Evaluation of Nuclear Heating, DPA and Induced Radioactivity in Main Components

- Overview calculation methods & results
- Give a base for designing main components which are subjected to nuclear processes

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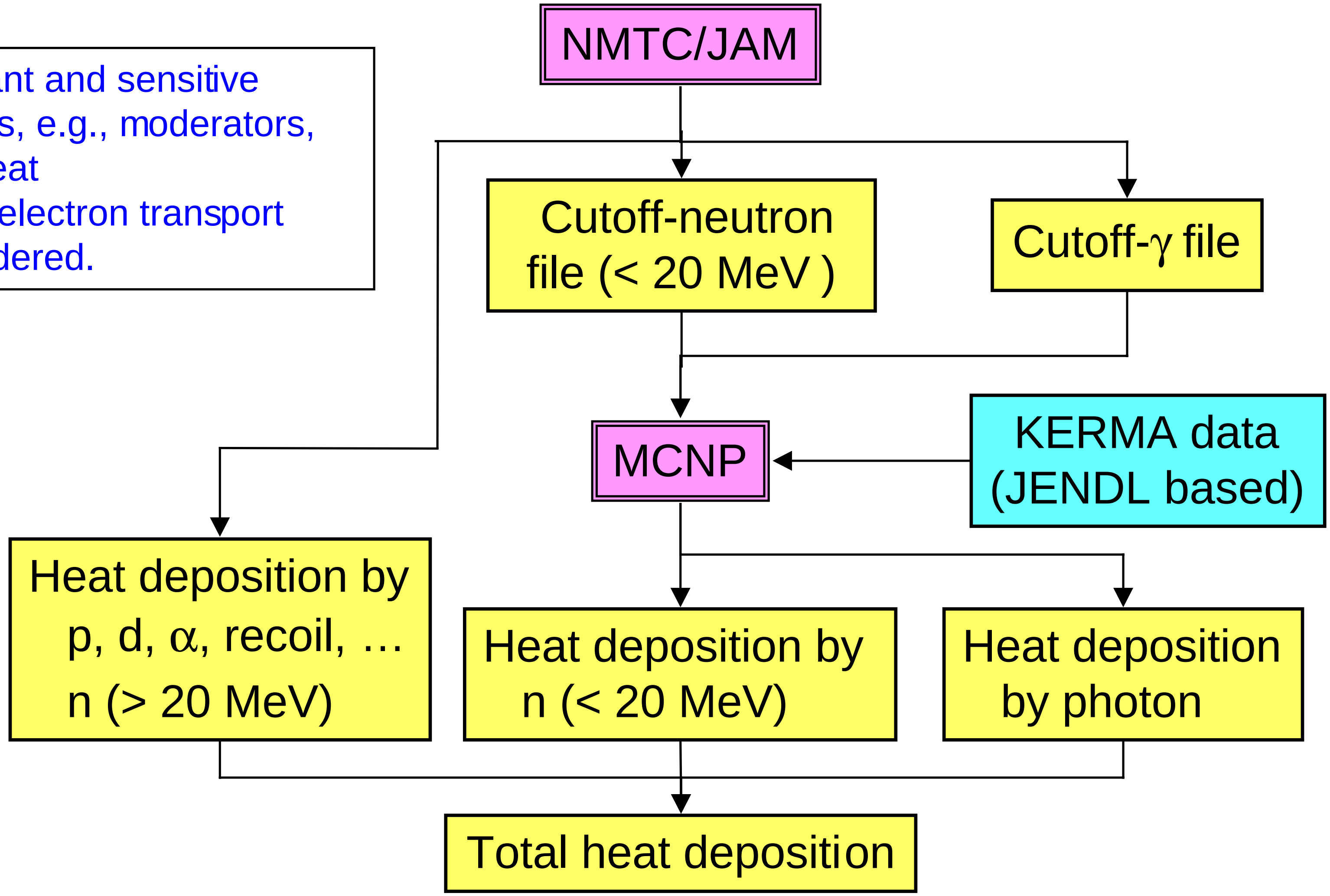
Nuclear Heating: Code & Data

