# Residual Radiation Dose at J-PARC Linac

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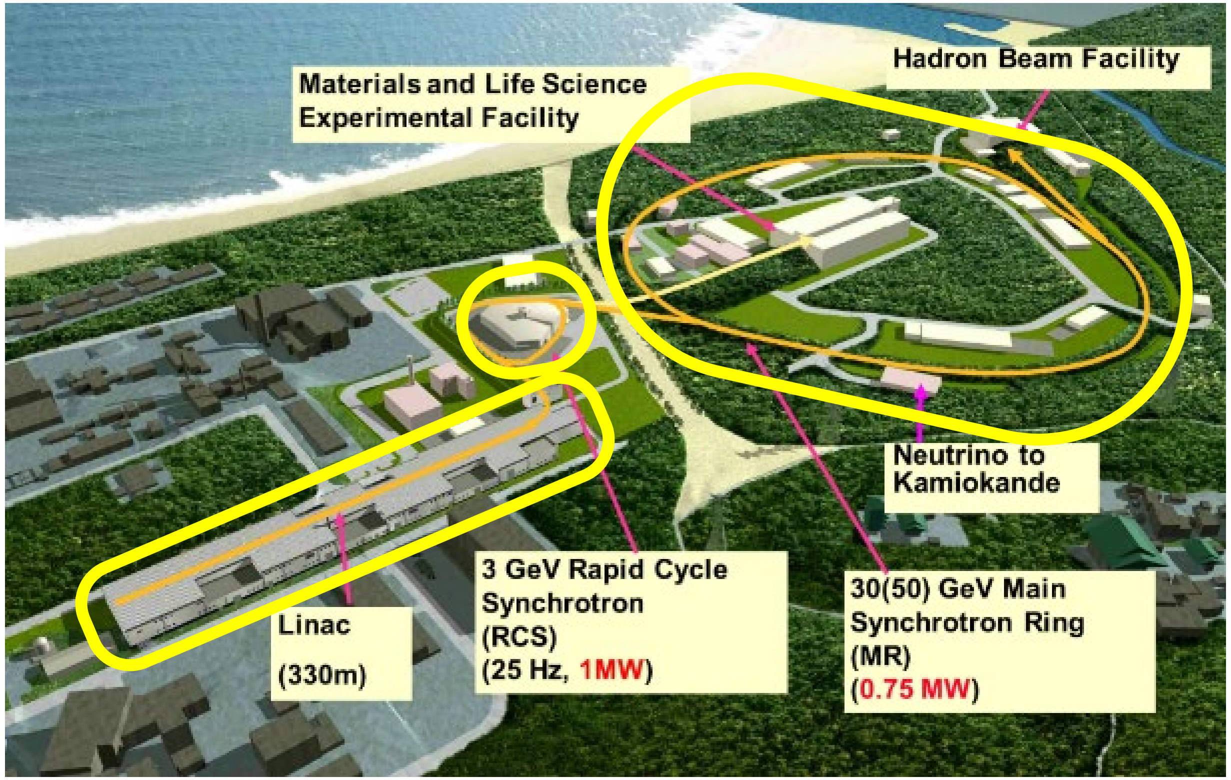
# J-PARC (Japan Proton Accelerator Research Complex)




The accelerator at J-PARC consists of a

- ・LINAC(400MeV)
- ・Rapid-Cycling Synchrotron(3GeV )
- ・Main Ring Synchrotron(30GeV)

The accelerated beams are delivered to three experimental facilities.

- ・Materials & Life Science Experimental Facility
- ・Hadron Beam Facility
- ・Neutrino Facility

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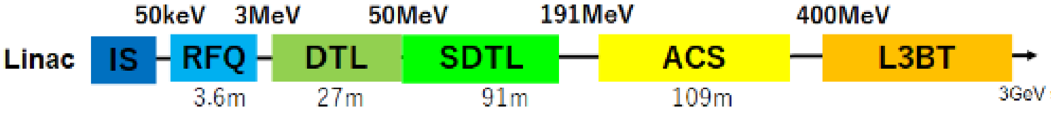
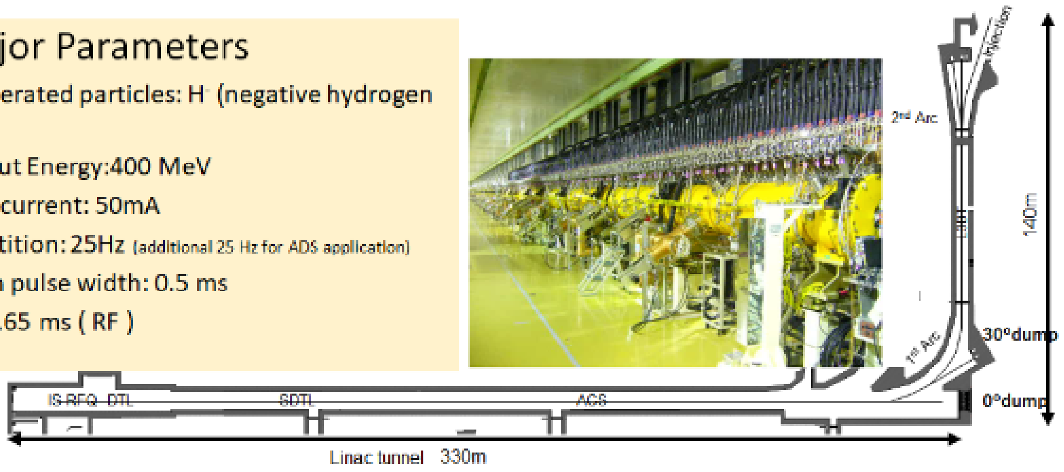
# LINAC(Linear Accelerator)




- Major Parameters
  - Accelerated particles: H- (negative hydrogen ion)
  - Output Energy:400 MeV
  - Peak current: 50mA
  - Repetition: 25Hz (additional 25 Hz for ADS application)
  - Beam pulse width: 0.5 ms
  - 0.6-0.65 ms ( RF )



