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PI 56

Investigation of detachment in Double-Null configurations in the TCV tokamak

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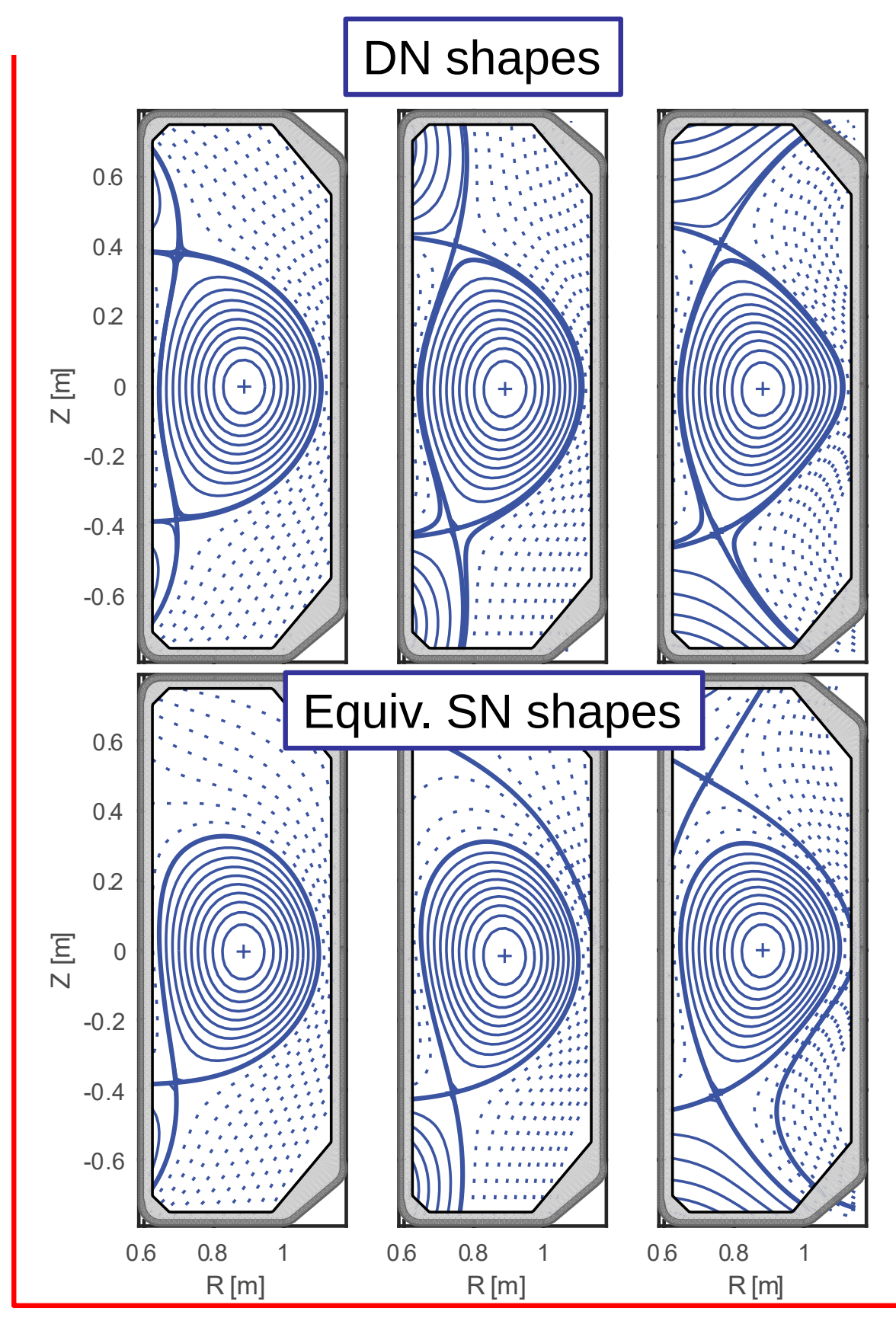
Introduction & Motivation

Divertor detachment associated with low target temperature & heat fluxes [1-2]
→ **Attractive regime** for fusion devices
Alternative divertor configurations can provide improved detachment characteristics at outer leg (lower threshold, increased controllability…) ([2] and references therein) but risk to aggravate conditions at inner leg

