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XP-945: ELM Pacing via Vertical Position Jogs

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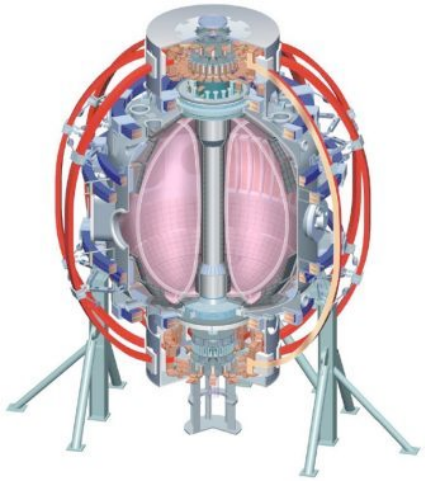
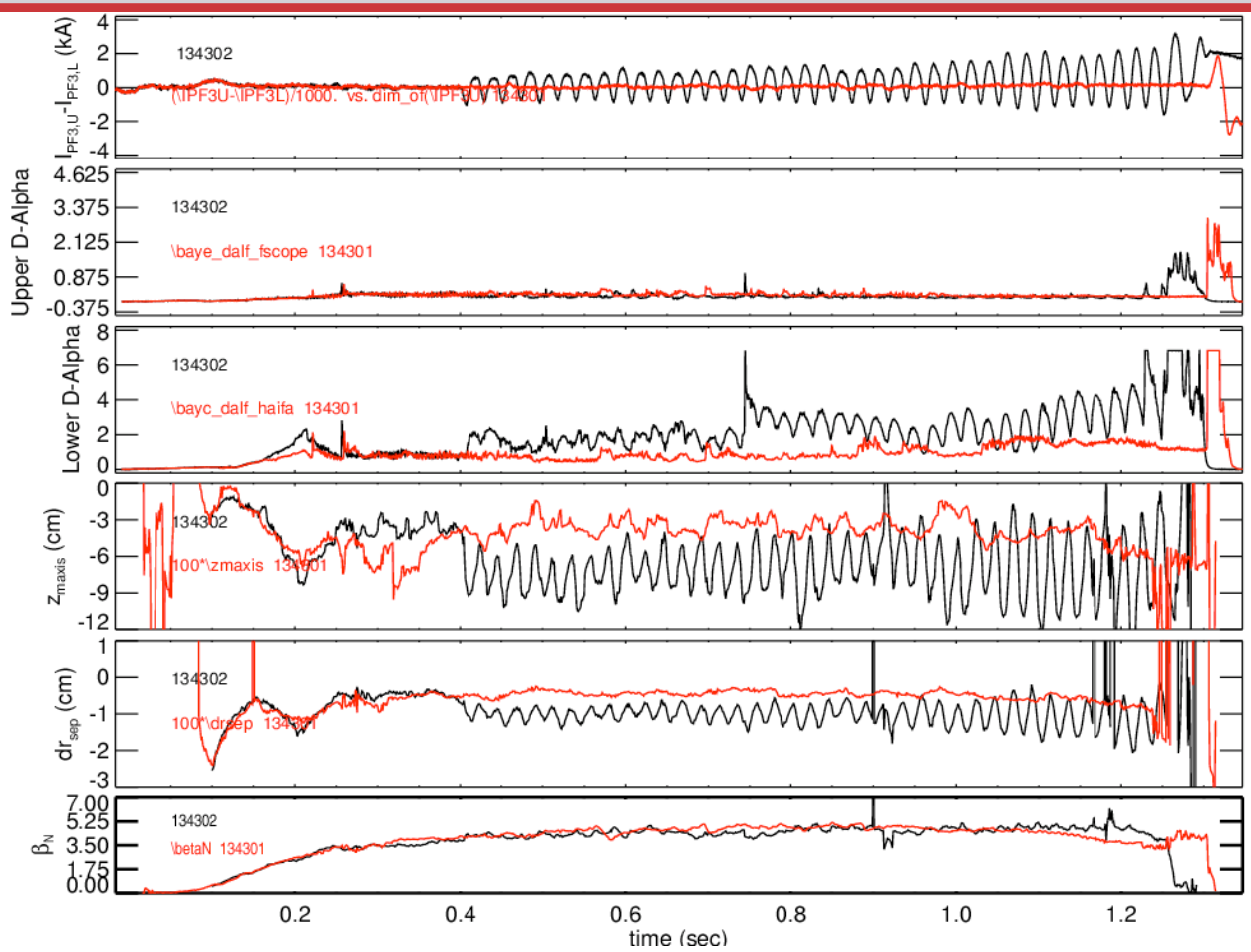


