# *E-lite 360° neutronics model of the ITER tokamak*

*6th October 2022*

G. Pedroche[1], R. Juarez[1], M. J. Loughlin[2], R. Pampin[3], P. Martinez[1], M. De Pietri[1], J. Alguacil[1], F. Ogando[1], P. Sauvan[1], A. J. Lopez-Revelles[1], A. Kolšek[1], E. Polunovskiy[2], M. Fabbri[3] and J. Sanz[1]

gpedroche@bec.uned.es

www.tecfir.com

[1] *TECF3IR, Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain*

[2] *ITER Organization, Saint-Paul-lez-Durance, France*

[3] *Fusion for Energy (F4E), Barcelona, Spain*

*3rd Workshop on Calibration of ITER Neutron Diagnostics*

## Disclaimer

This presentation reflects the views only of the author, and Fusion for Energy cannot be held responsible for any use which may be made of the information contained herein.

The views and opinions expressed herein do not necessarily reflect the views of the ITER Organization. The content of this presentation does not commit the ITER Organization as nuclear operator.

# Outline

**Introduction – Presentation of E-lite**

**Example of application of E-lite**

**Conclusions**

# Outline

**Introduction – Presentation of E-lite**

Example of application of E-lite

Conclusions

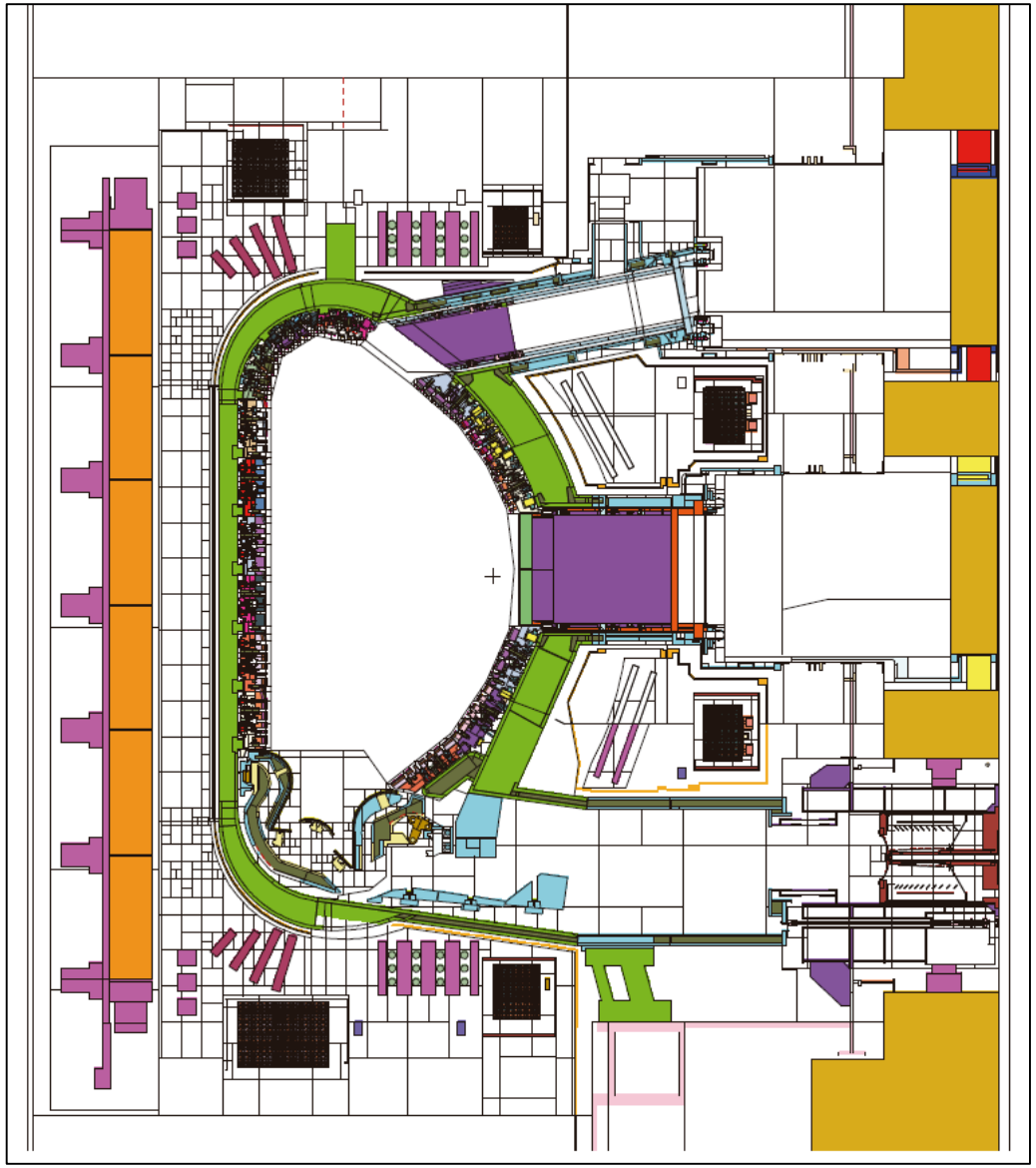
**An accuracy of 10% is demanded to the absolute measurement of the fusion power on ITER**

**Our understanding is that neutronics calculations will be relevant to support the accurate calibration of ITER neutron detectors**

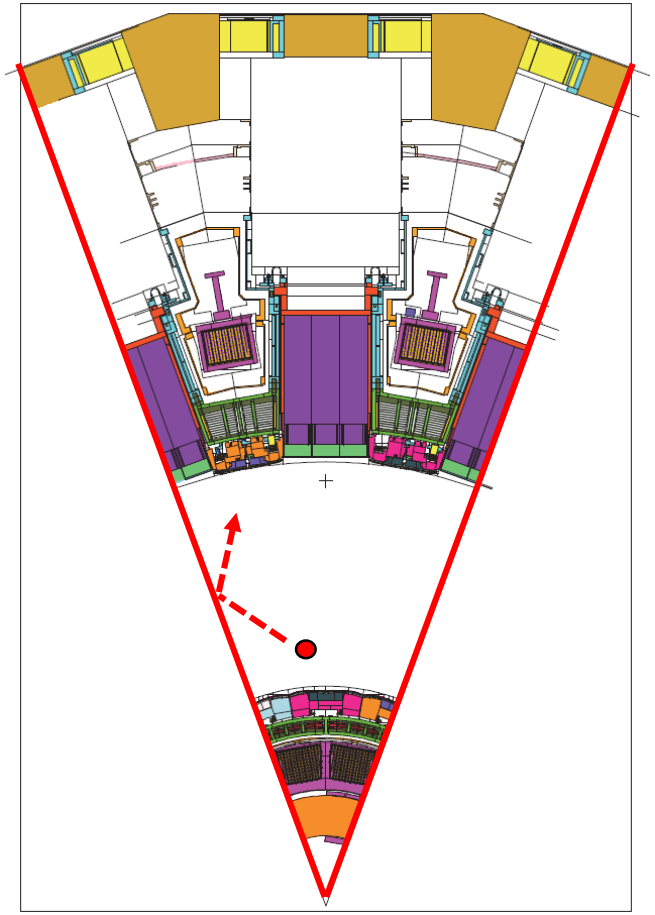
**To succesfully support the calibration, uncertainties in the neutronics calculations (uncertainties in nuclear data, source modeling, geometrical modelling…) have to be minimal**

