Partially Coherent Fluctuations in Novel High Confinement Regimes of a Tokamak

István Cziegler

UCSD, Center for Energy Research
Center for Momentum Transport and Flow Organization

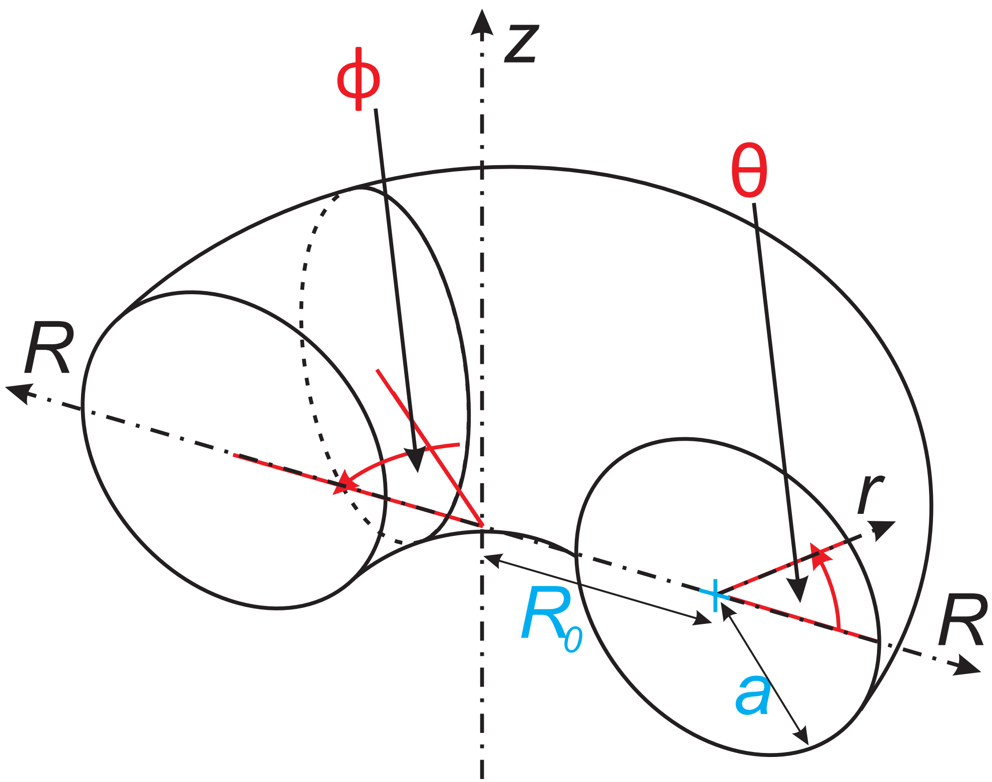
Columbia Seminar

Feb 2, 2012

OR

Edge Fluctuations and You

Tokamak and notations for toroidal geometry

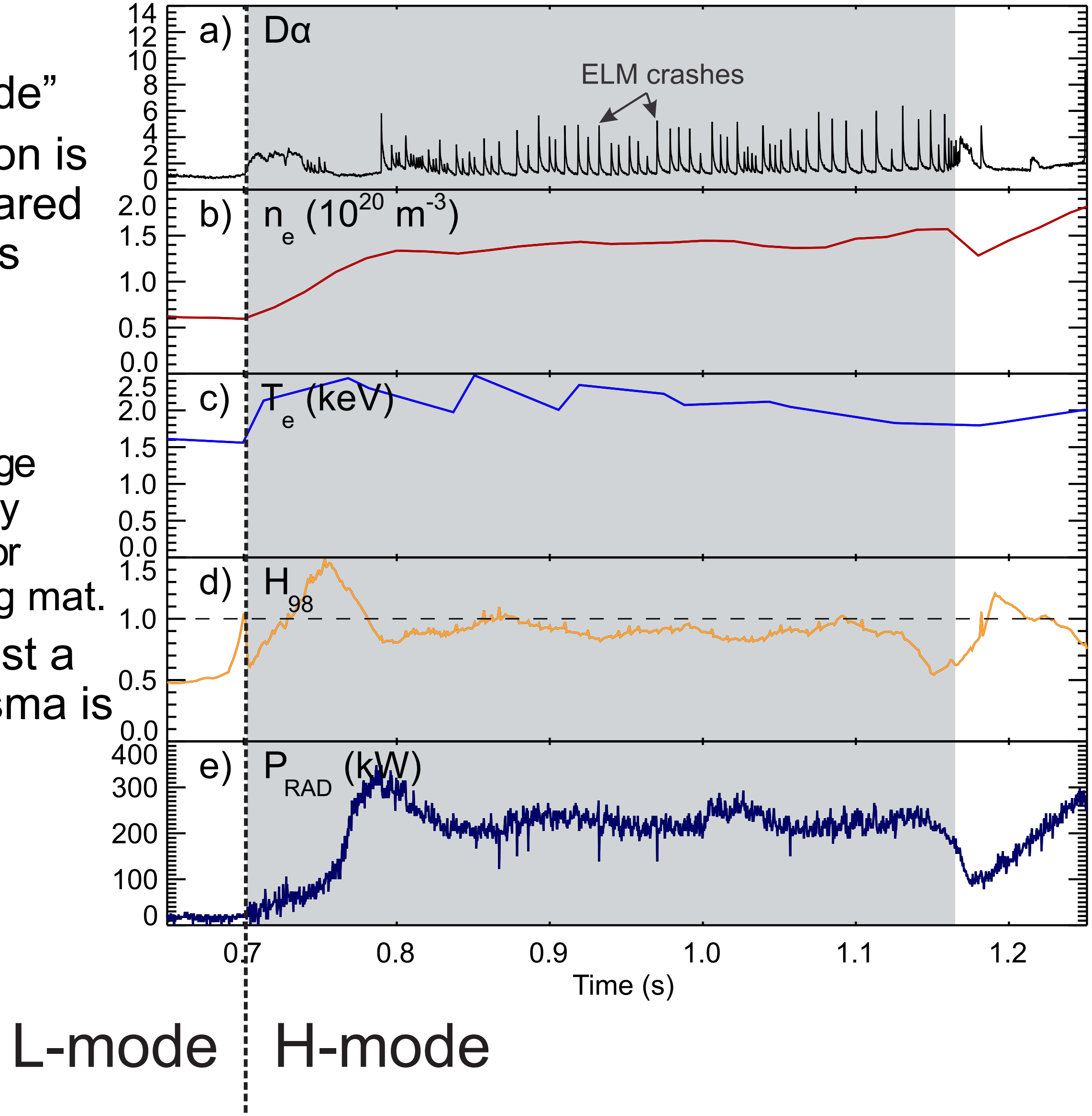


R - major radius
r - minor radius
ϕ -toroidal angle
θ - poloidal angle

- Tokamak is a magnetic confinement device
- strong toroidal field confines particles
- field lines bent into torus to prevent losses
- necessary poloidal field provided by toroidal plasma current
- flux surfaces exist

An operational mode of high confinement was discovered in the 80's that features reduced turbulence.

- No first principles theory exists yet to predict the onset and cause of "H-mode"
- Empirical work shows that the transition is related to the creation of strongly sheared flows that break apart turbulent eddies
  - Complex 'self-organization'
  - ExB shear mostly present in periphery of plasma; transport barrier
  - …and leads to local edge instabilities..Edge Localized Modes, ELM which periodically relax the edge gradient--these have a major impact on heat loads on plasma facing mat.
- Empirical scaling shows that there exist a critical power across boundary of plasma is needed to initiate H-mode
  - Also sensitive to plasma shape and the presence of a "divertor" and vacuum cleanliness.

