Beam Test Possibilities in Japan

Tatsushi NAKAMOTO

KEK

Necessary Irradiation Source

IT Quads. for HL-LHC

Mean Energy, Flux and DPA averaged over 4 Hot Spots (L, R, T, B)

Particle j	<E> (GeV)	RMS (GeV)	Flux ($cm^{-2}s^{-1}$)	DPA/yr	DPA (%)
p	2.93	10.7	1.3e8	1.75e-5	5
n	0.22	3.7	2.3e9	8.24e-5	26
π, K	13.8	41.6	5.4e8	4.78e-5	15
μ	11.3	19.7	6.3e5	1.70e-9	-
γ	0.018	0.35	8.6e10	~2.e-5	6
e	0.077	0.5	9.8e9	2.47e-5	8
Sub-thresh.					40

Sub-thresh = j-particles with E<100 keV + all fragments

WAMSDO 2011, CERN, Nov. 14, 2011 Exploring Parameter Space in SC - N.V. Mokhov 25

- Mean energies of the particles are rather higher.
- Effect of pions, kaons, muons. fragments?

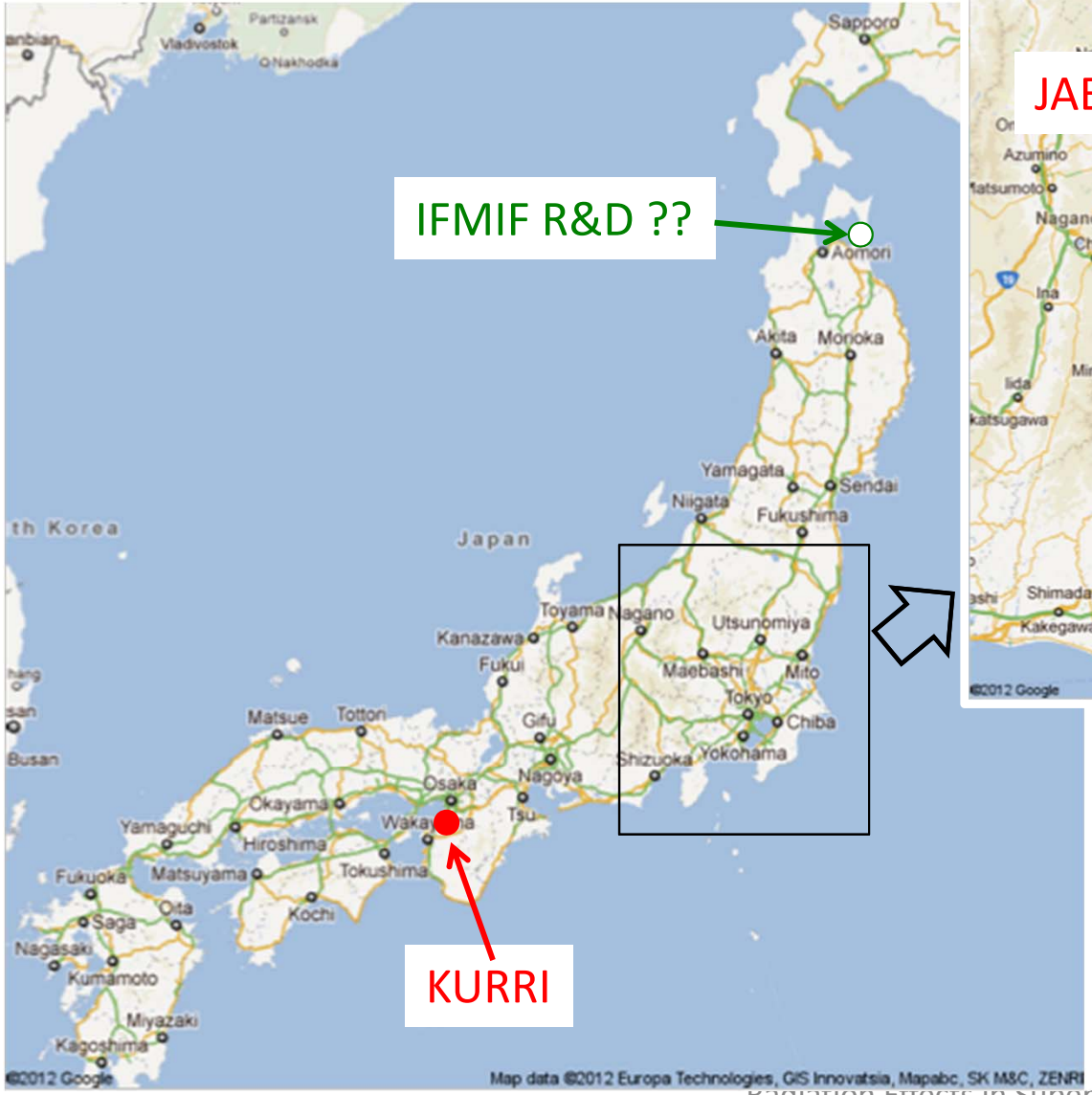
➔ NO (a few?) facilities to simulate the radiation parameters perfectly.

Evaluation using by available facilities. >> Scaling is essentially necessary.

Facilities for Materials Irradiation

- Sources of irradiation for SC magnet materials
  - Neutrons: Nuclear reactors (> 0.1 MeV), 14 MeV n by DT
  - Protons: Accelerators
  - Electrons: Accelerators
  - Gamma rays: ^{60}Co , etc
  - **Pions: ???**
  - **Ions (high energy): ???**
- Some Requirements
  - Sample size (irradiation area): > 10 mm*10 mm, t > 1 mm
    - ➔ Criteria(?): E_p > 10 MeV, E_e > ~MeV
  - Spatial uniformity: function of scanning in accelerators.
  - Fuence or absorbed dose in acceptable machine time: 10^{22} p/m^2, > 10 MGy
  - Sample environment: temperature, ambient gas or vacuum
    - ➔ Trade-off: irradiation temperature or fluence
  - Allowable limit of radioactivity
  - Evaluation apparatuses

Overview of Facilities in Japan

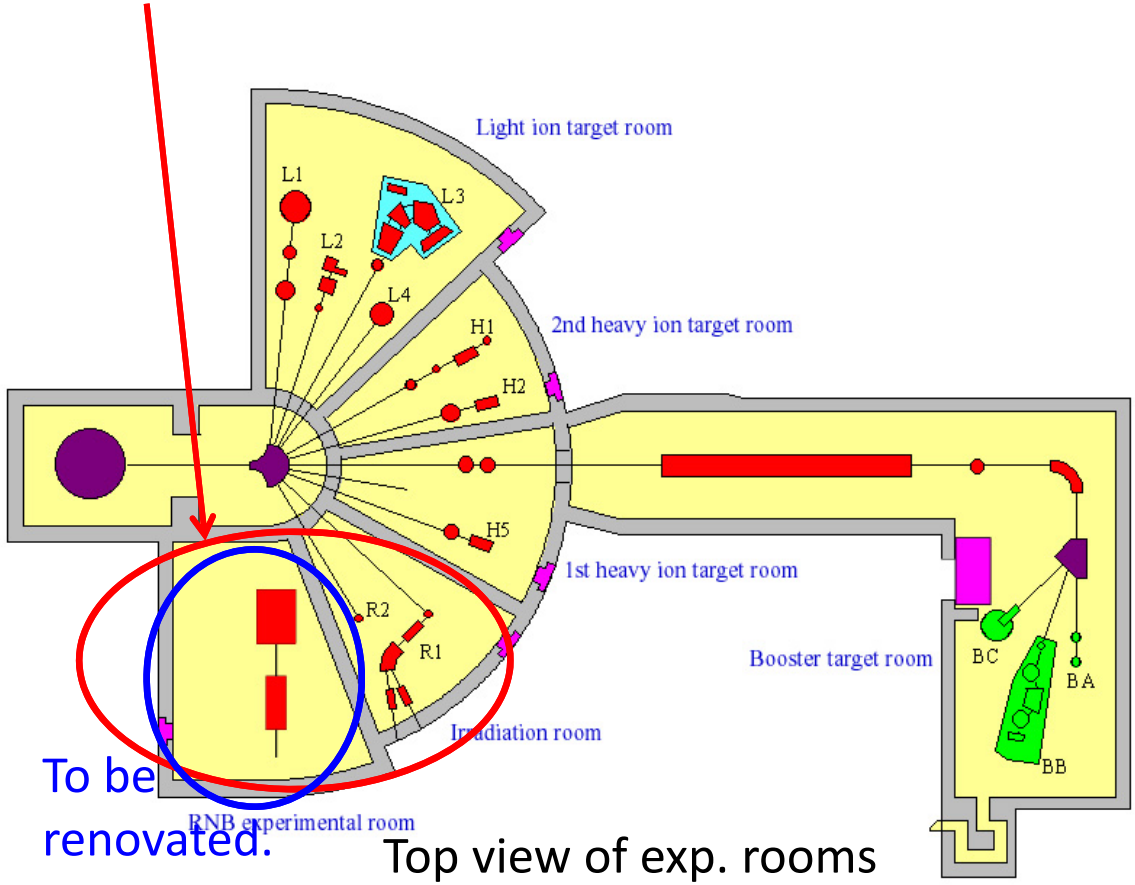


Fukushima Daiichi
Nuclear Power Plant

- Facilities in East Japan were damaged by the earthquake at March 11, 2012.
- But most of them have been recovered.

