Investigation of the time evolution of the hump frequency observed at the LHC run 2010

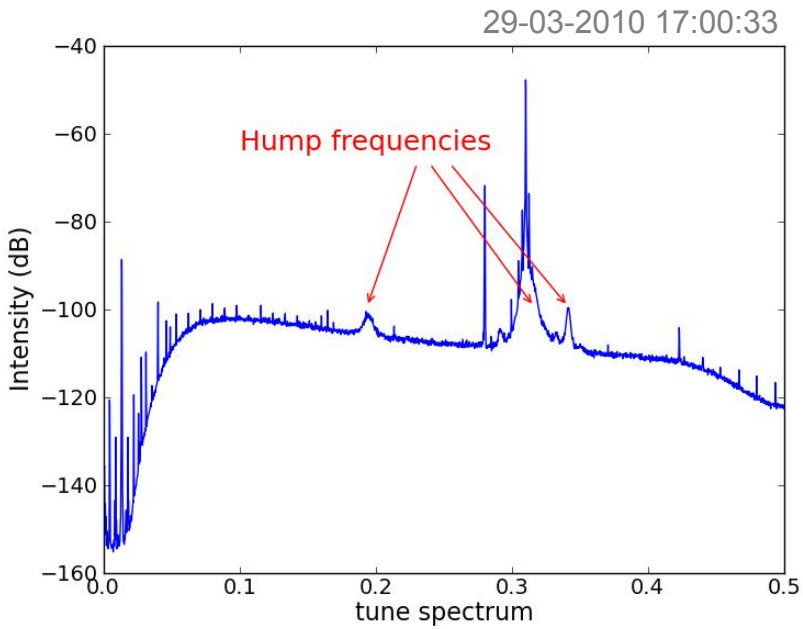
C. Alabau Pons, G. Arduini and R. de Maria

Introduction: the “hump” signal (1/2)

- What is the hump

→ during the 2009 and 2010 LHC run, an unknown source is causing vertical oscillations of the beam (amplitudes of few micrometers)

→ a few weak and broad excitation bands (so-called hump) are observed with the tune measurement system (BBQ) (mainly in the vertical plane for Beam 2)



Frequency spectrum (in units of the revolution frequency, 11.245 kHz)
Beam 2-Vertical

- Horizontal and vertical tunes: 0.28 and 0.31

- Different harmonics of the hump: 0.19, 0.34 and 0.31

- Other sharp lines due to the Uninterruptible Power Supplies (UPS): 8 kHz and its hamonics

→ the hump frequency is slowly varying with time

Introduction: the “hump” signal (2/2)

- Consecuences

→ emittance blow-up and luminosity loss is observed when the hump frequency approaches the beam tunes

- Atenuation

→ the transverse feedbak system can reduce the effect on the beam to a certain extent

- Source investigation

→ the identification of the perturbation source proved to be extremely difficult

→ although many systems in the accelerator have been under investigation, the source is still unknown [1,2,3]

- Signal during the 2011 run

→ the hump is in 2011 approximately a factor 2 or more weaker than in 2010 and its frequency is relatively stable and far from the beam typical frequency

→ it is still important to understand the source of the hump

[1] G. Arduini *et al.,* ¨Hump: How did it impact the Luminosity Performance and Status¨, Proceedings of the LHC Beam Operation Workshop, Evian, December 2010.

[2] W. Höfle *et al.,* ¨LHC Transverse Damper Observations versus Expectations¨, Proceedings of the LHC Beam Operation Workshop, Evian, December 2010.