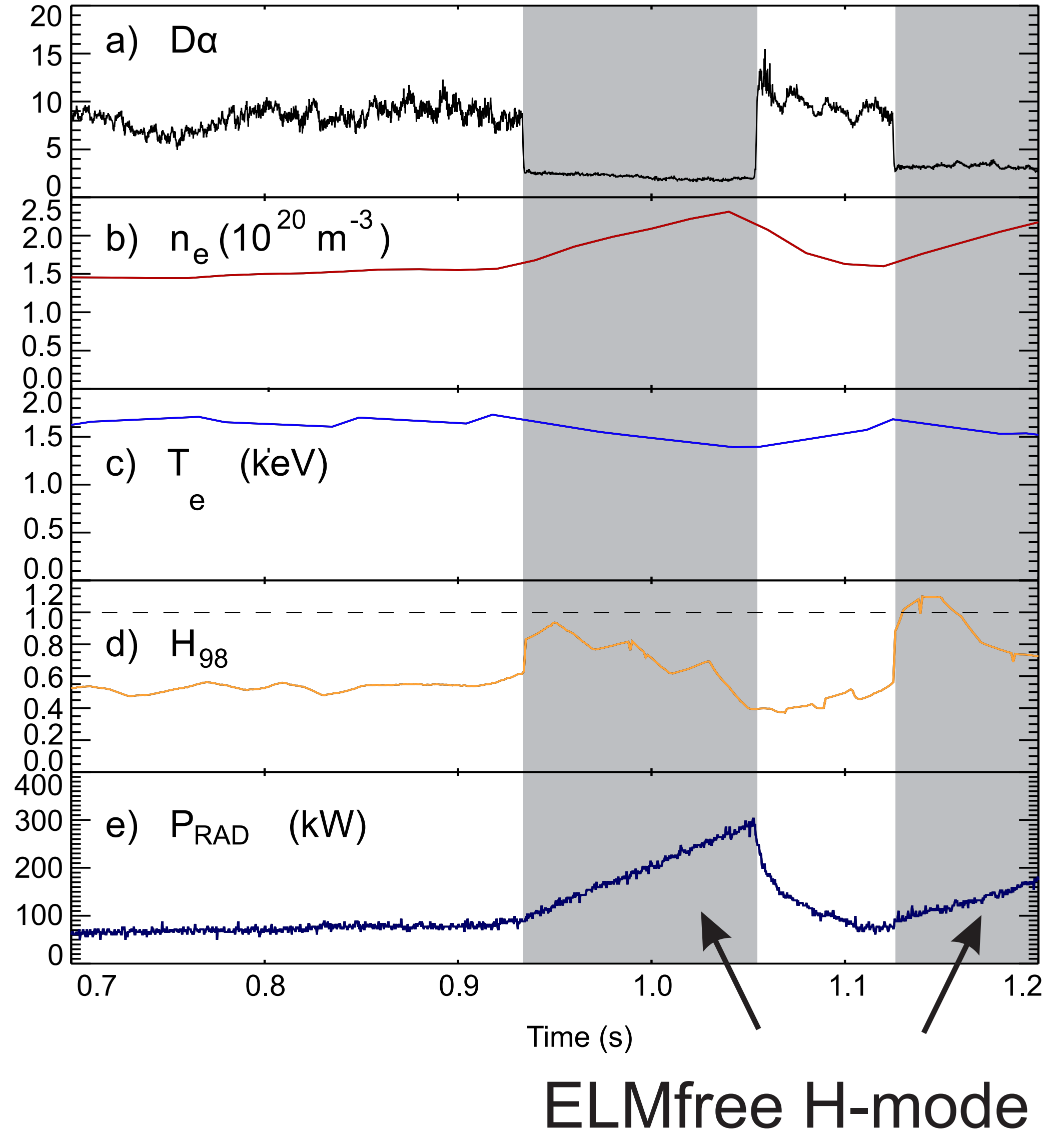


Why aren't we happy with garden variety H-modes?

- ELM ejections already limit the lifetime of plasma facing components
- Real fusion devices need to be ~10x larger:
  1000x volume, yet only
  100x surface!
- ELMfree H-modes exist with near zero edge turbulence, BUT:

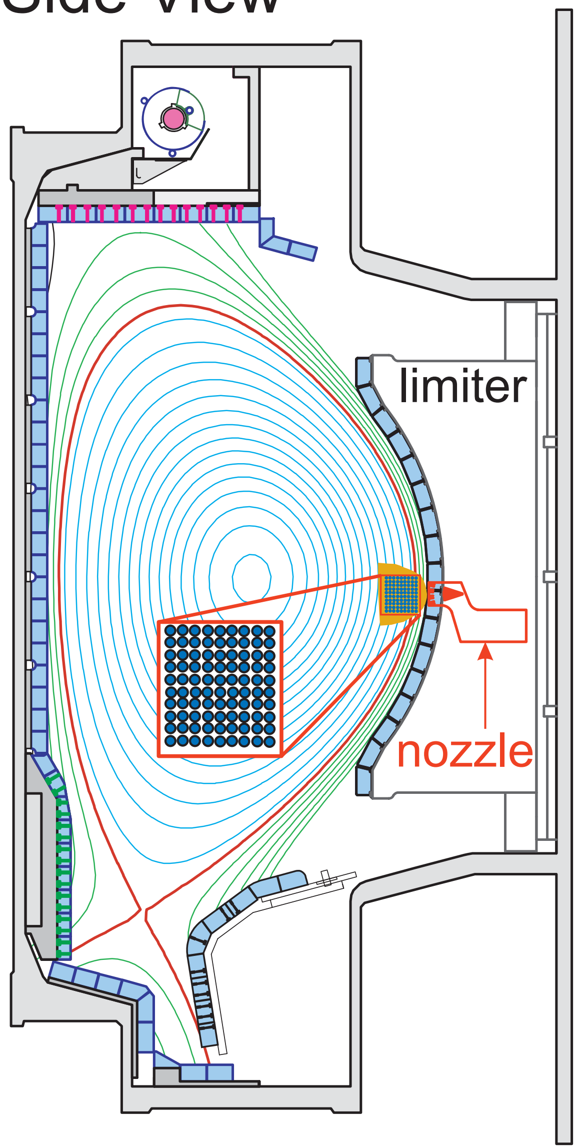
$$P_{BS} \propto n_e T_e^{1/2} \sum_i n_i Z_i^2$$

  bremsstrahlung leads to collapse
- energy and mass (and impurity) transport processes are coupled



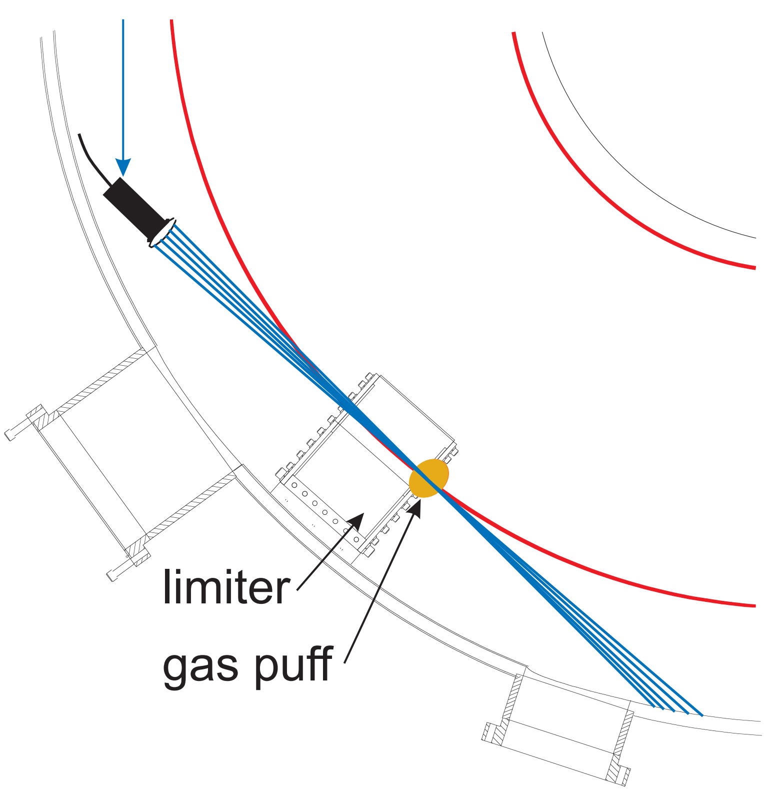
Experimental setup of the new 2D fast Gas-Puff-Imaging diagnostic

