Improved Performance in DIII–D Hybrid Discharges with a Dominant 4/3 Tearing Mode

by

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in collaboration with

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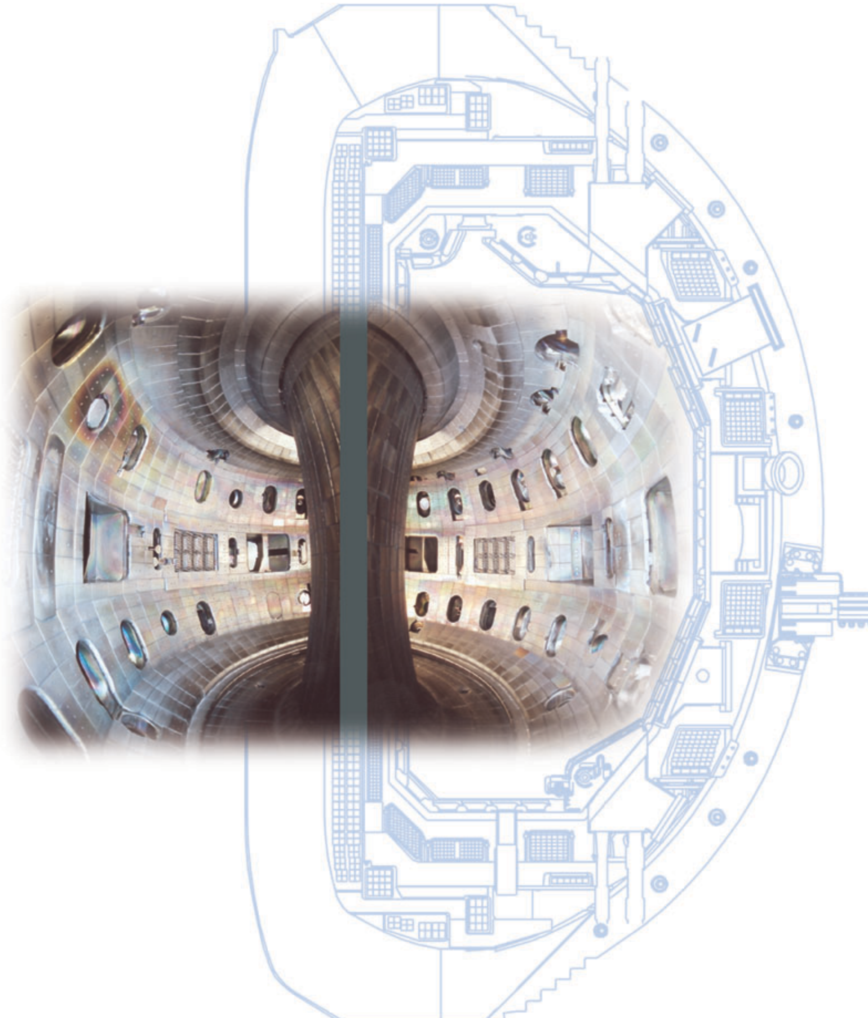

