ACTIVITIES ON ADS AT JAEA

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New Structure for ADS Development at JAEA: Midterm Plan

Description in "Midterm Plan" of JAEA

- Partitioning
  - New Extractant, Process Design, Laboratory Demonstration, ….
- Transmutation
  - General
    - Nuclear Data and Reactor Physics
    - Material Properties of MA and LLFP
  - FBR
    - Design, Fuel Irradiation, ….
  - ADS
    - Design
    - Accelerator
    - Spallation Target (Material, Thermal-hydraulics)
    - Lead-Bismuth Eutectic (LBE) Technology (Corrosion, Po Behavior,..)
    - Dedicated MA Fuel
- Scenario Study
- Benefit of P&T on HLW Management

New Structure for ADS Development at JAEA: Directorates Concerning R&D on ADS

Nuclear Science and Engineering Directorate
- Director General: O. Oyamada
- Deputy Director General: T. Ogawa

Research Co-ordination and Promotion Office

- **Division of Nuclear Data and Reactor Engineering** — *R&D on ADS*
- **Division of Fuels and Materials Engineering** — *R&D on ADS fuel and materials*
- **Division of Environment and Radiation Sciences**
- **Nuclear Applied Heat Technology Division**

Quantum Beam Science Directorate

- **Proton Accelerator Facility Development Unit** — *Development of J-PARC accelerators and facilities*

J-PARC Center — *Operation and maintenance of J-PARC*

Advanced Nuclear System Research and Development Directorate — *R&D on FBR cycle*

Scenario Study: Characteristics of ADS and Possible Scenarios

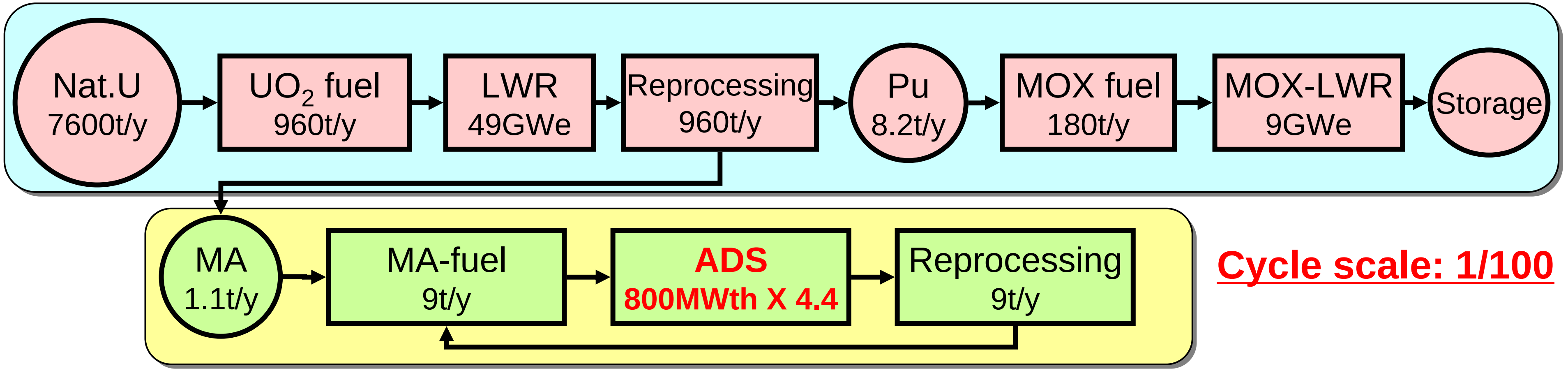
- Two significant advantages of the dedicated transmutation strategy:
  (1) It can accommodate various situations of the commercial power generation fuel cycle **in an appropriate and flexible manner**.
  ---- Suitable to the transient phase from LWR to FBR.
  (2) **MA can be confined into a small-scale dedicated fuel cycle**.
  ---- Helpful for the deployment of the FBR.

- Taking these advantages into account, three typical situations of nuclear fuel cycle with the dedicated transmutation system can be assumed:
  a. LWR – ADS
  b. LWR – FBR – ADS
  c. FBR – ADS

- In this scenario study, the total capacity of the nuclear power generation is fixed at 58 GWe for all the situations.

Scenario Study:
a. LWR–ADS

- **"Pseudo Equilibrium State" with UO_2-LWR + MOX-LWR (58GWe)**

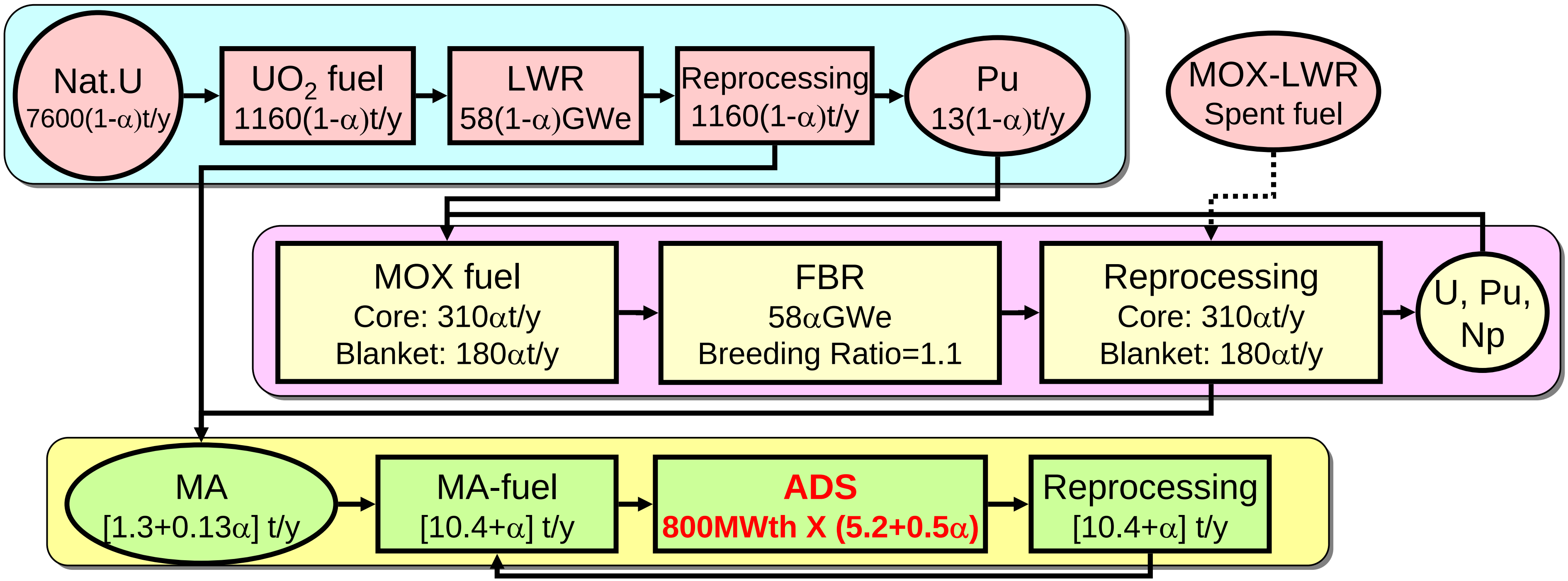


- MA can be managed in a **very small dedicated fuel cycle**.
- Pu will be stored as MOX spent fuel and then used as FBR fuel.

Scenario Study:
b. Transient from LWR to FBR

- **"Transient Phase" with UO_2-LWR + MOX-FBR (58GWe)**

α: Ratio of FBR deployment

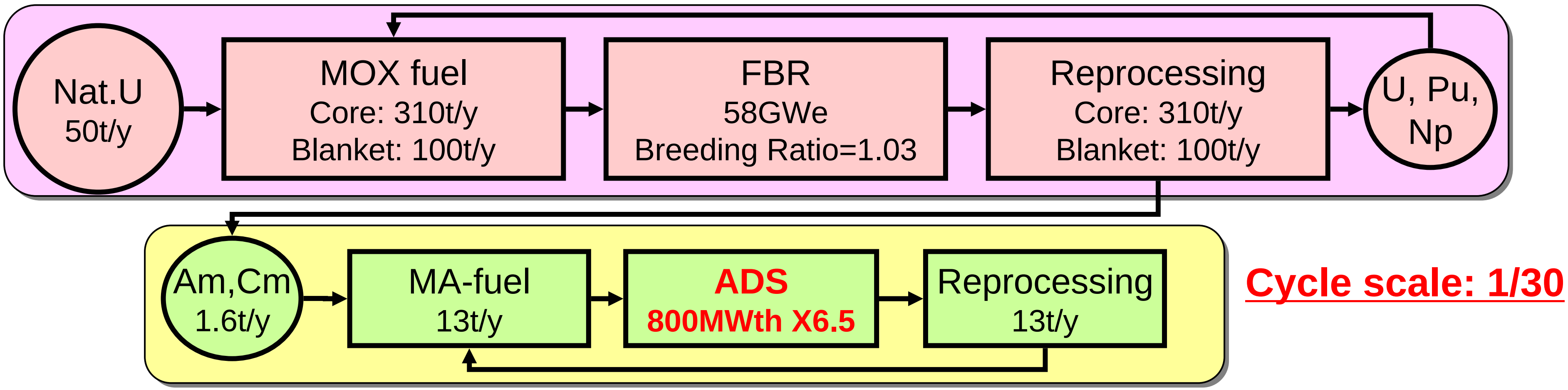


α	Size of LWR fuel reprocessing	Size of FBR cycle	Size of ADS cycle	Number of ADS
0.2	930t/y	98t/y	10.6t/y	5.3
0.5	580t/y	250t/y	10.9t/y	5.5
0.8	230t/y	390t/y	11.2t/y	5.6

- Size of ADS cycle will not be affected by the situation of LWR and FBR cycles.