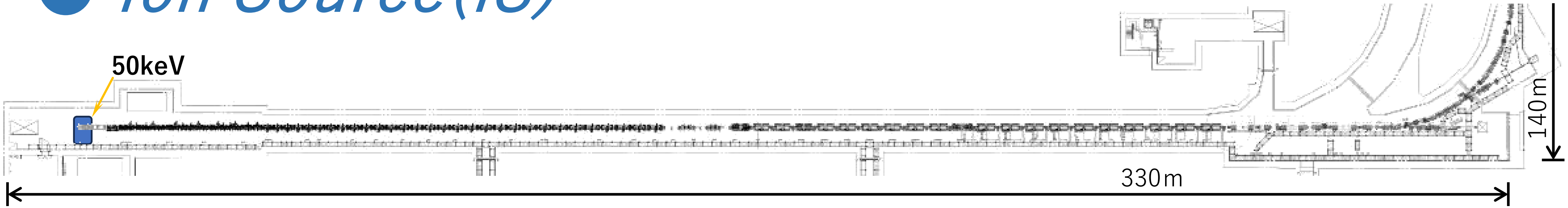

History

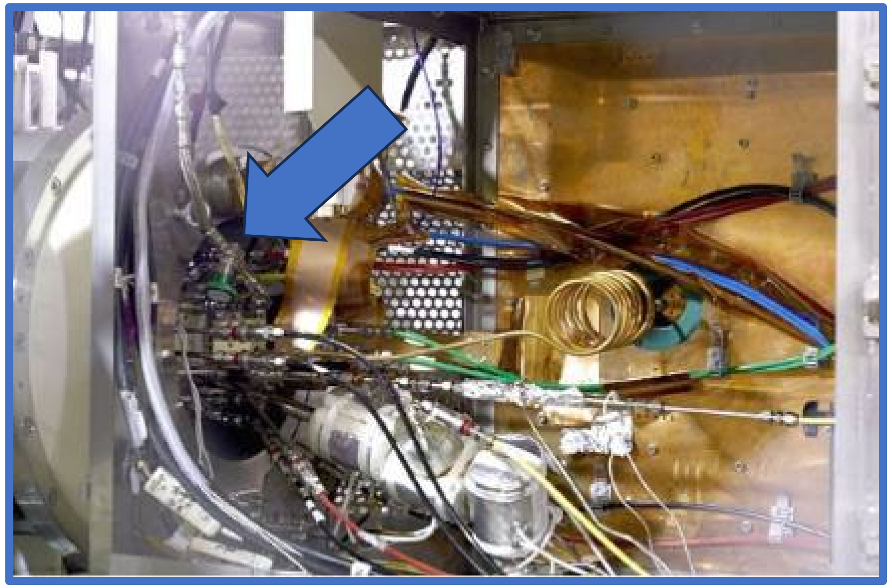
- In 2008, MLF user operation started with linac beam current of 5mA.
- In 2009, beam current was increased to 15mA and operated for about next five year.
- In 2014, after linac upgrade was completed, beam energy was increased to the design value of 400 MeV and 30mA operation started.
- In 2018, peak current of **50mA (nominal)** operation was started.

The major beamline components

- Ion source
  - Produces negative hydrogen ions
- Accelerator cavities
  - Radio-frequency quadrupole (RFQ),
  - Drift tube linac (DTL),
  - Separated-type DTL (SDTL),
  - Annular-ring coupled structure linac (ACS).
- Magnets
  - Solenoids, Quads, and Dipole magnets
- Beam monitors
  - Profiles, positions, current monitors

# ● *Ion Source(IS)*

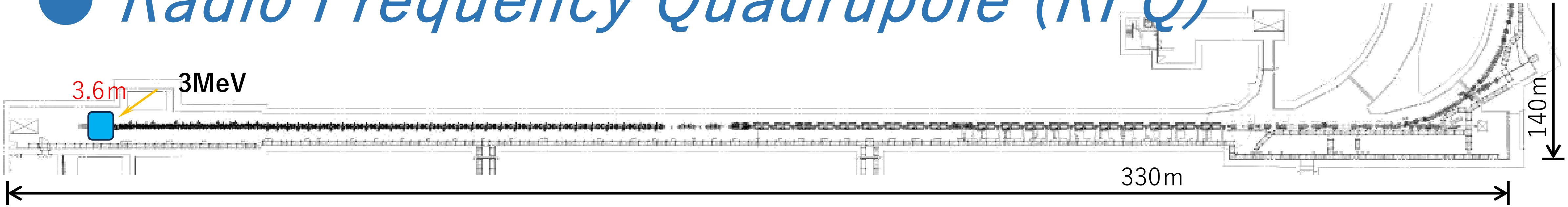


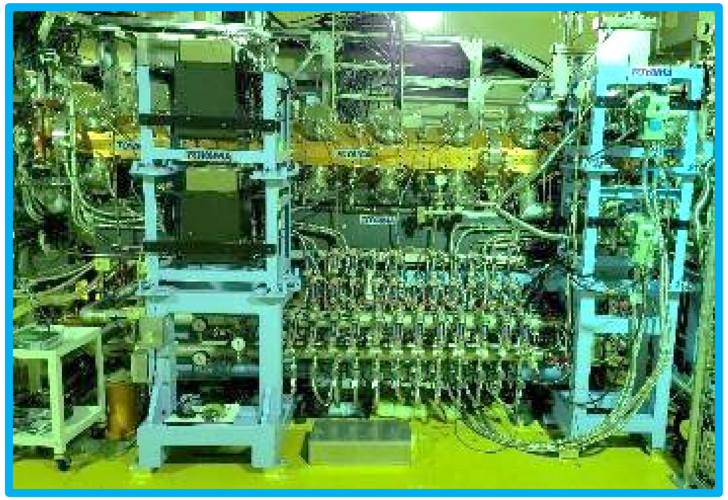



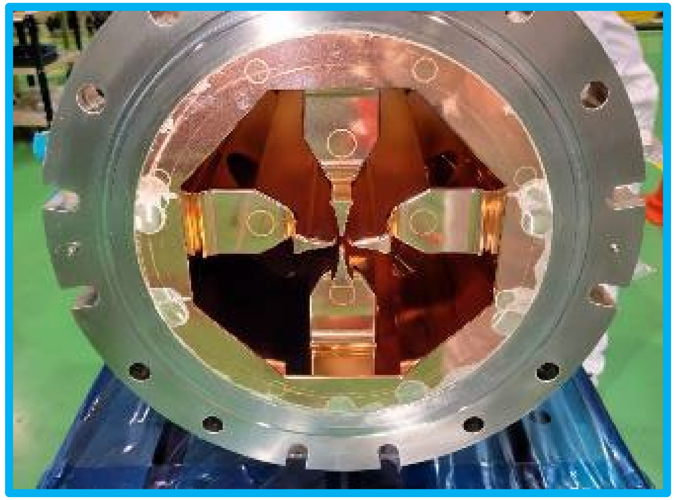
**The Cs seeded RF-driven negative ion source**

- Cesium vapor injected into the chamber to enhance the negative ion production.
- Plasma is generated by RF power.
- Negative hydrogen ions are extracted and introduced to the RFQ with 50 keV.

# Radio Frequency Quadrupole (RFQ)

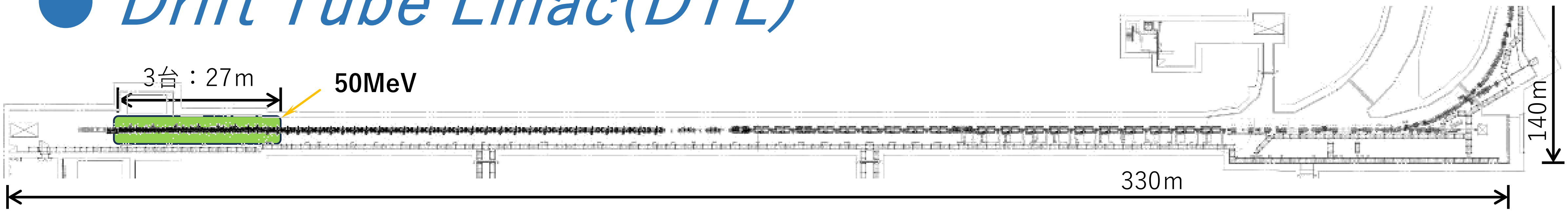


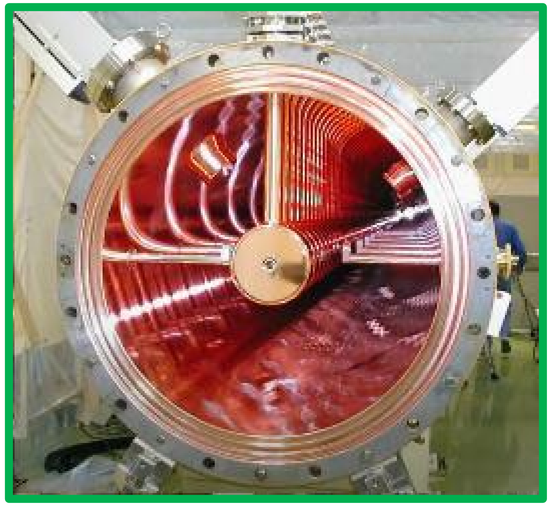





- The RFQ is the first accelerator that accelerates the beam generated from the ion source with a radio frequency electric field.
- The beam is accelerated to 3 MeV.
- After the RFQ, there is about 3m long beam matching section(composed of focusing magnets, beam bunchers, a beam chopper system, beam monitors, and so on)

