Nonlocal transport in the scrape-off layer

P. Manz[1,2], F. Fischer[1], G. Birkenmeier[1,2], D. Carralero[2], G.Fuchert[2], S. Marsen[3], B. Nold[4], M. Ramisch[4], T.T. Ribeiro[2], B.D.Scott[2], U.Stroth[2,1], R.S. Wilcox[5]

[1]Technische Universität München, Germany
[2]Max-Planck-Institut für Plasmaphysik, Garching, Germany
[3]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany
[4]Institut für Grenzflächenverfahrenstechnik und Plasmatechnologie, Universität Stuttgart, Germany
[5]Oak Ridge National Laboratory, OakRidge TN, USA

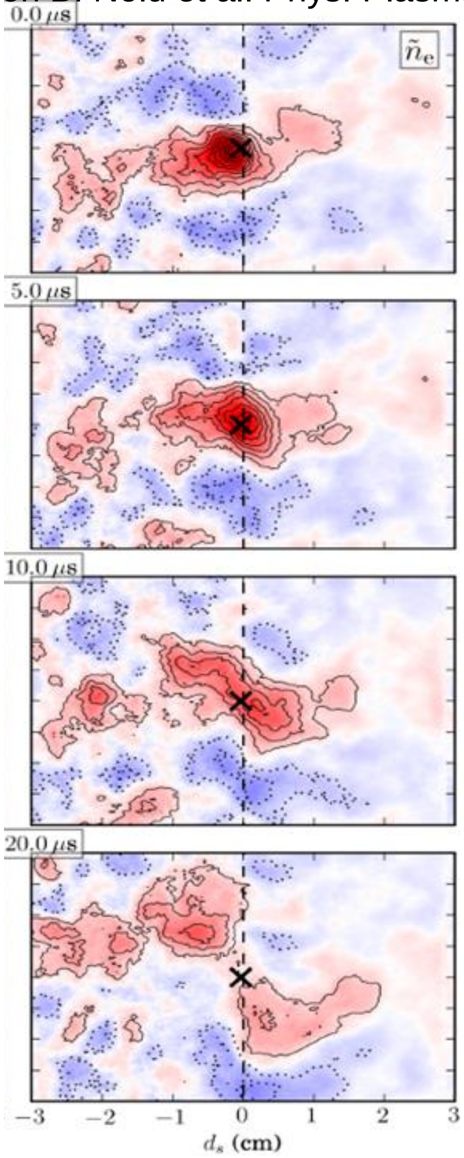
EFTSOMP Workshop, Lisbon, 30.6.2015

Why turbulence in the far SOL?

- Conditional averaged picture at the shear layer
- Statistics of blob trajectories
- Relation between turbulence spreading and blob generation
- Results from HSX, TJ-K, WEGA

Blob generation

GEMR simulation B. Nold et al. Phys. Plasmas 2014



theory:

D.A D'Ippolito et al. Phys. Plasmas 2011

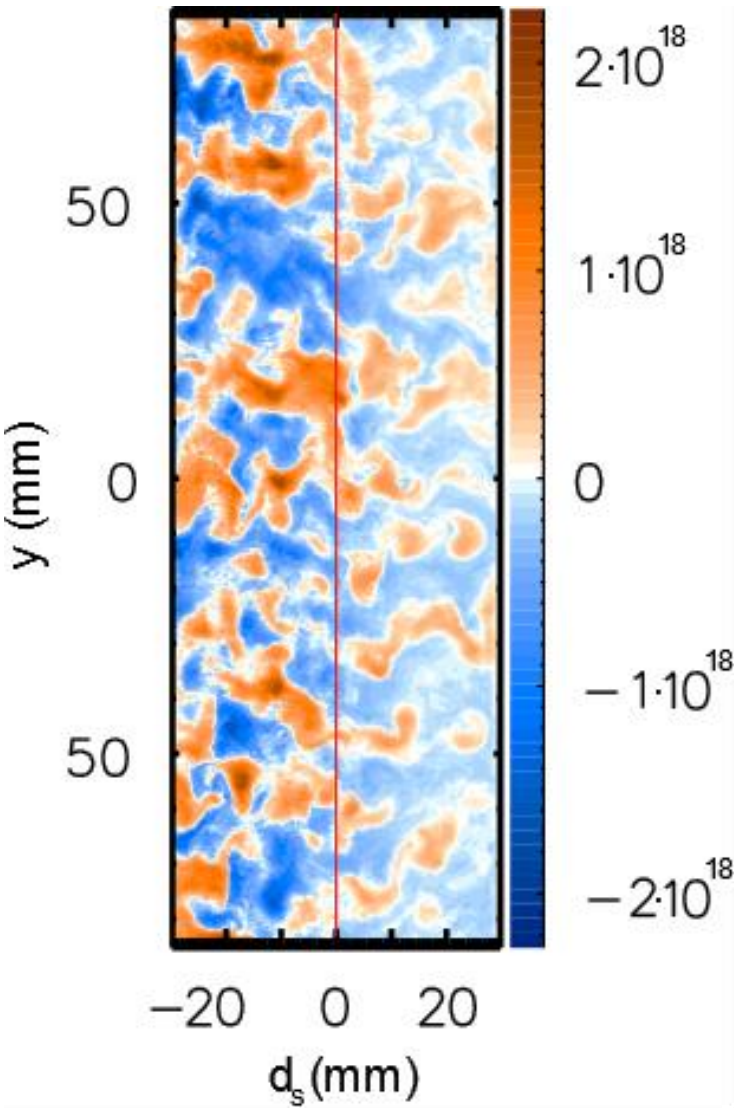
-Interchange instability generates radial extended structures (streamer)

