CWGM8.0 on EP
March 17

Energetic ion losses induced by various MHD modes on LHD

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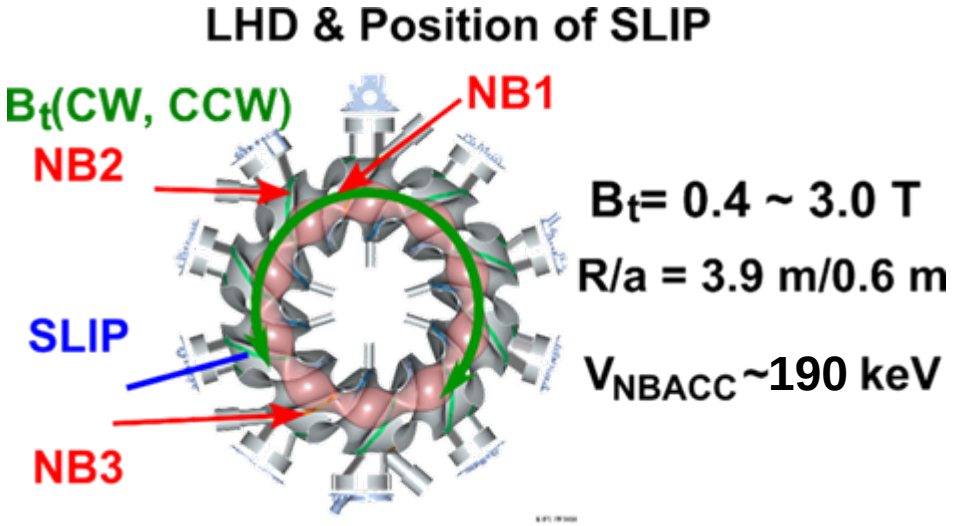
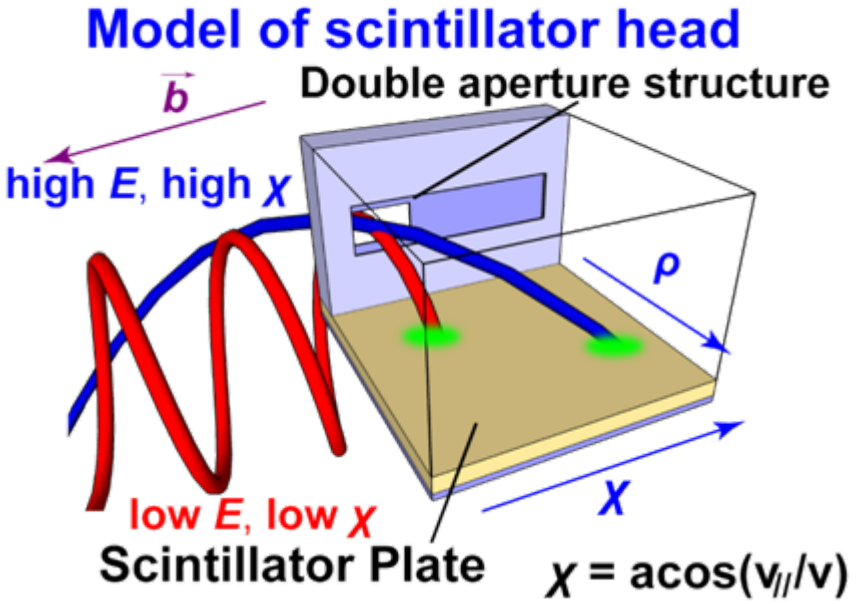
Background

- **Energetic ion loss induced by MHD mode can cause the local damage of PFC in fusion device.**
- **Stellarator/Helical device: TAE, GAE or EPM induced losses are observed in previous experiments such as CHS, W7-AS.**
- **However, the loss process is still uncertain.**

- **LHD: usual TAE/EPM induced losses are observed in relatively high-beta plasma. In addition, pressure driven MHD mode induced loss is obtained.**
- **We need to understand loss process of energetic ion induced by MHD modes to reduce anomalous loss of energetic ion.**

