NSTX-U

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Some Comments on Starting-Up and Operating With Lithium and Boronization

Stefan Gerhardt

about a billion conversations, over 7 years, with all of you…

PC TF Meeting
1/20/2015

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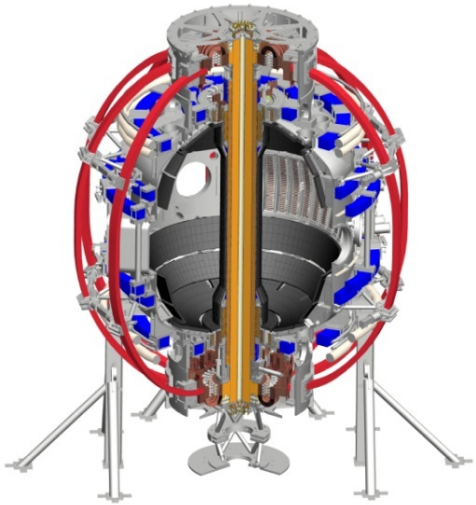


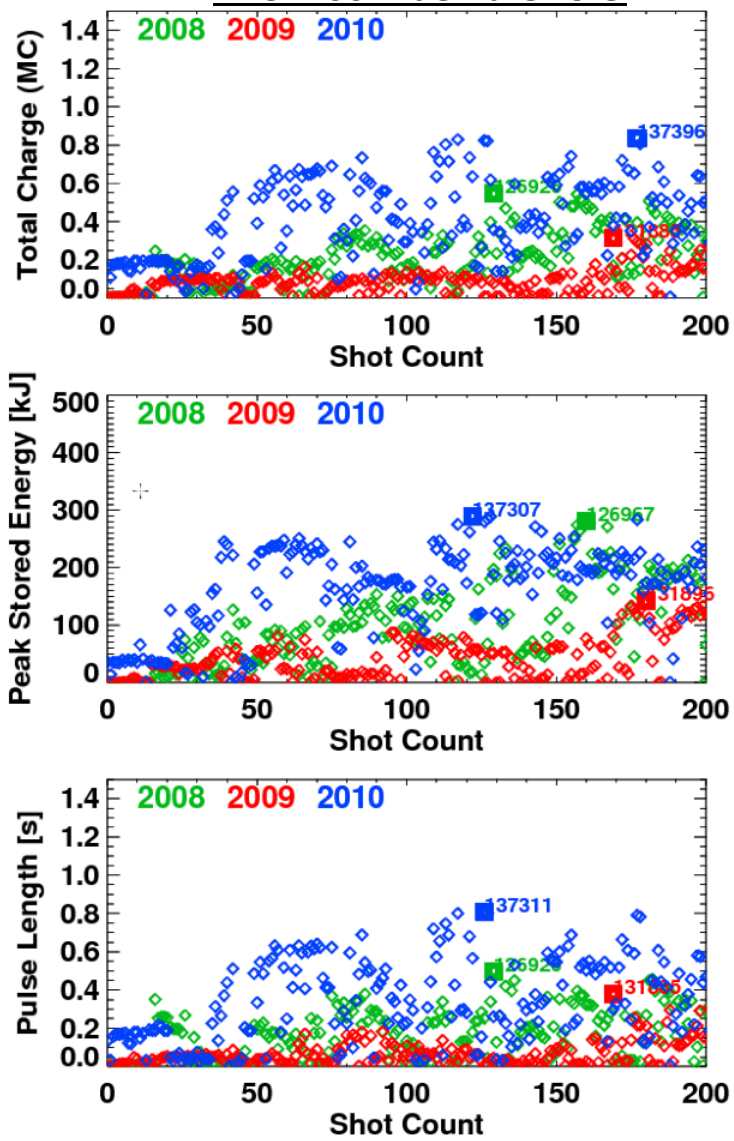
Hi!