-Shear flow breaks streamer up into blobs

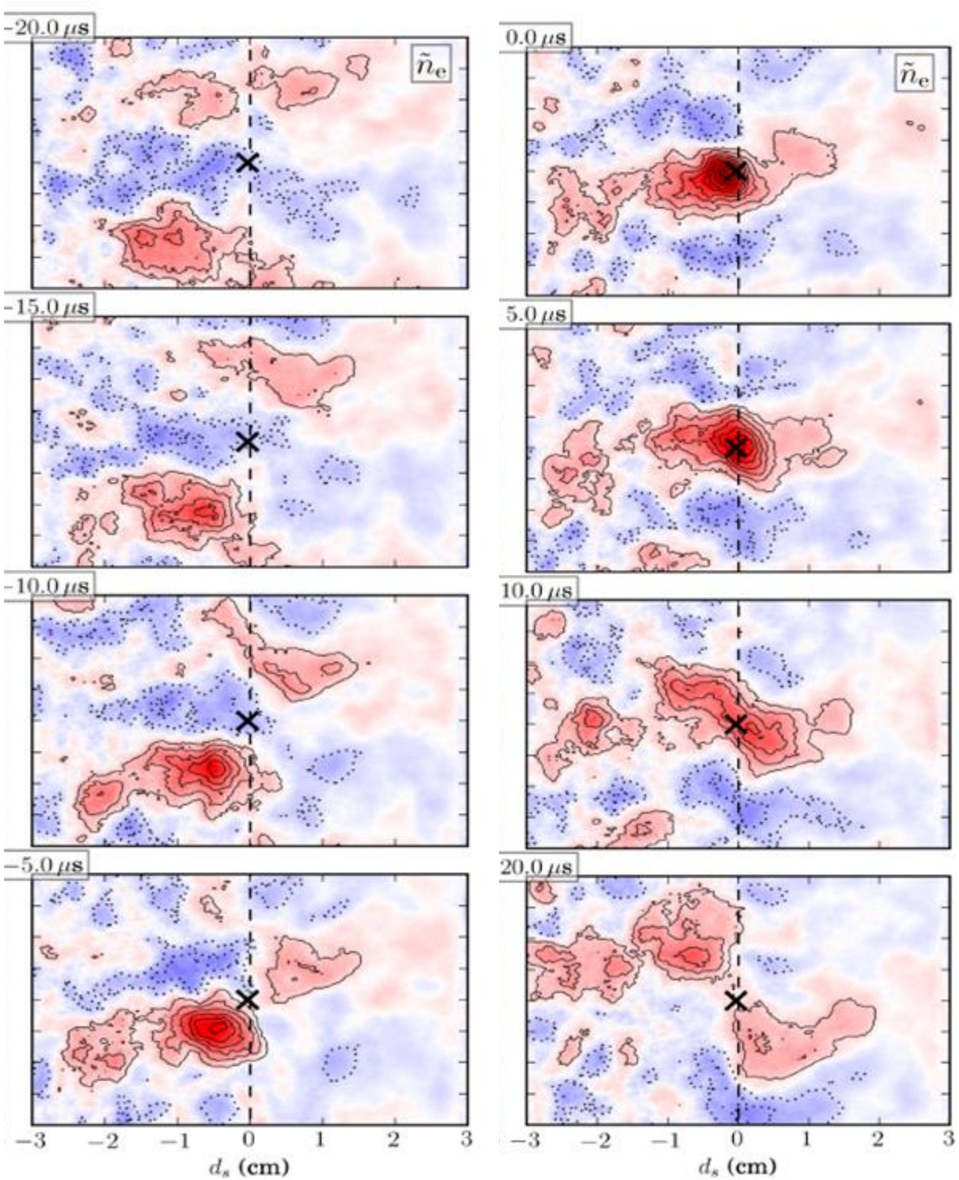
GEMR

- delta-f qyrofluid code

- electron and ion density (-> potential)
- perpendicular and parallel ion and electron temperature (finite Larmor radius effects)
- parallel ion dynamics (ion sound waves)
- electromagnetic (magnetic fluctuations)
- solves equilibrium (global)
- 3D
- transtion from closed to open field lines (sheath connected boundary conditions) at separatrix



Deterministic cartoon



Blob generation

- blobs merge

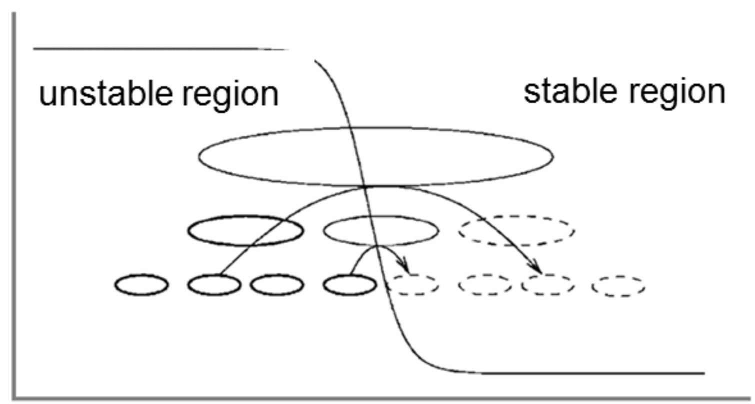
- exchange particles and energy

- break up

B. Nold et al. Phys. Plasmas 2014

(turbulence spreading)

O.Gürcan et al. Phys. Plasmas 2005



Plasma blob trajectories

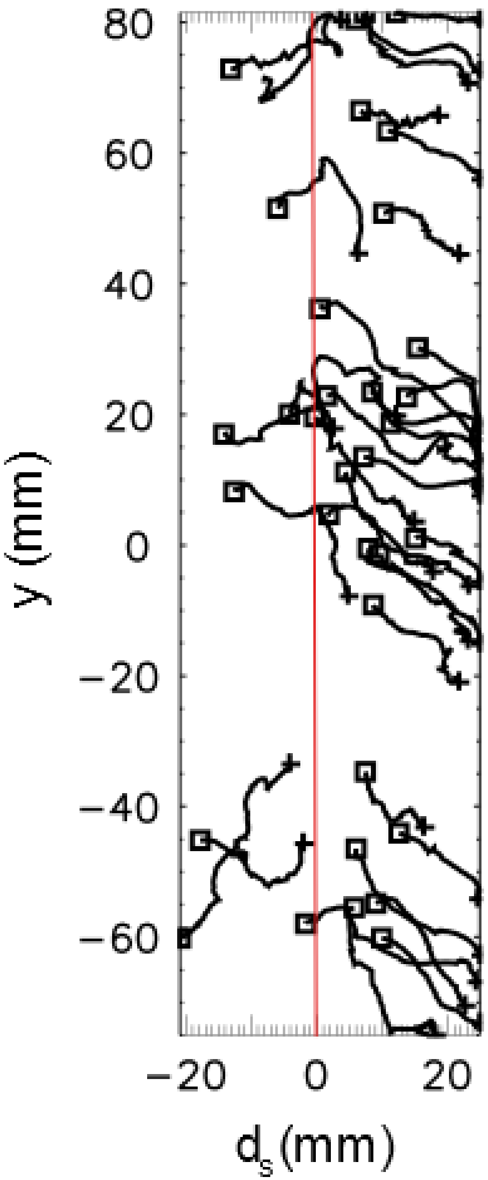
Blob definition:

Identify possible blobs at every time step:

