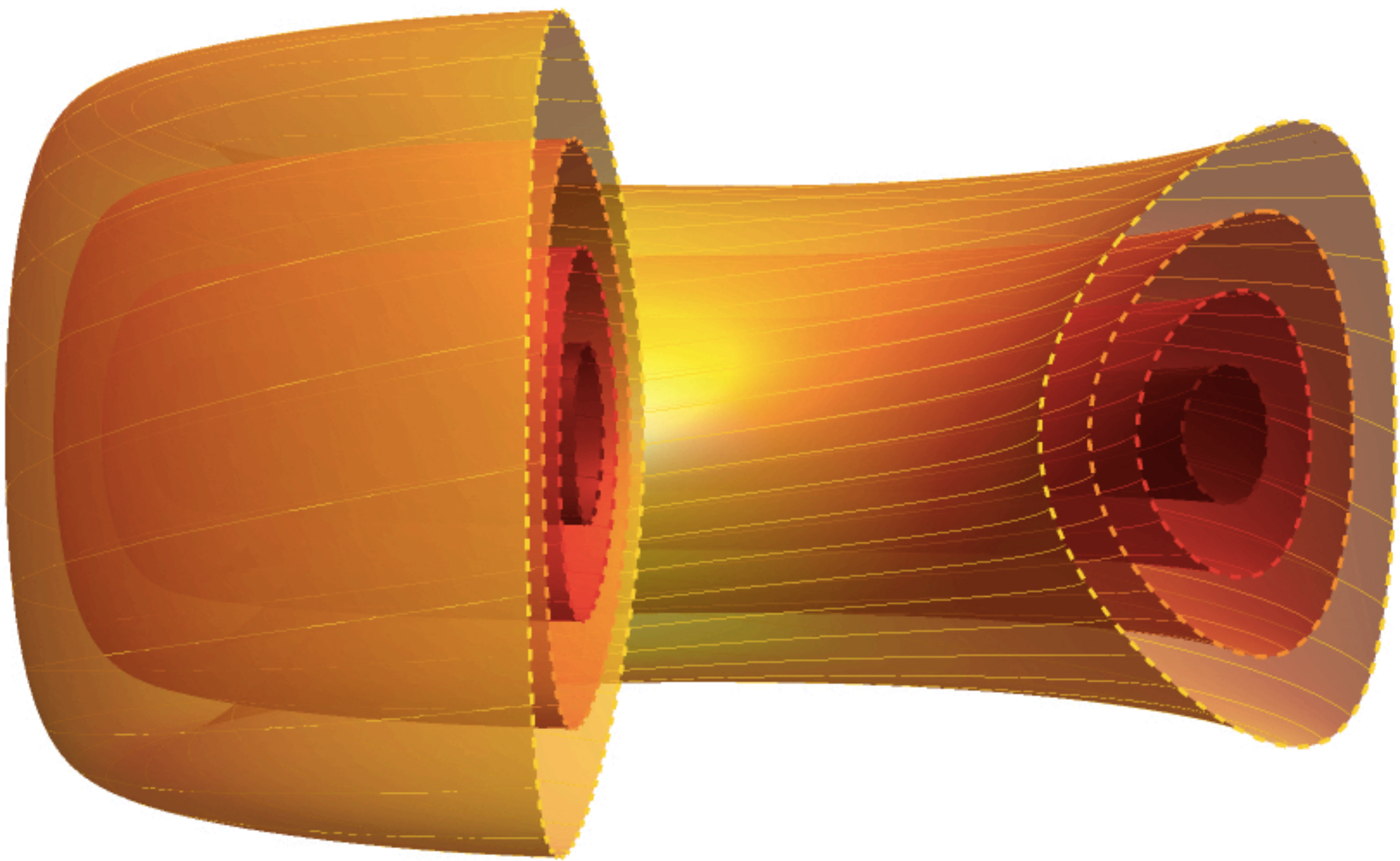
Opening remarks



Justin Ball

2023 Annual TSVV 2 Workshop

17 July 2023

Practical details

- Dinner tonight at 19:30 at Le Petit Port
  - I’ll leave on foot from the lab at 19:00, talking the scenic route along the lake
- Coffee/snacks will be provided in the afternoon breaks (and are always available next door, but you have to pay)
- To give your talk it is easiest to either:
  - connect to the zoom channel and present using your own laptop (with audio via the seminar room computer)
  - upload your talk to the workshop indico page, then download it and present from the seminar room computer

Mid-term gate review **[IMPORTANT]**

- Evaluation by the EUROfusion scientific board to determine if and how the project should continue!!!
- Held on 12 September 2023
- Composed of a 40 minute overview presentation (but no report)
- In our workshop, I'll attempt to summarize and synthesize results to start this process
- Presentation and discussion after the core turbulence, MHD & fast particles, and edge turbulence sections
- Identify what I've forgotten and important gaps we're missing in our project

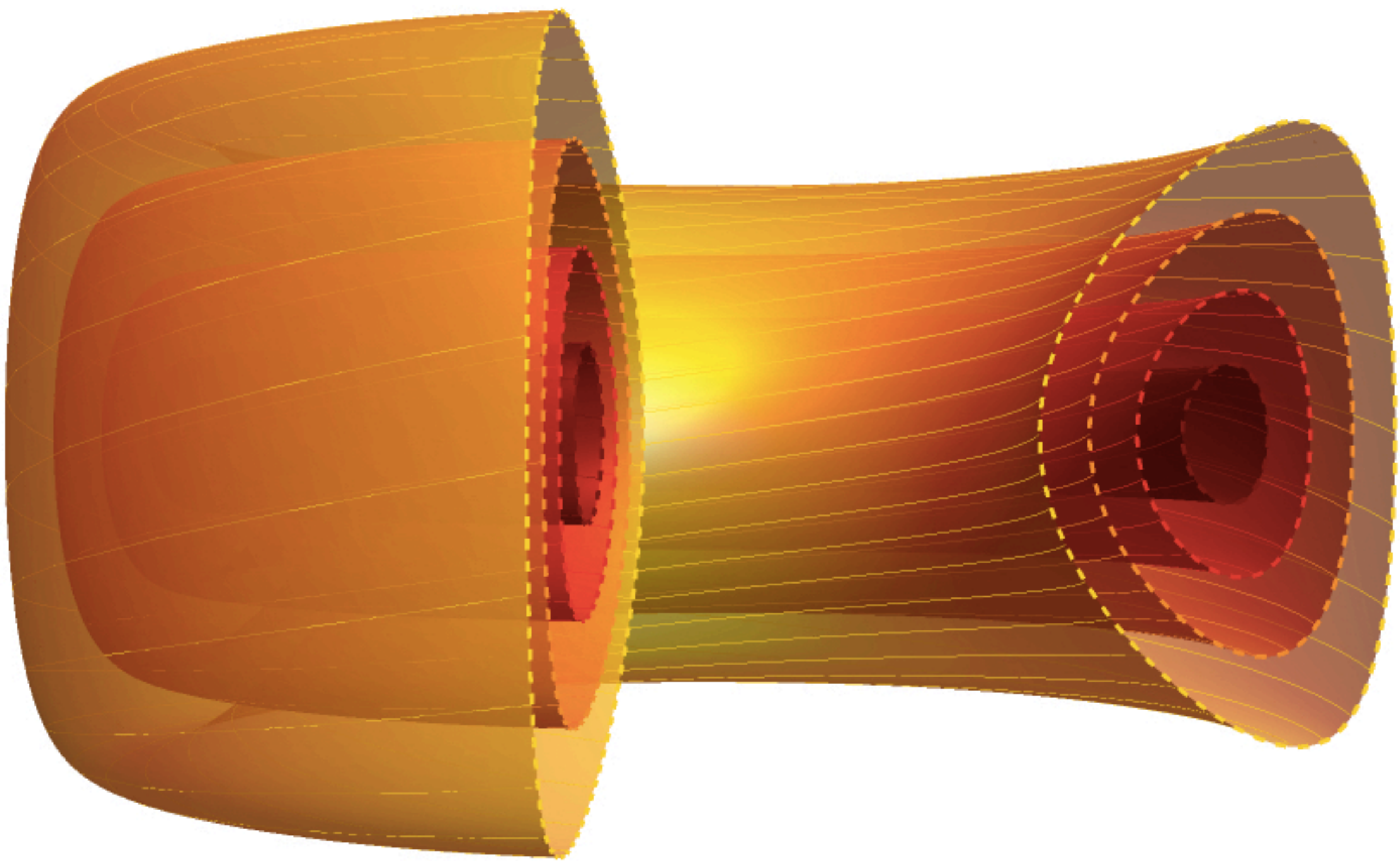
Marconi news: operation extended until July 2024

- Allocation will be “revised” to account for addition of December 2023-February 2024
- 38% through the allocation period (March 2023-**February 2024**)
- 29% of the following conventional A3 allocation has been used:
    - GENE: 440k node-hours = 110k (Alberto) + 155k (Alessandro) + 175k (MJ)
    - GBS: 170k node-hours
    - HYMAGYC: 20k node-hours
    - SOLEDGE3X: 170k node-hours
- 23% of the following GPU C1 allocation has been used:
    - ORB5: 180k node-hours

On to the talks.

(thank you all for your contributions)

State of the art: Core turbulence summary discussion



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2023 Annual TSVV 2 Workshop

17 July 2023

Basics of NT

J. Duff, et al. *Phys. Plasmas* (2021).
A. Marinoni, et al. *PPCF* (2009).
R. Mackenbach, et al. *JPP* (submitted).
G. Merlo, et al. *PPCF* (2015).
G. Merlo, et al. *PPCF* (2023).

- GK simulations generally display a transport reduction in NT for ITG and TEM (holding the background kinetic and q profiles constant) [Alb,Ale,Gio,Jus,MJ,Mackenbach,Marinoni,Merlo2015]
- Usually need kinetic electrons to observe this[Gio,Jus]
- At conventional and large A, we have a physical picture: NT is helpful due to FLR effects as well as a mismatch between the magnetic drift velocity and the ion (or electron) diamagnetic drift velocity for ITG[Ale,MJ,Merlo2023] (or TEM[Ale,Marinoni])
- Nonlinear saturation physics are also considerably different[MJ]
- At constant kinetic and q profiles, the stiffness is almost always similar[Alb,Ale,Jus,Merlo2015], while the critical gradient is different

Validation with experiment

A. Marinoni, et al. *PPCF* (2009).
G. Merlo, et al. *JPP* (2023).

- GK simulations can be consistent with experimental results[Gio,Ale,Jus,MJ,Marinoni,Merlo]
- Can capture the effect of varying X-point and non-X-point triangularity independently in single-null discharges[Ale]
- Do <u>not</u> accurately capture effect of toroidal field or plasma current reversal[Ale]
- Simulation consistent with experiment for extreme δ cases

Parametric dependence of NT

R. Davies, et al. *PPCF* (2022).
R. Mackenbach, et al. *JPP* (submitted).
G. Merlo, et al. *JPP* (2023).

- NT effect is larger at high δ[Jus,MJ], large A[Ale,Jus], high $\hat{s}$[Jus,Merlo,Ale], and high κ [Ale,Jus,Mackenbach]
- In single-null discharges, it might be slightly beneficial for confinement to have positive X-point triangularity[Ale]
- In spherical tokamaks, NT can reduce confinement for TEM[Ale] and KBM[Davies] turbulence, though not for ITG[Ale]
- NT can also reduce confinement for horizontal elongation[Ale]

Scaling to a power plant

R. Davies, et al. *PPCF* (2022).
G. Merlo, et al. *JPP* (2023).

- Finite machine effects (i.e. profile shearing) scale similarly between NT and PT in flux tube simulations with non-uniform magnetic shear[Jus] and global simulations[Gio?]

- Global simulations of experimental scan at constant heating power indicate NT is more affected by global effects[Merlo], but the gradients are steeper in NT due to its better confinement

- At conventional aspect ratio, finite β effects similar in NT and PT[MJ,Alb] (holding the background kinetic and q profiles constant)

- MTM[Ale] and KBM[Davies] seem stronger for NT in spherical tokamaks

- KBM turbulence much stronger for L-mode rather than H-mode profiles[Alb]

Reduced modeling

- ASTRA-TGLF with SAT2 successfully benchmarked against GENE[Pao,Alb]
    - NT sometimes shows a confinement improvement, but more often shaping has no effect[Pao]
- Might be consistent with most of the confinement improvement for NT coming from $\rho > 0.9$?
    - Still useful to look at fluxes as a more sensitive indicator?

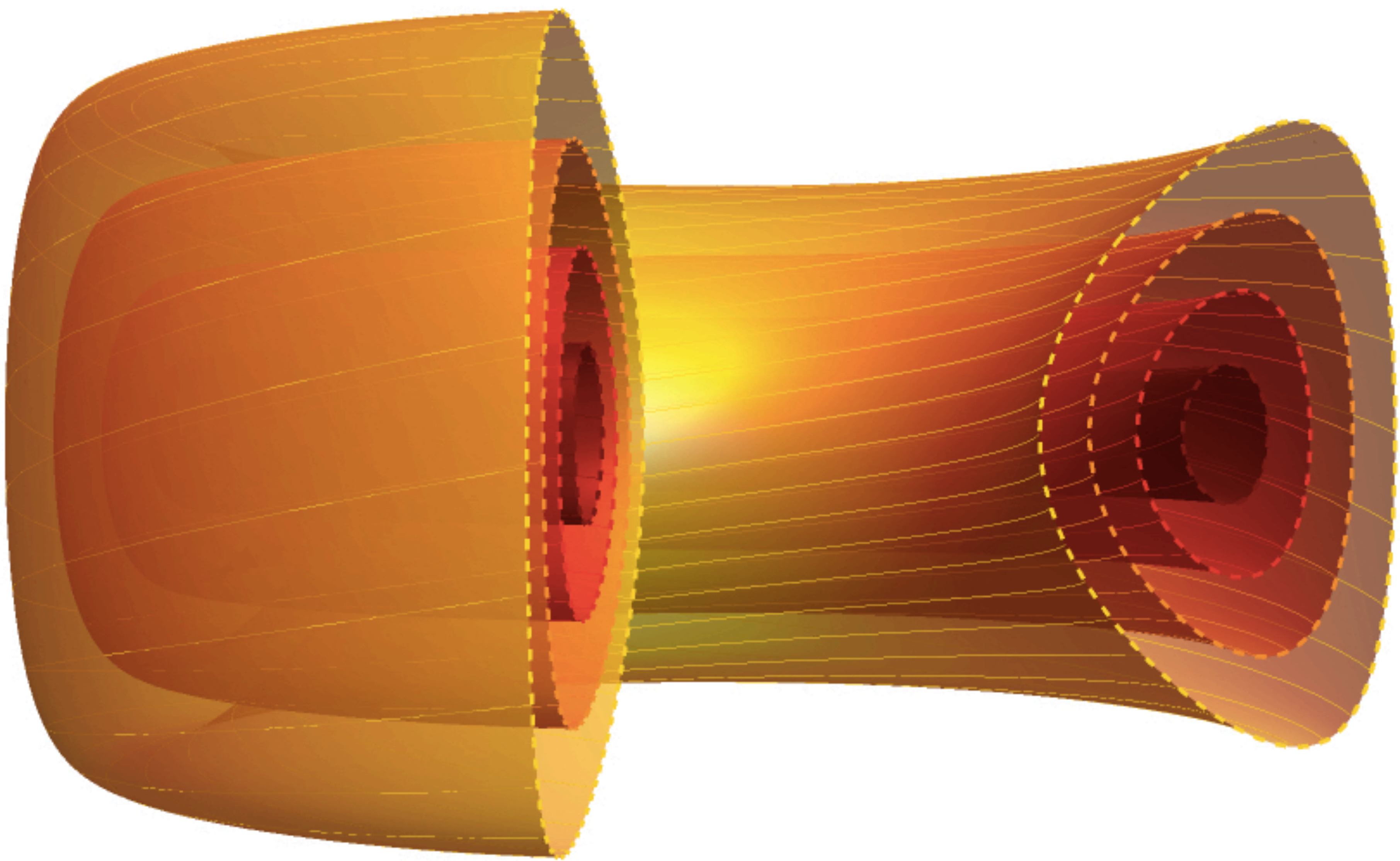
Areas of priority

- Electromagnetic turbulence:
  - EM turbulence seems significantly worse for NT in spherical tokamaks
  - there may be a significant difference between L- and H-mode profiles[Alb]
- We tend to focus on constant gradient comparisons, but one is really considering L-mode NT against H-mode PT
- Impurities: Any results so far? Alberto's paper? Alessandro? Julien Dominski?
- ASTRA-TGLF benchmarked against GENE for DTT, but issues for DTT-like shapes in TCV
  - Does DTT NT really not recover the pedestal? Could GENE be wrong or effect only arises from $\rho > 0.9$? Look at geometric coefficients
- Reactor-scale equilibria would be useful

Announcements

- Please upload talks to indico (or just email to me)
- Depart from here at 19:00 for dinner
- Change to the schedule: talks don't start until 09:30 tomorrow, but this room is available to work/discuss in

State of the art:
MHD & fast particles summary discussion



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2023 Annual TSVV 2 Workshop

18 July 2023

Alfven eigenmodes

P. Oyola, et al. *IAEA* (2023).
A. Karpushov, et al. *EPS* (2023).

- Fast particle-driven Alfven eigenmodes seem either unaffected[Mishchenko] or stabilized[Oyoda] in NT, which appears consistent with experiment[Oyoda,Karpushov]
- Fast ion losses resulting from Alfven eigenmodes are smaller[Oyoda], which appears consistent with experiment[Oyoda,Karpushov]
- Density and safety factor profile effects might be the most important

Pedestal ballooning stability

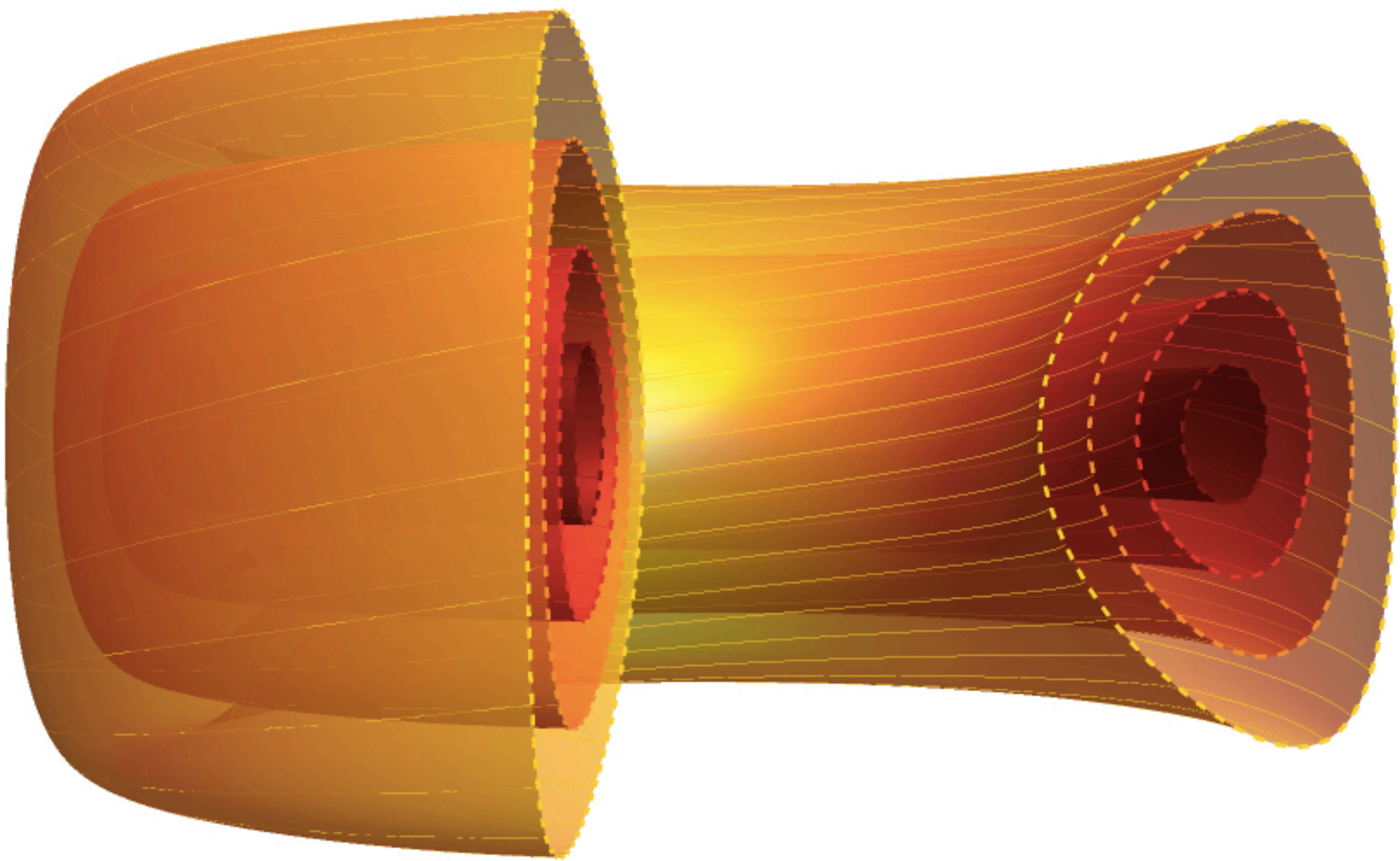
S. Saarelma, et al. *PPCF* (2021).
O. Nelson, et al. *Nucl. Fusion* (2022).
O. Nelson, et al. *arXiv* (2023).

