Reactor imaging technology for fuel debris detection by cosmic ray muon

Measurement status report in Unit-1

March 19, 2015

Tokyo Electric Power Company

東京電力 TEPCO

IRID

本資料の内容においては、技術研究組合国際廃炉研究開発機構（IRID）の成果を活用しております。

1. Introduction

- Fluoroscope technology development using cosmic ray muon is under progress by IRID and HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION (KEK) as part of subsidized project of Agency for Natural Resources and Energy related to “FY2015 Decommissioning / Contaminated Water Management subsidy”

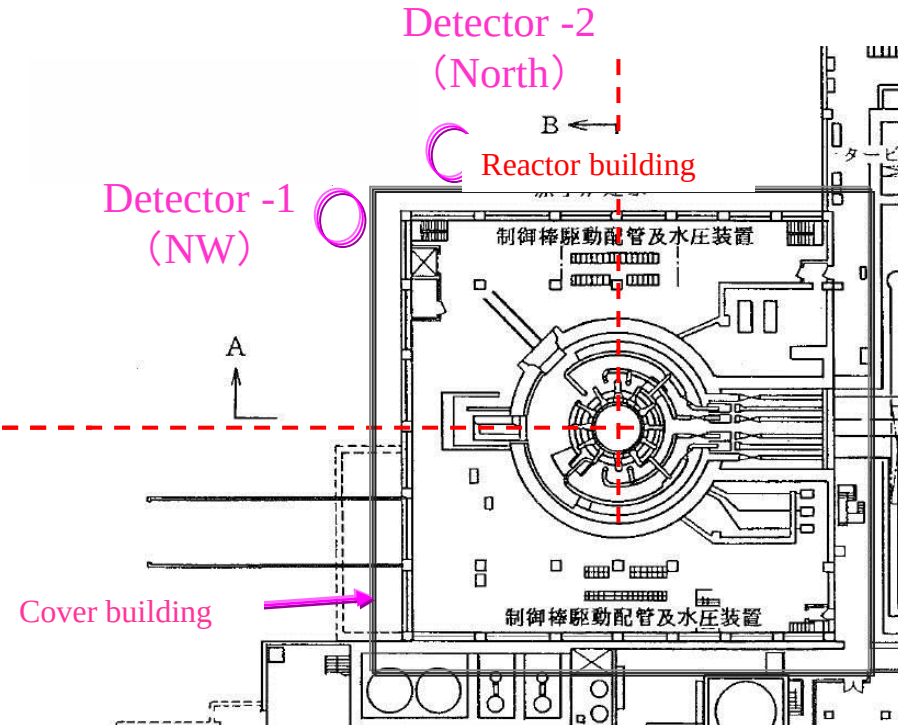
- On 12 February, the data measurement began after detector installing process completed (such as power reception and cable connection to the detector)
- Since then, the data had been accumulated until 10 March (altogether 26 days) and analyzed as first evaluation.
- The information is released in this report since sufficient data was collected at reactor core area located at the center of the observation view where huge amount of data was accumulated.

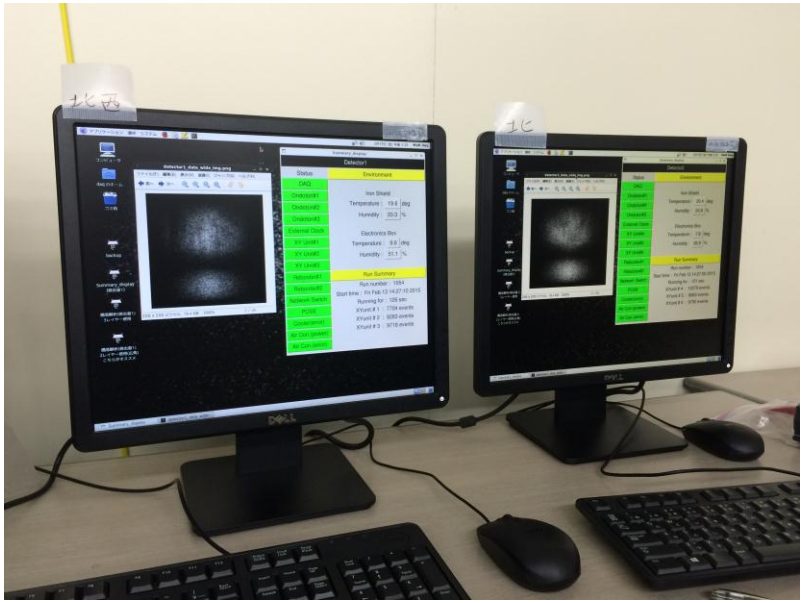
<Measurement Result>

- Currently, large lumps of fuel (measuring more than 1m) have not been confirmed at the reactor core where the fuel used to be located. This result is basically consistent with TEPCO’s previously announced estimation of the reactor and the containment vessel conditions.
- The result measured this time will become very relevant information in order to grasp the debris location to proceed with the decommissioning operation.
- After the result which indicates that the melted fuel moved downward, the plan is to conduct the investigation of the lower part of containment vessel, and identify the distribution status of fuel debris remaining in the lower part of reactor by using robots. Those results obtained by the investigations above will be reflected in the debris removal plan.

2. Completion of Muon detector system installation

■ The work began 9 February and Was completed 12 February. Detector-1 was installed at north-west side and Detector-2 was installed at north side of reactor building





■ A day after the measurement began, system confirmation was made on 13 February. Muon rays were measured stably by each detector.