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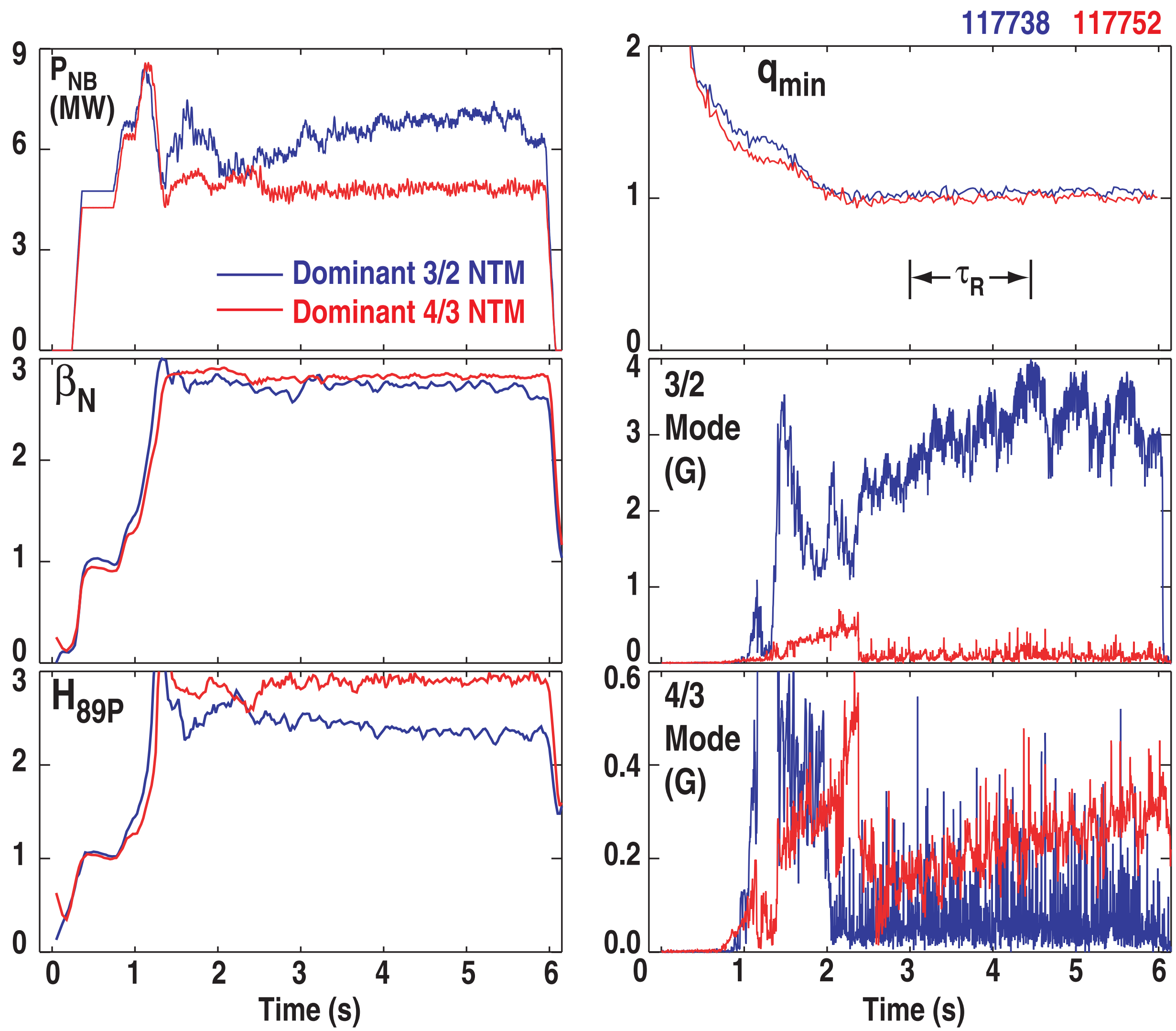
Introduction

- **Hybrid regime in DIII–D refers to long duration, high performance discharges achieved by**
  – Preheating during current ramp to produce a safety factor profile with low central shear and $q > 1$
  – Quickly raising beta to near stability limit so that a neoclassical tearing mode (NTM) is triggered before sawteeth begin

- **Usually a small $m/n = 3/2$ NTM develops which (for $q_{95} > 4$) maintains $q > 1$ indefinitely and inhibits sawteeth**

- **This talk focuses on cases where an $m/n = 4/3$ NTM develops spontaneously instead, resulting in improved energy confinement albeit with sawteeth**

Hybrid Discharges Can Develop Either Dominant 4/3 NTM or Dominant 3/2 NTM, Depending on Initial Conditions



- 4/3 and 3/2 modes compete for same free energy source, so they don't usually co-exist
- Discharge with dominant 4/3 NTM has ≈ 25% higher H_{89P}-Factor
- Dominant 4/3 NTM discharge also has $q_{min} < 1$ and sawteeth