[3] G. Arduini *et al.,* LHC Machine Committee, 10/03/2010, https://espace.cern.ch/lhc-machine-committee/Minutes/1/lmc_47.pdf

Time evolution of the hump frequency (1/3)

Investigation of the time evolution of the hump frequency:

- The data acquired with the BBQ have been systematically analysed for a long period of the 2010 LHC operation (from March to September)

- From March to the end of May, the hump signal is present all the time in the frequency spectrum, sweeping different frequency ranges

Time evolution of the hump frequency (1/3)

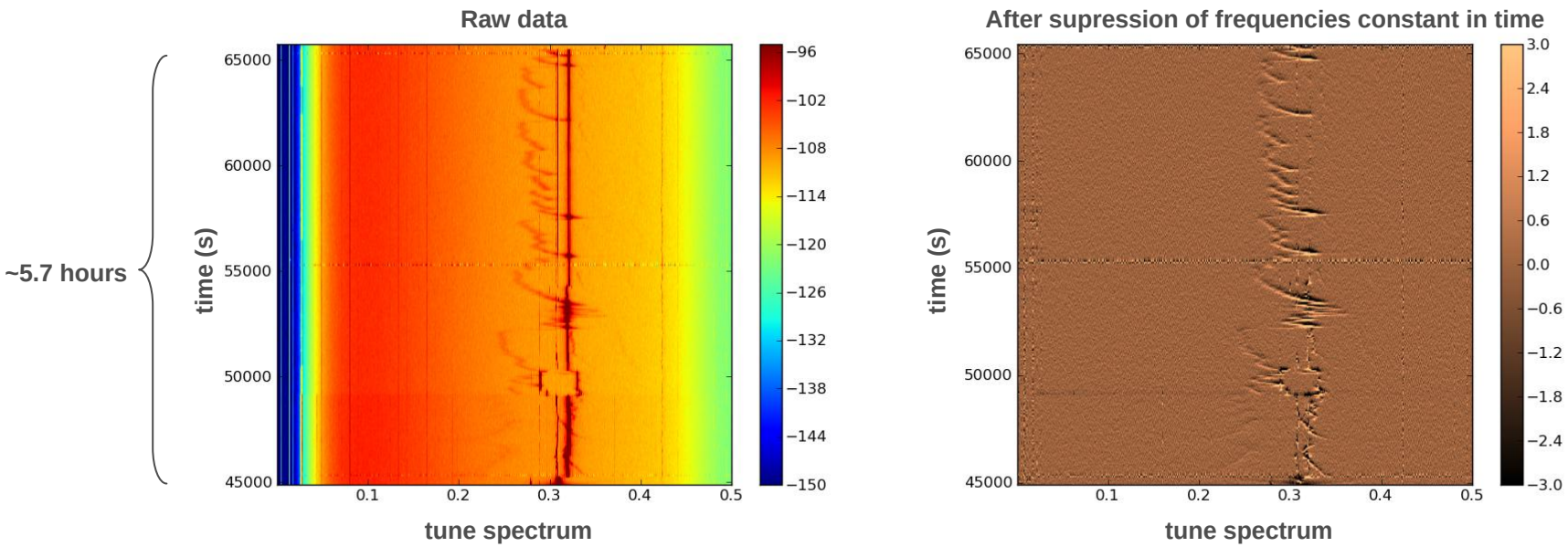
Investigation of the time evolution of the hump frequency:

- The data acquired with the BBQ have been systematically analysed for a long period of the 2010 LHC operation (from March to September)

- From March to the end of May, the hump signal is present all the time in the frequency spectrum, sweeping different frequency ranges

Frequency spectrum *vs* time, Beam 2-Vertical

21st April 2010



Time evolution of the hump frequency (1/3)

