Analysis of heat load data

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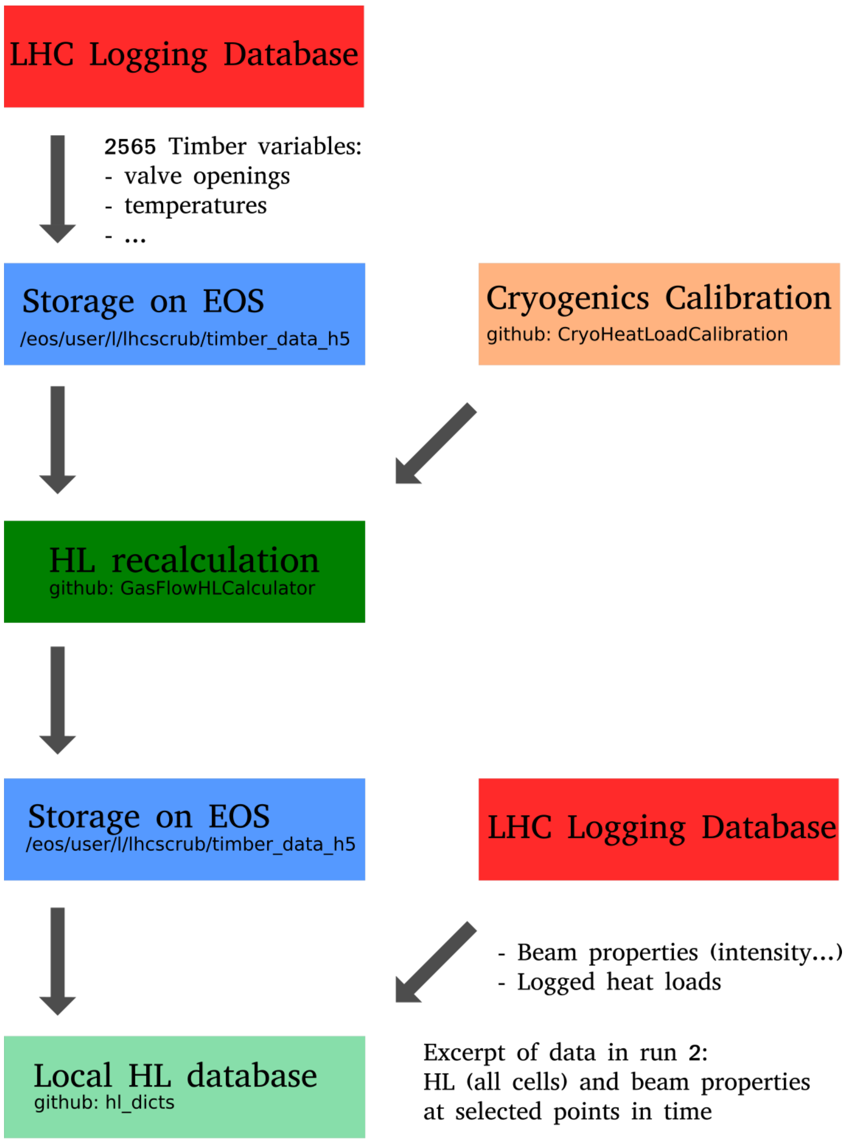
Many thanks to TE-CRG and in particular to K. Brodzinski, B. Bradu and S. Claudet

Electron Cloud meeting - 14 July 2017

Outline

- **Introduction**
- **Arc heat loads**
  - Scrubbing run and intensity ramp-up
  - Full evolution during Run 2
  - Cell-by-cell analysis
  - Evolution vs bunch intensity
- **Instrumented cells**
  - Scrubbing run and intensity ramp-up
  - Full evolution during Run 2
  - Cells in S45 vs cell in 31L2
  - Quadrupole behavior during the ramp
- **Observations with B2 and B2 separately**
- **Ongoing work on LSS magnets**

Introduction



- Analysis performed using a set of **tools developed in close collaboration with the cryo team**
- Heat loads over the entire Run 2 are **recomputed using the most recent calibration** data from TE-CRG in order to analyze a consistent set of data
- Recalculation is done using a tool **implemented in Python by Philipp based on matlab scripts (and a lot of help) provided by Benjamin**
  - → Many thanks!
- For each fill we maintain **files with the heat loads of all cryo cells** and a **reduced set of data** (heat loads at selected points of the cycle), easier to manipulate to sudy long term evolution

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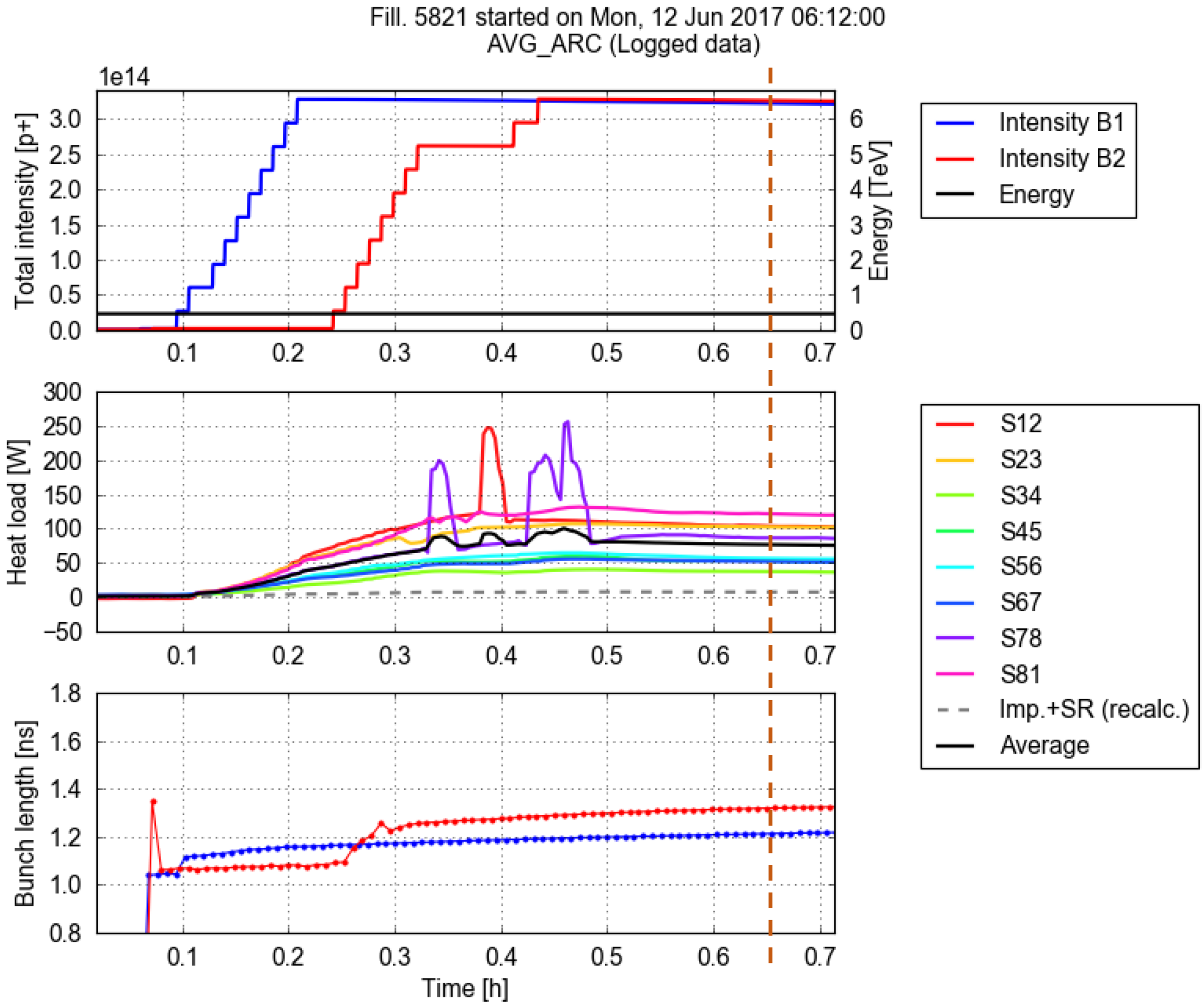
Heat load evolution during the scrubbing run

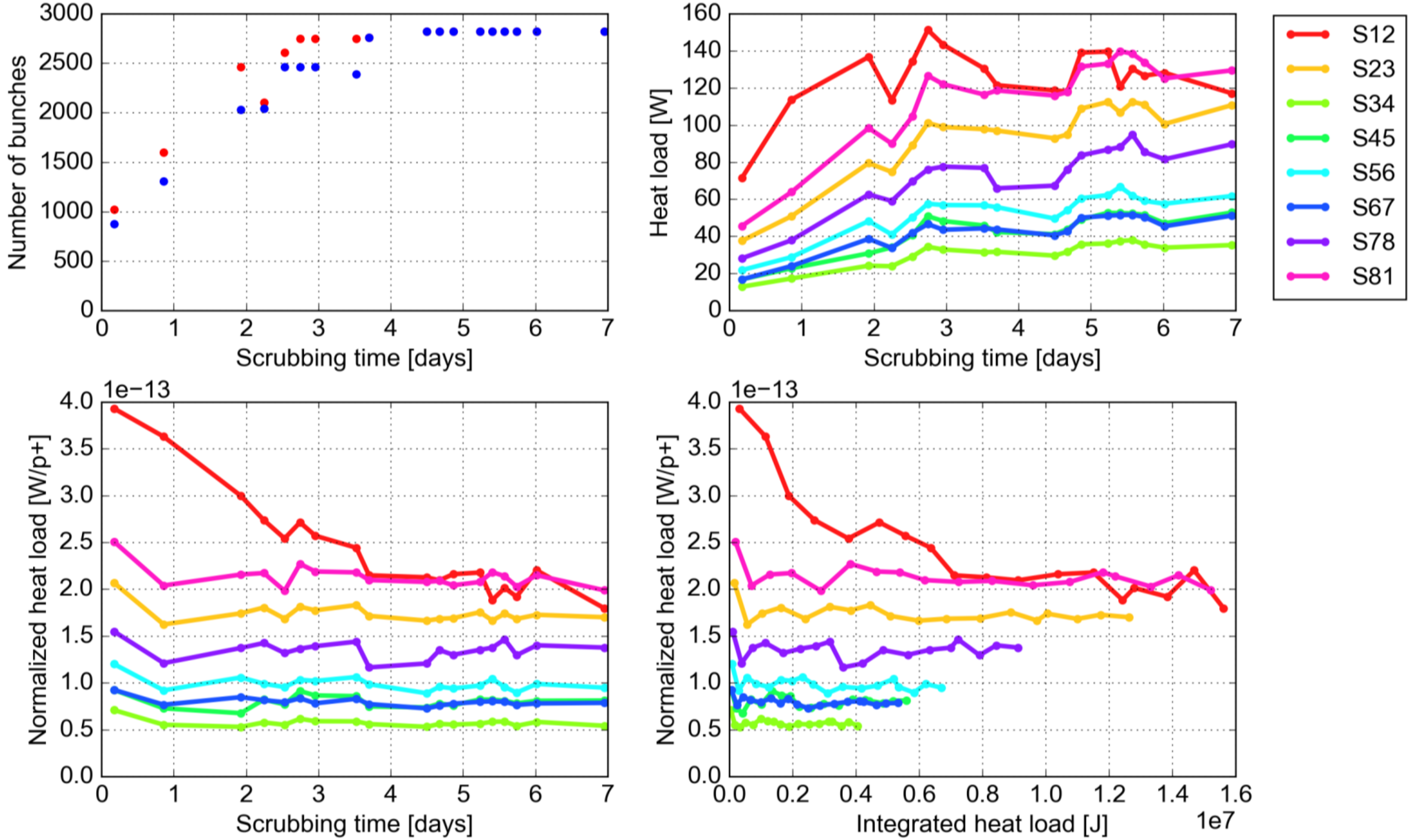
- We selected for each scrubbing fill an **instant after the end of the injection process** and after transients on heat loads are extinguished



Arc heat loads during the 2017 scrubbing run

- The data at the selected samples is used to have an **indication of the heat load evolution** during the scrubbing run

Nbun inj.	72	144	144/288	288



Arc heat loads during the 2017 scrubbing run

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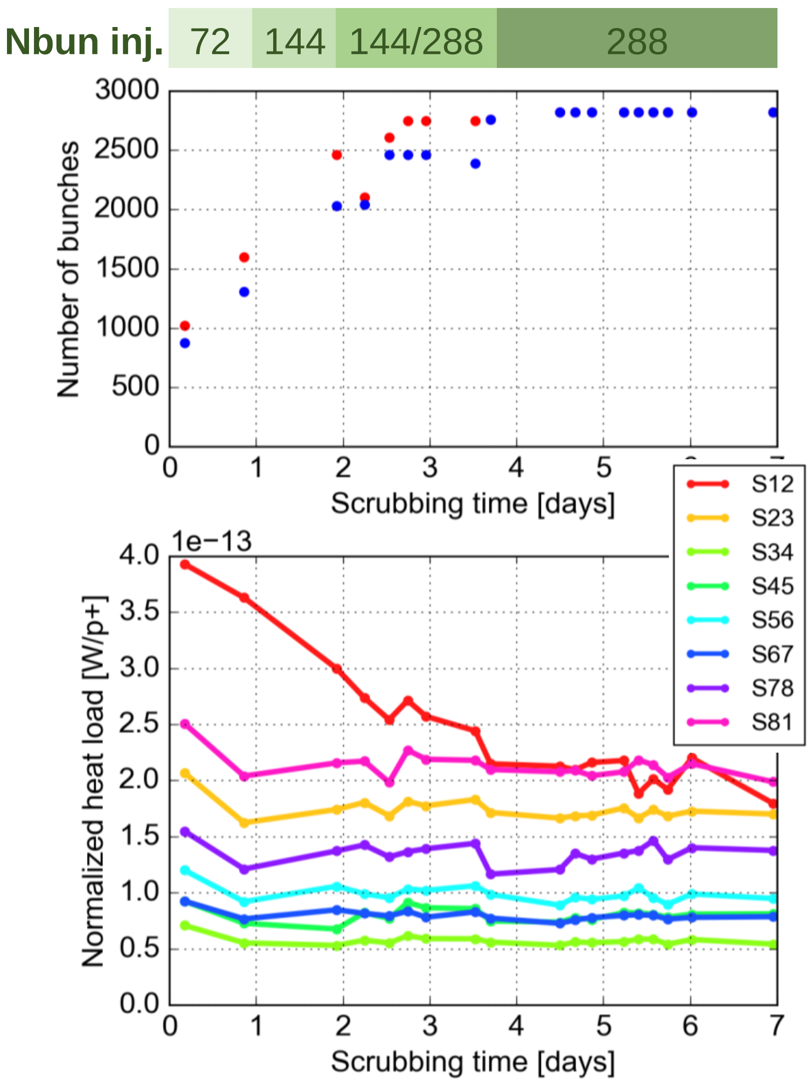


Main observations:

Sectors which stayed cold during the EYETS:

- Conditioning observed only **over the first 24h** (recovery of the deconditioning from the EYETS)
- **Difference between sectors** very similar to end-2016 and un-affected by the scrubbing run

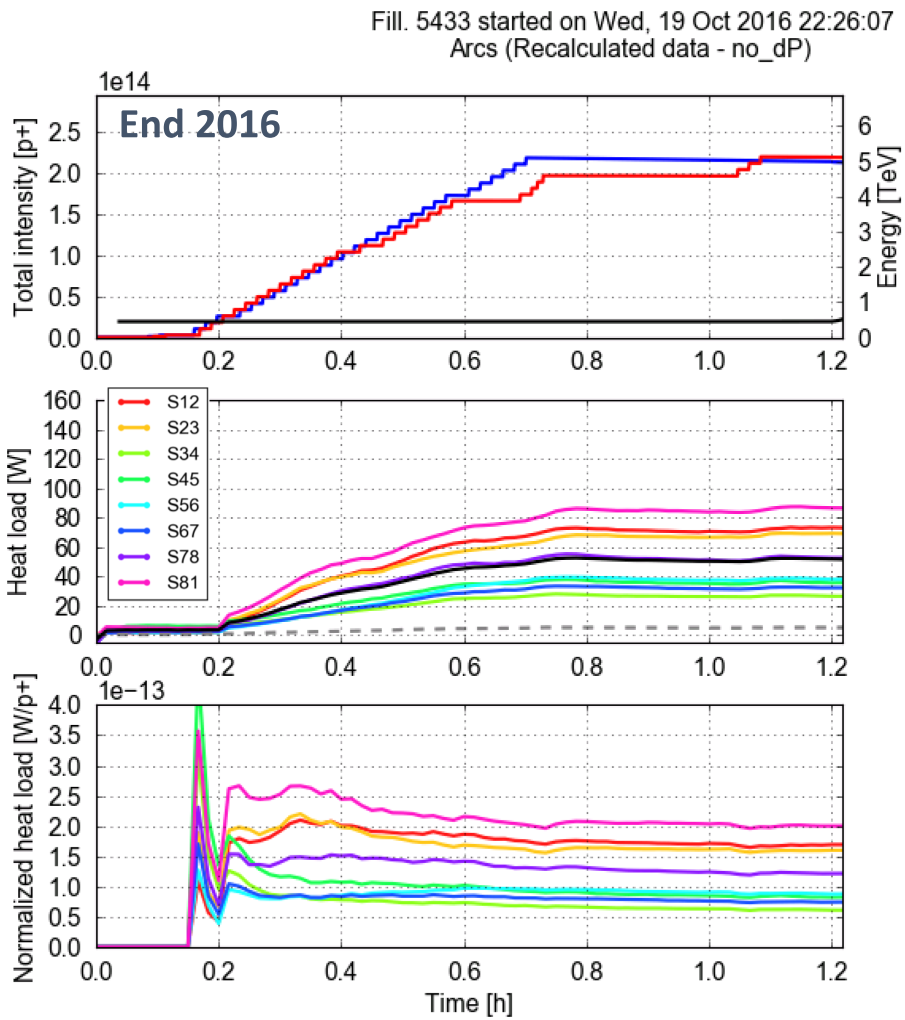
Sector 12 (opened during EYETS):

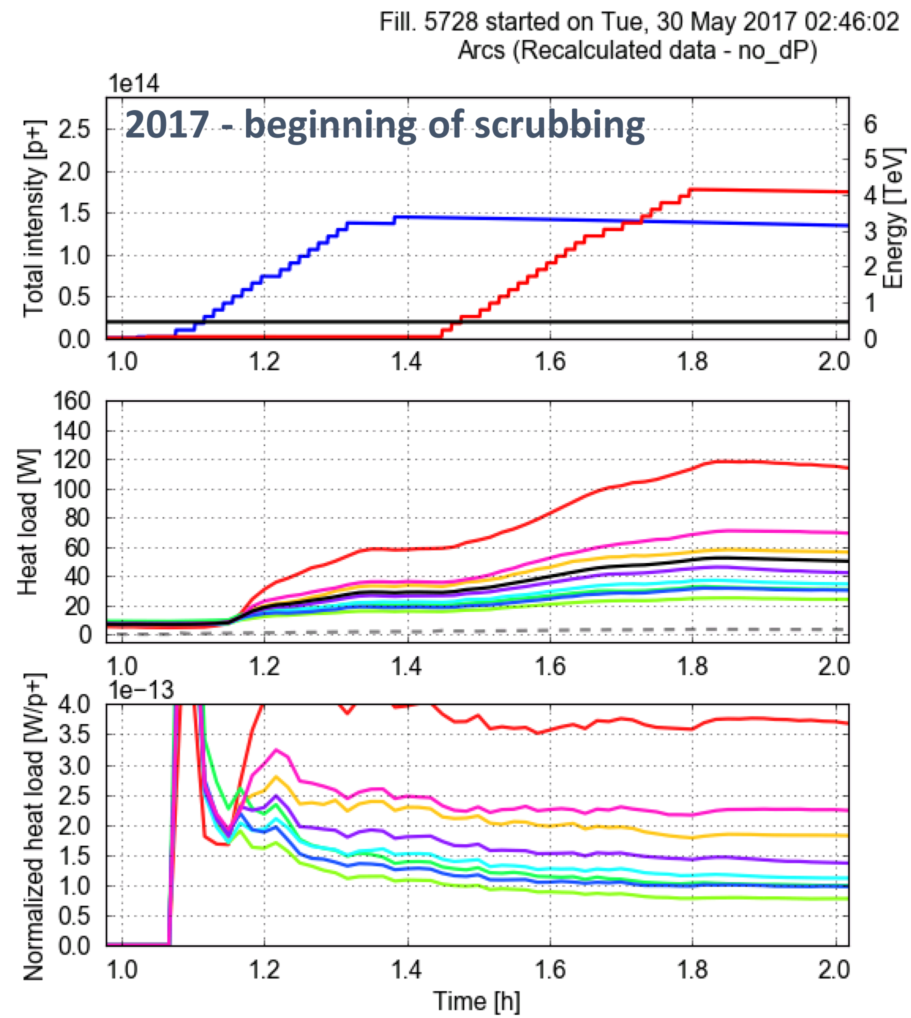
- Evident conditioning observed over **the first 4 days**
- **On day 4 heat load similar to end-2016** were reached
- **No evolution observed thereafter** (important info for planning future scrubbing runs)

Three days of scrubbing with **trains of 288b had no impact** on heat load levels nor on the difference between sectors

Arc heat loads during the 2017 scrubbing run

- On the last scrubbing day we performed a **reference fill with trains of 72b.** for direct comparison against the beginning of the scrubbing run and against 2016
  - → **Changes are evident mainly on Sector 12**





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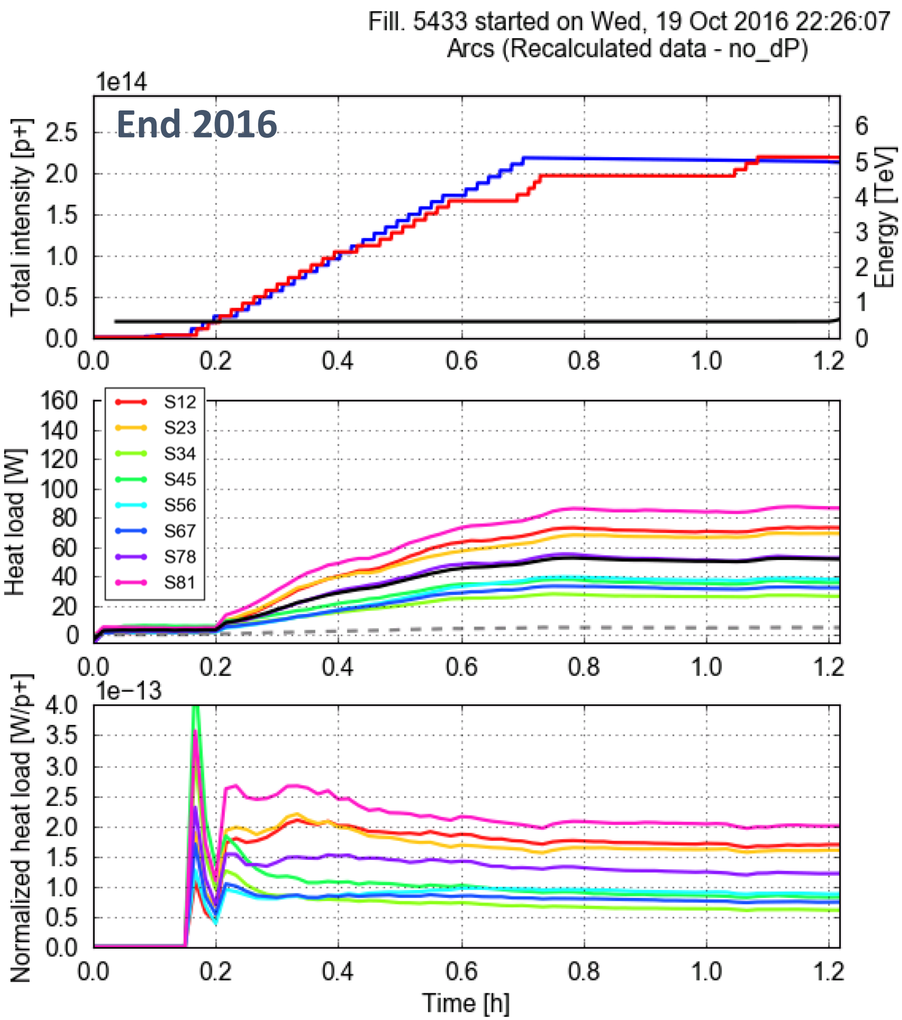
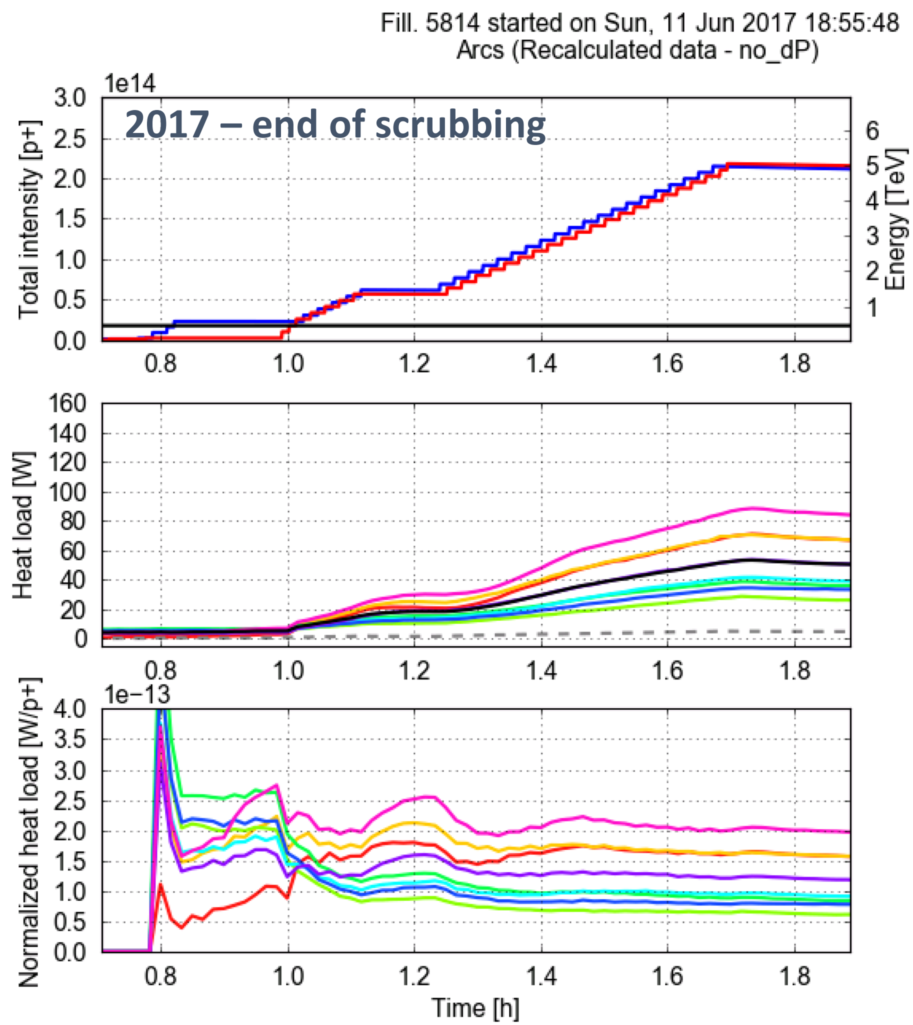
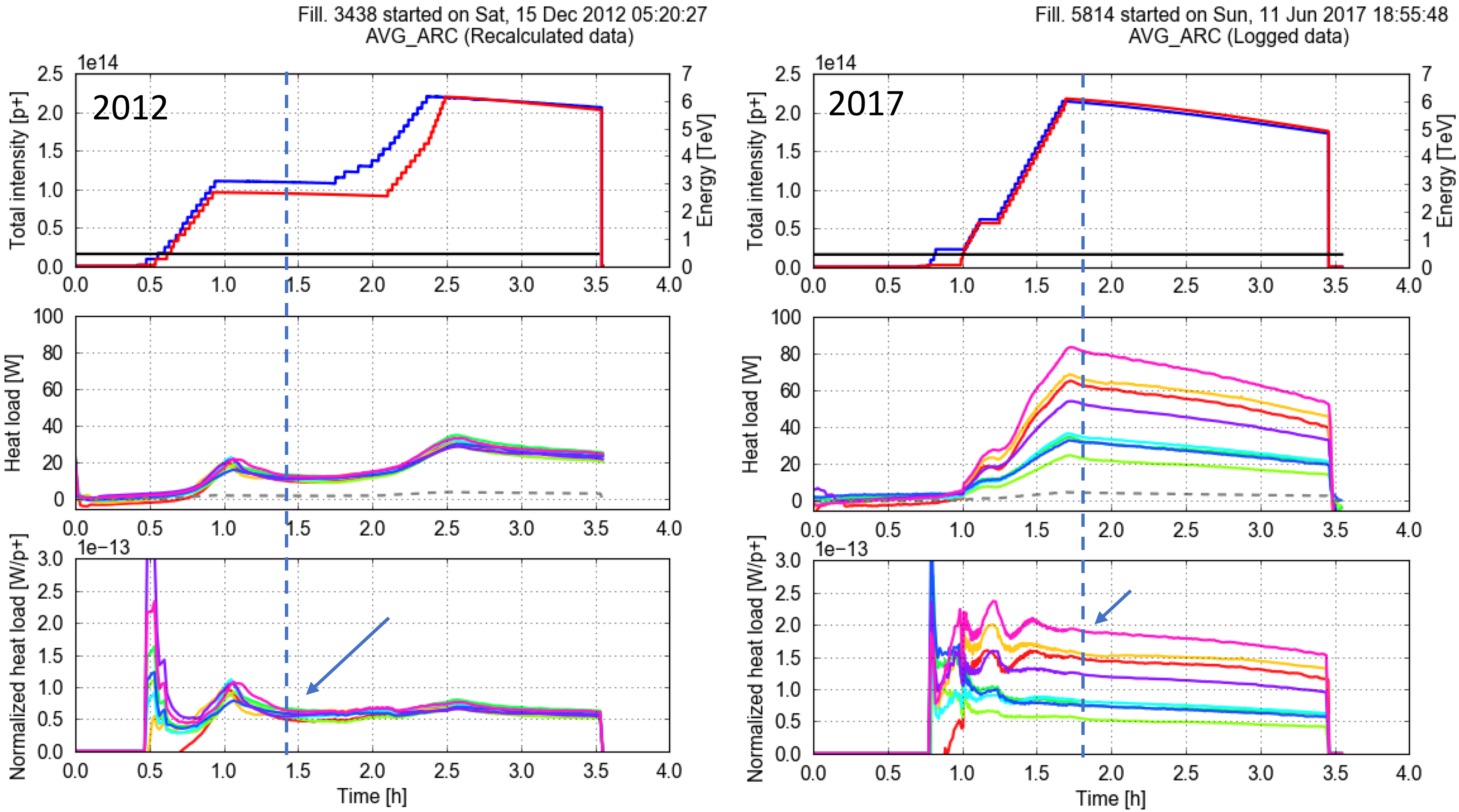
  → **Changes are evident mainly on Sector 12**





