# Numerical Study of the Impact of Fast Ions on TEM-driven Turbulence


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## MOTIVATION & BACKGROUND

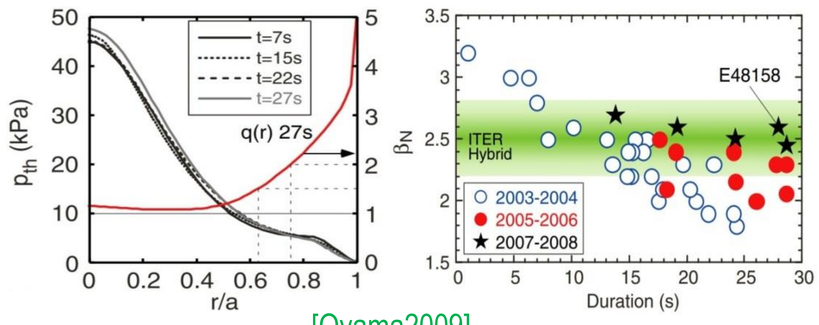
- Well-established beneficial impact of fast ions on Ion-Temperature-Gradient (ITG) turbulence:

➢ **Experimentally**: ✓ Improvement of ion confinement in JET L-mode plasmas and subsequently in several other devices (also H-mode plasmas)

➢ **Numerically**:
- ✓ Stabilization of ITG turbulent transport due to Fast-Ion-triggered complex mechanism involving enhanced zonal flows found by gyrokinetic simulations [Citrin2013,Zarzoso2013,DiSiena2019,DiSienaFEC2020]
- ✓ Similar behavior expected in ITER ITG-dominated plasmas [Garcia2018,Mazzi2020b]

**Open question**: **What is the fast-ion impact on different turbulent regimes?**

## TEST-BED CASE: JT-60U #48158 HYBRID SCENARIO




[Oyama2009]

- High $\beta$ ($\beta_N = 2.6\%$)
- Inner region: Low magnetic shear → Very demanding simulations
- High fraction of Fast Ion (NBI) pressure
- Previous gyrokinetic analyses @ $\rho_{tor} = 0.33$ [Garcia2014]
  - ➢ Turbulent transport dominated by Trapped Electron Modes (TEMs) → Suitable for comparison to well-studied ITG case

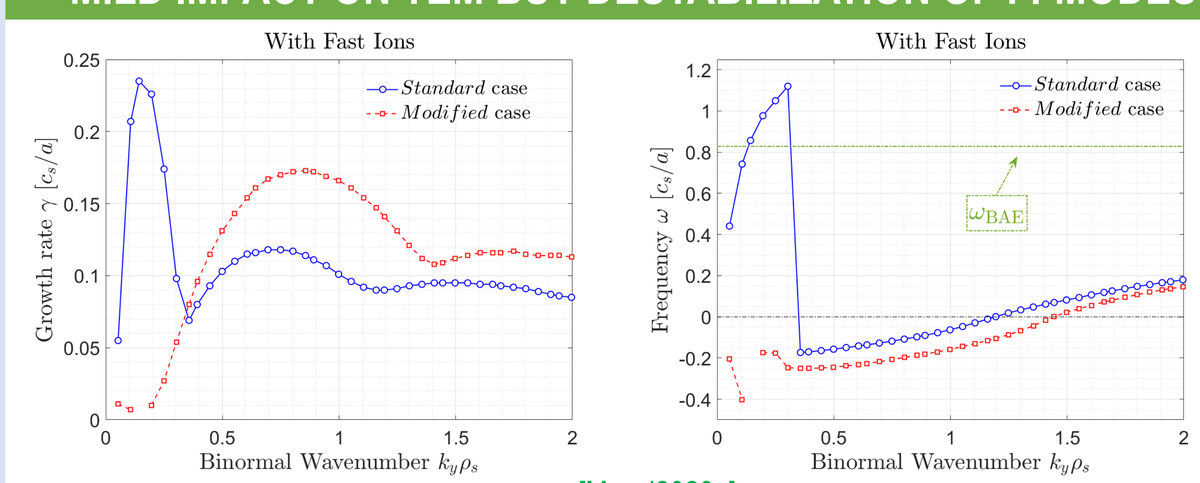
## NUMERICAL TOOL: GENE

- Local (flux-tube) @ $\rho_{tor} = 0.33$ (core)
- Input parameters provided by CRONOS [Artaud2010]
- Simulations include:
  - ➢ Kinetic electrons
  - ➢ Electromagnetic effects ($\delta B_\perp$ & $\delta B_{||}$)
  - ➢ Experimental geometry
  - ➢ Carbon impurity & fast deuterium from NBI

GENE

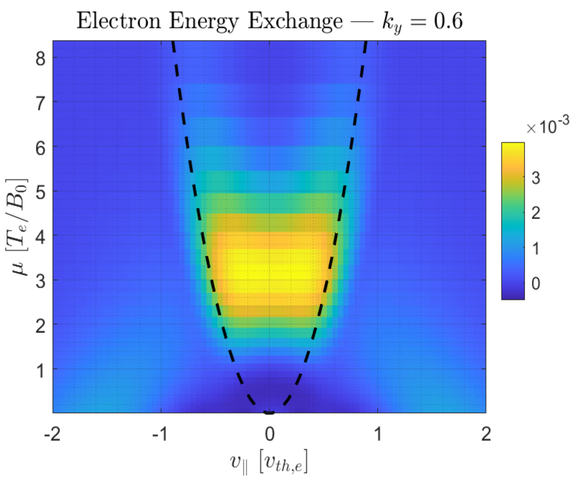
[Jenko2000]

