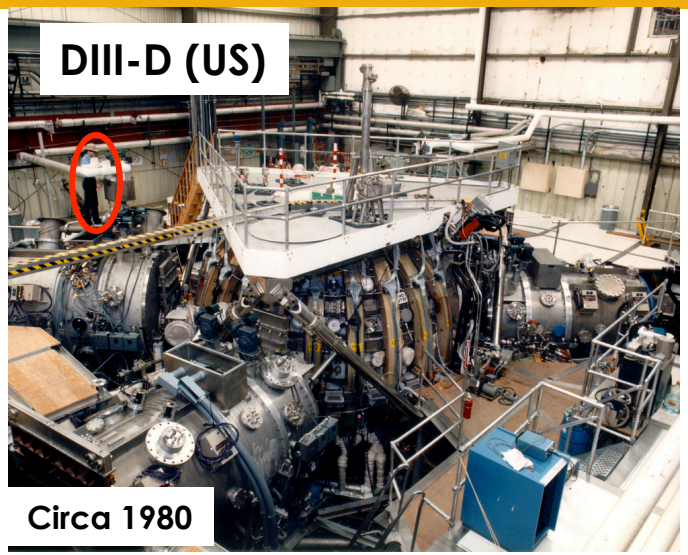
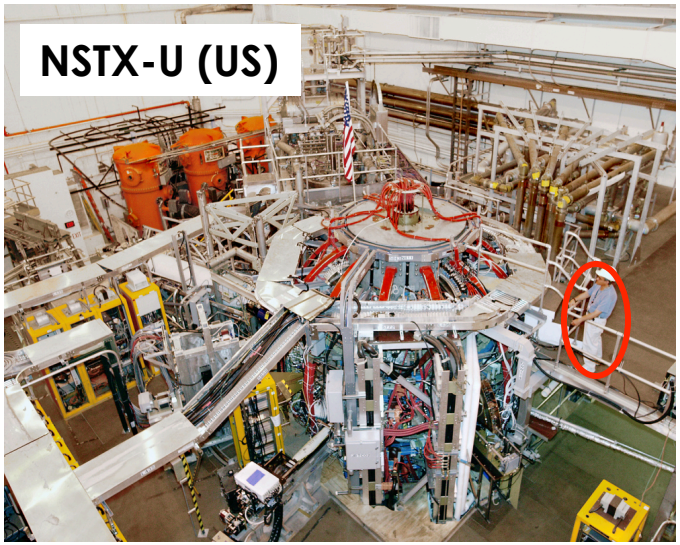
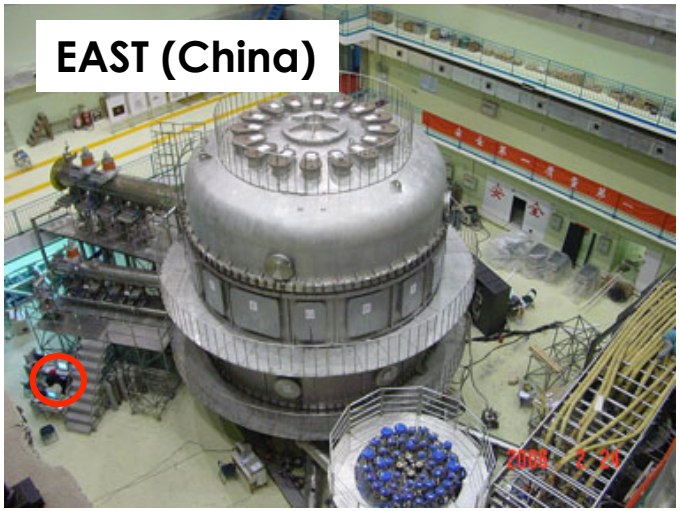
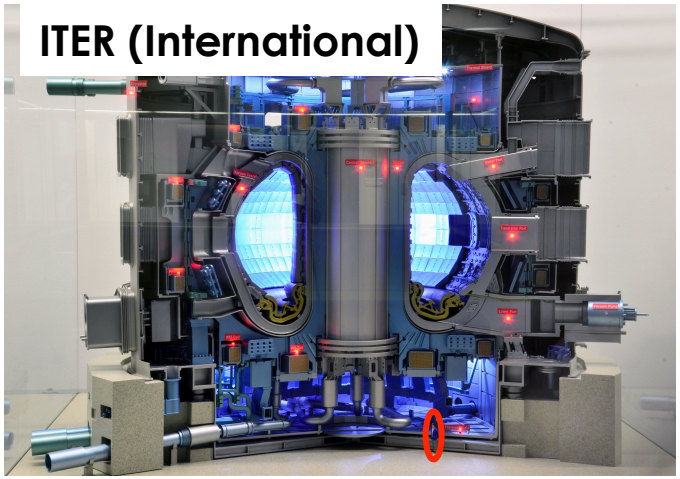
UCLA diagnostic development and plasma physics on fusion research devices around the world









Terry L. Rhodes

Physics and Astronomy Dept., UCLA and

Plasma Science and Technology Institute

For the Plasma Diagnostics Group, UCLA

Presented at the UCLA Plasma Fest 2015

UCLA

Strong education component located at the two premier fusion plasma research devices in the US – DIII-D and NSTX-U

