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# Gas-Puff-Imaging on Alcator C-Mod

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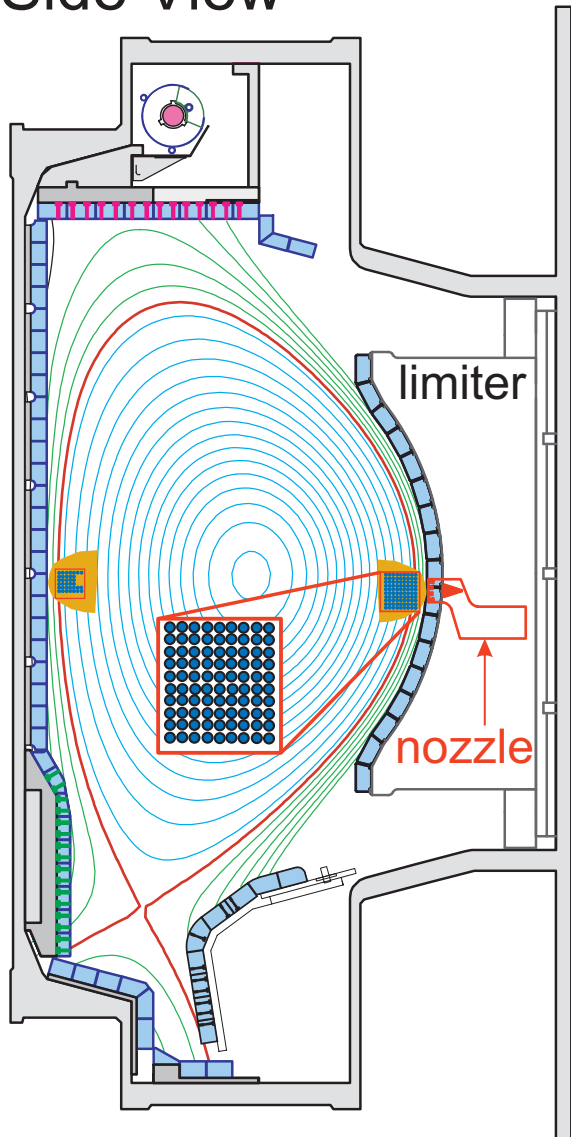
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Pedestal Workshop 7-8 September 2010