Side View



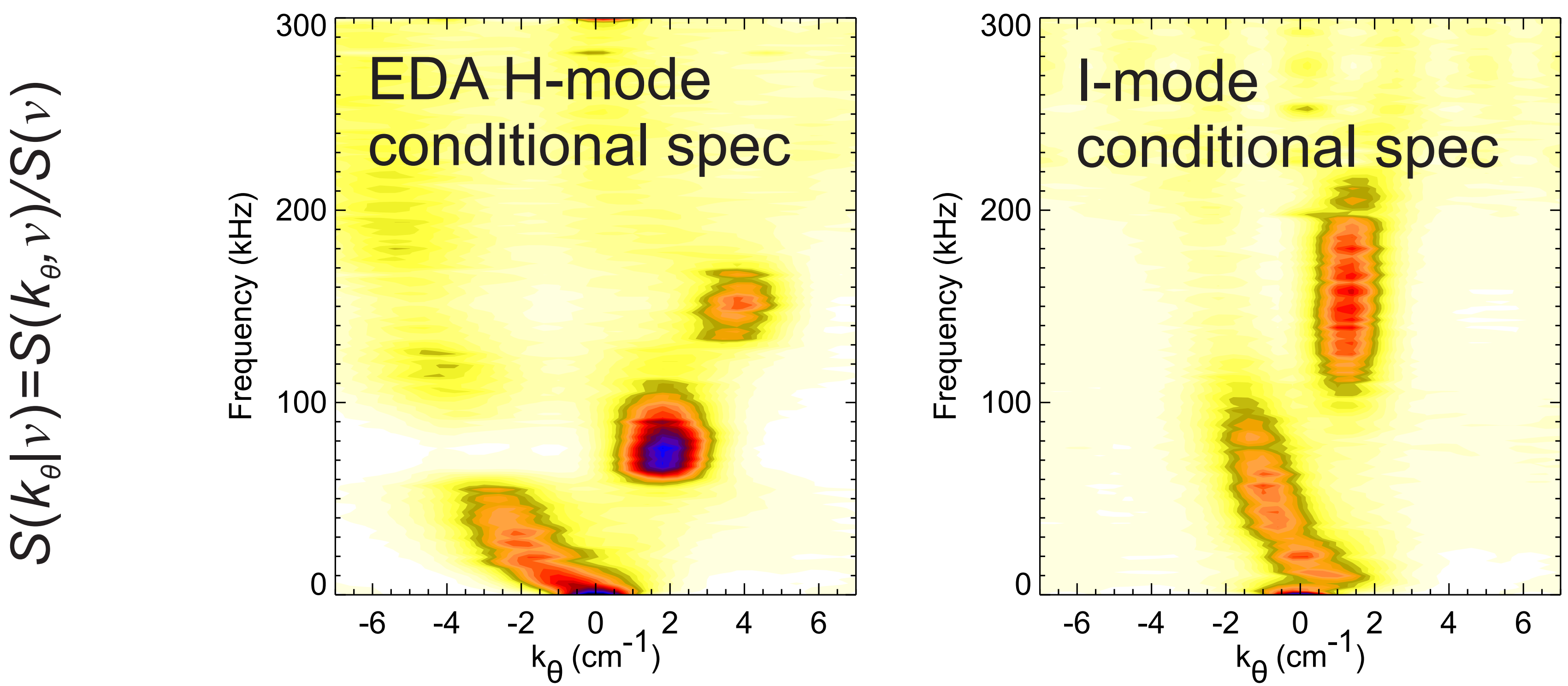
- gas puff injects neutral D_2, or He sensitive to n_e, T_e
- small toroidal extent (~5cm) allows localization
- 90 channels cover ~ 4.4cm x 4cm
- views coupled to APD arrays, sampled @ 2MHz

