Turbulence in NT TCV: experiments and simulations

Alessandro Balestri

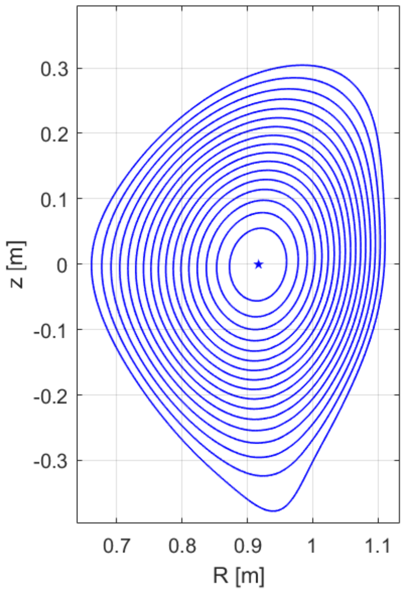
30.11.2022 – TSVV2 annual workshop

Swiss Plasma Center

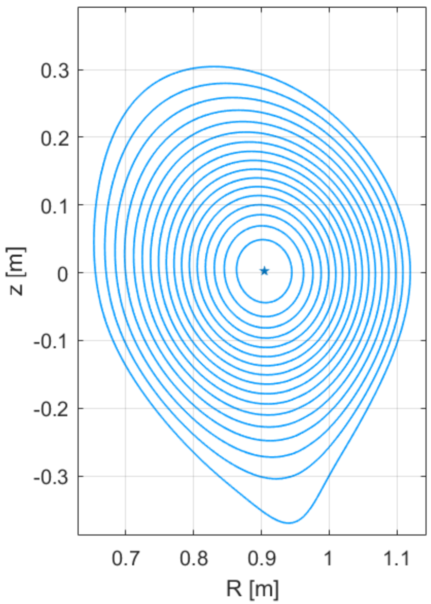
Overview

- Investigate the effect of the **Up-Down triangularity imbalance** on the confinement in **diverted** configurations
  - **Experimental side**: The upper or lower triangularity are varied within a shot, while all the other plasma parameters are kept fixed. The global confinement is then assessed by looking at the normalized beta and energy confinement time.
  - **Gyrokinetic simulations**: GK GENE simulations have been performed at fixed radius (rho=0.9) in order to isolate the effect of the shape.

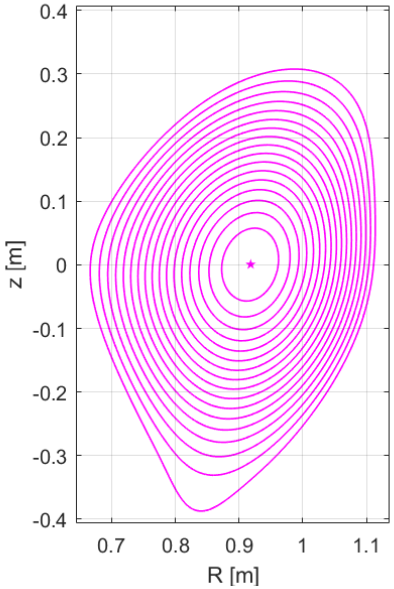
Overview of the scenarios



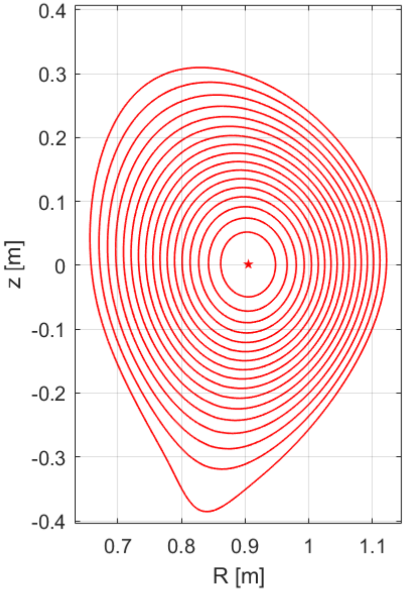
NN



PN



NP



PP

EPFL

Effect of Up-Down triangularity imbalance in diverted configurations: Experimental evidences

Swiss
Plasma
Center

List of shots – Ohmic discharges

A. Balestri

δ^{top} scan with δ^{XP}<0

- 67057 (LSN)
- 67063 (LSN)
- 68954 (LSN)
- 68176 (LSN)
- 68927 (USN)
- 67064 (LSN)
- 67068 (LSN)

δ^{top} scan with δ^{XP}>0

- 68783 (LSN)
- 68924 (USN)

δ^{XP} scan with δ^{top}<0

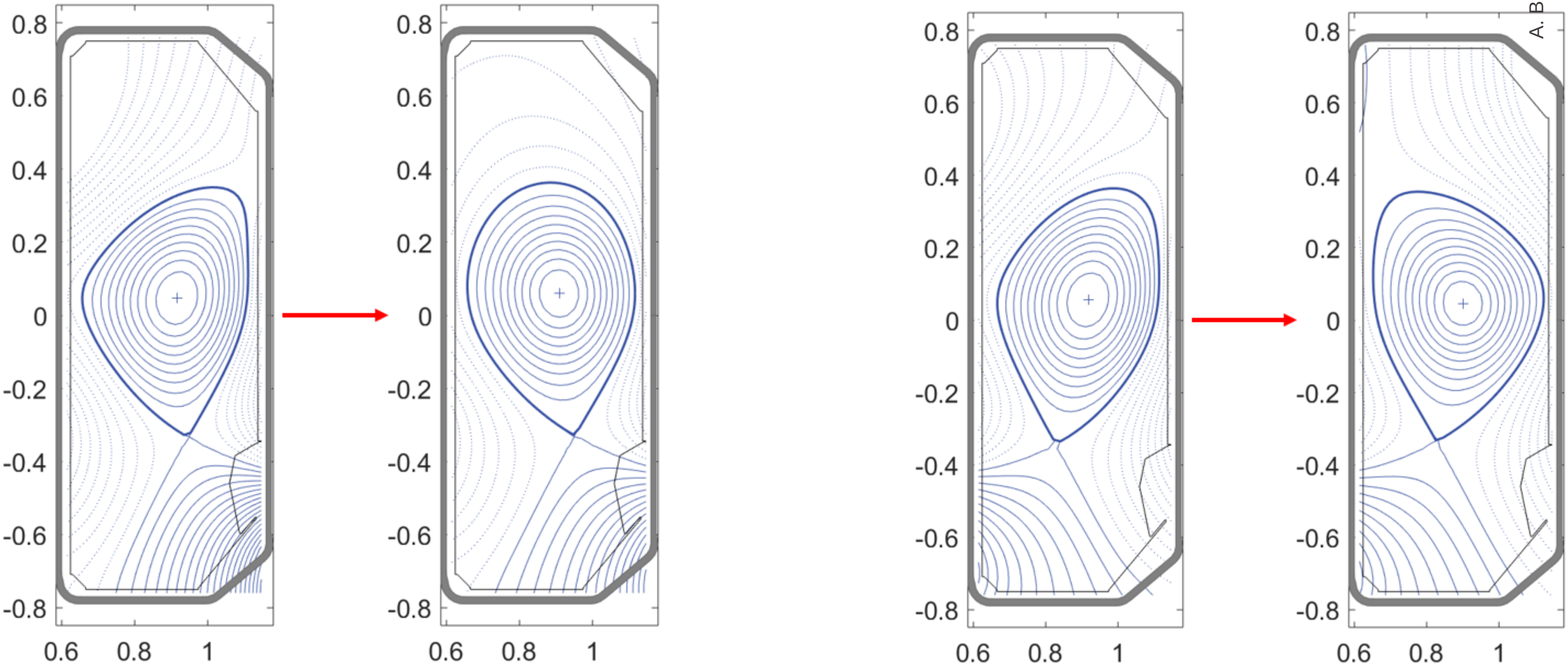
- 68943 (USN)

δ^{XP} scan with δ^{top}>0

- 68785 (LSN)
- 68934 (USN)

