Analysis of triangularity effects on edge turbulence with the GBS code

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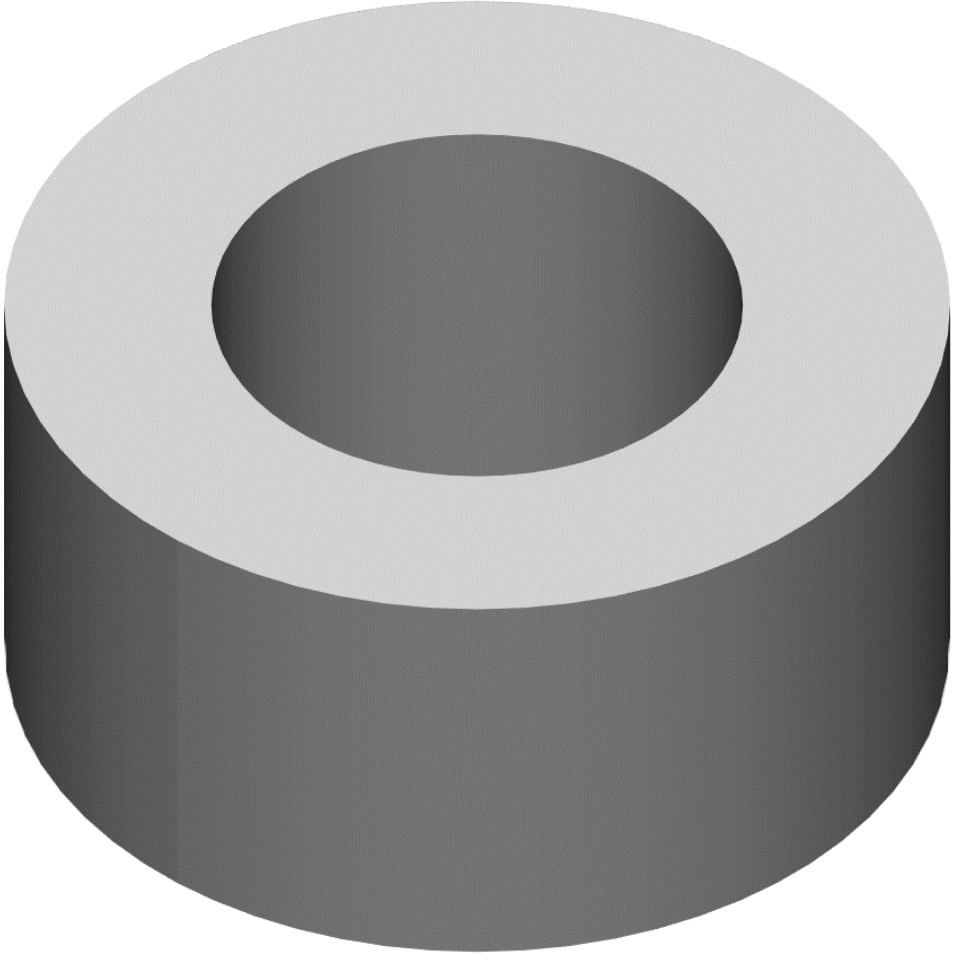
Milestones and deliverables

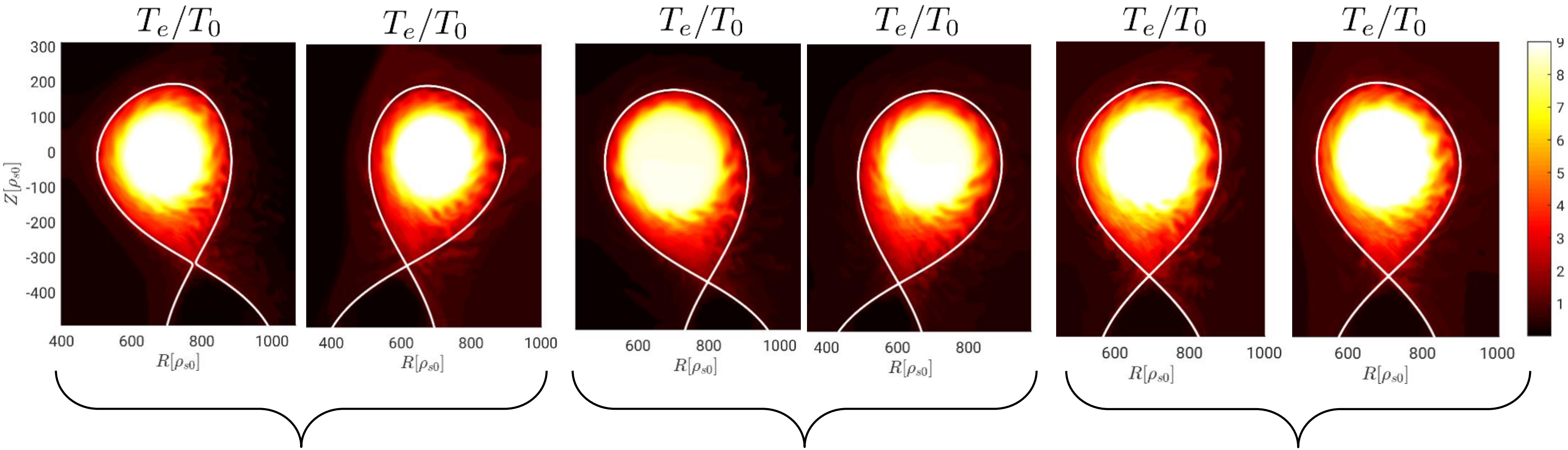
- Perform GBS simulations to address the effects of negative triangularity in single-null geometry without neutrals (2021)
  - ✔ Simulation scan with various configurations and collisionality
  - ✔ Preliminary analysis of GBS simulations
  - ○ Analysis of linear simulations (similar to Riva *et al,* PPCF 2017)

