Status and Open Issues for GYRO - DIII-D Validation

Presented by C. Holland

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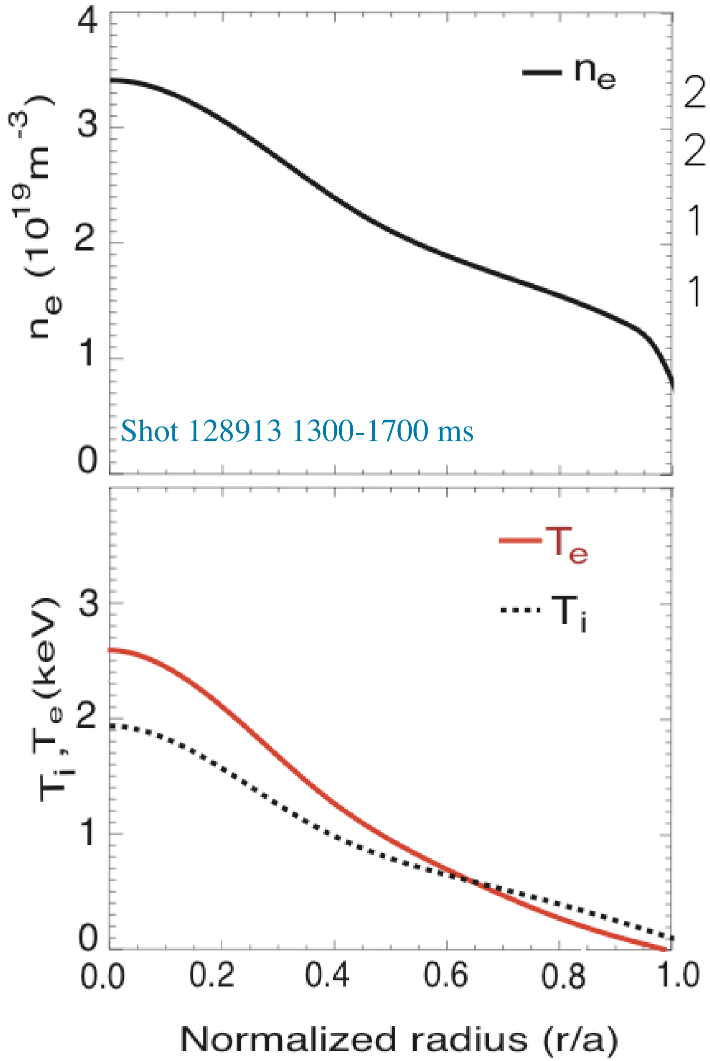
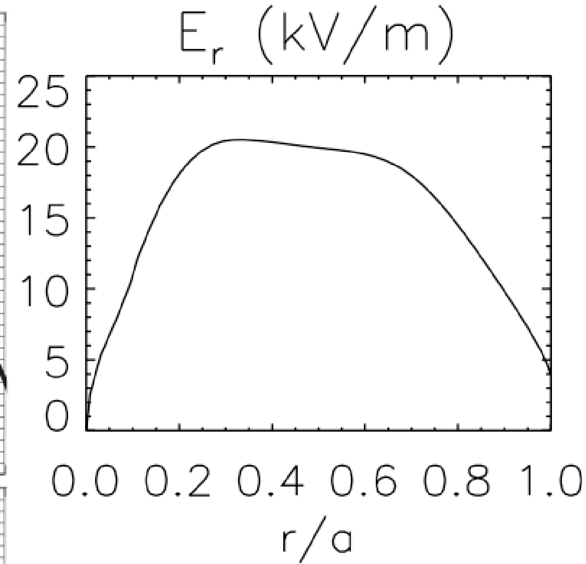
With help from: R. Waltz, J. Candy, G. Staebler, G. McKee, M. Shafer, A. White, T. Rhodes, R. Prater, J. DeBoo, G. Tynan, and many others

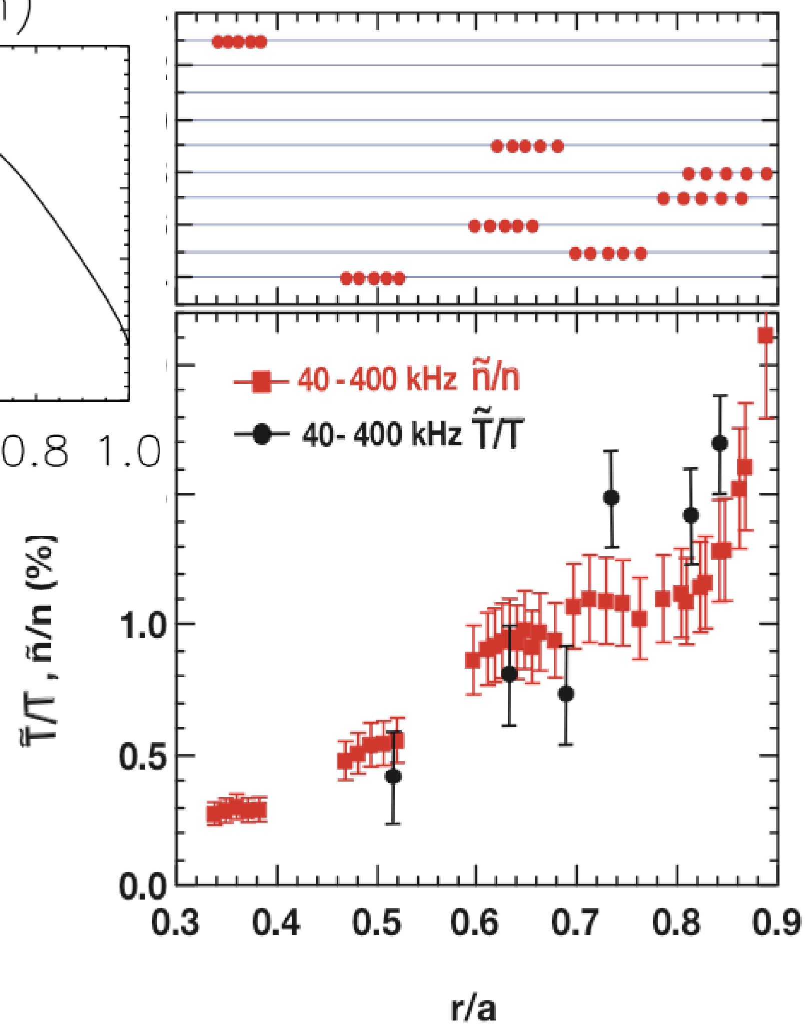
Outline

- **Review current results**
- **Issue #1: Particle fluxes**
- **Issue #2: Underprediction of heat fluxes and fluctuation levels at large r/a**
- **Thoughts on what to do next + lessons learned**
- **Caveat:** this analysis is all using set of L-mode discharges from A. White's 2007 expt. Not clear yet how general these results are.

