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Dependence of momentum and particle pinch on collisionality

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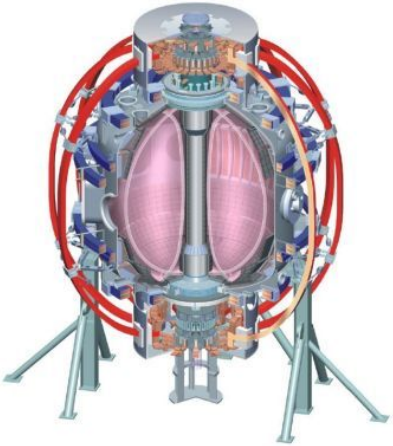
and the NSTX Research Team

NSTX Results and Theory Review
Transport and Turbulence Topical Science Group
September 15-16, 2009



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Dependence of momentum and particle pinch on collisionality

- Aims:
  - Compare dependence of momentum pinch velocity on collisionality with analytic theory and/or gyrokinetic predictions
  - Compare momentum pinch velocity with particle pinch velocity

- Technique:
  - Use n=3 non-resonant magnetic perturbations to distort the rotation profile, allowing for separation of the roles of momentum diffusion vs convection (pinch).
  - Scan collisionality by varying Ip, Bt at fixed q
    - As reported by Kaye et al, IAEA 2006
  - Use Ne puffing and/or supersonic gas injection to perturb edge density and measure particle transport properties

Motivation

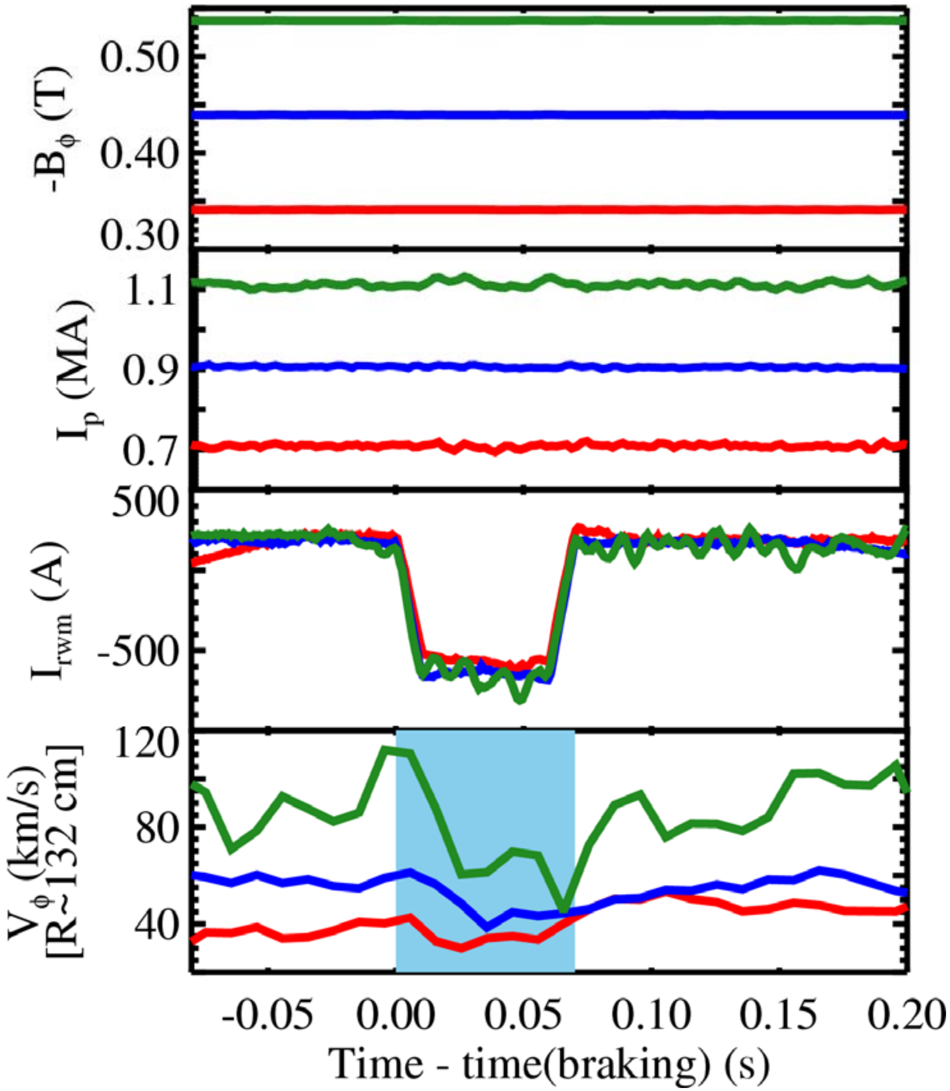
- Rotation widely acknowledged as playing critical and beneficial role in the performance of fusion plasmas
  - Stabilization of resistive wall modes and neoclassical tearing modes
  - Confinement improvement through turbulence suppression (*E* x *B* shear)

- Understanding momentum transport key to obtaining predictive knowledge of rotation for future devices
  - Momentum pinch physics important part of problem

- Size of momentum pinch will determine how peaked rotation will be in future devices
  - ITPA JEX TC-15

