EUROfusion

Non-linear MHD modelling of pellet triggered ELM in JT-60SA

S. Futatani, S.J.P. Pamela, E. de la Luna, L. Garzotti, J. Garcia, G. T. A. Huijsmans,
M. Hoelzl, A. Cathey, JOREK Team

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Outline

Motivation

- Pellet pacemaking is one of the ELM control techniques.
- The physics of ELM control by pellets is known [Futatani 2014] but estimation and comparison with experiment have to be managed.
  ➔ More theoretical and numerical modeling studies are required.
- Non-linear MHD simulations by JOREK [see other IAEA contributions by JOREK colleagues]

Previous simulation of pellet ELM triggering

– ASDEX Upgrade plasma

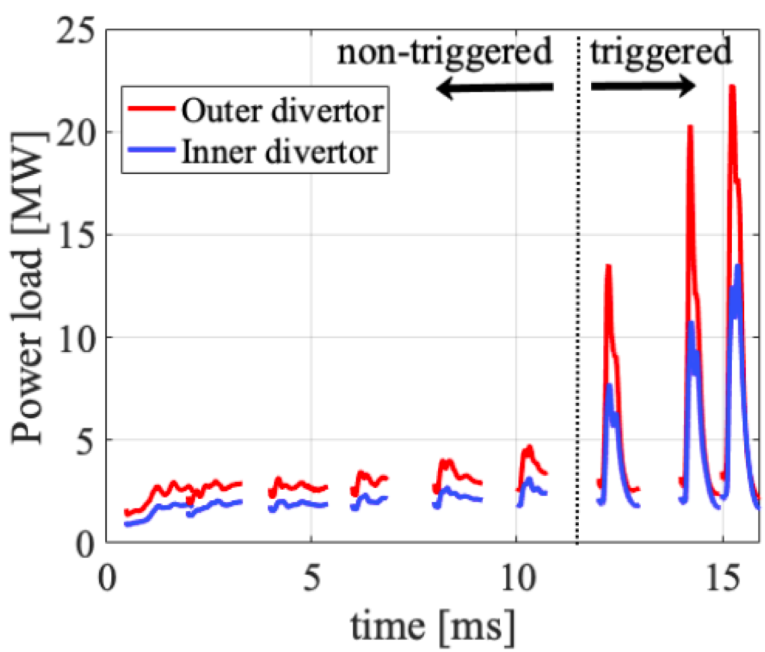
Non-linear MHD simulations of JT-60SA

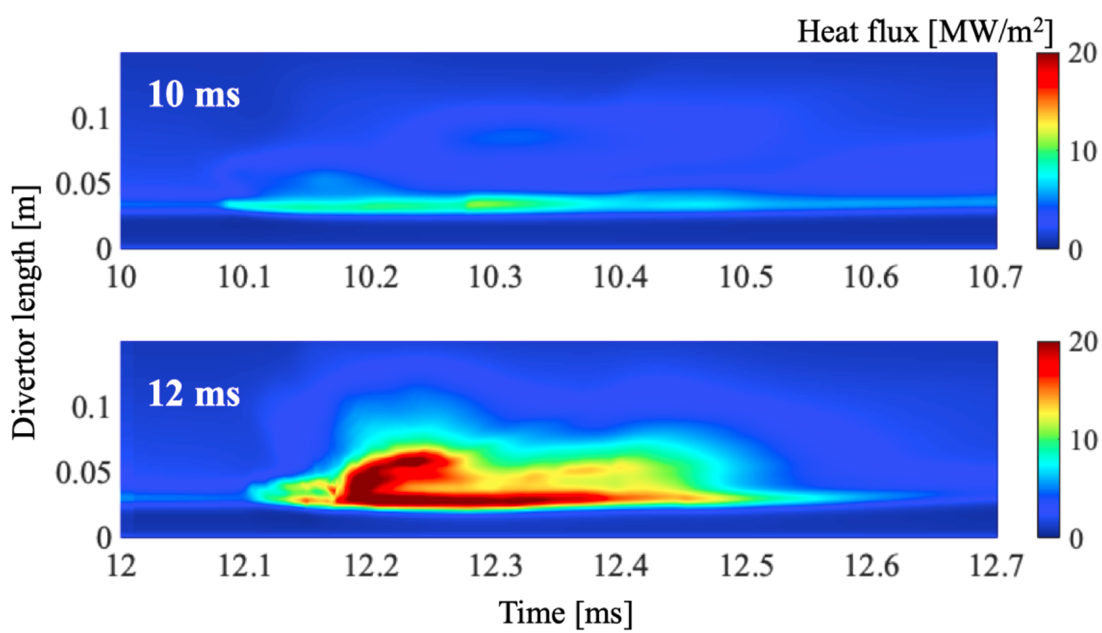
- Spontaneous ELM
- Pellet triggered ELM
  - Pellet injection in pre-ELM condition
  - Pellet injection in post-ELM condition

