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Dynamics of turbulent transport in the Scrape-off-Layer of the CASTOR tokamak

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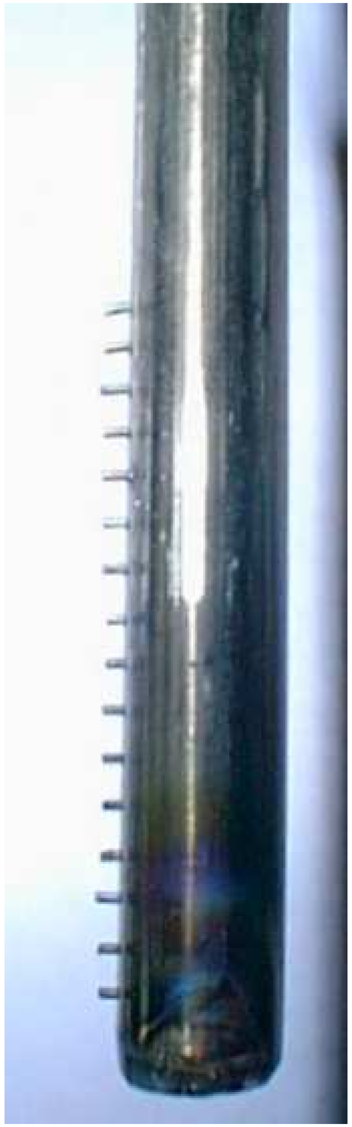
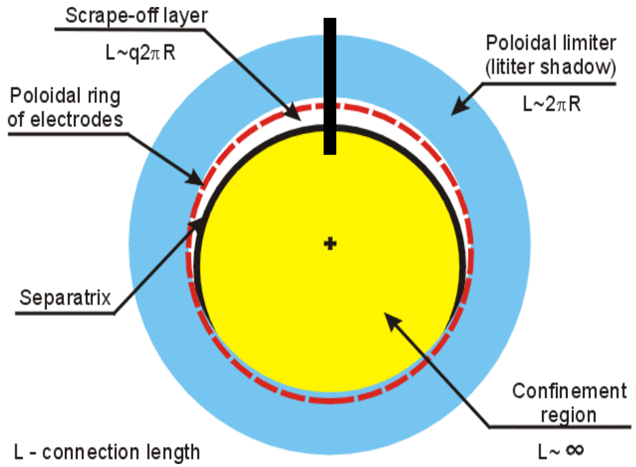
The rake probe in Castor
16 probes, 1 mm diameter
Radially separated by 2.5 mm



The CASTOR tokamak

- *R=0.4 m, a=0.085 m*
- *Bt=1.3T, Ip=12 kA,*
- *<ne>=1 $10^{19} m^{-3}$.*
- *The duration of the quasi-stationary phase of the discharge is 20 ms.*

The probe is inserted from the Top



Acquisition rate 1 MHz during 5ms, all channels synchronized.

Selection and following of events on the rake probe

Goal: to observe the propagation of selected events on the array of probes as a function of time:

→ observation of single trajectories

information on the transport by turbulence, radial propagation of blobs etc ..

Difficulty: the events deform during their propagation

A solution:

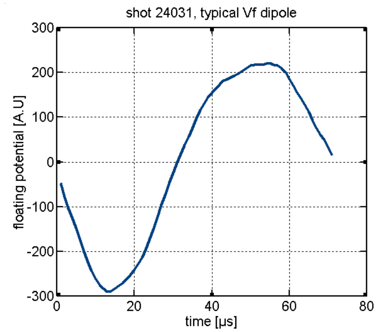
Select an event in the data:

use a correlation function defined specially for this event

to track the propagation of the event allow a level of correlation smaller than one (typically from 0.6 to 1).

