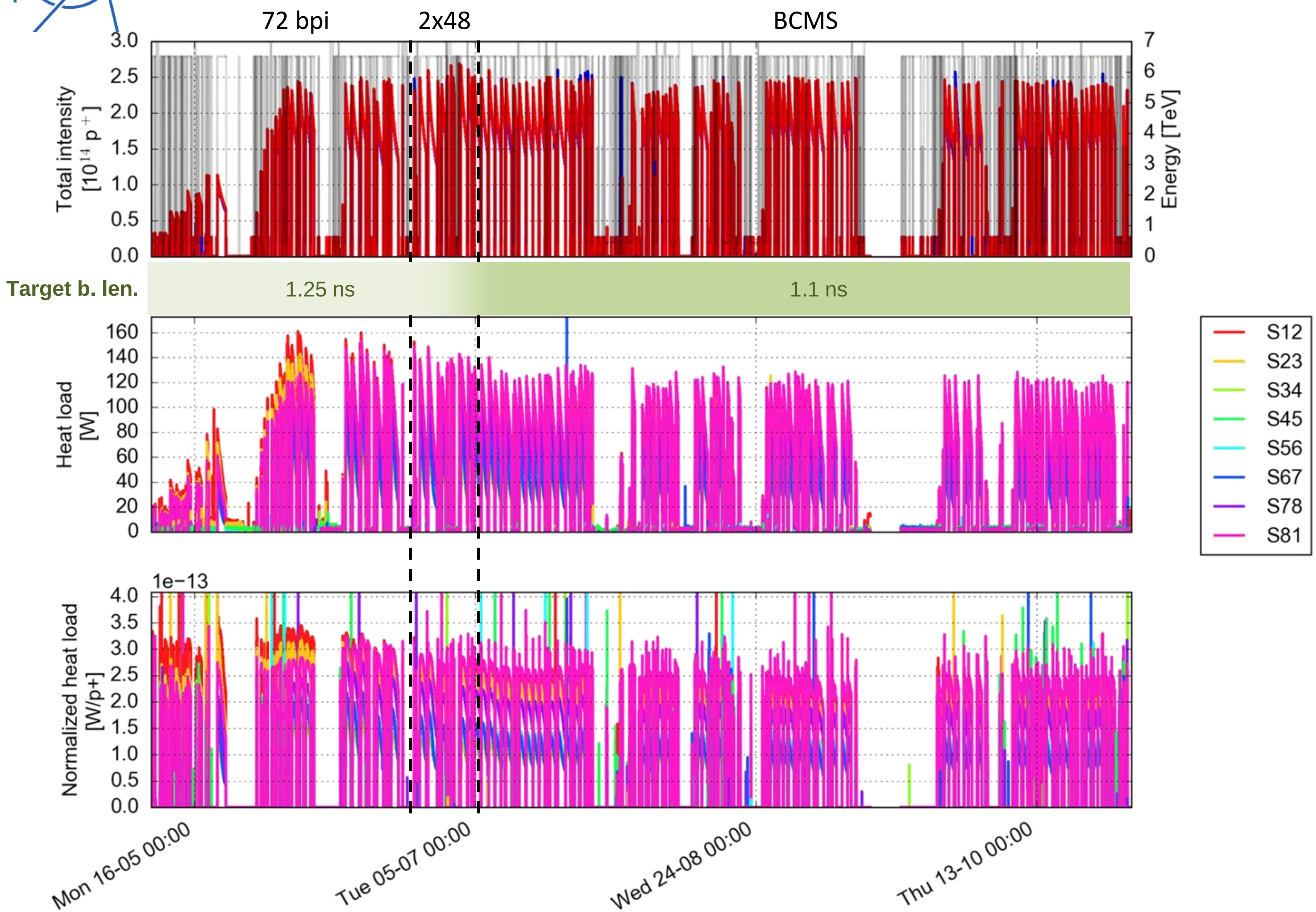
Follow-up on LHC observations

P. Dijkstall, G. Iadarola, L. Mether, G. Rumolo

e-cloud meeting – 3 November 2015

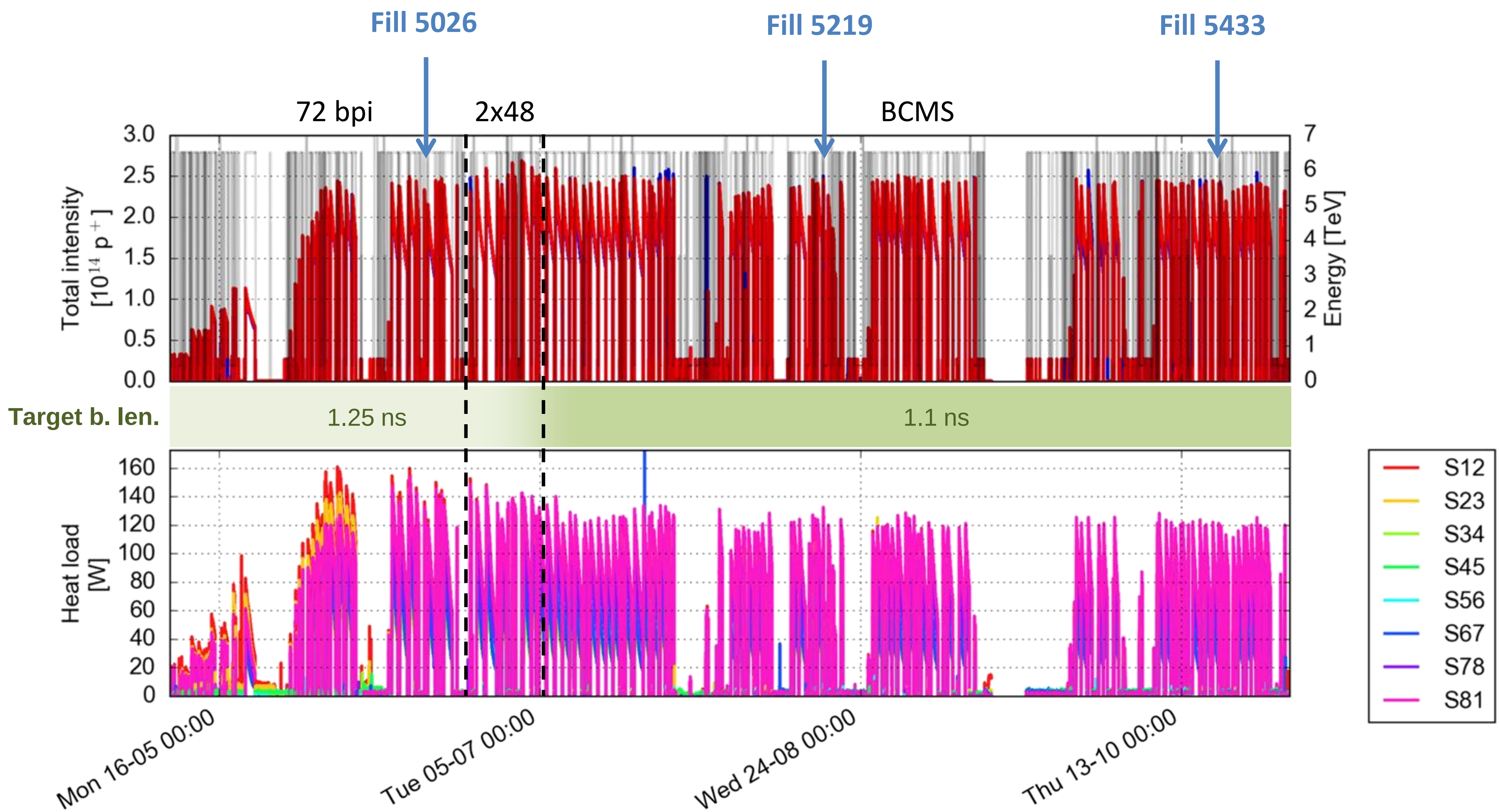
Arc heat load evolution during 2016

Heat load evolution



Reference fills

- We performed **reference fills** for **heat load comparison** to disentangle possible scrubbing from changes in beam configuration



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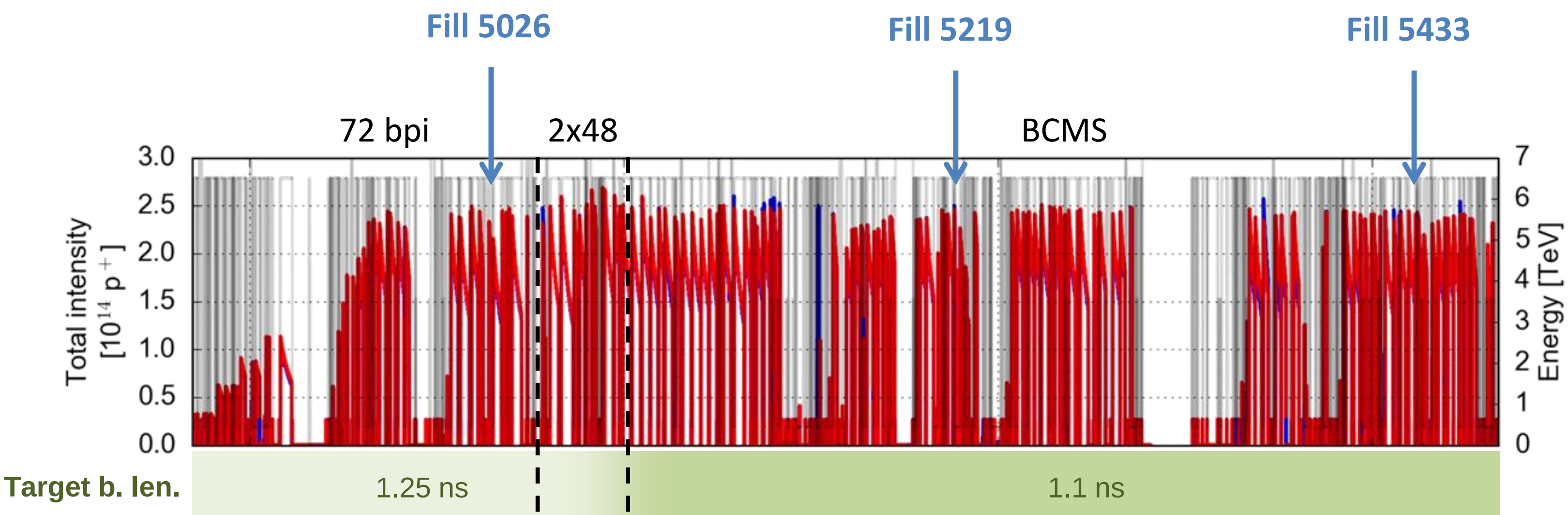
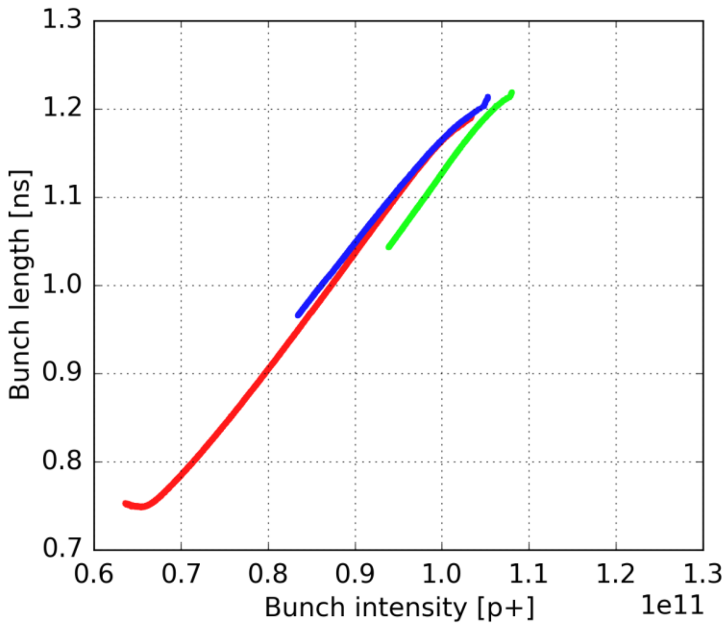


Reverted to settings of fill 5026:

- **Filling scheme**: 2040 bunches in trains of **72b** (standard production scheme in the PS)
- **Target bunch length** for controlled blow-up in the ramp: flat at 1.25 ns
- **Octupole knob at injection:** -1.5 (higher values used for BCMS beam)

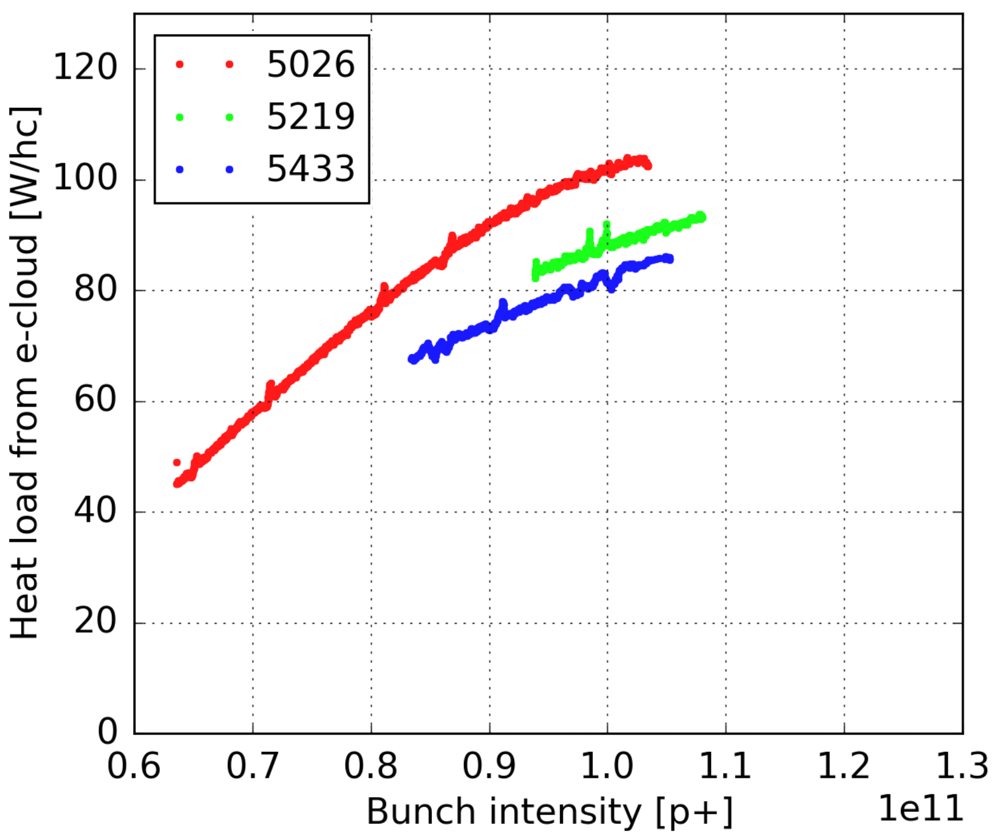
Reference fills

- **Reduction of ~20% or more** on the heat load at 6.5 TeV is observable in all sectors



Bunch length evolution quite reproducible

Sector 12



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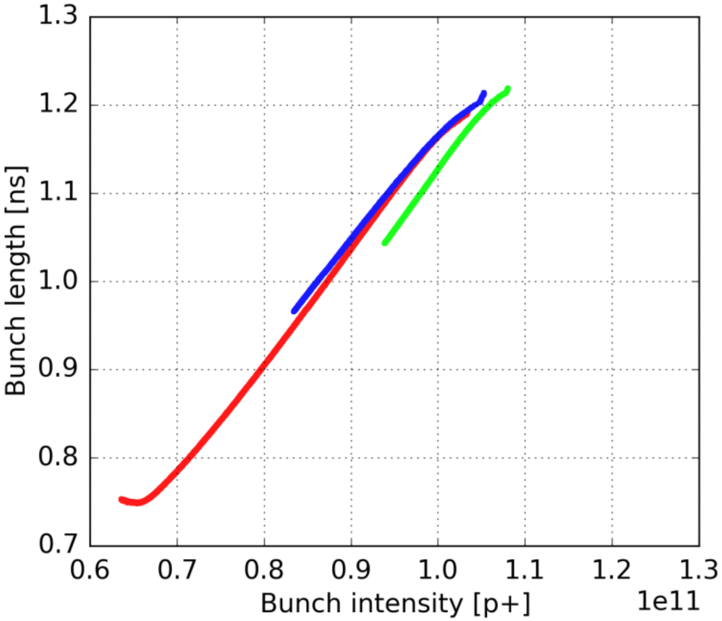

