ITPA GLOBAL H-MODE DATABASE UPDATE

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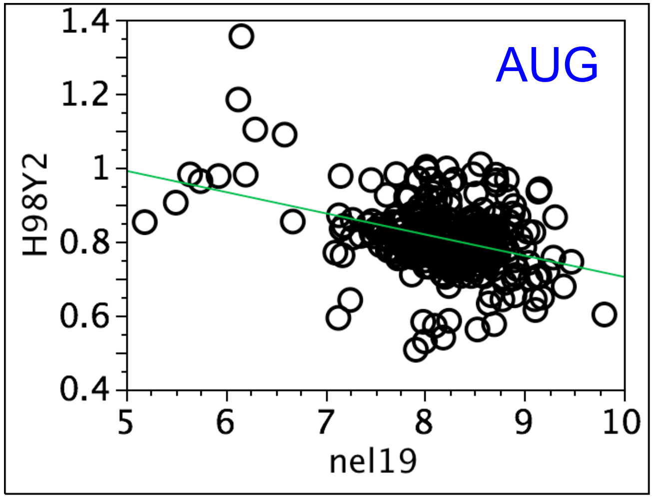
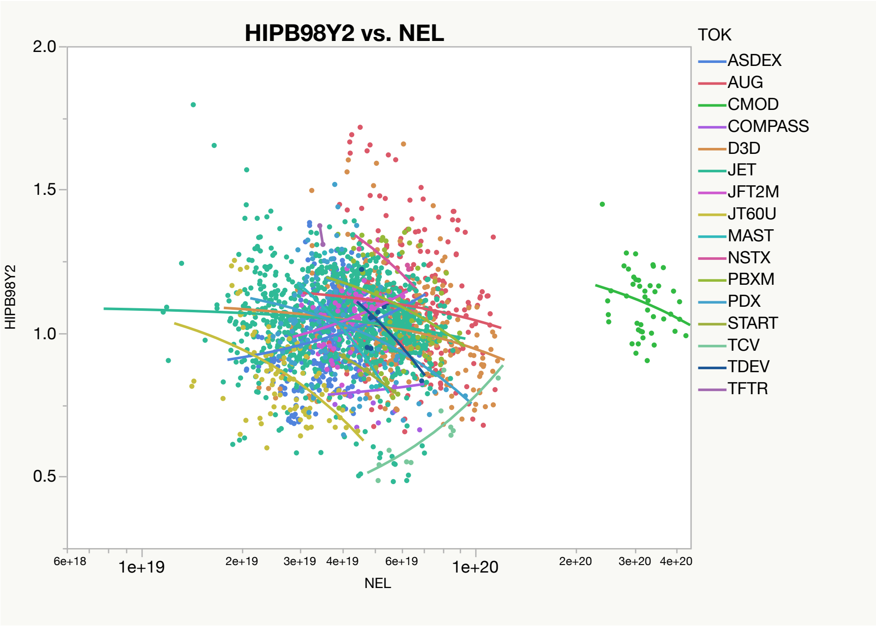
20 Nov. 2018

Genesis of upgrade effort

- IO has encouraged community to update database and scaling
  - Some parametric trends in scaling not reproduced machine-to-machine
  - Scaling is old (1998); more data is available
  - 98y,2 scaling may not adequately reflect trends in ITER H-mode-baseline collection of discharges (Luce, IOS)





Genesis - Very few of the entries in the present database approach ITER baseline conditions

- McDonald et al. (2007) defined "ITER-like" subset
  - Standard selection +
  - $1.4 < \kappa < 1.85$
  - $1.6 < q_{cyl} < 2.5$
  - $1.83 < M < 2.17$

- In (private) database DB4V5, Standard Selection+**ITER-Like** (as above) yields very small, not entirely descriptive dataset

TOKAMAK	**Count**
JET	53
MAST	3
NSTX	1
PBXM	72
TCV	17
Total	**146**

Scope of task

- Improve quality of predictions and inform and address physics investigations
- In the latter case, a separation between core and pedestal needs to be made
- Both objectives important, but requires careful consideration of what to include in update
  - More of the same will not be sufficient
  - Need to expand in types of entries, info in each entry
- Expect scaling to change as data closer to the ITER baseline included

