Appendix 5

The Radioactive Material Leak Accident at the Hadron Experimental Facility of J-PARC

June 21, 2013

First External Expert Panel

J-PARC Center

Naohito Saito

Issues with respect to the Accident

① Release of radioactive material to the outside of the radiation controlled area and to the environment outside of the Hadron experimental hall (HD hall)

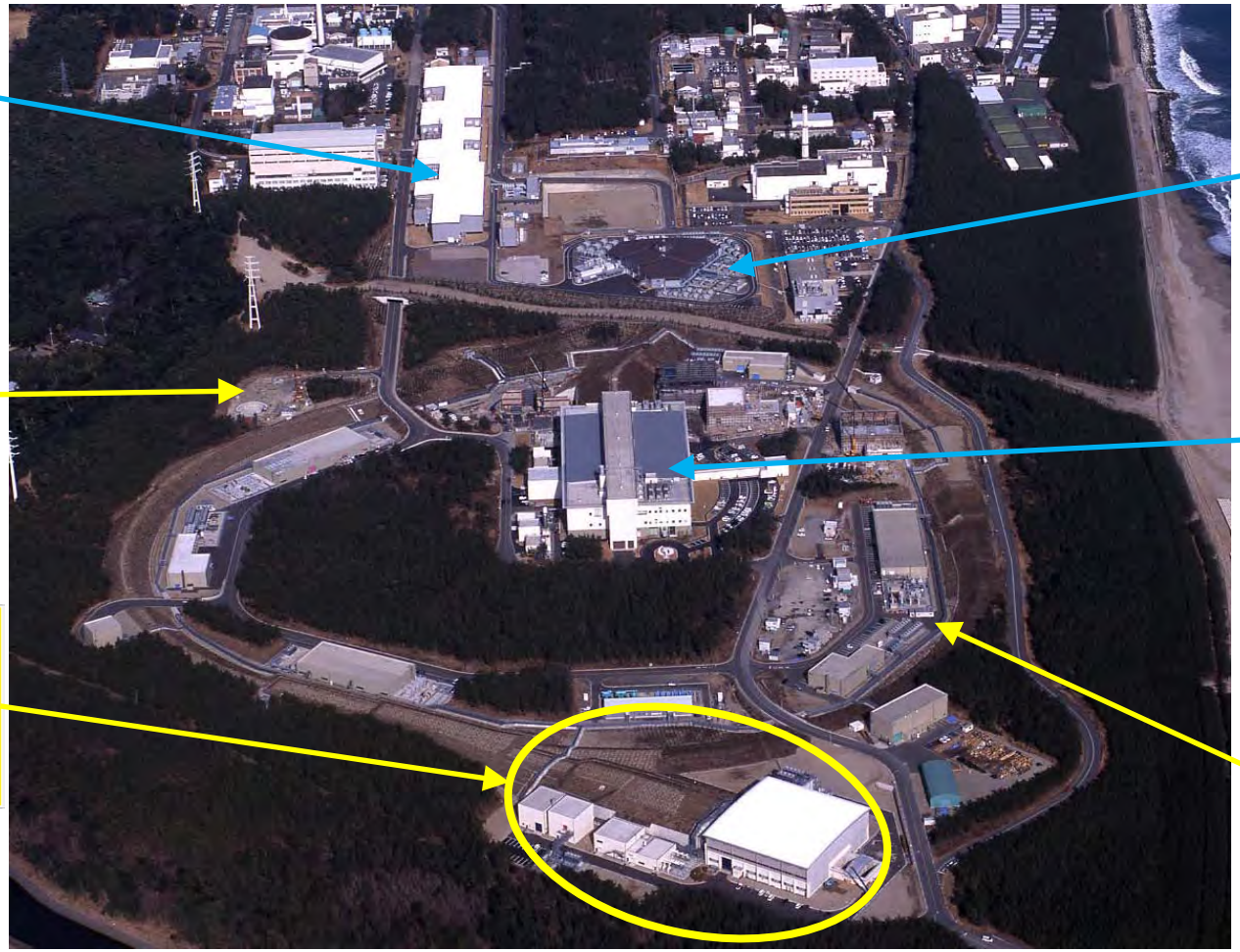
② Delays in reporting to the relevant authorities, the local communities and the media

③ Internal radiation exposure on workers who inhaled contaminated air in the HD hall

④ Failure in timely disclosure of information

What is J-PARC?

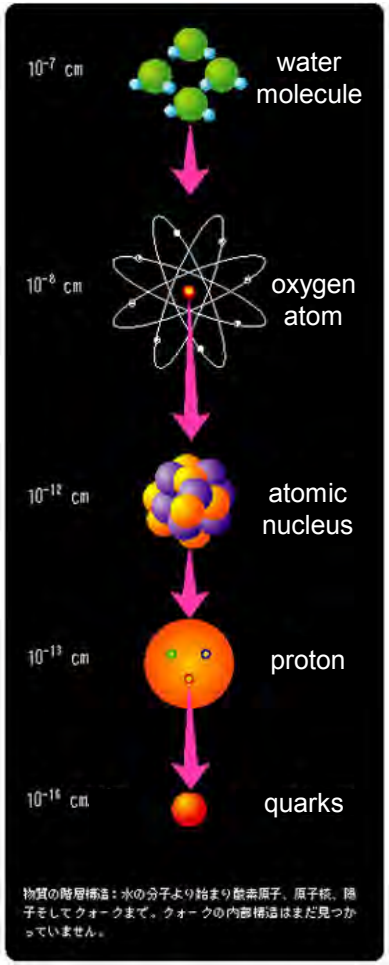
- Jointly built and operated by Japan Atomic Energy Agency (JAEA) and High Energy Accelerator Research Organization (KEK)
- Opened for researchers in the world to study a wide range of research fields from the origin of the universe to the development of new medicine



Hadron Experimental Facility

A research facility for elementary particle and nuclear physics
- to investigate the fundamental components of matter
- to explore how they interact and constitute matter

Construction began in 2004 and was completed in January 2009. After commissioning, the users experiments started in January 2010.



Hadron Experimental Hall:

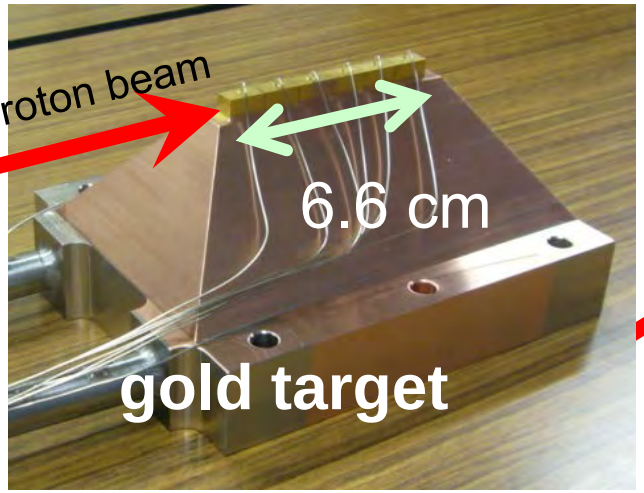
The building is 56 m long, 60 m wide, 16 m roof height with 6 m deep semibasement structure to accommodate experimental instruments.

Hadron Experimental Facility:
It consists of the Hadron experimental hall and associated machine and power supply buildings, etc.

