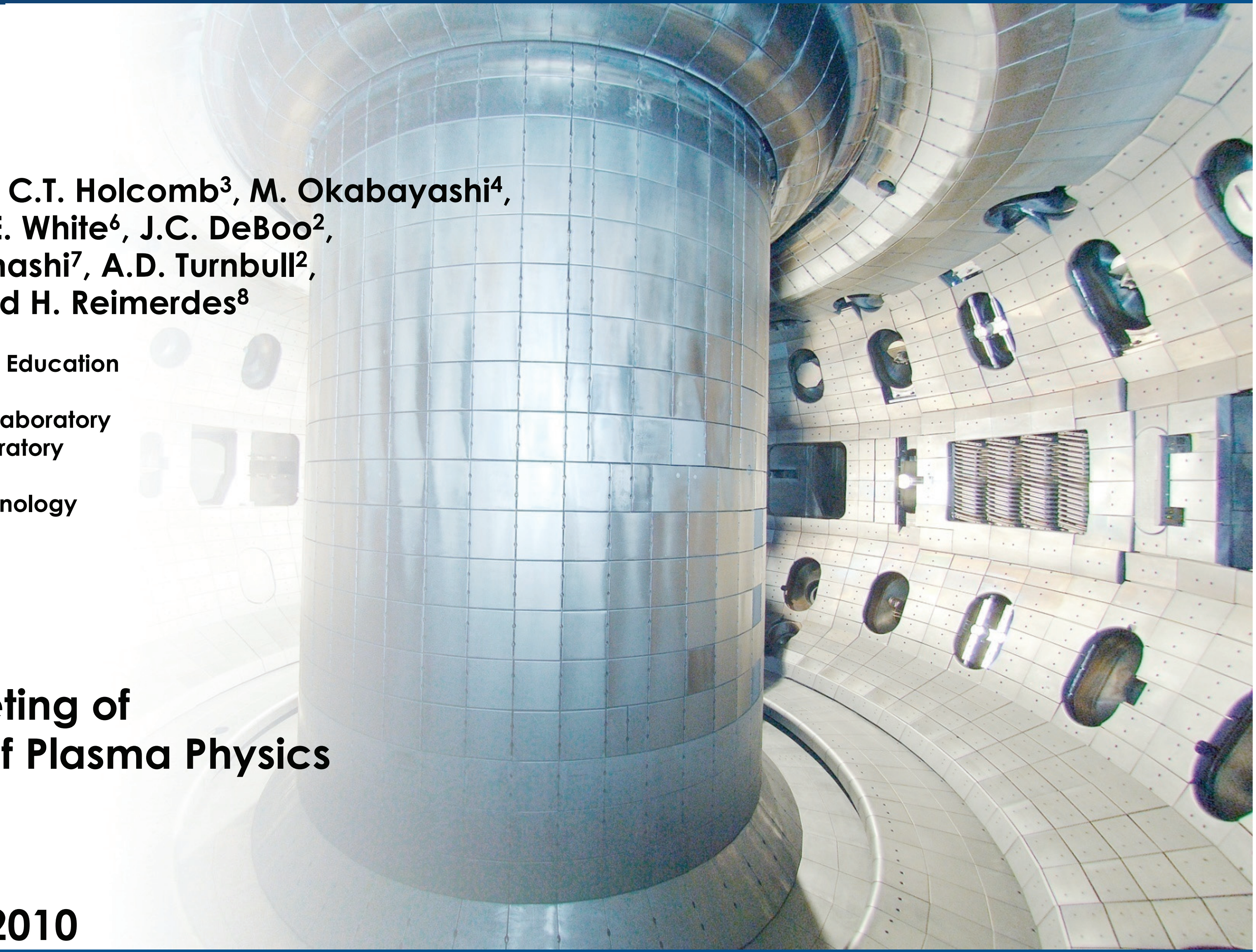
Impact of the Current Profile on Transport and Stability in High Noninductive Current Fraction DIII-D Discharges



by
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Presented at the
52nd Annual Meeting of
the APS Division of Plasma Physics
Chicago, Illinois

November 8-12, 2010

Goal: Find an Optimum q Profile and j_{EC} Configuration for High f_{NI} Operation

- **In high f_{NI} discharges, j_{BS} and q are nonlinearly coupled through the q dependence on transport**
- **ECCD has to be used to**
  - Provide part of the off-axis NI current
  - Produce a tearing stable equilibrium

$\left.\begin{array}{l} \\ \\ \end{array}\right\}$ *compatible?*

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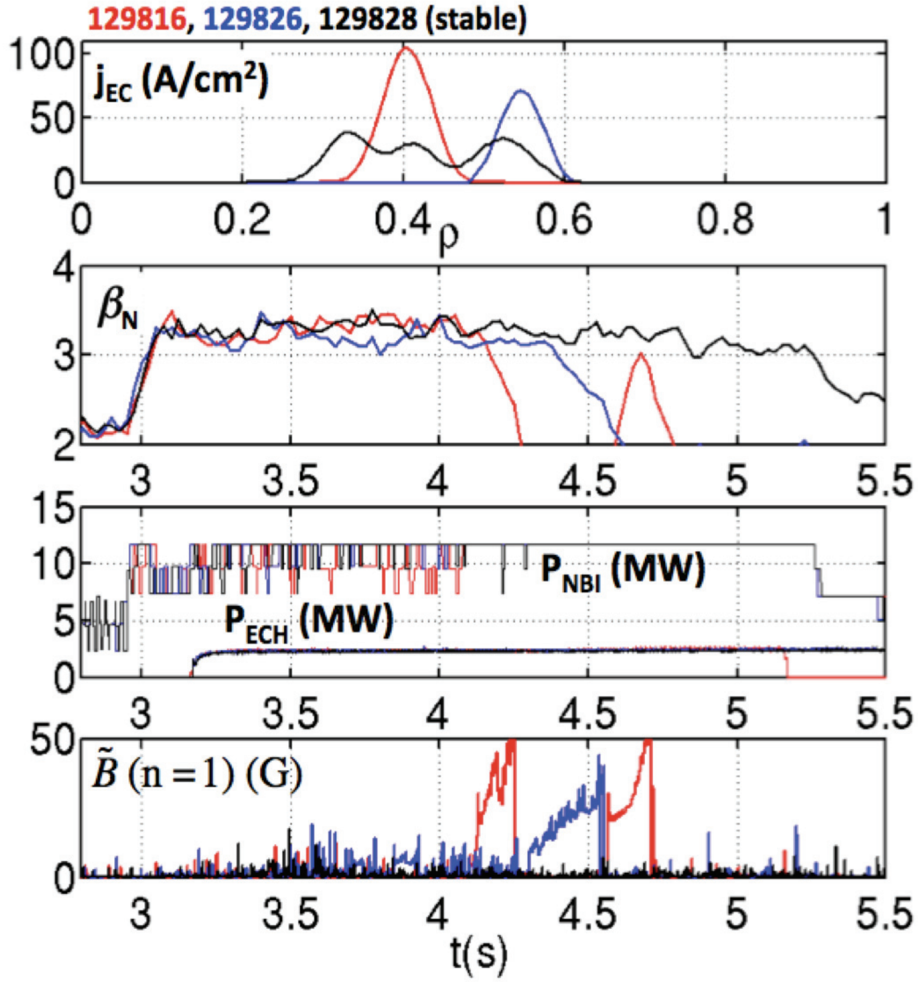
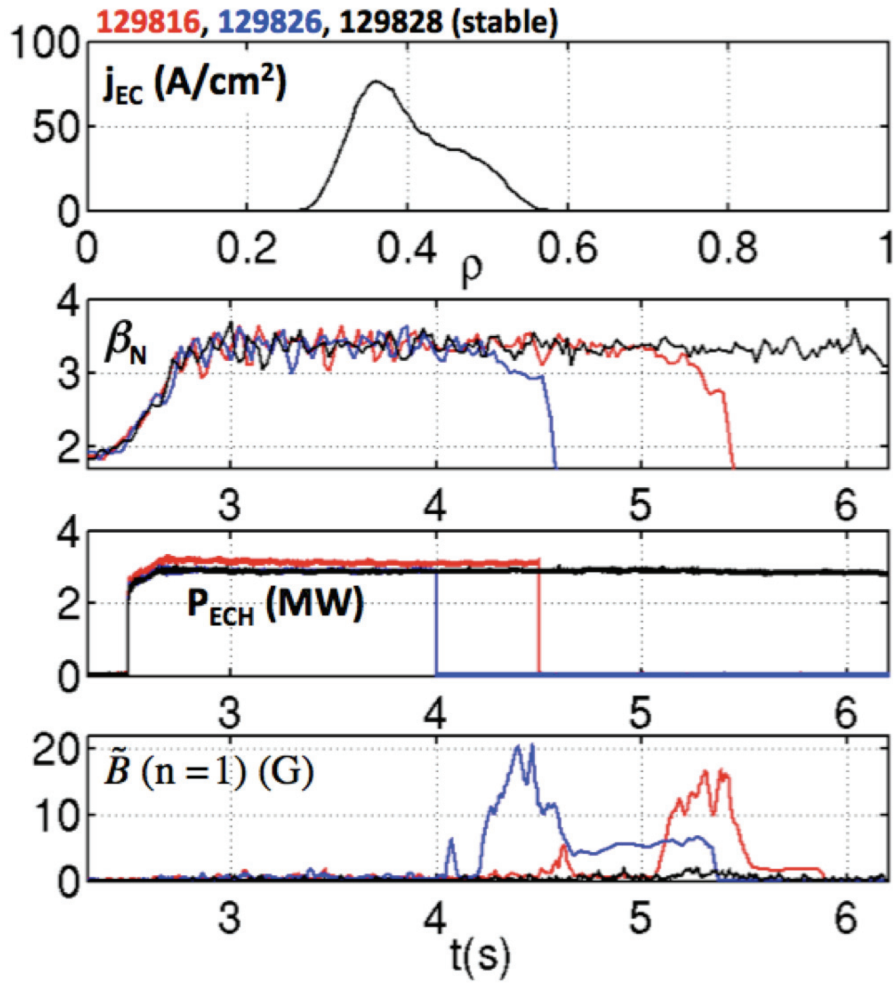
  } *compatible?*
- **Scans of q_{min},q_{95} with fixed j_{EC}**
  - Maximum f_{NI}
  - Study alignment of j_{NI} and J
  - Transport variation with q_{min}, q_{95}
- **Scans of ECCD configuration with fixed q profile for stability**

