Japan ADS Project

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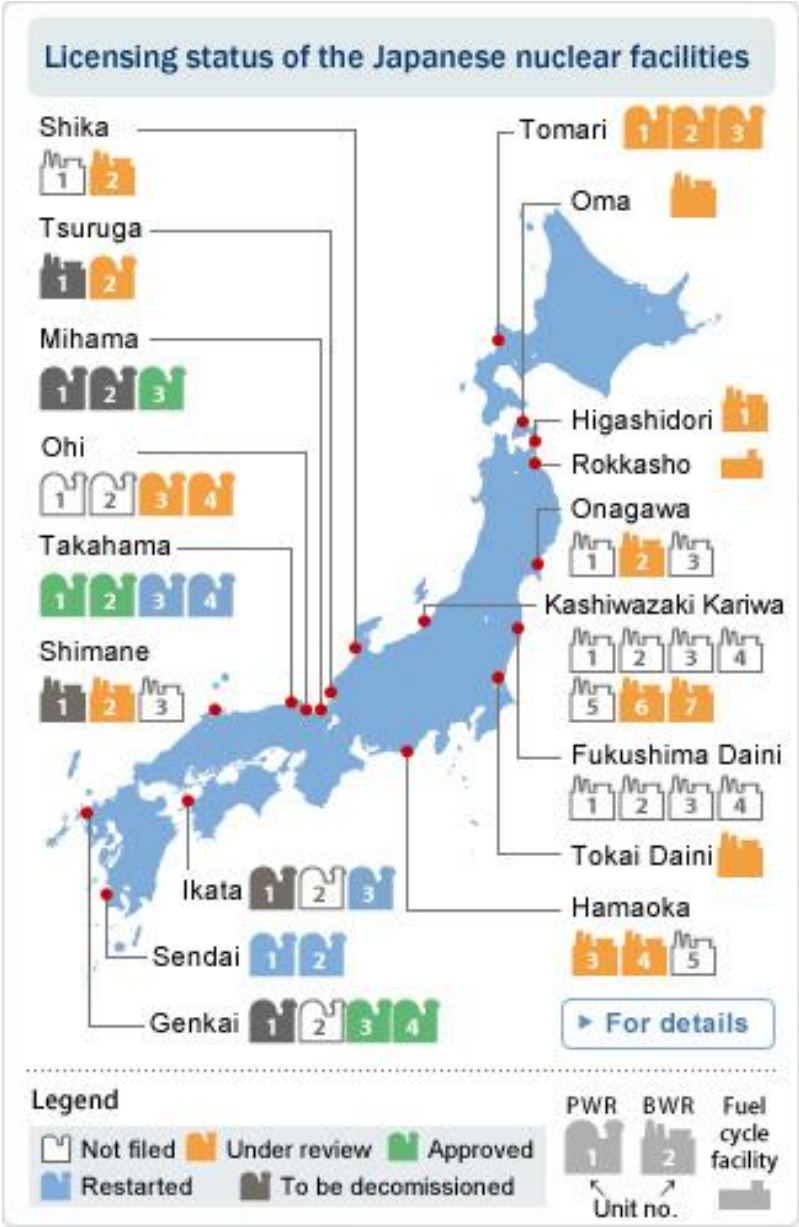
National Policy for Nuclear Energy

Current status of the NPPs in Japan

- Before March 2011, 54 units (48.8GWe) were operated in Japan.
- After March 2011, 6 units excluding Fukushima Daiichi 6 units were decided to be decommissioned.
- Nuclear Regulatory Authority (NRA) was newly established on 2012 and new safety regulations were issued by NRA.
- NRA approved basic design of 10 units and 5 units were restarted

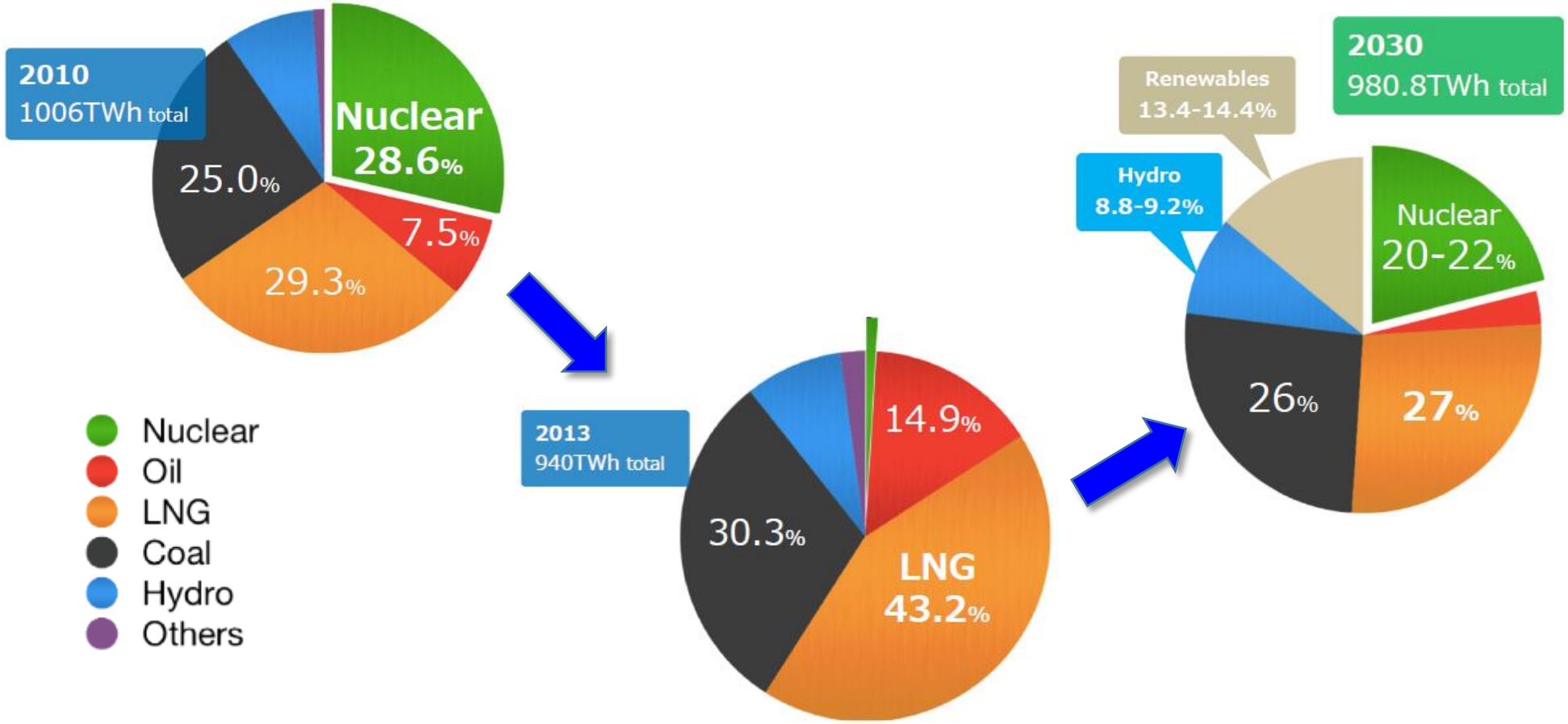


http://www.genanshin.jp/english/index.html

“Strategic Energy Plan” in Japan

“Strategic Energy Plan” issued in Apr. 2014

- Nuclear power is an important base-load power source.
- Dependency on nuclear will be decreased.
- Future volume of nuclear capacity will be carefully examined.



“Strategic Energy Plan” in Japan

- **Position of Nuclear Power**

  Nuclear power is an important base-load power source as a low carbon and quasi-domestic energy source, contributing to stability of energy supply-demand structure.

