Session 3-1 : Irradiation Tests for Fusion Materials

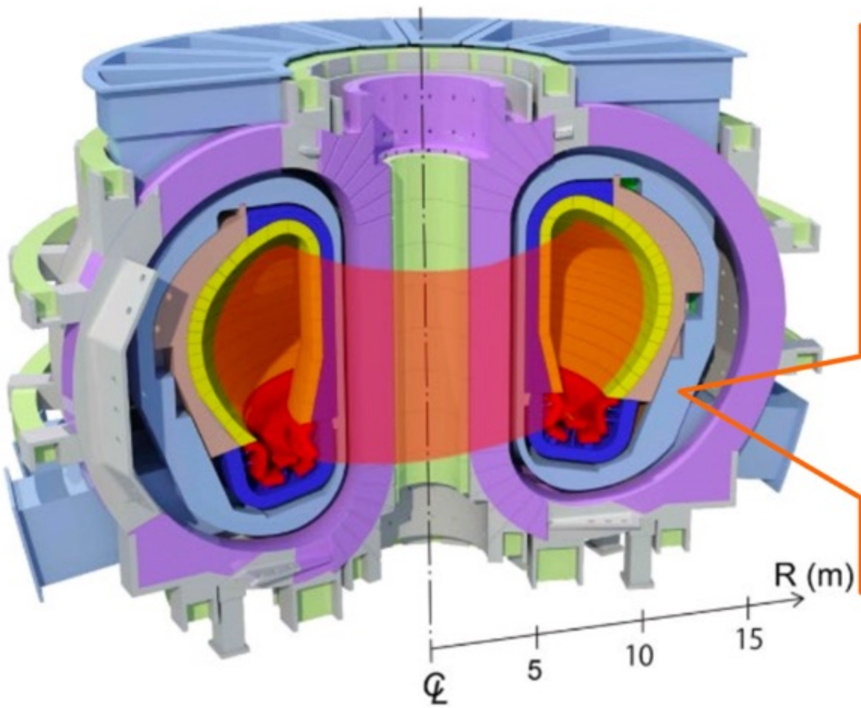
New Concept of Neutron Multiplayer and Necessary Irradiation Tests

Etsuo Ishitsuka

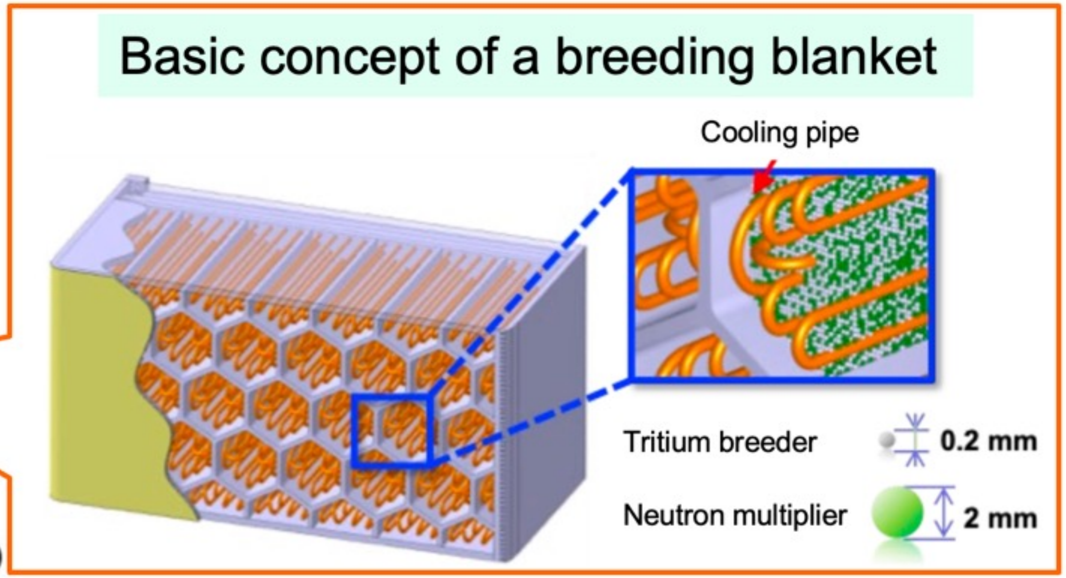
Ibaraki University,

Research and Education Center for Atomic Sciences (RECAS)

JA DEMO (water cooling)