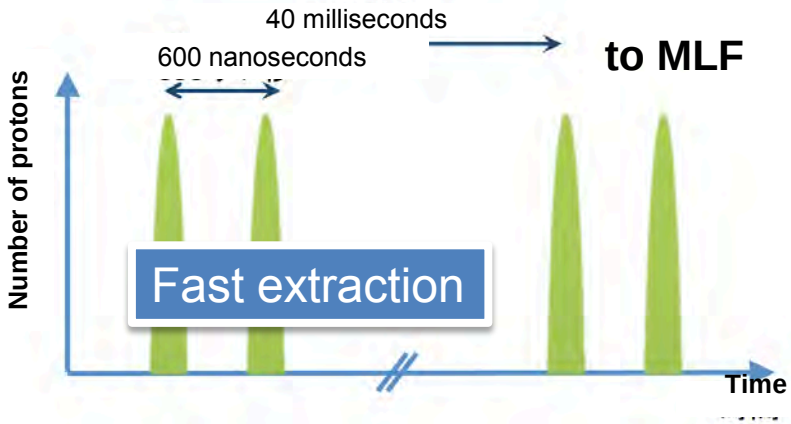
Outline of the Accident

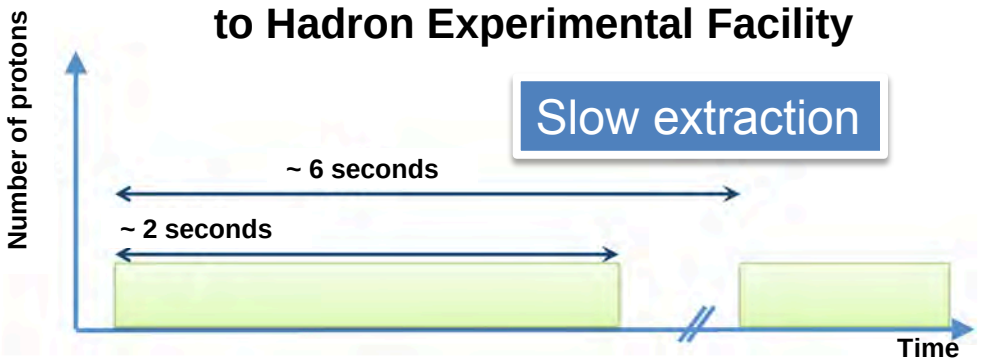
11:55 on May 23

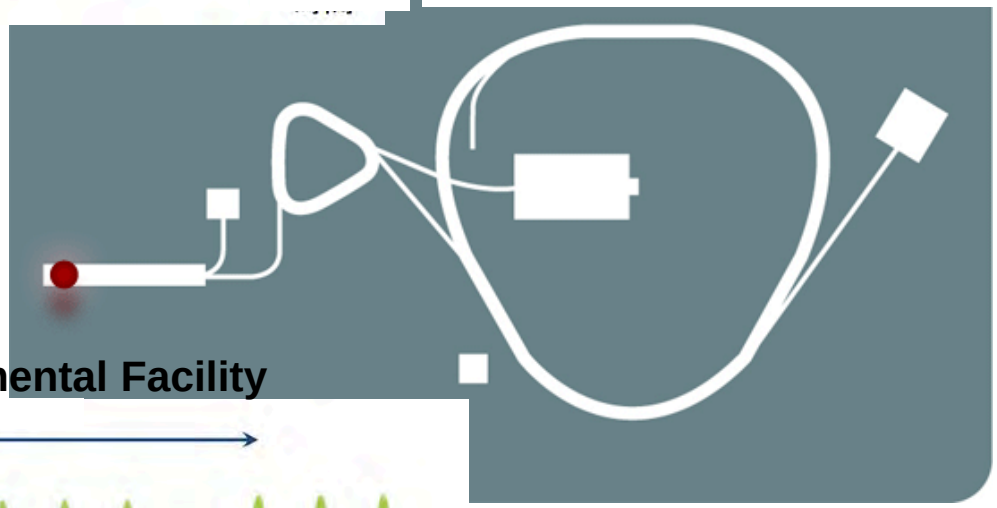
- An abnormal proton beam was injected to the gold target.
- The target heated up to a extraordinarily high temperature.
- Radioactive material was released from the target.
- The radioactive material was leaked into the HD hall.
  → Workers were exposed to radiation.
- The radioactive material was released to the outside of the radiation controlled area and to the environment outside of the HD hall.

