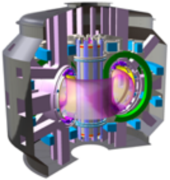

Power exhaust studies in the Divertor Tokamak Test facility

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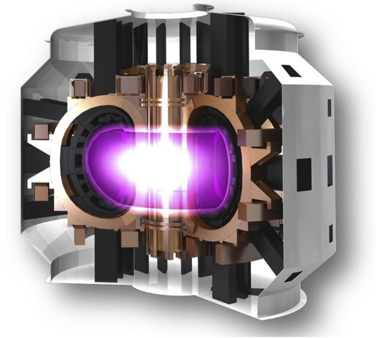
Introduction

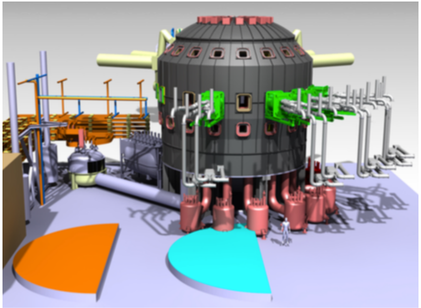
- A new tokamak, named Divertor Tokamak Test (DTT) will be built in Italy
- Its main scientific goal will be to **investigate energy and particle exhausts in order to withstand the load expected in fusion power plant** (Mazzitelli *et al.* 2019)
- The budget for the experiment has been approved and secured
- It will be built in Frascati with an estimated **construction time of 7 years** and an expected **operation time of 25 years**



DTT at a glance

B_t [T]	I_p [MA]	Vol [m^3]	P_{aux} [MW]	R/a [m/m]	Pulse length [s]
6	5.5	≈ 28	45	2.14/0.65	~ 100

- DTT flexible design to accomodate the best candidate divertor concept by EUROfusion after PEX activities (around 2022-2023)
- Up-down symmetry to allow DN configuration
- The foreseen additional power and power mix **must guarantee significant DEMO relevant results**



DTT at a glance

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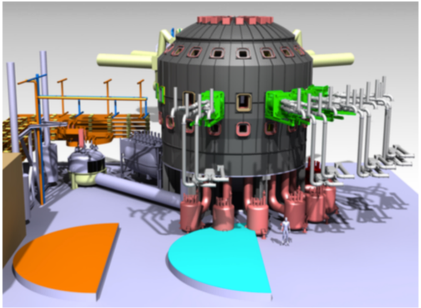
6	5.5	≈ 28	45	2.14/0.65	~ 100

n/n_G	0.45
P_{sep}/R	15
$\langle T_e \rangle$ [keV]	6.1
$\langle n \rangle [10^{20} m^{-3}]$	1.72
k	1.89
δ	0.46
β_N	1.5
ν^*	2.5
ρ^*	2.8



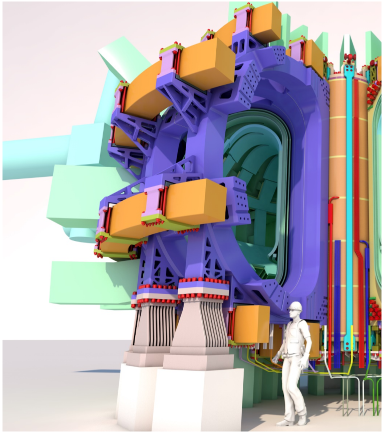
DTT Technology

	TF	CS	PF	In-vessel
Number	18	6	6	6
Type	Nb3Sn	Nb3Sn	Nb3Sn	Cu

On-going design of additional HTS coil to be inserted into the Central Solenoid (10% flux increase test))

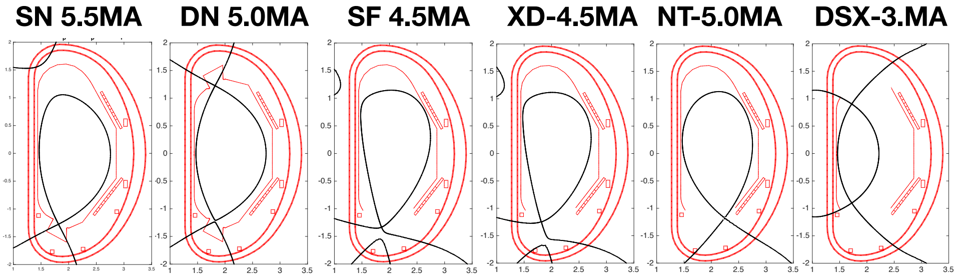
Vessel 2 stainless steel vessel shells of 1.5cm. 2 toroidally discontinuous stabilizing plates of 4cm

