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Study on Asymmetric Parfait Cores with Low Void Reactivity and Recycled MAs for the Fast Reactor

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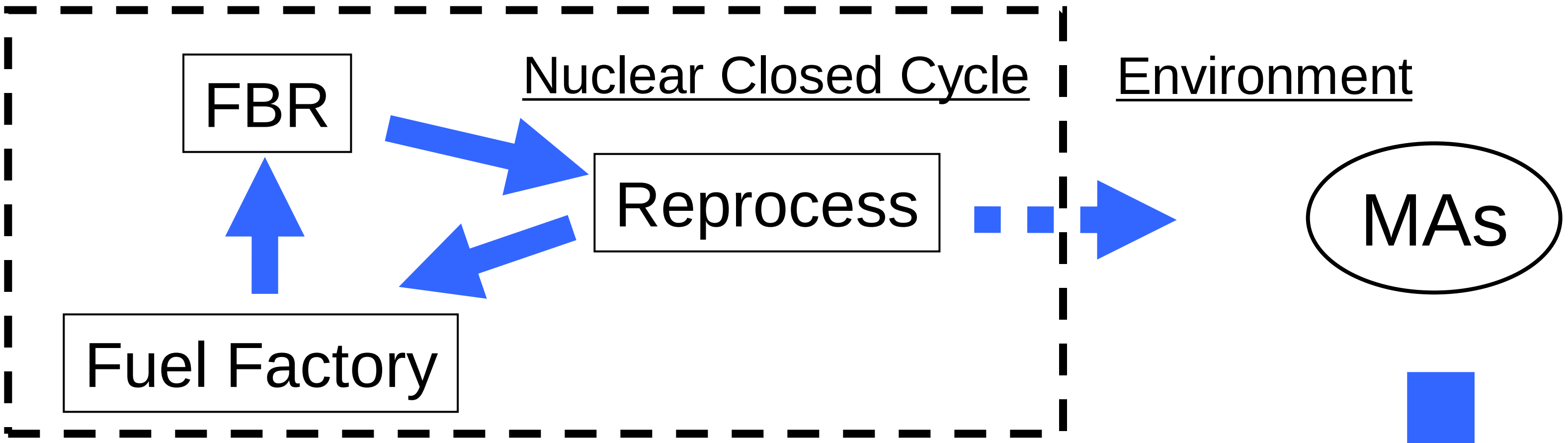
Environmental Harmonization by Nuclear Fuel Cycle

Disposal of MA for Environmental Harmonization



Amount of MAs should be lowest

→ One idea: Burn by fast neutron

Fast Reactor which can burn many MA

Concept of Fast Reactor as MA Burner

1. MA burner region

→ Asymmetrically core which has MA burner region in inner core.

2. Good safety feature including sodium void reactivity for ULOF and burnup reactivity for UTOP

→ Sodium plenum at upper of core for increasing neutron leakage.

↓

Asymmetric Parfait Core (APC) with concave form

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Evaluation Flow

First Step

MA has positive effect to sodium void reactivity

➡ Sodium void reactivity is evaluated by changing inner core height as parameter and select reference core geometry (No MA in MA burner region)

