Data curation for high Performance Scenarios: (Steady-state + post) pellet injection
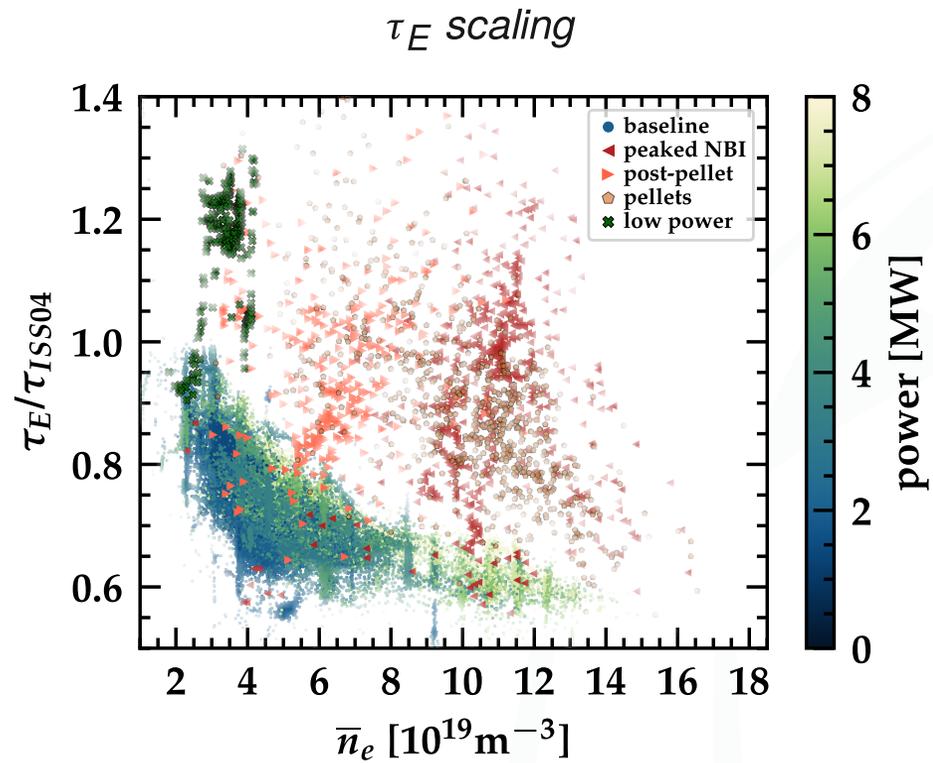
O. P. Ford for the W7-X Team

17.02.2026 TG Core Profiles

τ_E scaling

Reminder: Peaked density scenarios

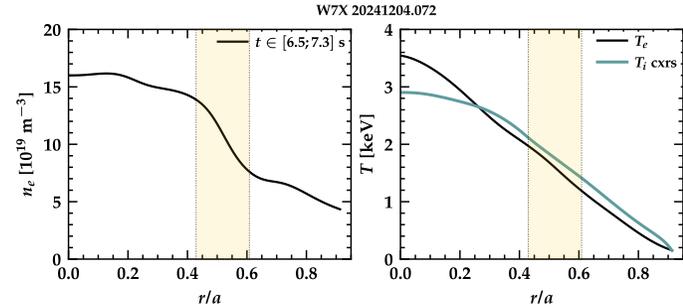Currently there are 4 main known operational scenarios:

1: Post-pellets

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(e.g. in press release 2025)

3: Low-power + ?
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4: NBI + ECRH reintroduction
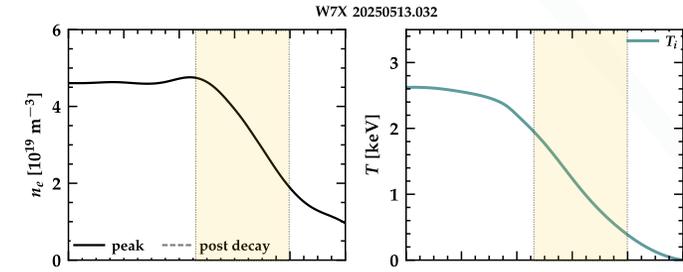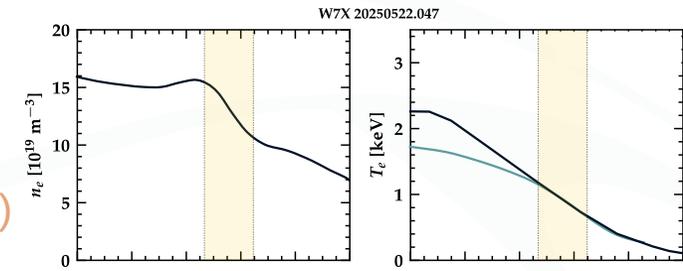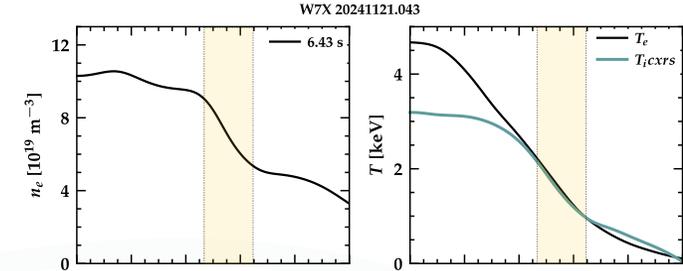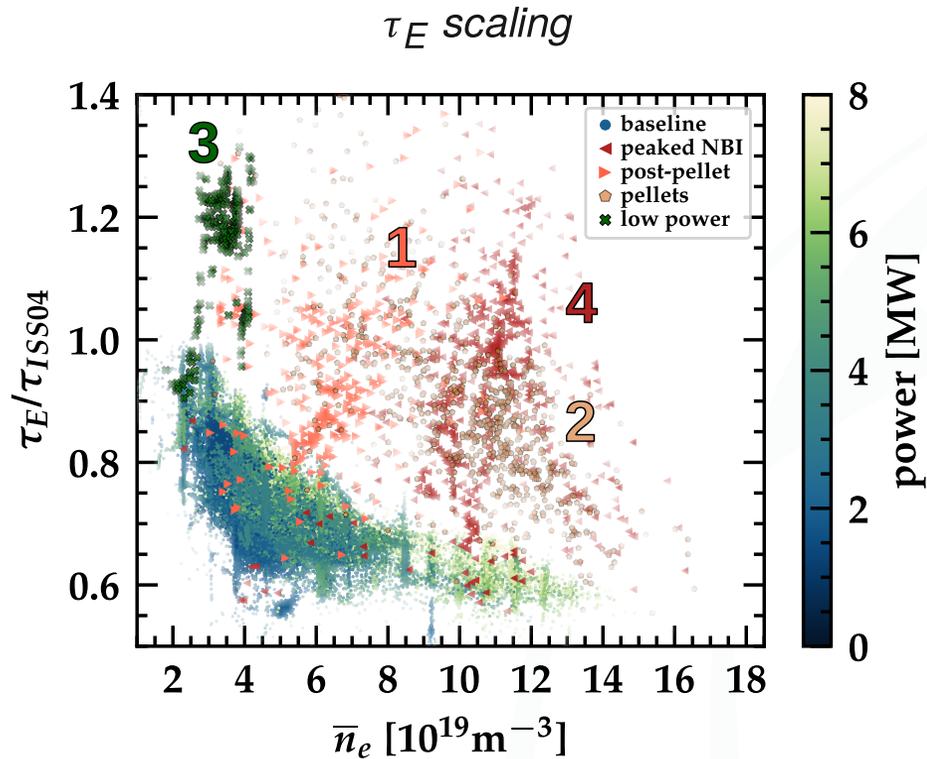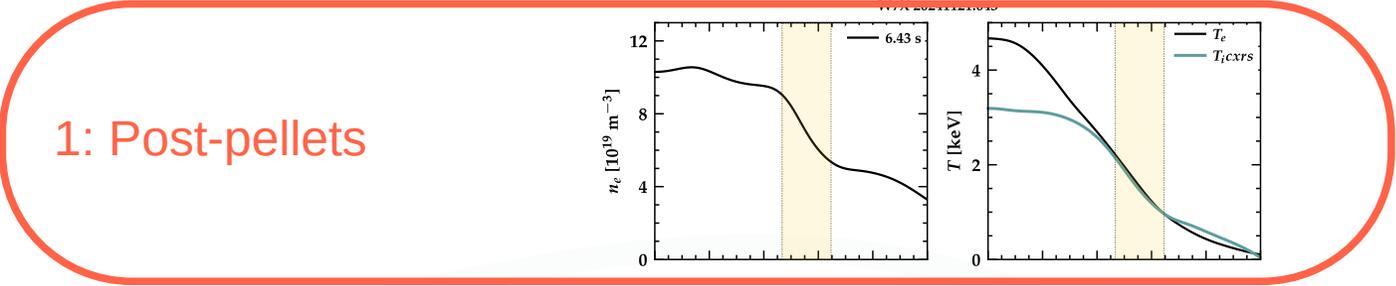(e.g. in record n T τ.
+PRL submission)

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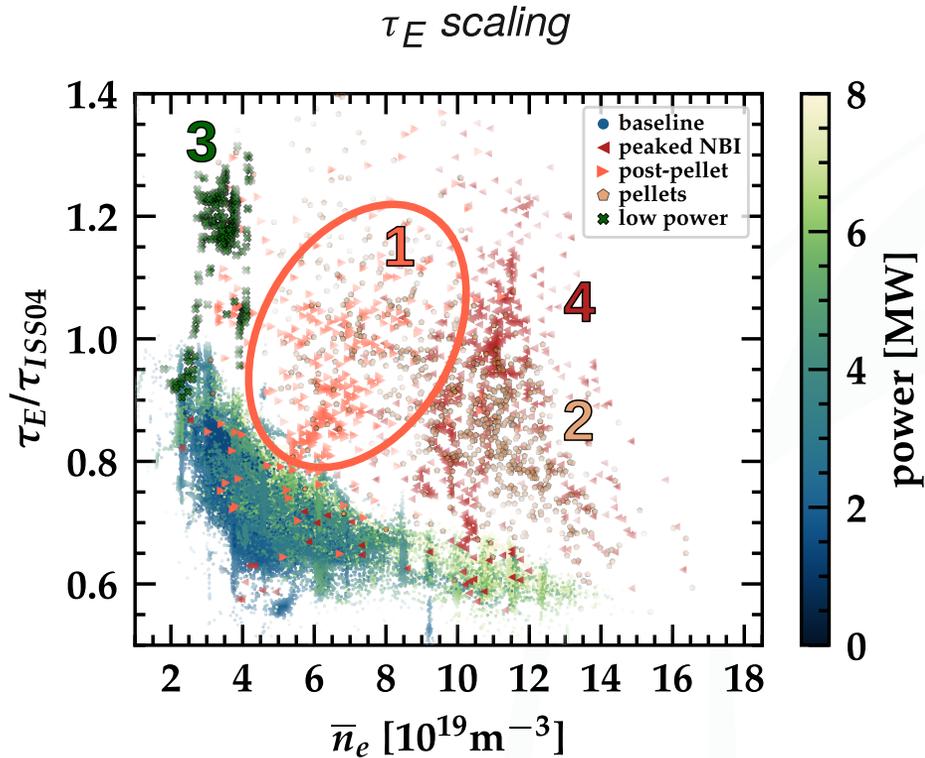Currently there are 4 main known operational scenarios:

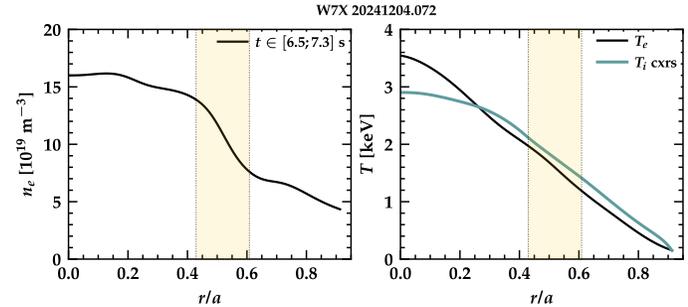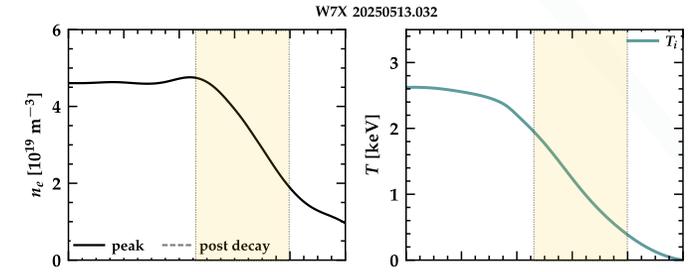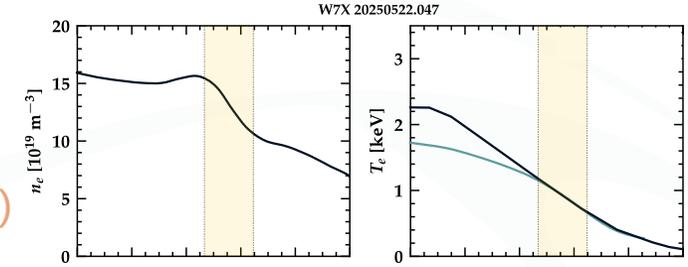To begin with, we are looking at #1.

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Post-pellet injection

Rapid pellet injection followed by a long phase of slowly evolving profiles.

W7-X 20241121.034 | UTC: 11:43:11| T0: 1732189391899000000

20241121.034
2.5MW X2 ECRH power - central deposition
Slow evolving profiles give particle and heat transport.
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Back-transition: Threshold behaviour of transport with no external changes.

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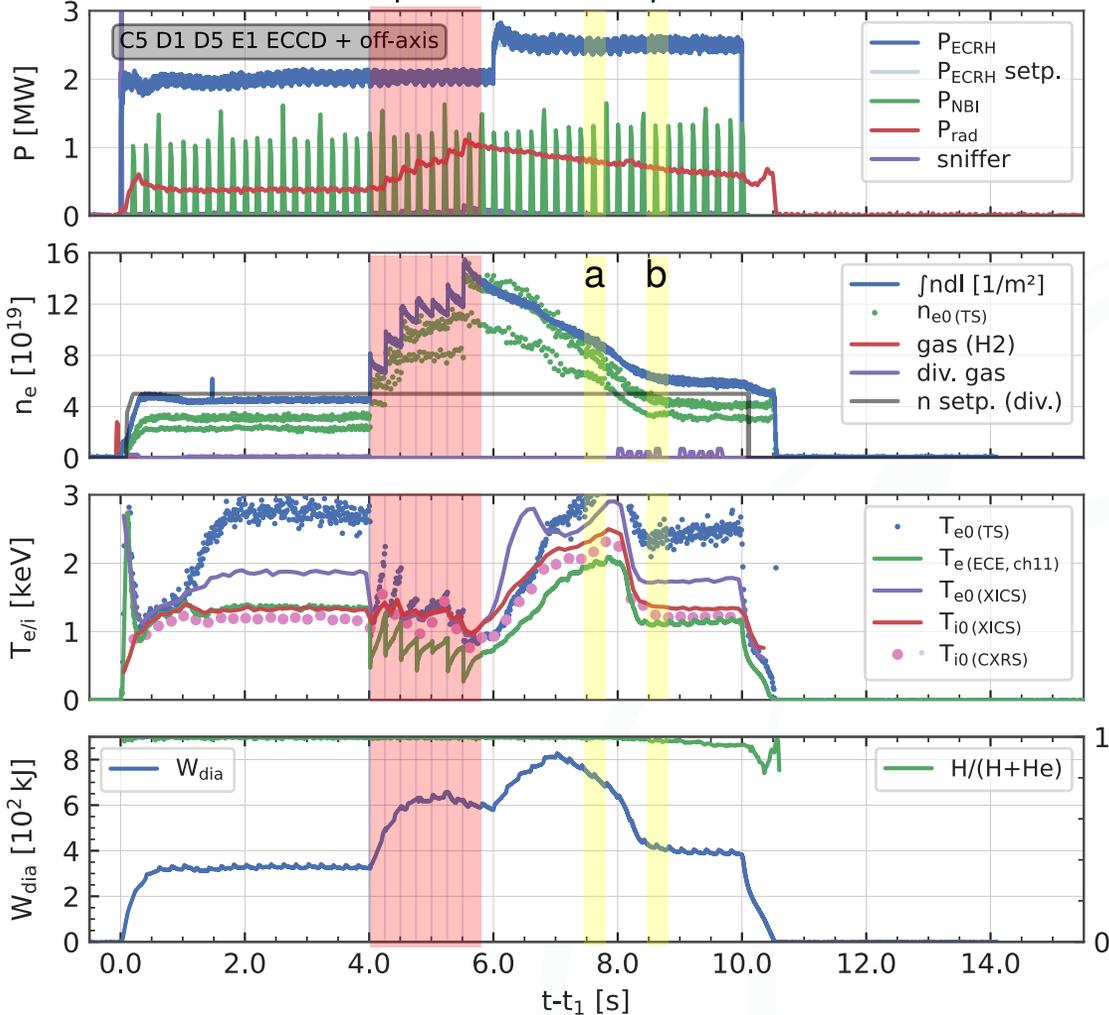
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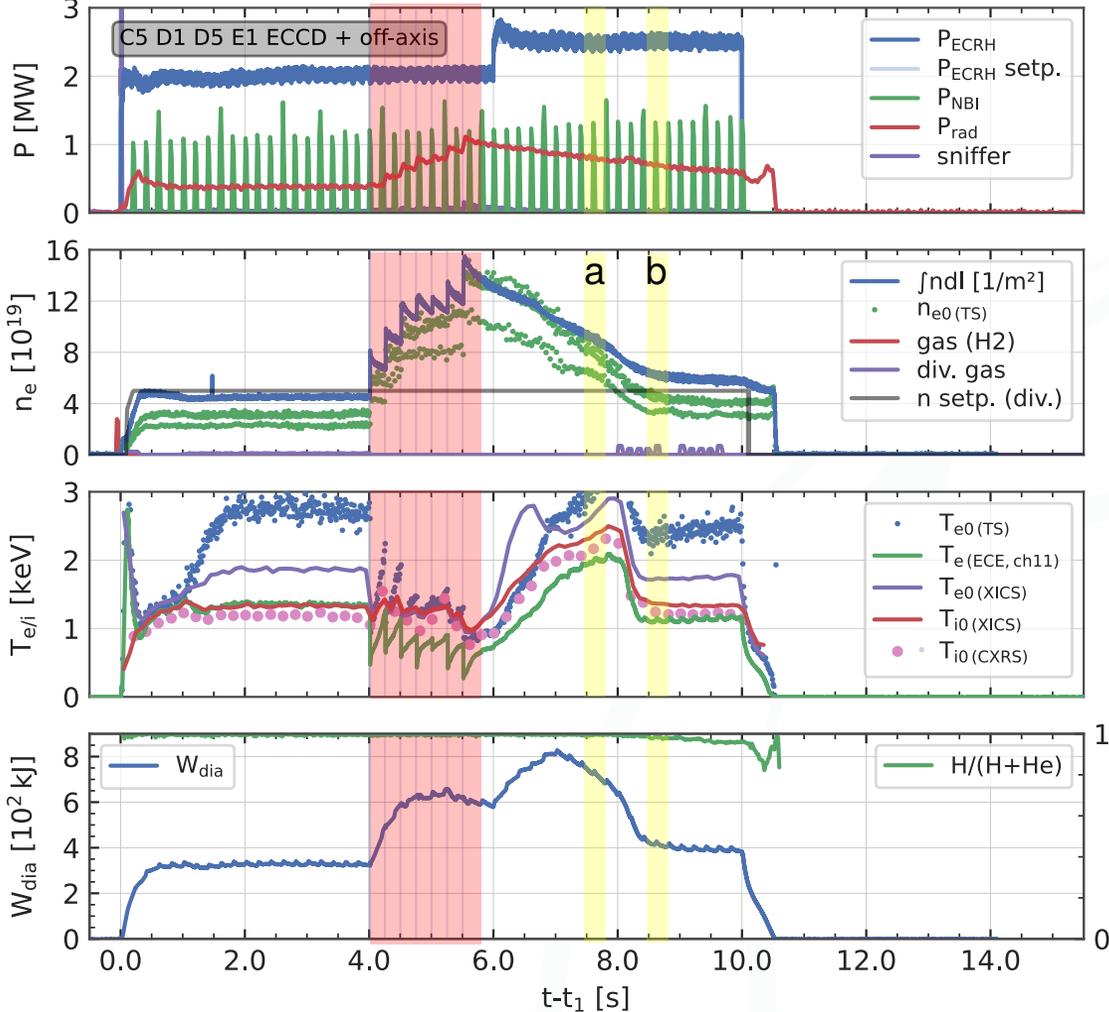
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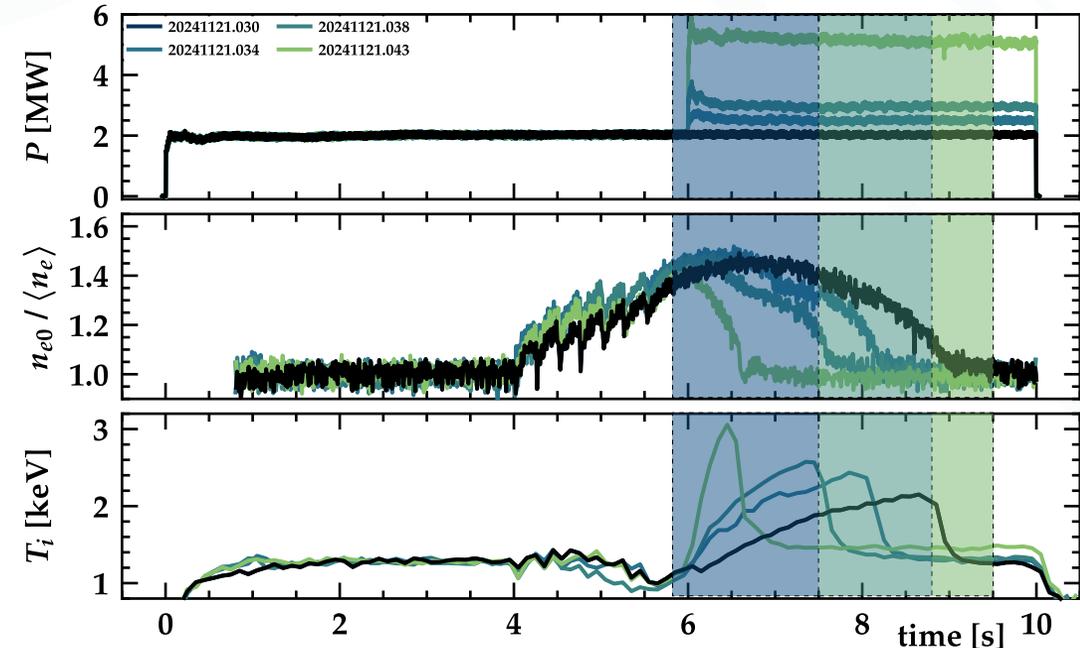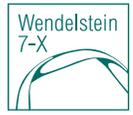**b)** After back-transition.

