EFFECTS OF ICRF ON PLASMA ROTATION IN TFTR

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see **invited talk by J.R. Wilson sFraI1.06 Friday morning**
poster by C.S. Chang pThpP2.28 Thursday afternoon

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ICRF Can Modify Plasma Rotation in Tokamaks

Background:

Effects are noted on many tokamaks in a variety of regimes.

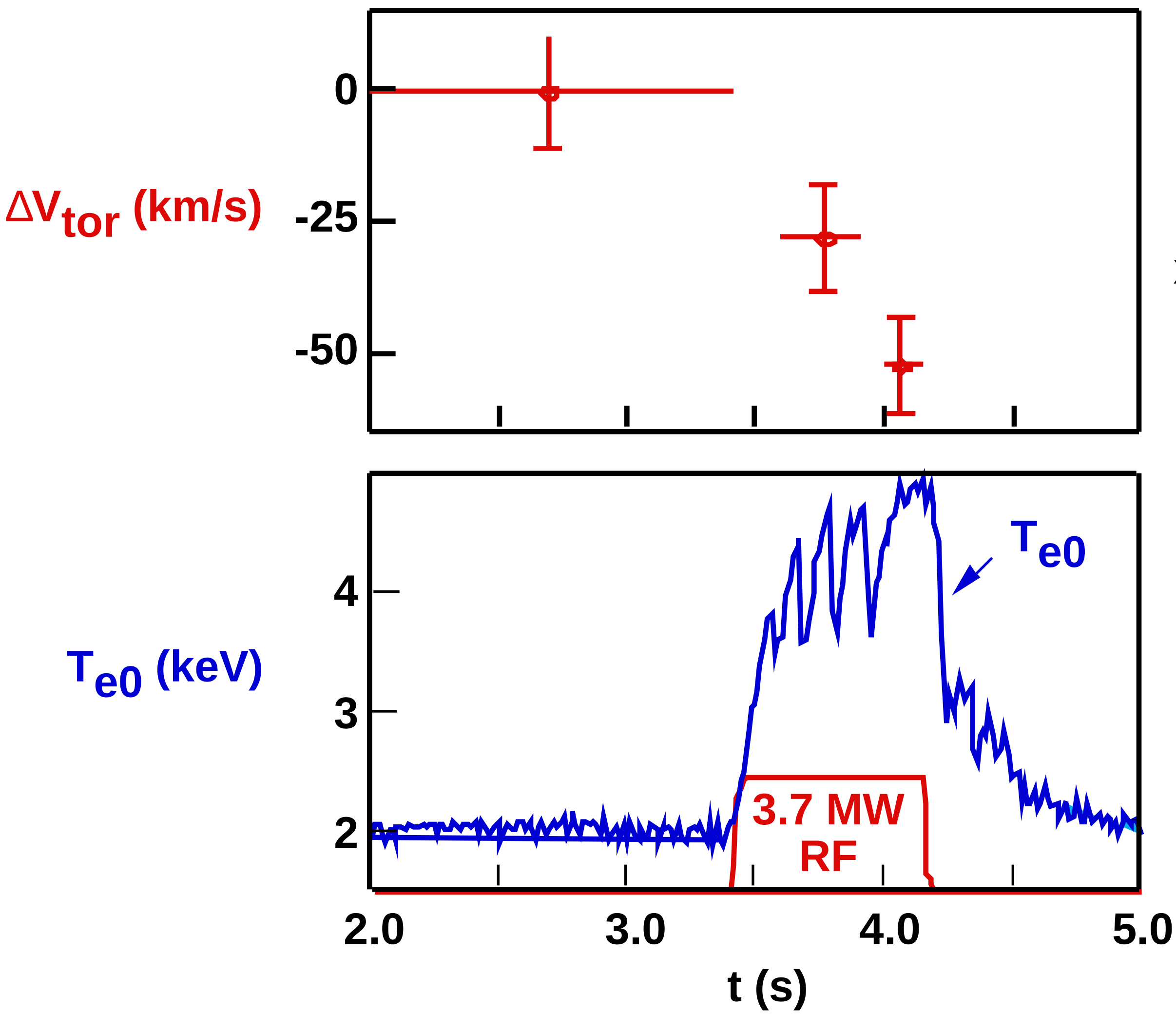
Relevance:

Potential rotation control in ITER for mode stabilization
Modification of transport barrier dynamics in ERS / NCS regime
Potential trigger mechanism for internal transport barrier formation

Overview:

Survey the magnitude of the effect in different regimes on TFTR.