Scintillator-based lost-fast ion probe (SLIP)



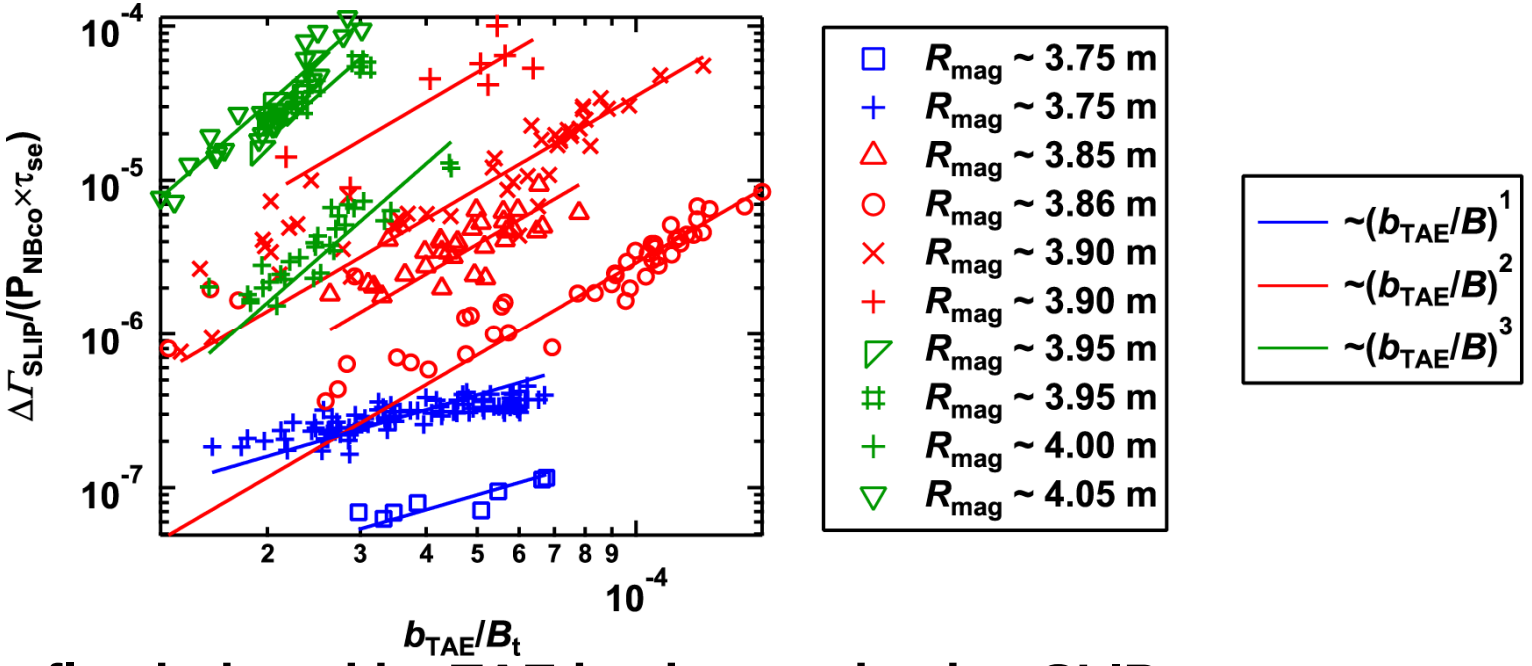


E: energy of ion, χ : pitch angle

- **Double aperture structure** has a role in discriminating E/χ of detectable ions
- **Scintillation point** gives the information of E and χ of lost ions
  - Scintillation points are measured with a CMOS camera and a 4×4 PMT array.
- **Two sets of double apertures are equipped. "Bi-directional lost-fast ion probe"**
  - It is applicable to both cases of CW or CCW direction of B_t

