

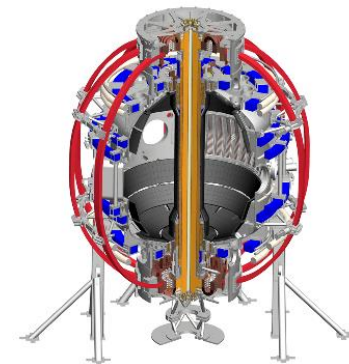


# XMP-151: L-mode development results

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NSTX-U Results Review  
9/21/2016



# Summary: Goal of XMP-151 was to establish expanded L-mode scenarios for core and boundary XPs

- Four parts of XMP based on desires expressed in meeting on April 4, 2016

## 1) Establish higher power L-mode

- Stationary, sawtooth discharges with 2.5-2.9 MW achieved using HFS fueling and various NBI 1 combinations
- Strong  $n=2$  mode (3/2 tearing?) often develops
- Edge rotation also likely locked by 2/1 mode
- Wanted to try using LFS fueling (influence on inner wall “dancing rings”/MARFEs & MHD?)

## 2) Assess beam tangency radii

2A) Try individual sources at  $\sim 1$  MW on a shot-by-shot basis

- Clear changes in MHD, but unreliable HFS fueling and beams that afternoon ( $\rightarrow$ L-H-L)
- Was planning to repeat

2B) Try 2-source combinations ( $\sim 1+1$  MW): peaked vs. broad; tan. vs. perp.

- Not done

## 3) Establish upper $I_p$ limit

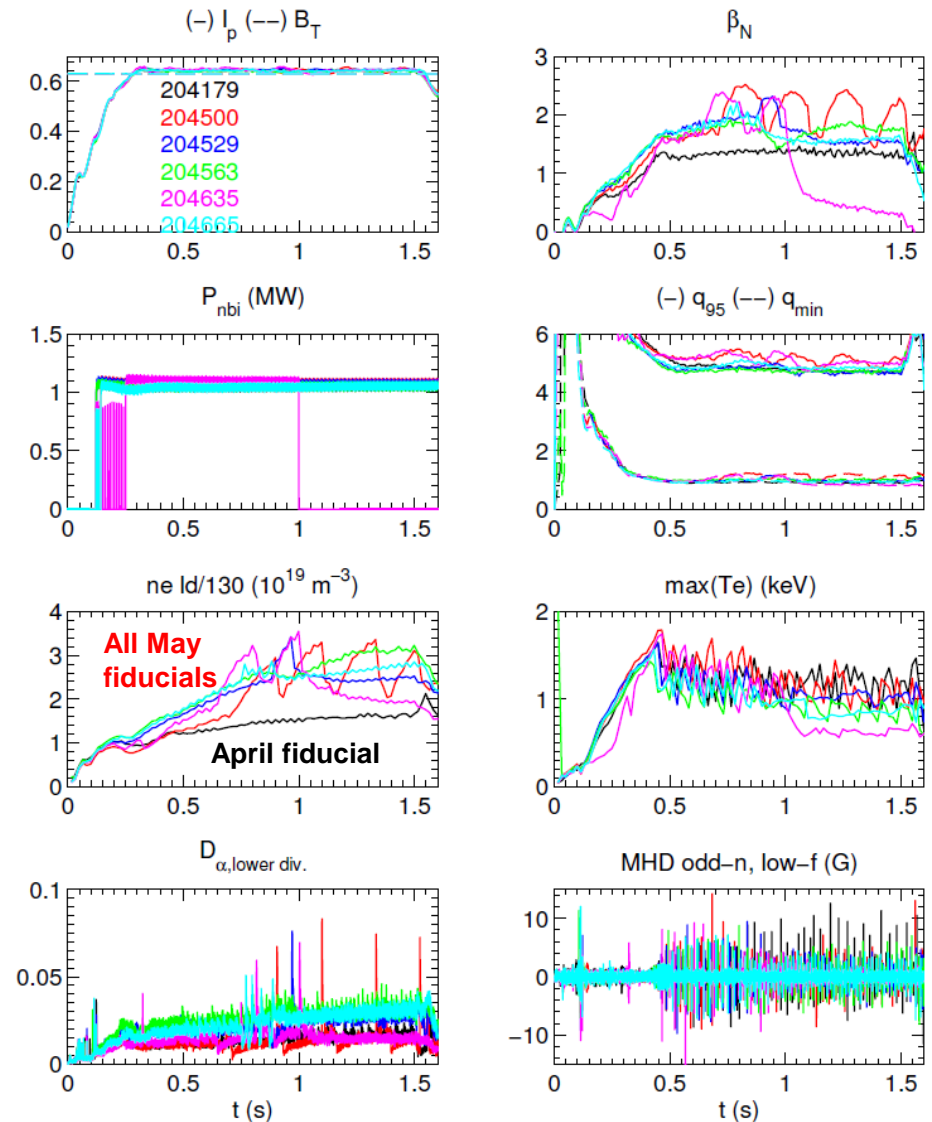
- Achieved up to 1 MA
- Did not have time to find upper limit

