Review of XP-916

TAEs studies in L-mode, center-stack limited deuterium plasmas

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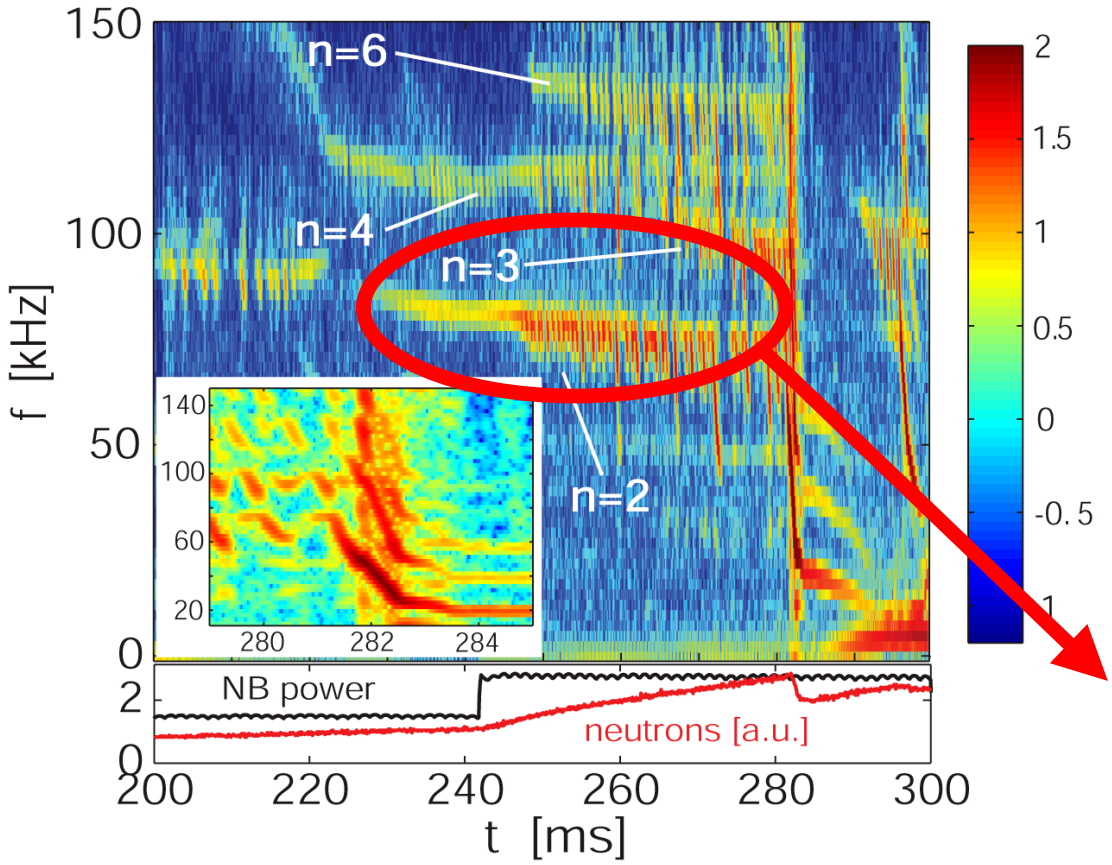
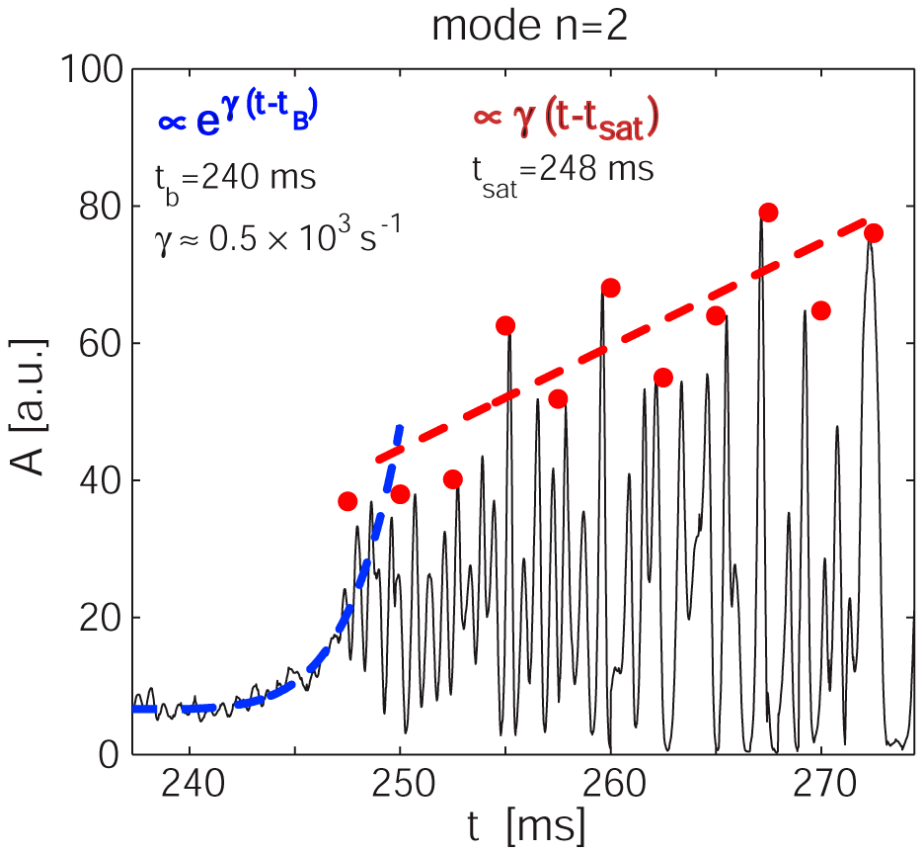
Good results from past years motivate detailed studies of TAE dynamics