- Experimentally NT plasmas don't transition to H-mode
- Can be understood through infinite-n ballooning stability[Ant,Oli,Saarelma,Nelson], which is affected by the local magnetic curvature[Oli,Nelson]
- If the maximum (or negative?) in the local magnetic shear can reach the good curvature region, then access to the 2nd region of ballooning stability is possible, enabling the transition to H-mode[Oli,Nelson]

Areas of priority

- Kink MHD stability with KINX and validation against TCV experiment
- Kinetic corrections to MHD stability
- Fast ion confinement, tearing stability, and their interplay with XTOR
- Study fast ion deposition and impact of changes in density and q profiles on the Alfven eigenmode drive
- Need to investigate external kink stability, but internal kink studied by Martynov at EPFL

State of the art:
Edge turbulence summary discussion



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SOL decay width

E. Laribi, et al. *Nucl. Mater. Energy* (2021).
D. Silvagni, et al. *PPCF* (2020).

- Compared to PT L-mode, SOLEDGE, GBS, TOKAM3X, and a theory-based scaling law (consistent with experimental database) all indicate that NT has a ~30% narrower SOL width when $\delta = 0.3 \rightarrow -0.3$[Kyu,Pao,Laribi]

- SOL width in PT H-mode can be a factor of two narrower than for PT L-mode[Silvagni]

- Change in particle diffusion is more dramatic than for energy diffusion?

- Regardless of geometry or regime, cross-field transport is significantly correlated across the separatrix?

- Thus, NT L-mode has longer τ_E than PT L-mode so it will have a narrower λ_q, but the confinement improvement isn't localized in a narrow pedestal just inside the separatrix so it will have a broader λ_q than PT H-mode

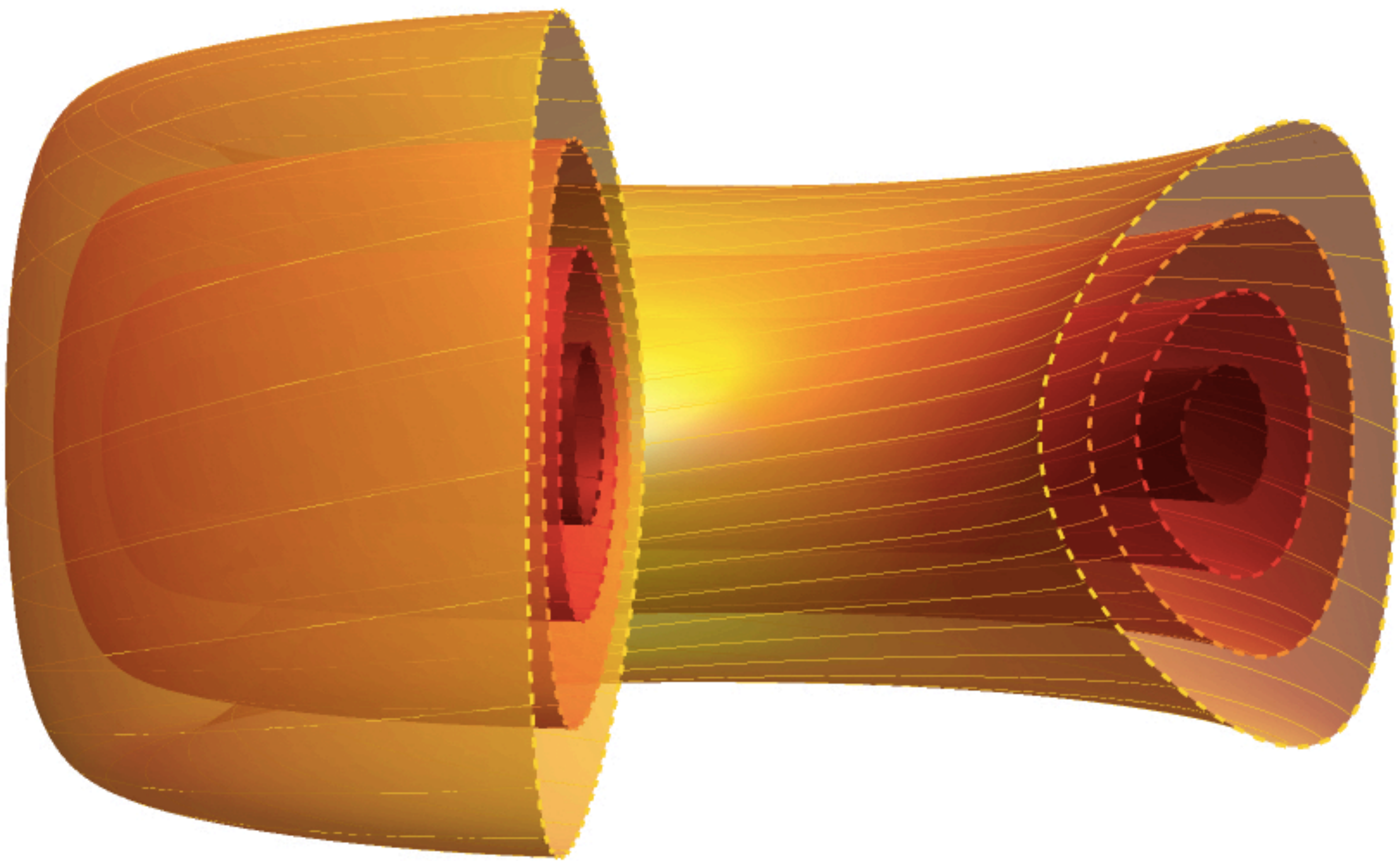
Detachment

- Harder to achieve in NT[Tonello]

Areas of priority

- Extrapolation to a power plant (potentially with theory-based GBS scaling law or TCV->AUG->DTT SOLEDGE2D study)
- SOLPS can maybe study detachment
- Can we use these edge simulations to provide a better boundary condition for the core reduced modeling?
- Behavior in single versus double-null (as core turbulence suggests they may be substantially different[Ale])
- Can differences in SOL behavior explain experimental study changing the direction of the toroidal magnetic field and plasma current? SOL codes need to use drifts to see any effect, but they are often found to be small

Milestone summary discussion



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2023 Annual TSVV 2 Workshop

18 July 2023

Announcements

- Please upload slides on indico (or email to me)
- Special issue on NT in Nuclear Fusion edited by M. Kikuchi
  - Deadline at the end of November

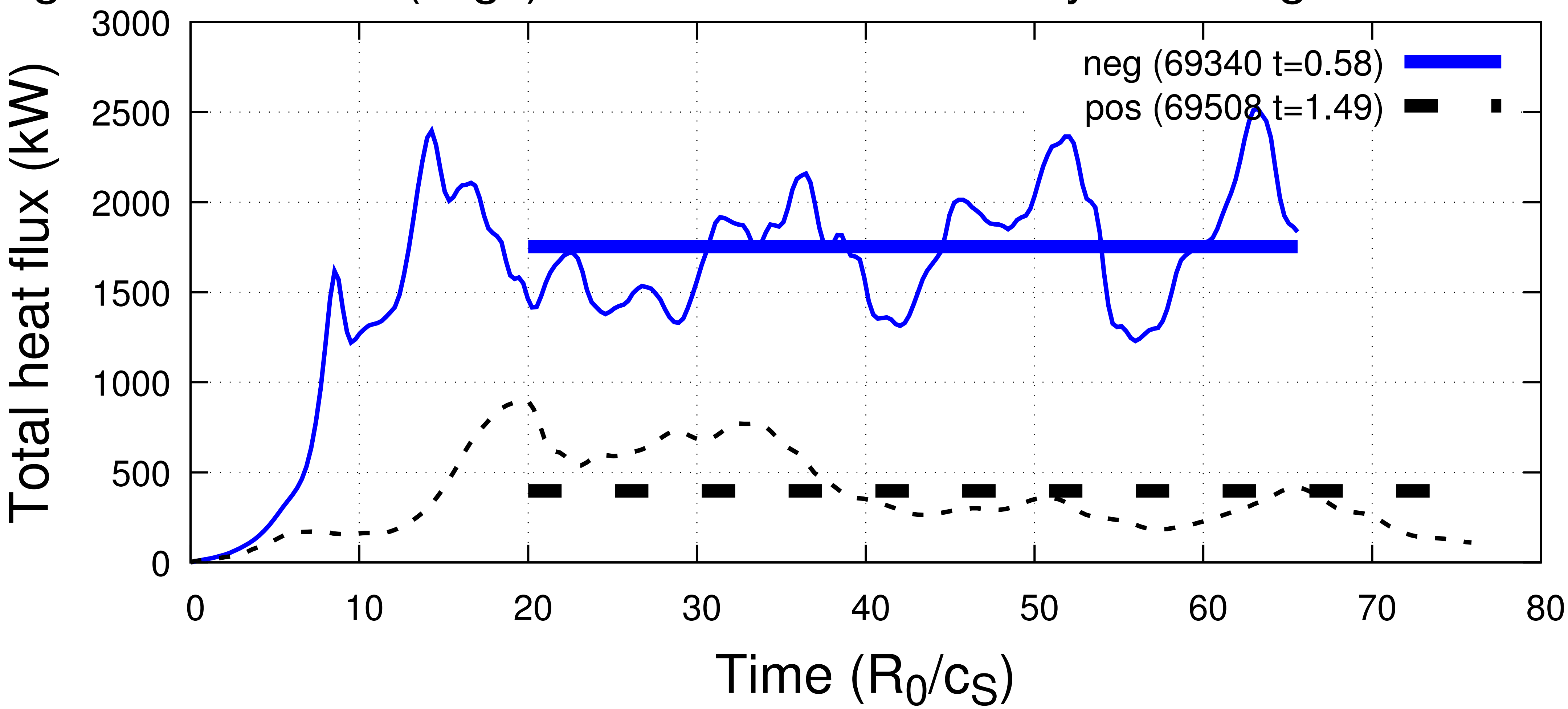
Deliverable 1 summary — turbulent transport

Milestone	Description	Participants	Target date
M1.1.1	Use local electrostatic GK simulations to assess magnetic equilibria and plasma profiles for consistency with design objectives	J. Ball	02.2021
M1.1.2	Perform local electrostatic GK simulations of PT and NT equilibria and swap individual geometric coefficients and plasma parameters to identify the dominate terms	J. Ball	08.2021
M1.1.3	Perform comprehensive study of critical gradient and stiffness as a function of minor radius using local GK simulations	J. Ball	12.2021
M1.1.4	Investigate possibility of further improvements using other plasma shapes	J. Ball, G. Di Giannatale	12.2025
M1.2	Integrate findings from the ERG on global flux driven GK simulations of TCV-like NT discharges (including impurity transport) into this TSVV; specifically comparing trends against the GENE results when possible	P. Donnel, J. Ball	8.2022
M1.3.1	Perform GBS simulations to understand the effect of plasma triangularity on single-null configurations with no neutrals	K. Lim	12.2021
M1.3.2	Perform GBS simulations to understand the effect of plasma triangularity on double-null configurations with no neutrals	K. Lim	12.2022
M1.3.3	Perform GBS simulations to understand the role of neutral dynamics on single- and double-null configurations in negative-triangularity plasmas, exploring the detachment regimes	K. Lim	12.2023
M1.3.4	Perform GBS simulations to understand the effect of plasma triangularity on alternative exhaust configurations	K. Lim	12.2025
M1.4	Predictive simulations using SOLEDGE3X for power exhaust on NT DTT L-mode discharges	P. Muscente	6.2024

Deliverable	Description	Participants	Target date	Evidence of achievement
D1.1	**Report*** on properties of core and pedestal turbulent transport in NT as compared to PT, in particular identifying the important physical effects responsible for the difference	J. Ball, G. Di Giannatale	12.2022	See pinboard ID 34331, 32978, paper, conference proceeding, conference contribution
D1.2	Report on properties of power exhaust in current NT experiments as compared to PT	K. Lim, P. Muscente	12.2022	See pinboard ID 34453 and conference contribution
D1.3	Report on power exhaust prospects for NT reactors as compared to PT	K. Lim, P. Muscente	12.2024	N/A
D1.4	Report on using understanding of NT to optimize the plasma shape further	J. Ball, G. Di Giannatale	12.2025	N/A

M1.1.1: Use local GK to assess exp. consistency

- At first simulations of TCV equilibria dramatically disagreed with experiment, but agreement within (large) error bars was found by including collisions



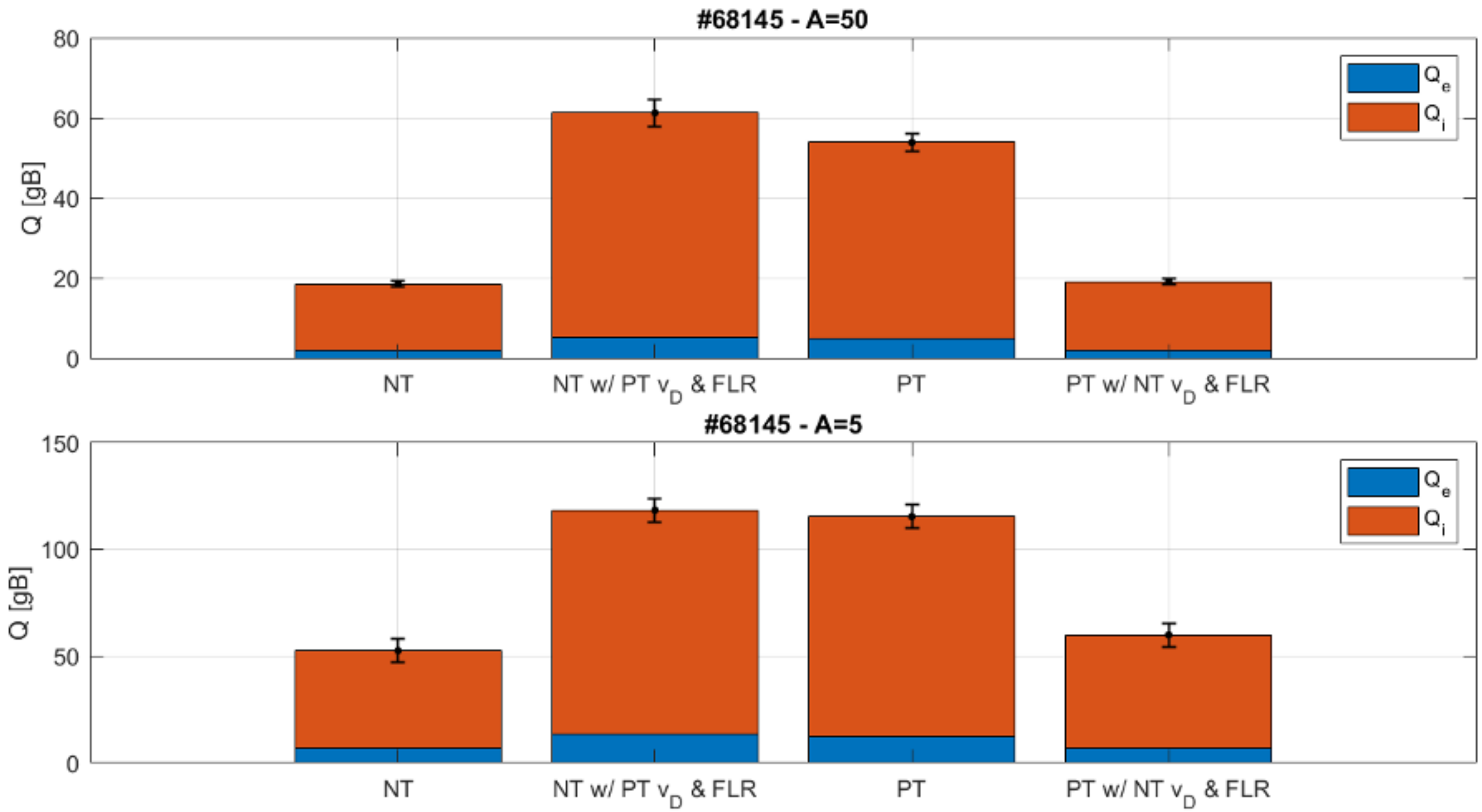
Description	Constants of comparison	Machine	Discharge	Time (sec)	elong	delta	betaN	P_nbi (kW)
Diverted, PT	Ip, betaN, ne	TCV	69508	1.49	1.43	+0.28	1.12	735
Diverted, NT	Ip, betaN, ne	TCV	69340	0.58	1.42	-0.28	0.97	362