- **Steady approach for key issues to be solved without putting off implementing measures into the future**

  (1) Spent fuel management

  - ✓ Drastic reinforcement of measures for final disposal of high-level radioactive waste
  - ✓ Expanding storage capacity of spent fuels
  - ✓ **Promotion of technology development on volume reduction and mitigation of degree of harmfulness of radioactive waste**
  - ✓ Promotion of R&D for technologies including **nuclear transmutation technology using fast reactors and accelerators**

  (2) Nuclear fuel cycle

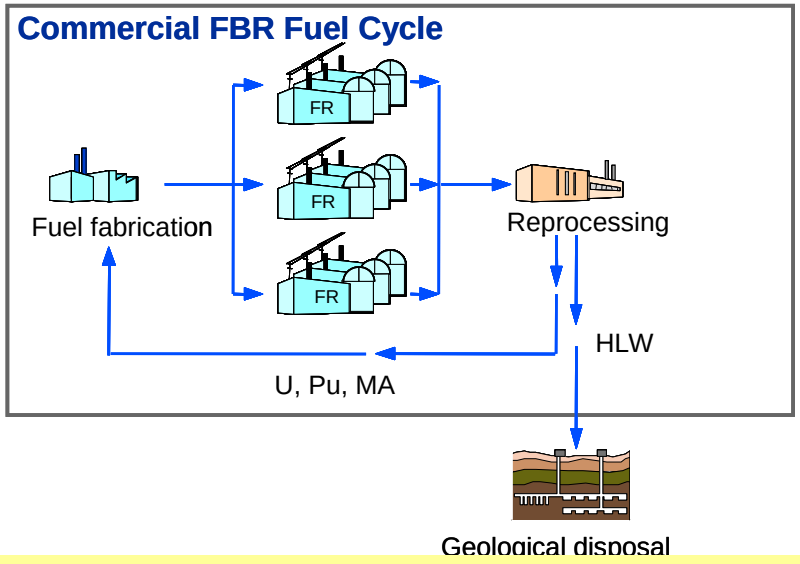
  - ✓ **The basic policy of Japan is to promote a nuclear fuel cycle** that reprocesses spent fuels and effectively utilizes the plutonium retrieved.

Partitioning and Transmutation Technology

R&D on P&T in JAEA

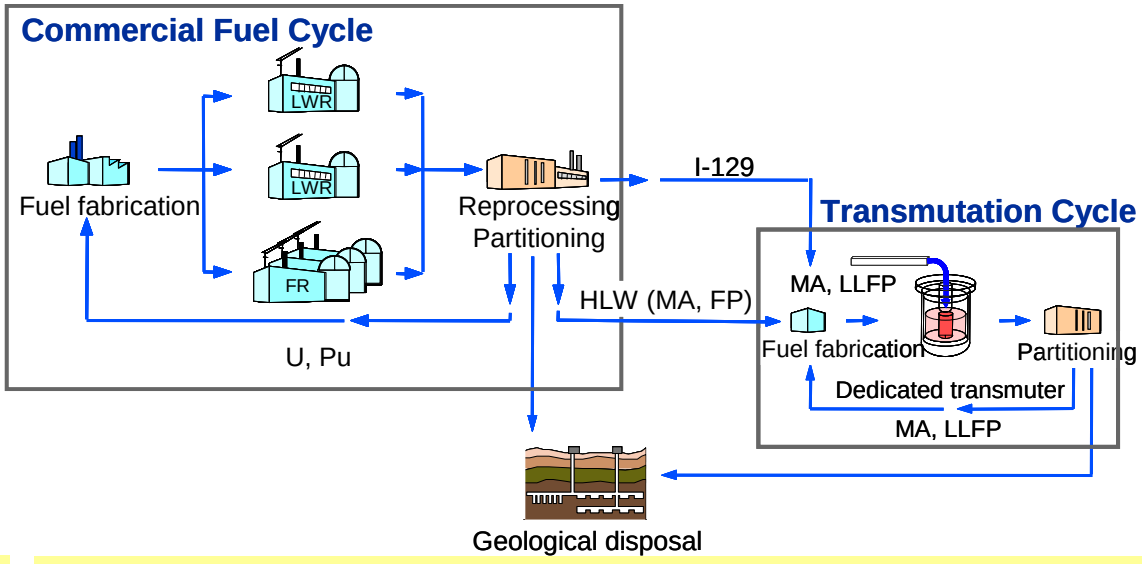
- Partitioning and Transmutation (P&T) technology is expected to be effective to mitigate the burden of the HLW disposal by reducing the radiological toxicity and heat generation.
- JAEA has been studying this technology for more than 20 years.

Homogeneous cycle



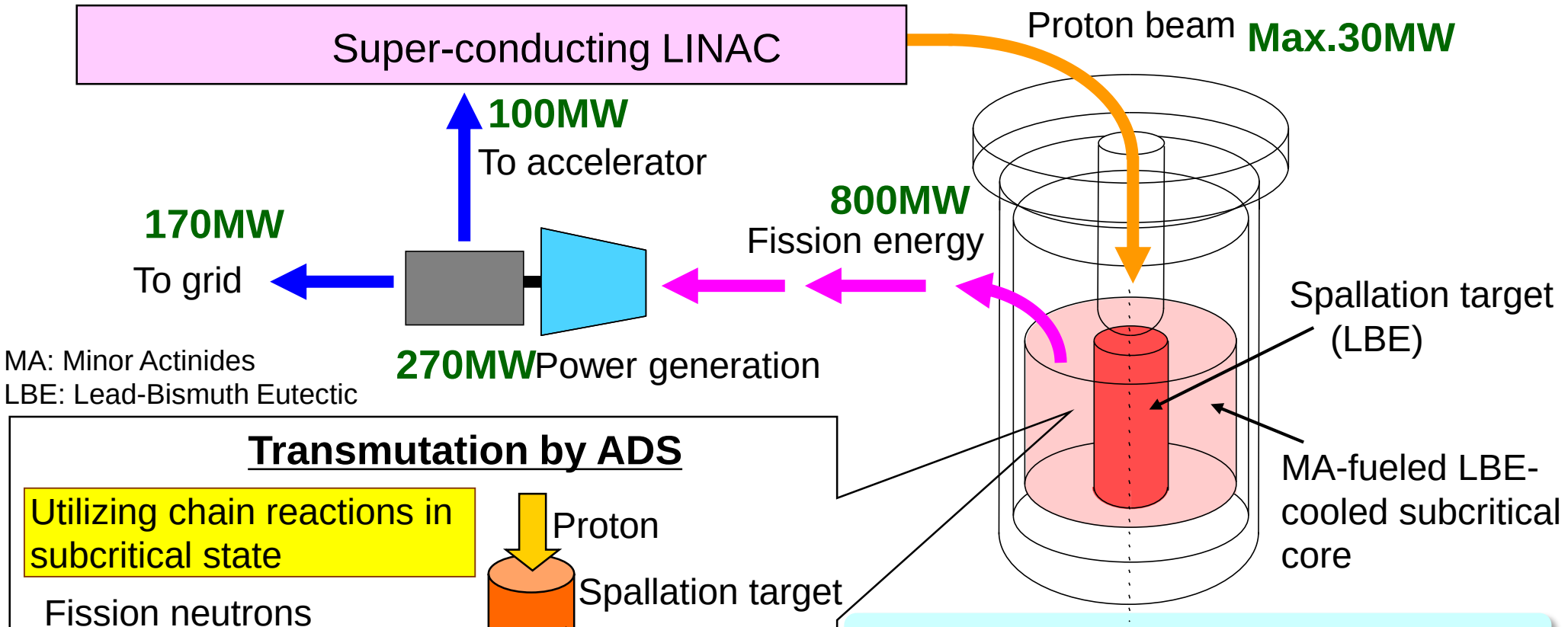
- MA is homogeneously mixed to FBR fuel with small amount up to 5 wt.%.
- **MA transmutation is performed in all electricity generating FBR plant.**

Double-Strata (ADS)



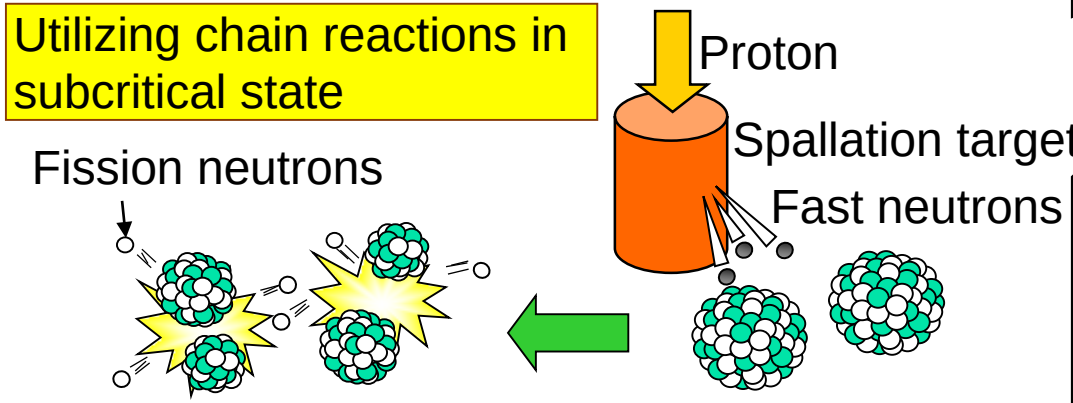
- **Dedicated (second) transmutation fuel cycle with Accelerator-Driven System (ADS) is added to commercial fuel cycle.**
- MA recovered from commercial fuel cycle is confined in the compact transmutation cycle.