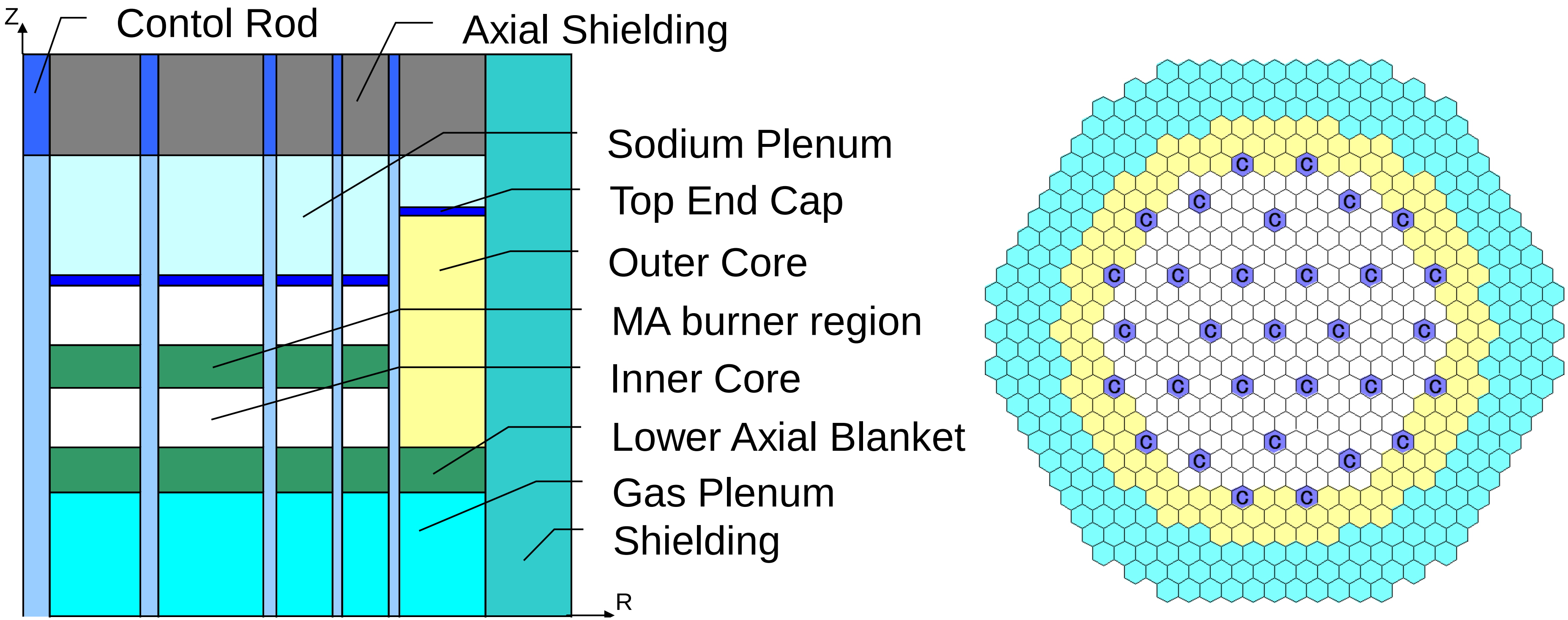
Second Step

Using geometry which is adapted in first step

➡ Amount of Burnt MA and the reactivity are evaluated by adding MA to MA burner region

Asymmetric Parfait Core (APC)

- Inner and Outer Core: MOX fuel (Same composition)
- MA burner region: Nat-U + MA
- Lower Axial Blanket: Nat-U



Analysis Method and Fuel composition

Analysis Method

-Nuclear Data Library: JENDL-3.3
-Code: STANBRE(7g, RZ-Dif), TWODANT(70g, 2D Trans.)

Fuel Composition (High and Low Pu-fissile are used)

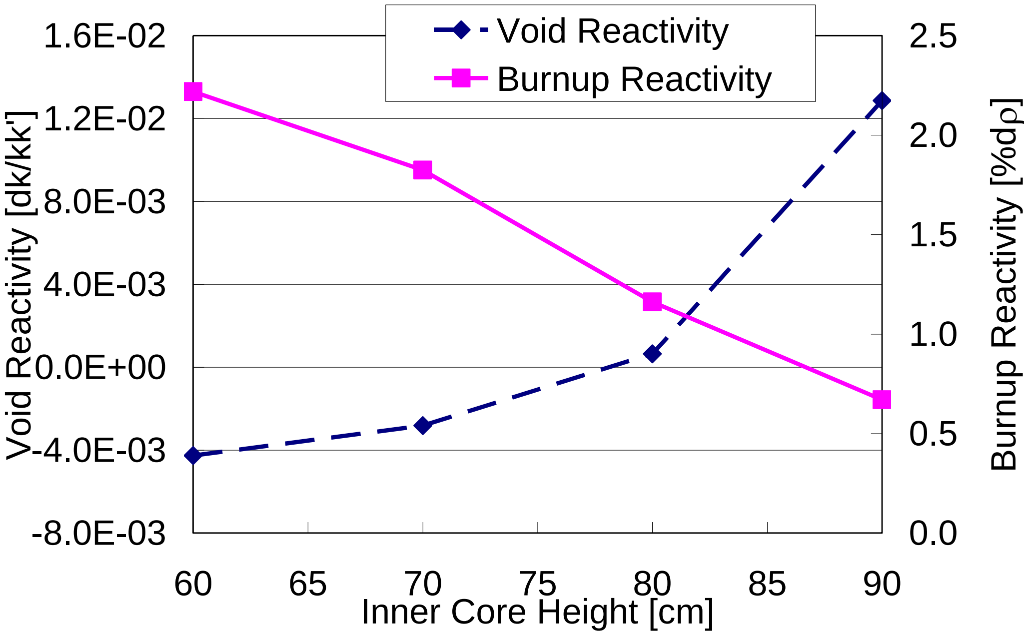
Element	Isotopes	Mass content (%)		Element	Isotopes	Mass content (%)	
		High Pu-fissile	Low Pu-fissile			High Pu-fissile	Low Pu-fissile
U	U235	0.3	0.3	MA	Np237	49.1	16.9
	U238	99.7	99.7		Am241	30.0	60.6
Pu	Pu238	0.0	3.6		Am242m	0.1	0.2
	Pu239	58.0	47.4		Am243	15.5	15.7
	Pu240	24.0	29.7		Cm242	0.0	0.0
	Pu241	14.0	8.2		Cm243	0.1	0.1
	Pu242	4.0	10.4		Cm244	5.0	5.1
	Am241	0.0	0.8		Cm245	0.3	1.3
					Cm246	0.0	0.1

APC Core Specification

Item	Specification
Thermal Power	2400MWt
Cycle Length	400EFPD
No. of Refueling Batch	5
Core Type	Uranium-Type Asymmetric Parfait Core (U-APC) (Internal Blanket,One Pu Enrichment for core-fuels)
Core Height (IC / OC)	60, 70, 80, 90cm (parameter) / 100cm
Axial Blanket Thickness (Upper / Lower)	0 / 20cm
Axial Shielding Material	B_4C
Radial Blanket	0
Core Diameter	428cm
Fuel Type	MOX
Fuel Volume Fraction	50.5%
Structure Volume Fraction	21.9%
Sodium Volume Fraction	27.6%
Sodium Plenum Length (IC/ OC)	78, 68, 58, 48cm (parameter) / 38cm