Ip and Bt scans at fixed q were successfully completed

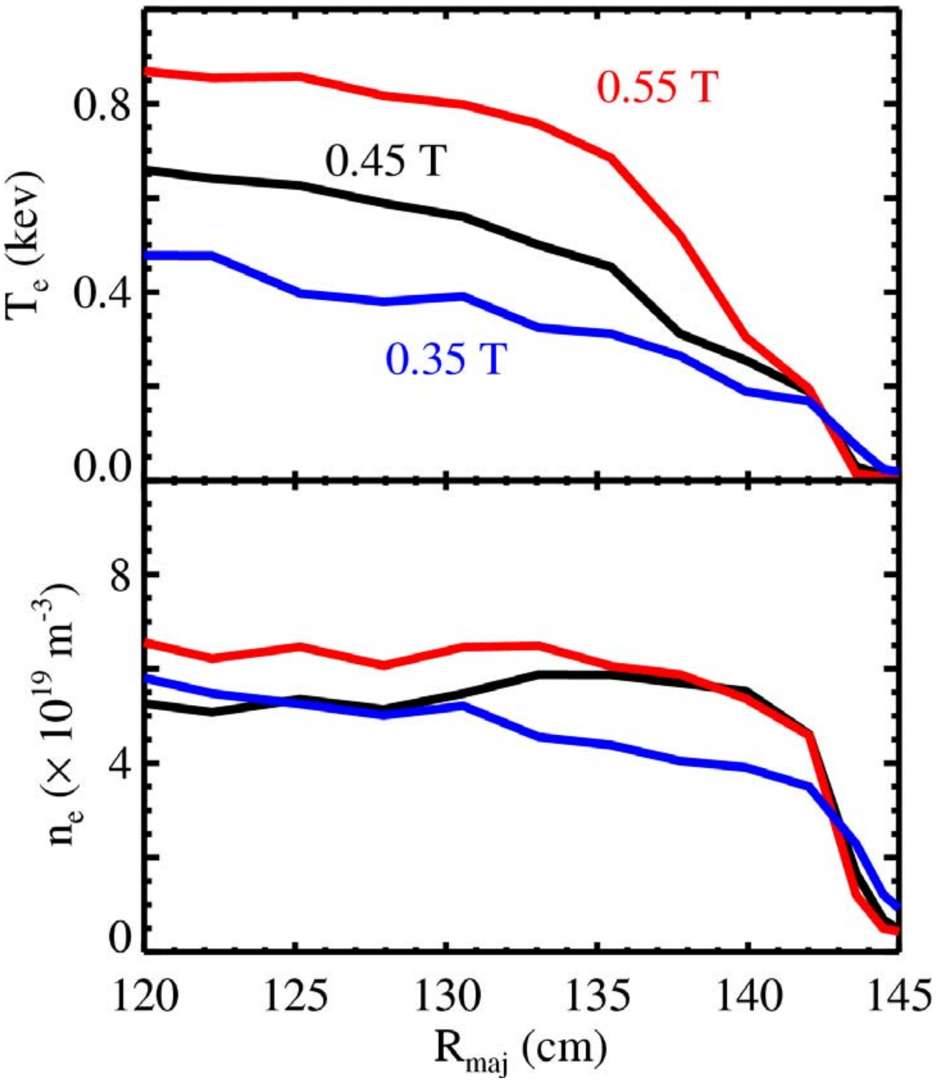
- Obtained data for both momentum and particle pinch
- Achieved approximately factor of two variation in collisionality



Collisionality variation achieved through changes in Te

- “Traditional” collisionality scan keeps density constant and varies temperature
  - Main knob turns out to be B, $\nu^* \sim 1/B^4$

- Obtained density profiles kept relatively fixed during scan
  - Some minor variation inevitable, but needs to be included in analysis

