Development of a Validation Database and Metrics for Characterization of L-mode Shortfall

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Collaborators

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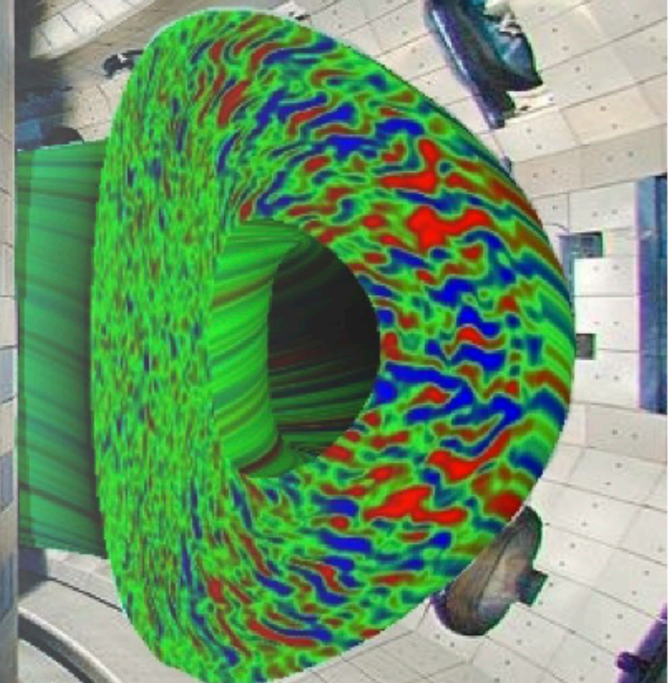

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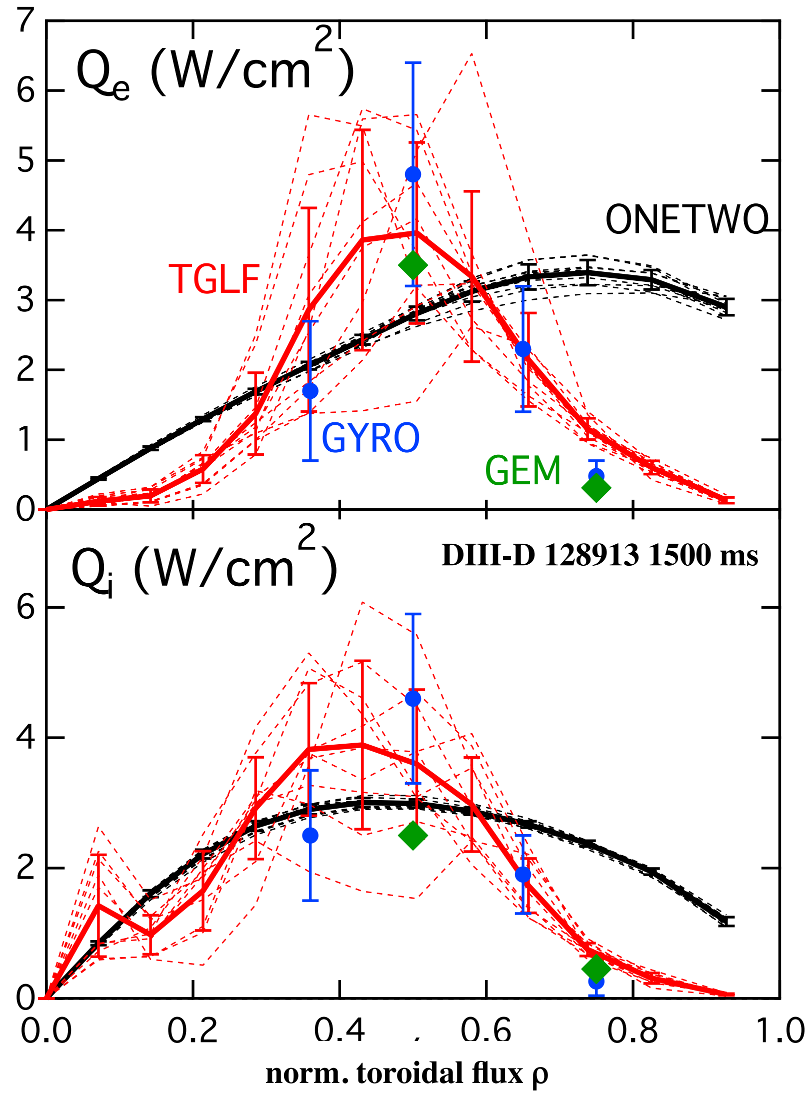
“Near-edge shortfall”: Multiple gyrokinetic & gyrofluid codes appear to systematically underpredict near-edge transport

- **Results below show consistency between quaslinear TGLF, fully nonlinear GYRO transport predictions**
  - For both codes, transport predictions are made for an ensemble of 10 independent sets of input profile, and ensemble statistics used to quantify uncertainty
- **Quantitatively similar flux results at ρ = 0.5 and 0.75 predicted by global, PIC GEM code [Chen & Parker, J. Comp. Phys.** 220 **839 (2007)]**
- **Similar shortfall observed in nonlinear gyrofluid simulations of TFTR by Beer et al [M. Beer, Ph.D. Thesis]**



