Validation - an experimentalist's perspective

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Goal of the Exercise:

Show that a class of simulations reproduces the essential turbulent transport physics across a wide range of experiments, operating conditions, and devices

Use those simulations to provide insight into the future performance of new experiments

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Hierarchy of Approaches & Requirements:

- **Lowest level:** Effective transport rates (fluxes or transport coefficients)
- **Intermediate level:** Turbulence & mesoscale structure statistics (spectra, corr functions, amplitudes, cross-phases, ZF/GAM amps, frequencies
- **Deeper level:** Nonlinear dynamics of the turbulence/mesoscale system

↓ Increasing Diagnostic Complexity & Analysis

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Hierarchy Also Extends Across Devices, Conditions, and Models

- **Collisionless/weakly collisional finite beta plasmas:**
  - Core of tokamaks, stellarators;
  - GK Simulations
- **Collisional plasmas w/ finite beta**
  - Edge region;
  - collisional GK simulations, fluid simulations
- **Highly collisional plasmas w/ low beta**
  - Separatrix/SOL; small confinement devices & lab plasmas
  - collisional GK simulations, fluid simulations

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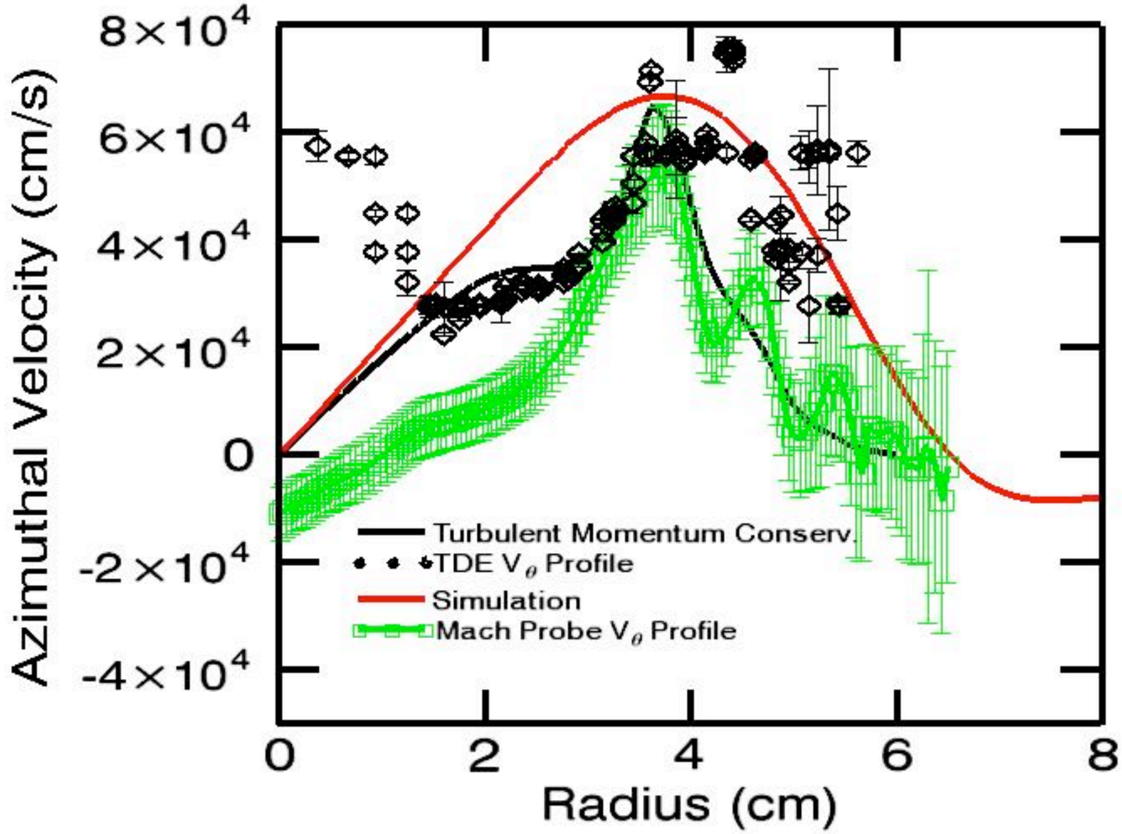
An Example: Zonal Flow Generation from Collisional Drift Turbulence in a Lab Plasma



Tynan et al April 2006 PPCF

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Comparing G.K. simulations with turbulence data:

Current approach based on fluid picture of plasma

Simulation results:

$$\tilde{f}_{i,e}(\vec{x},\vec{v},t)$$

reduced results:

$$\int \tilde{f}(\vec{x},\vec{v},t)d\vec{v}, \int \vec{v}\tilde{f}(\vec{x},\vec{v},t)d\vec{v}, \ldots$$

↓

Synthetic diagnostic reproduces spatio-temporal response of turbulence diagnostics

→

Data analysis tools for experiment and virtual data

(spectra, corr functions, PDFs, etc…)