A Broad EC Deposition Helps to Avoid Tearing Modes that Limit the Duration of the Discharges

Broad vs narrow deposition



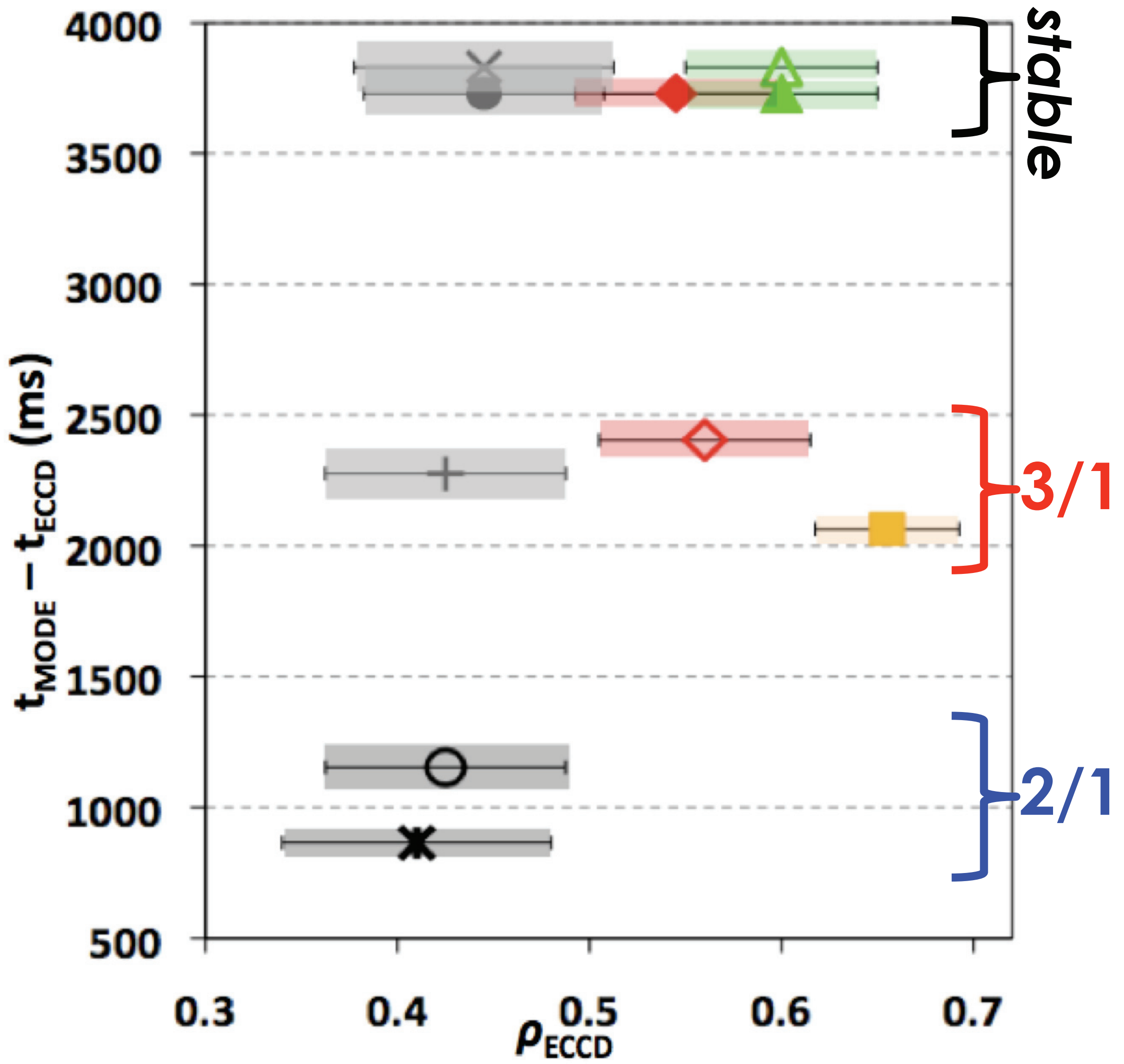
With vs without broad deposition



➔ Experiment to investigate broad deposition location

The Systematic Broad EC Deposition Scan Produces Both Stable and Unstable Discharges

