



HAL
open science

A model of interchange turbulent transport across separatrix with sheared flows

Mathieu Peret, Nicolas Fedorczak, Laure Vermare, M Ramisch, B Schmid

► **To cite this version:**

Mathieu Peret, Nicolas Fedorczak, Laure Vermare, M Ramisch, B Schmid. A model of interchange turbulent transport across separatrix with sheared flows. 25th Joint EU-US TTF Meeting - the EU-US Transport Task Force, Sep 2021, E-Conference, United Kingdom. . cea-03350079

HAL Id: cea-03350079

<https://cea.hal.science/cea-03350079>

Submitted on 21 Sep 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Mathieu Peret¹, Nicolas Fedorczak¹, Laure Vermare², M. Ramisch³, B. Schmid³ Tore Supra & WEST teams



¹ CEA, IRFM, F-13108 Saint-Paul-Lez-Durance, France

² LPP, Ecole Polytechnique, F-91128 Palaiseau, France

³IGVP, University of Stuttgart, 70569 Stuttgart, Germany



Context and motivations

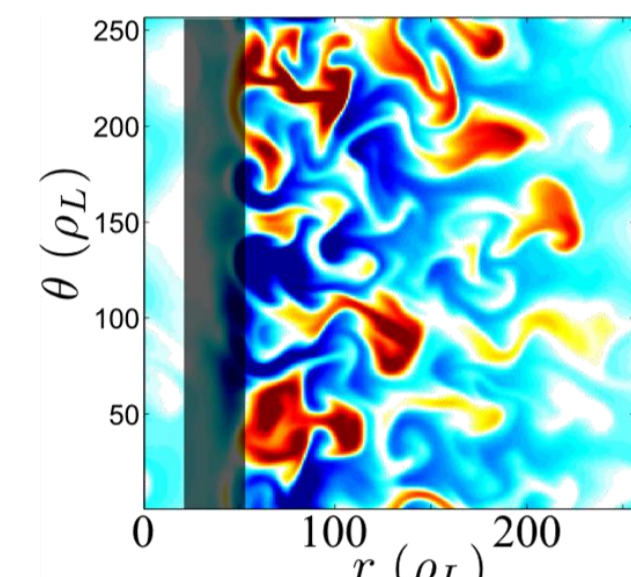
- Filamentary turbulent transport is thought to be responsible of the turbulent transport across flux surfaces in tokamak plasma edges and scrape-off layers (SOL) as proposed by the isolated filament model (IF model)[1-3]
 - Link between turbulent transport and confinement properties as SOL width or energy confinement time not fully understood
 - Interplay between turbulence & shear flow : turbulence mitigation & shear flow generation through Reynolds stress → increase of confinement
 - Geometry strongly impacts both transport & edge shear flow generation : favourable/unfavourable configuration [4]
- Analytical model of edge transport with shear flows is needed