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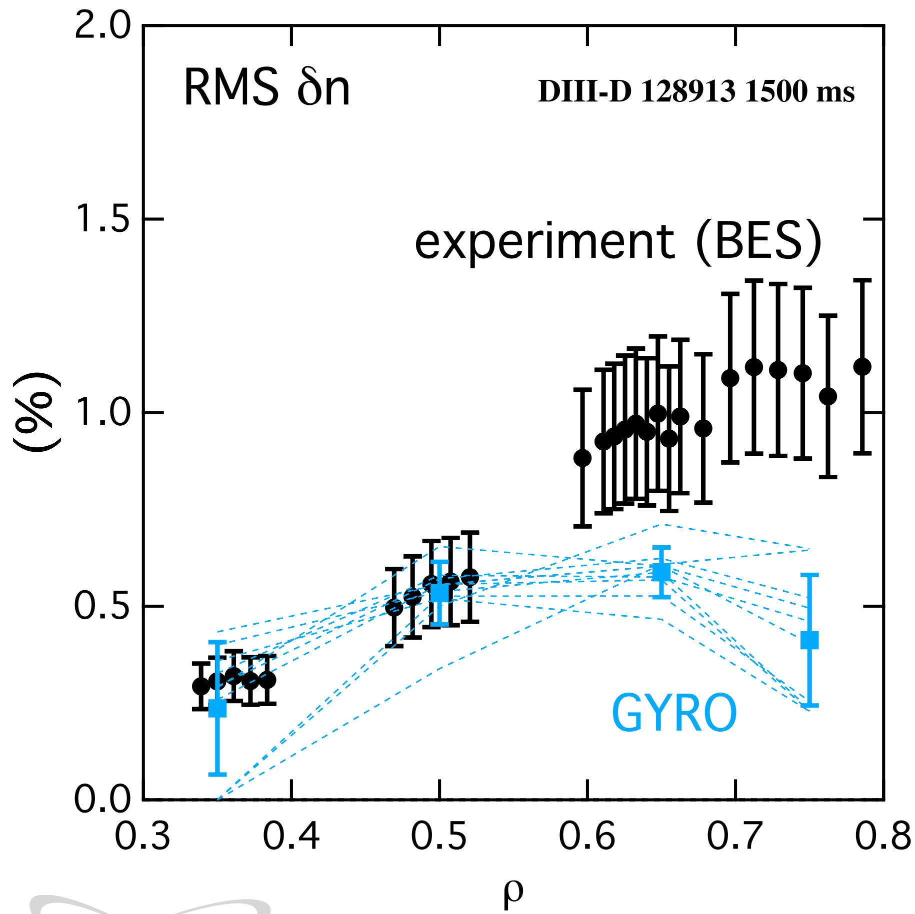
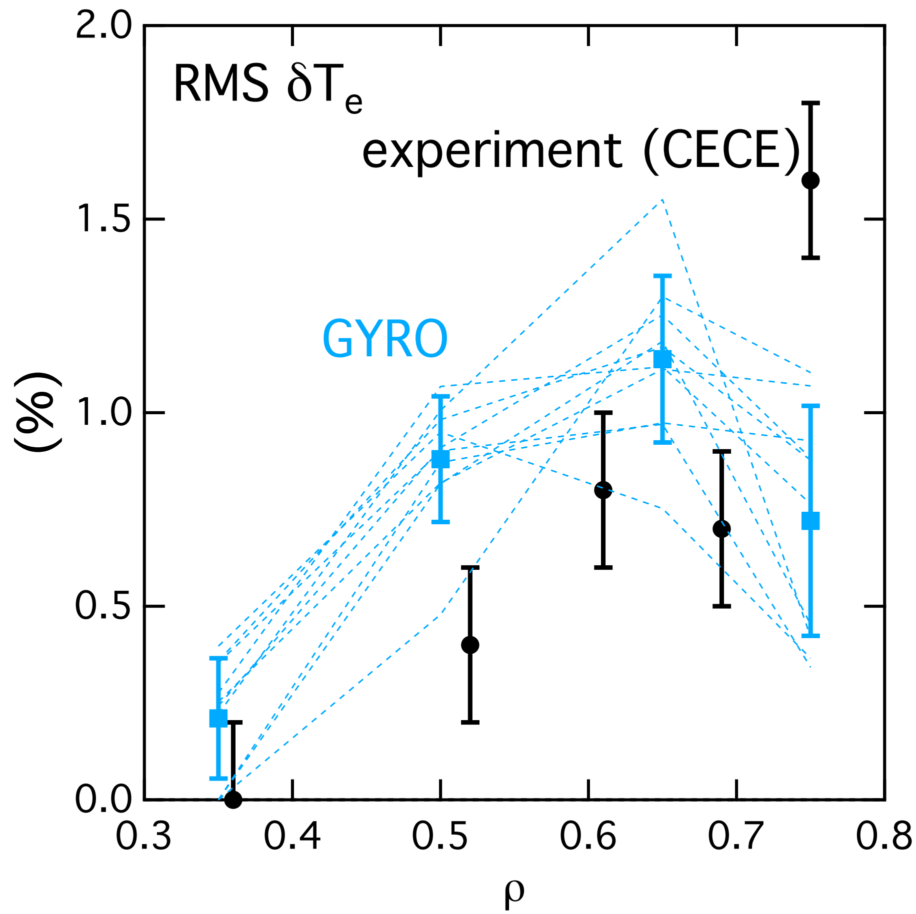
GYRO fluctuation predictions exhibit similar "underprediction" trends as flux predictions

- **Based on previous results, use simple estimate rather than full synthetic calculations**

$$\delta f_{syn} \approx \frac{1}{2}\delta f^{GYRO}_{midplane}$$





To characterize robustness and scalings of shortfall, we have begun to analyze a new set of metrics over a collection of DIII-D validation experiments

- **Using data from DIII-D TMV and related experiments, profile and powerbalance analysis carried out for**
  - 8 neutral beam injection (NBI) heated L-modes (some with additional ECH)
  - 5 electron cyclotron heated (ECH) L-modes
  - 7 NBI heated H-modes (some with additional ECH)

- **For NB-heated L-modes, 10 realization ensembles of equilibria, profiles, and power balance results have been generated**
  - Generally built by splitting 200 ms averaging window in 10 20 ms windows

- **For each condition, use the quasilinear TGLF transport model to calculate <u>local</u> flux-matching gradients at radii of interest**
  - At a given radius, hold local n_e, T_e, T_i, V_{tor} fixed, but vary local a/L_{ne}, a/L_{Te}, and a/L_{Ti} to match power balance particle and energy fluxes
  - Use normalized metric $\mathbf{E_L = (a/L_{TGLF} - a/L_{expt})/(a/L_{expt})}$ to assess local fidelity of TGLF
  - This approach allows better incorporation of stiffness than previous local tests

