Task:DIV-IDTT.S.07-T005-D001-D002
Progresses on equatorial coils and stabilizing plates

E. Acampora[2], R. Ambrosino[1,2], A.Castaldo[3]

1. DTT S.c.a.r.l. 2. CREATE /University of Naples Federico II 3. ENEA

WPDIV-DTT Midterm meeting

23th June 2022

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

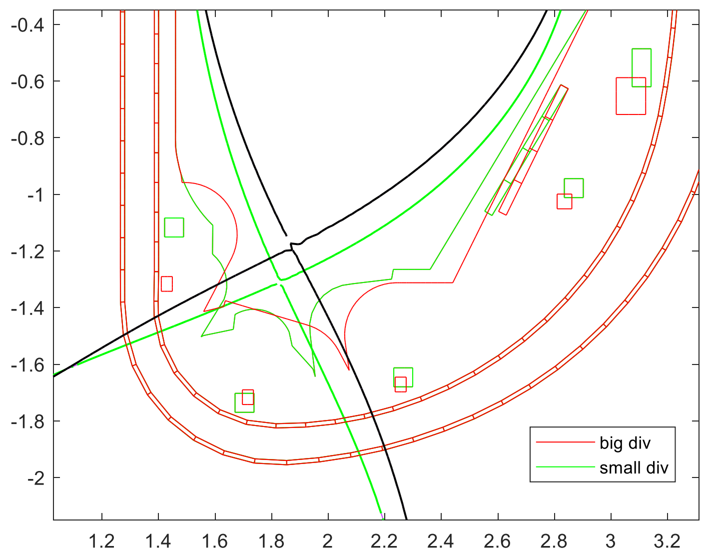
Preliminary observations

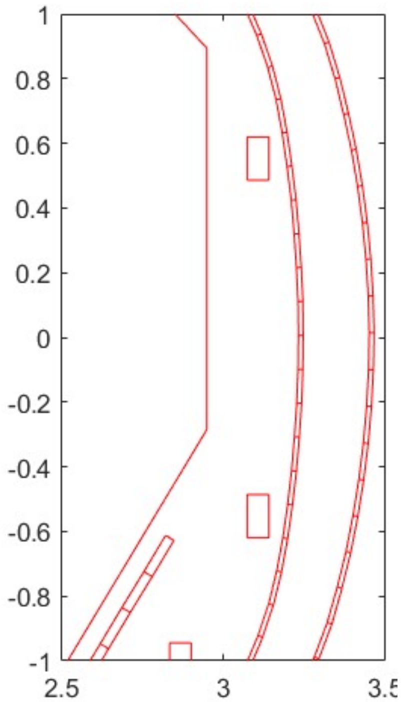
- A parametrical analysis of the passive stabilizing plates is required due for two main reasons:
  - Variation of the VS coils positions:

R = 3.1076m; Z = ±0.553m → R = 3.07m; Z = ±0.653m

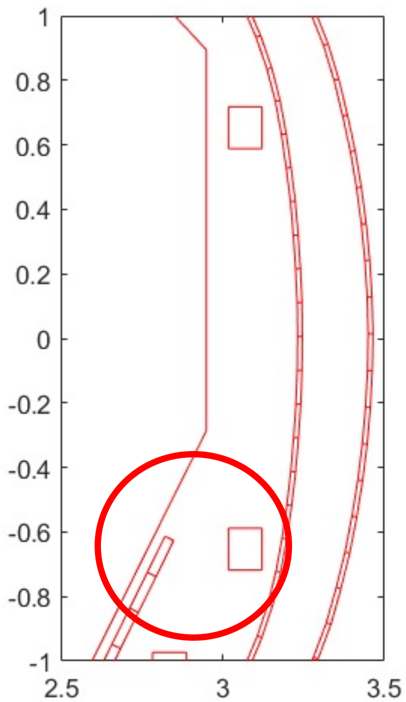
  - From "small" to "big" divertor concept:

→ Vertical offset of 15 cm of nominal plasma





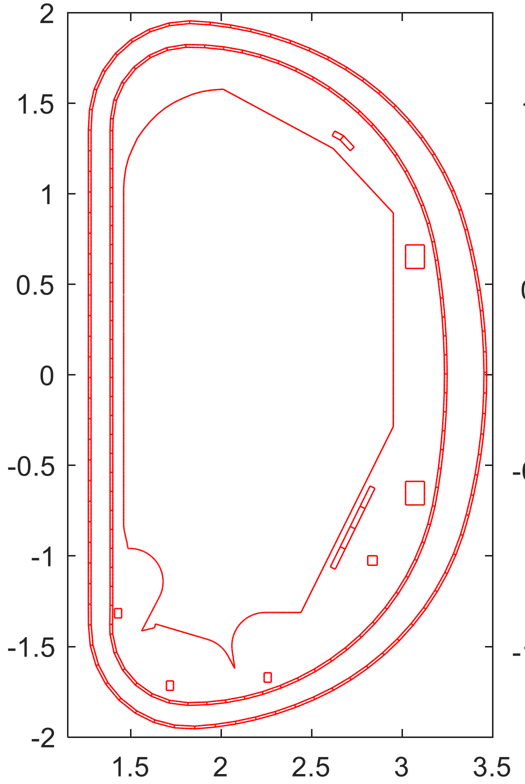
Old VS coils position



New VS coils position

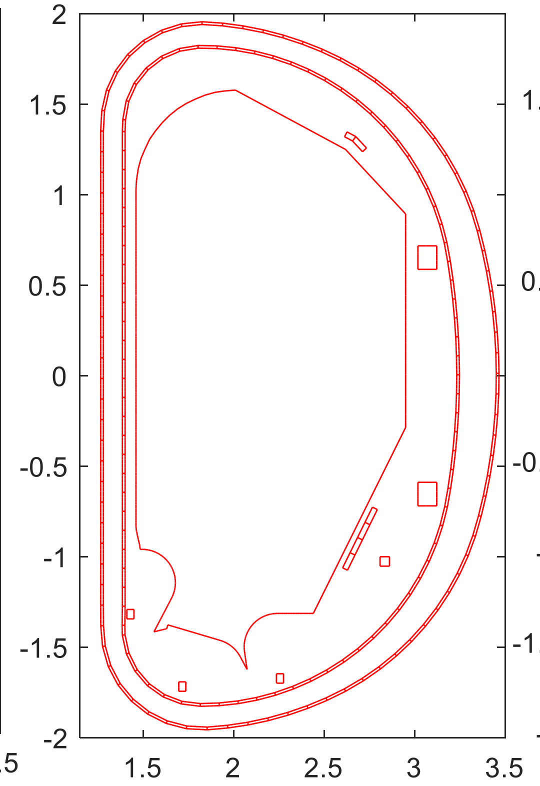
Considered configurations for the passive plates