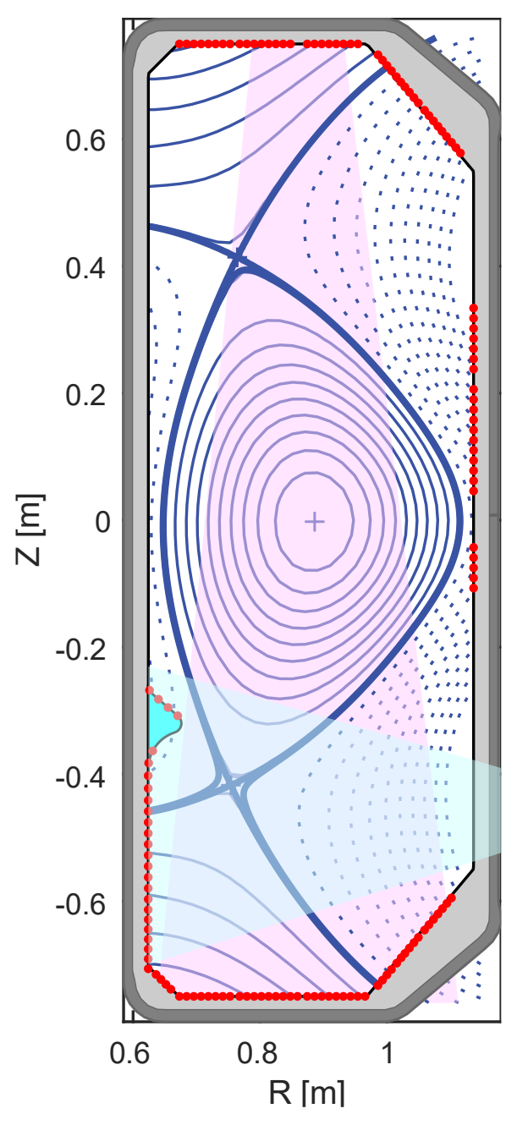
Double-nulls (DN) are a promising candidate for an exhaust solution :
→ Majority of power shared between **two outer legs.** [3,4,5]
→ Advanced geometries can be applied to both active legs [6]
→ Possibly increase of radiated fraction

Experimental setup



Wide range of DN configurations
Typical scenario :
→ $\langle n_e \rangle$-ramp
→ L-Mode, Ohmic only, I_P=300 kA
→ Inner/outer gaps ~ 2.5cm

Main diagnostics used:
Langmuir Probes [7], IR camera, Bolometry, eq. reconstruction, Multi-spectra imaging (CIII)

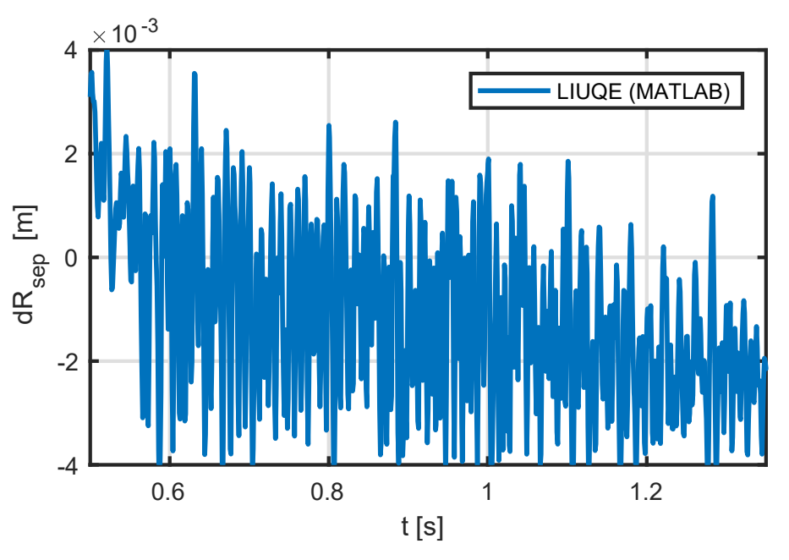


→ Discharges performed in Fav./Unfav. grad B_t
(always w.r.t. lower X-Point)
→ DN configurations compared with **equivalent LSN configurations**

Magnetic balance

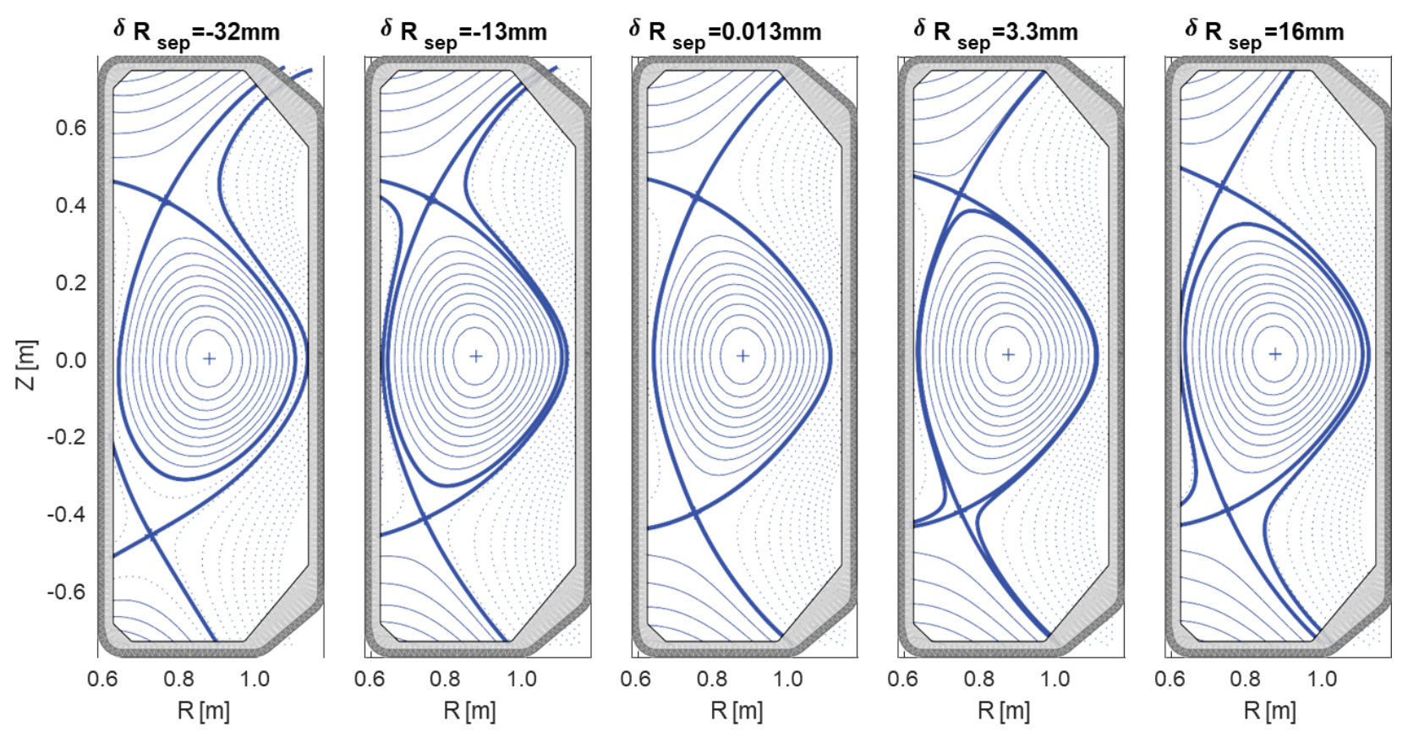
Magnetic balance (distance between the two separatrices) is a **critical parameter** for Double-Null experiments.

