Neutral Beam-Ion Prompt Loss Induced by Alfvén Eigenmodes in DIII-D

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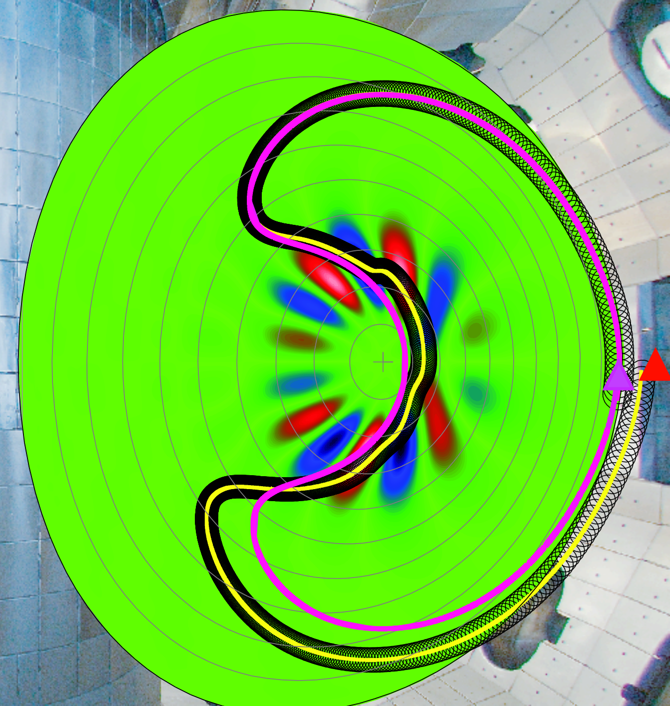

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DIII-D NATIONAL FUSION FACILITY SAN DIEGO

UCIrvine University of California, Irvine

Overview

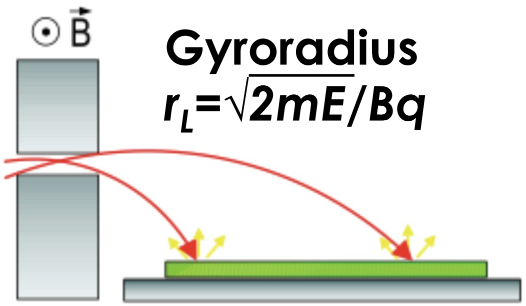
- **First experimental observation of prompt beam-ion loss driven by Alfvén eigenmodes**

- **Those losses give insight in the interaction between the AEs and fast ions during a single poloidal transit**
  - New diagnostic application

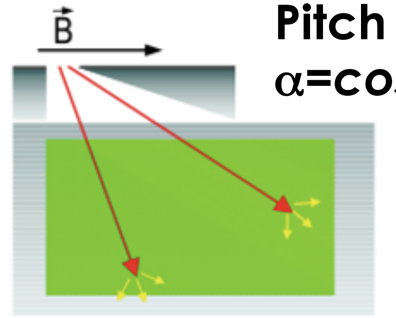
- **The process causes enhanced, concentrated losses at the first wall**
  - Investigate for ITER

AE-Induced Prompt Losses are Observed by Fast Ion Loss Detectors (FILDs) in DIII-D

- The FILD obtains the energy and pitch resolved fast-ion losses with a bandwidth of 500 kHz