Profiles + Fluctuations



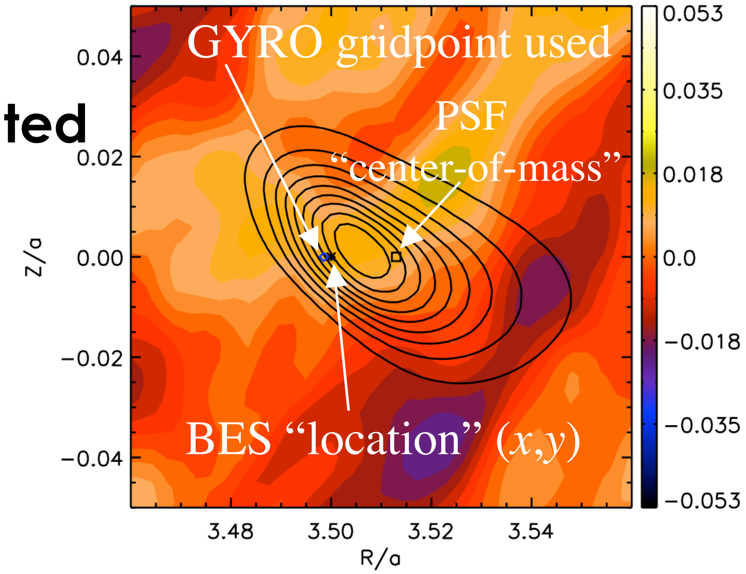




Ex: Applying BES PSF to GYRO Simulation Data

- **IDL post processing tool written to generate synthetic BES array; PSF form taken from calculation by M. Shafer**

- **Tool first interpolates PSF data (generated on a regularly spaced (R,Z) grid) onto a grid compatible with GYRO data (which uses a field-line following (r,θ,α) coordinate system)**



- **At each time point of interest, record**
  - Synthetic signal defined as

$$\delta n_{synthetic}(x,y,t) = \frac{\int d^2x' \psi^{PSF}(x-x', y-y')\delta n_e^{GYRO}(x',y',t)}{\int d^2x' \psi^{PSF}(x-x', y-y')}$$

  - GYRO signal at gridpoint closest to nominal BES location (term this signal the unfiltered GYRO signal in this poster)

Synthetic Diagnostic Array Layout

- **Create a 5x6 synthetic BES array centered in middle of simulation**
  - Offset 4 cm below midplane as in experiment
  - 0.9 cm radial spacing, 1.2 cm vertical
    - probably slightly too big; working to resolve
  - Use same PSF for all channels

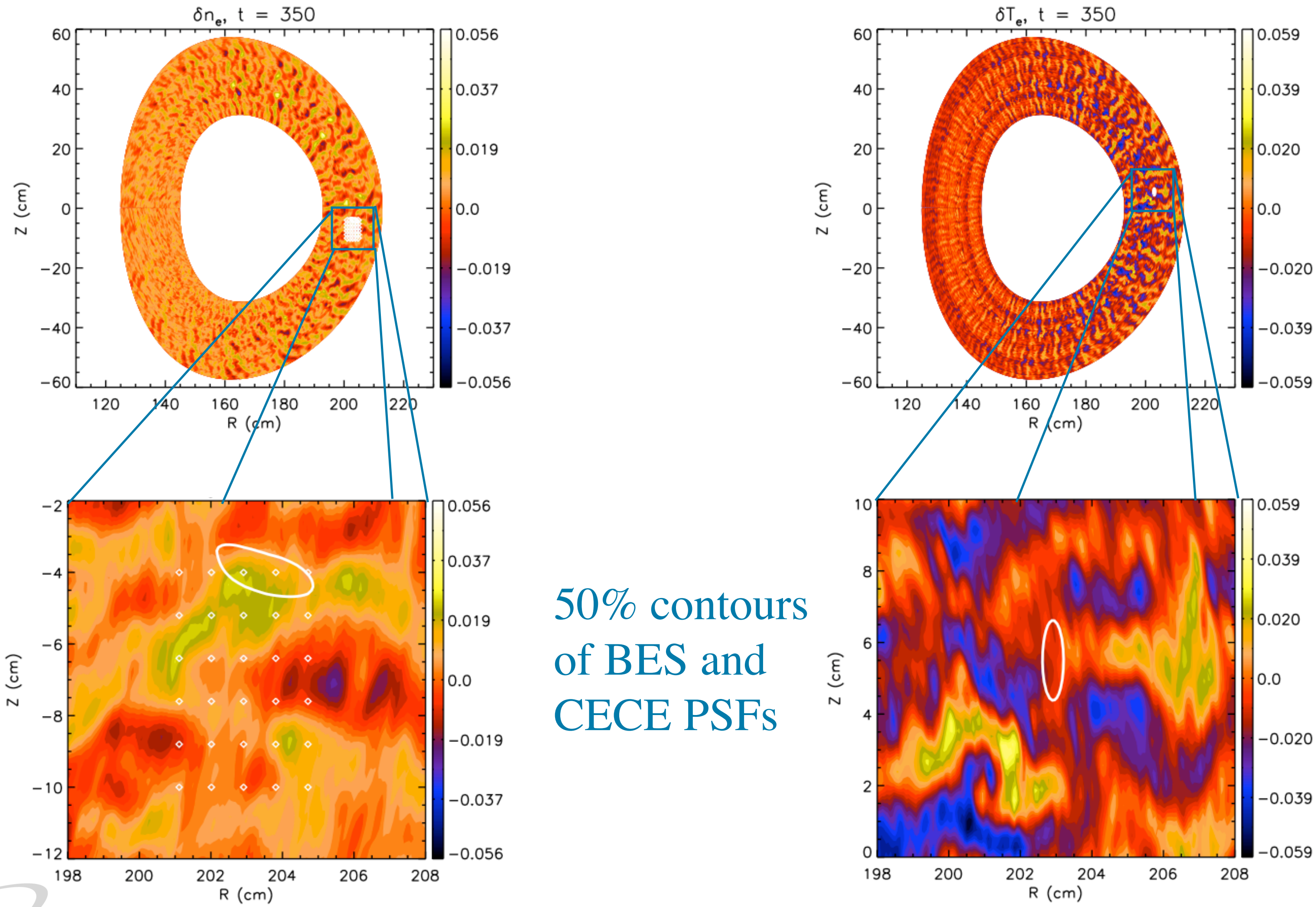
- **Create 5 synthetic CECE measurements across radius**
  - Offset 5.5 cm above midplane, also as in experiment
  - Use pairs asymmetric Gaussian for PSF/"spot" function
  - Radial $1/e^2$ diameter = 1cm, 3.8 cm vertically
  - Because sim is local, all radial locations should be equivalent, can average to improve syn. CECE statistics

- **Do calculations at 4 equidistant toroidal angles to get more statistics**

- **General note: believe synthetic BES diagnostic to be fairly mature and complete, but synthetic CECE results should be considered to be more preliminary**
  - Still need to consider several physics effects for CECE, such as relativistic electrons and temperature anisotropy