Void and Burnup reactivity change vs. IC height

Fuel: Low Fissile Fuel
Case: IC=60, 70, 80, 90cm



Sodium Void Reactivity

-Negative from IC=70cm
-Difference IC60 and 70cm is small

Burnup Reactivity

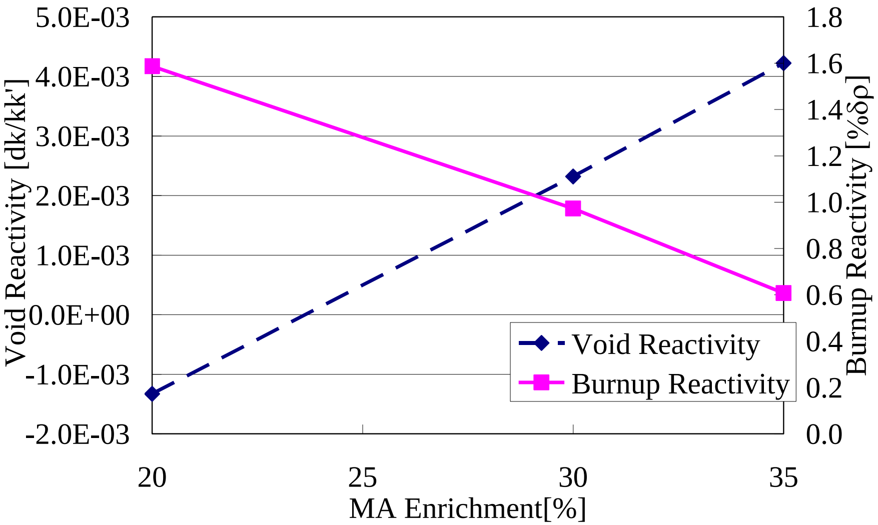
-Also same difference

IC70cm is selected as reference

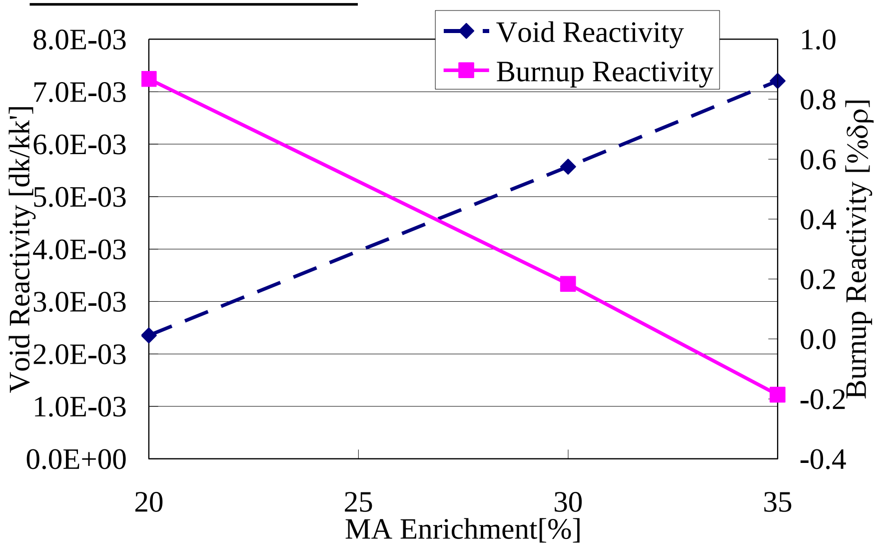
	Inner Core Height [cm]			
	60	70	80	90
Pu Enrichment [%]	23.9	22.7	20.9	19.3
Max. Power Density [W/cc]	380	352	304	309

Void and Burnup reactivity change vs. MA fraction

High Pu-fissile



Low Pu-fissile



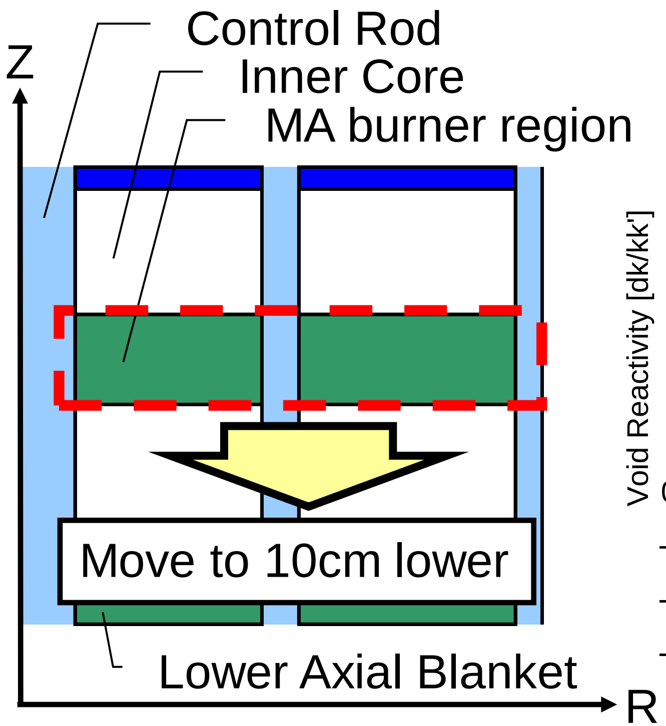
High Pu-fissile: **About 25% of MA** can be inserted
Low Pu-fissile: **No negative** void reactivity

