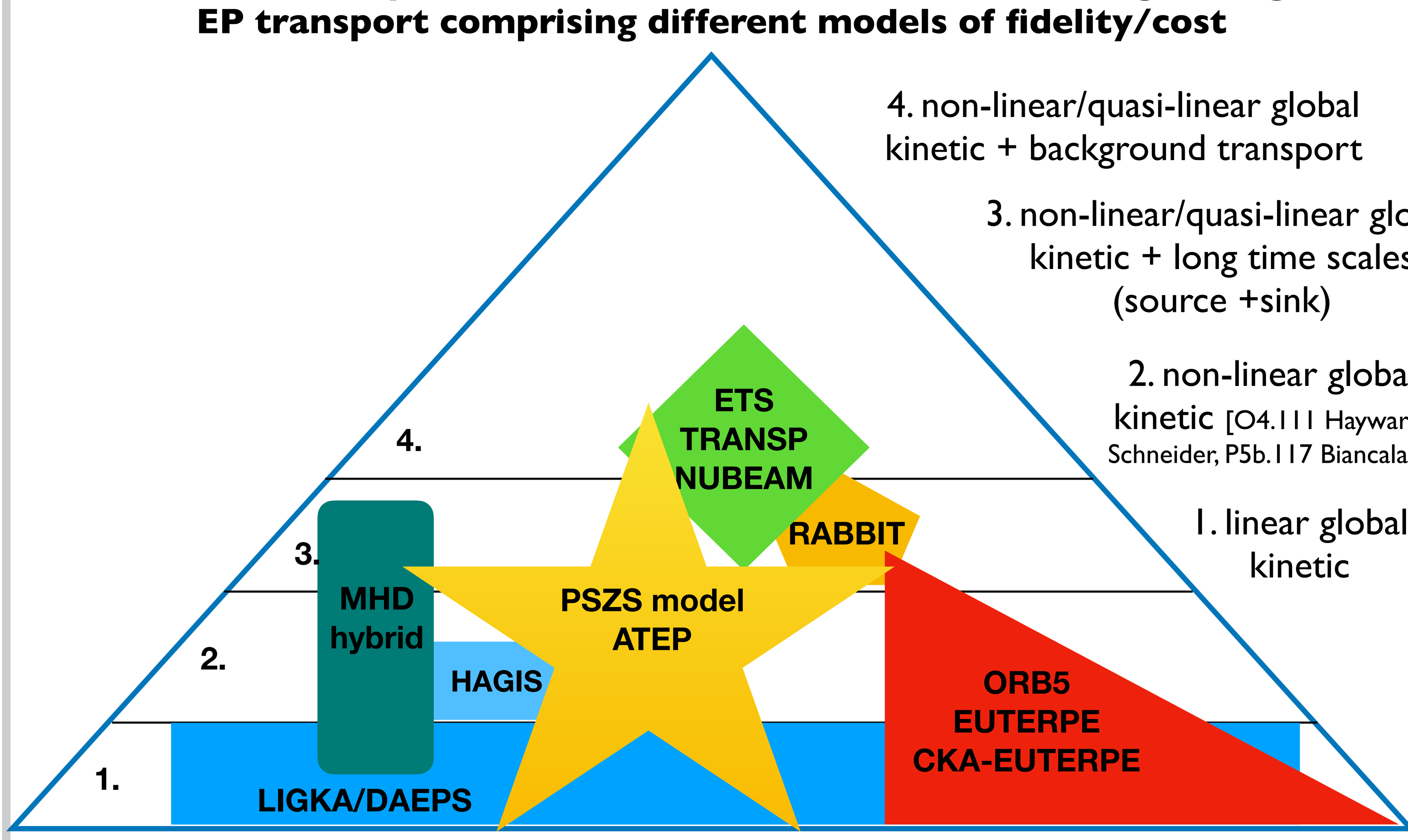
Energetic particle driven instabilities during the L-H transition in ASDEX Upgrade [P1a.105]