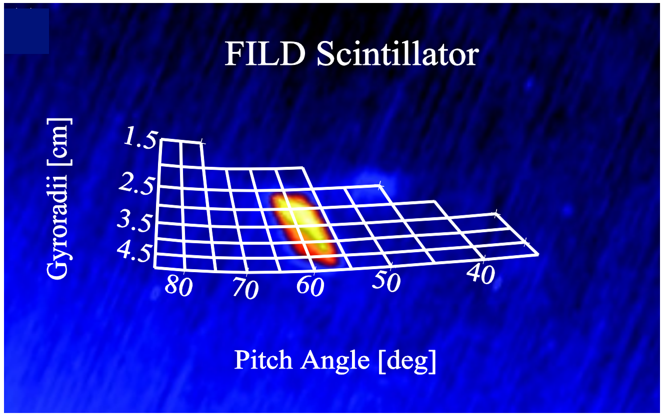


Gyroradius
$r_L=\sqrt{2mE}/Bq$

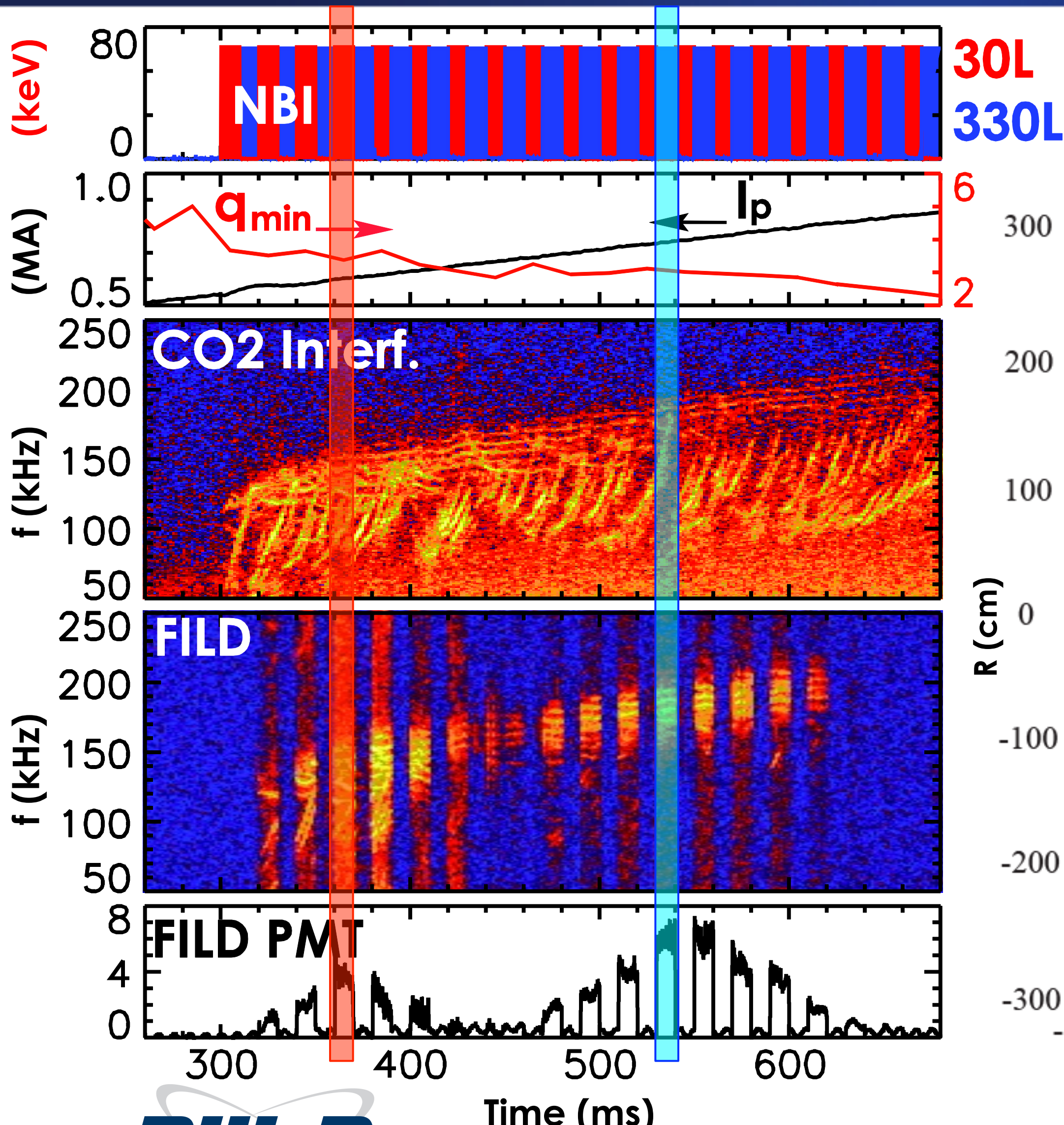


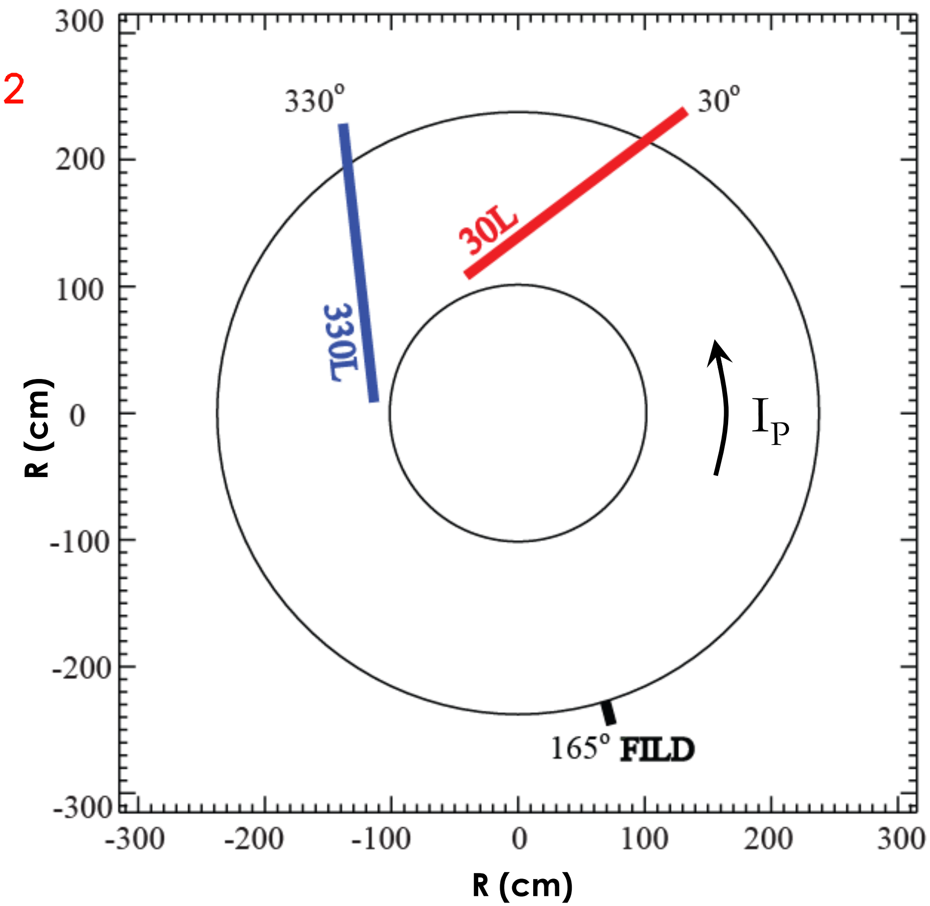
Pitch Angle
$\alpha=\cos^{-1}(v_{\parallel}/v)$

