TSVV-02: Negative triangularity and plasma shaping

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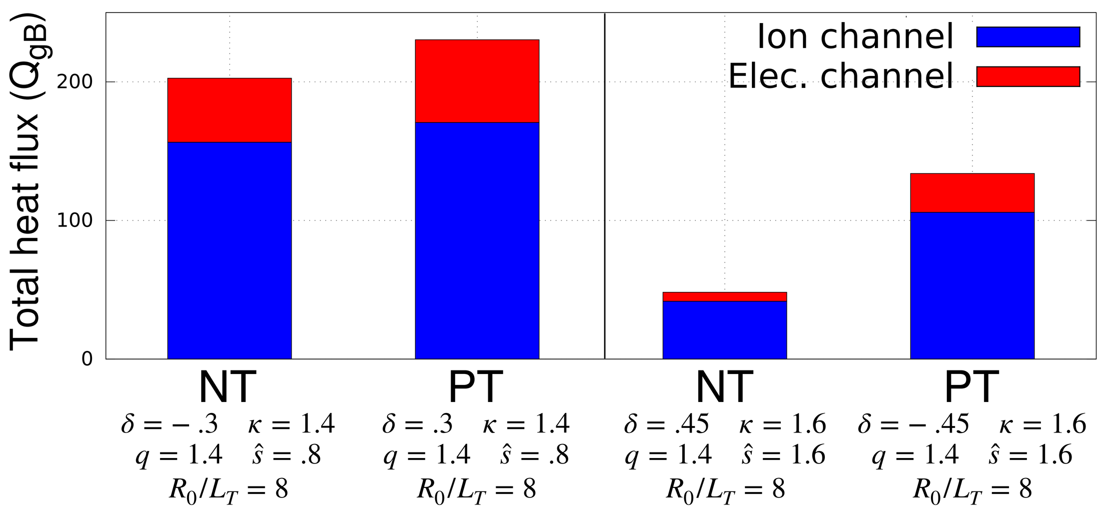
Introduction

- L-mode negative triangularity (NT) plasmas have been experimentally observed to achieve comparable confinement to H-mode positive triangularity (PT)
- NT shape blocks H-mode, preventing ELMs
- It is hoped that the NT SOL will be similar to L-mode as well as "everything else" (e.g. MHD stability, fast particle confinement, impurities)

Parametric dependence

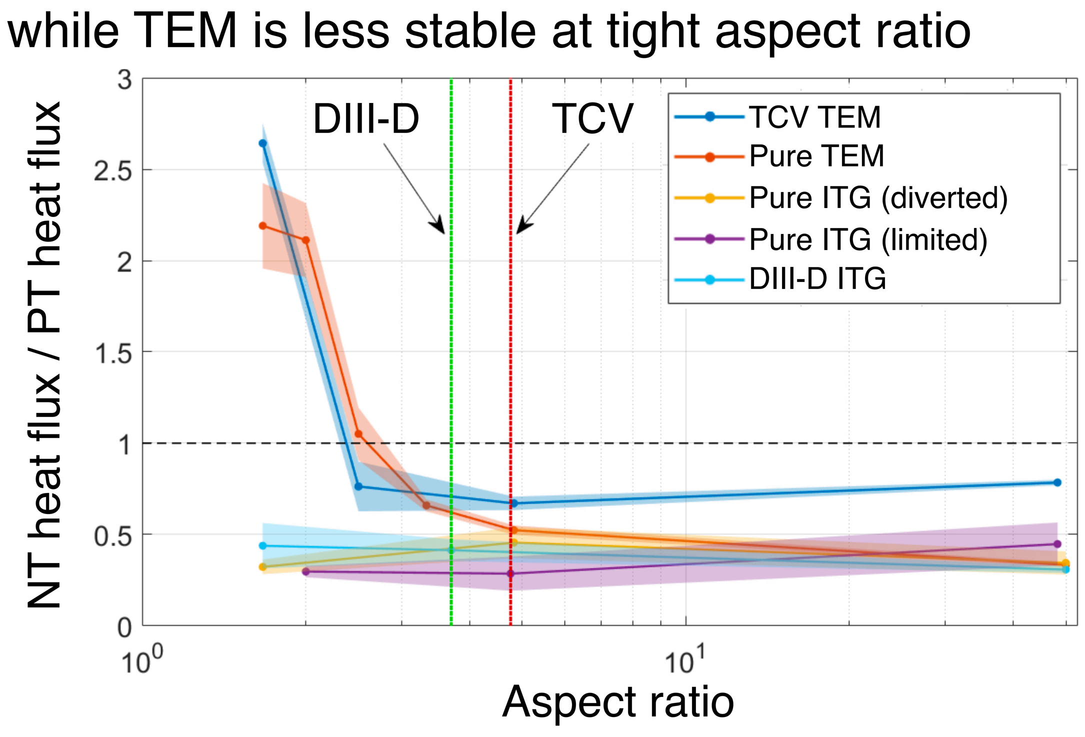
- Large multi-dimensional scan to find interesting dependencies that maximize benefits of NT



