Accelerator Facility Accident Report

31 May 2013

Incorporated Administrative Agency - Japan Atomic Energy Agency
Inter-University Research Institute - High Energy Accelerator Research Organization

Subject: Radioactive Material Leak at the Hadron Experimental Facility of Japan Proton Accelerator Research Complex (J-PARC)

Time and Date of Accident: Approximately 11:55 am on 23 May 2013

Accident Location: Hadron Experimental Facility, J-PARC

Description of Accident:

It is presumed that due to a malfunction of the beam extraction system, the gold target of the Hadron Experimental Facility (hereafter HD Facility) was damaged and radioactive material was discharged into the room that contained the target and the primary beamline. The radioactive material then leaked into the experimental hall where workers were exposed to radiation.

Area monitors around the boundary of the controlled area registered an increase in ambient radiation. Higher than normal levels were also observed for a short period at the three monitoring posts and stations near to J-PARC of the neighboring Nuclear Fuel Cycle Engineering Laboratories. Accordingly, it is reasoned that there was a radiation leak from within the controlled area of the HD Facility.

Radiation Leakage and Exposure within the Controlled Area:

It is presumed that the gold target of the HD Facility was damaged and radioactive material was discharged into the room that contained the target and the primary beamline. The radioactive material then leaked into the experimental hall.

Thirty four (34) registered radiation workers in the controlled area of the HD Facility received total (internal plus external) radiation doses between 0.1 and 1.7 mSv.

Radiation Leakage into the Environment and It's Effects:

Simulations indicate that the leaked material would have diluted and decayed as it dispersed in a narrow range towards the west of the HD Facility. It has been estimated that the maximum

integrated radiation dose at the site boundary closest to the HD Facility was 0.29 μSv (preliminary).

Cause of the Accident:

A detailed investigation will be carried out.

Immediate Response and Future Measures:

All J-PARC accelerators have been shut down and access to the hadron experimental hall has been restricted. Taking into account the findings of the investigation, all necessary measures to prevent a reoccurrence of the accident will be examined.

1. Subject

Radioactive Material Leak at the Hadron Experimental Facility of Japan Proton Accelerator Research Complex (J-PARC)

2. Time and date of accident

Approximately 11:55 am on 23 May 2013

3. Accident location

Hadron Experimental Facility, J-PARC

4. Circumstances of the accident

4.1 Operation status at the accident

The Hadron Experimental Facility (hereafter HD Facility) (Fig. 1) of J-PARC, completed in January 2009, is located at the south end of the site of the Nuclear Science Research Institute of the Japan Atomic Energy Agency (JAEA).

In the Hadron experimental hall, the proton beam extracted from the 50 GeV Synchrotron (hereafter MR) is brought onto a gold target to produce secondary particles, such as K-mesons, π-mesons and others. These secondary particle beams are transported to several experimental areas in the hall for carrying out various experiments. The entire HD Facility consists of the experimental hall, the power supply building and the mechanical support building (Fig. 2). The plan view of the experimental hall is shown in Figure 3.

At around 11:55 of 23 May, due to a malfunction of the beam extraction system of the MR, a beam consisting of 2×10^{13} protons was delivered to the gold target (Fig. 4) within a very short time (5/1000 of a second), whereas normally a total of 3×10^{13} protons were slowly and evenly extracted and delivered to the target over a period of 2 seconds. As a result, the gold target is considered to have momentarily reached an extremely high temperature and possibly to have been partially damaged.

Fig. 4 shows the design of the gold target. It is a square rod of gold (W6 mm x H6 mm x L66 mm) which is mounted directly on top of a copper block which is water-cooled for removal of heat. Thermocouples are used to monitor the target temperature. This target assembly is housed in a metal container as shown in Fig.5.

Major events from 23 to 25 May are chronologically listed in the appendix.

(1) *Prior to the accident*

The proton beams had been delivered from MR to the Hadron experimental hall since 13 May. The operation mode on 23 May involved the delivery of 3 x 10^{13} particles per 2 seconds.

(2) *At the accident*

At around 11:55, the Machine Protection System (MPS) that controls beam delivery to the experimental hall detected an anomalous condition and the beam delivery was halted. The shift leader of MR, the person in charge of the power supply, and the Hadron beam operator on shift inspected the situation and reset the MPS. One test shot of the beam was delivered to the target to confirm the normalcy of the beam trajectory. The delivery of proton beam was resumed at around 12:08.

