Experience with 25ns beams in the LHC and future perspectives

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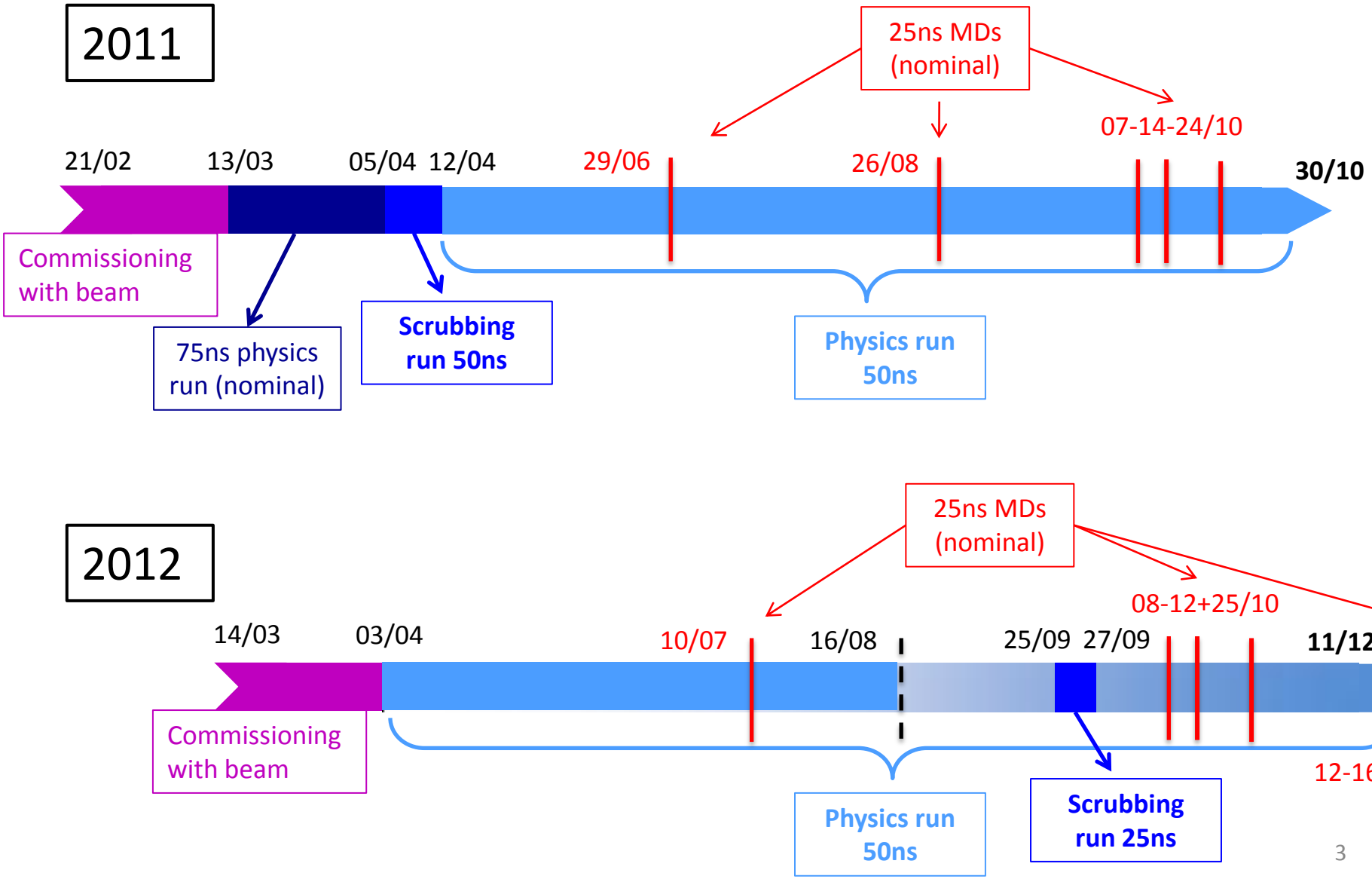
Focus of the talk → Review our present knowledge on electron cloud in the LHC with 25ns beam & anticipate future operation

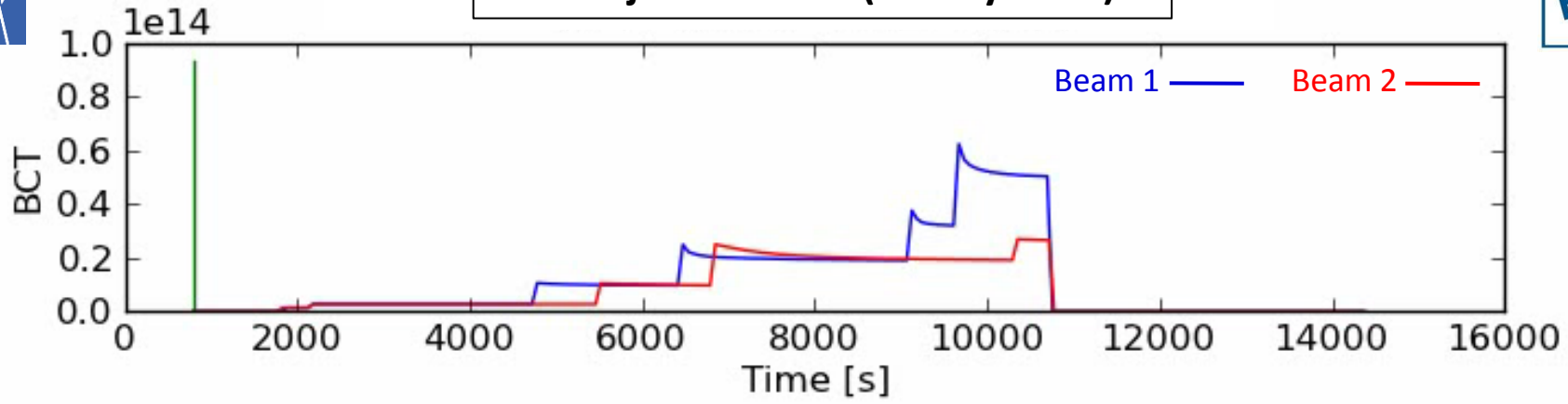
- ☑ 25ns tests in the LHC in 2012
- ☑ SEY evolution
- ☑ Scrubbing runs and operation after LS1
- ☑ Required yearly scrubbing time

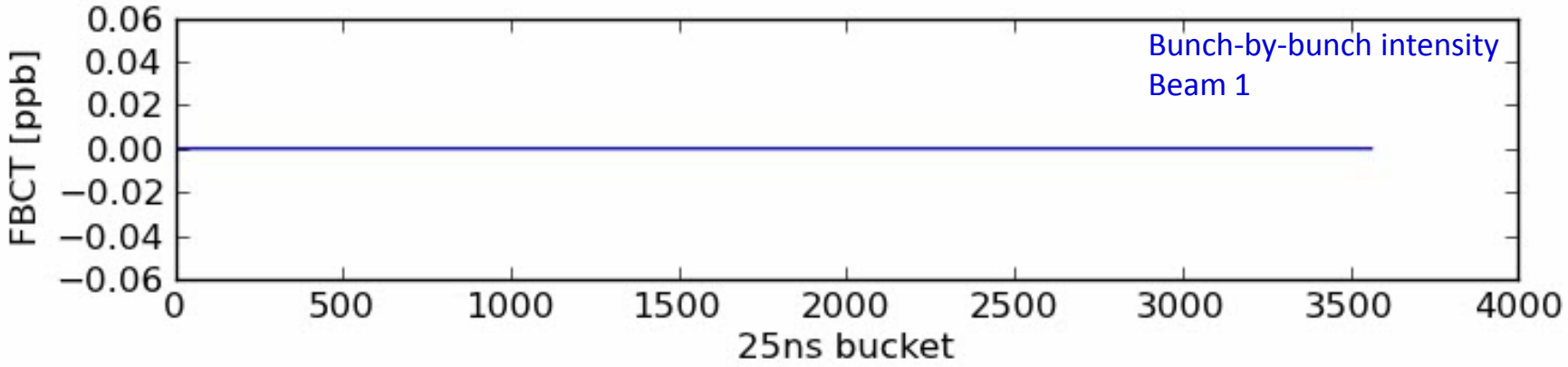
Milestones of 25ns beam in the LHC

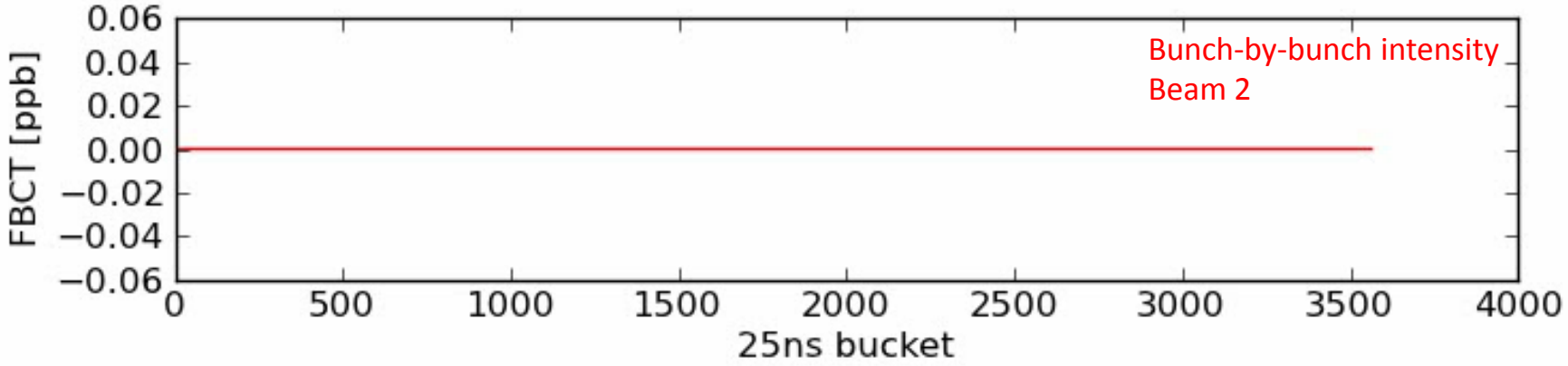


25ns TESTS in 2012 and SEY EVOLUTION

2012 injection tests (10 July 2012)