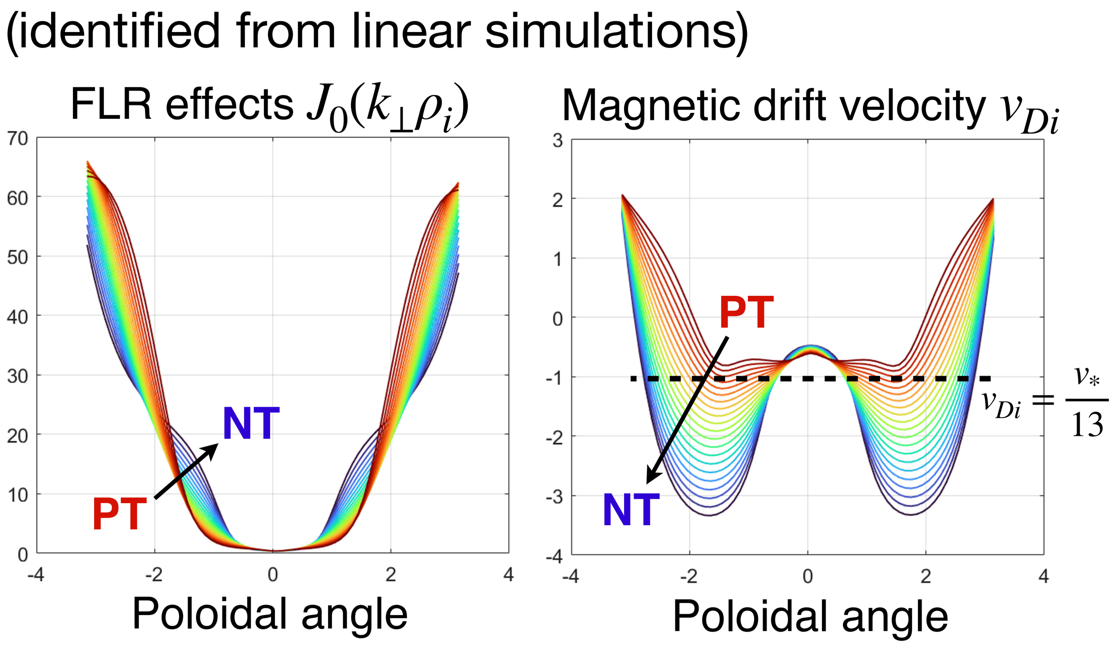
- NT more helpful at high $|\delta|$, high $\hat{s}$, high κ, and large aspect ratio[1,2]

Physics of confinement improvement[1]