(δR_{sep} [distance between the two separatrix mapped upstream])

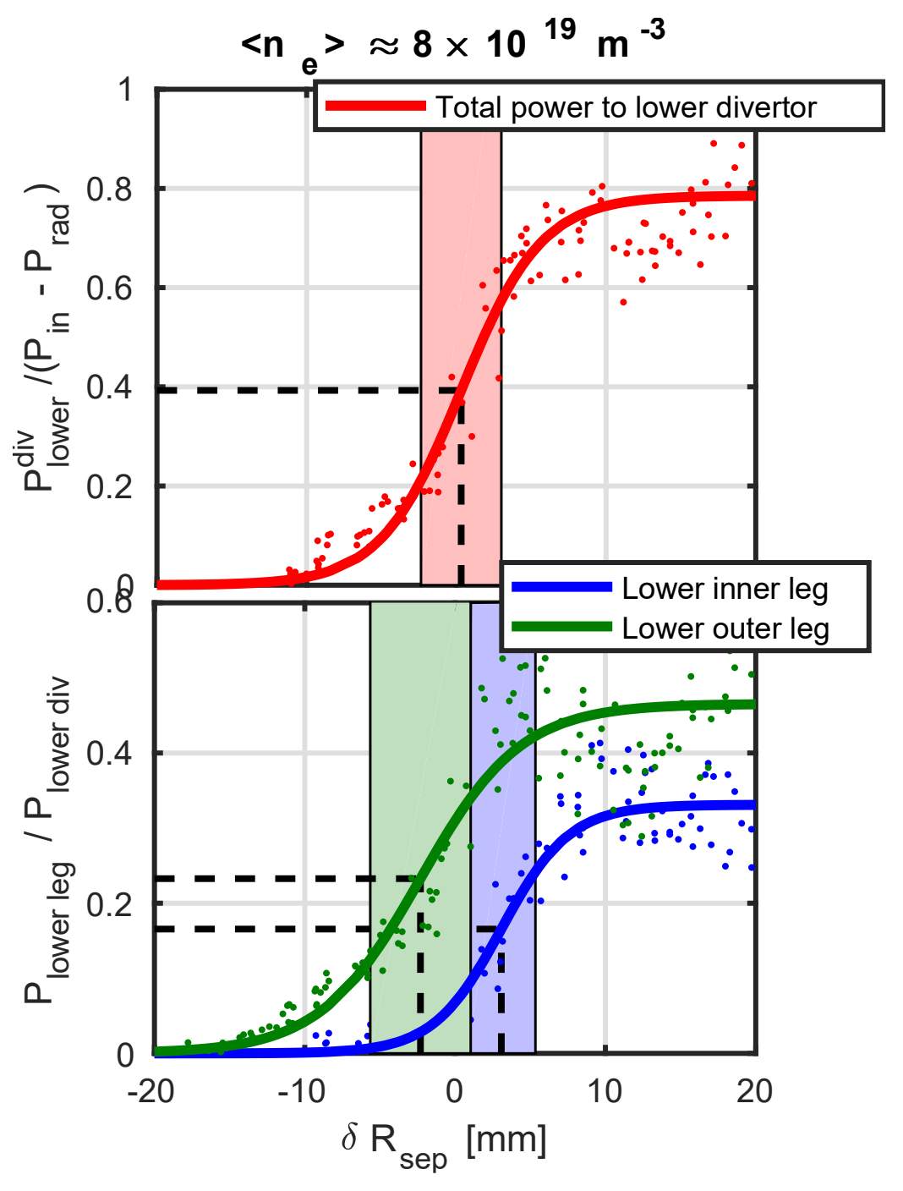


→ Balance assessed using LIUQE (equi. reconstruction)
→ Typical within [-3mm,3mm] , ≤ λ_q (~5mm from IR)

