Electron gyro-scale fluctuations in NSTX plasmas

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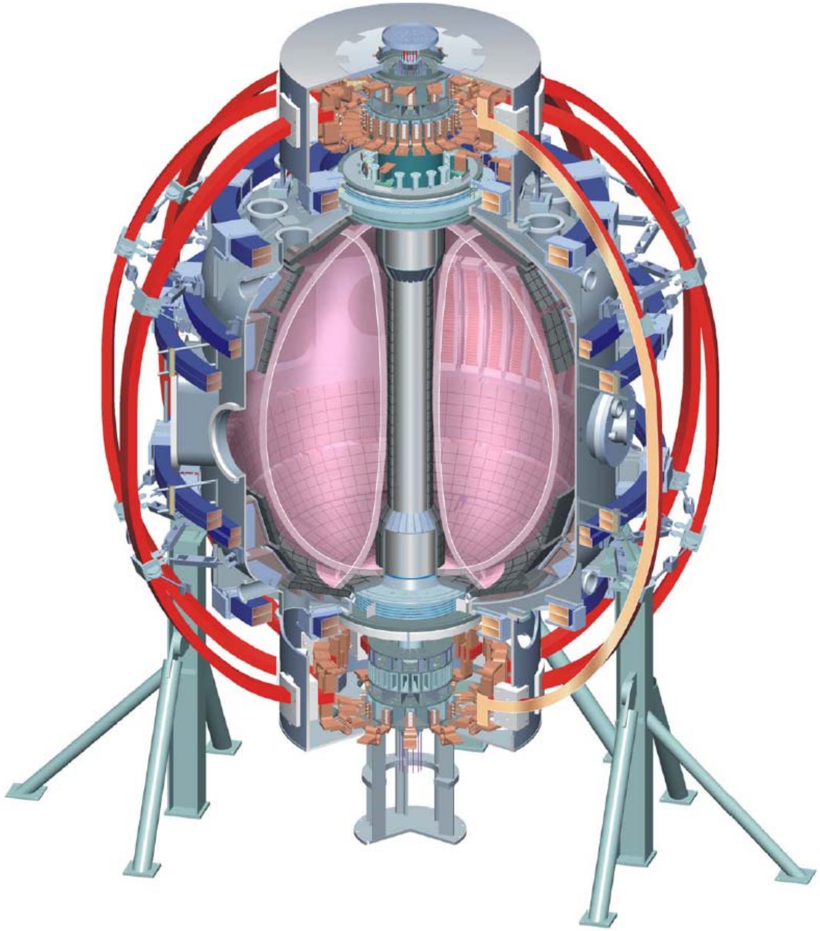
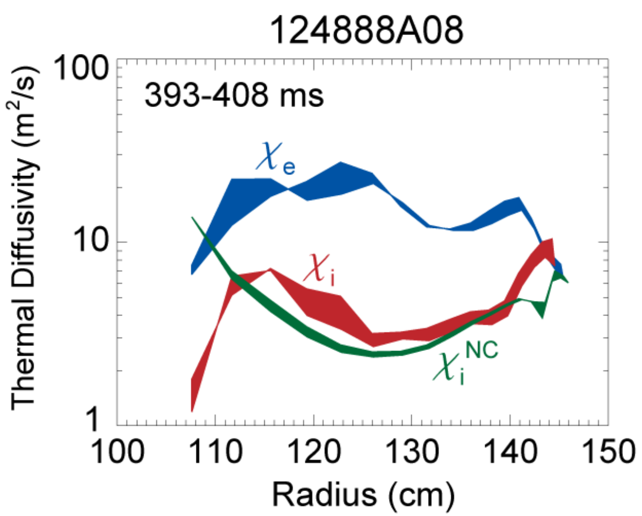


Key points

- Prominent electron gyro-scale fluctuations are observed at many locations in NSTX plasmas
- Measurements and calculations support the conjecture that ETG turbulence exists in NSTX plasmas
- ExB flow shear suppression explains the saturation dynamics for some measurements

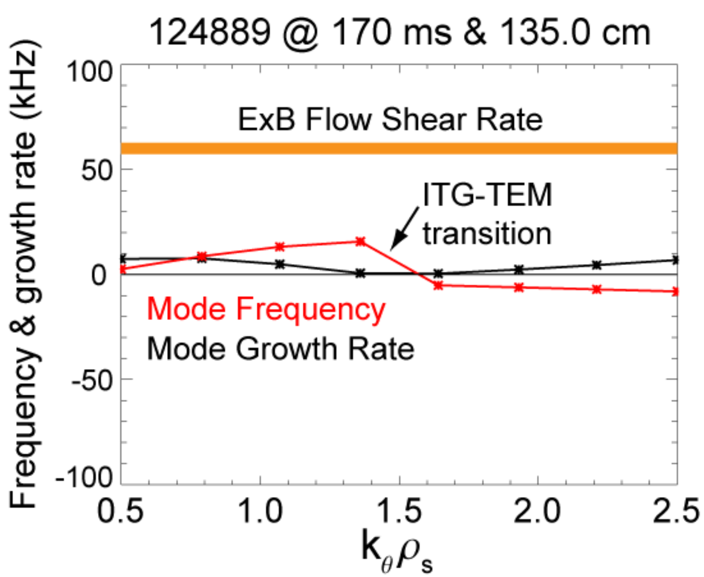
NSTX plasmas are well-suited for investigating ETG turbulence & electron thermal transport

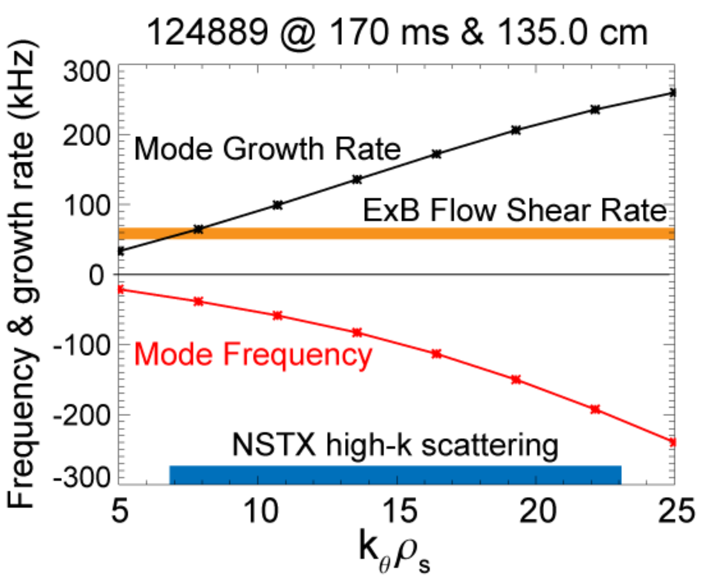


In NSTX H-mode plasmas, electron thermal transport is dominant; ion thermal transport is at or near neoclassical