## 4) Establish lower BT scenarios (0.55, 0.45, 0.35 T)

- Not done

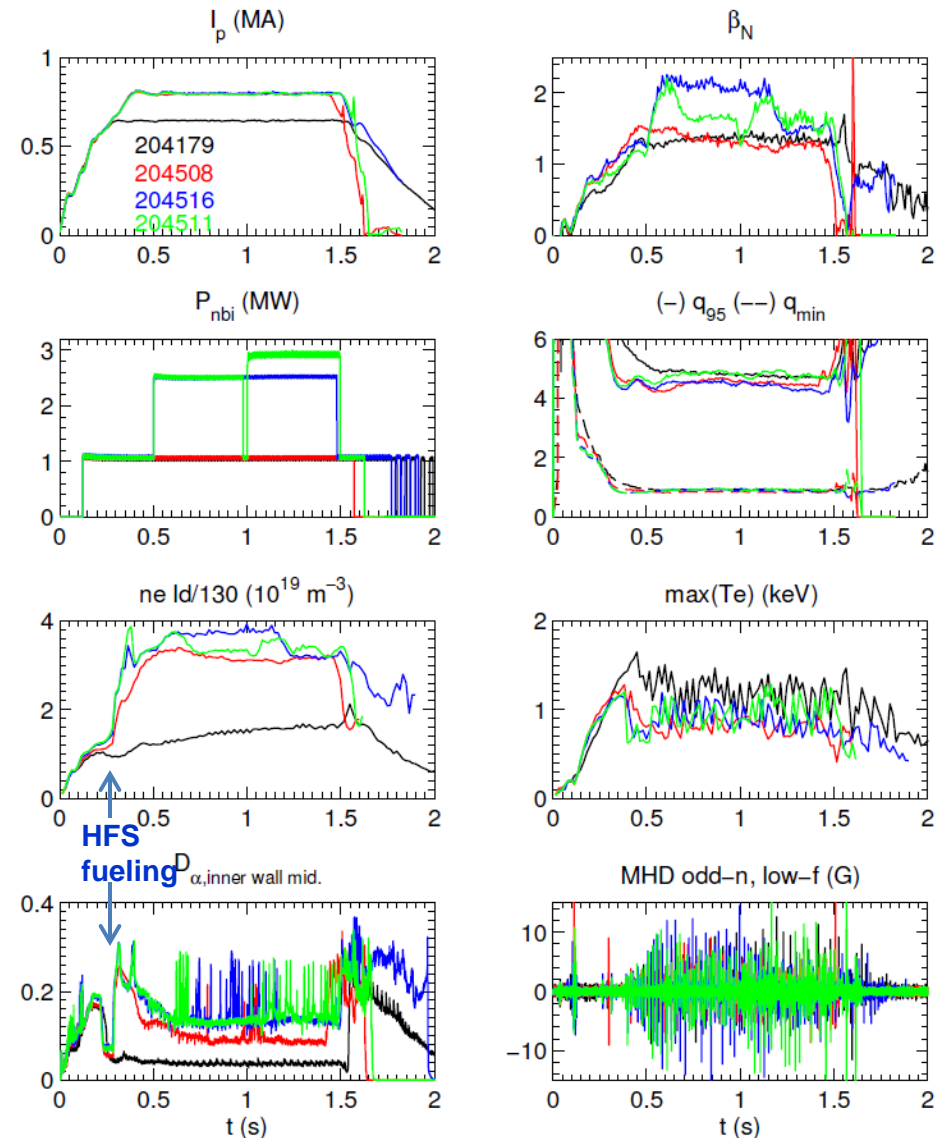
# All May L-mode fiducials (204500+) exhibit L-H/H-L and/or n=2 MHD