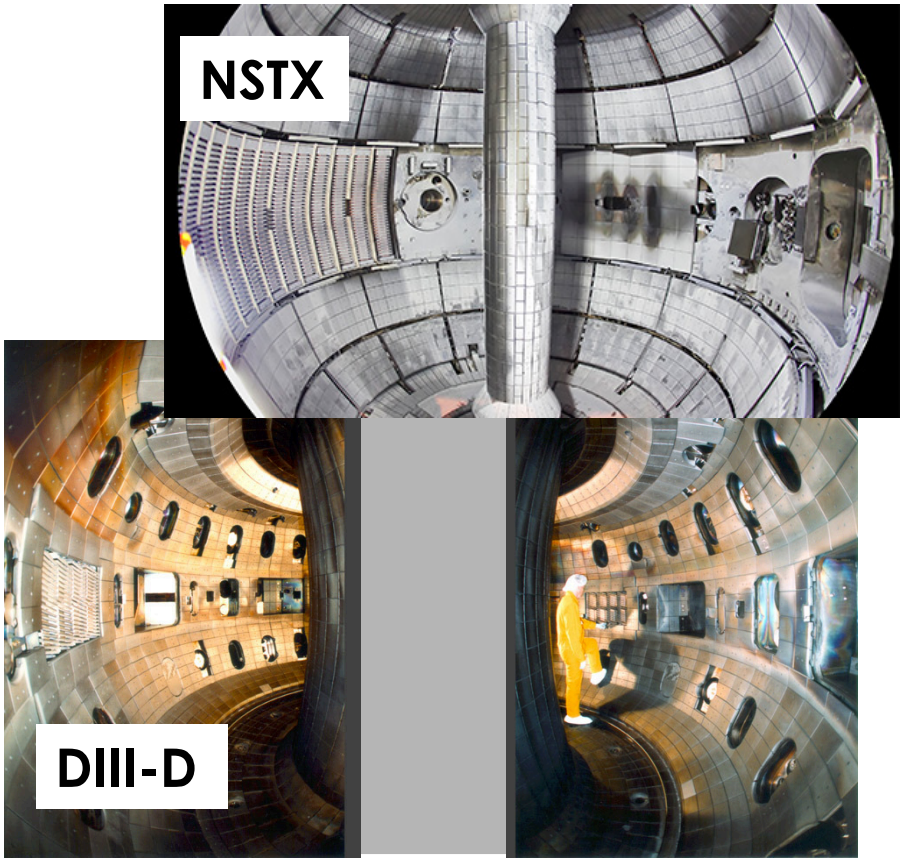
Large effort led over the years by Dr. Tony Peebles – now Emeritus Researcher

Researchers (10)

WA Peebles (PI)
EJ Doyle (PI)
L Schmitz (PI)
N Crocker (PI)
T Rhodes (PI)
S Kubota
G Wang
L Zeng
K Barada
C Sung

Prof/Graduate Advisor

T Carter



- Graduate students
  - Mr. Laszlo Bardozci
  - Ms. Shawn Tang
  - Mr. Jeff Robertson
- Postdocs
  - Dr. Kshitish Barada
  - Dr. Choongki Sung
- Previous students (7)
  - Dr. Jon Hillesheim
  - Dr. Jie Zhang
  - Prof. Anne White, MIT
  - Prof. JH Lee, Korea
  - Prof. KW Kim, Korea
  - Dr. Curt Rettig
  - Dr. Tom Lehecka

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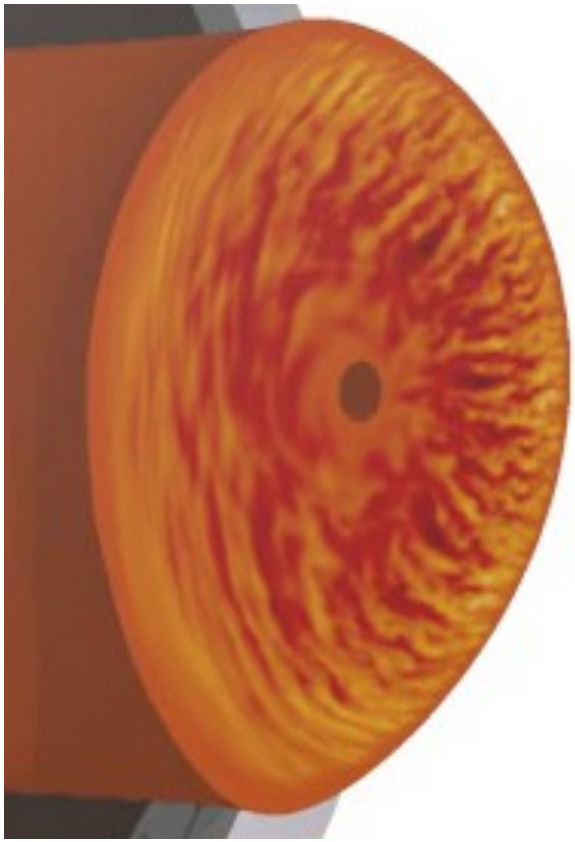
Broad range of diagnostics developed measuring both mean and fluctuating values