Ex: sh#128455, Multiple TAEs destabilized by ~2.3MW of NB power



Complex dynamics, synergetic effort between experiment and theory required

Major goals of XP-916

- Develop **target plasma**
  - Deuterium L-mode, center-stack limited, with presence of TAEs and TAE avalanches
- Provide “ideal” case for **code validation** (M3D-k) and extensive theory-experiment comparison
- Study dependence of **TAE dynamics** and induced fast-ion transport on plasma parameters
  - Plasma rotation, B_{tor}, density, q-profile, n and T_e, ...

Two days allocated for this XP, divided into two parts

- Part#1: target plasma development 1/2 day
- Part#2: parameter scan 1+1/2 day

- Part#1 can be run early (February/March)
- Part#2 requires 8-channel reflectometer (April?), possibly HHFW (at least 2MW)

Parameter scan, goals

- **Plasma rotation**: reduce Doppler shift corrections, modify TAE gap through velocity shear
- **Toroidal field**: modify $\beta_{fast}/\beta_{thermal}$
- **Density**: modify $\beta_{fast}/\beta_{thermal}$
- **Code validation** shots: acquire database for code validation and theory/experiment comparison
- $\mathbf{T_e}$, through HHFW: modify TAE dynamics (damping)
- **NPA + f-FIDA** scan: document fast ion distribution (velocity space)
- **Shape** (elongation): modify TAE coupling through q-edge

Parameter scan, priority

- Priority of scans:
  - (i) Plasma rotation (velocity shear)
  - (ii) B_{tor}
  - (iii) Density
  - (iv) Code validation shots
  - (v) T_e, through HHFW [option]
  - (vi) NPA + f-FIDA scan [option]
  - (vii) Shape (elongation) [option]