Data processing I

Select an event (E) in the data:



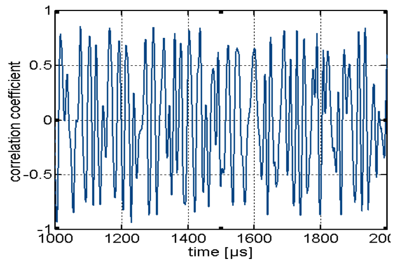
Define a correlation function for this event

$$C(t_j) = \frac{\sum_{i=1}^{M} S(t_j + i\Delta t).E(i\Delta t)}{\sqrt{\sum_{i=1}^{M} S(t_j + i\Delta t)^2 . \sum_{i=1}^{M} E(i\Delta t)^2}}$$

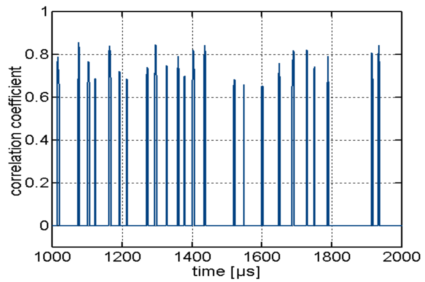
Where E is the event, $S(t_j)$ is the signal in a time window of same duration than the event E, starting at time t_j

Calculate a correlation coefficient of the time series with this event for each time step.

One obtains a correlation function for the selected event as a function of time



Set to zero all values below a chosen threshold (0.65 in this case)



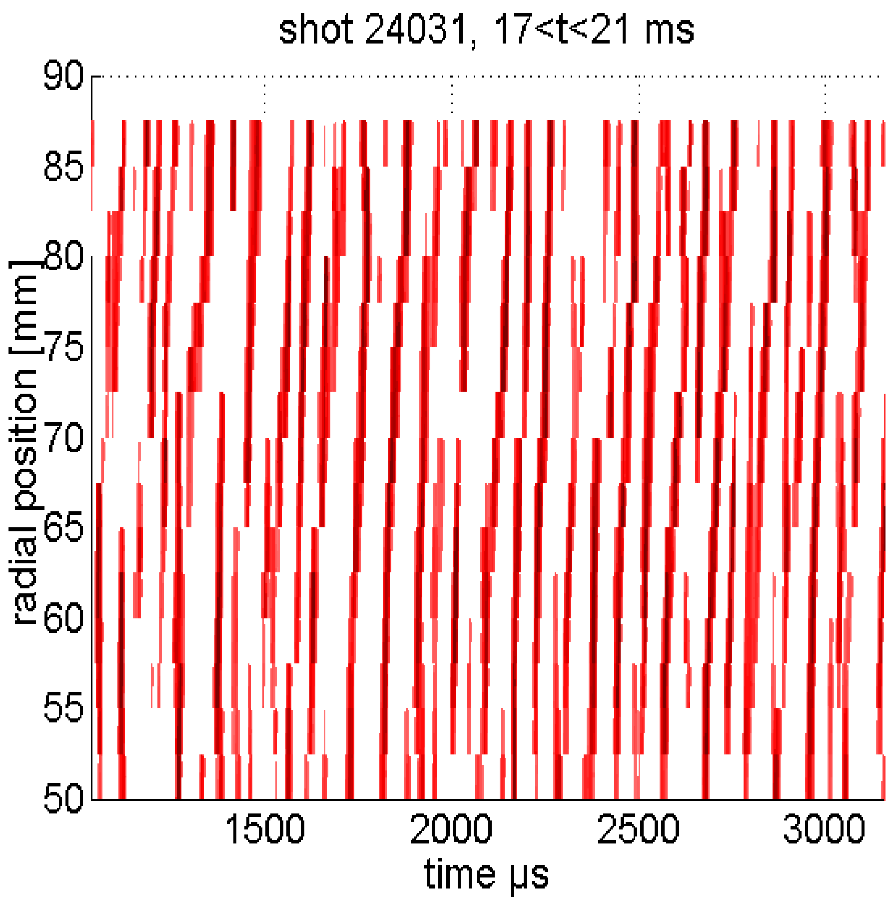
Data processing II

Repeat procedure for all probes

The final output of the procedure is a correlation coefficient for a specified type of event as a function of time and radial position.