During a δ-scan **all the plasma parameters and powers were kept fixed.**

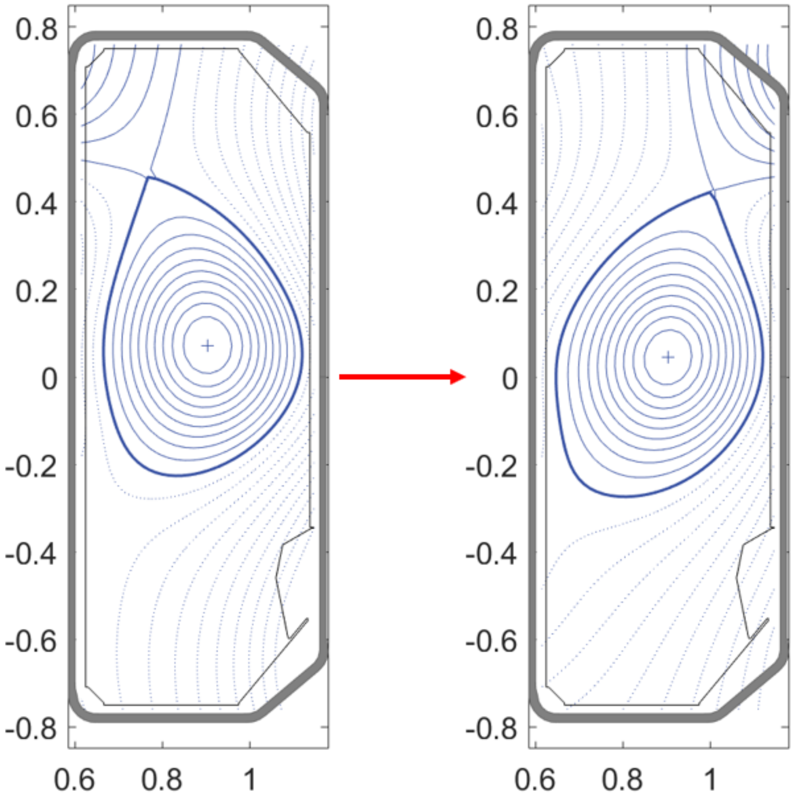
δ^{top} scan



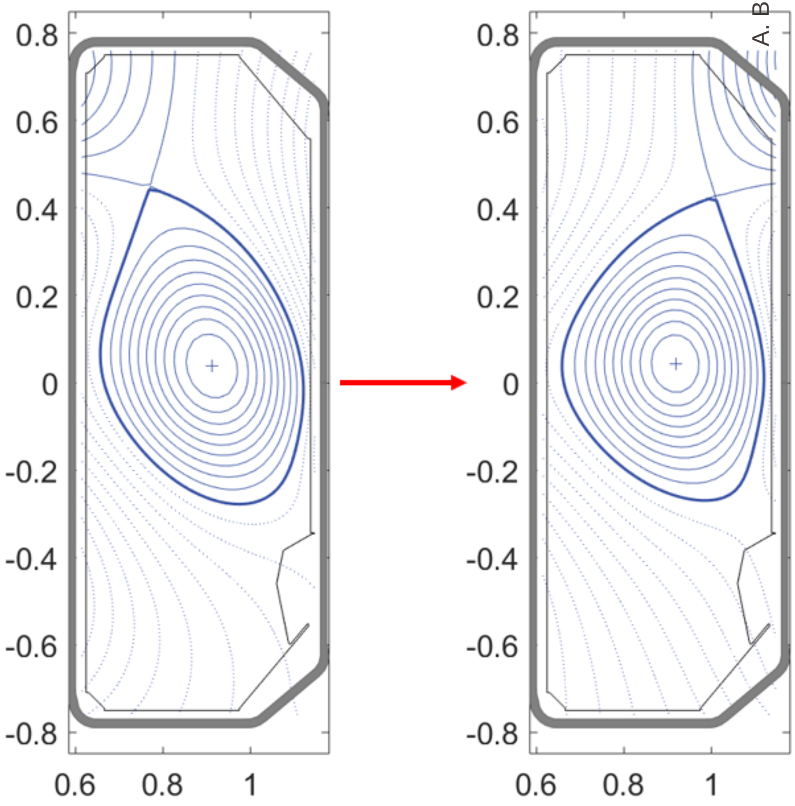
δ^{top} scan with δ^{XP}<0

δ^{top} scan with δ^{XP} >0

δ^{XP} scan

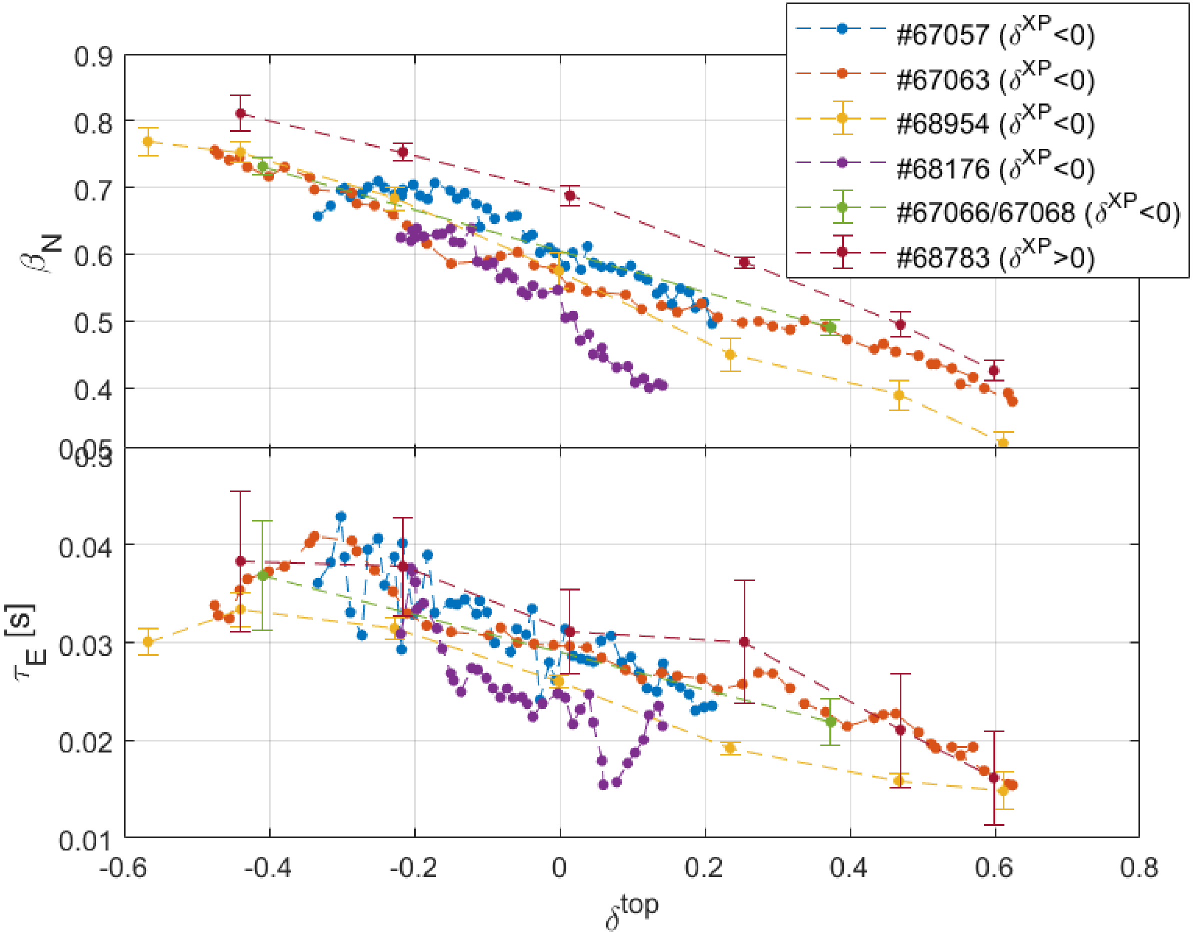


δ^{XP} scan with δ^{top} >0