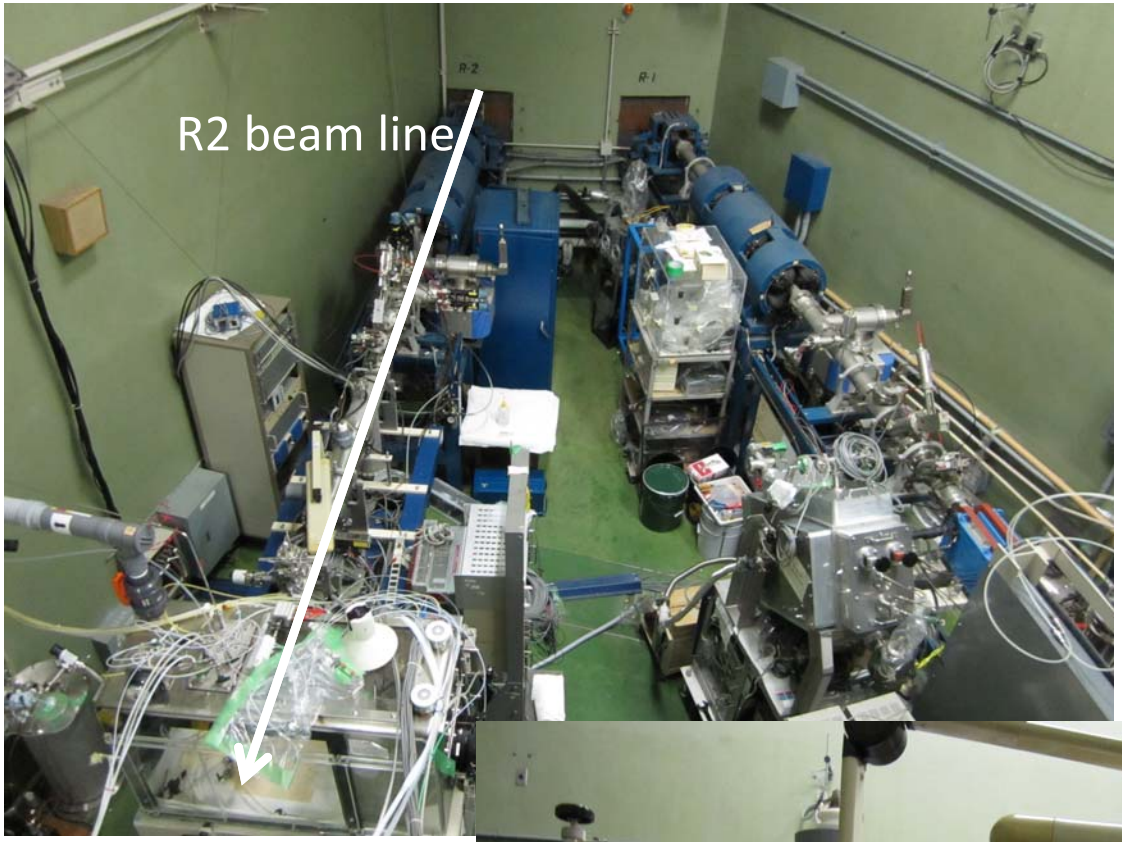
JAEA Tokai: Tandem Accelerator

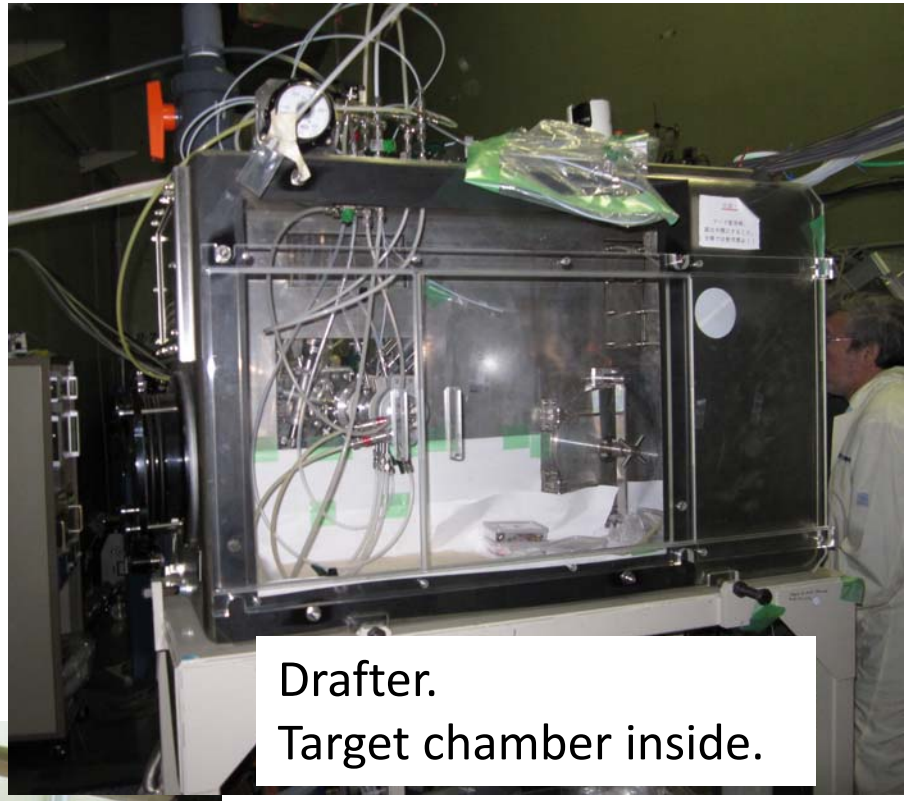
- Operation restarted at Sep. 2011.
- Proton: 1 μA at 33 MeV, 1.5 μA at 15 MeV.
- Other ions acceleration by booster is possible.
- Scanning by electro static deflectors (x-y) at R2 beam line: 10 x 10 mm^2
- Allowable unsealed radioactivity: 1 MBq for usual nulclides.
- Usage Fee: 50 kJYen/d



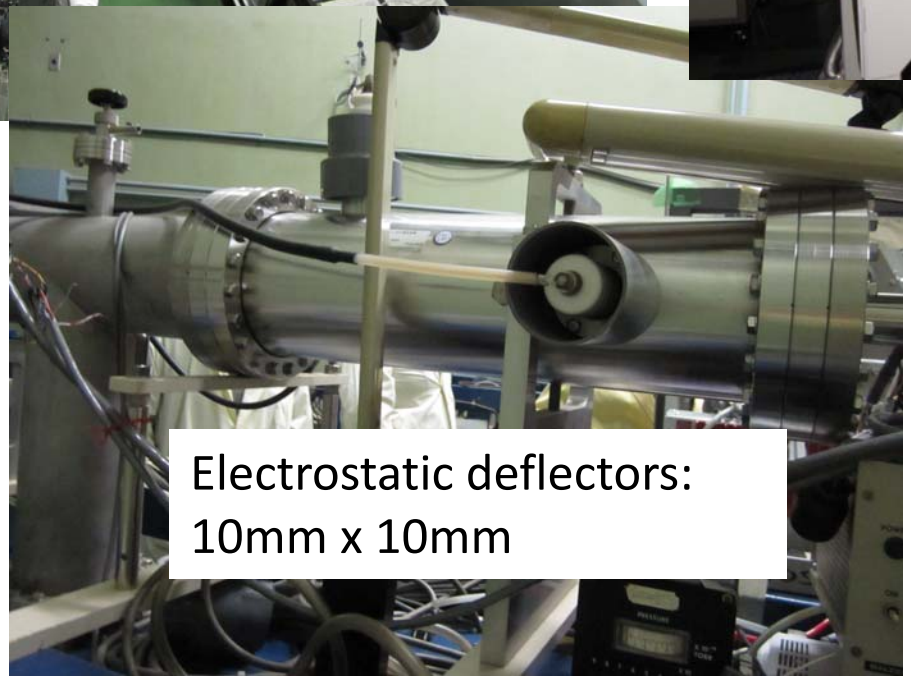
Top view of exp. rooms

JAEA Tokai: Tandem Accelerator(2)





Drafter.
Target chamber inside.