- Lithium had many benefits to NSTX operations.
  - Enabled a 10 minute shot cycle with reliable plasmas.
    - Allowed more science to get done.
  - Improved confinement.
  - Eliminated ELMs.
    - Though this is also a bad thing.
  - Controlled the deuterium inventory!!!
  - Reduced the density in front of the antenna.
  - Probably more…

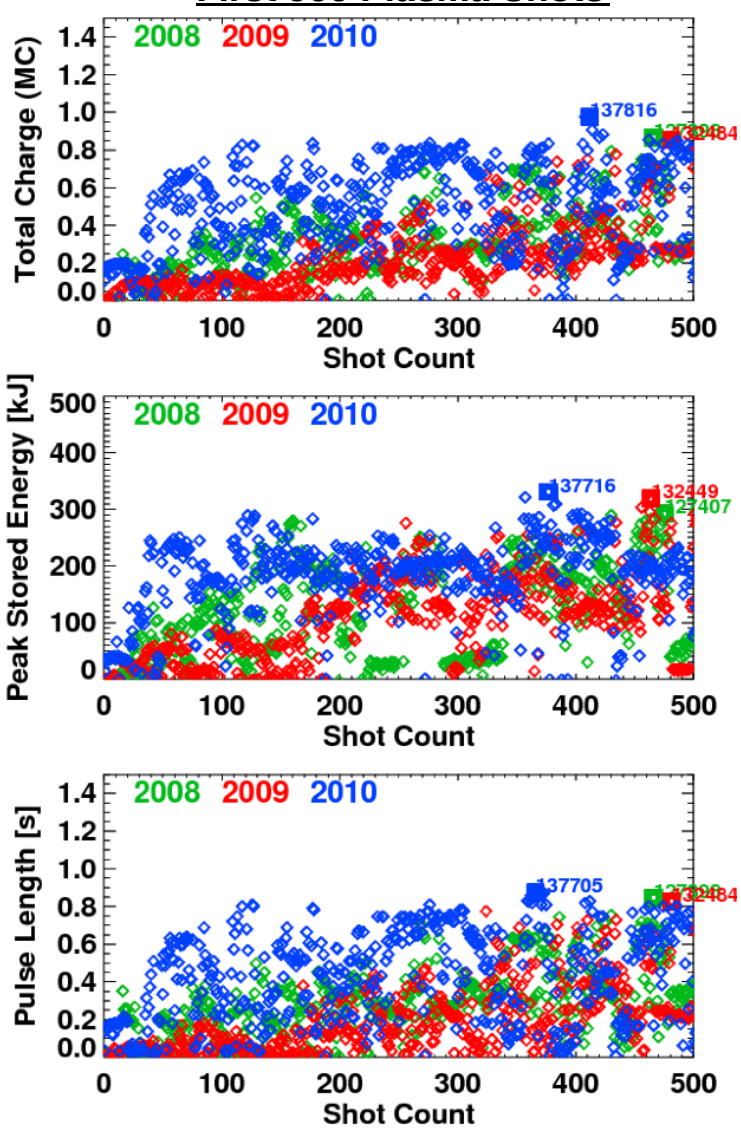
- This short presentation.
  - Compare the 2010 startup with LITER to previous startups.
  - Comments on these benefits in the context of NSTX-U

The 2010 "MegaEvaporation" Startup Was Far Better Than the Previous Two Boronized Startups

