2021 Annual TSVV 2 workshop, 02/12/2021

EUROfusion

A NT DTT? Equilibria and turbulence

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ISTP Consiglio Nazionale delle Ricerche

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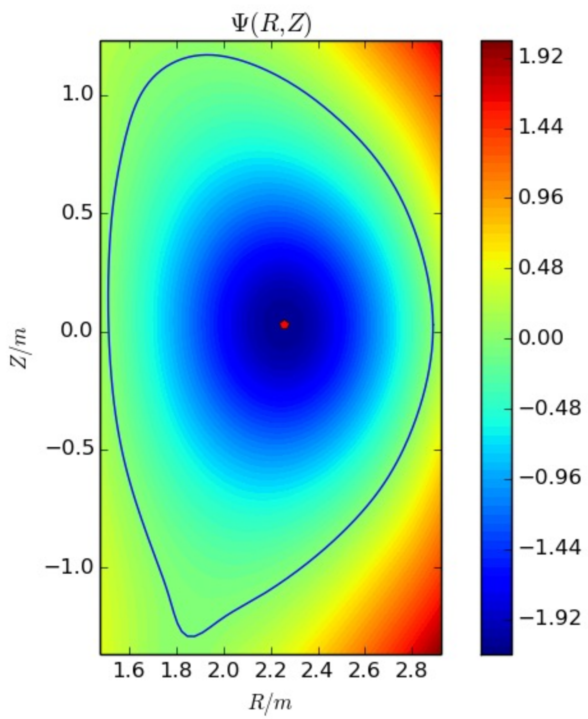
Analysis

- **GOAL**: investigate if a negative triangularity (NT) DTT scenario could be expected to have better fusion performances, due to a reduction of the turbulent transport;
- Linear and nonlinear flux-tube gyrokinetic simulations with the GENE code at fixed radii, comparing a pair of reference DTT scenarios with positive triangularity (PT) and NT;
  - Characterize the turbulence regimes in PT and NT;
  - Evaluate the differences in the linear spectra and absolute flux levels;
  - Investigate the effects of all the important physics ingredients such as collisions, impurities, electromagnetic (EM) effects;
  - Study the turbulence properties: spectra of linear eigenvalues and nonlinear fluxes, velocity space properties, etc...

DTT reference full power scenario with PT and Ne: equilibria and profiles from transport runs

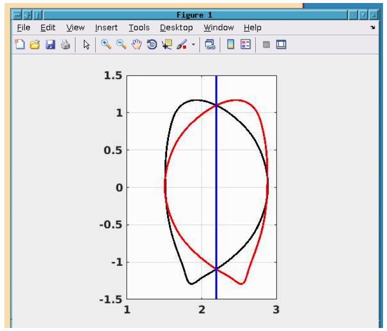


Comparison with NT:

3 strategies

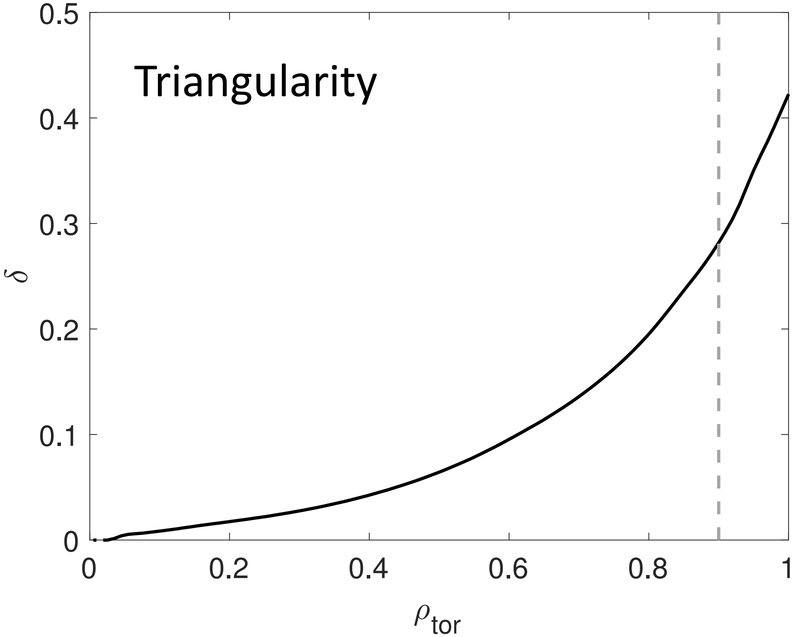
Compare with **'real' NT** corresponding case coming from transport runs;

Locally approximate the equlibrium with **Miller** analytical model, than change the sign of the triangularity (and derivative);

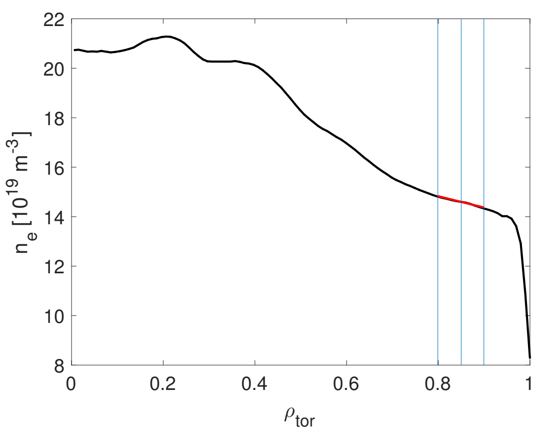


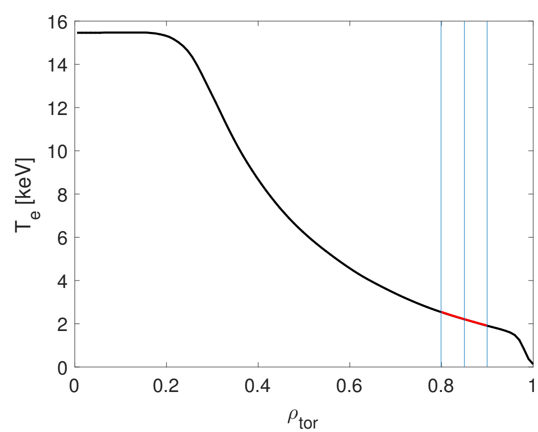
Manually flip the triangularity of the eqdsk, flipping the boundary and running CHEASE with fixed boundary.

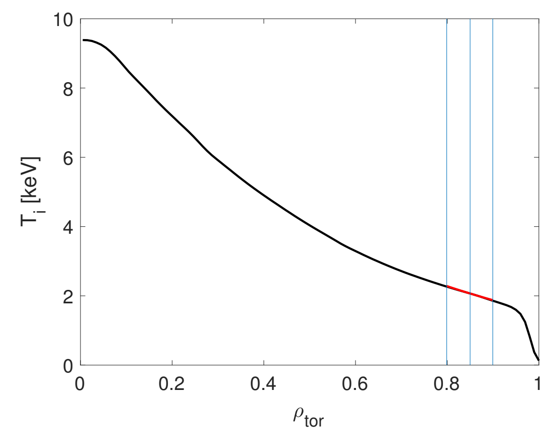
PT case: radius of analysis ρ_{tor}=0.85



