ADS development in Japan

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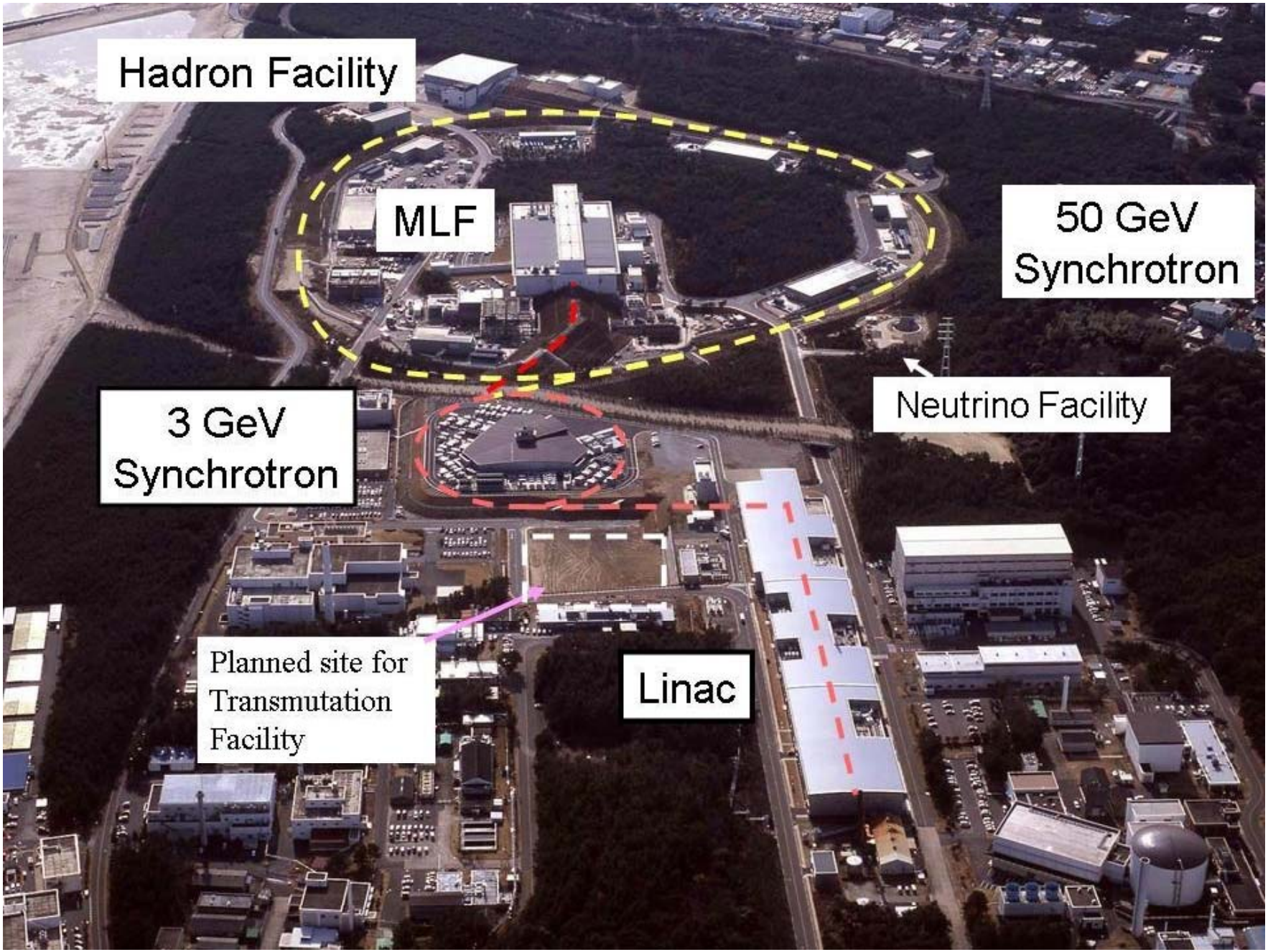
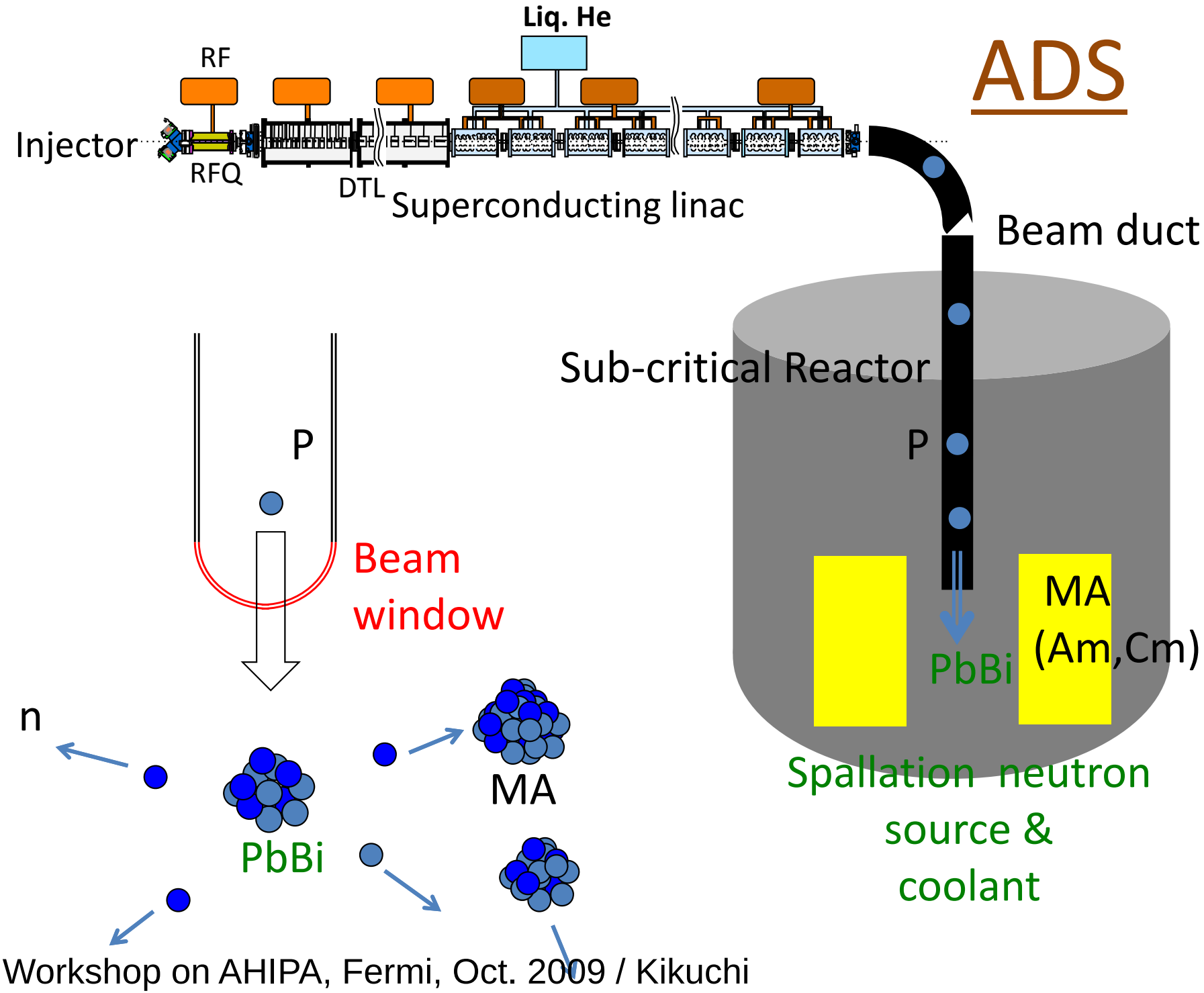
J-PARC

(October 20, 2009)



Workshop on AHIPA, Fermi, Oct. 2009 / Kikuchi

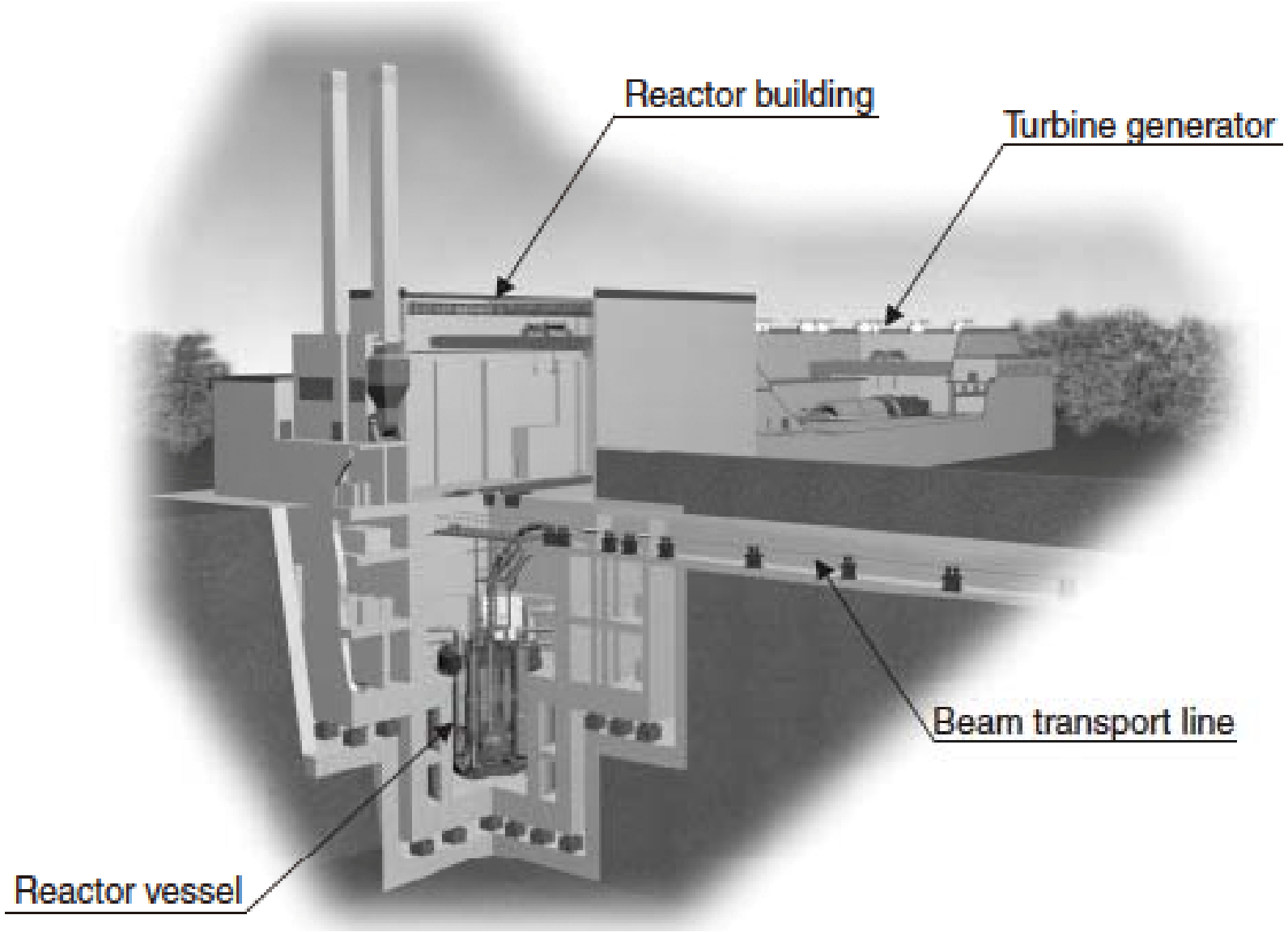
ADS


Liq. He
RF
Injector
RFQ
DTL
Superconducting linac
Beam duct
Sub-critical Reactor
P
P
Beam
window
MA
(Am,Cm)
PbBi
Spallation neutron
source &
coolant
n
MA
PbBi