- Comparison between GBS simulations and TCV experimental measurements in the SOL (2023)
  - ✔ The TCV shots to simulate are defined
  - ✔ Simulations started
  - ○ Running until steady-state
  - ○ Comparison to experimental data



Overview simulation results

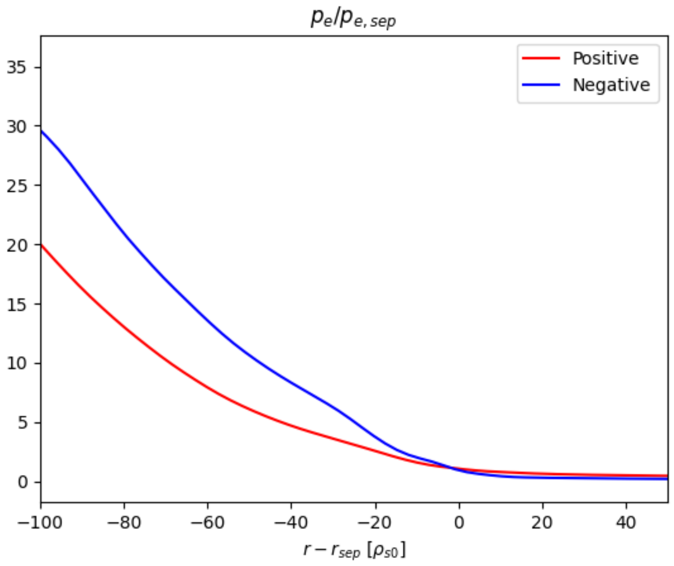
- Scan of magnetic equilibria (scan in triangularity)
- Two values of collisionality

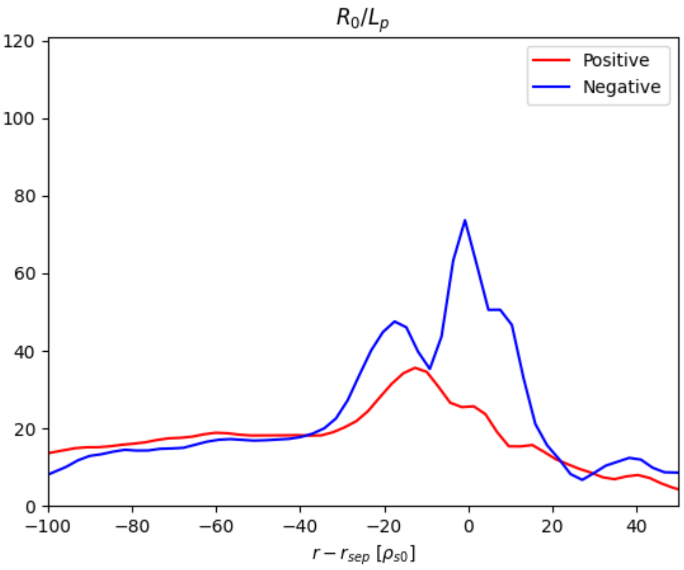


$\delta = \pm 0.3$ $\delta_l = \pm 0.2$ $\delta_u = \pm 0.08$

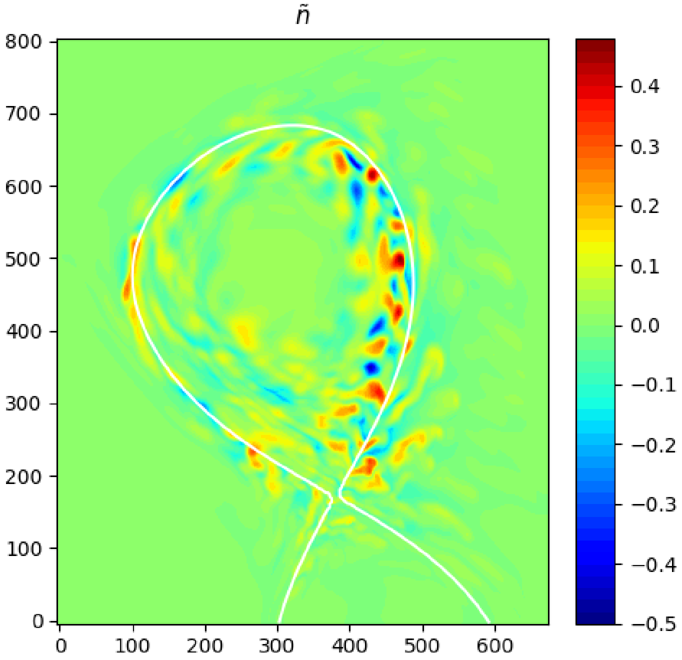
Pressure radial profiles for the “global” triangularity case