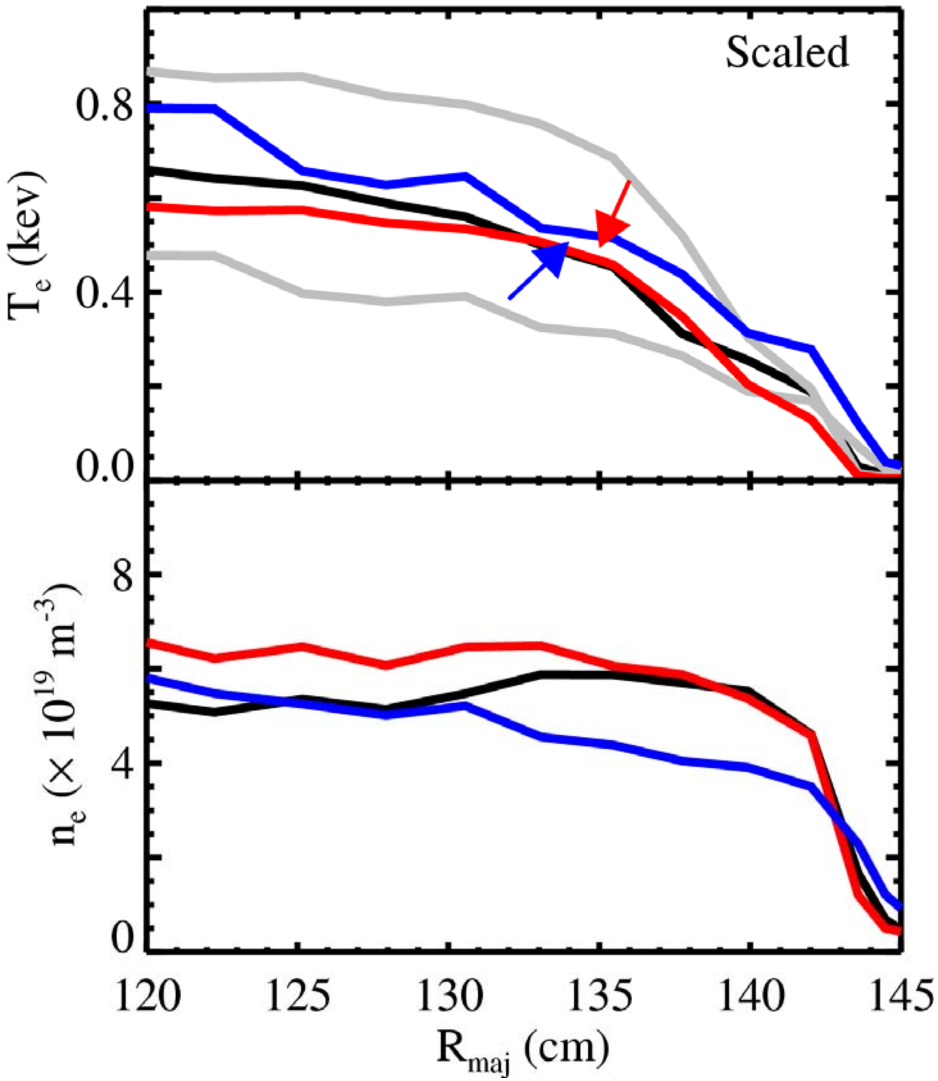


Dimensionless scaling of temperature shows reasonable matches during the scan

- “Traditional” collisionality scan keeps density constant and varies temperature

- Obtained density profiles kept relatively fixed during scan

- Collisionality scan built up from multiple discharges around these targets



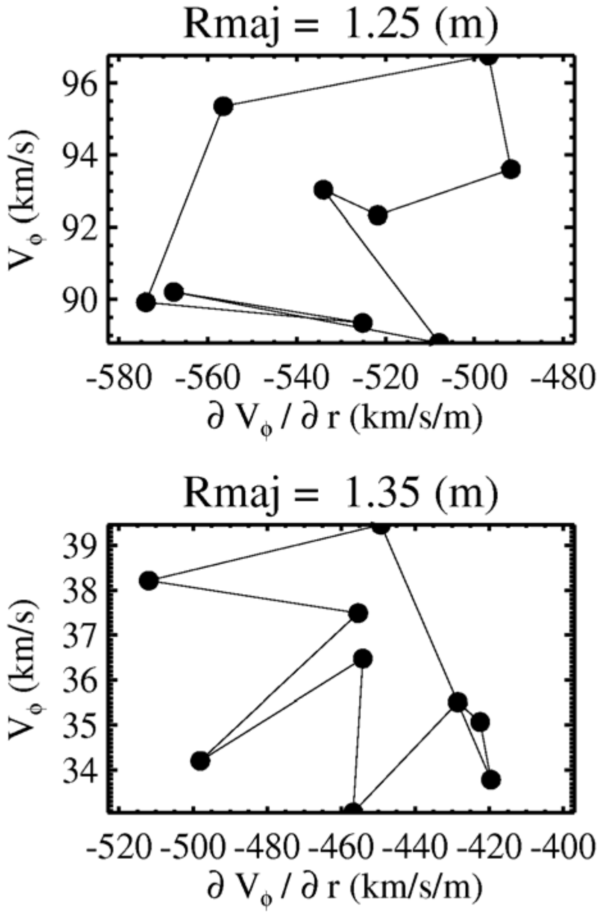
n=3 Perturbation Provided Necessary Non-Local Distortion to Rotation Profile

- Simple model for momentum flux

$$\Gamma_\phi = -mnR\left(\underbrace{\chi_\phi \frac{\partial V_\phi}{\partial r}}_{diffusion} - \underbrace{V_\phi V_\phi^{pinch}}_{convection}\right) + \Gamma_{RS}$$

- Residual stress drive of intrinsic rotation assumed unperturbed
  - Believed to be relatively localized to edge in any case