- 204179 was last fiducial prior to April 11-29 maintenance period
- All fiducials May 2-20 exhibited L-H/H-L transitions
  - Only showing fiducials with ~1 MW
  - A couple ohmic cases (missed beams) ran OK
- $\beta_N$ ,  $q_{95}$ ,  $q_{\min}$  from EFIT01 in these slides



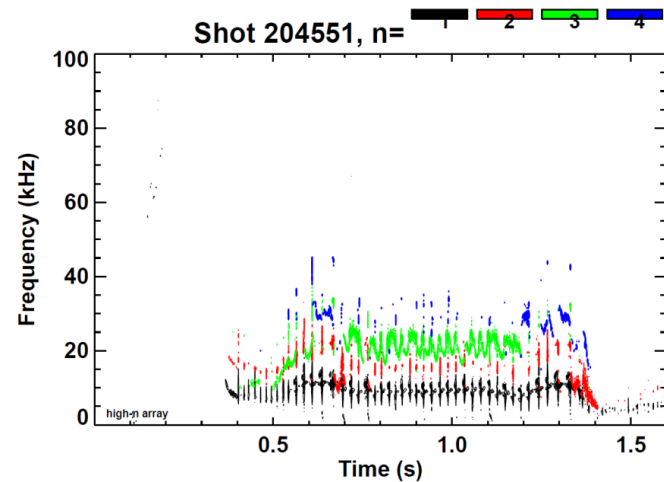
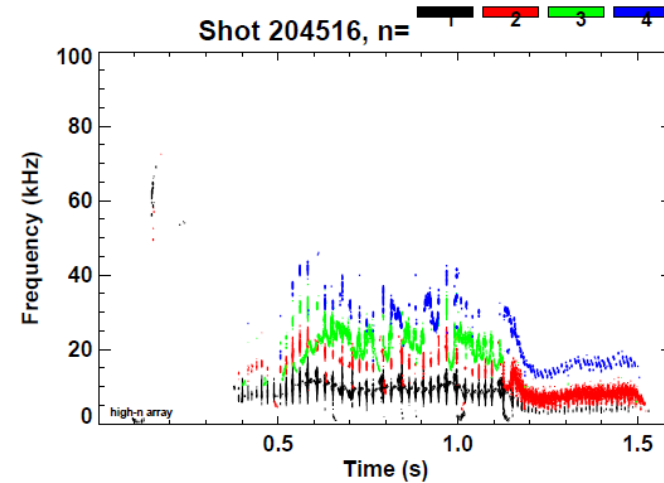
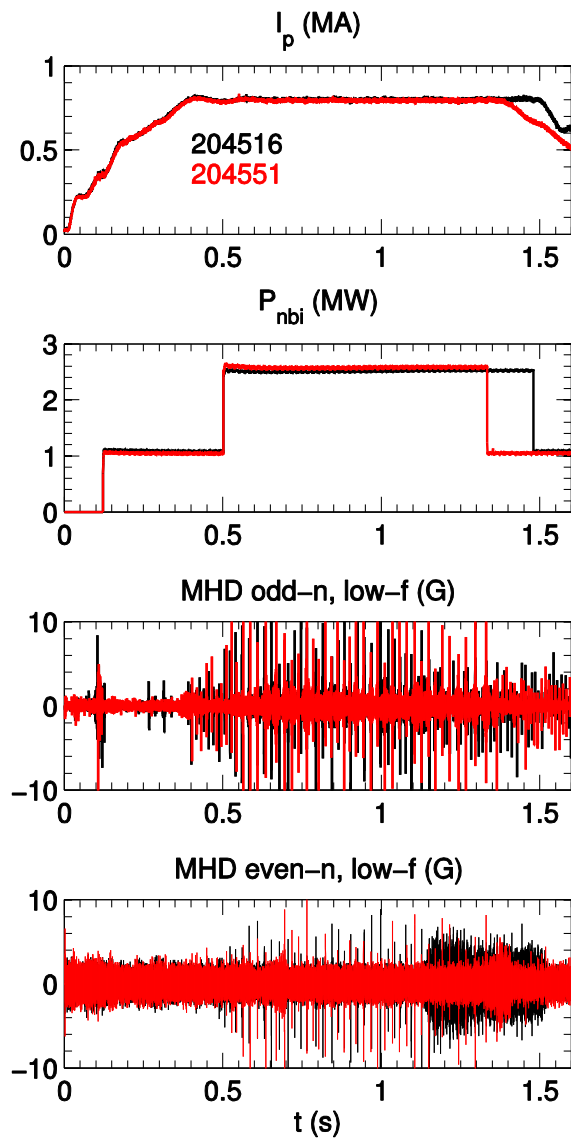
# Part 1 (5/5/2016) – 800 kA w/ increased HFS fueling & NBI 1 power

