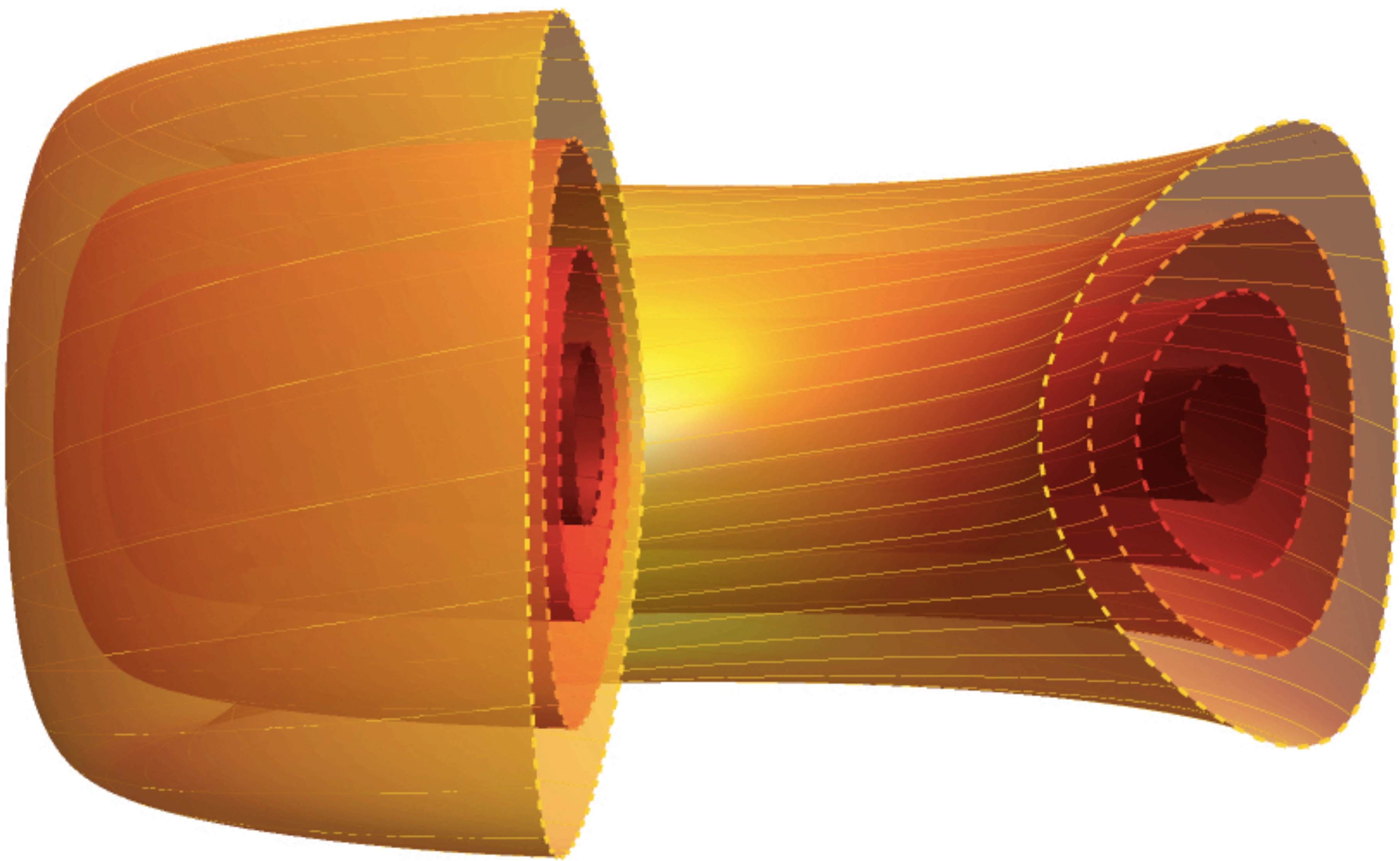
Opening remarks



Justin Ball

2024 Annual TSVV 2 Workshop

23 September 2024

Practical details

- Dinner tonight at 19:30 at Restaurant le Débarcadère
  - We’ll leave on foot from the lab at 19:00, talking the scenic route along the lake
- Wifi: eduroam and freewifi-epfl (registration required)
- 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