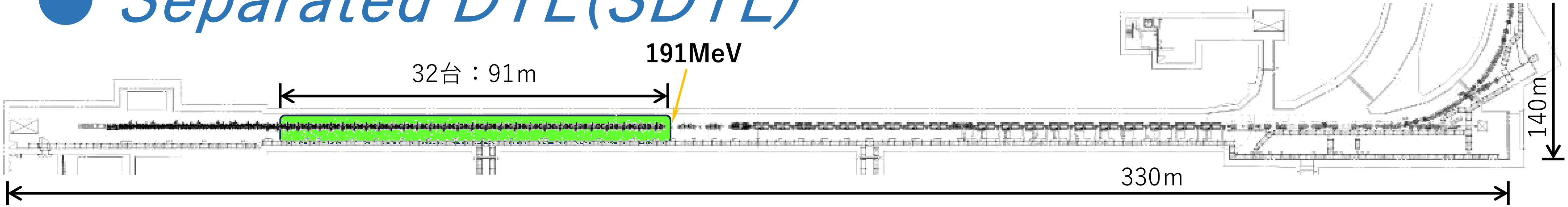
# Drift Tube Linac(DTL)

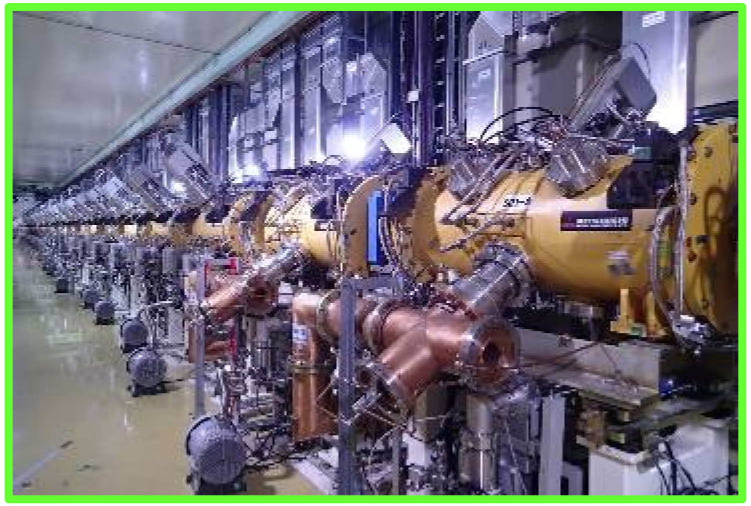


- Inside the DTL cavity, a series of copper plated cylinders called drift tubes(DTs) are aligned.
- The beam passes through the center of DTs and is accelerated by an electric field between adjacent DTs.
- The beam is accelerated to 50 MeV at the exit of the DTL section.
- The drift tubes also contain electromagnets that focus the beam.
  The minimum beam aperture in this section is 13 mm.

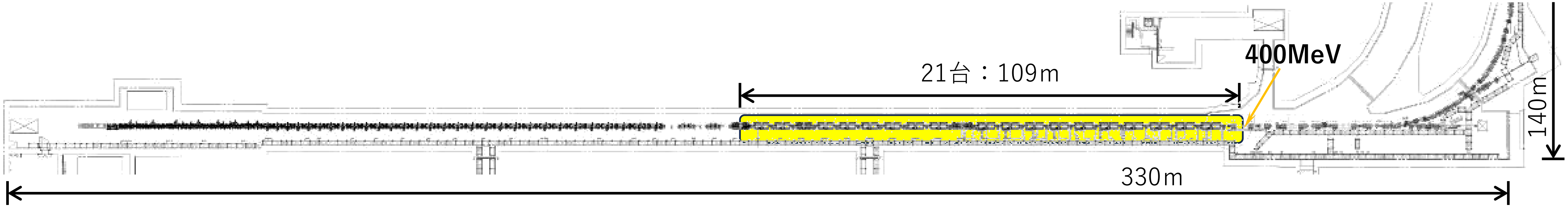
# ● Separated DTL(SDTL)

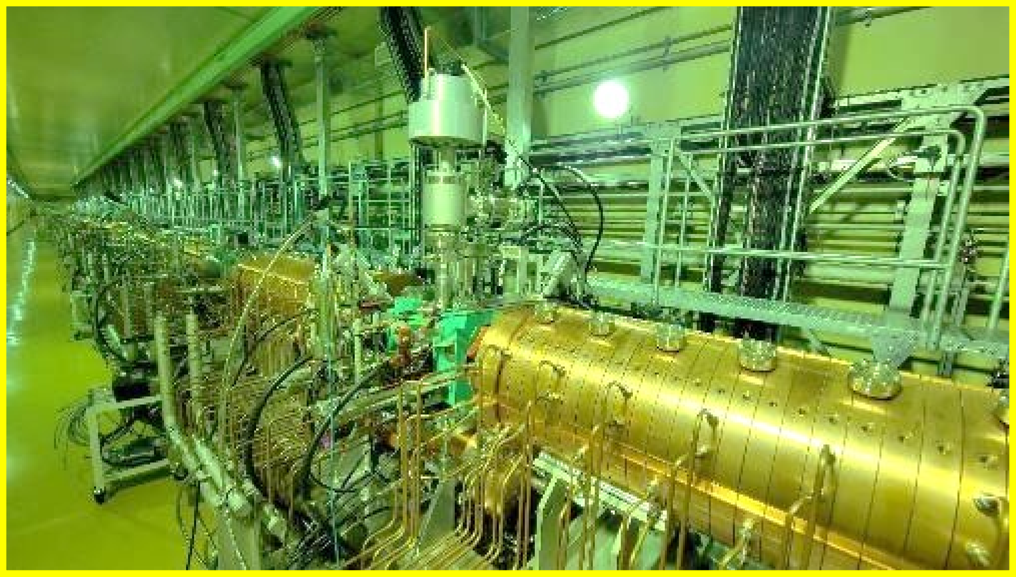


- Next structure is SDTL, in which the electromagnets are separated from the DT. Quadrupole doubles are distributed between tanks.
- The beam is accelerated to 191 MeV at the exit of this section.
- The beam aperture is 36 mm.

# ● Annular-ring Coupled Structure Linac(ACS)



- The final stage of the LINAC accelerator is ACS.
- The same as the SDTL section, beam focusing magnets are distributed between accelerator modules.
- The beam is accelerated to 400 MeV.
- The beam aperture is 40 mm.

