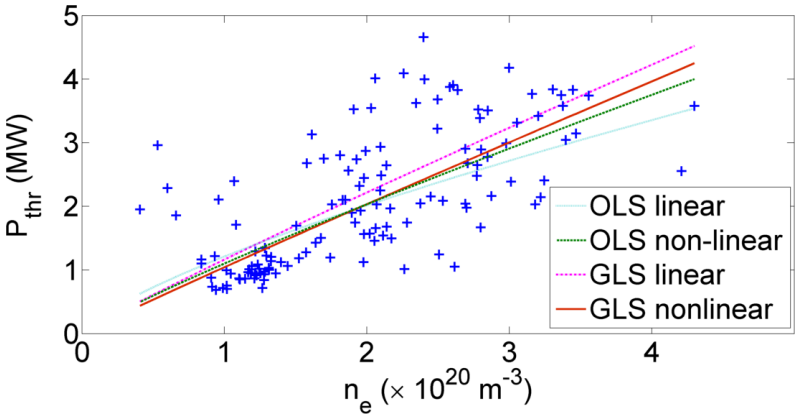
A New Methodology for Scaling Laws with Arbitrary Error Distributions: Case Study for the H-Mode Power Threshold

- In fusion, regression analysis is an essential tool for scaling laws and theory building.
- Ordinary least squares (OLS) regression is the common approach, but is often unsuitable to handle the complexities and uncertainties of fusion data.
- This work proposes a new regression method, called *geodesic least squares* (GLS), that is general and robust.
- The scaling of the L-H power threshold is estimated, resulting in predictions for ITER that are higher than before.
- Regression analysis for fusion data requires suitable techniques and careful interpretation.

Method	$\hat{P}_{\mathbf{thr},0.5}$ (MW)	**CI** (MW)
OLS lin.	48	$+7.6$ / -6.6
GLS lin.	62	–
OLS nlin.	62	± 10
GLS nlin.	64	–

Predictions of P_{thr} for ITER ($\bar{n}_{\mathrm{e}} = 0.5 \times 10^{20}$ m^{-3}), using OLS (with 95% confidence interval) and GLS. Linear regression is performed on the logarithmic scale (lin.) and then nonlinear regression on the original scale (nlin.). GLS gives similar results in both cases, demonstrating its robustness.



Experimental threshold power versus density, together with regression fits at constant field and surface area in Alcator C-Mod. GLS captures the pattern better than OLS.