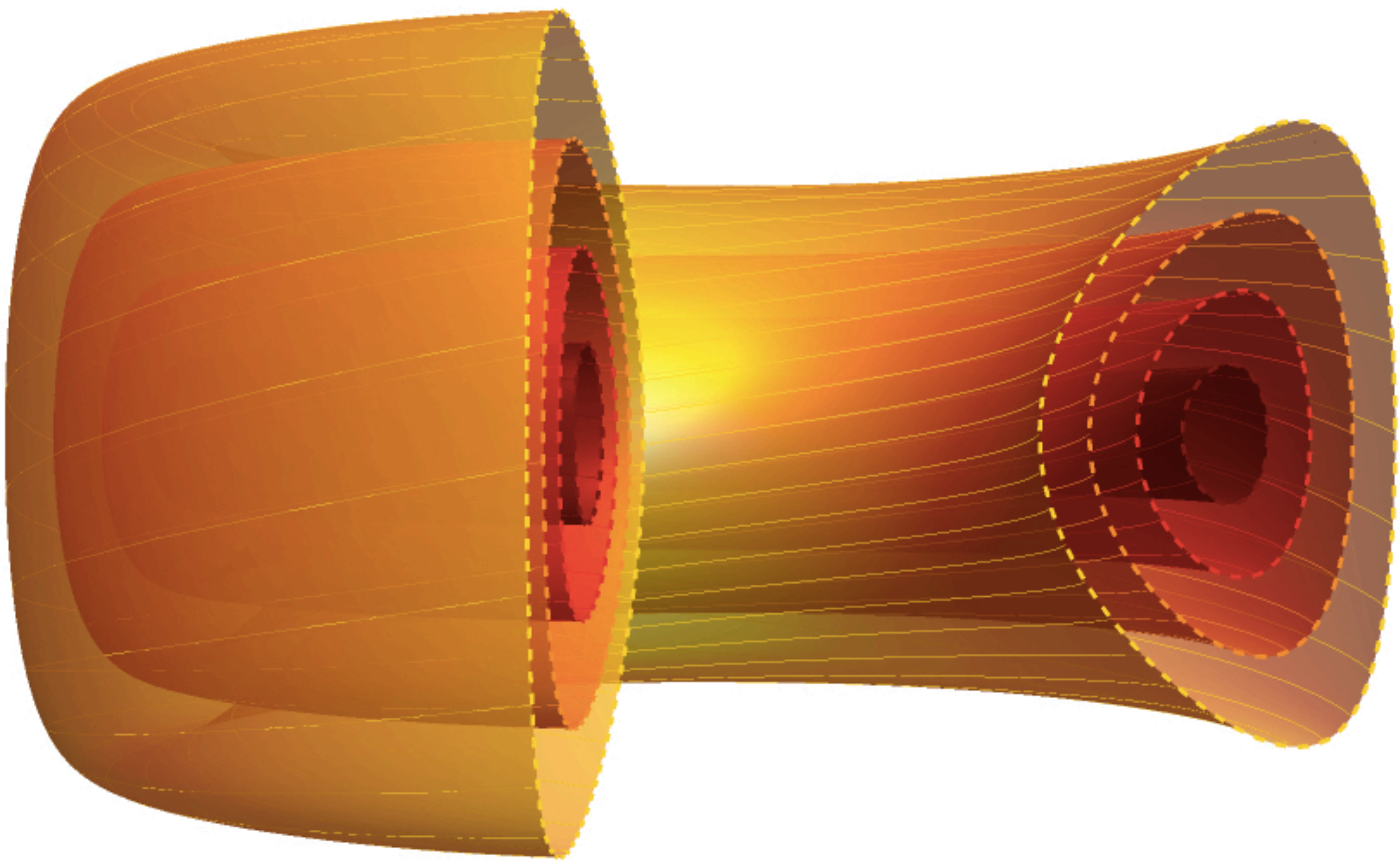
Practical details

- Please upload your presentation to the Indico meeting webpage (or simply email it to me and I can)
- Coffee & snacks will be provided in the morning/afternoon breaks (and are always available next door, but you have to pay)

On to the talks.