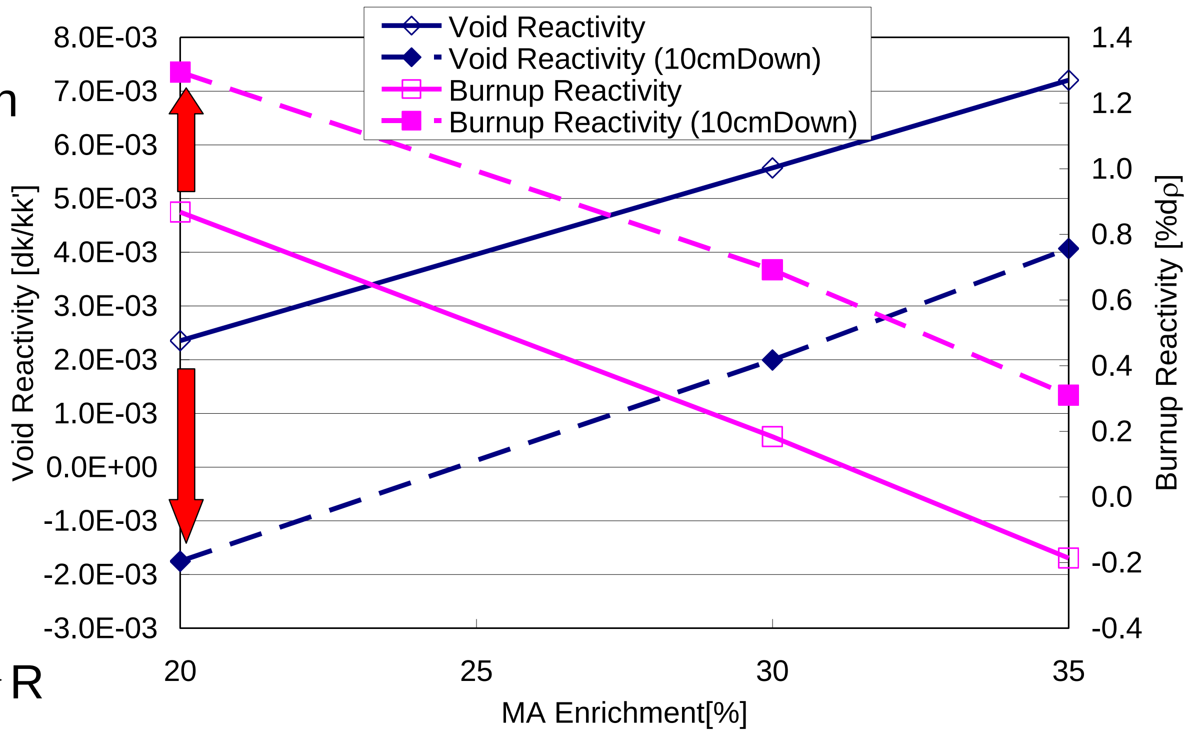
For achieving negative void in case of low Pu-fissile

→ Need to increase neutron leakage to upper sodium plenum

→ Moving MA burner region to lower position and increasing upper inner core region