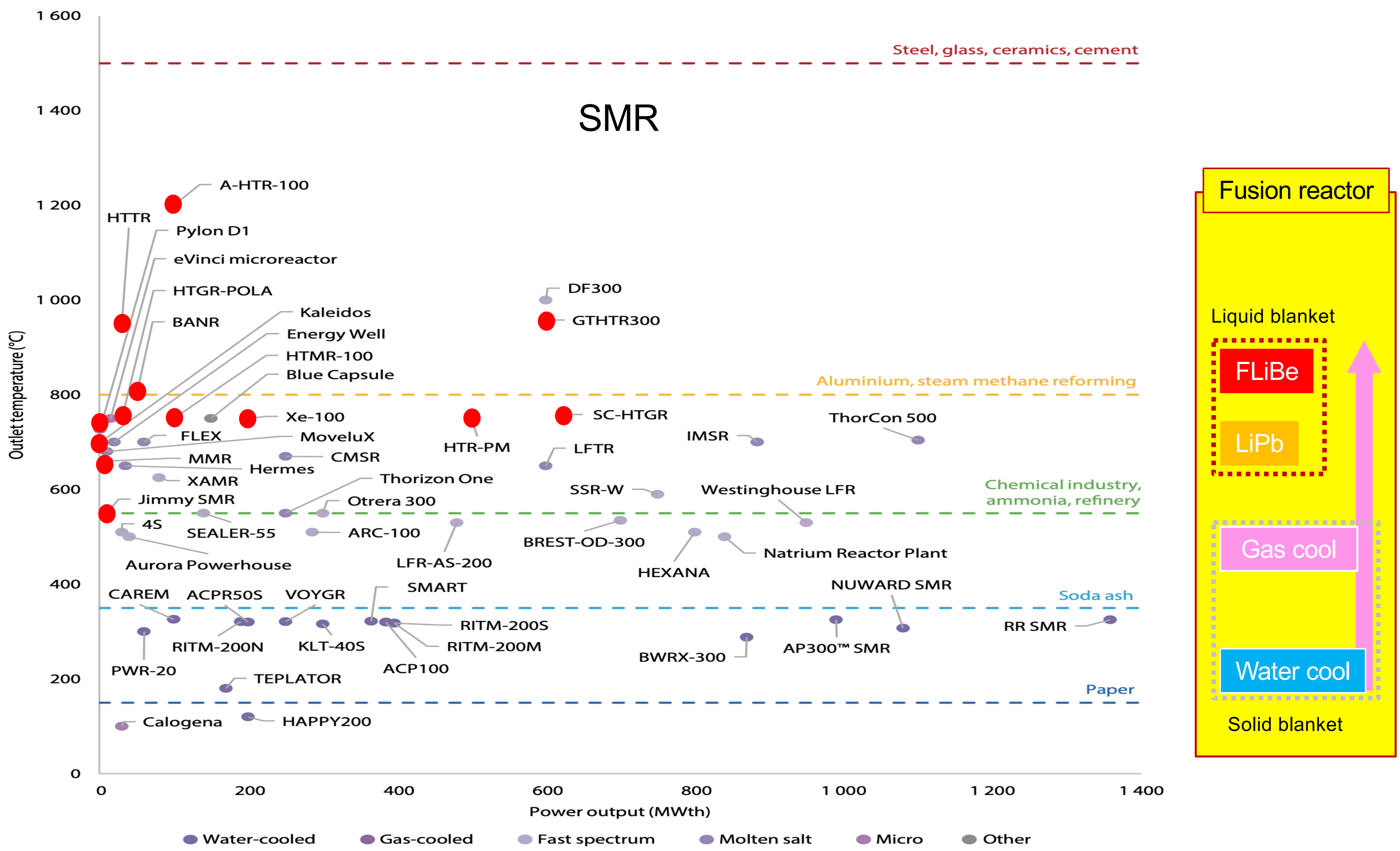


JA DEMO



Proposal for a higher-temperature neutron multiplier
→ Improved power generation efficiency
(high-temperature gas cooling)
→ Improved safety
(swelling and tritium inventory reduction)

Fission vs Fusion

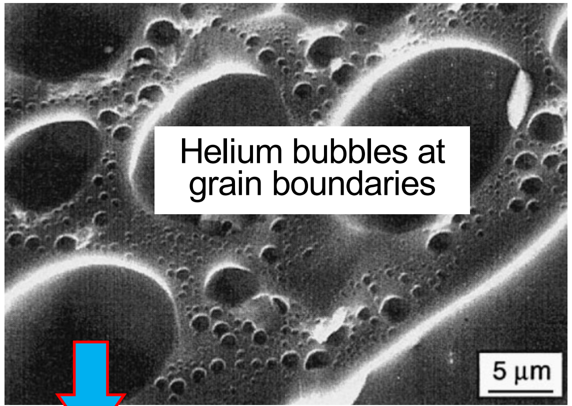


https://www.oecd-nea.org/jcms/pl_90816/the-nea-small-modular-reactor-dashboard-second-edition