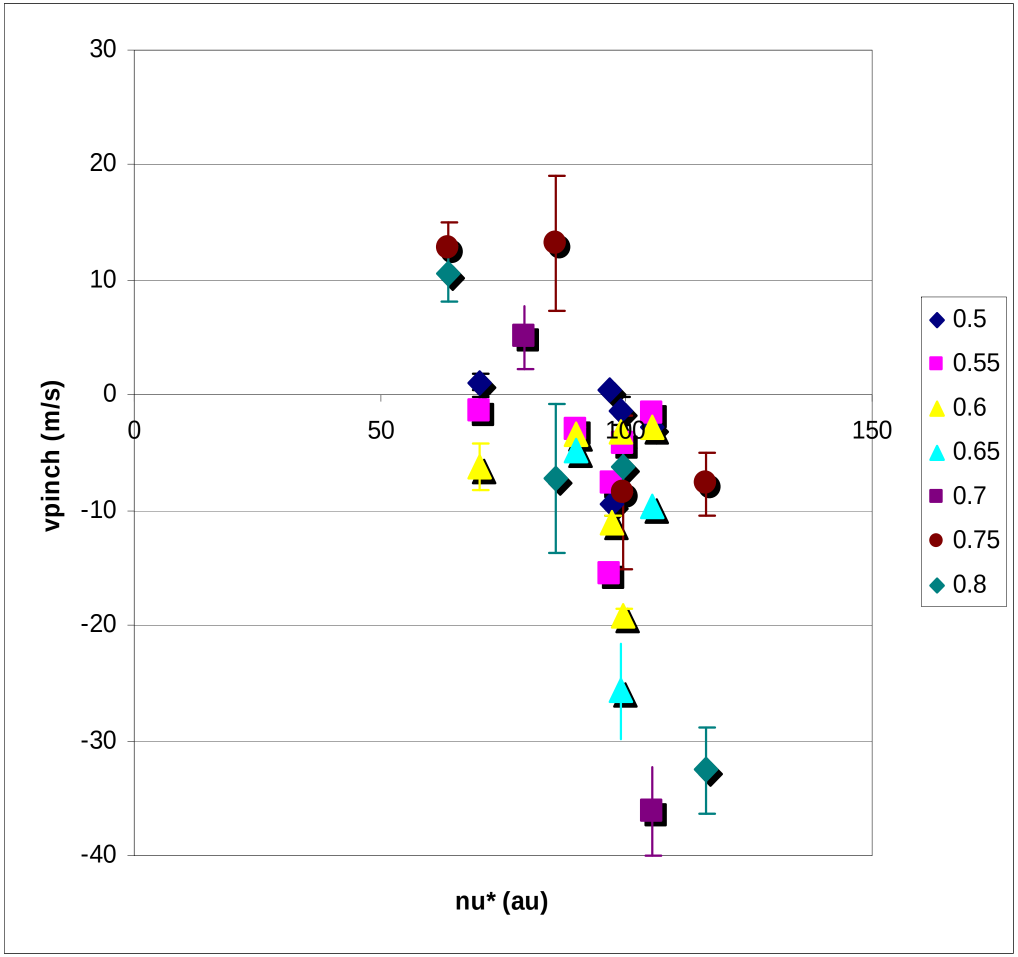
- Elliptic tracks of dV_ϕ/dr vs V_ϕ indicate that determination of χ_ϕ and V_ϕ^{pinch} possible.
  - Avoid co-linearity of data set



Inferred pinch velocity shows a collisionality dependence

- Comparisons with theory beginning

- Aspects that influence momentum pinch
  - Recoil pinch from particle flux
  - Nature of microturbulence (ITG vs TEM)
  - Trapped electron collisionality regime (collisionless/collisional etc)

