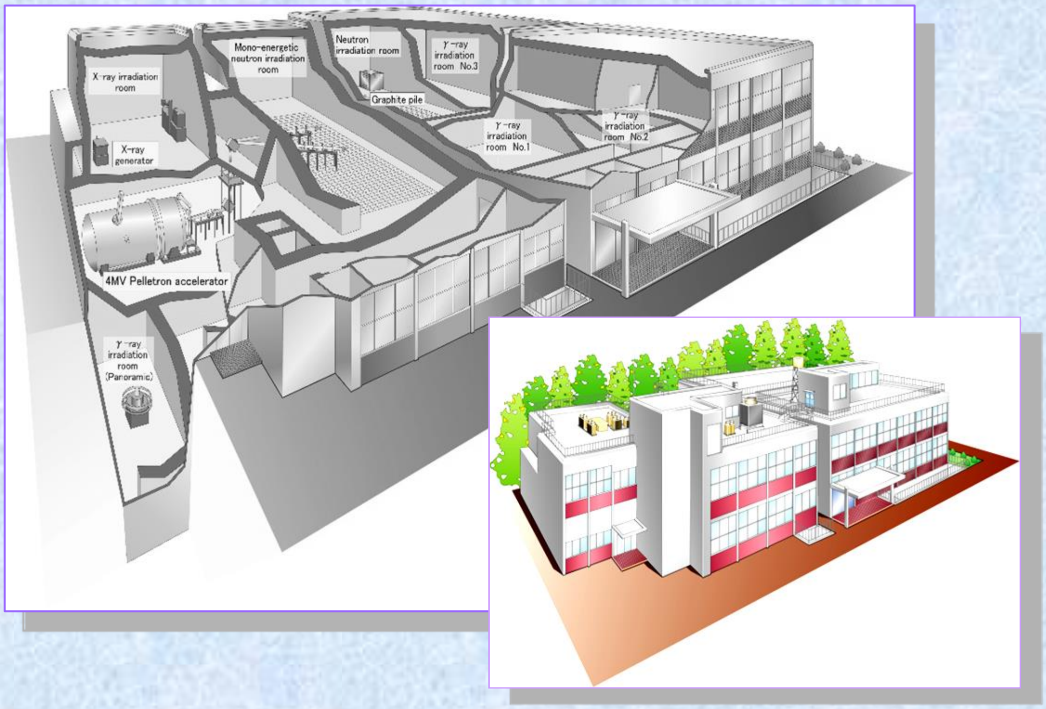
# Facility of Radiation Standards

## *FRS*



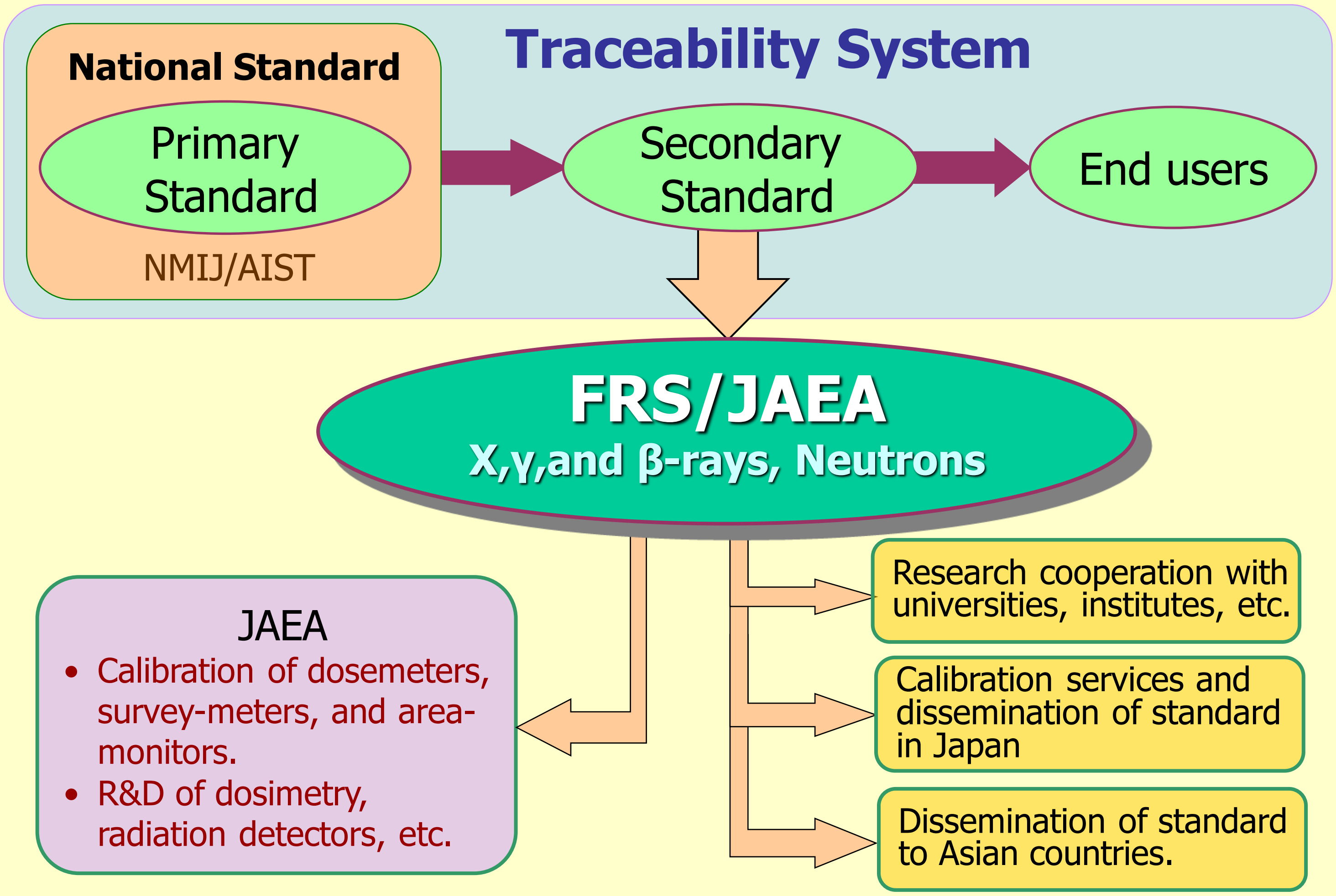


Department of Radiation Protection,
Nuclear Science Research Institute,
Japan Atomic Energy Agency

# Facility of Radiation Standards

It is important that radiation measuring instruments are calibrated by the standardized procedures and radiation standard for calibration are related to the national standards (traceability).

The Facility of Radiation Standards(FRS) is equipped with calibration fields using X-ray generators, gamma-ray irradiators, beta and neutron sources, which are traceable to the national standard. The fields are used not only for the calibration and type-test of radiation measuring instruments but also for R&D on dosimetry and research coordination.