Spectral Filament Model

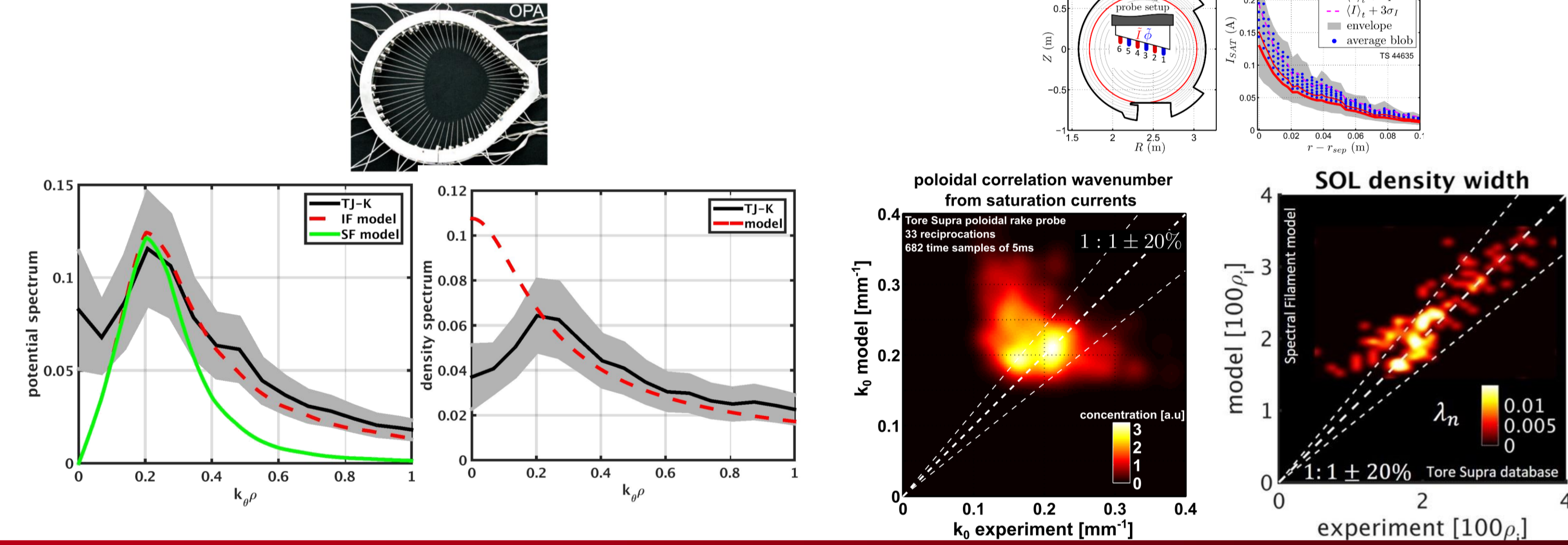
- TOKAM2D isothermal model : Braginskii's equation averaged on field line + flux conservation in scrape-off layer (SOL) [5] :

$$(\partial_t - D_{\perp} \Delta_{\perp})n = [n, \Phi] - n\sigma_{\parallel} e^{(\Lambda - \Phi)} + S$$

$$(\partial_t - \nu \Delta_{\perp})\Delta_{\perp} \Phi = [\Delta_{\perp} \Phi, \Phi] + \sigma_{\parallel} (1 - e^{(\Lambda - \Phi)}) - \frac{g \partial_y n}{n}$$