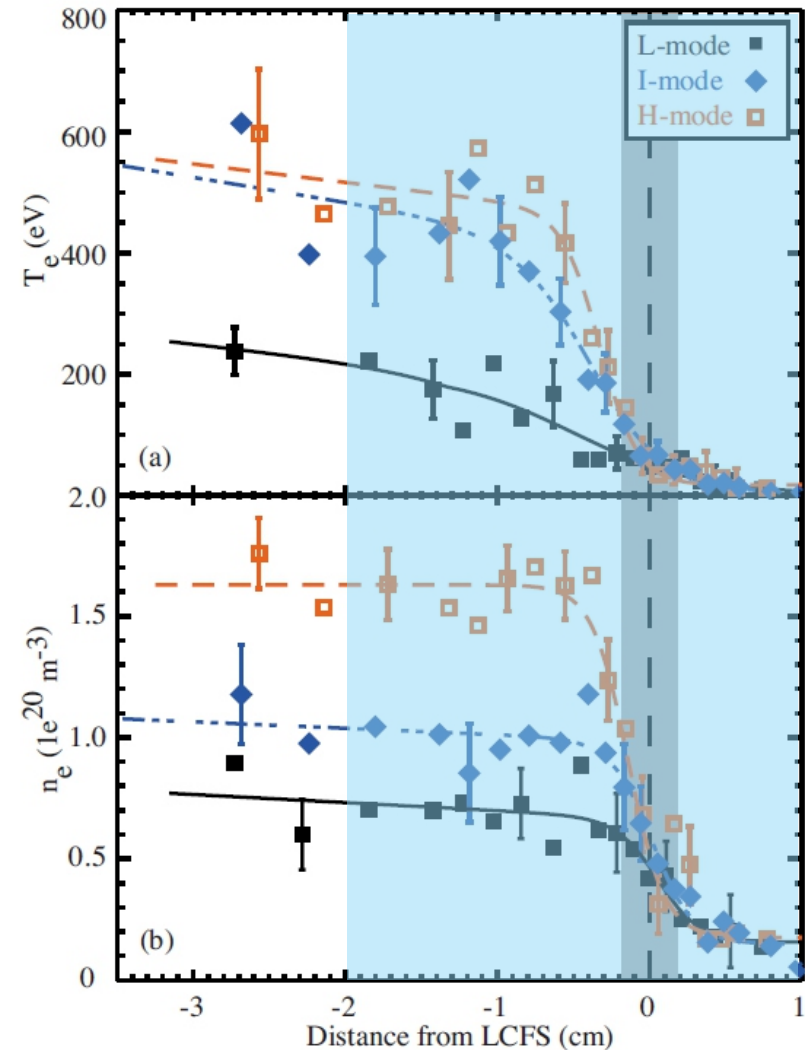
# Experimental setup

## Gas-Puff-Imaging diagnostics

### Side View



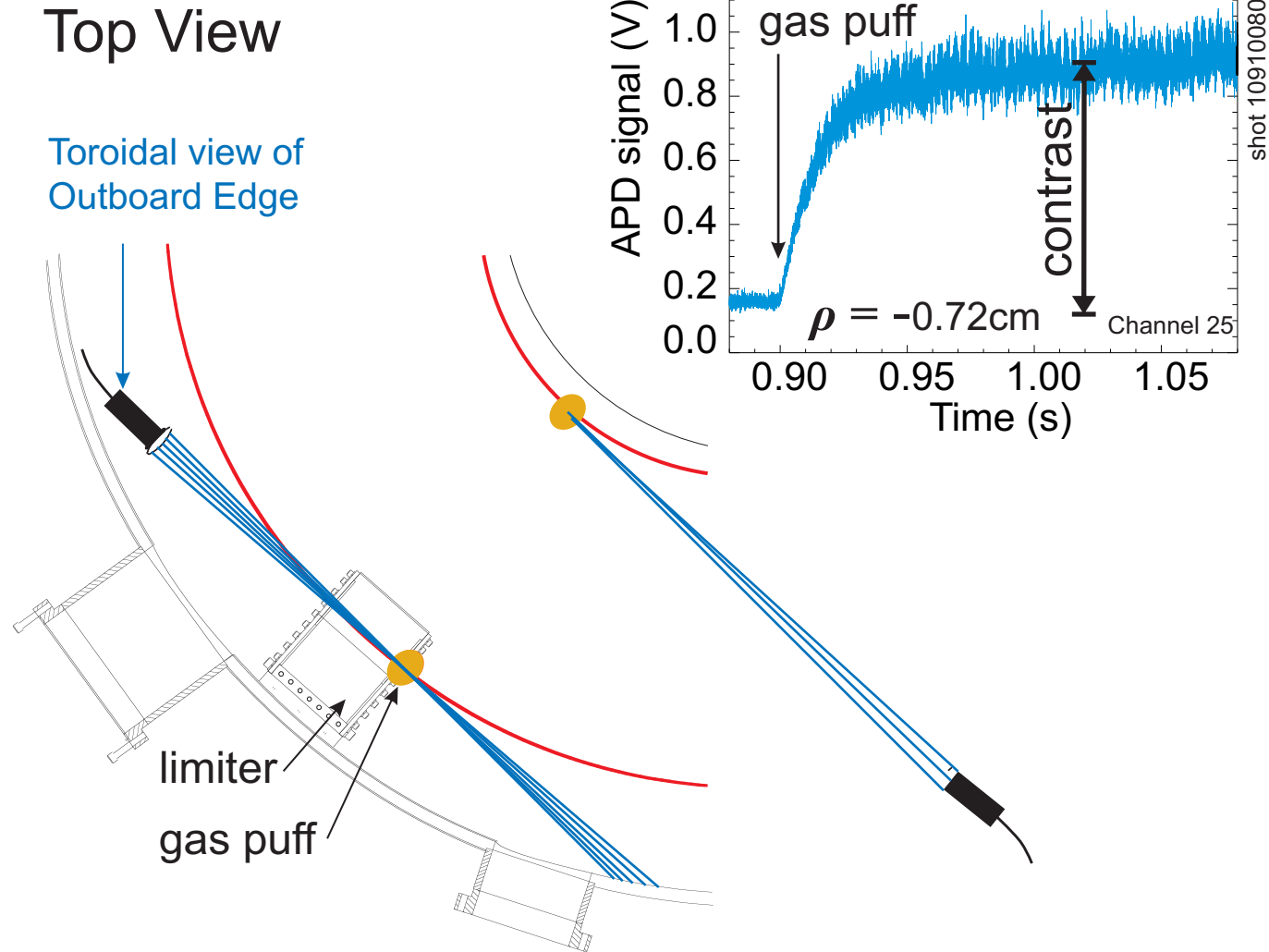
- 90 outboard channels cover  $\sim 4\text{cm}$  (radial) x  $4.4\text{cm}$  (vertical)
- LoS horizontal
- outboard views coupled to APD arrays, sampled @  $2\text{MHz}$
- 23 inboard views coupled to PIN photodiodes, @  $1\text{MHz}$
- $k_{\text{pol}} < 7\text{cm}^{-1}$
- $\delta k_{\text{pol}} \sim 0.3\text{cm}^{-1}$



# Experimental setup

## Gas-Puff-Imaging diagnostics

- gas puff injects neutral  $D_2$ , He sensitive to  $n_e$ ,  $T_e$
- small toroidal extent ( $\sim 5\text{cm}$ ) allows localization:
- $\sim 4\text{mm}$  radial
- $\sim 5.5\text{mm}$  vertical
- puffing minority species affords high contrasts (x200 instead of x5)