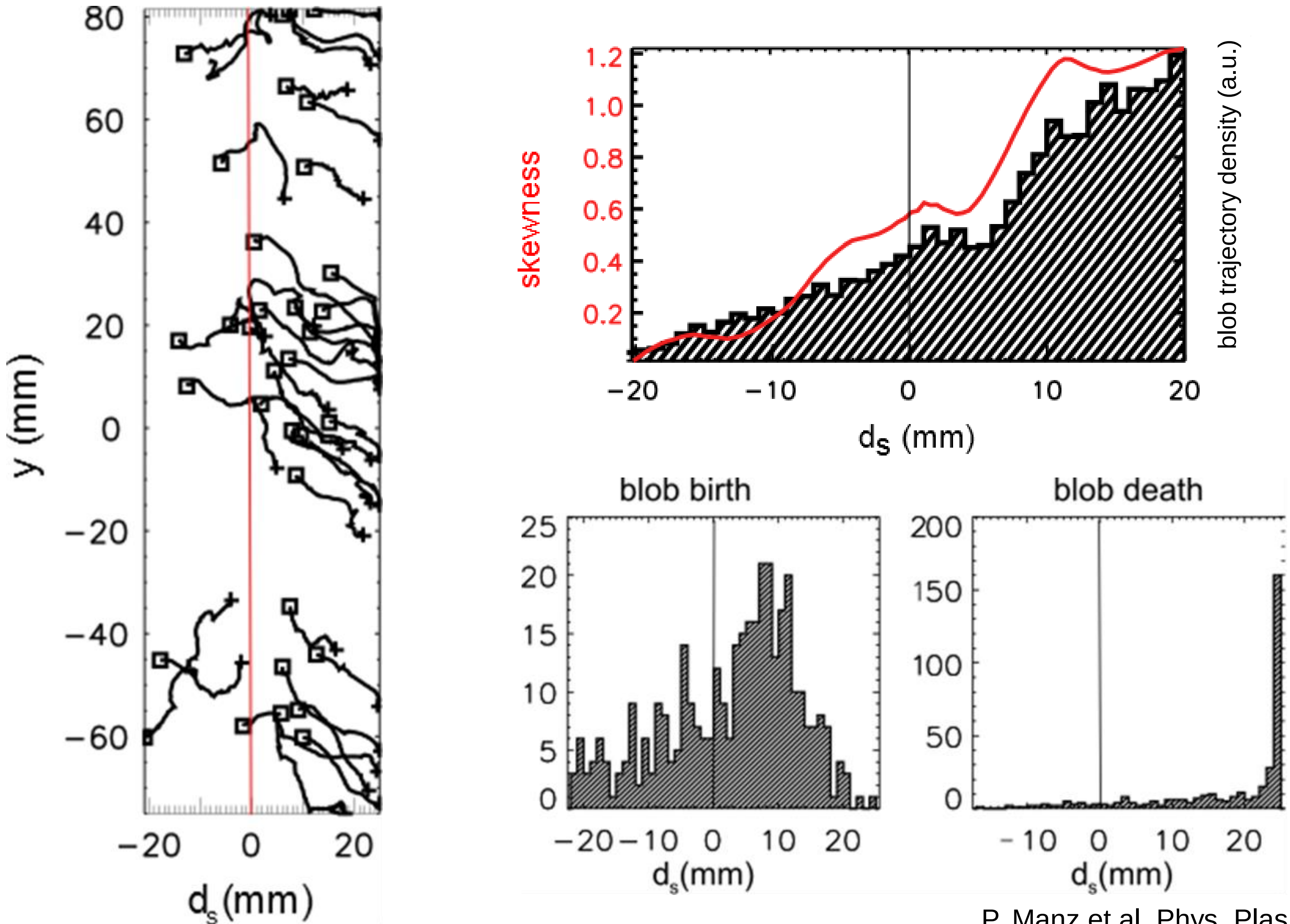
(i) positive density perturbations exceeding the standard deviation by a factor of 2.5

(ii) has to fulfill (i) over a connected spatial extent (11 points in the simulation grid ~ 5mm)

(iii) track possible blobs for a least 50 time steps (~25 µs)



Statistics of blob trajectories



P. Manz et al. Phys. Plasmas 2015

Spreading model

mean free energy

$$\frac{1}{2}\frac{\partial\langle n\rangle^2}{\partial t} = -\frac{\partial}{\partial r}(\langle n\rangle\langle\tilde{v}_r\tilde{n}\rangle) + \left\langle\frac{\partial n}{\partial r}\right\rangle\langle\tilde{v}_r\tilde{n}\rangle.$$

turbulent energy

$$\frac{1}{2}\frac{\partial\langle\tilde{n}^2\rangle}{\partial t} = -\left\langle\frac{\partial n}{\partial r}\right\rangle\langle\tilde{v}_r\tilde{n}\rangle - \frac{1}{2}\frac{\partial}{\partial r}\langle\tilde{v}_r\tilde{n}^2\rangle$$

Spreading model

mean free energy

$$\frac{1}{2}\frac{\partial \langle n\rangle^2}{\partial t} = -\frac{\partial}{\partial r}\left(\langle n\rangle\langle \tilde{v}_r\tilde{n}\rangle\right) + \left\langle \frac{\partial n}{\partial r}\right\rangle\langle \tilde{v}_r\tilde{n}\rangle .$$

energy exchange

turbulent energy

$$\frac{1}{2}\frac{\partial \langle \tilde{n}^2\rangle}{\partial t} = -\left\langle \frac{\partial n}{\partial r}\right\rangle\langle \tilde{v}_r\tilde{n}\rangle - \frac{1}{2}\frac{\partial}{\partial r}\langle \tilde{v}_r\tilde{n}^2\rangle$$

Spreading model

mean free energy

$$\frac{1}{2}\frac{\partial\langle n\rangle^2}{\partial t} = -\frac{\partial}{\partial r}\left(\langle n\rangle\langle\tilde{v}_r\tilde{n}\rangle\right) + \left\langle\frac{\partial n}{\partial r}\right\rangle\langle\tilde{v}_r\tilde{n}\rangle.$$

turbulent energy

energy exchange

$$\frac{1}{2}\frac{\partial\langle\tilde{n}^2\rangle}{\partial t} = -\left\langle\frac{\partial n}{\partial r}\right\rangle\langle\tilde{v}_r\tilde{n}\rangle - \frac{1}{2}\frac{\partial}{\partial r}\langle\tilde{v}_r\tilde{n}^2\rangle$$