Ph. Lauber[1], V.-A. Popa[1], T. Hayward-Schneider[1], M. Falessi[2], G. Tardini[1], M. Weiland[1]
Eurofusion ENR ATEP [3], TSVV#10 [4] and the ASDEX Upgrade Team
[1] Max-Planck-Institut für Plasmaphysik, IPP, Germany [2] ENEA, Fusion and Nuclear Safety Department, Frascati (Roma), Italy
[3] see ENR ATEP Team: https://wiki.euro-fusion.org/wiki/Project_No10 [4] see Eurofusion TSVV#10 Team: https://wiki.euro-fusion.org/wiki/TSVV-10

motivation & main results

- off-axis NB heating is crucial for current profile control, particularly in ramp-up phases
- ASDEX Upgrade (AUG) scenarios with exclusive off-axis heating brings $E_{NB}/T_{thermal}$ and $\beta_{fast}/\beta_{thermal}$ closer to future experiments
- what is the effect of the observed EP instabilities on the background profiles?
- validate stability and transport tools on extended AUG data base, including experimental isotope studies: different βs, H,L-modes
- use IMAS to develop and validate an automated EP stability workflow - model trends instead of single time points
- validation of linear stability model as basis for the implementation of reduced EP transport models [see also P5a.113 Carlevaro, P5b.106 Falessi, P5b.107 Li/Zonca]

motivation: develop IMAS based tool to calculate electromagnetic, global EP transport comprising different models of fidelity/cost



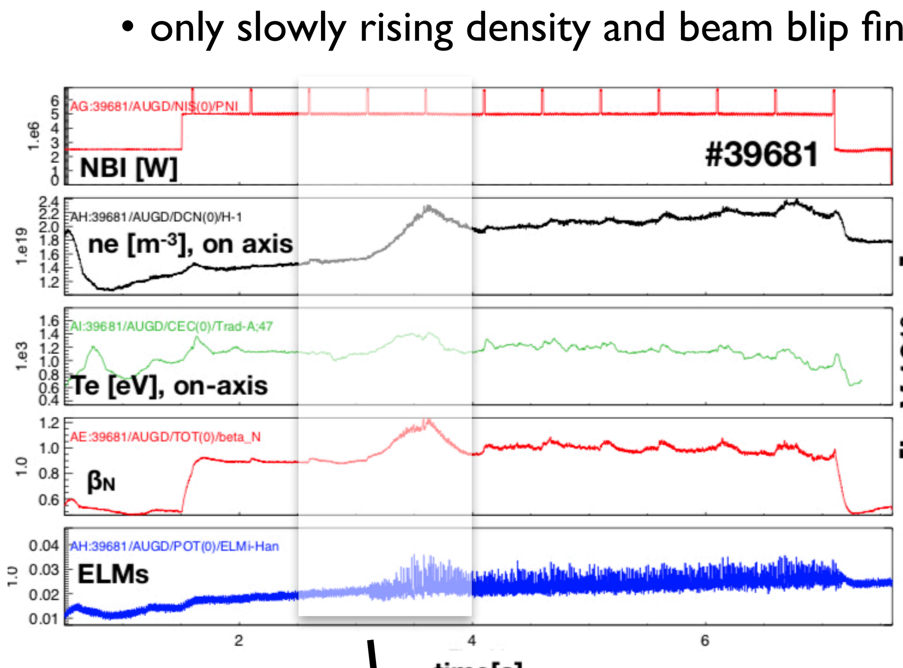
first implementation of ATEP code finished;
this poster: verification and validation [4,5]