TAE induced loss

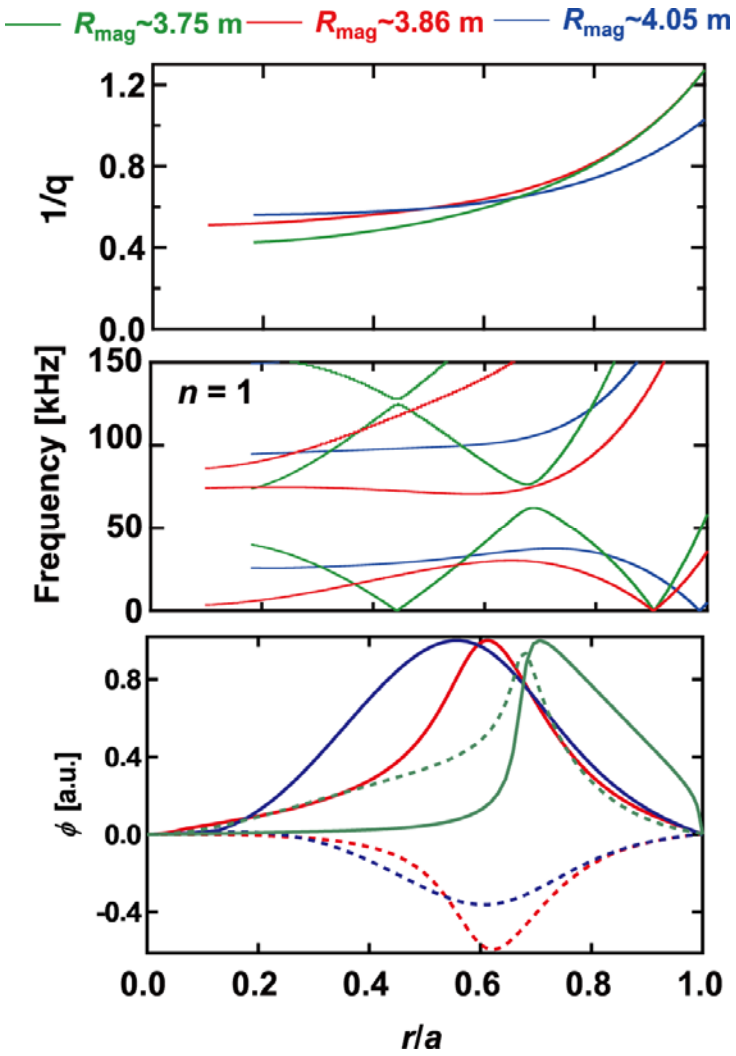
Loss flux dependence on TAE fluctuation amplitude