- The lost ions are of full-energy beam-ions and occur at similar pitch as the prompt losses (losses of ions born naturally on open orbits)



Losses Coincide with Different Beams Displaced Toroidally as *q* Evolves





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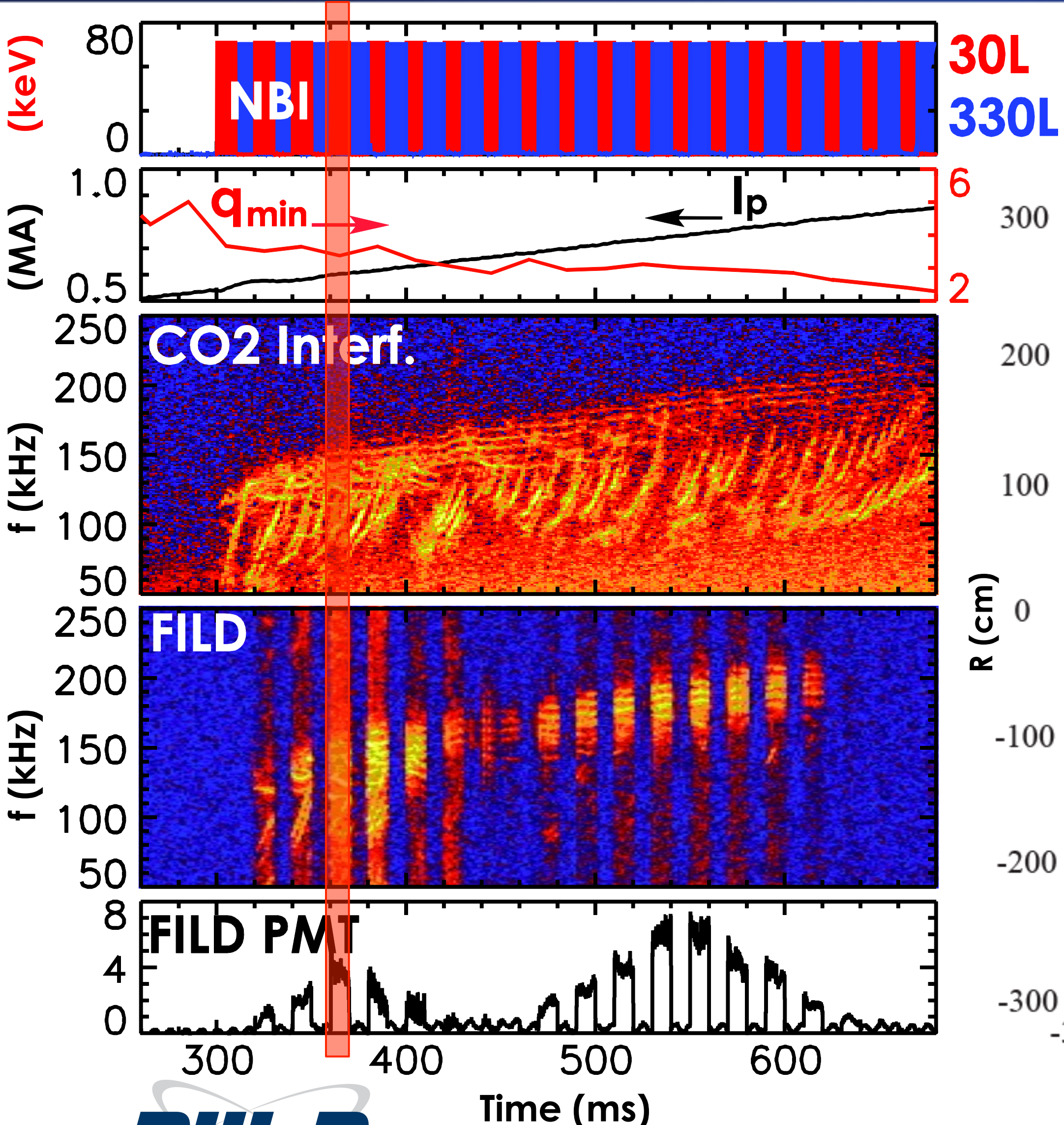