- The effect of gamma rays to the data was almost none. The value at the installation decreased by half since the beginning of the project (0.4=>0.2mSv/h)

⇒ Confirmation that the detector works without trouble

3. Density-length image from Detector-1 (Image created based on the reactor design drawing)

Density-length image from Detector-1 based on design drawing

When the density of substances existing inside is higher, the more muon are absorbed. The Black part inside the reactor shows reactor core location. (Assuming fuel is not damaged)

Density-length is the multiplying structure density and length along with incidence path from the detector, which represents the extent of muon attenuation

4. Measurement result of the 26 days-data by detector-1 ,2

- Some structure and equipment edges were distinguished, although the data shown were not so detailed as that created by design drawing

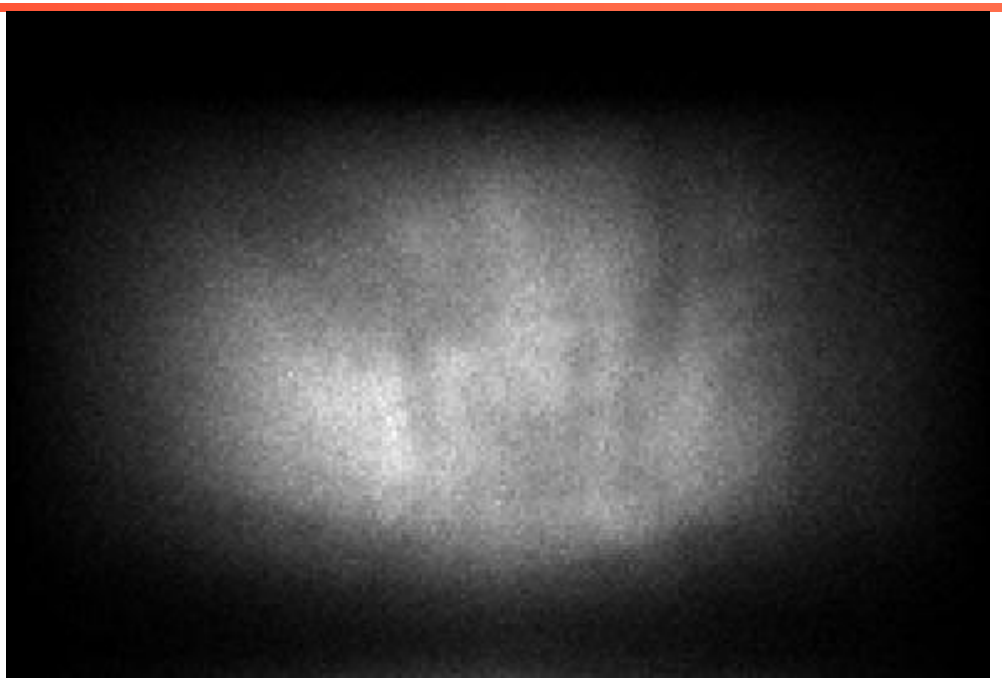


Photo 1: Taken by detector-2 (North side)

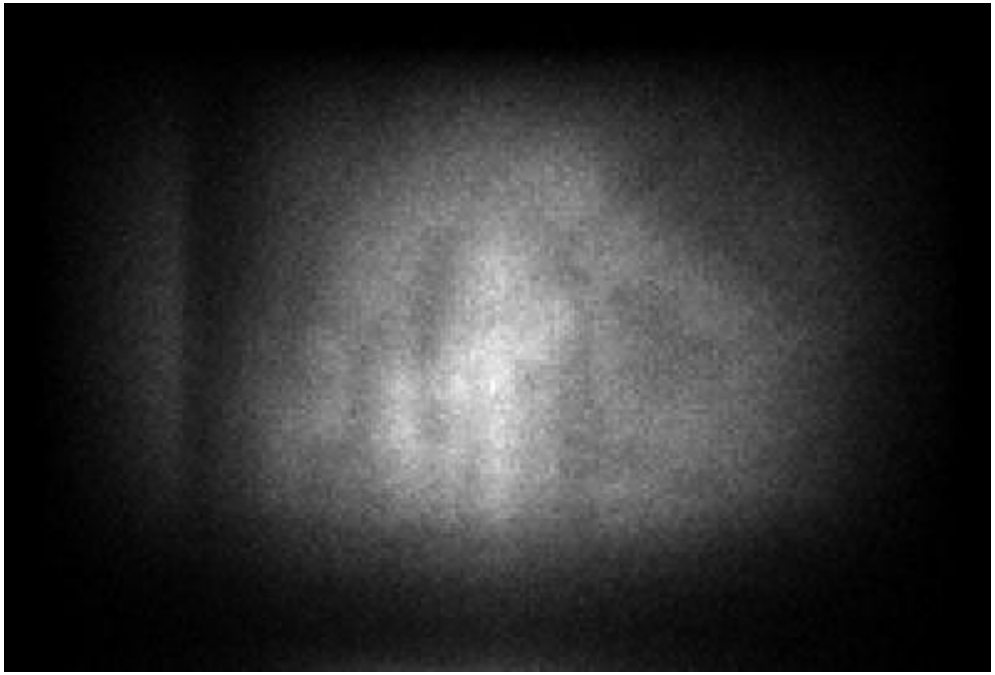
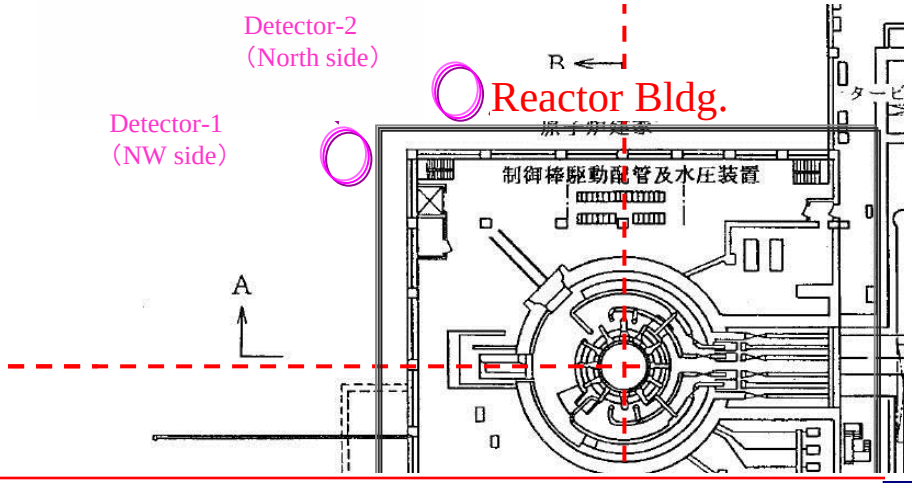