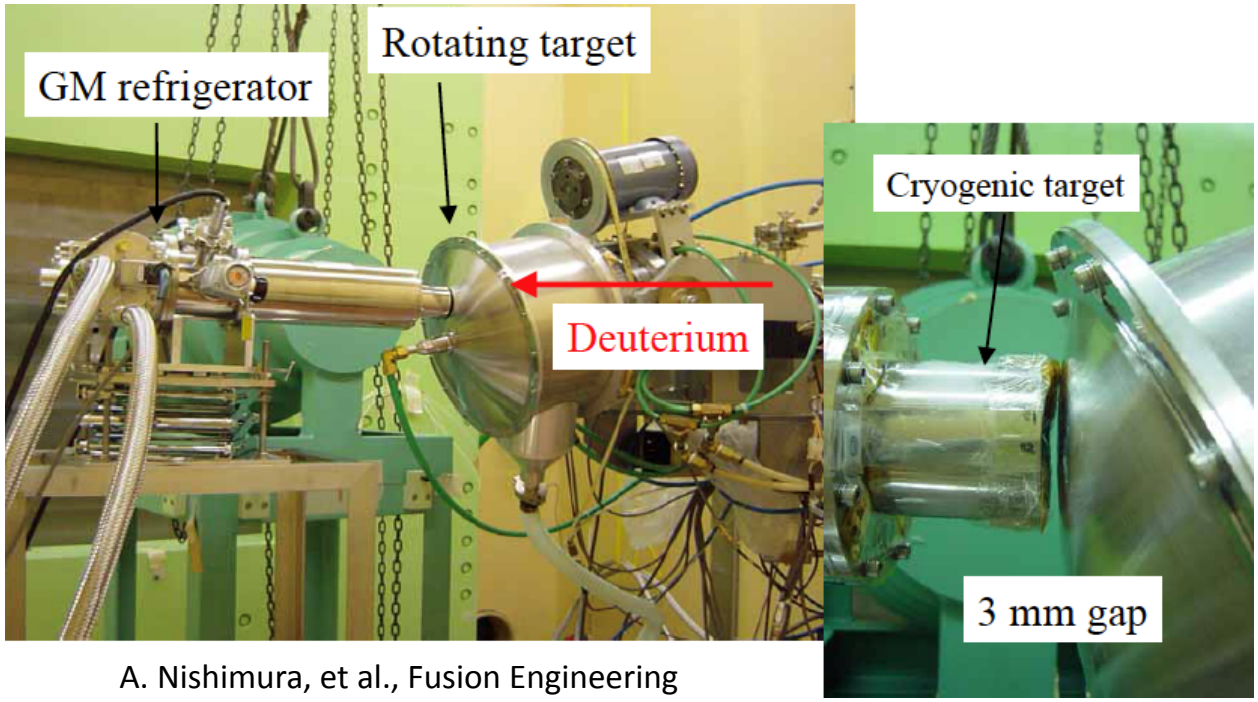


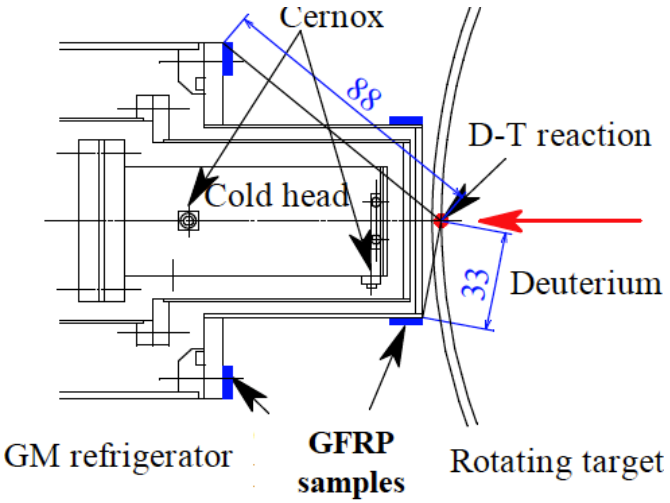
Electrostatic deflectors:
10mm x 10mm

- **Degas must be suppressed. Pumping near samples could be needed.**
- **Cooling of samples: water, gas flow…**

JAEA Tokai: FNS (Fusion Nutronics Source)

- **14 MeV neutron** from DT reaction.
- Production rate: 10^{12} n/sec at 10 mA, 10^{15} n/m^{2}s at 1 cm from target.
- 1 cycle: 7 hrs x 4 days. 4 cycles per year. >> 112 hrs only!!
- Repair work is being carried out. Operation for users will be started in 2012.
- New tritium target was successfully developed by JAEA. D beam intensities will be doubled.
- Former irradiation test for SC wires at 4 K by Nishimura (NIFS): **~10^{20} n/m^2**

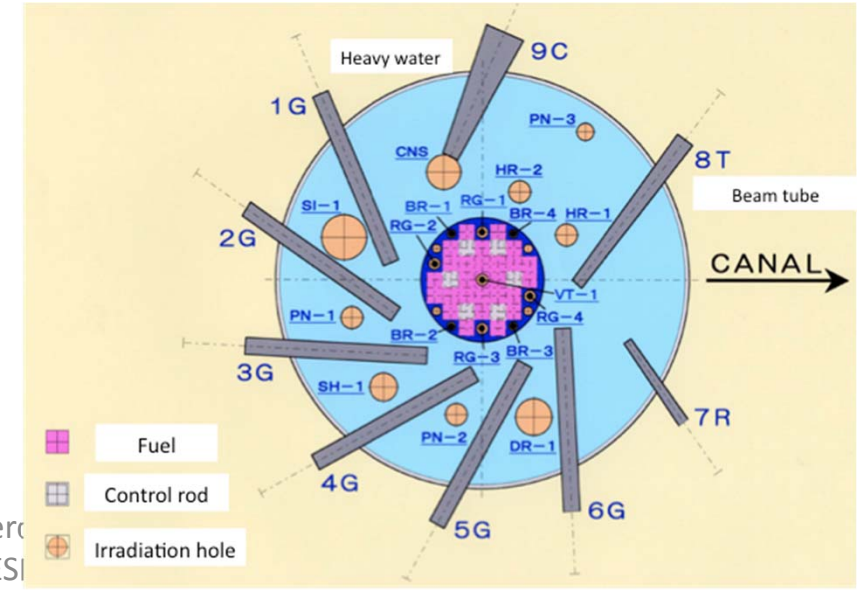




A. Nishimura, et al., Fusion Engineering and Design 75–79 (2005) 173–177.

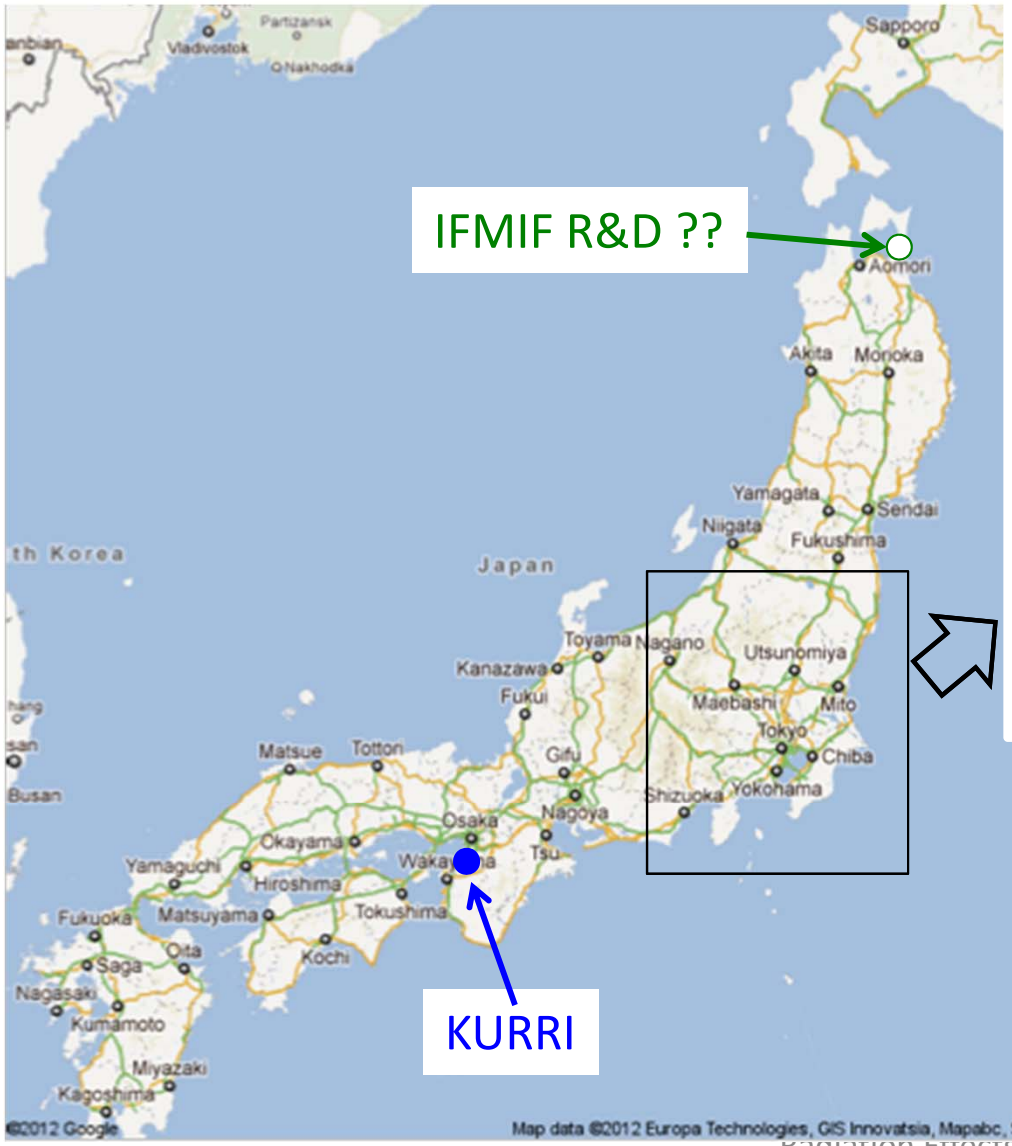
JAEA Tokai: JRR-3

- **Fission neutrons** by research nuclear reactor.
- 1 cycle: 26 days. 6-7 cycles per year.
- Fuel region: VT-1, RG, BR
  - Capsule: ϕ55 × L900, ϕ34 × L150. Water cooling (30 ° C). T_{sample}: ~100 ° C.
  - Nonstop irradiation during a whole cycle. 10^{18} n/m^{2}s >> **2×10^{24} n/m^2 at 1 cycle.**
- Heavy water reflector region: HR, PN, SI
  - Capsule: typ. ϕ30 × L150. Water cooling (30 ° C). T_{sample}: ~100 ° C.
  - Irradiation time: 1min. – 1 cycle. 10^{15} – 10^{16} n/m^{2}s >> **10^{21} - 10^{22} n/m^2 at 1 cycle.**
- Collaborative research contract with JAEA is necessary. (Or, usage fee will be charged.)
- **Concern: Soundness report is being checked by the government. Resume in 2012 ??**