Some electron cloud observables during the injection tests on 10 July 2012

⇒Dynamic pressure rise

⇒Bad lifetime and degrading transverse emittances towards the tail(s) of the batches

⇒Heat load in the arcs

Some electron cloud observables during the injection tests on 10 July 2012

⇒Dynamic pressure rise

- ✓ Mainly in common areas and never above the interlock value of 4e-7 mbar

⇒Bad lifetime and degrading transverse emittances towards the tail(s) of the batches

⇒Heat load in the arcs

Some electron cloud observables during the injection tests on 10 July 2012

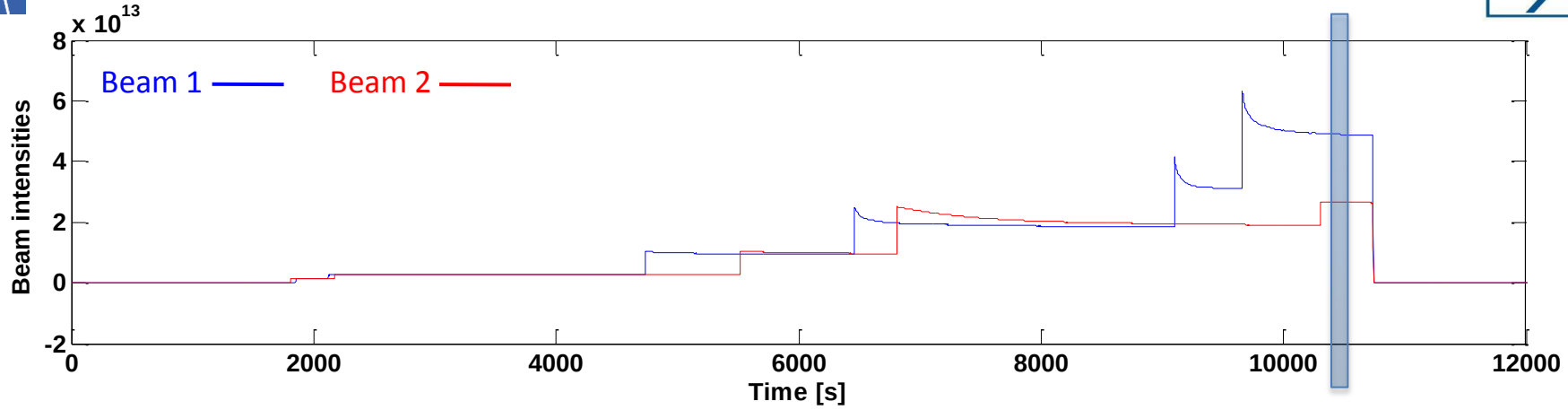
⇒Dynamic pressure rise

⇒Bad lifetime and degrading transverse emittances towards the tail(s) of the batches

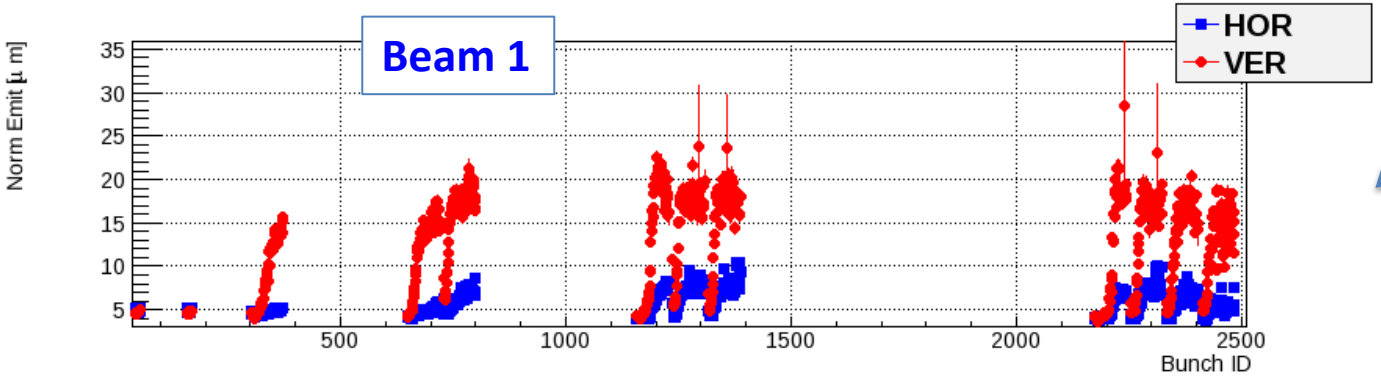
⇒Heat load in the arcs

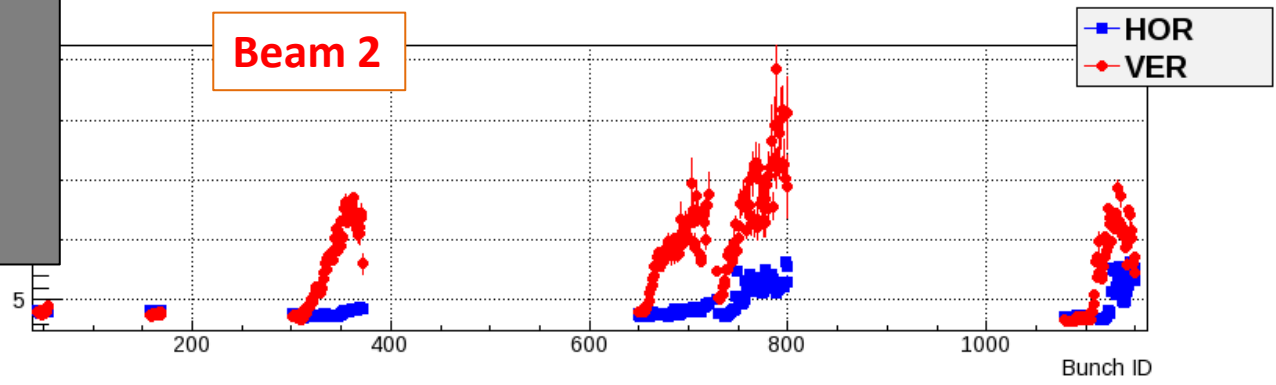
Beam evolution and emittances

10/07/12
12h55



BSRT Snapshots





- ⟶ Up to 4x emittance growth for both beams
- ⟶ Affecting last bunches of batches
- ⟶ Affecting especially the vertical plane

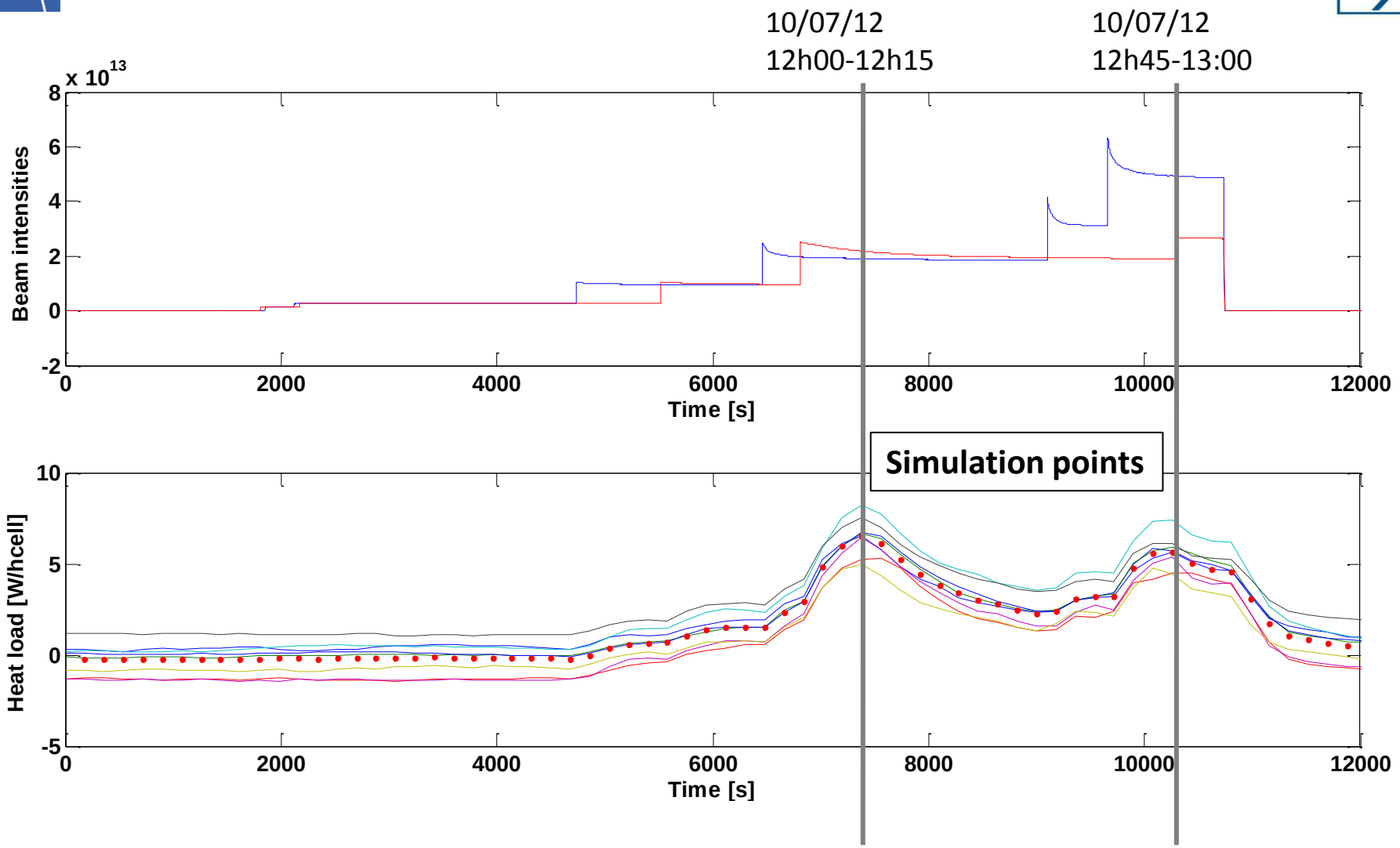
Some electron cloud observables during the injection tests on 10 July 2012