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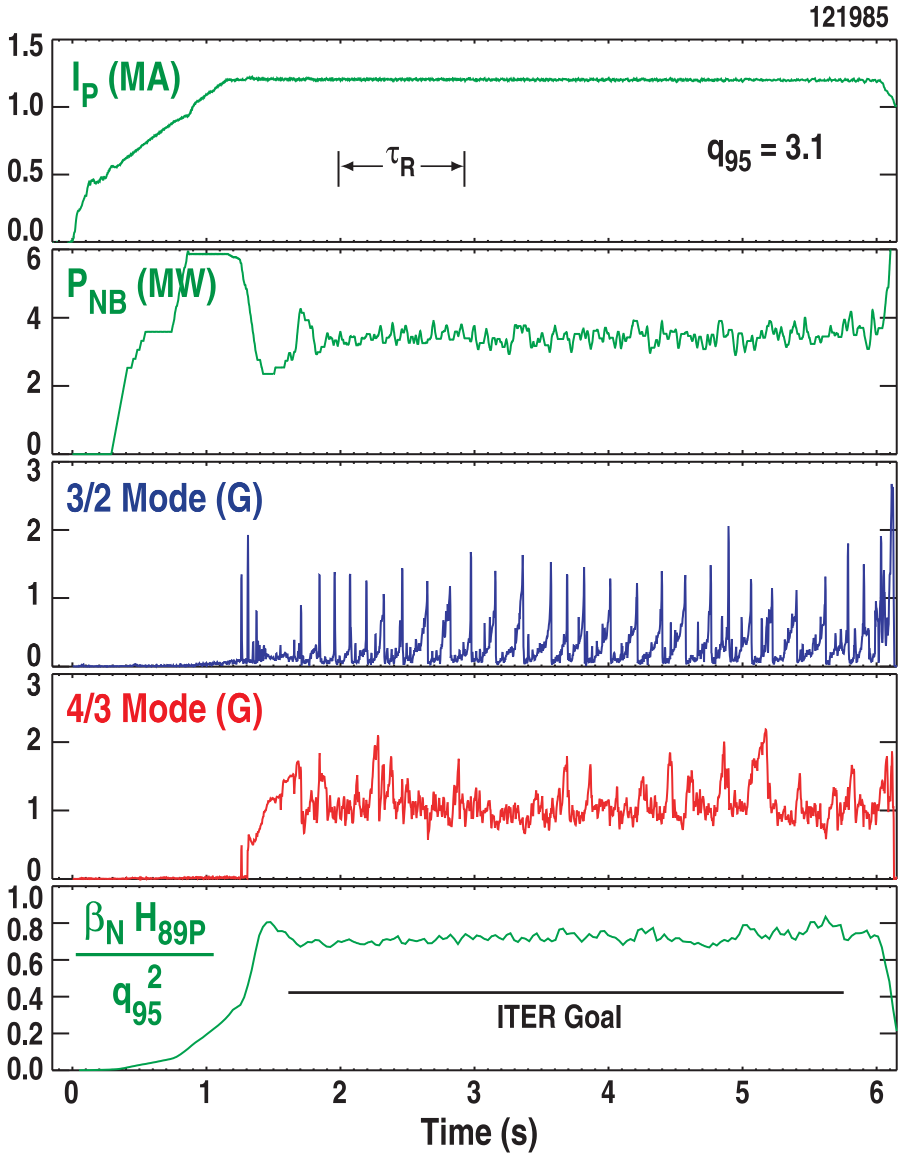
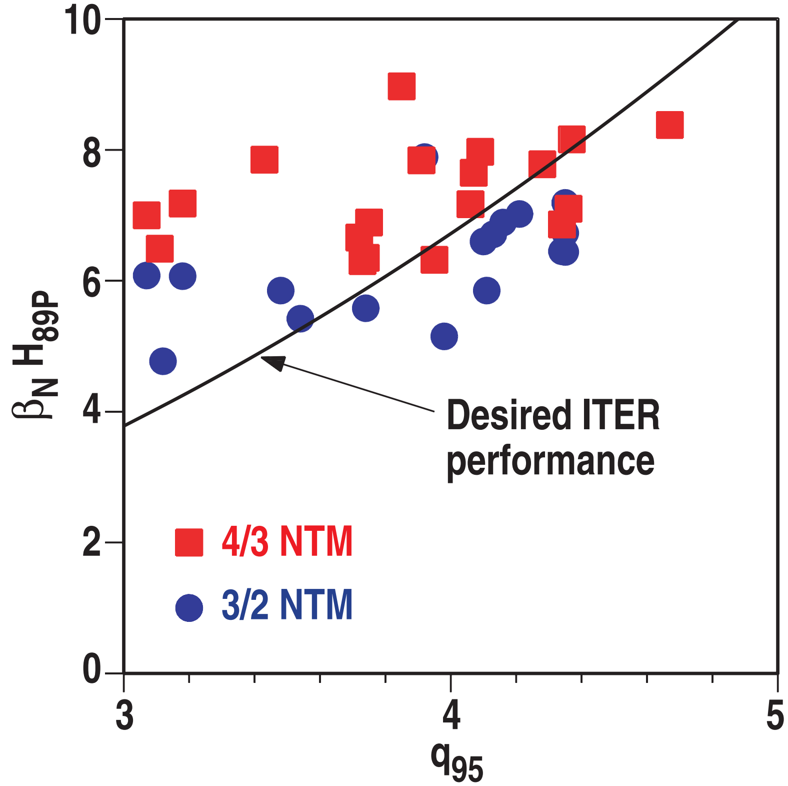
Hybrid Discharges with Dominant 4/3 NTM Achieved Performance 70% Above Desired ITER Value for $\tau_{dur} = 4.8\tau_R$