- Increased  $I_p$  from 650 to 800 kA
- Increased HFS fueling to eliminate L-H
  - Initial increases in LFS had little effect – **wanted to revisit this**
- Sustained shots with up to 2.5 MW (1B+1A) and 2.9 MW (1B+1C),  $\beta_N \geq 2$ 
  - Tried up to 3.5-4.3 MW but shots die from MHD (often associated with L-H/H-L)
- Crazy MARFE-like “dancing rings” observed in inner wall midplane spectroscopy ( $D_\alpha$ , O II, C II)
- All shots sawtoothing ( $\Delta t \sim 35$  ms,  $R_{inv} \sim 125$  cm)
  - Faster, weaker sawteeth ( $\Delta t \sim 20$  ms) with higher density and/or NBI 1C?
- Drop in  $n_e$ ,  $\beta_N$  often seen due to strong  $n=2$  MHD (e.g.  $\sim 1.2$  s in 204516)



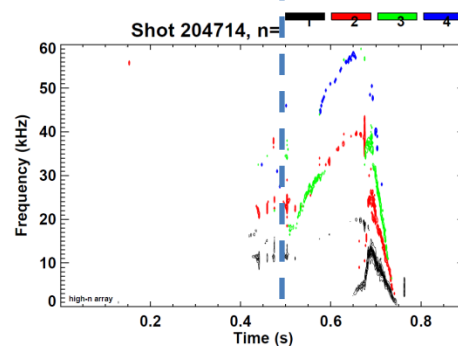
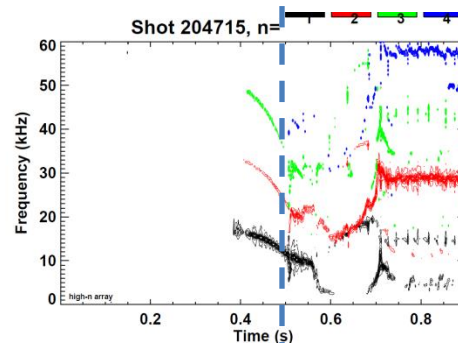
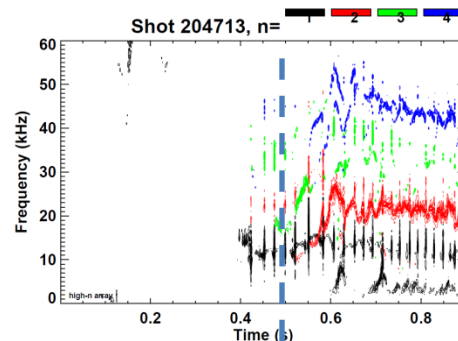
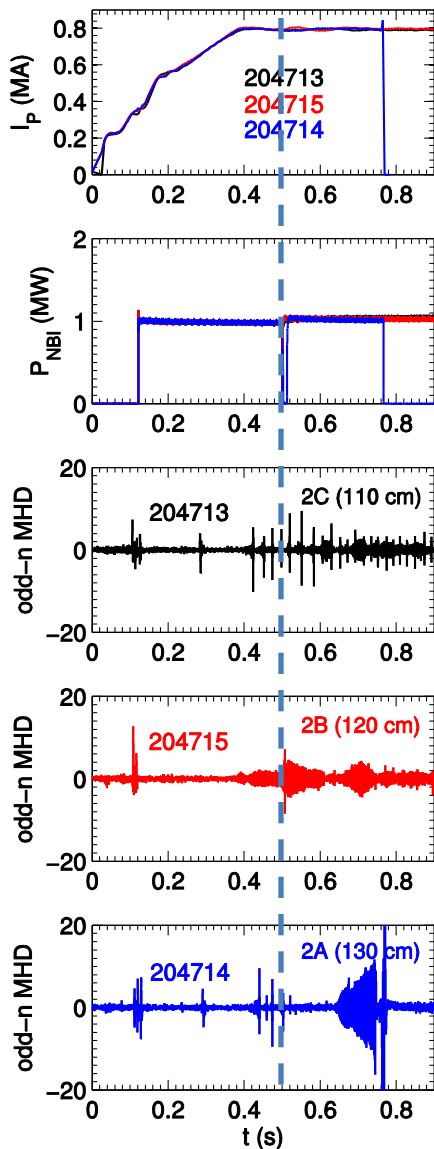
# Otherwise duplicate 800 kA shots, 204516 develops n=2 earlier than 204551 (clamps core rotation and density)