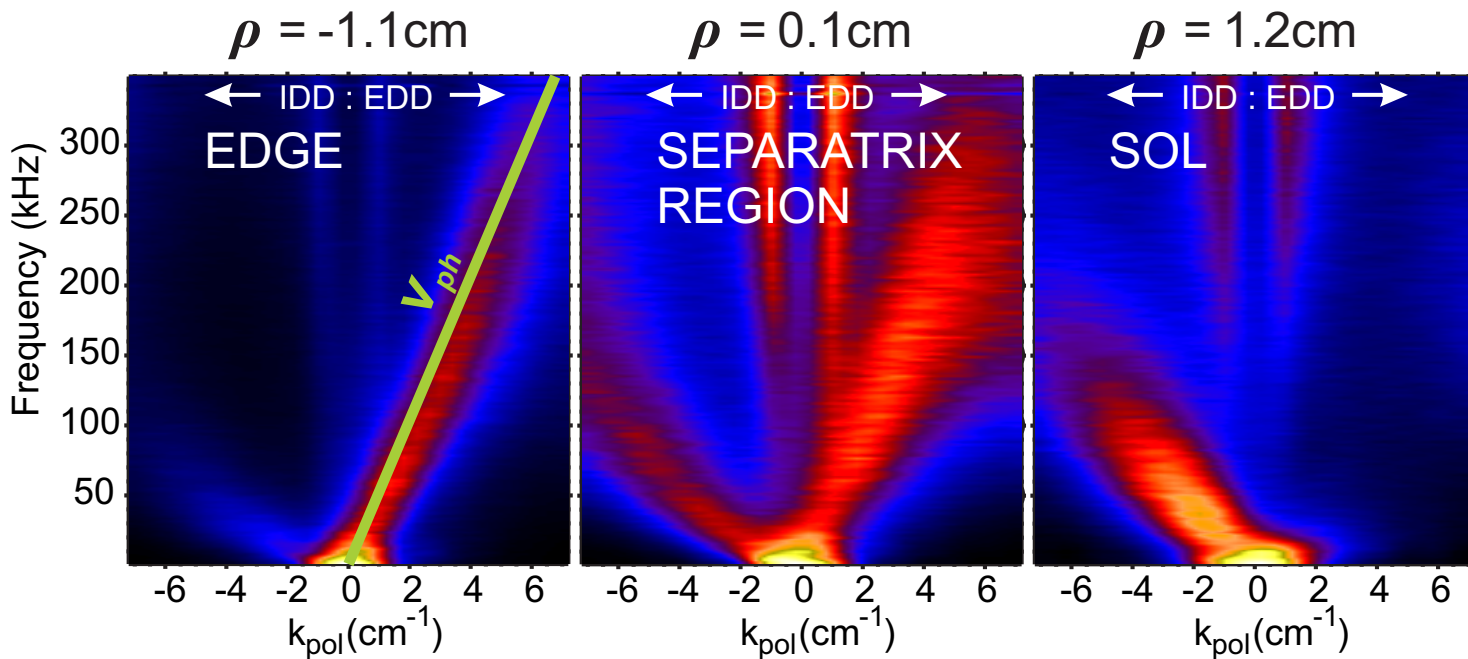
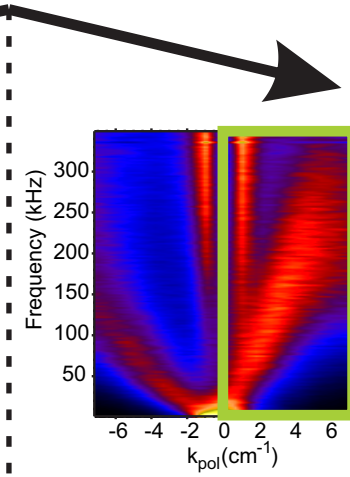


# Complete wavenumber frequency spectra decomposed into empirical dispersion and total power spectra

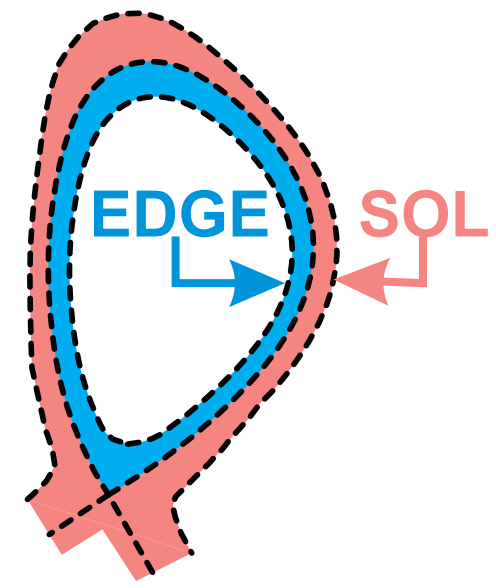
poloidal arrays + time history:  $S(k_\theta, \nu)$

