Goal of ITPA-EP group

- Develop tools to predict fast ion confinement in ITER, next generation fusion devices
  - the capability is needed to model ignition scenarios
  - localized losses may pose threat to PFCs
- "Anomalous" losses arise from external perturbations (MHD, RWM, error field) and 'emergent' phenomena (EPM, TAE, etc).
- Develop, benchmark and validate codes for calculating fast ion confinement in 3-D fields.
- Develop codes to self-consistently model 'emergent' phenomena.

Topics discussed at ITPA-EP meeting Culham, U.K. April 2013

1. EP-2: (fast ion transport by localized TAE) recommended to be closed.
2. Discussion continued on EP-2 follow-up JEX.
3. EP-4: (benchmarking/validation of non-linear codes) new data was presented
4. Discussions of direction for linear/non-linear modeling.
5. EP-6: (fast ion losses and heat loads from ELMs, RMPs and error fields).
6. Diagnostics on ITER were discussed, especially regarding downgrading of capabilities, e.g., coherent Thomson scattering alpha diagnostic and lack of 'flip'.
7. How to support potential JET D-T campaign
8. Analysis of new ITER scenarios, ramp-up
9. Expansion of studies beyond TAE (EPMs/fishbones)
10. Joint session with ITPA-MHD on runaway electrons

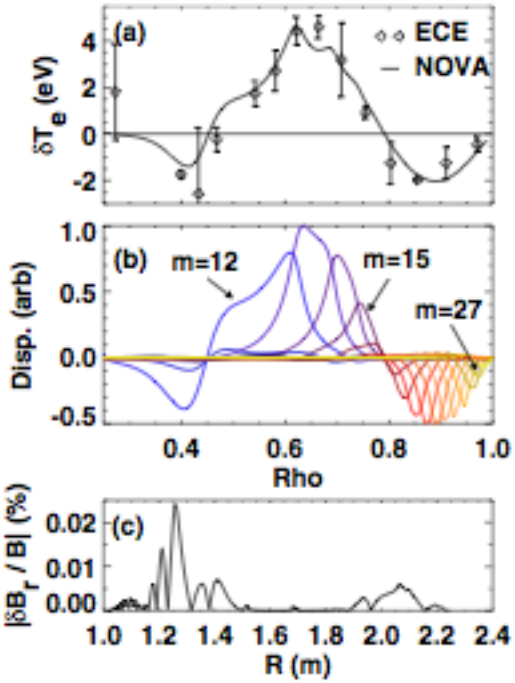
Linear modeling discussions

- The linear code benchmark and validation exercise was very successful.
- The validation against TAE damping rates measured on JET, while successful, didn't test beam damping or drive, however, and more work could be done there.
- Further, extrapolating to ST geometry is not so straightforward, so further experimental measurements of damping rates needed.
  - both MAST and NSTX-U plan antenna experiments

EP2 (Redistribution of fast ions by localized AE...)

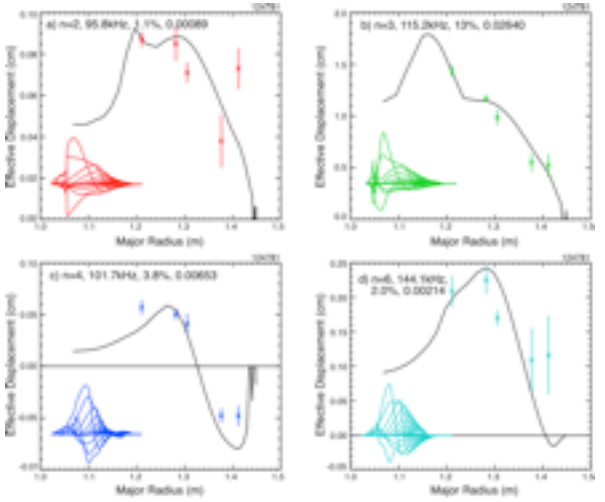
- Close EP-2, based on successful, semi-empirical, analysis of experimental ion transport:
  - NSTX TAE avalanches (strongly non-linear)
  - DIII-D "sea of rsAE/TAE"
  - JET ICRF driven TAE.
- Linear eigenmodes appear reasonable approximation to non-linear structure.
- Guiding center codes (e.g., ORBIT) with time-dependent modes appear adequate for modeling fast ion redistribution and losses.

