Investigating the double scale length of limited plasmas with nonlinear simulations of the TCV Scrape-Off Layer

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SUMMARY

- Numerical simulations of the TCV Scrape-Off Layer (SOL) performed with GBS code [1]

- Simulation based on TCV discharge #49170. The heat flux shows a double scale length in the SOL, agree with experimental results in [2]. A poloidal asymmetry is observed.

- Non-ambipolar currents found inside the short scale length
- Strong velocity shear near the Last Closed Surface (LCFS)
- 3 more simulations are performed increasing the resistivity
- Heat flux profile in the main SOL flattens with resistivity

MOTIVATION

- Heat loads in inboard limited plasmas measured in TCV with IR thermography [2]
- Resulting **parallel heat fluxes** profile $q_{||}(r_u)$ show **two scale lengths**:
  λ_s ~ mm close to LCFS
  λ_l ~ 10 λ_s in the main SOL,
- According to this, previous [3] and similar [4,5] results, ITER first wall panels design has been changed [6]
- Underlying physics not well understood yet
- Numerical simulations performed to enhance understanding

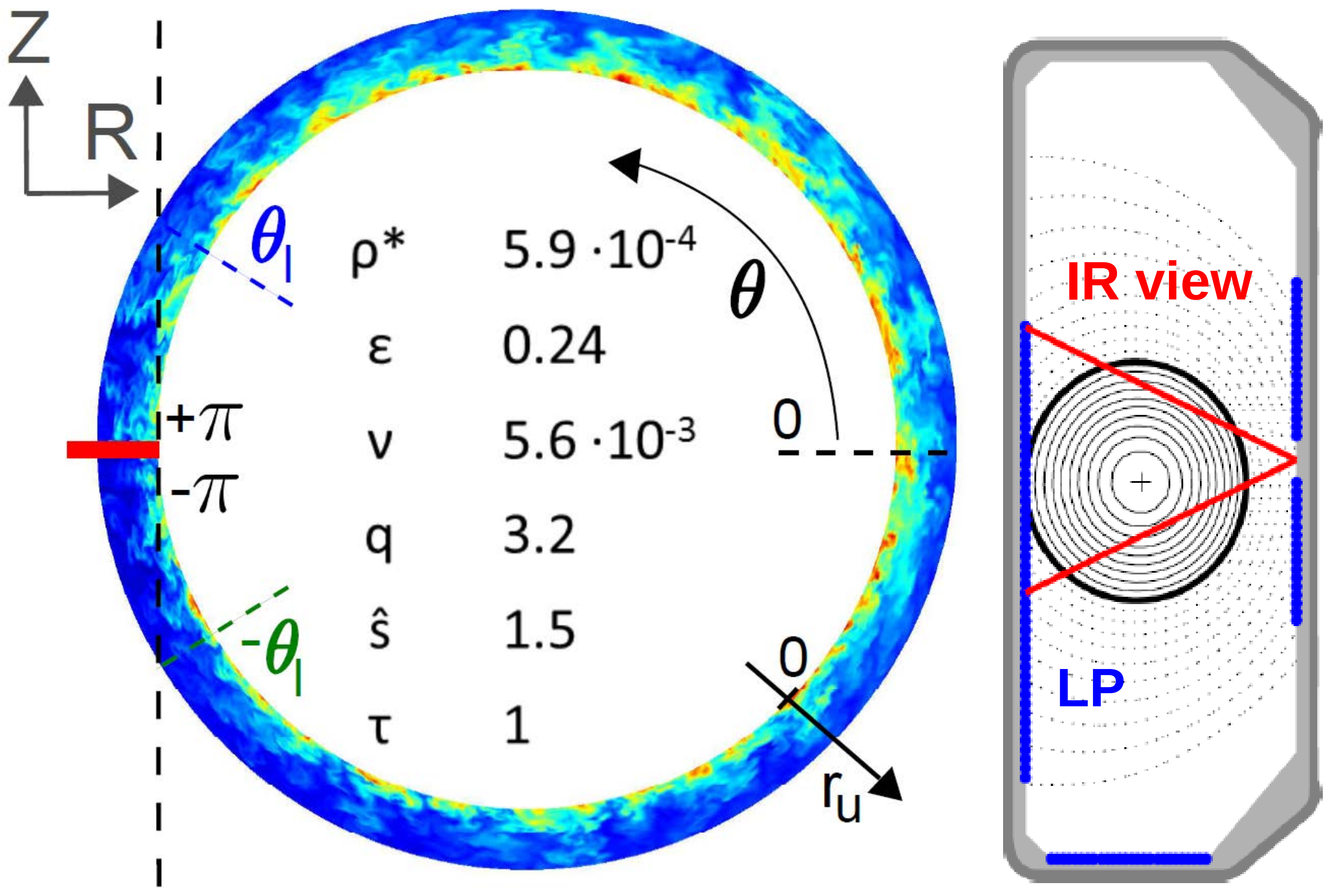
THE GBS CODE [1]