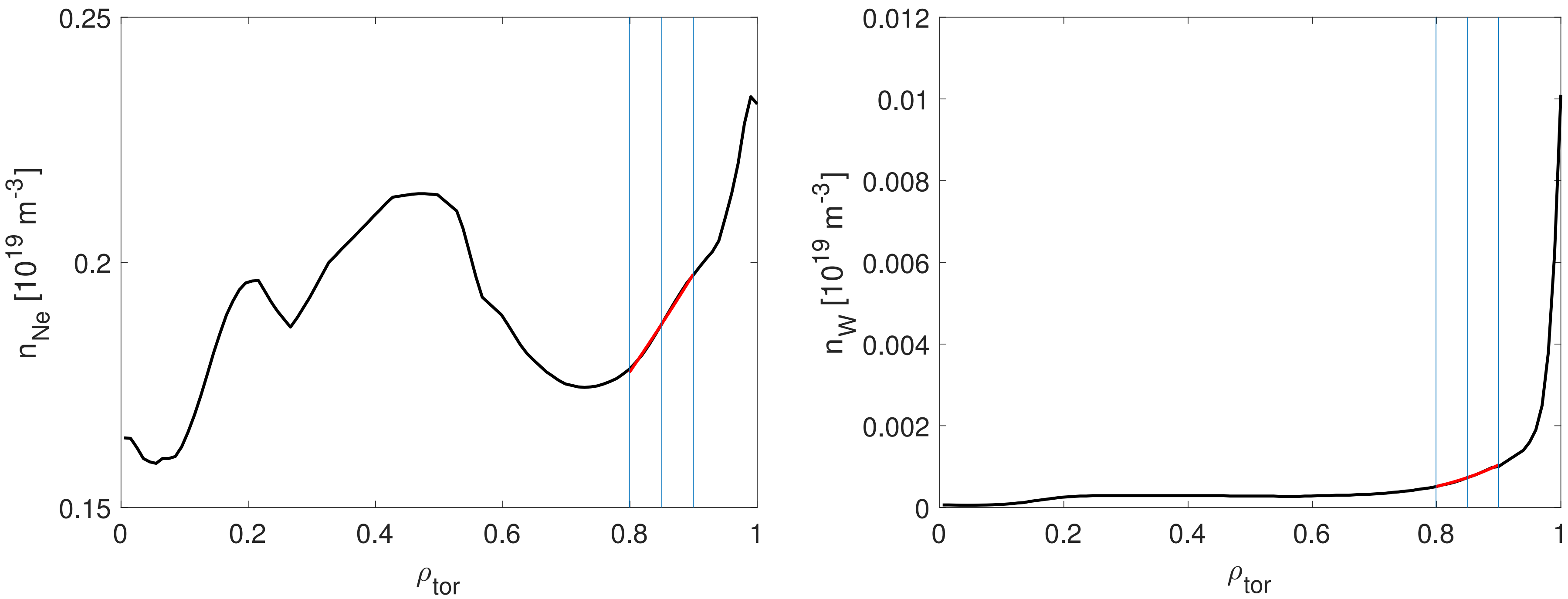
- The triangularity is sufficiently large;
- One is still ‘safely’ far from the pedestal;
- The profiles are not corrugated at this radius and the logarithmic gradients are well defined;







Impurities:



0.25
0.2
0.15
n_{Ne} [10^{19} m^{-3}]
0
0.2
0.4
0.6
0.8
1
ρ_{tor}
0.012
0.01
0.008
0.006
0.004
0.002
0
n_W [10^{19} m^{-3}]
0
0.2
0.4
0.6
0.8
1
ρ_{tor}

Reference parameters

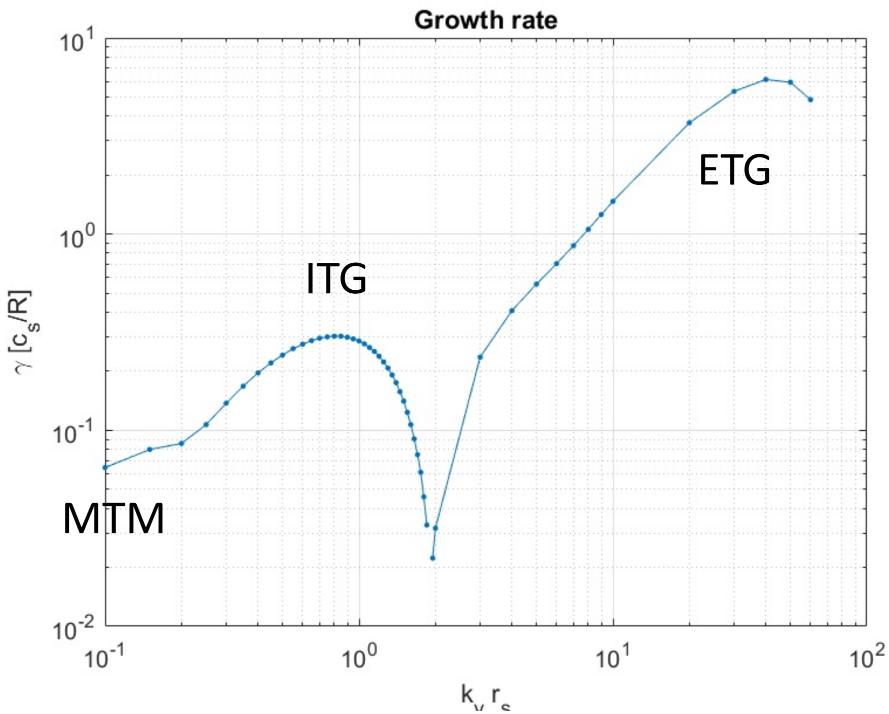
Radius of analysis: $\rho_{tor} = 0.85$

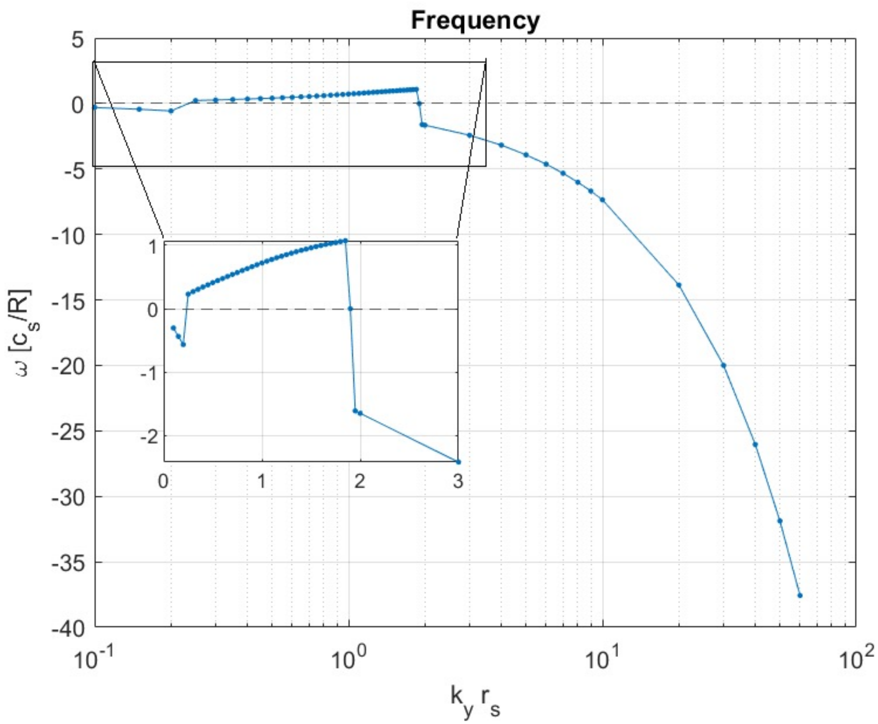
	electrons	Deuterium	Neon	Tungsten
$\omega_n = -dlog(n)/d\rho_{tor}$	0.31345	0.5310066690	-1.0645	-7.0449
$\omega_n = -dlog(T)/d\rho_{tor}$	2.8374	1.9518	1.9518	1.9518
n/n_e	1	0.870240235	0.0128	5.0279E-005
T/T_e	1	0.9360	0.9360	0.9360

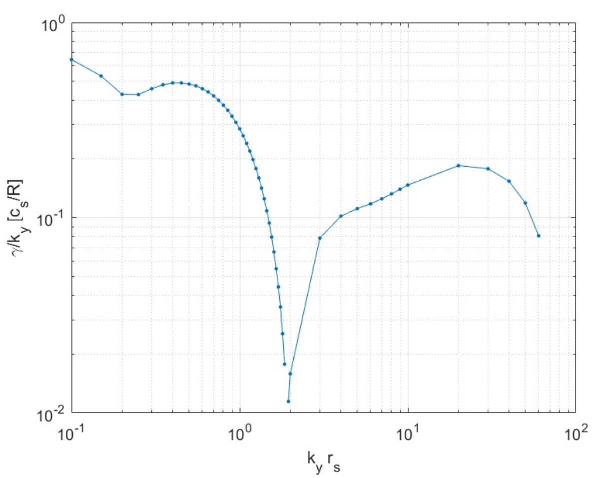
Other parameters:

$\beta_e = 3.439 \cdot 10^{-3}$
$\upsilon_c = 9.4977 \cdot 10^{-3}$
$B_0 = 6.146\ T$
$\rho_{tor,\ edge} = 0.8952\ m$
$T_e = 2.208\ keV$
$n_e = 14.519 \cdot 10^{19}\ m^{-3}$