In **TCV,** diagnostic coverage of *all* strike points not possible



→ Results must be interpreted in light of **possible magnetic unbalance**
→ Sensibility of results to magnetic configuration tested in dedicated discharges

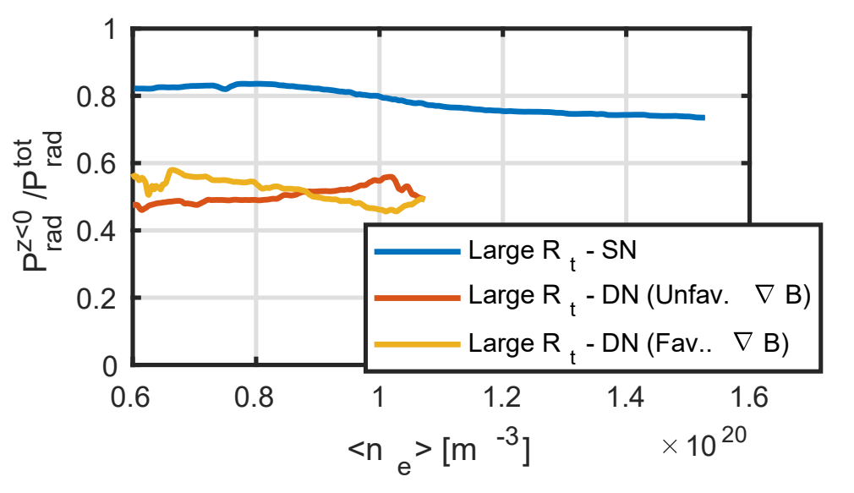


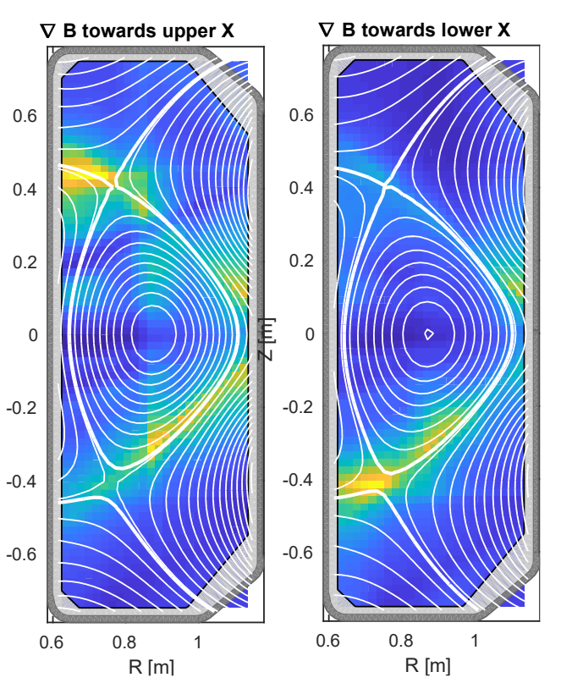
In unfavourable ∇B :
→ 50/50 power sharing for dR_{sep}=0 mm
→ Outer leg activates earlier than inner leg
→ With higher density, power seems to go preferentially to outer legs

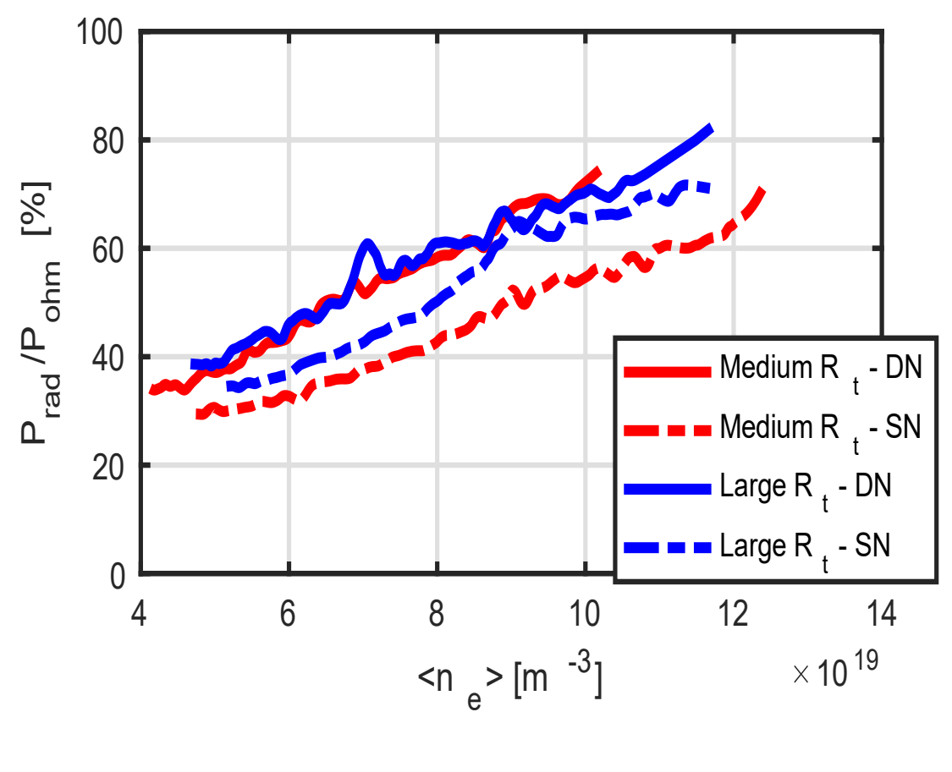
Data in favourable ∇B suggest asymmetry between inner/outer leg (not shown)