- Solves drift-reduced Braginskii equations in 3D
- Plasma turbulence determines both equilibrium profiles and fluctuations self-consistently
- Includes effects of finite aspect ratio, magnetic shear, ion temperature

SIMULATIONS OF TCV SOL

- Reference simulation based on TCV discharge #49170
- First GBS simulations of TCV with T_i dynamics
- Plasma density $n_{e,0}=5\cdot10^{18}$ m^{-3} and temperature $T_{e,0}$=25 eV at the LCFS computed from Langmuir probe data (flush mounted on central column, acting as limiter), give:
  - simulation size $\rho^* = \rho_s/R$
  - normalized Spitzer resistivity $\nu = e^2 n_e R/(m_i \sigma_{||} c_s)$
- q_{edge}=3.2 from LIUQE equilibrium reconstruction

Differences:
- Limiter geometry (GBS, TCV)
- **B** and **I**$_p$ parallel in the experiment, antiparallel in the simulations

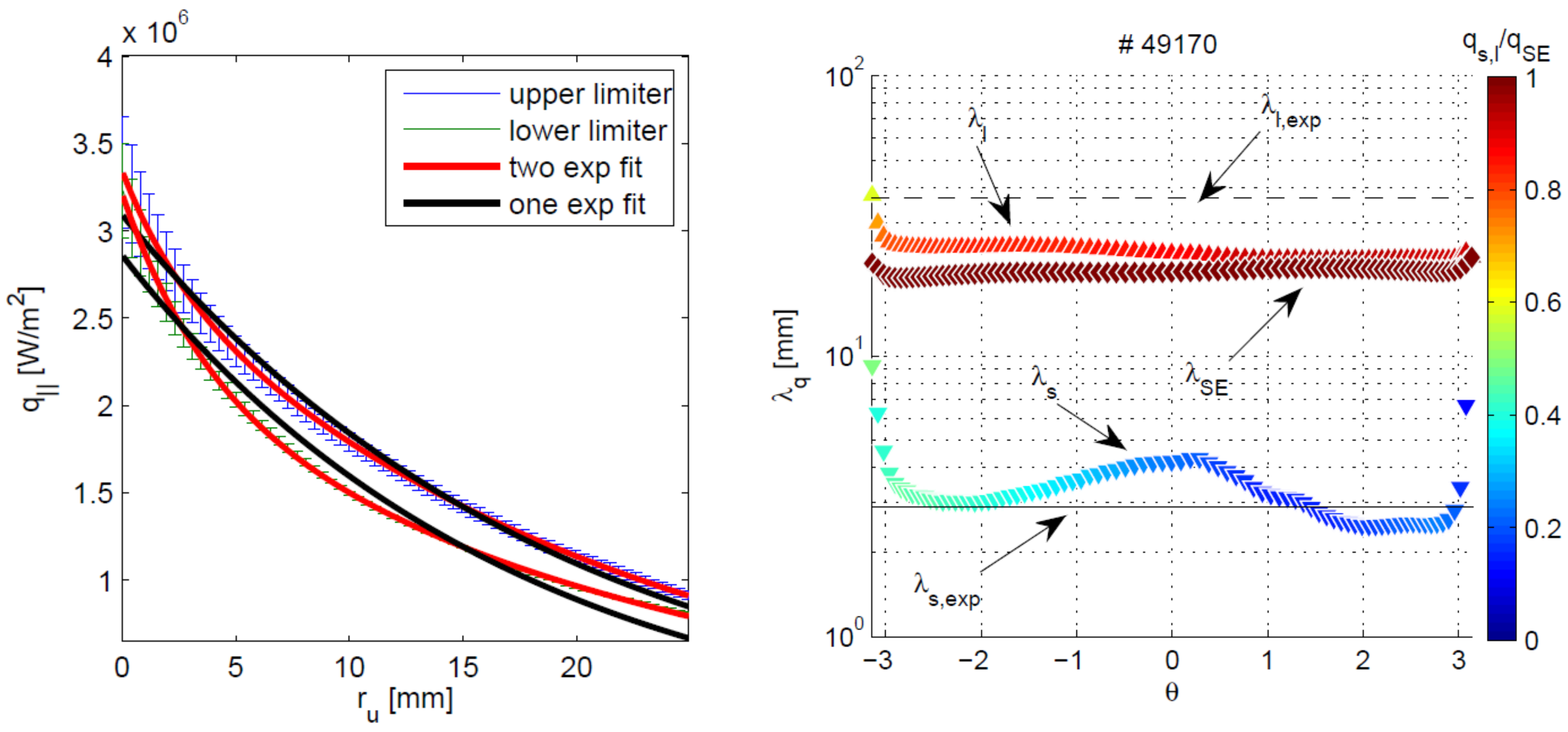


ρ*	$5.9\cdot10^{-4}$
ε	0.24
ν	$5.6\cdot10^{-3}$
q	3.2
ŝ	1.5
τ	1

Quantities of interest

