

Session Planning

OP2.4-SOII-37 : NBI+ECRH High Performance in high-iota

O. P. Ford, T. Gonda, V. Perseo, M. Kriete, A. Knieps

TF-I Session Planning 02.10.2026



Session Planning

OP2.4-SOII-37 : NBI+ECRH High Performance in high-iota

O. P. Ford, T. Gonda, V. Perseo, M. Kriete, A. Knieps

TF-I Session Planning 02.10.2026



Session Planning

OP2.4-SOII-37 : NBI+ECRH High Performance in high-iota (Mission impossible)

O. P. Ford, T. Gonda, V. Perseo, M. Kriete, A. Knieps

TF-I Session Planning 02.10.2026



Proposals



Priority 1:

Proposal	Title	Short	Conduct?
oliford_017	NBI+ECRH reintroduction - Broad scan of ECRH power for stable HP phase.	'Clean' scan P_ECRH reintro. All else fixed. Execute balanced case.	#1xx
tomag_006	High-Z Impurity flushing with ECRH in NBI+ECRH HP	LBO into stable best, with modulation.	#2xx
dacar_021	Access to increased triple product at low edge density scenarios	Repeat LDHP "after cleaning". Re-introduce NBI to lift. Add ECRH to control density.	#3xx

Proposals



Priority 1:

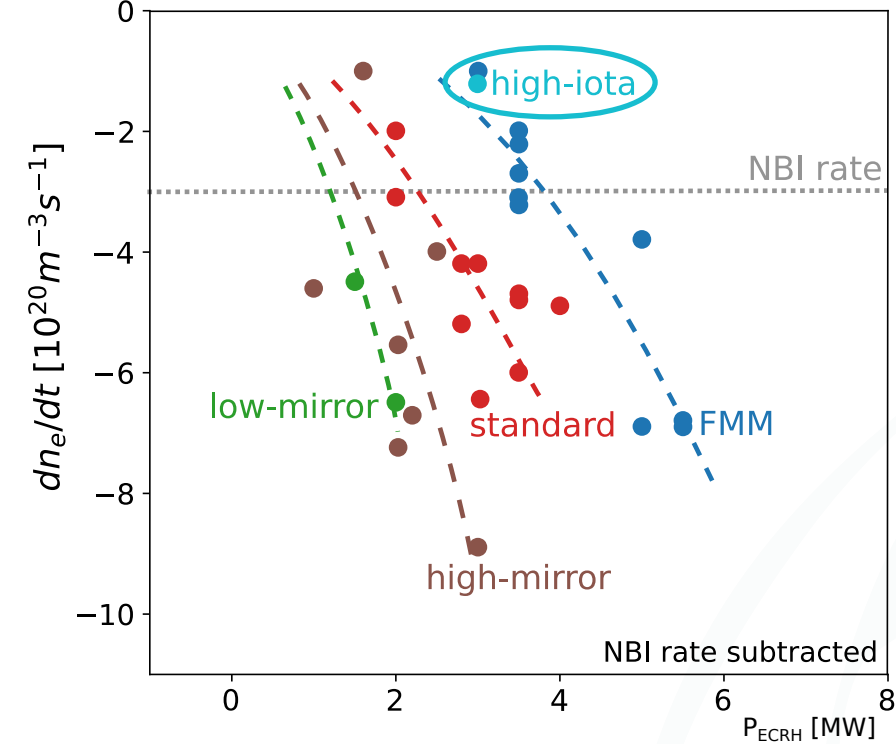
Proposal	Title	Short	Conduct?
oliford_017	NBI+ECRH reintroduction - Broad scan of ECRH power for stable HP phase.	'Clean' scan P_ECRH reintro. All else fixed. Execute balanced case.	#1xx
tomag_006	High-Z Impurity flushing with ECRH in NBI+ECRH HP	LBO into stable best, with modulation.	#2xx
dacar_021	Access to increased triple product at low edge density scenarios	Repeat LDHP "after cleaning". Re-introduce NBI to lift. Add ECRH to control density.	#3xx

Priority 2:

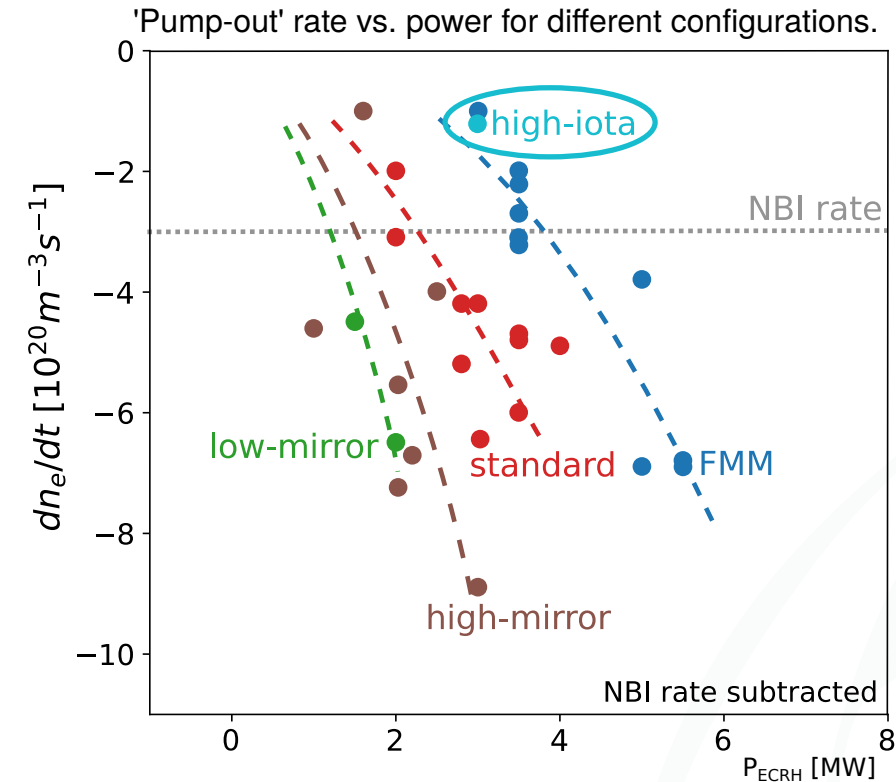
akraemer_018	Understand improved confinement at low power and peaked density	Repeat LDHP in FTM.	auto #3xx
anla_031	Stationary Density Peaking with Feedback Controlled ECRH+NBI	P_ECRH control, extend to 10/20s.	maybe #200
anla_032	Impact of Impurities in Feedback Controlled ECRH+NBI High Performance Scenarios	Inject Fe, W, Ti into above	auto #2xx
caki_044	Piggyback fast ion loss measurements with MPM floating probes	Piggyback anything NBI	no probe?
vamu_005	power deposition studies during steady state high performance discharges	Modulate P_ECRH at end of stead-state HP with stable ne.	try in #130
gawe_049	A comparison of HP scenario characteristics of W7-X with the high-density ITB on Heliotron J	Complex. Balanced beams using both boxes, He!?	
jadel_008	CXRS flow measurements in NBI-ECRH reintroduction	Cross NI20 / NI21 drive and blips for flow measurements.	med prior #400
pepo_011	Exploring fast ion confinement in ECH reintroduction discharges with FIDA	Reintro with switching NI20/NI21 in 100ms cycles. Good also for jadel_008???	med prio #400
mzan_018	O-mode Co- and Counter-ECCD in high performance scenarios for stabilisation/destabilisation of	Repeat FTM hybrid with co/counter O2	low prio #420
stato_039	Reintroduction of medium power ECRH into peaked NBI-fueled high density plasmas with maximized Co- and Counter-ECCD to study the general effect of central iota-changes	Seems synergetic with mzan_018, but not sure.	low prio #420
oliford_016	Particle source scan in pure NBI	Fine NBI source scan pure NBI.	low prio #430
oliford_020	Early NBI +ECRH reintroduction for HP improvement with lower edge density.	Early NBI. Repeat from oliford_017 early.	low prio #440
stato_045	Variation of ECRH power deposition into peaked NBI-fueled high density plasmas to study the ef	Reintro with off-axis ECRH	
sban_005	Particle transport in high performance discharges	Finer scan of oliford_017	No, #1xx only
sban_007	Triggering particle confinement transition with NBI + low ECRH	Repeat one case from combined NBI+ECRH	low prio #450
ksena_020	Benchmarking SOL drift physics in W7-X: a reference dataset for JOEUK stellarator modelling	EIM, "one high-beta scenario". "plasma current kept the same"... nope.	piggy-back

oliford_017: Complete the scan of dn/dt vs P_{ECRH} .

'Pump-out' rate vs. power for different configurations.

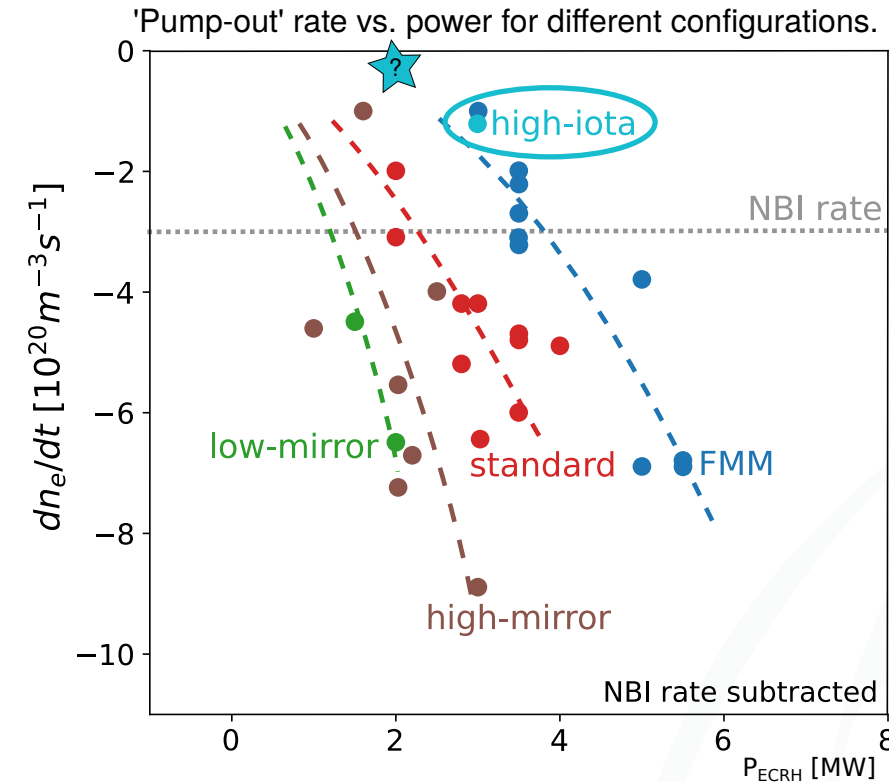


oliford_017: Complete the scan of dn/dt vs P_{ECRH} .



- Scan P_{ECRH} from definitely too weak to too strong pump-out.
- Database is chaotic - other parameters were changed.
 - we need a clean scan of transport changes.
 - > prefer not mixed with pellets.
- Only 1 attempt in high-iota. We expect FMM-like behaviour so need higher powers: 2, 4, 6MW O2.

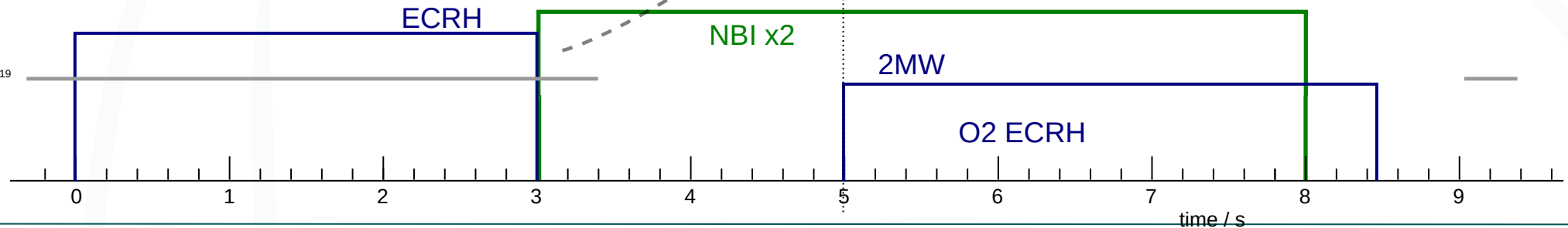
oliford_017: Complete the scan of dn/dt vs P_{ECRH} .



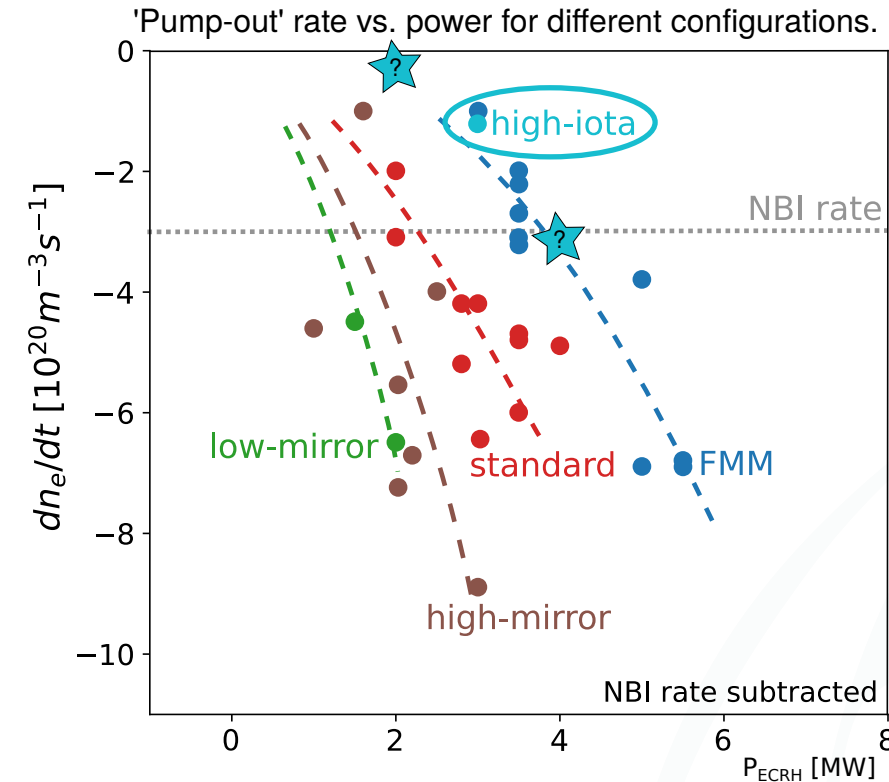
- Scan P_{ECRH} from definitely too weak to too strong pump-out.
- Database is chaotic - other parameters were changed.
 - we need a clean scan of transport changes.
 - > prefer not mixed with pellets.
- Only 1 attempt in high-iota. We expect FMM-like behaviour so need higher powers: 2, 4, 6MW O2.