M1.1.2: Swap geo. coeff. to find dominant terms

A. Balestri, et al. *EPS* (2023).

J. Parisi, et al. *Nucl. Fusion* (2020).

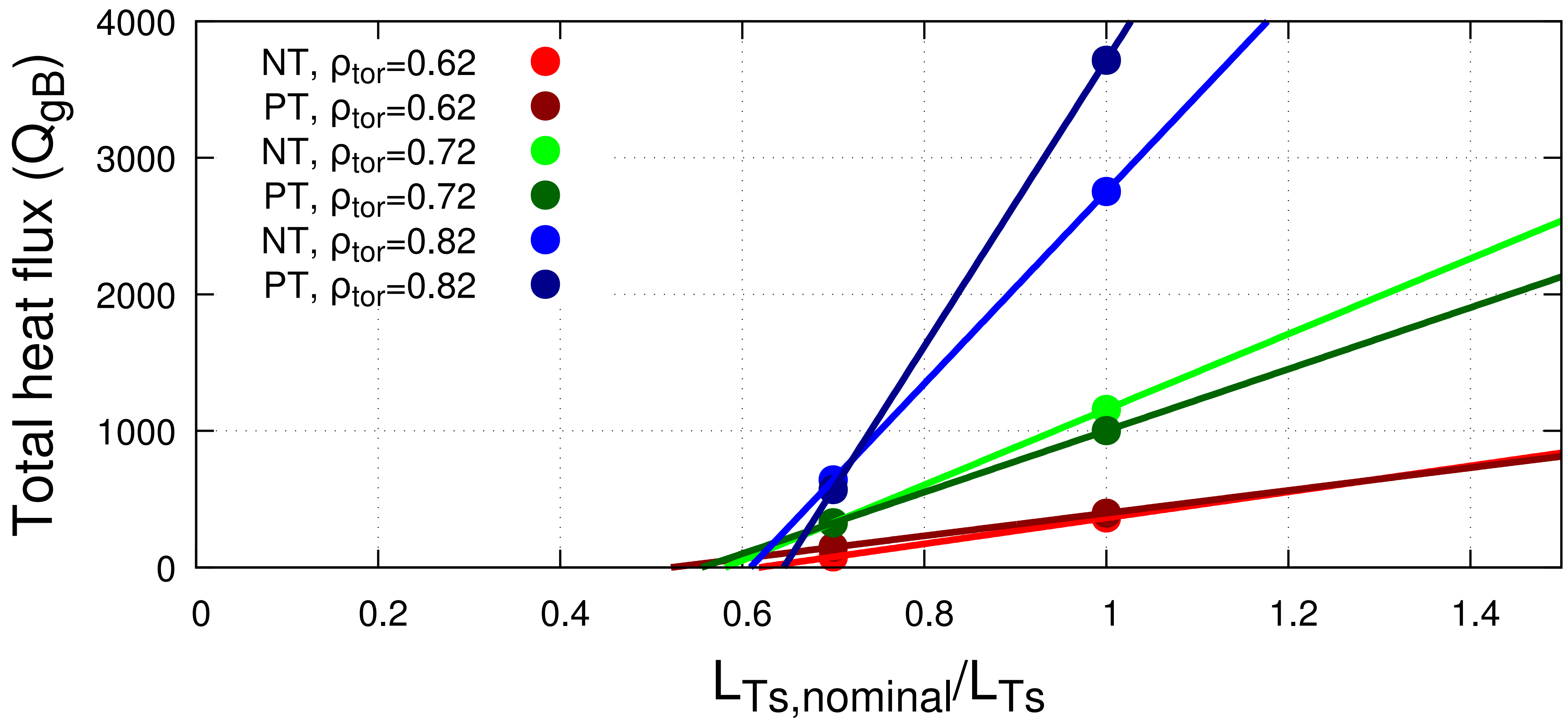
- Key to develop understanding was to first look in the large aspect ratio limit
- Physical picture shows that magnetic drifts and FLR effects are dominant
- Also studied aspect ratio A dependence, revealing NT can be harmful in spherical tokamaks



M1.1.3: Critical gradient and stiffness study

J. Ball, et al. *EUROfusion IDM* PMI-5.2.1-T050 (2020).
G. Merlo, et al. *PPCF* (2015).

- When effect of δ is isolated, profile stiffness is similar, critical gradients less so
- True for ITG-dominated EU DEMO scenarios (below), idealized pure ITG cases, Merlo's original TEM TCV cases



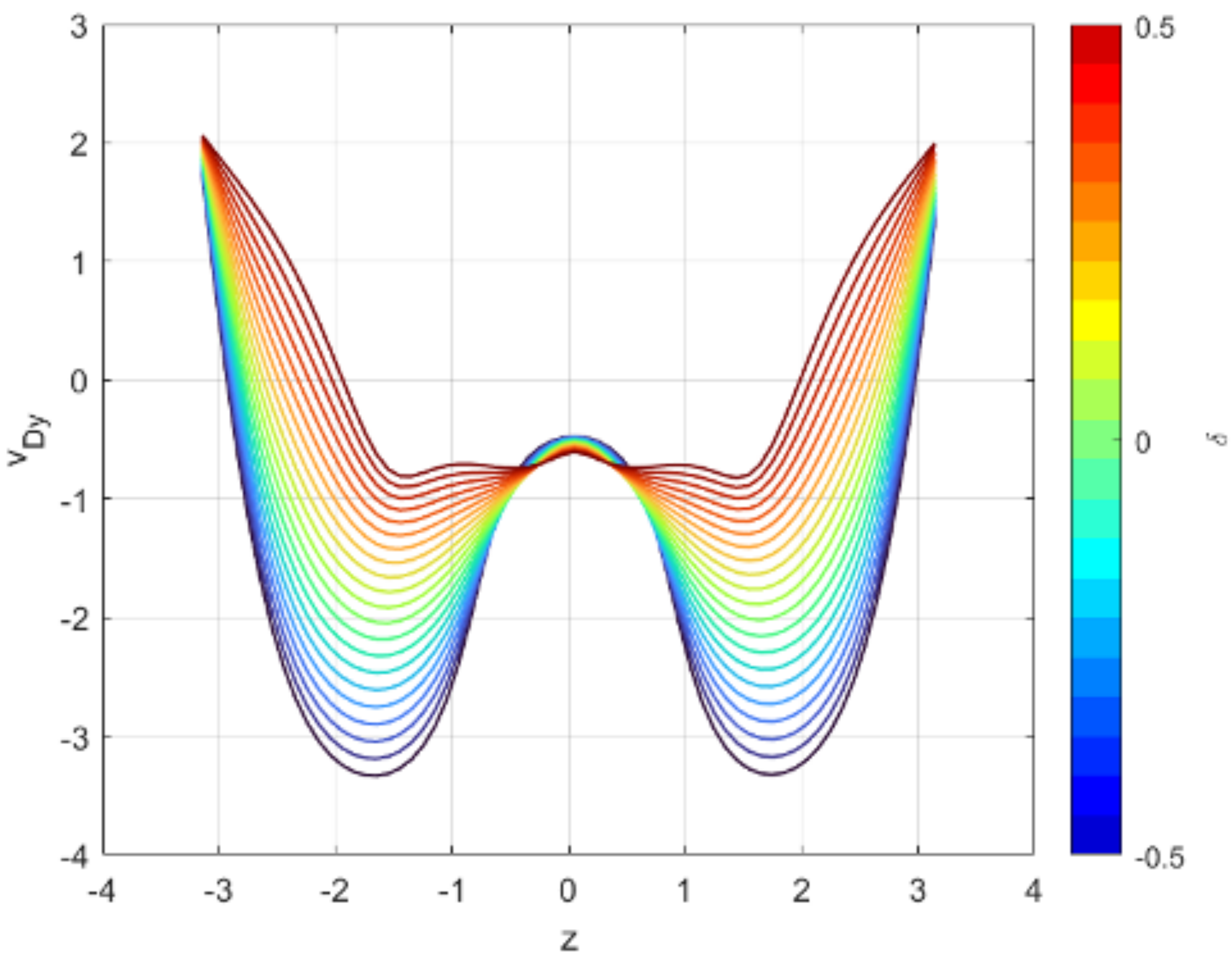
M1.1.4: Investigate improvements beyond NT

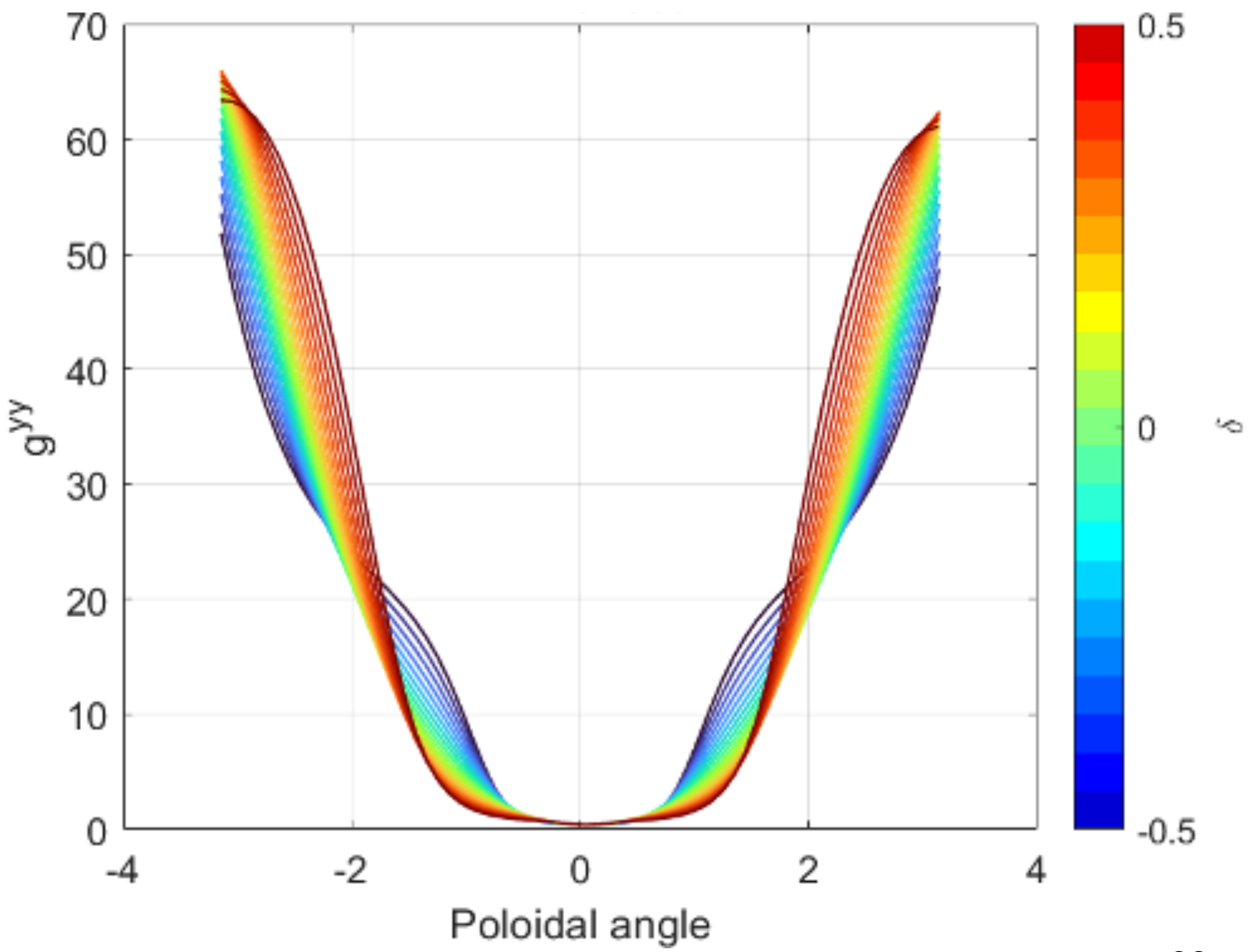
A. Balestri, et al. *EPS* (2023).

J. Parisi, et al. *Nucl. Fusion* (2020).

- Physical picture from M1.1.2 can be used to quickly evaluate other shapes in the large aspect ratio limit

- So far nothing obviously better, but haven't looked too much



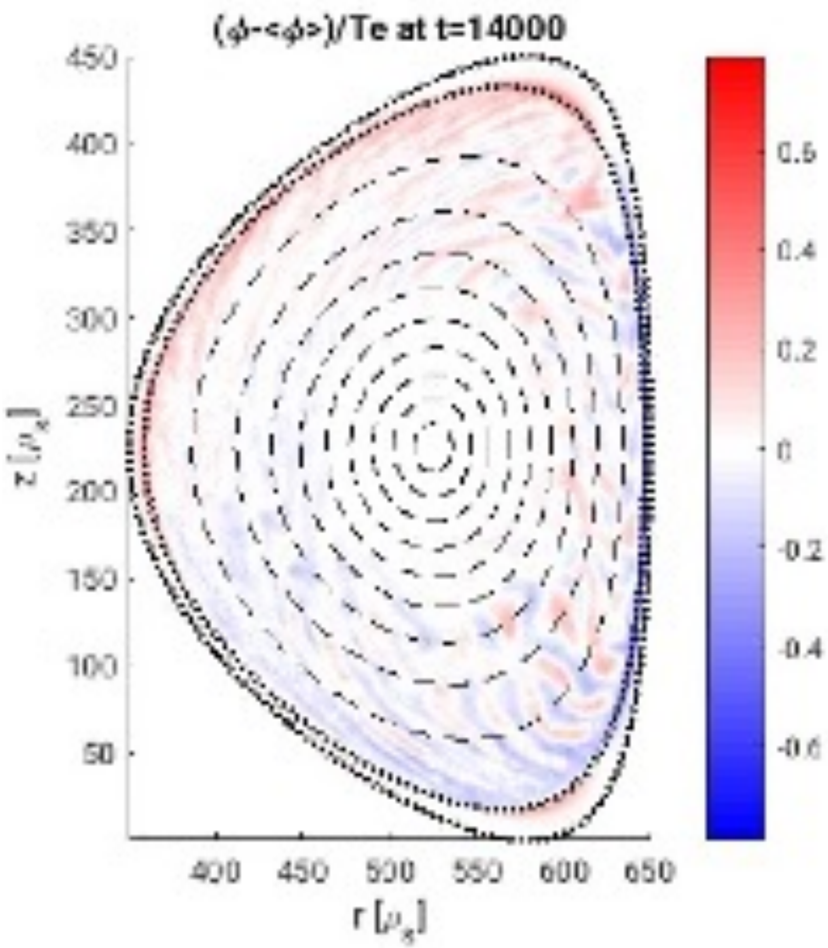


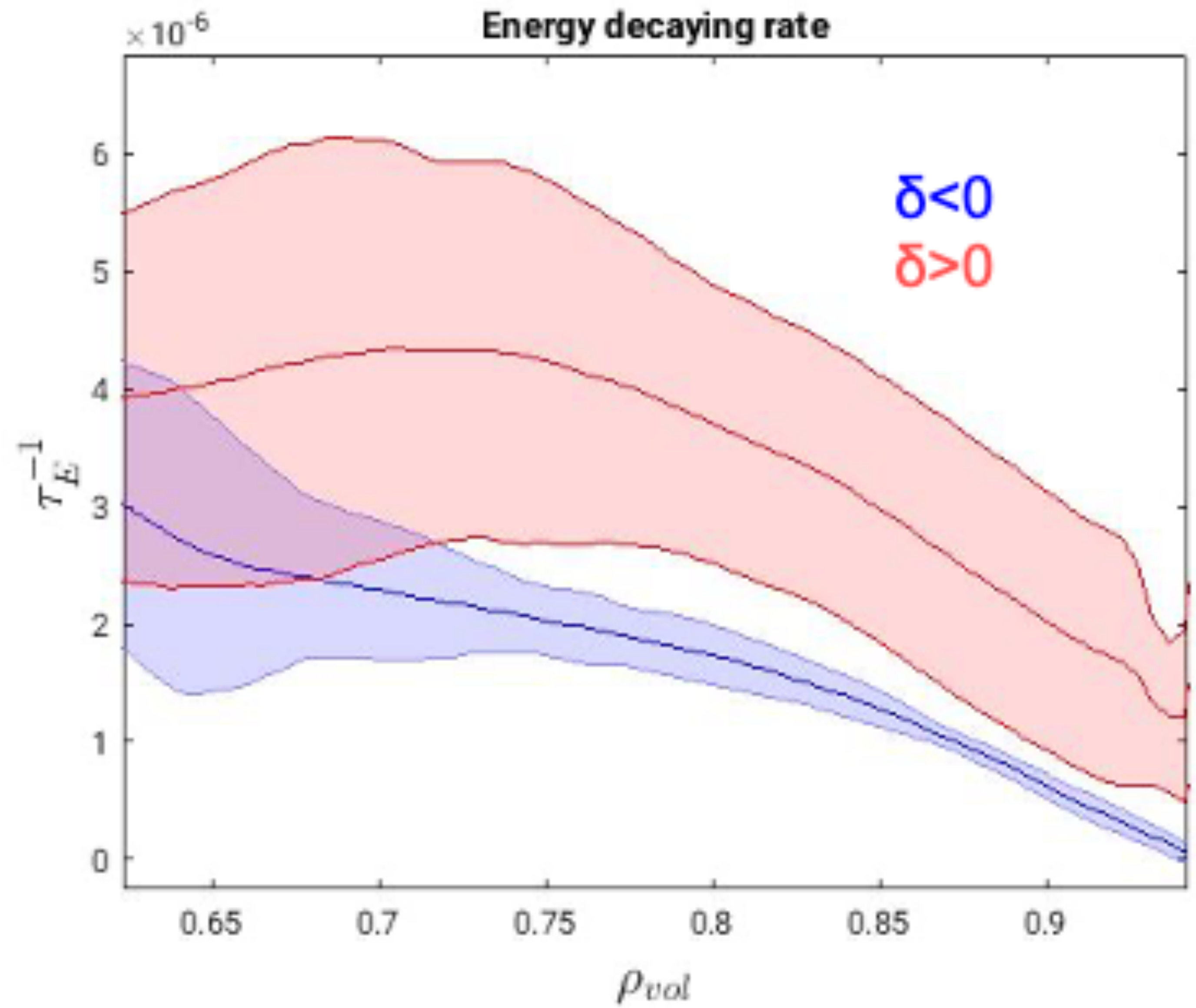
M1.2: Integrate findings of ERG

P. Donnel. *EUROfusion IDM TRA-ERG.AWP20.EPFL* (2022).

- Initial ORB5 simulations indicate improved confinement in NT, but needed to model at least trapped electrons kinetically and collisions were also important

- Not in quasi-steady state

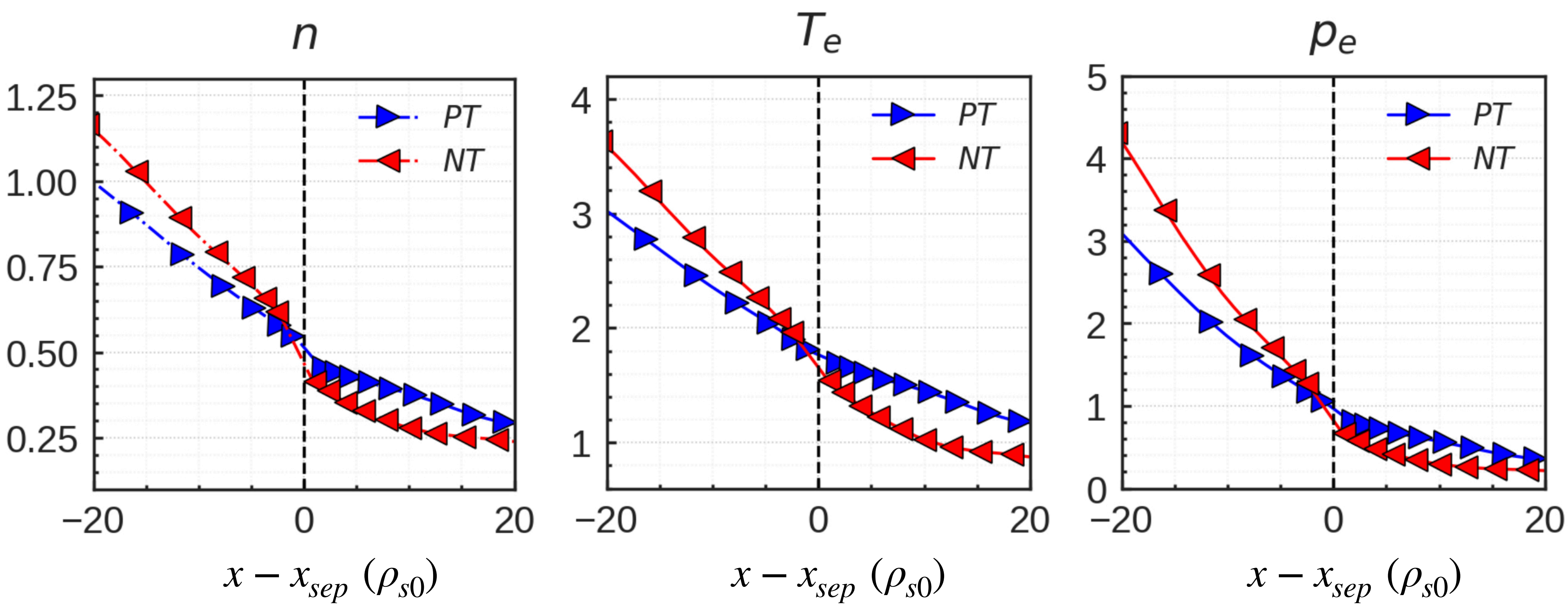




M1.3.1: GBS single-null simulations

K. Lim, et al. *PPCF* (2023).

- GBS using $\delta = \pm 0.3$ finds that NT improves the energy confinement time, but steepens the profile gradients at the separatrix, thereby reducing λ_q by ~30%



