Progress report : Non-linear MHD simulations of pellet triggered ELM in JT-60SA

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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 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.

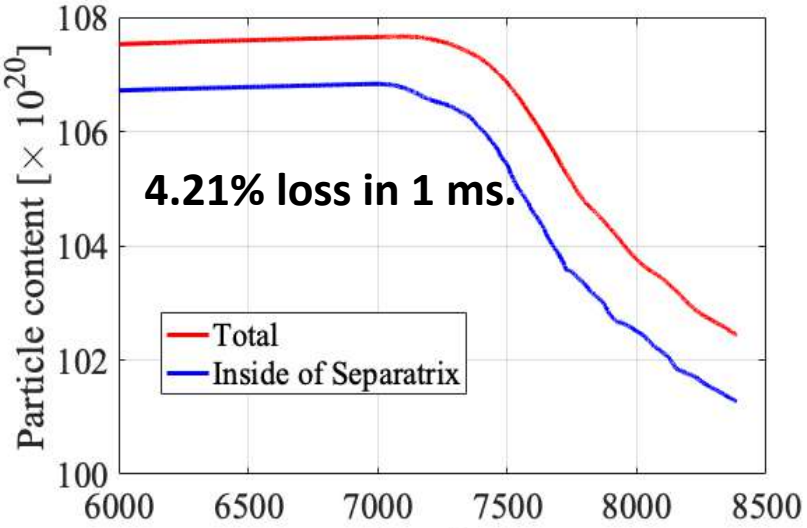
Status 2020

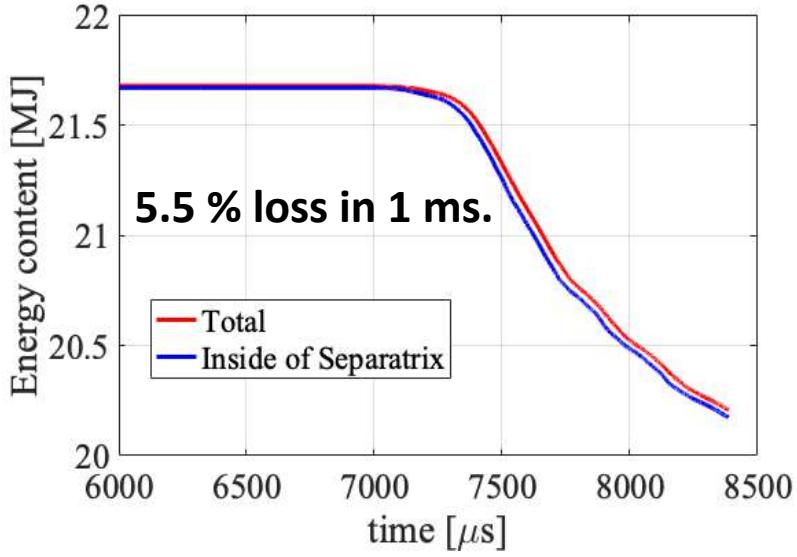
- The initial approach of the pellet injection simulations for JT-60SA has been carried out.
  - Equilibrium from CRONOS
  - Natural ELM
  - Pellet triggered ELM
  - Pellet injection in stable plasma

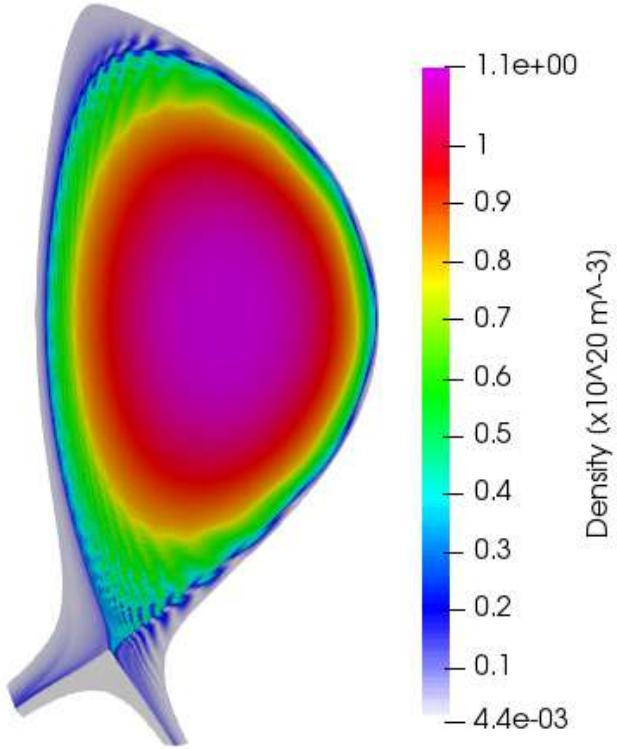
- Conclusions and Research plan for WPSA