## LINEAR ANALYSES WITH FAST IONS: MILD IMPACT ON TEM BUT DESTABILIZATION OF FI-MODES



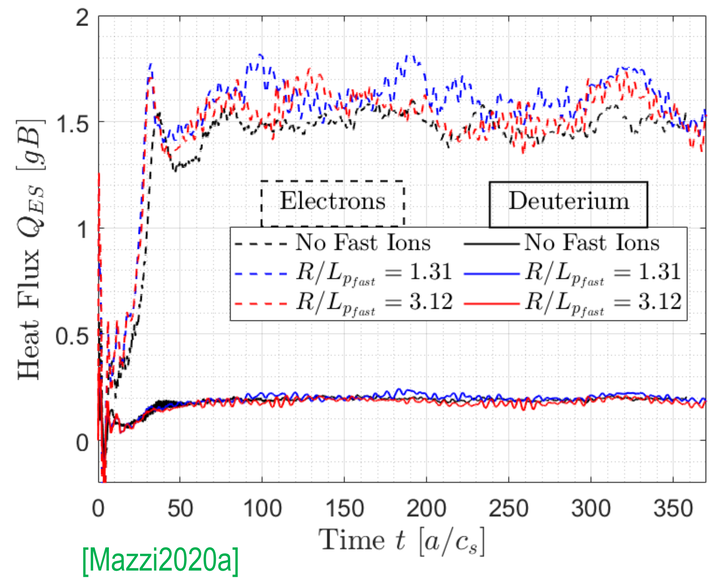

[Mazzi2020a]

- Dominant mode at ion-scale: TEM
- Fast Ion impact on linear spectra:
  - ➢ Mild destabilizing effect on ion-scale
  - ➢ Excitation of low-$k_y$ mode
  - ➢ The mode is identified as Fast-Ion-driven BAE
- In order to avoid possible nonlinear coupling, FI-BAE must be stabilized *(modified* configuration*)*



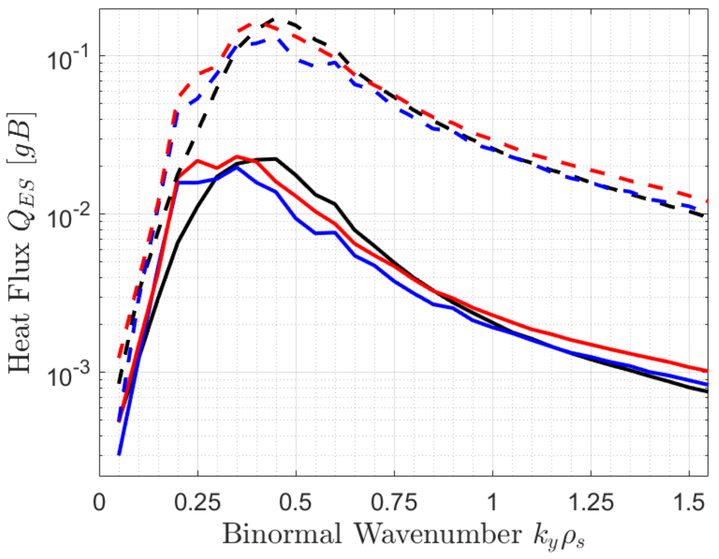

## MAIN RESULTS: NO IMPACT OF FAST IONS ON TEM-INDUCED HEAT FLUXES

- *Modified* setup has been employed to avoid nonlinear synergy between various unstable modes → TEMs dominate the turbulent regime
- TEM-induced heat flux not affected by Fast Ions:
  - ➢ Heat flux time traces almost overlap
  - ➢ Spectra revealed small shift towards lower $k_y$




[Mazzi2020a]

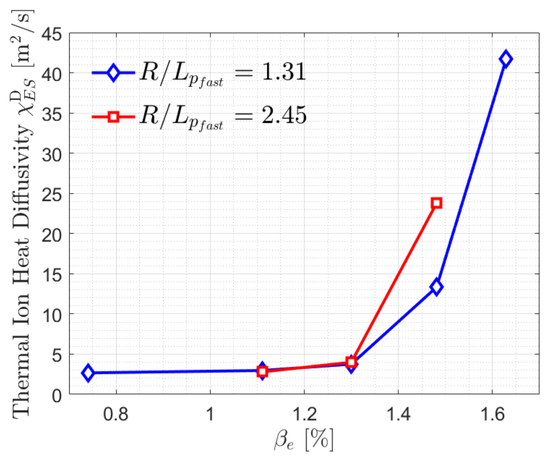
- Possible explanation → Weak impact of Zonal Flows as a saturation mechanism in $\nabla T$-driven TEM [Merz2008]




## THRESHOLD IN ACHIEVABLE PRESSURE REGIME

- Numerical experiment: Evaluating $\beta_e$ impact
- Threshold in $\beta_e$ ($\approx 1.3\%$) → Destabilization of FI-driven modes
- When FI-modes unstable → Large increase of thermal turbulent transport

Limit in achievable pressure regime consistent with Fast Ion impact on ITG transport [Citrin2015]




## CONCLUSIONS

- Impact of Fast Ions on TEM-dominated JT-60U pulse #48158:
  - ➢ Mild impact on TEM linear growth rate
  - ➢ Strong Fast-Ion pressure gradient leads to destabilization of FI-BAE
  - ➢ No impact on TEM-driven turbulent heat fluxes
- Possible explanation for different ITG/TEM behavior → Difference on the saturation mechanism: $\nabla T$-driven TEMs weakly affected by Zonal Flows

**Beneficial effect of fast ions may be limited by turbulent plasma regime!**

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