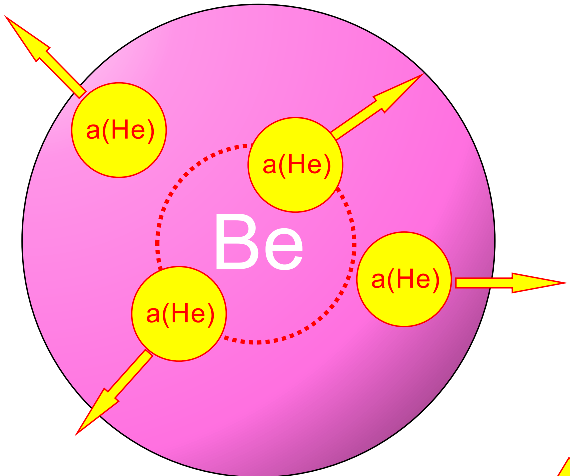
Idea for swelling reduction

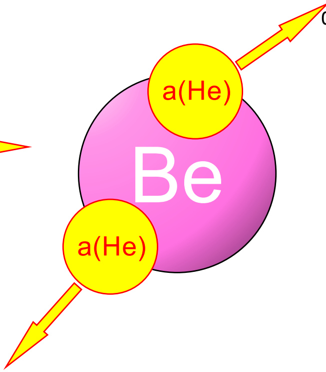
$^{9}Be(n_f,2n)2^{4}He$

1) Risk of blanket vessel destruction due to swelling caused by helium generation