top priority

lower priority

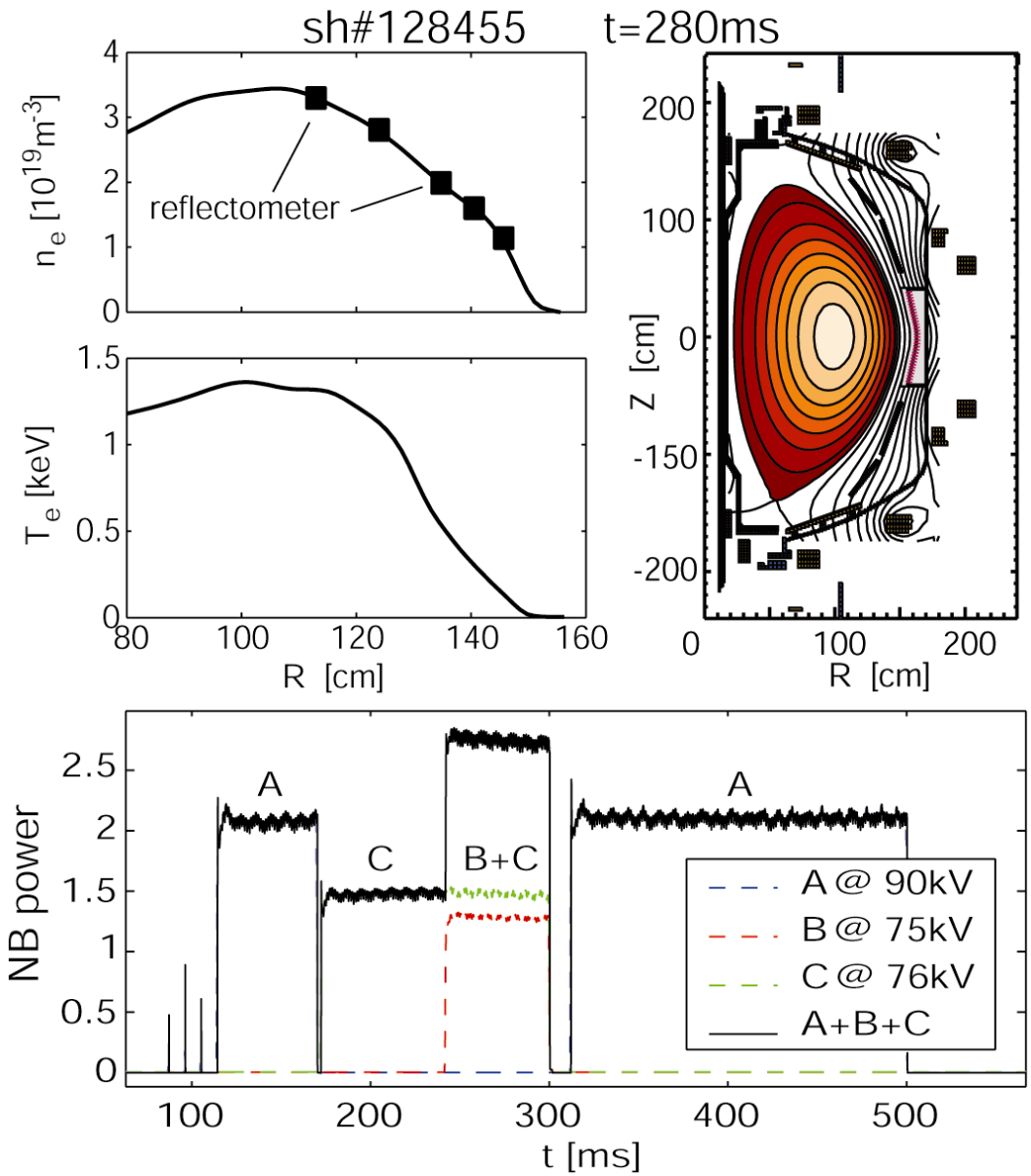
- NB power scan for (ii) → (iv) and (vii)

If (i) successful and no noise on NPA, ssNPA: EFC coils ON at optimum I value for (ii) → (vii)