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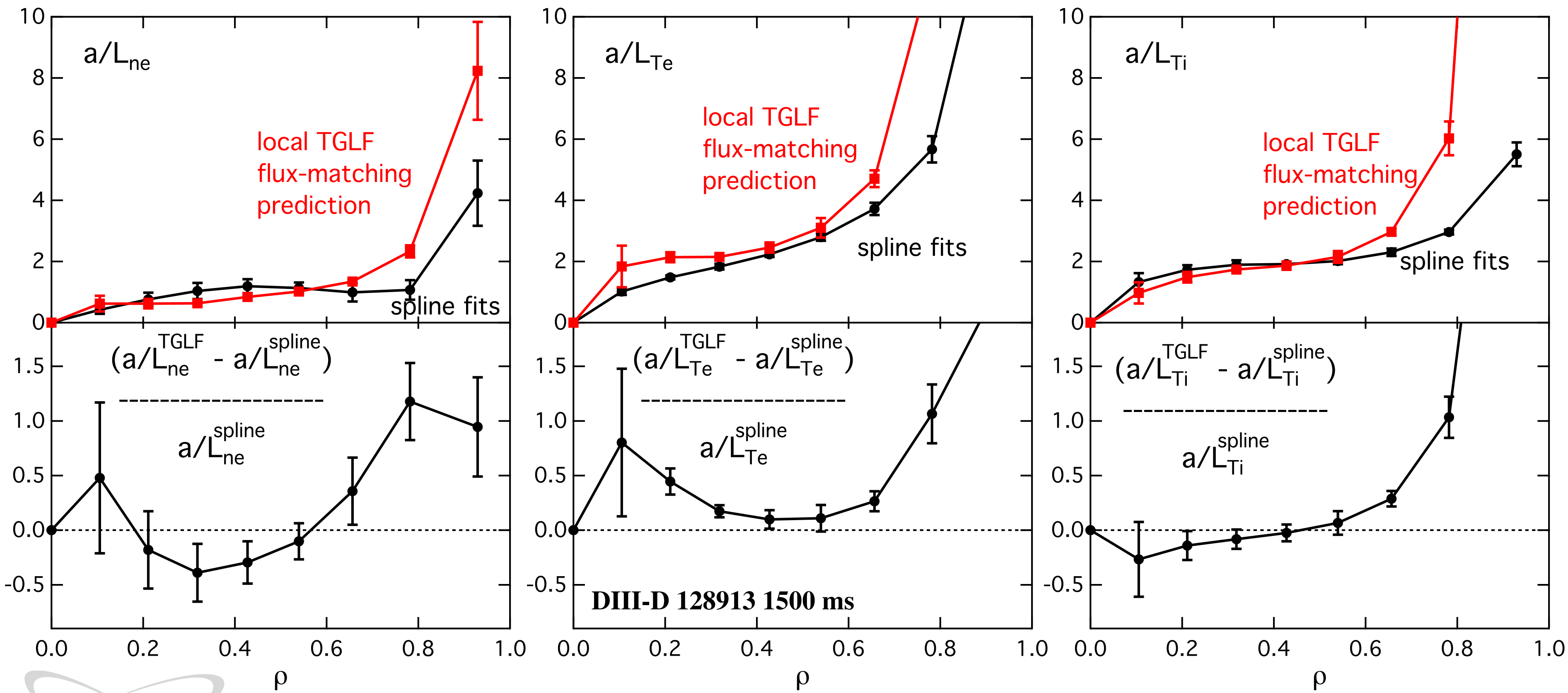
Example: comparison of local flux-matching scale lengths predicted by TGLF against experiment for beam heated L-mode

- **Currently, use spline fits to data as proxy for direct calculation of gradients from data (TBD in future)**
- **Metric uncertainties are 95% confidence interval defined using *t*-statistic**

$$\sigma_E = t^*(0.025,N)\sqrt{\frac{\sigma^2_{TGLF}}{N_{TGLF}} + \frac{\sigma^2_{expt}}{N_{expt}}}$$



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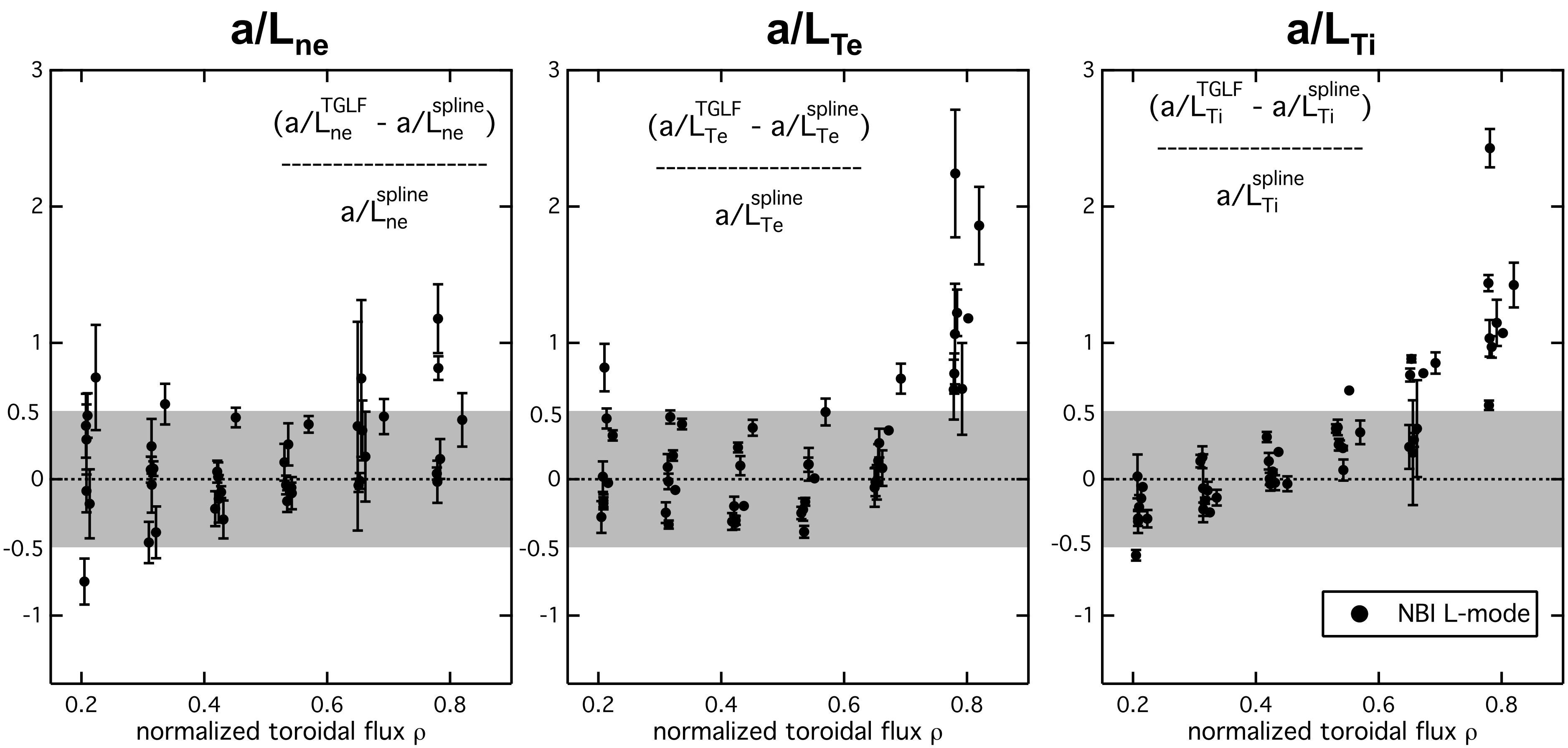
Local flux-matching temperature gradients are consistently larger than experiment in near-edge region for NBI-heated L-modes