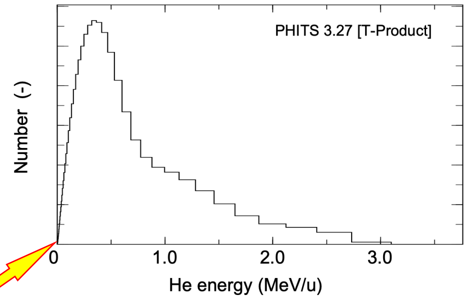


2) Actively utilized recoil helium by reducing beryllium size

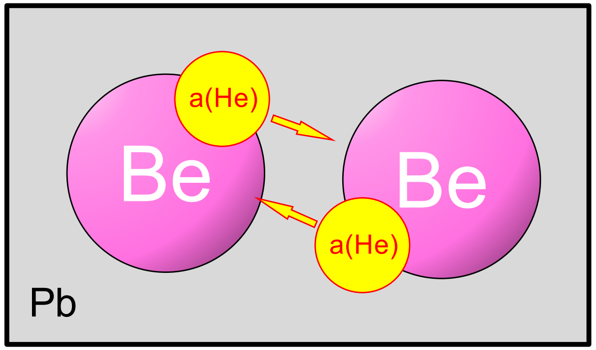




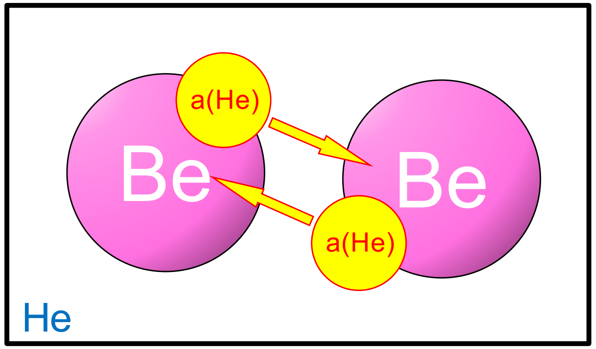
Smaller size is better



+ Neutron multiplication,
+ Gamma rays shielding, by lead



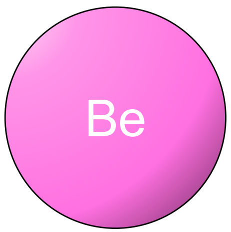
4) Lead shield α irradiation



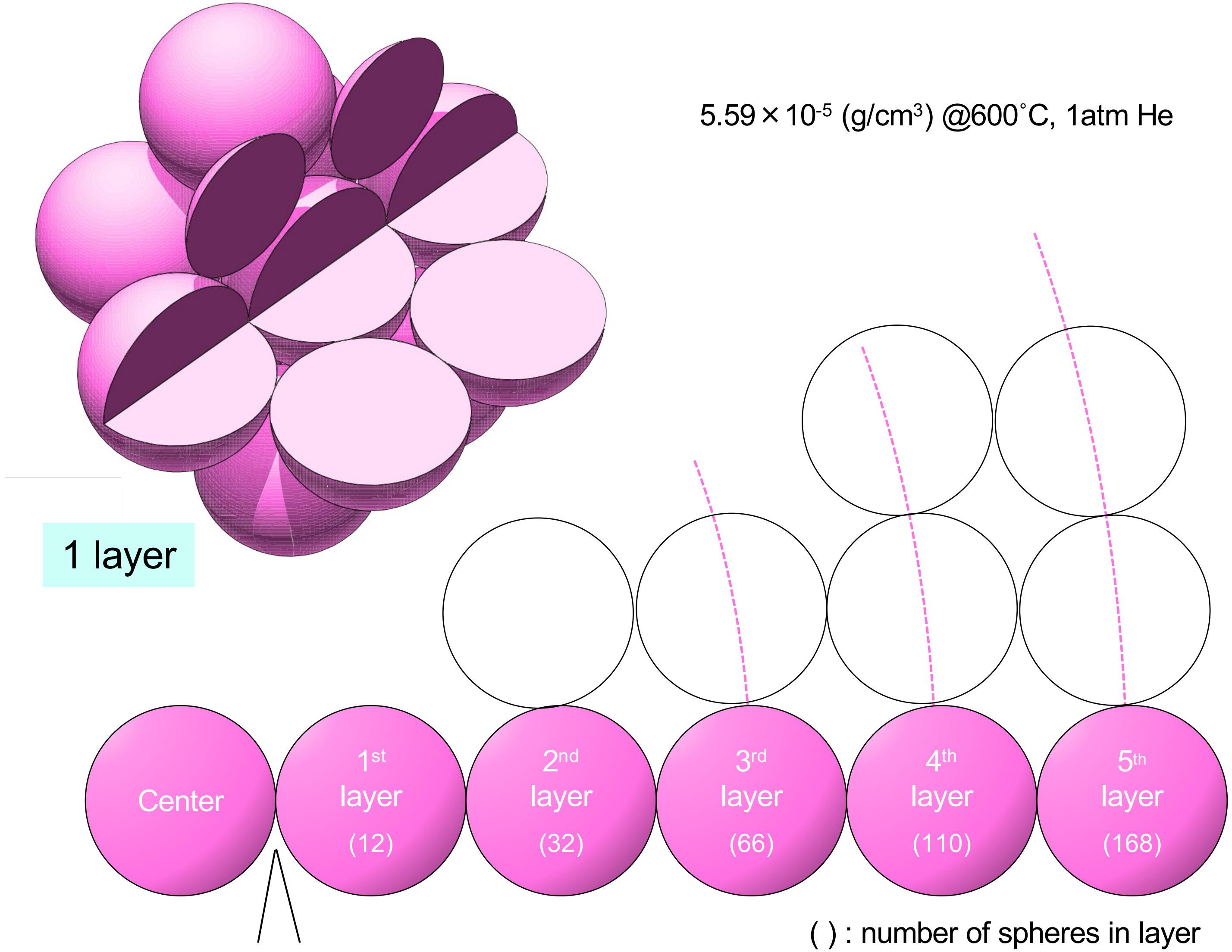
3) But, α irradiation from surrounded beryllium