Linear eigenvalues: k_y scans:



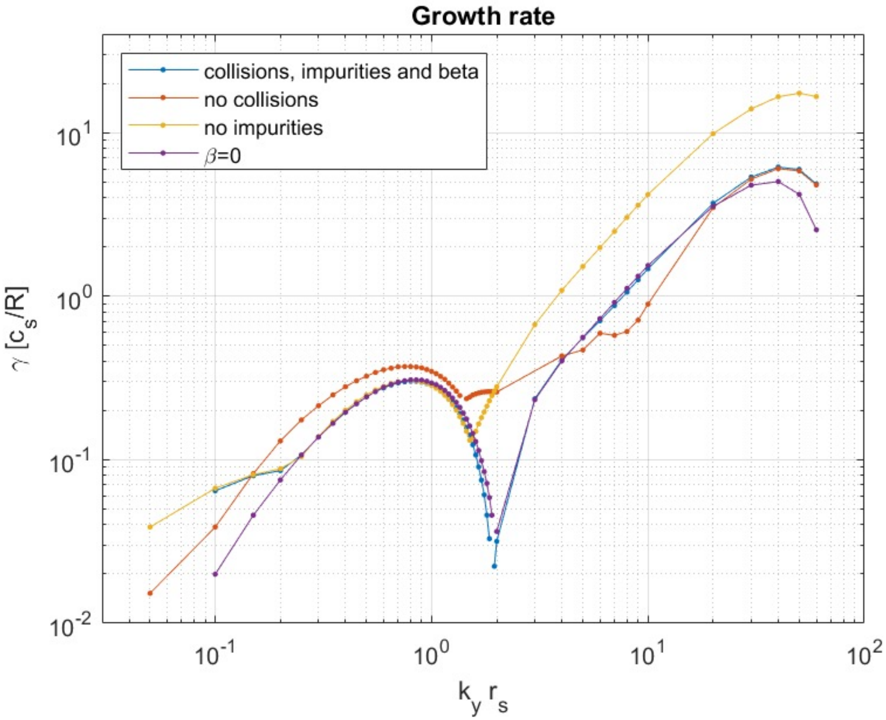


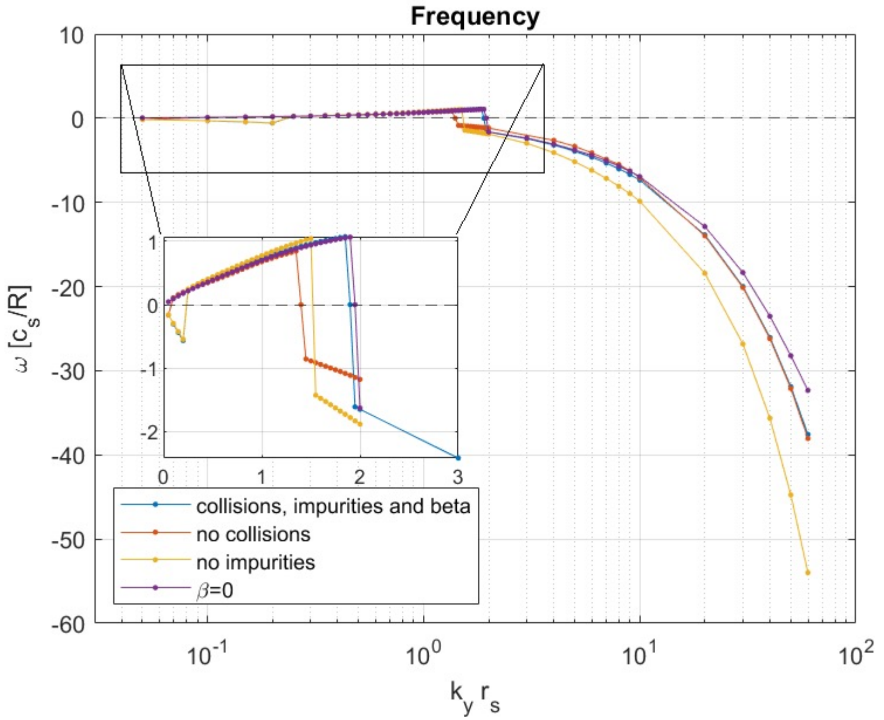


ETG should not play a role nonlinearly (γ/ky peak: much larger at ion scales)

Effect of impurities, collisions and β_e:

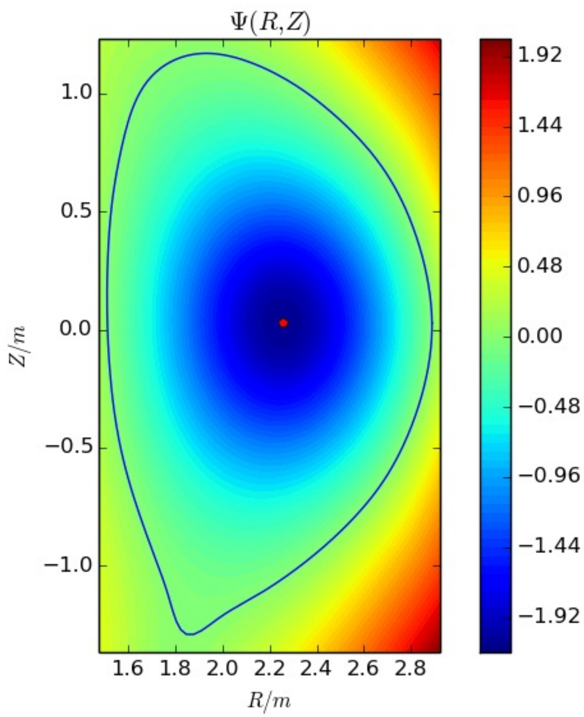
- Impurities: stabilize the TEM/ETG branch and the transition from ITG to TEM happens at smaller k_y;
- Collisions: stabilise the TEM (TEM/ETG?) intermediate-ky region and moderately stabilize the ITGs;
- Electromagnetic (finite β_e does not impact the results).



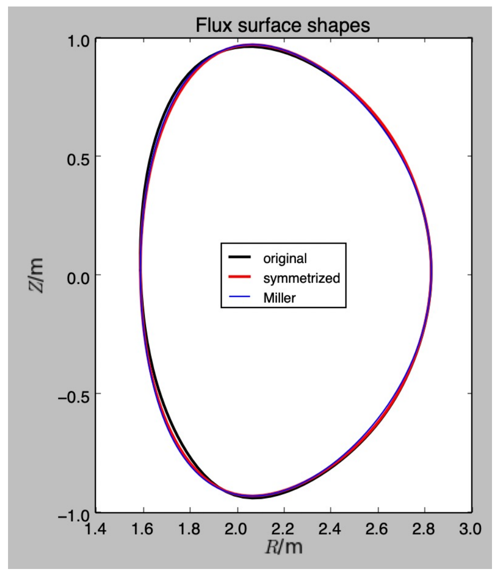


Simulations with Miller's equilibrium for positive and negative triangularity

EQDSK



Miller at ρ_{tor}=0.85



Flip δ and its shear in the NT Miller parameters

Compare

Miller: PT

q	-2.1476
$\hat{s}$	3.6218
α_{MHD}	0.41463
ε	0.2802
Elonagation (κ)	1.5345
Triangularity (δ)	0.23145
Squareness (ζ)	-0.012814
s_{κ}	0.76666
s_{δ}	1.0504
s_{ζ}	-0.16805