- **No similar trend send for density gradients**



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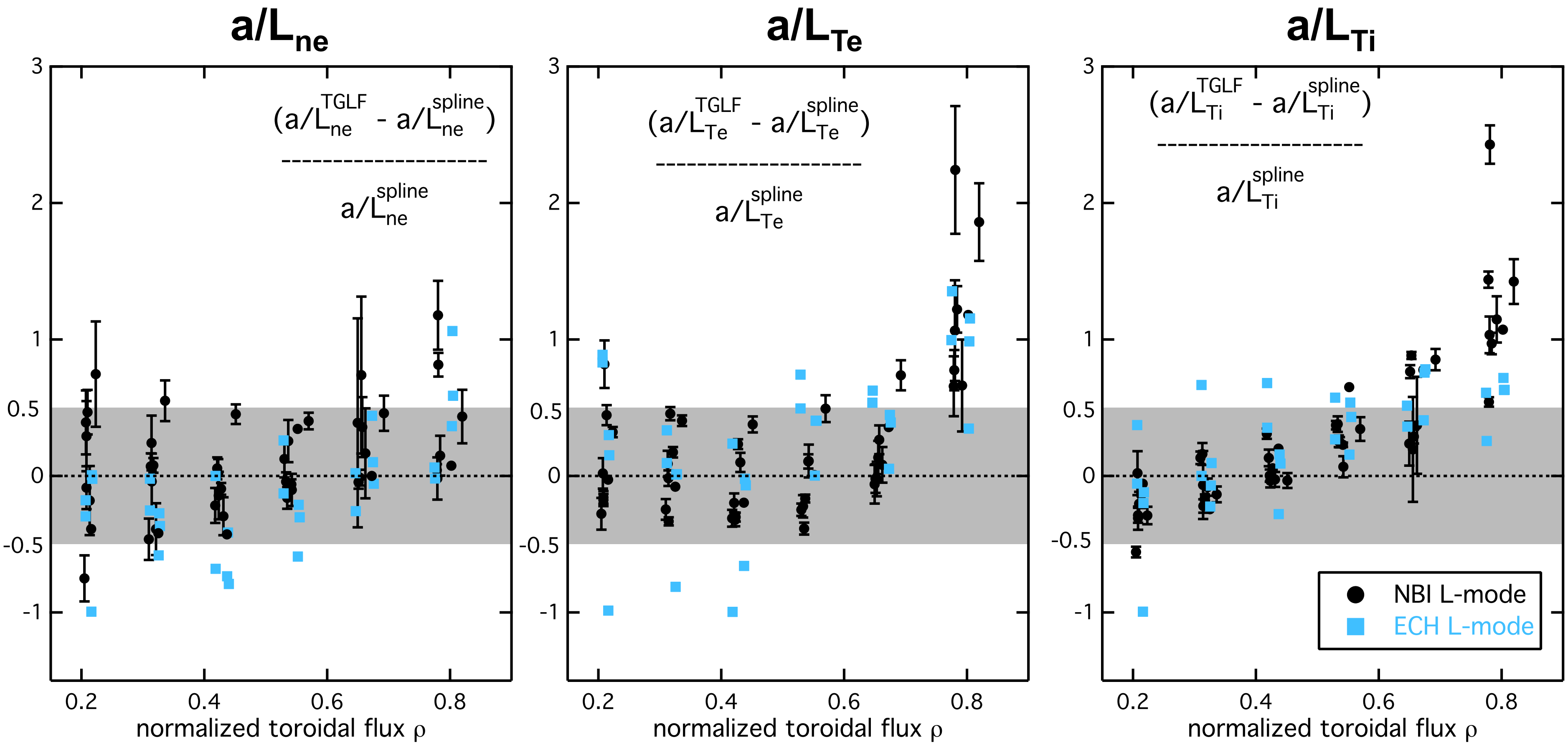
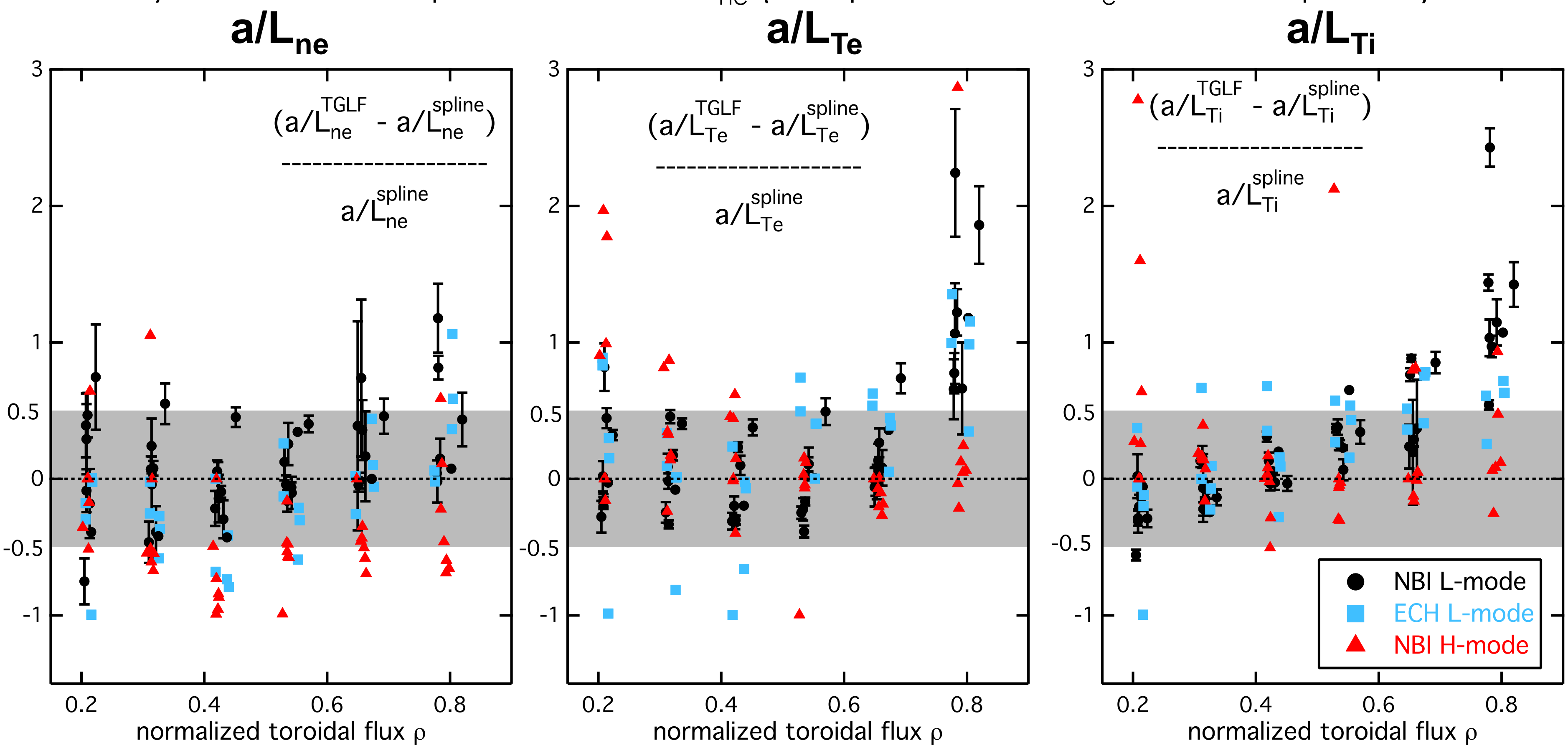
ECH-only L-modes show similar trends in gradients as beam-heated cases