Calculation model

5.59×10^{-5} (g/cm^3) @600˚C, 1atm He



Single



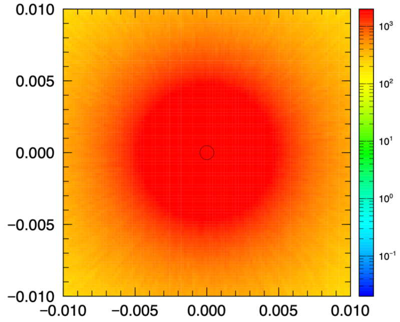
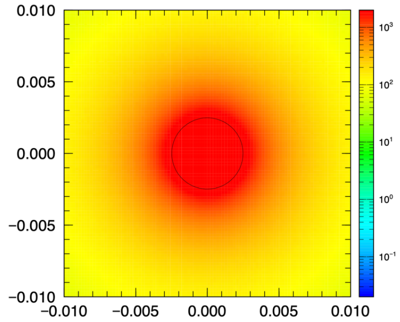
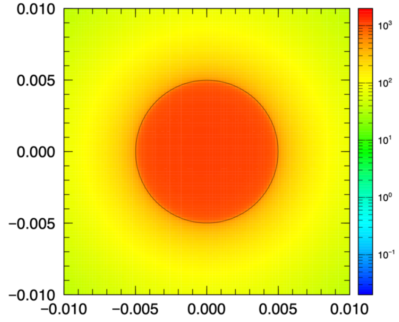
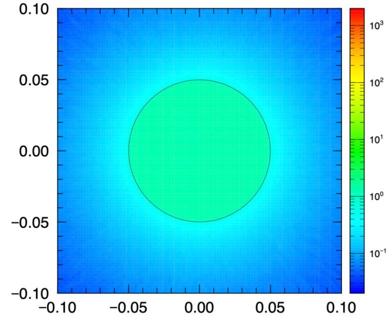
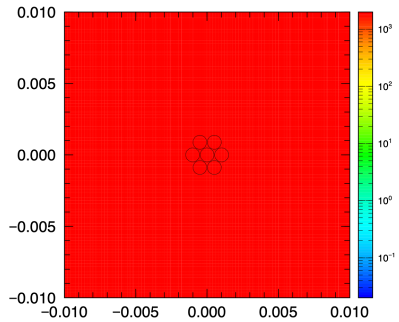
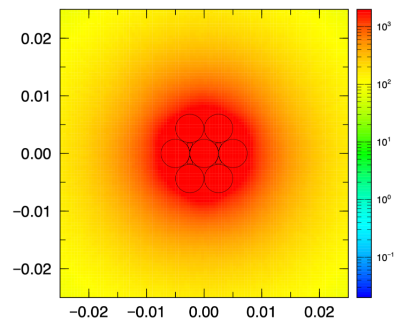
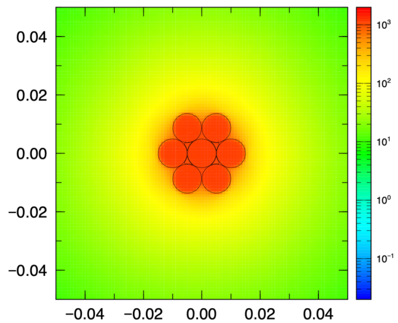
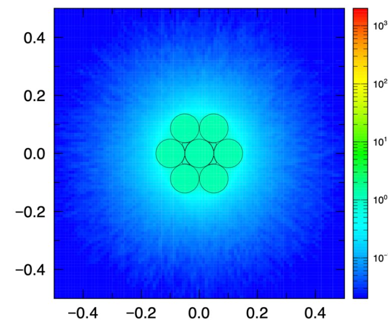
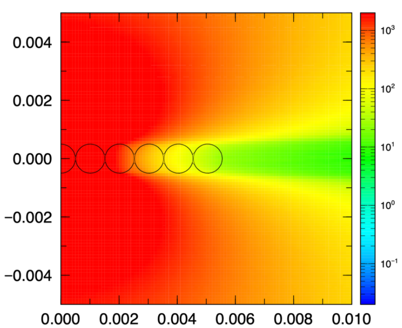
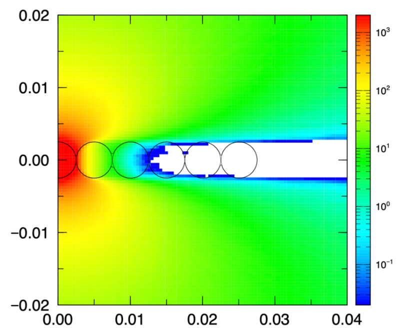
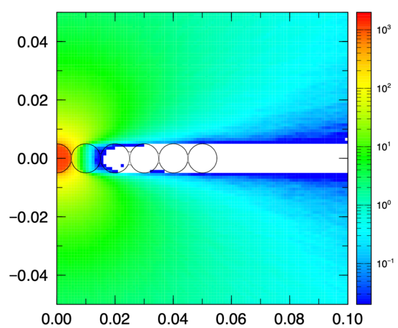
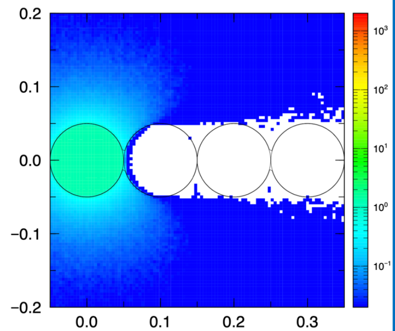
1 layer

