# Hydrogen Isotope Research Center (HRC), University of Toyama

HRC is one of the largest tritium research facilities in Japanese universities and licensed to handle 8 TBq (217 Ci) tritium per day and 555 TBq (15 kCi) per year.

Research Staffs: 3 Professor, 3 Associate Professor, 1 Assistant Professor
1 Research Fellow, 1 Foreign Researcher (Guest Professor)

Education: Department of New Energy Science (Ph. D. course)
Department of Chemistry (Master course)

## *Main Directions of Research*

(1) Development of safe handling techniques of tritium for fusion reactors

(2) Hydrogen isotope behaviors in fusion reactor materials

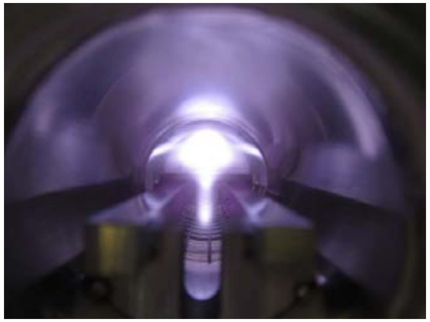
(3) Development of functional materials for hydrogen energy system (catalysis, separation membrane, hydrogen embrittlement etc.)

# *Uniqueness of Tritium Facility*

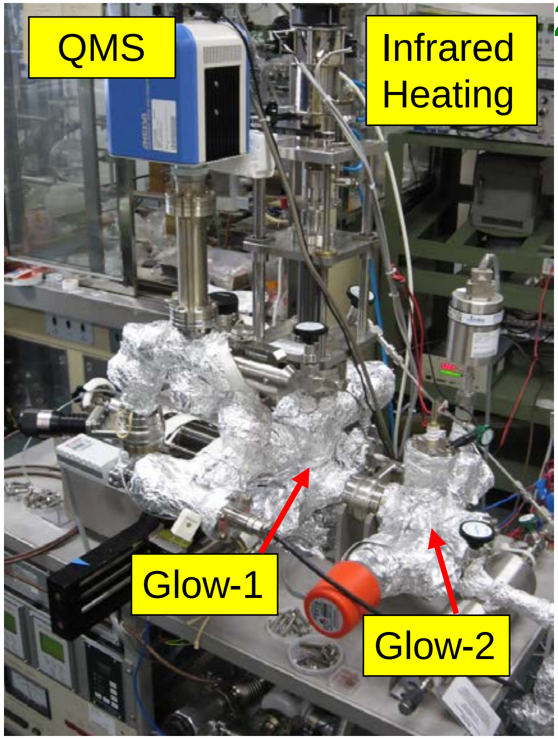
## *Very high flexibility and wide variety of research*

(1) Handling of tritium in any chemical/physical form

- ✓ Tritium gas exposure
- ✓ Tritium ion implantation (~keV)
- ✓ Tritium glow discharge
- ✓ HTO vapor exposure



(Glow Discharge)



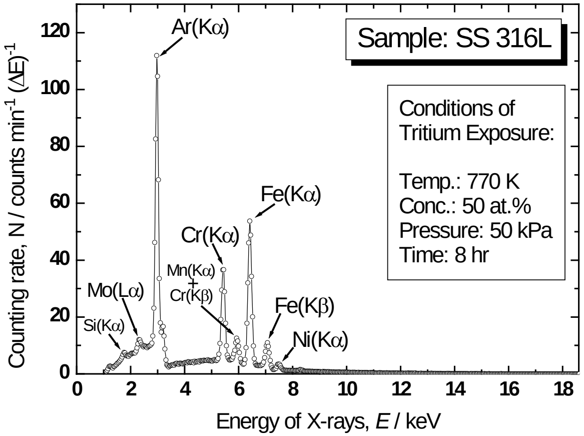

(Apparatus)

(2) Various instruments for tritium measurements

- ✓ β-ray-induced X-ray spectrometry (BIXS)
- ✓ Imaging plate (IP)
- ✓ High sensitivity calorimeter

(3) Various tools for characterization of tritium-containing materials.

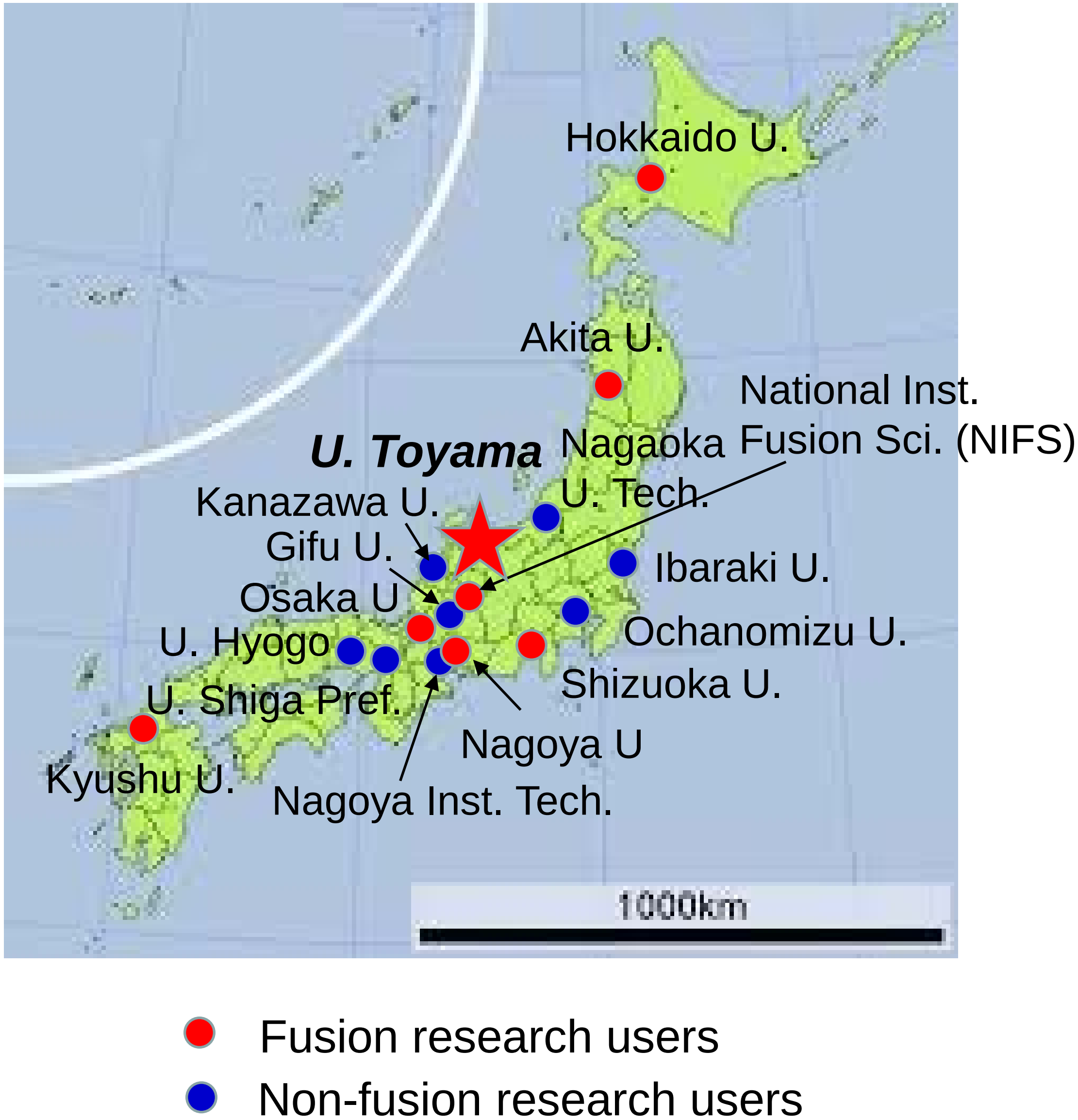
- ✓ X-ray photoelectron spectroscopy
- ✓ Field-emission scanning electron microscope
- ✓ X-ray diffraction