Background and Summary

- ITER (and larger devices) cannot have large ELMs
  - ITER is limited to (?) <0.6% of stored energy lost per ELM
  - DEMO requirements are an order of magnitude less.
- Need to mitigate, or completely suppress, ELMs.
  - Suppression techniques include some RMP results, QH mode.
  - Mitigation could mean ELM pacing with 3-D fields, small-ELM regimes, pacing via pellets, or *plasma position oscillations*.
- Attempted in XP-945 to "pace" ELMs via vertical jogs.
  - Use the commands available in the double-null isoflux algorithm to rapidly vary the plasma vertical position.
  - Used 6 Hours on June 1st, and 4 hours on June 12th.
  - We did develop recipes for jogging the plasma, and, to some extent, were able to trigger ELMs.

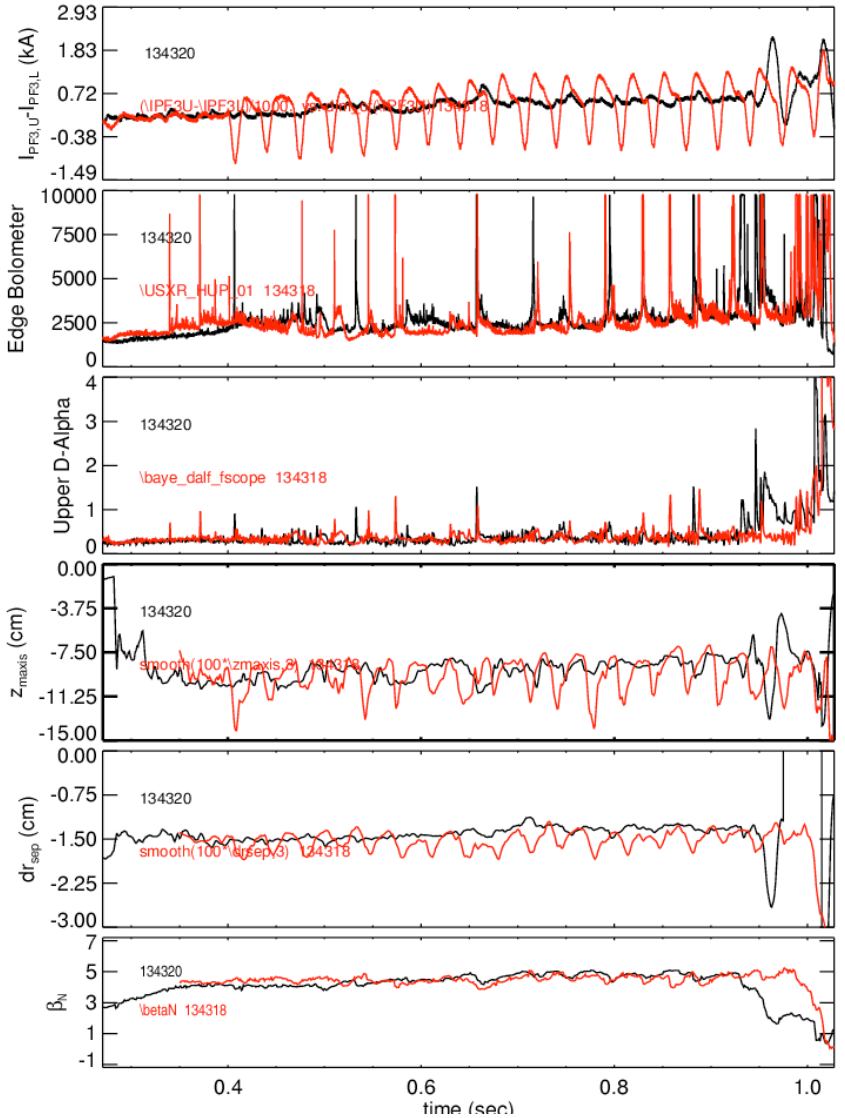
Plasma Was Surprisingly Tolerant of Jogs