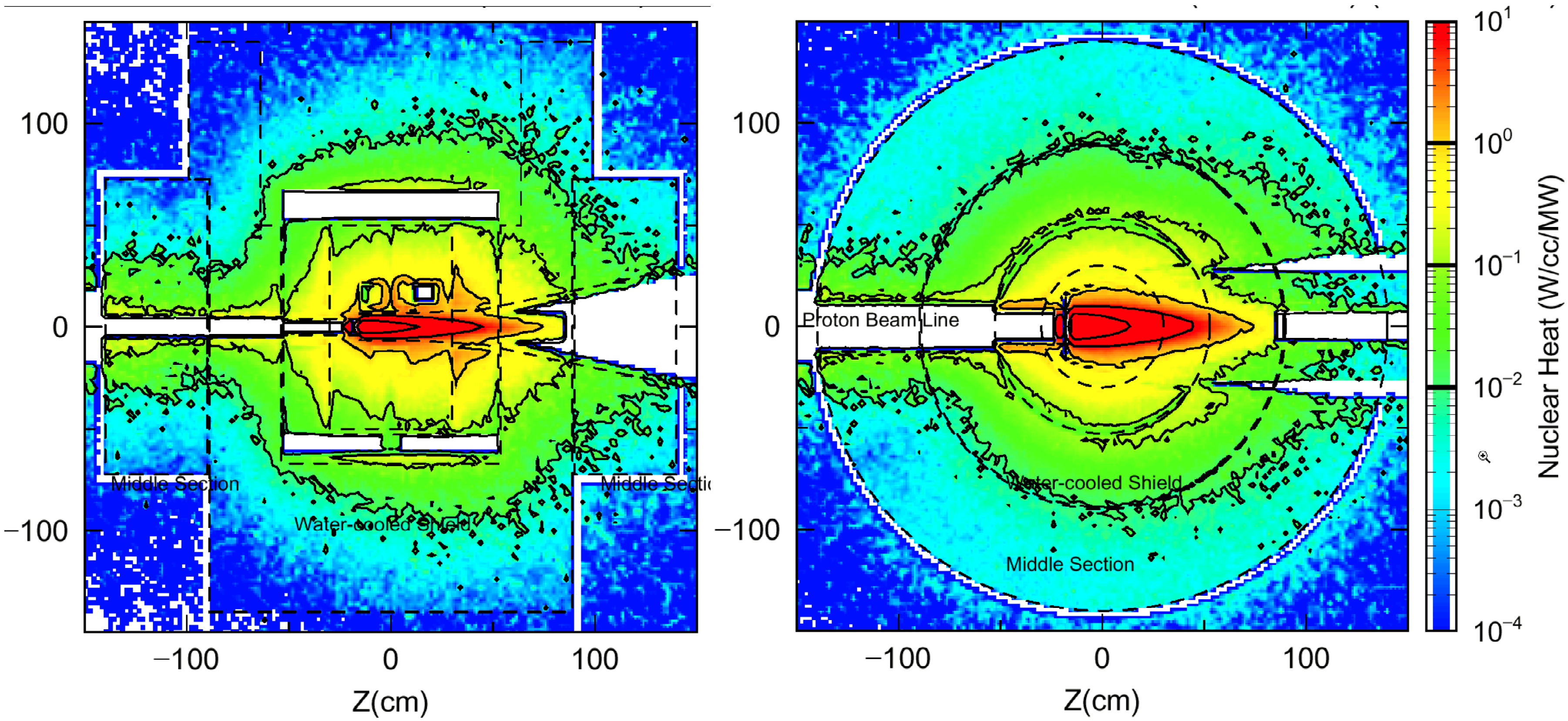
For important and sensitive components, e.g., moderators,
- decay heat
- detailed electron transport

were considered.