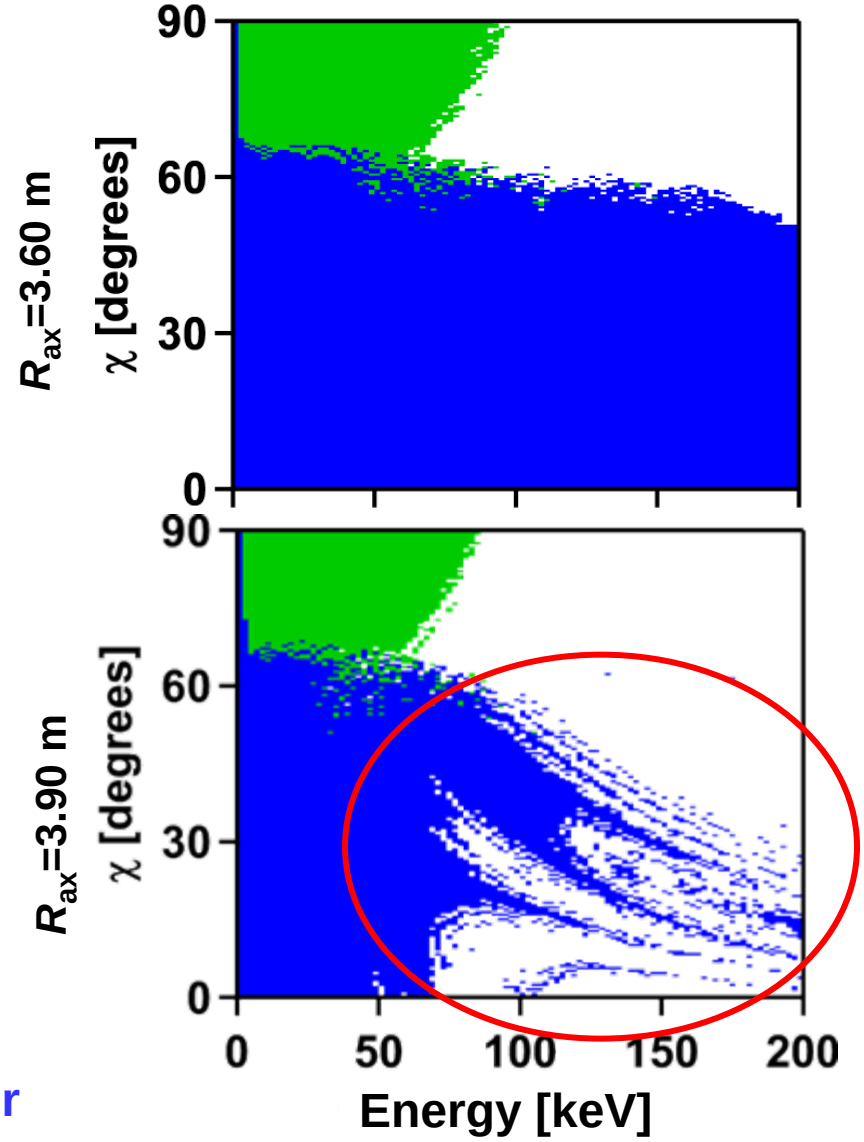
- **Loss flux induced by TAE is observed using SLIP.**
  - **Peak of TAE : *r*/*a* ~ 0.6**
- **Energy/pitch angle of lost ions are 100~150 keV/~40º at SLIP position.**
- **Dependence of loss induced by TAE on TAE fluctuation amplitude become steeper as increasing R_{mag}.**
  - **Expansion of TAE eigenfunction, and loss cone thought to be candidate.**