- **Part#1: target plasma development**

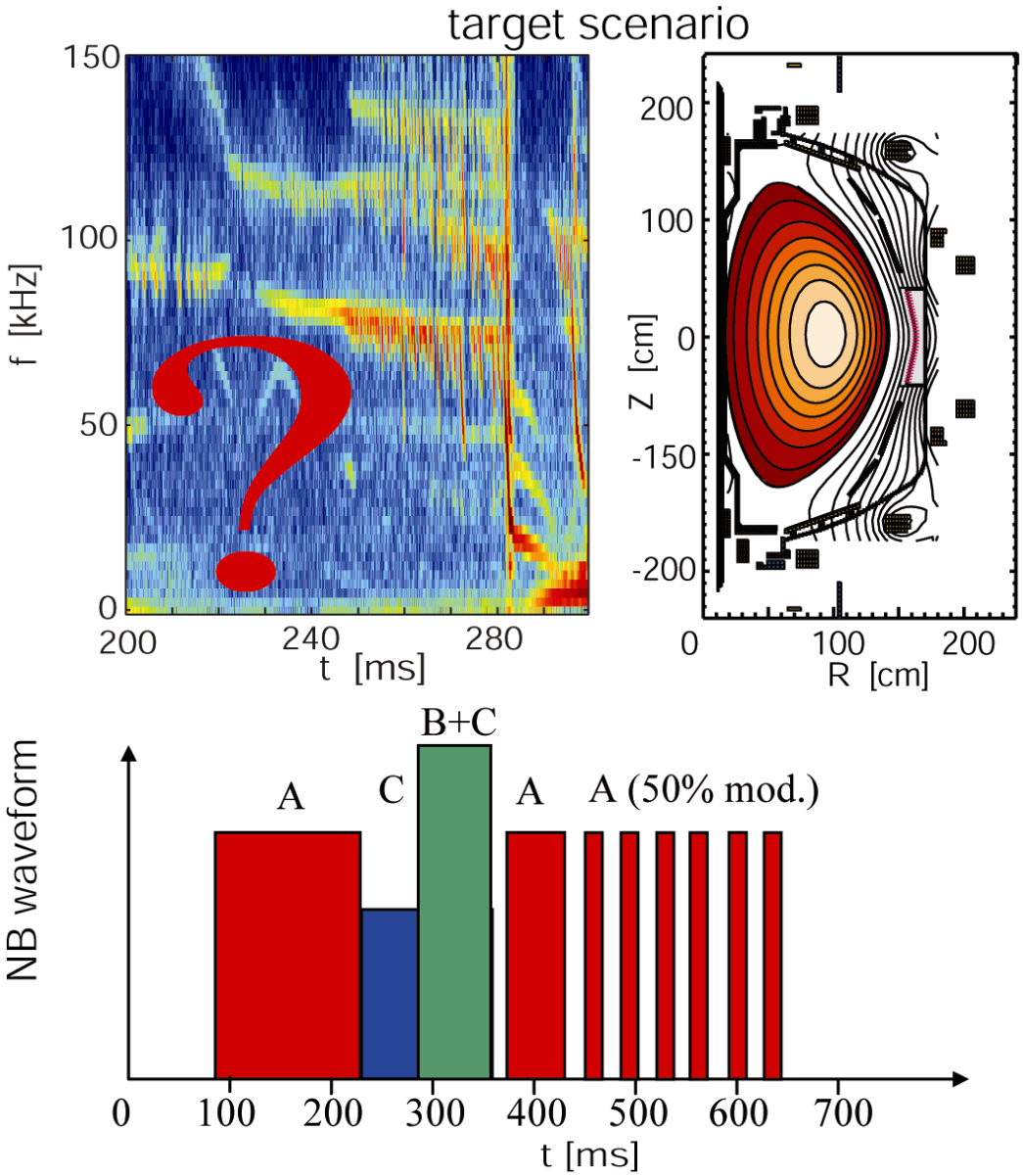
Target plasma: modify sh#128455

- I_p=0.9MA, B_{tor}=4.5kG
- kappa ~ 2
- Helium, LSN



Target plasma: modify sh#128455

- I_p=0.9MA, B_{tor}=5.5kG
- kappa ~ 2
- Use deuterium, LFS injection
- Reduce inner gap
- Modify NB waveform
- Check for TAEs
- Backup: sh#121522, 123862