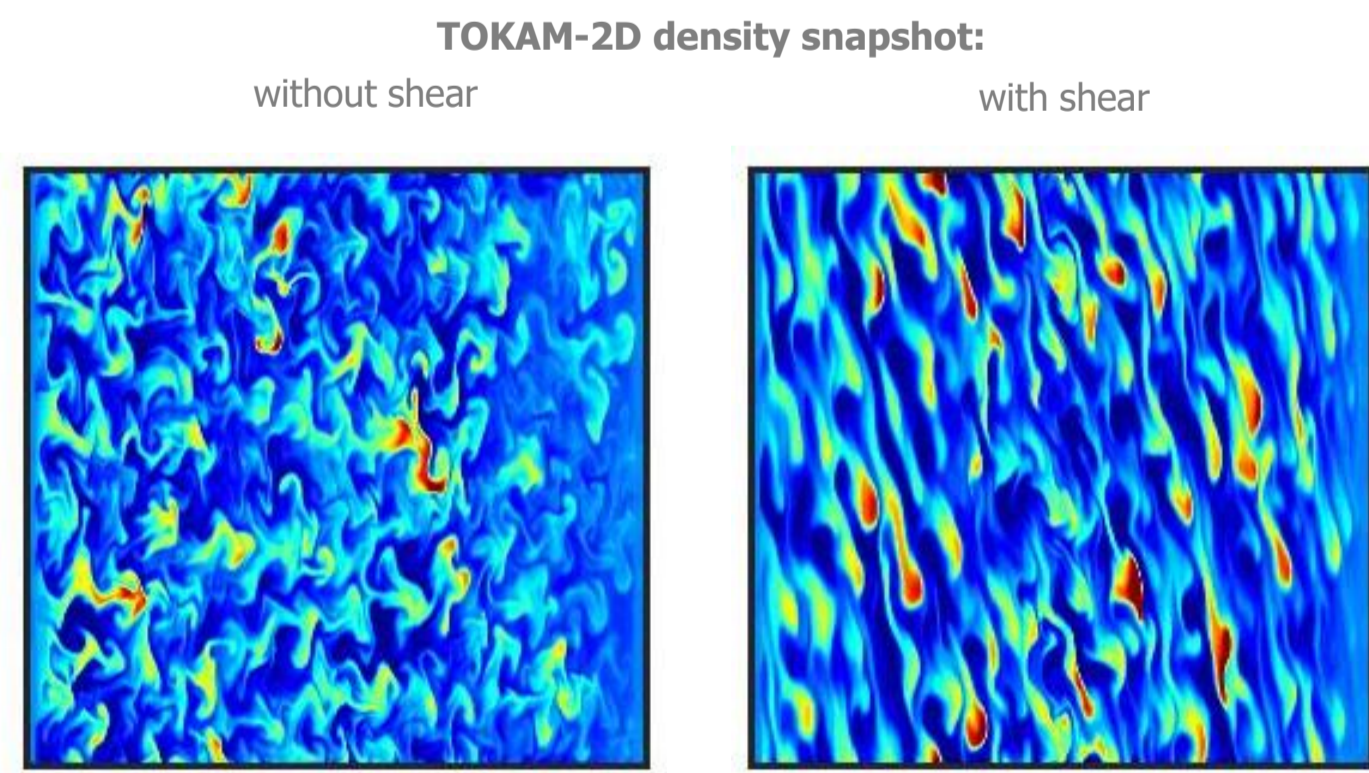


- Quantitative description of limiter SOL properties [1,2] for :
 - Intermittent transport (blob)
 - Exponentially decaying equilibrium profiles
- Model reduction via poloidal spectra inspired from isolated filament model [3]
 - Sheath loss & mode coupling saturation phenomena
 - Allows prediction for transport observables
- Verified with a 2D non-linear flux-driven simulation database
- Recovers poloidal spectra from TJK discharge & Tore Supra transport observables [6,7]



