XP-408: Rotation Damping Physics in High β_N ST Plasma

- XP already approved (XP-314)
  - Review goals and updated shotlist
- Goals
  - Determine the plasma rotation damping physics of ST plasmas at high β_N
    - Below the ideal no-wall beta limit $\beta_N < \beta_{Nno\text{-}wall}$
      - Rotation damping due to NTM, rotating modes, ELMs
      - Plasmas without strong modes (source vs. plasma viscosity)
    - Above the ideal no-wall beta limit $\beta_N > \beta_{Nno\text{-}wall}$
      - Study the global nature of toroidal rotation damping at $\beta_N > \beta_{Nno\text{-}wall}$
      - Test neoclassical toroidal viscosity theory
      - Study the dependence of rotation damping on toroidal field (q_{min}) and $\beta_N/\beta_{Nno\text{-}wall}$
  - Compare experimental results to all applicable theories

Examine All Terms in Plasma Toroidal Torque Balance Equation (1)

$$\rho r\left(\frac{\partial \Omega_\varphi}{\partial t}\right)=\frac{\partial}{\partial r}\left(\rho \mu_\perp r\frac{\partial \Omega_\varphi}{\partial r}\right)-rf_{non_resonant}+r\,S_\varphi/R_0^2-\frac{T_{\varphi\,EM}}{4\pi^2 R_0^3 w}\delta(r-r_s)$$

Inertia | Fluid Viscosity | Non-resonant torque | Source | Resonant J×B torque

- Inertia term: All measured. Upgraded CHERS should give much better results
- Fluid viscosity term: Two difficulties
  - Inaccurate second order derivative, should be better with new CHERS
  - Viscous coefficients. Local calculation near the island plus assumptions. New CHERS helps. Altering the position of island may give a better idea of the coefficient profile over radius

Examine All Terms in Plasma Toroidal Torque Balance Equation (2)

- Non-resonant torque term: Caused by RWM. Need to run at $\beta_N > \beta_{Nno\text{-}wall}$ and lower $B_t < 0.4$ T. Two important issues
  - Estimated δB profile is used. Now include full ideal theoretical eigenfunction (DCON)
  - Vary T_i profile: Density scan, higher density pushes T_i profile closer to T_e profile. Vary torque input (?)
- Source term: Calculated at steady state without any modes

$$\frac{\partial}{\partial r}\left(\rho\mu_{\perp} r \frac{\partial \Omega_{\varphi 0}}{\partial r}\right) + r\, S_{\varphi} \big/ R_0^2 = 0$$

  - Higher $B_t > 0.4$ T to suppress modes
  - Run long pulse in order to reach steady state
  - To be compared with TRANSP calculation
- Resonant $\boldsymbol{J}\times\boldsymbol{B}$ torque term: Caused by tearing mode. The position (r_s) and size (w) of island are very important
  - Change $\mathrm{Gap_{in}}$ $\mathrm{Gap_{out}}$, B_t scan
  - High resolution new CHERS