Accelerator Driven System (ADS)



Transmutation by ADS

Utilizing chain reactions in subcritical state



Characteristics of ADS:

- Chain reactions stop when the accelerator is turned off.
- LBE is chemically stable.
  ➔ **High safety can be expected.**
- High MA-bearing fuel can be used.
  ➔ MA from **10 LWRs** can be transmuted.

R&D for ADS in JAEA

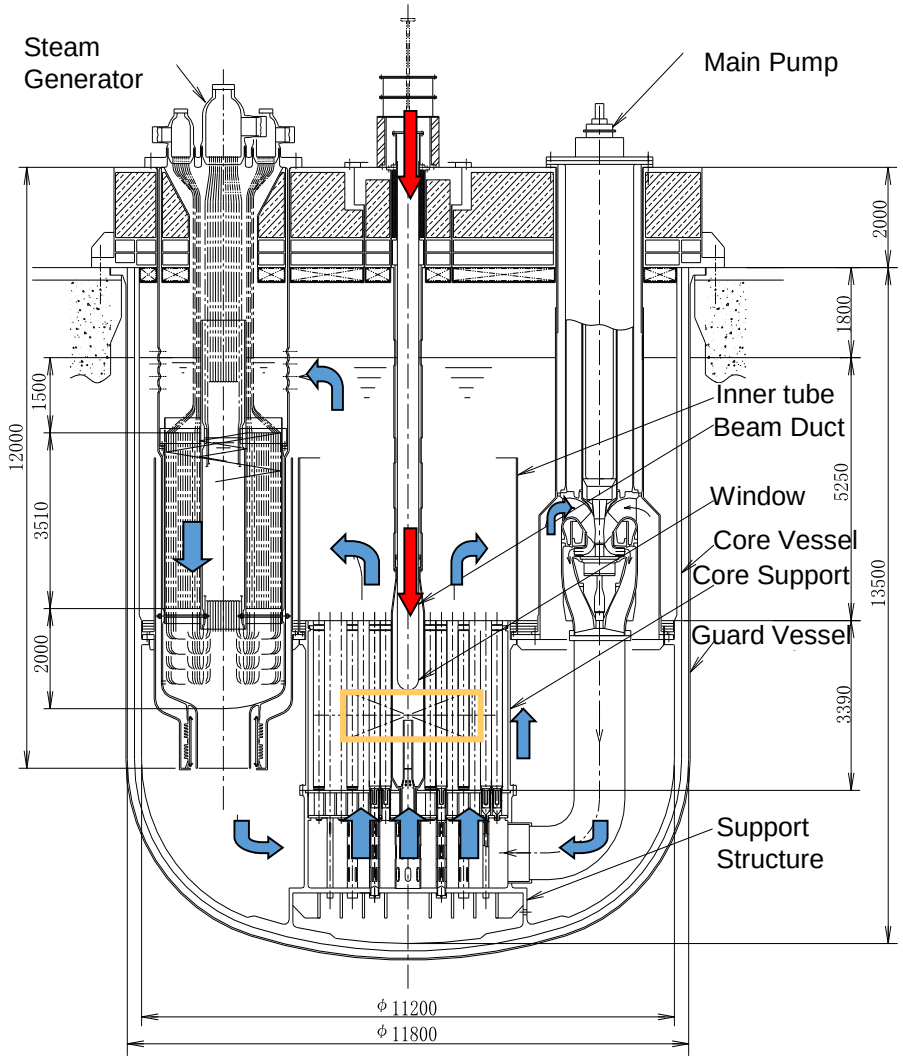
Conceptual Design of ADS in JAEA

Purpose : MA transmutation

- Proton beam : 1.5GeV ~30MW
- Spallation target : LBE
- Coolant : LBE
- Subcriticality : $k_{eff} = 0.97$
- Thermal output : 800MWt
- Core height : 1000mm
- Core diameter : 2440 mm
- Fuel inventory : 4.2t (MA:2.5t)
- Fuel composition :

  (MA + Pu)N+ZrN (Mono-nitride)
  Inner : 70%MA+30%Pu
  Outer : 54%MA+42%Pu
- Transmutation rate :

  250kg(MA) / 300EFPD



K. Tsujimoto, H.Oigawa, K.Kikuchi, et. al, "Feasibility of Lead-Bismuth-Cooled accelerator-Driven System for Minor-Actinide Transmutation", *Nucl. Tech.* 161, 315-328 (2008).

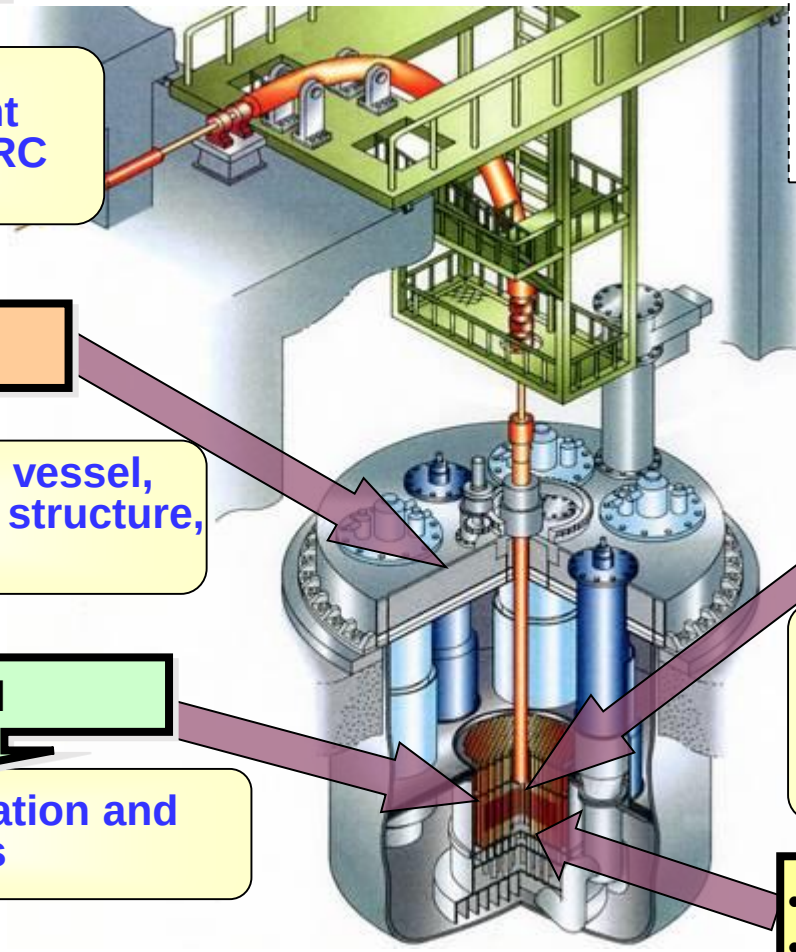
Technical Issues of ADS

J-PARC: Japan Proton Accelerator Research Complex
TEF-P: Transmutation Physics Experimental Facility
TEF-T: ADS Target Test Facility
SC-LINAC: Superconducting LINAC

•Accelerator

- R&D of SC-LINAC
- Reliability Assessment

➔Construction of J-PARC accelerator



•Structure

•Design study on reactor vessel, beam duct, quake-proof structure, etc.