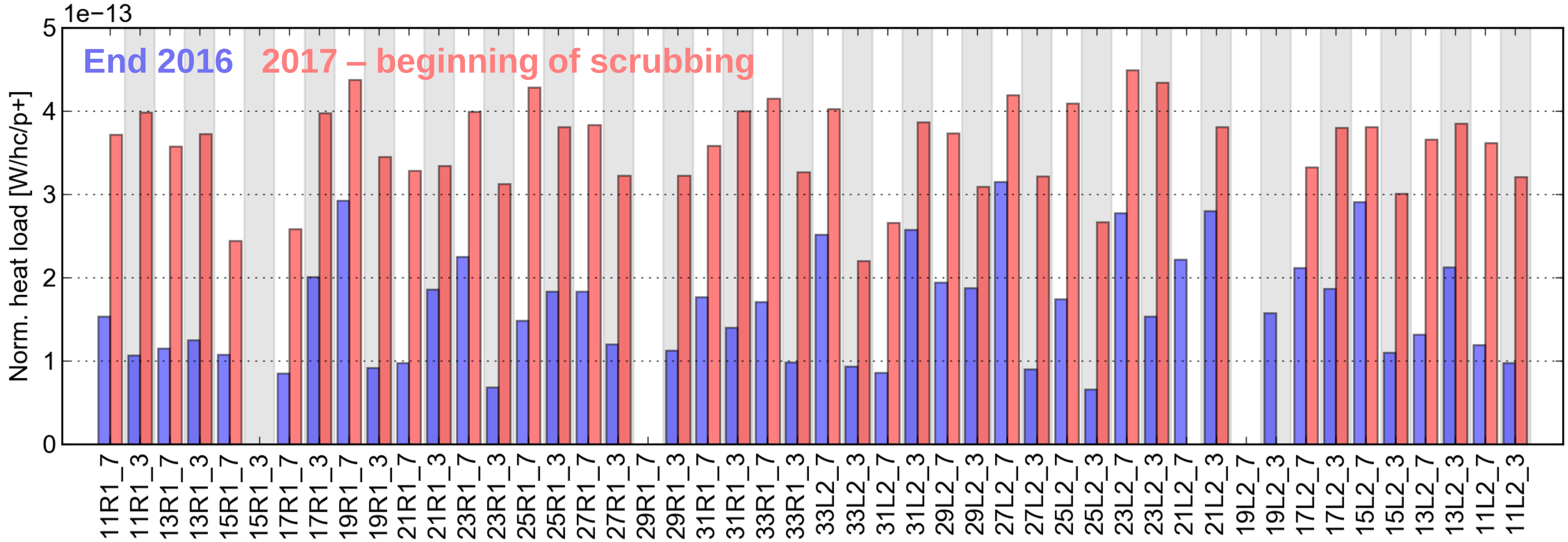
- **Opposite from S12 warm-up in 2016-17, LS1 introduced a big change in the heat loads** (detailed analysis to be presented at one of the coming meetings)

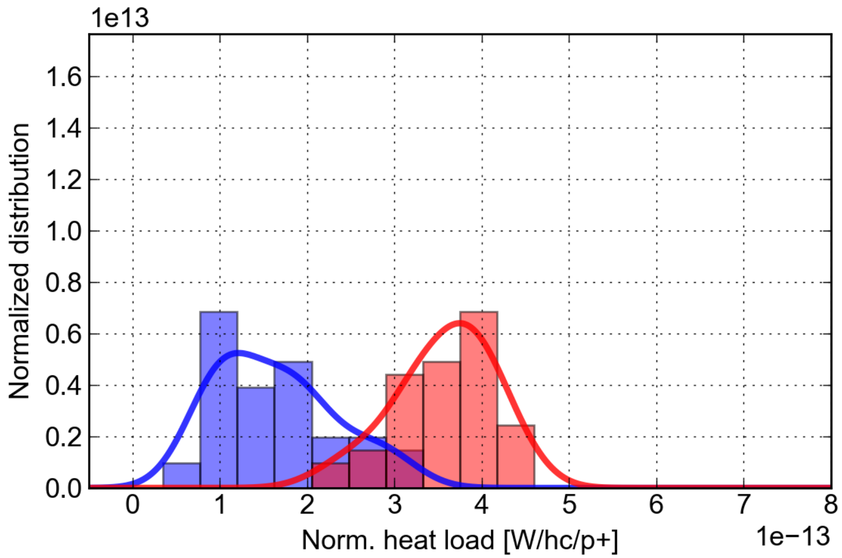
Comparison for 25 ns trains of 72 bunches at 450 GeV



Cell-by-cell analysis at 450 GeV: S12

- Heat load **increase observed on all cells**
- **Deconditioning tends to equalize the heat loads**

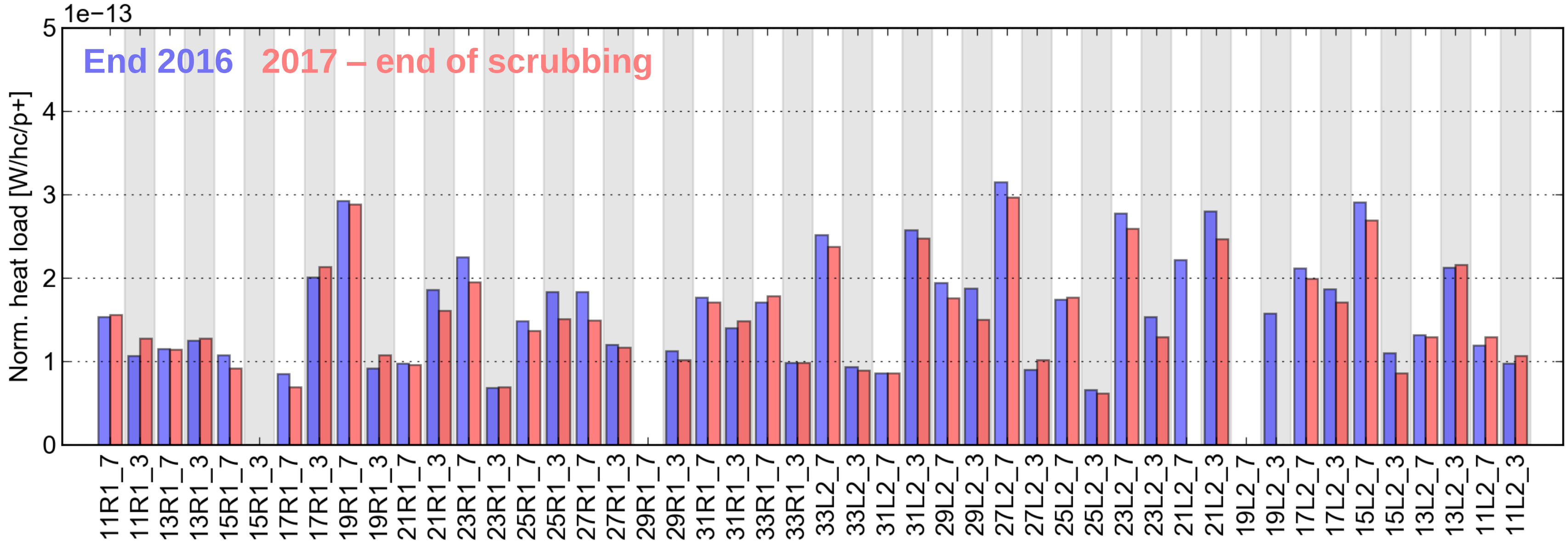


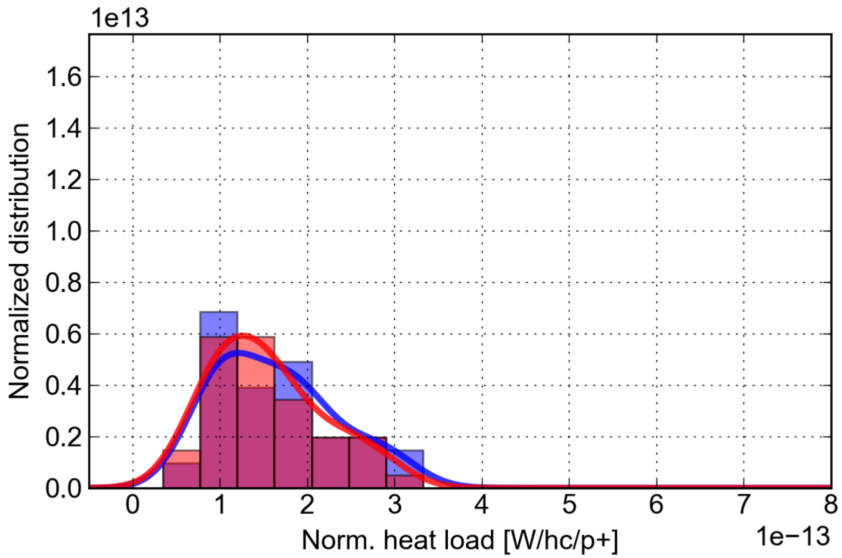


Fill	5433	5728
Started on	19 Oct 2016 22:26	30 May 2017 02:46
T_sample [h]	1.15	1.90
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	1308/1596
Intensity (B1/B2) [p]	2.14e14/2.20e14	1.37e14/1.77e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.22/1.26
H.L. S12 (avg) [W]	71.03	111.94
H.L. S12 (std) [W]	28.69	16.76
H.L. exp. imped. [W]	4.92	3.30
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.50

Cell-by-cell analysis at 450 GeV: S12

- Situation at the end of scrubbing run was practically **identical to end-2016**

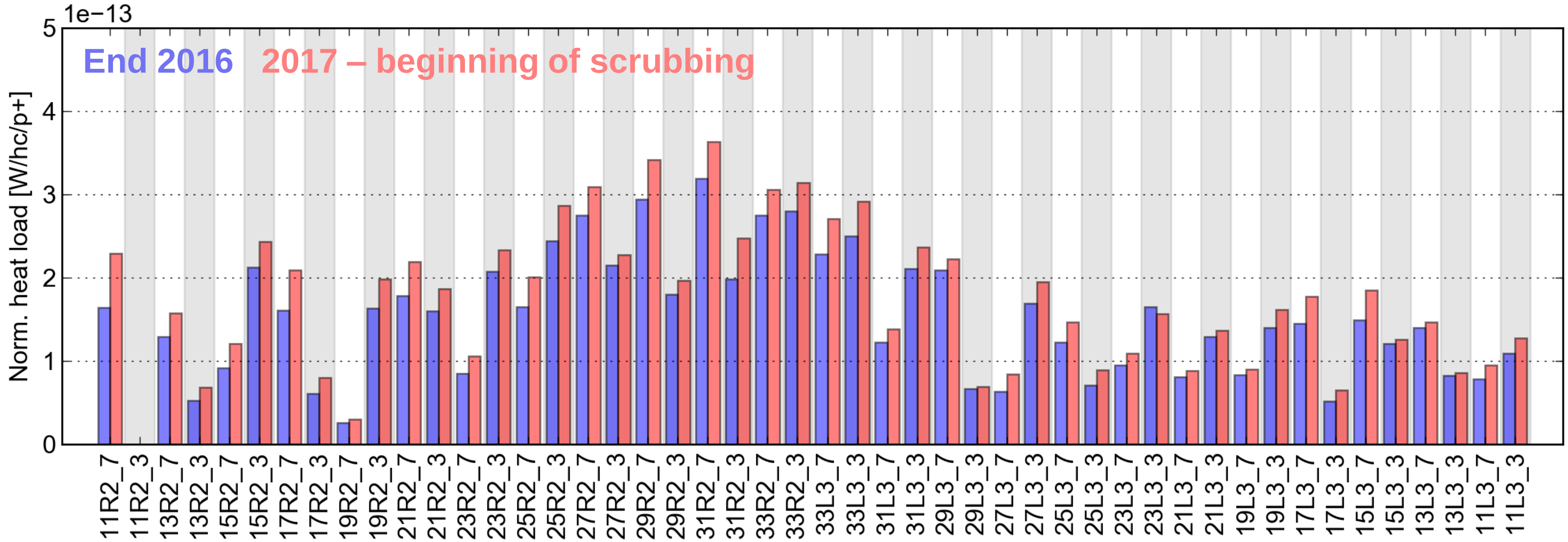


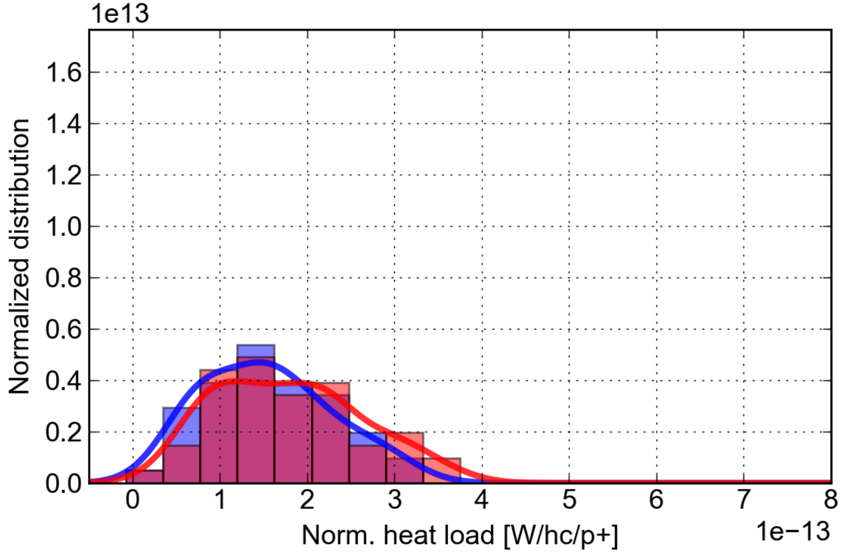


	End 2016	2017 – end of scrubbing
Fill	5433	5814
Started on	19 Oct 2016 22:26	11 Jun 2017 18:55
T_sample [h]	1.15	1.80
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	2040/2040
Intensity (B1/B2) [p]	2.14e14/2.20e14	2.13e14/2.16e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.15/1.28
H.L. S12 (avg) [W]	71.03	66.24
H.L. S12 (std) [W]	28.69	26.43
H.L. exp. imped. [W]	4.92	4.58
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.70

Cell-by-cell analysis at 450 GeV: S23

- Other sectors were already very similar by the end of the first scrubbing day

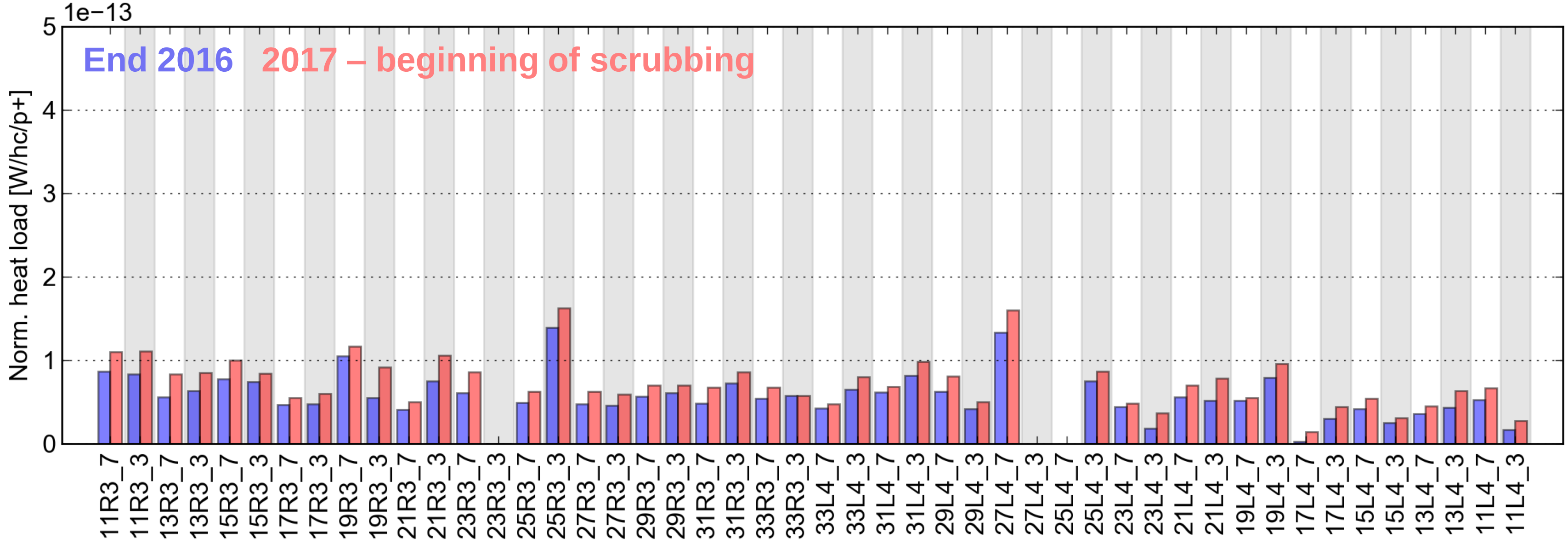


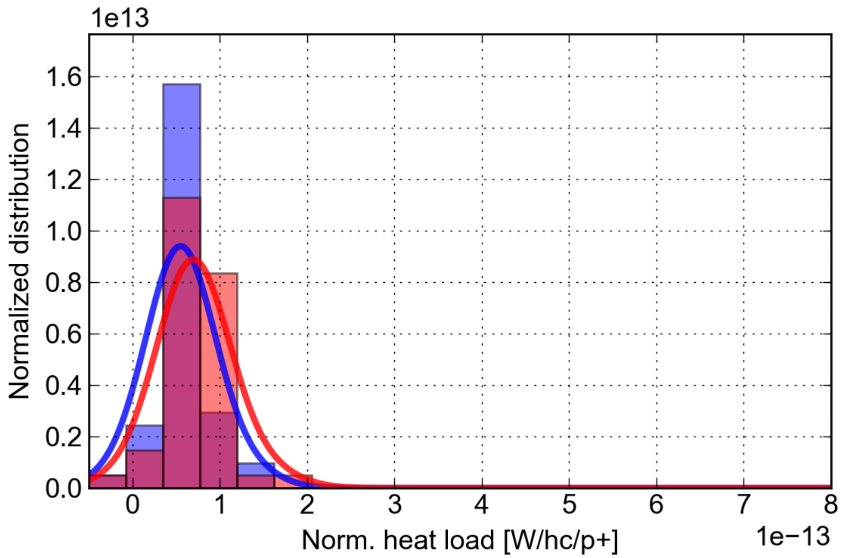


Fill	5433	5728
Started on	19 Oct 2016 22:26	30 May 2017 02:46
T_sample [h]	1.15	1.90
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	1308/1596
Intensity (B1/B2) [p]	2.14e14/2.20e14	1.37e14/1.77e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.22/1.26
H.L. S23 (avg) [W]	66.78	55.87
H.L. S23 (std) [W]	31.27	25.61
H.L. exp. imped. [W]	4.92	3.30
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.50

Cell-by-cell analysis at 450 GeV: S34

- Other sectors were already very similar by the end of the first scrubbing day

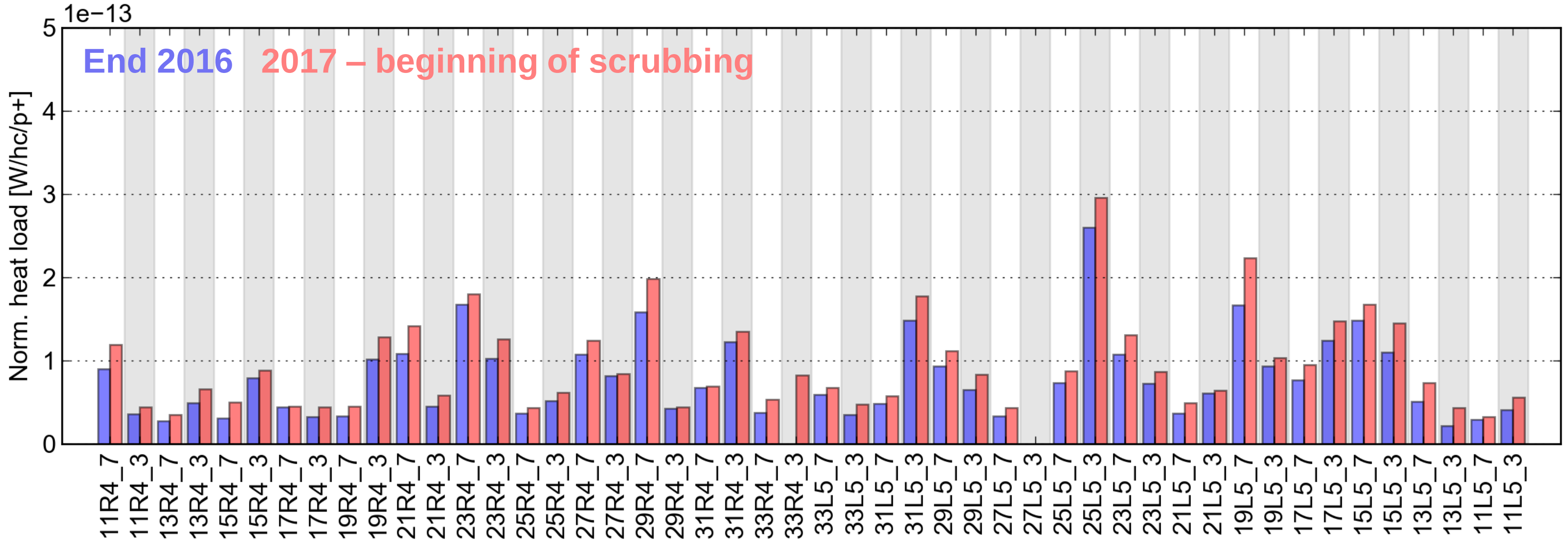


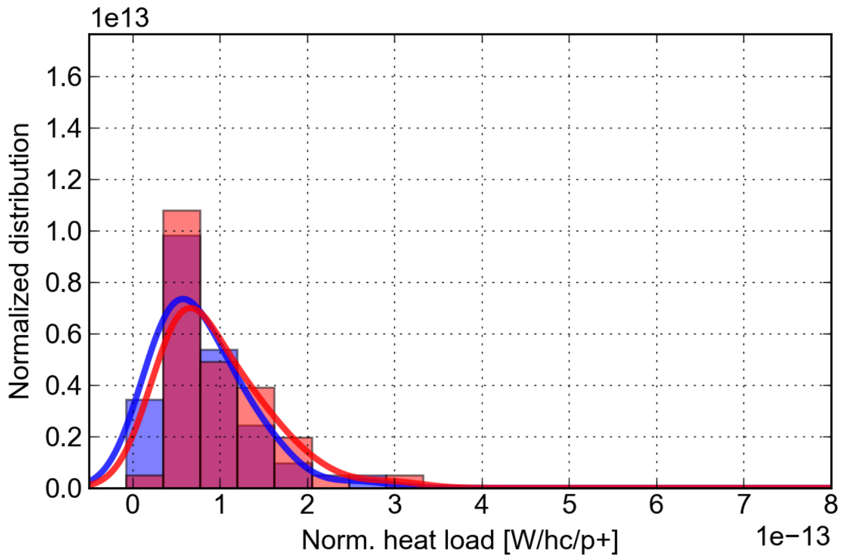


Fill	5433	5728
Started on	19 Oct 2016 22:26	30 May 2017 02:46
T_sample [h]	1.15	1.90
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	1308/1596
Intensity (B1/B2) [p]	2.14e14/2.20e14	1.37e14/1.77e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.22/1.26
H.L. S34 (avg) [W]	24.63	22.48
H.L. S34 (std) [W]	12.03	10.06
H.L. exp. imped. [W]	4.92	3.30
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.50

Cell-by-cell analysis at 450 GeV: S45

- Other sectors were already very similar by the end of the first scrubbing day

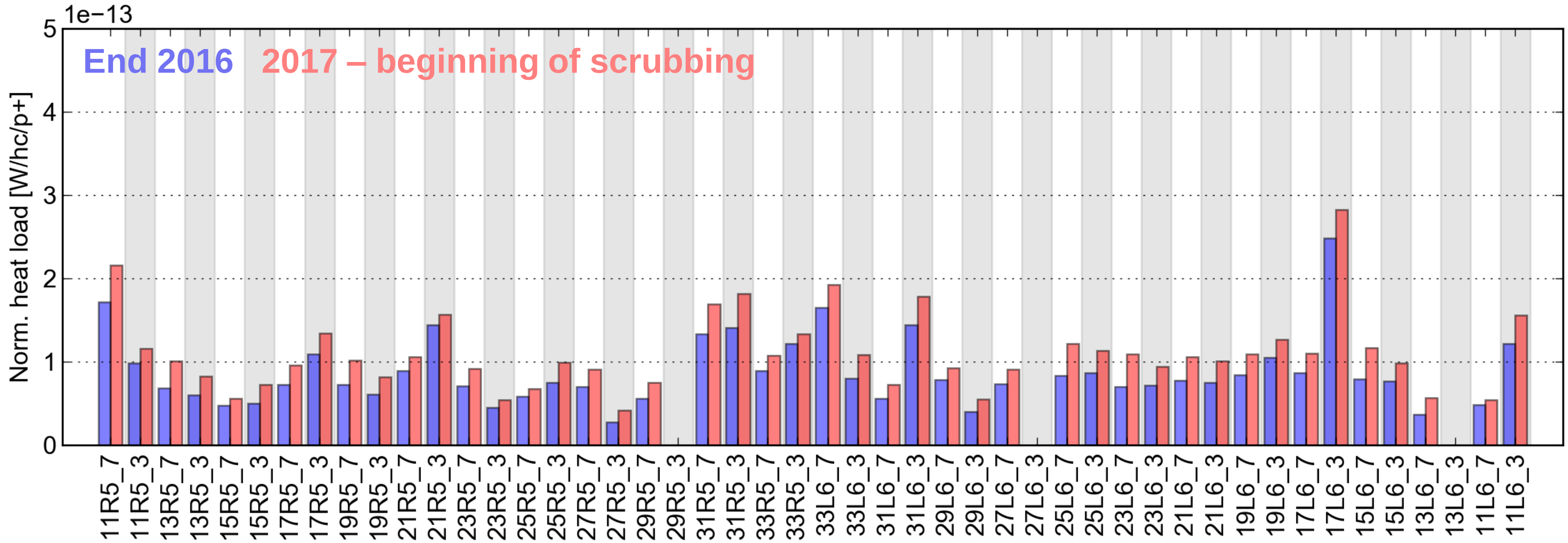


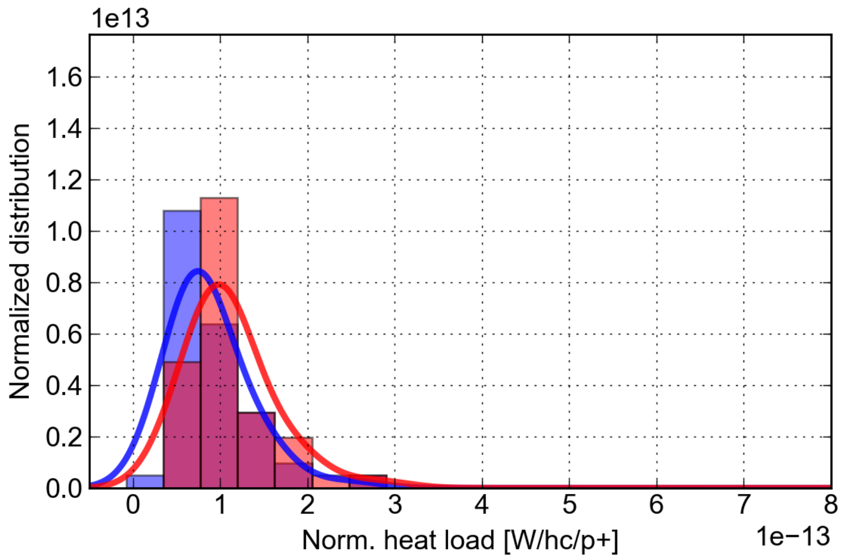


	End 2016	2017 – beginning of scrubbing
Fill	5433	5728
Started on	19 Oct 2016 22:26	30 May 2017 02:46
T_sample [h]	1.15	1.90
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	1308/1596
Intensity (B1/B2) [p]	2.14e14/2.20e14	1.37e14/1.77e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.22/1.26
H.L. S45 (avg) [W]	34.20	29.81
H.L. S45 (std) [W]	21.12	17.48
H.L. exp. imped. [W]	4.92	3.30
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.50