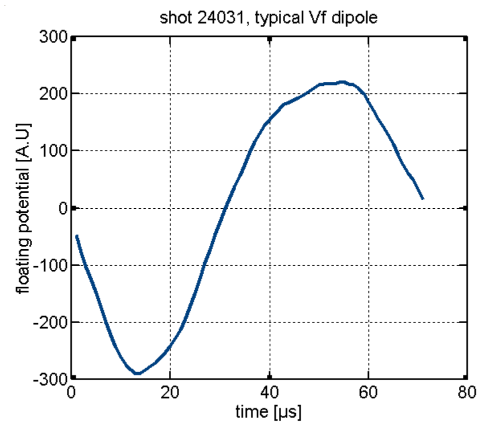
→ allows the observation of individual trajectories of a specified type of event on the probe

It is possible to observe the dynamics of individual events but also to make statistics about the trajectories for the same type of event.

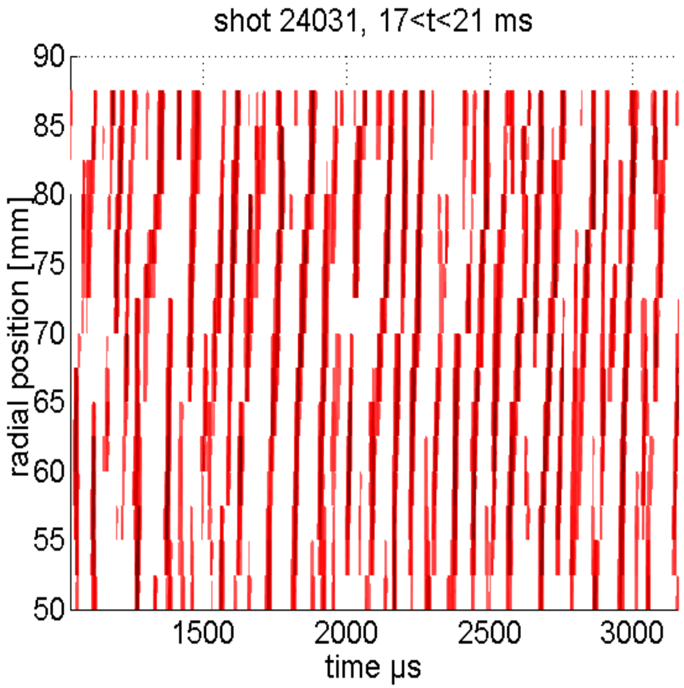


Potential Fluctuations

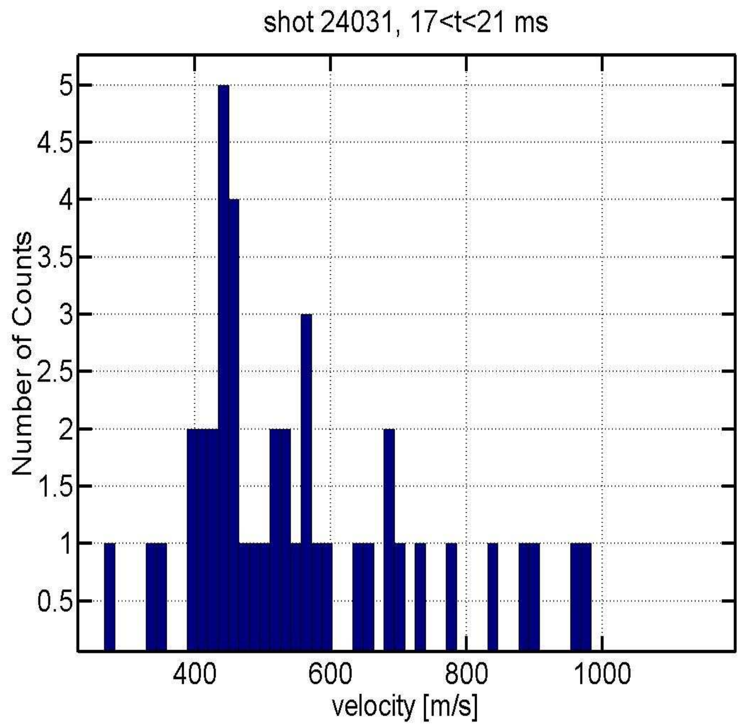
The typical potential structure: a poloidal dipole



