Little module (HeatLoadCalculator) available at:
https://github.com/giadarol/HeatLoadCalculators/

Latest release

v1.0.0

6133e76

HeatLoadCalculators

giadarol released this 5 days ago

Simple Heat Load Calculator for the beam screens of the Large Hadron Collider.
The module includes:

- Heating from impedance effects (image currents), taking into account:
  - effect of beam screen temperature
  - magneto-resistance effects
- Heating from synchrotron radiation (simple formula)
- Heating from e-cloud effects (using database of PyECLOUD simulations)
- Interface to LHC scrubbing follow-up tools to compute heat loads from measured beam data

Downloads

Source code (zip)

Source code (tar.gz)

Output from the HeatLoadCalculators module – Nominal LHC:

Evaluated scenario: Design report
- Beam energy 7000.0 GeV
- Bunch intensity: 1.15e+11 p
- Bunch length (4*sigma): 1.00 ns
- N. bunches: 2808

Heat load contribution:
- Impedance load (average half-cell): 115.0 mW/m/beam
- Synchrotron radiation load (average half-cell): 173.0 mW/m/beam

Impedance contribution breakdown:
- Impedance load in the dipoles: 119.5 mW/m/beam
- Impedance load in the quadrupoles: 105.2 mW/m/beam
- Impedance load in the drifts: 91.7 mW/m/beam

Output from the HeatLoadCalculators module – HL-LHC:

Evaluated scenario: HL-LHC
- Beam energy 7000.0 GeV
- Bunch intensity: 2.20e+11 p
- Bunch length (4*sigma): 1.20 ns
- N. bunches: 2748

Heat load contribution:
- Impedance load (average half-cell): 313.4 mW/m/beam (x2.7)
- Synchrotron radiation load (average half-cell): 323.9 mW/m/beam (x1.8)

Impedance contribution breakdown:
- Impedance load in the dipoles: 325.7 mW/m/beam
- Impedance load in the quadrupoles: 286.6 mW/m/beam
- Impedance load in the drifts: 250.0 mW/m/beam

Check synchrotron radiation vs design report

Synchrotron radiation

Model presently implemented:

- Compute energy loss per particle and per turn (formula)
- Rescale to get total power loss ($*N_{beam}/T_{rev}$)
- Assume that it is all deposited in the arcs (divide by $8*L_{arc}$ to get average deposited power)

Check synchrotron radiation against design report

Our calculation:

Synchrotron radiation load (average half-cell): 173.0 mW/m/beam

Design report:

Table 11.8: Distributed steady-state beam-induced loads in an LHC cell [mW m^{-1}]

Mode	Nominal		Ultimate	
Temperature level	4.6-20 K	1.9 K LHe	4.6-20 K	1.9 K LHe
Synchrotron radiation	330	1	500	1
Image current	360	1	820	2
Photo-electron cloud *	890	9	3040	30
Beam-gas scattering	0.4	48	0.4	48
Random particle loss	0-0.1	0-32	0-0.3	0-48
Total beam-induced *	1580	59-91	4360	82-130

* After beam cleaning

We reconstructed that this is for 2 beams

Consistent within 4%

Check synchrotron radiation against design report

Our calculation:

Synchrotron radiation load (average half-cell): 173.0 mW/m/beam

Design report:

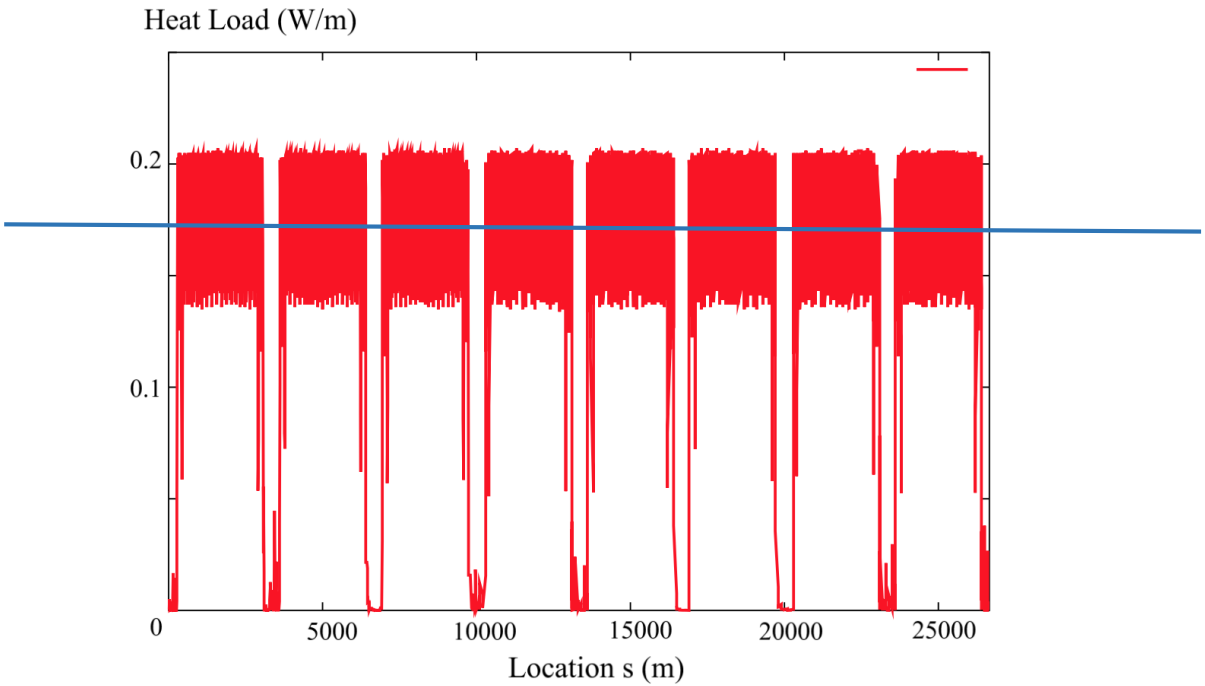

Figure 5.2: Synchrotron radiation as a function of position around the LHC:

Consistent!

Check synchrotron radiation against design report

Our calculation:

Synchrotron radiation load (average half-cell): 173.0 mW/m/beam

Design report:

Table 5.7: Summary of heat load on the arc beam screen for nominal LHC beam at 7 TeV. The three columns give the source, the latest relevant reference, and the peak heat load in mW/m.

source	Ref.	Peak power [mW/m] at 7 TeV
Synchrotron Radiation	[48]	220
Ohmic Losses	[52]	110
Pumping Slots	[53]	10
Welds	[2]	10

We reconstructed that this is for 1 beam

Inconsistent with our estimate and with Fig. 5.2 of the DR itself!

(220 mW/m/beam is the local emitted power in the bends, but photons are not emitted elsewhere)

Check impedance vs design report

Check impedance against design report

Model presently implemented in our module:

- **Resistivity:**
  - Dependence of temperature: curve from N. Kos
  - Dependence on magnetic field: Elias's procedure
  - Different values evaluated for dipoles, quadrupoles and drifts
- **Weld effect:**
  - Simple formula (see LSS note)

Check impedance against design report

Our calculation:

Impedance load (average half-cell): 115.0 mW/m/beam

Design report:

Table 5.7: Summary of heat load on the arc beam screen for nominal LHC beam at 7 TeV. The three columns give the source, the latest relevant reference, and the peak heat load in mW/m.