Design parameters

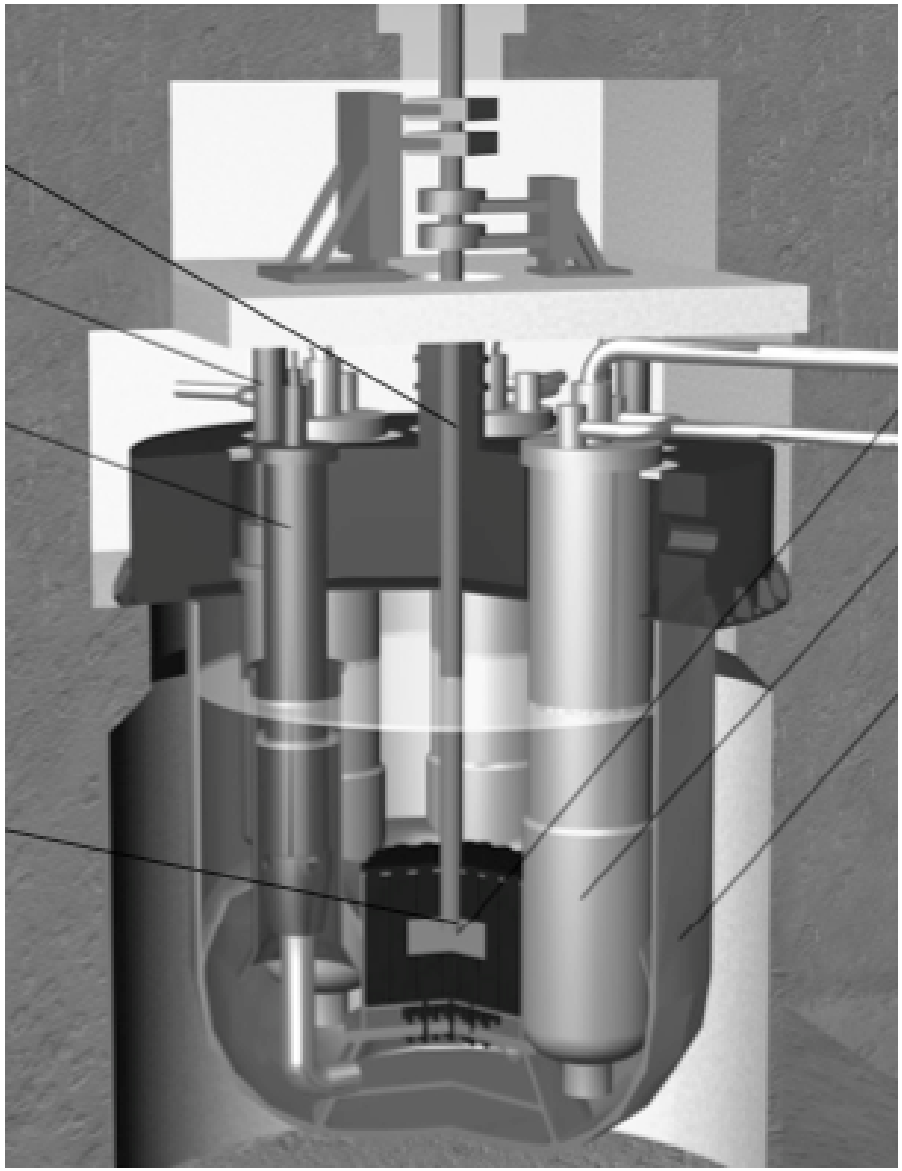
- Accelerator power: 20MW (1.3mA, 1.5GeV)
- Reactor power: 800MW
- SC-LINAC (0.1-1.5GeV): 472m
- Reactor size: 10m ϕ x 8m height
- LBE 5 ktons
- Earthquake resistant building

Conceptual view of JAEA ADS plant



Tsujimoto NST,V.44-3,2007

Image of ADS with window



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LBE Handbook,AESJ

Lead-alloy (LA) including lead-bismuth eutectics (LBE)

- In the last ten years, the study of utilization of lead-alloys (LA) including lead-bismuth eutectics (LBE) have been explored for an application to the nuclear waste transmutation systems and lead-bismuth cooled nuclear reactors.
- LBE is a candidate material for a spallation target and a reactor coolant.
- In the accelerator driven nuclear transmutation system (ADS), LBE is a candidate for both the subcritical-reactor coolant and the spallation neutron source target.
- In addition, lead or lead bismuth cooled fast reactor (LFR) is one of the four reactor systems proposed by the Generation IV international Forum (GIF).
- LBE cooled Long-Life Safety Simple Small Portable Proliferation-Resistant Reactor was also proposed. (Sekimoto)

F/M and Austenitic stainless steels

- The previous work for a use of materials such as ferritic-martensitic and austeniticstainless steels in LA is to keep an oxide layer on the surface of base metal by controlling an oxygen concentration. Gromov et al.
- Too little oxygen solution in LA will dissolve iron oxide and excess oxygen solution in LA will make lead oxide. The theory could indicate that an adequate oxygen concentration in LA exits between, for example, 10-6 to 10-4wt% in the temperature region of 400 – 700oC.
- Alternative is to cooperate with anti-corrosion elements like Al, which has a good function to guard base metal. Muller et al.

Corrosion study of the window under flowing LBE

- A choice of candidate materials for ADS beam windows was JPCA and F82H, which have data base of neutron irradiation.
- Candidates for fuel clad are HCMA12 and ODS, those are studied in FBR.
- Maximum temperatures were set to 450C and 500 with 100C constant temperature difference.
- Main flow velocity was 0.4 to 0.6 m/s in every case. Oxygen content was controlled to 2 – 4x10^{-5} mass%.
- Testing time durations are 500 to 3000 hrs. Round bar type specimens were put in the circular tube of the loop. Electron beam welded sections in the middle part of specimens were also studied.

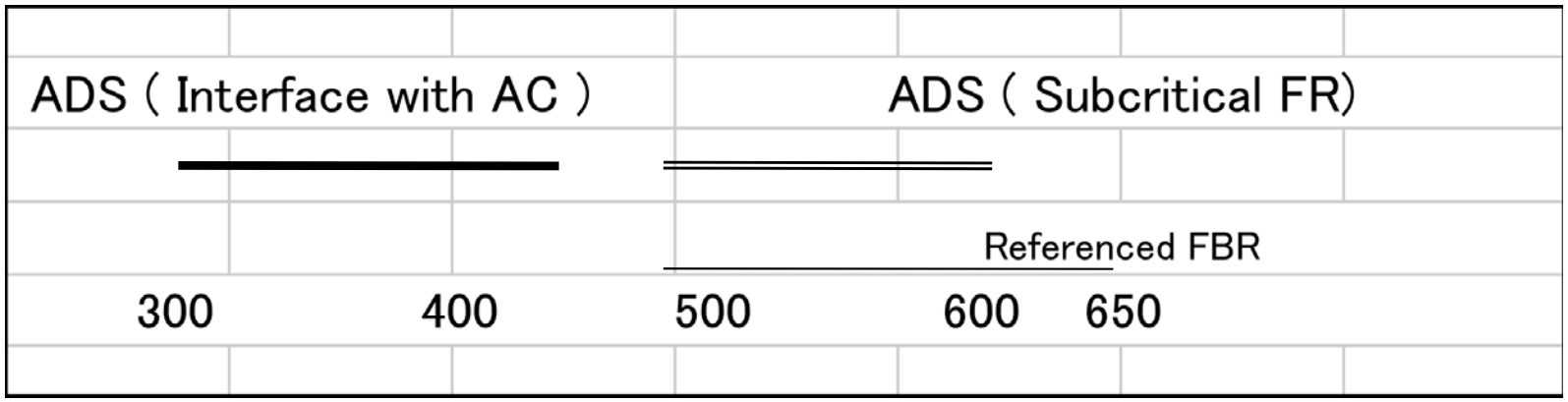
Materials for HLM application

	JPCA(SS316)	(GBE)	Alloy800H	F82H	F82H(ODS)	HCM12A
Corrosion	(350,400),450, 500	450		450, 500, (550*)		500, (530**,550*)
Irradiation(p)	20dpa		20dpa	20dpa	20dpa	20dpa
	Parent and Weld	Parent	Parent	Parent and Weld	Parent	Parent

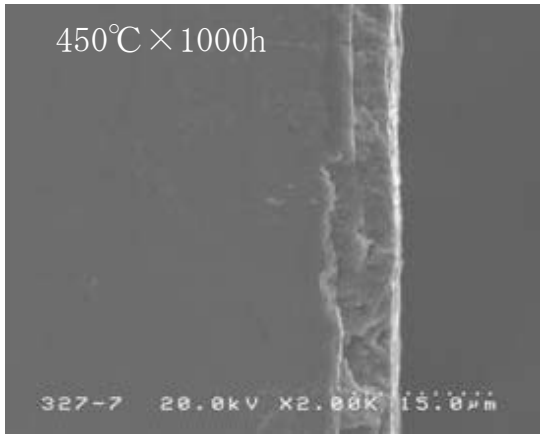
* TITech

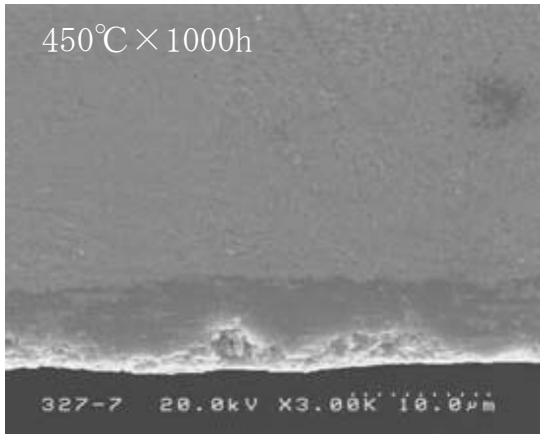
** University of Wisconsin-Madison

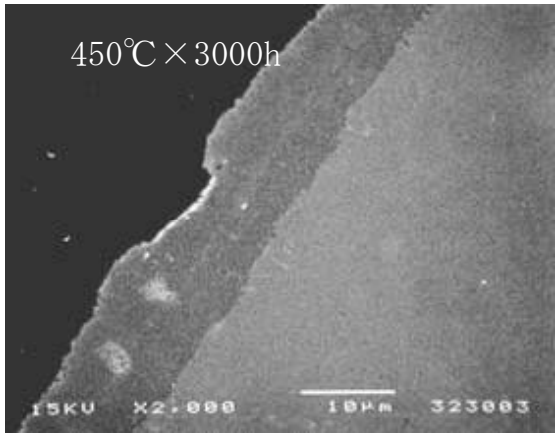
	316FR		ODS(9Cr, 12Cr)	HCM12A
Corrosion	500,550,600,650		500,550,600,650	500,550,600,650
Irradiation(n)	-		100-200	-