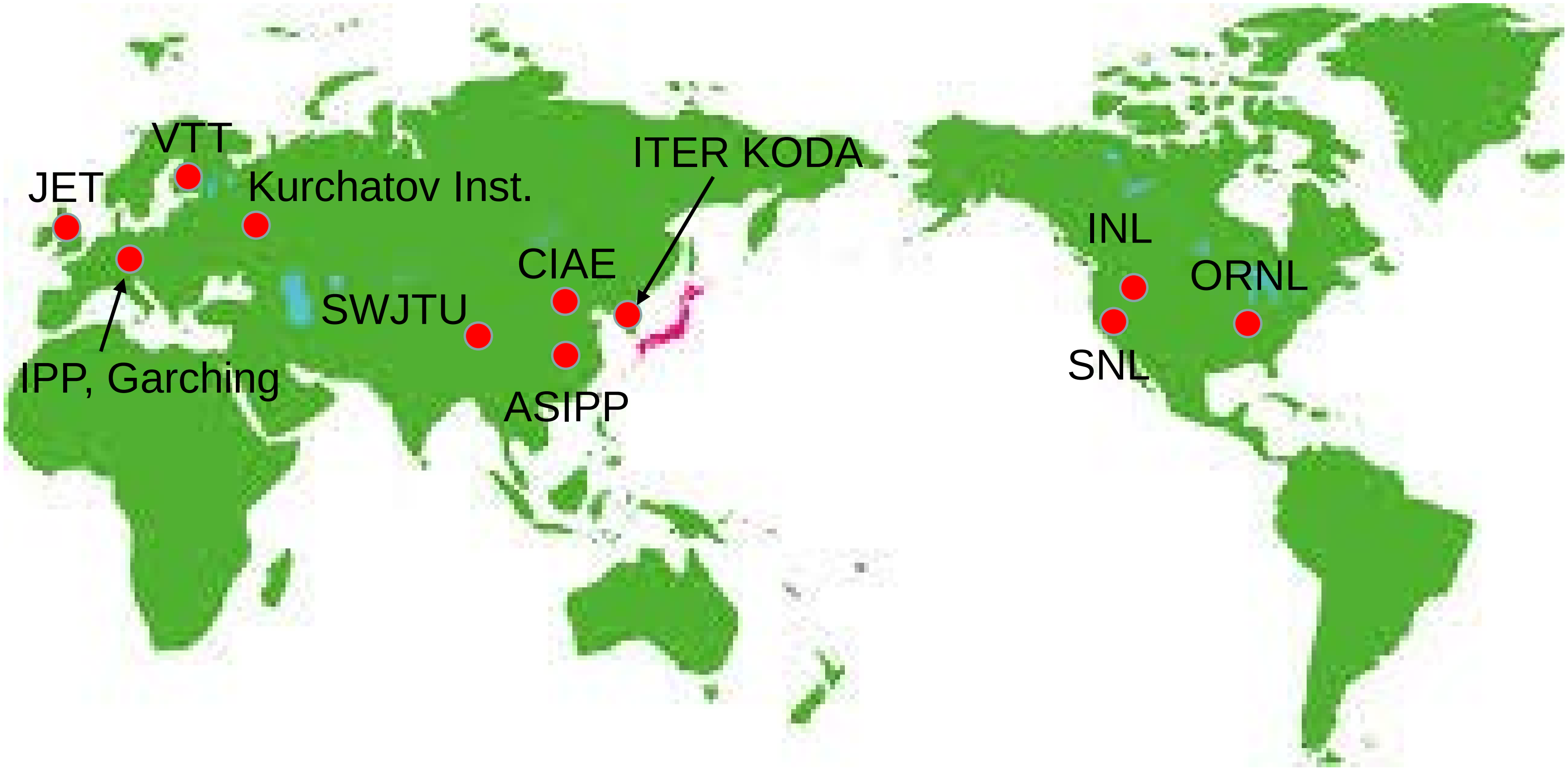

BIXS spectra of stainless steel

*HRC plays the role of a national user facility through collaboration program of NIFS for fusion research and that of U. Toyama for non-fusion research.*

*More than 20 groups uses HRC for fusion and non-fusion researches.*



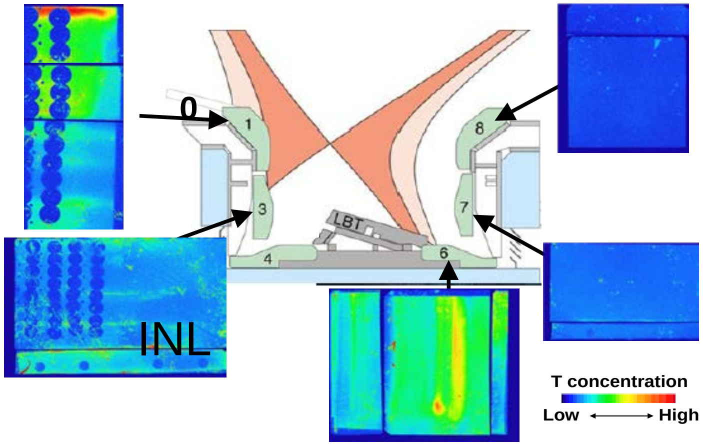

**HRC uses in Japan**




**Current international collaborators of HRC**

HRC is open for international collaboration.

