NBI heat and particle transport proposals OP2

O. P. Ford, S. Lazerson, ... mostly everyone

Profiles topical group meeting. 14th Match 2022

NBI proposals

Proposal list for NBI heat and particle transport/confinement.

Does not include:

- NBI comissioning --> S. Lazerson, TG Heating/TG Fast ions
- NBI heating and deposition physics --> S. Lazerson, TG Fast ions
- Impurity transport/accumulation in (pure) NBI plasmas --> O. Ford, TG Impurities
- NBI Current Drive --> TG Fast ions

NBI proposals

List merged from S. Lazerson
and from TG profiles 31.01.2022:

Sorry if I've missed yours!
(please tell me)

List will be updated by Sam.

Lead proponent	Topic	Short description	Objective	Notes
Lazerson	Confinement effect of ECRH on NBI (LHD Comparrison)	Evaluate the effect on global confinement of ECRH power on ECRH+NBI discharges by varying ECRH power and deposition location.	Investigation	Overlap with Ford:Threshold PECRH, but different analysis focus.
Lazerson → Fuchert	Density limits in NBI heated discharges	Probe density limit in NBI shots	Confinement	Do we need this separate from Lazerson:"High Density with NBI". Golo take over?
Ford	Pure NBI density peaking onset	Investigation of onset time and cause of particle transport supression. Scan of initial density, single sources and gas puff during peaking.	Investigation	
Ford	Pure NBI particle and heat transport extrapolation	Scan of number of sources 1-4 and source types. Balance fuelling and heating rates and examine extrapolation of anomalous particle and heat transport balance towards 8 beams.	Investigation	
Ford	Threshold of high turbulence in P_ECRH in NBI + +ECRH plasmas.	Scan P_ECRH between 0.5 and 2.5MW after density peaking in successive 2-source pure NBI discharges. Look for Q_tot raise as f(P_ECRH) repeating and filling in between existing points (#180919.055, #181009.034).	Investigation	
Ford	ECRH pump out dependence on ECRH deposition profile.	Scan of ECRH deposition position in pure NBI after peaking built-up (~3s). Also try pure NBI with continuous ECRH outside transistion location (rho>0.5).	Investigation	
Ford	Ti optimisation with NBI+ECRH.	Search for highest peak and for highest continuous Ti by balance of NBI and small amount of reintroduced ECRH. Vary timing of ECRH relative to onset time and ECRH power.	Optimisation	Relates to everything. Strong overlap with Beidler:Reproduction of W7AS high performance.
Ford	Optimised NBI+ECRH with Boron dropper	Add boron dropper to optimal NBI+ECRH scenario to see lowering edge gradients can rise Ti more.	Optimisation	Simple extension to Ford:Ti optimisation
Beidler	Reproduction of the W7-AS high performance discharges	As on pages 72-75 of the W7-AS review paper. Using NBI+ECRH mix.	Optimisation	Strong overlap with Ford:Ti Optimisation
Stange	Overtake peaked NBI-plasmas with O2-heating (beyond X2-cutoff)	Max power O2 ECRH into already very peaked pure-NBI shot. Try to raise Ti and Te together like in high-performance pellets shots.	Optimisation	Some overlap with Ford:Ti Optimisation
Stange	Overtake peaked NBI-plasmas with X3-heating at 1.75 T	As Stange:Overtake With O2, but with X3 in low field.	Optimisation	
Lazerson	Reactor Relevant Heating	Use of combined NBI and ECRH to achieve similar heating profiles to that of a larger reactor (https://doi.org/10.1088/1361-6587/ac35ee)	Execution	
Lazerson	High Power Discharge with NBI	Use of combined NBI and ECRH to achieve maximum power discharges	Execution	Similar to Stange:Overtake peaked NBI...
Lazerson	High Density with NBI	Use of NBI and gas puffs to reach densities above the O2 ECRH cutoff	Execution	
Lazerson	Low Density NBI discharges	Development of discharge scenarios with density below 1e19 m^-3 using ECRH and NBI (500 ms)	Execution	
Lazerson, Romba	He NBI Injection	He NBI in He plasma and He NBI into H plasmas.	Execution	Also something from Beurskens?
Lazerson	High Beta with NBI	5s NBI discharge at 1.25T	Execution	Not in Sam's list?
Ford	Profile shaping with combined pellet and NBI fueling	Pellet injection into NBI heated plasmas. Most likely standard, high mirror and low mirror configurations. Both discharges with pure-NBI and with ECRH+NBI.	Execution	
Lazerson	NBI takeover of ICRH	Develop scenario to takeover ICRH initiaed discharge by NBI (2.5T, 1.7T, 1.25T)	Execution	NBI comissioning?
Perseo	Detachment in NBI discharges	Add or switch to NBI to detached discharges	Investigation	Overlap Beurskens:Detachment and Zhang:Detachment
Beurskens	Detachment in optimised NBI+ECRH with seeding	Add seeding to NBI+ECRH optimised plasma to get detachment.	Optimisation	Based on Ford:Ti optimisation. Overlap with Perseo:Detachment in NBI
Zhang	Detachment in NBI discharges/Pellet plasmas	Peaked density profiles with ncore >> nX2 cut-off. But Typically NBI plasmas feature low edge density. Is this compatible with detachment?	Investigation	Overlap Perseo:Detachment. Was this particularly wanted or just assigned?
von Stechow	Turbulence limits of NBI density peaking	Peak the core density gradient as hard as possible with all sources and see (with fluctuation diagnostics) if density gradient driven TEMs or other instabilities start popping up. Dedicated experiment if no one else is asking for this, otherwise piggyback.	Investigation	Overlap with Ford:DensityPeaking, Lazerson:HighDensity
von Stechow	Turbulence in matched ECRH to NBI switch	Match ECH power so that PCI and reflectometers see a constant fluctuation amplitude during switchover.	Investigation	Dedicated experiment
von Stechow	Turbulence in ECRH pump-out	Detailed analysis of ECH density pump-out with turbulence diagnostics. Based on AUG and DIII-D observations. Probably mostly piggyback, but with best possible high time resolution kinetic profiles around ECH switch-on.	Investigation	
Geiger/Swee	NBI heat pulse propagation	Measurements with CXRS. Try to measure Qi.	Measurement	Maybe multiple proposals. Coordinated with Weir:NBI electron transport
Weir	NBI electron channel transport	Heat pulse propagation studies with O2-ECRH modulation	Measurement	Coordinated with Geiger:NBI HPP
Ford	Maximise e-i coupling	Obtained minimum possible Te-Ti to validate and determine offsets of TS, ECE, XICS, CXRS	Measurement	Partially covered by diagnostic commissioning in E3-DIA

1) Detailed transport studies
2) Performance optimisation
3) Execution of new or specific operation
4) New measurements (investigations with)

NBI proposals

Proposals related to:

1) Heat and main ion particle transport studies
2) Performance optimisation

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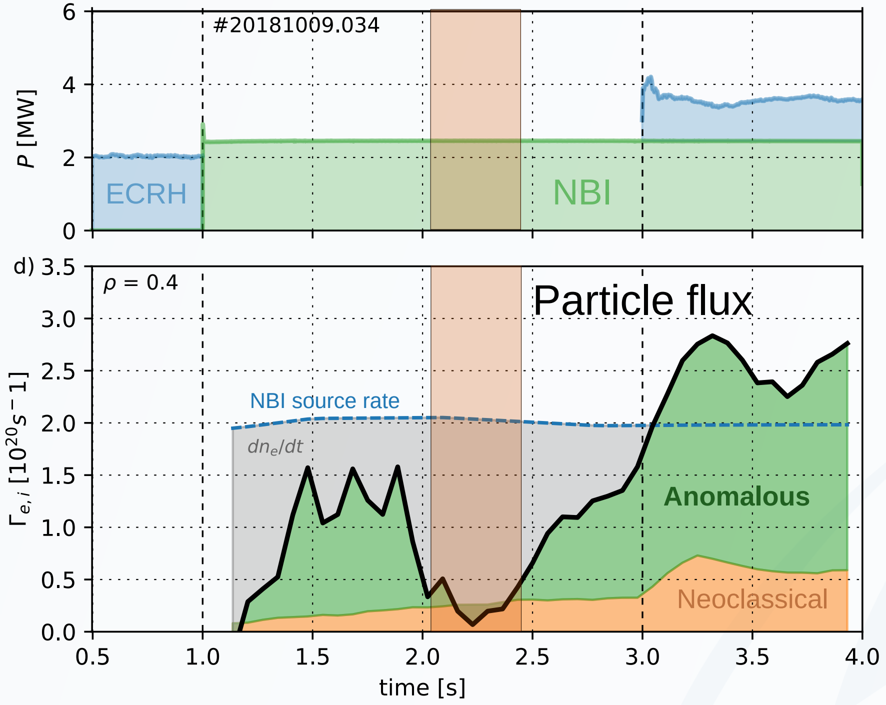
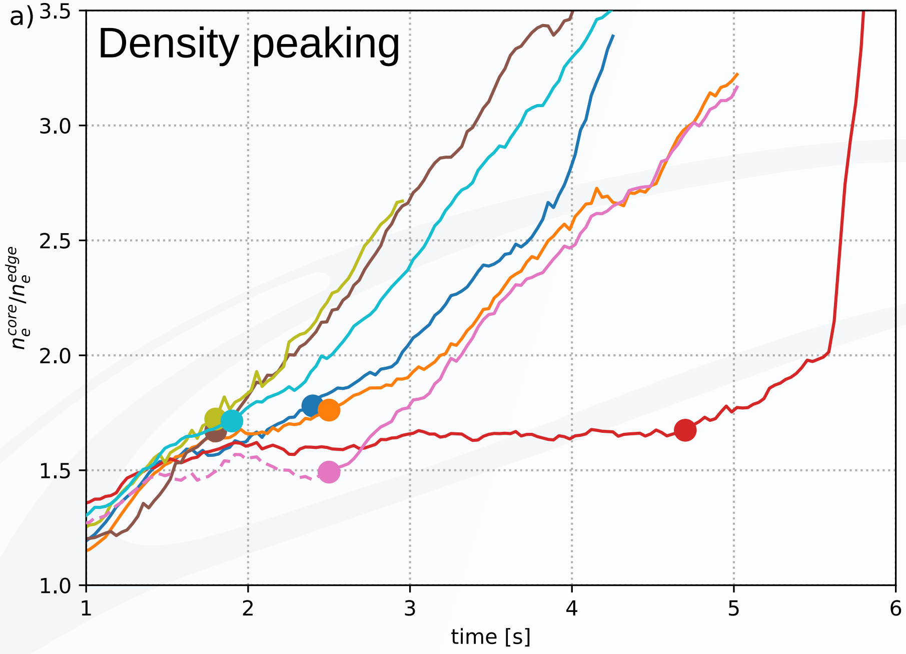
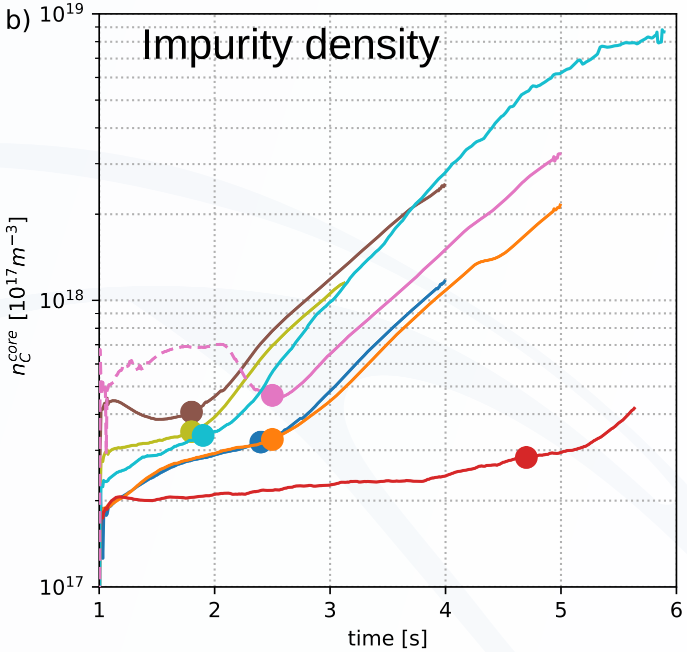
Pure NBI density peaking

Pure NBI discharges: Dramatic change of particle transport inside $\rho < 0.5$ at some onset time:







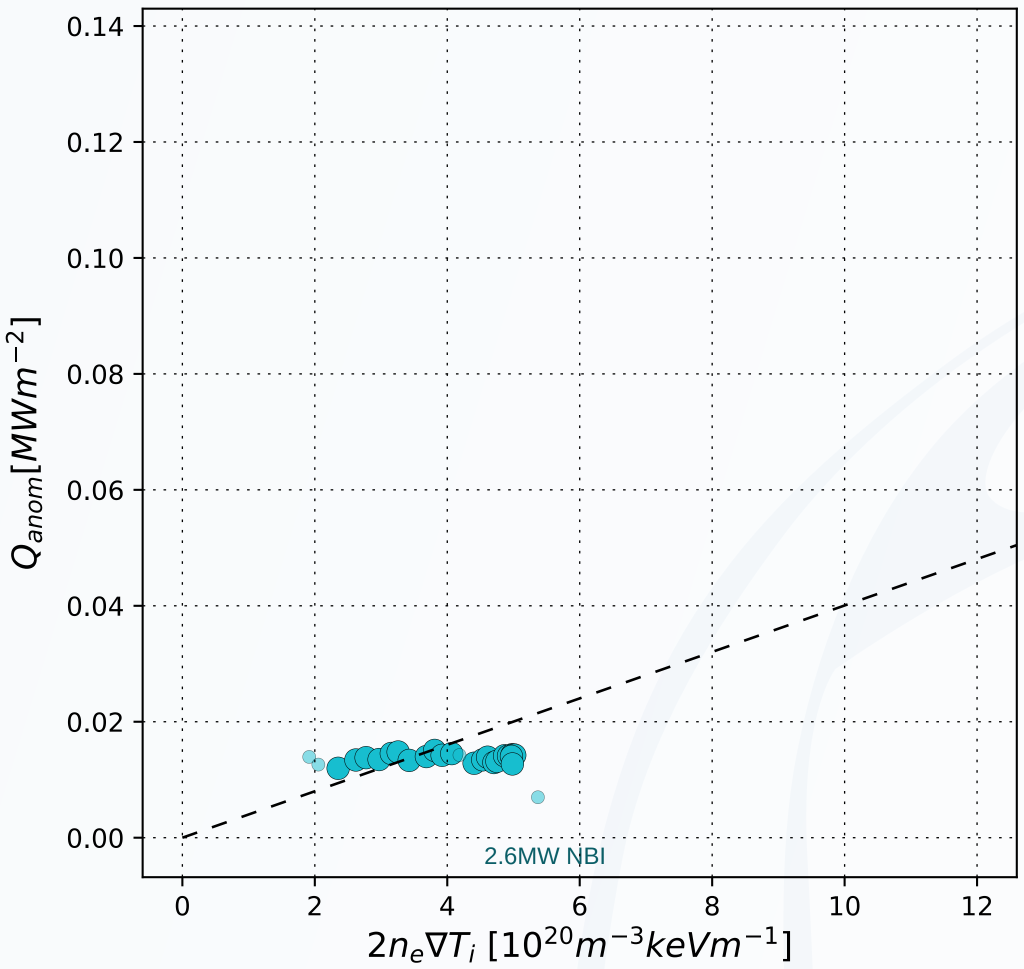
Plan:

1. Scan initial density with pre-fill and/or gas puff at very start. Switch to pure NBI Q7+Q8.
2. Where t_{onset} ~ 1s, try with each individual source Q7 and Q8. Still have $\Gamma \sim \Gamma_{NC}$?
3. Repeat with pulse gas puff in pure NBI phase. Increases n_e at edge, or just diffuses to central region?

Piggy-back: Impurity transport for cabon, argon, helium during. Extra shots with injection --> TG Impurities.

Threshold of high turbulence in NBI+ECRH plasmas.

Heat transport in NBI discharges split into 3 groups:



A) ECRH > 3MW ± NBI --> ITG dominated T_i clamped.
B) NBI --> High a/L_{ne}, low χ_{eff}, but low P/n_e.
C) NBI + 1MW --> Low χ_{eff}, T_i > 1.6keV.

Plan:
1) Pure NBI, allow density peaking build-up.
Scan additional 0.5 < P_{ECRH} < 3MW
2) For one value: Start with NBI+ high ECRH and drop to target P_{ECRH} value. Is there hysteresis due to a/L_{ne} or T_e/T_i?

Objective is clear Q_{anom} vs $n_e\nabla T$ scan.