BES and CECE Fluctuation PSF Visualizations in (R,Z) Plane for r/a = 0.5

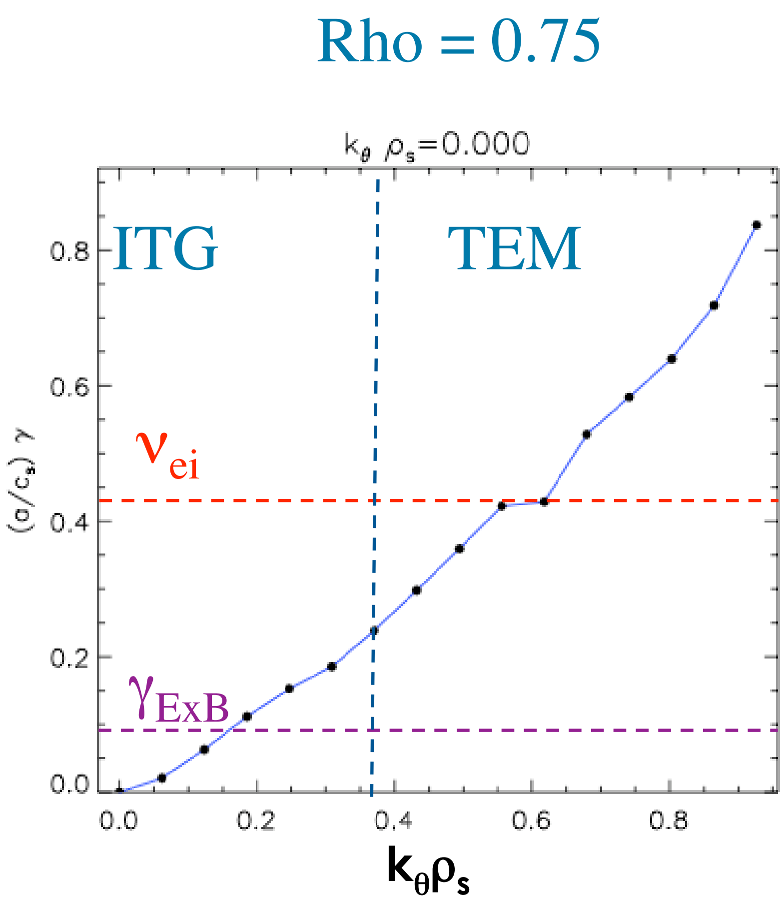
$$\frac{\delta n_e}{n_{e0}}$$

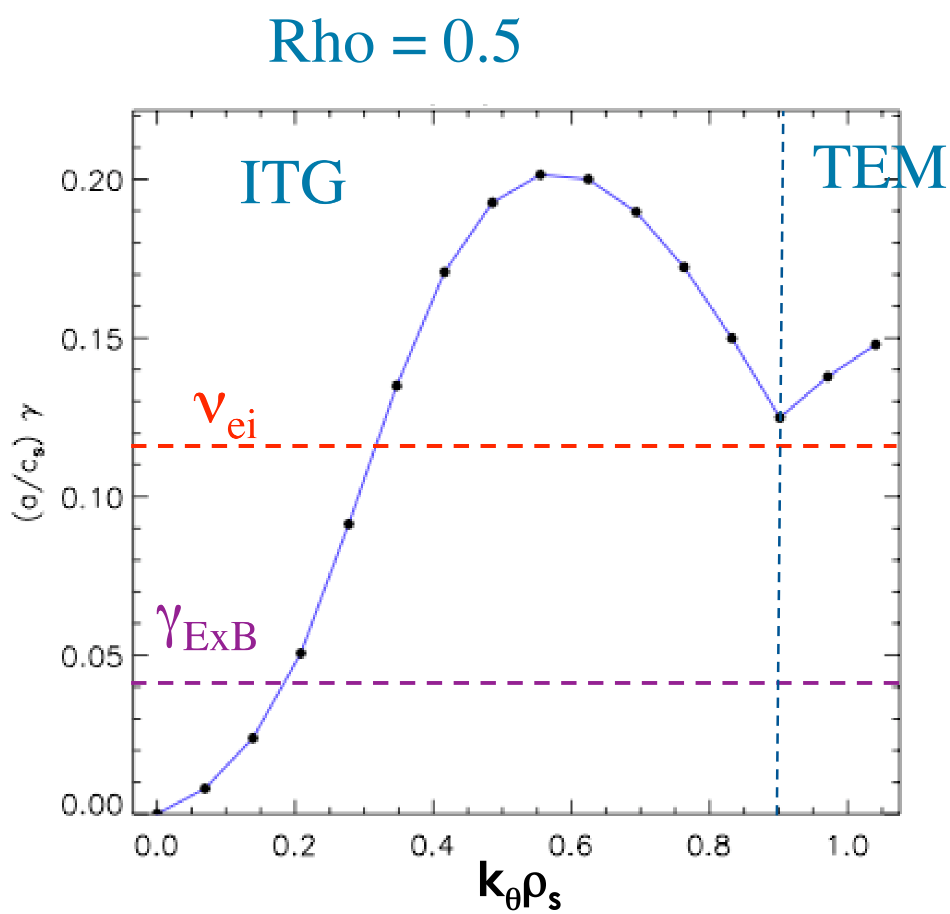


$$\frac{\delta T_e}{T_{e0}}$$

50% contours of BES and CECE PSFs

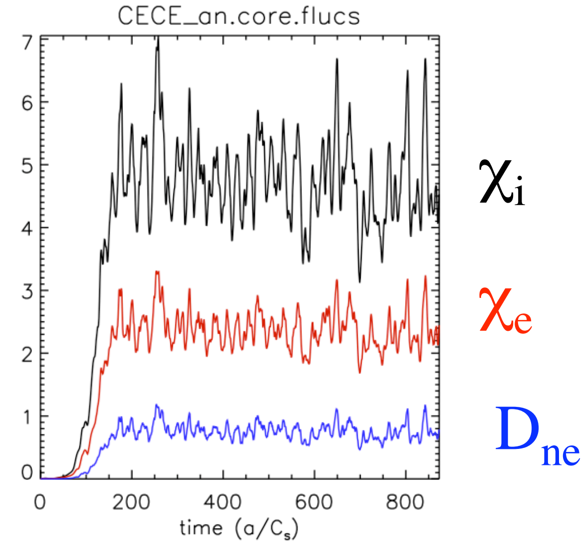
Linear growth rates

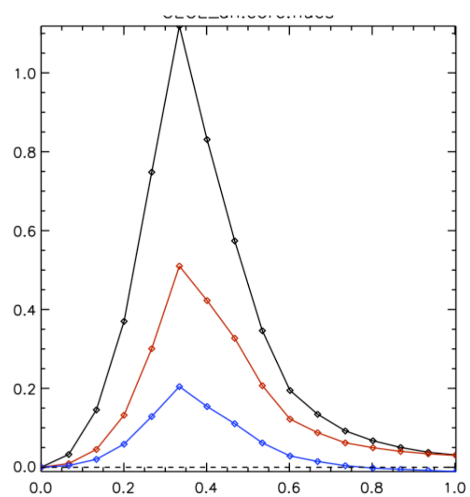




Fluxes vs. time and $k_\theta \rho_s$

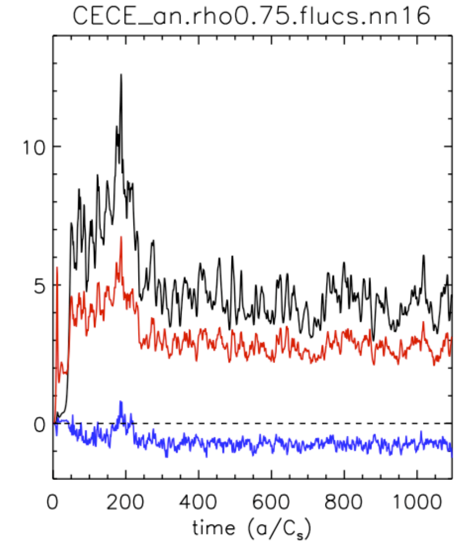