Transition of no-ELM and pellet ELM triggering of ASDEX Upgrade [S. Futatnai, A. Cathey, M. Hoelzl, etc. NF 2021]

- A “lag time” is observed in experiments; pellet injections at earlier stages leading no ELM crash while the pellet injections at later stages trigger ELMs.
- The JOREK ELM cycle simulation (incl. plasma flow) of ASDEX Upgrade (AUG) plasma is used as basis for the study [Cathey, Hoelzl et al., NF 2020].
- The post-ELM profiles build up until they reach the MHD stability limit and an ELM crash eventually occurs at about 16 ms.

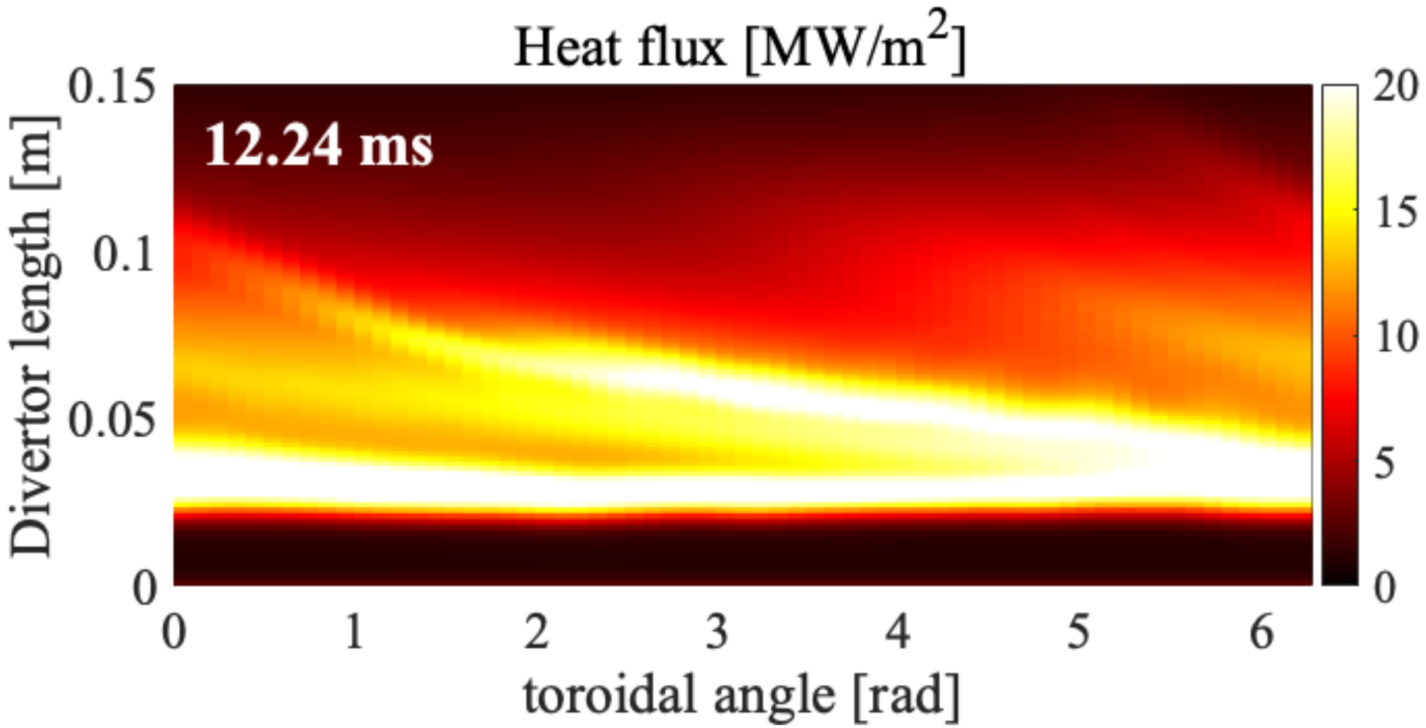
- There is a clear transition between 10 ms and 12 ms in terms of the power onto the divertor target.