⇒Dynamic pressure rise

⇒Bad lifetime and degrading transverse emittances towards the tail(s) of the batches

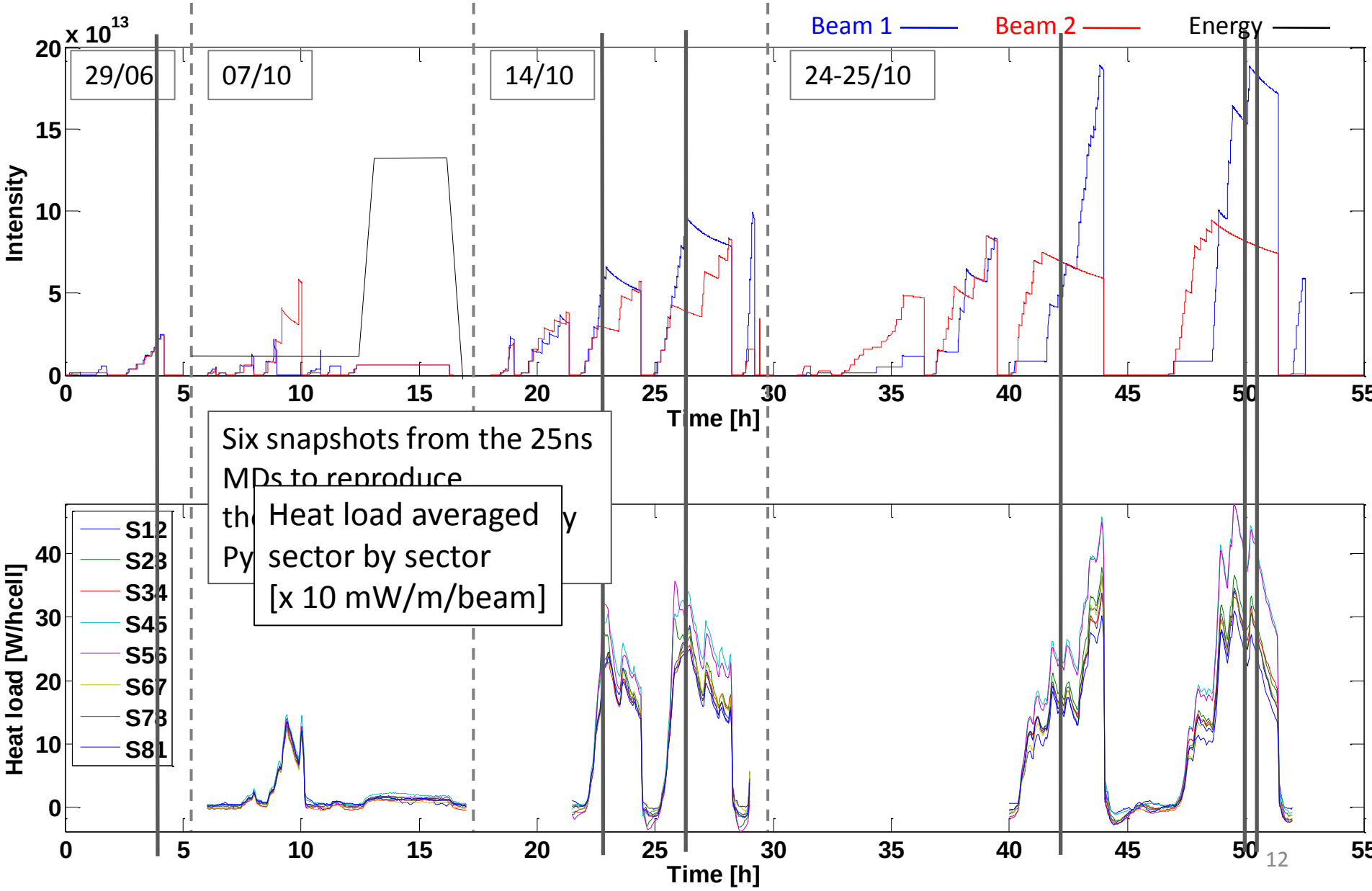
⇒Heat load in the arcs

Heat load

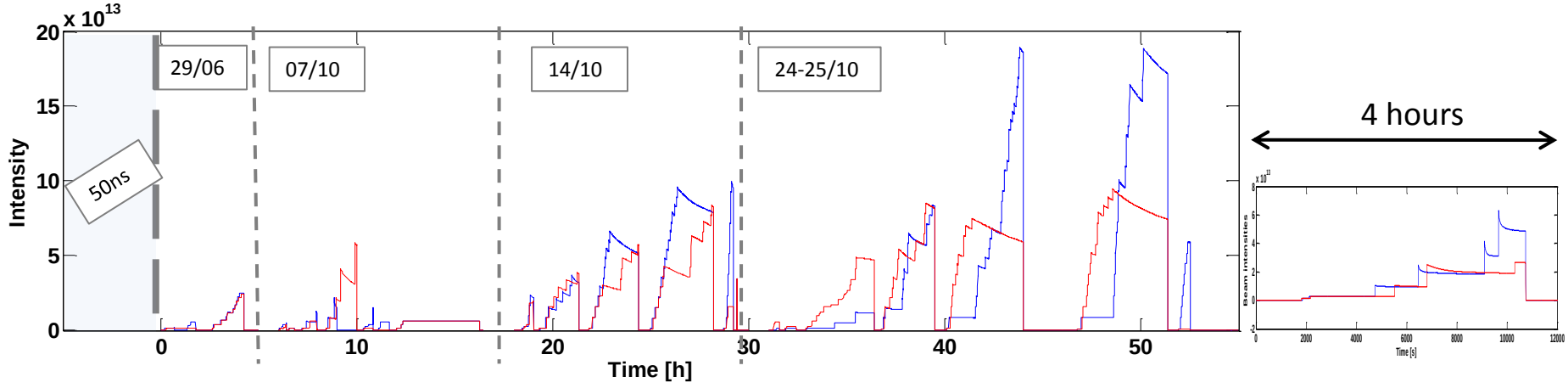


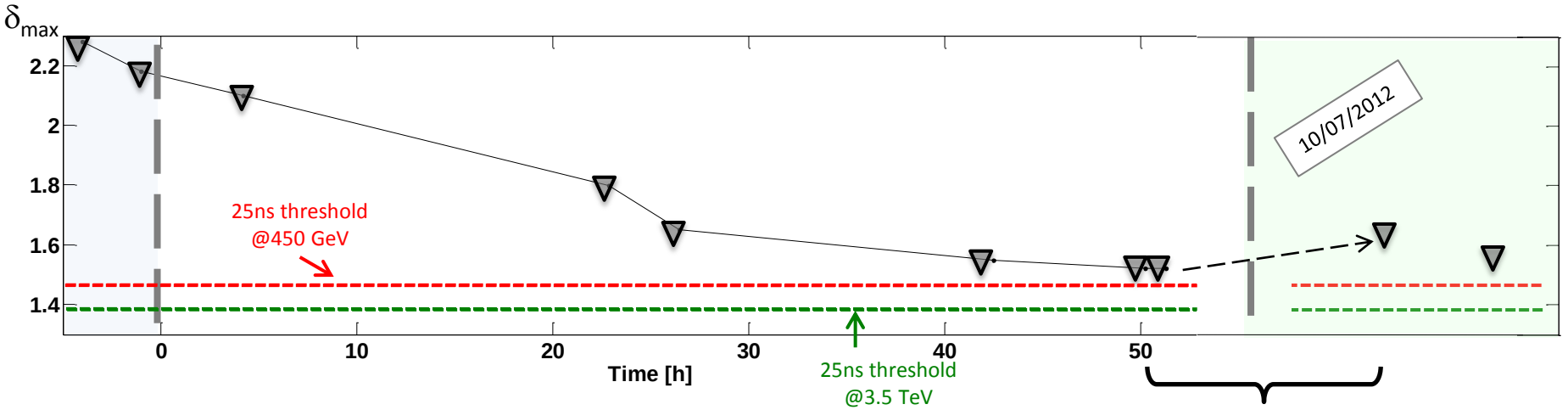
→ A clear increase in the heat load was measured in the arcs
→ This is due to Electron Cloud + Synchrotron Radiation + Image Currents

Flashback on 2011
(see Chamonix 2012)