$\rho = 0.5$
Use $t > 200$

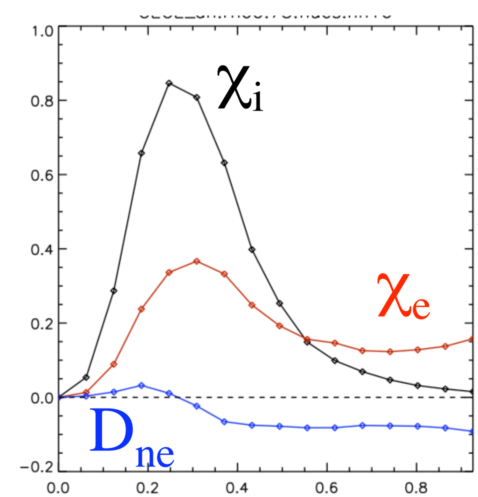




$k_\theta \rho_s$

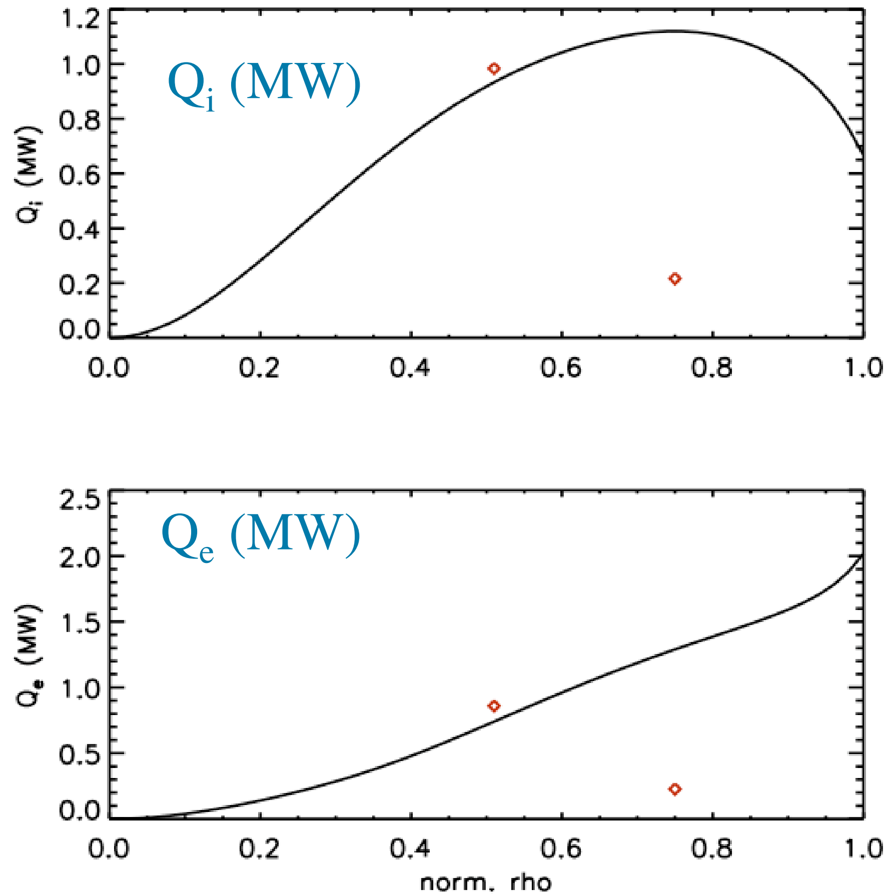
$\rho = 0.75$
Turn on γ_{ExB}
@ $t = 200$
Use $t > 300$

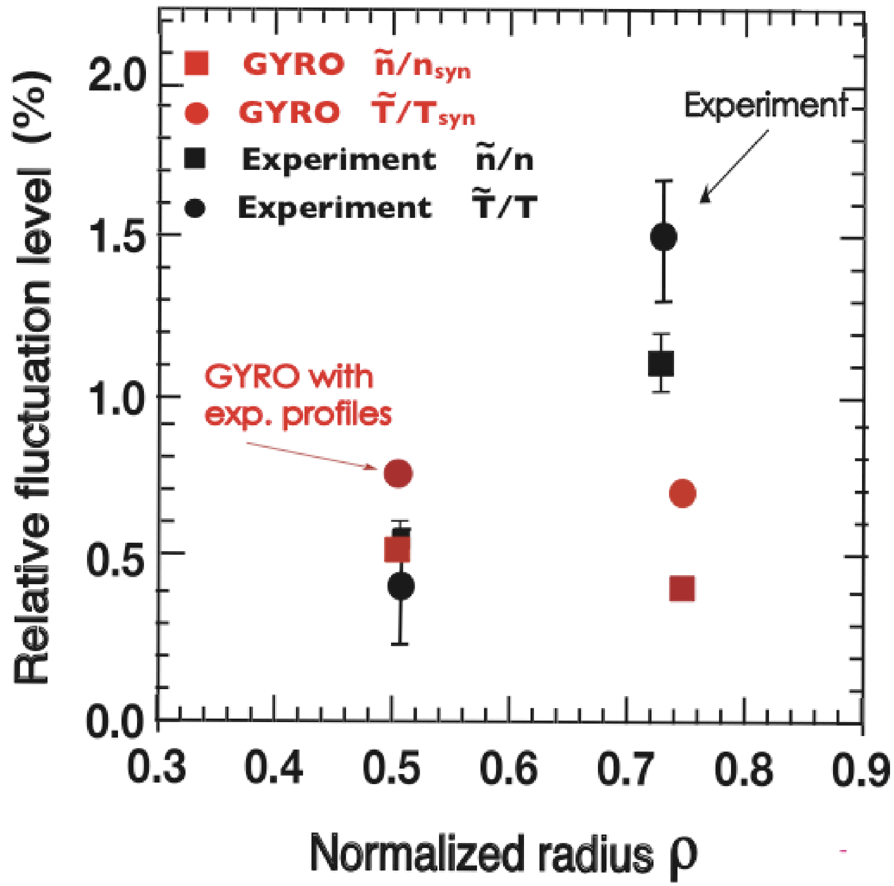




$k_\theta \rho_s$

Fixed-Gradient Sims Match Heat Fluxes and RMS Fluc. Levels at r/a = 0.5, underpredict r/a = 0.75





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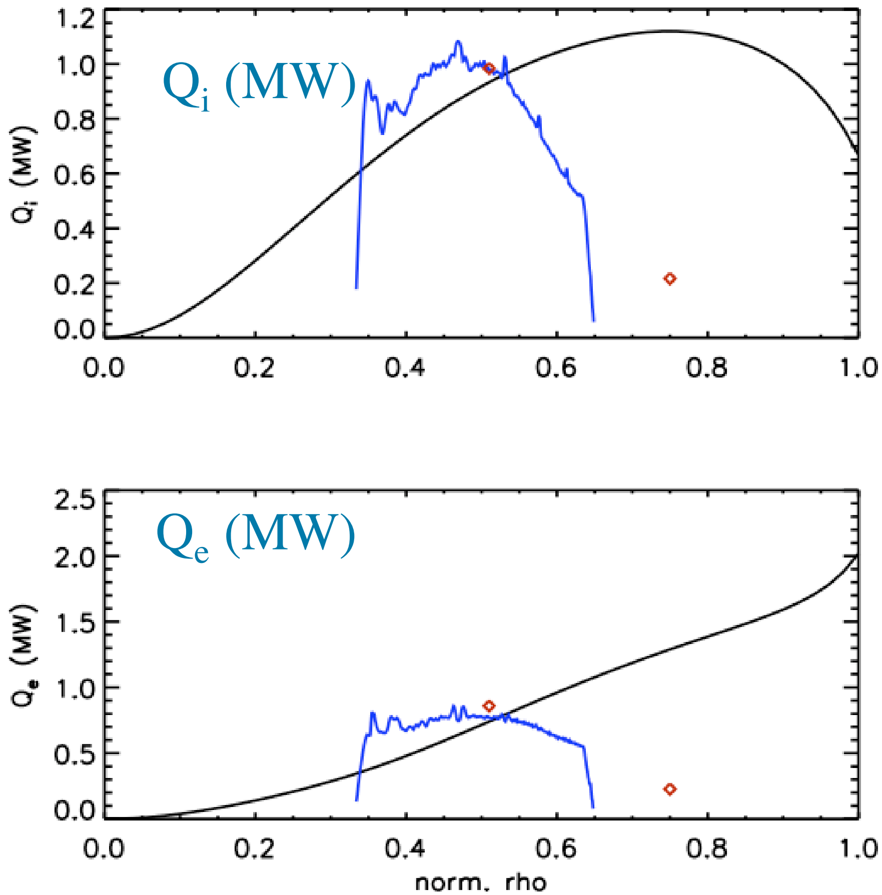

