Update on e-cloud activities

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Joint HiLumi LHC - LARP Annual Meeting, 11-13 November 2015, Fermilab, USA

Outline

- **e-cloud buildup with/without shielding baffle plates**
  For details:
  http://indico.cern.ch/event/396577/
  http://indico.cern.ch/event/446452/

- **Update on PyHEADTAIL simulations**
  For details:
  http://indico.cern.ch/event/394530/
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- **Lessons learned from the 25 ns run so far**
  For details:
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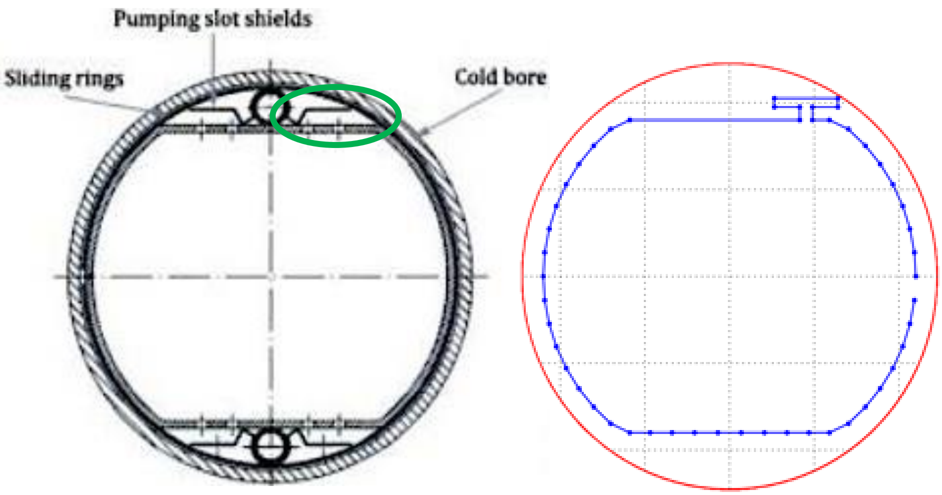
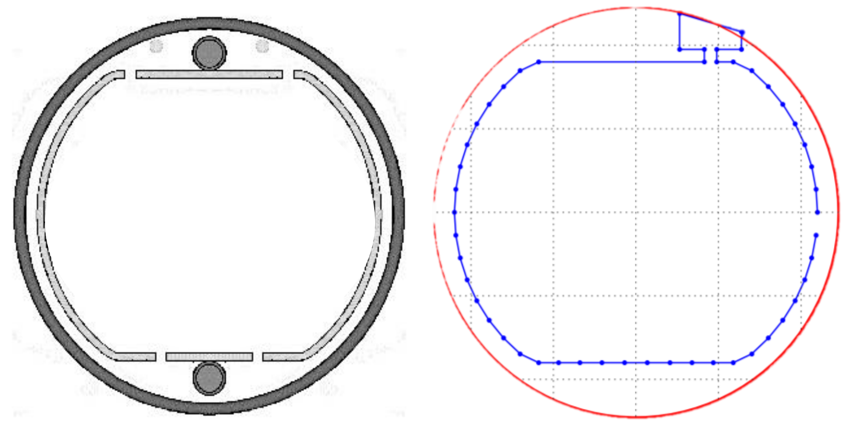
e-cloud buildup with/without shielding baffle plates