Scrubbing history of LHC arcs



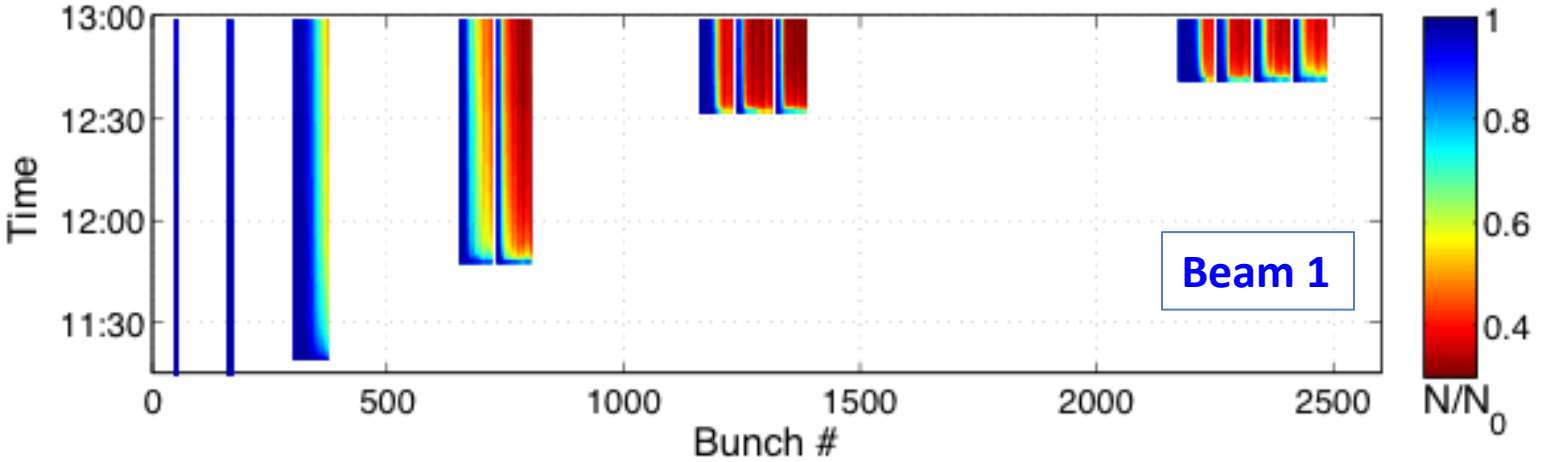


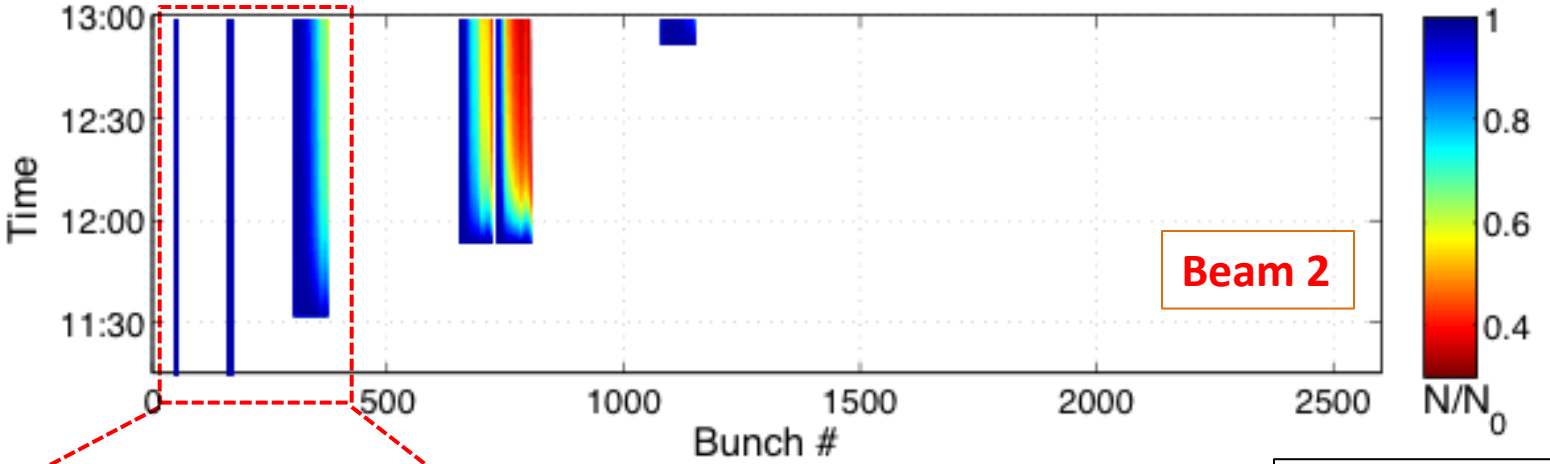
3w p operation (50ns) 2011 + ions + Winter shut-down + 3m operation (50ns) 2012

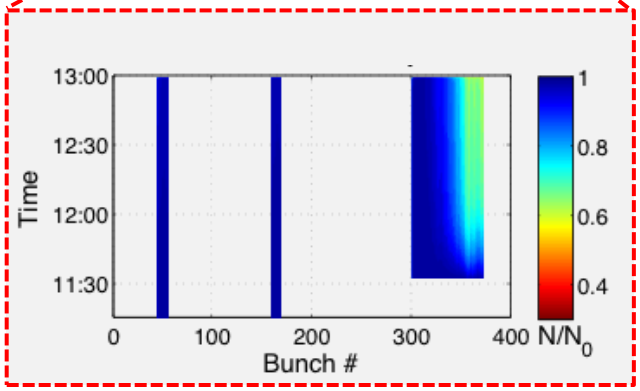
→ δ_{max} decreased from the initial **2.1 to 1.52** in the arcs after approximately 50h machine time with 25ns beams in 2011 (injected nominal and degraded)

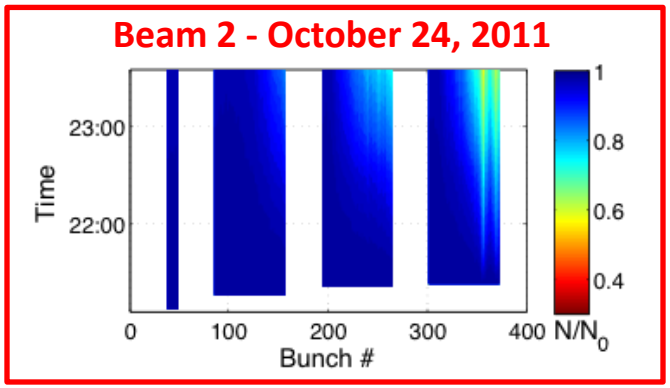
→ It was found to be slightly higher (**1.65**) in 2012, but it has already decreased to **1.55** at the end the injection tests (4h beam time, 1h between measurements)

July 10, 2012







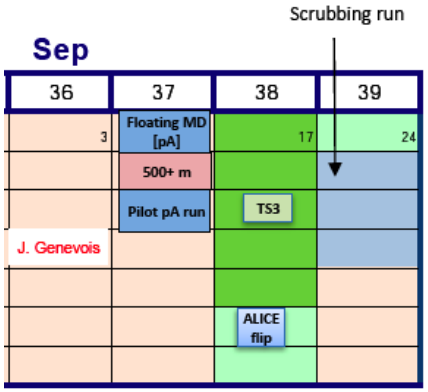


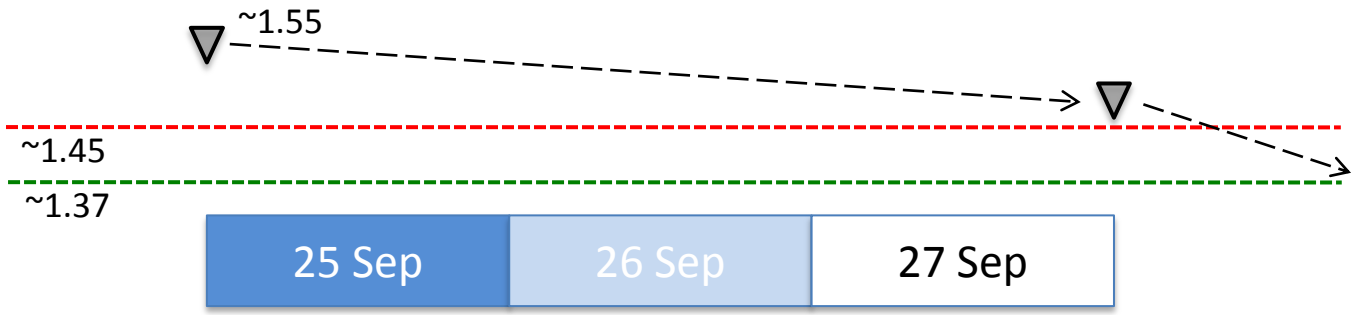
Beam observations

⇒ Deterioration in SEY confirmed by worse beam lifetime

SCRUBBING RUNS
in 2012 and AFTER LS1

Scrubbing run in 2012 + MDs





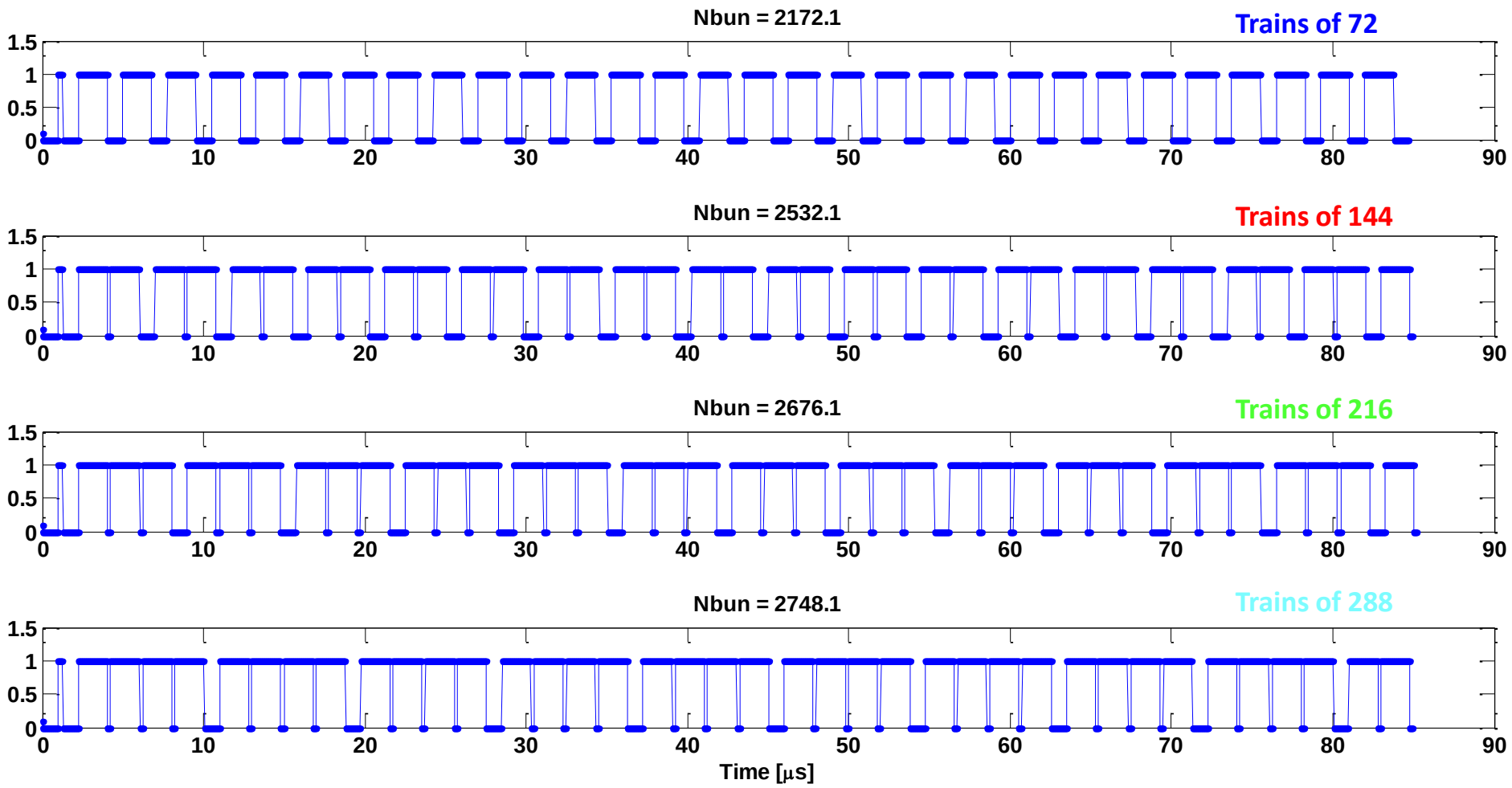
⇒ The 2012 **scrubbing run** is scheduled on 25–27 September 2012
- Continue scrubbing of the machine for 25ns beams and enable MDs using these beams before LS1
- Validate the scrubbing procedure and establish a strategy for operation with 25ns beams after LS1