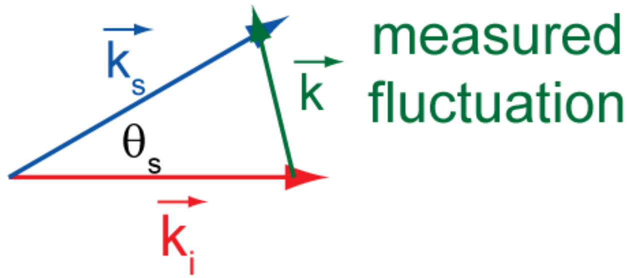
Evidence suggests ExB flow shear reduces or stabilizes ITG/TEM turbulence

See papers by Kaye (07, 06), Levinton (07), Stutman (06), and LeBlanc (04)





Collective scattering provides spatial and k-space localization for fluctuation measurements

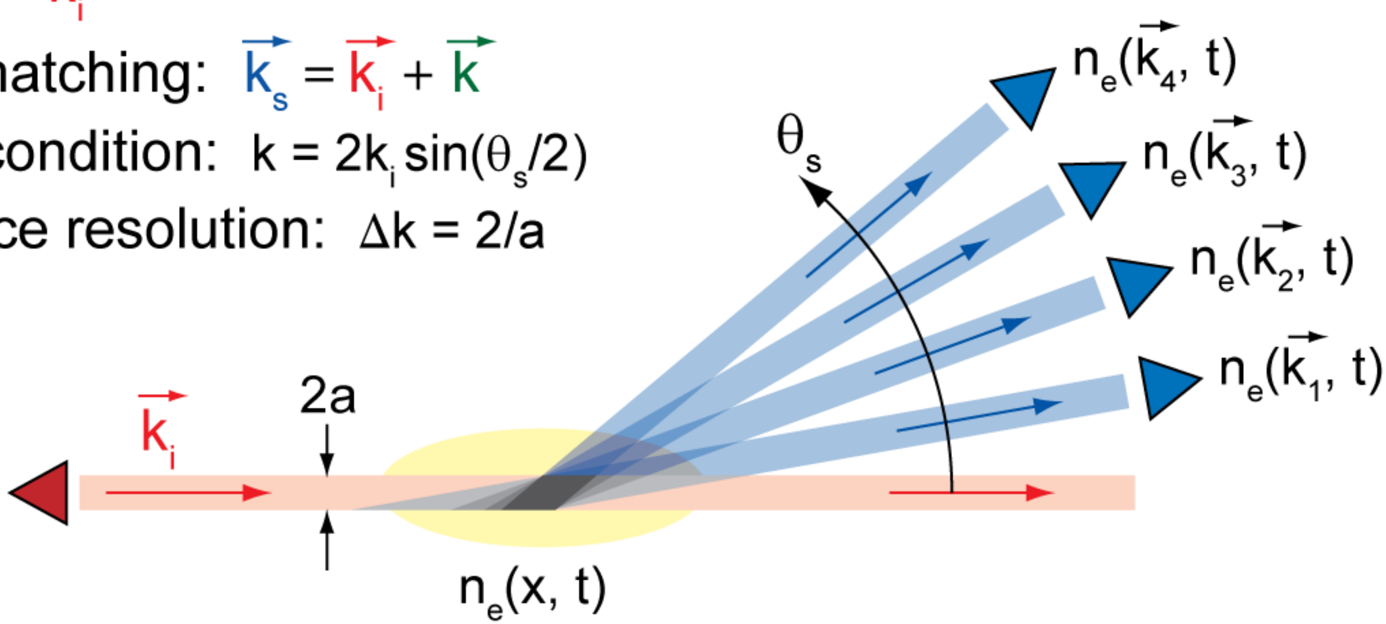


k-matching: $\vec{k}_s = \vec{k}_i + \vec{k}$

Bragg condition: $k = 2k_i \sin(\theta_s/2)$

k-space resolution: $\Delta k = 2/a$

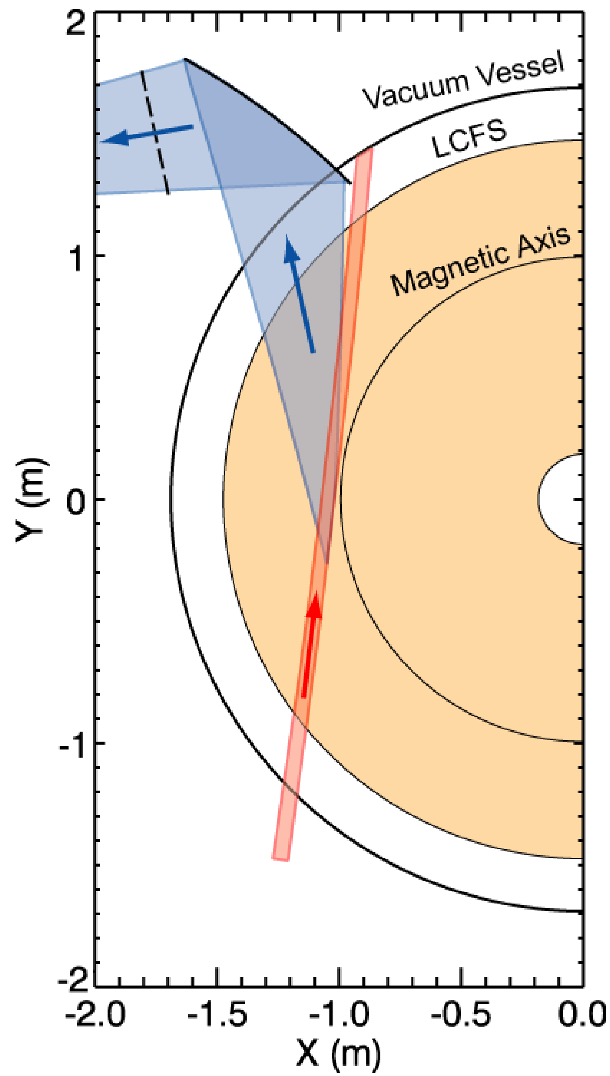
Multiple detection channels can probe the fluctuation k-spectrum