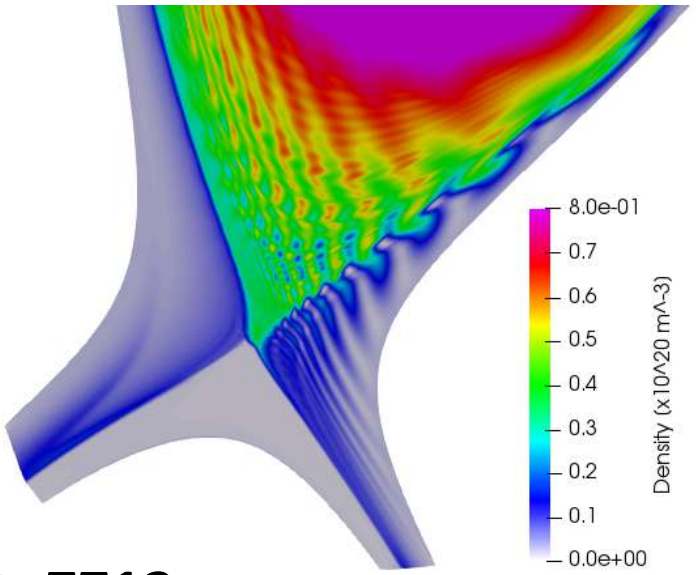
Natural ELM

- The natural ELM has been performed.





