



U.S. DEPARTMENT OF
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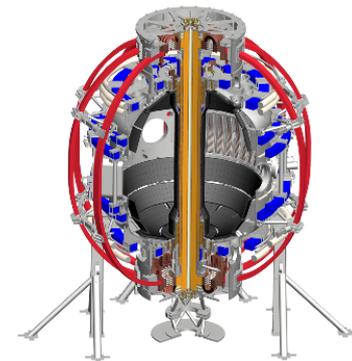
XP-1506: Low- β Locked Mode Studies

Preliminary results from January 21, 2016

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MS TSG Meeting
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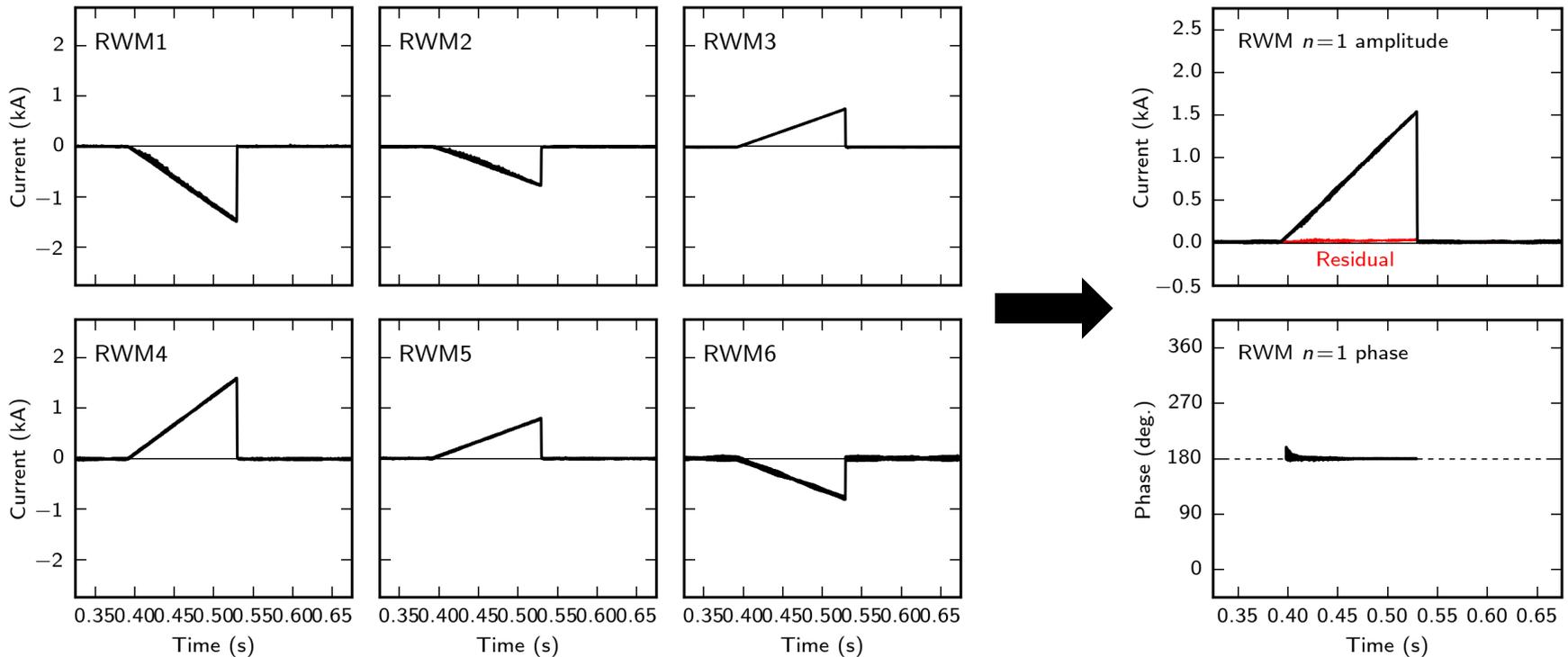
Summary of the Jan. 21 run

- Initial run of XP-1506
 - Goal to complete an initial compass scan
 - 600 kA, pure ohmic plasmas
 - $D_2, n_e \sim 0.6-1.4 \times 10^{13} \text{ cm}^{-3}$
- Summary of the afternoon (20 total attempted shots)
 - 3 development shots before applying $n=1$ fields [203007–203009]
 - 6 shots with applied $n=1$ fields to stabilize density and optimize vertical control [203010–203015]
 - 8 good shots (6 of them locked successfully) [203016–203023]
 - 2 shots lost to Level 1 trips before the shot [203024–203025]

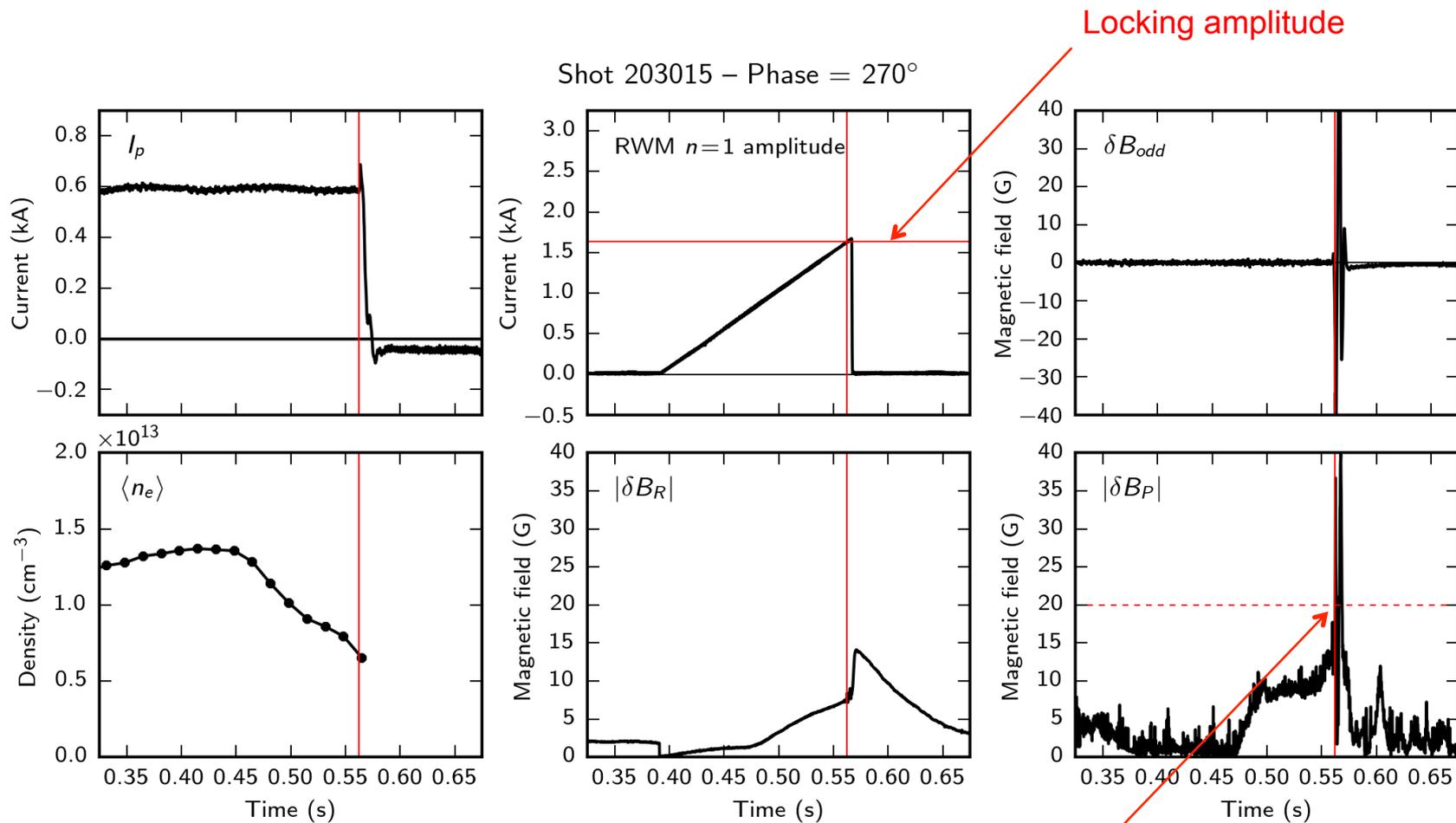
Successfully generated $n=1$ fields with the RWM coils

- Request ramping RWM currents in an $n=1$ pattern at fixed phase
- Fit $n=1$ function to the results: 6 RWM currents \rightarrow phase and amplitude
- The residual from the $n=1$ fit is very small (red)