- $S(k_\theta|\nu) = S(k_\theta, \nu) / S(\nu)$
- Shows dispersion and dominant frequencies
- Dispersions are found to be very nearly linear:
- $k_\theta(\nu) \rightarrow v_{ph} = 2\pi\nu / k_\theta$

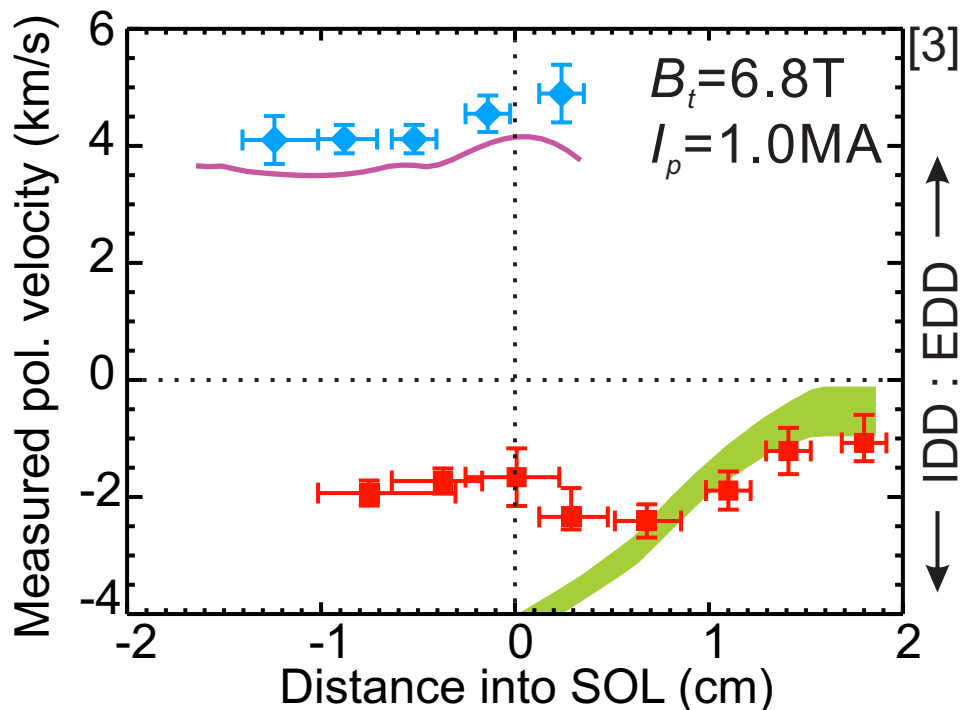
- $S(\nu) = S_{k<0}(\nu) + S_{k>0}(\nu)$
- Shows power spectra
- Characteristic scales can be seen



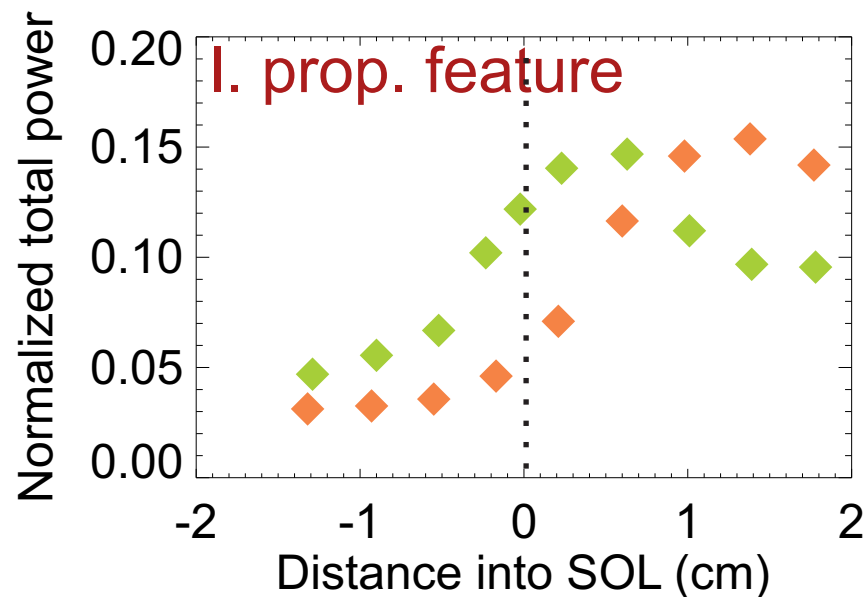
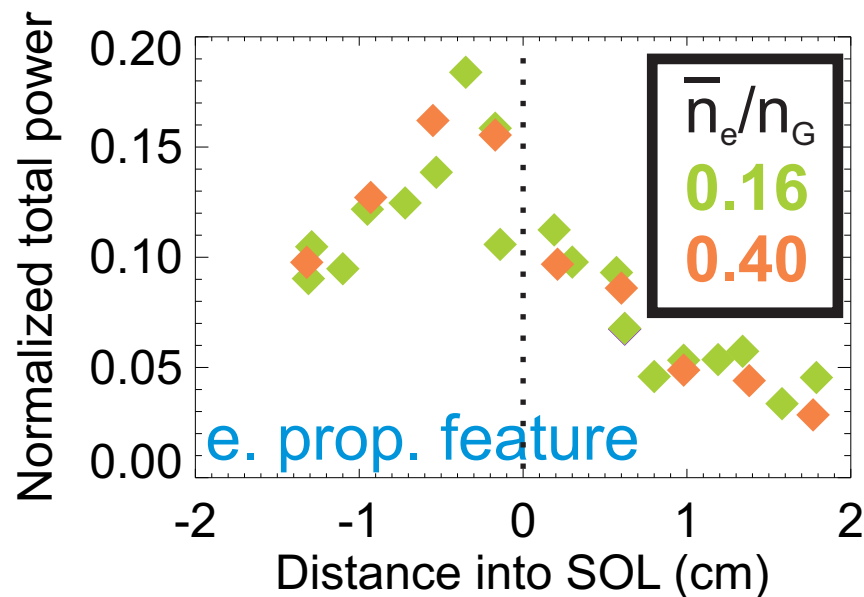
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EDD velocity in edge is close to  $\omega_* / k_{\text{pol}}$   
 far SOL IDD velocity matches ExB (expected for blobs)