The angular distribution of scattered light reveals the fluctuation k-spectrum

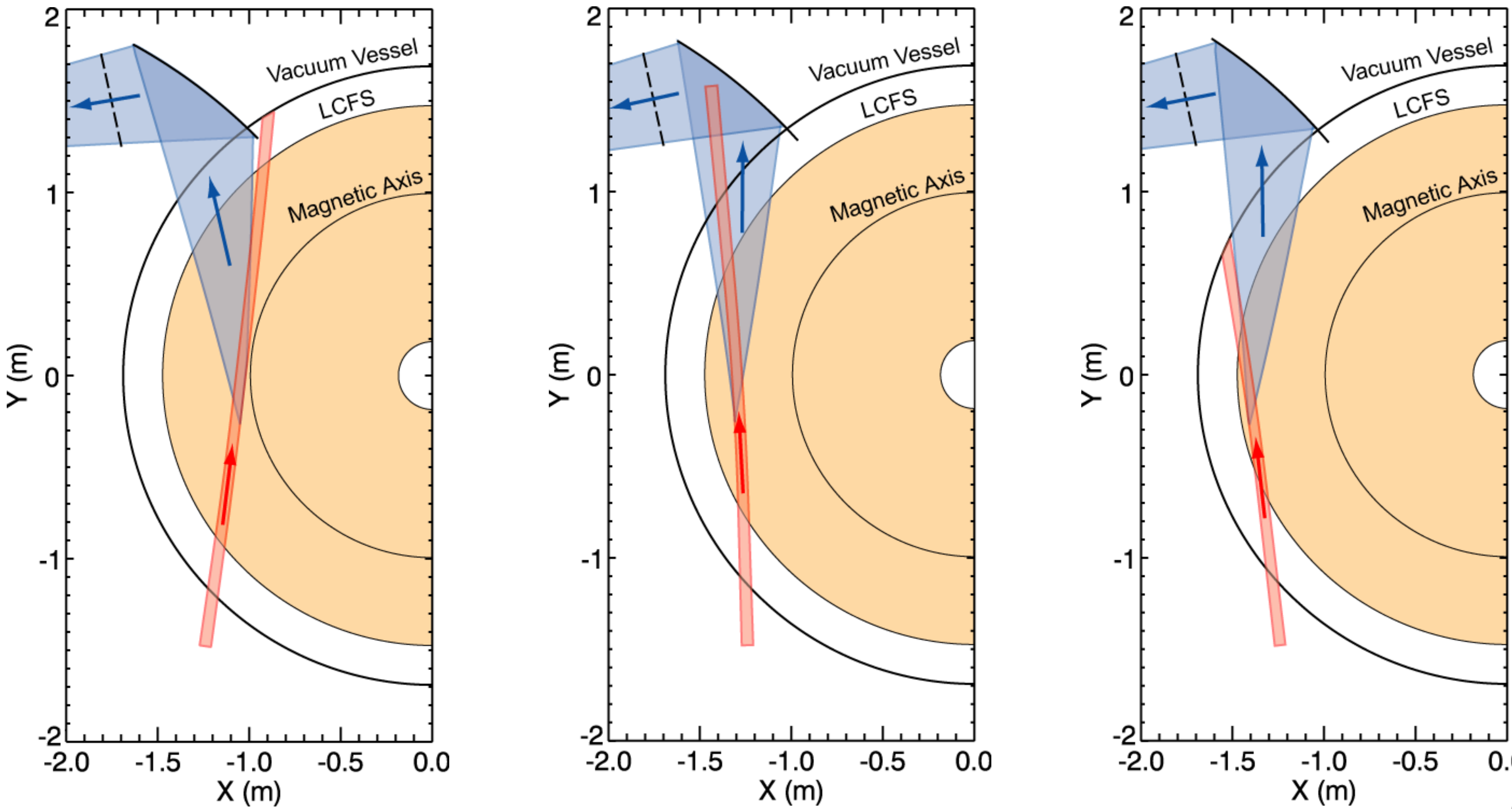
NSTX "high-k" scattering system measures fluctuations up to $k_{\perp}\rho_e \cong 0.6$

- 280 GHz microwave scattering system
- Five detection channels
  - $k_{\perp}$ spectrum at five discrete $k_{\perp}$
  - ω spectrum from time-domain sampling
- Tangential scattering
  - Probe and receiving beams nearly on equatorial midplane
  - System sensitive to radial fluctuations
- Steerable optics
  - Scattering volume can be positioned throughout the outer half-plasma
- First data during FY06 run campaign; upgrade late in FY07 run campaign



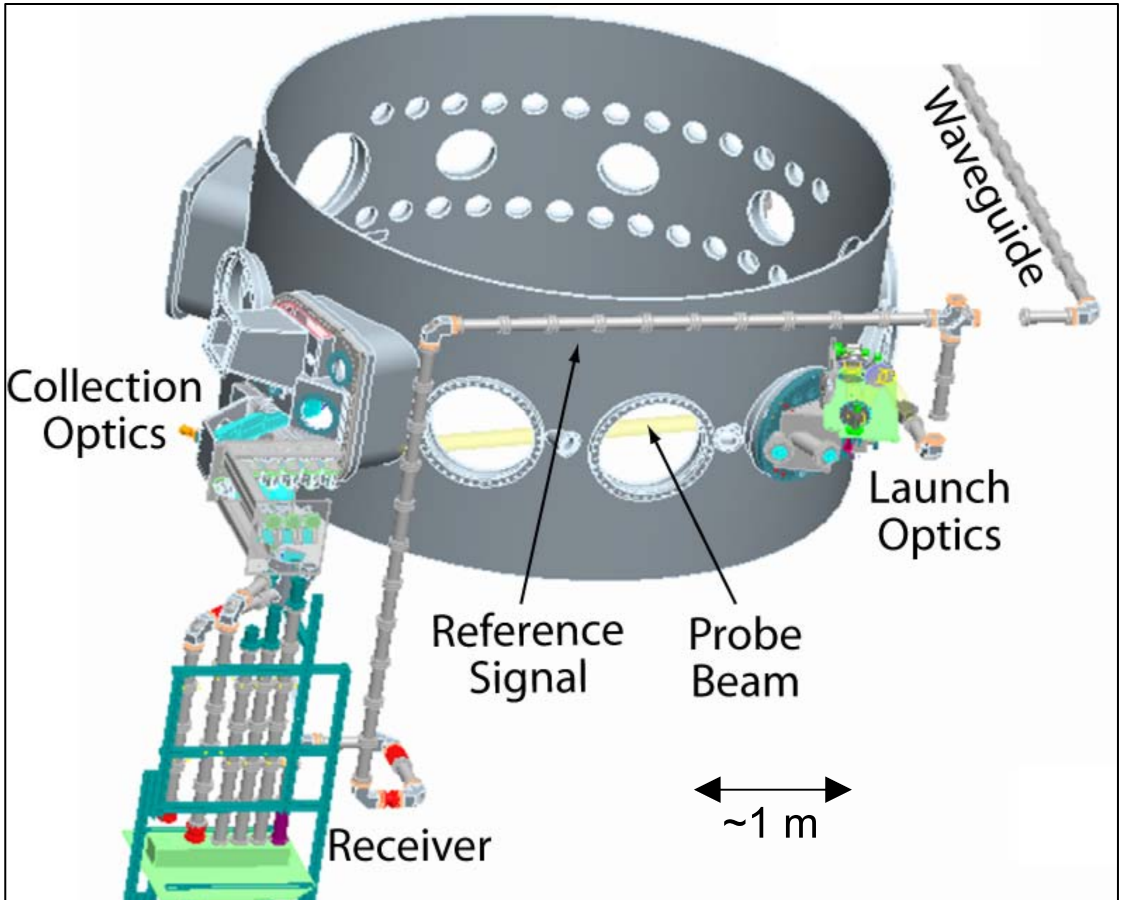
Steerable optics enable good radial coverage