local drive

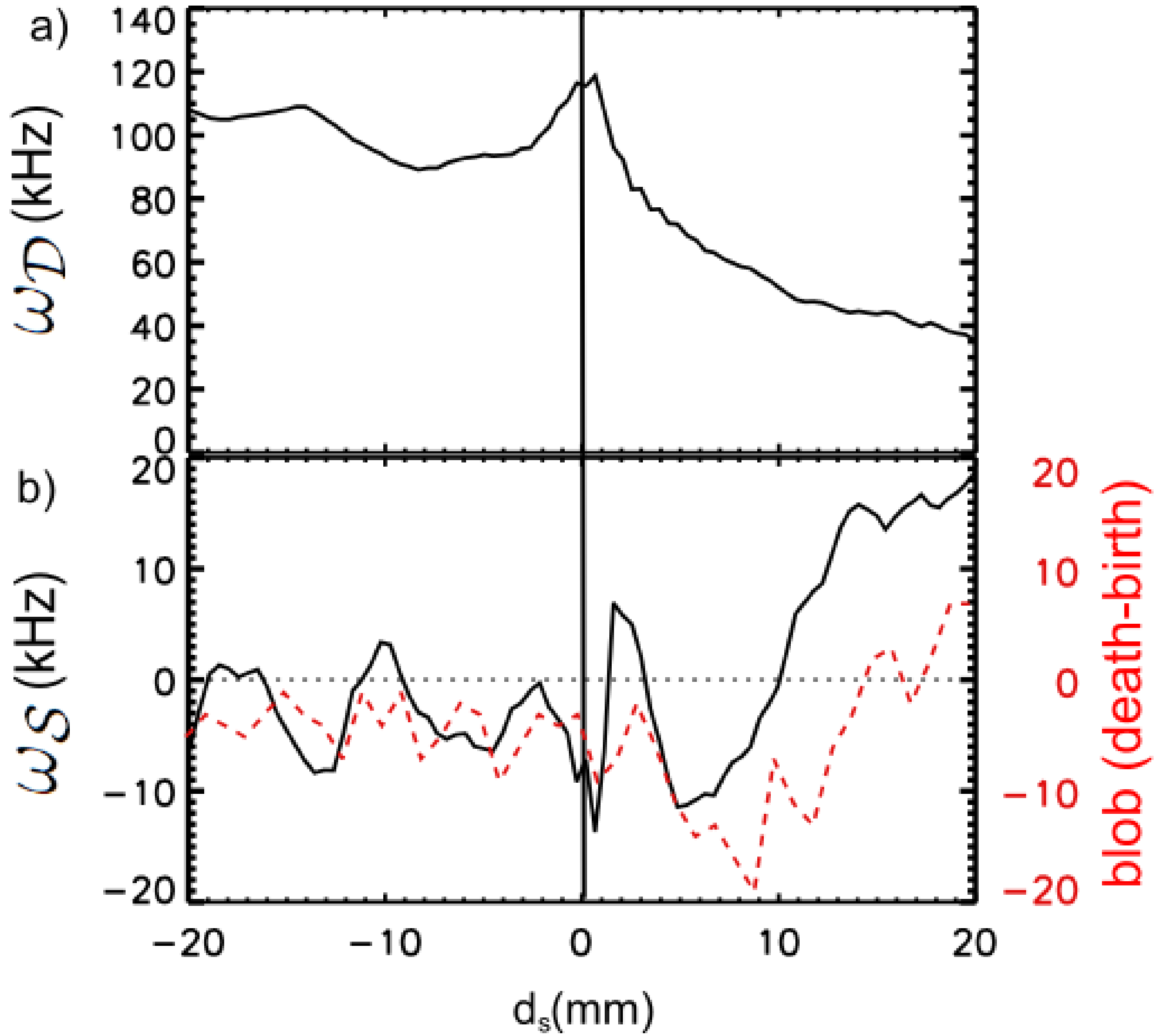
turbulent spreading

$$\omega_{\mathcal{D}} = \frac{-\langle\frac{\partial n}{\partial r}\rangle\langle\tilde{v}_r\tilde{n}\rangle}{\frac{1}{2}\langle\tilde{n}^2\rangle} \qquad \omega_{\mathcal{S}} = \frac{-\frac{1}{2}\frac{\partial}{\partial r}\langle\tilde{v}_r\tilde{n}^2\rangle}{\frac{1}{2}\langle\tilde{n}^2\rangle}$$

Local drive vs. spreading

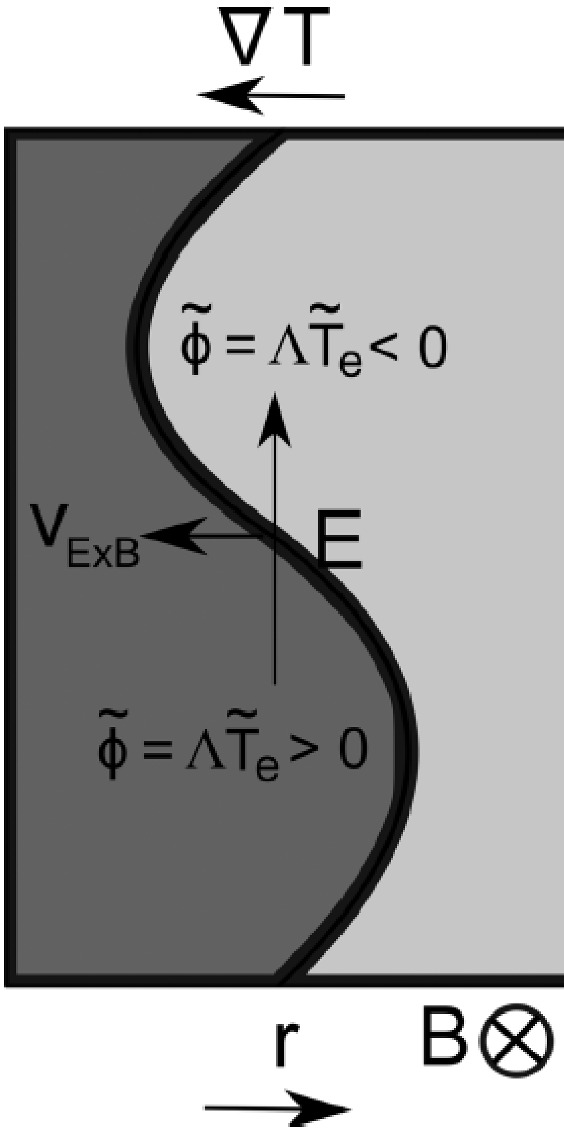
$$\omega_{\mathcal{D}} = \frac{-\left\langle \frac{\partial n}{\partial r} \right\rangle \langle \tilde{v}_r \tilde{n} \rangle}{\frac{1}{2} \langle \tilde{n}^2 \rangle}$$

$$\omega_{\mathcal{S}} = \frac{-\frac{1}{2} \frac{\partial}{\partial r} \langle \tilde{v}_r \tilde{n}^2 \rangle}{\frac{1}{2} \langle \tilde{n}^2 \rangle}$$