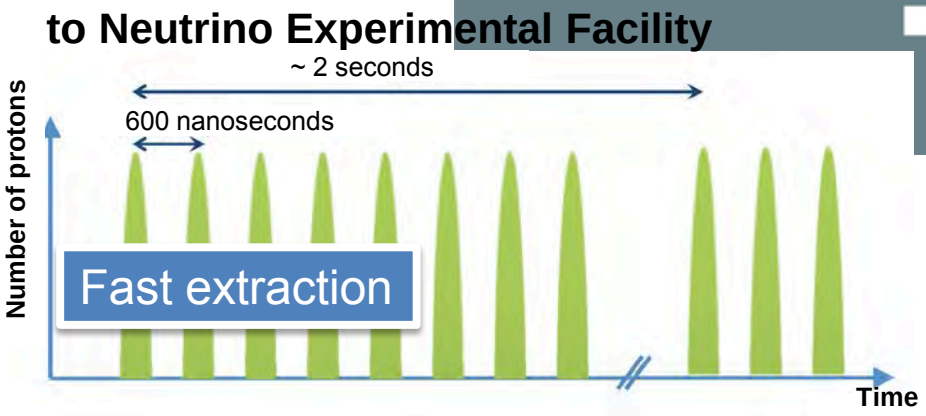


J-PARC Accelerators and Beam Extractions







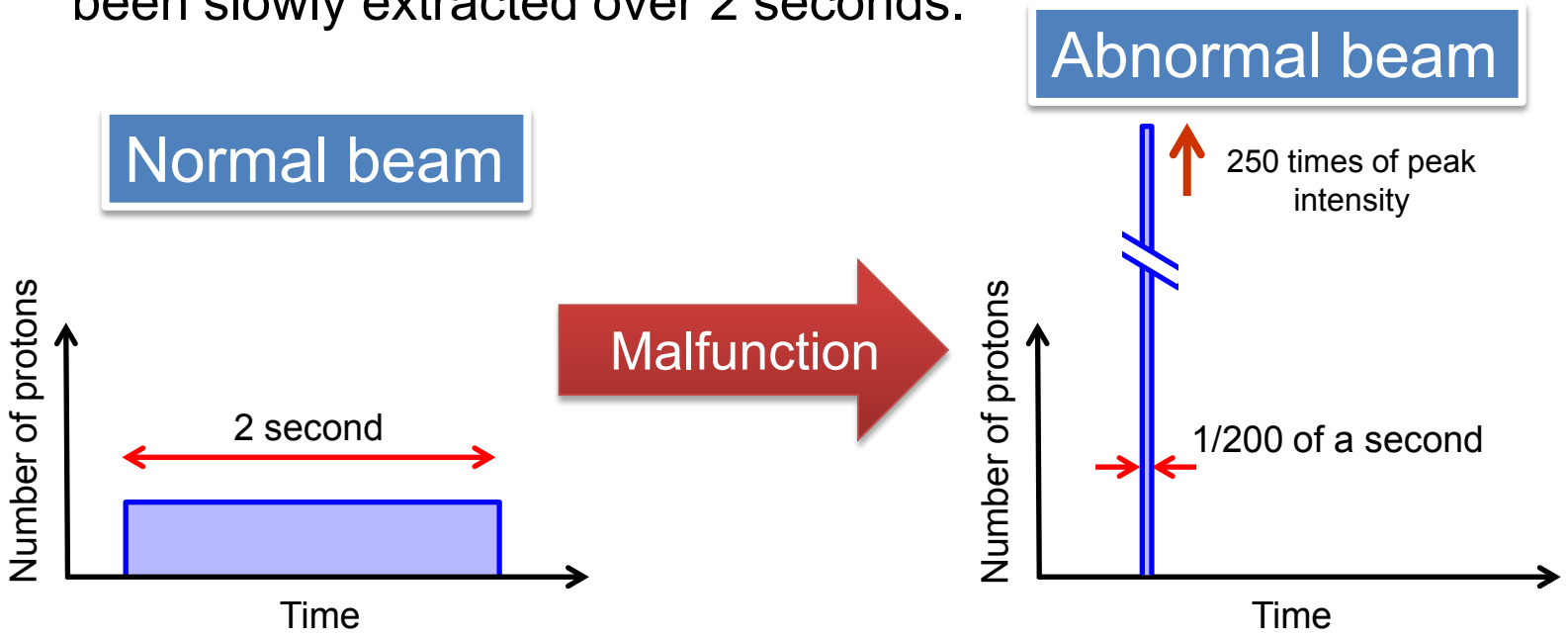


Time structure of the proton beams

Abnormal Beam

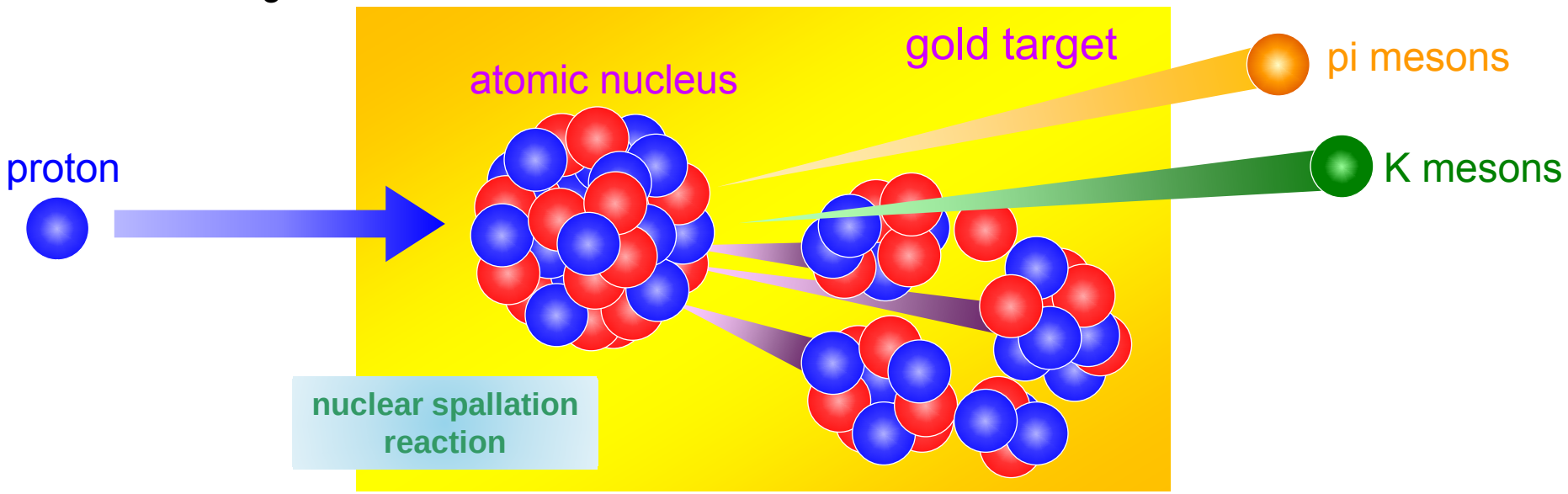
- At around 11:55 on May 23, the power supply system of a special magnet in the 50 GeV Synchrotron malfunctioned.

  → 2×10^{13} protons were extracted in a very short period of 5 milliseconds, while in normal operation 3×10^{13} protons should have been slowly extracted over 2 seconds.



Purpose of the Gold Target

- The target, when bombarded by high-energy protons, produces secondary particles (mesons), which then will be used for research
  - Radioactive material is produced by nuclear spallation reactions.
  - In normal operation the radioactive material stays in the gold target.
  - When the proton beam operation is stopped, nuclear spallation reactions stop and no new radioactive material is produced. Radioactive material decays within the target.

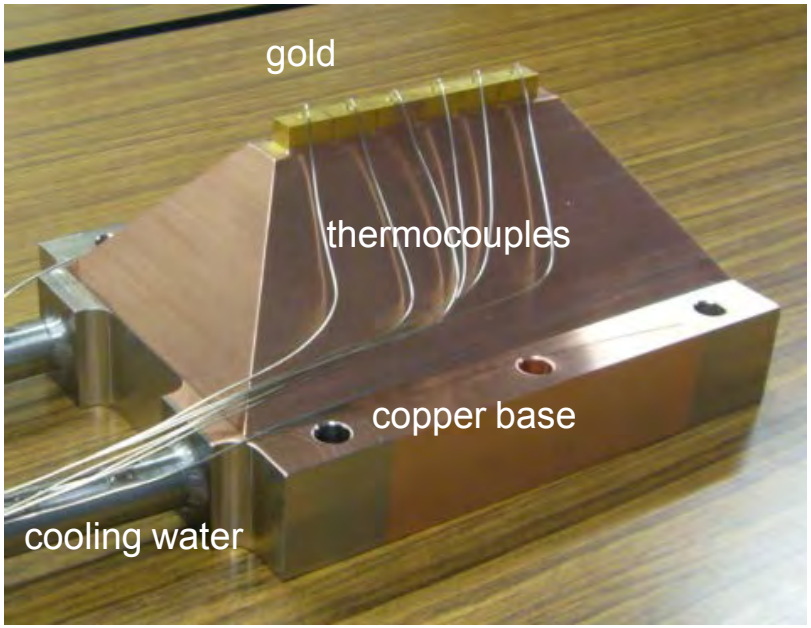


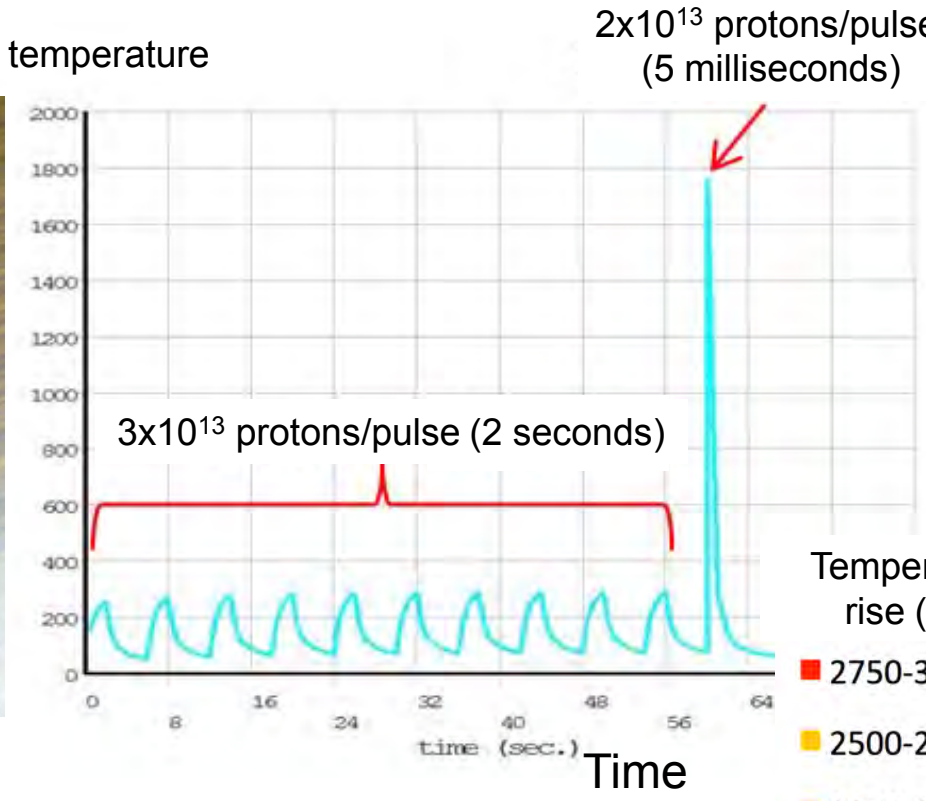
Gold, unlike uranium, is not a radioactive material.

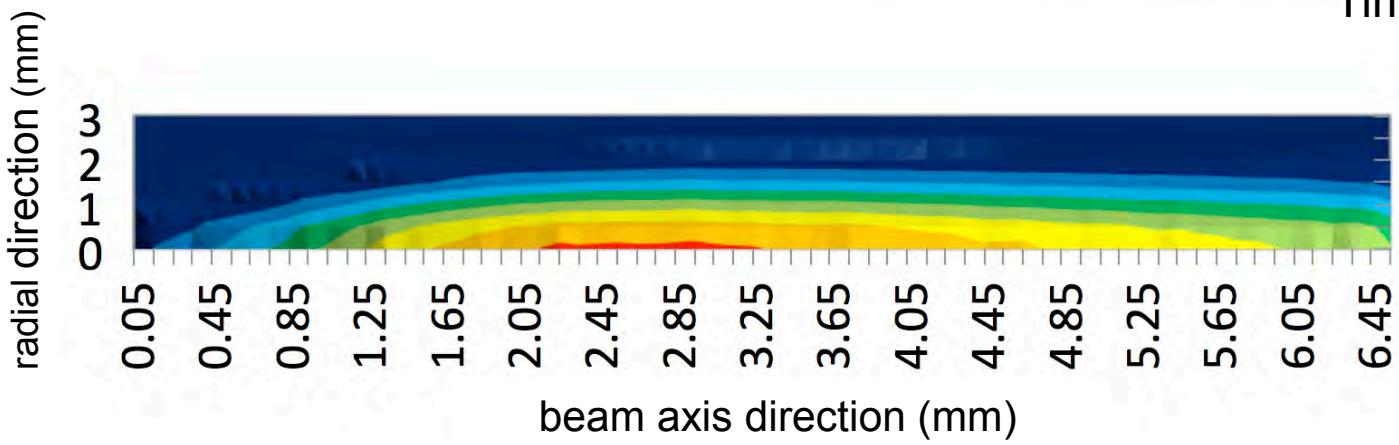
→ No nuclear chain reaction occurs.