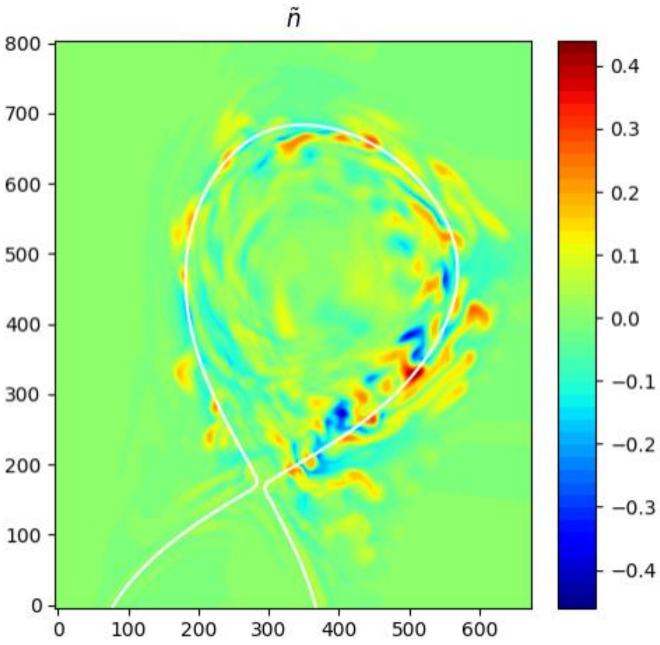
- Pressure gradient at the separatrix is steeper in NT than in PT
- Highest difference at the separatrix
- Confinement is better in NT
- Average over t = 10





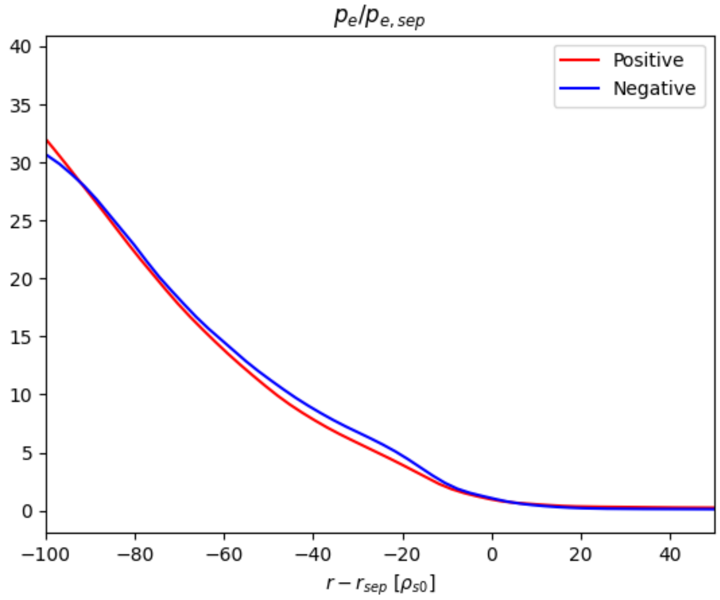
Density fluctuations are similar

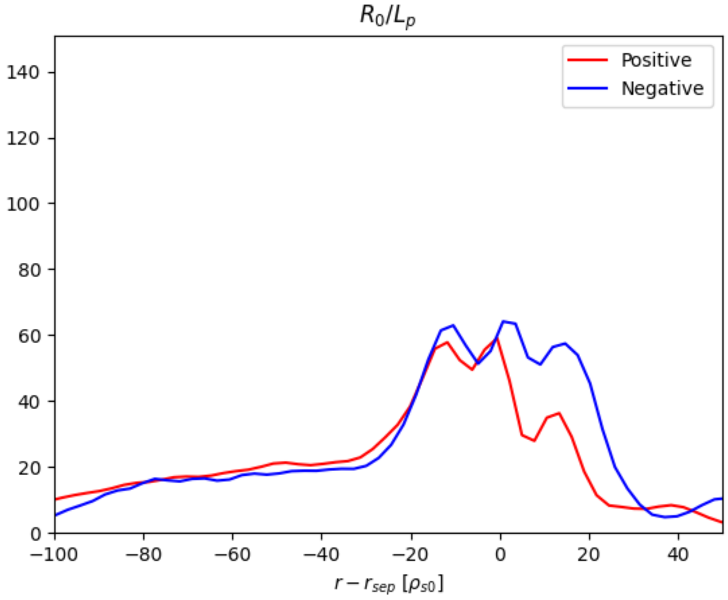




Pressure radial profiles for the lower triangularity case

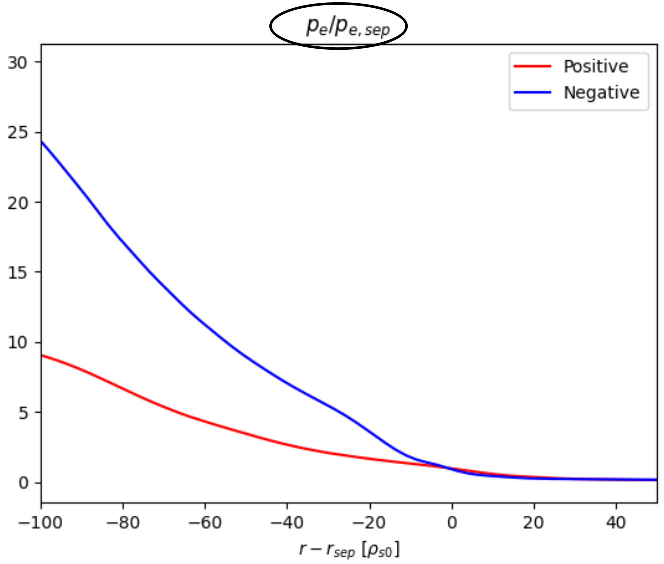
- Pressure gradient in the SOL is steeper in NT
- Similar pressure gradient in the edge
- Confinement a bit higher in NT

