NSTX 2010 Experimental Proposals: RWM Passive Stabilization Physics

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PPPL, Princeton, NJ
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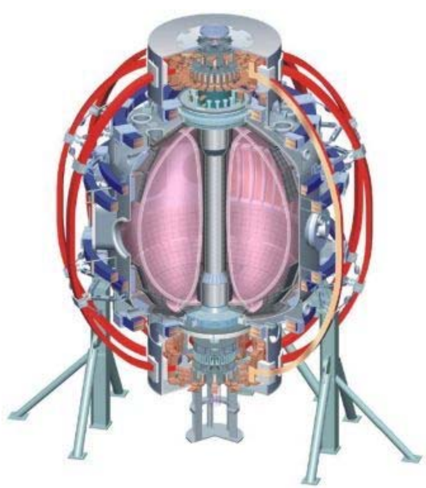

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RWM passive stability vs. rotation at low ℓ_i

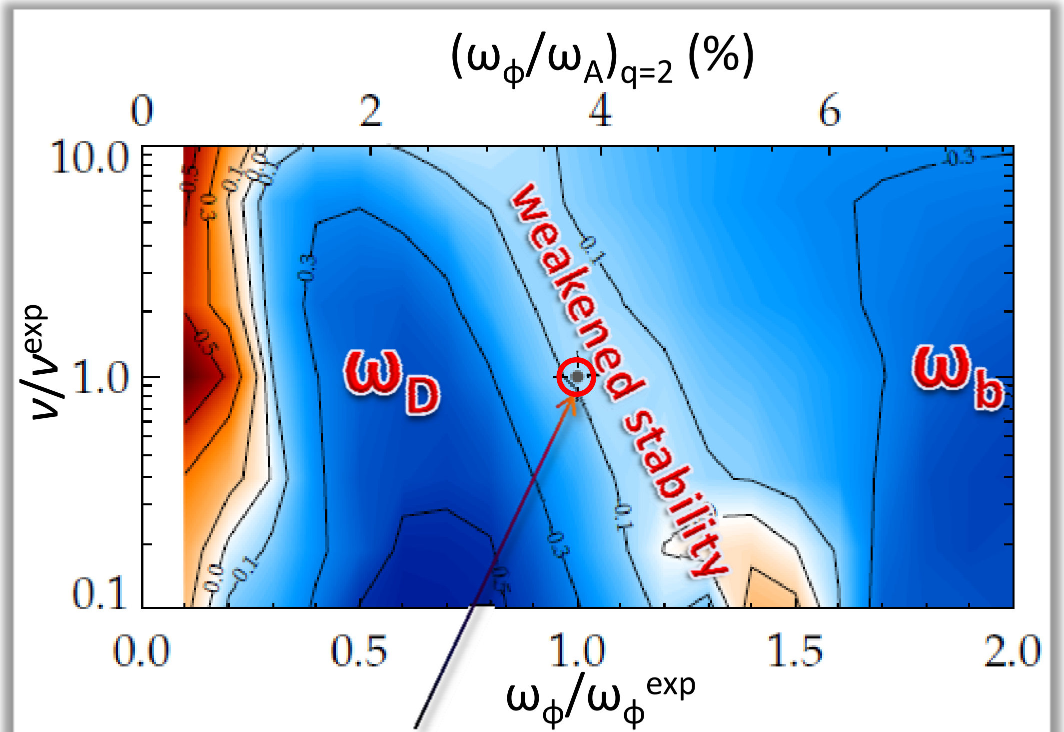
- Motivation
  - Kinetic theory indicates that plasmas with ω_ϕ in between ω_D and ω_b resonances have weakened stability.
  - It is key to understand passive stability in regimes of high importance to the future of the ST (low ℓ_i).
- Goals
  - Measure RWM γ and ω_r as a function of ω_ϕ in low ℓ_i plasmas with MHD spectroscopy and compare to kinetic theory prediction calculated by MISK.
  - Provide input to the eventual goal of realtime stability limit detection via resonant field amplification (RFA) measurement.