Overview of Facilities in Japan

Fukushima Daiichi
Nuclear Power Plant



JMTR(JAEA) & IMR(Tohoku Univ.) at Oarai

- **Fission neutrons** by Research nuclear reactor & hot laboratory for material study
- JMTR
  - 4 cycles per year
  - 2012 Plan: 1 x 10^{17} n/m^{2}s >> **3x10^{23} n/m^2 at 1 cycle.** T_{sample}: <100 ° C.
- IMR Hot Labo.
  - A number of apparatuses for material study are available.
    - TEM, NMR, X-ray diffractometer, mechanical testing machine, etc.
  - 15.5 T SC magnets w/ VTI: 4 K to RT, rating 500 A
  - Allowed radioactivity: ~GBq to ~100 GBq for 291 nuclides.
- **Concern about JMTR: Aiming to resume at Oct. 2012. Soundness is being checked.**

Nuclide	Max. Bq per day	Stockpile
^{54}Mn	320GBq	34.7GBq
^{60}Co	400GBq	41.1GBq
^{63}Ni	50GBq	43GBq
^{95}Zr	150GBq	1.7GBq
^{110m}Ag	300GBq	2.46GBq
^{181}W	160GBq	2.88GBq
^{185}W	2TBq	9.86GBq
^{55}Fe	10TBq	739GBq

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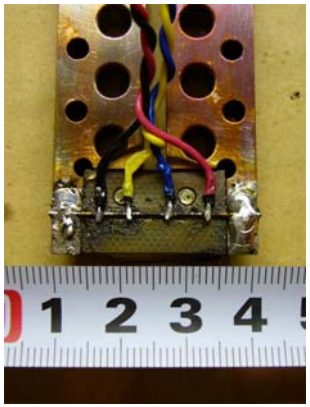
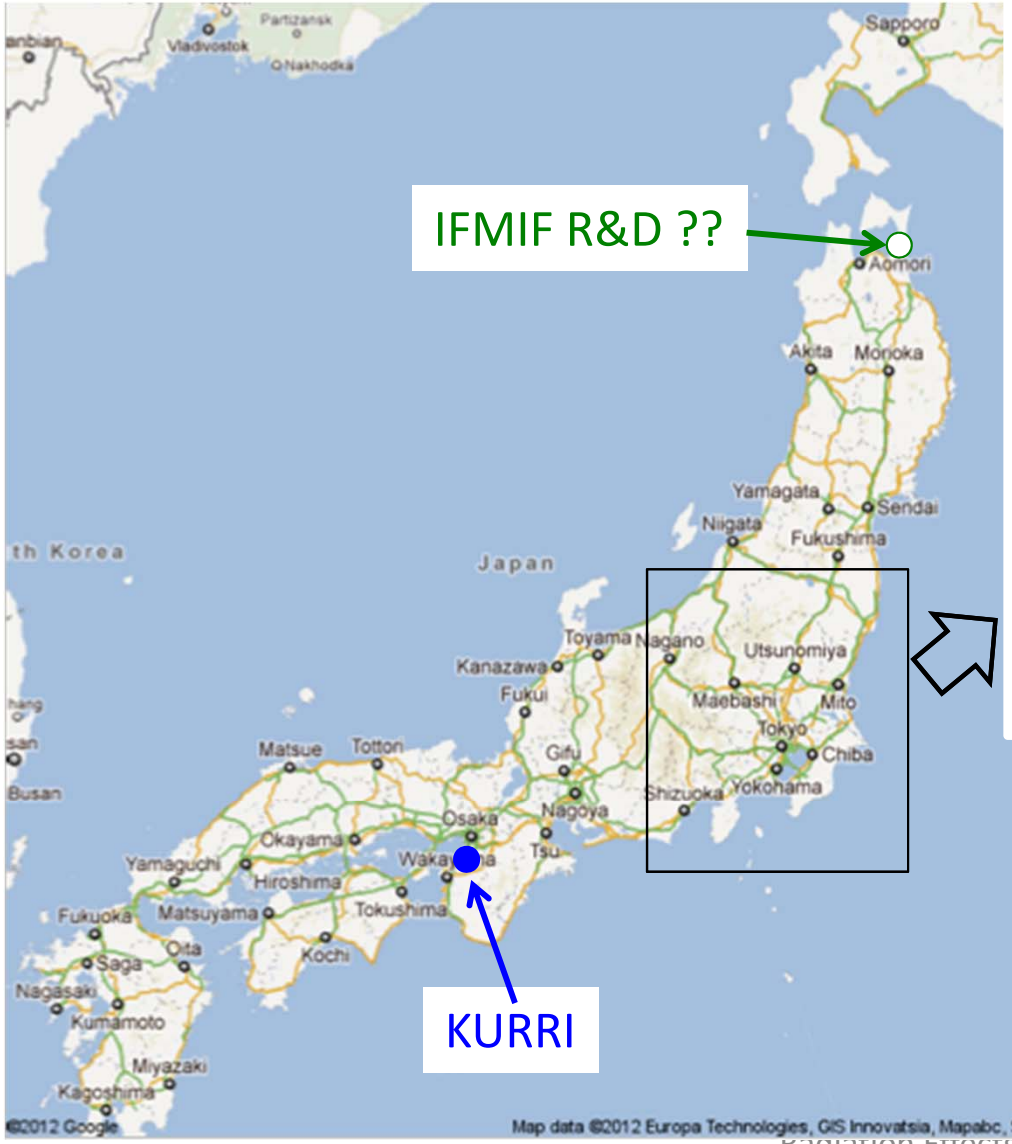


Courtesy of Nishimura (NIFS)

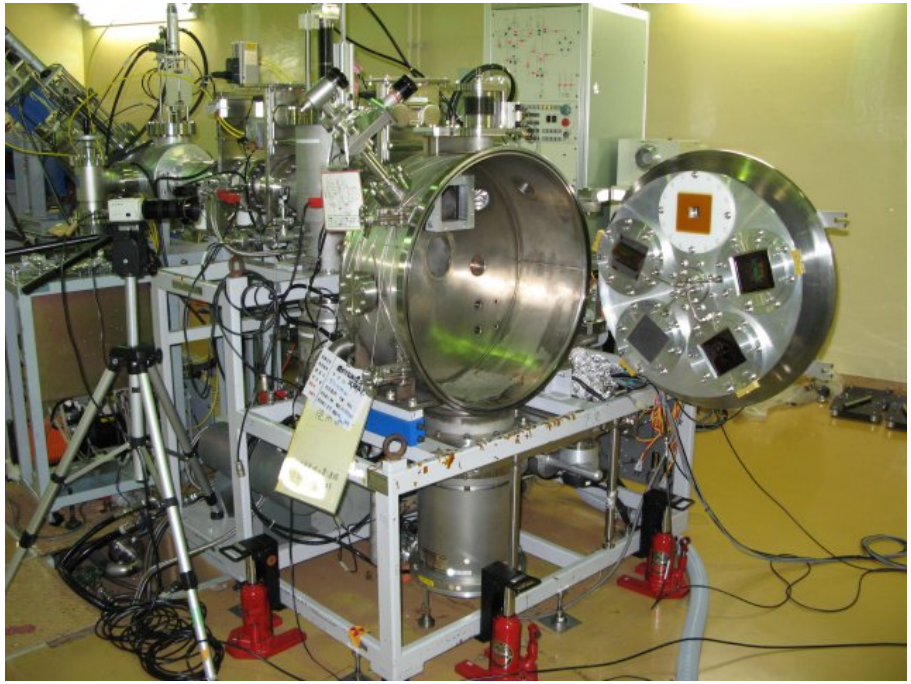
Overview of Facilities in Japan



Fukushima Daiichi
Nuclear Power Plant

JAEA Takasaki: TIARA

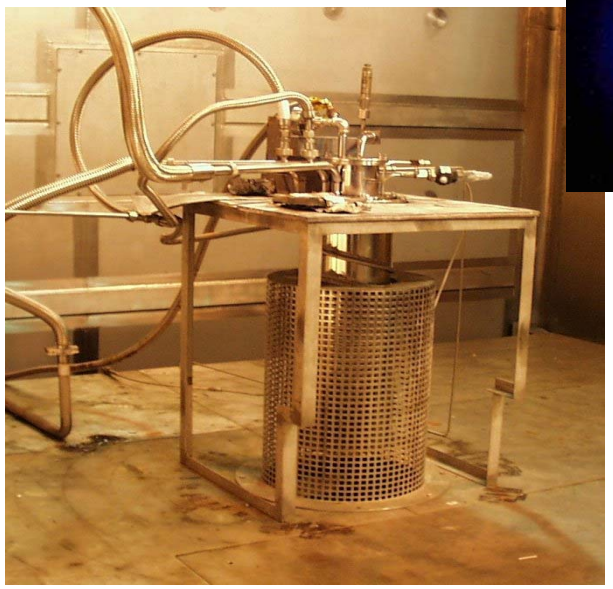
- AVF cyclotron + 3MV Tandem + 400 kV ion injector
- Protons: 10 - 75 MeV (max. 90 MeV) , max. 2 μA
  - * Replacement of beam shutter beyond E_p of 70 MeV.
- 3 operational cycles per year. Typical user time: 10 - 20 hrs in a cycle.
- Sample environment at LD1 beam line
  - Vacuum chamber + multiple samples holder (up to 4)
    - Degas must be suppressed.
  - RT by conduction cooling w/ water.
  - Sample chamber w/ LN2 conduction cooling is available. (But, not in use for > 10 years.)
- Irradiation area: max. 100 mm x 100 mm (uniformity: within 10 %)
- Collaborative research contract with JAEA is necessary. (Or, usage fee will be charged.)
- **Concern: Allowable radioactivity is rather lower. Check in advance.**