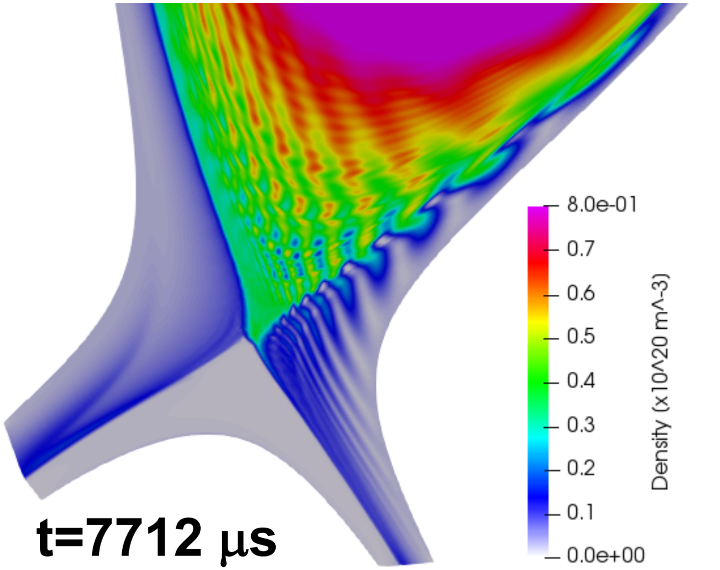
Transition of no-ELM and pellet ELM triggering of ASDEX Upgrade [S. Futatnai, A. Cathey, M. Hoelzl, etc. NF 2021]

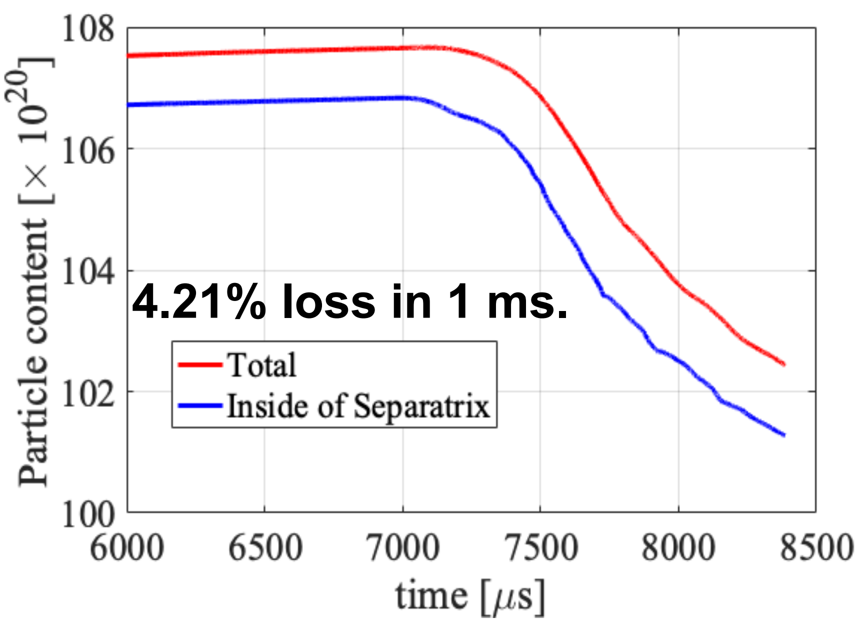
- The heat flux profile along the toroidal direction of the 0.8×10^{20}D pellet injected at 12 ms.
- The timing of the maximum power load onto the outer target, t=12.24 ms is shown.
- Toroidal asymmetry of the heat flux profile is observed.