Cell-by-cell analysis at 450 GeV: S56

- Other sectors were already very similar by the end of the first scrubbing day

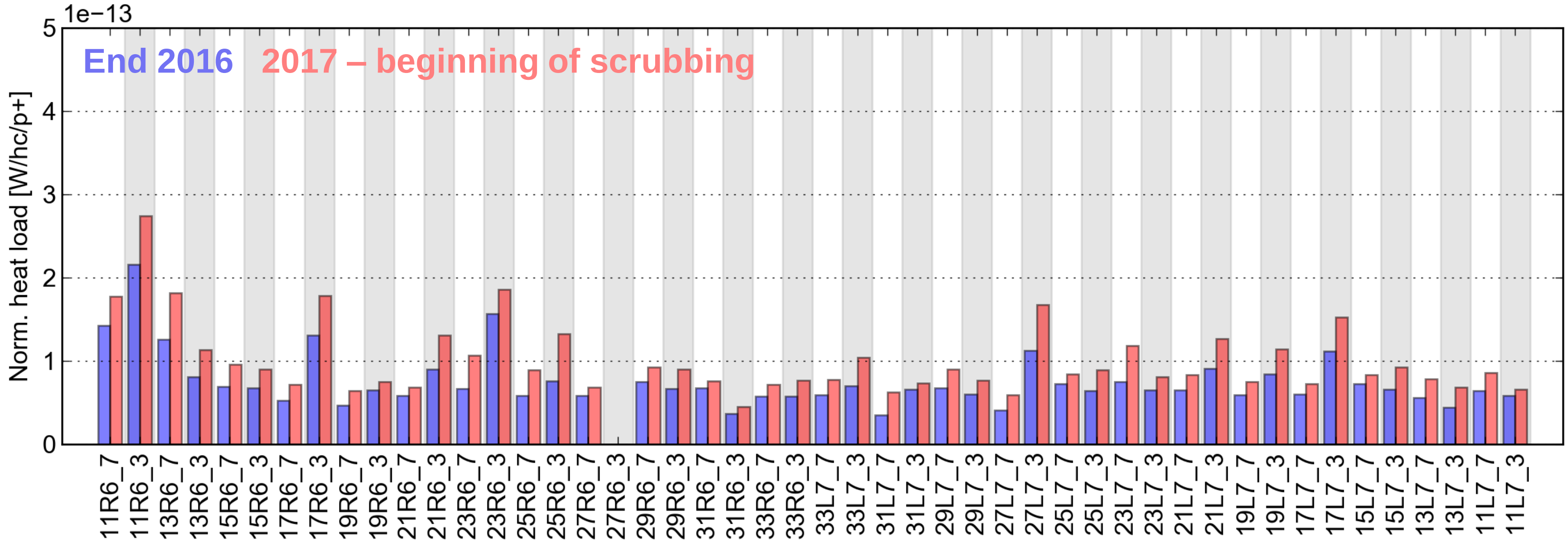


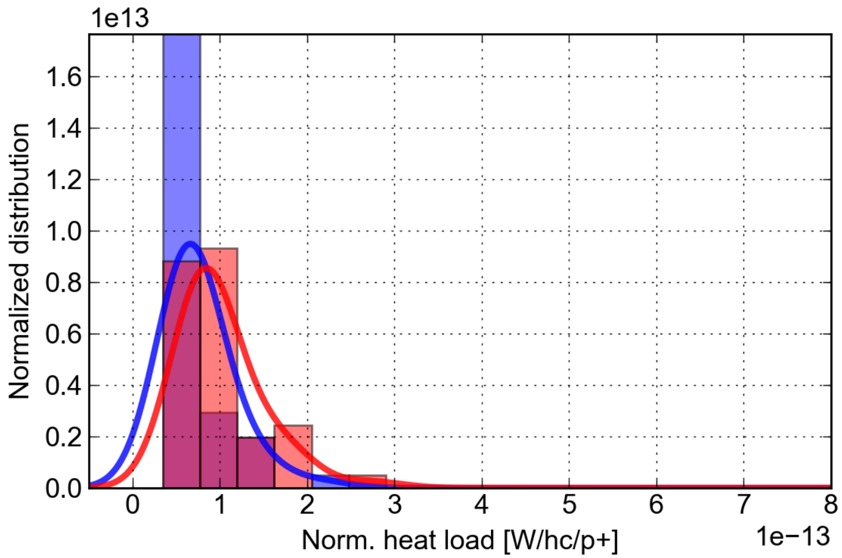


Fill	5433	5728
Started on	19 Oct 2016 22:26	30 May 2017 02:46
T_sample [h]	1.15	1.90
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	1308/1596
Intensity (B1/B2) [p]	2.14e14/2.20e14	1.37e14/1.77e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.22/1.26
H.L. S56 (avg) [W]	37.91	34.72
H.L. S56 (std) [W]	17.76	14.51
H.L. exp. imped. [W]	4.92	3.30
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.50

Cell-by-cell analysis at 450 GeV: S67

- Other sectors were already very similar by the end of the first scrubbing day

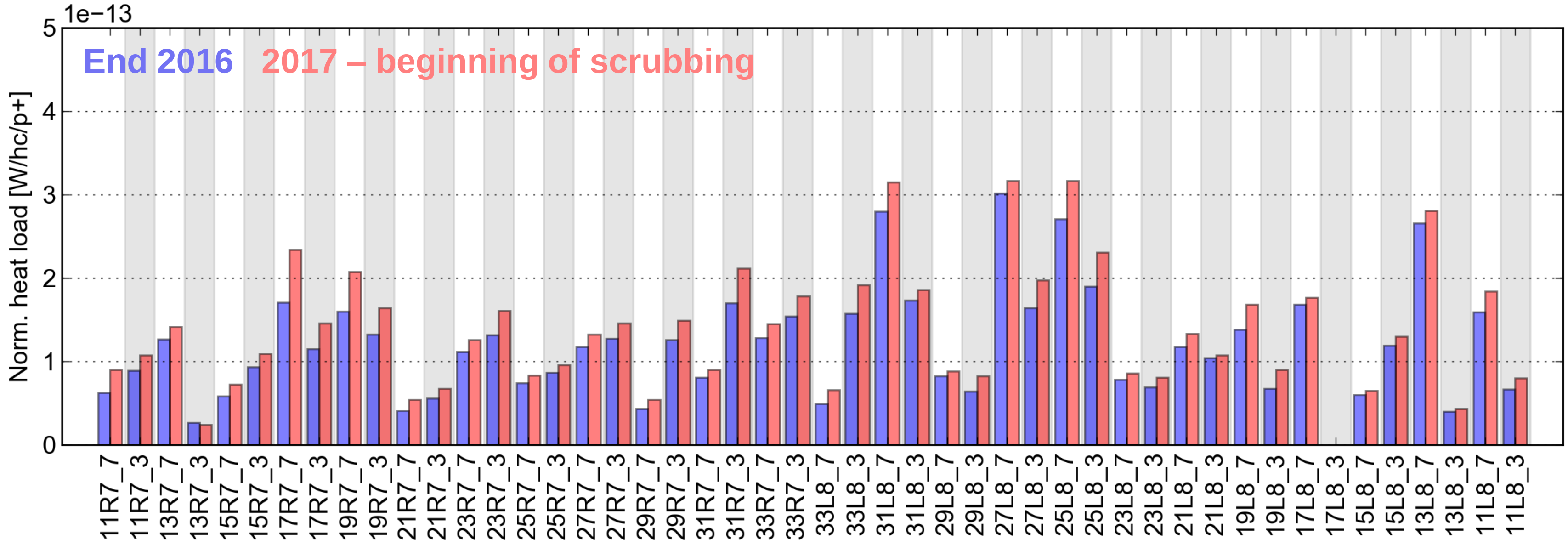


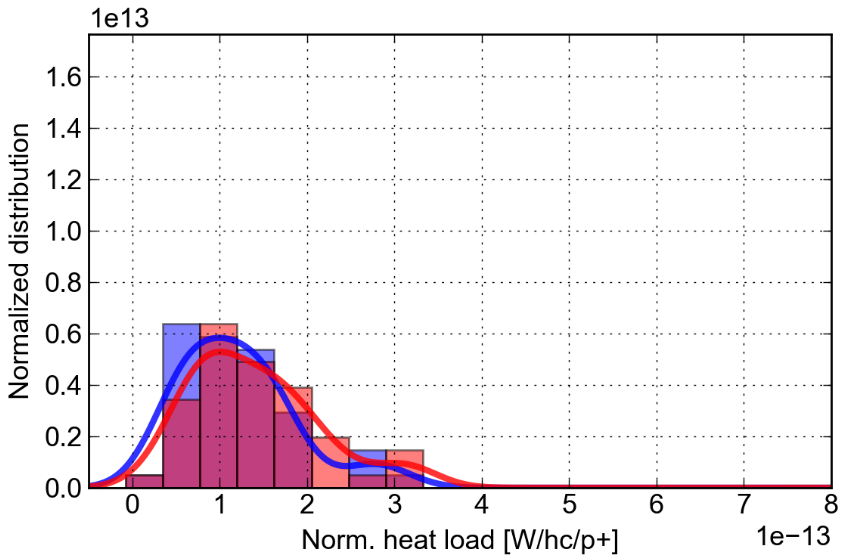


	(blue)	(red)
Fill	5433	5728
Started on	19 Oct 2016 22:26	30 May 2017 02:46
T_sample [h]	1.15	1.90
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	1308/1596
Intensity (B1/B2) [p]	2.14e14/2.20e14	1.37e14/1.77e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.22/1.26
H.L. S67 (avg) [W]	32.83	31.66
H.L. S67 (std) [W]	14.25	13.54
H.L. exp. imped. [W]	4.92	3.30
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.50

Cell-by-cell analysis at 450 GeV: S78

- Other sectors were already very similar by the end of the first scrubbing day

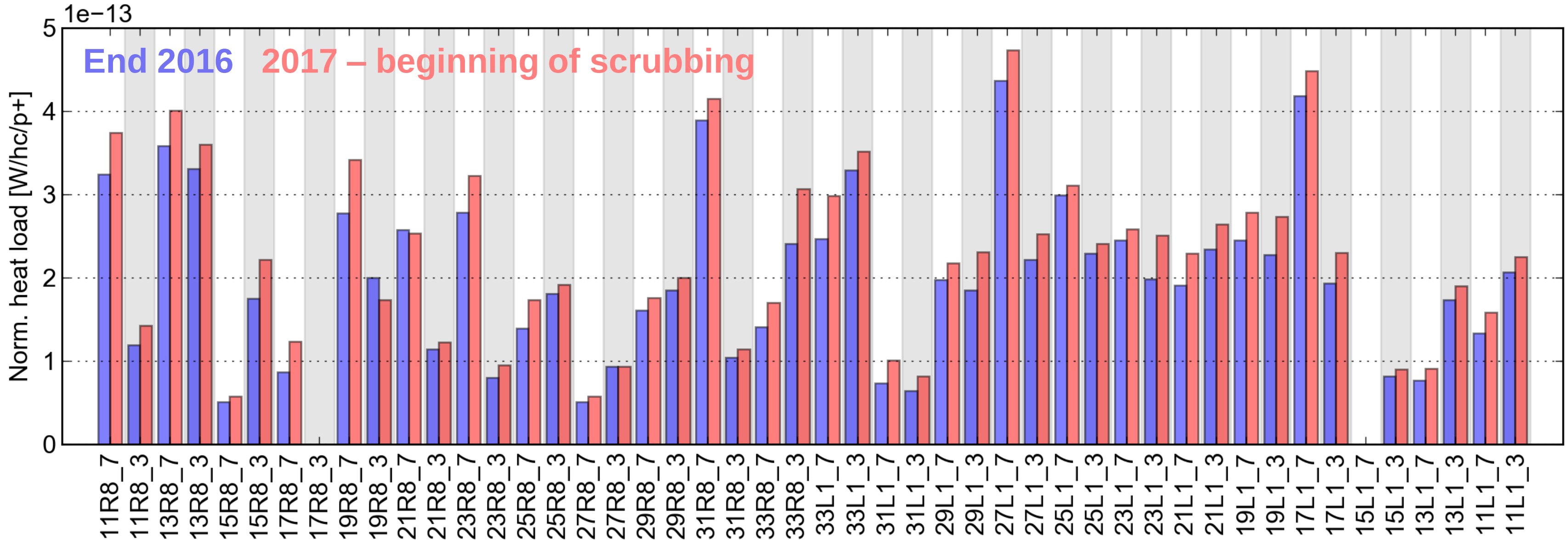


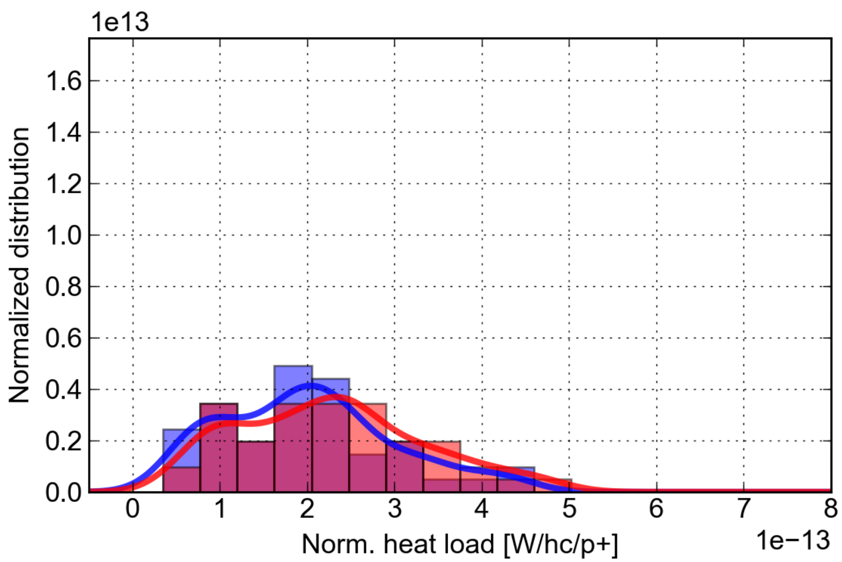


	End 2016	2017 – beginning of scrubbing
Fill	5433	5728
Started on	19 Oct 2016 22:26	30 May 2017 02:46
T_sample [h]	1.15	1.90
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	1308/1596
Intensity (B1/B2) [p]	2.14e14/2.20e14	1.37e14/1.77e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.22/1.26
H.L. S78 (avg) [W]	52.48	44.13
H.L. S78 (std) [W]	27.91	22.61
H.L. exp. imped. [W]	4.92	3.30
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.50

Cell-by-cell analysis at 450 GeV: S81

- Other sectors were already very similar by the end of the first scrubbing day

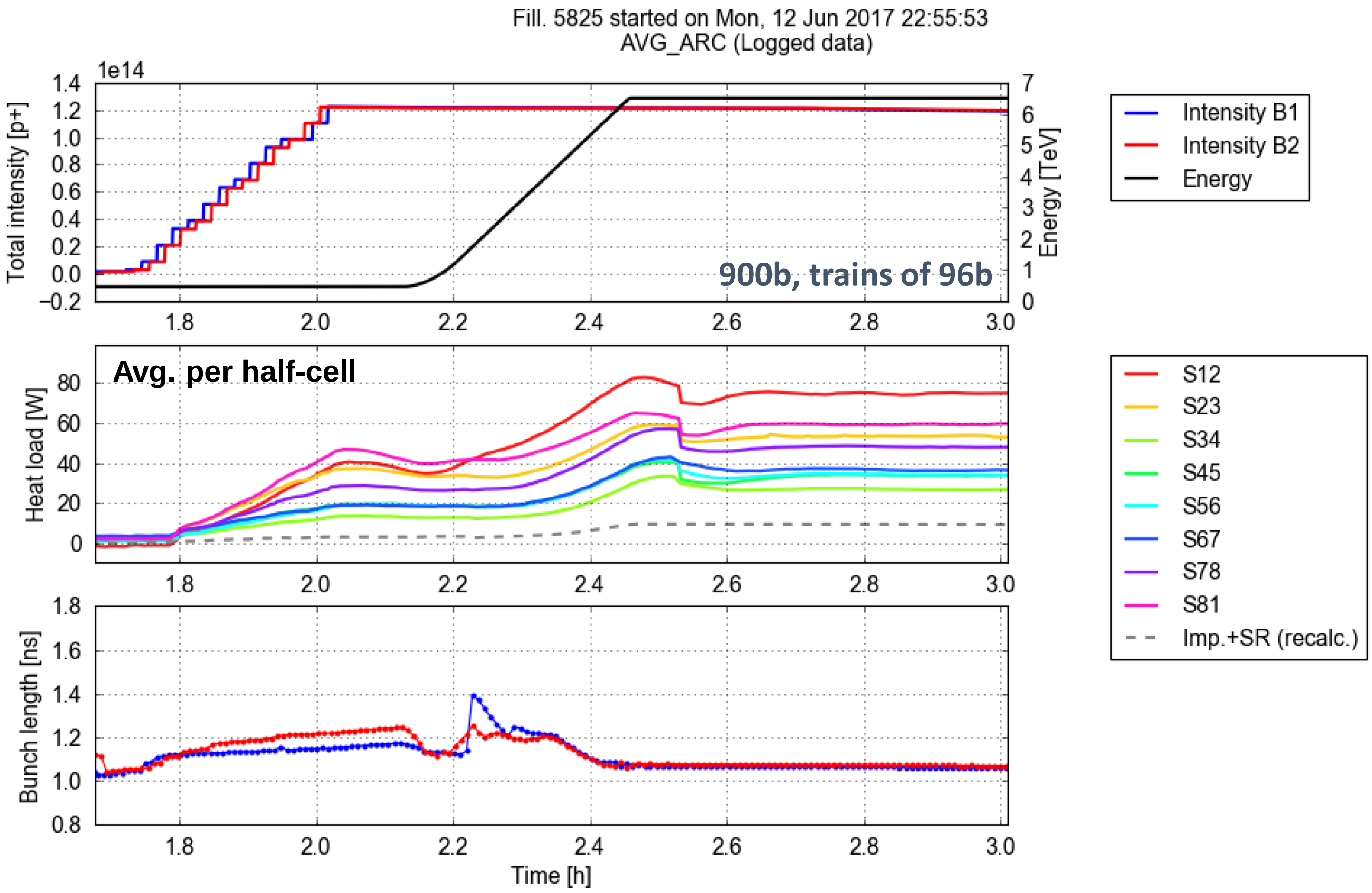




	(blue)	(red)
Fill	5433	5728
Started on	19 Oct 2016 22:26	30 May 2017 02:46
T_sample [h]	1.15	1.90
Energy [GeV]	450	450
N_bunches (B1/B2)	2040/2040	1308/1596
Intensity (B1/B2) [p]	2.14e14/2.20e14	1.37e14/1.77e14
Bun.len. (B1/B2) [ns]	1.17/1.18	1.22/1.26
H.L. S81 (avg) [W]	87.31	71.11
H.L. S81 (std) [W]	42.19	32.91
H.L. exp. imped. [W]	4.92	3.30
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.01	0.50

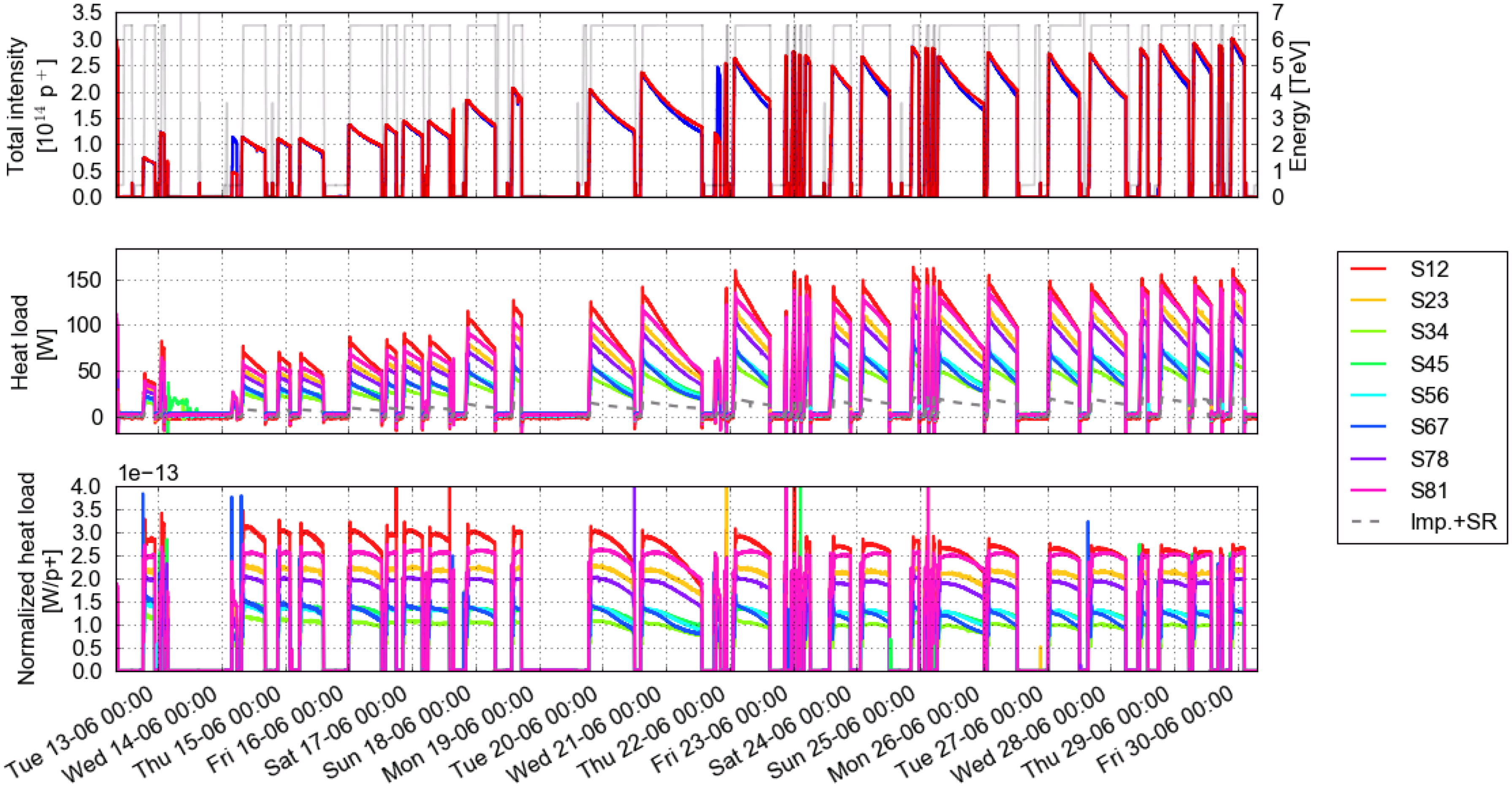
Observations from first physics fills after the scrubbing

- Still the **increase observed in the energy ramp is larger for Sector 12** (most likely due to bunch shortening and photoelectrons in regions that are not reached by e-cloud at 450 GeV)



Heat load evolution during the intensity ramp-up

- During the intensity ramp-up the heat load in S12 is getting **closer and closer to the other sectors**



Heat load evolution during the intensity ramp-up

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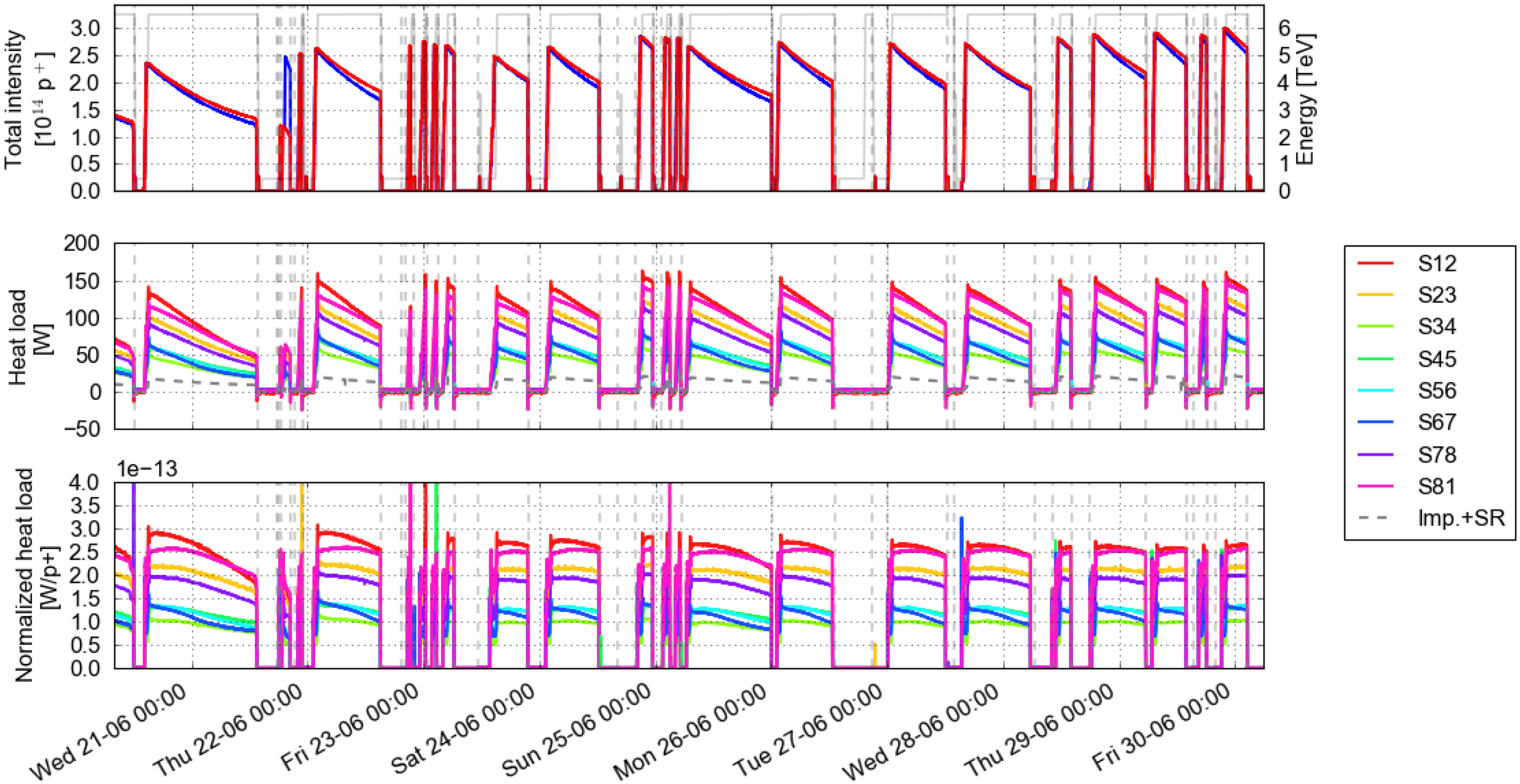
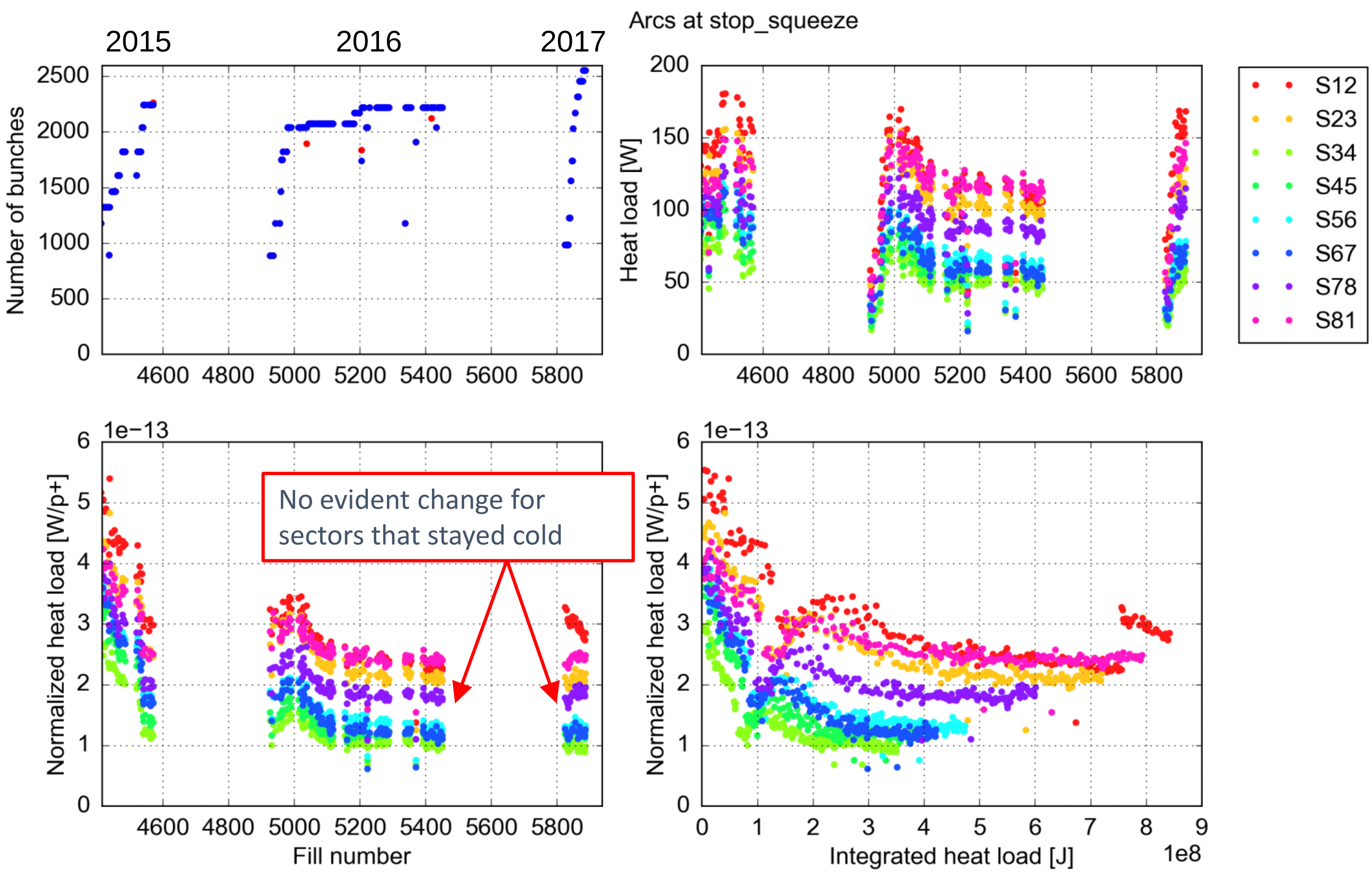