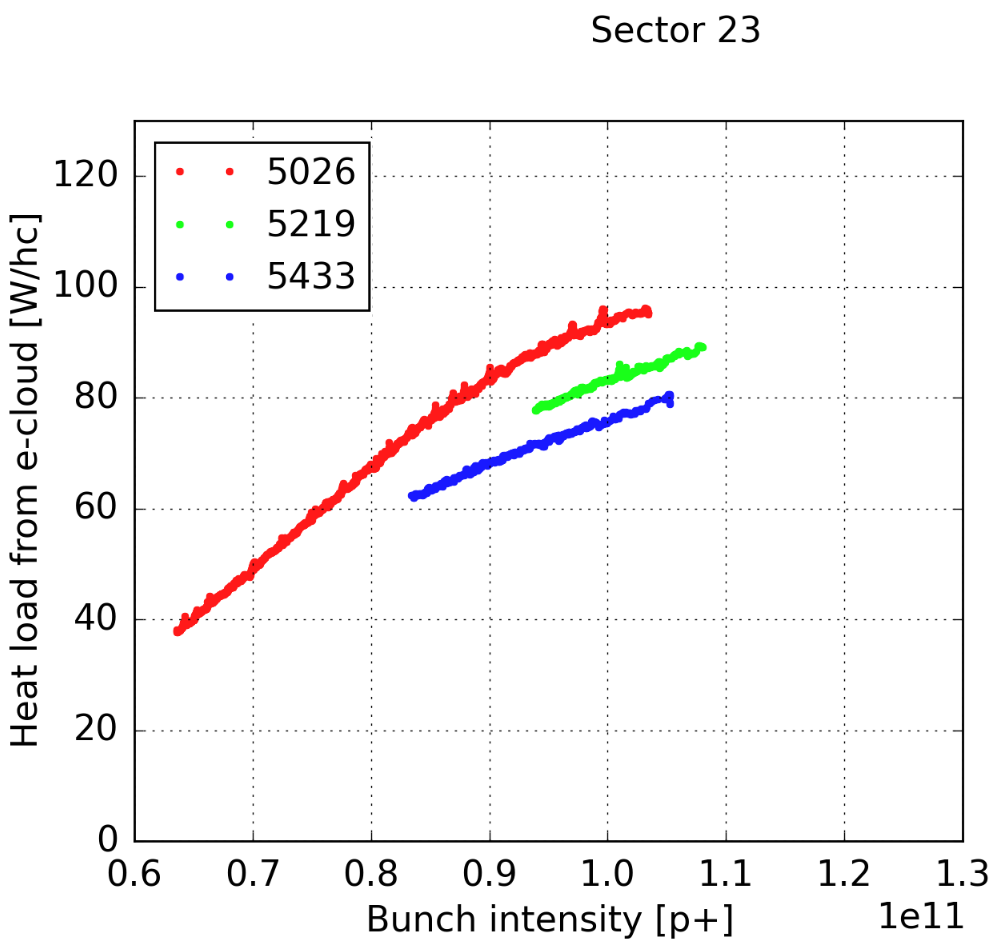

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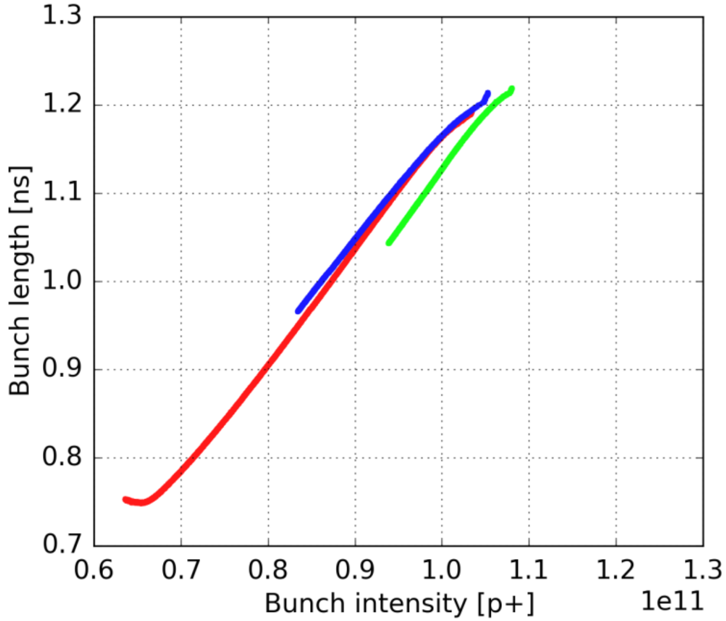
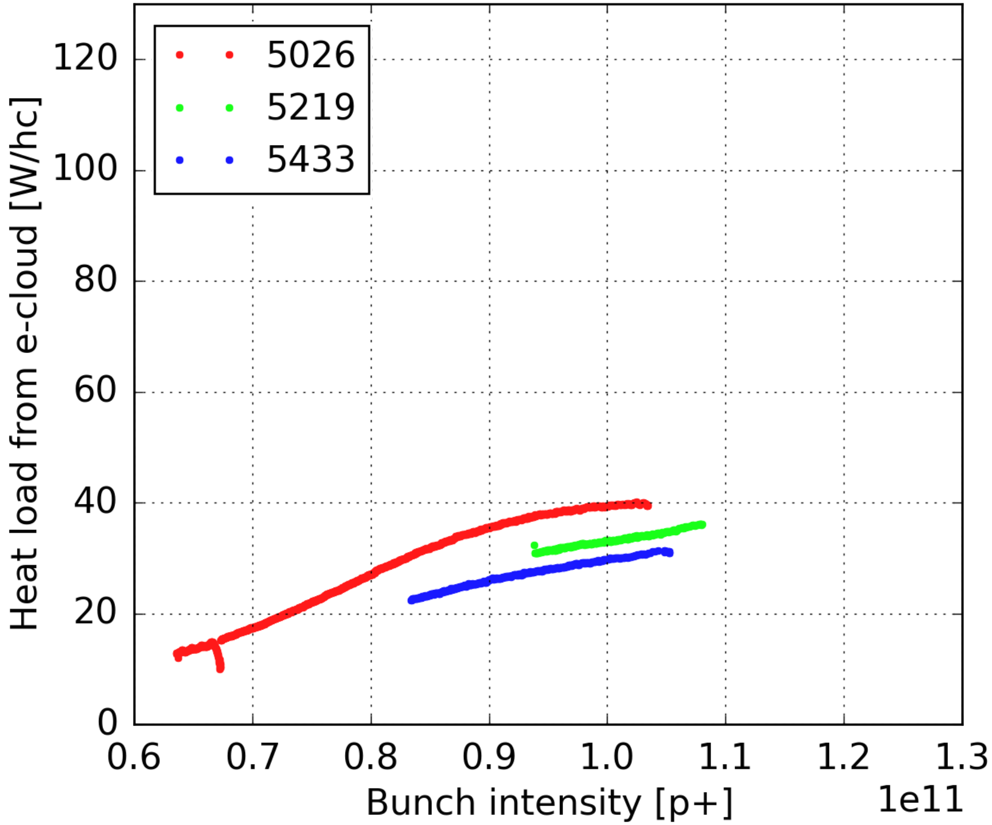


Sector 34



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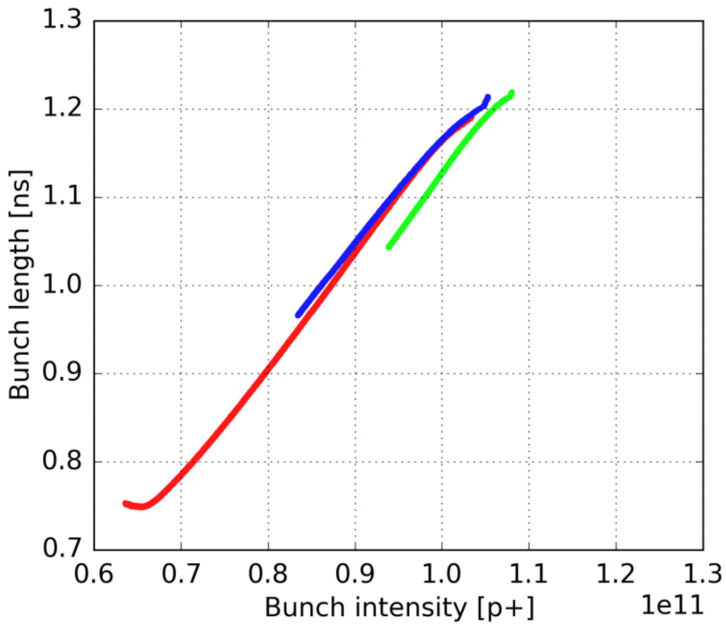
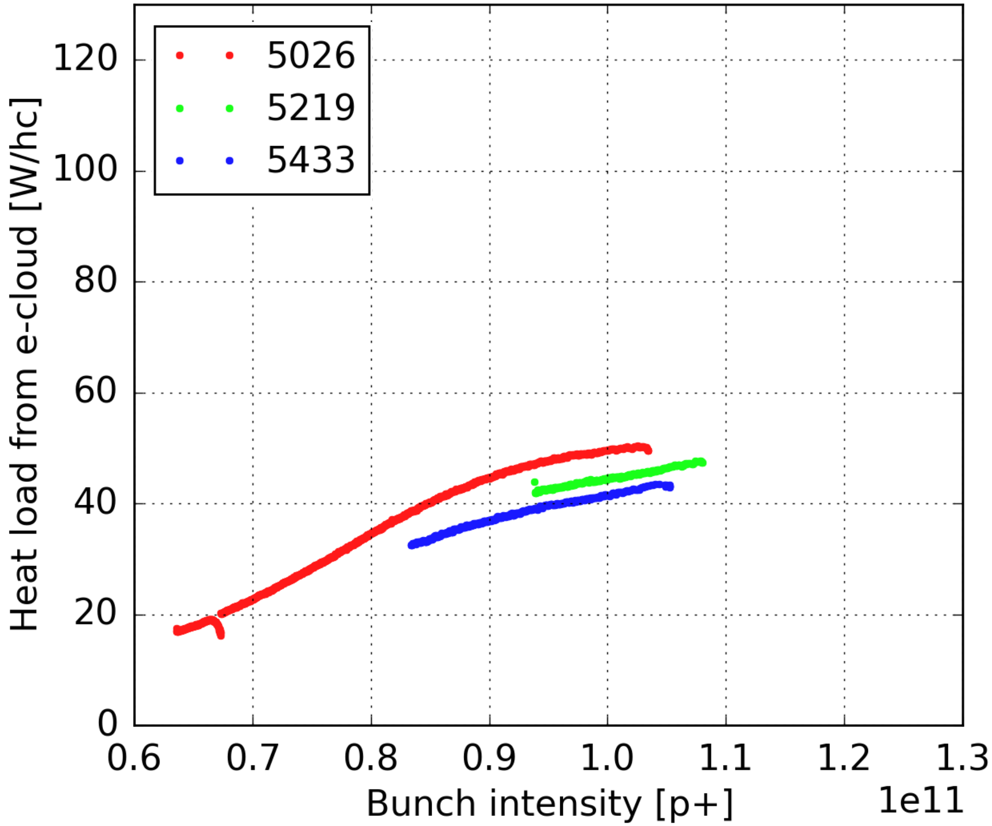


Sector 45



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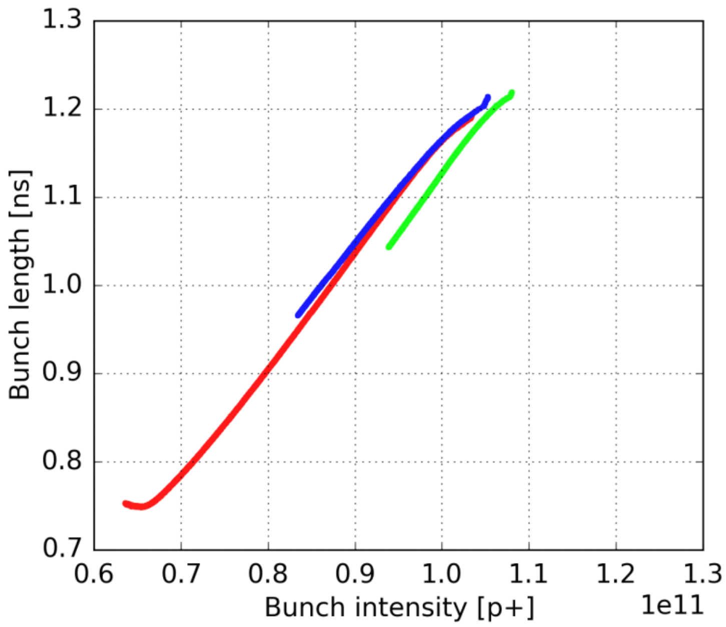
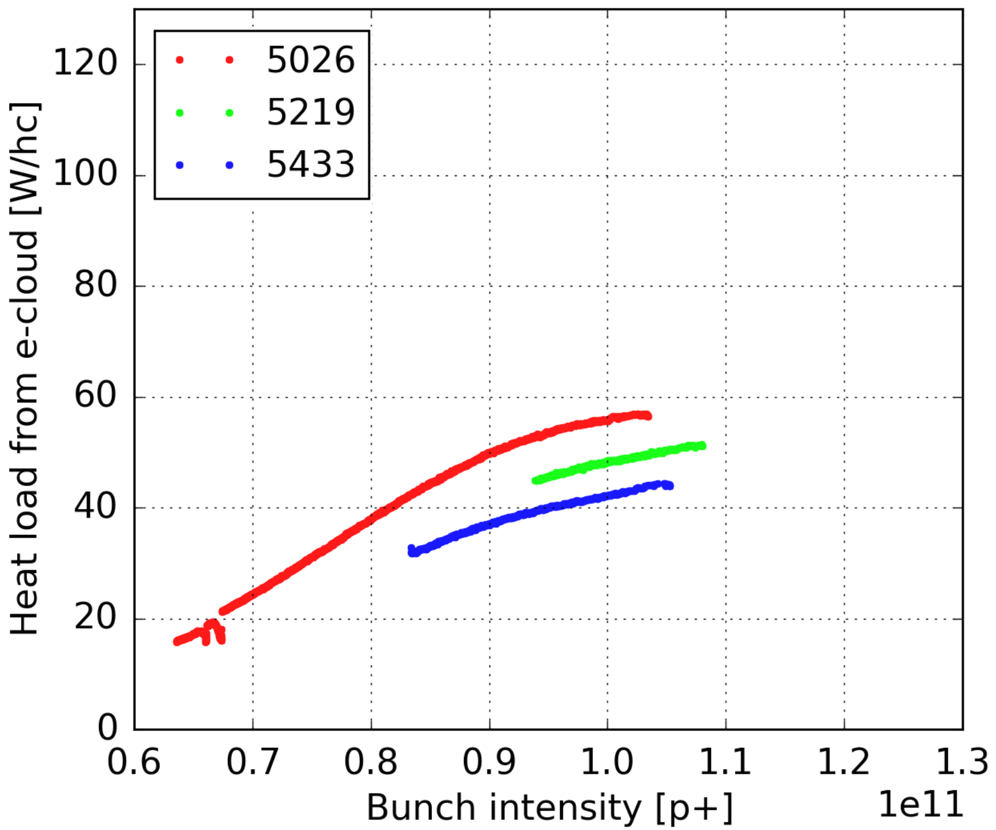


