Low- and Intermediate-k Fluctuation Diagnostics

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Ideas for Low- & Intermediate-k Measurements

NSTX

Issures for Low- and Intermediate-k Fluctuations

- Turbulence:
  - If ITG/TEM linear growth rates are well below ExB shearing rates, is turbulence micro-tearing?
  - Can we see interplay between turbulence levels, ExB, and zonal flows?
- Turbulent and coherent modes:
  - Structure and magnitude of δB.

List of Diagnostics and Measured Quantities

- Doppler Reflectometry
  - Fluctuations with k selectivity (2-10 cm^{-1}).
  - Time- and space-resolved velocity measurements.
    - > E_r (ExB shear and connection to turbulence)
    - > v_{phase} (when v_{ExB}~0, turbulence ID)
    - > δv_{ExB} (Zonal Flows, GAMs)
- Fast Radial-View Interferometry/Polarimetry Array
  - MHz time response.
  - $\delta\Psi$ proportional to δB (when beam is through axis).
  - J_0 from $d\Psi/dz$. Constraint to EFIT. Complements MSE.

Principles of Doppler Reflectometry

wavevector selection:
(Bragg condition)

$$K_\perp = 2k_0 \sin\left(\theta_{\mathrm{tilt}}\right)$$

wavevector resolution:
(Gaussian beam: w=e^{-1} width of amplitude)

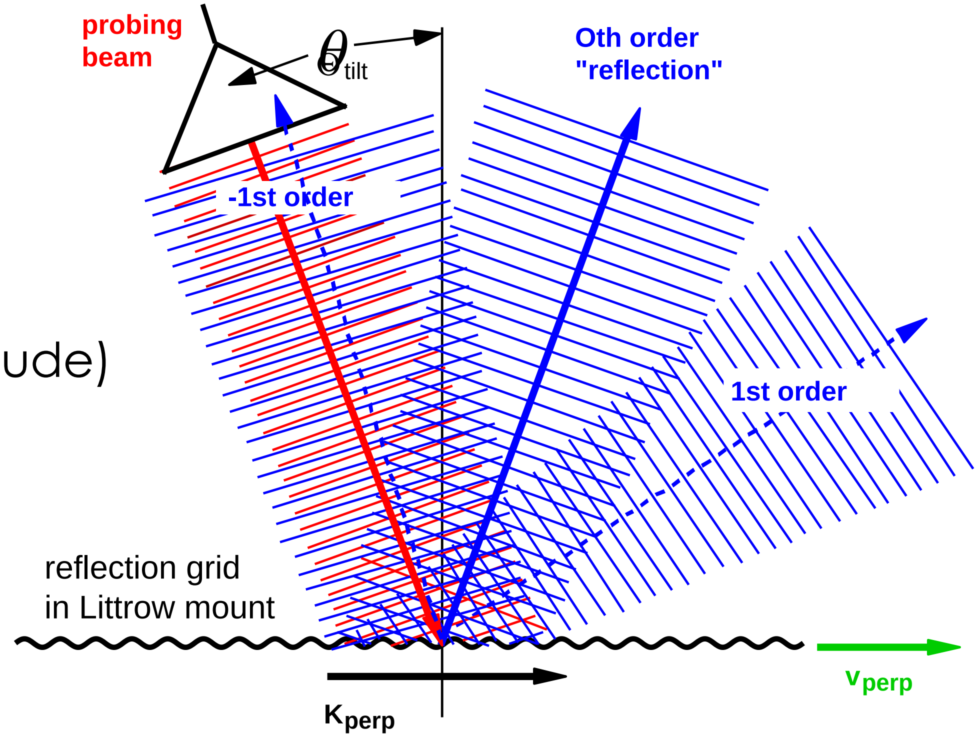
$$\delta K_\perp = 2\sqrt{2}/w$$

frequency shift (-1 order):

$$\Delta\omega = \vec{K} \cdot \vec{v} \simeq K_\perp v_\perp$$

fluctuation velocity:

$$v_\perp = v_{E\times B} + v_{\mathrm{ph}}$$

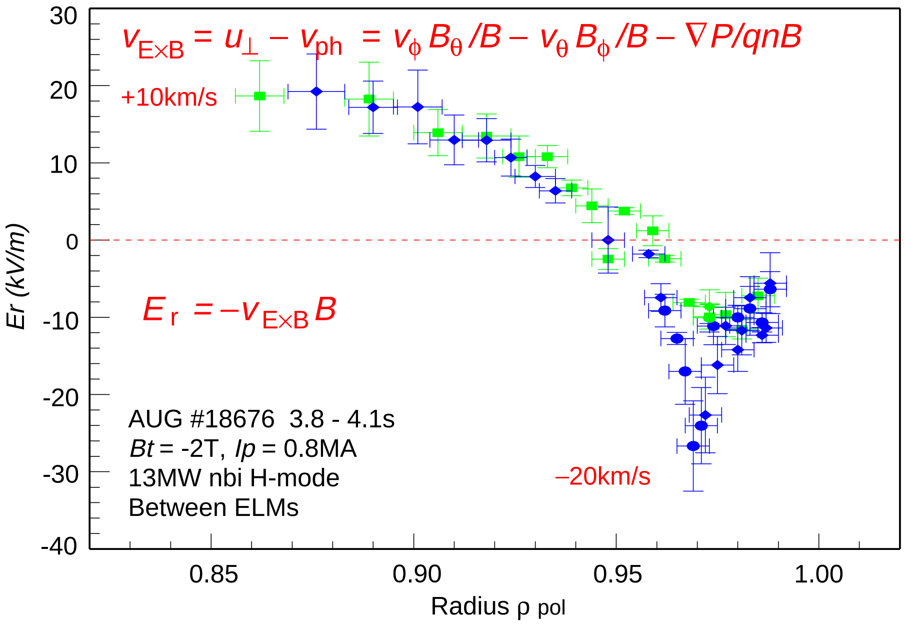


M. Hirsch, et al., PPCF (2001)

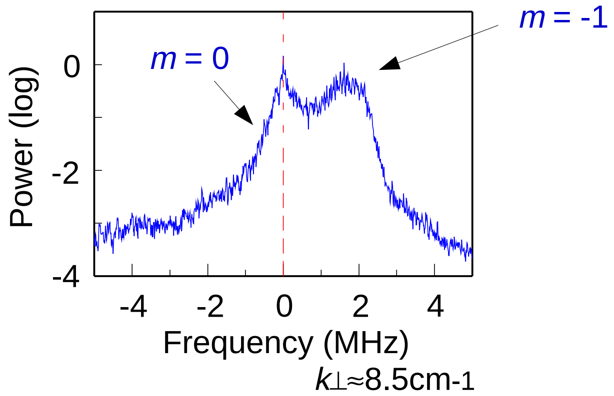
Measured quantities.

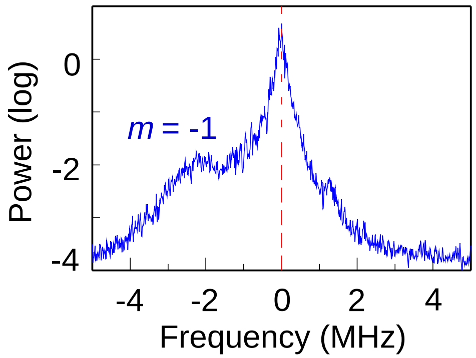
1) Tilt angle θ_{tilt} selects k .
2) For small δn/n, received power vs θ_{tilt} gives k spectrum.
3) Can measure mean flow and perturbations. If $v_{ExB} \gg v_{ph}$, then $\Delta\omega$ gives v_{ExB} or E_r. If v_{ExB}~0, $\Delta\omega$ gives v_{ph}.

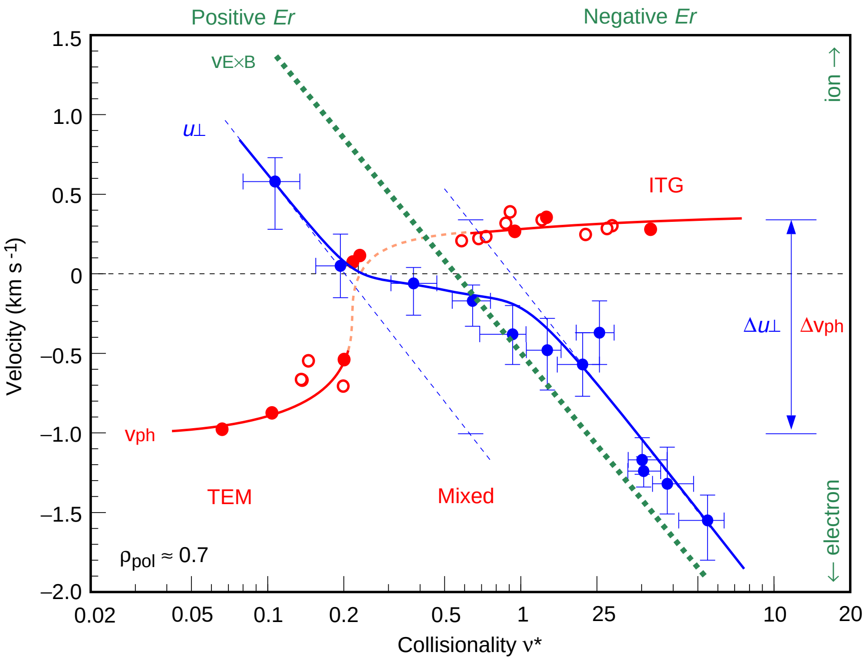
Doppler Reflectometry Results from ASDEX