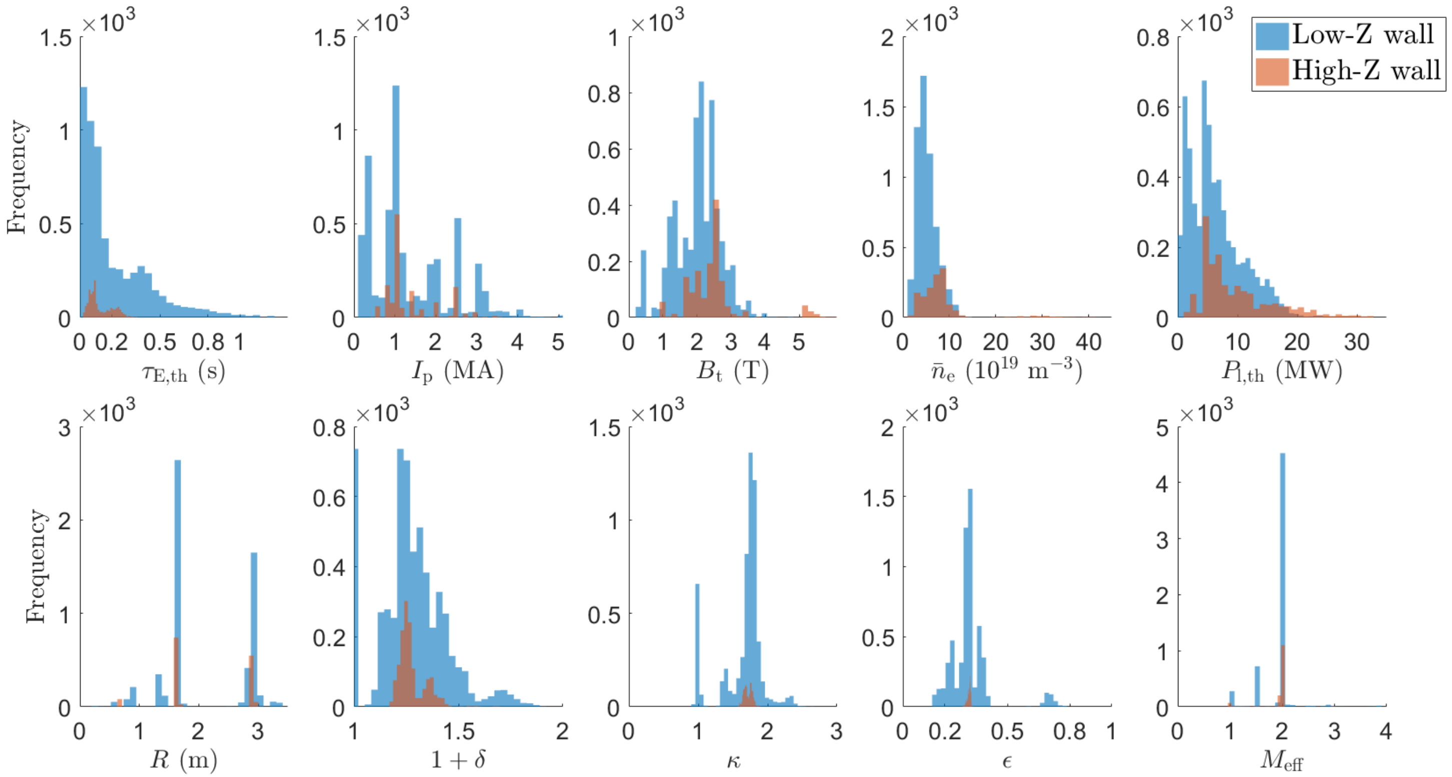
Issues to consider in update of DB

- Triangularity not included in old scaling, but is known to have an effect on confinement
  - Incorporate into scalings
- Rotation/torque/rotation shear have clear impact on local transport, confinement in various devices
  - Include data
- Include data from devices with high-Z divertor/walls
  - JET, AUG (+ already existing C-Mod)
- Confinement is known to depend on plasma characteristics close to or beyond pedestal
  - Include SOL/separatrix density (JET, AUG)
  - 2-term scalings (need more info re pedestal top positions)

Database update: DB5

- Addition of data from fully metallic wall/divertor devices
  - 627 time slices from JET-ILW H-modes
  - 825 from AUG full W wall
- Improved fast particle estimates (AUG)
- DB5v7: 13913 points from 19 devices
  - STD5: standard H-mode selection criteria 7294 points
  - STD5-SEL1: $q_{95}>2.8$, $1.3<\kappa<2.2$, $\varepsilon<0.5$, $Z_{eff}<5$ 5956 points
  - STD5-SEL2: $2.8<q_{95}<3.5$, $1.6<\kappa<2.0$, $0.28<\varepsilon<0.385$, $Z_{eff}<3$ 1674 points
- $n_{e,sep}$, $n_{e,SOL}$, torque added (JET, AUG)

Ranges of main scaling parameters in STD5



Individual device scalings

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- Scaling with I_p similar for ITER-like devices (S-Mod, DIII-D JET) except AUG, but weaker for other devices
- B_T dependence weak in ITER-like devices, slightly negative in AUG
- Scaling with nweak in ITER-like devices, slightly stronger in JET-C. Stronger dependence in smaller or more circular devices
- Power degradation weakest in ITER-like devices