Counter Toroidal Rotation Observed in ICRF-Only Plasma



$R_{2D} = R_H \sim R_{axis}$

Bitter and Hsuan
x-ray crystal detector

Phillips et al
PF B 4(1992) 2155

Caused by loss of rf-tail ions in minority H heating regime

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ICRF Can Reduce NBI-Driven Toroidal Rotation

- **Seen in both co- and counter- dominated discharges**

- **Magnitude of effect varies with ICRF heating scenario**
  - strongest reduction observed in DNB plasmas with D(H) heating

- **Reduction of V_{tor} seen in L-mode and Supershot plasmas:**

- **No significant effect observed in mode conversion scenarios**

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Toroidal Rotation Modifications Found by Comparison of NBI Shots with / without ICRF

Choose shots pairs with:

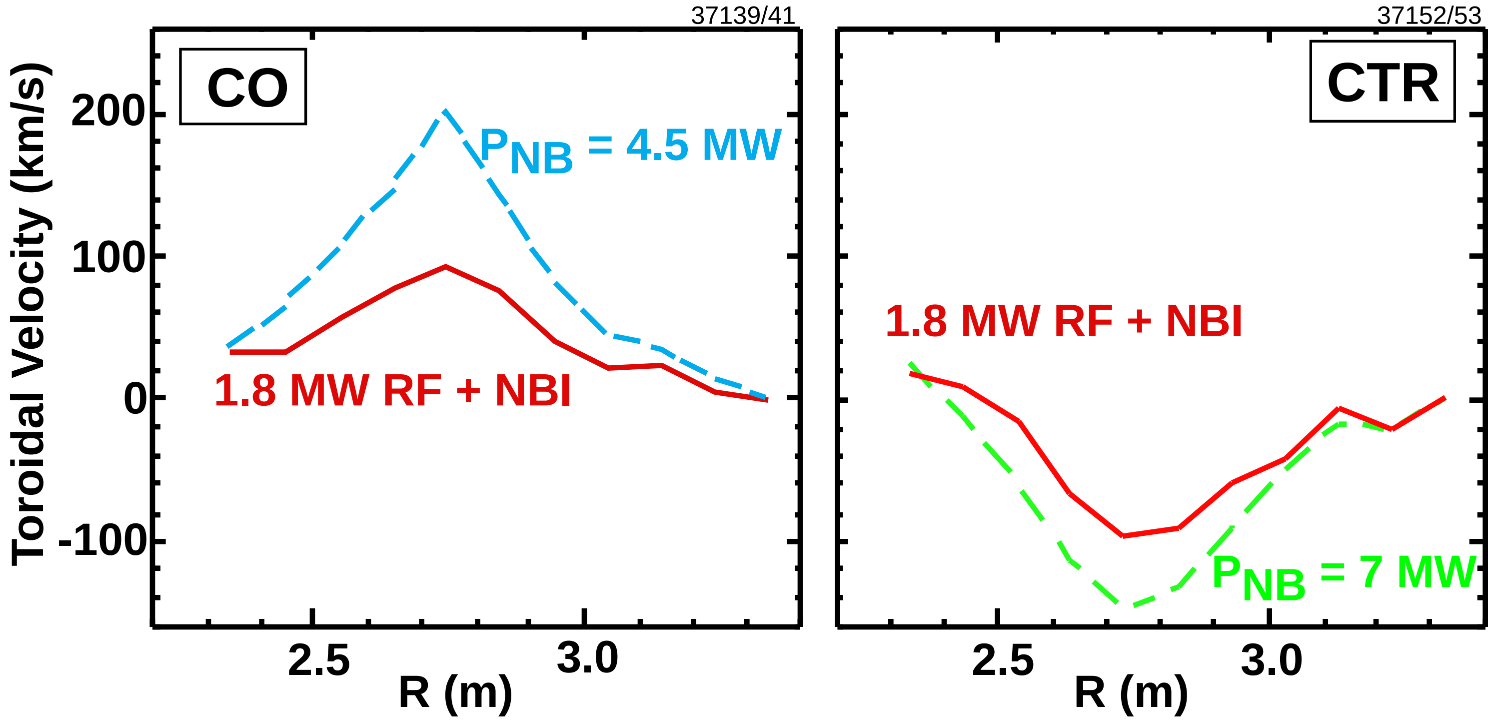
- **same NB injection (same power and co/ctr mix)**
- **same density evolution (differ by ≤ 10 %)**
- **same pre - rf target plasmas**