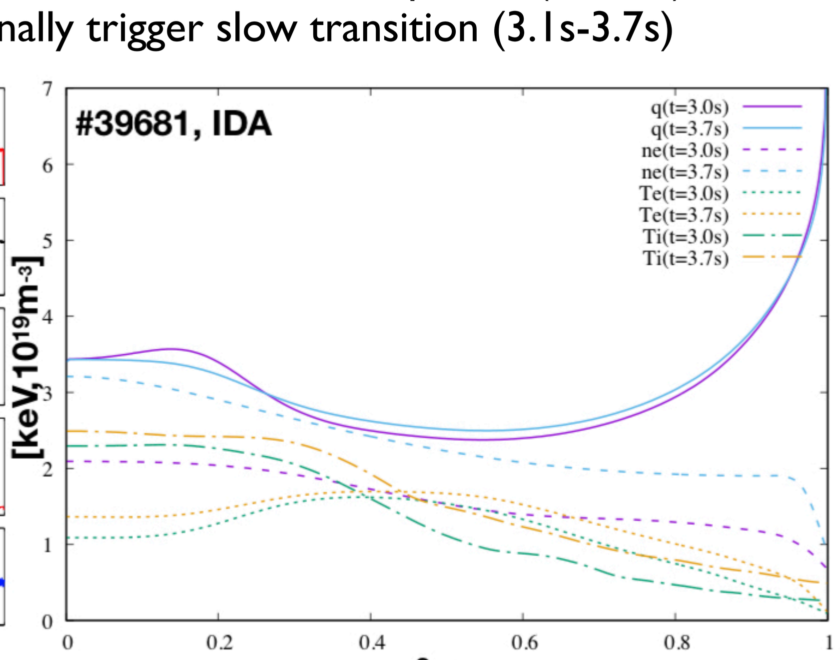
Dedicated isotope studies of strongly non-linear EP dynamics on ASDEX Upgrade [3, Lauber IAEA FEC 2018, 2022, P1a.112 Rettino]

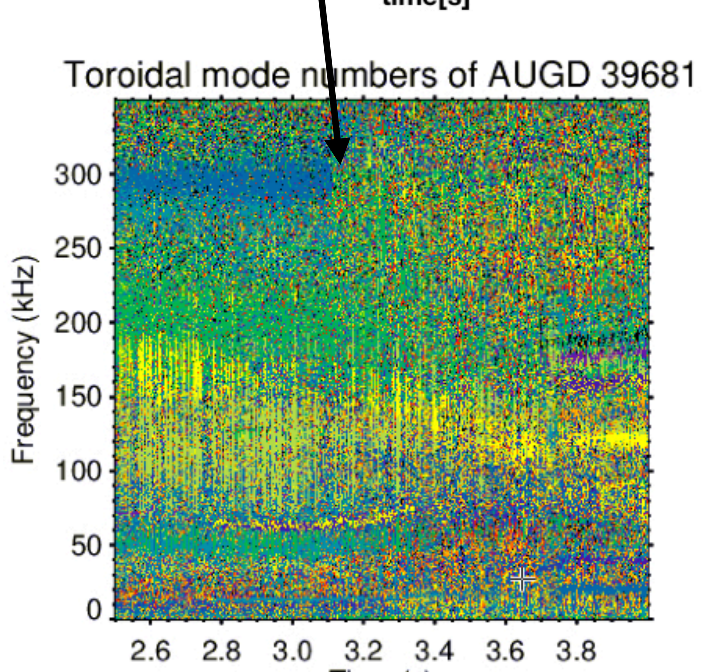
- with sub-Alfvénic beams (2.5-5MW)
- in current flat-top with stationary plasma conditions
- compatible with tungsten wall
- for EP physics relevant parameters: $\beta_{EP}/\beta_{thermal}$ ~1, $E_{NBI}/T_{i,e} \approx 100$
- database for different isotope mixes: deuterium (D) and hydrogen (H)