# Layout of FRS

The Facility of Radiation Standards, FRS, was established in 1980. This facility has been equipped with calibration fields of X-ray, γ-ray, β-ray and neutrons from radionuclide sources. In 2000, an additional facility with an accelerator for generating neutrons and some irradiation rooms was constructed, and the FRS has completed as the most comprehensive calibration facility for radiation protection in Japan.

| | |
|---|---|
| Building structure : | Reinforced concrete |
| Floor surface : | 4,153 $m^2$ ; 2 floors (partially 3 floors ) and a basement |
| Rooms : | 8 irradiation rooms, Radioisotope laboratory, Accelerator room, Operation room, etc. |

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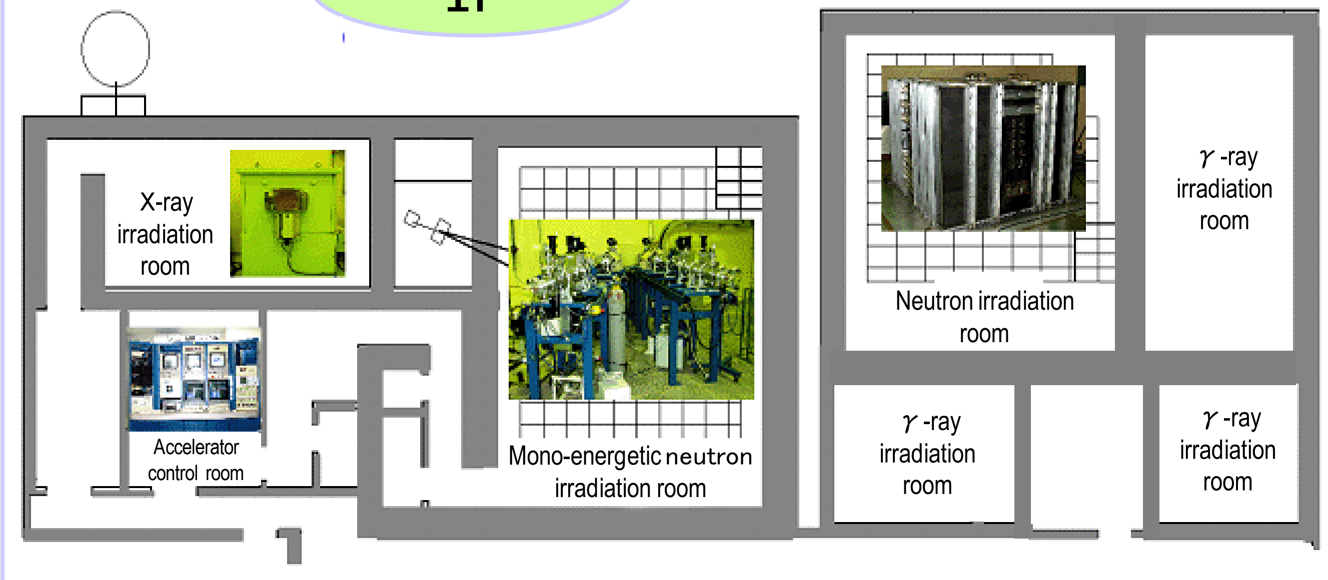