# ● *LINAC to 3GeV RCS Beam Transportation line(L3BT)*

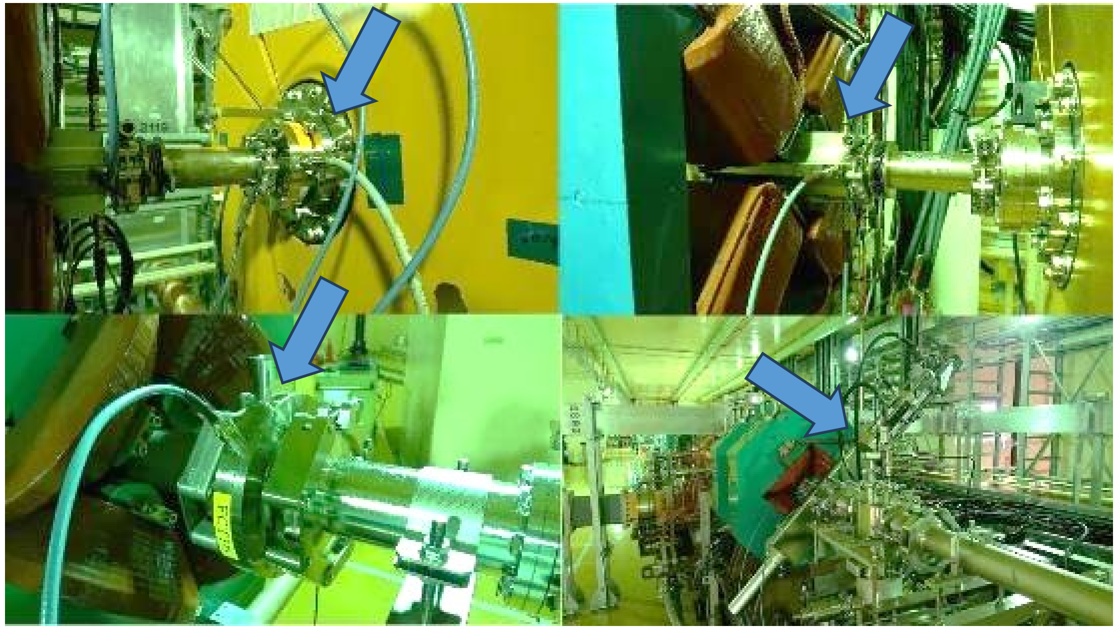

- L3BT is a beamline that transports accelerated beams to the RCS.
- It consists of beam ducts, electromagnets, monitors, gate valves, beam dumps, and so on.
- The first arc section locates at the end of the linac straight line. Six bending magnets are arranged.

# Other Components

- In addition to the acceleration cavity, the accelerator components include Beam monitors, Electromagnet, Gate valves, and beam dumps.
- Monitor measures the beam current, position, energy, and profile.

- Electromagnet
  Beam focusing, beam orbit correction
- Gate valve
  Dividing the vacuum area in the beamline
- Beam dump, Beam window

Beam current monitor　Beam position monitor



Fast current transformer　Beam profile monitor

Electromagnet

Gate valve　Beam window　Beam dump

# Measuring instruments and methods (contact)

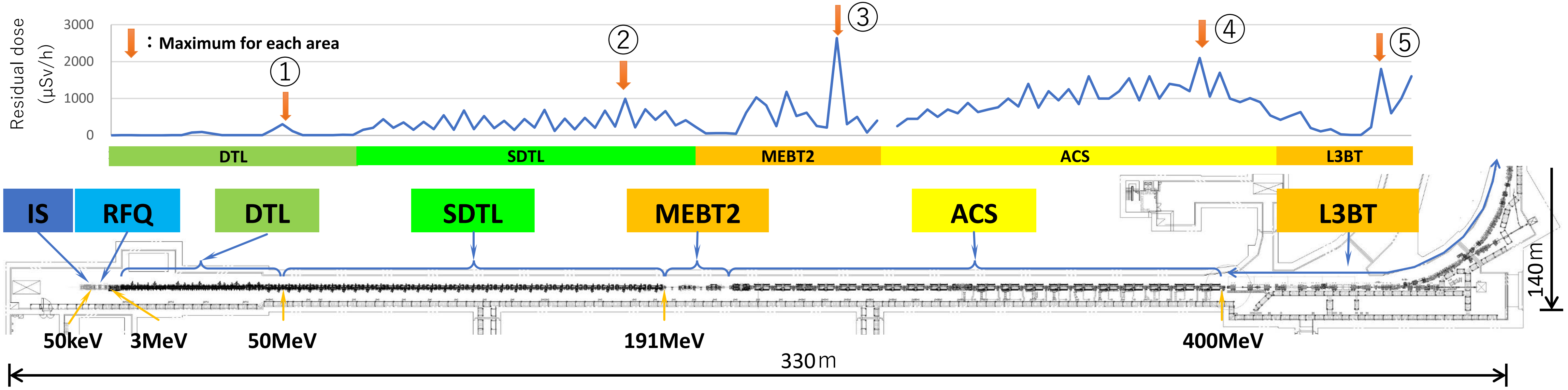
- Scintillation survey meters and semiconductor survey meters were used to measure the residual dose at the beamline.
- The measurement was performed by placing the detector directly on the accelerator cavity and beam duct on the beam transport line.

- Scintillation type survey meter

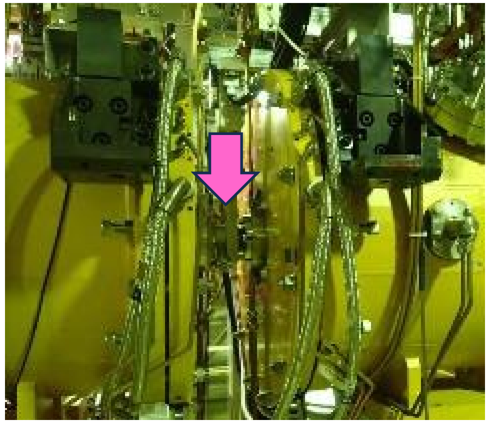
- Semiconductor detector type survey meters

# Residual Dose(contact)

Date: June 19th, 2024,
Five hours after the beam operation
Beam parameter : 50mA 0.5ms, 25Hz
Contact measurement