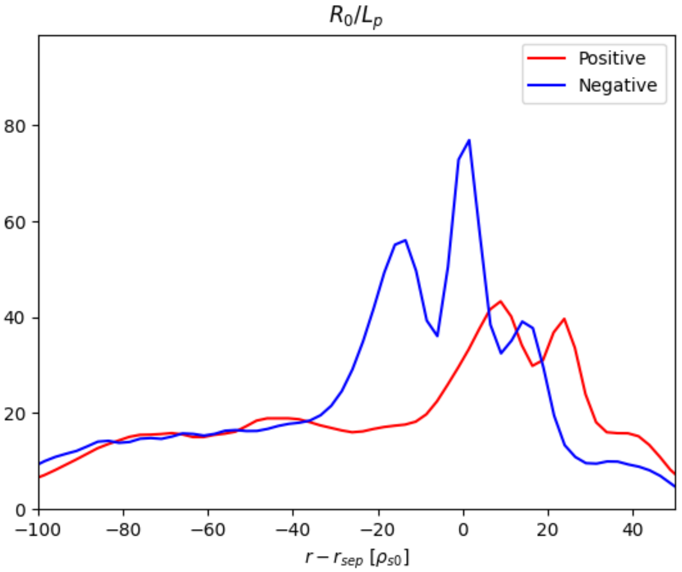




Pressure radial profiles for the upper triangularity case

- Pressure gradient in the edge/separatrix is steeper in NT
- Pressure gradient is the SOL is steeper in PT
- No difference in the confinement
- Need to run these two simulations further?





Pressure radial profiles for the upper triangularity case

- Pressure gradient in the edge/separatrix is steeper in NT
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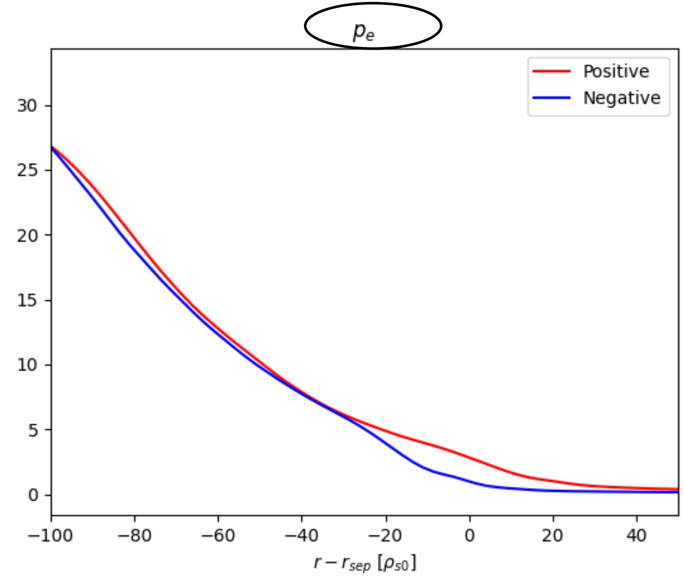
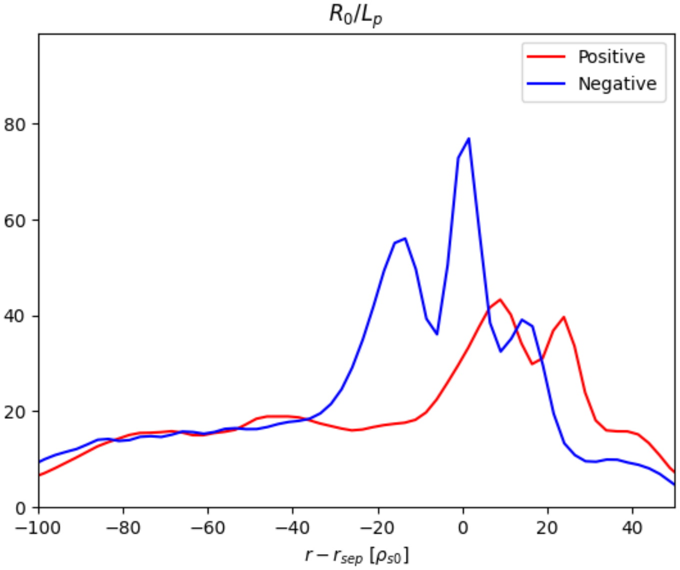
- No difference in the confinement
- Need to run these two simulations further?