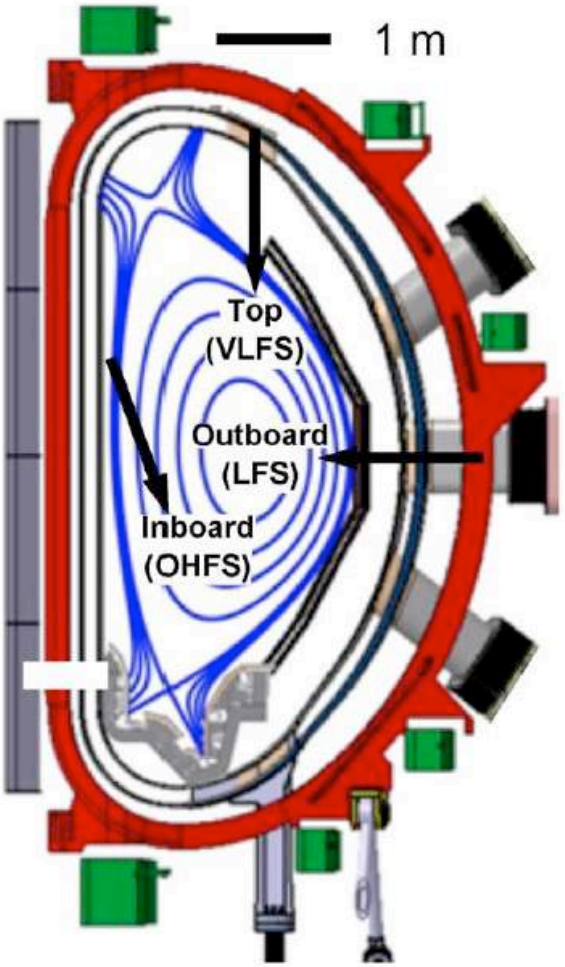


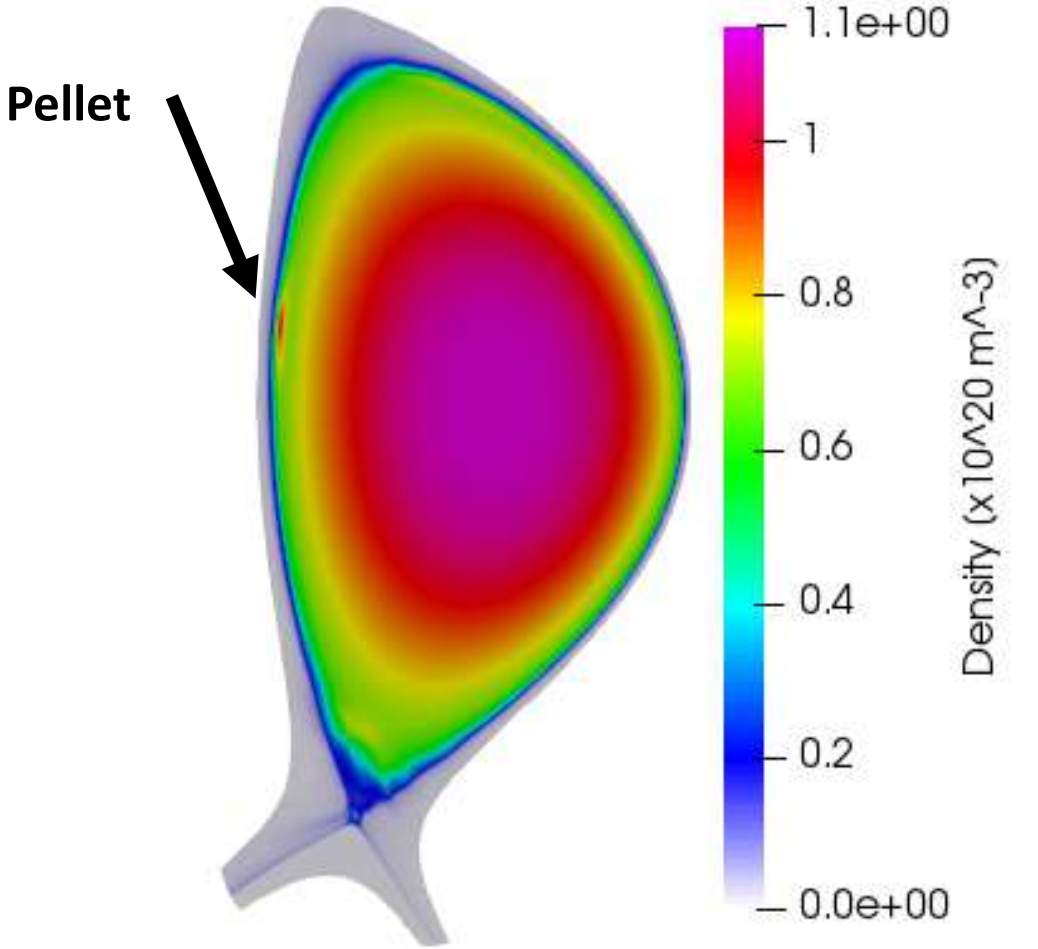


t=7712 μs

Pellet injection in JT60-SA

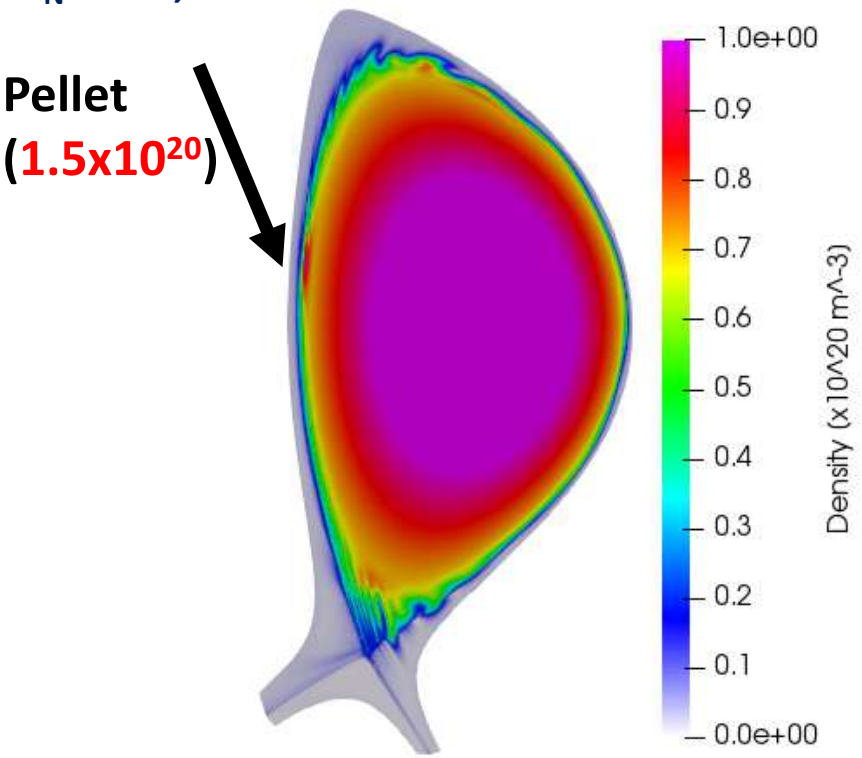
- The pellet simulations of JT-60SA scenarios (CRONOS simulation profiles) are in progress
  - m_p=0.8x10^{20} **D** [deuterium particles/pellet]. **Pacing pellet.**
- The pellets are injected from High Field side (HFS).
- The pellet injection velocity is **400 m/s.**