At around 13:30, it was acknowledged that the readings of gamma-ray area monitors in the experimental hall were increased to 4μSv/hr, 10 times higher than the normal. The person in charge of the beam production facility and the operator on shift discussed, over the phone, on the situation and ways to identify the cause. They noted that the health of the monitors could be confirmed by turning on ventilation fans mounted on building walls. If the radiation rate is reduced with the use of ventilation fans, the cause could be radioactive air. Otherwise, it could be due to problems in the beam trajectory or a malfunction of the area monitor. They turned on the ventilation fans between ~15:15 and 15:32.

At around 15:32, they recognized reduction in the radiation dose rate and then resumed the beam delivery for retuning the beam. However, as the dose rate increased again, they stopped the beam at around 16:15.

The person in charge of the radiation controlled area of the HD Facility discussed the issue with the radiation protection supervisor on the phone. Since the radiation dose rate in the hall was sufficiently lower than the does limit value of 25μSv/hr as stipulated by regulations (equivalent to the dose limit of 1mSv/week), they assumed no environmental effects to the areas outside the radiation controlled area by turning the fans on. Hence, they turned the ventilation fans on again to further reduce the radiation dose rate in the hall at around 17:30.

(3) *After the accident*

At around 17:30 the next day, 24 May, J-PARC received an inquiry from the Nuclear Fuel Cycle Engineering Laboratories that momentary rises in the radiation dose rate were recorded by their three monitoring posts and stations which are located near the HD Facility. The data logs of gamma-ray monitoring posts on the external boundary of the radiation controlled area

of the HD Facility were thoroughly reviewed. J-PARC found that radiation dose rate increased at around 15:00 and 17:30 on 23 May and that the increases coincided with the operation of ventilation fans in the experimental hall. They recognized for the first time a high possibility of leakage of radioactive materials to the areas outside of the radiation controlled area of the HD Facility.

At 21:10, J-PARC reported on this incident to the emergency number of the Nuclear Science Research Institute. The local emergency response headquarters was immediately established. At around 22:15, the headquarters confirmed that a statutory report was due. JAEA reported to the Nuclear Regulation Authority at 22:40 in accordance with laws and regulations, and reported to Ibaraki Prefecture, Tokai Village, and neighboring local governments using fax in accordance with agreements with local governments.

4.2 Reporting

As of 23 May, the radiation protection supervisors had recognized that: part of the gold target was damaged, radioactive material leaked into the hadron experimental hall, the floor and other areas were contaminated, and workers might have suffered internal radioactive exposure. However, they considered that the contamination was localized in the radiation controlled area, and the exposure was within the expected scope, and thus they evaluated that statutory reporting was not due.

At around 17:30 on 24 May, a report was received on momentary increases in the radiation dose rate at the three monitoring posts and stations near J-PARC of the Nuclear Fuel Cycle Engineering Laboratories. This was when a high probability of radioactive material leakage outside of the controlled area was noted for the first time, resulting in a report to the emergency number of the Nuclear Science Research Institute at 21:10 on 24 May.

Reporting was delayed due to these circumstances.

5. Radiation leakage and exposure within the radiation controlled area

Due to a malfunction of the beam extraction system of the MR, at around 11:55 the proton beam was brought onto the target in a time period (5/1000 of a second), much shorter than the normal two seconds. As a result, the gold target is considered to have momentarily reached an extremely high temperature and possibly to have been partially damaged, and discharge of radioactive material resulted in the room that contained the target assembly. Radioactive material then leaked into the hadron experimental hall. Workers were exposed to radiation in the hadron experimental hall due to this leakage.

A total 102 individuals entered the radiation controlled area of the HD Facility after the occurrence of this accident. Except for two users from overseas who have returned to their home countries, radiation dose measurements have been conducted on all of the remaining 100 individuals. Exposure has been confirmed for 34 registered radiation workers. Their total (internal plus external) radiation doses were between 0.1 and 1.7 mSv. This does not exceed the dose limit for registered radiation workers stipulated by law. The two users who returned to their home countries are scheduled to have measurements at medical institutions in their home countries.