Scenario Study:
c. FBR with ADS

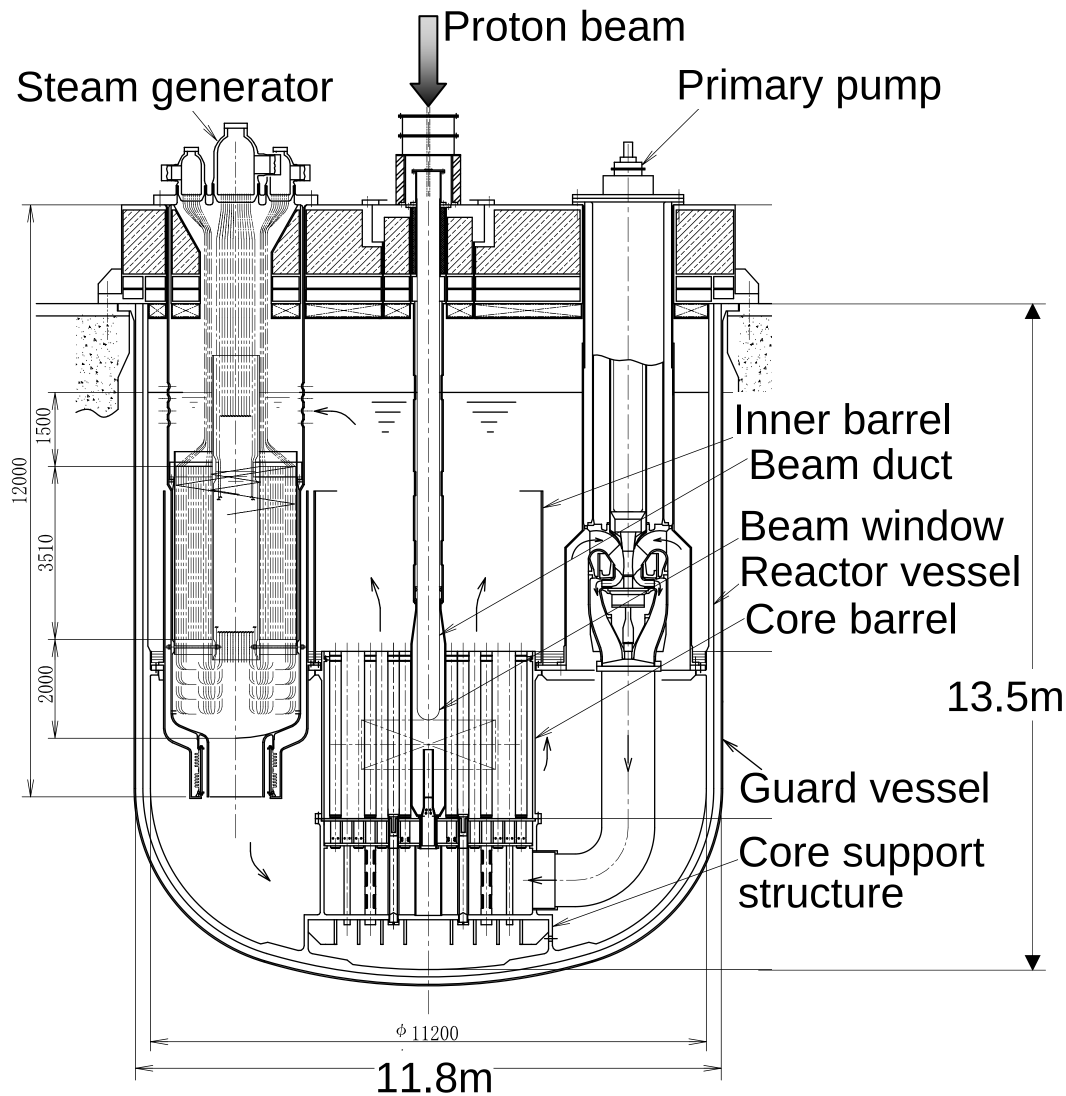
"Symbiotic State" with FBR (58GWe) :



- FBR and ADS co-exist **symbiotically and complementarily**.
- By adopting ADS and its dedicated transmutation cycle, MA can be confined and FBR cycle can be optimized from viewpoints of **reliability, safety and economy**.
- The scale of ADS cycle is about **1/30** of the commercial FBR cycle.
- The mass flow of the cycle will be about 13 t/y, which means about 50 kg/day of MA fuel will be enough to be fabricated.

Conceptual Design: Reference ADS

- Proton beam : 1.5GeV
- Spallation target : Pb-Bi
- Coolant : Pb-Bi
- Max. k_{eff} = 0.97
- Thermal output : 800MWt
- MA initial inventory : 2.5t
- Fuel composition :
  (MA +Pu)Nitride + ZrN
  Initial loading:
  Zone-1: Pu/HM=30.0%
  Zone-2: Pu/HM=48.5%
- Transmutation rate :
  10%MA / Year
- 600EFPD, 1 batch



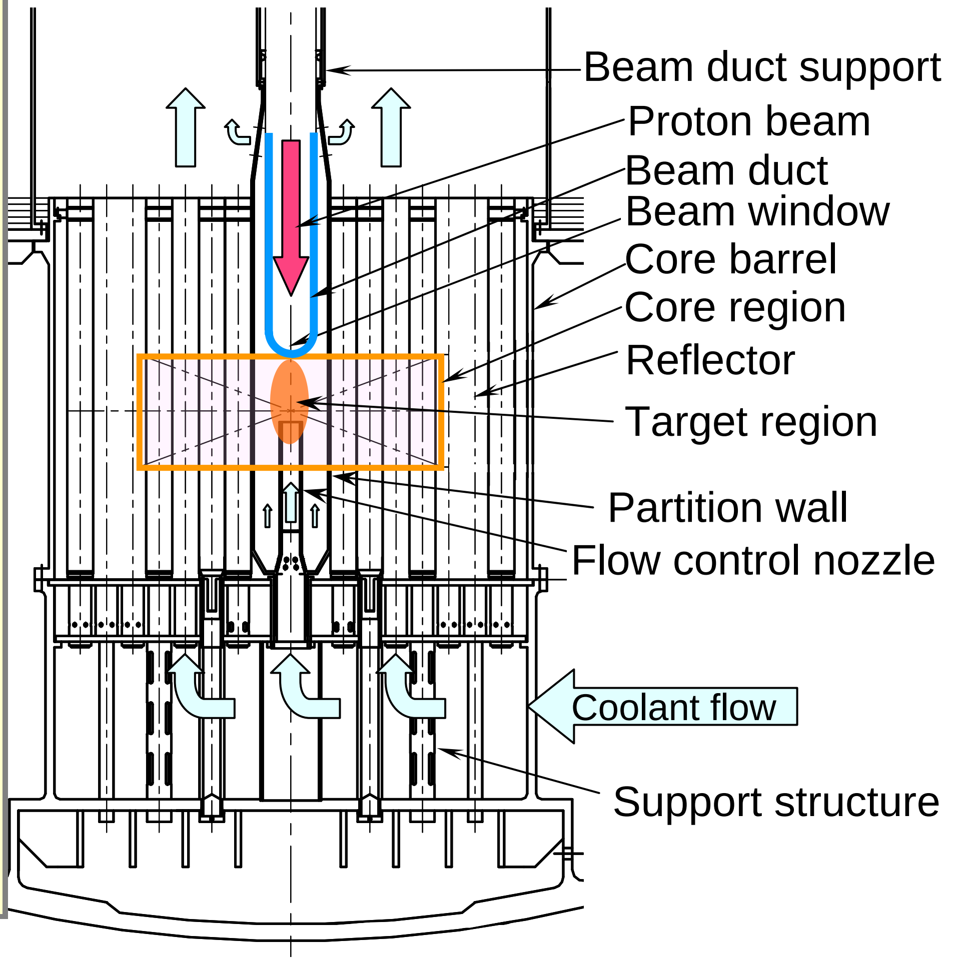
Engineering Feasibility: Spallation Target and Beam Window

- 30 MW proton beam with 1.5 GeV causes heat deposition of 15.7MW.

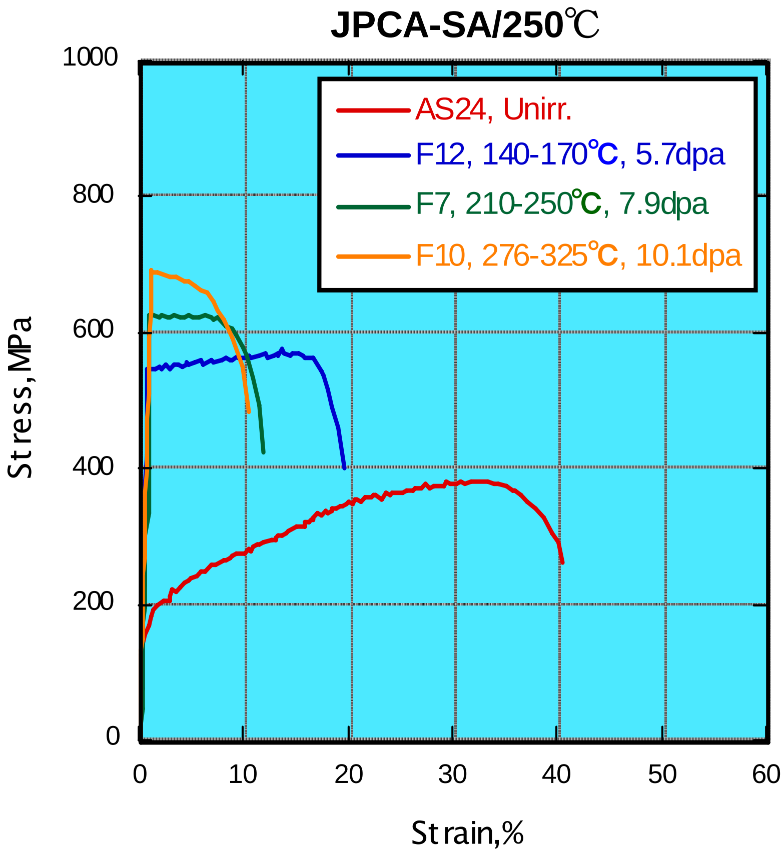
- Conditions and criteria for the beam window:
  - ✓ Inlet temp. : 300 ºC
  - ✓ LBE flow: < 2m/s
  - ✓ Temp. of outer surface: < 520ºC
  - ✓ Structural strength:
    Thermal stress, buckling, etc.

