ELM suppression with Resonant Magnetic Perturbations in NSTX

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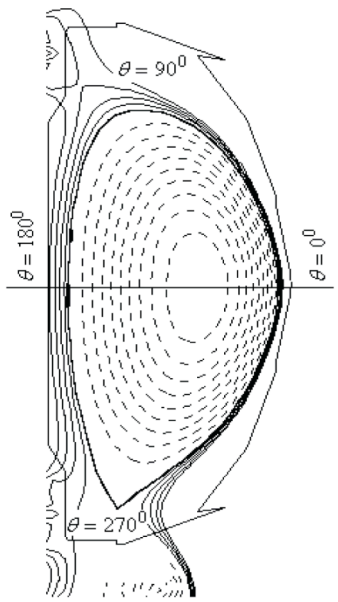
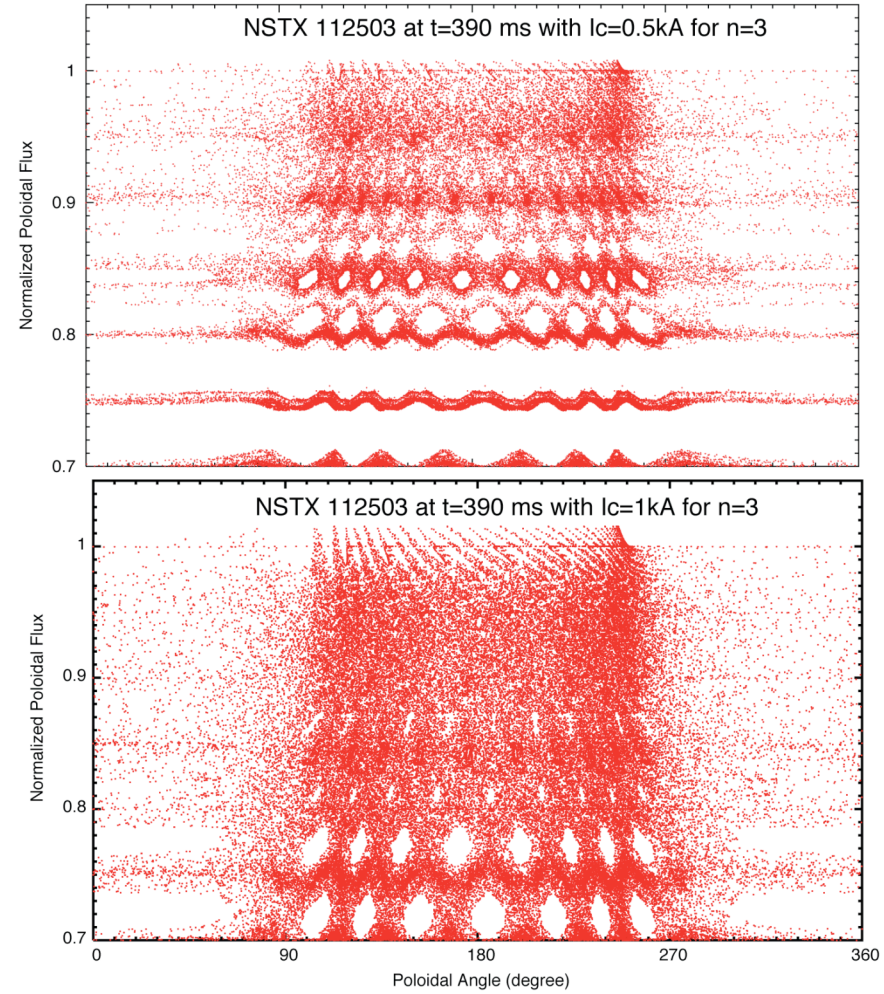
Modeled LSN



Shot 112503, time=390 ms



***In collaboration with:**
S. Kaye (PPPL) and R. Maingi (ORNL)

Resonant Magnetic Perturbation (RMP) ELM control studies on NSTX: motivation and goals