First 200 Plasma Shots



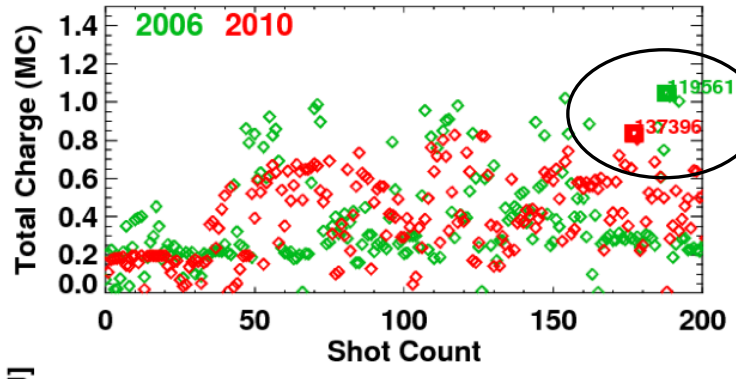
First 500 Plasma Shots

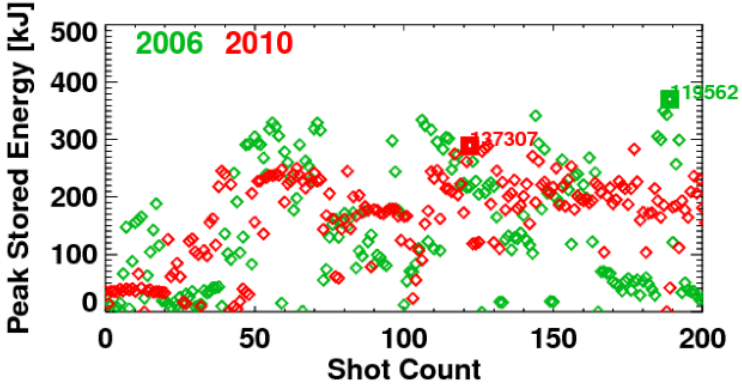


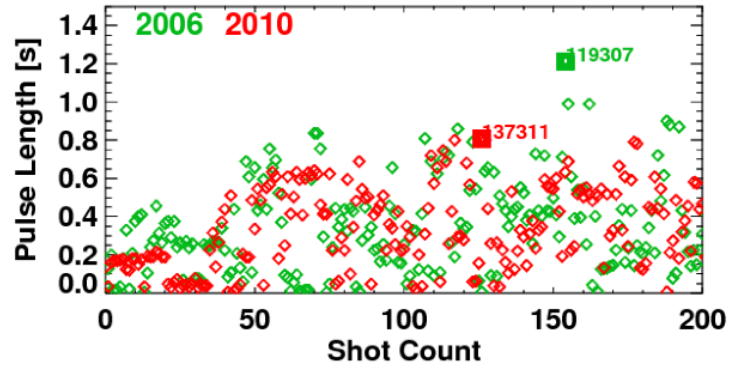
So Why Was 2010 is So Much Better?

- 2010: Large lithium evaporations to fill LLD.
  - No boronizations at all.
- 2009: We didn't clean out the previous years lithium.
  - Required lots of Ar, He glow to improve the plasma performance.
    - See: http://nstx.pppl.gov/DragNDrop/XP_Folder/XP_Schedule/FY09/Run_Overview_09.pdf
  - Ultimately used LITER to recover good performance.
    - Hair of the dog…
- 2008: New control computer had a lot of teething problems.
  - Will in some sense be closer to 2015 than other cases, with many modifications to the control/protection systems.
- So, go back much further to see what a "good" Boron startup looked like.
  - Take 2006 as the example.
  - And yes, the goals of the first ~300 shots were different in those years, but it remains an interesting comparison.