Wider scan shows different
ECRH pump-out effect:
#030 = 2.0MW, #034 = 2.5MW
#038 = 3.0MW, #043 = 5.0MW

More ECRH --> Faster n_e decay --> earlier back-transition.

generated Wed Nov 5 04:56:12 2025 - version 3.0 - contact: astechow@ipp.mpg.de - data missing: ['CXRS_ne', 'zeff_proxy'], []

MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK | Oliver Ford | ? January 2026   High Performance Scenarios - TG Core Transport   4 / 20   [02]
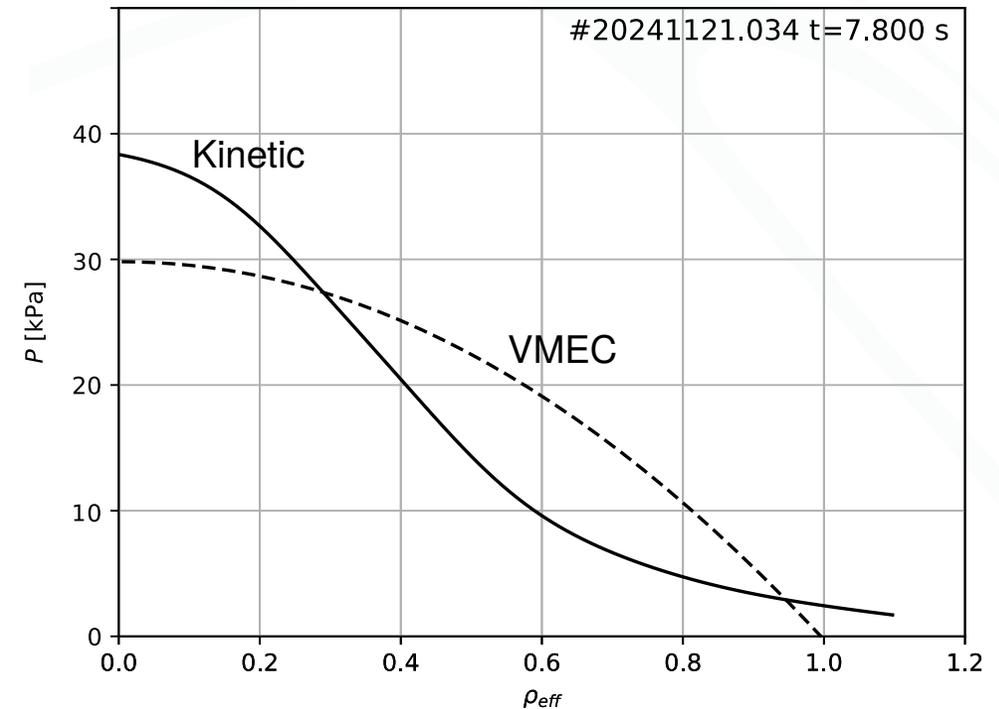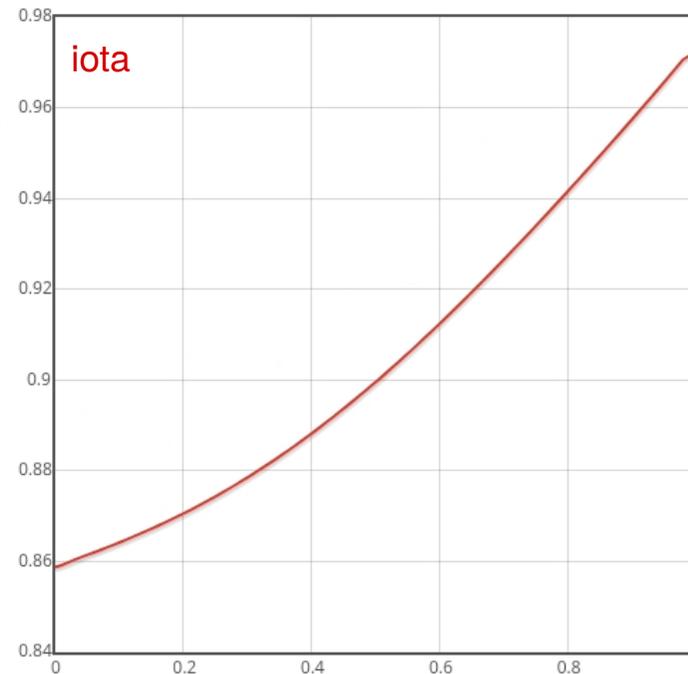
Standard "EIM" with B = +2.615T on axis.
best-fit VMEC from profile cooker for each phase:

High Ti phase: ⟨β⟩ = 0.6%, boz_EIMpl262_phi_2.026_p0_30.00_ppeak_2.00_Itot_0.00_Ipeak_0.00_v20190222135136
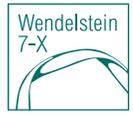After back-transition: ⟨β⟩ = 0.4%, boz_EIMpl262_phi_2.026_p0_20.00_ppeak_2.00_Itot_0.00_Ipeak_0.00_v20190222134845

Not perfect match to measured profiles, but limited effect on ρ mapping.

Plasma current is <1kA for the whole discharge.

20241121.034 - Configuration

Standard "EIM" with B = +2.615T on axis.

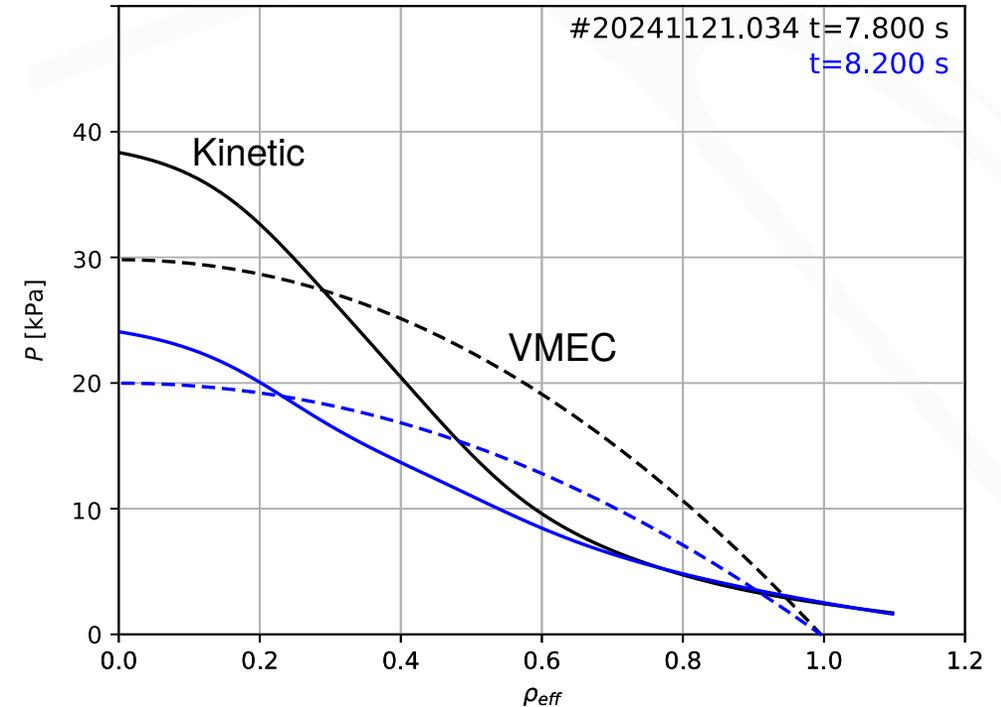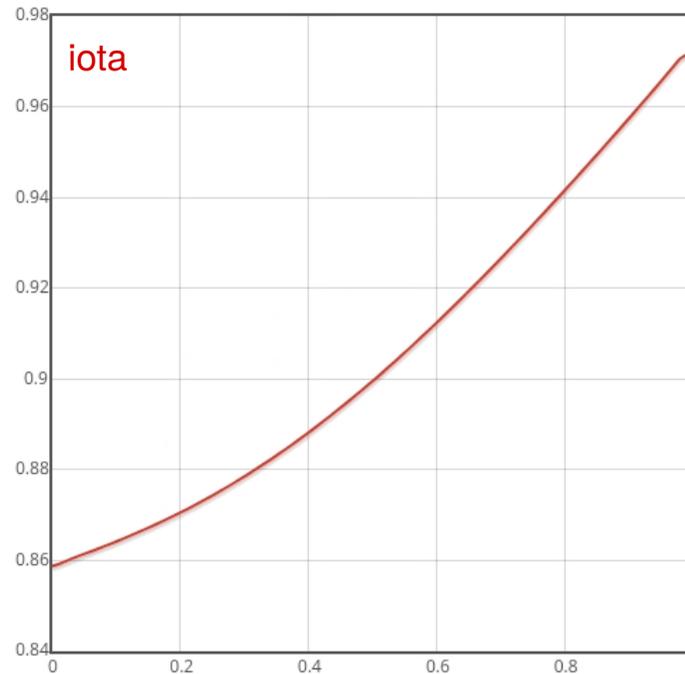best-fit VMEC from profile cooker for each phase:

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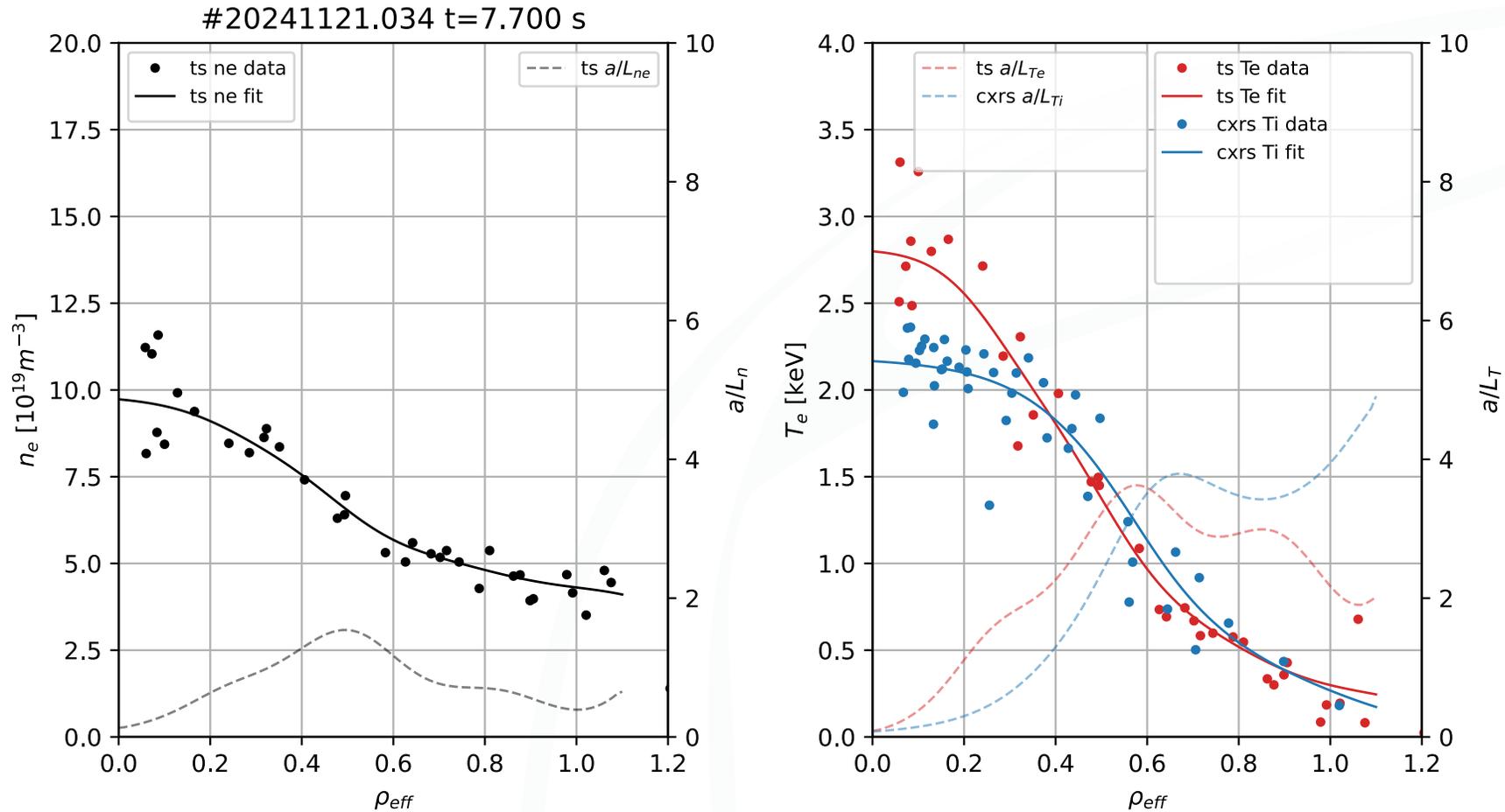Not perfect match to measured profiles, but limited effect on ρ mapping.
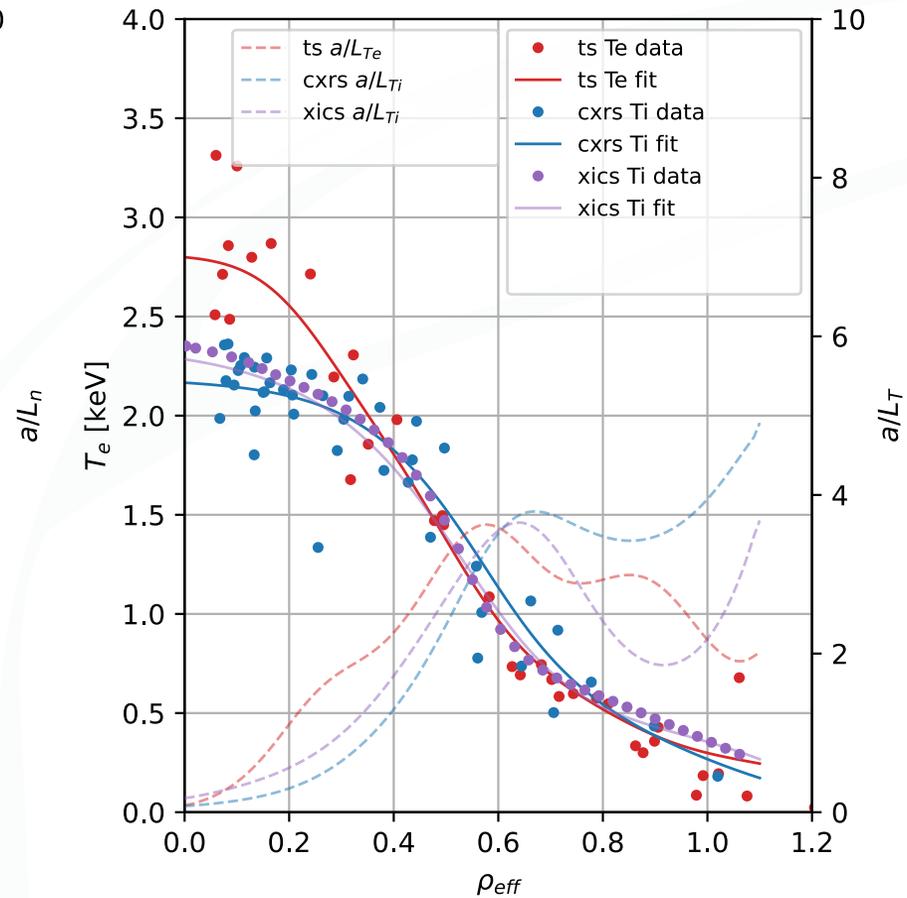
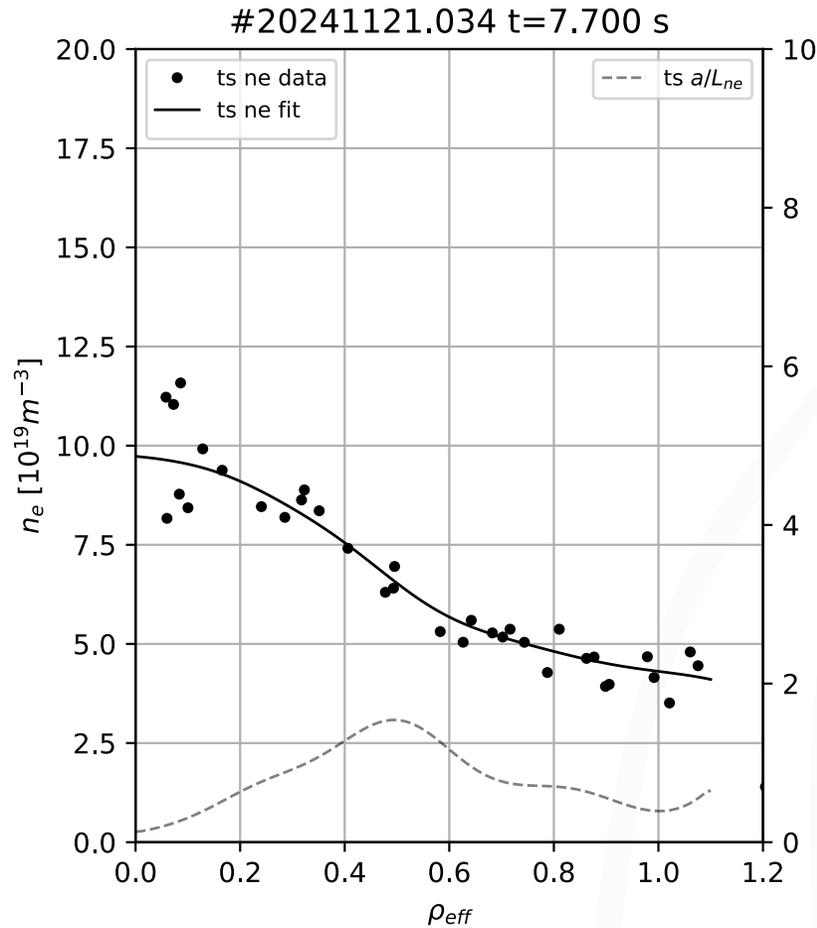Plasma current is <1kA for the whole discharge.