- Hybrid discharges equal or exceed ITER baseline performance over a large range of q_{95}, especially when 4/3 NTM is dominant

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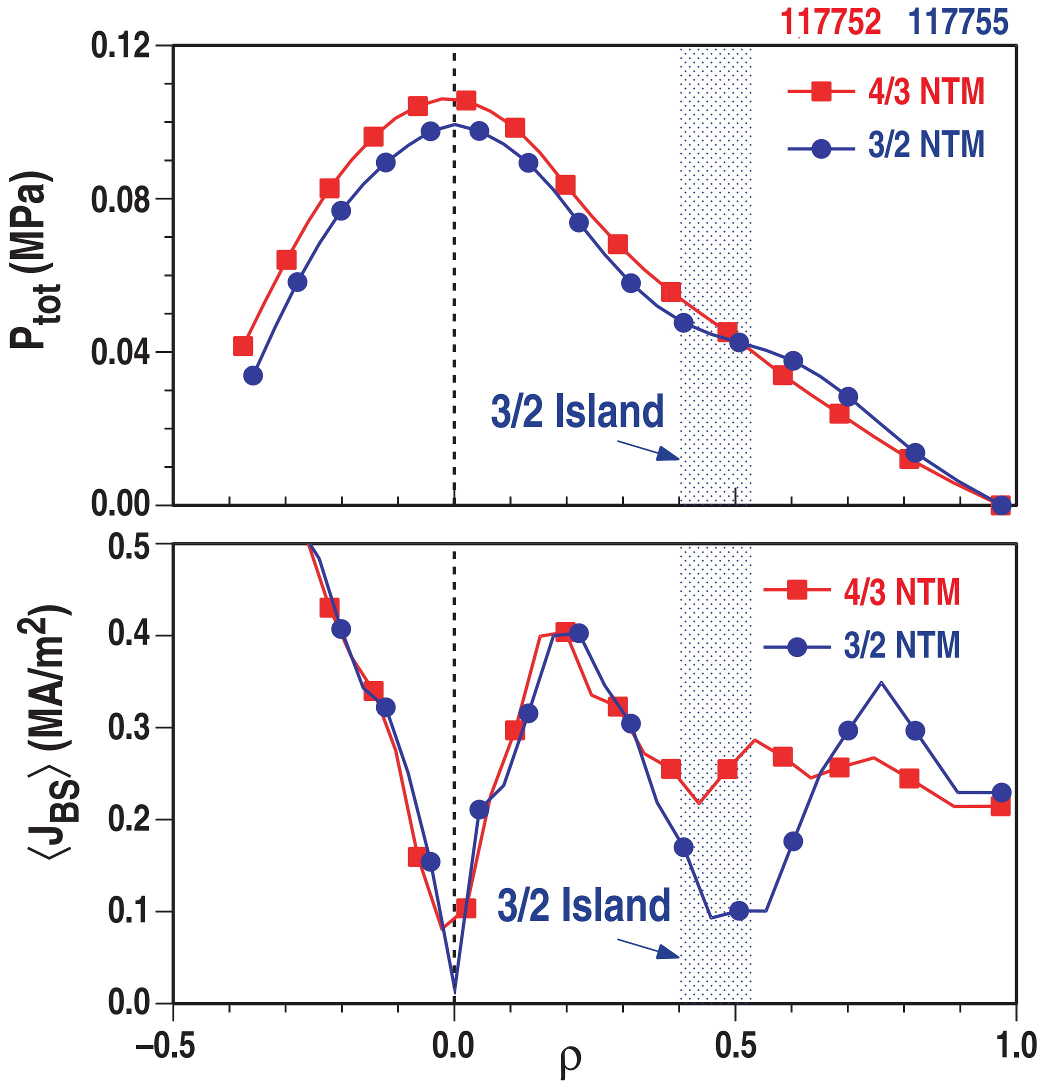
One Explanation for Lower Confinement in 3/2 NTM Hybrids is Flattening of Pressure Profile Near q = 1.5 Surface