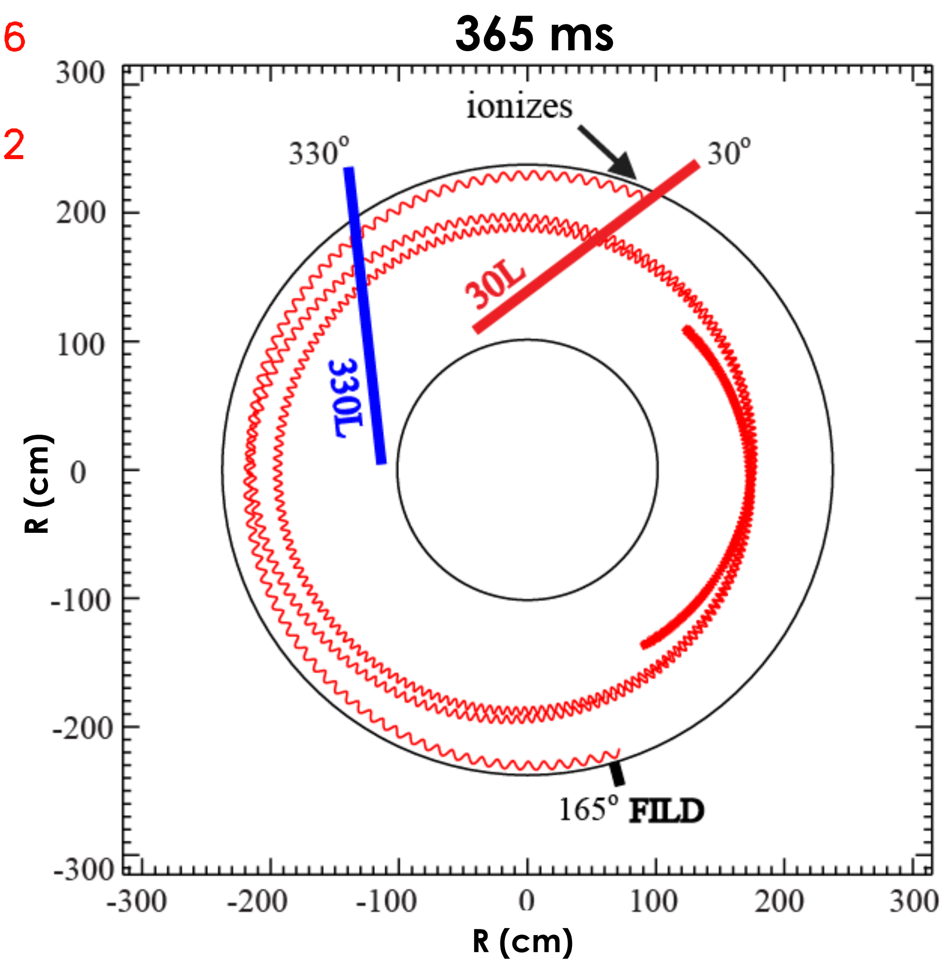

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