ID #1xx:

8×10^{19}



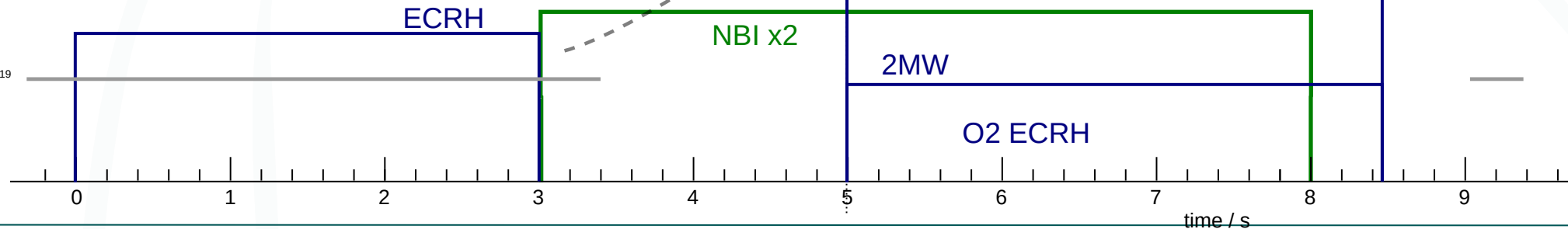
oliford_017: Complete the scan of dn/dt vs P_{ECRH} .



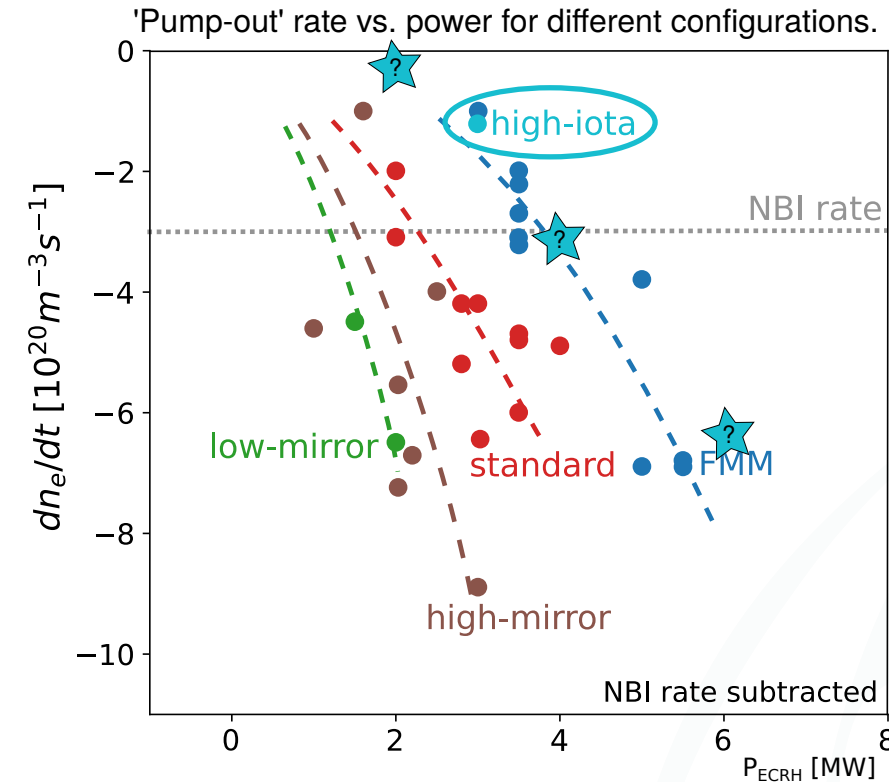
- Scan P_{ECRH} from definitely too weak to too strong pump-out.
- Database is chaotic - other parameters were changed.
 - we need a clean scan of transport changes.
 - > prefer not mixed with pellets.
- Only 1 attempt in high-iota. We expect FMM-like behaviour so need higher powers: 2, 4, 6MW O2.

ID #1xx:

8×10^{19}



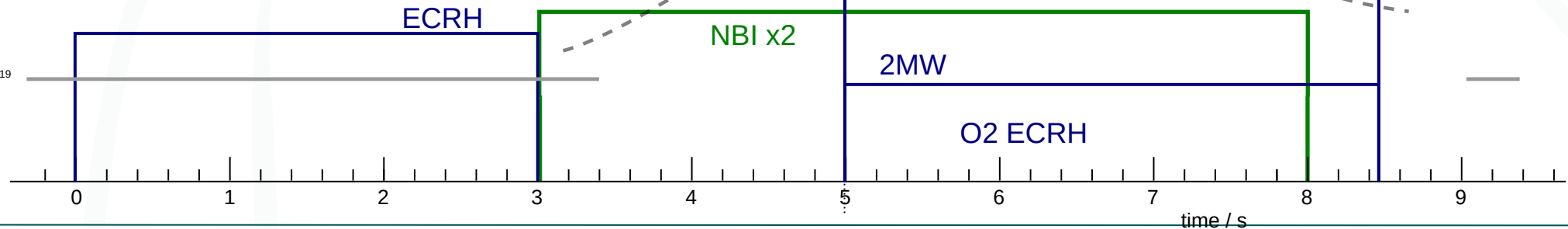
oliford_017: Complete the scan of dn/dt vs P_{ECRH} .



- Scan P_{ECRH} from definitely too weak to too strong pump-out.
- Database is chaotic - other parameters were changed.
 - we need a clean scan of transport changes.
 - > prefer not mixed with pellets.
- Only 1 attempt in high-iota. We expect FMM-like behaviour so need higher powers: 2, 4, 6MW O2.

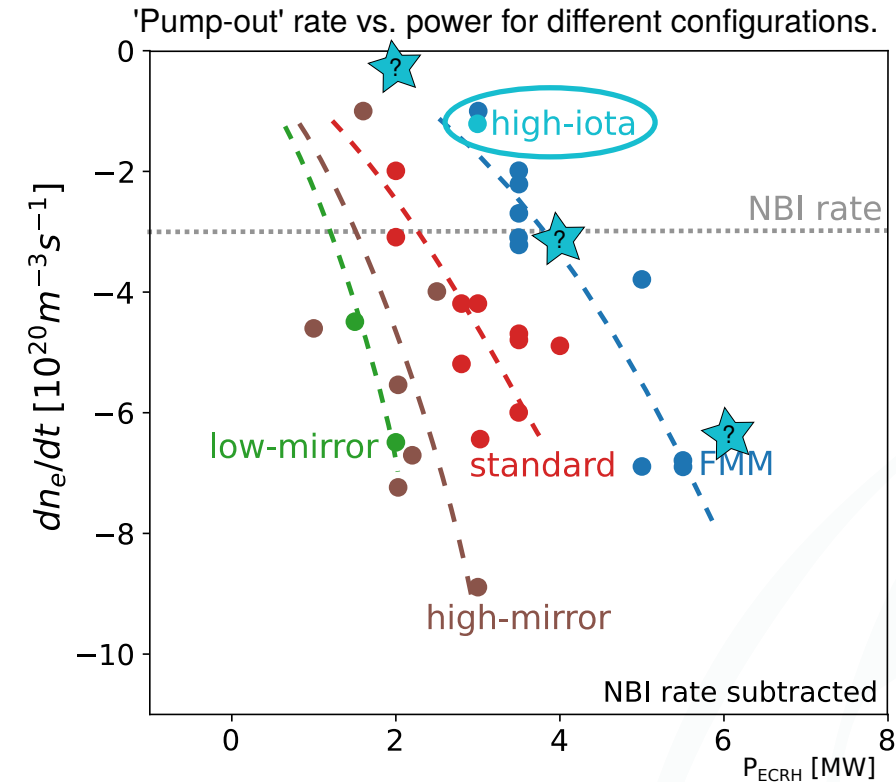
ID #1xx:

8×10^{19}

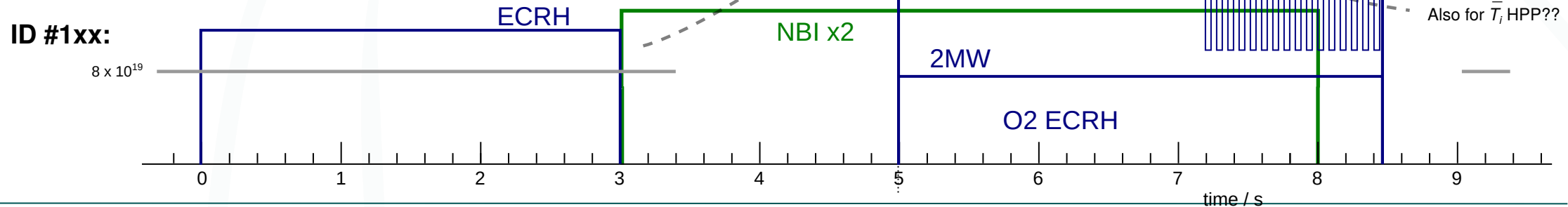


oliford_017, tomag_006

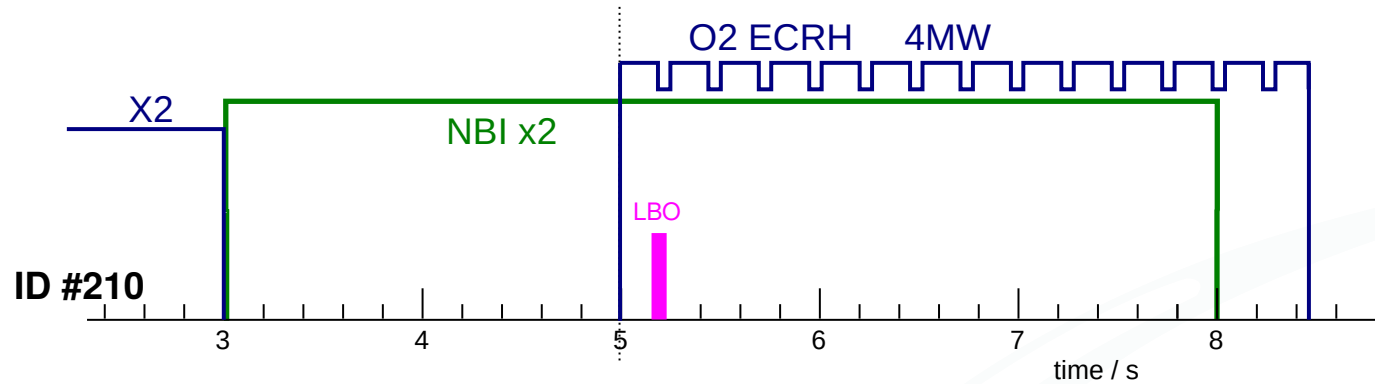
oliford_017: Complete the scan of dn/dt vs P_{ECRH} .



- Scan P_{ECRH} from definitely too weak to too strong pump-out.
- Database is chaotic - other parameters were changed.
 - we need a clean scan of transport changes.
 - > prefer not mixed with pellets.
- Only 1 attempt in high-iota. We expect FMM-like behaviour so need higher powers: 2, 4, 6MW O2.



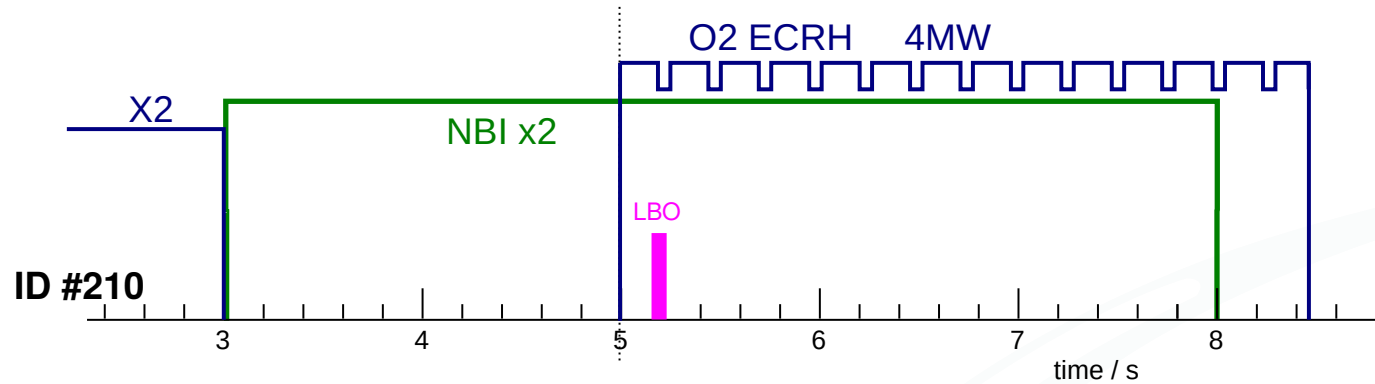
tomag_006: Repeat $\sim$ stable n_e and add LBO for high-Z transport. Modulate O2 to show pump-out.



Particularly requires $T_{e/i} > 2.1\text{keV}$ ---> FTM

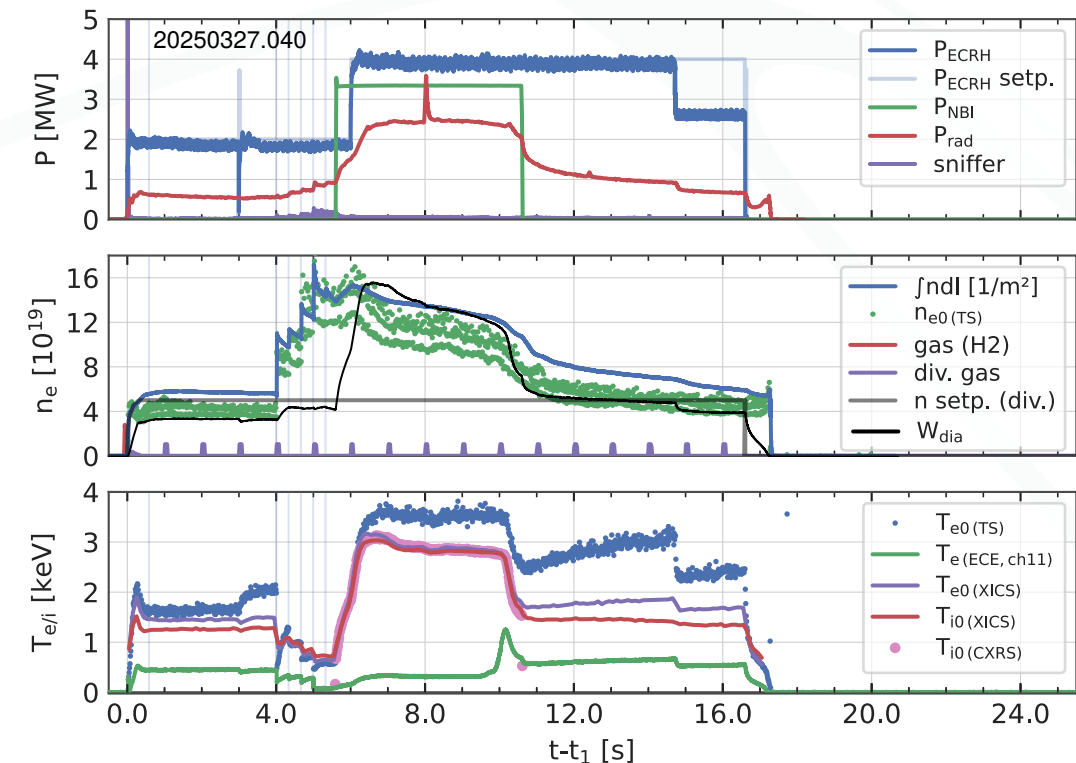
oliford_017, tomag_006

tomag_006: Repeat $\sim$ stable n_e and add LBO for high-Z transport. Modulate O2 to show pump-out.