CASE 1



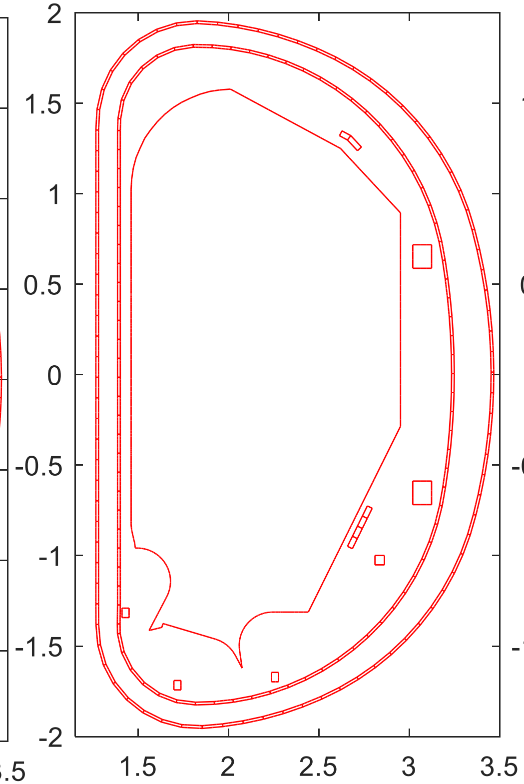
≃50 cm

CASE 2



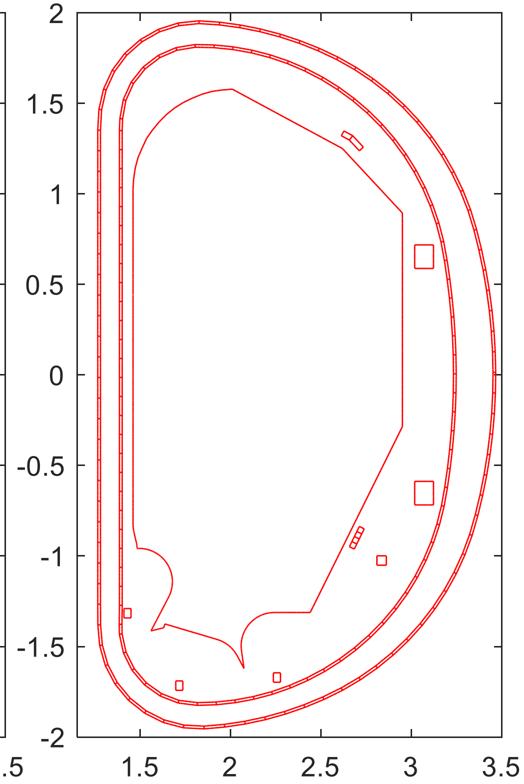
≃37 cm

CASE 3



≃ 25 cm

CASE 4



≃ 12 cm

CASE 5: <u>without lower stabilizing plate</u>

Performance Analysis Criterion

- To compare passive stability parameters (such as growth rate and stability margin) of notable plasma snapshots (EOF-SRD) in the 5 cases.

- To compare active stability performance markers, i.e. the VS system voltage and current requests to stabilize a VDE in the most critical case (BAP - *Best Achievable Performance*), in the 5 cases .

  - In agreement with the Gribov paper (Y. Gribov *et al* 2015 *Nucl. Fusion* **55** 073021):
    →'robust' operation corresponds to max(Z0)/a ≈ 10% (for DTT, max(Z0) ≈ 7 cm)

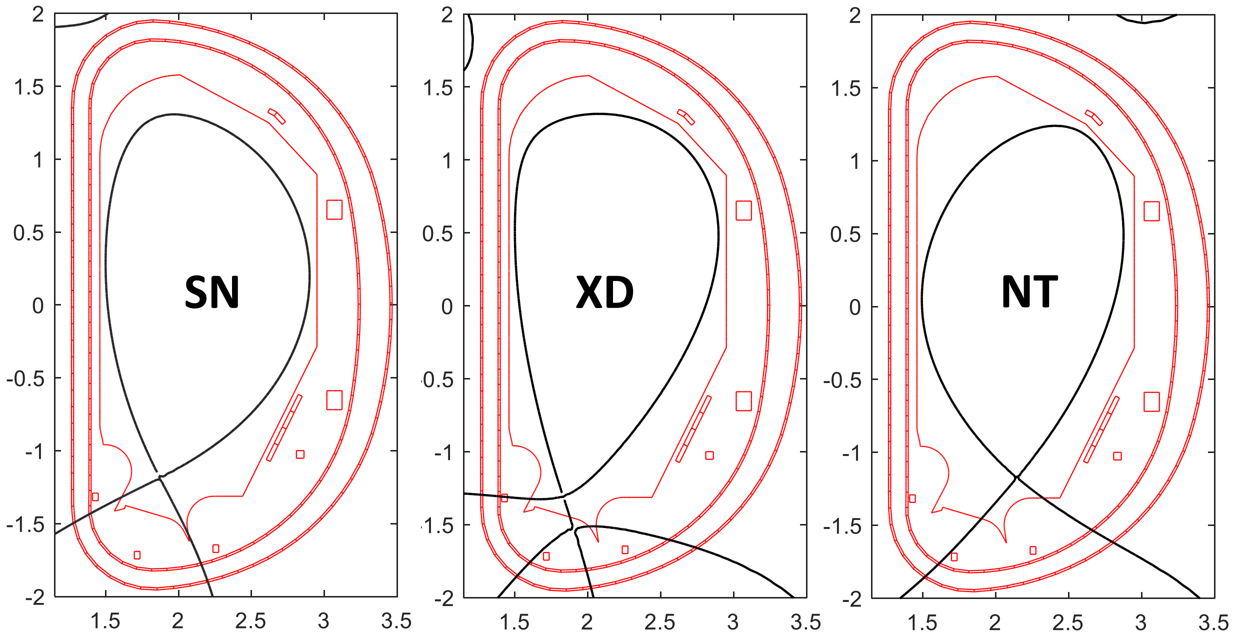
  - A constant voltage αV_0 is imposed in order to counteract the unstable mode, where V_0 is the minimum voltage able to stop the plasma vertical unstable mode for t→∞ and $\alpha > 1 \in R$ is a safety factor.

