Studies on Accelerator-driven System in JAEA
and
Transmutation Experimental Facility Program

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J-PARC Center, Transmutation Section
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Present Status in Japan

Present Status in Japan:

Nuclear Energy Policy before Fukushima

- "Nuclear Renaissance"
  - Nuclear power is a key to satisfy "Kyoto Protocol"
  - 50% of electricity will supply by NPP at 2030
- Atomic Energy Commission started to revise "Framework of the Nuclear Energy" at 2010

Present Status in Japan:

Policy After Fukushima Accident

- After Fukushima accident, reduction of nuclear power generation was discussed
- Last year, Liberal Democratic Party won a election of the House of Representatives
  - LDP still aims at decreasing nuclear power
  - Utilize current NPP with U-Pu cycle for stable electricity supply
  - New energy policy is under discussion

Present Status in Japan:

Nuclear Waste Management

- After the Fukushima accident, people's interest in the management of nuclear waste and spent nuclear fuel has been grew up and method to decide waste disposal site becomes major issue of nuclear power

- Atomic Energy Commission asked a review of high level wastes management to Science Council of Japan because the site selection process is not worked effectively

Interest for Transmutation in Japan

Recommendations of the Science Council of Japan as an answer to the Atomic Energy Commission's independent review request (Reported at 11.9.2012)

- Requires a fundamental review of waste disposal policy
- Manage the total amount and temporal safe storage of waste
  - Ensure Reversibility and Retrievability (Several hundred years)
  - During the SF storage, following study should be enhanced
    - Waste Transmutation
    - Safety of Fuel Storage
    - Stability of Geological Layer
- Construct a consensus building mechanism
- Take tenacious efforts to establish waste disposal site

Present Status in Japan:

Debates at House of Representatives(1/2)

- Question from Councilor Ai Aoki

In the country using nuclear power, the final disposal of spent nuclear fuel is a big issue…

Technology to transform long-lived nuclides into short-lived nuclides with neutrons produced by introducing protons from the accelerator to a heavy metal, is studied at J-PARC in Tokai-mura…

If the Transmutation Experimental Facility can be established, the R&D can be started…

Japan already have a facility and technology. Moreover, the excellent scientists are already exists. However, next year’s budget is only 100 million yen at this moment. I think that developing this technology is the greatest way where Japan contributes to the world. I would like to ask a minister's view about promotion of transmutation studies.

Present Status in Japan:

Debates at House of Representatives(2/2)

- **Answer by Prime Minister Abe**
  - If Transmutation technology becomes available, it will be recognized as very significant.
  - For this reason, in Japan Atomic Energy Agency, fundamental research using "Monju" and J-PARC has been performed.
  - Research on transmutation continues to advance steadily.

- **Answer by MEXT Minister Shimomura**
  - Radwaste disposal is a big issue of nuclear energy and transmutation is recognized as very significant. MEXT advances research for transmutation steadily.
  - 5 years has passed since the previous review by Atomic Energy Commission, progress of research should be evaluated and judged. Review of feasibility is planned to be discussed in a specialist's council.

National Review of P-T Technology

National Review Committee

- On July 9th, Ministry of Education, Culture, Sports, Science and Technology in Japan (MEXT) launched a review committee to evaluate current state-of-the-art of P-T
- Committee discussed following items
  - Current P-T research activities
  - Construction of TEF in J-PARC
  - Collaboration with MYRRHA project
- Report planned to be issued in October, 2013

National Review of P-T Technology:

Member of review committee

A. Yamaguchi (Chair)	Osaka Univ. (Safety)
S. Sawada	Hitachi Ltd. (Fuel Cycle)
S. Tanaka	Tokyo Univ. (Fuel Cycle)
K. Nakajima	Kyoto Univ. (Neutronics)
A. Hasegawa	Tohoku Univ. (Material)
R. Fujita	Toshiba Ltd. (Fuel Cycle)
Y. Yano	RIKEN (Accelerator)
Y. Wake	Keio Univ. (Economics)

Two methods of MA transmutation

- Application of Fast Reactor
  - Discussion started by former cabinet
  - MEXT launched a working group for MONJU application and usage for R&D of P-T
- Innovative system with ADS
  - Current cabinet describes the acceleration of P-T research in their Manifesto
  - MEXT also launched a working group to review current state of the art of P-T with ADS

National Review of P-T Technology:

Interim Report (Tentative)

- To realize P-T, preparation of facility should be required to handle certain amount of minor actinides. The plan to establish facilities should be continued.
- As for the Transmutation Experimental Facility in J-PARC project, step up to next stage is expected. Progress should be reviewed within 3 years.
- As for the participation to MYRRHA project, comprehensive cooperation is recommended not only by JAEA but also by universities and commercial sector. It is proper to begin negotiations with Belgium. Progress of the negotiation should be reported.
- The committee continues a review works of P-T technology

Waste Transmutation by ADS

Waste Transmutation by ADS:

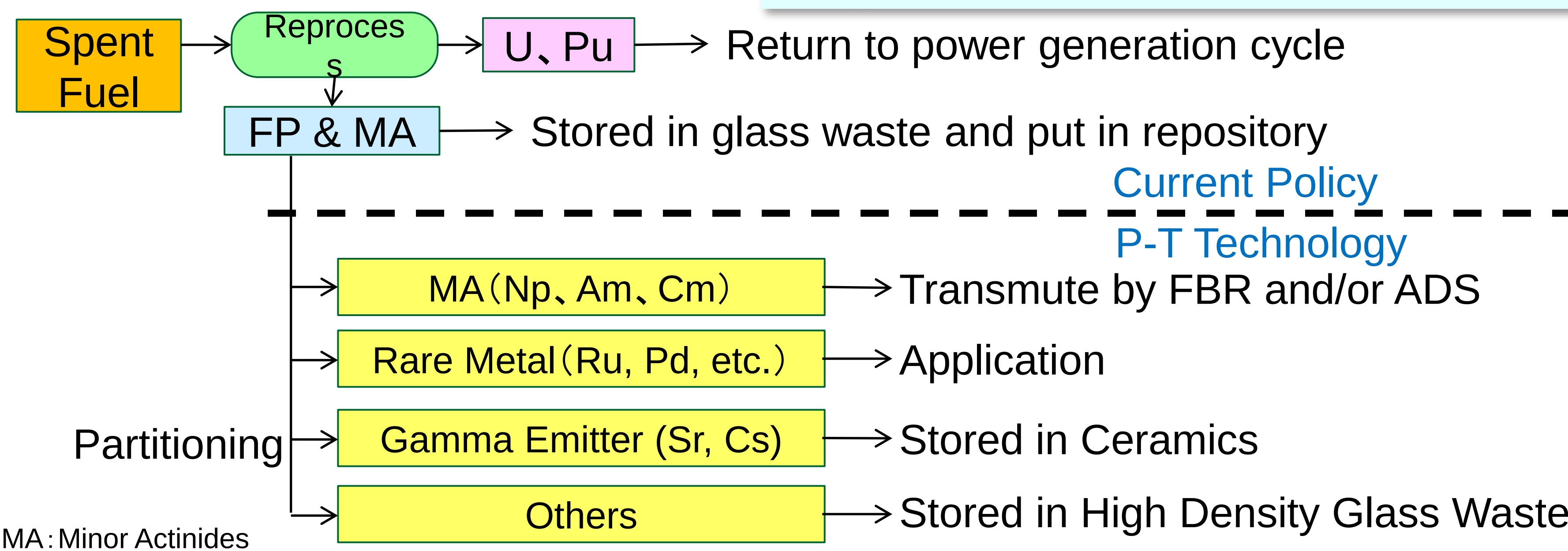
Partitioning & Transmutation

P-T Technology

Separate radionuclides according to their yield and half-life, and Transmute long-lived nuclide by nuclear reaction to reduce their lifetime and/or radiological hazard

Goals

- Reduction of long-term risk:
  Reduce radiological hazard of wastes
- Increase effective capacity of repository:
  Reduce heat release from wastes
- Use waste as useful resource:
  Application of rare metals（White metals, etc.）

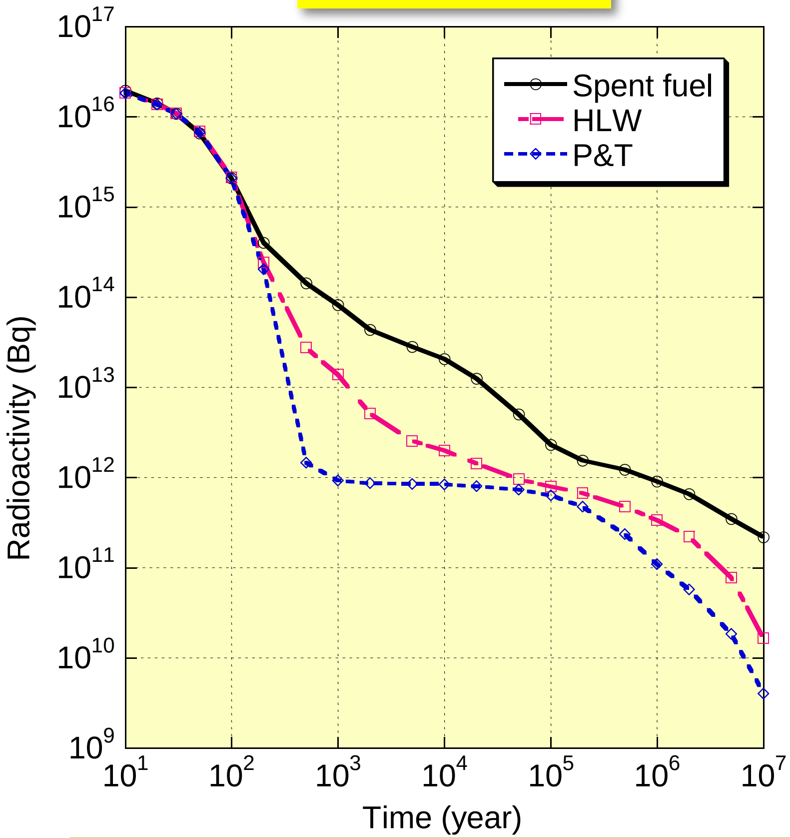


MA：Minor Actinides
FP：Fission Products

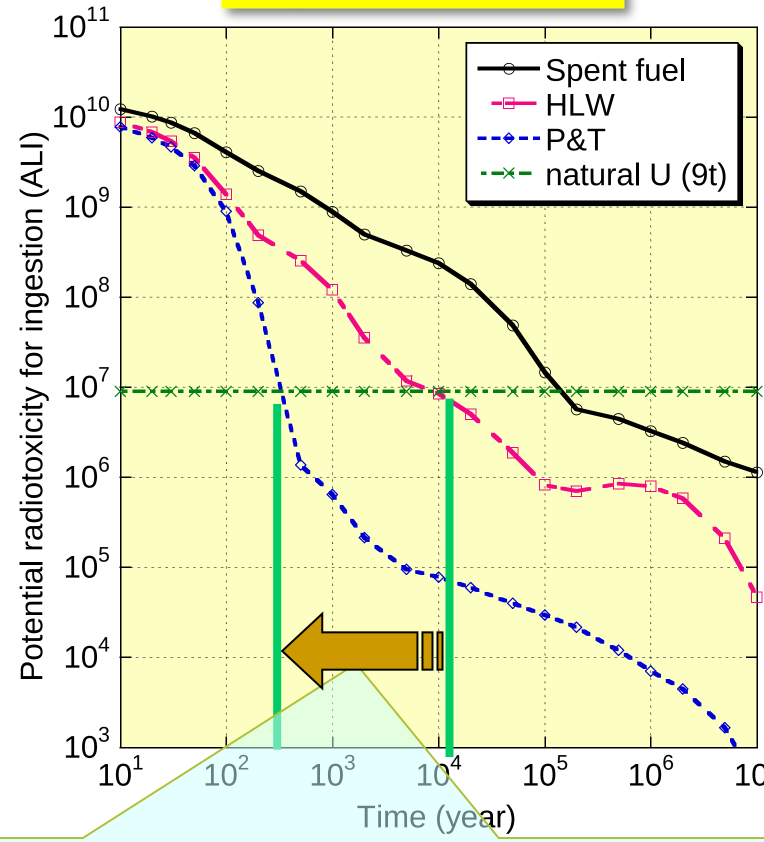
Waste Transmutation by ADS:

Reduction of activity and hazard

Radioactivity



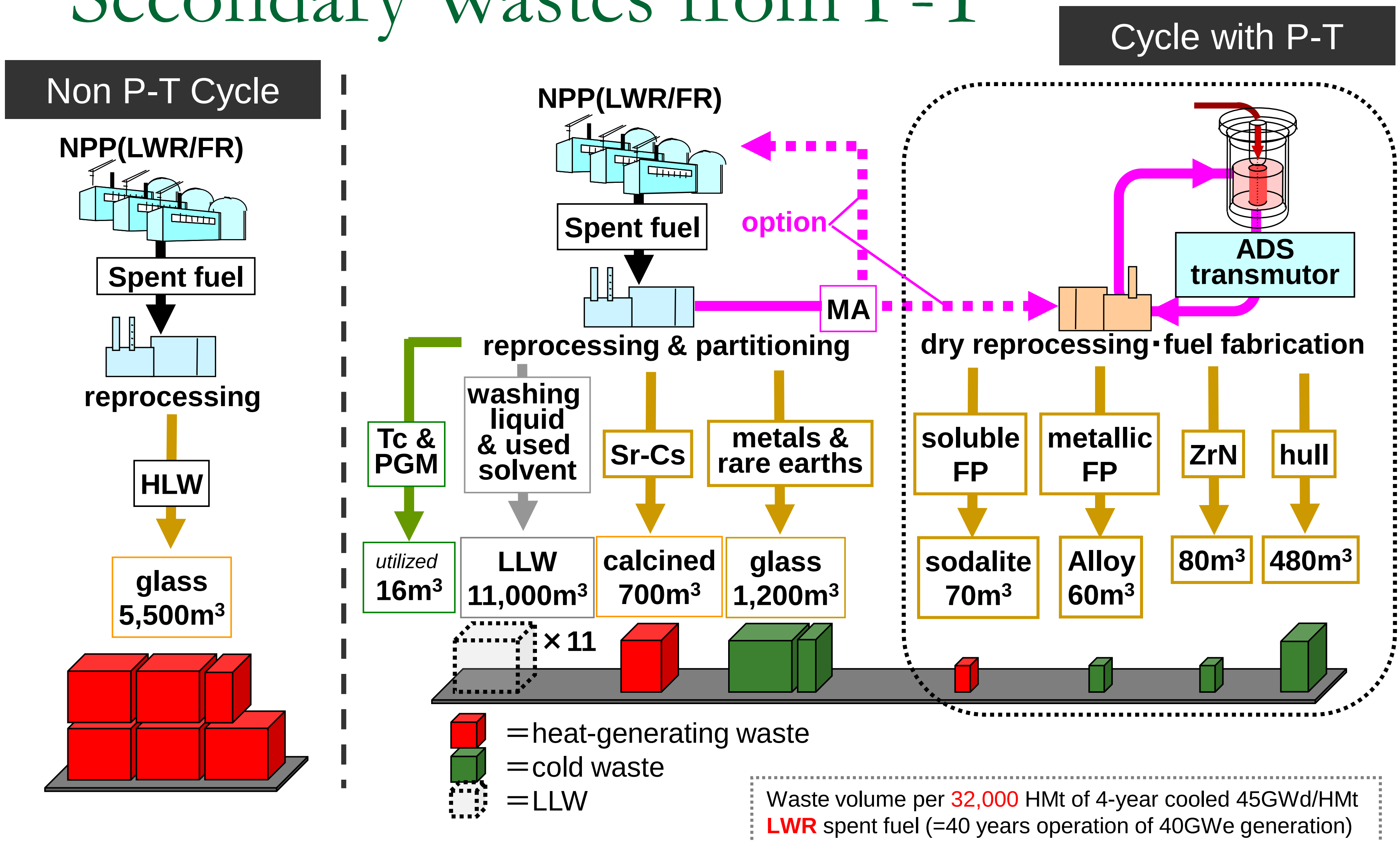
Ingestion Hazard



- **Toxicity can be reduced by 2 orders from current HLW, if 99.5% transmutation is achieved.**
- **Time needs to reduce the toxicity below the level of natural uranium can be shortened from 10,000y to several hundred years.**

Waste Transmutation by ADS:

Secondary Wastes from P-T



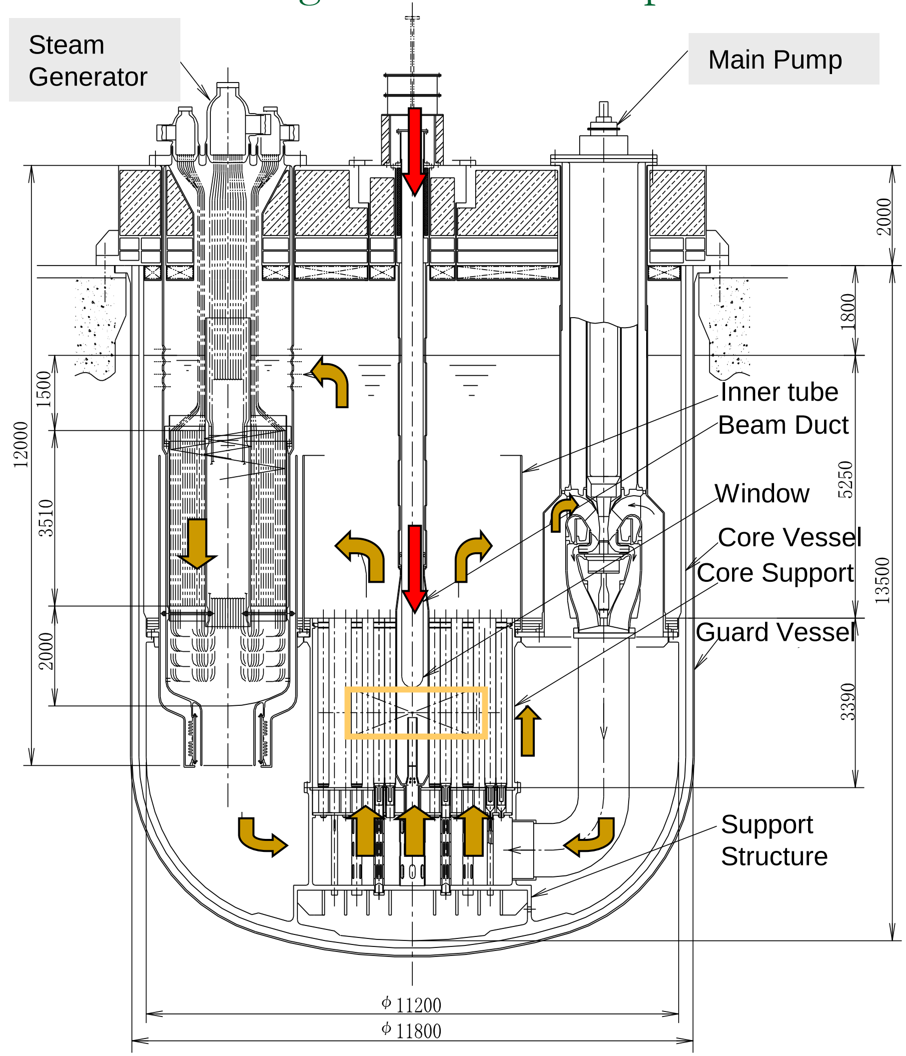
Waste Transmutation by ADS:

JAEA proposed ADS - LBE Target/Cooled Concept -

- Proton beam : 1.5GeV ~20MW
- Spallation target : Pb-Bi
- Coolant : Pb-Bi
- Subcriticality : $k_{eff} = 0.97$
- Thermal output : 800MWt
- Core height : 1000mm
- MA initial inventory : 2.5t
- Fuel composition :

  (60%MA + 40%Pu) Mono-nitride
- Transmutation rate :

  10%MA / Year (**10 units of LWR**)
- Burn-up reactivity swing : 1.8%Δk/k



Waste Transmutation by ADS:

Issues and R&Ds for ADS

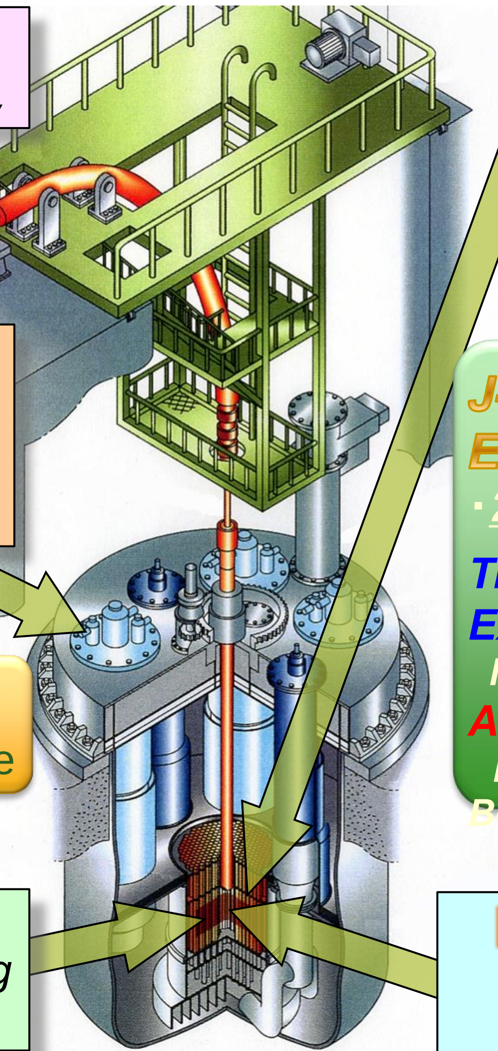
Accelerator
High Power, Reliability, Cost, etc.

J-PARC Accelerator
Operation Experience, etc.

Structure
Design of Reactor Vessel, Pumps, SGs, Quake-proof Structure, Beam Duct & Window, etc.

R&D using JAEA Experiences
Utilize existing resources & knowledge

Fuel, Cycle
Fabrication, Irradiation, Reprocessing of MA-bearing Fuel, etc.



MA-loaded Subcritical Core
Physics and Control of Subcritic Core with MA-bearing Fuel, etc.

J-PARC Transmutation Experimental Facility
- *2 Individual Facilities*

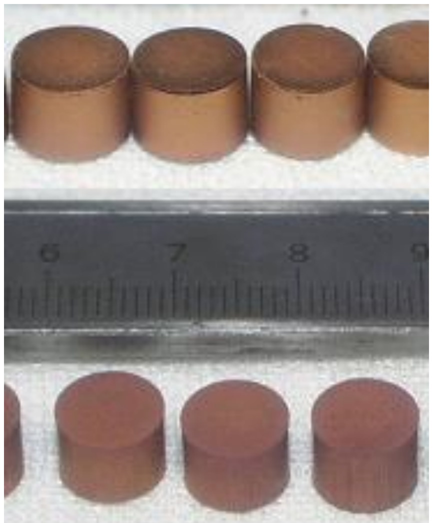
Transmutation Physics Experimental Facility*: *TEF-P
Neutronics Tests by Low Power Beam

ADS Target Test Facility*: *TEF-T
Material Irradiation by High Power Beam

Pb-Bi Spallation Target
Material Irradiation, Operation, Lifetime Evaluation, etc.

Irradiation Test of U-free Nitride in JMTR

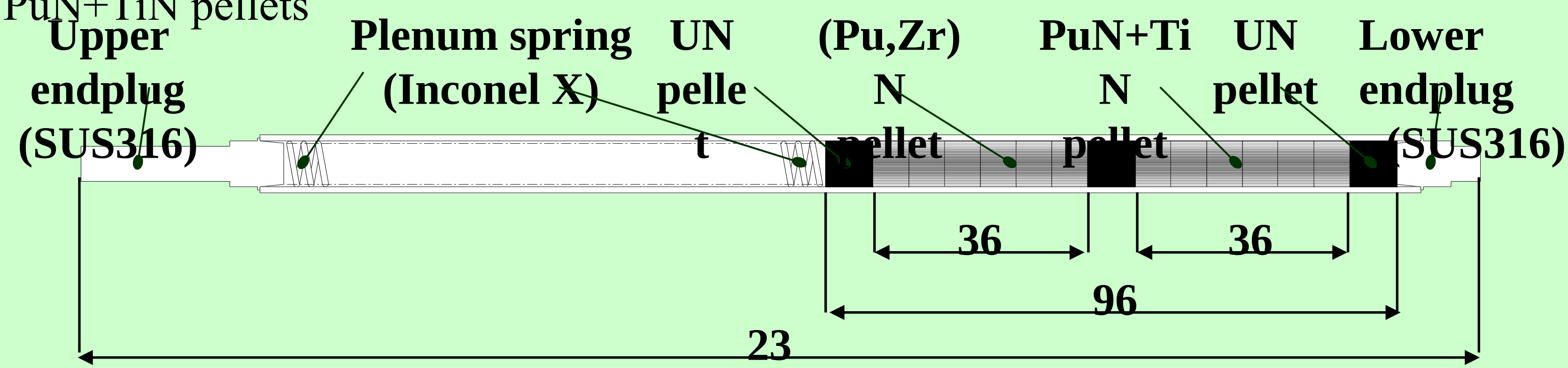
(Pu,Zr)N pellets



PuN+TiN pellets

	(Pu,Zr)N	PuN+TiN
Irradiation period	**May 2002 ~ Nov. 2004 (246 EFPD)**	
Av. linear power	**408 W/cm**	**355 W/cm**
Burnup	**14.7 at%-Pu**	**17.0 at%-Pu**
Max. fuel Temp. (Estimation)	**1273 K**	**1083 K**
Cladding tube	**SUS316, 9.40 mm∅, 0.51 mmt**	

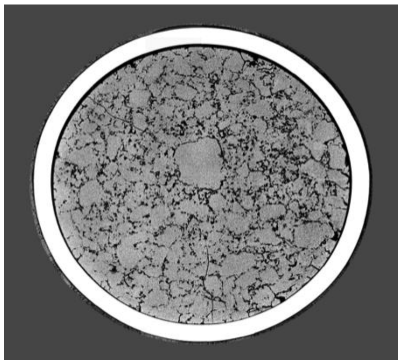
PIEs have been completed in JAEA's hot cells.



