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UCLA Research Plans for NSTX-U

Tony Peebles

Neal Crocker, Shige Kubota, and Jie Zhang
and the NSTX-U & DIII-D Research Teams

NSTX-U Diagnostic Planning Meeting
PPPL
July 26th, 2012

Coll of Wm & Mary
Columbia U
CompX
General Atomics
FIU
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MIT
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Nova Photonics
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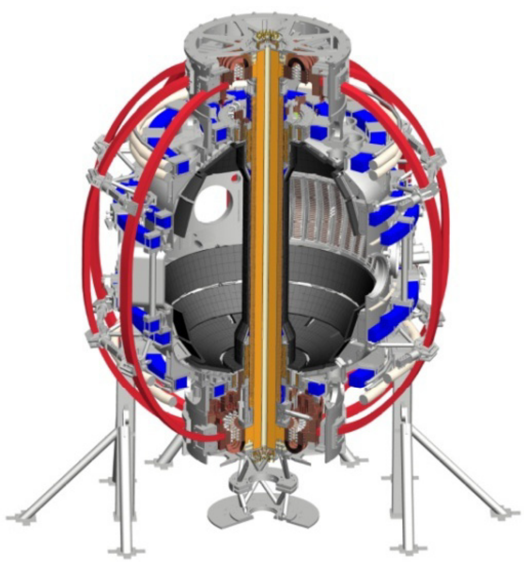

Culham Sci Ctr
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
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ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

Summary of UCLA Planned Research

- **Implications of budget reduction**
  - Reflectometry density profile system transferred to LTX - a loss to NSTX-U
  - NSTX-U effort will focus on **mutlichannel reflectometry** and installation of **new polarimeter** system
  - **Doppler Backscatter** system for NSTX-U is important – **no current support**
- **Continue contributing to "Waves and Energetic Particles" topical science area**
  - Utilize existing16 channel reflectometry for structure measurements and code validation - particularly interested in the role of CAEs and GAEs.
  - Port J reconfigured to provide access for above – four horns accommodated through central 8 inch flange. Discussions with Bob Kaita and Lane Roquemore
- **288GHz polarimetry planned for magnetic fluctuation measurements**
  - System was planned for NSTX but had to be transferred to DIII-D for test.
  - Research involves student thesis research – Jie Zhang
  - Installation on NSTX-U planned for Port G. Requires "special" tile on center stack. Discussions with Bob Kaita and Lane Roquemore.

UCLA contributions/plans in fast-ion driven mode research area

Recent Work:

- **TAE structure** measured and compared with theory
  - radial phase variation also measured; indicates non-ideal effects
  - structure measurements compared with M3D-K simulation (G. Y. Fu); reasonable agreement for both reflectometer amplitude and phase
    - Rotation affects radial phase variation
- **CAE and GAE structure** have been measured in 6 MW beam-heated H-mode plasma, suggesting CAE role in electron thermal transport.
  - comparison with HYM simulation (E. Belova) – promising initial results

Future work:

- Investigate non-ideal TAE structure
- Use validated TAE mode structures from M3D-K with ORBIT to predict fast-ion transport and loss
- **Use validated CAE and GAE structures from HYM with ORBIT to predict role in electron thermal transport**

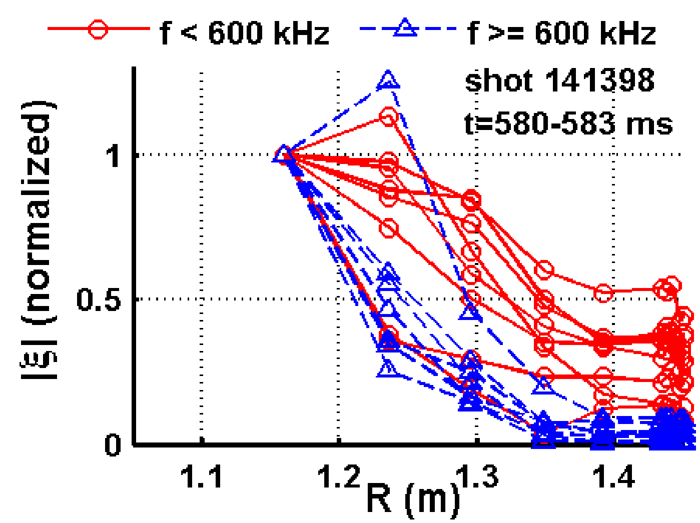
Core-localized CAEs identified in beam-heated H-mode plasma