Miller: NT

q	-2.1476
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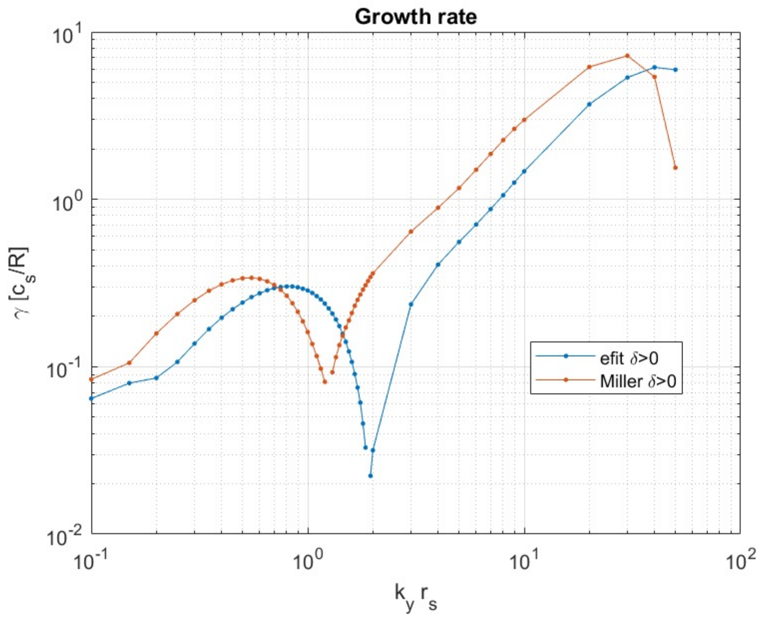
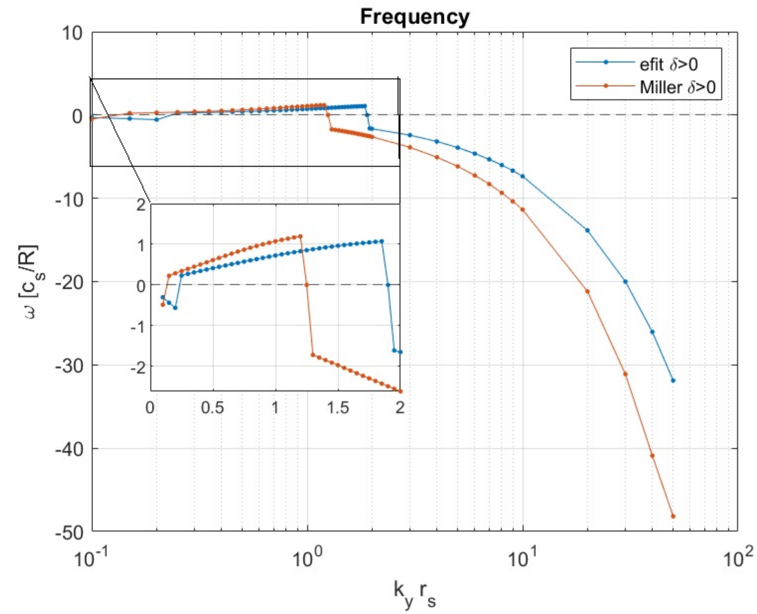
Linear simulations

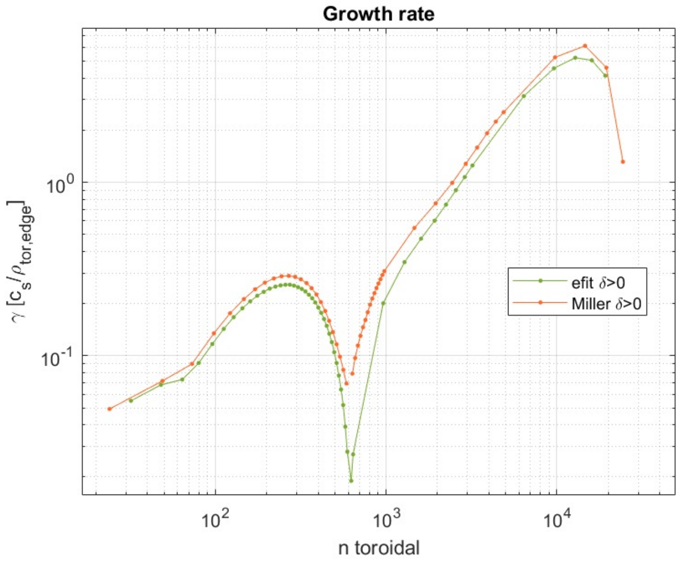
Linear eigenvalues: **good agreement between EQDSK and Miller**

vs $k_y\rho_s$:





Better: vs n (toroidal mode number) :

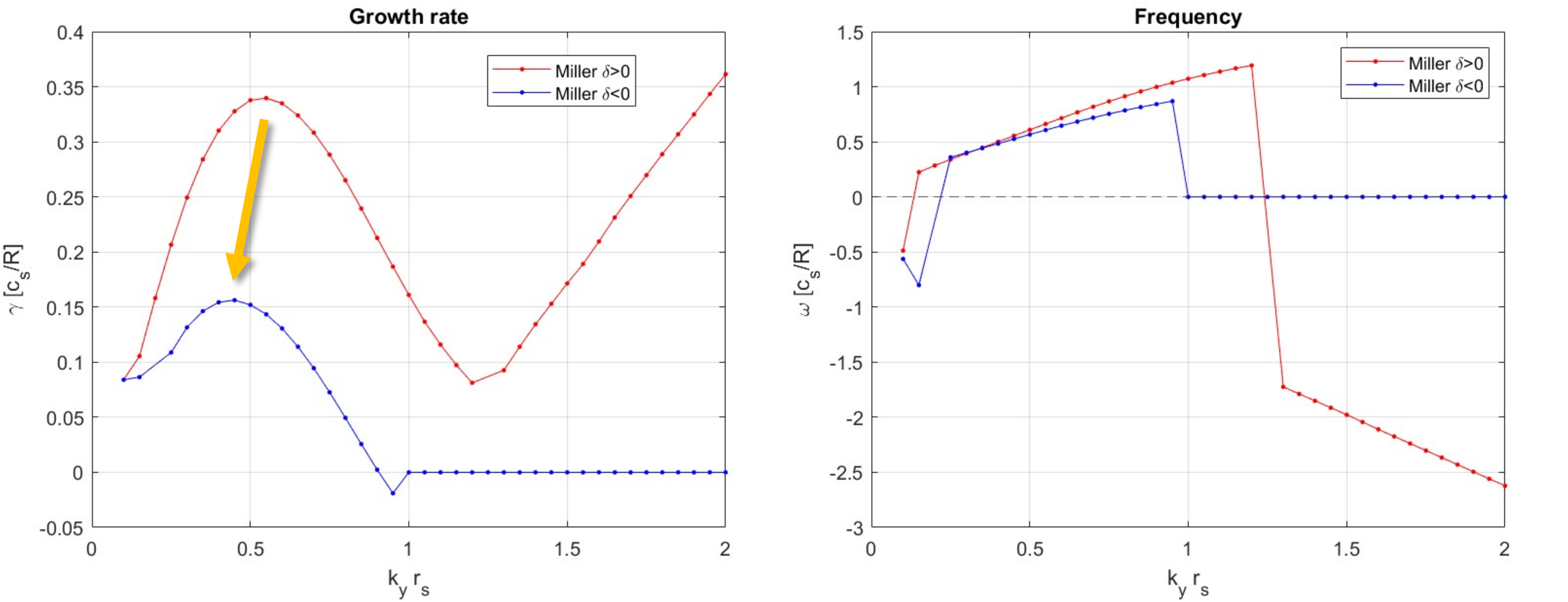


$k_y = nq/r = n/L_{ref}C_y$

$k_y\rho_s$: different for eqdsk and Miller:

Small difference coming from B_{ref} through ρ_s and larger difference (factor ~1.5) coming from different $L_{ref}C_y$

Linear eigenvalues: **difference between Miller PT and and Miller NT**



Strong linear stabilizing effect: - ~55% on ITG max growth rate

Nonlinear simulations

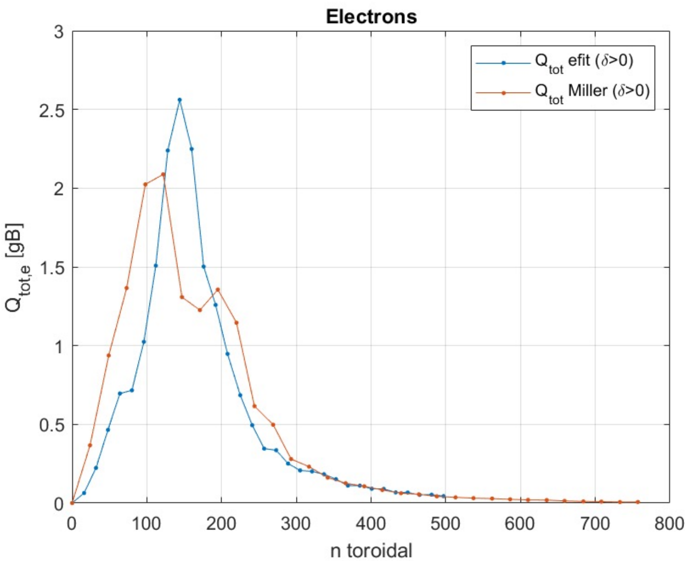
L_y=126ρ_s, L_x= 22 ρ_s, $k_{y,min}$ ρ_s =0.05, two grids