**To minimize the geometry modelling uncertainties, ITER neutronics models have become very realistic**

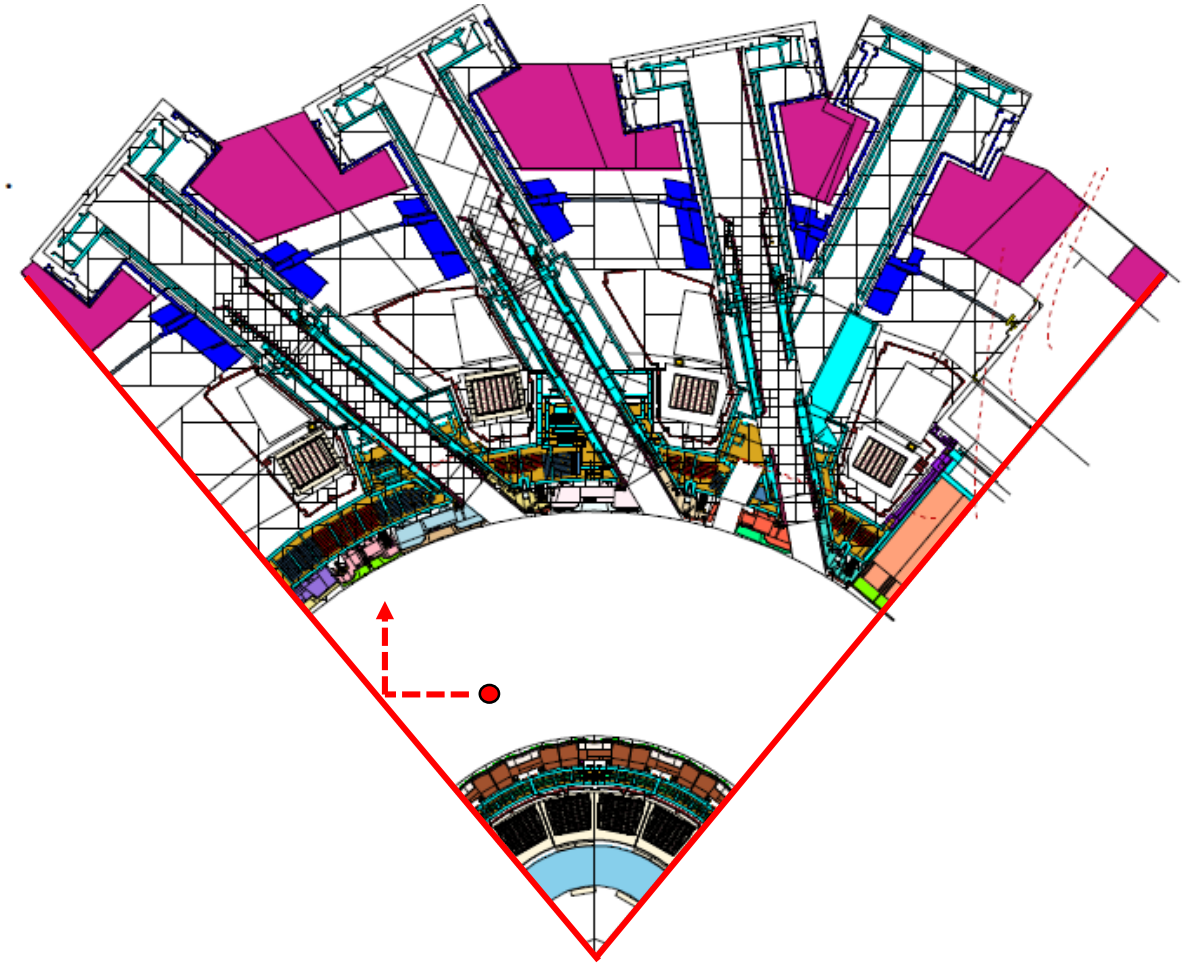
# C-model



# Reference models have always been partial models

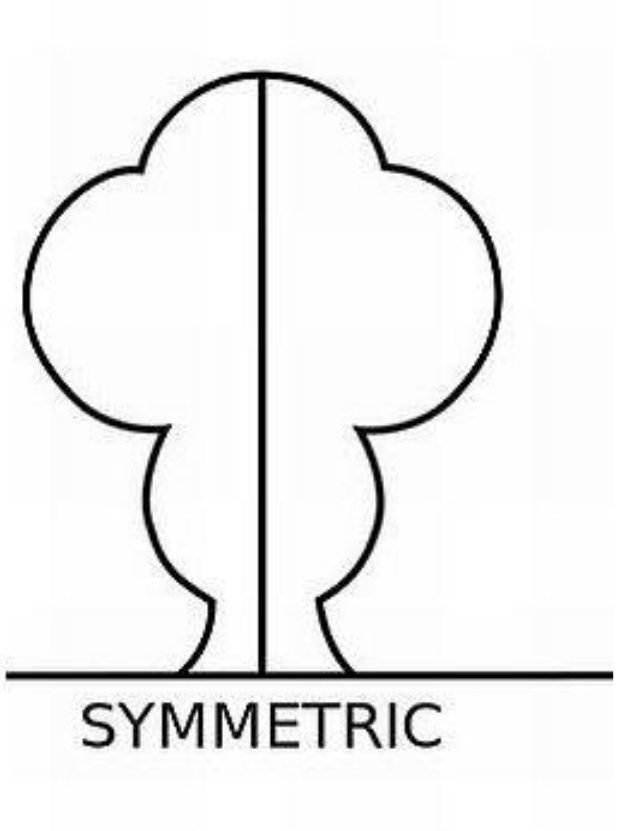


C-model (40°)