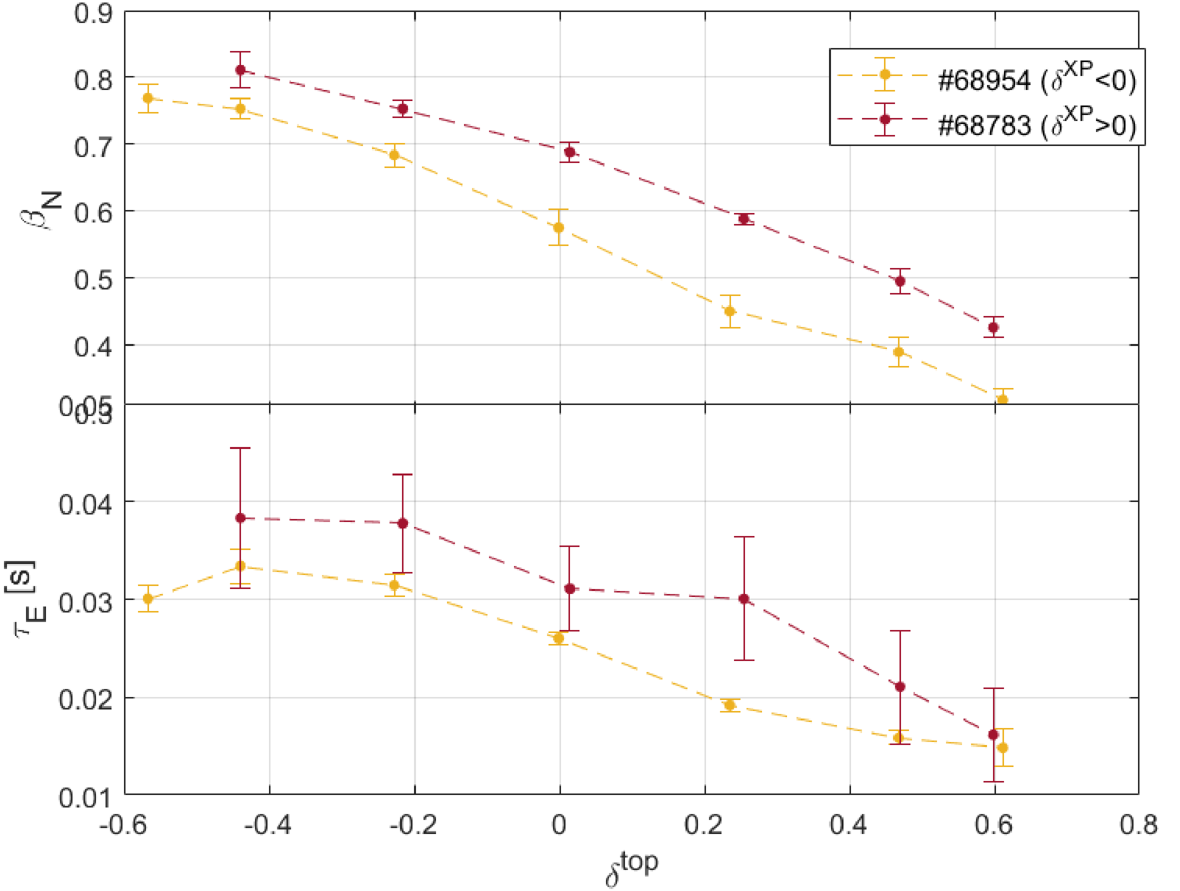
δ^{XP} scan with δ^{top} <0

Ohmic discharges (LSN) - δ^{top} scan



- δ^T <0 always leads to better confinement

Ohmic discharges (LSN) - δ^{top} scan

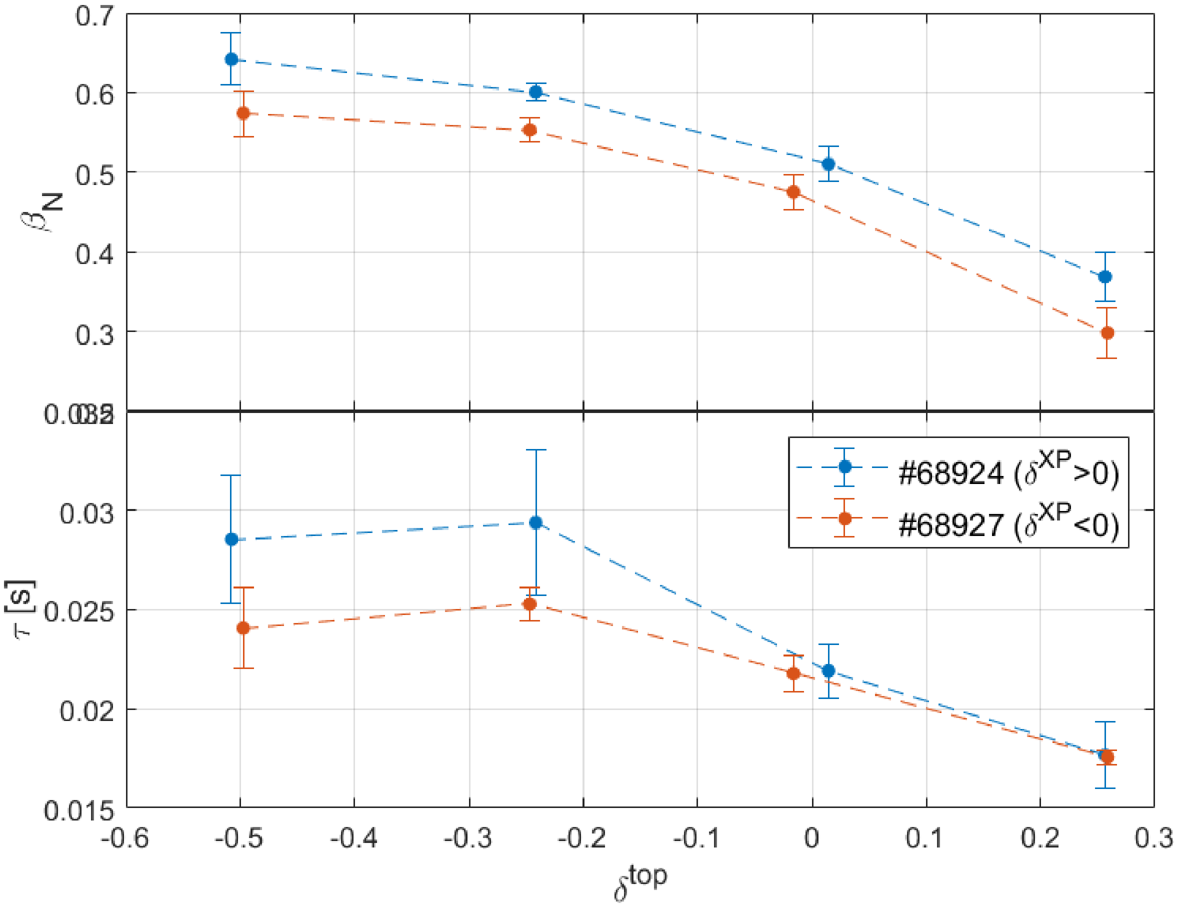


- $\delta^T < 0$ always leads to better confinement
- $\delta^{XP} > 0$ leads to slightly better confinement