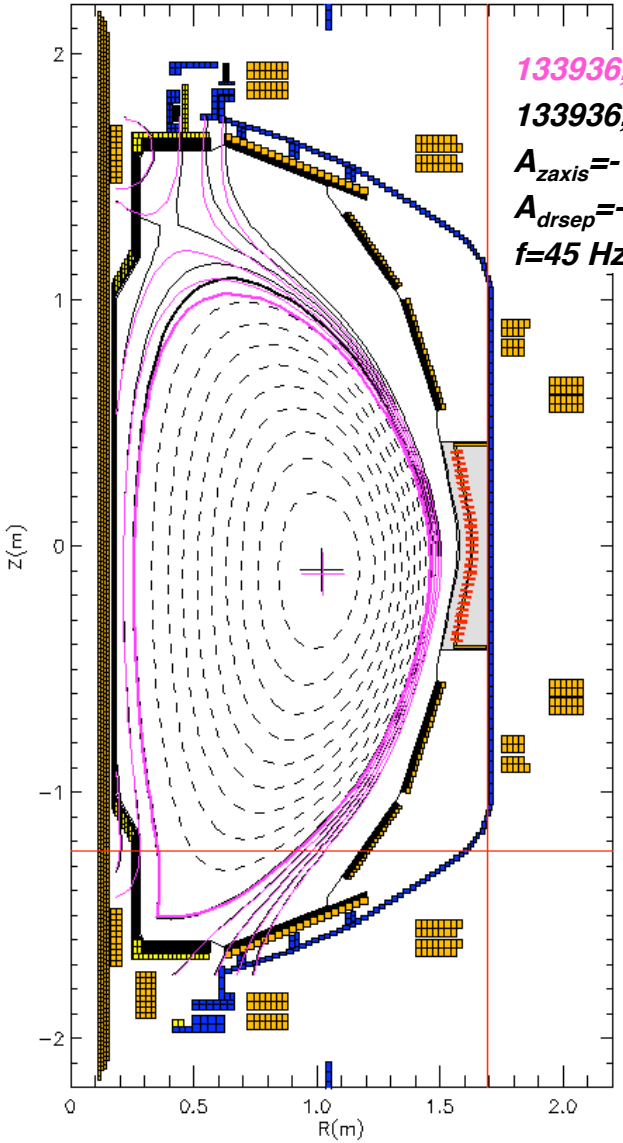
- 134301: Plasma tolerates 6 cm axis jogs with no degradation in confinement !
- But, no ELMS, why?
  - Too close to Lithiumization? Reference is ELM free.
  - Not biased down enough? Jogging seemed to work better at dr-sep~-2 cm

ELM Triggering was Observed

- Requested -3.5 cm jogs in dr_{sep}, with a request between jogs of -2 cm.
- Bolometer and upper divertor D_α show evidence of ELMs synchronized with the PF-3 coil current.
- Clear perturbations on the axis location and dr_{sep}.
- Performance is not degraded in shot with jogs.



