Shot log – experiment executed on 2/26/07
(Maingi, Hubbard, Meyer)

Goals:

1) determine if small ELM regimes in NSTX, Alcator C-MOD, and MAST are similar in the sense of a beta threshold
2) determine if the small ELMs themselves have the same structure/characteristics

Summary (19 shots ~ 5 hours): Achieved target shape at target q95=5.5 from 0.3 sec onward in latter shots, but did not get H-mode access, even with 6 MW of NBI power. In these cases, we typically ran into locked modes or L-mode beta limits at betan~3.5-4. This is typical at NBI power above 2 MW. Possible reasons:

1) High Ip for this delta ~ 0.48 (PLH goes up with Ip in NSTX)
2) High X-point, which has been shown to increase PLH at higher aspect ratio (neutrals!?)
3) Low kappa, long connection length – it is not obvious why this would play a role?

Ideas for next execution on NSTX:

1) Try few shots later in run with improved machine conditions
2) Go to kappa=1.8, where we have gotten H-modes before (check if C-MOD can match)
3) Run discharges in double-null – reduced PLH
4) Reduce Ip while maintaining q95, to reduce PLH

Turn on error field correction (EFC) coils, even if not perfectly optimized, to reduce locked mode tendency

XP 621 – Comparison of Small ELM Regimes Between C-MOD, MAST, and NSTX

A. Hubbard (MIT – C-MOD), R. Maingi, H. Meyer (UKAEA – MAST)

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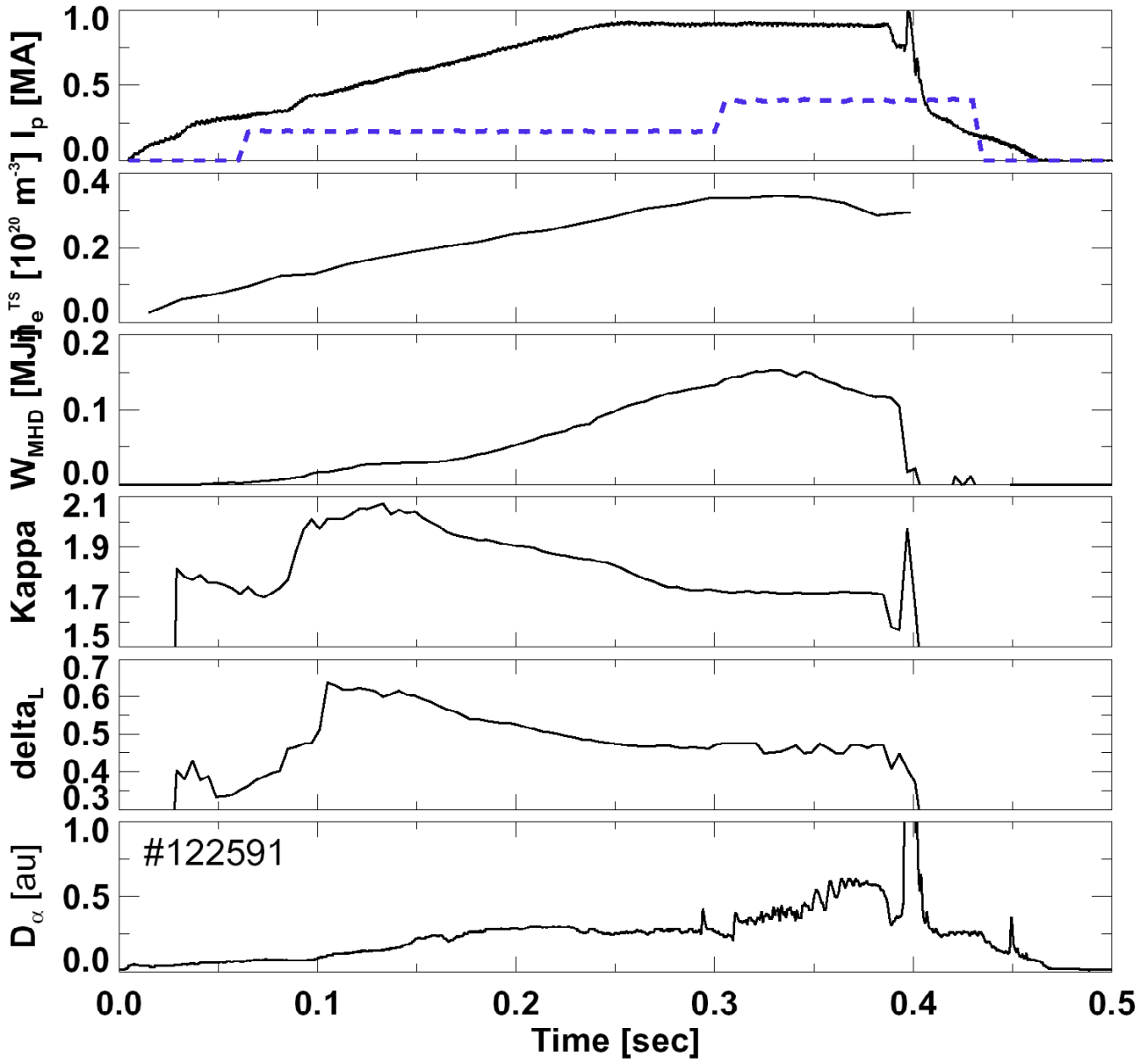
√ 1. Start with target #120769