Top View



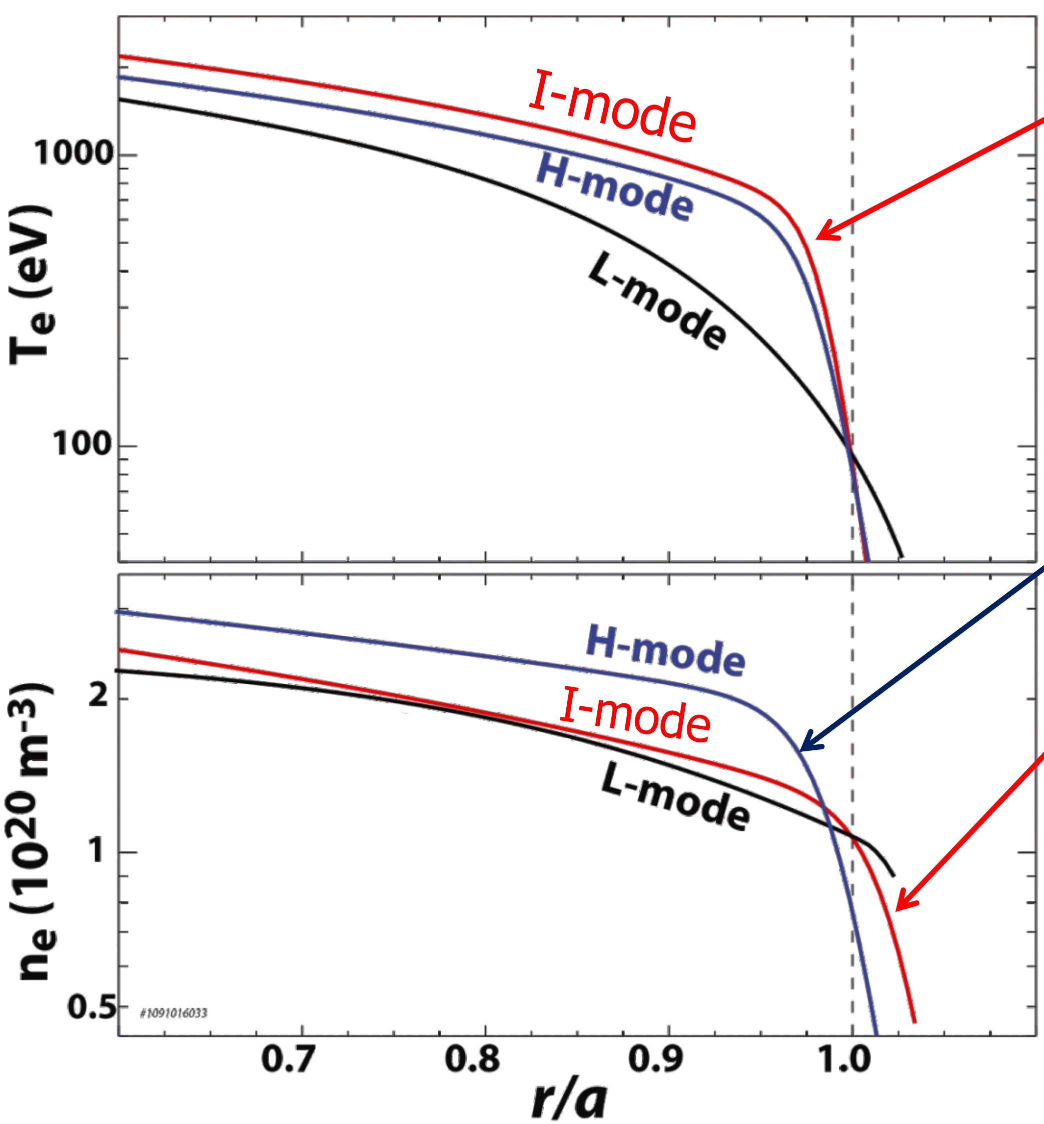
High confinement regimes with enhanced particle transport - EDA H-mode, I-mode

- In recent years both the EDA H-mode and the I-mode have started to be viewed as special high energy confinement regimes
- The QCM plays a significant role in regulating the edge transport and providing a non-explosive way of releasing impurities and relaxing the pedestal profile
- In the I-mode regime the WCM has been implicated as either a contributor to enhanced, essentially L-mode level particle transport or a part of the dynamics leading to the development of an energy transport barrier.



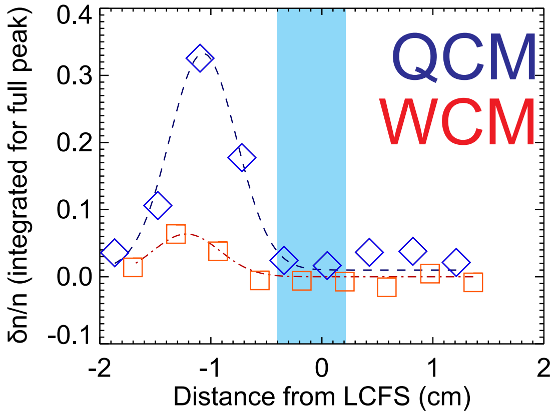
I-mode has T_e and T_i pedestal, no density barrier