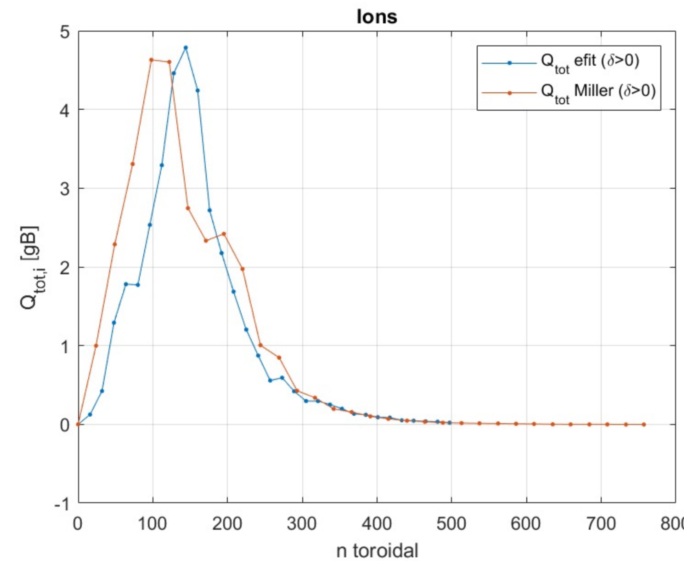
- ‘old grid’: $(n_x \times n_y \times n_z \times n_{v_\parallel} \times n_\mu) = (128, 32, 32, 48, 15)$;
- ‘new grid’: $(n_x \times n_y \times n_z \times n_{v_\parallel} \times n_\mu) = (128, 32, 32, 24, 8)$;

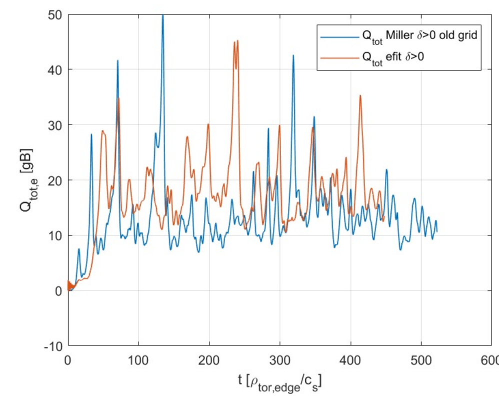
Nonlinear simulations: **good agreement between EQDSK and Miller**

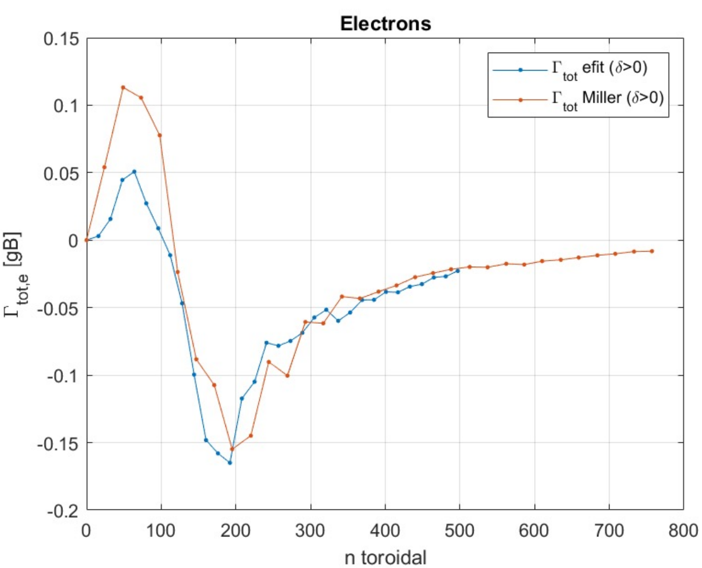
Flux spectra vs the toroidal mode number n:

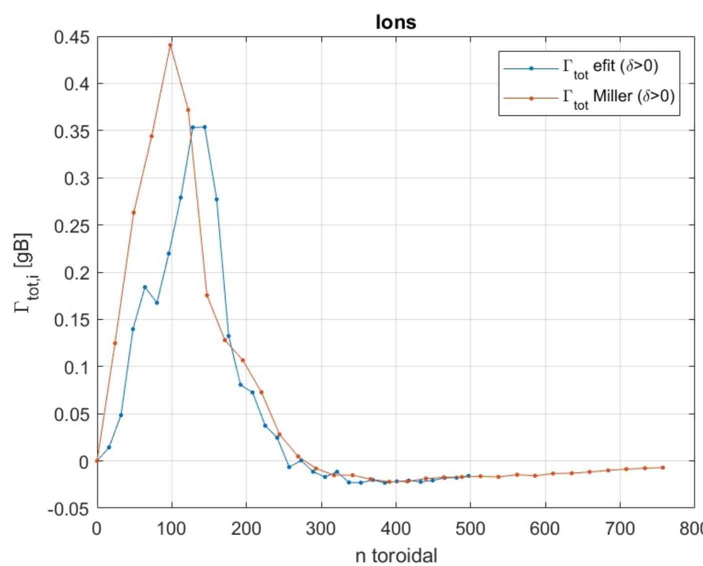
Time traces (electrons):