(thank you all for your contributions)

State of the art: Core turbulence summary discussion



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Basics of NT

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

- Impurity transport seems similar in PT and NT[Ale]

Basics of NT

G. Merlo, et al. *PPCF* (2015).

- Profile stiffness appears similar between PT and NT[Jus,Alb,Merlo2015]

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 not accurately capture effect of toroidal field or plasma current reversal[Ale]

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,Machenbach]

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

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

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

- At conventional aspect ratio, MTMs appear worse in NT, but can be avoided by increasing aspect ratio, reducing electron heating, and using single null (as it lowers $\hat{s}$)[Ale,MJ]

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?
- DTT can create a more proper "high delta" NT shape[Pao]

Areas of priority

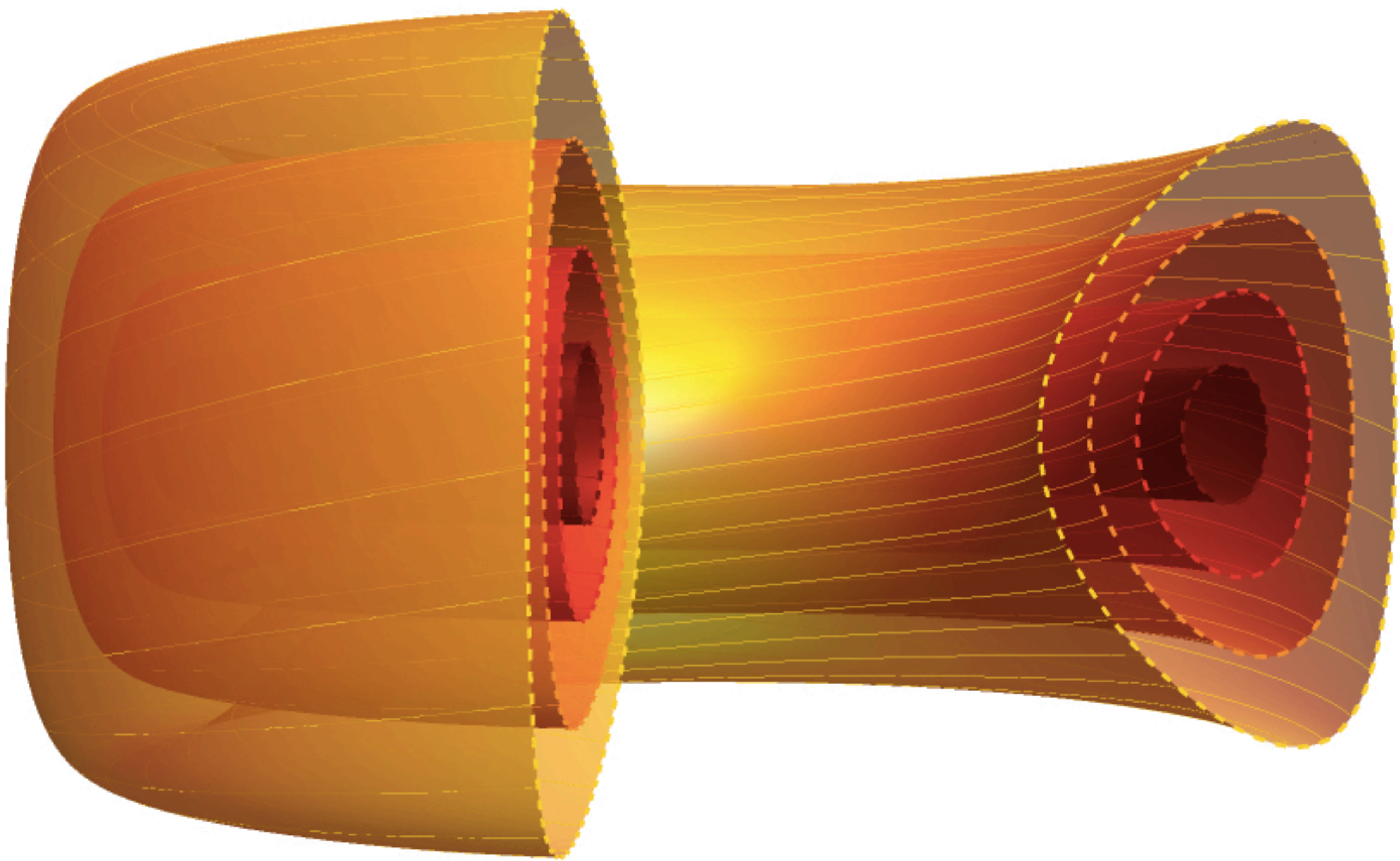
- Electromagnetic turbulence:
  - EM turbulence seems significantly worse for NT in spherical tokamaks
  - How important is it that MTMs are worse at conventional aspect ratio and what should we do about it?
  - There may be a significant difference between L- and H-mode profiles[Alb]
- Can we take boundary condition from BALOO?
- More on impurity transport?
- How do we proceed on the reduced modeling?
- Are there particular results that should be validated by experiment?

