LMD end of year meeting: Report and plans IFPILM (IPPLM)

I. Ivanova-Stanik, et al.

Institute of Plasma Physics and Laser Microfusion, Hery st. 23, 01-497 Warsaw, Poland

INSTYTUT FIZYKI PLAZMY I LASEROWEJ MIKROSYNTEZY
IM. SYLWESTRA KALISKIEGO

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Plan for 2025

Numerical evaluation of LM-CPS performance in COMPASS-U and AUG under high heat loads

The task will aim at evaluating the use of Ga/Sn and Li in COMPASS-U using COREDIV and at making the comparison of COREDIV modelling of AUG Sn-CPS experiment to ASTRA-SOLPS modelling.

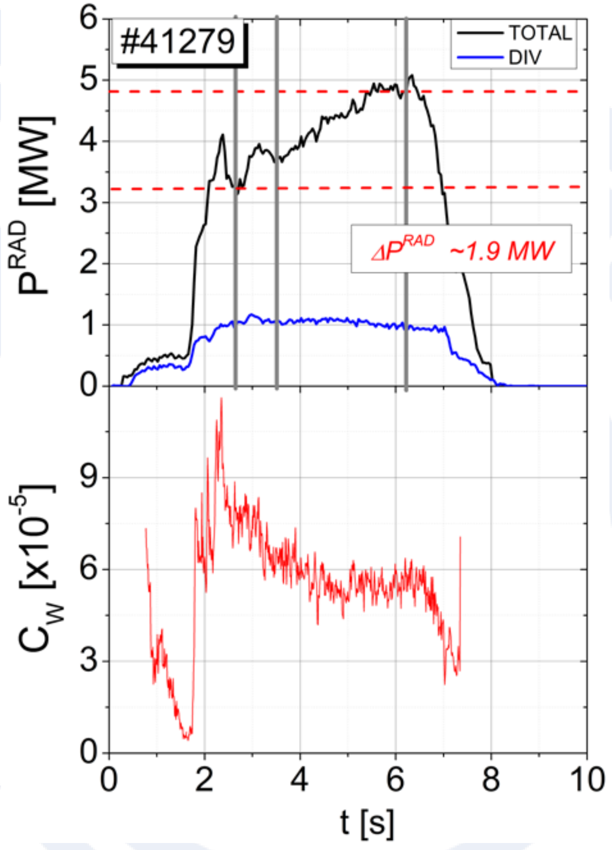
- Task objectives:
  - Evaluation of impurity limit for LMs in COMPASS-U (presented in september)
  - Evaluation of target temperature and power load limits (presented in september)
  - Examination of different LM options in COMPASS-U (presented in september)
  - Evaluation of code agreement with ASTRA-SOLPS modelling