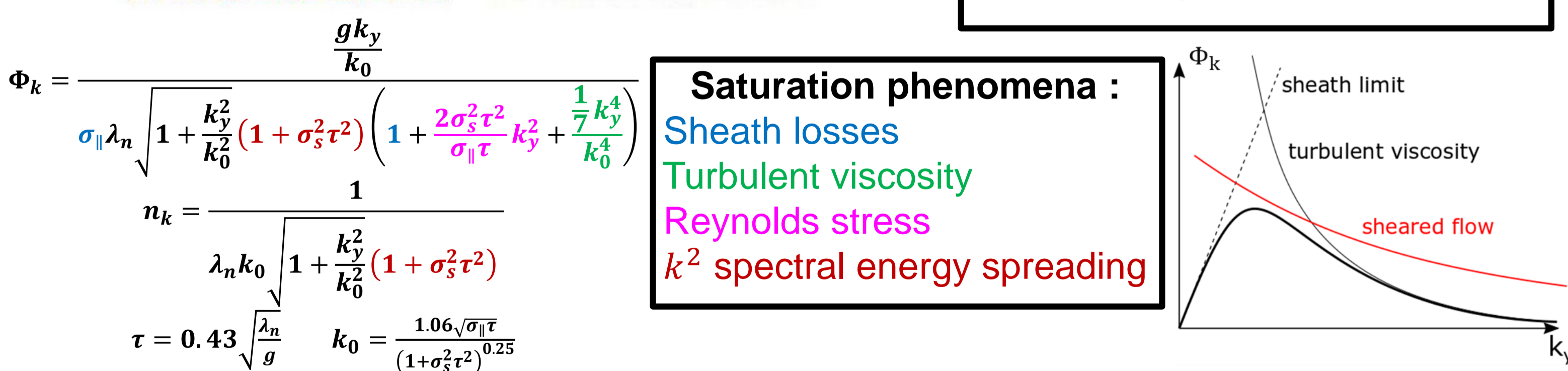
Sheared Spectral Filament Model

- Introduction of uniform shear σ_s + interchange recall → Constant tilt

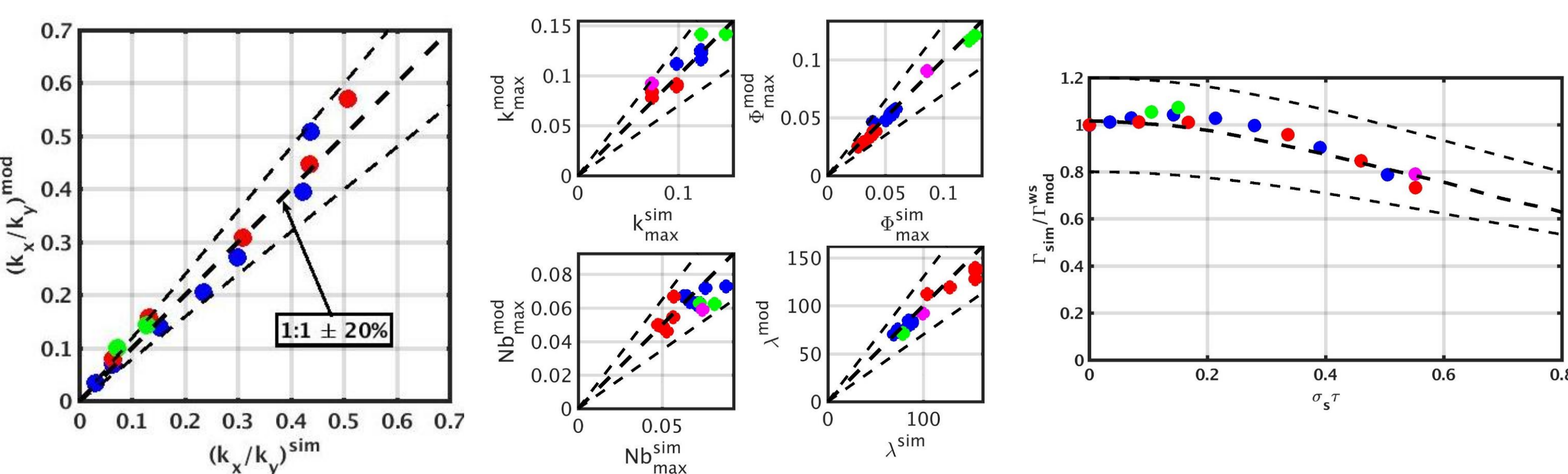


$$\partial_t k_x = -\sigma_s k_y - \frac{k_x - k_x^0}{\tau}$$

↑ Shear tilt
→ Interchange recall



- Verified against simulations (colors = pairs of $[g, \sigma_{\parallel}]$)