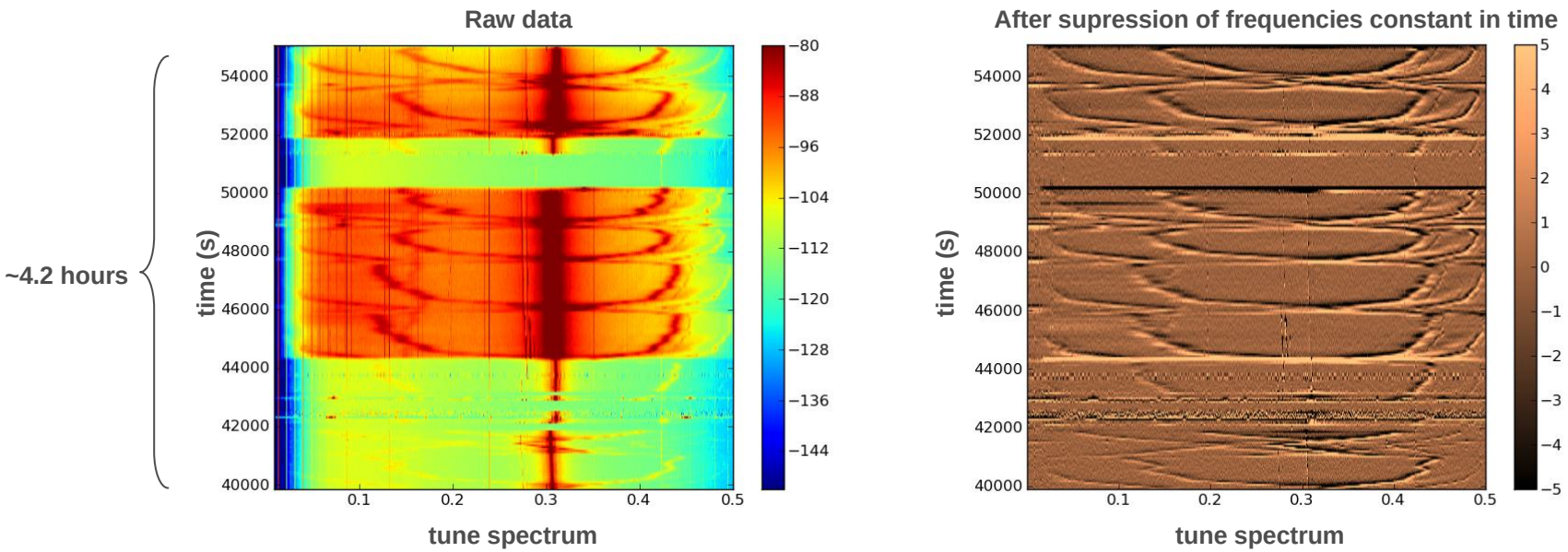
Investigation of the time evolution of the hump frequency:

- The data acquired with the BBQ have been systematically analysed for a long period of the 2010 LHC operation (from March to September)

- From March to the end of May, the hump signal is present all the time in the frequency spectrum, sweeping different frequency ranges