- Similarly, a theory-based scaling law that was developed predicts 40% lower λ_q for NT

M1.3.2: GBS double-null simulations

- To be done by Leonard (starting next week)

Deliverable 2 summary — MHD stability

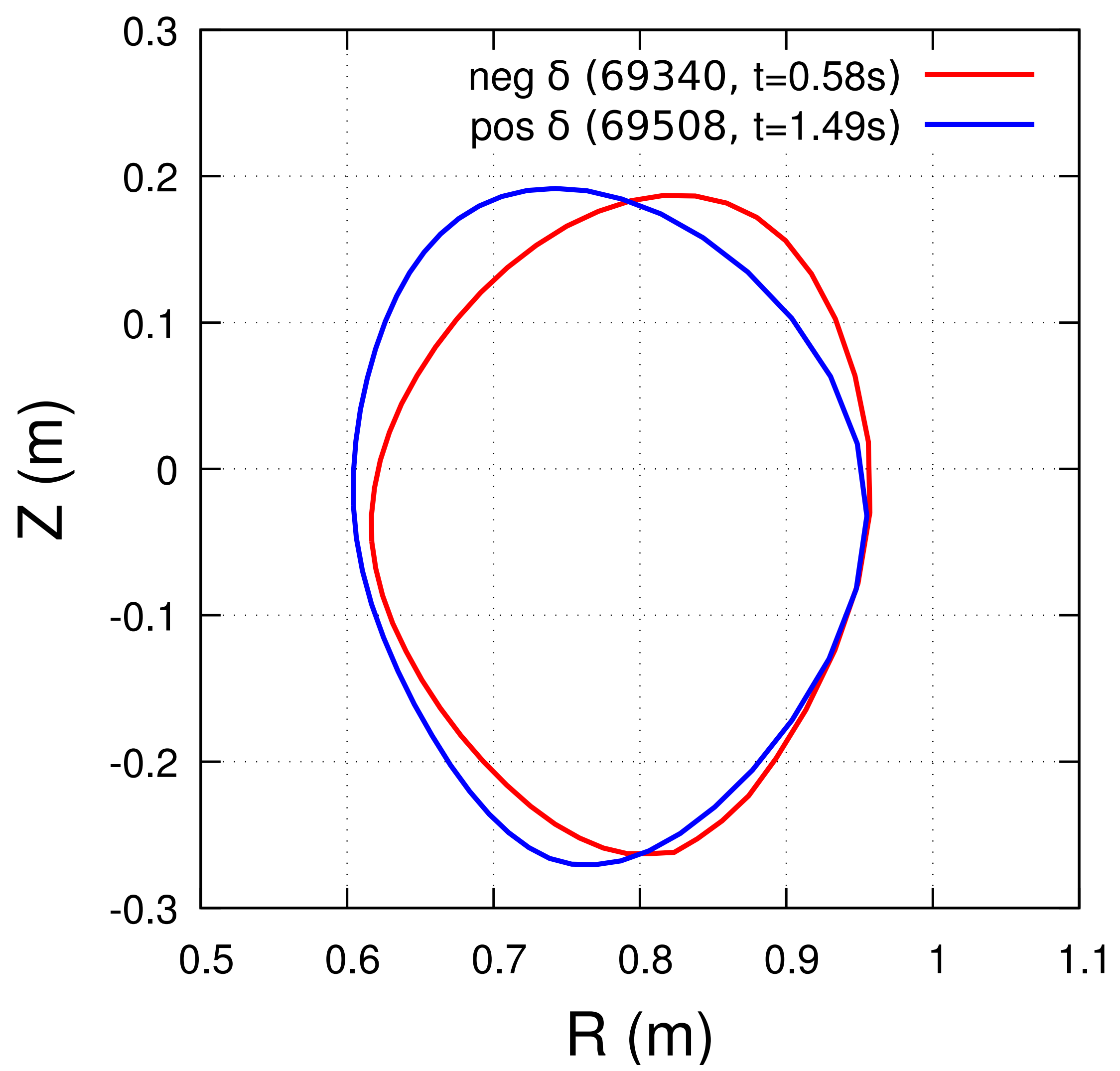
Milestone	Description	Participants	Target date
M2.1.1	Use KINX calculations to assess magnetic equilibria and plasma profiles for consistency with design objectives	A. Merle	6.2021
M2.1.2	Study ideal n=0, n=1 MHD stability with KINX	A. Merle	12.2022
M2.1.3	Study NT pedestal stability using EPED (after validating the empirical constants)	A. Merle	12.2025
M2.2.1	Use HYMAGYC to investigate kinetic corrections to MHD	G. Fogaccia	12.2021
M2.2.2	Use HYMAGYC to investigate Alfvénic modes driven by energetic particles, with particular reference to DTT NT equilibria	G. Fogaccia	12.2023
M2.2.3	Use HYMAGYC to investigate the kinetic effects of energetic particles and core ions on the renormalized plasma inertia (compressibility) in scenarios of interest to plasmas close to ignition	G. Fogaccia	12.2025
M2.3.1	Influence of NT on the stability limits of tearing modes and NTMs with XTOR-K	H. Luetjens	12.2021
M2.3.2	Nonlinear interactions between fast ions, tearing and NTMs in NT plasmas	H. Luetjens	12.2022

Deliverable	Description	Participants	Target date	Evidence of achievement
D2.1	Report on properties of tearing modes in NT as compared to PT	H. Luetjens	12.2022	Delayed by 6 months for technical reasons with XTOR-K
D2.2	Report on MHD stability properties of NT equilibria, including non-ideal effects in NT DTT equilibria and pedestal studies	A. Merle, G. Fogaccia	12.2023	N/A

M2.1.1: Consistency of equilibrium with objectives

TSVV 2 wiki.

- Due to experimental constraints, we did not fix proximity to MHD stability limits, but instead created multiple pairs of equilibria with different quantities (e.g. P_{heat}, $\langle n_e \rangle$, β_N) kept fixed between NT and PT



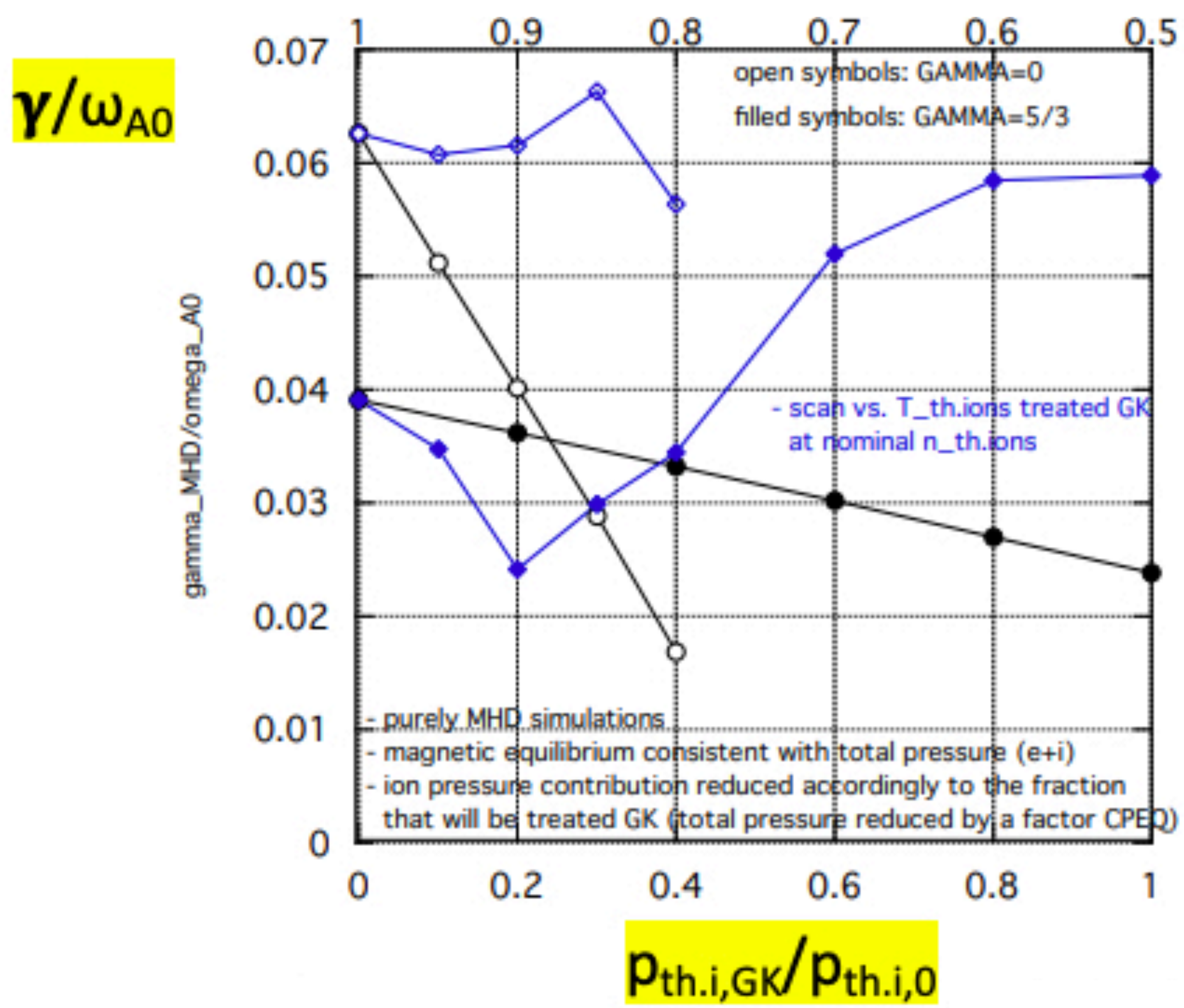
Comp. Num.	Description	Constants of comparison	Discharge	Time (sec)	elong	delta
1	Diverted, PT	q95, betaN	69515	1.02	1.43	+0.29
1	Diverted, NT	q95, betaN	69340	0.58	1.42	-0.28
2	Diverted, PT	q95, ne, Pheat	69515	1.02	1.43	+0.29
2	Diverted, NT	q95, ne, Pheat	69271	1.60	1.42	-0.27
3	Diverted, PT	Ip, betaN, ne	69508	1.49	1.43	+0.28
3	Diverted, NT	Ip, betaN, ne	69340	0.58	1.42	-0.28
4	Limited, PT	Ip, betaN, ne	69511	1.50	1.34	+0.35
4	Limited, NT	Ip, betaN, ne	69273	0.85	1.29	-0.29
5	Limited, PT	Ip, Pheat	69511	1.50	1.34	+0.35
5	Limited, NT	Ip, Pheat	69273	1.70	1.26	-0.26
-	Diverted, PT	-	69515	1.58	1.43	+0.34
-	Diverted, NT	-	69340	1.60	1.40	-0.27

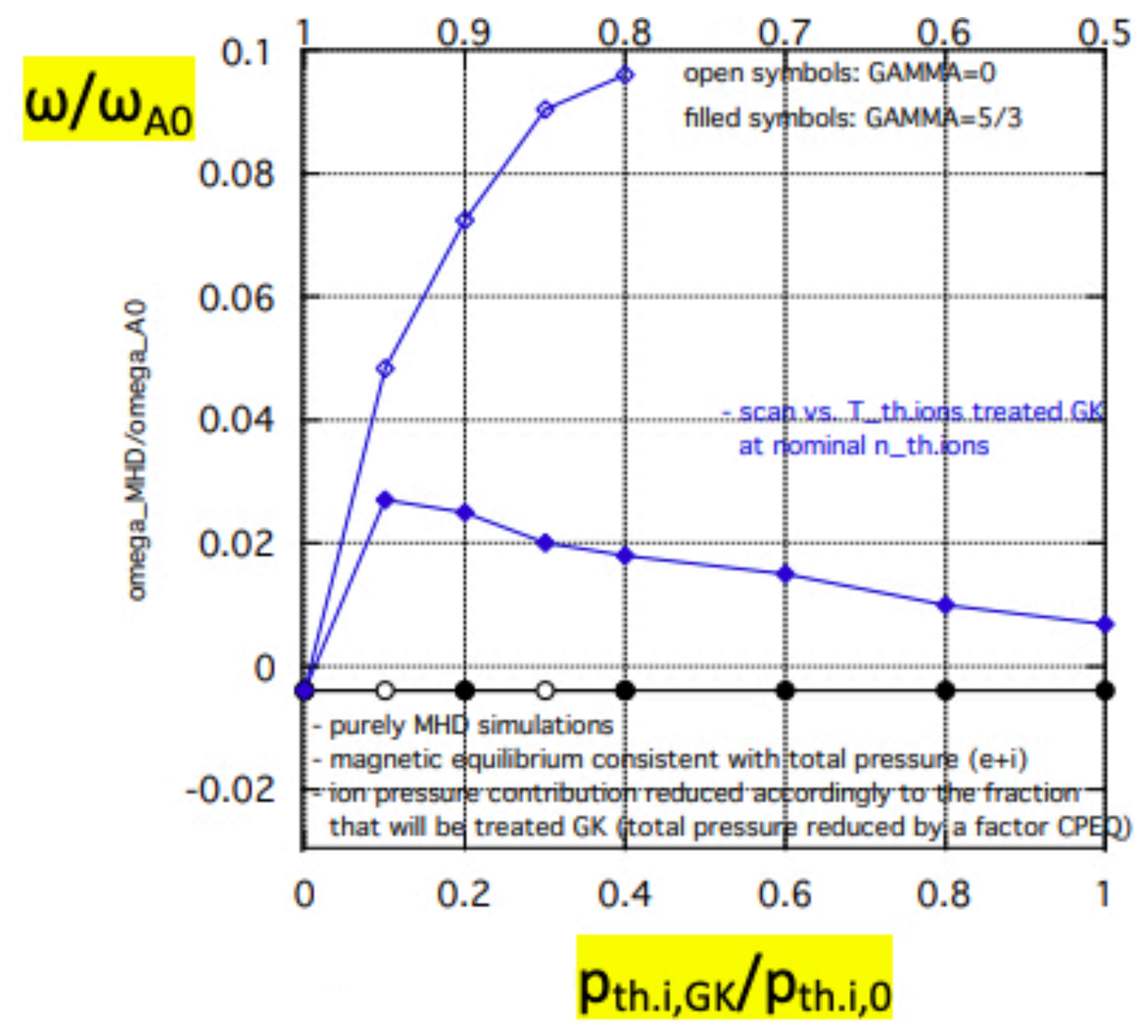
M2.1.2: Study n=0, n=1 MHD stability

- To be done, but may be partially addressed by Martynov thesis and Gregorio's work?

M2.2.1: Kinetic corrections with HYMAGYC

- Kinetic corrections have been investigated, but not for NT versus PT

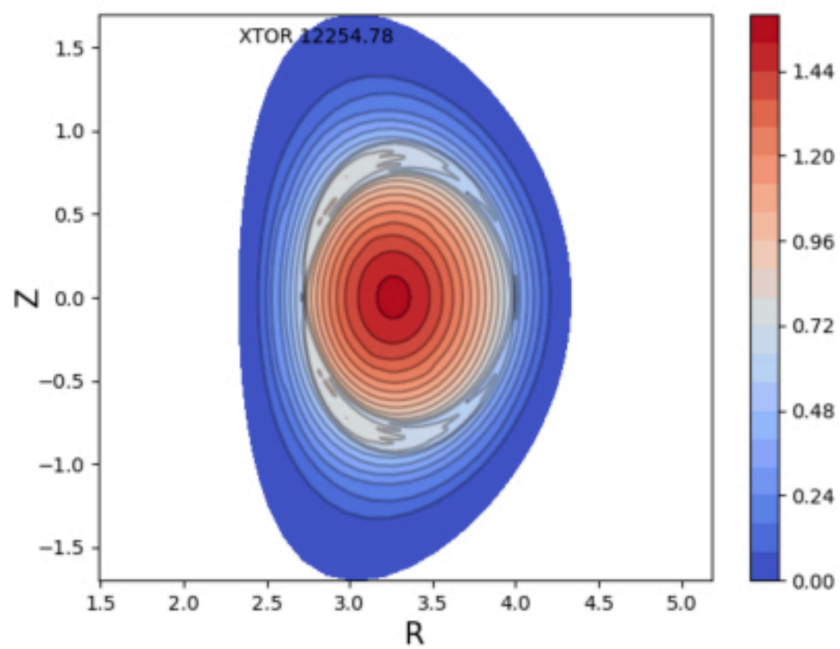


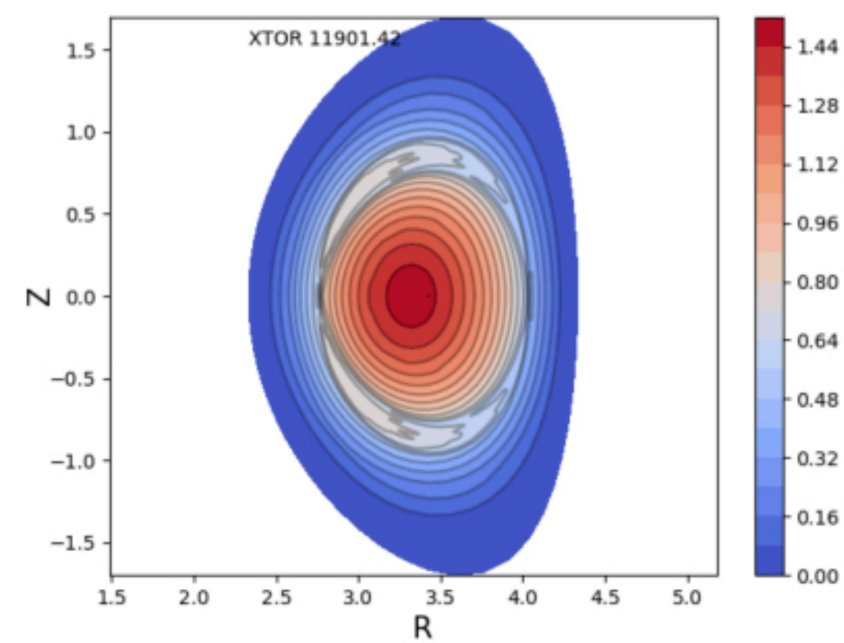


M2.3.1: Tearing stability with XTOR-K

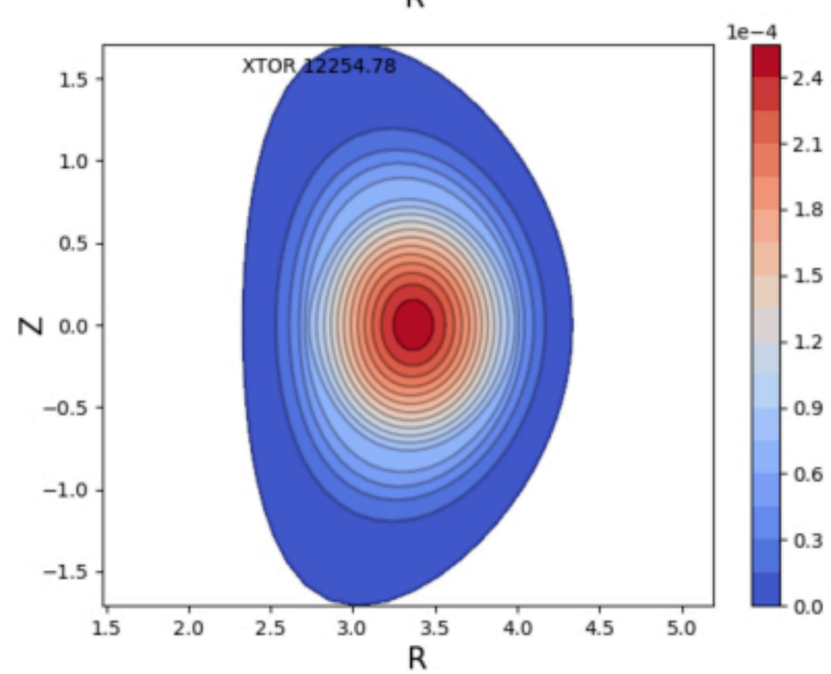
- Preliminary NT versus PT simulations of 2/1 tearing mode display little difference in linear growth rates, nor in saturated island size