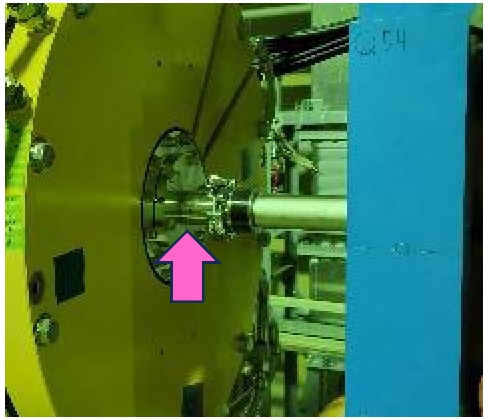



①0.30mSv/h



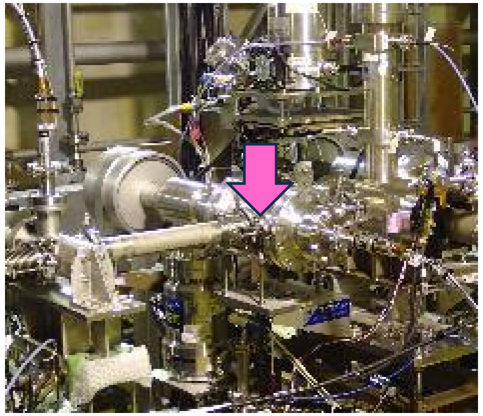
Gate valve between cavities

②0.99mSv/h



SDTL14B Cavity

③2.6mSv/h

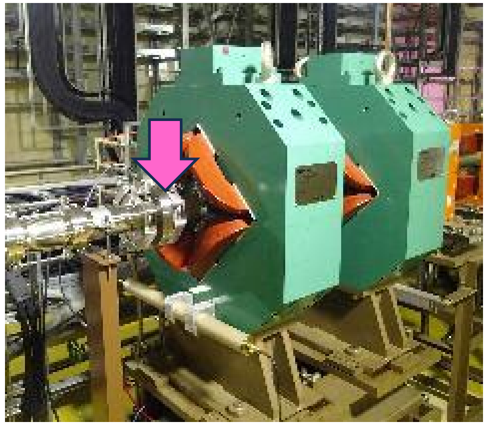


Beam duct

④2.1mSv/h

Beam line at ACS18

⑤1.8mSv/h



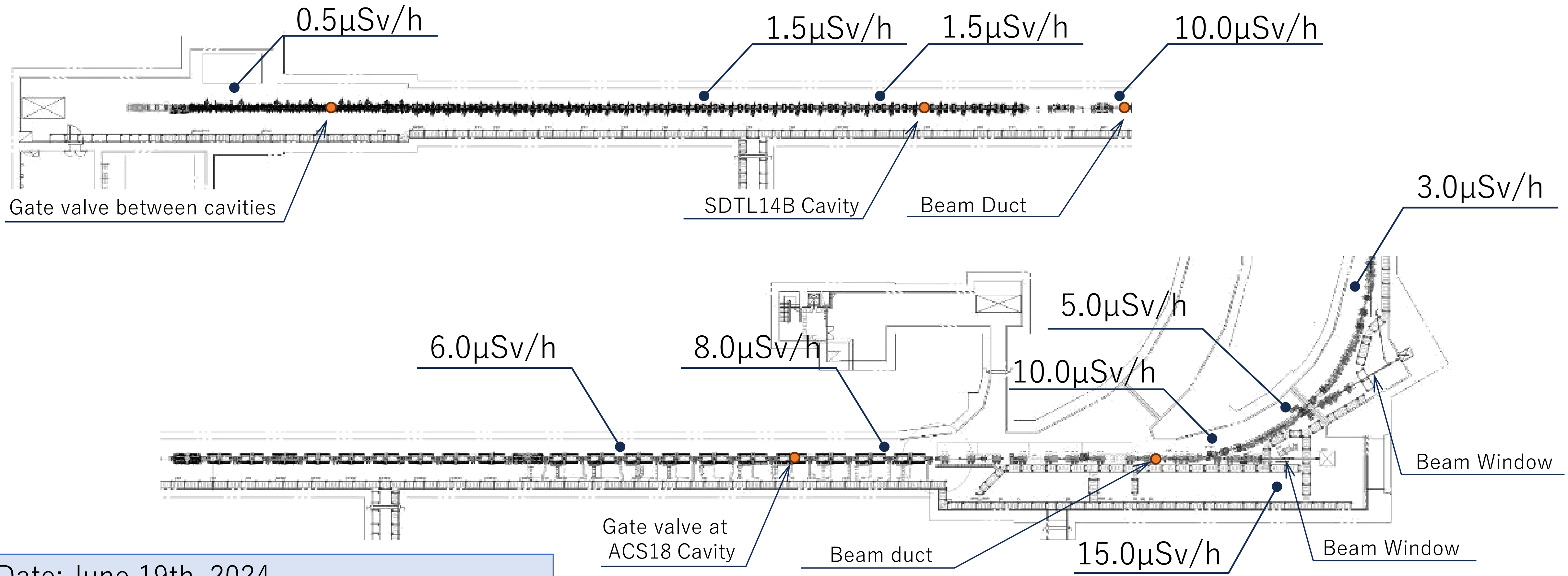
Beam duct

# ● *Measuring instruments and methods (1.5m away from the beam line)*

- An ionization chamber type survey meter was used to measure the residual dose from the beam line component.
- Measurements were taken at a position 1.5 m away from the beam line.


Ionization chamber type survey meters

# Residual Dose (1.5m away from the beam line)



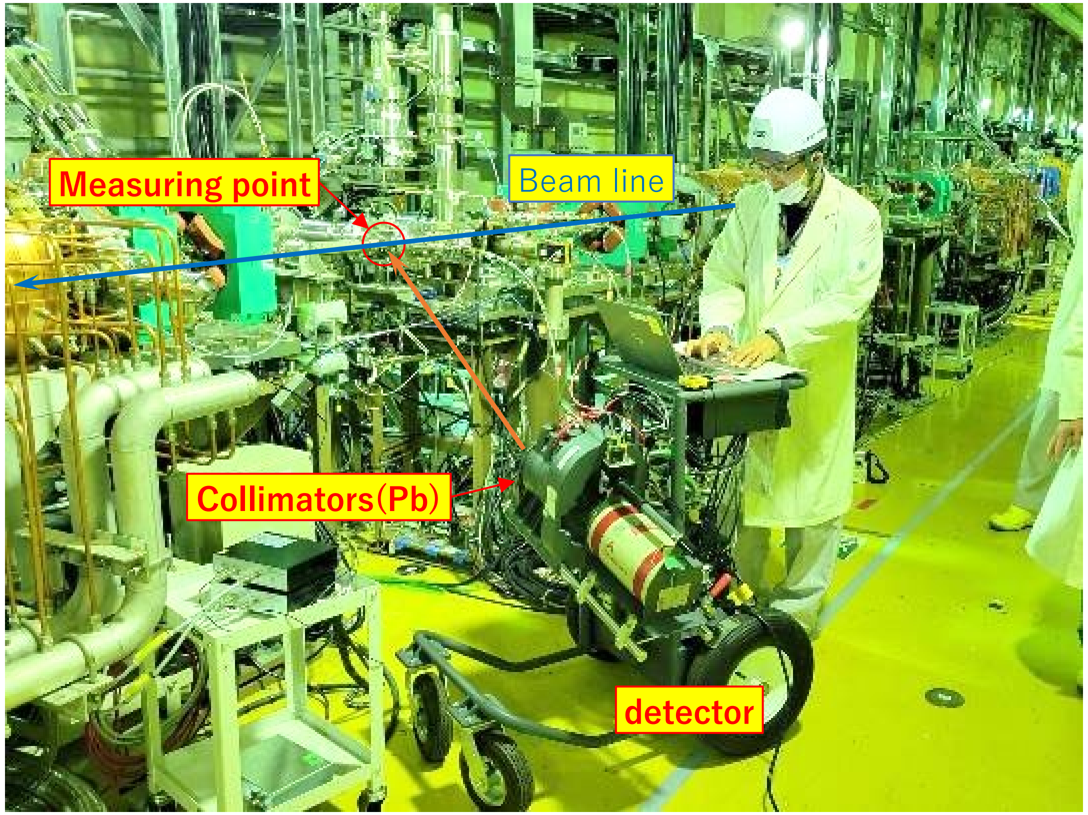

Date: June 19th, 2024,
Five hours after the beam operation
Beam parameter : 50 mA 0.5ms, 25 Hz
1.5m away from the beam line