An asymmetric dipole that creates a strong E_θ fluctuating field which gives a strong $v_r = E_\theta / B_t$ fluctuating radial velocity.

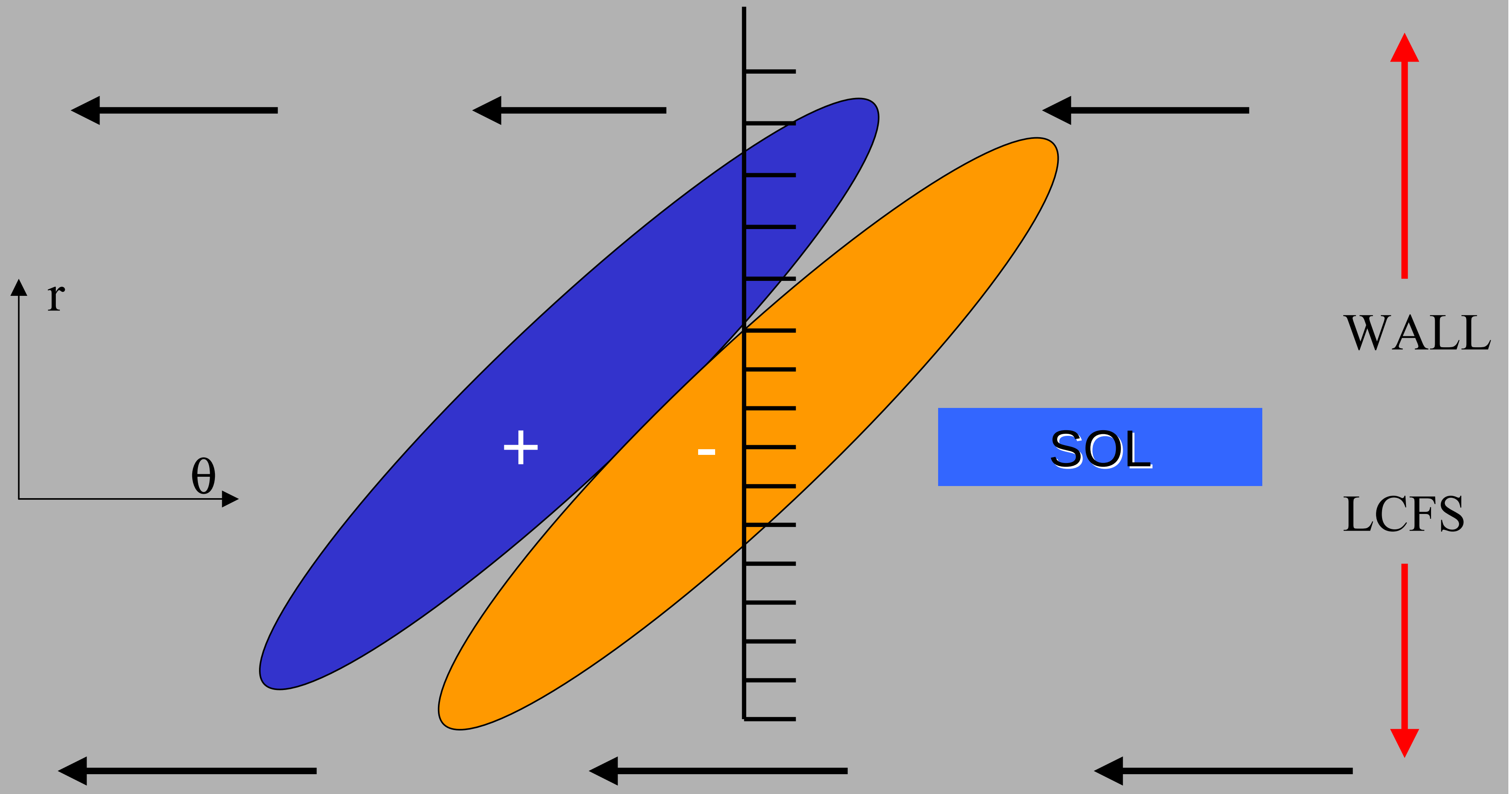


- Extend over 3cm
- Their slope allows to compute the apparent radial velocity



1. Mean value: $\langle v_{dipole} \rangle = 580$ m/s