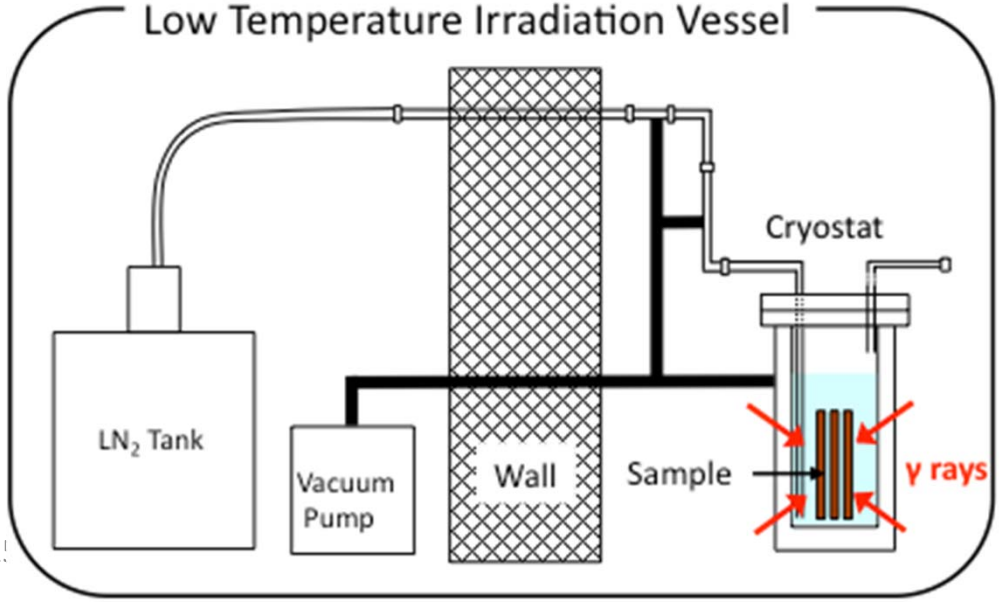


Rotating sample holder in LD1 beam line

JAEA Takasaki: ^{60}Co gamma ray source

- **Gamma-rays**: 6 irradiation rooms
  - Idesaki's group: 1 room for RT, 1 room for LT.
- Irradiation rate: 10 - 20 kGy/hr, 24 hrs.
- LN2 irradiation cryostat
  - Samples immersed in LN2 bath.
  - dose uniformity: < 30 %
  - LN2 consumption: 1300 L for 14 days (5 – 6 MGy). >> 150 kJYen
- **In the meantime, priority of irradiation given to the decontamination study related to the Fukushima nuclear plant accident.**

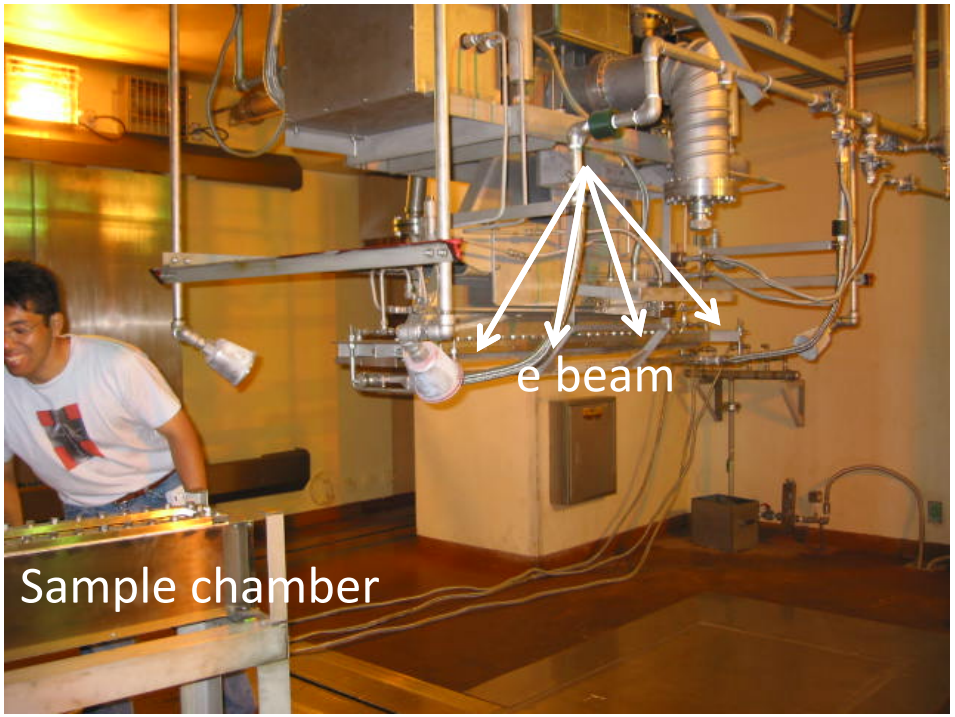


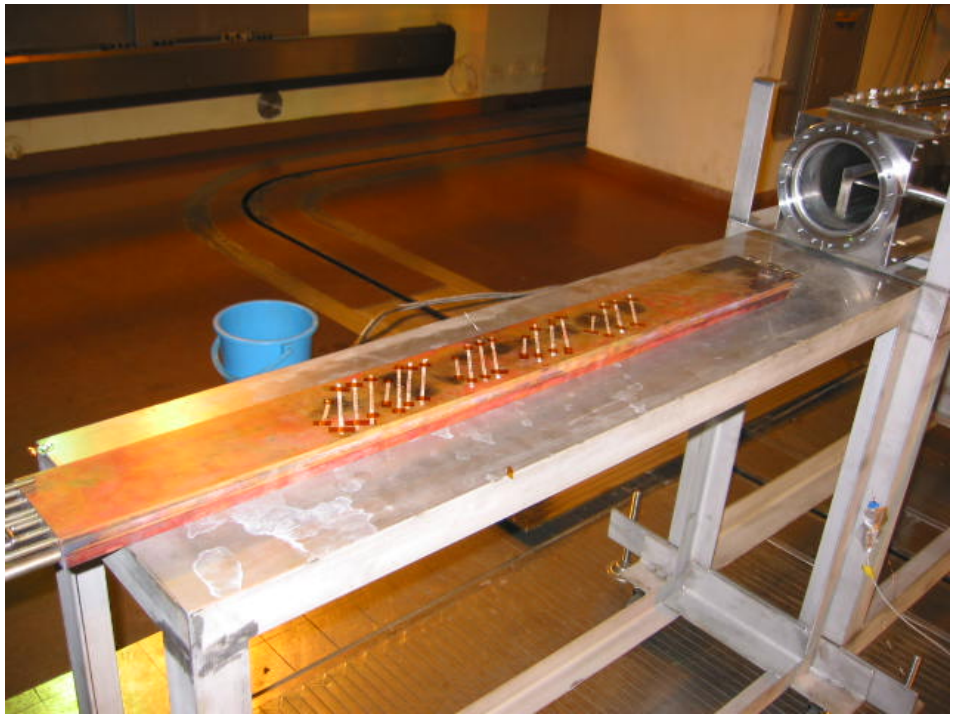


See talks by Ogitsu and Idesaki.

JAEA Takasaki: Electron Accelerator

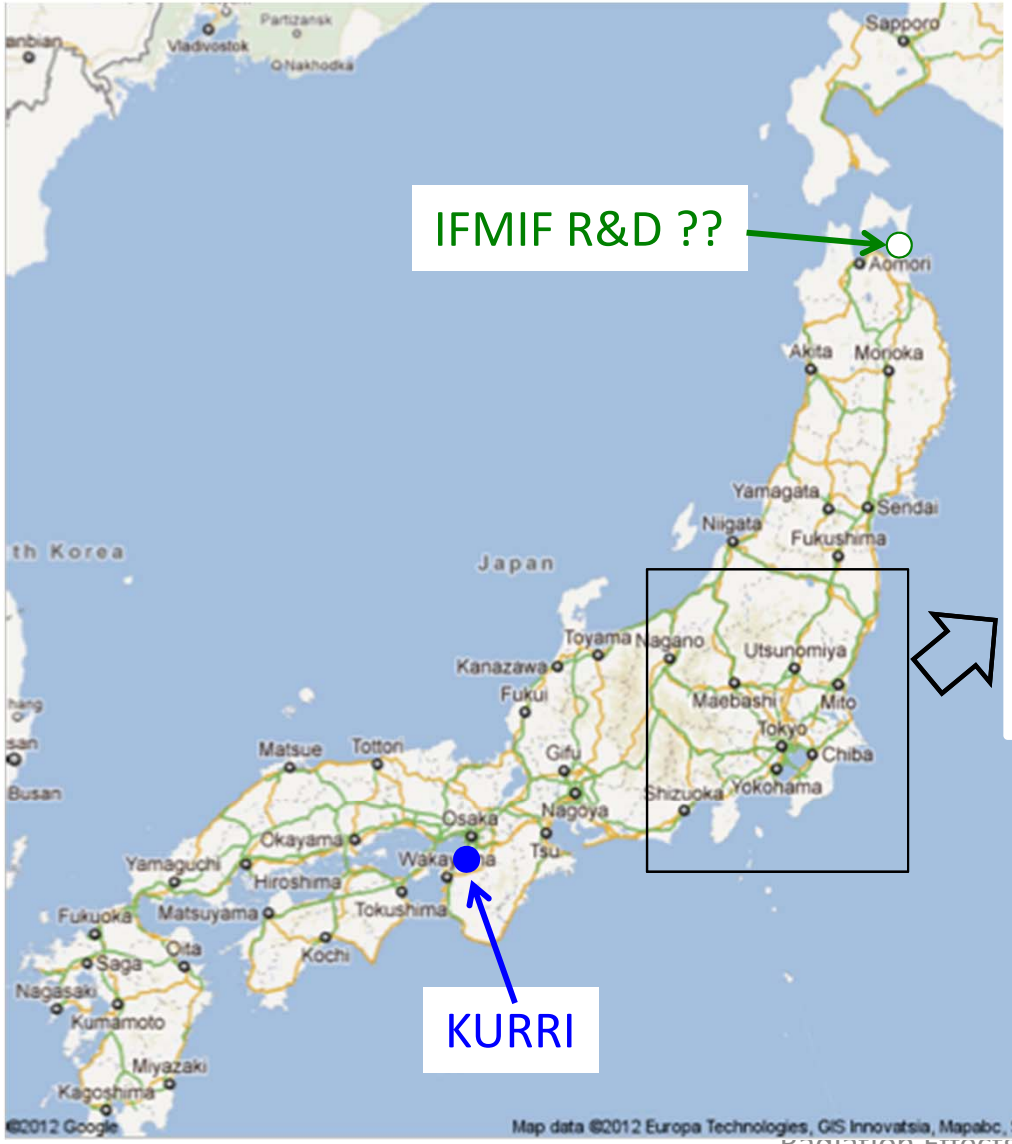
- **Electron**: E_e = 0.5 - 2 MeV, 0.1 - 30 mA.
  - The sample should be thin enough.
- 8 - 13 hrs/day >> ~40 MGy for typical resins
- Exposed in air or inert gas. Scanning: 50 x 1200 mm^2.
- T_{sample}: RT
  - Conduction cooling with water.
- Casual use??





