Wendelstein 7-X

Max-Planck-Institut für Plasmaphysik

NBI + ECRH reintroduction scenario in OP2.2/2.3

O. P. Ford, S.Bozhenkov, S.Bannmann, T. Stange, R. Lopez Cansino, W7-X Team

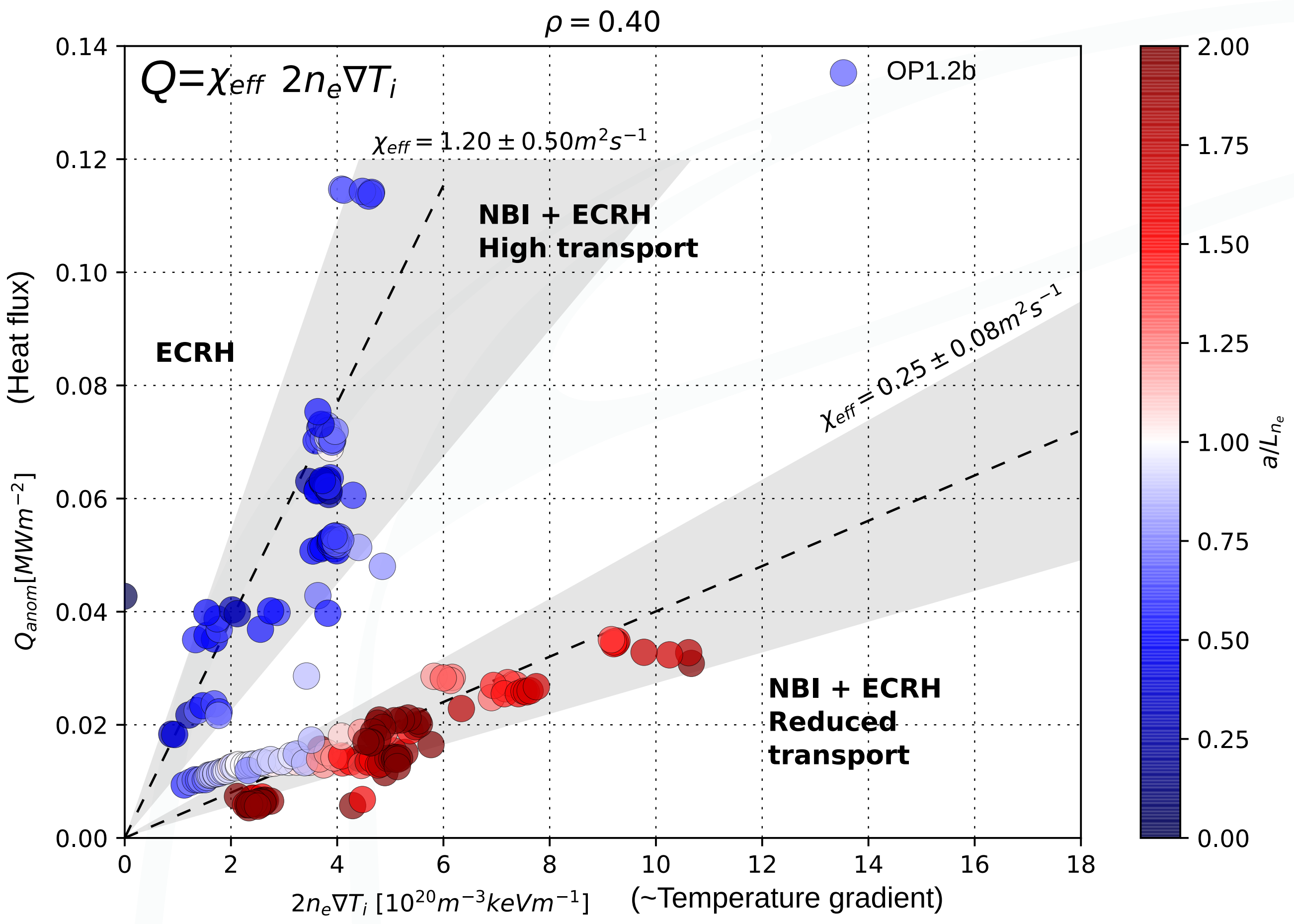
23.05.2025

MAX PLANCK GESELLSCHAFT

EUROfusion

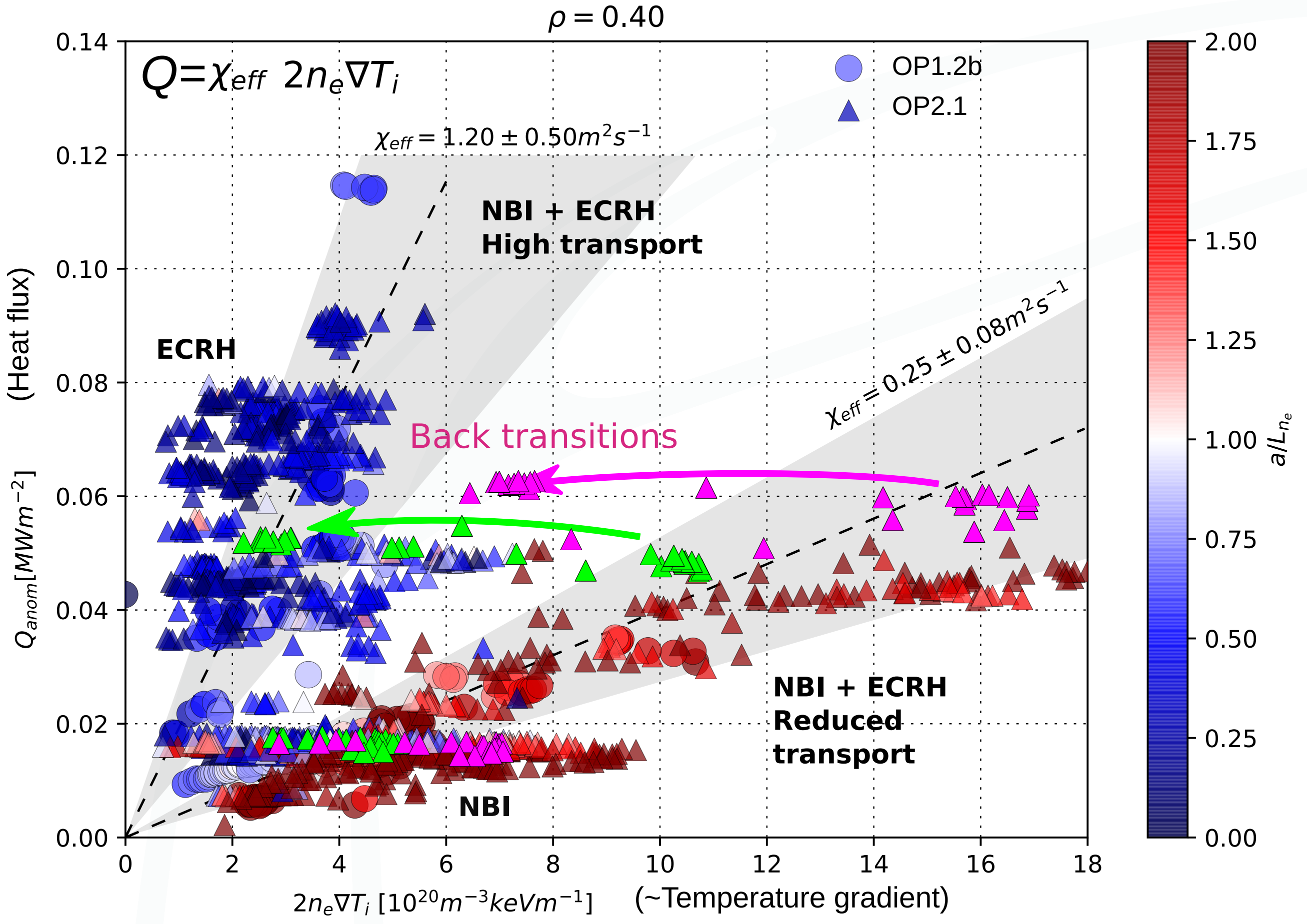
The ECRH reintroduction scenario

1) During pure-NBI, particle transport change causes strong peaking inside ~mid-radius.
2) With peaked density profiles (roughly a/Ln > 1.0), heat diffusivity is 4 times lower.
3) We add ECRH to take advantage of low χ_{eff}.
 but... ECRH 'pumps-out' density. Too much and we fall below required a/L_n --> back-transition to high χ_{eff}.



The ECRH reintroduction scenario

1) During pure-NBI, particle transport change causes strong peaking inside ~mid-radius.
2) With peaked density profiles (roughly a/Ln > 1.0), heat diffusivity is 4 times lower.
3) We add ECRH to take advantage of low χ_{eff}.
   but... ECRH 'pumps-out' density. Too much and we fall below required a/L_n --> back-transition to high χ_{eff}.