- Strong n=2 often develops after L-H-L



# Part 2A (5/13/2016) – First attempt trying all 6 NBI sources individually (1 MW)

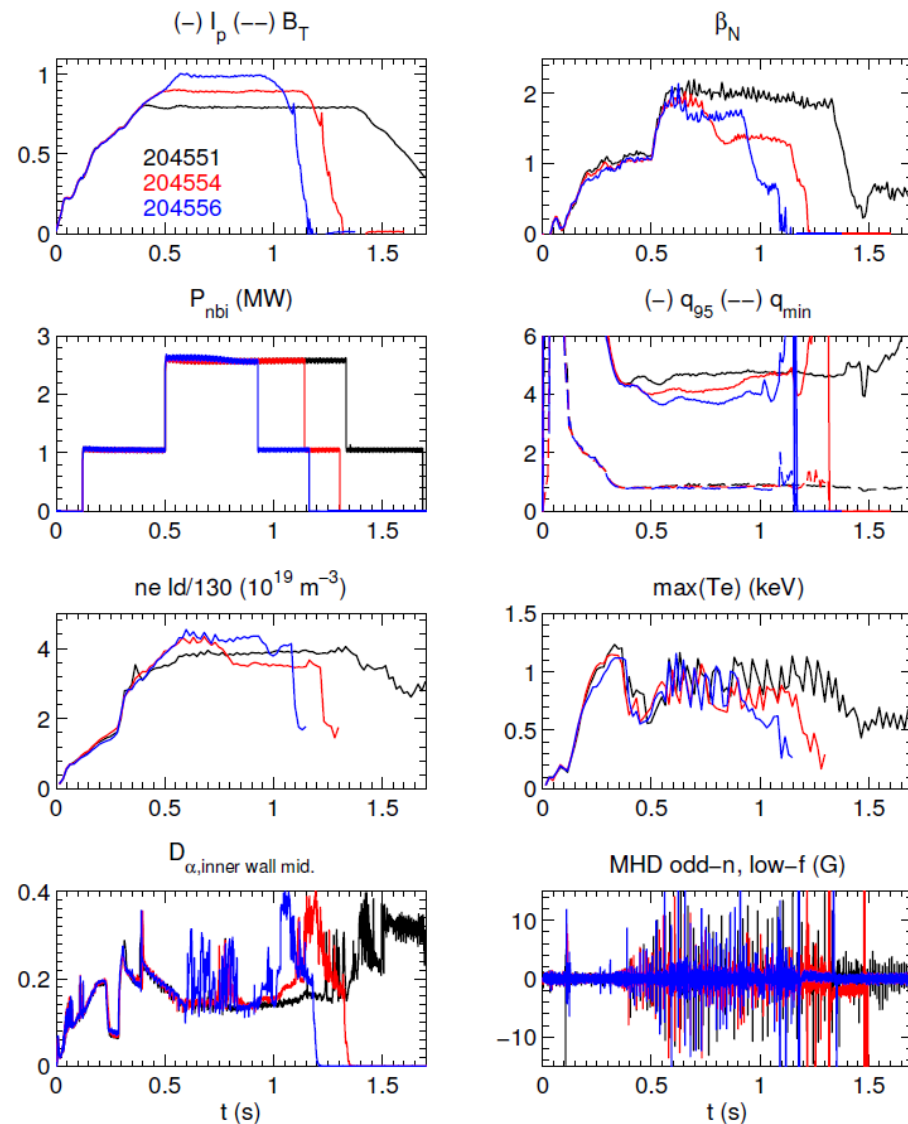
- Incorrect fueling (lots of L-H-L) and an unreliable beams that afternoon – **planned to repeat**