Radiation

- Radiation slightly biased towards X-Point for which gradB is favorable



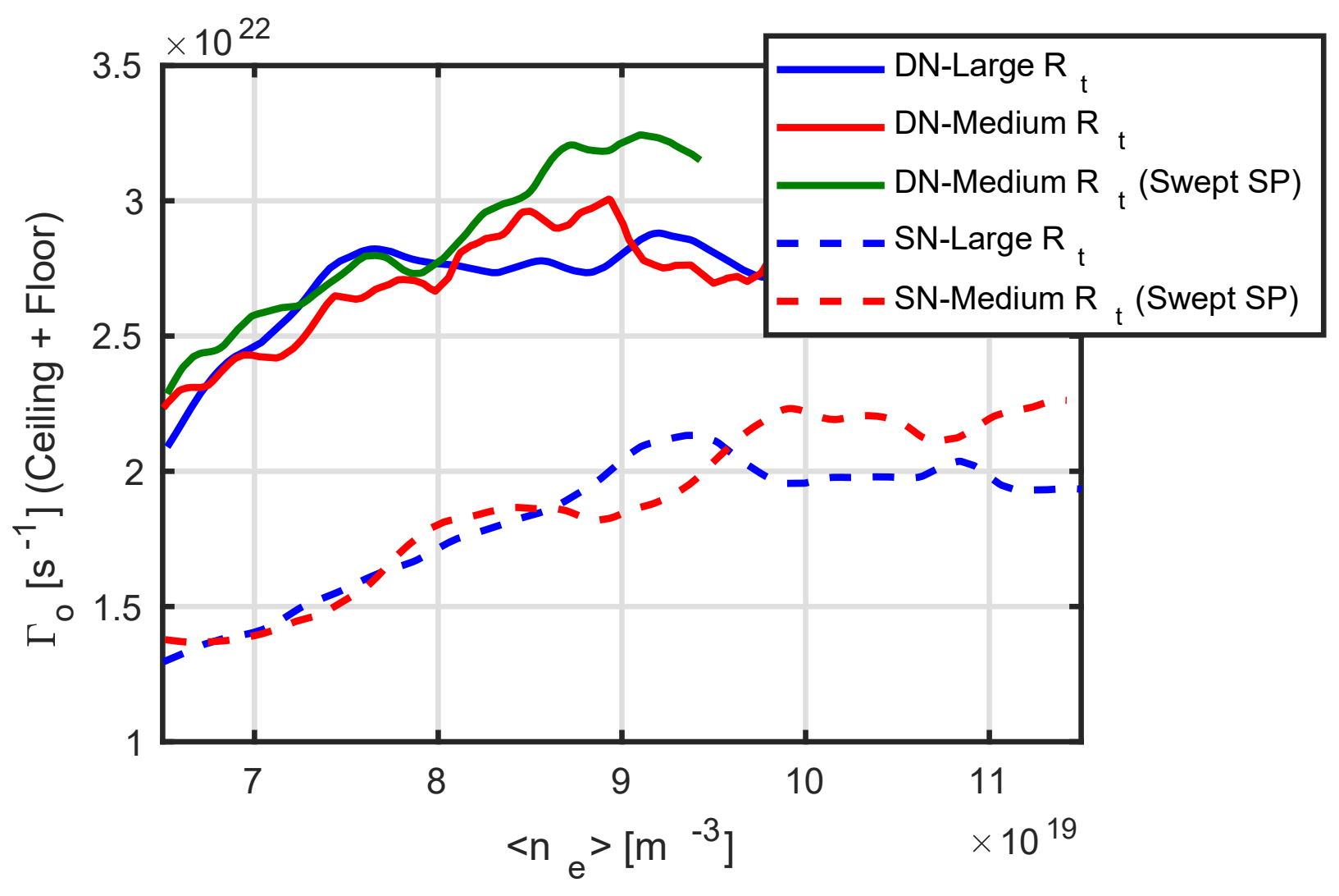


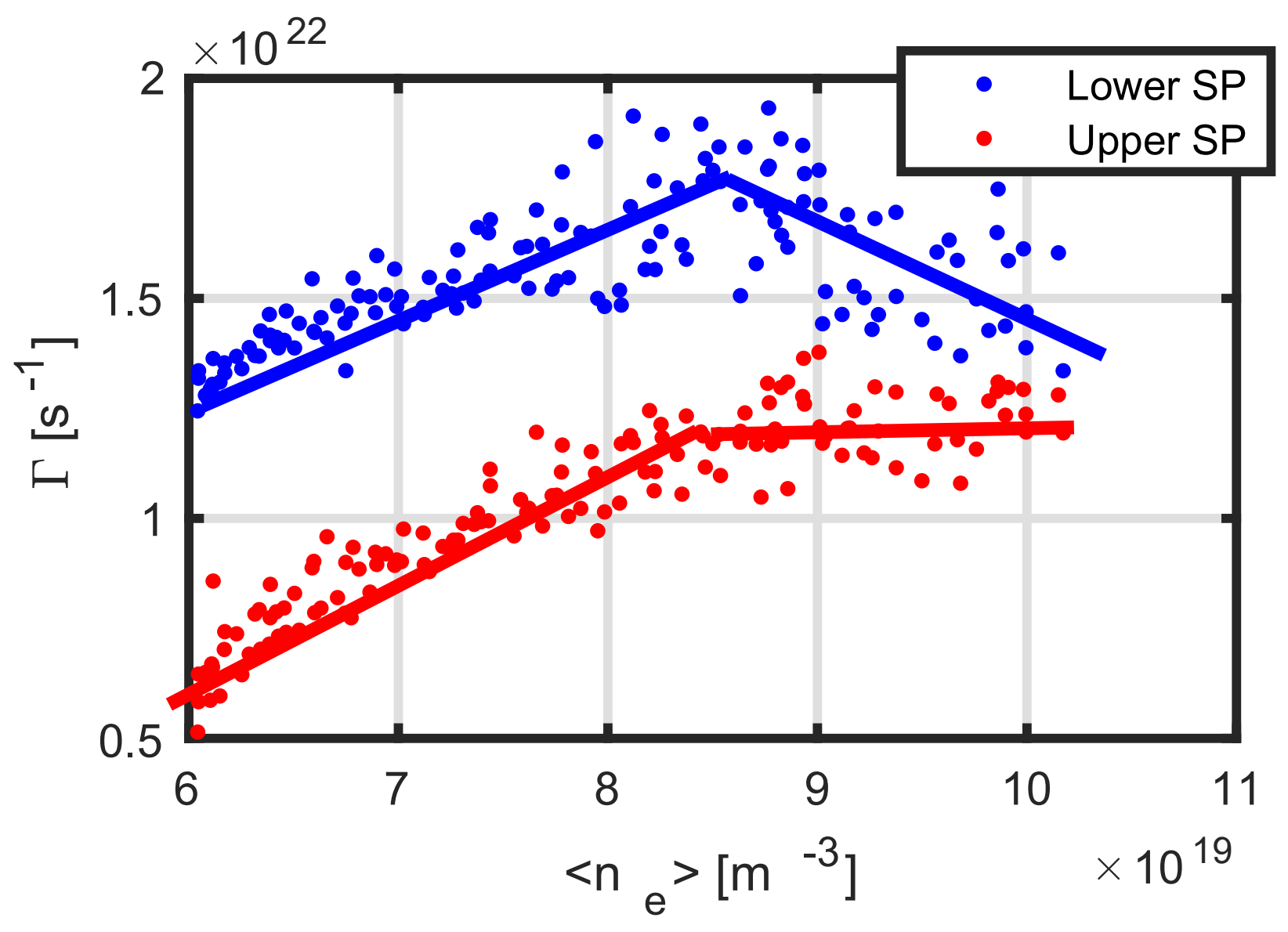


Higher radiated fraction for a given $\langle n_e \rangle$ (between 10% - 35%)
→ Interest of DN configuration for DEMO-like reactor where high radiation fraction must be reached

Target measurements

→ Total ion flux reaching floor + ceiling shows **saturation & (small) rollover**