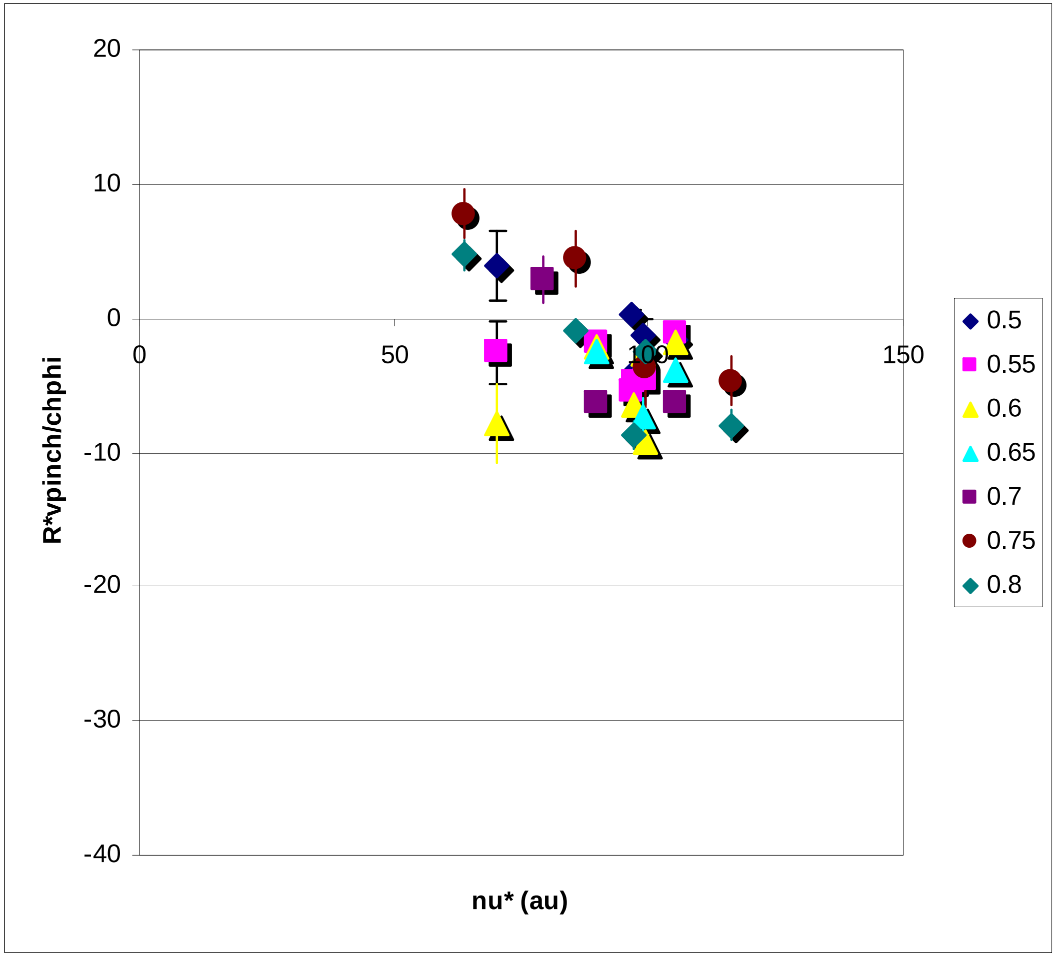


Pinch Appears to be Made Up of More Than Just TEP Part

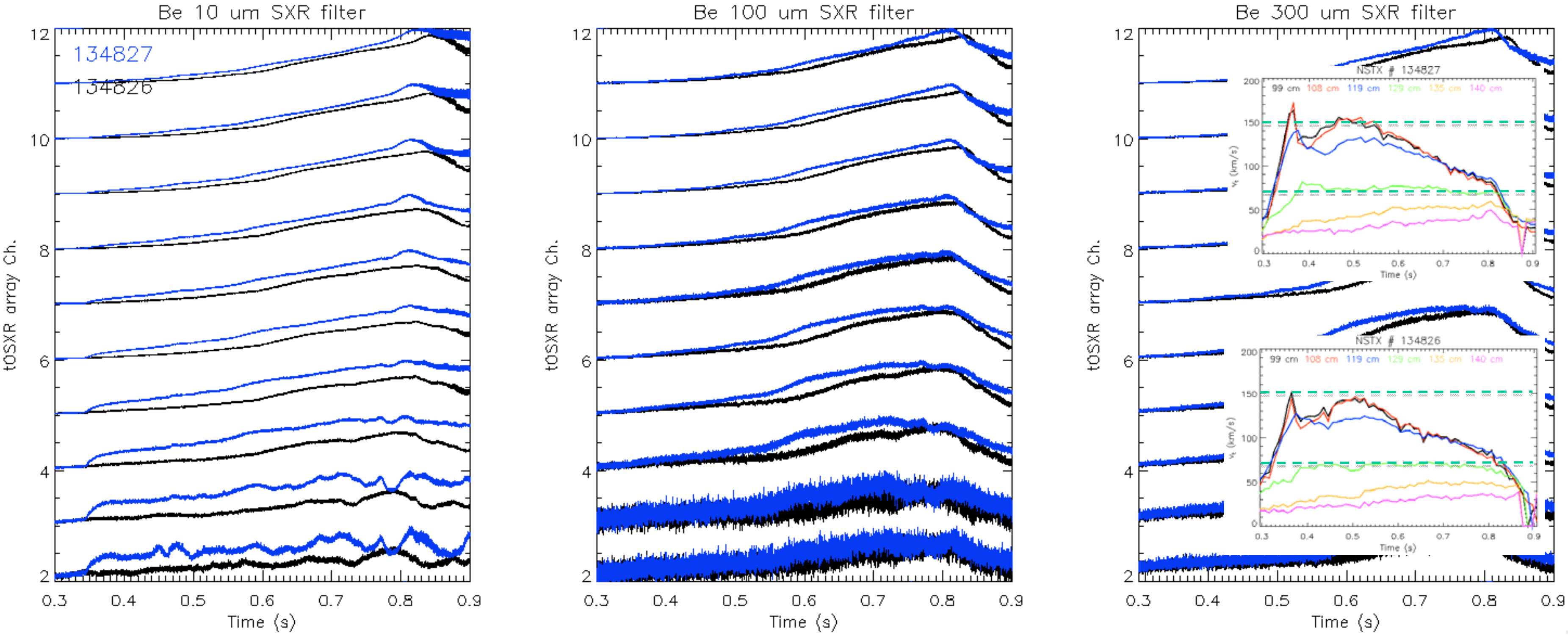
- Dimensionless pinch parameter from turbulent equipartition (TEP) is -4

$$\frac{RV_{pinch}^{TEP}}{\chi_{\phi}} = -4$$

- Is the remaining variation just R/Ln dependence, or other considerations?



Neon Injection in 0.9 MA – 4.5 kG H-mode Plasmas (Without nRMP braking) Show Monotonically Increasing SXR Signals

