TSVV02 report - Fast particle confinement

M. Vallar, P. Oyola, M. Garcia-Munoz
the **TCV team**, the **WPTE-RT11 team**

EPFL

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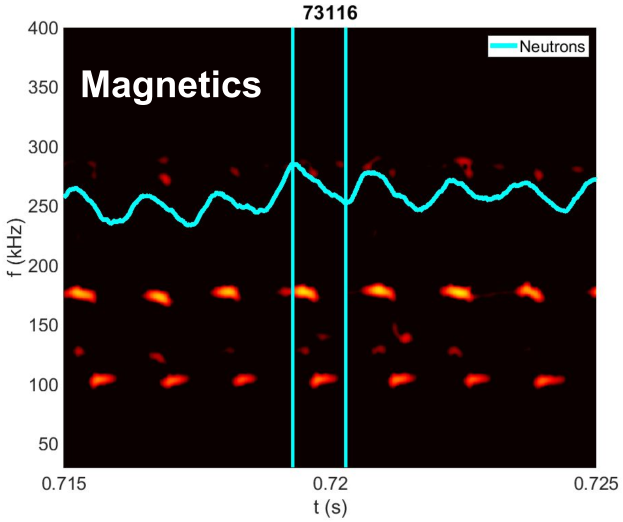
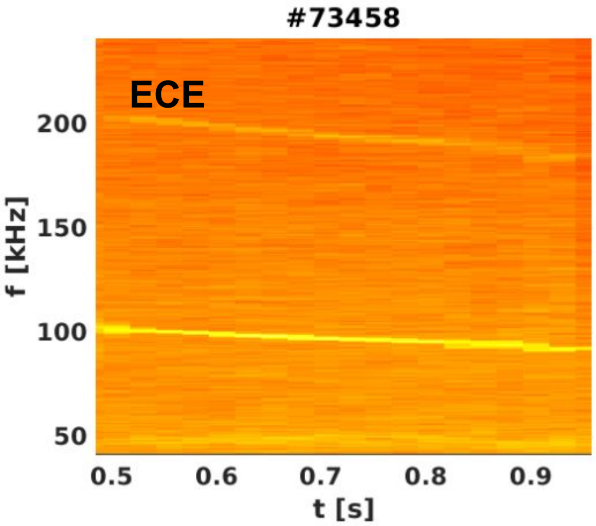
Perturbative modes
Non perturbative modes

TAE modes in +δ TCV

- TAE (n=1, m=2,3) in counter-current NBH (magnetics, ECE)
- Neutron rate (mainly beam-target) related to mode activity
- EP population marginally capable of destabilize the modes