LHC beam screen with baffle plate

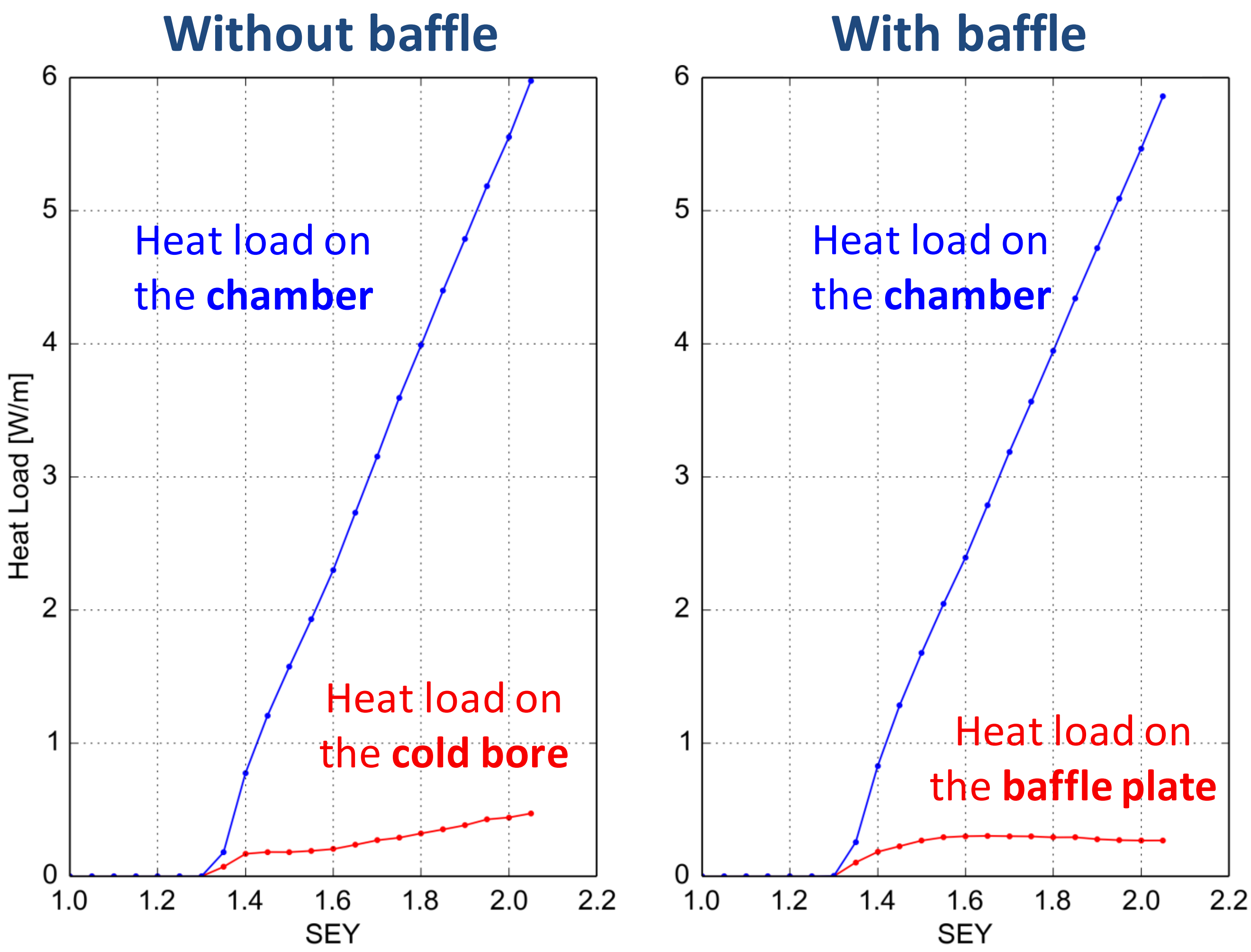


LHC beam screen without baffle plate



- **Goal:** check the need to shield the pumping holes to avoid multipacting with the cold bore
  - Check whether electric shielding provided by the beam screen is already sufficient to suppress multipacting
- **PyECLOUD had to be modified** in order to handle non convex boundaries:
  - Electron impact detection and handling
  - Boundary condition in the PyPIC space charge module (to continue using Shortley-Weller refined boundary)

Simulations results



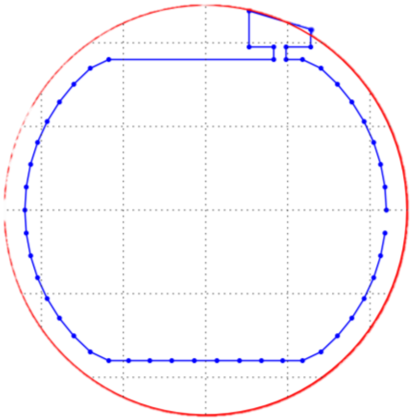
Arc dipole 450GeV

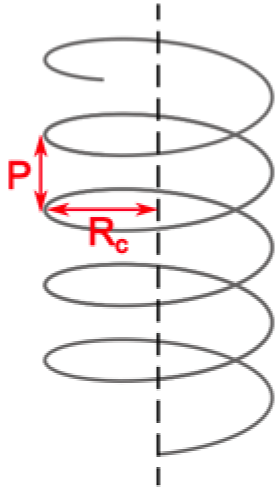
- Assuming the **SEY equal to 1.4**, the heat load deposited is **almost 0.15 W/m** for both cases

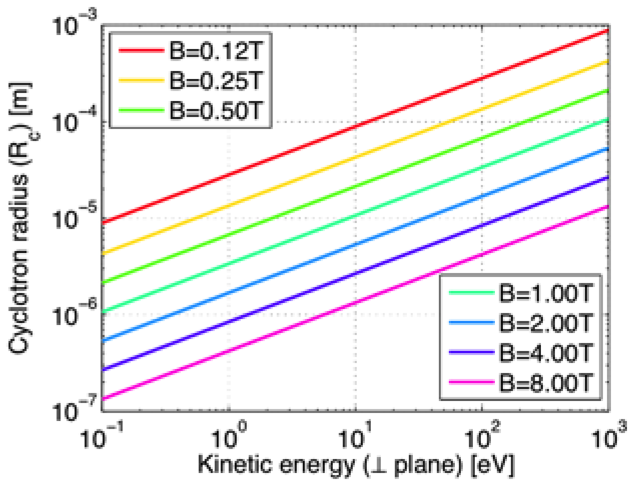
  → **baffles protect the cold bore from a non regligible heat load**

Underlying mechanim

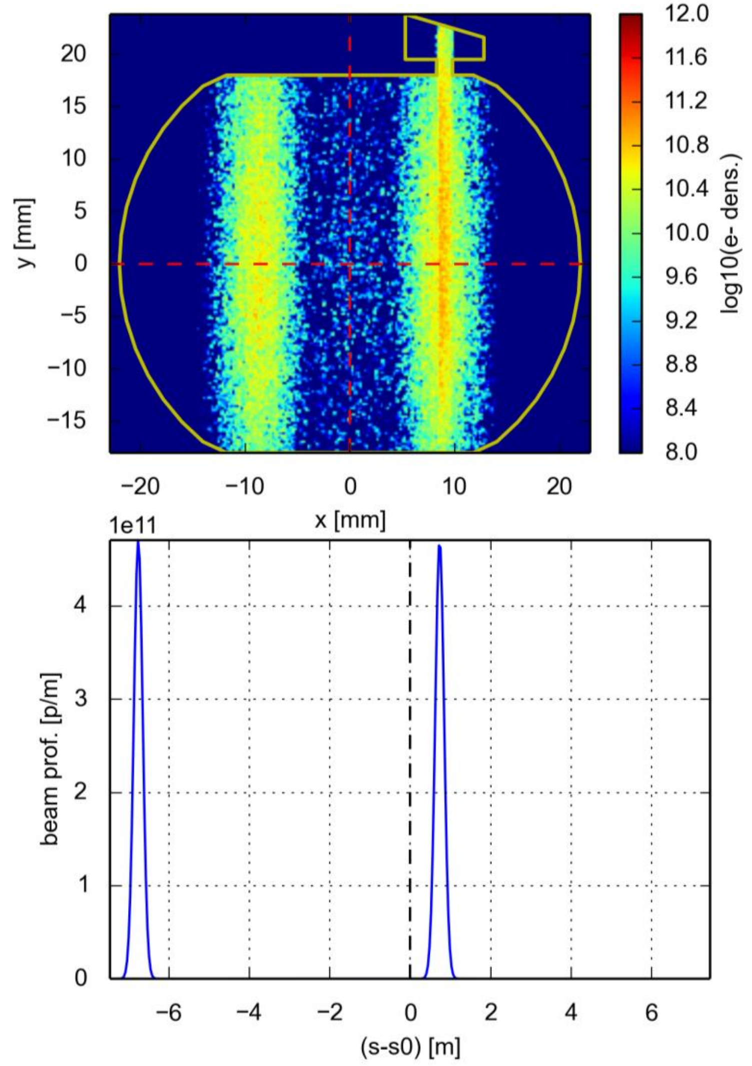
- At 450GeV **B=0.53 T**: cyclotron radius does not exceed few micrometers
  → Practically Electrons **practically move only in vertical**
- The **kinetic energy** of secondary electrons is **not larger than 30 eV**
  → It is enough for them to make **few mm per ns**
  → Electrons can make it to **go back into the chamber before the following bunch passage** even without being accelerated by the beam