Inboard $\rho = 0.05$	Intermediate $\rho = 0.4$	Outboard $\rho = 0.75$
$k_\perp \rho_e$ up to 0.6	$k_\perp \rho_e$ up to 0.3	$k_\perp \rho_e$ up to 0.2



Scattering system layout

NSTX

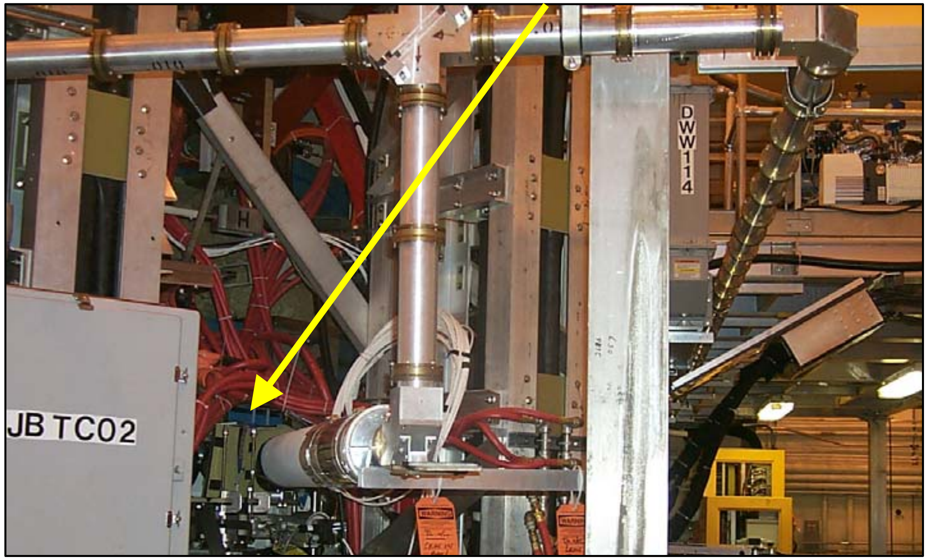


- BWO source
  - ~100 mW at 280 GHz
- Overmoded, corrugated waveguide
  - low-loss transmission
- Probe & receiving beams
  - quasi-optically coupled with 6 cm dia. waist
- Heterodyne receiver
  - five channels
  - two mixing stages
  - quadrature detection with 7.5 MHz bandwidth
  - reference signal from BWO

Scattering system pictures

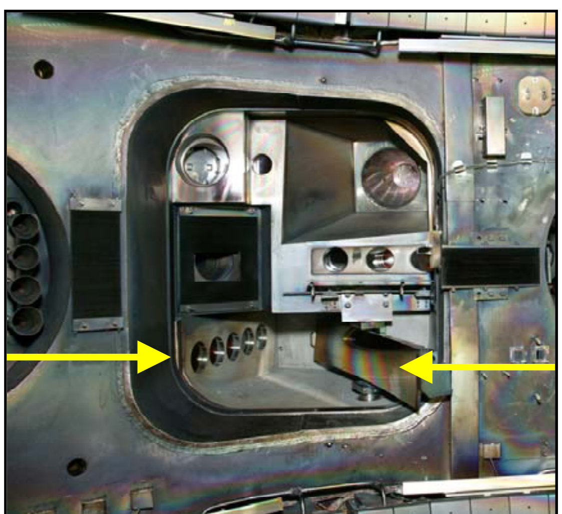
NSTX

waveguide and launch optics



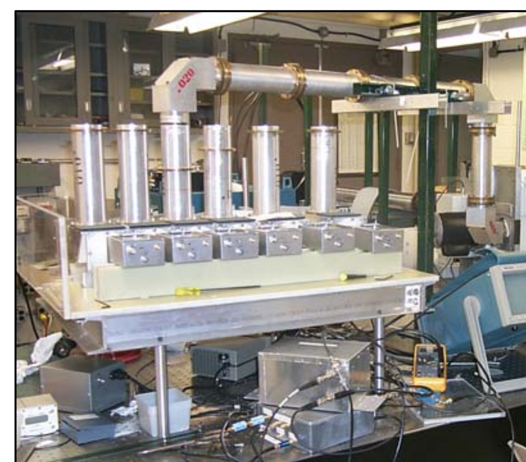
collection optics

five exit windows



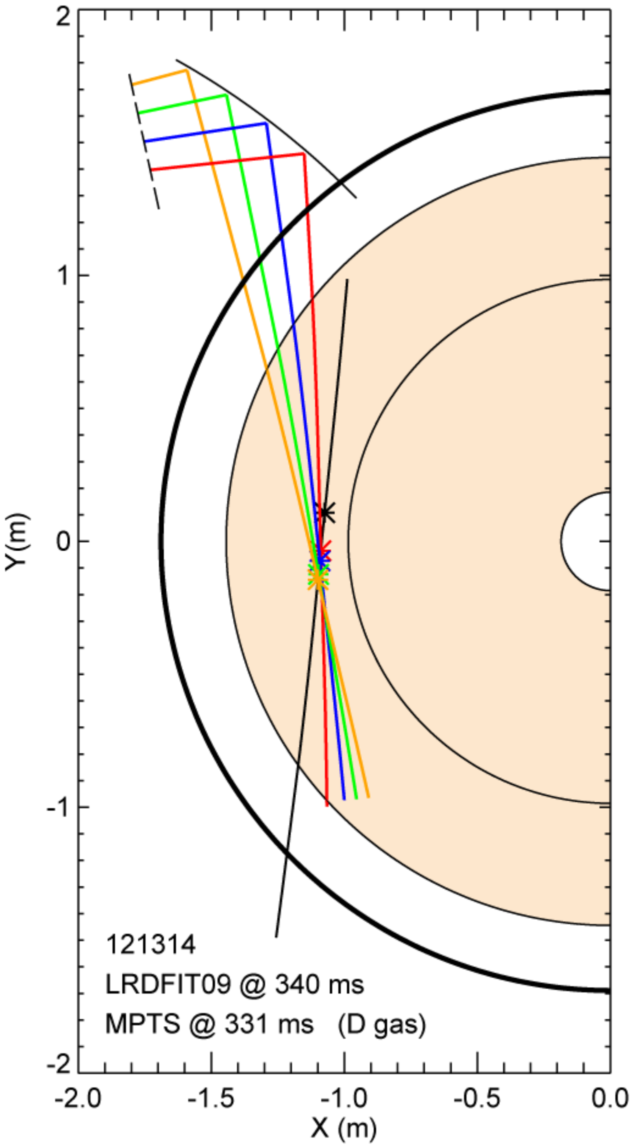
collection mirror

heterodyne receiver (5 ch + ref ch)