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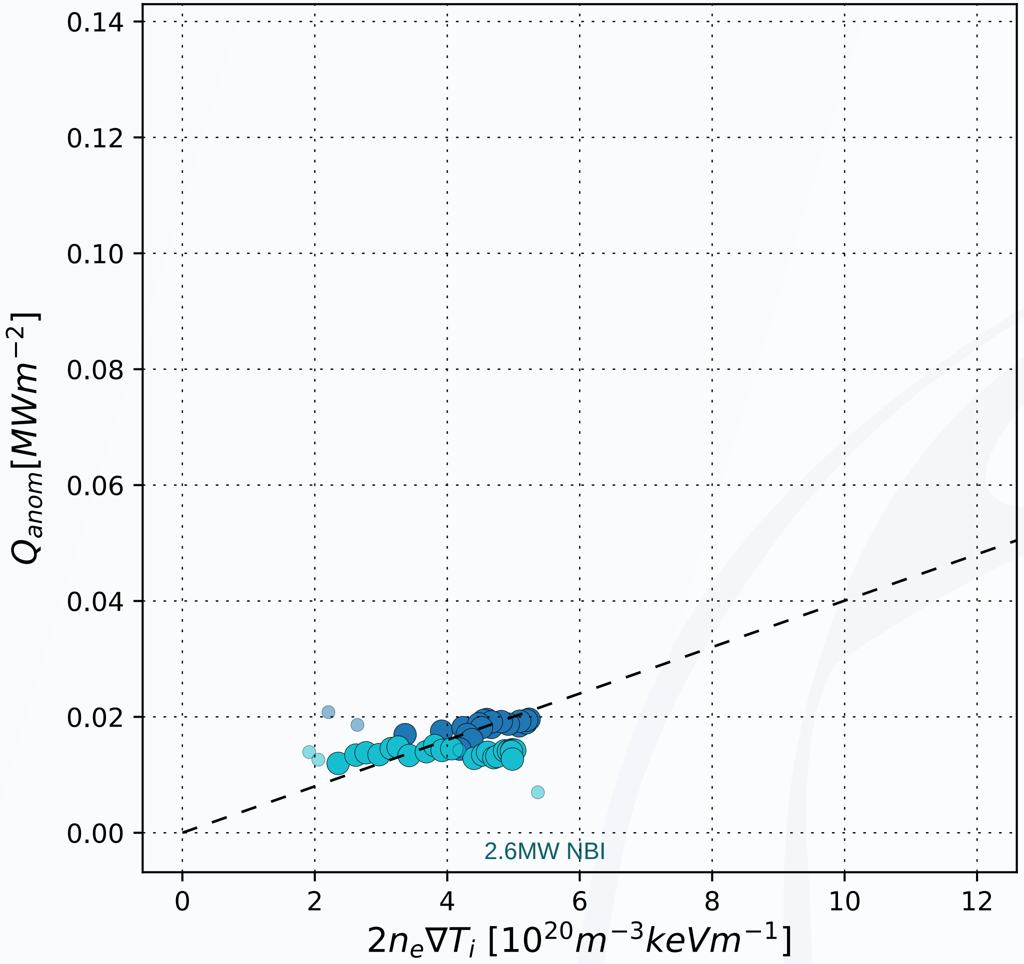

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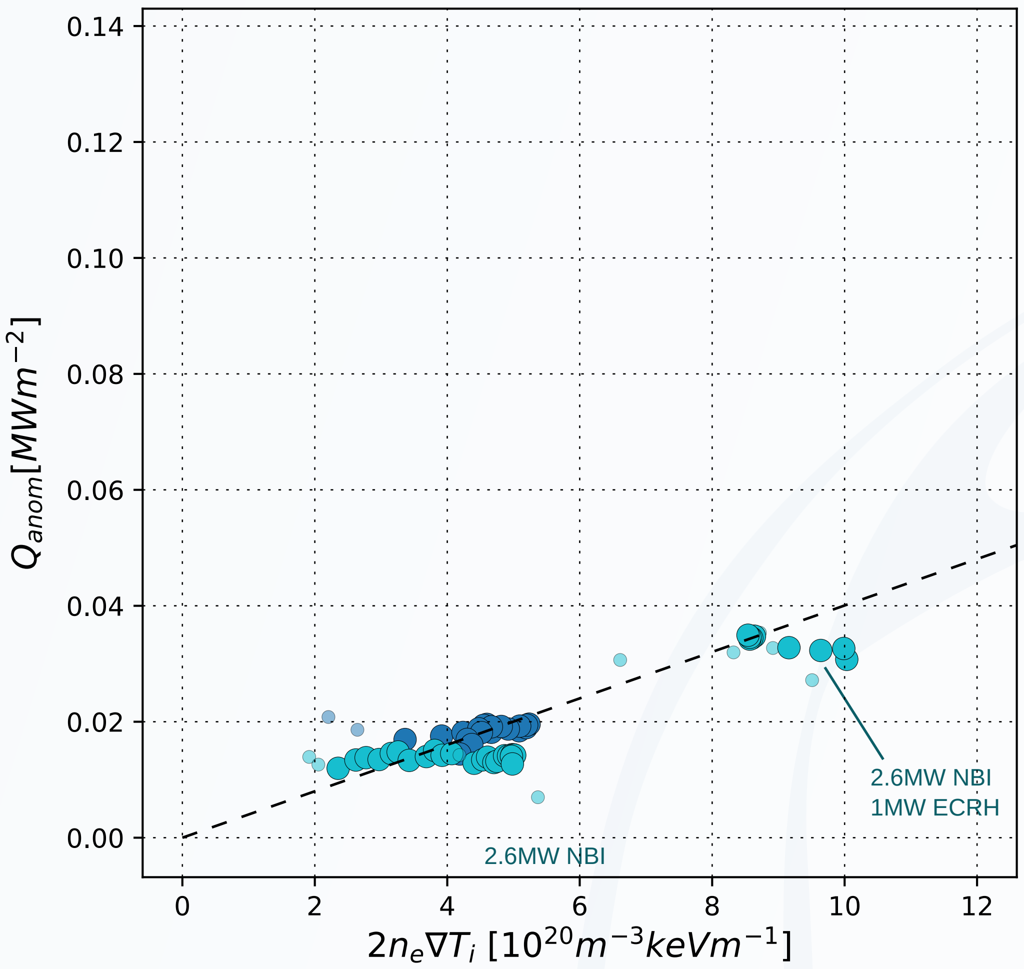

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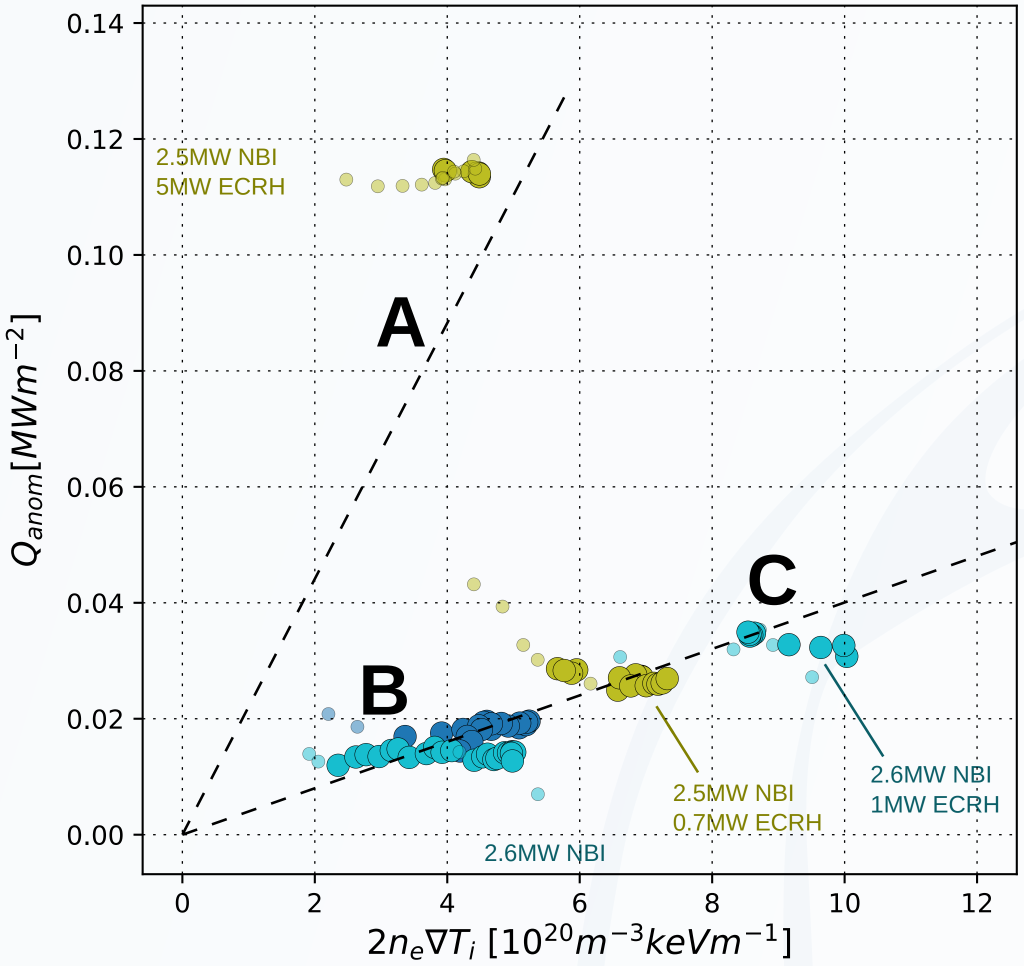