Nuclear Heating: Results

Nuclear heat density distributions @ 1 MW

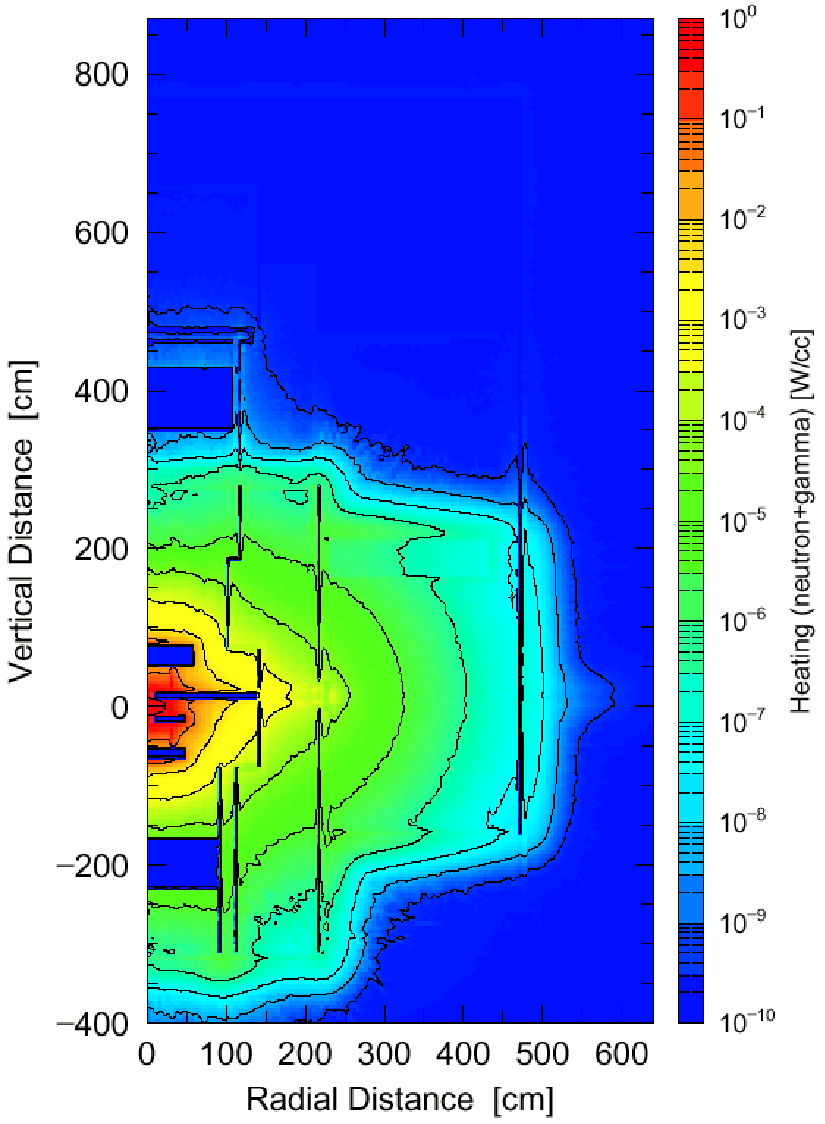


Vertical

Horizontal

Nuclear Heating: Results

Nuclear heat density distributions @ 1 MW



Nuclear Heating: Results

- Heat Load [kW]

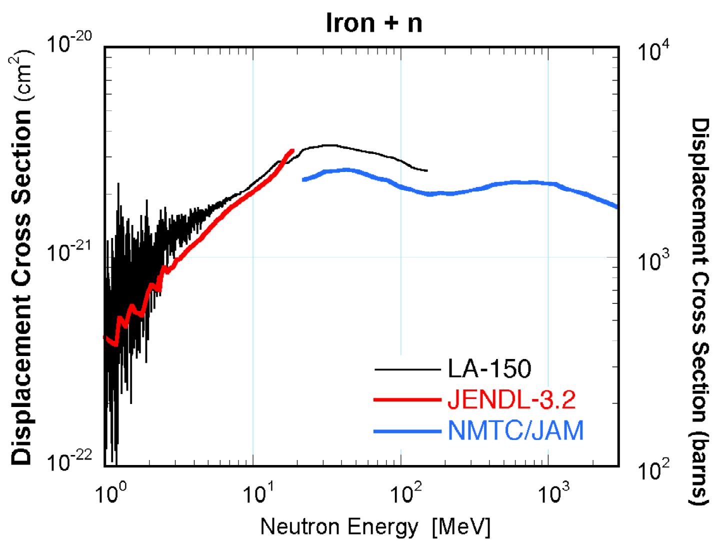
–	Target	533.9
–	Reflector	196.4
–	Reflector plug	11.0
–	Moderator	
•	H_2	4.2
•	H_2O	18.9
–	Proton beam window	3.1
–	Water-cooled shield	94.2
–	Helium vessel	28.1
–	Shield	~10.0
–	Total	~ 900 kW