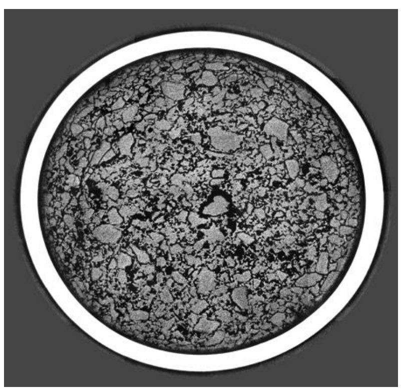
Waste Transmutation by ADS:

Results of PIEs for U-free Nitride

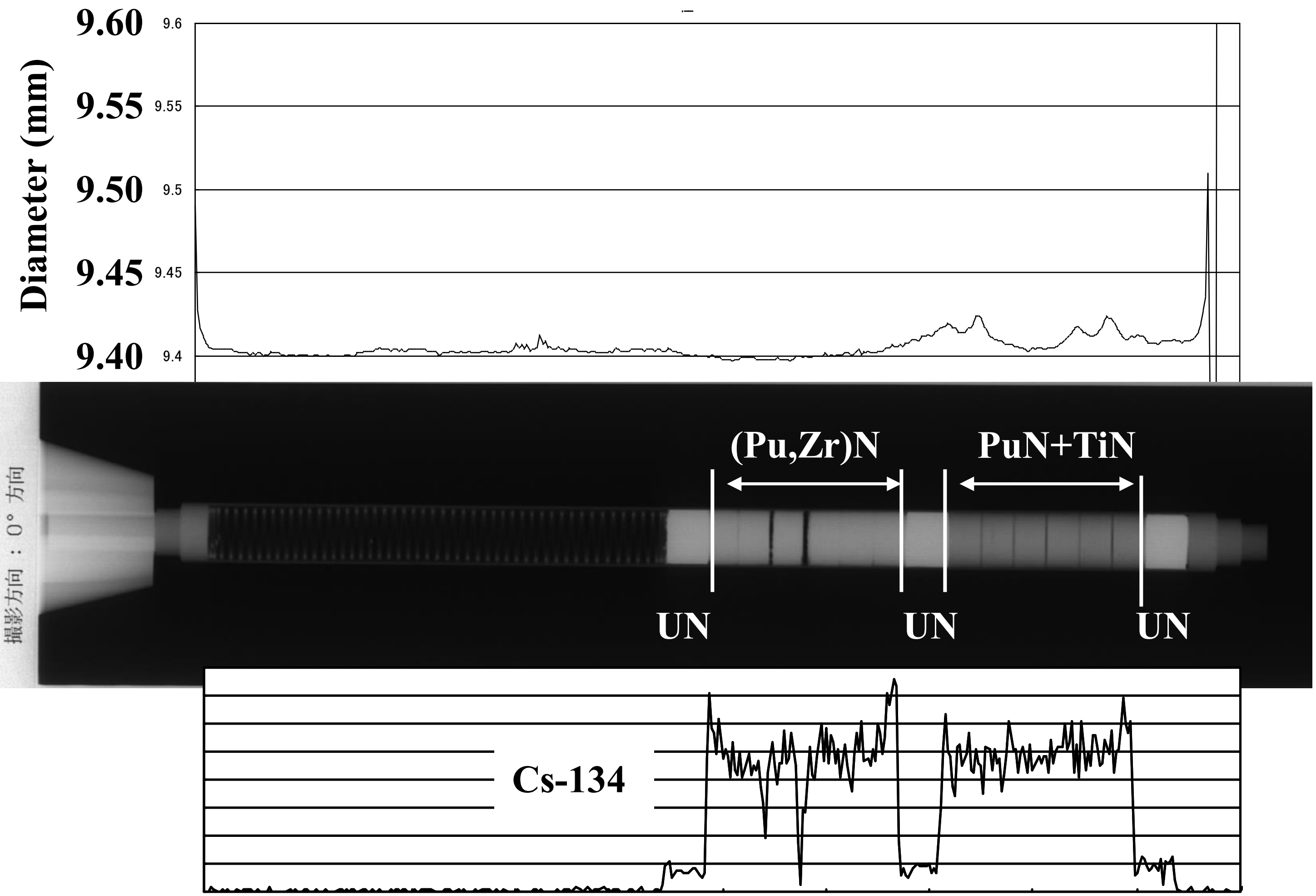
- Cross sections, profilometry, X-ray radiography and gamma scanning-



(Pu,Zr)N



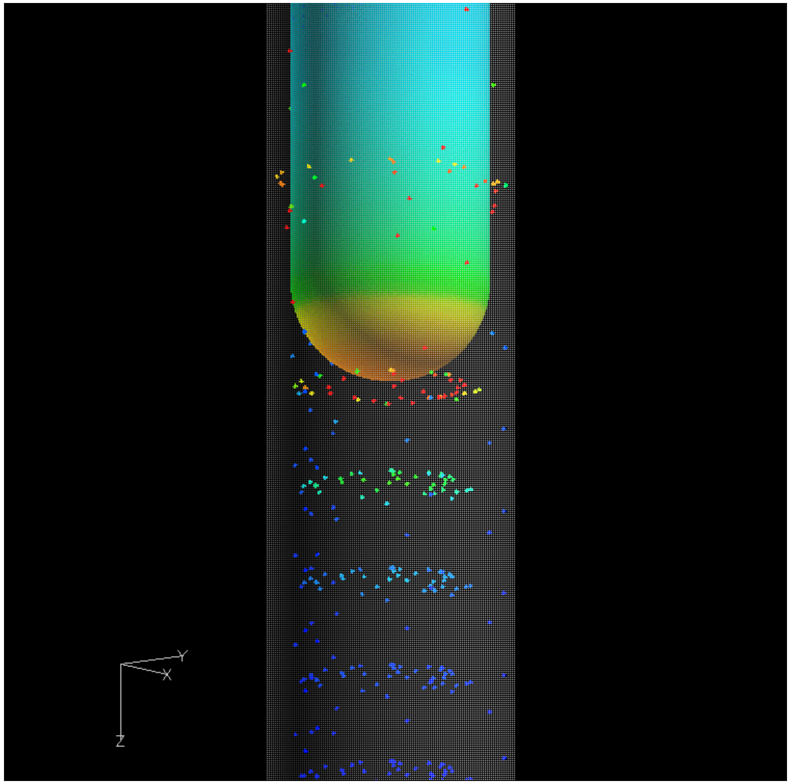
PuN+TiN



Waste Transmutation by ADS:

Beam Window Environment

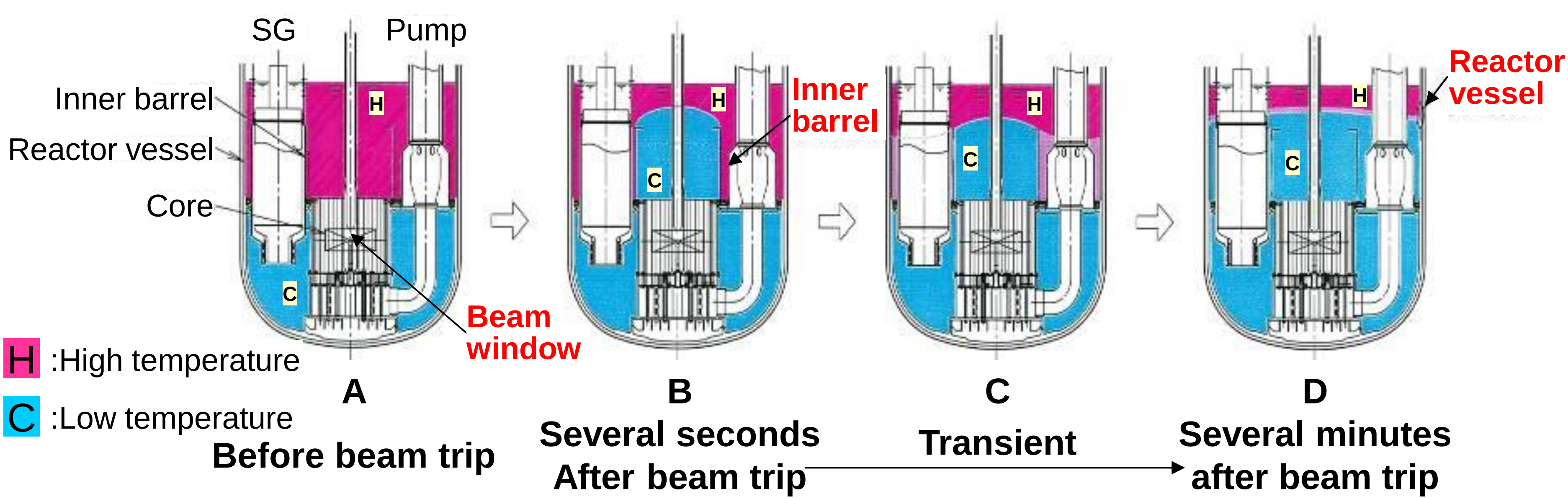
- •Irradiation
  - •Primary Protons
  - •Backscatterd & fission Neutrons
- •Heat Deposition by Charged Particles
- •Pressure difference between beam duct and spallation target
- •Corrosion by Liquid Pb-Bi



To estimate the lifetime of the beam window accurately, precise simulation of stress & heat removal is required.

Acceptable Beam Trip Frequency

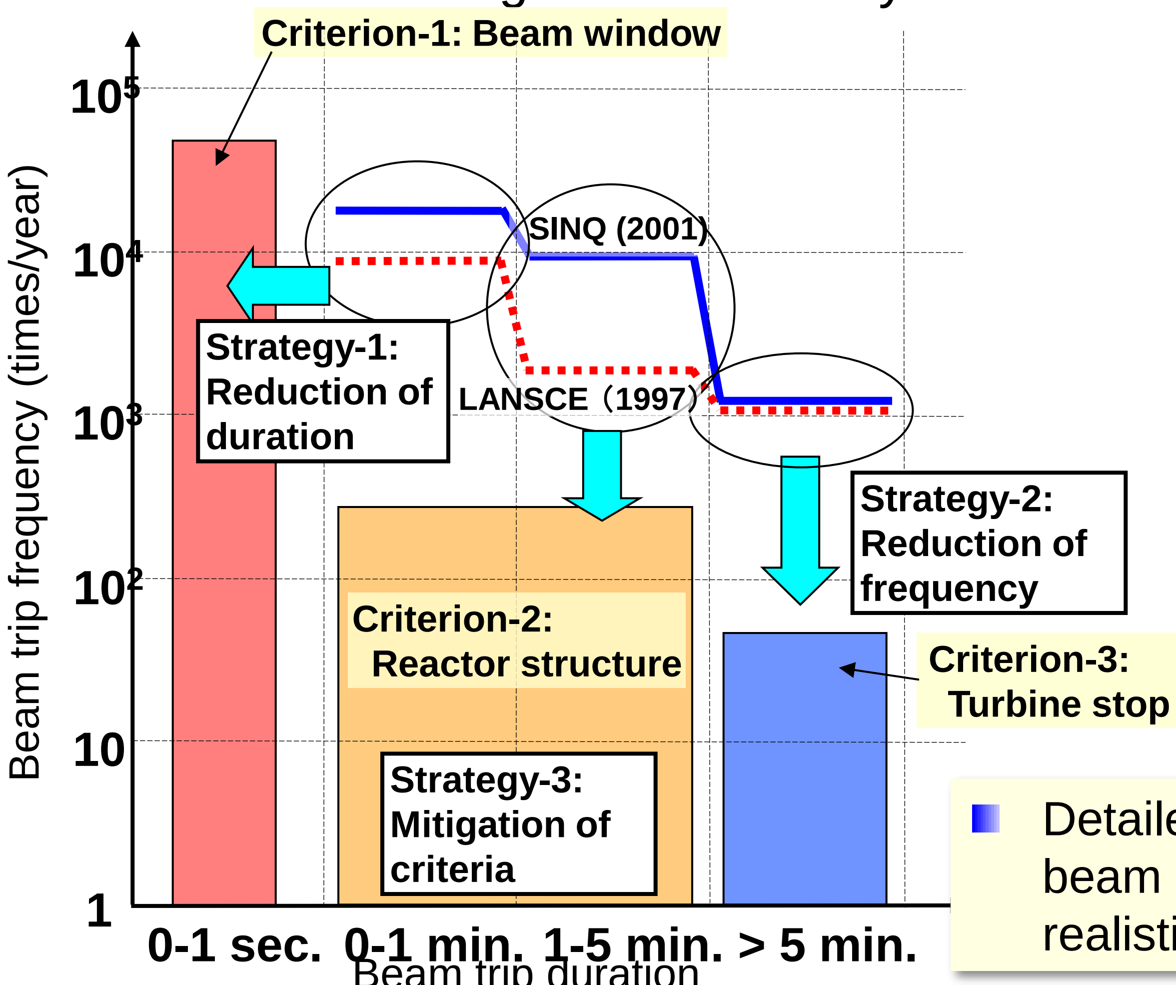
- **Thermal stress caused by beam trip** is estimated to know acceptable frequency of beam trip.
  - **Beam window**
  - **Inner barrel**
  - **Reactor vessel**
- The influence of the beam trip to the power generation system is also estimated.



Waste Transmutation by ADS:

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.

Waste Transmutation by ADS:

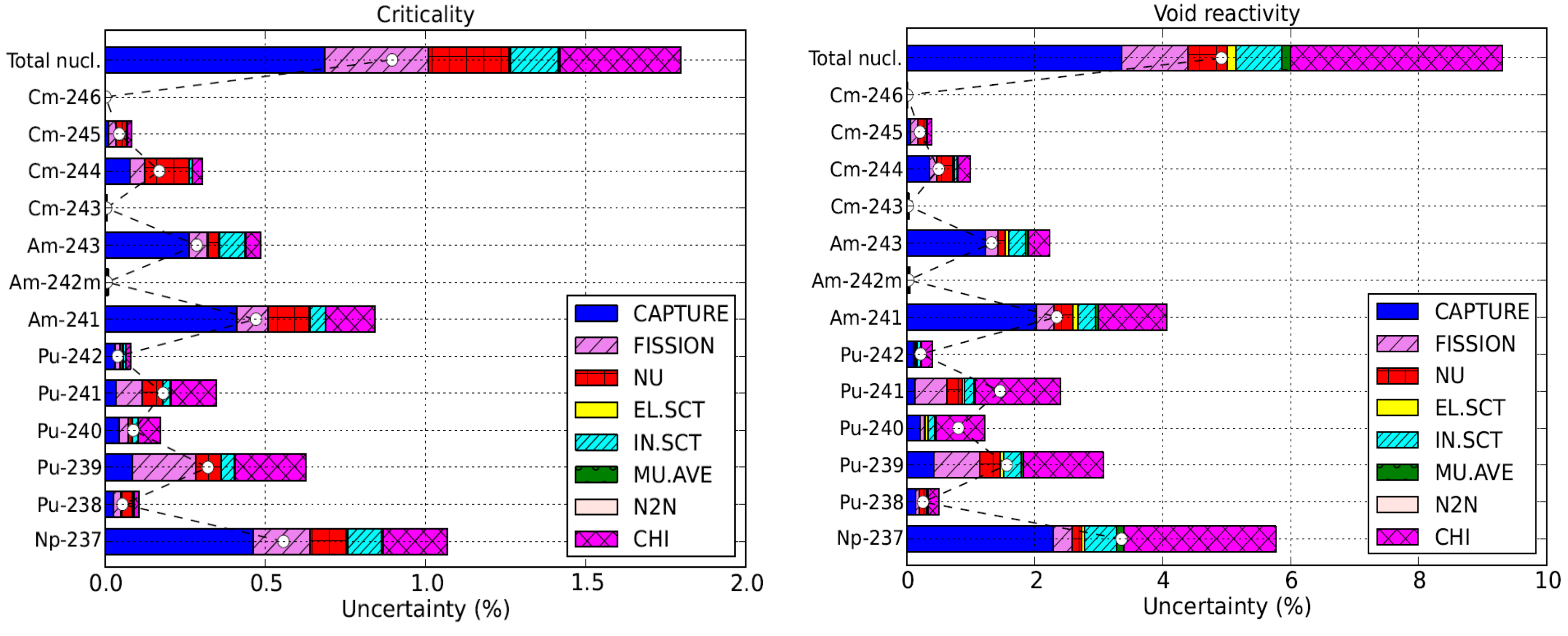
Summary of Allowable Criteria

- 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

Waste Transmutation by ADS:

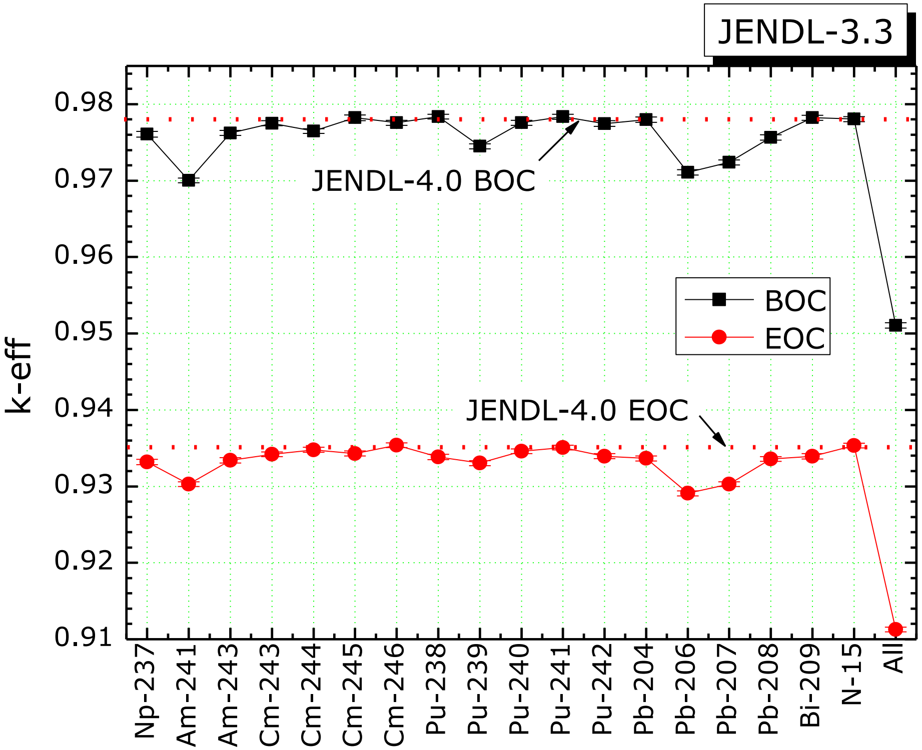
Evaluation of Nuclear Data Library

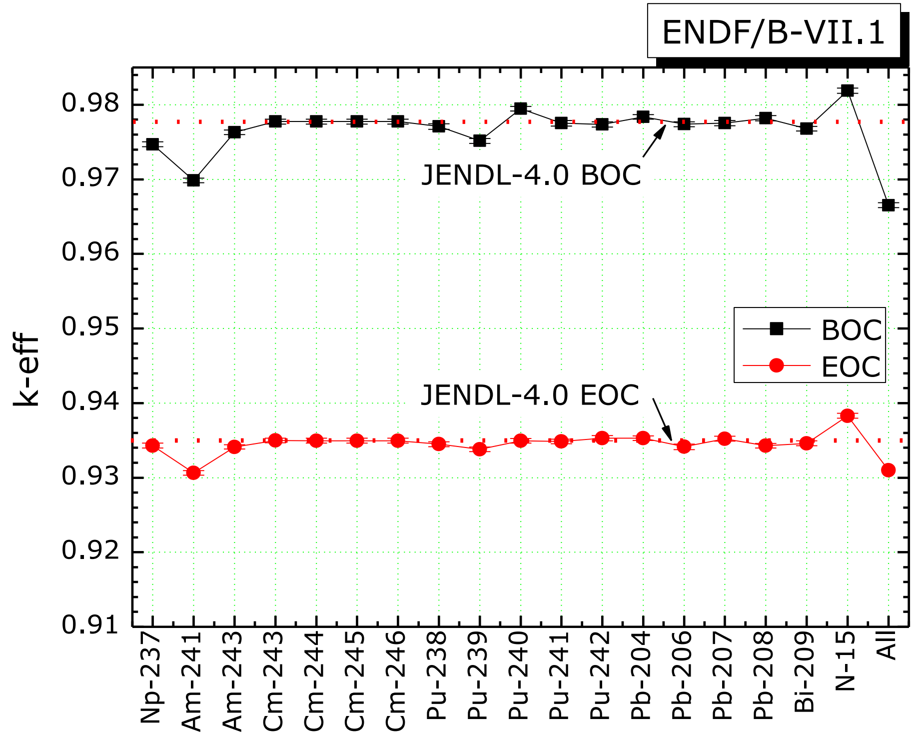


- Nuclide-wise contribution on the uncertainty of criticality and coolant void reactivity are calculated using covariance data in JENDL-4.0
- χ-vector, fission neutron energy spectrum, gives relatively large contributions to analysis values

Waste Transmutation by ADS:

Neutronic Design Accuracy



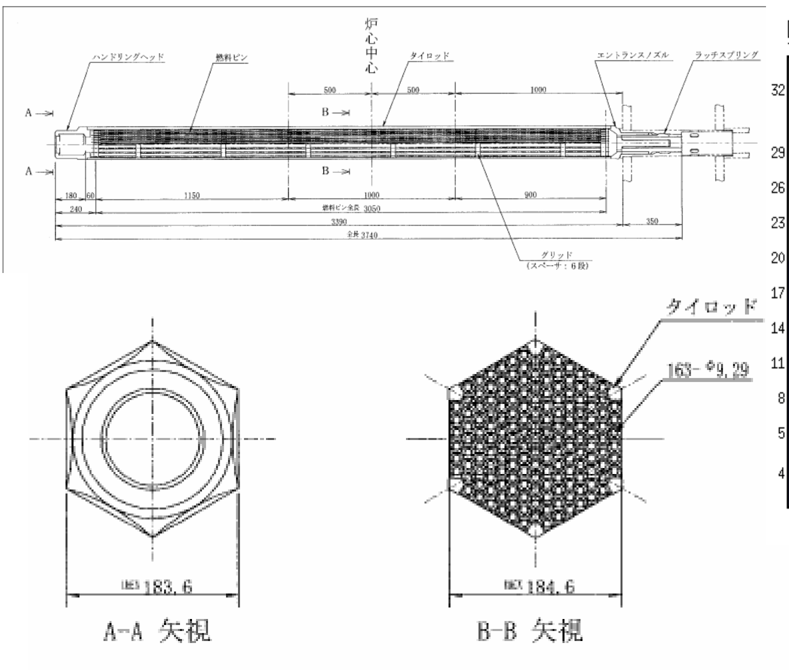


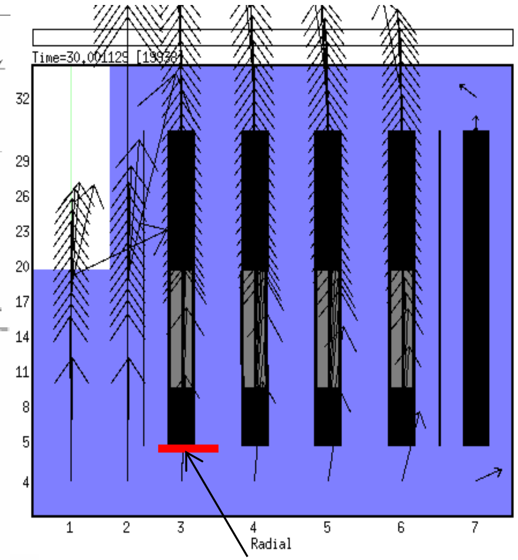
- Major nuclide cross sections are substituted from JENDL-4.0 to JENDL-3.3 or ENDF/B-VII.1
- Maximum difference in 3 libraries is ~3%Δk
- Very important nuclides such as Am-241, Pu-239 still have large contribution to the analysis results

*:T. Sugawara, et al., Atom Indonesia Journal, Vol. 38, 2, 2012 [To be published]

Waste Transmutation by ADS:

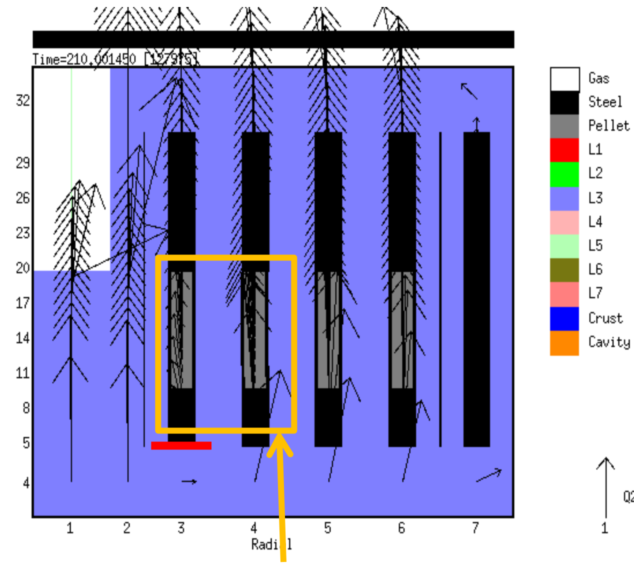
Safety Analyses of ADS





Position of blockage

Before blockage

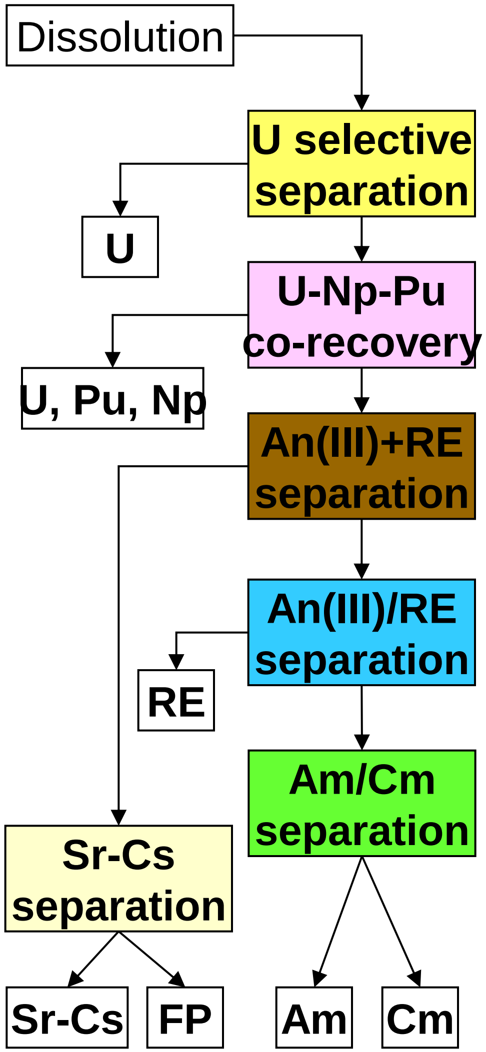


The flow direction changed

After blockage

- Various transient analyses for ADS safety evaluation based on Level 1 PSA is performed using SIMMER-III code
  - Transient analysis for Station Blackout (SBO) condition of ADS
  - Blockade of coolant inlet nozzle of fuel assembly by accumulation of Lead-Oxide (Unprotected Blockage Accident, UBA)
- Detailed analyses will be introduced by Dr.Sugawara

Activities for Partitioning in JAEA



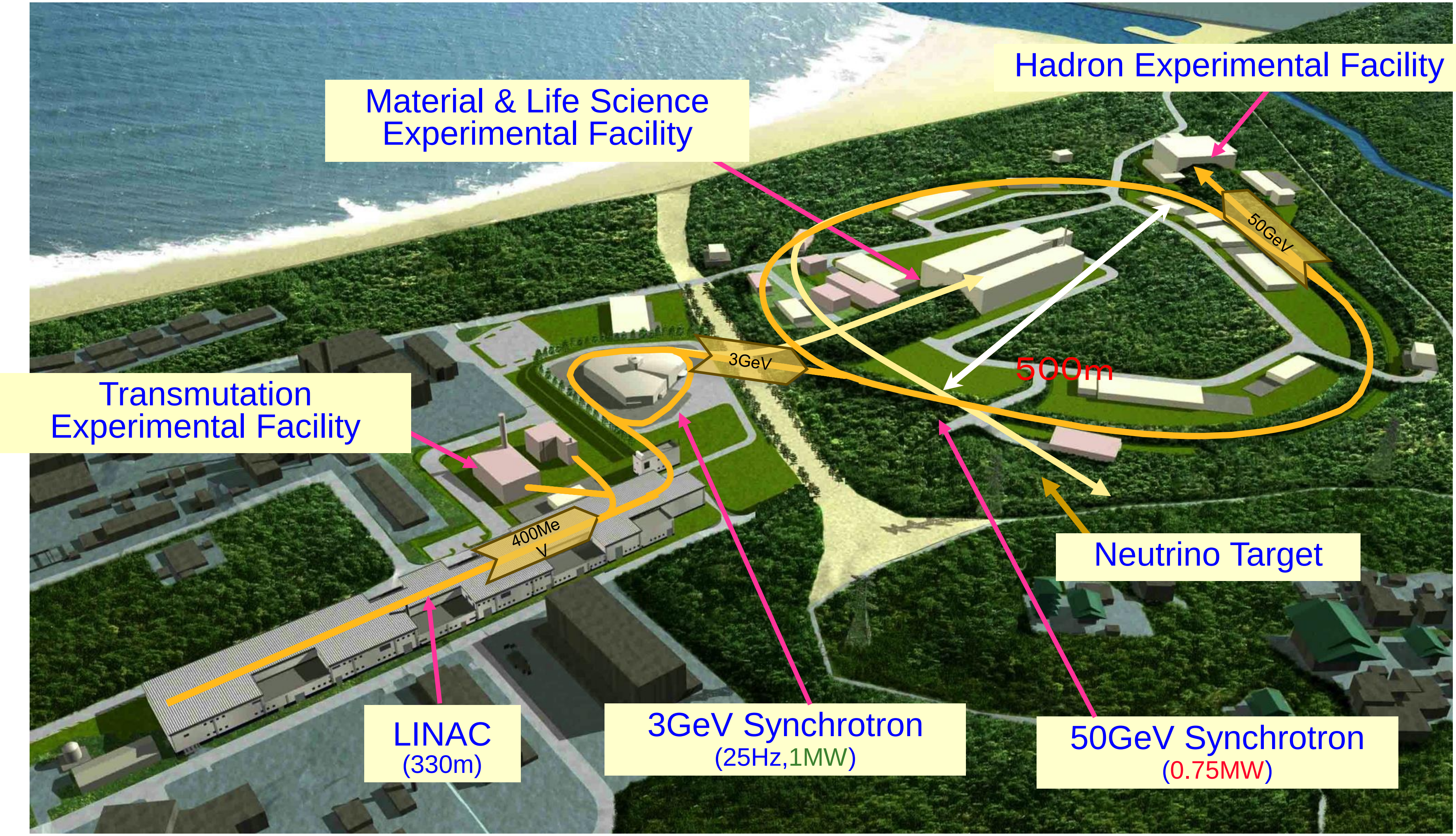
*Fast reactor cycle technology development (FaCT) project