EC build-up



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e-cloud instability simulations for the HL-LHC

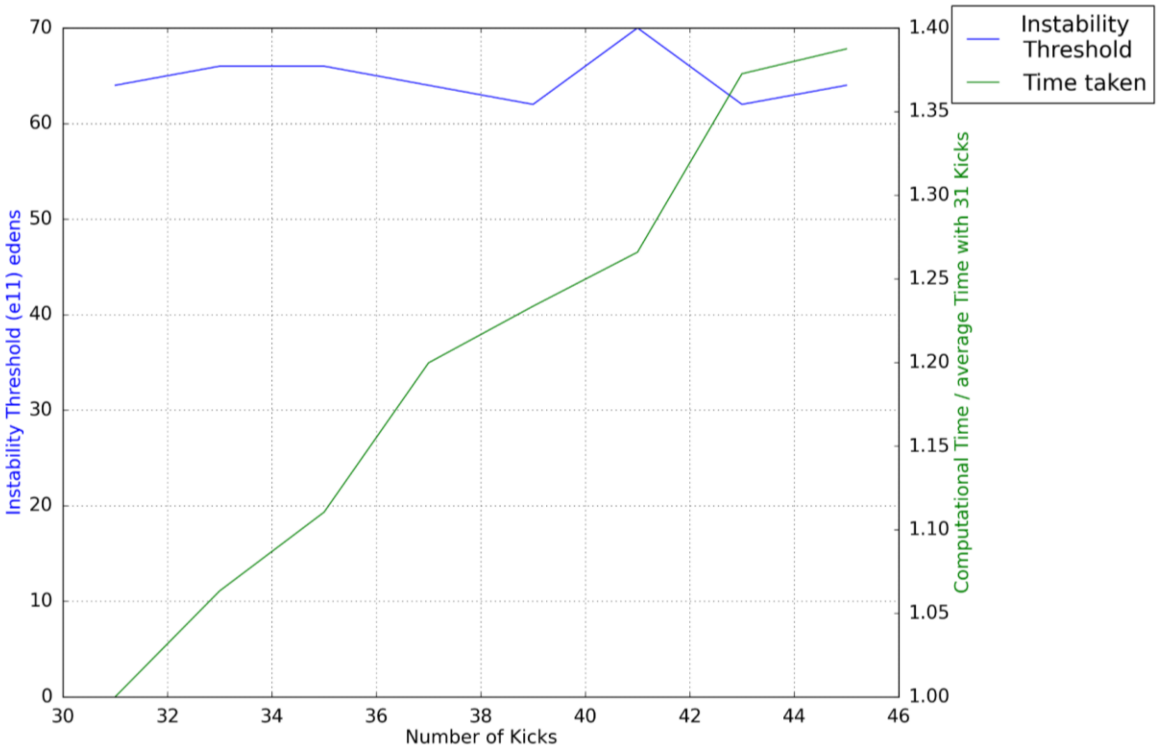
- We simulated the **interaction of a single bunch** with the electron cloud in the **dipoles and in the quadrupoles separately** scanning the bunch intensity and the electron density
- Before the bunch passage electrons are **uniformly distributed** in the chamber and **at rest**

Parameter	Value @ 450 GeV	Value @ 7 TeV
N (p/b)	$1.3 – 2.3 \times 10^{11}$	$1.3 – 2.3 \times 10^{11}$
$\varepsilon_{x,y}$ (μm)	2.5	2.5
σ_z (m)	0.1	0. 075
B (T, T/m)	0.53, 12	8.2, 187
V_{400MHz} (MV)	8	16
N_{el} (e^-/m^3)	$0.3 – 20 \times 10^{12}$	$0.3 – 20 \times 10^{13}$
$N_{segments}$	79	31
N_{MP} (e^-)	10^5	10^5
N_{MP} (p)	3×10^5	3×10^5
N_kicks	70	31
Grid zize (m)	0.2e-3	0.07e-3
Time step (ps)	10	5

- Simulations at 7 TeV are **numerically more challenging** due to the **smaller beam size** (need for finer grid) and **stronger magnetic fields** (need fro smaller time steps to resolve electron motion)

Convergence scans

- Continued validation of our new PyECLOUD-PyHEADTAIL simulation setup
- Over the last months extensive **convergence scans** (especially at 7 TeV) with respect to:
  - The **number of kicks**
  - The **grid size**
  - The **number of slices**
- Each parameter **scanned together with electron density** (for dipoles and quadrupoles)
- Each **simulation repeated 5 times** to mitigate dependence on initial conditions (seed)



Instability thresholds

- Basically confirmed preliminary results presented at Fermilab:

Arc quadrupoles
(~5% of the machine)

	1.3×10^{11} ppb	1.8×10^{11} ppb	2.3×10^{11} ppb
450 GeV	9×10^{12} e^-/m^3	9×10^{12} e^-/m^3	10×10^{12} e^-/m^3
7 TeV	1.2×10^{14} e^-/m^3	1.1×10^{14} e^-/m^3	1.2×10^{14} e^-/m^3