(behavior seen at low fx in TCV [2])
→ This happens at **lower threshold** than for equivalent **LSN**
($\langle n_e \rangle \approx 8.5 \times 10^{19}$ m^{-3} vs 10^{20} m^{-3})
→ Initial target ion flux higher than for LSN



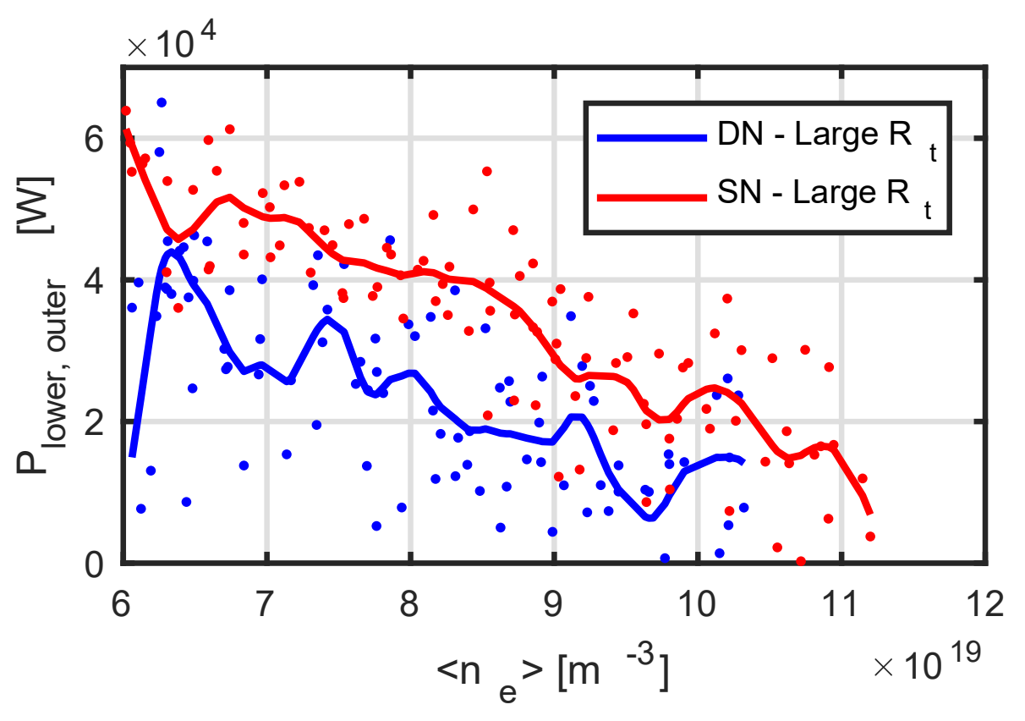


→ Integrated J_{sat} shows that both legs detach at similar $\langle n_e \rangle$
($\langle n_e \rangle \approx 8.5 \times 10^{19}$ m^{-3})