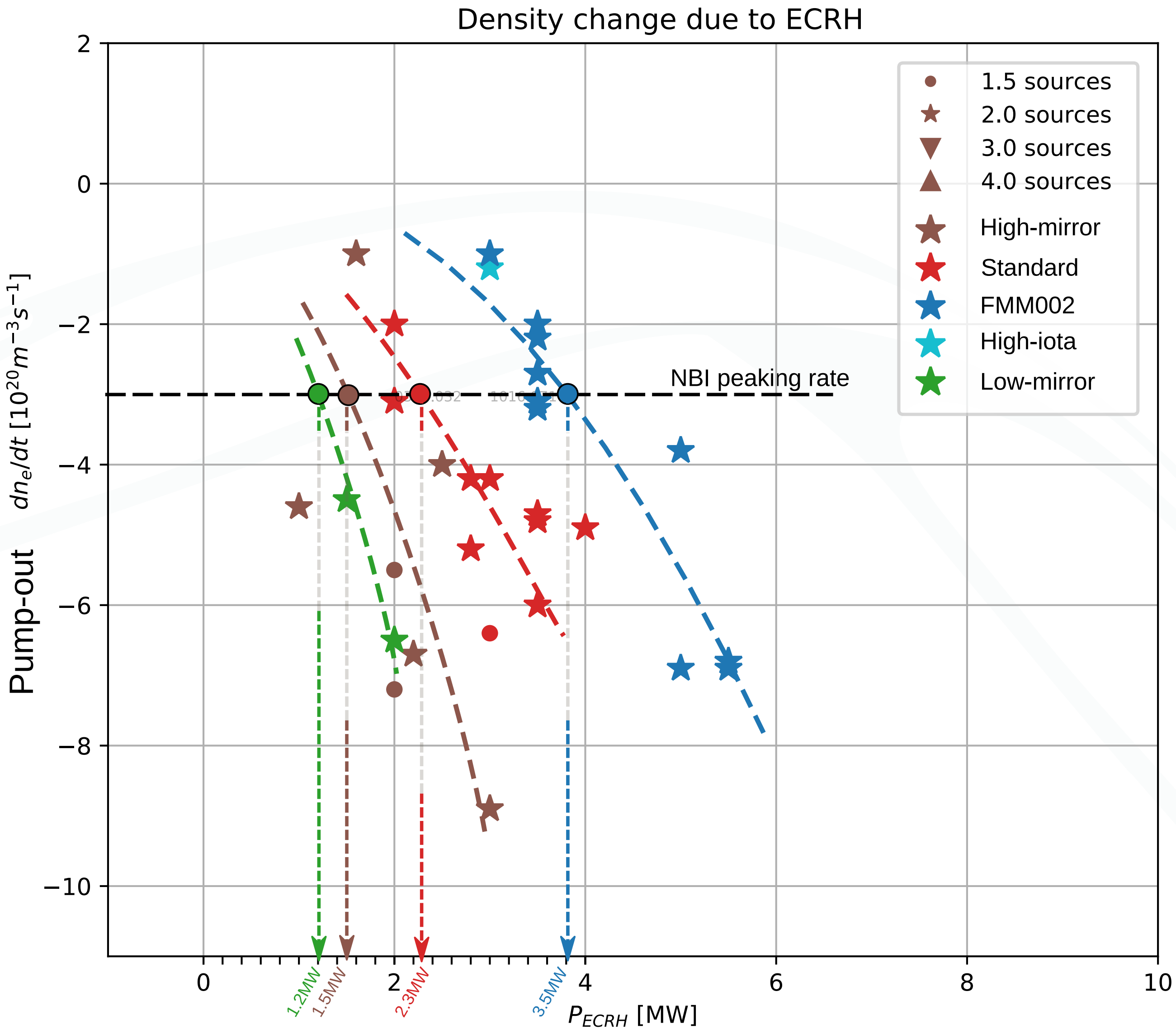


ECRH pump-out

In OP2.2/2.3 we explored the scenario is different configurations.
- Pump-out effect is *very* config dependent.

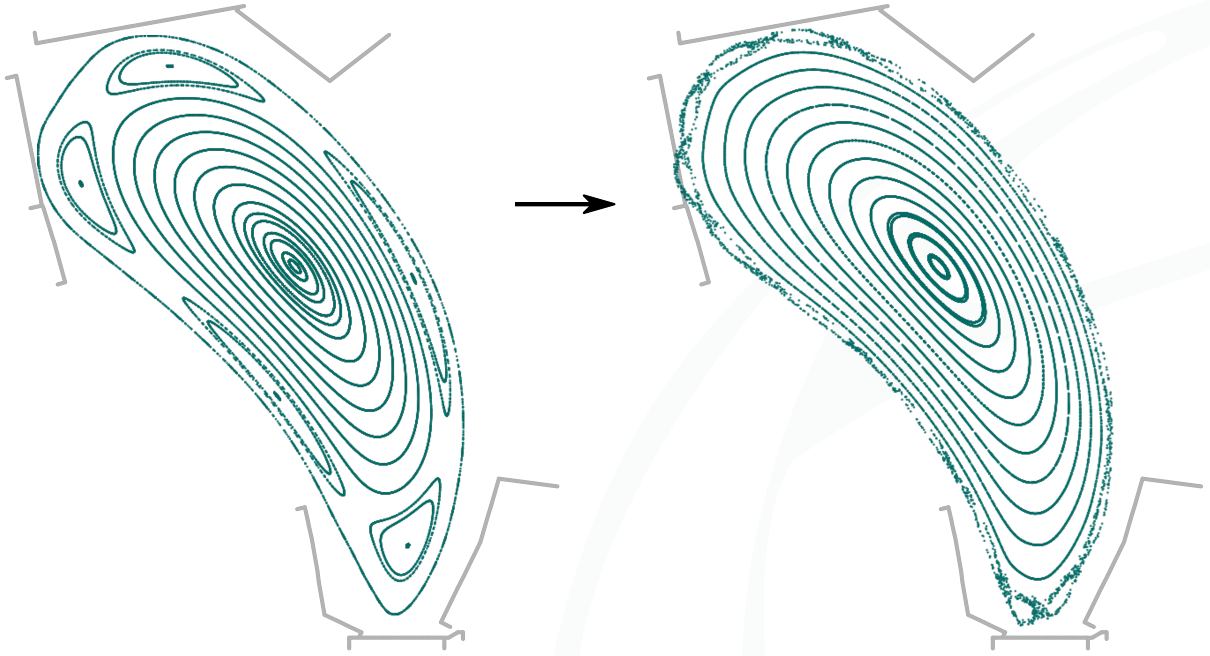
This gives a maximum power we can put into a given configuration for a given number of NBI sources:
e.g. for 2 sources:
High/low mirror: ~1.5MW
Standard: ~2.3MW
High iota (also FMM002): 3.8MW