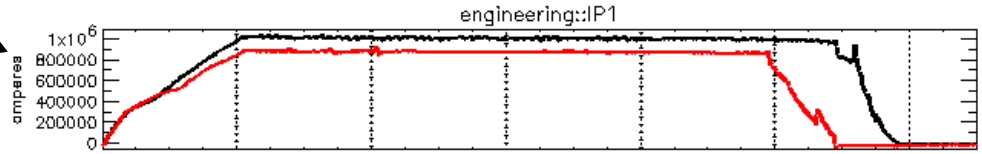
Compare The 2010 and 2006 Startups

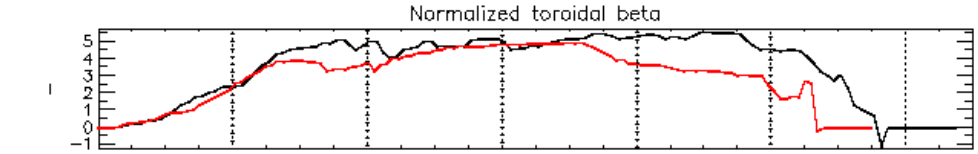


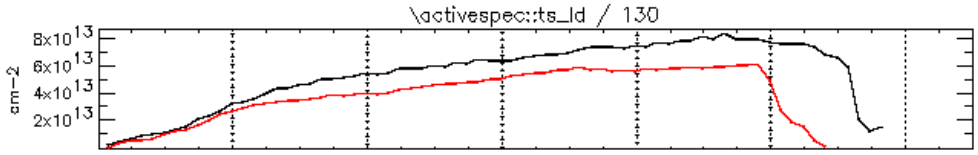


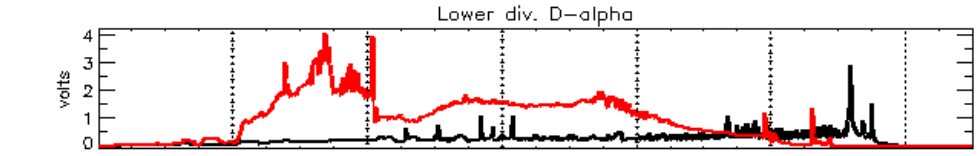


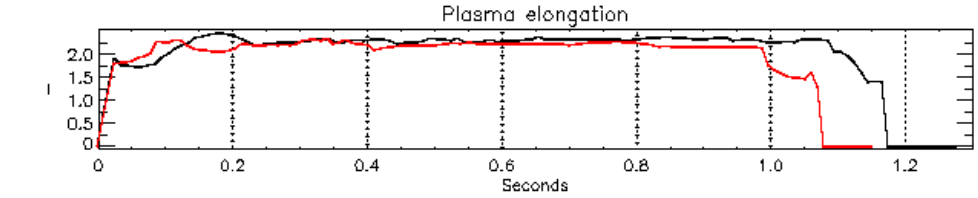
Shots:
119561
137396



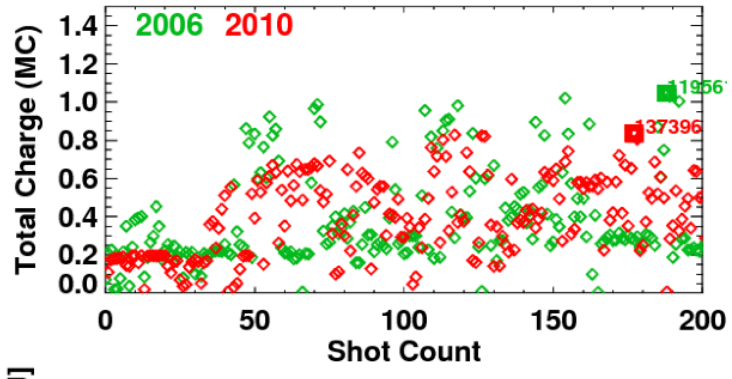


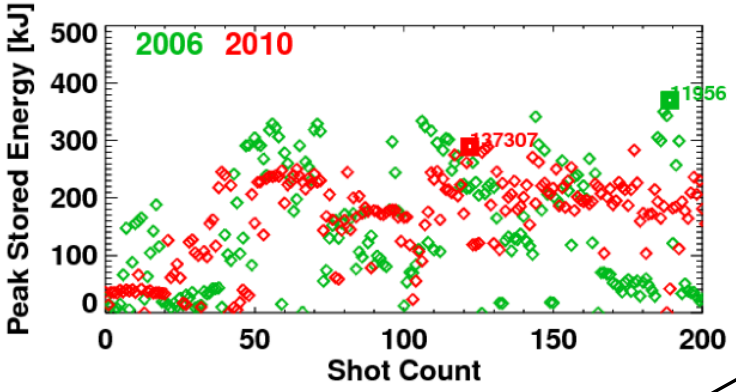


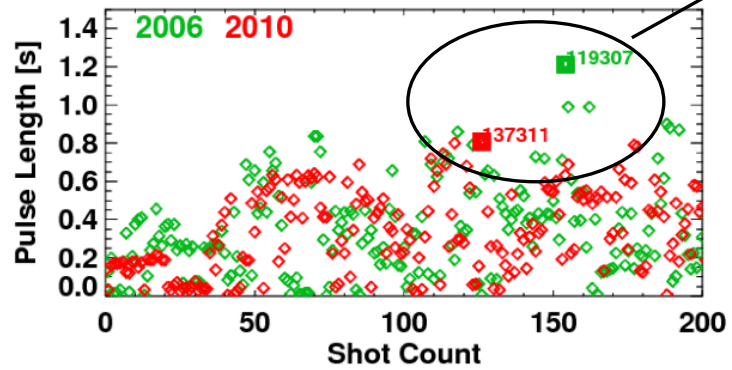




Compare The 2010 and 2006 Startups

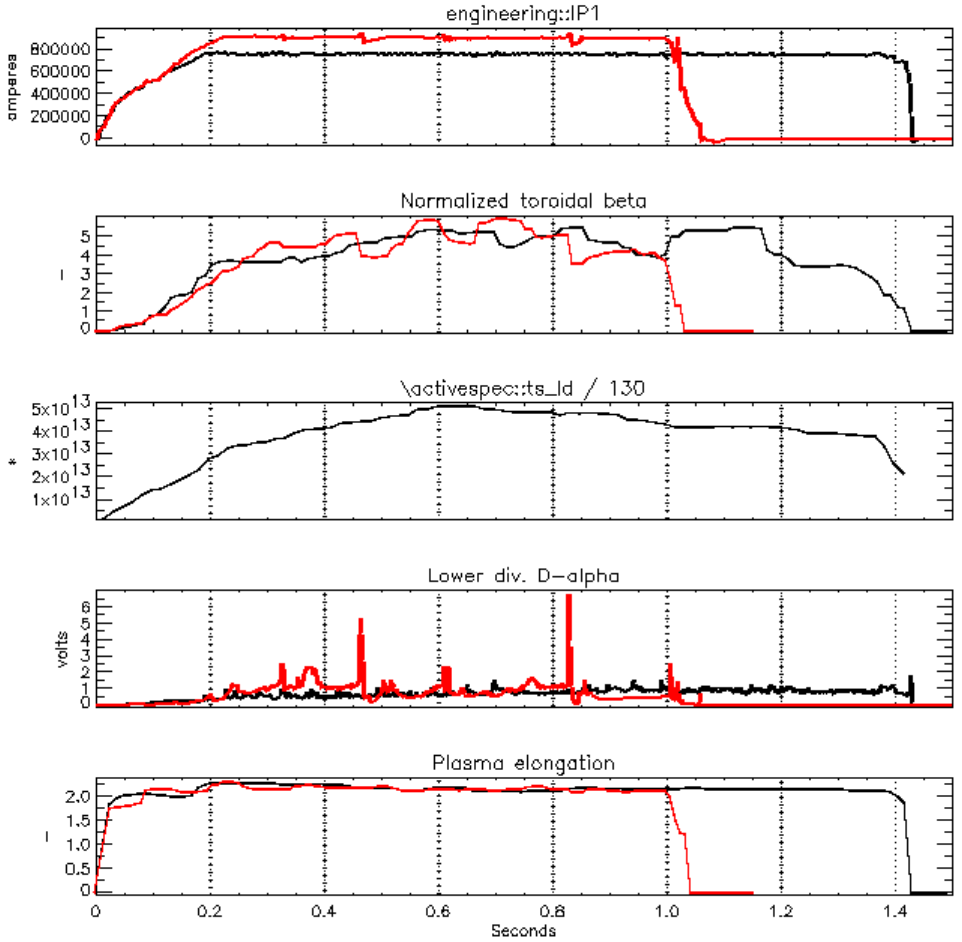






Shots:
119307
137311

NSTX



Compare the Early Run Conditioning

NSTX Operation FY'06

Week	Monday	Tuesday	Wednesday	Thursday	Friday
Sep 19, 05 – Feb 3	Outage				
Feb 6 – 10	**ISTP-1** Coil tests	**ISTP-1** Coil tests Plasma shot	**MP-20** Startup plasmas	MPTS calibration	
Feb 13 – 17	Maintenance		**MP-20** Calibration & Startup plasmas	Maintenance	Bakeout
Feb 20 – 24	Bakeout			Maintenance	
Feb 27 – Mar 3	**MP-20** Startup plasmas	**MP-20** Startup plasmas Boronization 50	**XP-616** Movable Glow Probe	**XP-616** Movable Glow Probe **MP-3** Magnetics calib'n	**XP-605** Divertor detach't **XP-626** SGI fueling