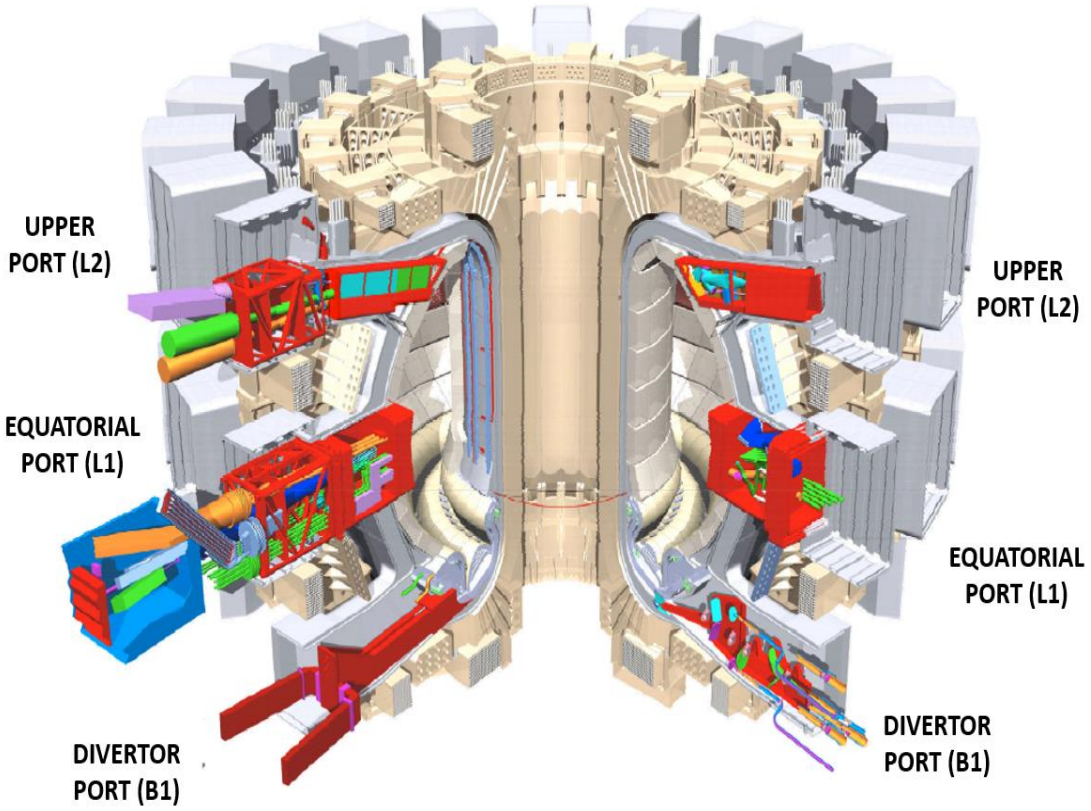


NBI model (80°)