- Tweak shape at 0.3 sec; lower target κ=1.7, δ_L=0.47; drop κ (drsep)
- Baseline with 2 NBI sources, i.e. enough to insure an L-H transition. The first NBI will go in at 60 msec and the second at 300msec.
- This shot had SGI at 1600 torr from 100-200ms. Add a little CS gas ~ 200 torr. Increase SGI duration from 100-300ms, and maybe pressure to 2400.
- Alternative: replace SGI with CS gas at 700-900 torr if needed for H-mode.
- Raise I_p to ~ 0.95 MA and keep B_t ~ 0.5 T
- Target q95 is 5.5, κ=1.7, δ_L=0.47; try to hold from 0.3-0.5 sec
- The goal is to trigger the H-mode in our target shape ~ 0.3 s. Make sure to check the inner gap stays finite, by increasing squareness if necessary. Can't use PF1a to do this – too much delta late in time (5-10 discharges)

~~2. Raise B_t ~ 0.55 and I_p=1.05 MA to maintain q95=5.5. The high B_t is needed to get target β_{ped} within the C-MOD range of 0.6%, and the I_p is needed to get target q_{95} and reasonable T_{ped} for target ν^* ~ 1. (2-5 discharges)~~

3. Vary the β_{ped} value by doing an NBI scan from 1 to 3 NBI sources; we expect 1-2 sources will yield access to the small ELM regimes. Use NBI modulation as needed to obtain finer control over P_{in} and therefore T_{ped}, β_{ped} and ν^*. (3-5 discharges)

4. Match ρ^*_{ped} and β_{ped} simultaneously by controlling the density ramp in NSTX, by controlling the gas fueling and using Helium discharge conditioning or increasing the HeGDC between shots, since β_{ped} depends on density but ρ^*_{ped} does not. This will give more independent control over T and n, allowing us to decrease ν^* and increase ρ^*_{ped} for given β_{ped}, mapping out more of the operational space and increasing overlap with C-Mod discharges. Adjust B_t to 0.5 T, 0.45 T, reducing I_p to maintain constant q_{95}, if needed to change ratio of ρ^*_{ped} to and β_{ped}. (5-10 discharges)


1.0
0.5
0.0
I_p [MA]
0.4
0.2
0.0
$\bar{n}_e^{TS}$ [10^{20} m^{-3}]
0.2
0.1
0.0
W_{MHD} [MJ]
2.1
1.9
1.7
1.5
Kappa
0.7
0.6
0.5
0.4
0.3
delta$_L$
1.0
0.5
0.0
D_α [au]
#122591
0.0
0.1
0.2
0.3
0.4
0.5
Time [sec]

Shot log – experiment executed on 2/26/07 (Maingi, Hubbard, Meyer)

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4) High Ip for this delta ~ 0.48 (PLH goes up with Ip in NSTX)
5) High X-point, which has been shown to increase PLH at higher aspect ratio
6) low kappa – it is not obvious why this would play a role.

Ideas for next execution on NSTX:

5) Try few shots later in run with improved machine conditions
6) Go to kappa=1.8, where we have gotten H-modes before (check if C-MOD can match)
7) Run discharges in double-null – reduced PLH
8) Reduce Ip while maintaining q95, to reduce PLH
9) Turn on error field correction (EFC) coils, even if not perfectly optimized, to reduce locked mode tendency
10) Give up on q95 match – what about matching q*?

Actual shot log

120769 – base shot with kappa=1.7, delta=0.48 at 0.3-0.5 sec, 2 MW NBI, Ip=0.72 MA, Bt=0.5 T; supersonic gas injector used instead of center stack continuous gas feed for ne control; result: no H-mode, large reconnection at 240ms. Shape match good to C-MOD at 0.3 and 0.5 sec. This shot has a pf1a (high delta coil) startup. PF2 (low delta) coils were switched on from 0.1-0.3 sec, transitioning the shape to target by 0.3 sec. Run on 5/19/06.

122479 – attempted reload of 120769 on 2/22/07, except that center stack gas at 1100 torr fill pressure replaced supersonic gas injector. Up/down oscillations during ramp-up due to change in rtEFIT from 2006-2007. Large reconnection ~ 0.28 sec. Not a good reproduction of #120769, but deemed sufficient by the run coordinator to continue on 2/26/07.

Actual shots from 2/26/07 – boronization on 2/25/07

122570 – standard high delta ~ 0.7, 1 MA, 0.45 T fiducial. Lasted ~ 420ms (short), but otherwise ok. Went into H-mode ~ 130ms and stayed in H-mode entire shot.