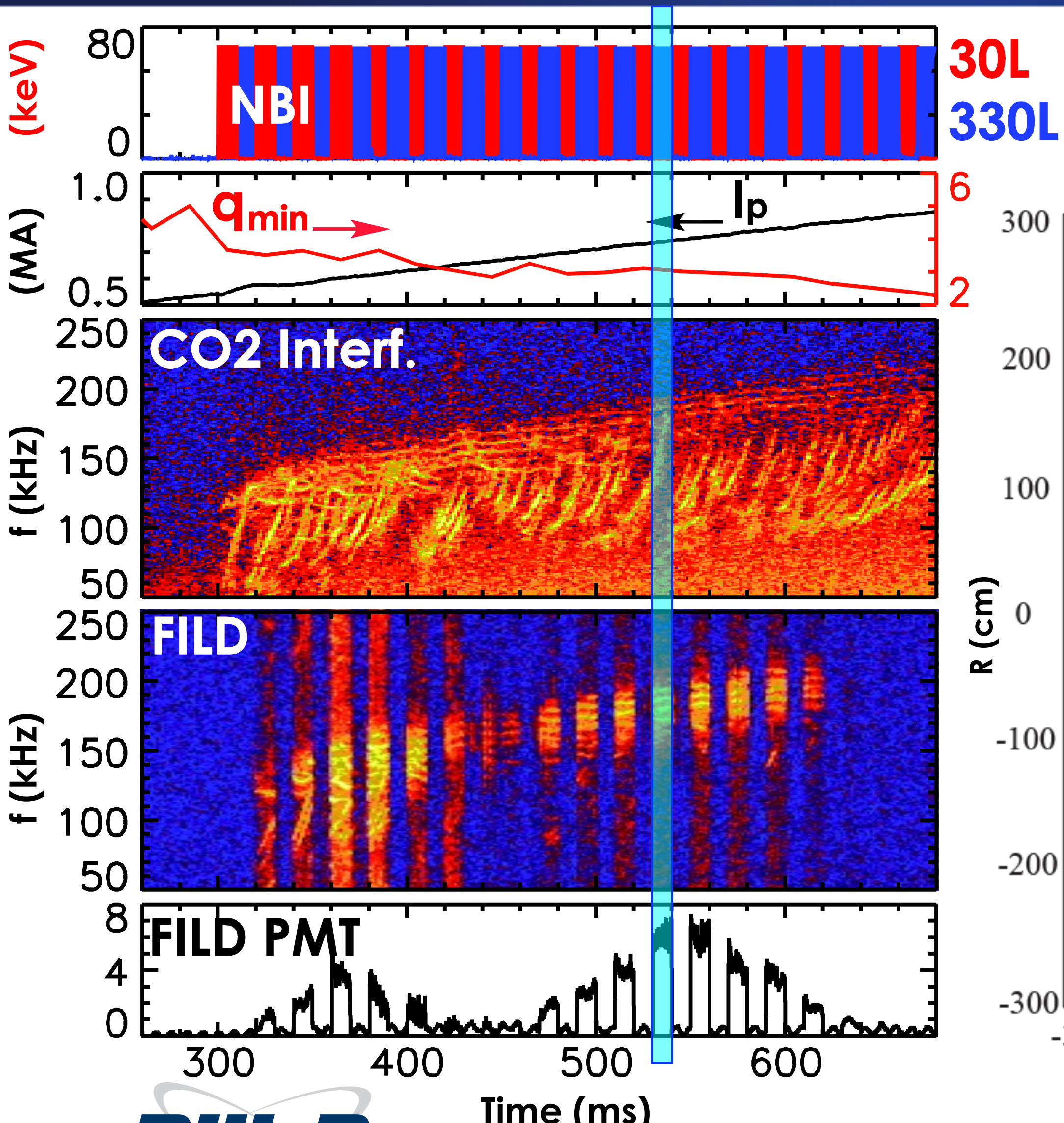
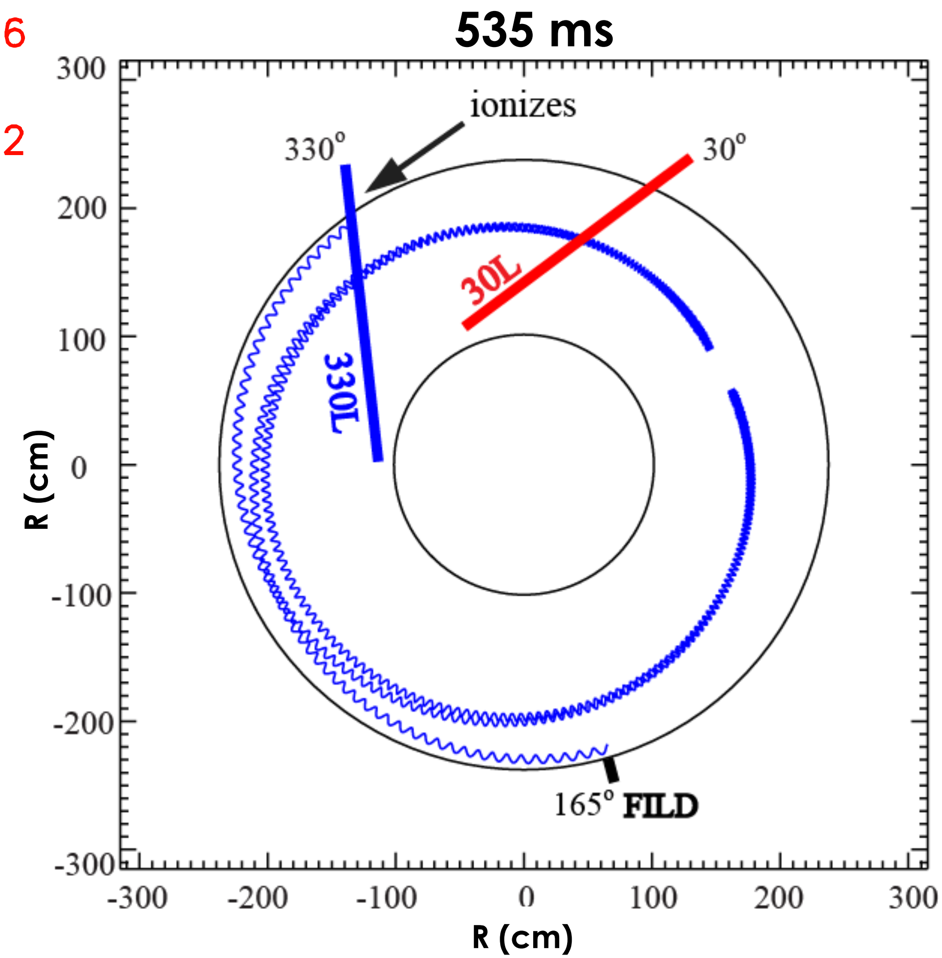
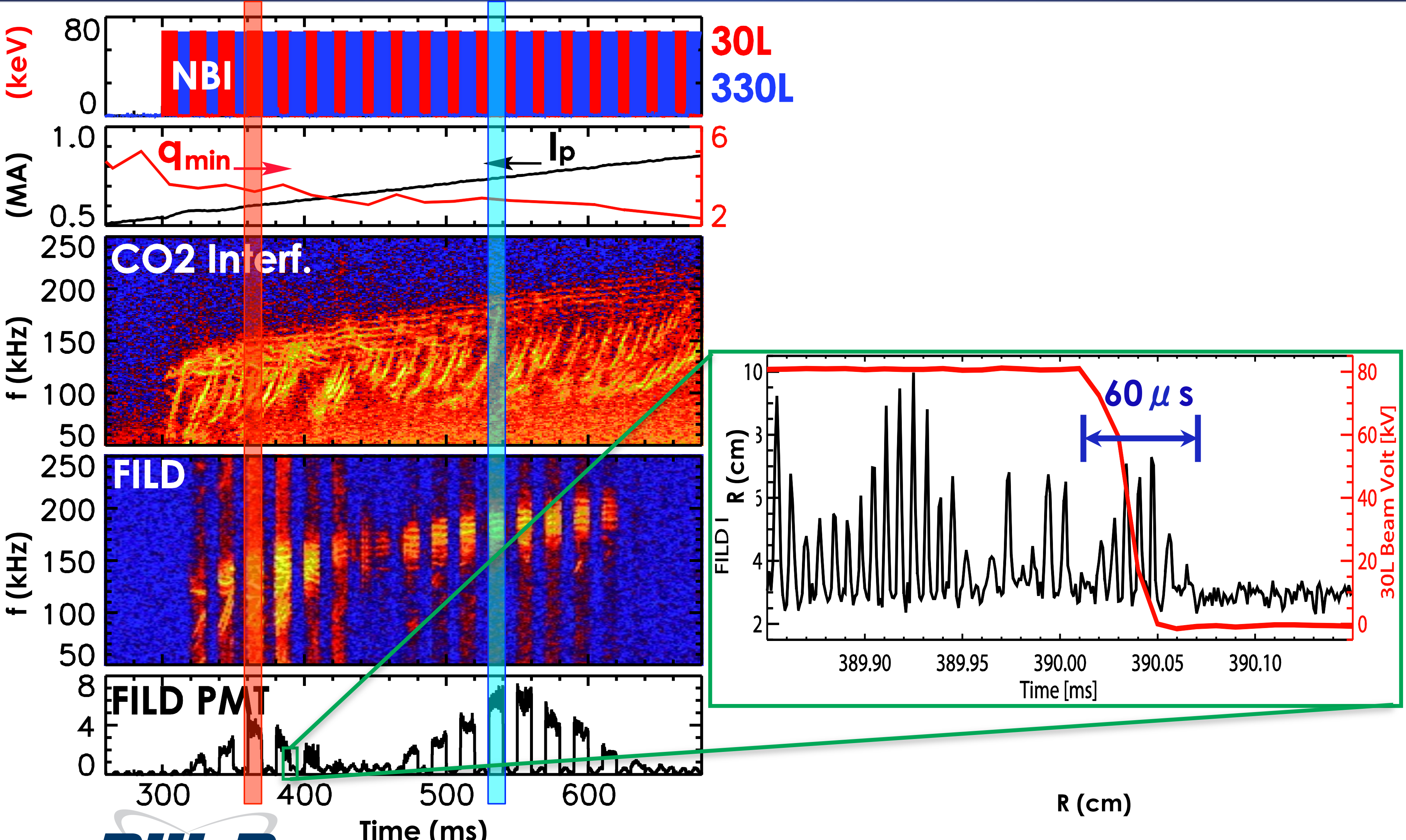