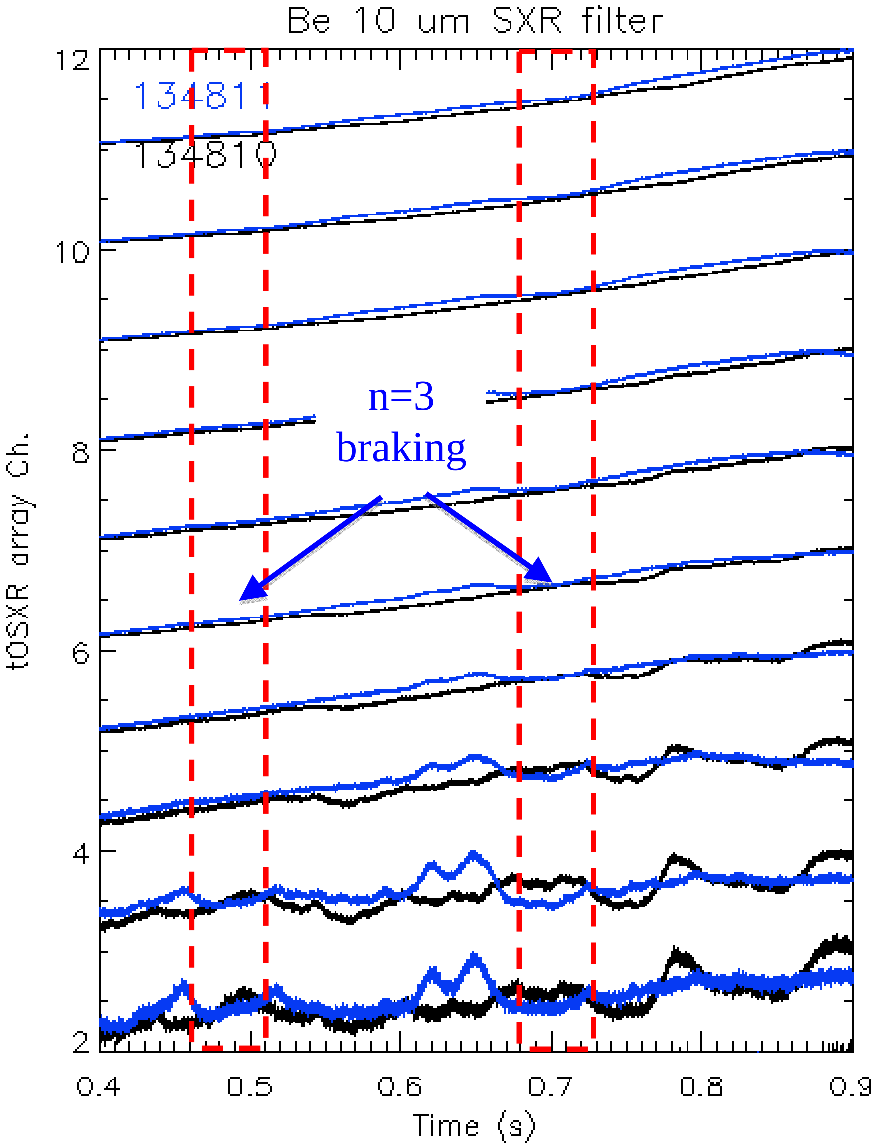


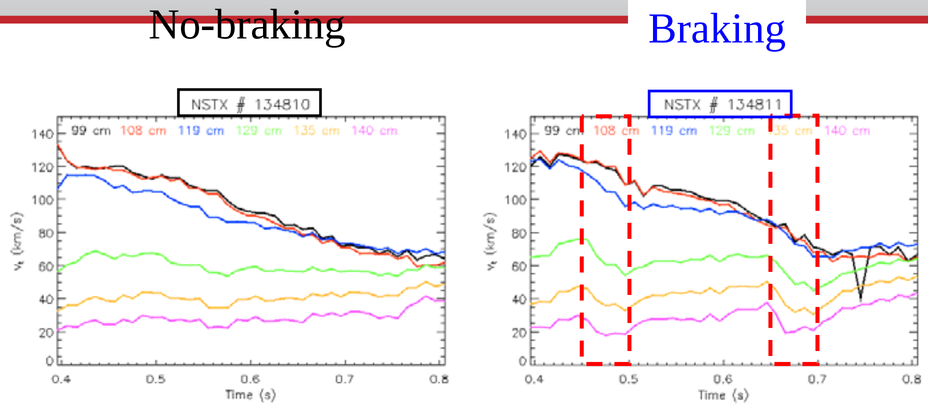
- Check the time history of v_θ (CHERS).

- Get D and V from average AND *time-dependent* MIST modeling. Initial condition for the braking experiment. Core rotation reduced from ~140 to 70 km/s.

- Can the time history of the diffusivity & convective “pinch” velocity be explained neo-classically? $D^{PS}(\Omega)\sim D^{PS}(1+M^*)^2$, *Romanelli, NF, 98*. $D^{PS}(\Omega)\sim D^{PS}f(\Omega)$, *Wong, PRL, 87*.

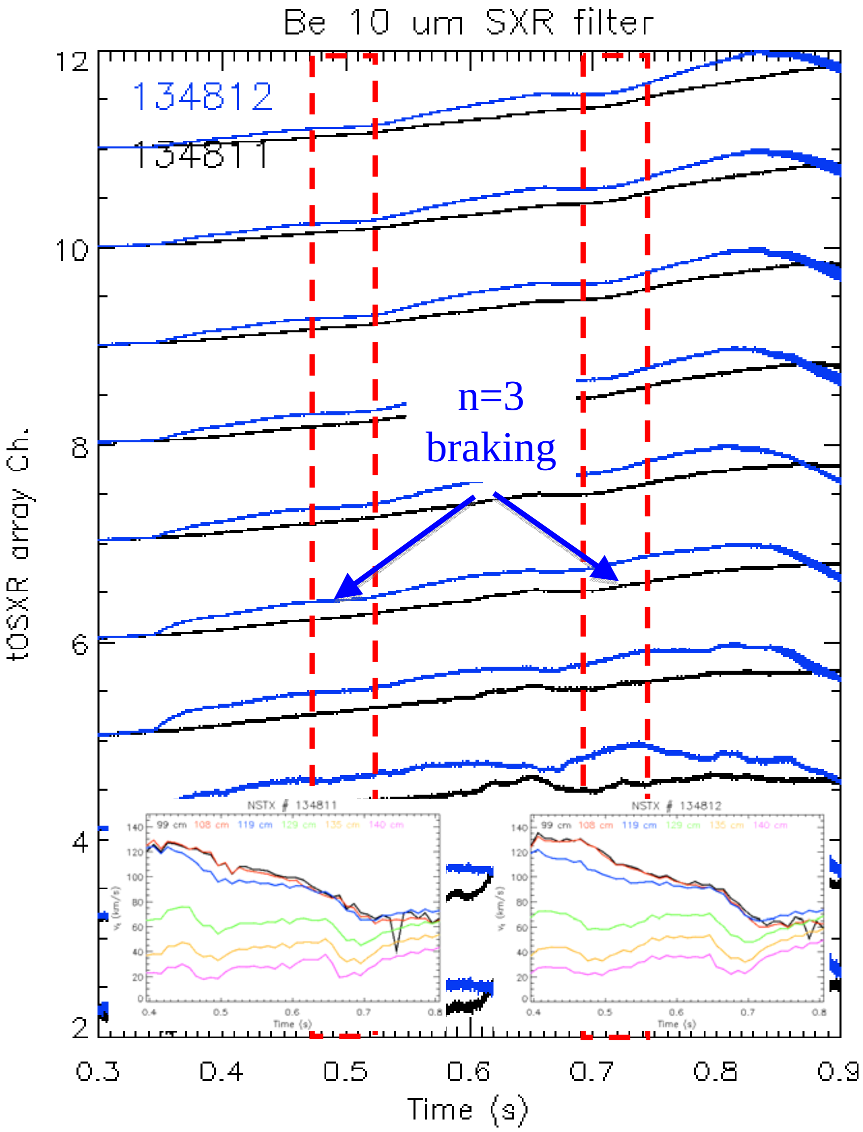
Magnetic Braking Appears to Slow Penetration of Impurities or Perhaps Even Expel Them