⇒ Need to further lower the SEY in the arcs from the presently estimated value of 1.55
- Effect of the filling pattern on scrubbing efficiency
- Effect of bunch intensity
  - → Scrubbing dose
  - → Beam stability

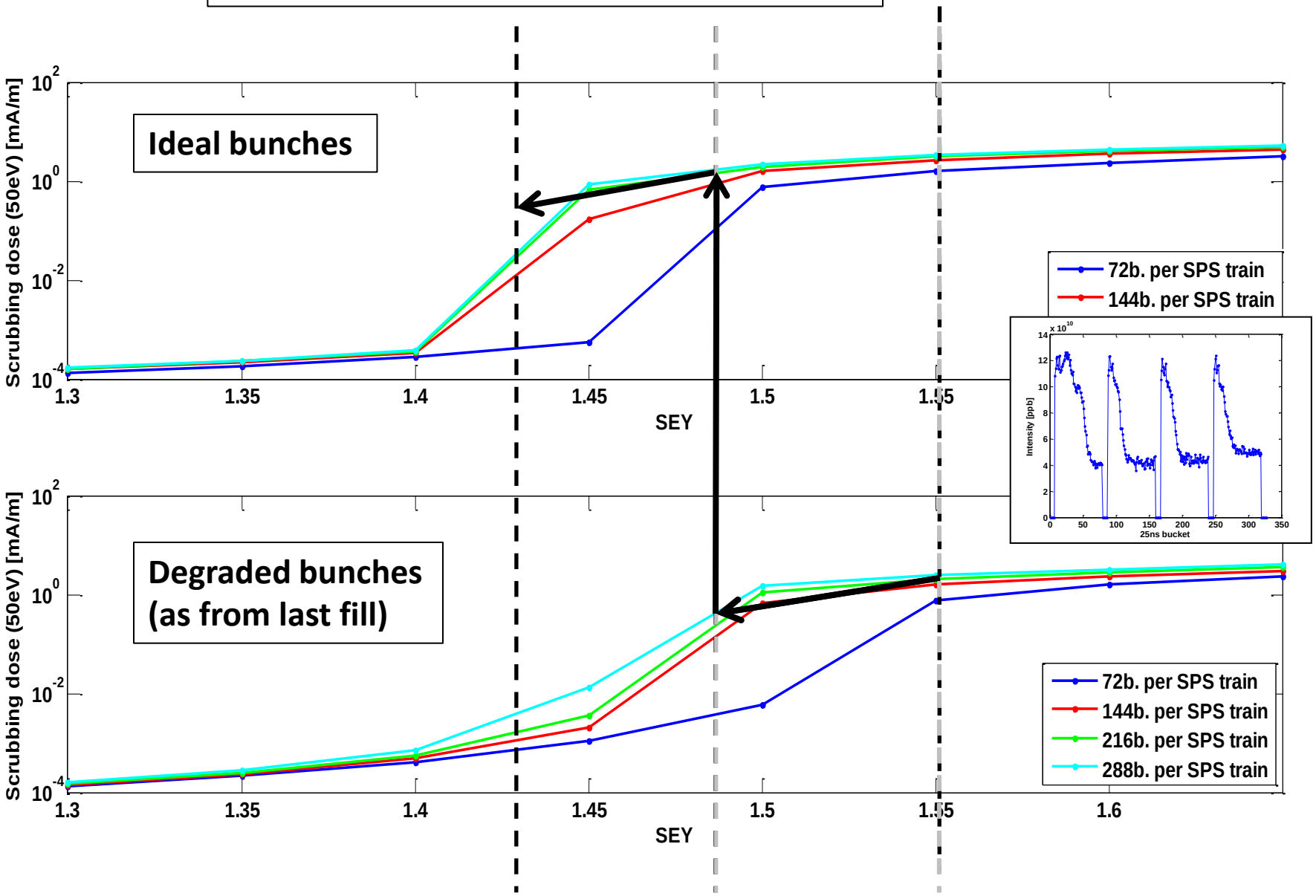
} @injection

- MDs: Ramping a stable beam configuration to high energy
  - → Photoelectrons
  - → Lower SEY thresholds for (significant) e-cloud build up

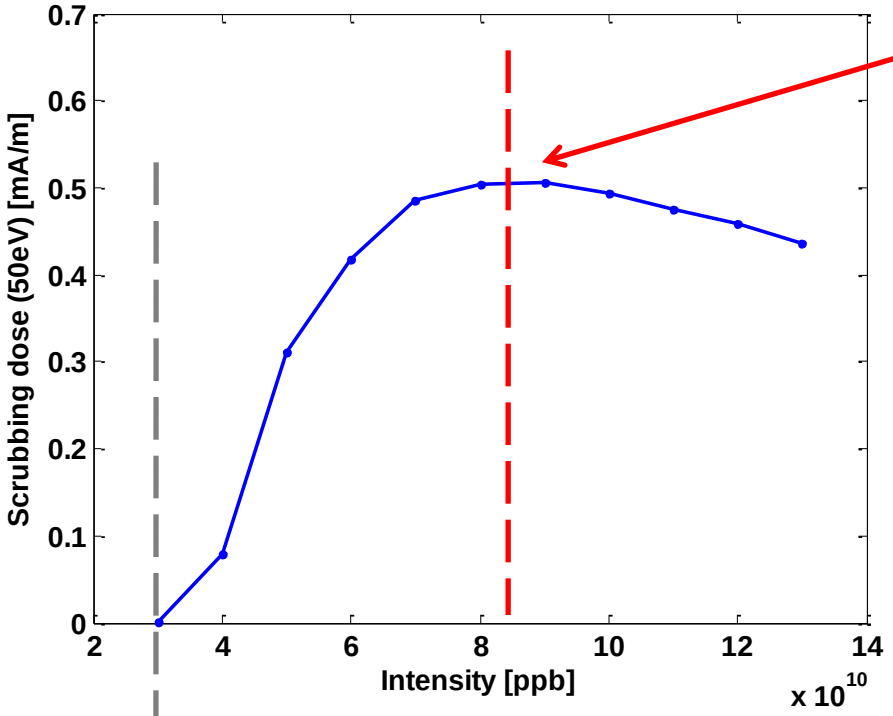
Effect of filling scheme



Effect of filling scheme
→ Scan in SEY at nominal bunch intensity



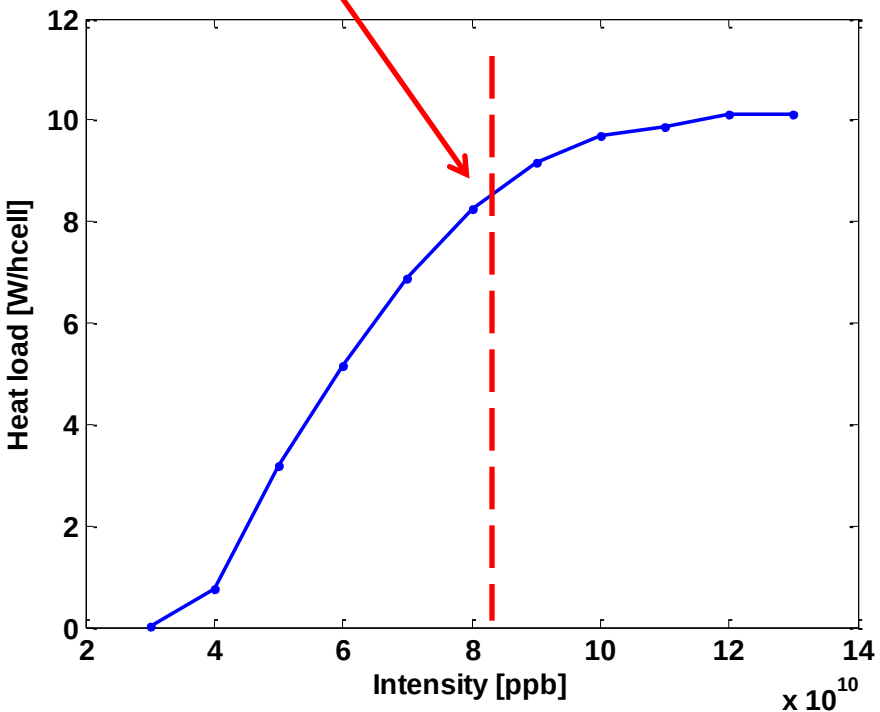
Effect of bunch intensity
→ Scan in bunch intensity at SEY_{max}=1.55