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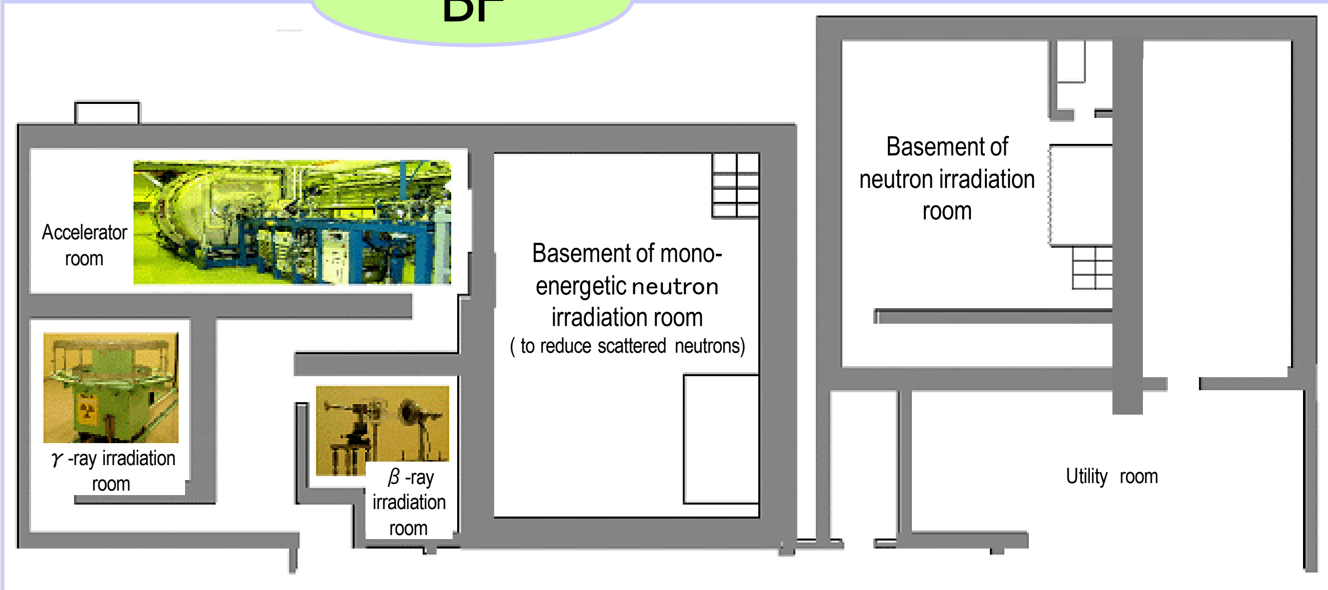
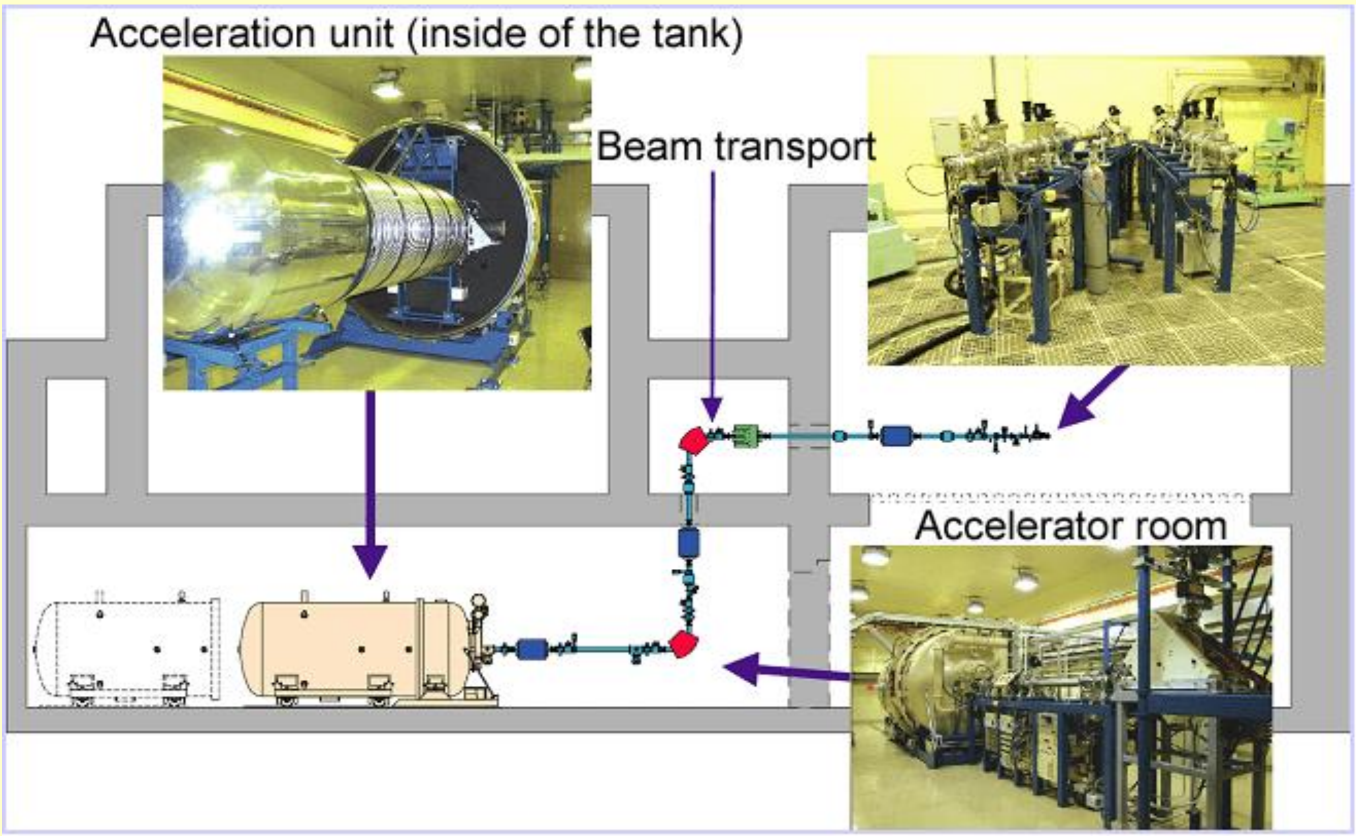