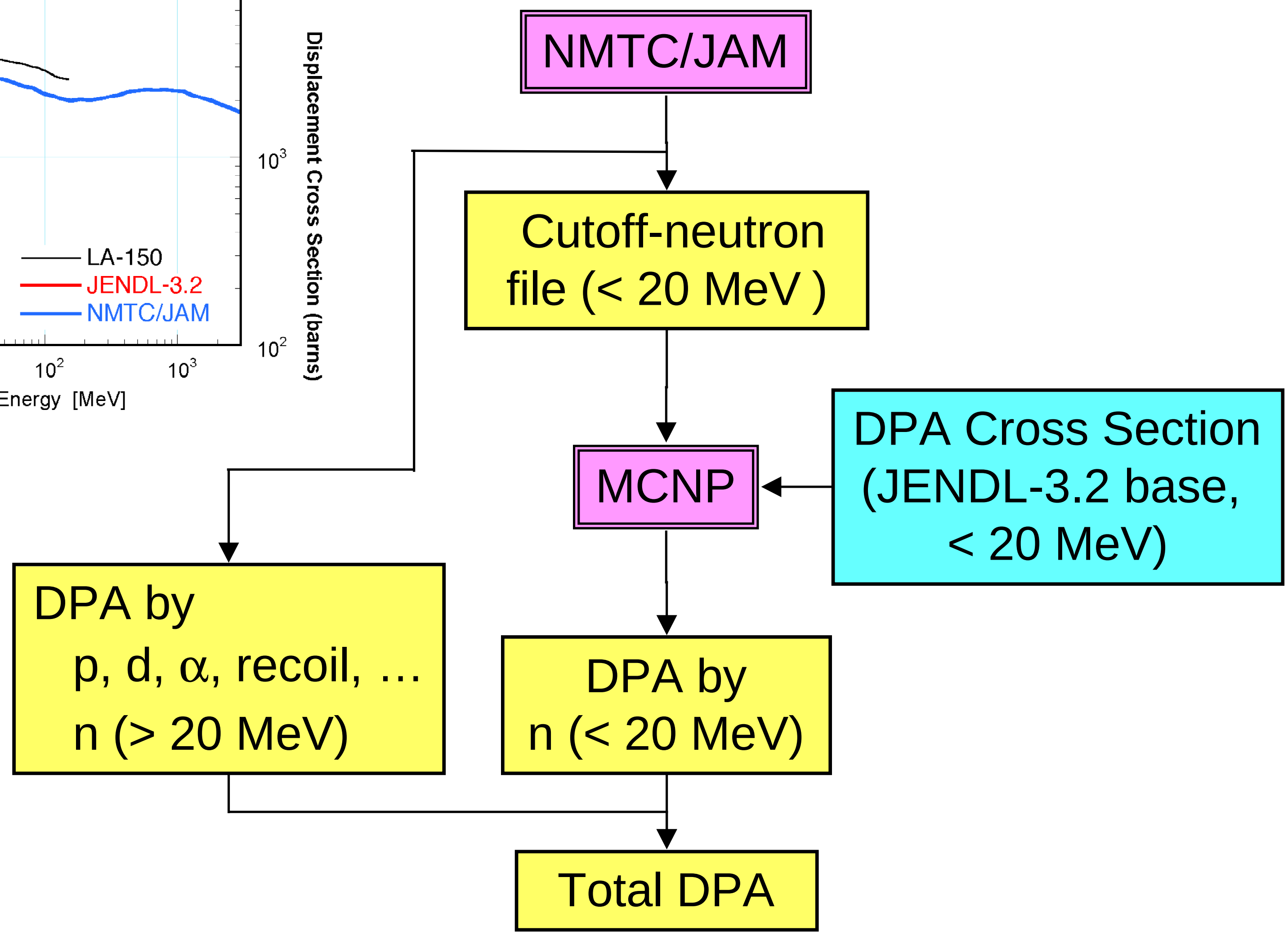
Peak heat density [W/cm^3]