- No Ne puff on these discharges
- Are we changing/introducing $V^{pinch}>0$?
- Neon puff should enhance SNR!
- Can this effect at “mid-radius” be explained neo-classically?
- $D^{PS}(\Omega) \sim D^{PS}(1+M^*)^2$, *Romanelli, NF, 98.*
  $D^{PS}(\Omega) \sim D^{PS} f(\Omega)$, *Wong, PRL, 87.*
- Get D and V from *time-dependent* MIST modeling.

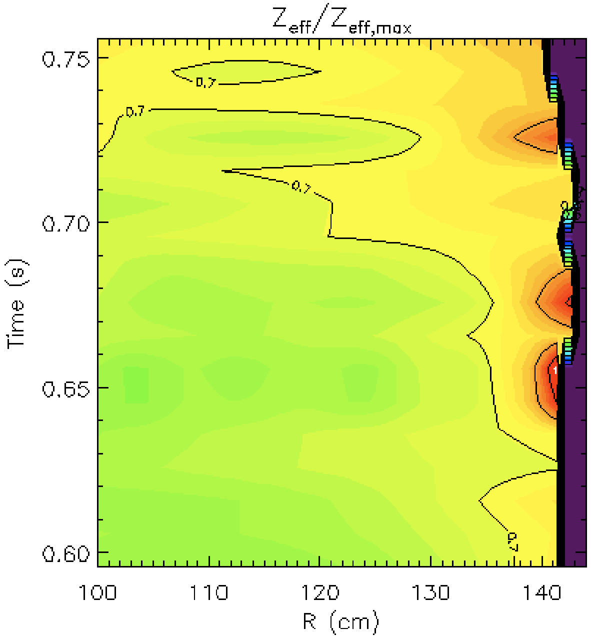
Same Result Observed with Ne Puff (With Increased SNR)



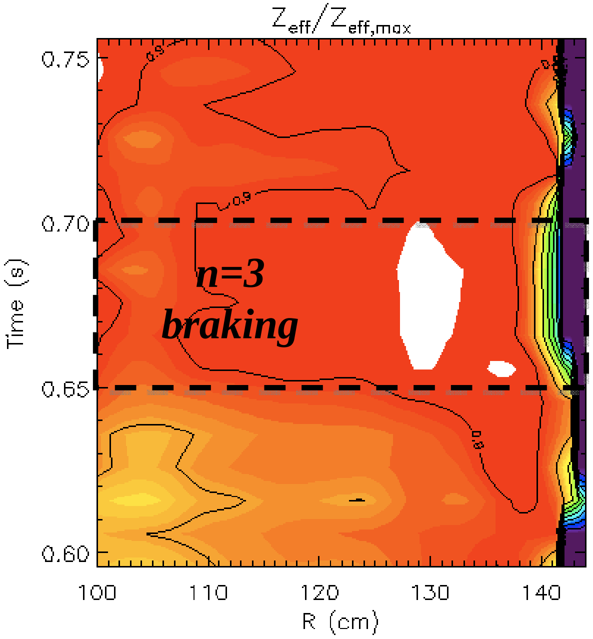
- The monotonically increase nature of the signals is changed when applied the n=3 magnetic braking.
- The medium- and high-energy signals from the tME-OSXR array (sensitive to fully-stripped Neon ions) observe similar behavior.
- Magnetic braking pulses produced similar time histories of v_ϕ profiles.
- Need of tomographic reconstruction to calculate neon SXR emissivity.
- Get D and V from *time-dependent* MIST modeling.
- Are we just reducing the transport or introducing a new V^{pinch} during the braking?