Expansion of eigenfunction and loss cone

q profile, SAS, eigenfunction



Loss cone of protons at certain position

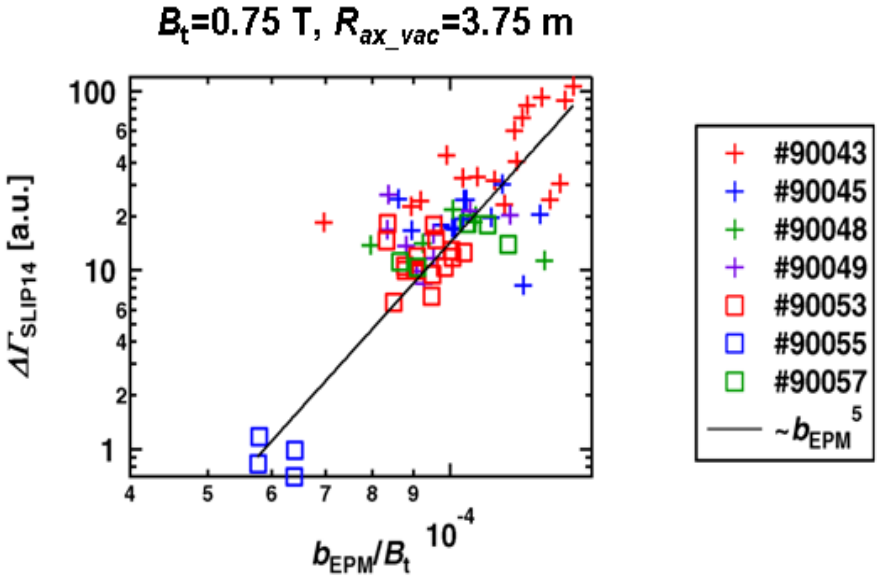


R_{mag} increases -> 1/*q* becomes flatter
-> radial width of ϕ becomes large

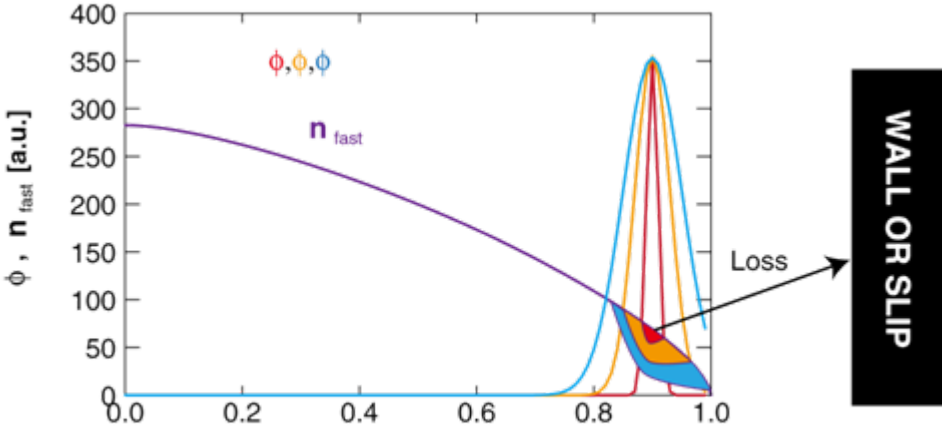
R_{ax} increases -> loss cone expands

EPM induced loss

Loss flux dependence on EPM fluctuation



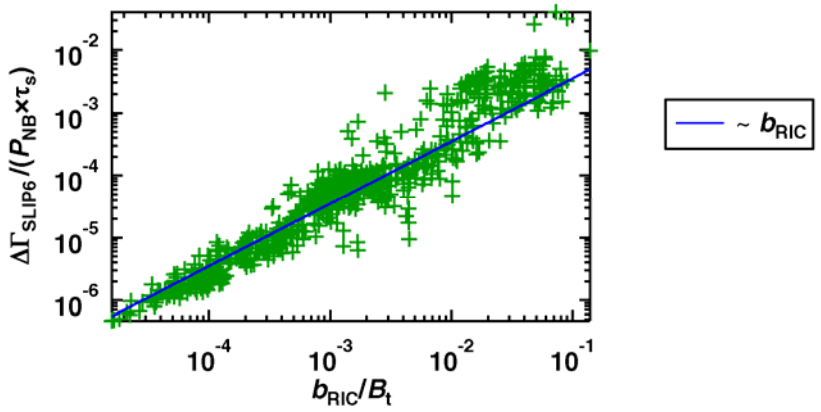
Model of EPM induced loss



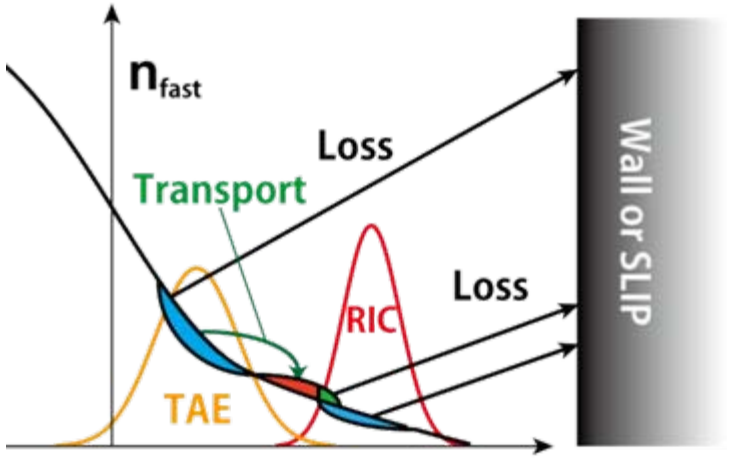
- **Energy/pitch angle of lost ions are 100~190 keV /~30º at SLIP position.**
- **Dependence of loss flux induced by EPM on EPM amplitude is sufficient comparing with TAE case.**
  - **Possible reason: large amplitude the position (*r*/*a*~0.9) seems to be outside comparing with TAE (*r*/*a*~0.6).**