Irradiation on HTS tape

Overview of Facilities in Japan



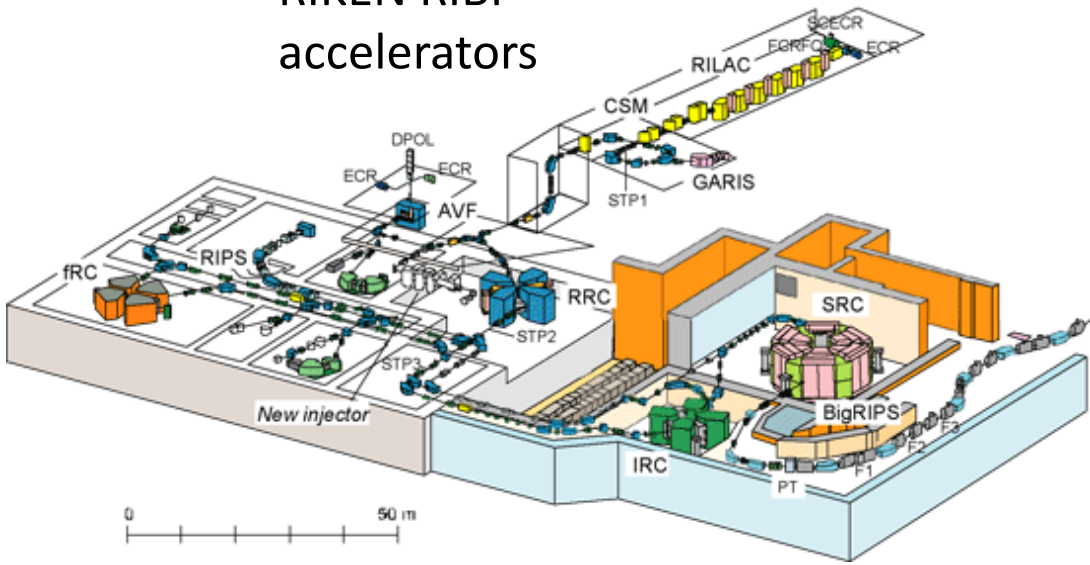
Fukushima Daiichi
Nuclear Power Plant

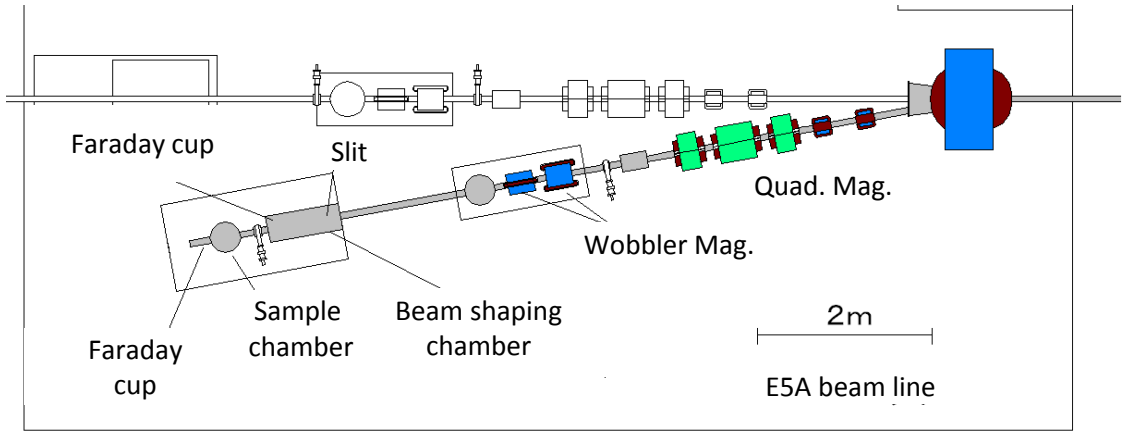
RIKEN: RIBF

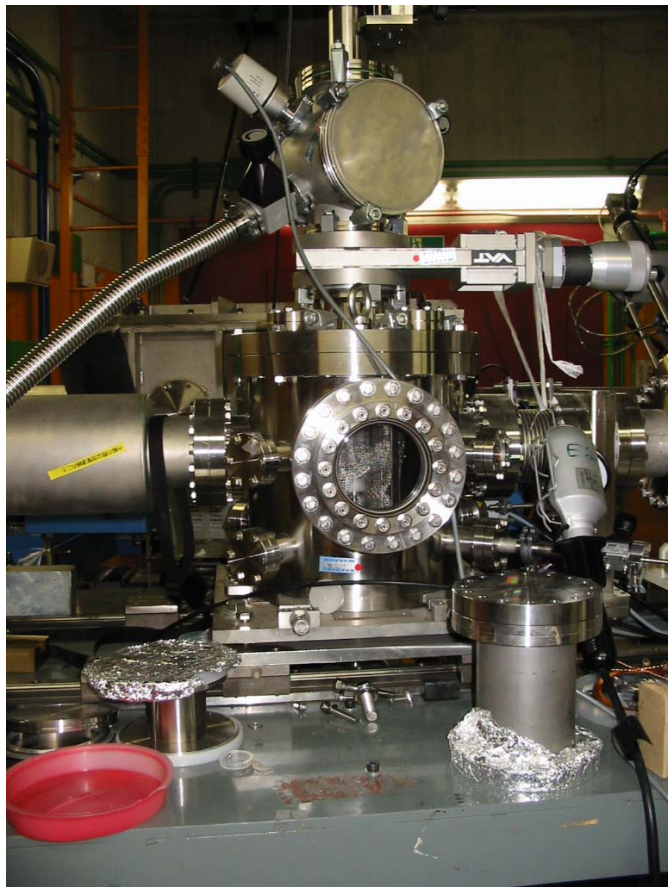
- Materials irradiation beam line: E5A
  - Protons from RRC: 70, 135, 210 MeV.
  - I_p = 10 nA
  - 10 x 10 mm^2 by Wobbler magnet
  - Uniformity within 10 %
- Sample Environment:
  - Vacuum, 10 K* – 373 K

    * Renovation of cryogenic facility is necessary.
- **Machine time proposal for PAC is very competitive.**
  - **Another beam line with 14 MeV protons (10 μA) from AVF cyclotron is available.**