Jog Amplitude Was Substantial



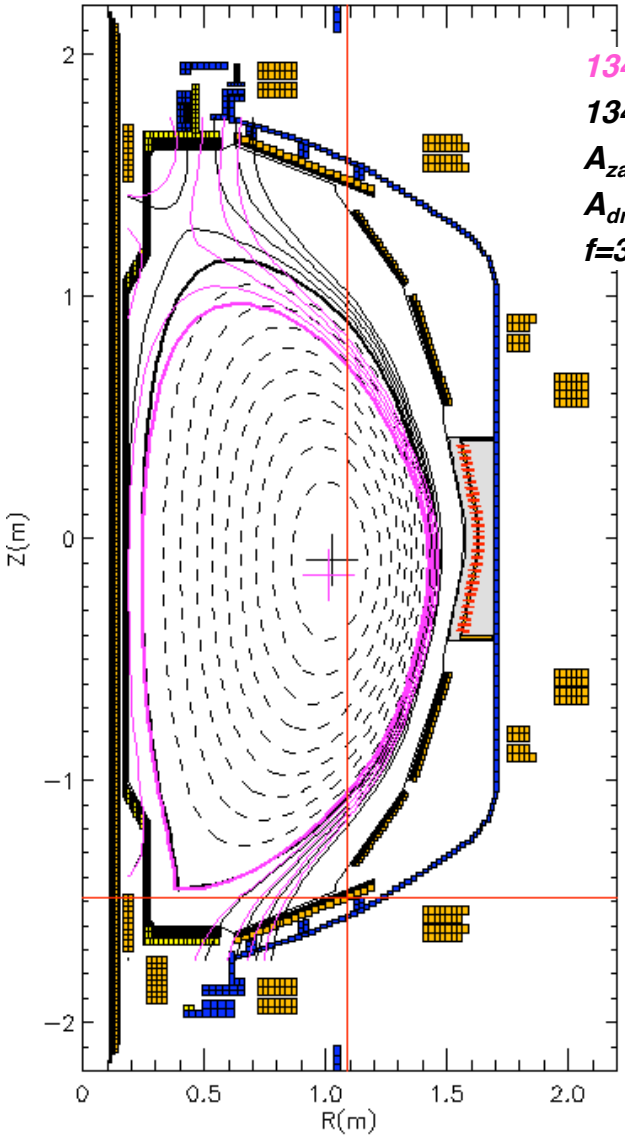
133936, t=0.592

133936, t=0.578

A_{zaxis}=-16 cm

A_{drsep}=-2 cm

f=45 Hz, t=10 msec



134318, t=0.715

134318, t=0.732

A_{zaxis}=0 cm

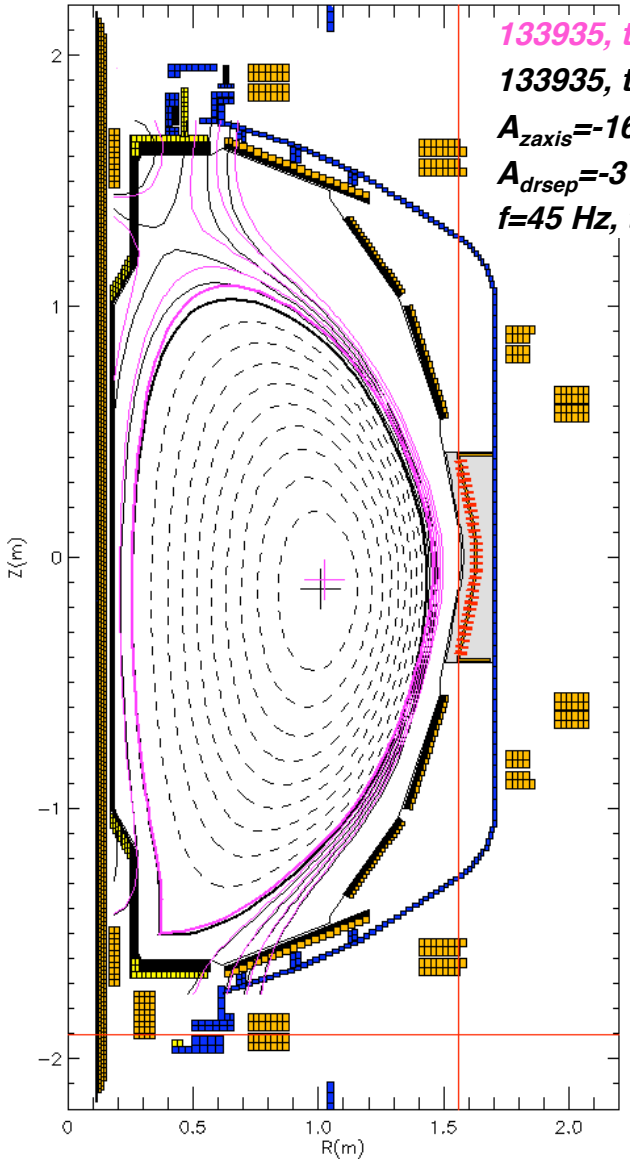
A_{drsep}=-3.5 cm

f=30 Hz, t=6 msec

Observations and Future Analysis

- Scheme for jogging the plasma was developed:
  - First tried jogs in z_{axis}, then synchronous in z_{axis} and dr_{sep}, and finally settled on jogs in dr_{sep} alone.
- Plasma was surprisingly tolerant of jogs, as long as dr_{sep} didn't become too small.
  - Comparing fiducial (134299) and an "identical" shot with 60 Hz, 4cm pk-pk jogs, 25 mg Li (134392), shot with jogs was arguably better.
  - Indications, however, that as the "average" dr-sep became more negative, the jogs became less benign (H->L backtransitions).
- Triggering ELMs via Jogs is NOT easy.
  - Shot 134392, beginning of 2nd day, fiducial shape, after large amount of Li, had 60 Hz, 4cm pk-pk axis jogs, and NO ELMs were triggered.