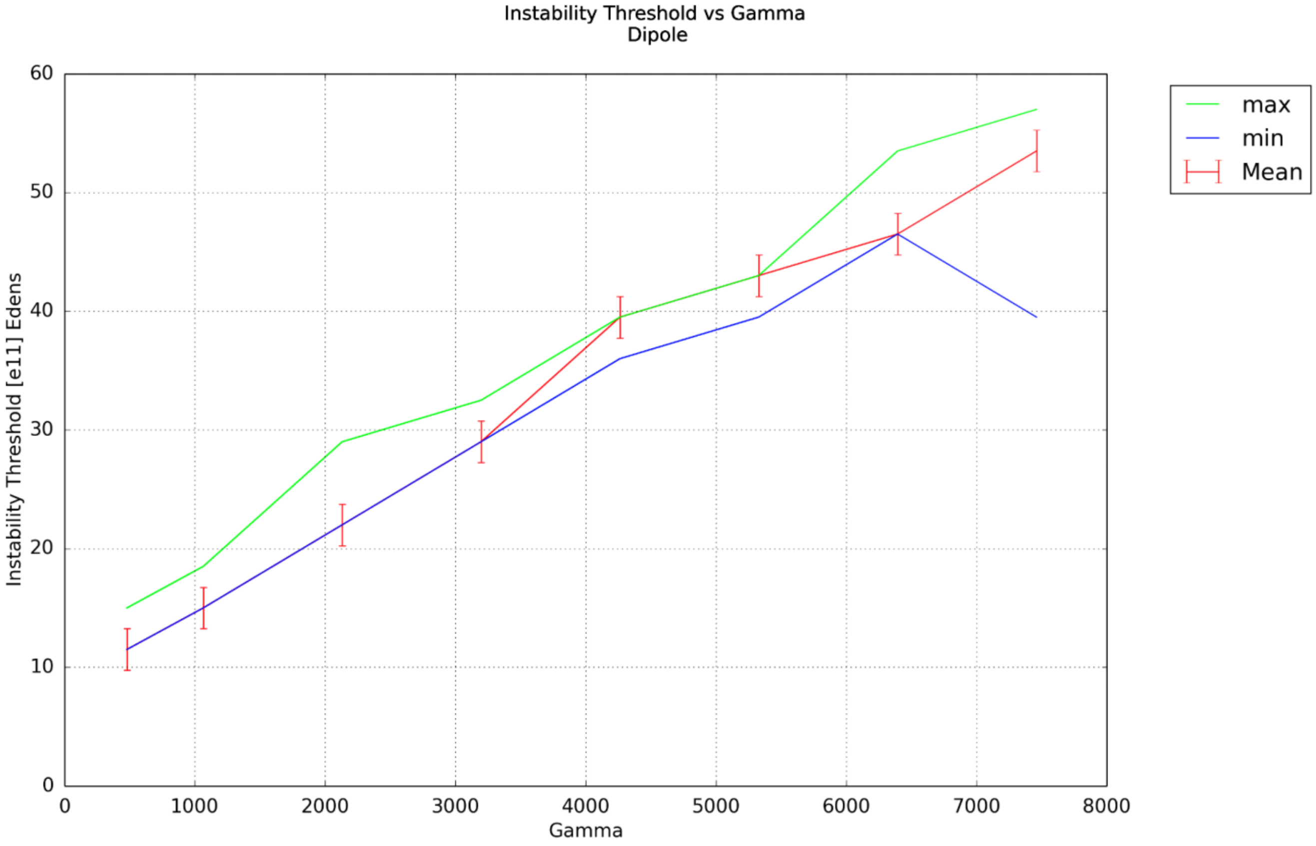
Arc dipoles
(~65% of the machine)

	1.3×10^{11} ppb	1.8×10^{11} ppb	2.3×10^{11} ppb
450 GeV	1.2×10^{12} e^-/m^3	1×10^{12} e^-/m^3	1×10^{12} e^-/m^3
7 TeV	8×10^{12} e^-/m^3	8×10^{12} e^-/m^3	9×10^{12} e^-/m^3

- **Dependence on bunch intensity is quite weak**
- The threshold e^- density for transverse instability **increases by one order of magnitude** going to 7 TeV → effect of **increased beam rigidity**

Dependence on beam energy

- Started with **simplified case** (easier to spot "suspect" behaviours of the code):
  - Constant bunch length
  - Constant RF voltage
  - Bunch matched do the backet
  - Magnetic fields increasing with energy
- Instability **threshold scales linearly with gamma**