Sector 56



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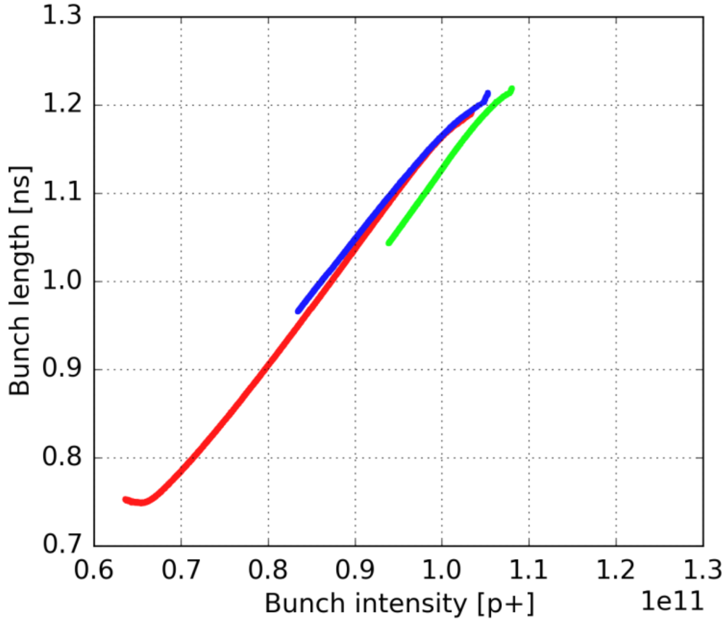
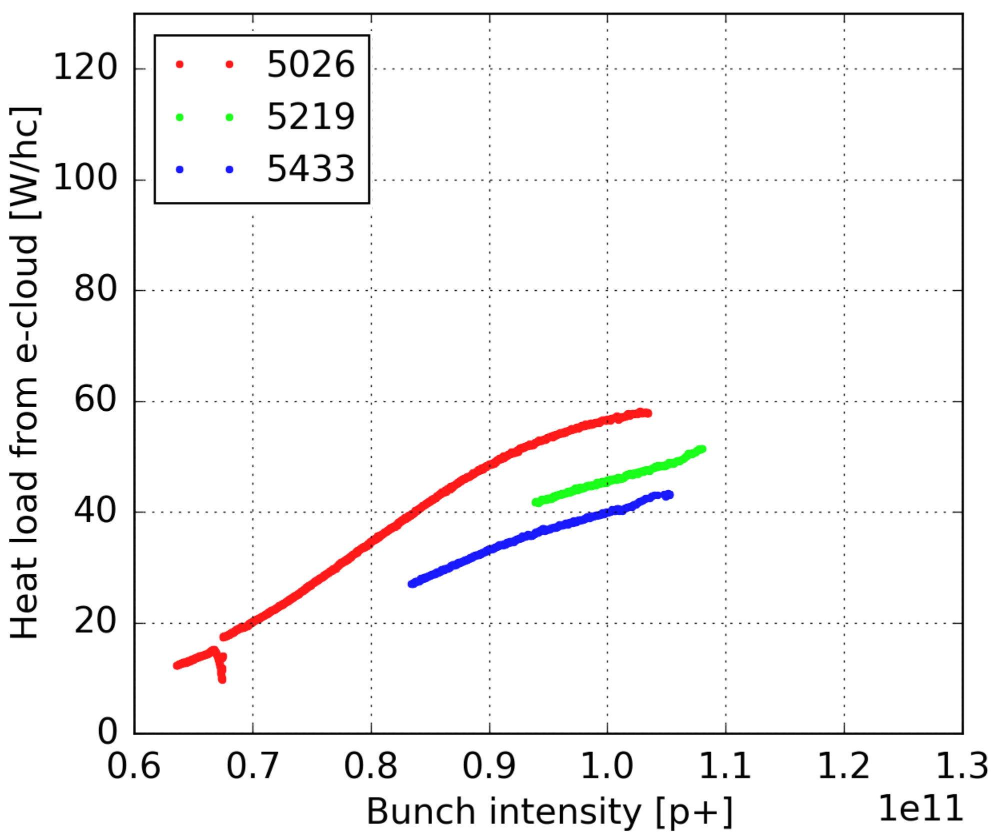


Sector 67



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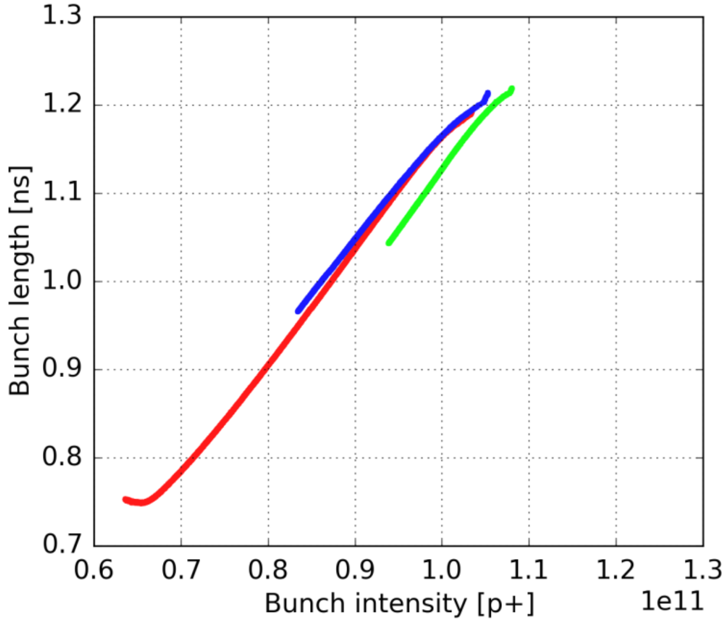
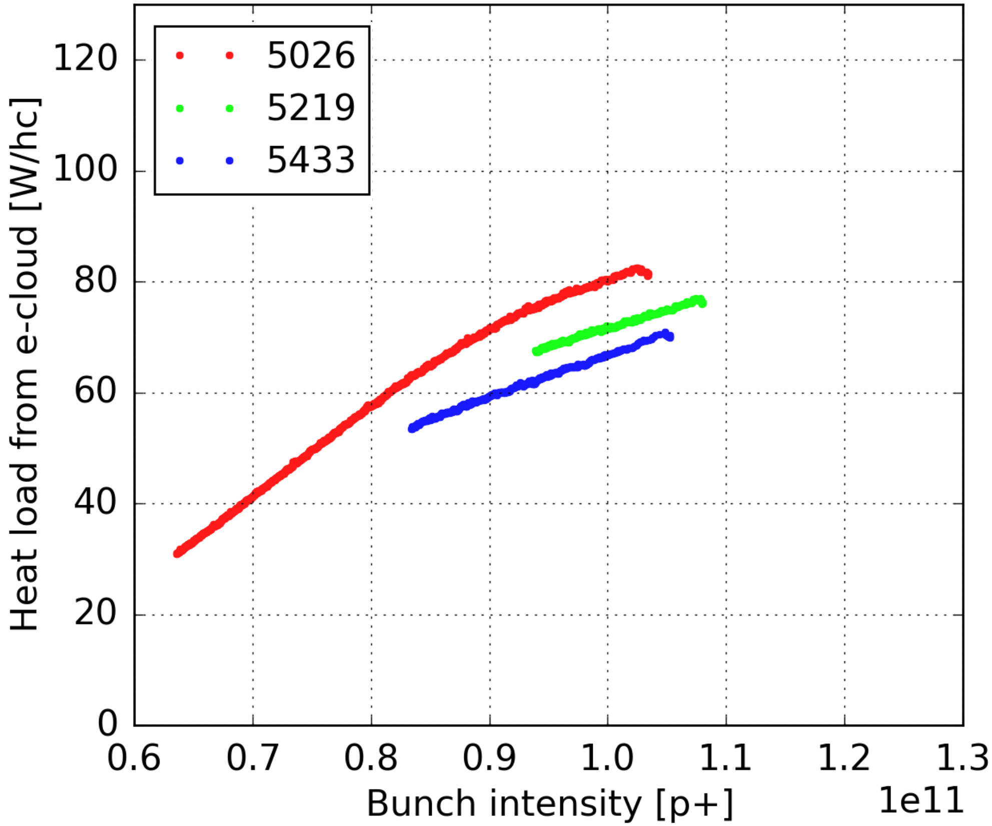
Sector 78





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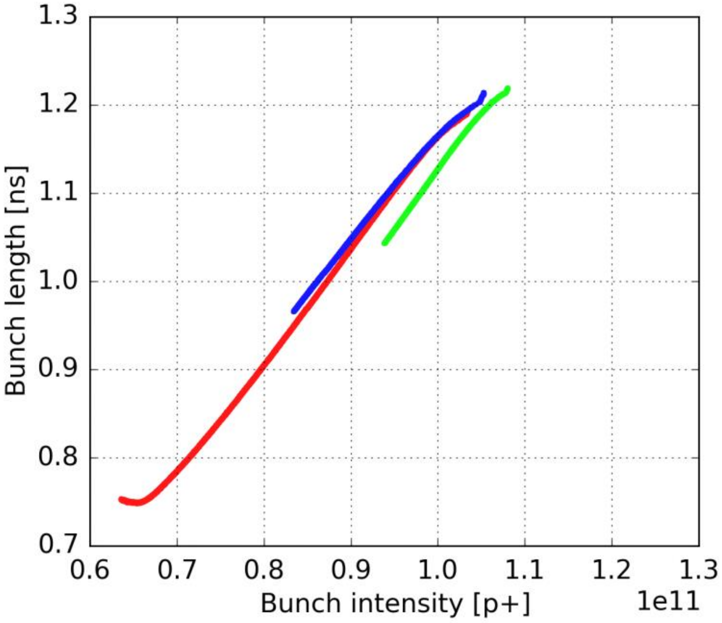
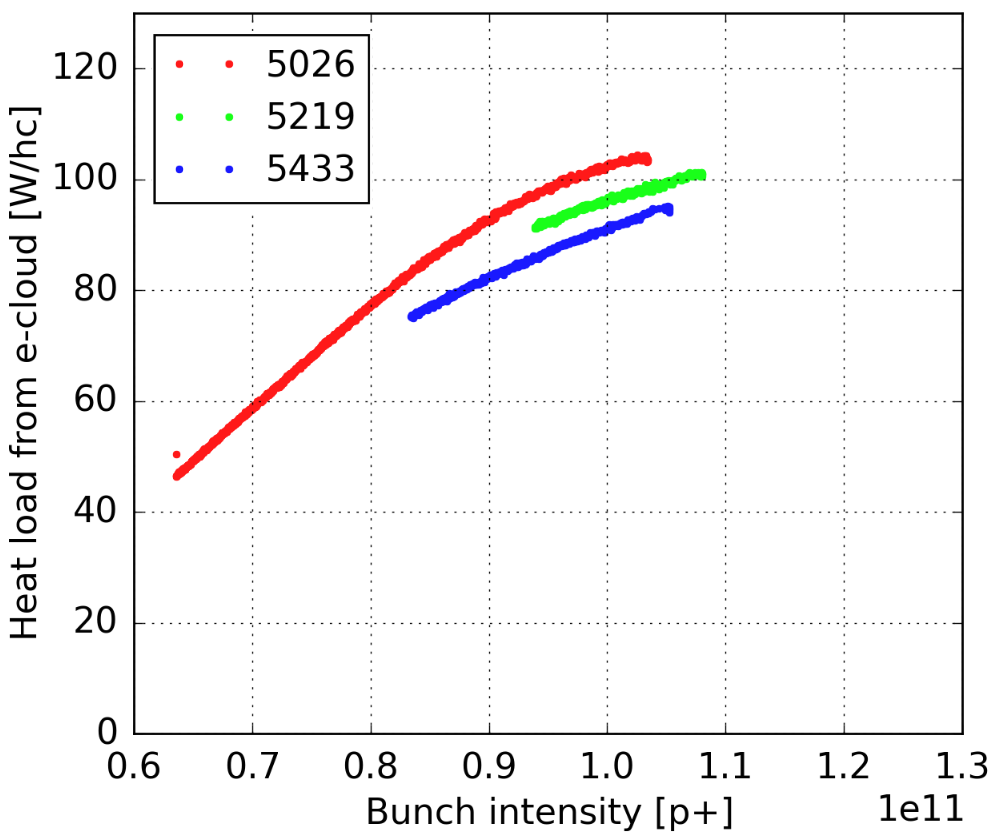
Sector 81

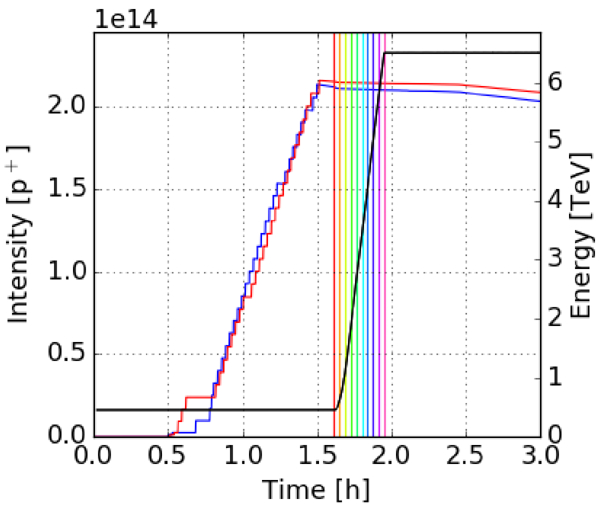


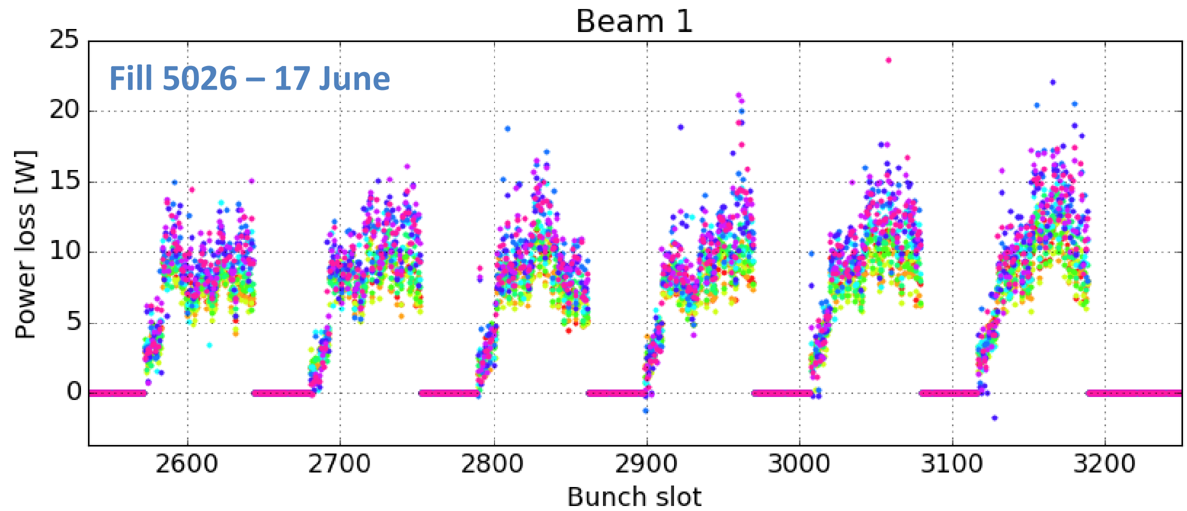


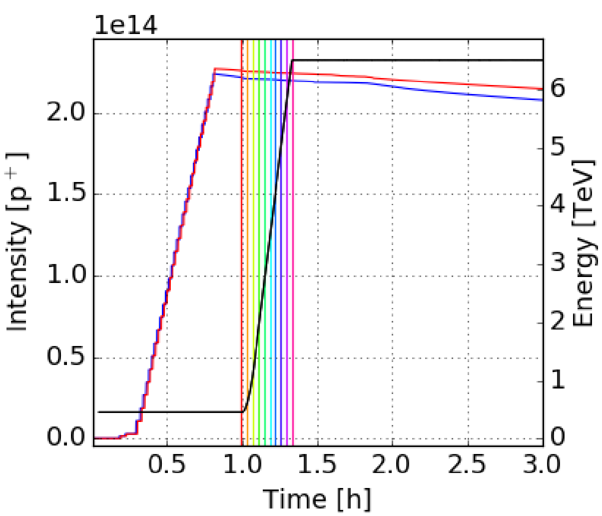
Intensity decreases during the fill (burn-off)