Example measurement parameters

NSTX



k-vectors should satisfy $k_{||} \ll k_{\perp}$

Ray tracing calculations

	Ch. 2	Ch. 3	Ch. 4	Ch. 5
r/a	0.27	0.28	0.29	0.30
d_{min} (cm)	0.1	0.1	0.1	0.1
$k_{\|\|}$ (cm^{-1})	0.1	0.0	0.2	0.0
k_r (cm^{-1})	6.9	11.0	14.6	17.8
k_θ (cm^{-1})	-1.6	-3.4	-4.4	-5.5
$k_\perp$ (cm^{-1})	7.1	11.5	15.2	18.6
$\|k_\theta/k_r\|$	0.23	0.30	0.30	0.31
$k_\perp \rho_e$	0.23	0.38	0.51	0.62
$k_\perp \rho_s$	14	22	30	37
k_T (cm^{-1})	-0.4	-0.7	-1.2	-1.3
f_D (MHz)	-1.0	-1.8	-3.0	-3.3

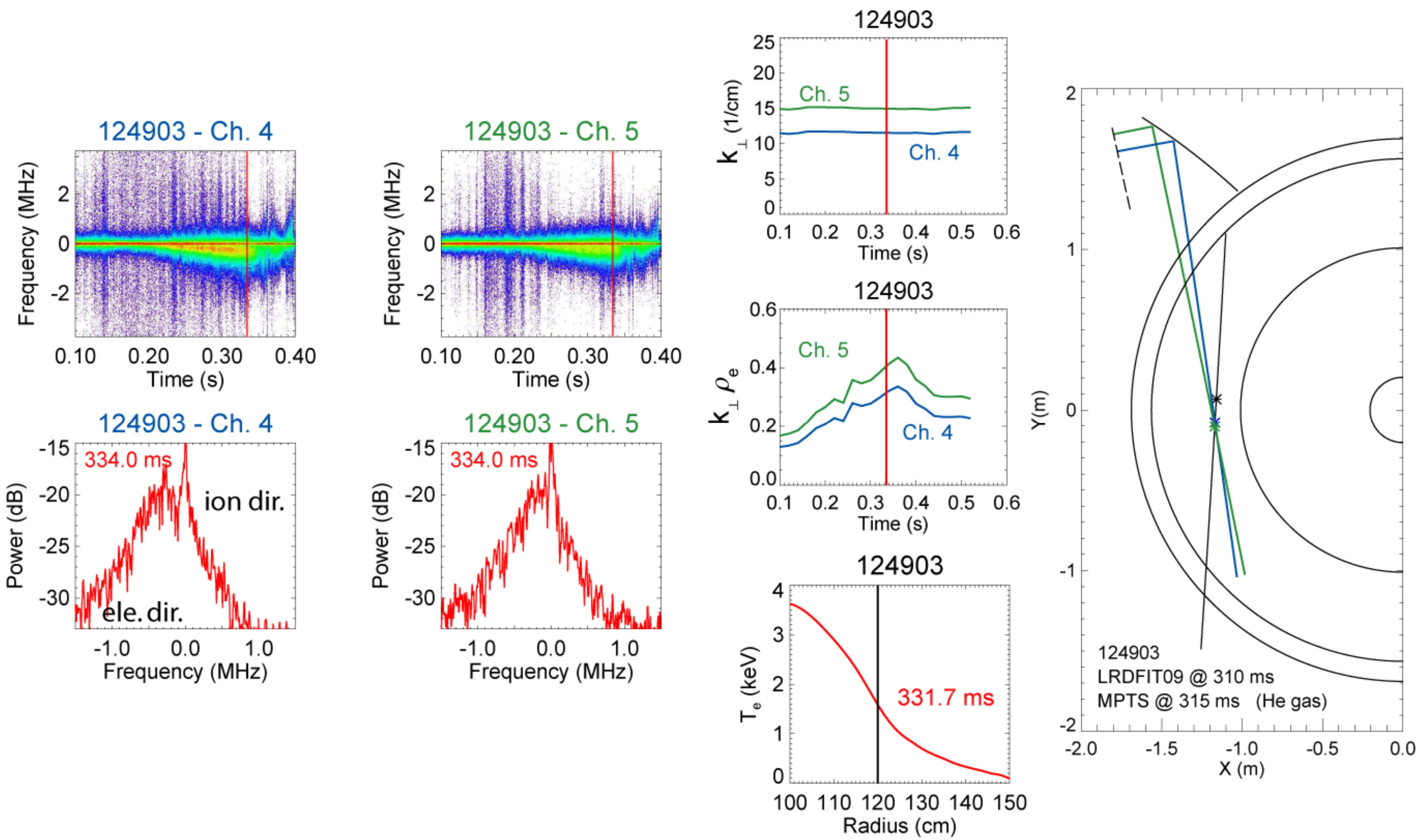
Alignment

Electron drift direction

Doppler shift in ion direction

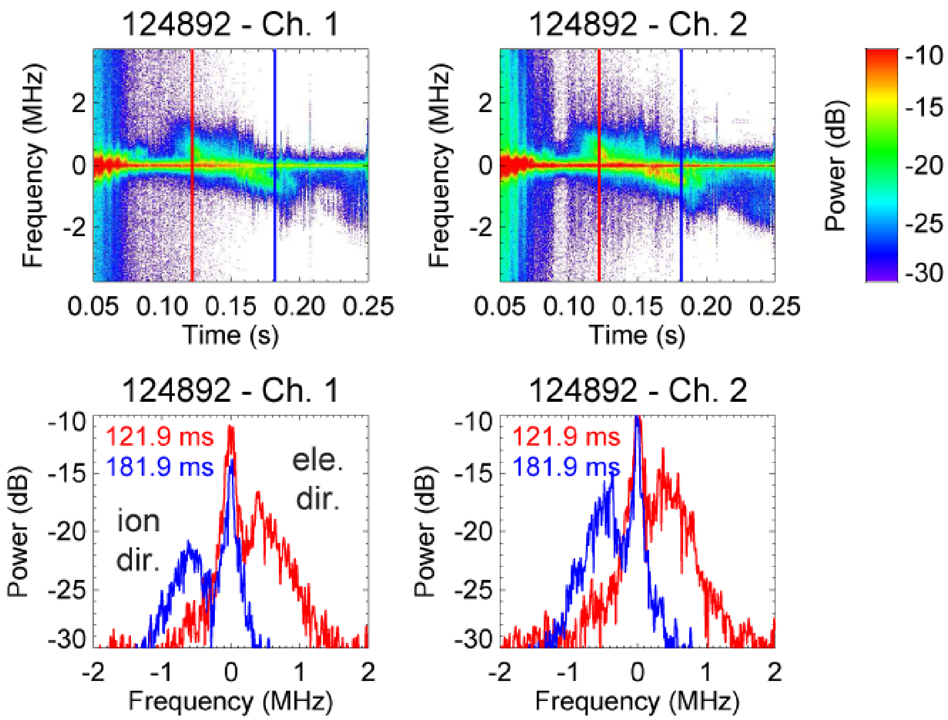
Measurements show enhanced fluctuations propagating in the electron drift direction