Z_{eff} Also Indicates Activity At Mid-Radius With n=3 Perturbation

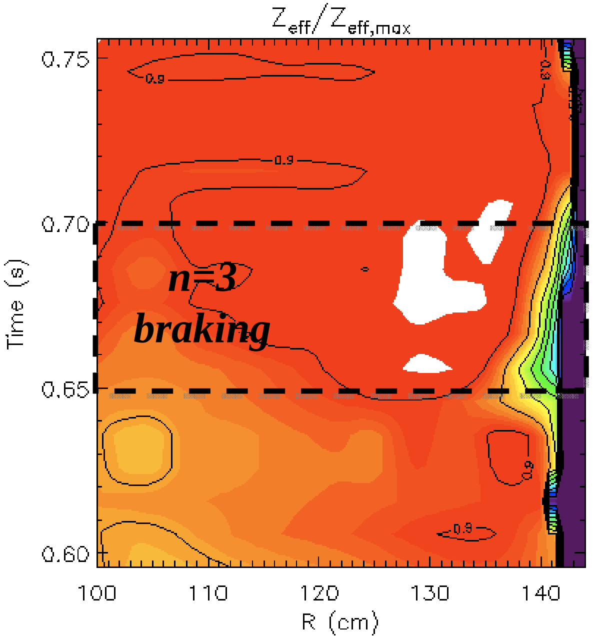
NSTX # 134810
(no braking, no neon)



NSTX # 134811
(braking pulse, no neon)



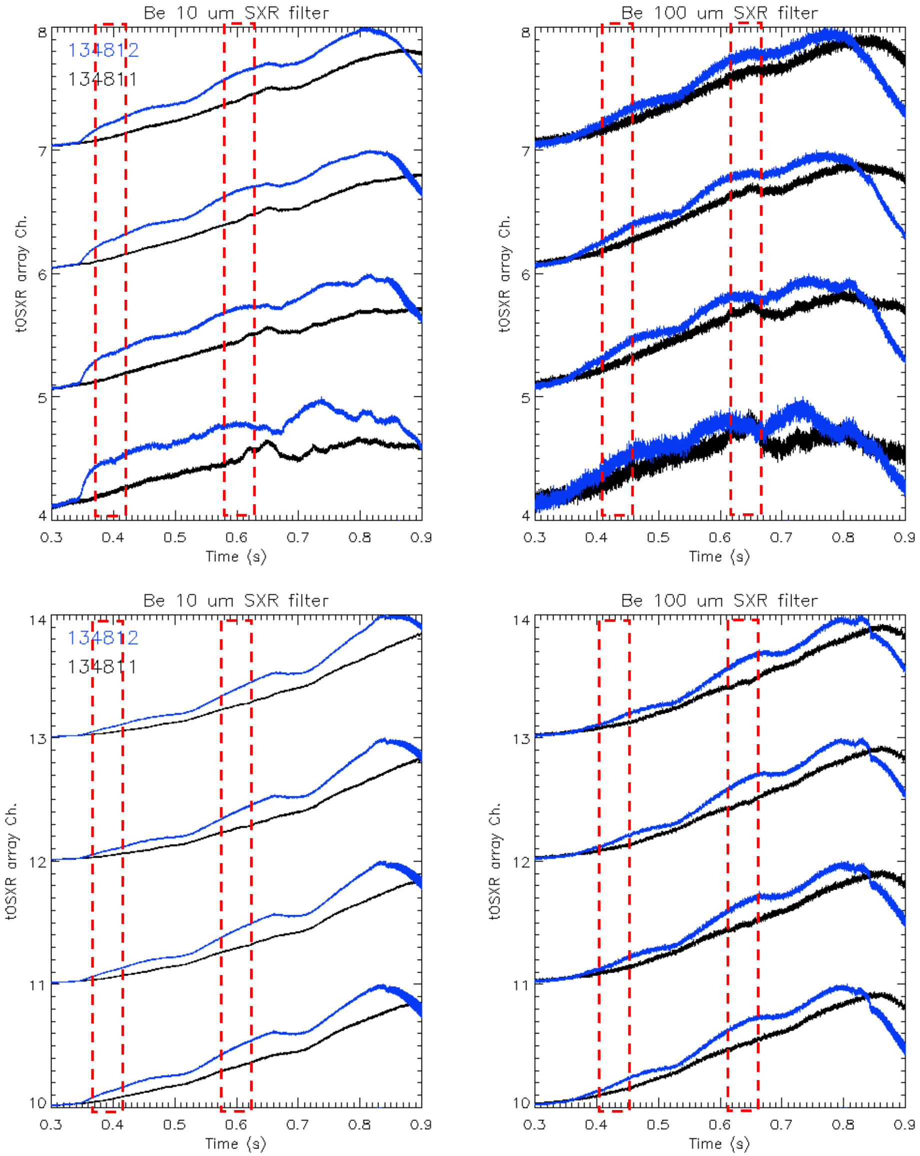
NSTX # 134812
(braking pulse, w/neon)



The Reduction of Impurity Penetration in the Core Appears Stronger Than The Edge, Compatible with Z_{eff} Observation

Edge/gradient regions

Gradient/core regions



- The signals filtered with the Be 10 and 100 μm foils are sensitive to He- + H-like, and fully stripped Neon, respectively.

- After each *n*=3 pulses the impurity pile-up seem to be faster.

- Get D and V from *time-dependent* MIST modeling.
  - D and V different with and without nRMP

- Need to do white plate calibration + tomographic reconstruction to provide localization.

- Need to invoke outward V^{pinch} to explain observation?