•Fuel

•Fabrication, irradiation and reprocessing tests

•R&D of Pb-Bi technology

➔Construction of TEF-T in J-PARC

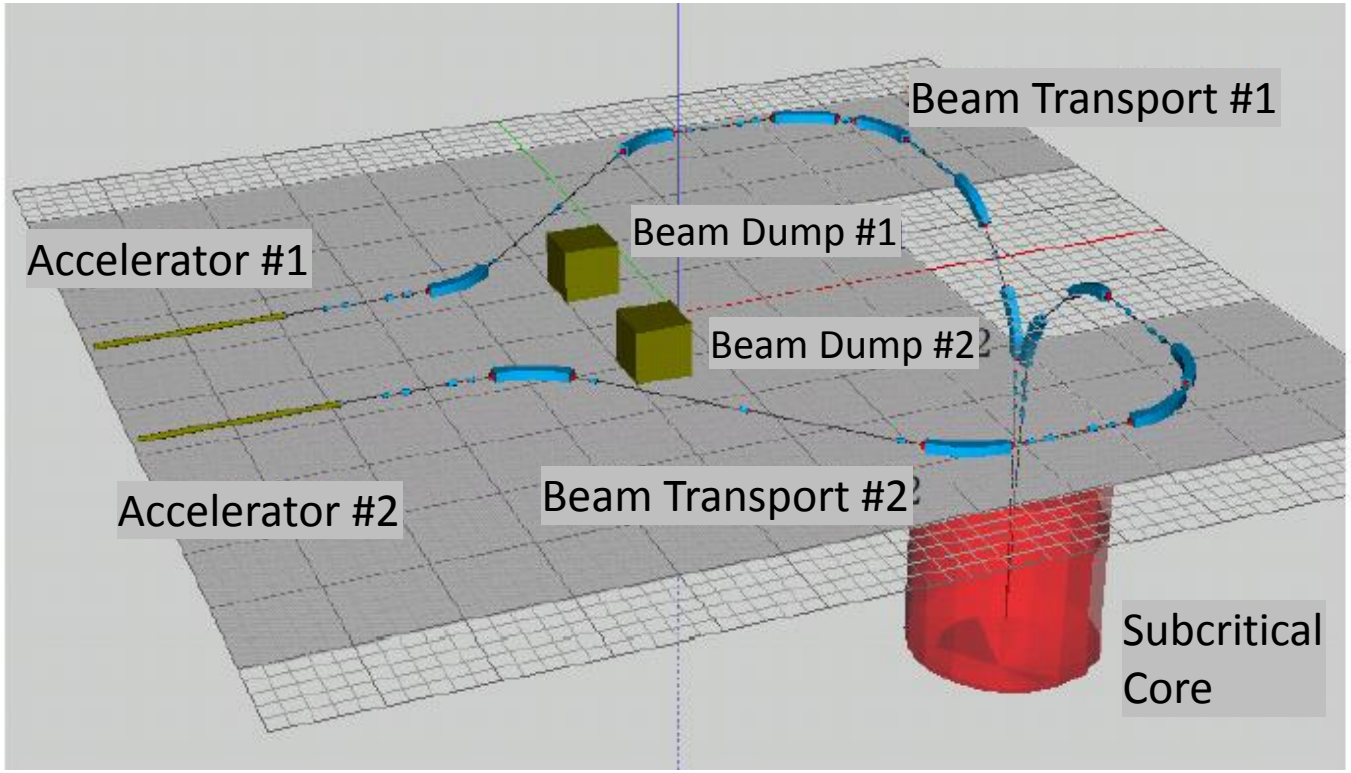
•Spallation Target, Material
•Operation of Pb-Bi system

•Experiments in existing facilities and analyses

➔Construction of TEF-P in J-PARC

- Reactor Physics
- Control of Subcritical System

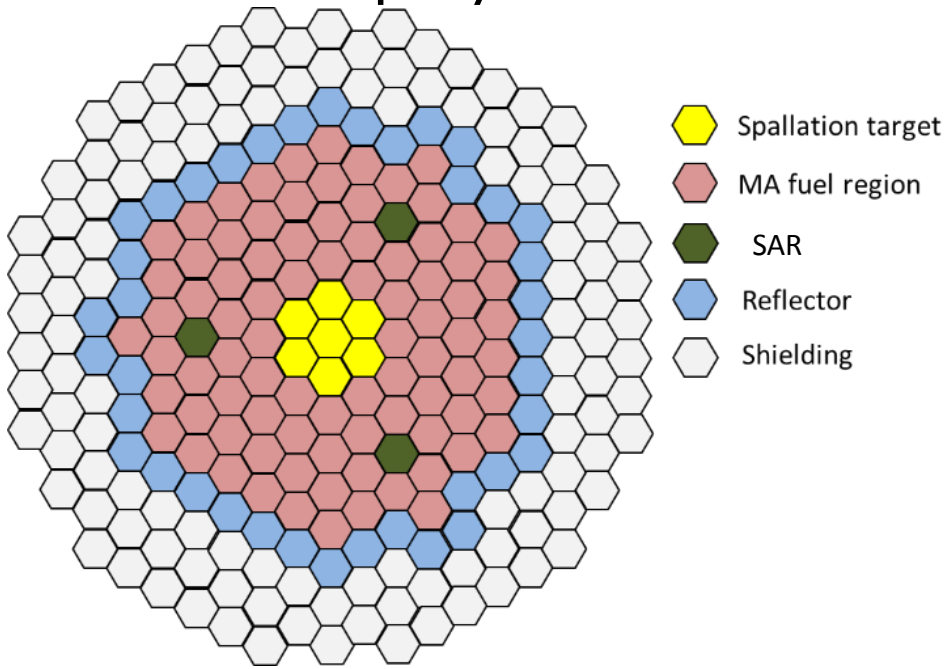
Increase Beam Reliability



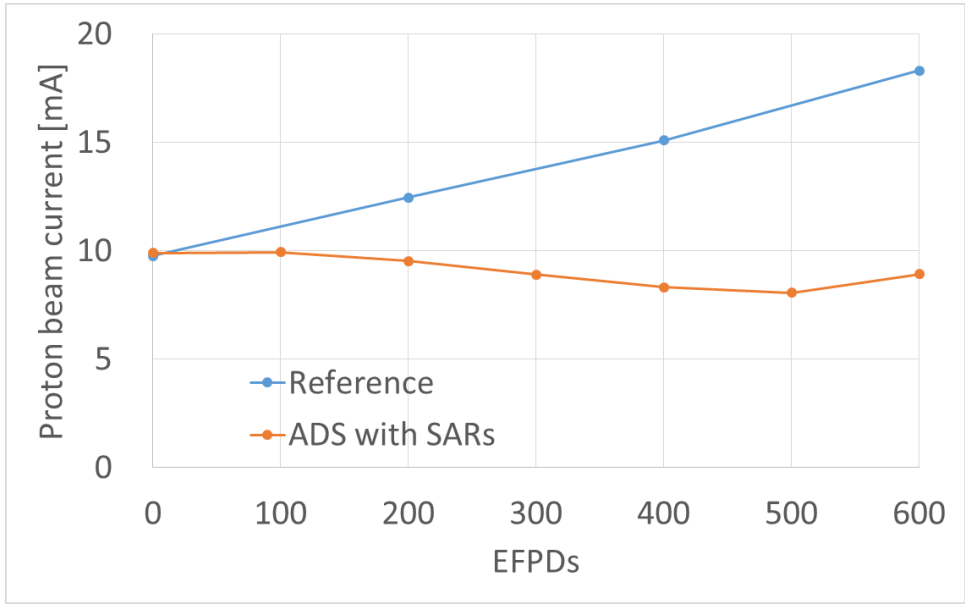
- Beam-trip is one of the critical issues for ADS
- To reduce the beam-trip frequency, double-accelerator concept is proposed
- By running two accelerators (50% of rated power/acc.), reliability requirement for ADS can be satisfied

k_{eff} adjustment by SAR

- To reduce the proton beam current, ADS with Subcriticality Adjustment Rod (SAR) was investigated
  - Install 3 B_4C SARs (Total Worth:1.5%dk/k)
  - Possible to keep proton beam current around **10mA** during the burnup cycle



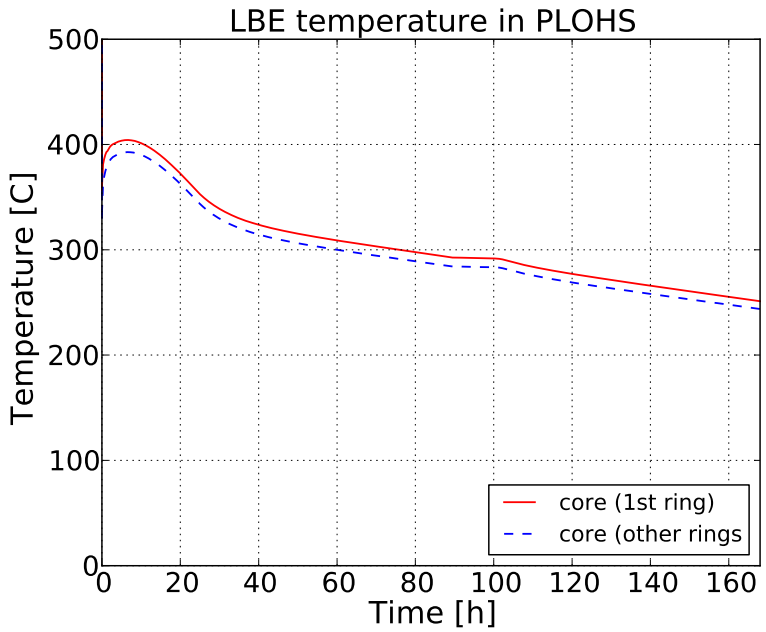
SAR Layout (Green)