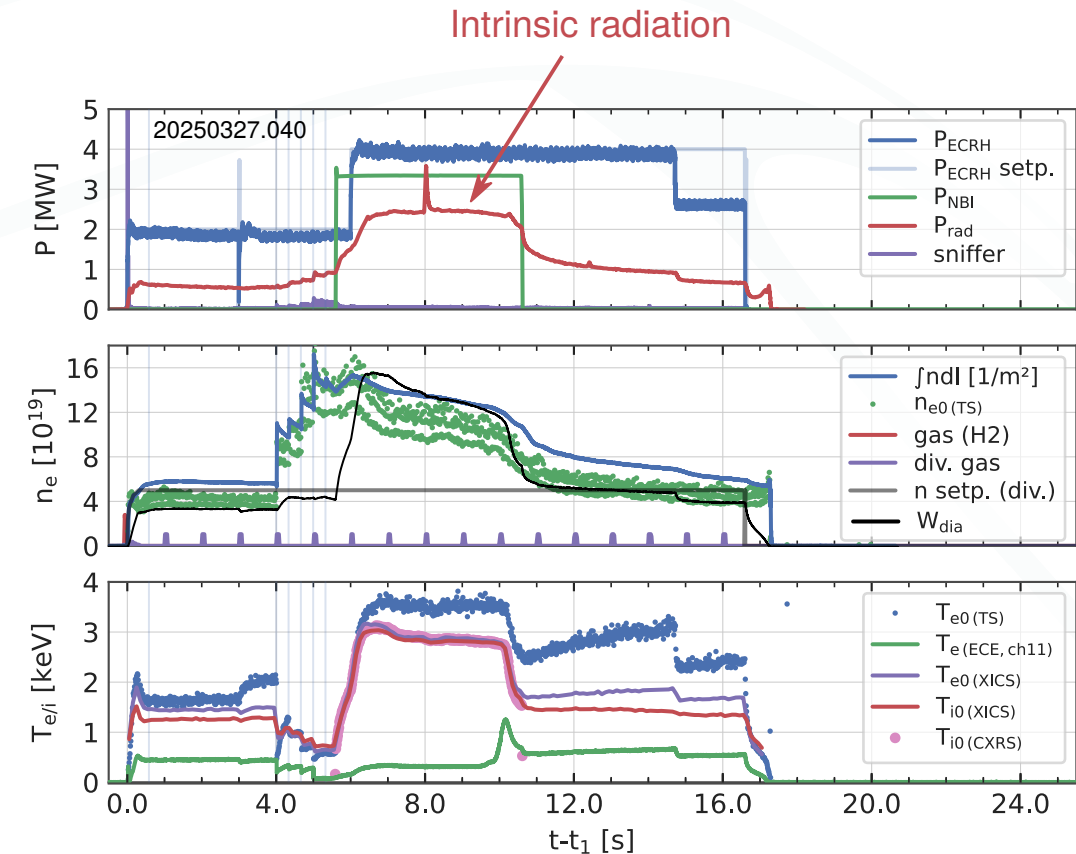
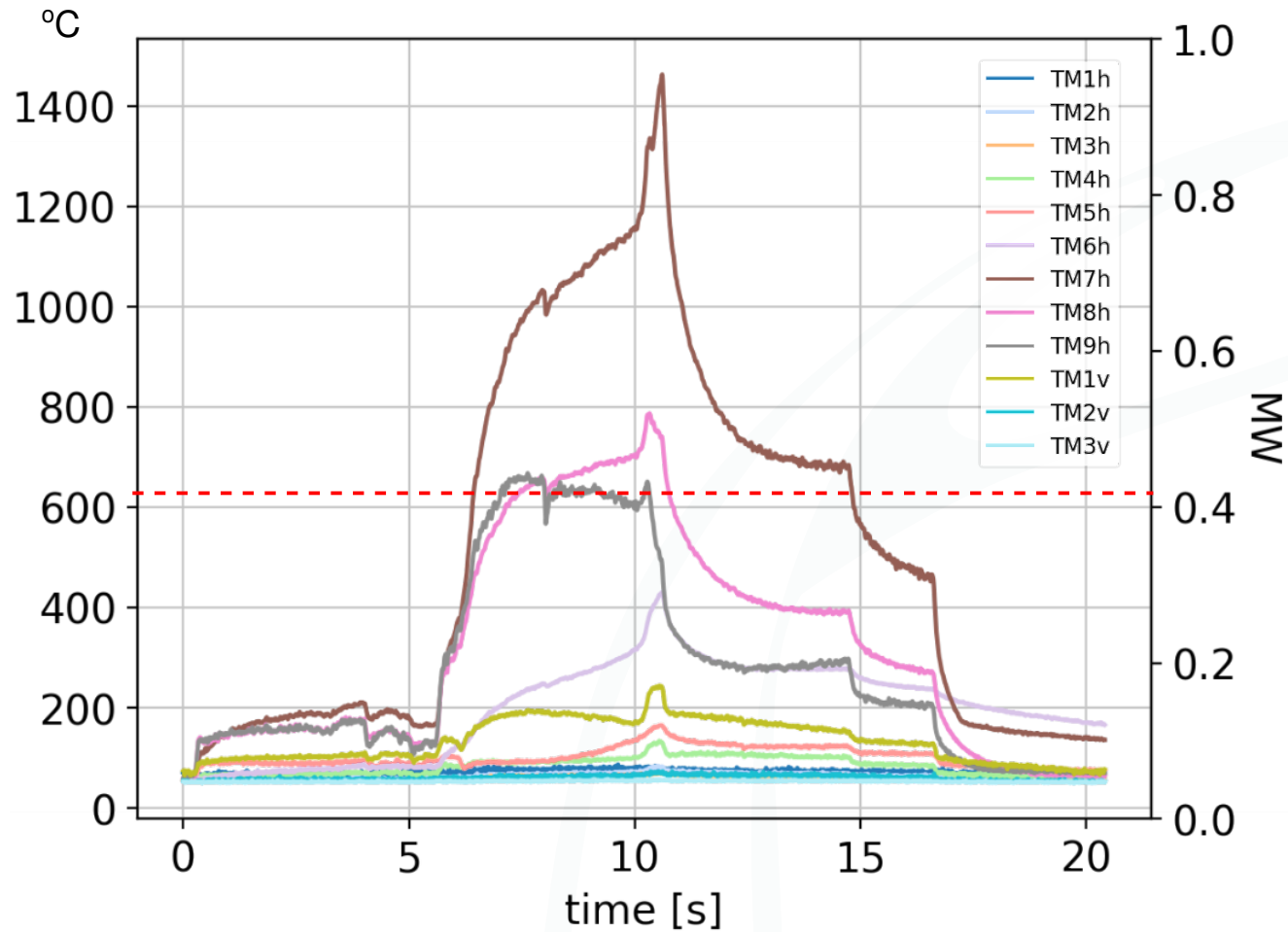
Particularly requires $T_{e/i} > 2.1\text{keV}$ ---> FTM

Best possible is repeat of hybrid pellet+NBI peaking:
Requires pellets, less predictable.



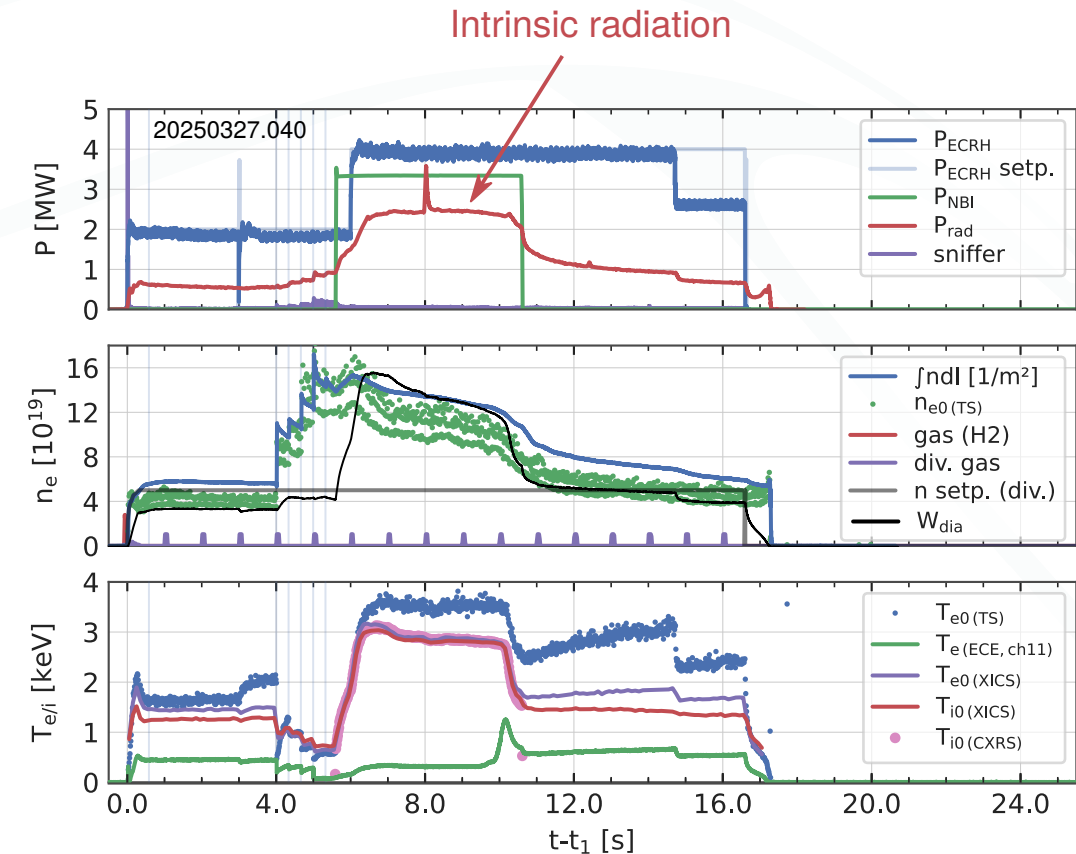
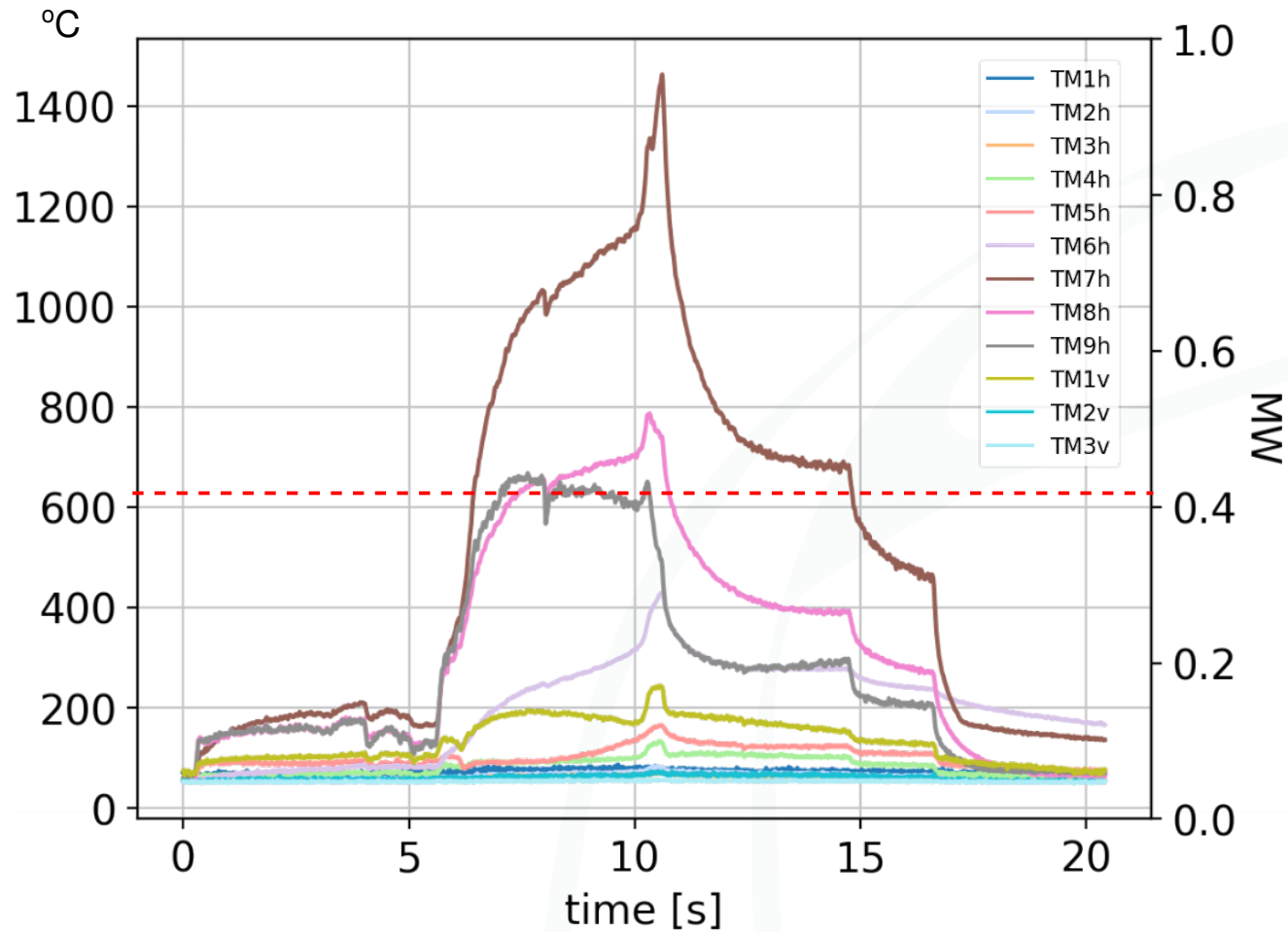
Heat loads

For both, usable programs are all at/above tolerable heat loads to TM7h (even then, limit now is lower):



Heat loads

For both, usable programs are all at/above tolerable heat loads to TM7h (even then, limit now is lower):

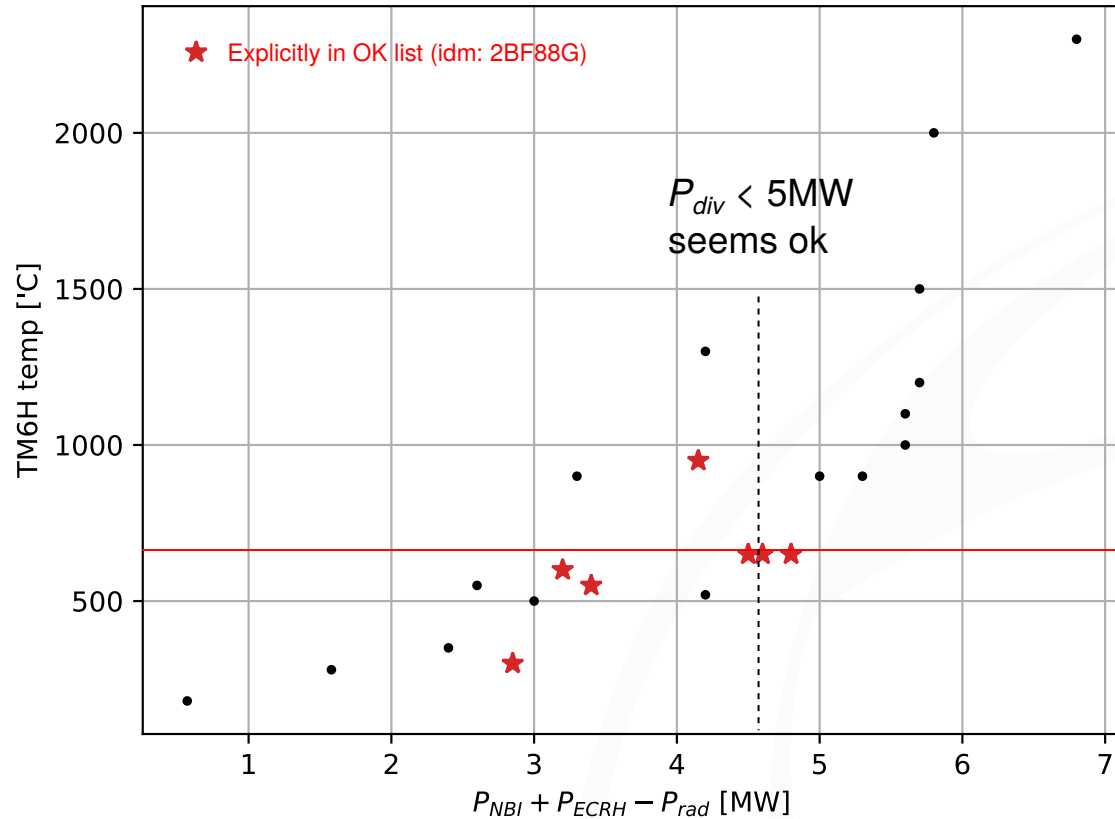


Heat loads

Selection of similar shots (mostly HP) from OP2.2/2.3:

Full juice DB: [V. Perseo]

- Similar but n_e plays strong role

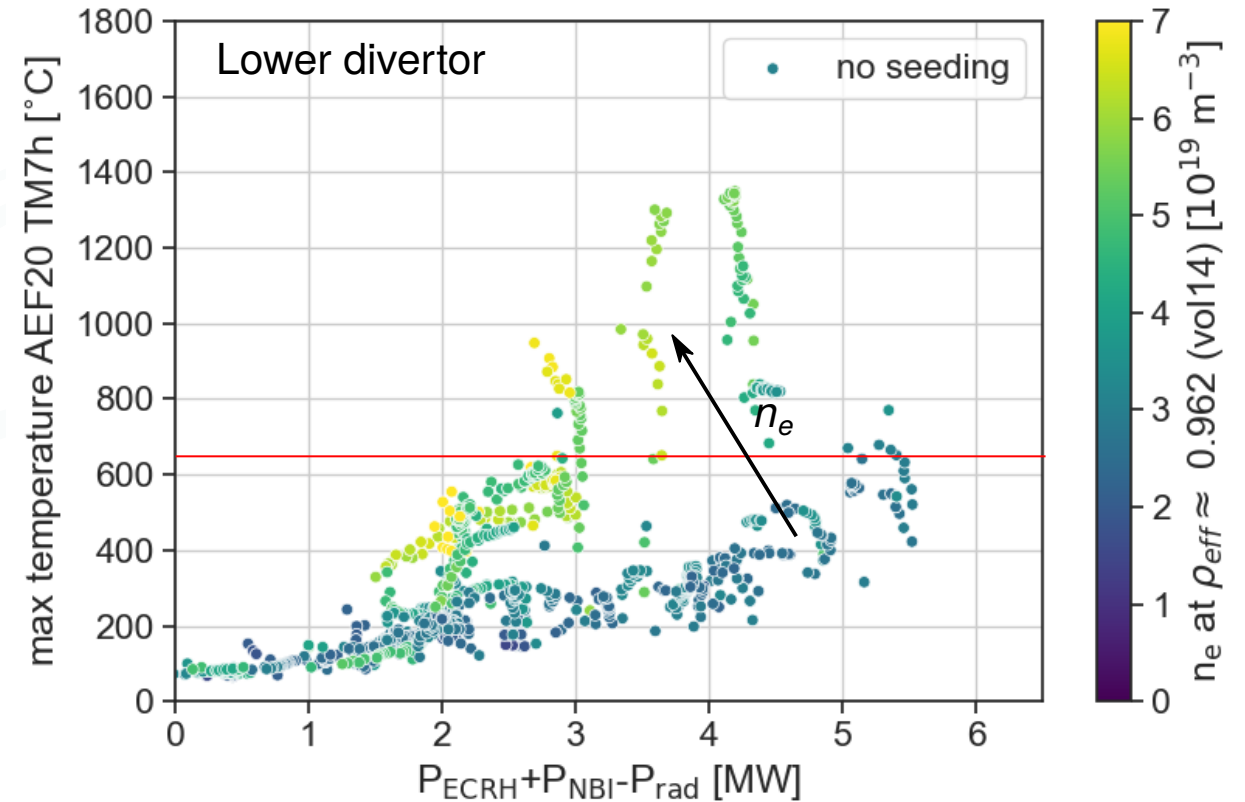
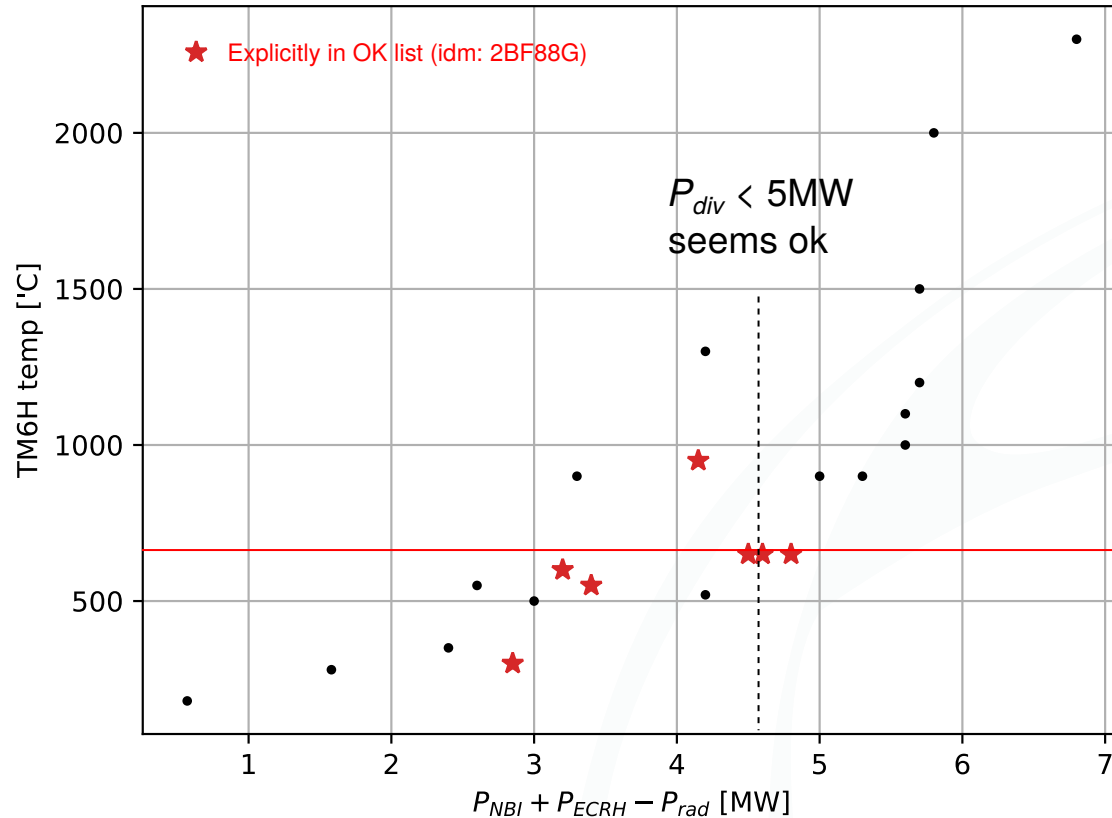


Heat loads

Selection of similar shots (mostly HP) from OP2.2/2.3:

Full juice DB: [V. Perseo]

- Similar but n_e plays strong role

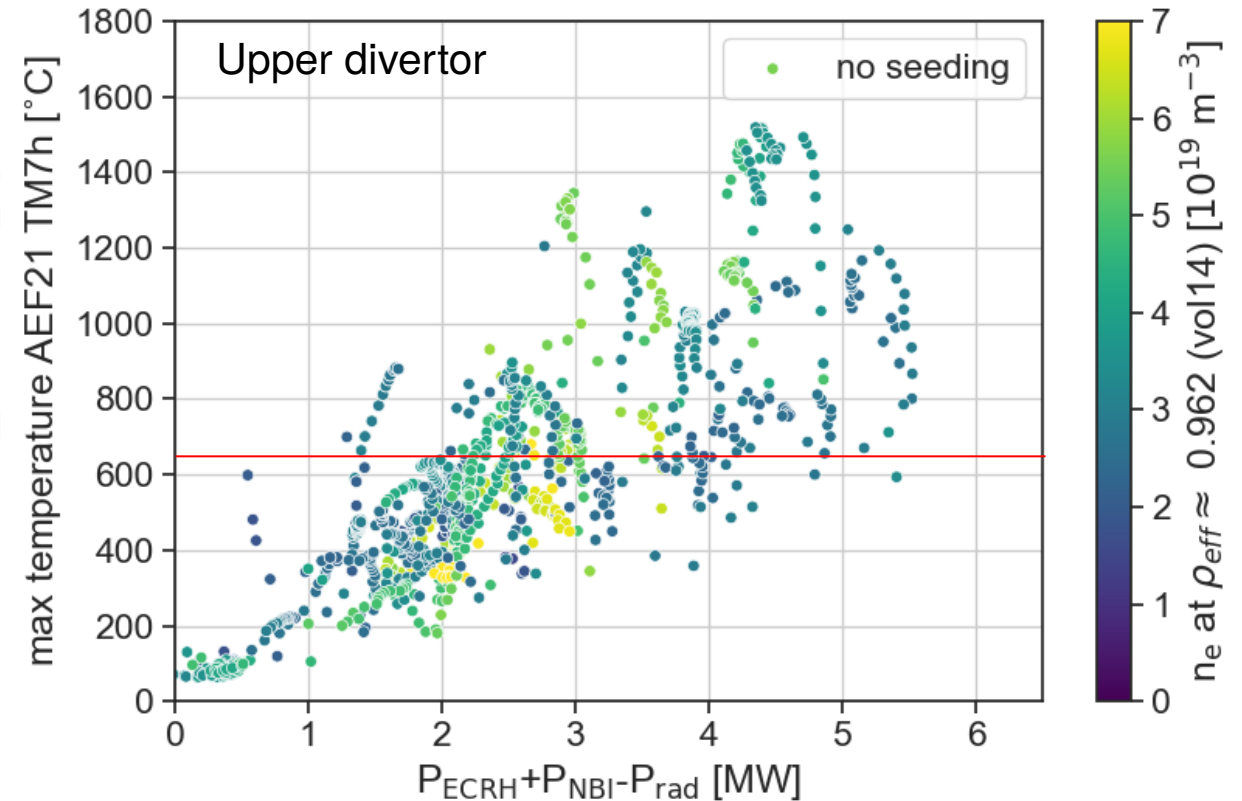
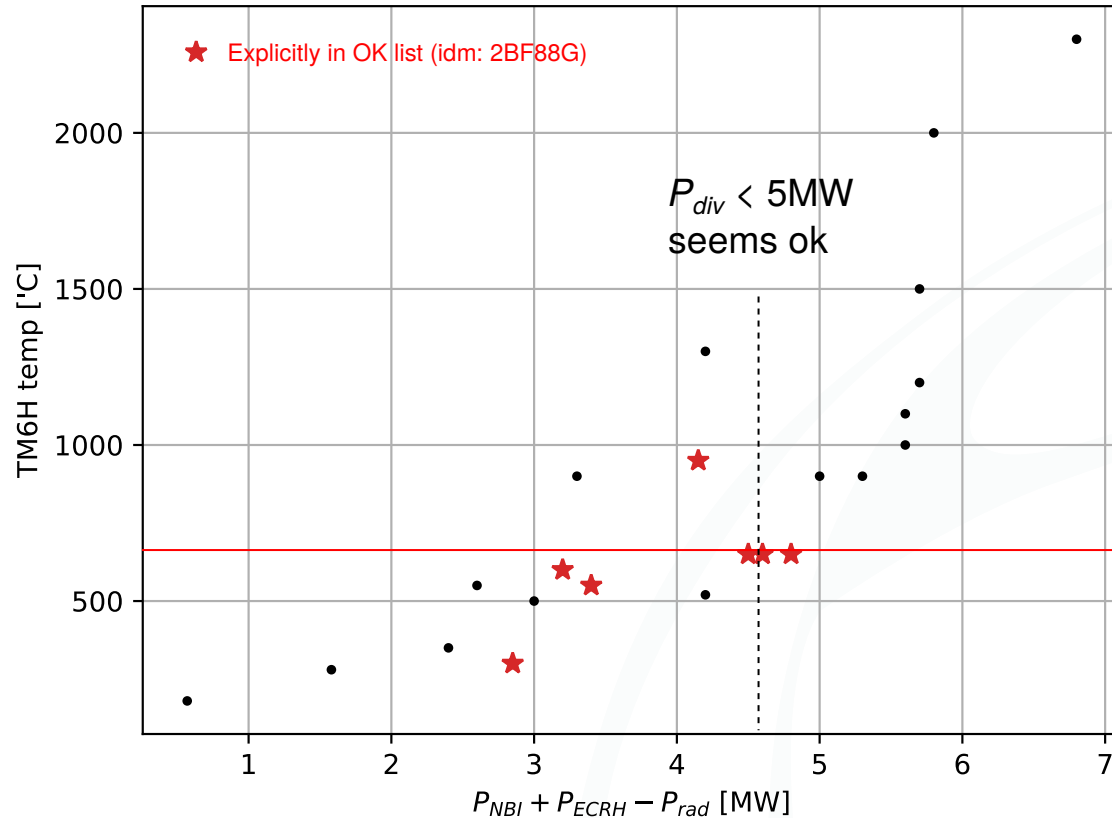


Heat loads

Selection of similar shots (mostly HP) from OP2.2/2.3:

Full juice DB: [V. Perseo]