Thomson Scattering and CXRS are good. Individual n_e, T_e, T_i profiles OK.

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XICS matches CXRS with offset of -0.2 keV.

#20241121.034 t=7.700 s
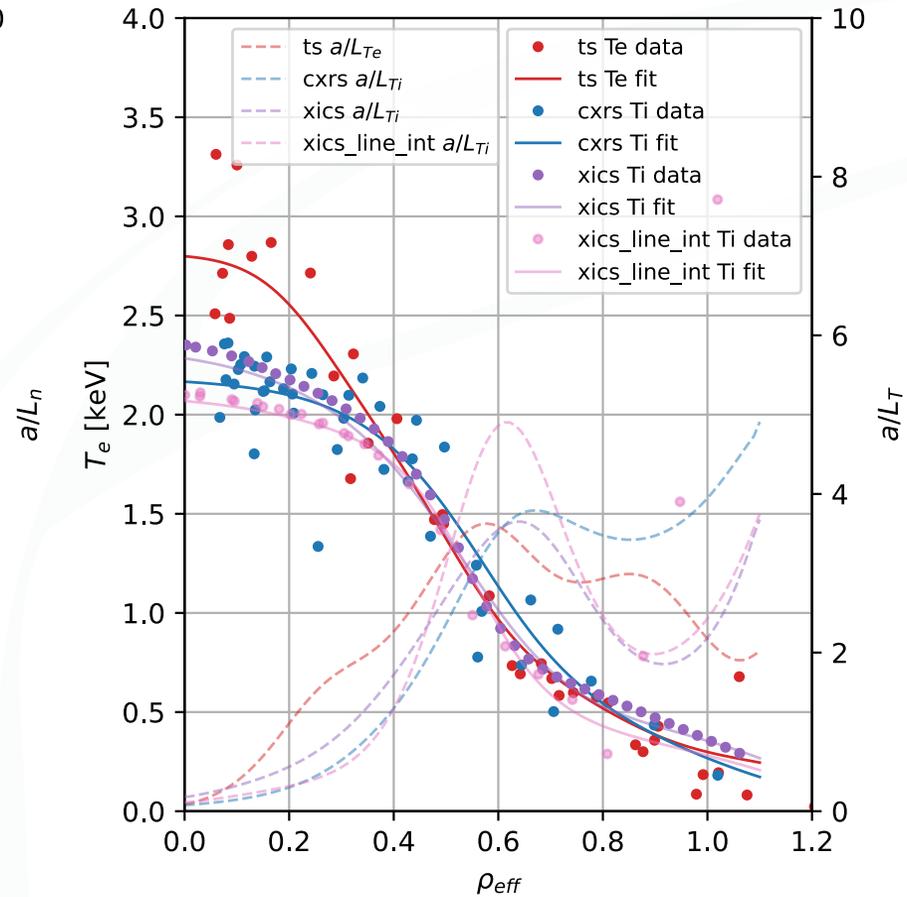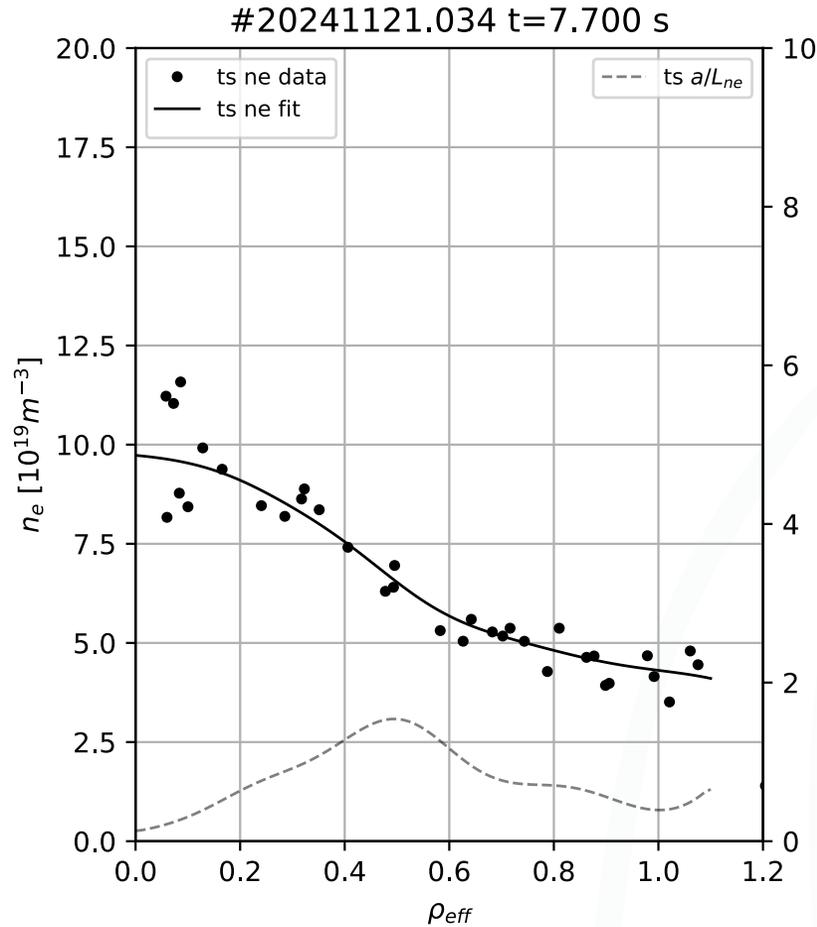
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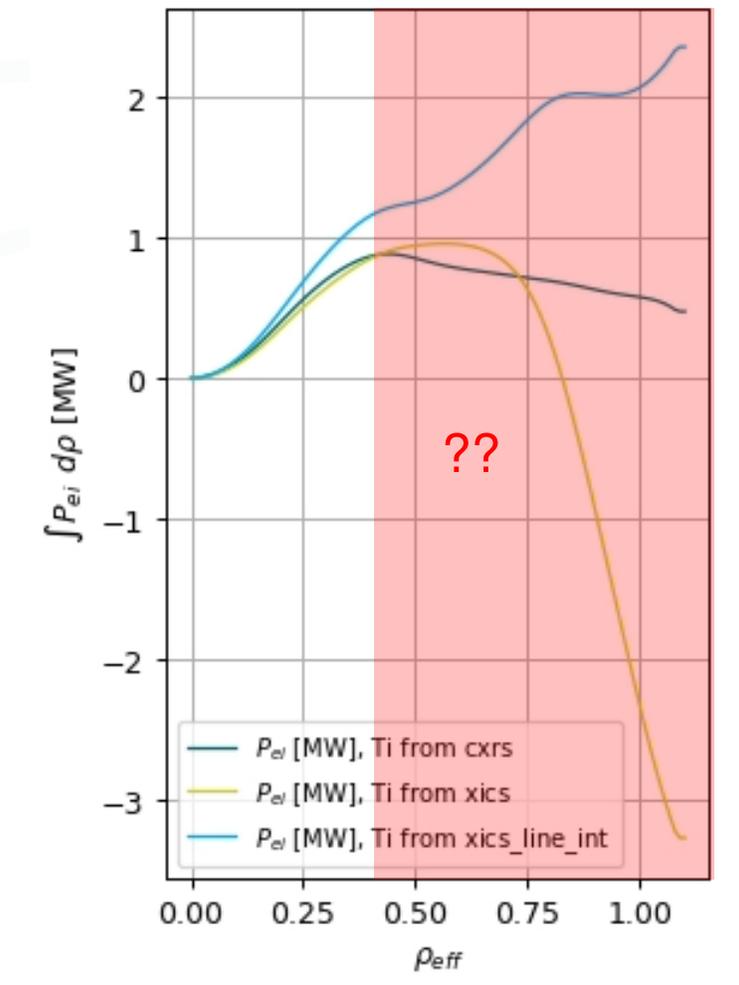#20241121.034 t=7.700 s
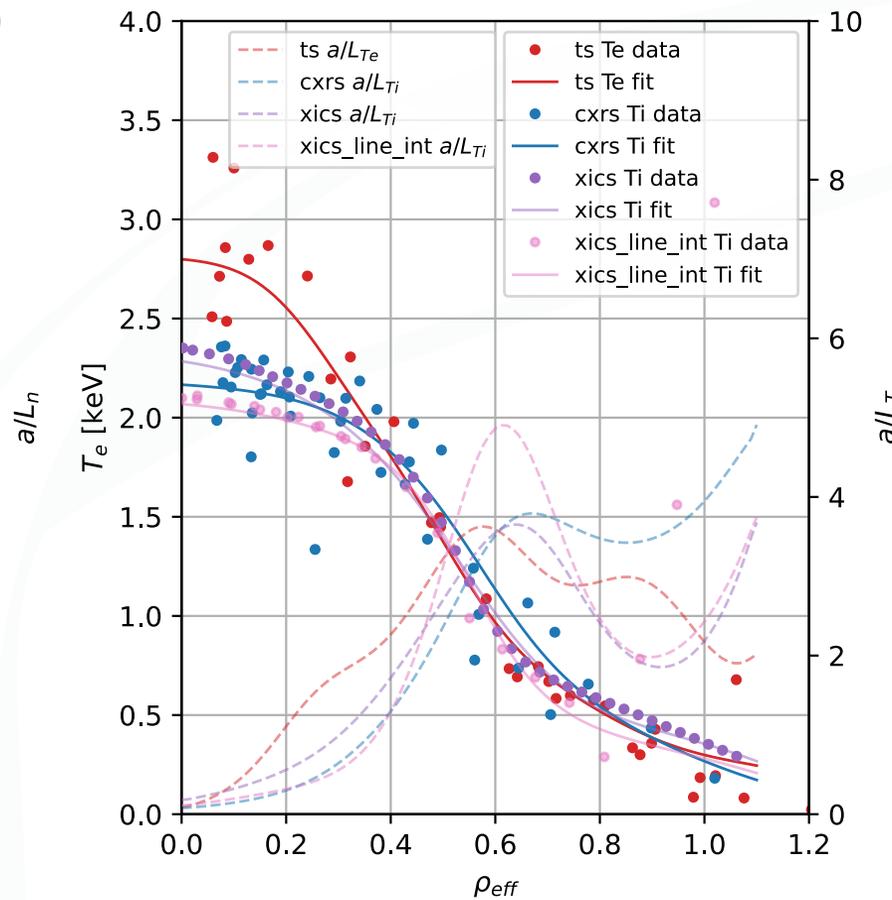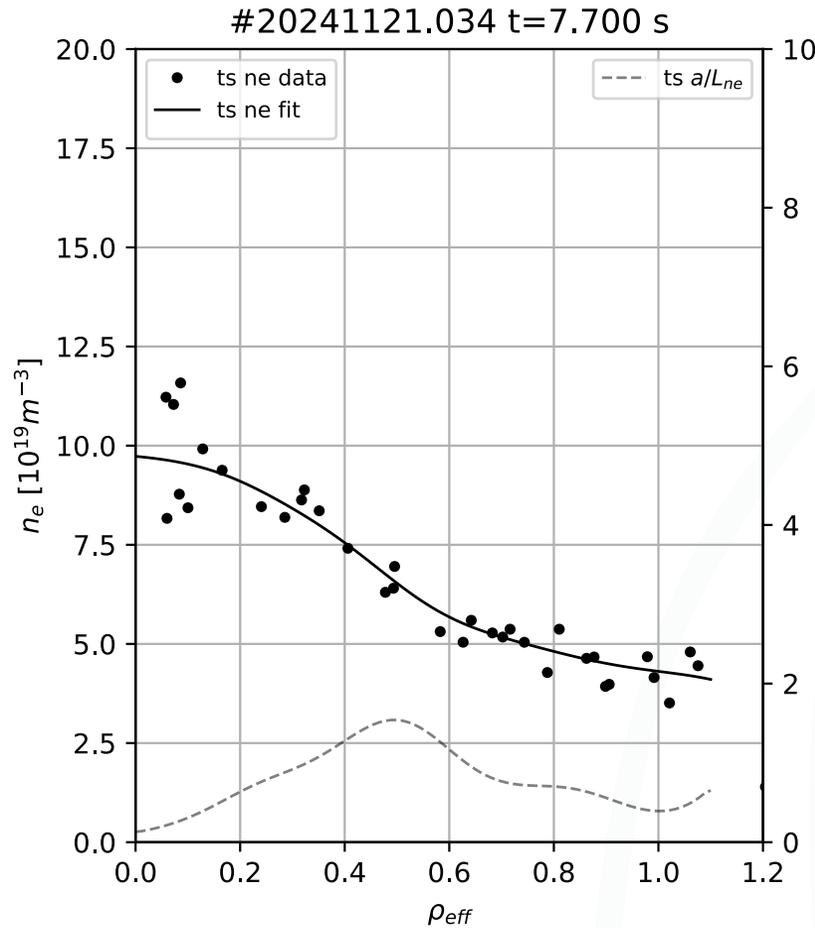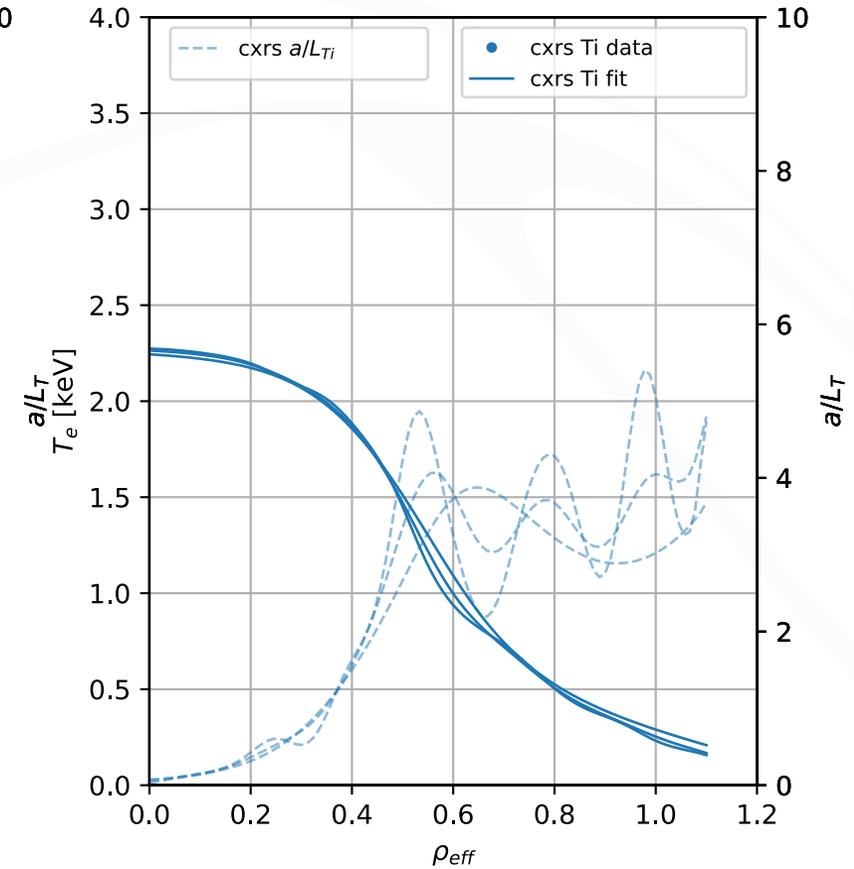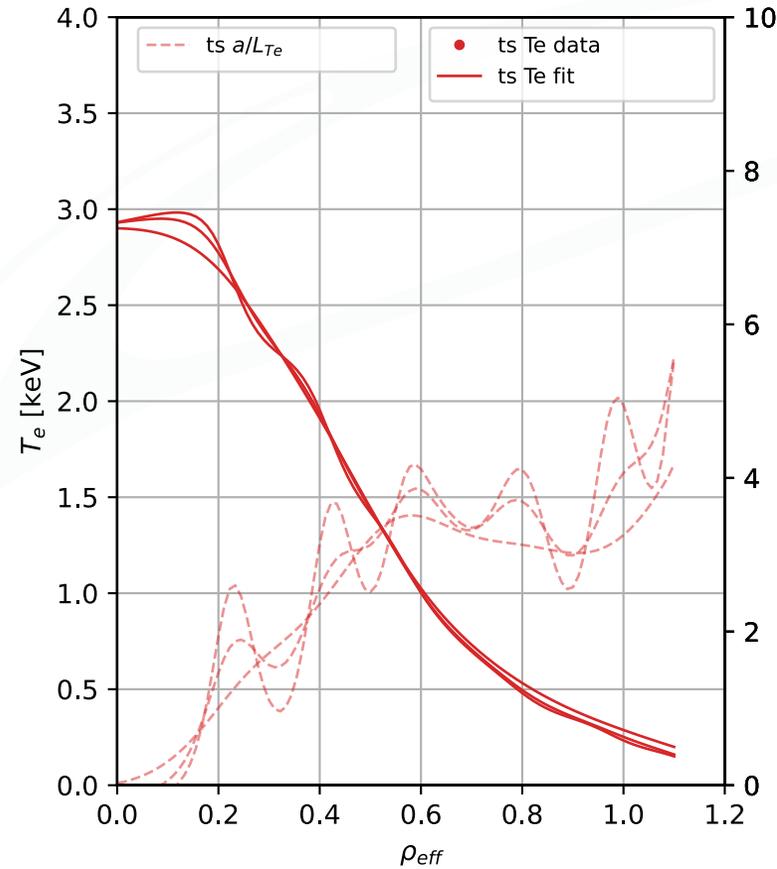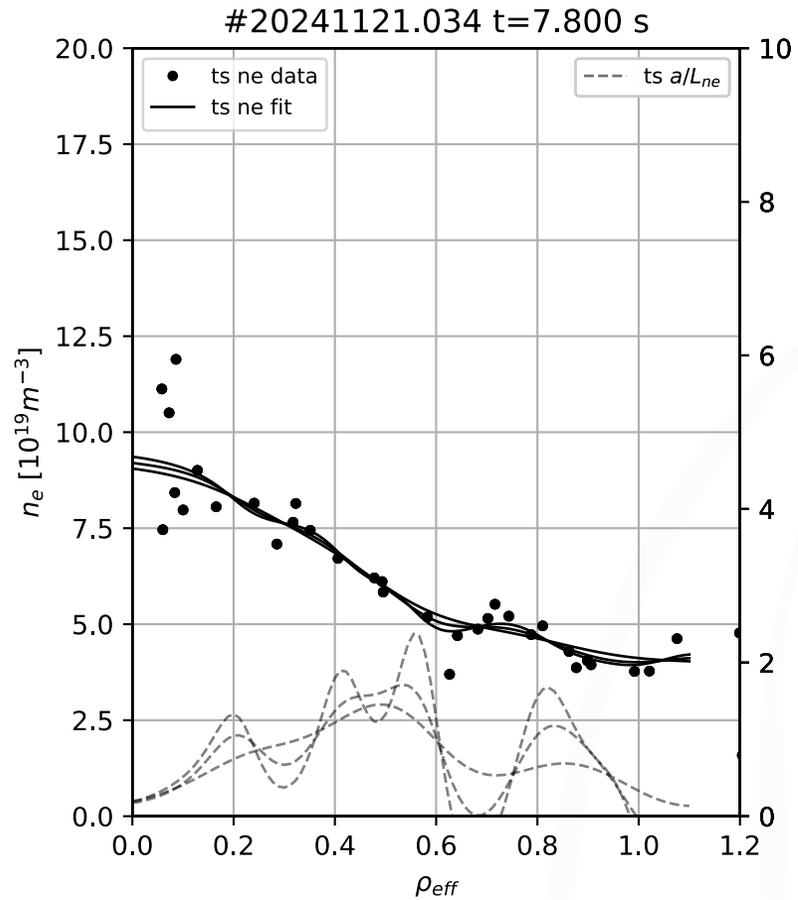
20251121.034 - Thomson Scattering