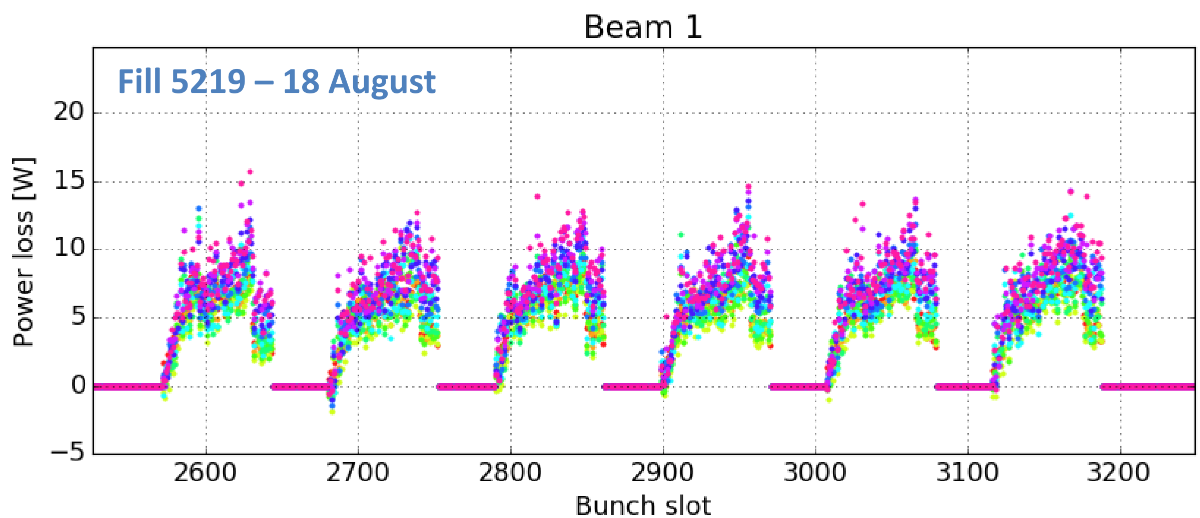
Stable phase comparison

- Also bunch-by-bunch power loss shows some improvement









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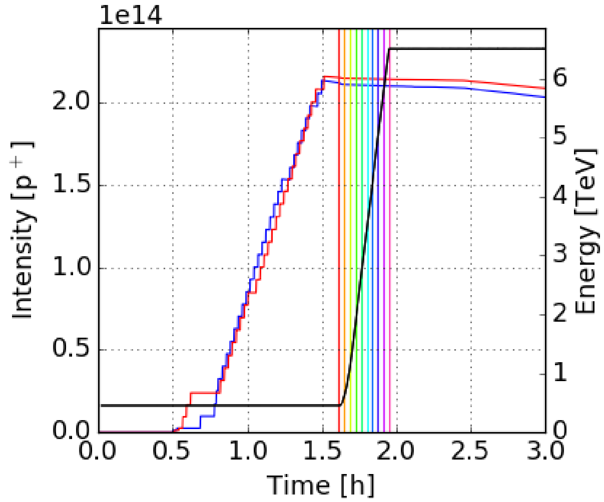

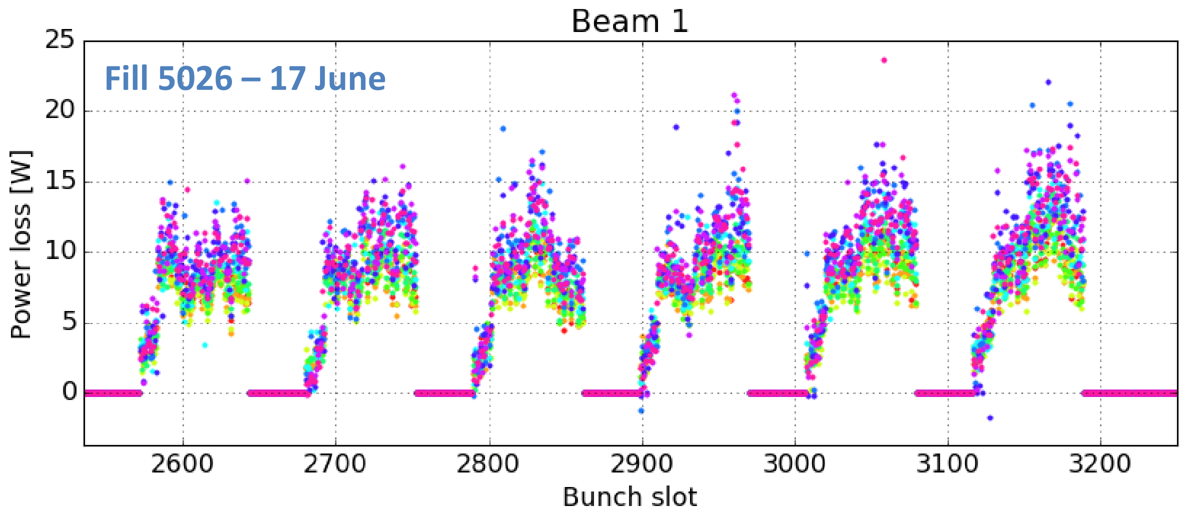

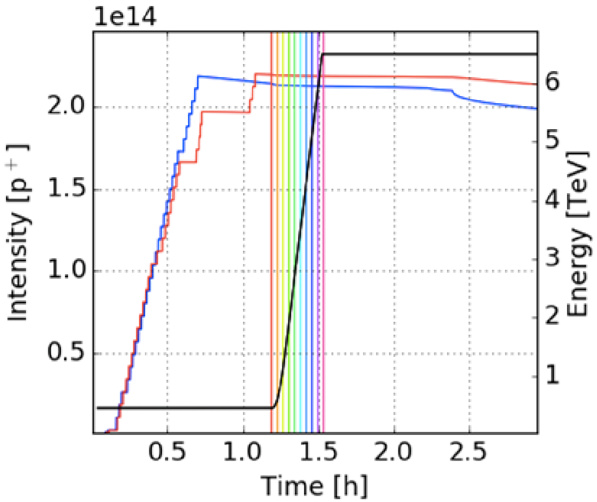

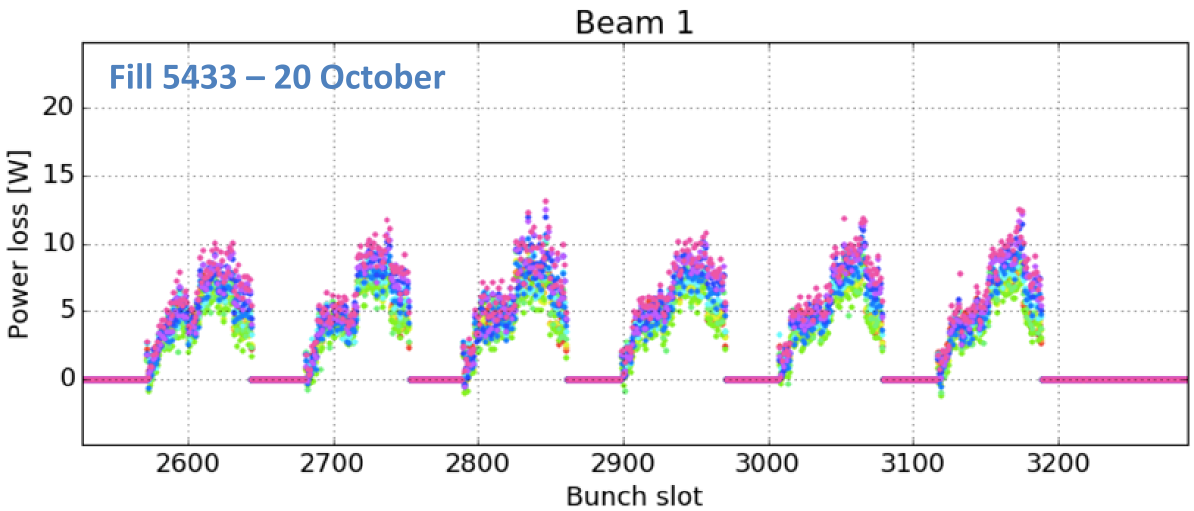

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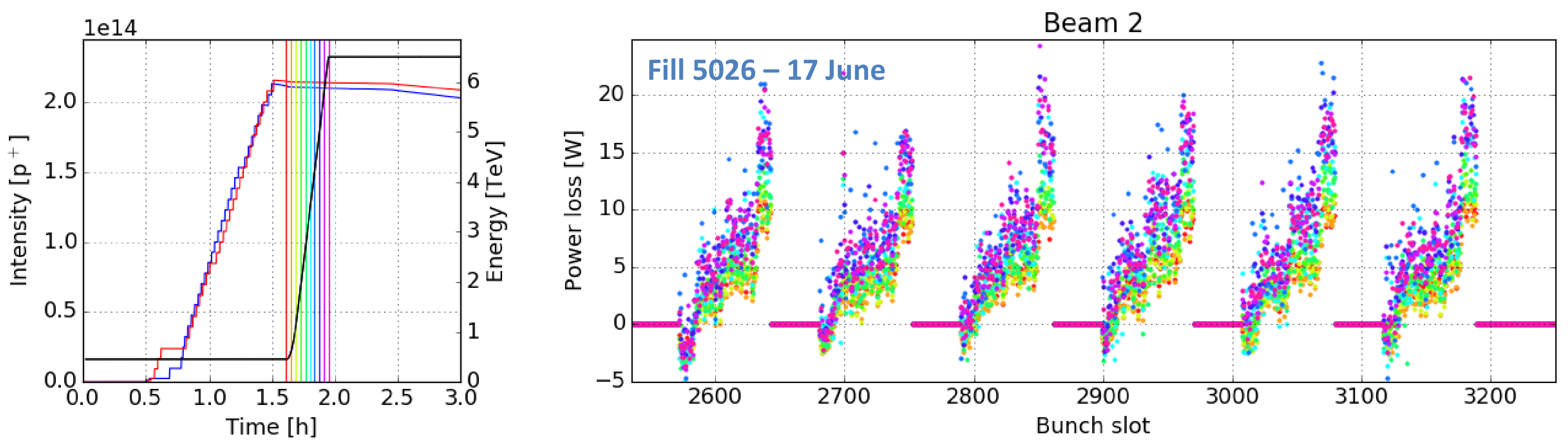

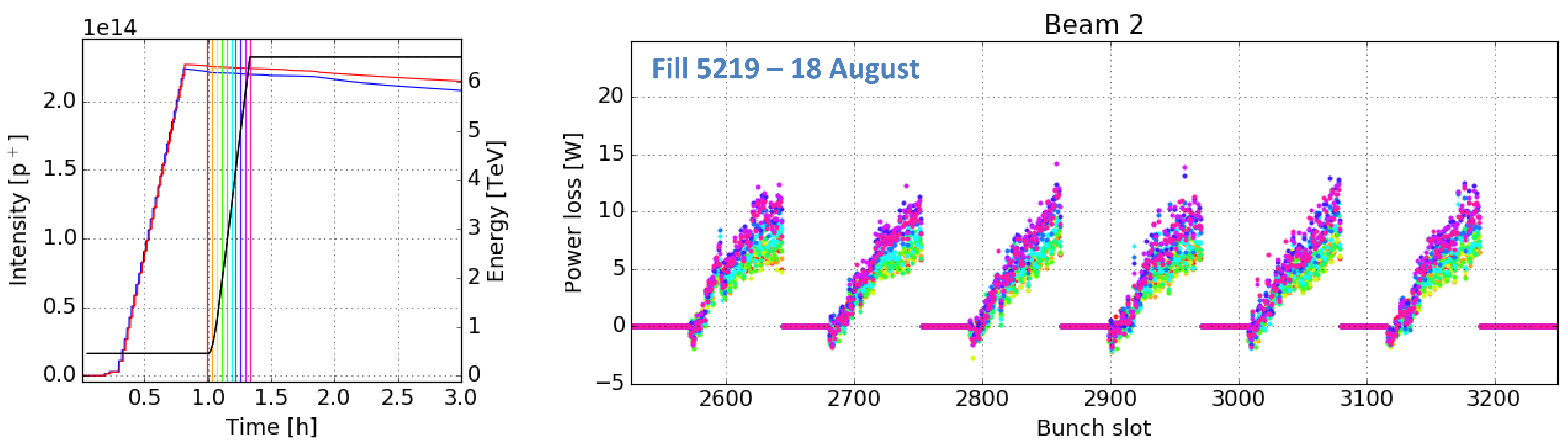

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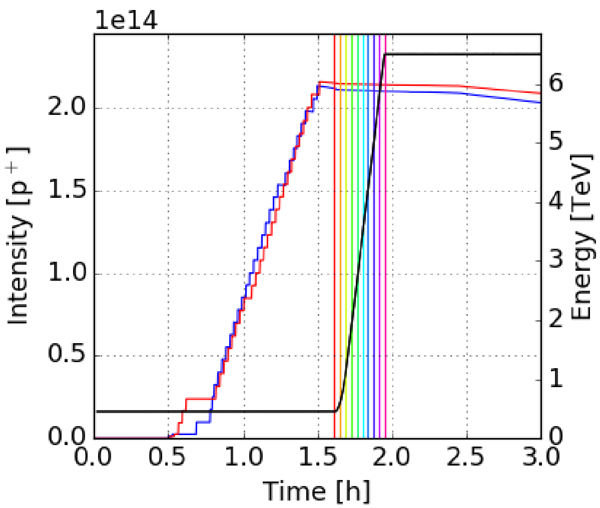

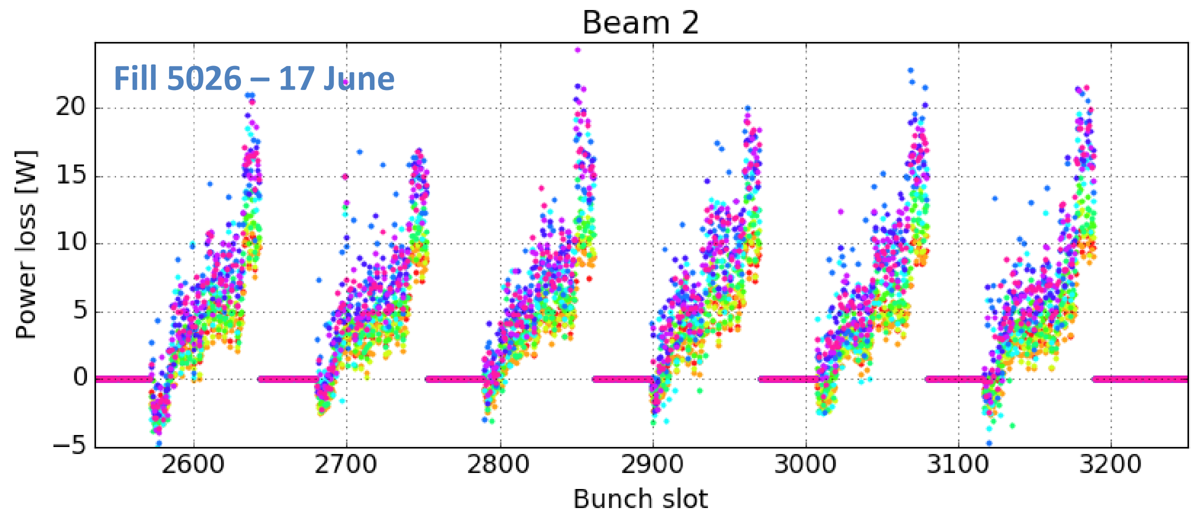

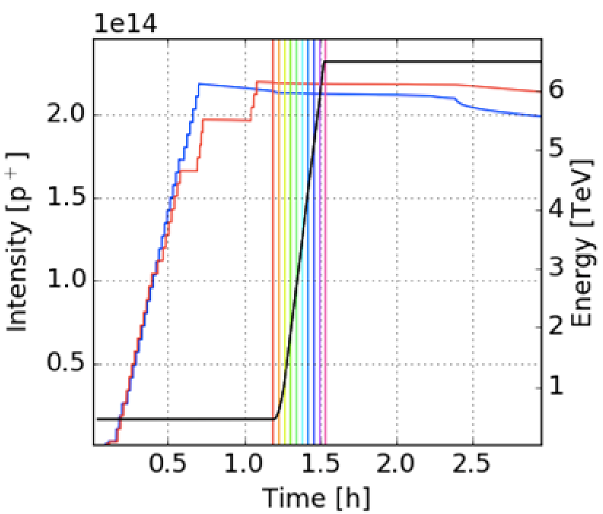

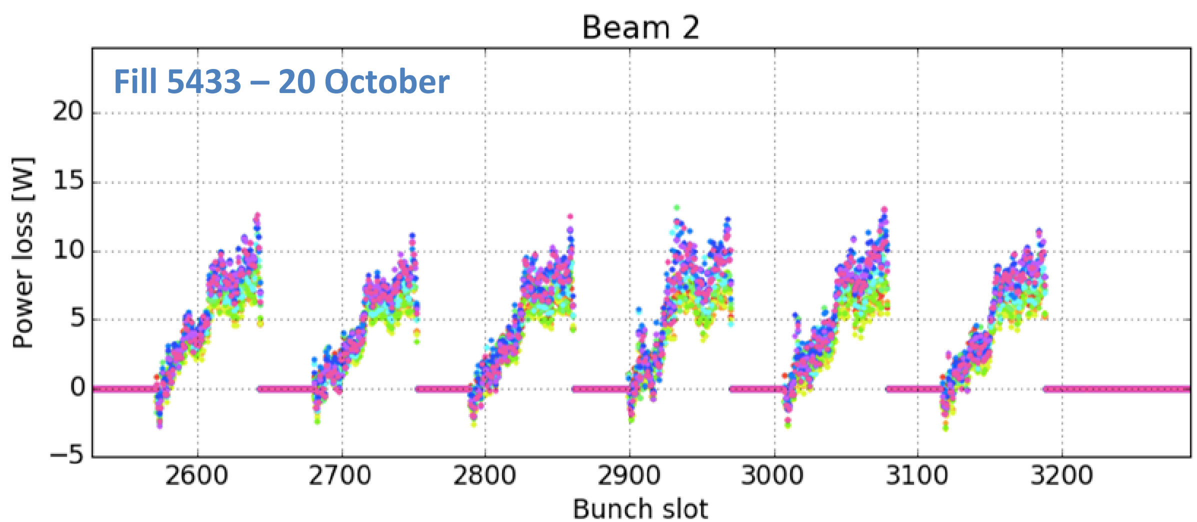

Heat load breakdown and SEY estimates

Sharing among different heat load contribution

What we know about the different contributions:

- **Impedance and synchrotron** radiation can be calculated with simple formulas

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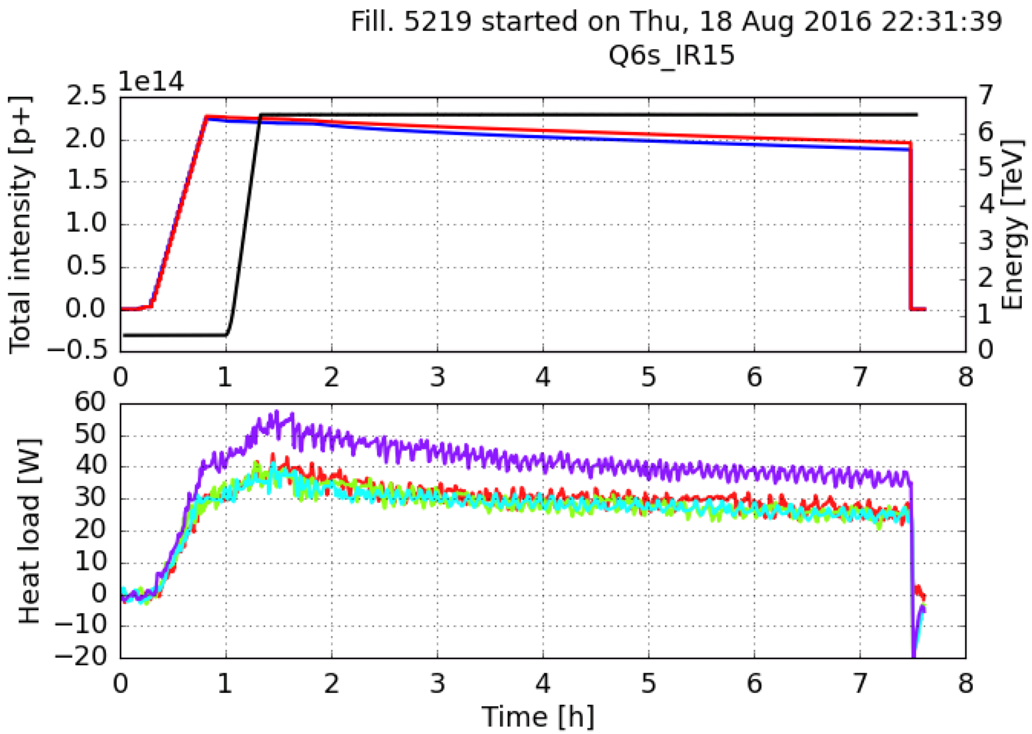
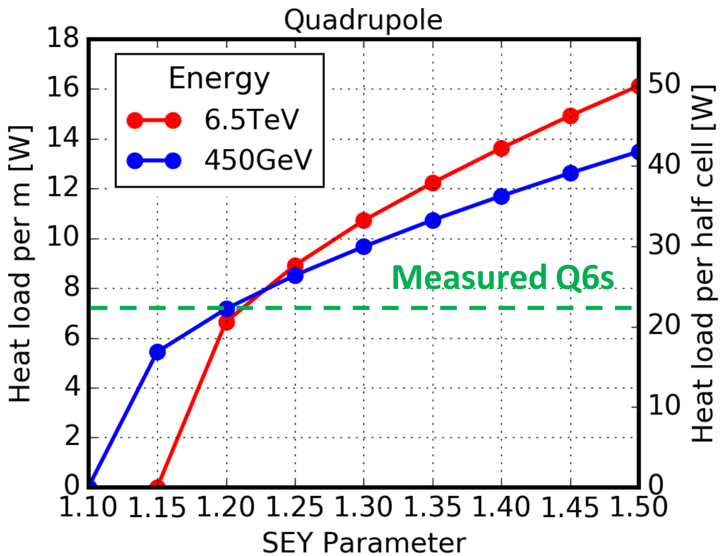
- Heat loads in the **quadrupoles** can be inferred from the **Q6 magnets** (same chamber)

→ Comparing against simulations we get **SEY$_{quad}$= ~1.2**





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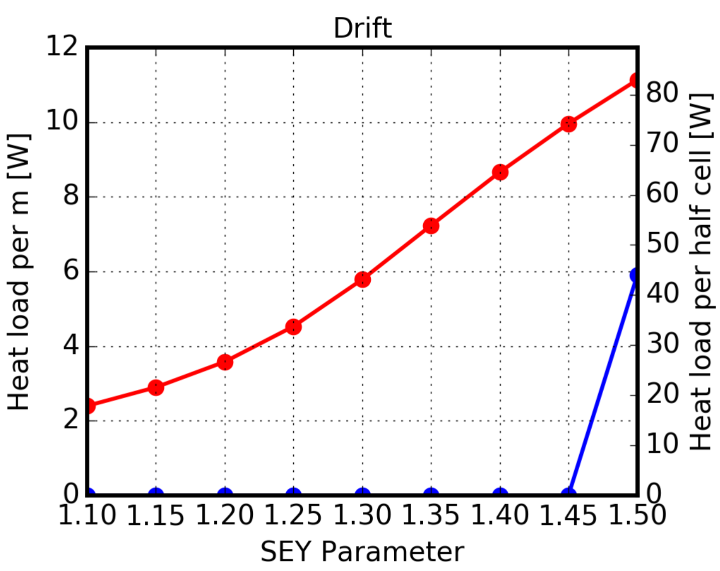
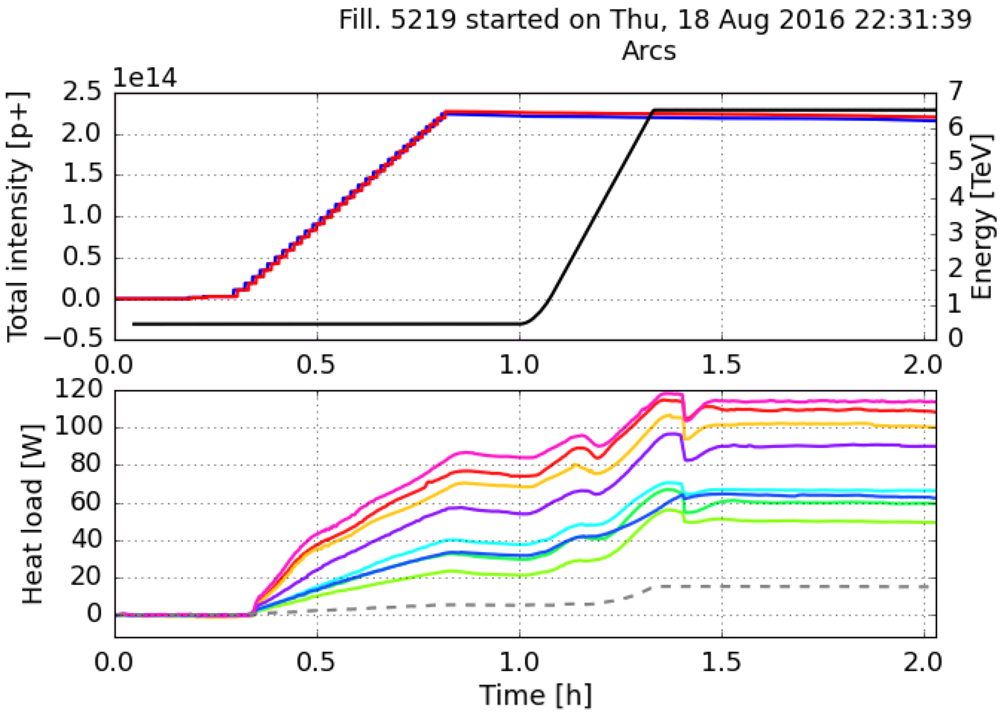
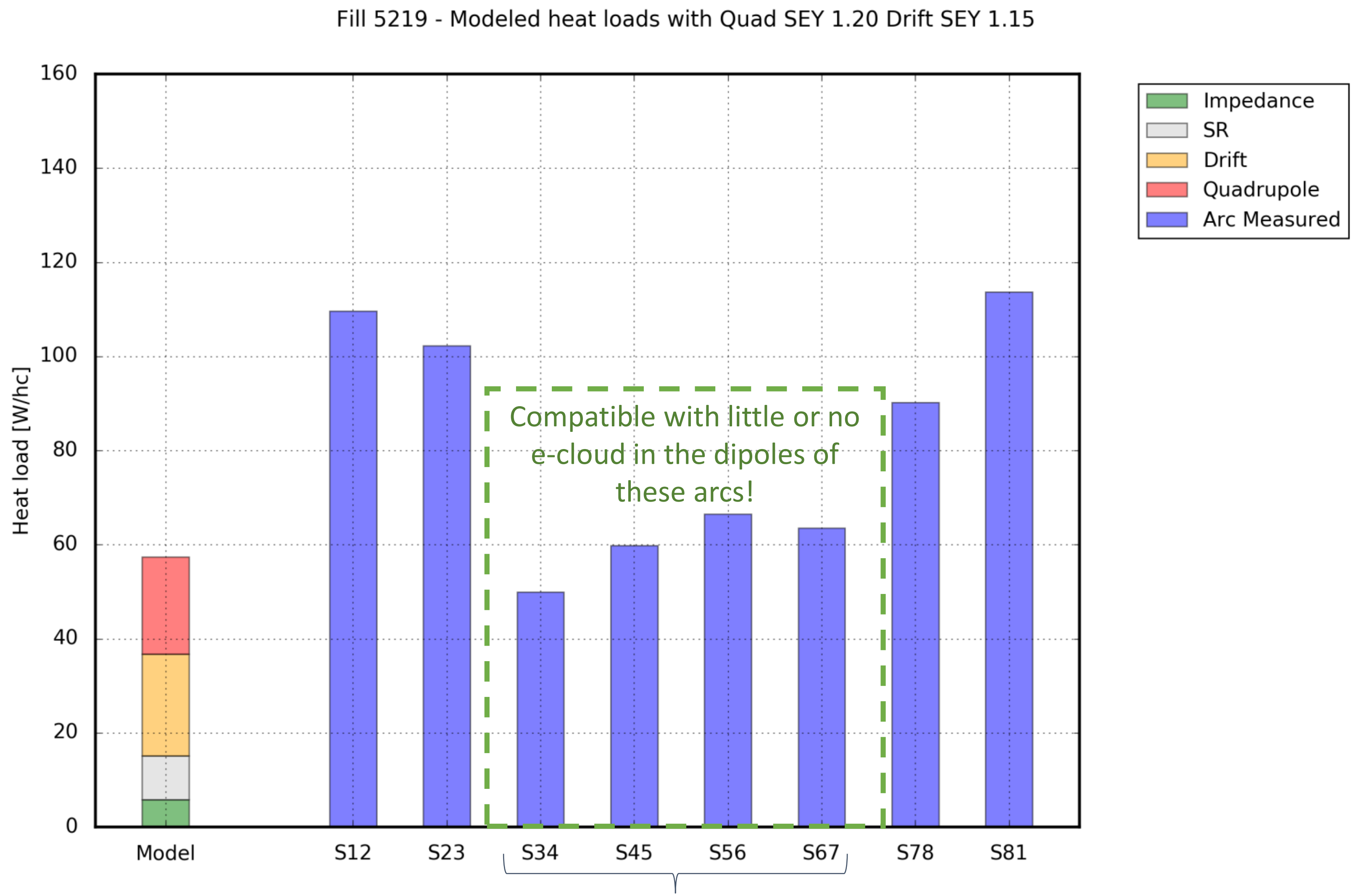
- Even with low SEY (~1.15) the **drift spaces** (for now we assume cell lenget not covered by main magnets) **give a significant heat load at 6.5 TeV** (photoelectrons from "direct impact" of SR are not neutralized by the B field)

  → It can explain partially (or even fully?) the heat load increase in the ramp



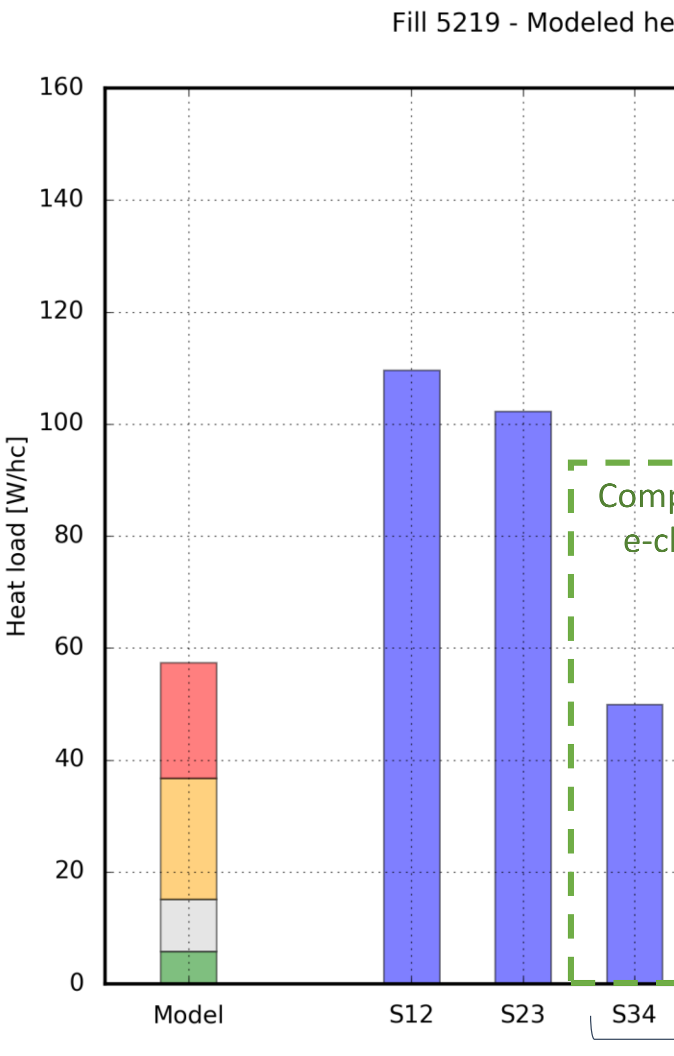


Putting it all together

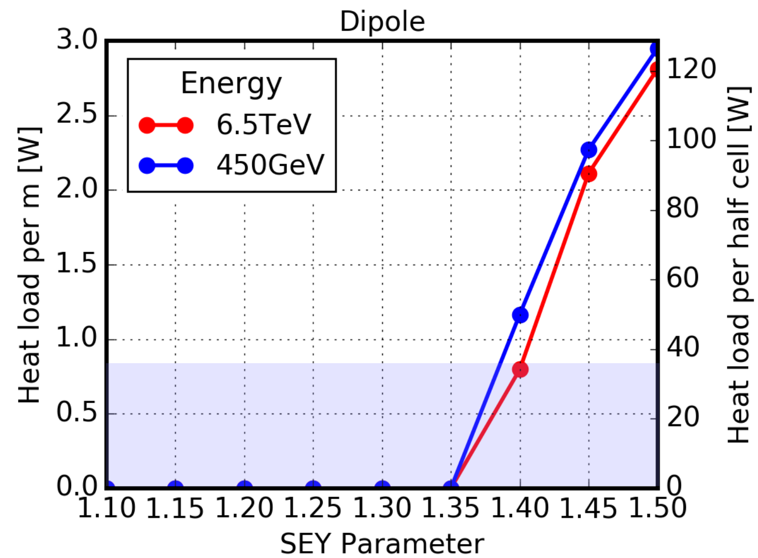


Inferred SEY$_{dip}$: 1.42 1.41 <=1.35 1.4 1.42

The **SEY in the arc dipoles** can be inferred comparing the **residual heat load** with PyECLOUD simulations