- Similar but n_e plays strong role

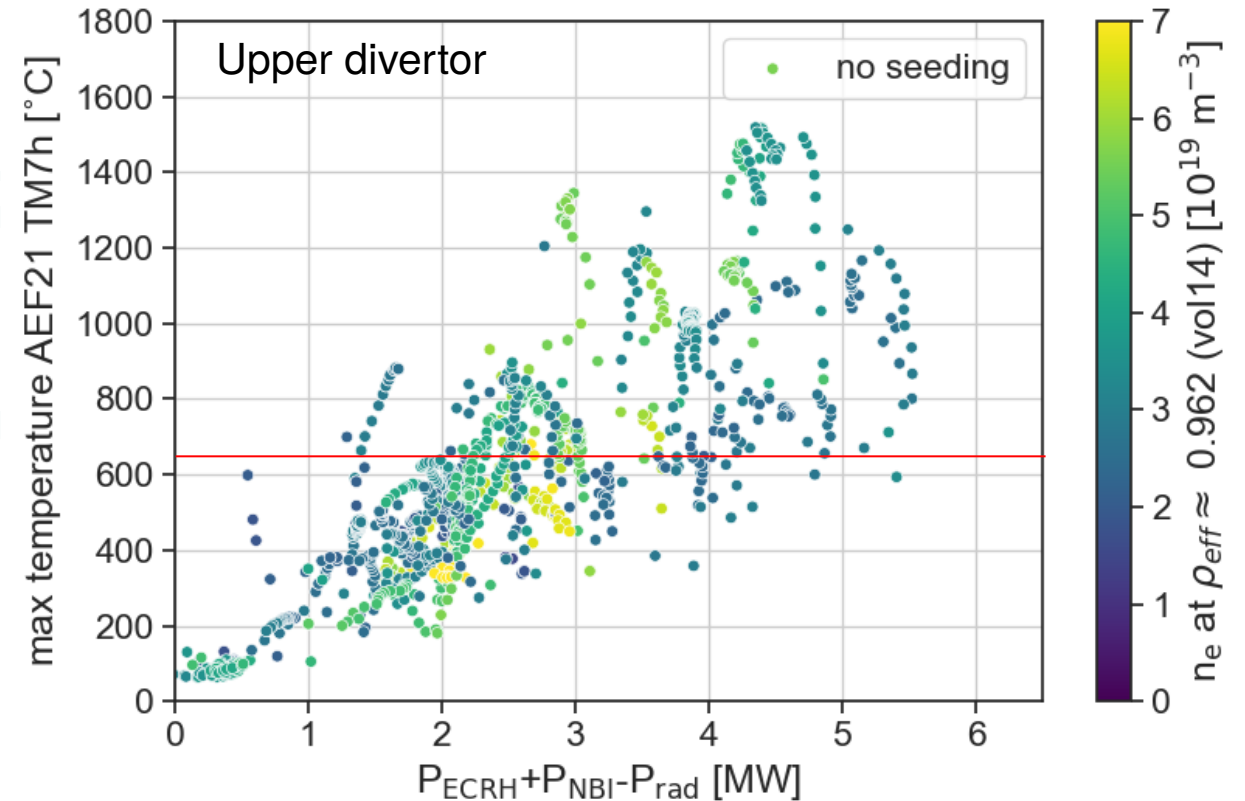
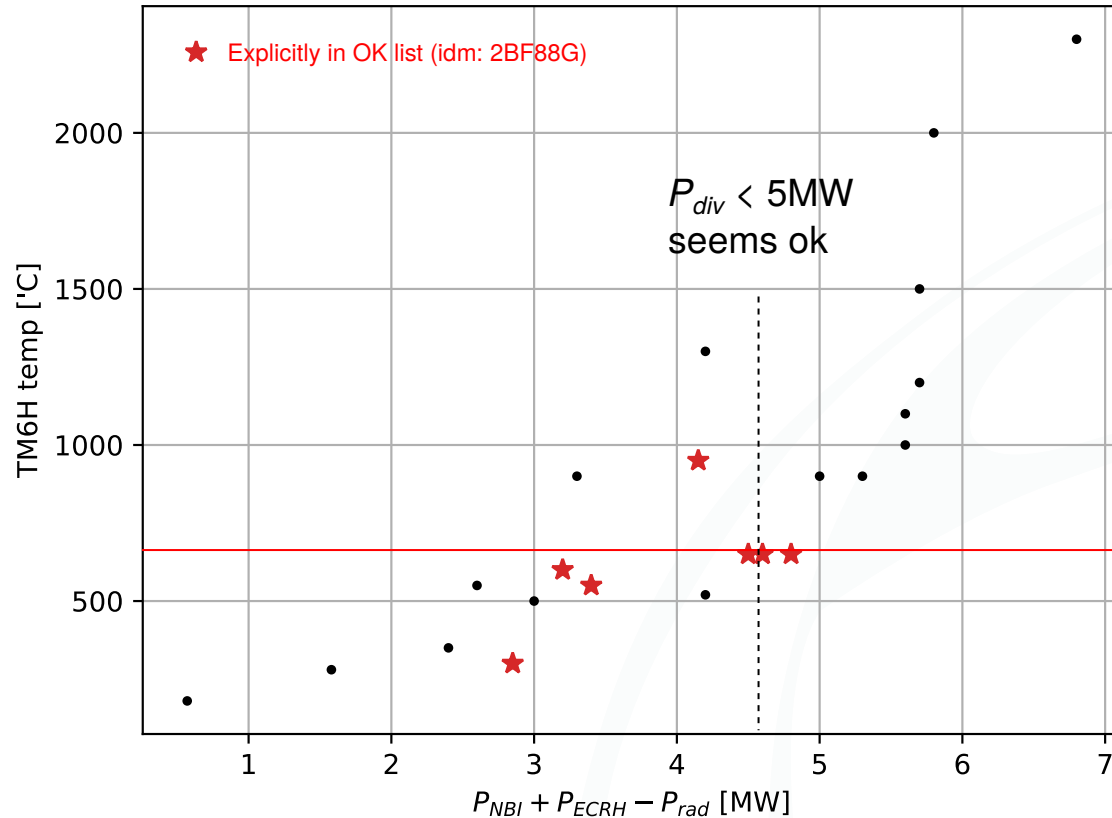


Heat loads

Selection of similar shots (mostly HP) from OP2.2/2.3:

Full juice DB: [V. Perseo]

- Similar but n_e plays strong role

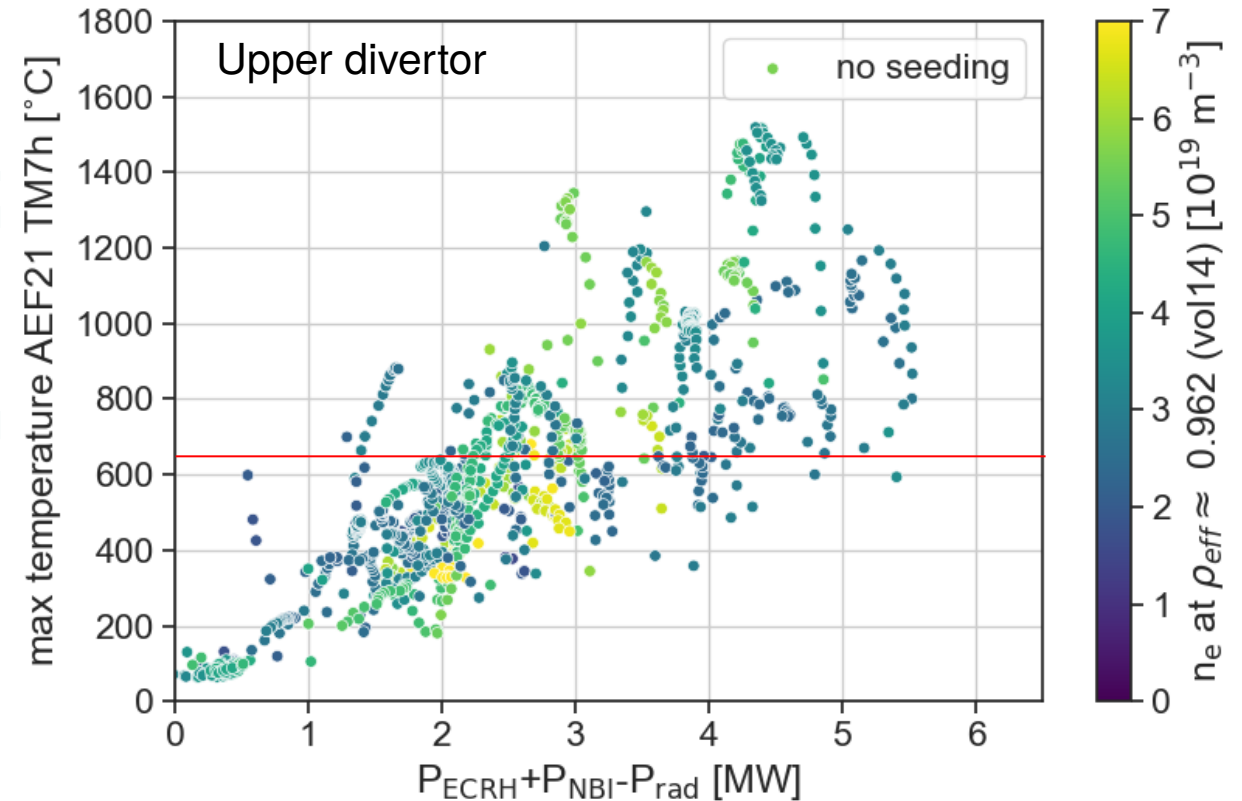
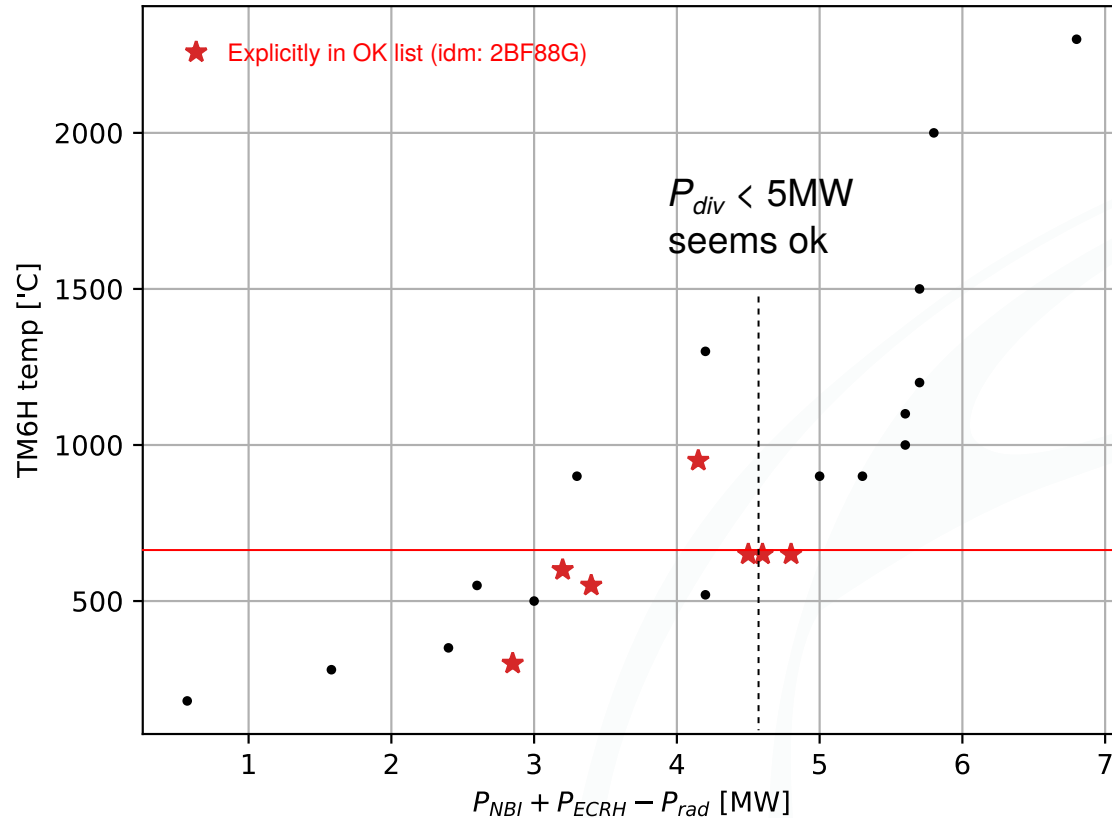


Heat loads

Selection of similar shots (mostly HP) from OP2.2/2.3:

Full juice DB: [V. Perseo]

- Similar but n_e plays strong role

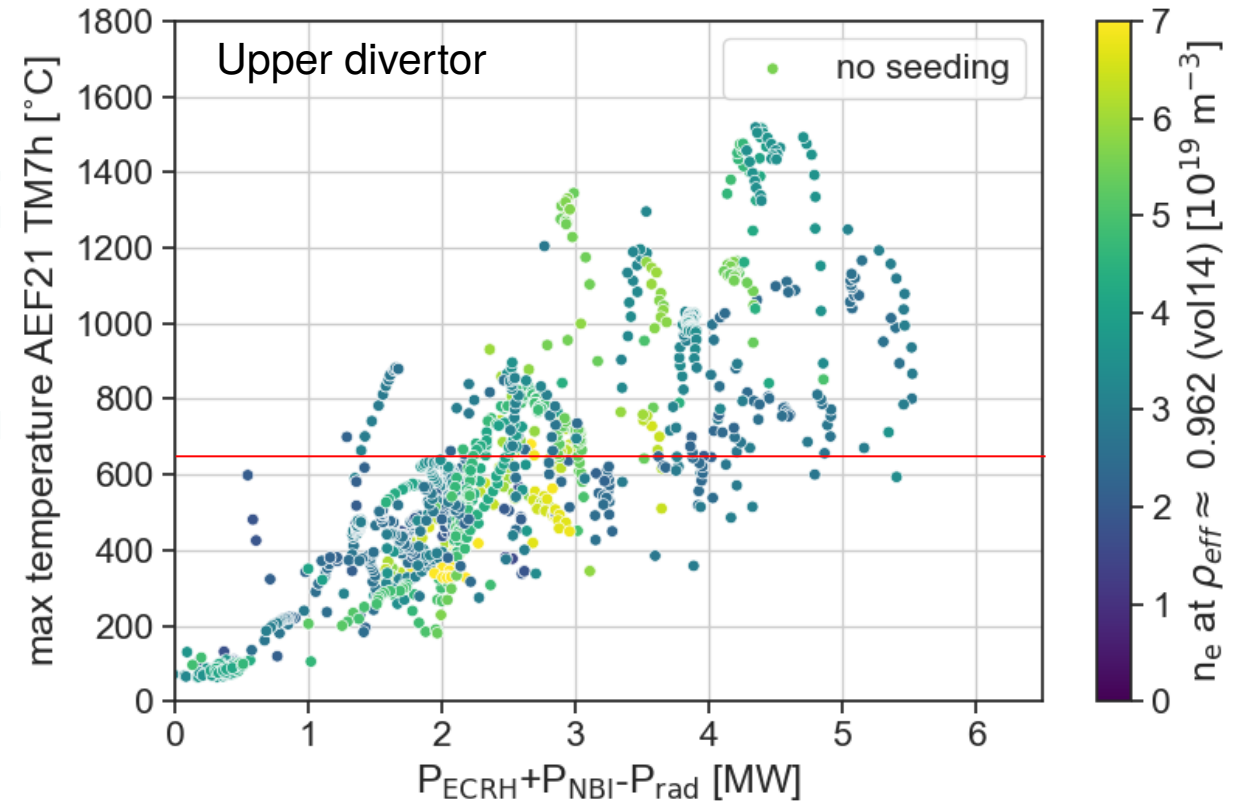
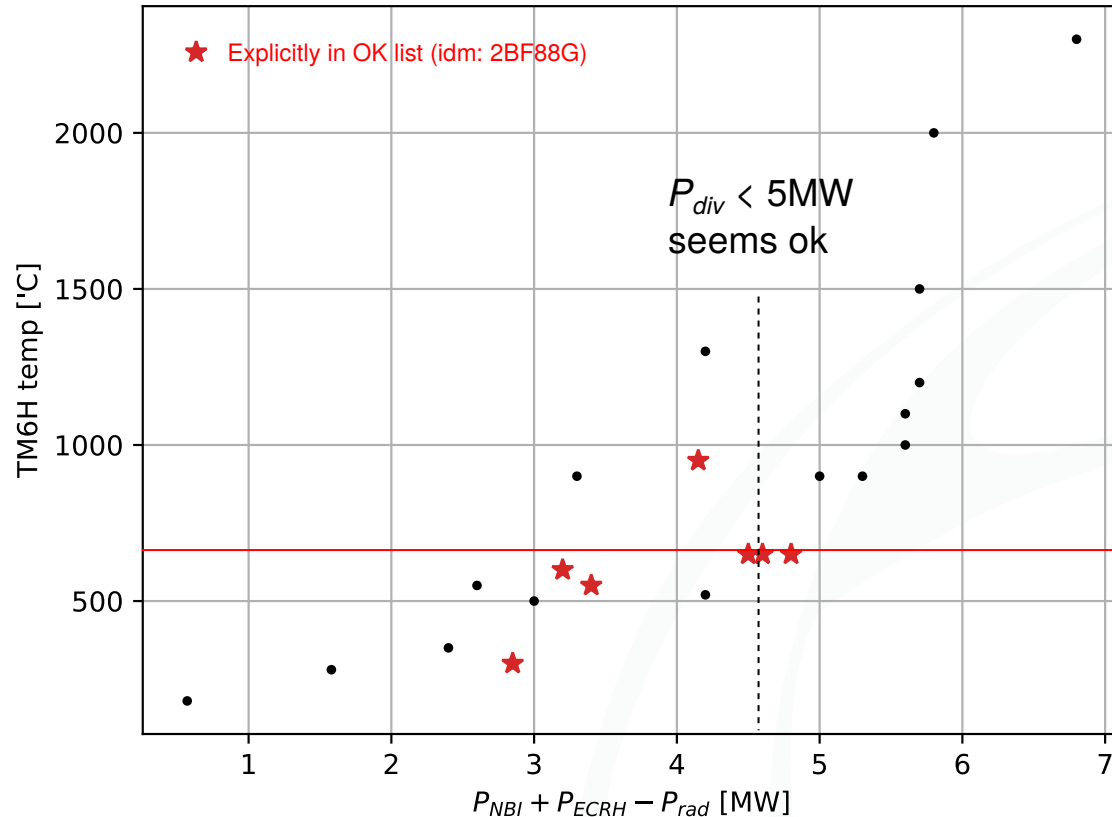