Semi-empirical studies on NSTX, DIII-D and JET have strengths, weaknesses

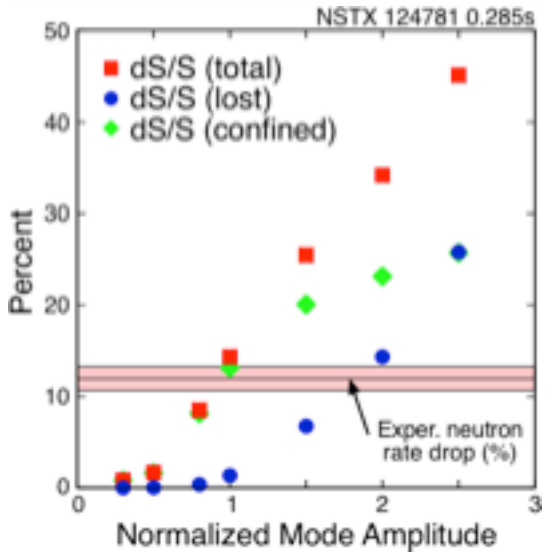


White, *et al.*, Plasma Phys. Control. Fusion **52** (2010) 045012

Fredrickson, *et al.*, Nucl. Fusion **53** (2013) 013006



- Linear eigenmode structures in good agreement on DIII-D, less resolution on NSTX.



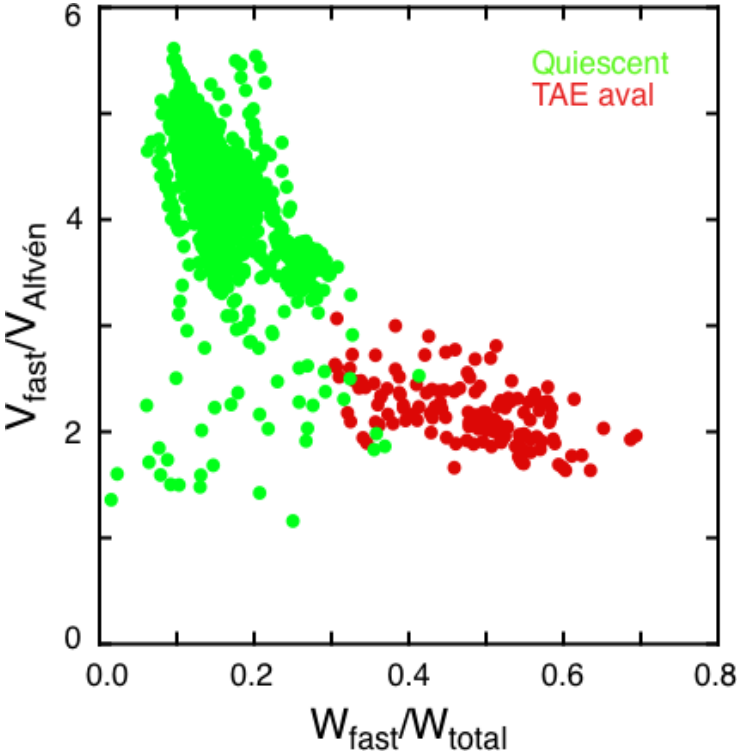
- Modeled fast ion redistribution in reasonable accord with measurements on NSTX.
- On DIII-D more challenging due to quasi-linear saturated experimental state.

EP-4 (benchmarking/validation of non-linear codes)

- Possibly too early to start full benchmarking, but start with simpler, reduced problem?
- Is important physics missing needed for validation?
  - drag and diffusion?
  - multimode interactions?
- Identification of experimental case for validation?
- Discussion will continue up to Beijing ITPA-EP meeting.

Follow-on XP to EP-2 is needed

- Non-linear codes not yet ready for validation?
  - No codes have all of the physics
  - Benchmark reduced-physics models?
- Alternative would be to develop empirical scalings to validate non-linear codes against?
  - Preliminary work on NSTX has shown positive results.



EP-6 (fast ion losses and heat loads from ELMs and RMPs)

- Experiments performed on many machines (reports from DIII-D, AUG, NSTX, MAST, JET, KSTAR and LHD).
- Losses are not axi-symmetric; calculation of localised heating needed.
- Potential tool for modification of fast-ion distribution.
- Modeling efforts, where completed, find reasonable agreement
  - plasma response important
  - interactions with TAE/EPM/sawteeth/etc important?
- Much more work is needed.

Diagnostics on ITER

- Concerns about the reduction in scope for the Coherent Thomson Scattering (CTS) confined alpha diagnostic.
- Plans for a fast lost ion probe (FLIP) have been discussed in recent meetings, but not in diagnostic plans.
  - probably couldn't survive full D-T phase, but would be useful in earlier campaign.
- General concern about keeping informed about changes in diagnostic plans.