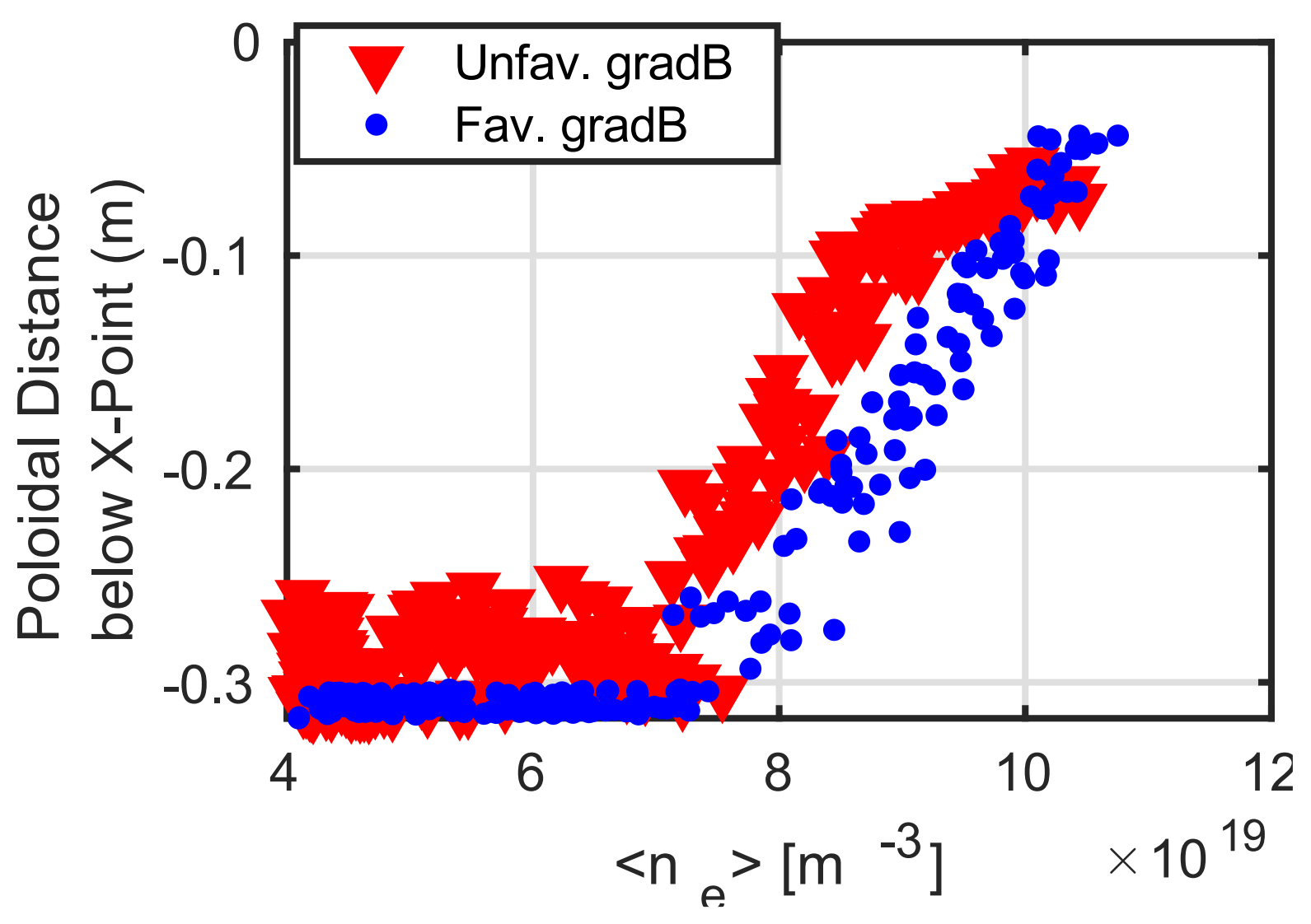
Detachment of both outer legs at similar line-averaged densities, lower than equivalent LSN

→ Integrated target ion flux show no difference vs outer target major radius [in line with previous TCV results in LSN]

→ Infrared thermography measurements show **lower power going to lower outer divertor in DN than LSN**, and **continuous decay as $\langle n_e \rangle$ is increased**, as expected.
→ From LP and IR, most of the flux does go to OSPs, with lower power on each OSP.