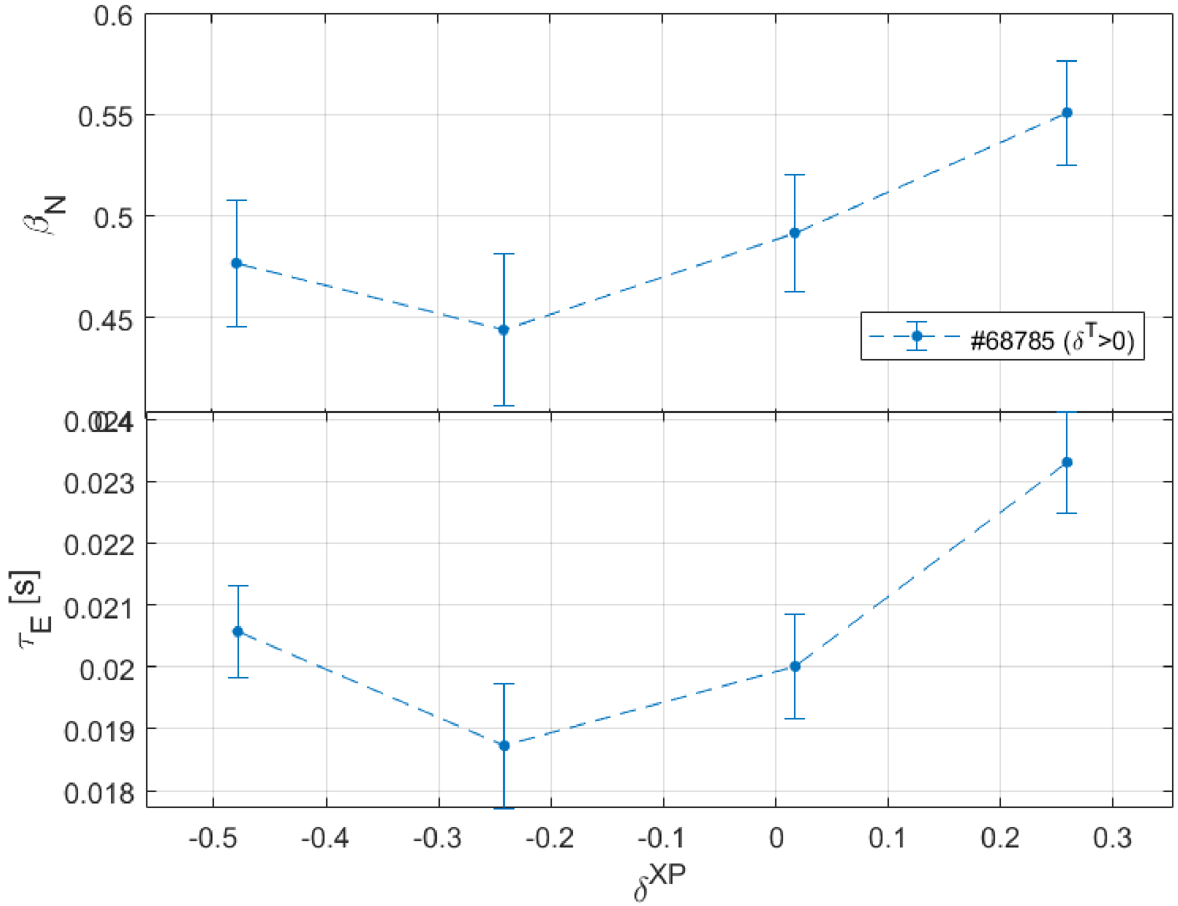
Swiss Plasma Center

Ohmic discharges (USN) - δ^{top} scan

A. Balestri



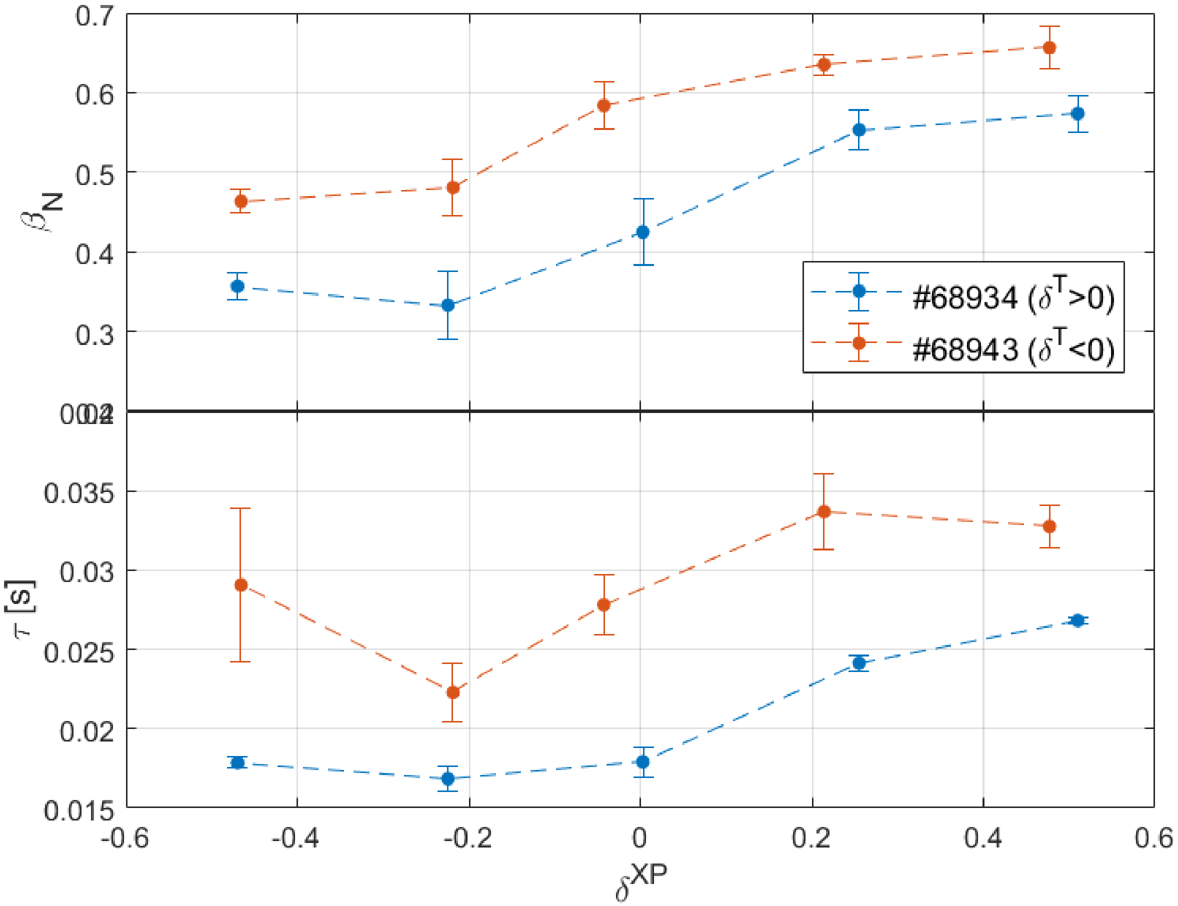
Ohmic discharges (LSN) - δ^{XP} scan



EPFL

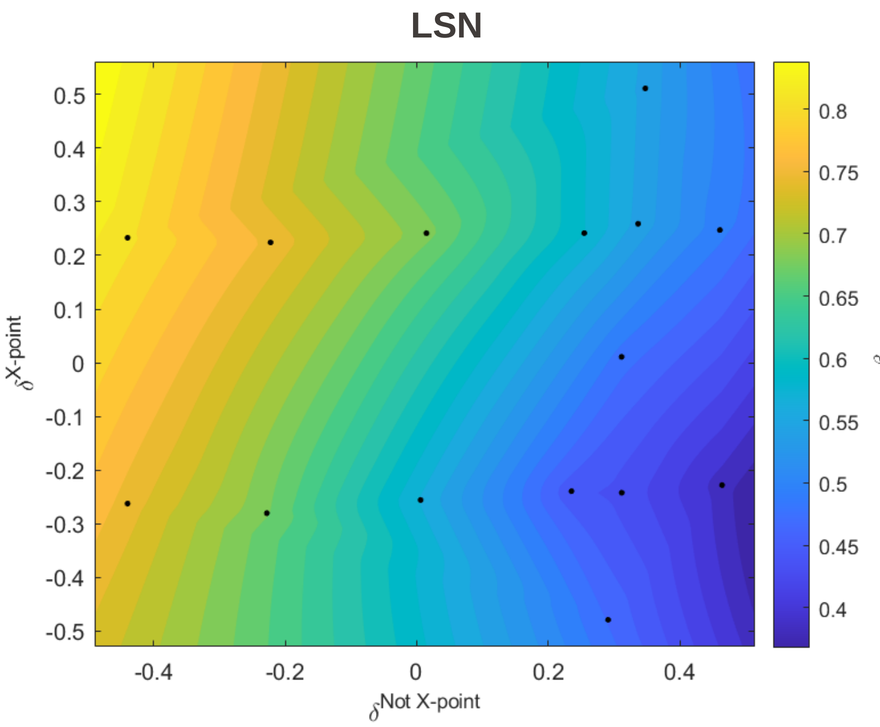
Ohmic discharges (USN) - δ^{XP} scan

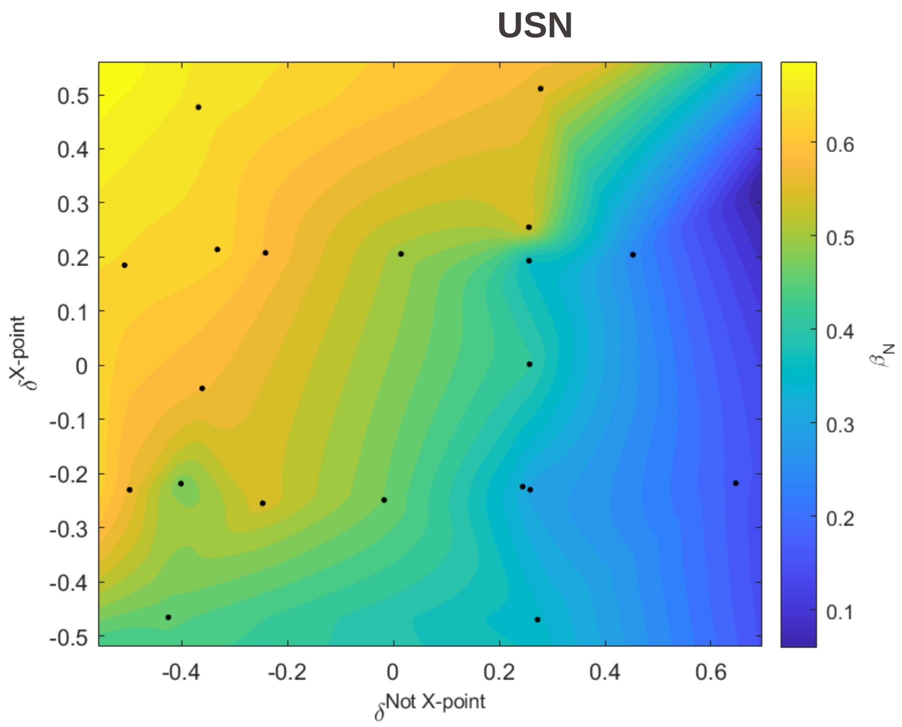
A. Balestri



Swiss Plasma Center

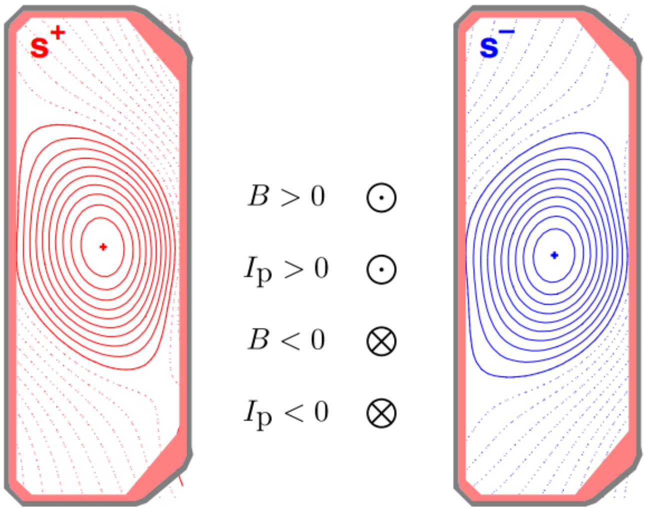
β_N over the "δ" space – Ohmic discharges

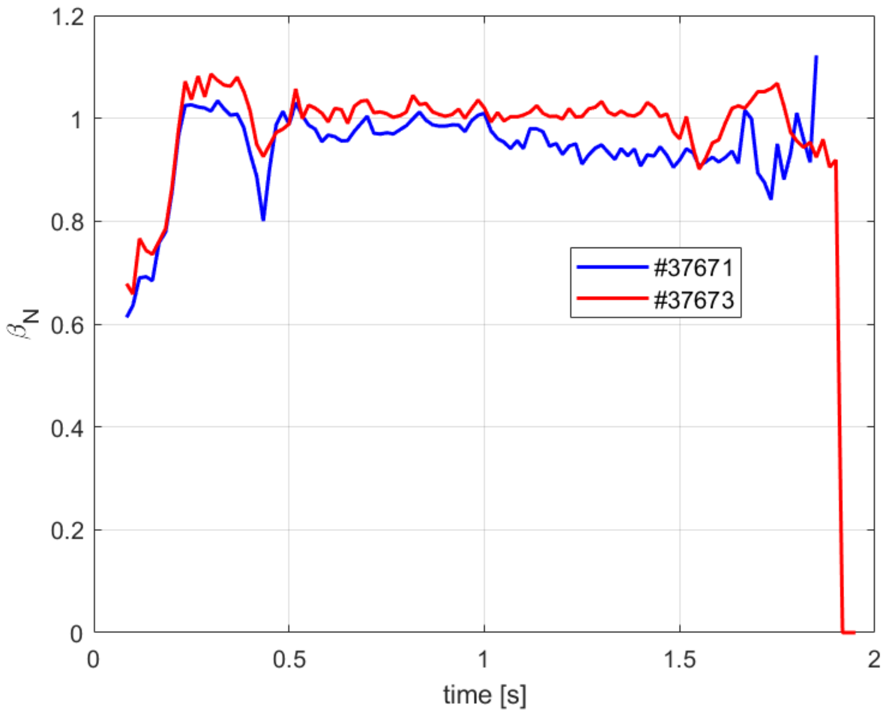




Limited configurations (previous study)

Y Camenen *et al* 2010 *Plasma Phys. Control. Fusion* **52** 124037