Frequency spectrum *vs* time, Beam 2-Vertical

13th May 2010

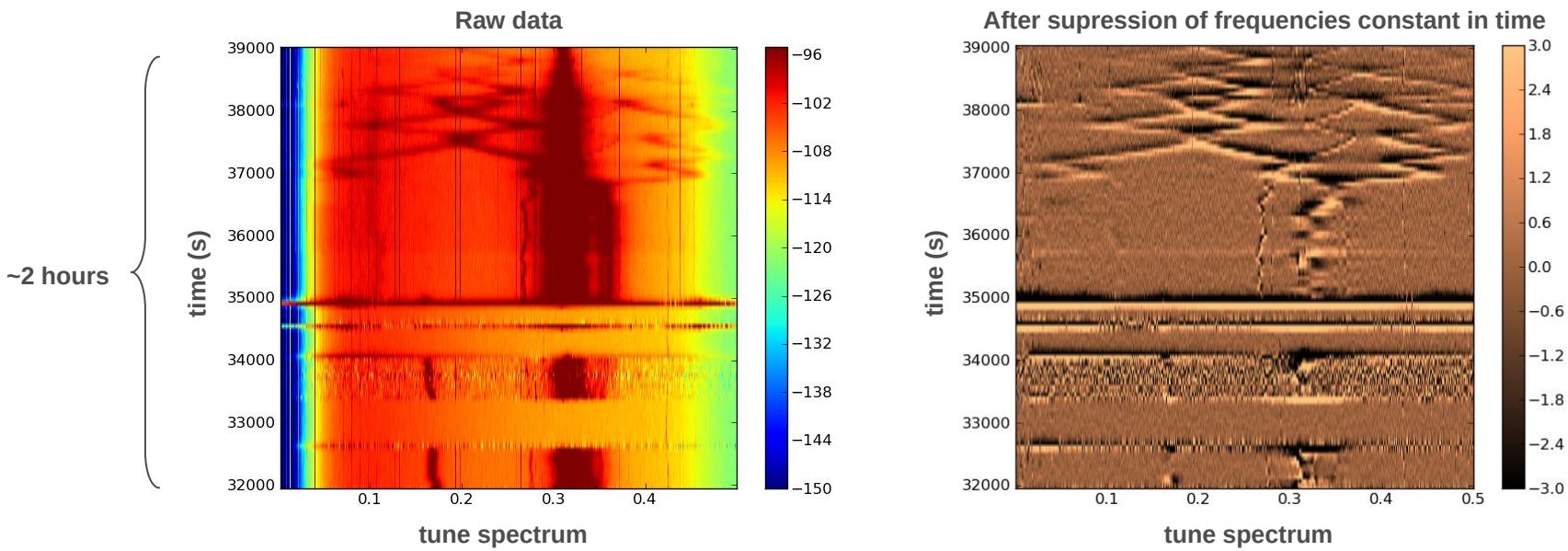


Time evolution of the hump frequency (2/3)

- During this period, no clear abrupt variation on time evolution of the hump frequency was observed, with the exception of:

Frequency spectrum *vs* time, Beam 2-Vertical

29th March 2010



Sudden change of the time evolution of the hump frequency occured at about 22:13

Time evolution of the hump frequency (3/3)

- From the 21st of May onwards, the hump is still present all the time, but it is more stable in frequency, with very small amplitude oscillations

- One characteristic observed regularly during this period is that the time evolution of the hump frequency can show sudden variations

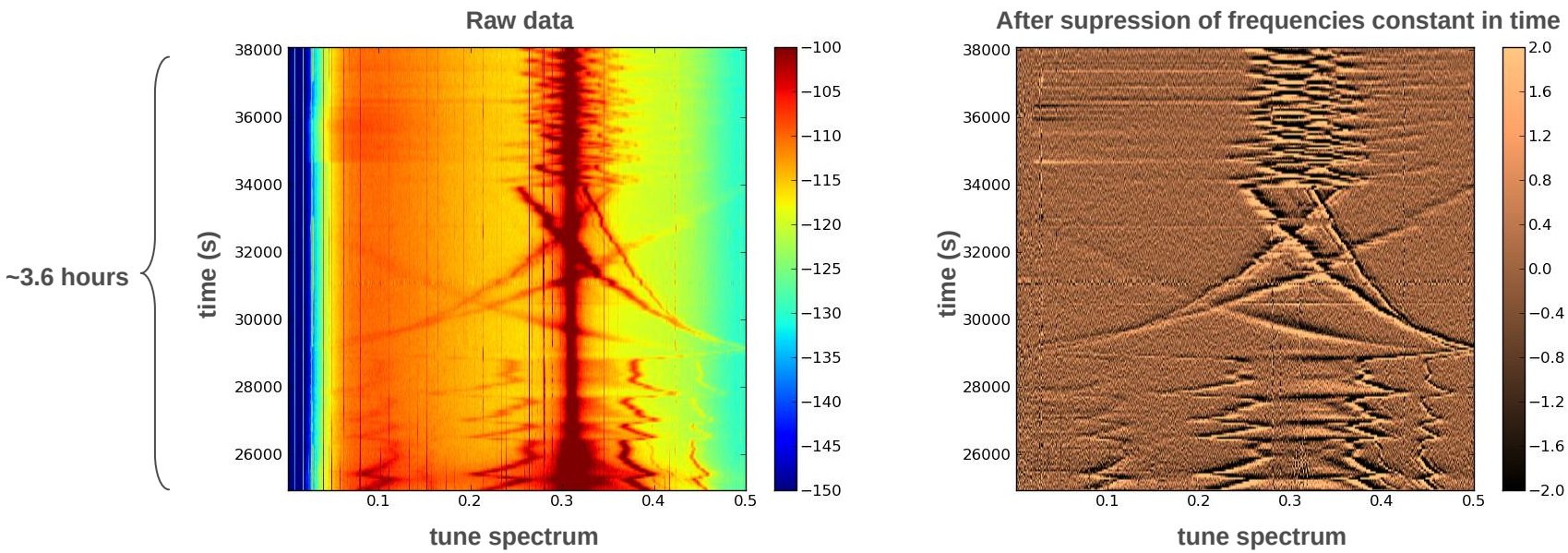
Time evolution of the hump frequency (3/3)