Heat loads

Selection of similar shots (mostly HP) from OP2.2/2.3:

Full juice DB: [V. Perseo]

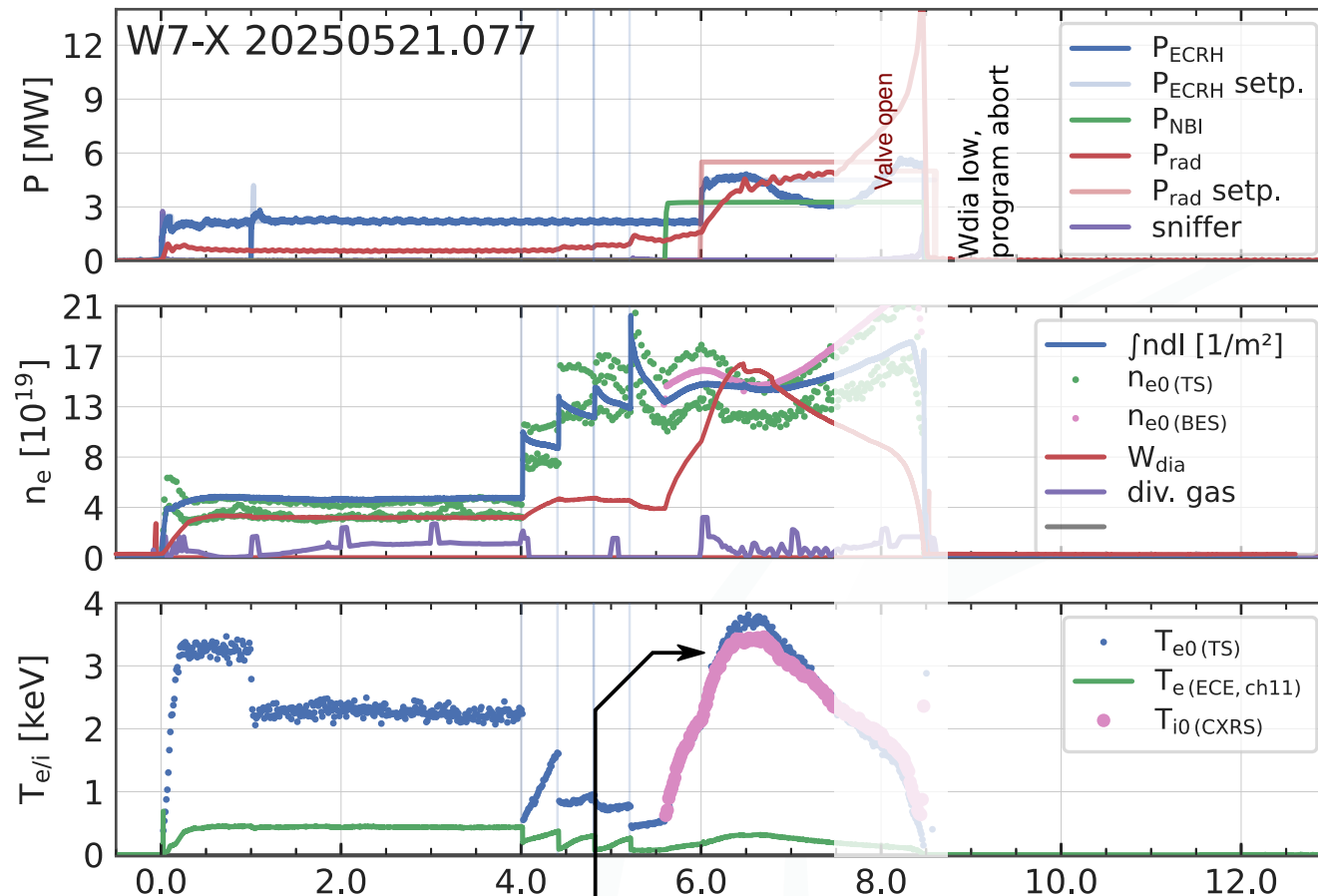
- Similar but n_e plays strong role



- Analysis of FTM heat loads in SOII-33 (2 days earlier).
- Hybrid pellets + NBI maybe have advantage of lower n_e^{sep} .

Heat loads - seeding?

Some of the OK attempts were $P_{div} < 5\text{MW}$ due to seeding:



High enough for tomag_006

- Neon accumulates in core and messes with power balance - difficult interpretation.
- We might need the P_{ECRH} feedback control (tested here) as well as P_{rad} feedback.
- P_{rad} feedback and divertor heat loads will be explored in detail in SOI-33 (2 days earlier)

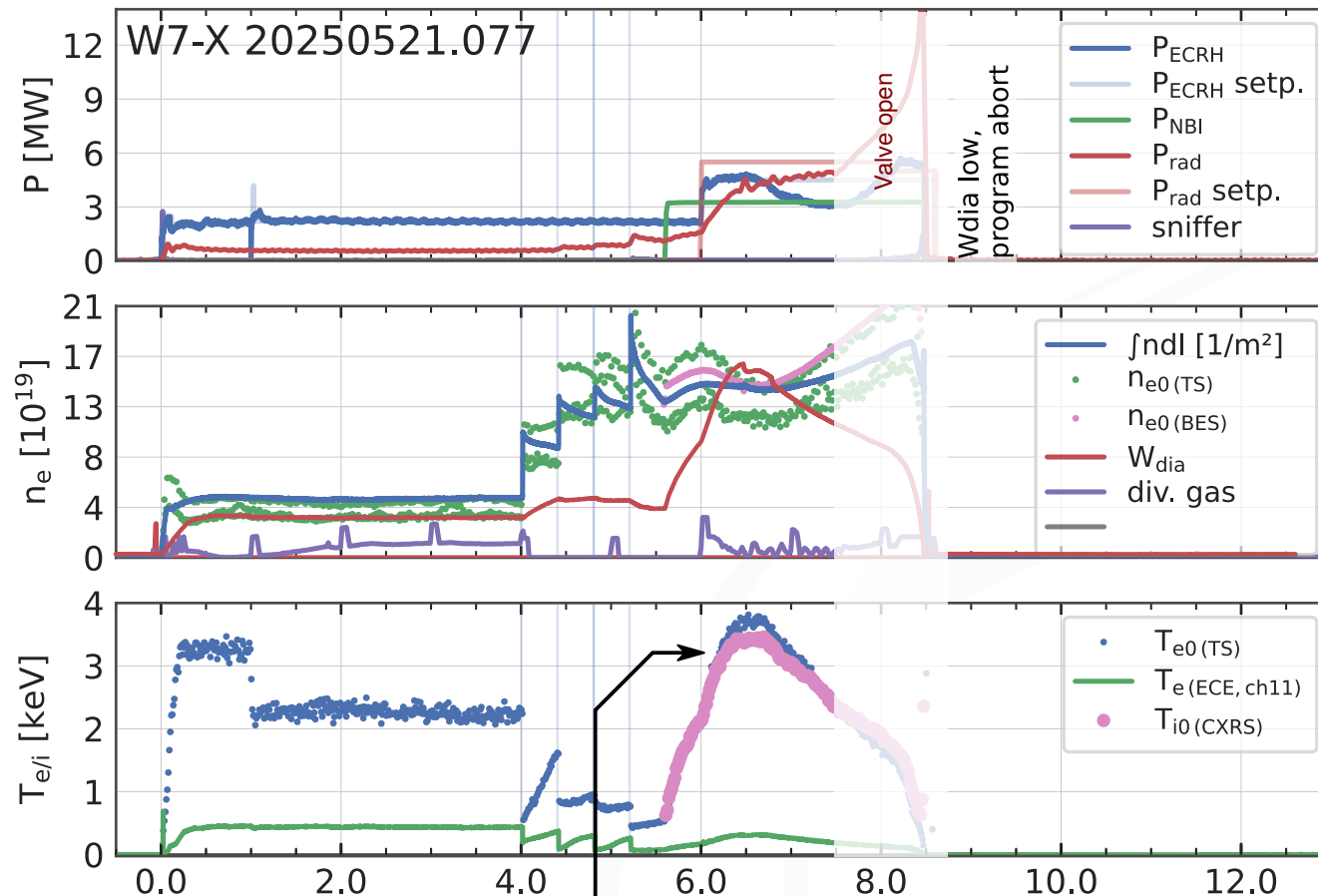
Options:

- 1) Only do other FTM things (next slides)
- 2) Run away, do HP in something not FTM.
- 3) Try and see where we get...

bad --> We waste some shot time.
 good --> We get a safe stable plasma with:
 $T_i > 3\text{ keV}$, $W_{dia} \sim 1.5\text{MJ}$ for 7.5s

Heat loads - seeding?

Some of the OK attempts were $P_{div} < 5\text{MW}$ due to seeding:



High enough for tomag_006

- Neon accumulates in core and messes with power balance - difficult interpretation.
- We might need the P_{ECRH} feedback control (tested here) as well as P_{rad} feedback.
- P_{rad} feedback and divertor heat loads will be explored in detail in SOI-33 (2 days earlier)

Options:

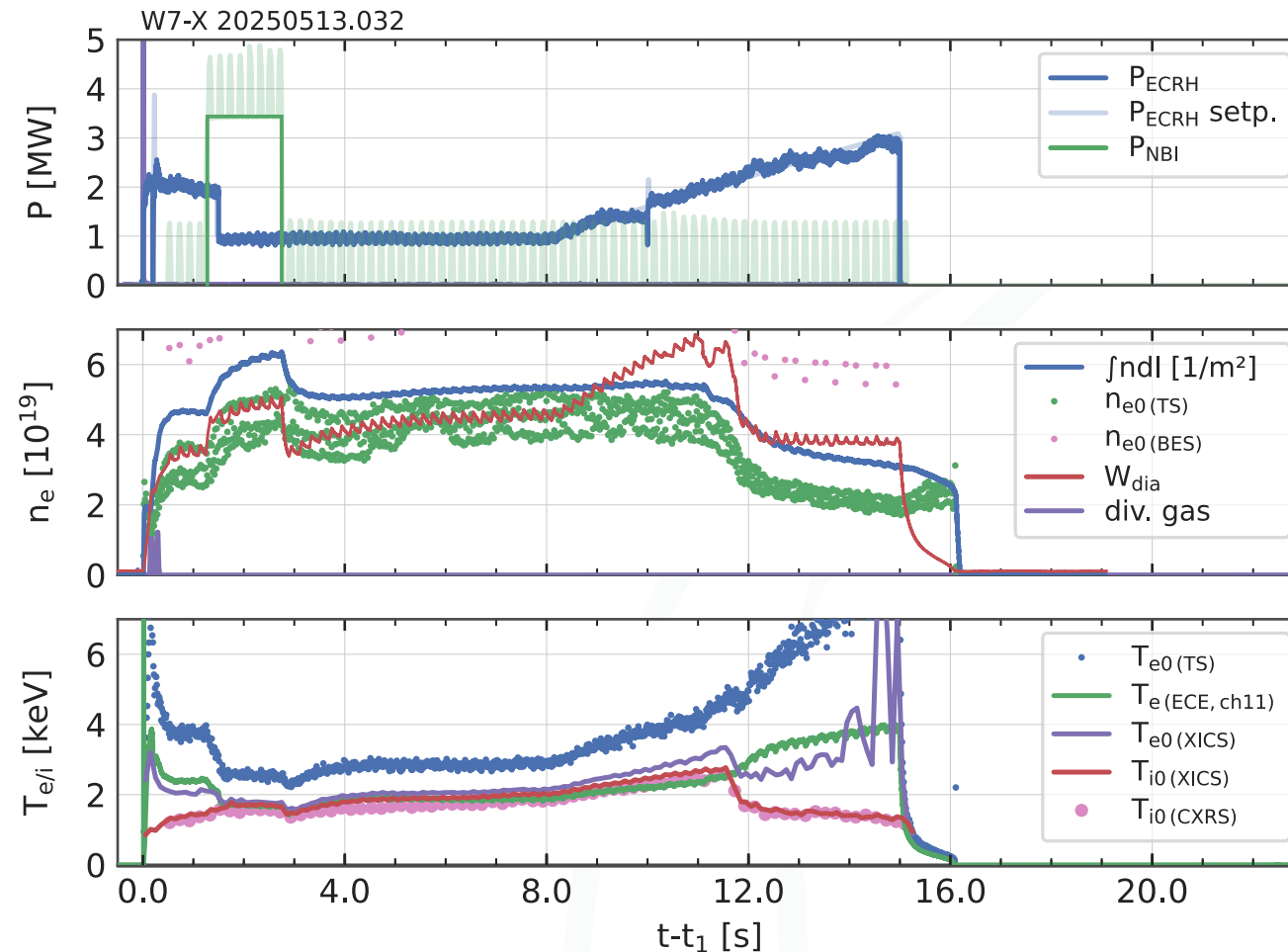
- 1) Only do other FTM things (next slides)
- 2) Run away, do HP in something not FTM.
- 3) Try and see where we get...

bad --> We waste some shot time.
 good --> We get a safe stable plasma with:
 $T_i > 3\text{ keV}$, $W_{dia} \sim 1.5\text{MJ}$ for 7.5s

Heat loads - seeding?

dacar_021: (prio1)