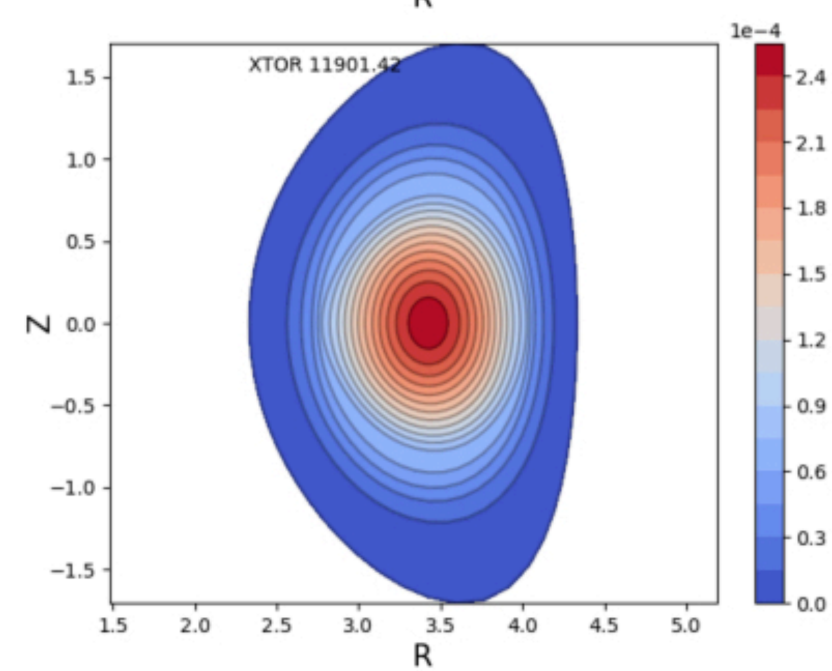
Toroidal current density:





Pressure:





M2.3.2: Fast particle & NTM interactions w/ XTOR

- To be done

Deliverable 3 summary — Experimental validation

Milestone	Description	Participants	Target date
M3.1	Establish initial magnetic equilibria and plasma profiles (a set based on existing experiment and a set based on DEMO) to be shared amongst the team	O. Sauter	1.2020
M3.2	Validation of trends from GK codes (local and global) using well-diagnosed TCV experiments	J. Ball, O. Sauter, G. Di Giannatale	12.2022
M3.3	Validation of SOLEDGE2D-EIRENE SOL simulations with experimental data (i.e. matching experimental observables by tuning cross-field diffusivities)	P. Muscente	6.2022
M3.4	Comparison of fast particle confinement and fast particle-driven modes between simulation and well-diagnosed TCV experiments	M. Vallar	6.2022
M3.5	Comparison between GBS single null simulations and TCV experimental measurements in the SOL	K. Lim	6.2023
M3.6.1	Validation of KINX global stability analysis against TCV experiments	A. Merle	6.2022
M3.6.2	Validate empirical constants used for calculating local ballooning stability in EPED for NT	A. Merle	12.2023

Deliverable	Description	Participants	Target date	Evidence of achievement
D3.1	Report on validation of core transport between gyrokinetic/TGLF simulations and present-day experiments	G. Di Giannatale, J. Ball, P. Mantica, O. Sauter	12.2023	See conference contribution
D3.2	Report on validation of pedestal MHD stability between EPED and TCV experiments	A. Merle	6.2024	N/A

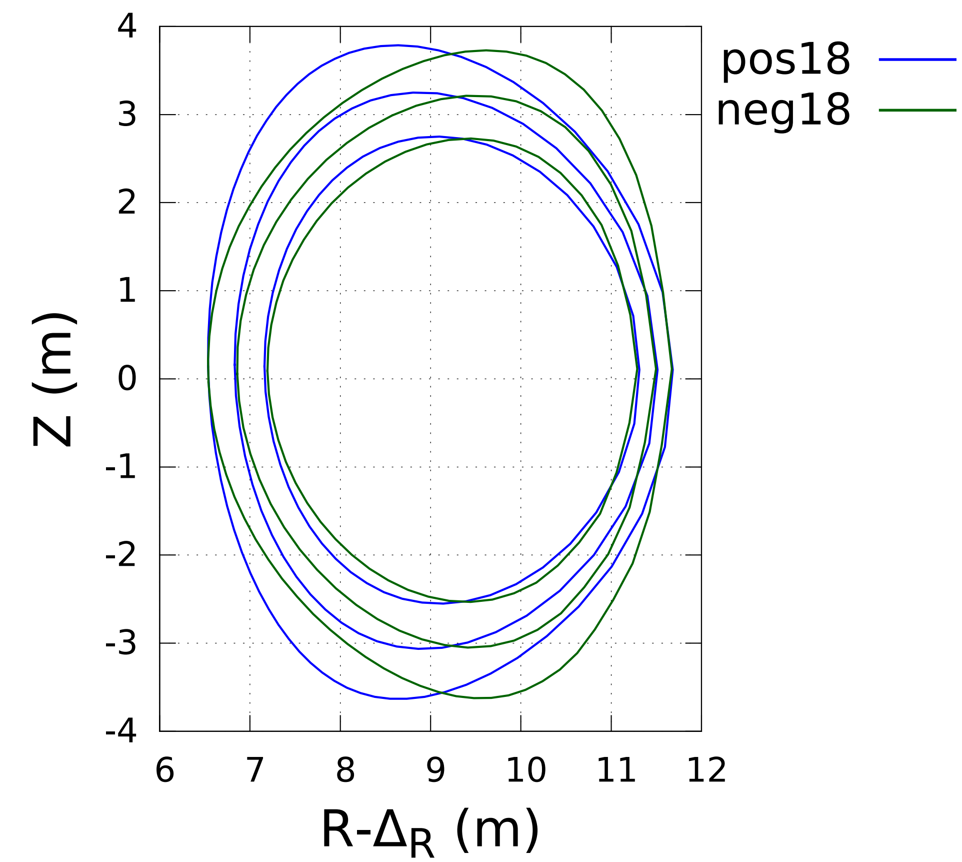
M3.1: Develop common set of NT/PT equilibria

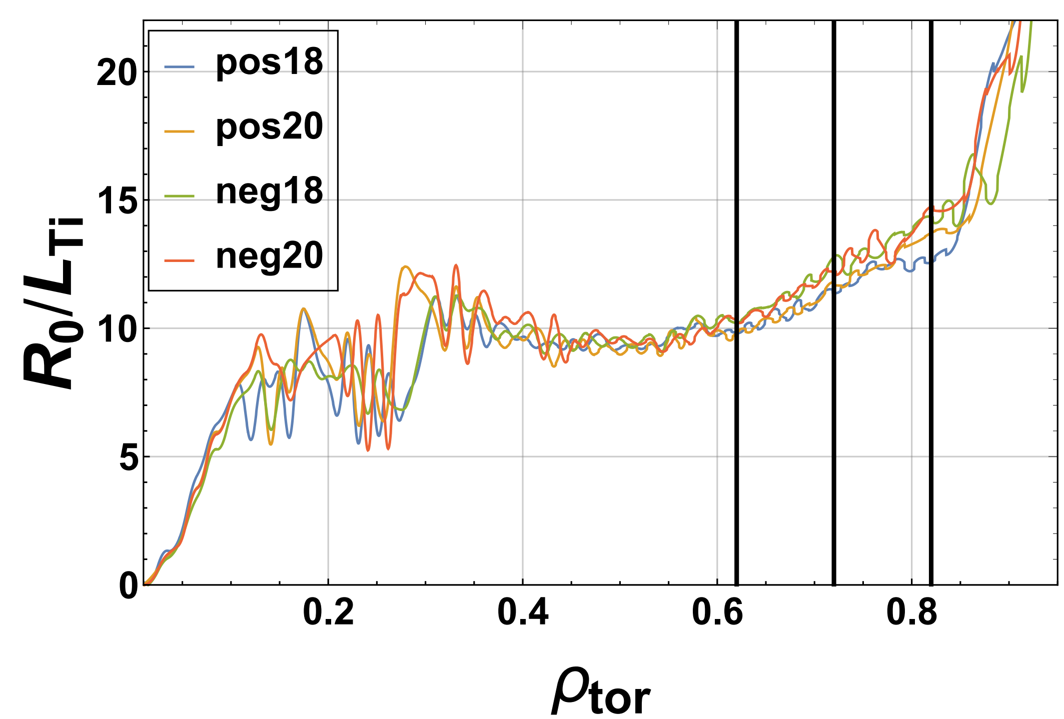
TSVV 2 wiki.

- 12 experimental TCV equilibria have been established and distributed to the team (and the wider community)

- 4 equilibria based on EU DEMO are available

Comp. Num.	Description	Constants of comparison	Discharge	Time (sec)	elong	delta
1	Diverted, PT	q95, betaN	69515	1.02	1.43	+0.29
1	Diverted, NT	q95, betaN	69340	0.58	1.42	-0.28
2	Diverted, PT	q95, ne, Pheat	69515	1.02	1.43	+0.29
2	Diverted, NT	q95, ne, Pheat	69271	1.60	1.42	-0.27
3	Diverted, PT	Ip, betaN, ne	69508	1.49	1.43	+0.28
3	Diverted, NT	Ip, betaN, ne	69340	0.58	1.42	-0.28
4	Limited, PT	Ip, betaN, ne	69511	1.50	1.34	+0.35
4	Limited, NT	Ip, betaN, ne	69273	0.85	1.29	-0.29
5	Limited, PT	Ip, Pheat	69511	1.50	1.34	+0.35
5	Limited, NT	Ip, Pheat	69273	1.70	1.26	-0.26
-	Diverted, PT	-	69515	1.58	1.43	+0.34
-	Diverted, NT	-	69340	1.60	1.40	-0.27



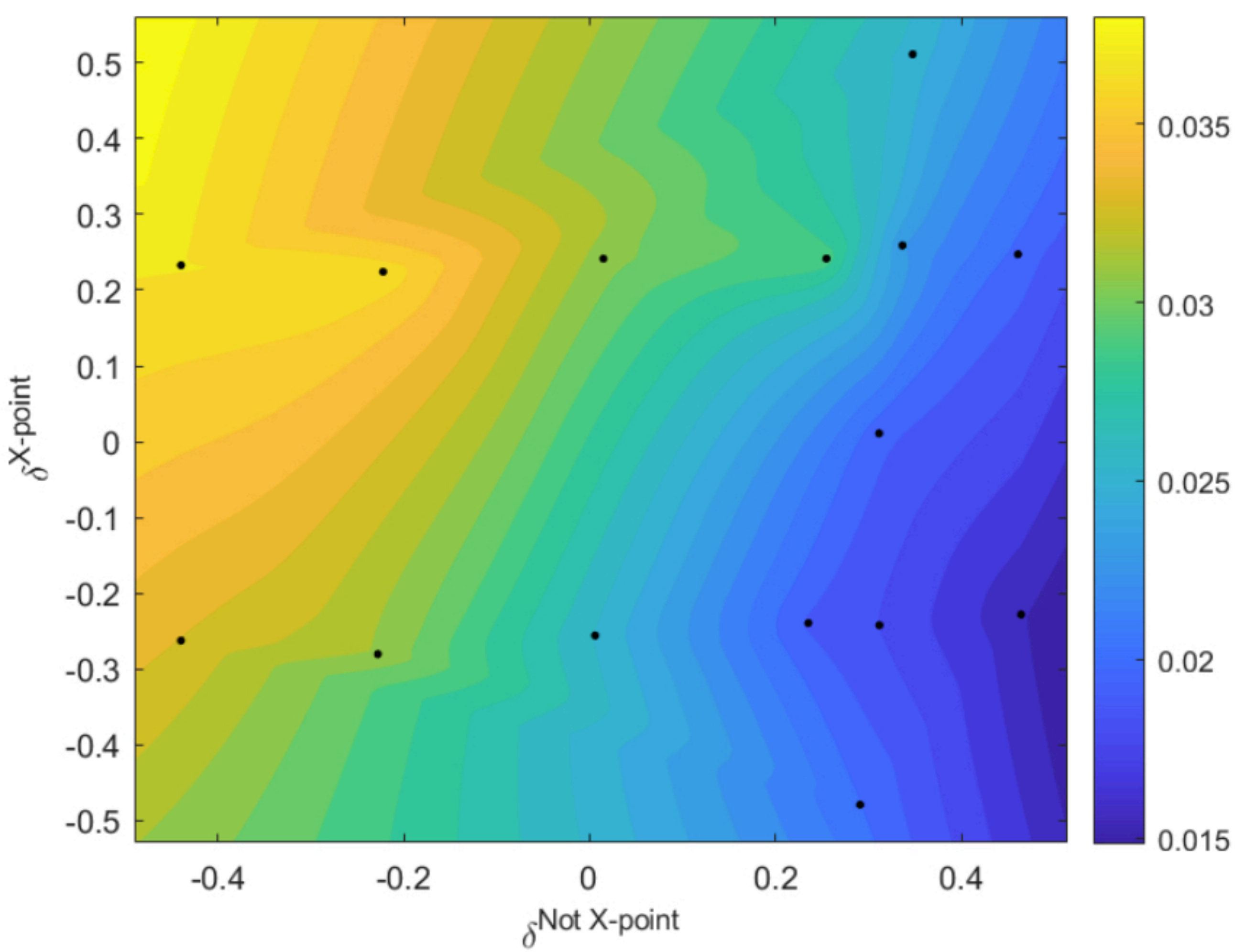


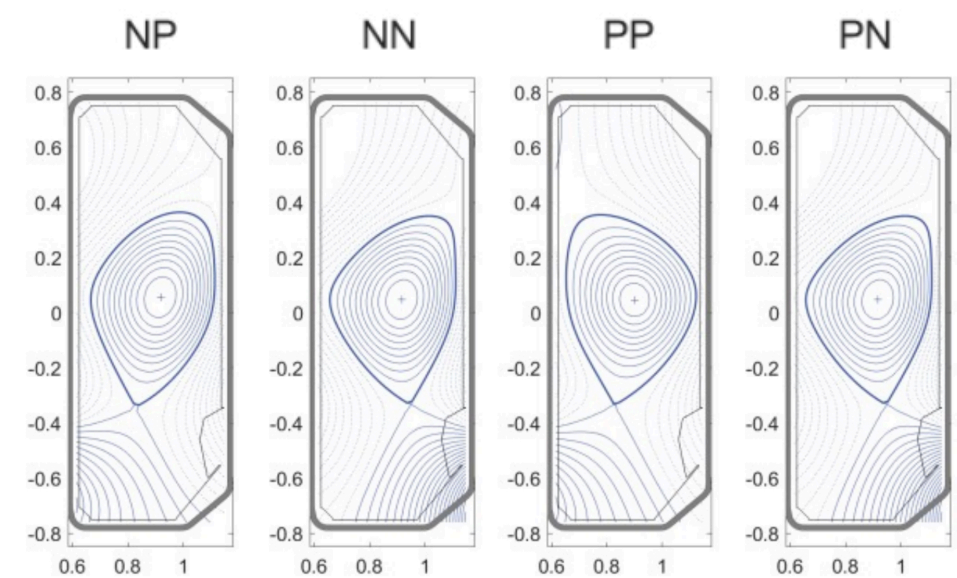
M3.2: Validate GK trends against TCV

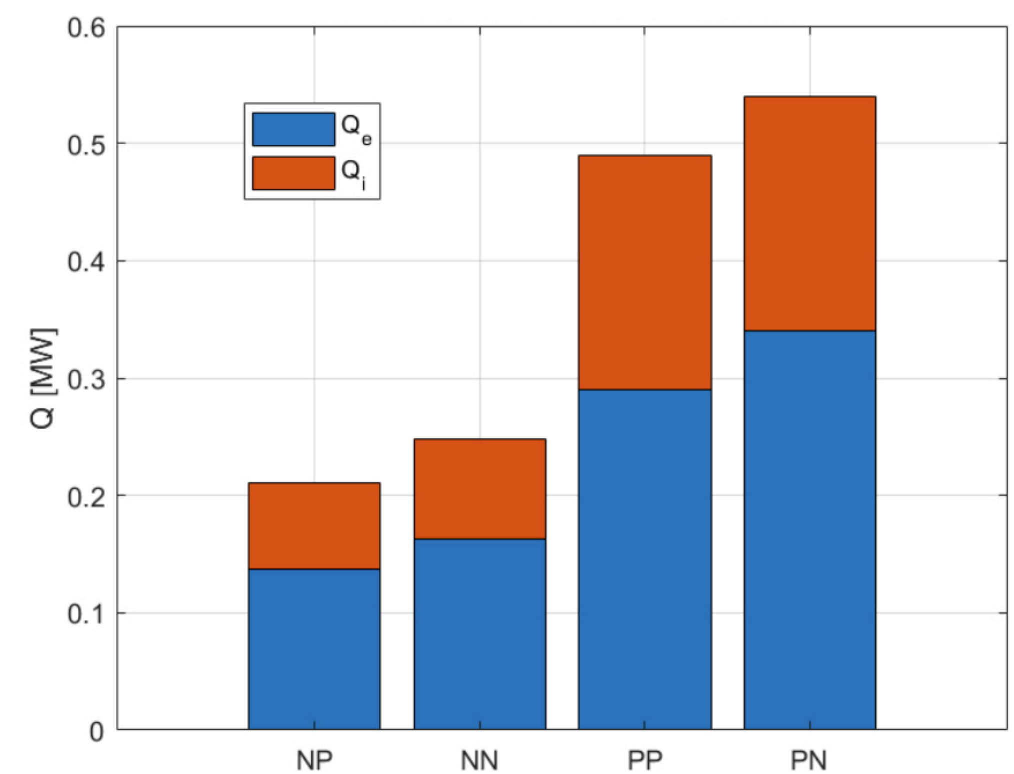
S. Coda, et al. *EPS* (2023).