P. Manz et al. Phys. Plasmas 2015

Conducting wall instability

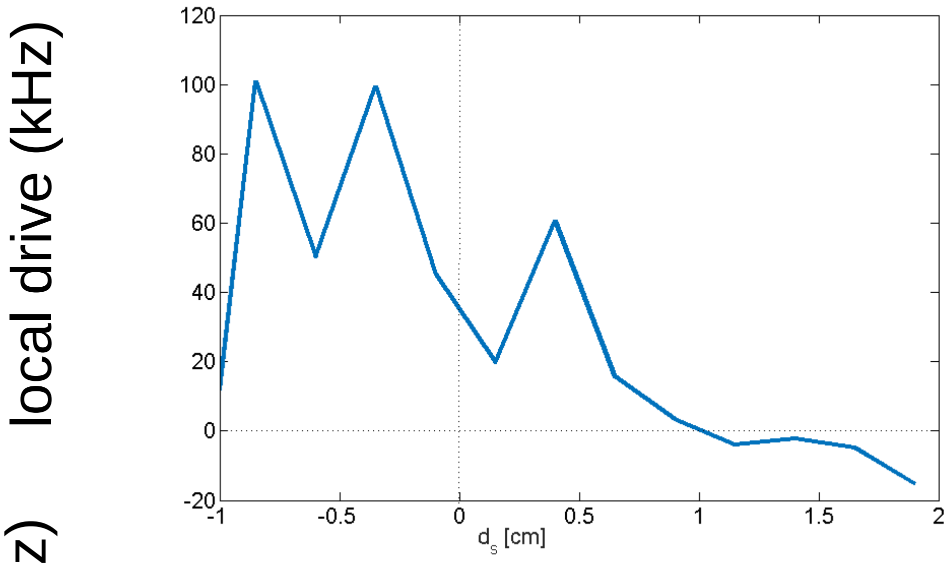


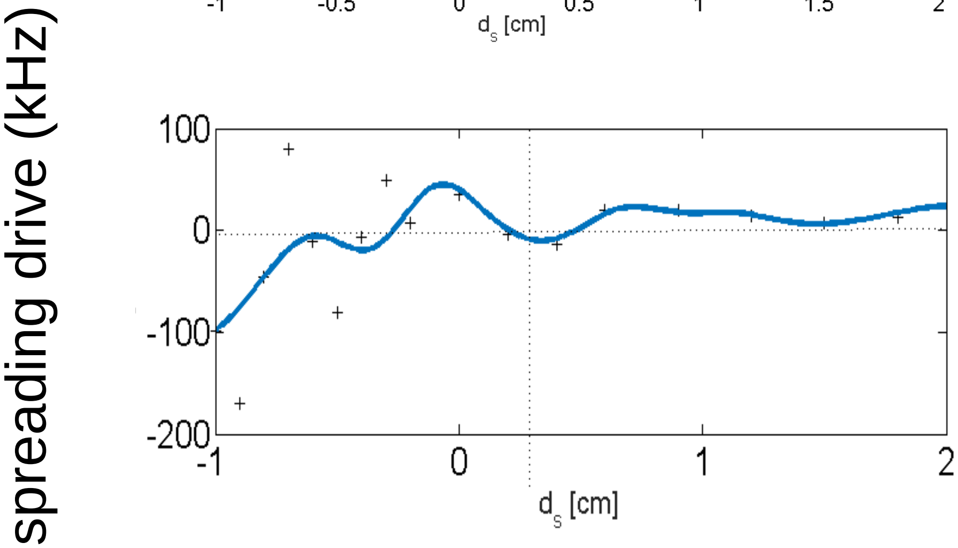
see talk by
Valentina Nikolaeva
today

P. Manz et al. Phys. Plasmas 2015

Results from HSX

ETDB (www.ipp.mpg.de/ISS/)





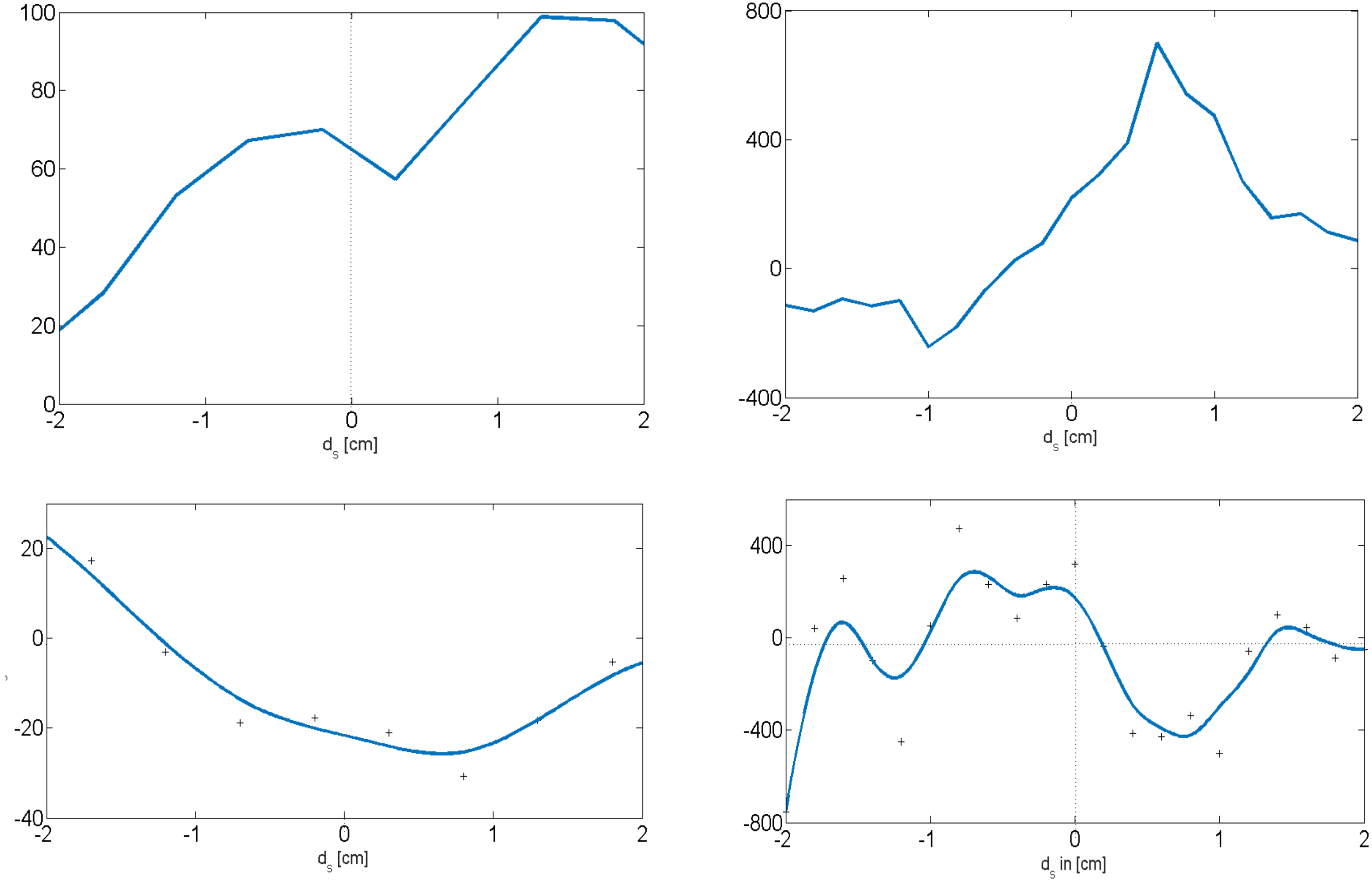
Results from TJ-K and WEGA

ETDB (www.ipp.mpg.de/ISS/)

TJ-K | WEGA

local drive (kHz)

spreading drive (kHz)



- Blobs are not generated at one particular position

- At ASDEX Uprade L-mode sheath connected conditions most blobs are generated outside the separatrix (CWI)

- Turbulence spreading a more suitable diagnostics for blob generation than the skewness alone