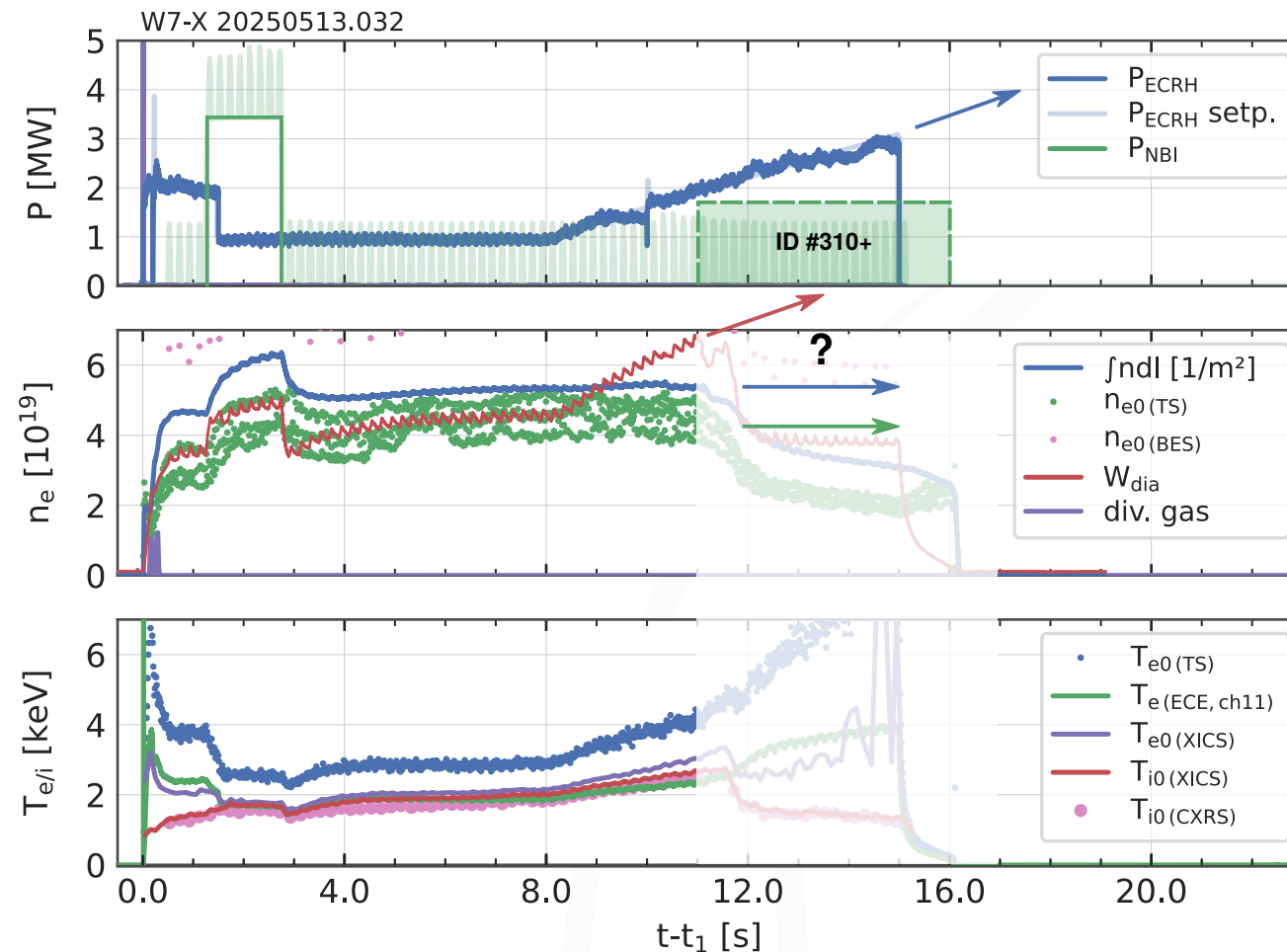
ID #300: Repeat the low-density (low-power) high confinement discharge, with reintroduced NBI:



Heat loads - seeding?

dacar_021: (prio1)

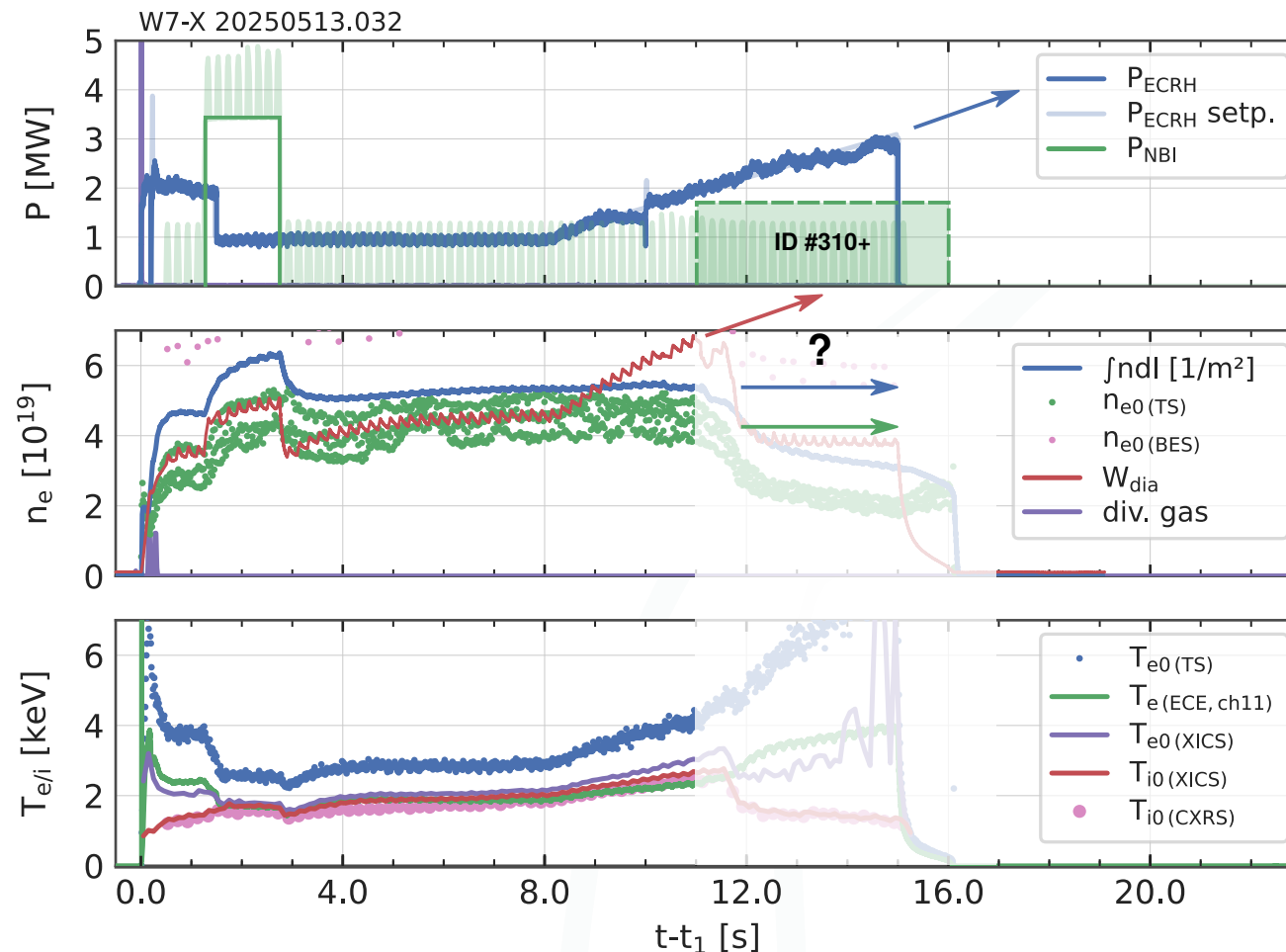
ID #300: Repeat the low-density (low-power) high confinement discharge, with reintroduced NBI:



Heat loads - seeding?

dacar_021: (prio1)

ID #300: Repeat the low-density (low-power) high confinement discharge, with reintroduced NBI:

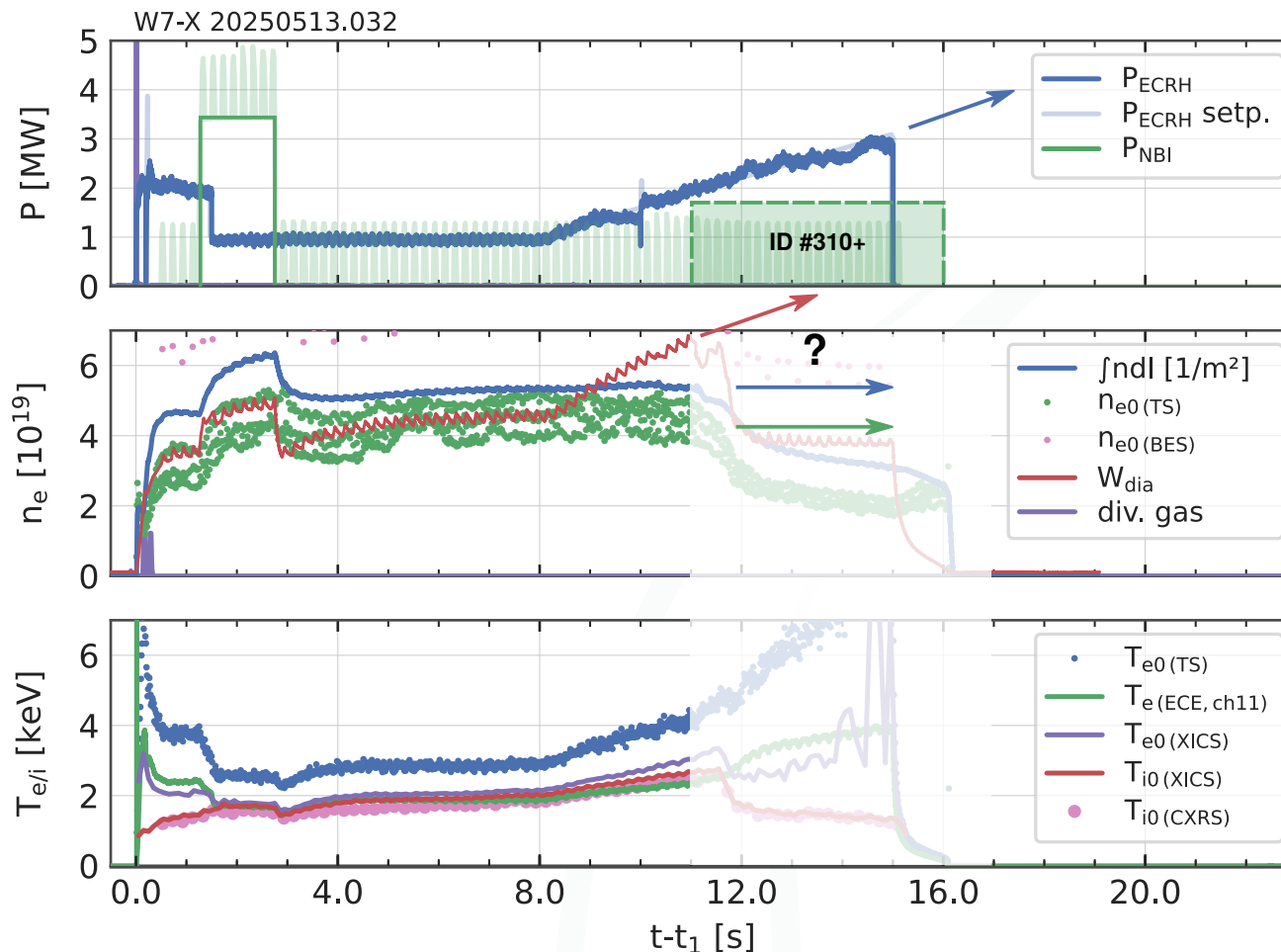


- Low density with $P \leq 5$ MW
--> heat loads should be ok.
- As shown requires NI20+21 (10s limit)
Can we ramp P_{ECRH} earlier?
- Raise P_{ECRH} if density control and heat loads allow

Heat loads - seeding?

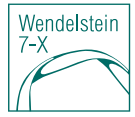
dacar_021: (prio1)

ID #300: Repeat the low-density (low-power) high confinement discharge, with reintroduced NBI:



- Low density with $P \leq 5$ MW
--> heat loads should be ok.
 - As shown requires NI20+21 (10s limit)
Can we ramp P_{ECRH} earlier?
 - Raise P_{ECRH} if density control and heat loads allow
 - Could this be done with a single pellet?
maybe try between NBI programs?
- > **ID #330**

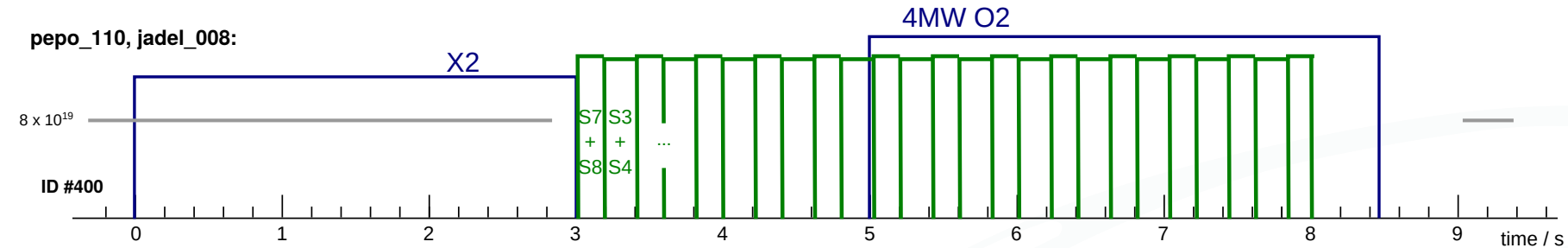
Priority 2



Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):

Priority 2

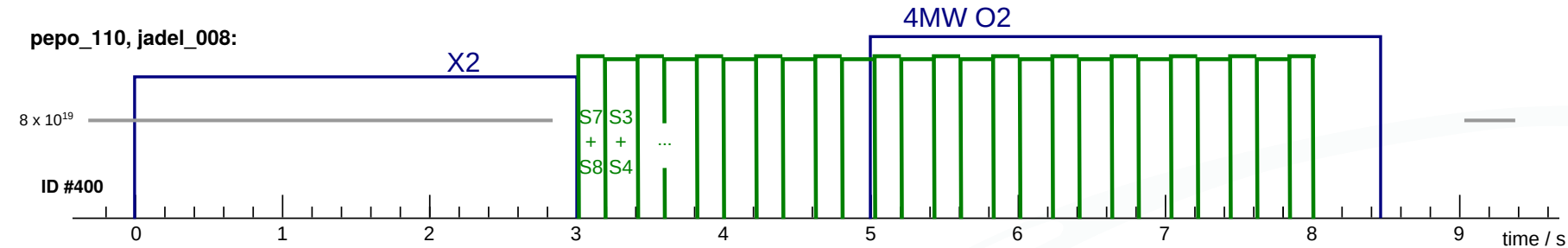
Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):



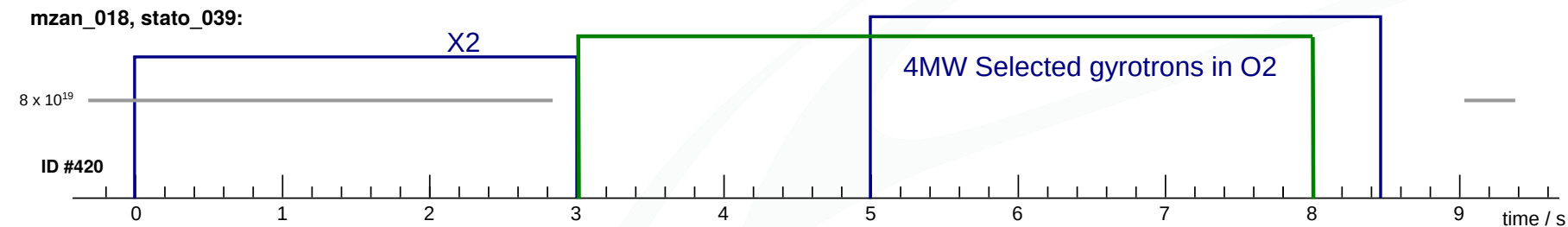
Switching NI20, NI21 for
diagnostic reasons

Priority 2

Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):