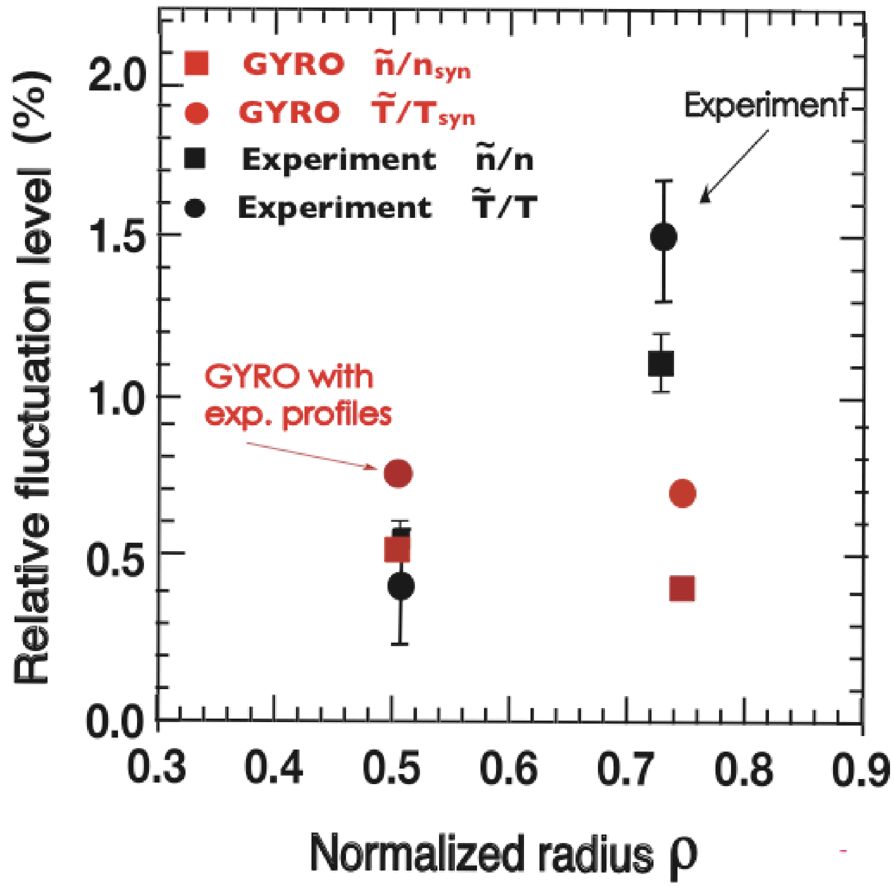

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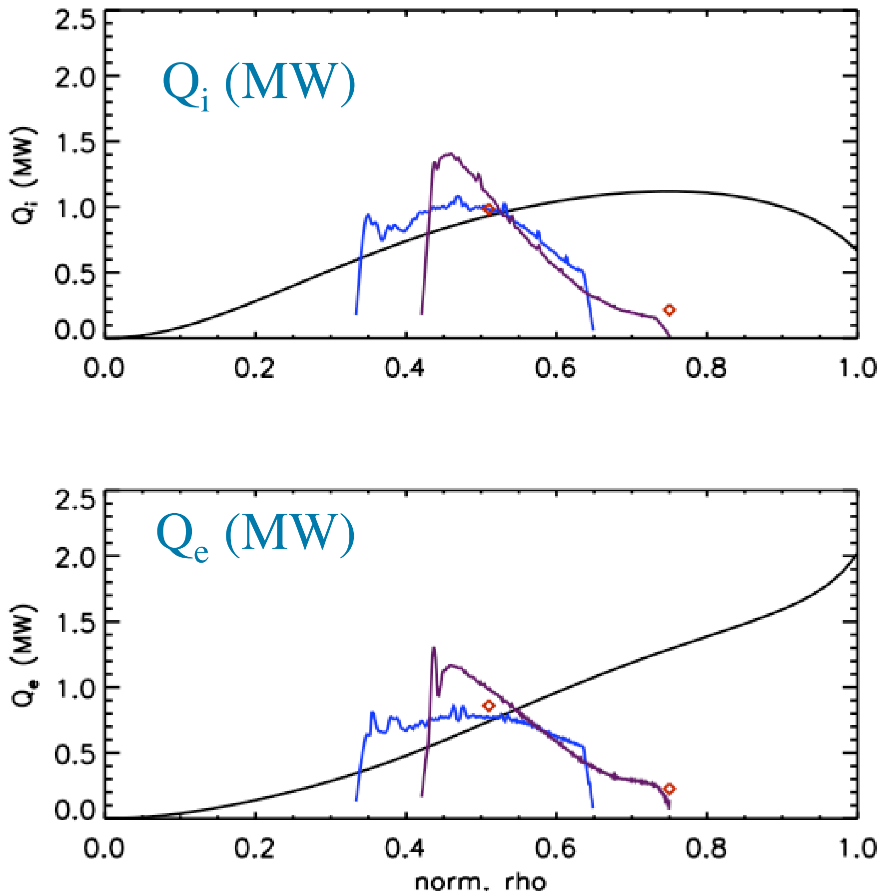
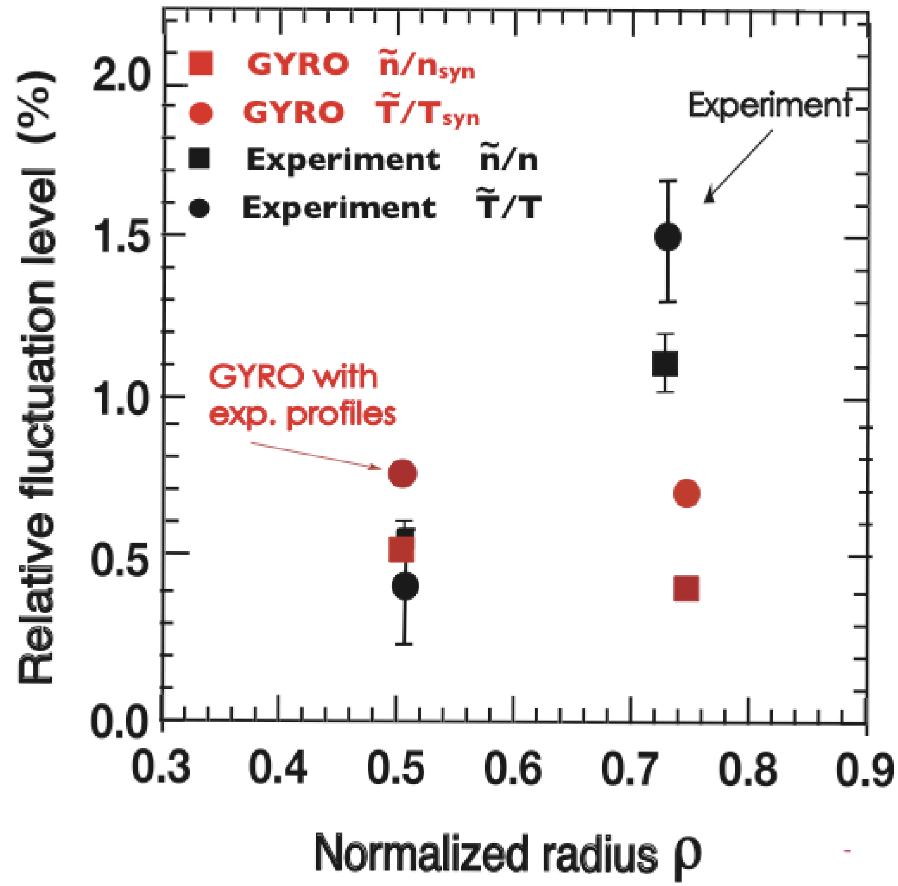
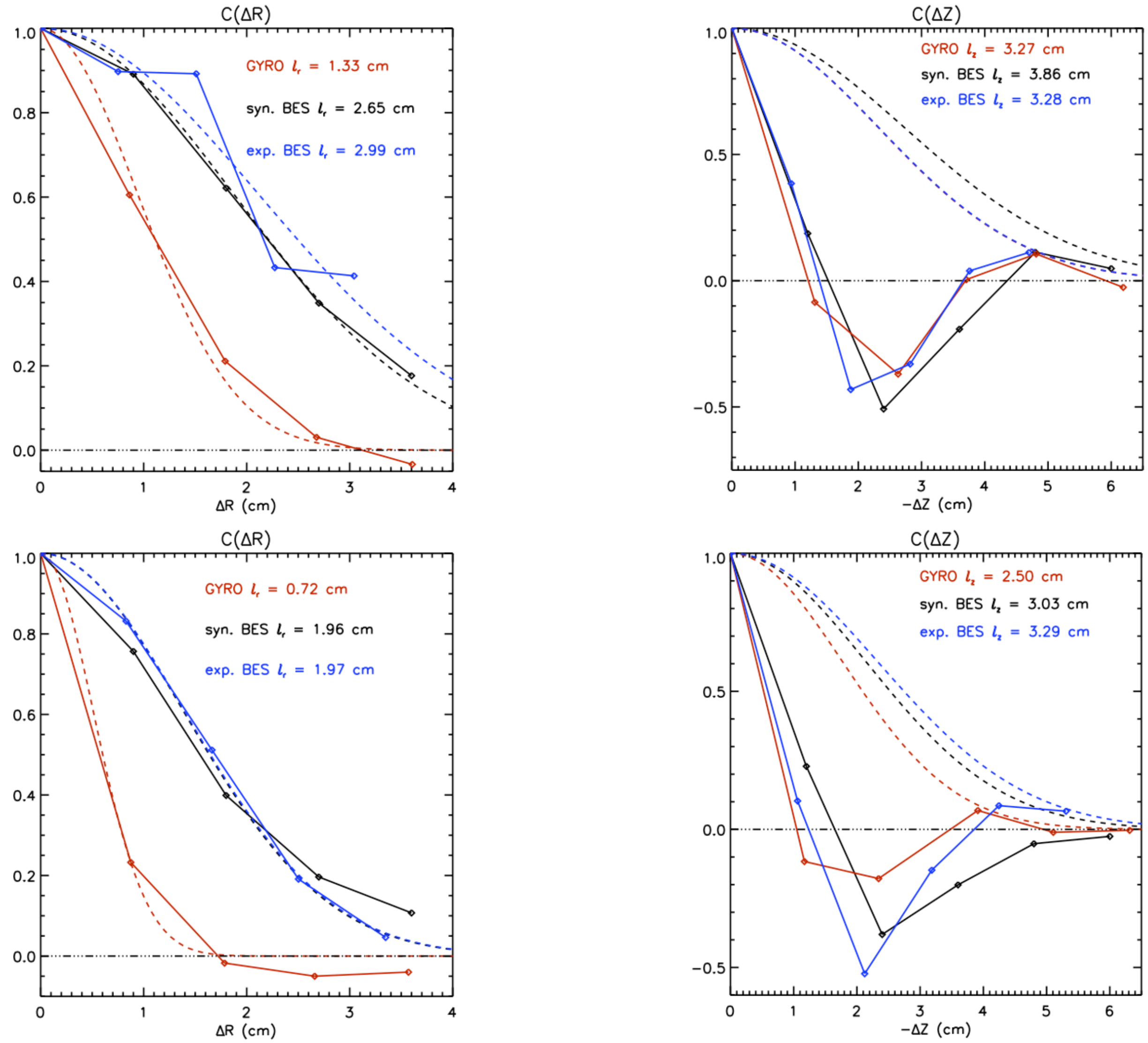