- Validated X-point versus non-X-point dependance for single-null TCV shots

- Also, GENE and ORB5 robustly find that NT is stabilizing relative to PT (when gradients are fixed between them)



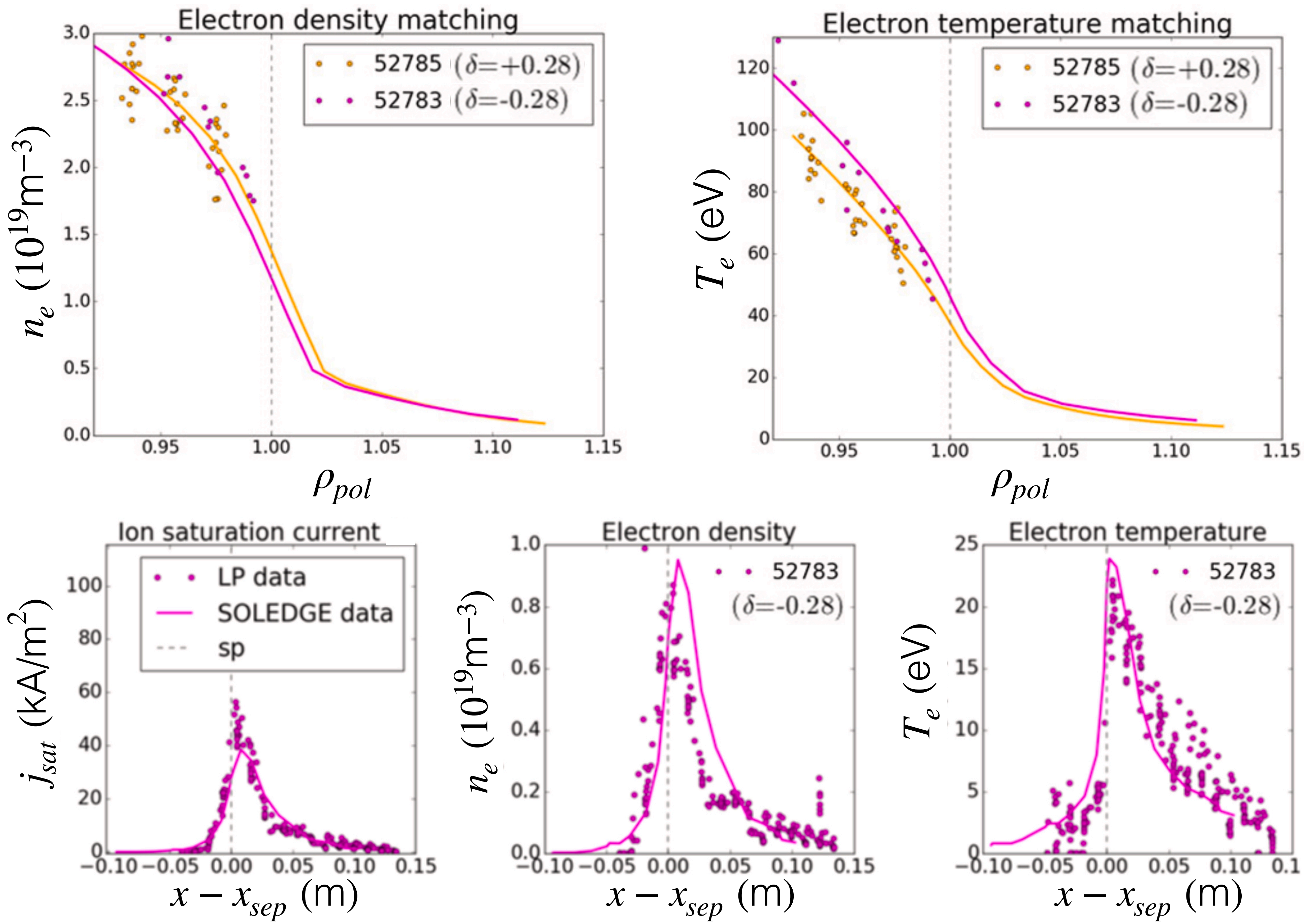




M3.3: Tune diffusivities in SOLEDGE to match TCV

P. Muscente, et al. *Nucl. Mat. Energy* (2022).

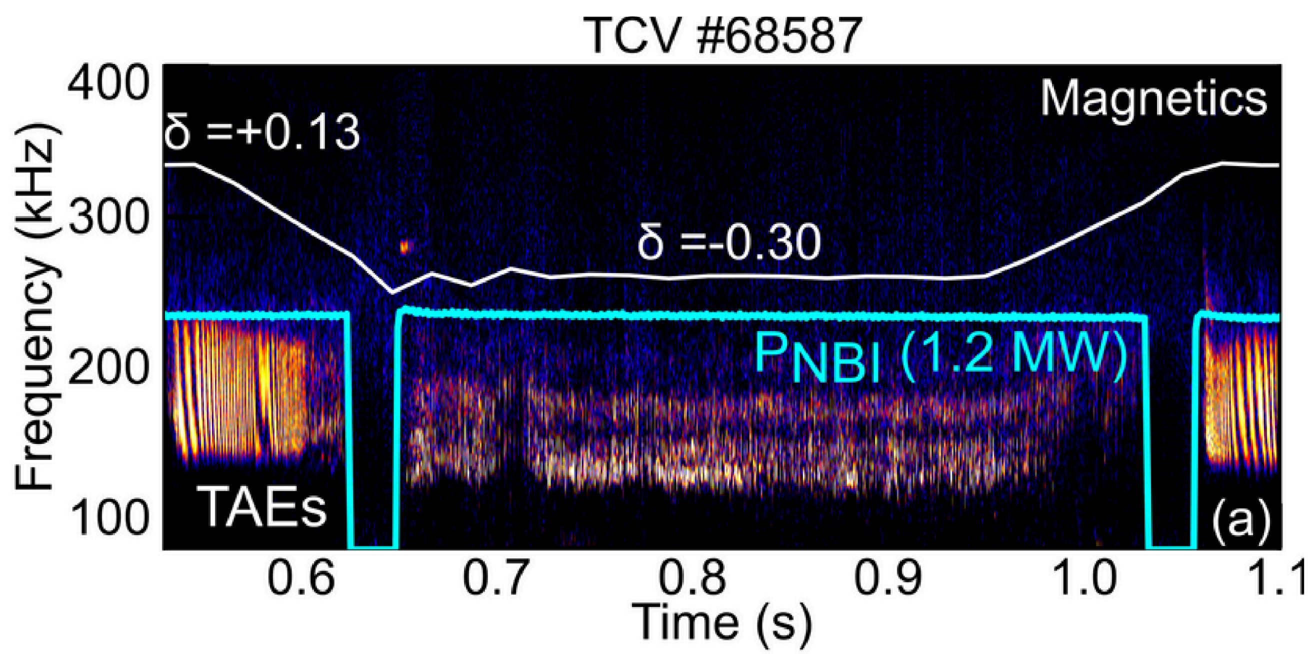
- Achieved the reasonable agreement shown below, which required NT to have a lower particle diffusivity at the separatrix than in PT

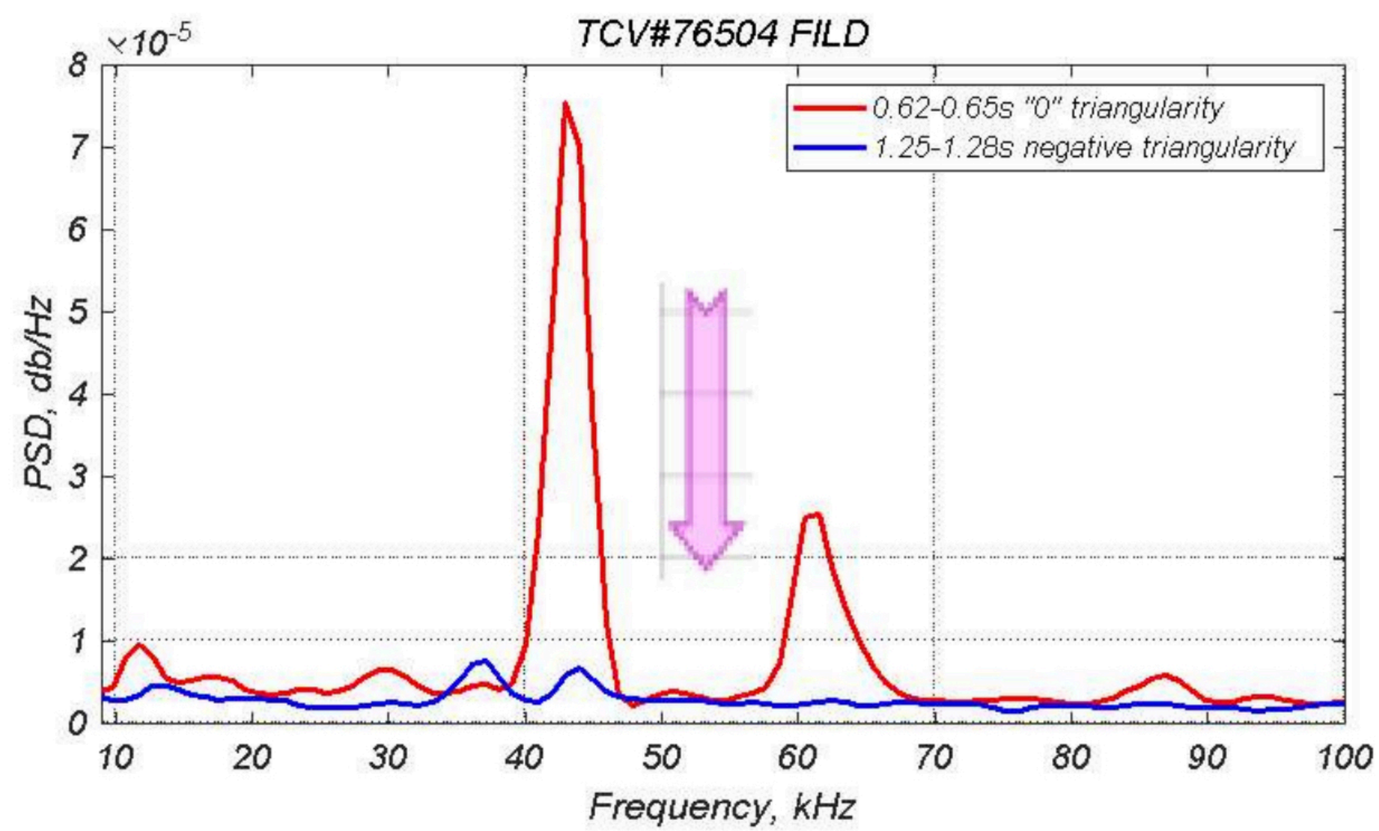


M3.4: Fast ion confinement & instabilities in TCV

P. Oyola, et al. *IAEA* (2023).
A. Karpushov, et al. *EPS* (2023).

- TCV experimental scenarios proved harder than expected to develop, so only qualitative comparisons were possible
- TAE signal increased with δ
- Fast Ion Loss Detector (FILD) signal increased with δ
- Both observations are good news for NT and consistent with simulation (see M5.1.1-3)

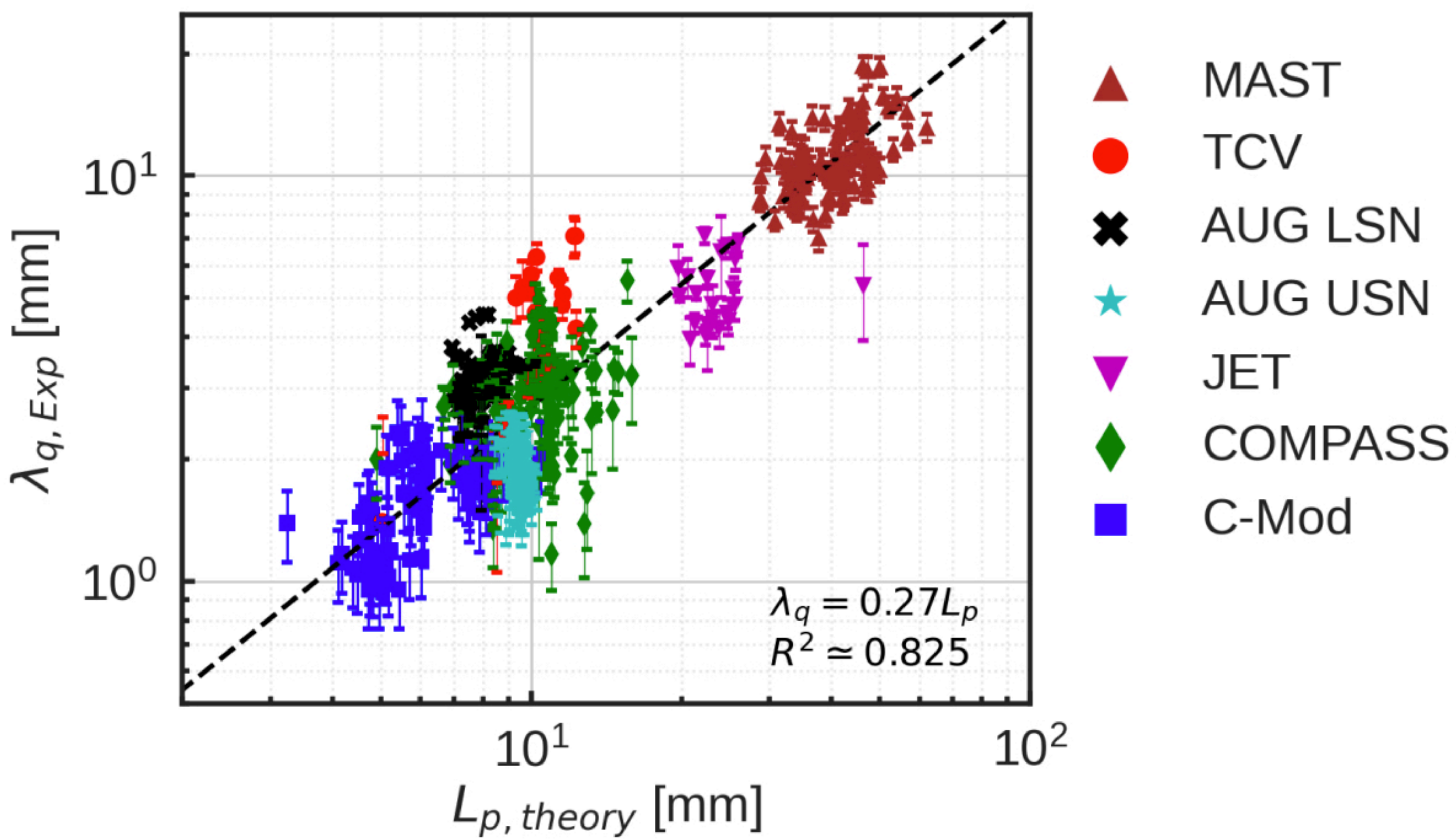




M3.5: SOL comparison between GBS and TCV

K. Lim, et al. *PPCF* (2023).

- A theory-based scaling law motivated from GBS results compared well against experimental measurements from a multi-machine database



M3.6.1: Validating KINX and TCV for MHD stability

- To be done

Deliverable 4 summary — Extrapolation to reactors

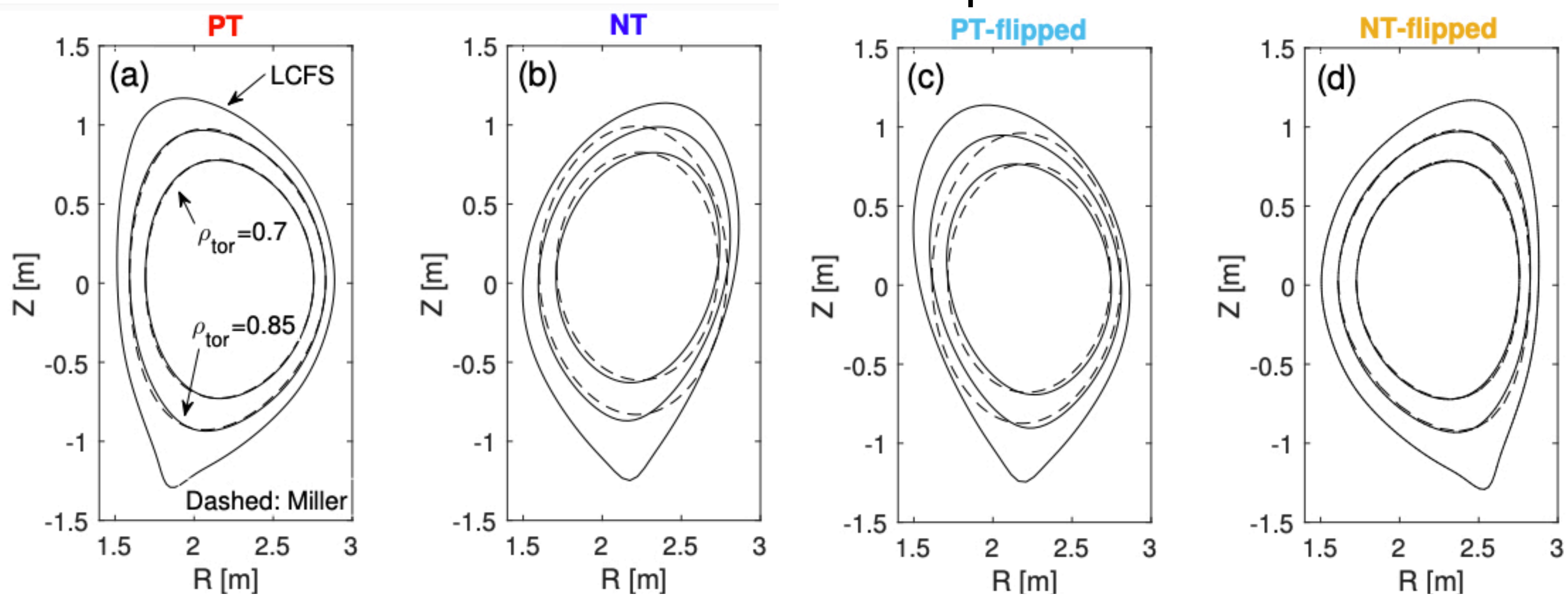
Milestone	Description	Participants	Target date
M4.1	TGLF integrated modeling of reactor-relevant DTT NT and present-day NT experiments to compare the effect of NT. In case no adequate TGLF setting is found, one can try to feed GK-deduced diffusivities into a transport code.	P. Mantica	12.2022
M4.2	Extrapolate to DTT and reactor-scales using SOLEDGE2D-EIRENE SOL simulations	P. Muscente	6.2023
M4.3.1	Perform electromagnetic local GK simulations to test impact at high β	J. Ball, M. Pueschel	12.2022
M4.3.2	Perform local GK simulations to extrapolate behavior to reactor scale devices	J. Ball	6.2023
M4.4	Use global flux driven simulations to extrapolate behavior to reactor scale devices	G. Di Giannatale	12.2023
M4.5	Use experimental-scale GBS simulations to study the scaling with size in order to extrapolate to reactor-scale devices	K. Lim	12.2024
M4.6	Extrapolate fast ion confinement to reactor-scale devices with neutral beams and alpha particles	M. Vallar	12.2023
M4.7	Synthesis of analysis results (e.g. transport, MHD) to optimize reactor-scale equilibria	O. Sauter, ALL	6.2023

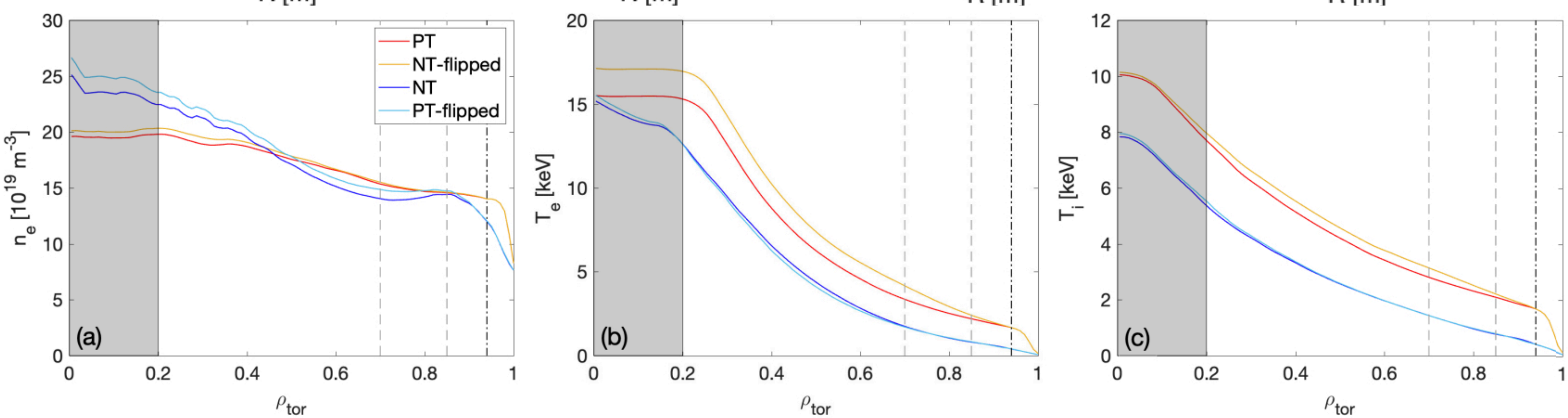
Deliverable	Description	Participants	Target date	Evidence of achievement
D4.1	Report on feasibility of a NT reactor	ALL	6.2023	To be done
D4.2	Report on fast particle confinement at reactor scales	M. Vallar	6.2024	N/A