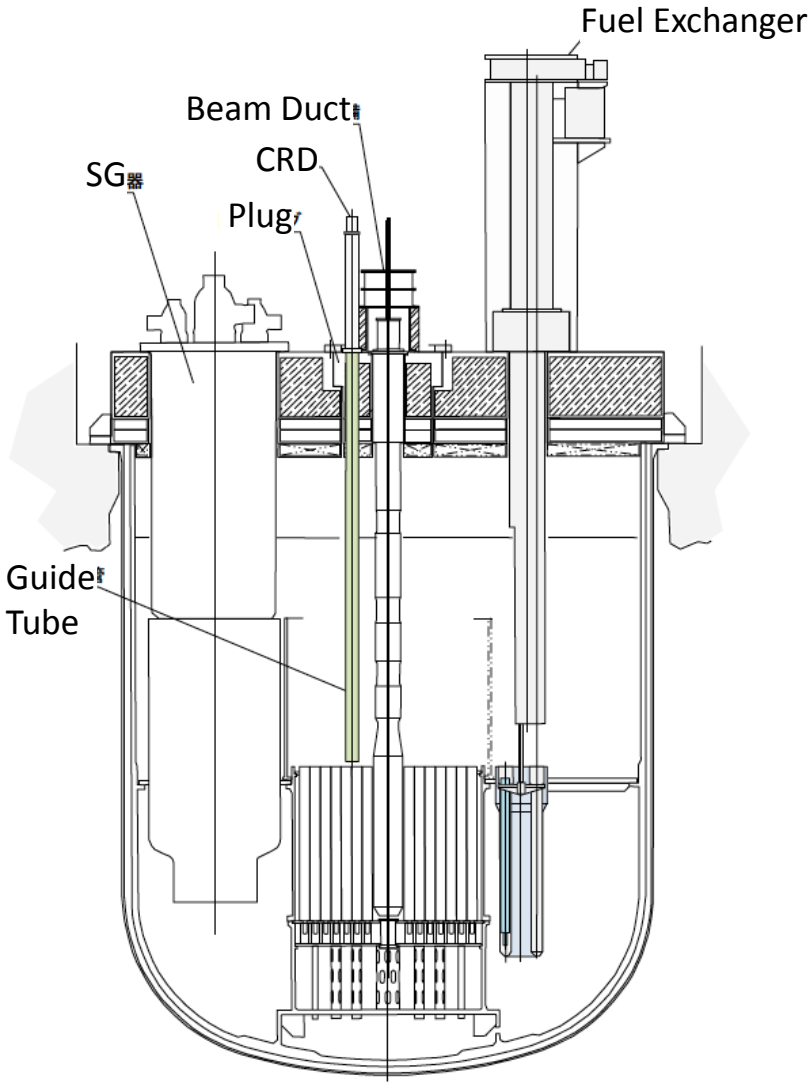
Change of proton beam current

Improvement of passive safety

- Reflecting the Fukushima Accident, conceptual design of DRACS (Direct Reactor Auxiliary Cooling System) is investigated
- PLOHS with DRACS was analyzed by RELAP5-Mod3
- It was confirmed the coolant temperature can be kept below 400°C even in the case of Station Black Out



Subcritical core arrangement



- Layout of reactor components including newly added equipment (ex. SAR) was performed
- The scheme to replace beam window and fuel is confirmed

Research Plan at J-PARC

Transmutation Experimental Facility (TEF)