## Representing the ITER machine with partial models has limitations




**Representation of the tokamak with partial models**



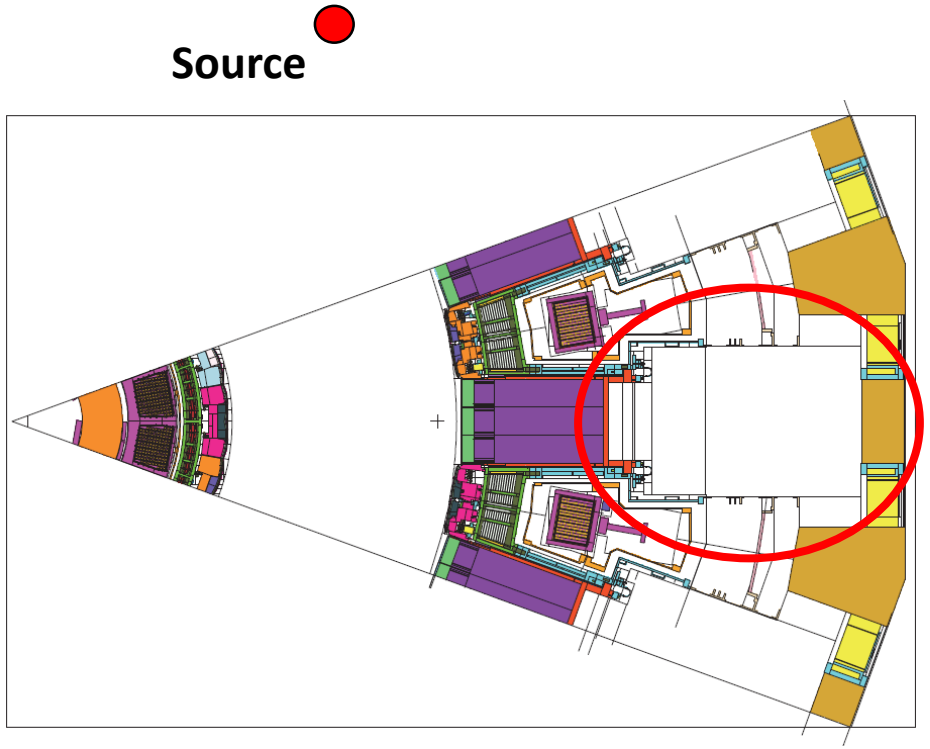

**ITER ports are the main source of asymmetry**

**The symmetry assumption is valid in many cases**

**However, there are cases in which it can introduce significant deviations in the results**

**This leads to unquantified uncertainties in the responses**

**In addition, partial models are not practical for certain applications**

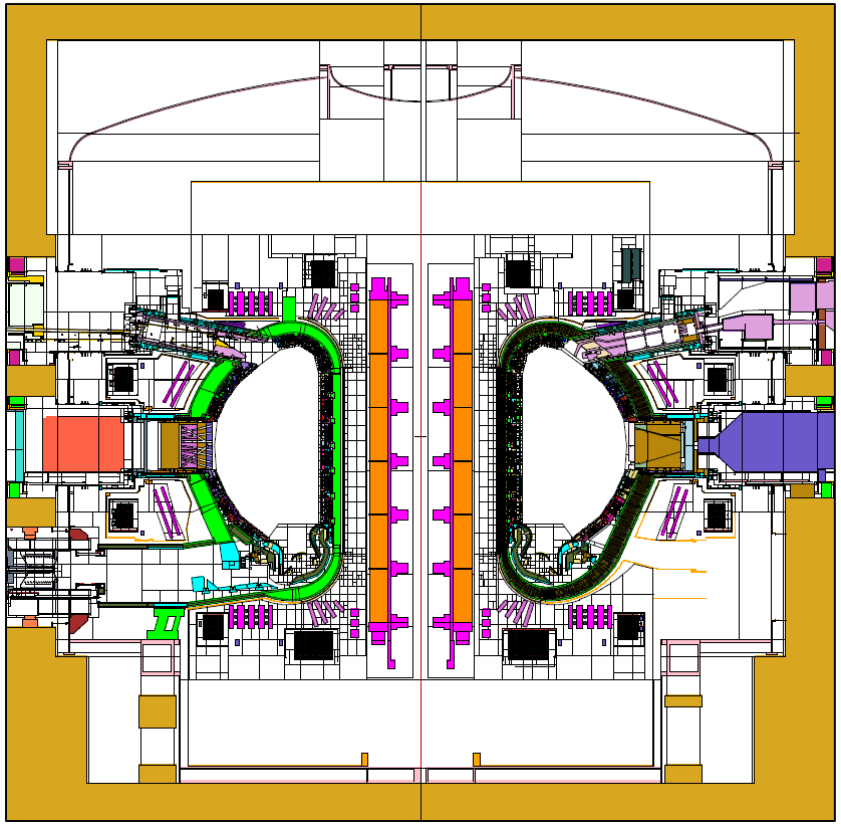


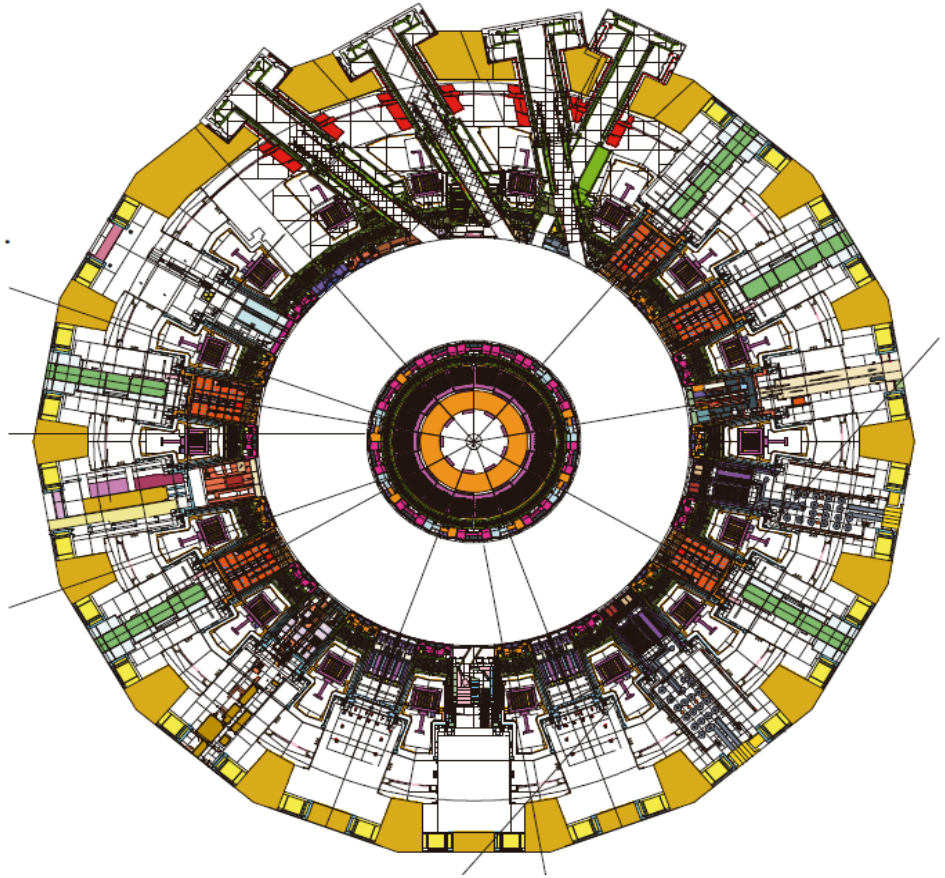

**Currently, to be able to simulate this situation with a partial model you need to remove the boundary conditions. Particles are transported through void!!!**

**These limitations affect the reliability and practicality of nuclear analyses that are important to demostrate the safe and succesful operation of ITER**

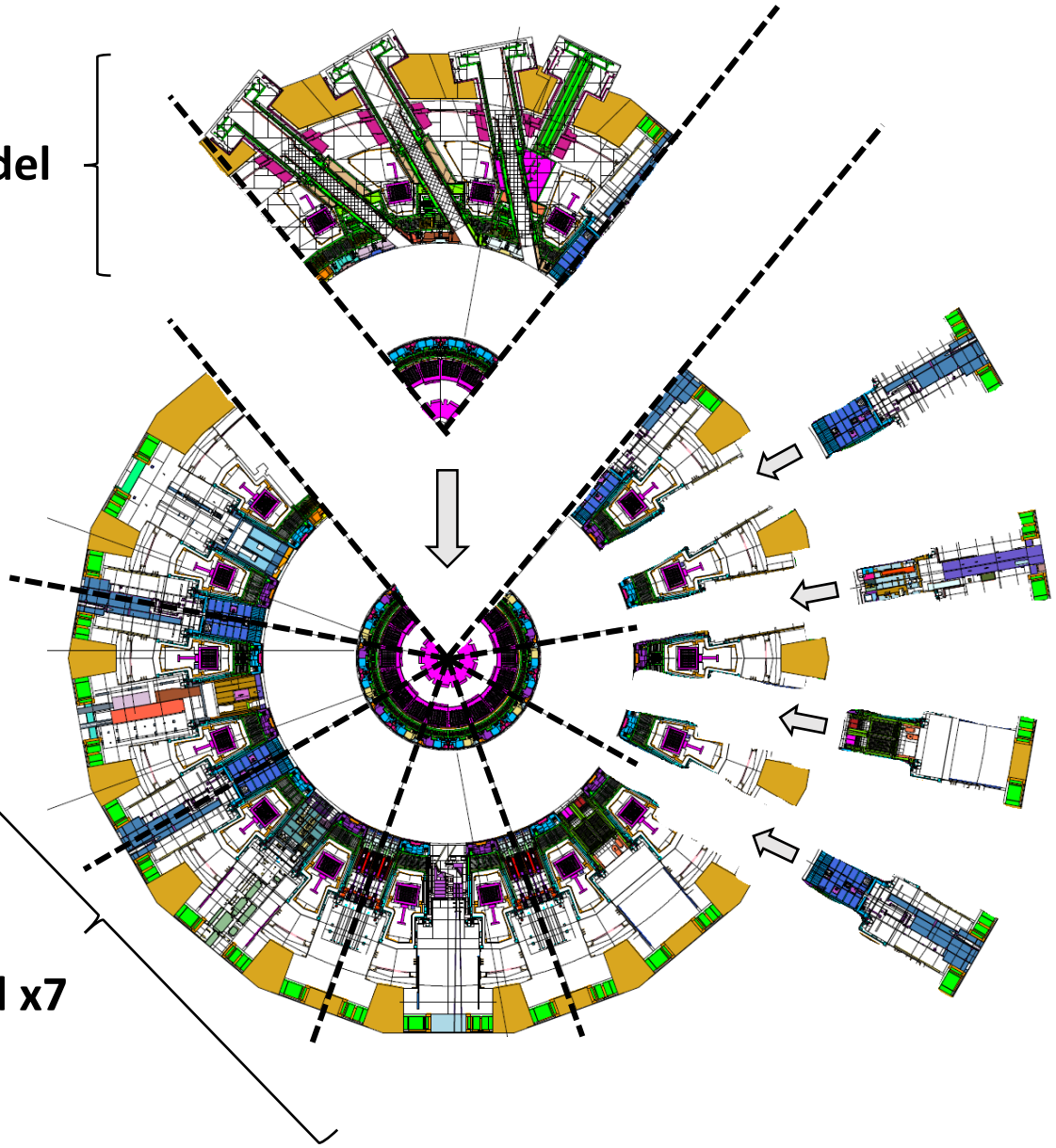
**Thanks to recent computational advances, it was possible to overcome these limitations by producing an even more complex and realistic model**

# E-lite





80° NBI sector MCNP model



Insertion of all available port plug models

40° C-model repeated x7

# E-lite

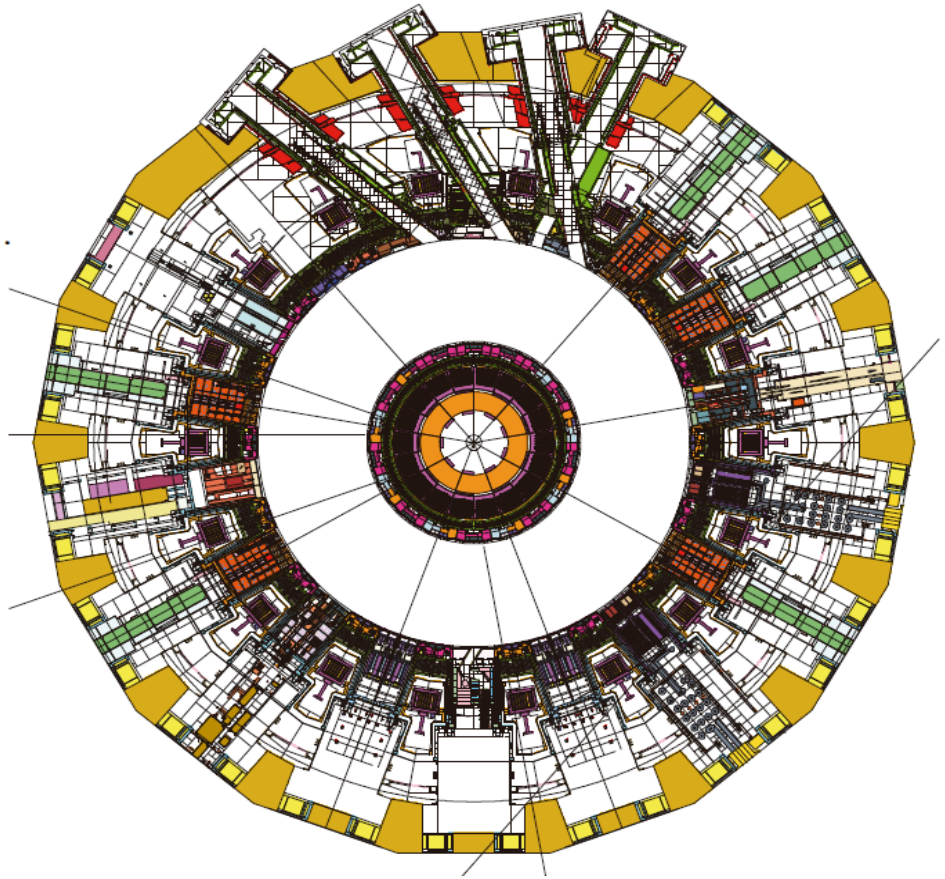
**It represents the 360° of the machine**