RWM passive stability vs. rotation at low ℓ_i

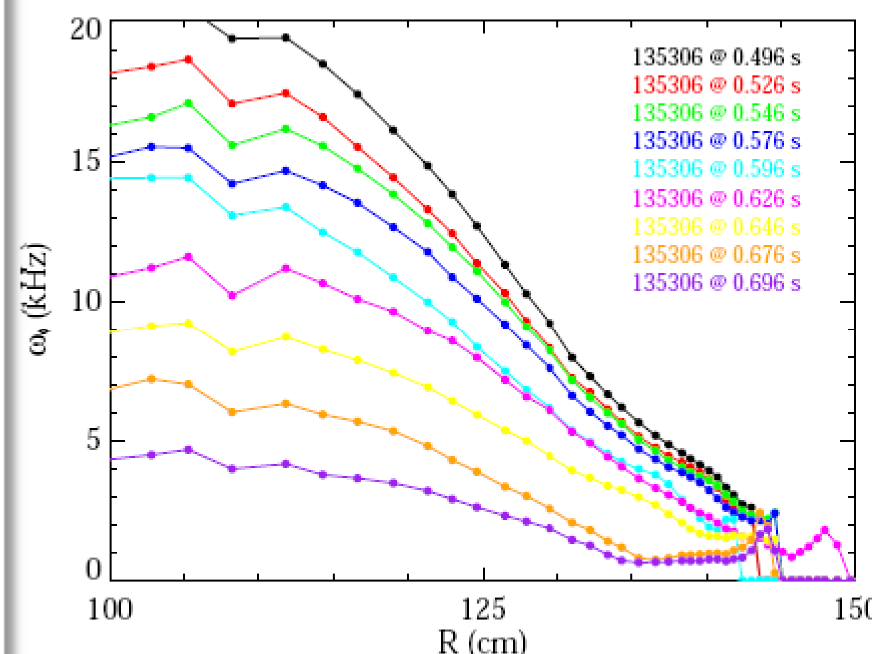
- Addresses:
  - NSTX Milestone R(10-1): Assess sustainable beta and disruptivity near and above the ideal no-wall limit.
  - ITPA: MDC-2: Joint experiments on resistive wall mode physics.
  - ITPA: MDC-12: Non-resonant magnetic braking.
  - ReNeW Thrust 16 proposed action: Implement and understand active and passive control techniques to enable long-pulse disruption-free operation in plasmas with very broad current profiles.

NSTX plasmas can go unstable at weakened stability rotation, or can navigate through to low rotation

- Weakened stability occurs at relatively high rotation when ω_ϕ is between ω_D and ω_b stabilizing resonances
  - Some shots are able to avoid RWM instability,make it to low ω_ϕ