Divertor 54 toroidal sectors or cassettes (symmetric wrt equatorial plane). Remote handling compatable



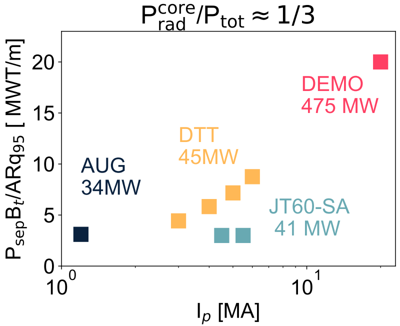
(Albanese *et al.* 2018; Di Gironimo *et al.* 2019)

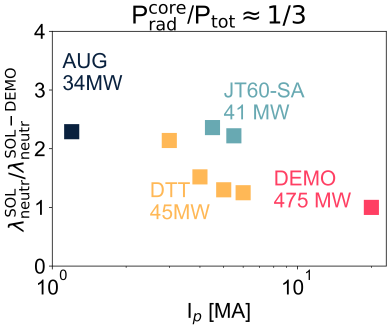
DTT Scenarios



The facility will offer sufficient flexibility to incorporate the best candidate divertor concept even at a later stage of its realization, on the basis of the results of PEX activities. (Ambrosino *et al.* 2019)

DTT Plasma scenarios





(De Baar et al., Final Report of the Plasma Exhaust Ad Hoc Group (PEX AHG), Phase 3 (2018))

- DTT can reach high levels of SOL loading with Demo Relevant $P_{sep}/R \geq 15$ MW/R
- SOL neutral penetration comparable to the one foreseen for DEMO
- Phase I 25 MW (15 MW ECRH, 3 MW ICRH, 7MW NNBI), Phase II 45 MW (20-30 MW ECRH, 3-9 MW ICRH, 7-15 MW NNBI) (Agostinetti *et al.* 2019; Ceccuzzi *et al.* 2018; Garavaglia *et al.* 2018)
- High density (core and pedestal) $n_{e,c} \approx 2 \times 10^{20}\mathrm{m}^{-3}$ and a $n_{e,ped} \approx 1.4 \times 10^{20}\mathrm{m}^{-3}$

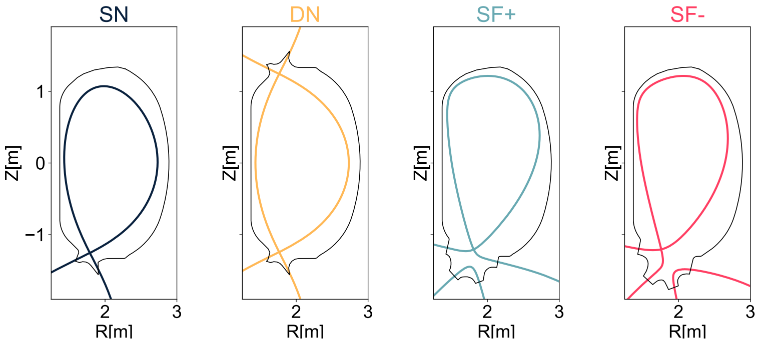
DTT Plasma exhaust studies

- Step ladder approach starting from simple modelling in order to capture the foundamental differences between the various magnetic configurations