- Turbulence spreading should play the key role for turbulence in the far-SOL (once the background gradient is small)

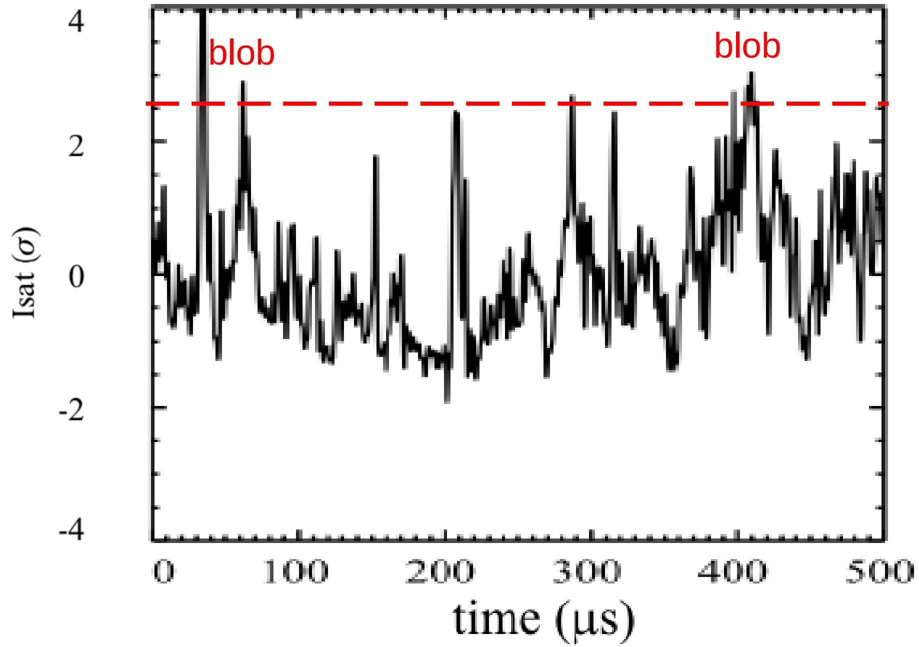
local drive

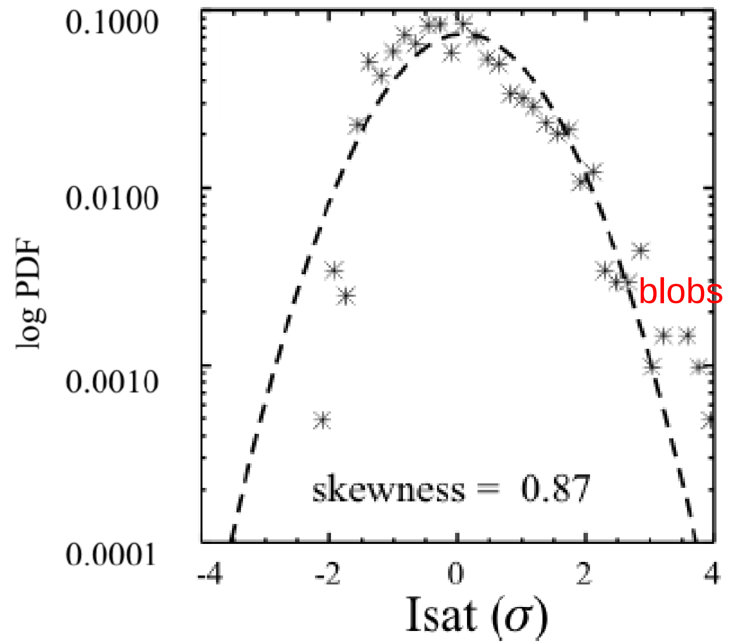
$$\omega_{\mathcal{D}} = \frac{-\left\langle \frac{\partial n}{\partial r} \right\rangle \left\langle \tilde{v}_r \tilde{n} \right\rangle}{\frac{1}{2} \left\langle \tilde{n}^2 \right\rangle}$$

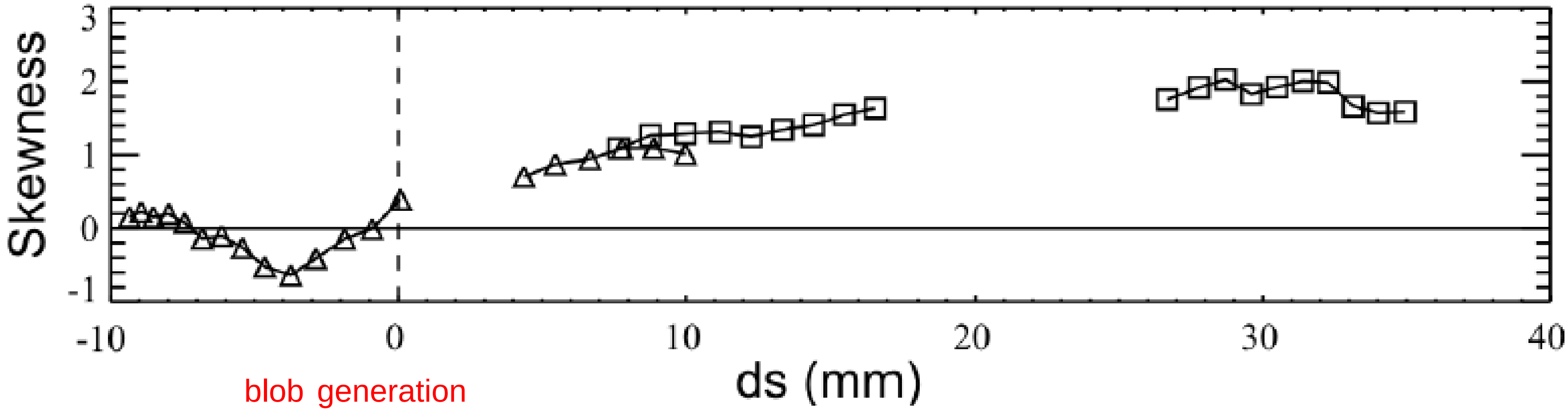
turbulent spreading

$$\omega_{\mathcal{S}} = \frac{-\frac{1}{2} \frac{\partial}{\partial r} \left\langle \tilde{v}_r \tilde{n}^2 \right\rangle}{\frac{1}{2} \left\langle \tilde{n}^2 \right\rangle}$$