	NEXT Process*	The other methods & technologies
U selective separation	Crystallization	･Precipitation by pyrrolidone ･Solvent extraction by TBP (modified PUREX) ･Solvent extraction by N,N-dialkylamide
U-Np-Pu co-recovery	Co-extraction by TBP	･Solvent extraction N,N-dialkylamide
An(III)+RE separation	Extraction chromatography (CMPO, TODGA)	･TRUEX (Solvent extraction by CMPO) ･Solvent extraction by DGA-extractants ･Solvent extraction by DIDPA
An(III)/RE separation	Extraction chromatography (BTP, HDEHP)	･SETFICS (Solvent extraction by CMPO with DTPA) ･TALSPEAK (Solvent extraction by DIDPA with DTPA) ･Solvent extraction (TPEN, TPA, PDA, BTP etc.) ･Extraction chromatography (PDA) ･Ion exchange (Tertiary Pyridine Resin-HCl-MeOH)
Am/Cm separation	-	･Ion exchange (Tertiary Pyridine Resin-HNO_3-MeOH)
Sr-Cs separation	-	･Novel inorganic adsorbent (cation exchanger) ･Extraction chromatography

Transmutation Experimental Facility Program

Transmutation Experimental Facility Program:

J-PARC: Japan Proton Accelerator Research Complex



Transmutation Experimental Facility Program:

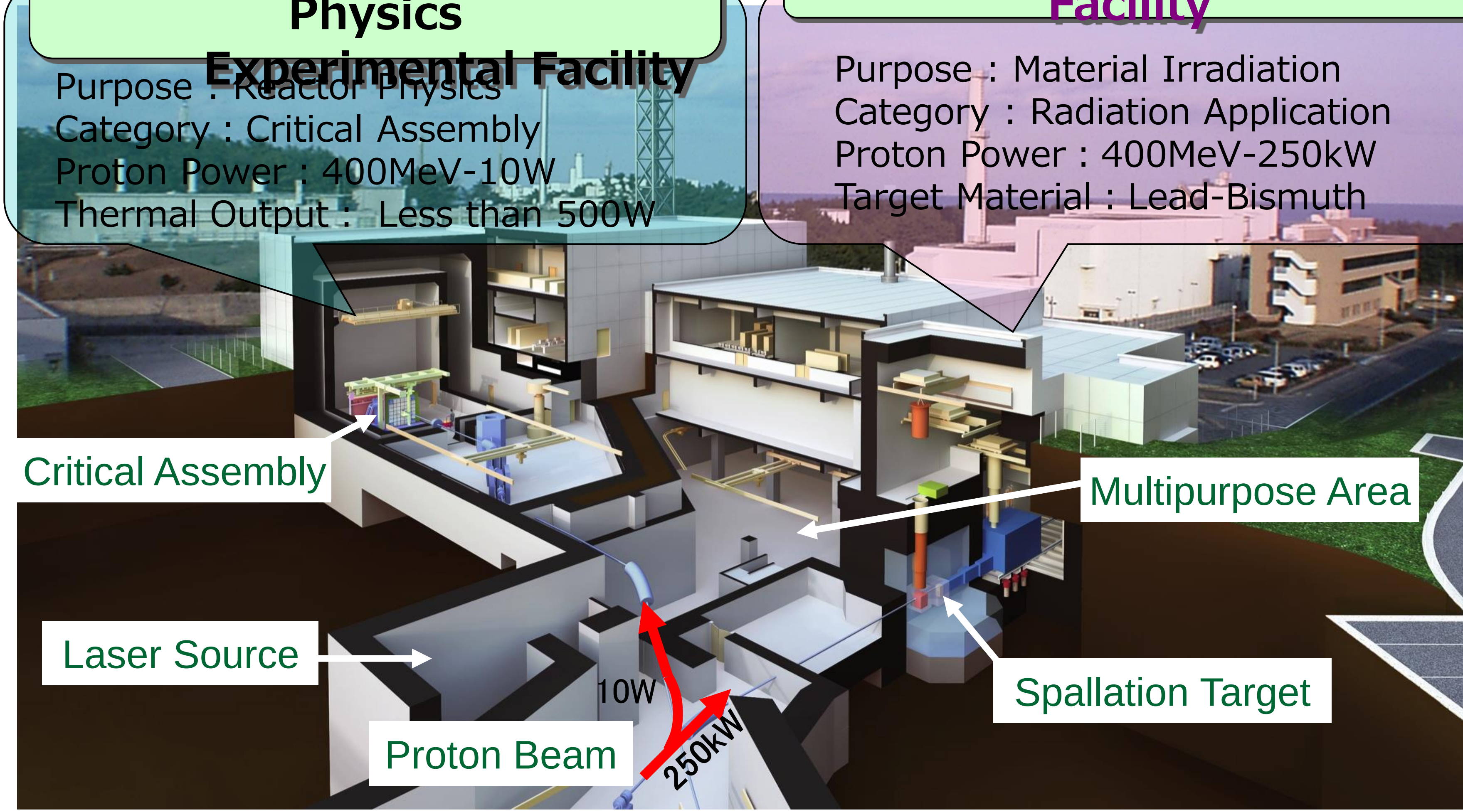
Transmutation Experimental Facility

TEF-P: Transmutation Physics Experimental Facility

Purpose : Reactor Physics
Category : Critical Assembly
Proton Power : 400MeV-10W
Thermal Output : Less than 500W

TEF-T: ADS Target Test Facility

Purpose : Material Irradiation
Category : Radiation Application
Proton Power : 400MeV-250kW
Target Material : Lead-Bismuth



Transmutation Experimental Facility Program:

R&D Items using TEF-T

Purpose of R&D	*R&D items*
Irradiation damage of beam window and structural material by protons and neutrons	Evaluation of soundness and lifetime of beam window
	Duplicated irradiation damage by protons and neutrons
	Establishment of material database for fast neutron irradiation
	Irradiation effect under stressed condition
Compatibility of material with flowing liquid metal under strong irradiation condition	Liquid metal corrosion and liquid metal embitterment under proton and neutron irradiations
	Compatibility of material with liquid metal as a function of temperature, velocity and oxygen concentration of the liquid
	Affect of spallation products
Operation and control of liquid metal spallation target system	Demonstration of performance of pump, flow meter, heat exchanger, oxygen controller under actual liquid metal spallation target
	Transient behavior of system at beam trip and re-start
	Containment of spallation products and polonium
	Technical issues on system operation and maintenance

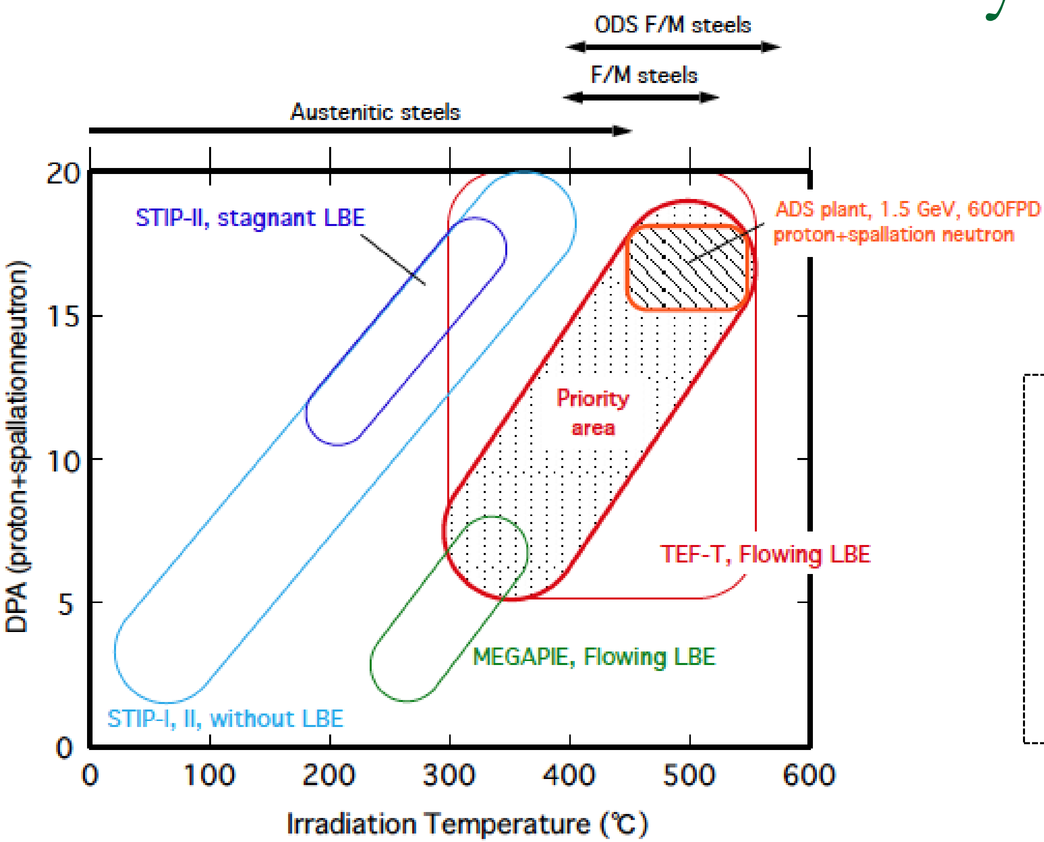
Transmutation Experimental Facility Program:

R&D Items using TEF-P

Purpose of R&D	*R&D items*
Validation of data & method to predict the neutronics in a fast subcritical system with a spallation source	Measurement of power distribution in sub-critical system
	Determination of k_{eff} and effective source strength
	Evaluation of influence of high energy neutrons
	Evaluation of influence of target, window and void in beam duct
	Simulation of Pb-Bi coolant
Performance test of a hybrid system driven by an accelerator	Feedback control of reactor power by beam intensity adjustment
	Investigation of system behavior at beam trip and re-start
	Evaluation of temperature effect of core and target
	Investigation of instability of system caused by subcriticality and annular arrangement of core
	Determination of energy gain factor
Transmutation performance of MA and LLFP	Measurement of cross section data by TOF technique
	Measurement of MA transmutation rate
	Measurement of MA and LLFP sample reactivity worth
	Study of moderated region for LLFP transmutation
	Simulation of MA-loaded nitride core

Transmutation Experimental Facility Program:

Material data taken by TEF-T target

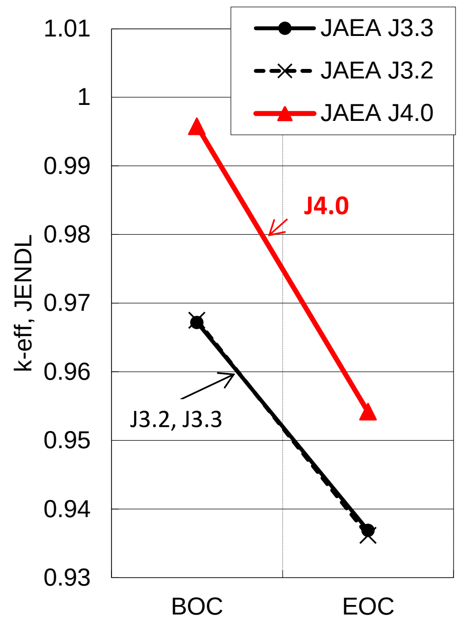


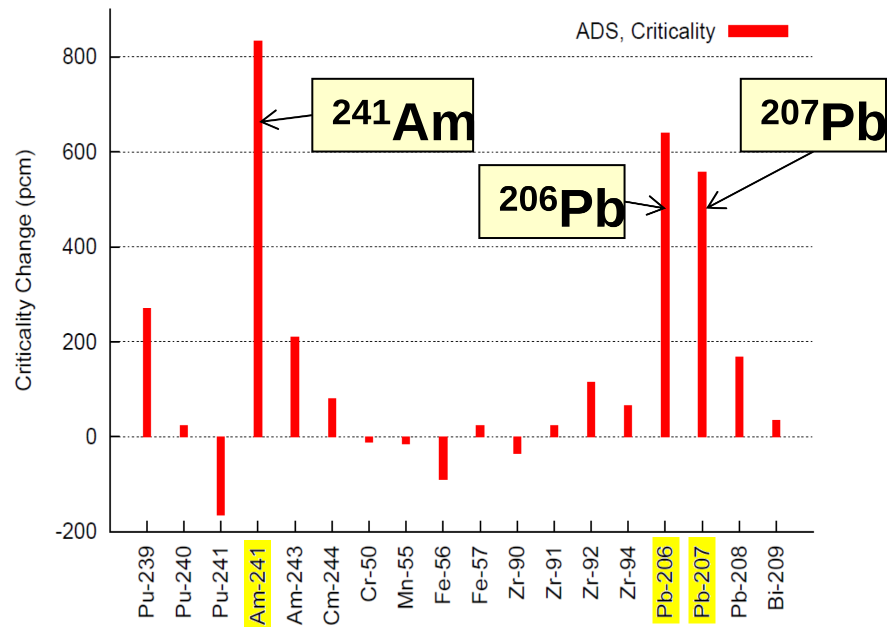
STIP-I,II
Irradiation in Stagnant Pb-Bi performed at PSI
MEGAPIE
World's first Pb-Bi spallation target with 1MW proton beam performed at PSI
SNS
High power spallation neutron source in USA
MLF
1MW Mercury spallation target of J-PARC

- Irradiation data at higher temperature range than existing experiments is required to realize ADS
- TEF-T can provide irradiation data for rated operation condition of MYRRHA

Transmutation Experimental Facility Program:

Needs for Neutronic Experiment using TEF-P



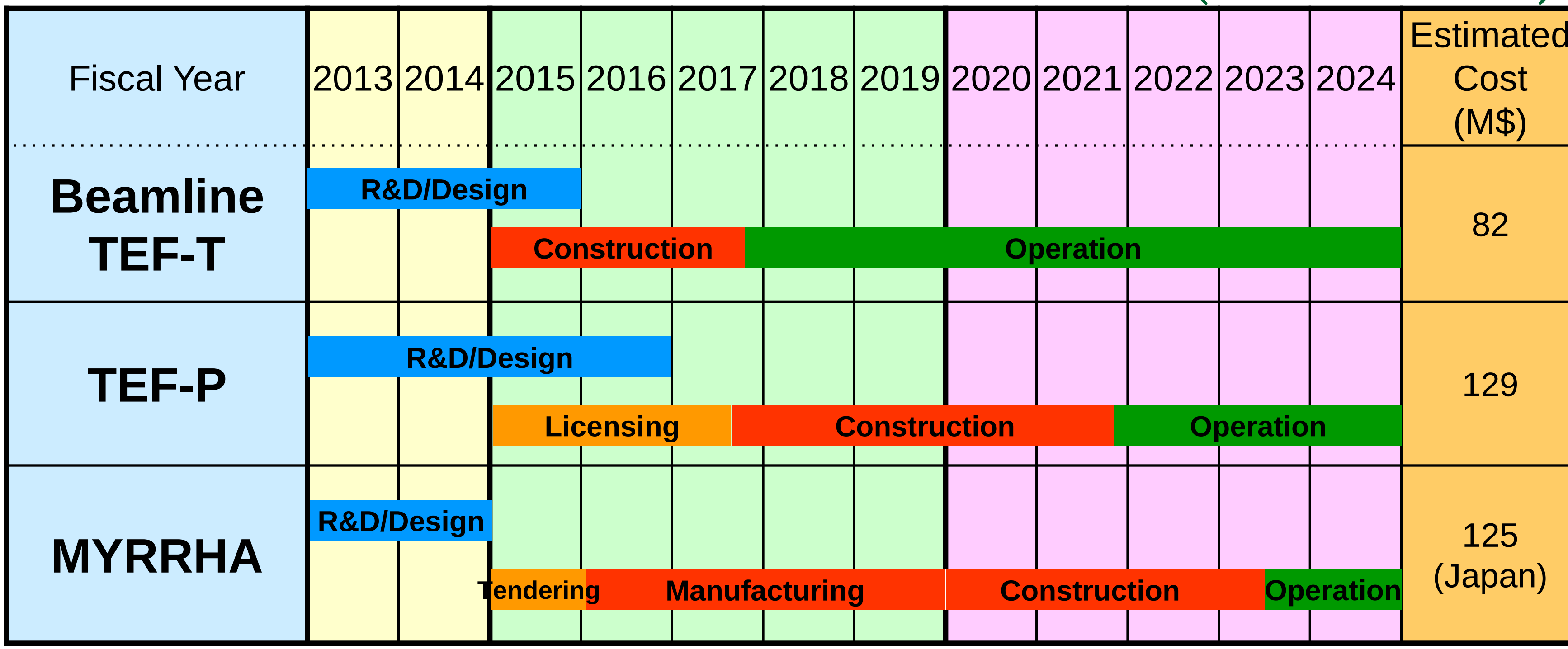


Calculated k-eff and breakdown of nuclide contribution for JAEA-ADS benchmark prepared by IAEA-CRP (800MW_{th}ADS-600EFPD)

- Latest library gives more than 2% difference than previous library
- Difference are mainly caused by Minor Actinides and lead isotopes
- Neutronic experiments using MA and lead should be performed

Transmutation Experimental Facility Program:

Construction Schedule and Cost (Tentative)

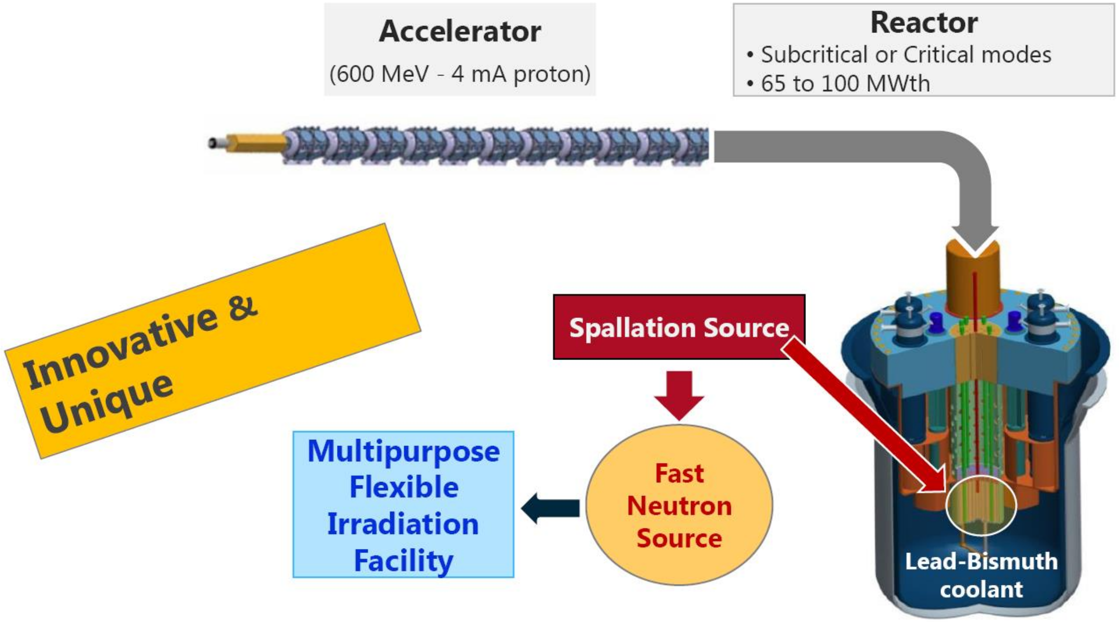


- When construction start at 2015,
  - Start TEF-T operation from 2017
  - Licensing for TEF-P start from 2015
- Cooperation with MYRRHA Project
  - Assuming 10% of total cost will be contributed from Japan (Total:960MEuro)
  - Provide irradiation data to MYRRHA full power operation (Irradiation:2018, PIE:2021)

Transmutation Experimental Facility Program:

Cooperation with MYRRHA project

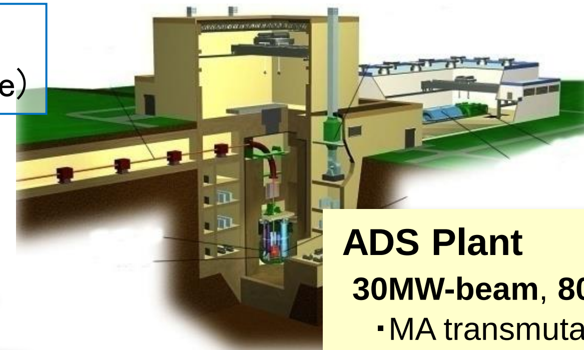
- Discussion to facilitate cooperation with TEF and MYRRHA was held at Oct.2012, with Dr. Aït Abderrahim
  - Start cooperative researches for cost and scenario for fuel cycle and flow dynamics experiments using JLBL-3 loop
  - Prepare to send “Expression of Interest”
  - Prepare roadmap to accelerate ADS RD&D works



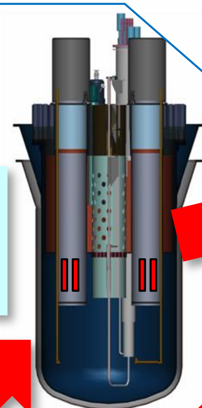
TEF-MYRRHA Joint Roadmap to Accelerate Establishment of ADS Transmutation

Power

ADS technology without MA fuel
(Pb–Bi core, Acclerator, Operation Experience)



ADS Plant
30MW-beam, 800MW$_{th}$
・MA transmutation

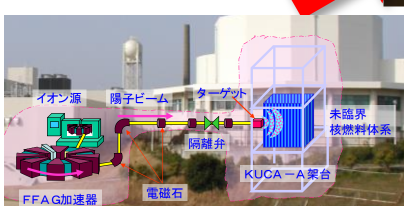


ADS Demo⇒MYRRHA
~2.4MW-beam, 50~100MW$_{th}$
・Demonstration of ADS

Improve Window Material

Physics of MA fuel and Target Development

	J–PARC	MYRRHA
Pur–pose	Elemental Technology (Target、Physics)	System demonstration
Power	Proton:250kW Core：500W(10W$_{beam}$)	Proton:2.4MW Core:50～100MW
MA	Simulate MA loaded core (Several tens kg)	Small Amount Irradiation



J-PARC Transmutation Experimental Facility
250kW-beam
・Pb-Bi target ・ADS core

- Lead the worldwide RD&D for transmutation technology in cooperation with J–PARC and MYRRHA
- Obtain knowledge & experience to realize ADS in 2030th

Basic tests (Pb–Bi loop, KUCA, etc.)

2010 2020 2030 2050 Year

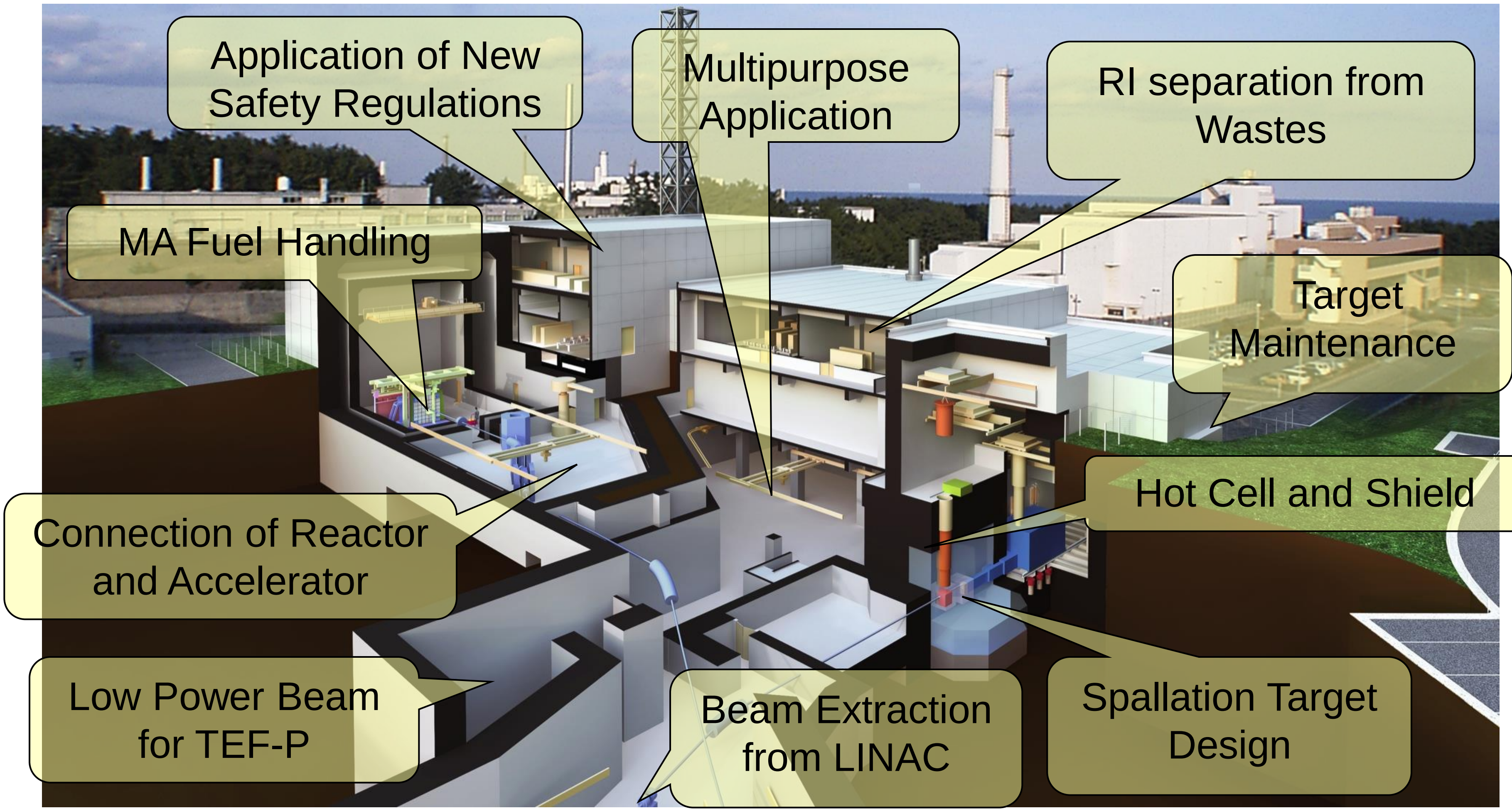
Transmutation Experimental Facility Program:

Current condition of facility site

Activities for TEF Construction

42

Urgent issues to accelerate facility construction



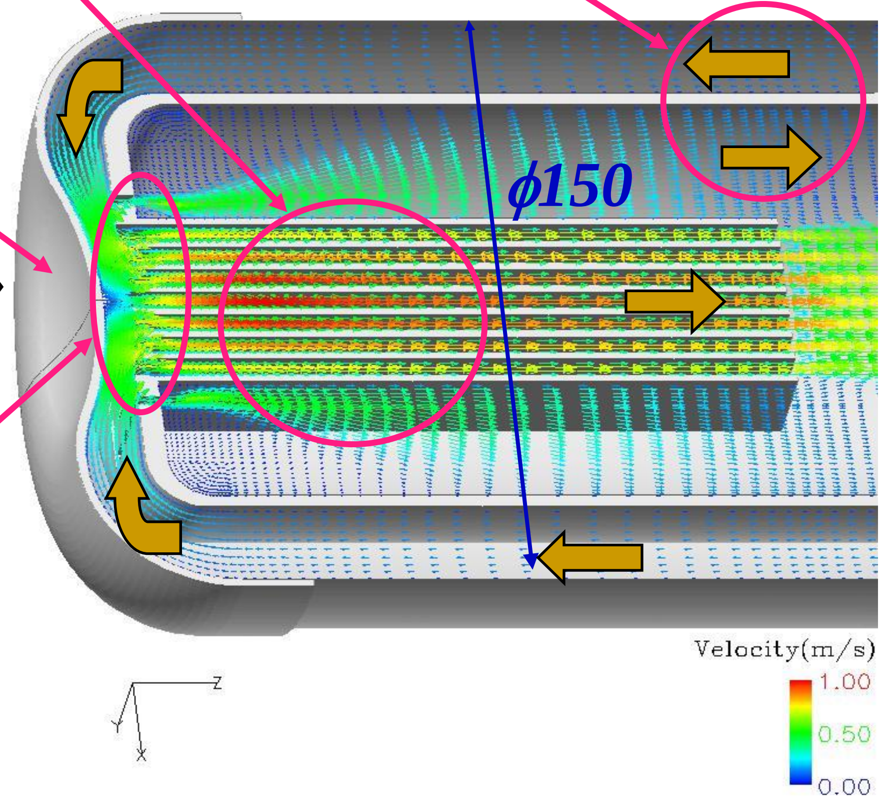
Design of Target Head - Concept

Irradiation sample holder:
To install plate specimens

Annular channel :
To flow Pb-Bi

Beam window :
To assist returned flow and reduce the thermal stress.