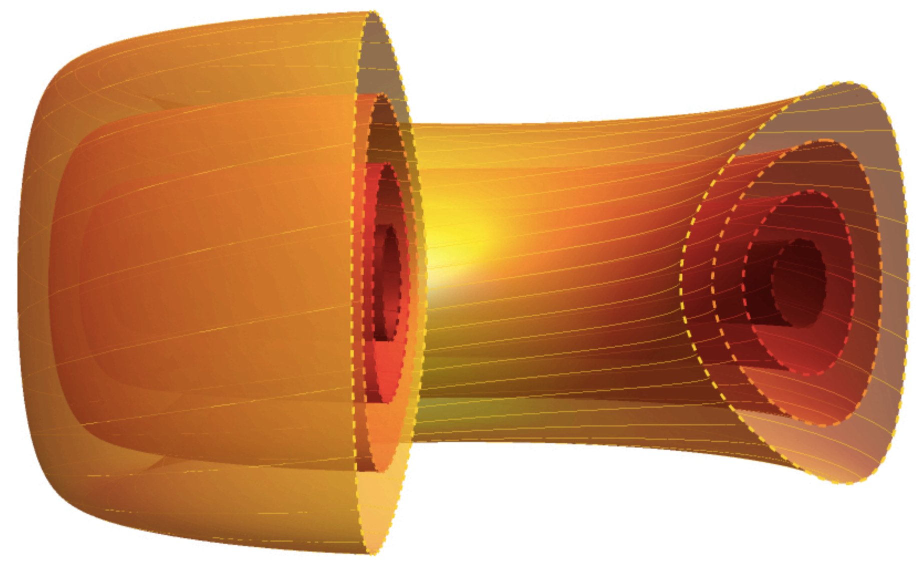
- ITG is more stable in NT at any aspect ratio, while TEM is less stable at tight aspect ratio



- For ITG, better understand by studying in large aspect ratio limit, as geometry only enters GK model through FLR effects and magnetic drifts
- In NT, FLR stabilization is stronger and magnetic drifts are further from ITG resonance condition[3] (identified from linear simulations)

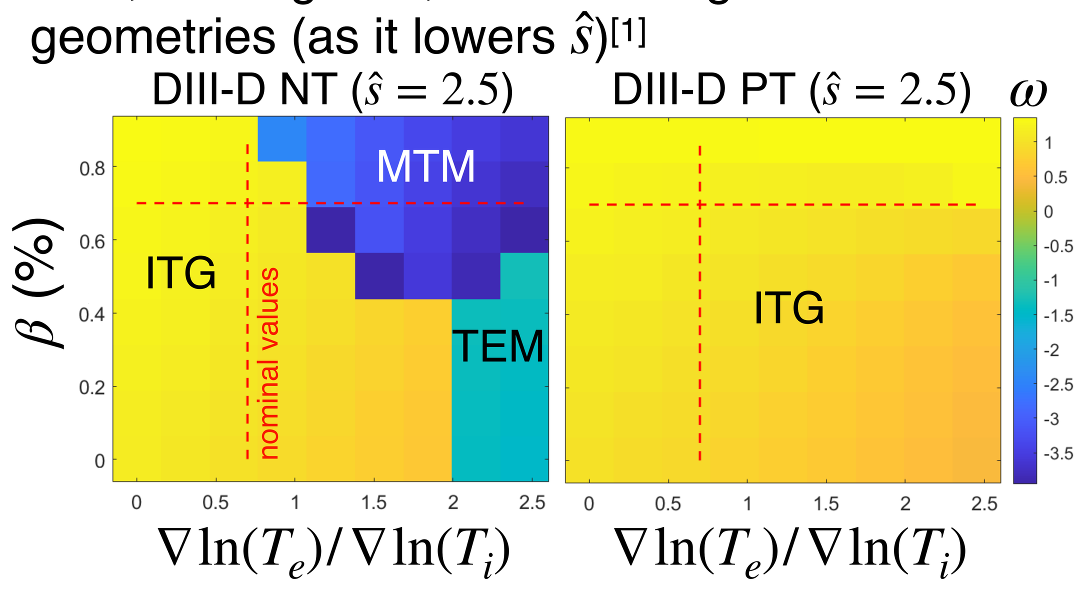


- Explains above parametric dependences and can be used to search for shapes beyond NT
- For TEM, finite extent of ballooning mode important to see stabilization from NT[4], which can also explain dependence on magnetic shear[2]