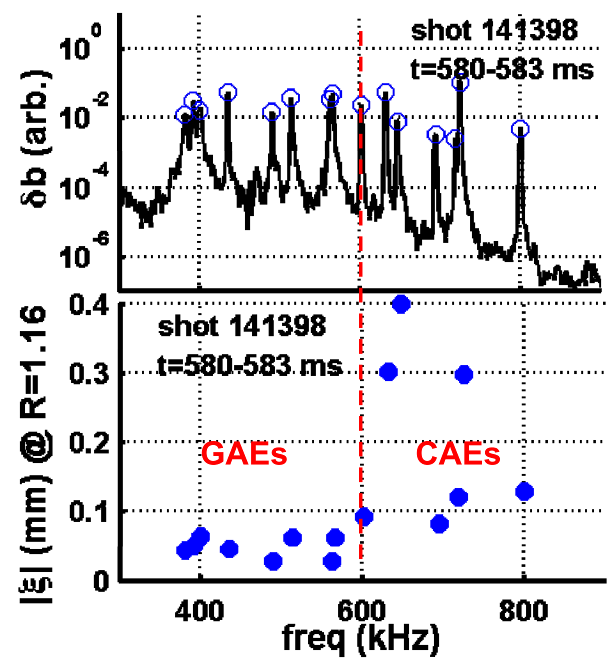
- motivates investigation as possible cause of enhanced χ_e

- High frequency **AE structure measured in core** of beam heat-heated H-mode plasmas ⇒ identified both CAEs *and* GAEs

- Observed modes fall in **two primary categories**:
  - **GAEs**: **Small amplitude + broad structure**,
    f < ~ 600 kHz, n = -6 – -8
    CAEs: Large amplitude + strongly core localized,
    f > ~ 600 kHz, n = -3 – -5

- **CAEs more strongly core localized** ⇒ *also* could cause anomalous thermal electron transport
  - CAEs share key GAE characteristics (D. Stutman) regarding their potential role in electron thermal transport: core localization & frequency

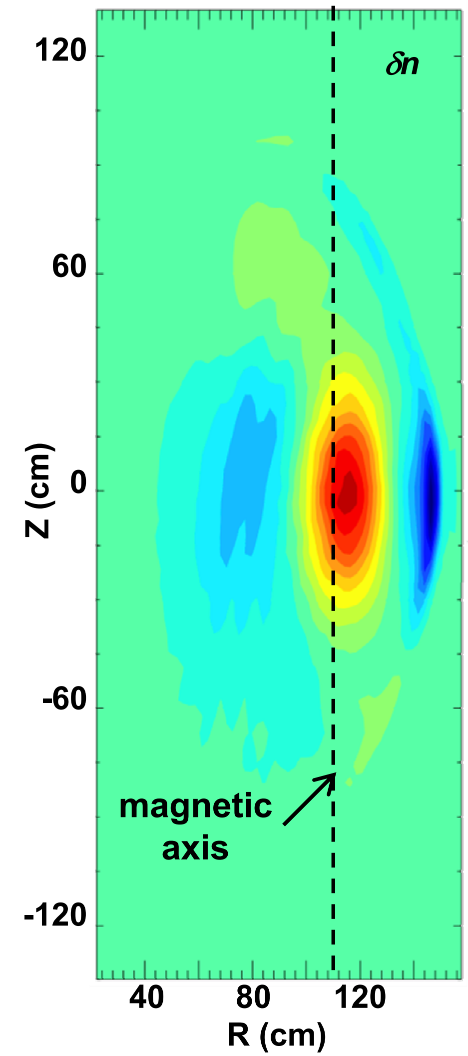




Recent simulations show unstable sub-MHz, low-*n* CAE (E. Belova) Comparison (i.e. validation) with measurements underway