Proton Beam

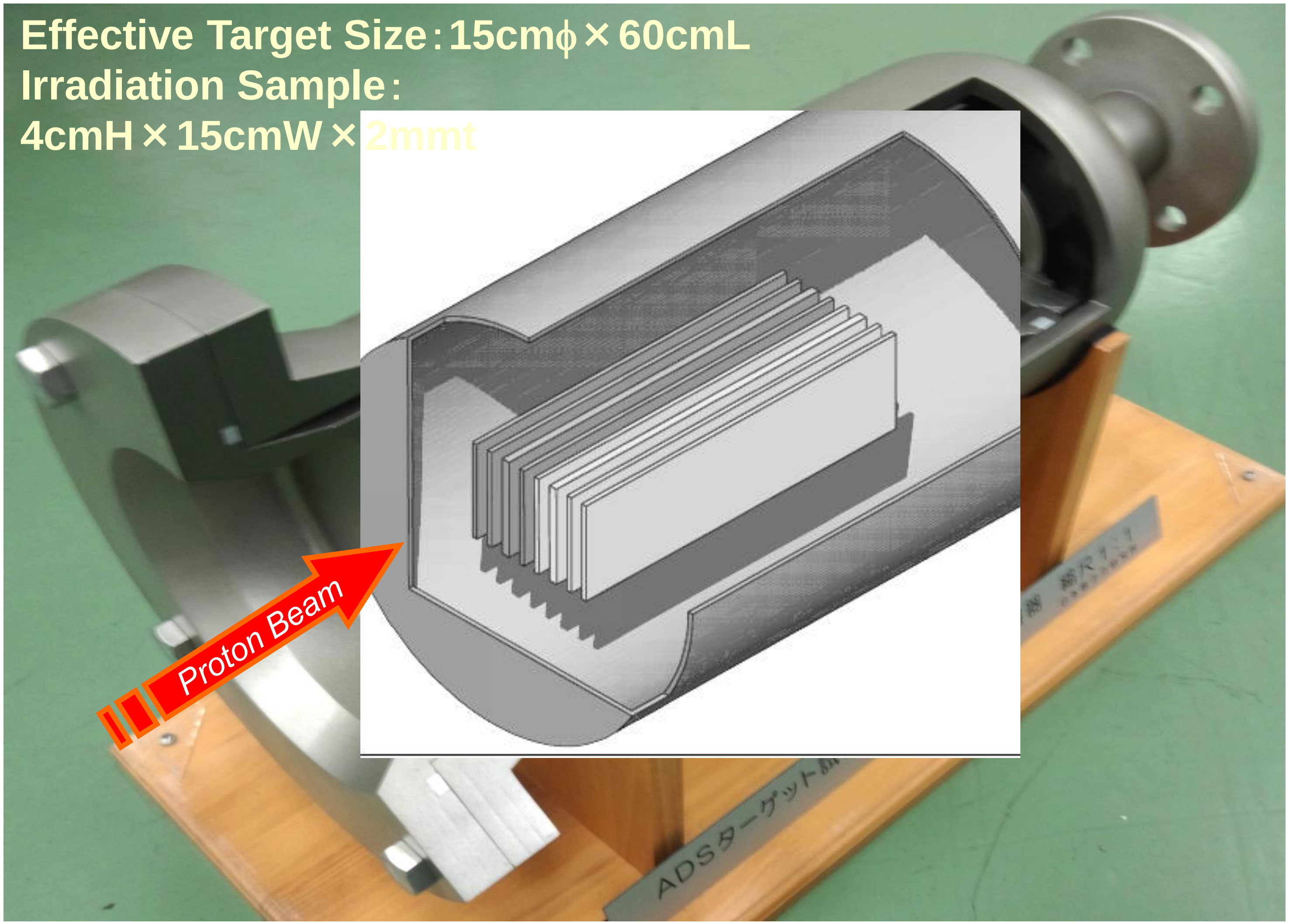


Perforated plate :
To improve heat removal at beam window and control a flow in sample region.

Design of Target Head - Eng. Model

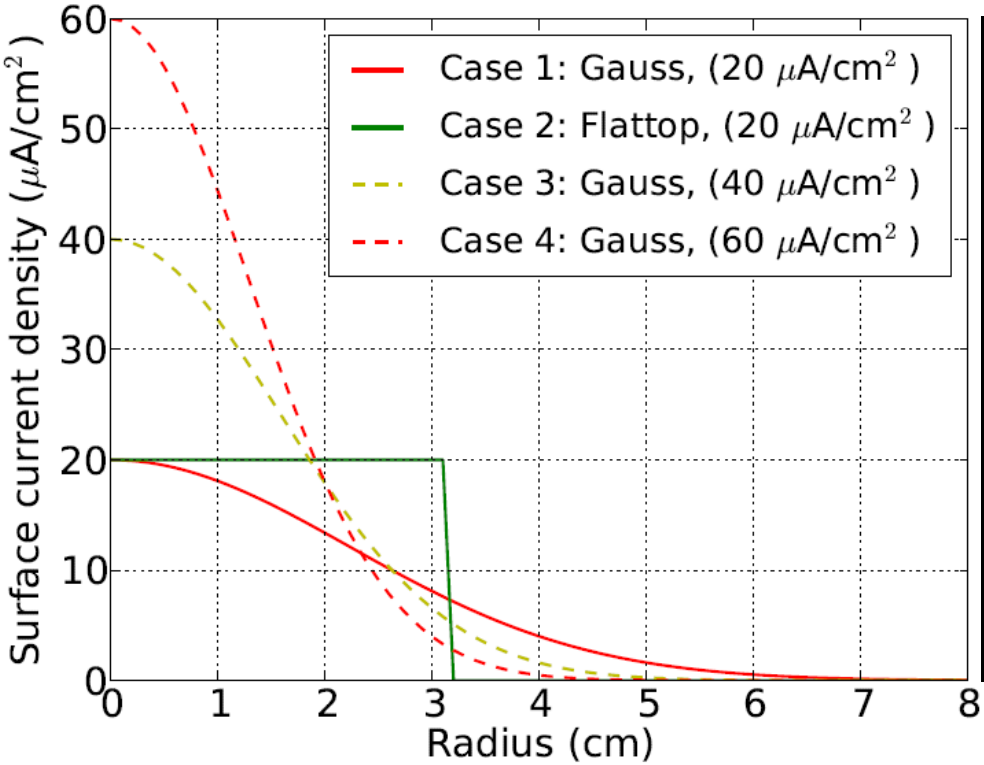
Activities for TEF Construction:

TEF-T Pb-Bi Spallation Target



Activities for TEF Construction:

Proton Beam Injection Conditions



Case	Profile	Peak Curr. (μA/cm²)	FWHM (mm)	Note
1	Gauss	20	52.4	Ref.
2	Flattop	20	(ϕ63)	ADS
3	Gauss	40	37.1	Ref. x2
4	Gauss	60	30.3	Ref. x3

FWHM: Full Width Half Maximum

- Beam Strength ：400MeV-250kW（625μA）
- Irradiation time ：4,500 hours/year（Max.）
- Pulse Shape ：25Hz・500μsec

Transmutation Experimental Facility Program:

Spallation Target Design

Thermal-hydraulics Analysis by STAR-CD

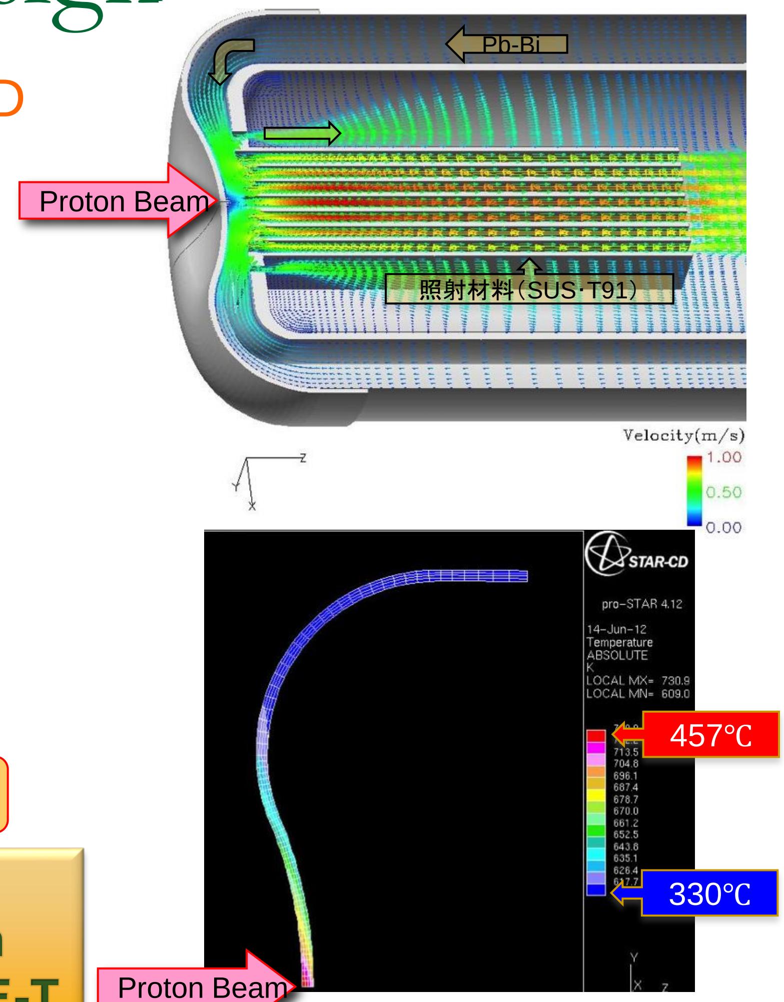
Geometry	3D 1/4 sector ~220,000 cells
Pb-Bi Flow	1 Litter/sec
Inlet Temp.	330ºC
Solver	Standard k-ε for High Re nr.
Material	316SS or T91 2mm thick
Proton	400MeV-250kW
Beam Prof.	Gauss (Peak:20μA/cm^2)

Structural Analysis by ABAQUS

Static Stress	0.3~0.5 MPa (Pb-Bi)
Thermal Stress	Data from Thermal Hydraulic Calc.

Allowable Beam Density: < 30μA/cm^2

Material irradiation tests by beam condition of ADS plant (Gaussian with 20μA/cm^2 peak) can be performed in TEF-T



Distribution of Flow Velocity and Temperature at Target Head

Activities for TEF Construction:

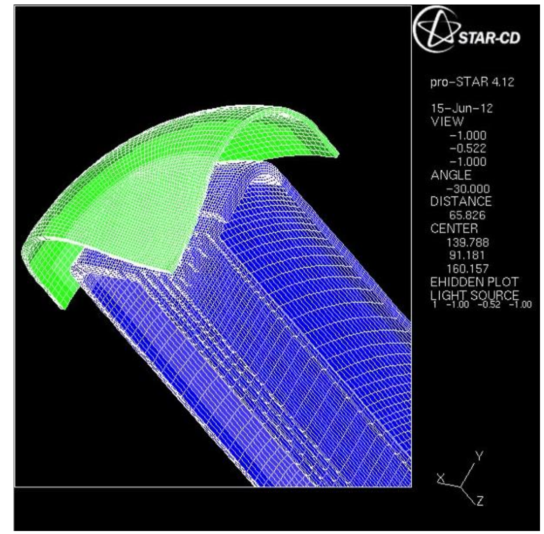
Design of Target Head - Model

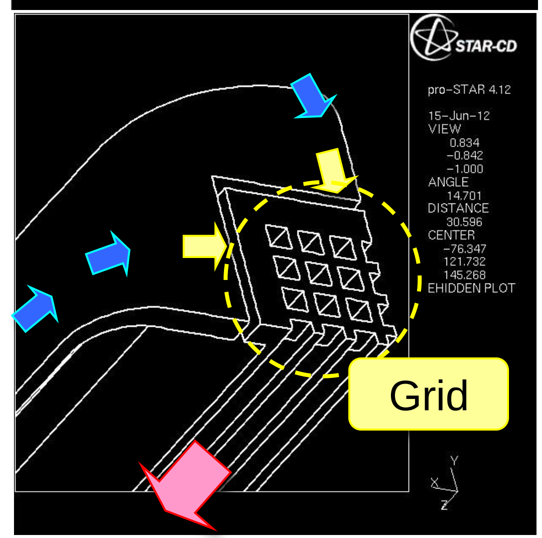
Thermal-hydraulics Analysis by STAR-CD

Geometry	Target for Irradiatio
	3D 1/4 sector ~220,000 cells
Pb-Bi Flow	1 Litter/sec
Inlet Temp.	330ºC
Solver	Standard k-ε for High Re
Material	316SS or T91 2mm thick
Proton	400MeV-250kW
Beam Prof.	Gauss (Peak:20μA/cm^2)

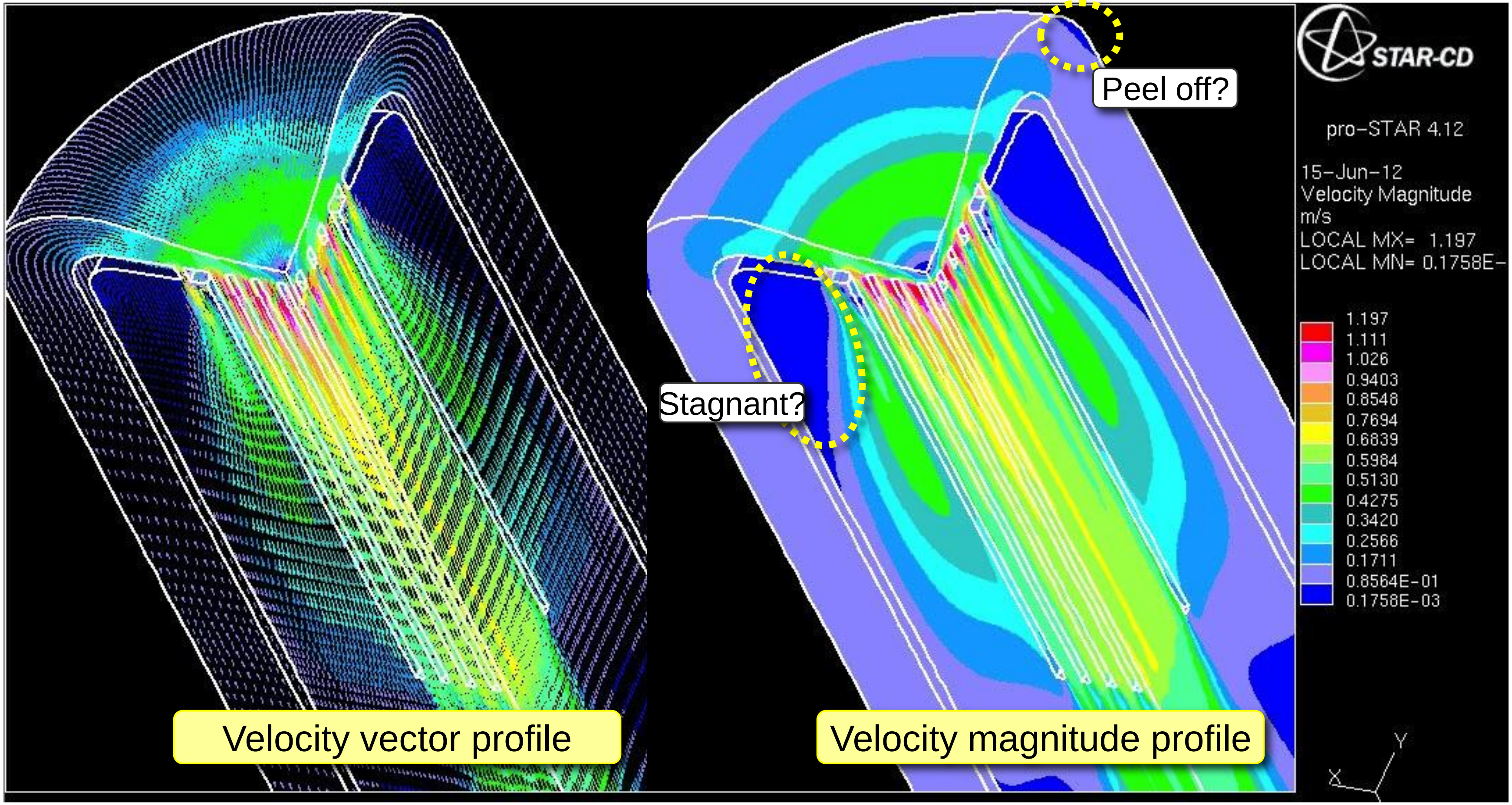
Structural Analysis by ABAQUS

Static Stress	0.3~0.5 MPa (Pb-Bi)
Thermal Stress	Data from THA



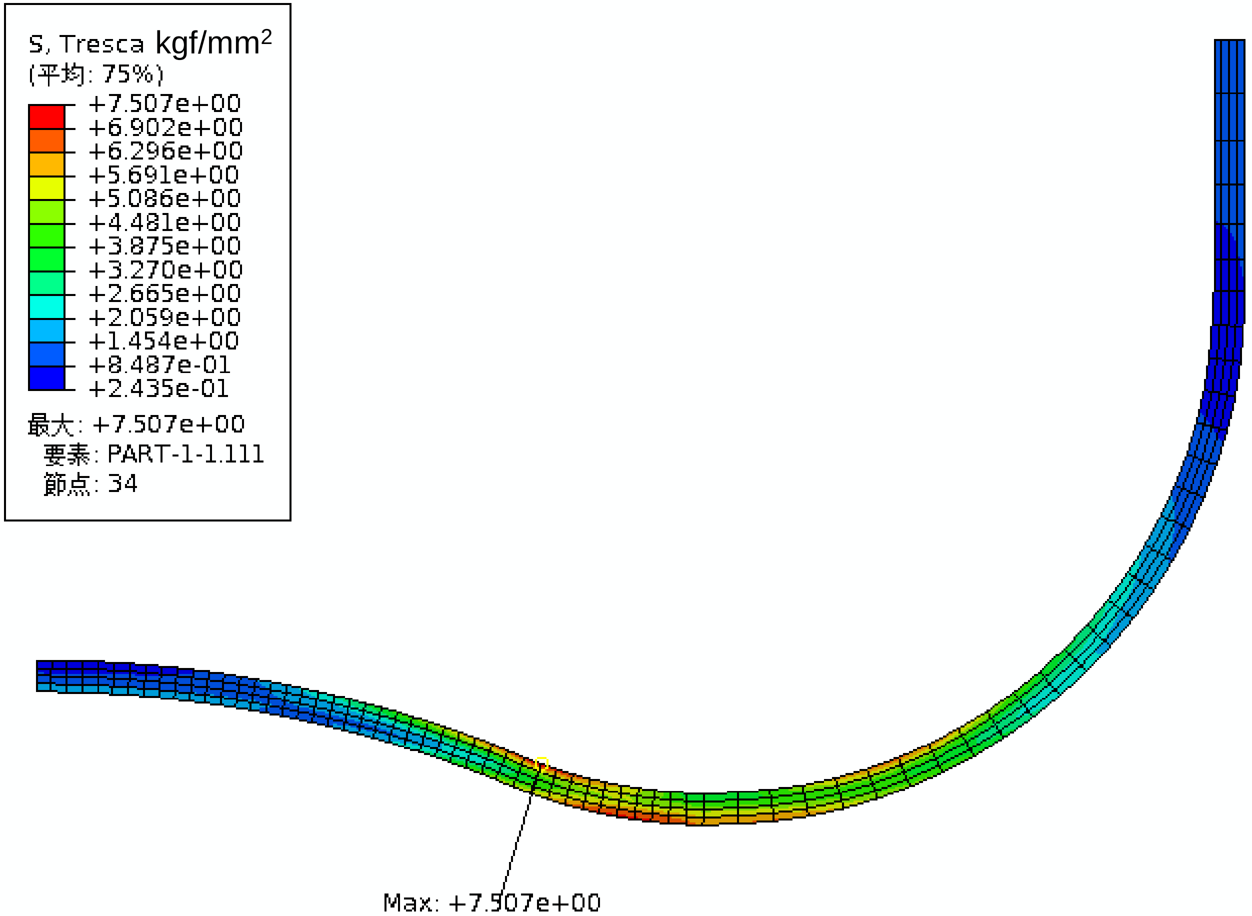


Design of Target Head - Pb-Bi flow



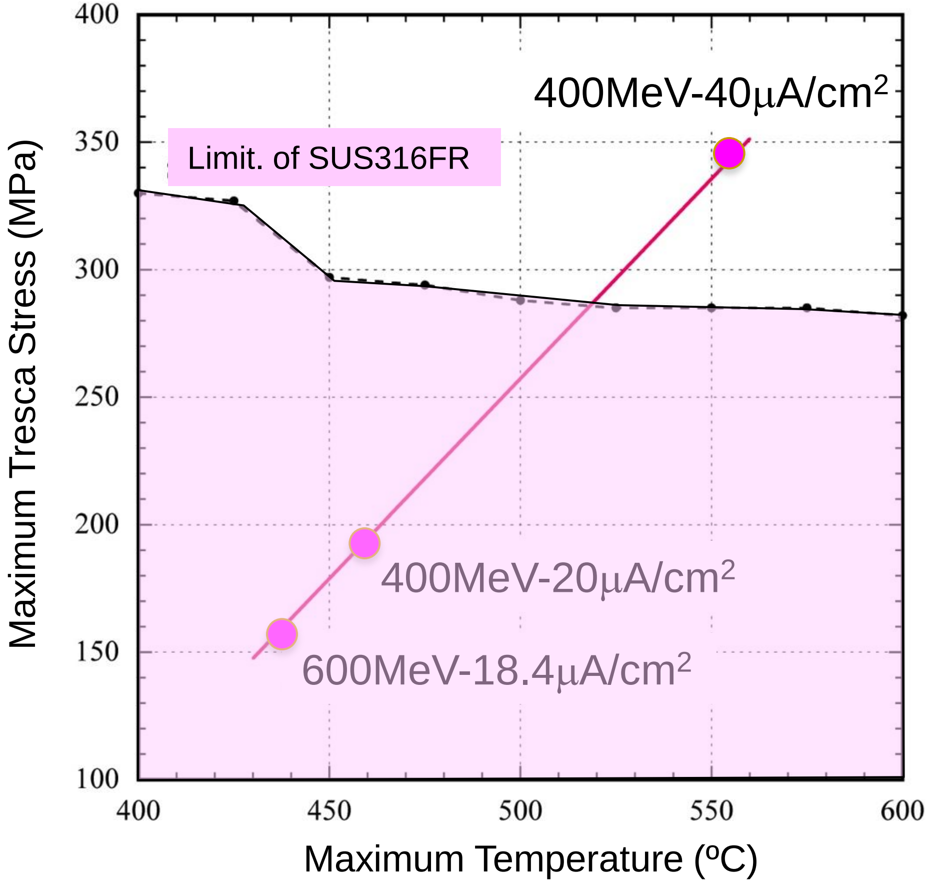
- Maximum Pb-Bi velocity of 1.2 m/s is observed just after the grid
- No specific gravity effect

Design of Target Head - Thermal Stress



- Static Inner Pressure : 0.3 MPa by Pb-Bi
- Tresca Stress : 7.5 kgf/mm^2 (~73 MPa)

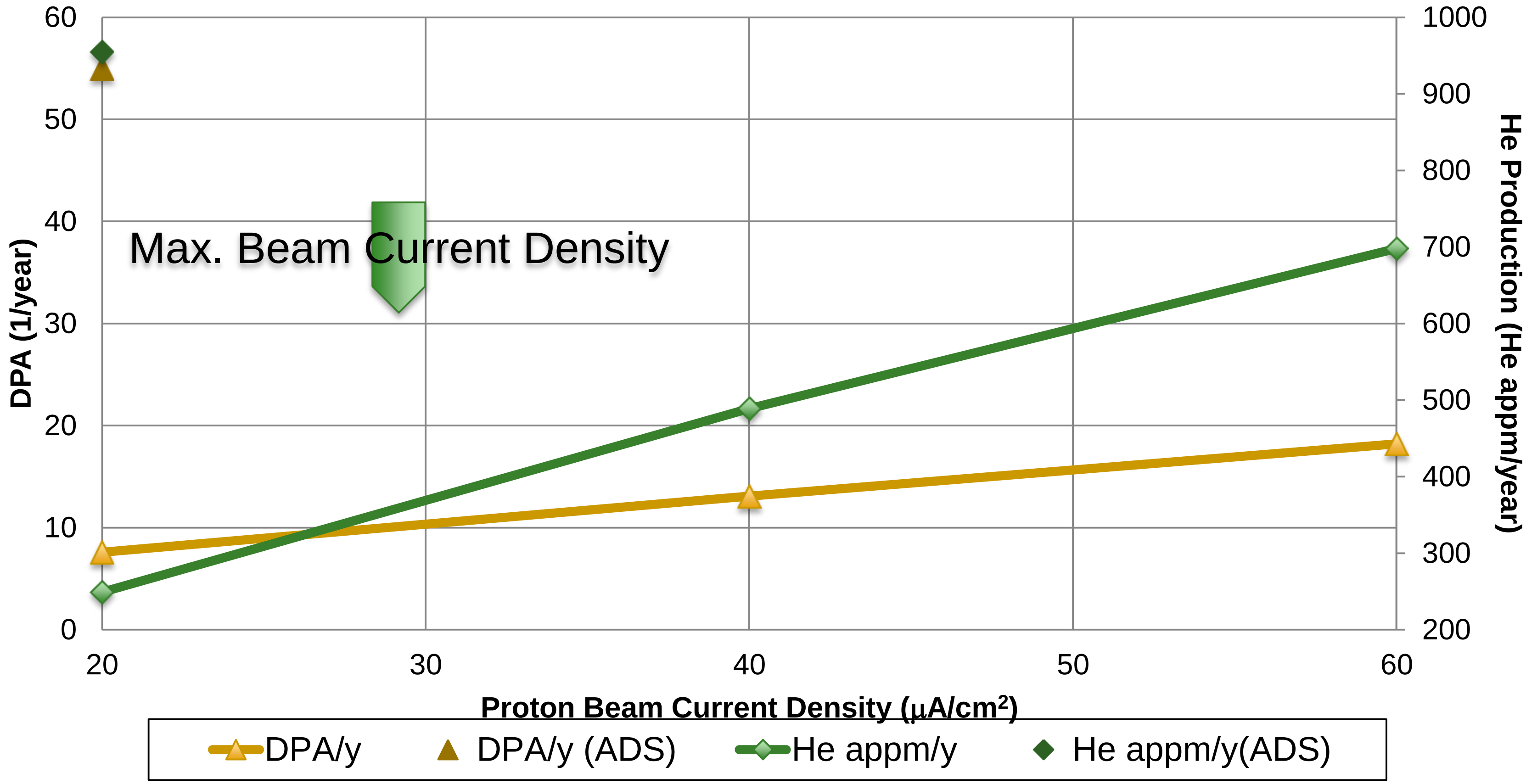
Design of Target Head - Stress Analysis



- Pb-Bi flow amount : 1 litter/sec
- Allowable Operation Condition : Lower than 400MeV – 30μA/cm^2