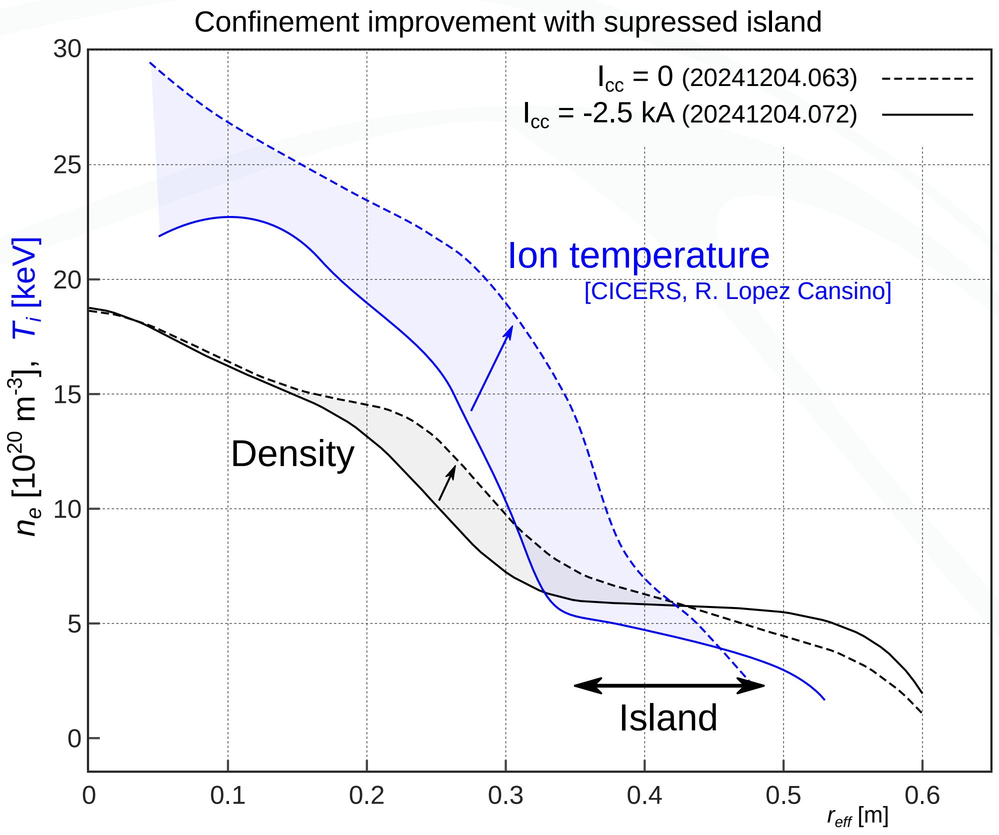
We chose FMM002 initially,
later also high-iota.