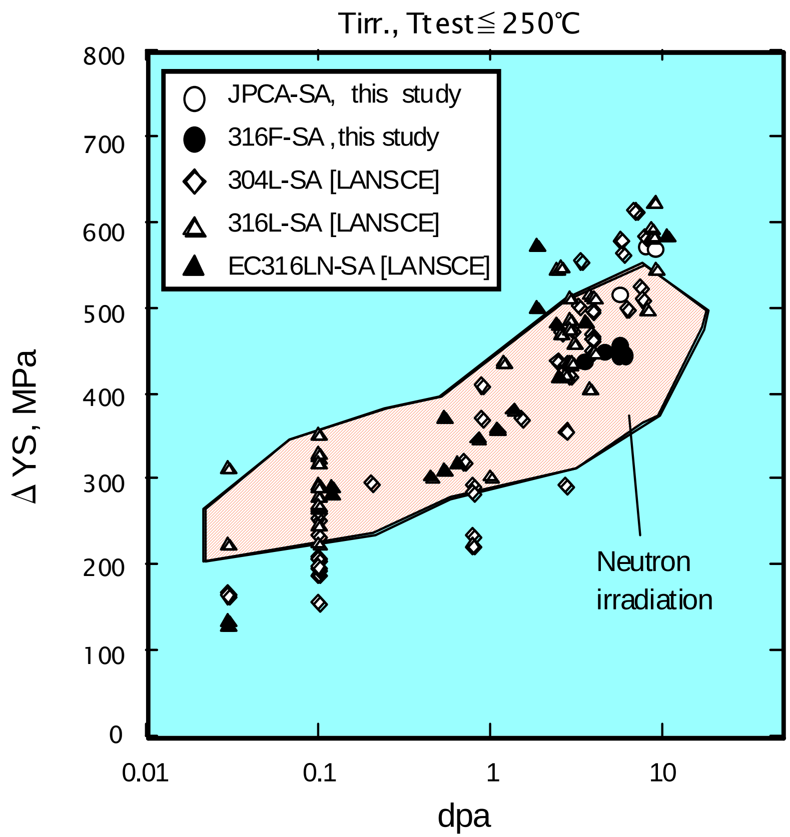
- The feasibility of the beam window was verified under the nominal operation conditions, but the effect of **corrosion**, **irradiation** and **fabrication accuracy** should be discussed.

- **We should accumulate experience on LBE spallation target.**



Engineering Feasibility:
Tensile Test of Irradiated Materials

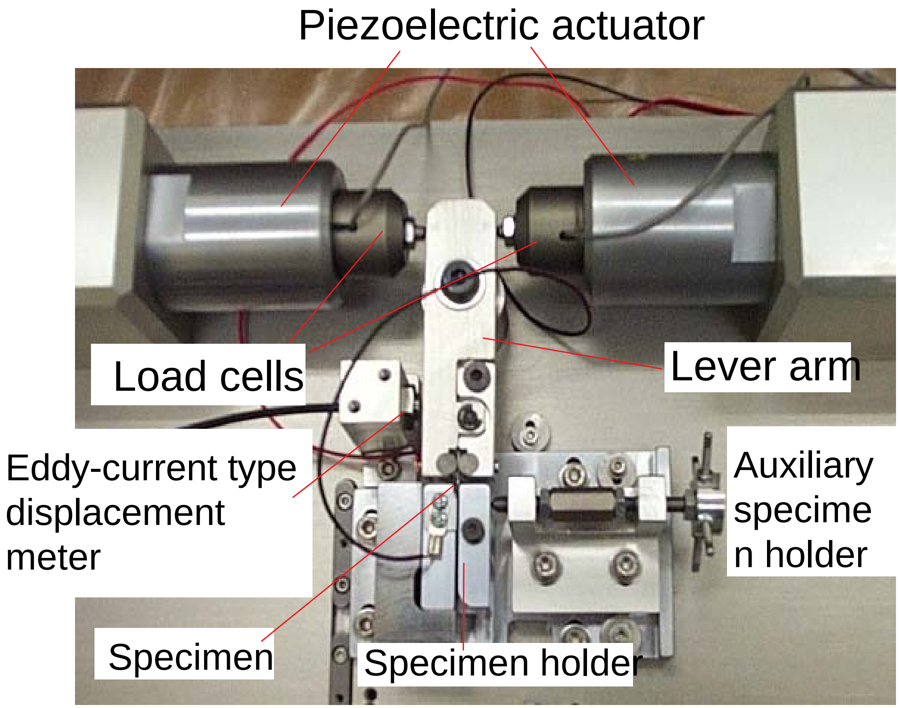


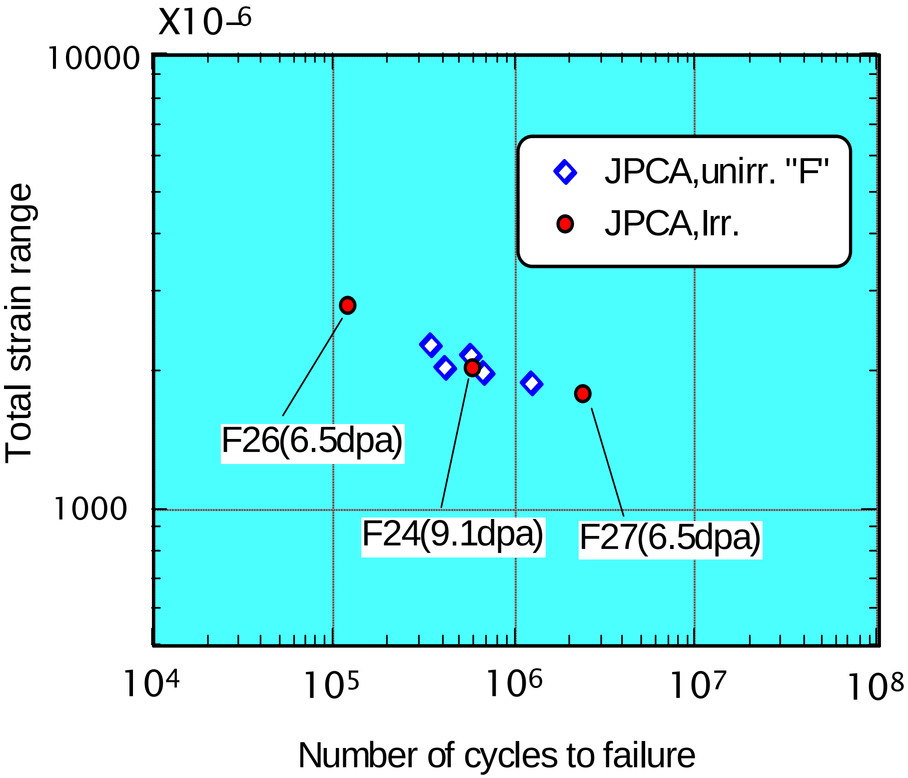


The increase in YS of irradiated specimens is within the fission neutron irradiated data band at lower dose. At higher dose, the increase in YS of JPCA-SA shows a tendency to exceed the upper bound the fission neutron irradiated data band.

Engineering Feasibility: Fatigue Test of Irradiated Materials

❖ **Bend fatigue tests for SINQ irradiated specimens**

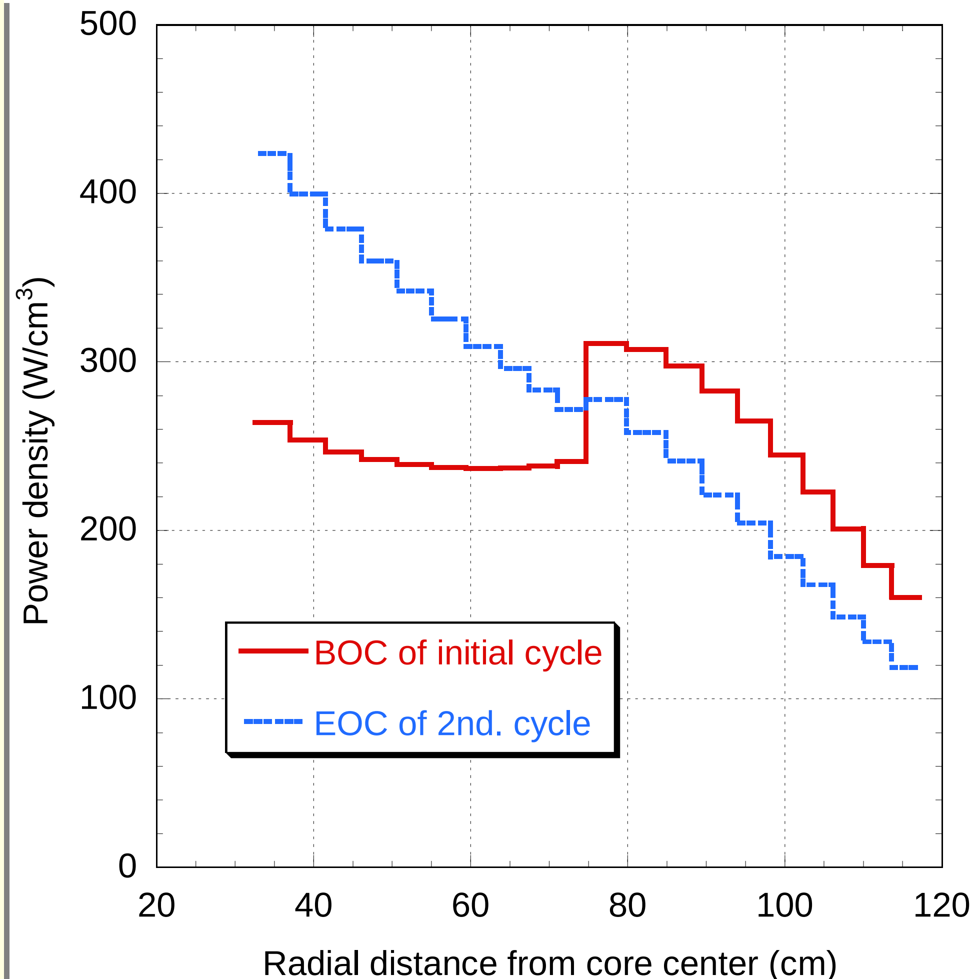




No or little change of the fatigue life was observed for the irradiated JPCA-SA and 316F-SA specimens.