v_{ExB}>>v_{ph} H-Mode E_r Radial Profile







v_{ExB}~0 TEM-ITG Transition

From G.D. Conway et al., IAEA06

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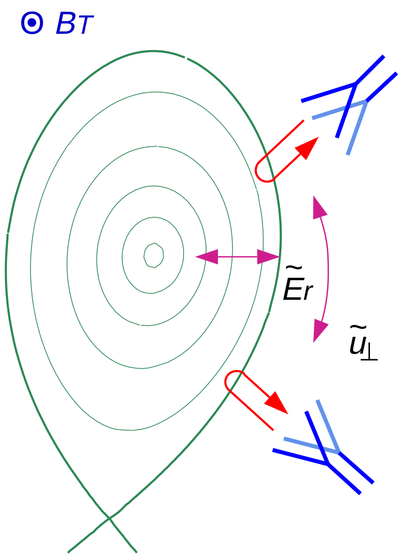
Case 3: $\tilde{v}_{E\times B}$ - Plasma flow perturbations



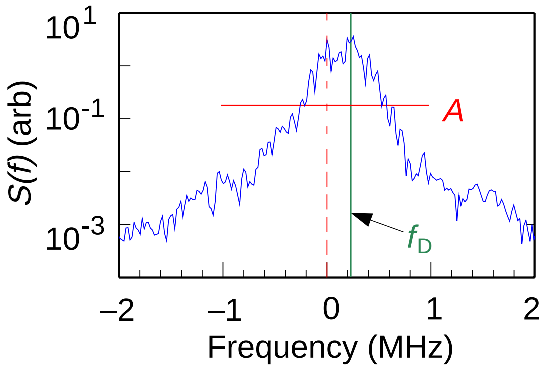
$$f_D = 2\,(v_{E\times B} + v_{ph})\,\sin\theta_t \,/\, \lambda_o$$

$\tilde{v}_{ph} = 0$ $\tilde{\theta}_t$ & $\tilde{B}$ small (no MHD)

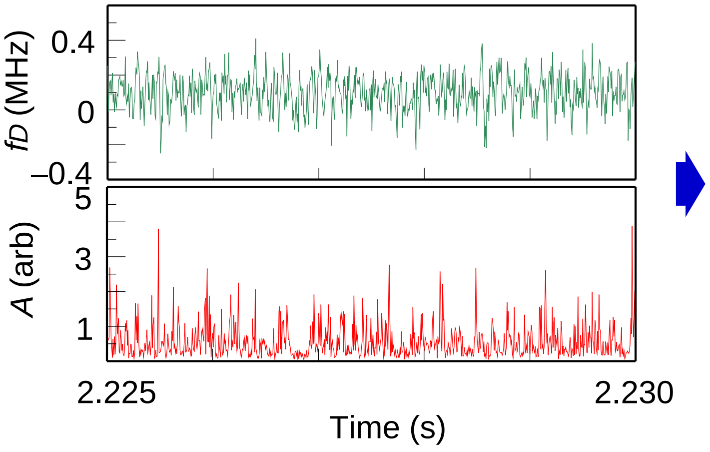
- $\tilde{E}_r \rightarrow \tilde{u}_\perp \rightarrow \tilde{f}_D$ while $\tilde{n}/n \rightarrow \tilde{A}$ at selected $k_\perp$
- MHD appears in both $\tilde{f}_D$ and $\tilde{A}$
- Coherent oscillations → Geodesic Acoustic Mode (Zonal flow)
- Important : Turbulence drives ZF → regulate turb. (saturation mechanism) → transport