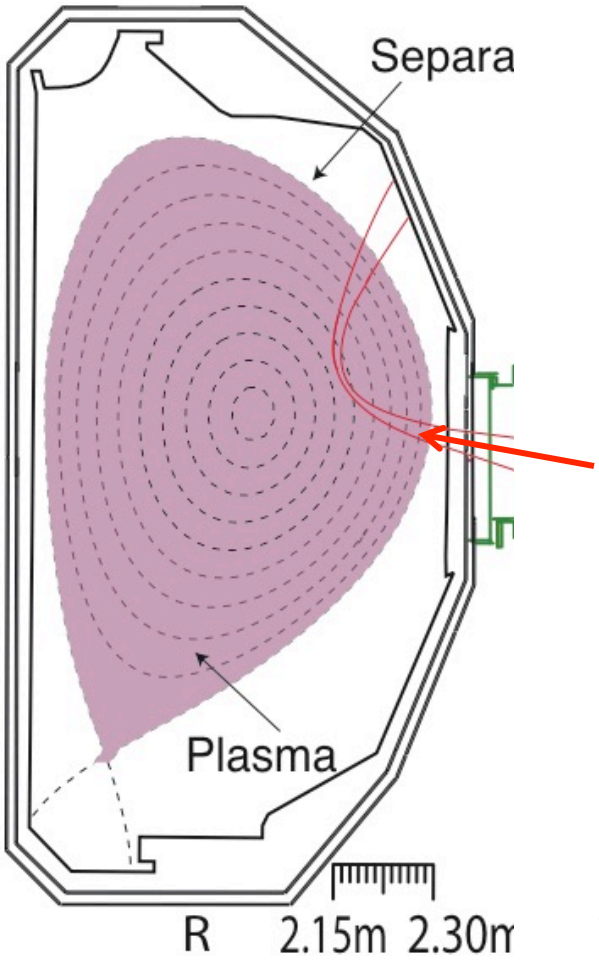
Cross section of tokamak

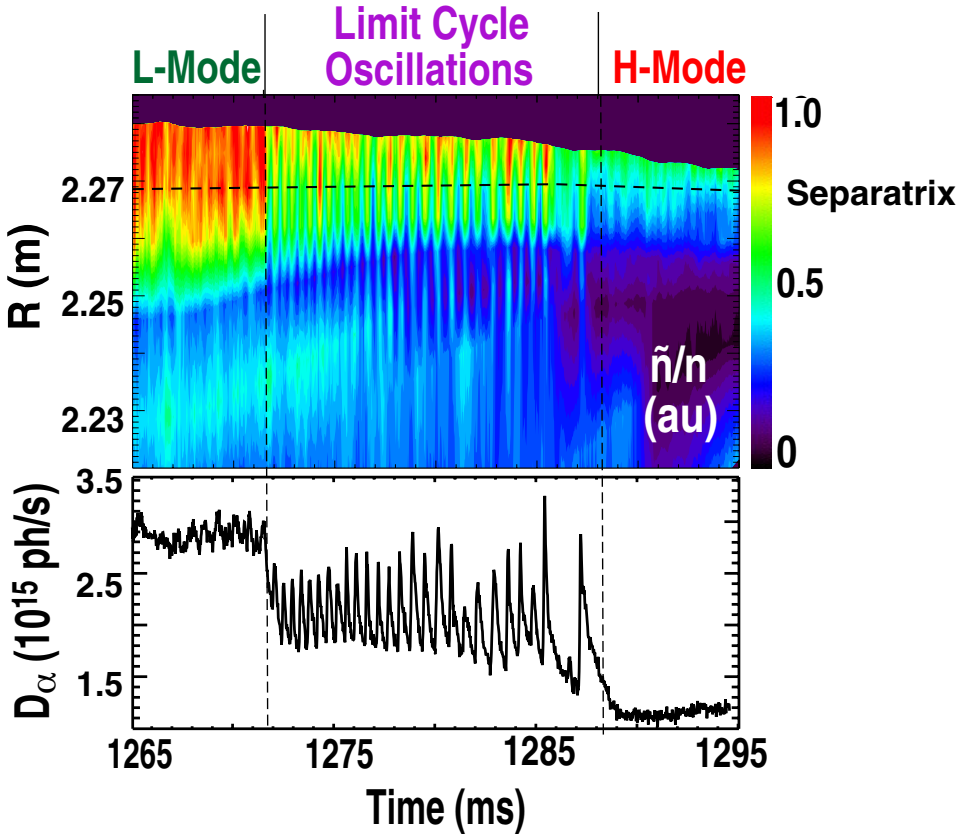


GENE turbulence simulation

Measurement	Diagnostic	Machine	method	Freq.
density fluctuations, **ExB** & zonal flows	Doppler backscattering	DIII-D, NSTX-U, ITER	scattering	33-96 GHz
temperature and its **fluctuations**	Correlation ECE	DIII-D	Emission	80-110 GHz
MHD mode structure	Fluctuation reflectometry	NSTX-U	Scattering	33-75 GHz
Internal **magnetic fluctuations**	cross-polarization scattering	DIII-D	Scattering	50-75 GHz
Density profile, particle transport	Profile reflectometry	DIII-D, NSTX, ITER, LTX	Phase delay	12-140 GHz
magnetic field and its **fluctuations**	polarimetry	NSTX, DIII-D	Polarimetry	288 GHz
average density	interferometry	NSTX-U, LTX	Phase delay	288 GHz
density fluctuations	Forward scattering	DIII-D, NSTX, LTX	Scattering	288 GHz