JET D-T campaign

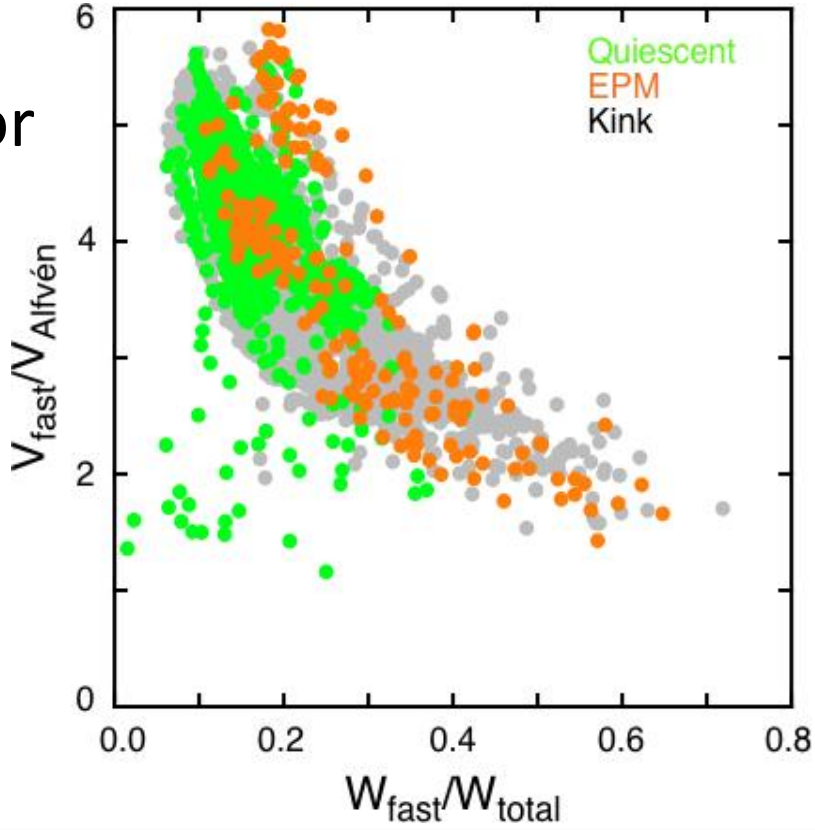
- Issues other than EP, like tritium retention, will likely drive JET-DT decision.
- What modeling should be done to support JET DT campaign?
- Can JET reach parameters that will be of interest to EP community?
  - More beam power available (≈35 vs 20 MW), but ITER-like walls reduce performance?
- Can TFTR alpha-driven TAE experiments be replicated on JET?

ITER planned scenarios evolve, need to keep up with stability predictions

- Need to identify likely operational scenarios, make predictions for stability.
- Additionally, codes are being improved, so old analysis should be revisited.
- Consideration as to whether new experiments can explore ITER relevant physics.
- Particularly, current ramp phase may be of interest for TAE stability/transport modeling.
  - higher q(0), reversed shear, lower density, may be less stable to TAE.

Expand studies beyond TAE (EPMs, fishbones,

- General consensus that fishbones/EPMs are as, or more, deleterious than TAE in present devices
  - Early simulations predicted fishbones not so important for ITER
  - revisit studies with better codes, new target plasmas
- What are predictions for next-step STs?



Summary: ITPA-EP Culham, U.K. April 2013

Linear TAE benchmarking and validation is a success, the future is non-linear physics, modeling and experiments.

- Good model for physics of chirping, but more work needed:
  - particularly with respect to ECH or other chirp/avalanche suppression/control techniques.
  - Mixed success in interpreting experimental results; more extensive theoretical model needed?
- Discussion regarding benchmarking (validation?) of non-linear TAE simulation codes.
  - Possibly too early to start full benchmarking, but start with simpler, reduced problem?
  - discussion will continue leading to Beijing ITPA-EP meeting.
- RMP and fast ions
  - important for understanding stability and losses from non-classical fast ion distribution and profiles

Summary: ITPA-EP Culham, U.K. April 2013

- Close and replace EP2 (Redistribution of fast ions by localized AE...)
  - Close EP-2, based on successful, semi-empirical, analysis of experiments on NSTX/DIII-D/JET.
  - The suggested replacement is some kind of database on various thresholds (TAE stability, TAE avalanche, chirping?, EPMs?), parameters to be determined (NSTX database presentation was “well received”).
- There is a revival of interest in EPMs on ITER.
  - Guoyong’s earlier work fostered the idea that fishbones were not an issue,
  - but analysis of new operating points, with new theoretical modeling should be done.
- Ongoing concern over down-sizing of EP-relevant diagnostics for ITER
  - Perhaps more direct interaction with the diagnostics ITPA group is needed.