- From the 21st of May onwards, the hump is still present all the time, but it is more stable in frequency, with very small amplitude oscillations

- One characteristic observed regularly during this period is that the time evolution of the hump frequency can show sudden variations

Frequency spectrum *vs* time, Beam 2-Vertical

13th June 2010



Sudden change of the time evolution of the hump frequency occured at 08:00 and 09:25 AM

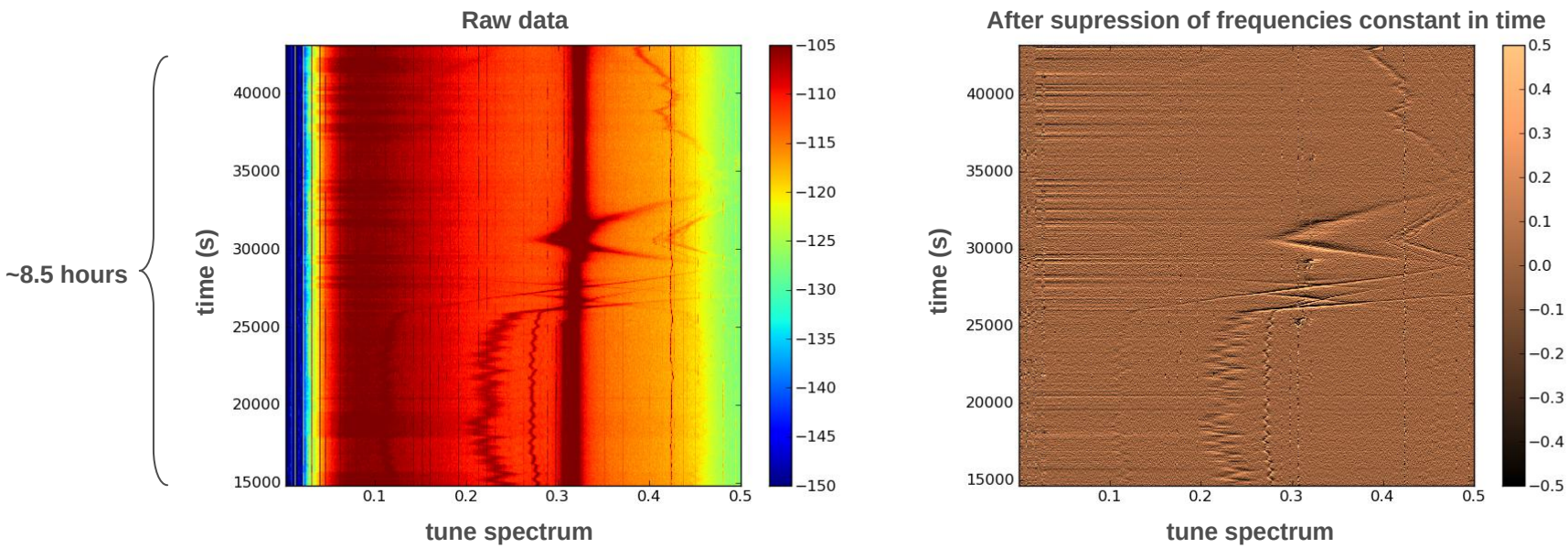
Time evolution of the hump frequency (3/3)