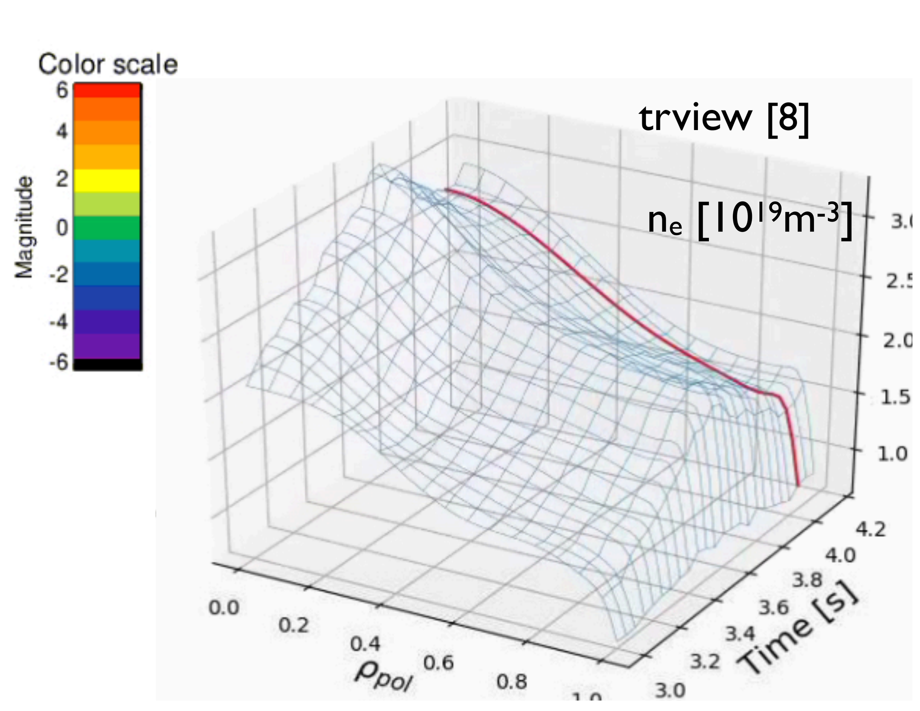
ideal for modelling: smooth transitions between different regimes:

- due to H-D mix, L-H transition does not occur with 5MW NBI power (1.5s-3s)
- only slowly rising density and beam blip finally trigger slow transition (3.1s-3.7s)