**The most detailed representation of the ITER tokamak**

**The most complex MCNP model ever produced in ITER**

**It has been adopted by IO as another reference model**

**Already used in ITER nuclear analyses of relevance**



**We believe E-lite could be useful to support the accurate calibration of ITER neutron detectors**

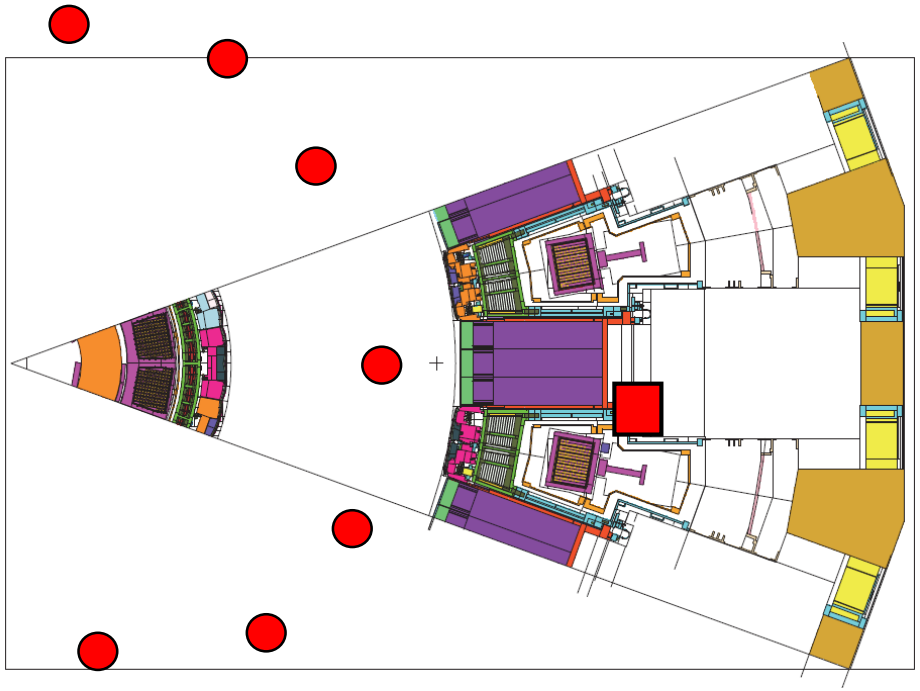
R. Juarez, G. Pedroche et al., “A full and heterogeneous model of the ITER tokamak for comprehensive nuclear analyses”, Nature Energy, Volume 6, 2021, https://doi.org/10.1038/s41560-020-00753-x

# Outline

Introduction – Presentation of E-lite

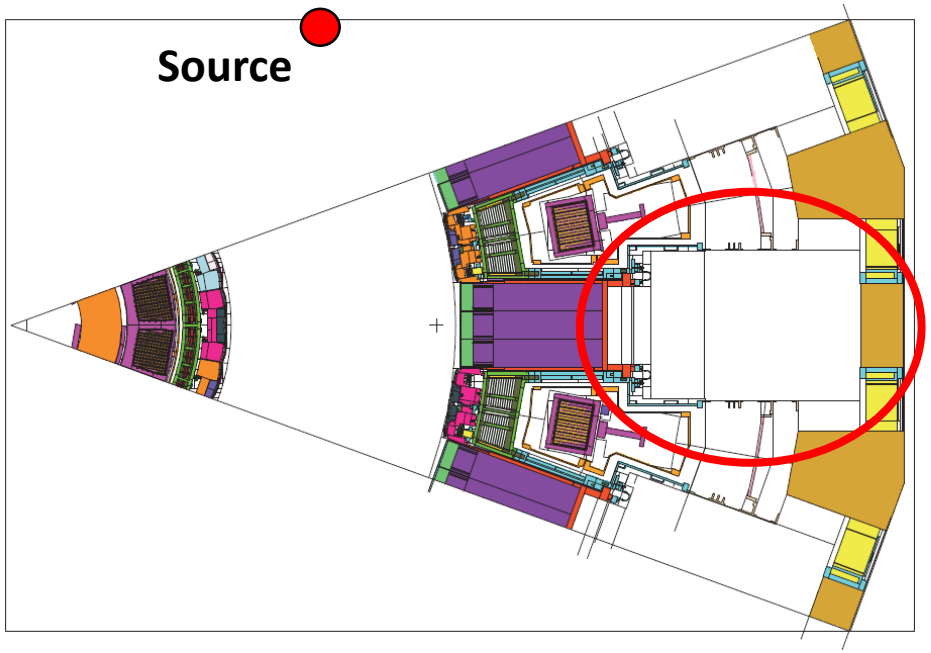
**Example of application of E-lite**

Conclusions

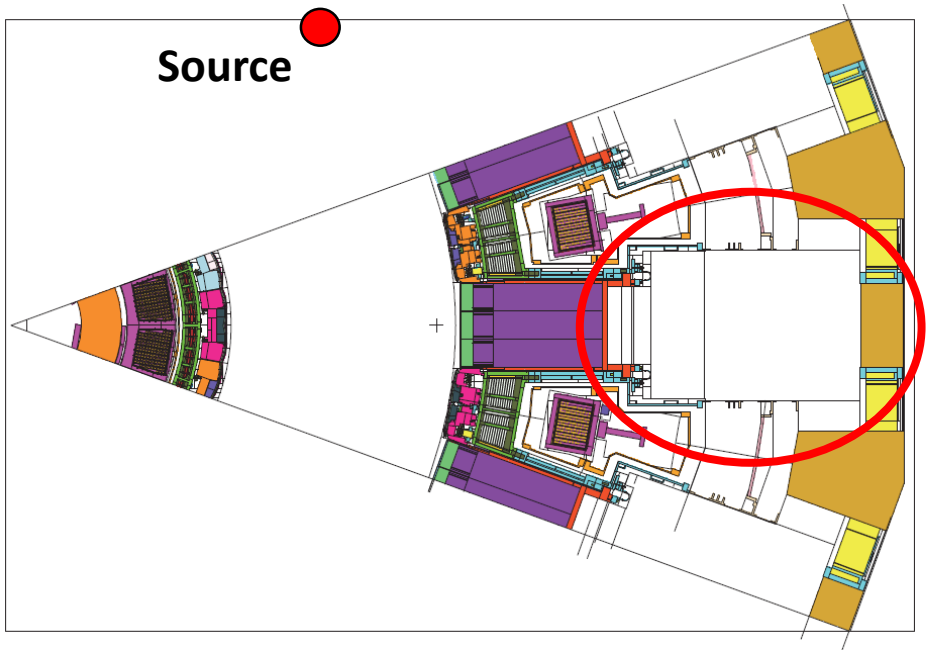


**Our understanding is that some calibration experiments are aimed at knowing the response of detectors due to a source located at different positions.**