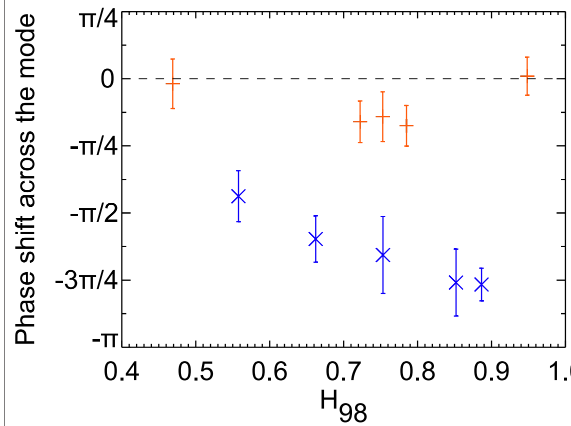
Edge/Pedestal/SOL Profiles

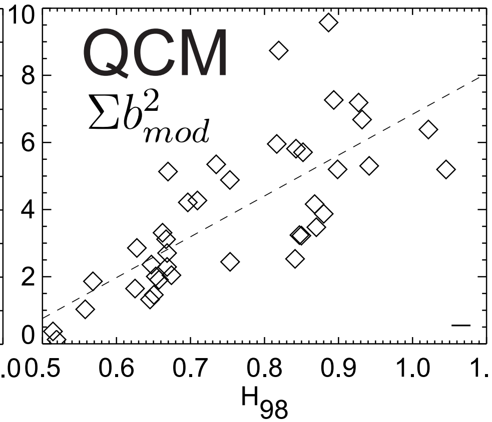


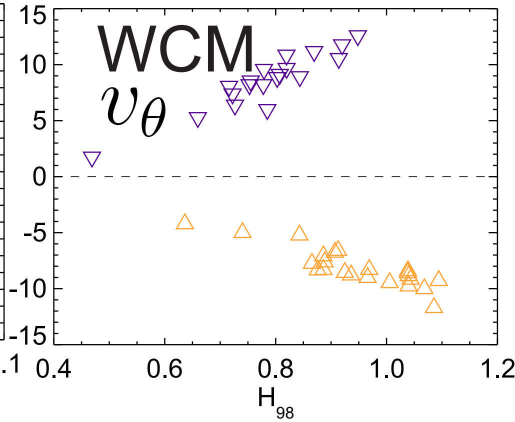
- Steep T pedestal (electrons and ions) leads to increased core T, stored energy
- H-mode has similar T pedestal, but much higher and steeper density pedestal.
- L-mode like density profile, broad SOL
- I-mode Access:
  - Unfavorable grad-B drift gives easiest access, largest operational window

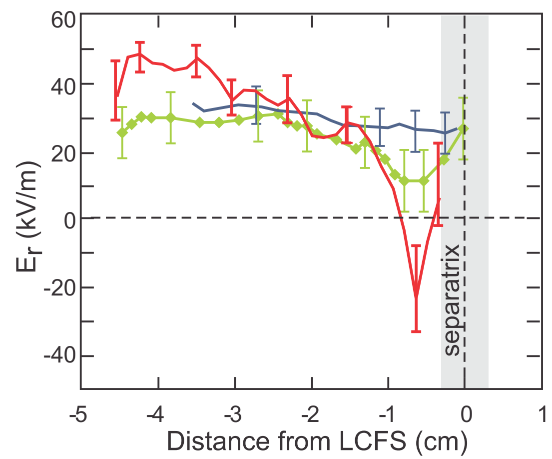
New results on the two fluctuations suggest flow shear is important in determining structure











The two features are radially localized to the same region where E_r well exists according to CXRS

- Both features show clear scaling with the confinement factor - known to scale with the depth of the electric well.
- The QCM develops a stronger and stronger harmonic structure
- The WCM speeds up linearly with the ExB drift

	$v^{\mathrm{mode}}_{\mathrm{lab}}$	E_r	$v^{\mathrm{mode}}_{\mathrm{plasma}}$
QCM	2.5 km/s	-44.5 ± 15 kV/m	-4.5 to -13.5 km/s
WCM	10.1 km/s	-20 to 18 kV/m	4.5 to 14.5 km/s

The propagation in the opposite directions is further corroborated by the typical onset spectrograms, showing the QCM spin down and the WCM spin up as their respective high confinement regimes develop from an L-mode plasma.