–	Proton beam window	310	Inconel-718
–	Target	630	Hg
–		320	SS-316L
–	Reflector	6.0	Al
–	Moderator	3.4	Al
–		1.2	H2
–	Water-cooled shield	0.8	SS-316L
–	Helium vessel	0.2	SS-316L

Values for 1 MW @ the PBW

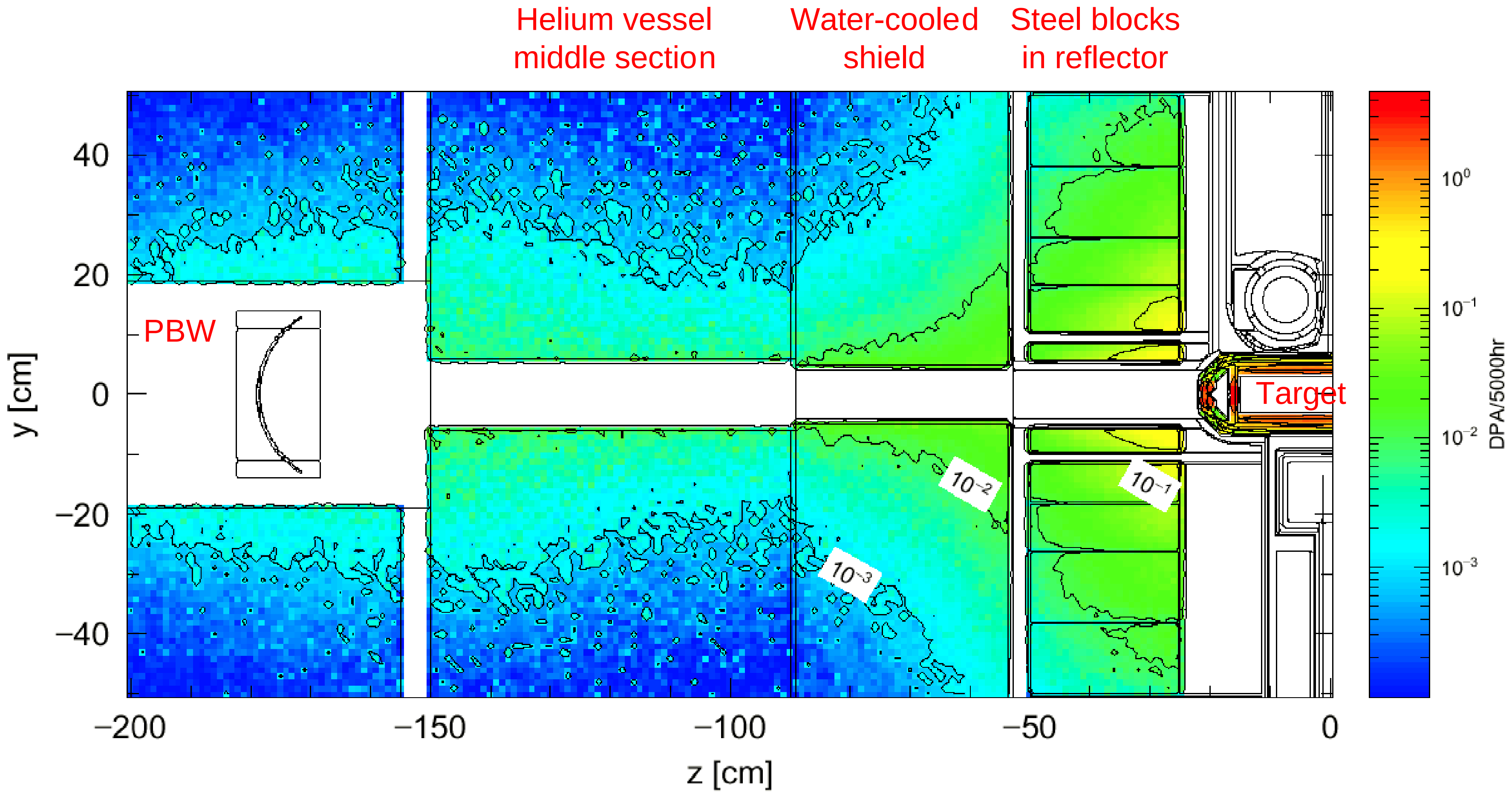
DPA: Code & Data





DPA: Results

DPA of iron & stainless steel for 1 MW-5,000 hr. operation

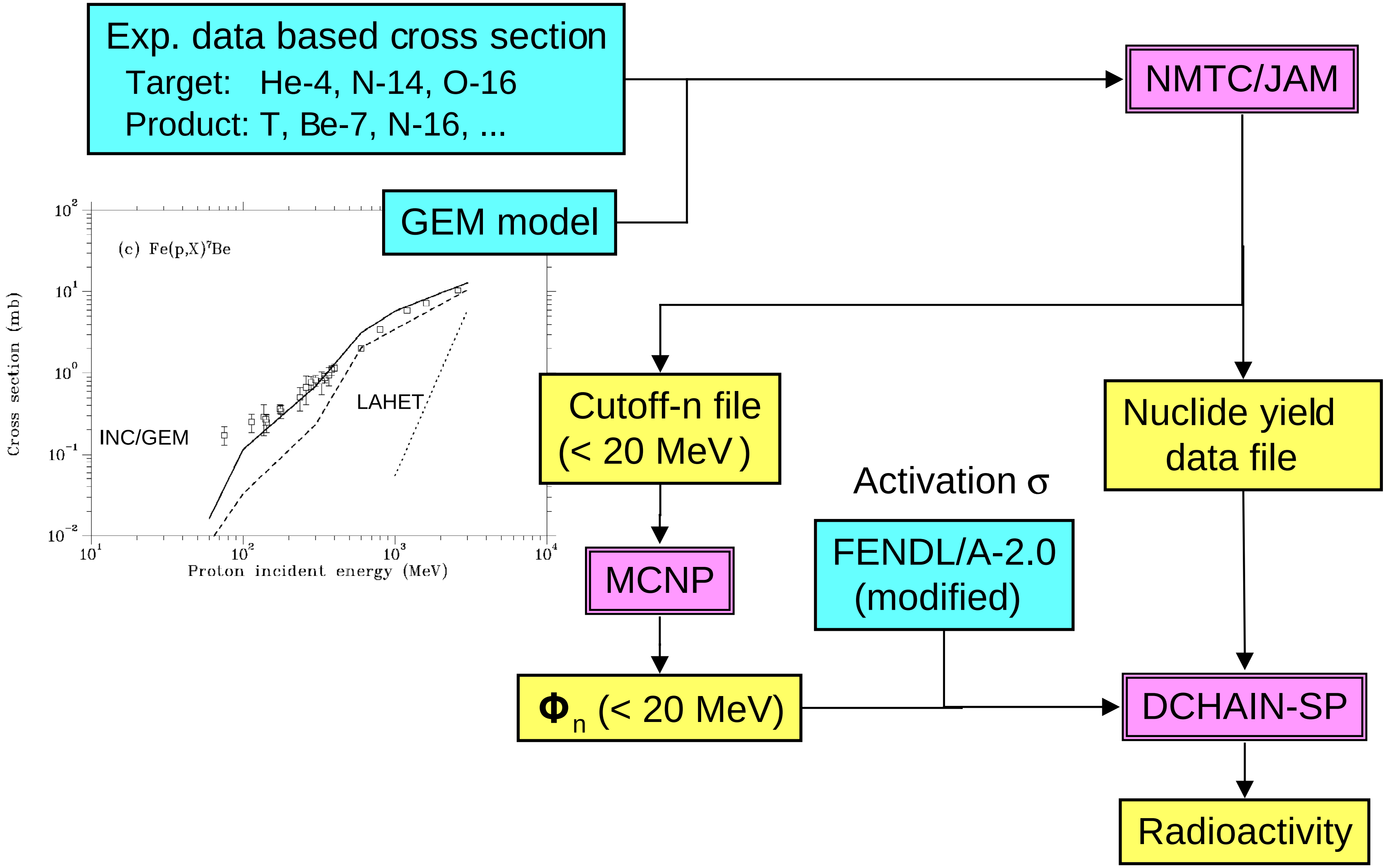


DPA: Results