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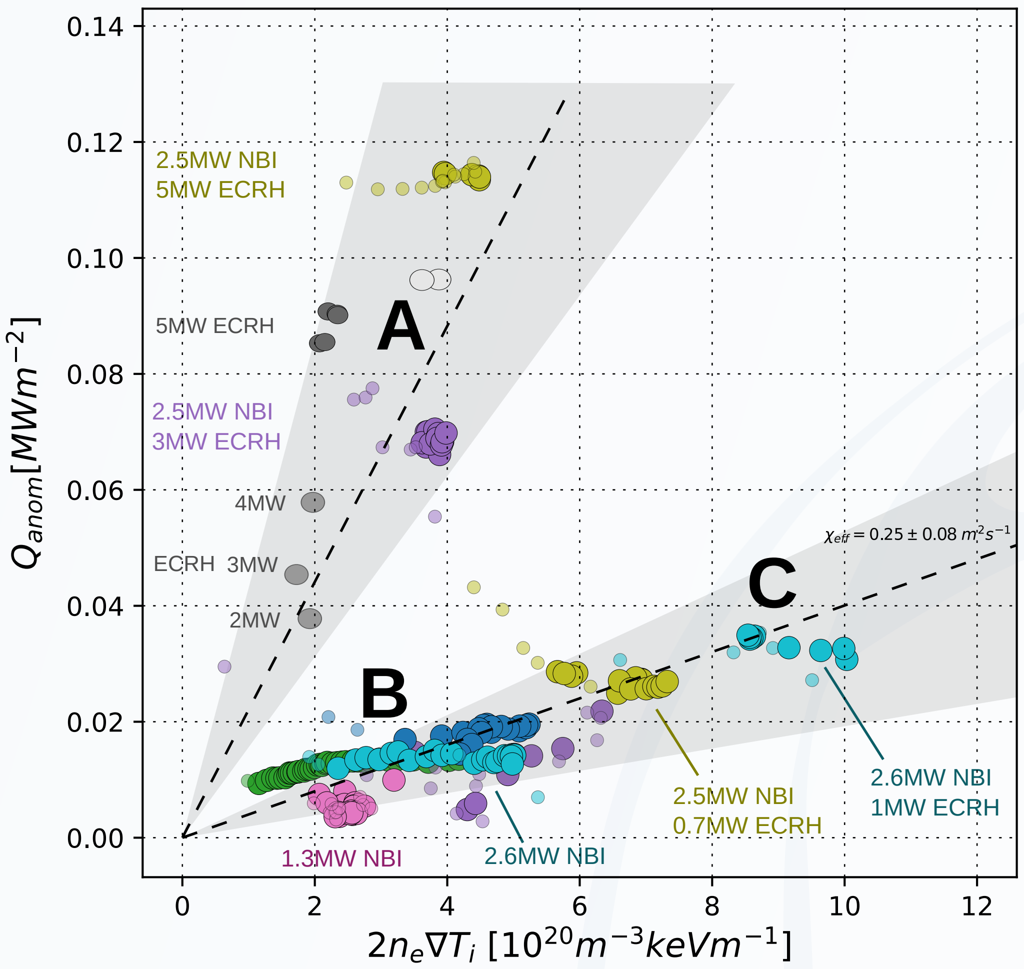

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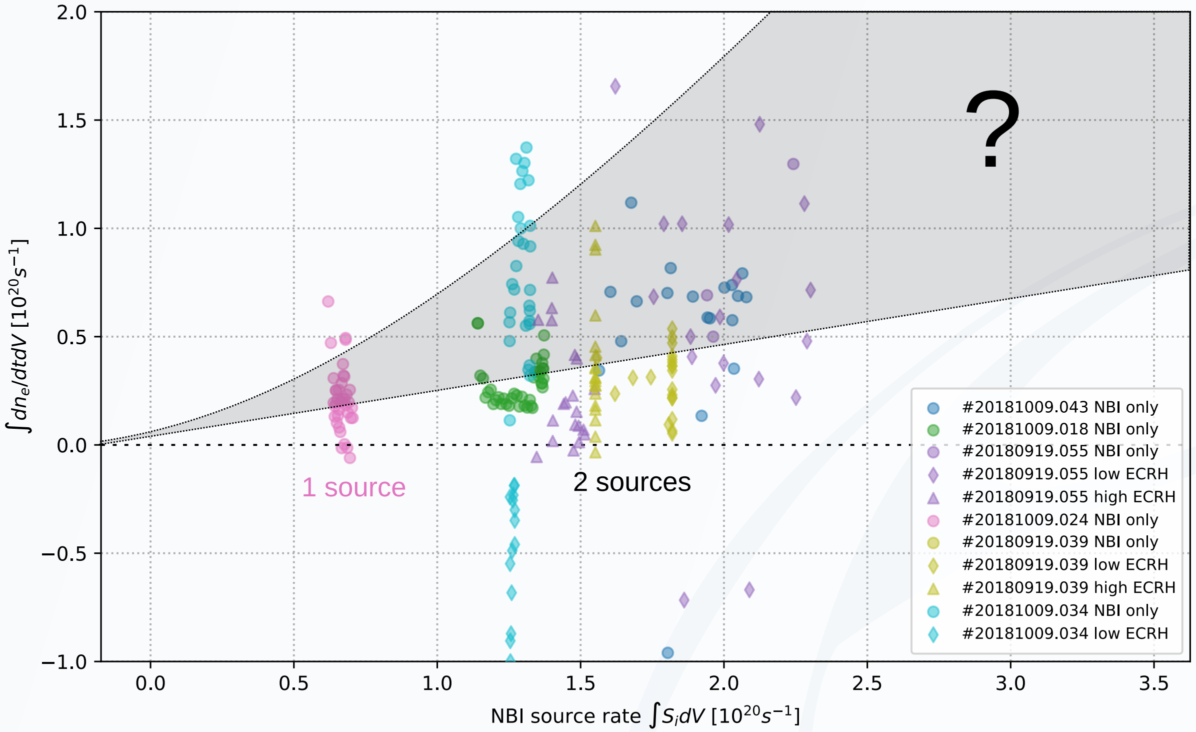
NBI particle vs heat transport scaling to 8 sources.

Pure NBI discharges showed low χ_{eff}, but low P/n_e. Scaling of ne with sources is not at all clear and needed for projections to 8 sources.



Plan:

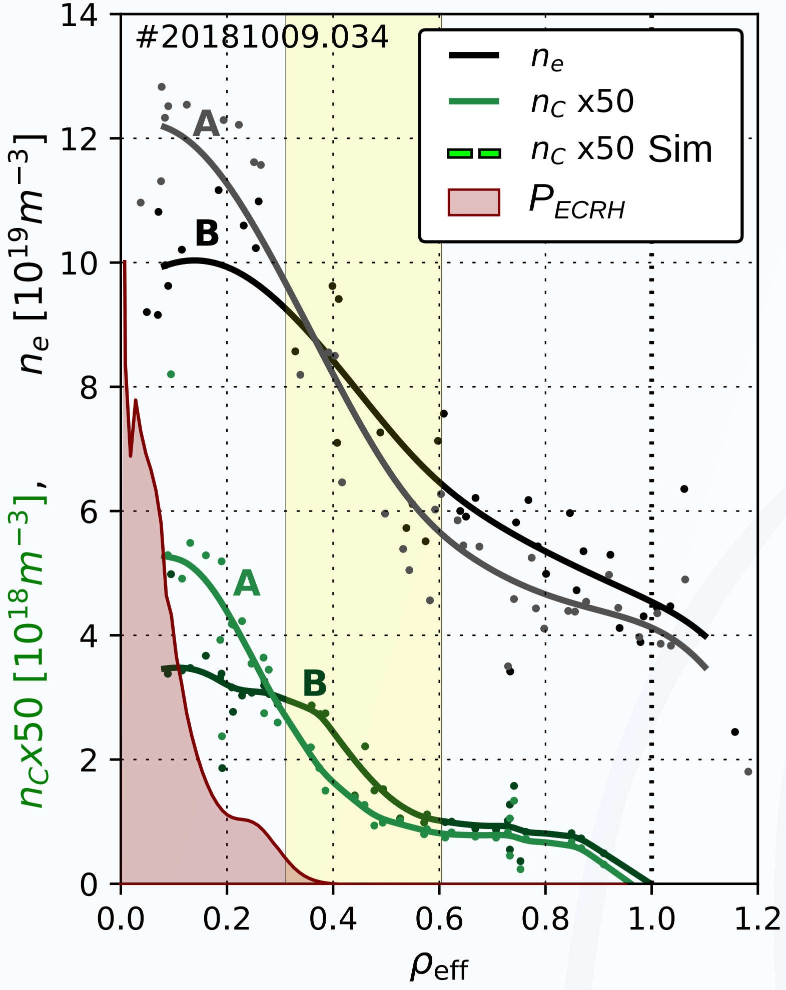
1) Scan of 1, 2, 3 and 4 NBI sources, min 3s.
   Collect density rise rate as function of N_{source} before and after particle peaking onset.
2) Switch source sets of 1 and 2 sources:
   Q7, Q8, (Q3+Q7), (Q4+Q8) to look for changes of deposition profiles on T_i and n_e.