- Large Type-I ELMs are a serious concern for burning plasma experiments (such as ITER):
  - A decision is needed soon on internal versus external ELM control coils for ITER
    - High priority ITPA and USBPO ITER Issue Cards
  - ***Data is needed from the NSTX EF/RWM coil to assess the efficacy of external coils***
    - NSTX EF/RWM coil closer to the plasma than the DIII-D C-coil ⇒ increased stochasticity
- Goals:
  - Significantly modify or eliminate large Type-I ELMs using n=3 EF/RWM coil RMPs
  - Develop more complete understanding of RMP ELM suppression physics

Previous results (XP525) provide indications of RMP ELM suppression

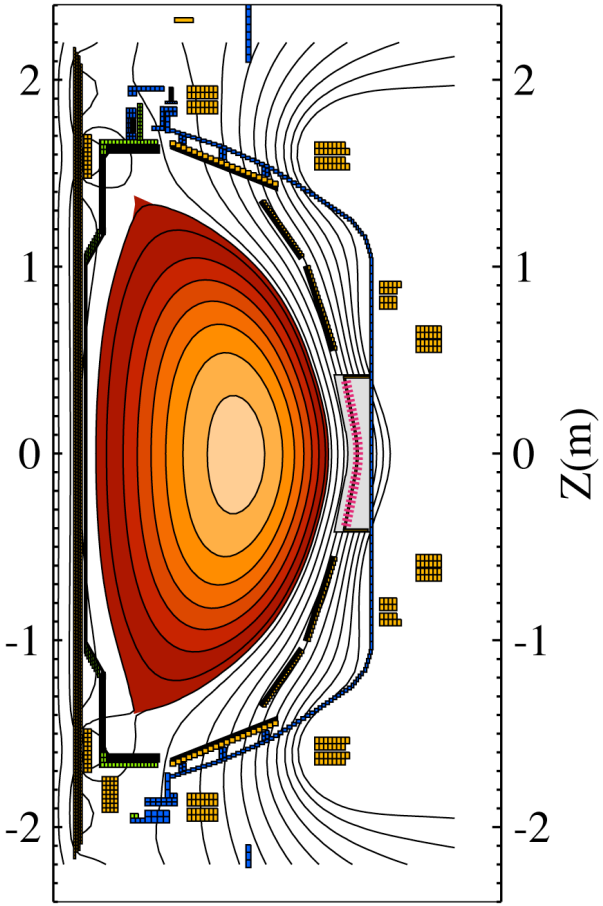
- LSN discharges (δ~0.45)
  - possible ELM suppression with RMP (300-1000A, n=3)
    - contaminated by large core (n=1) events
      - consistent with q=1 entering plasma and flattening the toroidal rotation profile
    - RMP pulse changed particle balance -> increased upper D_α baseline -> modified ELMs and L-H transition
    - L-H transition delayed from 180 ms to 235 ms due to increased upper D_α baseline
      - similar to high collisionality DIII-D ELM suppression cases: indicating changing wall conditions or higher impurity levels near the separatrix
      - Reducing the gas fueling rate from 1400 TL/s to 1300 TL/s helped but recycling increased progressively and large ELMs became less frequent prior to the n=1 events
  - RMP modifies recycling and wall sources from shot-to-shot
    - Evolving discharge conditions complicate analysis and interpretation