Reactivity change by re-positioning MA burner region



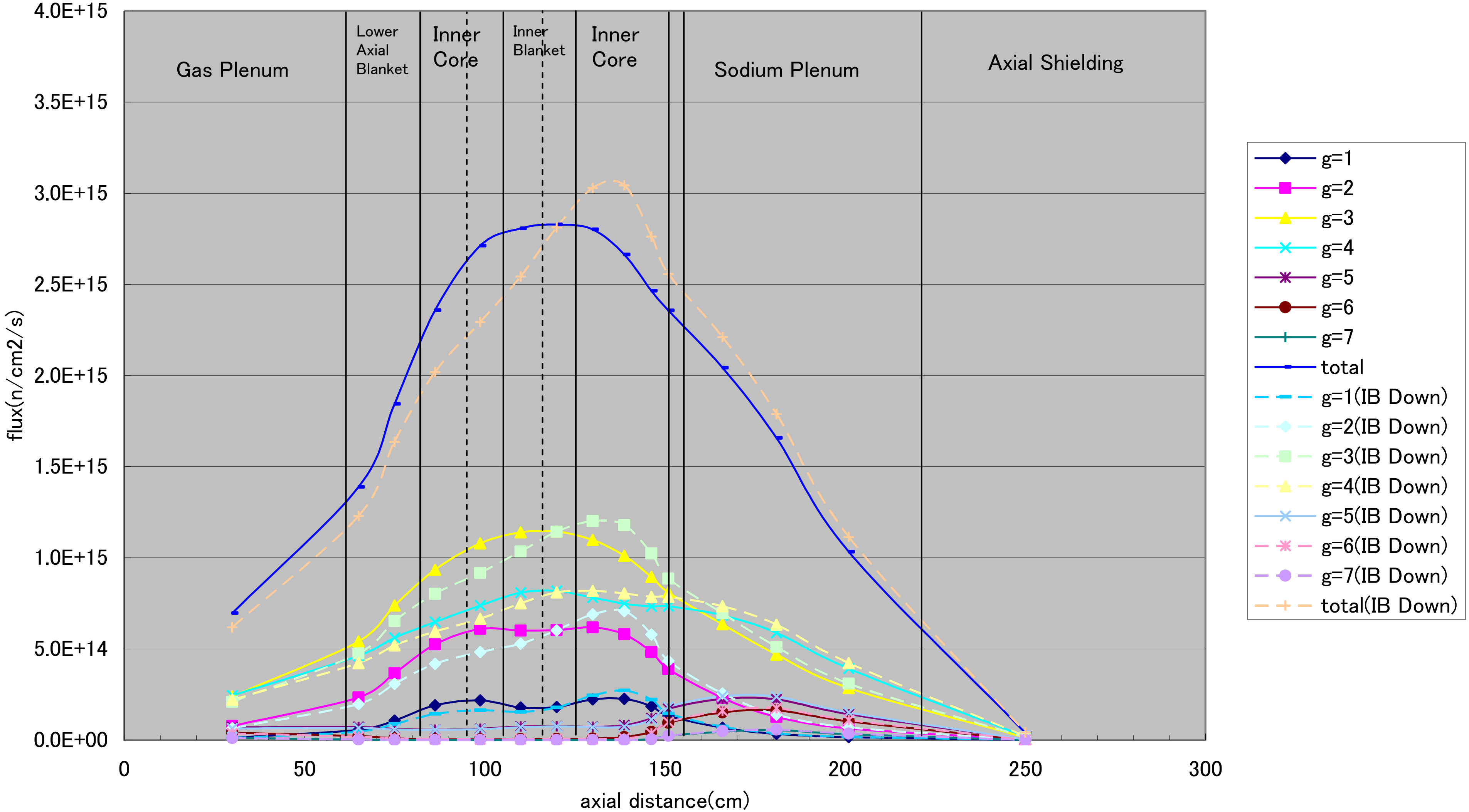


By moving MA burner region to lower position

Low Pu-fissile: **Negative** less than about 25% of MA

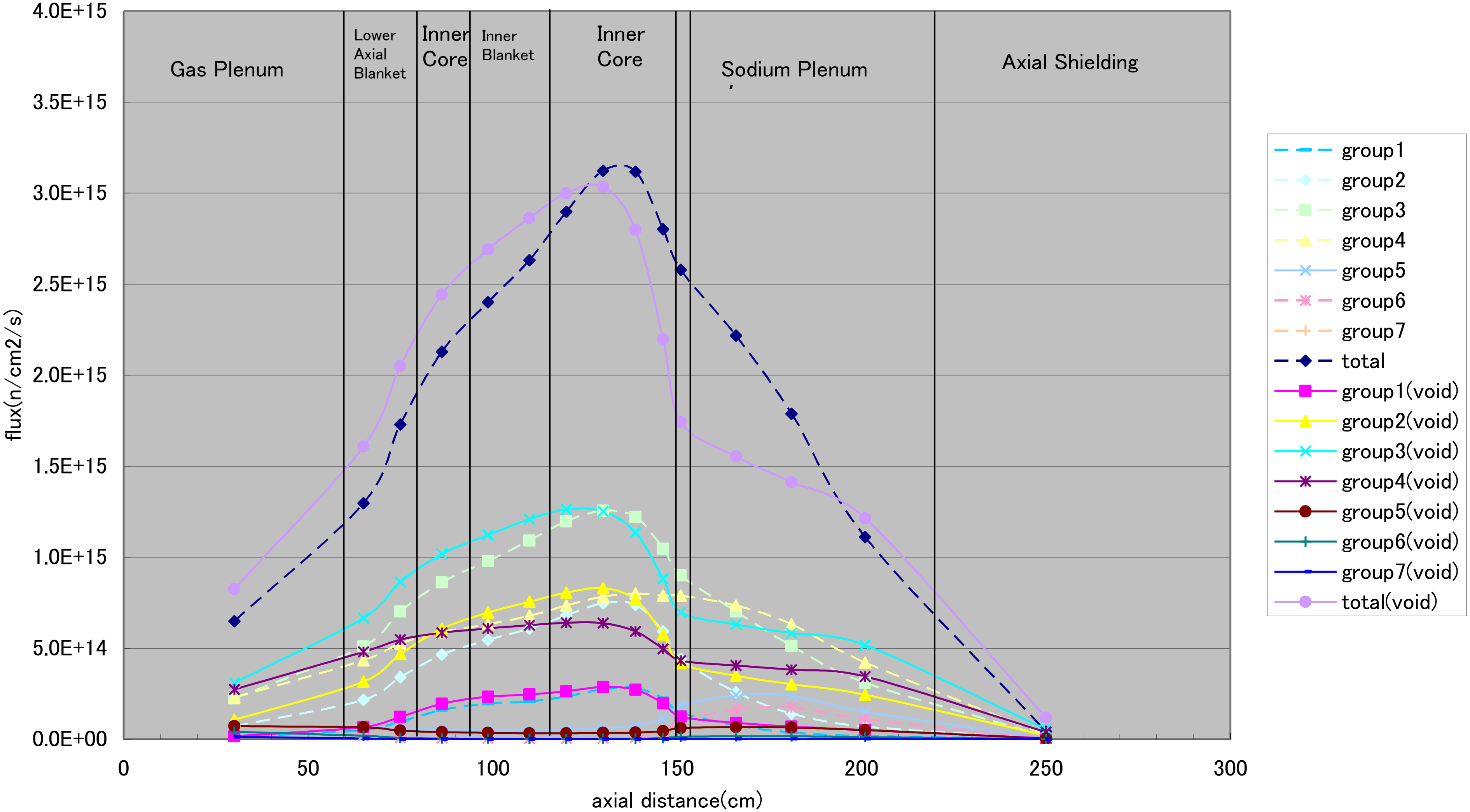
Flux Distribution by re-positioning MA burner region(1/2)

Before and after moving MA burner region to lower position



Flux Distribution by re-positioning MA burner region(2/2)