( ) : number of spheres in layer

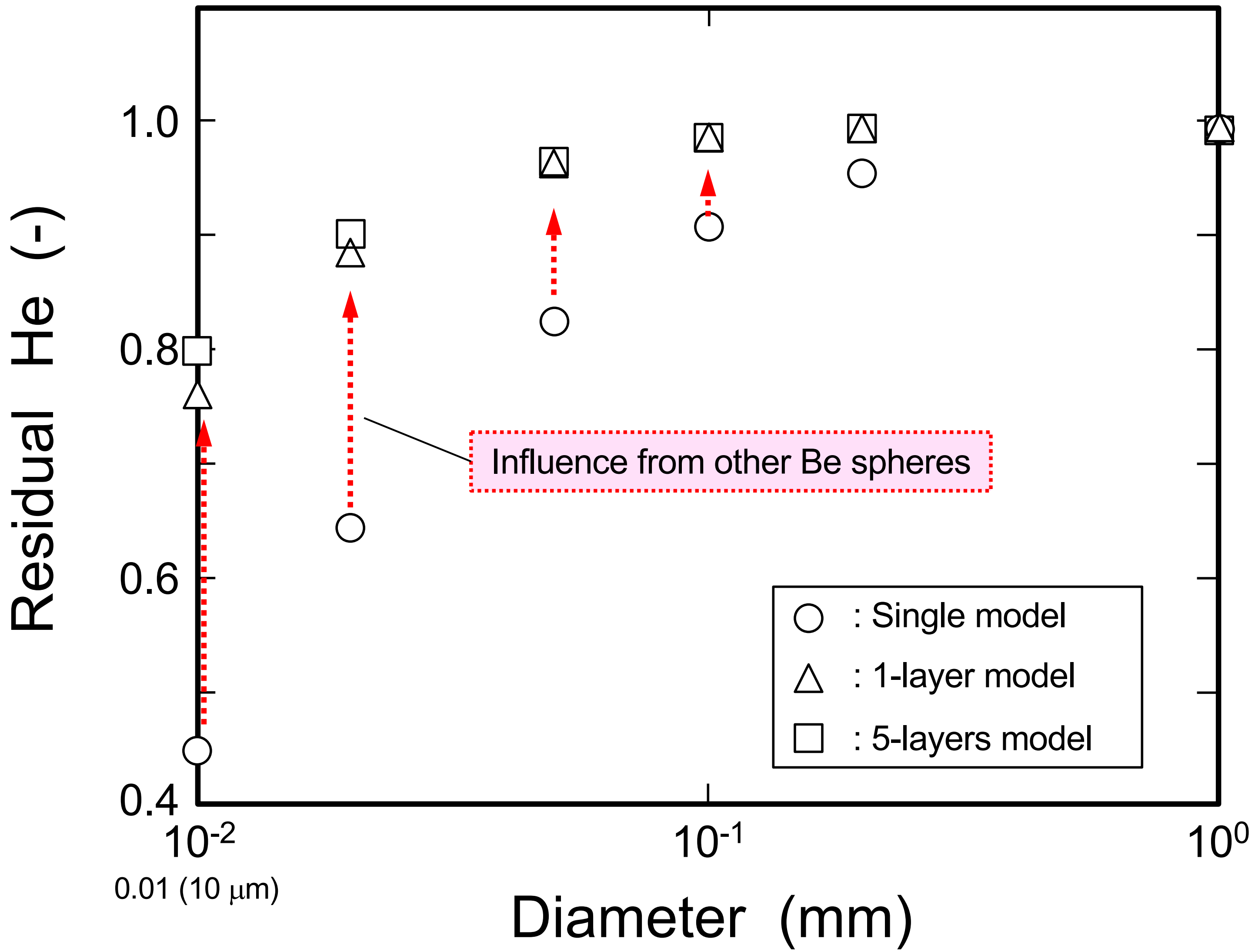
5 layers

2D He flux in Be

Unit: x, y axis (cm), He flux ($1/cm^2$/source)