- Simulations performed by E. Belova for 6 MW beam-heated equilibrium where CAEs identified
  - shot 141398, t = 582 ms
- Unstable sub-MHz **core-localized** CAE observed
  - $n = 4$, $f = 868$ kHz ($f = 0.35*f_{ci}$)
- **CAE has strong density peak near magnetic axis - similar to experiment**
- **Detailed structure comparison/validation to reflectometer measurements underway**
- **Future work**: use ***validated*** HYM mode structure for ORBIT electron transport calculations

HYM CAE n = 4, f = 868 kHz (0.35*f_{ci})
shot 141398, t = 582ms
(E. Belova)

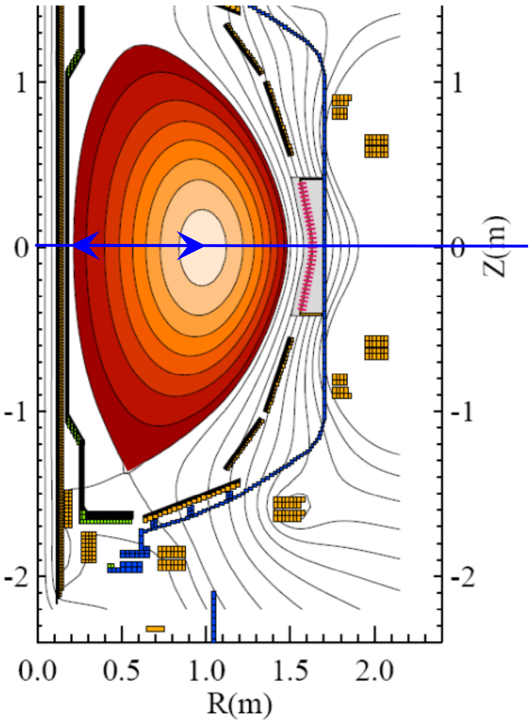


Magnetic fluctuations can play important role in fusion plasma stability and transport

- **Macroscopic stability can be perturbed by large scale instabilities driven by current or pressure gradients**
  - e.g. NTMs (Neoclassical Tearing Modes) degrade confinement, and often lead to disruption
- **Fast-ions lead to instabilities, e.g. Alfvén Eigenmodes**
  - Cause/modify fast-ion transport or loss $\Rightarrow$ modifies heat deposition (distribution of fusion α's, neutral beams)
  - CAEs and GAEs can also potentially cause anomalous electron thermal transport
- **Magnetic turbulence can also result in particle, energy and momentum transport**
  - e.g. Microtearing Modes are possible source of anomalous electron transport

Polarimetry: Magnetic field fluctuation measurement

Also constraint on central q; radial view sensitive interferometer for low start-up density



- Radial-view, retro-reflects from center-stack carbon tile
- At low magnetic field, polarization modifications are dominated by Faraday rotation.
- More complicated as field increases – Cotton Mouton effect + interactions **(J. Zhang RSI 81, 1 2010)**

