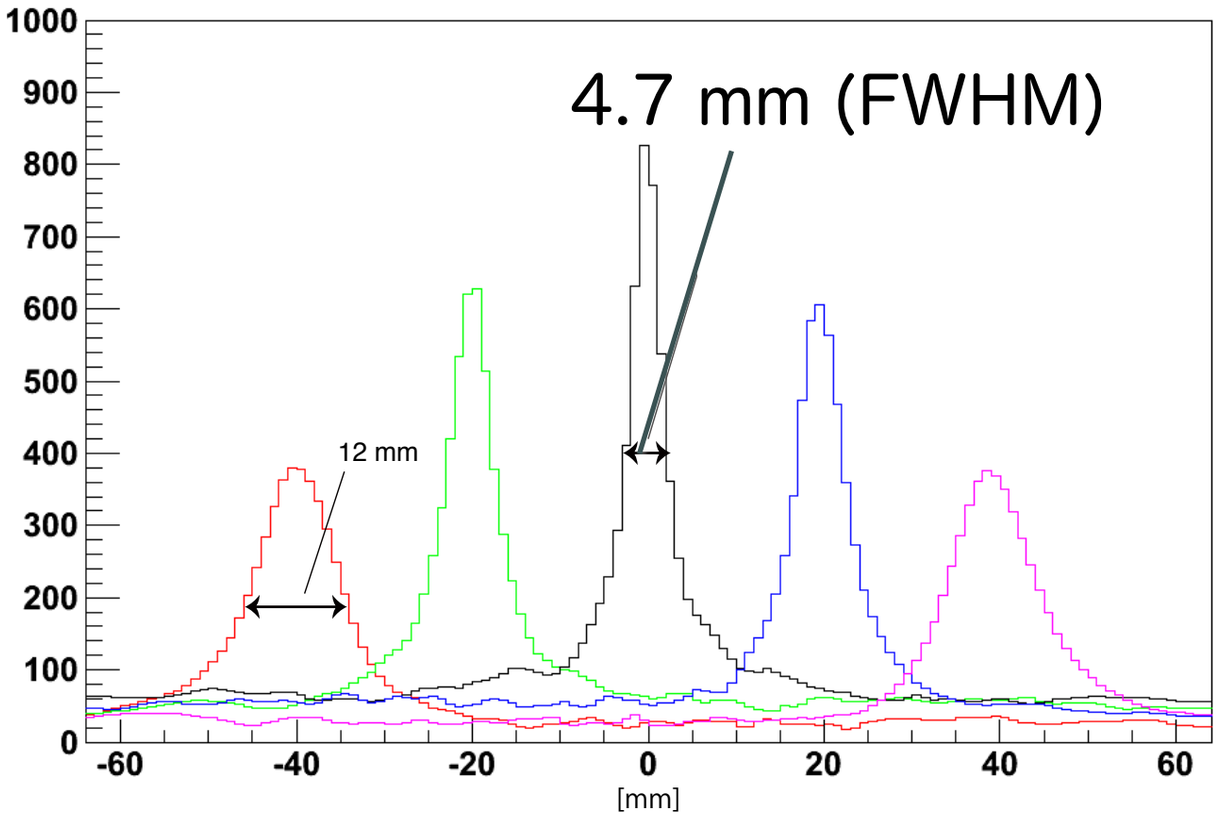
# Position resolution by simple back-projection