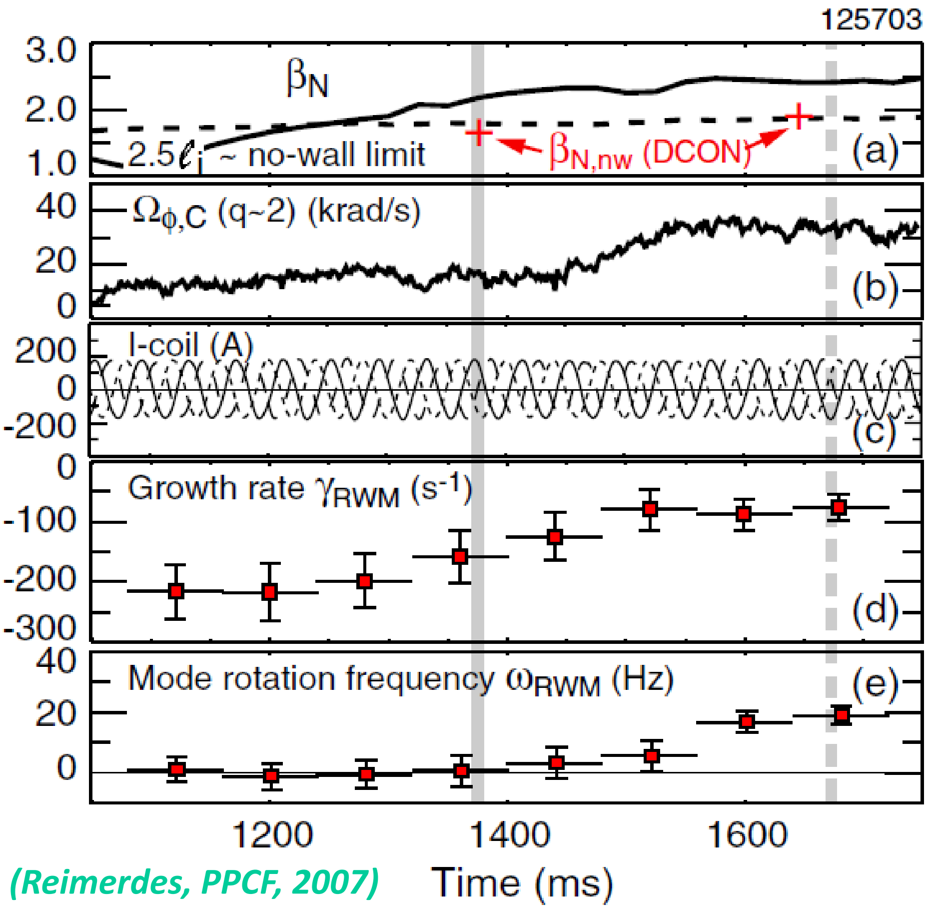


NSTX experimental instability

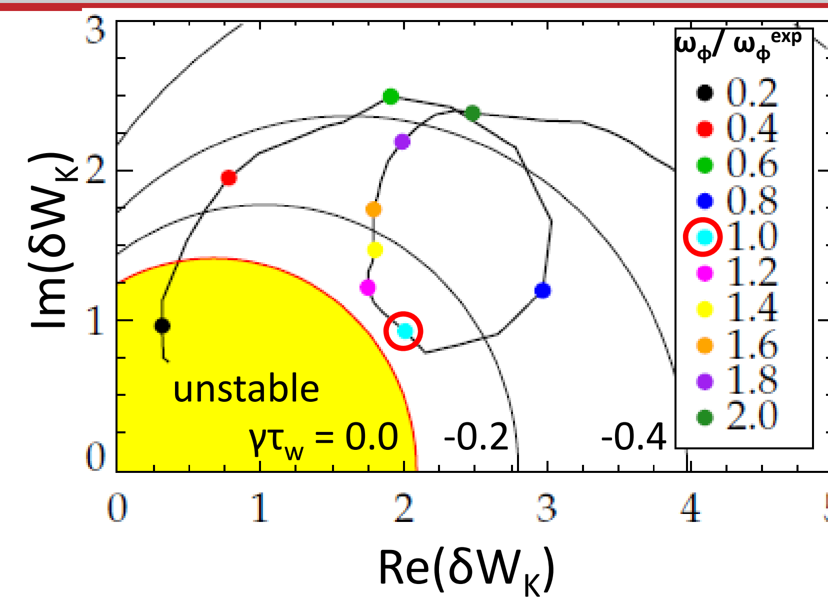


Active MHD spectroscopy can measure growth rate and mode rotation frequency

Comparing measured γ and ω_r to theory will improve understanding of RWM stability.



(Reimerdes, PPCF, 2007)