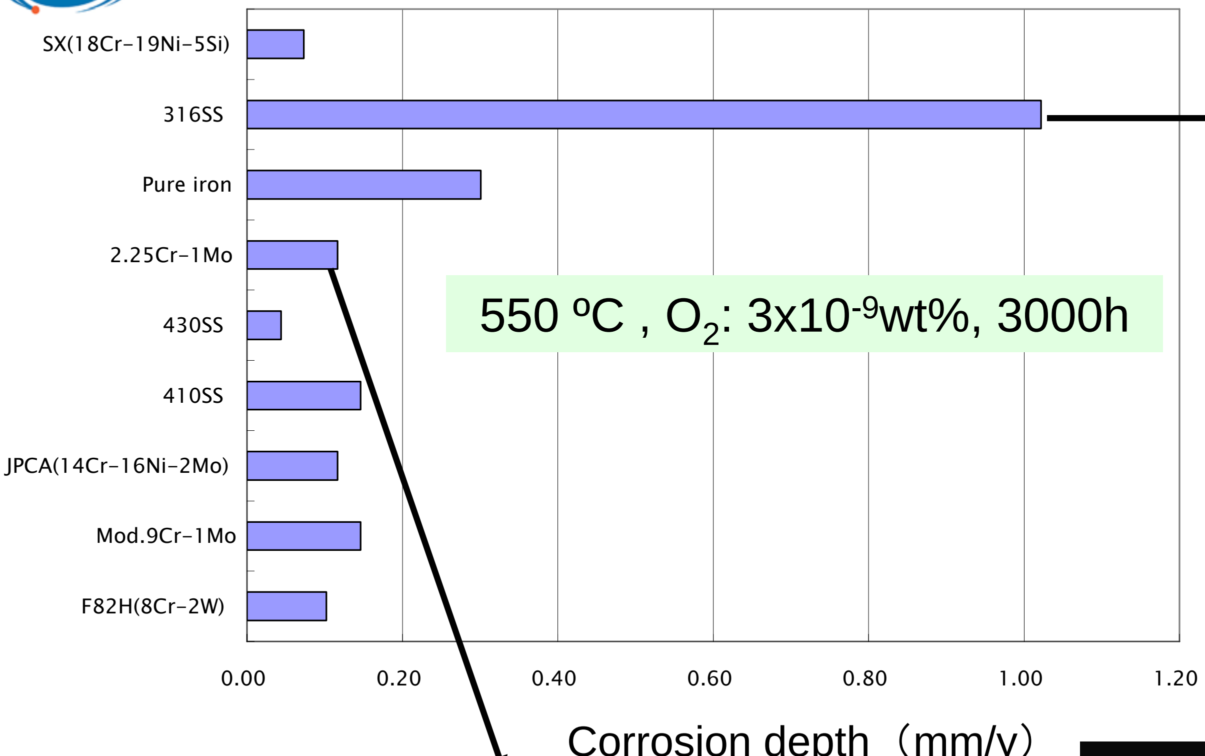
Engineering Feasibility: Reduction of Power Peaking

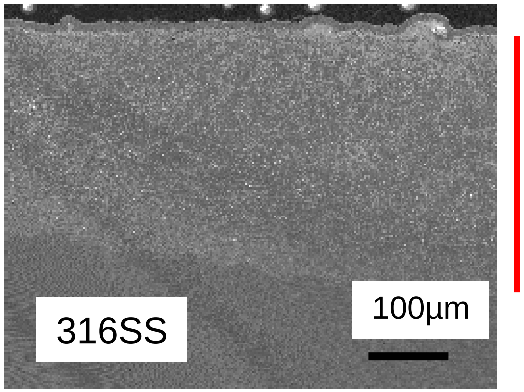
- It is important to reduce the power peaking factor throughout the whole burn-up stage.
- Power peaking will be the highest at **EOC of the 2nd. cycle**.
- **Two-zone core** is adopted to reduce power peaking.
- The hot spot pin will be about **600ºC** at EOC of the 2nd. cycle.
- Efforts to reduce this temperature below **550ºC** are being continued:
  - More detailed zoning
  - Adjustment of inert matrix (ZrN) at every burnup stage
  - Adoption of partial height fuel
  - Adoption of reactivity adjustment rods, etc.



Power density of two-zone core (axial position: center)

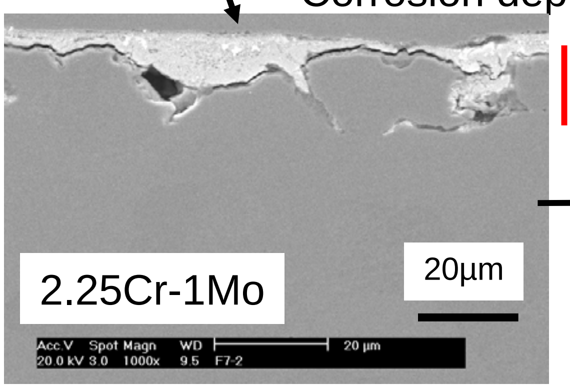
Engineering Feasibility: Static Test – Low Oxygen Concentration