H98y2 overpredicts confinement

- STD5-SEL1
- Overpredicts near Greenwald limit
- Overpredicts for high-Z wall devices

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Scaling results

ITER parameters used: I_p=15 MA, B_T=5.3 T, n_e=10.3e19 m^{-3}, R=6.2 m, ε=a/R=0.32, κ=1.7, δ=0.33, M_{eff}=2.5, P_{heat}=87 MW

	α_0	α_I	α_B	α_n	α_P	α_R	α_κ	α_ϵ	α_M	$\hat{\tau}_{\mathrm{ITER}}$ (s)
IPB98(y,2)	0.0562	0.93	0.15	0.41	−0.69	1.97	0.78	0.58	0.19	3.62

STD5 (ELMy + ELM-free)

95% confidence intervals

Method	α_0	α_I	α_B	α_n	α_P	α_R	α_κ	α_ϵ	α_M	$\hat{\tau}_{\mathrm{ITER}}$ (s)
OLS	0.049 ±0.002	1.1 ±0.02	0.085 ±0.020	0.19 ±0.02	−0.71 ±0.01	1.5 ±0.04	0.80 ±0.04	−0.043 ±0.046	0.25 ±0.03	2.7 ±0.1
WLS	0.040 ±0.002	0.99 ±0.03	0.11 ±0.02	0.29 ±0.02	−0.64 ±0.01	1.7 ±0.04	0.79 ±0.04	0.093 ±0.046	0.25 ±0.03	2.9 ±0.1
GLS	0.042 ±0.003	1.2 ±0.02	0.068 ±0.016	0.21 ±0.01	−0.78 ±0.01	1.6 ±0.03	0.88 ±0.06	−0.052 ±0.027	0.47 ±0.07	2.7 ±0.03

Strongest power degradation and isotope effect

W.r.t. IPB98(y,2) (ELMy):

- Stronger dependence on I_p, weaker on B_t
- Weaker dependence on $\bar{n}_\mathrm{e}$ and R
- No dependence on ϵ (but different κ definition)
- ITER predictions up to 25% lower

Scaling results - continued

STD5-SEL1

Considerable uncertainty

Method	α_0	α_I	α_B	α_n	α_P	α_R	α_κ	α_ϵ	α_M	$\hat{\tau}_{\mathrm{ITER}}$ (s)
OLS	0.045 $\pm$0.005	1.3 $\pm$0.03	$-$0.10 $\pm$0.04	0.13 $\pm$0.02	$-$0.71 $\pm$0.01	1.2 $\pm$0.06	1.1 $\pm$0.1	$-$0.32 $\pm$0.05	0.24 $\pm$0.04	2.6 $\pm$0.1
WLS	0.030 $\pm$0.005	1.3 $\pm$0.04	$-$0.069 $\pm$0.056	0.19 $\pm$0.05	$-$0.64 $\pm$0.03	1.3 $\pm$0.1	1.3 $\pm$0.2	$-$0.46 $\pm$0.08	0.094 $\pm$0.055	3.0 $\pm$0.2
GLS	0.023 $\pm$0.007	1.3 $\pm$0.04	$-$0.018 $\pm$0.067	0.17 $\pm$0.03	$-$0.79 $\pm$0.02	1.5 $\pm$0.1	1.9 $\pm$0.4	$-$0.38 $\pm$0.08	0.33 $\pm$0.13	2.5 $\pm$0.1

W.r.t. STD5: shape dependence varies

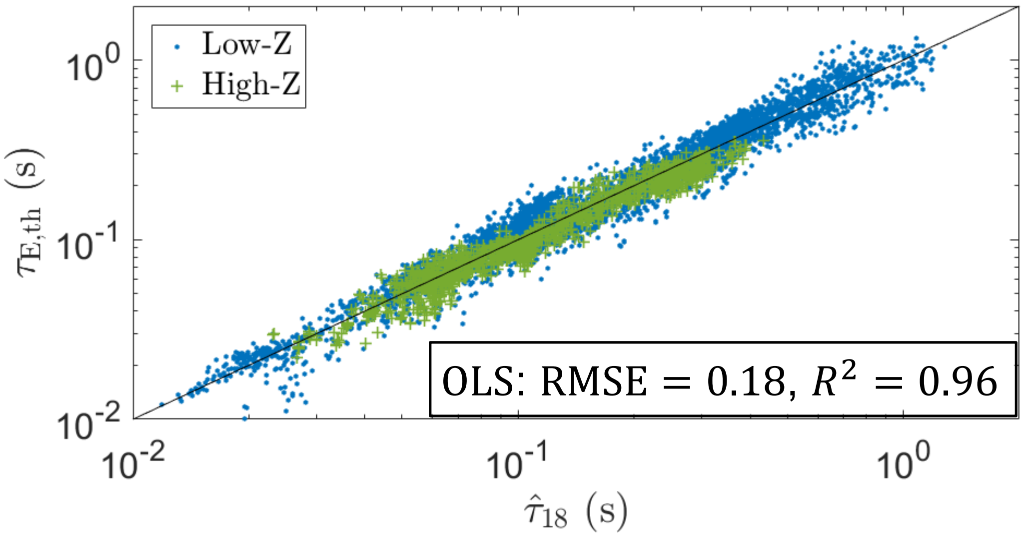
STD5-SEL1 (shape: δ, κ, ϵ)