FMM002 internal islands

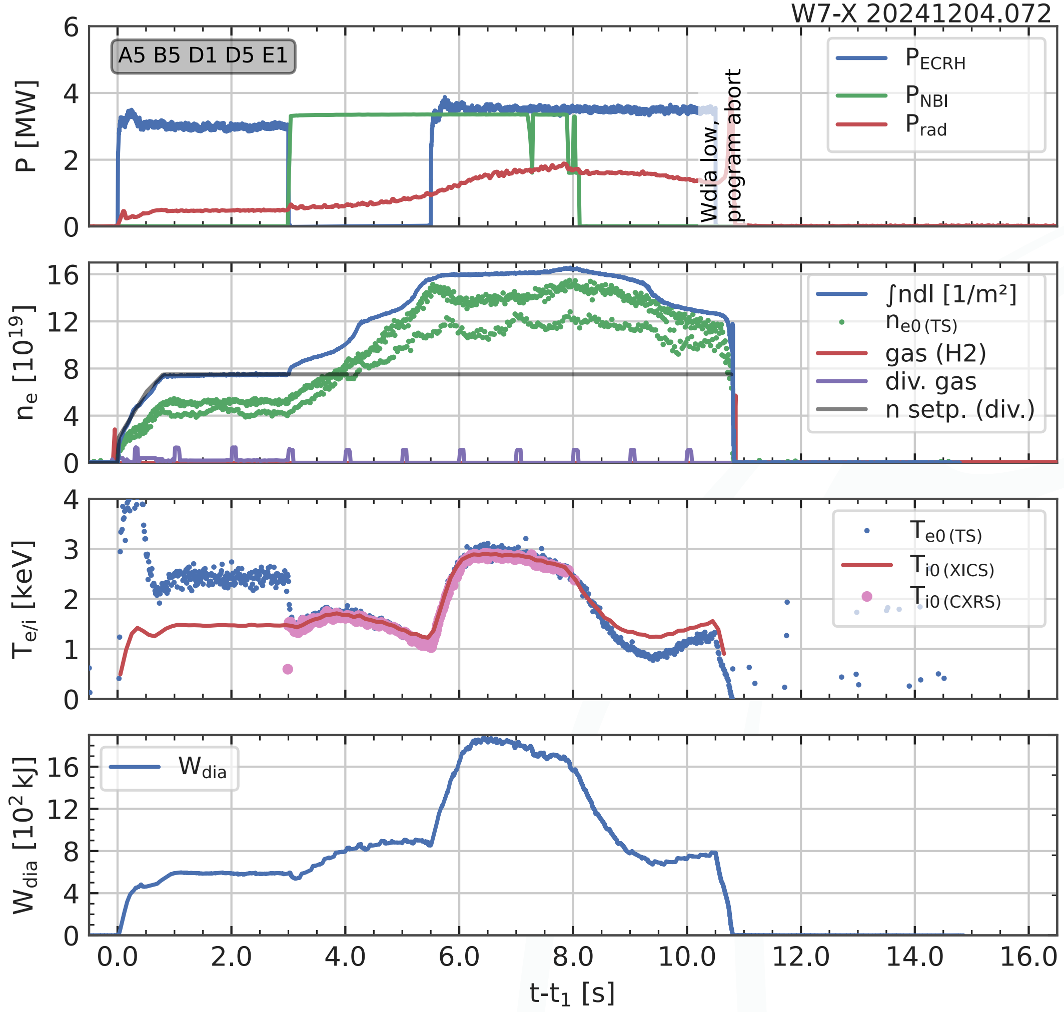
- FMM002 balance was quite good (T_i ~ 2.3keV, W_{dia} ~ 1.2 MJ) but this is a limiter configuration with internal island which flatten T_i profile.
- Using control coils to suppress the islands increases volume at high T_i.