# *Current Tritium-Related Research*




## (1) Tritium measurements

- ✓ Non destructive T measurements in solids using β-ray-induced X-ray spectroscopy, Imaging plate etc.
- ✓ T distributions on JET ITER-like wall tiles with IP and BIXS (collaboration with EUROfusion)
- ✓ Near-infrared spectroscopy for HTO detection with non-hygroscopic windows

## (2) Tritium/hydrogen isotope behaviors in fusion materials *including neutron-irradiated materials*

- ✓ Hydrogen isotope retention in neutron-irradiated tungsten (Japan-US collaboration TITAN and PHENIX, collaboration with IMR, Tohoku U.)
- ✓ Detritiation of fusion reactor materials

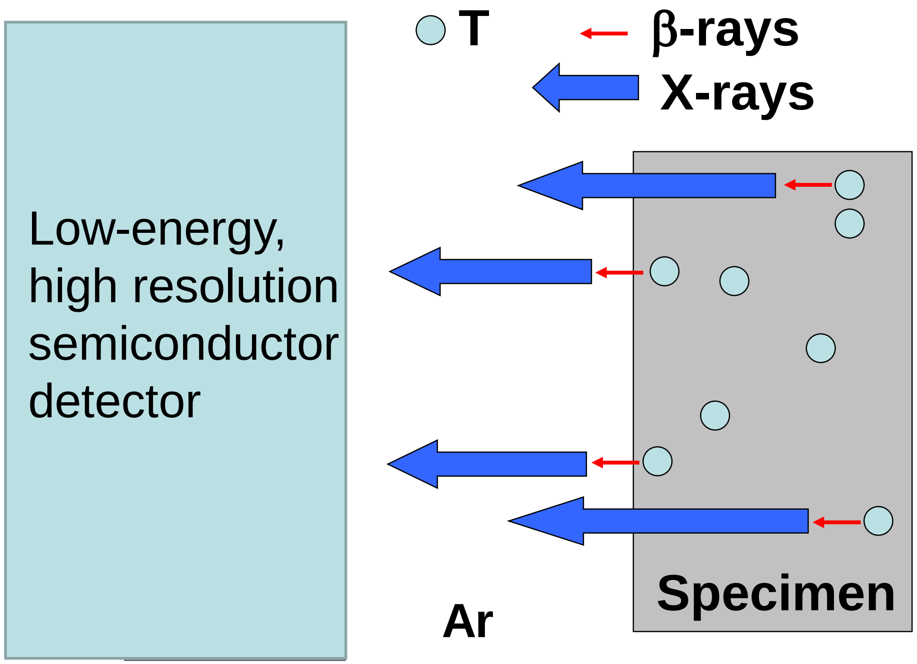
## (3) Application of tritium to materials science

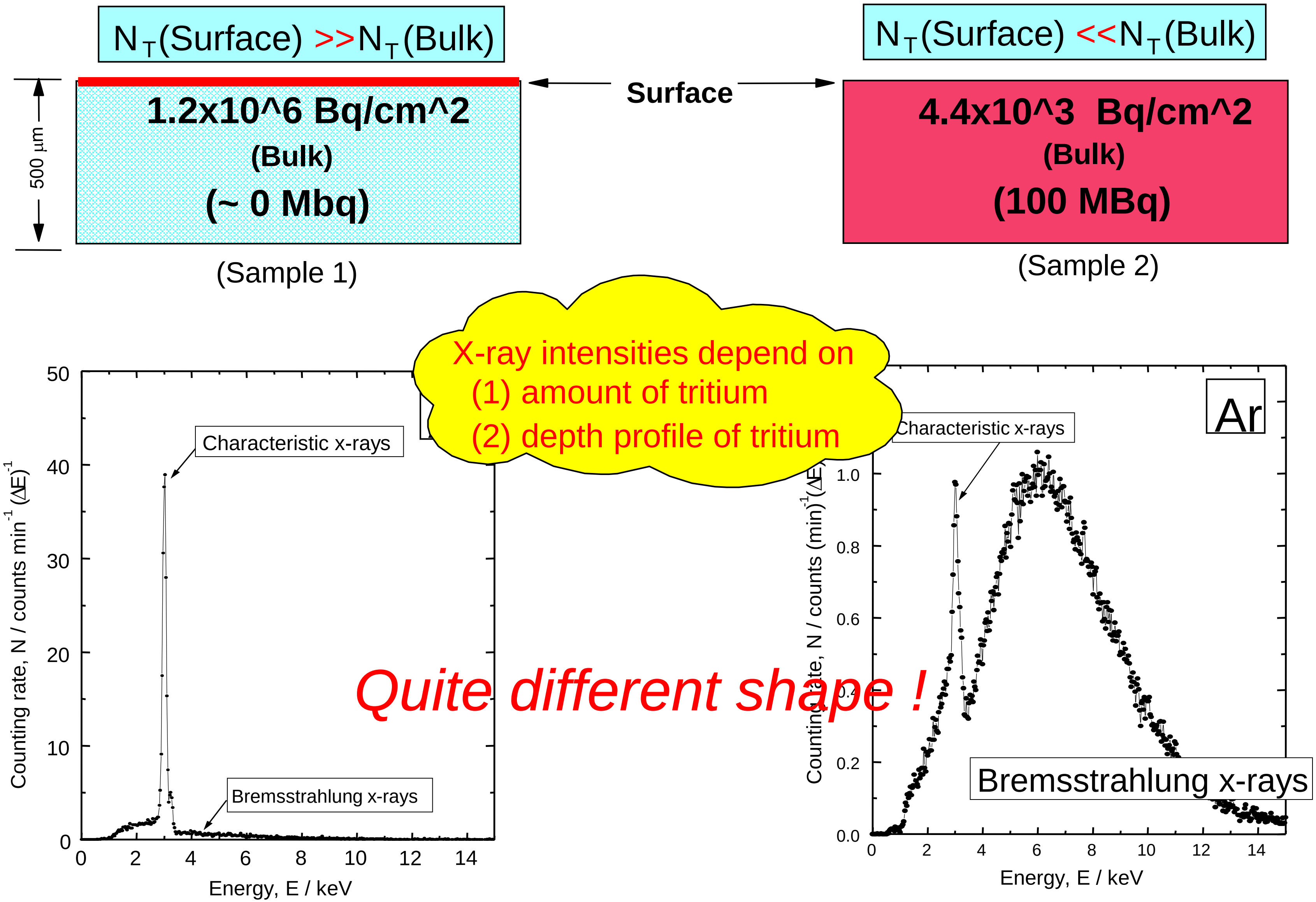
e. g. visualization of hydrogen isotopes in solids by autoradiography

