Fusion Neutronics Meeting

April 10, 2024

Study of the D1SUNED transport subroutines for future optimizations in benefit of ITER nuclear analyses

P. Guijosa[1], J. Alguacil[1], G. Pedroche[1,2], R. Juárez[1] & P. Sauvan[1]

[1]Universidad Nacional de Educación a Distancia (UNED)
[2]Universidad Politécnica de Madrid (UPM)

Introduction

In the last decade, the MCNP models used in ITER nuclear analyses have evolved significantly

Tokamak Models

(Partial)

↓

E-lite (360º)

Tokamak Complex Models

(Radmaps 2016 & 2020)

→ **ITER full model (prototype)** ←

Motivation

Since 2022, the UNED team has been working on the design of an ITER integral representation.

However:

The computational complexity of these models has been increasing:

- More surfaces
- More cells
- More materials

Computational demand

Although the UNED team has improved D1SUNED in the past:

- We need more improvements and optimisations

Transport is demanding

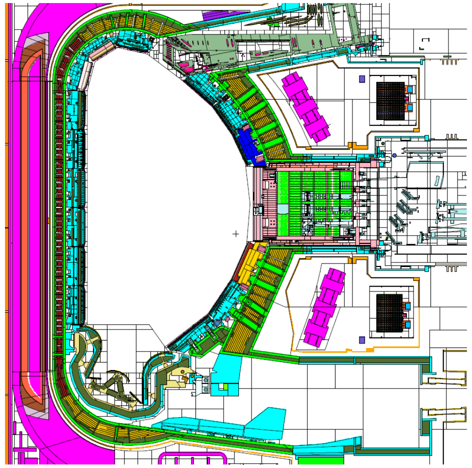
Even with HPC infrastructures, using integral representations for the ITER nuclear analyses seems challenging

→

We studied the time consumption of the transport subroutines of D1SUNED for future optimisations

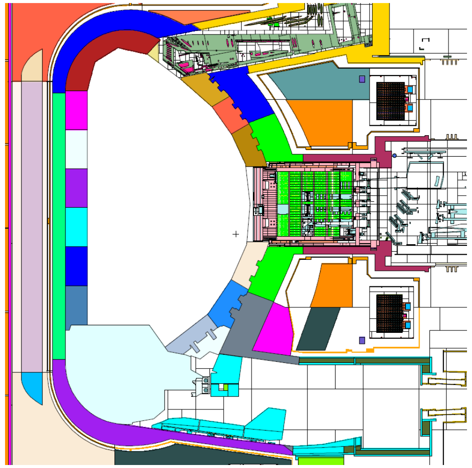
Methodology

Using E-lite



Heterogenous C-model

Using a homogenisation tool



Homogenised C-model

Transport in the HET model

Time consumptions by the transport algorithm for N transport using the HET model

Action	Time (min)	% Transport
chkcel	1214.04	3.00
track	14376.60	35.56
surfac	14913.84	36.89
Collisions	795.37	1.97
Bank	733.48	1.81
N data	4172.39	10.32
P data	-	-
Transport	40431.03	100.00

Time consumptions by the transport algorithm for NP transport using the HET model

Action	Time (min)	% Transport	Time NP/N
chkcel	7626.39	2.81	6.28
track	71891.55	26.46	5.00
surfac	34471.78	12.69	2.31
Collisions	9005.19	3.31	11.32
Bank	116561.11	42.90	158.91
N data	4509.49	1.66	1.08
P data	12182.84	4.48	-
Transport	271732.08	100.00	6.72

- The **75.45%** of the N transport time is spent by the geometry subroutines.

- The **42.90%** of the NP transport time is spent by the increase in the number of accesses to the secondary particle bank.