Skewness as the basic parameter





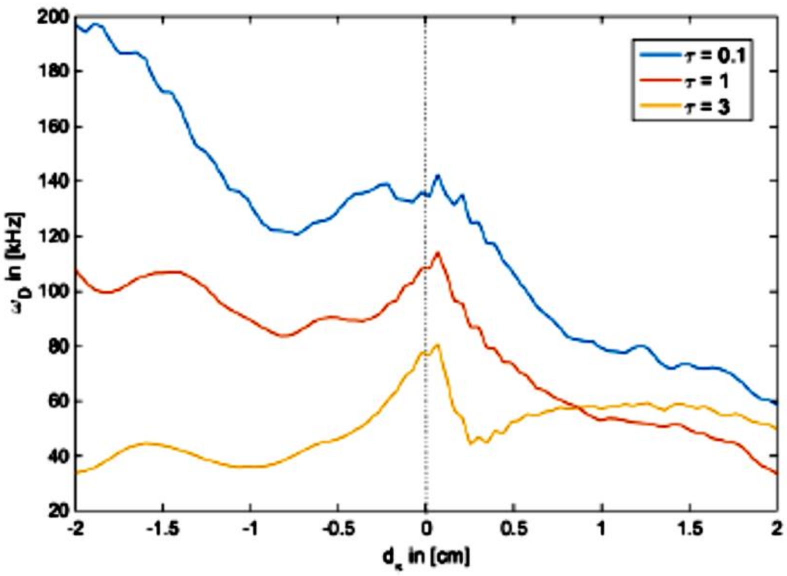


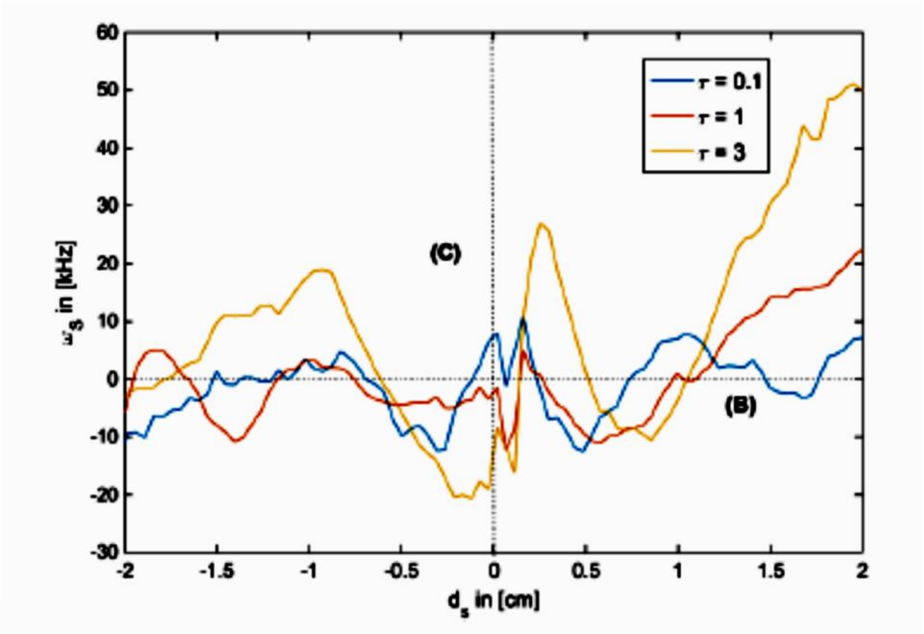
blob generation
position (skewness =0)