  - The maximum current correspond to the current request in the time instant when the plasma instability is recovered in the most critical case.

Performance Analysis Criterion

- The analysis has been performed for the following plasma configurations:

	Ipl [MA]	betapol	li
SN (EOF)	5.5	0.65	0.8
SN (SRD)	5.5	0.1	0.8
SN (SRD)	5.5	0.1	1.2
XD (EOF)	4.5	0.65	0.8
XD (SRD)	4.5	0.1	0.8
NT (EOF)	4.0	0.4	0.8
NT (SRD)	4.0	0.1	0.8



Passive Stability Results - SN

- The vertical tilt of 15cm of the nominal plasma shape, allows better coupling with the passive structures at 2 'o clock, enhancing passive stability performance.

- A preliminary comparison of the passive stability parameters of the "big" divertor and "small" divertor in the worst case possible (betapol=0.1, li=1.2) with and without lower plate:

Big div	Growth rate [s^-1]	Stability Margin
CASE 1	107.62	0.47
CASE 5	167.56	0.29

New geometry

Small div	Growth rate [s^-1]	Stability Margin
CASE 1	153	0.41
CASE 5	278	0.22

Old geometry

- It is possible to reduce the length of the lower stability plate without great criticalities.

BAPs of the SN snapshots

SCENARIO SN - V=1.5V0 - TURNS=20 - VDE=1cm							
	Growth rate [s^-1]	Stability Margin	z0 [cm]	zmax [cm]	Voltage [kV]	currents [kA]	Power [MW]
CASE 1							
EOF	50.28	0.77	1.00	1.26	-0.22	-0.63	0.14
SRD	54.50	0.75	1.00	1.26	-0.28	-0.72	0.20
SRD li=1.2	107.62	0.47	1.00	1.19	-0.49	-0.69	0.34
CASE 2							
EOF	51.02	0.76	1.00	1.25	-0.22	-0.62	0.13
SRD	55.22	0.74	1.00	1.25	-0.28	-0.70	0.19
SRD li=1.2	110.34	0.45	1.00	1.18	-0.49	-0.67	0.33
CASE 3							
EOF	52.25	0.75	1.00	1.25	-0.22	-0.62	0.13
SRD	56.69	0.73	1.00	1.25	-0.28	-0.70	0.20
SRD li=1.2	113.45	0.45	1.00	1.18	-0.50	-0.66	0.33
CASE 4							
EOF	55.24	0.72	1.00	1.23	-0.22	-0.59	0.13
SRD	59.80	0.70	1.00	1.23	-0.29	-0.67	0.19
SRD li=1.2	122.70	0.42	1.00	1.16	-0.51	-0.62	0.32
CASE 5							
EOF	67.46	0.54	1.00	1.16	-0.24	-0.51	0.12
SRD	72.04	0.54	1.00	1.16	-0.31	-0.57	0.17
SRD li=1.2	167.56	0.29	1.00	1.10	-0.56	-0.46	0.26