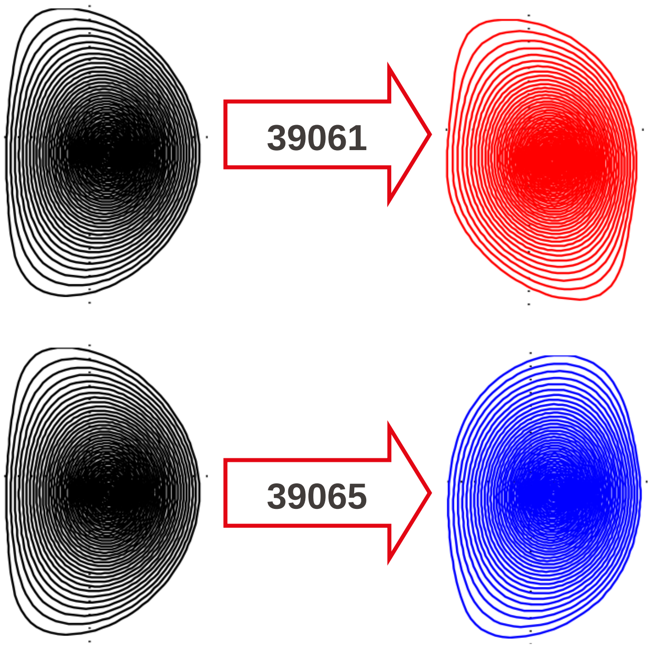


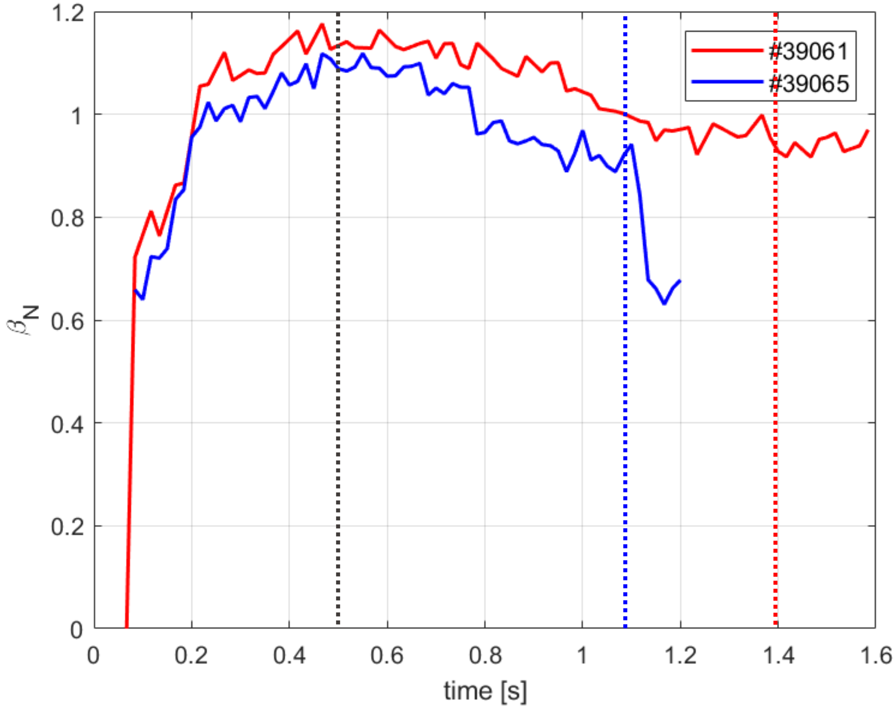


Swiss Plasma Center

Limited configurations (previous study)

Y Camenen *et al* 2010 *Plasma Phys. Control. Fusion* **52** 124037





Preliminary Conclusions and remarks

- The impact of δ^T on the confinement is larger than the impact of δ^{XP}.
- However, the configuration with the best performance in terms of global confinement is the one with negative δ^T and positive δ^{XP} (NP).
- This behaviour was not observed in (old) limited discharges, thus the improvement with positive δ^{XP} could be mainly due to the position of the X-point.