Photo 2 : Taken by detector-1 (NW side)



5. Interpretation of measured result by detector-1

Compare the measured result with actual structure and equipment layout of Unit 1

Density-length image
based on design drawing

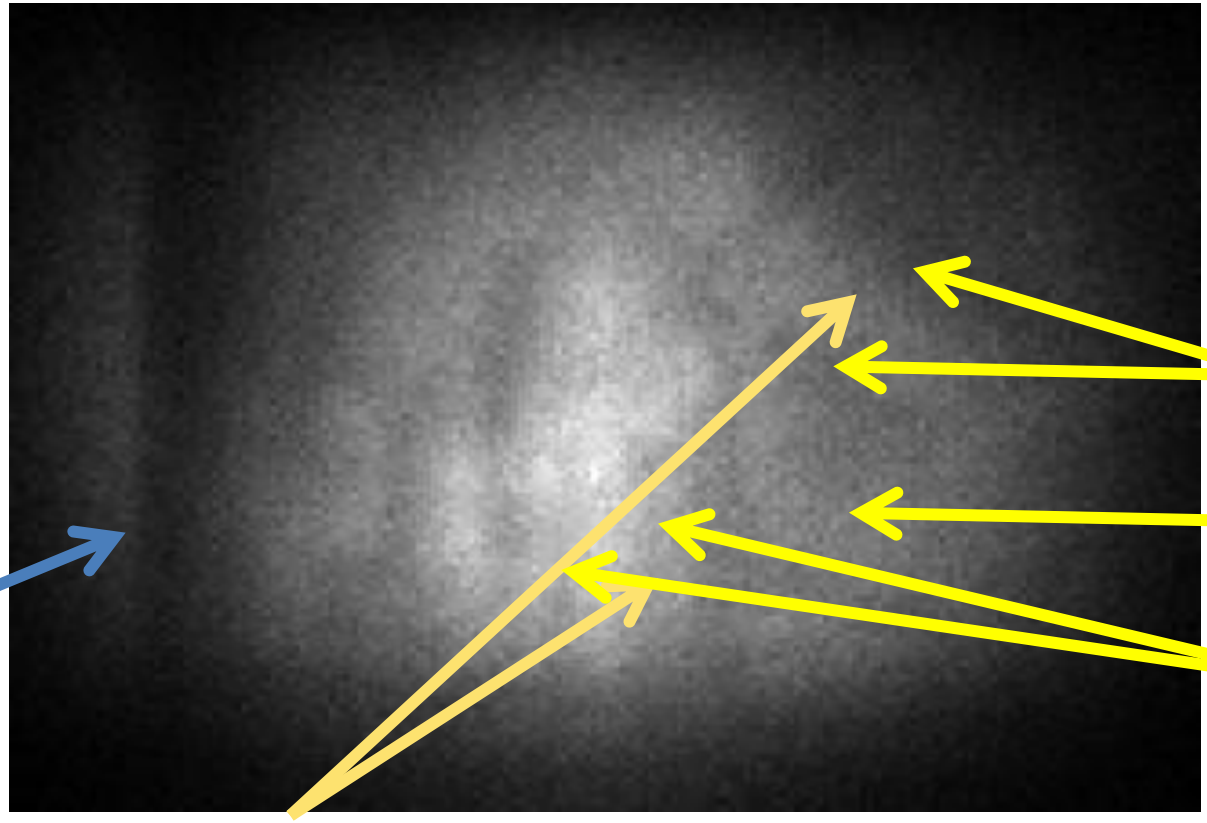
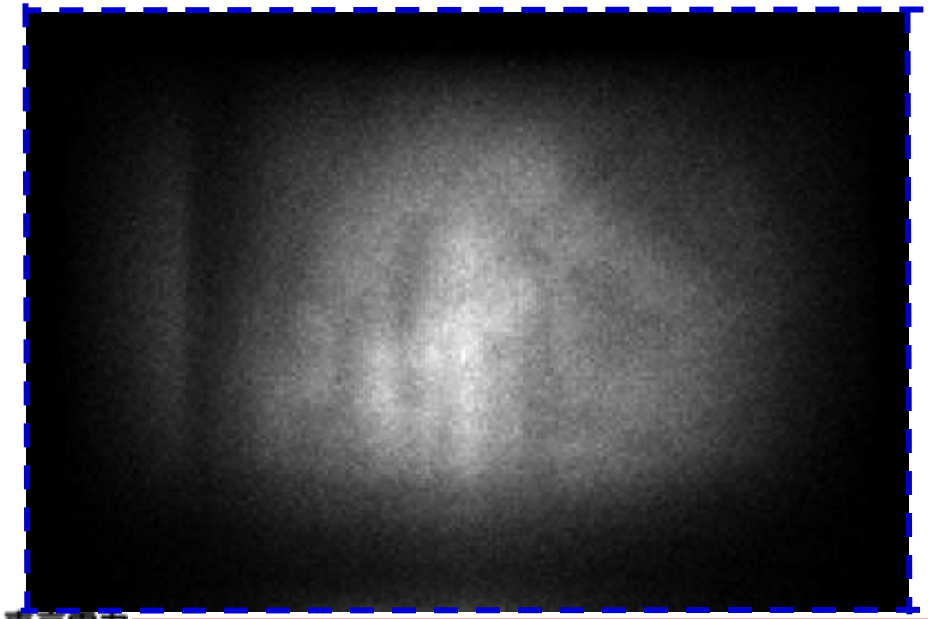
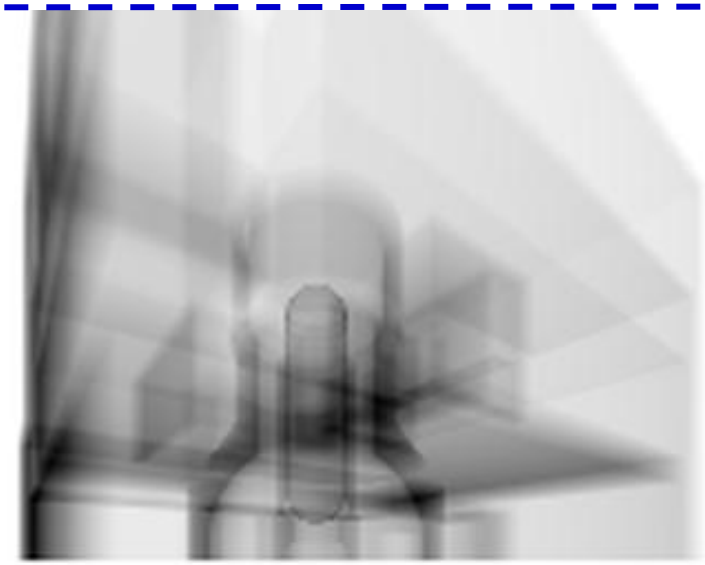