M4.1: Integrated modeling of DTT with TGLF

A. Mariani, et al. *Nucl. Fusion* (2023).

- Results indicate that NT is only beneficial at nominal DTT H-mode parameters and not at nominal DTT L-mode parameters





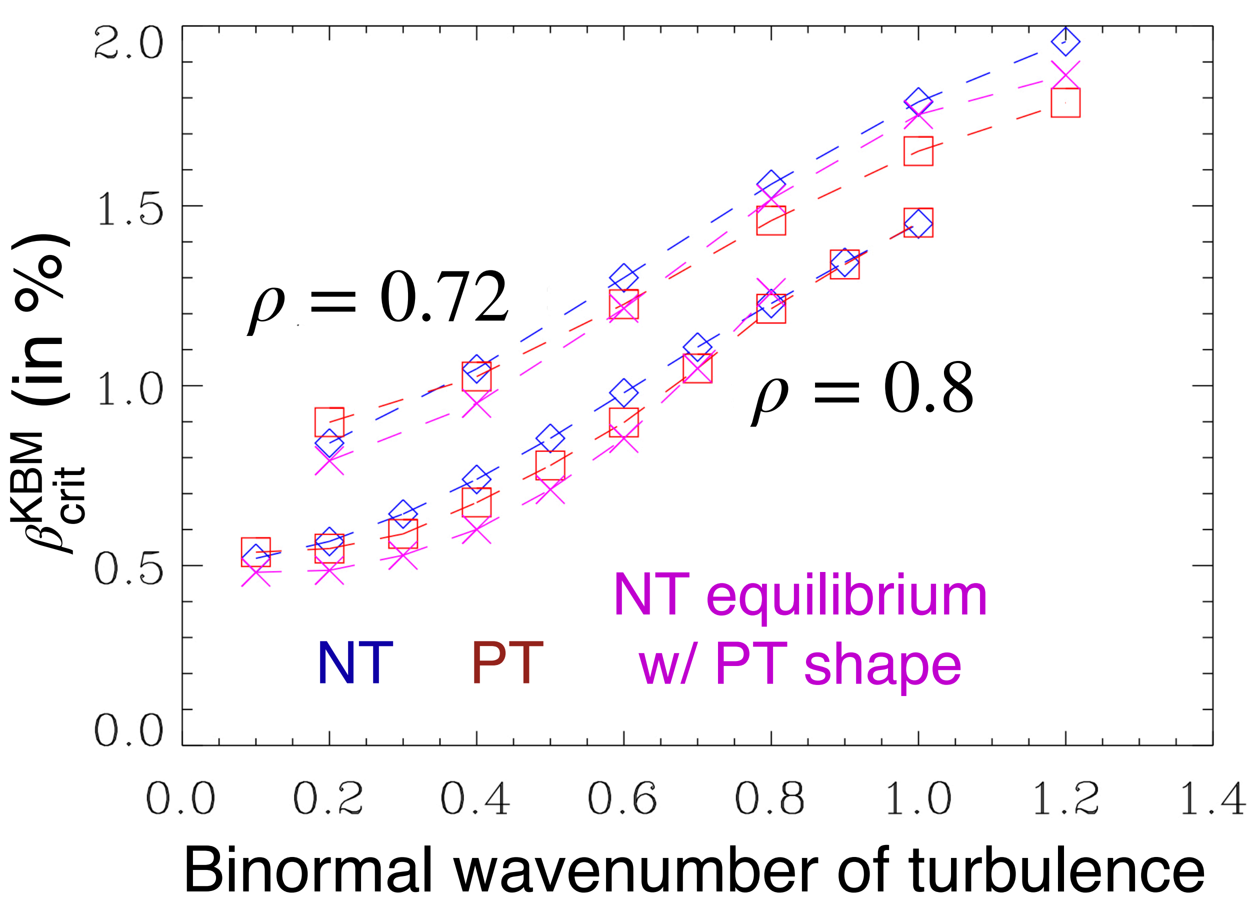
M4.2: Extrapolate SOL behavior with SOLEDGE

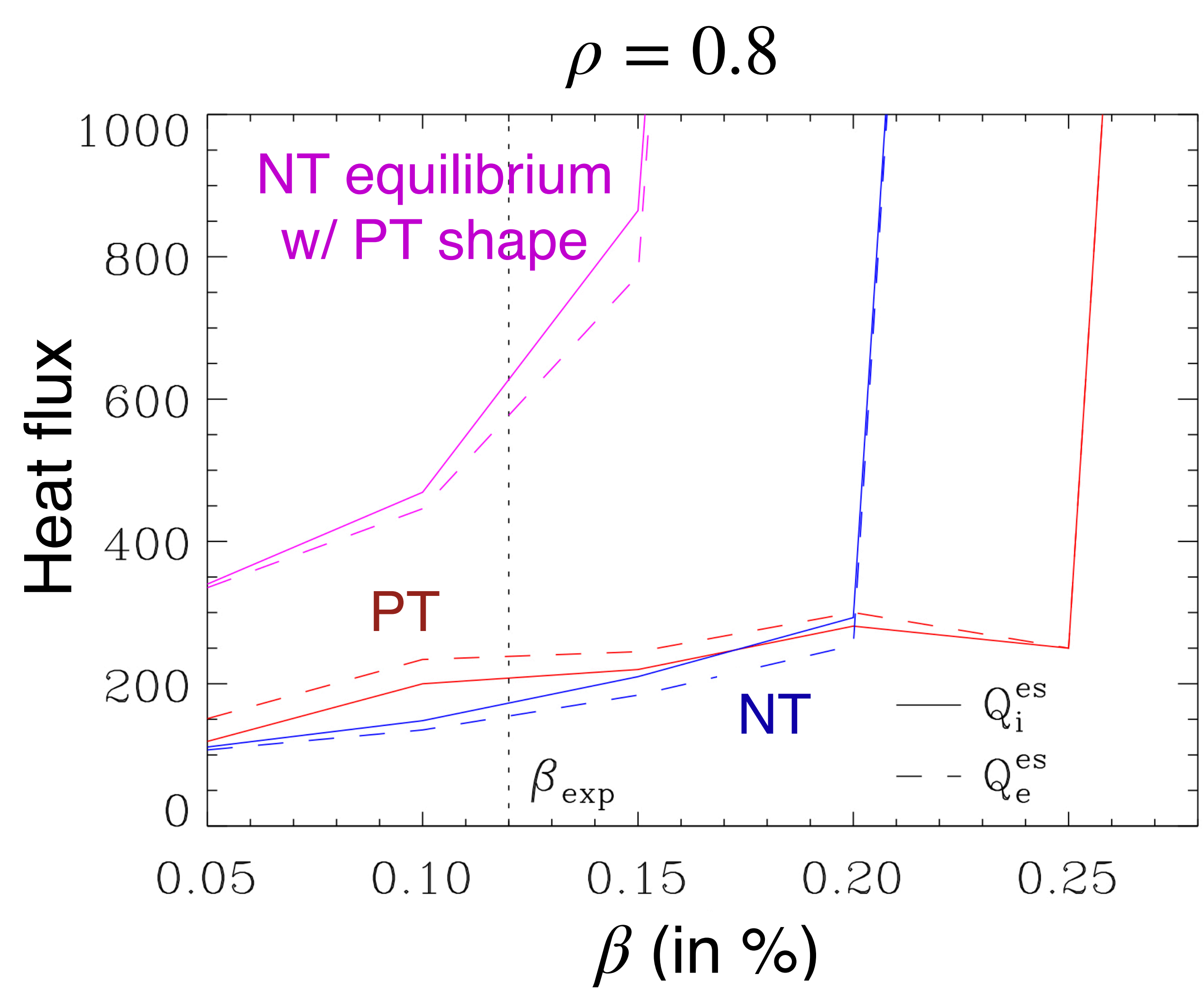
- To be done

M4.3.1: Test impact of β on core turbulence

A. Balestri, et al. *EPS* (2023).
R. Davies, et al. *PPCF* (2022).

- NT and PT TCV discharges scale similarly with β
- Critical β for the linear onset of KBM turbulence is similar as is the nonlinear effect of β on electrostatic turbulence





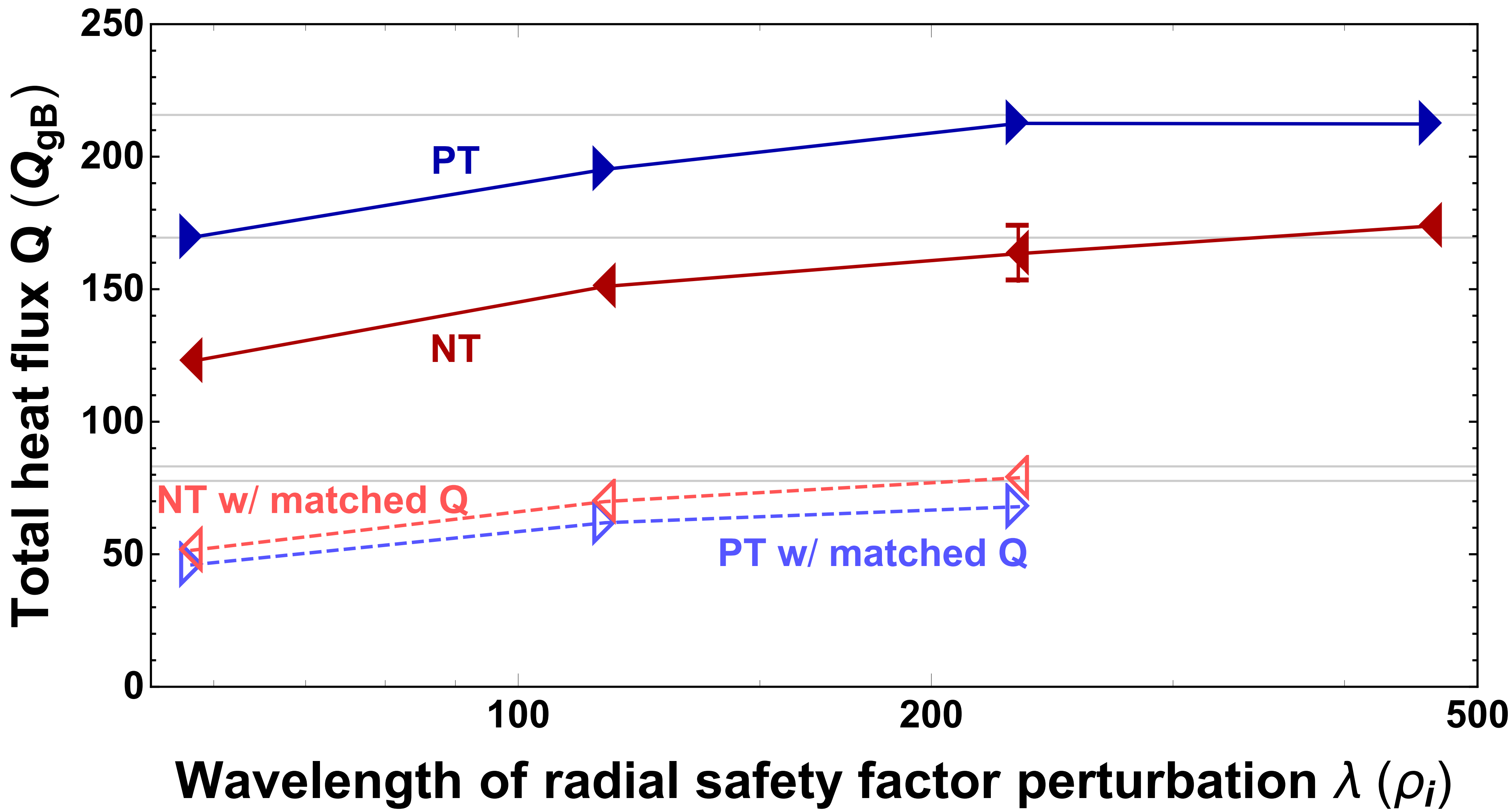
- MTM and KBM seems stronger for NT in spherical tokamaks

M4.3.2: Extrapolate to reactors with local GK

J. Ball, et al. *PPCF* (2022).

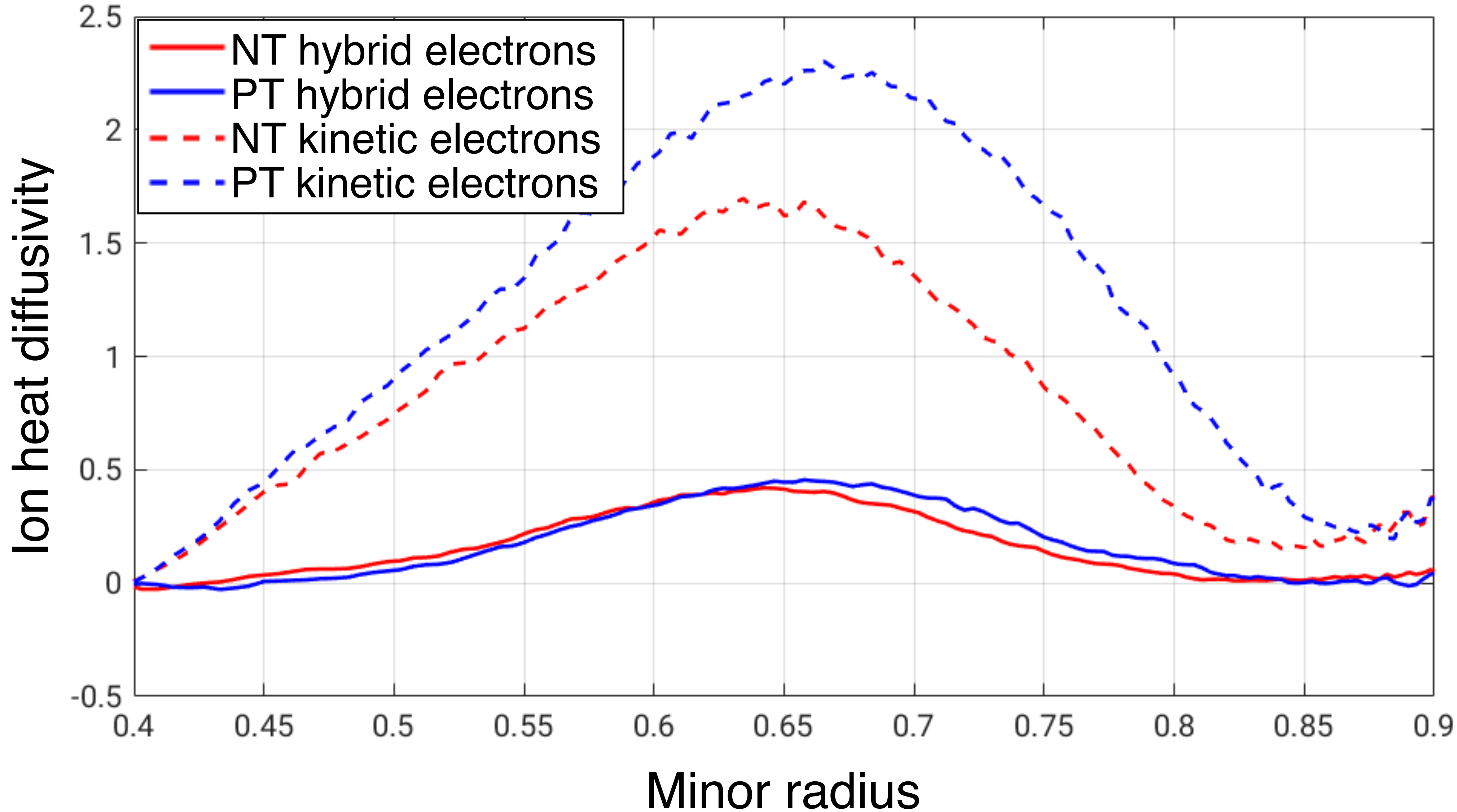
- We developed a novel flux tube incorporating profile shearing in safety factor profile in order to investigated impact of machine size

- NT and PT scale similarly to larger devices



M4.4: Extrapolate to reactors with global GK

- Using fully kinetic (yet artificially heavy) electrons reveals NT/PT distinction
- Numerical scan in ρ_* is in-progress



M4.7: Synthesize results to optimize reactors

- In progress as part of this presentation

Deliverable 5 summary — Fast ion confinement

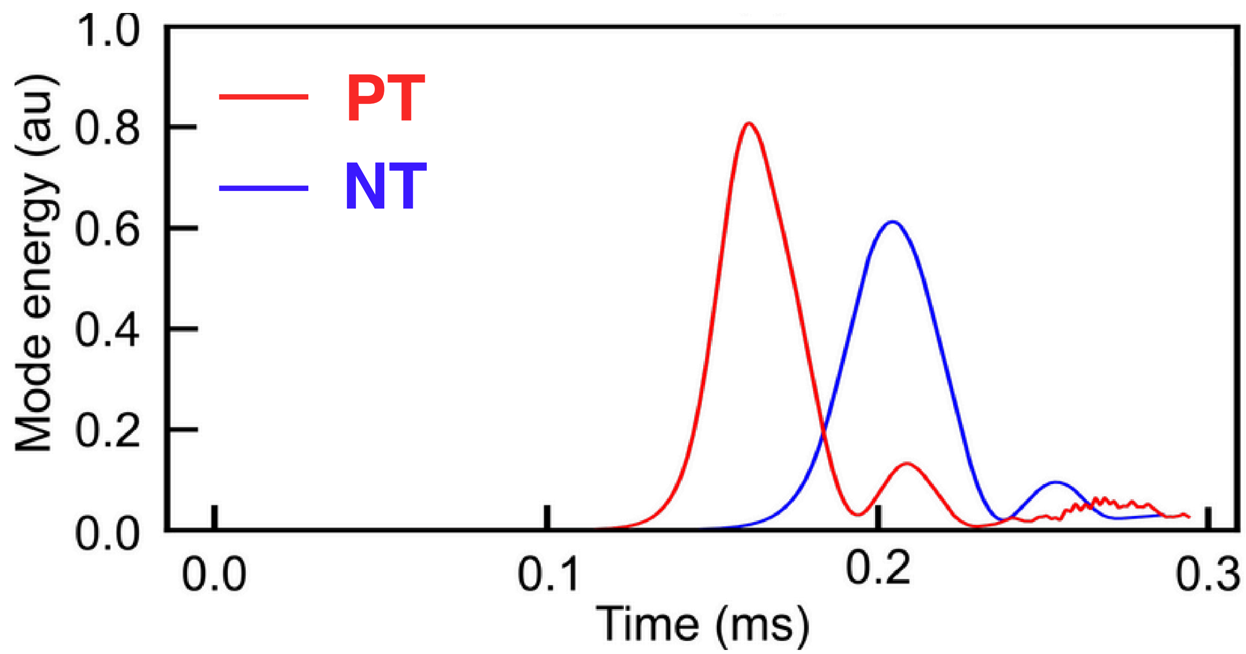
Milestone	Description	Participants	Target date
M5.1.1	Model fast ion transport using ASCOT and TRANSP/NUBEAM	M. Vallar	6.2021
M5.1.2	Model energetic particle-driven modes using LIGKA	M. Vallar	12.2021
M5.1.3	Model the impact of energetic-particle driven modes on fast ion confinement	M. Vallar	12.2022
M5.2	Fast ion confinement studies with XTOR-K	H. Luetjens	12.2022