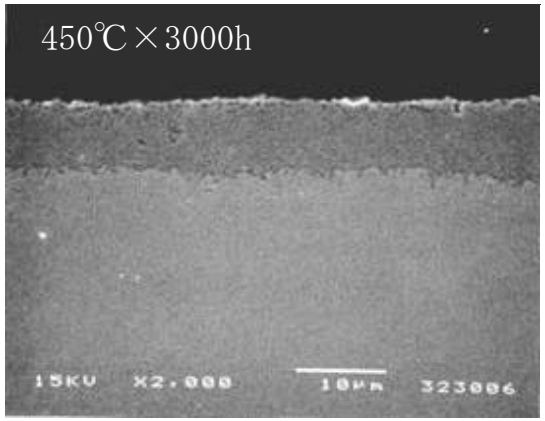


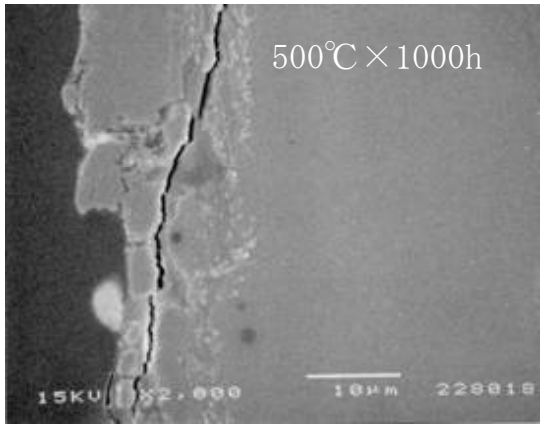
F82H parent material(L) and welded region(R)

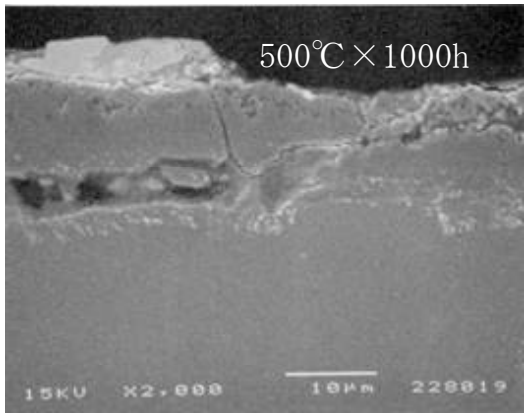




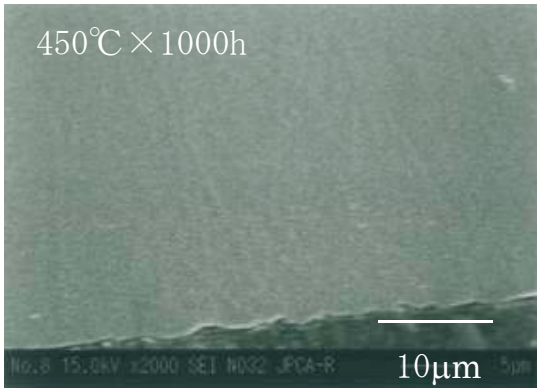


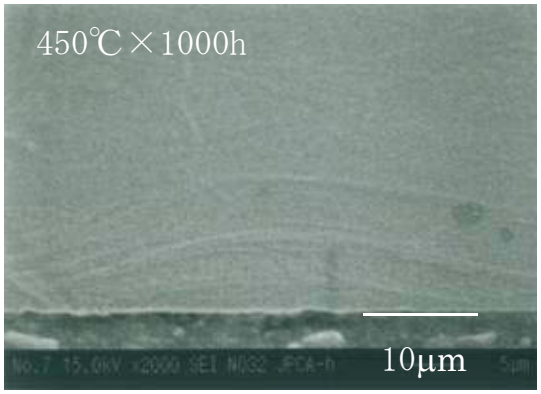


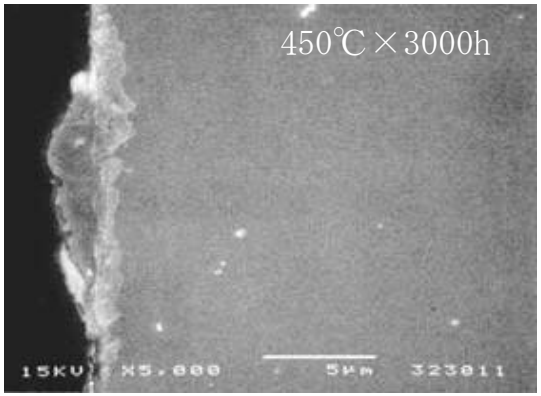


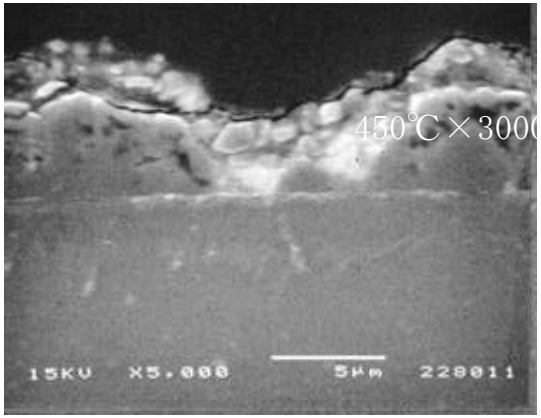


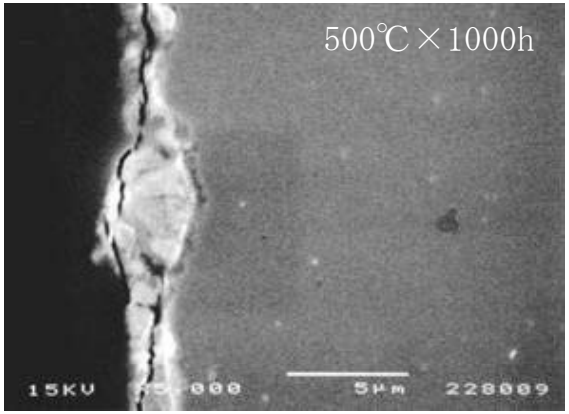
JPCA parent material(L) and welded region(W)

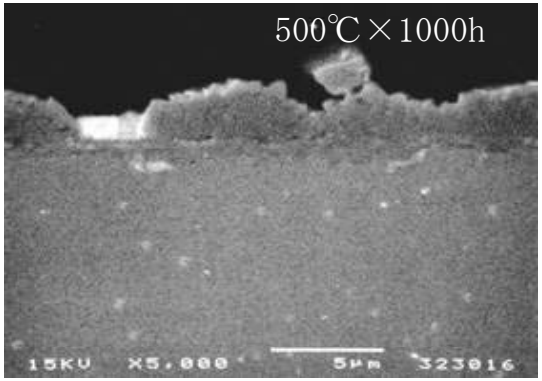












Corrosion rates of F82H and JPCA

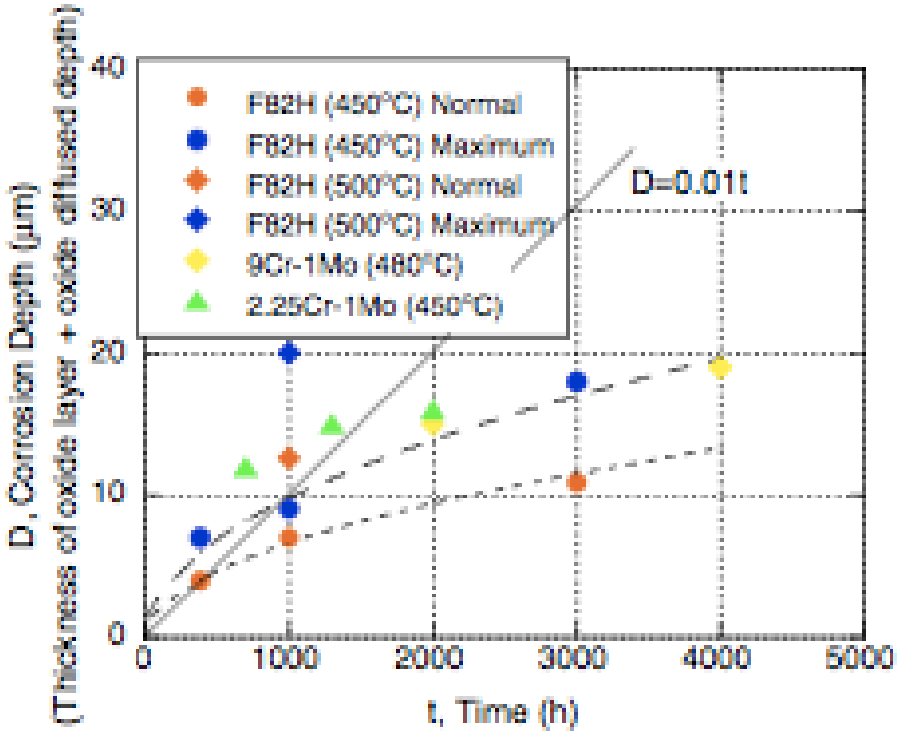


Fig. 12. Corrosion rate, μm h^{-1}, of F82H.

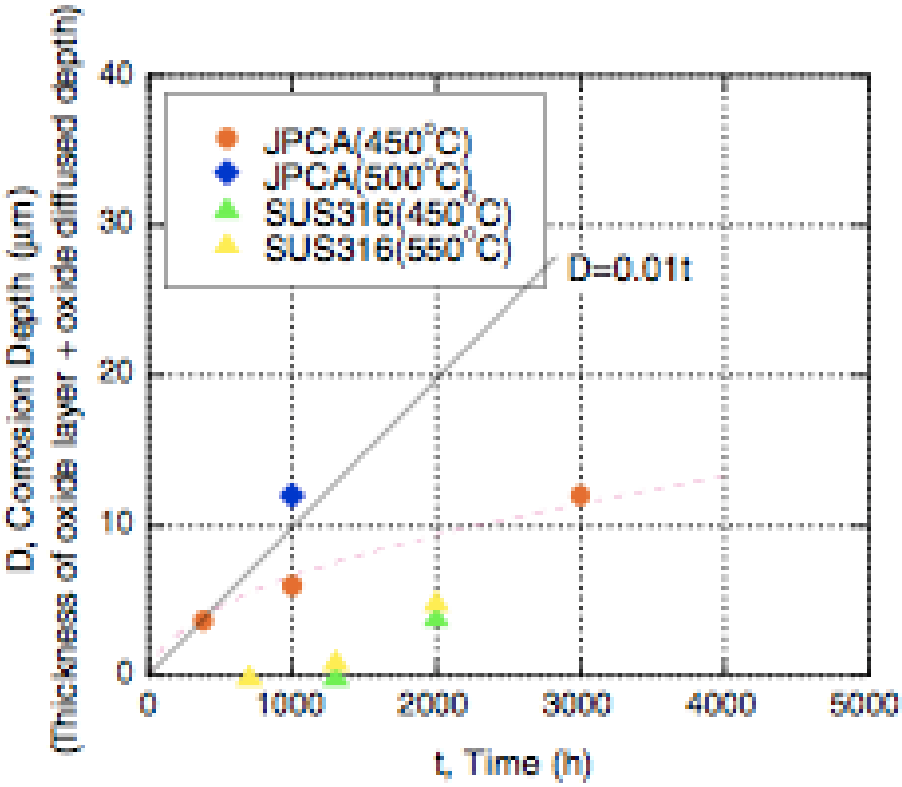
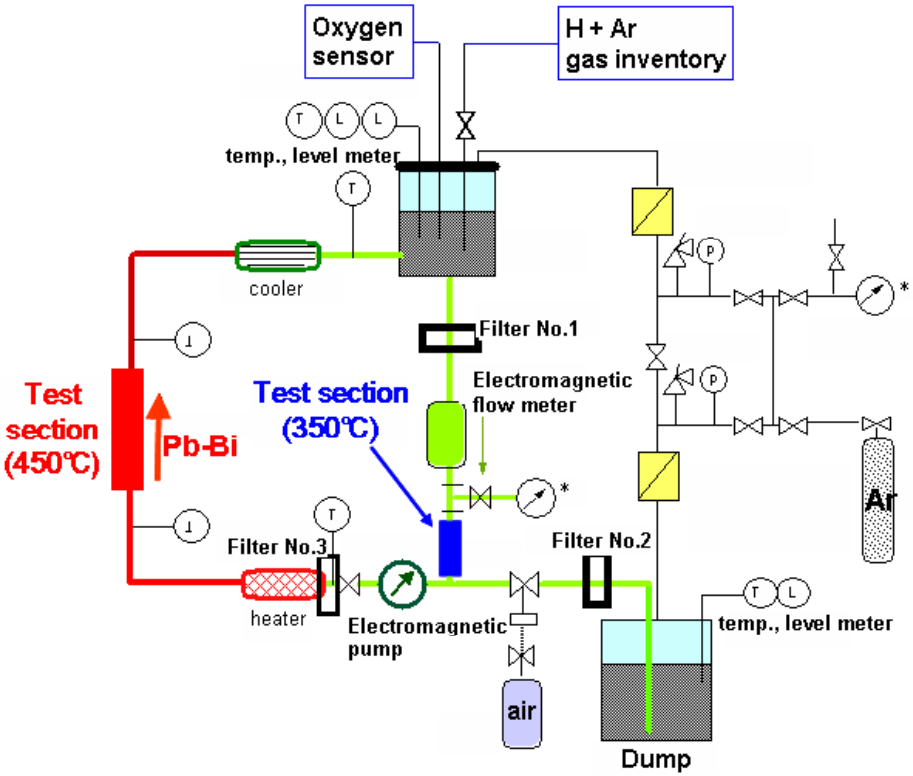