ASDEX-U –simulation finiszed

INPUT

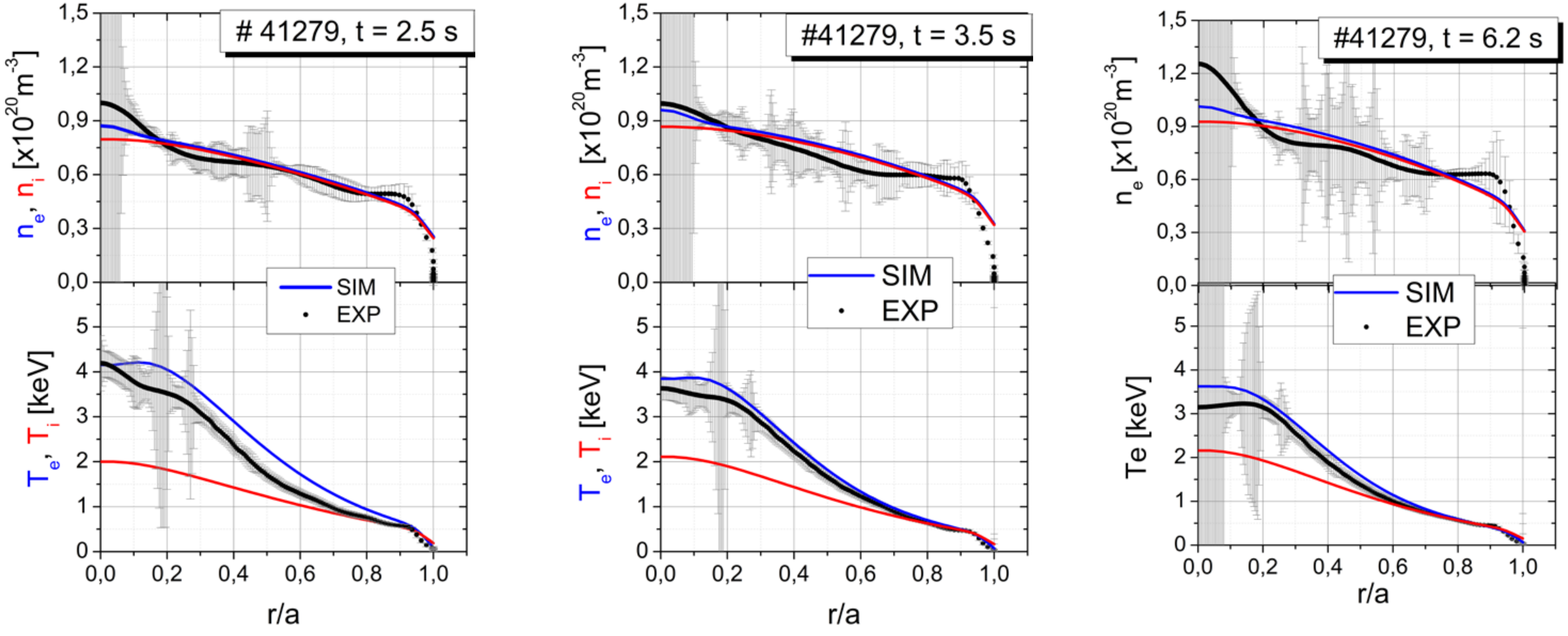
- In the plasma core, the anomalous diffusion coefficient of the impurities is set as $D_{imp} = D_i = 0.1\chi_e$
- Carbon (C), Sn and W are included as impurities in the D plasma.
- The W flux is computed self-consistently based on sputtering by C, Sn, and W self-sputtering.
- A perpendicular diffusivity $D_\perp = 0.3 m^2/s$ given as an input parameter.
- The temperature and density profiles at the outer and inner divertor are assumed to equal.
- The impurity recycling coefficient is fixed as =0.1 for C and Sn (low recycling impurity).
- An 'ad hoc' radial convective velocity is assumed in the core plasma for impurities as a code input, in order to better match the experimental radiation, density and temperature profiles. This radial convective velocity is the same for all impurity and all ionization states.

For analyzing pulse, we have no experimental data for effective charge stare Z_{eff} and radiation profile.