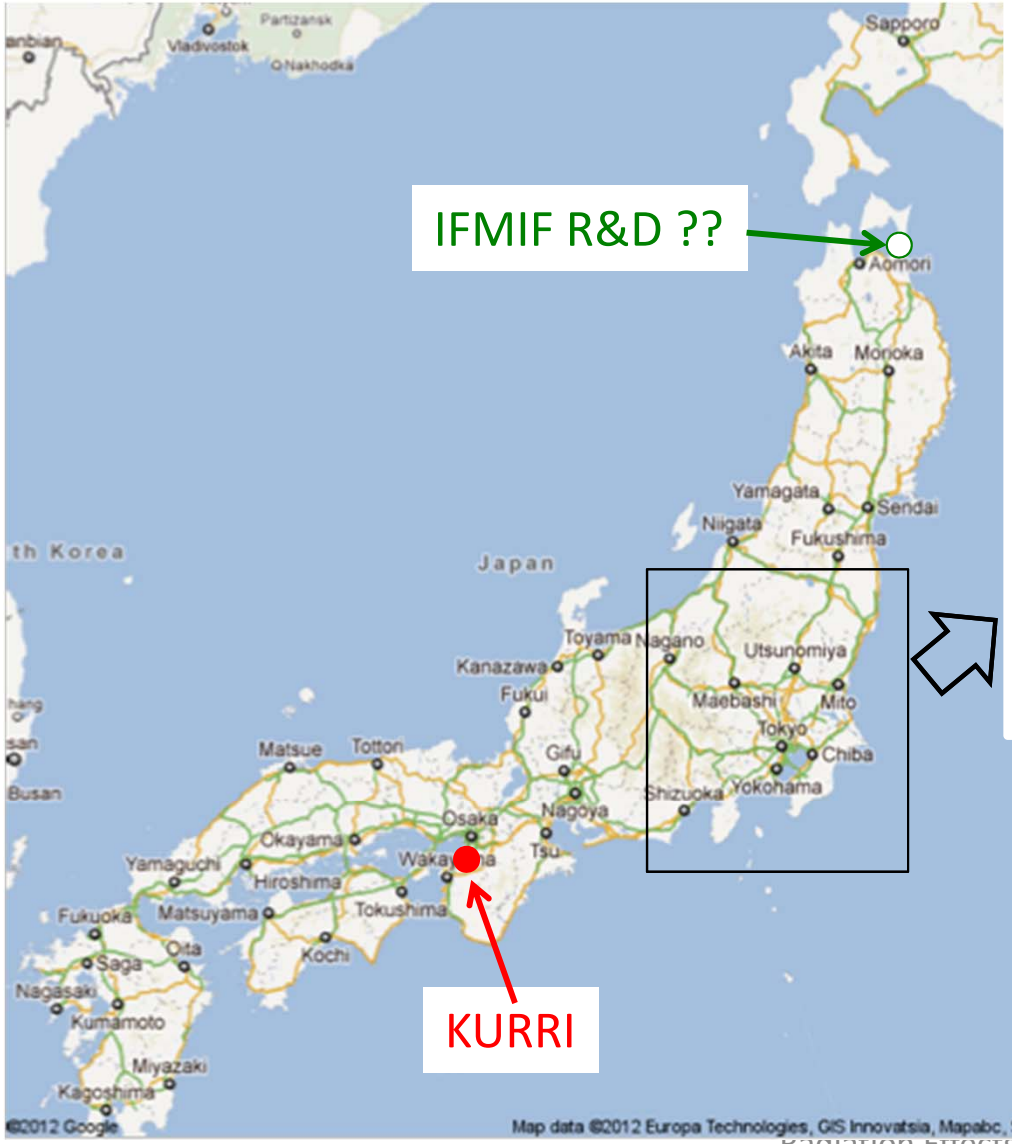
RIKEN RIBF accelerators







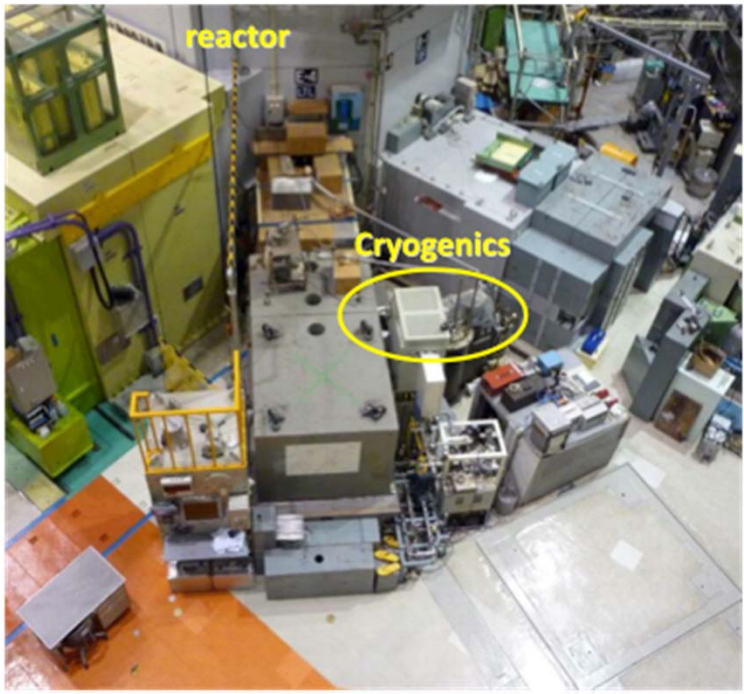
Overview of Facilities in Japan

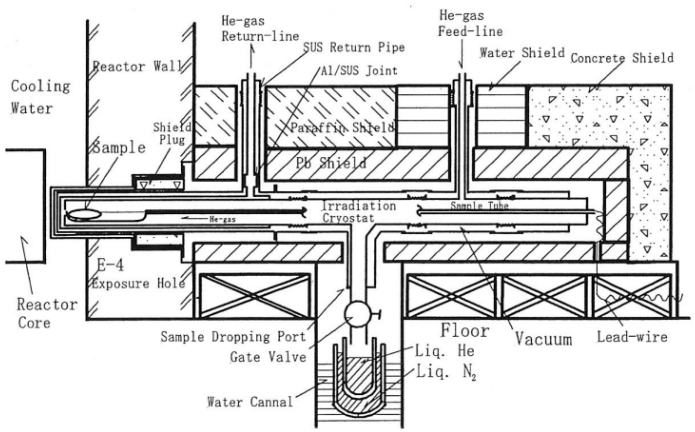


Fukushima Daiichi
Nuclear Power Plant

KURRI: Kyoto Univ. Research Reactor

- **Fission neutrons**. Operated as planned in 2011.
- 1 cycle: 1 MW x 46 hrs + 5 MW x 6hrs. ~25 cycles per year.
- Usual irradiation
  - Hydraulic Conveyer at reactor core
    - Aluminum capsule, ϕ_{th}: 8.2 x 10^{17} n/m^2/s, 70 hrs at 1 MW_{eq}
  - Pneumatic Tubes (Pn-1, 2, 3) at graphite reflector
    - PE capsule, ϕ_{th}: 2.8 x 10^{17} n/m^2/s, 1 hr at 1 MW_{eq}
  - Slant Exposure Tube: graphite reflector
    - Large-size samples, ϕ_{th}: 3.9 x 10^{16} n/m^2/s, 70 hrs at 1 MW_{eq}.
- Low Temperature Line: irradiation cryostat close to reactor core
  - Cooling by He gas loop: **< 20K**
  - ϕ_{fast} (E_n>0.1MeV): 1.4 x 10^{15} n/m^2/s at 1MW >> **10^{20} n/m^2** at 1 cycle



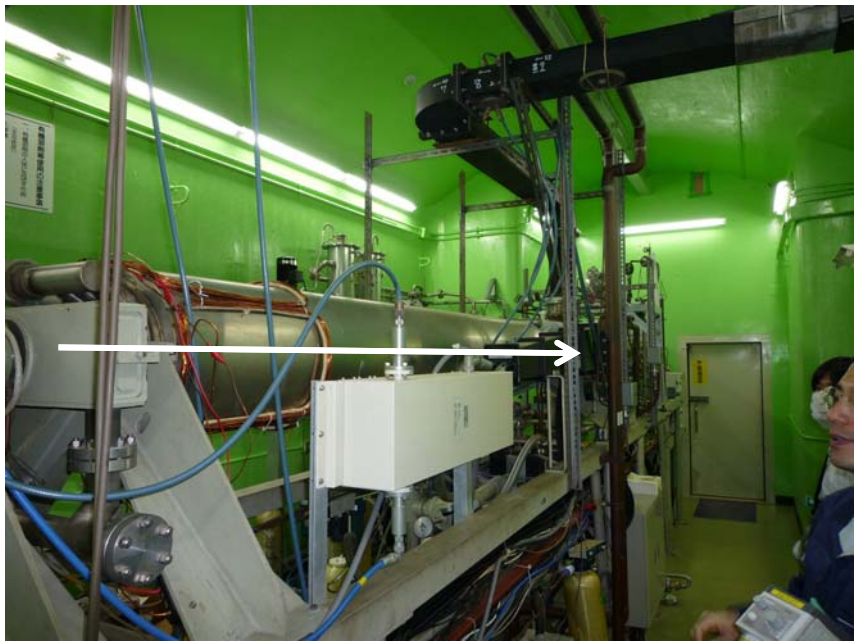


M. Okada et al., NIM A463 (2001) pp213-219

See Yoshida's talk.

KURRI: Electron Linear Accelerator

- 6 MeV < E_e < 32 (max. 46 MeV), max. 200 μA.
  - Very high absorbed dose rate: ~100 kGy/s
  - sample activation beyond E_e of 10 MeV
  - beam size: ϕ10 mm, NOT uniform.
- Operation: 11 weeks per year
- Sample environment
  - Water cooing chamber (immersed)
  - LN2 sample cryostat