- From the 21st of May onwards, the hump is still present all the time, but it is more stable in frequency, with very small amplitude oscillations

- One characteristic observed regularly during this period is that the time evolution of the hump frequency can show sudden variations

Frequency spectrum *vs* time, Beam 2-Vertical

1st July 2010



Sudden change of the time evolution of the hump frequency occured at 07:11 and 09:22 AM

Analysis of the sudden changes

- The sudden changes of the time evolution of the hump frequency have been investigated in order to identify

→ if they follow any temporal pattern

→ possible correlations with external factors or actions on any system of the machine

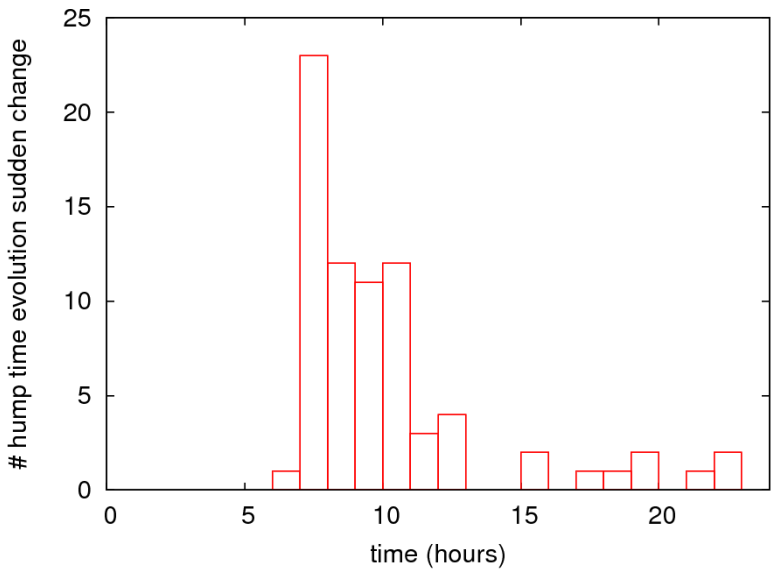
- The data acquired with the BBQ from the 22nd May to the end of September has been analysed

→ the time stamps of all the observed sudden changes have been noted

Analysis of the sudden changes over a day

Aim: to identify if there is any time interval over a day where these changes are most likely to happen

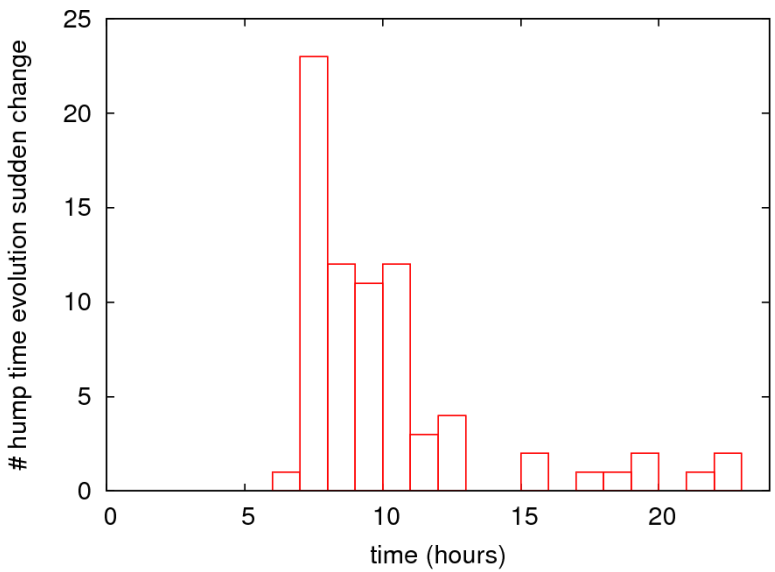
Histogram of the observed sudden changes of the time evolution of the hump frequency over the time of the day