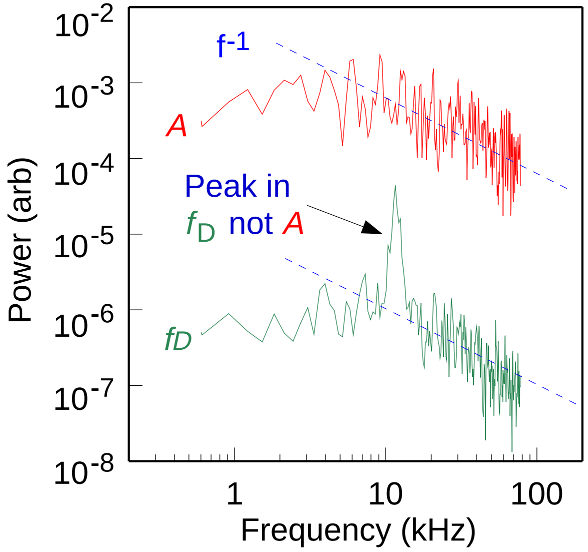
Complex spectra $A\exp(i\phi)$
sliding FFT

$f_D = \Sigma\, f.S(f) \,/\, \Sigma\, S(f)$, $A = \Sigma\, S(f)$

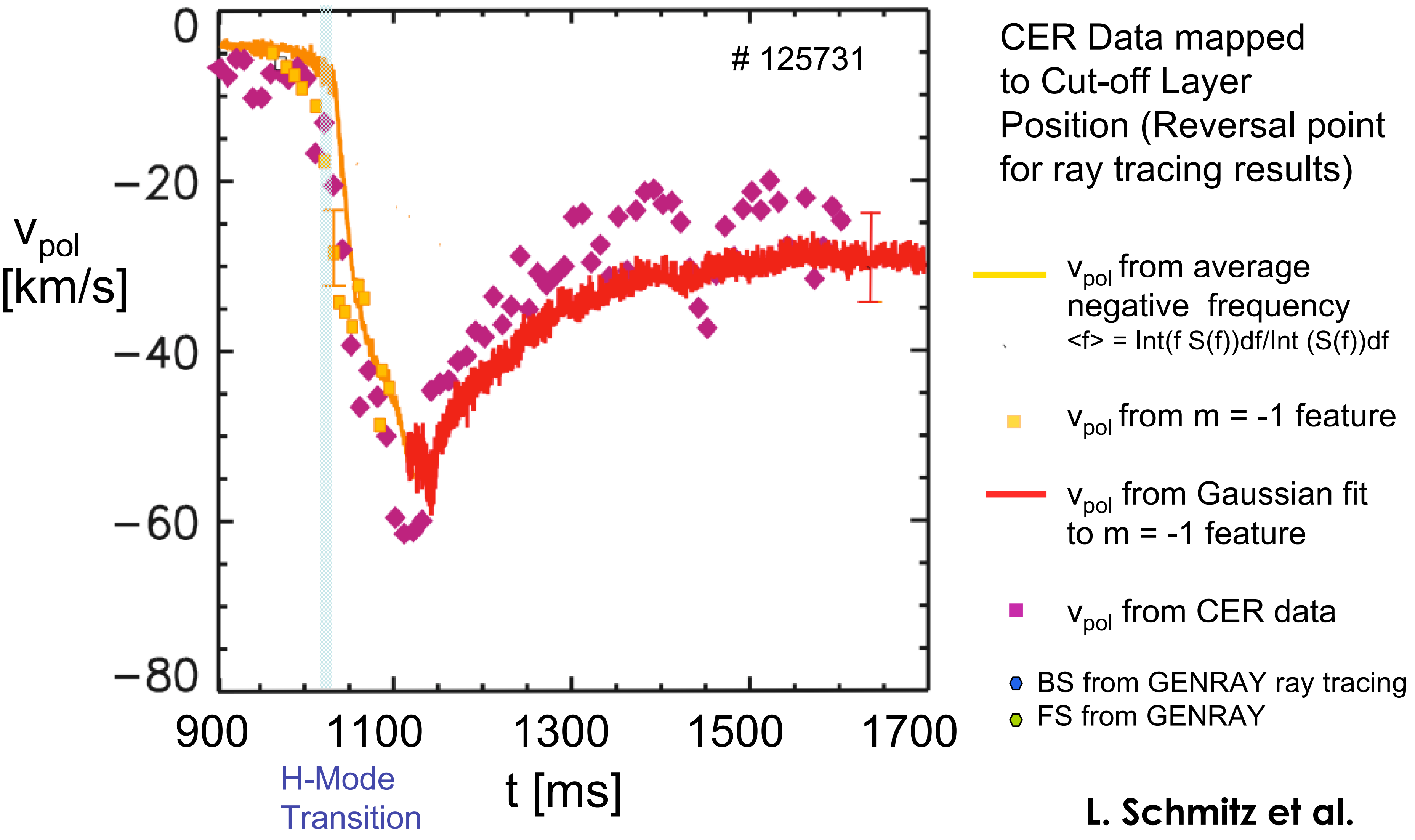


Generate time series of $\tilde{f}_D$ and $\tilde{A}$