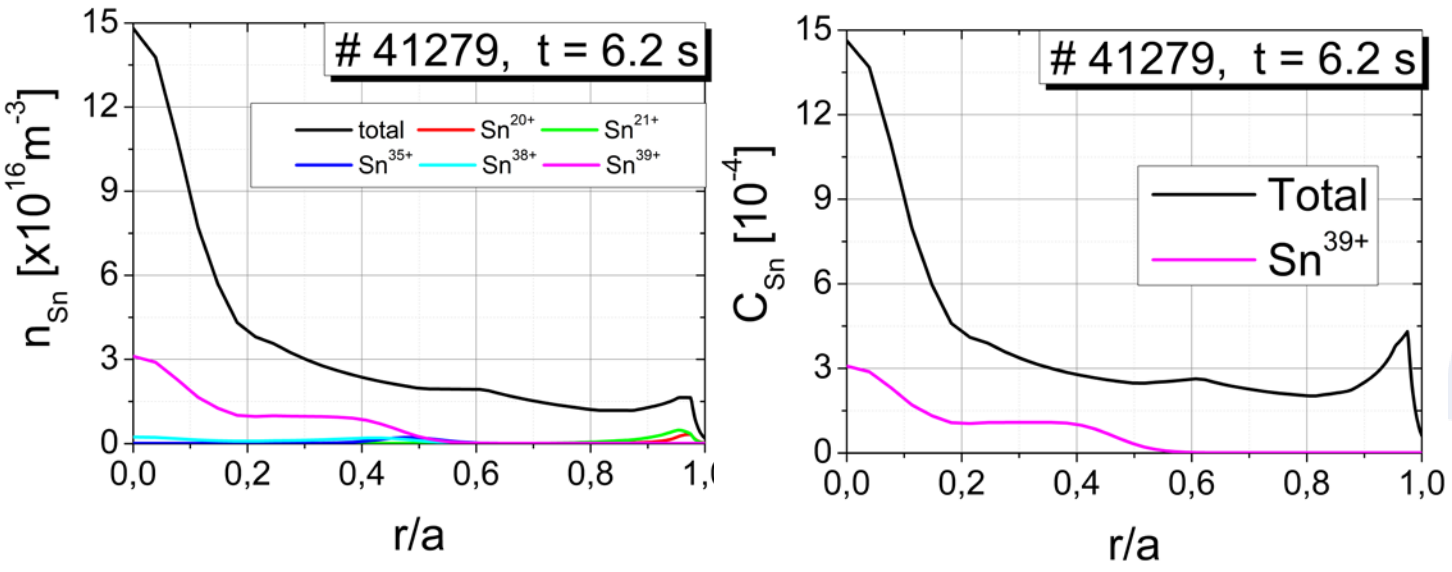
Time evolution of the plasma radiation and tungsten concentration for #41279

EXP&SIM density and temperature profile



To reproduce the experimental data, an Sn gas puff in divertor region of Γ_{Sn} **= 1.7×10^{18}** 1/s was used for t = 6.2 s. This value is lower about three times lower than the total Sn erosion measured by FVS (divertor visible spectroscopy but is three time higher of Sn erosion predicted by the HeatLMD simulation.

Sn density and concentration

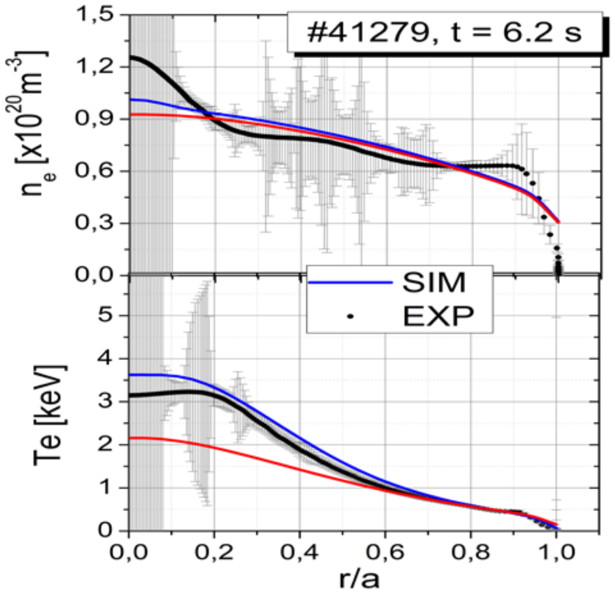


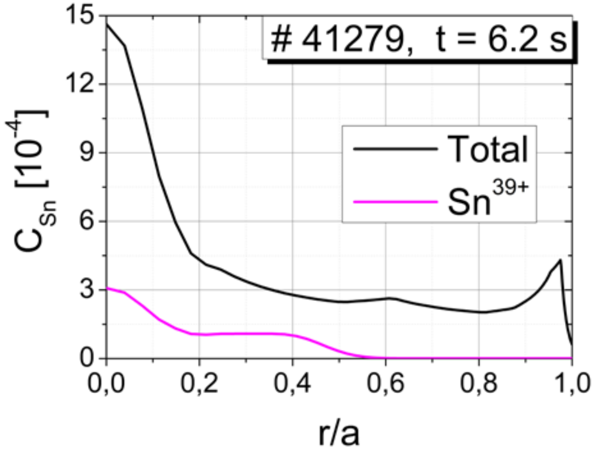
Total Sn and Sn ionization state: Sn^{20+}, Sn^{21+}, Sn^{35+}, Sn^{38+} and Sn^{39+} density (left) and concentration (right) for t=6.2s.