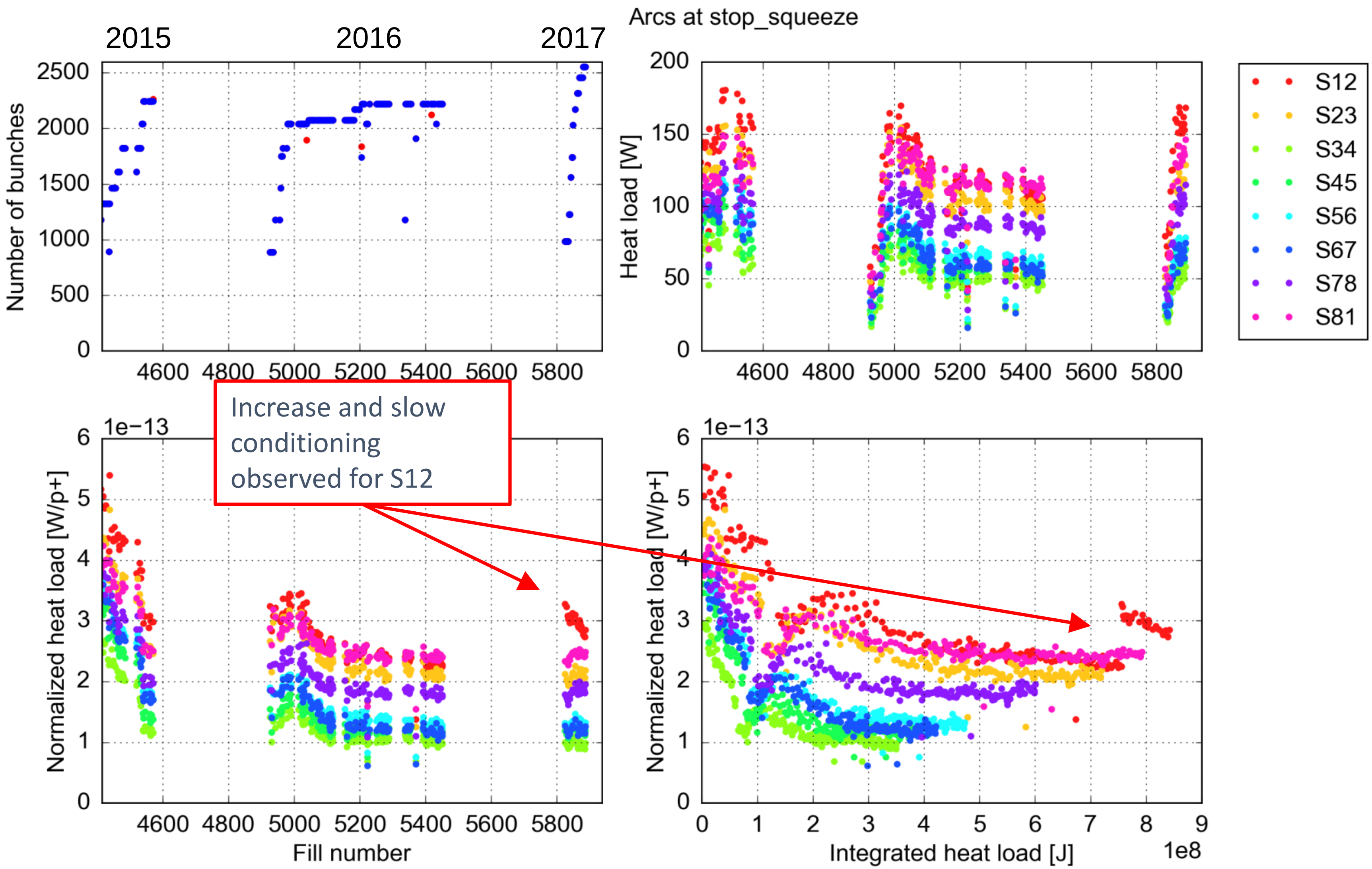
Arc heat load evolution during Run 2

- Complete evolution of the average arc **heat loads at 6.5 TeV over Run 2**
- Only **fills that reached stable beams** are included (→ fills from the scrubbing run are not included)



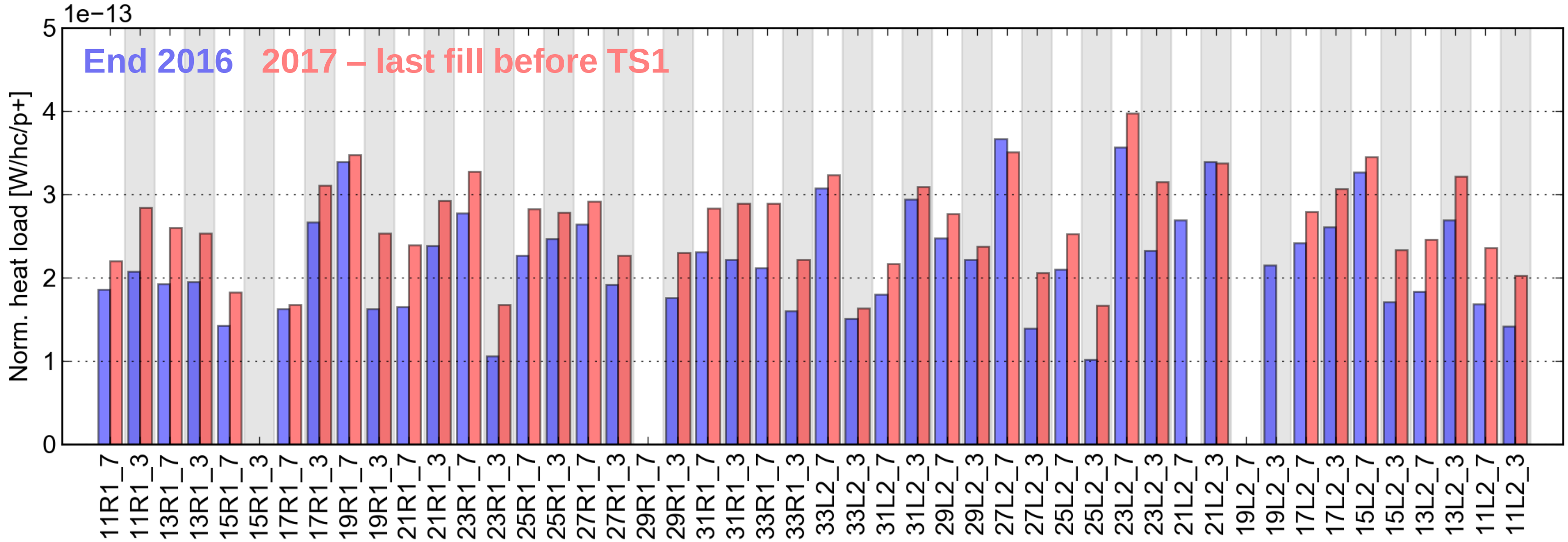
Arc heat load evolution during Run 2

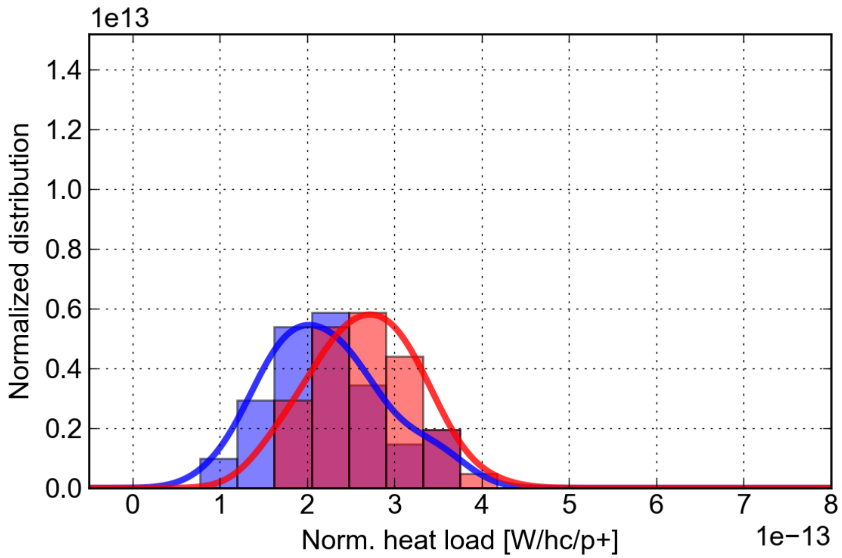
- Complete evolution of the average arc **heat loads at 6.5 TeV over Run 2**
- Only **fills that reached stable beams** are included (→ fills from the scrubbing run are not included)



Cell-by-cell analysis at 6.5 TeV: S12

- In S12 normalized heat load at 6.5 TeV slightly **larger than in 2016 for most of the cells**

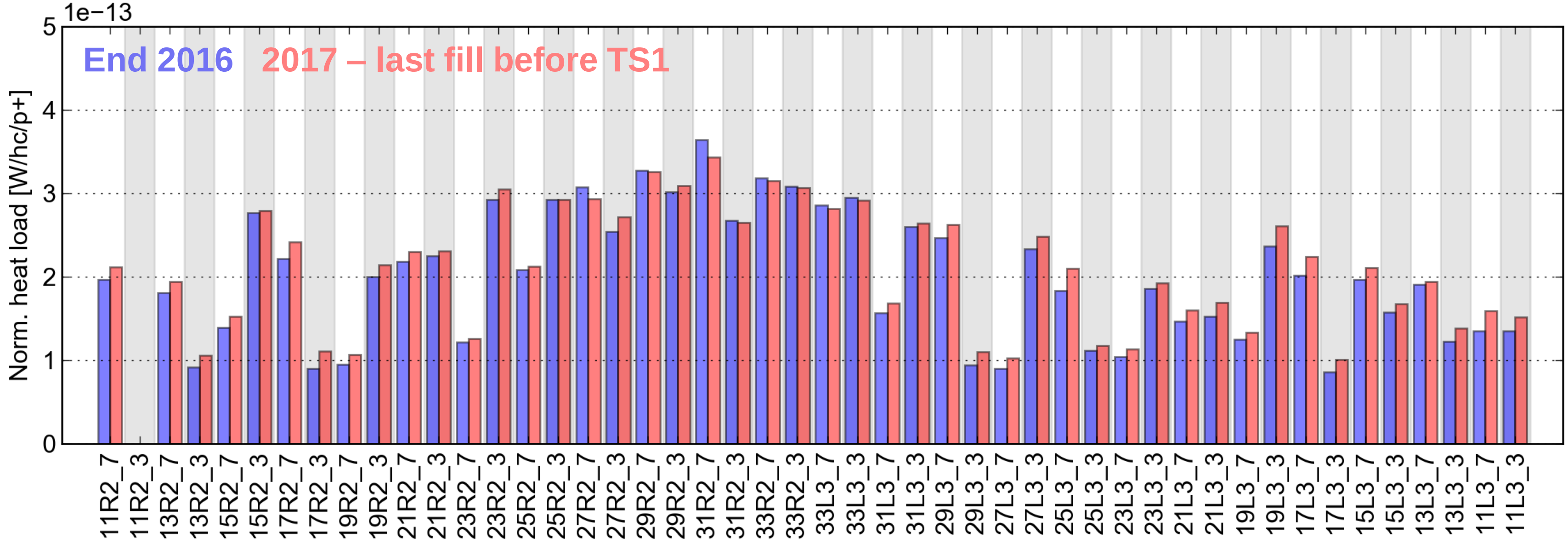


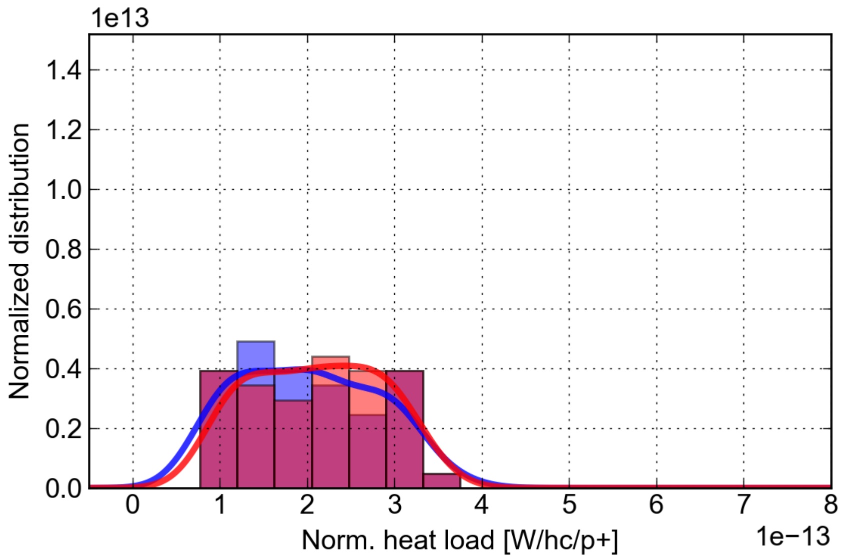


Fill	5451	5887
Started on	26 Oct 2016 07:49	29 Jun 2017 19:51
T_sample [h]	3.00	3.00
Energy [GeV]	6499	6499
N_bunches (B1/B2)	2220/2220	2556/2556
Intensity (B1/B2) [p]	2.34e14/2.35e14	2.85e14/2.93e14
Bun.len. (B1/B2) [ns]	1.08/1.05	1.05/1.06
H.L. S12 (avg) [W]	103.88	153.87
H.L. S12 (std) [W]	30.21	32.13
H.L. exp. imped. [W]	7.37	9.90
H.L. exp. synrad [W]	9.97	12.32
T_nobeam [h]	1.25	1.25

Cell-by-cell analysis at 6.5 TeV: S23

- For the other sectors, **heat loads are practically identical for most of the cells**

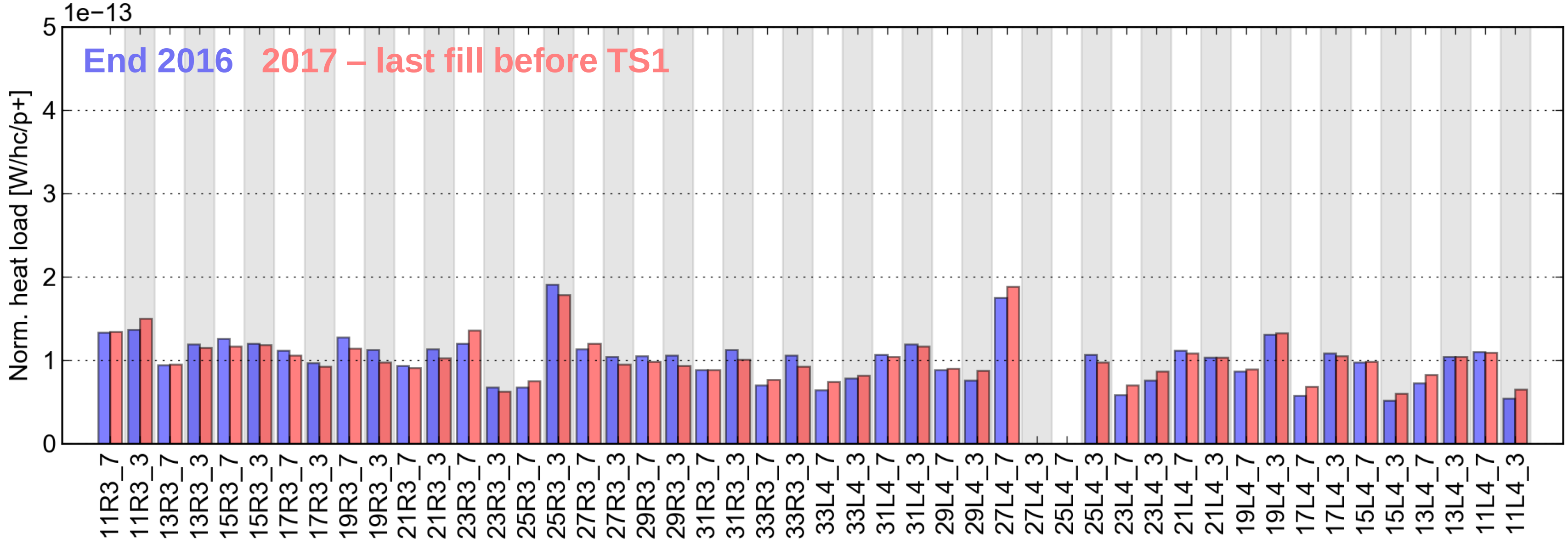


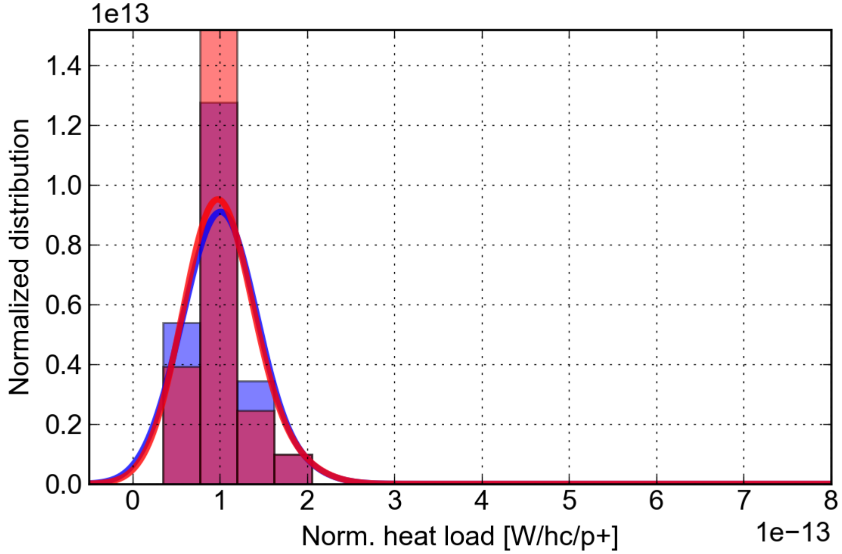


Fill	5451	5887
Started on	26 Oct 2016 07:49	29 Jun 2017 19:51
T_sample [h]	3.00	3.00
Energy [GeV]	6499	6499
N_bunches (B1/B2)	2220/2220	2556/2556
Intensity (B1/B2) [p]	2.34e14/2.35e14	2.85e14/2.93e14
Bun.len. (B1/B2) [ns]	1.08/1.05	1.05/1.06
H.L. S23 (avg) [W]	94.16	121.72
H.L. S23 (std) [W]	35.83	41.17
H.L. exp. imped. [W]	7.37	9.90
H.L. exp. synrad [W]	9.97	12.32
T_nobeam [h]	1.25	1.25

Cell-by-cell analysis at 6.5 TeV: S34

- In S12 normalized heat load at 6.5 TeV slightly **larger than in 2016 for most of the cells**

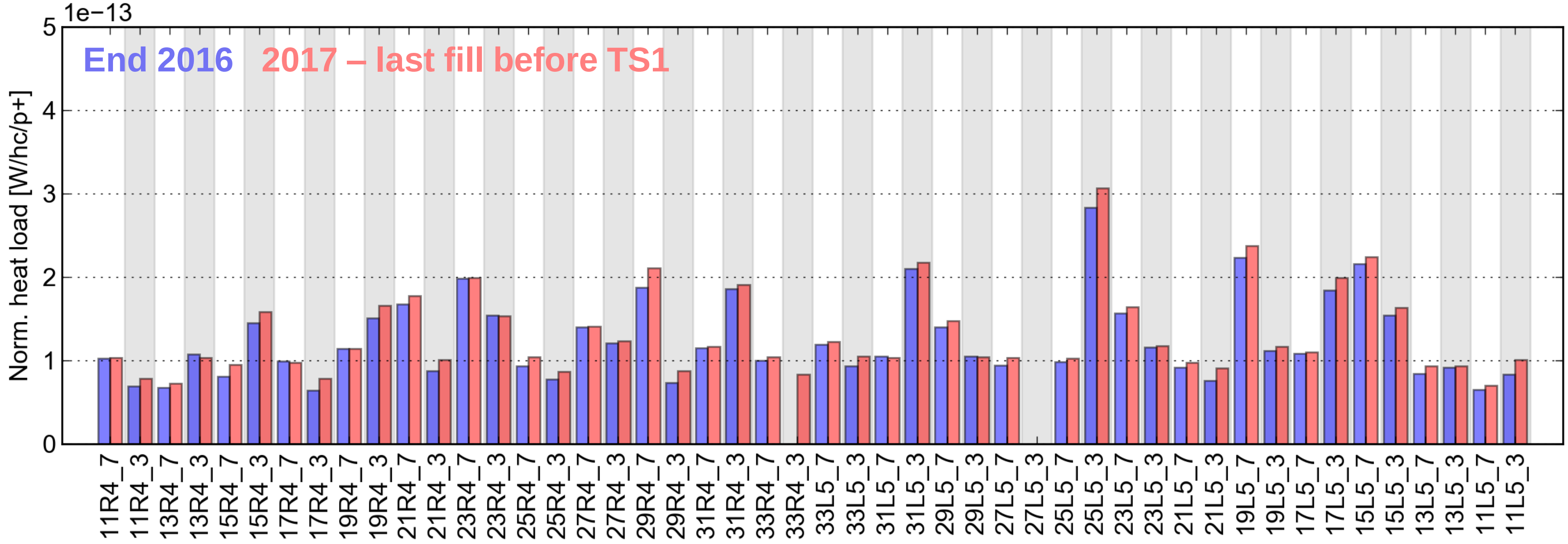


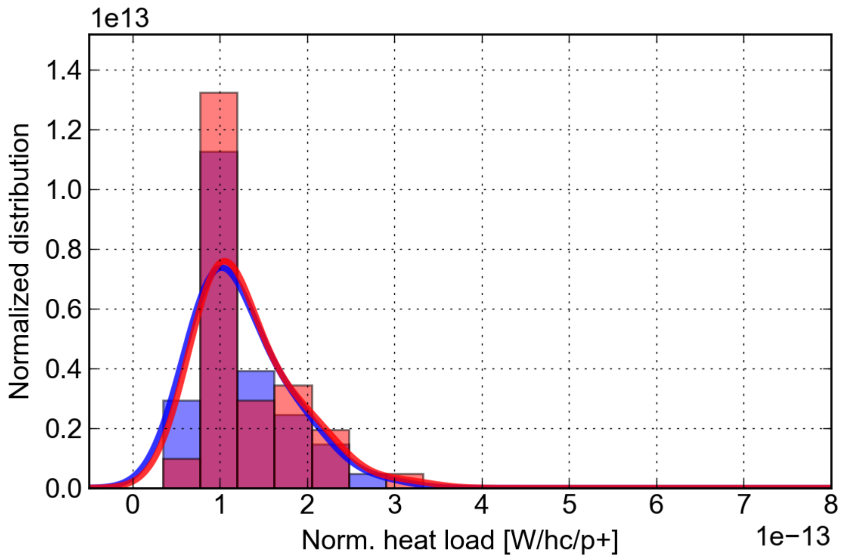


	(blue)	(red)
Fill	5451	5887
Started on	26 Oct 2016 07:49	29 Jun 2017 19:51
T_sample [h]	3.00	3.00
Energy [GeV]	6499	6499
N_bunches (B1/B2)	2220/2220	2556/2556
Intensity (B1/B2) [p]	2.34e14/2.35e14	2.85e14/2.93e14
Bun.len. (B1/B2) [ns]	1.08/1.05	1.05/1.06
H.L. S34 (avg) [W]	47.73	58.96
H.L. S34 (std) [W]	13.25	15.16
H.L. exp. imped. [W]	7.37	9.90
H.L. exp. synrad [W]	9.97	12.32
T_nobeam [h]	1.25	1.25

Cell-by-cell analysis at 6.5 TeV: S45

- In S12 normalized heat load at 6.5 TeV slightly **larger than in 2016 for most of the cells**

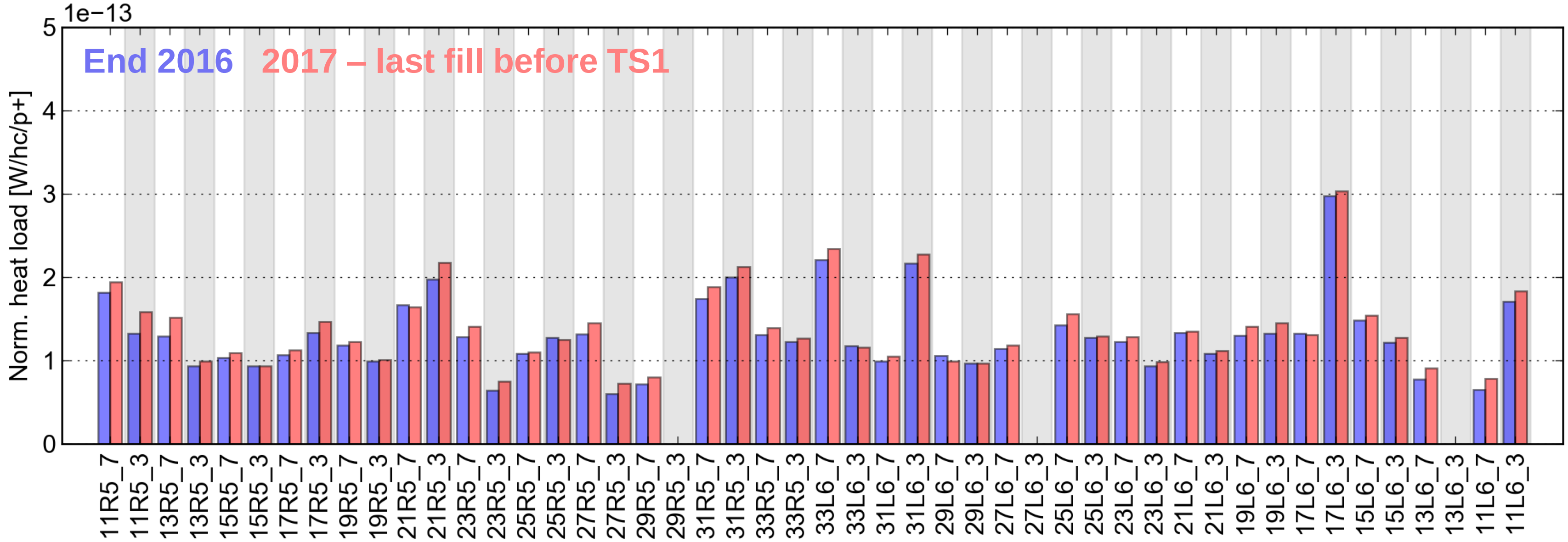


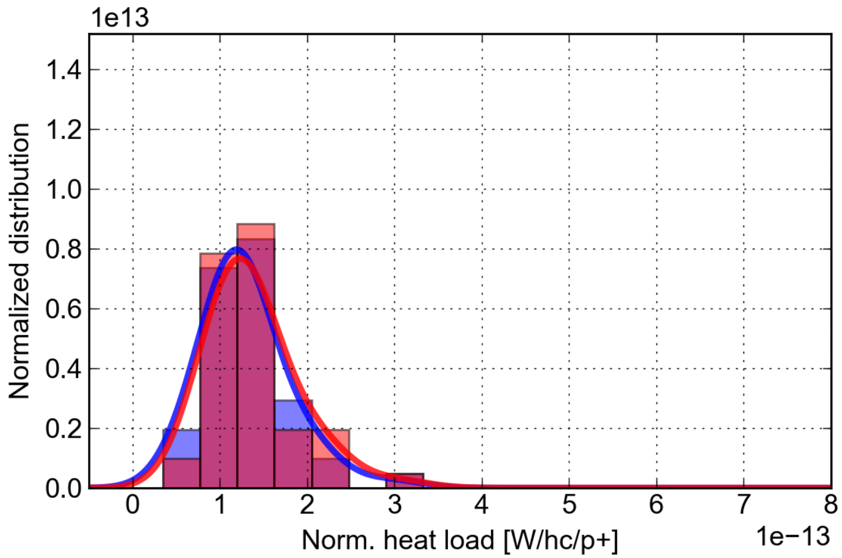


Fill	5451	5887
Started on	26 Oct 2016 07:49	29 Jun 2017 19:51
T_sample [h]	3.00	3.00
Energy [GeV]	6499	6499
N_bunches (B1/B2)	2220/2220	2556/2556
Intensity (B1/B2) [p]	2.34e14/2.35e14	2.85e14/2.93e14
Bun.len. (B1/B2) [ns]	1.08/1.05	1.05/1.06
H.L. S45 (avg) [W]	58.30	75.68
H.L. S45 (std) [W]	22.87	29.44
H.L. exp. imped. [W]	7.37	9.90
H.L. exp. synrad [W]	9.97	12.32
T_nobeam [h]	1.25	1.25

Cell-by-cell analysis at 6.5 TeV: S56

- In S12 normalized heat load at 6.5 TeV slightly **larger than in 2016 for most of the cells**

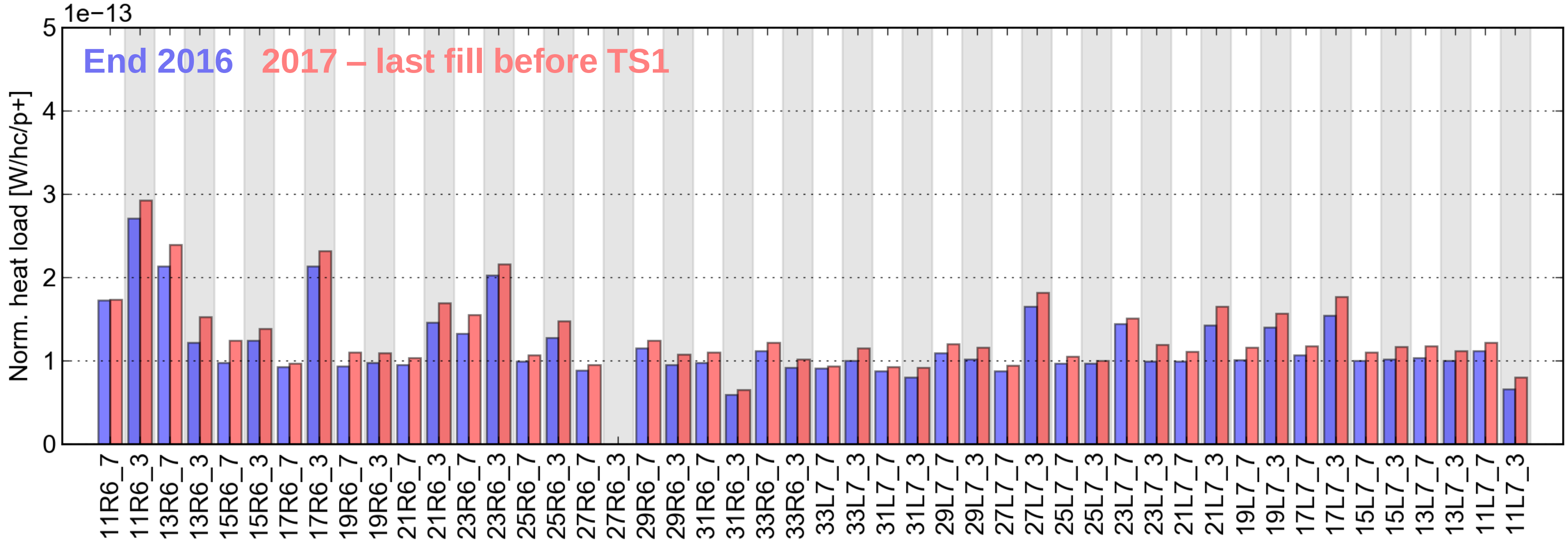


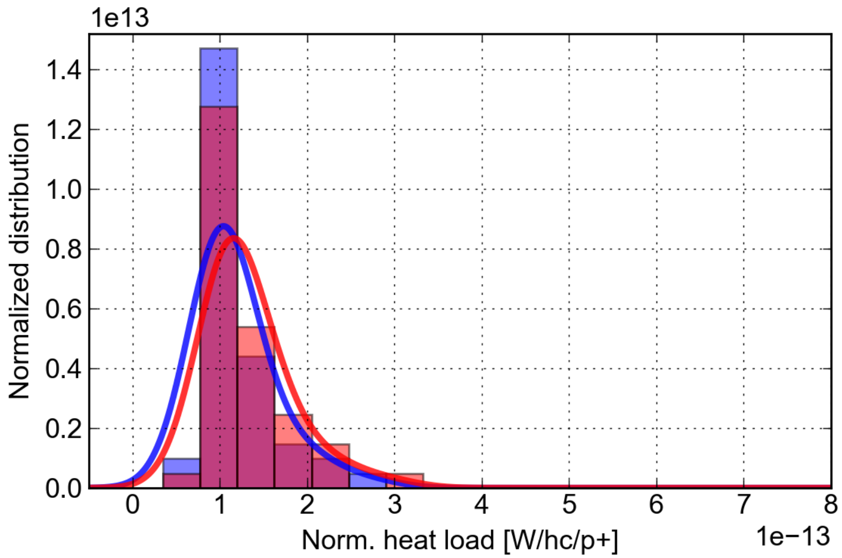


	(blue)	(red)
Fill	5451	5887
Started on	26 Oct 2016 07:49	29 Jun 2017 19:51
T_sample [h]	3.00	3.00
Energy [GeV]	6499	6499
N_bunches (B1/B2)	2220/2220	2556/2556
Intensity (B1/B2) [p]	2.34e14/2.35e14	2.85e14/2.93e14
Bun.len. (B1/B2) [ns]	1.08/1.05	1.05/1.06
H.L. S56 (avg) [W]	61.02	79.82
H.L. S56 (std) [W]	21.14	27.15
H.L. exp. imped. [W]	7.37	9.90
H.L. exp. synrad [W]	9.97	12.32
T_nobeam [h]	1.25	1.25