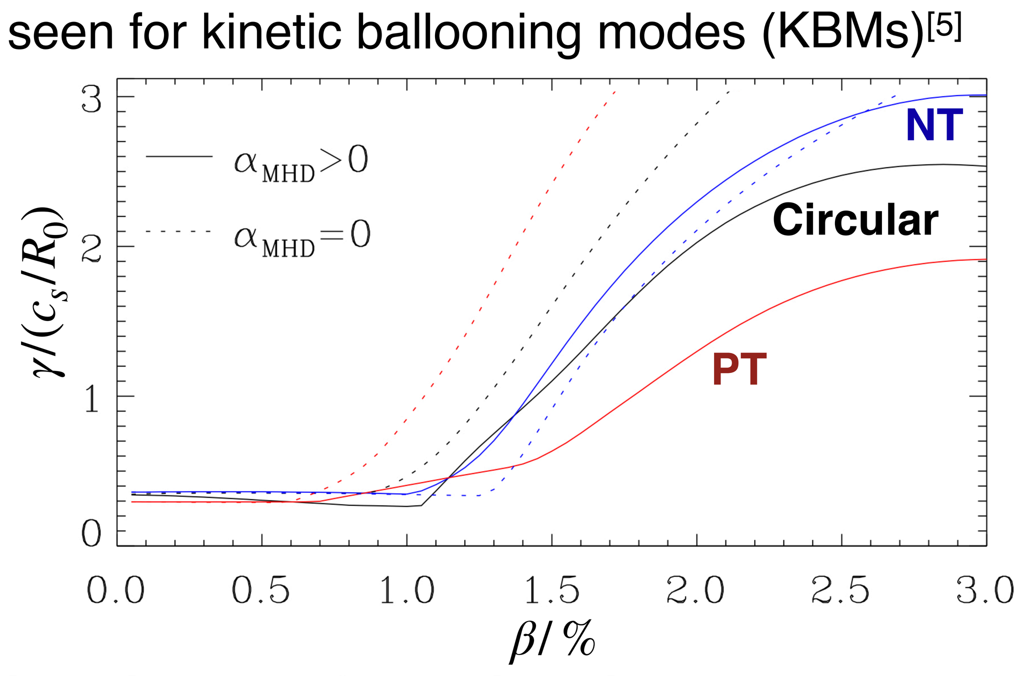


β-driven instabilities

- Microtearing modes (MTMs) are often stronger in NT, but can be avoided by increasing aspect ratio, heating ions, and avoiding double-null geometries (as it lowers $\hat{s}$)[1]