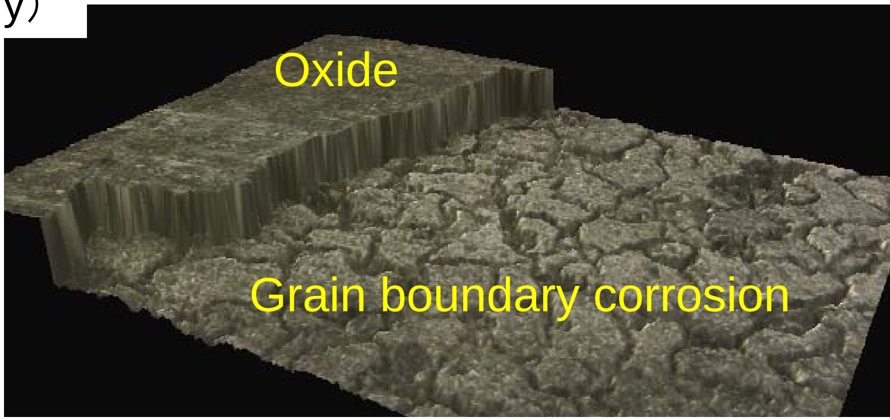




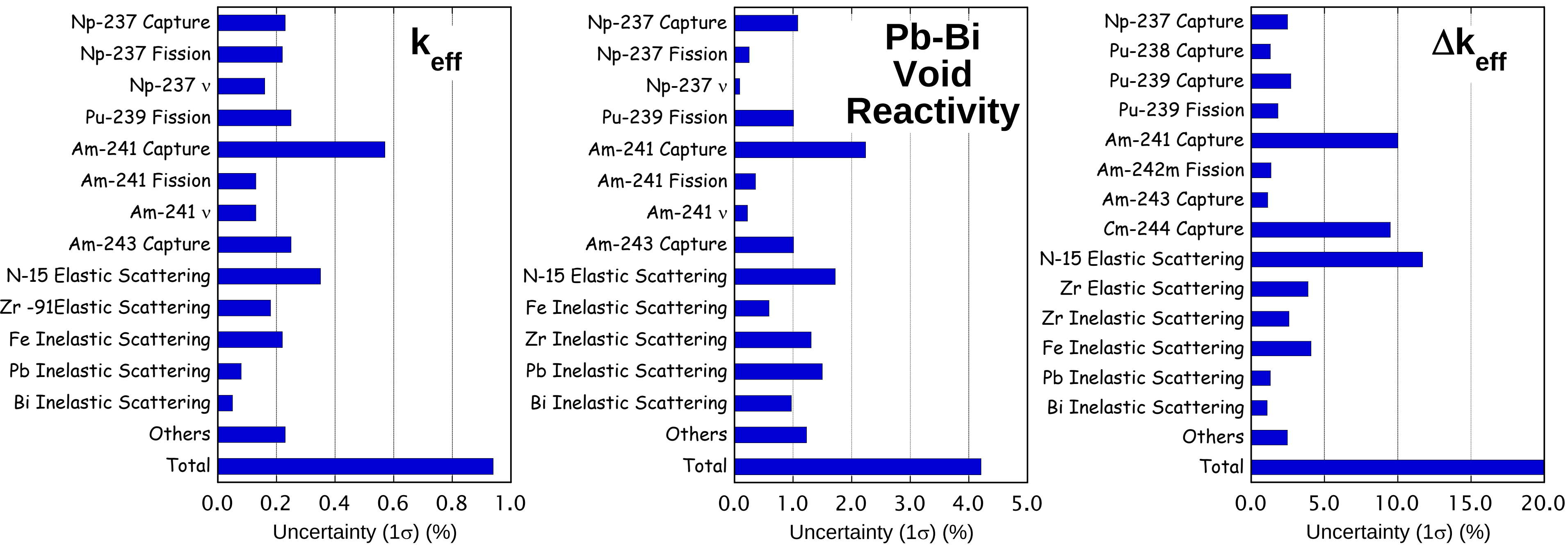
316SS shows deep corrosion

2.25Cr-1Mo steel shows grain boundary corrosion





Engineering Feasibility: Uncertainty Estimation for Neutronics Design

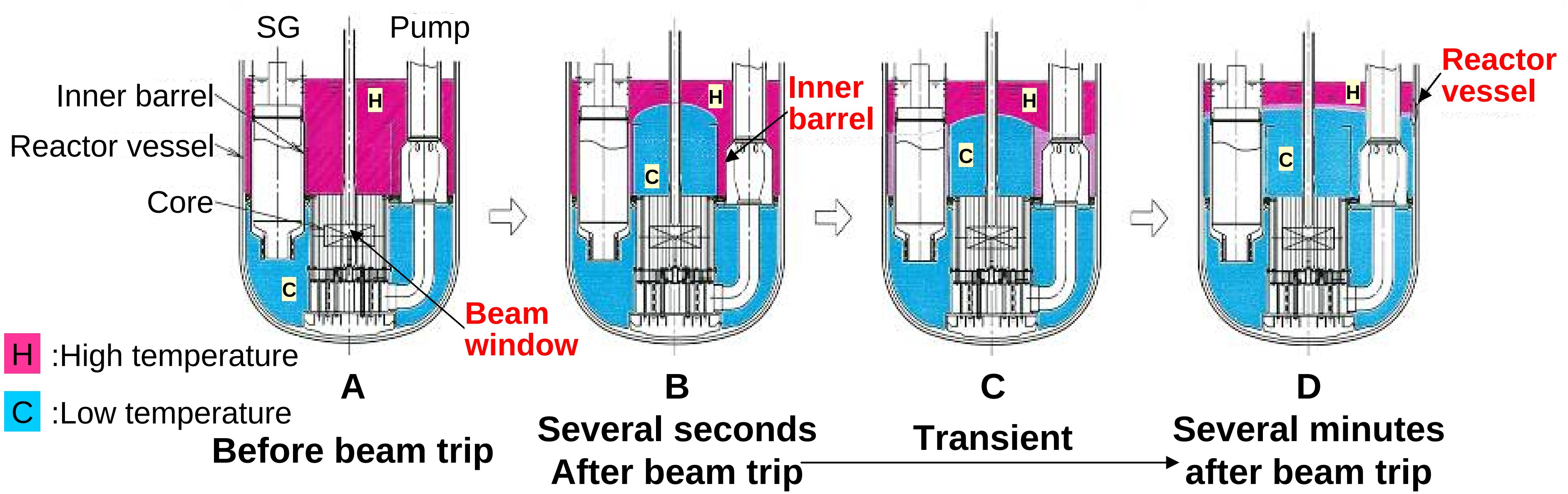


- The reactor physics parameters are very influential for the optimization of core design.
- Uncertainty of reactor physics parameters was estimated on the basis of the sensitivity of nuclear data and the error files evaluated for JENDL-3.3.
- **Large uncertainty was found in k_{eff} and burnup reactivity**.
- The capture reaction of **Am-241** has significant effect.

Reliability: Acceptable Beam Trip Frequency

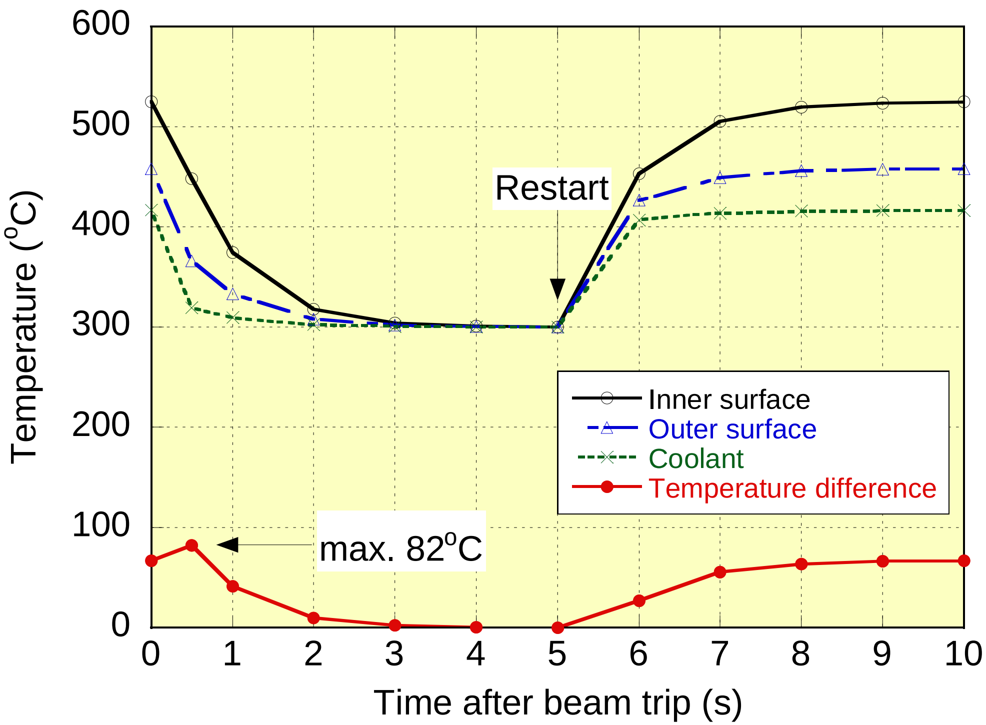
- **Thermal stress caused by beam trip** is estimated to know acceptable frequency of beam trip.
  1. **Beam window**
  2. **Inner barrel**
  3. **Reactor vessel**

- The influence of the beam trip to the power generation system is also estimated.



Reliability: Thermal Shock on Beam Window

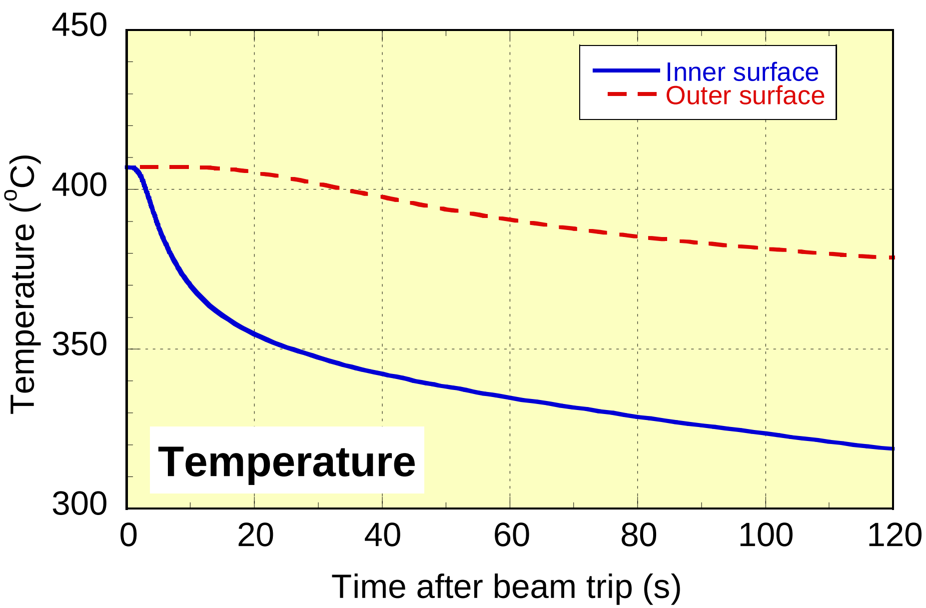
- Beam window :
  450mm$^{\phi}$, 2mm^{t}, 9Cr-1Mo steel,
  beam power: 30 MW
- Beam trip will cause max. **179 MPa** thermal stress 0.5 sec. after the beam trip.
- This thermal stress is much lower than a criteria to prevent buckling failure.
- The acceptable number of this thermal shock : about **10^5**
- Several beam trips per an hour is acceptable for 2 years (about 15,000 hours)
- It should be noted that this estimation is based on the material data without radiation damage.

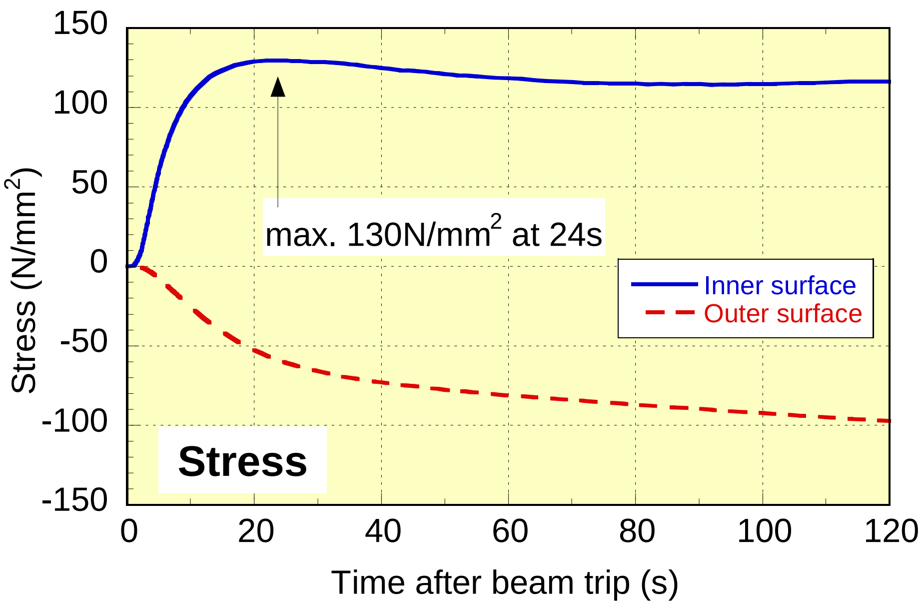


Temperature of beam window at beam trip transient

Reliability: Thermal Shock on Inner Barrel

- Inner barrel : 3cm^t, 9Cr-1Mo steel
- Beam trip will cause max. **130 MPa** thermal stress **24** sec. after the beam trip.
- The stress range will be **260 MPa** considering the following restart transient.
- The acceptable number of this thermal shock : about **10^4**
- 250 trips per year is acceptable for 40 years.