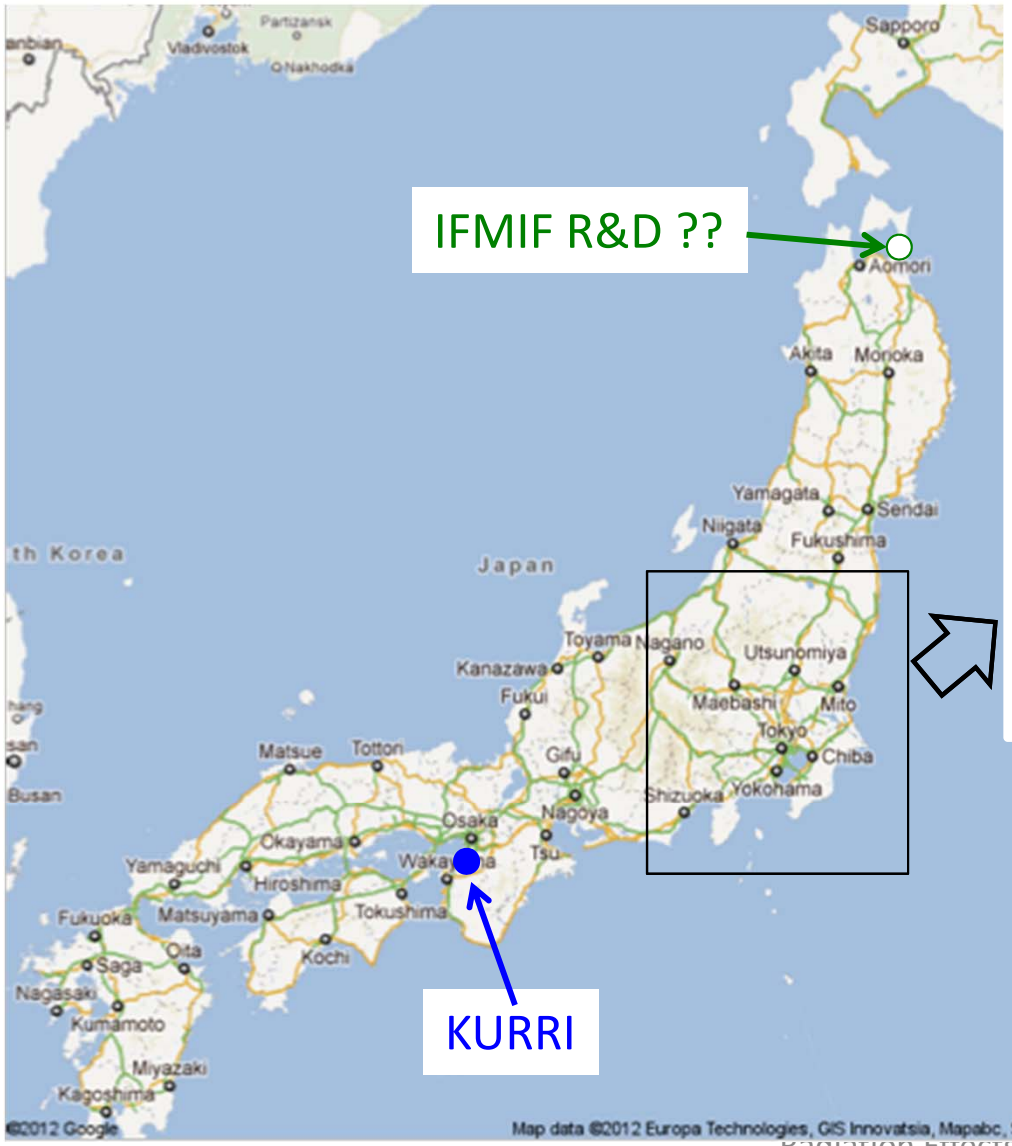


LN2 sample cryostat

Water cooling sample holder (inside)

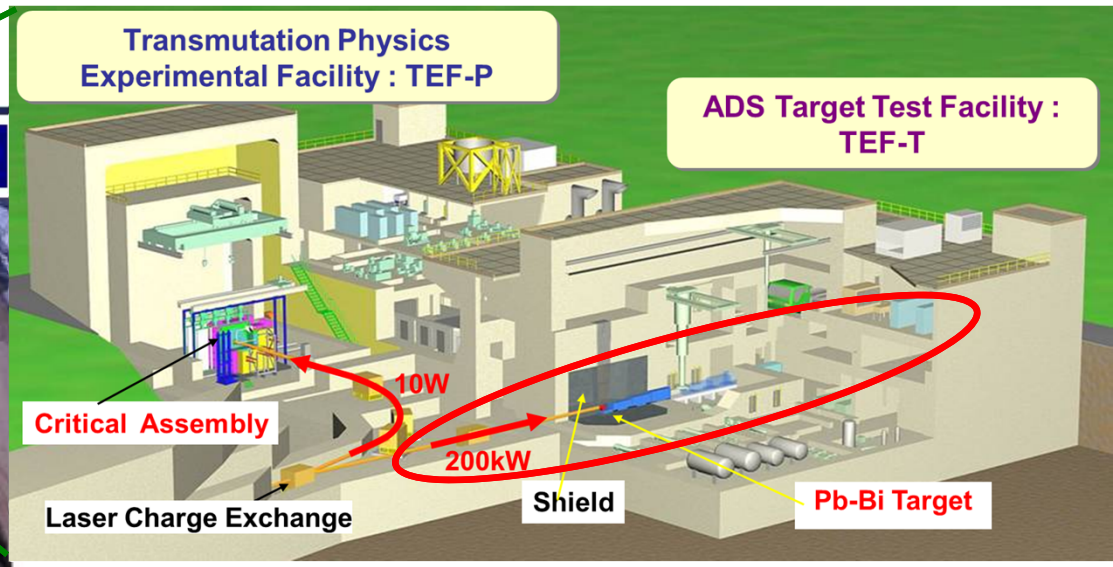
Overview of Facilities in Japan

Fukushima Daiichi
Nuclear Power Plant



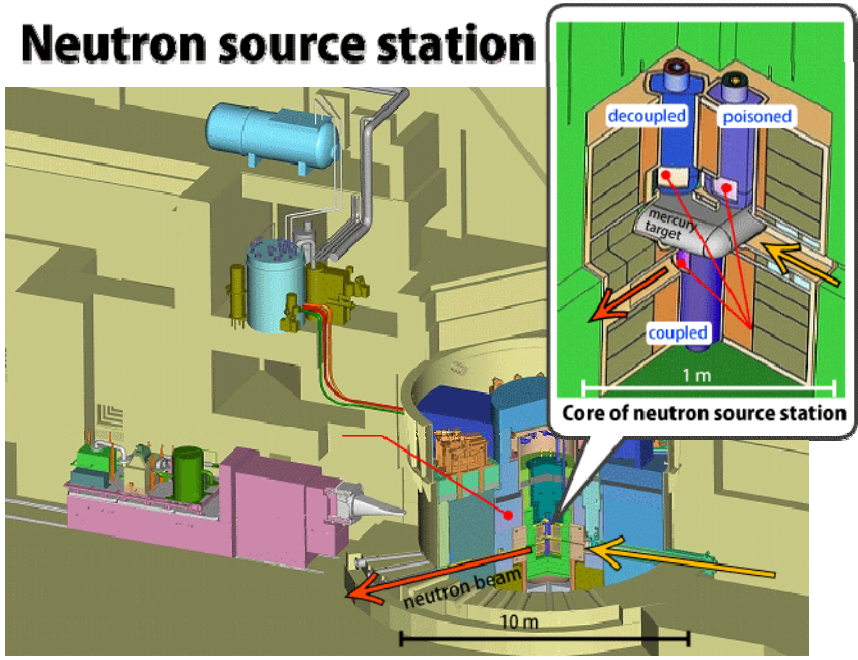
J-PARC

- **Proton** Linac
  - Currently, providing the beam to the RCS only: 180 MeV, 30 kW.
  - To be upgraded to 400 MeV soon.
  - Future project: Accelerator Driven Transmutation Experimental Facility. (600 MeV, 200 kW using SC RF cavities)
    - » Potential Irradiation Test at primary beam line (**TEF-T**).
    - » Construction budget has not been authorized yet... When???



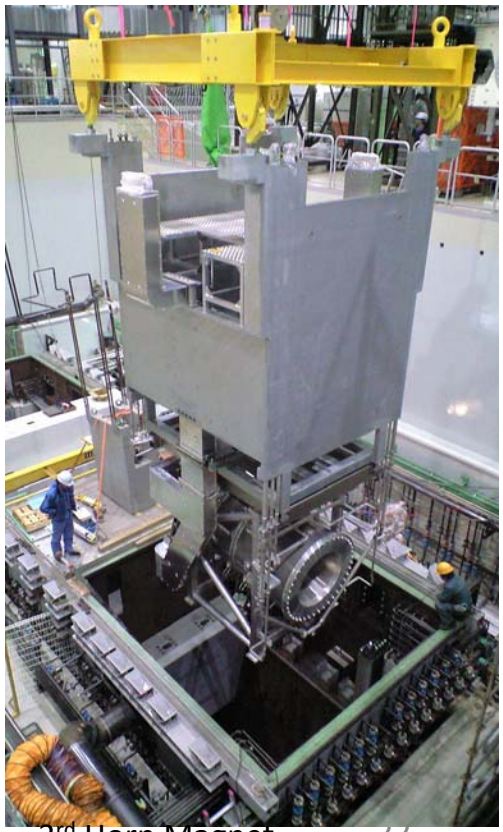
J-PARC (2)

- RCS: 3 GeV, 200 kW, 25 Hz
  - Providing the beam to MLF and MR.
  - To be upgraded to 1 MW.
- MR: 30 GeV, 150 kW
  - For T2K neutrino exp.(FX) and Hadron exp. (SX)
  - To be upgraded to 750 kW.



•Sample space around target system would not be allowed…
•Access is very restricted.
•Interference for the operation and the main experiment would be concerned, even though T2K neutrino target is appropriate for pion irradiation source…

At present, materials irradiation test at J-PARC is quite difficult.



3rd Horn Magnet Installation for T2K exp.

Summary

- Irradiation facilities in east Japan were damaged by the earthquake, but they were mostly recovered.
  - 2 research reactors are still in process of approval to resume.
- Material irradiation facilities
  - Protons
    - 3 accelerators: 10 MeV - 75 MeV (~μA), 210 MeV (10 nA)
  - Electrons:
    - 2 accelerators: 2 - 32 MeV (> 200 μA)
  - Neutrons:
    - 3 research reactors
    - 1 DT neutron sources (14 MeV)
    - Cryogenic irradiation at KURR and FNS
  - Gamma rays:
    - 2 facilities w/ ^{60}Co (JAEA-Takasaki, KURRI)
    - Samples in LN2
- Sample environment
  - Difficulty of cryogenic irradiation at accelerator
  - Trade-off: temperature and fluence