Thomson Scattering and CXRS are good. Individual n_e, T_e, T_i profiles OK.

XICS matches CXRS with offset of -0.2 keV. In central region relatively confident of correct ion heating.

but in gradient region $T_i = T_e$, so there is no hope of separating Q_e and Q_i.

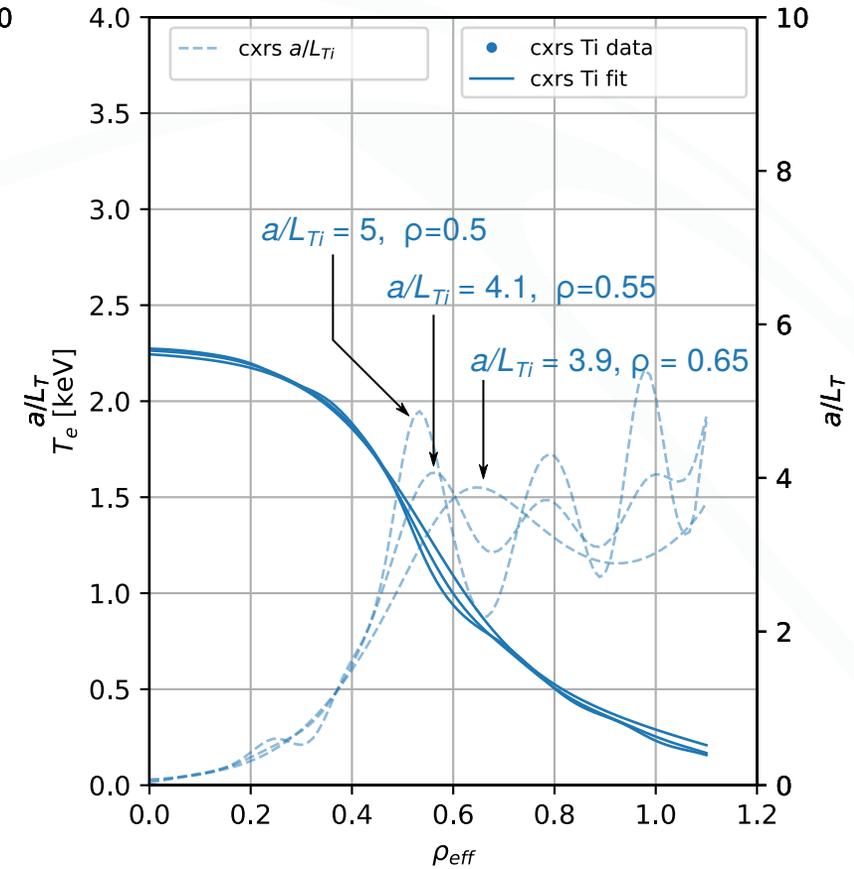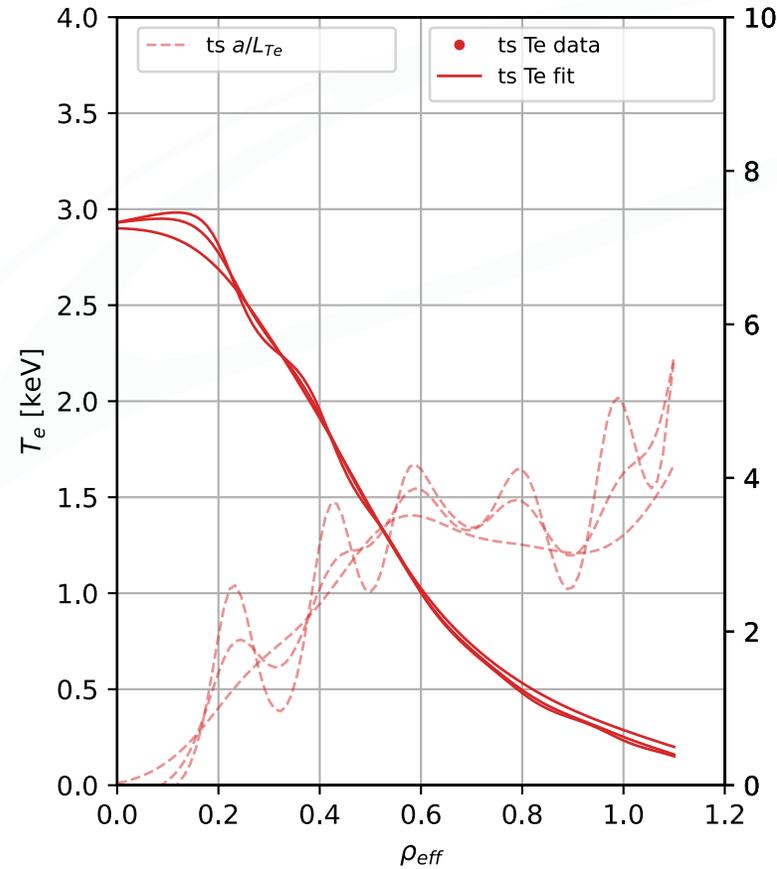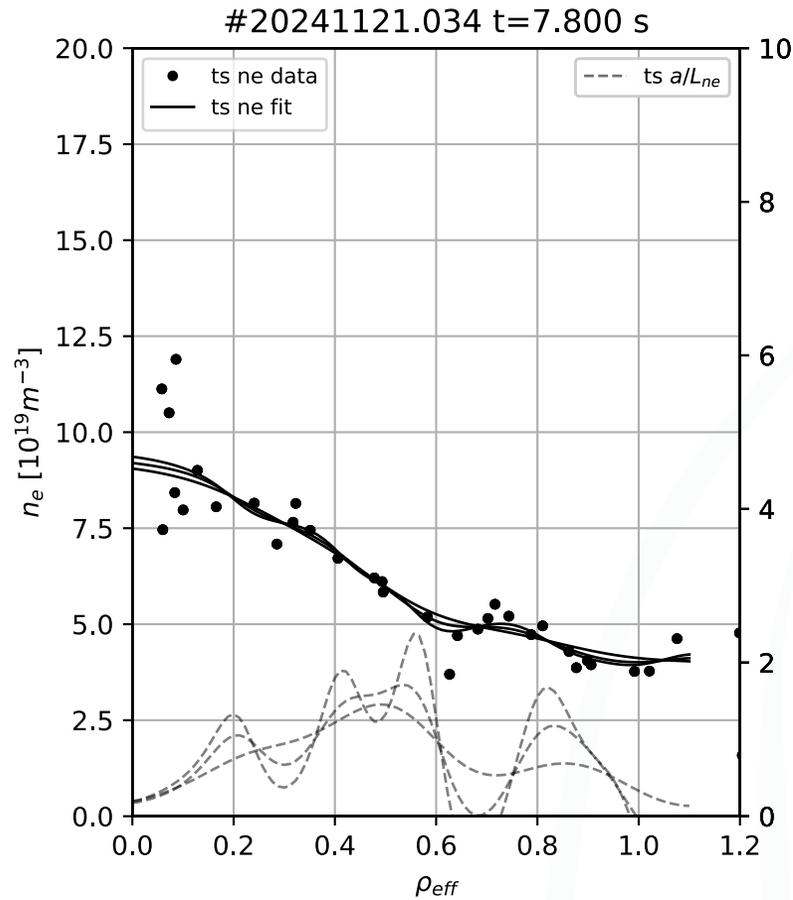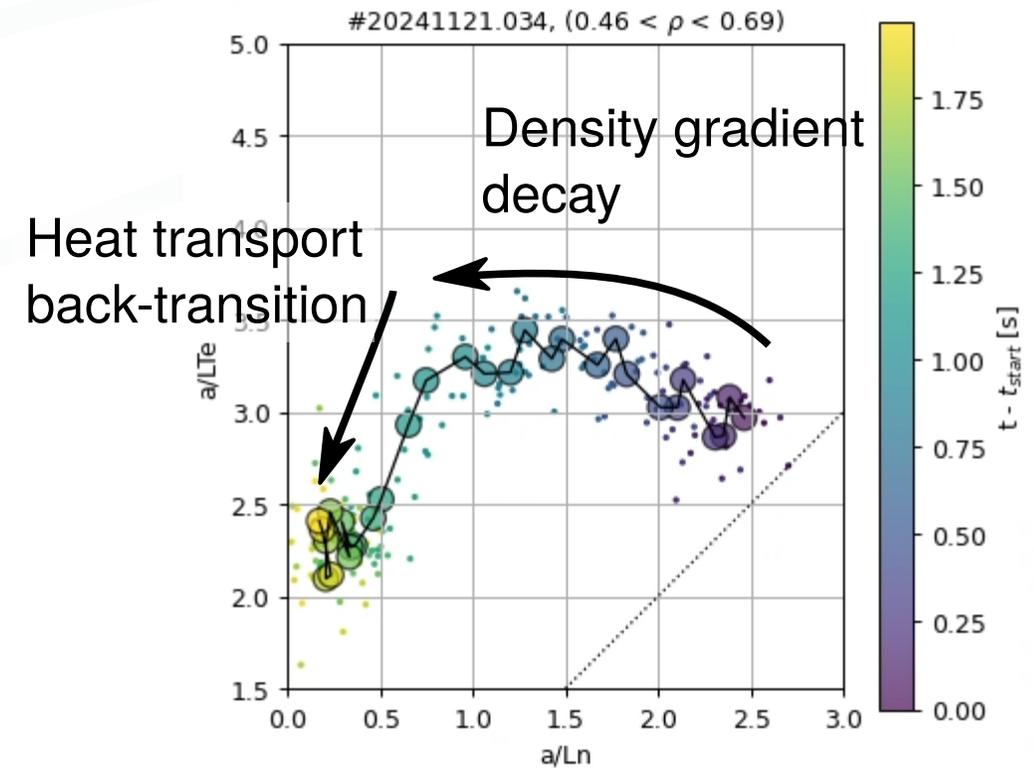# 20251121.034 - Fits and gradients

Gradient absolute values depend strongly on fitting parameters (smoothness).
- Peak values can in general always be higher, and move around in radius!
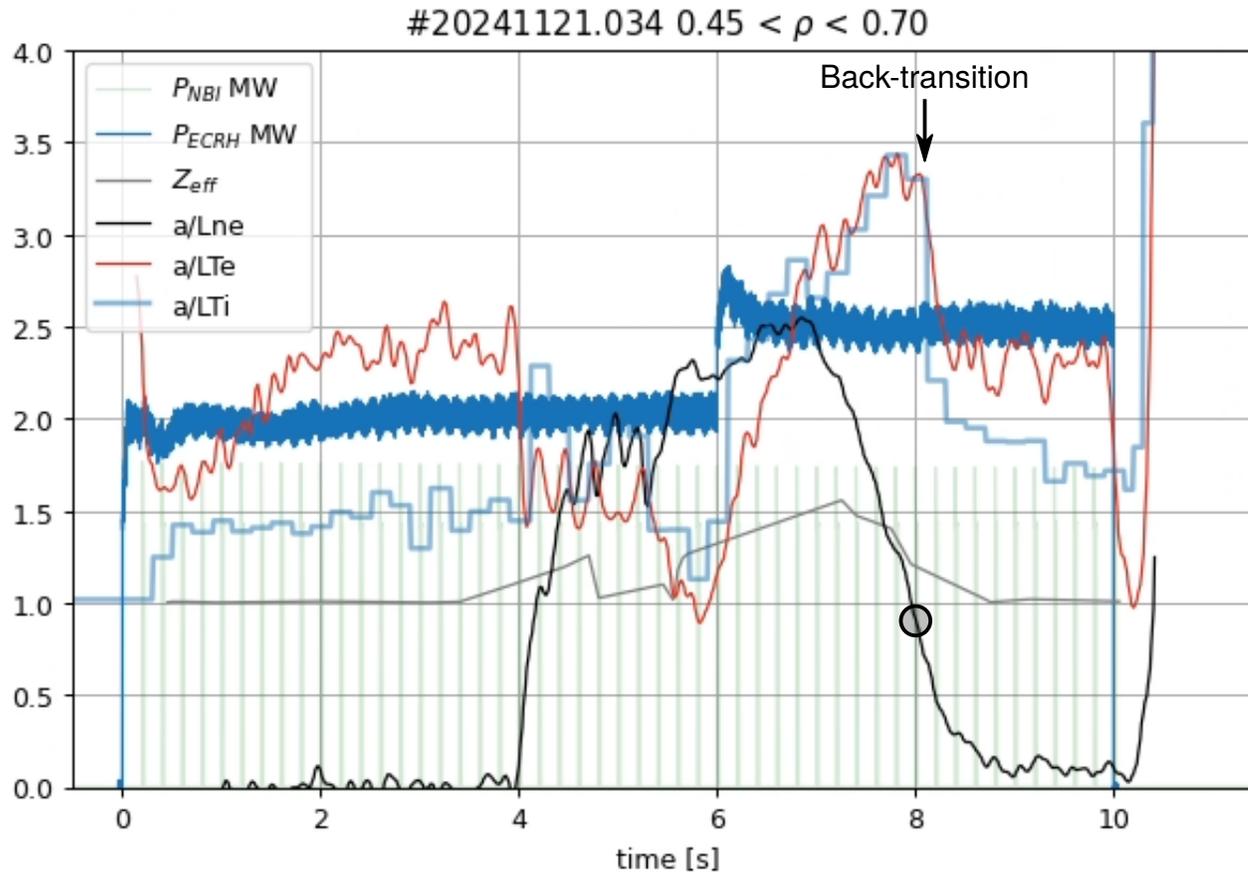
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#20241121.034 t=7.800 s

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The back-transition is abrupt and dramatic, despite a relative small change in density.