ICRF-Reduction of V_{tor} First Observed in L-Mode Plasmas

D majority - H minority RF heating in DNB-driven plasmas

$R_{2D} = R_H \sim R_{axis}$

substantial reduction seen in both co and counter-dominated discharges



Jaehnig, Fonck, Howell, and Knize APS 1988

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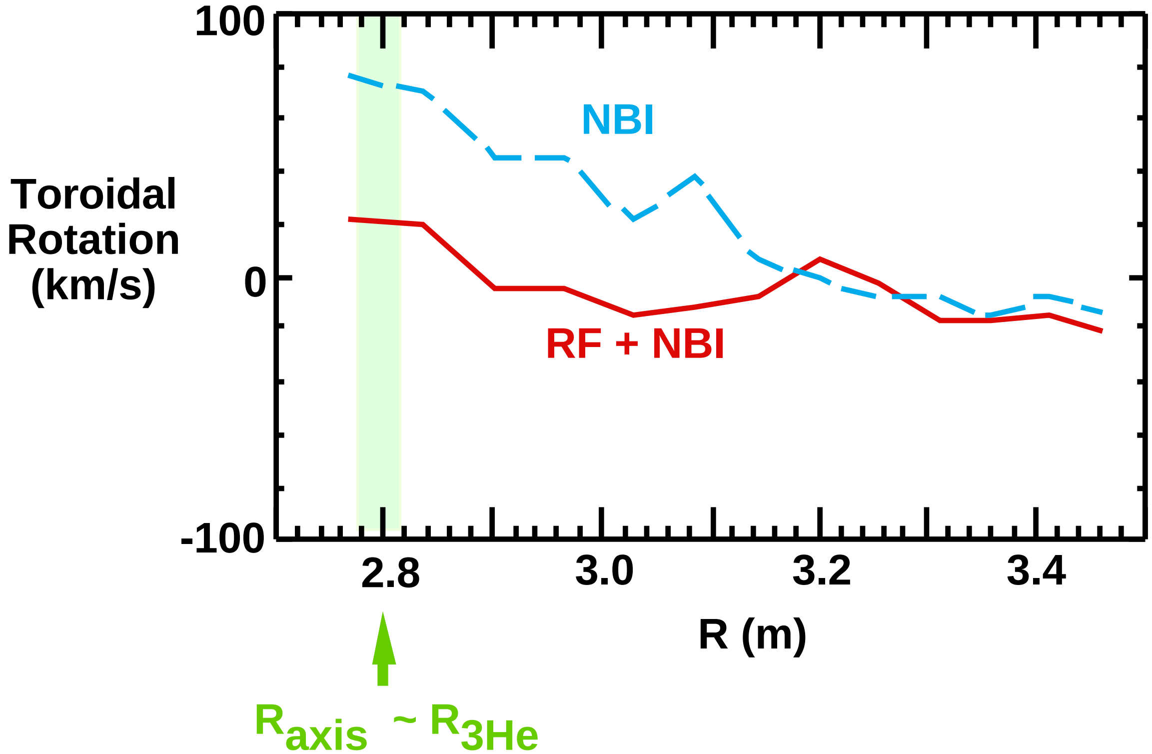
ICRF Reduces V_{tor} in Supershots in the minority ^{3}He regime