- The Sn^{39+} density peaks in the core plasma, while Sn^{20+}, Sn^{21+} peak near the pedestal.
- The central accumulation of Sn is consistent with impurity transport behavior previously observed -namely, accumulation for *r/a*< 0.7 and a strong inward pinch near separatrix - consistent with ASTRA modelling.

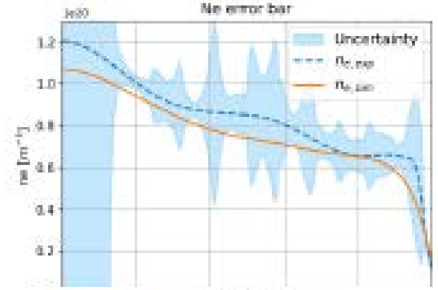
COREDIV & ASTRA

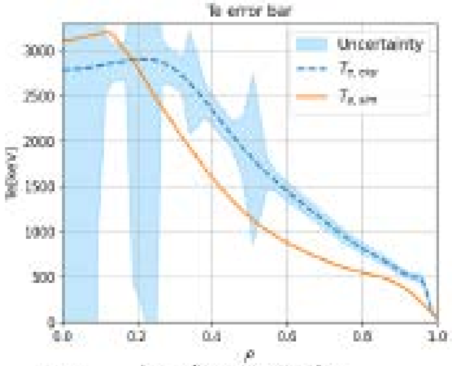
COREDIV

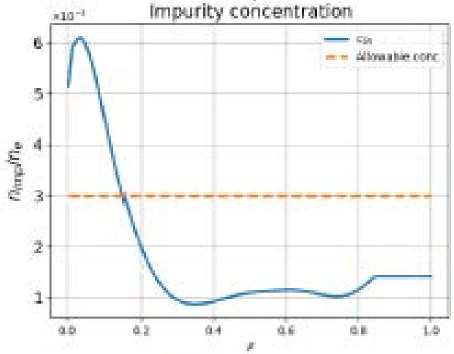


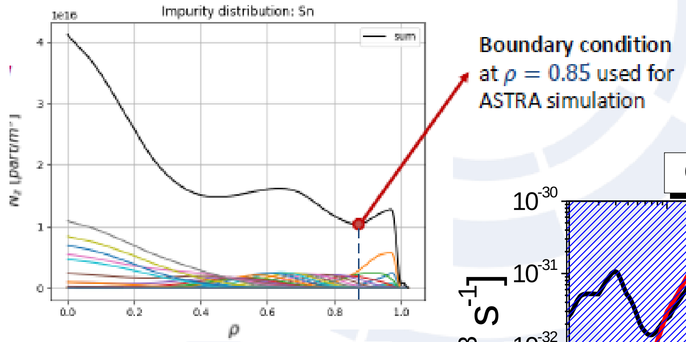