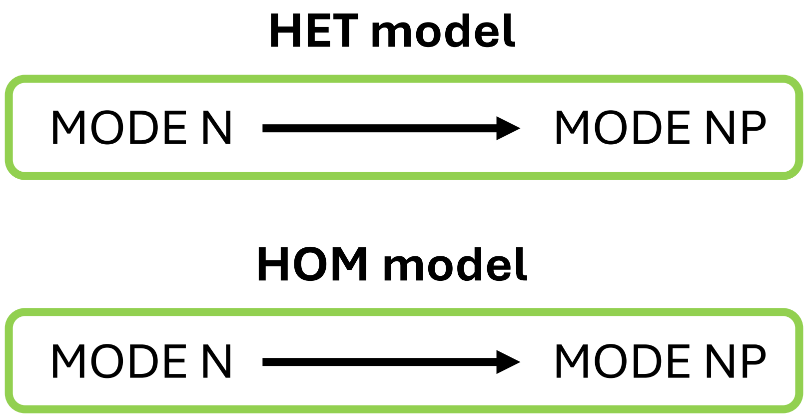
Transport in the HOM model

In the case of the **HOM model**:

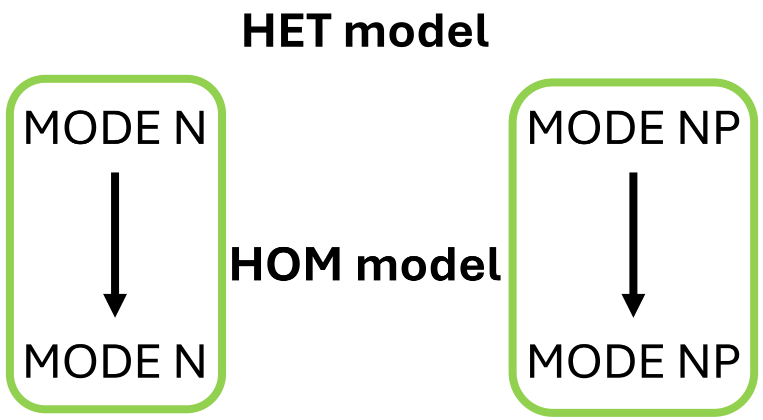
- In mode N, the geometry subroutines and the load of N nuclear data consume 34.62% and 38.44%. The bank accesses cosumes a 2.69%.

- 55.70% of the NP transport time is spent by the accesses to the secondary particle bank.

What did we do?



What can we do?



Transport in HET vs. HOM

UNED

Time consumptions by the transport algorithm for N transport using the HET and the HOM model

Action	Time (min)	% Transport	Time HOM/HET
chkcel	662.51	3.69	0.55
track	4359.91	24.27	0.30
surfac	1195.74	6.66	0.08
Collisions	594.87	3.31	0.75
Bank	483.46	2.69	0.66
N data	6903.79	38.44	1.65
P data	-	-	-
Transport	17960.95	100.00	0.44

- Transport time is reduced.

- The geometry subroutines are called less times and faster (x0.20 in mode N, x0.28 in mode NP).

It accelerates the simulations

Time consumptions by the transport algorithm for NP transport using the HET and the HOM model

Action	Time (min)	% Transport	Time HOM/HET
chkcel	3975.39	2.29	0.52
track	23223.73	13.36	0.32
surfac	4577.23	2.63	0.13
Collisions	7282.71	4.19	0.81
Bank	96820.03	55.70	0.83
N data	7091.96	4.08	1.57
P data	16752.42	9.64	1.38
Transport	173824.28	100.00	0.64

- Bank accesses and collisions decrease.

- Each load of nuclear data is more expensive.

Drawback?

Potential drawback

Does it entail a cost? We analysed Nuclear Heating (NH) tallies:

Relative deviations (%) of the NH tallies by contribution

Component	Total	Neutrons	Photons
Blanket	1.78	-14.09	6.67
Divertor	-8.98	25.12	-15.32
Vacuum Vessel	-53.10	0.21	-62.57
TFCs	-40.20	-32.72	-40.99
PFCs	120.37	132.32	118.82

The potential drawback is the distortion of the radiation fields forecast

To sum up

- Increase of the computational demand
- Transport phase is computationally expensive

It seems challenging to use integral representations

We studied the D1SUNED transport subroutines time consumptions

Results with HET model allowed to conclude:

- **The geometry subroutines are the main consumers for the N transport** → **Simplifying cells descriptions would be good too**
- **Accesses to secondary particle bank are for the NP transport**

We systematically demonstrated that the homogenization works as an acceleration technique → **However, it may entail the distortion of the radiation fields forecast**

Thank you for your time!