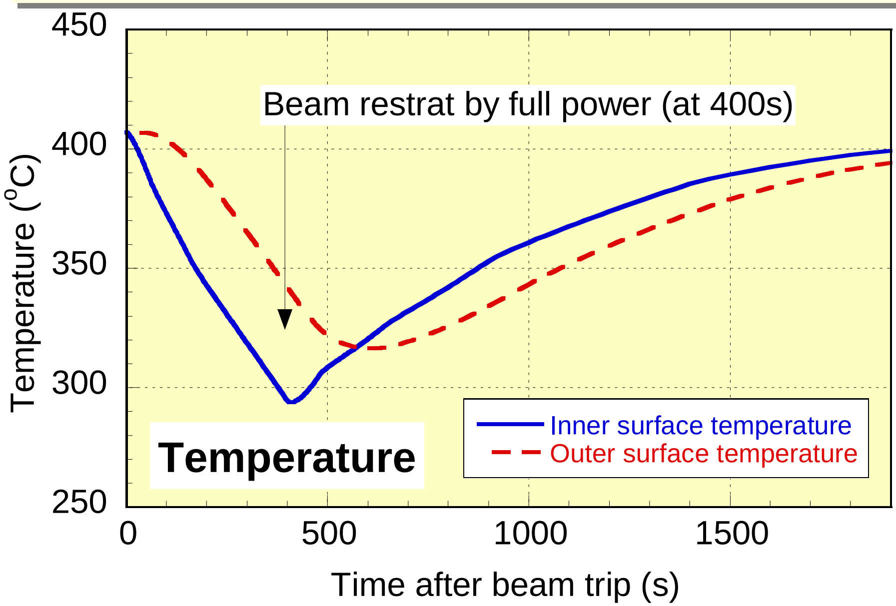


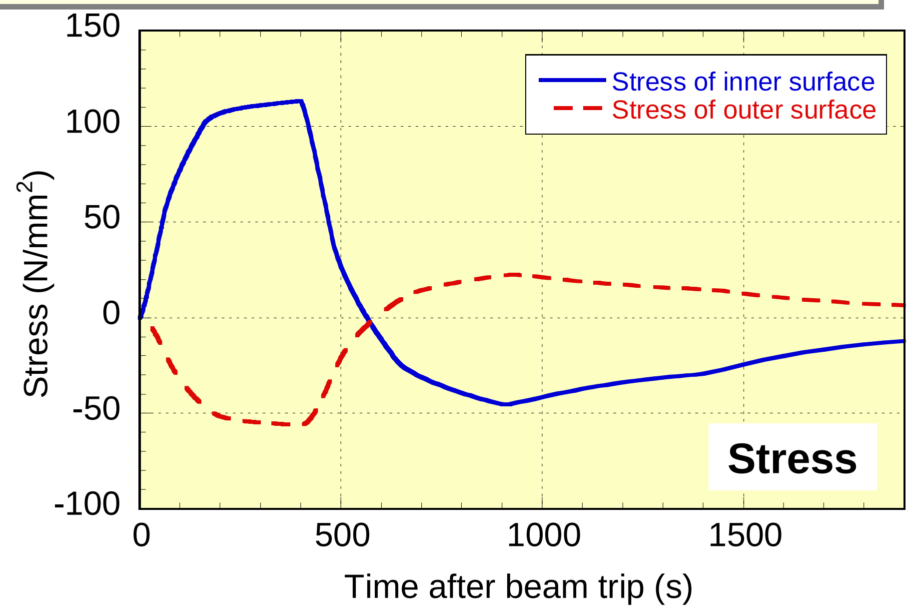


Temperature and stress of inner barrel at beam trip transient

Reliability: Thermal Shock on Reactor Vessel

- Reactor vessel : 5cm^t, 9Cr-1Mo steel
- Temperature difference between inner and outer surface will cause **113 MPa** thermal stress just before beam restart (400 s).
- Additionally, the formation of the temperature stratification and the LBE level lowering by thermal shrinkage will also cause **109 MPa**.
- In total, the stress range will be **270 MPa** considering the following restart
- The acceptable number of this thermal shock : about **10^4**
- 250 trips per year is acceptable for 40 years.

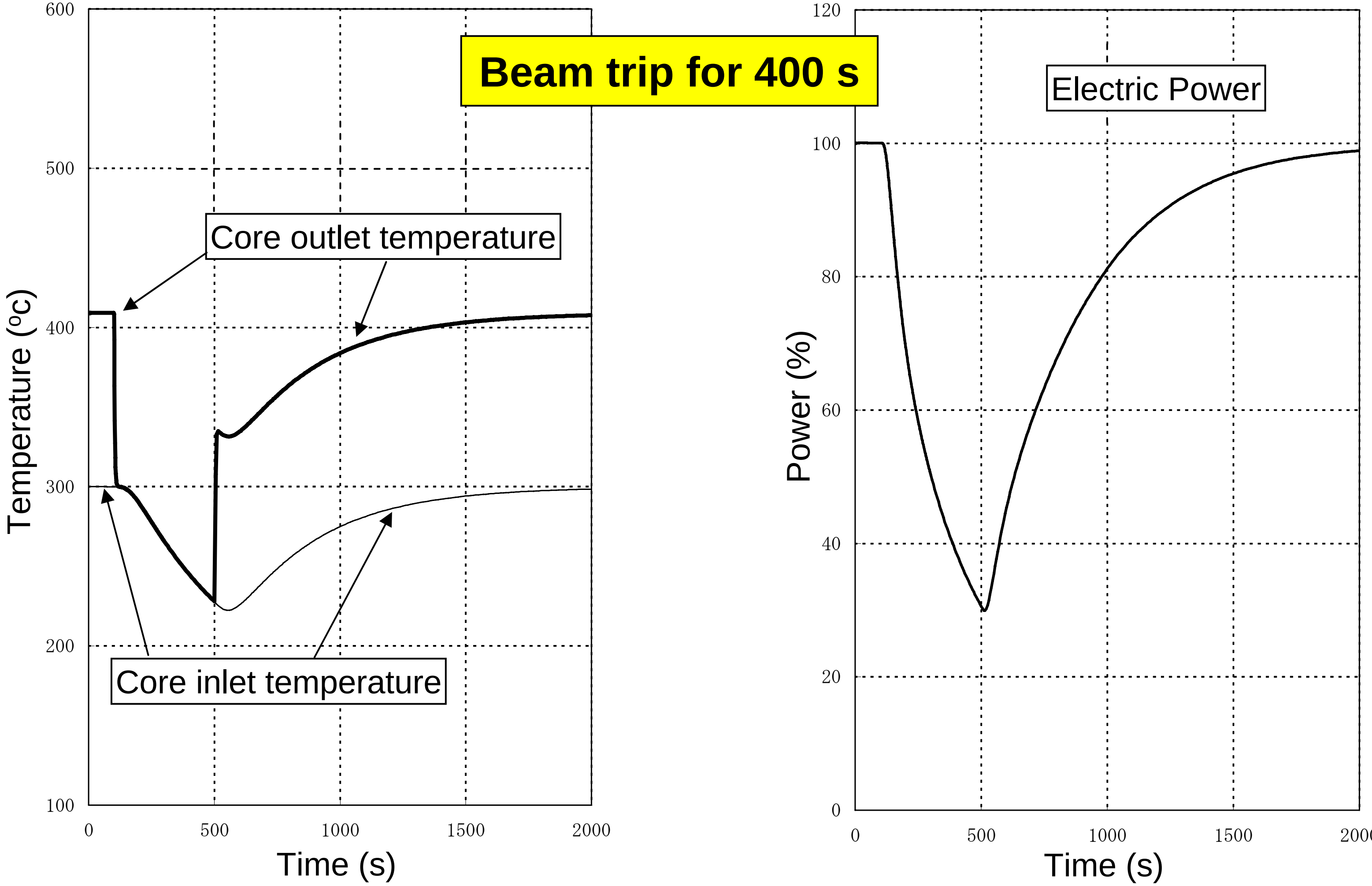




Temperature and stress of reactor vessel at beam trip transient

Reliability: Behavior of Electric Power Generation System

- Saturated steam cycle with steam drums enables us to continue power generation in case of short beam trip.



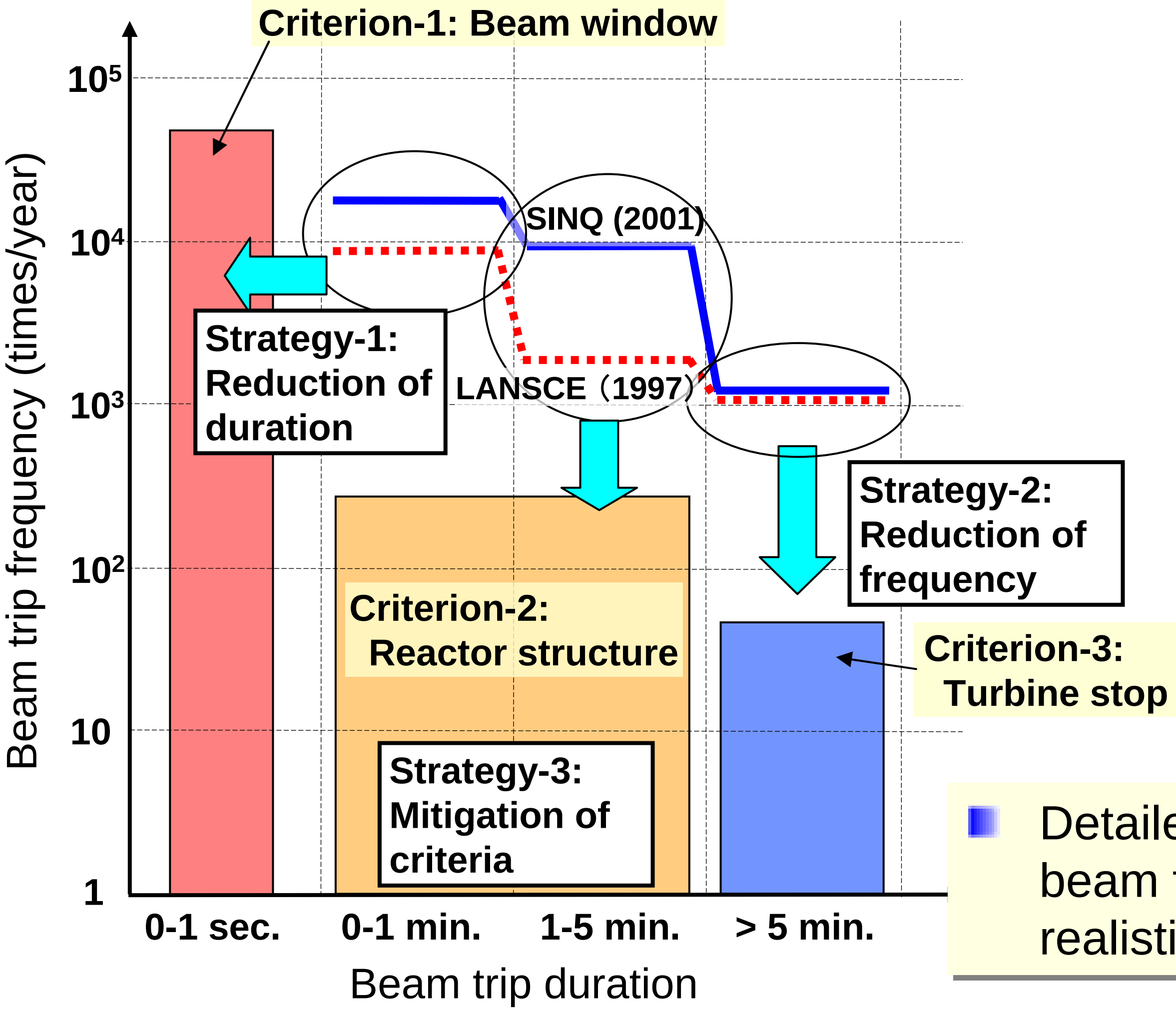
Reliability: Summary of Criteria

- Three criteria depending on the beam trip duration *T*

Beam trip duration *T*	Acceptable frequency	Remarks
T < 1 sec.	10^5 / 2 year (50,000 / y)	Beam window life time
1 sec. < *T* < 5 min.	10^4 / 40 year (250 /y)	Fatigue failure of reactor structure
T > 5 min.	Once a week (50 /y)	System availability