# 4MV Van-de-Grraff Accelerator

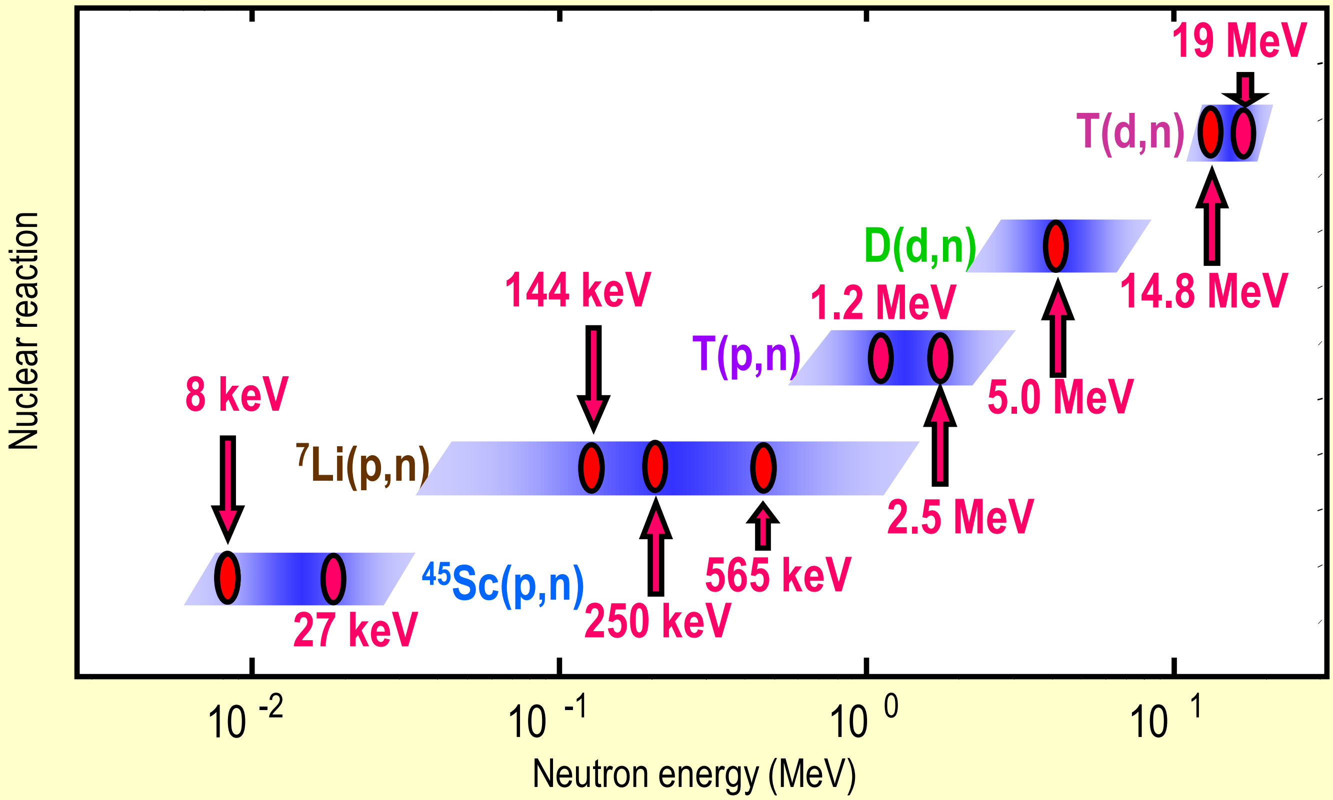



## Specifications of 4MV VdG Accelerator

| Model | Pelletron 4UH-HC (US NEC) |
|---|---|
| Acceleration voltage | 0.4 ～ 4.0 MV |
| Ion current | 0 ～ 50 μA |
| Particle | Proton and deuteron |
| Stability | Voltage: ±100 V, Ion current: ±0.1 % |
| Ion source | Positive ion duoplasmatron |
| Pulsed beam | Pulse width: 1.5ns (FWHM), Peak current: 10 mA,<br>Frequency: 0.5, 1, 2, and 4MHz |
| Ultimate vacuum | Acceleration system: $2\times10^{-8}$ mbar<br>Beam line: $2\times10^{-9}$ mbar |
| Beam efficiency | ≥95 % after 90° magnet |
| Faraday cup | Max. beam power: 1 kW, Transit time of shutter: 0.2 s |
| Beam profile monitor | Min. sensitivity: 1.0 nA |
| Ion vacuum pump | ≥120 L/min. |
| Fast acting valve | Transit time of shutter after detecting low vacuum: 35ms |
| Target thermal detector | 0 ～ 800 °C, Accuracy: ±1 % |
| Irradiation time with timer | 1 ～ $1\times10^{5}$ s |