# Non-destructive measurements of tritium distributions in solids using β-ray induced X-ray spectrometry (BIXS) and imaging plate (IP)

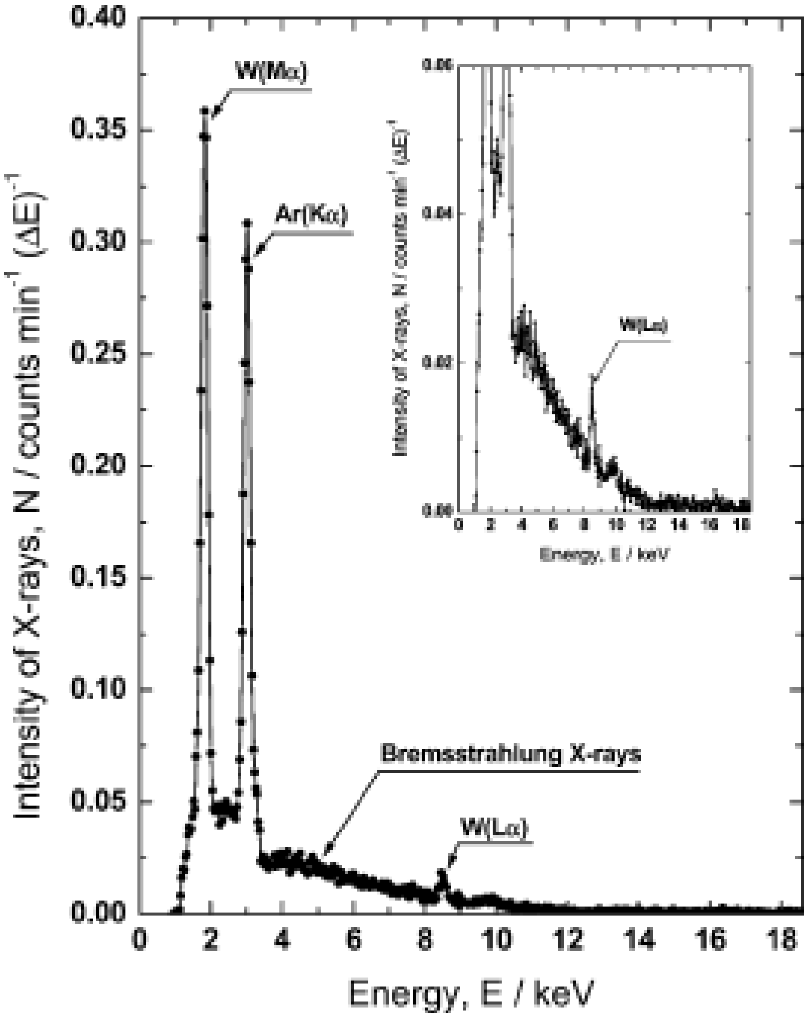
**Motivation**

Escape depth of low-energy b-rays from T is < 1 μm in solids, and hence it is impossible to evaluate T concentration in the bulk using β-ray counting techniques. On the other hand, X-rays induced by β-rays have larger escape depth (~ mm in low-Z materials and ~ 10 μm in high-Z materials).



