1st Energetic Particle ITPA group meeting in Lausanne and Field Work Proposal (FWP)

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- ▷ ITPA EP meeting, Lausanne, chair S. Günter, deputy chair K. Shinohara
  - ˜27 talks, 2.5 days:
    - ○ half on benchmark cases/discussions,
    - ○ ripples in ITER,
    - ○ nonlinear simulations
    - ○ EP transport experiments
    - ○ EFDA EP programme (Borba)
    - ○ other topics
- ▷ FWP discussion

SFG meeting, PPPL, December 4th, 2008

PRINCETON PLASMA PHYSICS LABORATORY

ITPA meeting presentations

Mukhovatov outlined ITER IO tasks.

- TF ripples are computed by Gribov for all reference scenarios. In reduced field/current scenarios at the start of the ITER ripples can be higher than in referenced ones. Benchmarks?
- quoted our earlier work on TAE stability where we showed that TAEs in ELMy plasma are stable, but in RS plasma are strongly unstable. Another our quasilinear model was also quoted that it predicts alphas diffusion on the order of 7%, which is a big number for ITER. This was argued to be in approximate agreement with Vlad simulatins from NF'06.
- Alphas profiles will be much broader after the sawtooth.
- One of the biggest problem for ITER is runaway electrons, which requires mitigation/control of generated disruptions. MHD group will be in charge of this, but some interaction with EP itpa group is desirable.
- The urgent tasks are massive material injection and stochastic magnetic field perturbations to mitigate those disruptions.
- As a rule of thumb ITER allows for ˜5% of lost alphas, but the question emerges on their localization as the localized fluxes can be more dangerous.

Spong reported on 3D equilibrium in ITER.

- Real equilibrium can significantly modify the ripple for example.
- 3D tools are applied for such calculations. TBMs as well as the steel material the ports are made of can also influence the equilibrium.
- Finite beta seems to have a strong effect on the ripples. Stronger plasma beta increases ripple penetration into the plasma and enhances alpha losses as a consequence.
- Alfvenic continuum is not expected to be much effected by 3D ripples.

S. Gunter reported on scintillator measured losses. NTMs induce losses of fast ions in Asdex.

- Islands in real space are created. They provide the resonant mechanism for EP (trapped) losses.
- A special pitch angle range corresponds to EP losses mostly for trapped EP. Losses are clearly seen on a separate domain in the pitch angle/ gyroradius plane.Passing EP are not as much responsible for the losses. Only few of them are lost.
- They applied ORBIT code and found similar results to the predictions of their Gourdon code. Trapped EP loss can be reduced by including ferritic inserts in Asdex.
- Results show that the loss correlation with TAE and BAE modes. Haegis code allows to look at different resonances in the phase space.
- BAE instability seems to have strong effects on the EP losses. Only one BAE mode was observed, whereas they see many TAE modes with n ranging from 1 to 5.
- An n=4 TAE and BAE may have overlapping resonances, so that they can induce global losses.

Y. Todo on nonlinear simulations of TAE modes in TFTR.

- Amplitude was found to be too large in his code in comparison with the data. Nonlinear MHD effects are studied.
- In a more recent work two types of TAE evolution are studied.
  - First is low EP beta case, and the second is large EP beta.
- In the latter case energy content of EPs continue to decrease after mode saturation. In the nonlinear saturated state n=0 mode is generated via MHD nonlinearity especially in the latter case via excitation of the GAM/BAE modes.
- The frequency seems to agree with simple theoretical expression for GAMs. This effects the amplitude saturation of the TAE itself, which is lowered.

Borba has presented an overview of the EFDA activity in the area of the EP.

- Such topics as code benchmark, diagnostics, and code development are covered.
- Closed integration with the ITPA group and local teams from home organizations was stressed.
- Joint activities and experiments were discussed.

Fasoli (spokesperson) on MDC-10 itpa task: “measurements of AE damping rates on different tokamaks.”

- included C-mod, JET, MAST, JT60U, NSTX and AUG.
- C-mod analysis by NOVA showed that strong variation in the damping rate is obtained even with small q0 variation on the order of 10%.
- On JET medium to high – n TAE modes were excited.
- It is difficult to measure their internal structures due to low signal.
- The data on the damping rates exist and is available for **code validations.**
- On MAST damping rate measurements show that the damping rate data is challenging to interpret because of many mode excitations.
- It was stressed again that the internal structure is desirable to measure.
- Accurate measurements are needed for accurate comparisons. Joint experiments were discussed in order to test the theory predicted trends in the parametric dependence of the damping rates vs plasma parameters.

Pinches reported on EP losses within MDC-11 as a spokesperson.

- This includes NSTX (Fredrickson).
- JET observations of TAEs in various regimes, such as Tornado modes, which are reside inside q=1 surface. Strongest losses.
- DIIID with many kinds of modes and published FI losses.
- AUG results emphase the BAE/TAE induced EP losses.