Shot 203018 – Phase = 180°



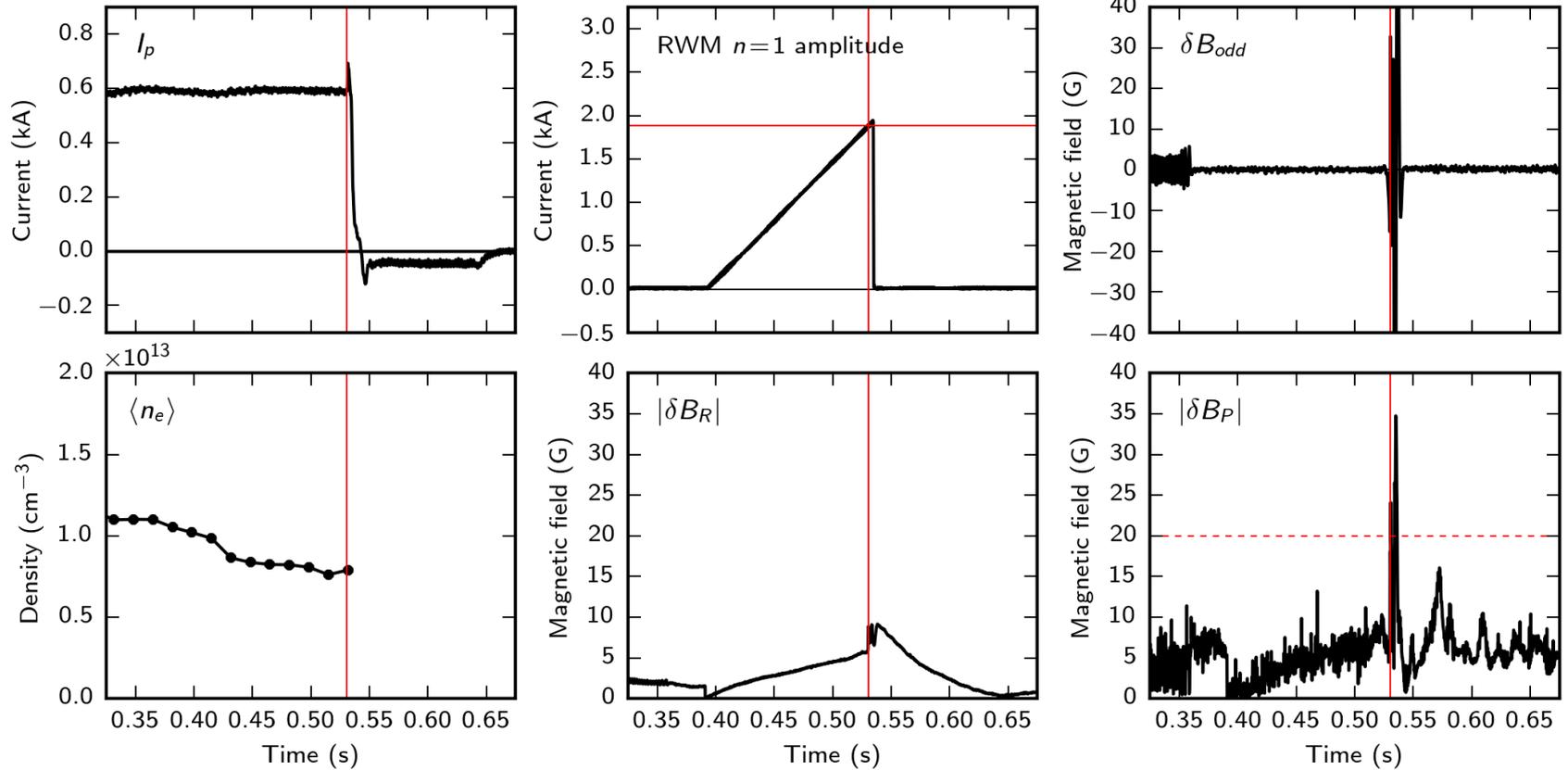
Locked modes are triggered in many cases



Determine t_{lock}

Pre-locking signal not always so obvious

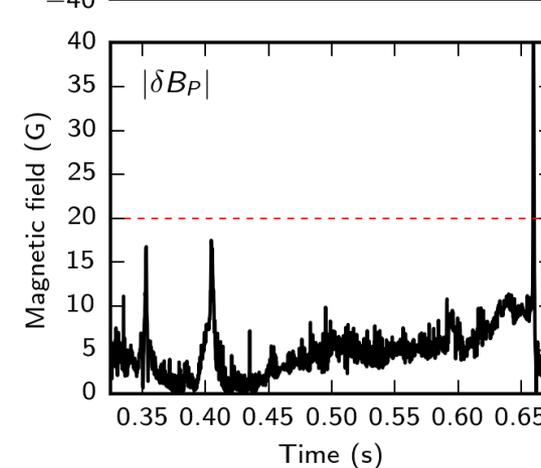
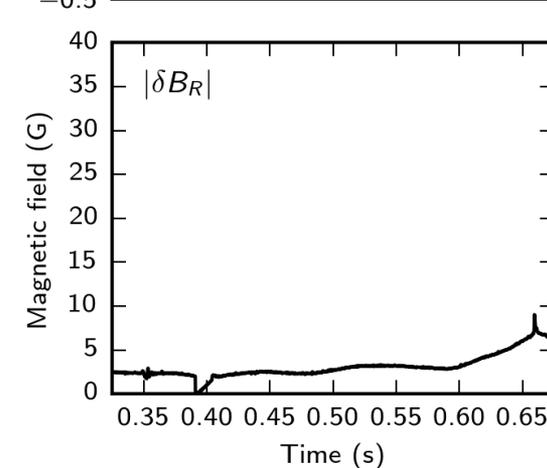
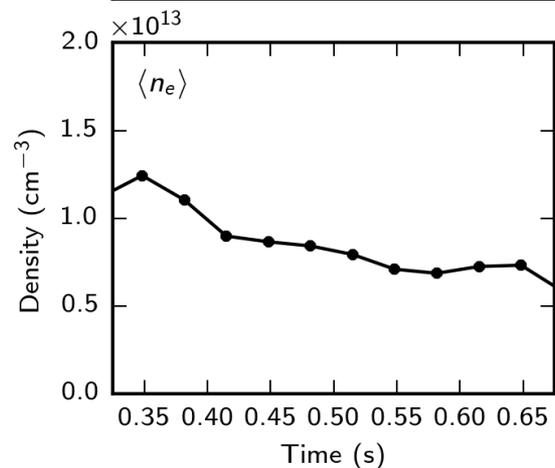
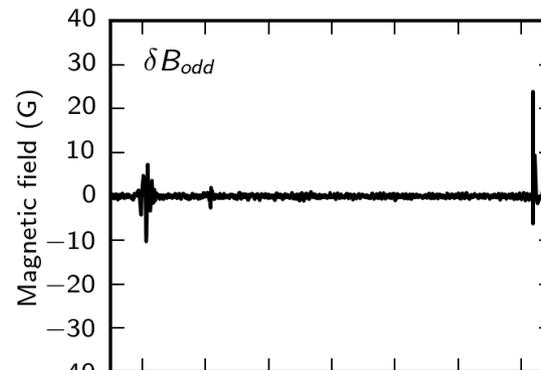
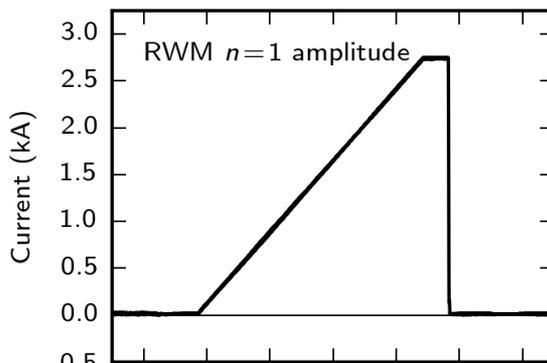
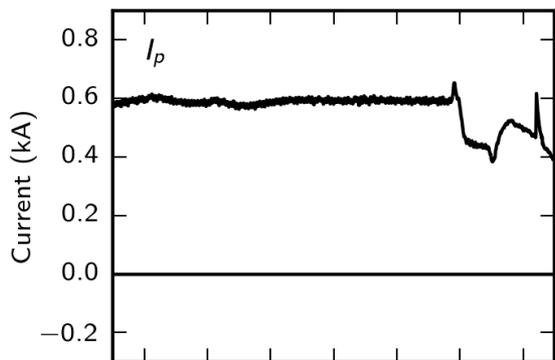
Shot 203023 – Phase = 135°



And some shots did not lock at all

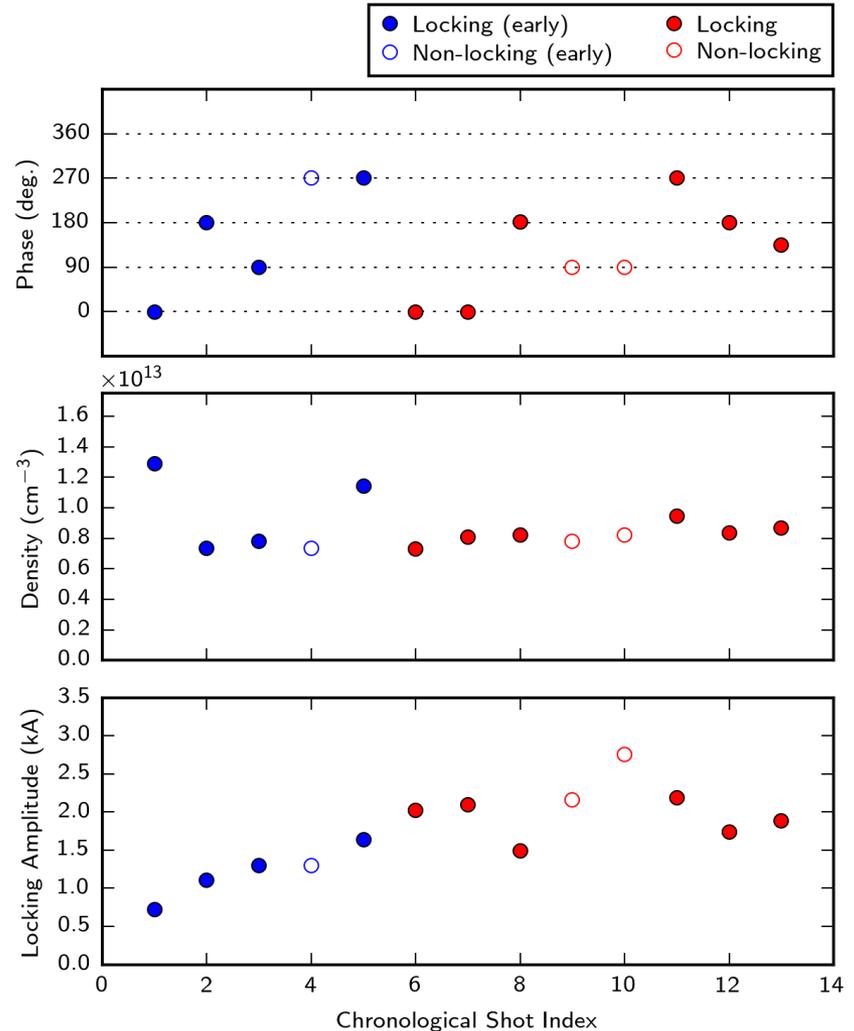
Reached max programmed RWM current without locking