Cell-by-cell analysis at 6.5 TeV: S67

- In S12 normalized heat load at 6.5 TeV slightly **larger than in 2016 for most of the cells**

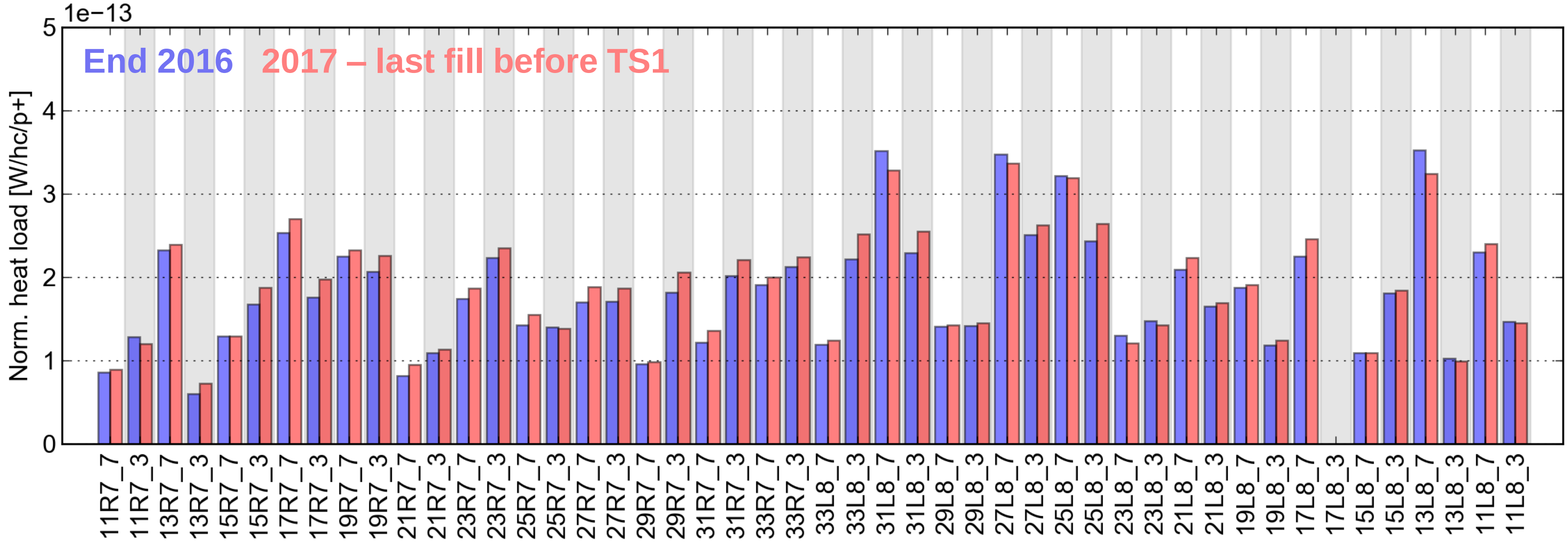


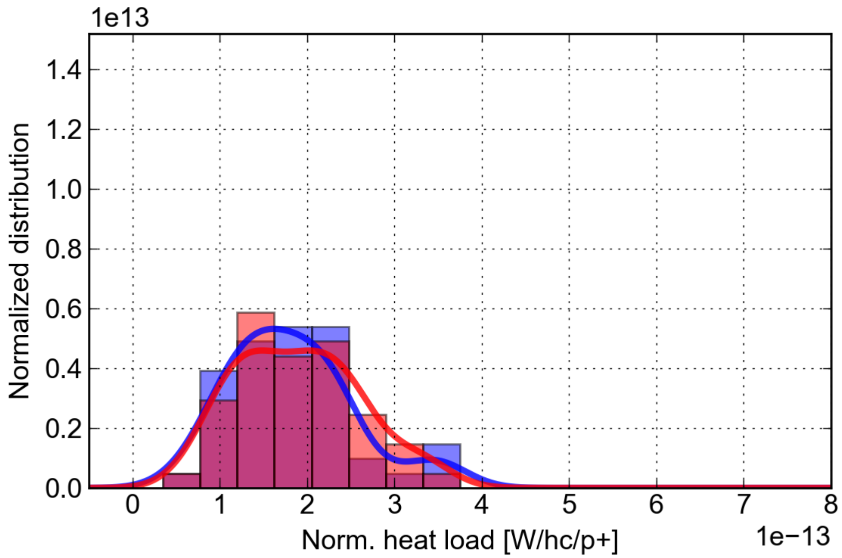


Fill	5451	5887
Started on	26 Oct 2016 07:49	29 Jun 2017 19:51
T_sample [h]	3.00	3.00
Energy [GeV]	6499	6499
N_bunches (B1/B2)	2220/2220	2556/2556
Intensity (B1/B2) [p]	2.34e14/2.35e14	2.85e14/2.93e14
Bun.len. (B1/B2) [ns]	1.08/1.05	1.05/1.06
H.L. S67 (avg) [W]	55.39	76.13
H.L. S67 (std) [W]	19.05	25.39
H.L. exp. imped. [W]	7.37	9.90
H.L. exp. synrad [W]	9.97	12.32
T_nobeam [h]	1.25	1.25

Cell-by-cell analysis at 6.5 TeV: S78

- In S12 normalized heat load at 6.5 TeV slightly **larger than in 2016 for most of the cells**

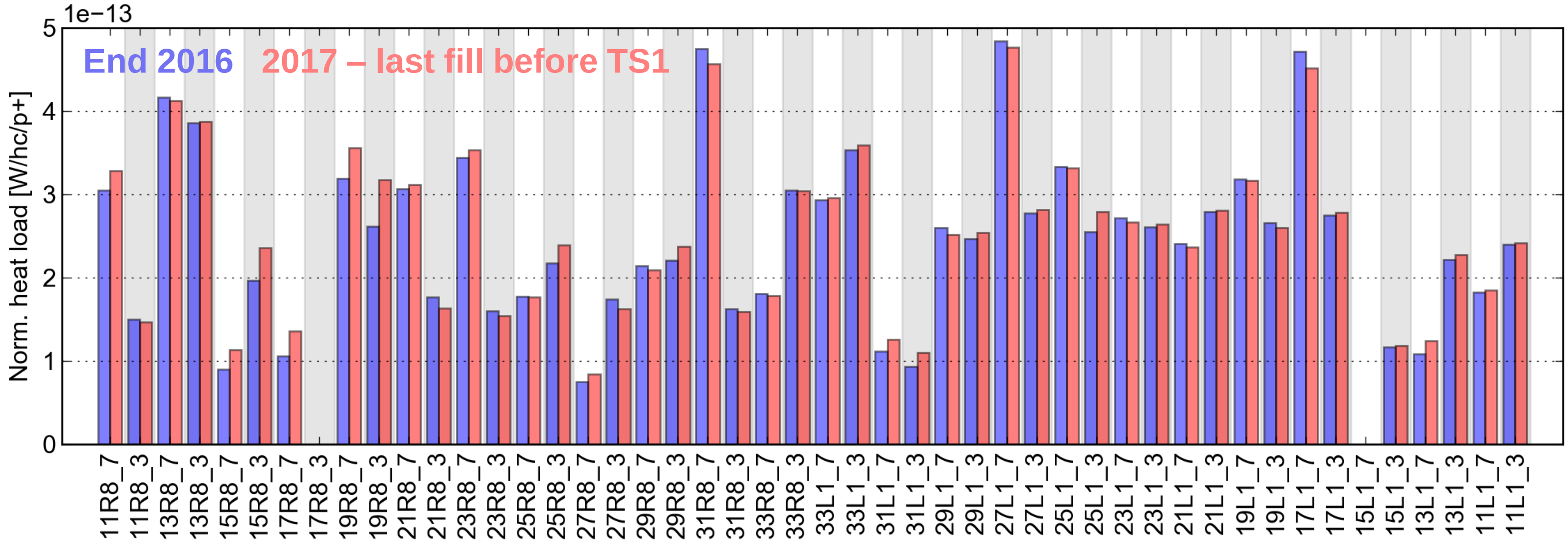


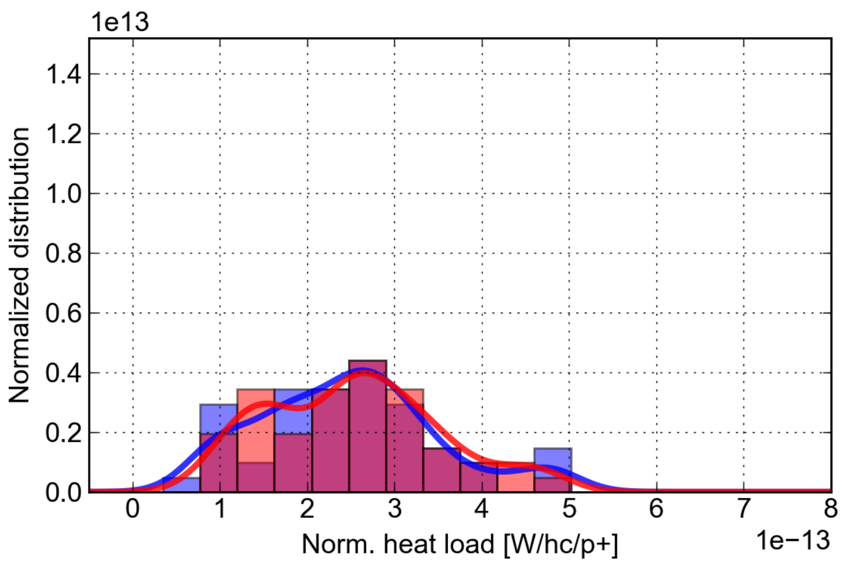


Fill	5451	5887
Started on	26 Oct 2016 07:49	29 Jun 2017 19:51
T_sample [h]	3.00	3.00
Energy [GeV]	6499	6499
N_bunches (B1/B2)	2220/2220	2556/2556
Intensity (B1/B2) [p]	2.34e14/2.35e14	2.85e14/2.93e14
Bun.len. (B1/B2) [ns]	1.08/1.05	1.05/1.06
H.L. S78 (avg) [W]	85.40	109.65
H.L. S78 (std) [W]	32.32	39.30
H.L. exp. imped. [W]	7.37	9.90
H.L. exp. synrad [W]	9.97	12.32
T_nobeam [h]	1.25	1.25

Cell-by-cell analysis at 6.5 TeV: S81

- In S12 normalized heat load at 6.5 TeV slightly **larger than in 2016 for most of the cells**

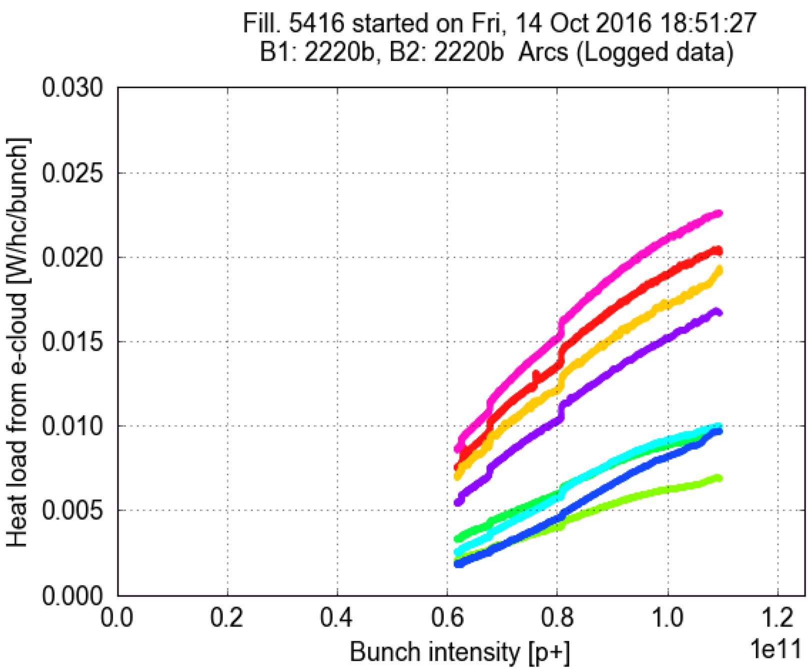




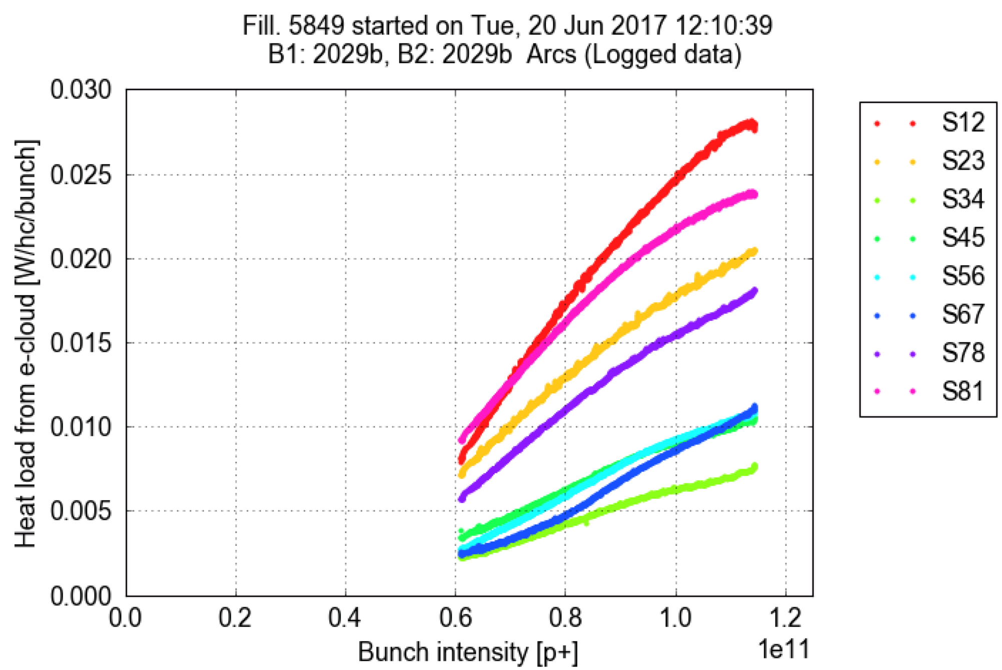
Fill	5451	5887
Started on	26 Oct 2016 07:49	29 Jun 2017 19:51
T_sample [h]	3.00	3.00
Energy [GeV]	6499	6499
N_bunches (B1/B2)	2220/2220	2556/2556
Intensity (B1/B2) [p]	2.34e14/2.35e14	2.85e14/2.93e14
Bun.len. (B1/B2) [ns]	1.08/1.05	1.05/1.06
H.L. S81 (avg) [W]	116.05	146.57
H.L. S81 (std) [W]	47.26	56.36
H.L. exp. imped. [W]	7.37	9.90
H.L. exp. synrad [W]	9.97	12.32
T_nobeam [h]	1.25	1.25

Dependence on bunch intensity from long fills

End 2016



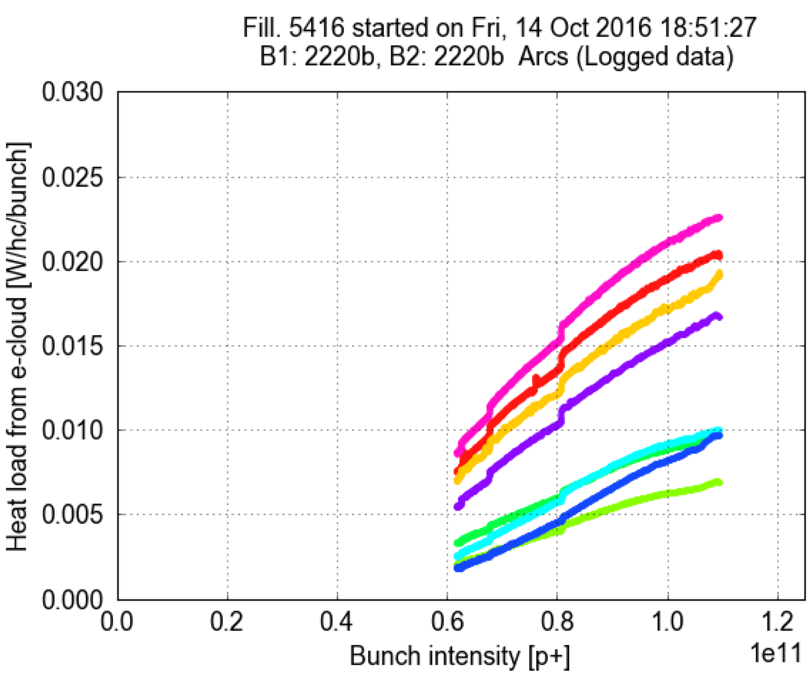
2017 (20/06)



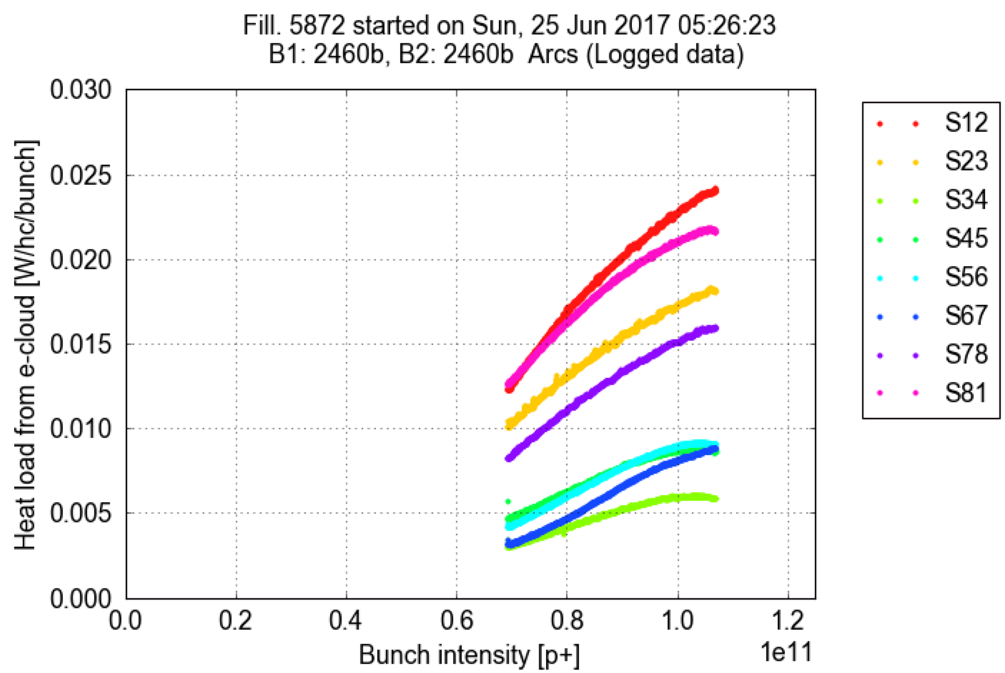
- Effect of **deconditioning visible mainly for high bunch intensity**

Dependence on bunch intensity from long fills

End 2016



2017 (25/06)



- Effect of **deconditioning visible mainly for high bunch intensity**

Outline

- Introduction
- Arc heat loads
  - Scrubbing run and intensity ramp-up
  - Full evolution during Run 2
  - Cell-by-cell analysis
  - Evolution vs bunch intensity
- **Instrumented cells**
  - Scrubbing run and intensity ramp-up
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  - Quadrupole behavior during the ramp
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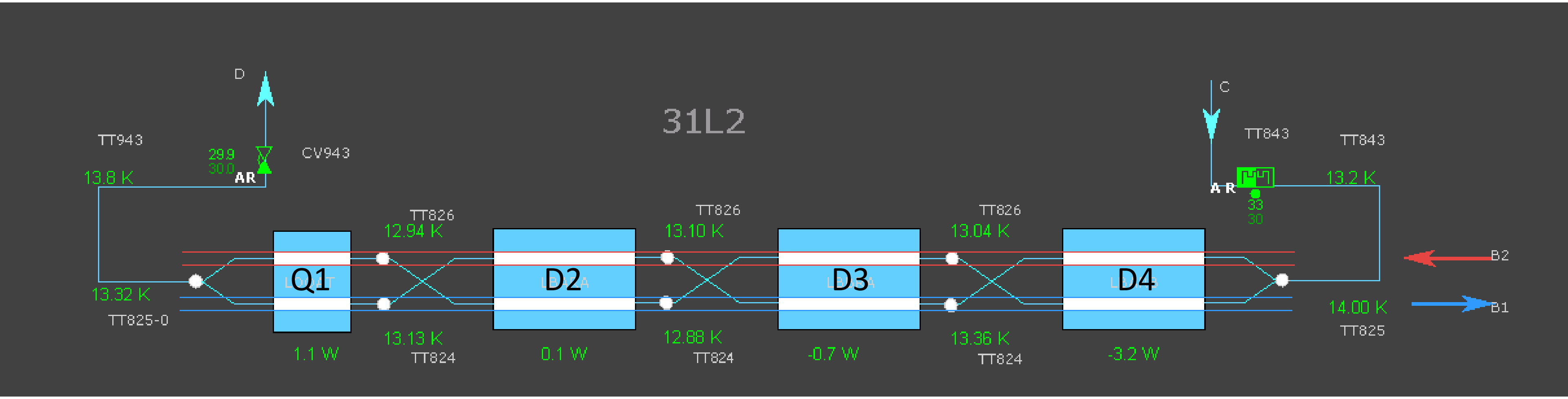
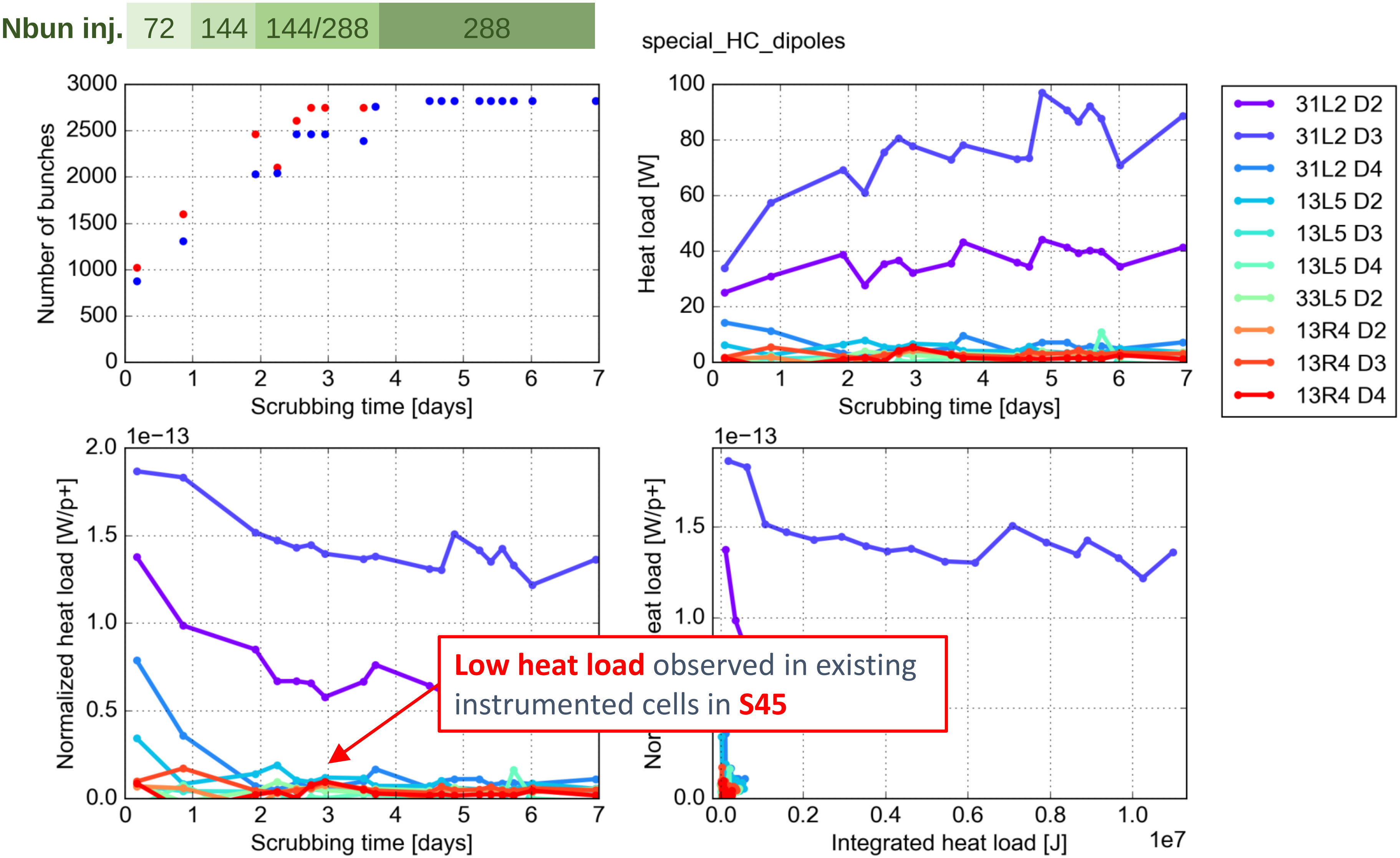
Heat loads in instrumented cells

- Cells equipped with **extra thermometers to measure the heat loads magnet by magnet**
    - **3 cells in S45** were instrumented during LS1 (they always showed relatively low heat loads 2016-17)
    - **1 cell in S12** instrumented during the EYETS (it shows a large heat load)



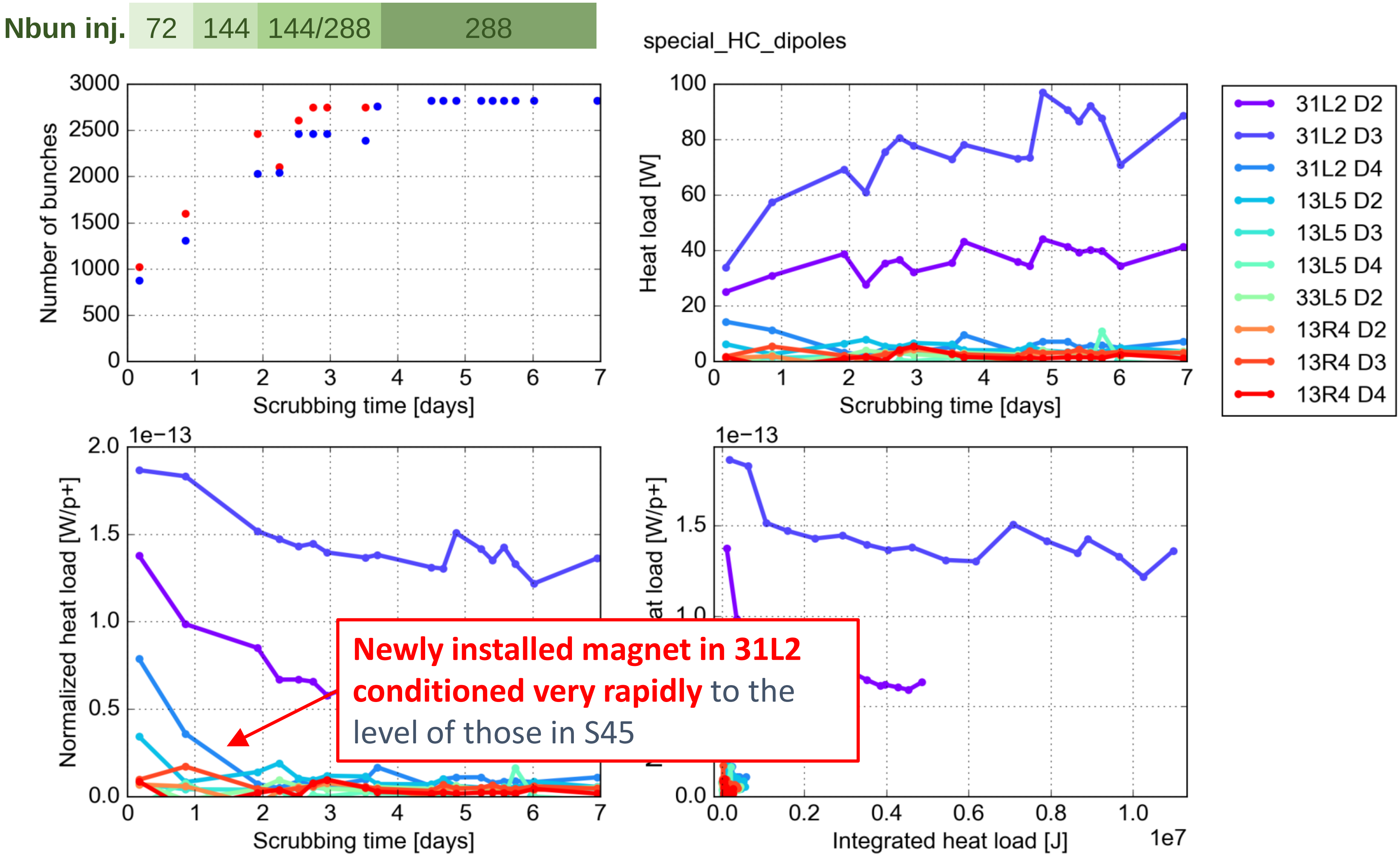
- Benjamin provided us with the procedure to reconstruct the load in each magnet and the list of devices for which the measurement is reliable