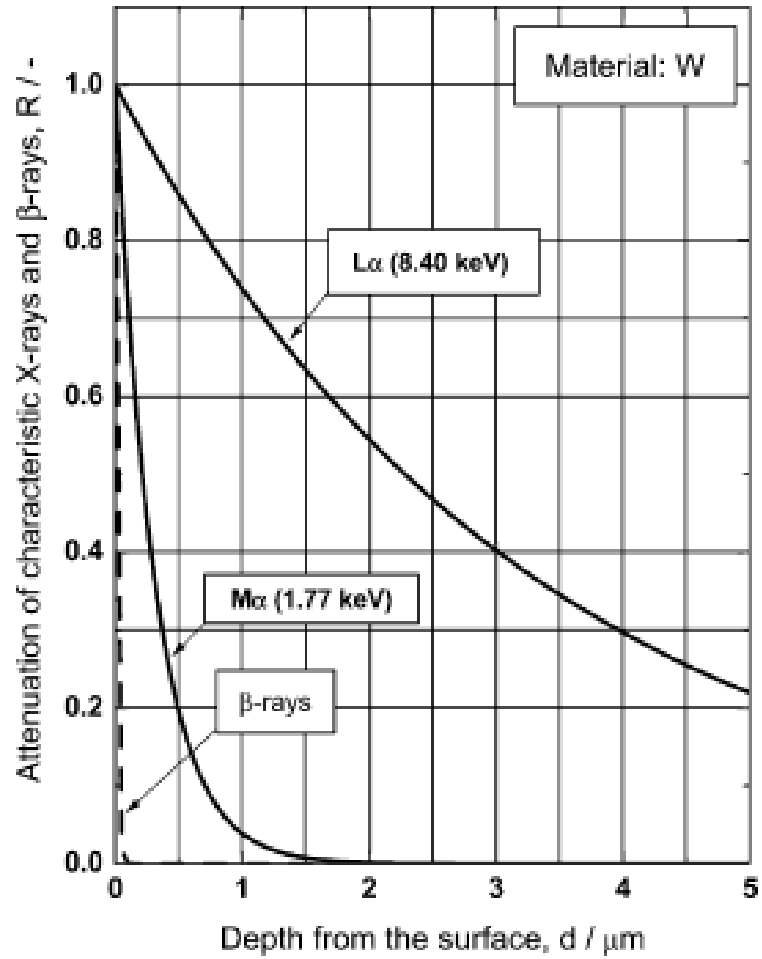



**It is possible to estimate the difference of tritium distribution from X-ray spectra by applying BIXS.**




Example of β-ray induced X-ray spectrum from tritium implanted W

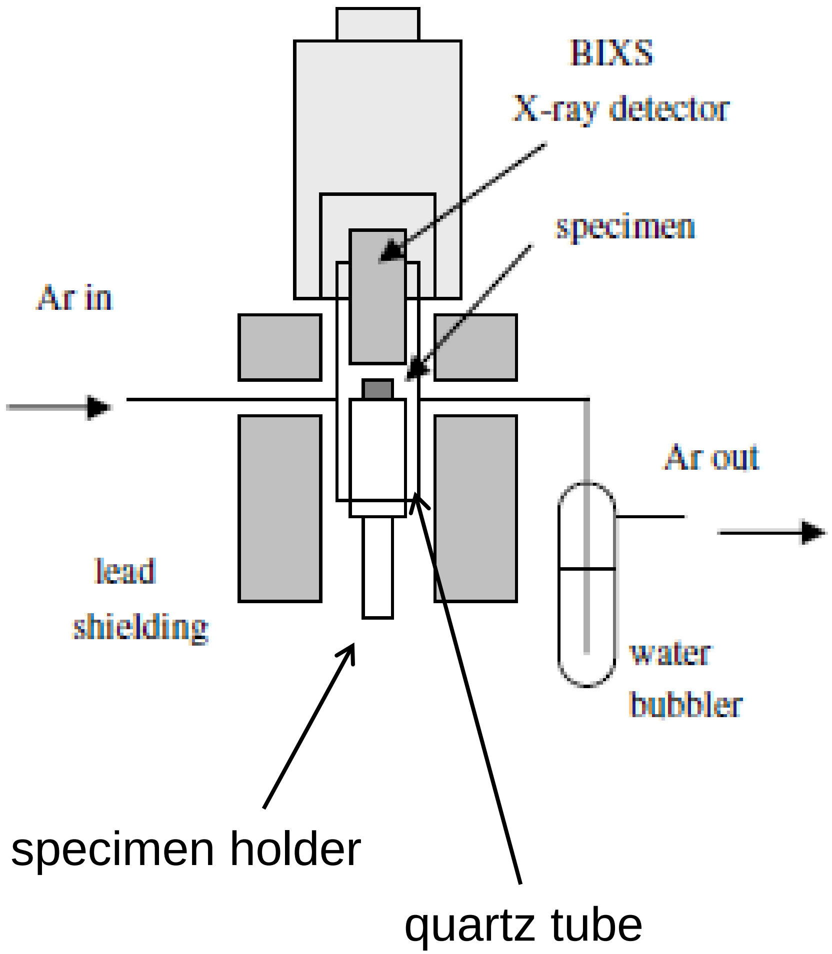
Matsuyama, JNM, 2002

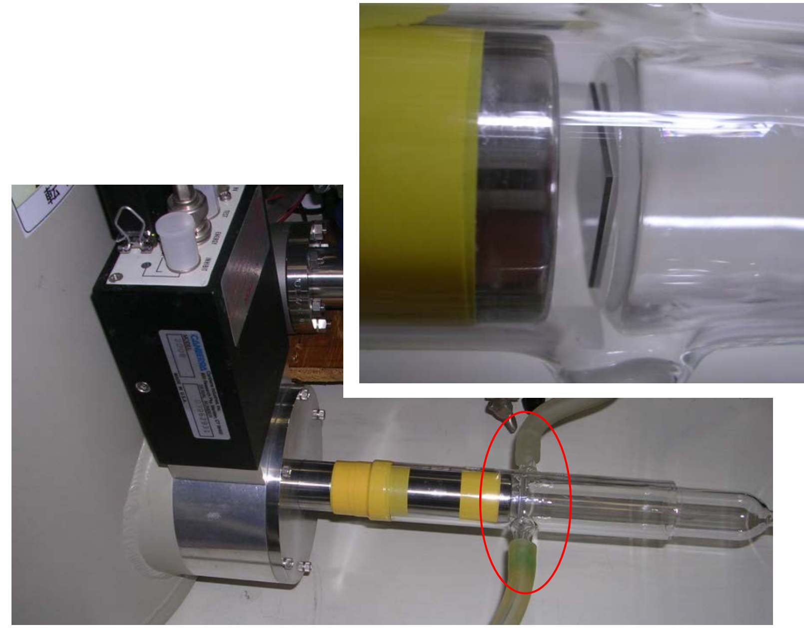


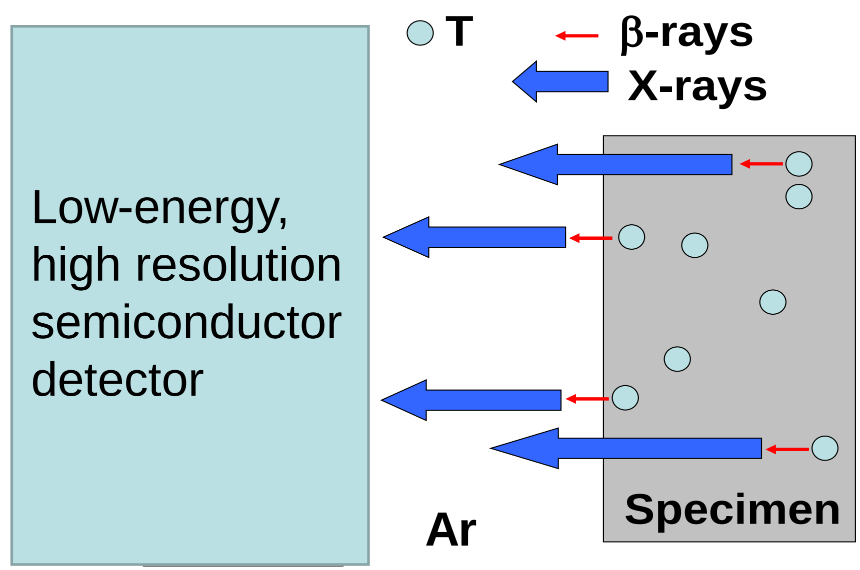

Attenuation of β-rays and X-rays in W

Matsuyama, JNM, 2002

# Typical arrangement of BIXS measurements





In the energy range of interest, X-rays are attenuated mainly by *photoelectron emission*. X-rays completely loose their energy in the process (1 or 0 process).