$$\Psi = 2.62\times10^{-13}\lambda^2\int B_{\parallel}(z)n(z)dz$$

$$\Psi = \Psi_0 + \tilde{\Psi}$$

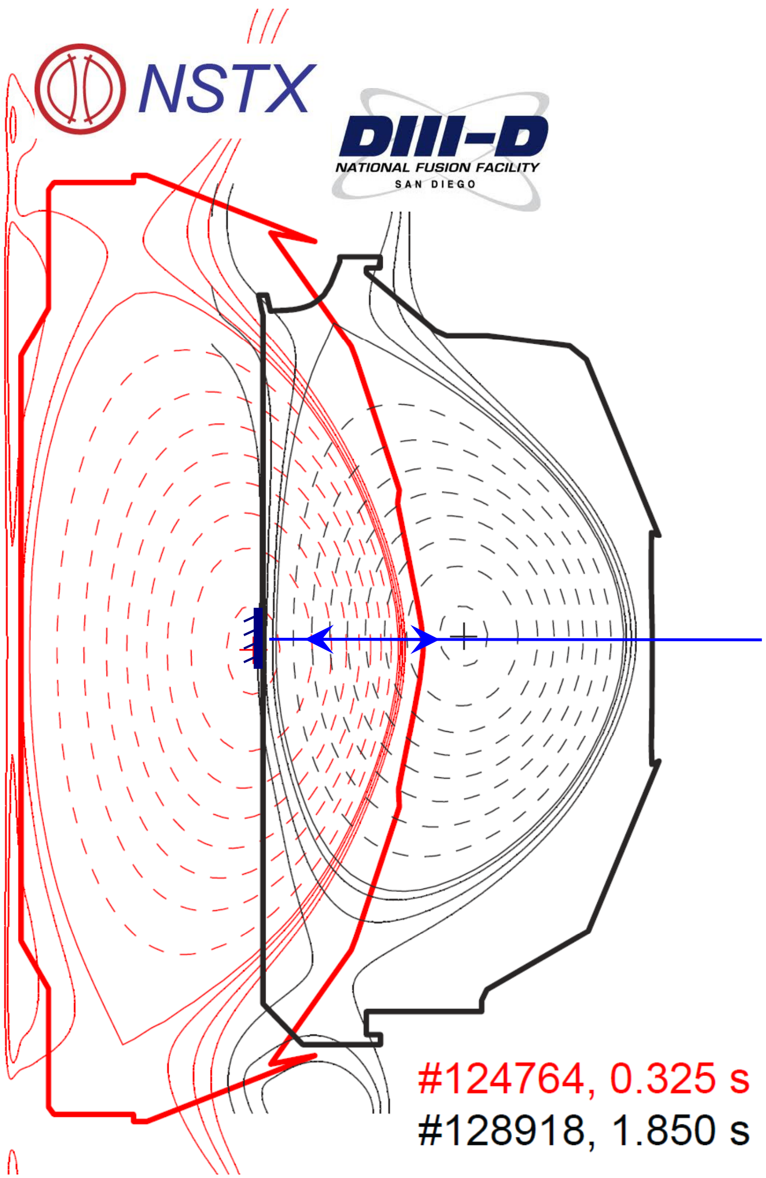
$$\tilde{\Psi} = 2.62\times10^{-13}\lambda^2\int\left[\tilde{B}_{\parallel}(z)n_0(z) + B_{\parallel,0}(z)\tilde{n}(z)\right]dz$$

Radial view is insensitive to density fluctuations as long as measurement close to mid-plane - where the equilibrium B along propagation direction ($B_{||}$) is small