6. Radiation leakage into the environment and its effects

It was confirmed that readings of the area monitors, which were installed at the external boundary of the controlled area near the hadron experimental hall, showed increases when ventilation fans were turned on (Figure 6). However, the data logs of radiation dose rates at monitoring posts in other places in the Nuclear Science Research Institute showed no signatures. On the other hand, at the three monitoring posts and stations of the neighboring Nuclear Fuel Cycle Engineering Laboratories, near J-PARC, momentary rises of the radiation dose rate, exceeding the normal range of fluctuation, were observed twice, and they were in coincidence with the release associated with operation of ventilation fans. They indicated that it is likely that radioactive material was allowed to leak from inside the hadron experimental hall to the surrounding environment (outside the radiation controlled area).

The radiation dose in the surrounding environment was evaluated by using two methods: an analytic method based on the diffusion formula for radioactive material, and the WSPEEDI-II numerical simulation software. Inputs to these evaluations include the results of nuclide composition analysis of air samples collected at the HD Facility, data logs of the gamma-ray area monitors installed in the facility, meteorological data for the time period in question, and other relevant information.

It is assessed that the released radioactive material was diluted and attenuated as it dispersed in a narrow strip towards the west. It has been estimated that the maximum integrated radiation dose due to the release of radioactive material would be 0.29 μSv at the site boundary closest to the HD Facility. The amount of released radioactive material is under continued evaluation.

7. Causes

The gold target was possibly partially damaged due to a malfunction of the beam extraction system of the MR, and radioactive material leaked into the hadron experimental hall. Operation of ventilation fans caused the leak of radioactive material out of the radiation controlled area.

A detailed investigation will ensue.

8. Response and measures

Operation of all J-PARC accelerators has been halted and access to the hadron experimental hall has been restricted. Investigations will be conducted regarding the cause of the malfunction of the beam extraction system, discharge of radioactive material from the target, and issues in the safety management.

On the basis of results from the investigations above, measures against reoccurrence of similar accidents will be examined.