- The simulations provide the evolution in (r,ϑ,ϕ) and time of plasma density n_e, electron and ion temperature T_e,T_i, electric potential φ, electron and ion parallel velocities v_e, v_i (all normalized)
- In the following, all quantities are averaged in time and toroidal direction ϕ
- Parallel heat flux computed as $q_{||} = \gamma_{sh} n_e \sqrt{\frac{T_e+Ti}{m_i}} T_e$
- γ_{sh}=7 sheath power transmission factor
- Current density computed as $j_{||} = e\, n_e(v_i - v_e)$
- To compare with experimental data limiter profiles are produced:
  - **upper limiter**: average over $\vartheta_l < \vartheta < \pi$
  - **lower limiter**: average over $-\pi < \vartheta < -\vartheta_l$

COMPARISON WITH EXPERIMENT: HEAT FLUX



- Radial profiles well fitted by a sum of two exponentials $q_{||}(r_u) = q_s e^{-\frac{r_u}{\lambda_s}} + q_l e^{-\frac{r_u}{\lambda_l}}$

- Heat flux profiles at the limiter are fitted up to r_u=25 mm to avoid edge effects
- Fit with one exponential unsatisfactory
  - upper limiter: **λ_s=2.7 mm, λ_l=22.3 mm**
  - lower limiter: **λ_s=3.7 mm, λ_l=25.3 mm**
  - similar to values from IR thermography: **λ_s=2.9 mm, λ_l=36.7 mm**