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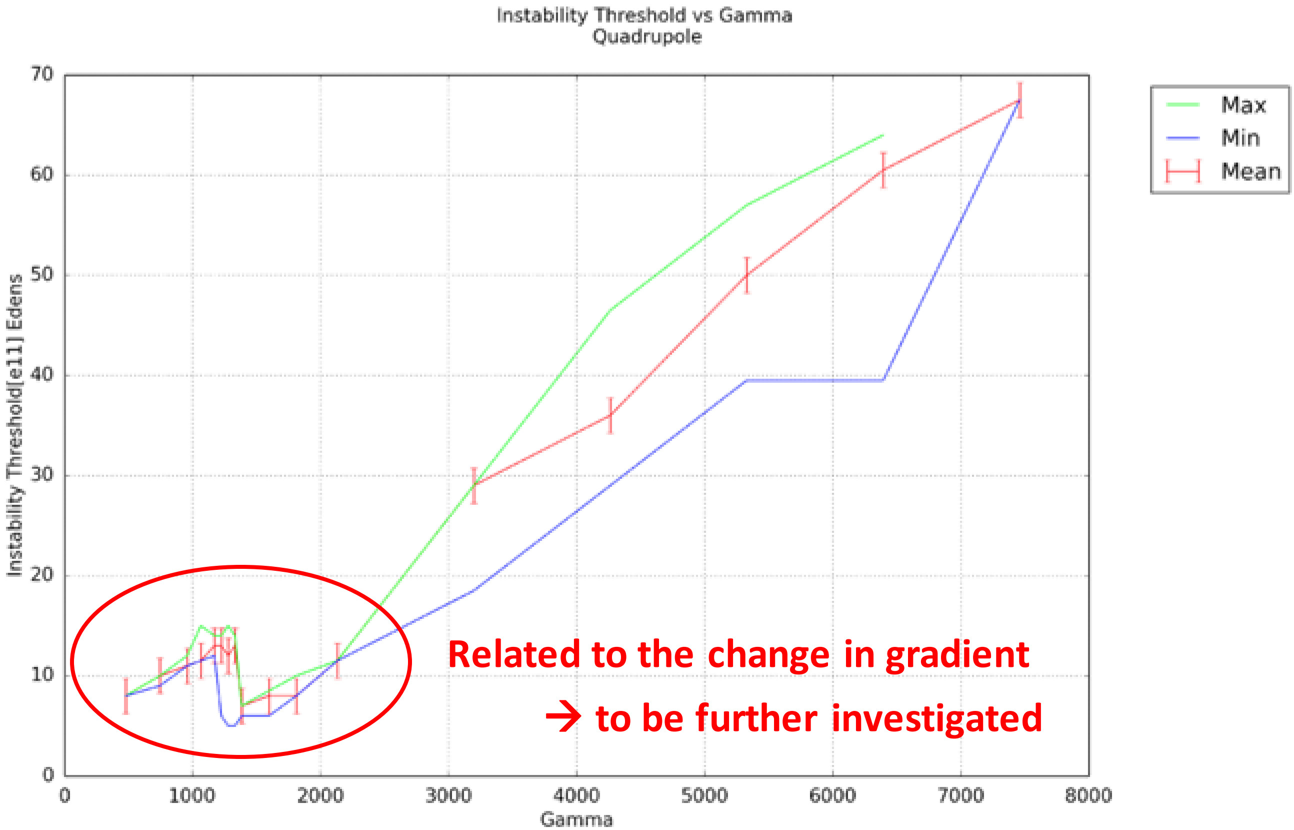
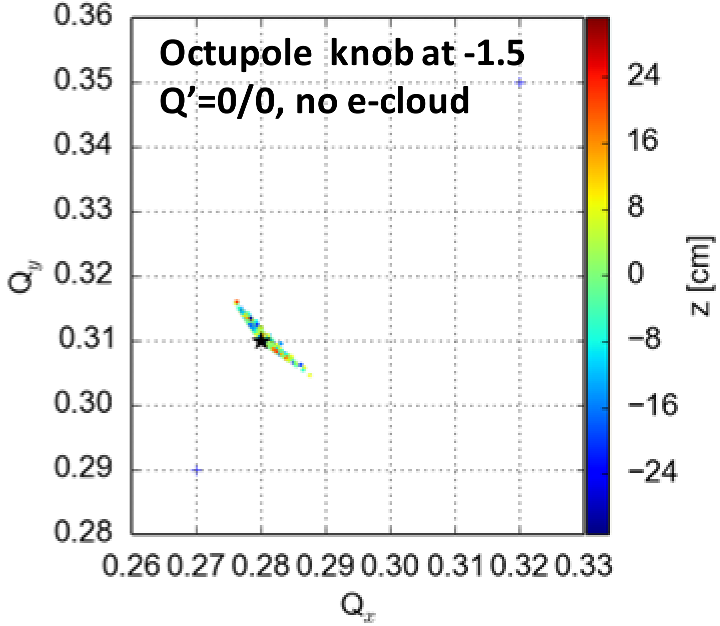
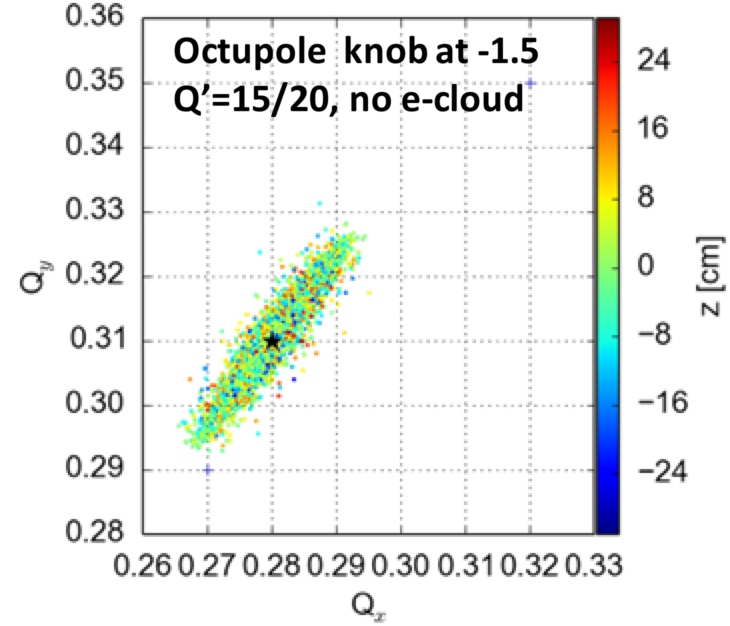
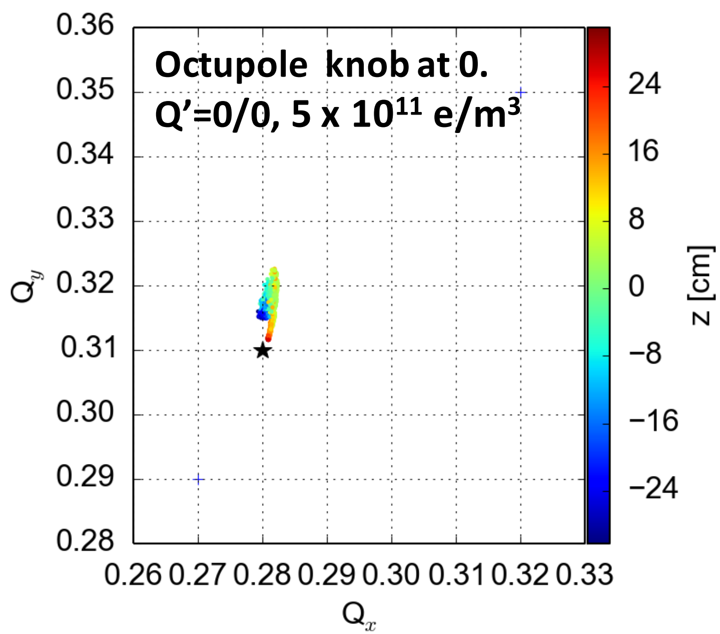