Transmutation Experimental Facility Program:

Sample Irradiation Amount



- Higher irradiation amount can be obtained by increasing beam density
- To simulate full scale ADS window, it requires 3-5 cycles of full power irradiation

Maximum DPA in irradiation sample

Sample No.	Case 1		Case 2		Case 3		Case 4	
	T91	SUS316	T91	SUS316	T91	SUS316	T91	SUS316
1	7.6	7.7	7.3	7.4	13.1	13.3	18.2	18.4
2	6.8	6.8	7.2	7.2	10.7	11.0	13.7	13.8
3	5.8	5.9	7.0	7.1	7.6	7.7	8.1	8.4
4	4.7	4.7	6.8	6.7	4.8	5.0	4.4	4.5
Window	6.0	—		—	11.1	—	15.9	—

【参考】Irradiation at window of ADS（800MWth-20MWbeam）: 55 (DPA/year)

- 8 DPA maximum at reference case
- Further high beam current density and multi-cycle irradiation should be required to simulate actual ADS

He Production in irradiation sample

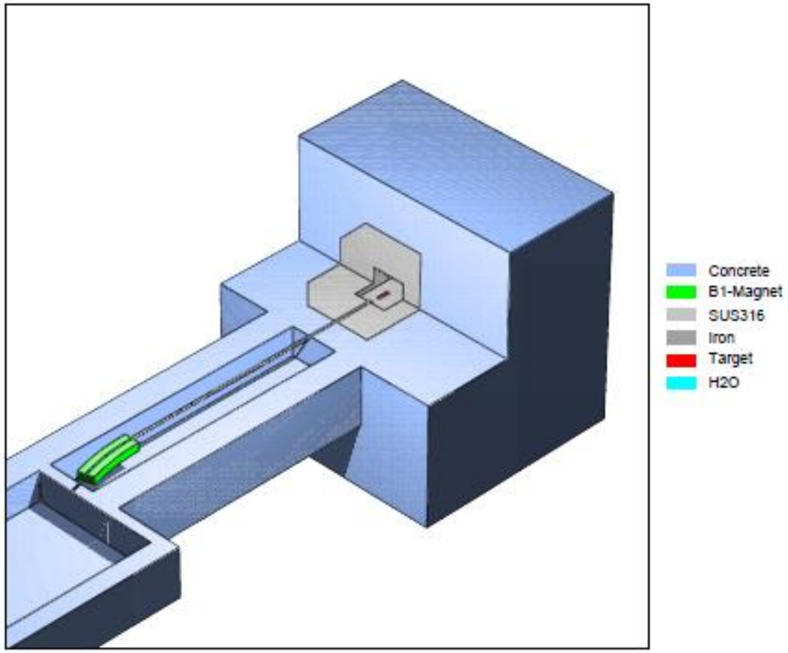
Sample No.	Case　1		Case 2		Case 3		Case 4	
	T91	SUS316	T91	SUS316	T91	SUS316	T91	SUS316
1	249	254	265	264	489	492	698	720
2	217	222	268	254	393	382	515	501
3	181	175	247	271	256	250	265	256
4	137	129	266	240	130	140	100	108
Window	274	—		—	511	—	798	—

【参考】Irradiation at window of ADS（800MWth-20MWbeam）: 955 (He appm/y)

- 250 He-appm maximum at reference case
- Multi-cycle irradiation is required to simulate actual ADS

Shield: Re-evaluation of wall thickness

- Design condition changes:
  - Operation condition : 600MeV-200kW to 400MeV-250kW
  - Facility layout: Include multipurpose experimental hall
- Detailed analyses to represent new floor plan was performed

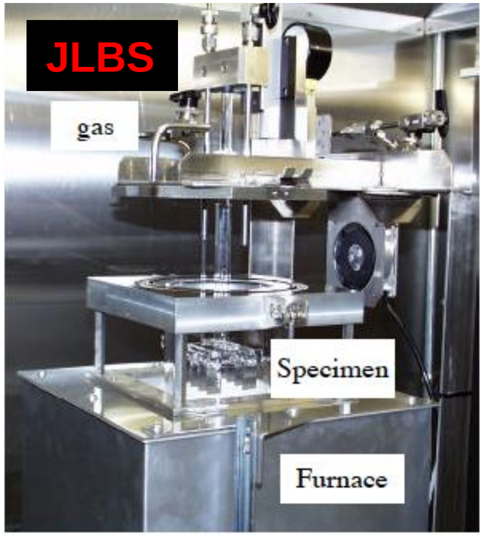


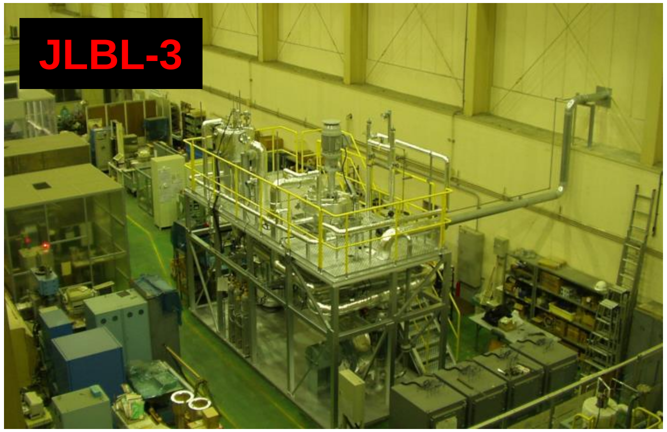
- Shield thickness is not significantly changed and is compatible with current facility location/layout.
- Detailed facility layout will be performed based on this shileld structure from FY2013

Estimated Cost: 2.5 M$

LBE test apparatus and loops

To examine the feasibility and applicability of the lead-bismuth eutectic (LBE) to TEF-T and ADS, JAEA has an experimental apparatus for static corrosion test and 4 experimental LBE loops.





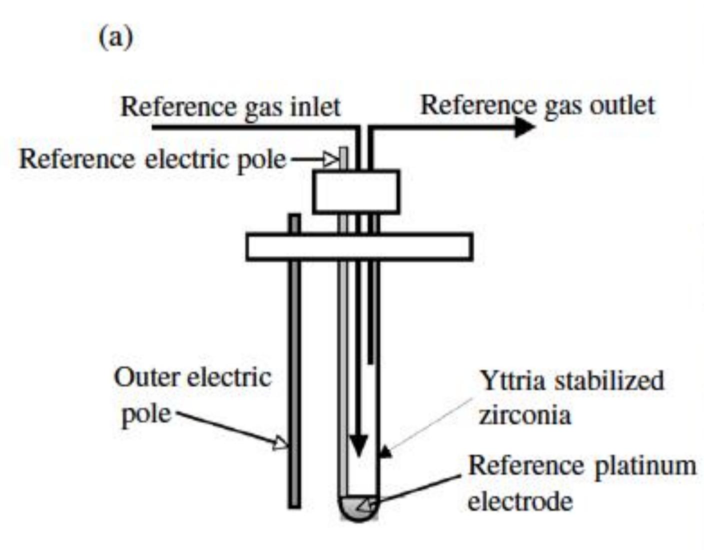
JLBS -Static corrosion test-

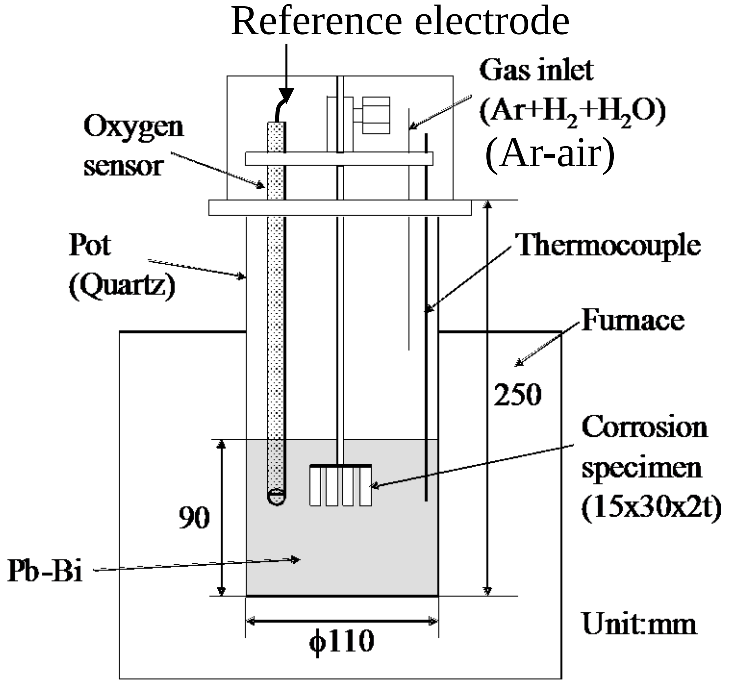
Purpose

(1) Corrosion of materials tests for ADS components under static condition.
(2) Screening tests of materials for ADS components.
(3) Corrosion mechanism of various materials in LBE

Results

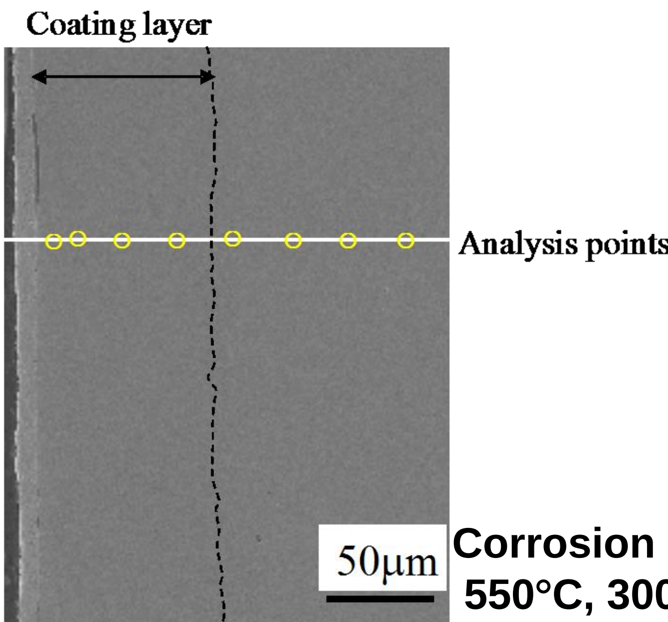
(1) Static corrosion tests under oxygen control condition
(2) And tests on various steels
(3) And tests on Al-coated steels (316SS)



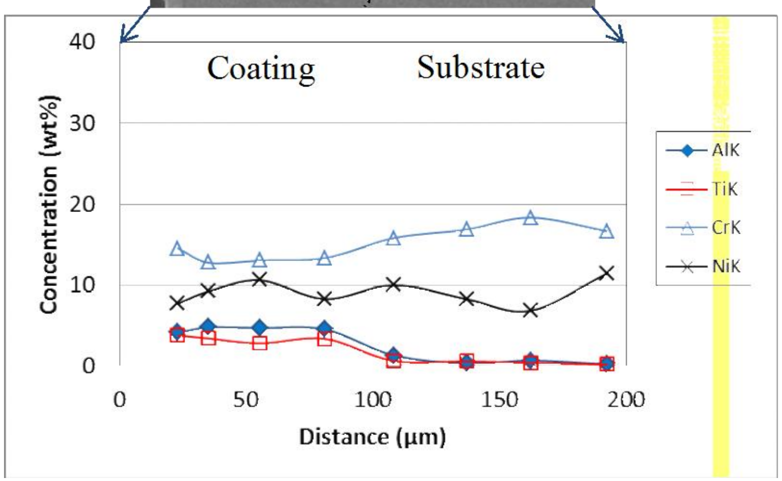


Kurata et. al., JNM 398(2010)165-171.

JLBS -Static corrosion test-



Corrosion test :
550°C, 3000h, [O];10^{-6}~10^{-3} wt%



Result of corrosion test for Al-coated steels

Optimization of condition of Al-coating steel

⇒No penetration of LBE is observed.

•The coating layer protects 316SS from severe corrosion attack.

•The thin Al-oxide film formed in LBE is a barrier against corrosion.

Present status and future plan

(1) Static corrosion tests on Al-coated steels (F/M steels)

(2) And tests on Si-added steels (316SS+5%Si, T91+1.5%Si)

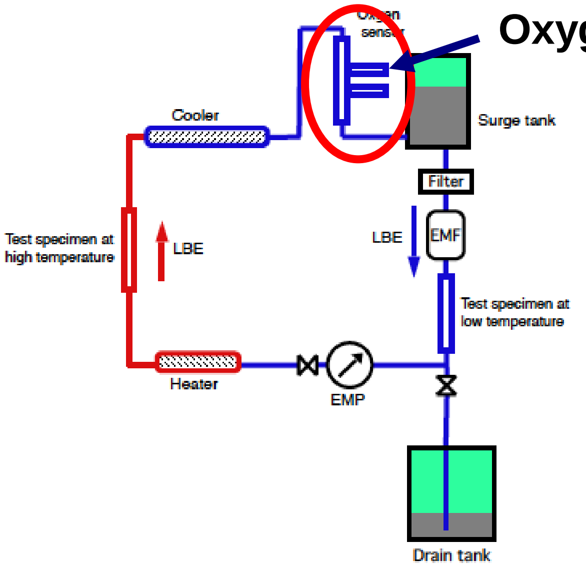
(3) Oxygen sensor test

JLBL-1 -Oxygen control & erosion test-

Purpose

(1)To evaluate the feasibility of structural materials for ADS

(2)To become proficient in the LBE handling techniques



To measure oxygen concentration
in flowing LBE at lower (<400℃) temperature.
Conventional type : vertical, free surface
→slugs, thermal shock,
New type : Installed horizontal direction

> Reference : solid（Fe_2O_3/Fe）
> Electrolyte : 8%mol YSZ
> Packing : Thermiculite®

Specifications of JLBL-1

Main material	316SS
Inventory	20 L
Max. pressure	5 bar
Max. electrical power	15 kw heaters
Max. temperature	450 ℃
Max. design temperature	500 ℃
Number of test section	2
Control of temperature difference system	**Available**
Oxygen control system	**Under preparation**
Flow rate of LBE	Max. 18 L/min
Flow rate observation	EMF

JLBL-1 -Oxygen control & erosion test-

Results

(1) Total time of operation is 30,000 hours

(2) 7 phase of erosion/corrosion tests (3,000 h X 6, 1,000h X 1) in flowing LBE

(3) No oxygen control (-10^{-8}wt%)

Present status of JLBL-1

- Oxygen control test
  300-400℃, Isothermal condition
  Flow-rate 5L/min.
- Oxygen sensors
  Sensor A : No output
  Sensor B : Output (20-200mV)

Control method of oxygen concentration
⇒ supplying Ar(carrier gas), H_2 and water

JLBL-2 -Flow measurement by UVP-

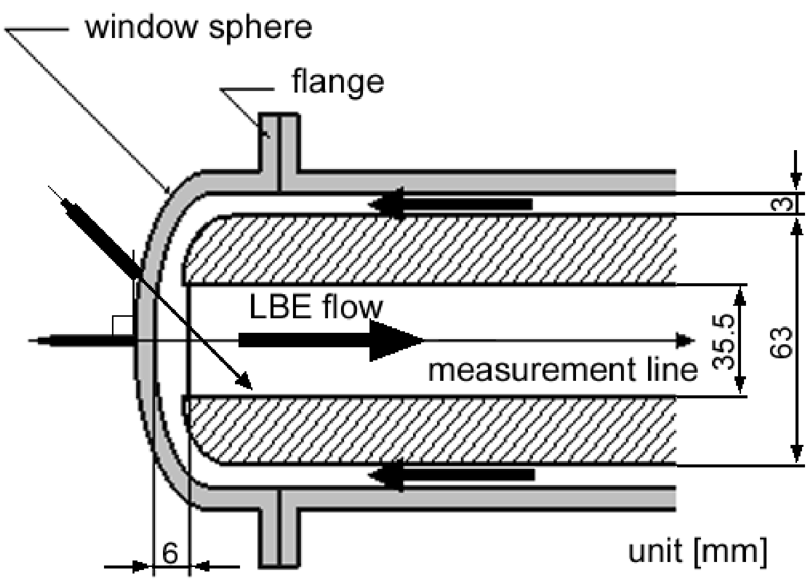
Purpose

(1)Flow study and proof test of sealed-annular tube type.

(2) Development of EMF using the electrode of non-contact type.

(3) Application of velocity measurement system for LBE flow.

Configration of flow measurement

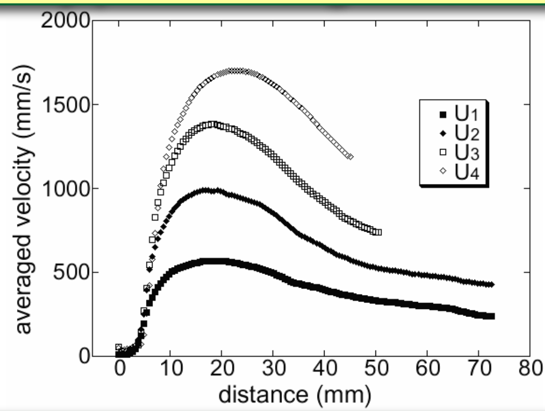


Specifications of JLBL-2

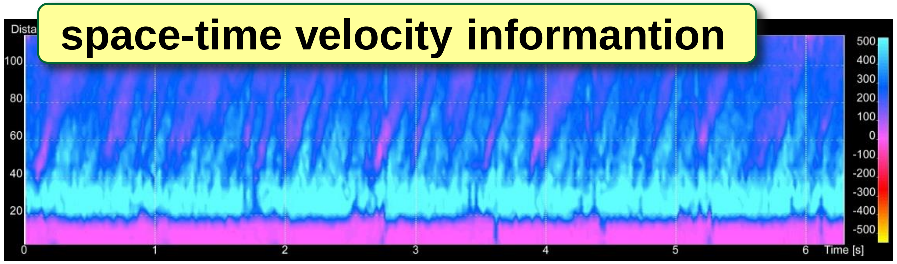
Main material	316SS
Inventory	20 L
Max. pressure	2 bar
Max. electrical power	5 kw heaters
Max. temperature	200 ℃
Max. design temperature	200 ℃
Number of test section	-
Control of temperature difference system	**Unavailable**
Oxygen control system	**Unavailable**
Flow rate of LBE	Max. 30 L/min
Flow rate observation	EMF

JLBL-2 -Oxygen control & erosion test-

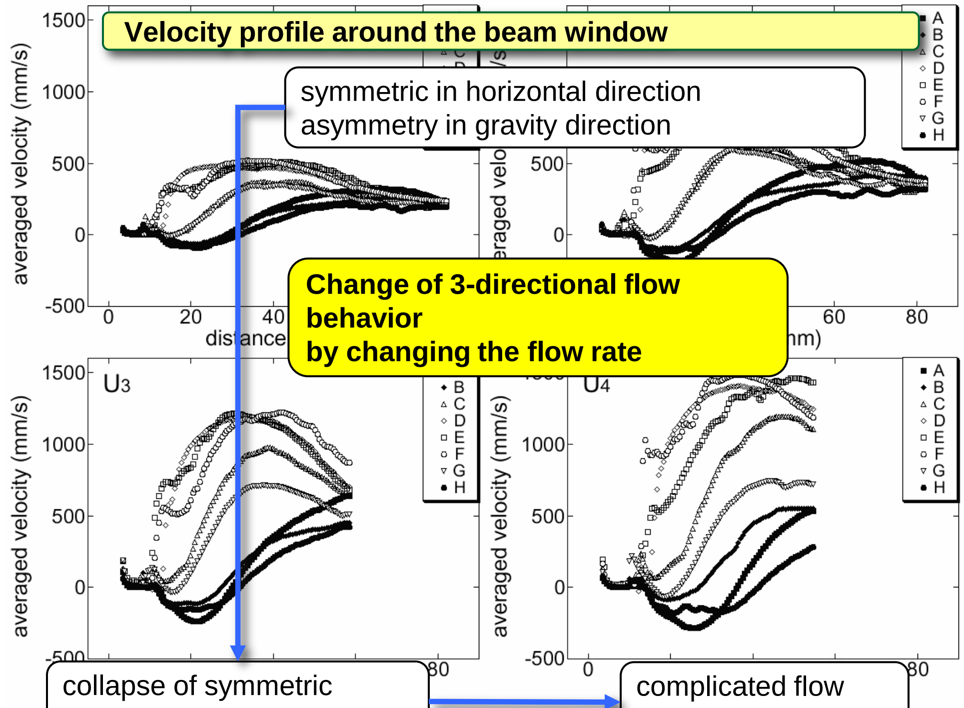
Velocity profile along the centerline



space-time velocity informantion



Velocity profile around the beam window



Results

(1) Measurement of velocity profile in LBE flow velocity profile by using UVP technique.

Present status of JLBL-2

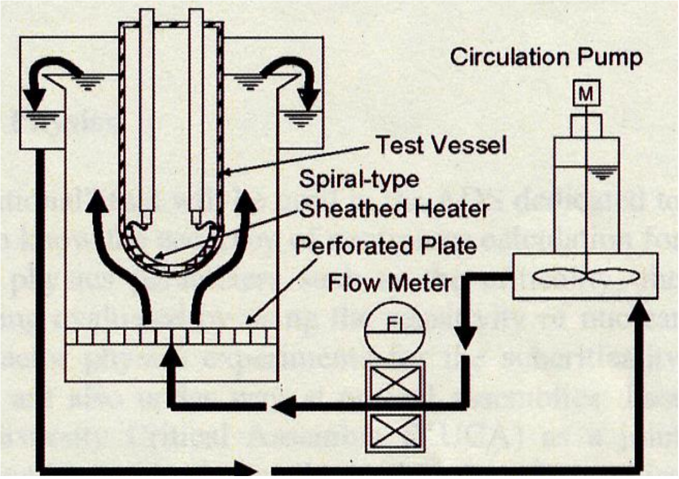
In the past studies, only short-term operation (-200h) has been performed in JLBL-2.

(1) Long-term operation (-5,000h) to proof the soundness of annular type target

JLBL-3 -Beam window test-

Purpose

1) Thermal fluid test of hemispherical type of beam window
2) Measurement of heat transfer characteristics around beam window
3) Proof test of mechanical pump and massive LBE flow.



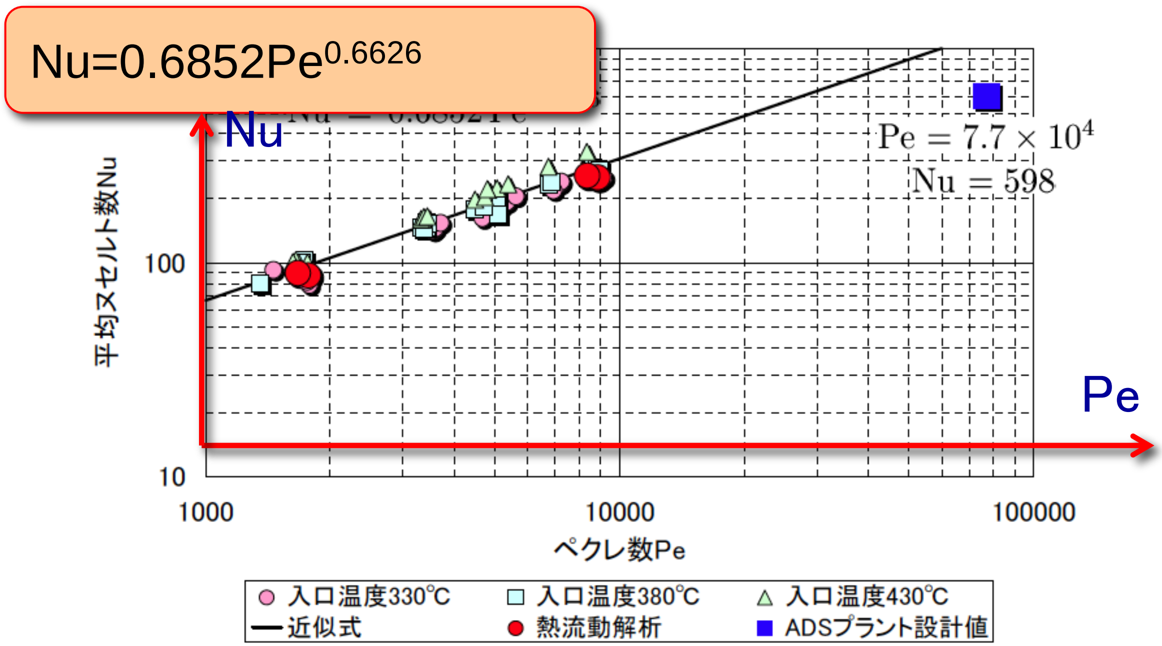
Outline of JLBL-3

Size of window model	Diameter 89.1mm Length 1000mm
Type of window model	hemisphere

Specifications of JLBL-3

Main material	316SS
Inventory	330 L
Max. pressure	7 bar
Max. electrical power	60 kw heaters
Max. temperature	450 ℃
Max. design temperature	500 ℃
Number of test section	1
Control of emperature difference system	**Available**
Oxgen control system	**Available**
Flow rate of LBE	Max. 500 L/min
Flow rate of observation	EMF

JLBL-3 -Beam window test-



Results

(1) Heat transfer characteristics of the hemispherical beam window was formulized.

(2) Over 500 L/min. LBE flow was achieved by mechanical pump.