Photo : Measurement result taken by detector-1 and the interpretation

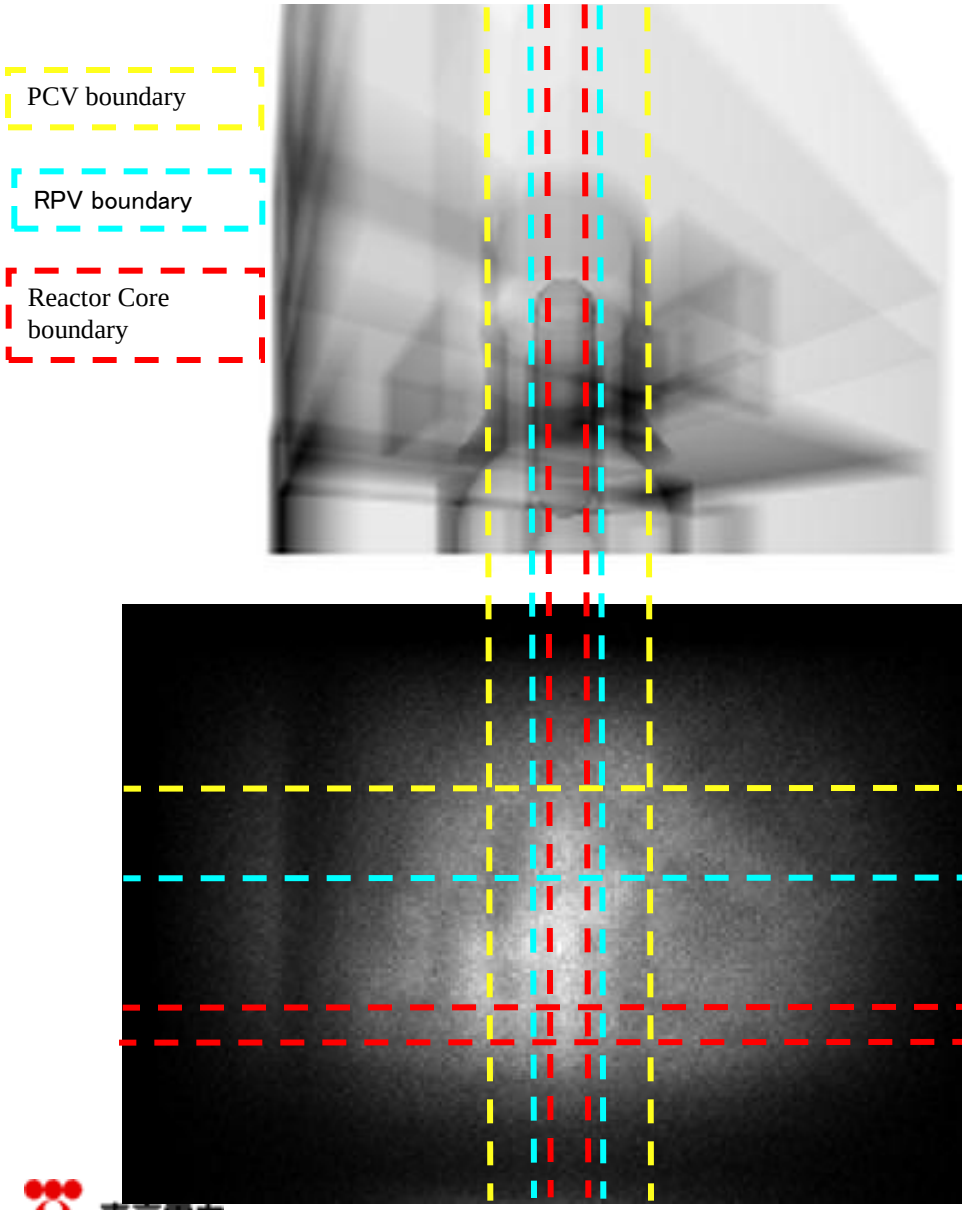
Structure edge can be identified clearly,
however high-density lump can not be distinguished inside RPV