Shot 203020 – Phase = 90°



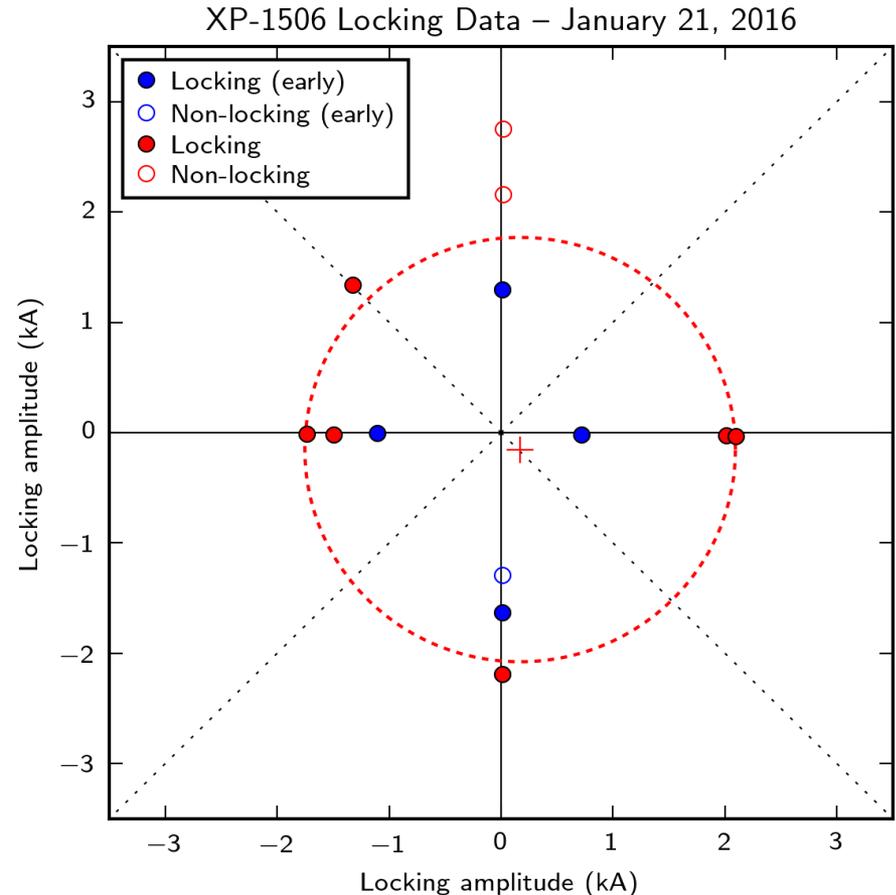
The locking thresholds evolved chronologically

- Scanned the applied phase around twice as the day evolved
- It took ~5 shots for the density to stabilize
 - These shots are labeled as ‘early’ shots
 - Not sure that density is entirely to blame for the observed early shot behavior
- The locking threshold rose monotonically at first, regardless of the phase
 - It’s not entirely clear what was changing from shot-to-shot
 - Repeated two shots at 0° midway through the day to establish repeatability
- During the later shots, two discharges at 90° phase failed to lock
 - Maximum applied amplitude = 2.75 kA
 - A 90° case did lock during the early shots



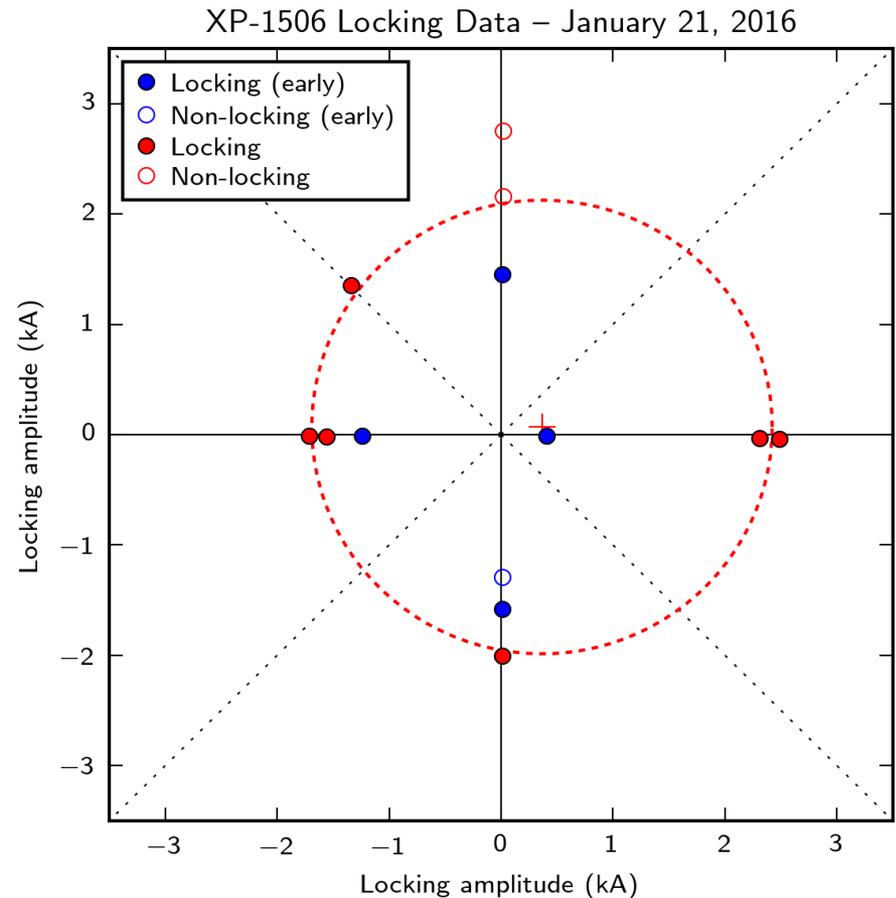
The compass data is a mixed bag

- Plotting details
 - All 13 shots are included
 - Only the 6 later shots that successfully locked (solid red) are included in the fit
 - There are four unique phases due to repeated shots at 0° and 180°
- Interpretation
 - All of the early shots locked at lower amplitude than the later shots
 - The 6-shot fit produces a reasonable circle with the origin centered at $I_0=230$ A, $\phi_0=318^\circ$
 - The glaring problem is that both non-locking shots at 90° lie outside of the circle



Density normalization cleans things up a bit

- Plotting details
 - All 13 shots are included
 - Only the 6 later shots that successfully locked (solid red) are included in the fit
 - There are four unique phases due to repeated shots at 0° and 180°
- Interpretation
 - All of the early shots locked at lower amplitude than the later shots
 - The 6-shot fit produces a reasonable circle with the origin centered at $I_0=372$ A, $\phi_0=11^\circ$
 - Better, but both non-locking shots at 90° still lie outside of the circle



Locked mode density scaling from Menard et al., *Nucl. Fusion* **50**, 045008 (2010)