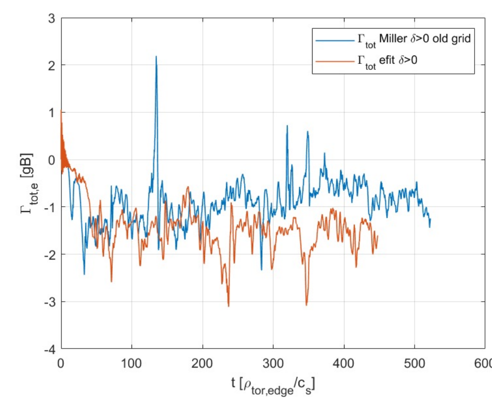




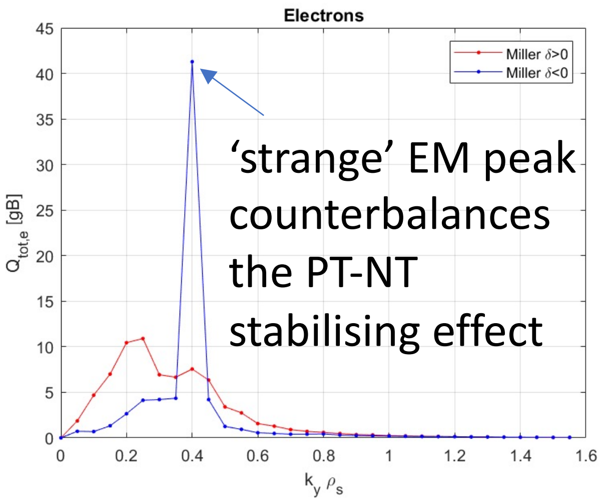


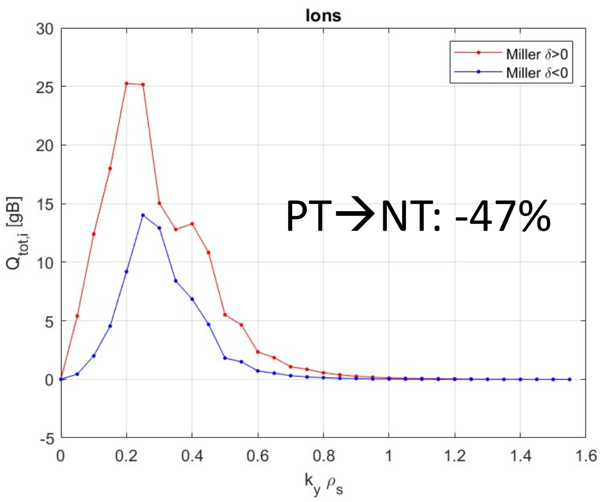




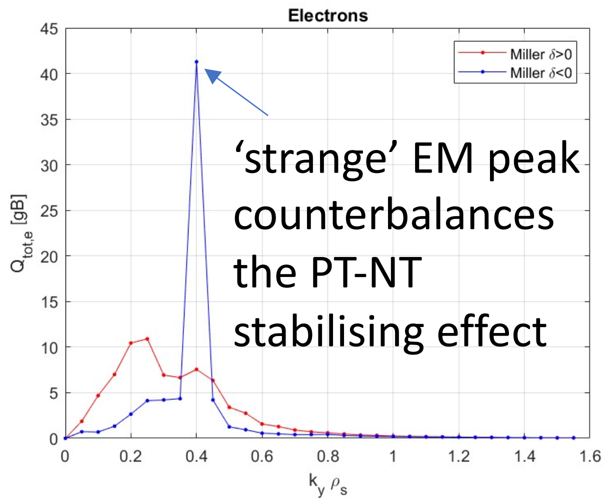


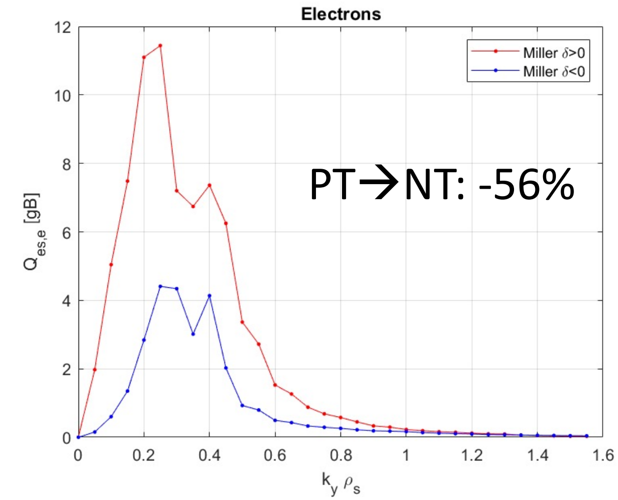
Nonlinear simulations:
difference between Miller PT and and Miller NT



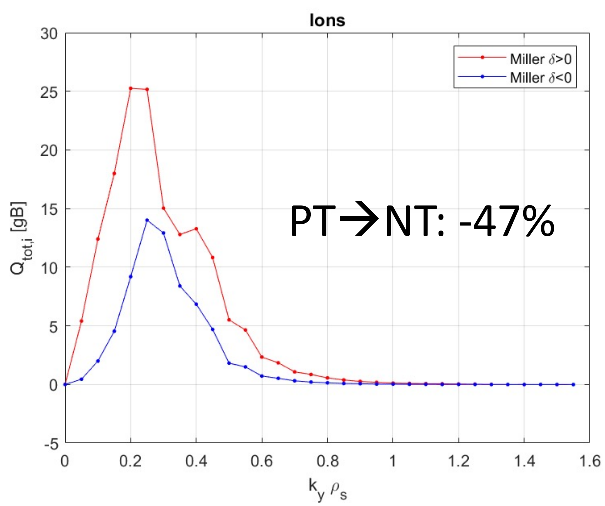


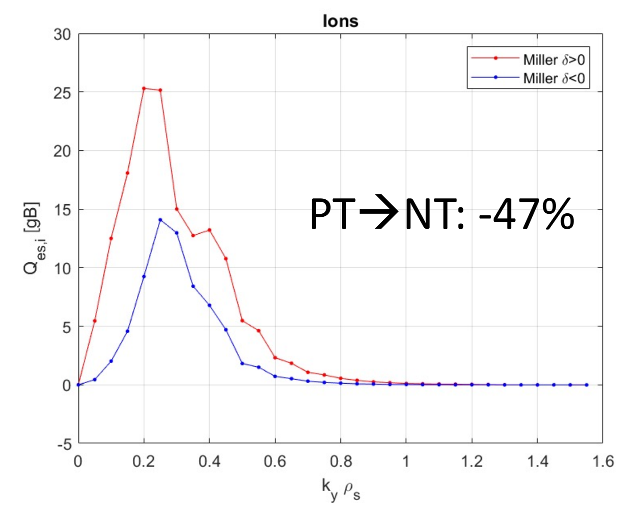
Nonlinear simulations:
difference between Miller PT and and Miller NT