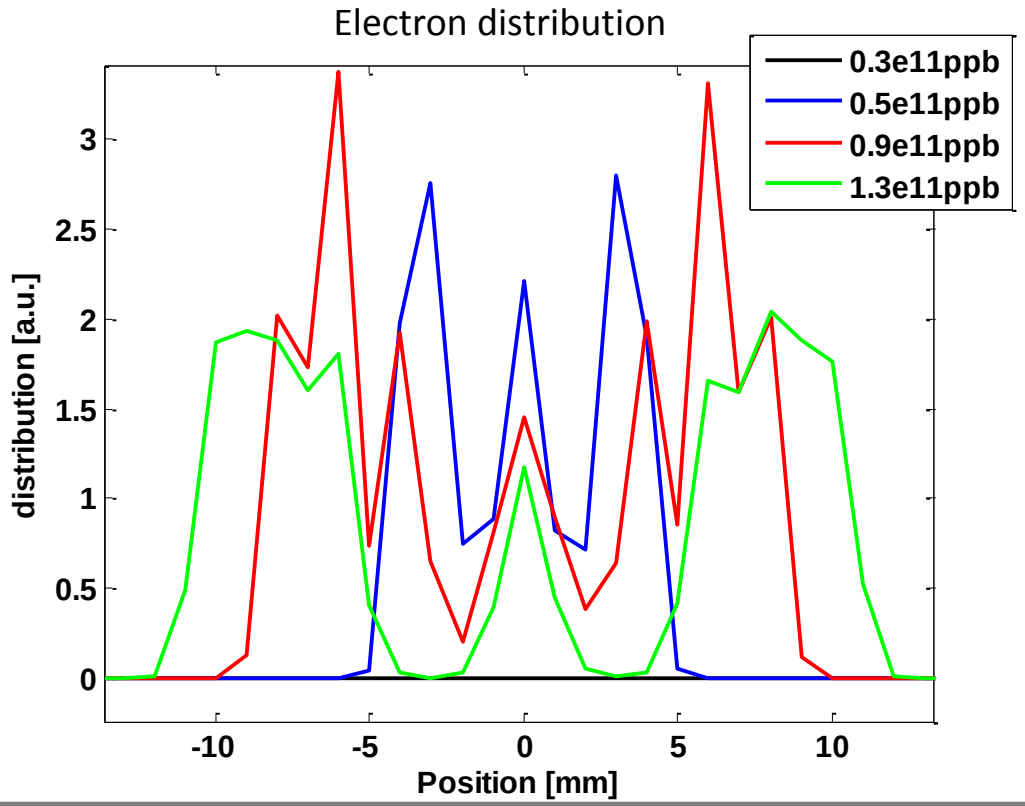
Max scrubbing dose @about 8 x 10^{10} ppb
(however, only 10% larger than at 1.3 x 10^{11} ppb)

Threshold value for
electron cloud build up

Heat load 20% lower than at 1.3 x 10^{11} ppb



Effect of bunch intensity
→ Scan in bunch intensity at SEY_{max}=1.55

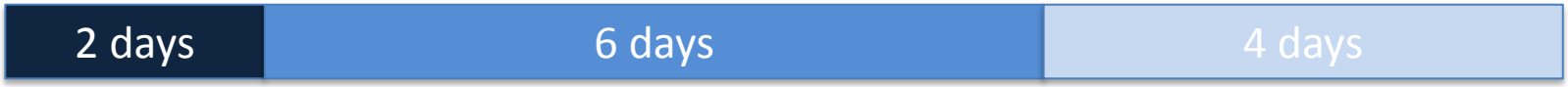


- Electron distribution in the dipole chamber:
  - The central density is higher for lower intensities
  - The two stripes move further out with higher intensities
- Lower intensity beams also tend to be more unstable due to larger central densities they generate
- All in all, it seems better to use higher intensities and move the beam radially to better scrub the central part

Effect of beam energy
→ Ramping to 4 TeV during MDs

- A few concurrent effects at top energy:
  - More production of photoelectrons causes higher electron densities (lower SEY threshold, ~1.37) and larger heat loads
  - \+ Due to the shorter bunches, the central peak in the electron distribution is less pronounced
  - \+ The beam is more rigid and generally more stable against coherent mechanisms (even with low chromaticity)
- Scrubbing the LHC at injection energy with filling patterns based on long bunch trains should give enough margin to ramp up a non-degraded beam with shorter trains
- Then the scrubbing process will continue thanks to photoelectrons

Scrubbing runs after LS1



⇒ Rough time estimate for **first scrubbing run after LS1** (2014)

- ~50h = **2 days** machine time, as was needed in 2011, to lower δ_{max} fr… to 1.55 (including set up of all injection steps, 72-144-216-288 bunches)
- An additional 20h net beam time with 2100 bunches to get t… limit at flat bottom), estimated with a simple model (Chamonix 2… ine time (applying scrubbing factor from 2011 = 0.14)
- At least **4 days** machine time for operation & fu… eV with increasing number of bunches (perhaps gradually inclu… ediate energies?)
- Total of **12 days** with very good machin… contingency

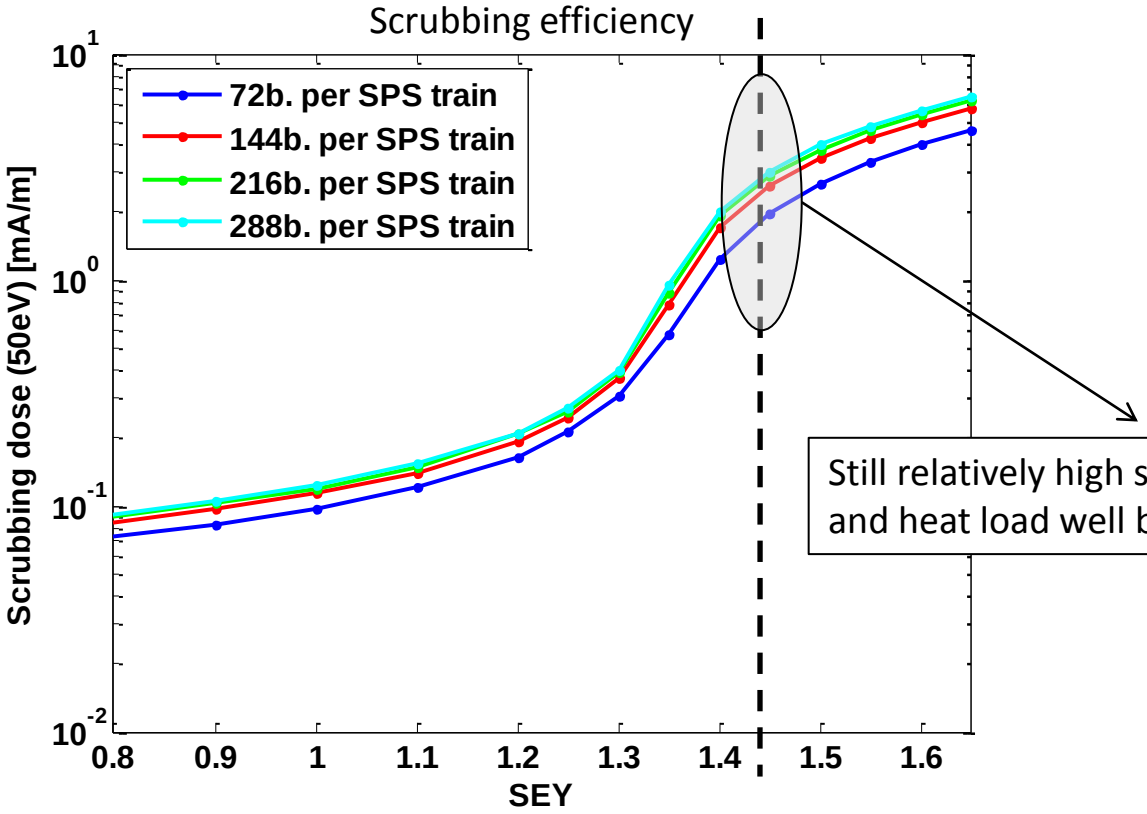
⇒ Scrubbing scenarios could also fo… proach

- First, "light" scrubbing with 25… @injection) to allow a period of electron cloud free operation with … mp up. Then, full scrubbing for 25ns operation

⇒ In subsequent yea… ould go much faster because, in absence of venting, de-conditio… k and re-conditioning much faster

Much to be yet validated with the 2012 scrubbing run + MDs with ramp to 4TeV

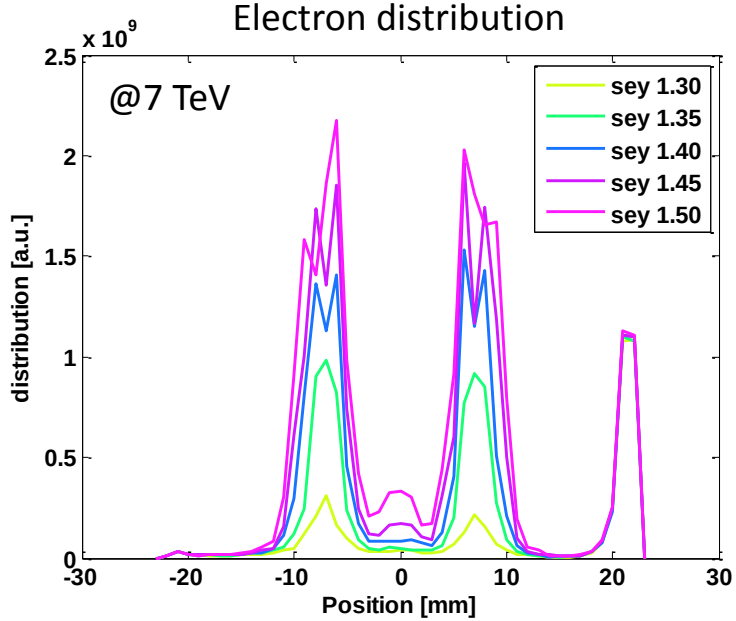
Effect of beam energy
→ Ramping to 7 TeV after LS1 with different filling patterns

