PARTICLE TRANSPORT IN ION AND ELECTRON SCALE TURBULENCE

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Introduction

This work deals with transport of main ions and impurities in micro turbulence driven by ion and electron temperature gradients, and trapped electrons. Results are obtained for both non- and quasi-linear simulations, using the gyrokinetic code GENE [1–3]. Transport properties are quantified by the gradient of zero particle flux for steady state in source free regions.

Results are compared with results obtained using a computationally efficient fluid model [4]. Of particular interest are conditions of steep gradients, relevant to eg. transport barriers. Results from $\hat{s}$–α geometry are compared with results with a JET-like magnetic equilibrium, and the effects on transport investigated. Further, the quality of He ash removal is studied.

Particle Transport

Particle transport for species j is derived from:

$$\Gamma_{nj} = \langle \delta n_j \boldsymbol{v}_{\boldsymbol{E}\times\boldsymbol{B}} \rangle, \tag{1}$$

where $\langle\cdot\rangle$ means a spatial averaging [5, 6].

This is divided (locally) into **diffusion** and a **advection**:

$$\frac{R\Gamma_j}{n_j} = D_j \frac{R}{L_{n_j}} + RV_j, \tag{2}$$

with R the major radius and R/L_{n_j} the normalised local density gradient.

In the source free core region advection ("pinch") and diffusion balance to give zero flux. The **zero flux peaking factor** quantifies this:

$$0 = D_j \frac{R}{L_{n_j}} + RV_j \Leftrightarrow -\frac{RV_j}{D_j}\bigg|_{\Gamma_j=0} = \frac{R}{L_{n_j0}} \equiv PF_j \tag{3}$$

Thus PF_j is interpeted as the **gradient of zero flux**.

For **trace impurities** D_Z and V_Z are independent of ∇n_Z. *Eq.* (2) is then linear in R/L_{n_Z}, and PF_Z is found by fitting a straight line to flux data. This is illustrated in *Fig.* 1.

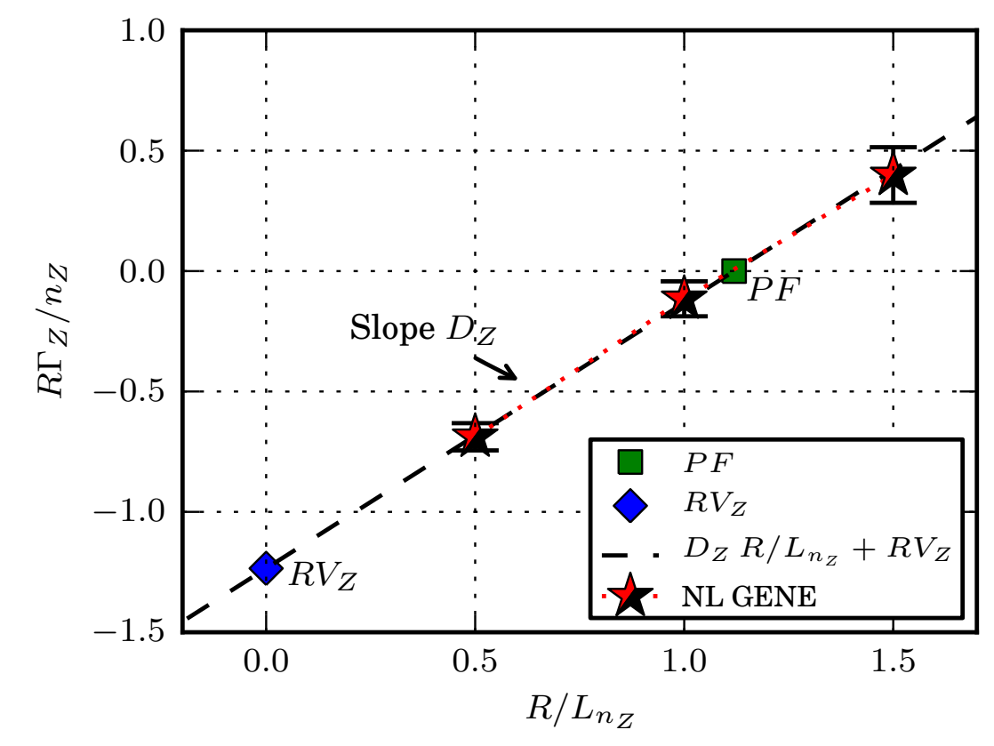

FIGURE 1: The **impurity flux dependence** on ∇n_Z, the validity of the linearity assumption of *Eq.* (2) for trace impurities, and how D_Z, RV_Z and PF_Z are estimated. Data from NL GENE simulations.