- **Pressure profile and pressure-driven current densities are directly determined from MSE data**

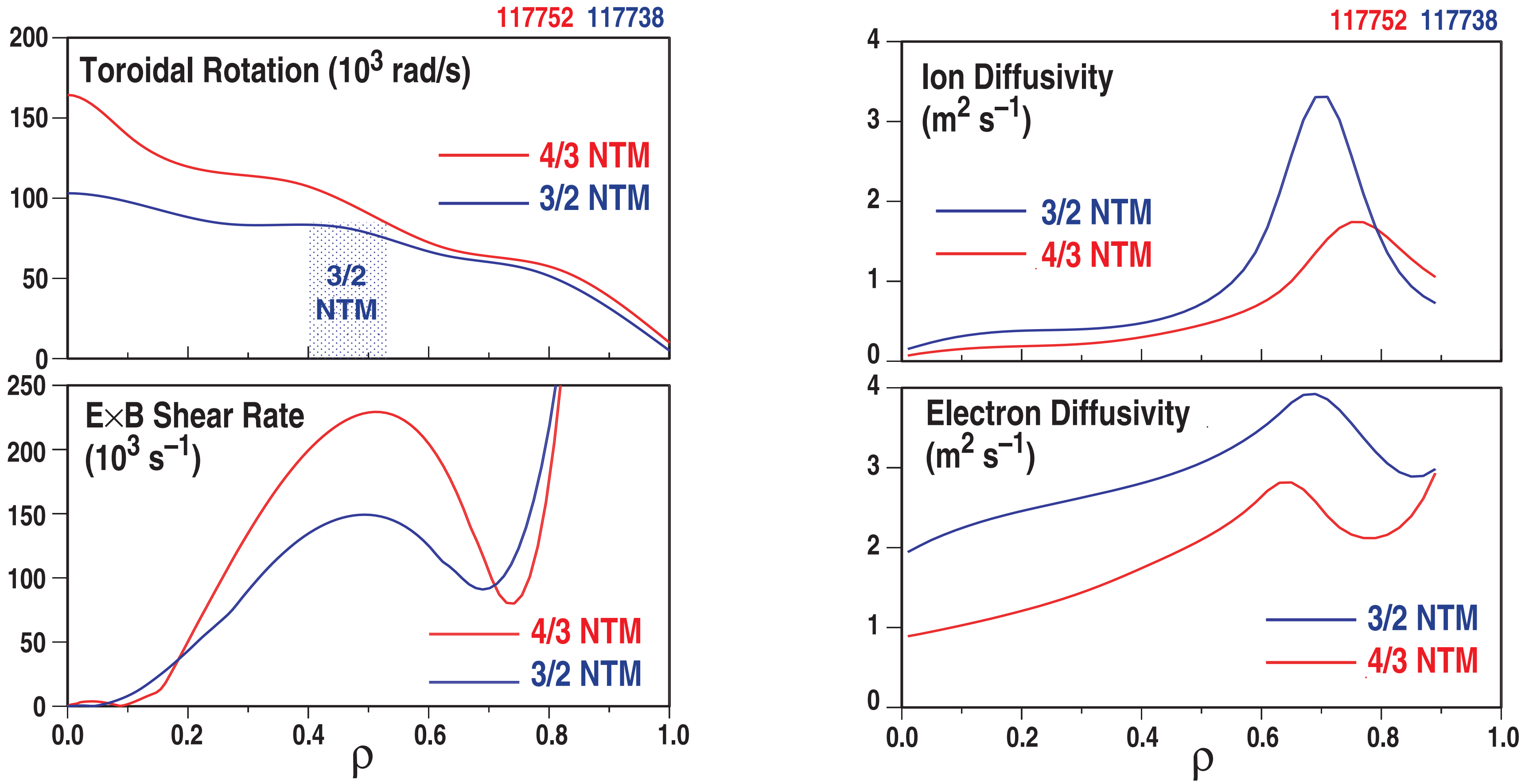
  C.C. Petty et al., Plasma Phys. Control. Fusion (2005) p. 1077