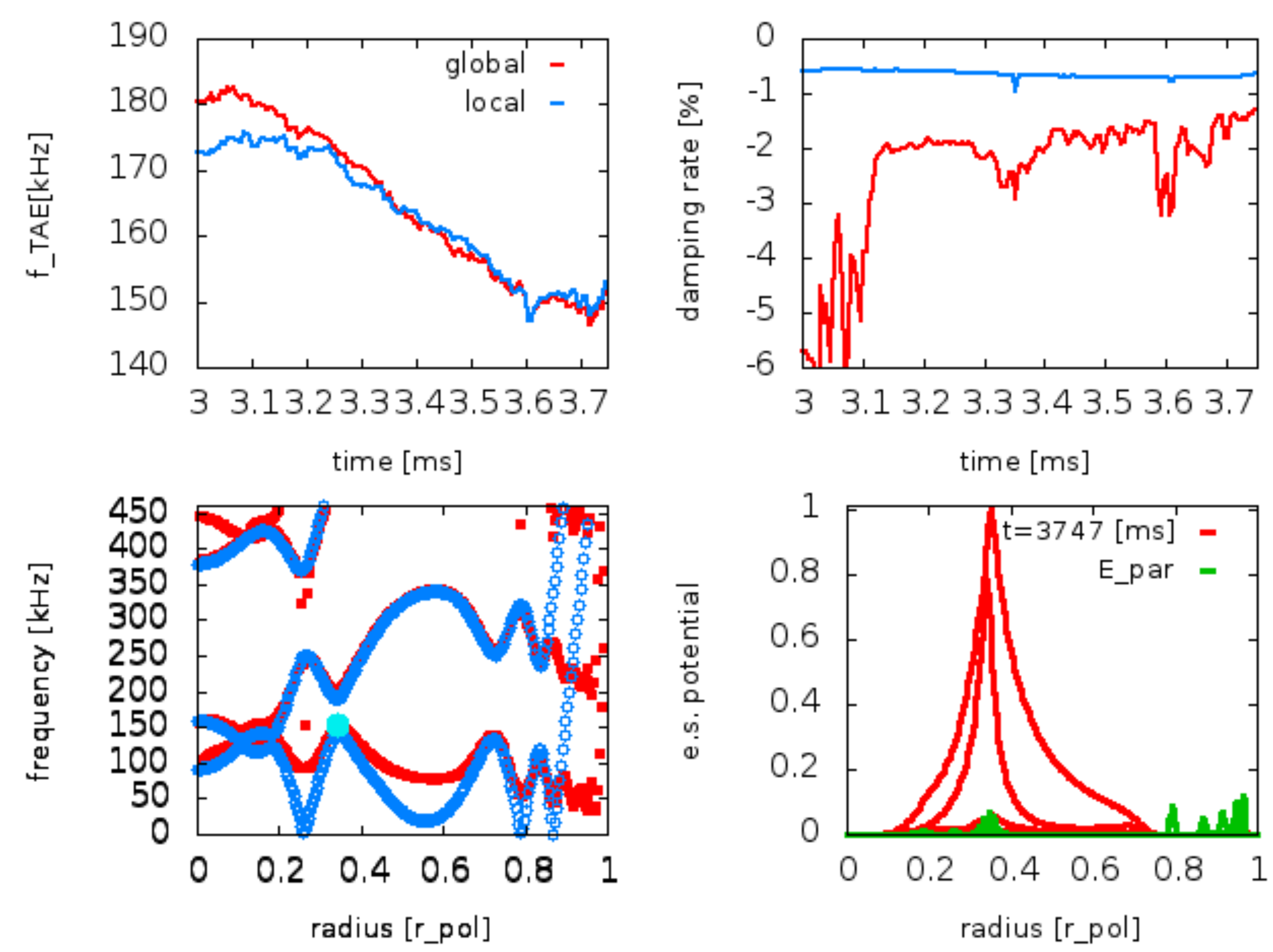




- modes in electron (positive mode numbers) and ion (negative mode numbers) diamagnetic directions are driven by positive and negative EP gradients
- as density rises, n=2 TAE drops in frequency
- although drive remains constant, TAE transitions from strongly bursting to steady-state
- n=-2 kink mode q=2.5 surface
- comparison of theoretical TAE mode frequency and experimental measurements allows us to determine local isotope mix ratio (experiment: H/H+D=0.35-0.45 line integrated)
- prominent n=-2 EAE at 300 kHz observed - too high frequency for principal resonances with NB ions (93keV) - unclear excitation mechanism, but probably similar to [Maraschek PRL, 1997]
- EAE jumps to 340kHz and then disappears in early LH transition - increased damping or different drive [10]?