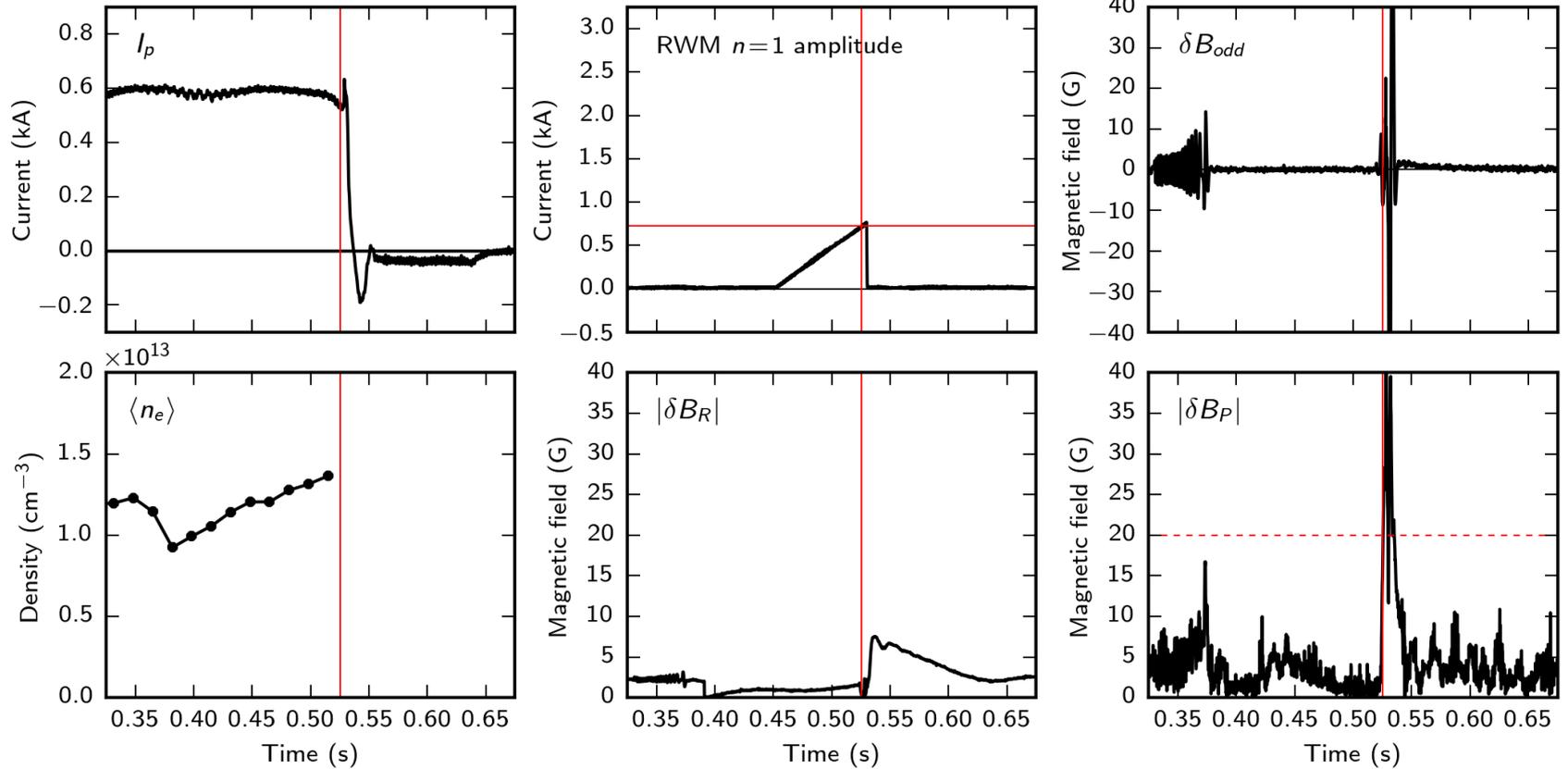
Thoughts on the next compass scan

- Discharge modifications
 - Run in helium instead of deuterium for more repeatable density evolution?
 - Lower the density to get more repeatable and/or cleaner locking?
 - Go to a limited rather than diverted target?
 - 20 kA rather than 8 kA OH pre-charge to extend the flattop → slower ramp
 - Run the SPAs all of the way to 3 kA instead of 2.5 kA
- Shot sequencing
 - Start by firing at a single phase to establish repeatability
 - Establish a good low density target (output of XMP-137?)
 - See if locking can be achieved (again) at 90°
 - Get at least six points to fill out the ellipse
 - After one scan is completed, return to the 8 kA OH pre-charge to identify differences from the 20 kA case?