6. Qualitative estimation of debris existence by comparing image with design drawing (detector-1)





6. Estimated position of debris by comparing design drawings with measured image (detector-1)



- Although the image of the measurement data is not so clear, it shows that the PCV, the PRV and the core are in positions where they should be.
- In addition, the boundaries of the PCV and RPV on the design drawings match those on the measurement data.
- However, the measurement data do not show the existence of high-density substances (fuels) in the original position of the reactor core.

7. Results of twenty-six day measurement with detectors 1 and 2

The results gained from the detector 1 (North West side) do not identify fuel debris inside the reactor, while those from the detector 2 (North side) appear to show something exists inside.

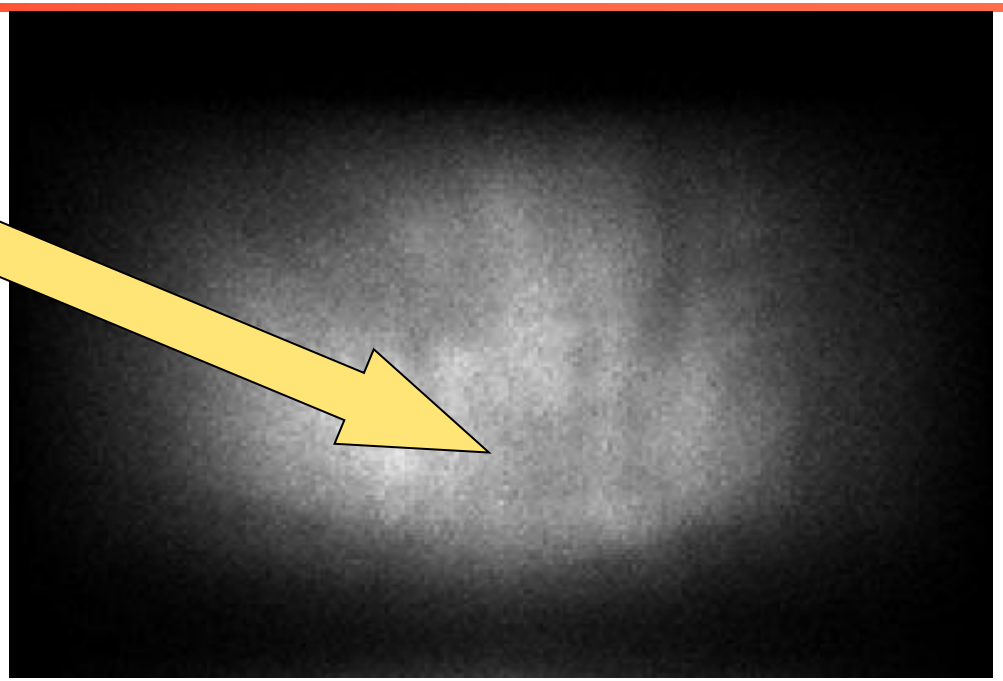


Figure 1. Measured image from the detector 2 (North side)