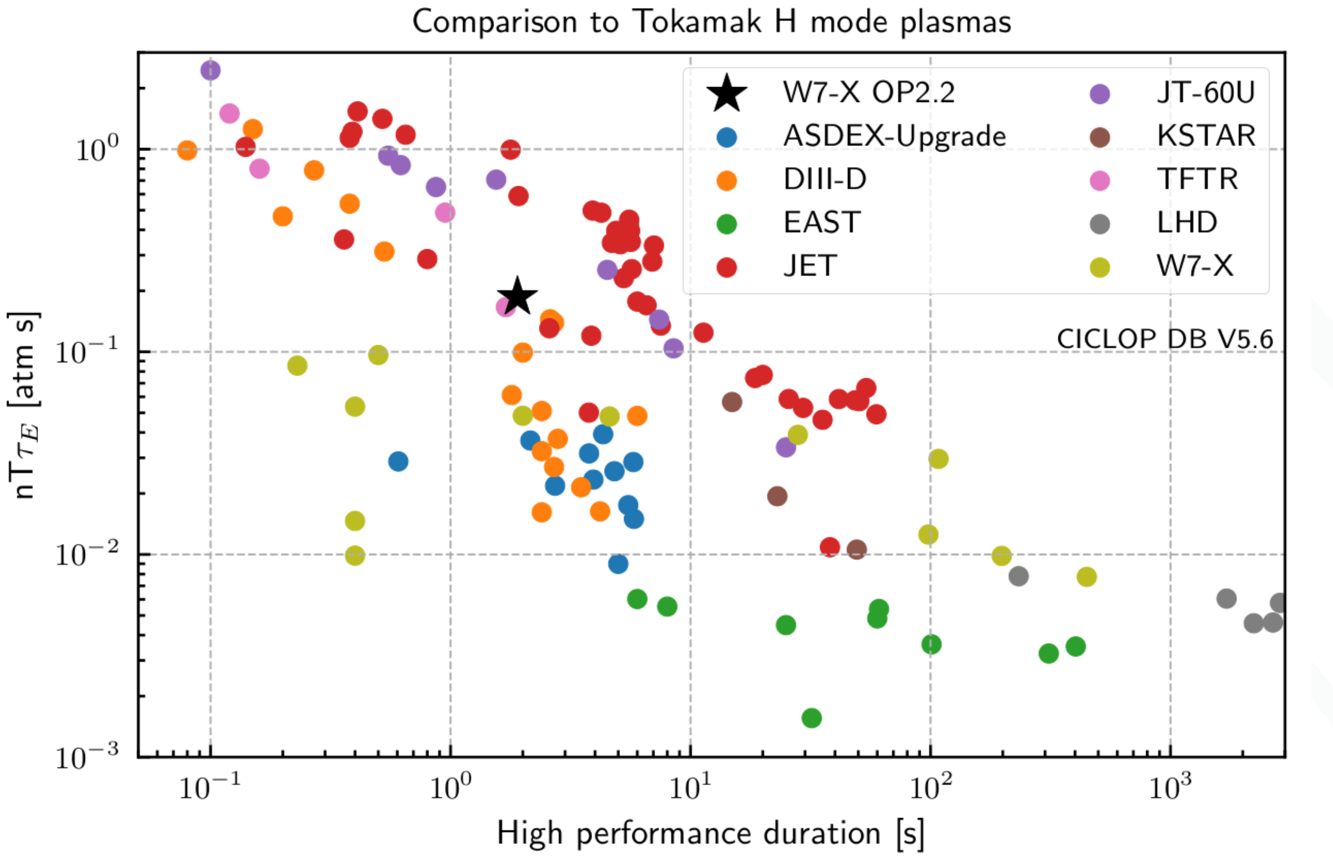




Record $nT\tau_E$

- Last ingredient was optimisation of field for good ECRH absoption.
---> 1.8MJ shot with record stellarator tripple product, at level of tokamaks, held for ~2s.