# γ-ray spectrometry with Ge semiconductor detectors

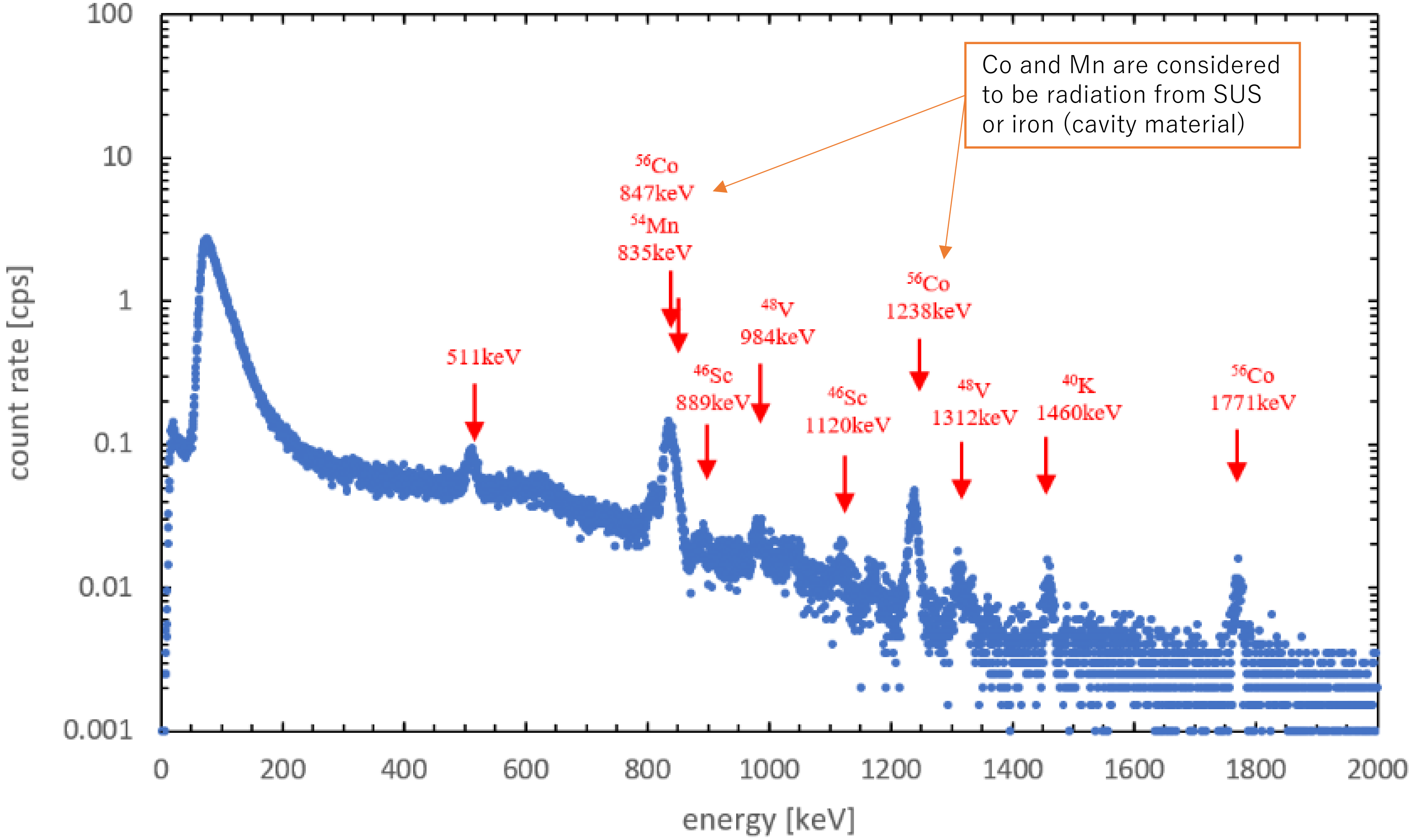
- Date: August 6, 2024(35 days after beam shutdown)
- Location: LINAC accelerator tunnel
- Measuring instrument:
  GR2018 (CANBERRA),
  LYNX (CANBERRA)
- Live time: 2000 ～ 4000sec

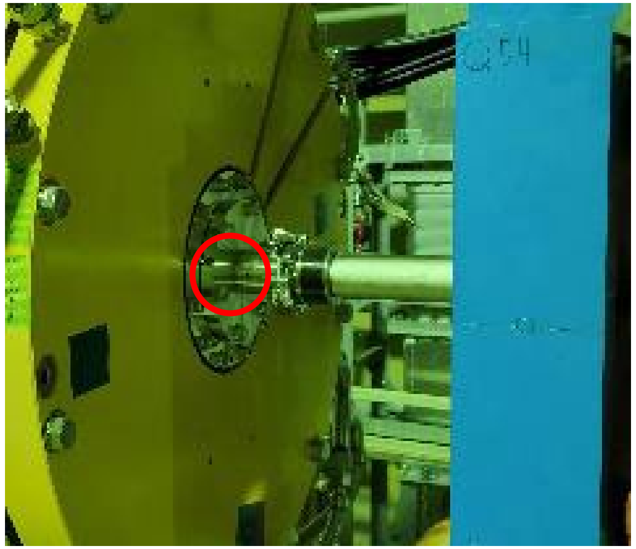
The detector is placed near the beamline and pointed at the measurement point.

The detector is covered by a lead collimator.



# 01 SDTL14B Cavity



- The endplate of the SDTL cavity and flanges are made of SUS, so the Mn and Co components are noticeable.