Before and after void in all of core



MA Mass Balance Characteristics

	Isotopes	No MA		20%		30%		35%	
		Load(kg)	Unload	Load	Unload	Load	Unload	Load	Unload
High Pu Fissile	Np	0	15	670	368	1008	547	1179	632
	Am	66	219	633	483	954	644	1116	721
	Cm	0	29	74	138	112	198	131	227
	MA	66	263	1377	989	2075	1389	2426	1580
	Burnt MA [%]	-296.0		28.2		33.1		34.9	
Low Pu Fissile	Np	0	15	229	135	345	194	403	222
	Am	66	219	1122	757	1655	1018	1923	1138
	Cm	0	29	92	171	138	239	162	273
	MA	66	263	1442	1064	2138	1451	2487	1633
	Burnt MA [%]	-296.0		26.2		32.1		34.4	

- Burnt MA fraction is almost same as added MA fraction
- Burnt MA rate: Np > Am > Cm*

*Cm increases by capture reaction of Am

Summary -Core Characteristics of Each MA Fraction-

(IC=70cm, Low Pu-fissile)

	MA Fraction [%]		
	20*	30*	35*
Pu Enrichment [%]	21.7	21	20.5
Ave. Power Density [W/cc]**	227	220	216
Max. Power Density [W/cc]	332	318	337
Breeding Ratio	1.02	1.03	1.05
Burnt MA Fraction [%]	26.2	30.1	32.3
Sodium void Reactivity [dk/kk']	-0.0018	0.0020	0.0041
Burnup Reactivity [%dρ]	1.29	0.69	0.31

* Position of MA burning region 10cm down
** Core only, BOC

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Conclusion (Result)

APC is Designed

APC with concave form concept is designed for low sodium void reactivity, low burnup reactivity, and high MA burning.

IC height 70cm as Reference Core

The reference core of APC without MA is determined by changing inner core height parametrically for lower void reactivity, and 70cm of inner core height is selected.

25% of Loaded MA can be Burnt

In cases of high and low Pu-fissile, about 25% of loaded MA can be burnt while keeping low sodium void reactivity and burnup reactivity.

Conclusion (Future Plan)

Adjust Blanket Geometry Size

core radius and height of inner blanket have to be also evaluated.

Homogeneous Loading of MA

MA is loaded to only MA burner region and homogeneous loading in core has to be considered for more burning MA and increasing safety characteristics.

Heterogeneous Effect of Sodium Plenum

Sodium plenum is treated as homogeneous only and heterogeneous effect may be large

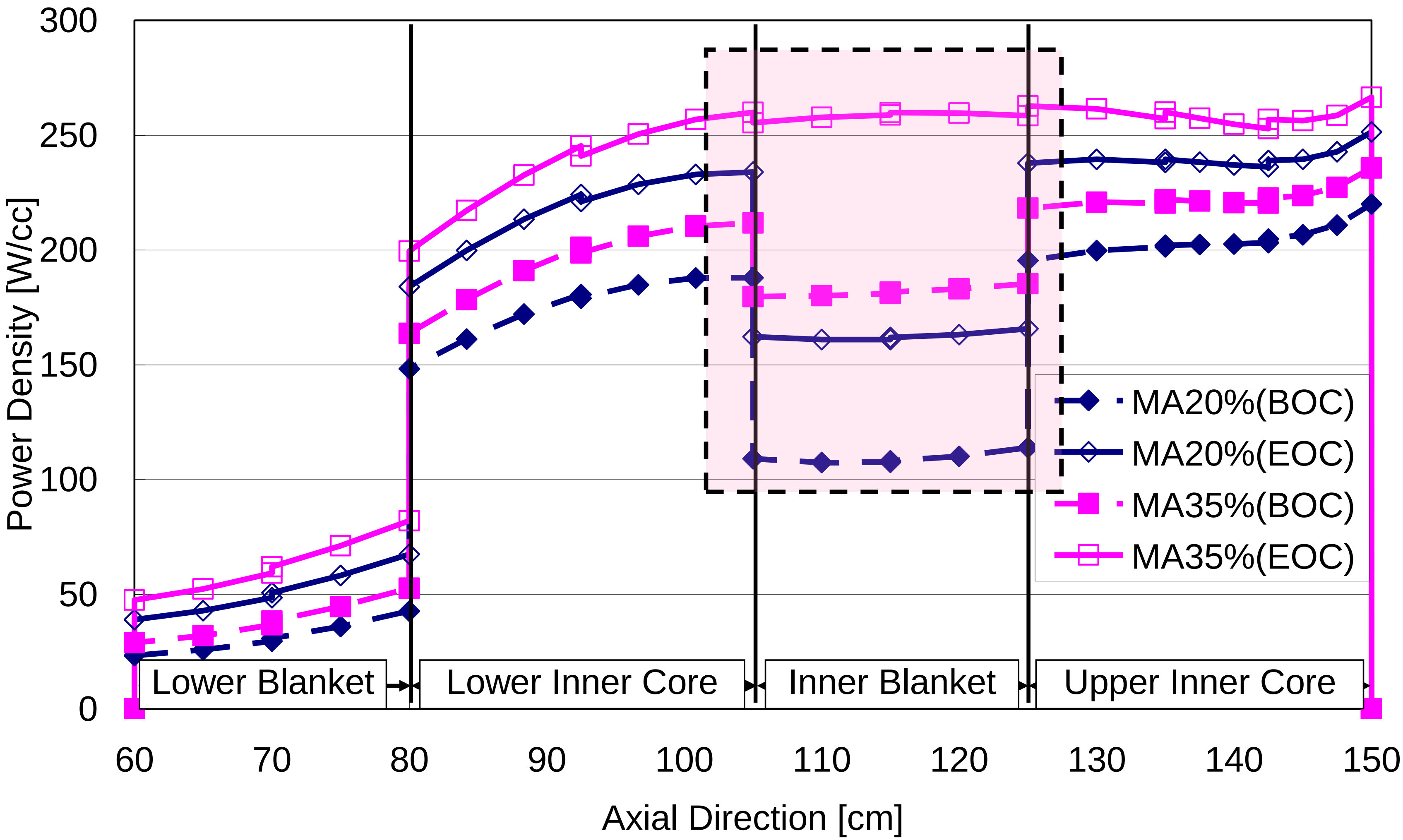
Manufacturability of Fuel Assembly

Not only core characteristics but also manufacturability of fuel assembly for high MA content fuel is necessary to evaluate.