In the dipoles we are **very close to the multipacting threshold** small changes in SEY have a big impact on the heat loads



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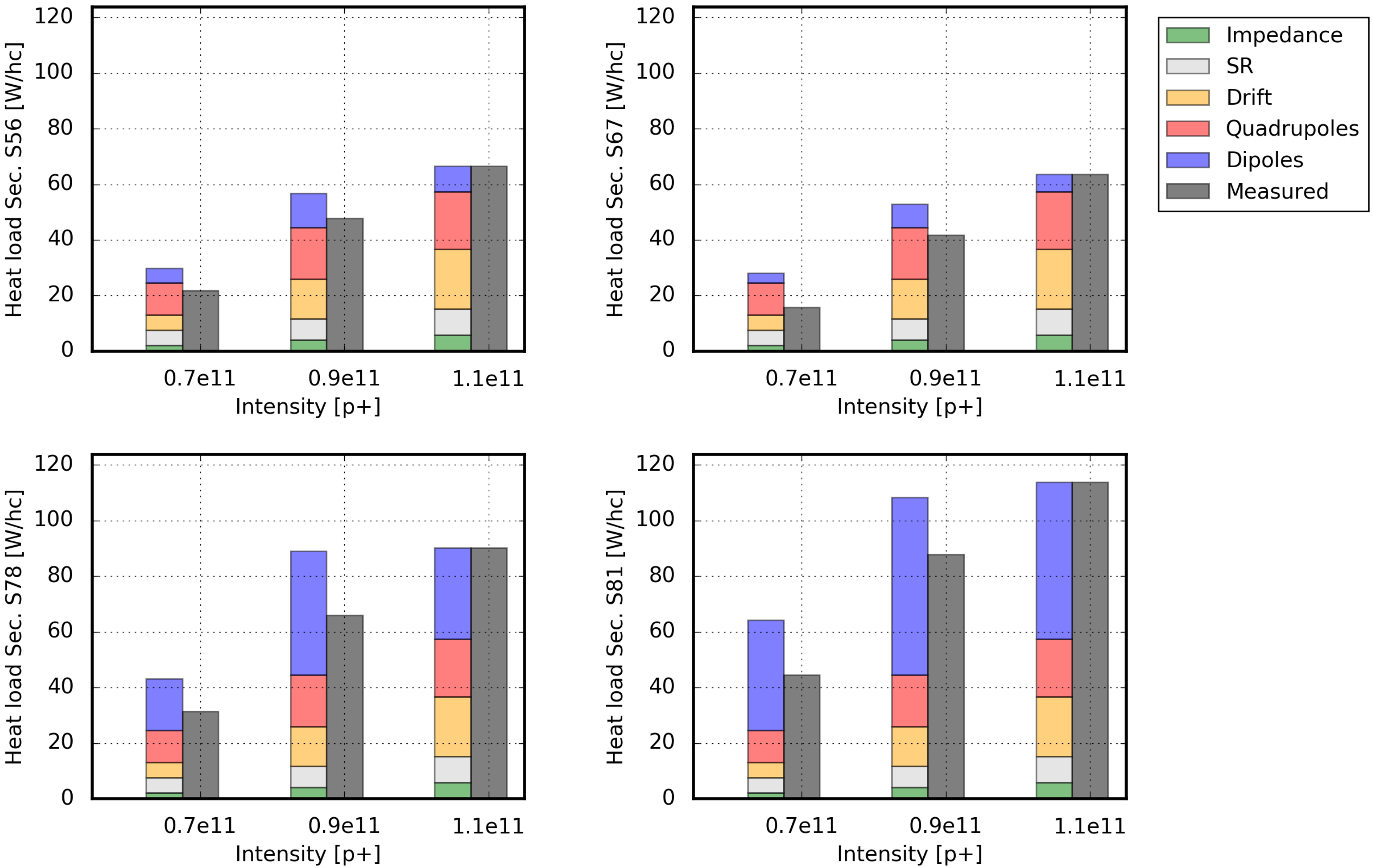
Dependence on bunch intensity
(measured in dedicated MD fills on 18-19 Aug.)

MD fills with different bunch intensity

The different components are expected to scale differently with intensity

→ Reasonably good agreement on the total, measured dependence a bit steeper than expected



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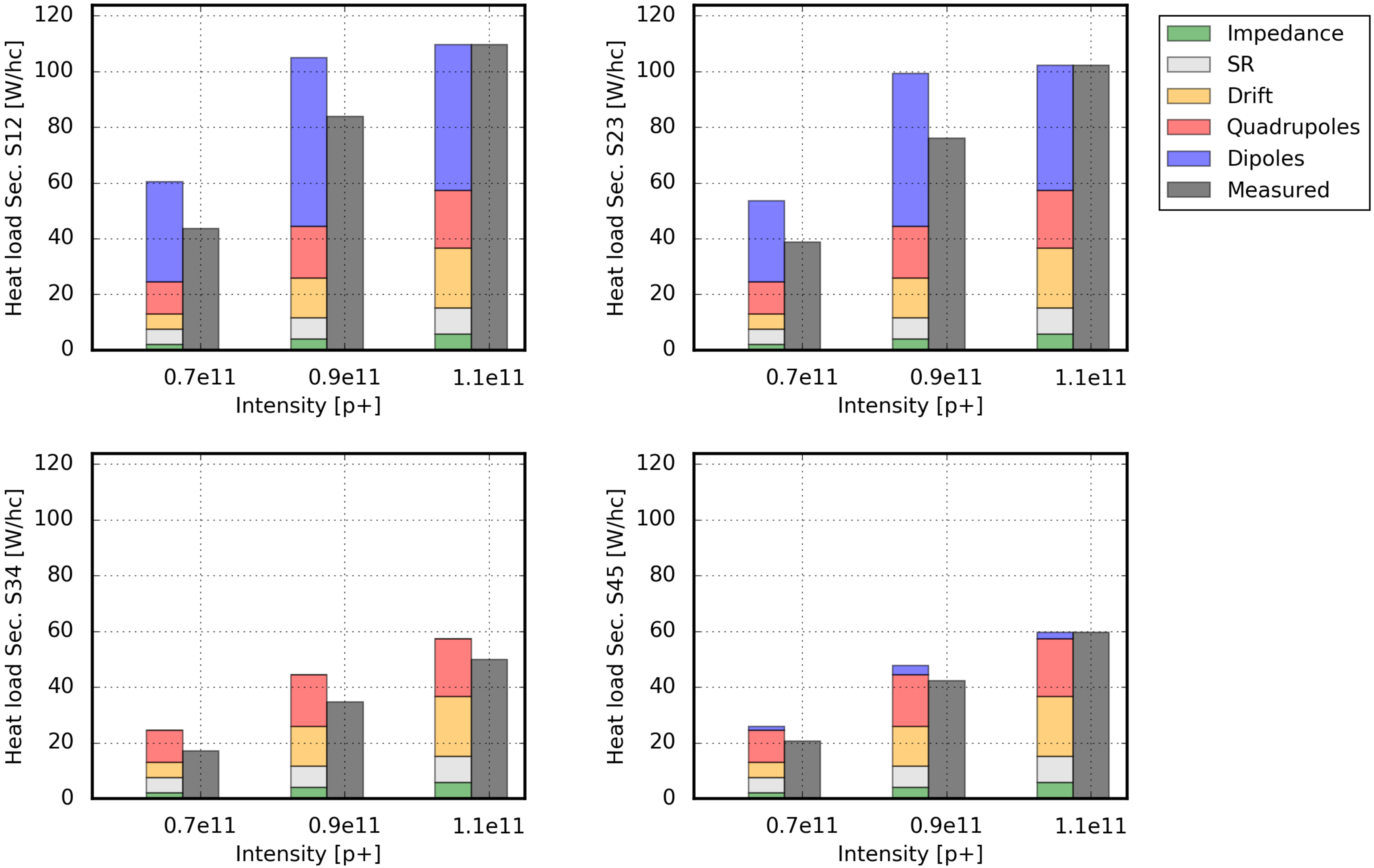

Computation of the integrated electron dose

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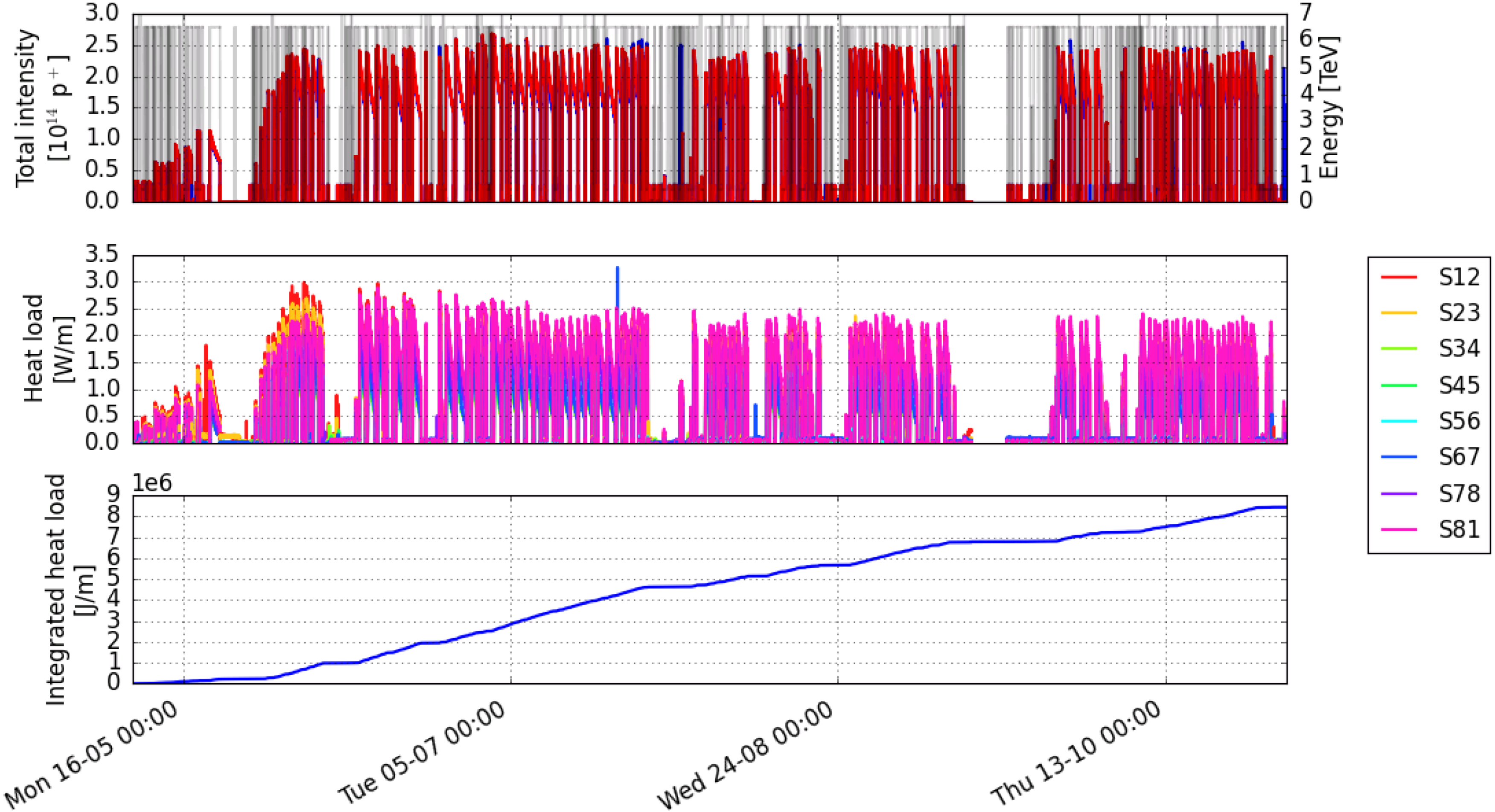
The **integrated heat load** can be directly from the cryogenics measurements



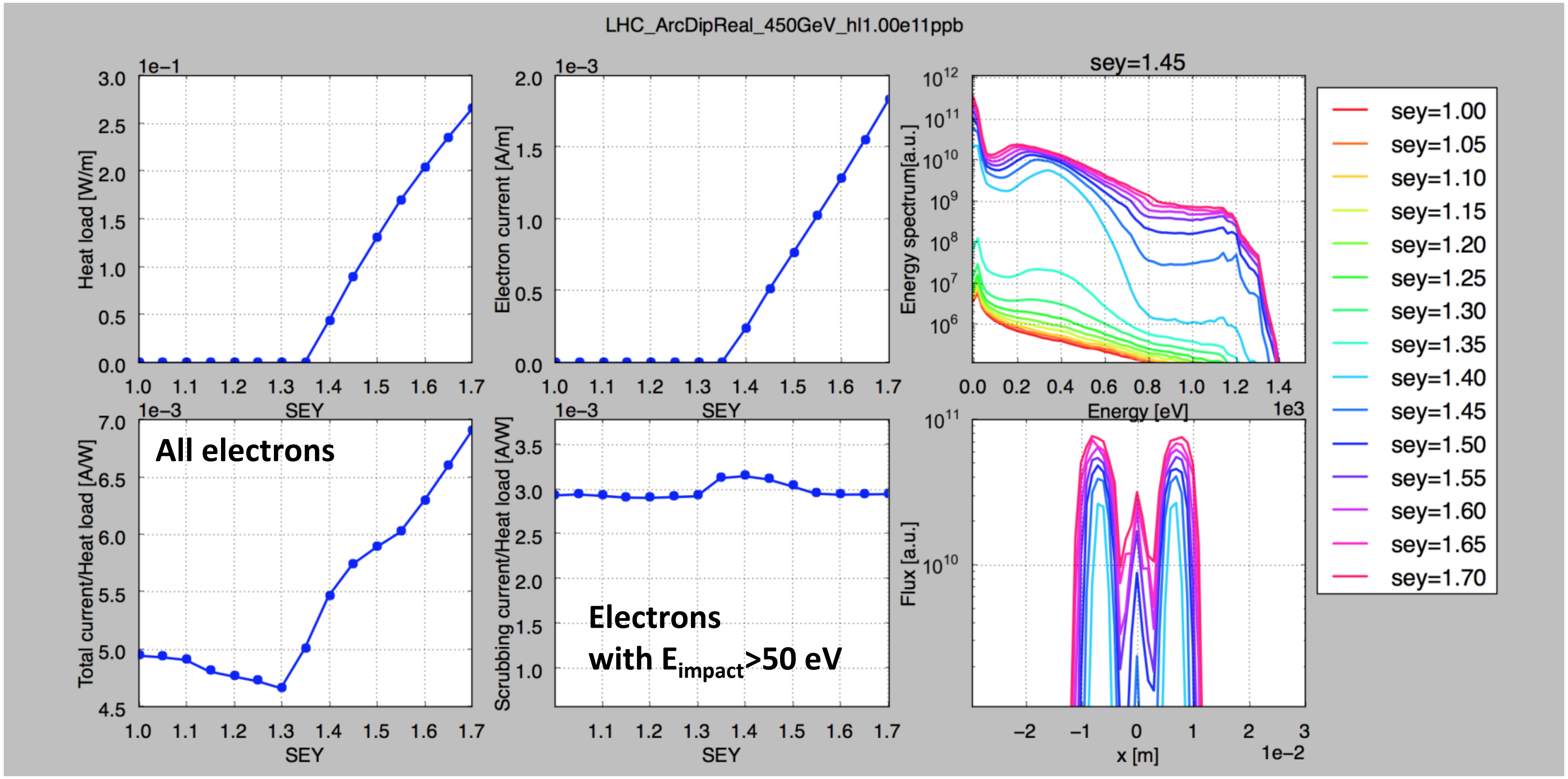
Computation of the integrated electron dose

