Geometrical Magnetic Field Effects on Turbulent Transport

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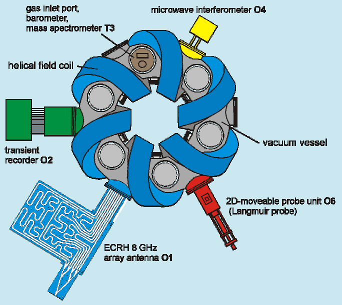
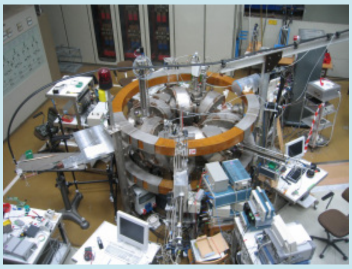
Introduction

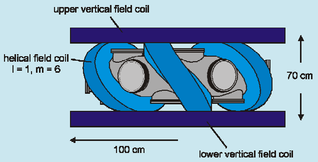
The three-dimensional structure of the stellarators magnetic configuration strongly affects the plasma dynamics. In particular, the magnetic field geometry influences the characteristics of plasma turbulence. In low-temperature plasmas in the torsatron TJ-K, fluctuation amplitudes and turbulent transport are compared with the relevant parameters of the magnetic field geometry as magnetic curvature and magnetic shear. The general properties of the turbulence in TJ-K agree with drift waves. However, the influence of the magnetic configuration has been found in the turbulent transport level, which seems to be sensitive to curvature effects. Measurements on a flux surface in the poloidal cross-section show maximum growth rates, increased fluctuation amplitudes and maximum transport in the region of bad curvature.

Torsatron TJ-K

Major plasma radius:	R = 0,6 m
Minor plasma radius:	a = 0,1 m
Magnetic field:	48 mT ≤ B ≤ 300 mT
Electron temperature:	$T_e \approx$ 10 eV
Ion temperature:	$T_i \approx$ 1 eV
Electron density:	$n_e \approx 5 \cdot 10^{17}$ m^{-3}
Working gases:	H, D, He, Ne, Ar
Iota:	0.13 – 0.4
Pulse Duration:	up to 45 min



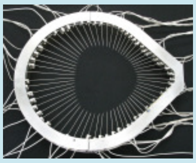


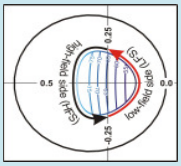


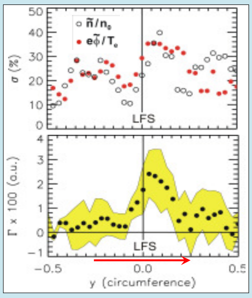
Poloidal Asymmetry

Turbulent transport varies on a flux surface

- Flux tube aligned poloidal array (64 Langmuir probes)







- Measurement of the ion-saturation current $I_{i,sat}$ and floating potential ϕ_f ➡ particle transport $\Gamma = \langle \tilde{n}\,\tilde{v}_r \rangle_t$

Dispersion relation and growth rates

Scale resolved drift wave dispersion relation and linear growth rate

- **Theory:**

Dispersion relation:

$$\omega_D = \frac{k_\perp v_{dia,e}}{1+k_\perp^2\rho_s^2} = \frac{c_s}{L_\perp}\frac{k_\perp \rho_s}{1+k_\perp^2\rho_s^2} \qquad \rho_s = \frac{\sqrt{m_i T_e}}{eB}$$

$$c_s = \sqrt{\frac{T_e+T_i}{m_i}}$$

Growth rate:

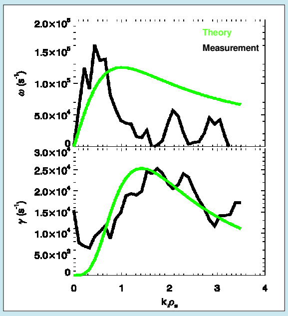
$$\gamma = \nu_{ei}\left(\frac{\omega_D}{k_\parallel v_e}\right)^2 \frac{k_\perp^2\rho_s^2}{1+k_\perp^2\rho_s^2} \qquad L_\perp = |\nabla \log n_e|^{-1}$$

- **Measurement:**
$\varphi(x,t)$ spatially resolved time series from Langmuir probes

$$\Phi(k,t) = \int \varphi(x,t)e^{-ikx}dx$$

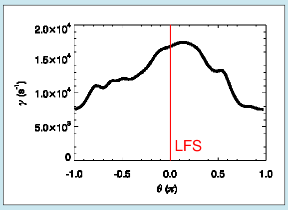
$$\omega = \frac{1}{\tau}\mathrm{Im}\left(\frac{\left\langle \Phi(k,t+\tau)\Phi^*(k,t)\right\rangle}{\left\langle \Phi(k,t)^2\right\rangle} - 1\right)$$

$$\gamma = -\frac{1}{\tau}\mathrm{Re}\left(\frac{\left\langle \Phi(k,t+\tau)\Phi^*(k,t)\right\rangle}{\left\langle \Phi(k,t)^2\right\rangle} - 1\right)$$