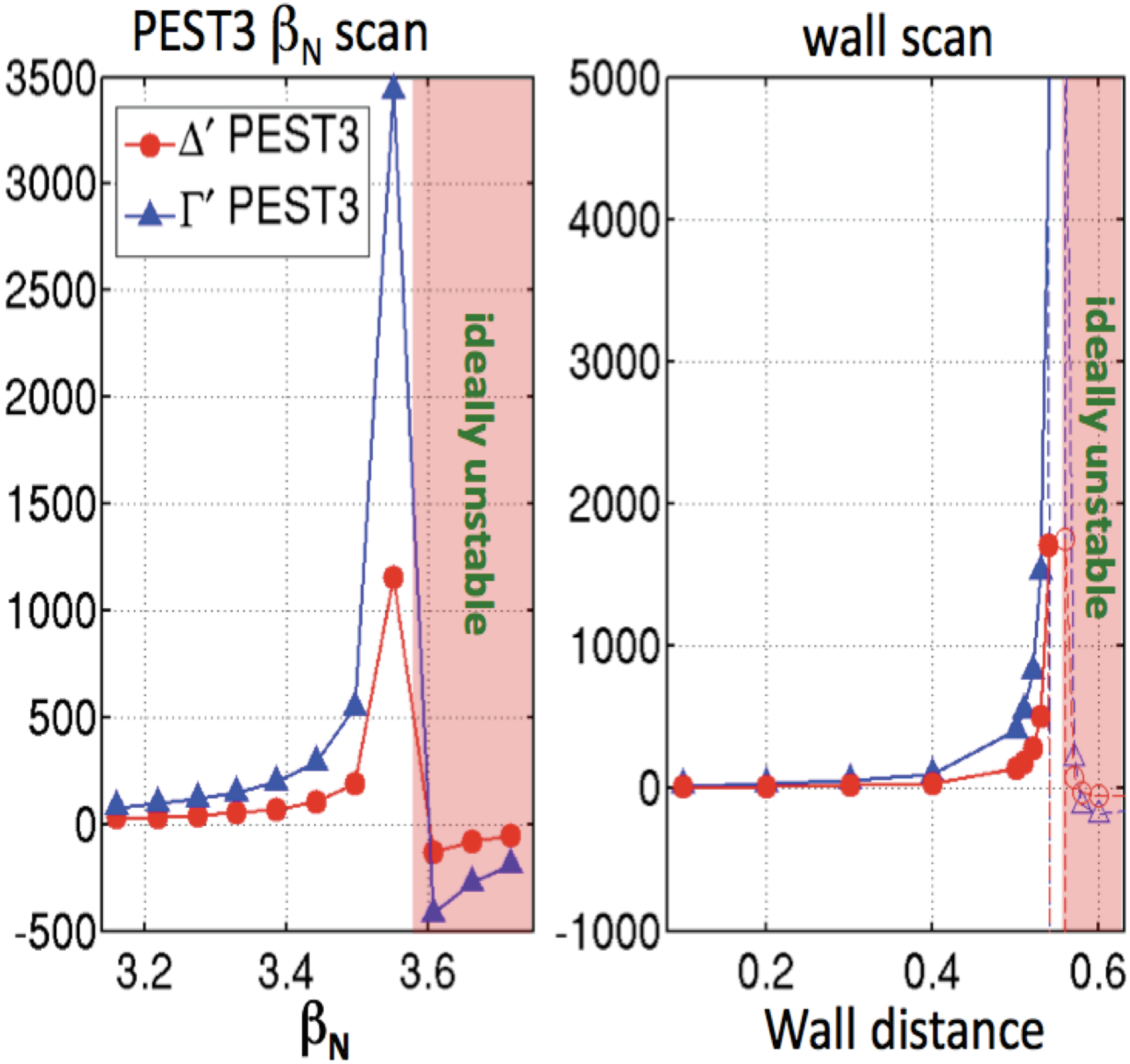
- **Several stable discharges**
  - Were obtained, even with
    - Outermost depositions
    - Low driven current
- Unstable discharges have both **2/1 and 3/1 modes**
- An explanation for the variability of the results is the **sensitivity of the tearing stability when close to the ideal limit**



Resistive Stability Calculations Confirm the Sensitivity of the Tearing Stability Close to the Ideal Limit

A new version of PEST3 is run on one experimental equilibrium

- **Ideal limit approached by**
  - Increasing the pressure (β_N)
  - Moving the wall away



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- **Ideal limit approached by**
  - Increasing the pressure (β_N)
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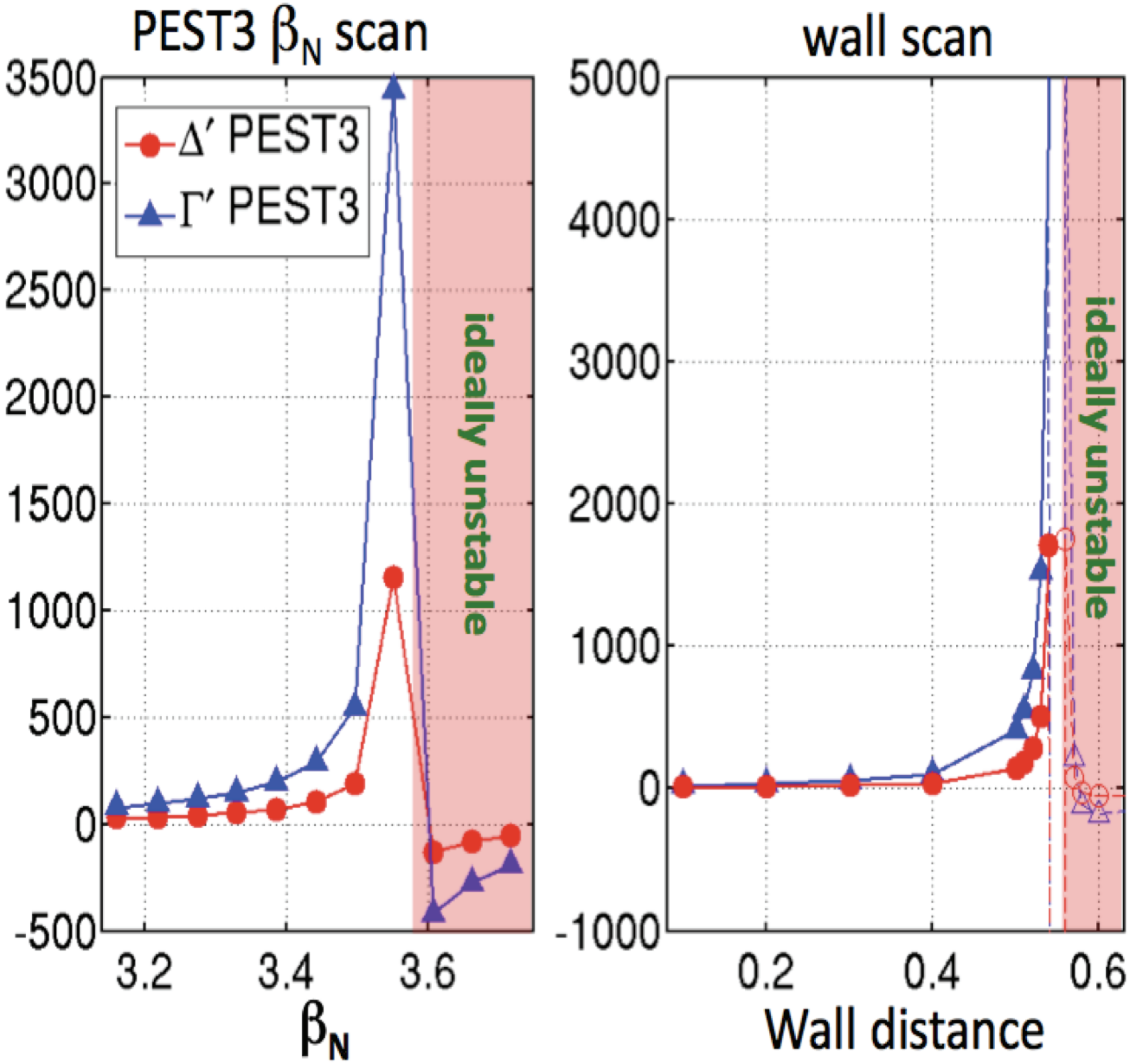
- **The classical tearing index Δ' increases sharply at the ideal stability boundary**
- **This new result** is similar to the previous study about the 2/1 triggered by q_{min} approaching 1 **(external vs internal mode)**



With Fixed EC Deposition, Scanned q_{min} and q_{95} at β_N=2.8 and Maximum P_{NBI}