Thank you very much for your attention.

Power Density Distribution (Central, MA:20,35%)

Larger power density of MA 35% than MA 20% by fission



MA Transmutation Characteristics (High Pu-fissile)

Isotopes	No MA		20%		30%		35%	
	Load(kg)	Unload(kg)	Load	Unload	Load	Unload	Load	Unload
Np237	0	15	670	368	1008	547	1179	632
Np Total	0	15	670	368	1008	547	1179	632
Am241	66	127	415	313	626	409	732	455
Am242m	0	6	1	18	2	25	2	28
Am243	0	87	217	151	326	210	382	238
Am Total	66	219	633	483	954	644	1116	721
Cm242	0	6	0	15	0	20	0	23
Cm243	0	0	1	1	1	2	1	2
Cm244	0	21	70	107	106	154	123	177
Cm245	0	1	4	14	6	20	6	23
Cm246	0	0	0	1	0	2	0	2
Cm Total	0	29	74	138	112	198	131	227
MA Total	66	263	1377	989	2075	1389	2426	1580
Burnt MA Fraction [%]	-296.0		28.2		33.1		34.9	

MA Transmutation Characteristics (Low Pu-fissile)

Isotopes	No MA		20%		30%		35%	
	Load(kg)	Unload(kg)	Load	Unload	Load	Unload	Load	Unload
Np237	0	15	229	135	345	194	403	222
Np Total	0	15	229	135	345	194	403	222
Am241	66	127	900	520	1321	710	1532	797
Am242m	0	6	3	33	5	46	6	53
Am243	0	87	218	204	329	261	385	288
Am Total	66	219	1122	757	1655	1018	1923	1138
Cm242	0	6	0	26	0	36	0	41
Cm243	0	0	1	3	1	4	1	4
Cm244	0	21	72	120	108	168	126	191
Cm245	0	1	18	18	27	27	31	31
Cm246	0	0	1	4	2	5	2	6
Cm Total	0	29	92	171	138	239	162	273
MA Total	66	263	1442	1064	2138	1451	2487	1633
Burnt MA Fraction [%]	-296.0		26.2		32.1		34.4	

Fig. Flux axial distribution of Outer Core(IC=70cm、EOEC、R_reg.=14)