- **Error trend strongest for a/L_{Te}**
- **Ensemble statistics still being analyzed for these cases**



No divergence in near-edge flux-matching gradients observed for H-modes

- **Largest errors for TGLF H-mode predictions are:**
  - overprediction of near-axis a/L_{te}- sawteeth may play role here
  - Systematic underprediction of a/L_{ne} (overprediction of Γ_e, too small pinch?)



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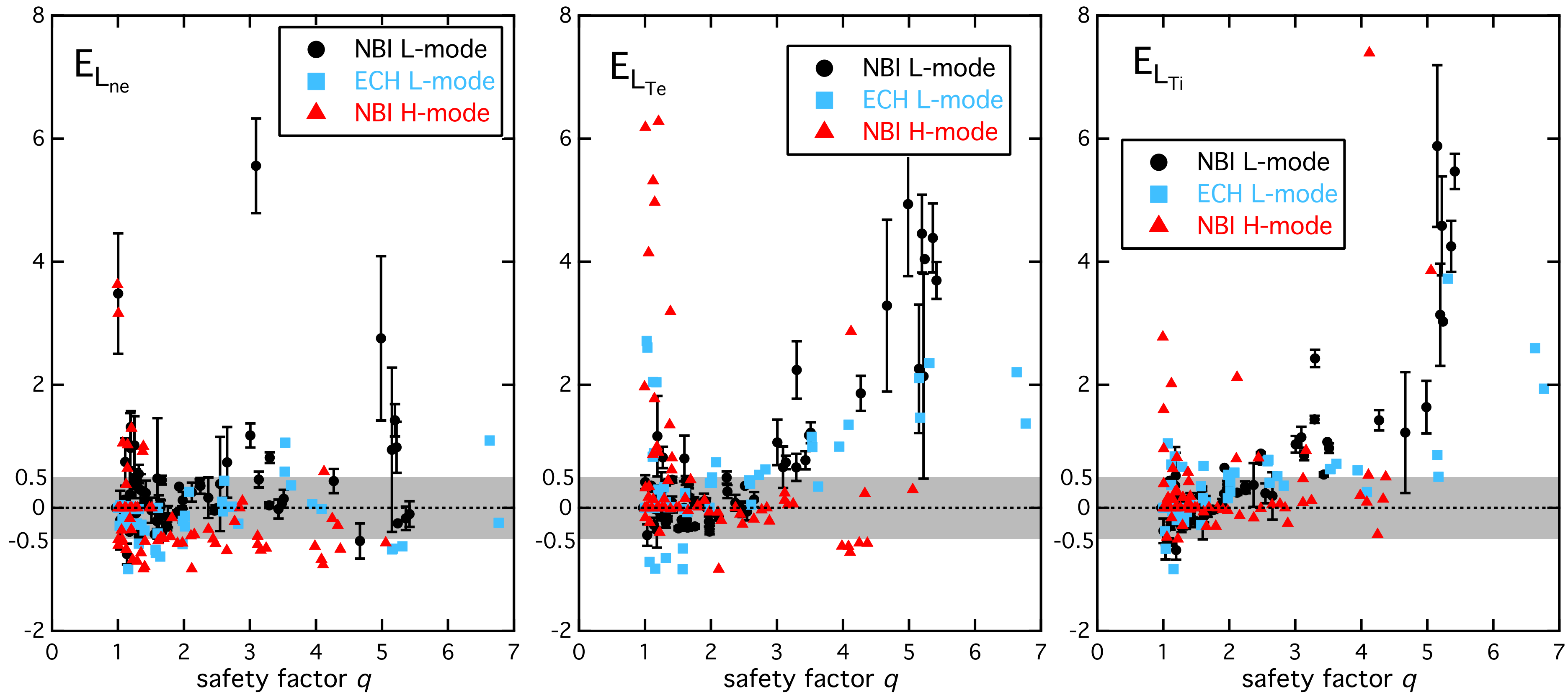
Database of local metric results allows for new ways of quantifying fidelity: e.g. model performance as function of safety factor *q*

Note: many H-mode results near q=1 and for all cases above q = 5 are not well-converged in flux; treat extremes as very preliminary



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Hypothesis: is the short-fall may a result of gyrokinetic (GK) ordering breakdown?