Reliability: Strategy to Reduce Beam Trip Frequency

- SINQ and LANSCE experiences show **1 or 2 orders** of frequency reduction might be necessary to meet the criteria.



Three strategies for reduction:

1. Reduction of the beam trip **duration** down to 1 sec.
2. Reduction of **frequency** for relatively long beam trip
3. Mitigation of the **criteria** by design consideration and detailed transient analysis.

- Detailed analysis on the causes of the beam trips is underway to explore the realistic solutions for Strategy-1 and 2.

Cost: Preliminary Estimation

Preliminary Estimation of ADS Cost (billion Japanese Yen = 10^9 JY)

Items	Construction	Operation and maintenance	Decommissioning	Total
ADS-reactor	**150**	**240[a)]**	**12[b)]**	**402**
ADS-accelerator	**76**	**122[a)]**	**6[b)]**	**204**
Total	**226**	**362**	**18**	**606**

a) 4% of construction cost per year. b) 8% of construction cost

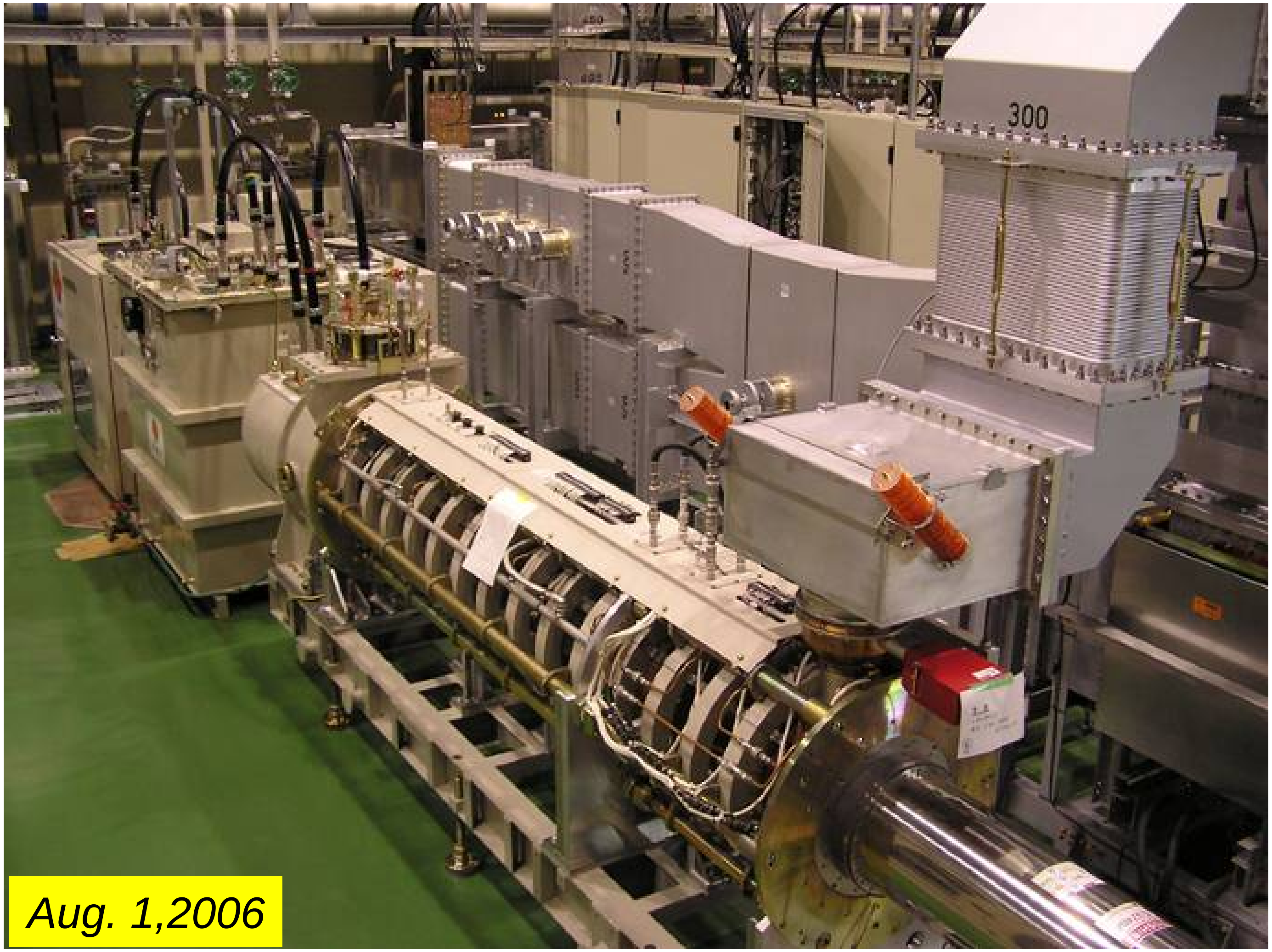
ADS Cycle Cost (10^9 JY)

Items	Cost
4 units of ADS	**2450**
Partitioning process	**570**
MA fuel fabrication	**520**
MA fuel reprocessing	**450**
Profit by ADS electric power	**-750**
Reduction of number of repository sites	**-1900**
Total	**1340**

- Balance : **0.12 ~ 0.13 JY/kWh** (discount rate : 0 %)
- about **2-3 % increase of the electricity cost** in Japan.
- Cost of ADS is the most influential.

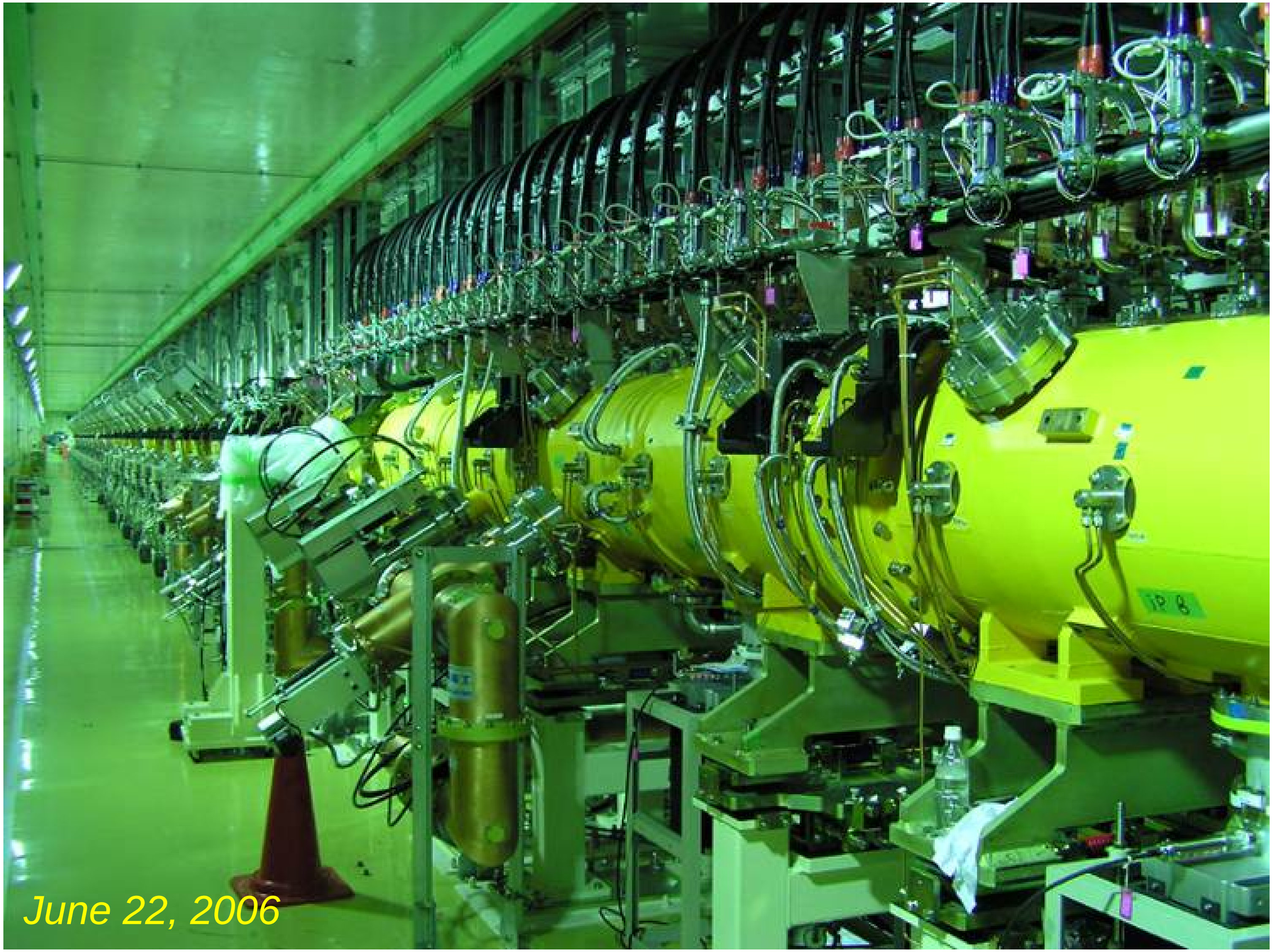
Current Status of J-PARC Project: Site Plan