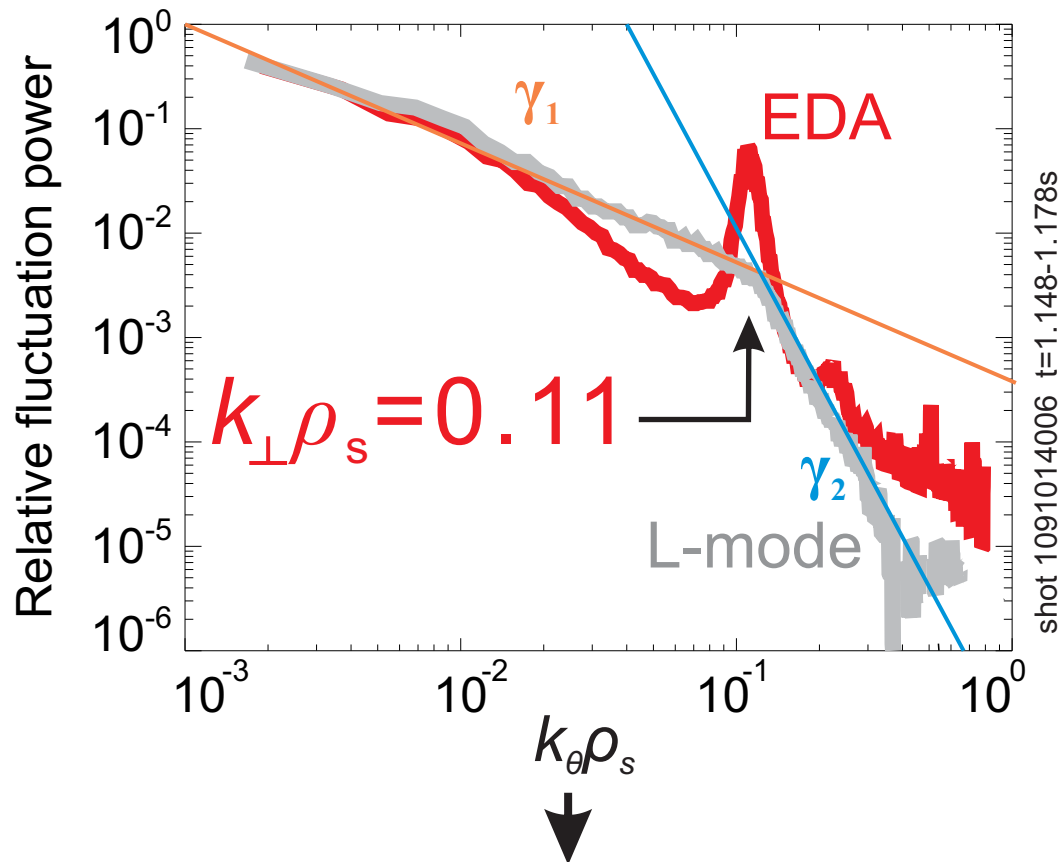


- **EDD propagation in the edge** is close to the **electron diamagnetic flow velocity estimated from TS profile**
- Poloidal velocity in the far SOL where **blobs** are seen matches **ExB velocity estimated from probe measurements**
- Overlap region between the two features