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Ohmic Losses	[52]	110
Pumping Slots	[53]	10
Welds	[2]	10

We reconstructed that this is for 1 beam

Consistent within 5 %

Check impedance against design report

Our calculation:

Impedance load (average half-cell): 115.0 mW/m/beam

Design report:

Table 11.8: Distributed steady-state beam-induced loads in an LHC cell [mW m^{-1}]

Mode	Nominal		Ultimate	
Temperature level	4.6-20 K	1.9 K LHe	4.6-20 K	1.9 K LHe
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Random particle loss	0-0.1	0-32	0-0.3	0-48
Total beam-induced *	1580	59-91	4360	82-130

* After beam cleaning

We reconstructed that this is for 2 beams

180 mW/m/beam → Inconsistent also with respect to table 5.7 of the DR

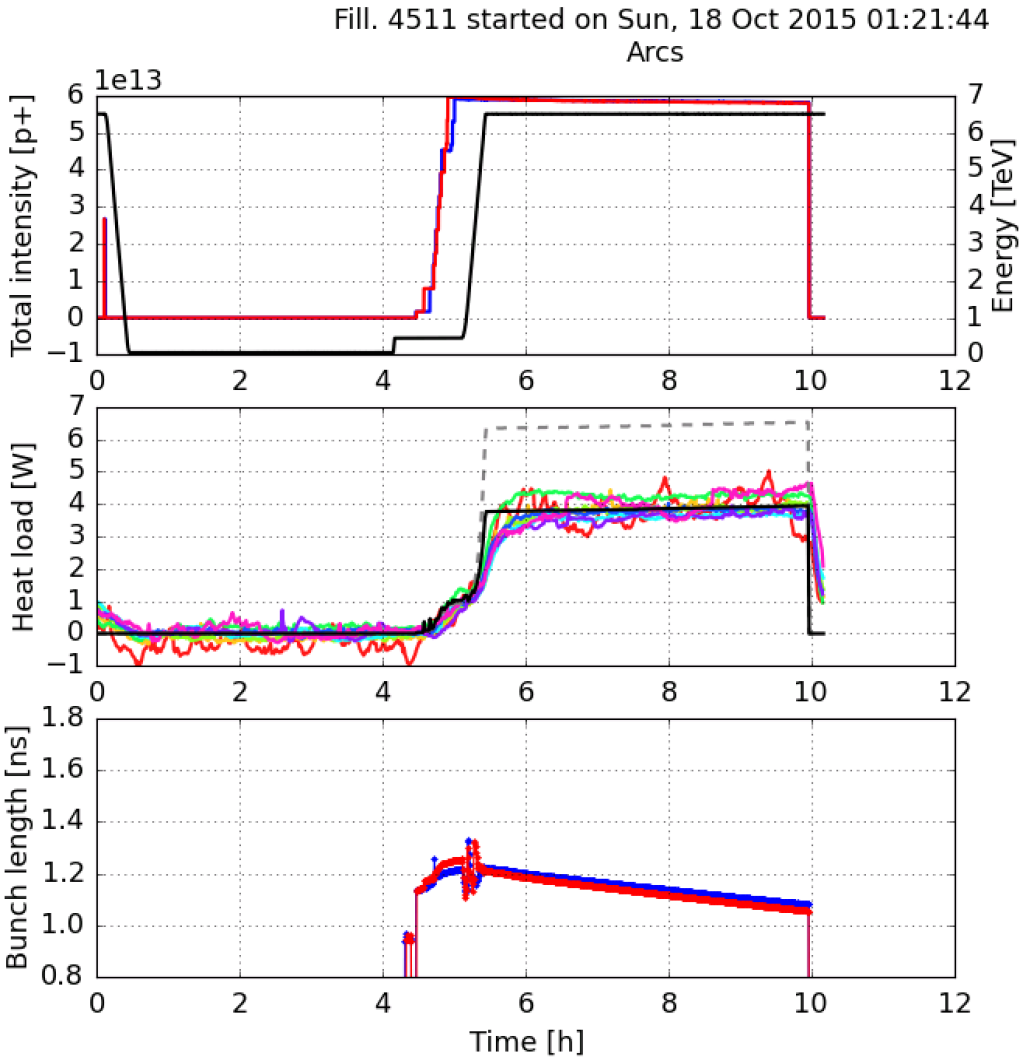
Daniel looked into minutes of the heat load working group (2000), it seems they account for BPM bellow contribution → being investigated by Elias/Benoit