2. Most probable value = 450 m/s
3. Standard deviation =250 m/s.

The meaning of the apparent radial velocity



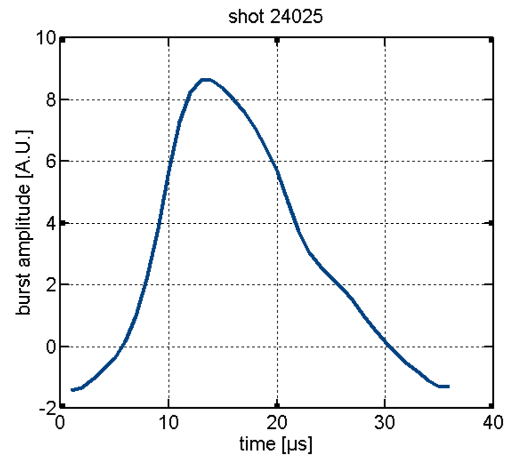
A poloidally moving inclined structure gives rise to an apparent radial velocity

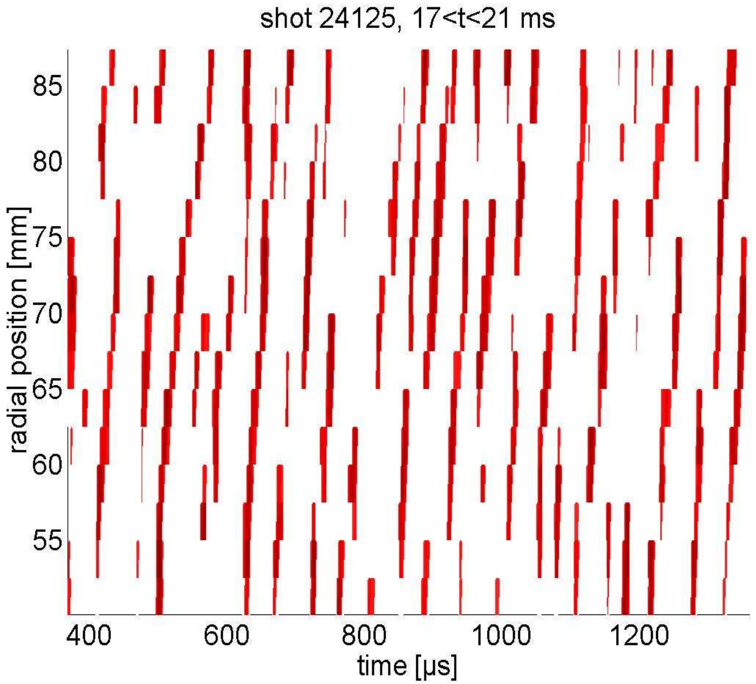
The apparent radial velocity is a mixture of radial an poloidal velocity