# Wavenumber filtered spectra $S_{k>0}(\nu)$ can yield information on underlying dynamics

## EDD propagating part



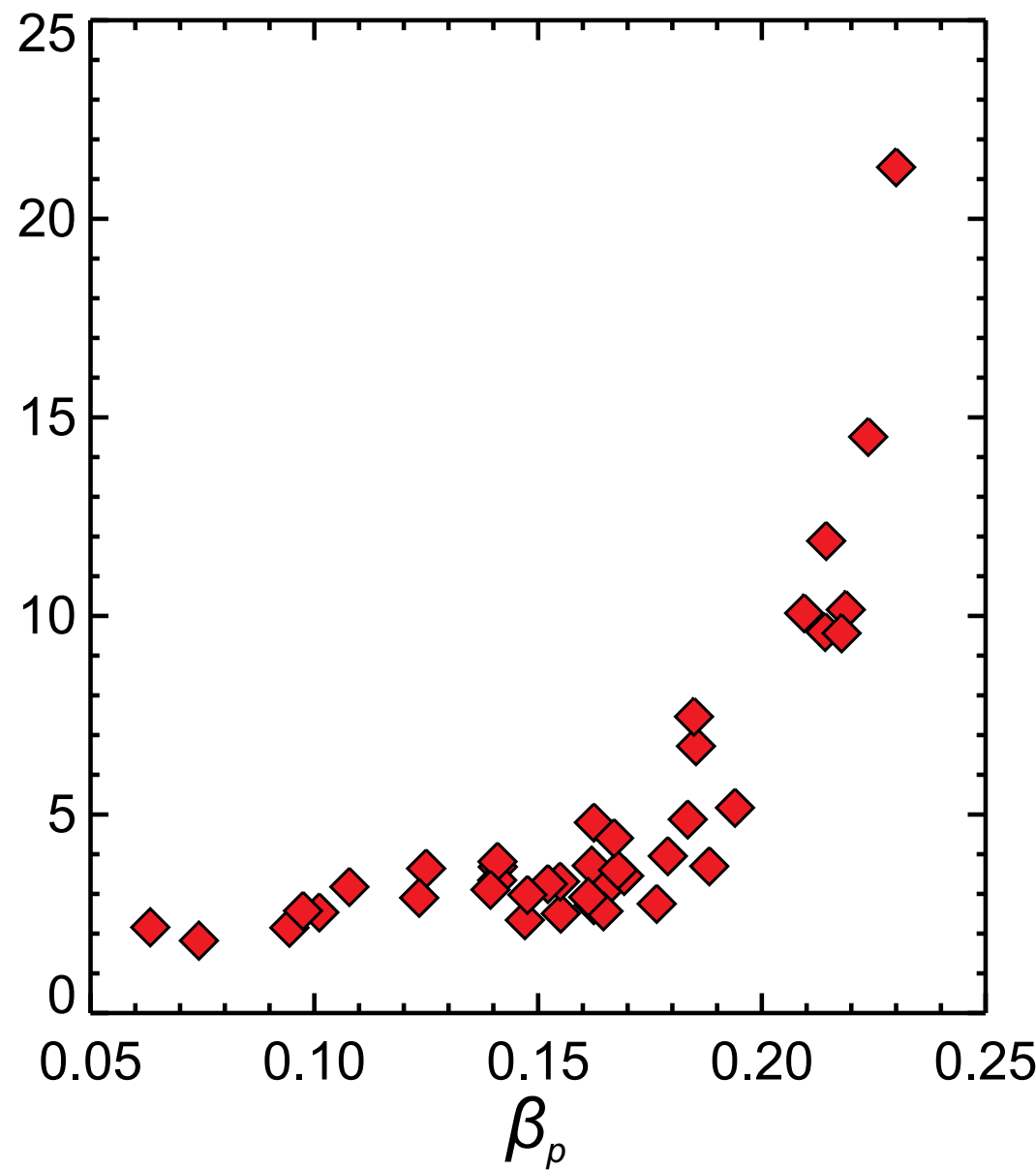
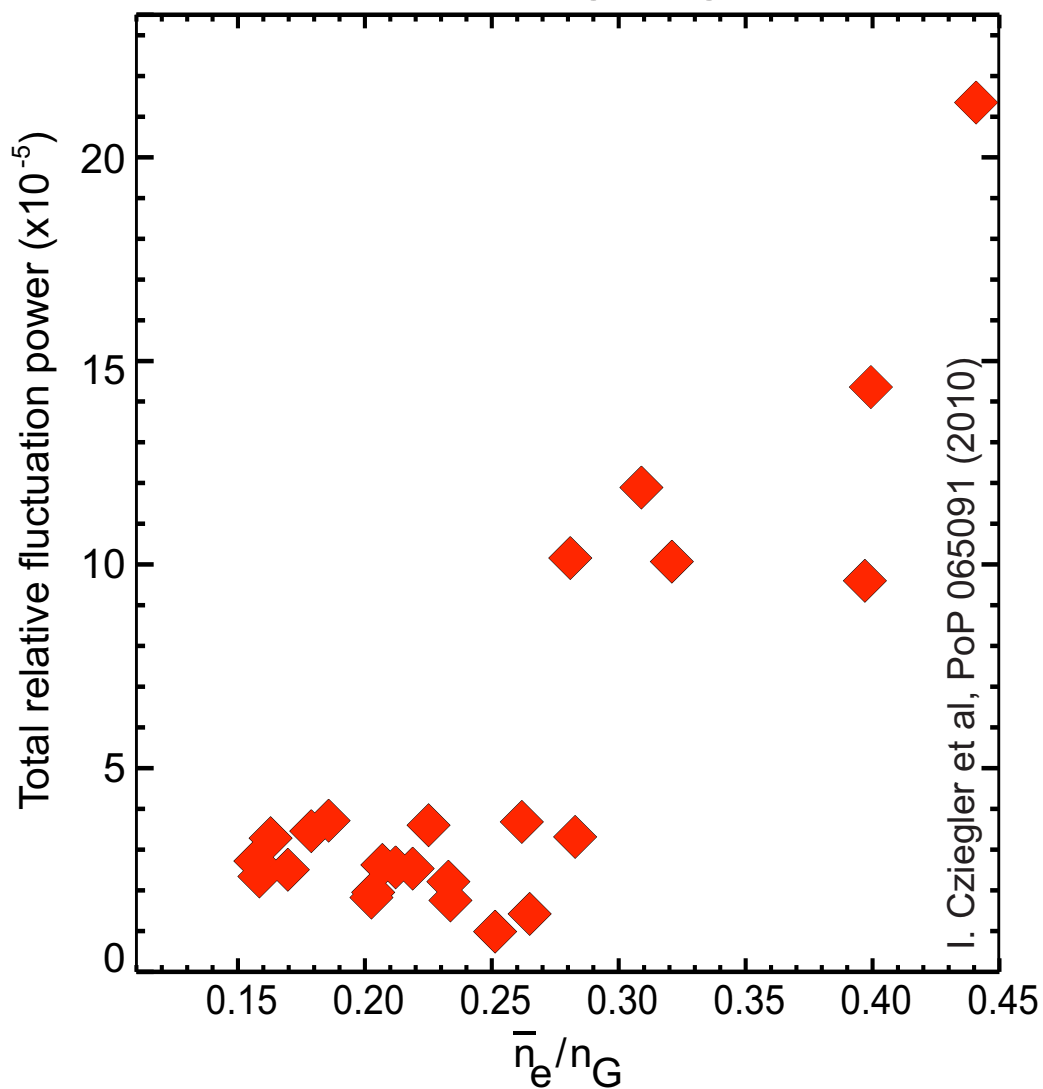
isotope tests would be interesting