Doppler backscattering (DBS) measures intermediate-k ñ and flows revealing fine-scale structure of turbulence (T Peebles, PI)





Lothar Schmitz et al, PRL 108, 2012

- Some interesting questions include what is the drive term/s for this turbulence, are all transitions similar but with different time scales, what is dependence on working ion species

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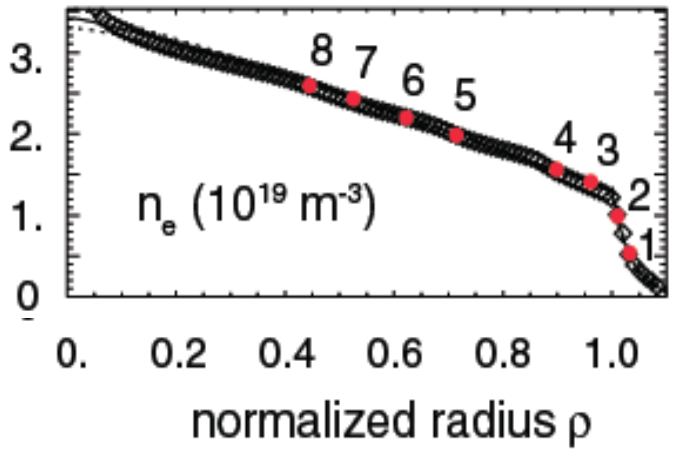
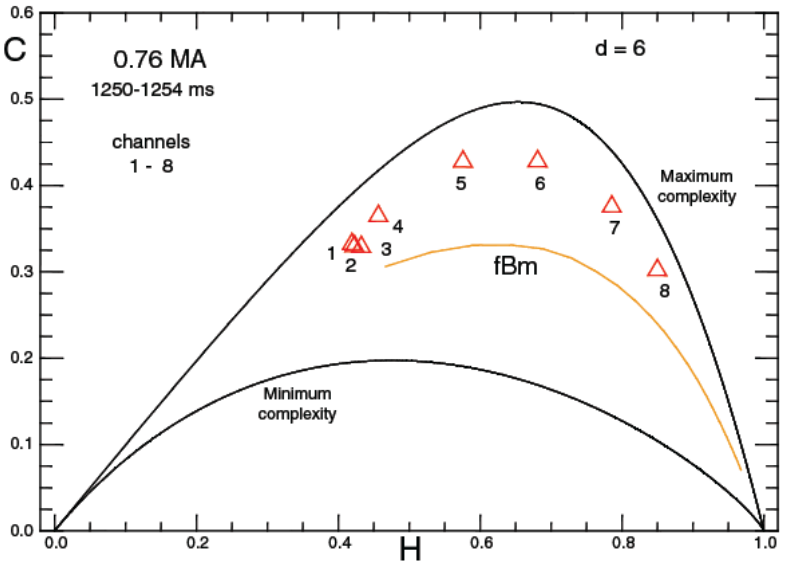
Density fluctuations found to be chaotic across large radial region on DIII-D tokamak



complexity-entropy plane (C-H plane)



- **Maggs, Rhodes, and Morales, Plasma Phys. Control. Fusion 57 (2015) 045004**
- **Questions include – somewhat similar results seen in TJ-K stellarator- how ubiquitous is this, what is type of turbulence involved, how well do first principles simulations reproduce this, are similar results found in "high-confinement" regimes?**