Fig. 13. Corrosion rate, μm h^{-1}, of JPCA.

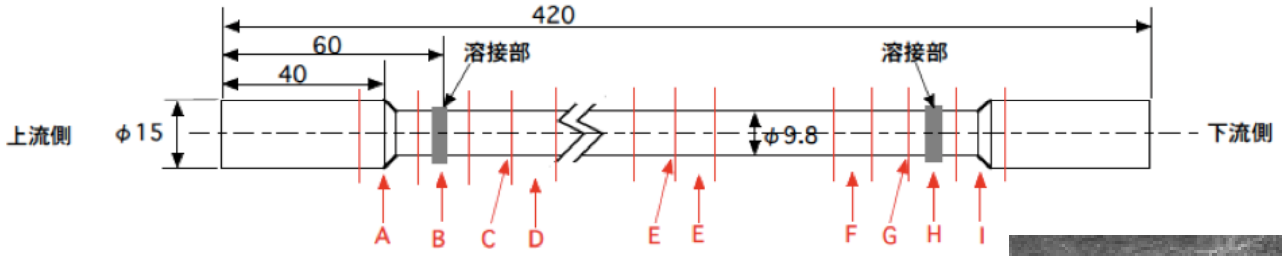
LBE handling

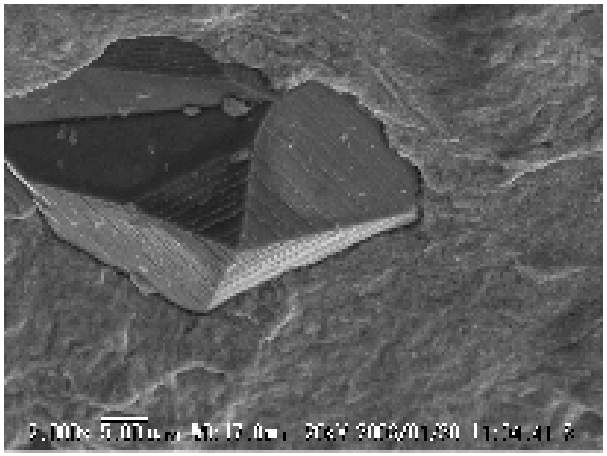
- LBE spallation target test had planned in J-PARC phase II program.
- LBE controlling techniques acquisition was a goal of R&Ds.
- LBE loops were run for the experiments on corrosion-erosion (JLBL-1), target flow simulation (JLBL-2) and thermal fluid characteristics (JLBL-3).

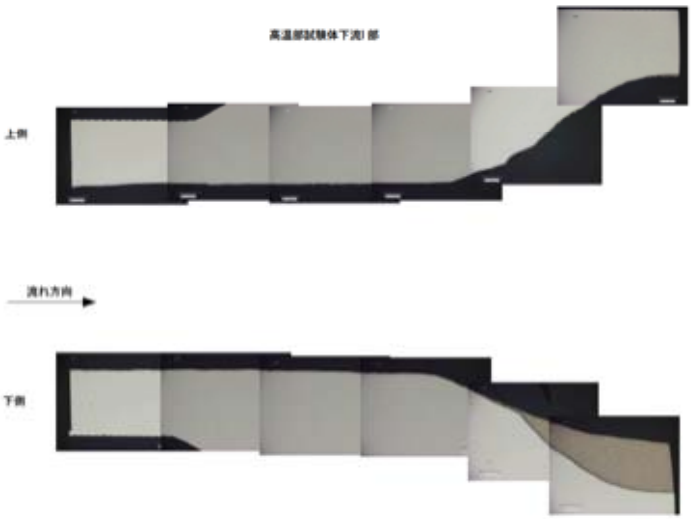
Lead Bismuth Loop - 1 for corrosion-erosion