BAPs of the SN snapshots

- Assuming a VDE event of 1cm, the plasma snapshot at $\beta_{pol} = 0.1$ and $l_i = 1.2$ requires:
  - Voltage $\alpha V_{0,MAX} = 0.51kV$
  - Current $I_{MAX} = 0.62kA$

- Taking into account that the current and voltage request evolve linearly with the VDE amplitude, to recover a VDE event of 7cm, we have:

  - Voltage $\alpha V_{0,MAX} \cong 3.57\ kV$
  - Current $I_{MAX} = 4.34\ kA$
  - Power $P_{MAX} = 15.49\ MVA$

- The definition of the number of turns can be used for the optimization of the current and voltage request at fixed power.

- Concerning the dynamical model of the power supply we can assume a response delay of the order to 150 μs with a time constant of 50 μs.

BAPs of the XD snapshots

SCENARIO XD - V=1.5V0 - TURNS=20 VDE=1cm							
	Growth rate [s^-1]	Stability Margin	z0 [cm]	zmax [cm]	Voltage [kV]	currents [kA]	Power [MW]
CASE 1							
EOF	81.73	0.61	1.00	1.24	-0.30	-0.52	0.16
SRD	95.74	0.56	1.00	1.20	-0.43	-0.58	0.25
CASE 2							
EOF	82.48	0.60	1.00	1.23	-0.30	-0.50	0.15
SRD	97.00	0.55	1.00	1.19	-0.43	-0.56	0.24
CASE 3							
EOF	85.47	0.59	1.00	1.22	-0.31	-0.50	0.16
SRD	99.78	0.54	1.00	1.19	-0.43	-0.56	0.24
CASE 4							
EOF	91.31	0.56	1.00	1.20	-0.32	-0.47	0.15
SRD	106.08	0.52	1.00	1.17	-0.44	-0.52	0.23
CASE 5							
EOF	123.80	0.38	1.00	1.12	-0.35	-0.35	0.12
SRD	135.65	0.37	1.00	1.10	-0.46	-0.38	0.17

BAPs of the NT snapshots

SCENARIO NT - V=1.5V0 - TURNS=20 VDE=1cm							
	Growth rate [s^-1]	Stability Margin	z0 [cm]	zmax [cm]	Voltage [kV]	currents [kA]	Power [MW]
CASE 1							
EOF	68.67	0.58	1.00	1.23	-0.23	-0.54	0.13
SRD	98.37	0.45	1.00	1.20	-0.30	-0.49	0.15
CASE 2							
EOF	69.35	0.57	1.00	1.22	-0.23	-0.52	0.12
SRD	99.84	0.44	1.00	1.19	-0.30	-0.48	0.14
CASE 3							
EOF	72.14	0.55	1.00	1.22	-0.24	-0.52	0.12
SRD	104.24	0.43	1.00	1.19	-0.31	-0.48	0.15
CASE 4							
EOF	76.87	0.53	1.00	1.20	-0.24	-0.50	0.12
SRD	112.47	0.41	1.00	1.17	-0.32	-0.45	0.14
CASE 5							
EOF	103.12	0.37	1.00	1.12	-0.27	-0.40	0.11
SRD	157.17	0.27	1.00	1.09	-0.34	-0.33	0.11

Conclusions

- Due to the last modification of the DTT device related to the divertor and the position of the in-vessel equatorial coils, the conceptual design of the stabilizing plate has been modified.

- The vertical movement of the plasma of the order of 10-15cm has improved the vertical stability performance of the configuration allowing a significant reduction of the plate dimension

- The result of the analysis has shown that a passive saddle coil, similar to the one in use in ASDEX-U, is a possible solution also for DTT

- Further analysis are needed to determine the material and the final dimension of the plate (ongoing)