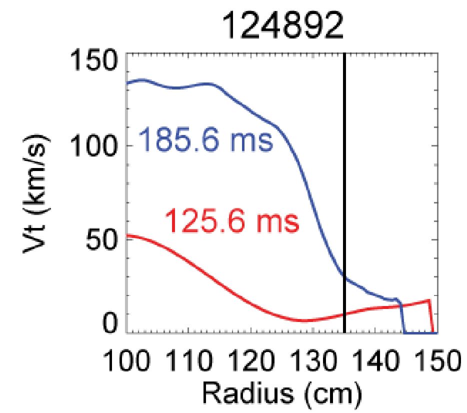
High-k measurements at R ≅ 120 cm and r/a ≅ 0.3

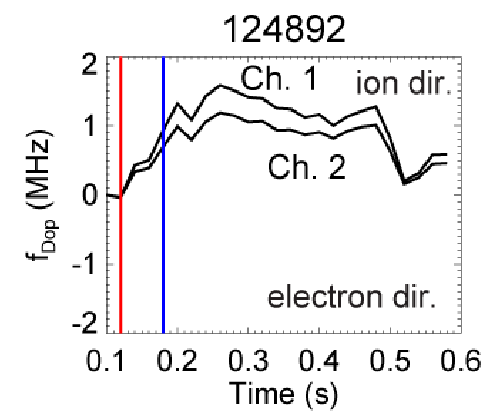


With strong rotation from NBI, fluctuations Doppler shift to the ion direction

High-k measurements at R ≅ 135 cm and r/a ≅ 0.6 with $k_\perp \rho_e \sim 0.1\text{-}0.2$







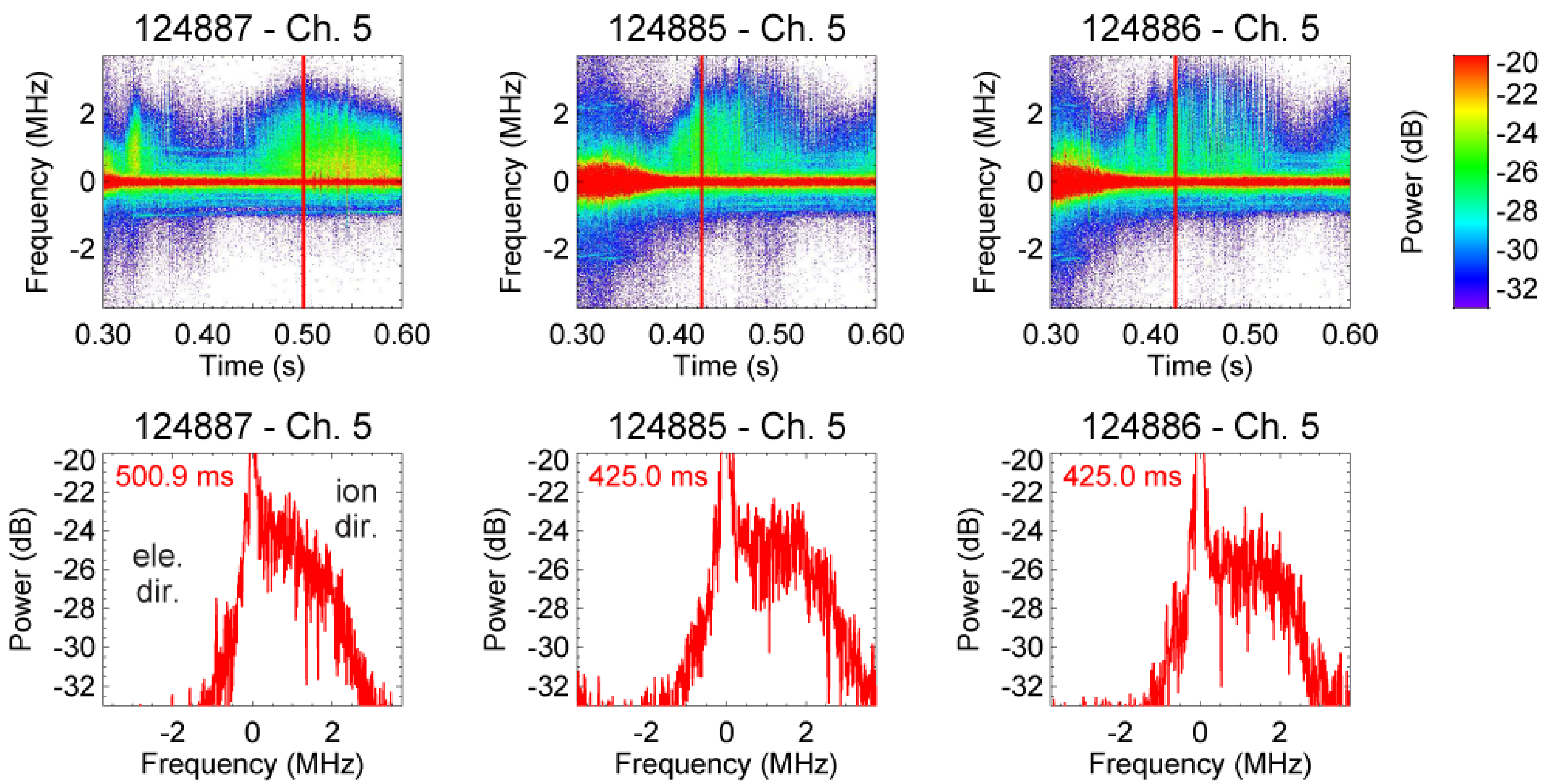
Fluctuations initially appear in the **electron drift direction,** then Doppler-shift to the **ion drift direction** due to NBI.