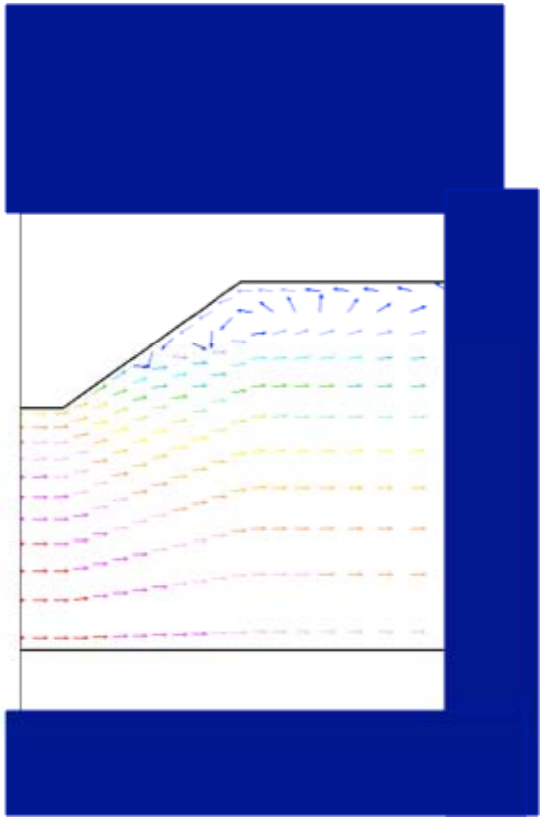


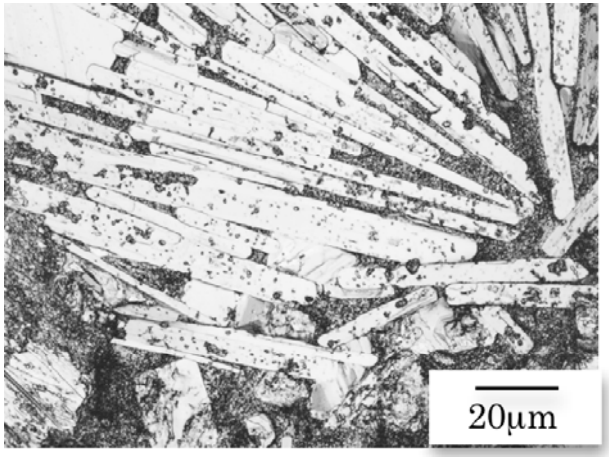
Erosion and mass transfer



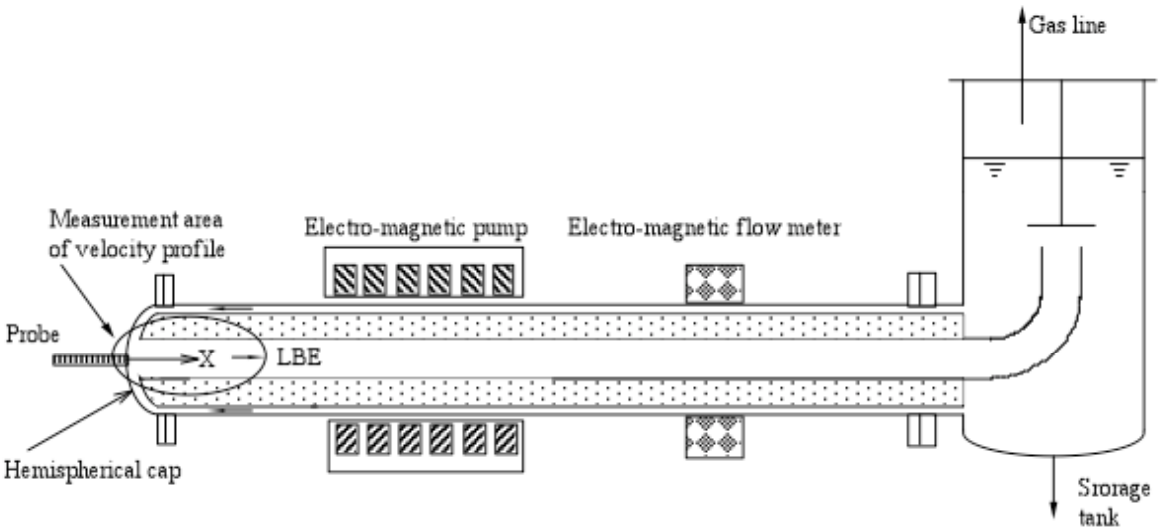


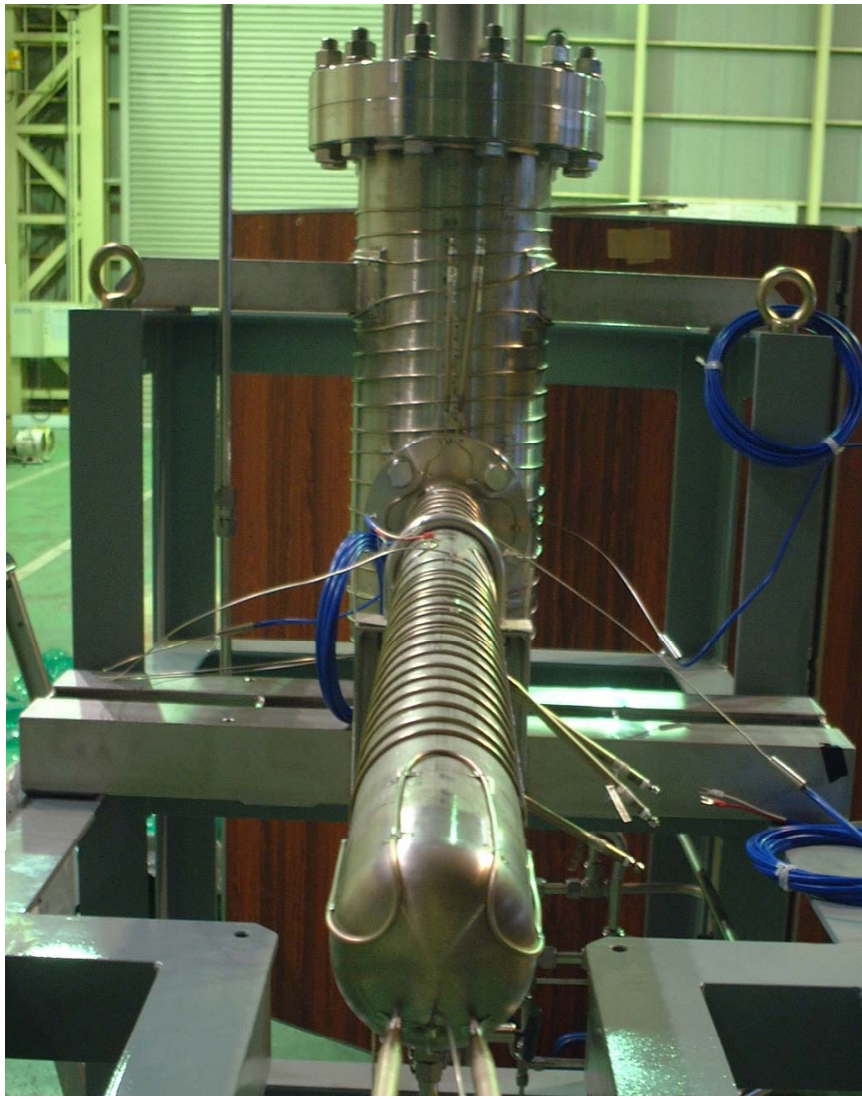


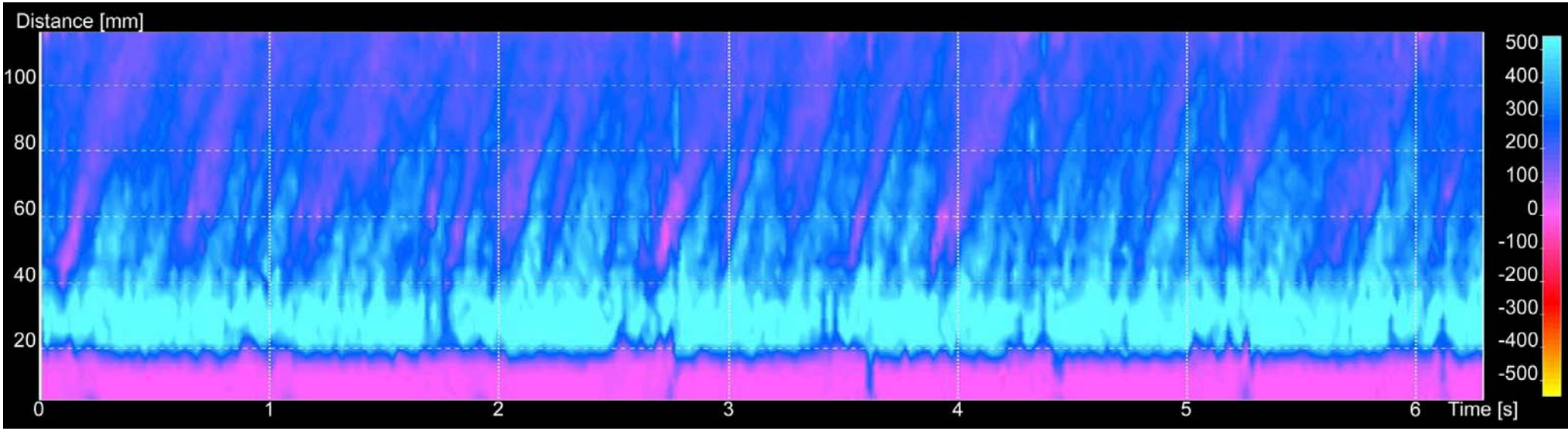


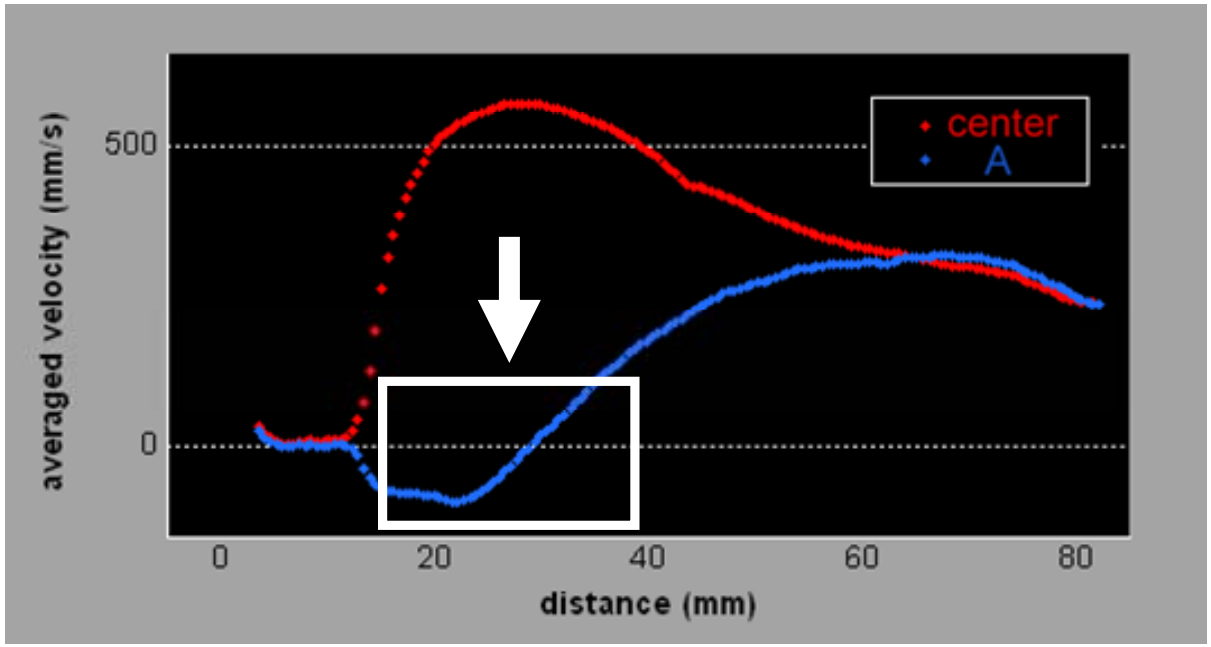


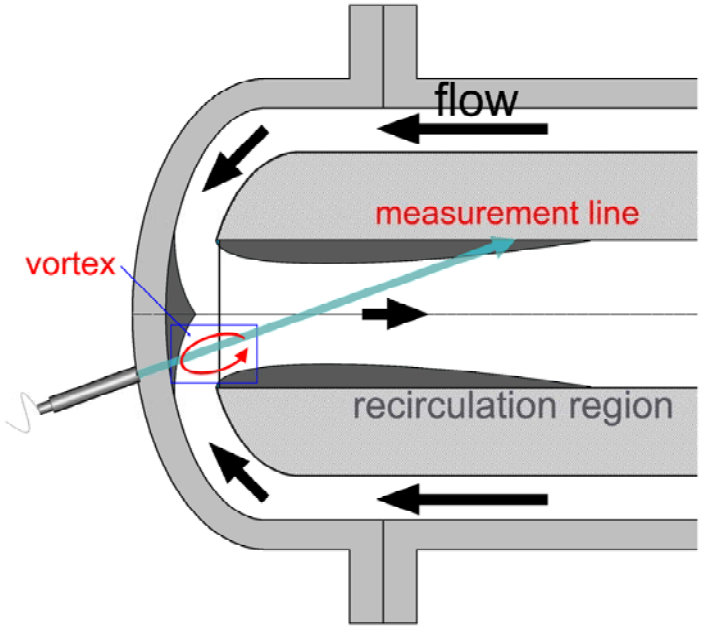
In JLBL-2
flow velocity measurement by Ultrasonic Doppler Method and Electro-magnetic flow meter were tested.