2.1 MW ICRF into 22.8 MW co - DNB target



R_{axis} ~ 2.8 m

R_{3He} ~ R_{axis}

R_D ~ 2.1 m

no core (r/a ≤ 0.5) beam - rf resonance but reduction effect remains

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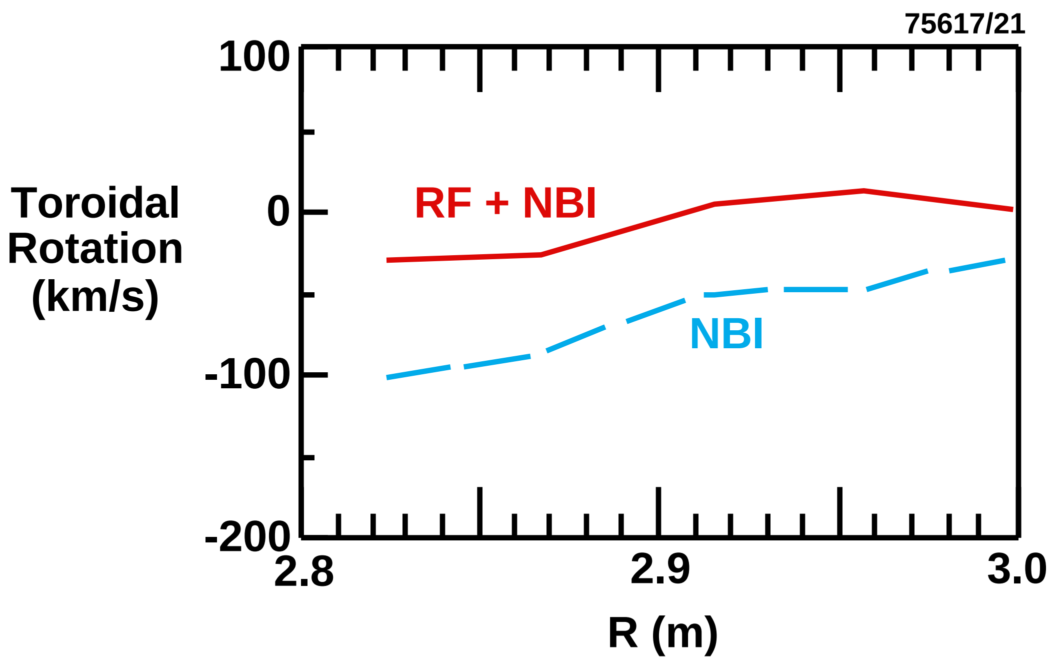
RF Reduces Counter - V_{tor} in Direct Electron Heating Regime

3D NBI-rf core cyclotron resonance with 2H layer off-axis at r/a ~ 0.75

9.5 MW counter DNB with 3 MW ICRF (90° phasing)



$R_{2H} = R_{4D} \sim 3.4$ m

$R_H = R_{2D} \sim 1.7$ m

$R_{3D} \sim R_{axis} \sim 2.8$ m

f = 63.6 MHz

$B_{T0} = 2.7$ T

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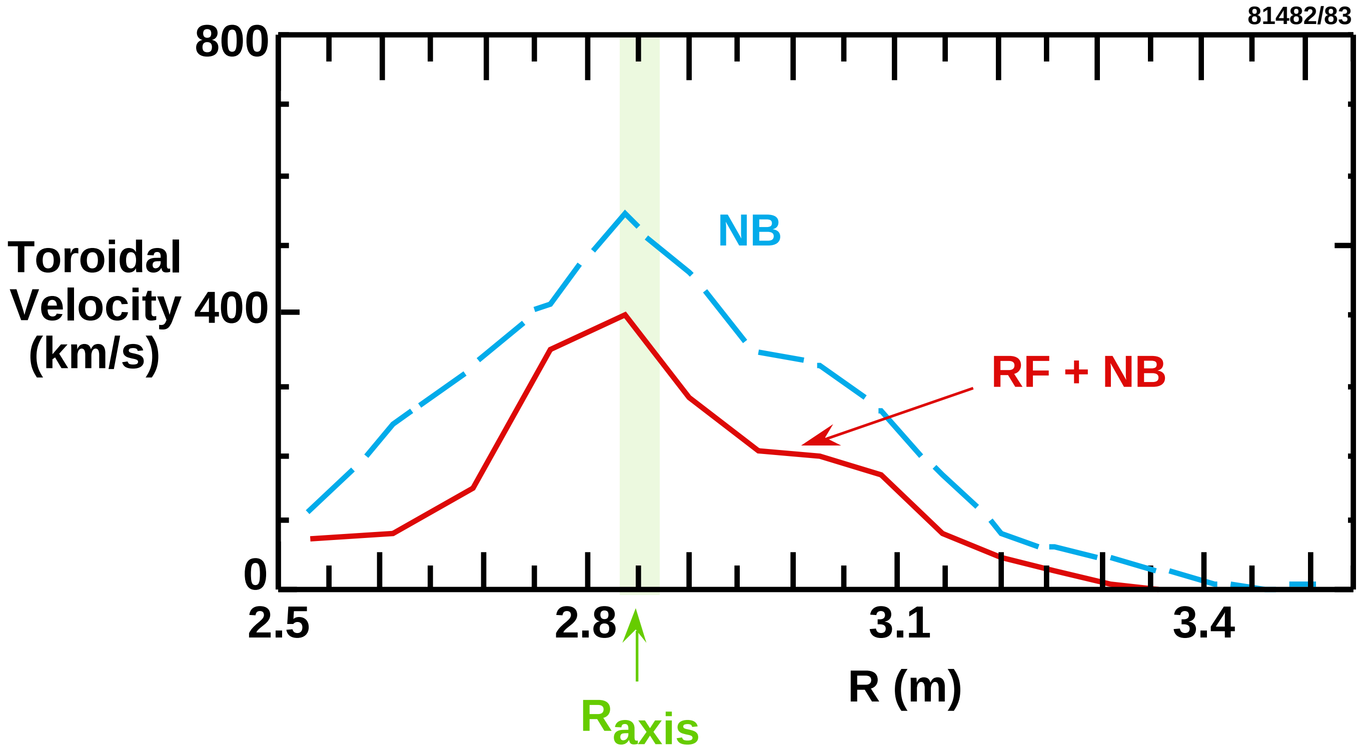
ICRF Reduces V_{tor} in DT Supershots with $2\Omega_T$ / Ω_H Heating