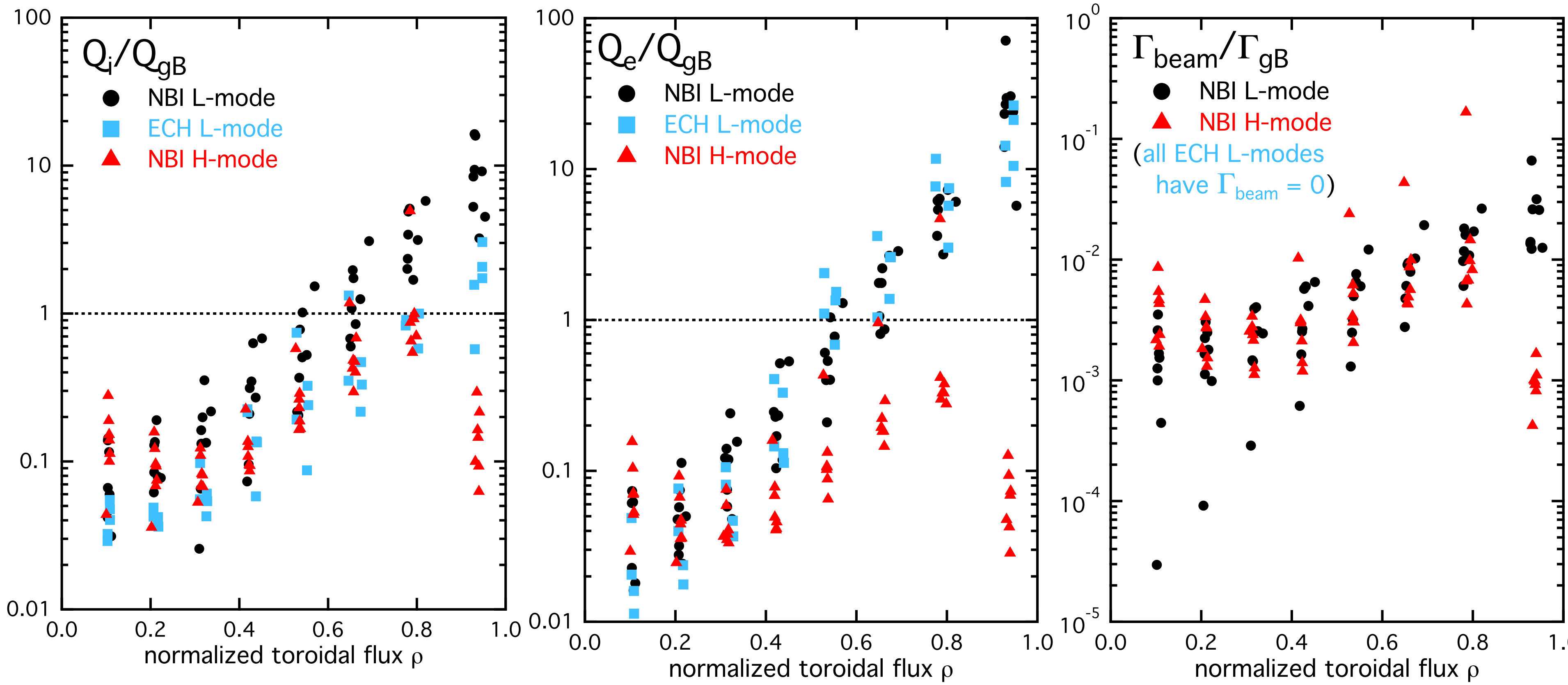
- **"Conventional" δf GK equations use $\rho^* = \rho/L$ ordering**
  - Require $f_0 = n_0 \exp(-mv^2/2T)$ to O(1)
  - Require $\delta f/f_0 \sim O(\rho^*)$
  - Requires $Q/(nTv_{th}) \sim O(\rho^{*2})$

- **Implies** $Q/Q_{gB} = Q/n_e T_e c_s \rho_s^{*2}$ **should be O(1)**
  - However, in near-edge (particularly L-mode), smallness of n_e and T_e make Q_{gB}, ρ_s small and thus Q/Q_{gB} large

- **For this work, define $L = \min(L_{Ti}, L_{Te}, L_{ne})$**
  - Effectively almost always L_{Te} for these plasmas
  - Note that alternate, equally valid choice of $L = a$ (midplane minor radius) yields values of ρ^* 3-5 smaller in near edge, Q_{gB} 10-20 smaller

L- and H-mode fluxes appear to be consistent with ordering assumption using $\rho^* = \rho_s/L$ inside norm. toroidal flux = 0.9

- Note that normalized H-mode electron energy fluxes Q_e are generally an order of magnitude smaller than L-modes; Q_i systematically lower than NBI L-modes as well
- Beam-driven particle fluxes always sub-gyroBohm in L- and H-mode