Shot-by-shot locking data

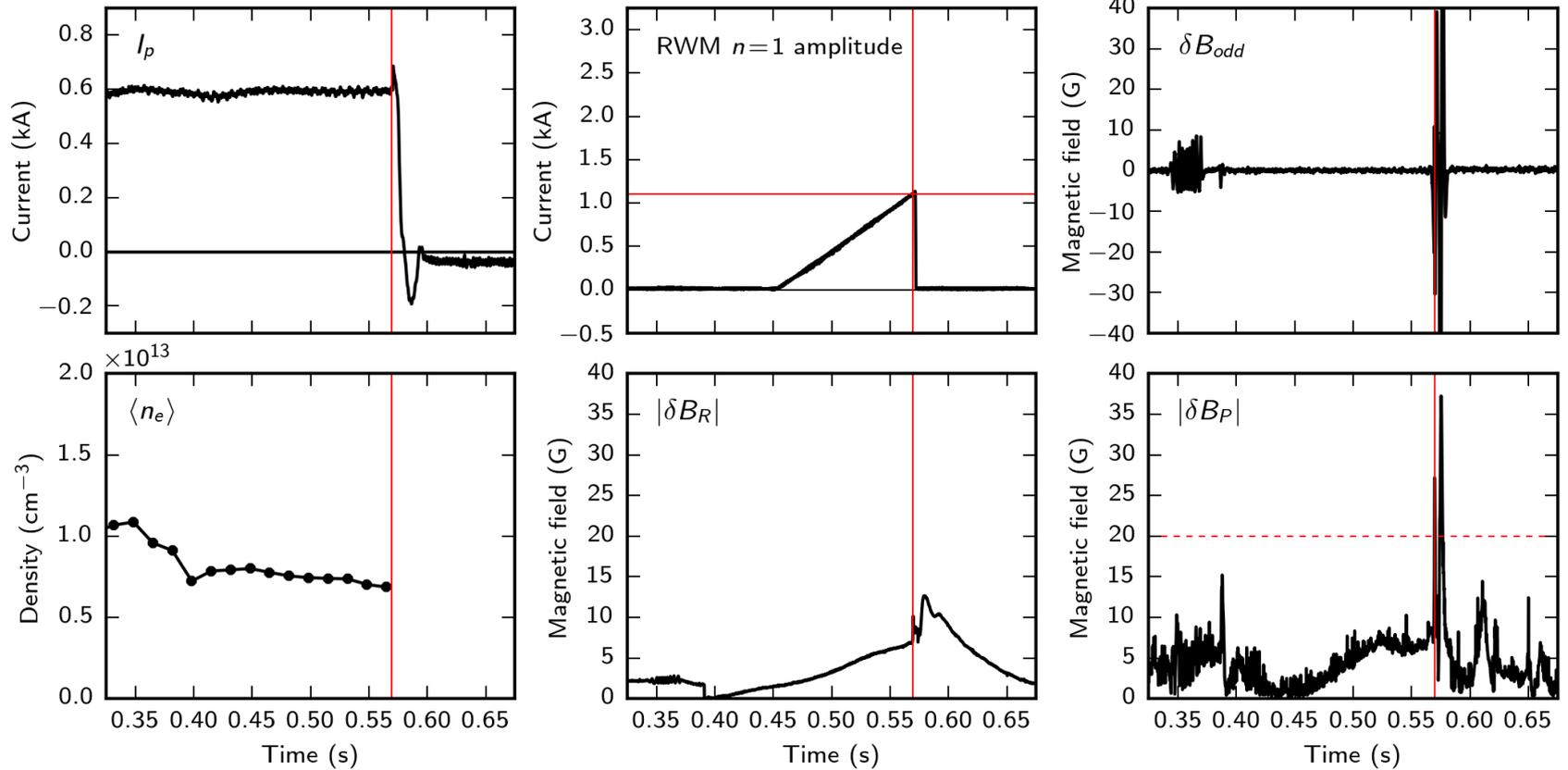
Shot 203010 – Phase = 0°

Shot 203010 – Phase = 0°



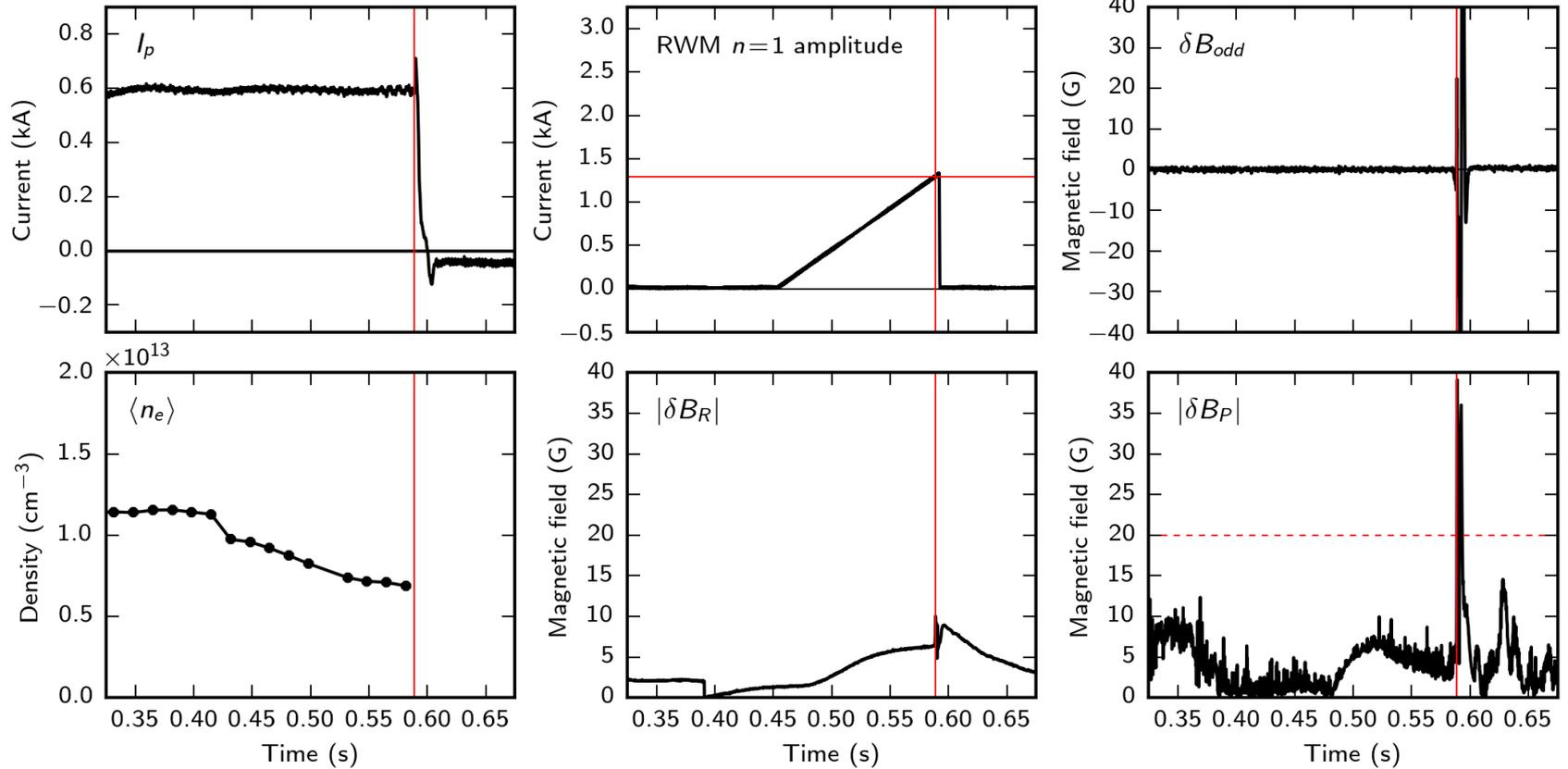
Shot 203012 – Phase = 180°

Shot 203012 – Phase = 180°



Shot 203013 – Phase = 90°

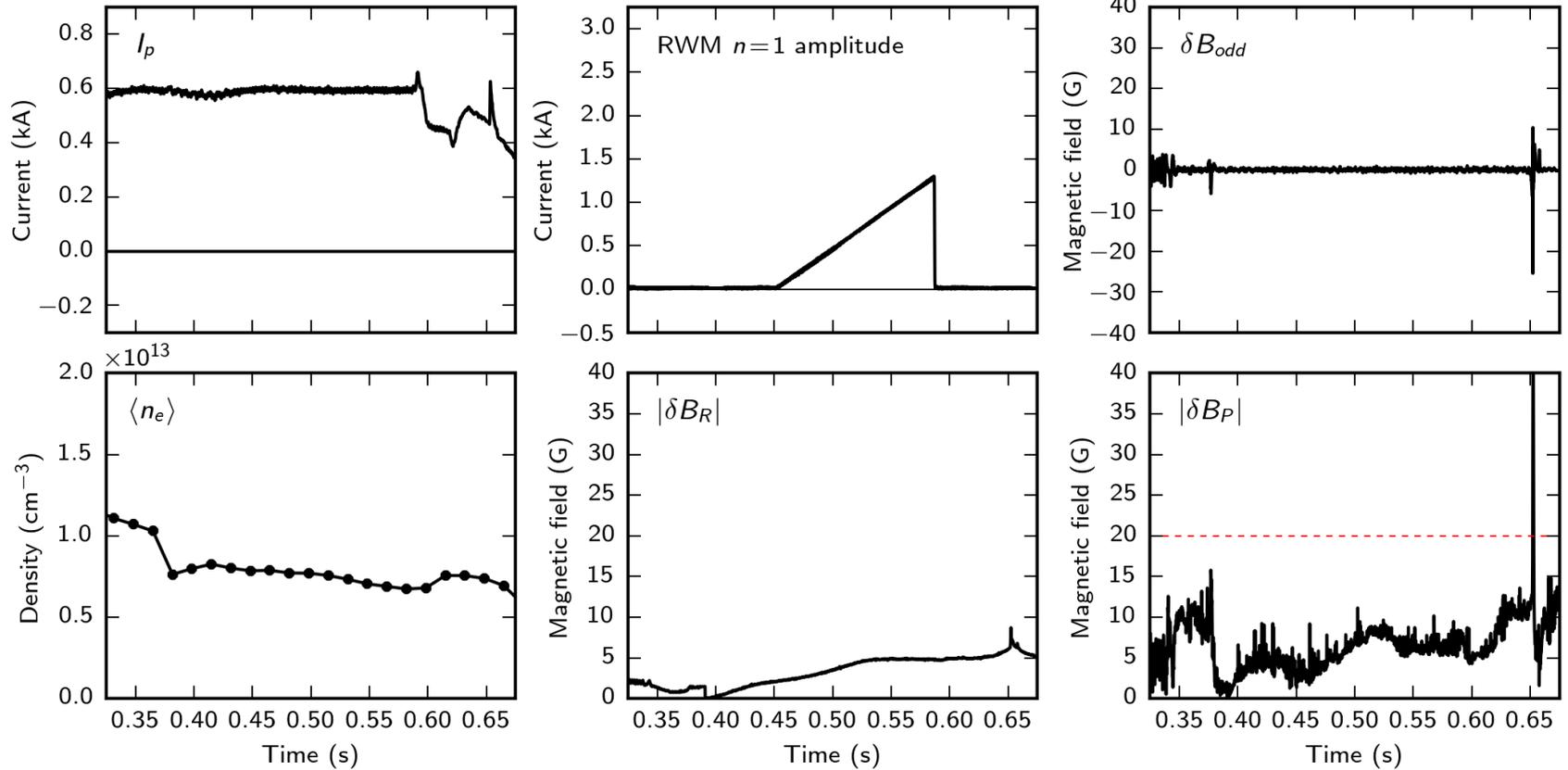
Shot 203013 – Phase = 90°



Shot 203014 – Phase = 270°