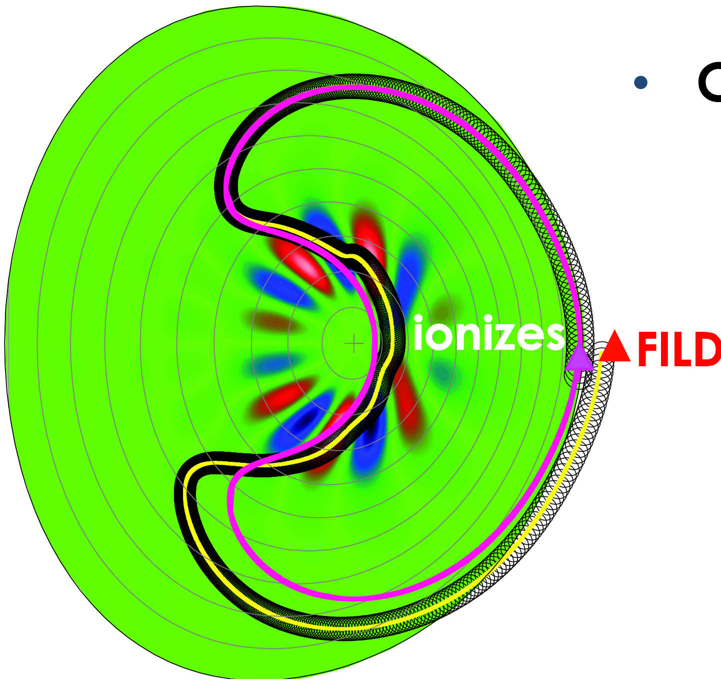
Raise and Decay Time of Loss Signal are Within ONE Poloidal Transit Time