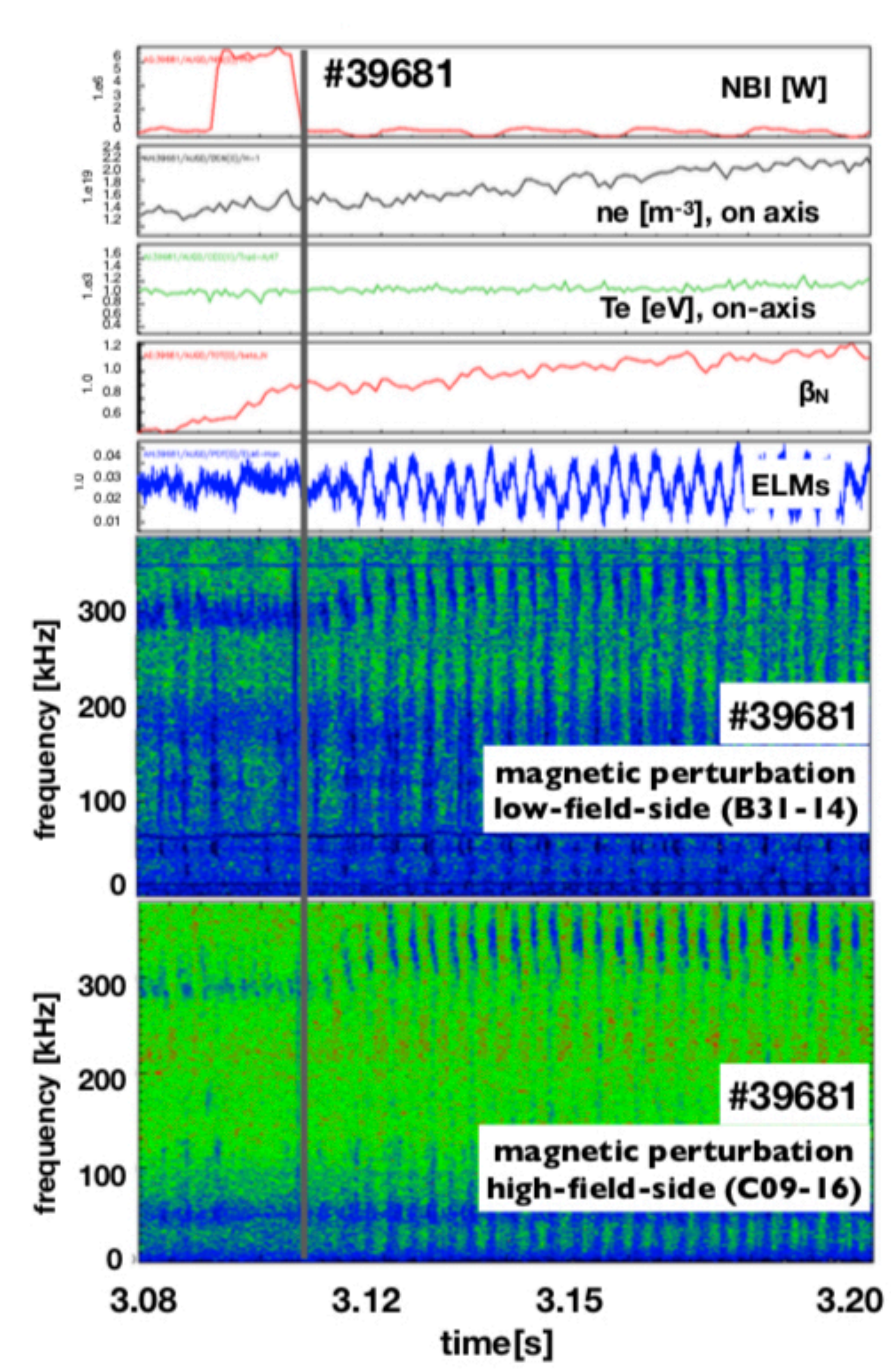
fully automated analysis using EP Stability WF, based on IDA and IMAS

- IDA [7] profiles and equilibria are stored in IDS using Trview [8] on Gateway
- automated EP stability workflow [1,2,6] is used to process co and counter-propagating TAEs
- here: 160 time slices with 5ms resolution: Helena, LIGKA local, global [9]