Mar 6 – 10	**XP-606** Transient CHI	**XP-606** Transient CHI **XP-533** CHI+induction Boronization 51	**XP-603** Long-pulse DN **XP-626** SGI fueling	**XP-604** Density scan **XP-626** SGI fueling	**XP-602** Long pulse with error field corr'n

NSTX Operation FY'10 (1)

Week	Monday	Tuesday	Wednesday	Thursday	Friday
Aug 2009 – Feb 12	Outage				
Feb 17 – Mar 8	Bakeout				
Mar 15 – 19	Outage			**ISTP-1**	**ISTP-1**
Mar 22 – 26	**ISTP-1**	**MP-3** Magnetic calib'n	**LLD prefill** ~15g LITER evap.	**MP-64** Initial operation First plasmas	**MP-64** Initial operation First NBI
Mar 29 – Apr 2	**MP-64** Initial operation **MP-66** Strike-point cntrl.	**MP-66** Strike-point cntrl.	**MP-66** Strike-point cntrl.	**MP-66** Strike-point cntrl.	**MP-66** Strike-point cntrl. **XP-1000** LLD characteriz'n LLD 250°C
Apr 5 – 9	**XP-1000** LLD characteriz'n LLD 250°C	**XP-1000** LLD characteriz'n (ELM free) LLD 250°C	**XP-1000** LLD characteriz'n LLD 320°C	**XP-1000** LLD characteriz'n (R_{OSP} to 0.70m) LLD 320°C	LITERs empty **MP-3** Magnetic calib'n **MP-33** MSE calib'n **XP-1004** Early EF corr'n

The FY-05 log shows a boronization 48 as the last one, so maybe #49 occurred in FY06?