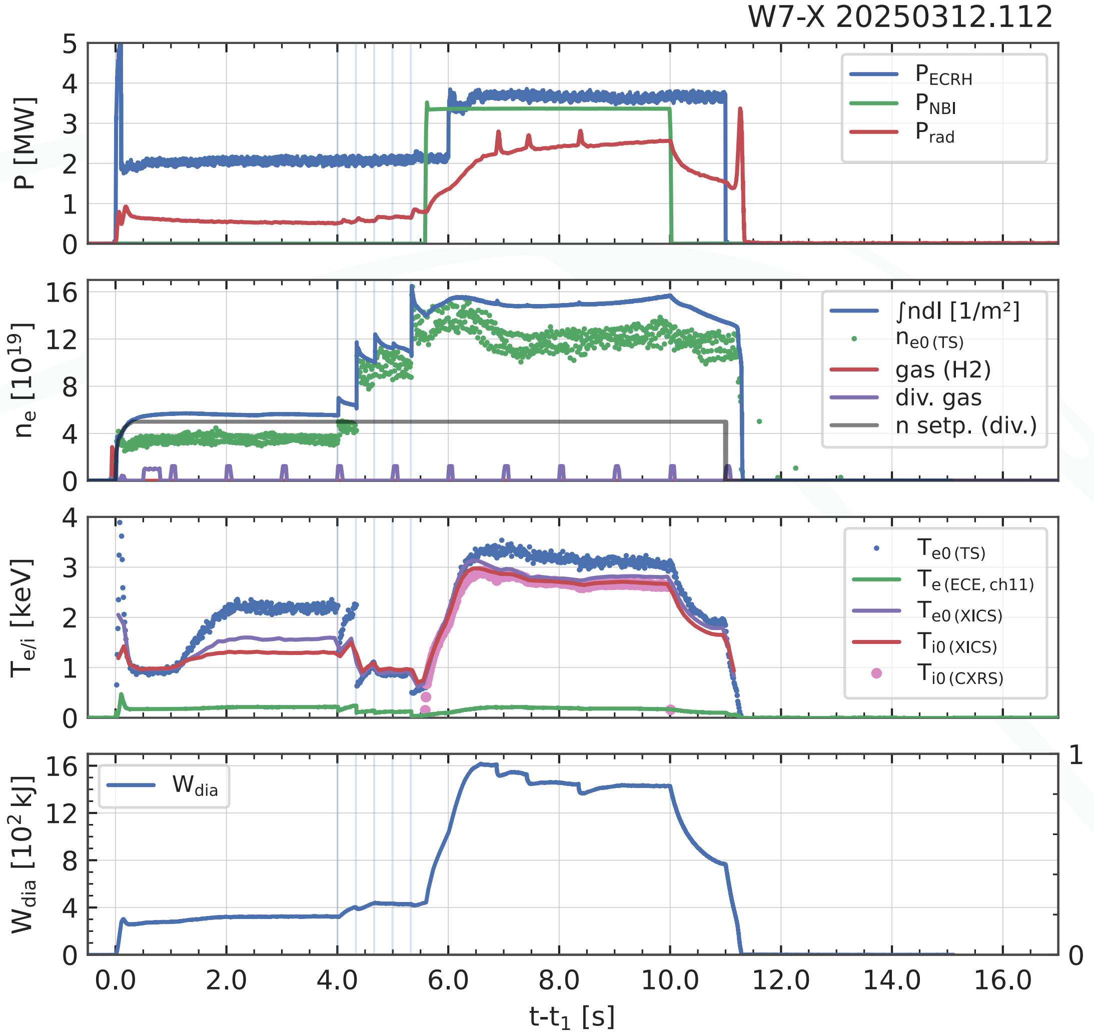


Hybrid pellets + NBI

- Pure-NBI peaking takes ~2s to build just enough density gradient.
- In OP2.3: Create starting gradient with a pellets.
  - steeper ∇n = more stable against back-transition

  - ∇n already at start of NBI = can extend to 5s.

- We also tested high-iota configuration:
  as good as FMM002 was without increased volume.



Seeding and accumulation

- To extend further, must mitigate divertor heat load.

1) KTM (High-iota, high-mirror)
   - Very benign heat loads.
   - T_i good, but not as good high-iota.

2) Use high-iota and add seeding (N or Ne).
   Neon feedback works well but radiates >= 0.5MW in core which disturbs the P_{ECRH} / P_{NBI} balance.
   --> Develop P_{ECRH} feedback on $n_e(0)$.

   - Strong core impurity accumulation observed, which needs to be addressed in future.