From **PyECLOUD simulations** we obtain a **conversion factor** of **3 mA/W**

→ Equivalent to an **average energy** of the impacting electron of **333 eV**

→ Consistent with simplified back-of-the-envelope calculation

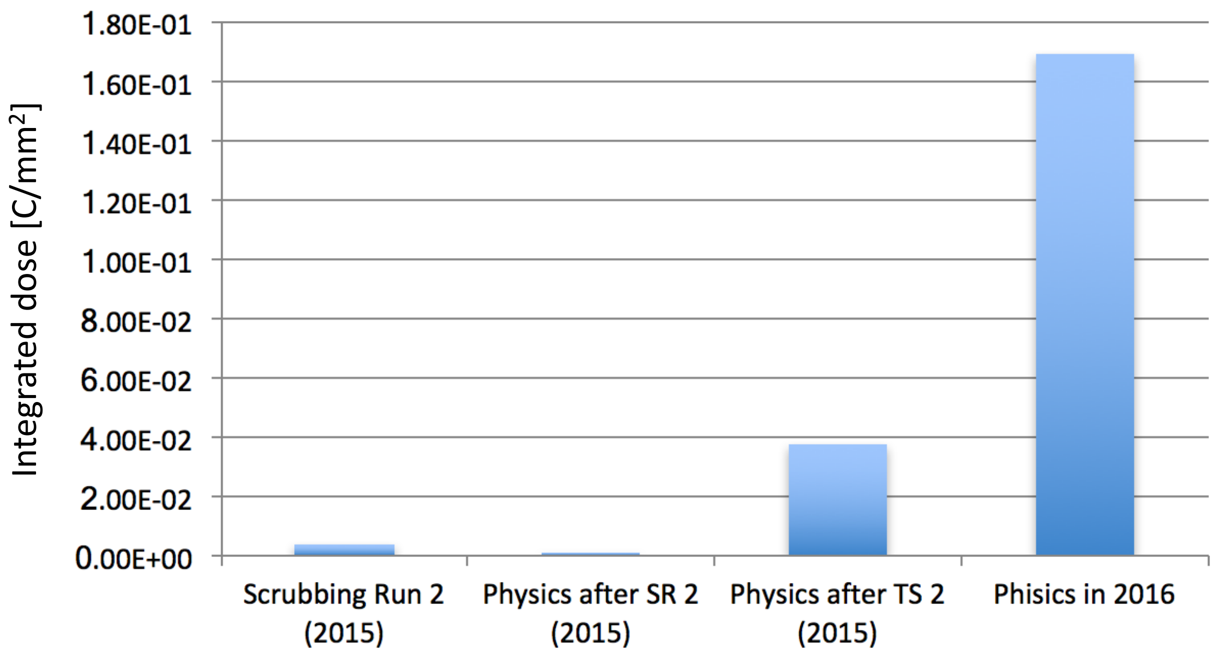
We count only "good" scrubbing electrons E_{impact}>50 eV



Computation of the integrated electron dose

For the arc dipoles of the “high-load” sectors

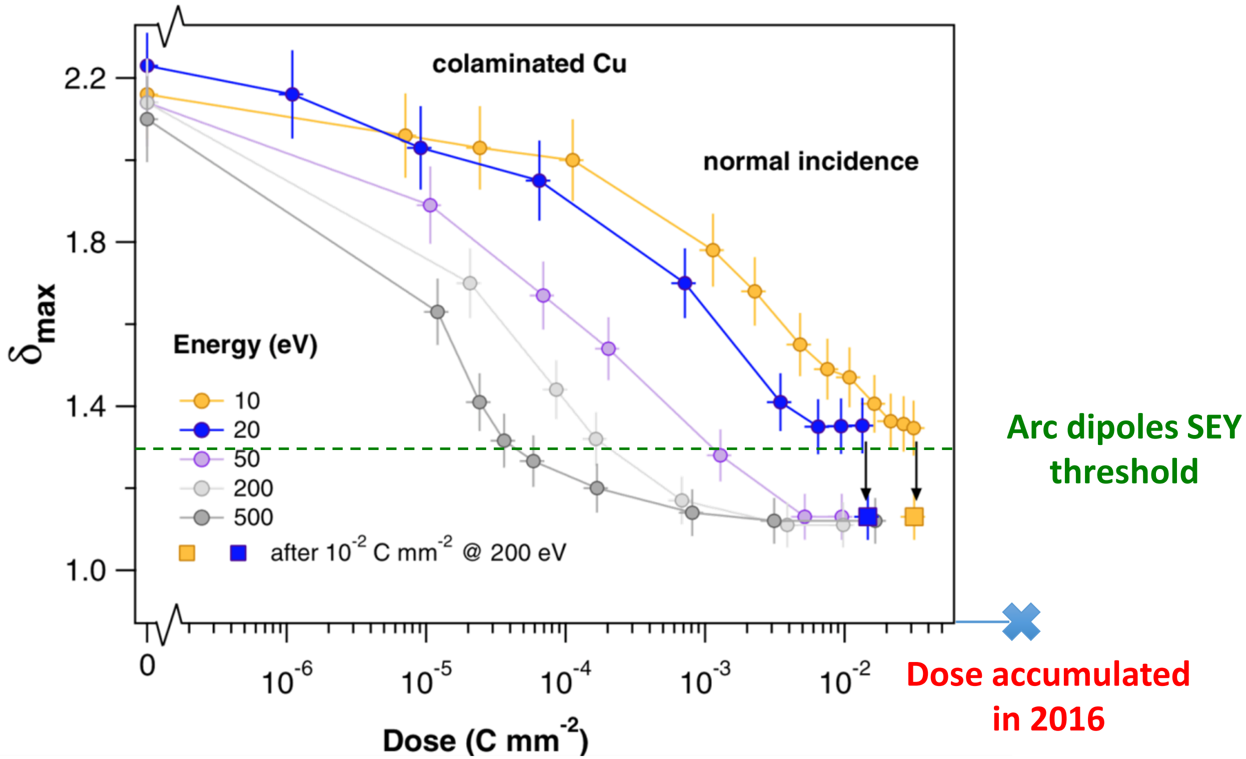
Calibration I/HL	3.00E-03	[A/W]	
Area	0.08	2 cm *2 (top bottom) *2 beam pipes	
Reduction factor (remove quad, imped, SynRad)	0.5		
Period	**Integrated heat load [J/m] (2 beams)**	**Integrated dose [C/m] (2 beams)**	**Integrated dose [C/mm2]**
Scrubbing Run 2 (2015)	1.90E+05	5.70E+02	3.56E-03
Physics after SR 2 (2015)	6.00E+04	1.80E+02	1.13E-03
Physics after TS 2 (2015)	2.00E+06	6.00E+03	3.75E-02
Phisics in 2016	9.00E+06	2.70E+04	1.69E-01



Computation of the integrated electron dose

According to lab measurements (300 K) **the dose accumulated in 2016 should be largely sufficient** to achieve full e-cloud suppression in the dipoles

→ ~achieved in S34, S45, S56, S67 but not yet in the others…

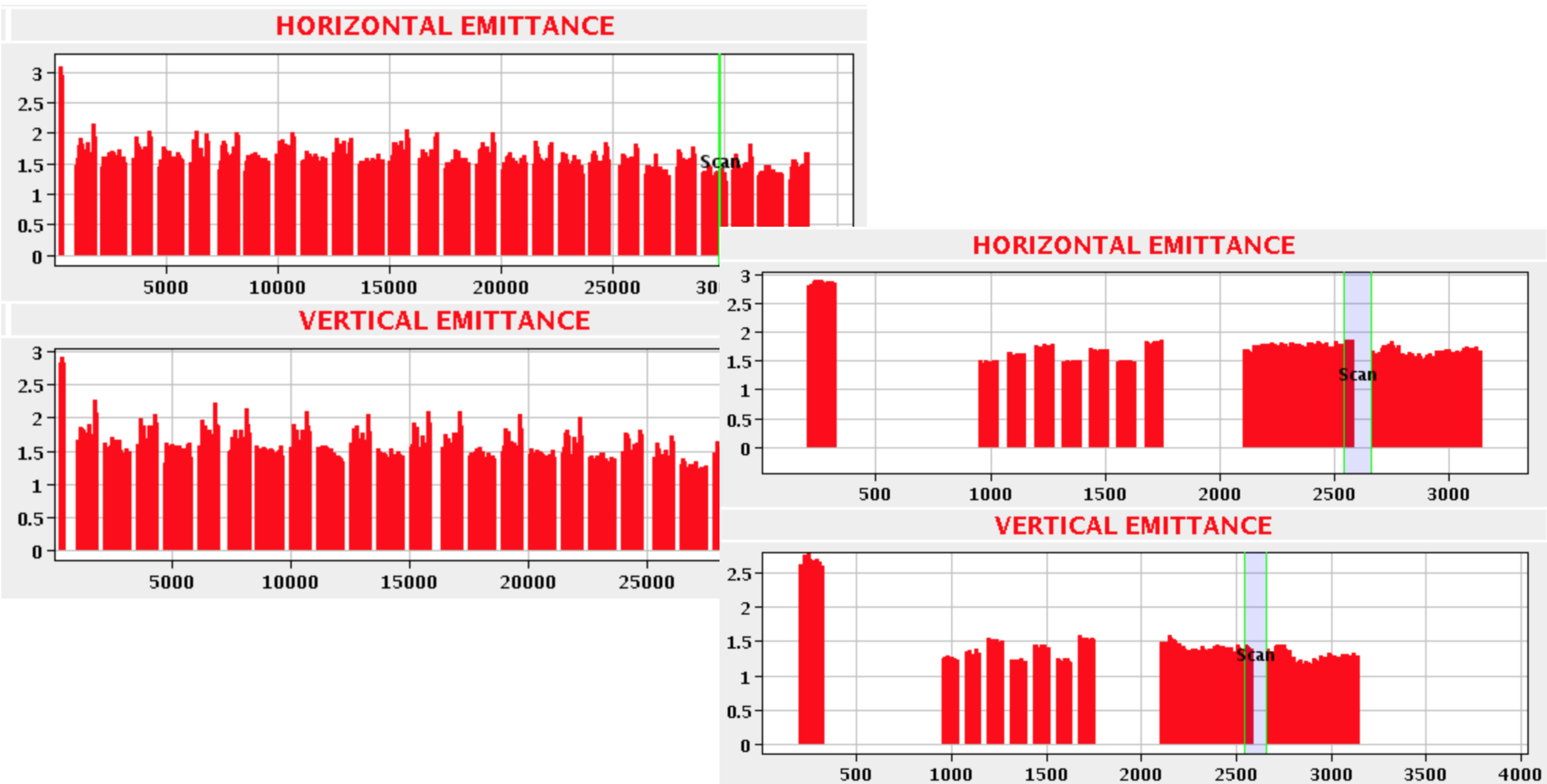


R. Cimino, V. Baglin et al., " Phys. Rev. Lett., vol. 109, p. 064801, Aug 2012

MD fills with combined filling scheme (8b4e and BCMS25ns)

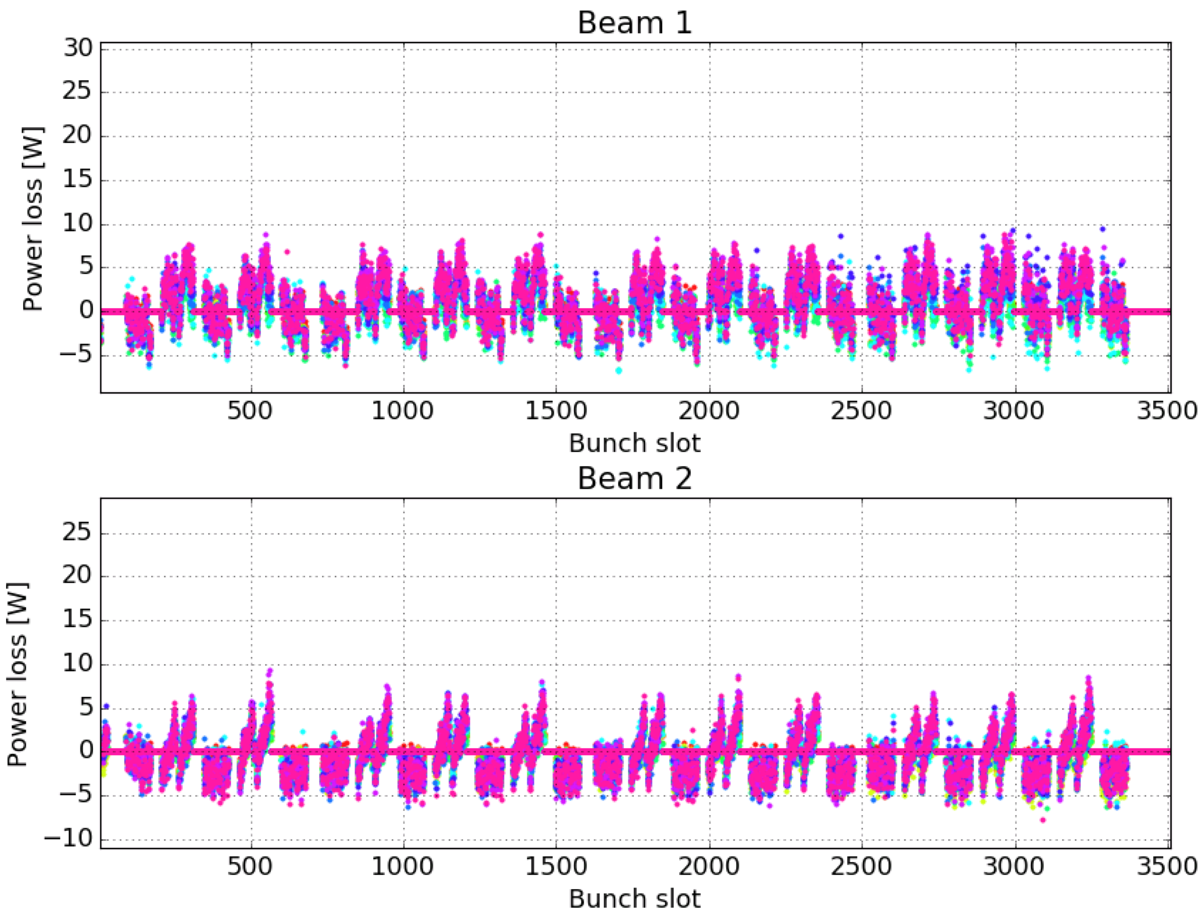
MD421: electron cloud with 25 ns beam variants

- The machine was filled with the **combined scheme** (share 45% 8b4e vs. 55% 25ns BCMS) with a total of **1908 bunches**
- Beams were accelerated and brought in collision using the operational machine settings We declared stable beams and stayed in collision for about 45 mins
- Collected **heat-load** and **stable phase data**