Summary first part

- Pressure gradient near the separatrix steeper in NT than PT for the “global” triangularity case

- Weak effect in upper and lower triangularity

- Although GK simulations suggest importance of kinetic effects, previous GBS simulations (limiter) show dependence on triangularity [Riva *et al*, PPCF 2017]

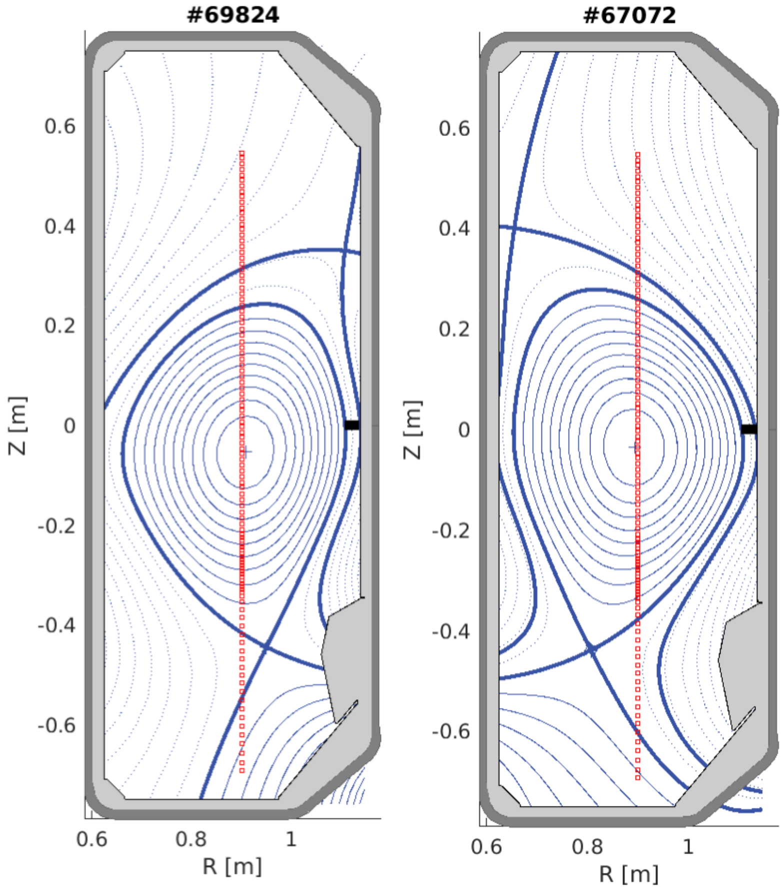
- Linear theory to understand possible effects of shaping on the growth rate

Description of the shots

- Ohmic L-mode, $P_{sol} \simeq 320$ kW
- B_t = 1.4 T → first GBS simulation with full field
- I = 220 kA
- Good SOL diagnostic coverage

#69824
- δ = -0.10
- Unusual big gap with wall

#67072
- δ = 0.20
- Good comparison with #69824



Simulations parameters

Normalization parameters

B_0 = 1.4 T , T_0 = 40 eV , $n_0 = 2 \times 10^{19}$ m^{-3} , R_0 = 0.906 m

Then: $\rho_{s0} = c_{s0} m_i /(e\, B_0)$ = 0.65 mm , $\tau_0 = R_0/c_{s0} = 1.5 \times 10^{-5}$ s → $\Delta t_{sim} \backsimeq 60\, \tau_0 \backsimeq$ 1 ms

GBS parameters

- Reference resistivity : $\nu_{GBS} = e^2 n_0 \tau_0/(m_i\, \sigma_{\|}) = 0.001$
- Electromagnetic effects : $\beta_{GBS} = 1 \times 10^{-6}$
- no Boussinesq approximation
- Half-size, full torus : R_0/ρ_{s0} = 1400 → large
- Grid resolution N_x = 219 , N_y = 400 , N_z = 128
- Cell size $2\rho_{s0} \times 2\rho_{s0} \times 68\, \rho_{s0}$
- Neutrals resolution N_{NX} = 73 , N_{NY} = 100
- Recycling coefficient to simulate carbon absorption