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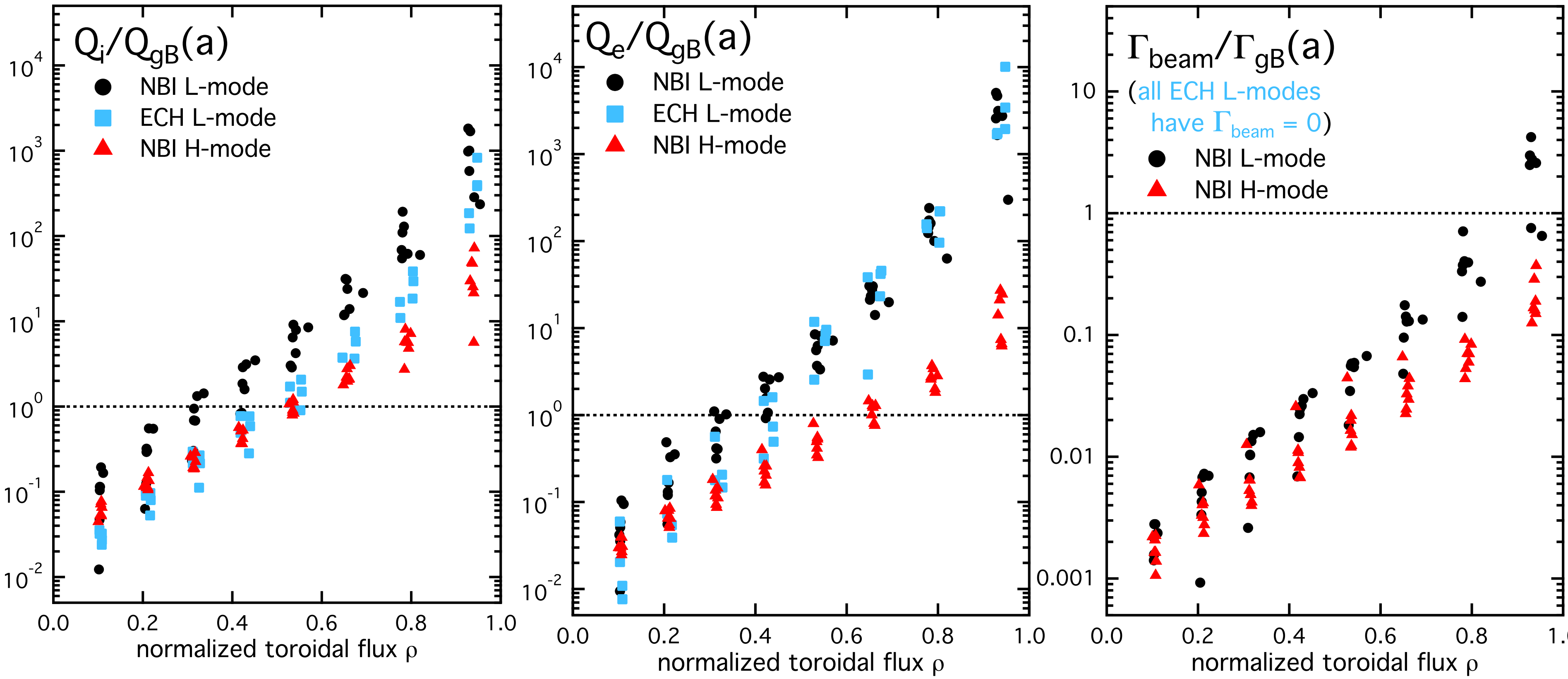
Note that use of $\rho^* = \rho_s/a$ yields significantly worse assessment of L-modes satisfying ordering assumptions

- **Strongest divergence between L- and H-modes remains in Q_e**
- **Beam-driven particle fluxes remain sub-gyroBohm for $\rho < 0.9$**



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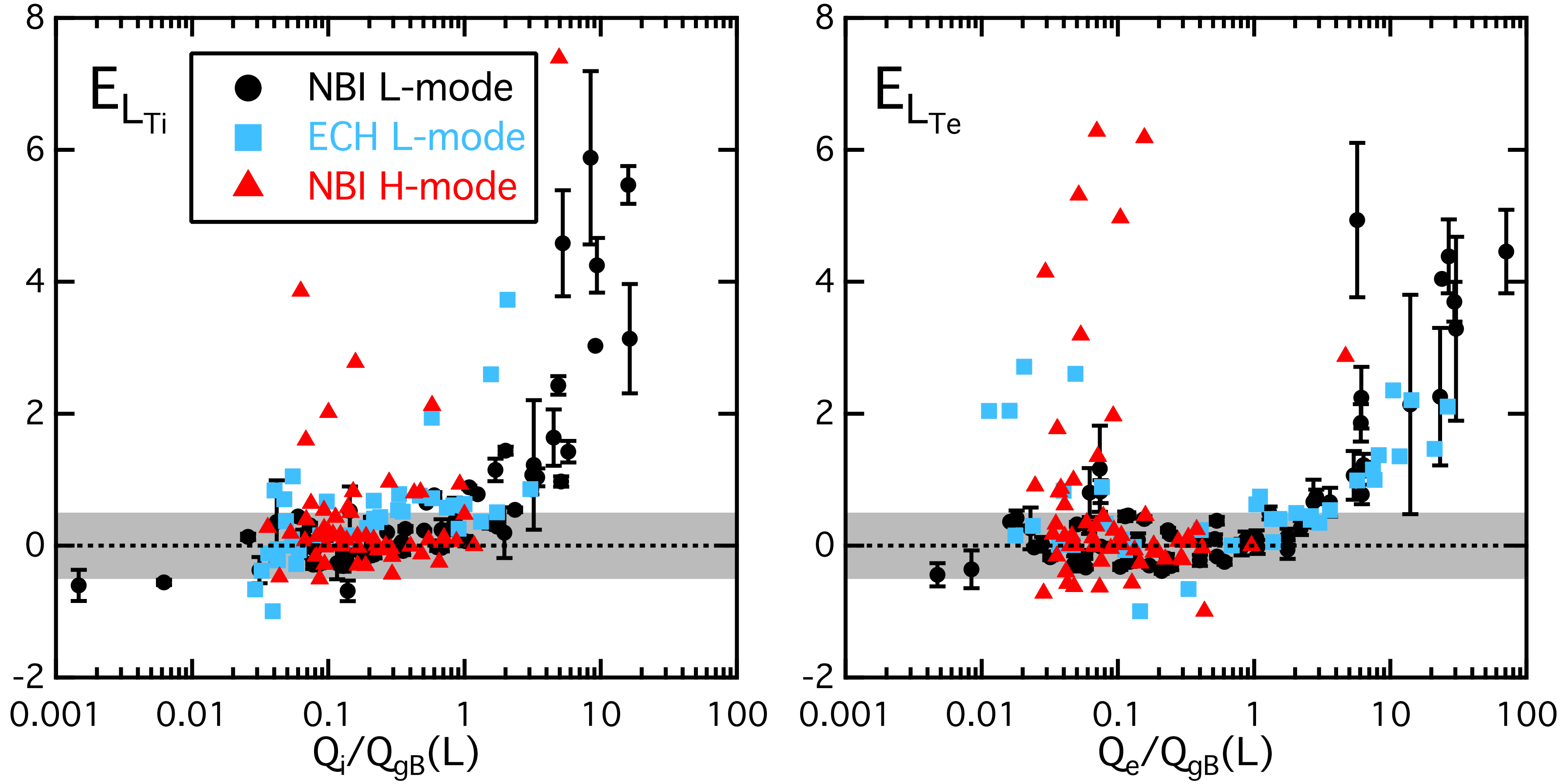
Database of local metric results allows for new ways of quantifying fidelity: e.g. model performance as function of experimental flux