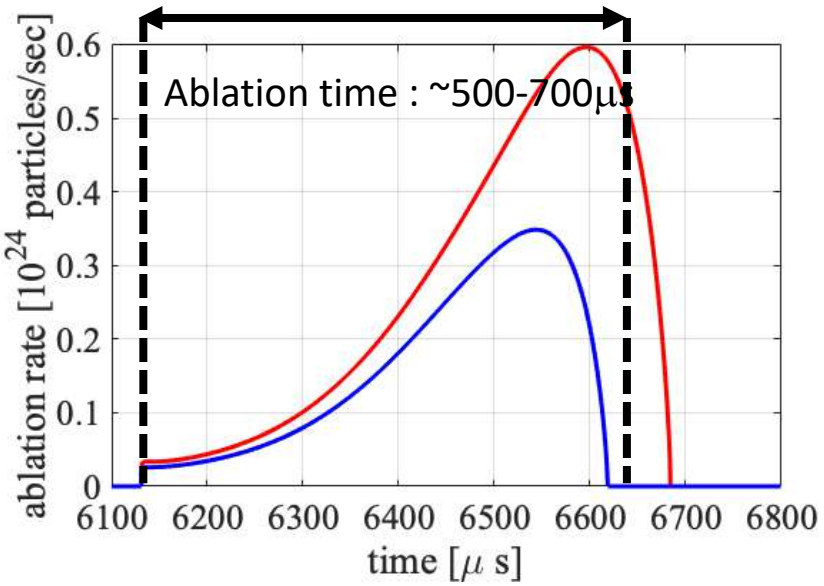




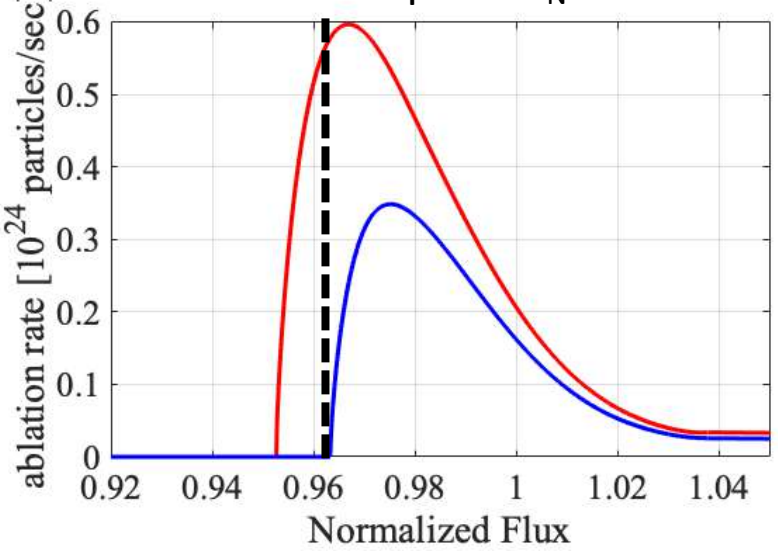
Pellet injection in JT60-SA

- Two pellet sizes, **0.8x10^{20}** and **1.5x10^{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**, and the **pellet reaches the full ablation at Ψ_N=0.965** where **the location of the pedestal top is at Ψ_N=0.93,** P=50 kPa.