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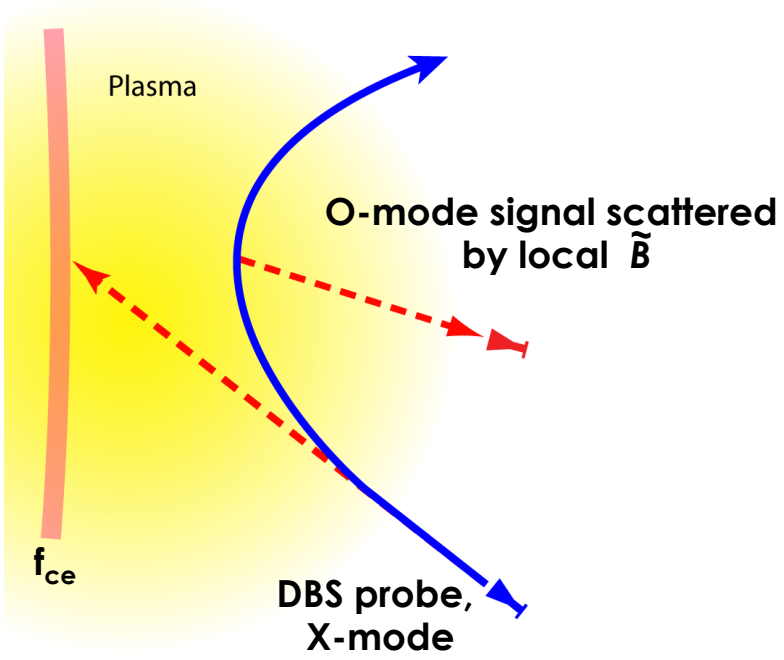
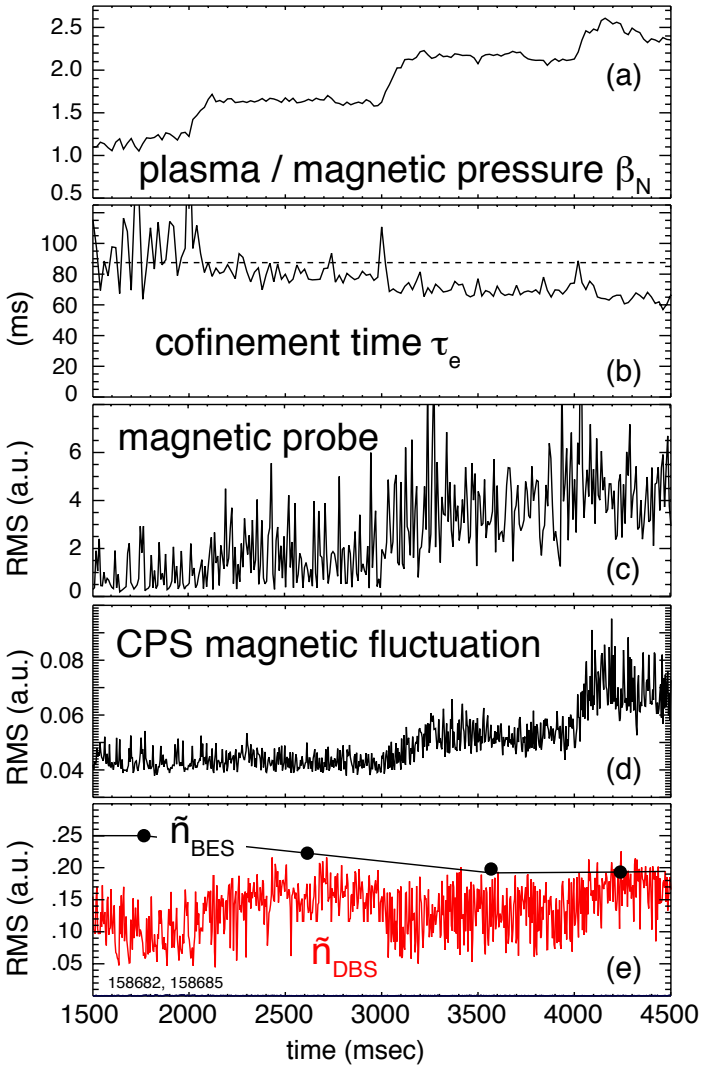
Cross-polarization scattering (CPS) measures internal magnetic fluctuations via E_{probe} generation of $J_{perp} \sim E_{probe} \times B_{fluctuation}$ (Rhodes, PI)





- **Behavior appears consistent with some known instabilities.**
- **Questions include - do other instability regimes have a strong magnetic component, how well do simulations reproduce this, …**
- **Kshitish Barada is currently working on an eight channel CPS system for DIII-D.**