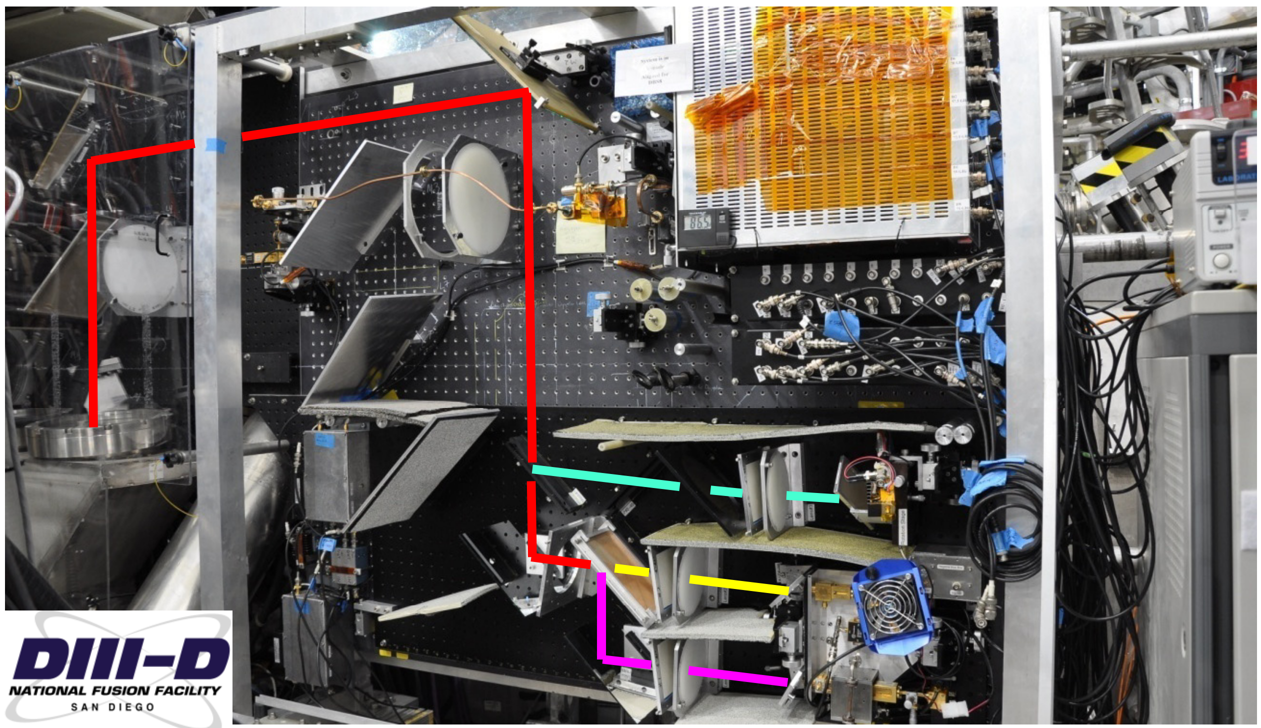
GYRO simulated magnetic and density fluctuations associated with micro-tearing modes in NSTX (Walter Guttenfelder) used to calculate expected polarimetry signal

Indicates internal direct measurement of microtearing magnetic fluctuations feasible in NSTX-U. **Prototype system transferred to DIII-D for testing**

Currently installed on DIII-D for plasma tests prior to future implementation on NSTX-U



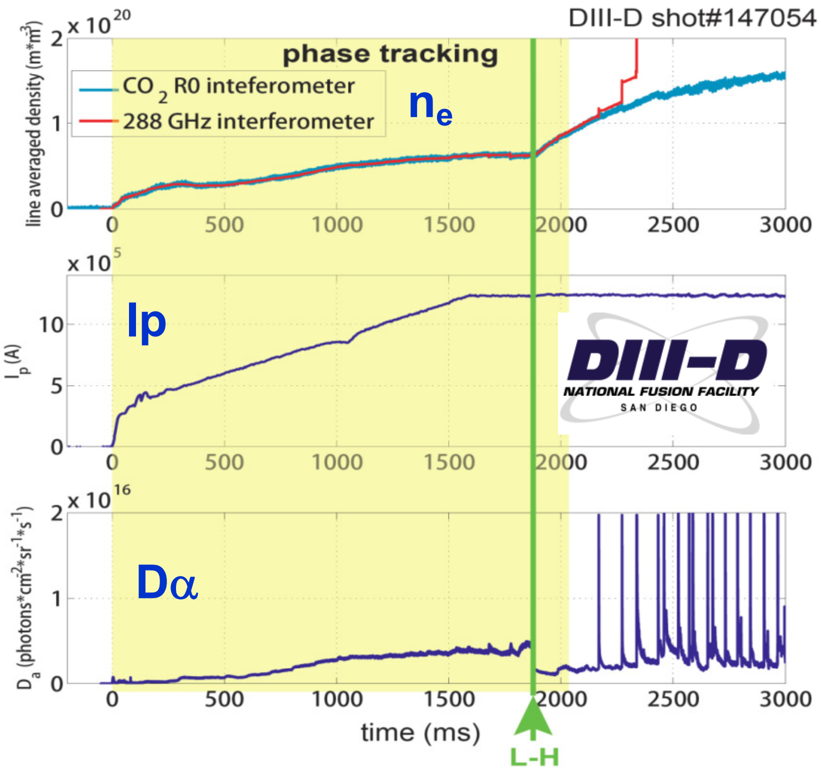
- Polarimeter was originally planned for NSTX with radial retroreflection geometry
- Installation on DIII-D utilizes the same radial retro- reflection geometry as NSTX
- Minimal perturbation to existing configuration at 60° R0 port