Balanced DN discharges also show indications of RMP ELM suppression

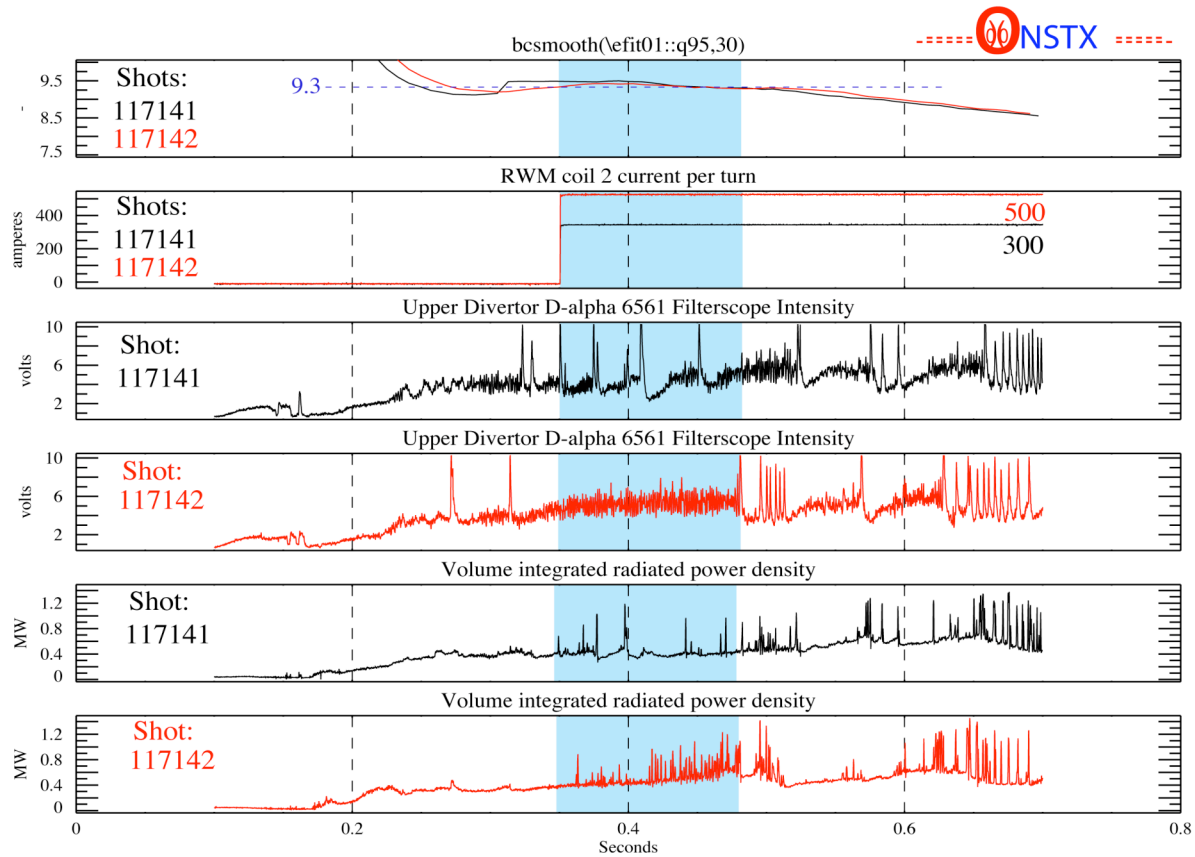
- Balanced DN discharges are somewhat more reproducible and have brief periods of RMP ELM modification
- One balanced DN case had a period of apparent ELM suppression when the RMP current was increased above 300 A
  - Discharge 117142 (n=3, 500A) had a relatively long period ($0.35 \leq t \leq 0.475$) with no Type-I ELMs
    - ELMs after 475 ms appear to be correlated with core fishbone activity
  - Robust ELMs did not reappear when RMP was turned off
    - Lagging RMP induced recycling changes may have changed ELM behavior
  - Shot-to-shot recycling hysteresis may be an issue
    - Need multiple RMP off shots to establish relation between recycling and ELMs

XP525 discharges with n=3 RMP coil currents of 0.5 kA suggest ELM suppression

XP525 Shot



EFIT02, Shot 117142, time=200ms



- Is the apparent ELM suppression seen in 117142:
  - Reproducible?
  - q_{95} dependent and/or shape dependent?