- Edge spectra often power laws
- Spectral indices are fairly reproducible - spectral transfer?
- Break-in-slope  $\nu^c$  may indicate:
  - dissipation scale
  - scale of energy input
- In the latter case:
  - $\gamma_1$  indicates “inverse cascade”
  - $\gamma_2$  indicates “forward cascade”

Total power of EDD turbulence observed to increase as a function of  $\beta_p$  or Greenwald fraction, consistent with turbulence driven transport

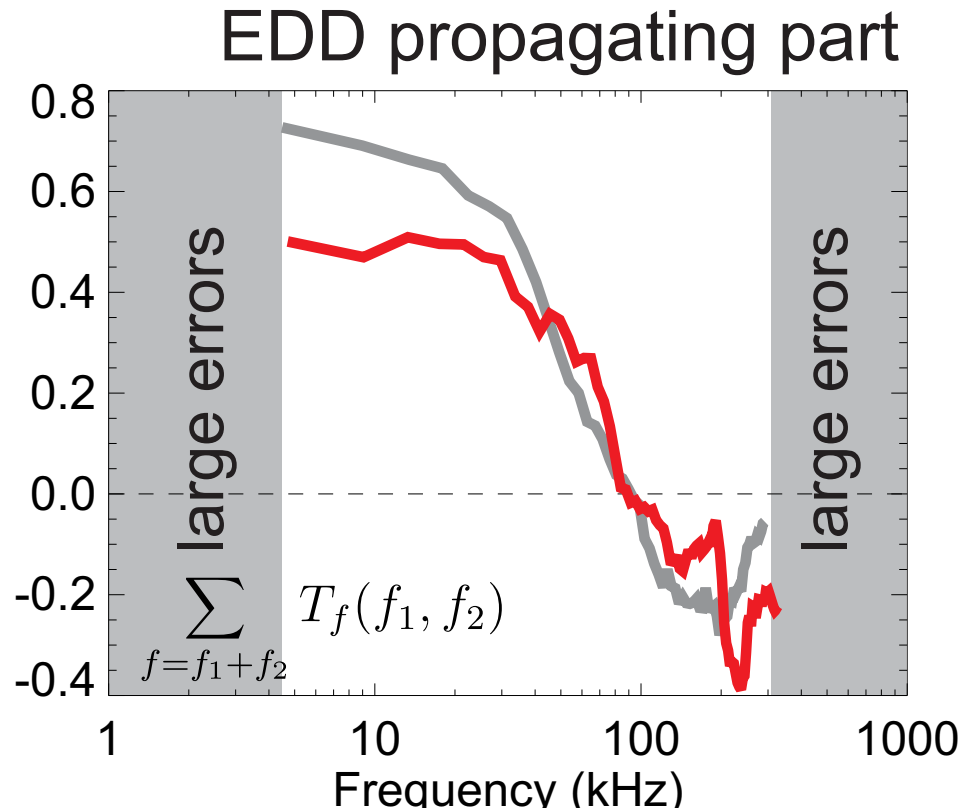
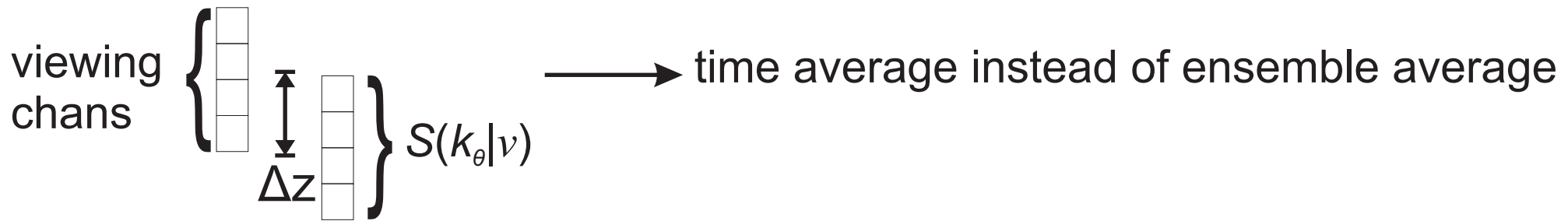
## EDGE REGION