# Part 3 (5/6/2016): Was able to increase plasma current to 0.9 & 1.0 MA at higher density, fueling

- To recover high density (following boronization & numerous short H-mode attempts) required HFS @ 1300 Torr for one shot
  - Returned to 900 Torr after
- Easily moved to 0.9 MA & 1.0 MA ( $q_{95} \sim 3.7$ )
  - Did this in a couple shots at the end of a day – **did not clearly identify Ip limit**
- $n=2$  MHD always develops eventually







# Some of my favorite XMP-151 shots

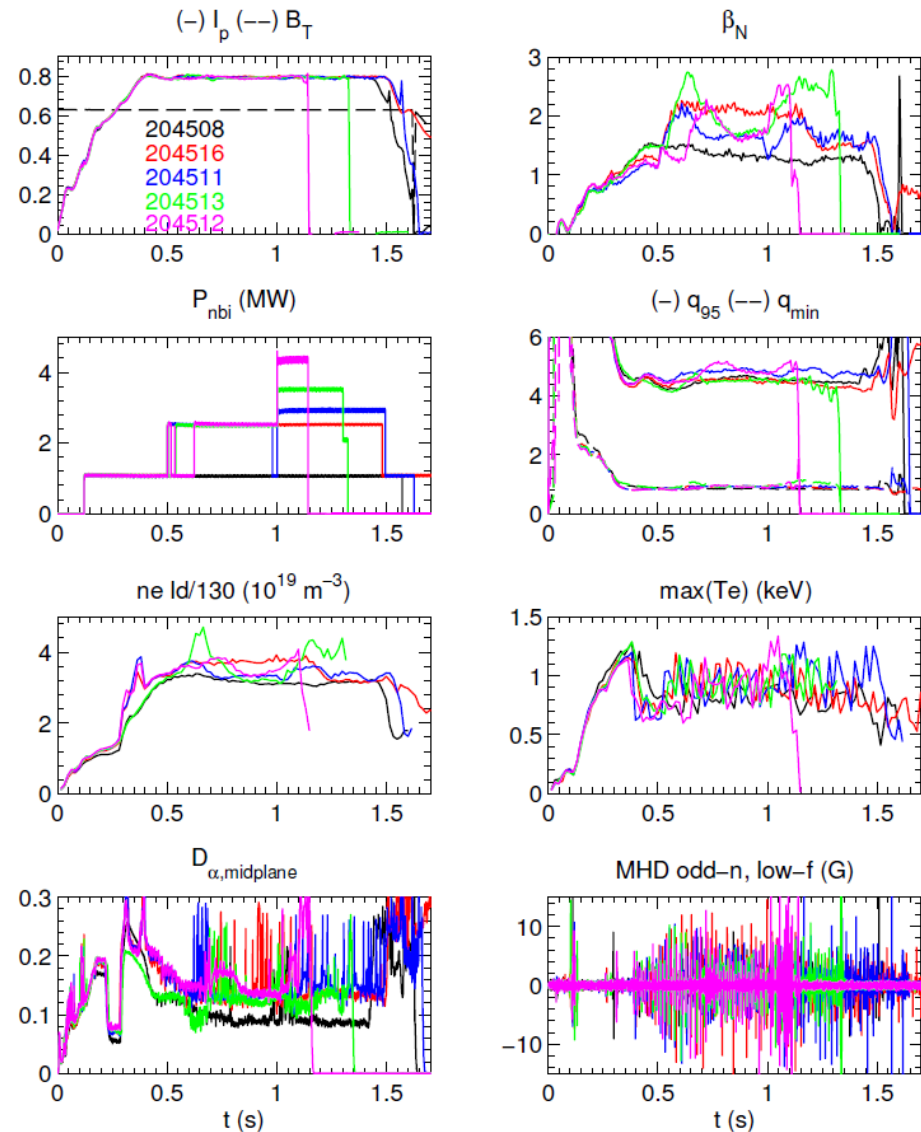
- (5/5/2016) 800 kA w/ increased HFS fueling & power
  - 204499-507 – fiducial, then increased fueling to prevent H-mode
  - **204508 – 1 MW, 1B (0.12 s), lasts >1.5 s ( $3 \times 10^{19} \text{ m}^{-3}$ )**
  - **204510 – 2.5 MW, 1B+1A (0.5-1.15 s)**
  - **204511 – 2.5 MW, 1B+1A (0.5-0.98 s), 2.9 MW, 1B+1C (1-1.5 s)**
  - 204512-515 – 3.5-4.3 MW attempts (1A+1B+1C) that die from H-mode/MHD
  - **204516 – 2.5 MW, 1B+1A (0.5-1.5 s)**
  - **204519 – 1A (0.12), 1B (0.5 s), lost 1A early (0.6 s)**
  
