NSTX

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XP1164: Collisionality scaling of turbulence at high beta & Assessment of core low-k turbulence and poloidal flow fluctuations

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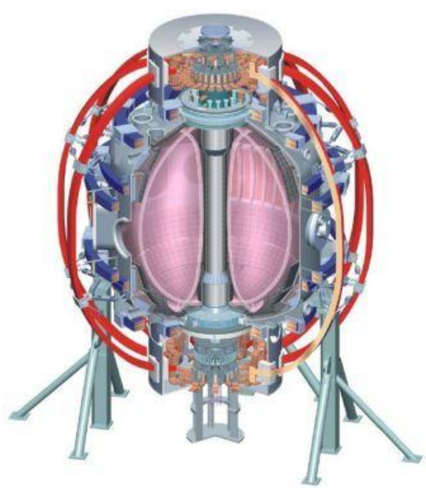
T&T TSG Group Review



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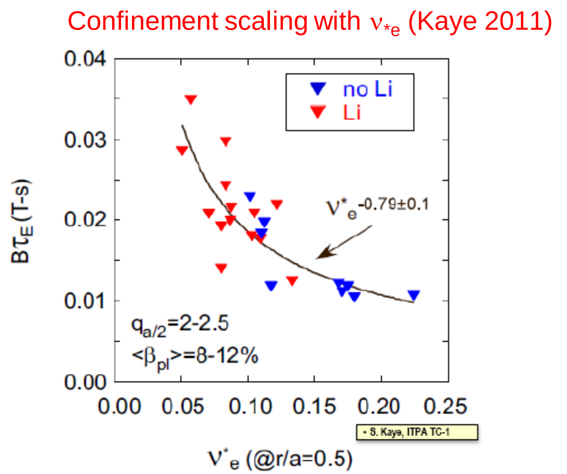
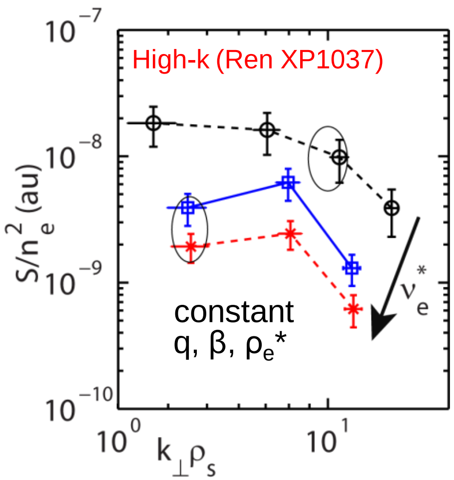
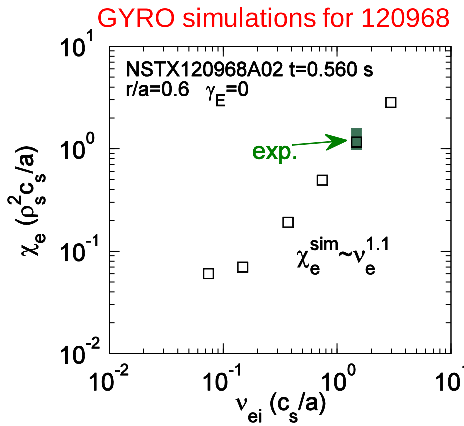
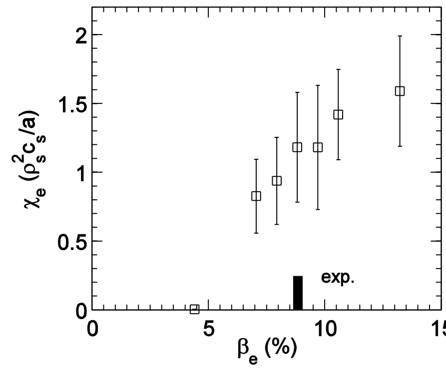
Experimental and theoretical motivation of ν_* scan at high β

- Favorable ν_* confinement scaling in STs: $\Omega_i \tau_E \sim \nu_*^{-(0.8\text{-}0.95)}$ (Kaye, NF07; 2011)
- Microtearing (MT) modes one possible explanation: $(\chi_e)^{MT} \sim \nu_{*e}$ (Guttenfelder PRL11)
- XP1037 (Ren) found high-k intensity increased with decreasing ν_*, opposite to naïve expectation from previous τ_E scaling and MT modes
- XP1037 operated at *lower* n_e, P_{NBI} ($\rightarrow\beta_e$) and Z_{eff} – ETG predicted unstable









⇒ Goal: complement XP1037 with turbulence measurements during ν_* scan at higher β_e and Z_{eff} to isolate microtearing modes (R11-1)

- Higher β_e and Z_{eff} (ν_e) maximizes microtearing instability
- Higher Z_{eff} is stabilizing to ETG

- Turbulence and transport data will be used for validation with gyrokinetics
- Use high n_e, ELM-free Li discharges for high β_e and Z_{eff}

$$\nu_e = \nu_{ei} \cdot \frac{Z_{eff} + H(v/v_{th})}{(v/v_{th})^3}$$

$$\left(\frac{a}{L_{Te}}\right)_{crit}^{ETG} \sim \left(1 + Z_{eff}\frac{T_e}{T_i}\right)(\cdots)$$