DT supershot with co-dominated TNB

no core ion resonance (r/a ≤ 0.5)



R_{2T} ~ 2.3 m

R_H ~ 3.4 m

$R_{3T} = R_H$

$R_{2D} = R_H$

R_D ~ 1.7 M

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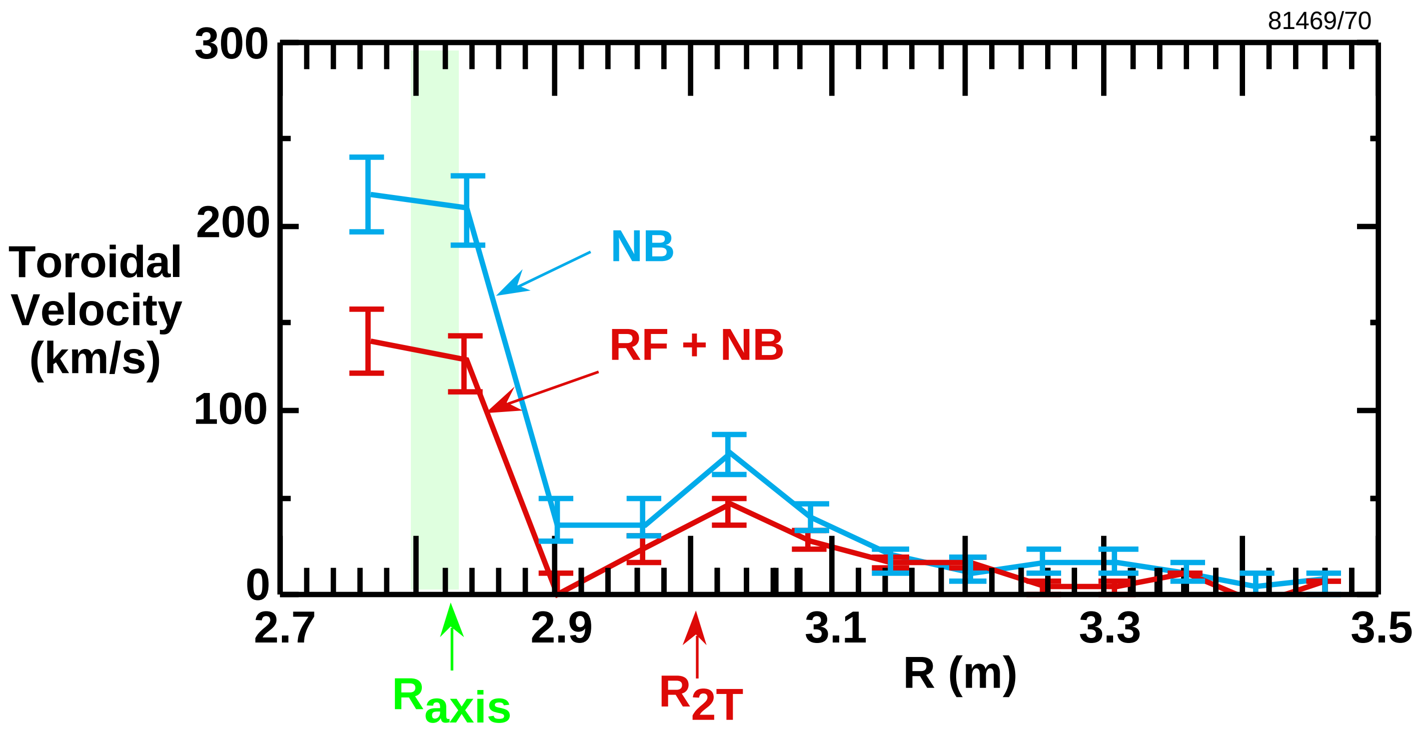
V_{tor} Reduction is Small in DT Supershots with $2\Omega_T$ Heating