Deliverable	Description	Participants	Target date	Evidence of achievement
D5.1	Report on fast particle confinement and fast particle driven instabilities in NT	M. Vallar, G. Fogaccia	12.2023	N/A

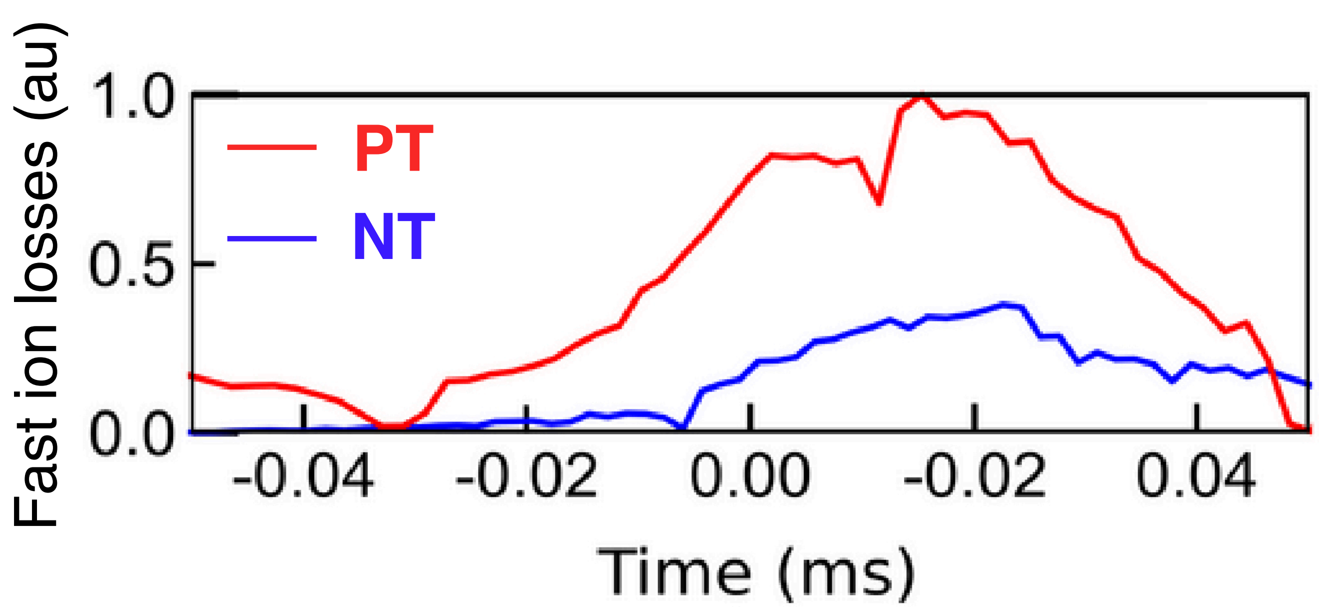
M5.1.1-3: Interplay of fast ion modes & transport

P. Oyola, et al. *IAEA* (2023).

- MEGA analysis of a pair of TCV equilibria show reduction in TAE amplitude by 30%



- Resulting TAE-induced fast ion losses to the wall are 3 times smaller in NT



M5.2: Fast ion confinement study with XTOR-K

- To be done

Deliverable 6 summary — Reduced modeling

Milestone	Description	Participants	Target date
M6.1	Detailed verification of TGLF SAT1 vs GK simulations and optimization of TGLF settings for standard DTT NT case and extreme NT DTT case	A. Mariani	12.2021
M6.2.1	Conduct encompassing linear and nonlinear gyrokinetic GENE flux-tube studies of PT and NT scenarios, specifically looking at saturation physics and nonlinear coupling, with a special focus on experimental cases	M. Pueschel	12.2021
M6.2.2	Test quasilinear gyrokinetics-based transport models for these cases against nonlinear scalings, and improve the models where necessary	M. Pueschel	12.2022
M6.2.3	Implement model in a bigger, possibly multi-physics framework (e.g. transport solver), and create a neural network that captures NT scalings	M. Pueschel (in collaboration with J. Citrin at DIFFER, and ACH support)	12.2023

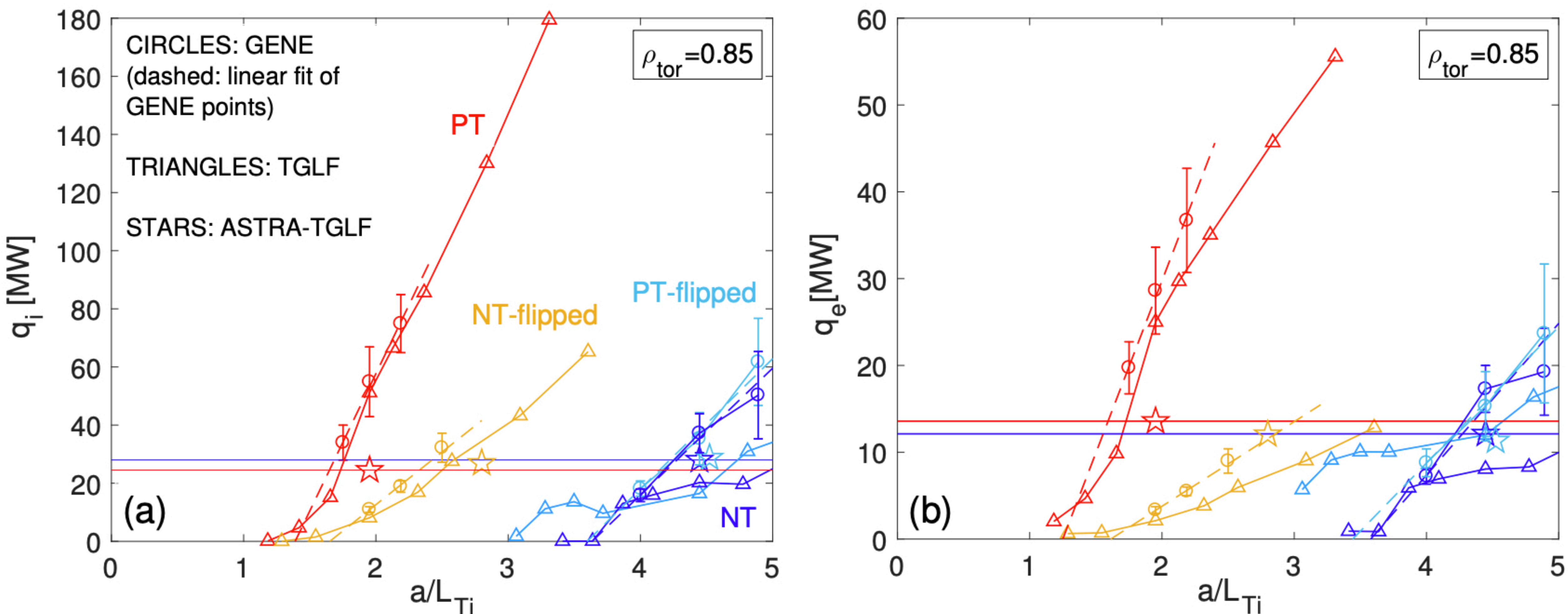
Deliverable	Description	Participants	Target date	Evidence of achievement
D6.1	Report on verification of TGLF with GENE for NT, detailing how to best simulate NT with the standard TGLF	A. Mariani, P. Mantica	12.2022	See pinboard ID 35620, 33950, conference contribution
D6.2	Report on linear instability and nonlinear saturation behavior for NT	M. Pueschel	12.2022	See pinboard ID 30201 and 31543
~~**D6.3**~~	~~Report on neural network for modeling NT~~	~~M. Pueschel~~	~~12.2024~~	Abandon given lack of DIFFER ACH?

M6.1: Verification of TGLF and GENE for DTT

A. Mariani, et al. *Nucl. Fusion* (2023).

- TGLF (using SAT2) coupled with ASTRA has been benchmarked against local GENE, but this was only successful for DTT case (and not TCV case)

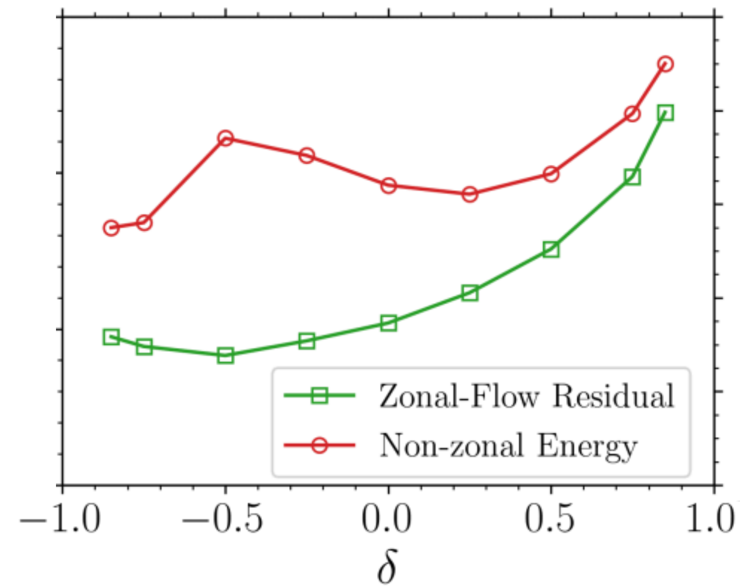
- Important effect seems to come from $\rho > 0.95$, which is not included



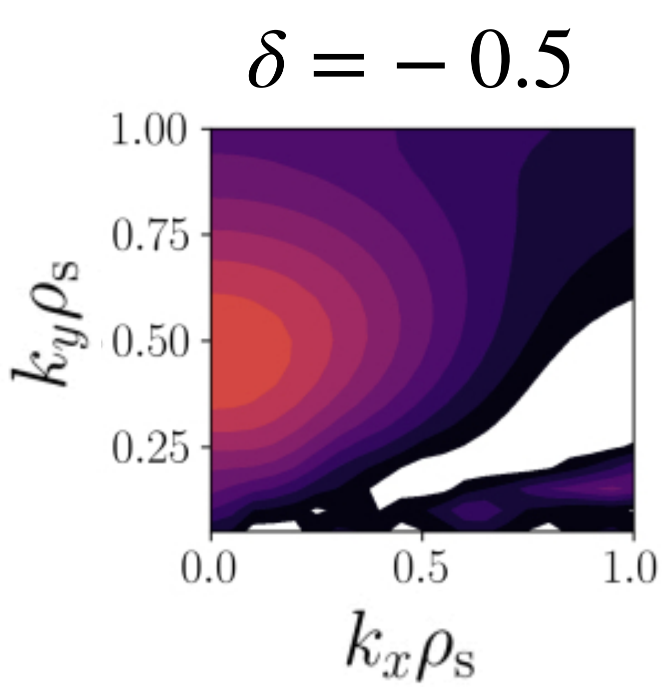
M6.2.1: Investigate saturation physics with GENE

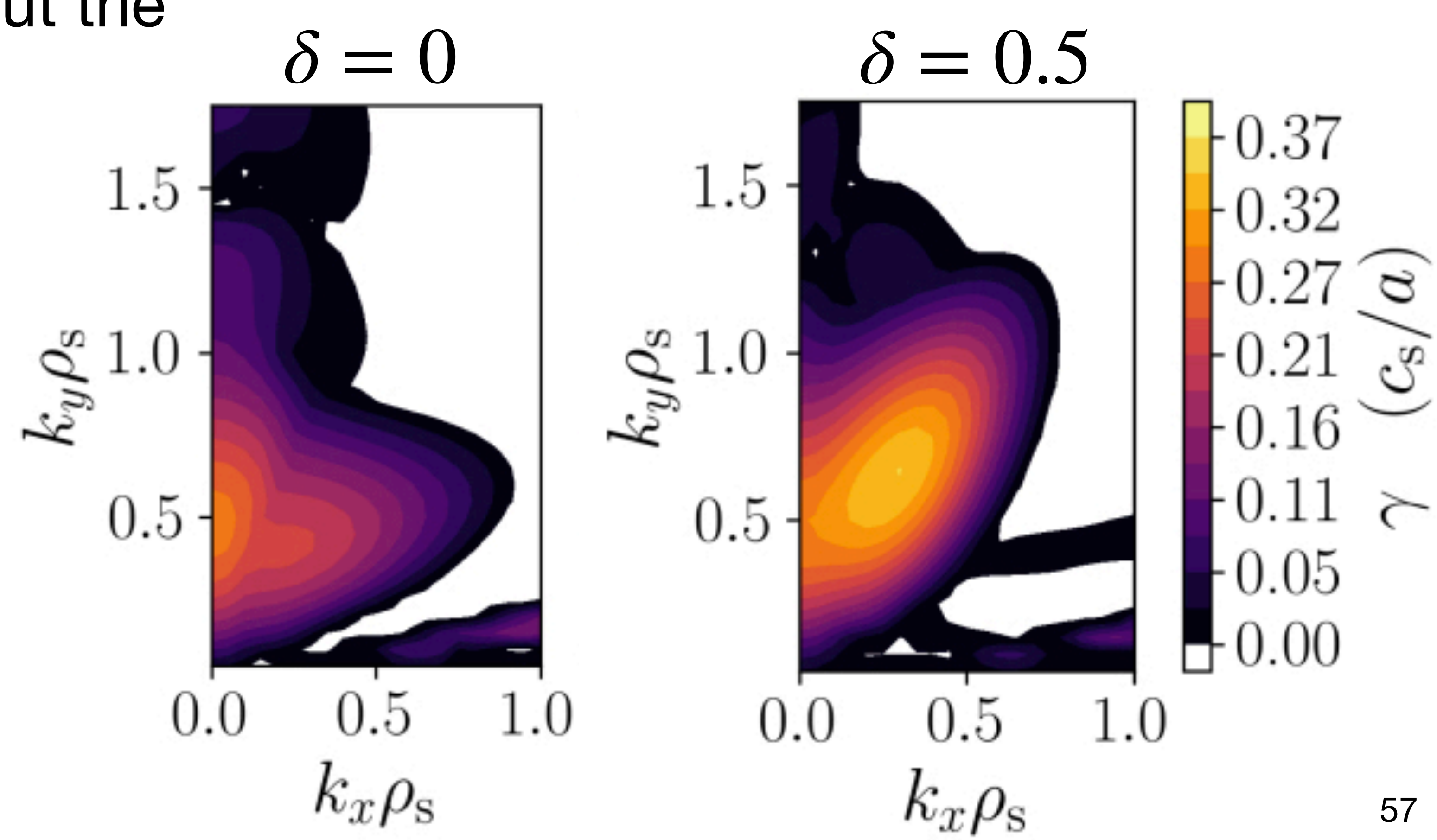
J. Duff, et al. Phys. *Plasmas* (2021).

- Proxies for zonal flow damping and drive indicate that NT makes more efficient use of zonal flows for saturation



- NT has a broader spectrum in k_x due to its straight, flat shape about the outboard midplane

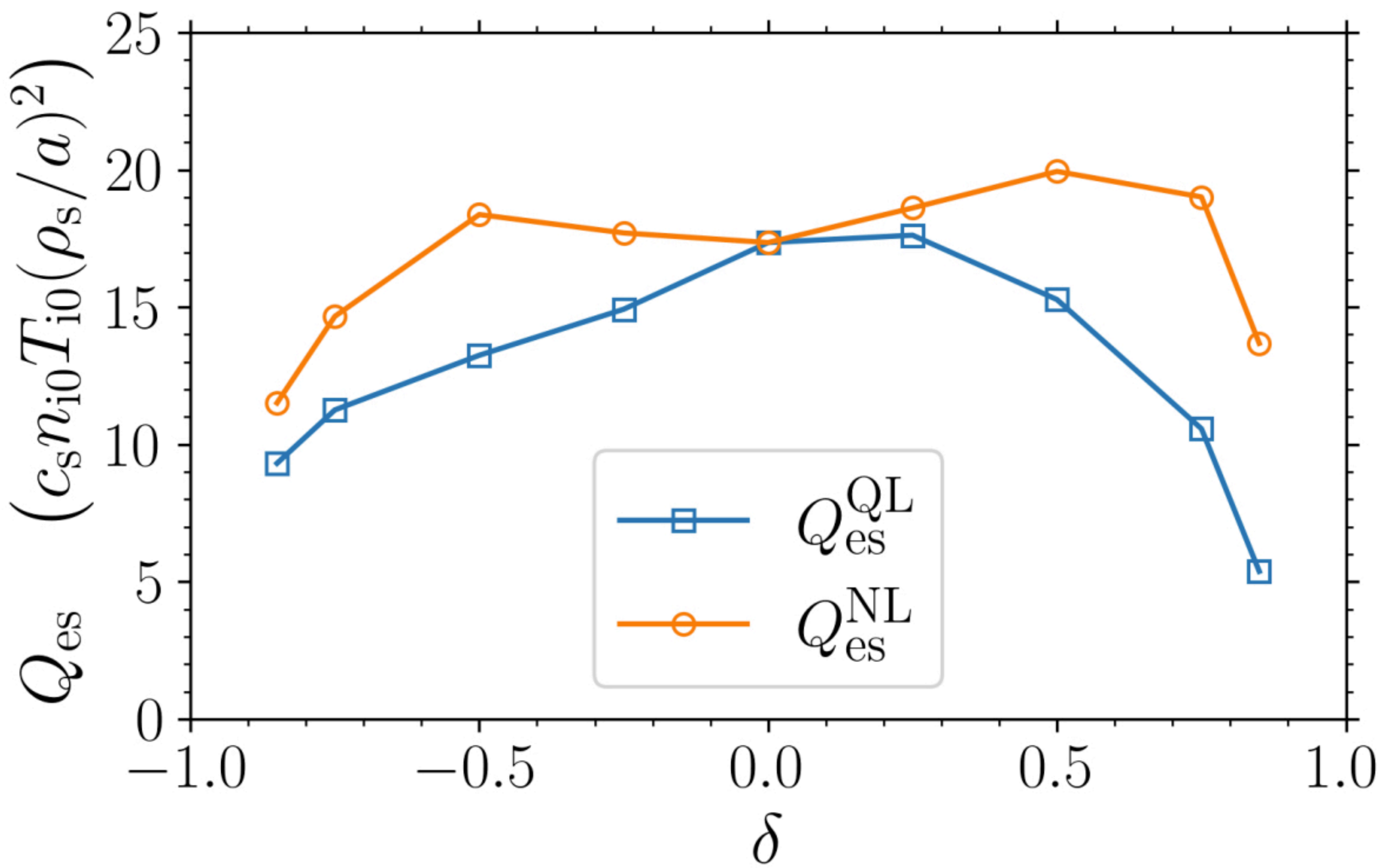




M6.2.2: Test quasilinear models against nonlinear

J. Duff, et al. Phys. *Plasmas* (2021).

- Standard mixing length quasilinear estimates can capture some of the variation with triangularity (e.g. strong decrease for $\delta > 0.5$), but overall only weak agreement



- SAT2 used in TGLF seems to do better

Thank you very much for your time and attention.

I hope you enjoyed our discussions and
the visit to Lausanne, short as it was.