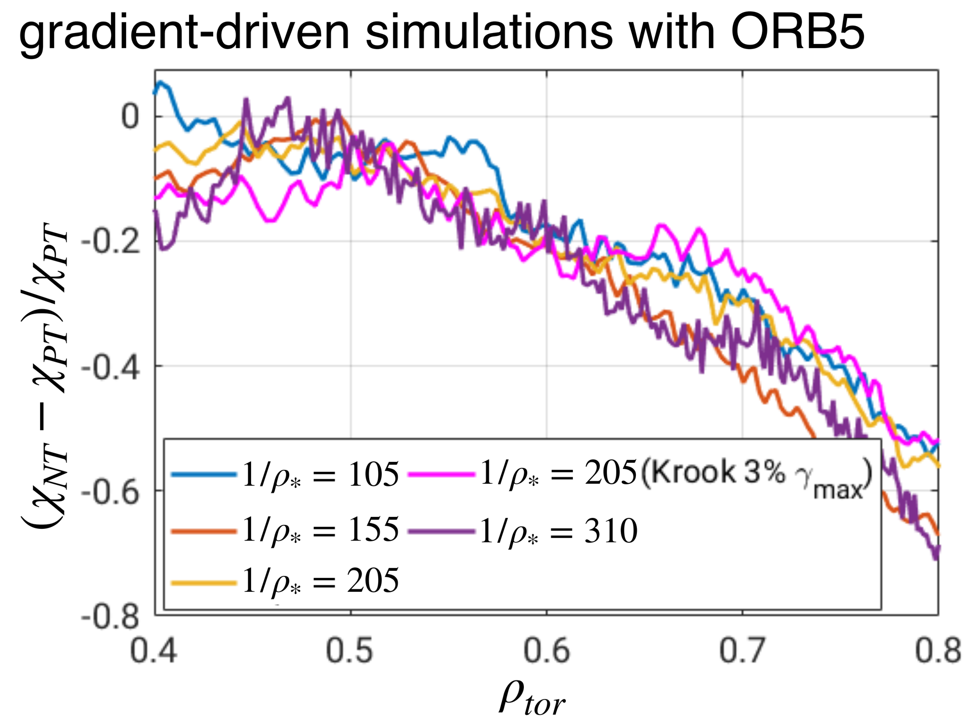


- At standard aspect ratio, higher threshold in NT seen for kinetic ballooning modes (KBMs)[5]



Direct impact of machine size

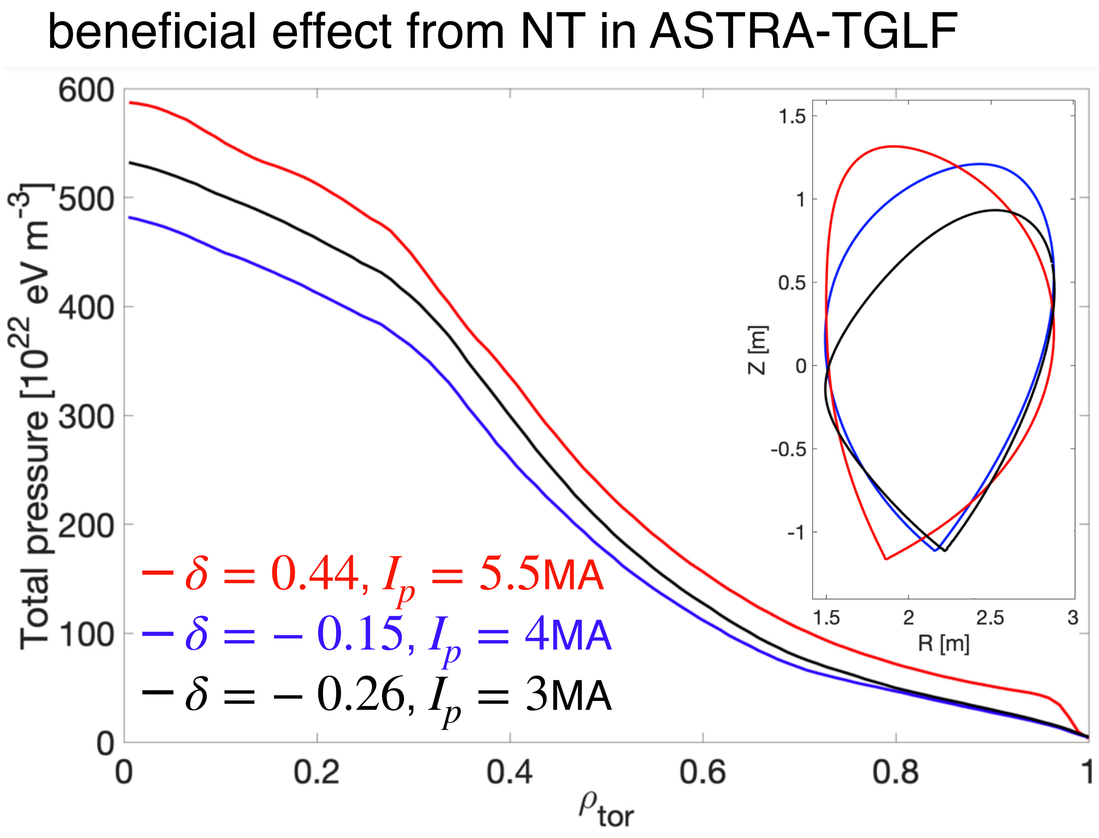
- PT and NT scale similarly with ρ_*[6,7] in global gradient-driven simulations with ORB5