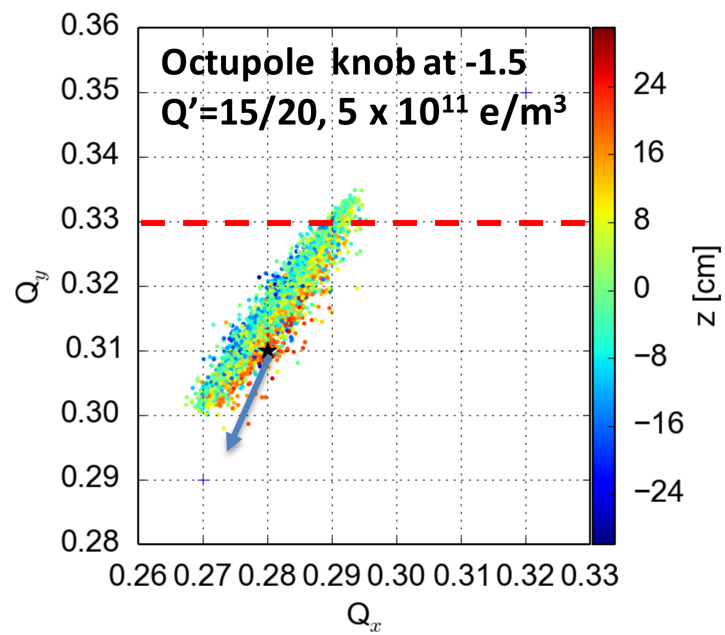
Tune footprints with ecloud, Q' and octupoles

Nominal bunch intensity

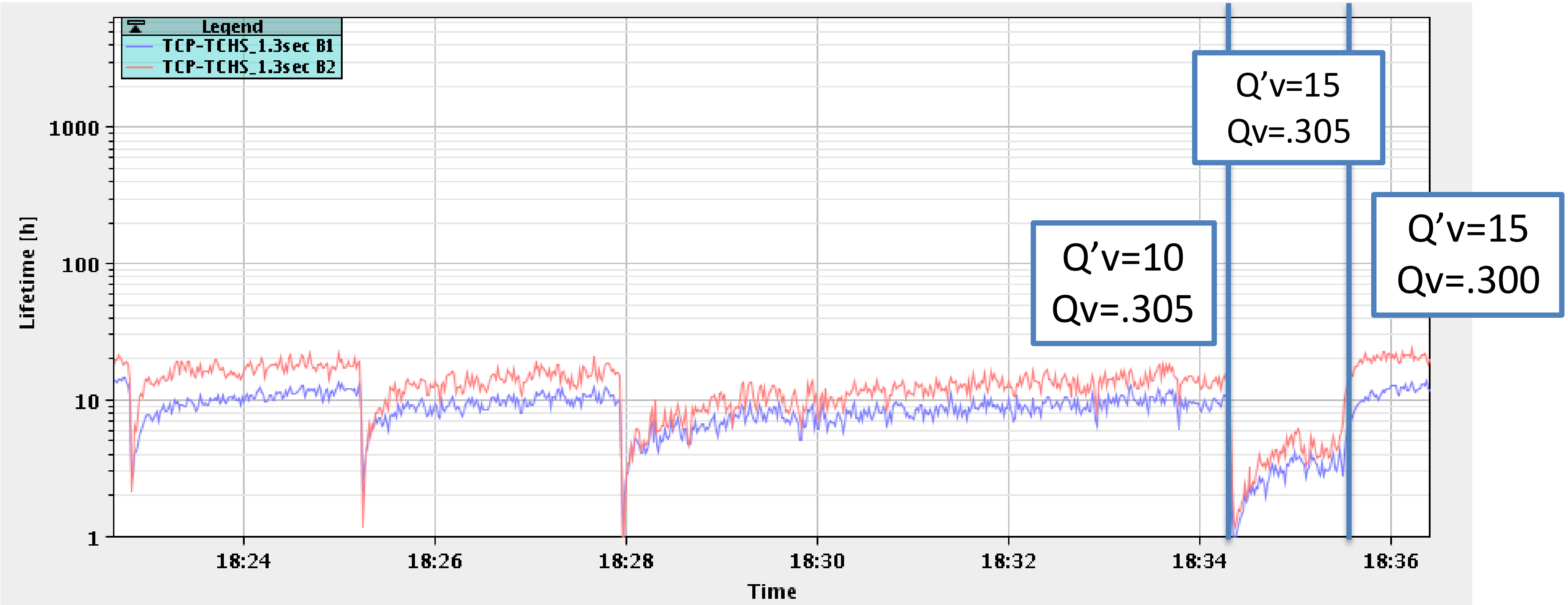








Consistent with recent machine observations:



- Losses are on **the trailing bunches of the train** (as expected)

