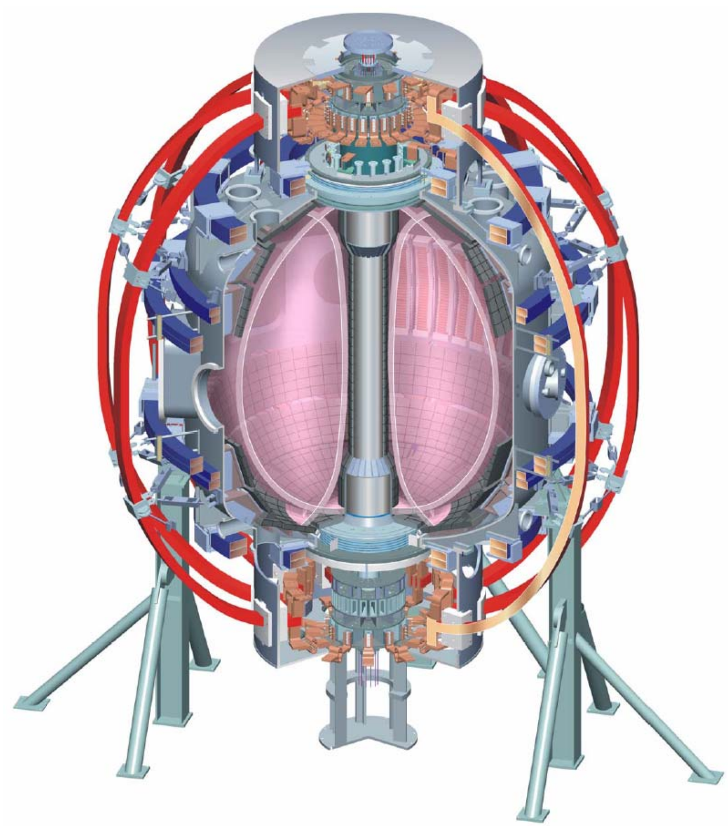
Supported by

XP513 on NSTX/MAST Similarity Experiment on iITB Formation and Evolution



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& Many Contributing
NSTX, MAST Team

XP review

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NSTX/MAST similarity experiment on iITB – of interest to plasma science, ITPA, and ST

- Goals of experiment, document and study
  - iITB formation and evolution in NSTX/MAST
  - Dependence of driven and ExB flow shear on input momentum
  - Flow shear and q-profile effects on iITB and low-k turbulence
- Scientific motivation: interplay between turbulence suppression and microinstability drive
  - Zone starts deeper (r/a ~ 0.5) and moves out
  - $\chi_i \sim \chi_{NC}$ over substantial zone (r/a ~ 0.7 – 0.9), sustained
  - Coupled to high toroidal flow shear
- Broad interest
  - Science of ion energy and momentum transport
  - Contribute to ITPA defined issue of iITB properties for ITER
  - Comparison study with DIII-D and AUG in 2006-2007

This study aims to clarify the physics of iITB formation and evolution in the presence of strong external torque

NSTX

ExB shear flow suppression of turbulence:

- Growth rates of drift-wave turbulence γ_m scales like:

$$\gamma_m = c_s / L_T \cdot G_1(\Lambda_T, s, q, \beta, \nu^*, \ldots)$$

- Pressure driven ExB shearing rate ω_{SE} scales like:

$$\omega_{SE} = c_s / L_T \cdot \rho_s^* \cdot G_2(s, q, \beta, \nu^*, \ldots)$$

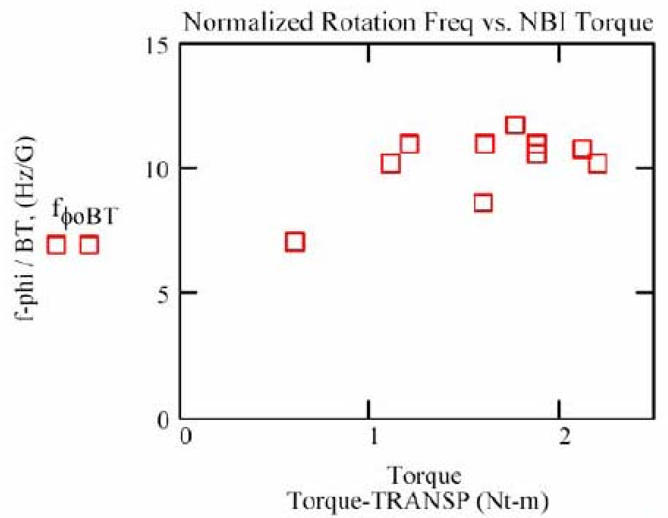
- Criterion for turbulence suppression $\omega_{SE}/\gamma_m > 1$ scales with ρ_s^*
- Large ρ_s^* favours suppression of anomalous transport in ST plasma
- Criterion for ITB formation $\rho_s^* > \rho_{ITB}^*$ if $\nabla p_i/n_i e$ term dominates E_r
- Alternative criterion $M_\phi > M_\phi^{ITB}$ if NBI driven toroidal flow dominates E_r