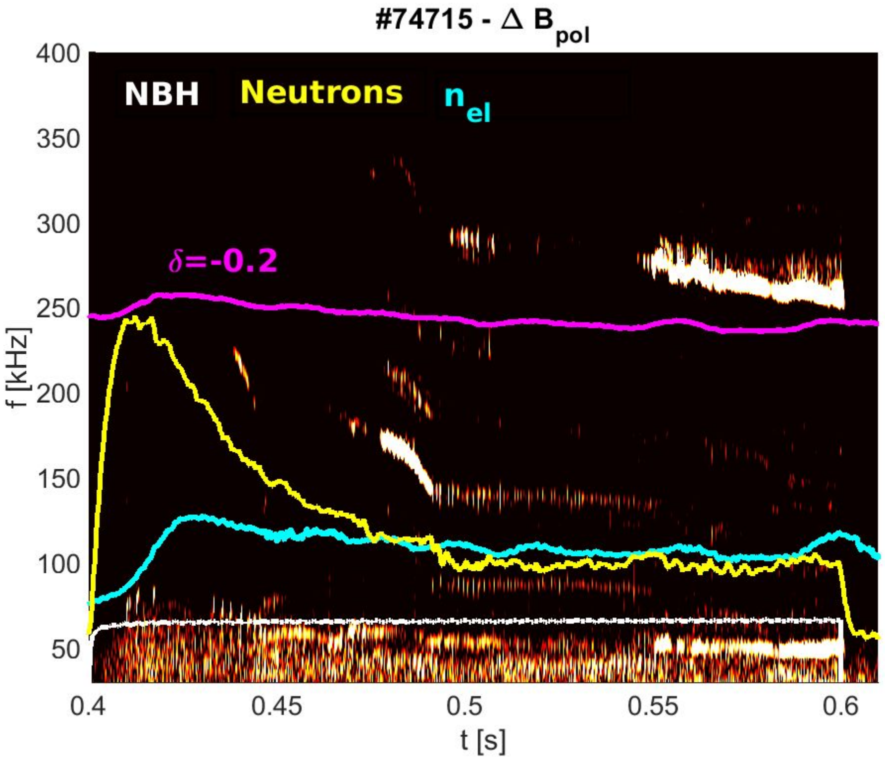




M. Vallar et al, 2022, submitted to NF

TAE modes in -δ TCV

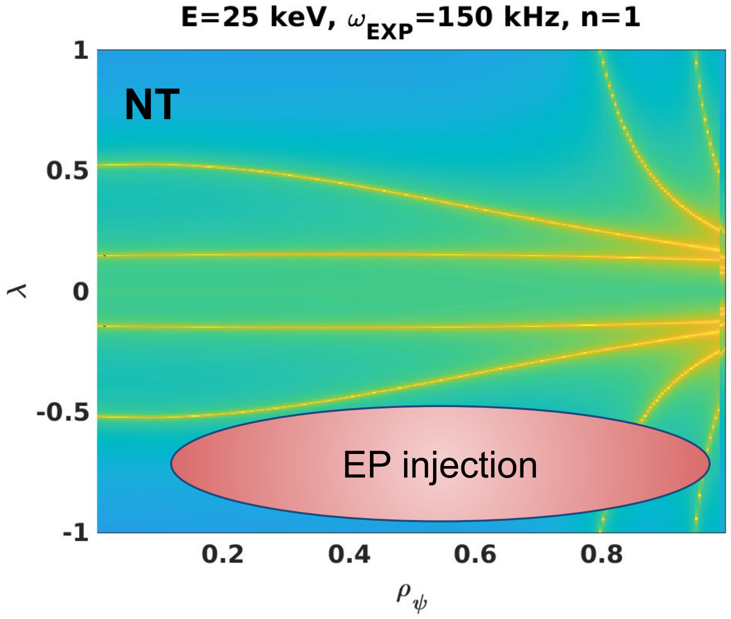
- P=900kW
  E<24 keV
- Lower EP energy needed to excite modes
- Wide population of modes
- Hardly repeatable (development ongoing..)
- Correlation between neutrons and EAEs(?) not clear

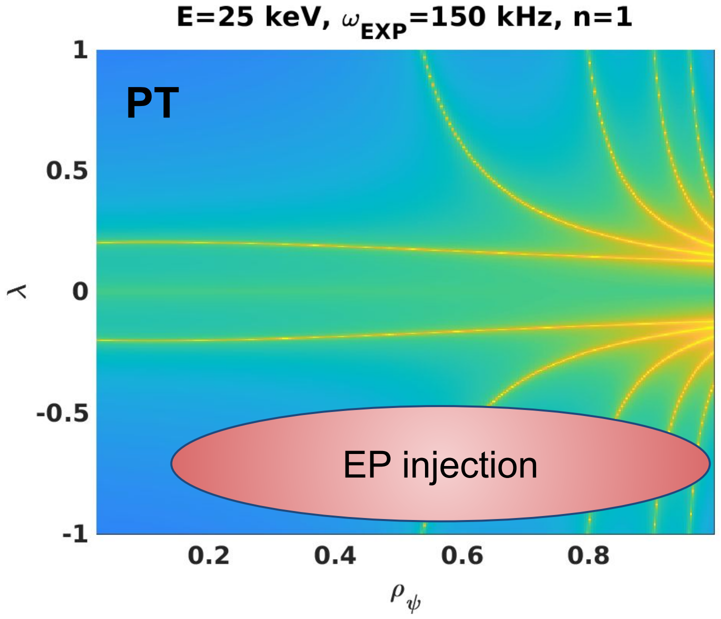


NT- Less favorable phase-space resonance

$$\Omega = \omega_{\mathrm{EXP}} - n \cdot \omega_\phi + p \cdot \omega_\theta$$

- EP need to meet a resonance condition to excite TAE modes
- NT resonances look to be in a different phase-space wrt PT