Prominent, persistent fluctuations observed in core

NSTX

High-k measurements at R ≅ 113 cm and r/a ≅ 0.2

$k_\perp \rho_e$ ~ 0.35-0.40 for channel 5

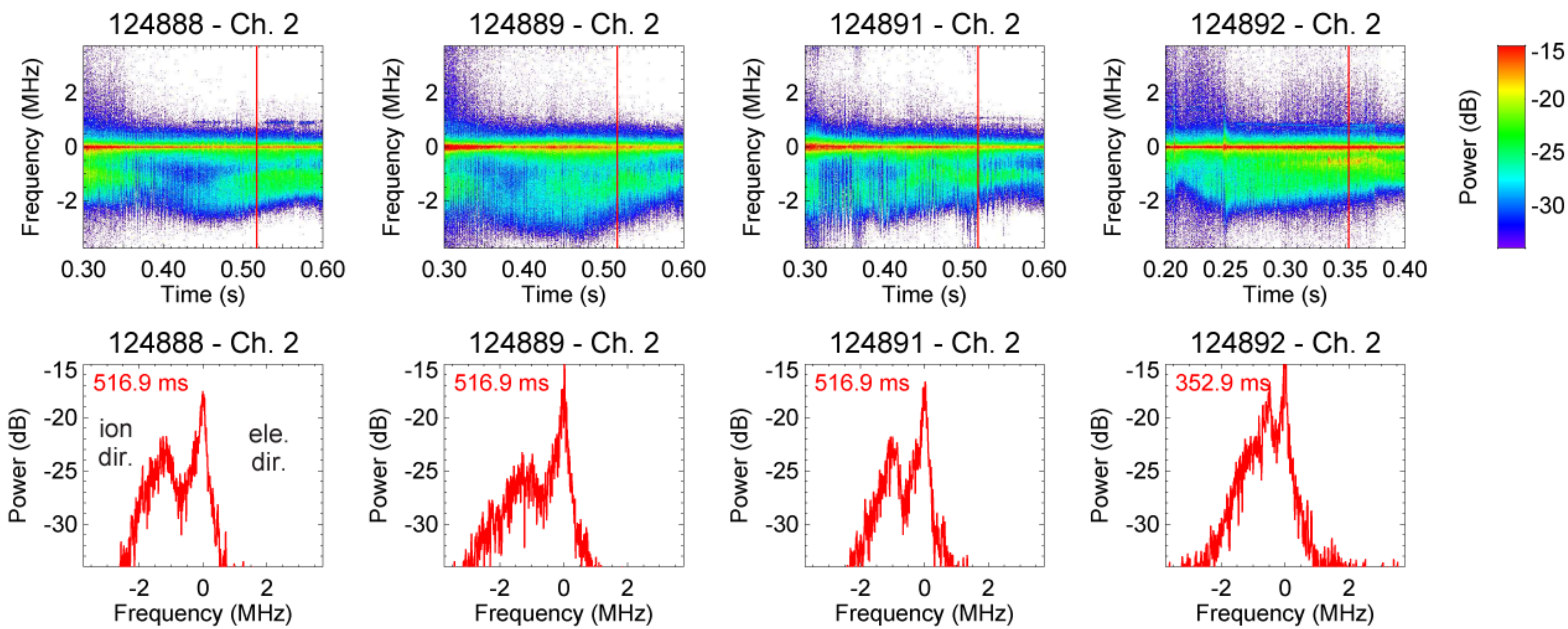


Features appear in the ion direction due to Doppler shift

Prominent, persistent fluctuations observed in outer-plasma

High-k measurements at R ≅ 135 cm and r/a ≅ 0.6

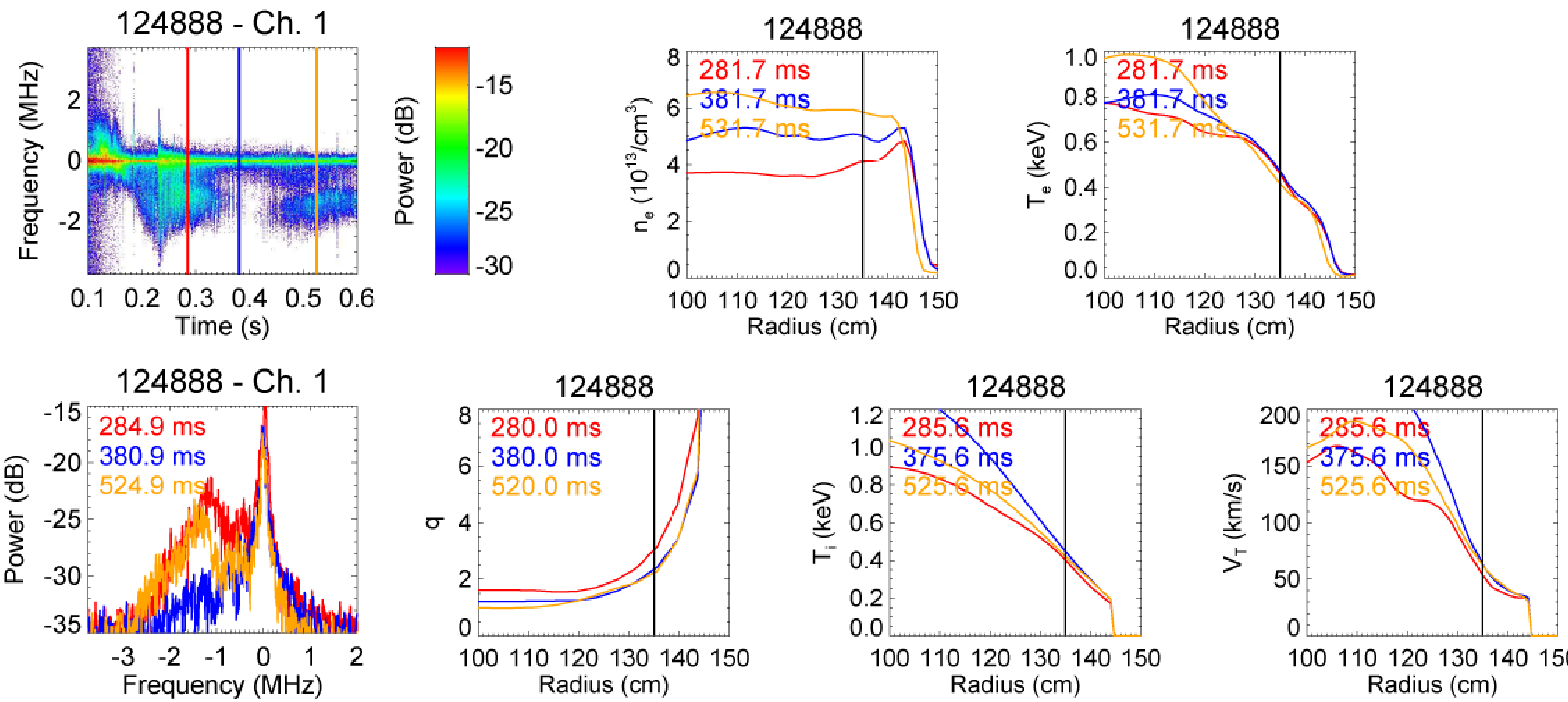
$k_\perp \rho_e \sim 0.10\text{-}0.15$ for channel 2



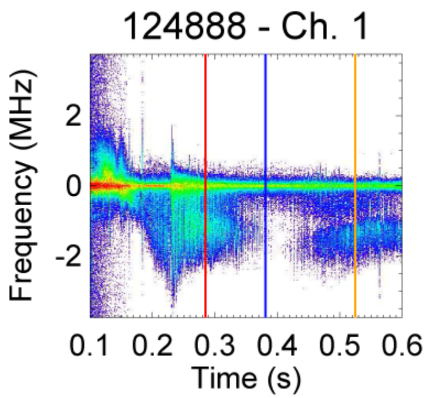
Ion/electron directions are reversed from previous slide.
Fluctuations again experience a Doppler-shift to ion direction.

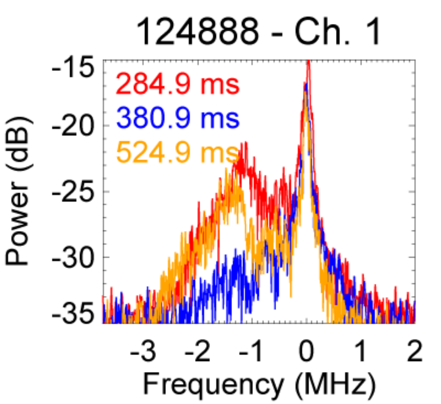
Why do fluctuations rise & fall?