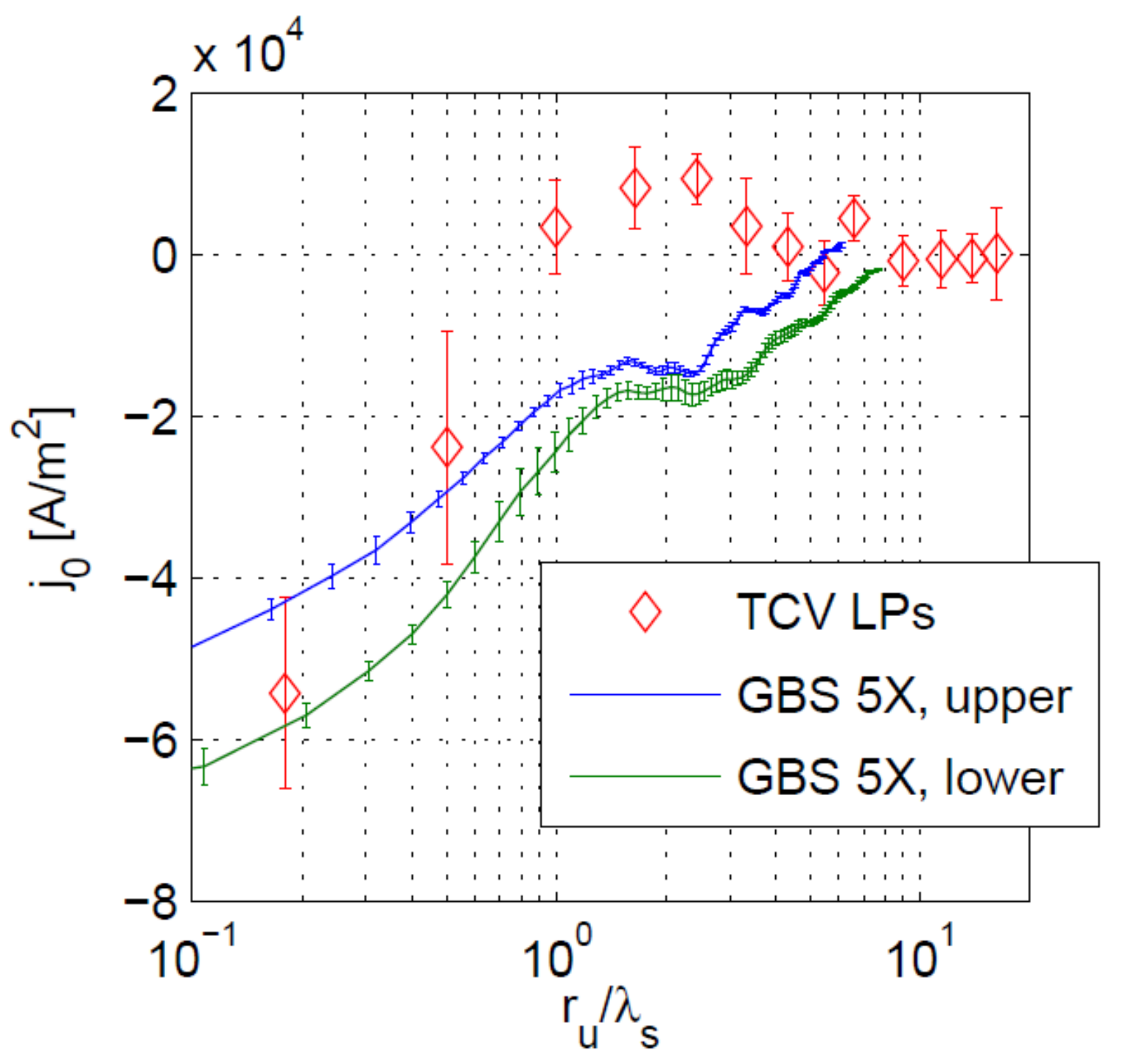
- Fit every $q_{||}(r_u, \vartheta = const)$ profile
- Poloidal variation of fit parameters: for $\vartheta > 0$ weaker narrow feature
- Probably due to **E**X**B**, mainly in the $\vartheta > 0$ direction

COMPARISON WITH EXPERIMENT: CURRENTS

- Electron currents are measured, using flush mounted Langmuir probes, to flow to the grounded limiter in the region $r_u \leq \lambda_s$

- Same trend is recovered in the simulation for $j_{||}$ computed on the two limiter sides

- Correlation between non ambipolar current and narrow feature (already observed in COMPASS [7])