EUROfusion

Announcements

- Please upload talks to Indico (or just email to me)
- Depart from here at 19:00 for dinner
- Tomorrow: 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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Alfven eigenmodes

P. Oyola, et al. *IAEA* (2023).
A. Karpushov, et al. *EPS* (2023).
M.A. Van Zeeland, et al. *Nucl. Fusion* (2019).

- Fast particle-driven Alfven eigenmodes seem either unaffected[Mishchenko] or stabilized[Oyoda] in NT, which appears consistent with experiment[Oyoda,Karpushov,VanZeeland]

- Fast ion losses resulting from Alfven eigenmodes are smaller[Oyoda], which appears consistent with some TCV[Oyoda,Karpushov], but not DIII-D[VanZeeland]

- Density and safety factor profile effects might be the most important?

Pedestal ballooning stability

S.Yu. Medvedev, et al. Nucl. Fusion (2015).
A. Merle, et al. *PPCF* (2017).
S. Saarelma, et al. *PPCF* (2021).
O. Nelson, et al. *Nucl. Fusion* (2022).
O. Nelson, et al. *PRL* (2023).
J. Parisi, et al. *PoP* (2024).

- Experimentally NT plasmas don't transition to H-mode
- A lot of work on pedestal stability[Medvedev,Merle,Saarelma,Nelson,Parisi]
- 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]
- A NT spherical tokamak is calculated to have much steeper edge pressure gradients[Parisi]