Current Status of J-PARC Project: LINAC Klystron Gallery



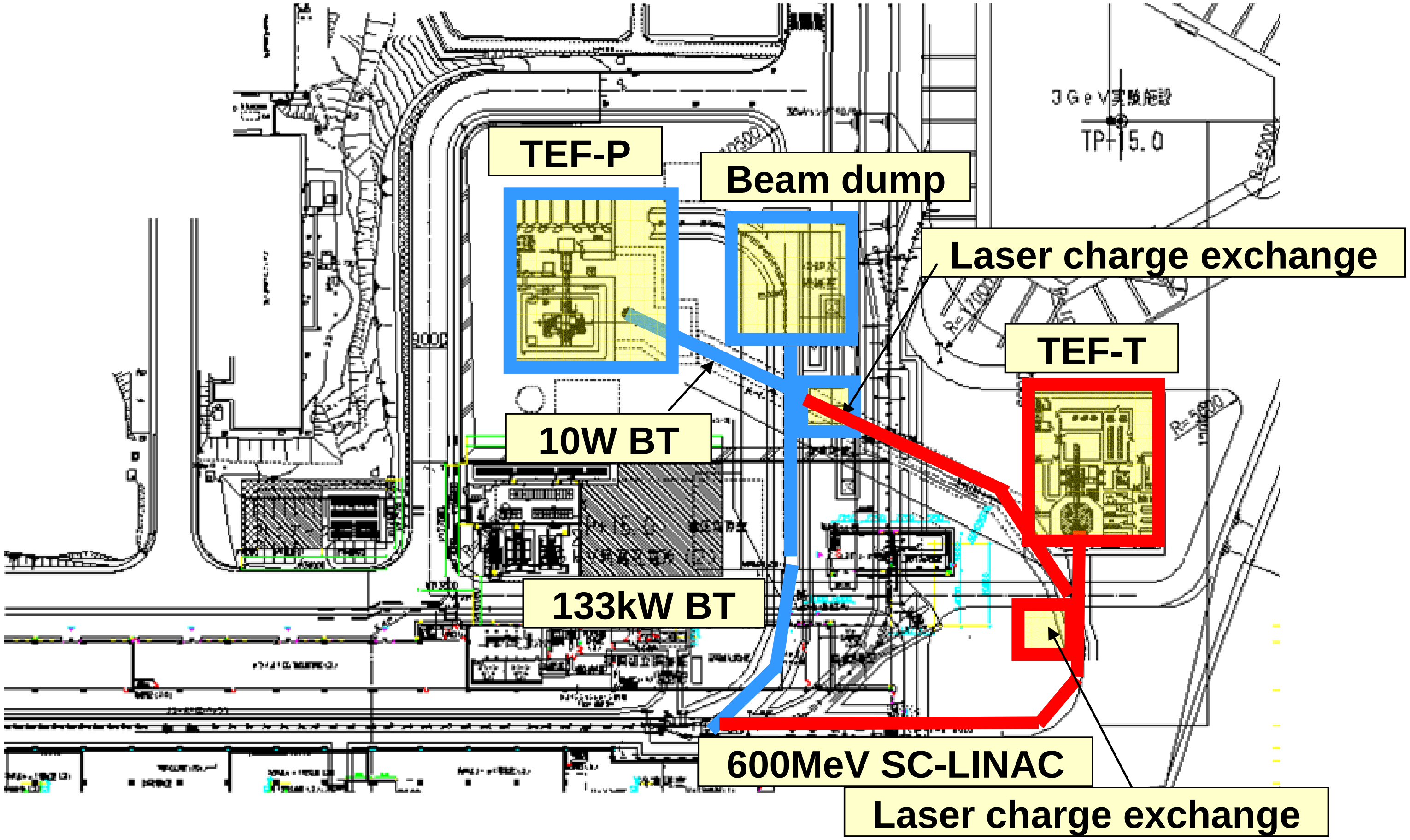
Aug. 1,2006

Current Status of J-PARC Project: LINAC Beam Line



Current Status of J-PARC Project: Transmutation Experimental Facility

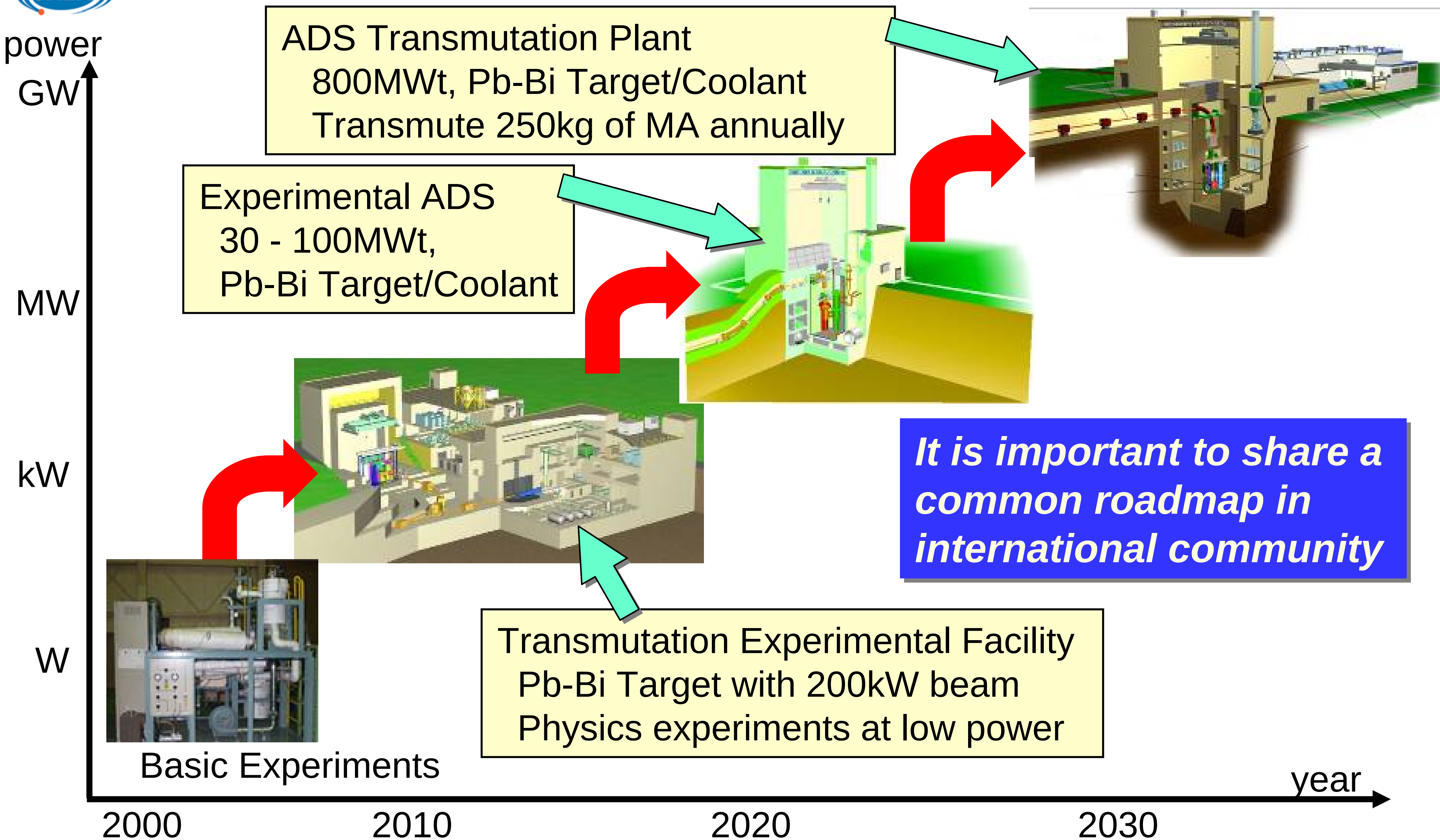
- Transmutation Experimental Facility (TEF) : **Phase-2 Program**.
- TEF consists of the Transmutation Physics Experimental Facility (**TEF-P**) and the ADS Target Test Facility (**TEF-T**).
- Because of the budget shortage, **step by step construction** will be necessary.



Current Status of J-PARC Project: Call for Preliminary Letters Of Intent

- The project team is calling for the ***Preliminary Letters Of Intent (Pre-LOI)*** for TEF.
- Purposes:
  - To know which groups have an interest in this activity .
  - To reflect the proposals on the specifications and layout of the TEF
  - To establish an appropriate collaboration scheme between J-PARC and the anticipated outside users.
- Up to now, we received about 30 proposals on
  - Reactor physics for ADS
  - Experiments using MA for both FR and ADS
  - High energy particle behavior
  - MA cross section measurement using pulsed spallation source
  - Engineering feasibility of LBE spallation target, etc.
- We are still accepting proposals, so please do not hesitate to contact us.

Step-by-step Approach for ADS and Importance of International Collaboration



Concluding Remarks

- The new organization JAEA continues the R&D efforts on the ADS.
- Scenario study shows the **flexible nature of ADS** to manage MA, and one of ultimate options would be **FBR-ADS symbiotic state**.
- **The engineering feasibility of ADS** is being studied on beam window and core performance.
- **The reliability of ADS**, especially for beam trip transient, is also being studied and the strategy to enhance the reliability is being discussed.
- The preliminary **cost estimation** shows that about 2-3% of cost increase would be expected to introduce P&T technology with ADS.
- The TEF of J-PARC Project is waiting for the approval, and the **Pre-LOI** is now being called for.