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.
<table>
<thead>
<tr>
<th>No.</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1.</td>
<td><strong>EP-2</strong>: (fast ion transport by localized TAE) recommended to be closed.</td>
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<td>2.</td>
<td>Discussion continued on EP-2 follow-up JEX.</td>
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<td>3.</td>
<td><strong>EP-4</strong>: (benchmarking/validation of non-linear codes) new data was presented</td>
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<tr>
<td>5.</td>
<td><strong>EP-6</strong>: (fast ion losses and heat loads from ELMs, RMPs and error fields).</td>
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<td>6.</td>
<td>Diagnostics on ITER were discussed, especially regarding downgrading of capabilities, e.g., coherent Thomson scattering alpha diagnostic and lack of ‘flip’.</td>
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<td>7.</td>
<td>How to support potential JET D-T campaign</td>
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<td>8.</td>
<td>Analysis of new ITER scenarios, ramp-up</td>
</tr>
<tr>
<td>9.</td>
<td>Expansion of studies beyond TAE (EPMs/fishbones)</td>
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<tr>
<td>10.</td>
<td>Joint session with ITPA-MHD on runaway electrons</td>
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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

- 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.


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
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.