Vertical stability

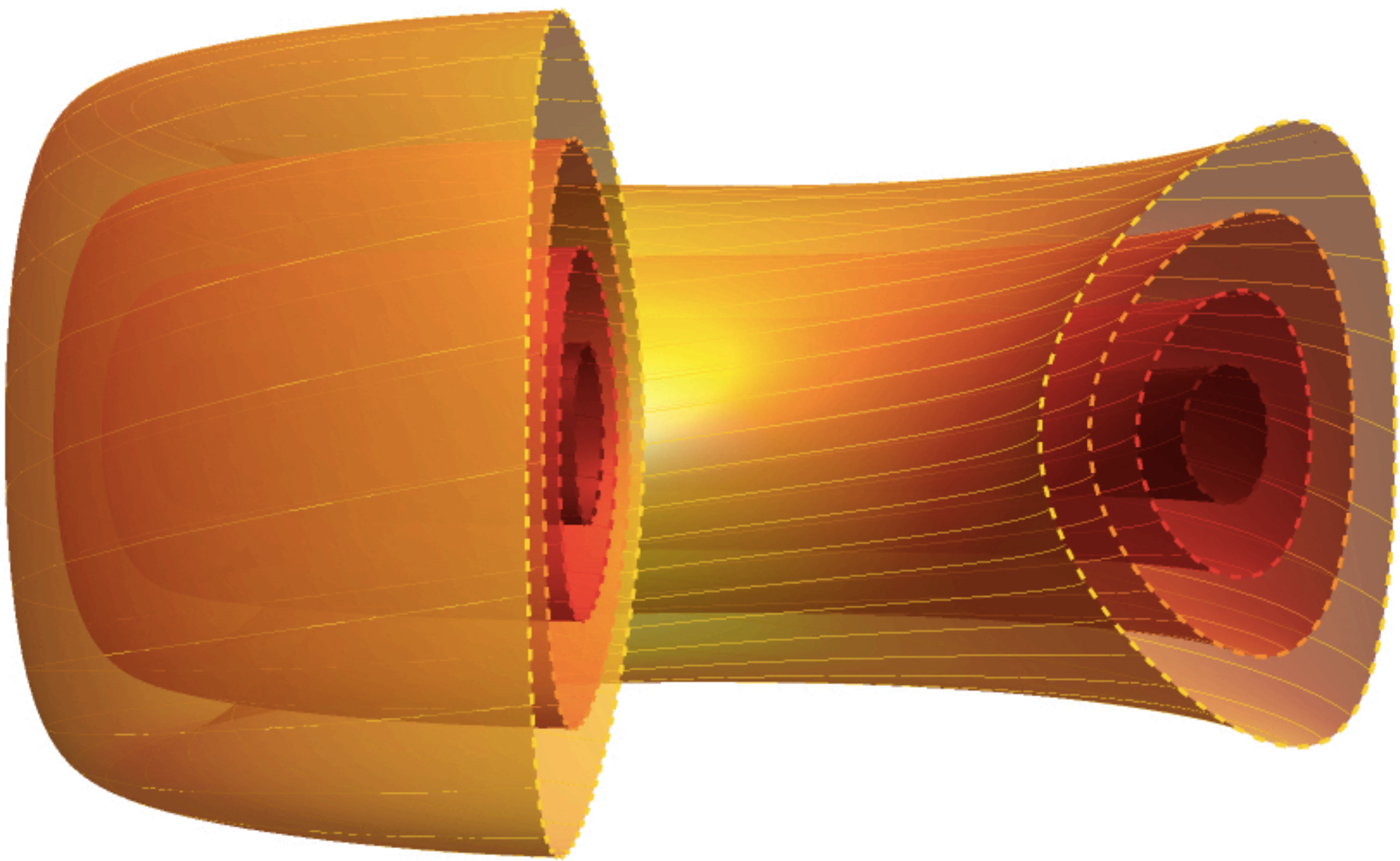
J. Song, et al. *Nucl. Fusion* (2021).
E. Rodriguez. *JPP* (2023).
S. Guizzo, et al. *PPCF* (2024).

- Considerable work on vertical stability[Stef,Song,Rodriguez,Guizzo]
- Calculations indicate NT will be limited to lower elongation[Stef,Song,Rodriguez,Guizzo], reducing performance
    - May be alleviated by passive conducting stabilizing plates[Guizzo]

Areas of priority

- Kinetic corrections to MHD stability?
- 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).
E. Tonello, et al. *PPCF* (2024).
O. Fevrier, et al. *PPCF* (2024).

- 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 $\delta = 0.3 \to -0.3$[Kyu,Pao,Laribi,Tonello,Fevrier,Becoulet]