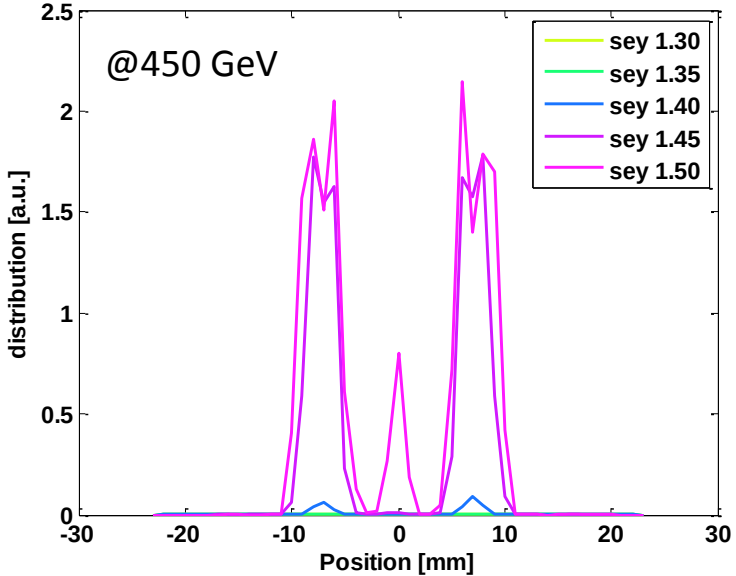


- Due to photoelectrons:
  - Threshold behaviour much less sharp than at injection
  - Effect of filling pattern only visible due to the different number of bunches (memory between batches is irrelevant)
- The absolute value of the scrubbing efficiency and heat load strongly depend on the reliability of our photoemission model

Effect of beam energy
→ Ramping to 7 TeV after LS1

Electron distribution





- Differences with injection energy:
  - Strong peak where the SR hits directly
  - Lower SEY threshold value for stripe formation
  - Much less pronounced central spike (effect of bunch length)
- Stripes in the same position → benefits from scrubbing @injection + more scrubbing possible
- Beam is more stable (low central density, higher energy)

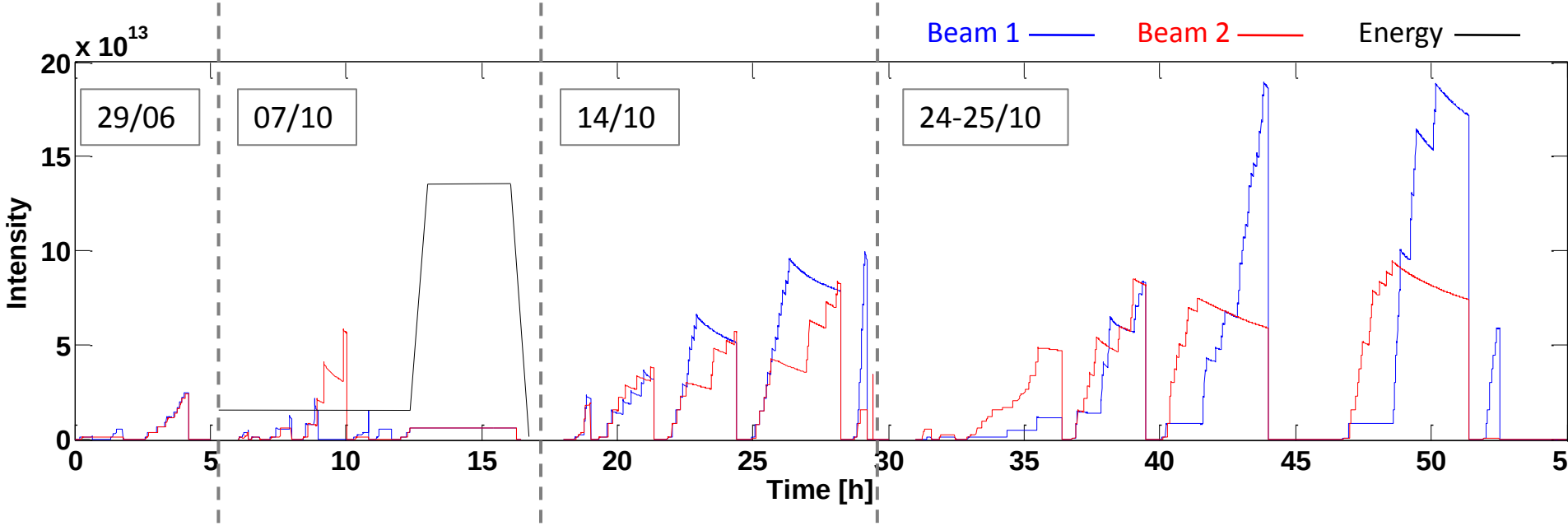
Summary and conclusions

⇒ The electron cloud still affects 25ns beams in the LHC
- SEY has come down to 1.55 and needs further lowering
- There is a slight effect of de-conditioning between runs, but re-conditioning appears to be faster

⇒ Scrubbing runs are needed to be able to run LHC with 25ns beams for possible future operation (after LS1)
- 2012
  - → Scrubbing run (3d) important to continue acquiring experience on operation with 25ns and scrubbing procedures (@injection)
  - → MDs with ramps to 4 TeV important to learn experimentally how the electron cloud effects behave with energy (and validate our models for extrapolation to 7 TeV)
- After LS1
  - → First scrubbing run might have to be long to recover acceptable SEY conditions (~12d)
  - → Future scrubbing runs should be shorter in absence of venting

SPARE SLIDES

25ns experience in 2011



DATE	SHORT DESCRIPTION
29 June	Injections of **9 x 24b trains per beam** with different spacings between them
26 August	Two attempts to inject a **48b train** with damper on and off: fast instability dumps the beam within 500 turns in both cases (SBI and CBI)
7 October	High chromaticity ($Q'_{x,y}$ ≈15): Injection tests with **trains of 72-144-216-288 bunches** from the SPS + ramp to 3.5 TeV & 5h store with **60b (12+24+24) per beam**
14 October	High chromaticity: injection of up to **1020 bunches** per beam in **72b trains** (decreasing spacings between trains at each fill: 6.3–3.2–1 μs)
24-25 October	Injection of up to **2100 bunches** in Beam 1 and **1020** in Beam 2 (1μs train spacing)

Scrubbing

δ_{max} in the arcs: estimation technique

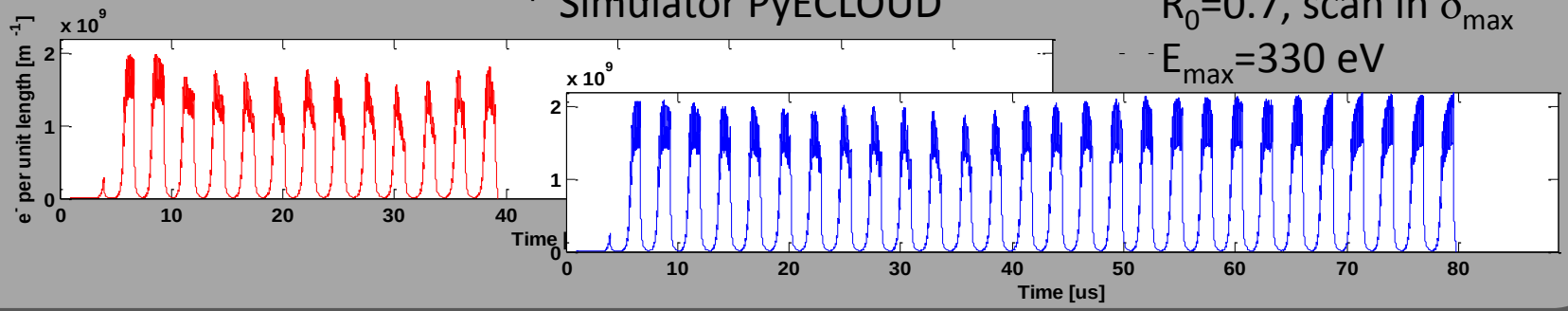
fastBCT + bunch-by-bunch b-length (B1)

fastBCT + bunch-by-bunch b-length (B2)

Simulator PyECLOUD

R_0=0.7, scan in δ_{max}

E_{max}=330 eV



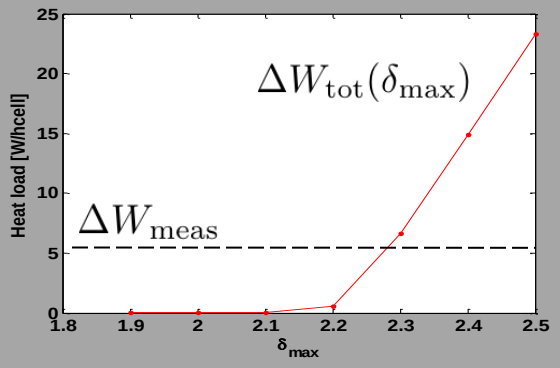
$\Delta W_{sim1}(\delta_{max})$ $\Delta W_{sim2}(\delta_{max})$

$\Delta W_{tot}(\delta_{max})$ **Total simulated heat load**

$\Delta E_{b1}(\delta^*_{max})$
$\Delta E_{b2}(\delta^*_{max})$ [mJ/turn]