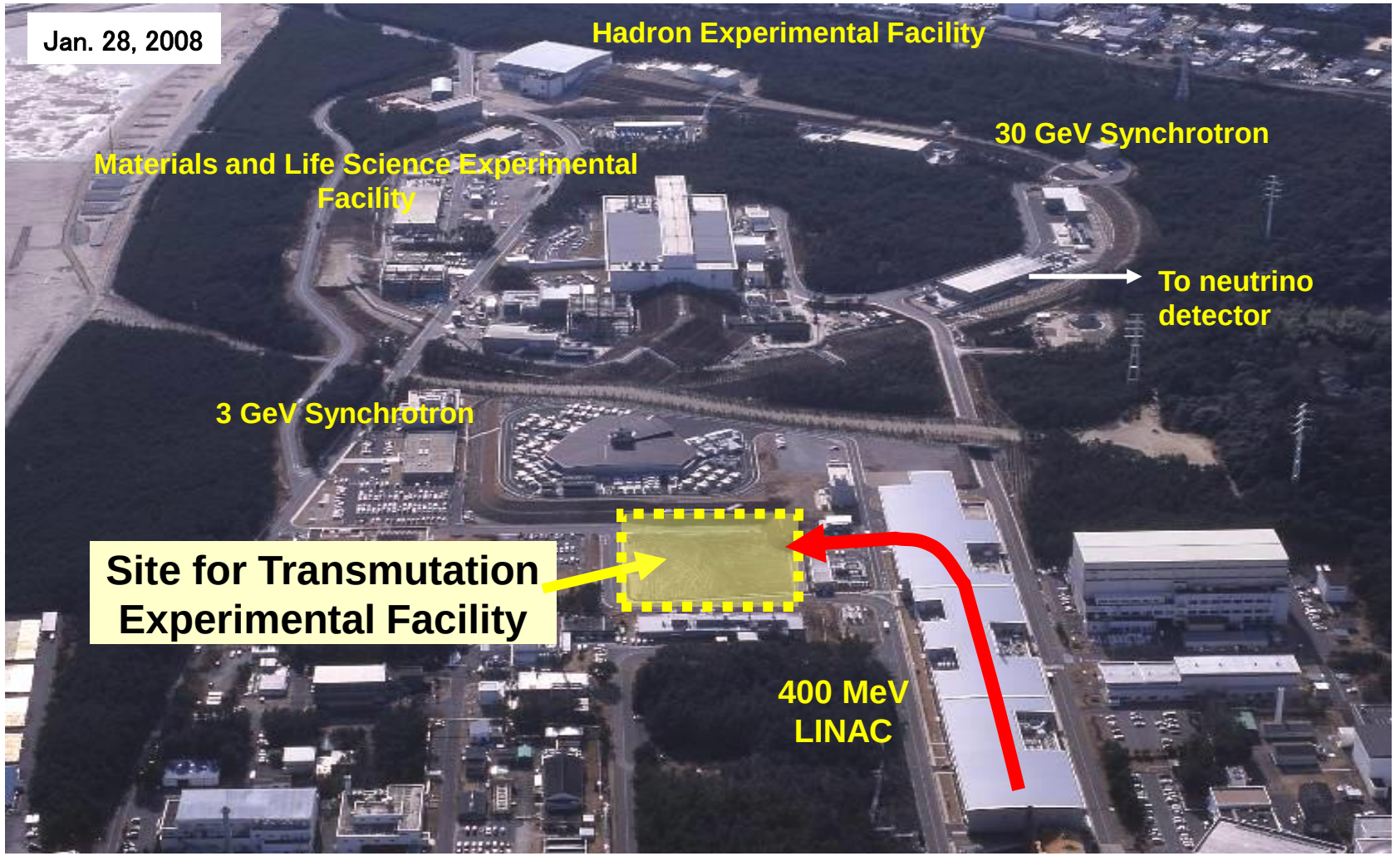


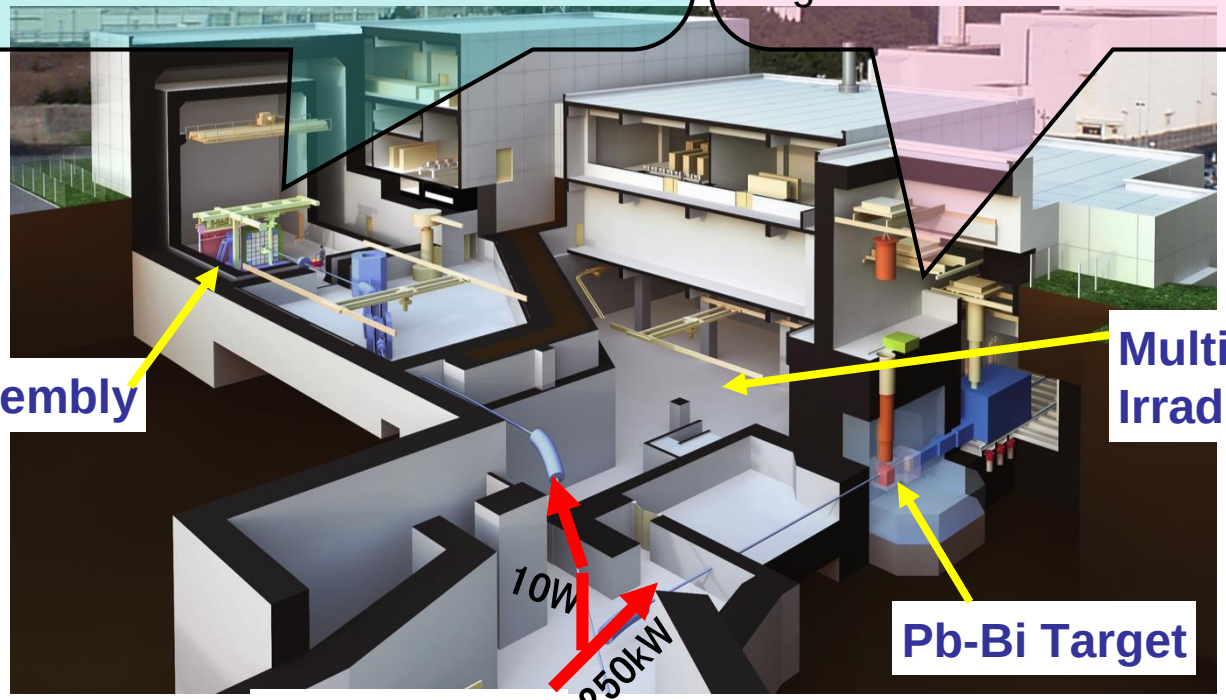
Image View of TEF

Transmutation Physics Experimental Facility: TEF-P

Purpose: To investigate physics properties of subcritical reactor with low power, and to accumulate operation experiences of ADS.
Licensing: Nuclear reactor: (Critical assembly)
Proton beam: 400MeV-10W
Thermal power: <500W

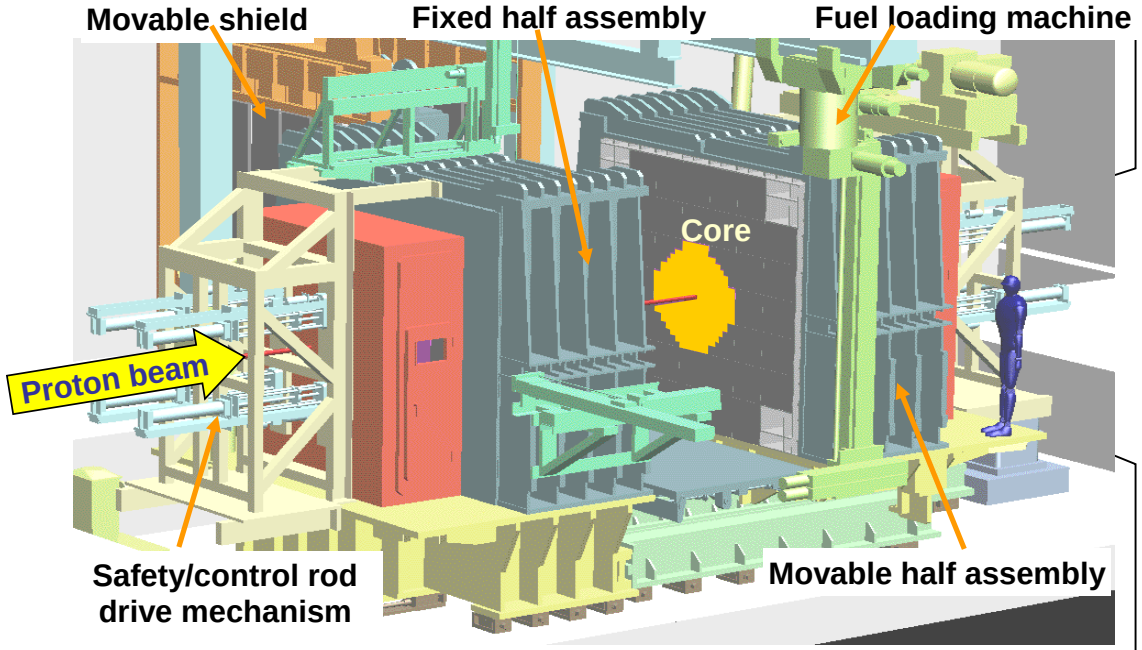
ADS Target Test Facility：TEF-T

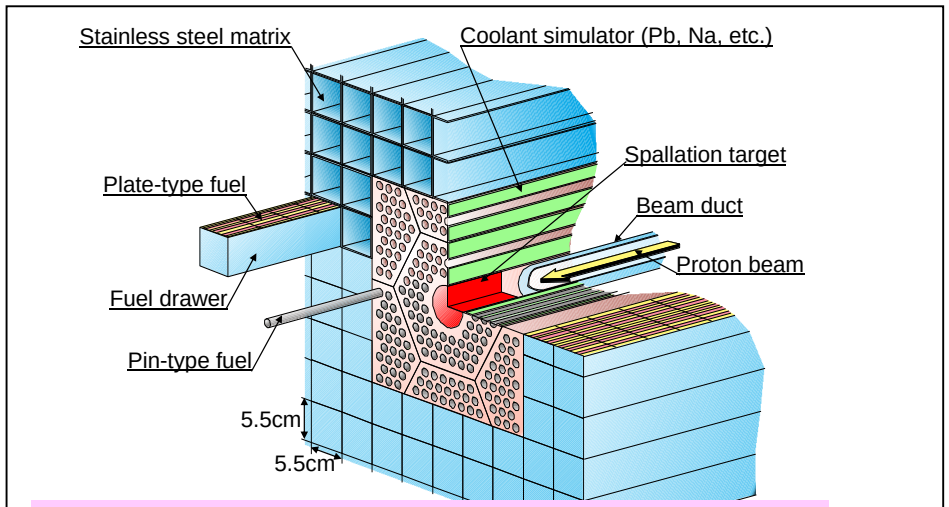
Purpose: To research and develop a spallation target and related materials with high-power proton beam.
Licensing: Particle accelerator
Proton beam: 400MeV-250kW
Target: Lead-Bismuth Eutectic (LBE, Pb-Bi)



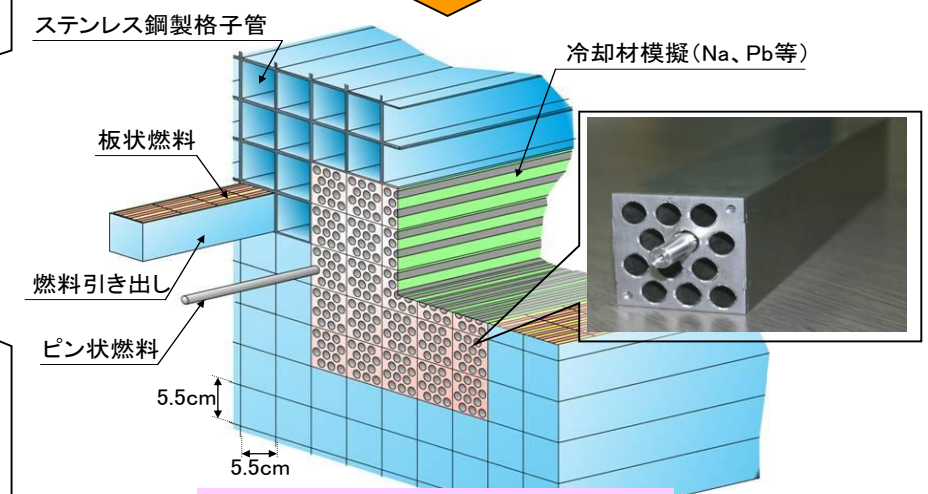
Transmutation Physics Experimental Facility (TEF-P)

- **TEF-P is designed to take over the experiences and functions of FCA to minimize the cost and risk for newly developed equipment.**
- **Low power critical facility for reactor physics and nuclear data of transmutation systems including ADS and FBR.**
- **By replacing central partial matrix tubes with pin-type assembly, MA fuel can be used with cooling and remote handling.**