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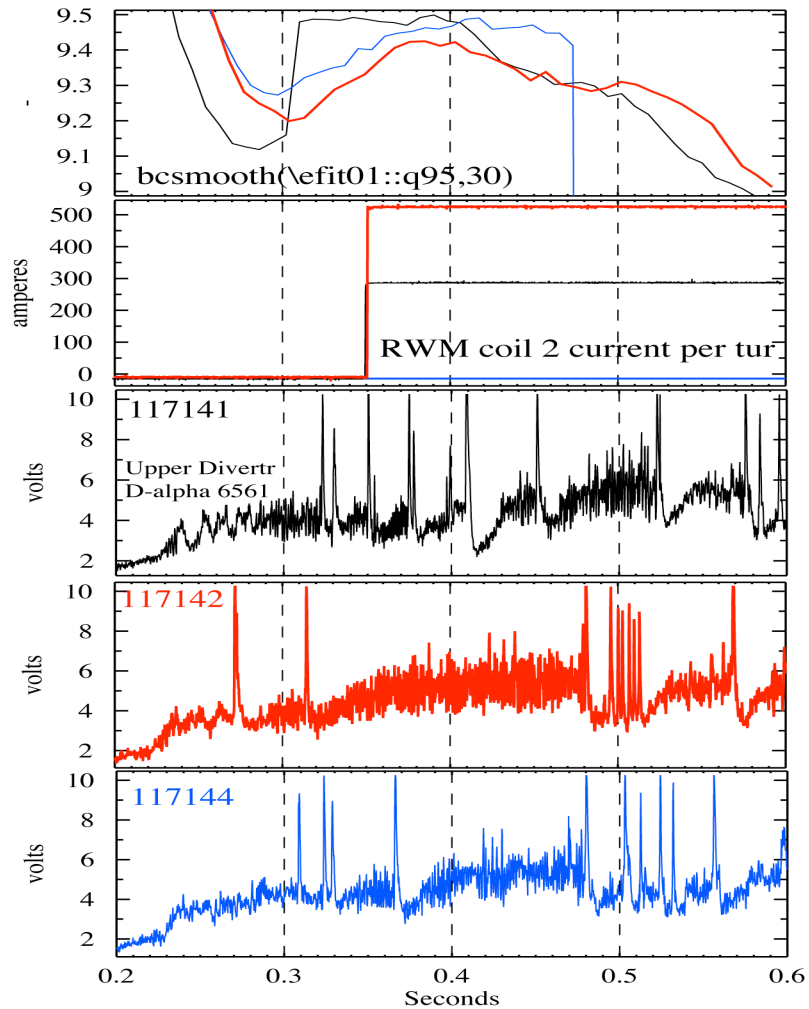
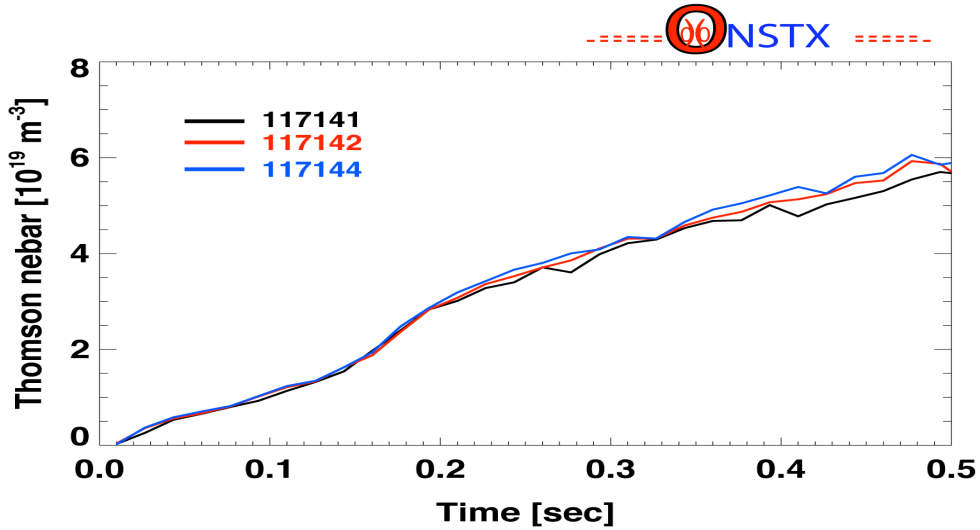
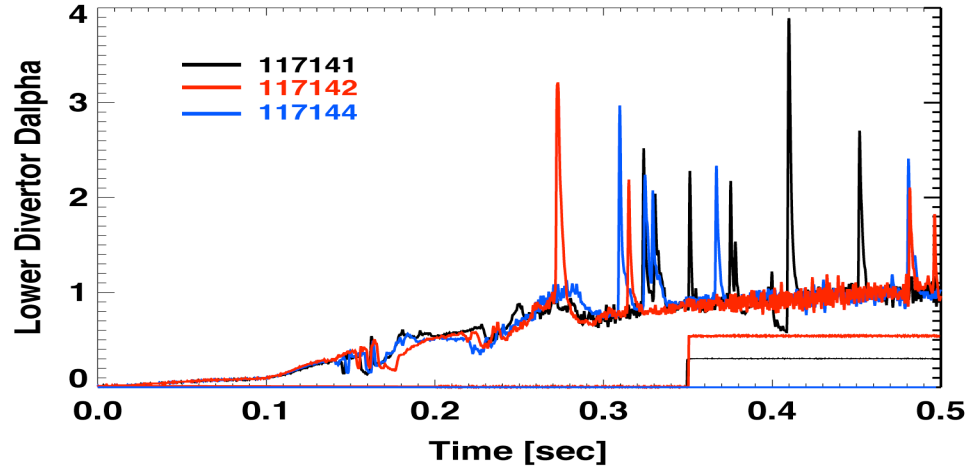
RMP induced recycling changes may affect ELMs on subsequent discharges