Correlation Function Comparisons

Rho = 0.5

Rho = 0.75



Obtain good agreement in "shapes" of spectra at both locations

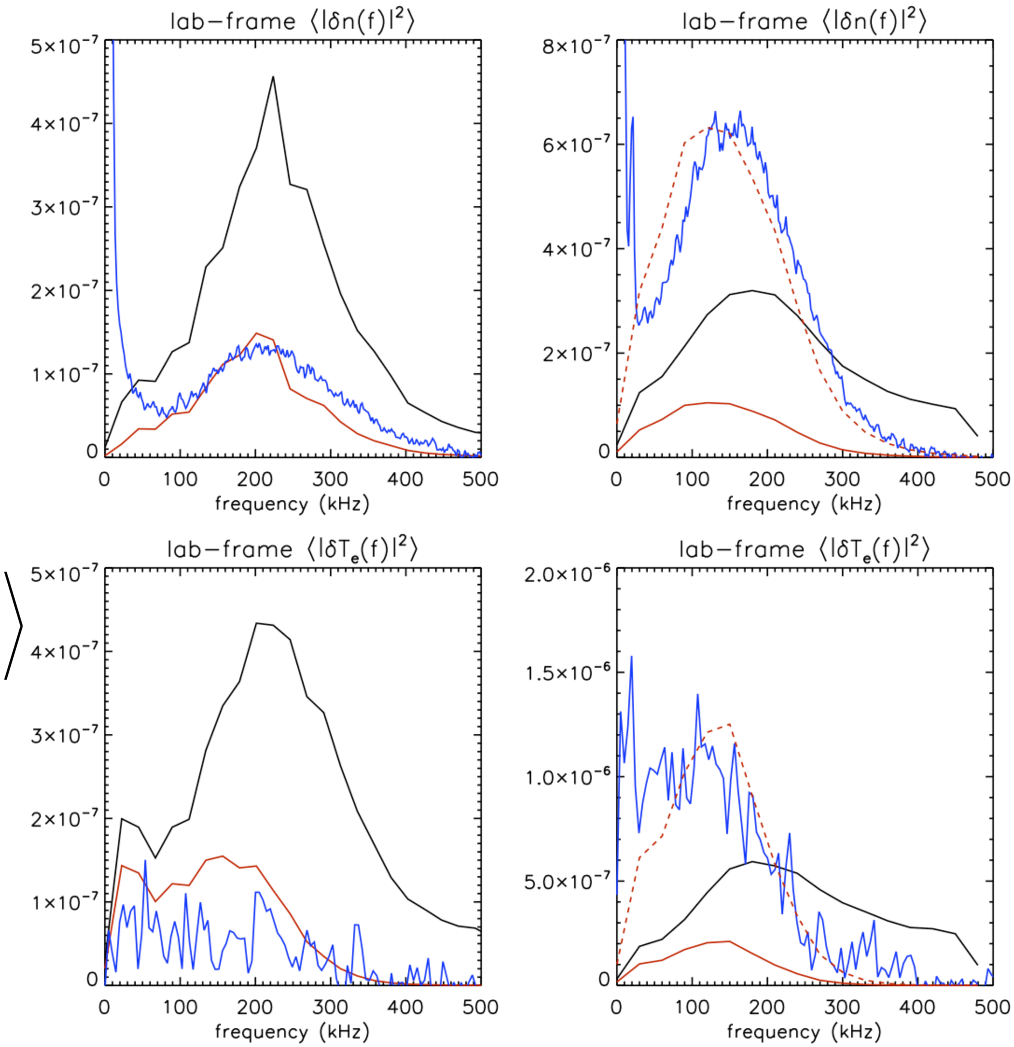
- **Observe good agreement b/w synthetic and exp. measured lab-frame frequency spectra**
  - Unfiltered GYRO in black
  - Dashed red curves are synthetic results "renormed" to exp. level

$$\left\langle \left|\delta n(f)\right|^2 \right\rangle$$

$$\left\langle \left|\delta T_e(f)\right|^2 \right\rangle$$

- **Key observation: seem to get "shape" of eddies right even if we don't get magnitude**