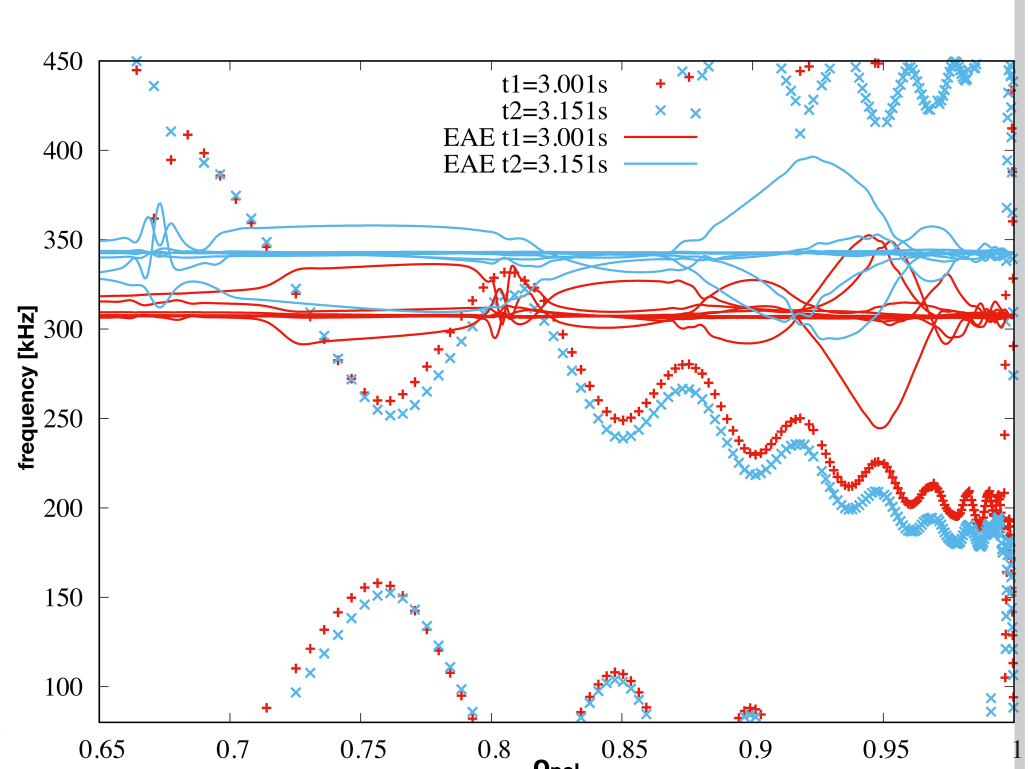


- note: damping rates can jump by 100% within 10 ms - core continuum damping very sensitive to q
- trend from high to low damping during the transition as observed in experiment
- all linear information stored in IDSs, uncertainty analysis based on IDA data possible

constrain nature of n=-2 mode at 300 kHz:



- n=-2 continua do not change significantly during the phase when 300kHz mode jumps to 340 kHz and then disappears
- LIGKA analysis shows that various weakly damped EAEs are present in gap between 250-400kHz
- jump in f seems to correspond to different EAEs at different time points
- since damping properties do not change, the underlying drive mechanisms must change
- change in ballooning structure not observed when comparing EAE mode structures



References:

[1] Ph. Lauber, S. Günter, A. Könies, and S.D. Pinches. LIGKA: A linear gyrokinetic code for the description of background kinetic and fast particle effects on the MHD stability in tokamaks. *Journal of Computational Physics*, 226(1):447 – 465, 2007.
[2] V.-A. Popa. Workflow-based energetic particle stability analysis of projected ITER plasmas. *Master Thesis, TU München*, 2020.
[3] see author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006.
[4] Eurofusion TSVV#10 team (P.I. A. Mischchenko). 2021.
[5] Eurofusion Enabling Research ATEP Team (P.I. Ph. Lauber). 2021.
[6] Popa V.-A. et al. *Presented at the 4th IAEA TCM on Fusion Data Processing (online meeting, Dec 2021)*, 2021.
[7] R. Fischer, L. Giannone, J. Illerhaus, P. J. McCarthy, R. M. McDermott, and ASDEX Upgrade Team. Estimation and uncertainties of profiles and equilibria for fusion modeling codes. *Fusion Science and Technology*, 76(8):879–893, 2020.
[8] G. Tardini https://www.aug.ipp.mpg.de/aug/manuals/transp/trview/index.html. 2022.
[9] Ph. Lauber https://pwl.home.ipp.mpg.de/. 2022.
[10] M. Maraschek, S. Günter, T. Kass, B. Scott, H. Zohm, and ASDEX Upgrade Team. Observation of toroidicity-induced alfvén eigenmodes in ohmically heated plasmas by drift wave excitation. *Phys. Rev. Lett.*, 79:4186–4189, Nov 1997.

MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

ASDEX Upgrade

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.