MD with combined filling scheme: stable phase data

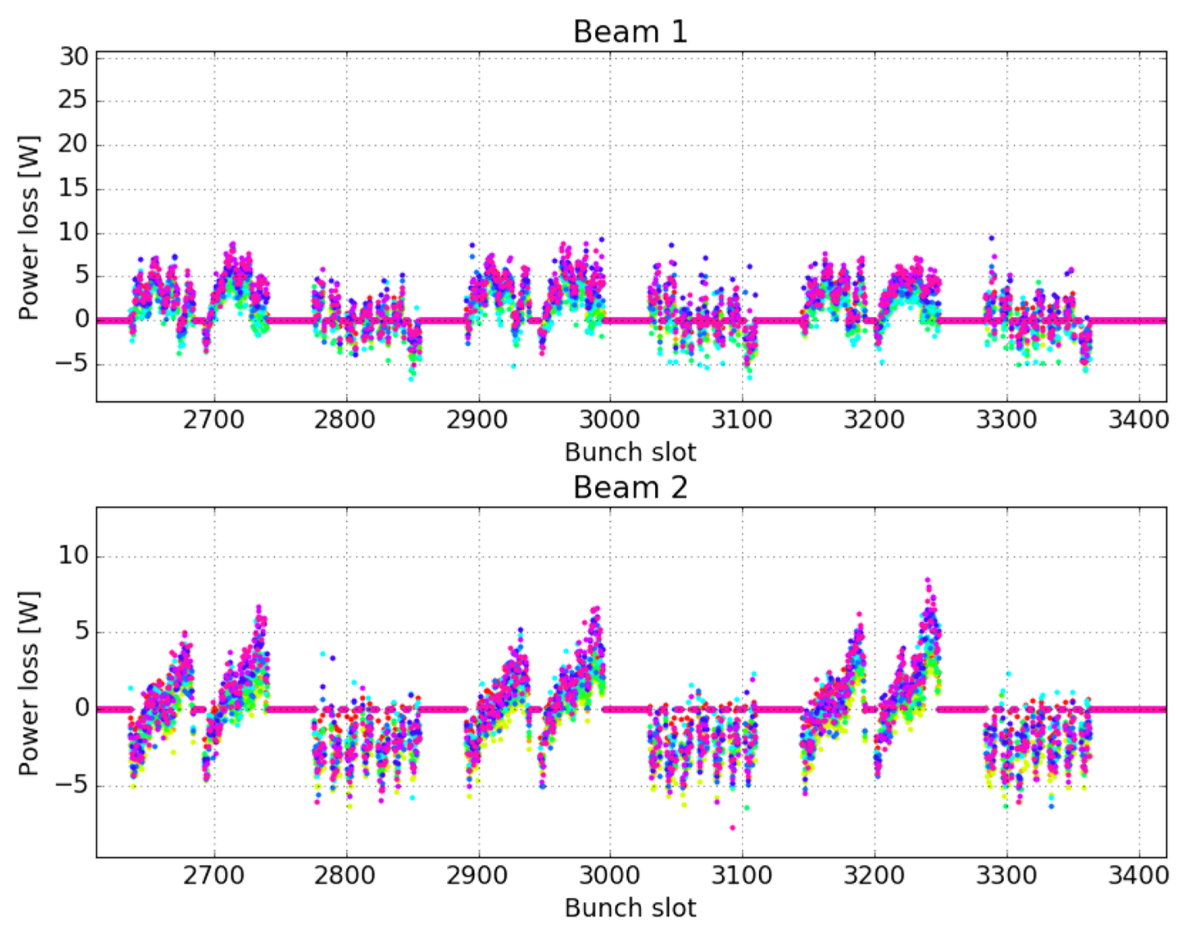
Data quality quality not amazing (especially for B1)…



MD with combined filling scheme: stable phase data

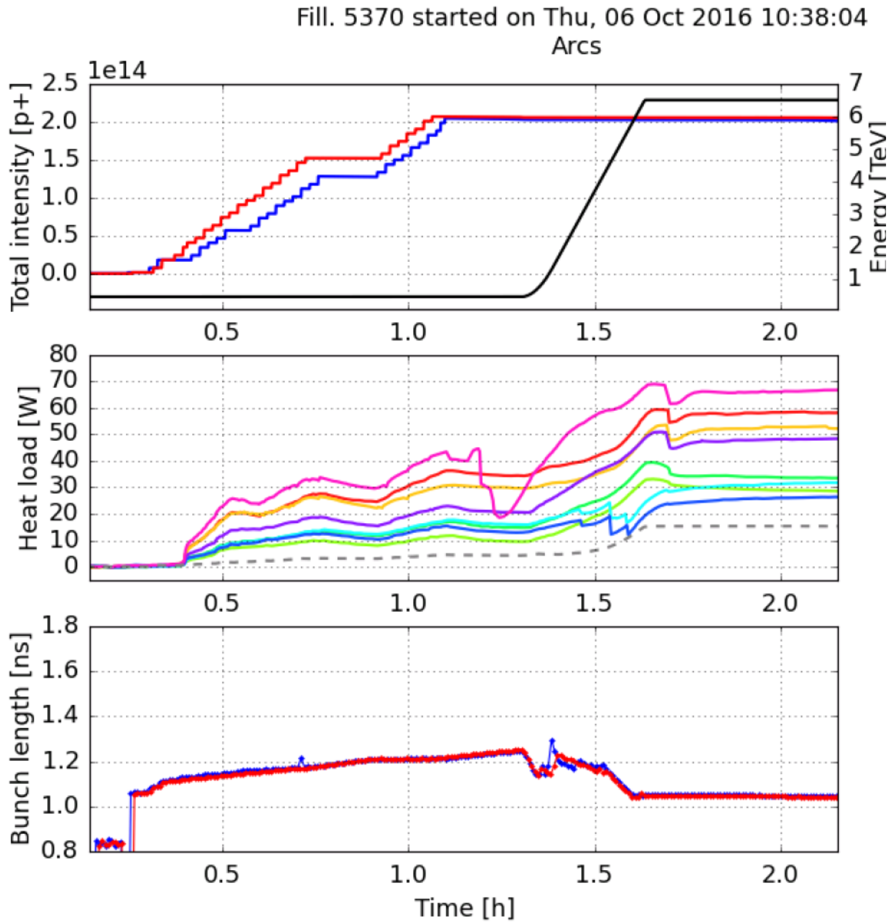
Data quality quality not amazing (especially for B1)…

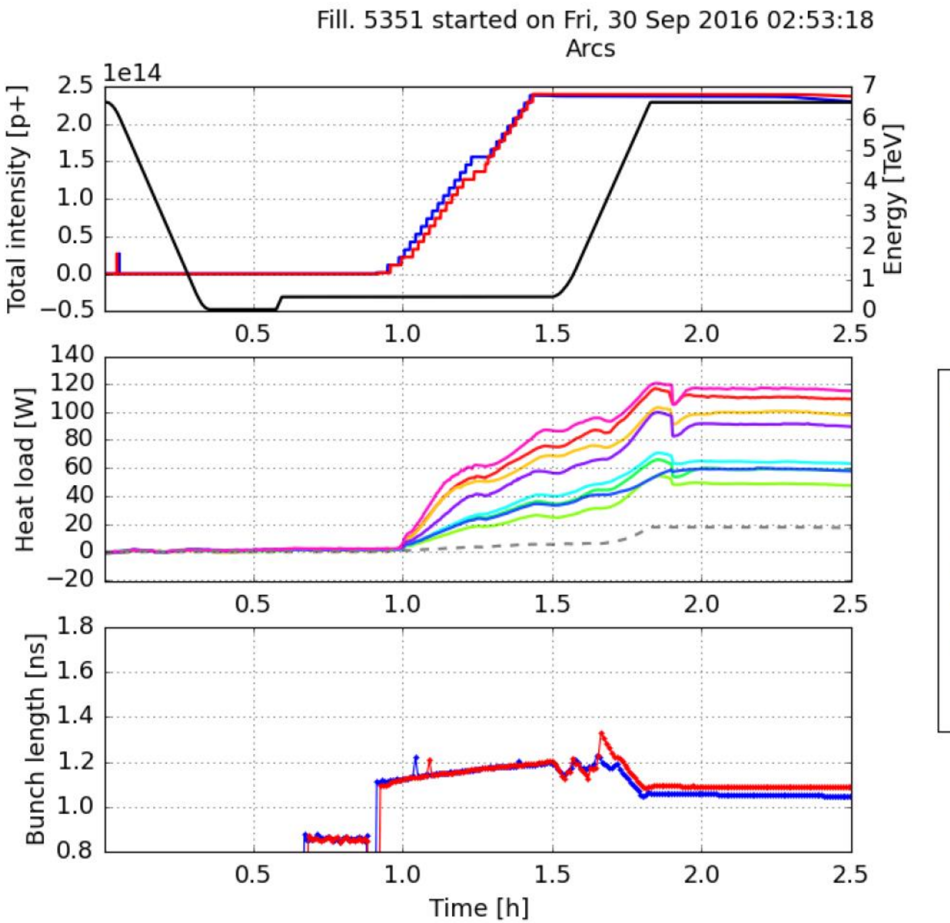
→ … but (at leas for B2) it clearly shows that **e-cloud buildup from standard beam does not "leak" into the 8b4e trains ☺**



MD with combined filling scheme: heat loads

→ A reduction of the **heat load per bunch from e-cloud of about 45%** was observed with the hybrid scheme



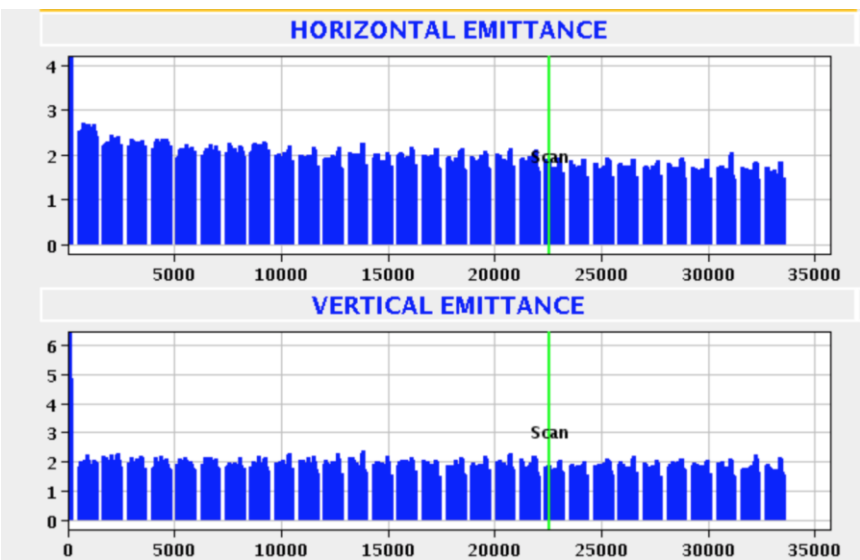


MD421: electron cloud with 25 ns beam variants

- We used the remaining time to **compare the settings necessary to stabilize** the 8b4e and the 25ns BCMS beam:
  - It was possible to fill the machine with **8b4e** trains with **5 units of chromaticity** in both planes and the **octupole knob at -0.5 (~6.5 A)** with no blow-up observed.
  - Then we injected the **25 ns BCMS** beam with the same settings noticing immediately a **strong blow-up**. We then gradually increased octupoles and chromaticity to suppress the blow-up. We found out that settings not too far from the operational ones are indeed needed to achieve emittances comparable to the 8b4e ones.

8b4e

Q’=5/5 I_{oct} = 6.5 A



25 ns BCMS

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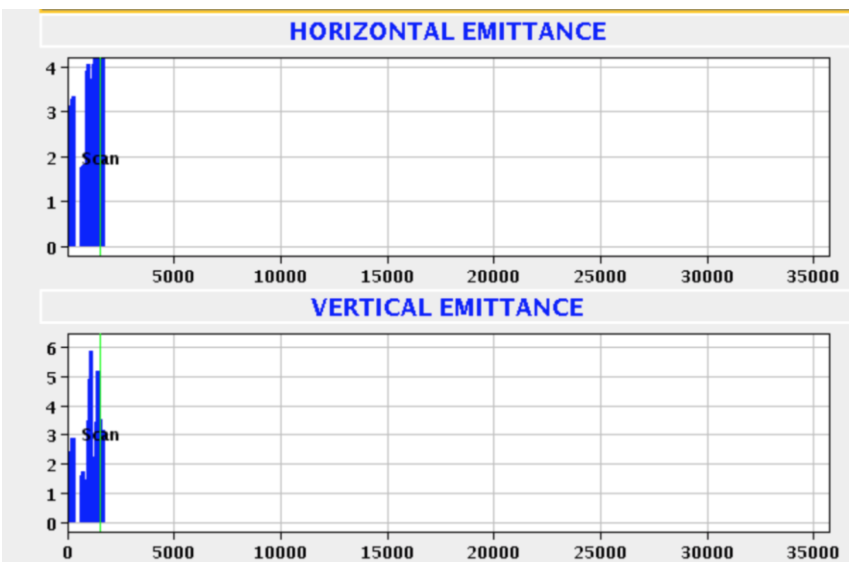
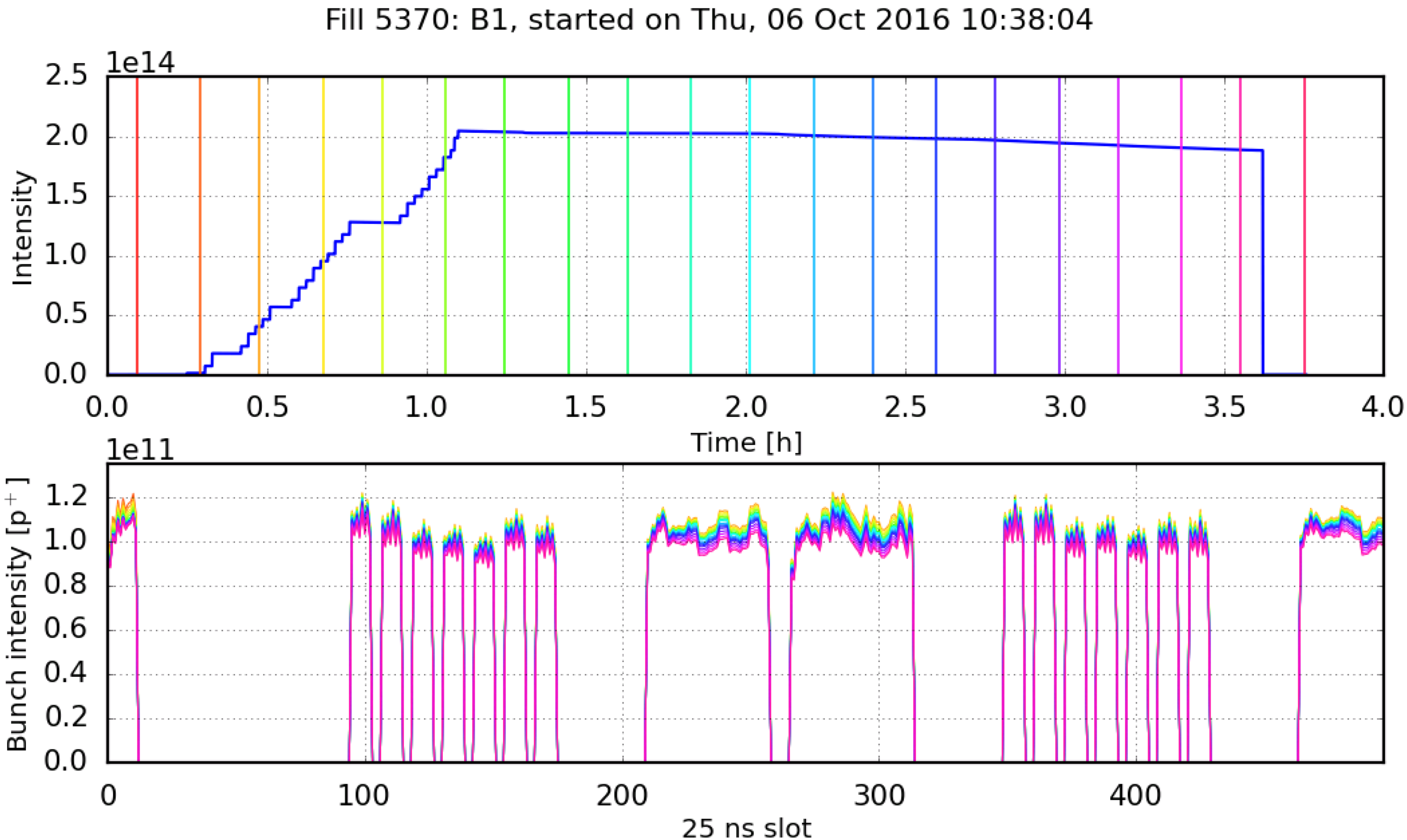


Thanks for your attention!


Fill 5370: B1, started on Thu, 06 Oct 2016 10:38:04
1e14
Intensity
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time [h]
1e11
Bunch intensity [p+]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
25 ns slot

Fill 5370: B2, started on Thu, 06 Oct 2016 10:38:04