In any case, not particularly aggressive in the boronizations.

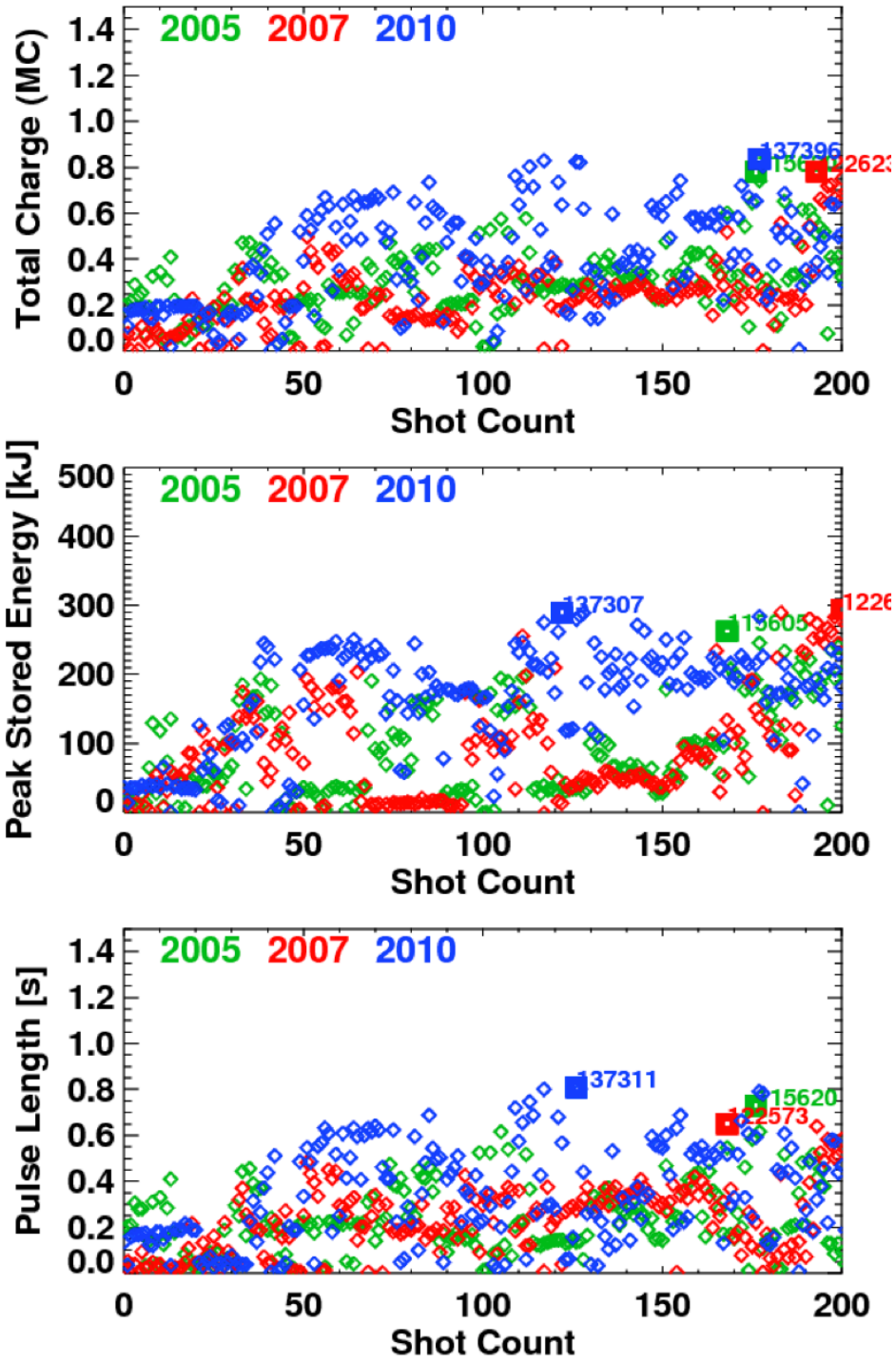
Appears that many of the good shots started at about 50 shots in, as part of XP-616

15 g of LITER evaporation before the first plasma!!!