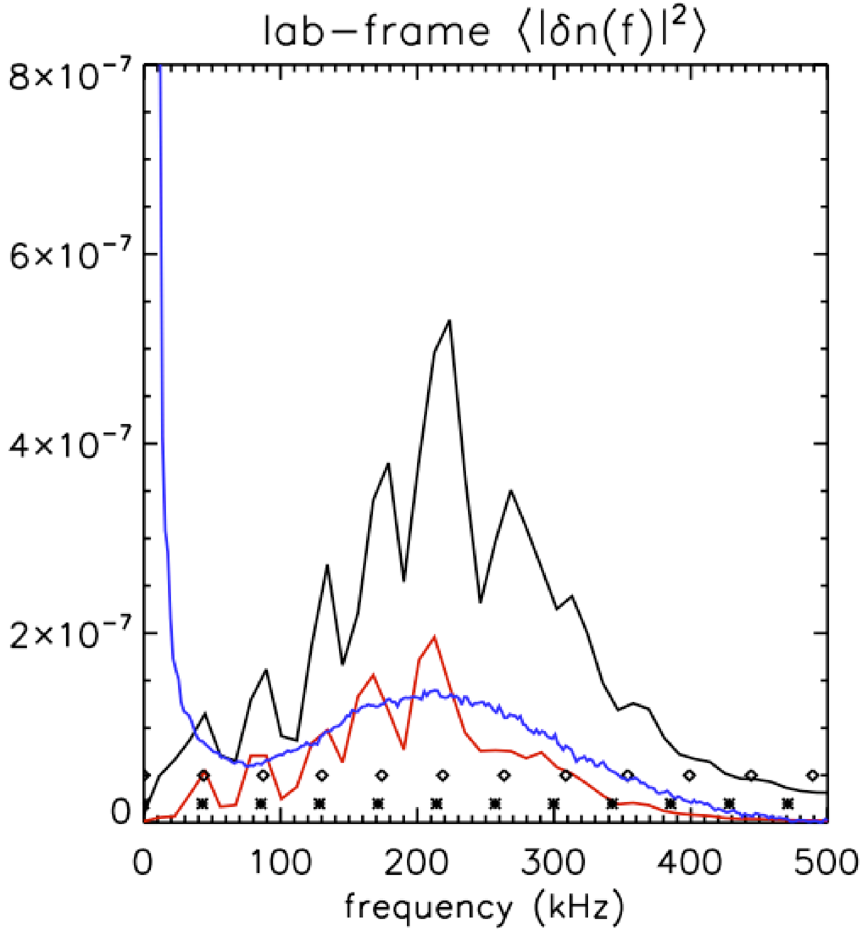
- **But this is using low frequency resolution for simulations (~20 kHz vs. 5 kHz for expt)…**