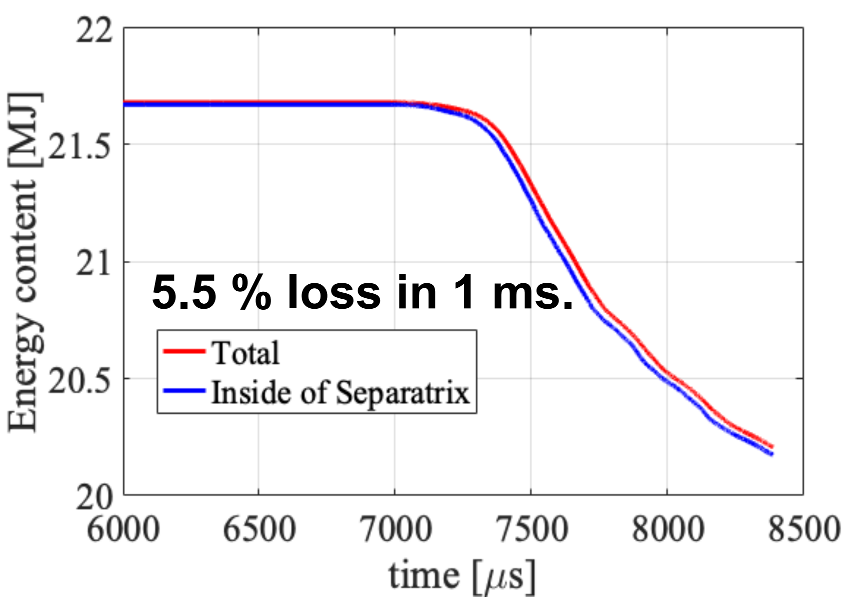


Natural ELM in JT-60SA

- JOREK simulations have been performed for a high current and high-power scenario (5.5 MA, 41 MW, single null divertor) obtained from a CRONOS calculation.
- The pedestal top pressure of pre-ELM condition is 55.5 kPa.
- Spontaneous ELM has been performed.