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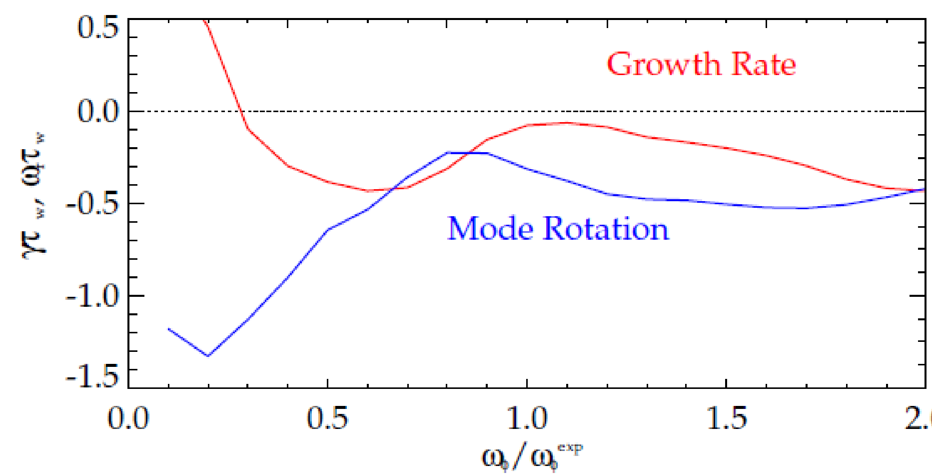
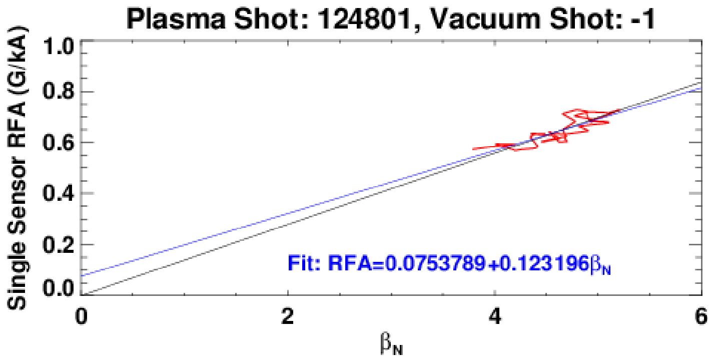
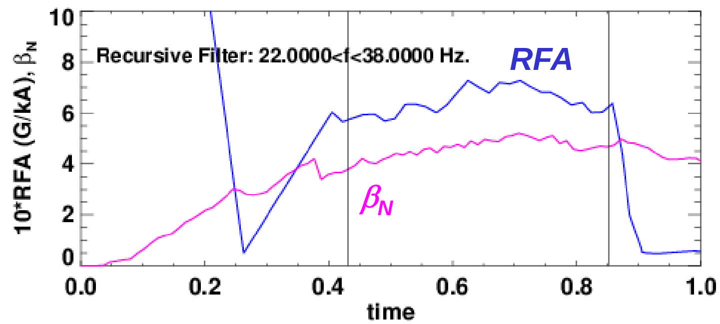


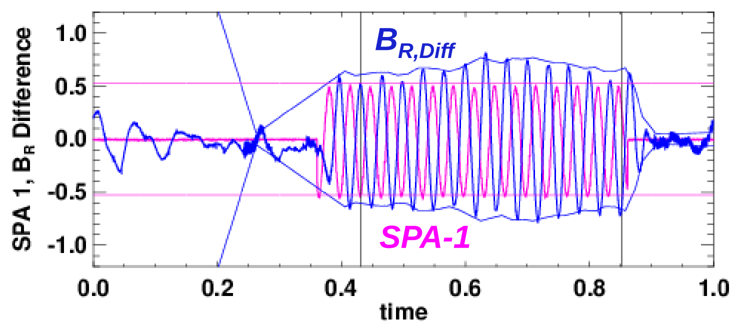
Realtime stability limit detection via RFA is an eventual goal

- This experiment can also provides valuable data to the eventual goal of realtime stability limit detection via RFA.
  - we will also make some scans of β_N.
  - Picks up from XP930 proposed last year for that purpose.

$$RFA = \frac{B_{R,Diff,Peak-to-Peak}}{I_{RWM,Peak-to-Peak}}$$







(Gerhardt, XP930 presentation, 2009)

RWM passive stability vs. rotation at low ℓ_i

- Approach
  - Establish target plasmas at low ℓ_i.
  - Optimize n=3 non-resonant magnetic braking to consistently get through to low rotation without RWM instability.
  - Add n=1, 30 Hz., 1kA peak to peak traveling wave for active MHD spectroscopy.
  - Change plasma conditions and repeat for comparison to theory at multiple conditions.
  - Do several β_N scans for the eventual goal of realtime stability limit detection via resonant field amplification (RFA) measurement.