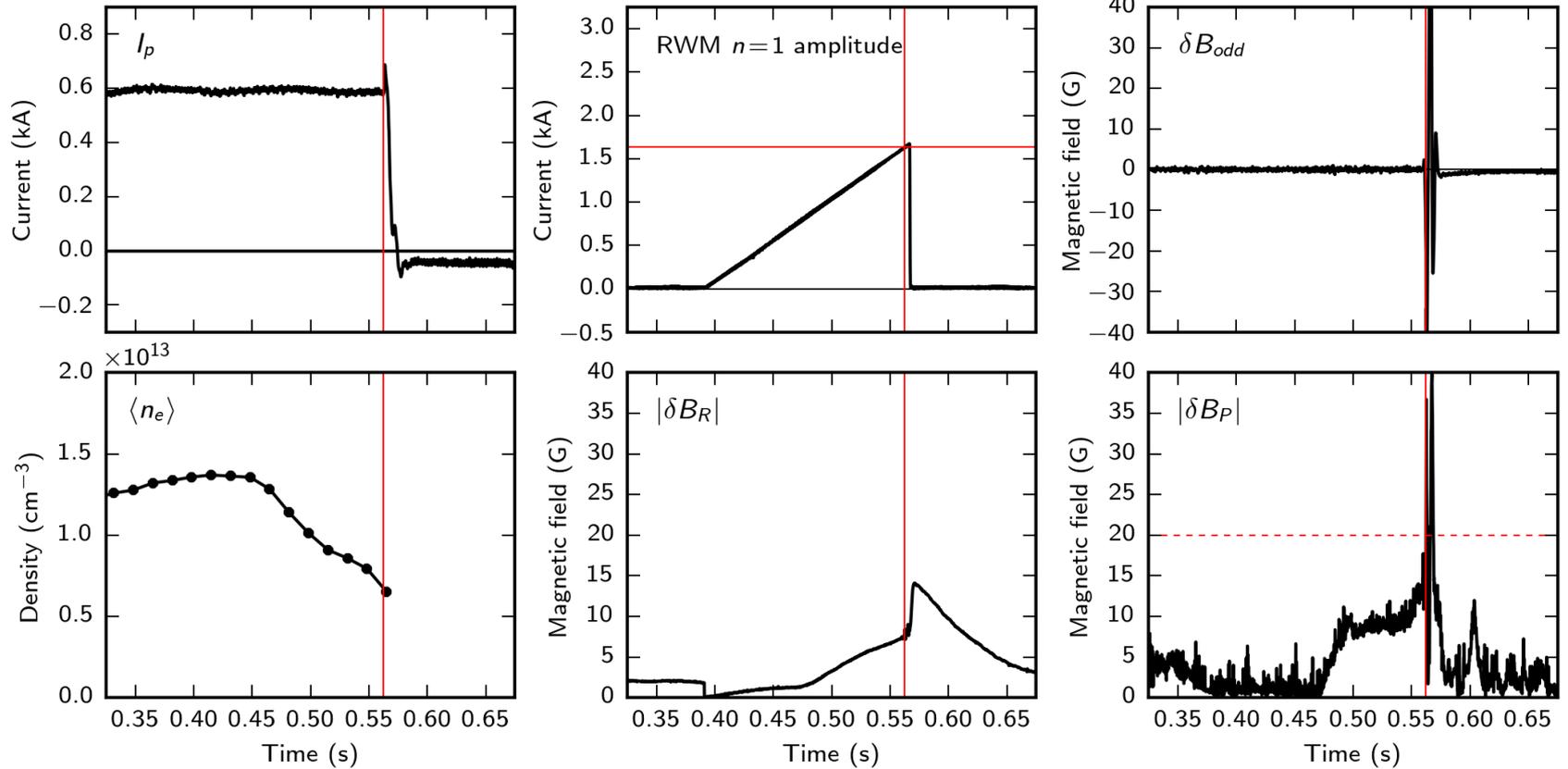
Reached max OH current before locking

Shot 203014 – Phase = 270°



Shot 203015 – Phase = 270°

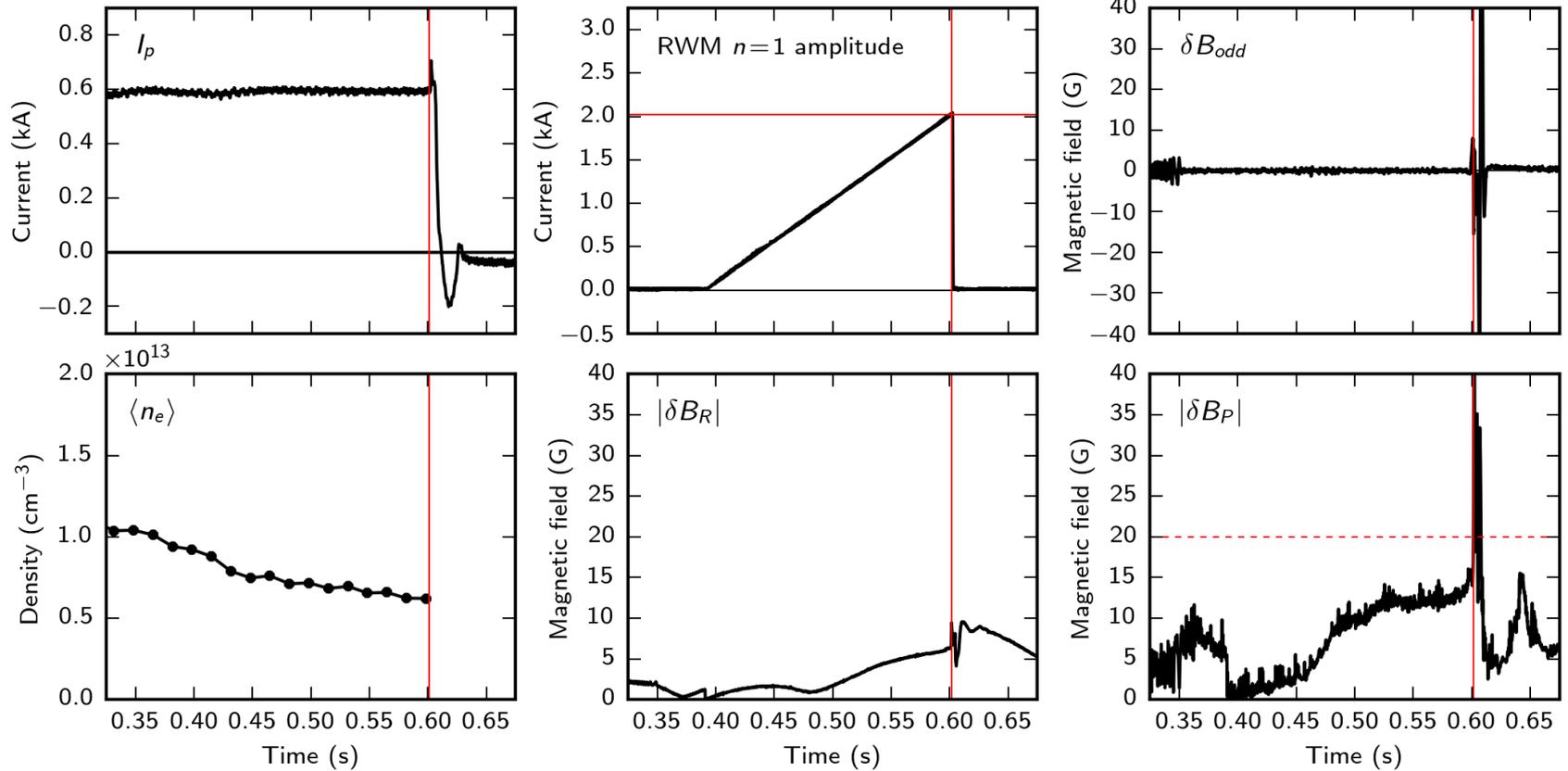
Shot 203015 – Phase = 270°



Shot 203016 – Phase = 0°

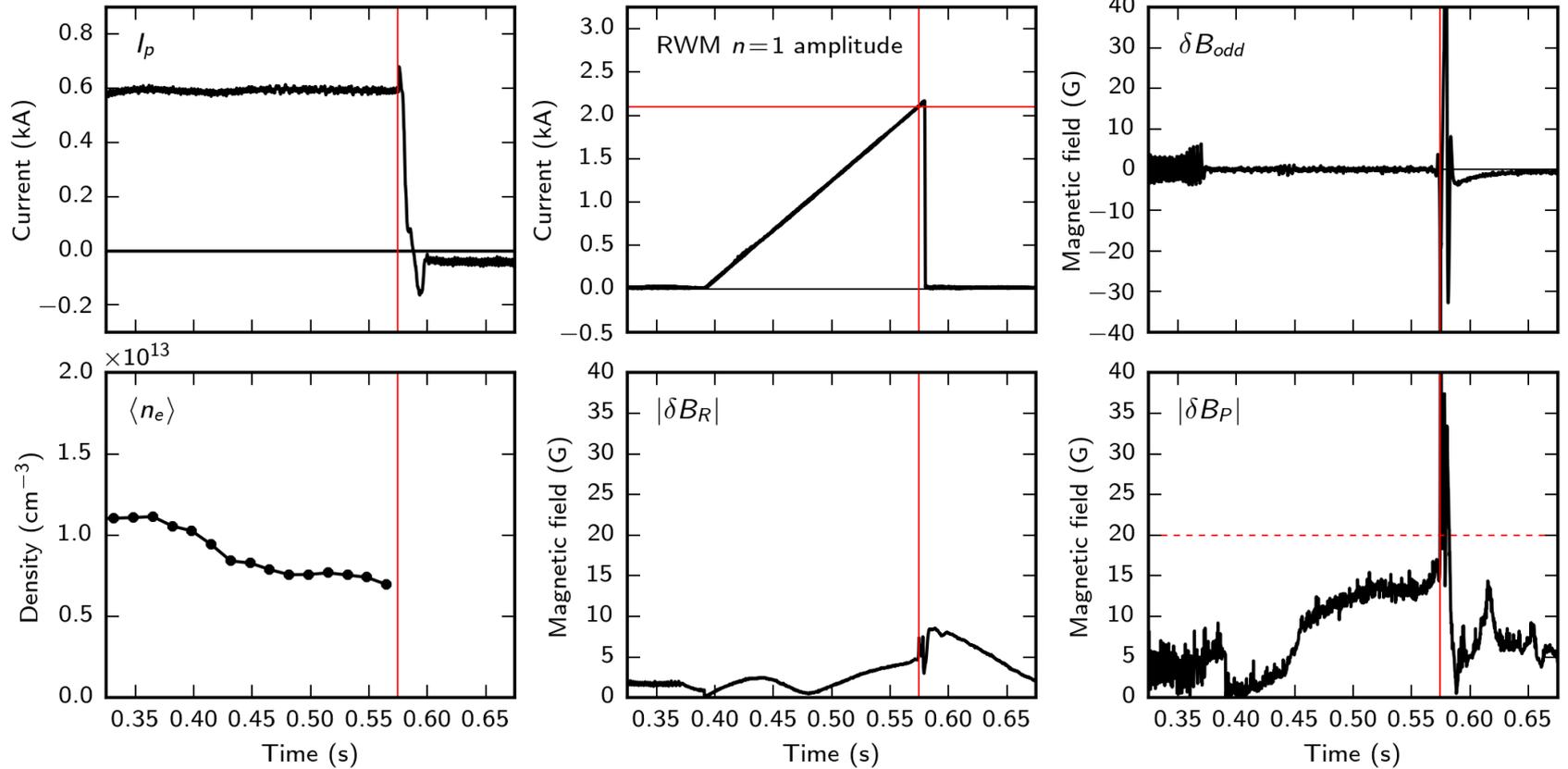
Locking just before max OH current

Shot 203016 – Phase = 0°