In general, D_j and V_j may depend on ∇n_j, and PF_j has to be found explicitly from the zero flux condition.

REALISTIC GEOMETRY AND ITG:

Simulations of impurity transport using a realistic *JET*-like magnetic equilibrium were compared to s-α-geometry for an **ITG** dominated discharge. Parameters were chosen to correspond closely to *JET L-mode discharge #67730*; see [6] for parameters.

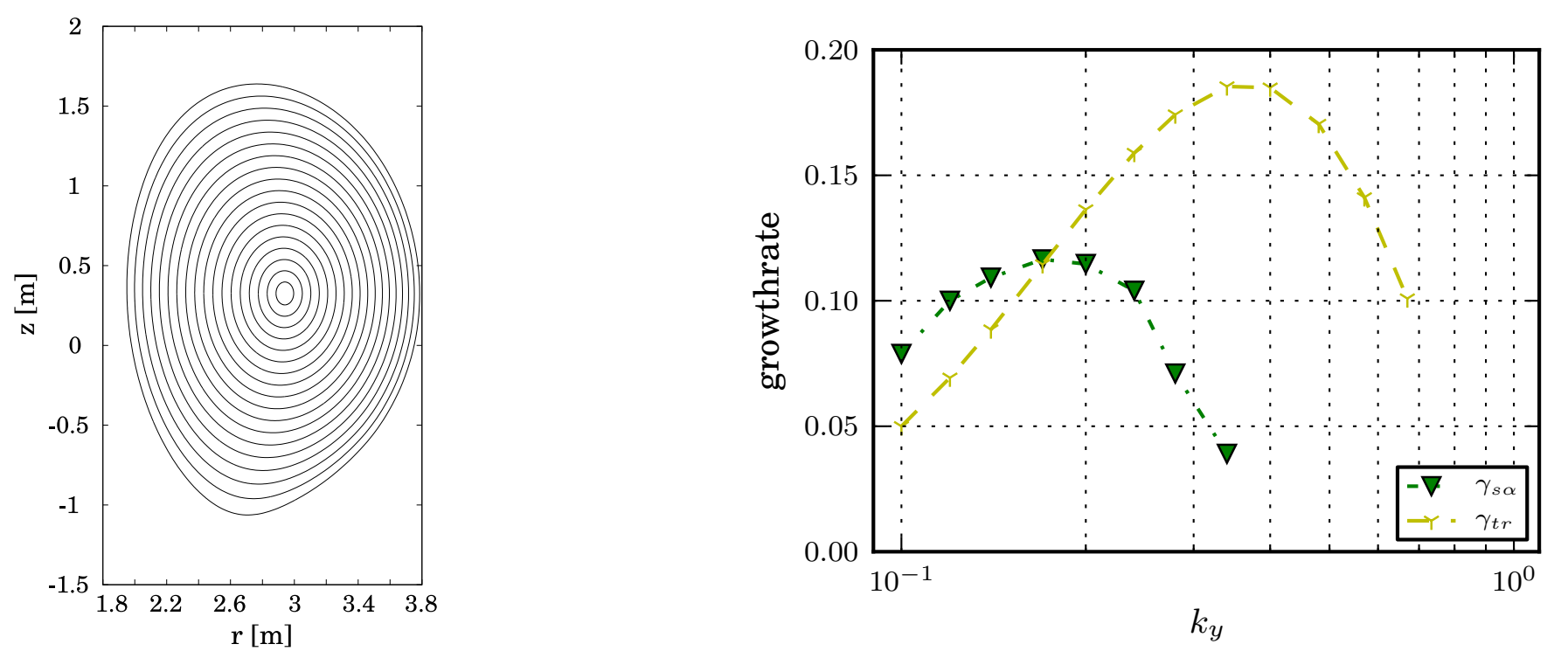

FIGURE 2: Realistic magnetic geometry *(left)* and the growthrate spectra for both geometries *(right)*.