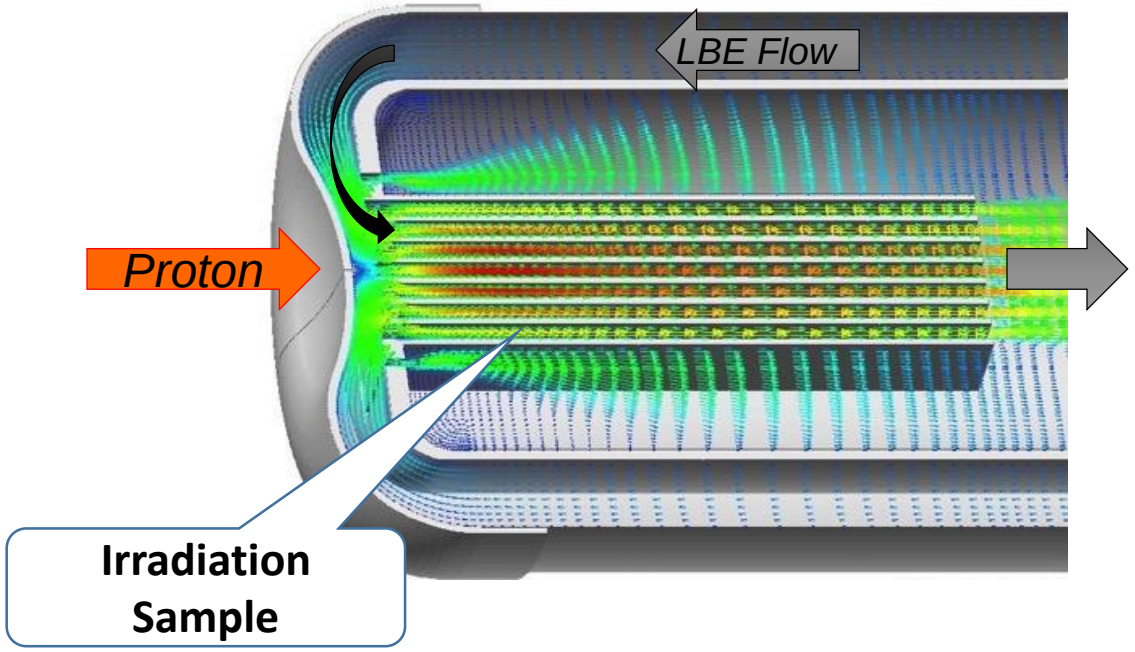
ADS experiments in "subctitical with proton beam"



Experiments in "critical mode"

ADS Target Test Facility (TEF-T)

- Experiments for irradiation damage of material by protons and neutrons
- Material irradiation test for material for beam window of ADS, structure material for FBR, and material for fusion reactor
- Development of database for engineering feasibility of ADS by experiments in various condition (ex. temperature and velocity of flowing LBE)

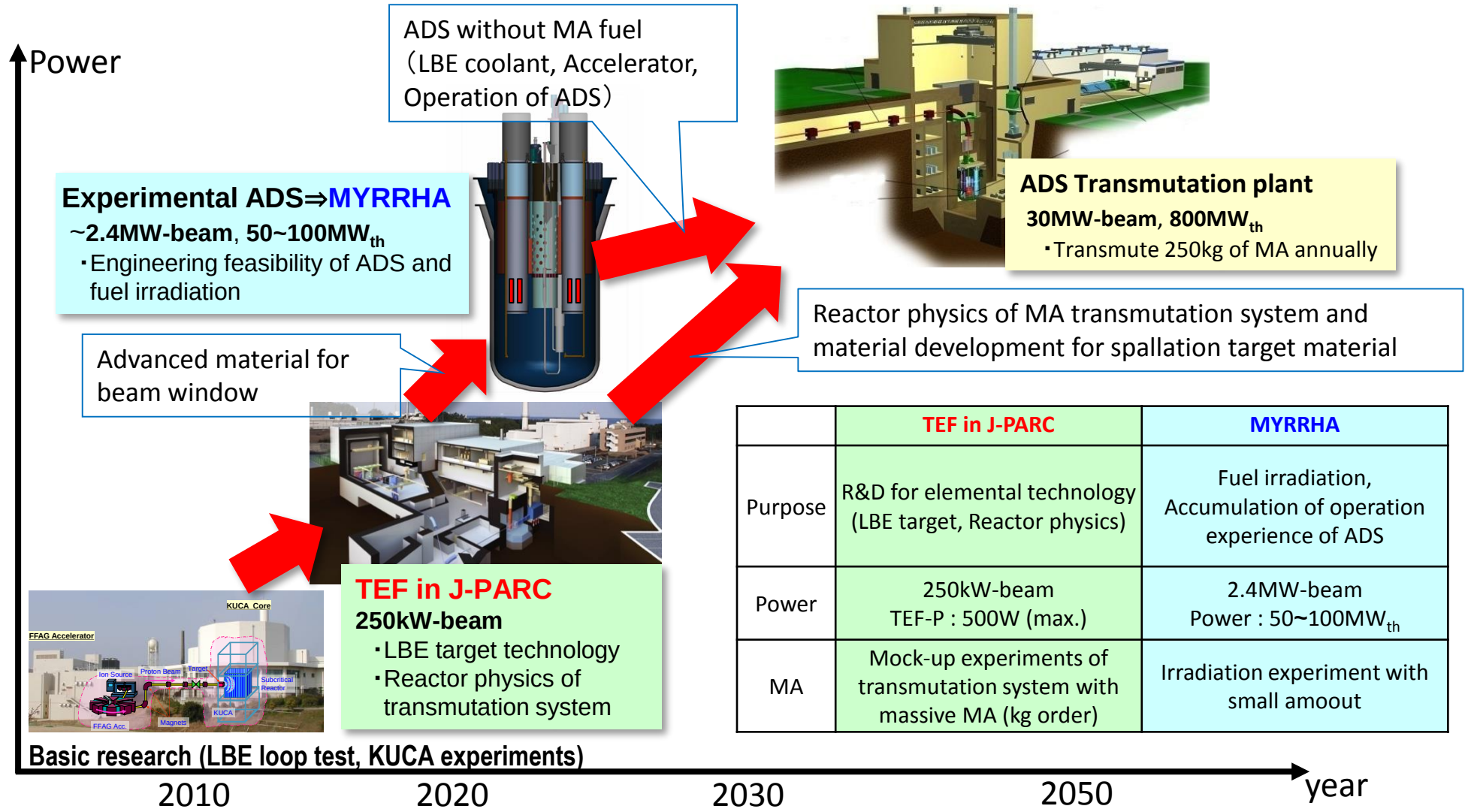


Candidate concept for LBE target in TEF-T

Test device for flow visualization by PIV method

(Full-scale transparent acrylic model of target vessel

Development of ADS Transmutation System



	TEF in J-PARC	MYRRHA
Purpose	R&D for elemental technology (LBE target, Reactor physics)	Fuel irradiation, Accumulation of operation experience of ADS
Power	250kW-beam TEF-P : 500W (max.)	2.4MW-beam Power : 50~100MW$_{th}$
MA	Mock-up experiments of transmutation system with massive MA (kg order)	Irradiation experiment with small amoout

Summary

- National Policy for Nuclear Energy
  - "Nuclear power is an important base-load power source"
  - "**GOJ will promote development of technologies for reducing the volume and harmfulness of radioactive waste** in order to secure a wide range of options in the future."

- R&D for ADS in JAEA and J-PARC
  - Current status and future plan on R&D of ADS were summarized.
  - Various basic R&D have been implemented, and new experimental facility, TEF, is proposed in the J-PARC project. TEF is expected to play important roles as an international research facility.