# Monoenergetic Neutron Calibration Fields

## Neutron energies and nuclear reactions




## Specifications of monoenergetic neutron fields

| Target and nuclear reaction | Neutron energy range (Energy range of incident particle) | Neutron energies for calibration* | Max. dose equivalent rate | Major specification of target |
|---|---|---|---|---|
| **Tritium** $^{3}H(d,n)^{4}He$ | 15～20MeV (d : 0.4~4.0MeV) | **14.8MeV, 19MeV** | 30μSv/h 3mSv/h | **$^{3}$H/Ti** Thickness : ~2mg/cm$^{2}$ |
| **Deuterium** $^{2}H(d,n)^{3}He$ | 3～7MeV (d : 0.4~4.0MeV) | **5.0MeV** | 20μSv/h 7mSv/h | **$^{2}$H-gas** Size of gas cell : 1cm*Φ* x 2.4cm |
| **Tritium** $^{3}H(p,n)^{3}He$ | 0.4～3MeV (p : 1.2~4.0MeV) | **1.2MeV, 2.5MeV** | 30μSv/h 15mSv/h | **$^{3}$H/Ti** Thickness : ~0.5mg/cm$^{2}$ |
| **Lithium** $^{7}Li(p,n)^{7}Be$ | 120keV～2.3MeV (p : 1.92~4.0MeV) | **144keV, 250keV, 565keV** | 20μSv/h 7mSv/h | **LiF** Thickness : ~0.1mg/cm$^{2}$ |
| **Scandium** $^{45}Sc(p,n)^{45}Ti$ | 8keV～30keV (p : 2.91~2.93MeV) | **8keV, 27keV** | ～2μSv/h | **Sc (metal)** Thickness : ~0.1mg/cm$^{2}$ |

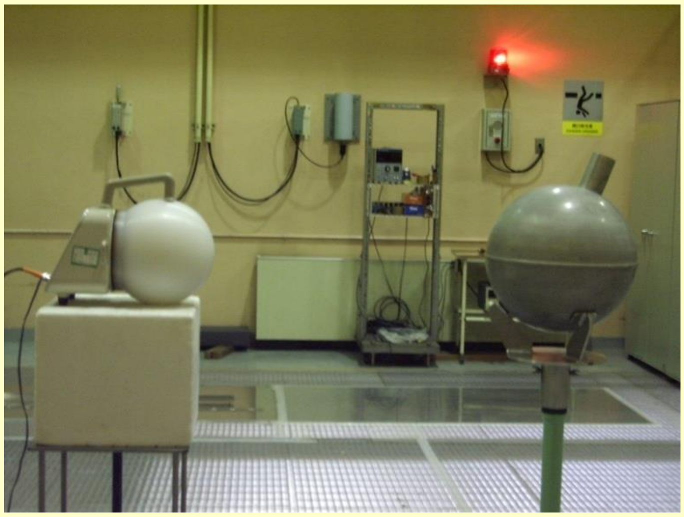
* Neutron energies specified in the international standard of 'Reference neutrons' (ISO 8529-1, 2001).