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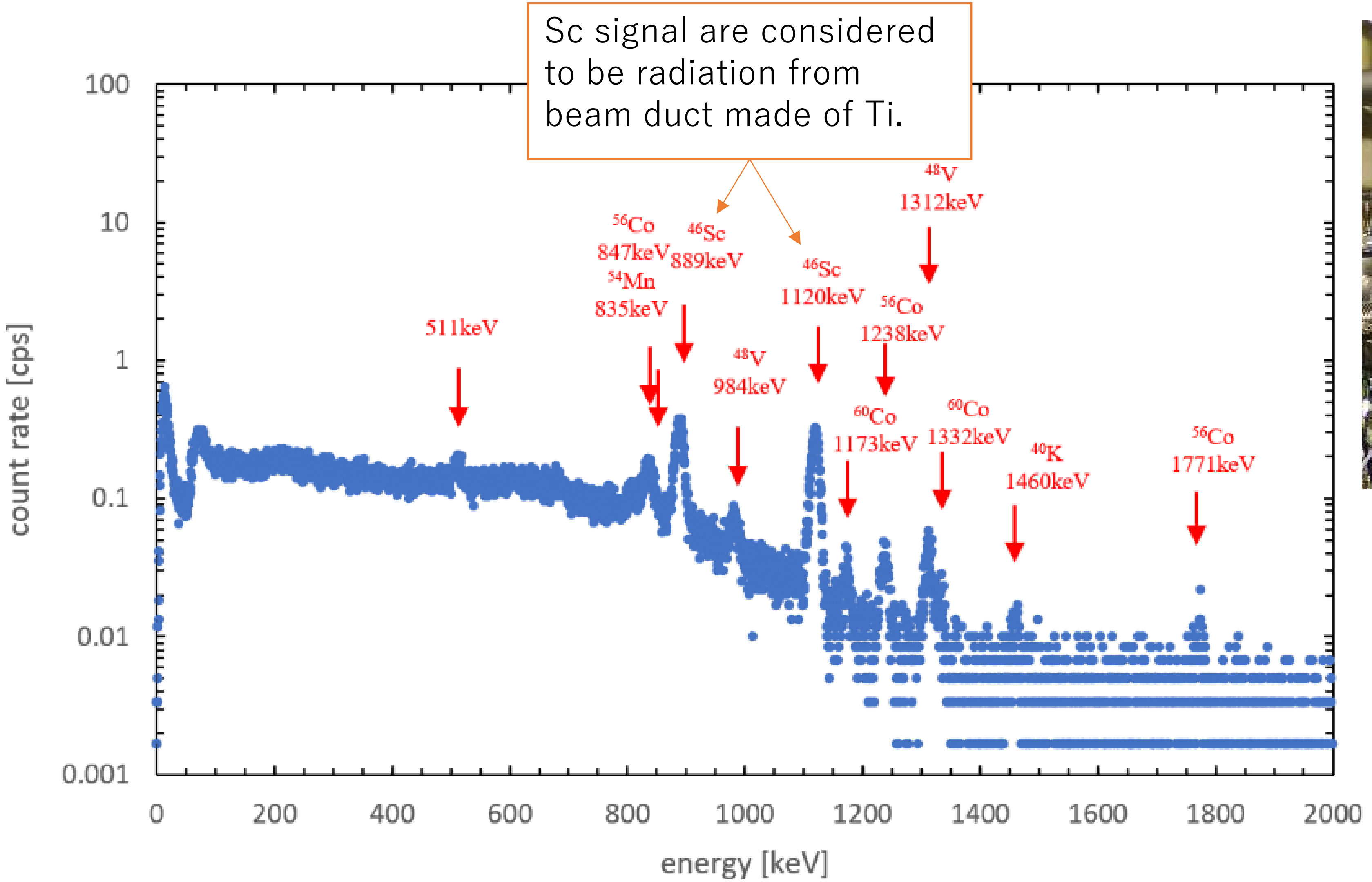
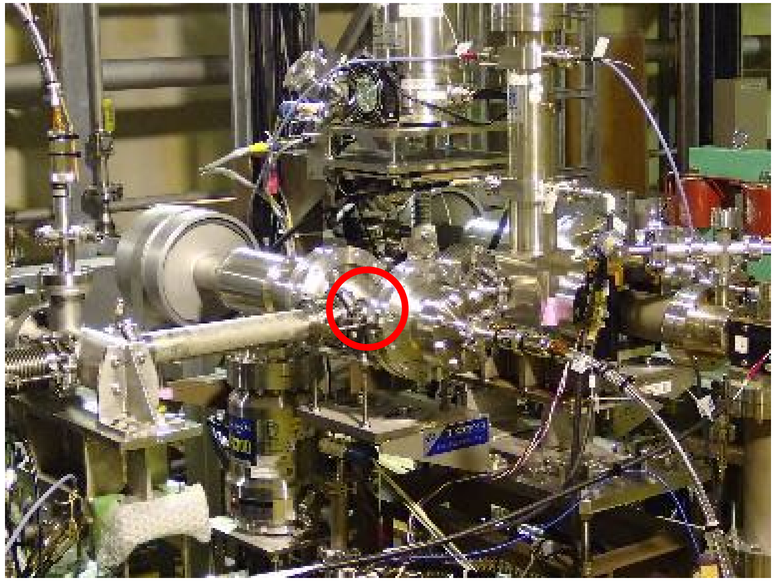
# 02 Beam duct



- Beam ducts are mainly fabricated from titanium, with the Sc being the major component.
- Since 35 days have passed after beam operation, short-lived nuclides have decayed.