Preliminary Measurements from DIII-D

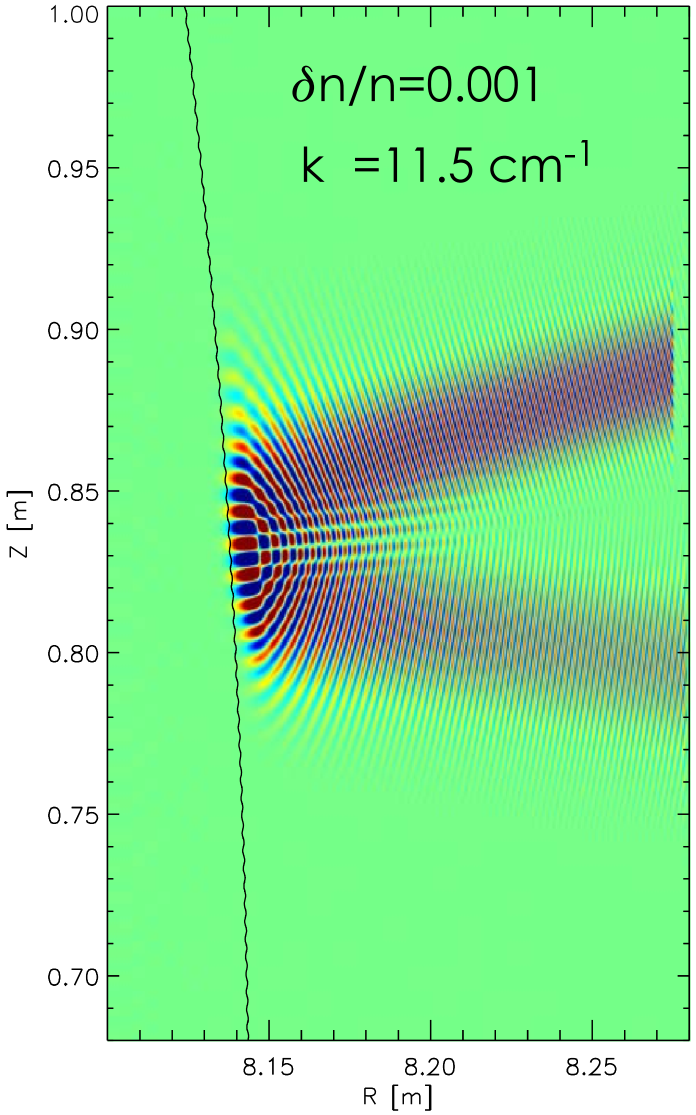


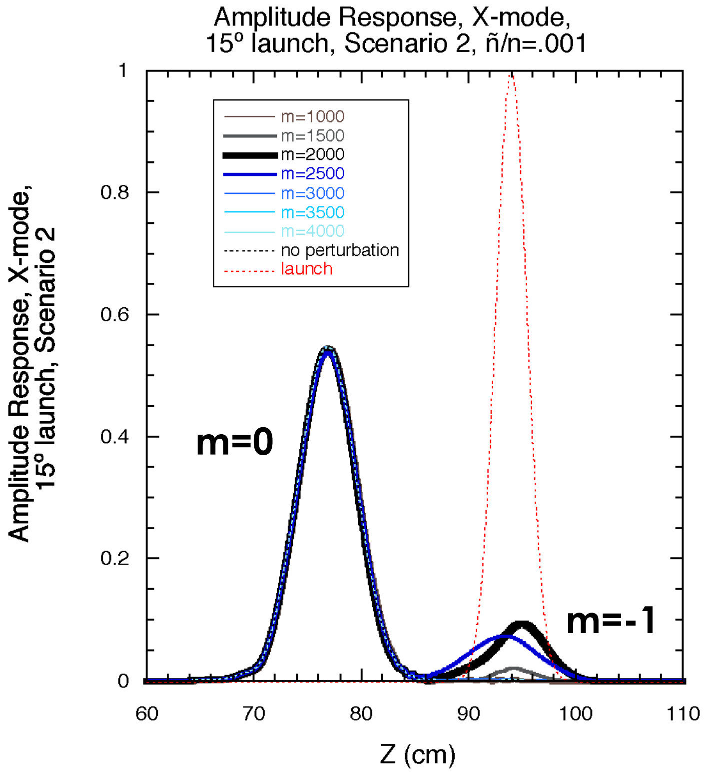
CER Data mapped to Cut-off Layer Position (Reversal point for ray tracing results)