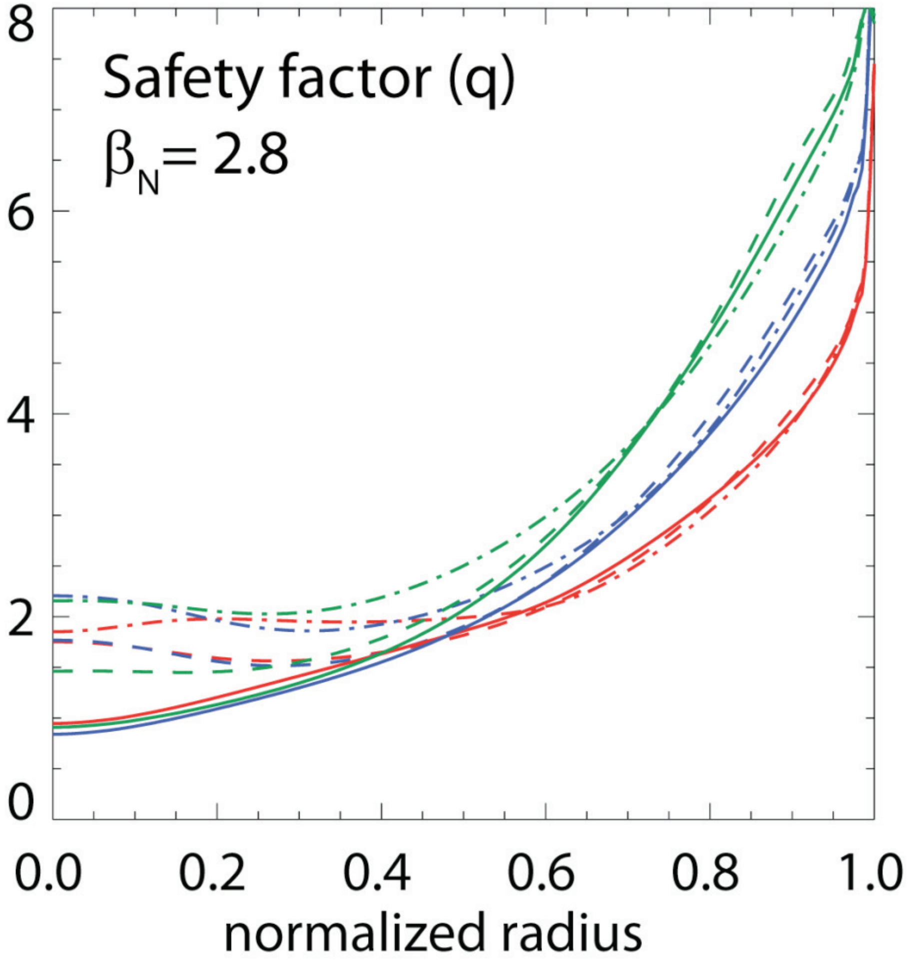
- **Goal: evaluate f_{BS}, f_{NI} and alignment of j_{BS} and j with varying q**

$$j_{BS} = f(q, \beta_N, f_p)$$

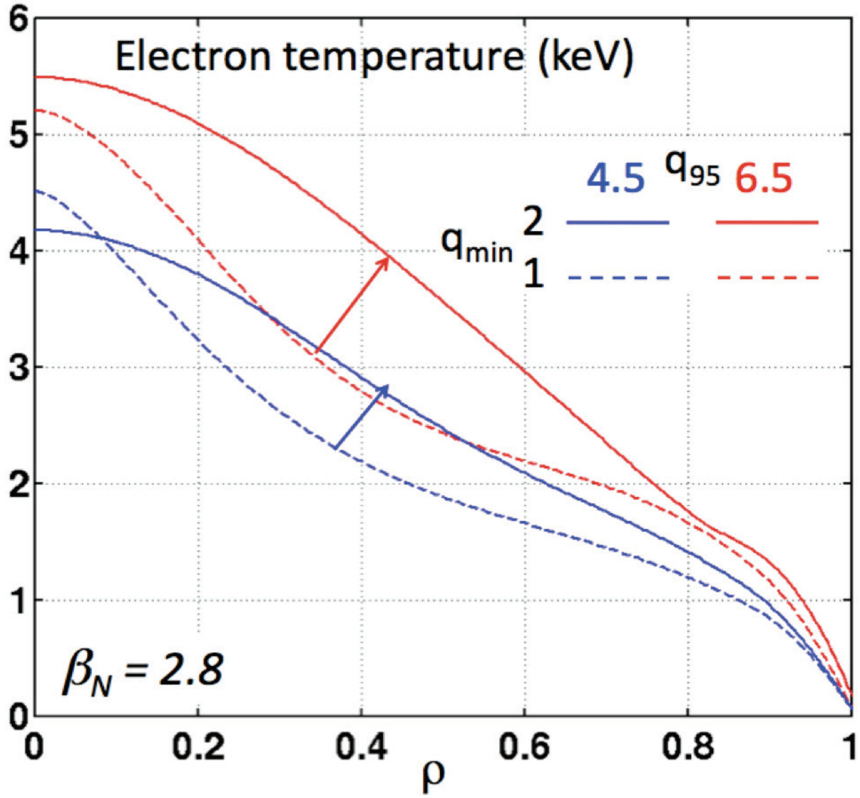
To understand how transport affects f_p

↓

- **Equilibrium and kinetic profiles averaged over phase of ~ constant β_N**
- **q_{min} ~ 1, 1.5, 2**
  q_{95} ~ 4.5, 5.5, 6.8
  β_N=2.8 and maximum β_N



The Profiles Broaden at High q_{min} and High-β_N



- **At the maximum β_N, all the profiles broaden**
- **They are roughly independent of q_{min}**

The density shows the same trend

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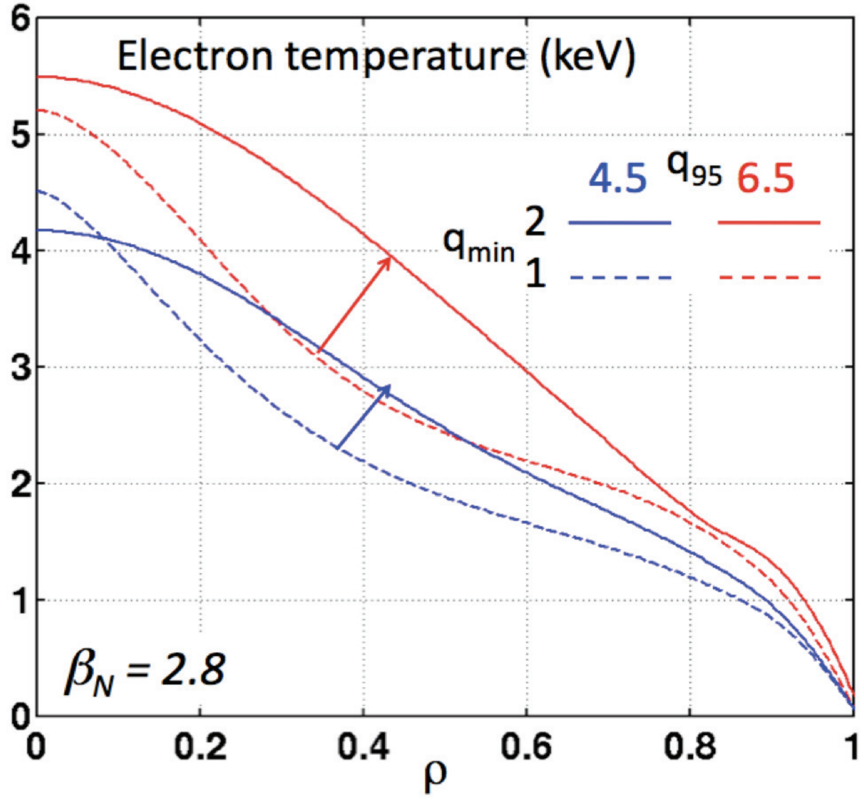
$f_p = ƒ(q\ ,\ \beta_N)$: f_p ↘ with q_{min} ↗



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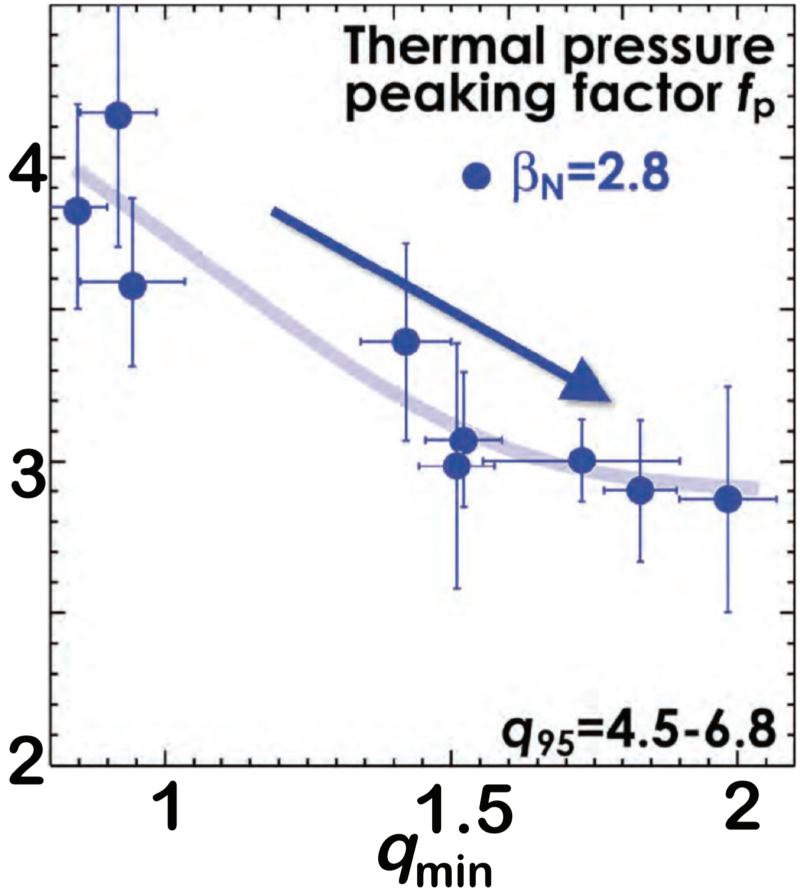