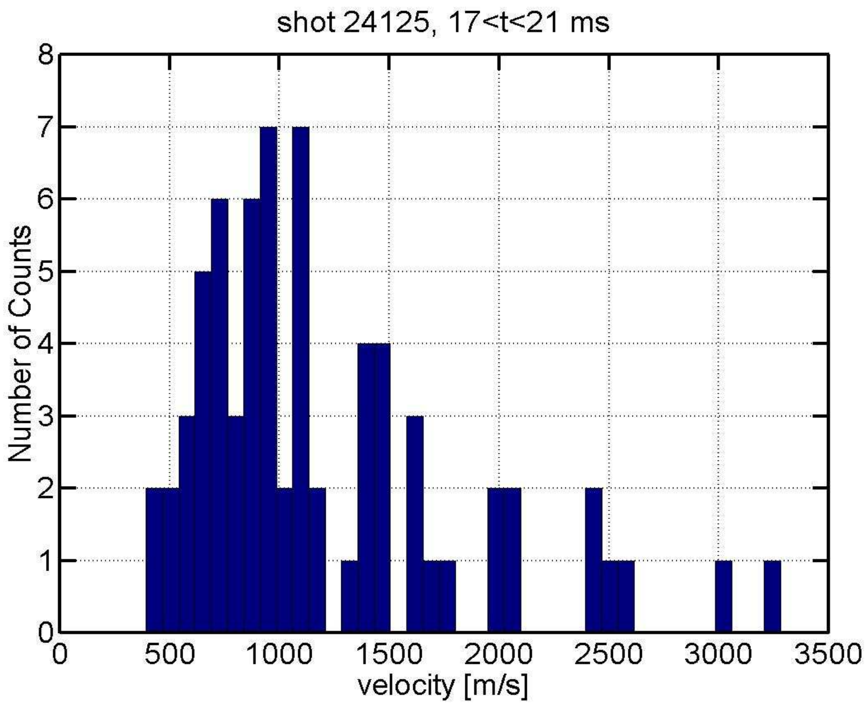
Density Fluctuations

The typical density event : A positive burst

radially elongated filaments of density rotating poloidally with the potential dipoles and streaming along the valleys of the potential.







•Radially extended over several cm.

1. Mean value $<V_{burst}>\sim 1300$ m/s
2. Most probable value = 950 m/s
3. Standard deviation i=1000 m/s.

Main results

I Potential Fluctuations

•In Castor, inclined and radially elongated poloidal dipoles rotate poloidally in the SOL with a sign compatible with the $E_r \times B_t$ velocity.

•Their radial extension is such that they connect without problem the regions around the LCFS to the wall, thus opening very efficient transport channels for the density.

•The fluctuating radial velocity is constant radially over the dipole

•Their mean apparent radial velocity is about 580 m/s

II Density Fluctuations

•The spikes observed on the Isat fluctuations are in fact radially elongated structures that rotate poloidally in the same direction than the potential dipoles.

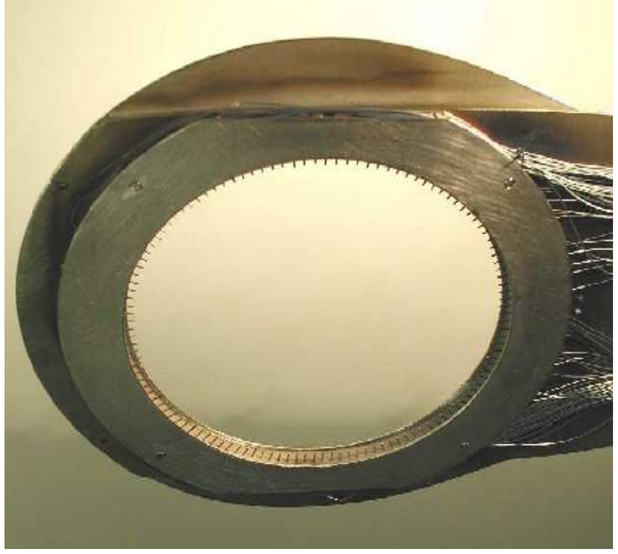
• They can very efficiently connect the LCFS to the wall, at least 3 cm in Castor.