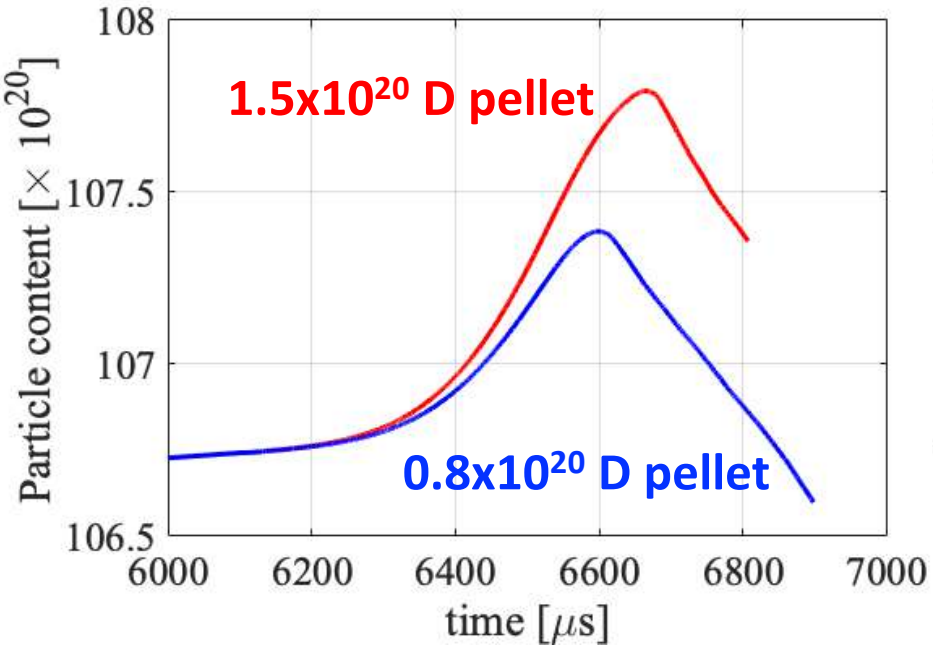
Penetration depth : Ψ_N=0.965

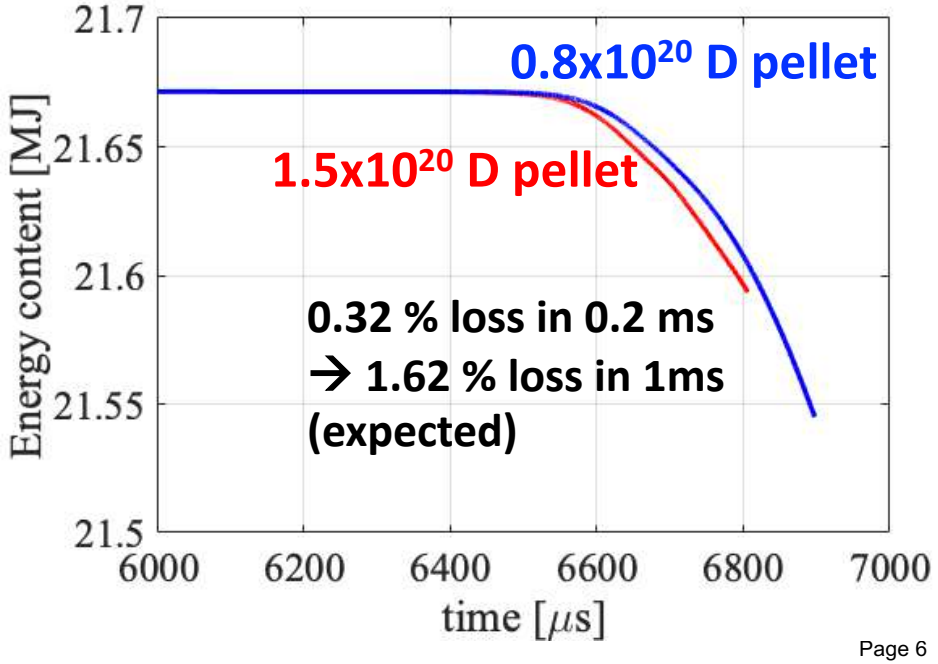


Pellet injection in JT60-SA

- The energy loss due to the pellet triggered ELM is much small (~ 1/5) compared to the natural ELM.

- Both of pellet size triggers an ELM. Because the pellets are injected in the plasma which are already unstable.