Assess poloidal correlation lengths in core region with expanded BES system

- Correlation length database (100+ entries) from 2010 BES data indicates poloidal correlation lengths are related to I_p and P_{NBI}:

$$L_c[\mathrm{cm}] \approx 8.4 \times I_p[\mathrm{MA}] + 2.3 \times P_{NB}[\mathrm{MW}] \pm 3.6$$

  - 2010 measurements obtained with 3 or 4 poloidally-separated channels at R=140 cm (r/a~0.85) using 16 or 24 BES channels
  - |B| scaling not clear from database

- **2011 goal: Assess poloidal correlation lengths with 6 poloidally-separated channels at R=130 and 136 cm (r/a~0.4 and 0.65) using 32 BES channels**

- Also, assess **poloidal flow fluctuations** and **flow shear** using 3x3 grid at R=130-136 cm

- Scan I_p, P_{NBI}, and |B|

- Require discharges with 200+ ms, ELM-free, MHD-quiescent periods

Engineering parameter space for ν_{*e}, P_{NBI}, I_p scans

Z_{eff} scan (first shots adding L_i)

ν_{*e} scan (fixed I_p/B_T, ~4 MW) (3 conditions)

P_{NBI} scan (0.9 MA/0.45 T) (+2 conditions)

I_p scan (B_T=0.45 T, ~4 MW) (+2 conditions)

I_p / B_T	0.35 (→0.38)	**0.45**	0.55 (→0.52)
0.7 (→0.76)	(3) P=4 MW	(7) P=4 MW	
0.9		(1) P=4 MW (4) P=3 MW (5) P=2 MW	
1.1 (→1.04)		(6) P=4 MW	(2) P=4 MW (2a) P=3,2 MW

Plan to pick baseline fiducial discharge (0.45T/0.9MA) from established high-Li discharges early in run (XP1133,...). Will be used prior to XP for:

- ray tracing calculations to locate high-k (two locations separated $\Delta R \approx 5$ cm, no NTC access required)
- linear gyrokinetic analysis to verify ETG stability, microtearing instability

Shot list (1 day, FY2011)

1) **Reproduce shot 138555 I_p=0.9 MA, B_T=0.45 T, P_{NBI}=4, low lithium (50 mg/shot)** (2+1 shots)
   - Best shape and Li to span I_p/B_T= 0.7/0.35→1.1/0.55 MA/T (ν_{*e}~B^{-4}) with "minimal" MHD, EPM, *AE
   - Outer gap ~10-13 cm for high res. TS, possibly isolate $W_{ped}(\nu_*)$ scaling
2) Acquire BES and high-k (R=135 cm) (2 shots)

3) **Increase lithium (250-300 mg/shot) to reach ELM-free, Z_{eff} =3-4**, if necessary reduce power to match T_e(R=135) (3 shots)
4) Acquire BES and high-k (R=135 cm) (2 shots)
5) Remotely move high-k (R=140 cm) (no NTC access) (2 shots)

6) Move to **I_p=1.1 MA, B_T=0.55 T**, match n_e, adjust P_{NBI} to match $T_e(r)/B^2$, adjust Li to match Z_{eff} (2+1 shots)
   - If unsuccessful, move to I_p=1.04 MA, B_T=0.53 T (+2 shots)
7) Acquire BES and high-k (R=140 cm) (2 shots)
8) Remotely move high-k (R=135 cm) (no NTC access) (2 shots)
   - If all goes well, try for 1 or 2 additional P_{NBI} (2,3 MW)

9) Move to **I_p=0.7 MA, B_T=0.35 T**, match n_e, adjust P_{NBI} to match $T_e(r)/B^2$, adjust Li to match Z_{eff} (2+1 shots)
   - If unsuccessful, move to I_p=0.76 MA, B_T=0.38 T (+2 shots)
10) Acquire BES and high-k (R=135 cm) (2 shots)
11) Remotely move high-k (R=140 cm) (no NTC access) (2 shots)
   - If this I_p/B_T is problematic, skip second high-k location

12) Move to **I_p=0.9 MA, B_T=0.45 T, P=3 MW** (return high-k to R=135 cm) (2+1 shots)
13) Move to **I_p=0.9 MA, B_T=0.45 T, P=2 MW** (2+1 shots)

14) Move to **I_p=0.7 MA, B_T=0.45 T, P=4 MW** (2+1 shots)
15) Move to **I_p=1.1 MA, B_T=0.45 T, P=4 MW** (2+1 shots)

Total shots = 31+11 = 42 shots (with contingency)

If too many shots:
Skip step 3, slower Li introduction as attempt to get Z_{eff} scan (3 shots) (possibly get similar data from XP1113, depending on high-k/BES configs.)
Skip steps 5,7,11, second high-k location (6 shots)

Operations and Diagnostics

Required

- All 3 beams available for power scan (always source A for MSE)
- Magnetics, TS, CHERS, MSE

- High-k (two locations separated by $\Delta R \sim 5$ cm; remote, no NTC access required)
- BES – 3 poloidal arrays (18 ch.); 1 radial array (+6 ch); 3×3 matrix (+ 3 ch)

- ME-SXR and trace impurity puffs (possibly contribute to JRT12)
  - No deleterious effects from Ne puff on BES last year (142184)

Desired

- Would ideally wait until after polarimeter installed (UCLA, estimated Aug-Sept 2011) for δB measurements, but not necessary

XP1037 operated at much lower n_e, β_e, Z_{eff}