Source size : D=1mm




2.6 x $10^{-6}$ @ 356 keV, 30 mm



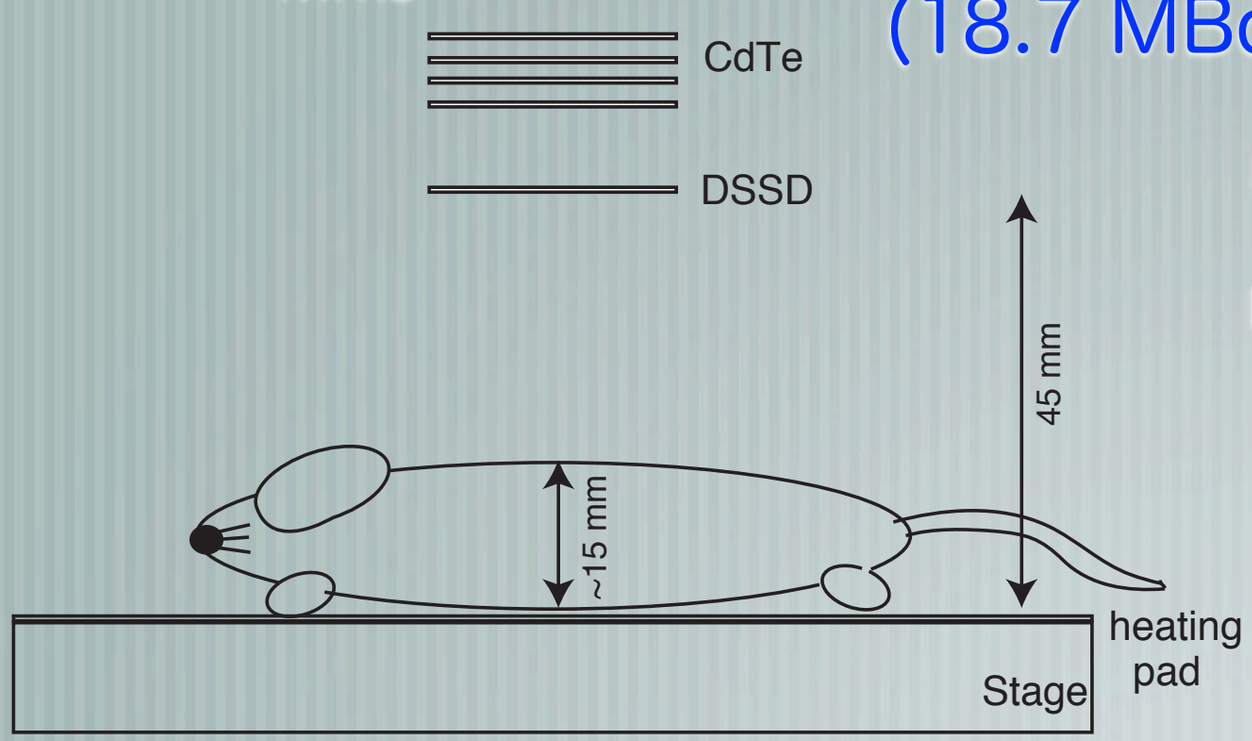




(Takeda et al. IEEE TNS submitted )

# Demonstration of multi-probe tracker

First imaging test with a living mouse by Si/CdTe Compton camera.

(Motomura et al. 2007 by Ge strip Compton camera)




Injected radiopharmaceuticals;

Iodinated ($^{131}$I) methylnorcholestenol

(18.7 MBq: 5,4 and 3-days before imaging)