DTT Plasma exhaust studies

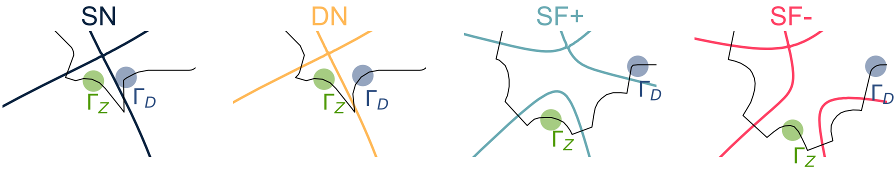
- Step ladder approach starting from simple modelling in order to capture the foundamental differences between the various magnetic configurations
- Based on relatively large $\lambda_{q,u} \approx 3$ mm kept constant for all the configurations
- SOLEDGE2D-Eirene (Bufferand *et al.* 2013) simulations without drift with the following parameters
  - $\chi_{\perp} = 0.15$ **m^2/s** and $D_{\perp} = 0.352$ **m^2/s** compatible with $\lambda_{q,u} \approx 3$
  - Tungsten wall and divertor
  - Fixed particle flux from the core $\Gamma_c = 0.3 \times 10^{22}\mathbf{s}^{-1}$ and gas-puffing $\Gamma_{puff} = 3 \times 10^{22}\mathbf{s}^{-1}$
  - P_{sep} power scan at high density $1 \times 10^{20}\mathrm{m}^{-3}$ ($n_{sep}/n_G \approx$ **0.25**)
  - Two different seeding scan with Ne and Ar at two values of separatrix greenwald fraction $n_{sep}/n_G \approx$ **0.12** and **0.25**

Modeled configuration



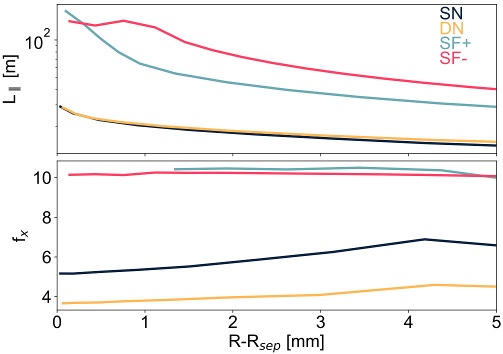
All the main configurations have been modeled with ad-hoc designed walls in order to ensure **similar grazing angle** $\alpha \approx 1.6°$.

Modeled configuration



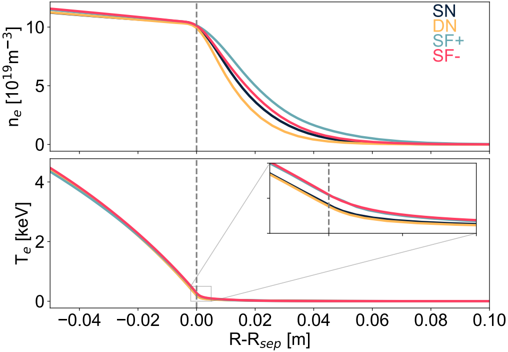
All the main configurations have been modeled with ad-hoc designed walls in order to ensure **similar grazing angle $\alpha \approx 1.6°$**. They all have **similar gas-puffing location**, **pumping surfaces located in the inclined dome plates in the PFR** and **seeding location on the dome**

Modeled configuration



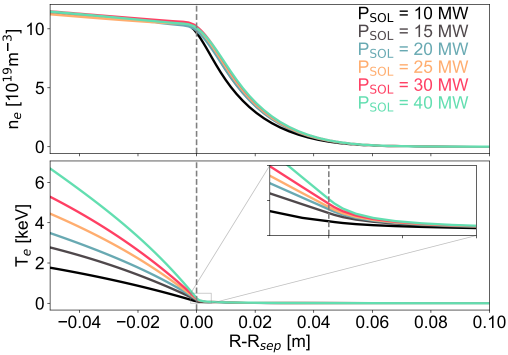
- A clear difference exists in term of $L_{\parallel}$ much higher for the SnowFlake configurations and f_x at the target

Modeled configuration



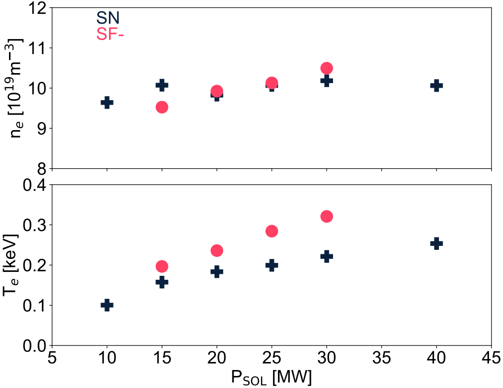
- A clear difference exists in term of $L_{||}$ much higher for the SnowFlake configurations and f_x at the target
- A first major difference is observed **in attached configuration**, with larger **upstream** SOL density in SF configuration
- Larger temperature at the separatrix observed in SF configurations