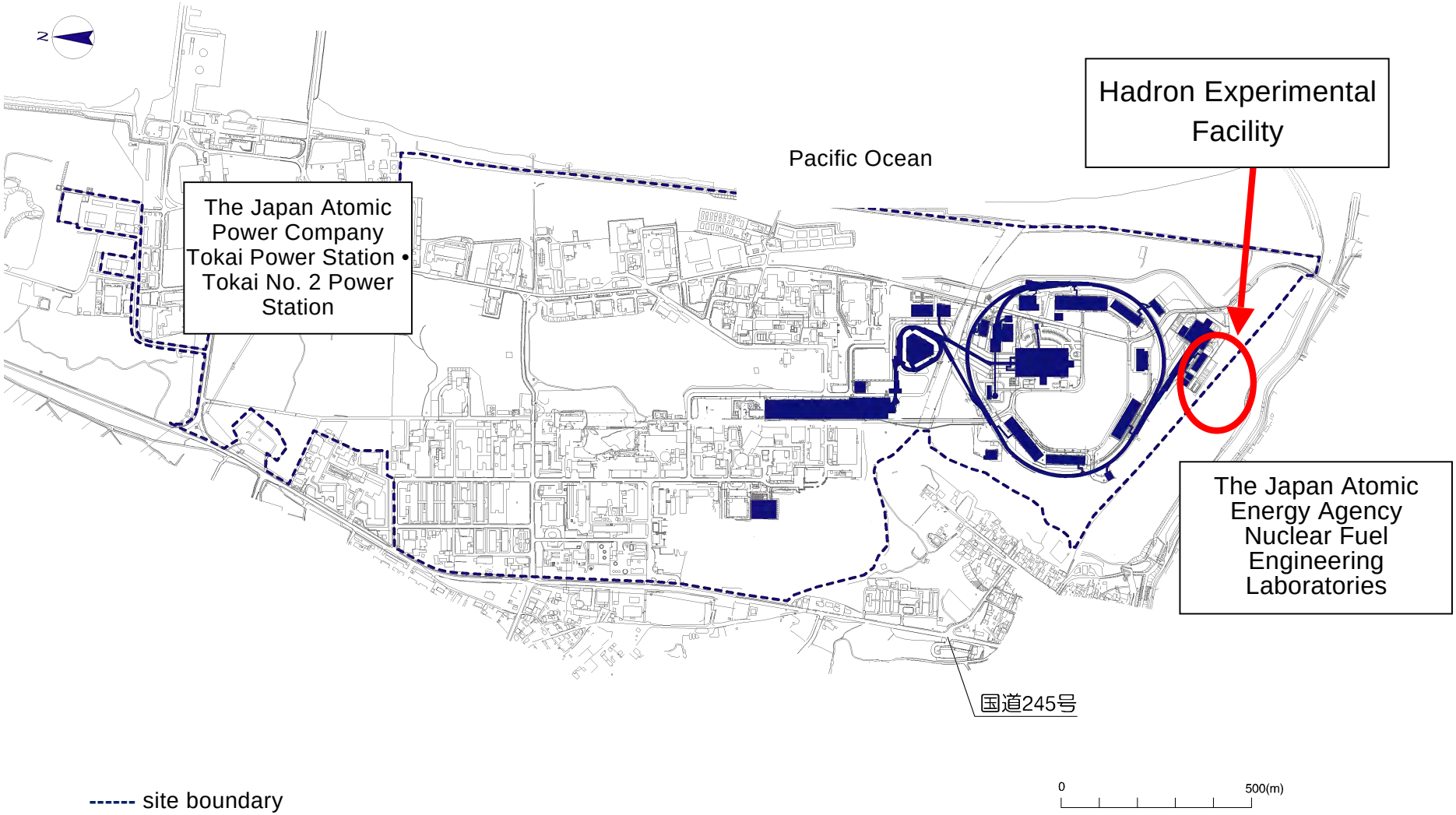

Figure 1: Location of Hadron Experimental Facility

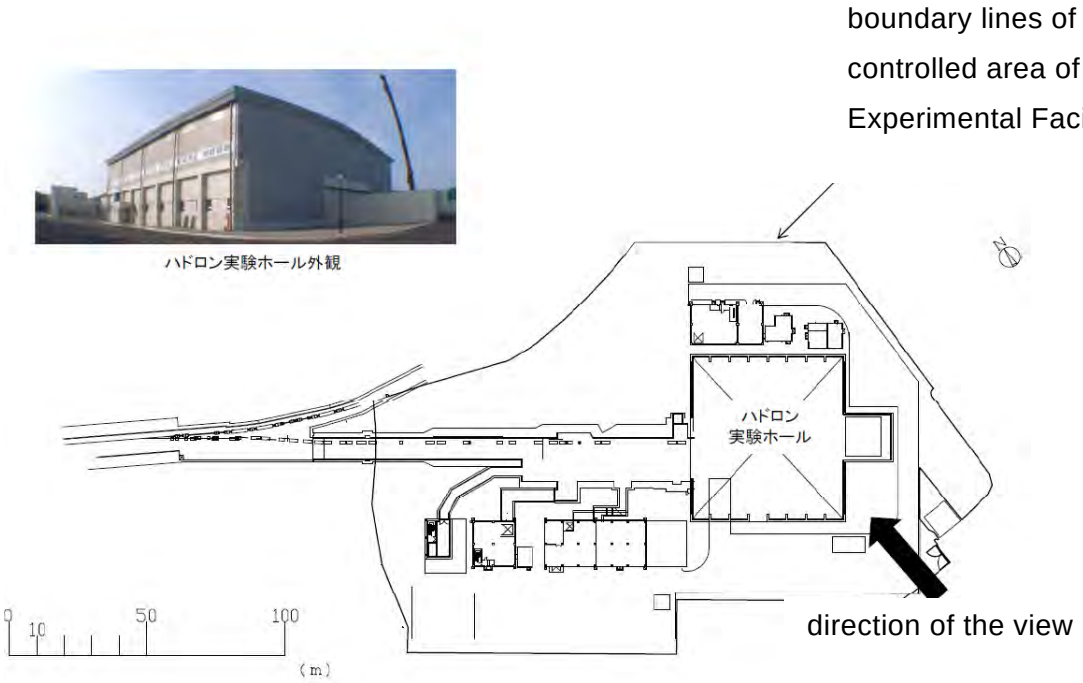

Figure 2: Hadron Experimental Facility