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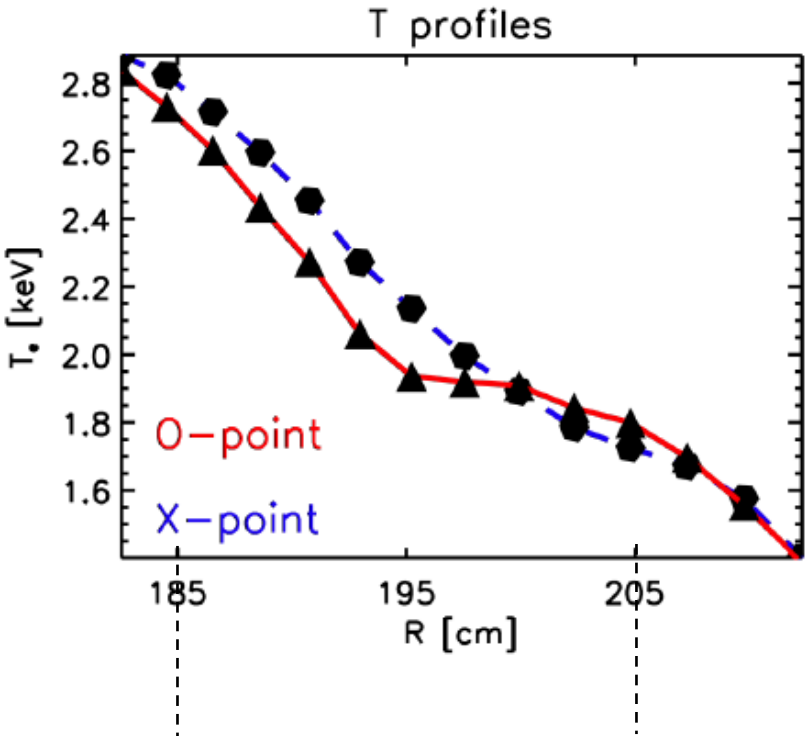
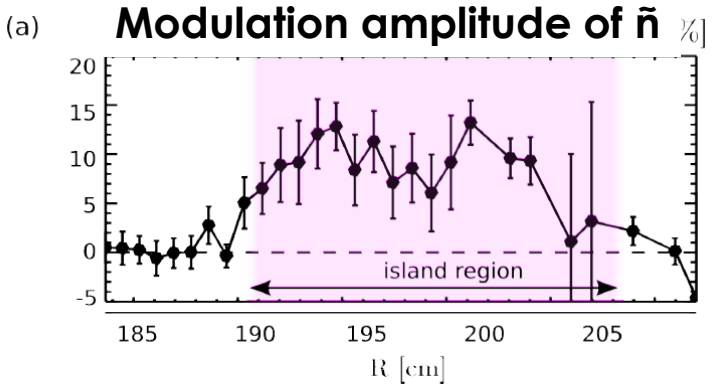
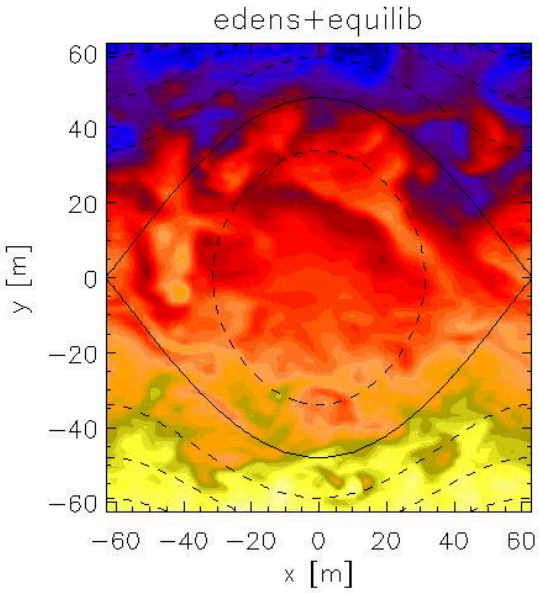
Internal MHD found to modulate local density fluctuations consistent with local changes in transport





- Work by László Bardóczi is the first reported on a local change in ñ due to tearing mode
- Fluctuation change appears consistent with change in drive (temperature gradient)
- Initial comparisons to non-linear GENE calculations appear to confirm this.
- Interesting questions include - how does this turbulence and the MHD interact, do they reinforce or inhibit each other, can one be used to control the other, etc.
- Journal article is being prepared on this



GENE simulation,
A. Bañon Navarro

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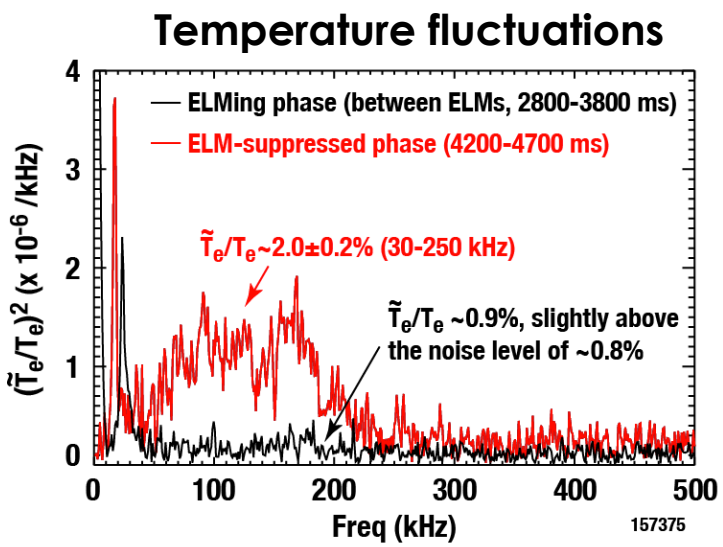
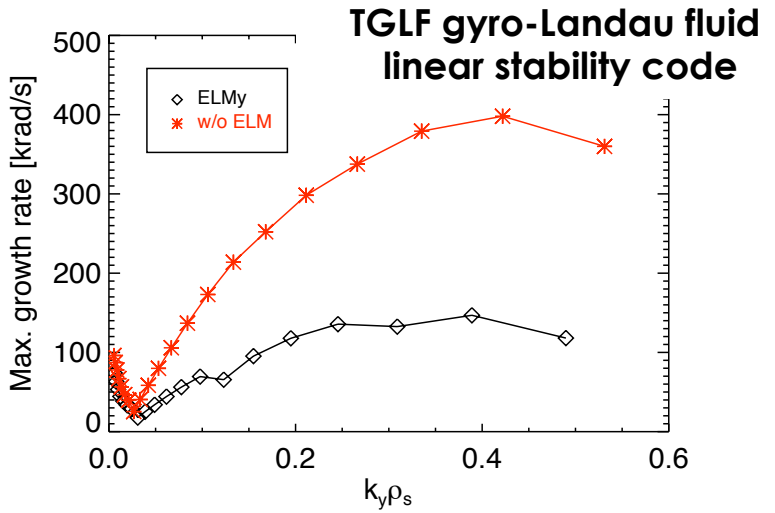
During suppression of edge instabilities (ELMs), broadband T_e fluctuations measured by CECE double at r/a~0.95





- Work by Choongki Sung and Guiding Wang find increased Te fluctuations which may be replacing transport by suppressed ELMs.
- Increase in simulation linear growth rates consistent with measurements (C.S.)
- Choongki Sung is currently working on an eight channel CECE system for DIII-D
- Interesting questions include what is the contribution of this turbulence to transport, can simulations replicate this behavior, what causes initial suppression of the edge instabilities, etc.