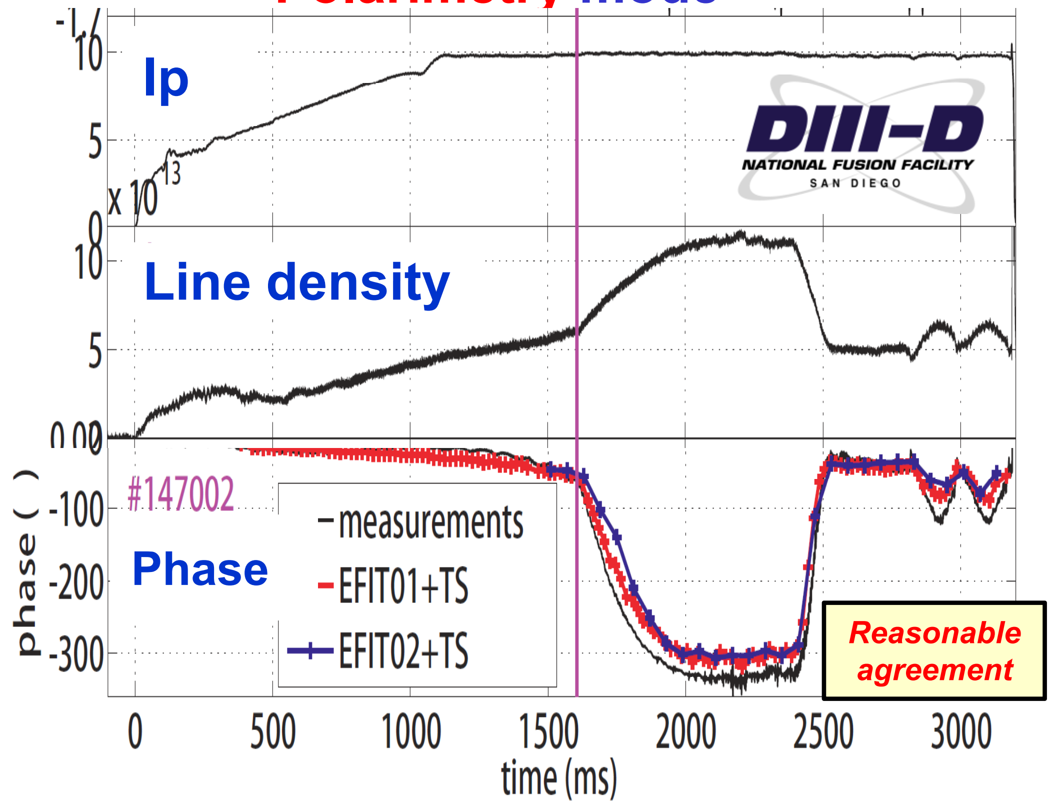
Preliminary DIII-D data indicates good initial operation

- low noise, high resolution interferometer; reasonable equilibrium polarimeter response

Interferometry mode



Polarimetry mode



Problem:

Dominant phase noise caused by feedback effects. Eliminated via quasi-optical isolators **(J. Zhang RSI 83, 10E321 (2012)**

However, residual phase noise still too large (~2 degrees) due to magnetic pick up and some potential alignment/vibration issues. Limits detectable magnetic fluctuation level

Recently improved, but further progress is necessary

Upcoming DIII-D half run day planned for August

GOAL: Investigate equilibrium polarimeter phase variation and phase spectra from fast-ion driven modes, tearing modes, etc.