5 MW ICRF into 19 MW co-dominated TNB DT supershot



R_{2T} ~ 3 m

R_D ~ 2.2 m

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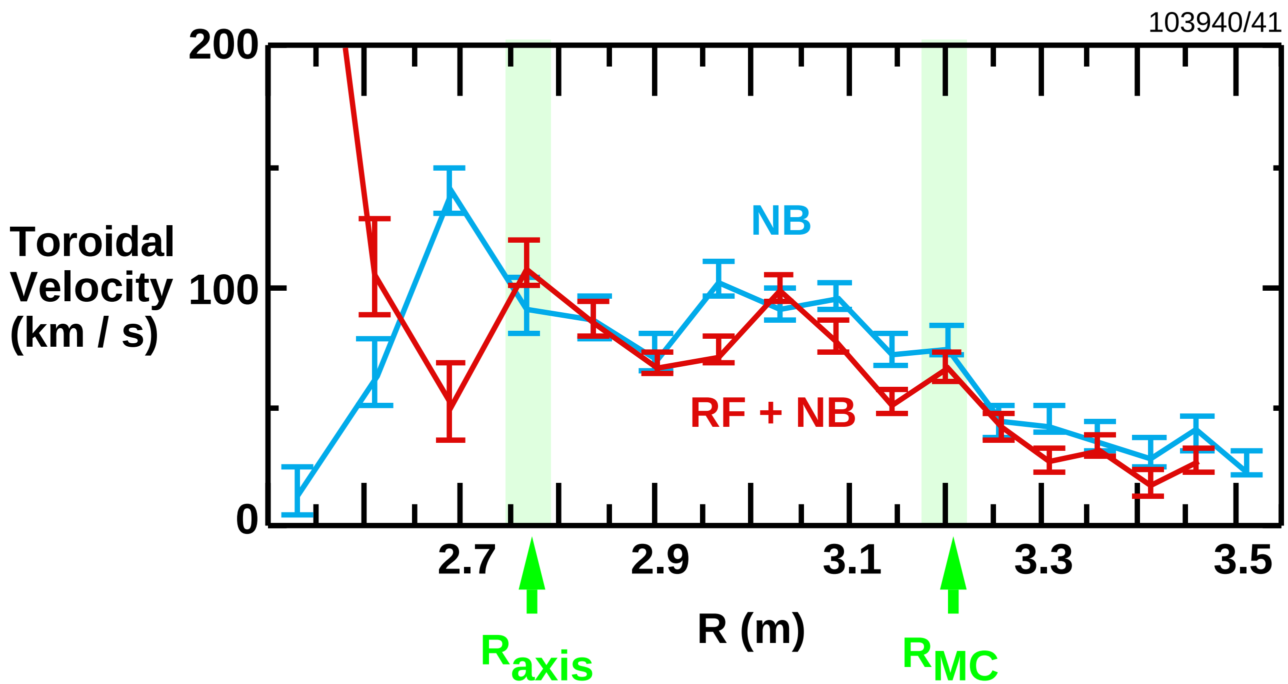
No Effect on V_{tor} Observed with Mode Conversion Heating

off-axis D - ^{4}He - ^{3}He Mode Conversion

2 MW RF into 4.7 MW co - DNB target



R_D ~ 2.5 m

$R_{4He} = R_D$

R_{3He} ~ 3.4 m

R_{MC} ~ 3.2 m

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POTENTIAL MECHANISMS

Loss of fast ions resulting in a counter torque?

ICRF causes counter-rotation to *decrease* instead of increase.
- acts like viscosity instead of torque

Change in beam momentum drive due to rf-beam resonance?

No effect observed in mode conversion regimes with co-existing beam-rf resonances

Reduction observed with no core beam ion resonance in D(^{3}He) regime.

Change in beam penetration due to increase in edge recycling / edge density?

Changes in edge density not sufficient to account for magnitude of effect.

Reduction not observed in mode conversion regime.

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SUMMARY AND CONCLUSIONS

- ICRF alone can drive modest counter rotation ~ 50 km/s
- ICRF can reduce co and counter NBI-induced toroidal rotation
  - up to 50% reduction found in D(H) heating scenarios
  - may provide alternate tool for barrier control in ERS / NCS regime
- No reduction effect observed with Mode Conversion Heating
- Physical mechanism is unknown - more than one may be operative
- Role of ICRF-induced induced toroidal flows via Reynolds stress should be investigated

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