Present status and future plan of JLBL-3

(1) Heat transfer test on various type of beam window

(2) Bundle test

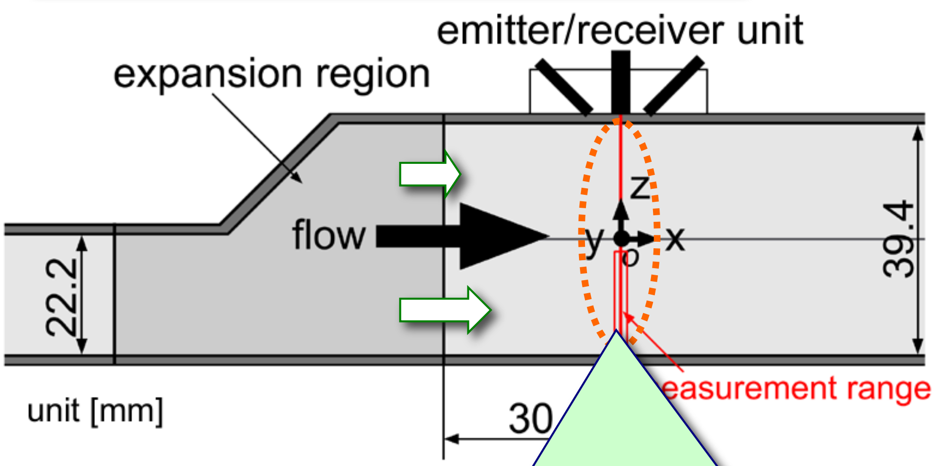
JLBL-4 -Development of advanced FM tec.-

Purpose

(1)Development of advanced flow measurement techniques
(2)Verification for stability of EMF output

◇Application to actual LBE flow

Configration of flow measurement

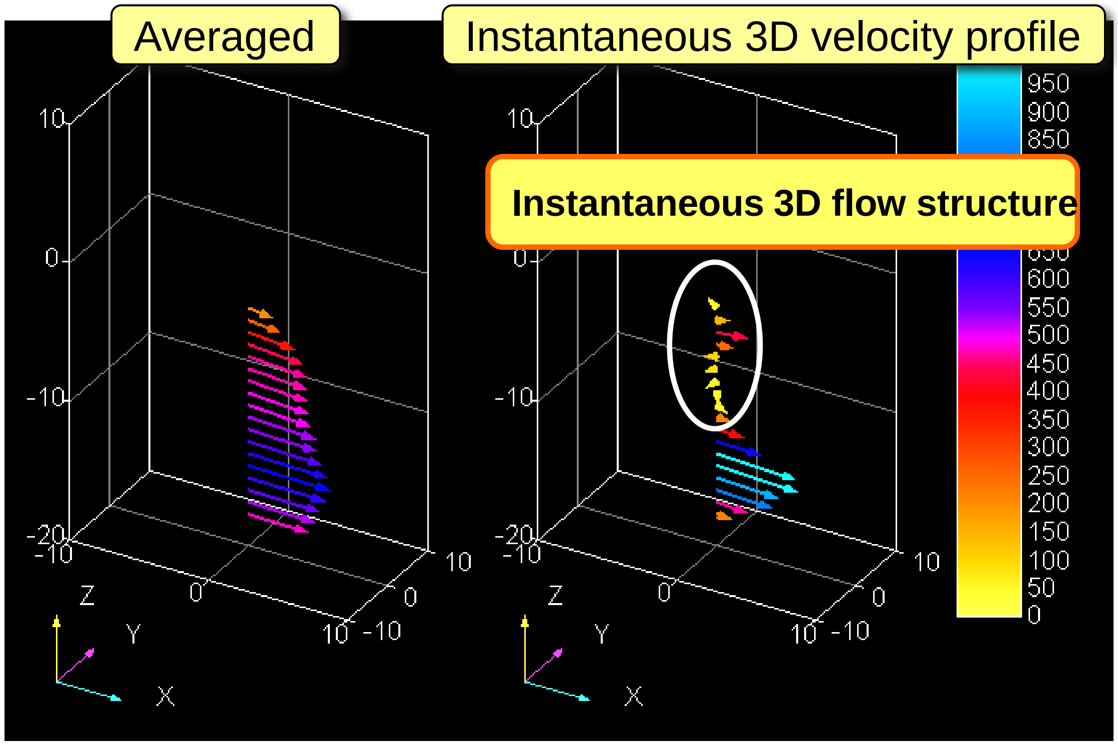


LBE flow rush into the expansion region
(Simulation of the outbreak point of erosion)

Specifications of JLBL-4

Main material	316SS
Inventory	20 L
Max. pressure	6 bar
Max. electrical power	7 kw heaters
Max. temperature	300 ℃
Max. design temperature	500 ℃
Number of test section	1
Control of temperature difference system	**Unavailable**
Oxgen control system	**Unavailable**
Flow rate of LBE	Max. 40 L/min
Flow rate of observation	EMF

JLBL-4 -Development of advanced FM tec.-



Results

(1) 3-dimentional velocity vector measurement system (Vector-UVP) was successfully applied to actual LBE flow

Present status and future plan of JLBL-4

(1) Verification for stability of EMF output in long-term operation by using ultrasonic flow meter

Problems of LBE handling in JAEA

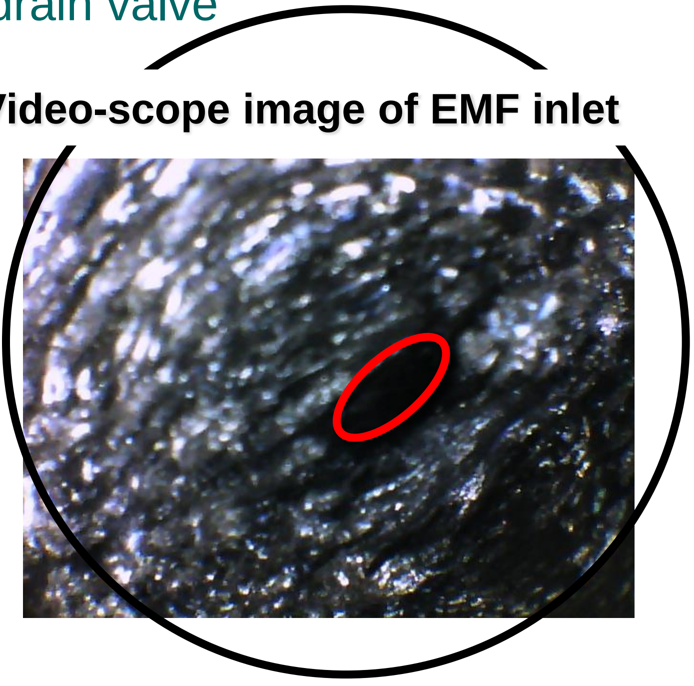
Problems of JLBL-1

(1) Blockage of flow channel by magnetic (Fe-Cr) particles. (Now repairing)

(2) LBE leakage due to the jamming by lead oxide at drain valve

(3) Stability of indicated value of EMF

Video-scope image of EMF inlet



Problems of JLBL-2

(1) In long-term operation, indicated value of EMF is unstable! (temperature=300℃)

Problems of JLBL-3

(1)The switching noise by the heater in the window appears the measured temperature

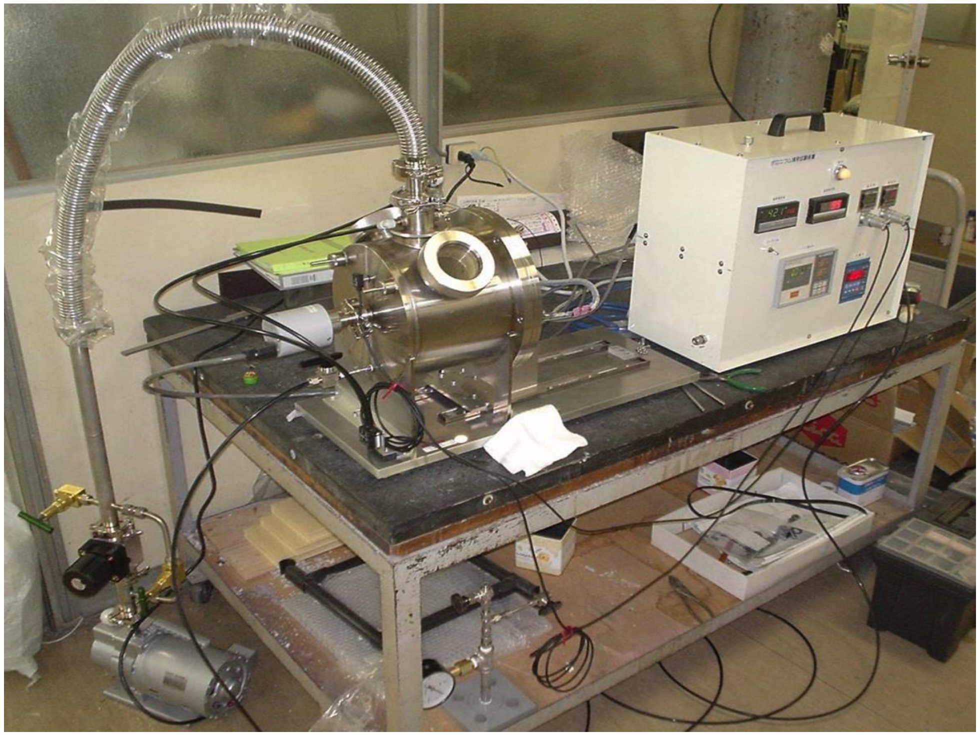
(2) Ceiling around the motor axis of the mechanical pump

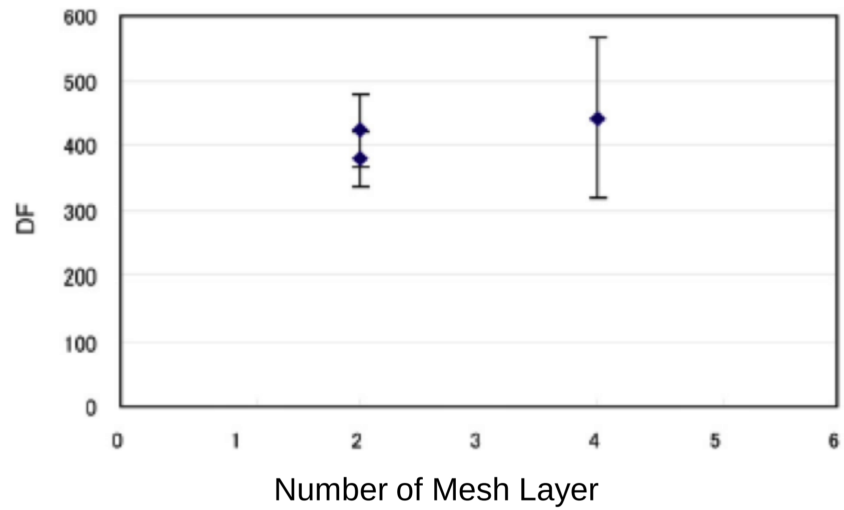
⇒ A large quantity of oxide is produced in the tank by invasion of the air.

⇒ In the case of Max. flow rate, oxide is rolled up in a pump, and flow becomes unstable.

Activities for TEF Construction:

Po removal tests

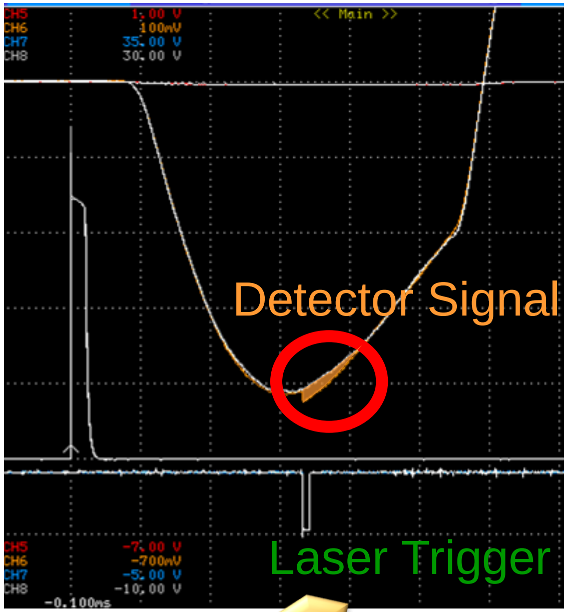


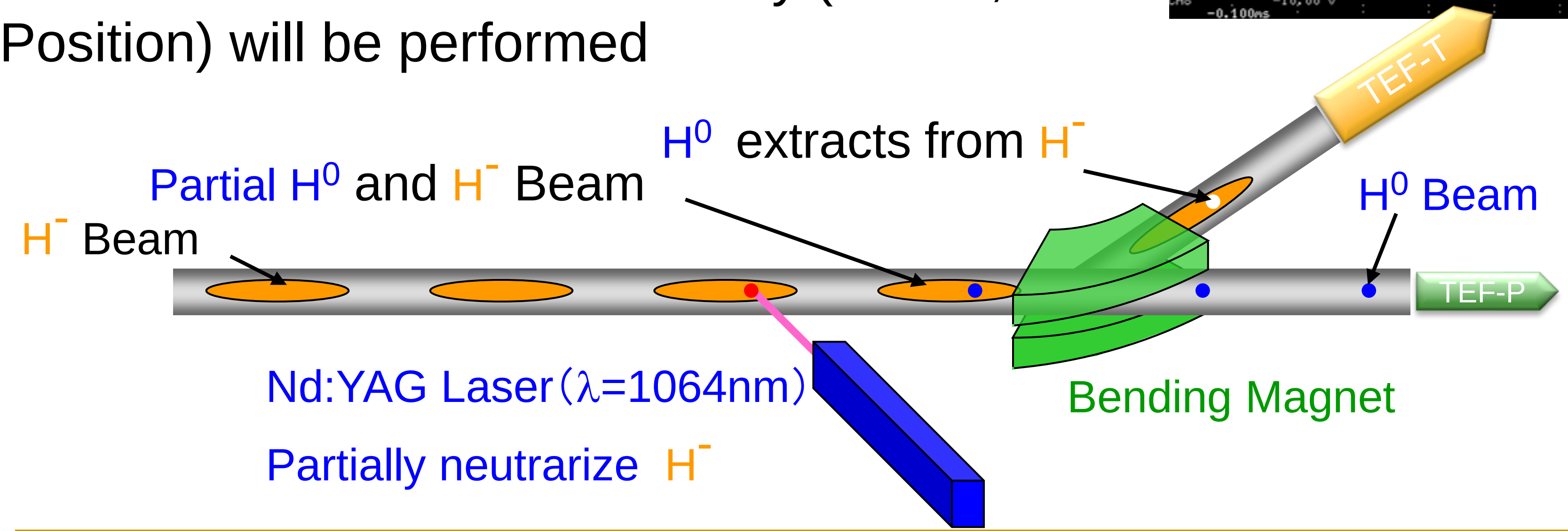


- Cooperative research with Tokyo Inst. Tech.
- Pb-Bi irradiated at JRR-4 was used
- 300~400 of decontamination factor is obtained by stainless mesh filter

Low Power Beam Extraction

- Succeed Beam Extraction at Bending Section
- Find Pathway to following items
  - Flexible beam extraction according to experiments
  - High quality beam by omitting beam hallow
  - Safe and stable beam supply for CA experiment
  - Short Pulse beam for multipurpose use
- Demonstration of Laser stability (Power, Position) will be performed

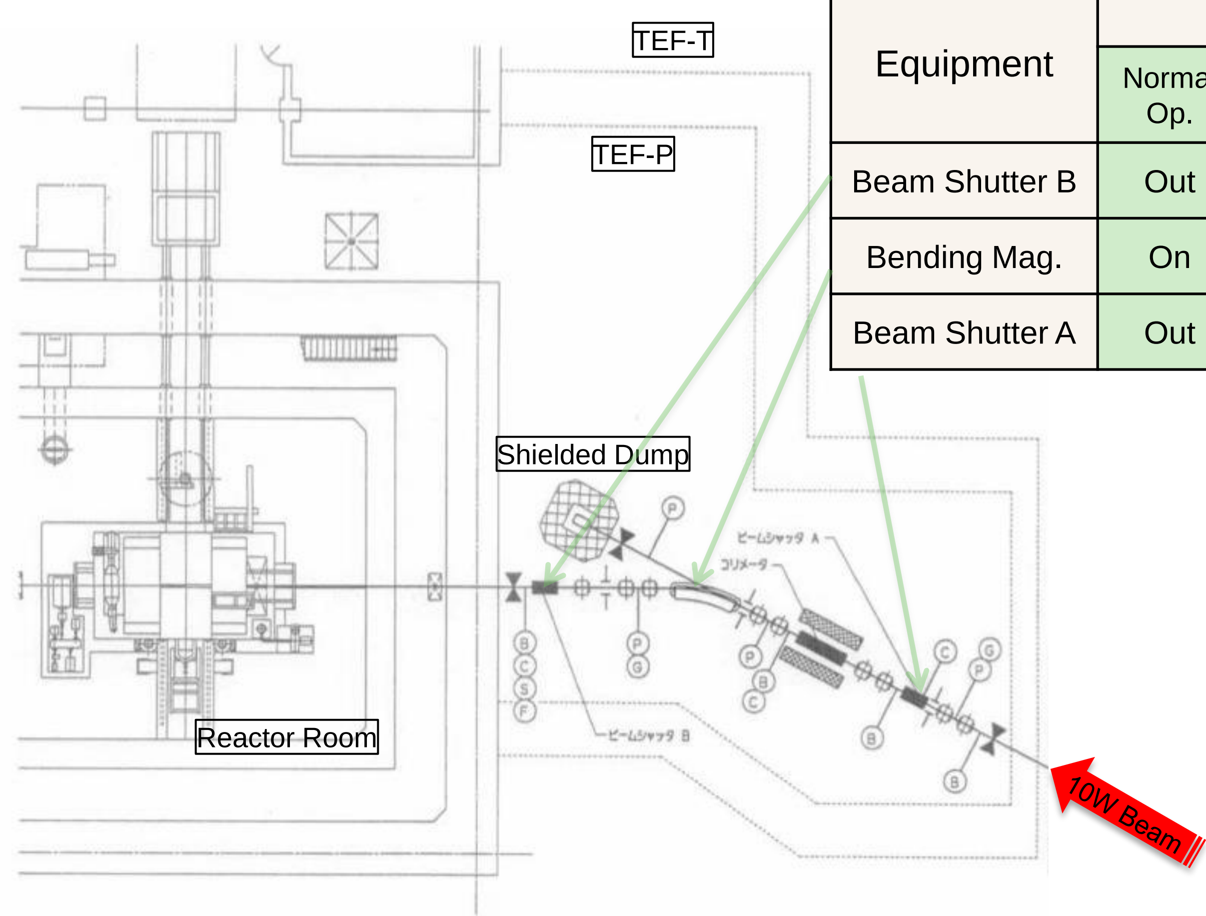




Activities for TEF Construction：

TEF-P Beam Introduction Modes

Equipment	Operation Mode				
	Normal Op.	Dump Exp.	Normal Stop	Reactor Scram	Beam Trip
Beam Shutter B	Out	In	In	In	In
Bending Mag.	On	Off	Off	Off	On
Beam Shutter A	Out	Out	In	In	In



符号	機器名称	個数(台)
	四極電磁石	9
	偏向電磁石	1
	ステアリングコイル	6
	ゲートバルブ	3
Ⓟ	イオンポンプ	4
Ⓖ	真空計	2
Ⓢ	真空センサ	1
Ⓕ	高速遮断バルブ	1
Ⓒ	電流モニタ	3
Ⓑ	BPM	3

Concept of MA-bearing fuel

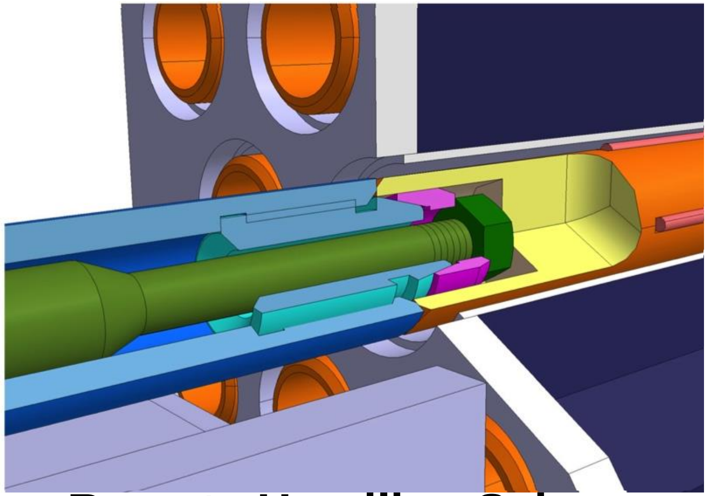
Specify importance of MA fuel experiments

Simulate neutron spectrum of actual FBR and ADS

- MOX+5%MA fuel, ADS fuel are installed in TEF-P driver zone (25cm×25cm×60cmL)
- Add 7 simulative experiments to existing data

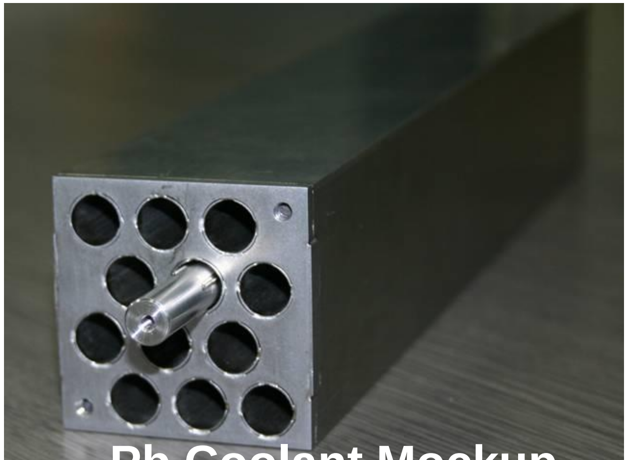
  Characterize effect of MA fuel experiments

  It is also found that cross section and covariance data must be checked



Remote Handling Scheme

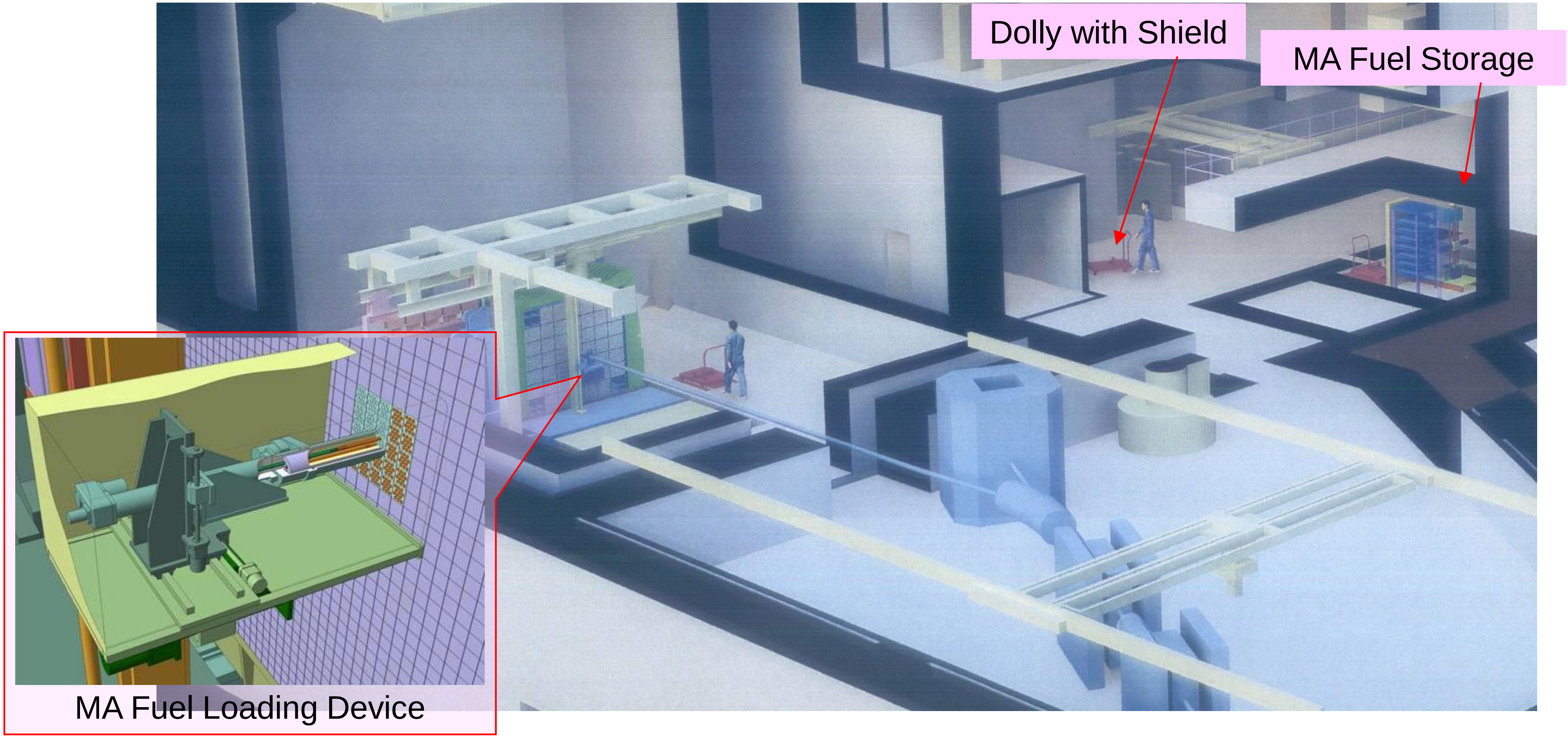
Experiment Item	FR: MA5% mixed MOX Fuel			ADS:(MA, Pu)N + ZrN Fuel		
	Initial	After Adjustment: 233 data	After Adjustment: 233 data+**7 simulations**	Initial	After Adjustment: 233 data	After Adjustment: 233 data+**7 simulations**
k-eff	**1.1**	**0.30**	**0.27**	**1.1**	**0.74**	**0.68**
Coolant Void Reactivity	**2.4**	**1.6**	**1.4**	**5.8**	**3.8**	**3.0**
Doppler Reactivity	**3.8**	**2.2**	**1.7**	**4.9**	**4.0**	**2.8**



Pb Coolant Mockup

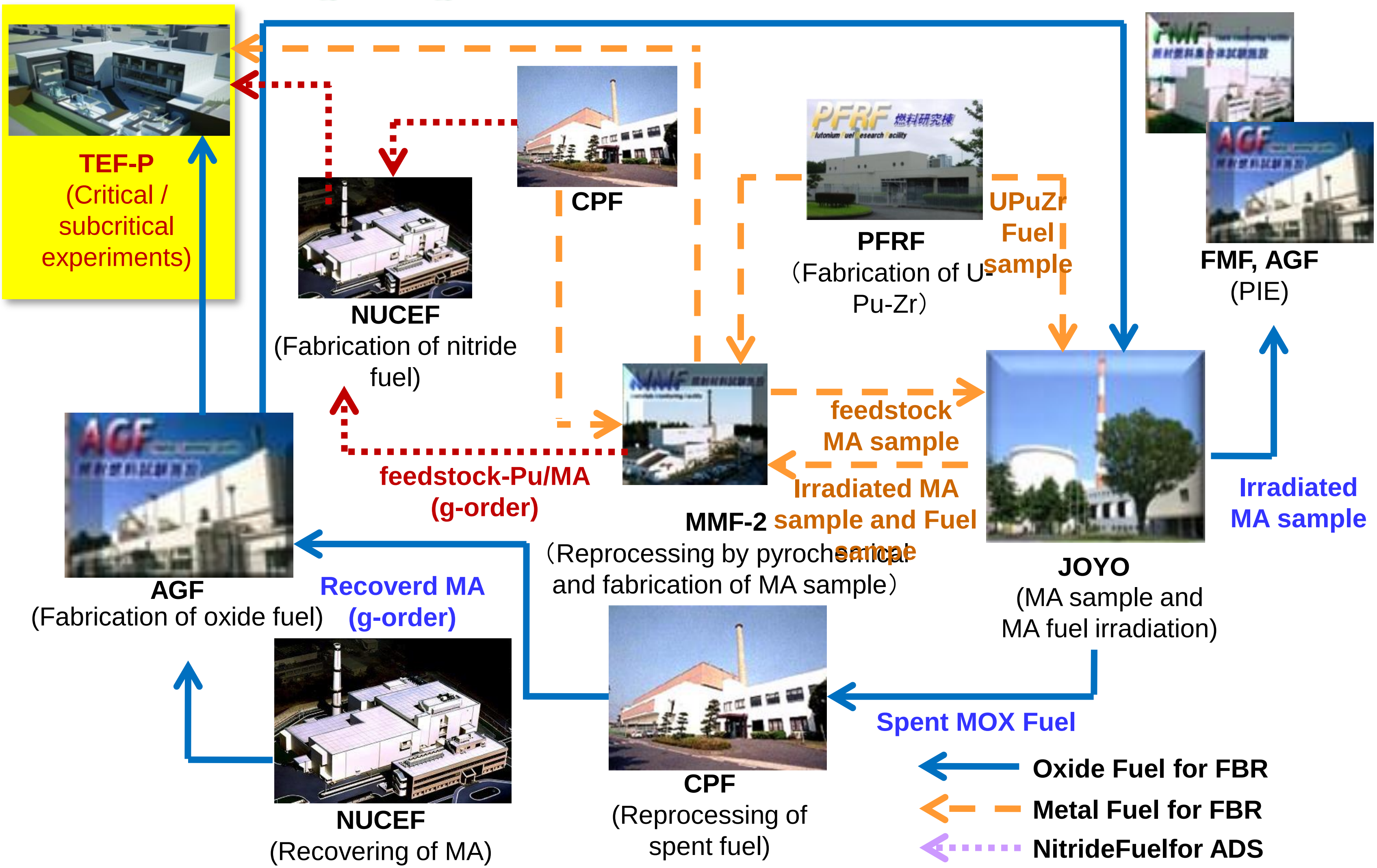
Activities for TEF Construction:

MA Fuel Handling Method



- Requires remote handling device to storage/transport/loading of MA fuel
- 6 fuel pins are stored in stainless cartridge for shielding and protection of critical accident
- Transport between storage and reactor room is done by human using dolly
- MA fuel storage equip the local Air-conditioning circuit with emergency power supply

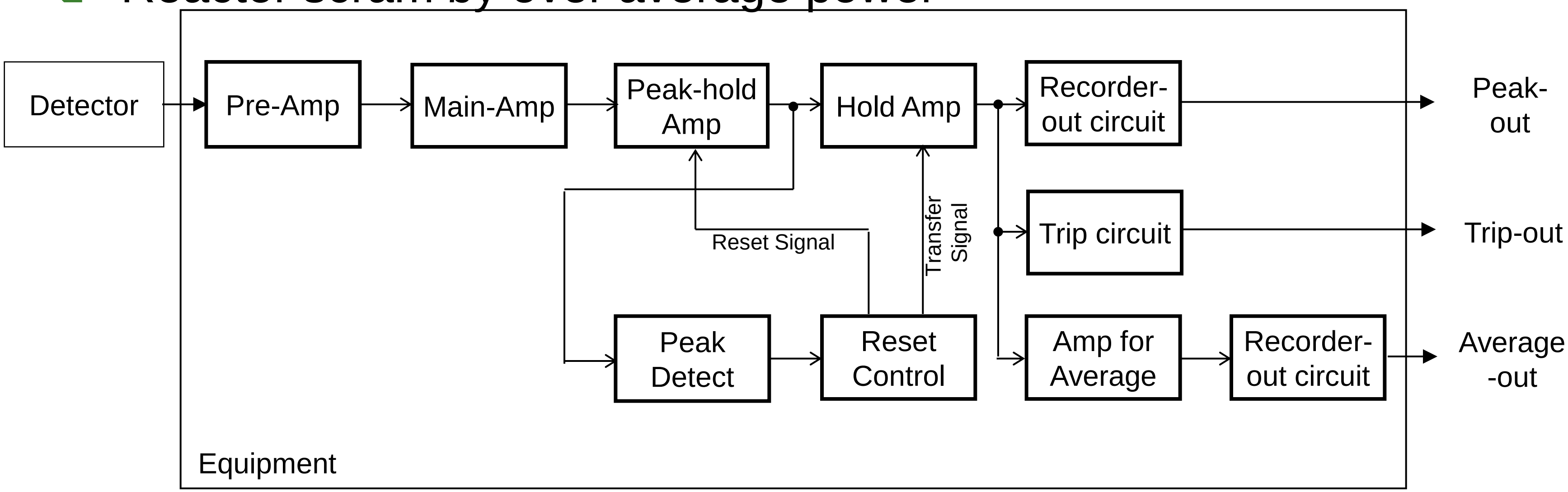
MA fuel preparation



Activities for TEF Construction:

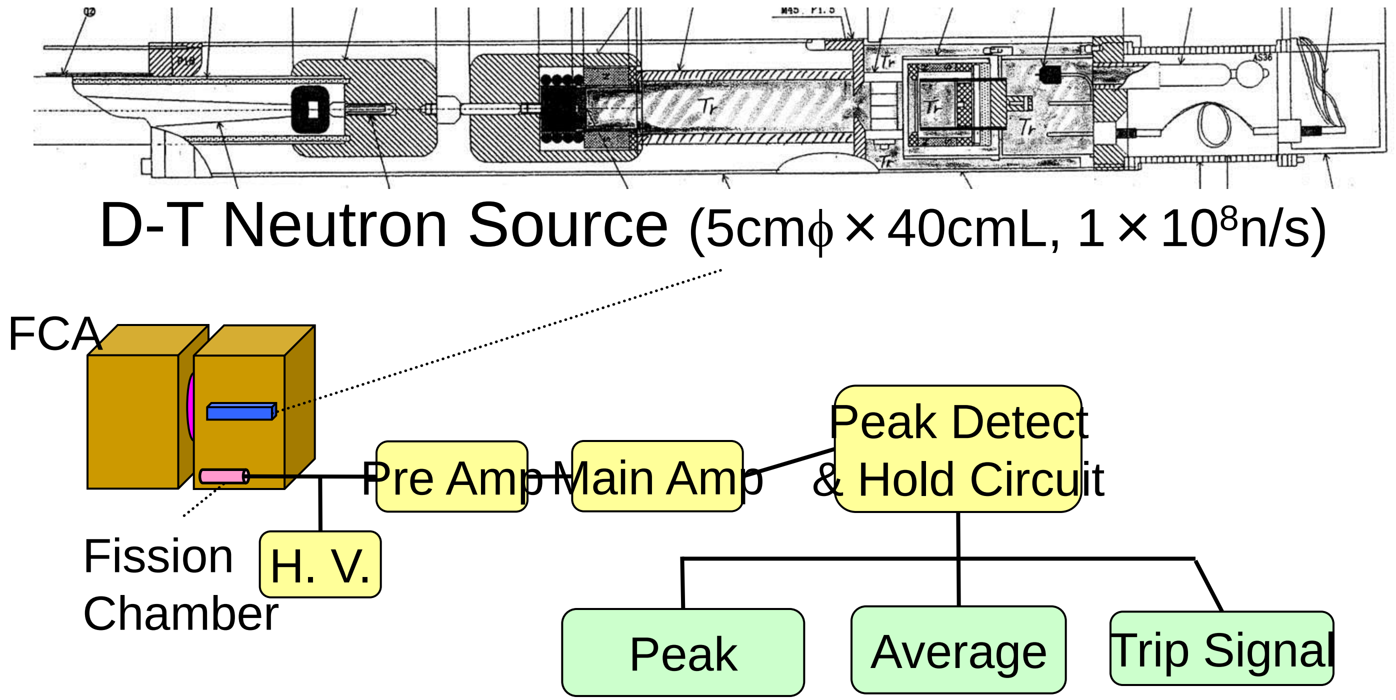
Development of Reactor Power Meter

- Because the J-PARC accelerator works by pulse beam operation, new reactor power meter should be established which satisfy following requirements
  - Peak power measurement and peak hold during a pulse
  - Average power determination
  - Reactor scram by over average power



Activities for TEF Construction:

Experimental Condition of field test at FCA

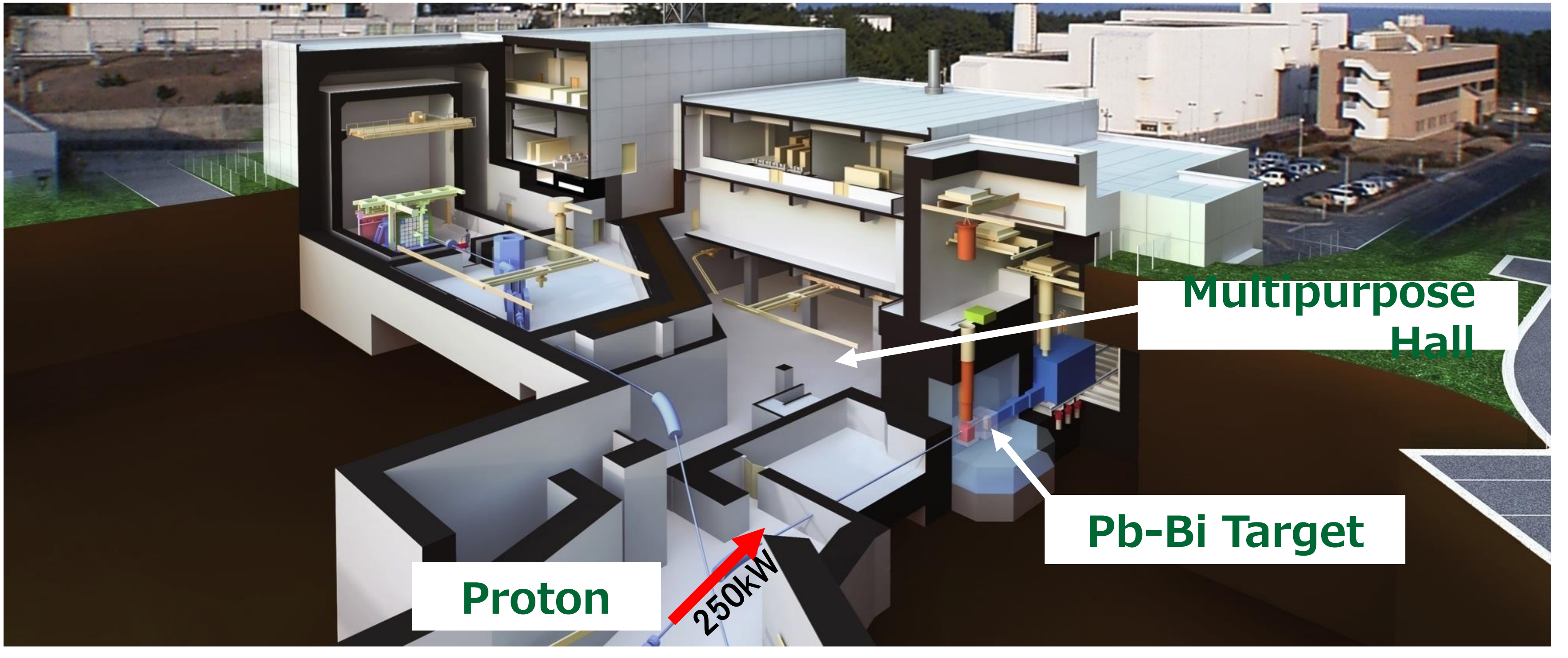


User Application of TEF-T

User Application of TEF-T:

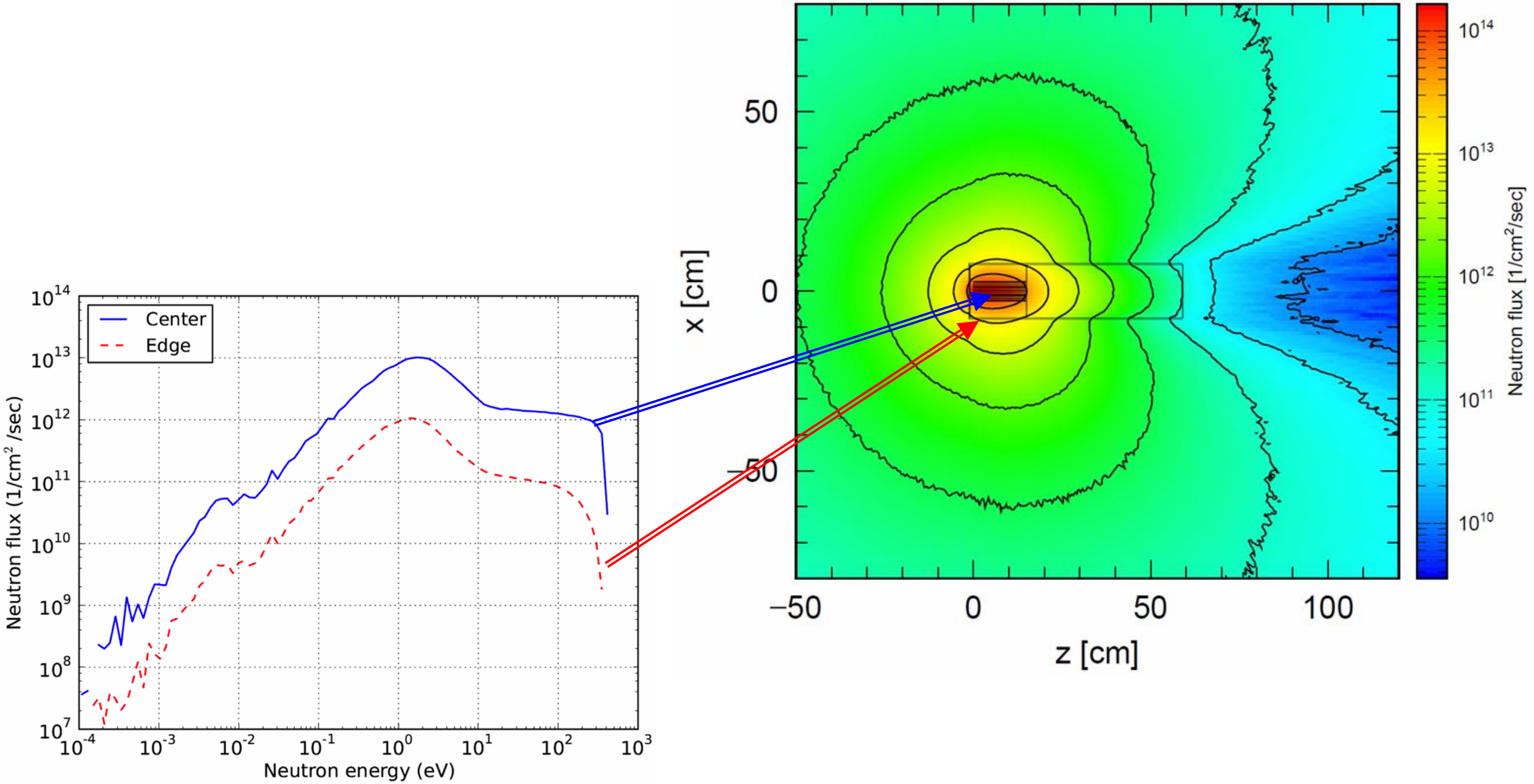
Multipurpose Utilization of TEF-T

- No proton/neutron irradiation fields exists in J-PARC
  - Material Irradiation   ADS beam window
  - RI production   Stable Supply for Medical/Industrial Use
  - Advanced Physics   Ultra-cold Neutron, Short-lived nuclei beam



User Application of TEF-T:

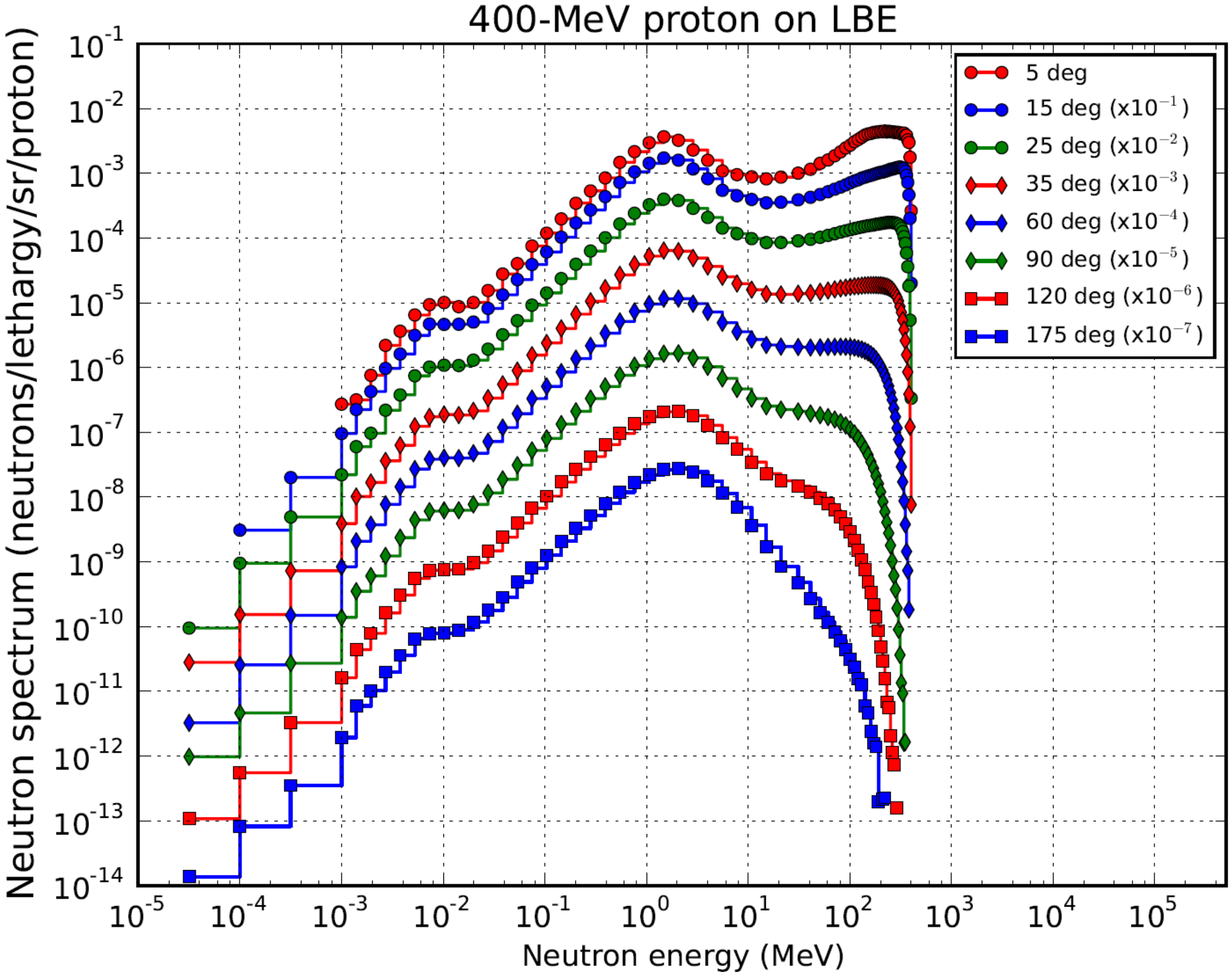
Neutron Field around Target



- 10^{13} of fast neutrons【1-10% of JOYO(100MW_{th}) reactor】

User Application of TEF-T:

Angular Energy Spectrum of Spallation Neutron from Pb-Bi target bombarded by 400MeV protons



Operation Limitation of TEF

- Facility operated based on J-PARC Schedule
  - Injected Particle：H^-
  - Beam Injected Time：4500 hours/year
  - Pulse shape：Repetition 25Hz・500μs Pulse width

- Operation Limitation from Site Location
  - Proton Beam Energy：400MeV
  - Maximum Beam Power：250kW

- Adjustable Parameters by TEF users
  - Proton Beam Profile
  - Operation condition of Pb-Bi target loop

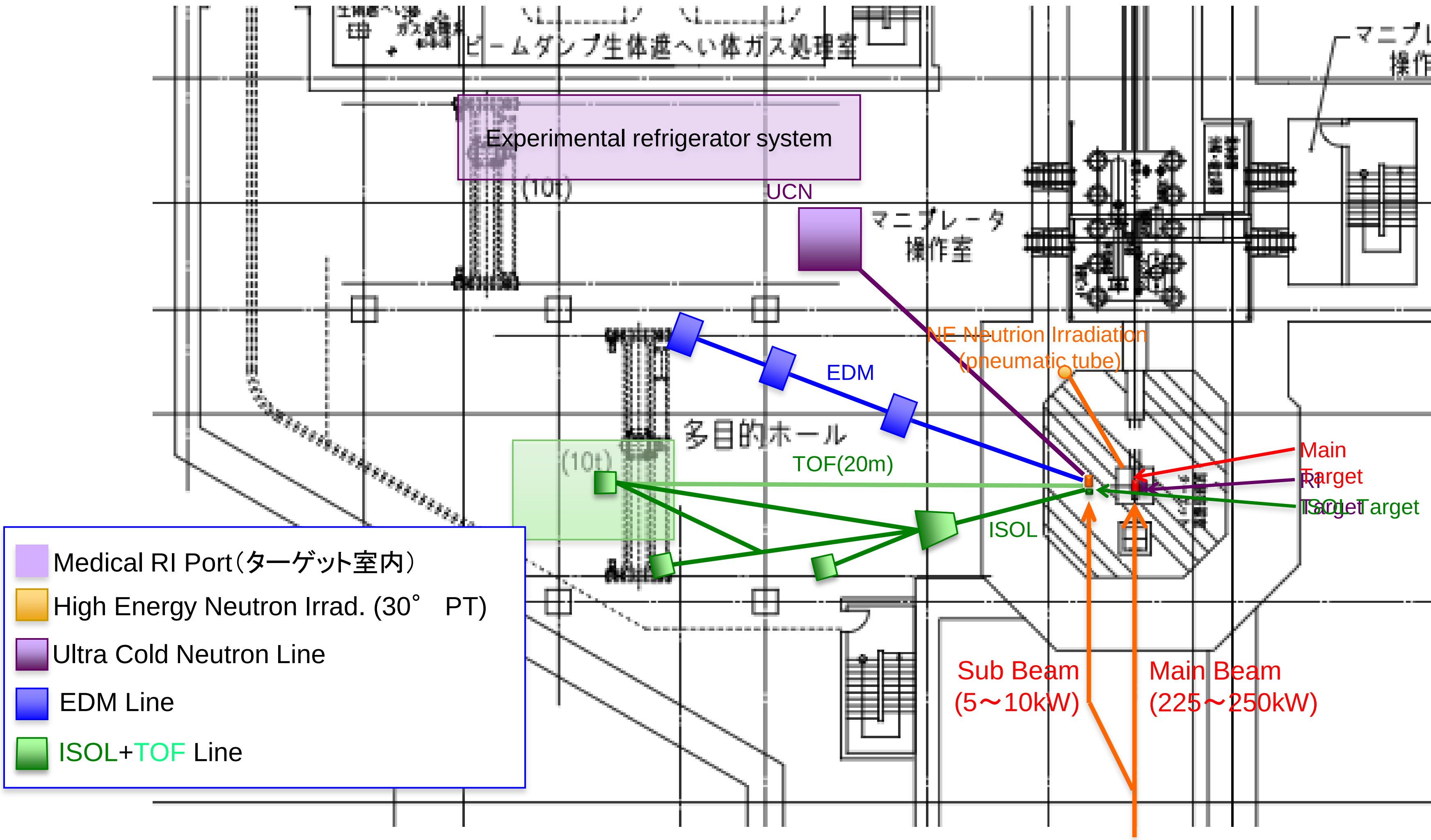
User Application of TEF-T:

Proposals from Potential User

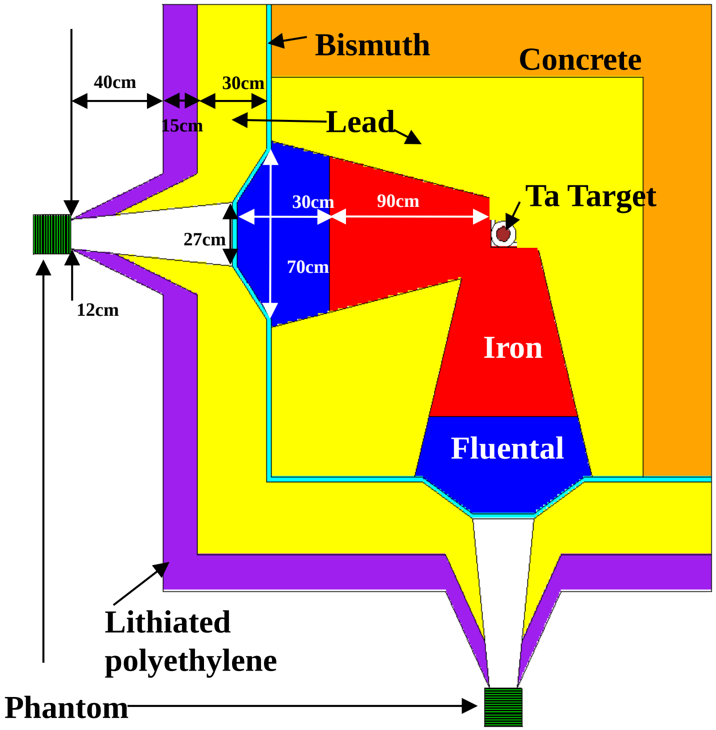
- TEF Letter of Intent（2008）
  - 38 Experiment proposal with over 100 interested researchers
- Research Committee for “Reactor Physics Facility for Future Actinide Management”（2008～2010）
  - Recommends preparation of experimental facility which handle certain amount of MA and Pu
- Workshop for Multipurpose Use of TEF-T (2013)
  - Over 90 participants agree to launch User Community for TEF-T

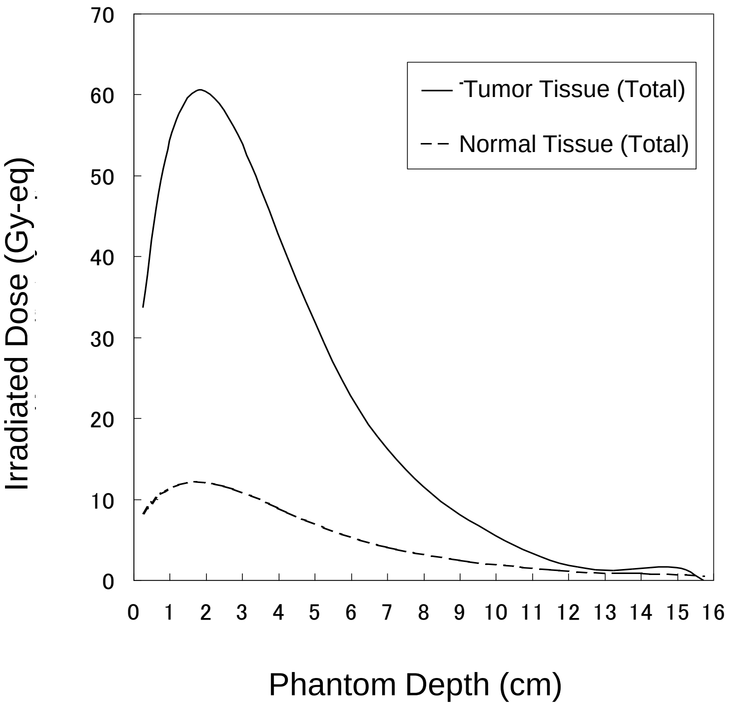
User Application of TEF-T :

TEF-T Hall Layout (Tentative)