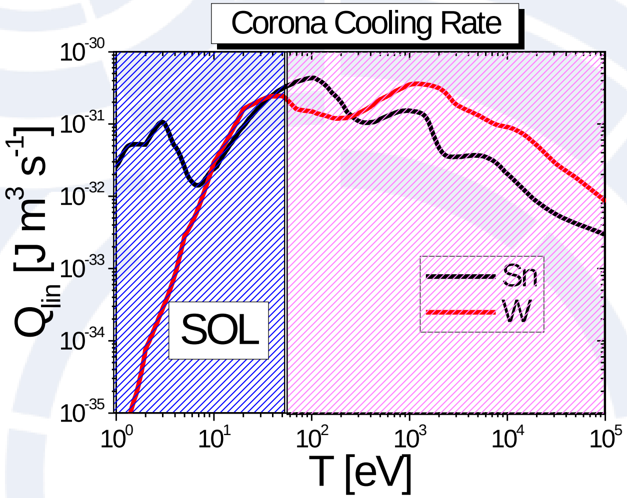
ASTRA











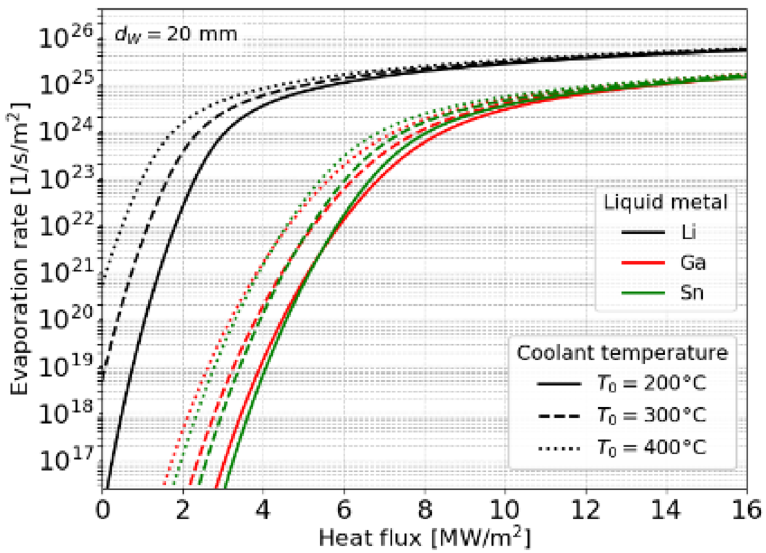
COREDIV	ASTRA
CORE+SOL	Only CORE (from r<0.85
W, C, Sn	Sn
Good matching n_e	Good matching ne
Good matching T_e	Bad matching Te

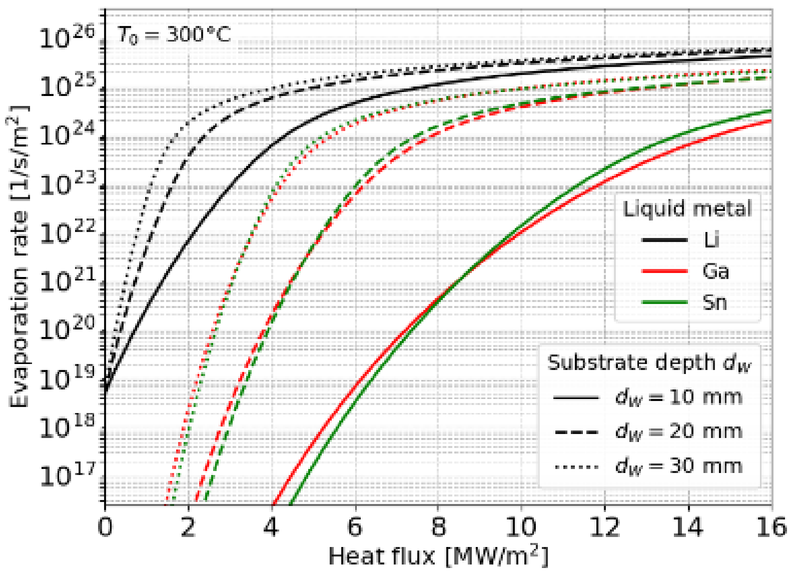
Summary parameters

Parameters	t = 2.5s	t = 3.5s	t = 6.2s
C_{Sn} [×10^{-4}]	0.08	1.53	2.84
C_W [×10^{-5}]	9.7	8.1	7.69
P_{Sn}^{CORE} [MW]	0.03	0.85	1.81
Γ_{Sn} [x10^{18} atm/s]	0.01	1.3	1.7
T_e^{plate} [eV]	22eV	14.8	11.9eV