L. Schmitz et al.

FDTD 2D Code for Design and Interpretation

ITER Doppler, Ez Contour
-15° Launch, f=160 GHz, X-Mode





- UCLA 2-D FDTD code developed for simulating dopper reflectometer response to 2-D profiles and turbulence.
  - O-mode, X-mode or mixed O- and X-mode (can handle mode conversion due to magnetic shear).

Fast Radial-View Polarimetry Principles

NSTX

Faraday Rotation Angle

$$\Psi = 2.62 \times 10^{-13} \lambda^2 \int n(z) B(\vec{z}) \cdot \vec{dl} = 2.62 \times 10^{-13} \lambda^2 \int B_{\|} n(z) dz$$

Fluctuating Part

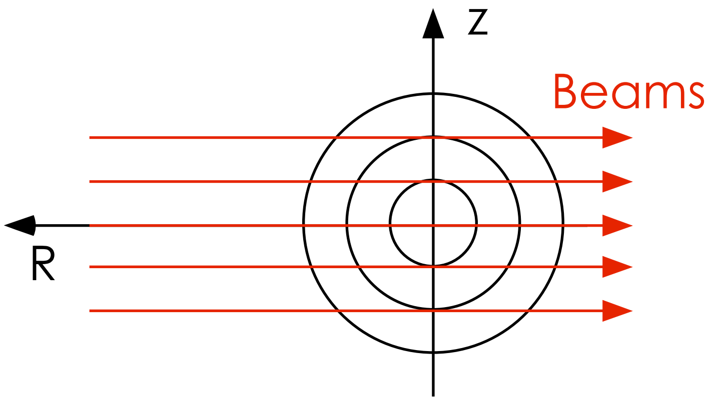
$$\tilde{\Psi} = 2.62 \times 10^{-13} \lambda^2 \int \left[\tilde{B}_{\|}(z) n_0(z) dz + B_{\|0} \tilde{n}(z) \right] dz$$

Equilibrium Part

$$\Psi_0 = 2.62 \times 10^{-13} \lambda^2 \int B_{\|0}(z) n_0(z) dz$$

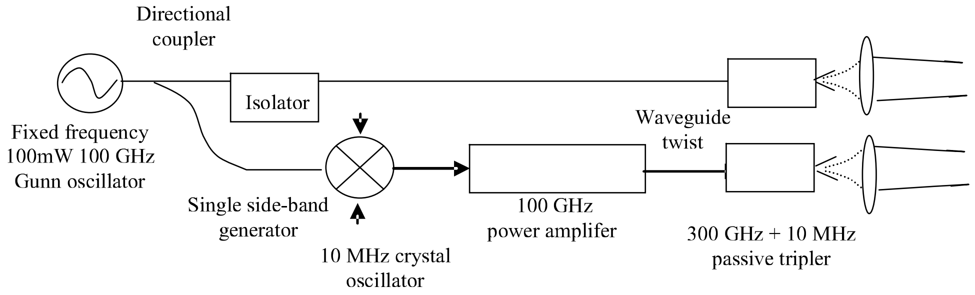
$$\frac{\partial \Psi_0}{\partial z} \propto \frac{\partial B_\theta}{\partial r} = J(0)$$

$$\tilde{\Psi}(z=0) \propto \int \tilde{B}_r(z) n_0(z) dz$$



Fast Radial-View Interferometry/Polarimetry Array on NSTX

Arrangement for Generating Two Orthogonally Polarized, Frequency Offset Beams



Optical Arrangement for Polarimetry on NSTX