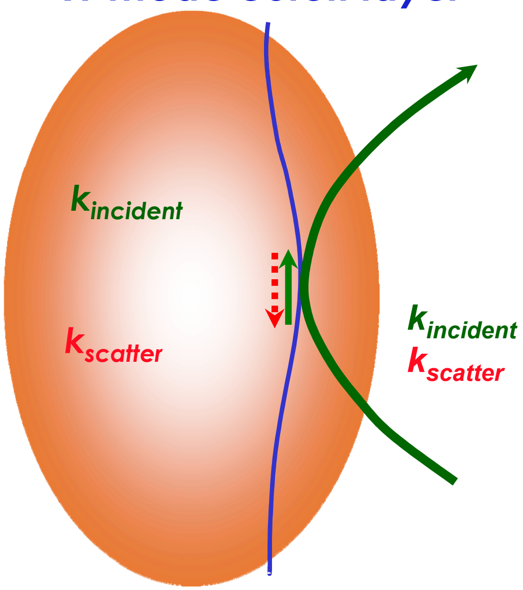
B_T scan, 0.5T, 1.2T, 2.0T - moves from Faraday rotation dominated to Cotton Mouton dominated operating regime

- $n_e \leq 4 \times 10^{19}$ m^{-3}, oval/circular shape, beam-heated L-mode
- **Plasma vertically scanned ±15 cm**. Varies height of polarimeter chord relative to plasma center – effectively a spatial scan
- Also investigate measured phase spectra from fast-ion driven modes, tearing modes, etc.
- **Measured polarimeter phase response will be compared to calculations using mode predictions as inputs to a synthetic diagnostic code**

Unfunded Doppler backscattering (DBS): intermediate k turbulence, E_r, GAMs, zonal flows and, potentially, wave E-field for fast-ion driven instabilities

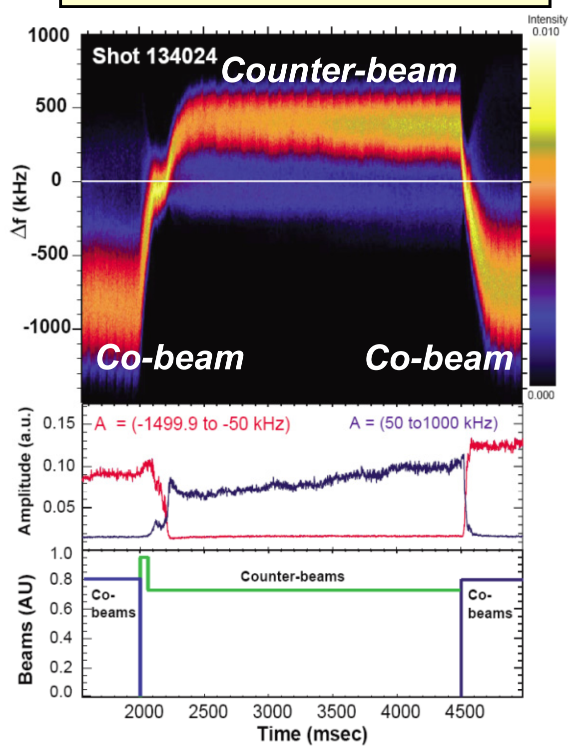
- DBS locally measures scattering from *intermediate scale (~3 – 20cm^{-1})* turbulence
- **Provides critical link between BES and high k scattering + …**
  - Doppler shift provides information on turbulent flow (~E_r), GAMs, etc.
  - Scattered power provides local info on turbulent fluctuation levels at intermediate-scale wavenumbers (~3 to 20cm^{-1})