**Being able to reliably simulate these situations computationally is useful because it allows to validate the neutronics models against experimental data. Once validated, the models can be used to simulate situations that cannot be recreated experimentally.**




**Currently, to be able to simulate this situation with a partial model you need to remove the boundary conditions. Particles are transported through void!!!**



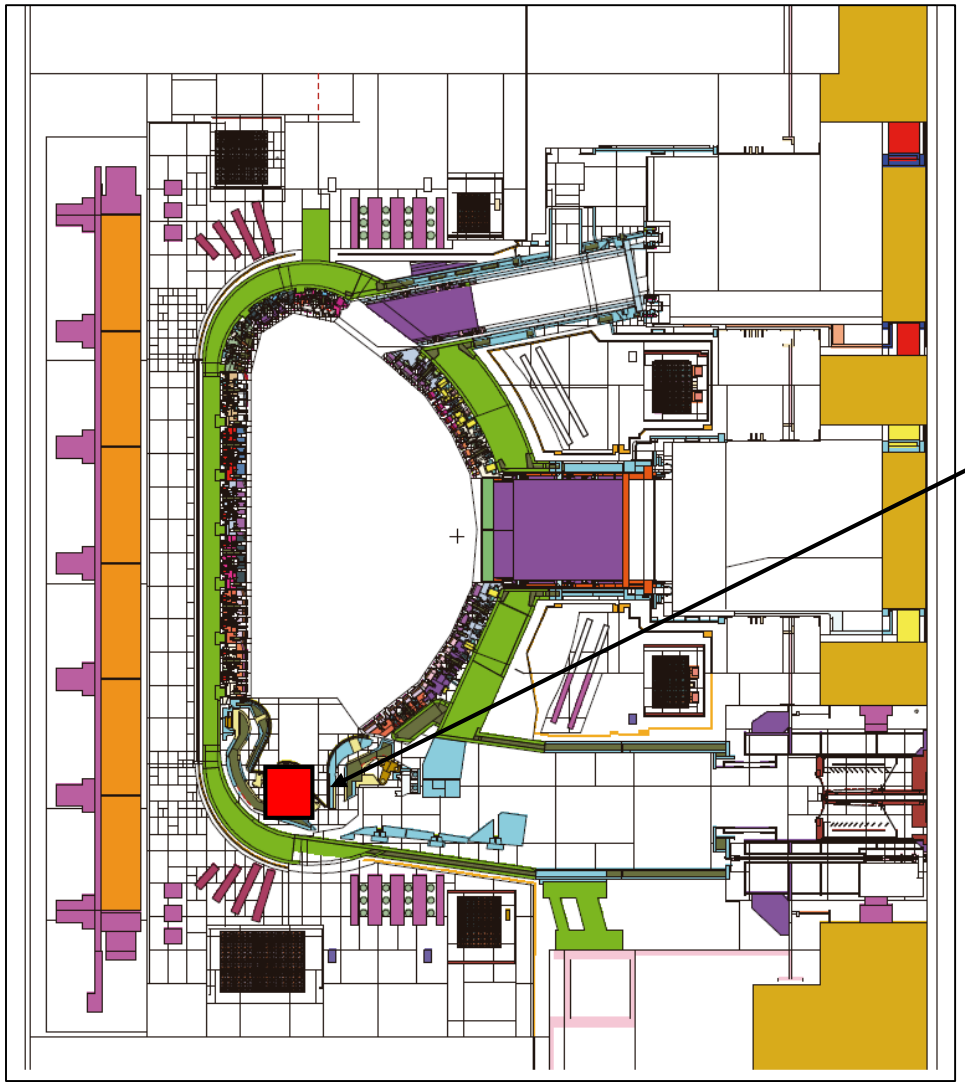

**Region of interest**

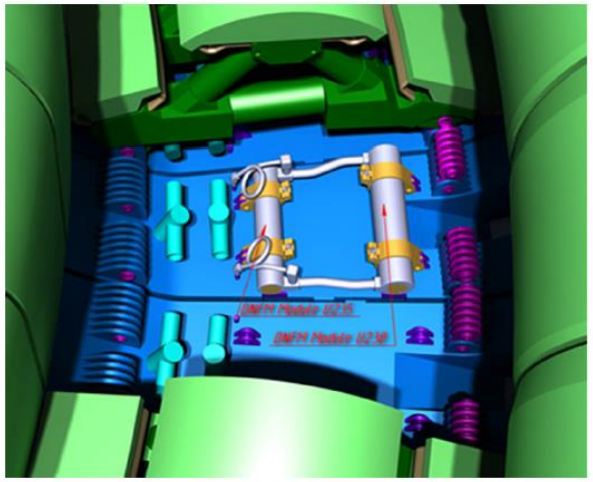
**We want to show the impact of using a partial model when dealing with this kind of situation.**

**To do so, we defined an exercise that represents a hypothetical calibration configuration and we ran simulations with both C-model and E-lite**