used for adrenal scintigraphy

marked accumulation to a thyroid

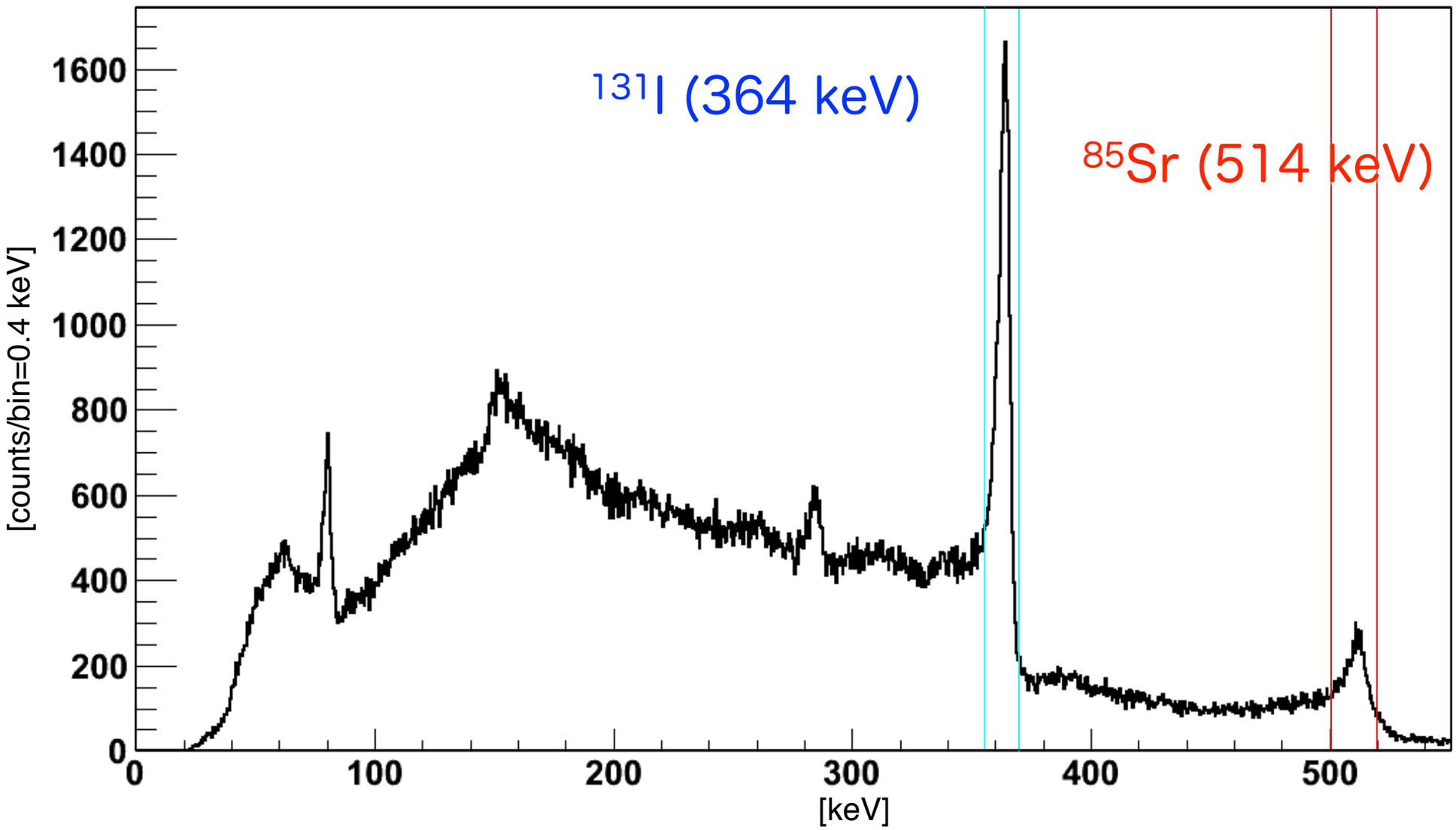
$^{85}SrCl_2$ solution

(2 MBq: 1-day before imaging)