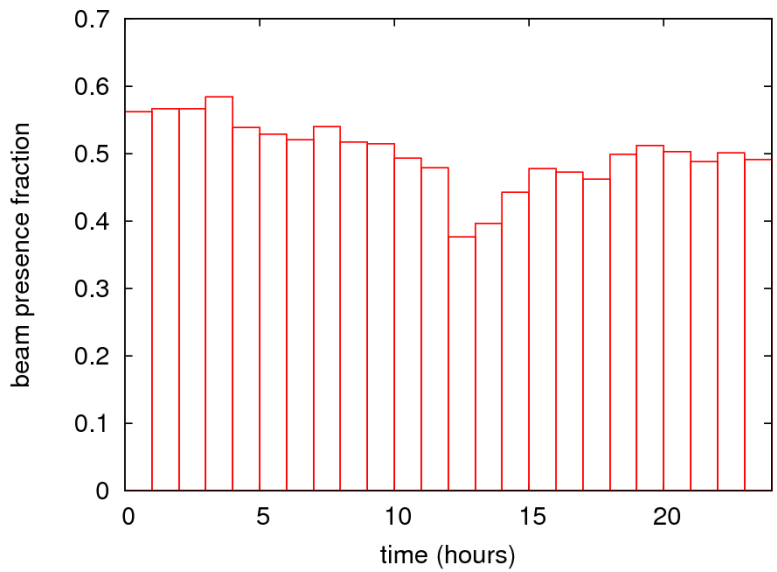
Analysis of the sudden changes over a day

Aim: to identify if there is any time interval over a day where these changes are most likely to happen

Histogram of the observed sudden changes of the time evolution of the hump frequency over the time of the day



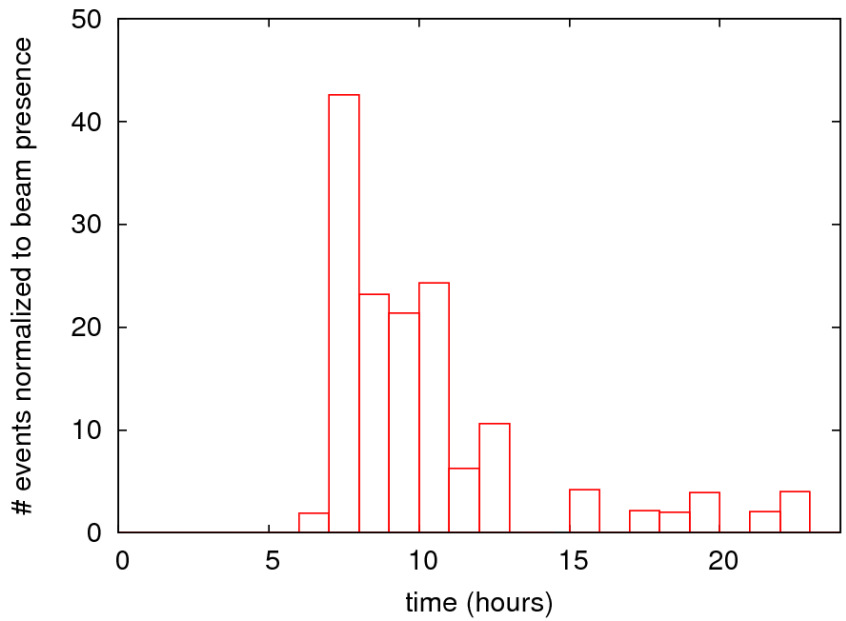
Beam presence fraction* over the time of the day



*We consider that there is beam presence when the averaged intensity over a minute is higher than 10^9 particles

Analysis of the sudden variations over a day

Histogram of the sudden changes over the time of the day normalized to the beam presence fraction