- (5/6/2016) 0.8, 0.9, 1.0 MA (1B, 1.1 MW, 0.12 s + 1A, 1.5 MW, 0.5 s)
  - 204547-550 – increase fueling to establish density & prevent H-mode
  - **204551 – 800 kA (ST → n=2 MHD @ 1.35 s)**
    - 0.9-1.2 sec best conditions for T&T analysis?
  - **204554 – 900 kA (ST → n=2 MHD @ 0.68 s???)**
  - **204556 – 1.0 MA (ST → n=2 MHD @ 0.9 s, after 1A turn-off)**

# Some of my favorite XMP-151 shots

- (5/13/2016) 800 kA, 1 beam (1 MW) tangency scan
  - 204709 – 1C (1 MW), first shot,  $n=3$  (2 kA),  $t > 1.0$  s (L-H-L, MHD, slow vert. osc.)
  - 204710 – 1C (1 MW), long shot but no SPAs
  - Following shots use 1B  $t < 0.5$  s &  $t > 1.3$  s, swap source between 0.5-1.3s
    - Also had very weak HFS fueling due to gas pressure reading issue, issues with L-H-L, vert. osc.
  - 204713 – 2C (drops out 0.95-1.09 s)
  - 204714 – 2A (ends at 650 ms from locked mode)
  - 204715 – 2B (good, 1 L-H-L at 520 ms)
  - 204716 – 1A (good, 2 L-H-L)
  - 204717 – 1C (good, 1 L-H-L)
  - 204718 – 1B (good, L-H-L, vert. osc. that slowly grows)
    - Finally realized we were getting almost no additional fueling
  - 204719 – 1B – higher fueling, too much, cools edge, plasma dies

# (5/5/2016) Many shots testing increased power up to 4.3 MW

- Many shots to vary NBI 1 power
  - 2.5 (1B+1A & reversed order)
  - 2.9 MW (1B+1C)
  - 3.5-4.3 MW (1B+1A+1C) – too high to avoid H-mode and/or shot-ending MHD
- Crazy MARFE-like “dancing rings” (D. Battaglia) observed in innerwall midplane spectroscopy ( $D_{\alpha}$ , O2, C2)
- Drop in  $n_e$ ,  $\beta_N$  often seen due to transition from sawteeth to  $n=2$  MHD (e.g.  $\sim 1.2$  s in 204516)



# Late Friday afternoon (5/13) it was observed that HFS plenum pressure reading was no longer accurate

- 204710 – FPDP Watchdog timer tripped at end of shot
- 204711-712 – no shots (didn't reset FOMS; clock cycle)
- 204713-718 → faulty HFS pressure reading
  - Fueling very late & weak based on plasma TV & EIES inner wall  $D_{\alpha}$
- Using data from previous days, fit  $\Delta t_{D_{\alpha-CS}} \sim 1/P_{HFS}^{1/2}$  – implies HFS pressures between 60-200 Torr for rest of Friday afternoon (we were requesting 400 Torr)
  - This is based on requested pressure in the Logbook, no measurement signal available in MDSplus?