VELOCITY SHEAR

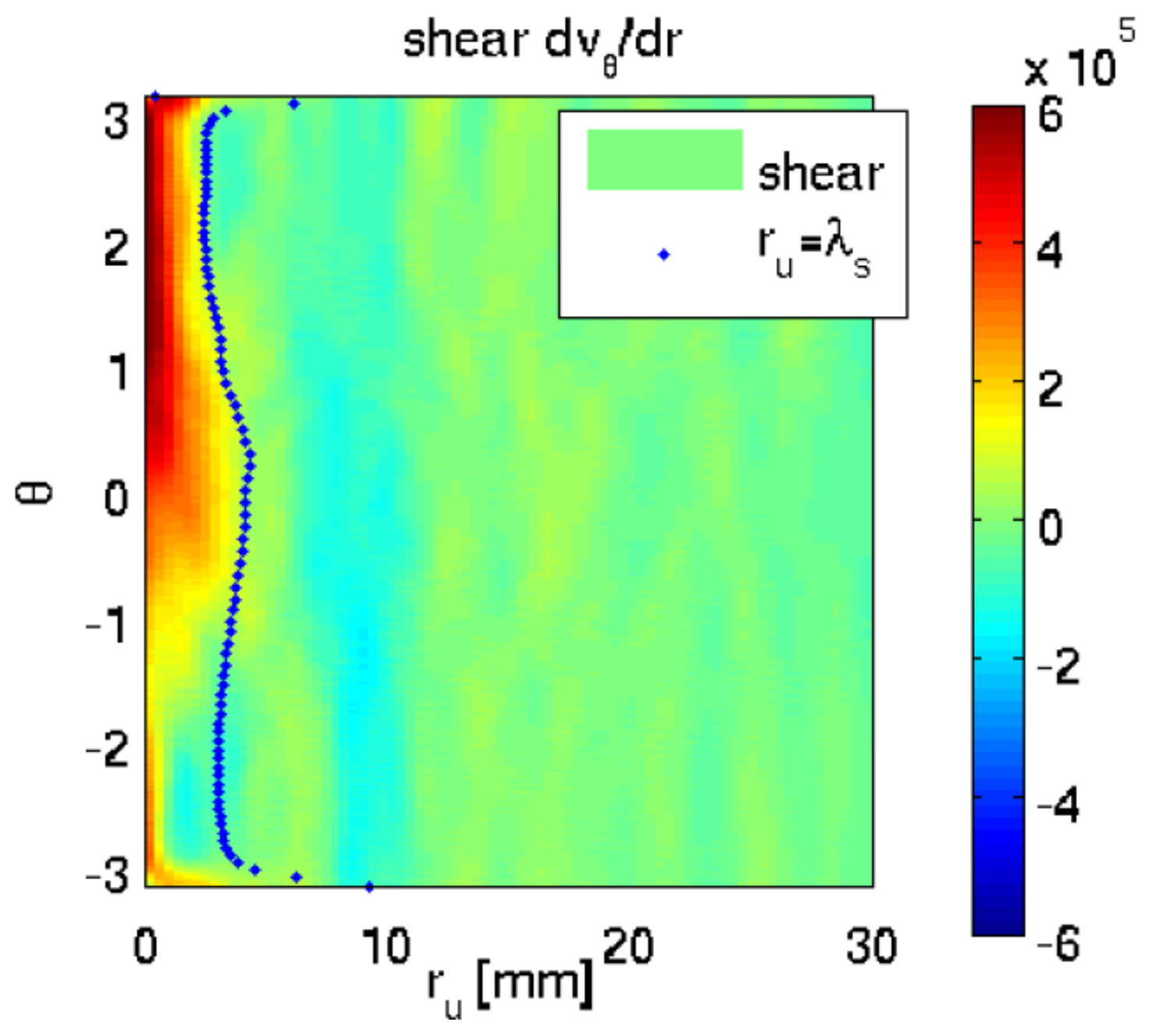
- **E**X**B** velocity mainly in $\vartheta > 0$ direction

- Velocity shear dv_ϑ/dr

- Strong for $r_u \leq \lambda_s$, ~0 outside

- Probably helps to stabilize main SOL instabilities (interchange) steepening the gradients near the LCFS

- Theoretical explanation of the influence of a sheared flow on the narrow feature is in progress