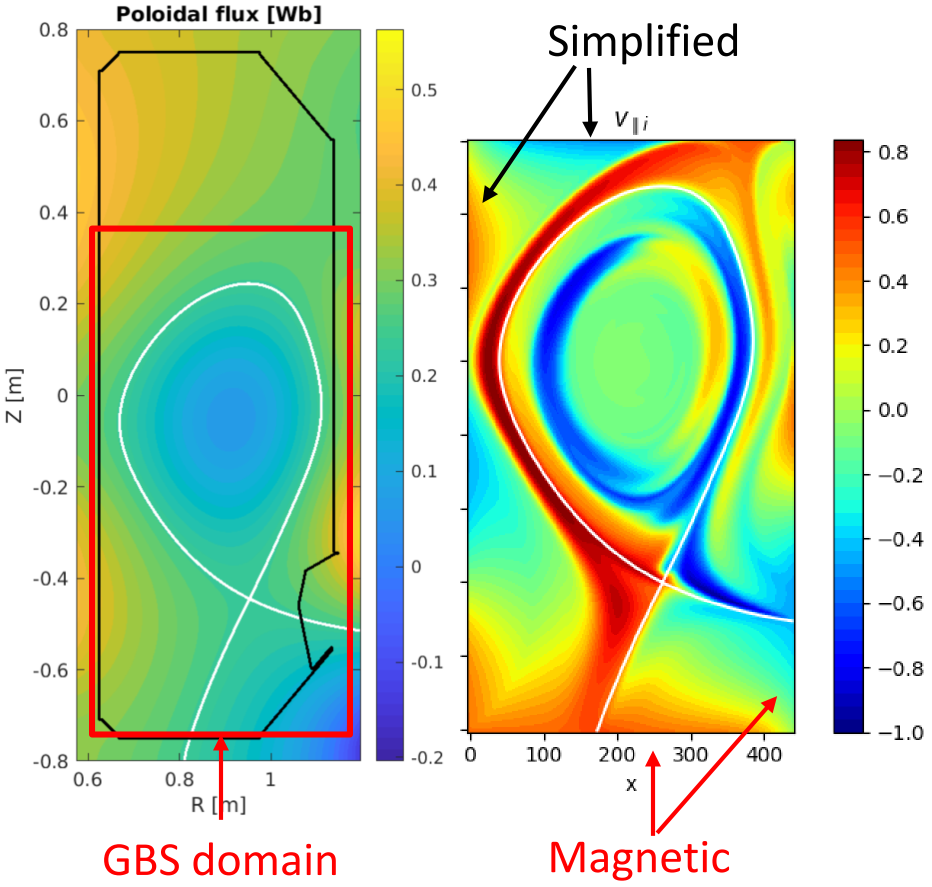
GBS adaptation to experiments

GBS box

- Rectangular box → no realistic wall
- Cut top domain to reduce points
- Right gap increased a bit

Boundary conditions

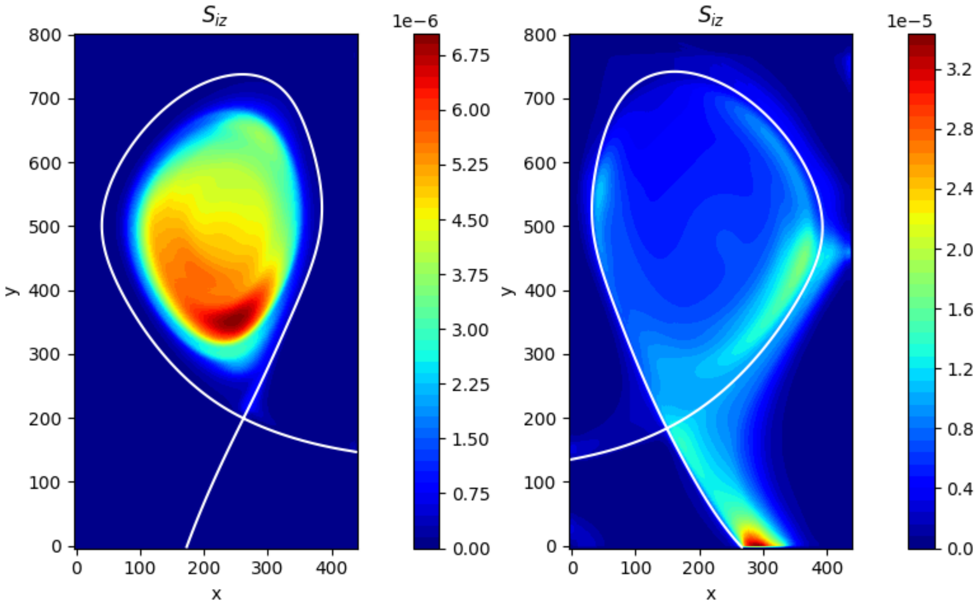
- Magnetic Bohm-Chodura sheat conditions [J. Loizu et al, Phys Pl., 2012]
- Simplified: $\phi = \Lambda T_e$



Density and power source

Density source

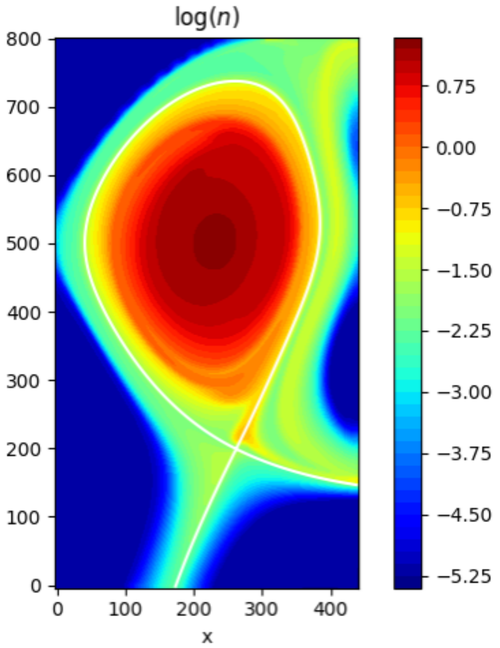
- Self consistently simulated through neutrals ionization $S_n^{neu} = n_n \nu_{iz}$
- Only in core for $\delta < 0$ (no steady state)
- Typical shape for $\delta > 0$