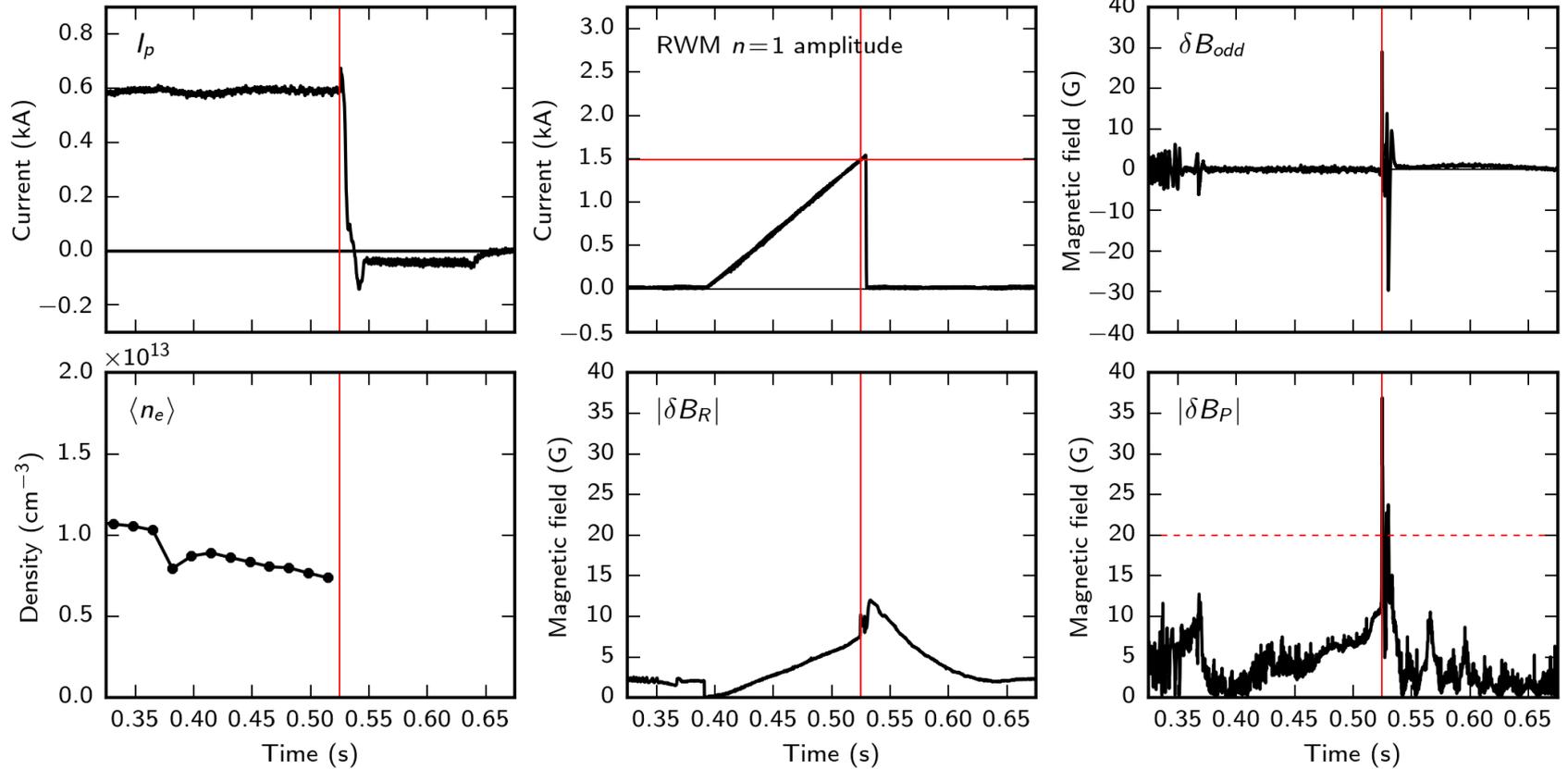
Shot 203017 – Phase = 0°

Shot 203017 – Phase = 0°



Shot 203018 – Phase = 180°

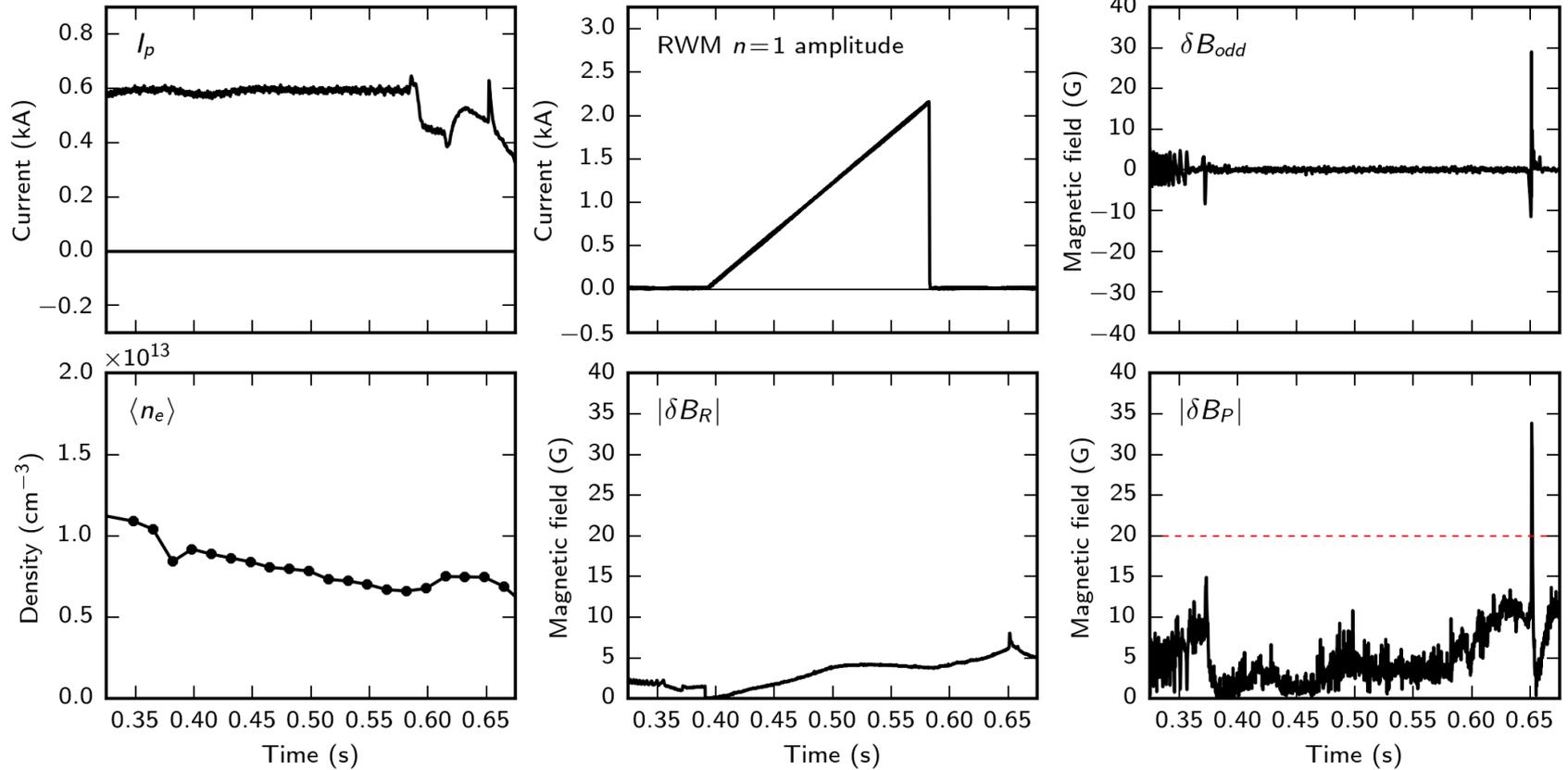
Shot 203018 – Phase = 180°



Shot 203019 – Phase = 90°

Reached max OH current before locking

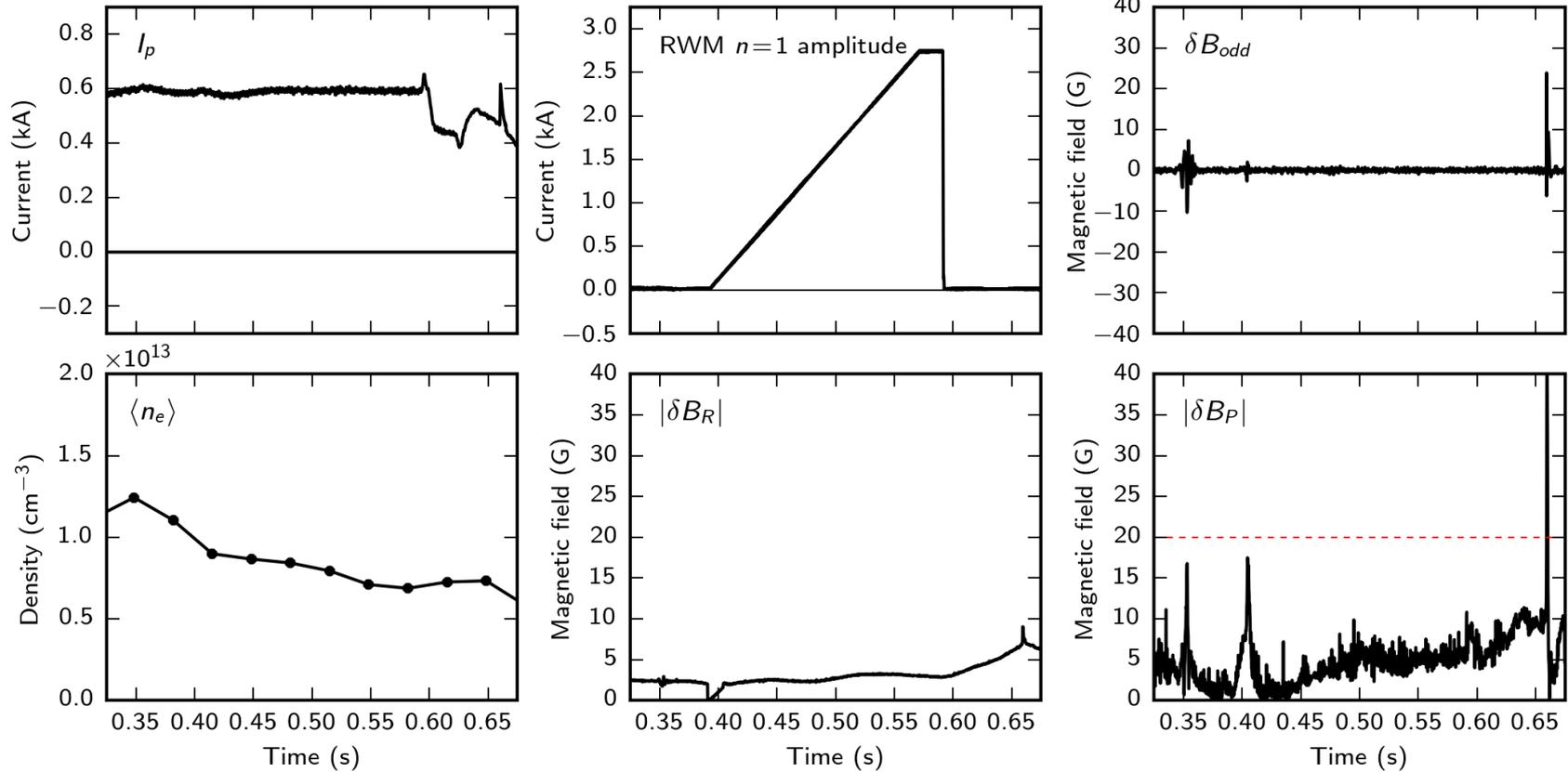
Shot 203019 – Phase = 90°



Shot 203020 – Phase = 90°