122571 – **STEP 1 OF SHOT PLAN** reload 122479; kappa=1.7, delta=0.48 at 0.3-0.5 sec, 2 MW NBI (source A), Ip=0.72 MA, Bt=0.5 T. No center stack gas fueling because of apparent timing problem, no H-mode, kappa OK by 0.4 s

122572 – try again – same fueling timing problem

122573 – try again, add source B from 0.3-0.34 sec.Center stack gas fueling is at 1100 torr plenum fill pressure. OK. Goes into H-mode ~190ms, followed by compound ELM, and then stays in H-mode until ~ 0.4 sec. Inner gap rather small throughout, got to target kappa of 1.7 ~ 0.5 sec. However this q95 is too high.

122574 – drop out 2nd NBI source at 0.3 sec. Still got nice long H-mode, which went out of H-mode ~ 0.4 sec. Kappa drops just after we go out of H-mode down to target value of 1.7. The q95 in this shot is still too high, compared with our desired value.

122575 – **STEP 2 OF SHOT PLAN** -begin development to get right q95=5.5: Ip=0.85 MA, Bt==0.5 T, 2 MW NBI. Kappa drops from 0.16-0.3 sec, going below 1.8 by 0.3 sec. Nice L-mode, no H-mode access.

122576 – go to q95=5.5: Ip=0.95 MA, Bt=0.45 T, 2 MW NBI. Kappa evolves as above, and no H-mode, as above.

122577 – add src. B from 0.3-0.34 sec; ohmic, no NBI.

122578 – try to fix bobble in ramp-up. Didn't work – reconnection at 0.25sec. Kappa does get down to 1.7 by the end of the shot.

122579 – repeat again trying to fix bobble in the ramp-up by slowing down the Ip ramp rate Get to flattop just before 0.2 sec. A little better. No reconnection at 250 ms, had some dithers, but no clear H-mode. Actually got to betan ~ 5 in this L-mode! That must be a first. No locked mode, until maybe very end near 0.45 sec – not clear.

122581 – add source B from 0.25 sec to the end of the shot. Slow down the Ip ramp rate again to get to flattop just after 0.2 sec. Maybe a slight dither at 0.29 sec, but no sustained H-mode. Got to target shape again by 0.3 sec. Locked mode at 0.31 sec. MHD seems to start very close to the time of the second source.

122582 – change timing of source B back to 0.3 sec, and change shape again. Slow down the Ip ramp rate again to get to flattop ~0.22 sec Inner gap went back to zero. No H-mode. Shot lasted to 0.42 sec.

122583 – tweak the shape again. Slow down the Ip ramp rate again to get to ~ 0.23 sec Great shape match at 0.3 sec at the right target q95=5.5, i.e. inner gap is fine. MHD starts again shortly after the second source comes on at 0.3 sec, hit the center stack hard at 0.32 sec, and shot falls apart afterwards.

122591 – reduce Ip to 0.9 MA, Bt=0.425 T. Also replace source B with source C, which drives less MHD sometimes. Same nice shape match out from 0.3 to almost 0.4 sec. Again MHD comes in after the second source at 0.3 sec, and mode slows down and locks at 0.39 sec. Still no H-mode, even though there were a couple of slowing down times.

122593 – Now add source B at 180 ms, so that we have 3 sources at 0.3 sec. Big locked mode ~ 0.25 sec, ugly. Betan ~ 3.5 by 0.25 sec, probably hit beta limit.

Here we decided to try the fiducial again to make sure something else was not wrong.

122594 – reload high delta 1 MA fiducial. Sucked – locked mode at 0.18 sec. Looks like fueling is too low.

122595 – try fiducial again – lasts longer to 0.28 sec, but still sucked compared to normal. Fueling definitely too low.

122596 – increased fueling on center stack to 1200 torr and repeat fiducial. Much better – shot lasted past 650 ms. Still some unsteady behavior, but otherwise just fine.

Back to XP 621 – however the rest of these shots sucked, with earlier locked modes than earlier in the day. In this phase of the day, H-mode access at 0.3 sec would have been too late.

122598 – reload 122591 and increase fueling to 1250 torr. This shot had 2 MW from 60 ms and added a second source at 0.3 sec. Shape match is fine at 0.3 sec again, but still no H-mode access and shot ends with locked mode.

122599 – increase outer gap to 10cm to reduce impact of fast ions on passive plates. No difference – locked mode ~ 0.26 sec. Did not make it to shape match phase.

122600 – tried to add source B at 100 ms – failed, no source B, and also moved source C earlier to 280 ms. The early source was to try to trigger an early H-mode. Locked mode came in before source C now.

122601 – repeat trying to get source B – no NBI, was ohmic.

122602 – drop Ip to 0.8 MA, and leave Bt at same level, to see if we can get into H-mode at higher q/lower Ip. Also added a source B blip from 100-140 ms. We did get an H-mode during the Ip ramp as expected, but large Elm triggered reconnection and center stack touch, destabilizing early locked mode.