Dipole magnets: scrubbing run data



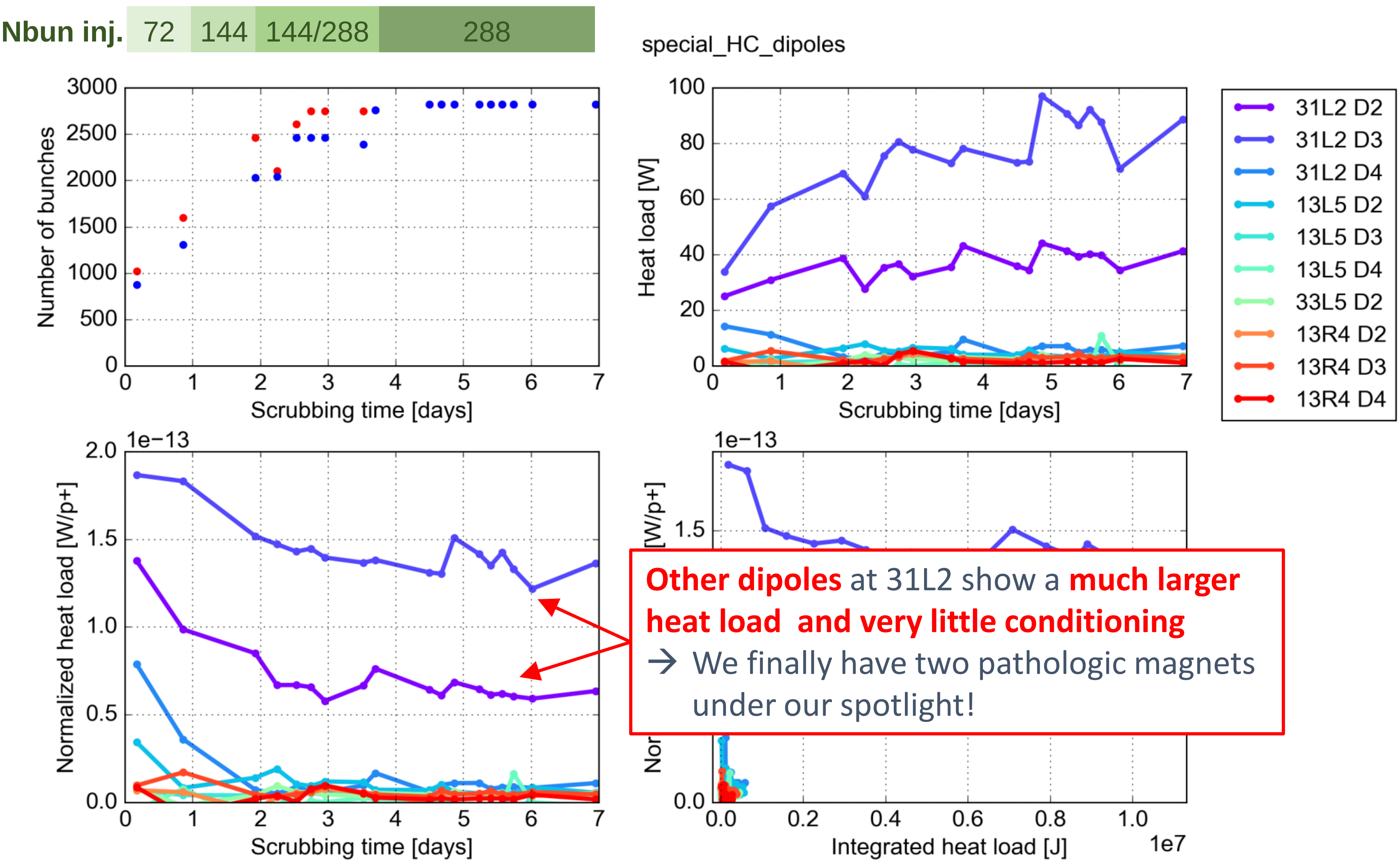
Low heat load observed in existing instrumented cells in **S45**

Dipole magnets: scrubbing run data



Newly installed magnet in 31L2 conditioned very rapidly to the level of those in S45

Dipole magnets: scrubbing run data

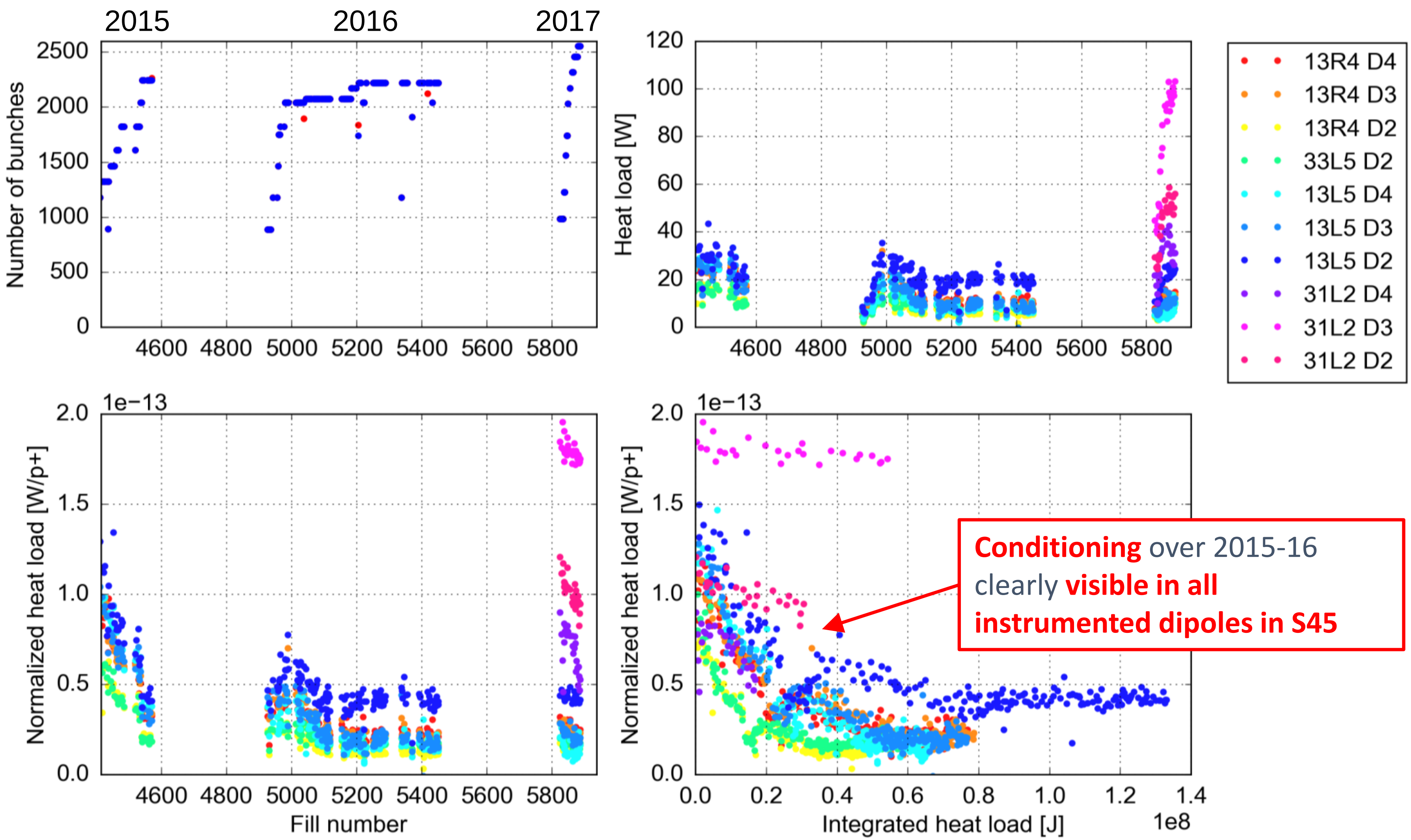


Other dipoles at 31L2 show a **much larger heat load and very little conditioning**

→ We finally have two pathologic magnets under our spotlight!

Dipole magnets: evolution at 6.5 TeV during run 2

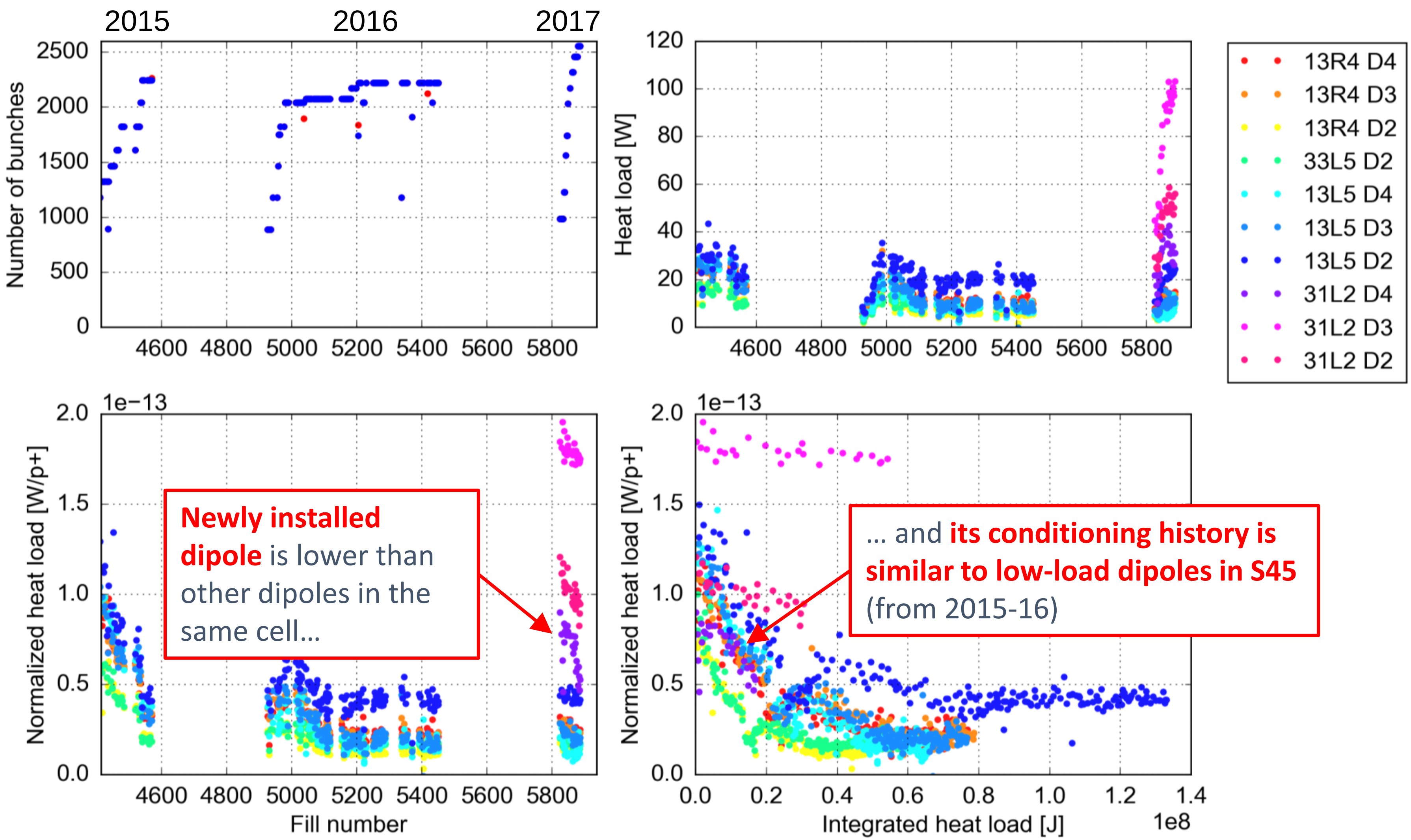
- Complete evolution of the average arc **heat loads at 6.5 TeV over Run 2**
- Only **fills that reached stable beams** are included (→ fills from the scrubbing run are not included)



Conditioning over 2015-16 clearly **visible in all instrumented dipoles in S45**

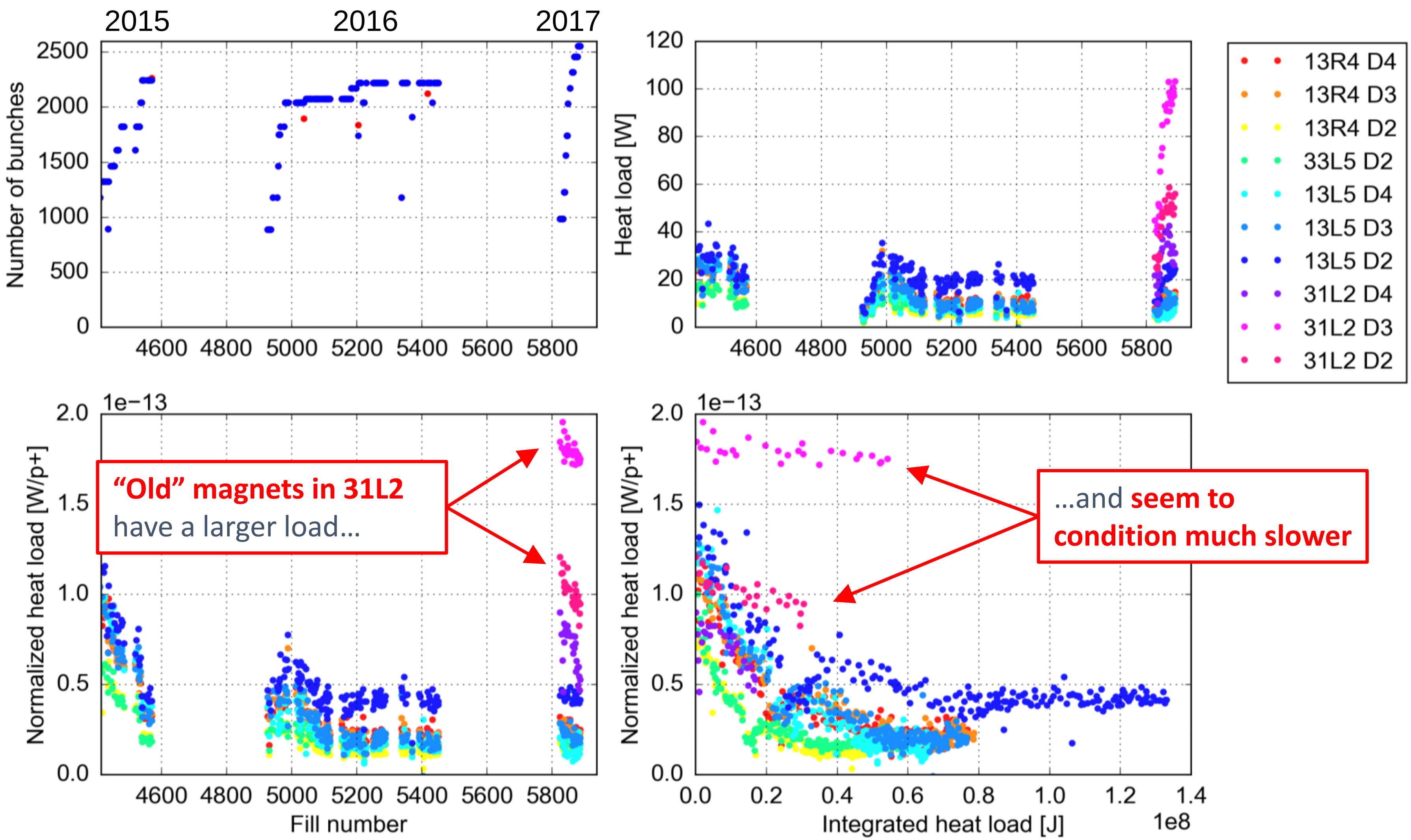
Dipole magnets: evolution at 6.5 TeV during run 2

- Complete evolution of the average arc **heat loads at 6.5 TeV over Run 2**
- Only **fills that reached stable beams** are included (→ fills from the scrubbing run are not included)



Dipole magnets: evolution at 6.5 TeV during run 2

- Complete evolution of the average arc **heat loads at 6.5 TeV over Run 2**
- Only **fills that reached stable beams** are included (→ fills from the scrubbing run are not included)

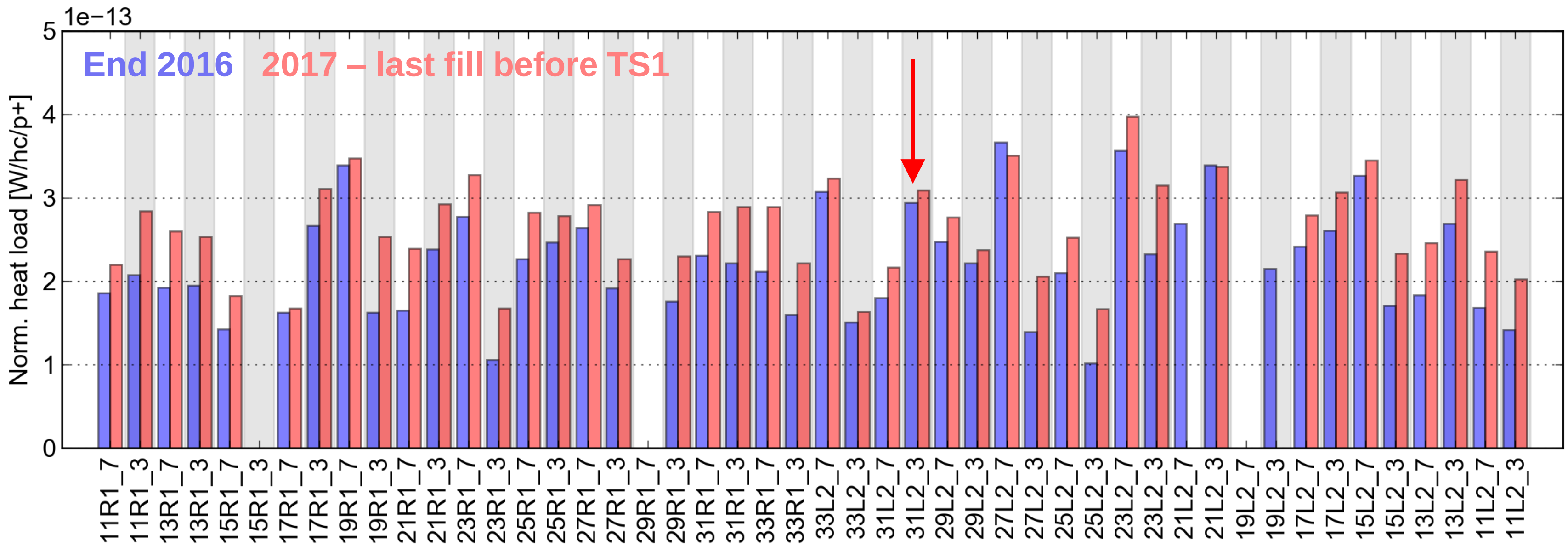


What about the dipole that was taken out?

- No magnet-by-magnet diagnostics in 31L2 before the EYETS but:
  - **Total cell heat load** measured now is **extremely similar to end-2016 values**
  - Other cells show that **other magnets have practically recovered** the end-2016 conditioning state

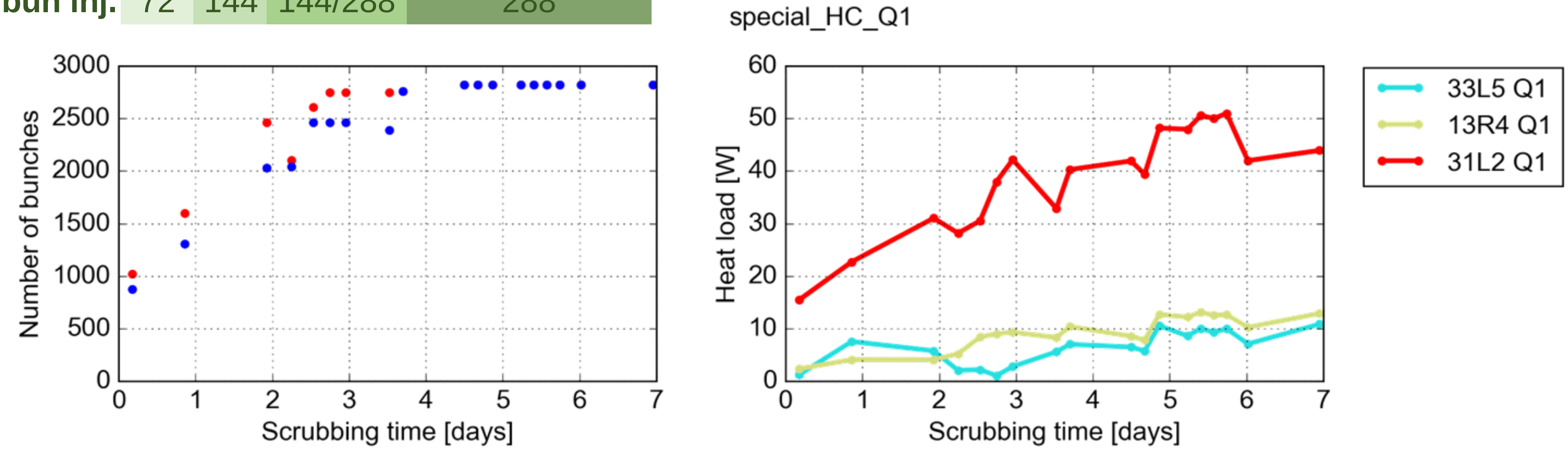
→ This means that the **old magnet was behaving similarly to the newly installed one**

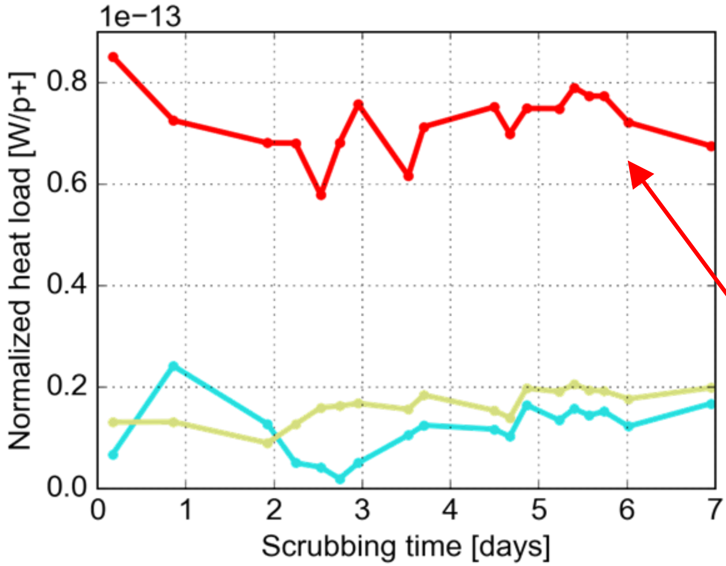
→ **The extracted magnet was a low-load magnet** (consistent with the fact that no issue was revealed by the lab analysis by Valentine, TE-VSC)

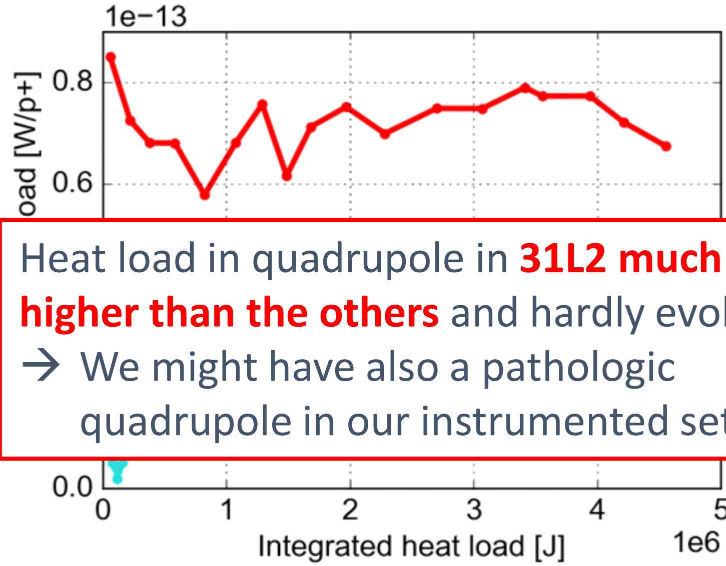


Quadrupole magnets: scrubbing run data

Nbun inj.	72	144	144/288	288



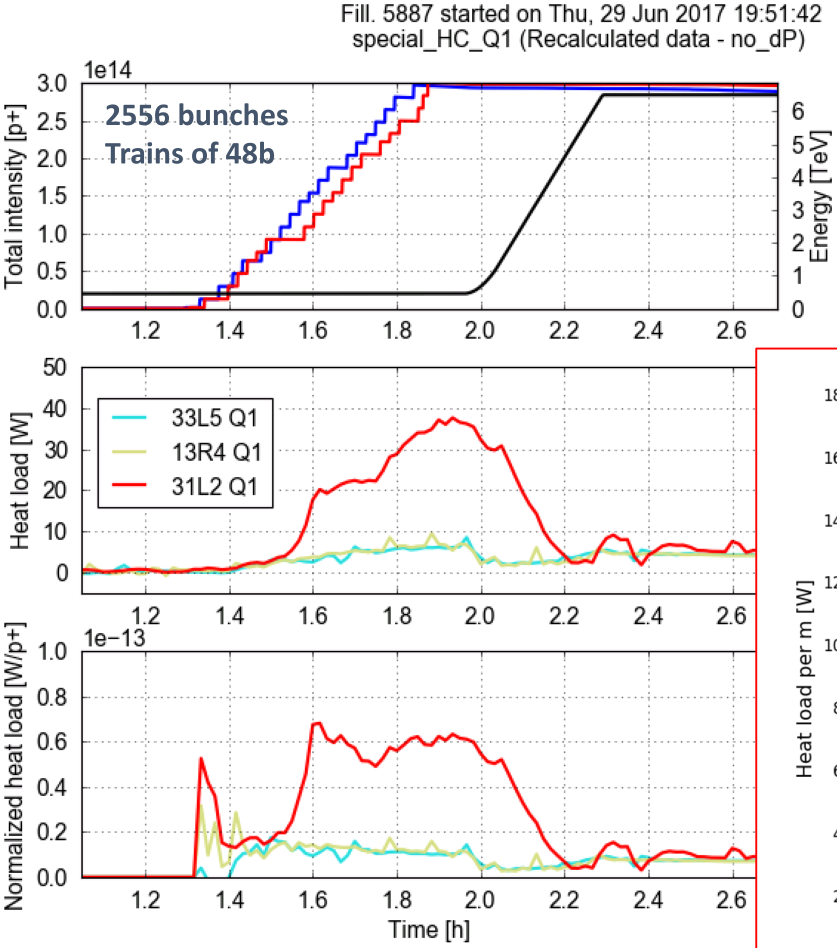




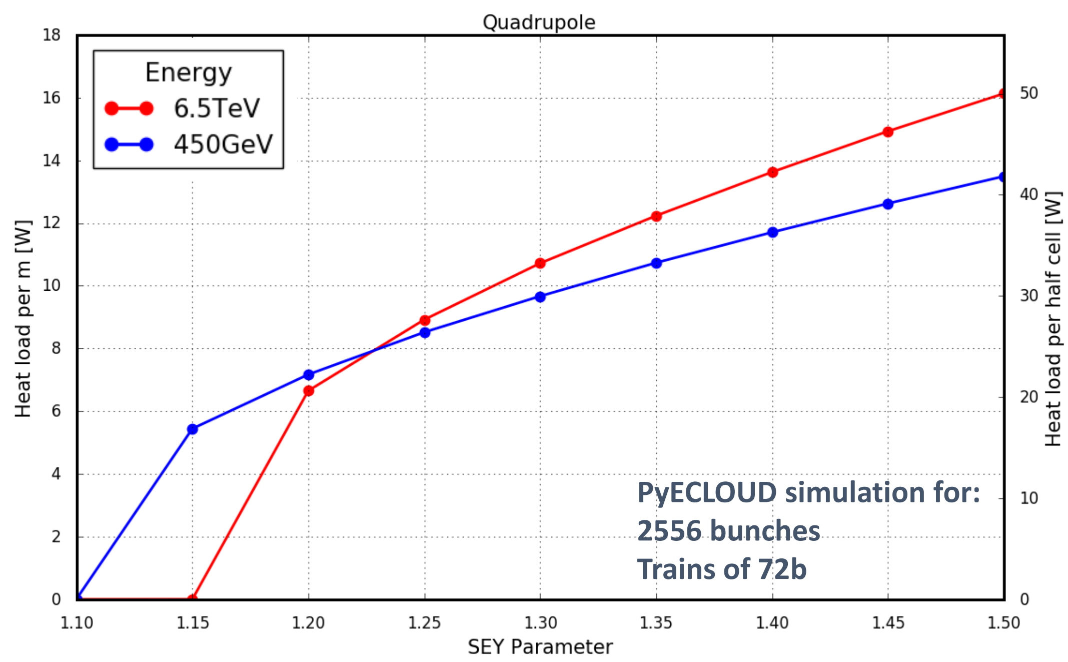
Heat load in quadrupole in **31L2 much higher than the others** and hardly evolving
→ We might have also a pathologic quadrupole in our instrumented set

Quadrupole magnets: dependence on beam energy

- The instrumented quadrupole in 31L2 shows a **strong decrease of the heat load during the energy ramp** (noticed by TE-CRG colleagues)



- Seems **consistent with (old) PyECLOUD simulations for low enough SEY ☺**
- To be checked in detail simulating 2017 beam configuration