General conclusions from XP525

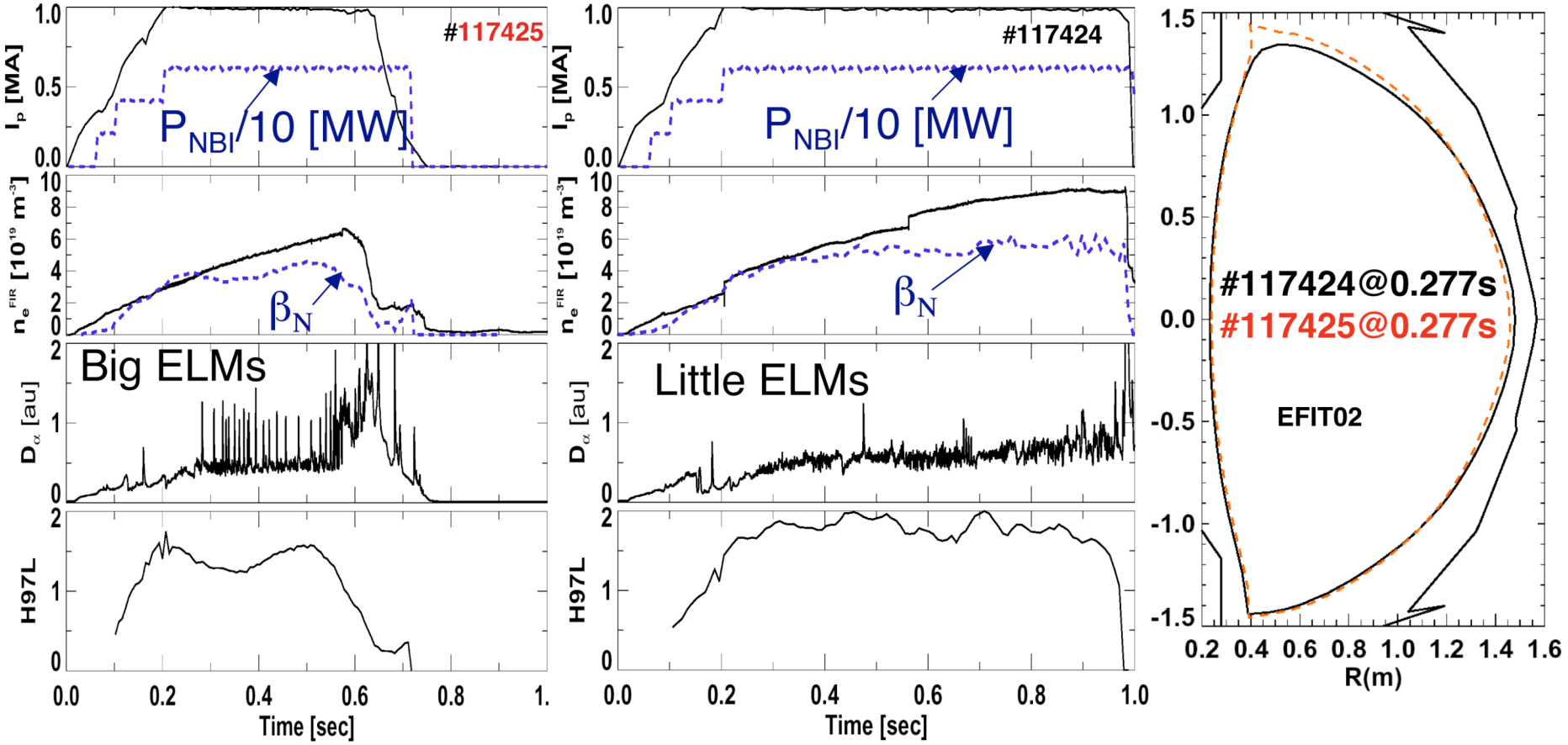
- Increased recycling delays L-H transition and reduces number of ELMs
- In LSN plasmas, the RMP increases recycling, delays L-H transition and reduces number of ELMs
  - shot-to-shot changes in wall conditions induced by RMP
  - downward biased discharges seem to be naturally high recycling early and have more irregular (fewer) Type-I ELMs
- Balanced DN shape has more frequent, regular, Type-I ELMs
- A shape with more stable wall conditions is needed
  - less dependence on changes in recycling due to RMP
  - larger more reproducible Type-I ELMs