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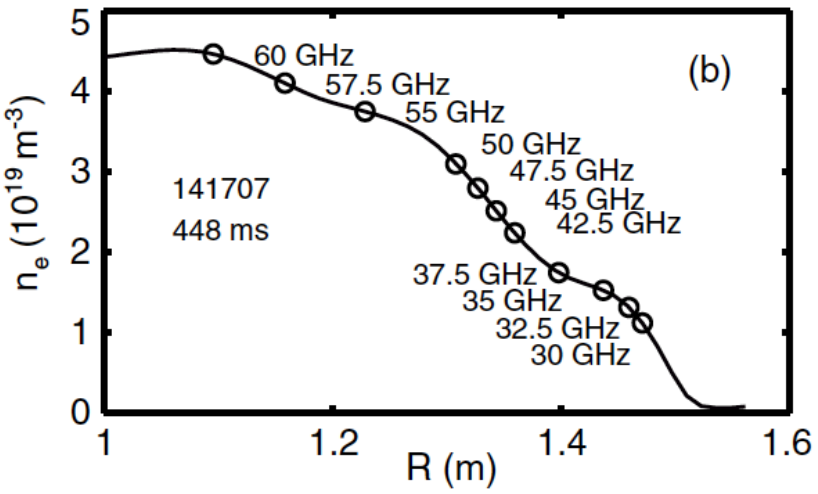
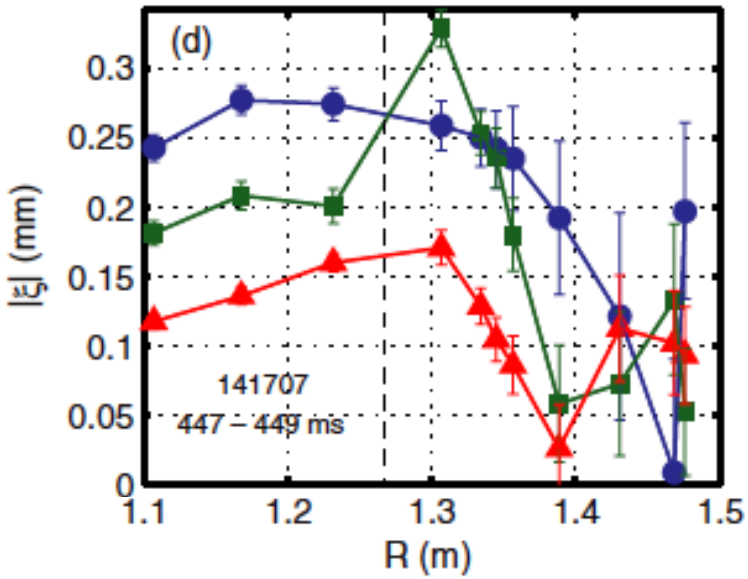
Internal Alfvén mode structure measured on NSTX by fluctuation reflectometer (Neil Crocker, PI)





- **Also, Shawn Tang is extending (Fredrickson, NucFus '14) to include CAE & GAE activity: amplitude, toroidal mode number, frequency to investigate stability of CAEs and GAEs and contribution to electron thermal transport.**