- **Maximum DPA for 1 MW, 5000 hr**

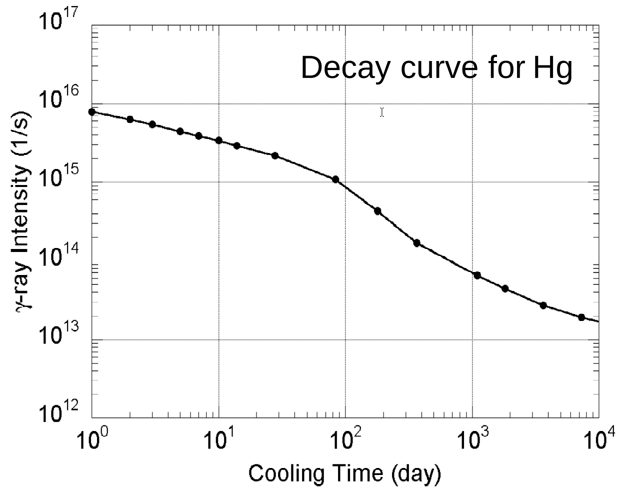
– Proton beam window:	4.0	Inconel-718
– Mercury target:	10.0	SS-316L
– Moderator:	3.0	Aluminum alloy
– Reflector:	3.5	Aluminum alloy
– Water-cooled shield:	~ 0.03	SS-316L
– Helium Vessel:	~ 0.01	SS-316L

Induced Radioactivity: Code & Data

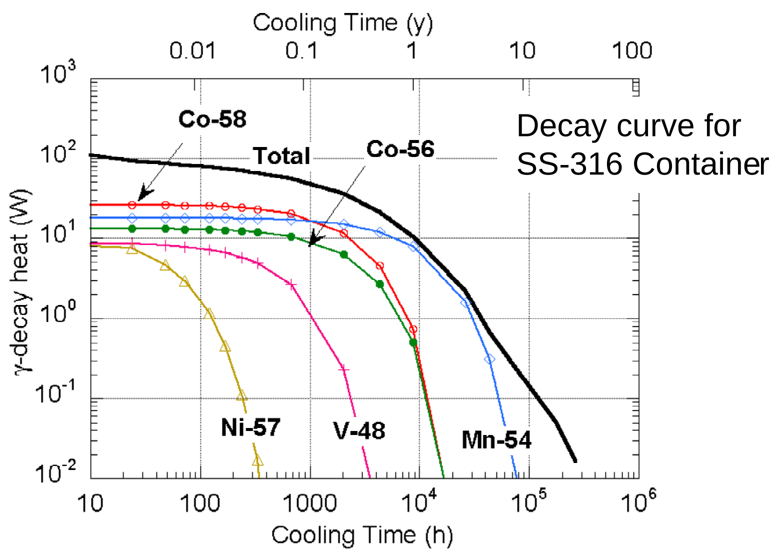


Induced Radioactivity: Results

TARGET



1 MW - 5000 hr. operation, 48 hr. cooling



Major radioactivity in mercury

Nuclide	Half-Life	Activity [TBq]
H-3	12.3 y	92.0
I-125	59.4 d	15.0
Xe-122	20.1 h	1.3
Xe-127	36.4 d	13.0
Hg-194	520 y	0.3
Hg-195g	9.9 h	94.0
Hg-195m	41.5 h	120.0
Hg-197g	64.1 h	1,600.0
Hg-197m	23.8 h	230.0
Hg-203	46.6 d	2,300.0

Induced Radioactivity: Results

Cooling Water

Total tritium activity after 30 years operation.