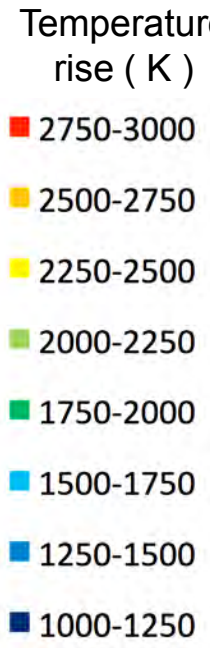
→ However radiations come out from radioactive material produced in nuclear spallation reactions induced by the proton beam in the gold target.

Target Temperature（Simulation Results）

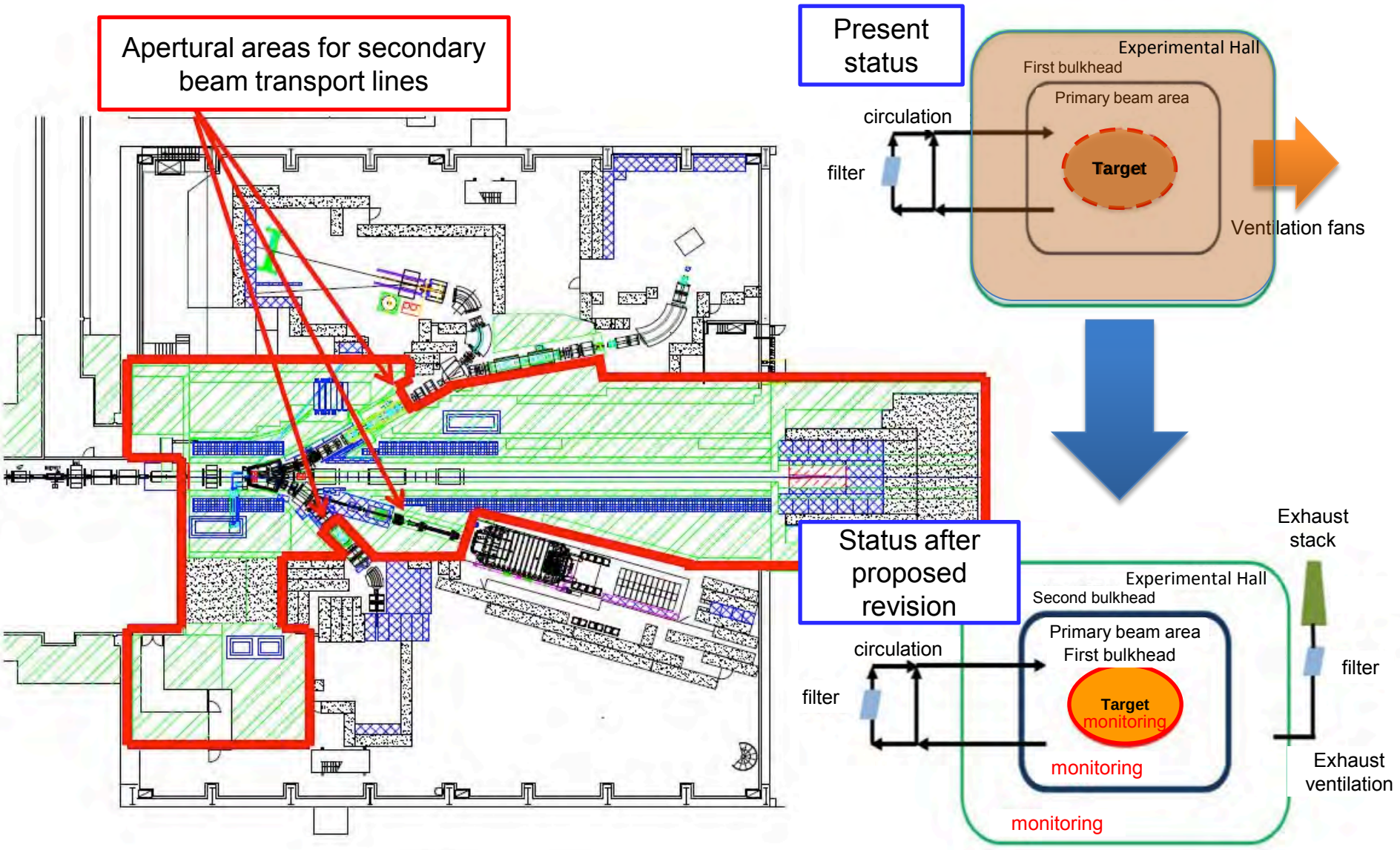








Hadron Experimental Hall



Chronological Sequence of Events

May 23, 2013

- 11:55 Delivery of proton beam from 50 GeV Synchrotron (MR) was halted by Machine Protection System (MPS).
- 12:08 MPS was reset following the regular resetting procedure after discussing with relevant people and delivery of proton beam for users' experiments was resumed.
- 13:30 Increase in radiation dose rate of an area monitor in the HD hall was acknowledged. The maximum value of 4 μSv/h is ten-fold of the normal value.
- 15:15 Ventilation fans were turned on. Further decrease in ambient dose rate was acknowledged.
- 17:00 Radiation survey of the HD hall found areas with high dose rate were localized.
- 17:30 Ventilation fans were turned on to reduce airborne radiation dose rate in the HD hall.
- 23:30 Completed evacuation and full-body radiation surveys of all workers in the radiation controlled area. Access to the HD Facility was restricted.

May 24, 2013

- 10:00 Members on the right held a meeting to discuss the situation. It was not considered this incident to be one for escalated reporting.
- 17:30 J-PARC Center received inquiry from Nuclear Fuel Engineering Laboratories concerning increased radiation levels recorded by their monitoring posts
- 18:00 Data logs of gamma-ray area monitors on the boundaries of the controlled area of the HD Facility were examined. Found increased radiation levels at around15:00 and 17:30 on May 23. Found that the increased dose rates coincide with the operations of ventilation fans in the HD hall.
- 21:10 Reported to an emergency post of the Nuclear Science Research Institute. Response headquarters was established.
- 22:40 As required by law, the first report to Nuclear Regulation Authority 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.

May 25, 2013

- 01:00 Found out that the maximum total exposure dose of the workers in the HD hall was 1.7 mSv.

Effects on the Environment 1/2

- **Evaluations based on measurements:**
  1. Increases of the radiation dose rates at monitoring stations of Nuclear Fuel Cycle Engineering Laboratories
  2. Nuclides and radioactivities found in the airborne sample from the HD hall
  3. Direction and velocity of the winds at the time of release of radioactive material on May 23