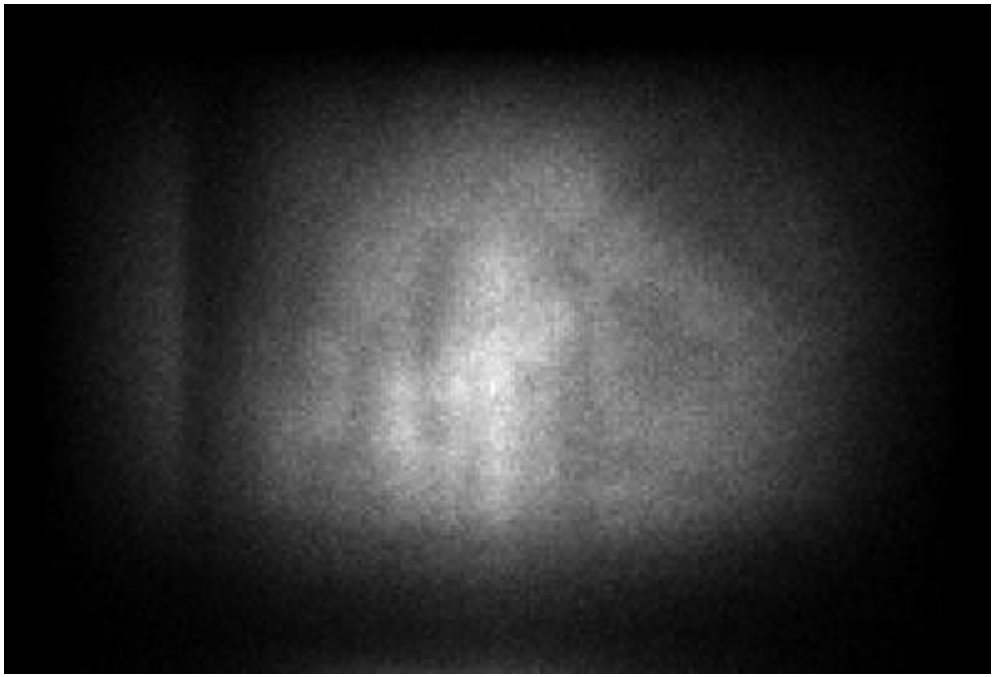
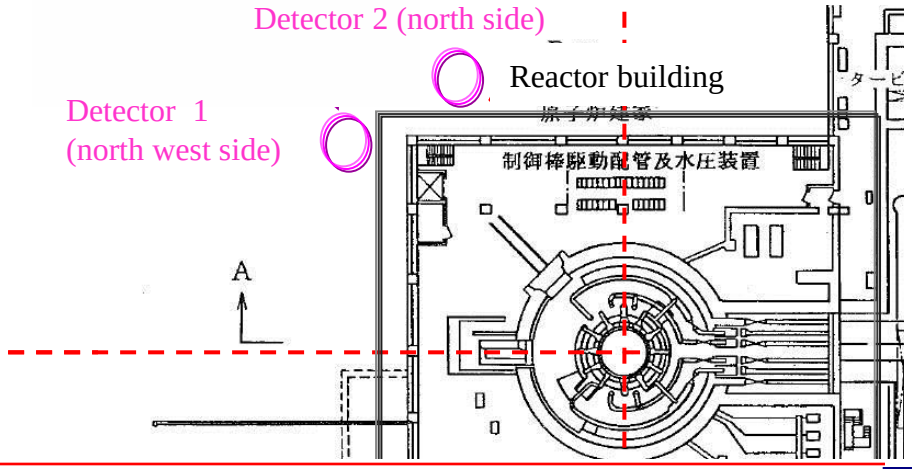
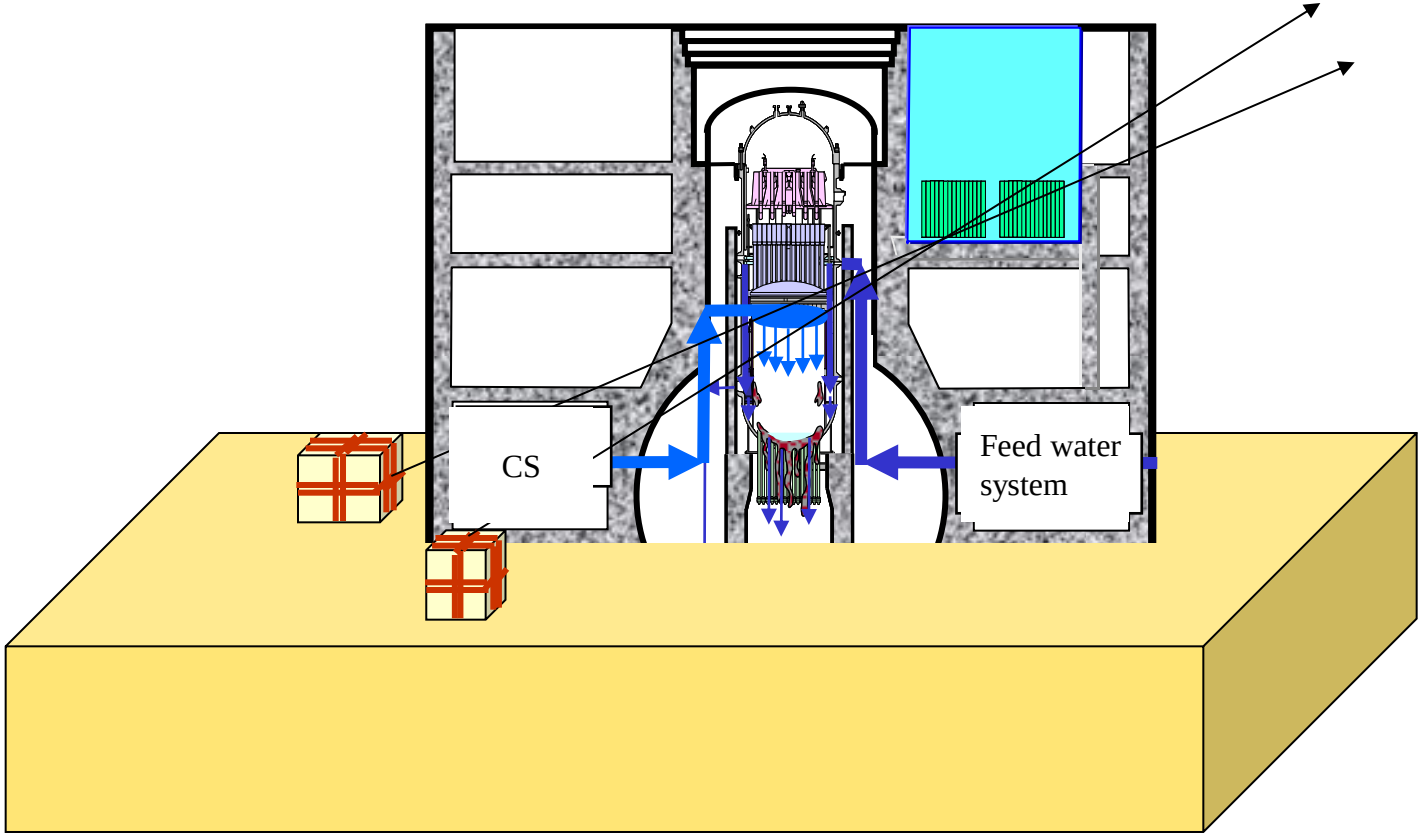