^{3}T

	Activity [TBq]
Safety-hull of the target	6.10
Reflector	7.20
Target trolley	0.07
Helium vessel	5.30
Proton beam window	0.64
Moderators	4.50

Saturated activity at an exit of each cooling channel for 1 MW operation

Nuclide	Half-Life [s]	Satureted Activity [MBq/cm3]			
		Safety-hull of the target	Reflector	Proton beam window	moderators
Be-7	4.6E+06	1.20	0.19	0.26	1.10
C-10	19.3	4.70	0.38	1.20	2.60
C-11	1223	2.70	0.55	0.32	2.90
N-13	598	2.00	0.35	0.31	2.00
N-16	7.1	180.00	33.00	3.10	190.00
O-14	70.6	7.50	0.58	2.30	4.70
O-15	122	19.00	3.10	2.30	18.00

Induced Radioactivity: Results

Moderators

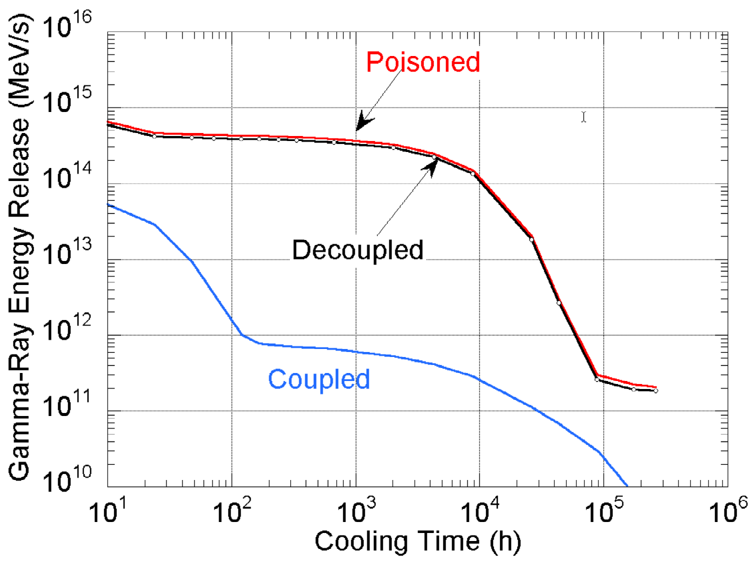
1 MW - 10 years operation, 5 days cooling

The activation level of the decoupled and poisoned moderators are 100 times as large as that of the coupled moderator after 100 hours cooling.

The ^{110m}Ag ($T_{1/2}$ = 250 days) that is produced by the $^{109}Ag(n,\gamma)^{110m}Ag$ reaction in the Ag-In-Cd-alloy decoupler is dominant.

Activity of ^{110m}Ag: ~ 10^{14} Bq

Decay curve for the three moderators



Induced Radioactivity: Results

Reflector

1 MW - 10 years operation, 5 days cooling

The activation level of neutron absorption liners made of the Ag-In-Cd-alloy is the largest due to ^{110m}Ag ($T_{1/2}$ = 250 days).

The activation level of SS-316 reflector blocks is also high. The most troublesome nuclide is Co-56, a high-energy gamma-ray emitter, produced from nickel.

--> We decided to use usual steel (nickel less) instead of stainless steel to reduce the activation level.

Major radioactivities in the reflector

	Nuclide	Half-Life	Activity [TBq]
SS-316	V-48	16.0 d	35
	Cr-51	27.7 d	2200
	Mn-54	312 d	460
	Fe-59	44.5 d	80
	Co-56	77.3 d	69
	Co-58	70.8 d	340
	Mo-99	2.75 d	220
Ag-In-Cd alloy	Ag-106m	8.28 d	28
	Ag-108m	418 y	0.23
	Ag-110m	250 d	260