Full-orbit Simulations Reveal Losses are Trapped Ions Scattered by AEs onto Loss Orbits on Their First Poloidal Bounce

- **Majority (> 98%) of *lost* beam-ions are expelled out from the plasma before completing their first drift-orbit**

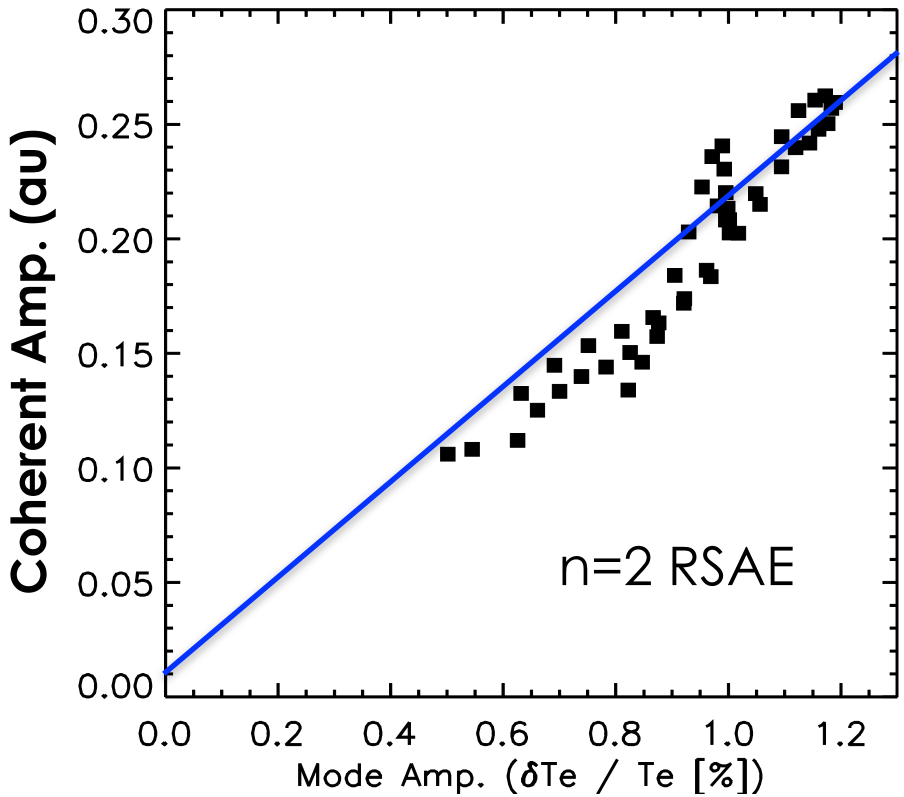
SPIRAL* code simulation



- **Coherent loss process**
  - A neutral ionizes on an unperturbed banana orbit that would carry it close to the FILD
  - This ion interacts with an AE in the plasma core
  - For the illustrated AE phase, the ion is "kicked" radially outward and is detected
  - For a different phase, the kick is smaller or radially inward and the ion misses the FILD