If n_e rise scales, add low ECRH as neccessary to control impurities and maintain sufficient P/n_e.

Passive impurity monitoring (C, O, trace Ar), but no injections.

Pump out dependence on ECRH deposition.

Peaked NBI impurity density profiles flattened with O2 ECRH. Possibly also true for main density.



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1) If better n_e profiles available, repeat to see if n_e also flat in deposition region.
2) Try with X2 ECRH before density is too high.
3) Scan X2 deposition position to see effect on n_Z and n_e.
4) (if possible). Try with deposition only outside $\rho > 0.5$.
5) Spread ECRH for low power density to maximise ne gradient for same P_{ECRH}.

Impurity monitoring C, Ar, He.
Finally impurity injection into the flattened core --> TG Impurities proposal.

Objectives:

1) Anomalous particle and impurity transport dependance on P_{ECRH} density.
2) Optimum ECRH power deposition for not reducing n_e gradient.

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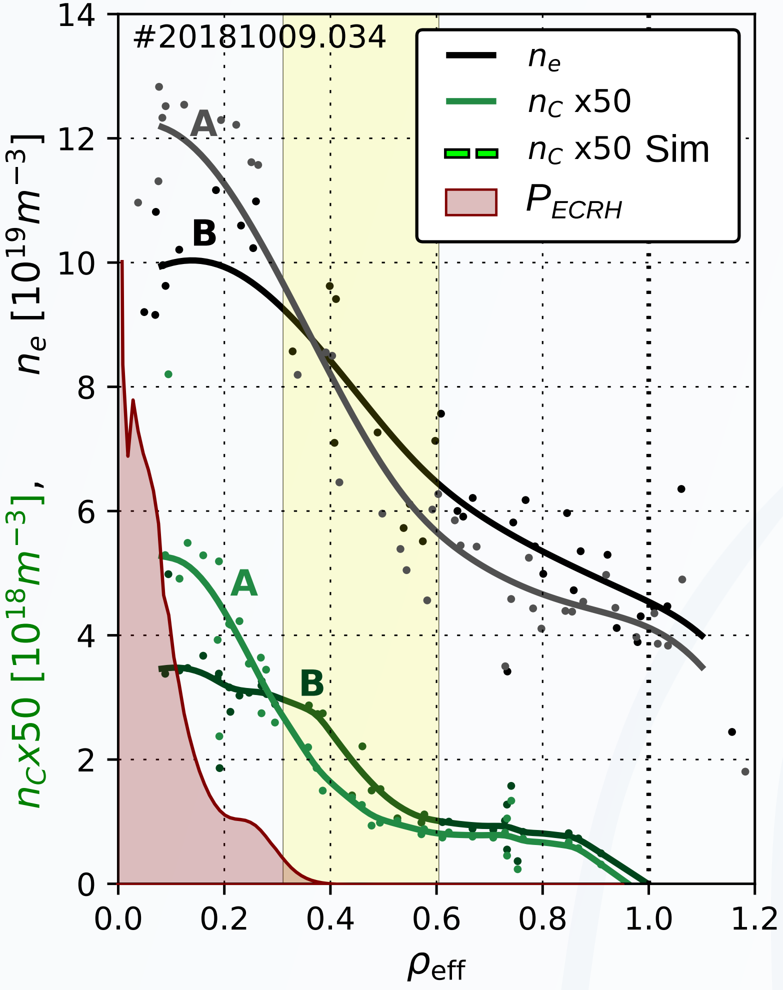

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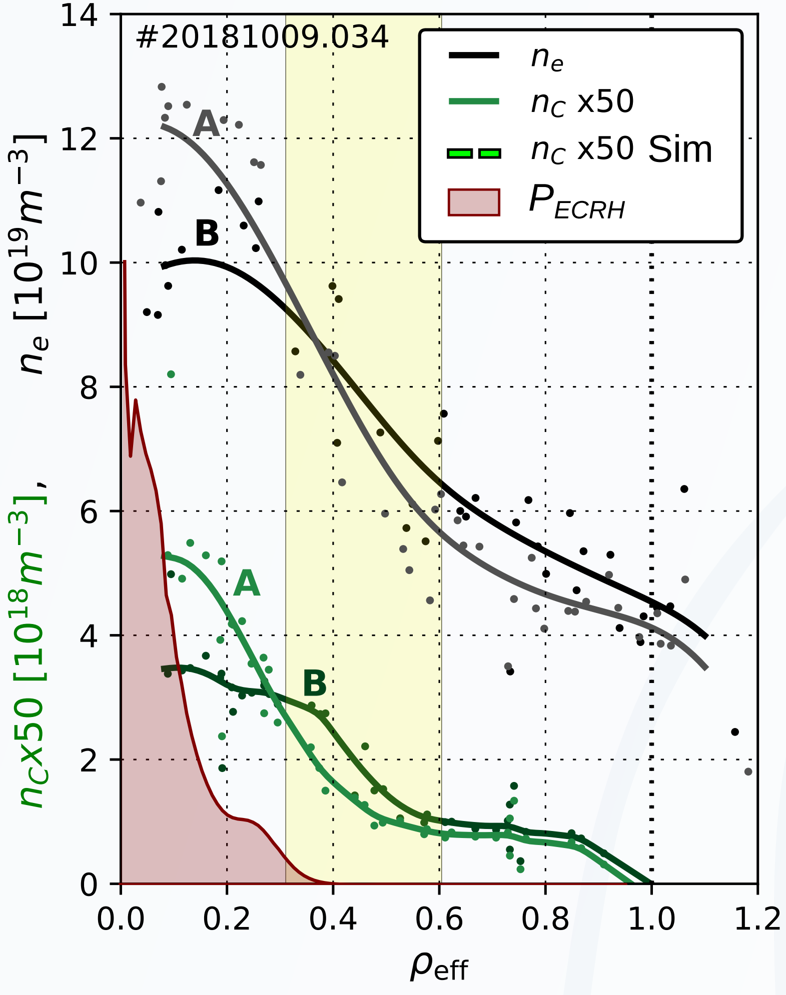