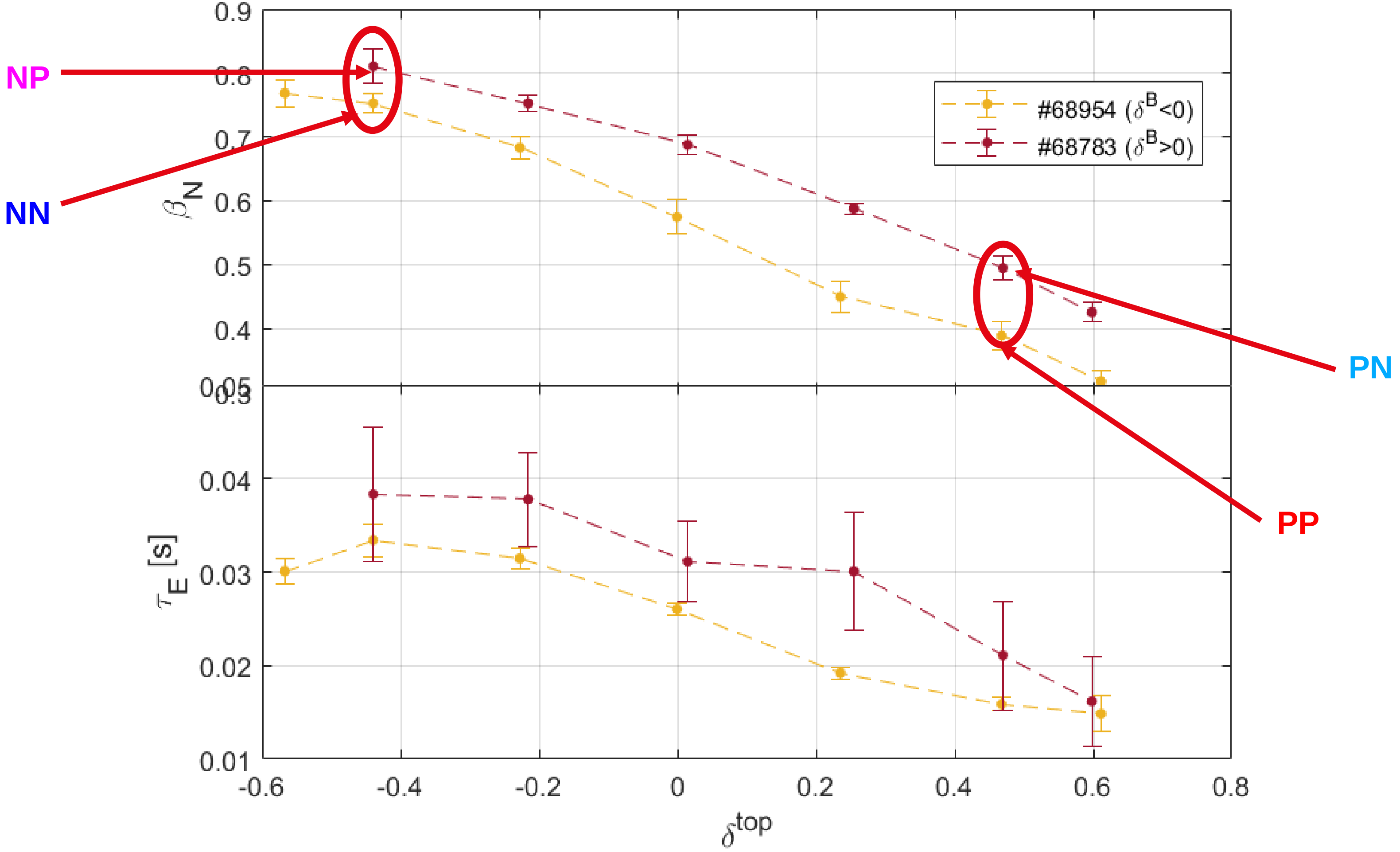
EPFL

Effect of Up-Down triangularity imbalance in diverted configurations: Gyrokinetic simulations

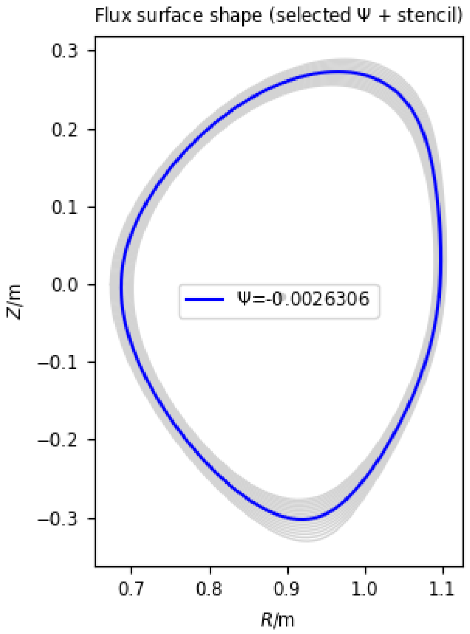
Swiss Plasma Center

Overview

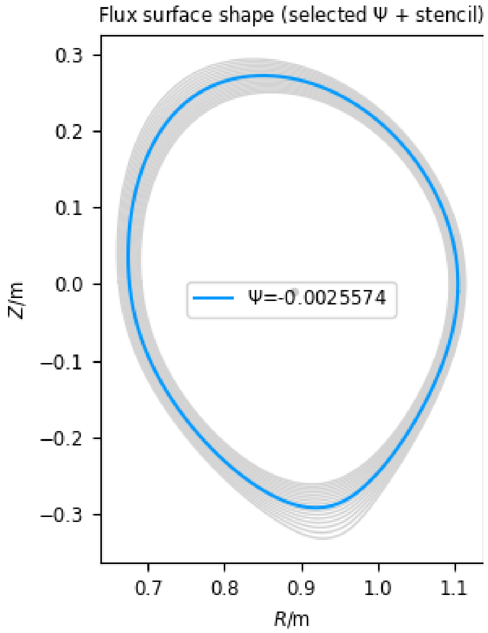
- GK simulations with GENE at $\rho_{tor} = 0.9$ with fixed kinetic profiles (from #68954) but different magnetic equilibria.
  - Goal: to isolate the effect of the shape and reproduce the experimental trend
- All simulations include:
  - finite beta
  - collisions
  - carbon as the main impurity
  - Generalized miller to reconstruct the equilibrium from the eqdsk files


NP
NN
PN
PP
0.9
0.8
0.7
0.6
0.5
0.4
β_N
#68954 (δ^B<0)
#68783 (δ^B>0)
0.05
0.04
0.03
0.02
0.01
τ_E [s]
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
δ^{top}