Modeled configuration



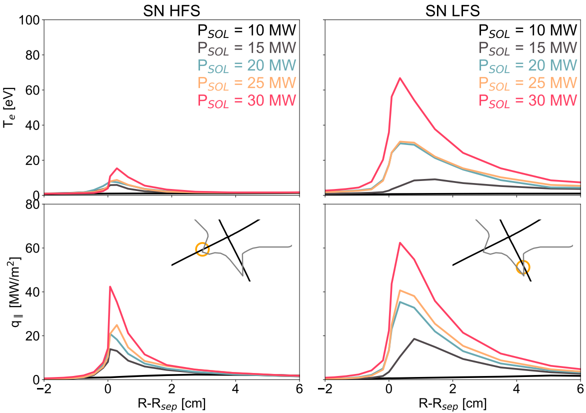
- In SN configuration P_{SOL} does not affect the density profiles and causes an increase of the separatrix temperature

Modeled configuration



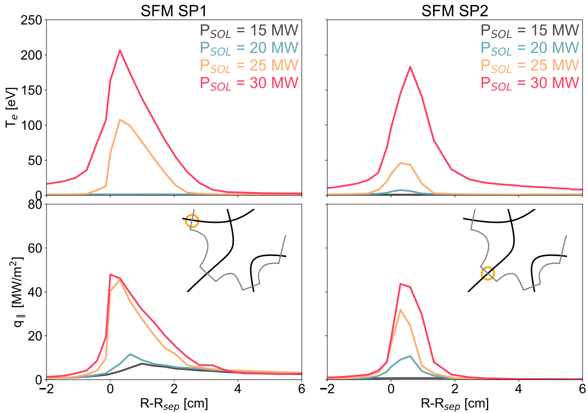
- In SN configuration P_{SOL} does not affect the density profiles and causes an increase of the separatrix temperature
- Comparing separatrix density and temperature during a power scan in SN and SF- reveals a Faster increase of $T_{e,sep}$ with power for SF- configuration

Target profiles in SN and SF- configurations



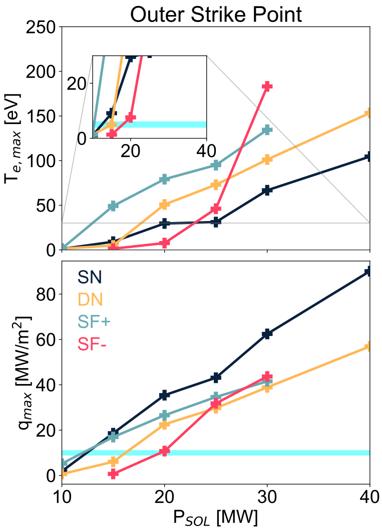
- **In SN configuration** Larger heat flux observed on the OSP (even without drift)
- A scan in power reveal a detachment threshold around 10 MW for SN configuration

Target profiles in SN and SF- configurations

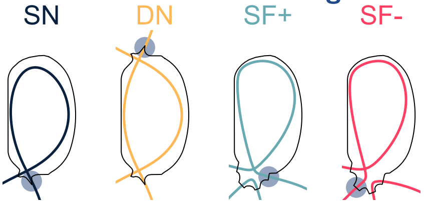


- In SF- configuration most of the power is diverted to SP1 and SP2. **The maximum heat flux always lower then SN configuration**
- **Higher temperature observed in attached condition in both the target**
- SF- configuration exhibits detachment at higher power $P_{SOL} \approx 15 - 20$ MW

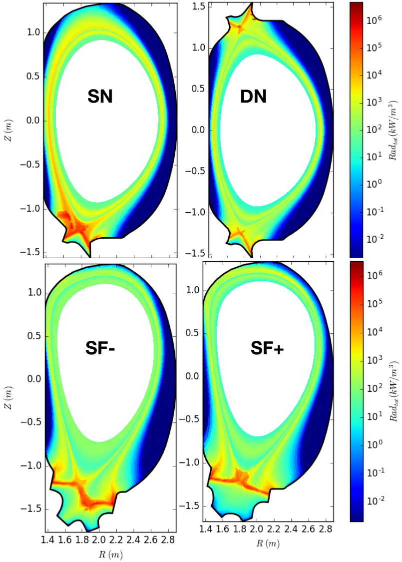
Power scan in SN, SF-, SF+ and DN configuration