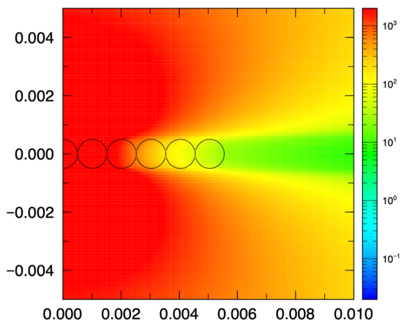
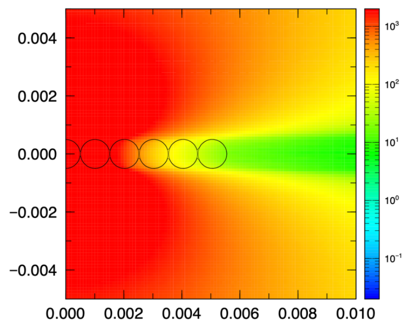
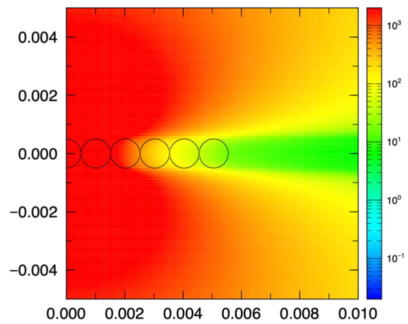
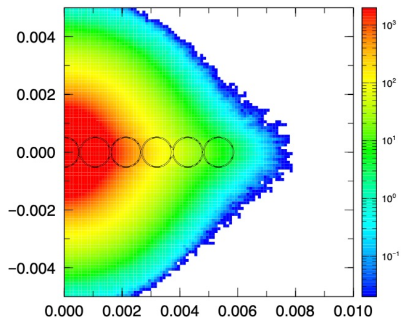
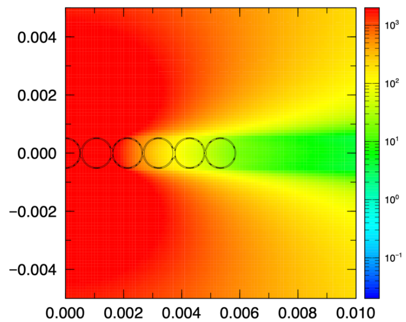
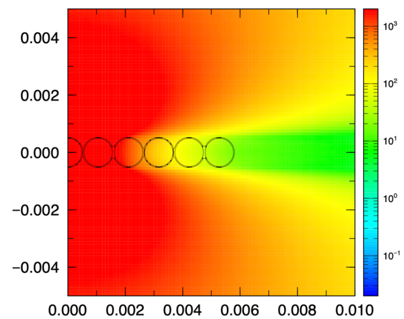
Model	Diameter (mm)			
	0.01 (10 μm)	0.05	0.1	1.0
Single				
1-layer				
5-layers				

Residual He in Be



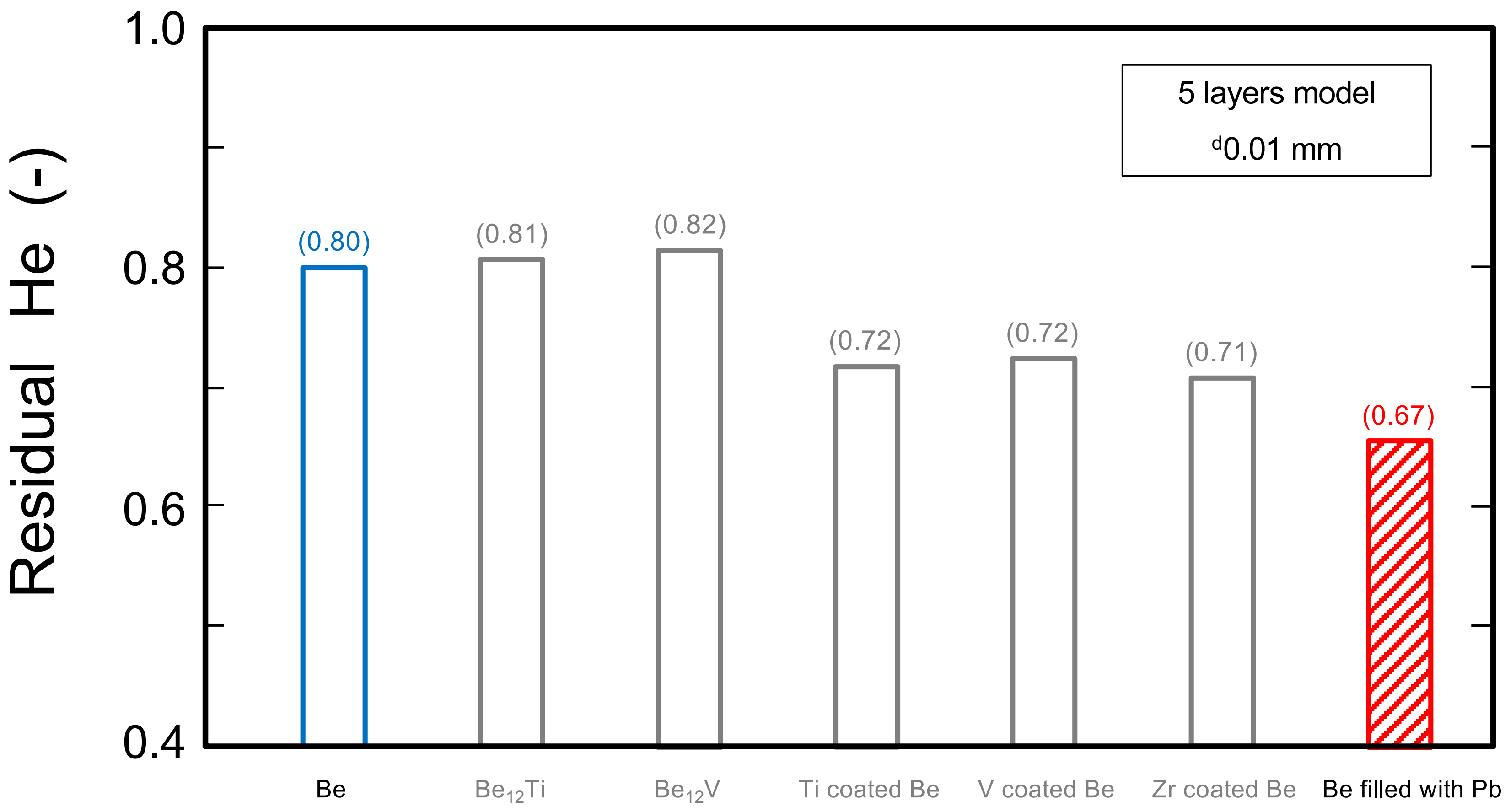
Effects of materials (1)