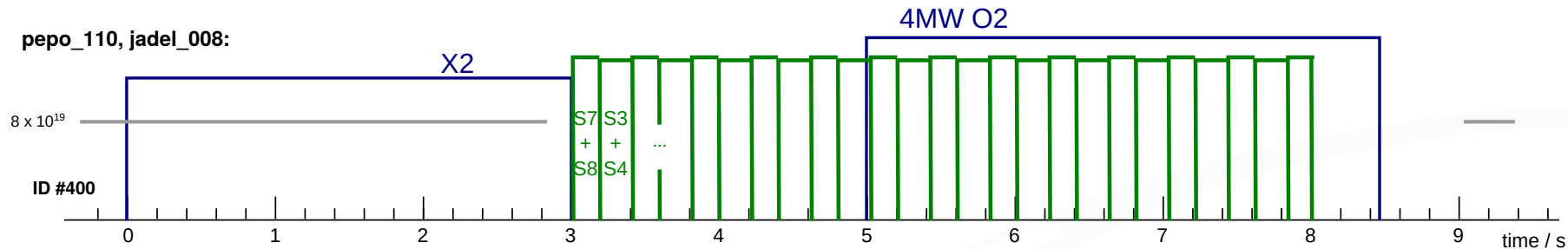
Switching NI20, NI21 for
diagnostic reasons



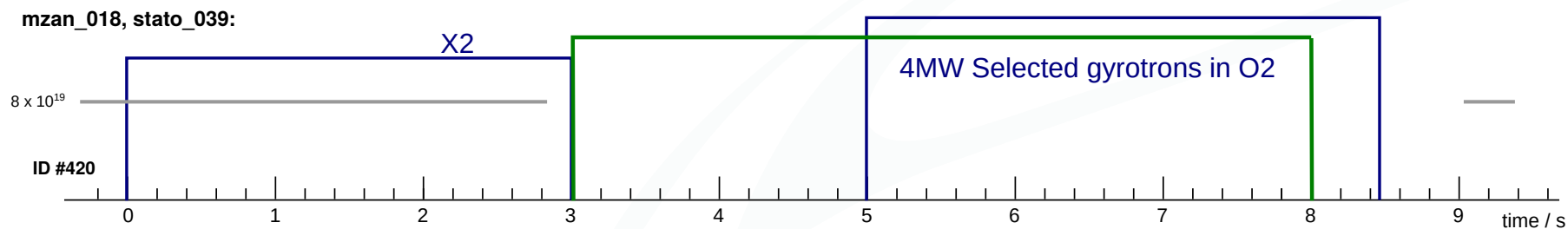
Switching O2 gyrotrons for
different current drive

Priority 2

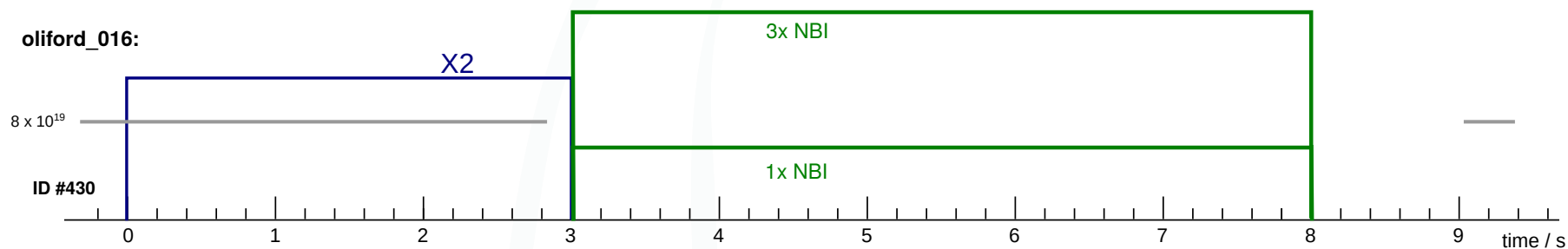
Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):



Switching NI20, NI21 for diagnostic reasons



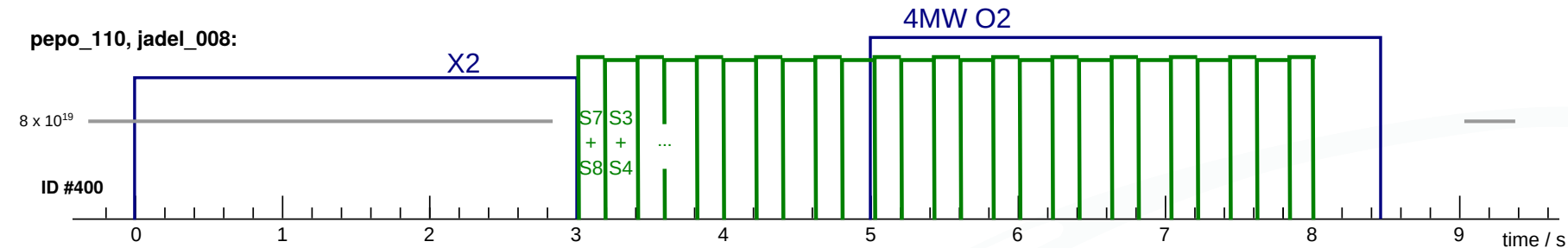
Switching O2 gyrotrons for different current drive



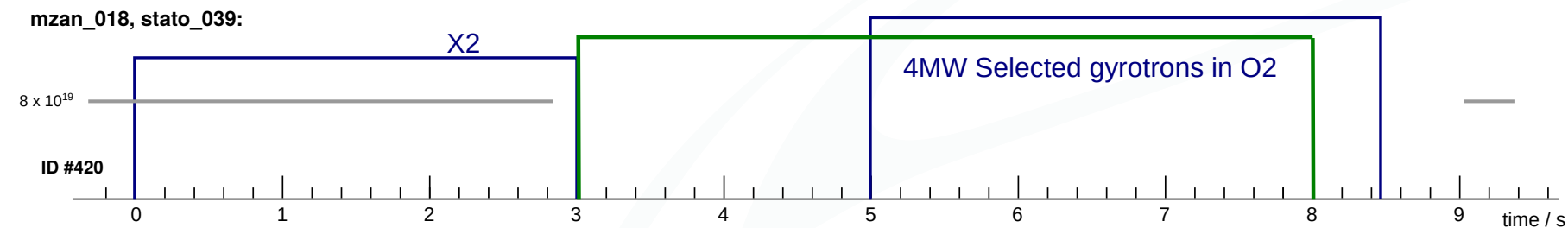
Pure-NBI different source counts to see n_e rise rate. (for future NBI upgrades)

Priority 2

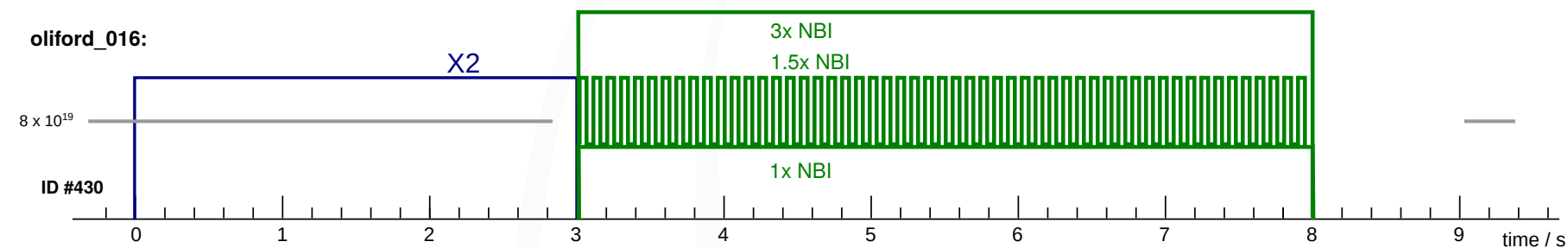
Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):



Switching NI20, NI21 for diagnostic reasons



Switching O2 gyrotrons for different current drive



Pure-NBI different source counts to see n_e rise rate. (for future NBI upgrades)

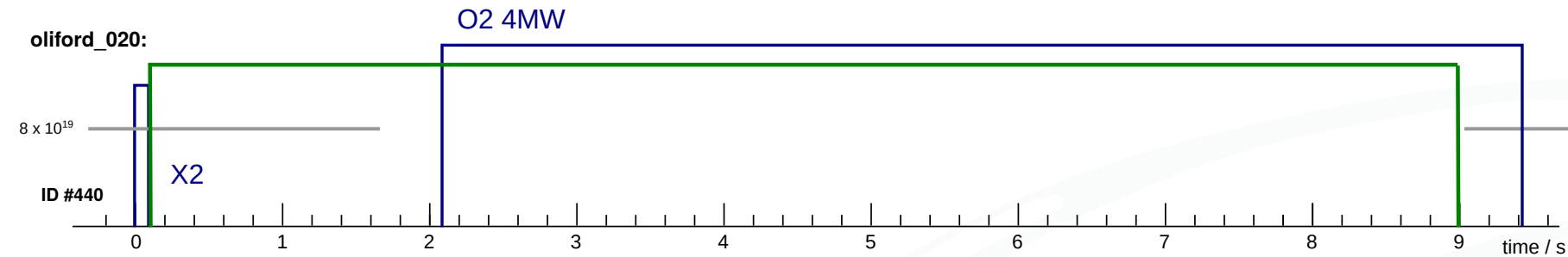
Priority 2



Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):

Priority 2

Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):



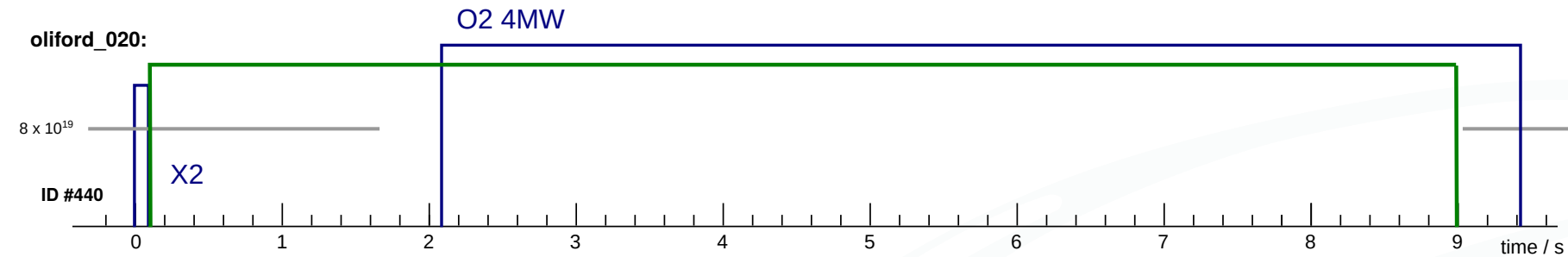
Early start NBI:

- compare low-field
- lower edge n_e
- higher edge a/L_n

(particularly FTM relevant)

Priority 2

Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):



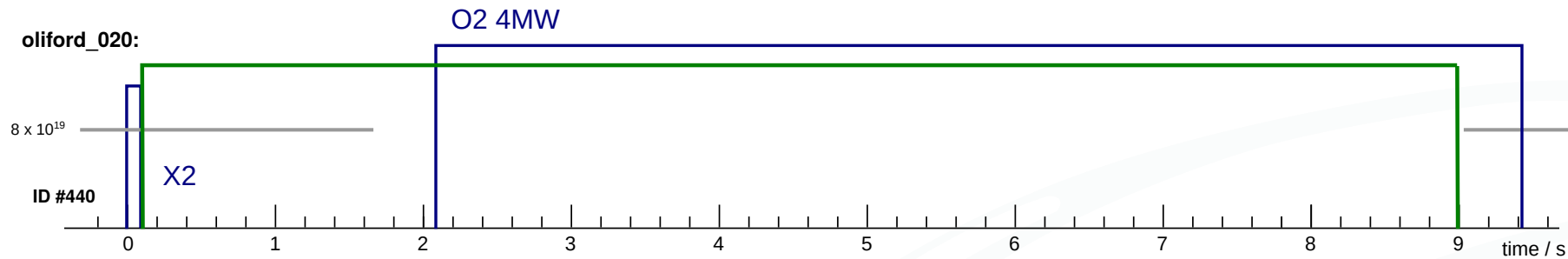
Early start NBI:

- compare low-field
- lower edge n_e
- higher edge a/L_n

(particularly FTM relevant)

Priority 2

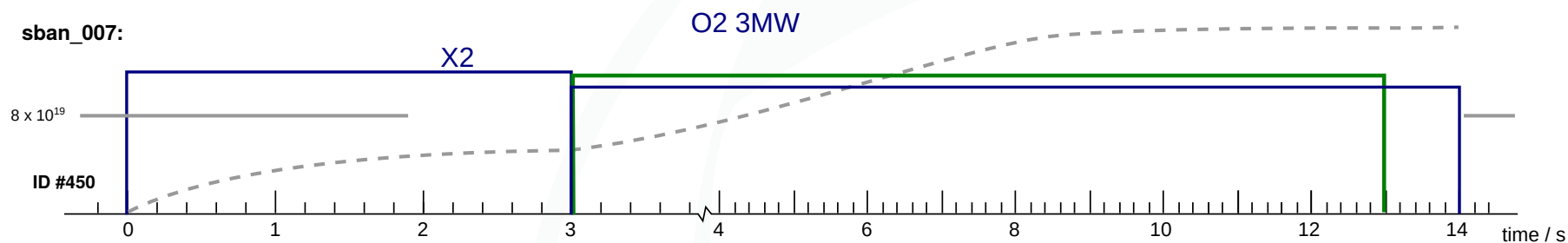
Many prio2 requiring special shots/modifications with NBI. Conduct near balance point if time (unlikely):



Early start NBI:

- compare low-field
- lower edge n_e
- higher edge a/L_n

(particularly FTM relevant)



Approach scenario
with continuous
NBI+ECRH over 10s

(This could be done in any config)

Shot plan

Current shot plan ~15 shots, but all NBI and expect lots of fighting with seeding and pump-out:

ID	Desc	n_NBI	P_NBI max	P_ECRH max	Required p_rad	Proposals
#110	ECRH reintro 1MW	2	3.3	1		oliford_017
#120	ECRH reintro 2MW	2	3.3	2 (1MW intrinsic)		oliford_017
#130	ECRH reintro 3MW (+seeding to 2MW) (+fast modulation for vemu_005)	2	3.3	3		2 oliford_017, vemu_005
#140	ECRH reintro 4MW (+seeding to 3MW) (+fast modulation for vemu_005)	2	3.3	4		3 oliford_017, vemu_005
#150	ECRH reintro 5MW (+seeding to 4MW)	2	3.3	5		4 oliford_017
#160	ECRH reintro 6MW (+seeding to 5MW)	2	3.3	6		5 oliford_017
#200	ECRH reintro 2.5 - 5.5MW feedback controlled	2	3.3	5.5		4.5 anla_031
#210	ECRH reintro 3MW, repeat with LBO and slow modulation	2	3.3	3		2 tomag_006, vemu_005
#300	Repeat LDHP after cleaning, (with earlier P_ECRH ramp)	2	0	2		-2.3 dacar_006, akraemer_018
#310	LDHP with additional NBI	2	1.7	2		-0.6 dacar_006, akraemer_018
#320	LDHP with additional NBI and raised P_ECRH (up to 3.5MW without seeding)	2	1.7	3		0.4 dacar_006, akraemer_018
#330	LDHP with 1 big pellet instead?? If works → inter NBI program					dacar_006, akraemer_018
#400	Reintro with alternating NBI, 100ms (S7,S8)-(S3,S4)	4	3.3	4		3 jadel_008, pepo_110,
#420	Repeat one balanced reintro with unbalanced O2	2	3.3	4		3 mzan_018, stato_039
#430	Pure NBI 1, 1.5, 3 sources	2	4.95			0 oliford_016
#440	ECRH reintro with early NBI	2	3.3	4		3 oliford_020
#450	Slow entry NBI+ECRH at slightly under balance point	2	3.3	3		2 oliford_020
#700+	Anything for kseno_020 if waiting for NBI ?					0 kseno_020