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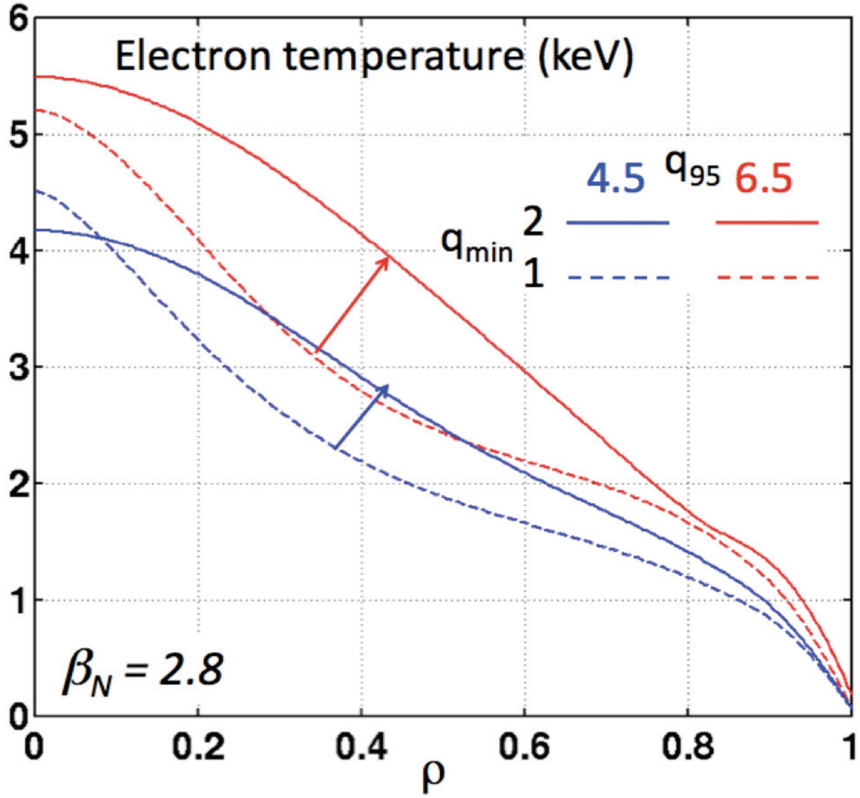

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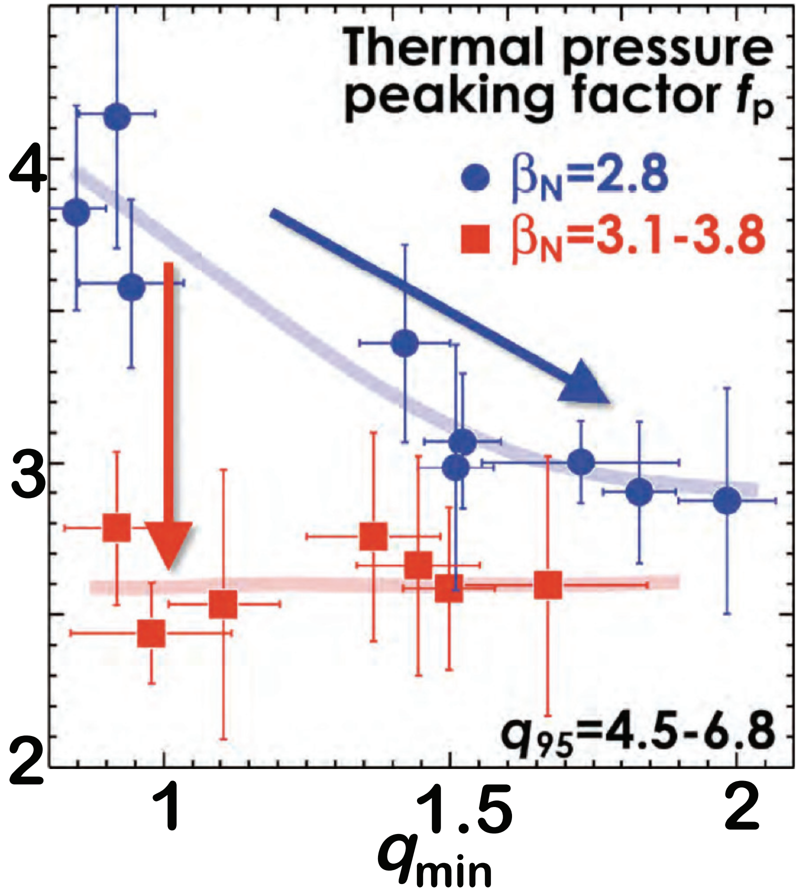