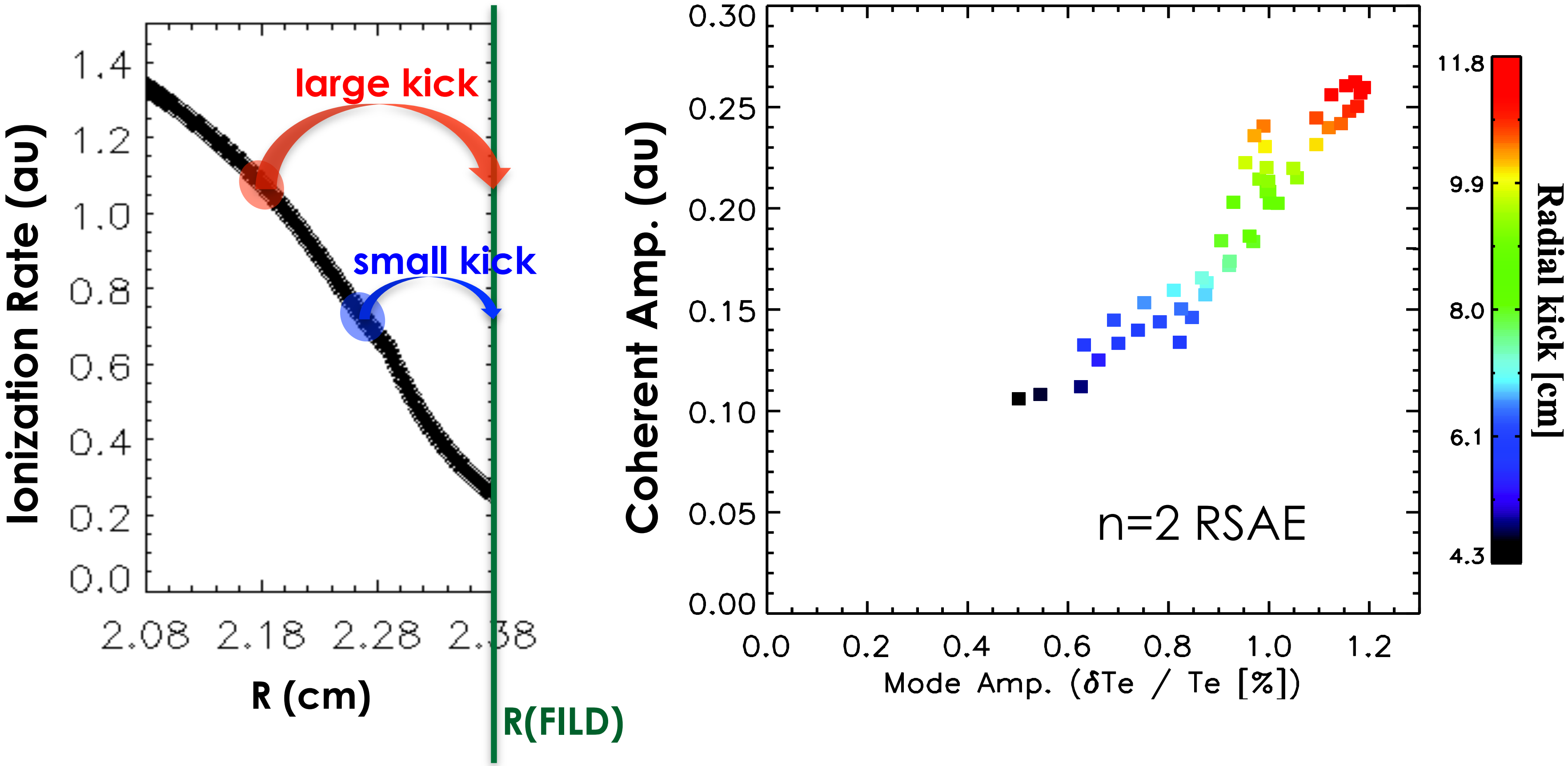
****G.J. Kramer et al., submitted to Plasma Phys. Cont. Fusion. (2012)***

Loss Amplitude Scales Linearly with Mode Amplitude



- **The slope of the linear relationship depends on the AE mode structure**
- **Reproduced by SPIRAL code simulations**

The Data Provide Direct Measurements of the Radial Excursion Induced by Individual Modes



We know the ionization rate and the coherent loss amplitude ⟶ Infer the radial kick experimentally

Concern for ITER: the Concentrated Escaping Fast Ions Can Damage Plasma Facing Components

- **The process found on DIII-D causes *enhanced*, *concentrated* losses at the first wall**
  - From confined co-injected beam ions
  - Resonant condition is not required
  - Nearly doubled the losses at the FILD location
  - The estimated loss spot size on the wall from SPIRAL is about $0.5m^2$

Implication for ITER

- **AEs predicted in ITER**
- **Off-axis co-injection in ITER**
- **Hot spots/localized heat loads on ITER wall from this new prompt loss mechanism should be investigated**

Summary

- Observed coherent losses are AE-induced prompt beam-ion losses, reproduced by SPIRAL full orbit simulations
- The data provides a direct measure of the radial "kick" imparted by each mode (AEs and other instabilities)
- Resonant interactions with modes are not required for these first-orbit losses. It can enhance the concentrated fast-ion losses on the ITER wall
- This will provide a test bed for the modeling of AE mode structures and induced fast-ion transport/loss