RWM Stabilization by Energetic Particles

- Motivation
  - Kinetic theory (still improving) indicates that energetic particles have a stabilizing effect on the RWM that is independent of ω_ϕ.
- Goals
  - Scan energetic particle content using RF heating.
  - Compare RWM stability to theoretical predictions, validating theory and improving understanding of energetic particle effects.
- Addresses:
  - NSTX Milestone R(10-1): Assess sustainable beta and disruptivity near and above the ideal no-wall limit.
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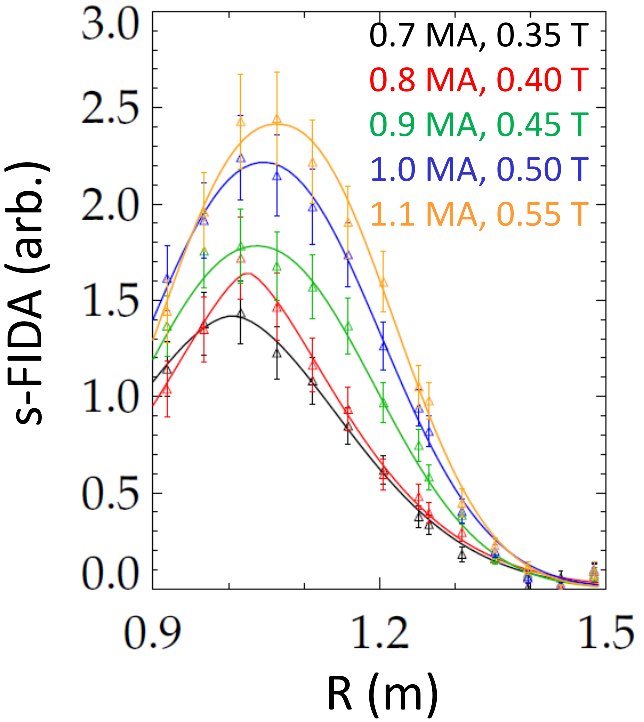
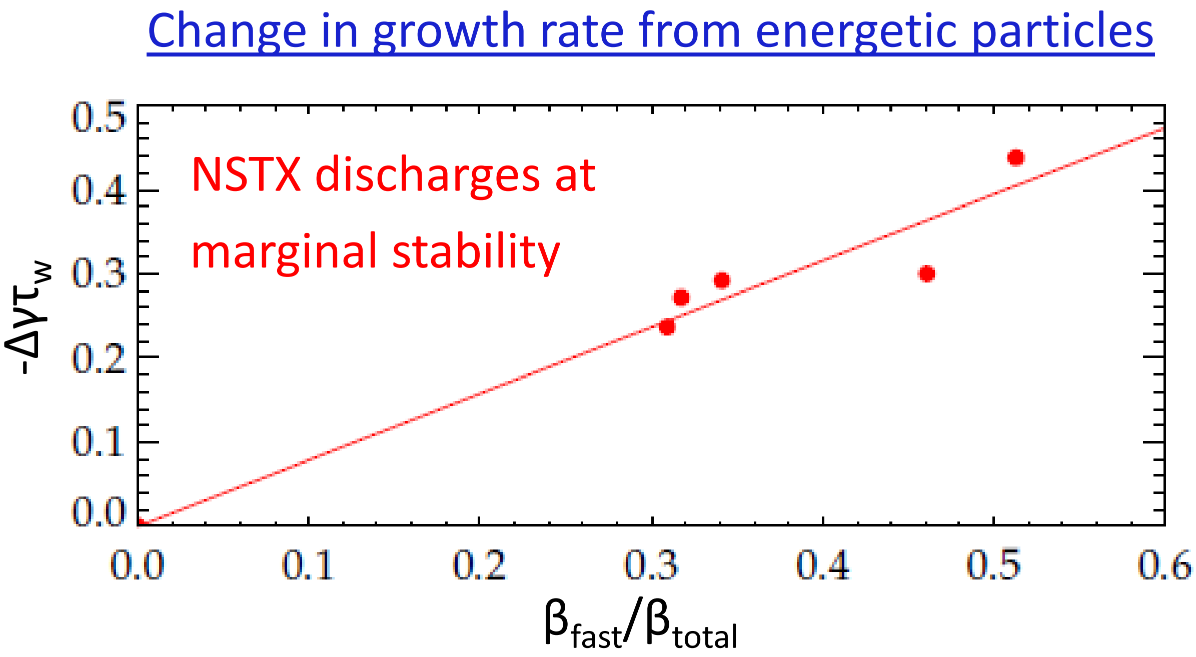
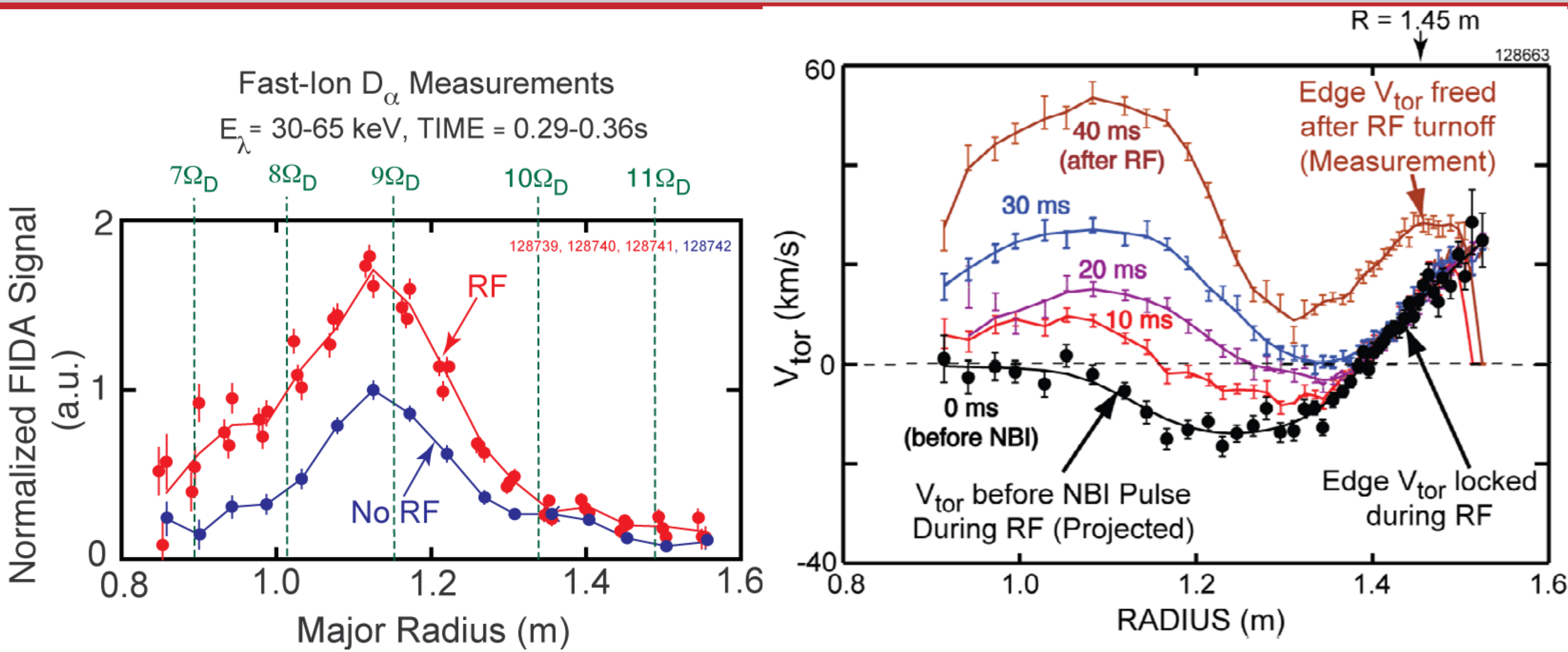
Energetic particles contribute linearly to RWM stability