- A power scan reveals that the **Outer Strike Point (OSP) exhibits the lower temperature in attached conditions in SN configuration**
- OSP detachment achieved in SN and DN configuration **only at very low power**:
- **SF- configuration detaches at higher power w.r.t the other configurations**

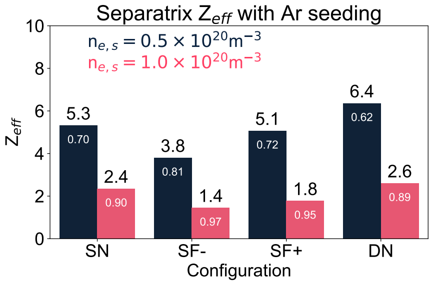


Impurity seeding



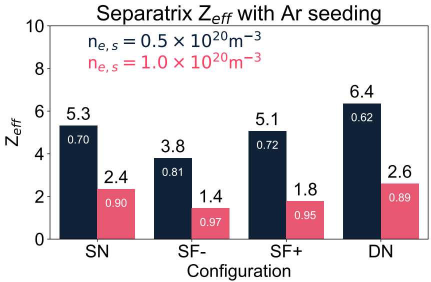
- **Ar seeding** with Density at the separatrix $n_{sep} = 10^{20} m^{-3}$ and $P_{sep} = 36MW$
- Ar puffing increases in order to reach 90% radiation fraction: **DEMO-like scenarios**

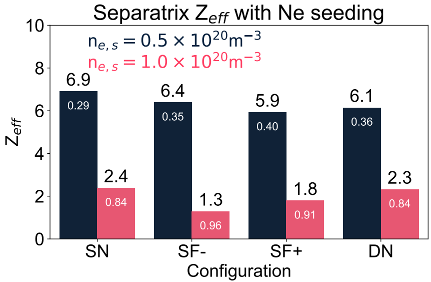
Impurity seeding



- At these level of $n_{e,sep}$ this is achieved with a $Z_{eff,sep}$ between 1.4 and 2.6 and low diluition
- **SF- configuration provides the lowest $Z_{eff,sep}$**

Impurity seeding





- At these level of $n_{e,sep}$ this is achieved with a $Z_{eff,sep}$ between 1.4 and 2.6 and low diluition
- SF- configuration provides the lowest $Z_{eff,sep}$
- **Ne seeding provides even lower Z_{eff} at high density likely due to lower temperatures**

Conclusions

- DTT tokamak will be built at Frascaty, Italy
- DTT device will provide non-nuclear plasmas performance with high level of SOL loading
- Initial Plasma Exhaust studies reveal that conventional SN configuration will require impurity seeding to reach detachment
- SF configuration able to reach pure D_2 detachment at higher P_{SOL}
- At high density reasonable seeded impurity concentration obtained in all the configurations, with alternative snow-flake solutions providing lower concentration at the separatrix
- Integrated modeling (not described here) started to combine core and edge modeling

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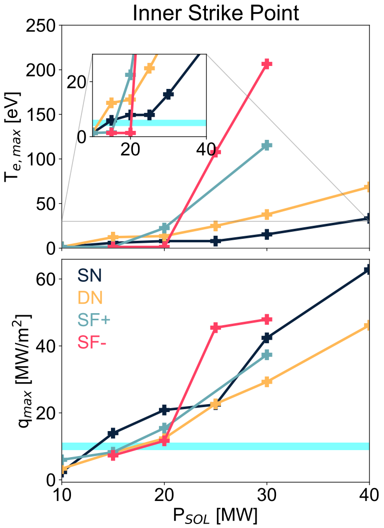
Spare slides: ISP power scan



- A power scan reveals that **at the Inner Strike point (ISP)**, the **SN configuration exhibits the lower temperature in attached conditions**
- ISP detachment achieved in SN and DN configuration **only at very low power**: **higher power feasible in SF configurations**