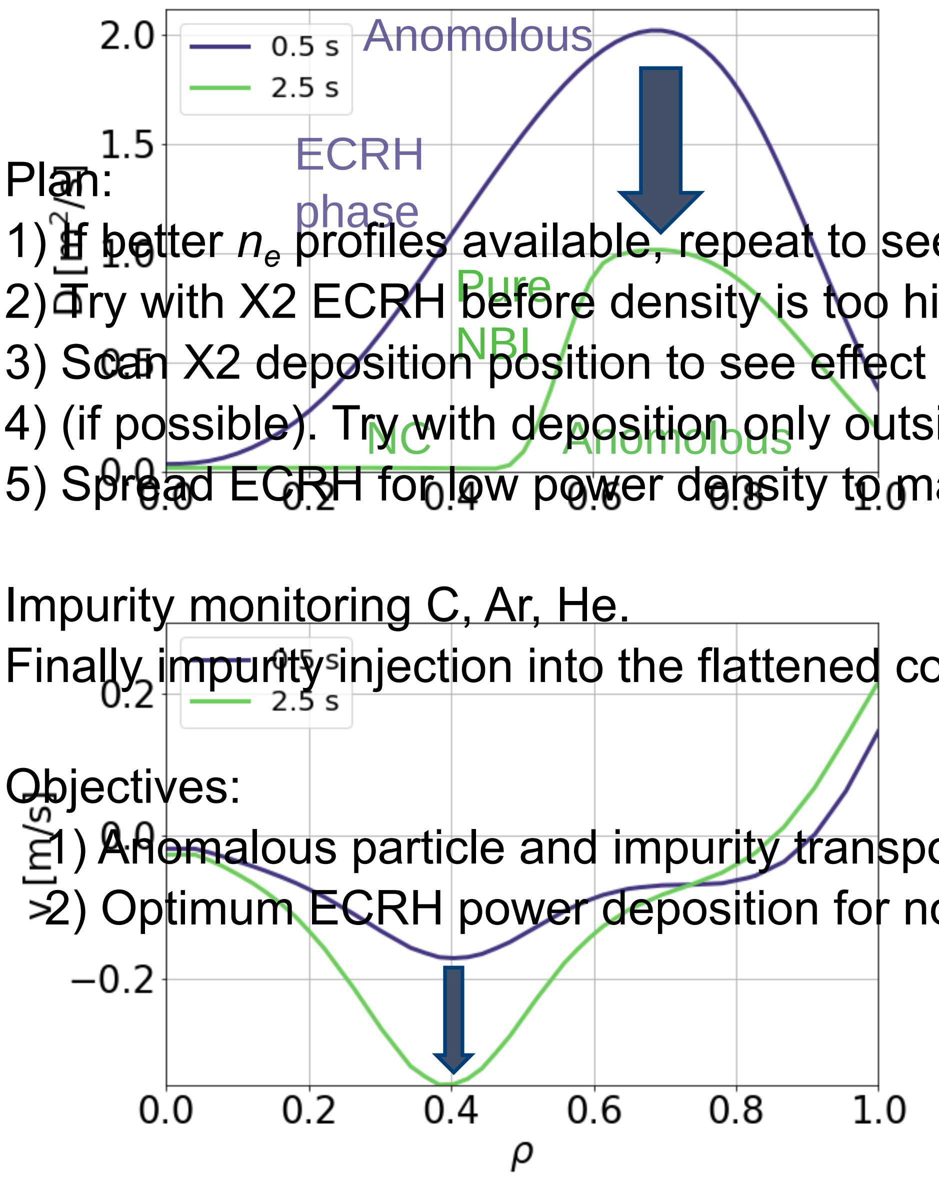

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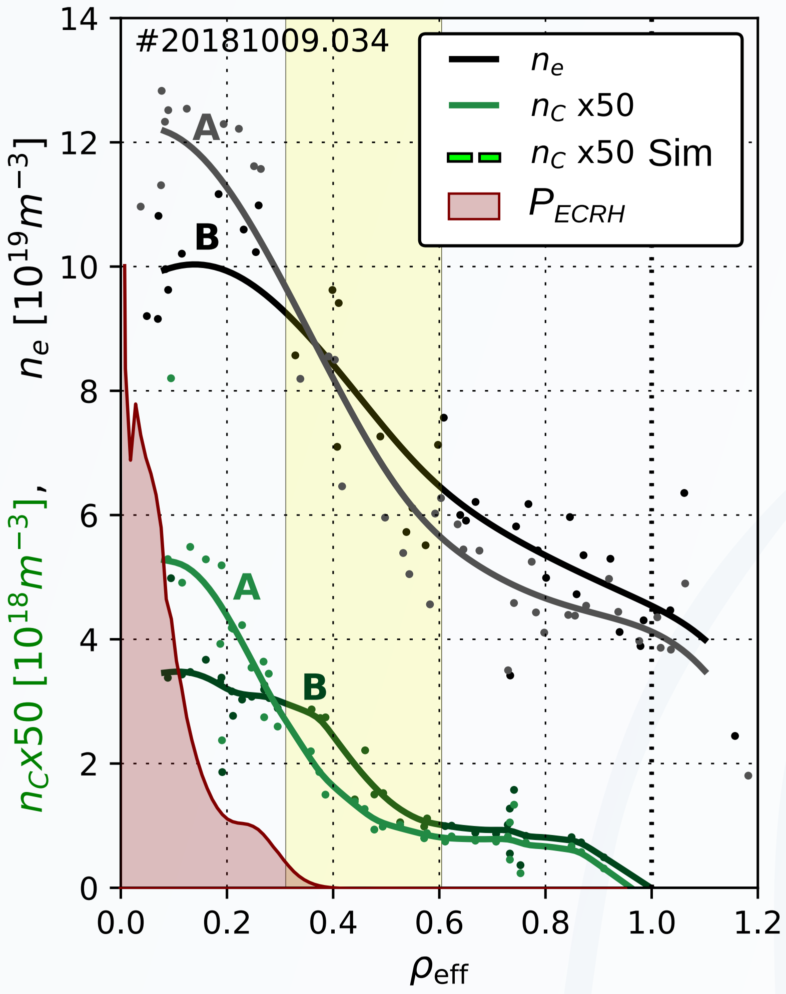

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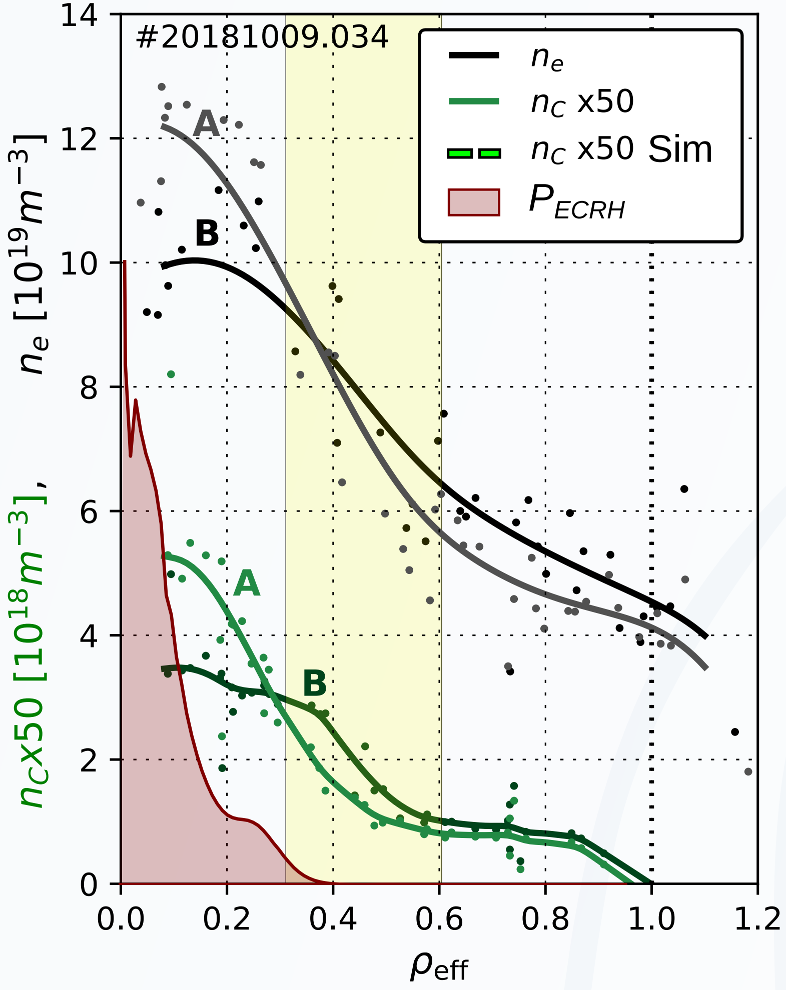

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3) Scan X2 deposition position to see effect on n_Z and n_e.
4) (if possible). Try with deposition only outside $\rho > 0.5$.
5) Spread ECRH for low power density to maximise ne gradient for same P_{ECRH}.