ITPA Tasks

1. **Destabilisation of Alfvén waves and Energetic Particle Modes (EPMs)**
   - measurements of damping rates of Alfvén waves (together with reliable mode identification: eigenfunction, frequency etc) and comparison with theory
   - investigation of the drive of different kinds of Alfvén waves (TAEs, BAEs, RSAEs,...) and EPMs depending on the fast ion distribution function (energy and pitch angle)
   - measurements of the influence of fast particle driven instabilities on the fast ion distribution function, expulsion of fast ions, comparison between experiments and state of the art non-linear theory/codes
   - definition of benchmark test cases for fast particle stability codes
   - development of relevant diagnostics, recommendations for ITER diagnostics
   - prediction of the role of fast particle driven modes in ITER conventional and steady state scenarios, including the power load on the first wall caused by the fast particle losses; recommendations for operation
2. **Effect of non-axisymmetric magnetic fields**
   - comparison between theoretical predictions and measurements of fast ion losses caused by magnetic field ripple and error fields in present day devices
   - prediction of the power loads to the first ITER wall caused by error fields, ferritic inserts, test blanket modules and perturbation fields (ELM mitigation coils)
3. **Interaction of fast ions with background MHD**
   - investigation of the interaction of background MHD and fast particle confinement in present day devices, comparison with theory

- prediction of the influence of NTMs and possible synergistic effects with field ripple/error fields on fast particle confinement in ITER
- influence of fast ions on sawtooth stability (leading role of MHD-TG in the development of control tools for ITER)

4. **Runaway electrons (leading role of MHD-TG)**
    - study of generation of runaway electrons by disruptions in present day devices, comparison with theory
    - development of mitigation/control tools for ITER, in particular perturbation fields Heating and current drive (support for IOS-TG only)
    - investigation of localisation of NBI heating and current drive
    - prediction of the role of NBI current drive on current profile control in ITER
    - momentum input
    - particle current drive

Benchmarks cases from ITPA summary

- Ripple loss/effects benchmarks ,
- Well diagnosed JET discharges with measured **linear** damping rates for low n (1 and/or 2) and intermediate n (˜5) shall be used (D. Testa, A. Fasoli)
  - Codes (persons involved): LIGKA (Ph. Lauber, S. Günter), NOVA-K (N. Gorelenkov), CASTOR-K (D. Borba), TAEFL (D. Spong), LEMan (N. Mellet, A. Fasoli), and TASK/WM(A. Fukuyama, Y. Todo).
- **Non-linear** benchmarks: interaction between the excited waves and the fast particle distribution function. The group again decided for a benchmark case to be chosen (N. Gorelenkov).
  - Codes involved: MEGA (Y. Todo), HAGIS (S. Pinches), HMGC (S. Briguglio), TAEFL (D. Spong), M3D (R. Nazikian), NIMROD (J. Carlsson).

FWP discussion

Theory:

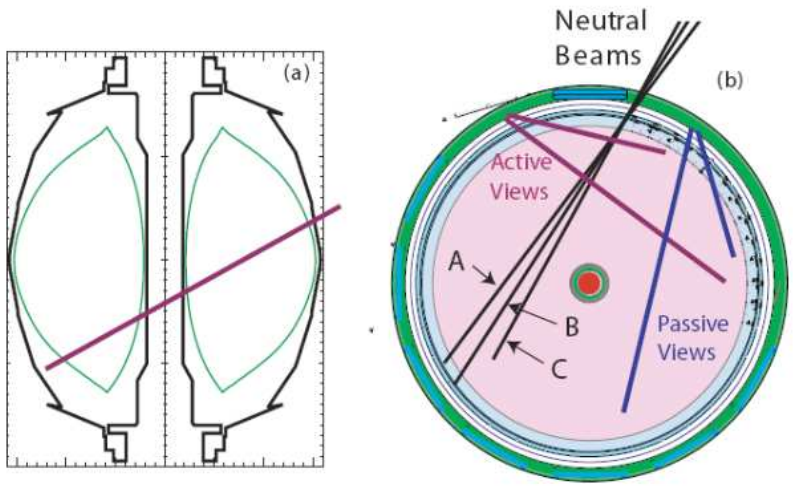
- PEPSC center
  - SWIMM, NOVA
  - DIII-D, NSTX, JET support

Experiments:

- NSTX
  - FIReTIP, NPA arrays?
- JET, DIII-D

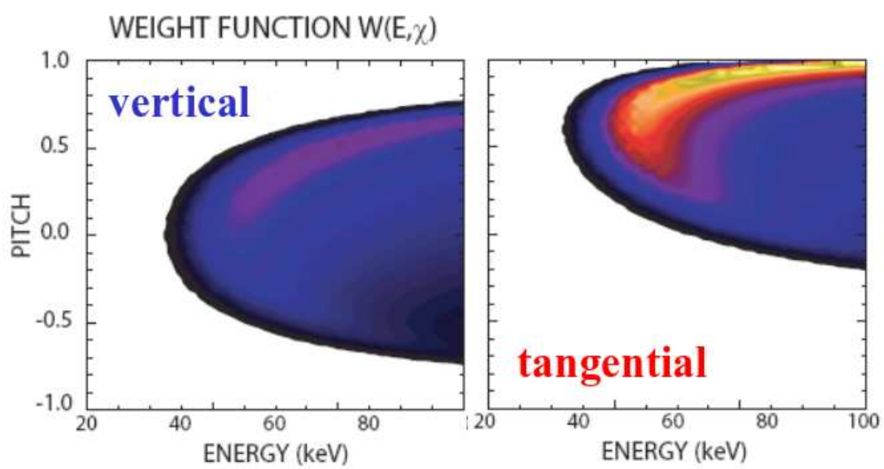
Proposal for *tangential* FIDA systems on NSTX

[Submitted to DOE, 2008 - PI: W.W. Heidbrink]



- Modeled on present FIDA systems (increased number of *fast* channels if possible)

- **Tangential views**, small tilt
  - Avoid reflections from vessel structures



- Estimated response, observed energy E_λ=40keV
- Tangential views (vs. existing vertical views):
  - Enhanced signal
  - Better localization in velocity space
  - Heavily weighted toward parallel velocity