Backup

Estimation of Beam-trip Frequency

Beam-trip duration	Allowable beam-trip frequency	100% to 0%
0 - 10sec	20,000	6,600
10sec - 5min	1,300	12,000
> 5min	42	1,500

Reduction of temperature difference

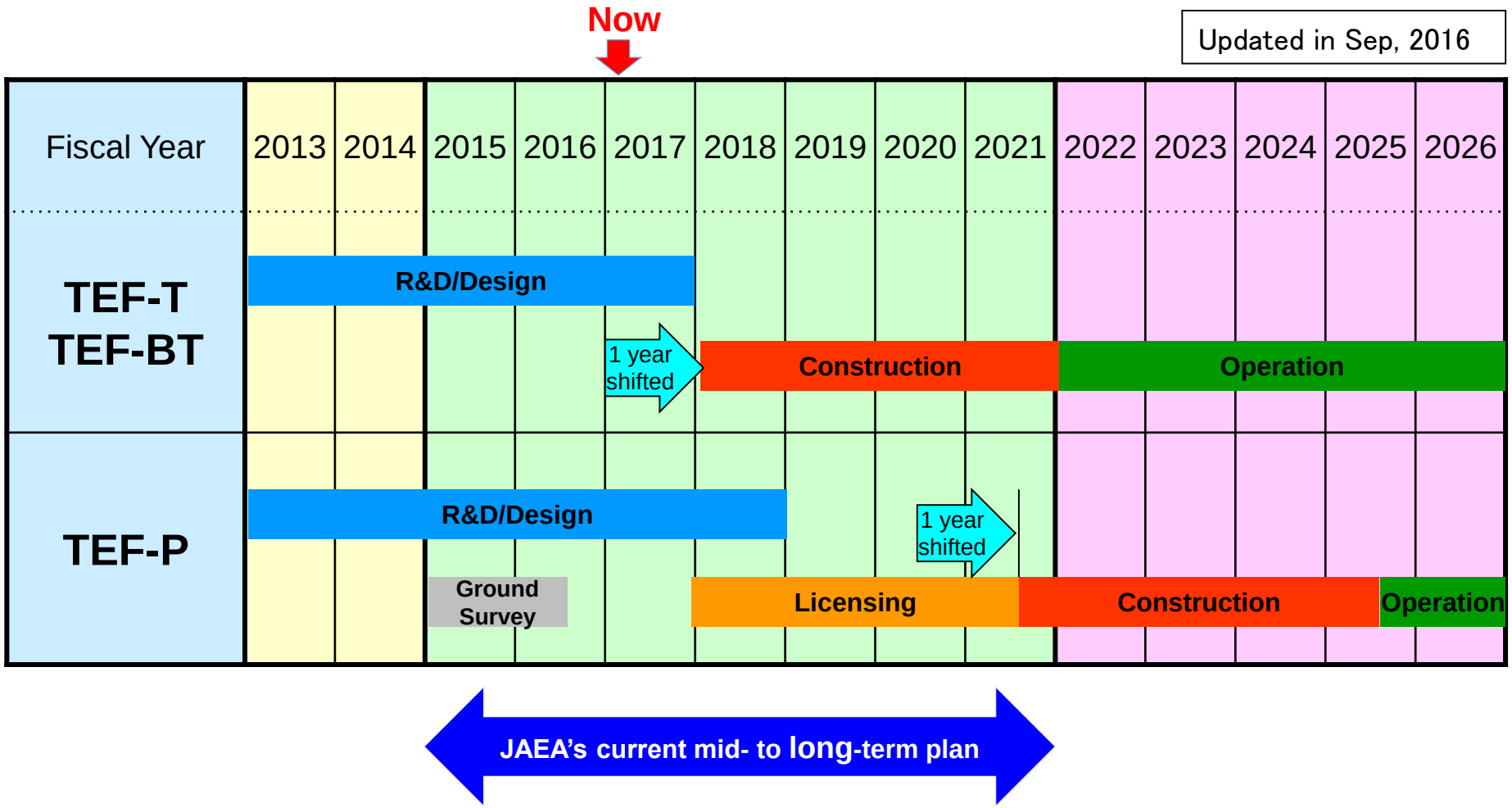
Multiplexing and downgrade of each component

Beam-trip duration	Allowable beam-trip frequency	100% to 50%	50% to 0%
0 - 10sec	500,000	465	47
10sec - 5min	17,000	10,507	508
> 5min	42	N/A*	21

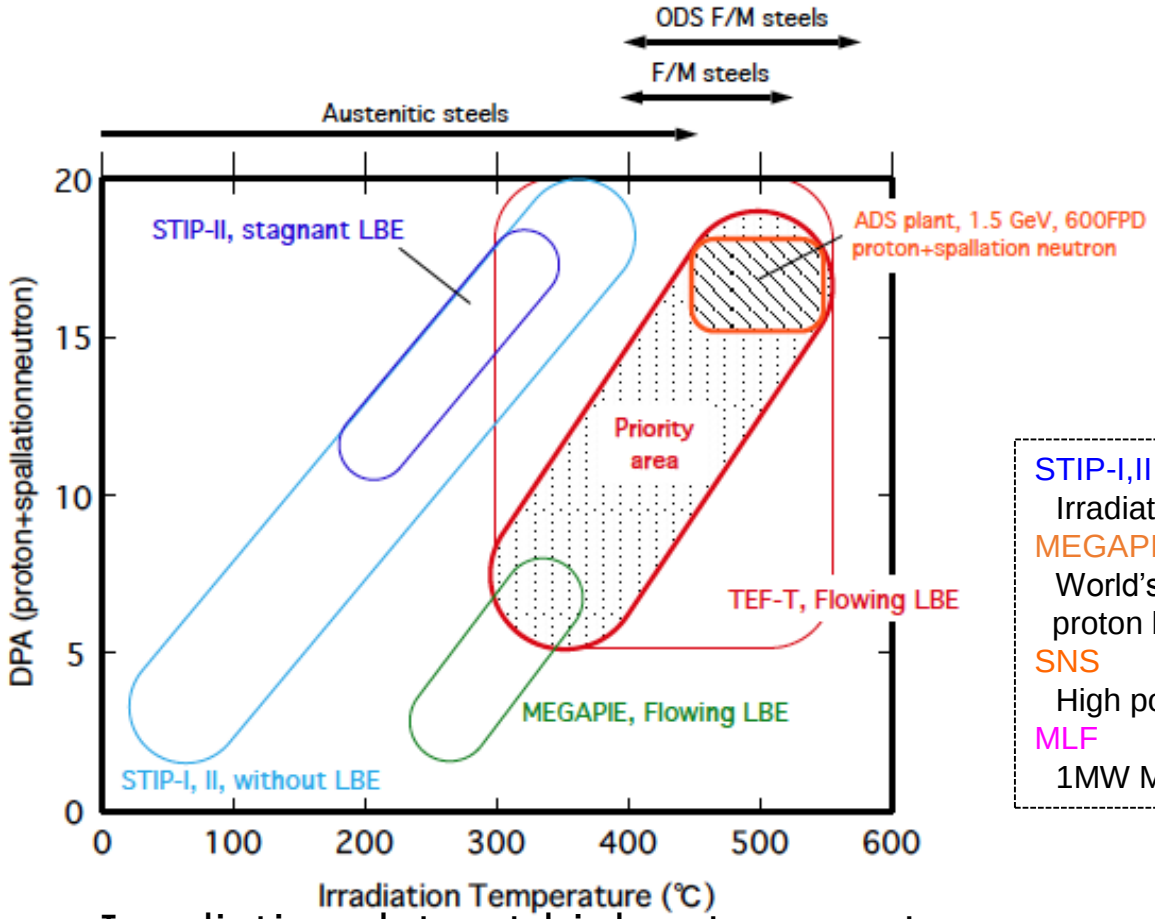
*: Due to the necessity to shutdown the system (to prevent the LBE freezing), the allowable beam-trip frequency was determined. However, in the 100% to 50% case, it was not necessary to shutdown the system.

Beam-trip frequency in the double-accelerator concept satisfied the allowable beam-trip frequency

Construction Schedule (Tentative)



Material data taken in TEF-T



STIP-I,II
Irradiation in Stagnant Pb-Bi performed at PSI
MEGAPIE
World's first Pb-Bi spallation target with 1MW proton beam performed at PSI
SNS
High power spallation neutron source in USA
MLF
1MW Mercury spallation target of J-PARC

- Irradiation data at higher temperature range than existing experiments is required to realize ADS
- TEF-T can provide irradiation data for rated operation condition not only for future ADS but also for MYRRHA

New Test Equipment for TEF-T Design

OLLOCHI Oxygen-controlled Lbe LOop for Corrosion tests in HIgh temperature

- Material corrosion database for various temperature, oxygen potential, LBE flow rate will be collected
- The loop will be operated from next April
- Addition of corrosion test section with mechanical stress are planned

IMMORTAL Integrated Multi-functional MOckup for TEF-T Real-scale TArget Loop

- Demonstration of safe operation of LBE loop by reflecting operation condition of J-PARC LBE Spallation target
- Tests for dynamic behavior of heat removal, functional tests of sensors, loop components are underway

Oxygen Sensor Calibration Device

- To prevent corrosion by flowing LBE, oxygen potential in LBE should be controlled in appropriate potential range (10^{-5} to 10^{-7} %)
- Development of oxygen potential sensor and loop tests for oxygen potential control mechanism are underway