# Neutron Calibration Fields

## Neutron calibration fields produced with RI-sources

**Graphite pile (for thermal neutrons)**

Neuton sources
$^{252}Cf$ : 2.0 GBq
$^{241}Am$-Be : 37 GBq



**$D_2O$ moderator (For $D_2O$-Cf neutron field)**

Neutron source
$^{252}Cf$ : 199.8 MBq

## Characteristics of neutron calibration fields

| Type of calibration field | | | Neutron source | dose equivalent rate, H*(10) (μSv/h) | dose equivalent average energy (MeV) | Calibration position |
|---|---|---|---|---|---|---|
| Thermal neutrons | Outside pile | | $^{252}Cf$ | 21 | $2.5\times10^{-8}$ | 40cm from the surface |
| Fast neutrons | ~1m above the grating floor | | $^{252}Cf$<br>$^{241}Am$-Be | 350 ～ 5700<br>7 ～ 110 | 2.3<br>4.4 | Distance 50~200 cm |
| Moderated neutrons | Graphite pile (outside) | A<br>B | $^{241}Am$-Be x2 | 49<br>21 | 2.2<br>2.1 | 75 cm from the surface |
| Moderated neutrons | $D_2O$-sphere (30cm$\phi$) | | $^{252}Cf$ | 2.6 ～ 18 | 2.1 | Distance 75~200 cm |

# γ-ray Calibration Fields

## γ-ray irradiators

**Panoramic γ-ray irradiator**

$^{137}Cs$ $^{60}Co$

## Characteristics of γ-ray calibration fields

| Type of irradiation | Sources and gamma ray energies | Range of ambient dose equivalent, $H^*(10)$ (μSv/h)<br>$10^0$ $10^1$ $10^2$ $10^3$ $10^4$ $10^5$ $10^6$ $10^7$ |
|---|---|---|
| Low-level Irradiator (I) | $^{137}Cs$(662 keV)<br>$^{60}Co$(1250 keV) | 7 μSv/h – 45 mSv/h<br>30 μSv/h – 1.1 mSv/h |
| Low-level Irradiator (II) | $^{137}Cs$(662 keV) | 4 μSv/h – 17 mSv/h |
| Medium-level Irradiator | $^{60}Co$(1250 keV) | 13 μSv/h – 1.0 Sv/h |
| Panoramic Irradiator (d = 50 cm and 70 cm) | $^{137}Cs$(662 keV)<br>$^{60}Co$(1250 keV) | 2.5 mSv/h ●● 4.8 mSv/h<br>40 μSv/h, 80 μSv/h ●● ●● 1.7 mSv/h , 3.3 mSv/h |
| Uncollimated radiation source (60 keV ～ 1250 keV) | $^{241}Am$(60 keV)<br>$^{137}Cs$(662 keV)<br>$^{60}Co$(1250 keV) | 8 μSv/h – 470 μSv/h<br>0.5 μSv/h – 350 μSv/h<br>0.5 μSv/h – 220 μSv/h |
| High energy γ-ray | p-F (6.2 MeV)<br>(accelerator) | 20 μSv/h – 2 mSv/h |

# X-ray Calibration Fields

## X-ray generators

**Medium and hard X-ray generator**

Max. tube voltage: 380 kV
Max. tube current: 30 mA

**Soft X-ray generator**

Max. tube voltage: 100 kV
Max. tube current: 70 mA

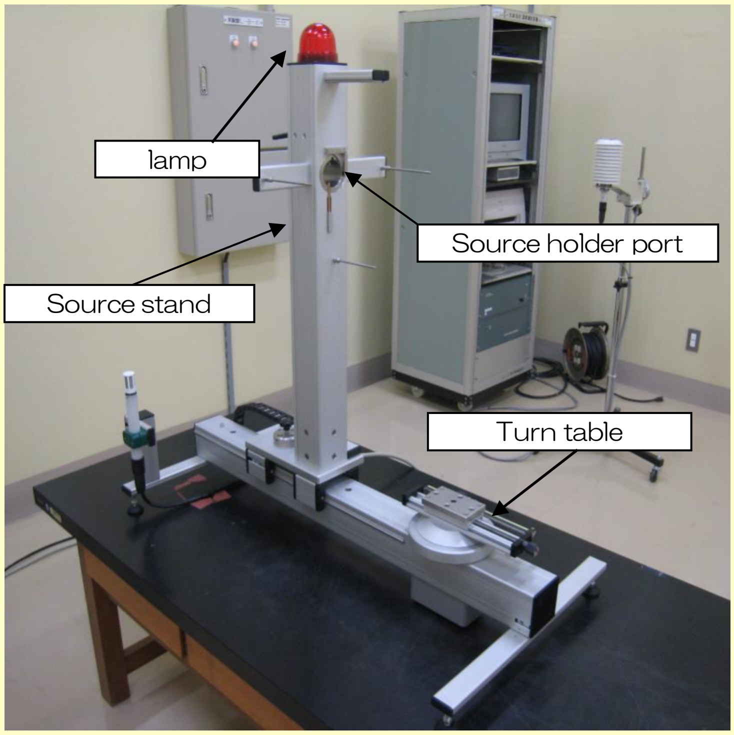
## Characteristics of X-ray calibration fields

| X-rays | Range of effective energies | Dose equivalent rate, $H^*(10)$ (μ Sv/h) $10^0$ $10^1$ $10^2$ $10^3$ $10^4$ $10^5$ $10^6$ $10^7$ |
|---|---|---|
| Soft X-rays (Under construction) | 5 keV ～ 90 keV | 2μSv/h QI 0.9 QI 0.8 QI 0.7 QI 0.6 90 mSv/h |
| Medium and hard X-rays | 20 keV ～320 keV | 2μSv/h 900 mSv/h |