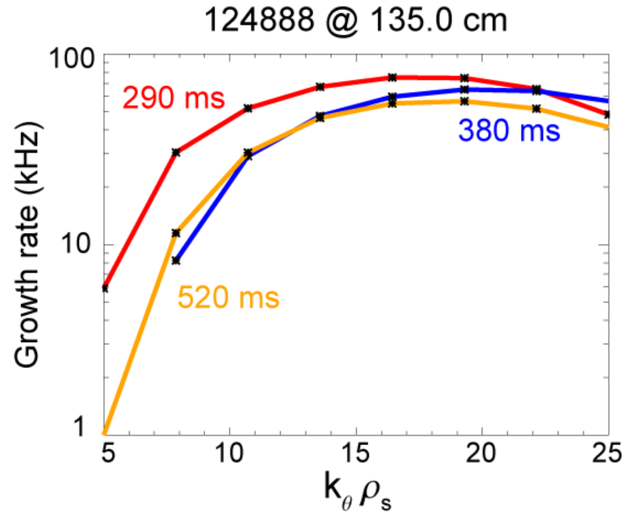
High-k measurements at R ≅ 135 cm and r/a ≅ 0.6

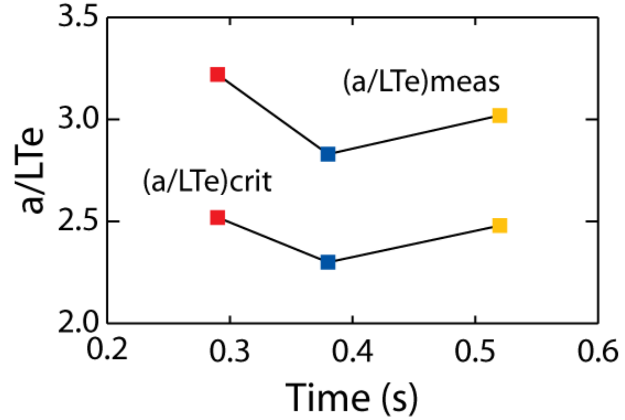


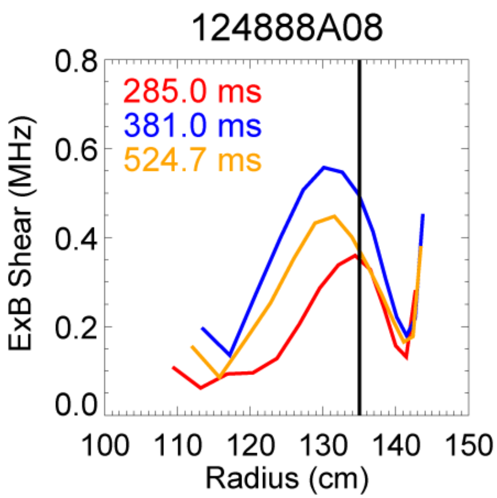
Fluctuations rise & fall with ExB shear







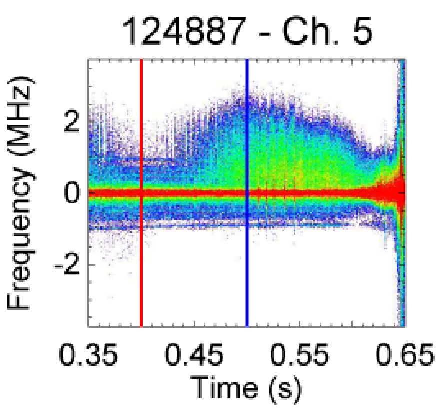


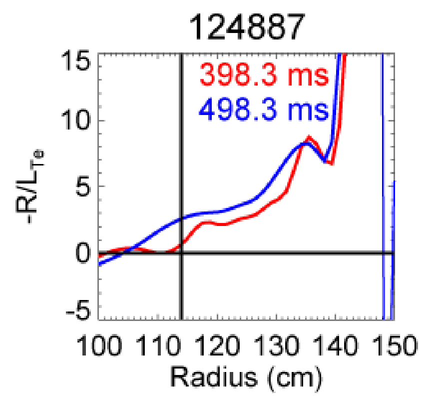


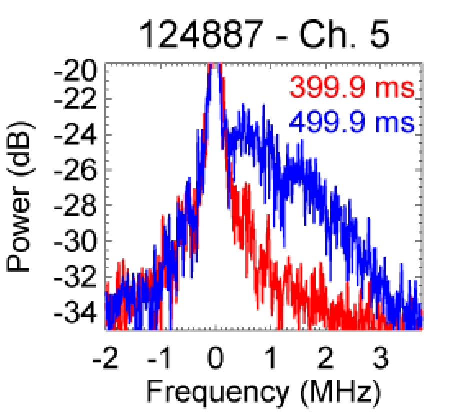
The ExB flow shear shows the necessary pattern to explain the rise and fall of fluctuations.

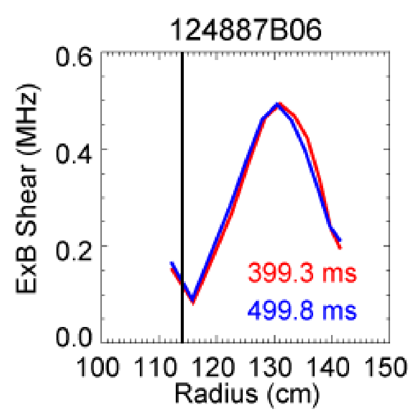
Fluctuations also respond to a/L_{Te}

Measurements at $r/a \cong 0.2$ and $k_{\perp}\rho_e \sim 0.35\text{-}0.40$

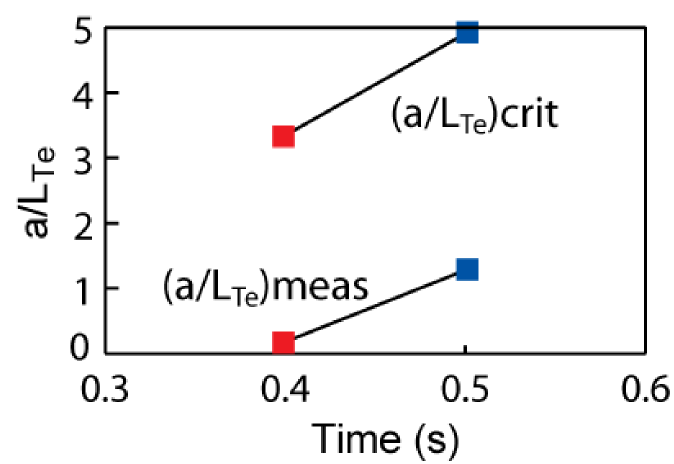








Preliminary:
The fluctuations grow as a/L_{Te} grows, but a/L_{Te} remains below the critical gradient.



Summary

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- Measurements and calculations support the conjecture that ETG turbulence exists in NSTX plasmas
- ExB flow shear suppression explains the saturation dynamics for some measurements