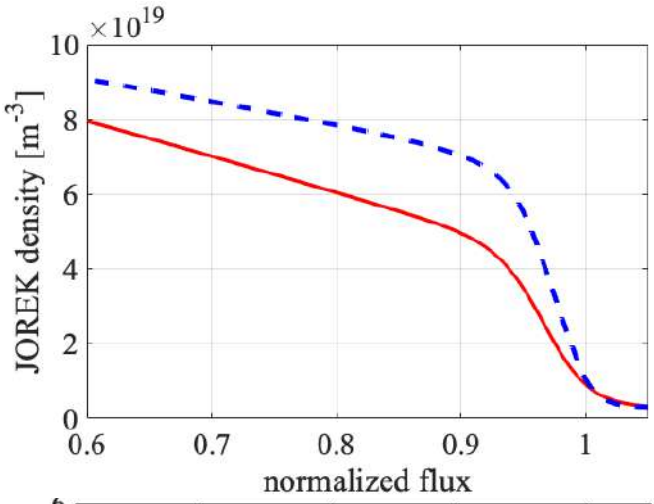


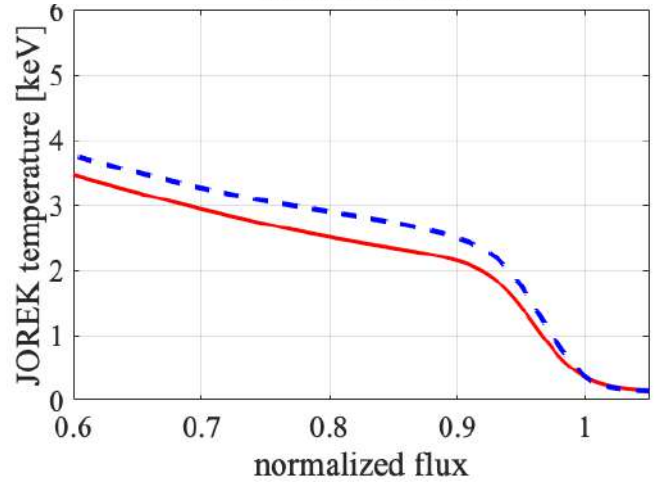
Pellet injection in JT60-SA

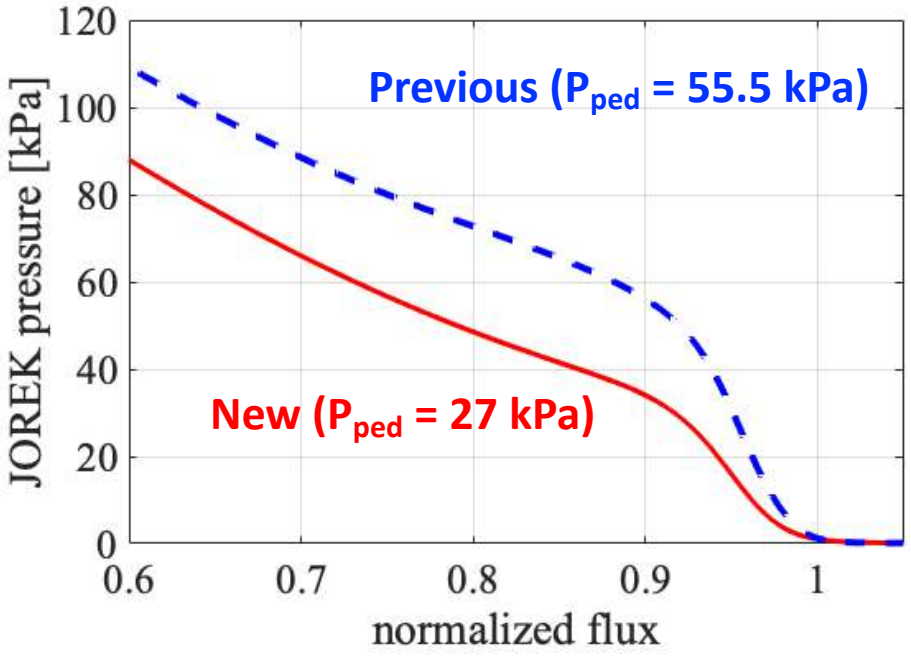
- Any pellet sizes (0.8x10^{20}D and 1.5x10^{20}D) can trigger an ELM if the plasma is unstable enough.
- The pellet injections in the stable plasma have been studied.
- The stable plasma is obtained by reducing the pedestal density and the temperature.

Previous (P_{ped} = 55.5 kPa) **New (P_{ped} = 27 kPa)**

Pedestal density : 6.5 x 10^{20} [m^{-3}] → 4.2 x 10^{20} [m^{-3}]
Pedestal temperature : 2.5 [keV] → 2.0 [keV]
Pedestal pressure : 55.5 [kPa] → 27.0 [kPa]