Non perturbative modes

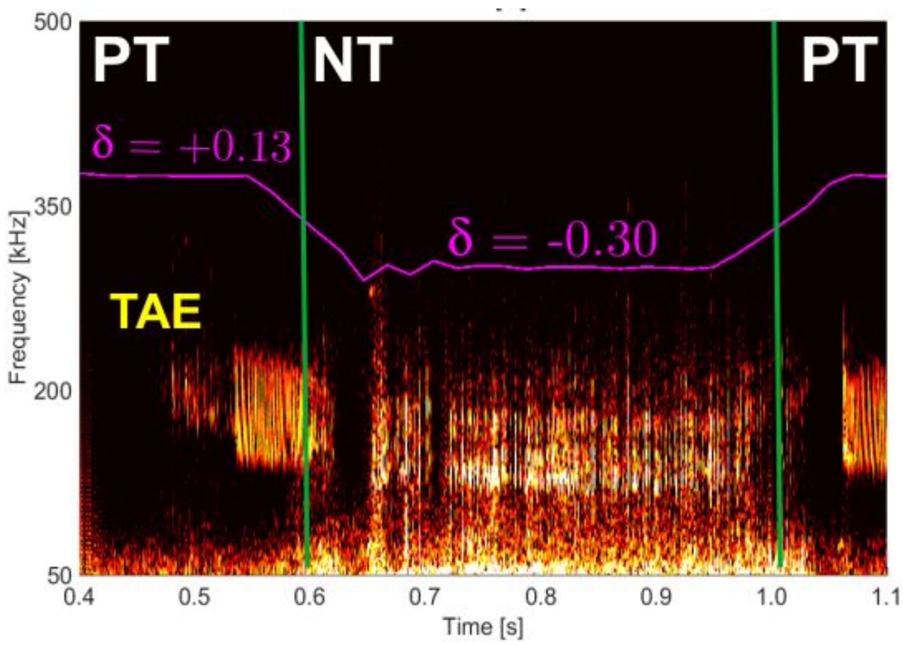
Non-perturbative modes in NT

High fast ion population -> non-perturbative modes

Main feature is the strong chirping (~100 kHz) below fast-ions time scales

Starting in SAW gaps, but overcoming also continuum damping

More info on M. Vallar - EPS 2022

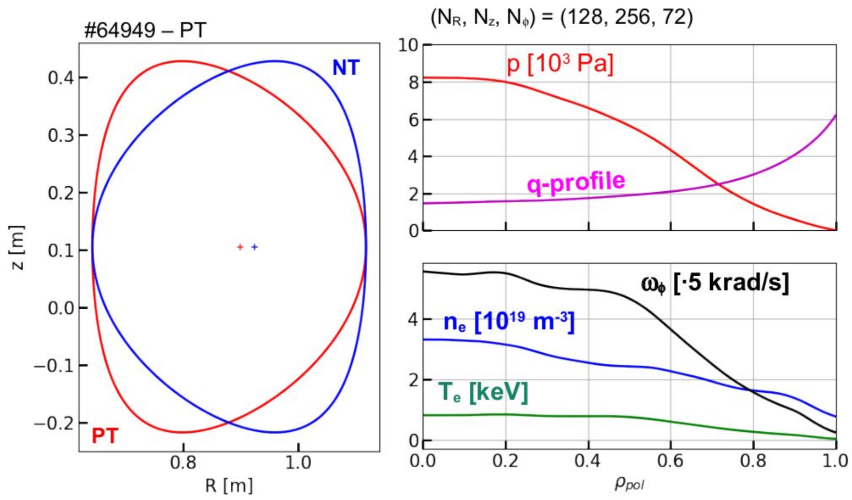


With P. Oyola, M. Garcia-Munoz - Uni. Sevilla, submitted to PRL

Same inputs, only opposite shape

MEGA [1] (hybrid-kinetic MHD) is used to compute mode nonlinear evolution

Artificial equilibrium with simply opposite shape



[1] Y. Todo et al., Phys. Plasmas 5, 1321 (1998)

Analytical FI distribution function

$$f_0 \propto e^{\frac{(\rho-\rho_0)^2}{2(\Delta\rho_0)^2}} \frac{1}{v^3 + v_{crit}^3} erfc\left(\frac{v - v_{birth}}{\Delta v}\right) e^{\frac{(\Lambda-\Lambda_0)^2}{2(\Delta\Lambda)^2}}$$

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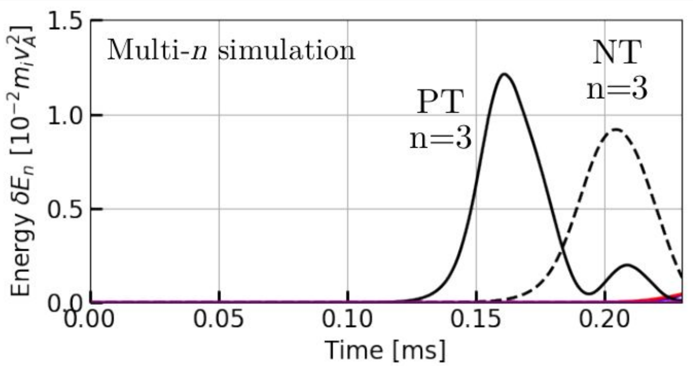
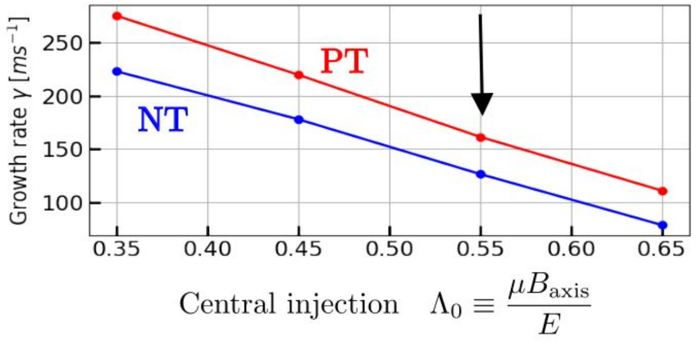
Growth rate is smaller in NT