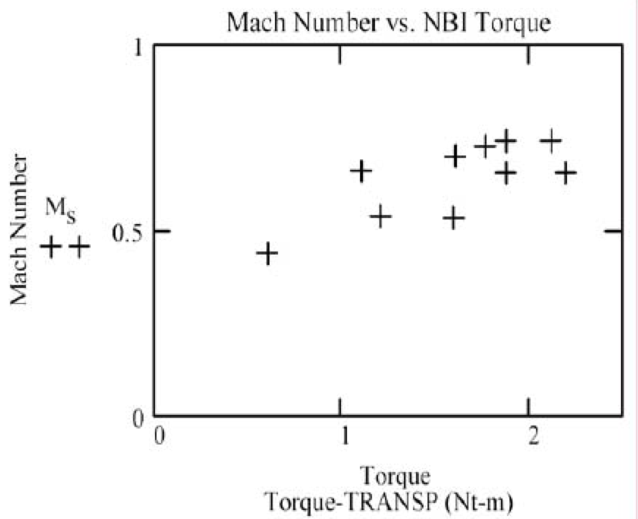
Note that tokamaks today are in similar regime, differing from ITER.

About 2/3 of XP435 was carried out, yielding interesting and helpful data

- Benefited greatly from rigorous review
- Thanks to excellent machine and NBI operation
- Allocated 5 hours, machine available for 4 hours
- B_{T0} = 3 kG
- Executed 18 shots successfully
- 11 shots with good data
- Designed 3 shots for MSE commissioning
- Initial analysis helps define detail of XP513

Data from XP435 sheds possible new light on relationship among τ_p, τ_ϕ, and τ_E in plasma core.





Simple 0D momentum balance with dominant tangential NBI heating:

Applied torque: $T_\phi = R_0 Q_b \sqrt{2m_b / eE_b}$

If NBI fuelling dominates in core:

Rotation frequency: $\omega_\phi = \sqrt{\frac{2eE_b}{m_b}} \cdot \frac{\tau_\phi}{\tau_p} \cdot \frac{1}{R_0}$

If NBI heating dominates and $T_i = T_e$, $Q_i = Q_e$:

Toroidal Mach number: $M_\phi = \sqrt{\frac{3\tau_p}{\tau_E}} \cdot \frac{\tau_\phi}{\tau_p}$

Independent of NBI power and energy!

Insight into ratios of τ's?

NSTX: Shot list

Beam Energy-Power Matrix

- Shotlist [**Case**: sources/energy (kV), flattop shots + beam stepping shot]:

	~4.4 MW	~3.3 MW	~2.2 MW
	I: B, A/90, 2+1	**II**: 0.5B, A/90, 2+1	**III**: B→A/90, 2+1
MAST Matches	**IV**: B, 0.5A, C/80, 2+1	**V**: B, A/85, 2+1	**VIII**: C, B, 0.67A/85, 2+1
	VI: B, A, C/70, 2+1	**VII**: B, A, C/60, 2+1	**IX**: B, A/60, 2+1

- Redo complete scan at 4.5 kG
- High priority for MAST identity cases (M5/005,047), needing NBI conditioning

NSTX	Power (MW)	MAST beam/energy(kV), power(MW)
VII: B, A, C/60, 3	3.3	SW/50, 1.5; SS/60, 1.8
VIII: C, B, 0.67A/85, 3	2.2	SS/70, 2.2
IX: B, A/60, 3	2.2	SW/35, 0.7; SS/60, 1.5

- Required successful shots: 18 out of 27 planned

Logic for shots

- Use best shape (DND or LSN) available, 4MA/s, line n_e ~1-2x10^{19}/m^{-3}, and κ ~ 2-2.2, δ ~ 0.5
- Maintain inner/outer gaps of 6-8 cm/12 cm for best plasmas
- Early H transition @~80 ms, for >400 ms sustained operation
- Cases I-III with 90 kV (A) first, for MSE, and NBI reliability
- Run shots with decreasing E_{beam} to minimize beam cycle
- Step in/out beam power after 200-300 ms into good flattop, after successful flattop beam shot in 3 tries for each case
- He GDC for 11.5 min for each shot; morning boronization desired
- Avoid large MHDs and ELMs for ~400 ms within flattop
- Encourage extensive diagnostics, to maximize science output

What's Next?

- Analyze XP435 results to guide XP
- Prepare for experiments on NSTX and MAST
- Complete XP513 at B_{T0} = 4.5 kG (May-June?)
- Carry out identity experiment on MAST (June?)
- Include appropriate existing shots from other XPs
- Include key physics elements in iITB evolution model – e.g., D. Newman et al, develop improved if necessary
- Utilize TRANSP & EFIT with strong flow and MSE
- Present, discuss with ITPA TP TG, and improve
- Write paper for review and journal