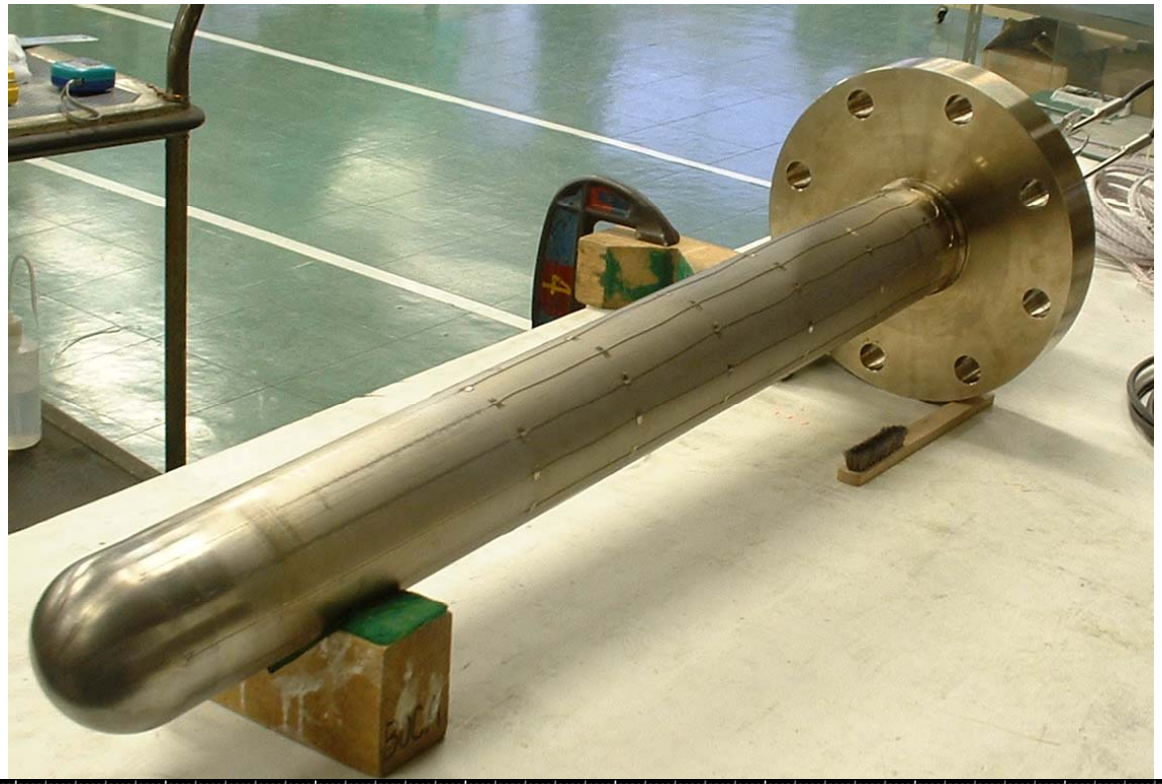


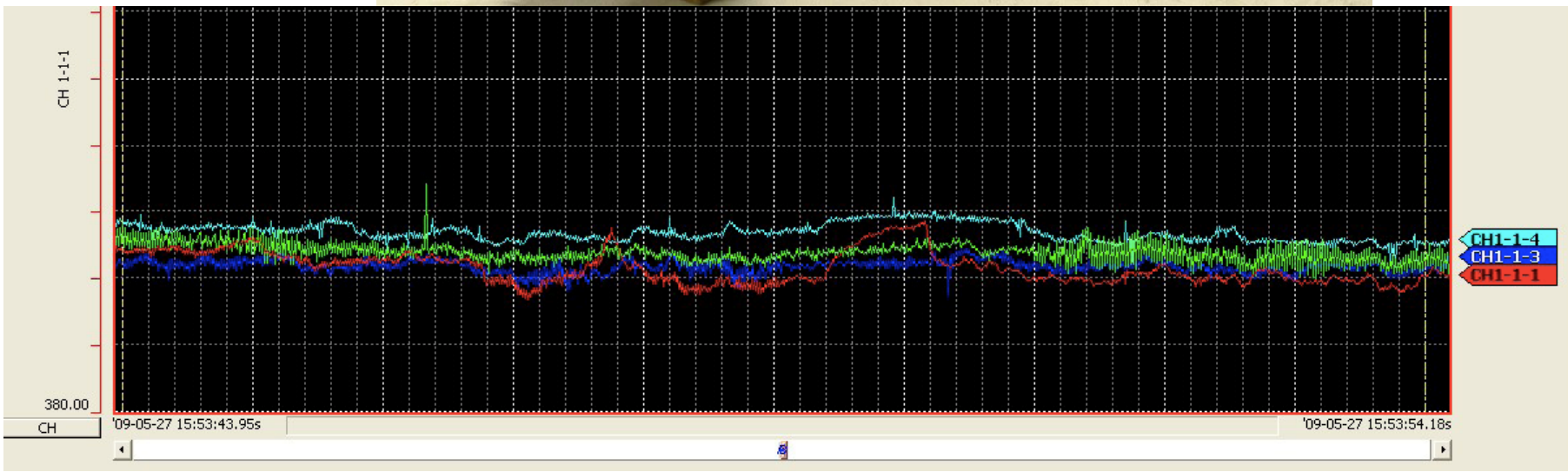


***The rolled vortex at the lower side of the loop was observed by UVP measurement.**

In JLBL-3 massive flow (500L/min) and thermal hydraulics were investigated

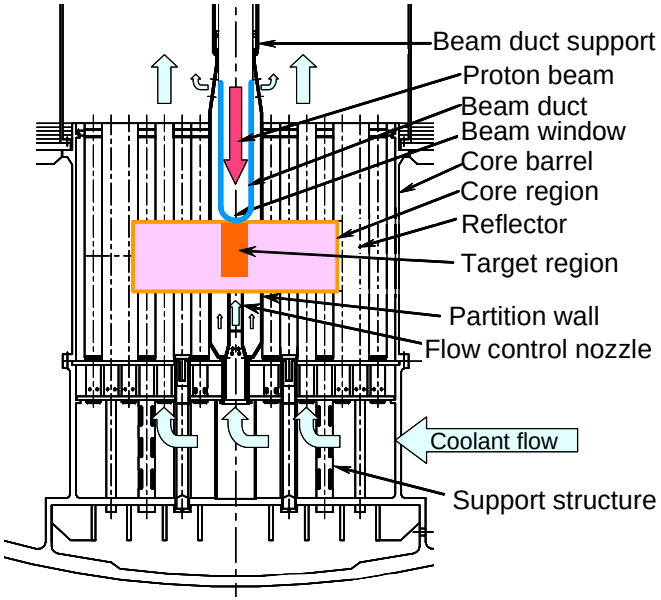
Flow induced temperature instability occurs at around LBE impinging area.

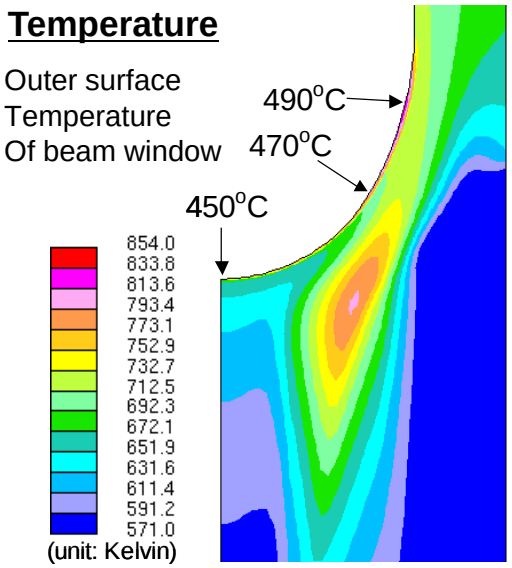


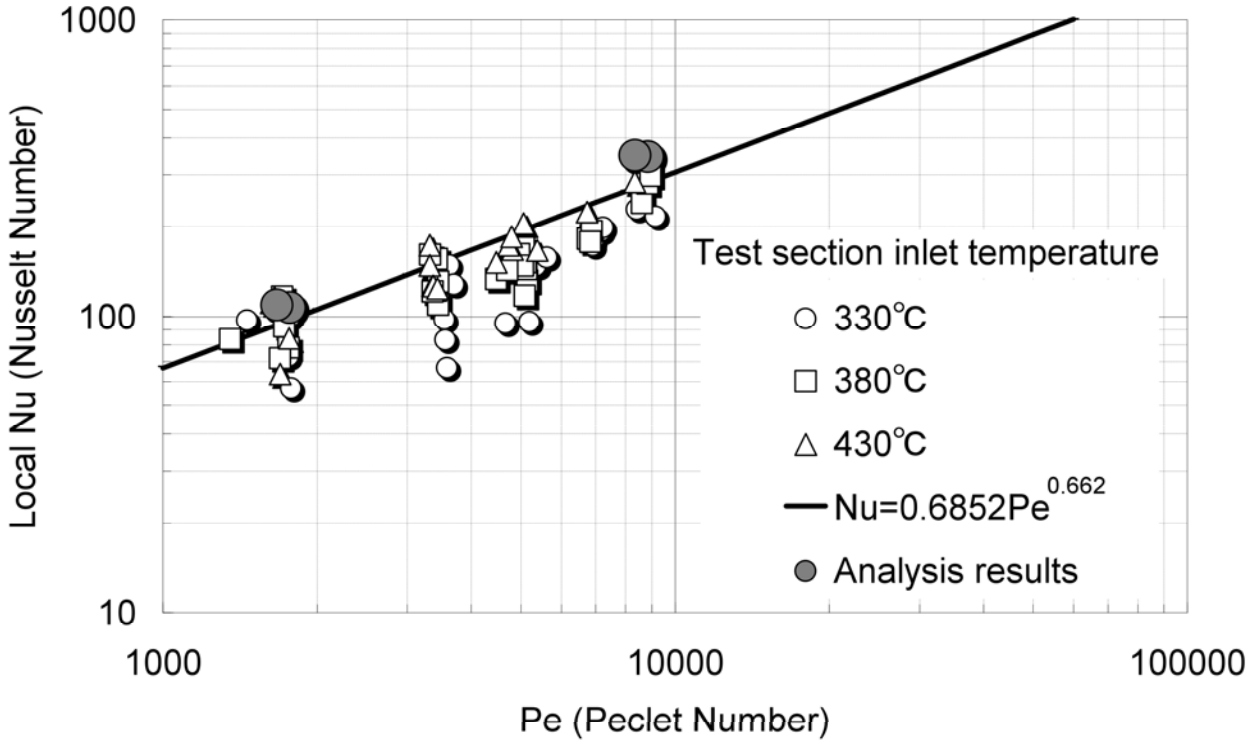


Heat transfer coefficient at the beam window

Hayashi et a. AESJ, 2008







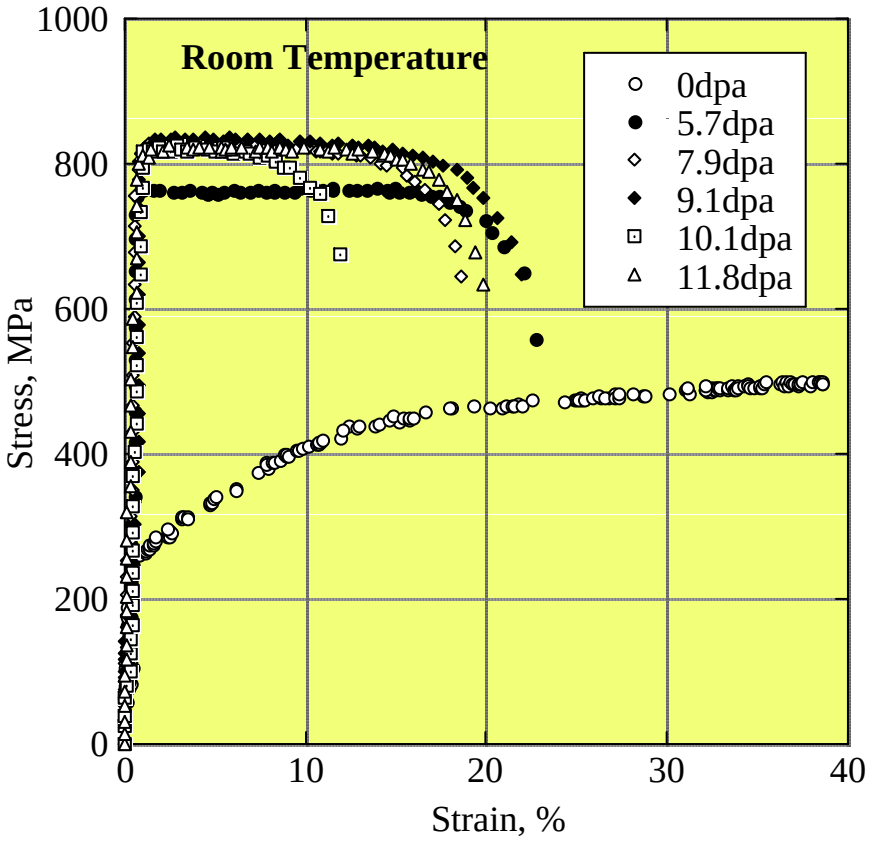
Window material irradiations

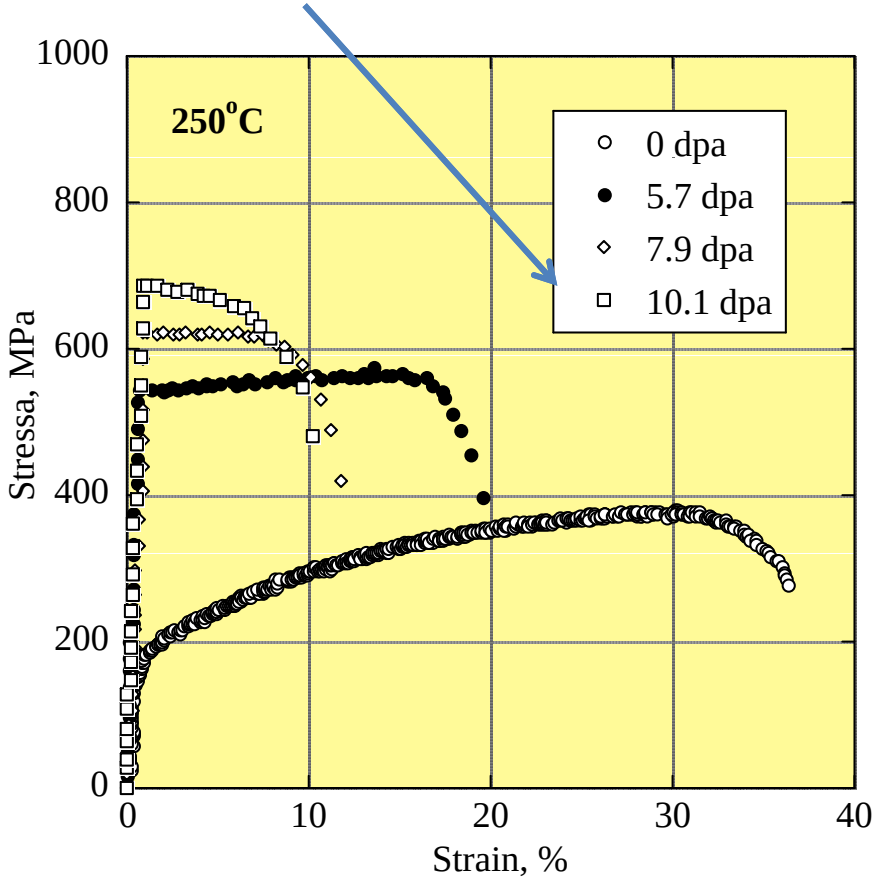
- Material samples were irradiated in the sample holders at SINQ (STIP-1, II, III & IV).