- **First direct measurement of "missing" bootstrap current near NTM island location**

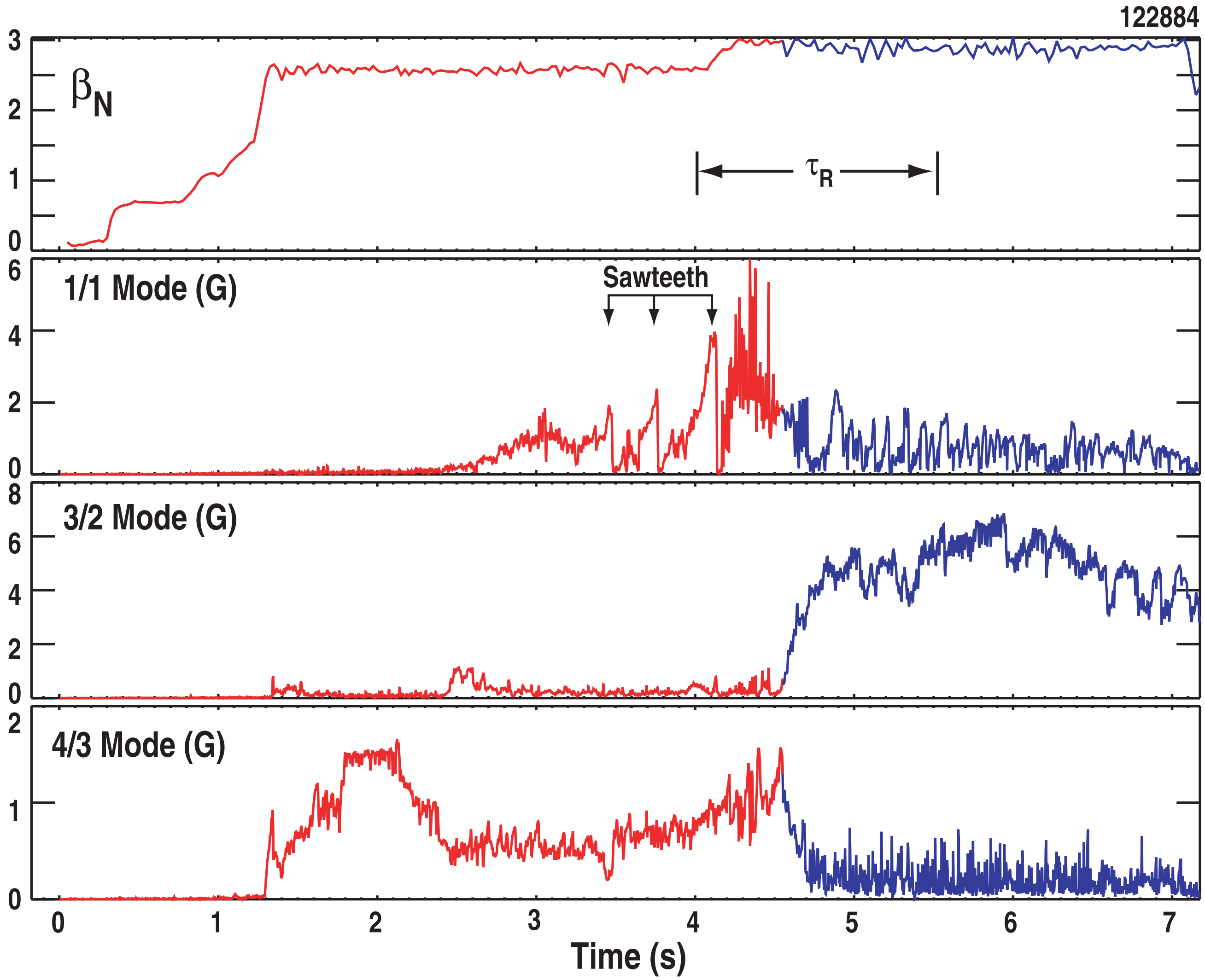
- **Chang-Callen belt model gives ≈ 8% loss of confinement due to 3/2 NTM (≈ 2% due to 4/3 NTM)**

Second Explanation is Higher Toroidal Rotation in 4/3 NTM Hybrids Yields More E×B Shear and Thus Lower Transport

- 3/2 mode couples to vessel wall as well as 2/2 sideband near axis when $q_0 \approx 1$, dragging down toroidal rotation profile
- 4/3 NTM hybrids have reduced transport in both ion and electron channels over most of radius



Raising Beta Above β_N = 2.8 Results in 4/3 NTM Losing Dominance to 3/2 NTM



- After β_N increase, 3/2 NTM develops in less than one current redistribution time
- Sawteeth present during 4/3 NTM disappear when 3/2 NTM becomes dominant, which is favorable for not triggering a 2/1 NTM

Conclusions

- **Hybrid discharges can develop either a dominant 3/2 NTM or a dominant 4/3 NTM, depending upon initial conditions**

- **Hybrid plasmas with dominant 4/3 NTM have up to 30% higher confinement times owing to**
  - Less flattening of pressure profile near island location
  - More E×B shear from increased toroidal rotation because of reduced island dragging effects

- **With q_{95} = 3.1, dominant 4/3 NTM hybrids have achieved $\beta_N H_{89P}/q_{95}^2$ = 0.7 for ≈ 5 current relaxtion times, exceeding the ITER baseline by 70%**

Additional Hybrid Presentations from DIII–D

- **Monday afternoon poster session:**

– Petrie	"Radiating Divertor with Hybrid Plasmas"	CP1.00016
– Politzer	"Role of 3/2 Tearing Mode in Hybrid Scenario"	CP1.00029
– Chu	"3/2 Island and its effect on Central Tokamak Region"	CP1.00030
– Makowski	"Measured and Simulated MSE Signals of a tearing Mode"	CP1.00031

- **Thursday morning poster session:**

– Wong	"Density Fluctuation Measurements"	QP1.00010
– McKee	"Core Turbulence Structures"	QP1.00021