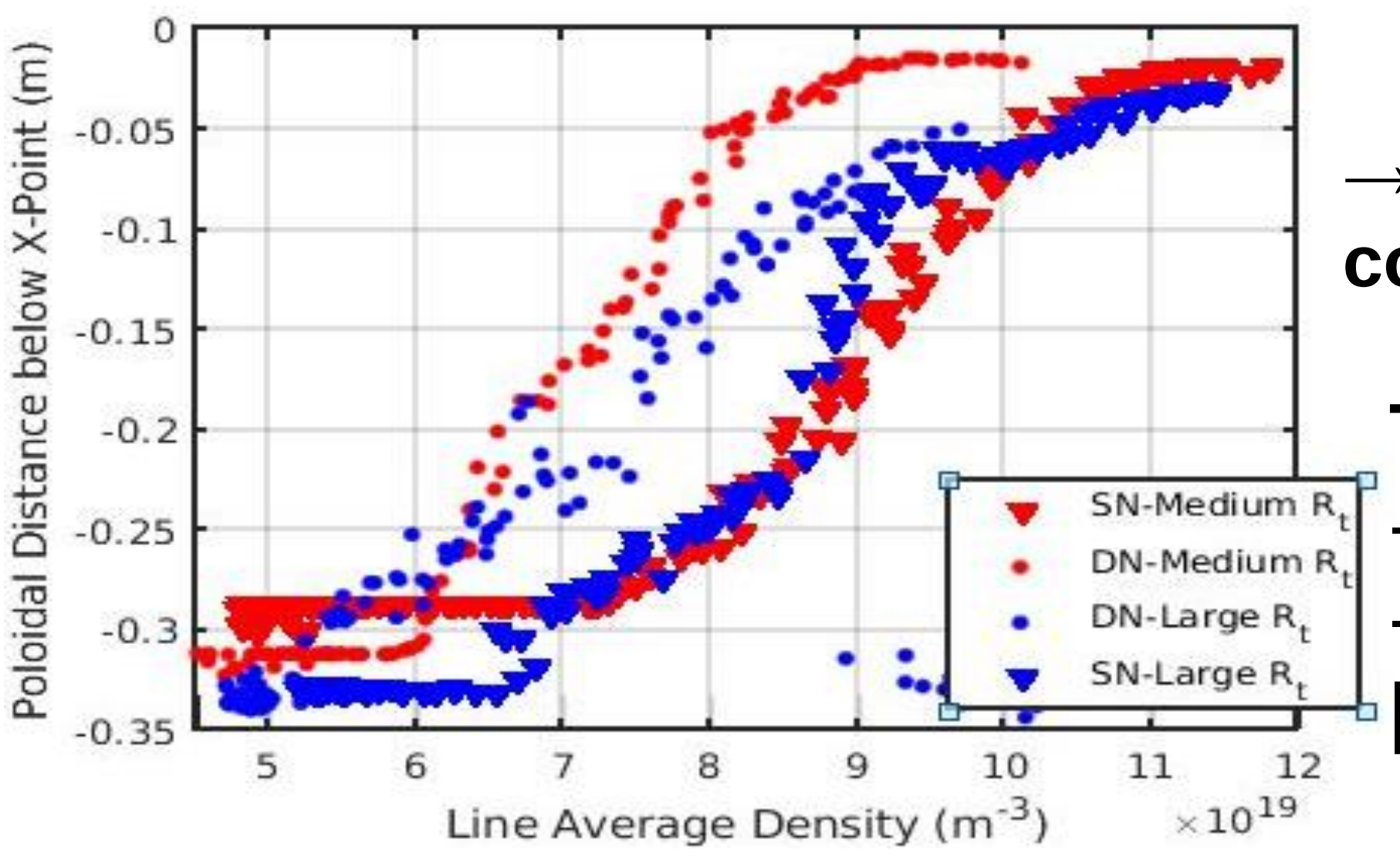


CIII radiation front



Position of CIII front along outer (lower) divertor leg :
→ Taken as indicator for detachment [1,8]

Repeating shots in fav/unfav. gradB, reconstruct CIII movement along both outer legs
→ Both legs detach at approx. same time, in agreement with LP.



→ **Movement** of CIII front **earlier in DN configurations** (lower threshold)

Threshold similar for different R_t :
- Opposite to 2PM expectations
- Consistent with previous TCV exp. [2]

Confirms that the non-observation of R_t–effect [2] is **not** due to a change of power sharing between inner/outer targets

Conclusions

First results of detachment physics in Double-Null in TCV show :
- Higher radiated fraction for a given $\langle n_e \rangle$ (between 10% - 35% higher) than in LSN
- Access to detached regime of both legs at similar $\langle n_e \rangle$, lower threshold than in LSN (~ 20% difference)
- As in previous LSN studies, no clear evidence of a R_t–effect for the detachment onset.
  → Power sharing between inner/outer leg not responsible for this effect in LSN

[1] A. W. Leonard *et al* 2018 *Plasma Phys. Control. Fusion* **60**
[2] C. Theiler *et al* 2017 *Nucl. Fusion* **57** 072008
[3] Petrie *et al* 2001 *J. Nucl. Mater.* **290**
[4] G.De Temmerman *et al* 2011 *J. Nucl. Mater.* **415**
[5] D. Brunner et al 2018 *Nucl. Fusion* **58** 076010
[6] G. Fishpool et al 2013 *J. Nucl. Mater.* **428**
[7] De Oliveira *et al* 2019 *Rev. Sci. Instrum* **90**, 083502
[8] J. R. Harrison *et al* 2016 *Nucl. Mater. Energy* **12**

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