Let us look to the ES fluxes alone

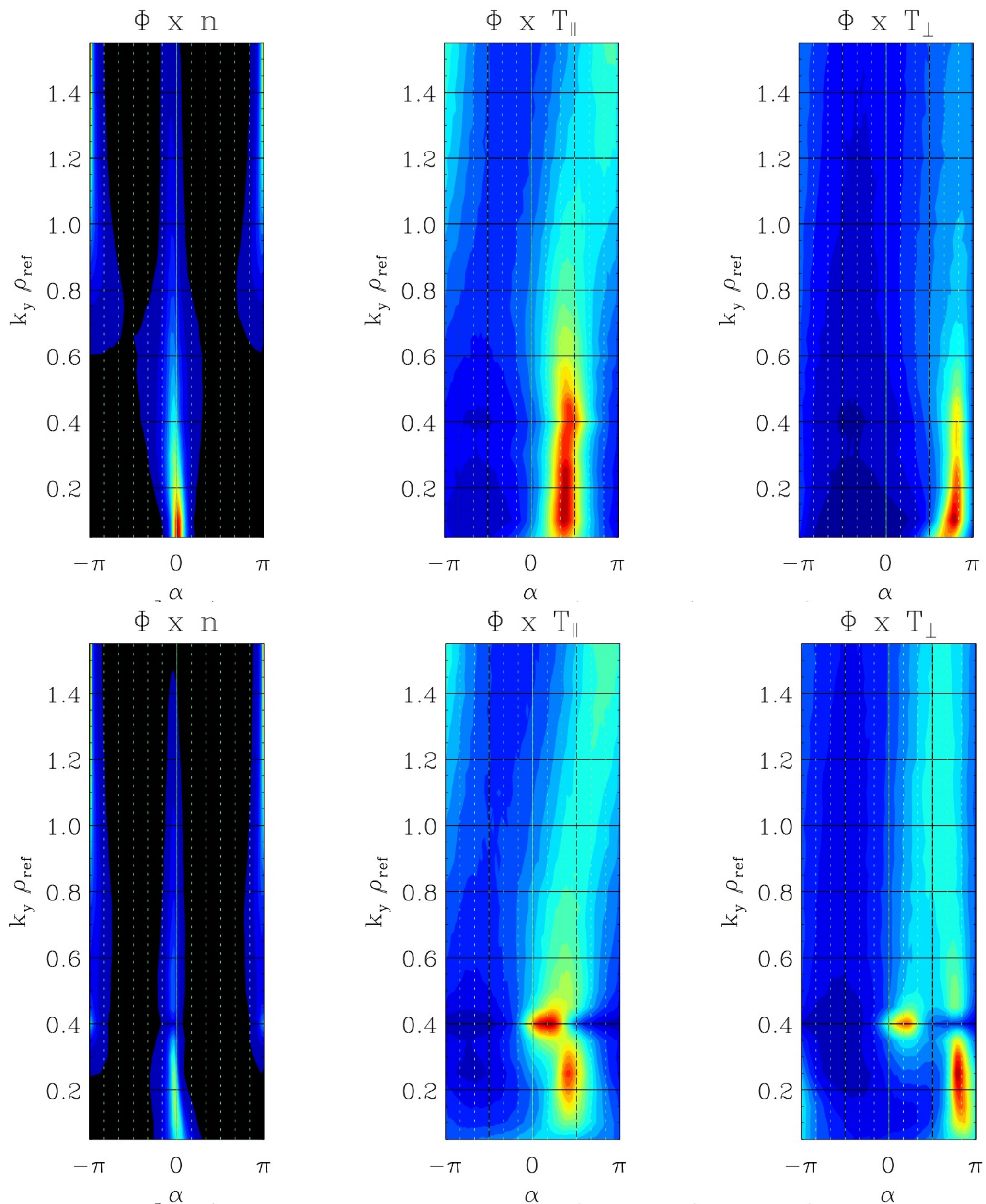




Cross-phases: Miller, comparing PT and NT

PT

NT



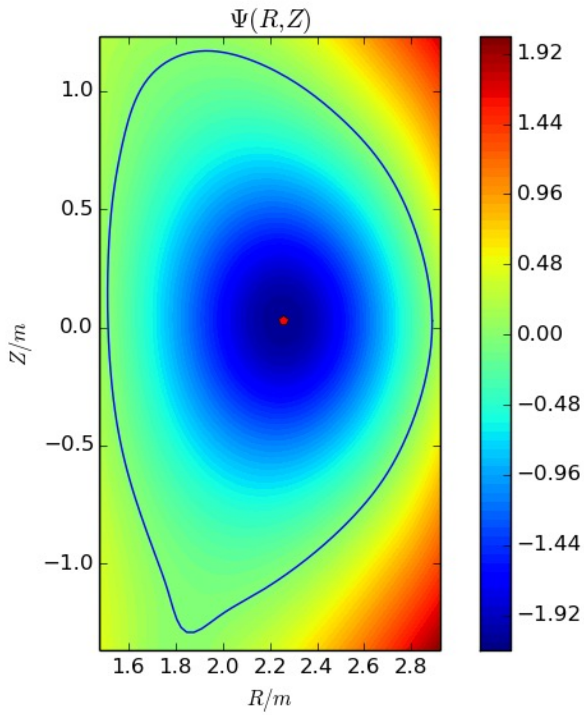
The stabilizing effect is of order -50% for both electron and ion heat fluxes, similar to the effect on growth rates

Is this stabilizing effect mainly affecting the saturation values of the potentials, rather than the cross phases between fluctuations?

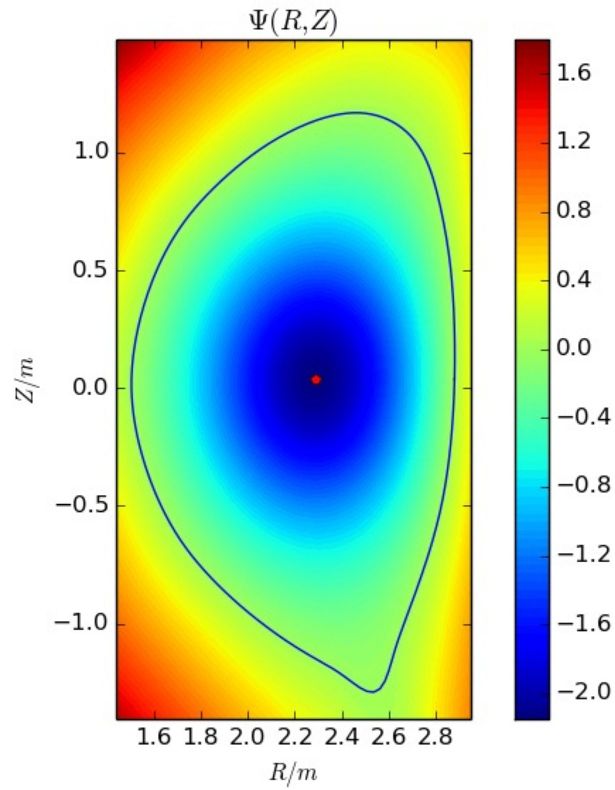
ES cross phases: similar between PT and NT (except for the EM effect at ky=0.4)

Simulations with EQDSK equilibrium for PT and 'manually flipped' NT

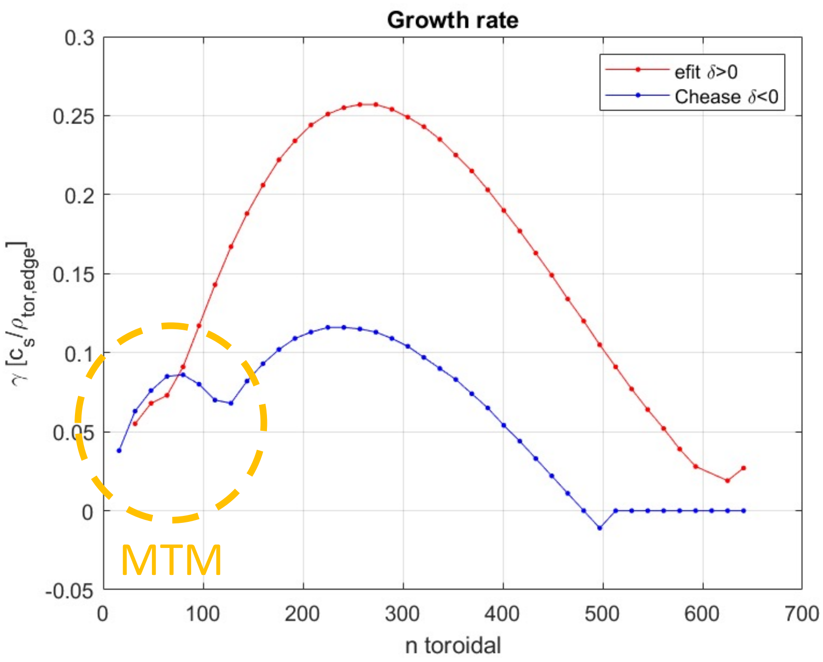
EQDSK PT

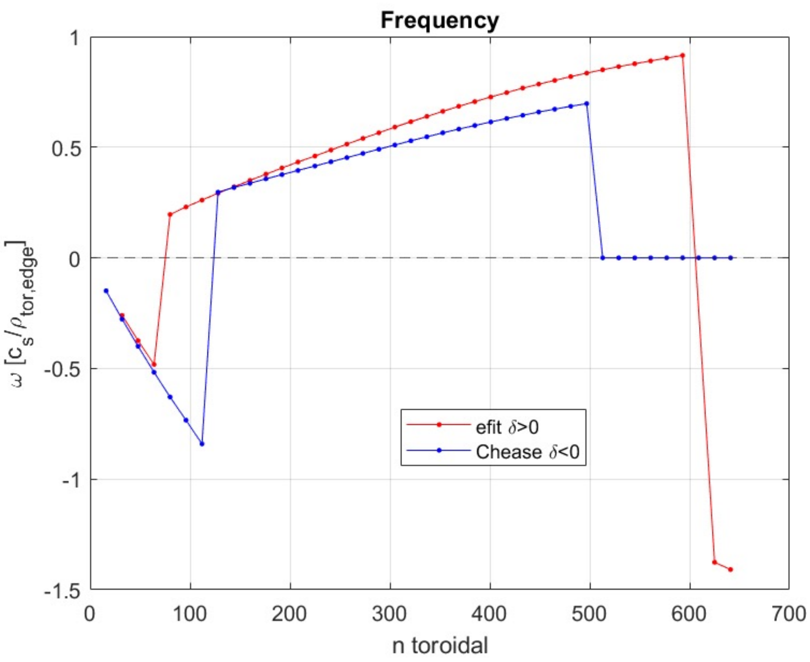


EQDSK NT manually flipped with CHEASE



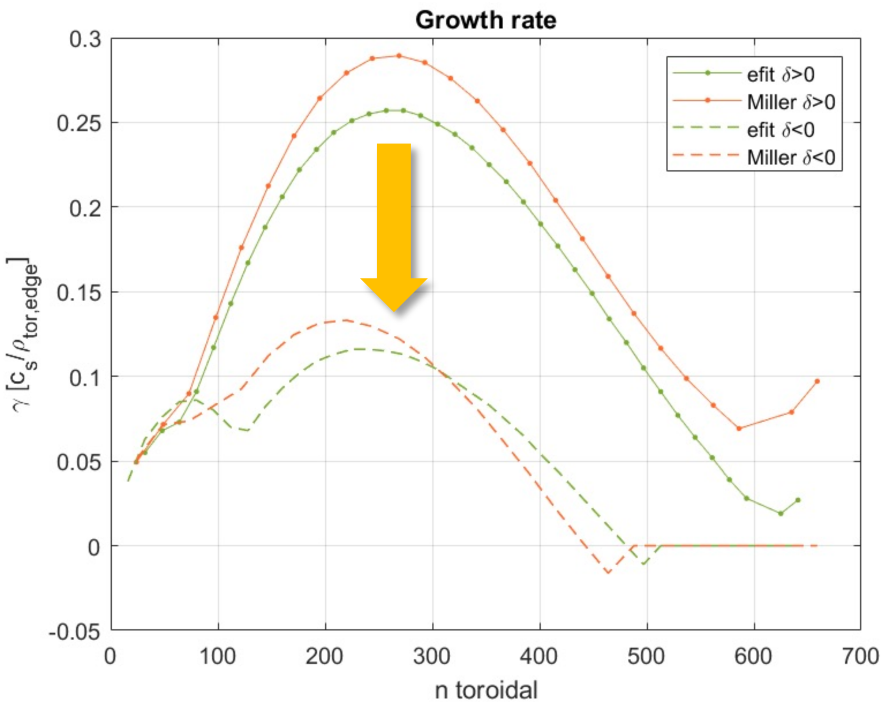
Linear eigenvalues: **difference between PT and NT**