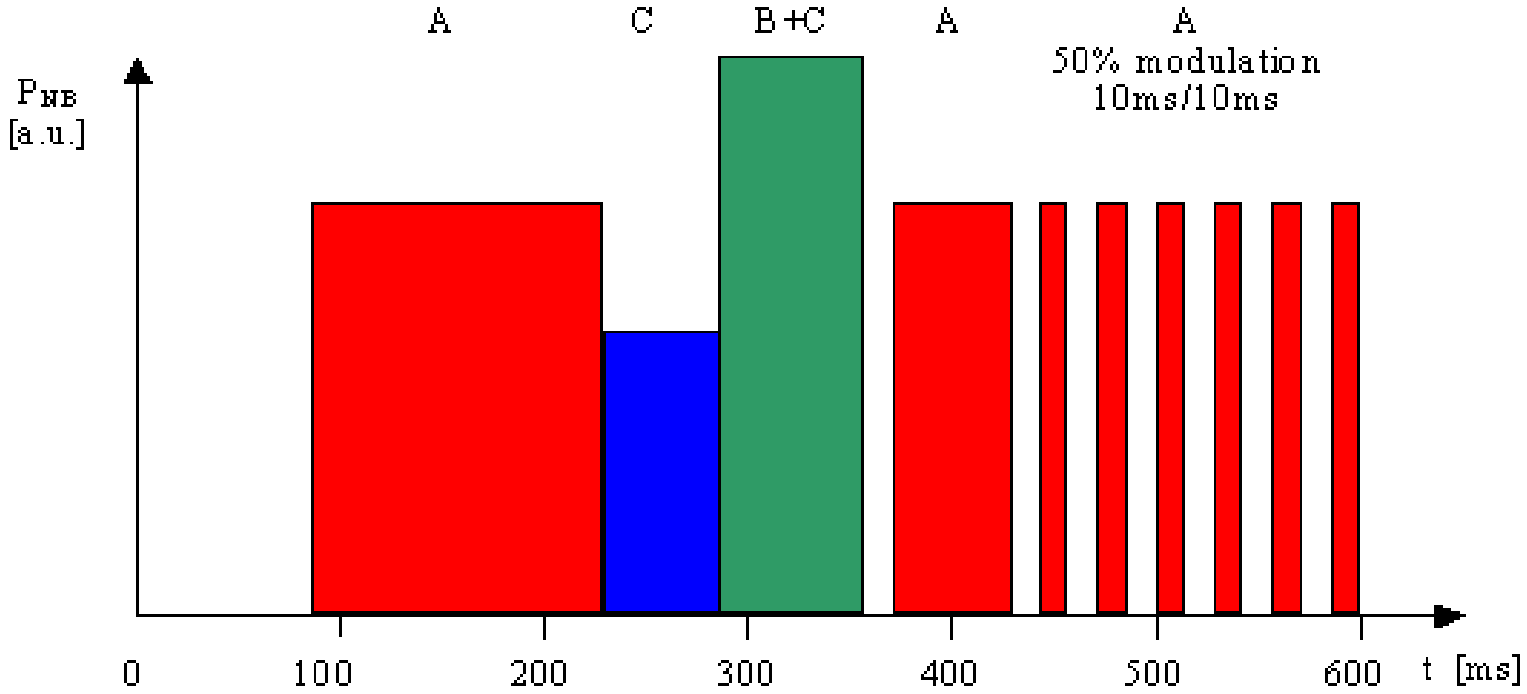
Baseline scenario at highest toroidal field, Btor=5.5kG

- Easier to destabilize TAEs (improved fast ion confinement?)
- Lower v_{fast}/v_{Alfven} more relevant for future devices
- Better coupling of HHFW power
- Smaller rho-fast present advantages for
  - Numerical codes/theory
  - Interpretation of experimental data (e.g. FIDA, NPAs)

Target plasma optimization

- Optimize density for reflectometer measurements
  - $n_0 \sim 3.2 \times 10^{19}$ m^{-3} at t ~ 350 ms
- Keep plasma in L-mode (at least up to ~400ms)
  - Center-stack limiter and LFS fueling should be enough
- Look for TAE activity: adjust NB timing, power
- Perform NB power scan to determine threshold for TAEs and avalanches
  - Source C voltage primary knob, change B voltage if needed

NB timing modified with respect to model shot



- Extend source A to beginning of flat top for MSE data
- Delay B turn-on (extend quasi-stationary phase of TAEs?)
- Source A modulated after 410ms (diagnostics checkout)
- Beam notch 350→360ms (diagnostics checkout)
- **Possible modifications during shot development**

- **Part#2: parameter scan**

Parameter scan: Plasma rotation

- EFC coils turn on at 200 ms
  - Configuration: n=3 braking, start with I_{efc}=500kA
- Optimize current
  - Binary search, scan of I_{efc}
  - Minimize rotation/shear, but...
  - Avoid plasma collapse, mode locking
  - If TAEs disappear: adjust beam voltage (source C)
- Need CHERS, possibly pCHERS
- Max 8 shots