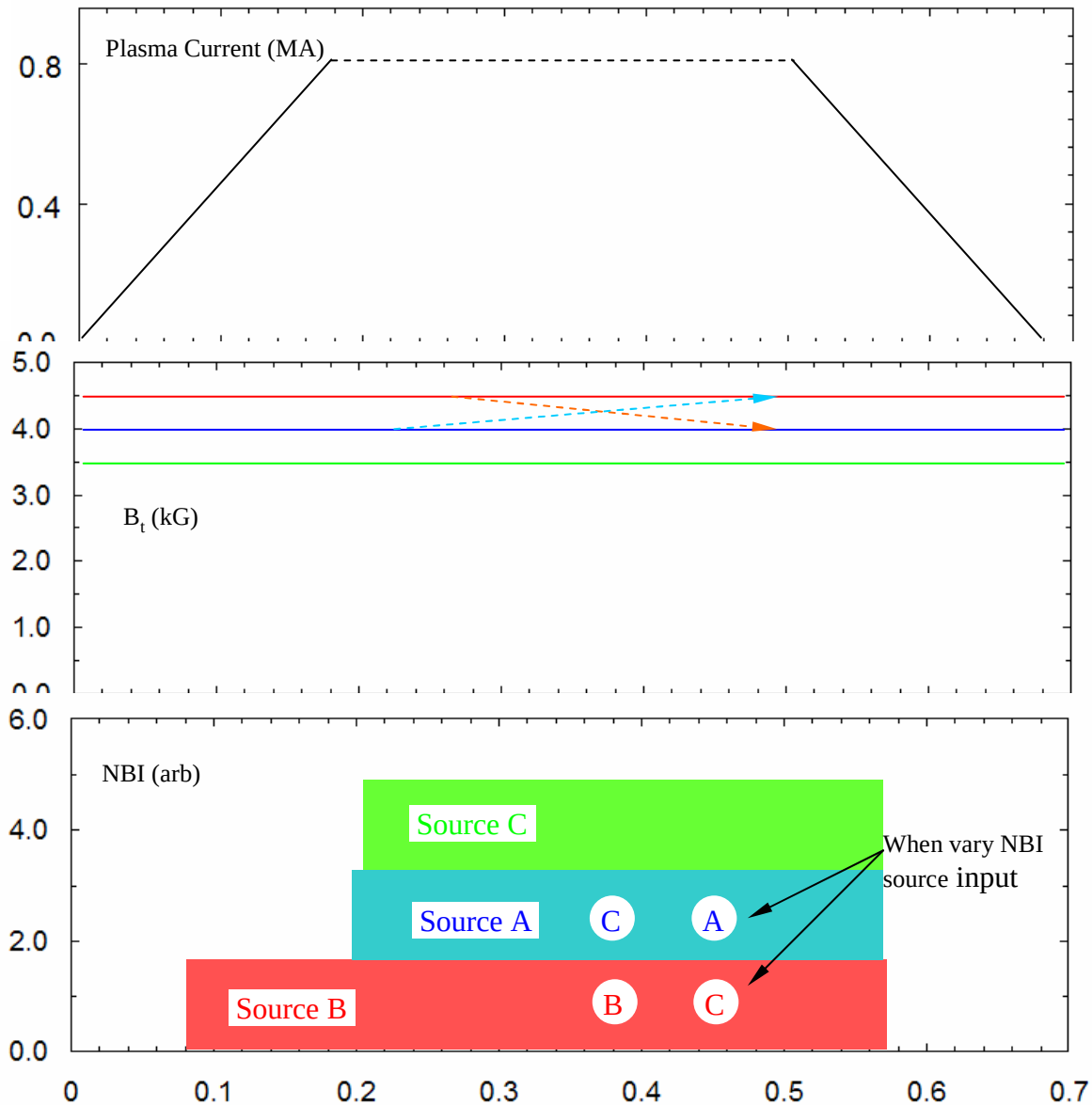
XP Could be Completed in 1.5 Days (1)

Task	Number of Shots
A. Control Shots	3
($\beta_N<\beta_{N\ no\ wall}$, $B_t>0.4$T, $\beta_p<0.4$, $\tau_{flat\ top}>0.3$s)	
❑ B_t=0.45T, 1 NBI source (source B), I_p=0.8MA, LSN	
❑ If significant rotating modes exist, increase I_p=1MA	
B. Rotating mode plasmas	6
($\beta_N<\beta_{N\ no\ wall}$, alter position of island w.r.t. passive plates)	
❑ Repeat A, B_t=0.35, 0.4T	
❑ Change Gap_{in}, Gap_{out}	
C. Try to produce "pure" RWM plasmas	18
(Produce plasmas with $\beta_N>\beta_{N\ no\ wall}$, 2 or 3 NBI sources)	
i. Highest β_N	
❑ 3 NBI sources, B_t=0.45T for calculating source term	1
❑ Vary NBI time to change RWM onset conditions	2
❑ Slow B_t ramp down to vary rotation evolution	2
▪ $0.45 \rightarrow 0.4$ T	
▪ Find the critical B_t (q_{min}) to launch RWM (Present theory: $\Omega_{crit}/\Omega_A=1/4q^2$)	
❑ Slow B_t ramp **up** ($0.4 \rightarrow 0.45$ T) to vary $\beta\sim V_\phi$	2

XP Could be Completed in 1.5 Days (2)

Task	Number of Shots
ii. Lower β_N	
❑ 2 NBI sources (A+B) (reference 108197), B_t=0.45T	1
❑ Slow B_t ramp down to vary rotation evolution	2
❑ $(0.45 \rightarrow 0.4\ \mathrm{T})$	
❑ Find the critical B_t (q_{min}) to launch RWM	
❑ Vary NBI source input (sources B+C, C+A) (Possibly change T_i profile (?))	4
❑ Slow B_t ramp down to vary rotation evolution	
iii. Density scan with "pure" RWM or higher β_N plasmas (Change T_i profile)	4
D. Vary fuel rate and configuration to produce ELMy or ELM-free H-mode plasmas (β_N<$\beta_{N\ no\ wall}$, B_t>0.4T, β_p<0.4)	6
❑ Fueling rate (plenum pressure) scan	
❑ Run DND to produce large ELMs	
Total	33

Slow B_t Ramp to Vary Rotation Evolution



Required and Desired Diagnostics

- Required
  - CHERS toroidal rotation measurement; edge CHERS
  - Locked mode and internal RWM detector measurements
  - USXR
  - Toroidal Mirnov array
  - Thomson scattering
- Desired
  - Fast camera
  - Diamagnetic loop
  - Flux loops and integrated poloidal Mirnov coil data
  - FIReTIP interfrometer/polarimeter
  - 2-D x-ray detector (GEM)
  - Neutron detectors
  - H-alpha cameras