taken up in new bone growth

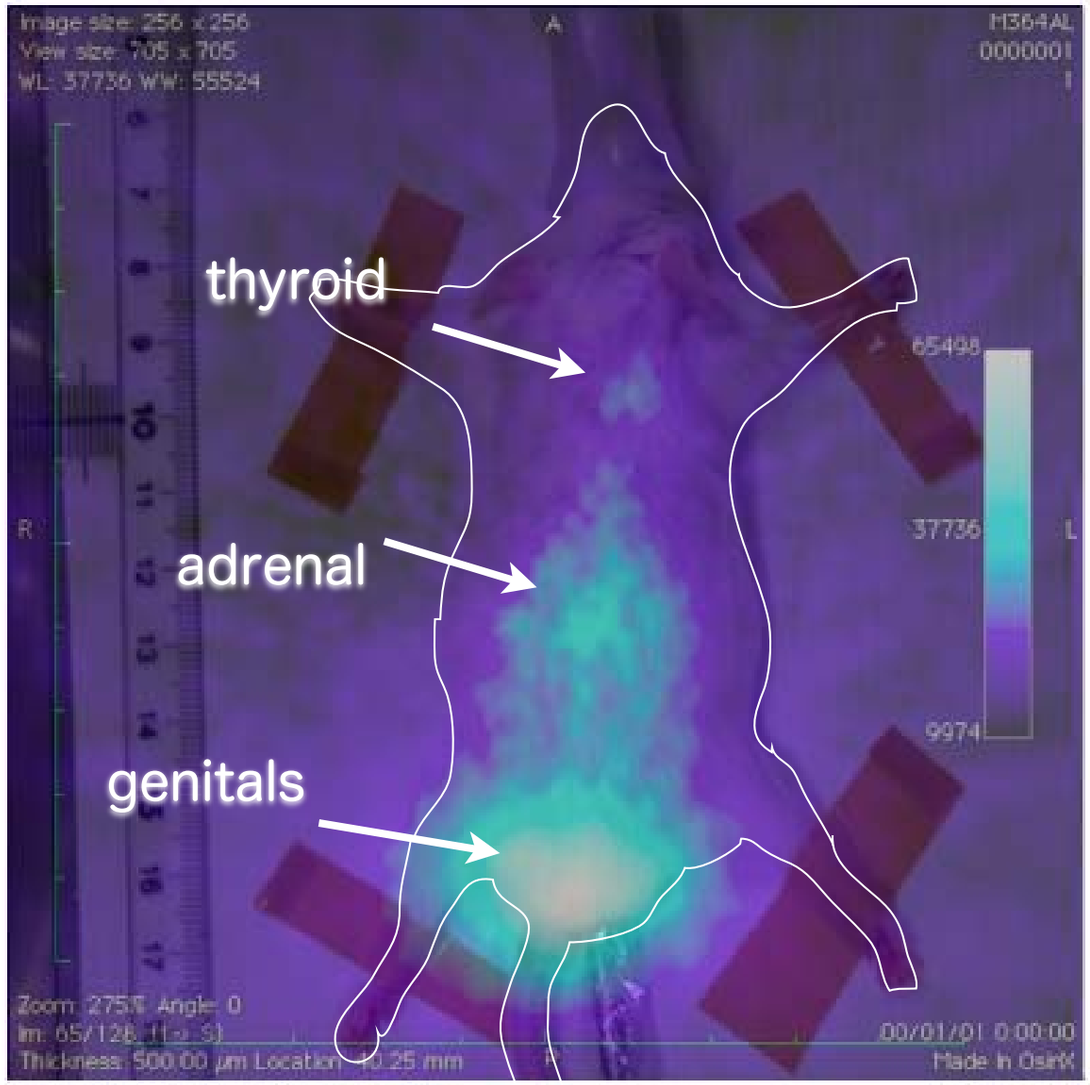
scanning for bone lesions

# Spectrum after 6 hours observation

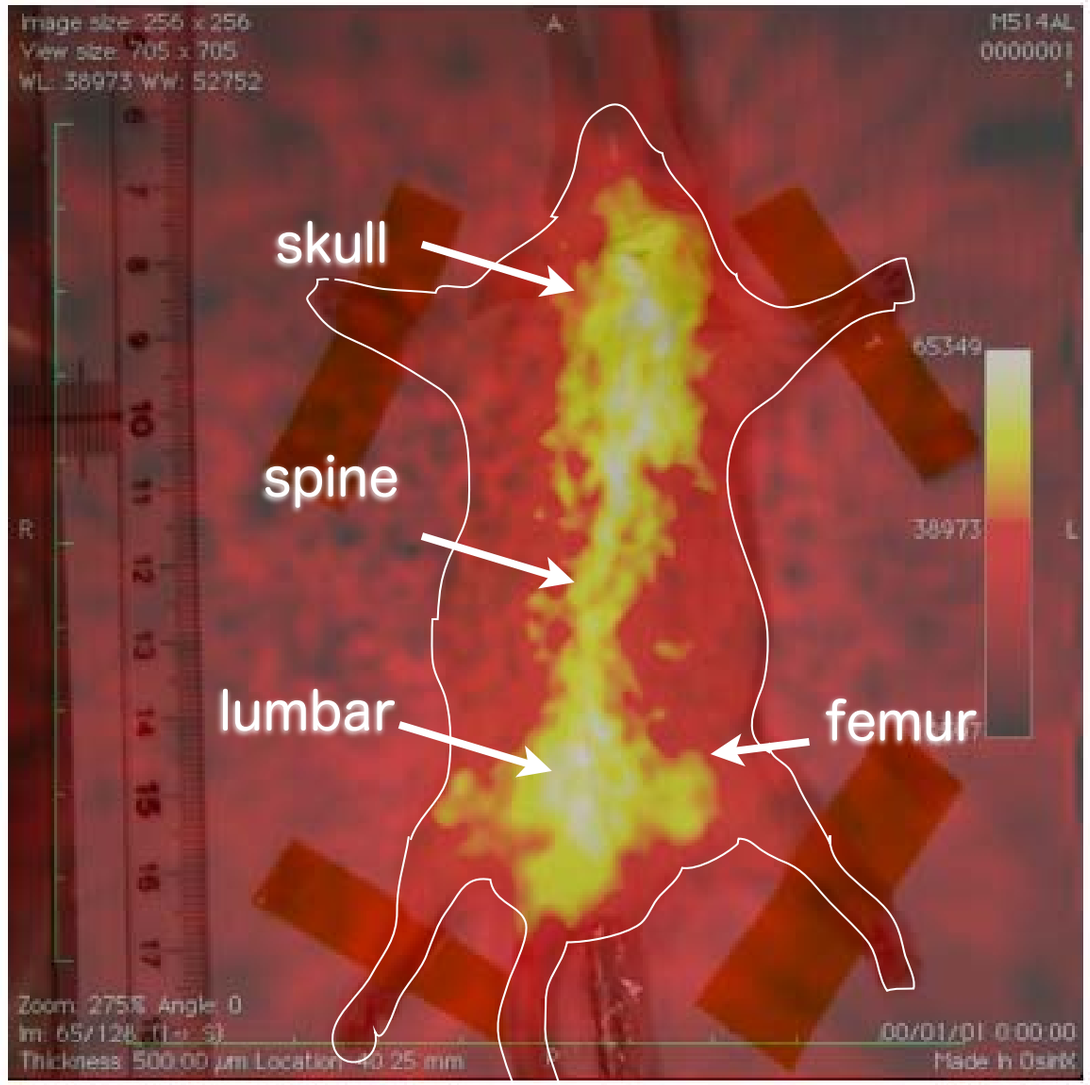


# Imaging results

## $^{131}$I(364 keV)




## $^{85}$Sr(514 keV)




Feasibility of a multi-probe tracker is demonstrated !!

# Conclusion and future prospects

1. We have developed compact Compton imaging systems based on Si and CdTe detector.

2. Feasibility of a multi-probe tracker is demonstrated by Compton imaging.

3. Position resolution and efficiency in this stage aren't sufficient for practical applications. Experiments using Mrk5, consisting of 250 um pitch Si-DSD and CdTe-DSD, are on going.

4. Application to clinical imaging has been started with Takashi Nakano, Yoshiyuki Suzuki,Kota Torikai (Gumma U.)