Boron Neutron Capture Therapy



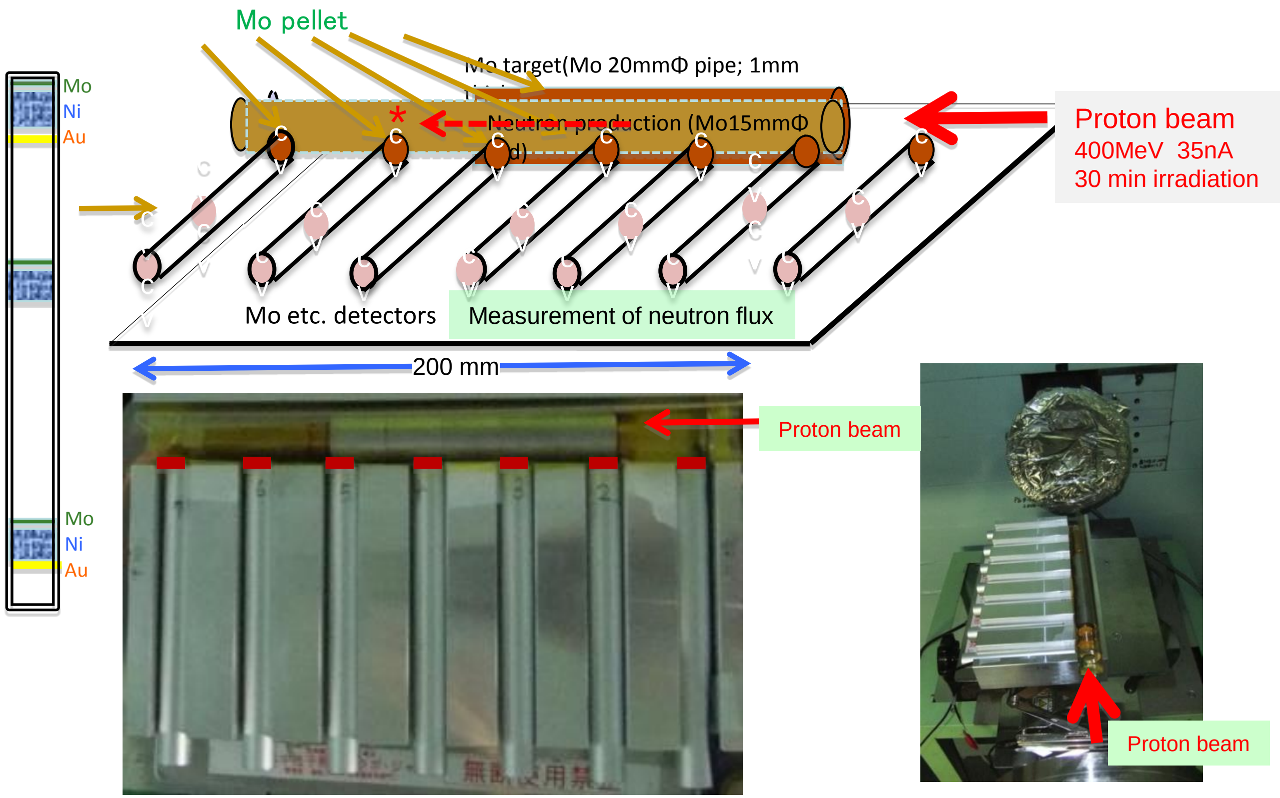


- Special target station for BNCT
  - Locates in front of the Main Target with thin target
- About 1 hour irradiation with 45μA proton beam

Medical Isotope Production (1/2)

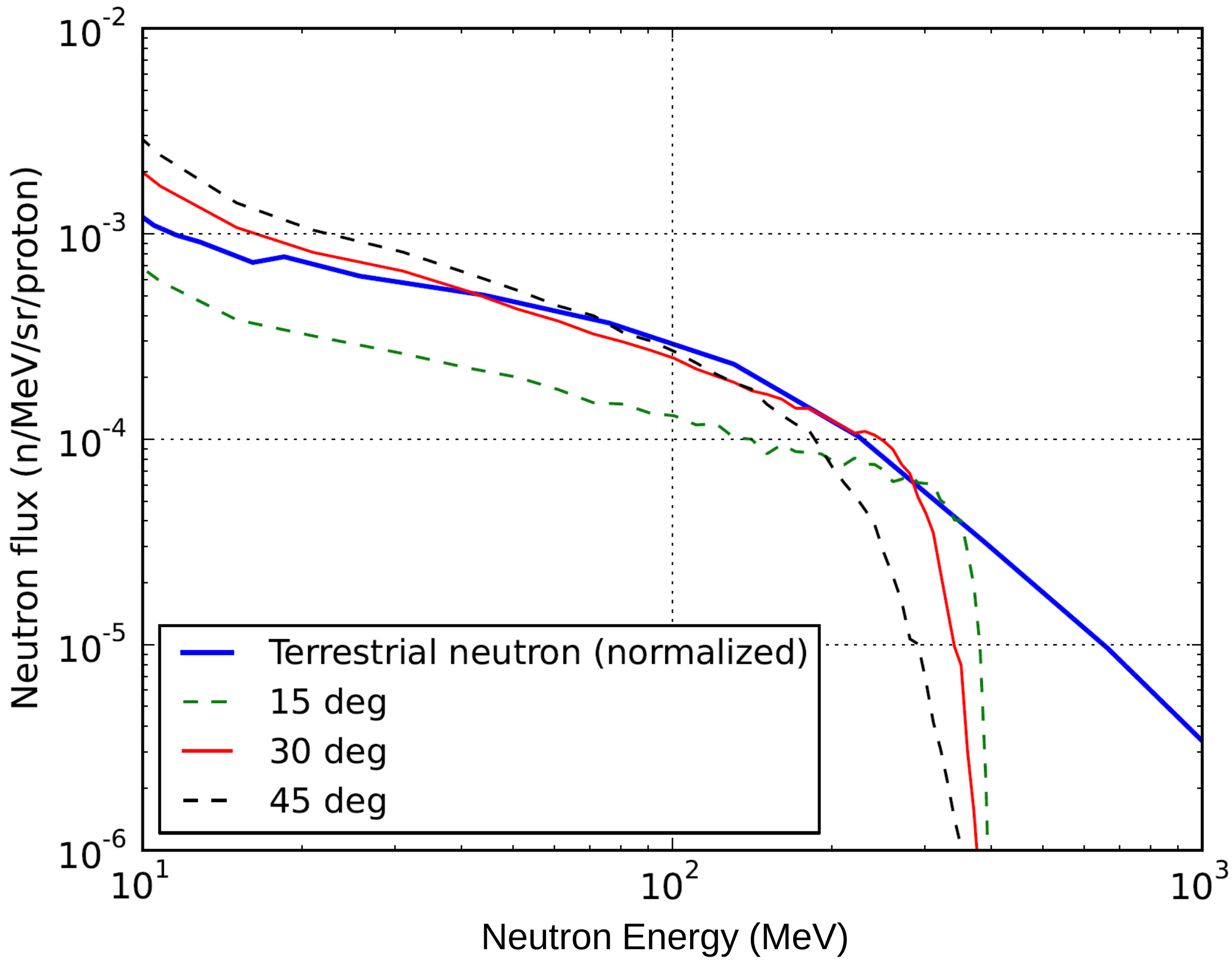
- Production of ^{99m}Tc
  - Fully produced by research reactors
  - Japan: World's #2 consumer, 100% imported
  - Supply shortage was occurred by trouble of old Canadian reactor NRU
- Needs Alternative and Domestic Supply
  - Mo target: Clean, and non-prorifiratio
  - Production by Research Reactor: JMTR/JAEA
  - Production by Proton Accelerator: J-PARC

Medical Isotope Production (2/2)



- Measurement by RCNP/Osaka-Univ: 3MBq/μA·hr/gram
- J-PARC(300μA-10hrs): 9 GBq/gram can be produced

User Application of TEF-T:
Evaluation of Cosmic Ray Damage to Semiconductor



Comparison of Energy Spectrum of Spallation Neutron and Terrestrial Neutron

User Application of TEF-T:

Proposal from J-PARC Cryogenics Section

- Survey irradiation effects of superconducting materials
  - Cables, Structural mats., Heat Transfer mats., etc.

- Irradiation under ultra-cold temperature condition (4 - 80^{o}K)

- Measured in magnetic field in same temperature condition

Participation to MYRRHA Project

Participation to MYRRHA Project:

Merit of Participation

- Features of MYRRHA：
  1. The world's first high power subcritical reactor
  2. The world's first heavy liquid metal cooled reactor except Russian submarine

- ✓ Even though the MA transmutation is not performed, it is expected that many knowledge and experience can be obtained as ADS Demonstrator

- ✓

- Relation with J-PARC TEF：

TEF-T : Supply data of beam window performance to MYRRHA for rated operation and future ADS development

TEF-P: Supply experimental data of neutronics and nuclear cross sections for future ADS and/or FR for MA Transmutation

In cooperation with J-PARC and MYRRHA, it will be possible to solve technical issues to realize ADS transmutation in 2030_{th}

Participation to MYRRHA Project:

Contribution to the Project

- Each participants should pay at least 48M Euro including 4.8M Euro minimum to be paid within 2014
- 10% of total budget (96M Euro) is expected as Japanese contribution
- Both in-cash contribution and in-kind contribution is available

➢ We expect in-kind contribution as much as possible

Ex.
- Material irradiation data obtained at TEF-T
- Beam Window test data using existing JAEA Pb-Bi test loops
- Supply of the superconducting LINAC Components
- Production of a reactor vessel and/or the reactor components
- Fabrication and supply of the MOX Fuel

Participation to MYRRHA Project:

Anticipated cost saving for ADS Development

item	Budget (M$)	Cost for Int. Cooperation	Note
TEF Construction	2,200	2,200	
TEF Operation	2,000	2,000	10M$ X 20 years
MYRRHA Construction	12,500	1,250	10% of total budget
MYRRHA Operation	9,000	900	10% of (30M$ X 30 years)
Total	25,700	6,350	
ADS Plant Construction	23,000	---	
ADS Operation & Decommissioning	38,000	---	Op.: 4% of construction X 40y Dec. 8% of construction Power selling is not considered

- When cooperation with MYRRHA has done, projected cost decreased to 25%
- At construction phase of TEF & MYRRHA (-2023), annual cost is about 400M$
- Cost can be saved by considering in-kind contribution
- Worldwide participation to the TEF program should also be considered

Summary

Present Status in Japan

- After Fukushima, interest in spent fuel management has been increased
- National review by MEXT is underway
  - Transmutation by Critical Reactor “Monju”: Under review works
  - Transmutation by ADS: Interim report issues in October, 2013

Waste Transmutation by ADS

- Area of waste disposal site can be reduced as 1/100 by P-T Technology
- ADS is designed as a dedicated transmutor
- Large scale experiments are required to solve technical issues of ADS

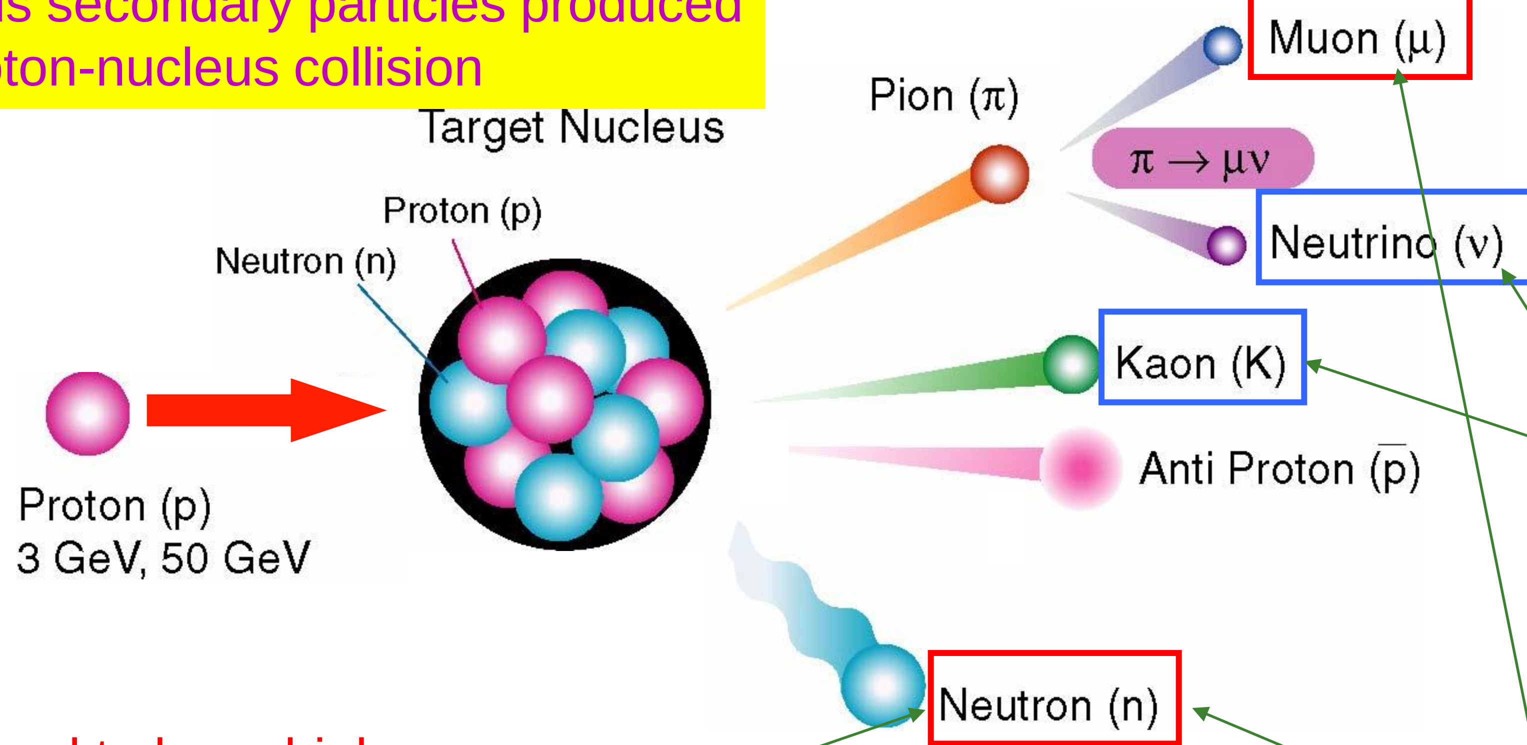
Transmutation Experimental Facility Program

- Facilities for structural material irradiation (TEF-T, 400MeV-250kW$_{beam}$) and reactor physics (TEF-P 400MeV-10W$_{beam}$)
- User community for multipurpose usage of TEF-T has launched
- Soundness of the Pb-Bi spallation target has been studied
- Construction Schedule
  - TEF-T will be built first and TEF-P will be constructed afterwards
  - Licensing procedures for TEF-P construction will be processed simultaneously with TEF-T construction
  - Cooperative study with MYRRHA increases a feasibility to realize ADS

Backup Slides

Science goals of J-PARC

Various secondary particles produced by proton-nucleus collision



Need to have high-power proton beams

→MW-class proton accelerator

Intensity Frontier

Materials & Life Science at 3 GeV
Nuclear & Particle Physics at 50 GeV
R&D toward Transmutation at 0.6 GeV

MULTI-PURPOSES

A Brief History of J-PARC

2000 Aug. Pre-Review

2003 Dec. Gov't Review 1
2007 Jun. Gov't Review 2

2010 Oct. Upgrade Plan included in the Master Plan of Japan Science Council and the Roadmap of MEXT

2012 Jun. Gov't Review 3 (next 5 –years plan)

2000

2008

2010

2012

2001Start Construction

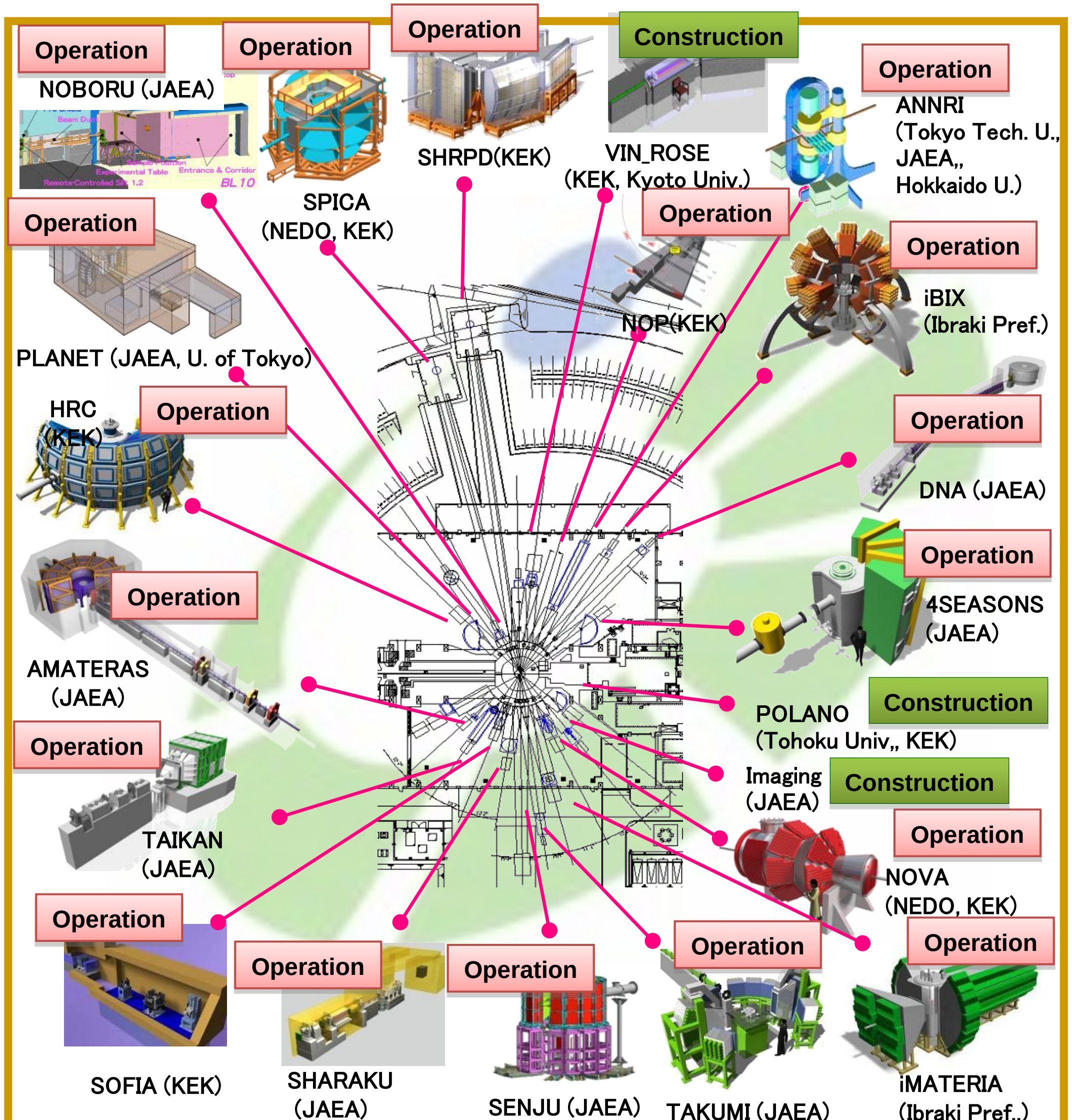
2008.5 1^{st} Neutron beam
2008.9 1^{st} Muon beam
2009.2 1^{st} beam to Hadron Exp.
2009.4 1^{st} beam to Neutrino Exp.

2011.3.11 East-Japan Earthquake stopped operation

Ex. J-PARC Director, Prof. Nagamiya restarted J-PARC accelerators after recovery from the earthquake.

2012.1.24 Operation for users was resumed

Status of Neutron Instruments



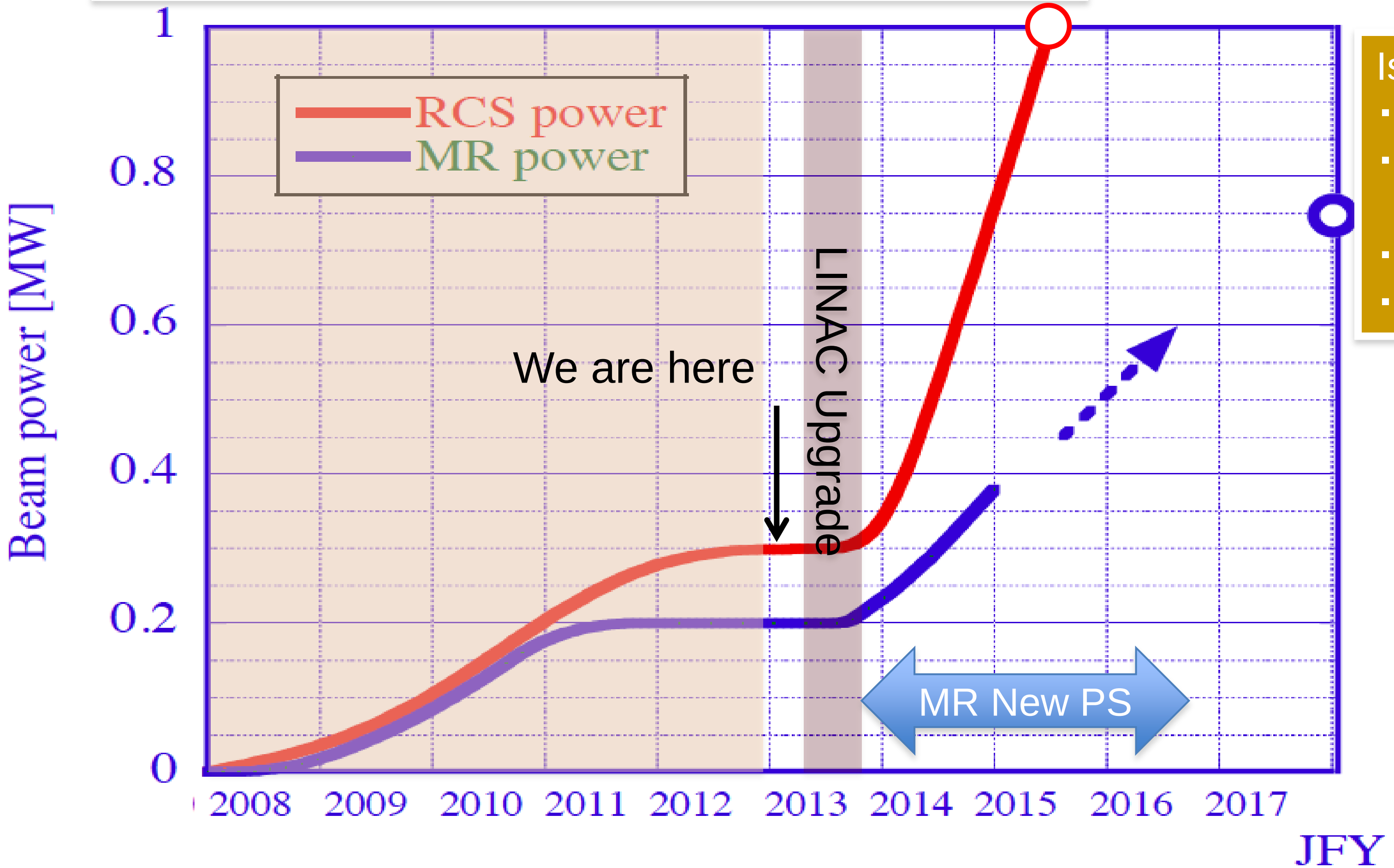
- 23 Neutron Beam Ports
- From academic to Industrial uses
- In operation: 18
  Under construction: 3
- Constructed by
  - ･KEK
  - ･JAEA
  - ･Ibaraki Prefecture
  - ･Kaken-hi (Gov. direct funding)

  (KEK and JAEA: J-PARC MLF)
- Operation days/year
  200 days/year (Goal)
  (176 days in 2012)
- Number of staffs including out-sourcing 150+70

Schedule for Power Upgrade

FY2013: Linac 400MeV, FY2015: RCS MW

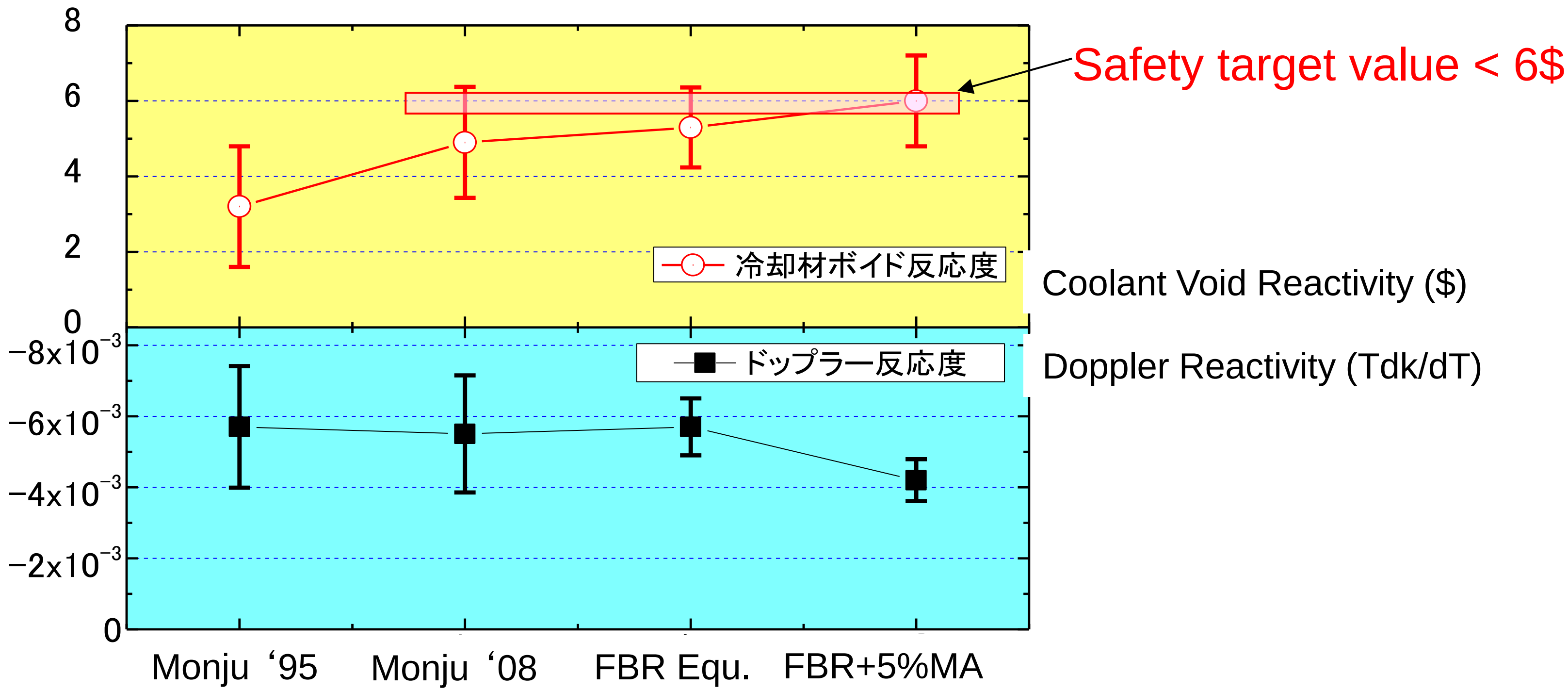
Development of PS, FY2018: MR 0.75 MW



Issues for MR
- PS
- High gradient Cavity
- High repetition
- Shielding

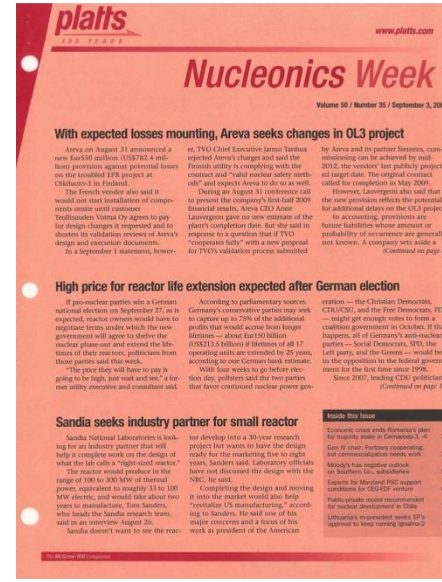
MA Transmutation by power reactor (1)

- Transmutation by power reactor have some difficulties
  - Safety review of FBR “Monju” gives serious increase of coolant void reactivity



MA Transmutation by power reactor (2)

- Dr. Bouchard (GEN-IV Chair) said how to fabricate MA-spiked fuel is not simple and has to be done remotely, as does reprocessing. He also express concern that SFR technology, including safety and nonproliferation measures will prove difficult to deploy at a reasonable cost (even in non MA-spiked fuel).
  Nucleonics Week Vol.50, No.35 (Sep. 3, 2009)


platts
www.platts.com
Nucleonics Week
Volume 50 / Number 35 / September 3, 2009

With expected losses mounting, Areva seeks changes in OL3 project

High price for reactor life extension expected after German election

Sandia seeks industry partner for small reactor

Inside this issue

- From EDF's point of view, a partial recycling of MAs in heterogeneous blankets may then be adopted if it is feasible and if technological and economic advantages outweigh possible drawbacks. Heat load and the associated activity from glass canisters will have to be managed in the fast reactor themselves, the reprocessing plants, the fabrication plants, the reactor fuel handling sections, the transport casks and interfaces.
  - N. Camarcat et al., Global'09, Paper 9079