Figure 2. Measured image from the detector 1 (North west side)



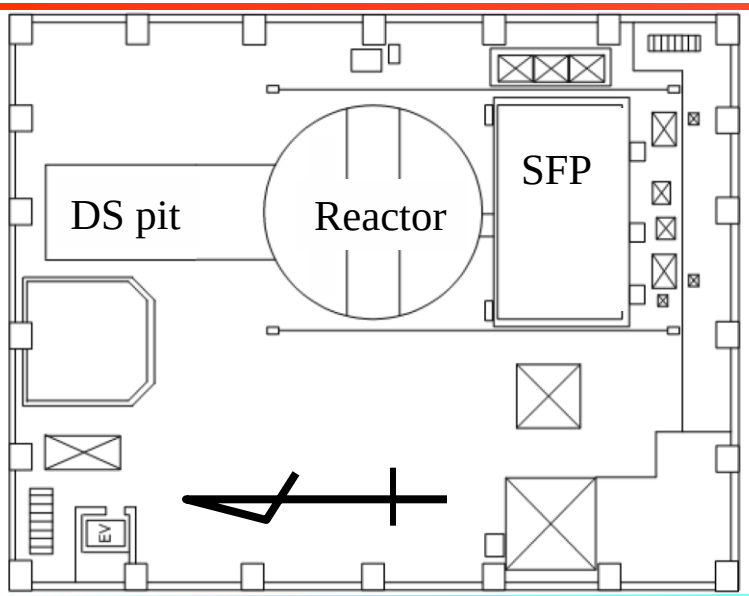
8. Reconstruction method for 3D images of high attenuation material position



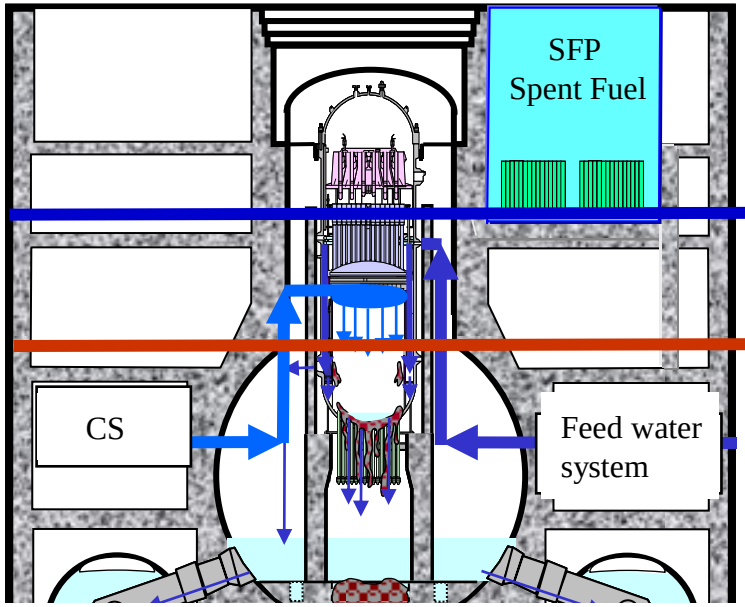
In principle, permeation method can only provide 2D images. The use of two detectors, however, makes the reconstruction to create 3D images possible by combining the data from the two different angles and finding the intersections of the cosmic rays traveling to high attenuation materials .

The position of the black objects on the data measured by the detector 2 (north side) will be estimated by three-dimentionally assessing them.

9.3D evaluation of position of high attenuation materials in cross sections



Cross section
of Operation floor



Cross section
Of SFP floor

Cross section
of core

Figure 1. Reactor Building layout (above: the operation floor on 5th floor, below: cross sections

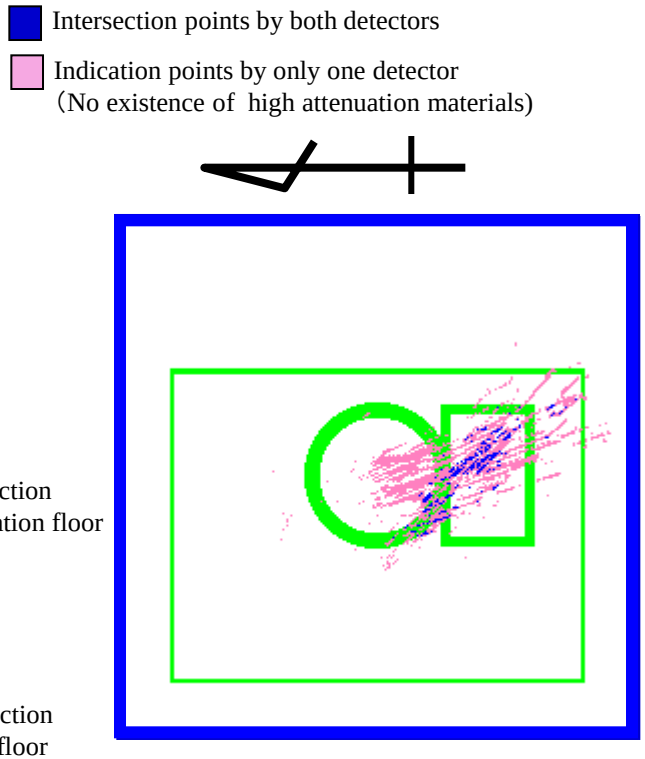


Figure 3. Evaluation of the cross section of the SFP floor
Some intersections（South side of Bldg, Corresponding to SFP）