**The exercise highlights the benefits of having E-lite**

# Description of the exercise



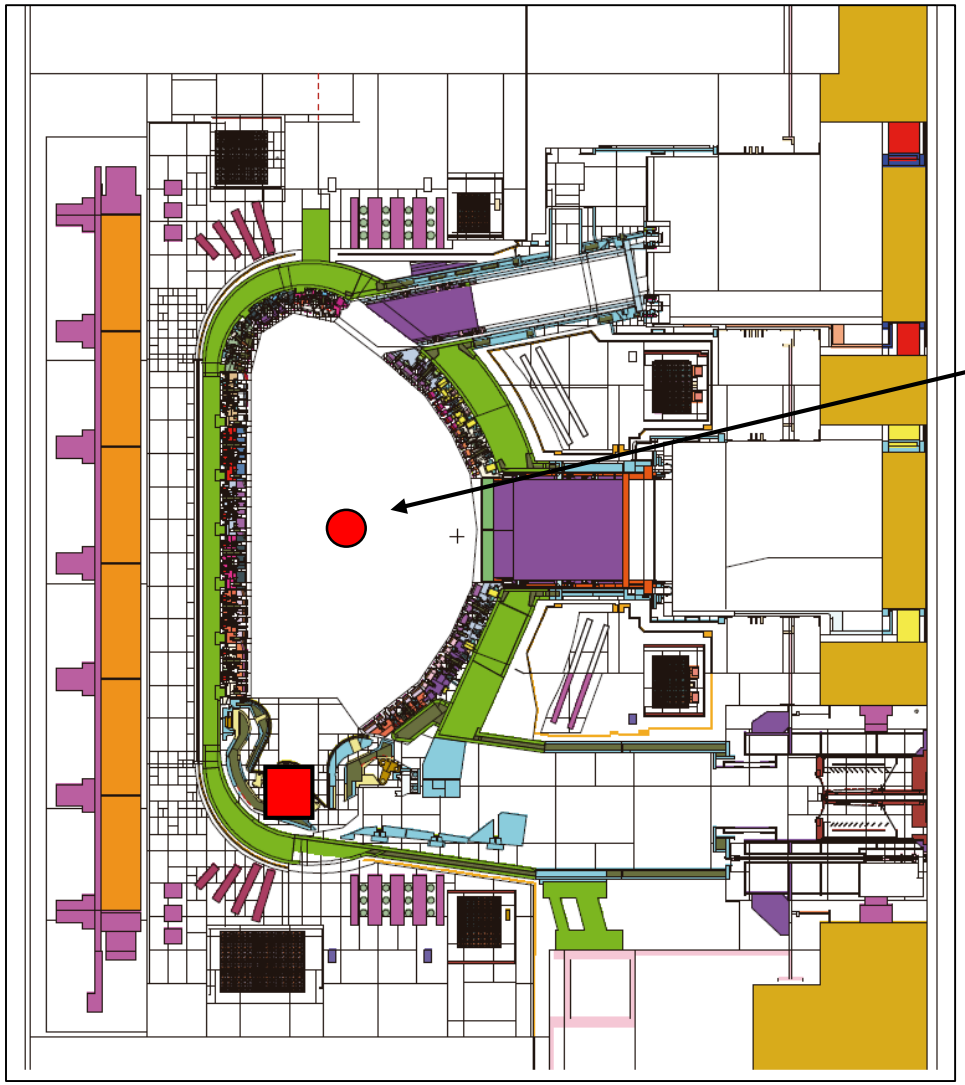


**Divertor Neutron Flux Monitor (DNFM)**

**Location of DNFM: Under the dome of Divertor cassette (port #14)**

**DNFM with fission chambers of $^{235}U$ & $^{238}U$**

# Description of the exercise

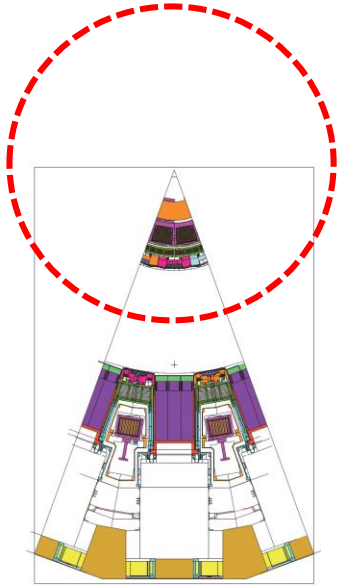


**Neutron source: Point-wise isotropic 14.1 MeV neutron source**

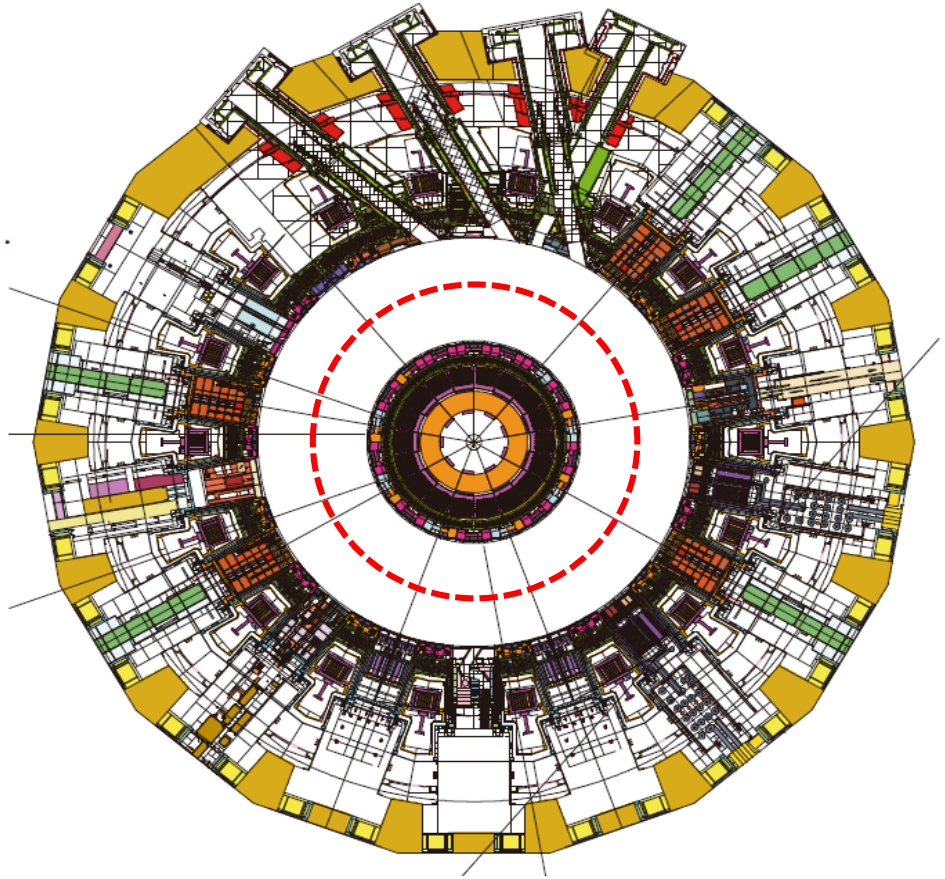
**The source is moved through different toroidal positions**