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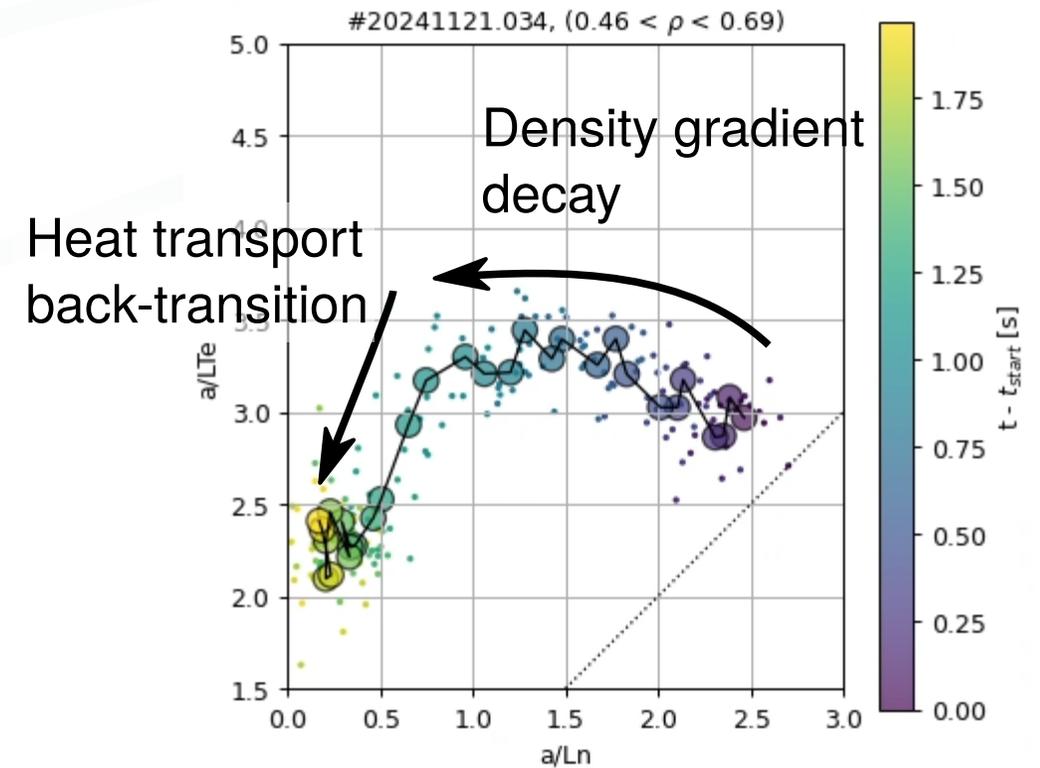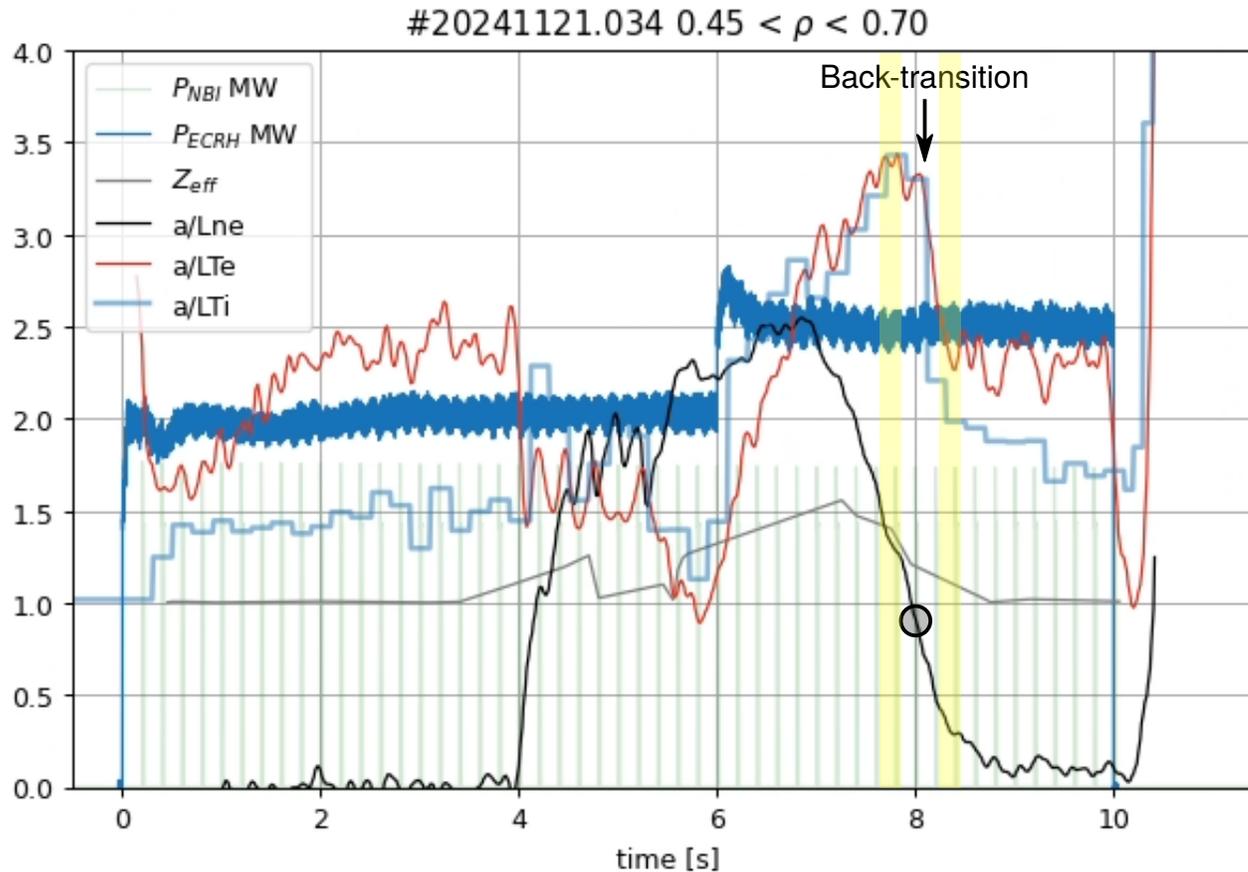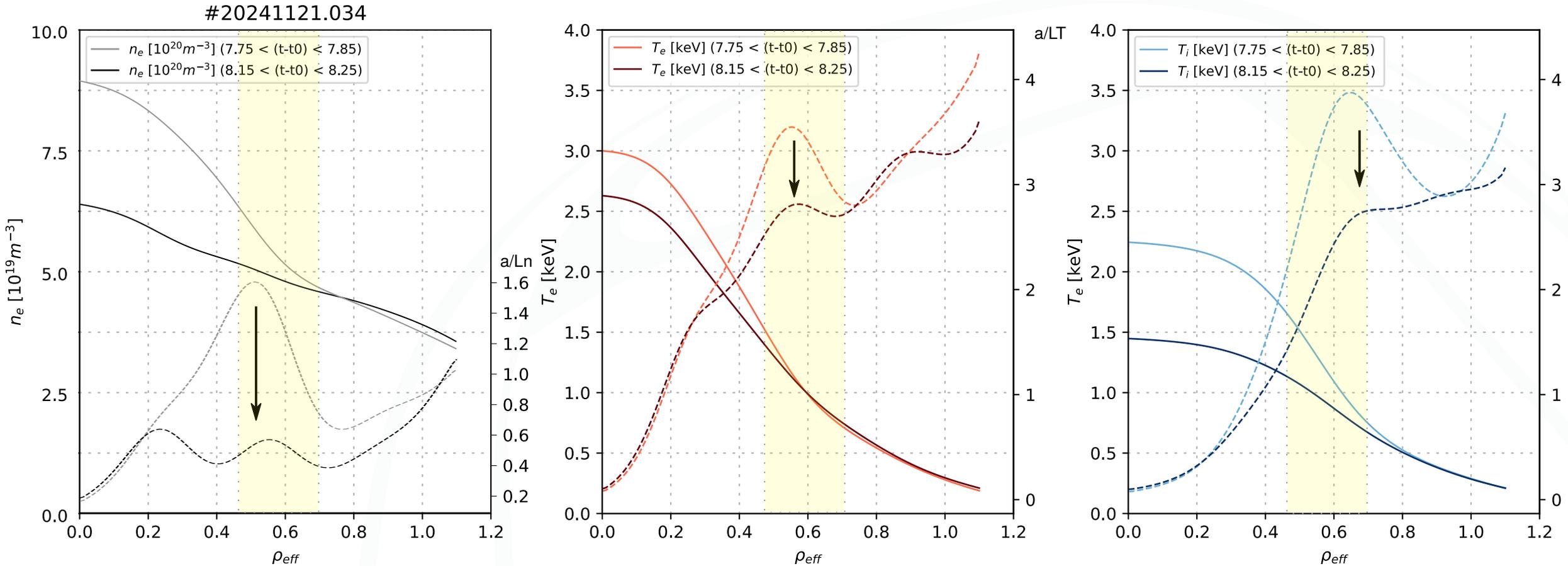
20251121.034 - Back-transition

As the density decays, the plasma transitions back to the normal W7-X turbulent dominated scenario.
The back-transition is abrupt, despite a relative small change in density (a/L_n = 1.5 --> 0.5)
Not clear if a/L_n, a/L_{Te} and a/L_{Ti} peaks are exactly the same place. Average ($0.45 < \rho < 0.7$) to capture all.

Summary - Post-pellet injection

We're looking to reproduce and explain the following from theory:

1) Dramatic change of heat-transport at $\rho \sim 0.5$ as a/L_n passes ~ 1.

Summary - Post-pellet injection

We're looking to reproduce and explain the following from theory:

1) Dramatic change of heat-transport at $\rho \sim 0.5$ as a/L_n passes ~ 1.

2) Particle transport - Slow changes of density after pellets
   - Less significant recycling flux - most of the particle came from the pellets.
   - Evolution after pellets - don't care about pellet deposition.
   - Clean scan of P_{ECRH} (i.e. a/L_{Te}).
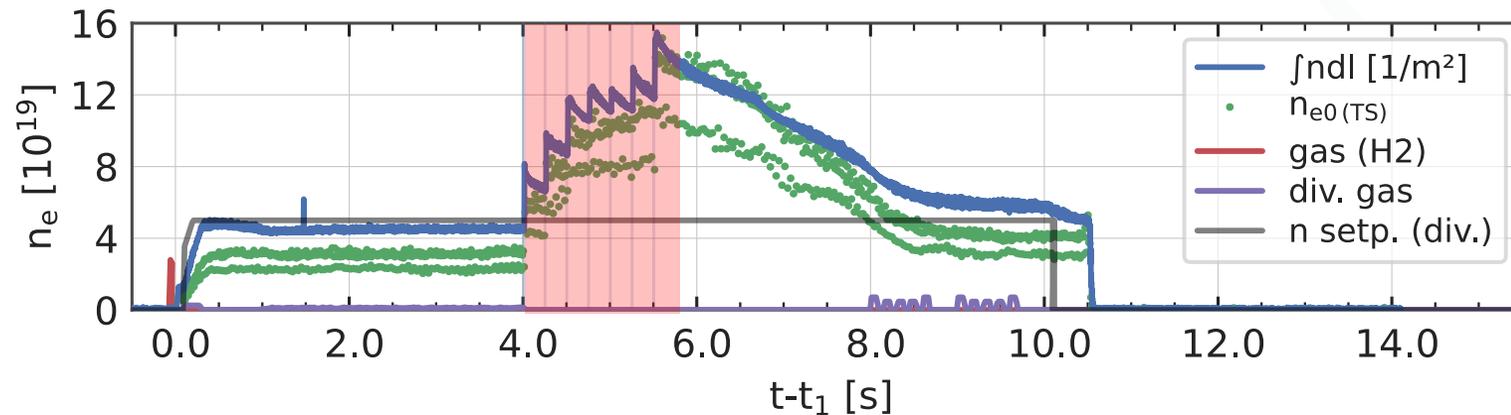
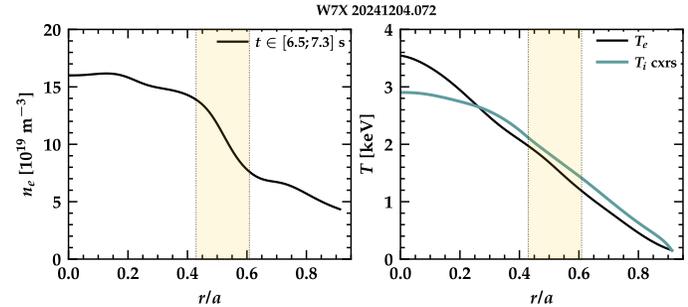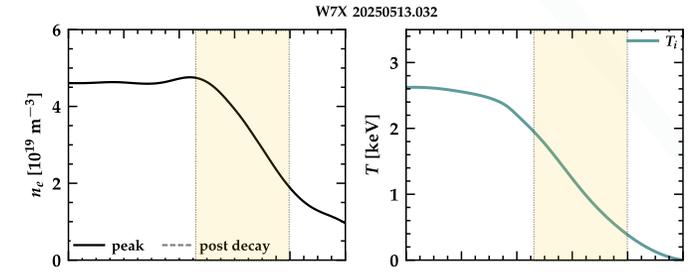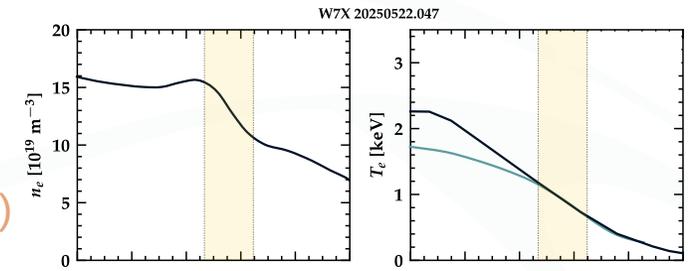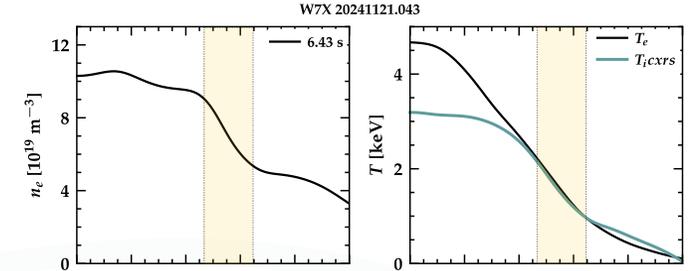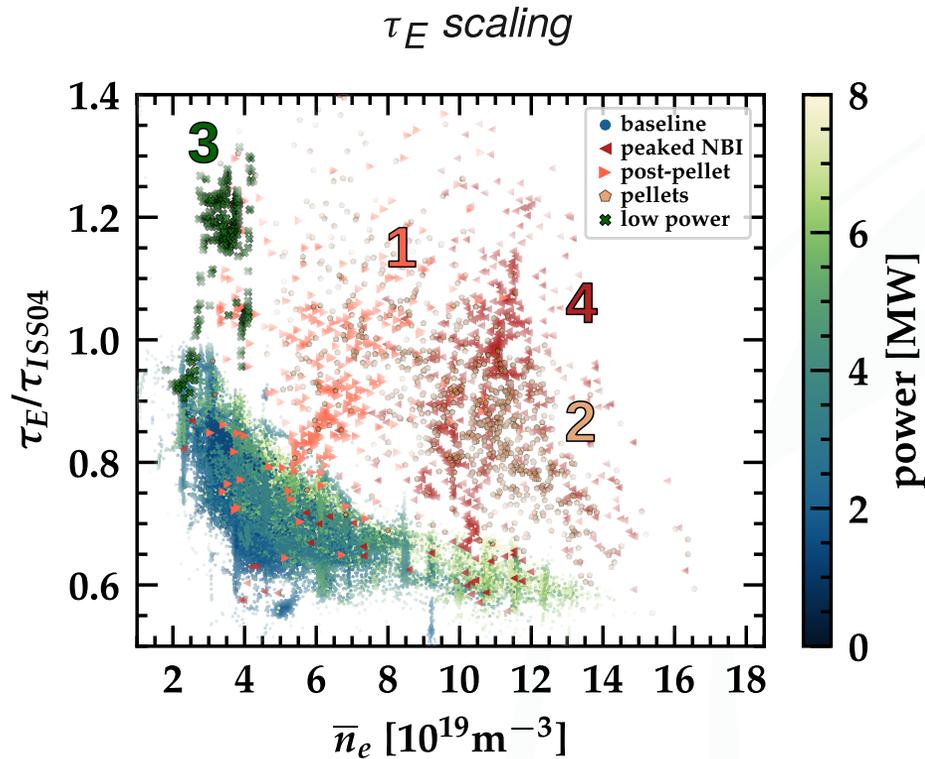Currently there are 4 main known operational scenarios:

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Reminder: Peaked density scenarios
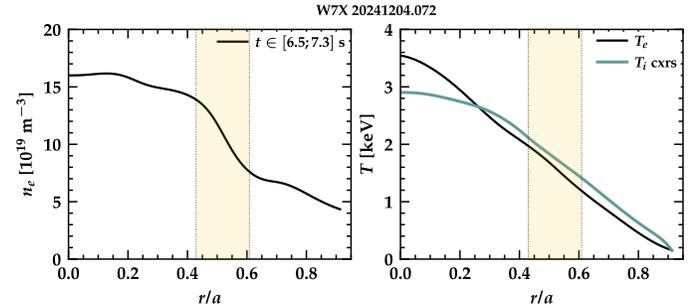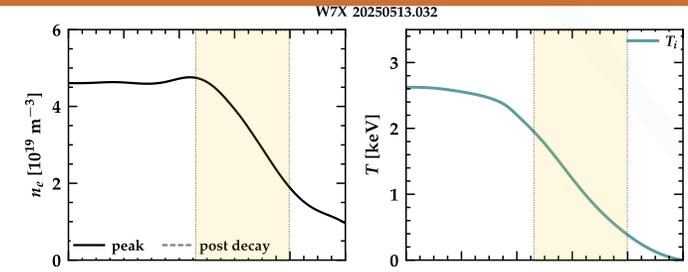
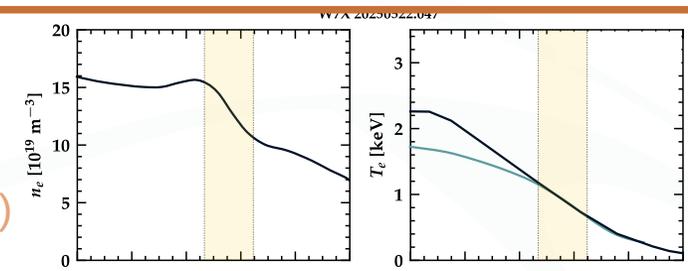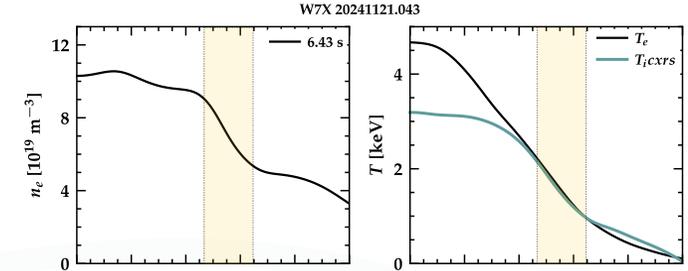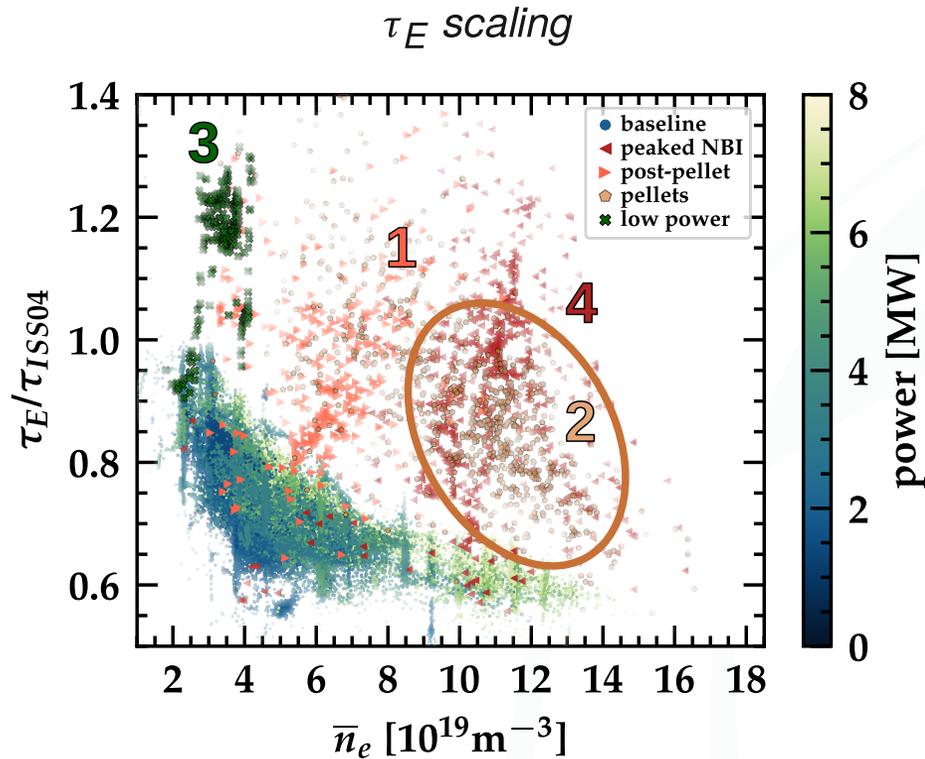Currently there are 4 main known operational scenarios:

To start with, we are looking at #2.