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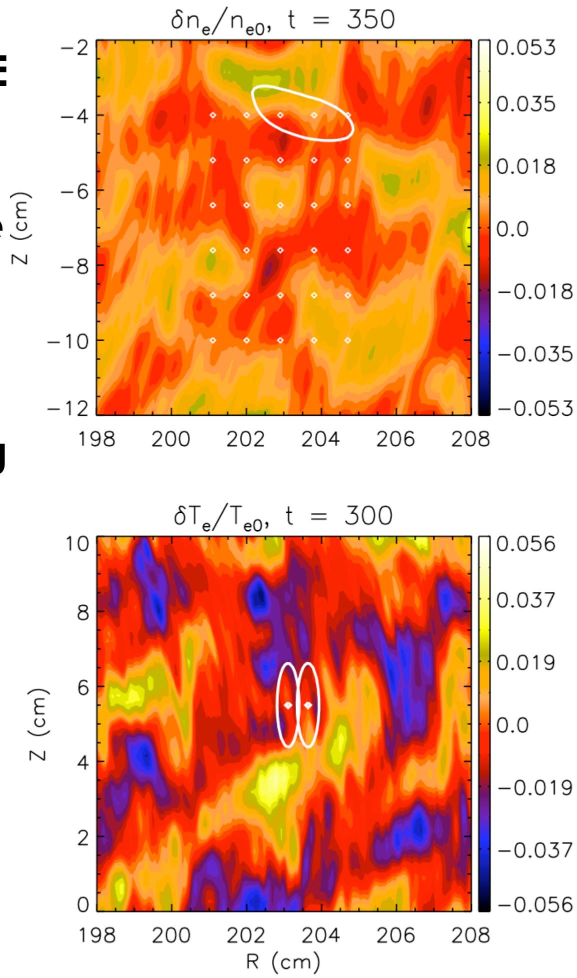
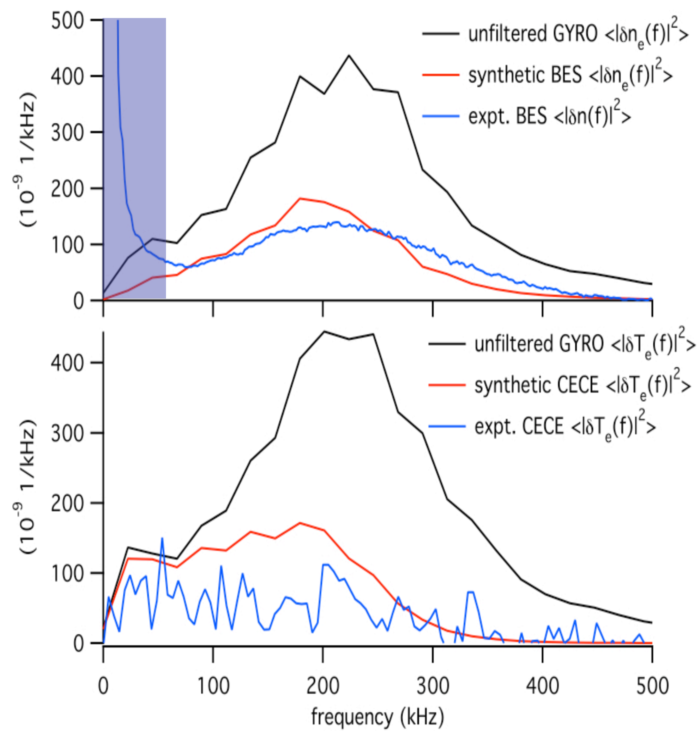
New Synthetic Diagnostic Capability Allows Direct Comparisons of Simulated and Measured Turbulence Characteristics

- **Synthetic BES and CECE diagnostics have been developed as IDL post-processing tools for use with GYRO simulations**

- **Short term goal is to develop corresponding IDL interface for GTC which will use same tools**





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Application to Particle-based GK Simulations (e.g. GTC,…)

- Turbulence Analysis Requires Ensemble Averaging to Obtain Meaningful Result
- Experiments Use Ergodic Thm (Time Average = Ensemble Average)
- Simulation run time is short (~msec currently)
- Particle based approach MUST quantify significance of noise which will limit simulation duration
- **Impact:** Use spatial sampling of statistically independent regions; **may also need to consider ensembles of runs**

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Status of Validation in this Project

- Several core plasma virtual diagnostics already exist (BES, CECE, PCI) or could be developed (Reflectometry, Scattering)
- Results have been integrated with DIII-D Turbulence Analysis Tools
- Need to develop interface between GTC Codes and Virtual Diagnostics
- Need to develop mesh generation from experimental configurations for input to GTC
- **NEED TO RECRUIT A POST-DOC (UNDERWAY)**

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Likely Future Directions

- Consider how to integrate wave-particle physics into this process (going beyond fluid picture)
- Integrate into collisional edge/SOL GK simulations & cross-compare against fluid edge/SOL simulations
  - Would enable cross-model and small expt/confinement expt cross-comparisons
- Link core & edge/SOL simulations

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