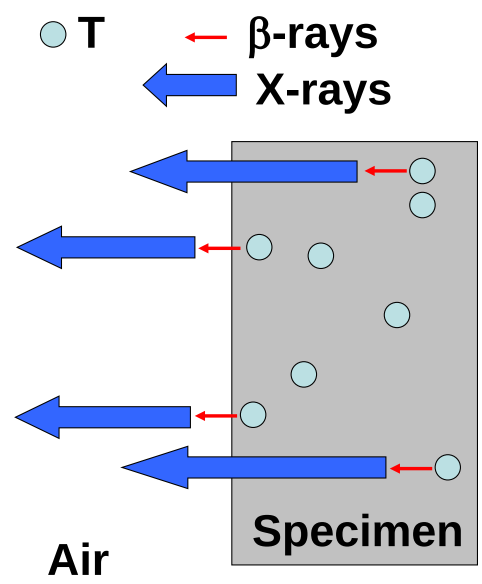
In many materials, attenuation coefficient $\mu(E)$ is smaller for higher energy X-rays.

$$I / I_0 = \exp[-\mu(E)\, x]$$

In other words, high energy X-rays can escape from larger depth.

*Consequently, if T penetrate into deeper region in materials, X-ray spectrum shifts to higher energy side.*

**Simulation results of change in bremsstrahlung X-ray spectra from T-containing ZrNi alloy as a function of penetration depth of T.**
[Matsuyama et al., FED **39-40**(1998)929.]



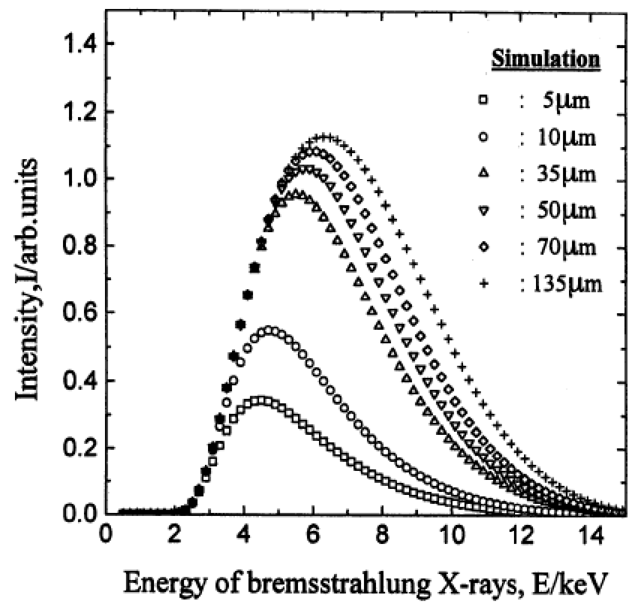
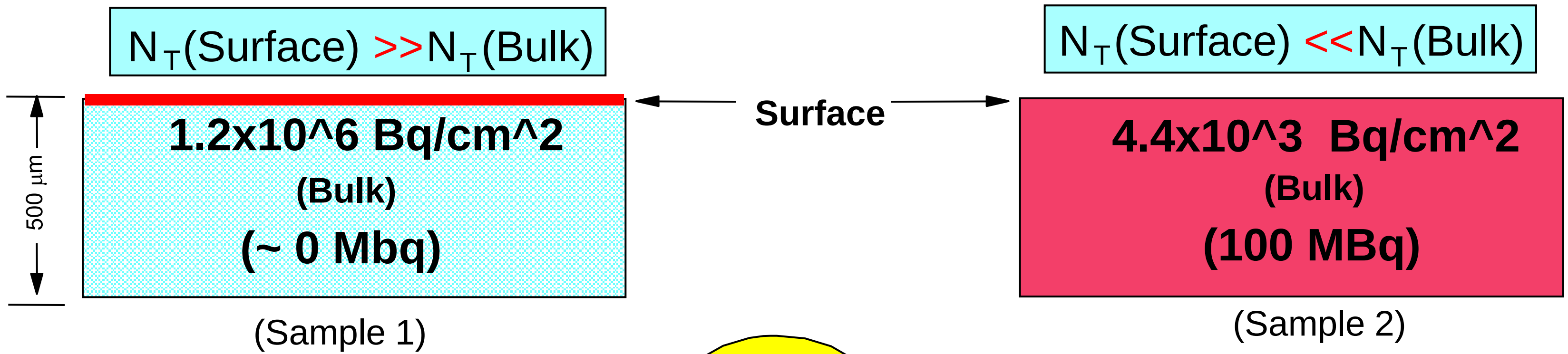
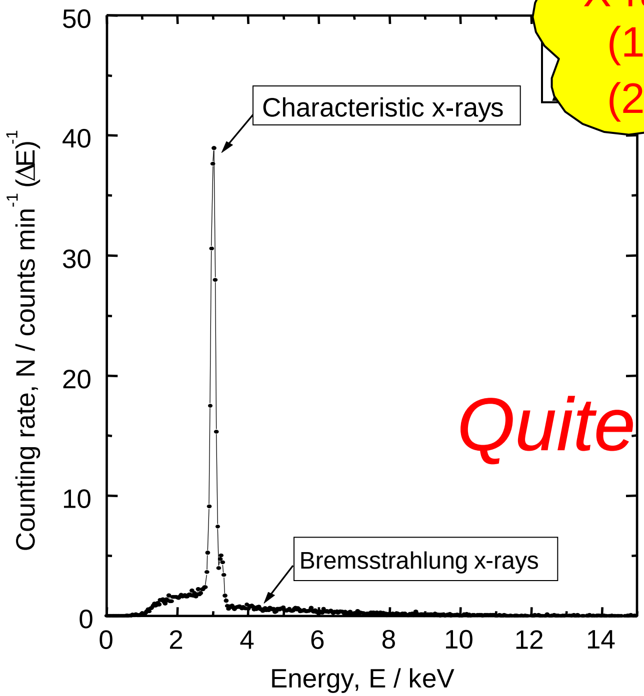