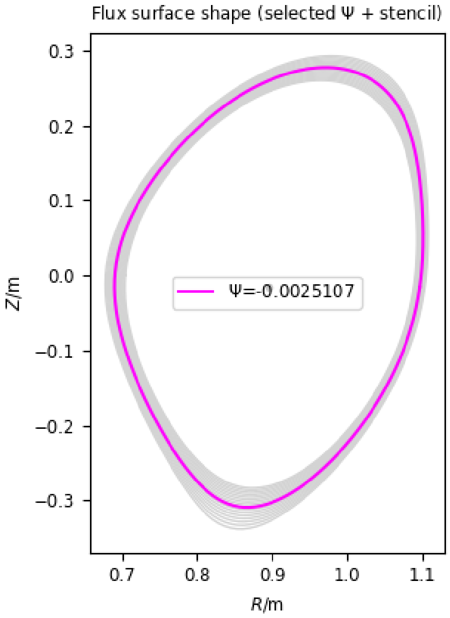
GK simulations – magnetic equilibria



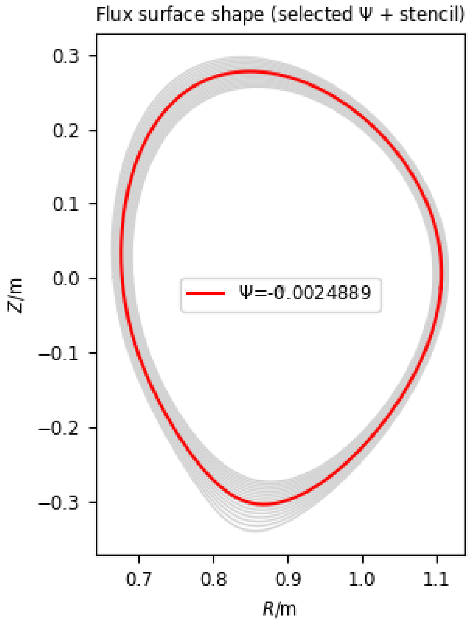
#68954 at t=0.8



#68954 at t=1.55



#68783 at t=0.8

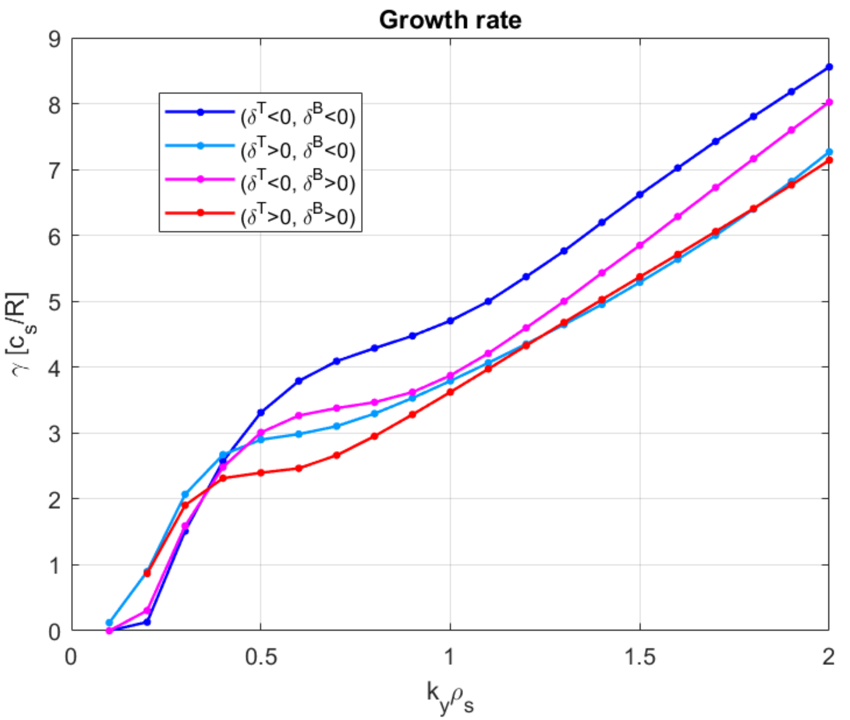


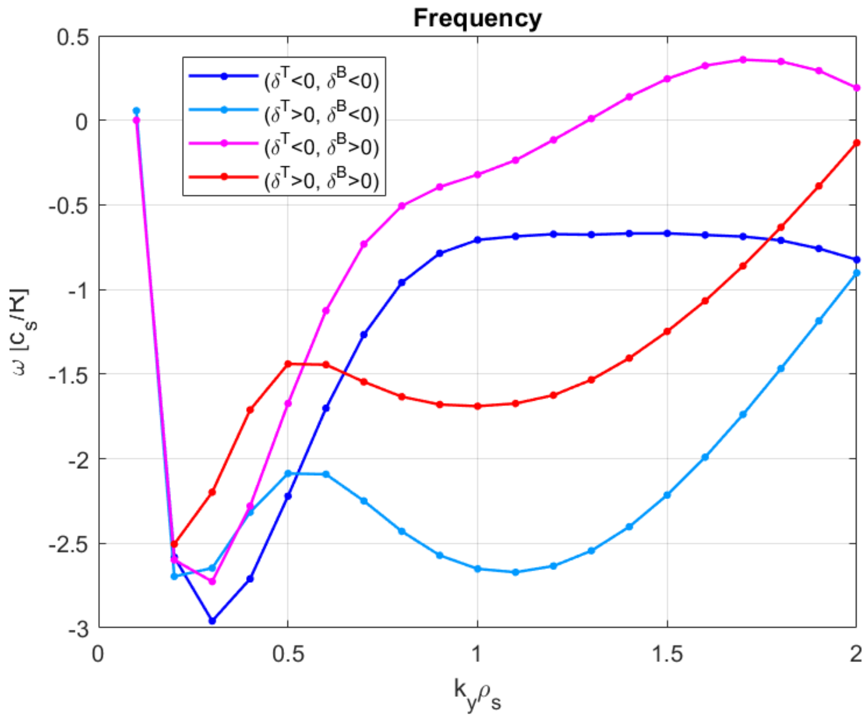
#68783 at t=1.55

EPFL

GK simulations – Linear growth rates & frequencies

A. Balestri





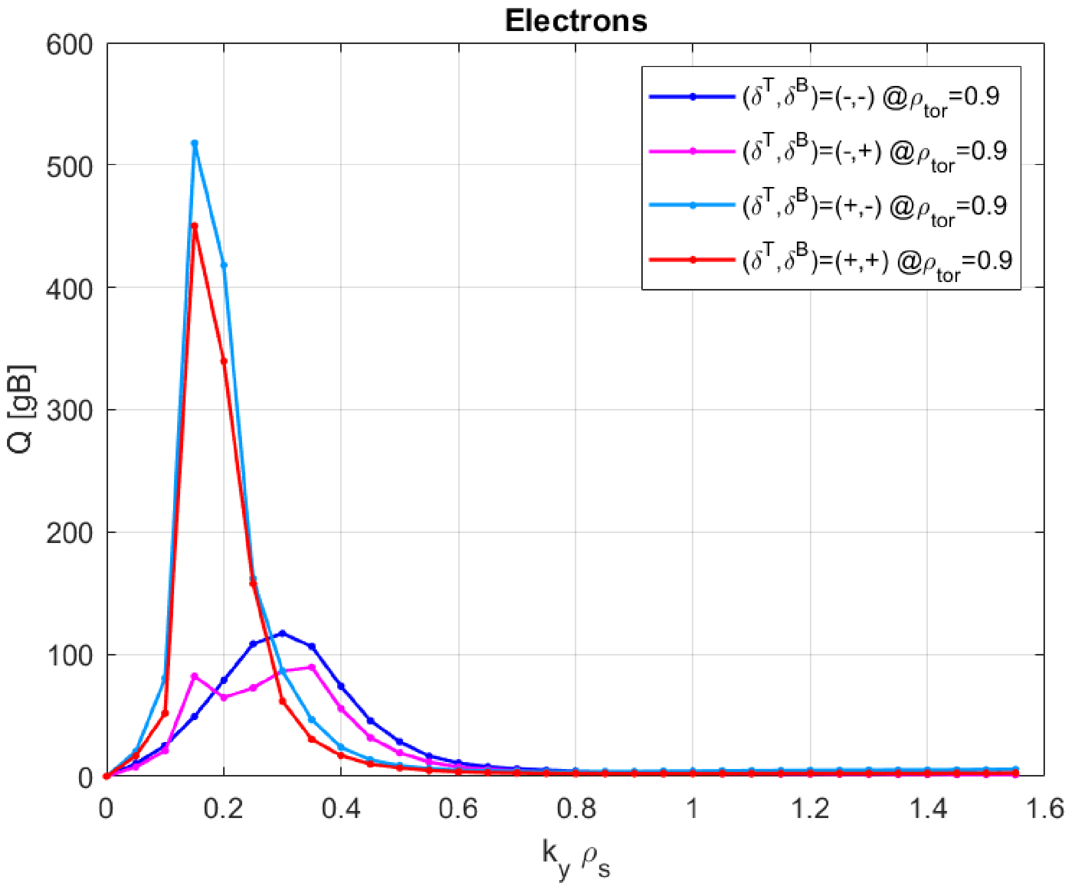
Swiss Plasma Center

GK simulations – Electron heat flux (NL)

A. Balestri

(δ^T, δ^{XP})	$Q_e\ [gB]$
$(-,-)$	698.7
$(-,+)$	573.4
$(+,-)$	1364.3
$(+,+)$	1111.9

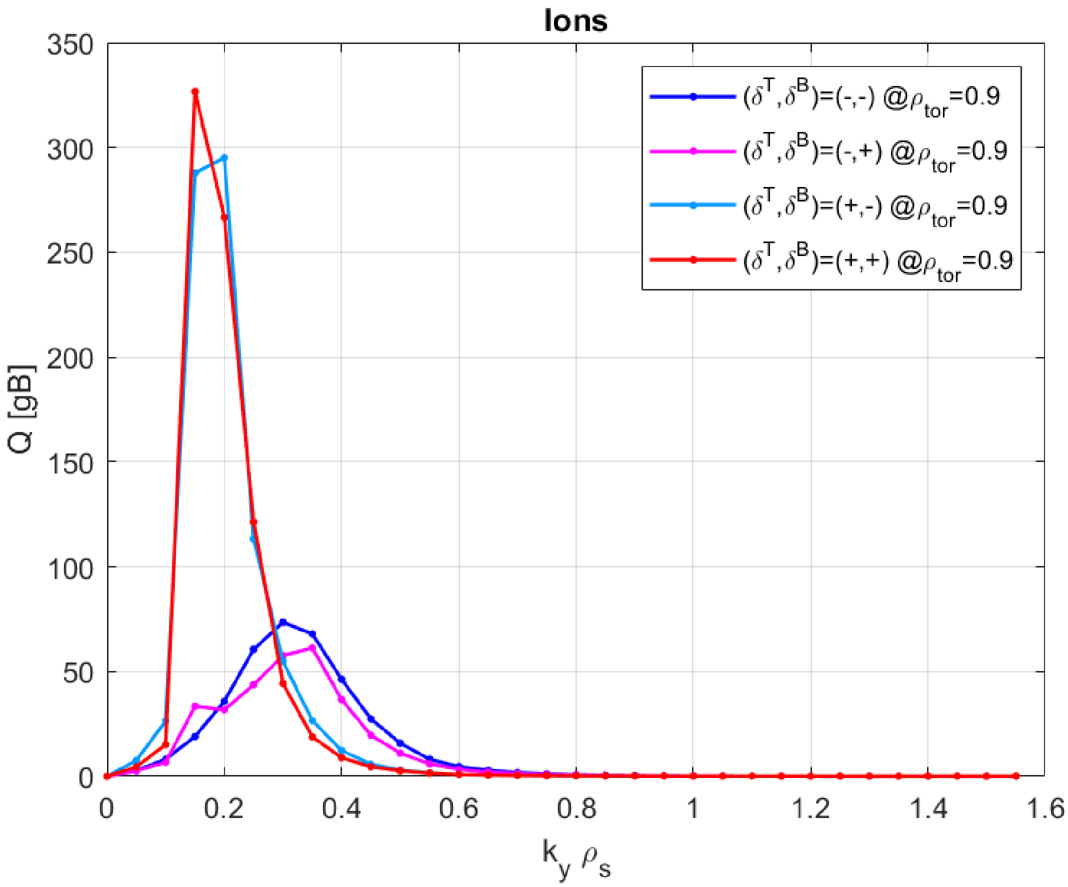
- NP with lowest heat flux.
- δ^{XP} positive is better wrt the δ^{XP} negative counterpart.
- Impact of δ^T is larger than δ^{XP}.