- Recently ORB5 achieved the first GK flux-driven PT-NT comparison, which successfully recovered the experimental trends for R/L_T

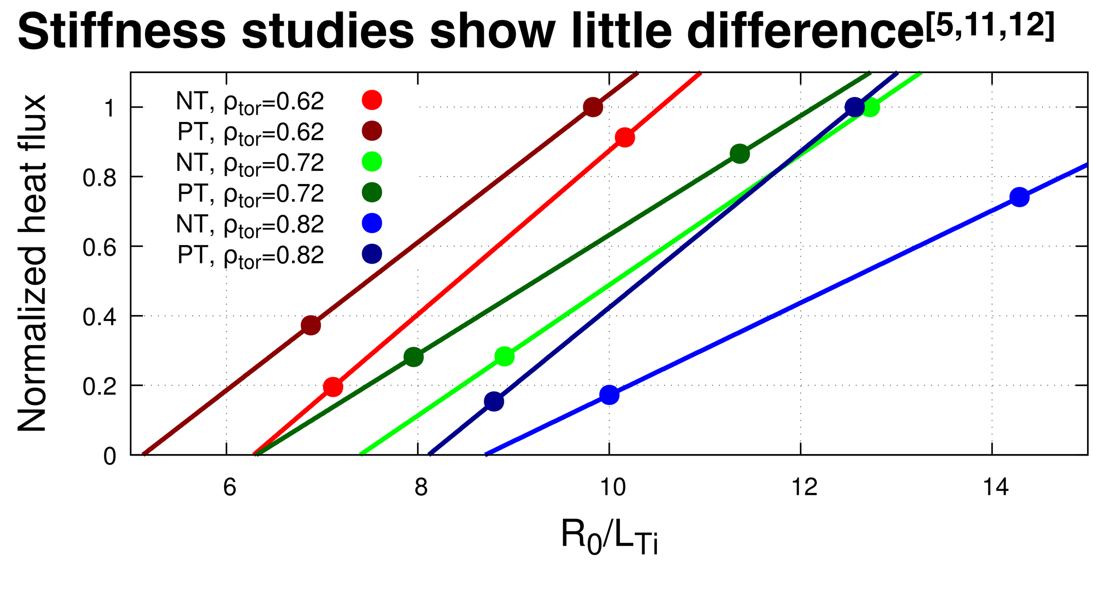
Reduced modeling of DTT[5,8,9,10]

- New "high-δ" DTT shape exhibits more of a beneficial effect from NT in ASTRA-TGLF



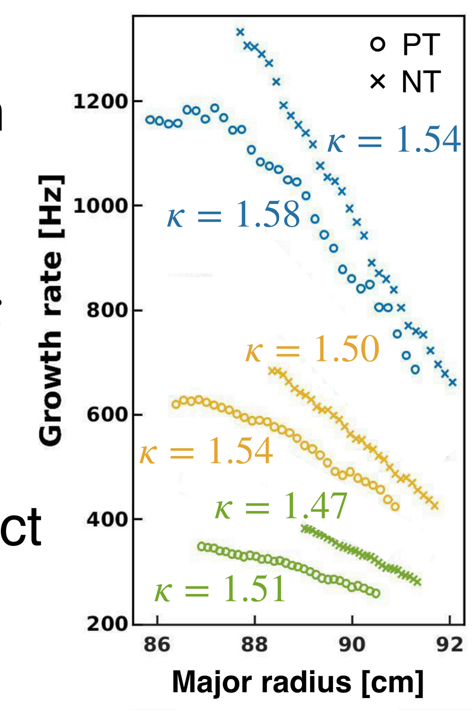
- Biggest effect comes from the very edge

Stiffness studies show little difference[5,11,12]