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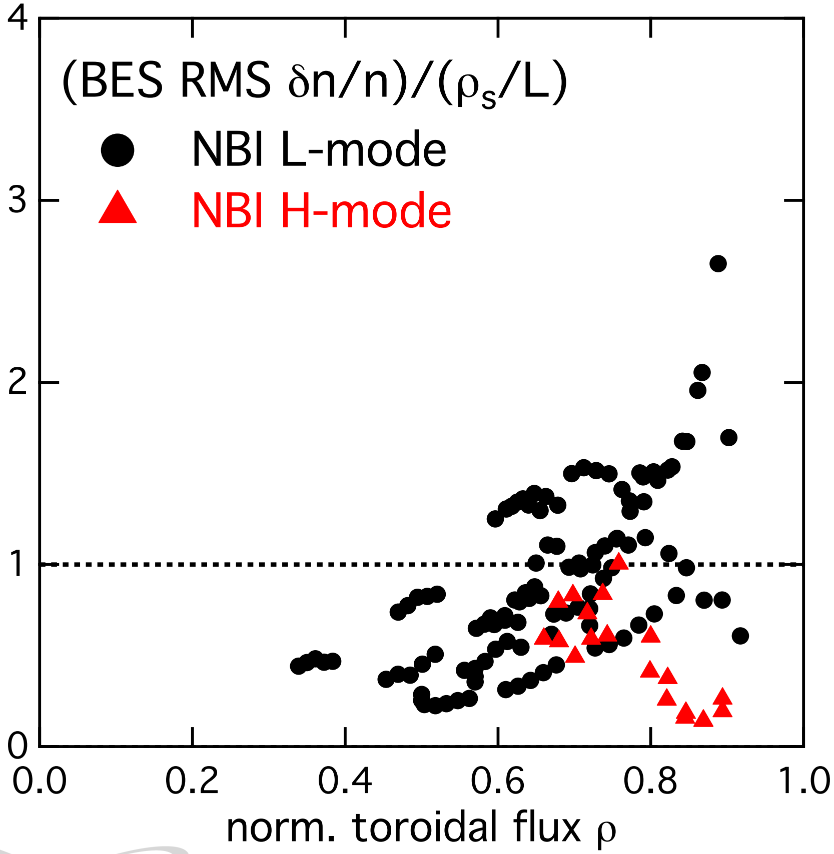
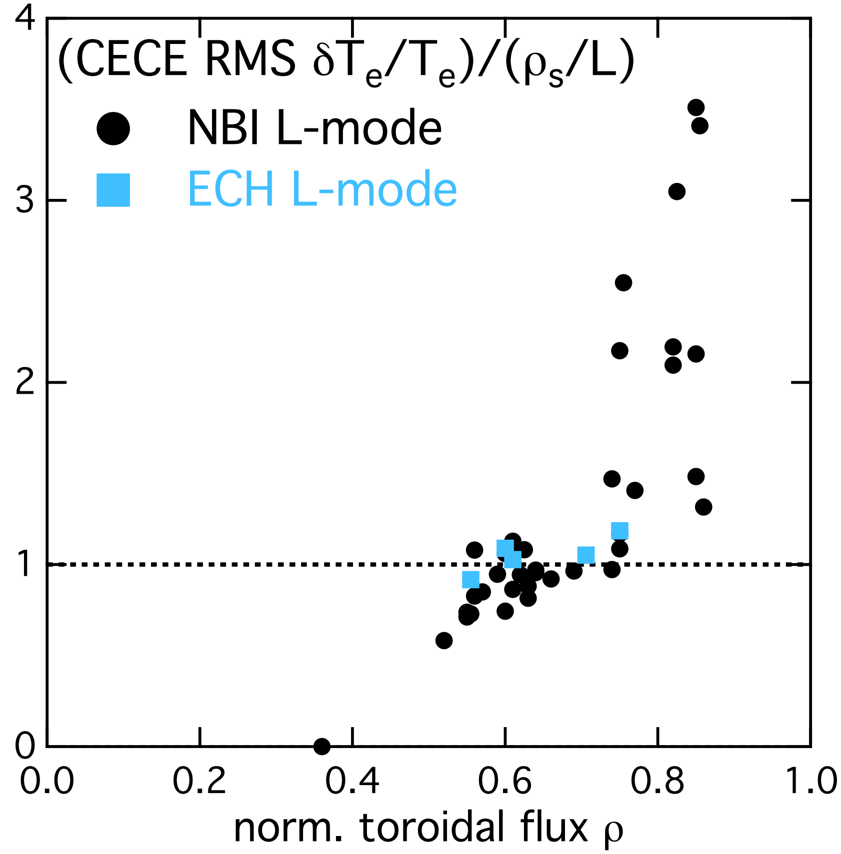
RMS fluctuation amplitudes normalized to ρ_s/L show similar consistency with assumed ordering as fluxes

- **Note that previous synthetic diagnostic studies find that BES, CECE transfer functions both yield ~50% attenuation of RMS levels**
  - “Actual” experimental levels probably 2x larger





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