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2: 'Steady-state' pellets
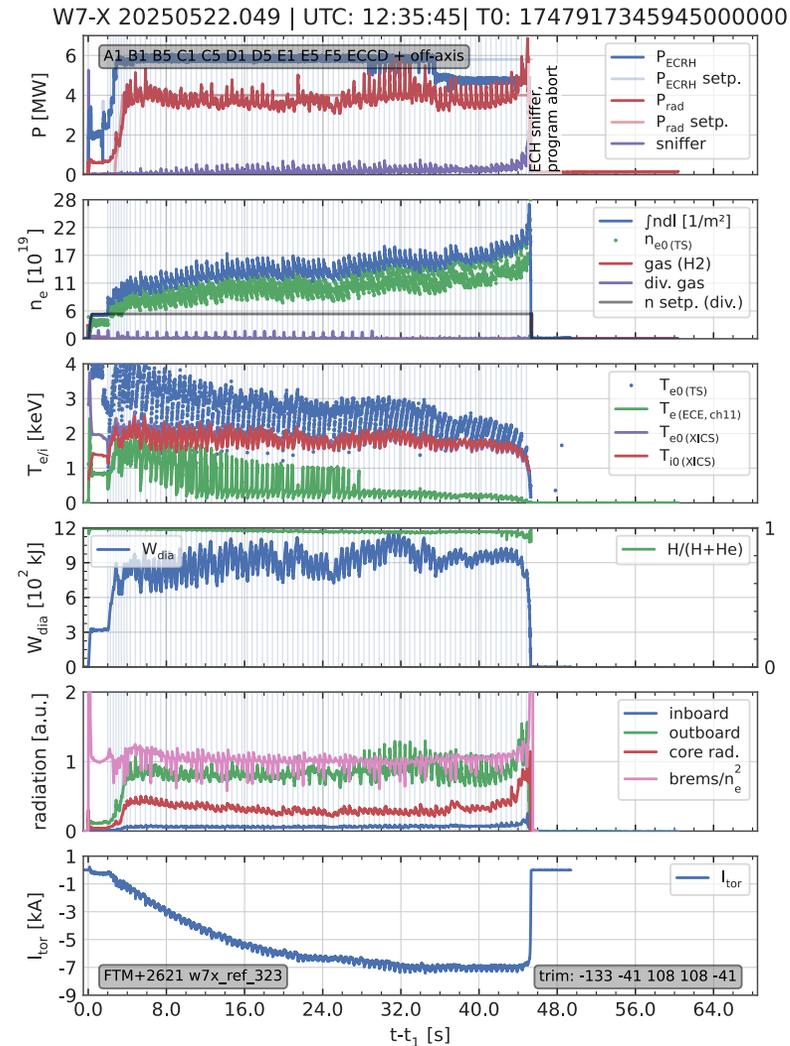(e.g. in press release 2025)

3: Low-power + ?
'intrinsic' peaking

4: NBI + ECRH reintroduction
(e.g. in record n T τ.
+PRL submission)

Steady-state pellet injection

Two main candidates looked at so far, we look at the right case as it's more consistent.

W7-X 20250522.049 | UTC: 12:35:45 | T0: 1747917345945000000

20250522.049
40s total,
Intermittent performance
Seeding
Ti = 1.8 keV
f_ren = 0.8
n.T.tau = 0.3

W7-X 20250327.046 | UTC: 12:32:42 | T0: 1743078762237000000
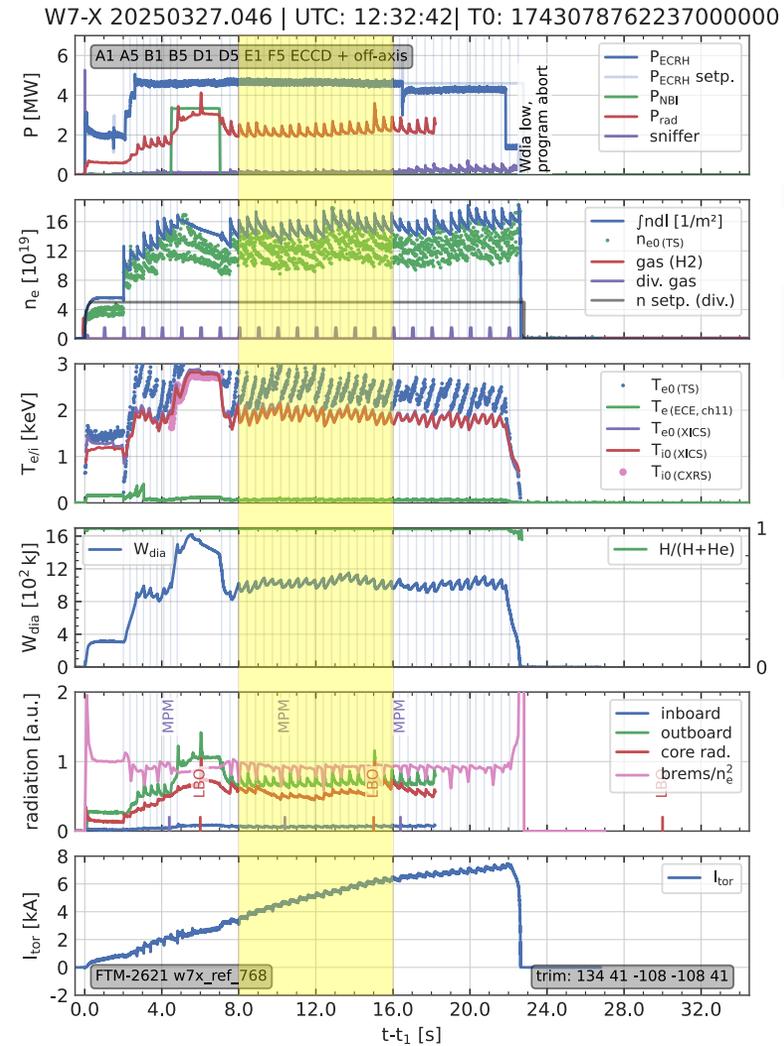
20250327.046
20s total,
8s of quasi-steady-state.
No seeding.
Ti = 1.9 keV
f_ren = 0.9
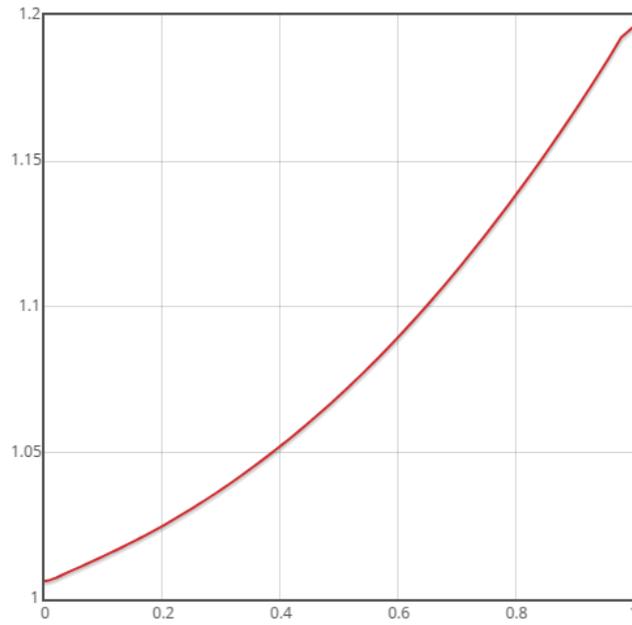n.T.tau = 0.5

High-iota "FTM" with B = -2.62T on axis.

During SSPI phase automatic best-fit VMEC from profile cooker is:

boz_FTMpl262_phi_1.721_p0_95.00_ppeak_4.00_Itot_0.00_Ipeak_0.00_v20210122000322

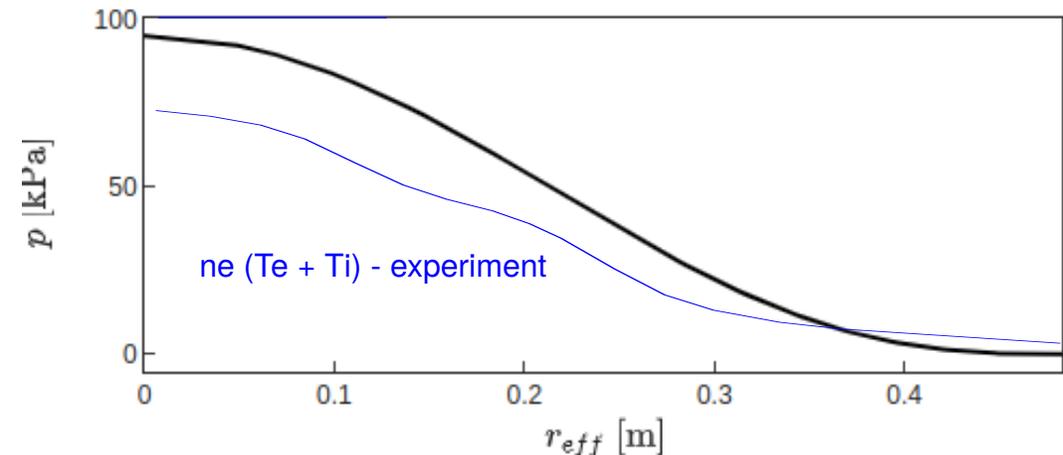Pressure profile is above that from *ne(Te + TI)*. Wdia mismatch??

ID is the same on average and at peak and min density.

Plasma current rises from 0 to max 7 kA and is ignored in this VMEC run.
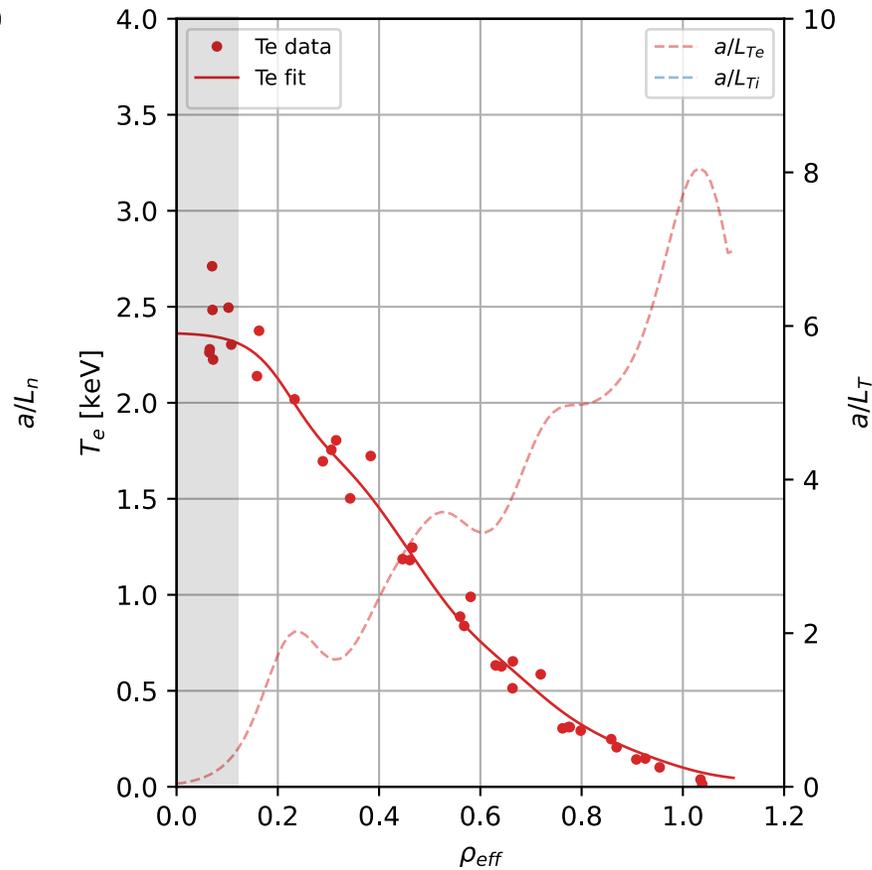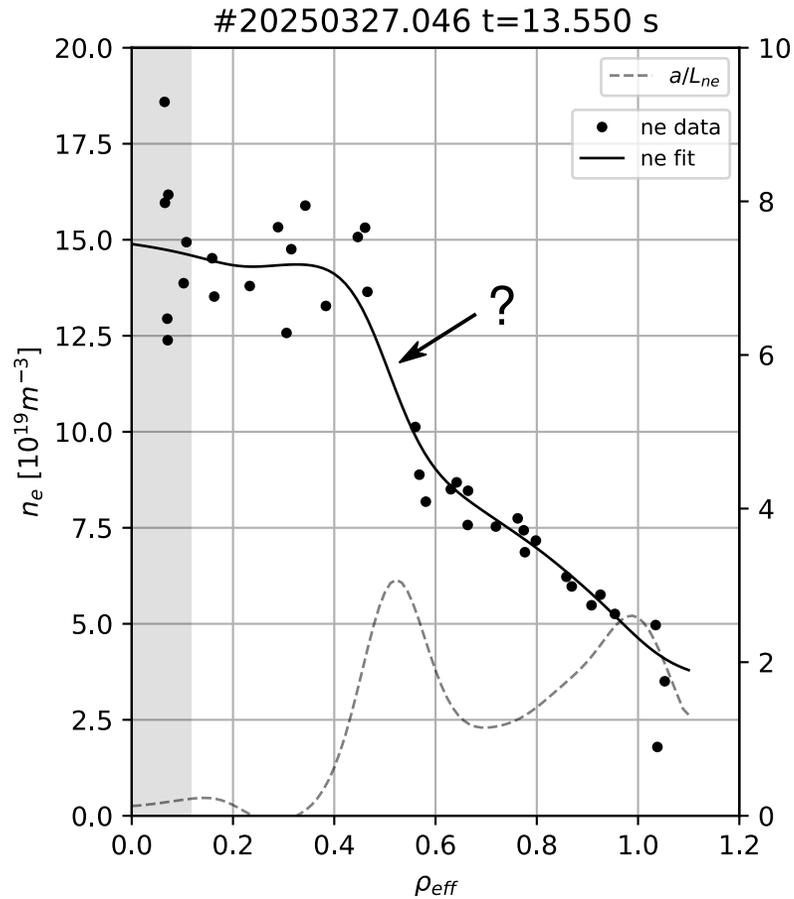
20250327.046 - Thomson Scattering

Thomson Scattering is quite good. Individual ne, Te profiles OK.

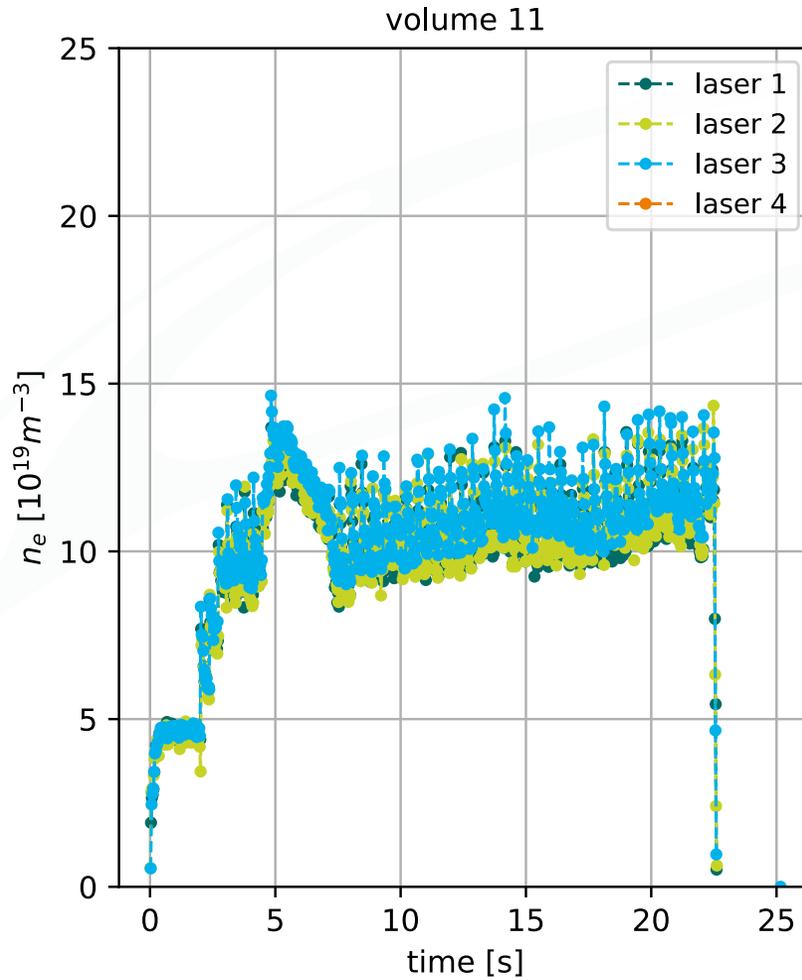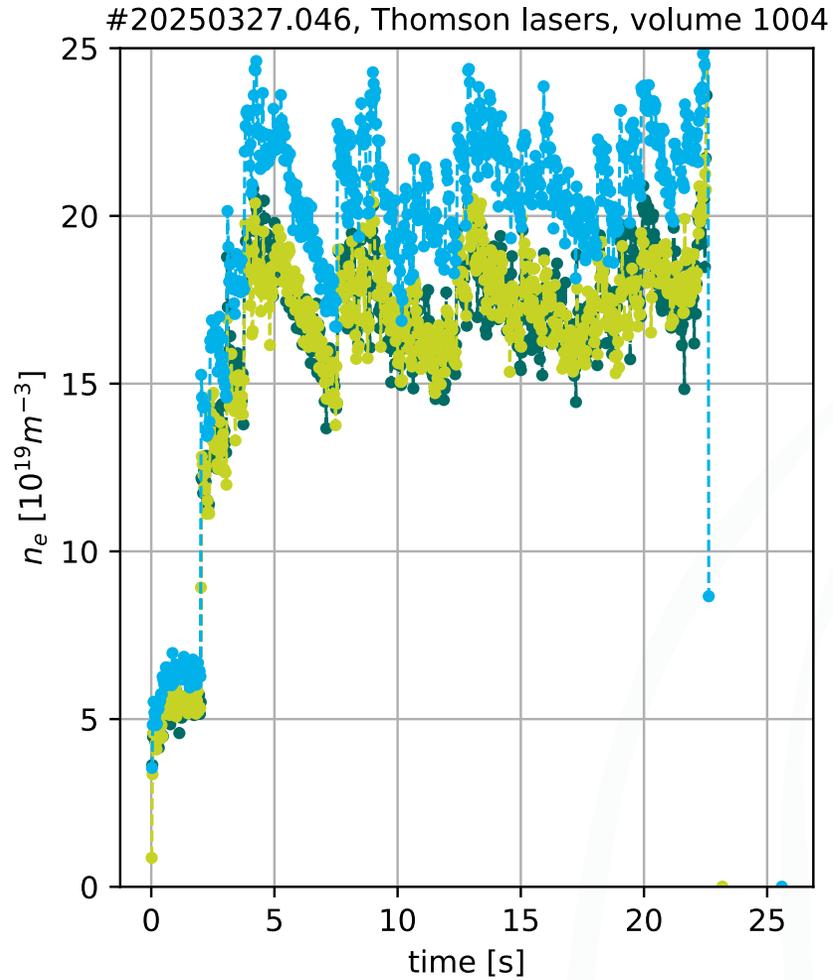Very strong gradient at rho~0.5 is not really resolvable. We believe it is at least a/Ln > 5. It could be more.