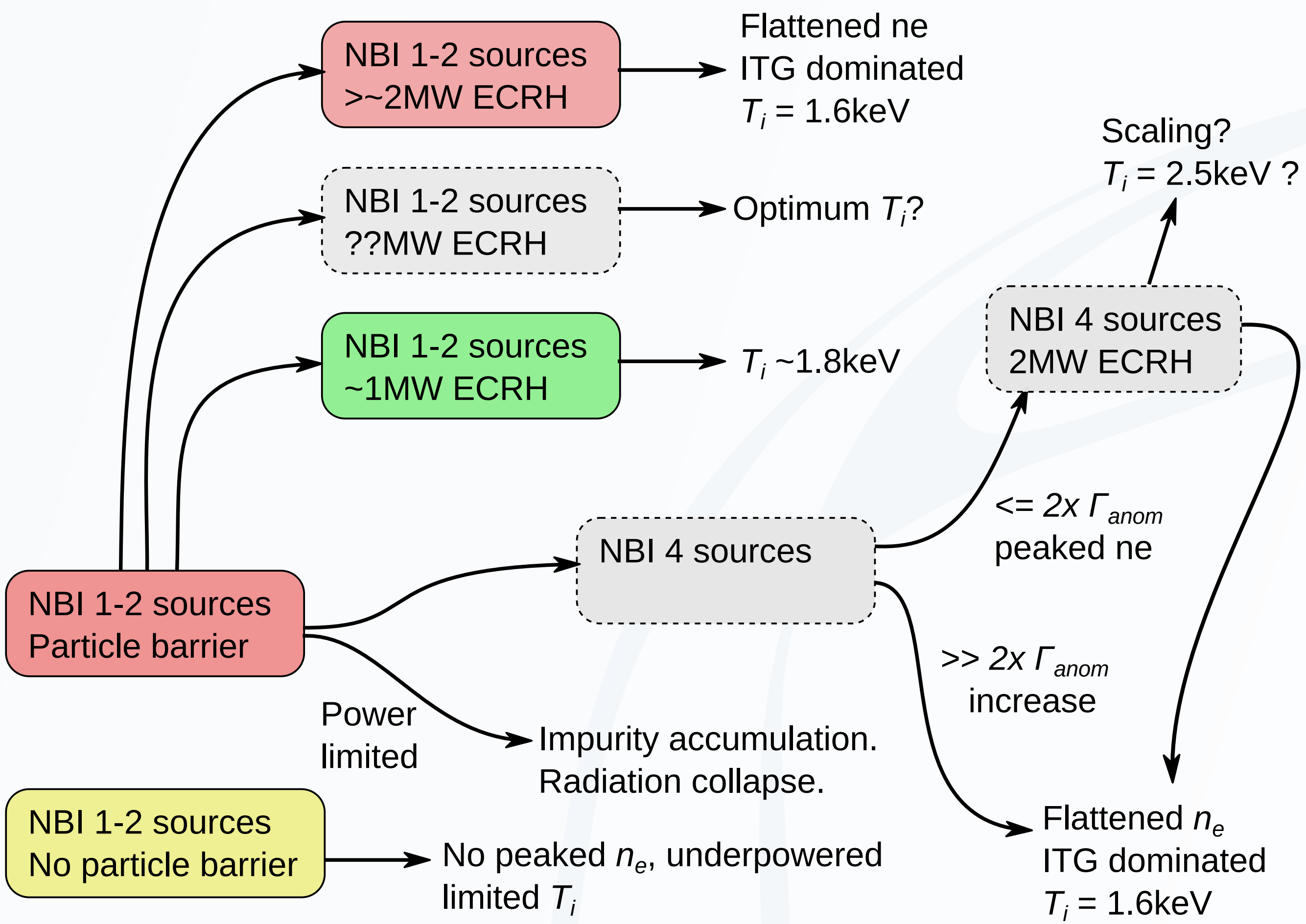
Impurity monitoring C, Ar, He.
Finally impurity injection into the flattened core --> TG Impurities proposal.

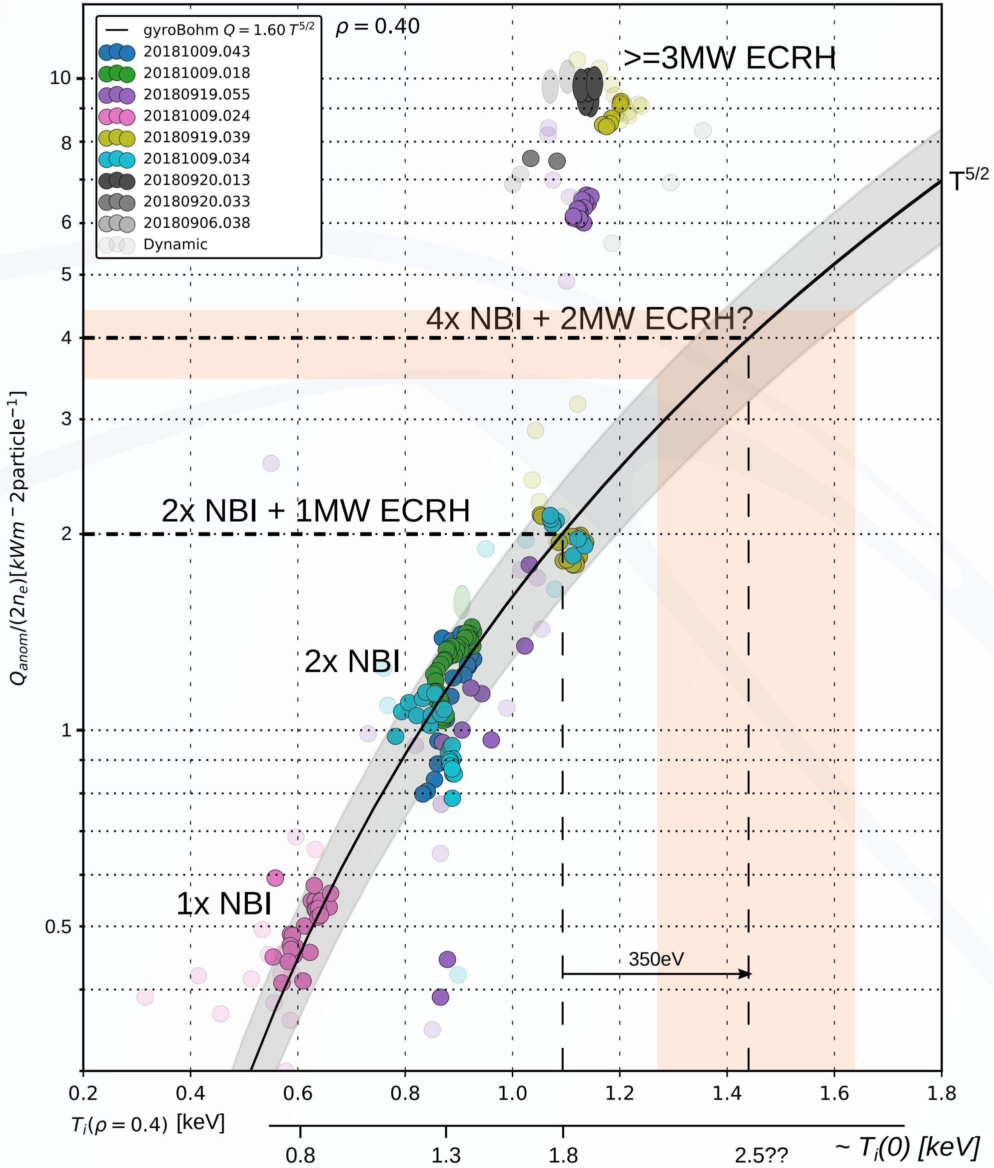
Objectives:

1) Anomalous particle and impurity transport dependance on P_{ECRH} density.
2) Optimum ECRH power deposition for not reducing n_e gradient.

T_i optimisation in NBI +ECRH plasmas.

Direct scenario development to maximise Ti with NBI+ECRH combinations using informaion gathered from other proposals.