With realistic geometry the growthrate spectrum:

- is destabilised
- shifts to higher $k_\theta\rho_s$

This is due to modified curvature and FLR effects, mainly from elongation, and is consistent with fluid results in [7].

This has important repercussions for impurity transport:

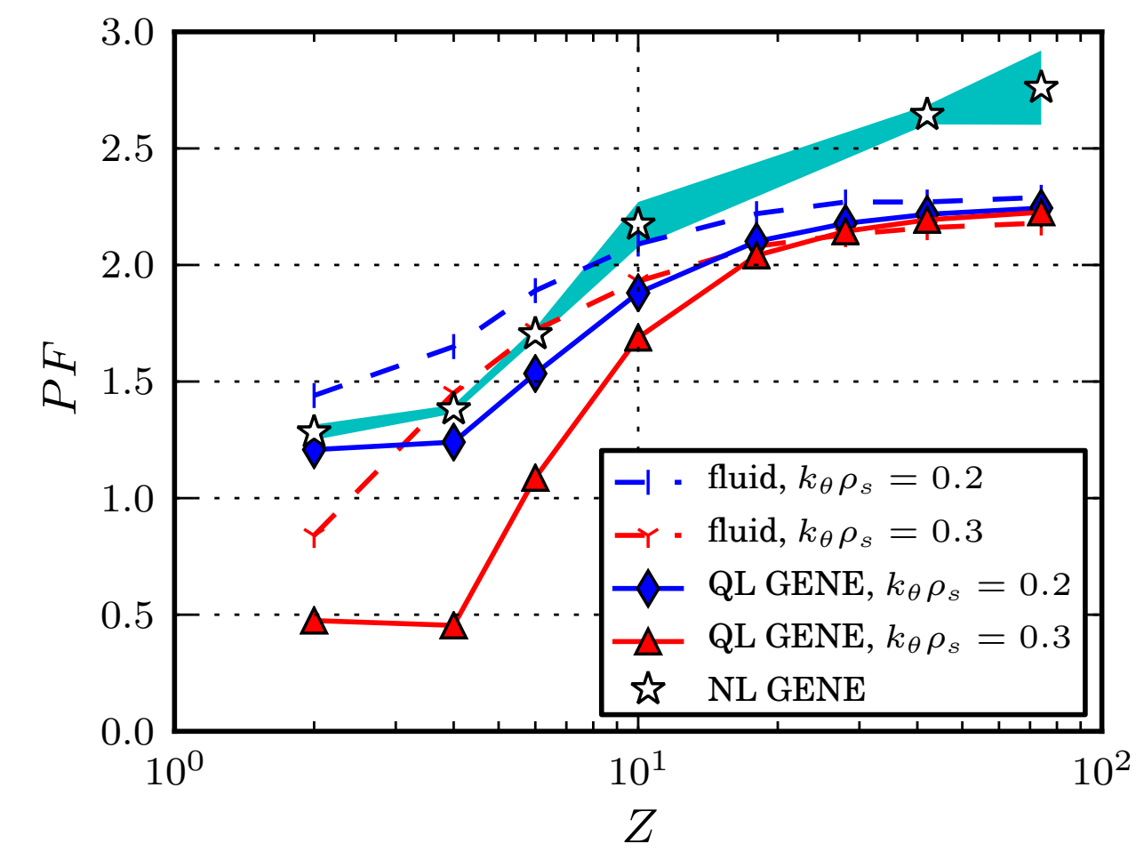

FIGURE 3: Scalings of PF_Z with **impurity charge**, ITG mode dominated discharge with $\hat{s}$–α geometry [6]. An estimated uncertainty of σ is shown in cyan.