GK simulations – Ion heat flux (NL)

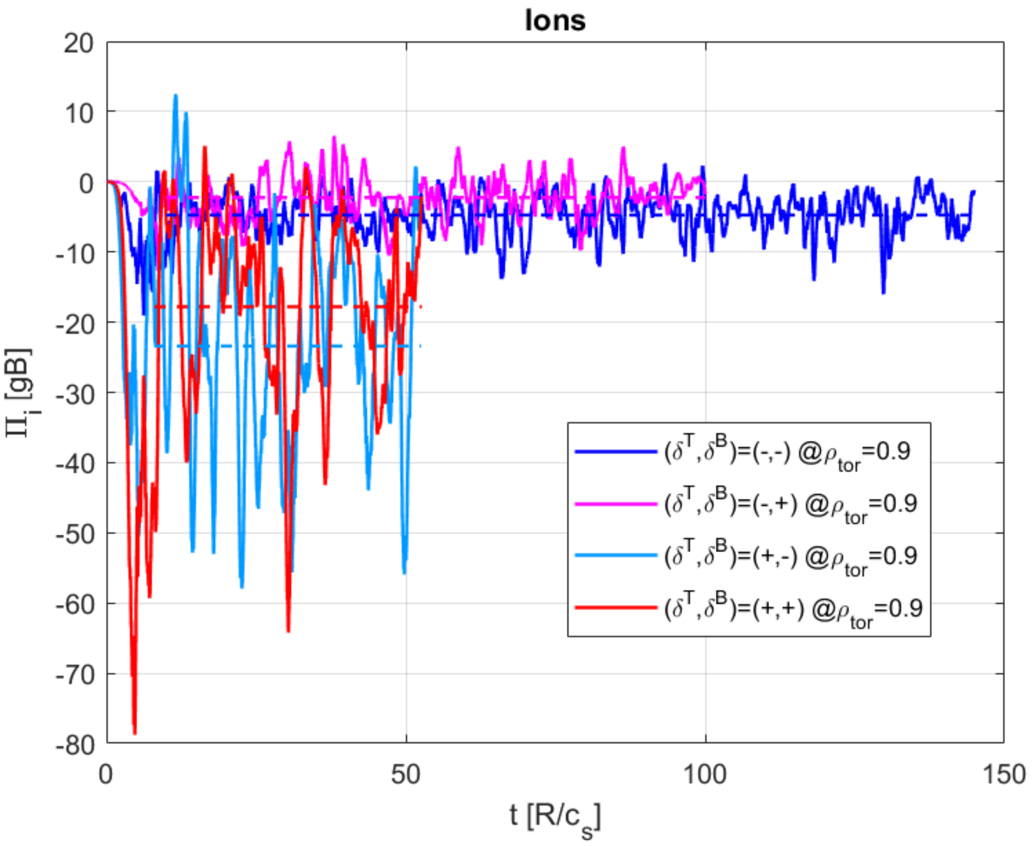
(δ^T, δ^{XP})	$Q_i\ [gB]$
$(-,-)$	373.4
$(-,+)$	321.1
$(+,-)$	833.8
$(+,+)$	817.4

- The effect of δ^{XP} on the ion heat flux is less important than before.



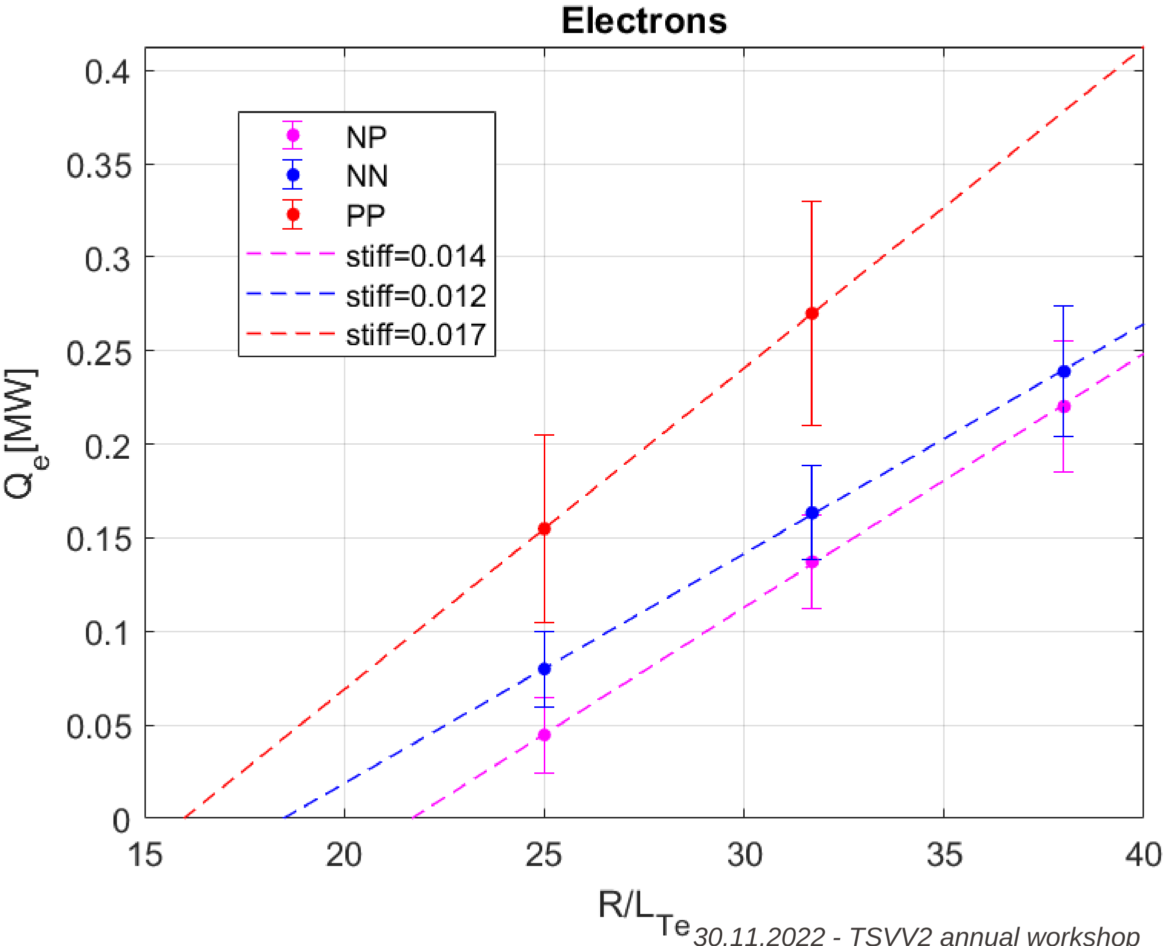
GK simulations – Ion momentum flux (NL)

(δ^T, δ^{XP})	$\Pi_i\ [gB]$
$(-,-)$	-5.09
$(-,+)$	-2.25
$(+,-)$	-23.3
$(+,+)$	-16.6



GK simulations – Electron stiffness

- The stiffness does not change between NN and NP, while the critical gradient does
- The main effect of the XP is thus related to the critical gradients?



Conclusions

- Experimental evidences show an asymmetry between the impact of δ^T and δ^{XP}.
- The NP configuration showed the best global confinement when compared to NN, PP and PN.
- The comparison with limited configurations suggests that this improvement is specific for diverted shapes and mainly due to the position of the X-point.
- The NP could have better confinement because of the combined beneficial impact of a negative δ^T and the XP in the HFS.

- GK NL simulations are in agreement with the experimental trends, i.e. confirmed the asymmetry between the impact of δ^T and δ^{XP} and when the kinetic profiles are fixed and only the shape is changed, the NP configuration has the lowest fluxes.
- The analysis of the stiffness showed that the main impact of δ^{XP} is on the electron critical gradient.