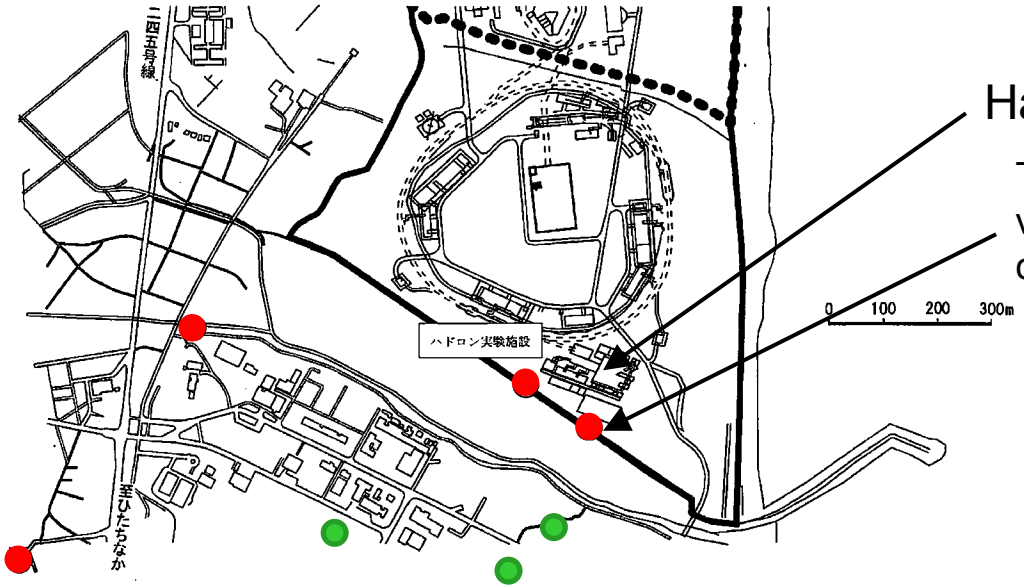
- **Two kinds of calculation methods used in estimations:**
  1. Analytical method based on diffusion equations for radioactive material
  2. The WSPEEDI−II code

nuclei	half life	radioactivities (Bq)
^{43}K	22.3 hours	64.0
^{24}Na	15.0 hours	63.5
^{199m}Hg	42.6 min.	61.0
^{197}Hg	64.9 hours	39.5
^{76}Kr	14.8 hours	32.4
^{131}I	8.02 days	28.6
^{82}Br	35.3 hours	19.5
^{195m}Hg	41.6 hours	18.4
^{123}I	13.3 hours	17.2
^{95}Nb	35.0 days	9.10
total amount		353

Radioactive material in the 500 ml airborne sample collected from the Hadron experimental hall.

Effects on the Environment 2/2

- The released radioactive material distributed within a narrow area of the west from the HD hall.
- The maximum integrated radiation dose at the site boundary is estimated to be 0.29 μSv at a location close to the HD hall.



Hadron Experimental Hall

The point shows the maximum value of radiation dose from the calculation results.

monitoring posts that observed momentary increases of radiation dose rate on May 23.

locations where soil samples were taken on May 26

Nuclear Fuel Cycle Engineering Laboratories

- Examination of soil samples from four locations.

→ No radioactive material originating from the accident was detected at any of these locations.

Delays in Reporting and Announcing

【May 23】

Our investigation indicates the following:

- A part of the gold target was damaged. Radioactive material leaked into the HD hall and contaminated the floor, etc.
- Workers in the HD hall may were exposed to internal radiation.

← The leaders considered that contaminations were limited to a radiation controlled area and the exposure dose was below what was expected in normal operation. Hence they considered that this incident would not have to be reported as an accident.

【May 24】

Small increases of the dose rates were found at around 15:00 and around 17:30 on May 23, in coincidence with the operations of ventilation fans on that day.

→ The leaders determined that radioactive material had leaked to the area outside the radiation controlled area and they reported to an emergency post of Nuclear Science Research Institute.

Radiation Exposure

Measurement on internal and external radiation exposure doses of all the persons who entered the radiation controlled area of the HD Facility after the accident:

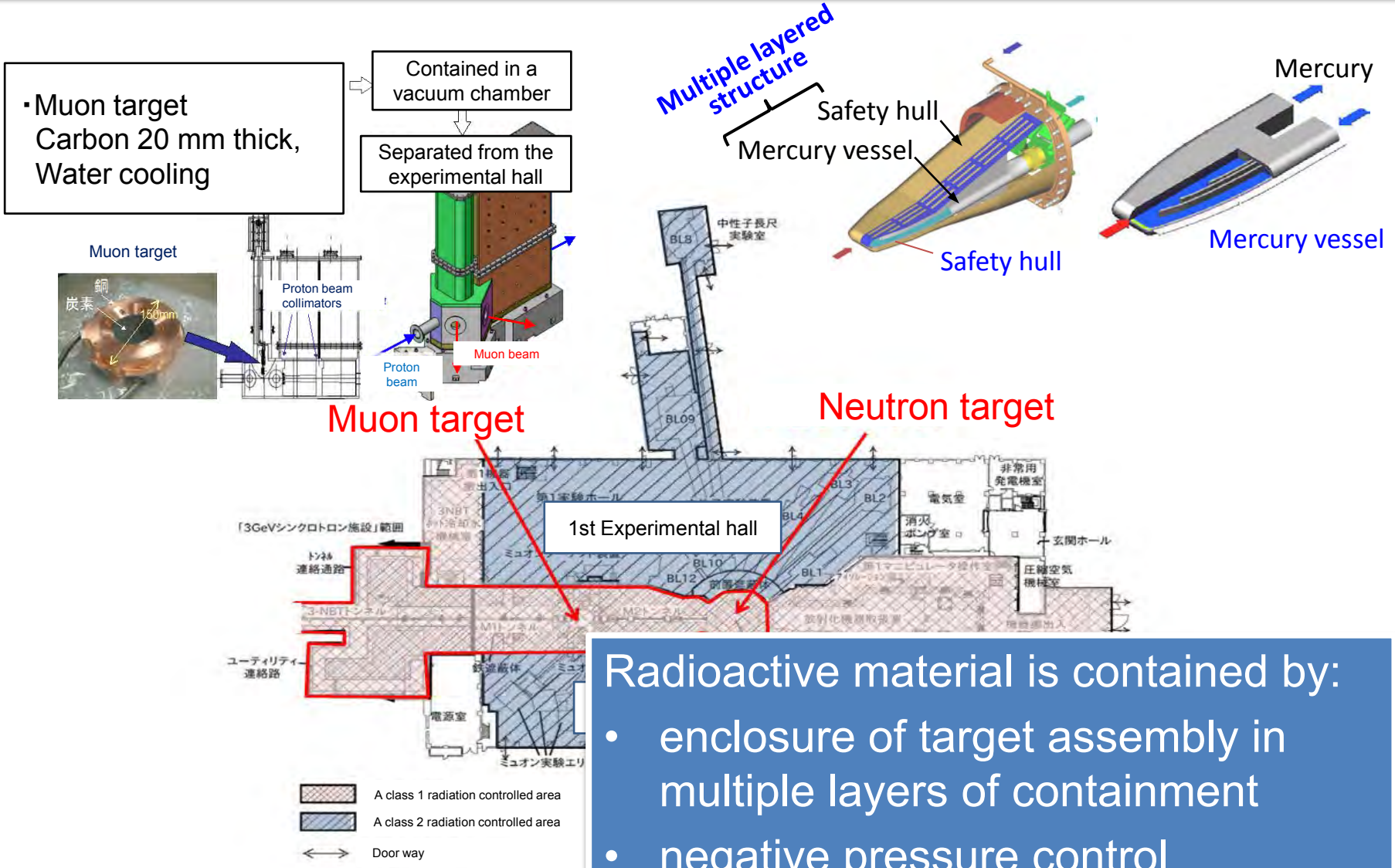
- Total number of personnel：102
- Number of personnel with detectable dose：34

  Note: All are registered radiation workers. Individual doses are in the range of 0.1−1.7 mSv.
- Number of personnel with no detectable dose：66

  The remaining two, who were from overseas, had their whole body counter measurements at home later, and have been found to have no detectable dose.