‘H18’

Method	α_0	α_I	α_B	α_n	α_P	α_R	α_δ	α_κ	α_ϵ	α_M	$\hat{\tau}_{\mathrm{ITER}}$ (s)
OLS	0.036 $\pm$0.003	1.3 $\pm$0.03	$-$0.07 $\pm$0.03	0.12 $\pm$0.02	$-$0.70 $\pm$0.01	1.3 $\pm$0.1	0.63 $\pm$0.06	1.1 $\pm$0.1	$-$0.34 $\pm$0.05	0.27 $\pm$0.03	2.6 $\pm$0.1
WLS	0.021 $\pm$0.002	1.3 $\pm$0.03	$-$0.055 $\pm$0.029	0.20 $\pm$0.02	$-$0.65 $\pm$0.01	1.3 $\pm$0.1	0.78 $\pm$0.06	1.3 $\pm$0.1	$-$0.49 $\pm$0.04	0.10 $\pm$0.03	3.1 $\pm$0.1
GLS	0.020 $\pm$0.005	1.3 $\pm$0.04	$-$0.03 $\pm$0.04	0.14 $\pm$0.02	$-$0.76 $\pm$0.01	1.4 $\pm$0.1	0.72 $\pm$0.05	1.7 $\pm$0.3	$-$0.42 $\pm$0.07	0.41 $\pm$0.07	2.6 $\pm$0.1

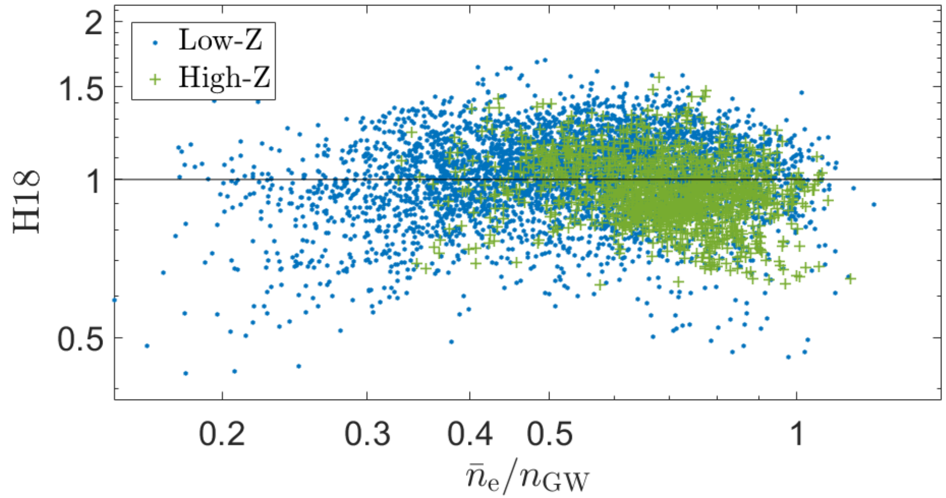
We are NOT suggesting ‘H18’ is a formal replacement for H98y2

Scaling results - continued



Moderate dependence on δ

Confinement enhancement factor $\mathrm{H18} = \tau_{\mathrm{E,th}}/\hat{\tau}_{18}$ *vs. Greenwald fraction for STD5-SEL1 (GLS).*



Summary and future steps

- DB updated with high-Z wall data, additional variables
- Single devices scalings reveal trends represented in 98y2
  - ITER-like devices show more favorable trends
- Scaling with updated DB
  - Weaker dependence on toroidal field and density
  - Noticeable influence of triangularity on confinement
  - Further subsets (ELMy, no ELM, GELM, SELM, no PBXM) reflect "variations on the theme"
- Include additional data (some in ITER-relevant regimes)
  - DIII-D, C-Mod, EAST, Globus-M
- Further analysis to focus on data and variable selection, model comparison, treatment of data subsets (weighting)
- Dimensionless scalings