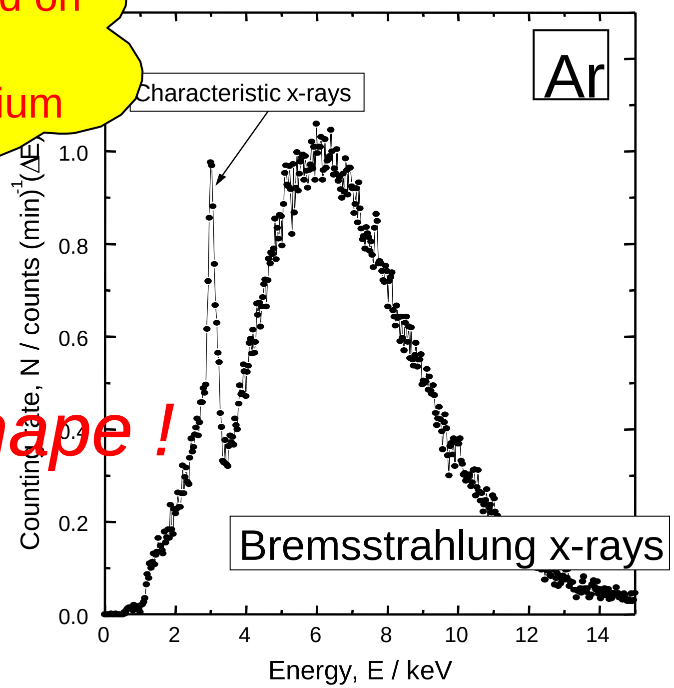

Fig. 5. Change in simulated bremsstrahlung X-ray spectrum with thickness of tritium containing layer.




X-ray intensities depend on
(1) amount of tritium
(2) depth profile of tritium



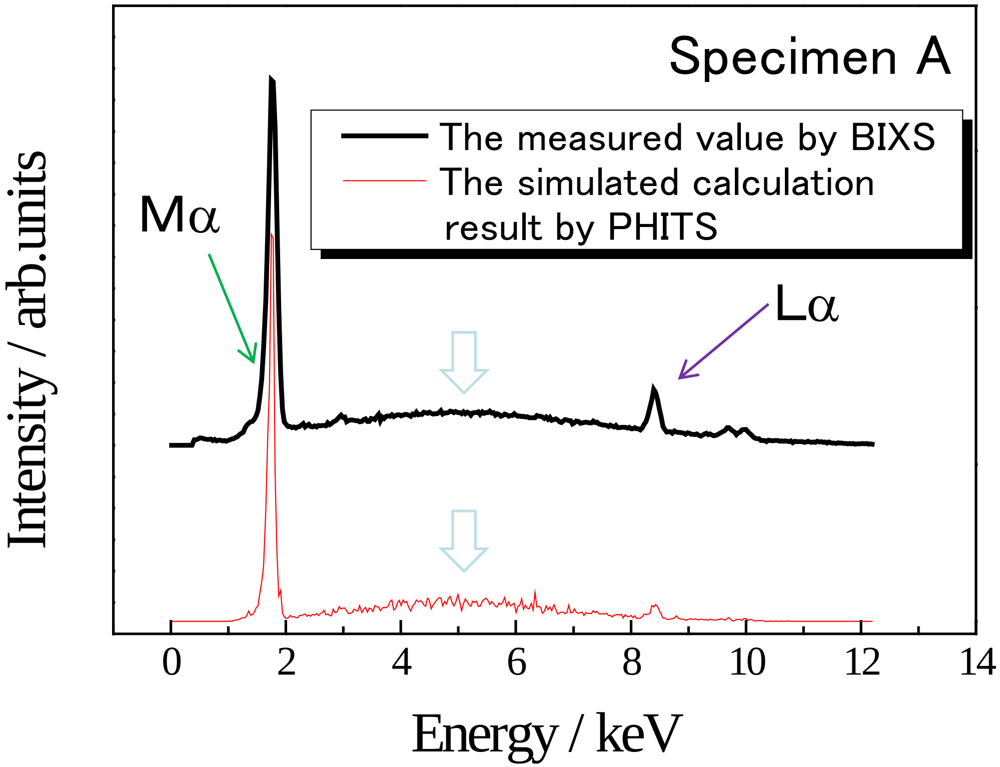

*Quite different shape !*




**It is possible to estimate the difference of tritium distribution from X-ray spectra by applying BIXS.**

# W specimen with uniform T distributed up to a depth of 2μm

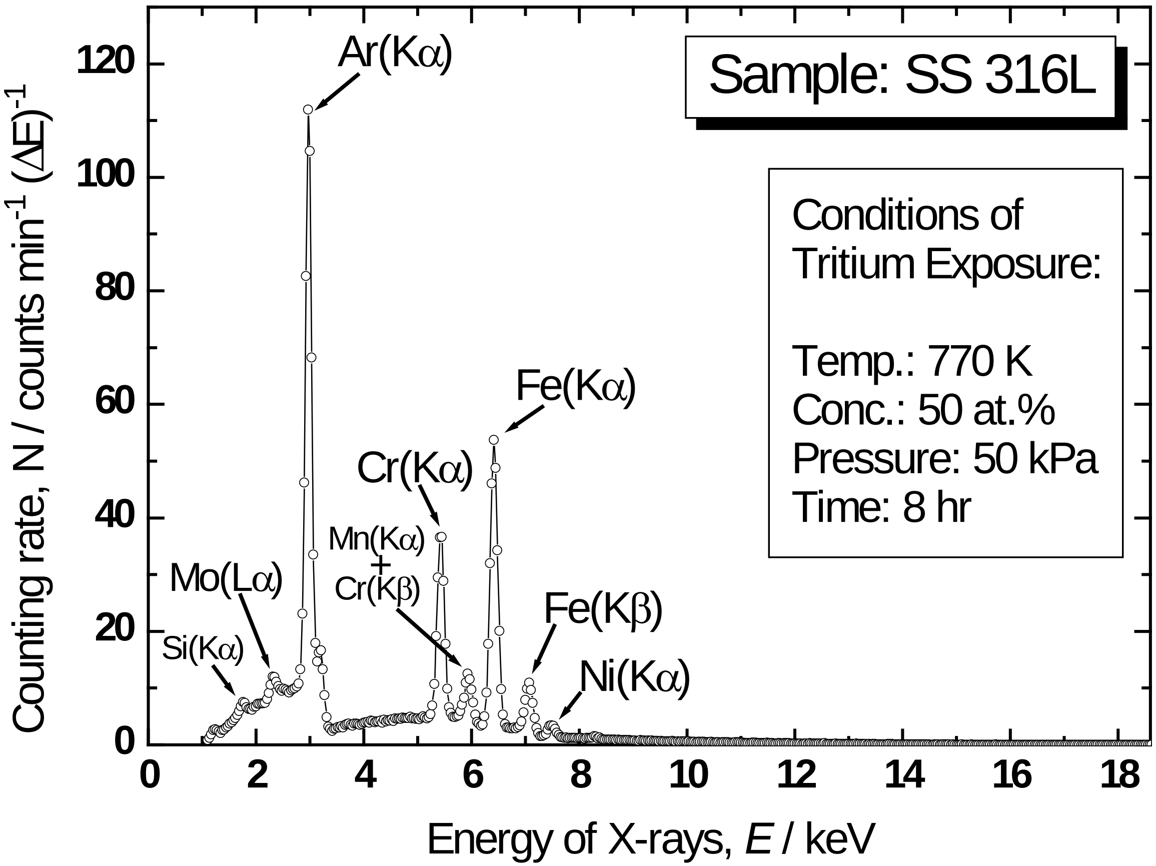
X-ray spectrum can be calculated with assumed T depth profile using Monte Carlo particle transportation codes. Depth profile of T can be determined by “best fitting”.