Check against machine data

Comparison against machine data

More here

100 ns, run with β*=90 m in 2015



Measured:

- S12
- S23
- S34
- S45
- S56
- S67
- S78
- S81

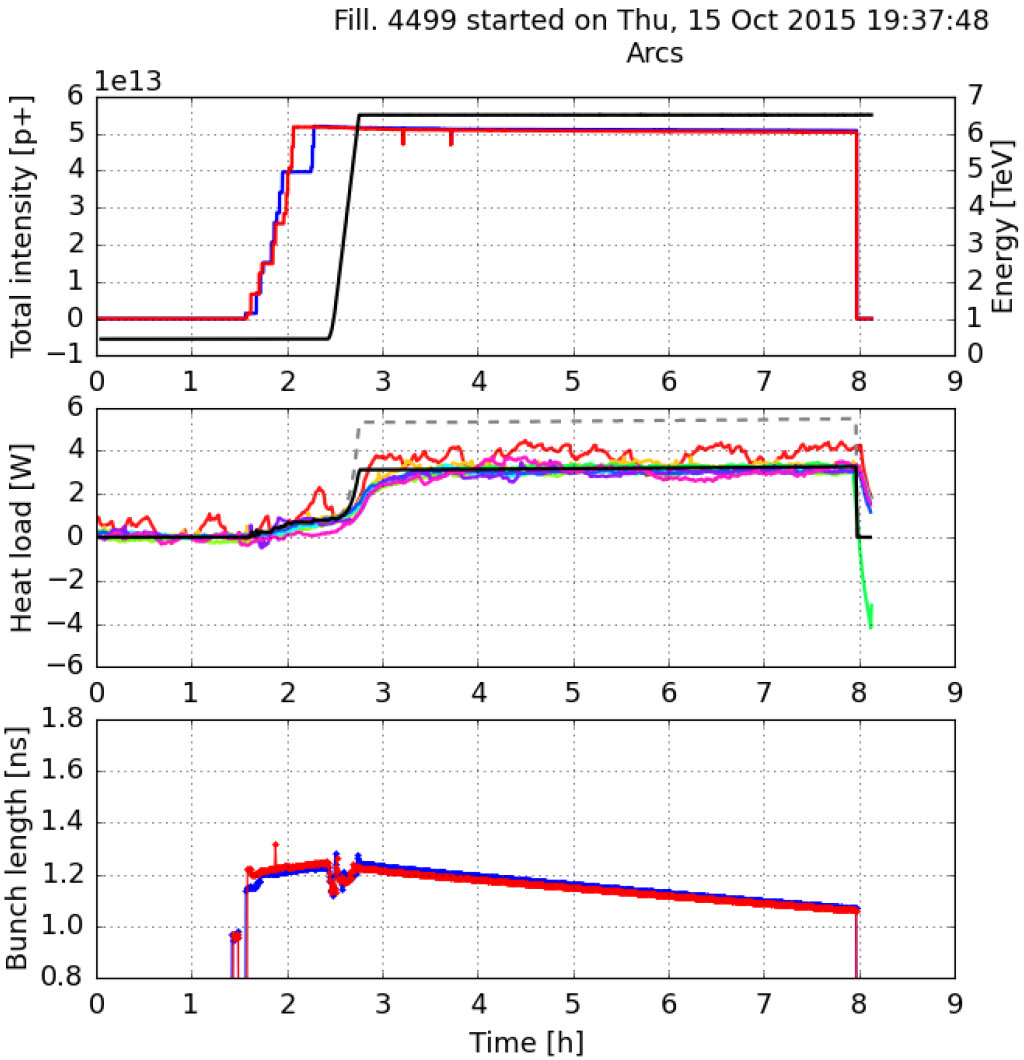
Calculated:

- **Timber** (SR overestimated by factor 2, different assumptions for impedance)
- **HeatLoadCalculators** Module (used now)

Comparison against machine data

More here

100 ns, run with β*=90 m in 2015



Measured:

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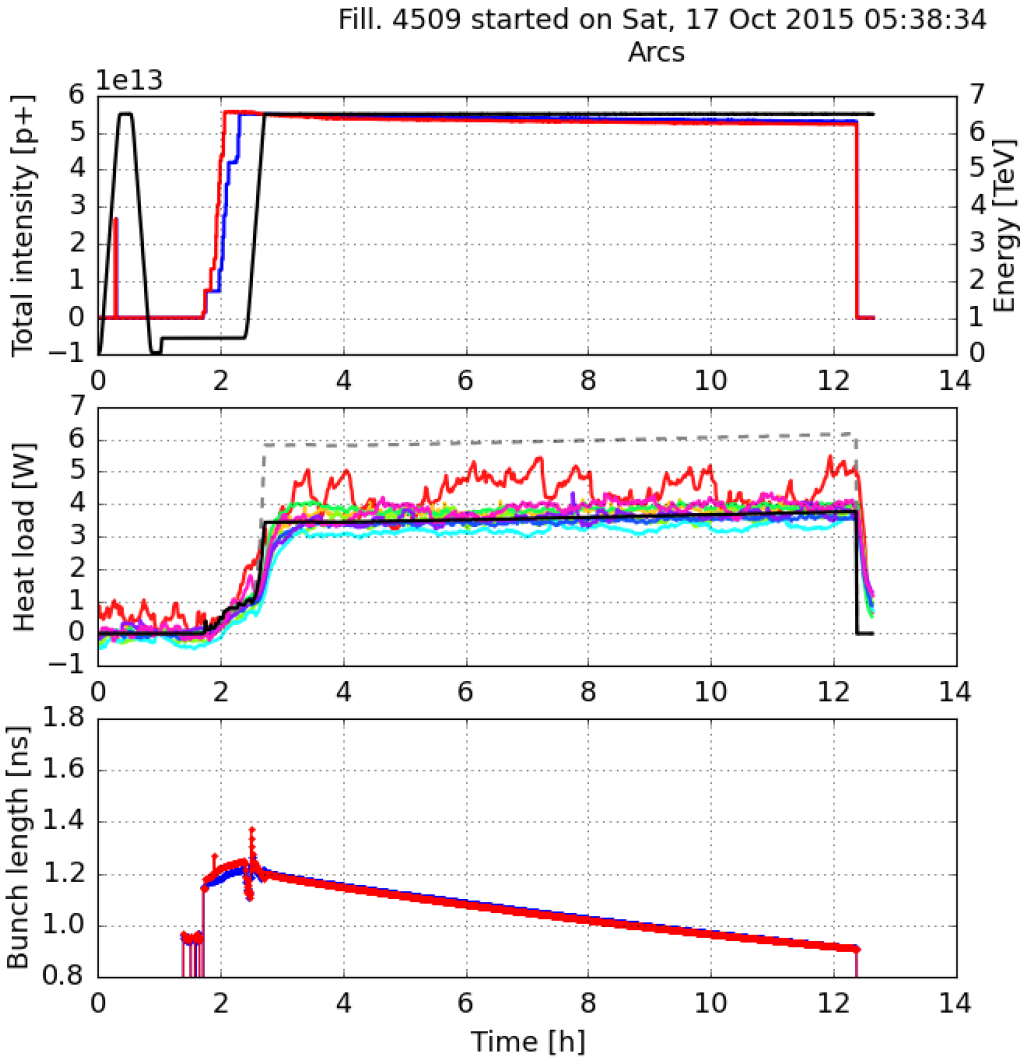
HeatLoadCalculators
Module (used now)

Comparison against machine data

More here

100 ns, run with β*=90 m in 2015



Measured:

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Calculated:

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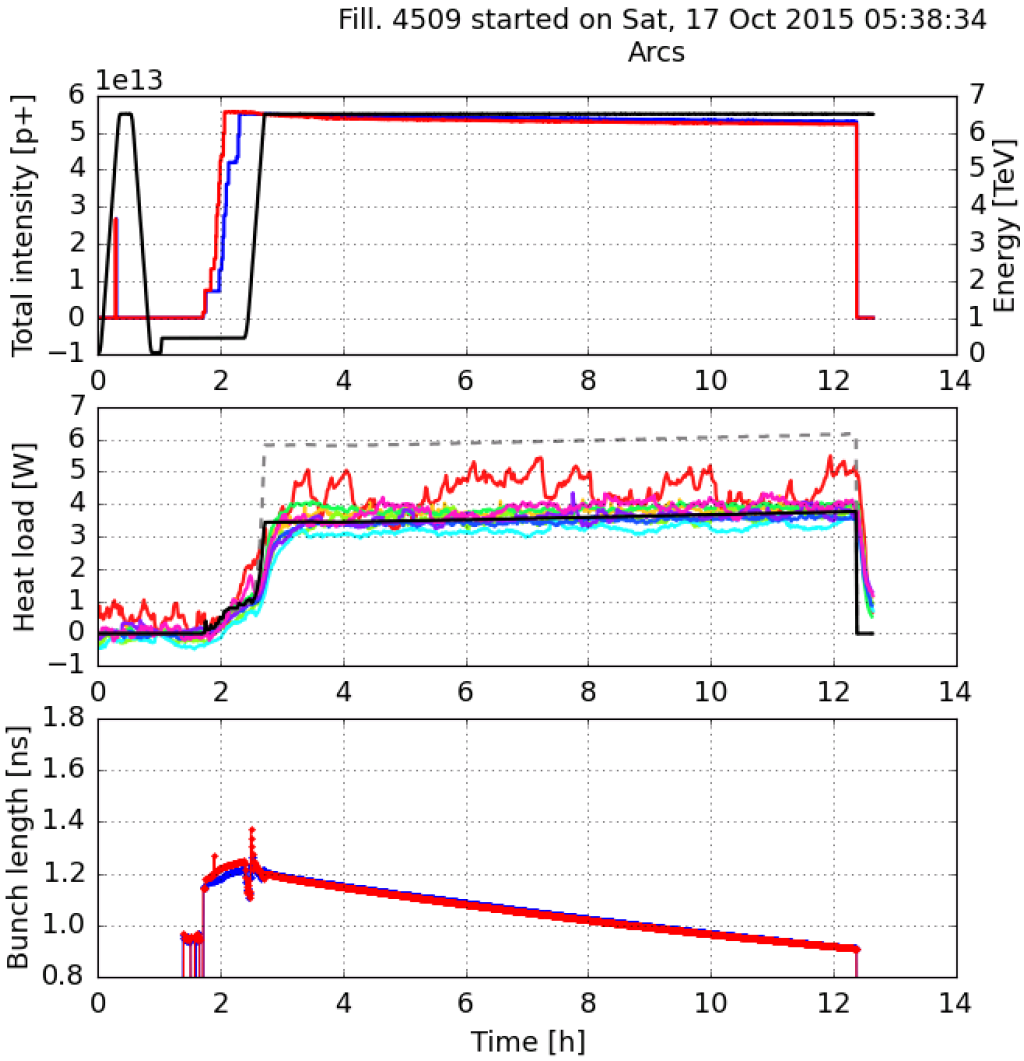
HeatLoadCalculators Module (used now)

Comparison against machine data

More here

100 ns, run with β*=90 m in 2015



Measured:

- S12
- S23
- S34
- S45
- S56
- S67
- S78
- S81

Calculated:

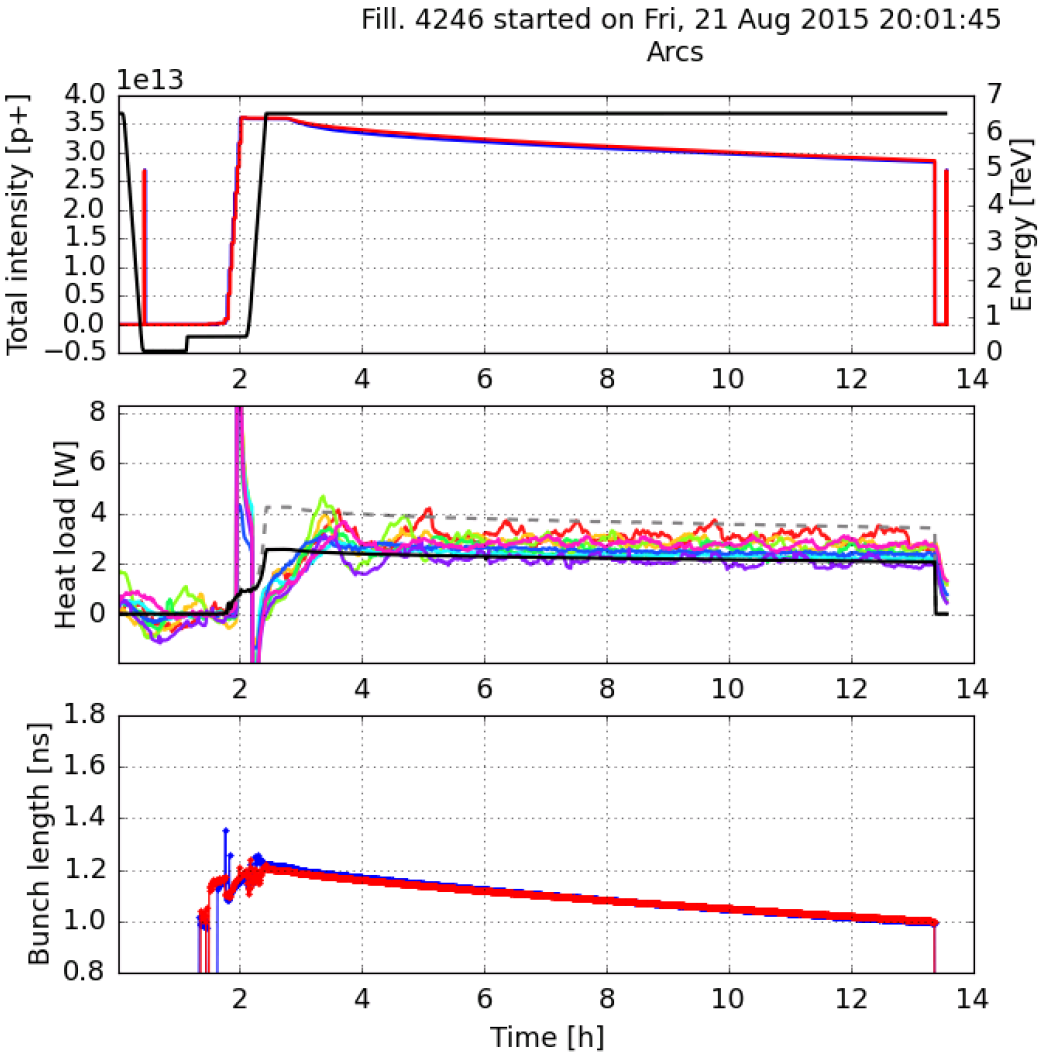
Timber (SR overestimated by factor 2, different assumptions for impedance)

HeatLoadCalculators Module (used now)

Comparison against machine data

More here

50ns, physics 2015



Measured:

- S12
- S23
- S34
- S45
- S56
- S67
- S78
- S81

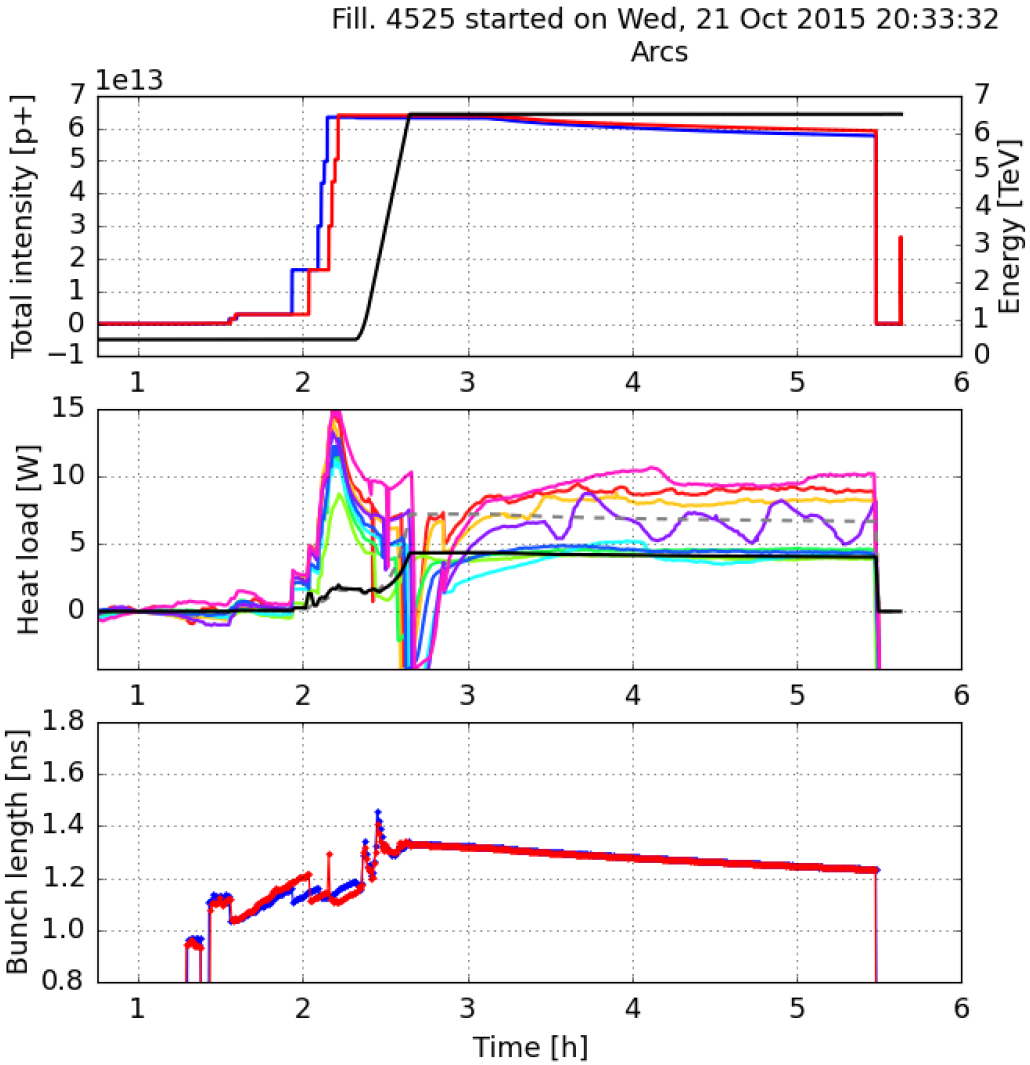
Calculated:

- **Timber** (SR overestimated by factor 2, different assumptions for impedance)
- **HeatLoadCalculators** Module (used now)

Comparison against machine data

More here

8b4e test 2015



Measured:

- S12
- S23
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- S56
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- S78
- S81

Calculated:

- **Timber** (SR overestimated by factor 2, different assumptions for impedance)
- **HeatLoadCalculators** Module (used now)