Large reproducible Type-I ELMs are more common in DN plasmas (ref. discharge 117425)

Balanced DN or biased slightly up

Biased slightly down

Difference in $\Delta_r^{sep} \sim 0.5$cm



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Considerations for planning subsequent RMP ELM suppression experiments

- Establish upward biased DN discharge (similar to 117421, 117425 and 117427) with lower initial recycling and large regular ELMs
  - Reduced tendency for recycling to dominate the ELM behavior
- Verify dependence of ELMs on dRsep
  - Carry out 3-4 shot fine scale dRsep scan prior to RMP discharges
    - Identify best baseline discharge for large Type I ELMs with frequency > 50 Hz
- Increase outer gap to 20 cm or more to reduce TF ripple effects
  - RMP radial decay is relatively small for lower poloidal modes numbers
  - Consider doing a 2-3 shot gap scan to assess ripple and recycling effects
- Consider dedicating 5-10 discharges to low recycling (R=0.7? with Li wall conditioning) at the end of the day to assess possible low ν_e^* operating regime

Proposed experimental outline

- Reproduce discharge 117425
- Tune shape (dRsep, gapout, δ, κ) to obtain large, reproducible, Type-I ELMs
- Apply n=3 RMPs with currents between 0.5 kA $\leq I_{RWM/EF} \leq$ 3.0 kA
- Repeat best $I_{RWM/EF}$ with 60° toroidal phase shift
- If significant ELM modification/suppression is observed
  - Verify reproducibility - coil on/off shots (reference and physics documentation data)
- Scan q_{95} to assess resonant window using either I_p or B_T (B_T preferred)
- Assess shaping effects on ELM modification/suppression
  - dRsep, gapout and upper and lower δ's
- Assess effects due to pedestal collisionality and density (if time permits)

NSTX resources and desired diagnostics

- Required NSTX resources:
  - Reference shape 117425
  - I_p = 1.0 MA,
  - I_{TF}=56 kA,
  - κ =2.0,
  - Upper/lower δ, =0.6 ± 0.1/ 0.6 ± 0.1,
  - deuterium gas,
  - NBI sources A/B/C (@90 kV),
  - EF/RWM configured for maximum DC current (n = 3)
- Desired (<u>required</u>) diagnostics:
  - <u>bolometer arrays</u>, CHERS, divertor fast camera, <u>edge rotation spectroscopy</u>, <u>filterscopes</u>, FIReTIP, GPI, infrared camera, Langmuir probes (PFC tiles and RF antenna), <u>full magnetics</u>, fast lost ion probes, MSE, neutral particle analyzer, plasma TV, <u>fixed freq. reflectometer</u>, <u>Thomson scattering</u>, <u>soft x-ray</u>, visible brems
- Run days requested:
  - 1 (2 if day 1 is successful)