•The ratio burst/ background density increases along the radius.

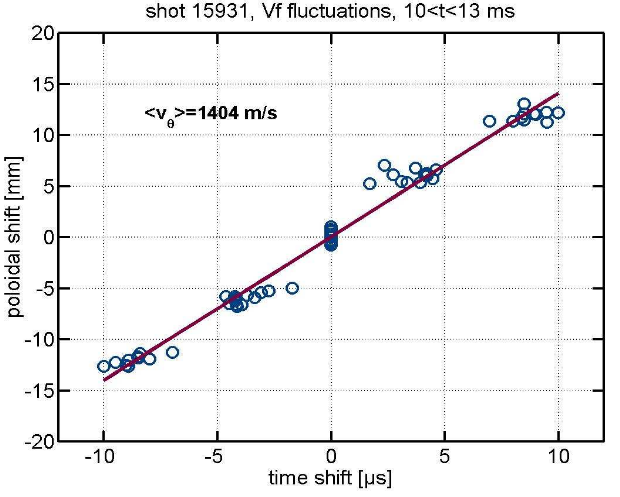
•Their mean apparent radial velocity is about 1300 m/s

The density bursts have an higher apparent radial velocity than the potential dipoles.

Simultaneous measurement of poloidal velocity of potential and density fluctuations

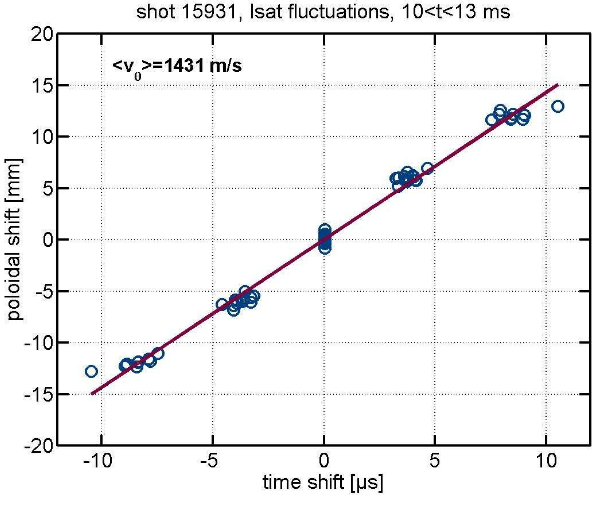


Potential



The density and potential fluctuations have the same poloidal velocity=1400m/s. <u>Consequence:</u> the difference in their radial apparent velocity must be attributed to a difference in their radial velocity.

Density



Bursts move radially faster than dipoles!

DISCUSSION

The density is streaming along the potential contours of the radially elongated poloidal dipoles. The dipoles survive the streaming of the density.

In the frame work of an interchange turbulence such as described by the 2D fluid code “TOKAM”[1]:

Decoupling between potential and density and the existence of radially elongated structures indicate :

Short Parallel connection lengths,

High collisionality, mostly charge exchange with neutrals.

- The parallel connection length in Castor is of the order of 10 m.

- The fraction of neutrals at the edge of castor seems sufficient to produce a high viscosity. A lower estimate of the neutral density put them at 10^{17} m^{-3} with a mean free path of the order of the plasma radius. This means that the neutral density is several percent of the plasma density in the SOL of Castor and this is in the range needed by the TOKAM code to produce a turbulence dominated by streamers-like features and where the density is decoupled from the potential field.

[1] *Y. Sarazin, Ph. Ghendrih, Phys. Plasmas,* ***5****,4214 (1998) .*