- MEGAPIE target is operated at PSI in 2006. PIE will start at JAEA.

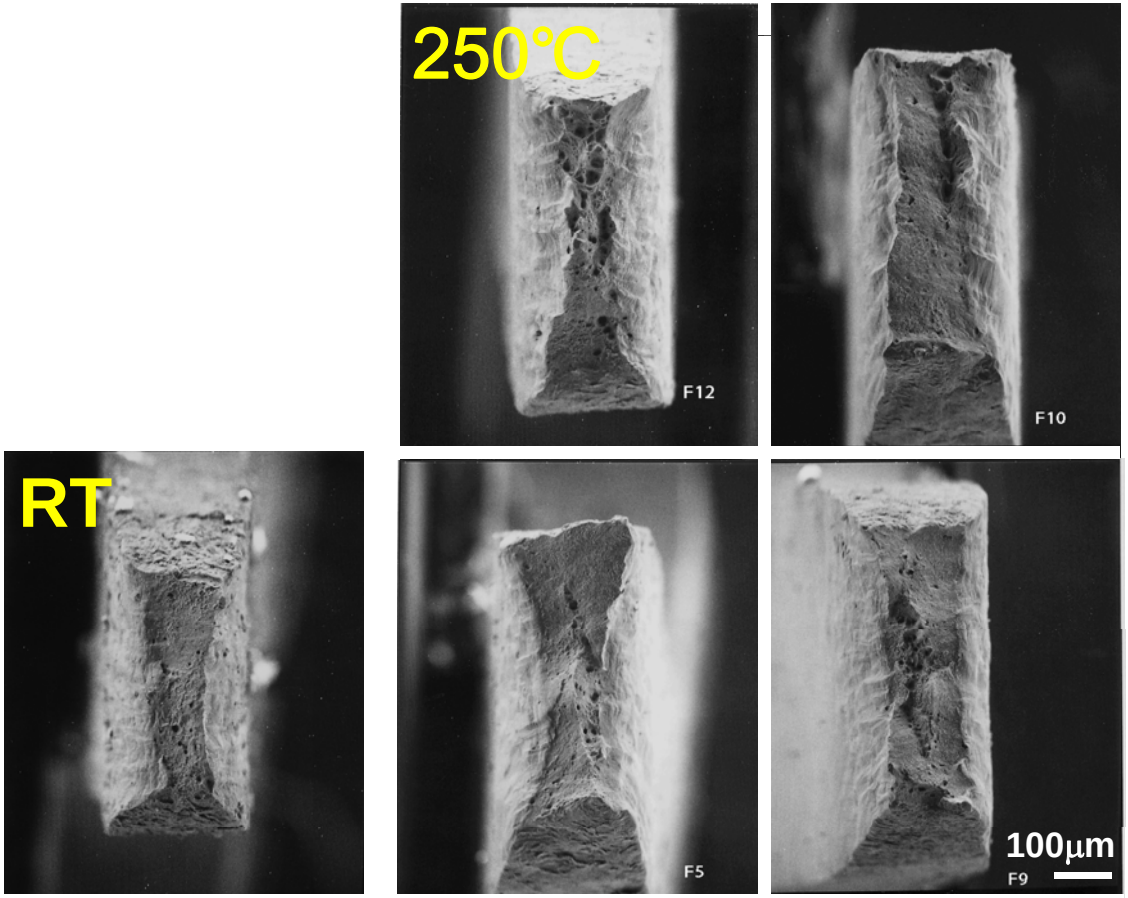
STIP – I JPCA irradiated at SINQ

800appmHe, 580MeV





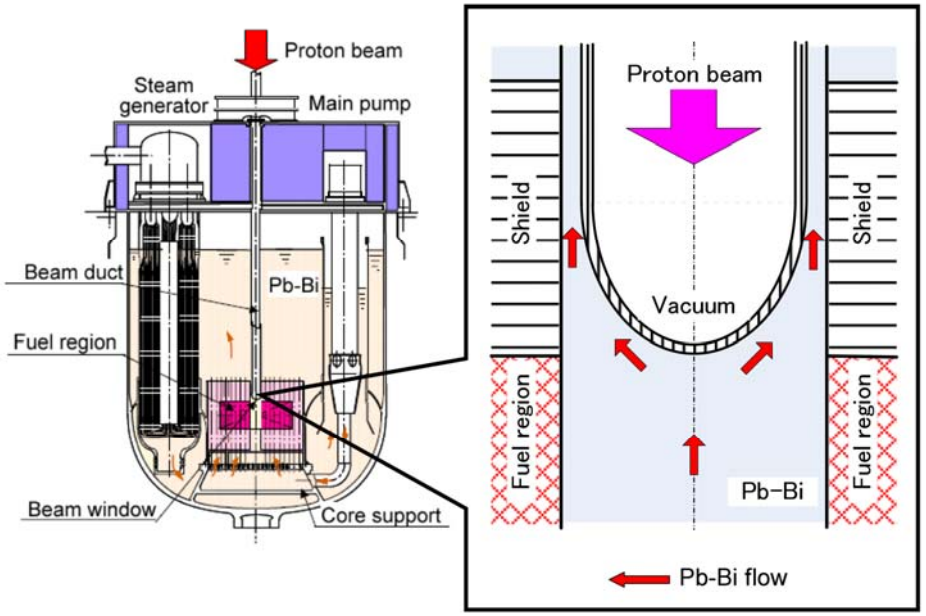
- Yield stress increases and ductility decreases with increase of dpa

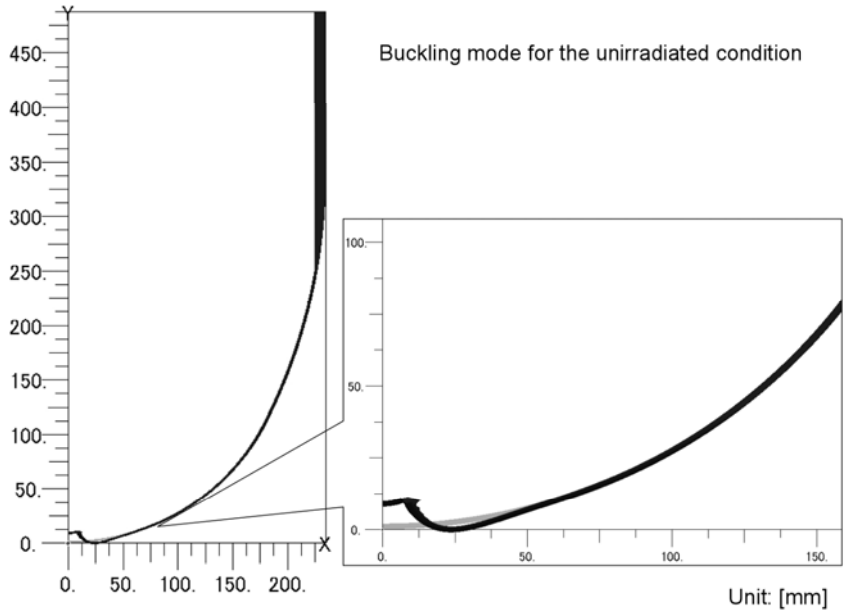


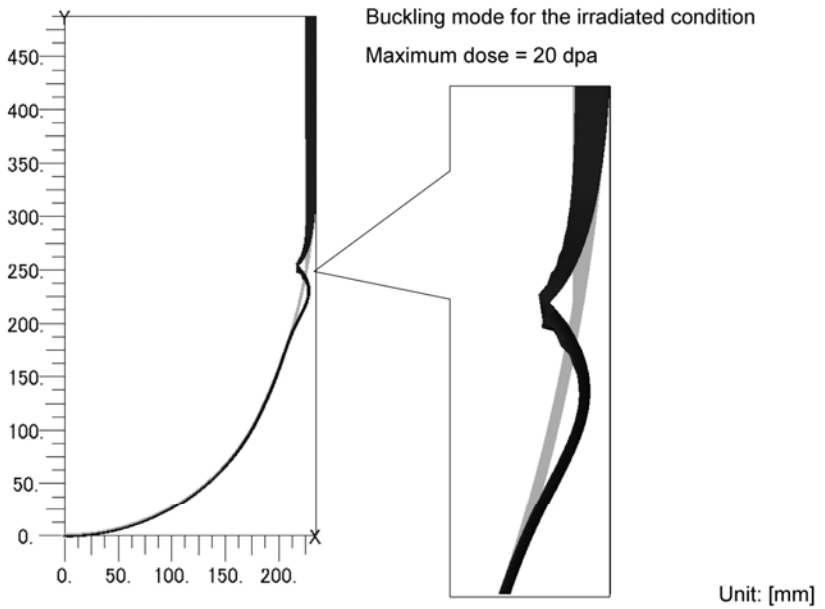
- **Transgranular fracture surface in 10.1dpa、285℃（727appmHe）**

Irradiation effect of buckling mode on the beam window

Sugawara et al. NUMA

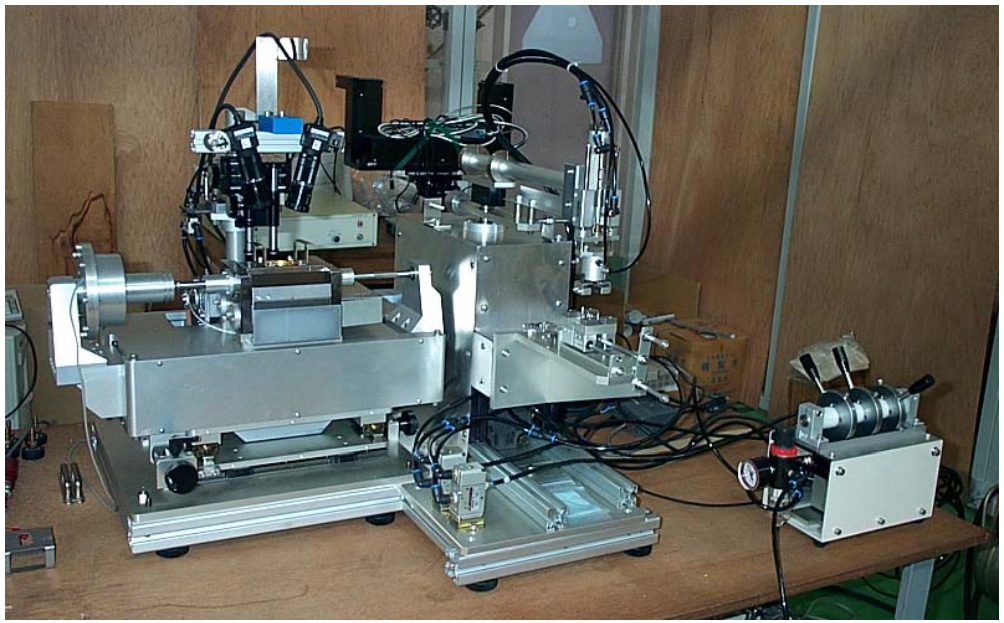






Fatigue

- Fatigue data of parents, EB and TIG materials are needed more.