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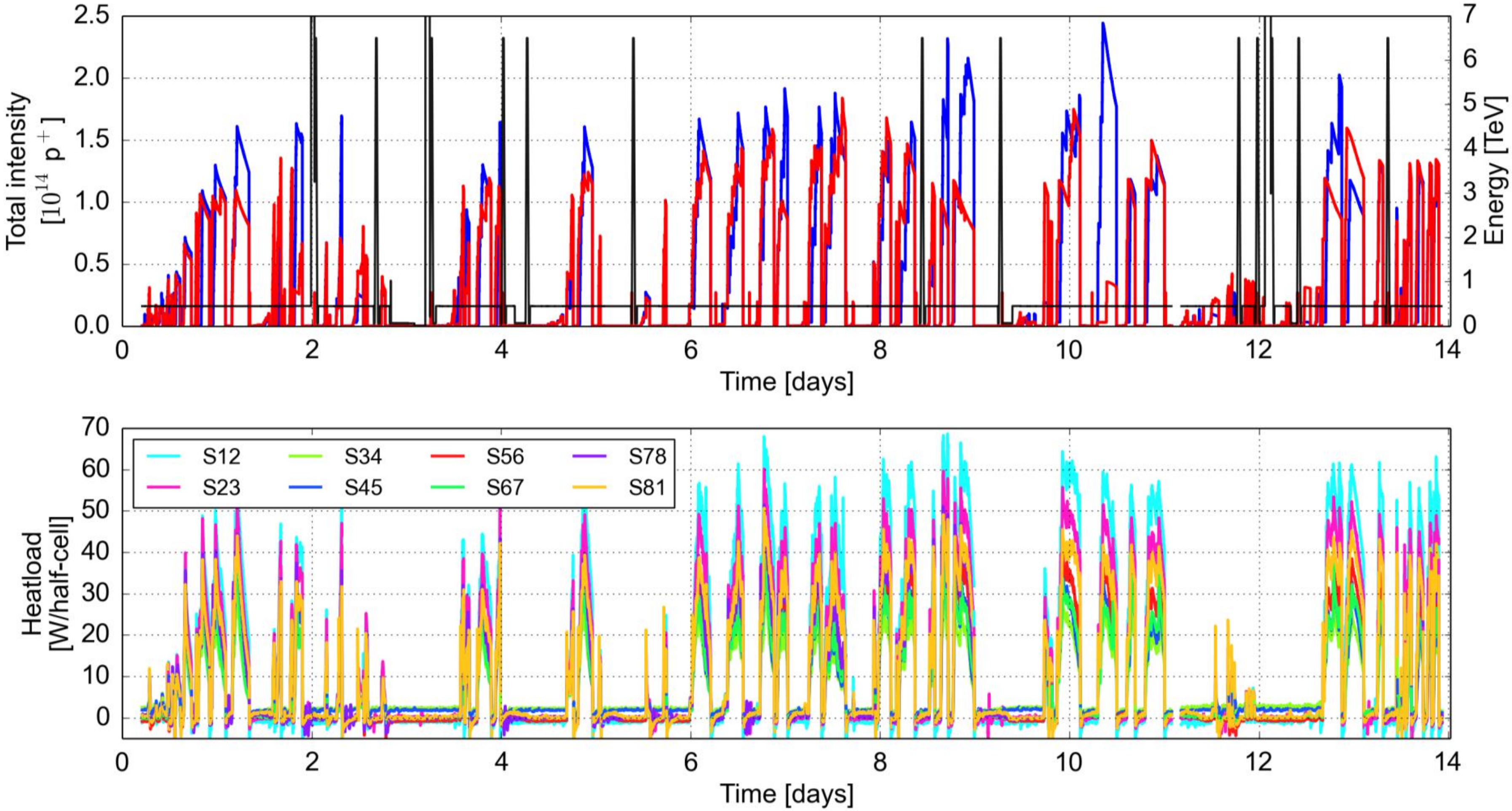
Lessons learnt from experience with 25 ns beam in 2015

Scrubbing Run for 25 ns operation (25 July - 7 August 2015)



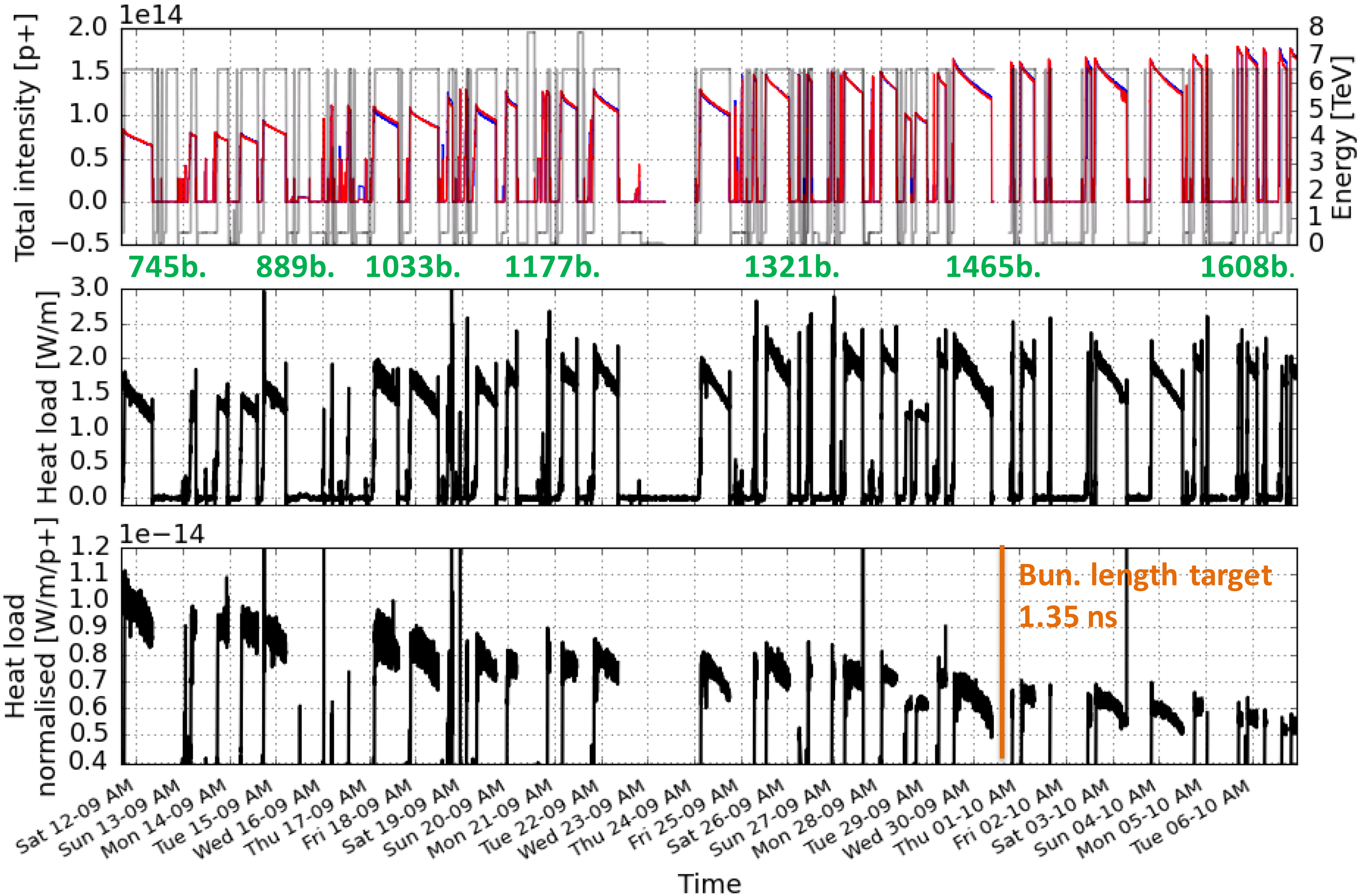
Scrubbing accumulated during Run 1 **lost completely during the shutdown**