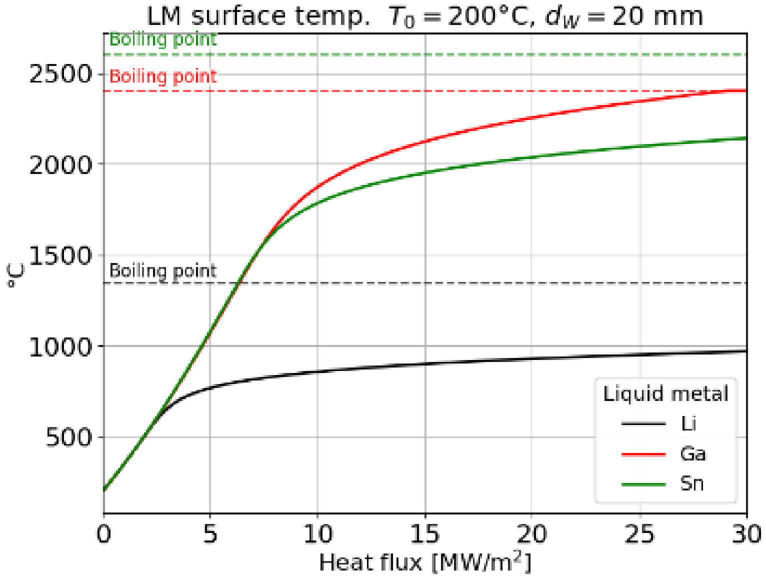
Table 1 summaries the simulated average Sn and W concentration, Sn radiation in core plasma (P_{Sn}^{CORE}) Sn gas puff level (Γ_{Sn}) and temperature on in the strike point (T_e^{plate}).

Ga: evaporation rate





The Li, Ga and Sn evaporation rate versus perpendicular heat flux



Surface temperature versus perpendicular heat

- The model predicts that the evaporation rate of Ga at a given heat flux is lower than that of Li and comparable to Sn.
- Limitations on the operational temperature window of Ga restrict the acceptable heat loads.

Model for Ga evaporation is prepared.

The results are presented in the PLASMA 2025, 15-29 September 2025, Warsaw, Poland as oral: M. Poradzinski and I. Ivanova-Stanik, "Modelling Gallium impurity sources in liquid metal divertor: comparision with Tin"

CONCLUSION

The COREDIV code has been used to perform self-consistent core–edge simulations for the future COMPASS-U tokamak with a Sn-based liquid metal divertor. The main conclusions are:

- The COREDIV code successfully simulated the Sn LMD scenario in a fully self-consistent manner.
- For Sn impurity injection, maintaining H-mode operation becomes challenging when the Sn and W layer thicknesses (d_W and d_{Sn}) are small. For an angle α= 3° H-mode operation is sustained for all analyzed d_W and d_{Sn}
- Sputtering of Sn by deuterium ions exceeds Sn self-sputtering only for α< 3°
- In scenario #5400, H-mode operation becomes difficult for Sn puffing when the core concentration exceeds C_{Sn}>3.0x10^{-4}

This report presented an interpretative modelling analysis of impurity transport in ASDEX Upgrade for a liquid tin module operating in H-mode. By combining experimental diagnostics with the COREDIV integrated modelling, we reconstruct the impurity behaviour across the core and edge regions.

To reproduce the experimentally observed W concentration and total radiation, a strong inward impurity pinch is required near the separatrix and for r/a <0.2 As a consequence, the impurity charge state distribution deviates from the coronal equilibrium, with the peak of Sn^{39+} located at r/a=0. Very good agreement was obtained for the measured n_e and T_e profiles.

The evaporation model for gallium has been prepared for future LMD studies.

PLAN 2026-2027

COREDIV modelling of COMPASS-U and DEMO using Ga (Ge as proxy) to compare with Sn (and Li)

PLAN

- For COMPASS-U: scenario # 24 300 and # 5400
- For DEMO, which scenario?

Simulation for EU DEMO 2018: R_T = 9.002 m, a = 2.904 m, I_p = 17.75 MA, field B_T = 5.855T, ε = 1.65, $\langle n_e \rangle_{VOL}$ = 7.261 × $10m^{-3}$ P_{LH} = 120.8MW, H_{98} = 1.1 and auxiliary heating power P_{aux}=50MW, for which is prepared analysis with Li divertor (M. Poradzinski *Fusion Engineering and Design 146 (2019) 1500–1504)*

or new scenario (obligatory need the PROCESS data for n_e, T_e and T_i)