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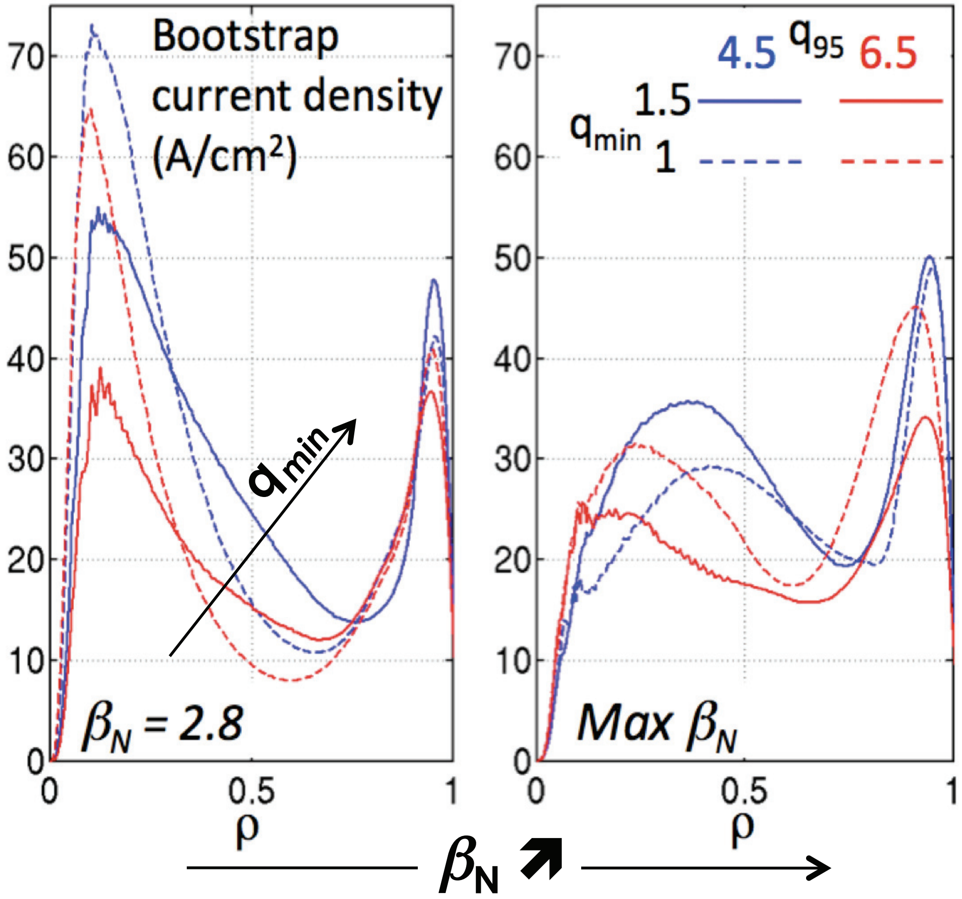
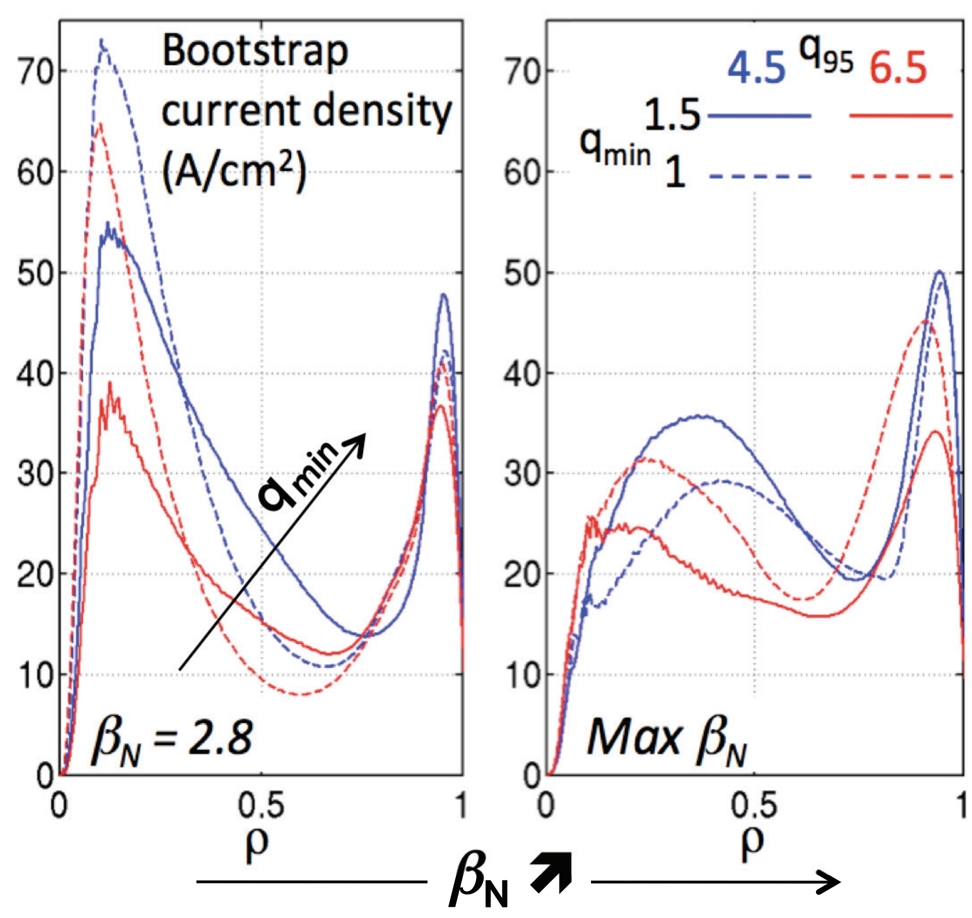
The Changes in the Profiles Impact the j_{BS} Alignment and the Bootstrap Fraction



- j_{BS} broadens with increasing β_N
- At higher q_{min}, it looses the central peak

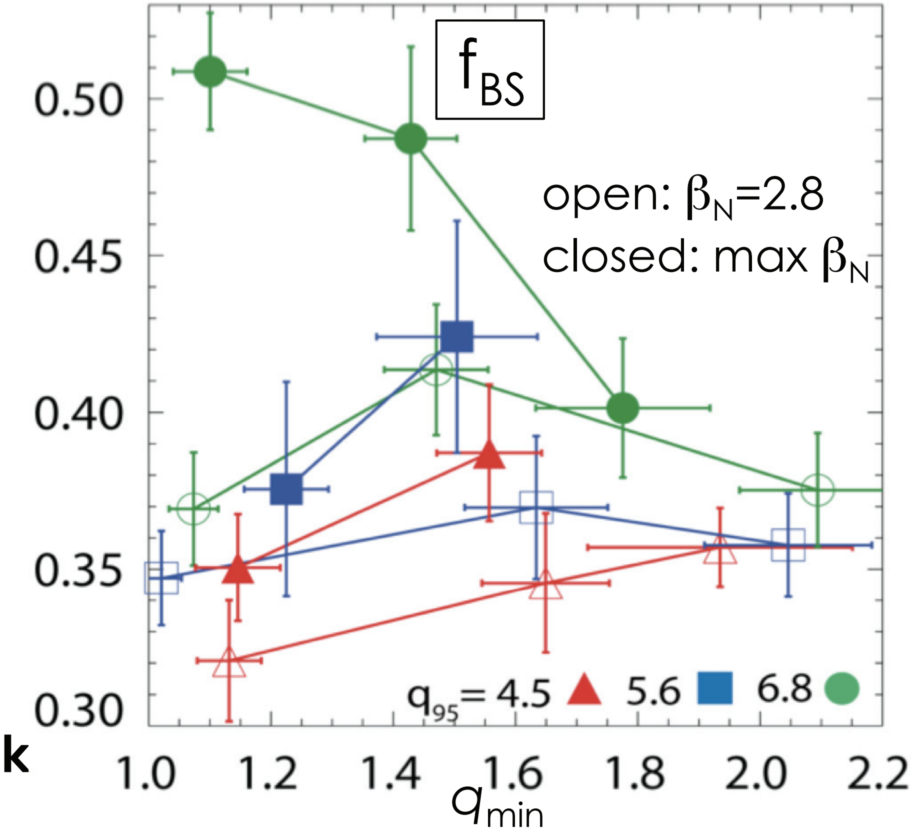
The Changes in the Profiles Impact the j_{BS} Alignment and the Bootstrap Fraction



$f_{BS} = f(q\ ,\ \beta_N,\ f_p)$:

f_{BS} ↗ with q_{95} and β_N

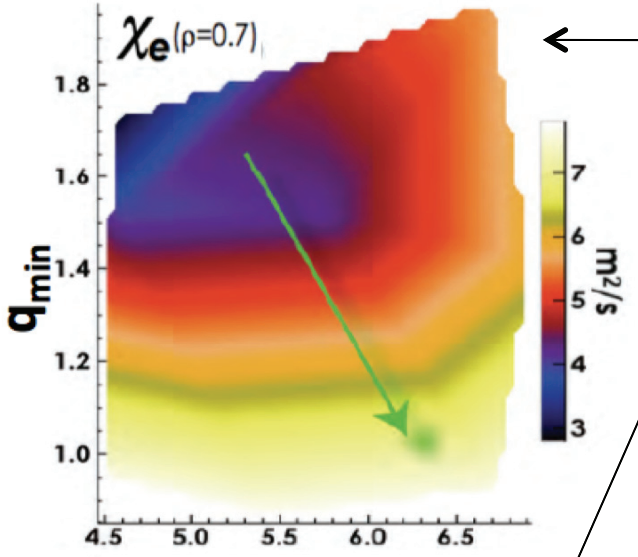
f_{BS} does not increase with q_{min}

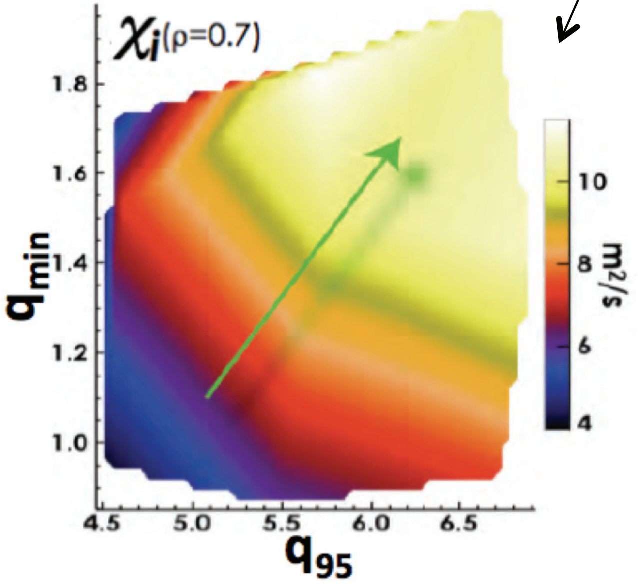


- j_{BS} broadens with increasing β_N
- At higher q_{min}, it looses the central peak

