

1. Cyclotron facility at CYRIC

K=110 MeV Cyclotron

- Two cyclotrons are used for researches and education in
 - Nuclear physics,
 - Nuclear chemistry,
 - Nuclear engineering,
 - Nuclear pharmacy,
 - Nuclear medicine.
- A clinic of university hospital for PET patients.
- Officially open to internal users of university. (25% of users come from outside)

HM12 Cyclotron
(production of positron emitters for PET)

2. Location of CYRIC and Earthquake

Location of CYRIC and the Earthquake

- Sendai city is located 300 km north of Tokyo.
- The earthquake happened 70 km from Sendai.
- The maximum seismic intensity in Sendai was Level 6+.
- Many aftershocks happened including 170 Level 4 as of June 8th, 2011. (5 M7+, 82 M6+, 502 M5+)
- Fukushima nuclear power plant is 100 km away from Sendai city.
- As of June, radiation level in Sendai is below the global average (2.4 mSv/year).
- A task force of Tohoku University for the accident was established at CYRIC.

Area flooded by Tsunami (Tsunami didn't affect us)

Lifelines at CYRIC and at Downtown Sendai

- Electricity and water supply were stopped for 5 days
- Supplies of food, drinks and daily necessities were severely limited for 2 weeks.
- Supplies of kerosene for stoves and gasoline were severely limited for 3 weeks.
- City gas was stopped for 1 month.

Public transportation around Sendai

- Subway was partially resumed on Mar. 14.
- Bus was partially resumed on Mar. 14. (for university campus - Mar. 21)
- Trains were partially resumed on Mar. 31.
- Bullet train was resumed on Apr. 25.

Road to recovery of CYRIC (March)

- Mar. 11 earthquake happened
- Mar. 14 inspection for the buildings
- Mar. 15 recovery of electricity with confirming safety
- Mar. 17 recovery of water supply (toilet available)
- Mar. 23 first report on the damage situation

3. Damage of cyclotron pillars

- The K110 MeV cyclotron is placed on two reinforced concrete (RC) pillars, whose dimensions are 1.7 (W) × 0.8 (D) × 4 (H) m.
- Upper portions of the pillars were partly damaged.
- This caused a serious tilt of the horizontal plane of the cyclotron.
- One end of the cyclotron is 4 mm higher than the other (4 mm/4 m).
- The cyclotron should be leveled to within 200 μm/4 m.

reference point ±0 mm

+3.9 mm, +4.5 mm, +0.7 mm, +1.5 mm, -1.0 mm

4. Damage around the cyclotron

- Serious cracks on the floor
- Vacuum connection for pulser
- Supporting base for pulser
- Crack on acceleration chamber
- Beam line for pos. ions
- Main coil
- Rail for sliding short
- Beam line for neg. ions
- Bolt fracture at chamber-yoke connection
- RF circuit
- Scratch inside RF cavity
- Water leakage at connectors (more than 400)

5. Damage of shielding doors

- Drive mechanism were broken
- 15 tons doors were fallen down on the floor
- Doors were misaligned and chain were fractured
- Rails were sloped due to sink the foundation
- Door couldn't close due to sloped rail. This caused LS for radiation safety didn't work.
- Door didn't move due to incline.

- difficulty in bringing in tools for restoration work
- failing to satisfy the requirements for radiation safety

6. Other damage in cyclotron facility

- Buildings of CYRIC
 - Many cracks were observed, but not serious damage.
- HM12 cyclotron
 - Fixing pins were broken.
 - A water filling device for ¹⁸F was dropped and damaged.
 - Pipes for cooling water were damaged.
 - No fatal damages for the cyclotron were found.
- Ion sources
 - Some vacuum pumps were broken.
- Beam lines
 - Some beam lines sank 3 mm and displaced 1 mm.
 - 7 beam ducts were broken.
 - 10 electromagnets were broken.
- Experimental hall
 - 20 shielding blocks were displaced.
 - Air-conditioning duct was fallen down.
 - Lathe was fallen down.

7. Summary of damage

Costs for repair (CYRIC accelerator facility)

- K110 cyclotron : approx. 3.8 million-dollar
- HM12 cyclotron : approx. 0.2 million-dollar
- Beam line : approx. 2.5 million-dollar
- Power supply : approx. 1.2 million-dollar
- Shielding doors : approx. 1.4 million-dollar
- Total : approx. 9.1 million-dollar

The costs for repair was covered by the government. No one injured at CYRIC.