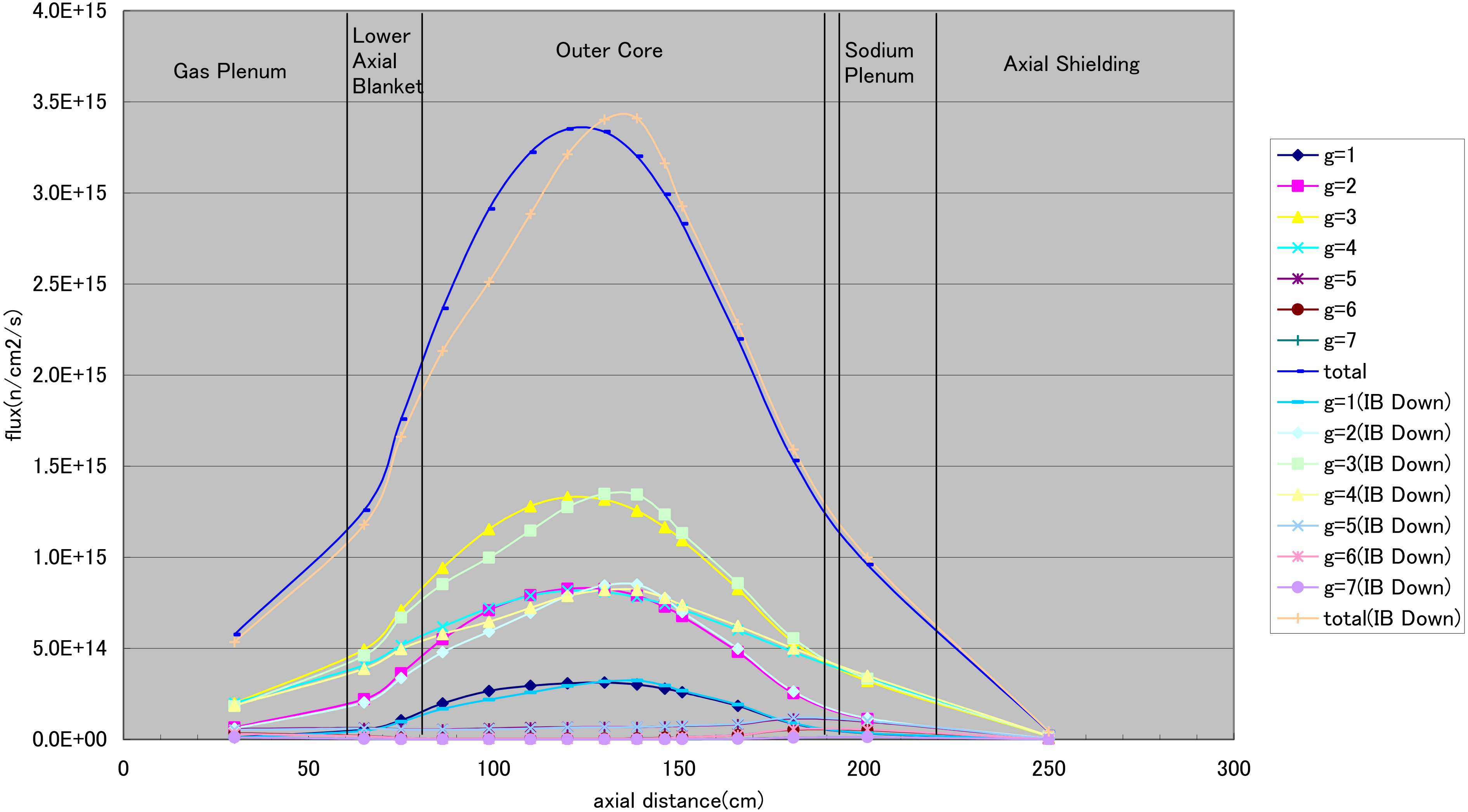


Fig. Flux axial distribution of Outer Core(IC=70cm、IB Down、MA20%、EOEC、R_reg.=14)

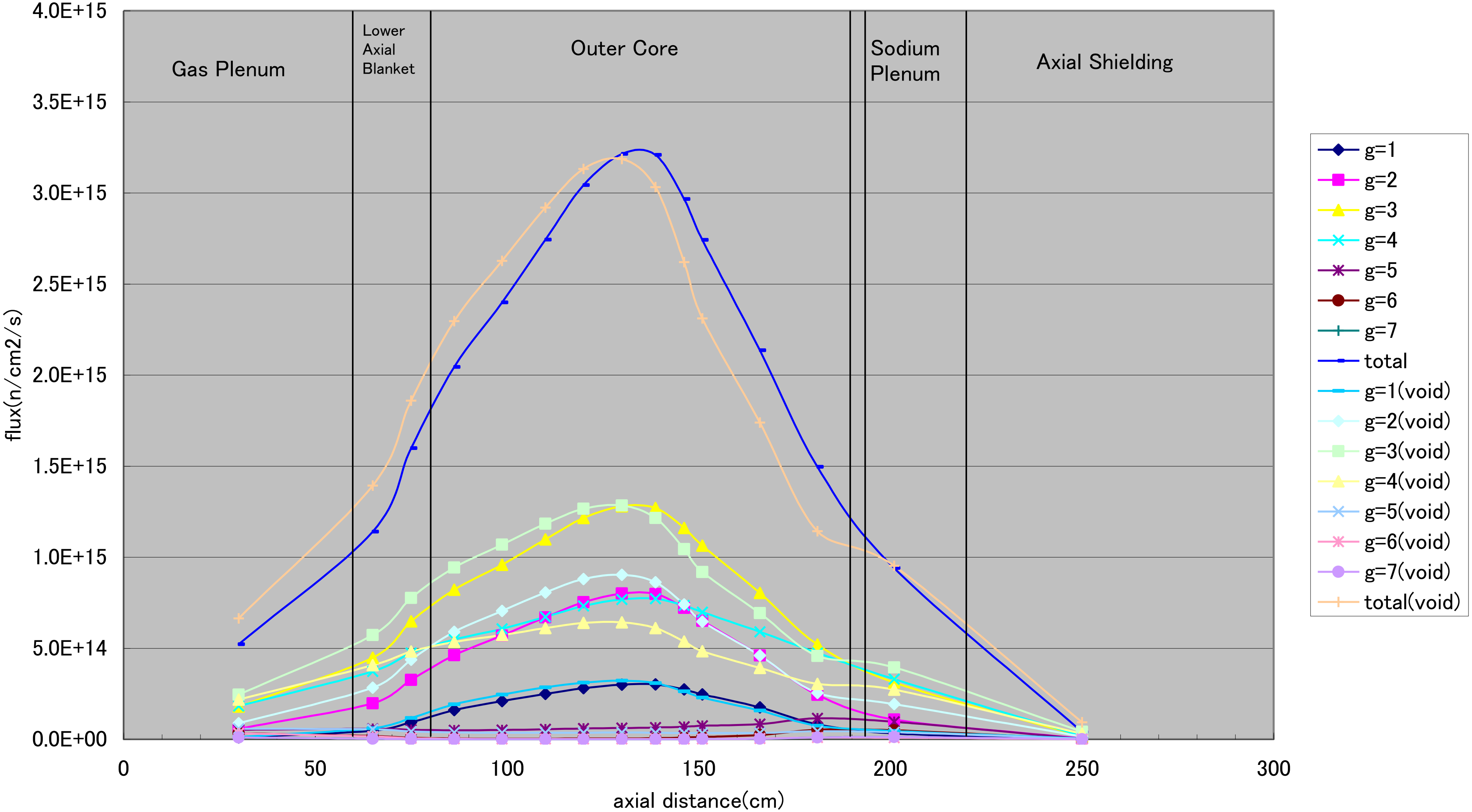


Fig.　Low Pu-fissile composition(IC=70cm,IB 10cm down)