QI: Quality Index = Effective energy of X-rays / Maximum energy of X-rays generated

# β-ray Calibration Fields

## Setup of β-ray Calibration Field (Example)




β-ray irradiation system

Source holder

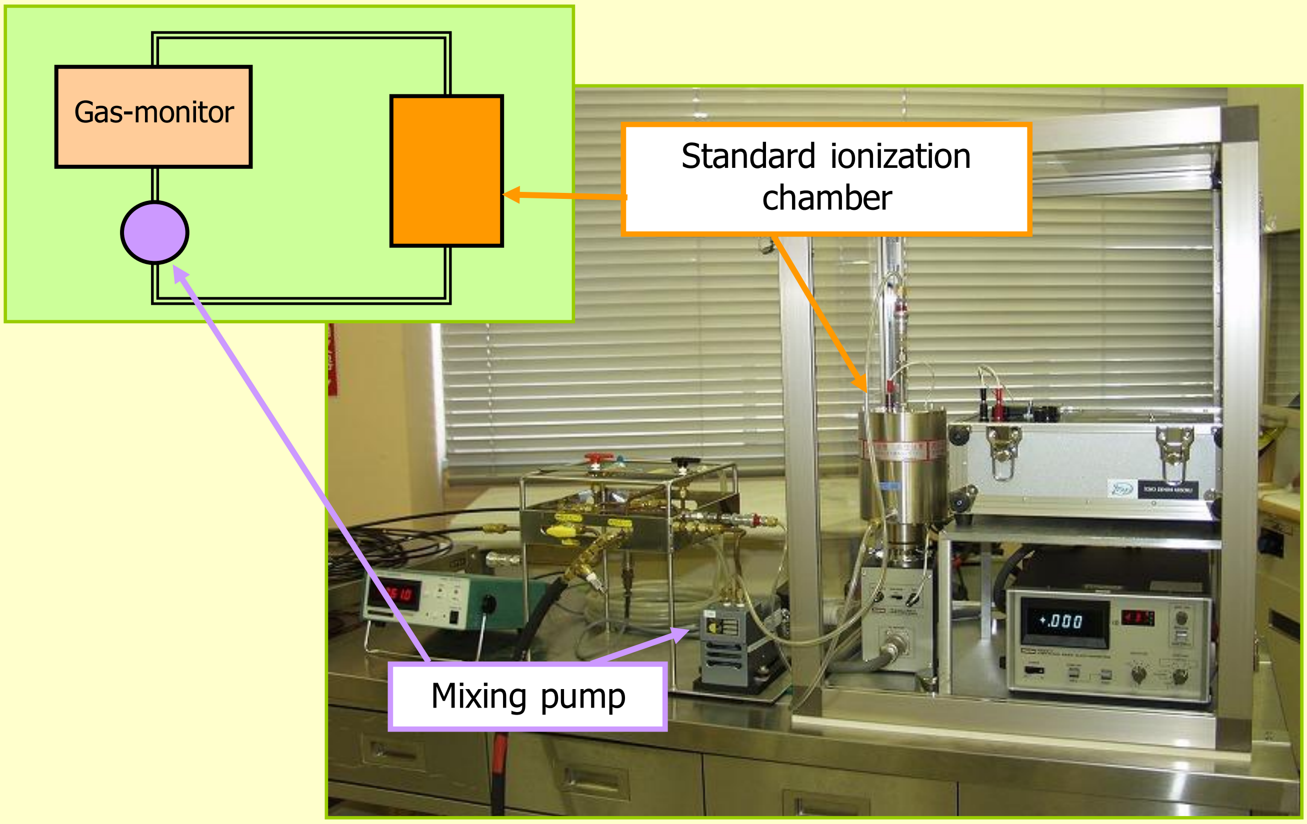
Beam flattening filter

## Characteristics of β-ray calibration fields

| Source | $^{90}Sr$ (460 MBq) | | | | | $^{85}Kr$ (3.7 GBq) | $^{147}Pm$ (3.7 GBq) |
|---|---|---|---|---|---|---|---|
| Average β-ray energy (MeV) | 0.8 | | | | | 0.24 | 0.06 |
| Irradiation distance (cm) | 11 | 20 | 30 | | 50 | 30 | 20 |
| Beam flattening filter | - | - | Needed | - | - | Needed | Needed |
| 70 μm tissue equivalent absorbed dose rate ($mSv\ h^{-1}$) | 432 | 126 | 36.0 | 54.0 | 21.6 | 180 | 10.8 |