→ **Deconditioning observed** even after the (after running in low e-cloud conditions)

Heat load evolution during the last weeks

After scrubbing **e-cloud still observed** in the machine

→ but **further scrubbing visible during intensity ramp up**



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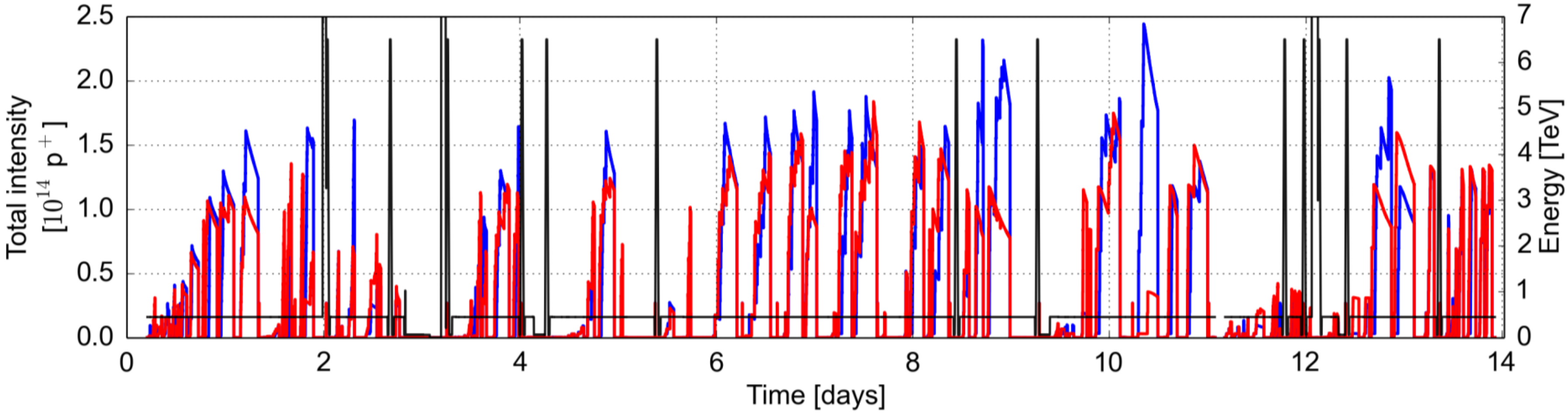
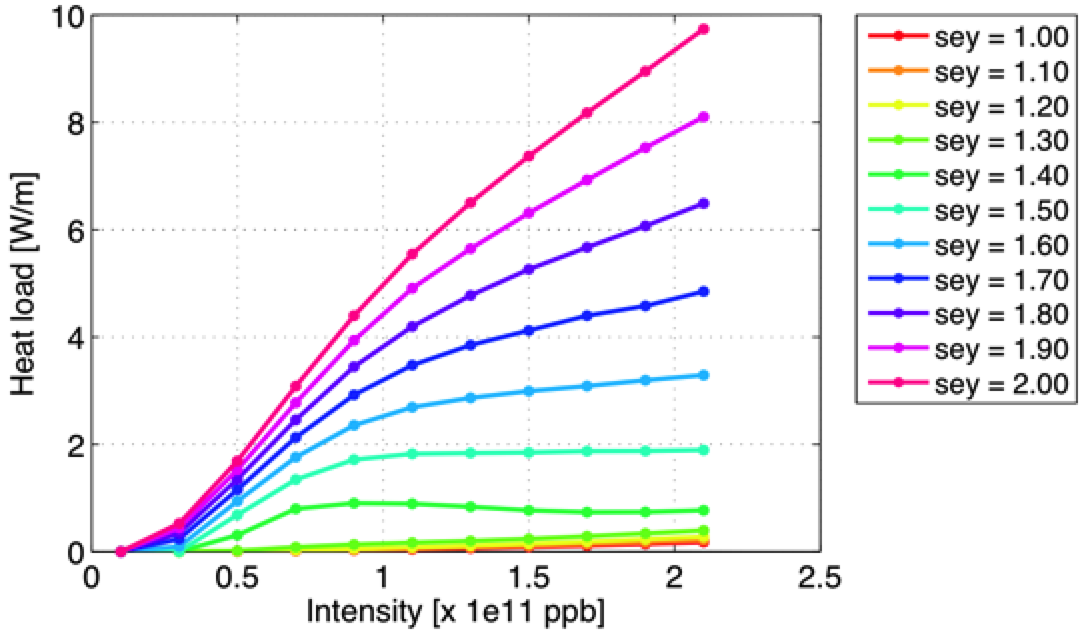


Scrubbing efficiency relies on our capability to keep injecting and preserve good beam quality:

- Injection speed can be limited by **transients on heat loads** observed when injecting beam. Important **improvements from**:
  - → **Feedforward** algorithm on Cryo regulation
  - → **Optimization of Cryo Maintain limits** on beam screen temperature
- Improved **vacuum in MKI region** and **more robust TDIs** would significantly help
- **Transverse damper** performance is crucial to keep the beam in the LHC (even in presence of intra-bunch instabilities)
- Need to run with **high Q' and octupoles** → **Tune optimization** can strongly improve beam lifetime

Scrubbing in the HL-LHC era…



Dependence on bunch intensity is **quite steep for high values of the SEY** and flattens down when approaching the threshold:

→ cooling capacity important to minimize required scrubbing time

Thanks for your attention!