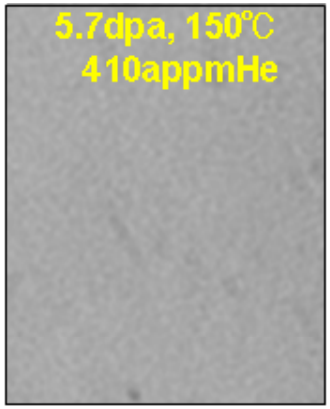
Irradiation Damage on the window in the 800MWth ADS after 300 FPDs

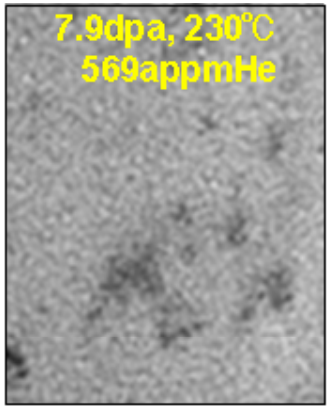
Nishihara, Kikuchi, NUMA 2008

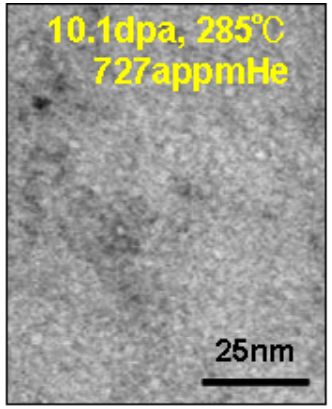
Particle		*I*	*P*	*N*	*C*	Total
Flux (/cm^2/s)		7.57*E* + 13	5.53*E* + 12	8.28*E* + 13	4.32*E* + 15	4.49*E* + 15
Averaged energy (MeV)		1500	107	42	0.75	
Cross section (b)	Heat (MeV b)	224	1010	6.4	1.1	
	DPA	2155	2148	1697	419	
	^{1}H	1.59	12.78	0.338	4.5E-3	
	^{2}H	0.37	0.013	3.3E-3	7.3E-7	
	^{3}H	0.083	1.9E-3	3.4E-4	4.9E-7	
	^{3}He	0.066	1.4E-3	1.3E-4	3.5E-11	
	^{4}He	0.36	0.039	0.021	5.8E-4	
Reaction	Heat (W/cm^3)	229	75	7.2	63	375
	DPA (300 FPDs)	4.2	0.31	3.6	47	55
	^{1}H (appm,300 FPDs)	3119	1831	725	503	6179
	^{2}H (appm,300 FPDs)	727	1.8	7.2	0.082	736
	^{3}H (appm,300 FPDs)	163	0.27	0.72	0.054	164
	^{3}He (appm,300 FPDs)	130	0.20	0.28	3.9E-6	130
	^{4}He (appm,300 FPDs)	709	5.5	45	65	825

- He bubble formation on JPCA was observed at lower temperature compared to EC316LN on STIP-I irradiated samples
- Effect of Ti modification?
- **Ti as an over sized atom lowers the mobility of vacancies**

JPCA

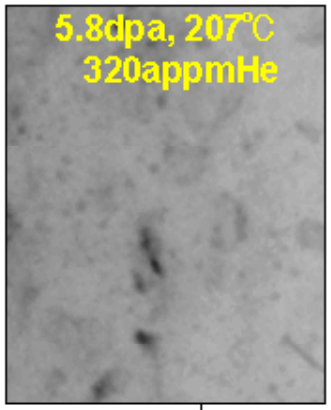


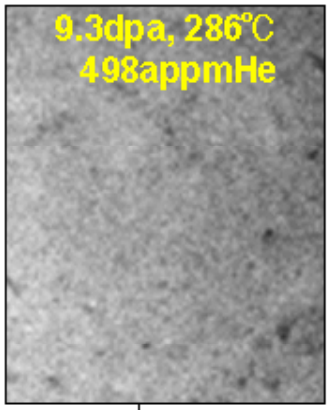


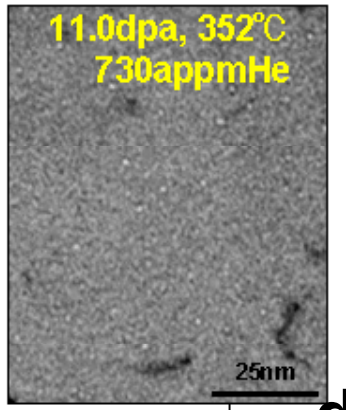


wt%	Fe	Cr	Ni	Mo	Mn	Ti	C	Si	P	S	N
JPCA	Bal.	14.14	15.87	2.29	1.54	0.22	0.058	0.5	0.026	0.004	0.003
316LN	Bal.	17.45	12.2	2.5	1.81	-	0.024	0.39	-	-	0.067

316LN







5 6 7 8 9 10 11 **dose (dpa)**

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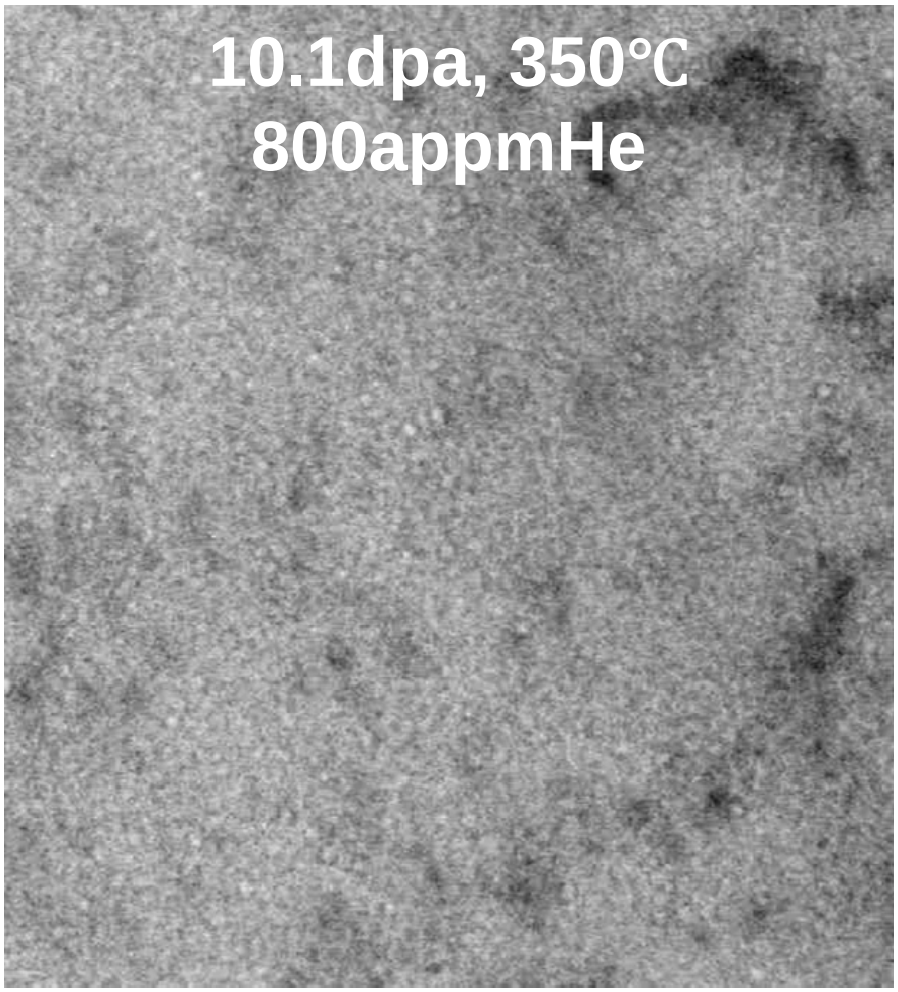

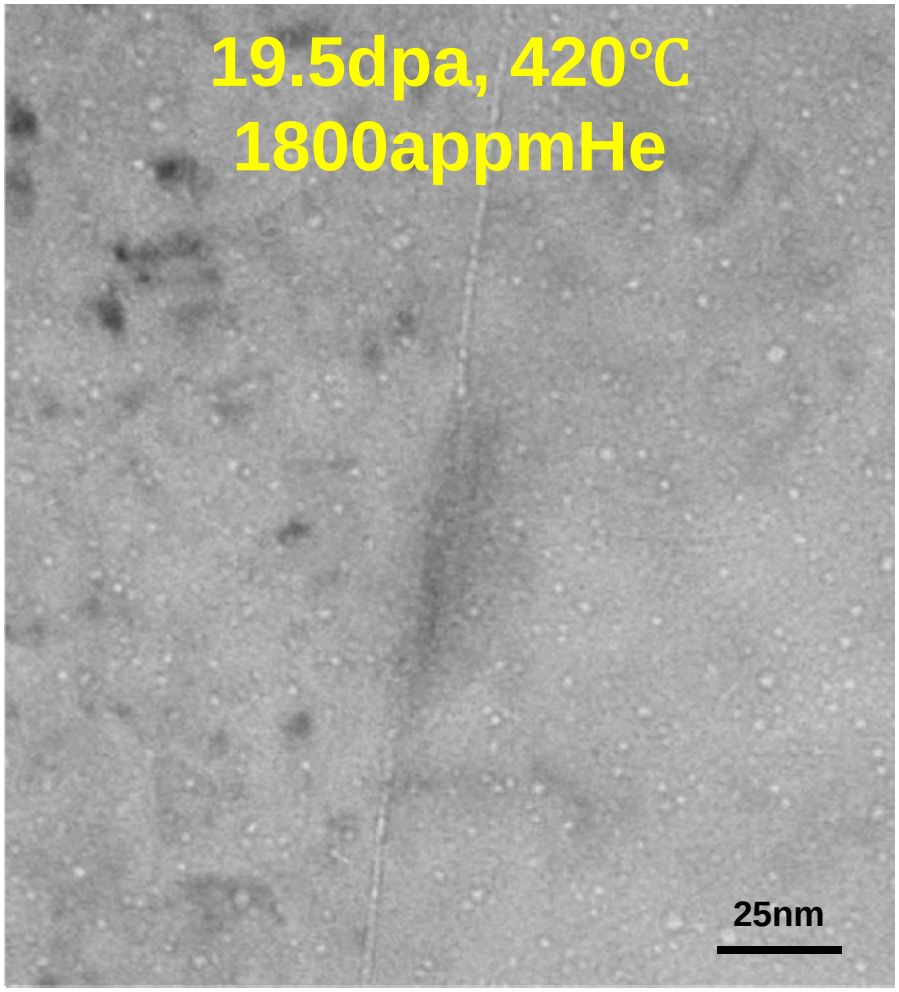

- **In the sample irradiated to 19.5dpa to 450℃, some bubble agglomeration to boundaries is observed**
- **Agglomeration was not observed on the sample irradiated to 10.1dpa, 350℃**
- **Any influence on mechanical properties ?**

Achievements of our Practice

- Proton irradiation

  Data acquisition for austenitic steel and F82H have been complete up to 20 dpa soon. Nano structure investigation is being processed.

- JLBL-1

  Materials property under LBE flow was obtained through 21000 hrs run.

  Oxygen sensor property and performance of EMP were investigated.

  Erosion-corrosion and mass transfer were detected.

- JLBL-2

  EMF performance was investigated. Ultrasonic Doppler prove visualized LBE flow.

- JLBL-3

  Massive flow control was experienced (500L/min). Heat transfer coefficient of the beam model was formulized.