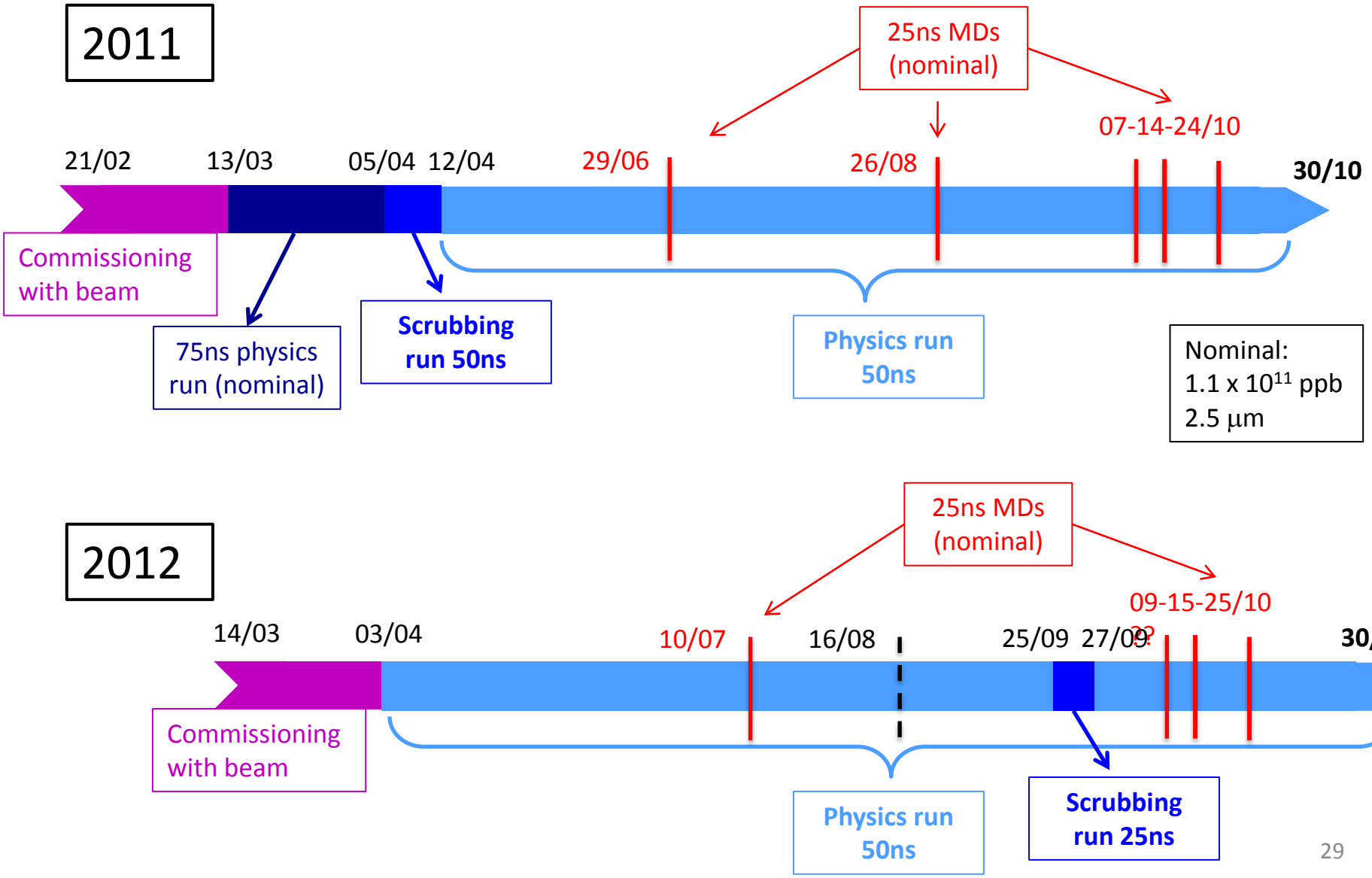
Measured heat load

ΔW_{meas}



δ^*_{max}

Milestones of 25ns beam in the LHC



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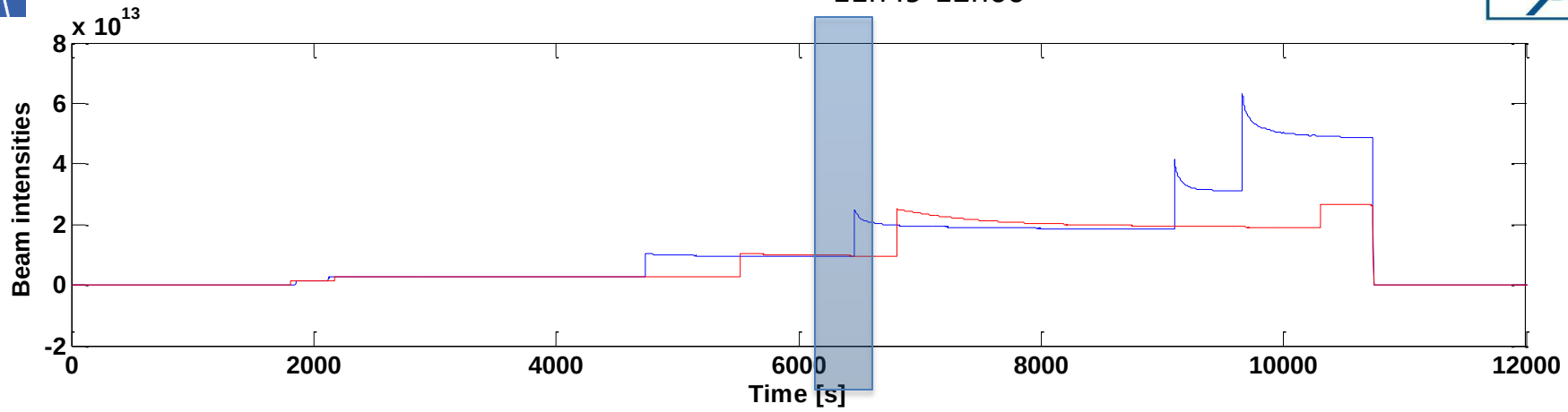
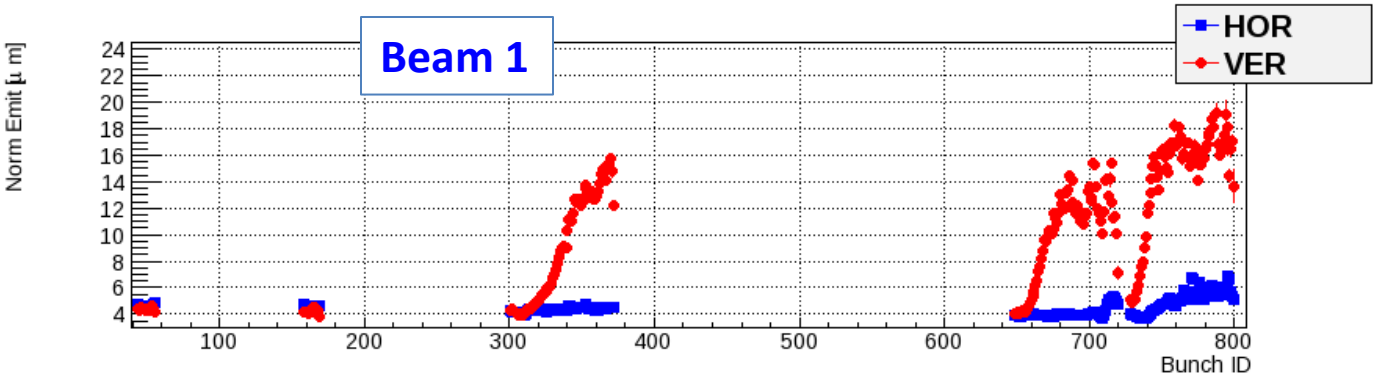
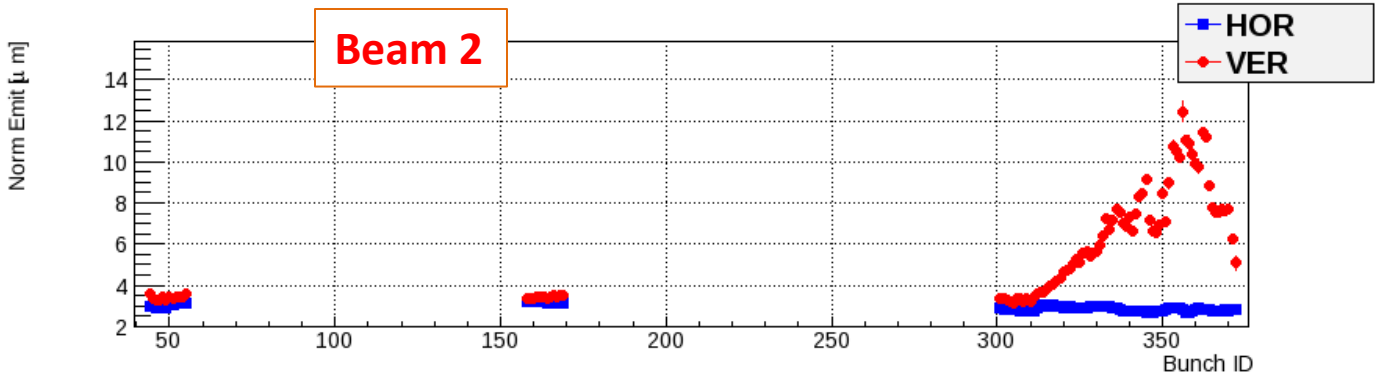
11h49-12h00







Scrubbing run in 2012

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- Continue scrubbing of the machine for 25ns beams and enable MDs using these beams before LS1
- Validate the scrubbing procedure and establish a strategy for operation with 25ns beams after LS1

⇒ Need to further lower the SEY in the arcs from the presently estimated value of 1.55
- Effect of the filling pattern on scrubbing efficiency
- Effect of bunch intensity
  - → Scrubbing dose
  - → Beam stability
- Ramping to high energy (probably to be done in MDs after the scrubbing run)
  - → Photoelectrons
  - → Lower SEY thresholds for e-cloud build up

⇒ After 2012 scrubbing + 25ns studies in MDs, we will have collected enough data to predict the evolution of the LHC performance with 25ns beams.