Resistive interchange mode (RIC) induced loss

Loss flux dependence on RIC fluctuation

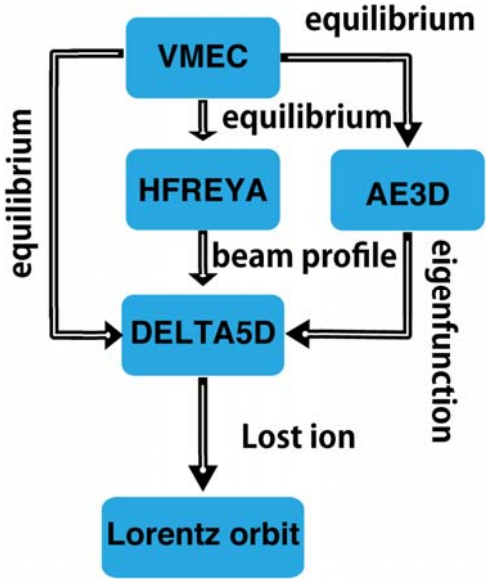


Model of synergy effect



- **RIC: peak position *r/a*~0.9**
  f_{RIC} << f_{ep} in lab frame
  ->no wave-particle interaction
- **Loss flux dependence on magnetic fluctuation amplitude shows loss process is convective.**
  - **Energetic ion existing near the loss cone can be lost due to RIC**
- **Moreover, synergy effect: TAE+ RIC loss is observed.**

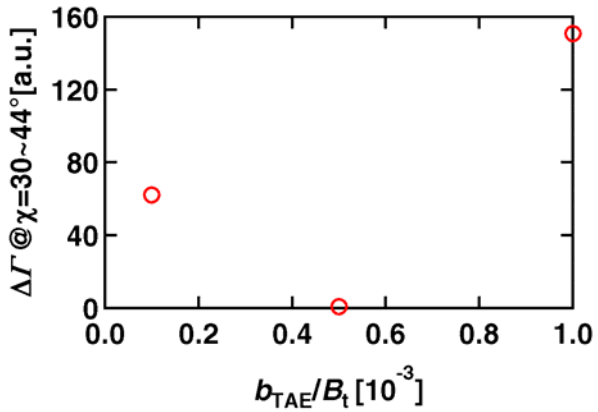
Initial result of model calculation



- Model calculation is held.
- TAE fluctuation: $b = \nabla \times \alpha B$
  - No interaction between modes and particles

- Loss flux comes to χ ~ 40° does not increase with increasing fluctuation amplitude.
  - It is not applicable that TAE fluctuation is treated as a external fluctuation.
  - Wave-particle interaction need to be included?

Loss flux as a function of fluctuation amplitude



Summary

- **Energetic ion driven MHD mode such as TAE and EPM induced loss is observed.**
  - **Loss flux dependence on TAE fluctuation becomes steeper as increasing R_{mag}.**
  - **Loss flux dependence on EPM fluctuation is steeper than that of TAE.**
- **MHD modes driven by plasma pressure (RIC) induced loss is observed.**
- **Model simulation**
  - **TAE can not be treated as a external fluctuation.**

- **Wave-particle interaction needs to be considered to clarify the loss process of energetic ion.**
- **The effect of magnetic structure on loss process is also need to be figure out.**