Points near axis are scattered and different between the two optical systems. Don't trust gradients for rho < 0.2.

n_e profiles are normalised to interferometer. Profile shape from TS varies somewhat between the 3 Thomson lasers: We ignore laser 3 for this shot.

#20250327.046, Thomson lasers, volume 1004

volume 11

Ion temperature only available from XICS during pellets phase (no NBI for CXRS).
During NBI phase near start of shot, XICS is at least 200eV lower than CXRS, as usual [see 10.1063/5.02194690.1063/5.0219469] .
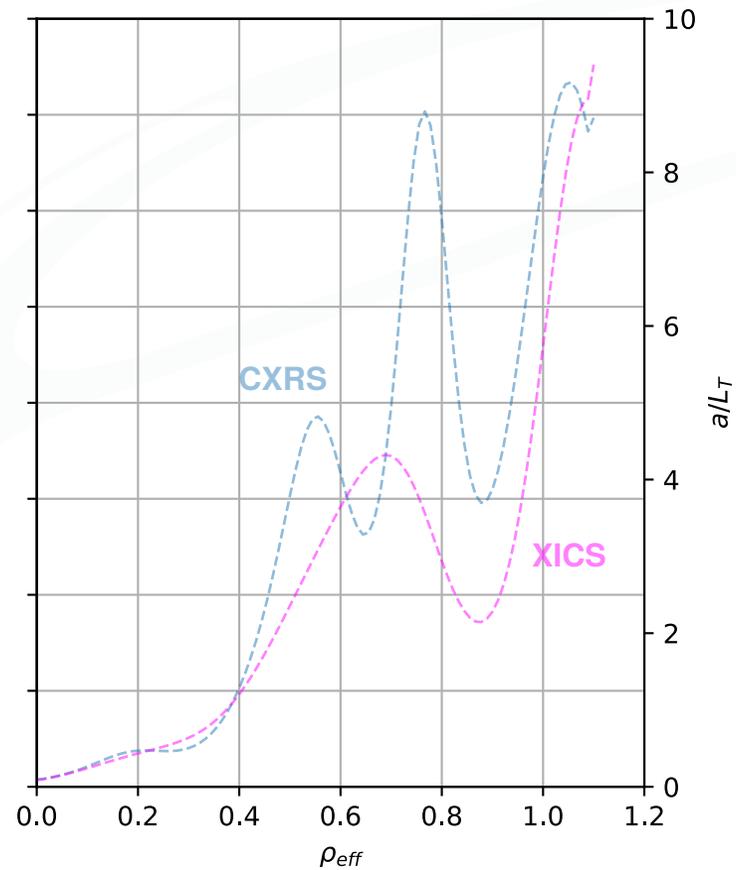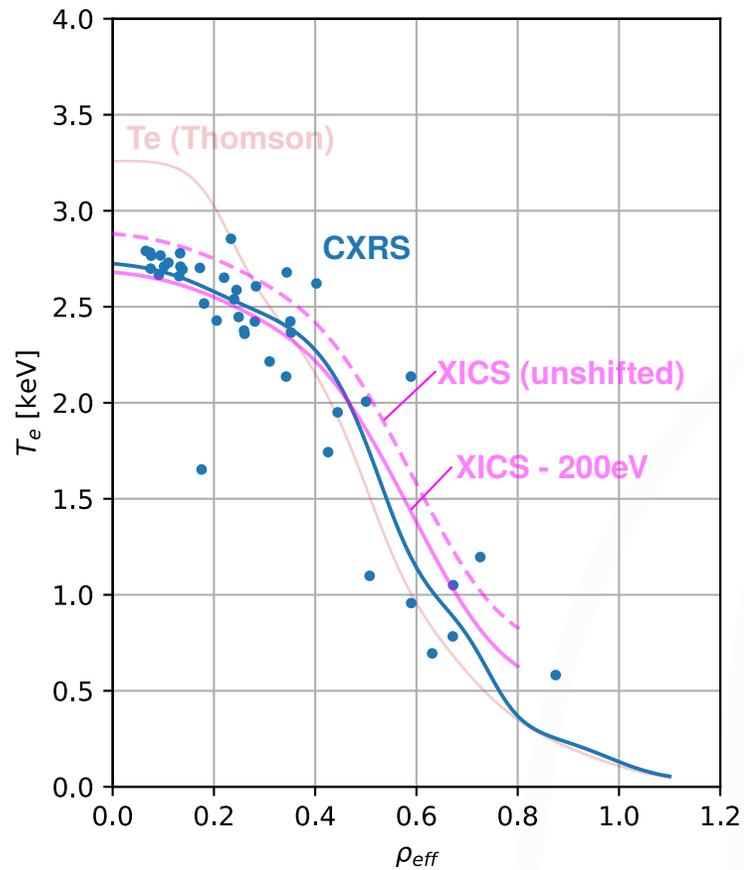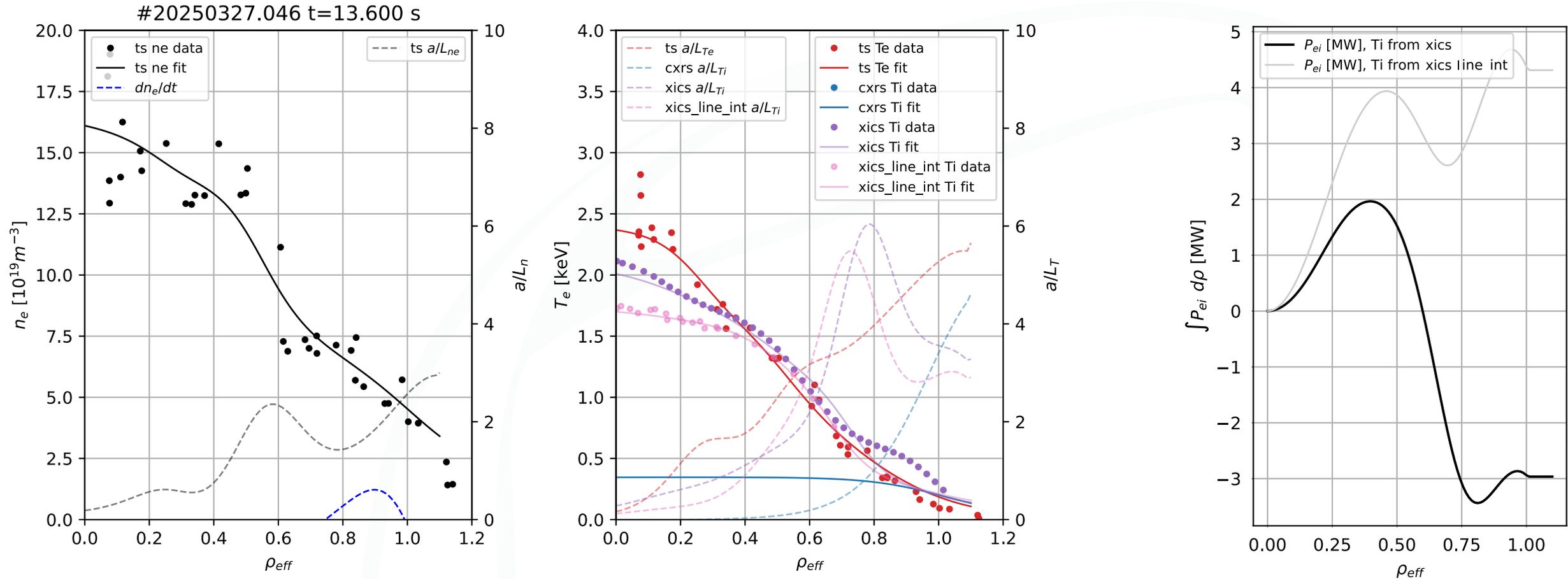Gradients are similar once XICS is corrected.
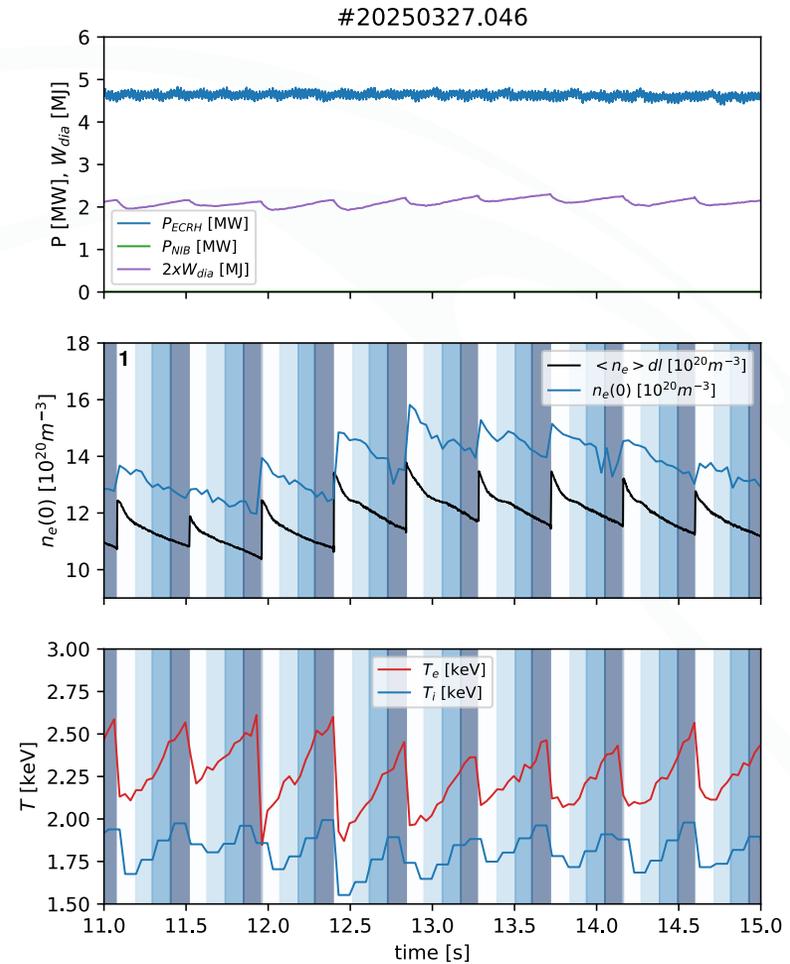
20250327.046 - Ion temperature

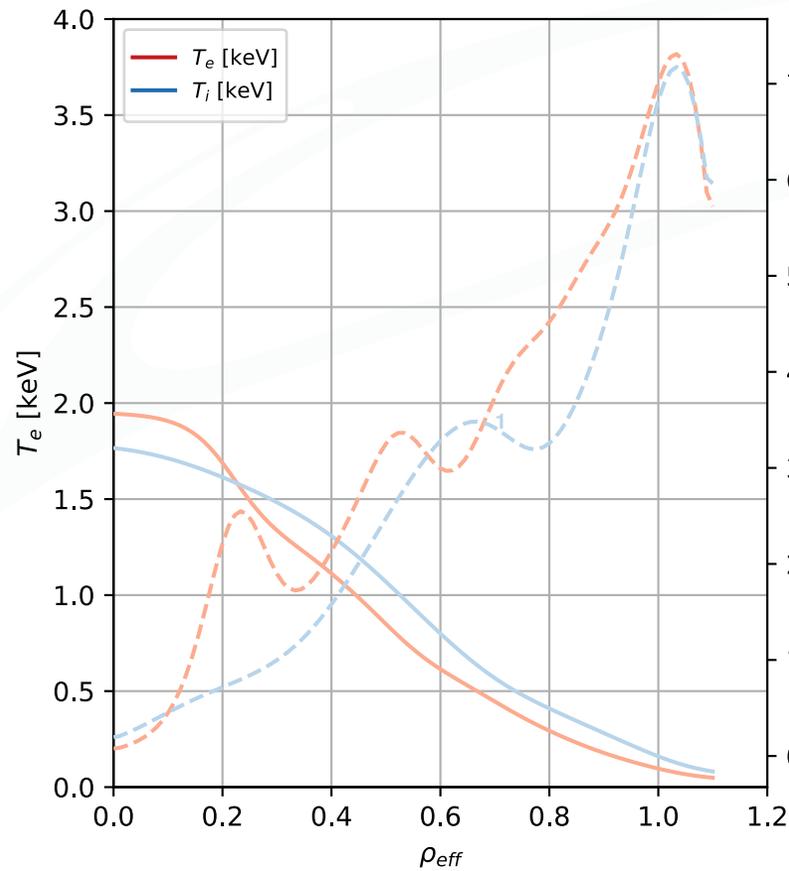Ion temperature only available from XICS during pellets phase (no NBI for CXRS).
XICS profiles probably give reasonable core T_i. Gradient region $T_i > T_e$ suggests transfer of power from ions back to electrons.
  --> implies **strongly** reduced Q_i. - Plausible but $T_i = T_e$ is within uncertainty.

Pellet cycle is relatively stable, and we can bin and average over time since last pellet for better profiles:

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20250327.046 - Pellet cycle

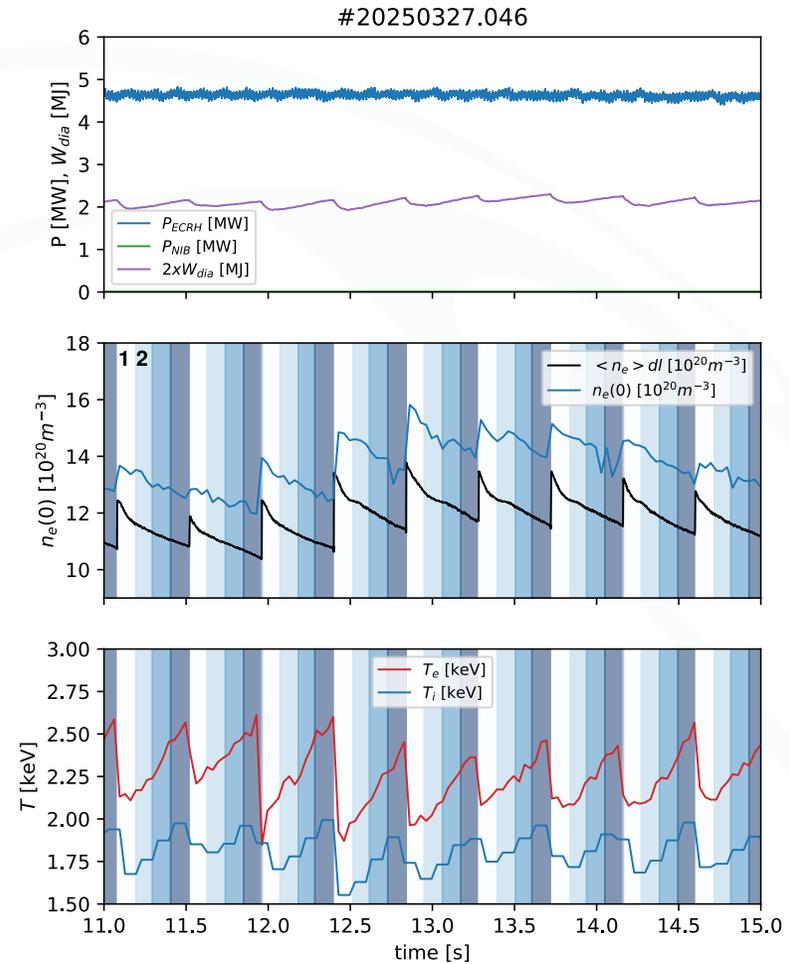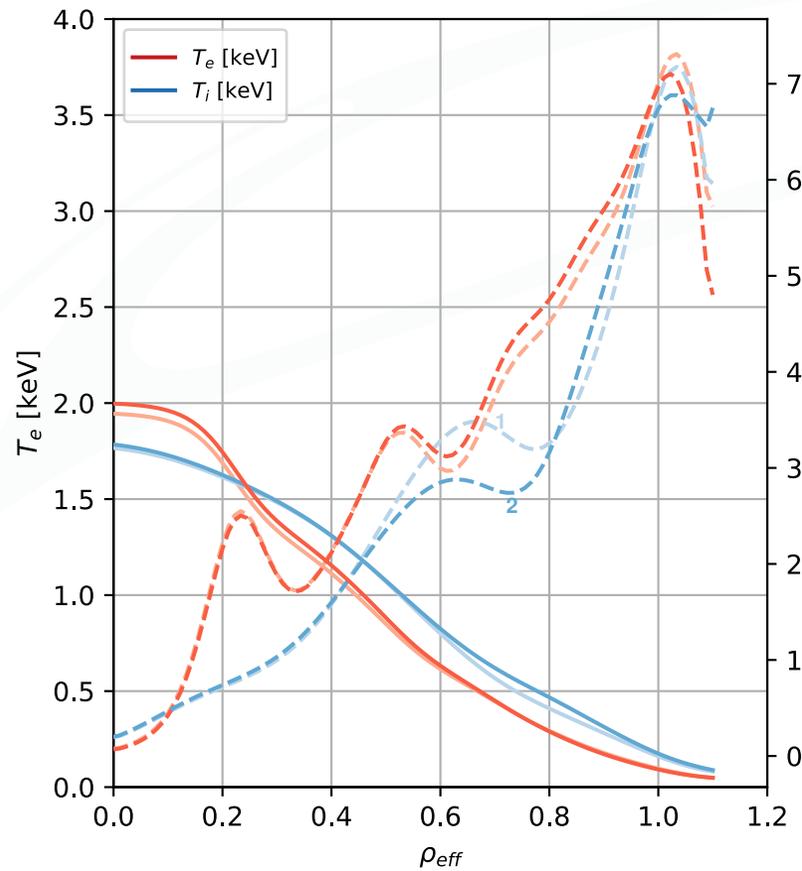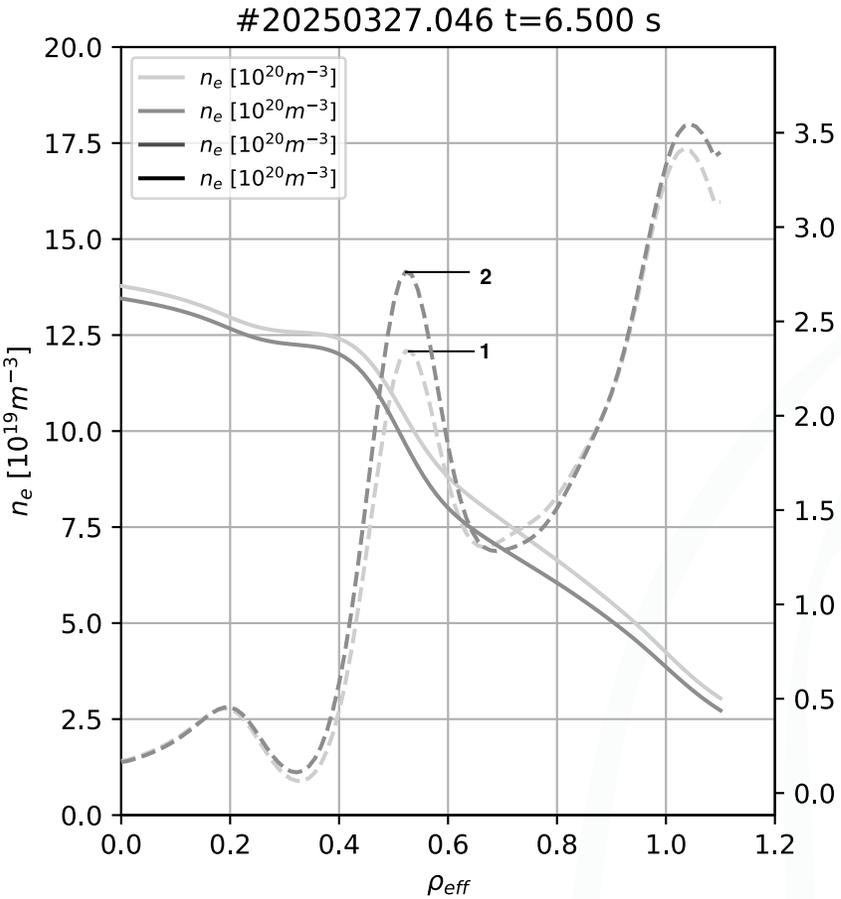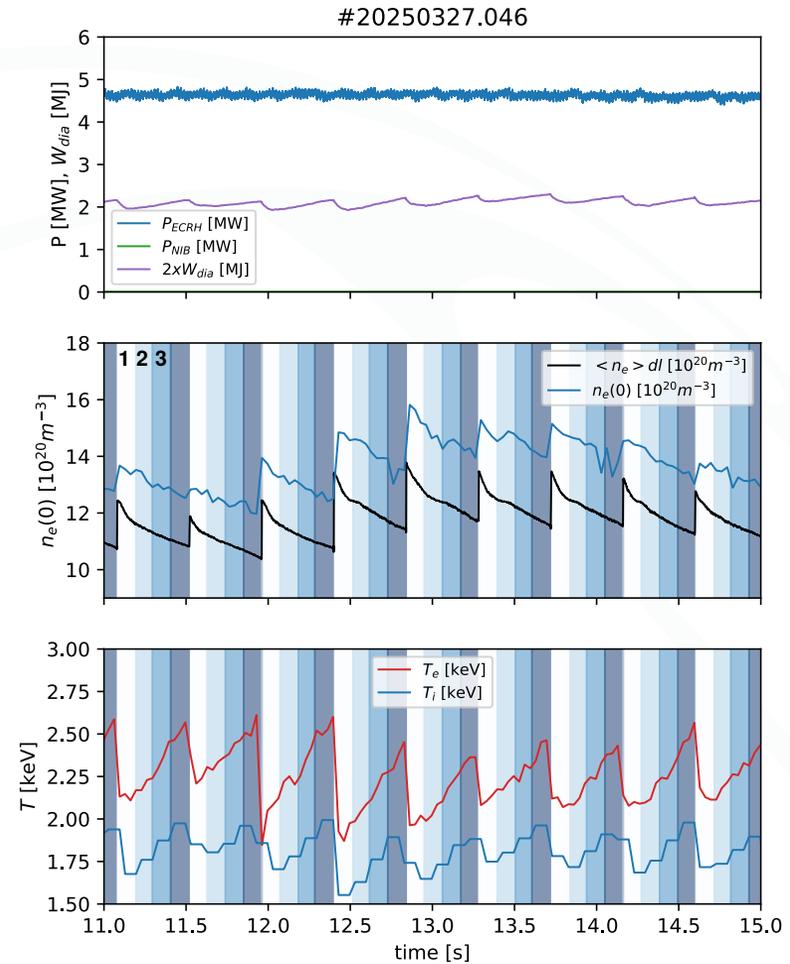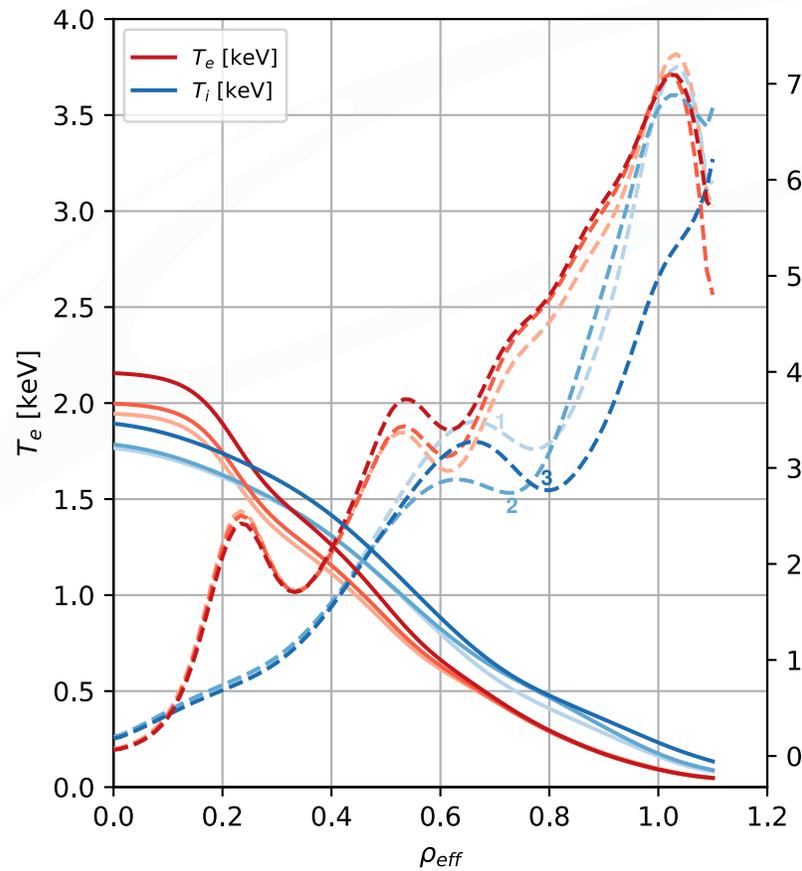Pellet cycle is relatively stable, and we can bin and average over time since last pellet for better profiles:

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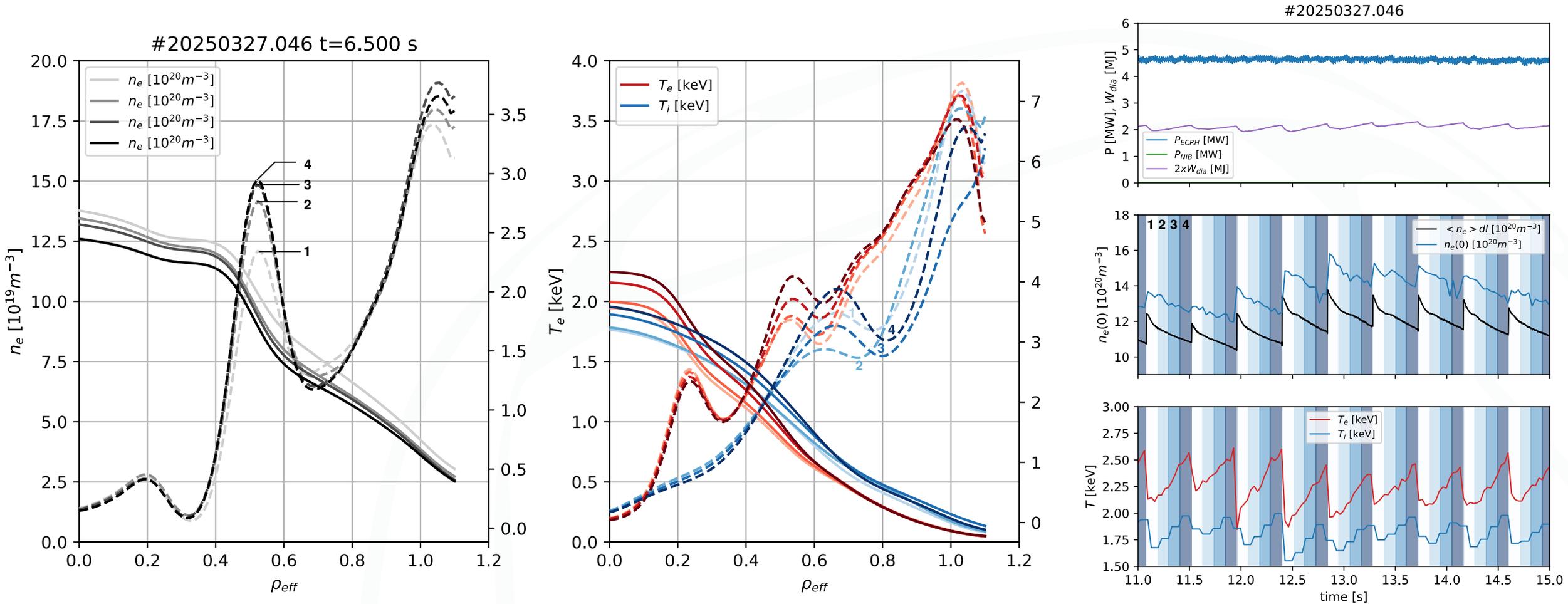
20250327.046 - Pellet cycle

The location of peak a/LTe and a/Lne coincide. Probably a/LTI would too if we had the diagnostic resolution.
If we average a wide enough radial region, we can see the dynamics of the high-gradient region in the gradient plane.
Note: The radial average reduces the magntiude of *a/L*. Also, remember that the **peak *a/Ln*** might be anywhere to the right!

Files / structure
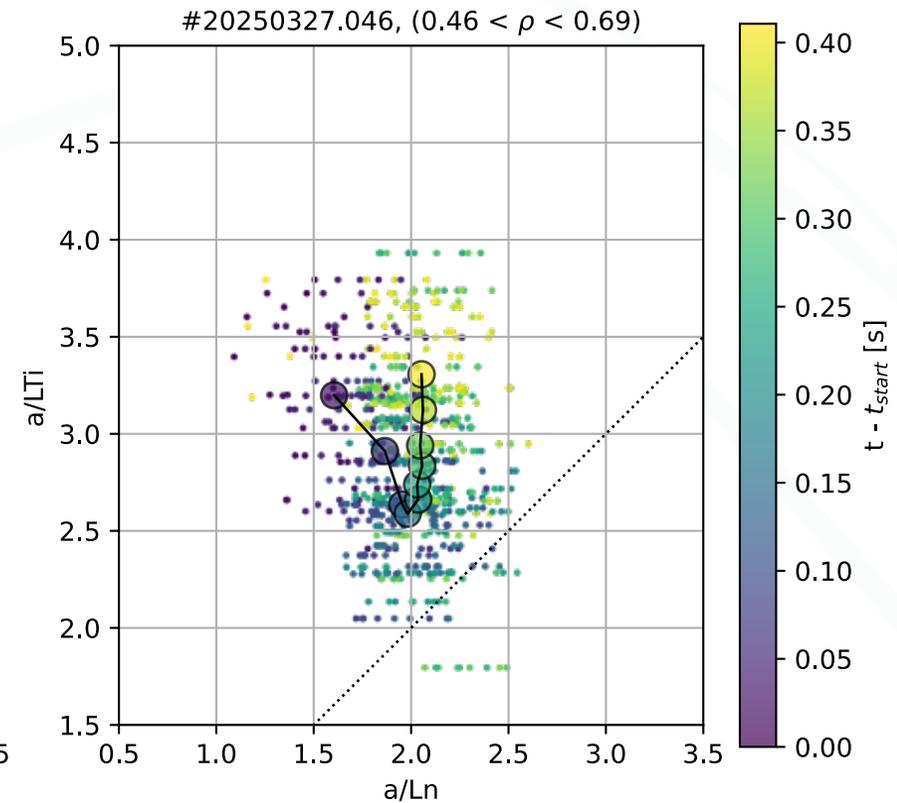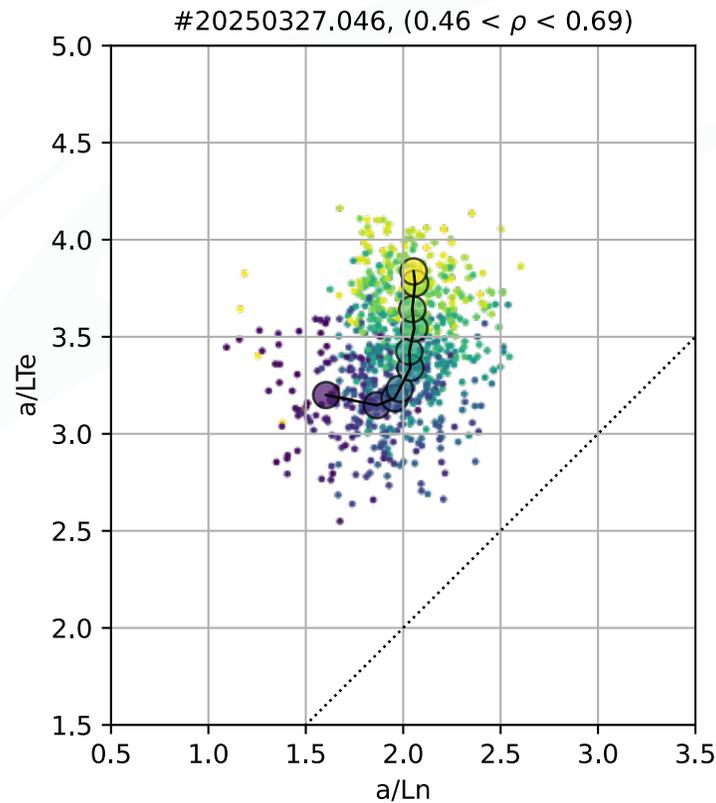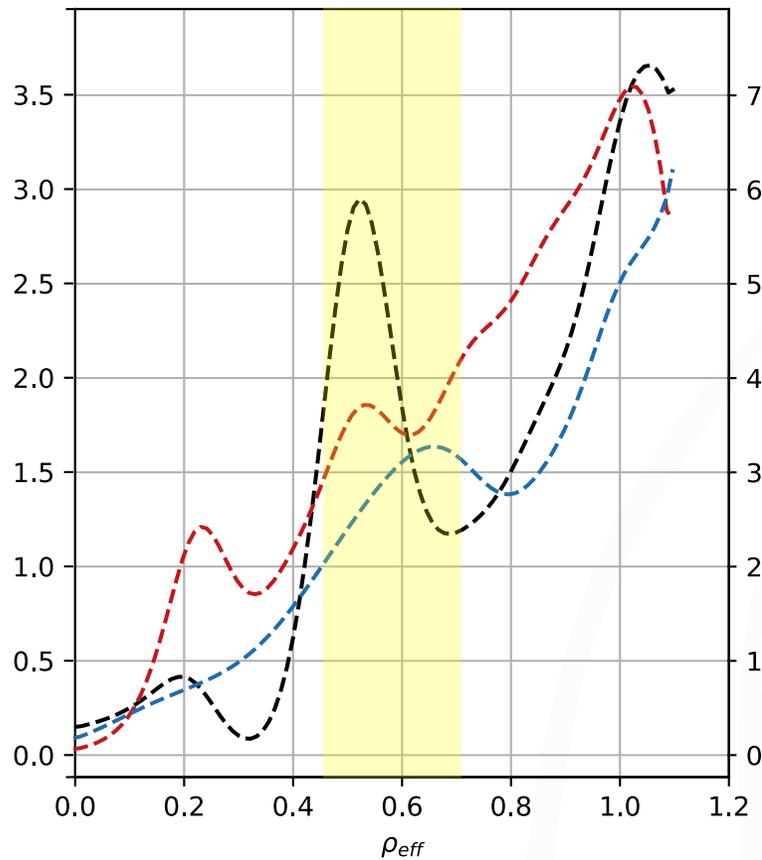
IPP TOK / Proxima: https://cloudstorage.ipp-hgw.mpg.de/f/1231037673
W7-X Team: https://cloudstorage.ipp-hgw.mpg.de/s/3T6eaDZbBHtFbqR (pass: w7x-team)

 ... but using profile cooker, w7xdia and your own fitting is highly encouraged!!

Directory structure is organised as:
 scenario / shot / ...

Files:
 selected.json - fitted profiles of named selected time points as mentioned in this presentation.
 fits.json - automatic fits of profiles at all Thomson Scattering time points
 raw_data.json - raw diagnostic data used to generate the fits
 cycle_binned.json - pellet cycle averaged fitted profiles
 xxxxx.wout - VMEC wout file (downloaded from VMEC web service)

Summary

Two pellets scenarios:
- Post-pellet:
  - Slow evolution of density with particle transport and no significant sources.
  - Redundant T_i data (two diagnostics).
  - Back-transition: Sudden change of heat transport with no external changes.
  - Strong reduction of heat transport localised at mid-radius.

- 'Steady-state' pellet injection
  - Repeated evolution, average steady state with 'continuous' particle source.

General comments on profile fitting:
- Absolute gradient values dependant on fitting settings (smoothing).
- Look at both XICS and CXRS T_i profiles for sense of uncertainty.
- Shift XICS by fixed offset to match T_e at edge.
- Calculate $\int P_{ei}\, d\rho$ to determine if T_e - T_i difference is plausible.