ASDEX Upgrade: B. Nold et al. PPCF 2010

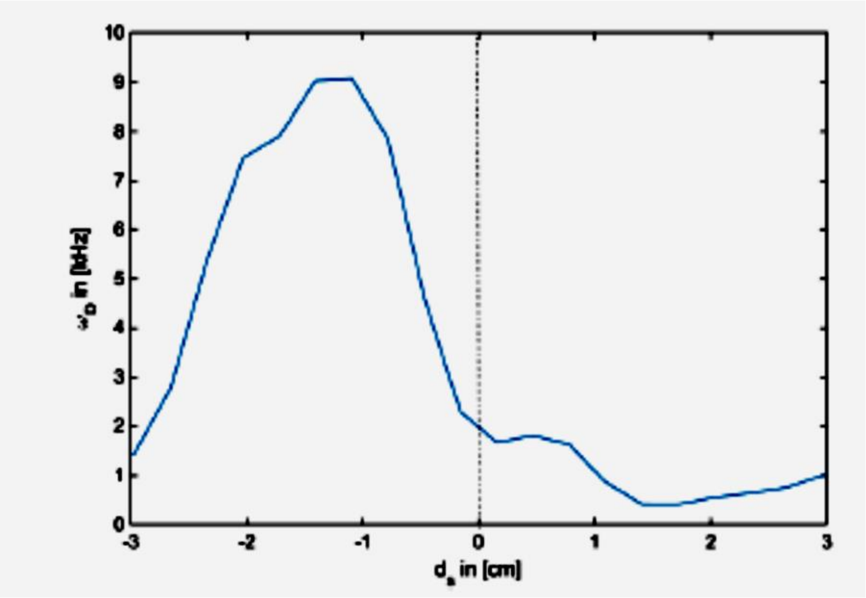
Additional material

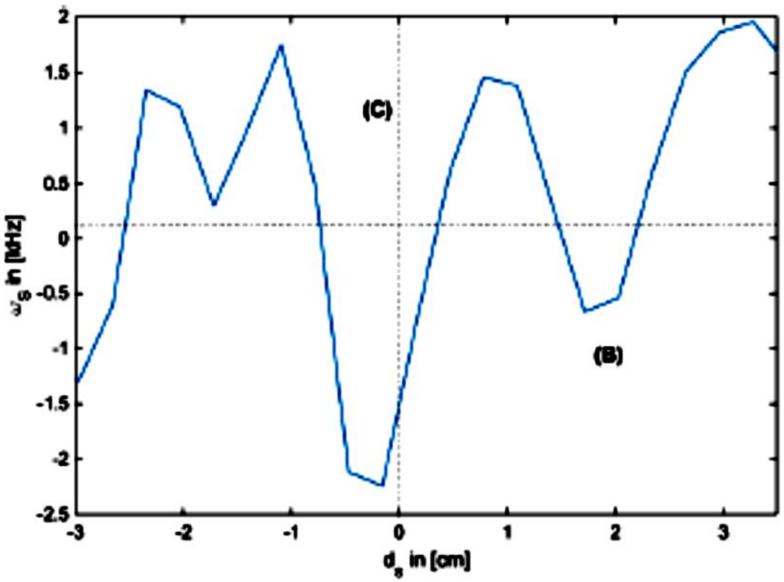
GEMR (AUG) finite Larmor radius effects



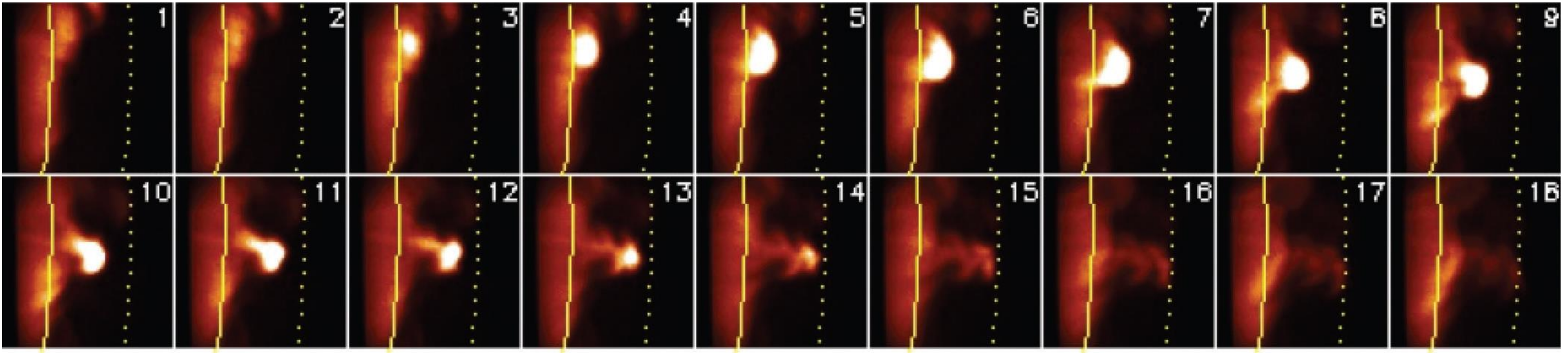


GEMR (TJ-K)





Blobs propagate radially outward



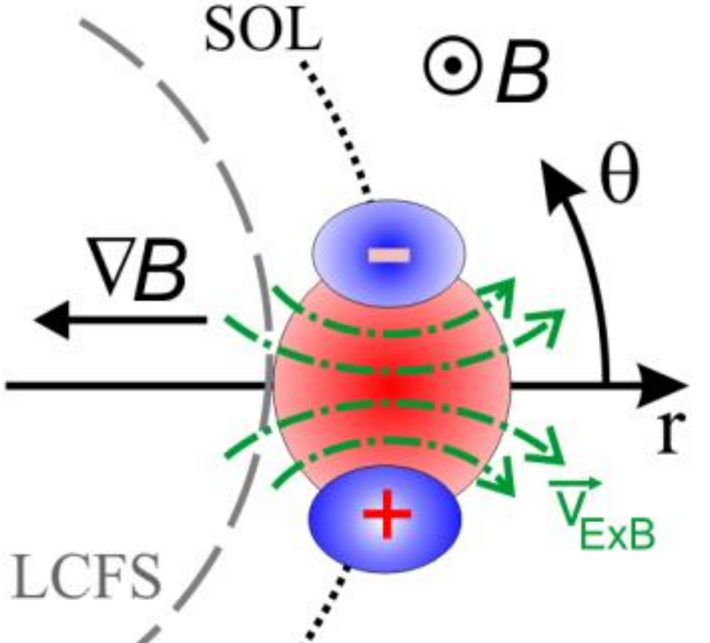
[GPI by R. J. Maqueda, D. P. Stotler, S. J. Zweben and The NSTX team, J. Nucl. Mater. (2011)]

- **charge separation by curvature/gradB drift**

$$\mathbf{v}_D^{\nabla B} = -\frac{W_\perp}{q}\frac{\boldsymbol{\nabla}_\perp B \times \mathbf{B}}{B^3}$$

- **ExB drift accelerates blobs radially**

$$\mathbf{v}_D^{E\times B} = \frac{\mathbf{E}\times\mathbf{B}}{B^2}$$

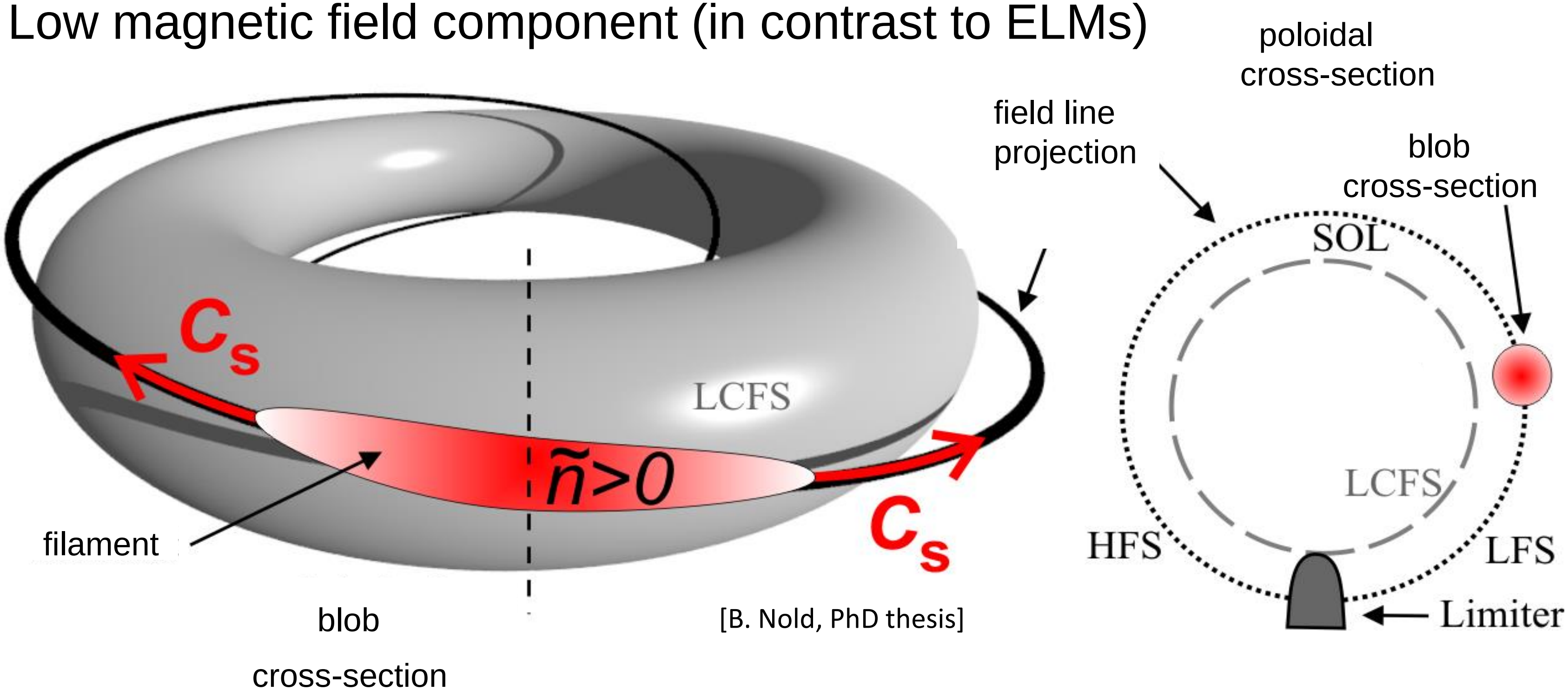


[B. Nold, PhD thesis]

Plasma filaments or blobs

Blobs are intermittently expelled density filaments in the scrape-off layer (SOL)

- Elongated along the magnetic field line
- Low magnetic field component (in contrast to ELMs)



[B. Nold, PhD thesis]