The growth rate is smaller in NT

Independent on injection angle or fast particle location





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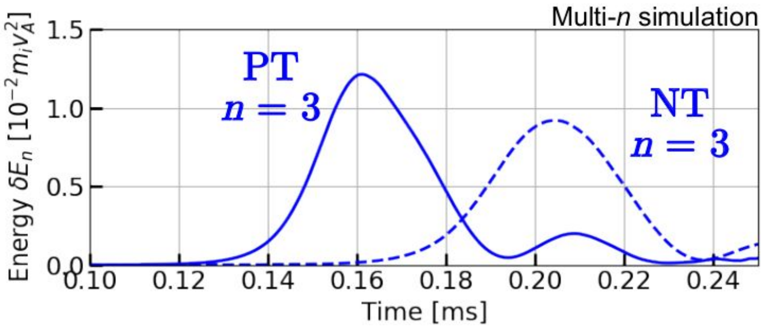
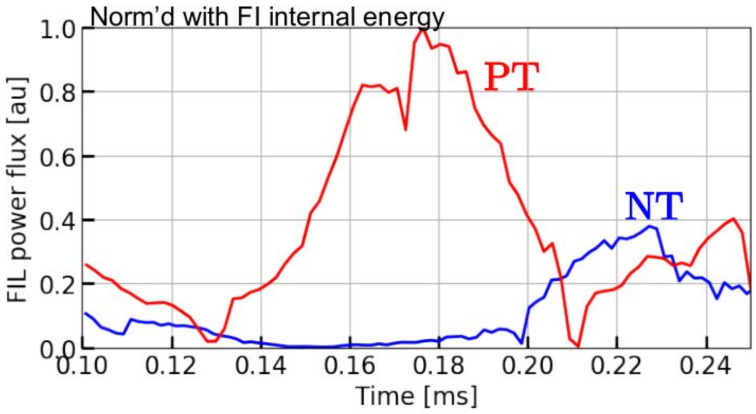
Synthetic FI losses lower in PT

Synthetic loss of FI is smaller in NT wrt PT

This has been observed also for perturbative modes on FILD





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Conclusions and future work

- TAEs in NT need lower beam power/energy to be excited
- NT scenario hardly reproducible, development ongoing
- The resonance condition is less favourable in NT

- MEGA simulations to model perturbative modes evolution
- NT has smaller growth rates wrt PT
- Synthetic losses in NT are reduced

- Comparison with experimental data foreseen
- Delta scans for non-perturbative modes foreseen

Thank you for your attention!

Backup

- Energetic particle and MHD dynamics coupled through EP current density[1]

$$\rho \frac{\partial \vec{v}}{\partial t} = -\rho(\vec{v}\cdot\nabla)\vec{v} - \nabla p + \left(\vec{j} - \vec{j}_{\mathrm{h}}'\right)\times\vec{B} - \nabla\times(\nu\rho\nabla\times\vec{v}) + \frac{4}{3}\nabla(\nu\rho\nabla\cdot\vec{v})$$

$$\frac{\partial p}{\partial t} = -\nabla\cdot(p\vec{v}) - (\gamma-1)p\nabla\cdot\vec{v} + \nabla\cdot\left[\chi_\perp\nabla_\perp(p-p_{\mathrm{eq}}) + \chi_\parallel\nabla_\parallel(p-p_{\mathrm{eq}})\right] + (\gamma-1)\left[\nu\rho(\nabla\times\vec{v})^2 + \frac{4}{3}\nu\rho(\nabla\cdot\vec{v})^2 + \eta\left(\vec{j}-\vec{j}_{\mathrm{h}}'\right)\cdot\left(\vec{j}-\vec{j}_{\mathrm{eq}}\right)\right]$$

- PIC δf method for fast particles

- Cylindrical coordinates $(R,\ \varphi,\ z)$

[1] Y. Todo *et al.*, Phys. Plasmas **5**, 1321 (1998)