- 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

O. Fevrier, et al. *PPCF* (2024).

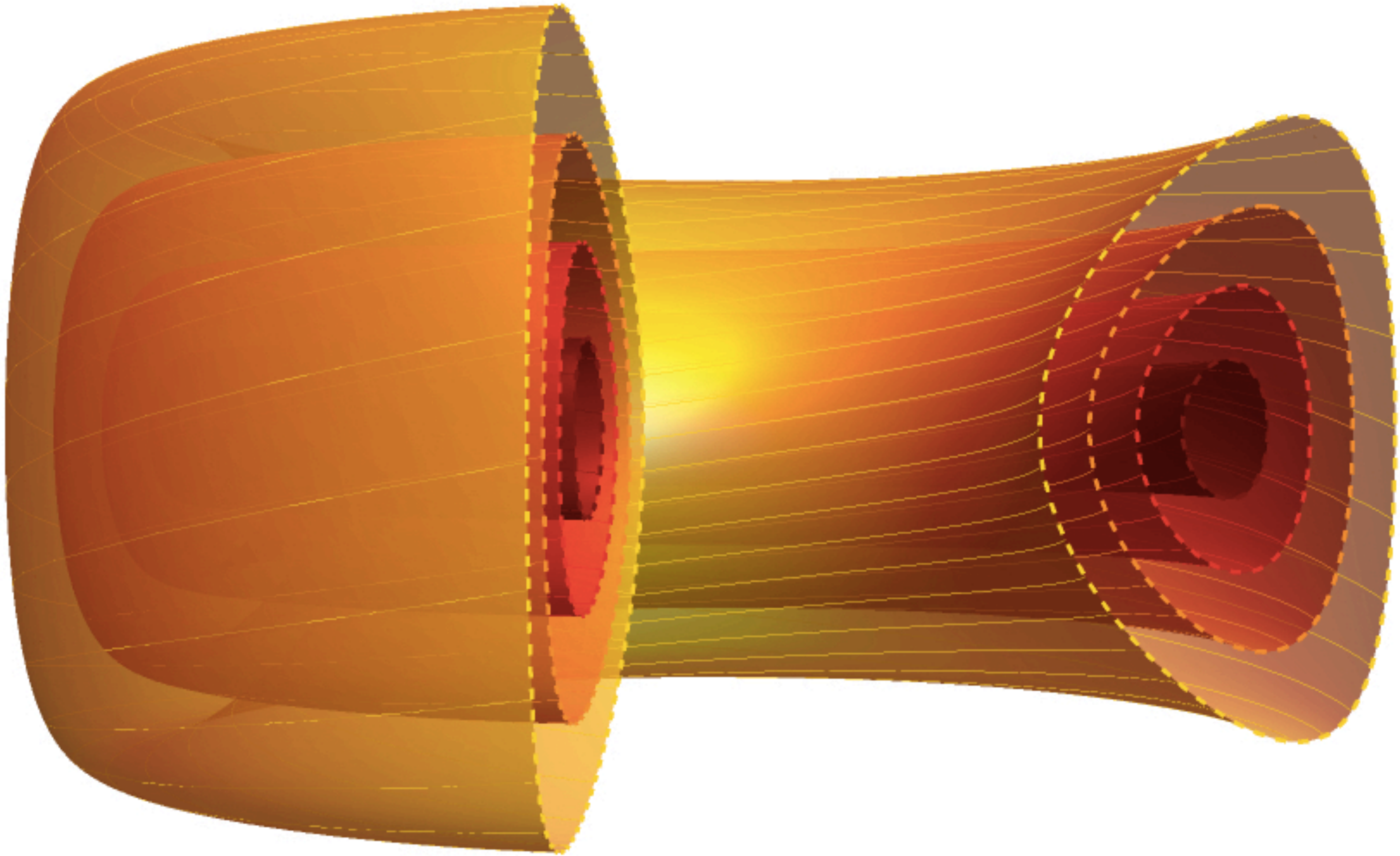
- Harder to achieve in NT relative to PT L-mode[Fevrier]

Areas of priority

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

- Extrapolation to a power plant (potentially with theory-based GBS scaling law or TCV->AUG->DTT SOLEDGE2D study)
- GENE-X simulations?[Ulbl]
- 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
- Different optimal edge impurity seeding in NT (as there is no longer a minimum heating power that must be preserved)?

Final summary discussion



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Announcements

- Please upload slides on indico (or email to me)
- Advanced Computing Hub tasks?

Discussion questions

- What are the main risks that still need to be addressed for a NT DEMO?
- Are ASDEX-U results consistent with other tokamaks?
- What are the most significant drawbacks of NT that would need to be compensated for in a design optimization? In what ways do we expect NT to optimize differently than PT?
- What should be the benchmark for comparison with NT (e.g. standard ELMy H-mode, one of the ELM-free scenarios)?
- Are NT profiles less dependent on the boundary condition, making them easier to predict?
- What else?