- XP932 in 2009 scanned energetic particle content with B_t,I_p
  - Larger $\beta_{fast}/\beta_{total}$ leads directly to greater stability in kinetic theory.
  - β_N also changed in this scan. Use RF to change energetic particle content at constant β_N.

RF heating affects energetic particles and plasma rotation



- Use of RF as a tool for changing E.P. content and rotation:
  - enhancement and broadening of fast ion profile with HHFW.
  - edge rotation locked, and core rotation damped during HHFW.

RWM Stabilization by Energetic Particles

- Approach
  - Establish target plasmas without RF heating and apply n=3 non-resonant magnetic braking to get unstable RWM.
  - Establish target plasmas with RF heating.
  - Determine the effect of RF heating on plasma rotation, in conjunction with n=3 non-resonant magnetic braking.
  - Brake plasmas to get unstable RWM.
  - Change RF heating to alter the energetic particle content at similar β_N. If rotation substantially changes as well, change braking to try to return to a similar state.

RWM Passive Stabilization Physics - Diagnostics

- Required diagnostics / capabilities
  - Ability to operate RWM coils in n = 3 configuration
  - RWM sensors
  - CHERS toroidal rotation measurement
  - Thomson scattering
  - USXR
  - MSE
  - Toroidal Mirnov array / between-shots spectrogram with toroidal mode number analysis
  - Diamagnetic loop
  - FIDA
- Desired diagnostics
  - FIReTip
  - Fast camera
  - CHERS poloidal rotation measurement

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