# Description of the exercise

**The source is moved through different toroidal positions**

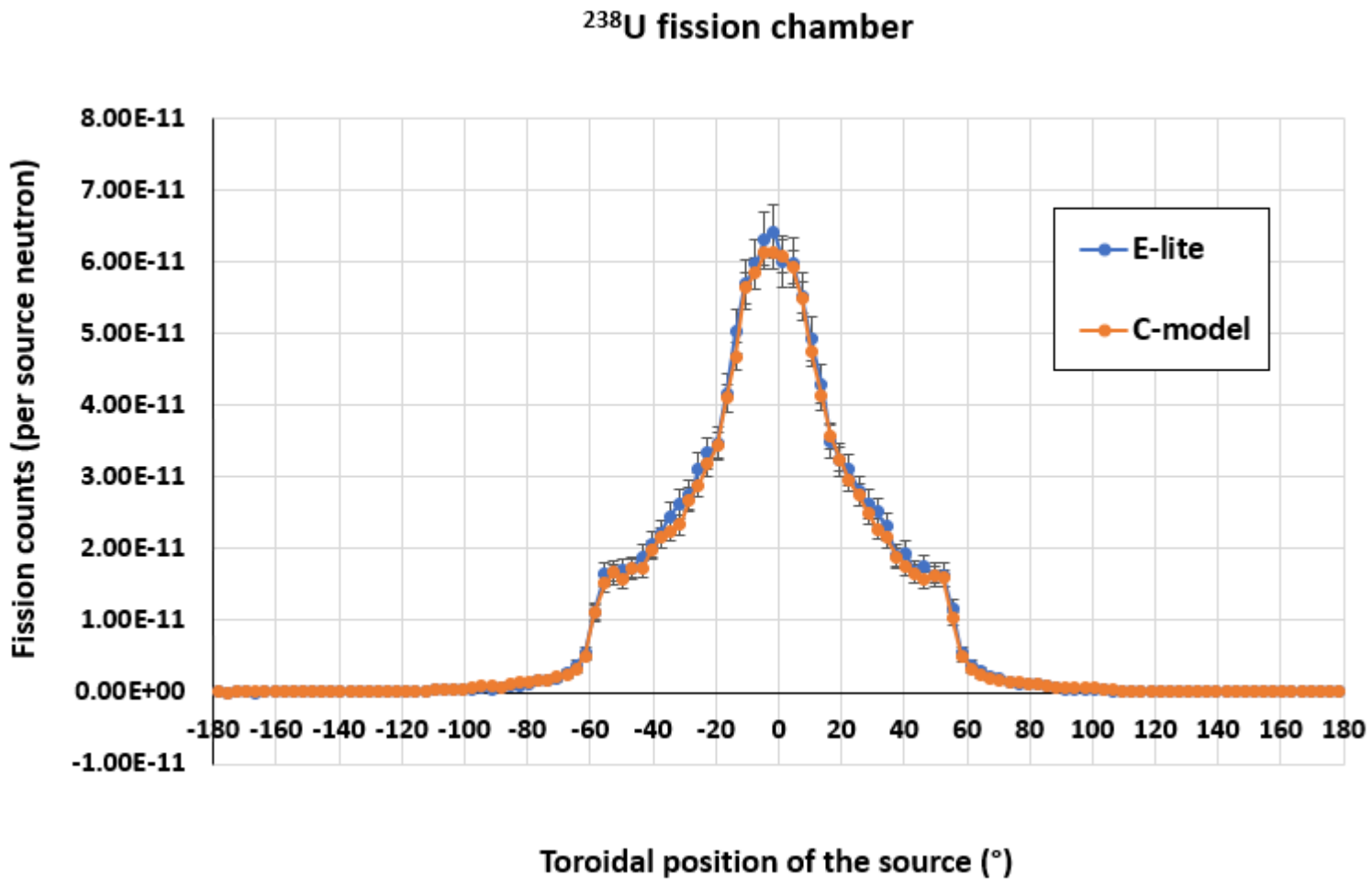


**C-model**



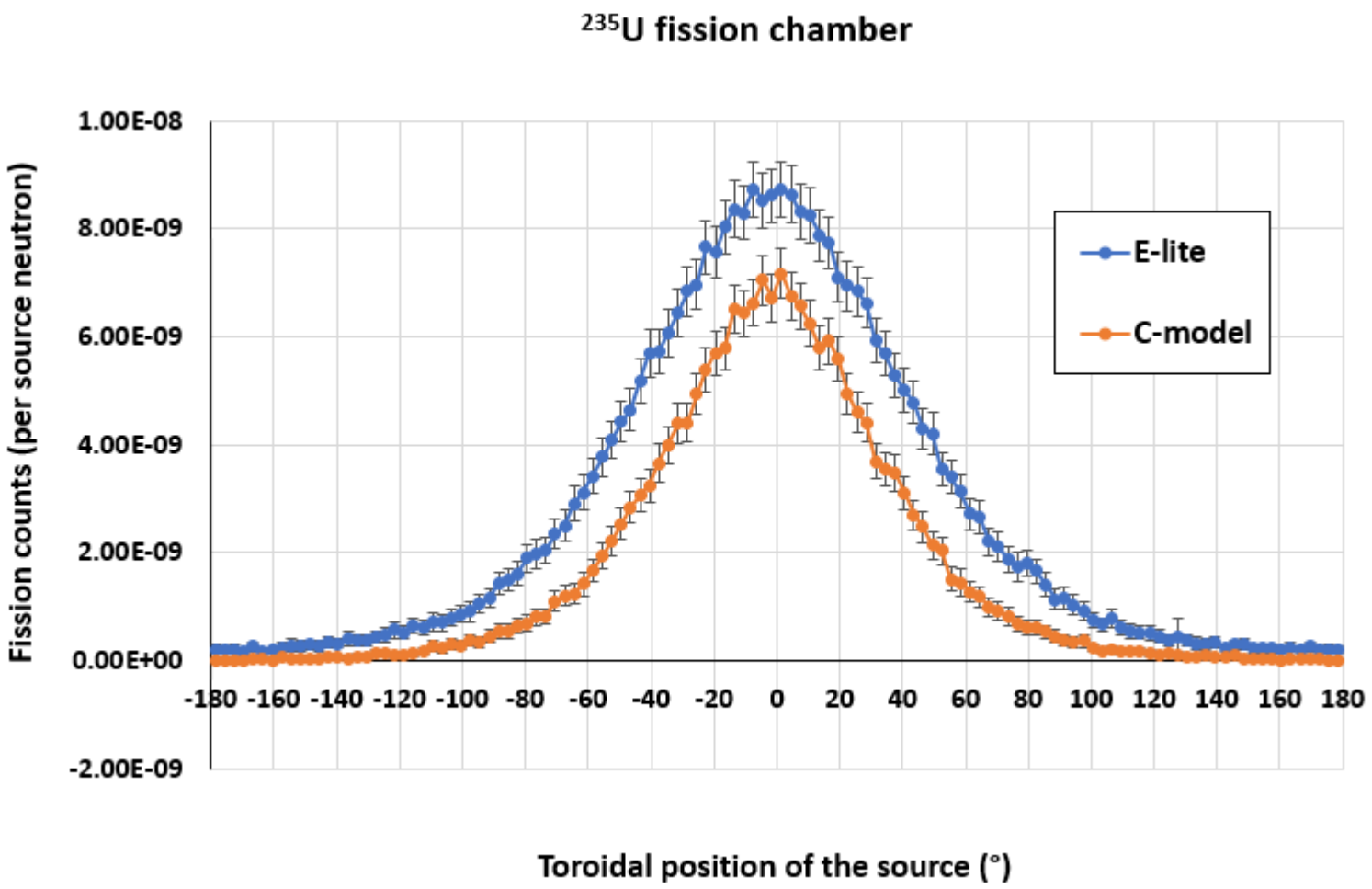
**E-lite**

# Results




- Almost no difference between E-lite & C-model results (within simulation error)
- Fission events are dominated by high energy neutrons. Scattered (low energy neutrons) do not induce fissions
- Therefore, not representing a significant part of the machine does not have an effect
- Using a partial does not have an impact in this case.
- <u>However, we could only reach that conclusion because we had E-lite to compare with</u>

# Results




- Relatively high difference between C-model & E-lite results (20-70 %)
- Scattered (low energy neutrons) induce fissions
- Therefore, not representing a significant part of the machine results in a lost of scattered neutrons
- Using a partial model has a significant impact.
- <u>E-lite is necessary to obtain a reliable result in this case.</u>

# Outline

Introduction – Presentation of E-lite

Example of application of E-lite

**Conclusions**

# Conclusions

**We have presented E-lite, the first detailed 360° neutronics model of the ITER tokamak**

**The model has been adopted by IO as another reference model, available to all the ITER neutronics community**

**We have shown an example of application of E-lite relevant for the calibration of ITER neutron detectors**

**Results suggest that E-lite can be useful to support the accurate calibration of ITER neutron detectors**

**E-lite can simulate situations that cannot be currently treated with partial models reliably**

**UNED hopes that E-lite can be widely used to support the calibration of ITER neutron detectors**

**UNED is interested in collaborating in ITER's calibration process by sharing its expertise in ITER neutronics calculations (e.g. collaborate in the validation of E-lite against experimental data)**

**THANK YOU FOR YOUR ATTENTION**