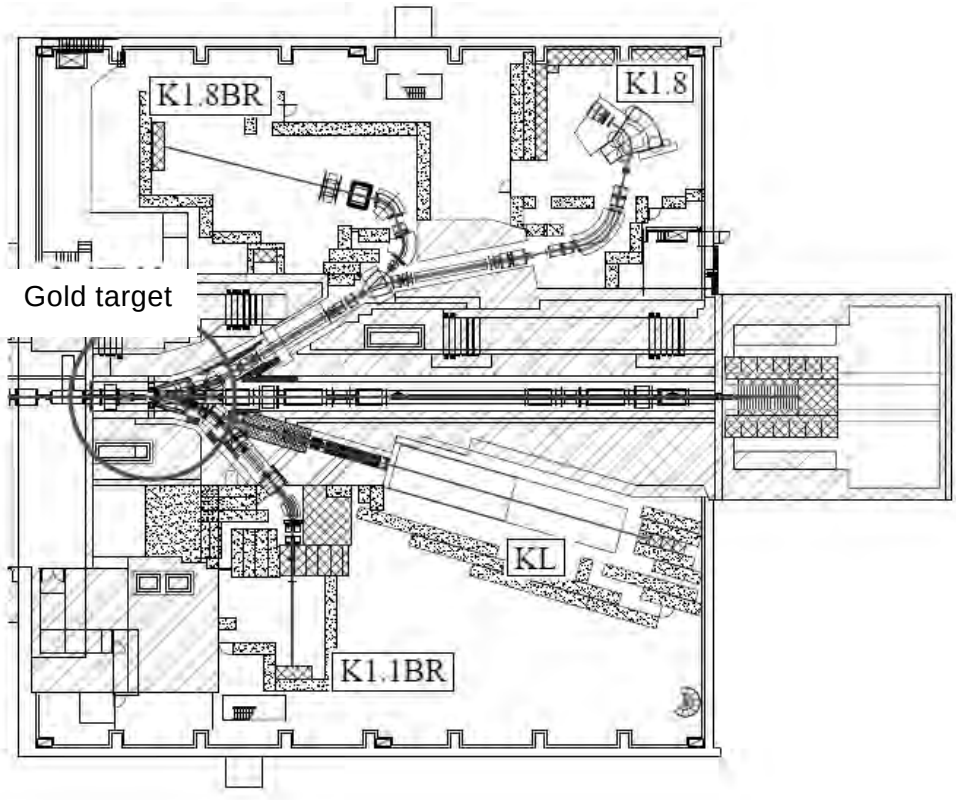

Figure 3: Plan View of Hadron Experimental Facility (as of 2013)

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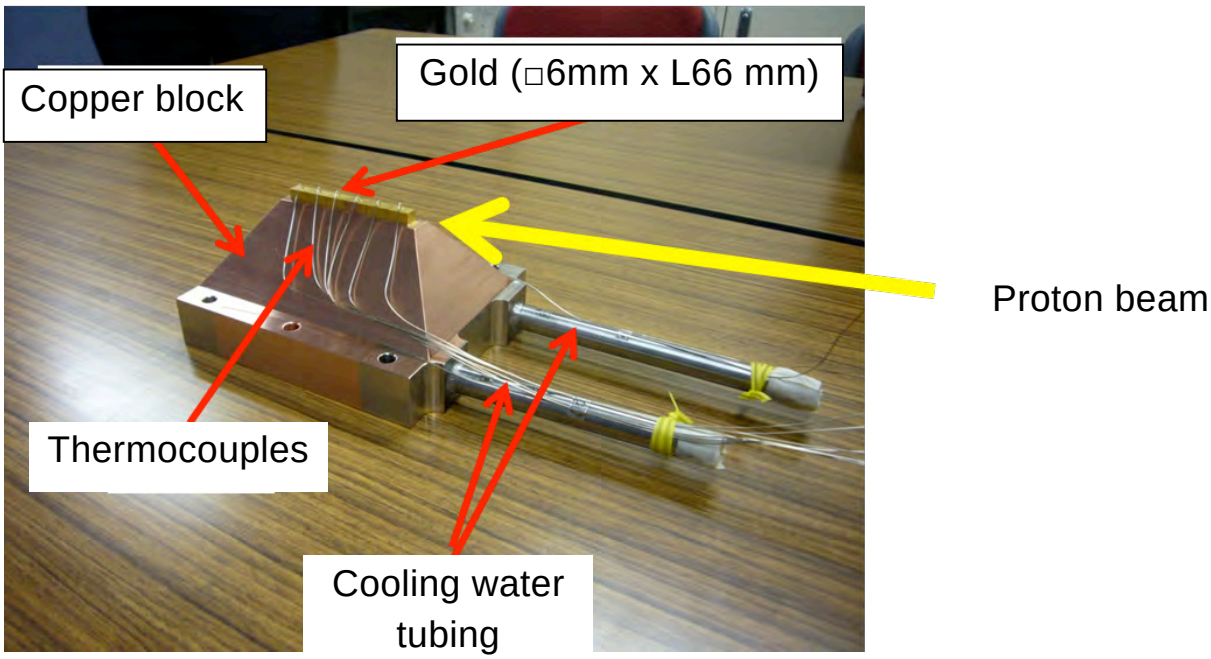