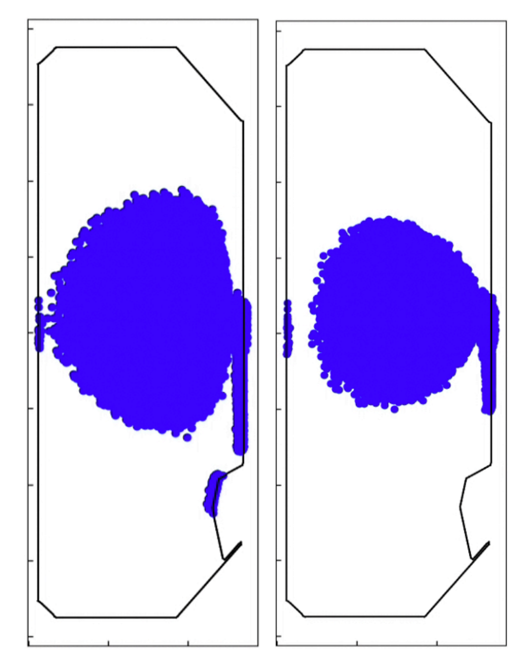
MHD stability

- Vertical stability worse in NT, which looks to limit elongation[13,14]
- Minimal direct effect of δ on NTMs, but difference between L-and H-mode profiles could have impact
- NT blocks H-mode by closing access to 2nd stability region of infinite-n ballooning modes[15,16]



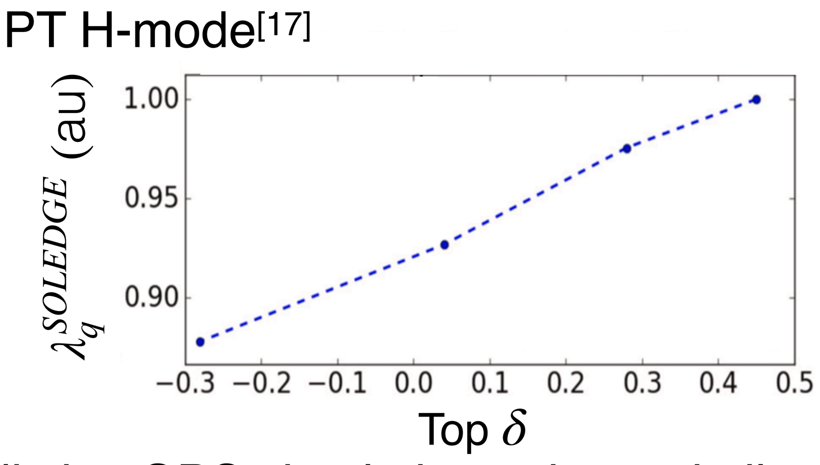
Fast particles

- ASCOT5 analysis of TCV shots indicate that, while NBI-driven fast ion losses hitting FILD diagnostic are higher in NT, total losses are actually ~10% smaller

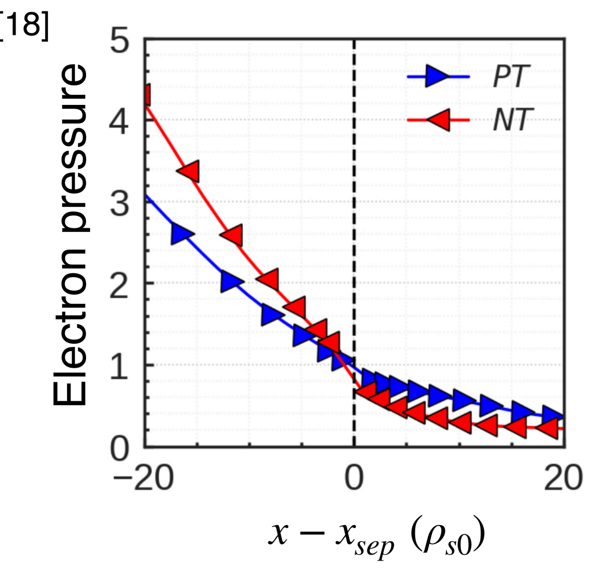


SOL dynamics

- Interpretative analysis of TCV and AUG with SOLEDGE2D-EIRENE indicates the NT SOL width will be intermediate between PT L-mode and PT H-mode[17]