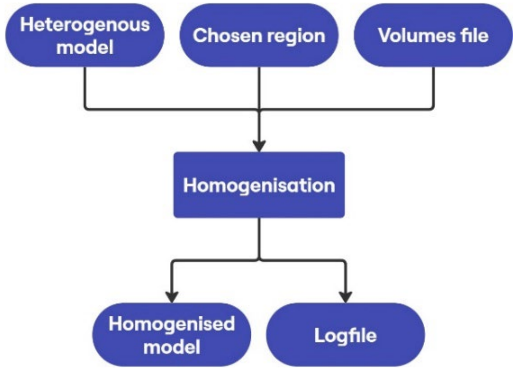
Additional slides

Models

Integrated parts from E-lite to the C-model

Region of the C-model	Integrated part of E-lite
Blanket Modules	Detailed Blanket Modules
Equatorial Port #11	Representative Diagnostics Equatorial Port
Equatorial Port #12	Diagnostics Equatorial Port #12
Equatorial Port #13	Ion Cyclotron Heating system
Upper Port #11	Representative Diagnostics Upper Port
Upper Port #12	Electron Cyclotron Heating systems
Upper Port #13	Electron Cyclotron Heating systems

Homogenisation workflow:



Homogenised Blanket, Divertor, Vacuum Vessel, TFCs and PFCs

Calls to the subroutines

Calls to the bank and the collisions subroutines using the HET model

Action	N transport	NP transport	NP/N
Collision	9.88e9	4.88e10	4.94
Bank	6.79e7	1.08e10	159.40

Calls to the bank and the collisions subroutines using the HOM model

Action	N transport	NP transport	NP/N
Collision	7.41e9	4.03e10	5.44
Bank	4.64e7	9.04e9	194.75

Calls of subroutines for the N transport

Action	HET	HOM	HOM/HET
chkcel	9.55e9	7.09e9	0.74
track	1.69e10	8.81e9	0.52
surfac	2.39e10	1.02e10	0.43
Collision	9.88e9	7.41e9	0.75
Bank	6.79e7	4.64e7	0.68
N data	1.44e10	8.18e9	0.57

Calls of subroutines for the NP transport

Action	HET	HOM	HOM/HET
chkcel	4.73e10	3.88e10	0.82
track	7.93e10	4.60e10	0.58
surfac	1.10e11	5.16e10	0.47
Collision	4.88e10	4.03e10	0.83
Bank	1.08e10	9.04e9	0.84
N data	1.44e10	8.18e9	0.57
P data	5.48e10	3.56e10	0.65

Homogenization results

NH (in Watts) results for N and P

Component	HET	HOM	Rel. Dev. (%)
Blanket	4.56e7	4.64e7	1.78
Divertor	5.98e6	5.44e6	-8.98
Vacuum Vessel	2.05e6	9.59e5	-53.10
TFCs	3.32e3	1.98e3	-40.20
PFCs	1.04e2	2.30e2	120.37

NH (in Watts) results for N

Component	HET	HOM	Rel. Dev. (%)
Blanket	1.08e7	9.24e6	-14.09
Divertor	9.37e5	1.17e6	25.12
Vacuum Vessel	3.08e5	3.09e5	0.21
TFCs	3.16e2	2.13e2	-32.72
PFCs	1.20e1	2.78e1	132.32

NH (in Watts) results for P

Component	HET	HOM	Rel. Dev. (%)
Blanket	3.49e7	3.72e7	6.67
Divertor	5.04e6	4.27e6	-15.32
Vacuum Vessel	1.74e6	6.50e5	-62.57
TFCs	3.00e3	1.77e3	-40.99
PFCs	9.24e1	2.02e2	118.82