Other Facilities at J-PARC

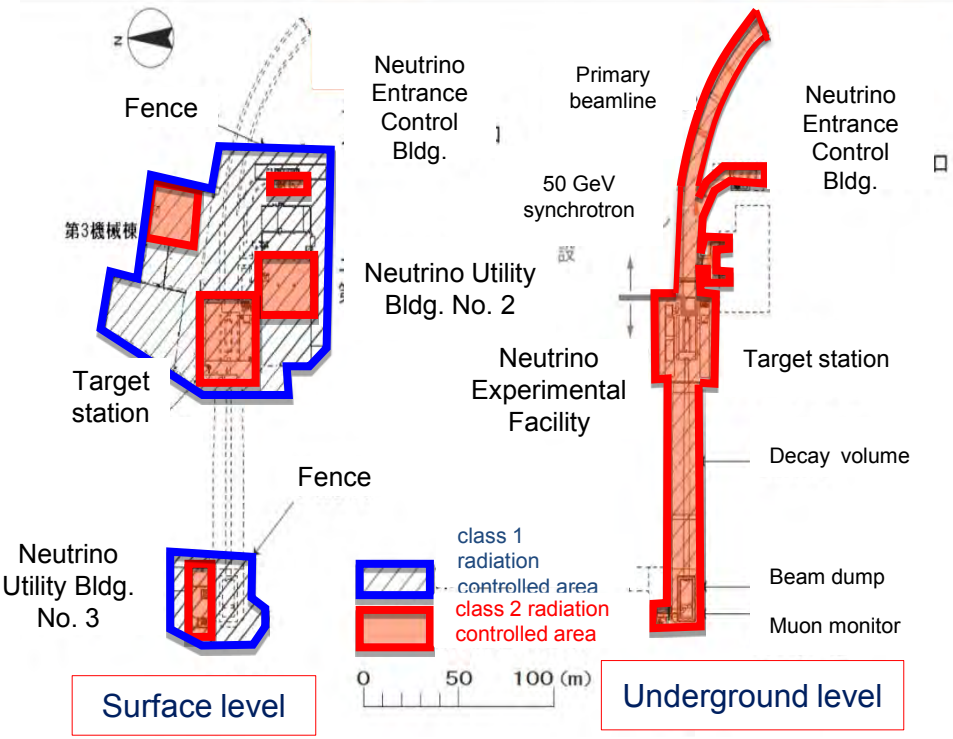
Materials and Life Science Experimental Facility

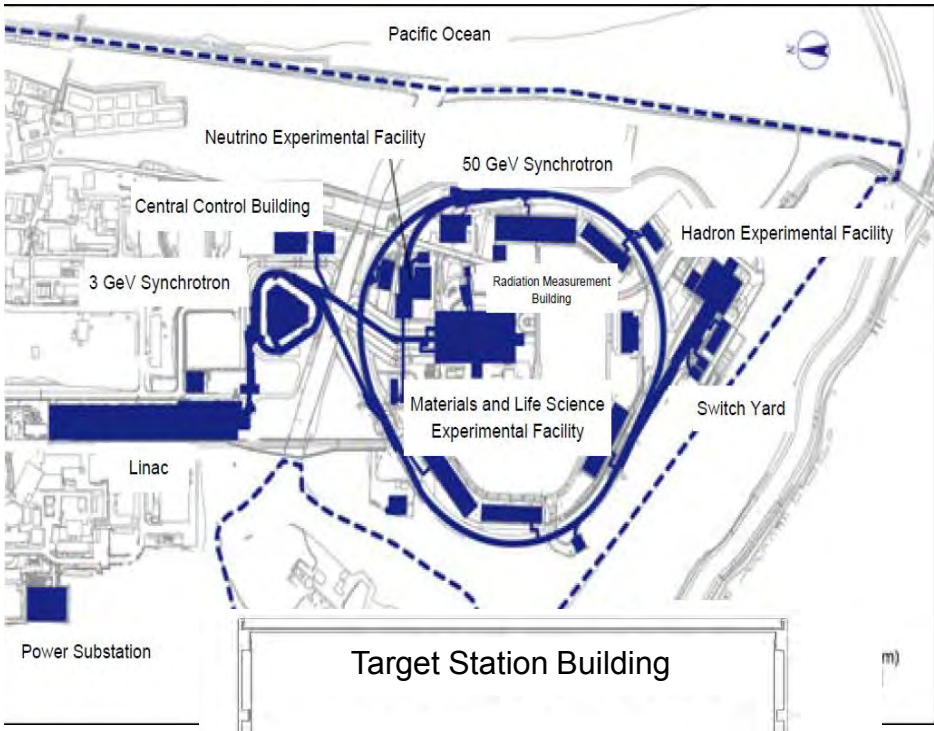


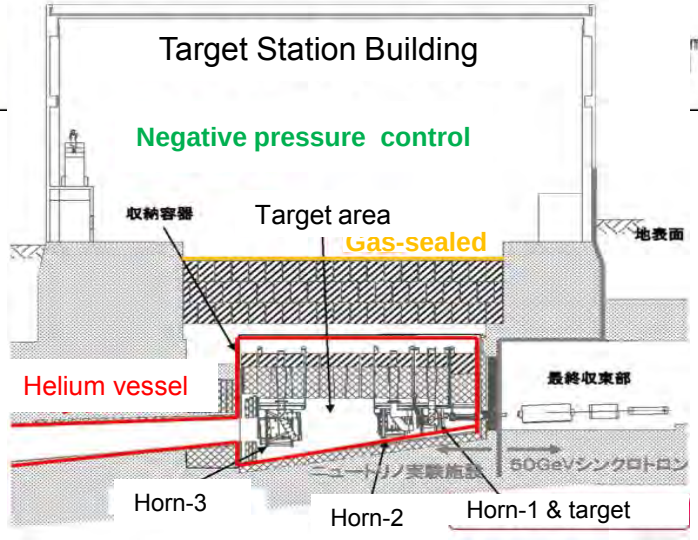
Radioactive material is contained by:

- enclosure of target assembly in multiple layers of containment
- negative pressure control

Neutrino Experimental Facility





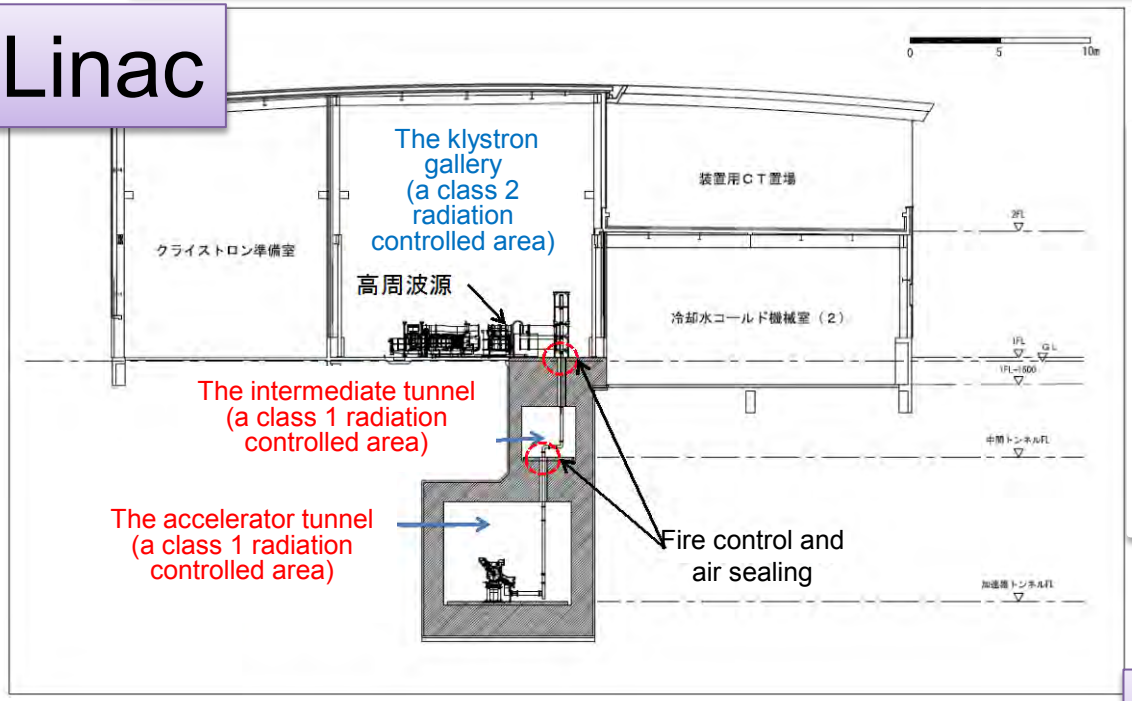


Radioactive material is contained by:

- filtered exhaustion of interconnection areas
- negative pressure control

Accelerator Facility Complex

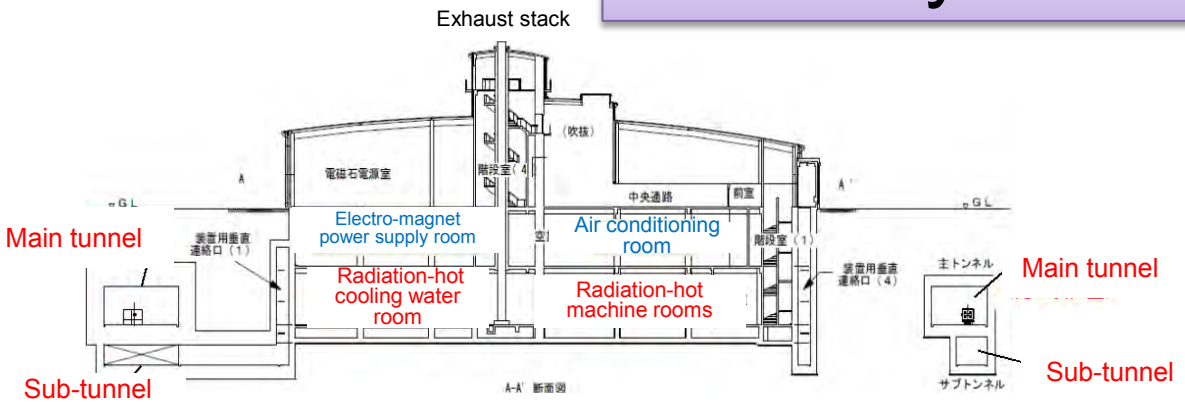
Linac



Radioactive material is contained by:

- two-layered containment
- filtered exhaustion of interconnection areas

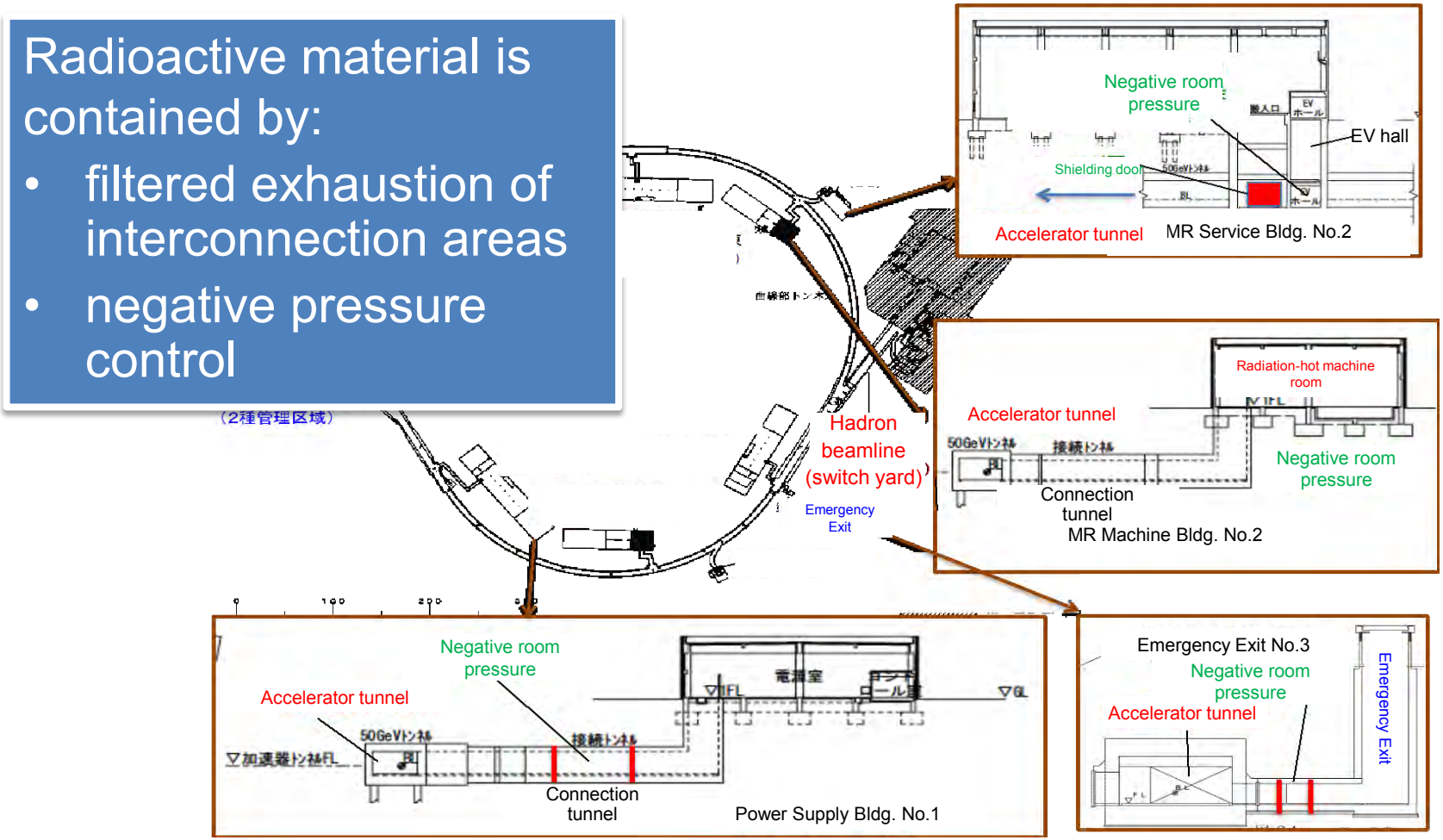
3 GeV Synchrotron



Accelerator Facility Complex

Radioactive material is contained by:

- filtered exhaustion of interconnection areas
- negative pressure control



50 GeV Synchrotron

Plans for the Near Future

- Continued investigation of facilities and instruments
  - Target area of the HD Facility
  - Power supply unit which experienced the malfunction causing the abnormal beam extraction

Determination of the causes and development of preventive measures

- Evaluation of the total amount of radioactive material released from the HD Hall to the environment
  - Detailed analysis of the air sample which was collected at the HD hall
  - Simulation to reproduce the radiation dose rates observed in the HD Facility