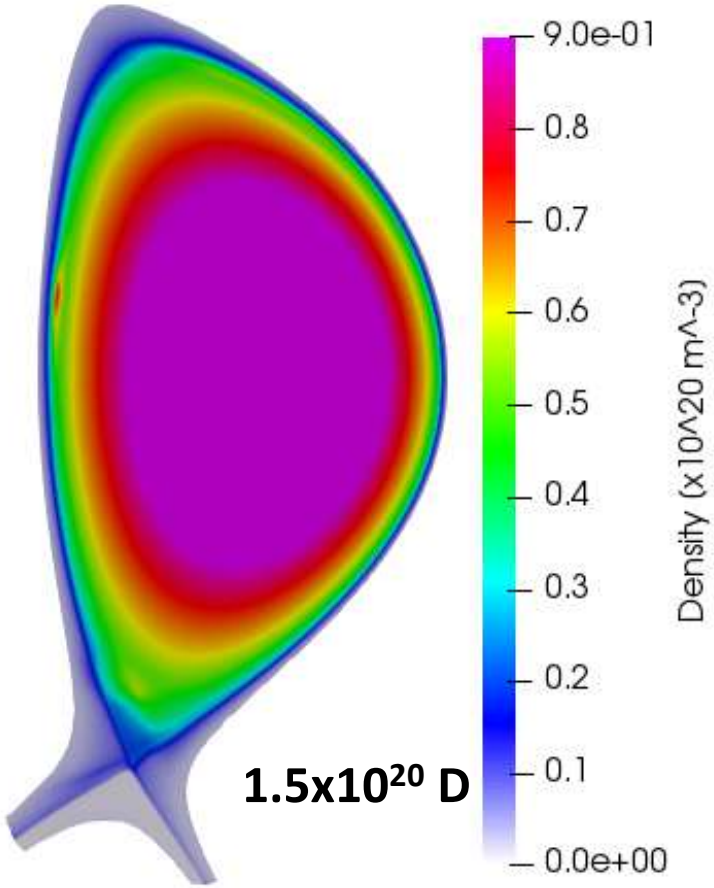


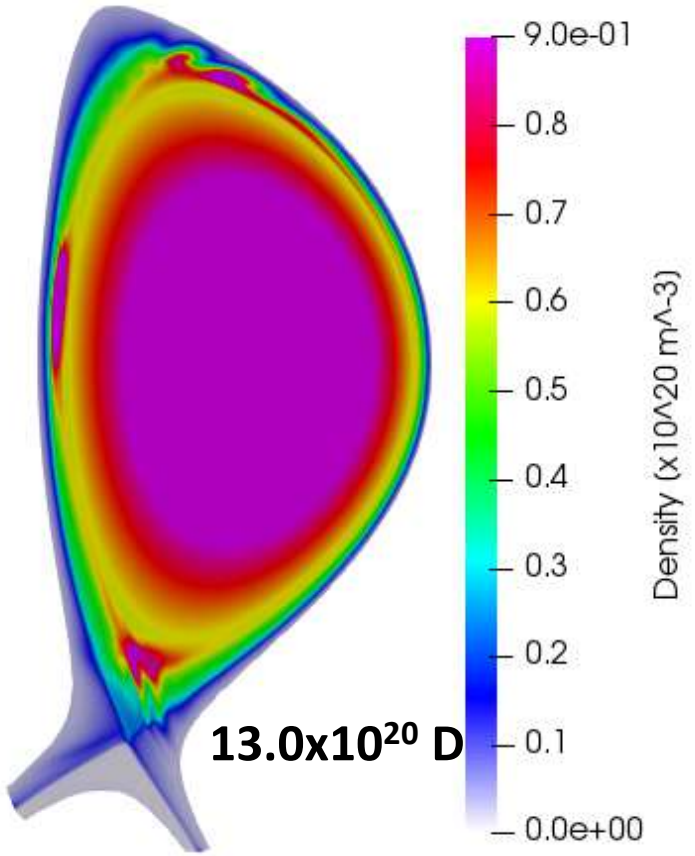




Pellet injection in JT60-SA

- The 1.5x10^{20} D pellet (twice large than the reference size of pacing pellet) is injected.
- The pellets are injected with same condition, but the 27 kPa pedestal pressure plasma.
- 1.5x10^{20} D pellet does not trigger an ELM. The plasma is very stable.
- 13.0x10^{20} D pellet injected from HFS. The maximum size of ”Fueling pellet” is tested (for my interest). If the pellet is large enough, the plasma can be unstable.





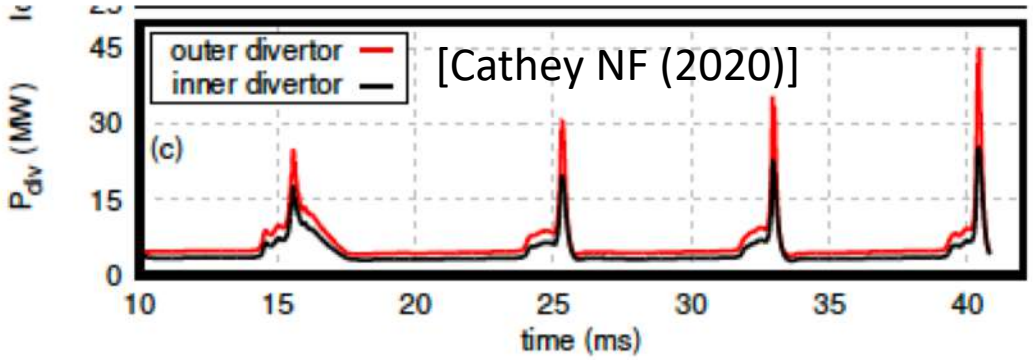
Conclusion 2020 and Plan 2021

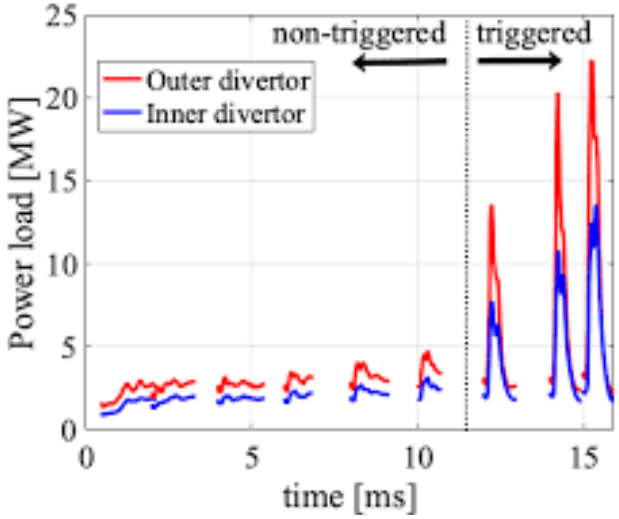
Summary 2020

- Now, we know that the 0.8x10^{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.