**Comparison of measured and simulated spectra for Specimen A**

Characteristic points of X-ray spectrum was well reproduced by Japanese Monte Carlo simulation code PHITS.

# Example of the Observed X-ray Spectrum for Tritium-Exposed Stainless Steel Samples




Example of X-ray spectrum induced by β-rays emitted from the surface and bulk of SS316L sample.

**Charac. X-rays:**

[1. Measuring Device]

Si(Kα)=1.74 keV

[2. Working Gas]

Ar(Kα)=2.96 keV

[3. SS316 Sample]

Mo(Lα)=2.29 keV

Cr(Kα)=5.41

Mn(Kα)=5.89

Cr(Kβ)=5.95

Fe(Kα)=6.40

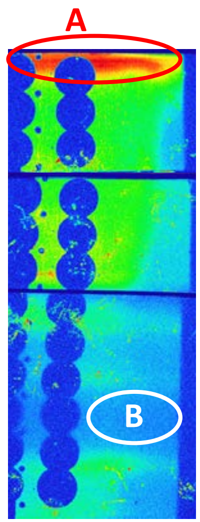
Fe(Kβ)=7.06

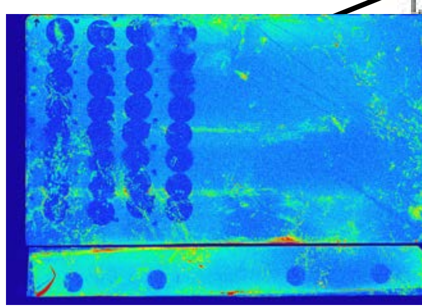
Ni(Kα)=7.48

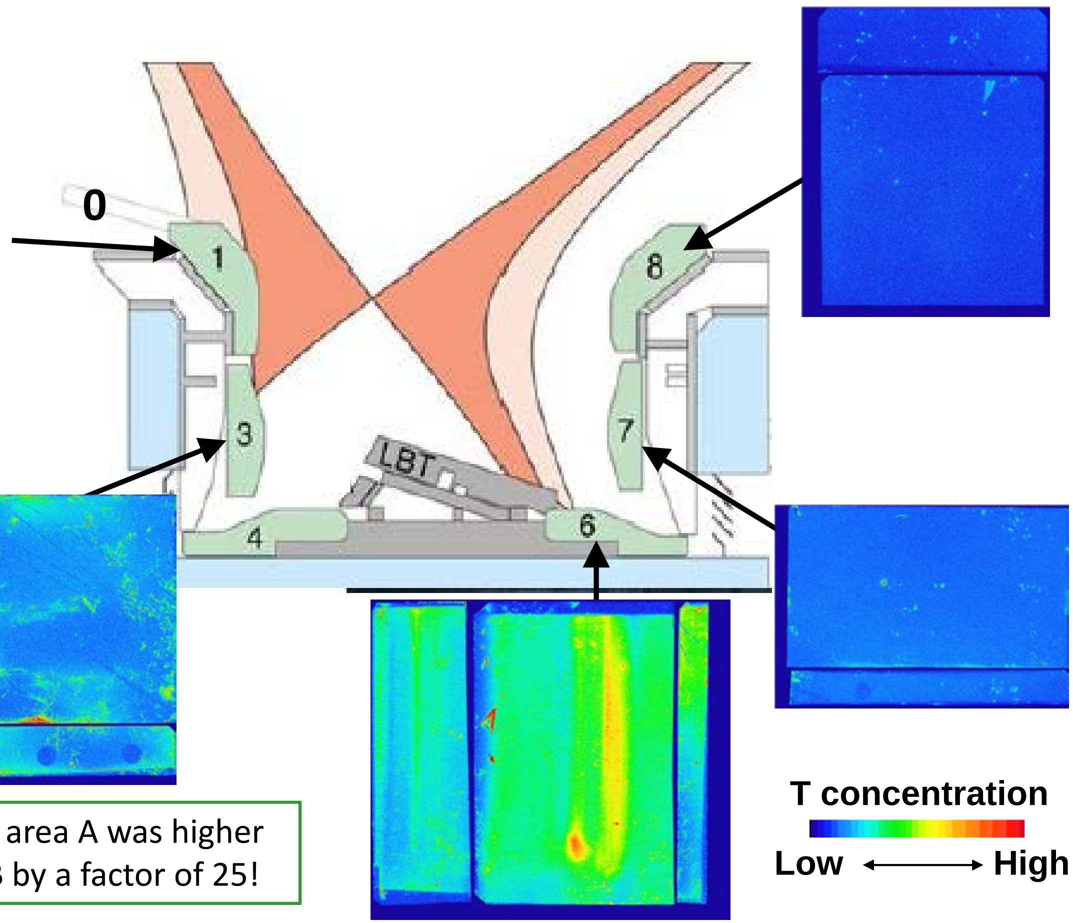
***Elemental analysis is also possible from an X-ray spectrum !***

Imaging plate provides 2-D tritium distribution image non-destructively and is good for T analysis in wide area. Combination of IP and BIXS allows 3-D measurements of T distribtions.

T distribution measured in JET ITER-like wall tile measure with IP






T concentration in area A was higher than that in area B by a factor of 25!

# *Summary*

- ✓ Hydrogen Isotope Research Center, University of Toyama has tritium laboratory with high flexibility.
- ✓ Development of tritium measurement techniques and examination of tritium behaviors in fusion and non-fusion materials are in progress with collaborations with Japanese Universities and foreign partners.
- ✓ International collaboration is welcome.