Tohoku University

- Safety search for all the students and staffs of Tohoku University was completed on Apr. 13.
- Two undergraduate students were killed by Tsunami.
- Damage to buildings : Dangerous -- 28 buildings (4.7%)
 - Caution needed -- 48 buildings (8.2%)
- Reconstruction/repair costs : approx. 560 million-dollar
- Damage to facilities : approx. 440 million-dollar
- Damage to students residences : (completely destroyed/partially damaged) 526

8. Road to recovery

- Repair of shielding doors were assigned the highest priority.
- Repair of K110 cyclotron was started after shielding door was temporarily repaired.
- Repair of HM12 cyclotron was started after shielding doors were completed.
- Realignment of beam lines was started after determination of reference point for K110 cyclotron.

| | 2011 | 2011 | 2011 | 2011 | 2011 | 2011 | 2011 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 |
|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Shielding door | ① | | | | | | | | | | | | |
| K110 cyclotron | | ② | | | | | | | | | | | ★ |
| HM12 cyclotron | | | | | | | | ③ | | | | | |
| Beam lines (around cyclotron) | | | | | | | | | ④ | | | | |
| Beam lines (experimental hall) | | | | | | | | | | ④ | | | |

9. Repair of Shielding doors

- Shielding door was fully moved to outside.
- Rail (inside) was realignment and leveling. (①)
- Concrete was casted. (②)
- Shielding door was closed. (③)
- Rail (outside) was realignment and leveling.
- Concrete was casted. (④)

Completion

- Jacked up 15 tons shielding door
- Positioning using chain block and jack (②)
- Replacement of driving mechanism (③)

10. Repair of cyclotron pillars

- Beam lines around the cyclotron were removed. (①)
- Cyclotron was slightly jacked up with 4 hydraulic jacks. (②,③)
- Pillars were surrounded by steel sheets. (④)
- Cement grout was poured inside the steel sheets. (⑤)
- Epoxy grout was poured by putting pressure to fill interstices. (⑥)

11. Realignment of cyclotron

- Equipment such as RF cavities were removed. (①)
- Acceleration chamber was removed. (②,③)
- Cyclotron was positioned with an accuracy of 200 μm. (④)
- Hydraulic jacks were removed.
- Cyclotron was reassembled.
- Vacuum and water leakages were inspected. (⑤)
- Drive systems of probes, deflector, etc. were checked.
- RF, high-voltages, and currents were applied for inspection.
- Beam lines around the cyclotron were realigned. (⑥)

12. Acceleration test

July 3, 2012

Beam current extracted from cyclotron

adjust Q-lens

open beam stopper

We have succeeded in acceleration for the first time since the earthquake.
(The beam was 30 MeV proton)

13. In progress and to do

In progress

- Realignment of beam lines
- Vacuum test of beam lines

To do

- Check for moving mechanism of beam monitors
- Rebuilt (partly) and check of control system
- Acceleration test for heavy ions
- Beam transport test

Beam time will be resumed in late October.

| | 2012 | 2012 | 2012 |
|---------------------------------|------|------|------|
| | 8 | 9 | 10 |
| Realignment of beam line | → | | |
| Vacuum test | → | | |
| Control system (rebuilt) | → | | |
| Control system (test) | → | | |
| Acceleration and transport test | | | ★ |

14. earthquake countermeasures

Before the great earthquake

- Racks for books, power supplies, tools, etc. are fixed on the wall.

After the great earthquake

- Brackets of yoke (①,②,③,④)
 - Upper yoke is lifted up and supported with 4 threaded rods.
 - To avoid fall down of the upper yoke by aftershocks, 6 brackets were installed.
- Jacks for the cyclotron (⑤,⑥)
 - To reduce a stress on the cyclotron pillars when earthquake strikes, 6 jacks were installed.
- Shielding blocks (⑦)
 - To avoid displacement, shielding blocks were provided a solid connection.
- Wireless transceiver (⑧)
 - When the great earthquake happened, we had no communications due to the electric outage.
 - We have introduced high-power transceivers to ensure communications in the facility.
- Earthquake early warning by Japan Meteorological Agency (⑨)
 - When two or more Seismometers detect P-waves, the JMA automatically analyzes the data and distributes the warning information through TV, radio, mobile phone, and internet, before the arrival of S-waves.
 - We have introduced an internet version in the cyclotron operation room.