X-mode cutoff layer

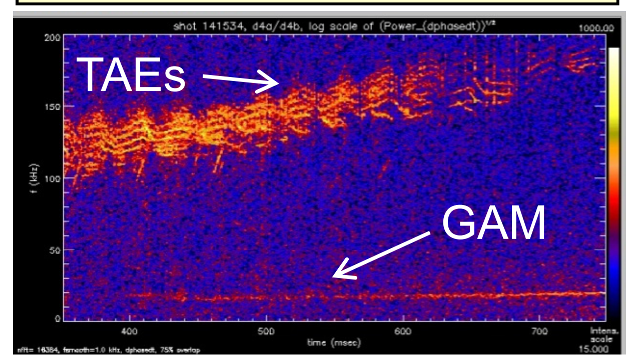


Phase analysis of DBS data reveals the GAM

Quadrature data for co- and counter beams



Phase data illustrating oscillating flows caused by GAMs and TAEs



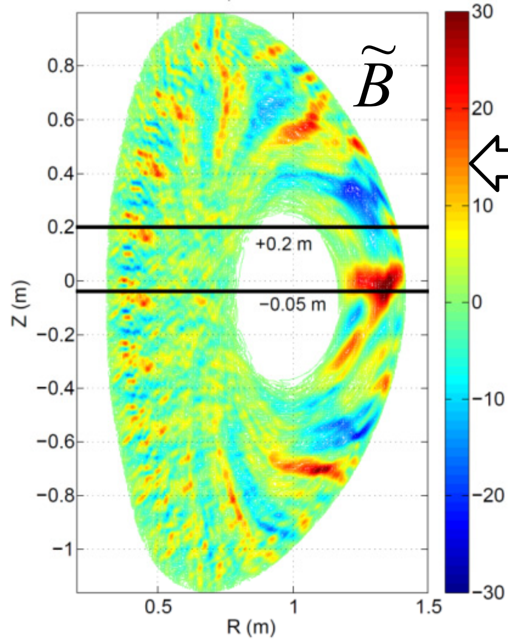
Not currently funded.
UCLA seeking support

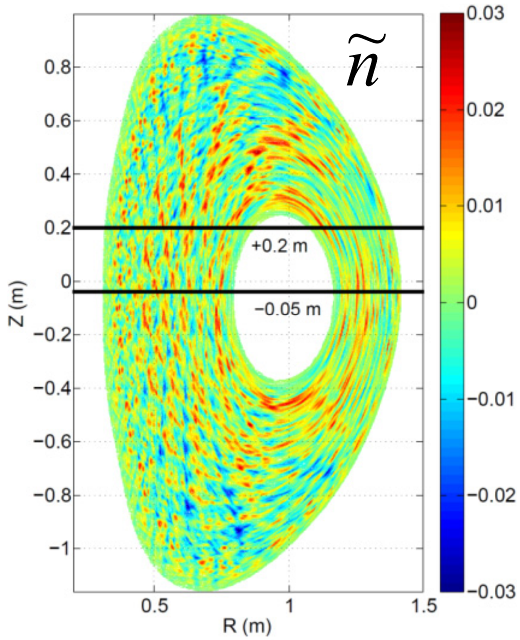
Requires a minimum 6 inch port

Possible in Port J – discussed with Bob Kaita and Lane Roquemore

Back-up Slide

Calculations of microtearing polarimeter response – NSTX





GYRO calculations (Walter Guttenfelder) illustrate structure of magnetic and density fluctuations associated with micro-tearing in NSTX

These calculations were used as input for polarimetry "synthetic diagnostic" calculations

The calculated polarimetry phase fluctuations were insensitive to density fluctuations as long as the measurement occurred close to plasma mid-plane.

Consistent with expected situation for Faraday rotation dominated case.