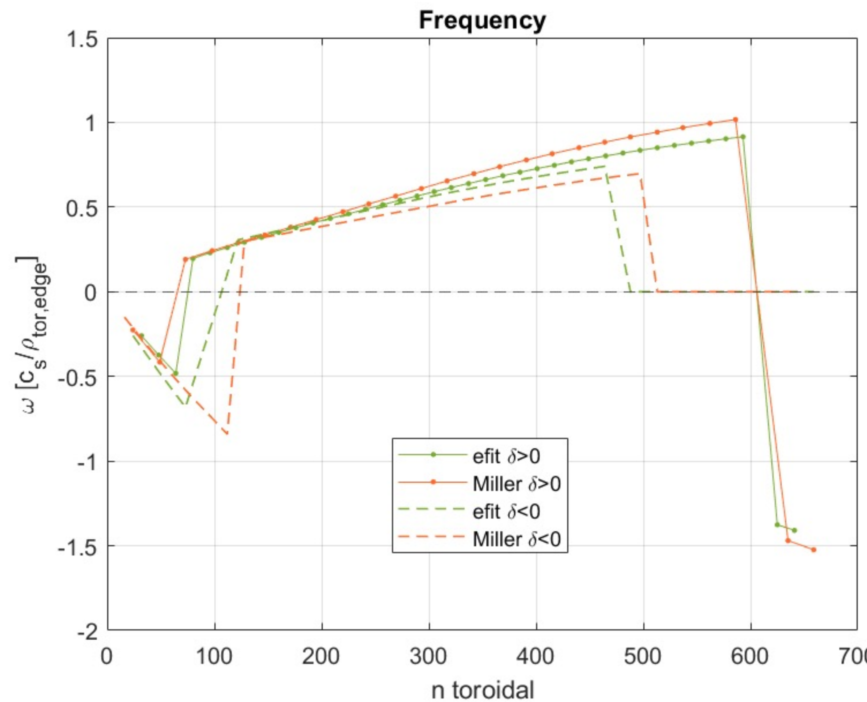




Strong linear stabilizing effect: - ~55% on ITG max growth rate
(same stabilization as with Miller geometry!)

Linear eigenvalues: **consistent picture comparing EQDSK and Miller approximation…Miller is sufficient to get the PT-NT ITG linear stabilization physics**





-55% linear stabilisation going from PT to NT

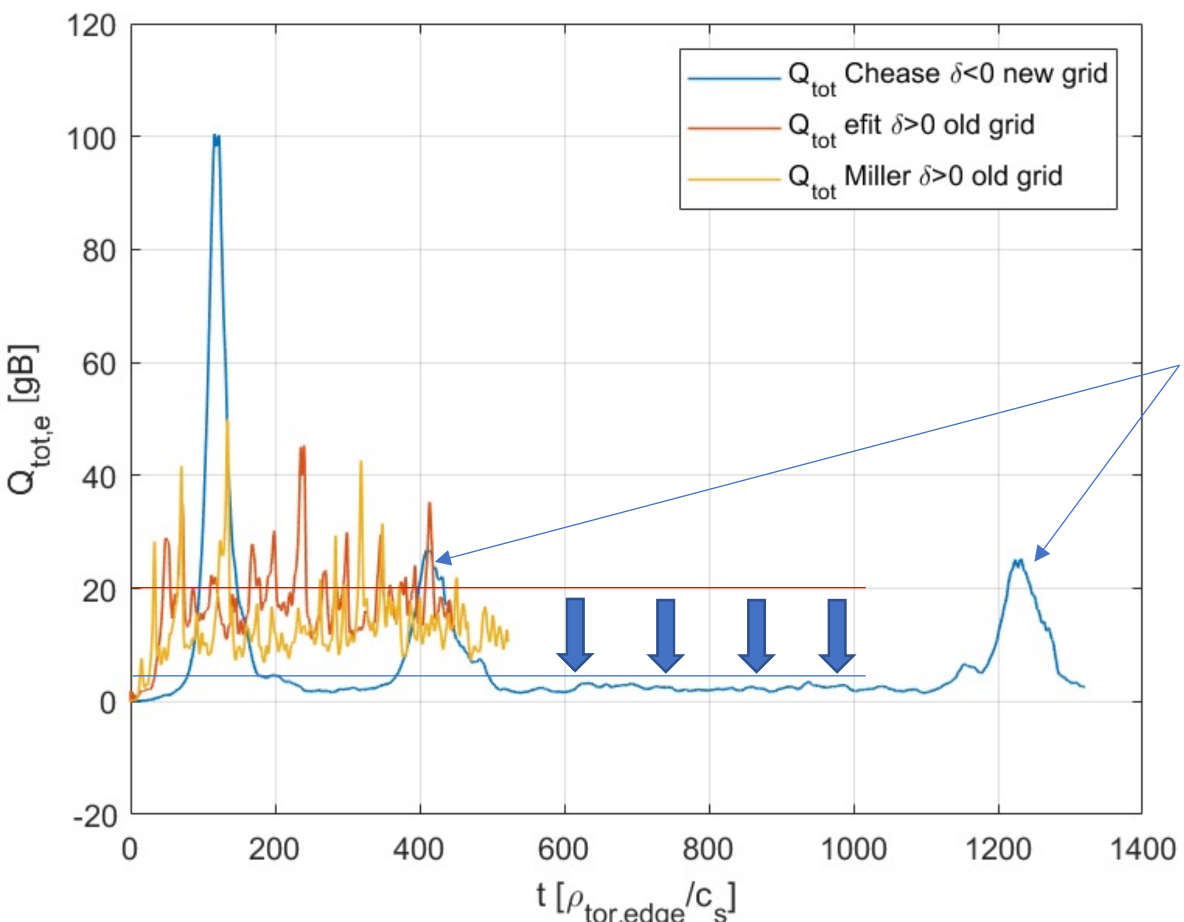
Nonlinear simulations

L_y=126ρ_s, L_x= 69ρ_s, $k_{y,min}$ ρ_s =0.05, two grids

- 'old grid': $(n_x \times n_y \times n_z \times n_{v_\parallel} \times n_\mu) = (128, 32, 32, 48, 15)$;
- 'new grid': $(n_x \times n_y \times n_z \times n_{v_\parallel} \times n_\mu) = (128, 32, 32, 24, 8)$;

Nonlinear simulations:
difference between EQDSK PT and and EQDSK NT

Reduction of the heat fluxes going from PT to NT: → **Electrons: -64%**
Ions:-70%



'peaks' of q_e due to B fluctuations (EM flux)

For Miller equilibrium the EM contribution was constant in time, with the EQDSK it is concentrated in 'bursts'

Summary: nonlinear PT-NT stabilization of heat fluxes

	Total heat fluxes (ES+EM):	Only contribution from ES potential fluctuations:
Miller	Electrons: no effect Ions:-47%	Electrons: -56% Ions:-47%
EQDSK	Electrons: -64% Ions:-70%	Electrons: -79% Ions:-70%

- A little bit larger effect with EQDSK;
- The EM contribution to q_e for the Miller case neutralizes the stabilisation, but this has to be investigated.

Main conclusions and future work

- More work on the numerical convergence of the simulations;
- Understand the impact of EM fluctuations on the results in NT;
- Study the variation of the stiffness of T_i and T_e when changing the triangularity from PT to NT , by varying R/L_{Ti}, R/L_{Te};
- Separate the contributions to the fluxes from trapped and passing particles;