Figure 4: Gold Target before Installation

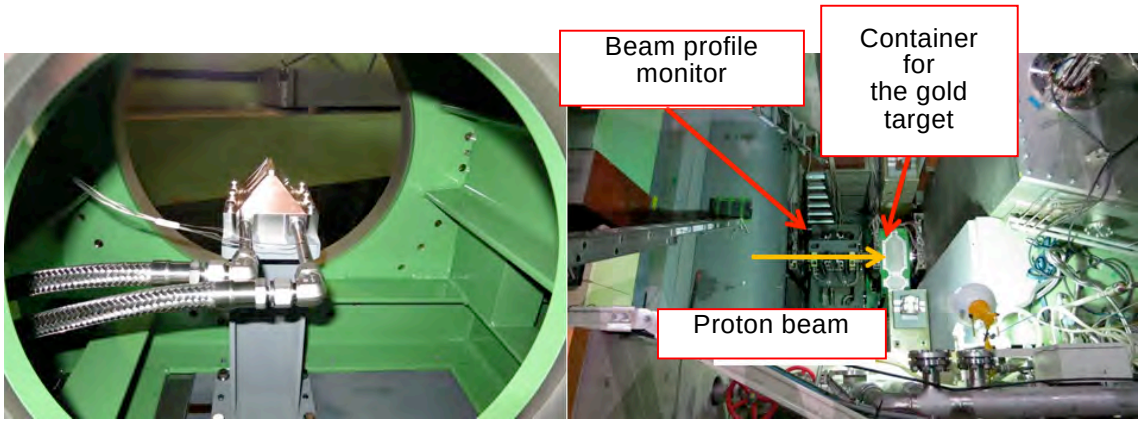

Figure 5: Container for the gold target

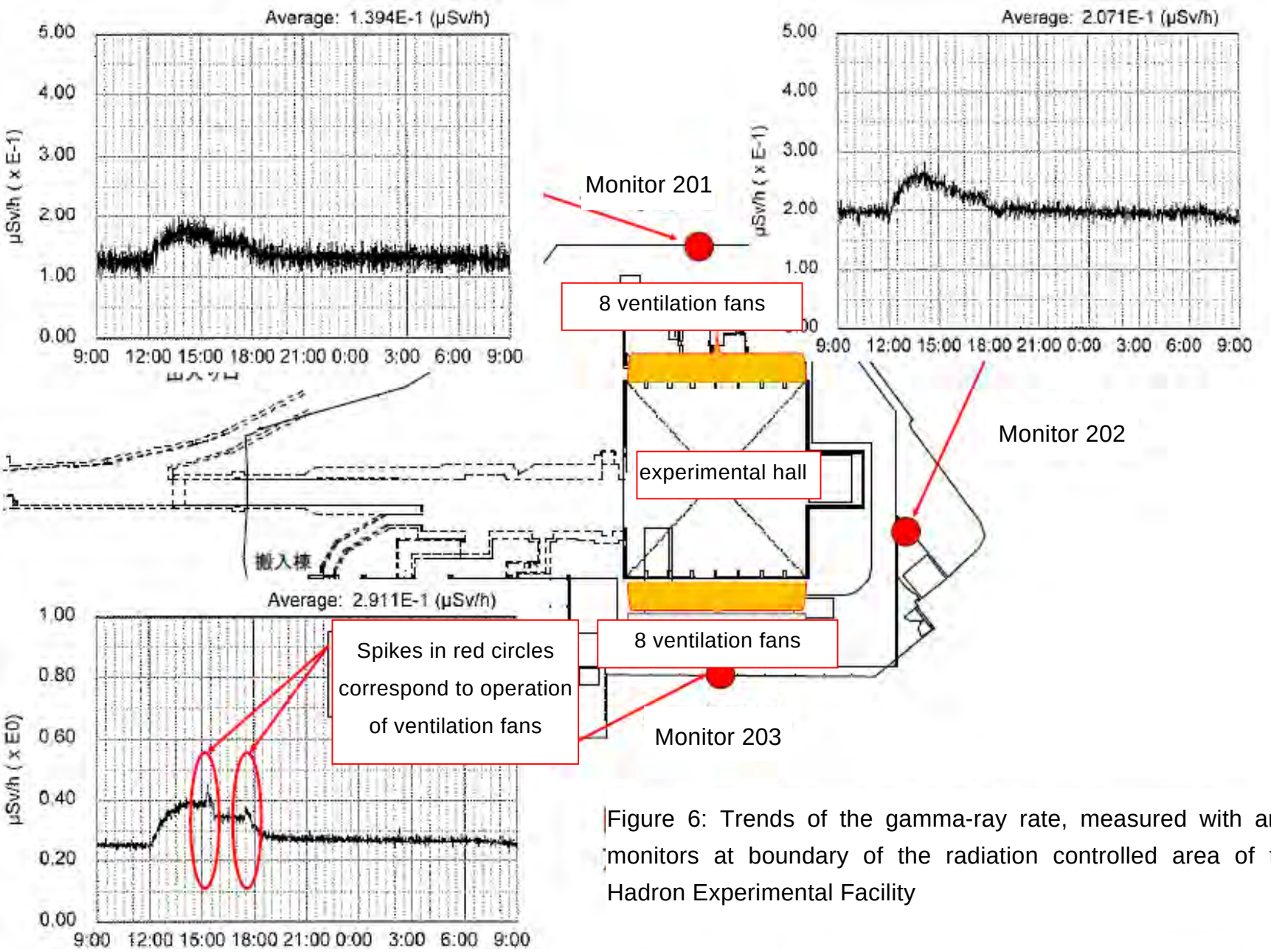

Figure 6: Trends of the gamma-ray rate, measured with area monitors at boundary of the radiation controlled area of the Hadron Experimental Facility

Appendix

Chronological Sequence of Events

23 May 2013

11:55 Delivery of proton beam is halted by Machine Protection System (MPS).

12:08 MPS was reset and delivery of proton beam was resumed.

12:30 An increase in the background level was noted on an instrument used for experiments (neutron detector).

13:30 An elevated radiation dose rate in the experimental hall was acknowledged. Ten-fold increase (to 4 μSv/h) was measured with a gamma-ray monitor.

14:26 Beam was stopped. Reduction in gamma-ray dose rate was observed.

15:15 Further reduction in ambient dose rate was found when ventilation fans were turned on.

15:32 Ventilation fans were turned off and beam extraction was resumed

16:00 Higher-than-normal radiation rate in the experimental hall (4-6 μSv/h) was measured with a survey meter. An increased gamma-ray rate was also noted.

16:15 Beam operation was stopped.

17:00 Radiation survey of experimental hall found localized areas of high dose rate.

17:20 An air sample was collected in the experimental hall for measurements.

17:30 Ventilation fans were turned on to reduce airborne radiation dose rate in experimental hall.