Parameter scan: Toroidal field

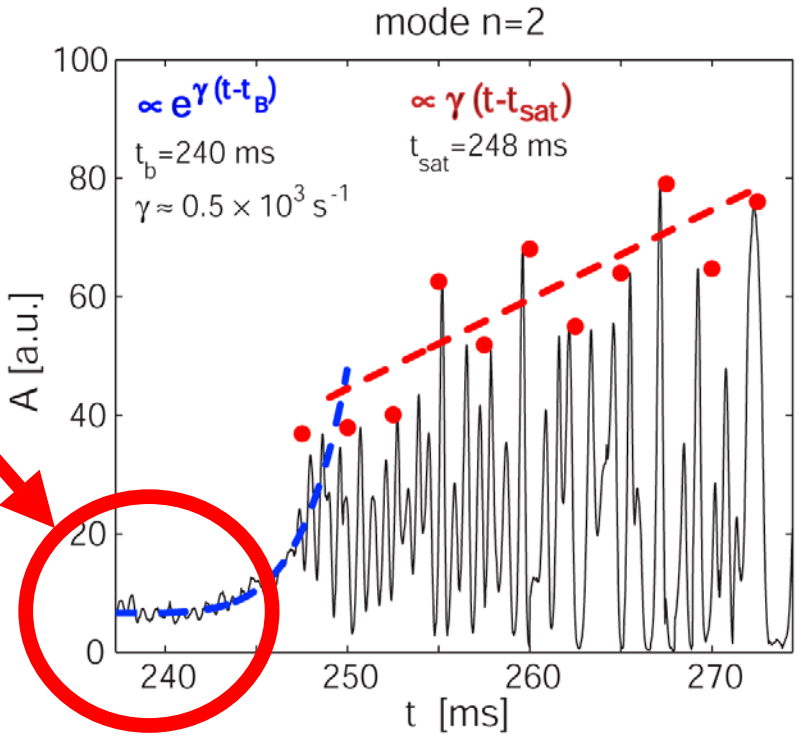
- Start from target plasma (B_{tor}=5.5kG)
  - Keep EFC coils ON if stable plasma & good signals on NPA/ssNPA achieved
- Decrease B_{tor} to 4.5kG, then 3.5kG
  - Reduce plasma current to ~match *q* from ref. shot
- For each value perform NB power scan
  - If TAEs/avalanches disappear: increase source C voltage by 5kV, repeat
  - If TAEs/avalanches still present: decrease source C voltage by 5kV, repeat
- Max 8 shots

Parameter scan: Density

- Start from target plasma (n_0~$3.2x10^{19}m^{-3}$ at 350ms)
- Decrease density: n_0~$2x10^{19}m^{-3}$ at 350ms
- Perform NB power scan
  - If TAEs/avalanches disappear: increase source C voltage by 5kV, repeat
  - If TAEs/avalanches still present: decrease source C voltage by 5kV, repeat
- If time permits: increase density: n_0>$4x10^{19}m^{-3}$ at 350ms, repeat NB power scan
- Max 6 shots

Optimized discharges for code validation

- Start from target plasma
- Remove source B: extend duration of quasi-stationary phase of TAEs to ~50ms
  - Check quality of mode structure measurements from reflectometer



- Adjust source C voltage to vary amplitude of TAEs (steps of 5kV)
- Max 8 shots

Decision point: what's next?

- If HHFW is available, move to *T_e scan*, else
- If shots are well reproducible and good signal on NPA and ssNPA, move to *NPA and f-FIDA scan*
- If time permits, perform *elongation scan*

Parameter scan: Electron temperature

- Start from target plasma (T_0~1.2keV at 300ms)
- Keep same NB timing/power as in reference shot
- Perform HHFW power scan
  - Start with P_{RF}=2MW
  - HHFW turn ON after ~30ms from onset of TAE
  - Two RF pulses, duration ~150 ms
    - Second pulse during Source A modulation (t > 410ms)
  - Increase/decrease P_{RF}, steps of 500kW
- Max 6 shots

NPA vertical scan, f-FIDA filter scan

- Repeat target plasma, good reproducibility needed for first 400ms [at least]
- Perform NPA vertical scan
  - Positions t.b.d. based on results from previous scans
- Perform f-FIDA filter angle scan
  - Focus on different portions of fast-ion spectrum
  - Change angle from shot to shot: 0, 10, 2, 8, 6, 4 deg.
- Max 8 shots

Parameter scan: Elongation (& q-edge)

- Start from target plasma (kappa ~ 2)
- Change kappa to <1.8 and >2.2
  - Stable L-mode configuration is preserved?
- For each value perform NB power scan
  - If TAEs/avalanches disappear: increase source C voltage by 5kV, repeat
  - If TAEs/avalanches still present: decrease source C voltage by 5kV, repeat
- Max 8 shots

Summary of shots

- Part#1, target plasma development 16 shots
- Part#2, parameter scan ~ 45 shots
  - Plasma rotation 8 shots
  - Toroidal field 8 shots
  - Density 6 shots
  - Code validation discharges 8 shots

Top priority

***options**

  - Te through HHFW* 6 shots
  - NPA/f-FIDA* 8 shots
  - Elongation* 8 shots

lower priority

Required diagnostics

- Plasma equilibrium
  - MPTS, CHERS (possibly pCHERS), MSE
- MHD activity
  - Magnetics
- Mode structure
  - Reflectometers, USXR, TOSXR (FIRETIP? High-k?)
- Fast ions
  - Neutrons, sFLIP, NPA, ssNPA, FIDA