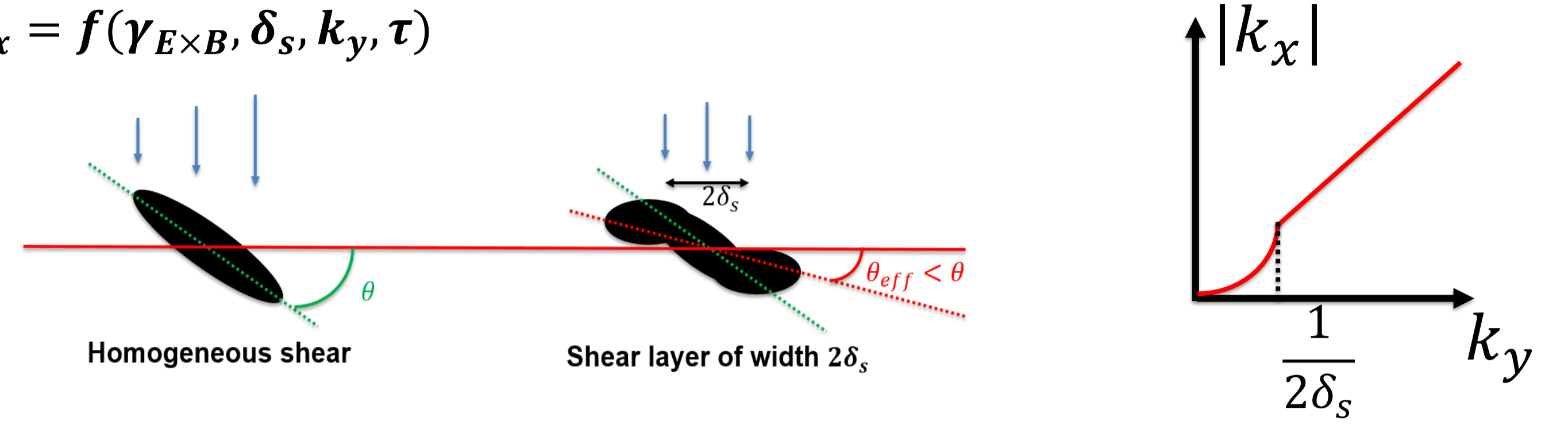


Impacts of the geometry on turbulence

- Pedestal structure size $\sim 10\rho_L \sim 1\text{cm}$ ~ shear layer width δ_s

→ Mitigation of structure tilt

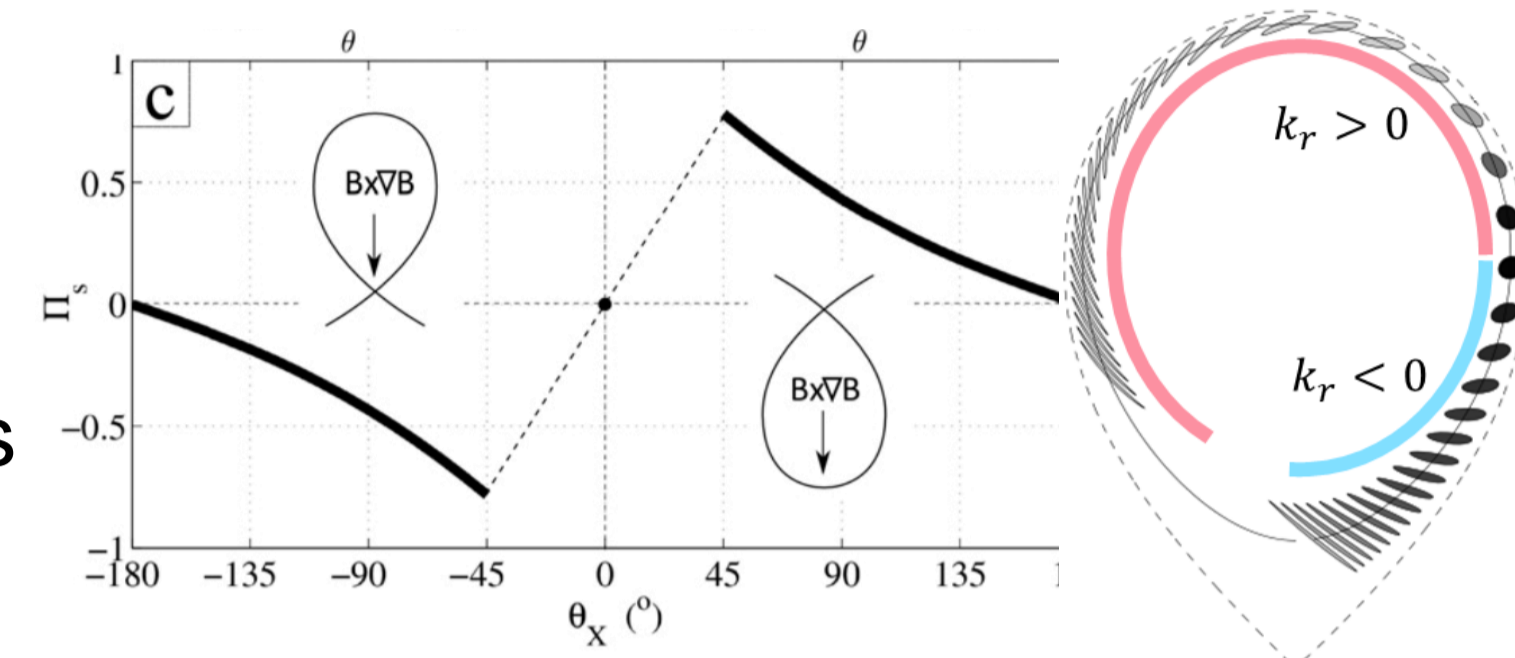
$$\rightarrow k_x = f(\gamma_{E \times B}, \delta_s, k_y, \tau)$$