Evacuation of workers from the experimental hall began.

19:00~20:00 Systematic measurements of radiation dose rate and surface contamination carried out in experimental hall.

23:30 Completed evacuation and full-body radiation surveys of all workers in radiation controlled area. Access to area restricted.

24 May 2013

17:30 J-PARC received inquiry from Nuclear Fuel Engineering Laboratories concerning increased radiation levels recorded by their monitoring posts at around 15:00 and 17:30 the previous day (23 May).

18:00 Data logs of gamma-ray monitoring posts on the boundaries of the controlled area of the Hadron Experimental Facility were examined. Found increased radiation levels at around 15:00 and 17:30 on 23 May. Found that the increased dose rates coincide with operation of ventilation fans in experimental hall.

21:10 Report to an emergency post of the Nuclear Science Research Institute

21:19 Nuclear Regulation Authority was contacted by telephone

21:40 Ibaraki Prefecture was contacted by telephone.

21:43 Tokai Village was contacted by telephone.

22:40 As required by law, the first report to the Atomic Energy Regulatory Committee was transmitted by facsimile transmission.

22:40 As required under the terms of relevant Agreements, the first report was faxed to Ibaraki Prefecture, Tokai Village and other authorities.

25 May 2013

01:00 Found out that the maximum radiation dose received by workers was 1.7 mSv (Provisional)