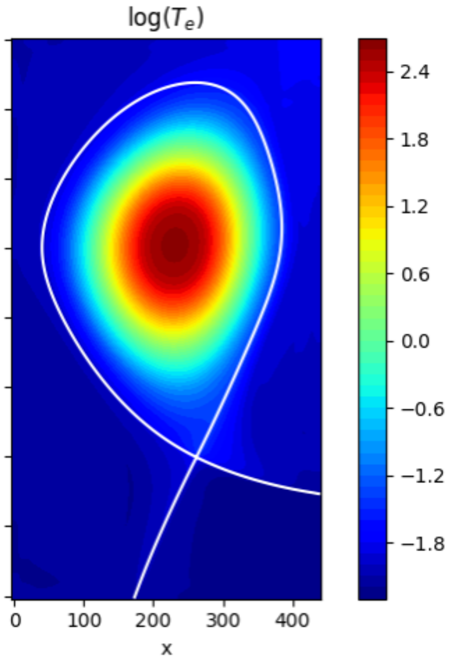
Power source

- Artificial electron temp source $S_{Te}^{GBS} = 0.015$
- Power source $S_P = (S_{Te}^{GBS} + S_{Te}^{neu} + S_{Ti}^{neu})\, n + S_n^{neu}\, (T_e + T_i) \backsimeq 400$ kW
- Power source controlled reducing S_{Te}^{GBS}

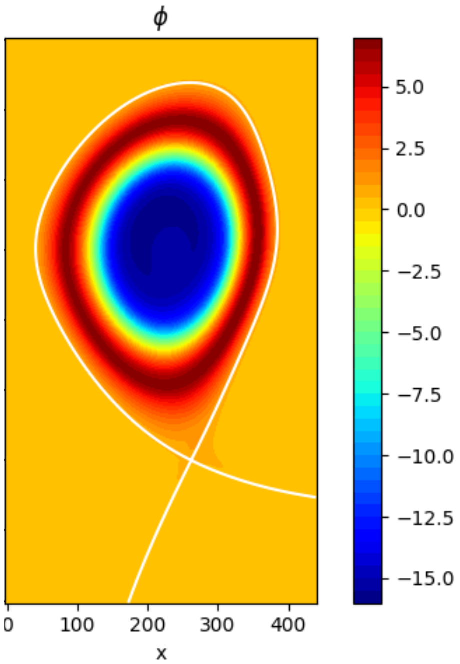
Profiles overview (no steady state)



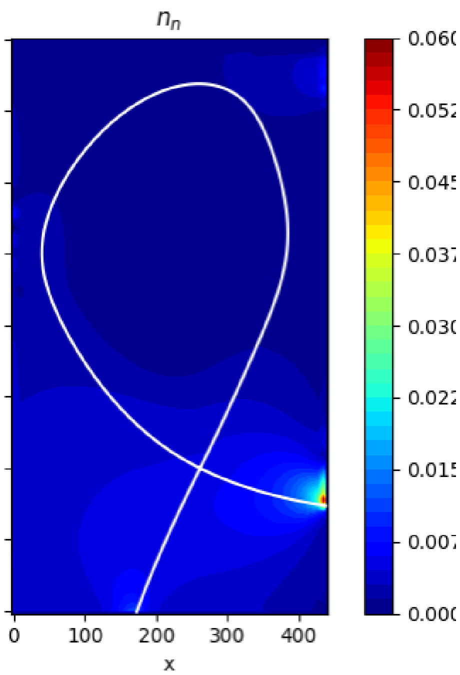
Low **n** at separatrix
Strange peak in LFS