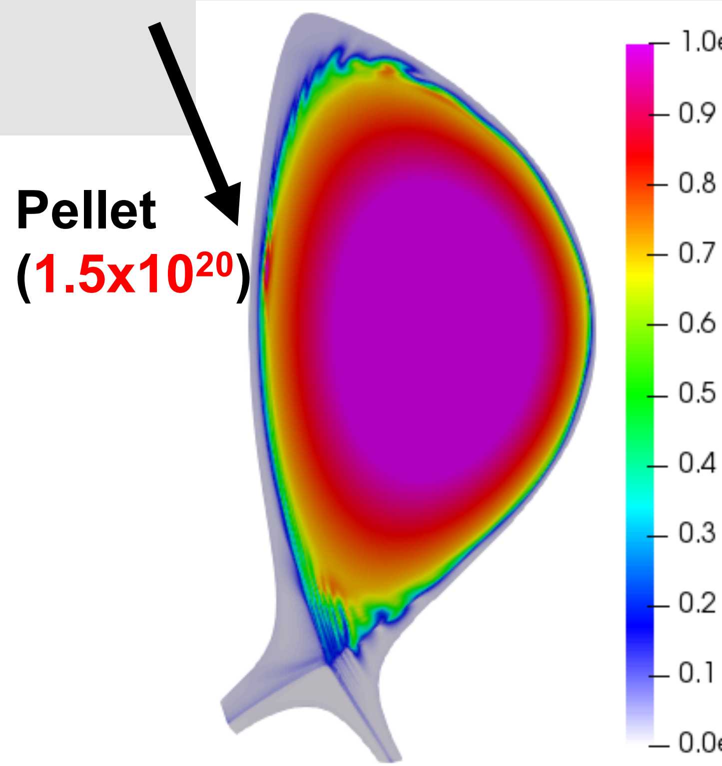


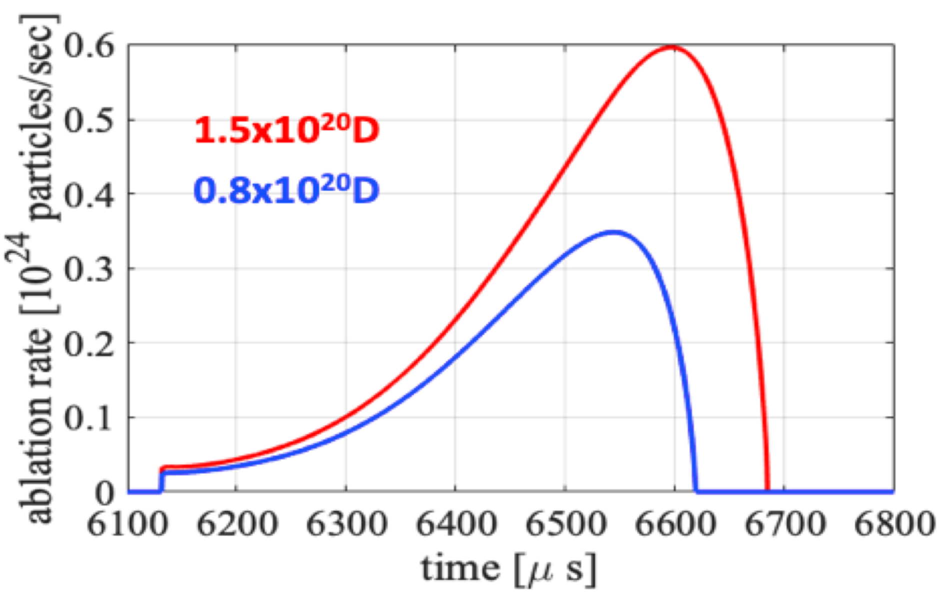


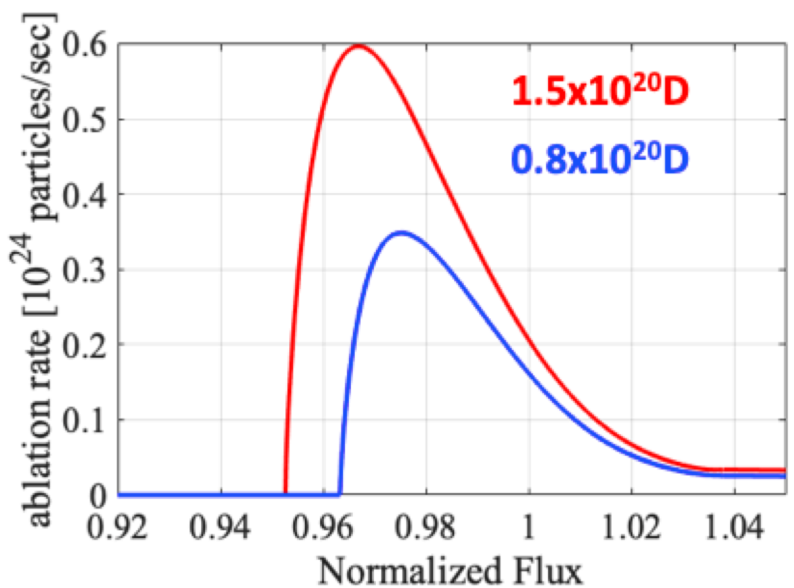


Pellet injection in JT60-SA

- Two pellet sizes, **0.8×10^{20}** and **1.5×10^{20}** are studied.
- Pellets are injected from HFS, with 400 m/s.
- The pellet ablation profiles (versus time and versus normalized flux) are plotted.
- **The pellet ablation time is ~500-700μs.**
- Pellet **reaches the full ablation in the pedestal region (pedestal top is at Ψ_N=0.93),** P=55.5 kPa.