EDD propagating part



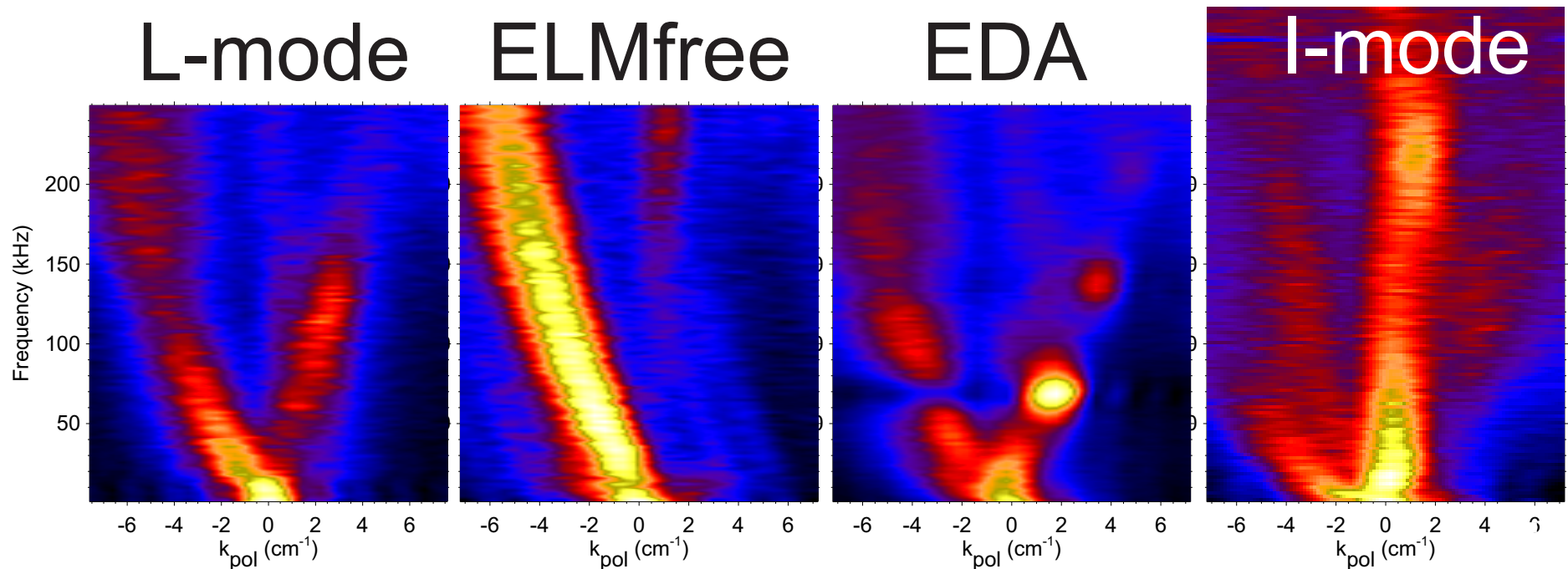
# Low noise levels allow bispectral analysis over a large spectral region: energy input at the same scale for H-mode and L-mode

From  $S(k_\theta|v)$  we can move to spatial separation rather than time using  $k_\theta(v) \rightarrow v_{ph} = 2\pi v/k_\theta$ , and the appropriate Galilean transformation for the velocities.





All confinement regimes found to have “fingerprint” turbulence patterns in the pedestal - JFT-2M shape, ELMy regime is still missing



Due to the vertical arrays of views spanning the pedestal, ELM precursors are expected to be visible and their poloidal wavenumbers to be resolved - what characteristics of the models (P-B, KBM, etc) are testable?