  - This target would have easily ELMed under the Canik/Maingi/Sontag pulsed n=3 method.
  - Problem may have been i) dr_{sep} too near zero, or ii) proximity to Li application.
  - In any case, triggering only shown to work for dr_{sep}<~1 cm.
  - Triggering "efficiency" remained low.
- Analysis Tasks
  - Reconstruct the edge current density, using equilibrium reconstruction, TRANSP, or other available tools.
  - Look at the time evolution of shots that had partial triggering…why did some jogs work?
  - Look into the feasibility of pedestal stability analysis.
- Future Experimental Work (Speculation…)
  - Are some equilibria better-suited to these experiments. Low-delta? What is the allowed dr_{sep} range?
  - Can the triggering be made more efficient?

Plasma Successfully "Jogged"



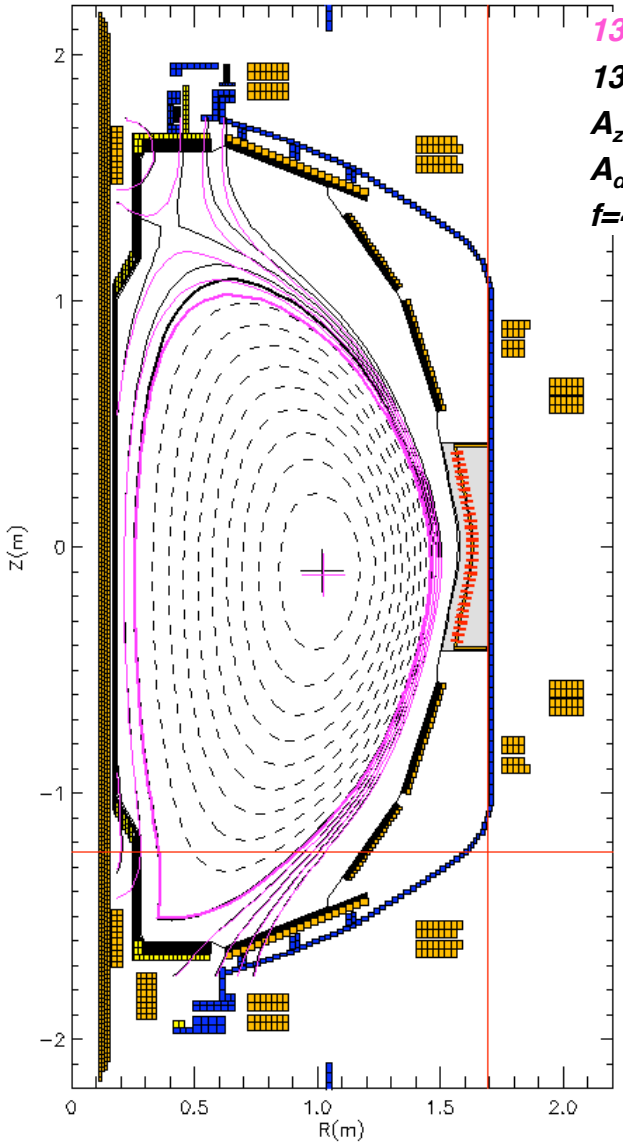
133935, t=0.71

133935, t=0.698

A_{zaxis}=-16 cm

A_{drsep}=-3 cm

f=45 Hz, t=6 msec



133936, t=0.592

133936, t=0.578

A_{zaxis}=-16 cm

A_{drsep}=-2 cm

f=45 Hz, t=10 msec