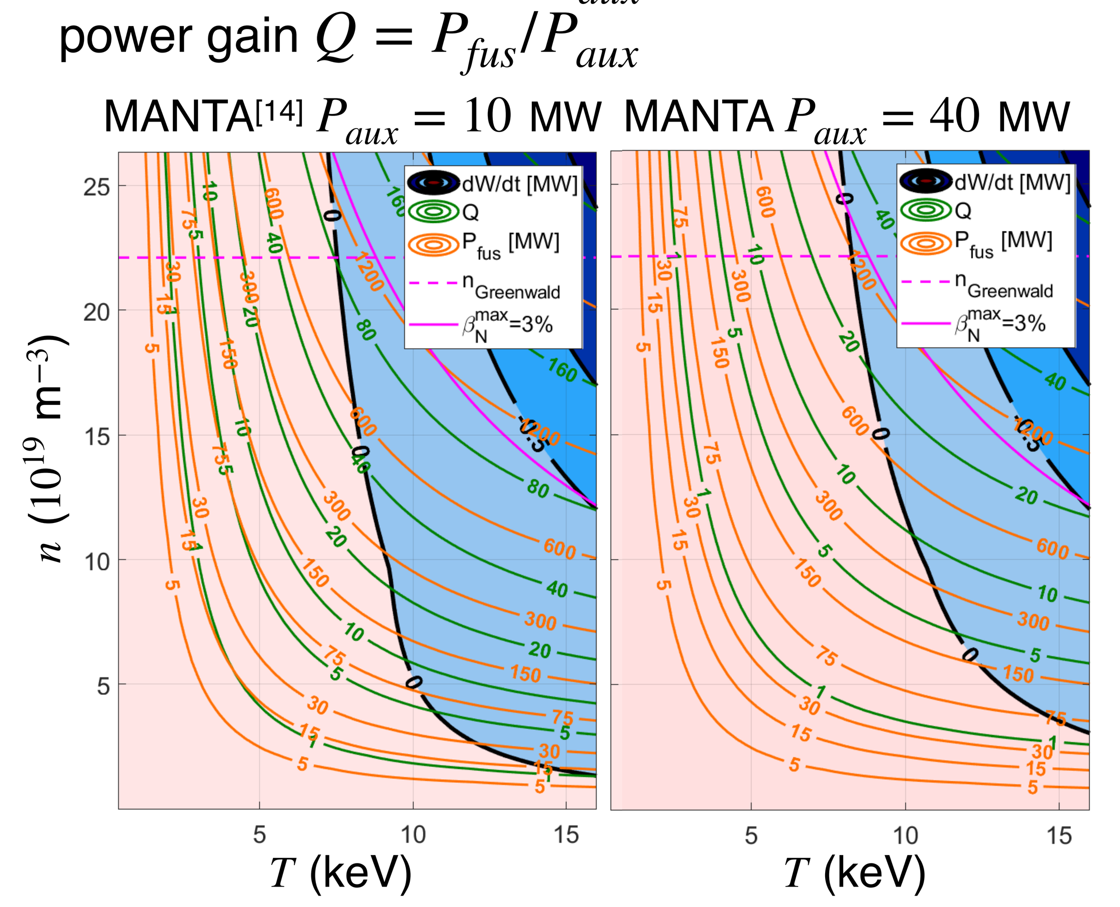


- Predictive GBS simulations give a similar conclusion[18]



NT power plants optimize differently[14,19]

- NT has no L-H threshold, so no lower limit on auxiliary heating power P_{aux}
- Can calculate optimal P_{aux} to maximize fusion power gain $Q = P_{fus}/P_{aux}$



Future plans

- GK transport modeling of H-mode pedestal with artificial NT shape to seek soft transport limit (e.g. MTMs)
- Explore promising shapes beyond NT[1,20,21]
- Analyze JET NT discharges
- Predictive SOL simulations with SOLEDGE3X to complement GBS
- Reduced modeling of experimental discharges
- Investigate detachment dynamics

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