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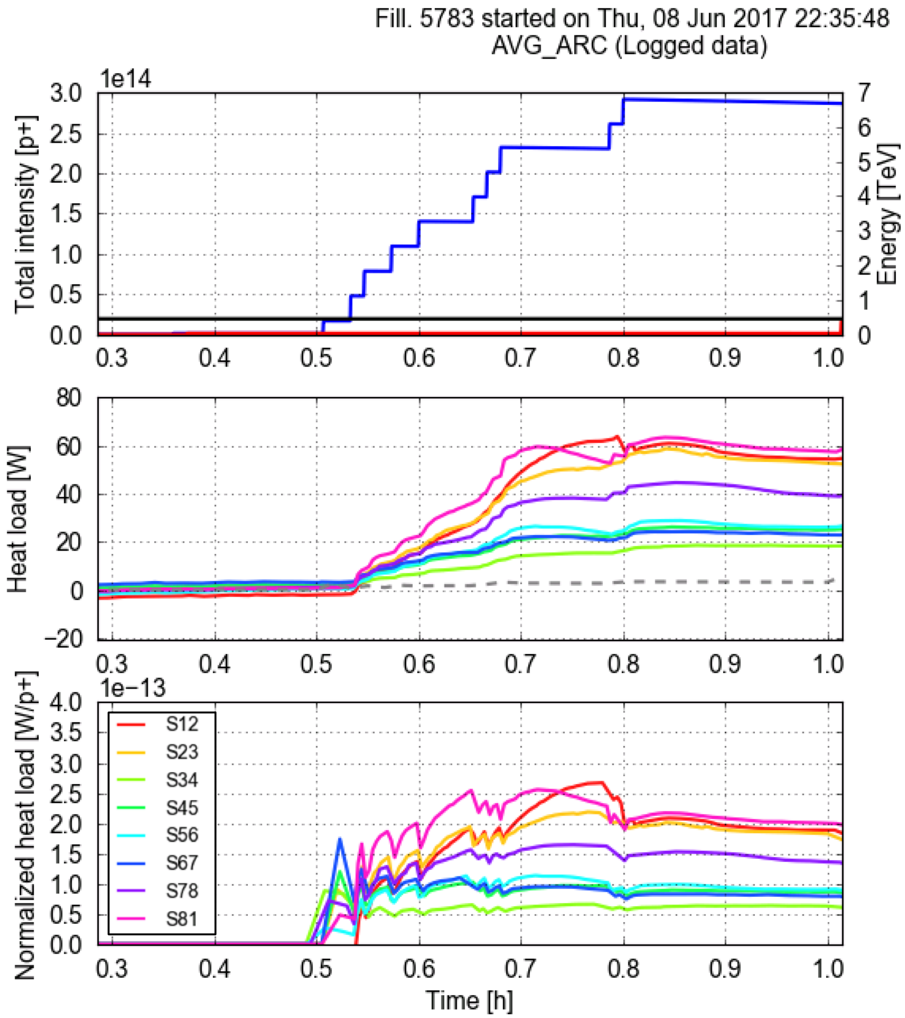
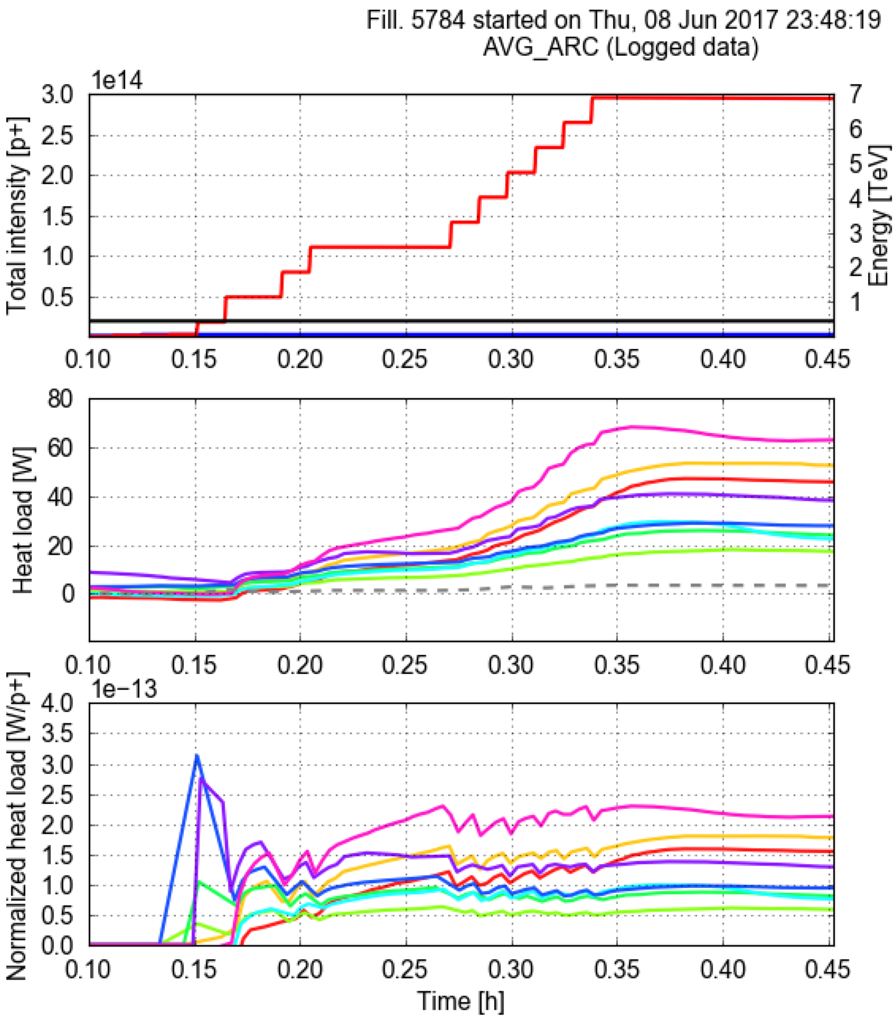
Differences on the arc averages

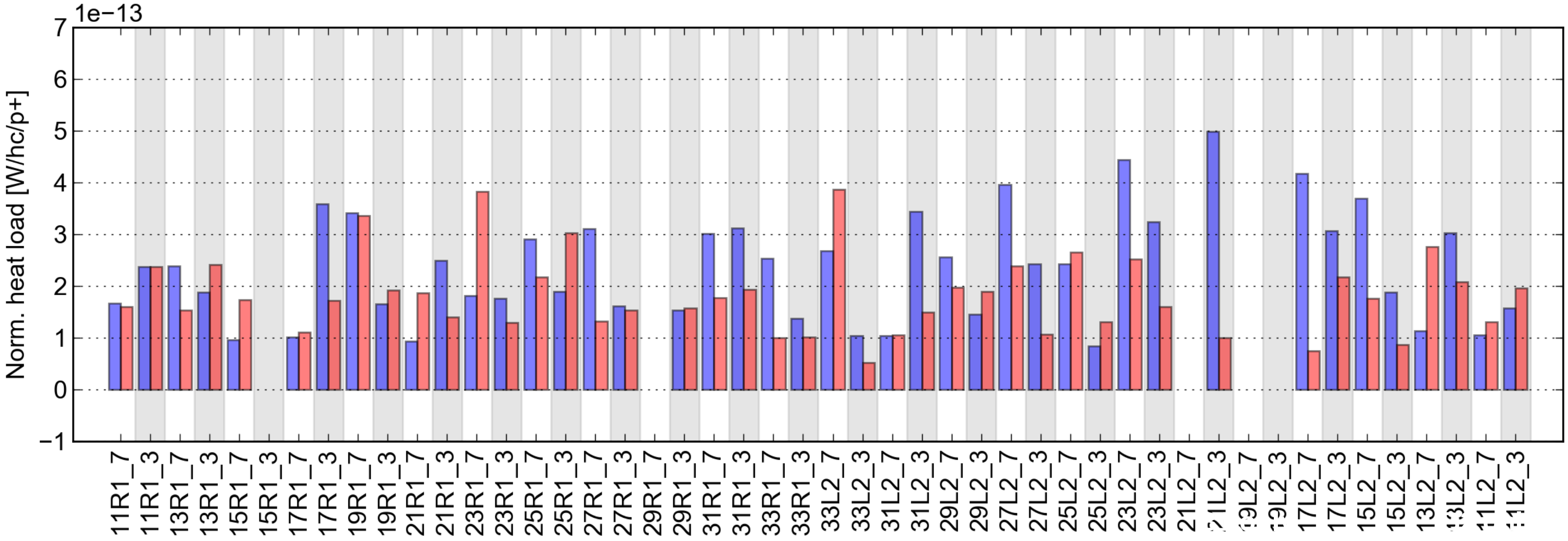
- In the test performed at the end of the Scrubbing Run **different heat loads were measured with B1 and B2 separately** especially for **Sector 12**
- **Detailed analysis** including all sectors and data from 2015-17 available here and here

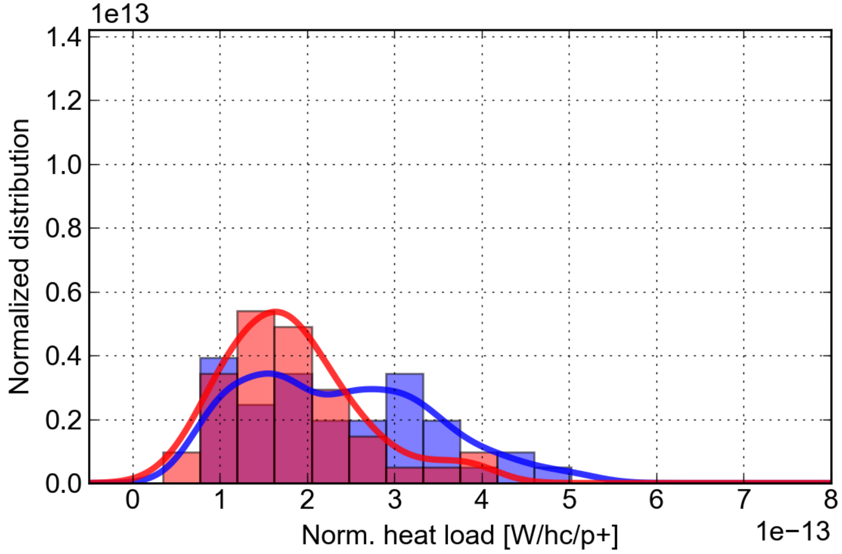




Cell-by-cell comparison

- Looking at the cell by cell pattern in S12 we see that the **asymmetry is not evenly distributed along the arc**

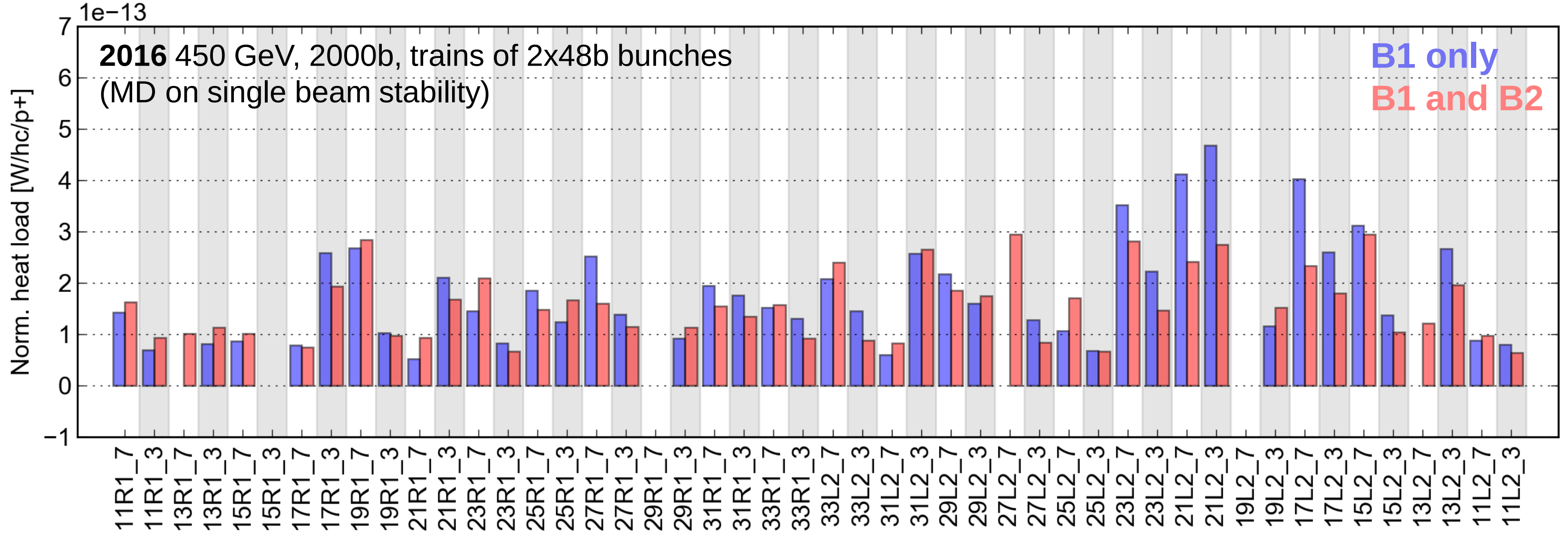


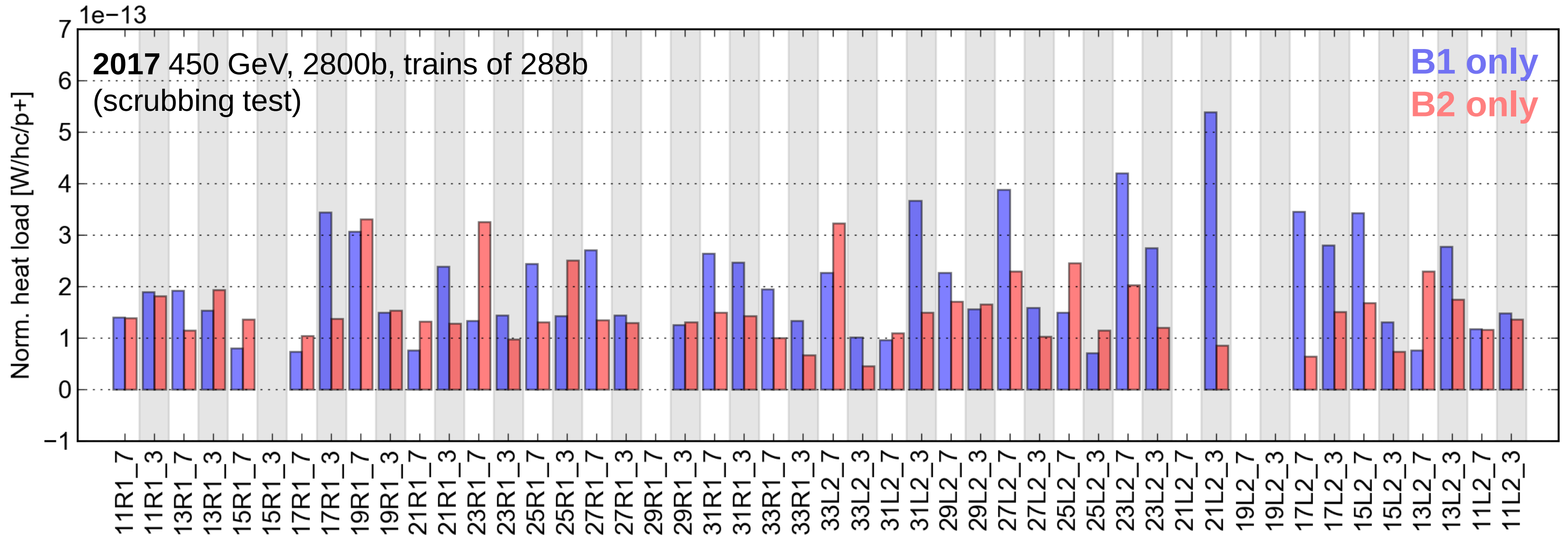


	B1 only	B2 only
Fill	5783	5784
Started on	08 Jun 2017 22:35	08 Jun 2017 23:48
T_sample [h]	0.92	0.55
Energy [GeV]	450	450
N_bunches (B1/B2)	2748/12	24/2760
Intensity (B1/B2) [p]	2.89e14/1.33e12	2.65e12/2.92e14
Bun.len. (B1/B2) [ns]	1.16/1.08	1.18/1.18
H.L. S12 (avg) [W]	68.35	53.92
H.L. S12 (std) [W]	30.36	22.27
H.L. exp. imped. [W]	3.29	3.29
H.L. exp. synrad [W]	0.00	0.00
T_nobeam [h]	0.50	0.14

Cell-by-cell comparison

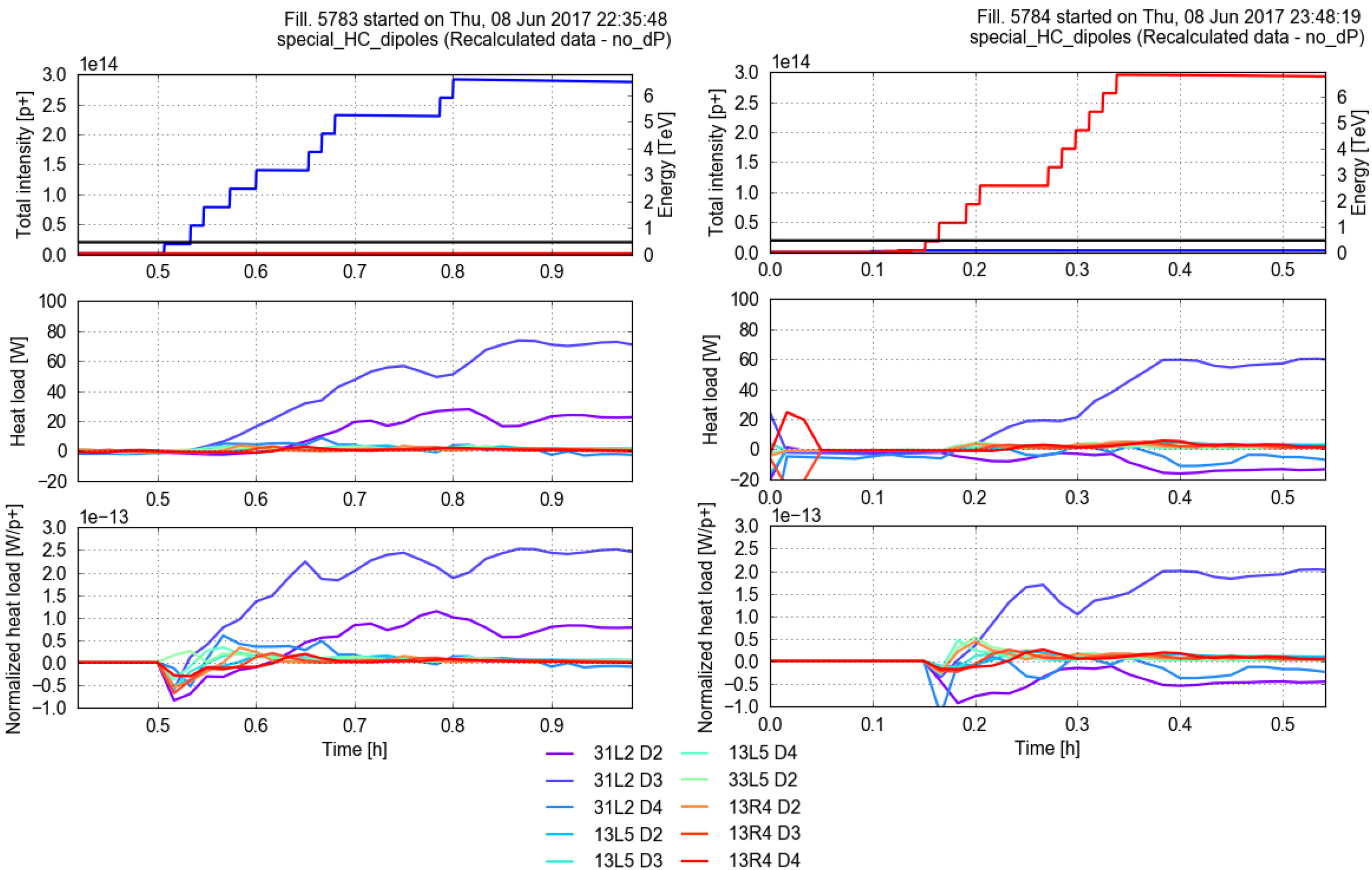
- The asymmetry **was less strong in 2016**





Instrumented cells: single beam observations

- Asymmetries are **observed also in the instrumented dipoles in 31L2** (quadrupoles still to be checked in details)



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  - Quadrupole behavior during the ramp
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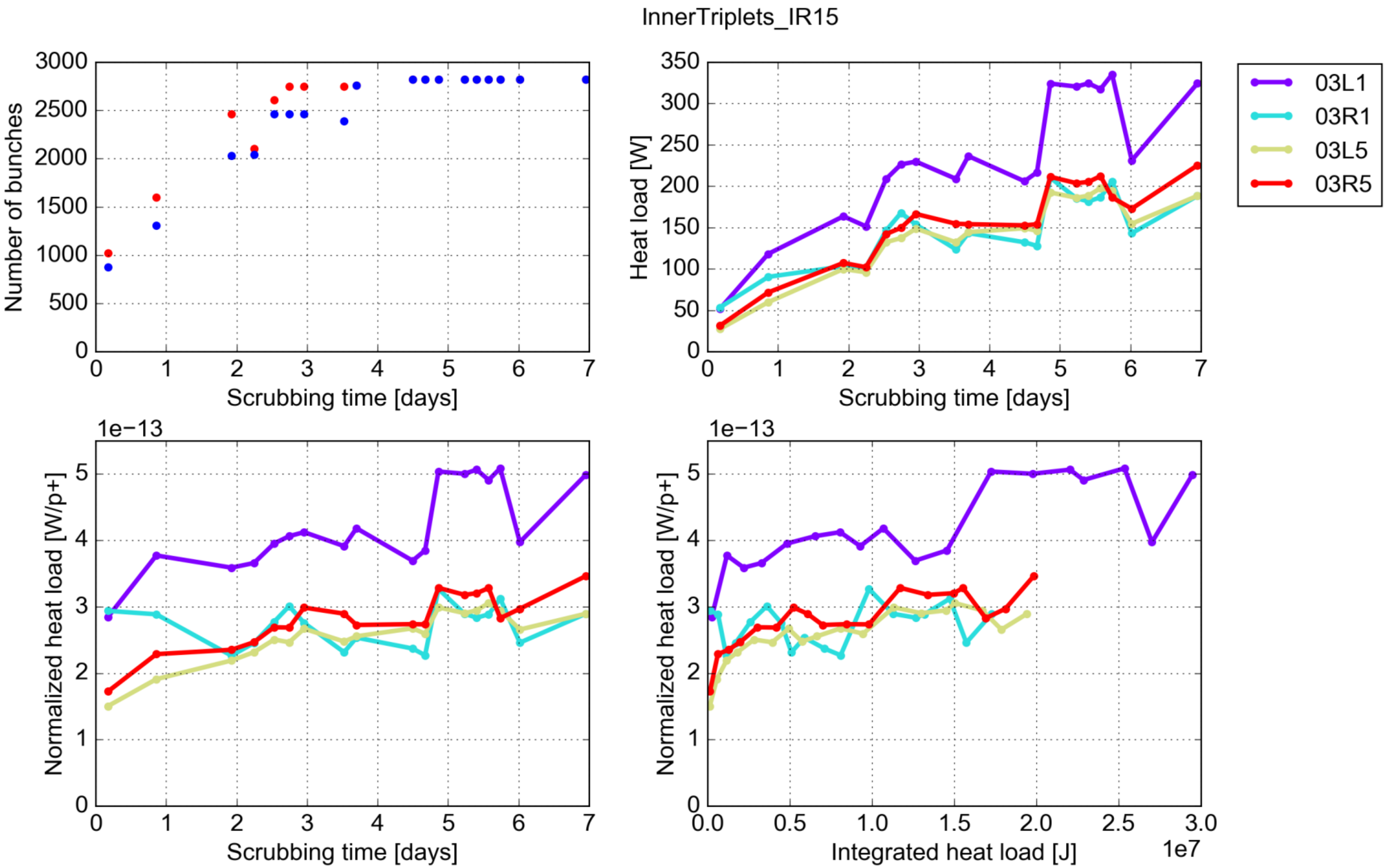
Work in progress!

- **The cryo team is carefully scrutinizing the LSS magnets** to identify those for which heat load measurements are reliable
- For the time being we focus on Inner Triplets, and Q5/Q6 matching quadrupoles in IR1 and IR5