Cause of the Profile Changes: Electron and Ion Transport Scale Differently with q

- χ_e decreases with increasing q_{min}
- χ_i increases with increasing q_{min} and q_{95}





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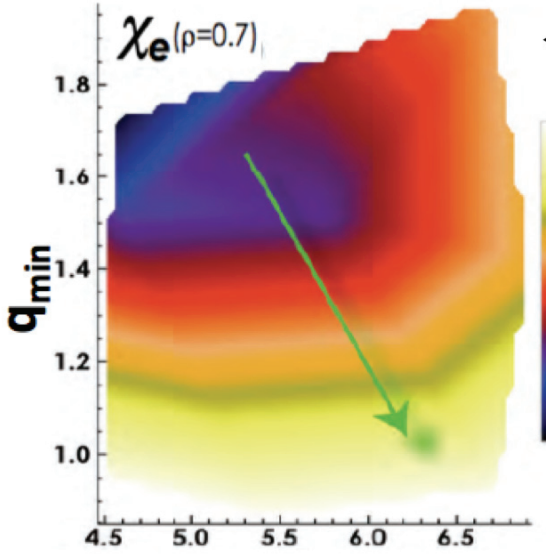
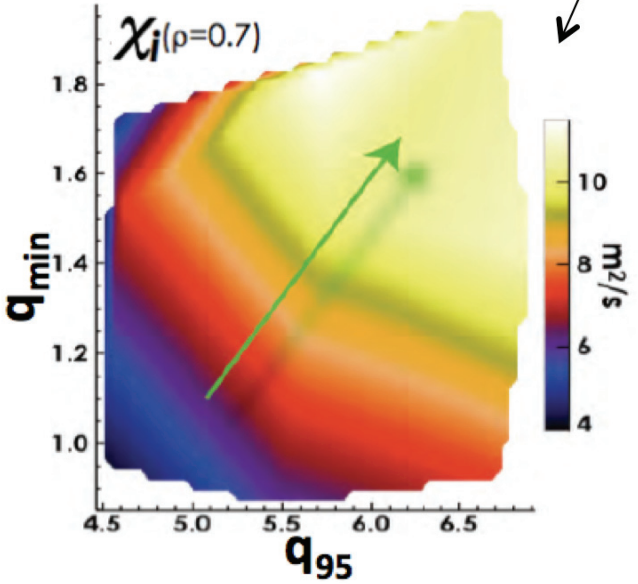
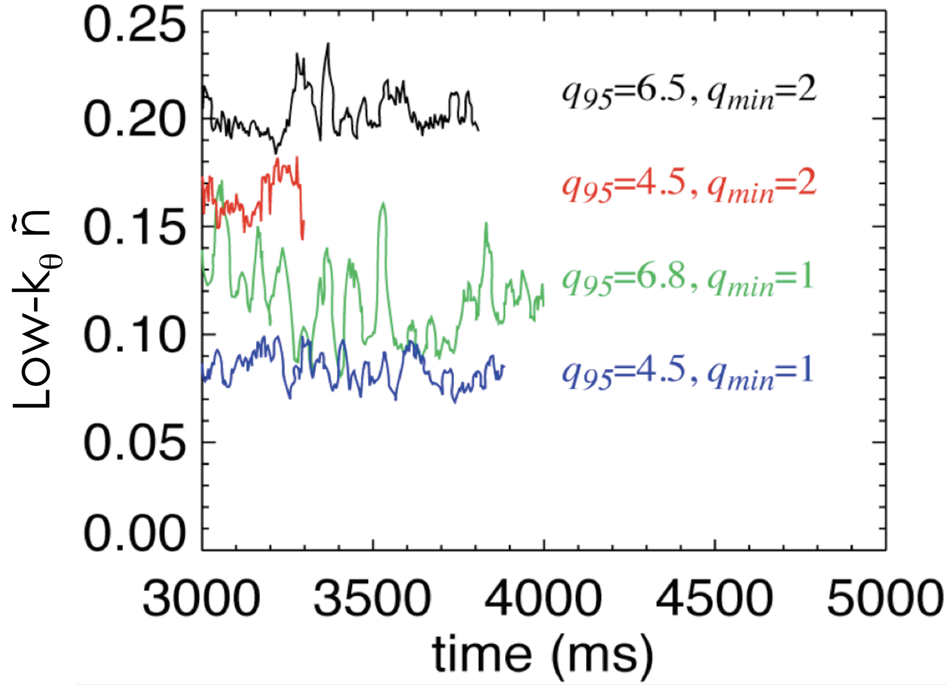




- χ_e **decreases with increasing** q_{min}
- χ_i **increases with increasing** q_{min} **and** q_{95}

<u>Experiment</u> - FIR density fluctuations:

Energy in the low-k_θ **range (ITG) increases with** q_{95} **and** q_{min} ✔



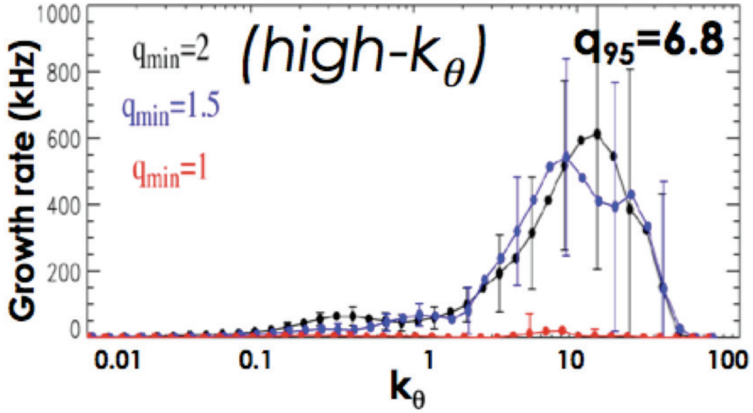
Modelling: Can a Linear Code Provide Insight into the Transport Physics of these Discharges?

TGLF results:

high-k_θ:

γ ↗ with q_{min} ✗

(χ_e ↘ with q_{min})



high-k_θ:

γ ↘ with q_{95} ✗

(χ_e ~constant with q_{95})

C. Holcomb UP9 00041 (Thursday PM)

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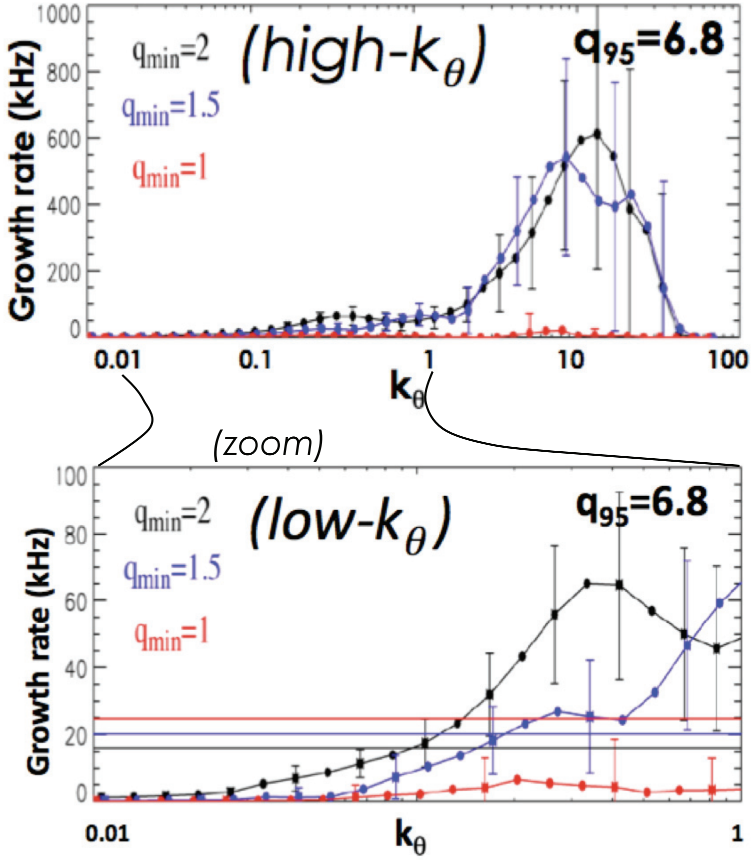


high-k_θ:
γ ↗ with q_{min} ✗

(χ_e ↘ with q_{min})

high-k_θ:
γ ↘ with q_{95} ✗

(χ_e ~constant with q_{95})

low-k_θ:
γ ↗ with q_{min} ✔

(χ_i ↗ with q_{min})

low-k_θ:
γ ↘ with q_{95} ✗

(χ_i ↗ with q_{95})