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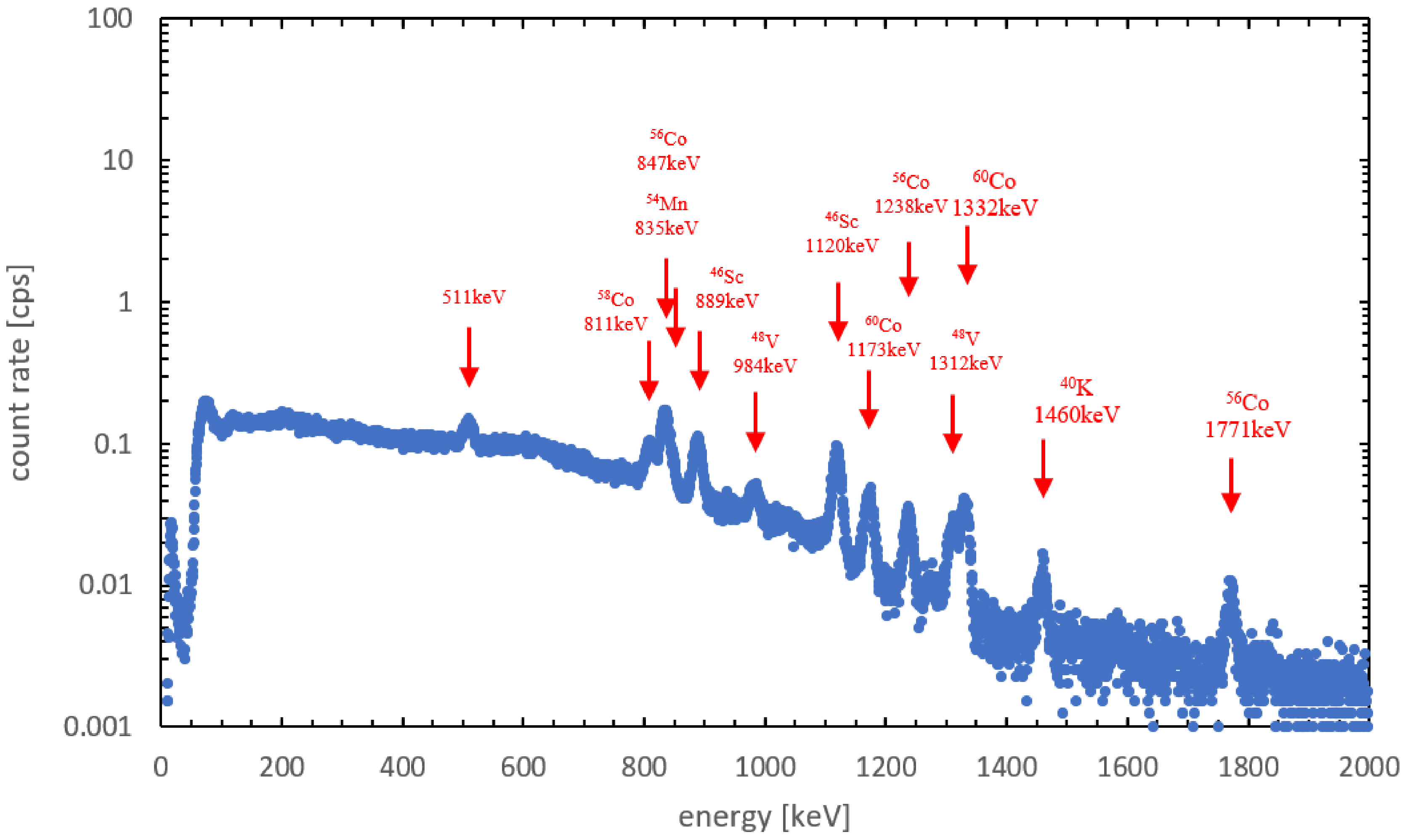
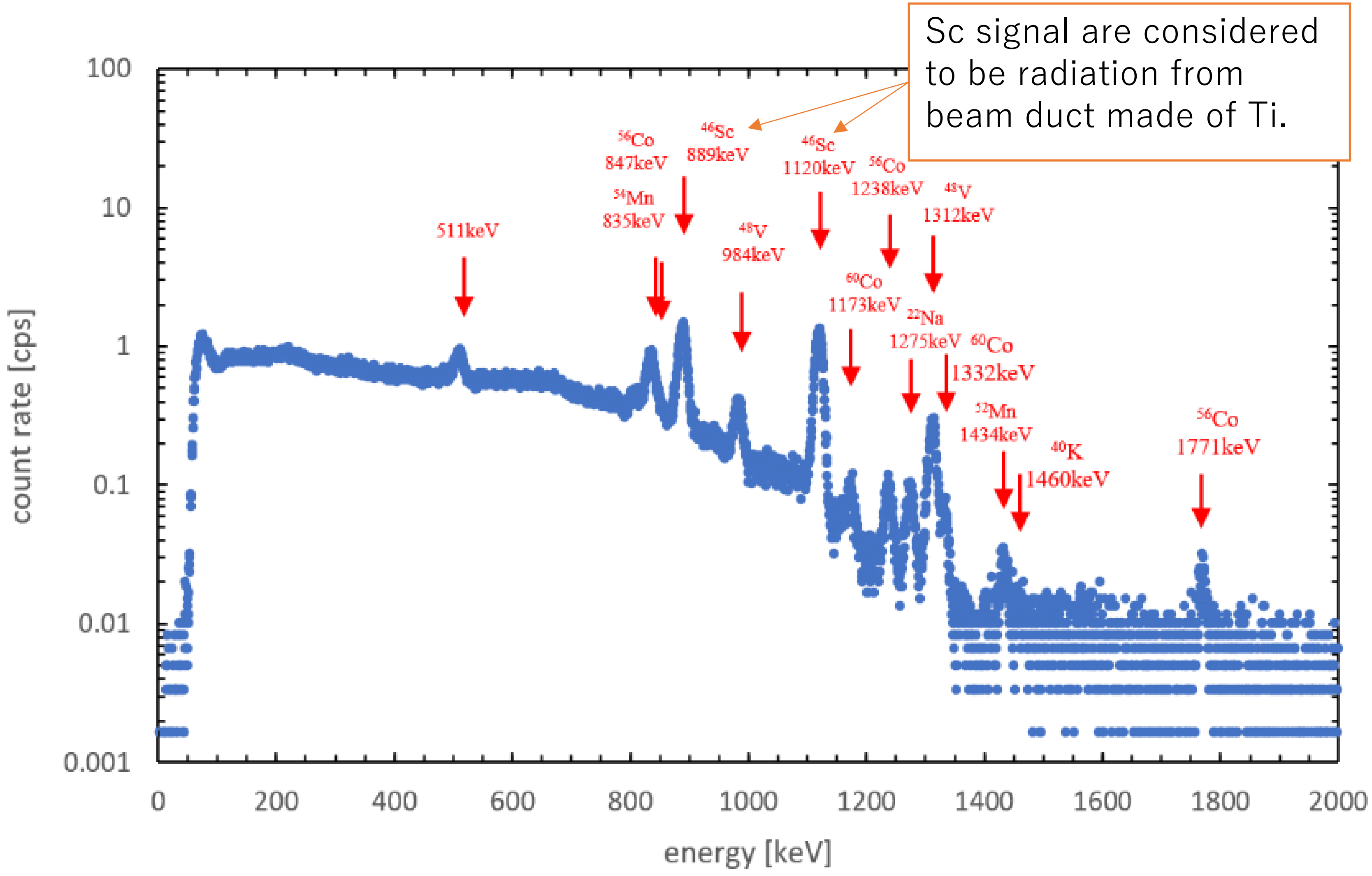
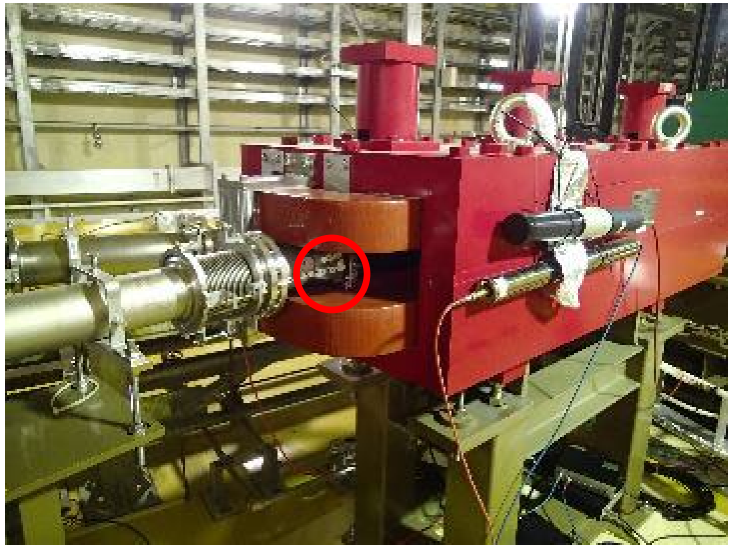
# 03 Beam line at ACS18




- Beam line composed of gate valve, Ti duct, and position monitor.
- Overall spectra from these material were measured.

# 04 Bending magnet



- Beam duct inside the bending magnet is made of Ti.
- The major radiation component is from Ti.

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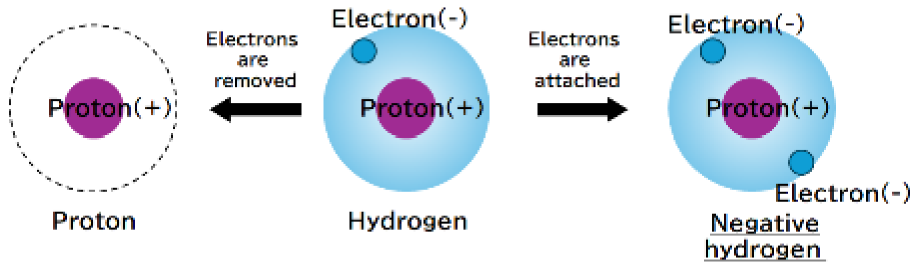


# Causes of LINAC Radiation

- **The causes of residual radiation can be categorized into the following beam loss prosses.**

➢ Beam halo

A low-density beams formed around a high-density beam impinges on and radiates the accelerator components.

➢ Electron stripping with residual gas（main cause at SDTL)

Accelerated H- particles interact with residual gas in the beam line, causing electrons to be stripped and H0 to be produced. The H0 particles, which are out of control, cause the accelerator components to be activated.

➢ Electron stripping by beam-particle interaction(main cause at SDTL and ACS)

The electrical interactions that occur within the high-intensity H- beam strip off electrons and produce H0.

➢ Beam not accelerated normally(main cause at bending magnet)

At the arc section, beams with energies different from the design are not bended normally and hit the beamline components.

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# ● Summary

・Five hours after the beam operation(user operation), the residual dose was 2.6 mSv/h for the beamline contact measurement and 15 μSv/h for the 1.5 m away from the beam line. (June 2024)

・The residual dose tends to be higher downstream.

・As a result of $\gamma$-ray spectrometry measurement, the major component of the radiation was identified as radiation from the constituent materials of the beamline equipment.

・Currently, residual doses are controlled to the extent that they do not pose a problem during routine maintenance work. However, in the vicinity of areas with high residual doses, work is carried out after consideration of measures to reduce radiation exposure.