- X-point or limiter :

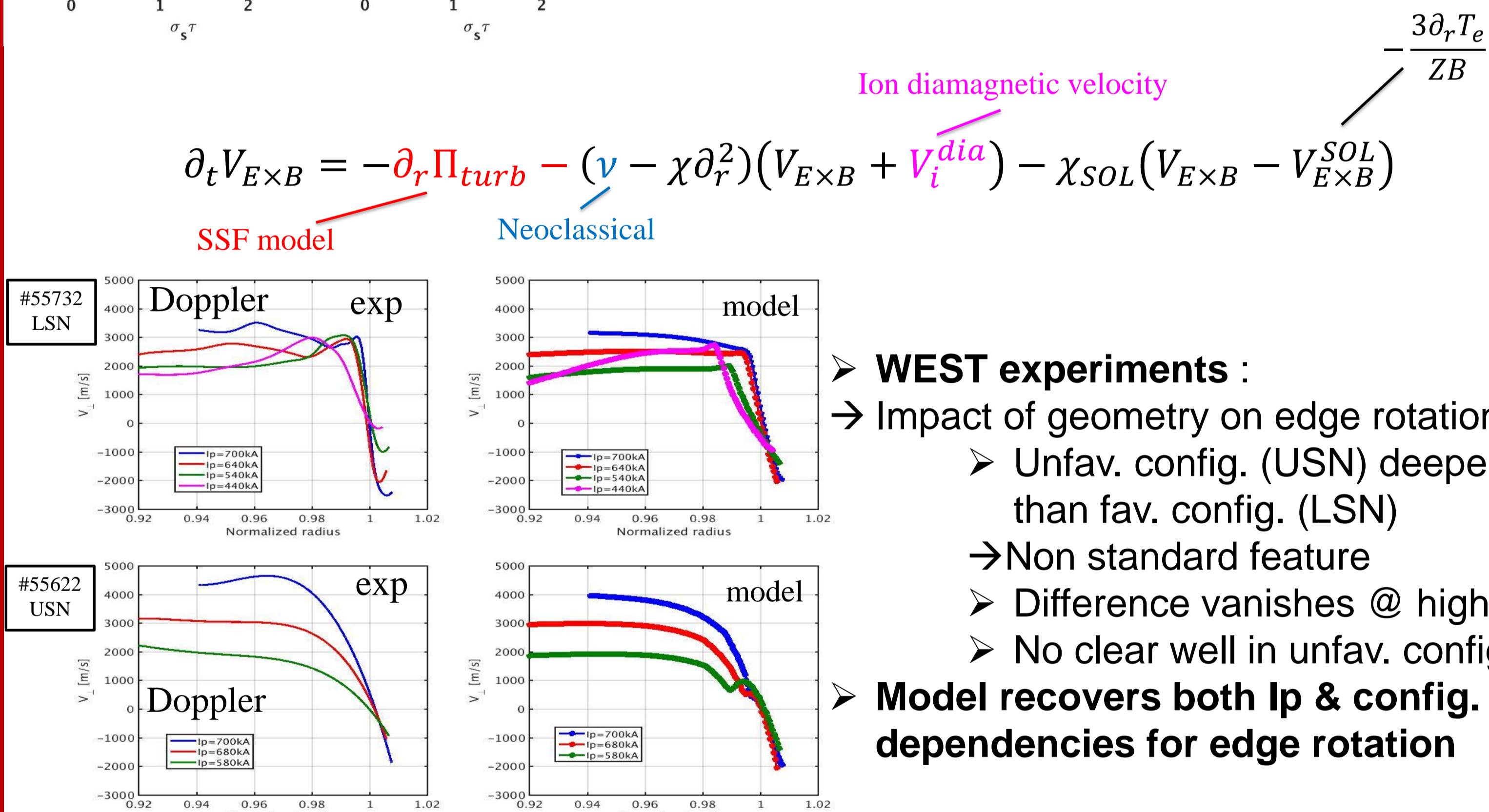
→ Non-zero flux surface average of magnetic shear induced tilt [8,9]