Poloidally resolved drift wave growth rate

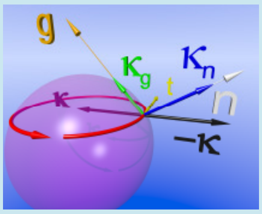
- Wavelet-analysis applied to probe data yields poloidal resolution of the growth rate
- Growth rate has maximum values in the region of bad curvature
- Additionally a small shift to the top side

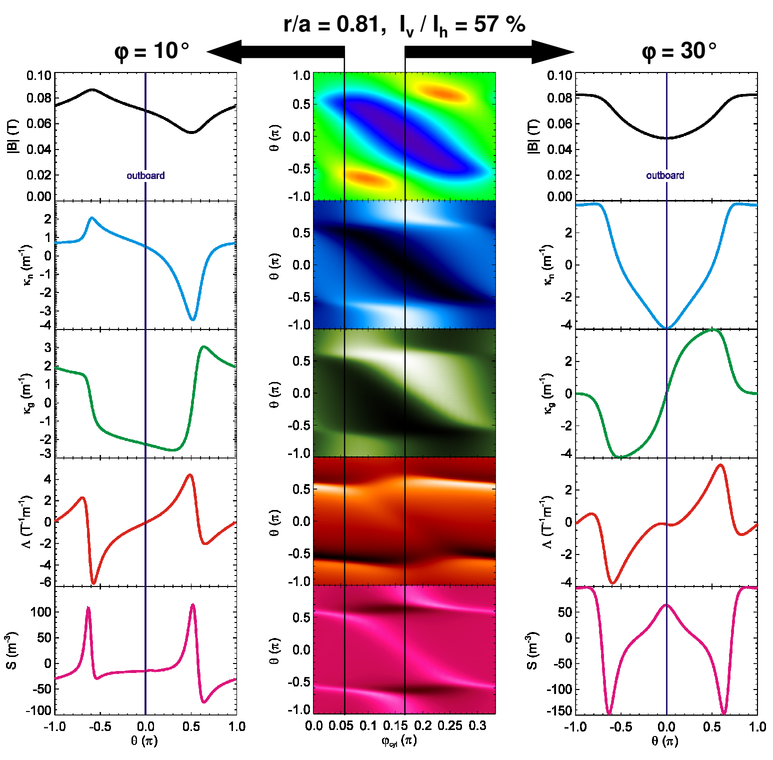


Geometry of the magnetic field

Parameters vary on a flux surface

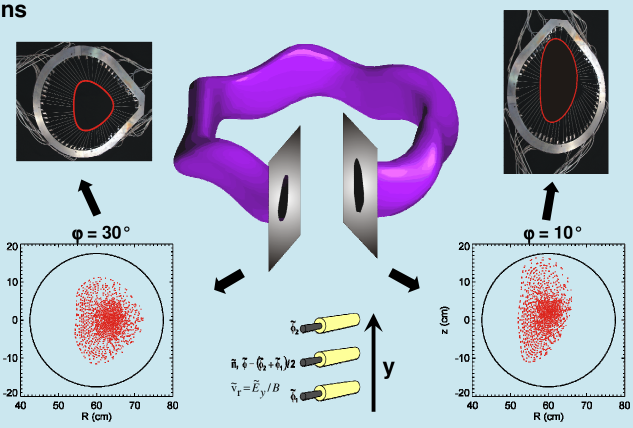
- Magnetic field strength |B|
- Normal curvature $\kappa_n = \vec{\kappa}\cdot\left(\frac{\nabla\rho}{|\nabla\rho|}\right)$
- Geodesic curvature $\kappa_g = \vec{\kappa}\cdot\left(\frac{\nabla\rho}{|\nabla\rho|}\times\vec{e}_\parallel\right)$
- Integrated local magnetic shear $\Lambda = \frac{g^{\rho\xi}}{g^{\rho\rho}}$ $\qquad \xi = \theta - \iota\varphi$
- Local magnetic shear $S = -\vec{B}\cdot\nabla\Lambda$





Poloidally resolved transport studies

Simultaneous measurement of turbulent transport at two toroidal positions



- Measurement with two 64-Langmuir-probe-arrays (flux tube aligned)
- Different behaviour of transport at different positions will show the influence of magnetic field geometry

Summary

- Fluctuation amplitudes of ϕ_f and $I_{i,sat}$, the turbulent transport levels, and the measured growth rates have local maxima in the region of bad curvature ($\kappa_n < 0$).
- Additionally, a small shift of this maximum to the top of the poloidal cross section is observed.
- This is possibly caused by influences of the geodesic curvature or magnetic shear.
- Use of a second poloidal array at an other toroidal position and comparison with theoretical growth rates (e.g. Nasim et al. PPCF 46 (2004)) will elucidate the influence of normal and geodesic curvature, and (integrated) local magnetic shear on drift wave turbulence.