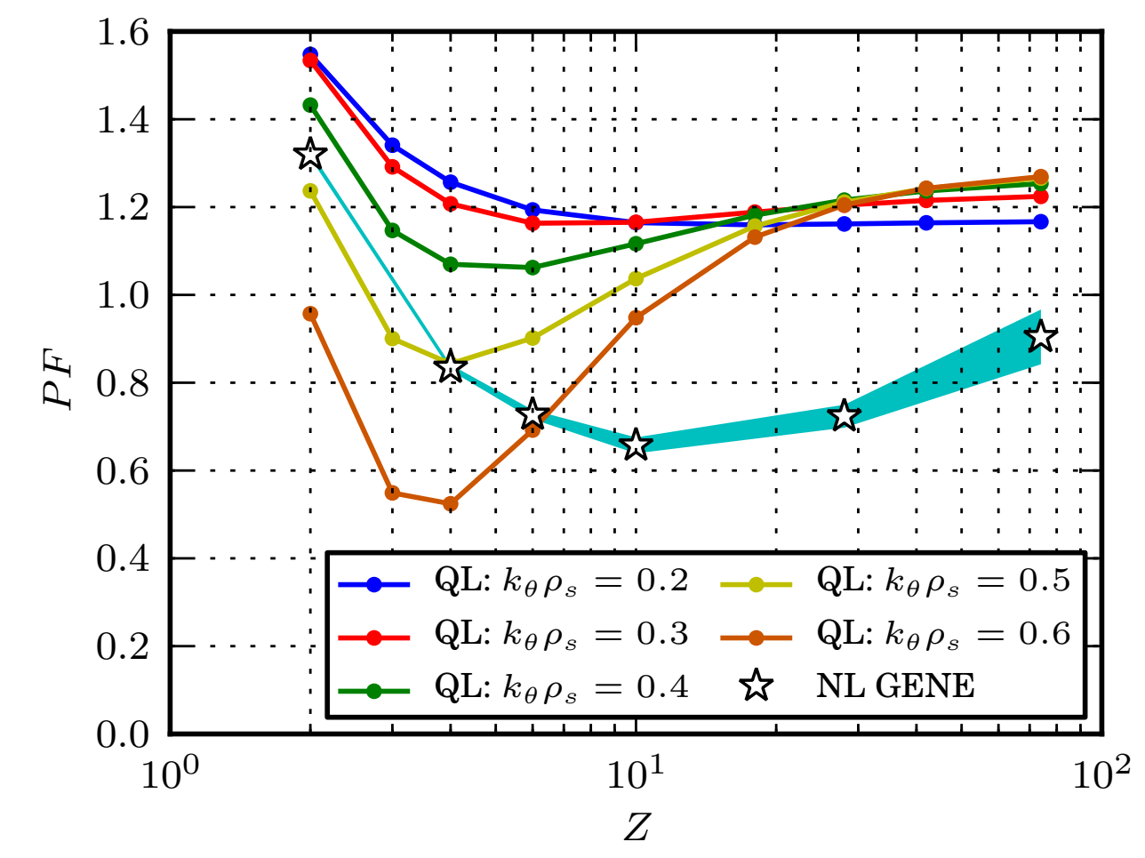

FIGURE 4: Scalings of PF_Z with **impurity charge**, ITG mode dominated discharge with realistic JET-like geometry. An estimated uncertainty of σ is shown in cyan.

- reduction of PF_Z for high Z in realistic case
  - lower levels due to reduction of **curvature pinch**
- QL results over estimate PF_Z for high Z
- change in sign of (outward) **thermopinch** for low Z: $\Rightarrow$ increase in PF_Z for low Z impurities in realistic case
- NL and QL impurity pinch qualiatively agree with [6, 8]

SELF-CONSISTENT PEAKING OF MAIN IONS AND IMPURITIES:

Simulations were performed of steep gradients where **TE** mode turbulence dominates; see [9] for parameters.

Peaking factors for background *and* impurities were calculated self-consistently from the condition $\Gamma_{i,e} = 0$:

1. background peaking ($PF_e = R/L_{n_e0}$) calculated with trace levels of impurities
2. impurity peaking ($PF_Z = R/L_{n_Z0}$) calculated using this value as background density gradient