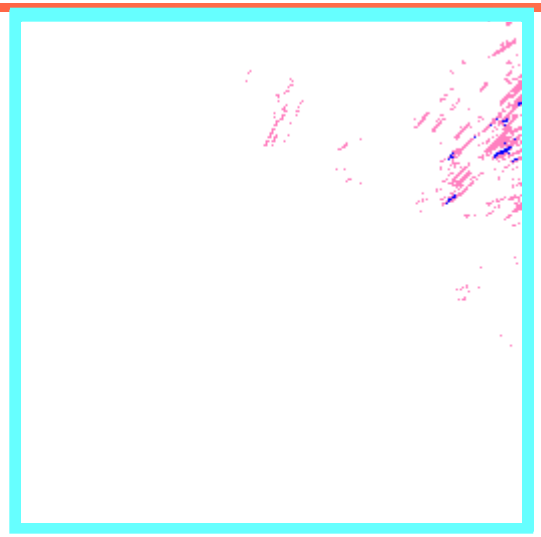


Figure 4. Evaluation of the cross section of the operating floor
No intersections (some noise detected)

Figure 2. Evaluation of the cross section of the core
No intersections

10. Summary

- Estimation results based on 26-day measurement data with the use of the detectors 1 and 2
  - High attenuation materials except fuel debris, such as the PCV wall, the R/B wall and the Reactor Core Isolation Cooling Condenser, have been identified.
  - On the other hand, current data shows no large fuel debris of more than 1m in the original core position.
  - There is a strong possibility that there is no water accumulated in the core area of RPV. (Reference: it was assumed through the water level gage calibration in May of 2011 that there was no water accumulated in the core area.)
  - Through the 3D evaluation, it has been estimated that there is fuel debris in the SFP. (How big they are will be calculated later.)
- These results agree with the TEPCO's estimation of the current core and PCV status.
- TEPCO will continue the measurement until it gains enough data to conduct the statistical analysis. To make it happen, it will ask for continued support from its cooperative third parties as well as the site.
- The estimation results this time are important to locate where fuel debris inside the PCV is. Knowing the location is essential for the steady decommissioning work.
- Given that the data gained from the measurement this time implied that a lot of debris have melted and fallen, TEPCO will start investigating the lower parts of the PCV to map the debris by employing robots. Taking into consideration the results of various investigations into the inside of the PCV, TEPCO will work out plans to remove the debris.

Ref: Investigation of the interior of reactor containment vessel in unit 1

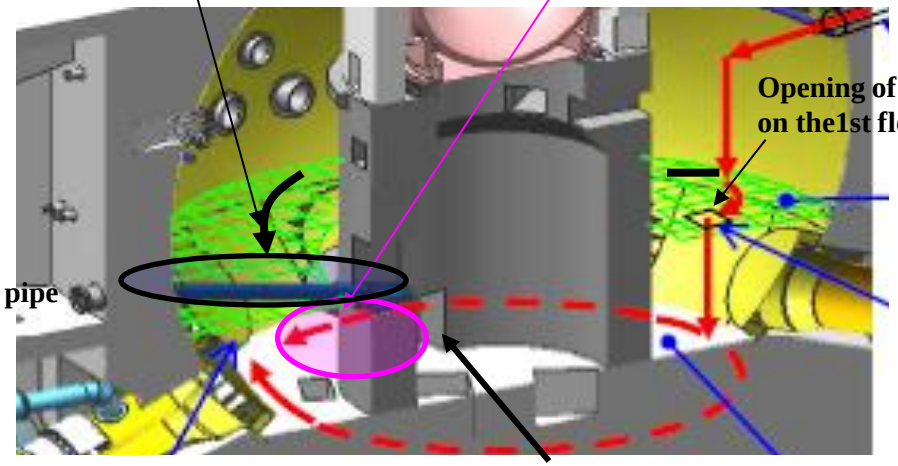
【Investigation area】: Underground floor pedestal (Outside)
【Investigation and equipment development steps】
Proceed with the investigation from B1→B2→B3 in turn from outside pedestal
(1)Investigation from reachable distance X-100B(Φ100mm)
① Planned investigation on grating at ground floor outside pedestal (to determine whether CRD rail can be used) : B1 (Planned for around April, 2015.4)
② Specific investigation of screen image obtained at underground floor outside pedestal and operator entrance : B2 (Planned for FY 2015-16)
(2) Investigation from X-6
①Install debris formation measuring apparatus for further recognition. : B3 (Planned for FY 2016-2017)

B1. Investigation on the surface of grating on the first floor except for the area of the pedestal (Around April 2015 planned to start) : use of X-100B pipe

B2. Investigation on the condition of the underground floor and the entrance/exit for workers except for the area of the pedestal (During FY2015-FY2016 planned to start) : X-100B pipe

Photo of the exterior of B1 device

The process of the operations and the way of the investigation may change depending on the site environment and the progress status of the development of the equipment.



The decision on whether the B3 investigation will be carried out depends on the results of B2 investigation.

B3. Investigation on the condition of the underground floor and the entrance/exit for workers except for the area of the pedestal (During FY2016-FY2017 planned to start) : use of X-6 pipe (debris detection devices installed)

Planning the investigation into the inside of the pedestal after the one into Unit 2