Evaluation of the effects on the environment

Appendix 3

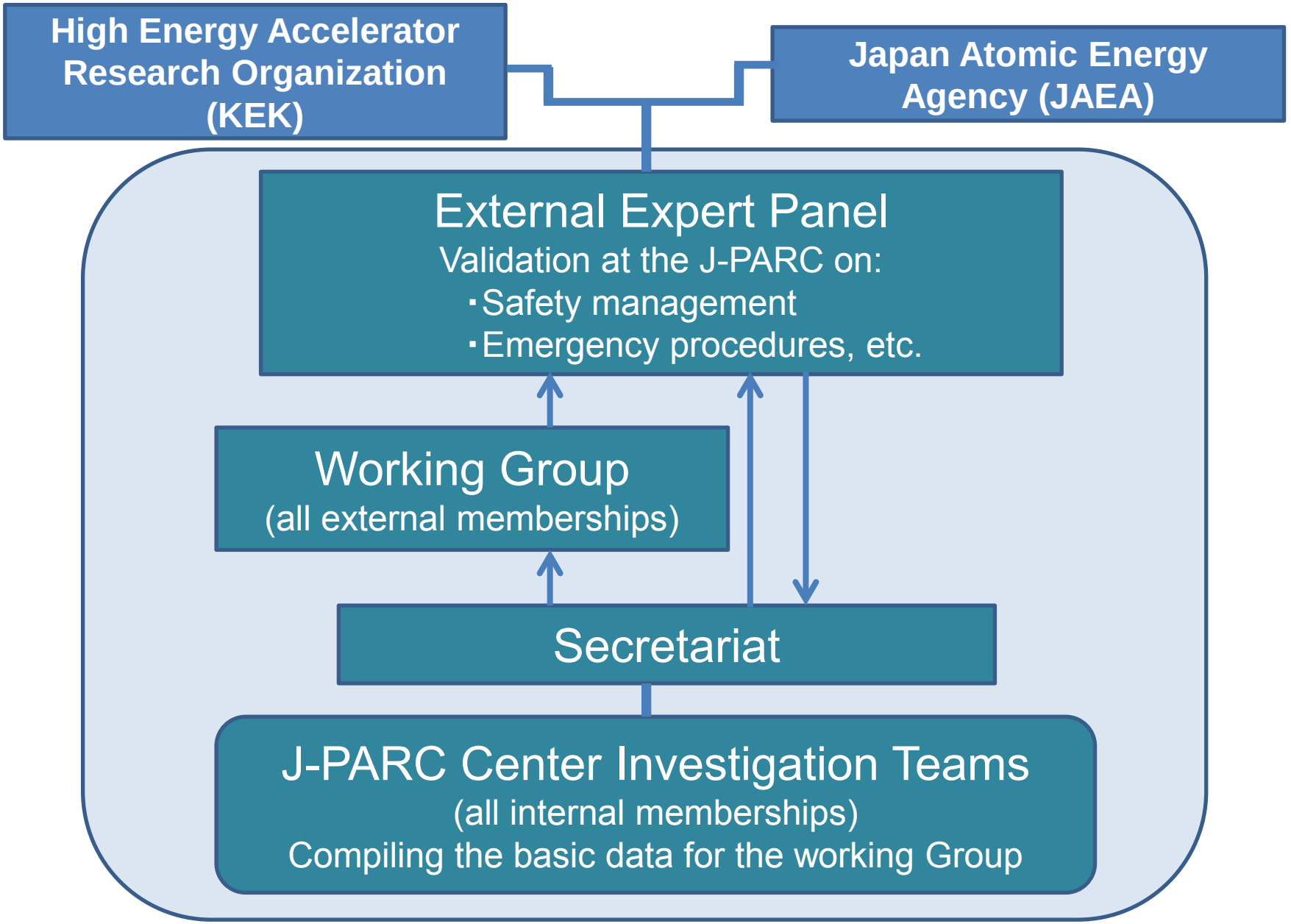
June 21, 2013

The First Meeting of External Expert Panel to Review the Radioactive Material Leak Accident at the Hadron Experimental Facility of J-PARC

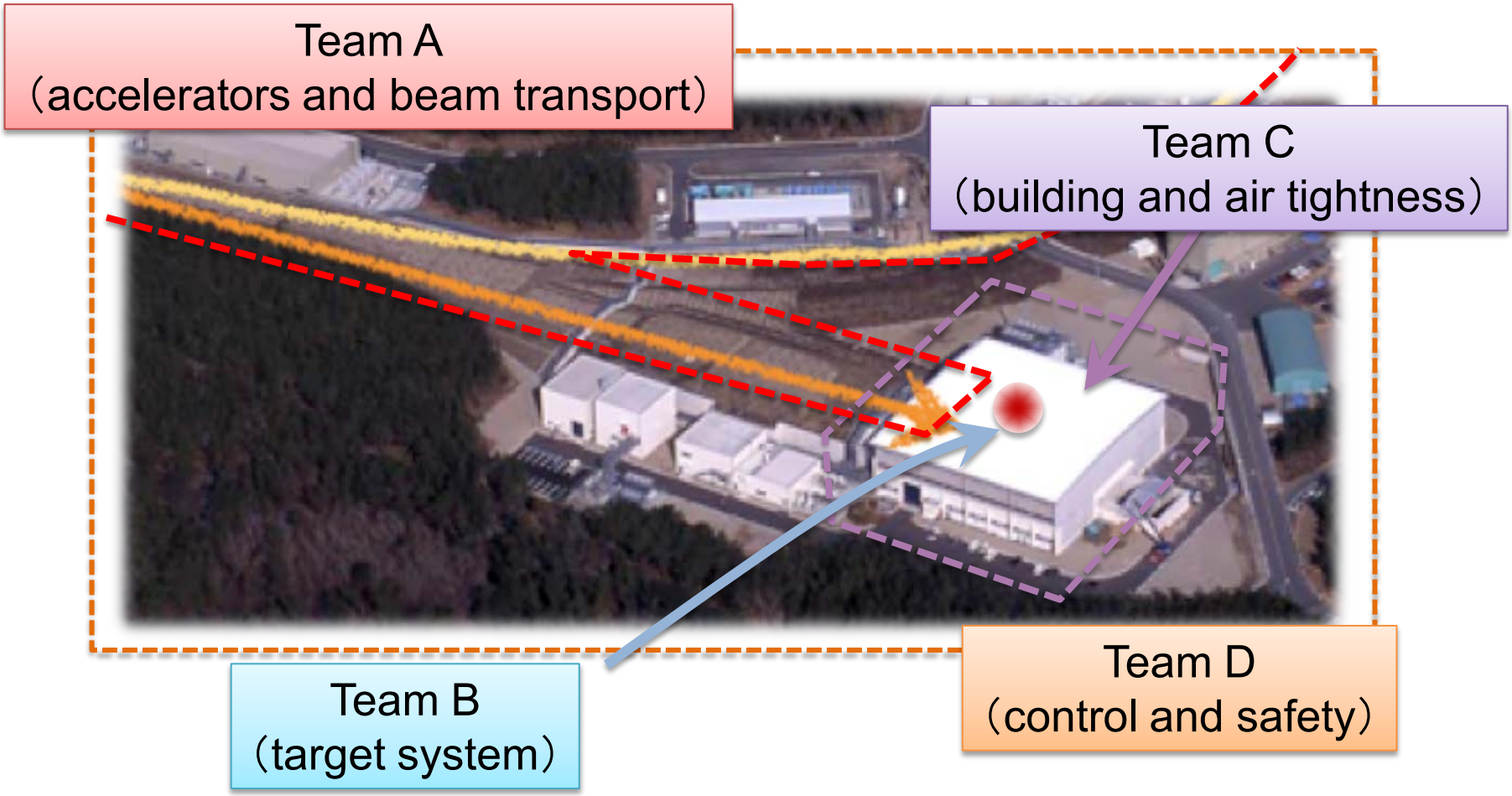
External Expert Panel: Viewpoints of Evaluation

- ☐ Evaluation of overall response to the accident, including the organizational framework
  - Investigation of causes of the accident, analysis of contamination, radiation exposure and environmental impact
- ☐ Evaluation of countermeasures
  - Revalidation of safety management system including developing preventive measures against recurrence of similar accidents and review of radiation controlled areas in the J-PARC facilities
- ☐ Organization of J-PARC
  - Relationships between the accident and the organization and operation of the J-PARC center that is jointly managed by KEK and JAEA
- ☐ Efforts to promote the safety culture, etc.

Organization of the External Expert Panel



Investigation Teams



Examination of Timeline of Incidents

Timeline of incidents, judgements and actions

Serial numbers in red are listed events in the "Chronological Sequneceof Events" of the 1st Official Report .

Timeline serial number		Beam	Incident			Who took action:	Who made a judgement on what and why
			Time	Source of infor-mation	Item (What happened / What was done)		
	Date				Hadron operation was scheduled for 24 hours this day. Three out of the four beamlines at the HD experimental hall was conducting beam experiments, while the remaining one was preparing the experimental setup.		
1	5/23/13		~11:55	zlog HDlog	MPS set in to stop beam operation (Detected signals) - MR-EQ "over voltage", "tracking error" - MR-RQ "over current" - MR-BLM - HD experimental facility BLM		
2			~12:06	zlog Hearing	Acc. Shift Leader asked for Mag. PS's opinion concerning the EQ anomaly. The Magnet power-supply staff immediately checked the control screen of EQ at CCR. While this was the first occurrence of a tracking error on EQ, the MPS status of the PS was able to reset with the standard procedure. EQ over-voltage is a relatively familiar status, and usually it can be reset without problems.	Acc. Shift Leader Mag. PS staff	Magnet power-supply staff considered that the PS returned to its normal status.
3			~12:06	zlog Hearing	Magnet power-supply staff reset the MPS status of RC overvoltage" is a relatively familiar error condition, an it can be restarted without problems. This time, the m restarted without problems, too.		
4			~12:06	zlog Hearing	Acc. Shift Leader reset the MPS status of MR-BLM on t consideration that it was due to miss-firing of the fast extraction kicker, since the BL-MPS was associated wit abrupt beam loss of the MR.		
5			~12:06	zlog HDlog Hearing	HD Shift Leader checked the status of magnet PS curre vacuum in the proton beam line, and reported them t Manager of Radiation Generator of HD , who were in After consultation, HD Shift Leader reset the BLM MPS reported to Acc. Shift Leader that the beamline is in a state.		

Incident, Action, Judgement, and Reason

- Incident of abnormal beam
- Damage of the gold target?
- Contamination in the hall
- Release of radioactive material
- Delays in reporting the incident, suspending accelerator operation, and stopping ventilation fans

Summary

- Overview of the accident
  - occurrence, hall contamination, exposure, leakage of radioactive material to the outside of the radiation controlled area and responses after the accident
- Status of the other facilities
- Status of the investigation
  - hardware aspects (facilities and instruments)
  - software aspects (safety management system)
  - the Working Group, secretariat and investigation teams