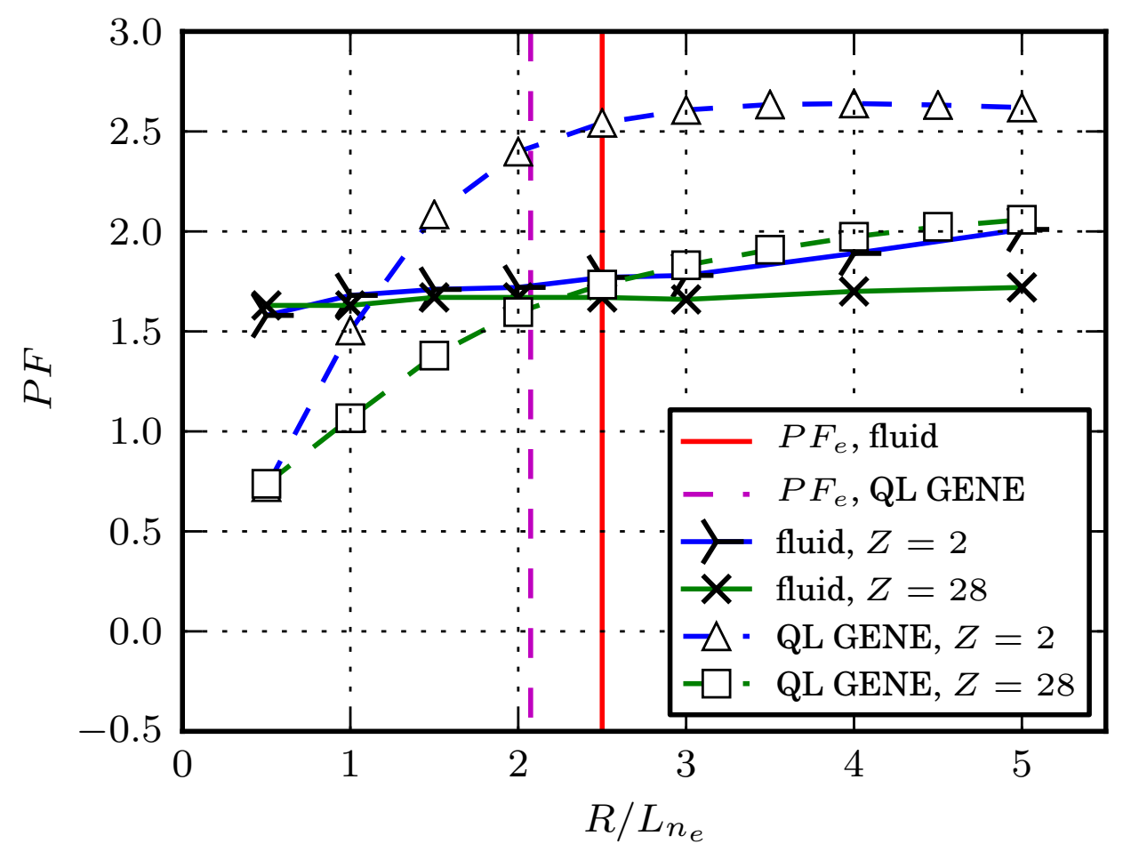

FIGURE 5: Scaling of PF_Z with **electron density gradient** (R/L_{n_e}) with $R/L_{T_e} = 5.0$ and $R/L_{T_{i,Z}} = 2.0$ at mid-radius in $\hat{s}$–α geometry.

- NL and QL PF_Z saturates at ~ 2 for steep gradients $\Rightarrow$ pinch balanced by diffusion
- saturation at levels well below **neo-classic** estimates
- peaking of impurities is lower than background gradient for $R/L_{n_e} \gtrsim 2$, with:
  - self-consistent $PF_Z \lesssim PF_e$
  - fluid and GK agree well

HELIUM PUMP OUT:

Efficient removal of the He ash requires $\tau_E/\tau_{He} \geq 0.15$ [10]. This **confinement time ratio** can be estimated by $D_{\mathit{He,eff}}/\chi_{\mathit{eff}}$, where for $T_e = T_i$:

$$\chi_{\mathit{eff}} = \frac{\chi_e R/L_{T_e} + \chi_i R/L_{T_i}}{R/L_{T_e} + R/L_{T_i}}. \tag{4}$$

For a simple comparison between ITG and TE cases an estimate of $D_{\mathit{He}}/\chi_{\mathit{eff}}$ is sufficient [8]. Results from NL GENE indicate that TEM is at least as efficient as ITG mode turbulence at removing He ash for the parameters studied:

	$D_{\mathit{He}}/\chi_{\mathit{eff}}$:
ITG ($\hat{s}$–α) [6, 8]:	1.0
TE ($\hat{s}$–α) [8]:	1.7
ITG (*JET-like*):	2.2

ETG TURBULENCE IN BARRIERS:

For ETG modes focus is on the density gradient leading to zero main ion particle flux, related to the formation and sustainment of the edge pedestal. Parameters are chosen to correspond to barrier like parameters for *ASDEX Upgrade* [11], with

$$R/L_n = \frac{1}{2} R/L_{T_e} = \frac{2}{3} R/L_{T_i} \tag{5}$$

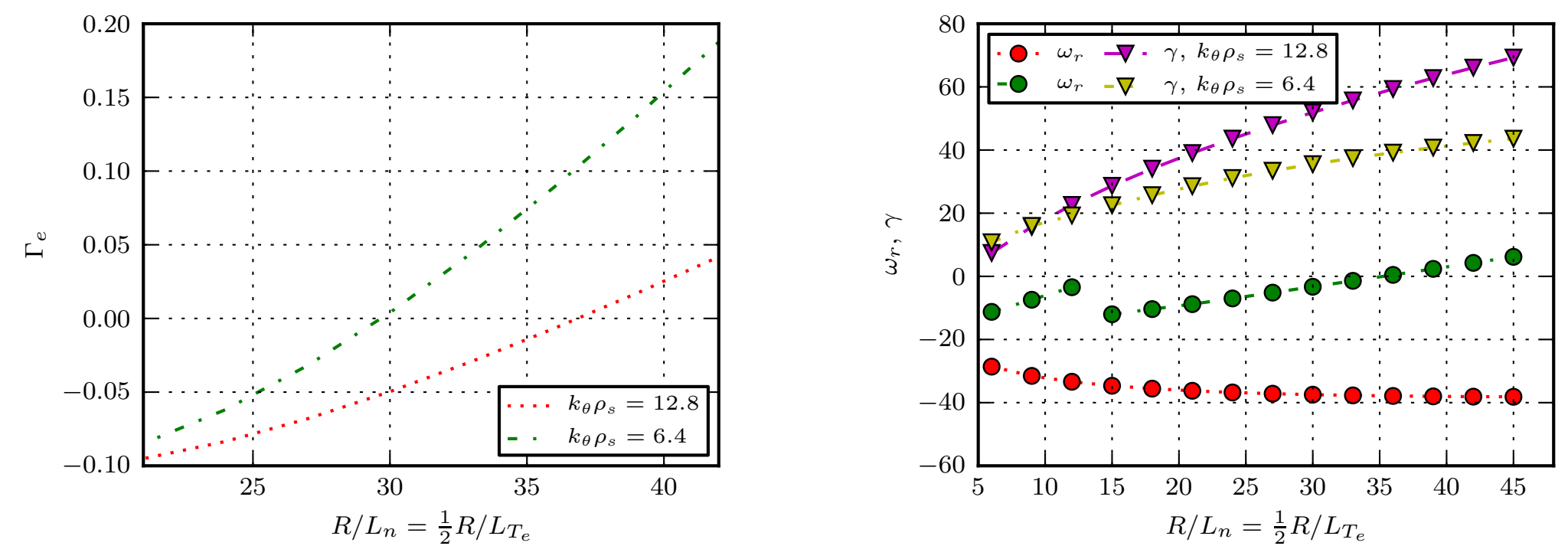

FIGURE 6: Scaling of main ion particle flux *(left)* and linear eigenvalues *(right)* with gradients as in *Eq.* (5) at radius $r/a \approx 0.9$ in $\hat{s}$–α geometry.

- zero flux observed at very steep gradients
  - in line with fluid results in [12]
- for ETG fluctuation and transport level estimates see: **TH/P7–04** *(J. Anderson)*

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The simulations were performed on resources provided on the Lindgren [13] and HPC-FF [14] high performance computers, by the Swedish National Infrastructure for Computing (SNIC) at Parallelldatorcentrum (PDC) and the European Fusion Development Agreement (EFDA), respectively.

this poster kills fascists!

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