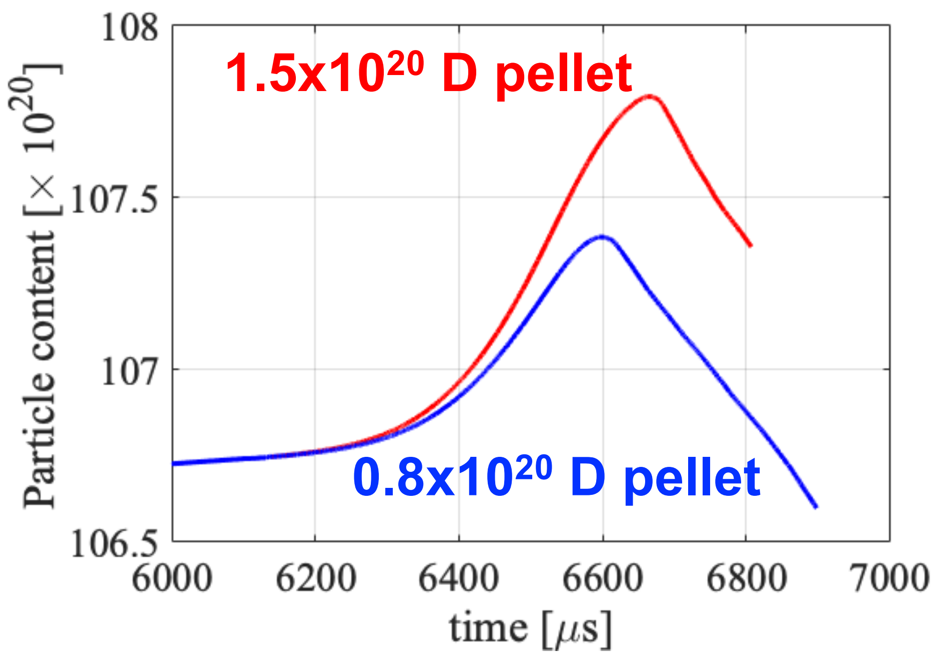


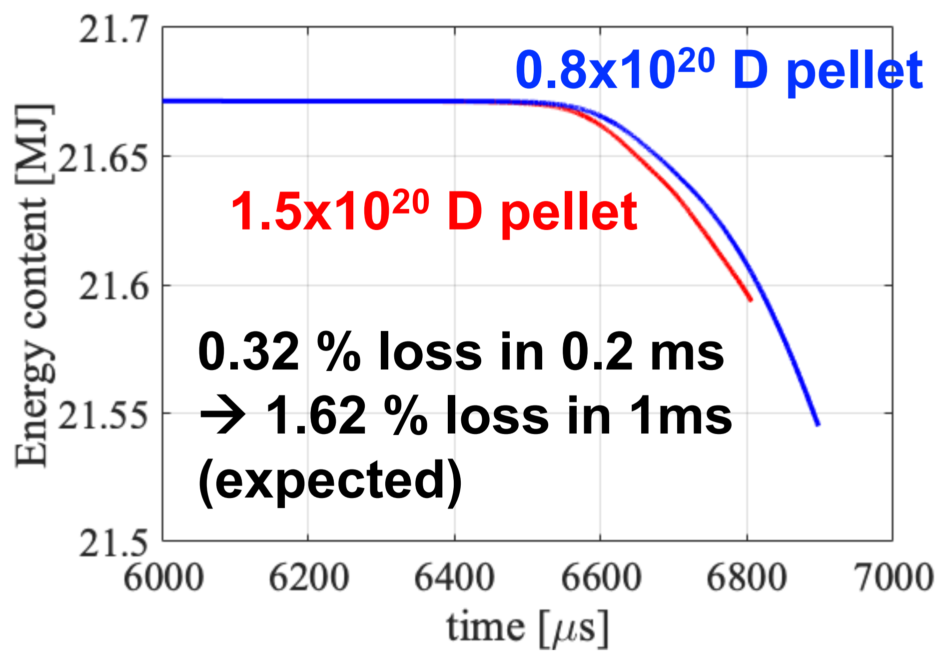


Pellet injection in JT60-SA

- The energy loss due to the pellet triggered ELM is much small (~ 20 %) compared to the natural ELM. These simulations are still to be seen as preliminary.
- Both of pellet size triggers an ELM. Because the pellets are injected in the plasma which are already unstable.

- In the post-ELM condition which assumes the plasma of 27 kPa pedestal top pressure, no-ELM is triggered with any pellet sizes.





Conclusion

Conclusion of ASDEX Upgrade analysis

- Realistic neoclassical and diamagnetic plasma flows are included for the first time in pellet ELM triggering simulations.
- The work demonstrates that a lag time can be reproduced by JOREK simulations. We observe a pellet-size dependency, that seems not present in the experiment (to be confirmed).
- Heat deposition asymmetry is observed.

Preliminary conclusion of JT-60SA analysis

- Non-linear MHD simulations without plasma flow have been performed.
- The 0.8×10^{20} D pellet (reference pellet size for ELM pacing)
  - triggers an ELM in the plasma which has 55.5 kPa pedestal pressure.
  - does not trigger an ELM in the plasma which has 27 kPa pedestal pressure
- Realistic plasma flow (diamagnetic term, neoclassical term, etc) which can evolve the pedestal profile will be included in the future work.