Low $\mathbf{T_e}$ at separatrix



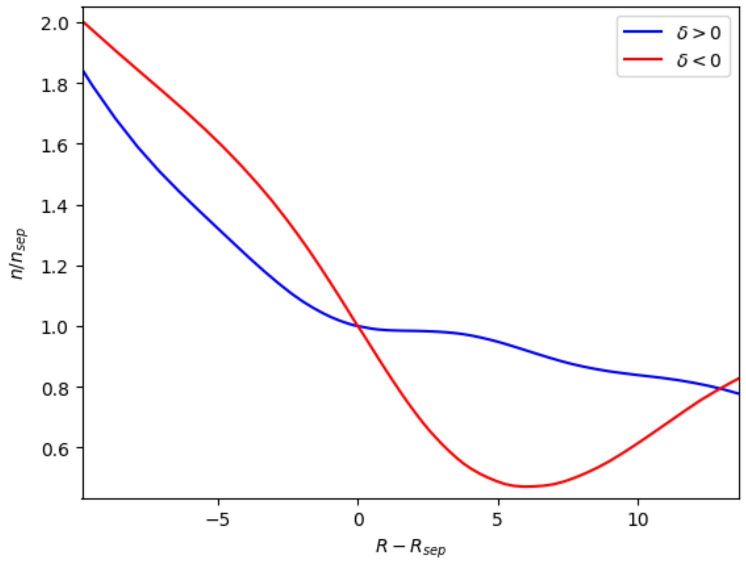
Potential well amplitude decreasing

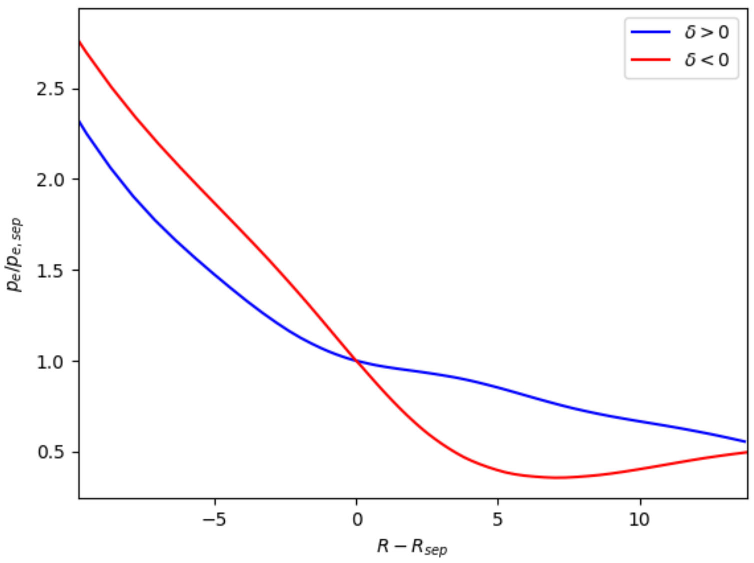


Neutral density peaks where ion flux higher

Comparison with different triangularity

- Profiles normalized to separatrix value
- n increase near wall for δ < 0 (no steady state)
- Steeper profiles for δ < 0 → lower transport

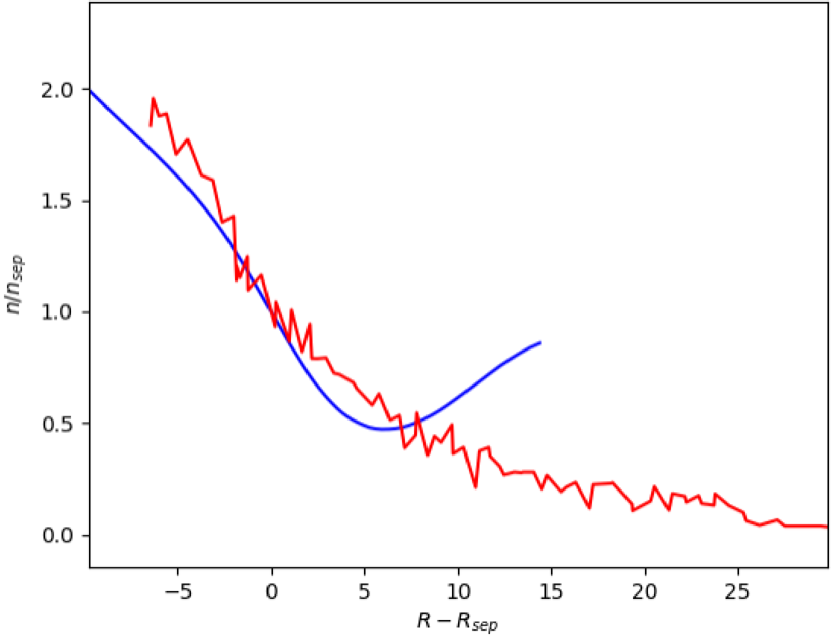


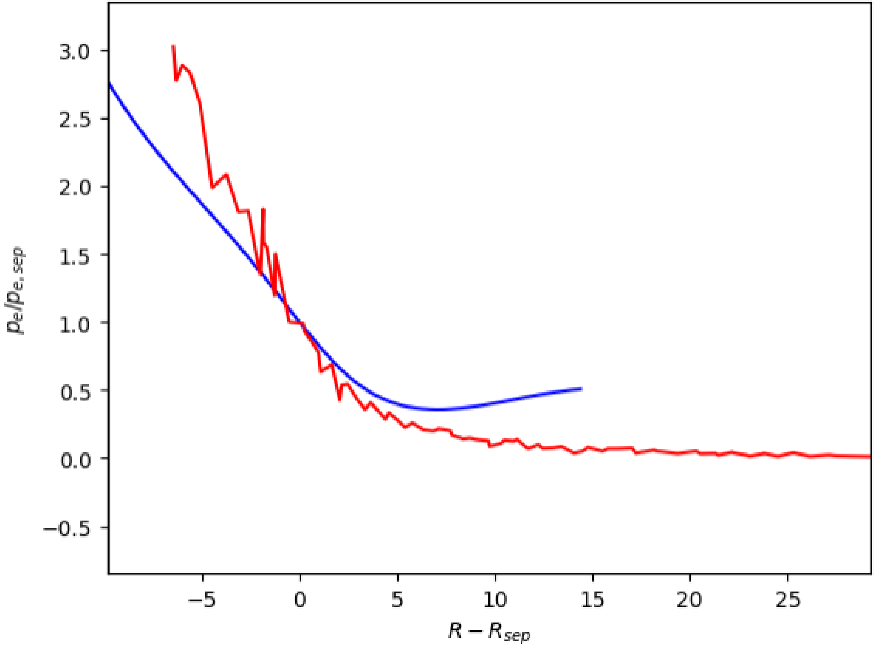


Comparison with fast probe profiles

- Profiles normalized to separatrix value
- Simulations reproduce density profile for $R\text{-}R_{sep} < 5$
- Pressure profile not well reproduced also in edge

N.B. : comparison made between half-size simulation and full-size experiment





Summary

- Two running half-size GBS simulations, positive and negative triangularity
- Steady state not reached, potential well (in core) decreasing
- Still no turbulence observed
- Density and temperature profiles steeper with $\delta < 0$
- Density profile reproduces probe profile near separatrix
- Density profile increases near right wall → possible due to ionization near wall

- Continue run until good turbulence statistic
- Adjust temperature source to have match with probe measurements
- Transport estimate with different triangularity
- Comparison with limited results (suppression of RB with $\delta < 0$ [Riva *et al*, PPCF 2017])