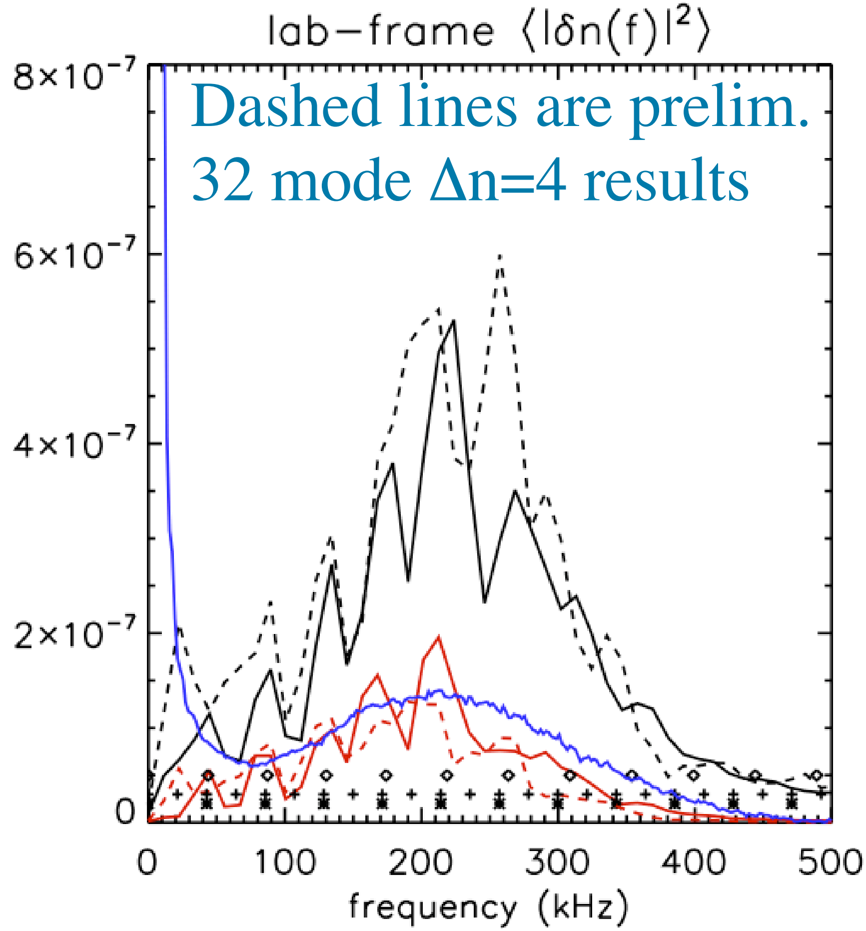


$\rho = 0.5$ $\rho = 0.75$

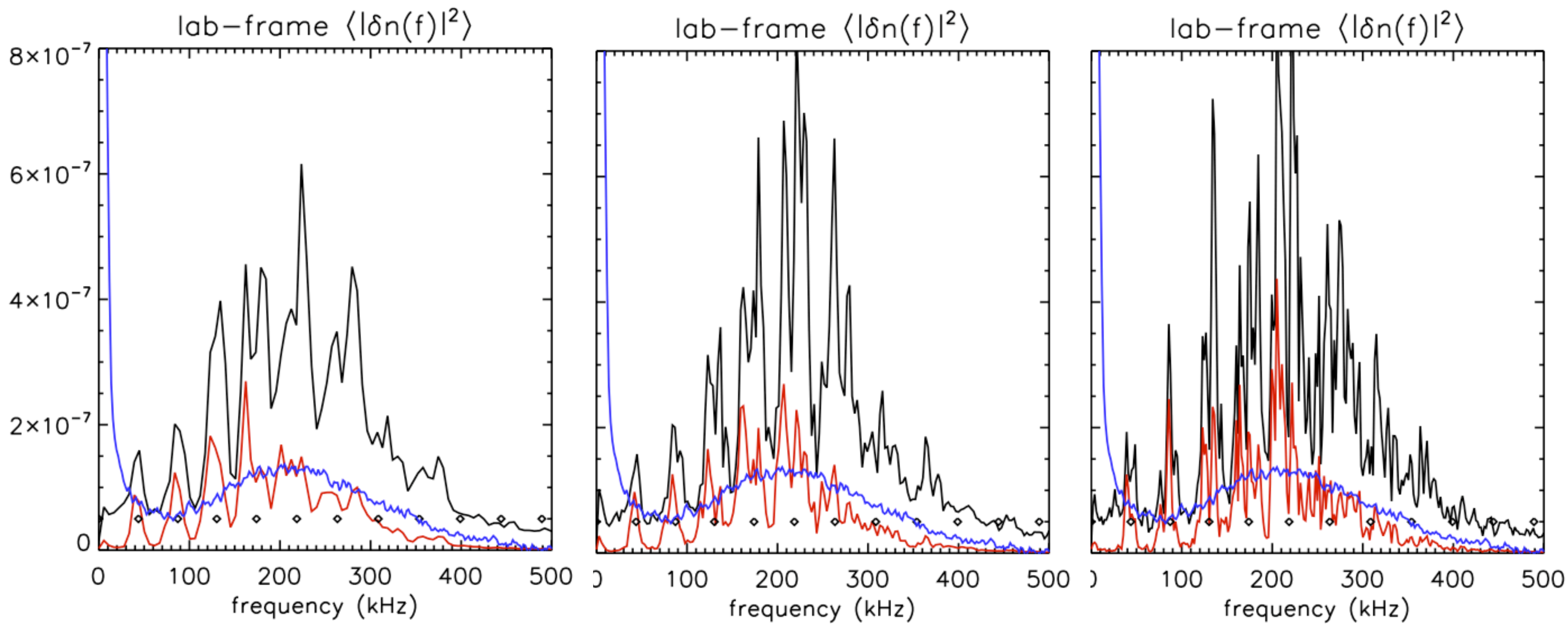
Increase frequency resolution brings out finite Dn structure of synthetic signals

- **If we calculate synthetic specta with double freq resolution, observe features well-correlated with discrete *n* values**
  - Features robust with even higher resolution, but SNR decreases quickly





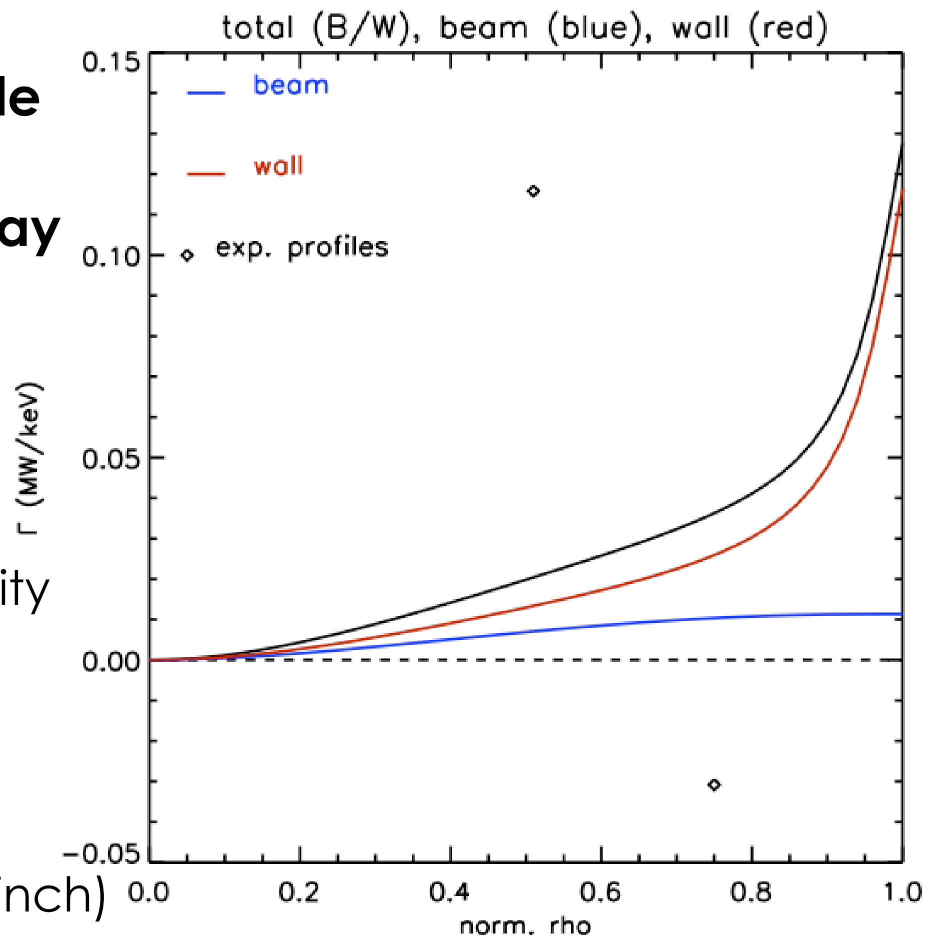
SNR vs. frequency resolution



Issue 1: Particle fluxes

- **According to ONETWO, particle flows dominated by highly uncertain wall source- can't say how well GYRO is predicting flows**

- **Implications-**
  – Probably better to keep density profile fixed in flux-matching TGYRO simulations here
  – Impact on intrinsic rotation studies (where rotation pinch may be correlated particle pinch)



Issue 2: Underpredicting heat fluxes at r/a > 0.5

- **Key observations:**
  - deficit is in Q_i -> issue is not just missing ETG/paleo
  - "Shapes" of synthetic (i.e. long-wavelength) signals match well against experiment
  - Particle flux at r/a = 0.75 currently pinch-dominated from high(er)-k modes
  - **Suggests we need more power in long wavelengths**

- **Possibilities**
  - Dynamic impurities? Z_{eff} <= 1.3
  - Lack of up-down asymmetry in simulations?
  - Missing long-wavelength transport
    - Simple est. suggests below (but maybe near) KBM threshold, RBM maybe? But should show up in GYRO, EM had little effect on NL results. Need additional local/non-local analysis?
  - Numerical issues due to high collisionality
    - ν_{ei} = 0.4 a/C_s at r/a = 0.75; hope to address with upcoming ν^* experiment
  - Profile uncertainty and stiffness
    - use TGLF to take a pass, but initial GYRO runs found less stiffness than earlier rho-star simulations
    - Need work on translating b/w TGLF + GYRO I/O, ExB shear differences and uncertainty
    - Uncertaintiy in mag. equilibrium? Use of Miller model (rather than 2D EFIT)?
  - Core-edge coupling: turbulence from SOL/edge region "spreads" in
    - **CAN'T BE ADDRESSED BY GYRO- need edge GK eqn., open field lines, neutrals, etc.**
    - **But**: how far in do we realistically think it spreads (r/a = 0.8? 0.7? 0.6??)
    - Less drastically, need to go to non-local, flux-matching simulations?

Some thoughts on V&V realities (in no particular order)

- **Not obvious L-mode transport is always as stiff as sometimes assumed**
  - But: even large local gradient changes don't lead to big changes in profiles
  - Q: how much variation is there across "typical" L- and H-modes
- **Don't count on having a reliable particle flux measurement (esp. in low-power L-mode) until wall recycling/source can be better constrained**
  - May impact momentum physics validation as well
- **Errors in magnetic equilibrium and translation to sim. input files common and at least as significant as n_e/Te/T_i/E_r profile uncertainties**
- **Efficient data storage not very compatible with syn. diagnostics**
  - Syn. diagnostics often use multiple interpolations in implementation
- **Simulating collisional edge"-ish" (ρ = 0.75) plasmas very challenging**
  - Story will be more than just multi-scale ETG+ITG I suspect
  - How big do we think spreading from SOL in is?
- **Validation experiments will involve strong trade-offs between fluctuation SNR, equilibrium profile measurements, model applicability, and range of parameters one can independently scan**