- **The linear growth rates do not reproduce the experimental trends**

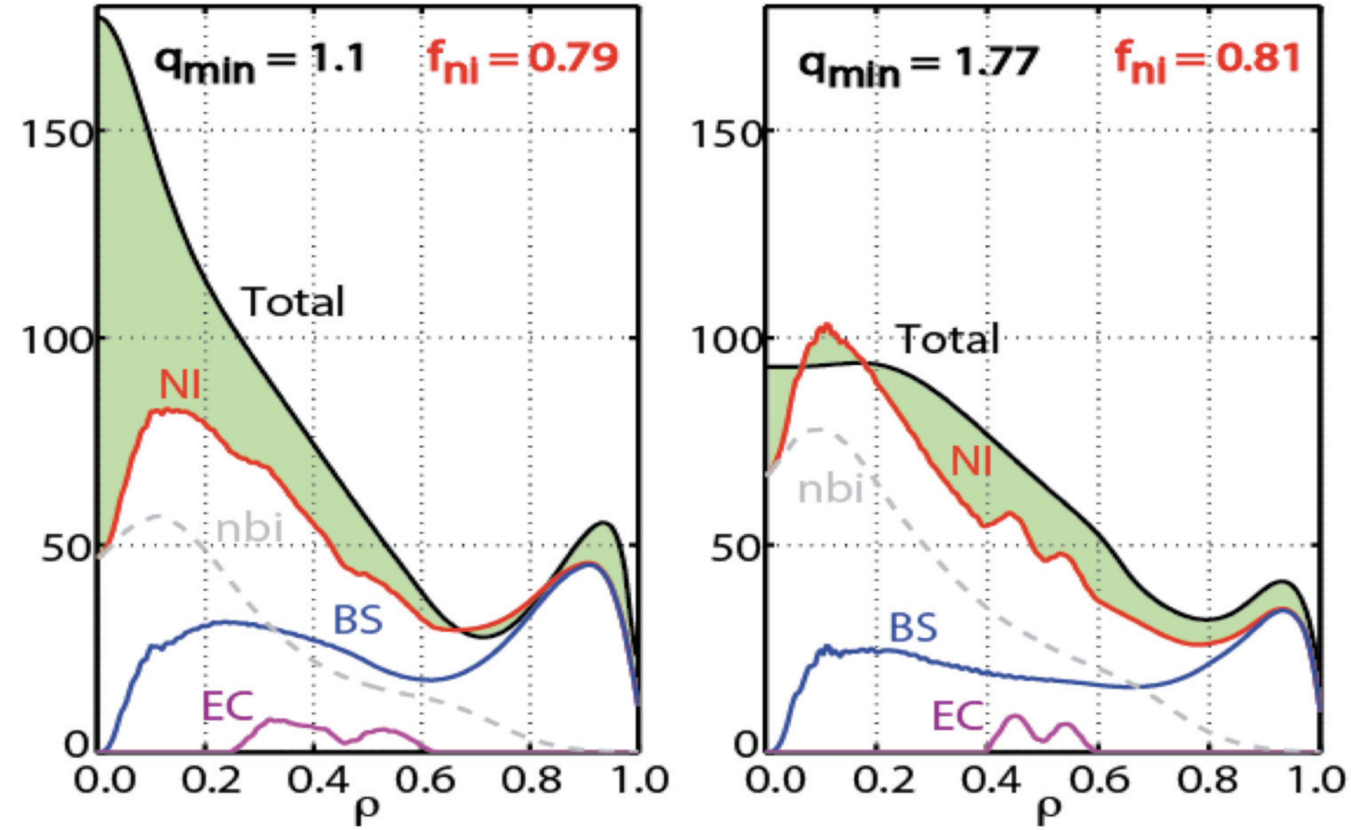
Nonlinear runs are needed : test whether GYRO can reproduce the experiment

C. Holcomb UP9 00041 (Thursday PM)

Highest f_{NI} at Max q_{95}, and the Shape of j_{NI} Best Matches j at q_{min} ≥1.5

- **The j_{EC} position is good for stability and NI current drive**
- **j_{BS} does not change significantly with q_{min}**

Components of the Current Density (A/cm^2) at $q_{95} = 6.8$ and max β_N



- **Need additional NI current off axis — at ρ ≈ 0.2 – 0.8 → off-axis beam line**

Summary and Conclusions

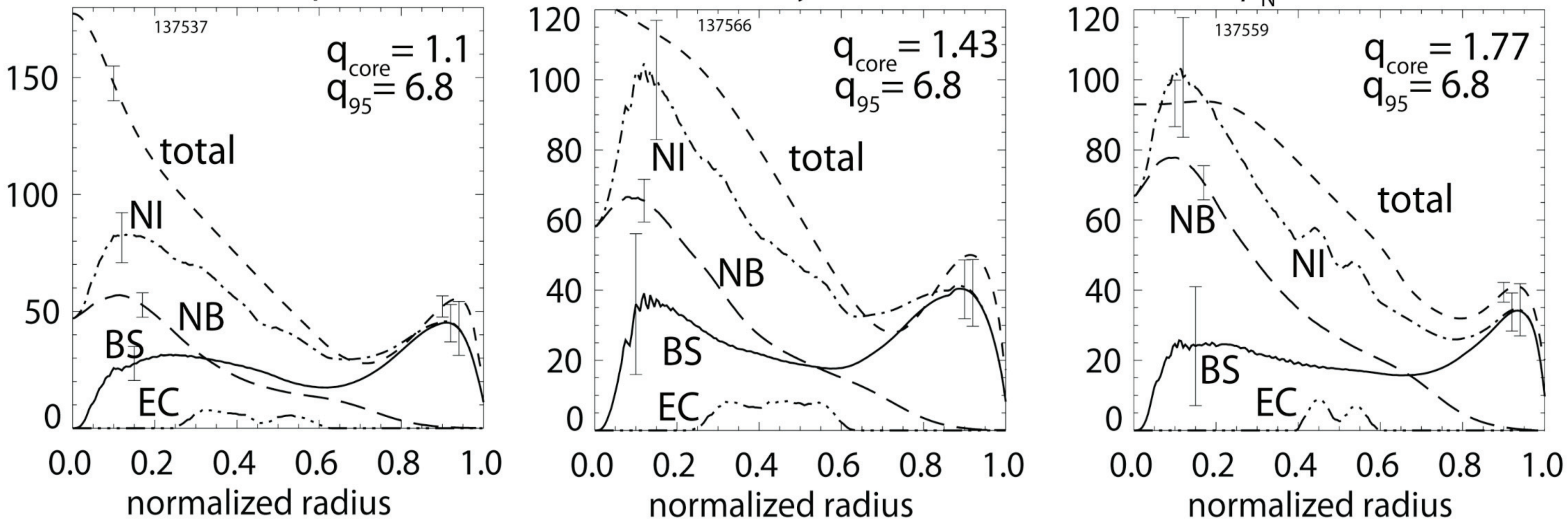
1. With the available sources, the **highest f_{NI} is obtained at q_{95}~6.5 and the the best alignment at $q_{min} \geq 1.5$**

2. An off-axis **broad EC deposition** is better suited for stability and the needed CD

3. The **electron and ion transport scale differently** with q in the experiment, and a **linear model is not sufficient** to describe the results

4. Theoretical work confirms that the **variability in the presence of tearing modes** is likely due to the proximity to the ideal stability limit

Components of the current density (A/cm^2) at the maximum β_N



To Achieve f_{NI} = 1at $q_{95} \approx 5$, Significantly Increased J_{NI} Located Off Axis is Required