# Calibration of Gas- and Water- Monitor

## Closed gas-loop with a standard ionization chamber for gas-monitor calibration

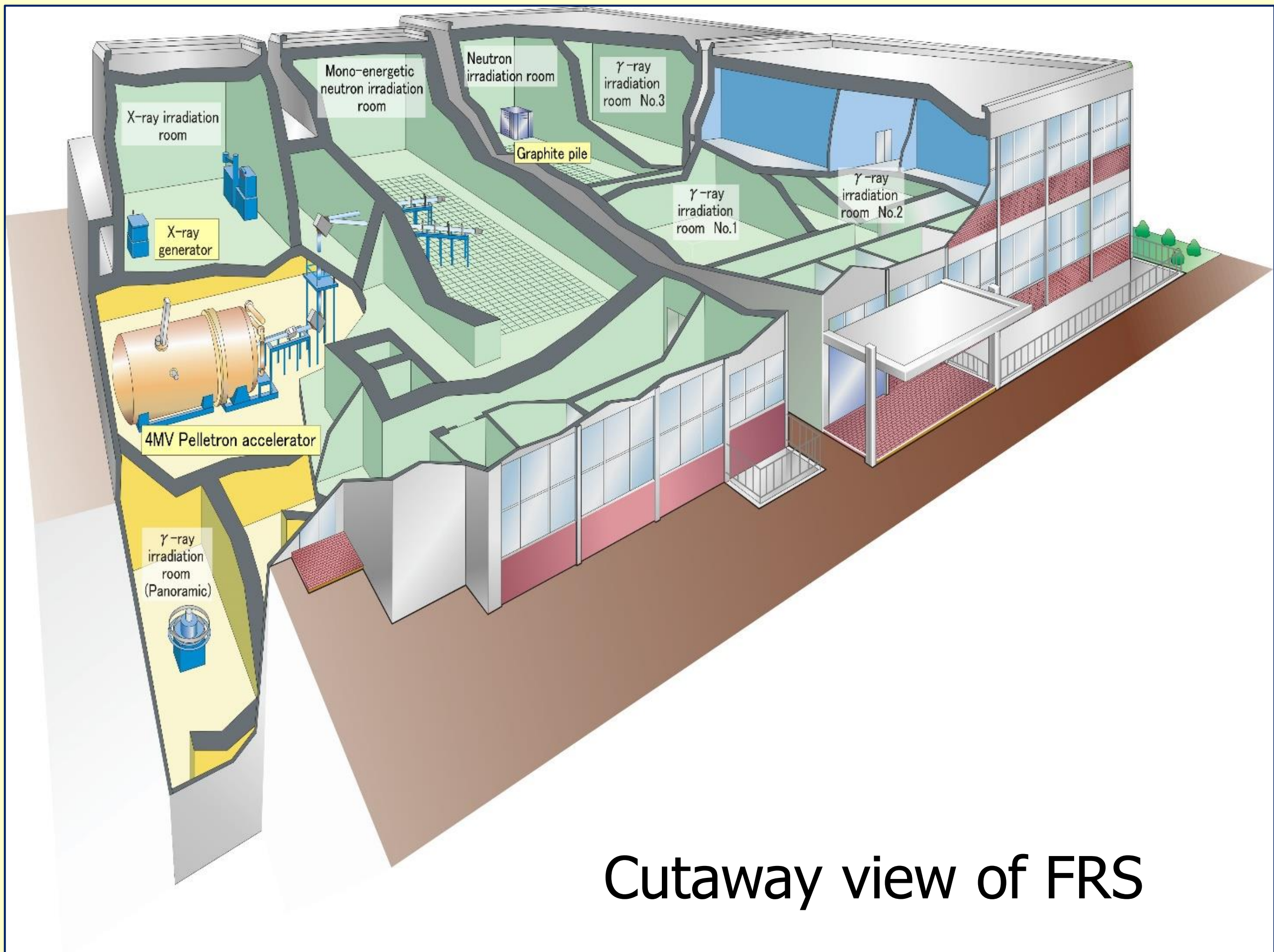



## Radionuclide and activity concentration available for gas-monitor calibration

| Radionuclide | β-ray energies | Calibration range |
|---|---|---|
| $^{3}H$<br>$^{14}C$<br>$^{41}Ar$<br>$^{85}Kr$<br>$^{133}Xe$<br>$^{135}Xe$ | 19 keV～1.2 MeV | 0.3 Bq/cm$^3$ ～ 30 Bq/cm$^3$ |

## Radionuclide and activity concentration available for water-monitor calibration

| Radionuclide | β-ray energies | Calibration range |
|---|---|---|
| $^{51}Cr$<br>$^{137}Cs$<br>$^{60}Co$ | 320 keV～1.25 MeV | 1 Bq/cm$^3$～1000 Bq/cm$^3$ |




Cutaway view of FRS

# Memo

Japan Atomic Energy Agency
Nuclear Science Research Institute
Tokai, Naka-gun, Ibaraki, 319-1195, Japan
Information: Department of Radiation Protection
Telephone: +81-29-282-5205, Facsimile: +81-29-282-6063
Web-site
JAERI: http://www.jaea.go.jp/