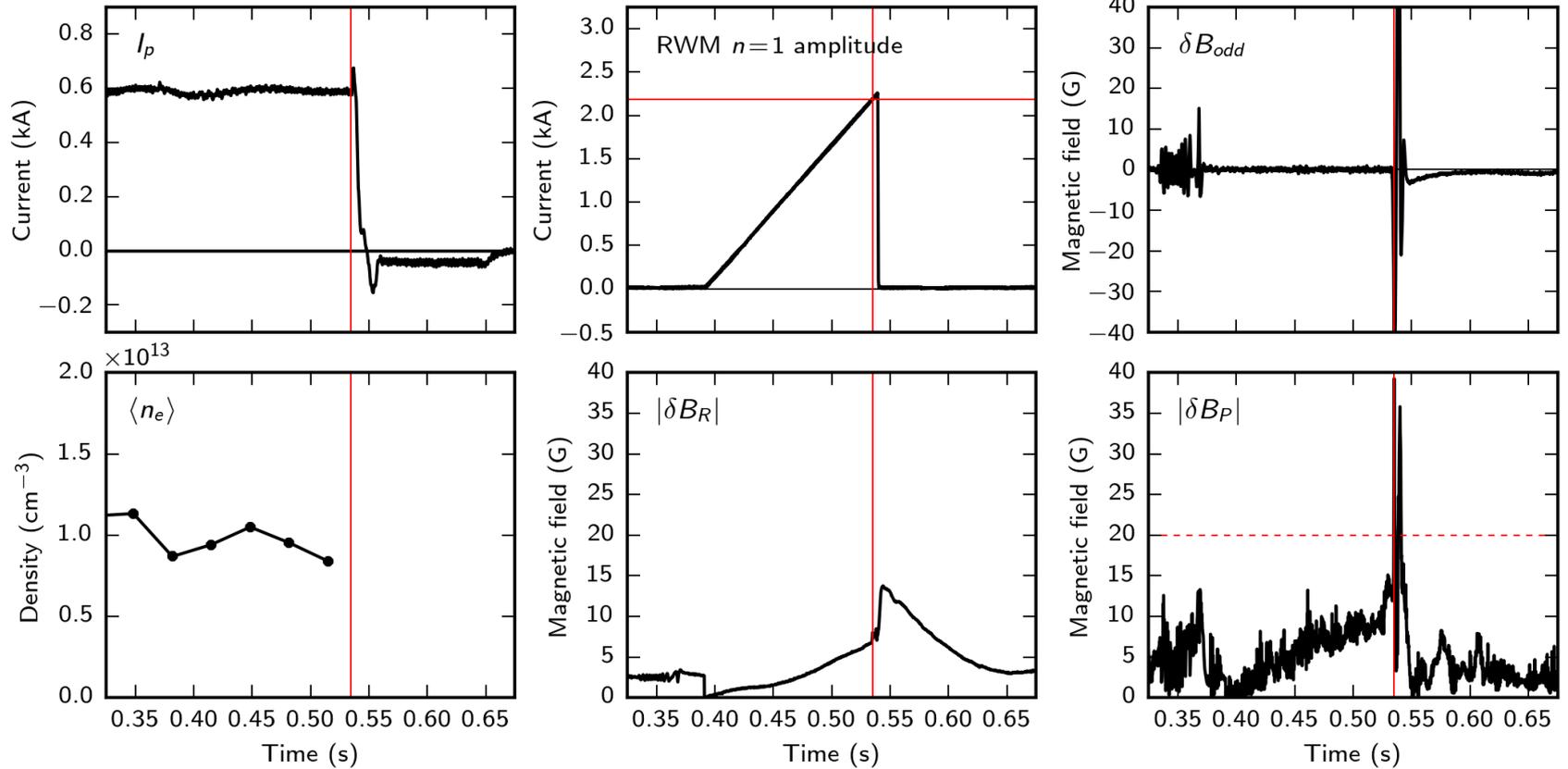
Reached max programmed RWM current without locking

Shot 203020 – Phase = 90°



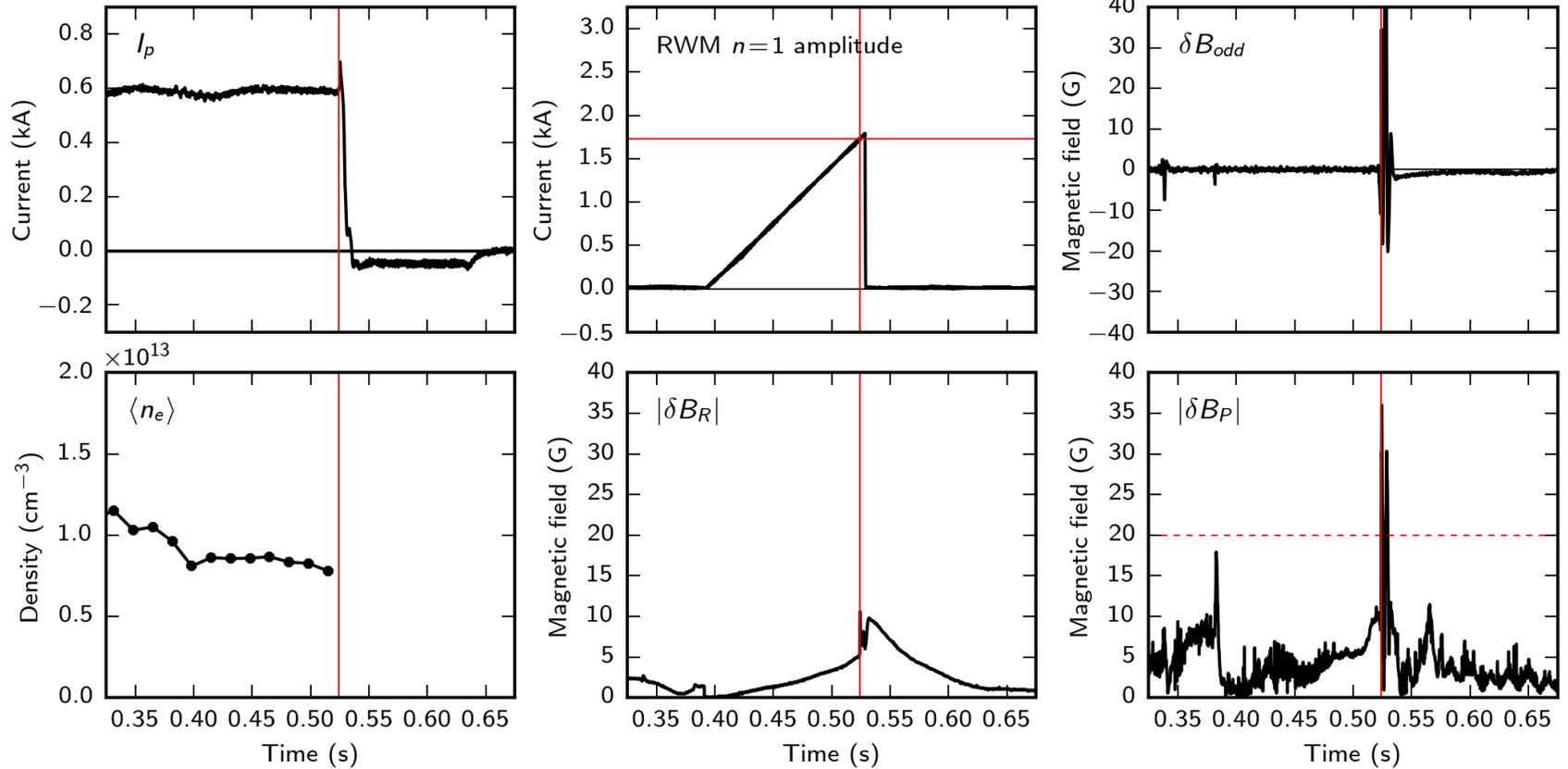
Shot 203021 – Phase = 270°

Shot 203021 – Phase = 270°



Shot 203022 – Phase = 180°

Shot 203022 – Phase = 180°



Shot 203023 – Phase = 135°

Shot 203023 – Phase = 135°