Crocker, et al., 2011 Plasma Phys. Control. Fusion 2011

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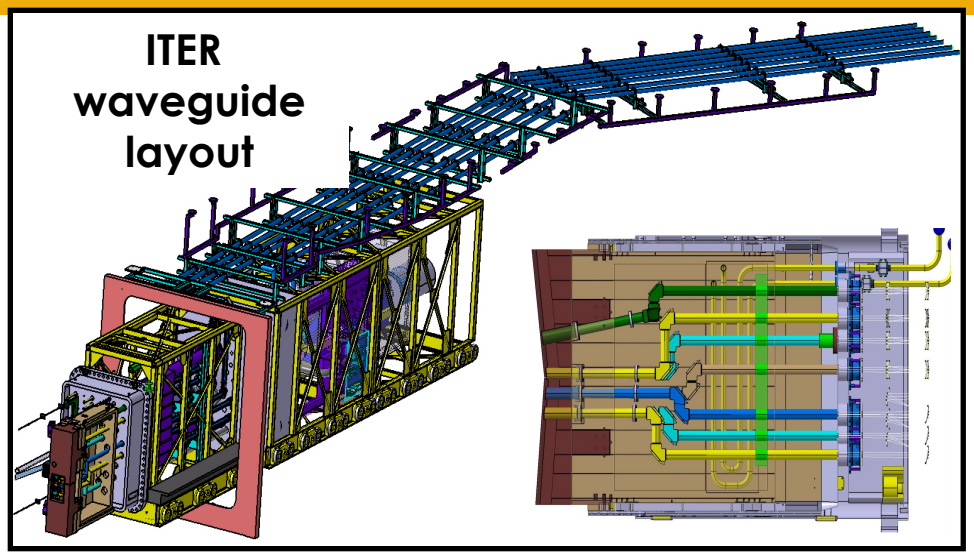
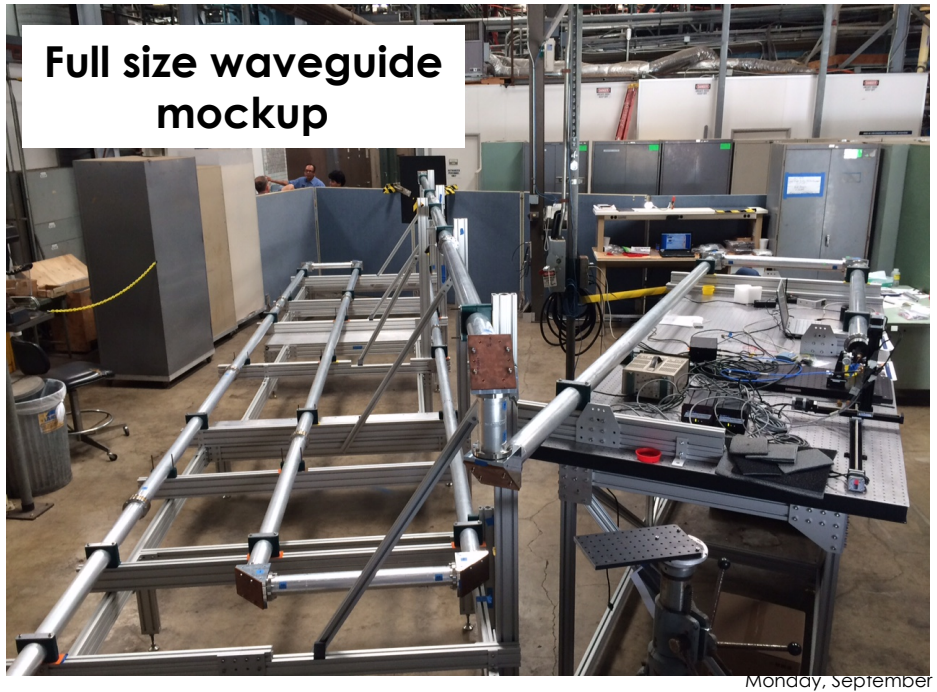
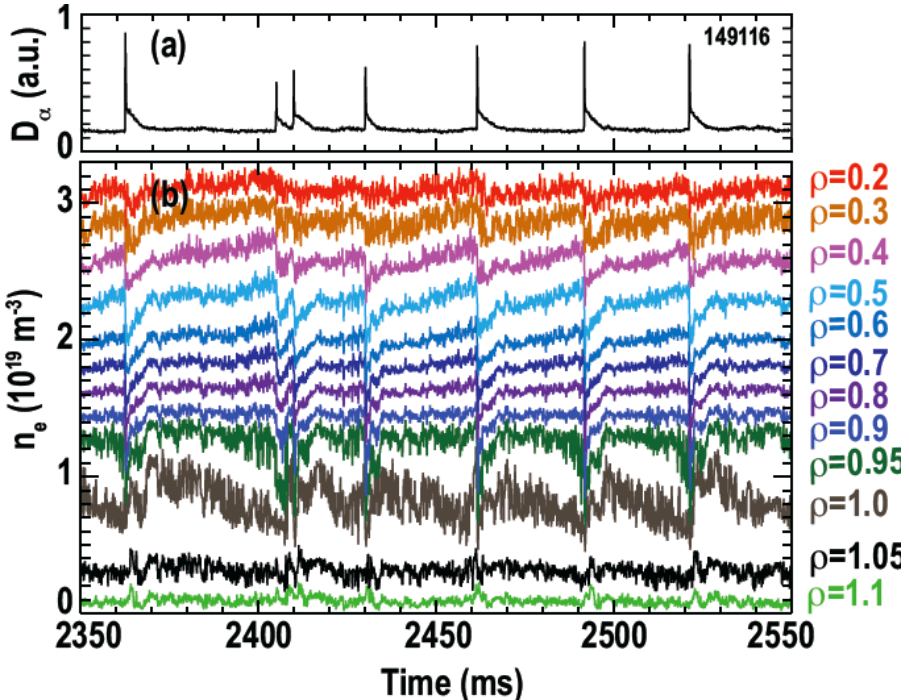
ITER low field side reflectometer mockup and tests underway by UCLA team (Ed Doyle, PI)





- Proof of principle system demonstrated on DIII-D
- High time, space resolution (25μs, <1cm) density reflectometer resolves very fast instability events (ELMs) in DIII-D plasma
- On ITER, 40 m corrugated circular waveguide, 6.35 cm diameter



In conclusion, UCLA engaged in a multi-machine effort involving education and training of students and postdocs with interesting science and technology

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