Unit: x, y axis (cm), He flux ($1/cm^2$/source)

Model	Materials		
	Be	$Be_{12}Ti$	$Be_{12}V$
5 layers ^{d}0.01 mm (600˚C, 1 atm)			
	Be filled with Pb	Ti coating (0.29* μm)	V coating (0.23* μm)
			

* : Same atomic proportions with intermetallic compounds

Effects of materials (2)



History of Neutron Multipliers

Development Year	1990s		2000 ~	2010 ~	2025 ~
Material name	Porous Beryllium	Beryllium pebble	Beryllium Intermetallic Compounds	Beryllium Intermetallic Compounds pebble	Beryllium powder Lead filling
Chemical form	Be		$Be_{12}Ti$, $Be_{12}V$ etc.		Be, Pb
Melting point (˚C)	1287		$Be_{12}Ti$: 1520 $Be_{12}V$: 1700		Be: 1287 Pb: 328 (Used in liquid form)
Neutron multiplication effect	2 (Smaller by void volume)	2 (Smaller by void volume)	3 (Smaller by Ti, V volume)	1 (Smaller by void and Ti, V volume)	4 (Added lead multiplication effect in Be gap)
Swelling reduction measures (Movement of He)	1 (Most of He remains in Be. He released into the voids)	1 (Most of He remains in Be. He released into the voids)	2 (Most of He remains in material. High strength prevents deformation)	3 (Most of He remains in material. High strength prevents deformation. He released into the voids)	4 (Recoiled He is actively utilized by smaller-sized. Approximately 33% is emitted to system outside)
Processing and reuse	3 (High cost of reshaping)	3 (High cost of reshaping)	2 (High cost of reshaping at high temperature. Separation of Ti, V, etc. is difficult)	1 (High cost of reshaping at high temperature. Separation of Ti, V, etc. is difficult)	4 (Easy to separate by differences of melting point and density, no need to reshape, potential for long-term use)
Production cost (Scale)	3 (Laboratory scale)	3 (Laboratory scale)	2 (Laboratory scale)	1 (Laboratory scale)	4 (Industrial scale)
Total evaluation	9	9	9	6	16

Higher number means better

Problems for irradiation test

- ✓ High-temperature neutron irradiation tests require a temperature-controlled irradiation capsule with a measurement line costing 0.3-0.5 M$.
- ✓ Online measurement of helium and tritium requires irradiation equipment costing a few M$.
- ✓ Protection against tritium released from beryllium is necessary (required to dismantle capsule devices while absorbing tritium).
- ✓ It cannot be achieved with small research budgets.
- ✓ International cooperation is necessary.