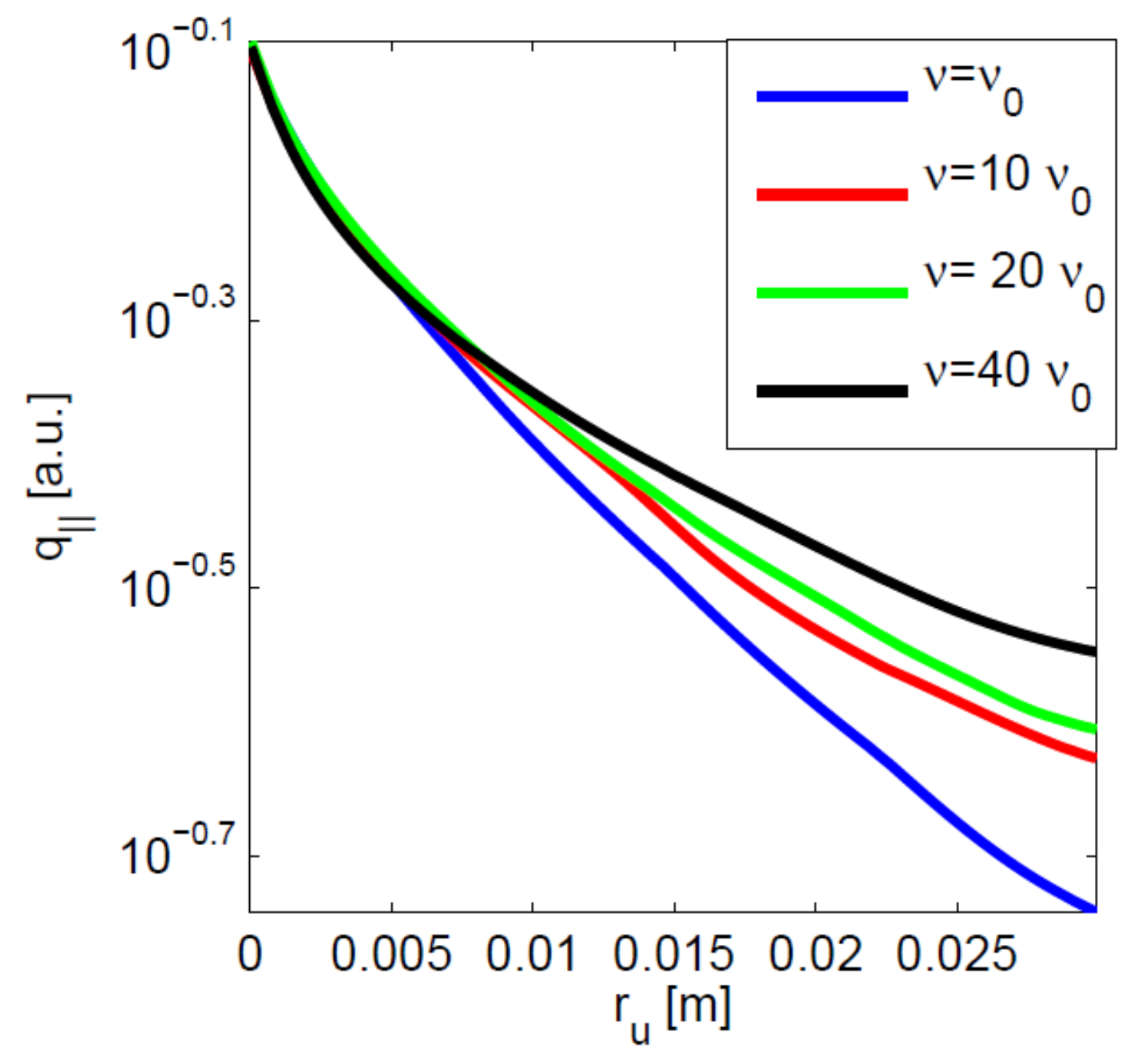
THE ROLE OF RESISTIVITY – preliminary results

- Excess power in the SOL due to the narrow feature

$$\Delta P_{SOL}=4\pi R_{LCFS}\frac{B_\vartheta}{B_\varphi}\int_0^\infty [q_{||}(r_u)-q_{||,main}(r_u)]\,dr_u = 4\pi R_{LCFS}\frac{B_\vartheta}{B_\varphi} q_s \lambda_s$$

  Experimentally shown to decrease with resistivity [2]

- 3 additional simulations, where the normalized Spitzer resistivity ν is increased by a factor 10, 20 ,40 (not converged due to time constraints)
- As ν is increased, the profiles in the main SOL flatten
- Narrow feature still present



OUTLOOK

- Quantitative comparison with experiments on the role of resistivity once a sufficient statistics is obtained
- More detailed analysis of stastical properties of n_e , V_{pl} fluctuations
- Comparison with LP data
- Simulation with q_{edge}=5.2 ongoing
- More TCV experiments planned at the end of 2015 for the MST-1 campaign. In particular:
- He plasmas experiments

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