And then continued heavy evaporation.

2005 & 2007 Startup Were Not as Good as 2006

- Can see the impact of very different experimental programs.
  - 2007: Ohmic locked mode experiment & HHFW coupling
- But around the 35th-60th shot, similar performance across the years.
  - And similar tracking of the peak stored energy and pulse length across the first 40 shots.
- Caveat: these do not analyses do not look at the radiated power, H-mode timing, and rotating MHD…which may or may not have been different in 2010.
  - So I'm not saying that the B startup was strictly better, only that it might not have been strictly worse.



Relevant Changes from NSTX -> NSTX-U

- Bakeout:
  - **Old System:** Upper divertor was not baked well because the upper ceramic break could not be properly cooled.
  - **New System:** Ceramic breaks at top and bottom can be cooled, allowing symmetric bake.
- Boronization System:
  - **Old System:** Single gas inlet at the midplane
  - **New System:** Gas inlets at each of upper divertor, lower divertor, and midplane.
- CS Fuelling:
  - **Old System:** 1/8" lines for both the shoulder and midplane injectors.
  - **New System:** 1/8" and ¼" lines for each of the shoulder and midplane locations.
- GDC:
  - **New System & Old System:** 2 GDC electrodes
  - **Very Old System (2006):** Also had a movable glow probe.
- OH Coil:
  - **Old System:** Could cool fast enough to support 10 minute shot cycle.
  - **New System:** Very very complicated story…but unclear if it will support operations faster than 15 minutes.
- Shape & Position Control
  - **Old System:** Mature ramp-scenario, control schemes, library of shots to reload…PFC conditions generally set the pace of the startup.
  - **New System:** Must redevelop null, ramp, shape and position control…

Other Notes

- Likelihood of an emergency vent?
  - Lithium does not play will with air.
  - We don't know the chances of needing a "quick vent" early in operations, but we do know that it will be harder to recover from if Li is in NSTX-U.
- LITER shutters and lithium inventory?
  - FY10 run started in mid-late March, and we were struggling by mid September w/ the LITER shutters.
    - About 1 month lost in there due to OH coil repairs.
    - Ultimately ran the final month w/ evaporation early in the AM, and reluctance on the part of session leaders to take afternoon sessions.
  - If we contemplate a longer run, then we should be very cognizant of early LITER usage.
- Fire and forget conditioning.
  - Boronization requires resources during the glow, but none during the run day.
  - LITER will take significant technician and engineer resources during the run day.
- PAC:

Sufficient time for systematic studies introducing lithium conditioning in a methodical way would be desirable. This approach is important both in the assessment of the impact of more lithium coverage (e.g. with the introduction of the granule injector and upward-facing evaporator system) and running fiducial experimental shots that elucidate boronization contemplating future use of a cryo-pump. From the standpoint of the engineering design of a cryo-pump system planned for FY17, it will be critical to evaluate particle balance under both non-lithiated conditions and those with different Li coating conditions providing a unique database that steps

Personal Recommendations

- The NSTX-U TSG leaders should break XPs into three groups.
  - Those that specifically require boronized conditions
  - Those that specifically require lithium conditioned PFCs.
  - Those that simply need specific plasma conditions, that might be achieved with either technique…these in the "gray area"
- The NSTX-U team, under the guidance of the PC TF, should pursue an aggressive program to optimize the boronized state.
  - Optimization Targets
    - Minimal deuterium inventory evolution at $0.5<f_{GW}<0.8$ (or whatever)
    - Controlled Z_{eff} <2 (or 2.5, or whatever)
  - Optimization Tools
    - Mega-boronization?
    - Optimized fuelling with new injectors?
    - Revisit He GDC pressures/durations?
  - And then should pursue the same goals with LITER conditioning.
- The timing of the (first) boron -> lithium transition should be determined by:
  - The count of XPs that specifically require either conditioning technique.
  - The ability of the "gray area" XPs to achieve their goals under boronization.
  - Our confidence in not needing a vent.
  - The anticipated duration of the run.

Thanks!