Plan 2021

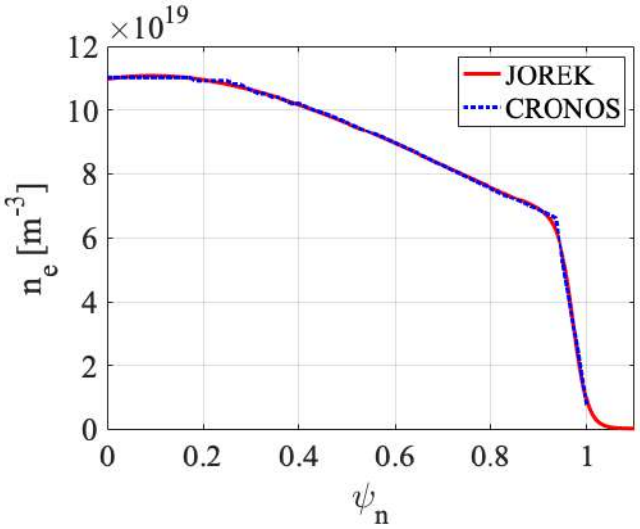
- It may be nice to know if 0.8x10^{20} D pellet triggers an ELM in a 40 kPa pedestal pressure plasma.
- It would be nice if the realistic plasma flow (diamagnetic term, neoclassical term, etc) can evolves the pedestal profile. [Cathey, Hoelzl, NF 2020]
- The pellets will be injected inter-ELM phase (same approach with [Futatani et al., NF 2021]).

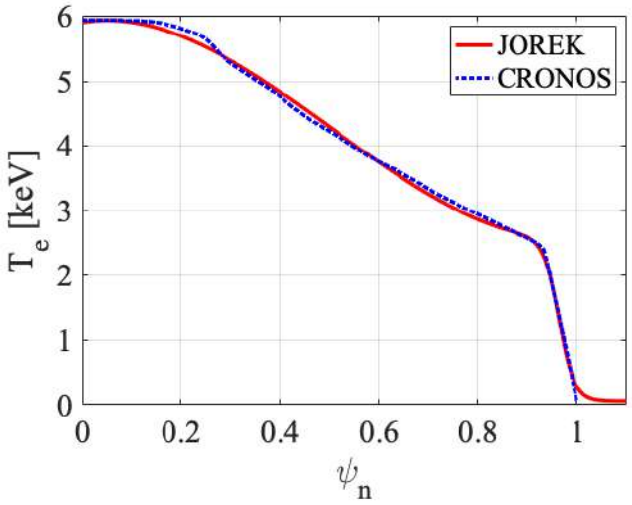




Appendix : Equilibrium to be studied

- The JOREK input file has been prepared based on CRONOS simulation of JT-60SA provided by J. Garcia.
- The initial profiles are matched with the CRONOS simulation.





- The pressure profile shows the location of the pedestal top is at Ψ_N=0.93, P=55.5 kPa.
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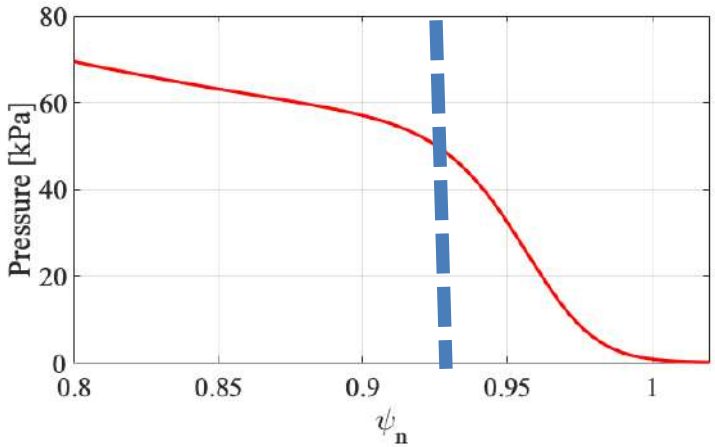

S. Fu