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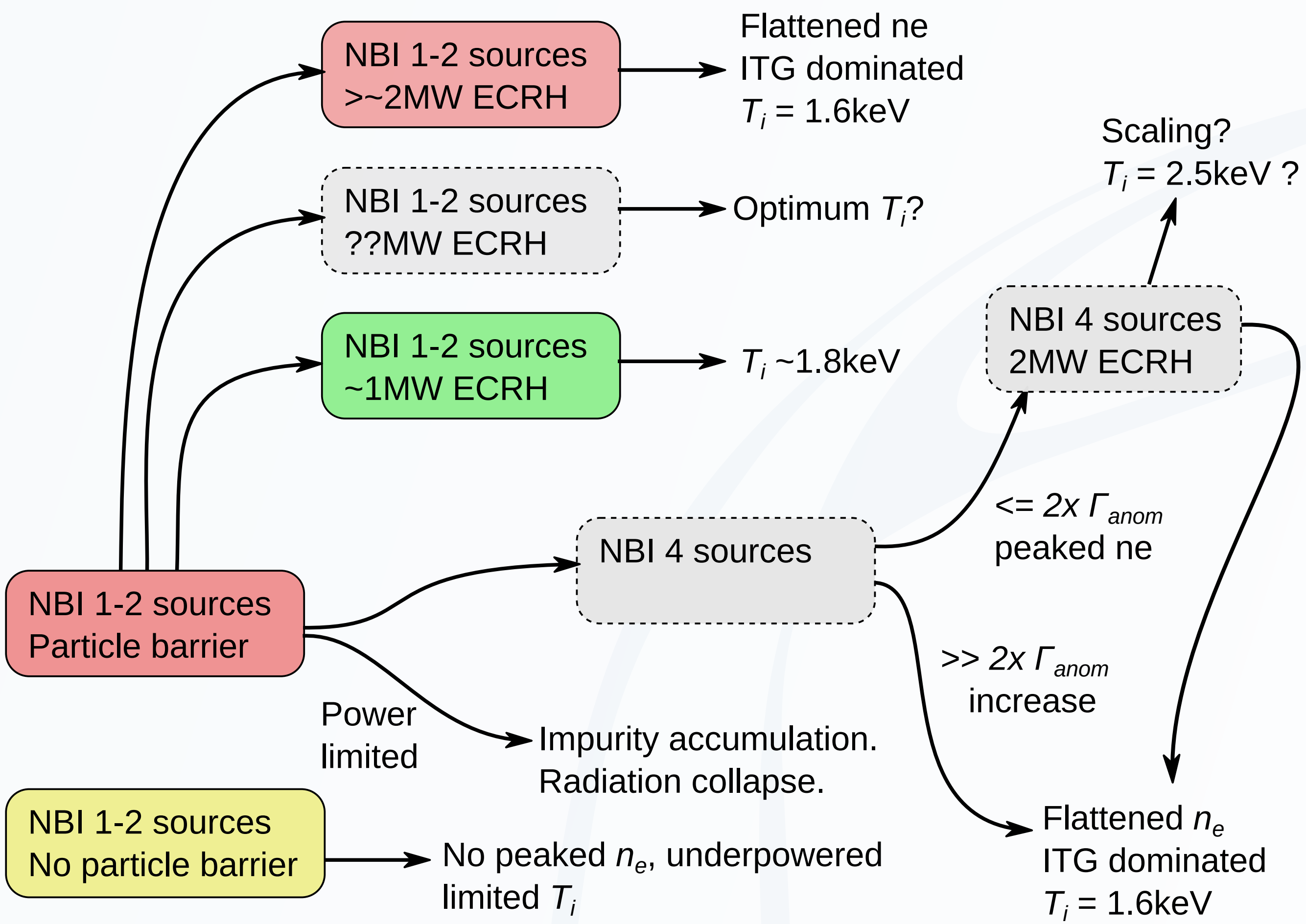

1) Search timing of ~1MW ECRH reintroduction into pure NBI (Q7+Q8) discharge
(inform from proposal "NBI density peaking", X2 vs O2 depends on timing.)

2) At best timing, find best ECRH power in range ~0.5 – 2.5MW
(P_{ECRH} from "NBI+ECRH ITG threshold"
Deposition profile (if X2) from "ECRH pump out")

3) Increase to 4 NBI sources, same optimal P_{ECRH}.
4) Increase P_{ECRH}. Is turbulence threshold now at higher or lower Q?

Hold for max available time, no disturbances.
Optimise for max stable T_i and for max peak T_i.

5) Repeat optimum in NC sub-optimal configuration.

NBI proposals

Proposals related to:

1) Heat and main ion particle transport studies
2) Performance optimisation

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Proposals related to:

3) Execution of new or specific operation

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NBI proposals

Proposals related to:

4) New measurements / use of

Geiger/Swee	NBI heat pulse propagation	Measurements with CXRS. Try to measure Qi.	Measurement	Maybe multiple proposals. Coordinated with Weir:NBI electron transport
Weir	NBI electron channel transport	Heat pulse propagation studies with O2-ECRH modulation	Measurement	Coordinated with Geiger:NBI HPP
Ford	Maximise e-i coupling	Obtained minimum possible Te-Ti to validate and determine offsets of TS, ECE, XICS, CXRS	Measurement	Partially covered by diagnostic commissioning in E3-DIA

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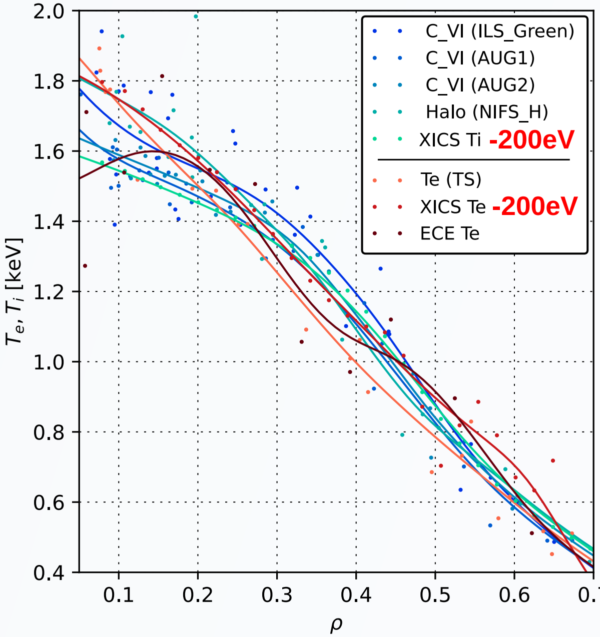
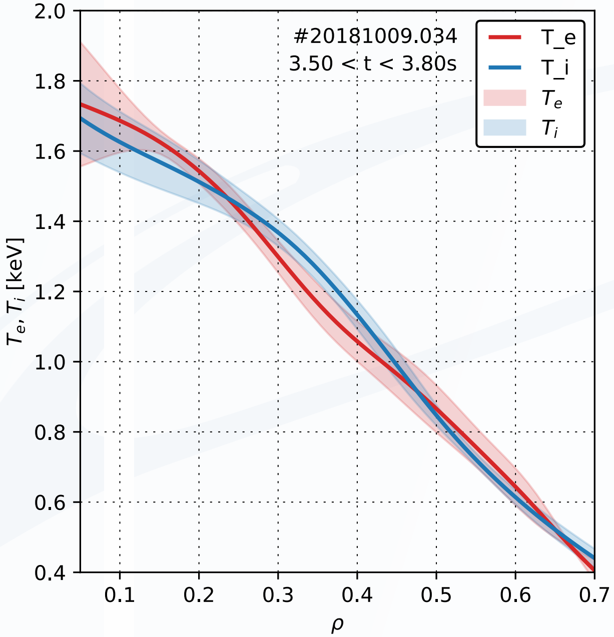
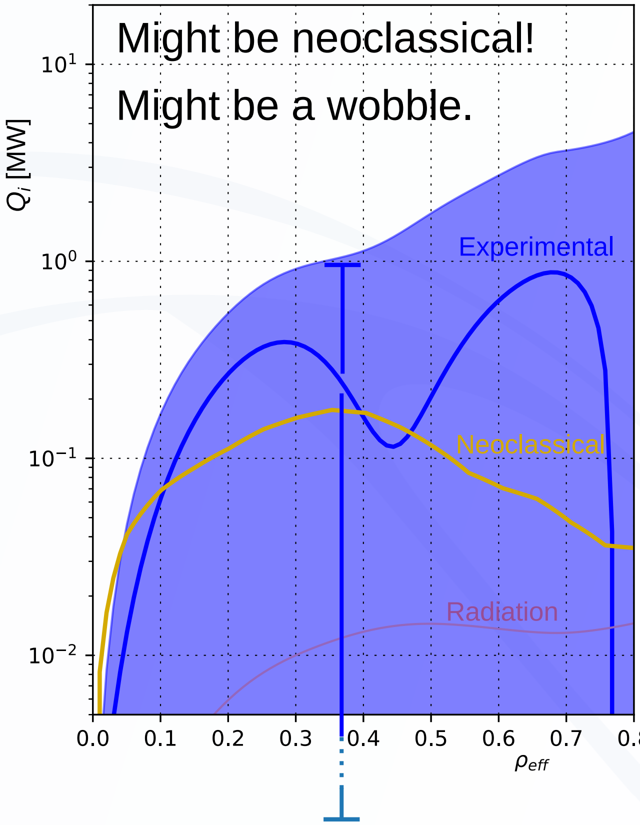
Optimise for electron-ion coupling

- At high collisionality, Q_i and Q_e from power balance only possible if T_e - T_i accurate to ~30eV (definitely not!).
  - Pure NBI: Basically no chance
  - NBI+ECRH: Maybe, a bit:







Plan: - Spread ECRH deposition to minimise local power density.
- Long stable ECRH plasmas with range of densities from just below cut-off to well above with O2.
- Carefully optimise for all diagnostics simultaneously:

XICS: Ar puff. CXRS: Ar and He puffs. NBI blips alternating Q7,Q8,(Q3,Q4) for CXRS

ECE: n_e below cut-off. TS: ....

NBI Proposals

-- End --