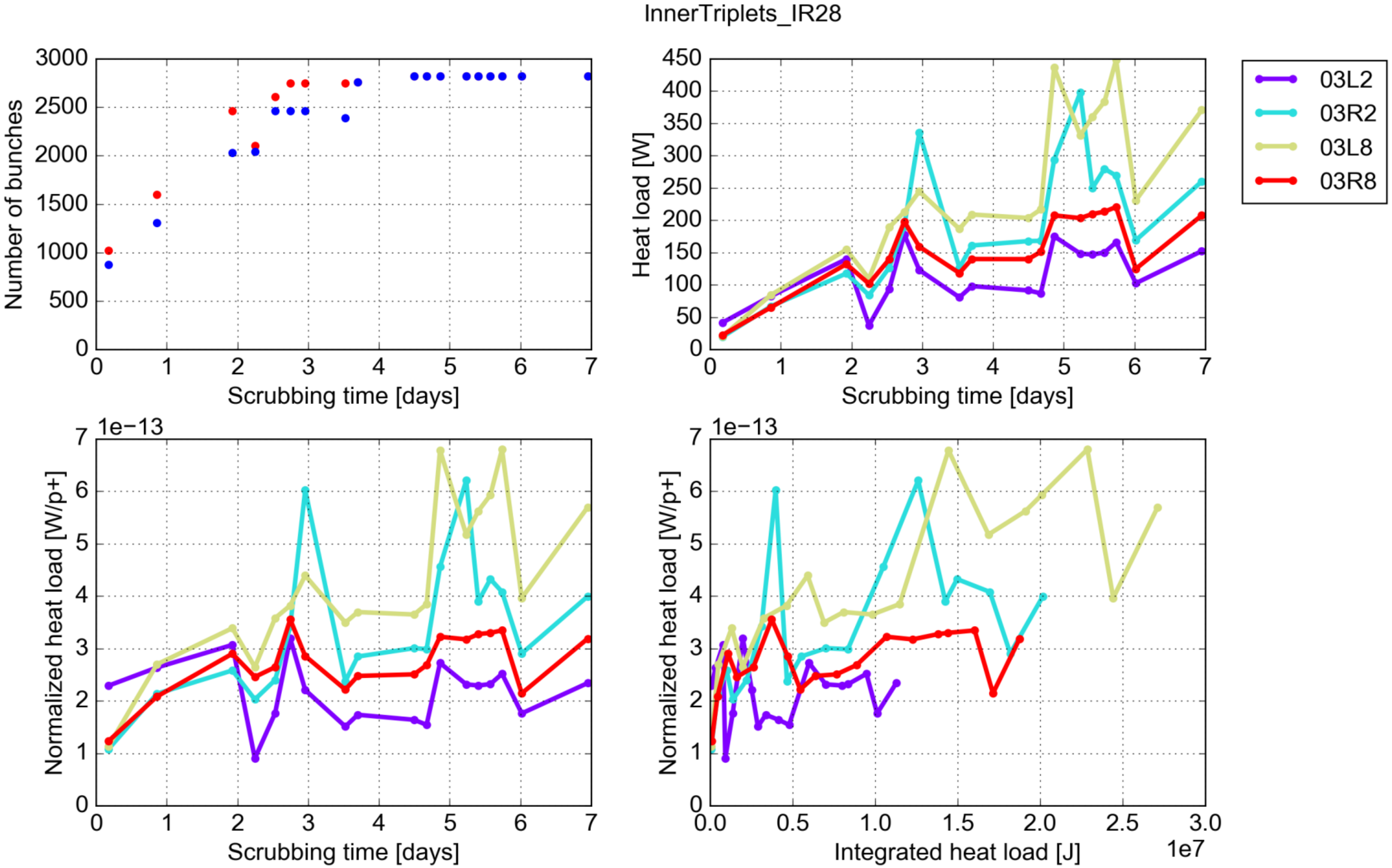
Other devices: scrubbing run

- No clear observation of scrubbing

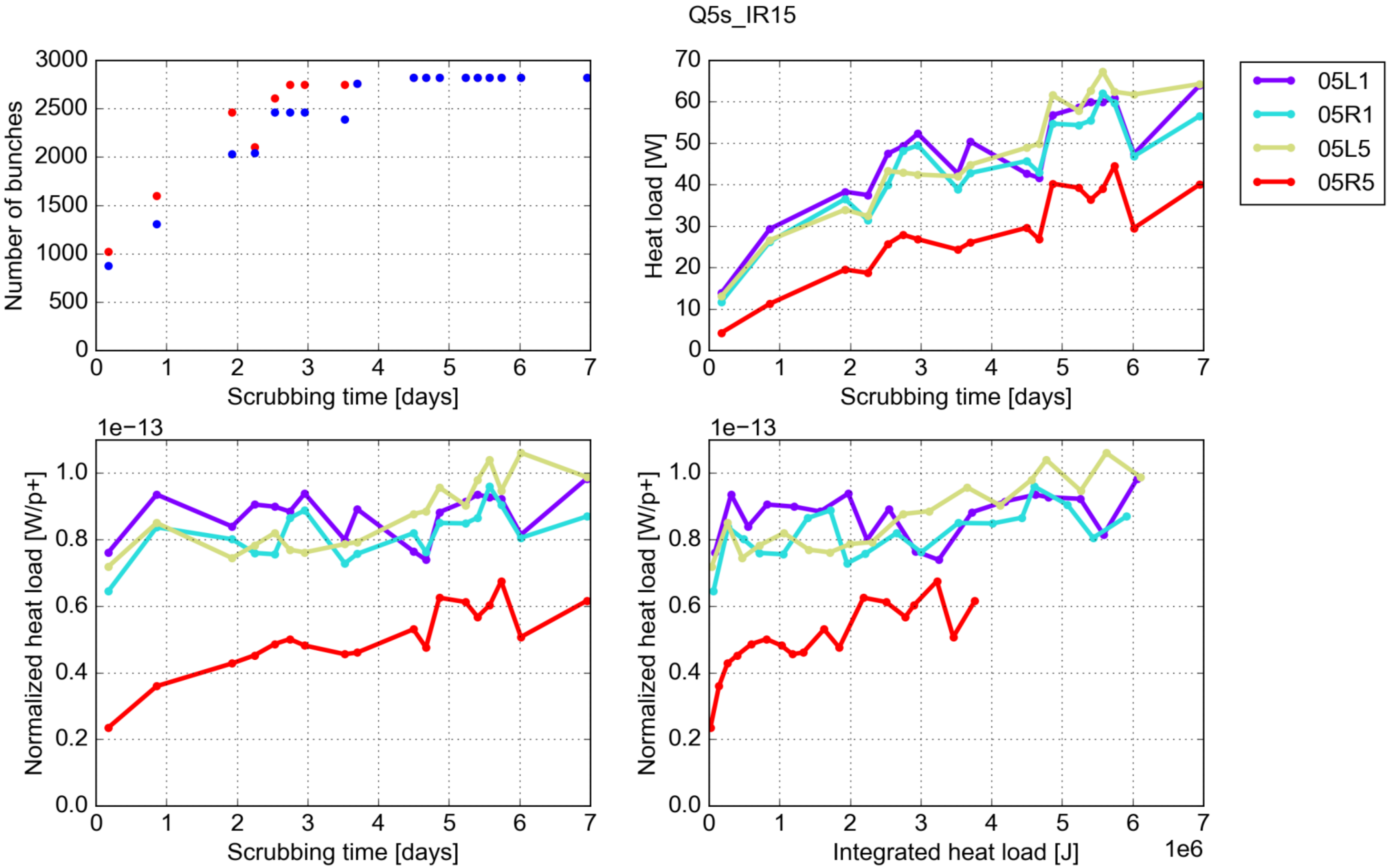


Other devices: scrubbing run

- No clear observation of scrubbing

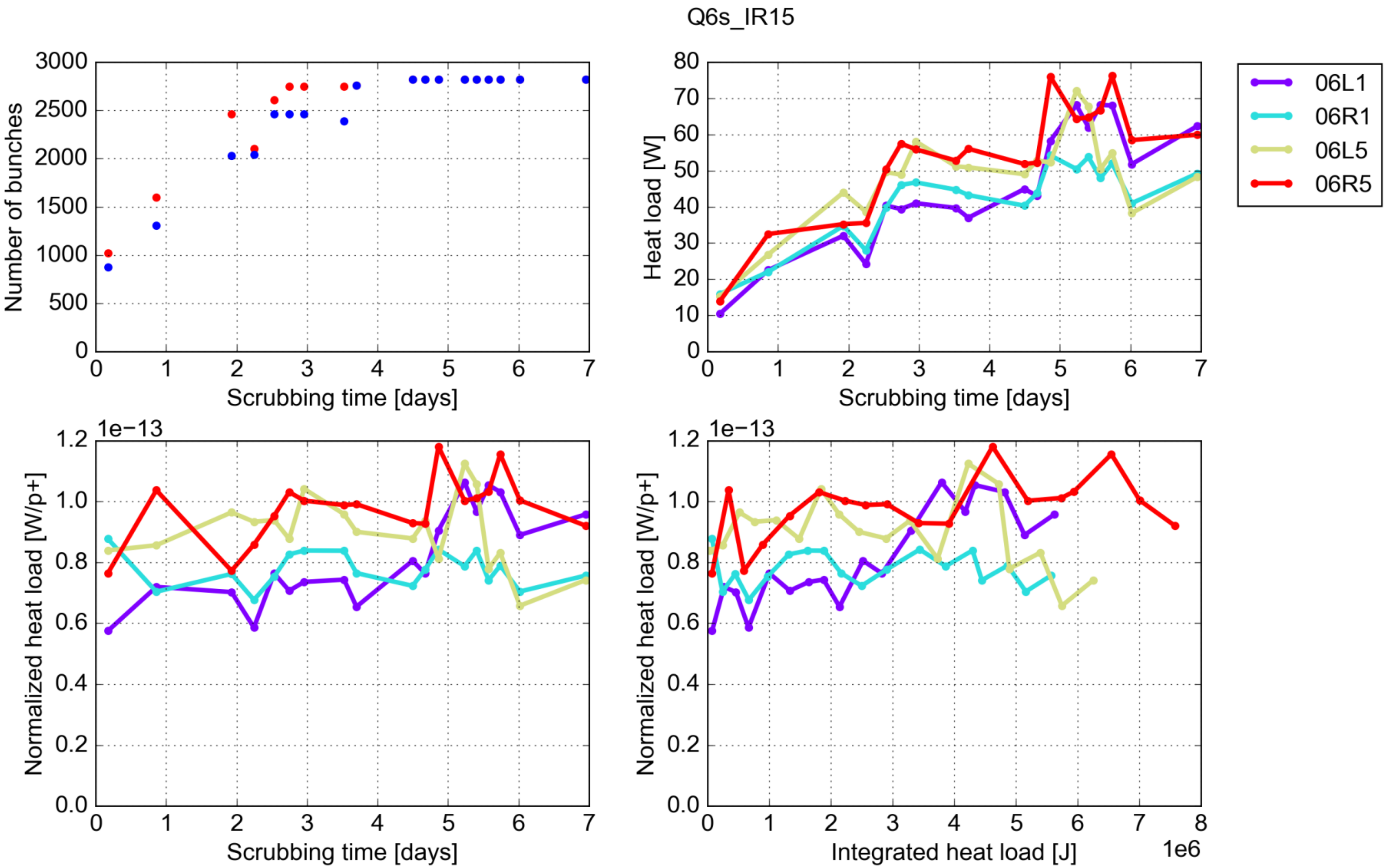


- No clear observation of scrubbing



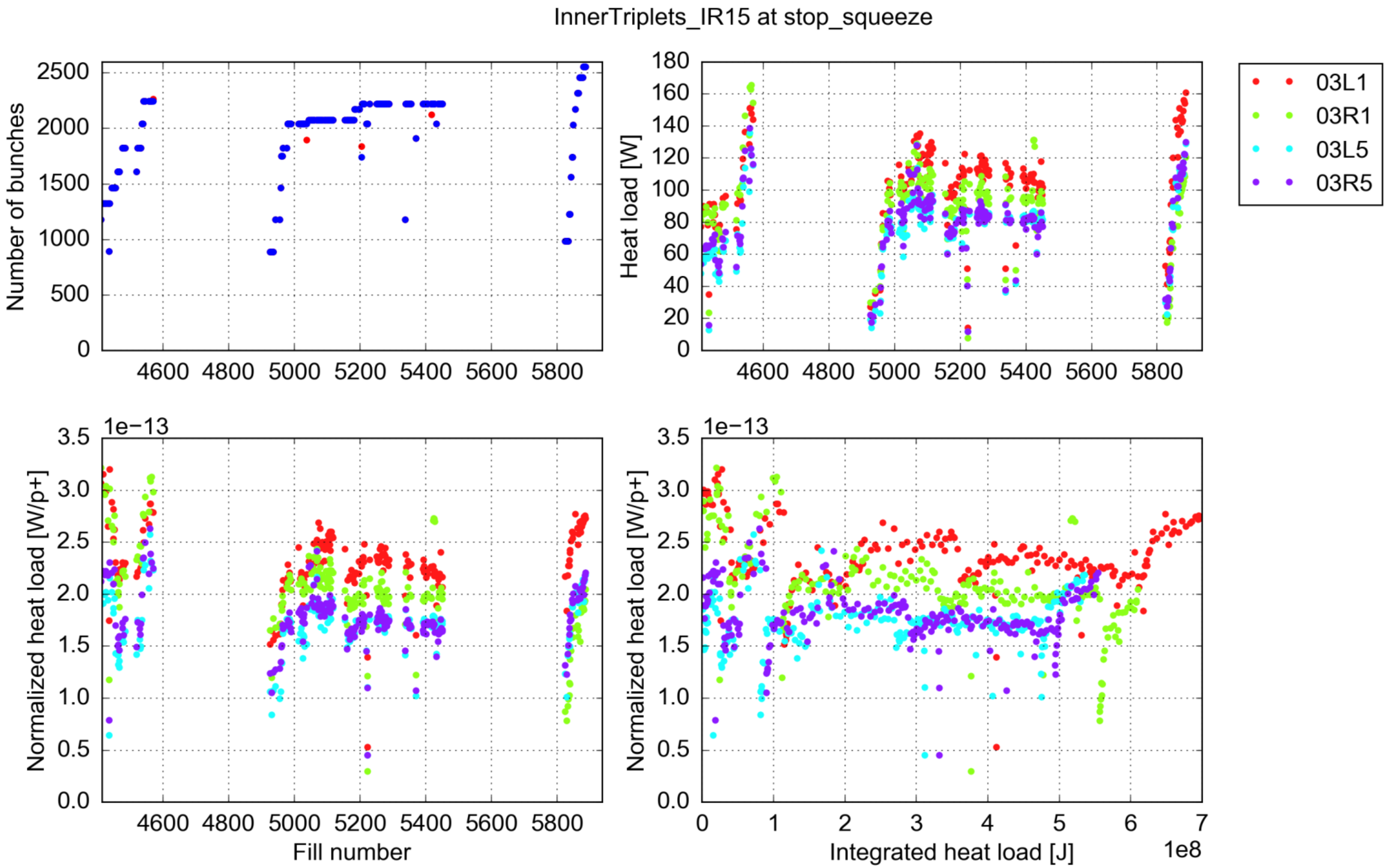
Other devices: scrubbing run

- No clear observation of scrubbing



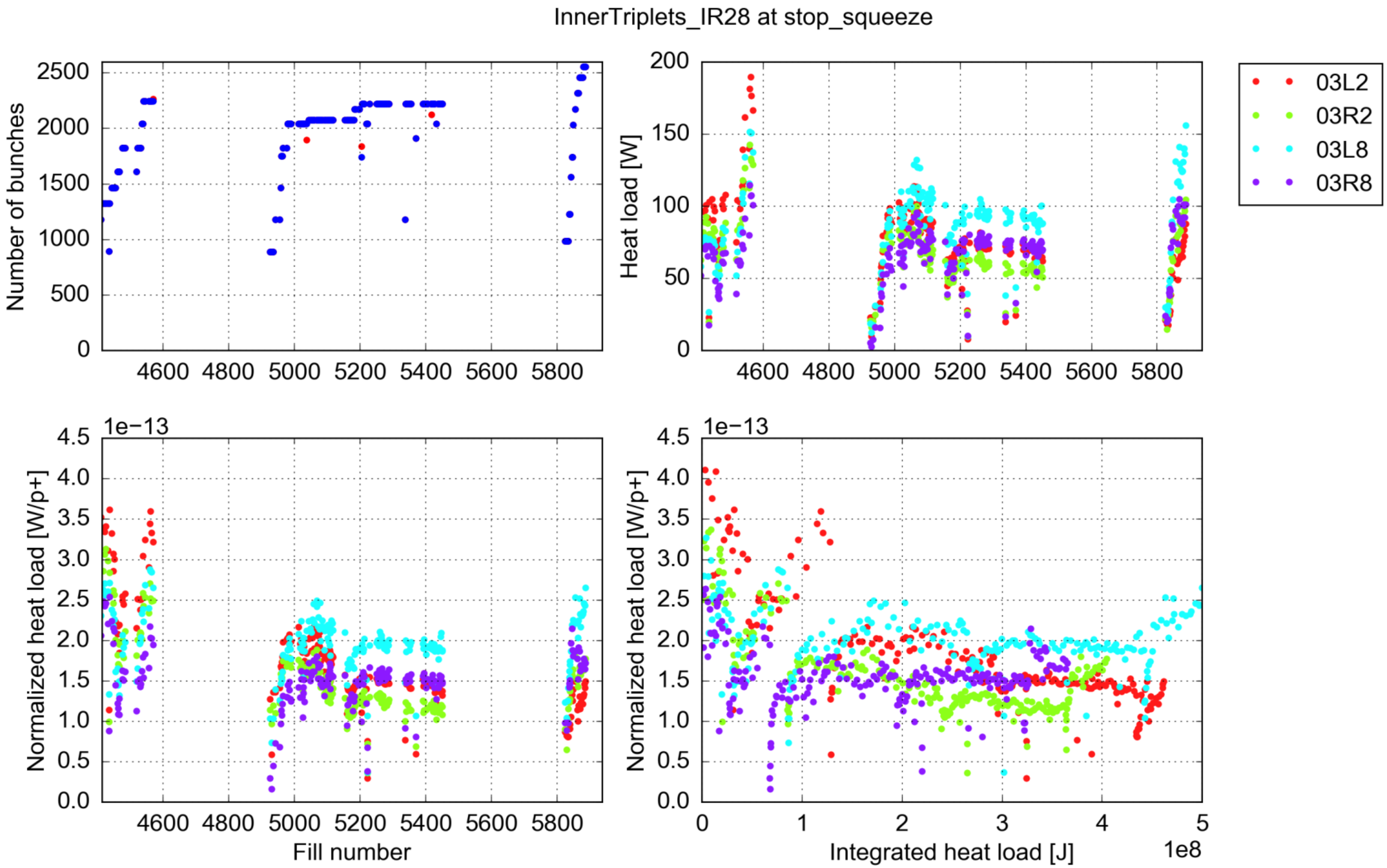
Other devices: evolution at 6.5 TeV during Run 2

- No clear observation of scrubbing



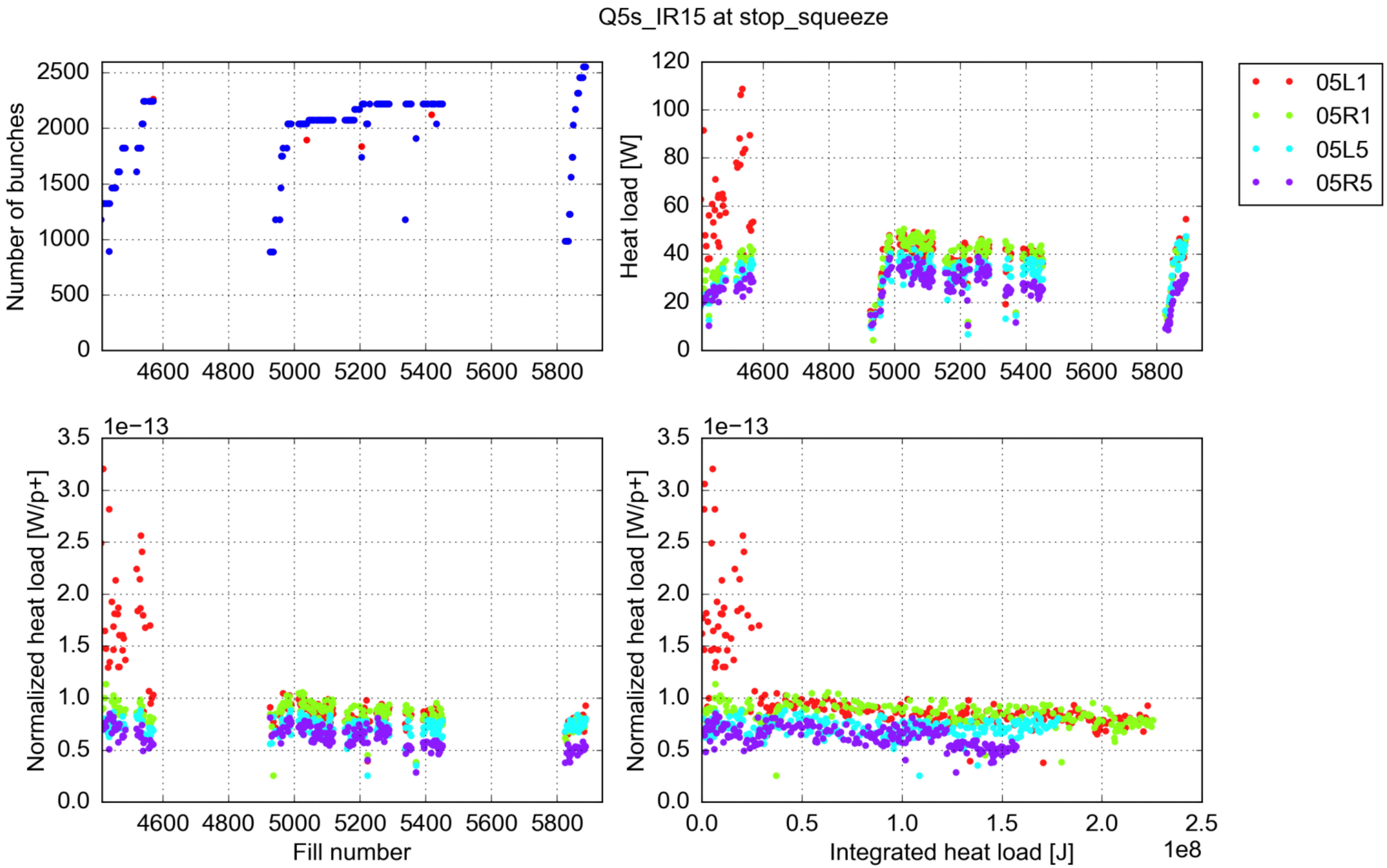
Other devices: evolution at 6.5 TeV during Run 2

- No clear observation of scrubbing



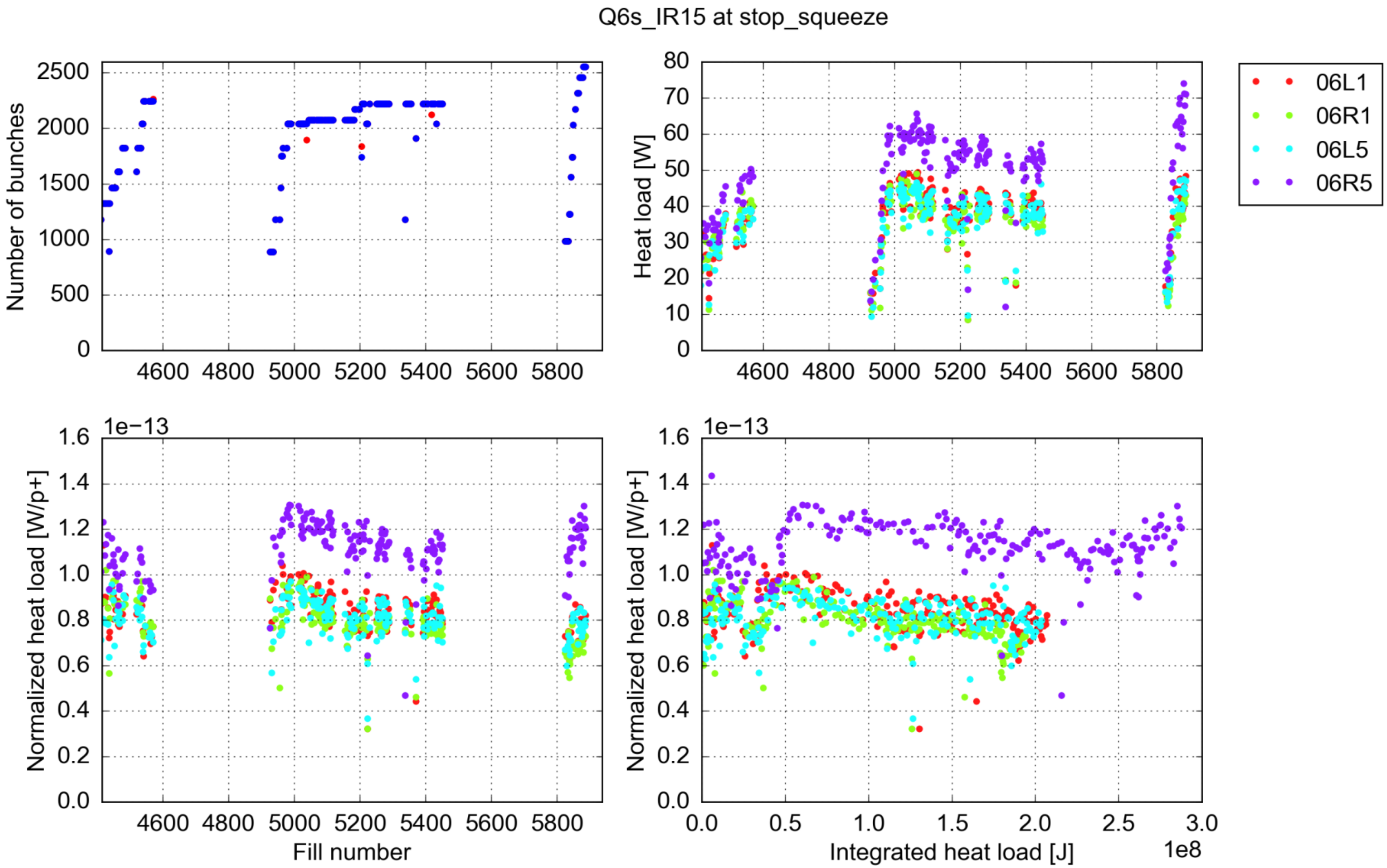
Other devices: evolution at 6.5 TeV during Run 2

- No clear observation of scrubbing



Other devices: evolution at 6.5 TeV during Run 2

- No clear observation of scrubbing



Summary and conclusions

- Heat load evolution has been analyzed using **tools developed in collaboration with TE-CRG** (heat loads recomputed with the most recent calibrations for the entire Run 2 to have a consistent set of data)
- **Arc heat loads** during the 2017 **scrubbing run** (450 GeV):
  - For **sectors that were not exposed** to air the end-2016 values were recovered in **~24h**, then normalized heat loads stayed **unchanged during the rest of scrubbing run**
  - **Sector 12** (opened during the EYETS) was conditioned down to end-2016 values in ~4 days. After than no evolution was observed
  - Three days of scrubbing with **trains of 288b had no impact** on heat load levels nor on the difference between sectors
  - By the end of the scrubbing run the **cell-by-cell heat load pattern was the same observed at the end of 2016**
- Arc **heat loads at 6.5 TeV**:
  - **Sector 12** showed larger heat load at high energy even after the scrubbing at 450 GeV was complete. Conditioning was observed during the intensity ramp-up.
  - **Other sectors** that were not exposed to air **restarted from values similar to the end-2016**

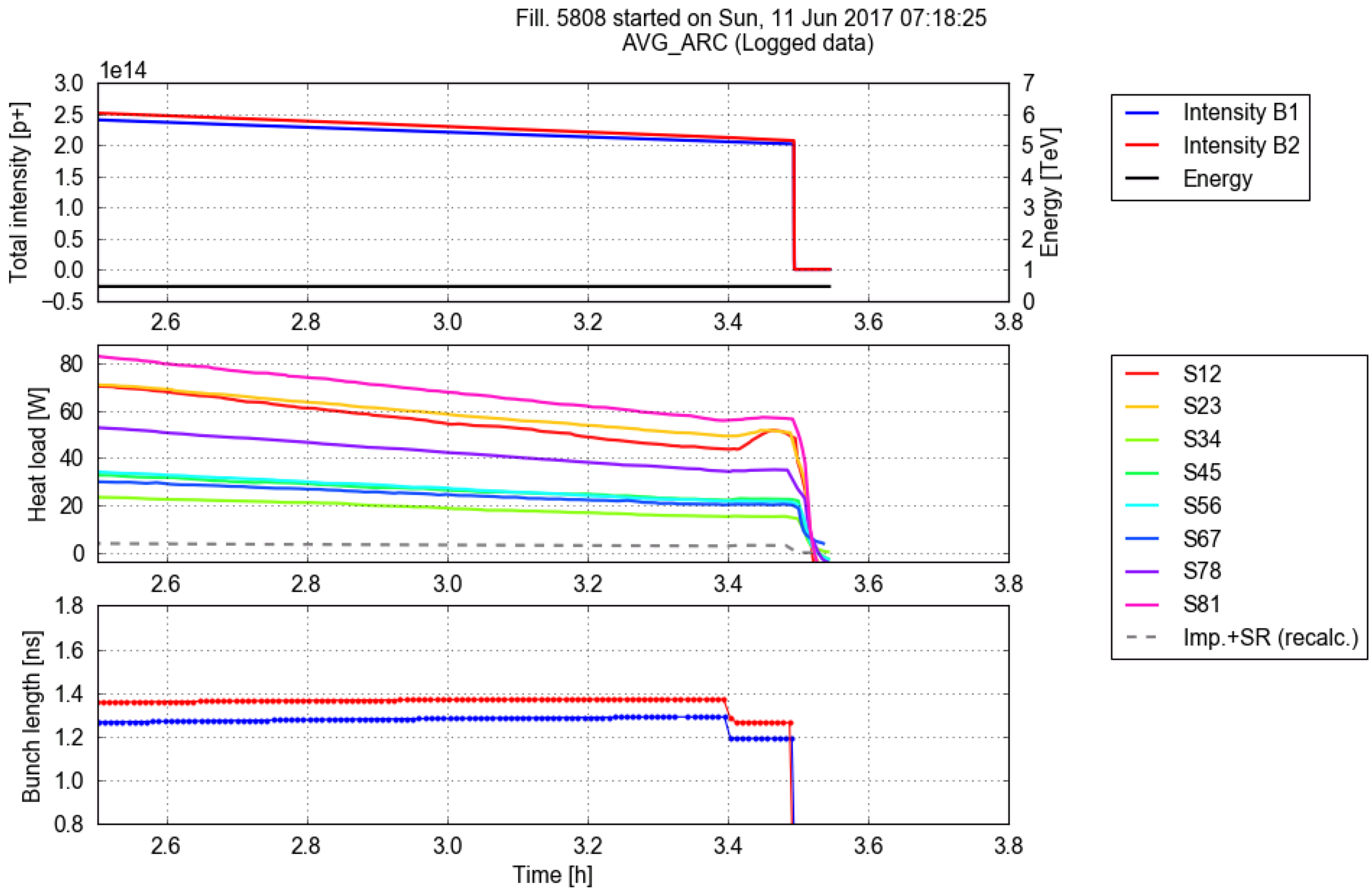
Summary and conclusions

- Heat loads in **instrumented cells in S45**
  - As in 2016 instrumented cells in S45 **show very small loads**. Looking backwards we find that they were scrubbed efficiently in 2015
- The situation is different for **new instrumented cell in S12**:
  - **Newly installed dipole conditioned quickly** (similarly to behavior of S45 instrumented dipoles in 2015)
  - Instead, **other magnets** that were already there in 2016 **show much larger heat loads** and conditioned very slow → we finally have a few "ill" magnets under close observations
  - Instrumented **quadrupole** shows a **strong heat load decrease in the ramp** → compatible with PyECLOUD simulations ☺
  - Comparing total heat loads with data from last year it seems that the **magnet that was extracted out had a relatively low heat load**…
- Some **asymmetries** are observed in arcs and instrumented cells when comparing fills with **B1 and B2 alone** (detailed analysis available here and here)
- **Analysis of LSS magnets is ongoing** in collaboration with the cryo team

Thanks for your attention!

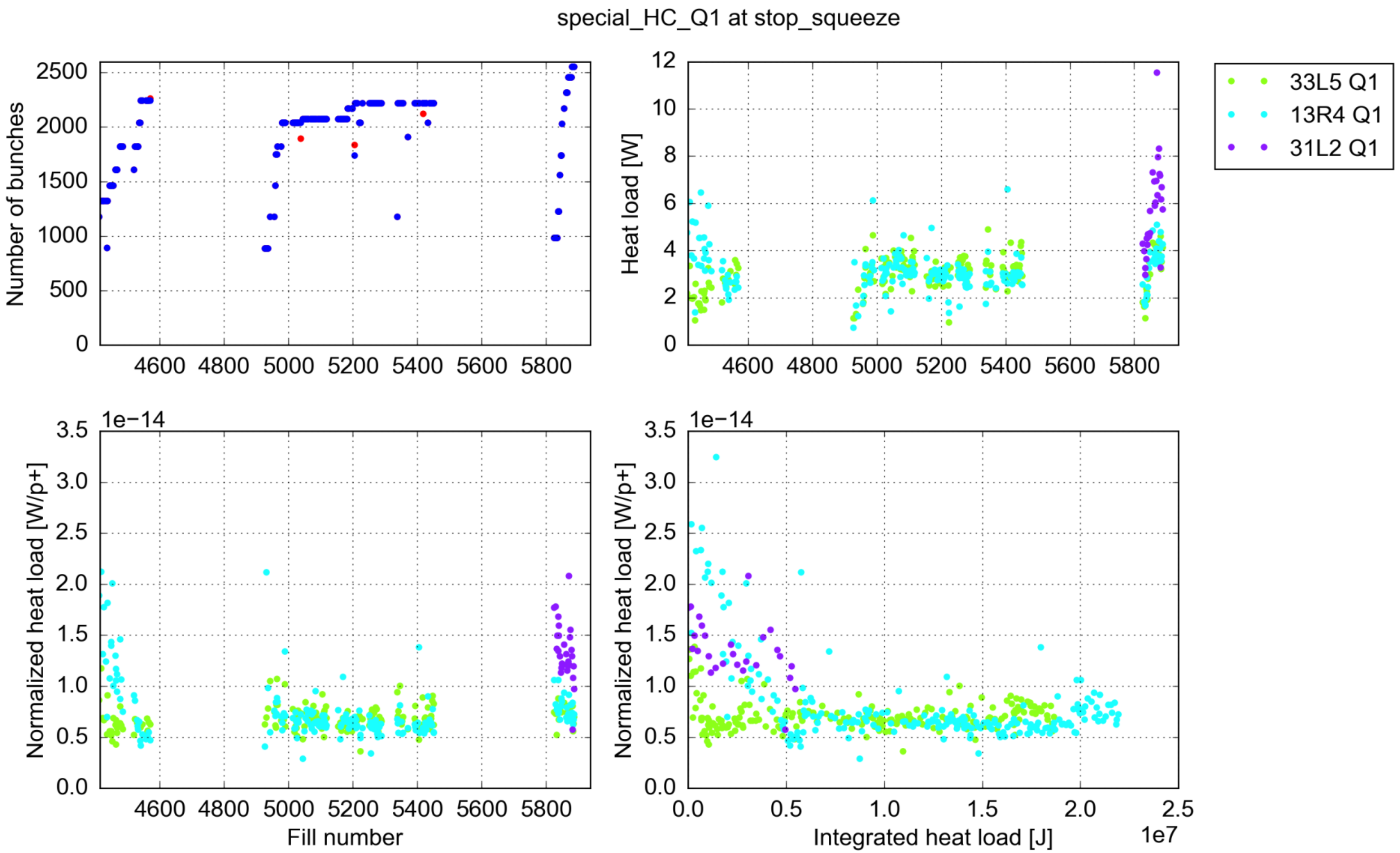
Heat load in Sector 12: effect of the voltage

- At the end of a scrubbing fill **bunches have been slightly shortened** by increasing the RF voltage → **heat load increase was observed mainly in S12**



Quadrupole magnets: evolution at 6.5 TeV during run 2

- A bit more tricky to interpret…



Quadrupole magnets: evolution at 6.5 TeV during run 2

- A bit more tricky to interpret…