→ Magnetic shear induced Reynolds stress



1D flow generation model : comparison with experiment

- Weak to strong shear regime transition @ $\sigma_s \tau \approx 0.4$
- Reynolds stress increases with k [10] → k_0 decreases
- Reynolds stress shows maximum at regime transition
- Similar radial flux drops in both regimes → weak impact of Reynolds stress
- Decrease flux by factor 2 needs : $\sigma_s \approx [0.5 - 1] \times 10^{-2} w_i \approx 10^6 \text{s}^{-1}$
- Corresponds to $\frac{10 \text{ km.s}^{-1}}{1 \text{ cm}}$ as for L-H transition in pedestal



- WEST experiments :
 - Impact of geometry on edge rotation
 - Unfav. config. (USN) deeper than fav. config. (LSN)
 - Non standard feature
 - Difference vanishes @ high I_p
 - No clear well in unfav. config.
- Model recovers both I_p & config. dependencies for edge rotation

Conclusion and perspectives

- Derivation of a model of edge turbulent transport verified against simulations & validated against experiment
- Derivation of a model of impact of background shear on interchange :
- Spectral model + structure tilt model
- Validation against 2D flux-driven simulations for turbulence properties (Φ_k, n_k, k_0) & transport (Γ_r, λ)
- Impact of shear on density and potential perturbations phase shift not treated → does not seem to be important in our simulations
- Spatial variation of shear taken into account
- 1D model on shear flow generation by Reynolds stress with magnetic shear :
- Validation of the 1D model against WEST experiment
- Recovery of geometry and I_p dependencies of edge rotation

References

[1] N. Fedorczak et al, Nuclear Materials and Energy 12 (2017)
 [2] N. Fedorczak et al, Contrib. Plasma Phys. (2018)
 [3] S.I. Krasheninnikov, Physics Letters A (2001)
 [4] B. LaBombard et al, Physics of Plasmas (2008)
 [5] Y. Sarazin et al, Physics of Plasmas, Volume 5, 12 (1998)
 [6] N. Fedorczak et al, Nuclear Materials and Energy (2019)
 [7] M. Peret et al, Nuclear Fusion (2021)
 [8] N. Fedorczak et al, Physics of Plasmas (2012)
 [9] N. Fedorczak et al, Plasma Physics and Controlled Fusion (2013)
 [10] O. Gürcan, et al. Physical Review Letter (2012)