→ Most of the changes occured in the morning, notably between 7 and 8 AM

→ A few cases were observed in the afternoon and evening

→ No sudden changes were observed during the night

Analysis of the sudden variations over a day

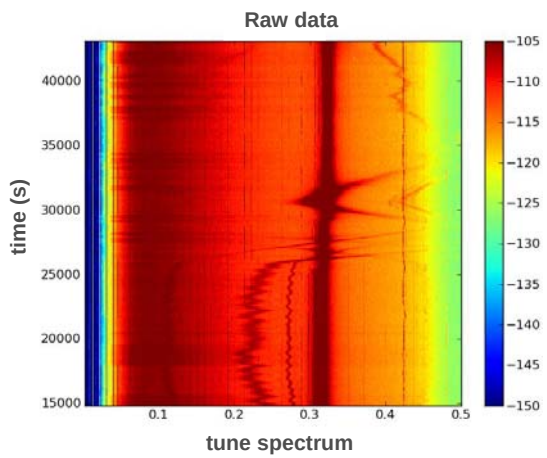
During July, the pattern of the time evolution of the hump frequency was rather reproducible

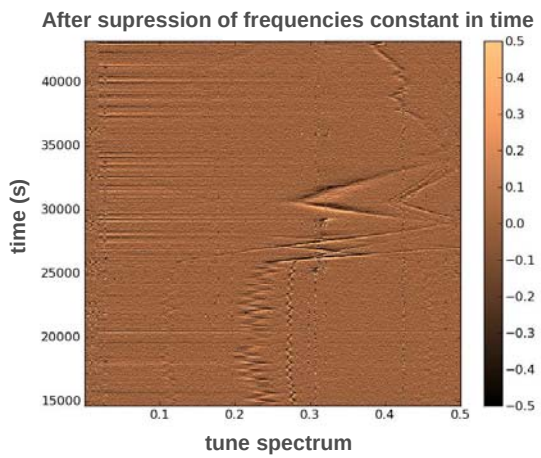
→ about 10 of the sudden changes were produced in different days at around 07:10 AM ± 15 minutes (two other cases at about 8:30 and 10:30 AM)

→ the hump signal passed from a situation of stable frequency in time, to big oscillations sweeping a broad frequency span

→ in all the above cases, one or two hours after, there was another sudden variation coming back to a situation where the hump frequency was more stable

→ in most of the days of July where no sudden change was observed in the morning, there was no beam during this period of the day





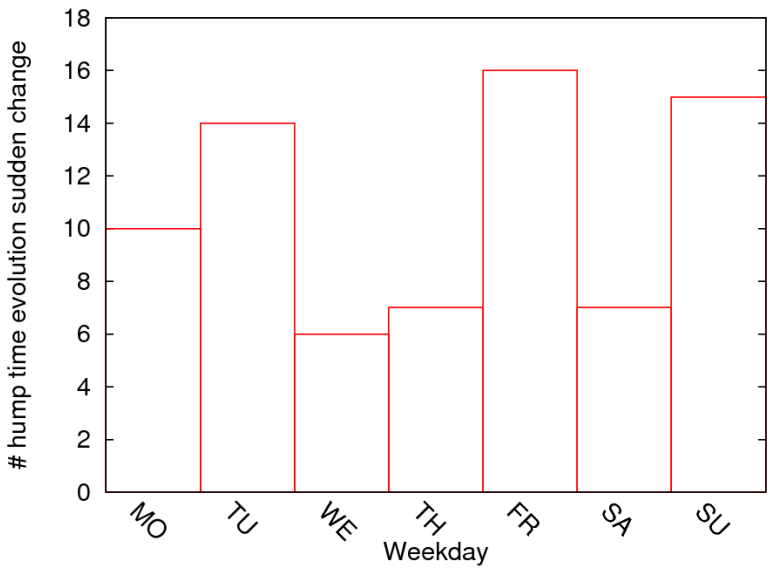
1st July 2010

Sudden changes at 07:11 and 09:22 AM

Analysis of the sudden changes over a week

Aim: to identify if the sudden changes occurs more frequently on certain days of the week

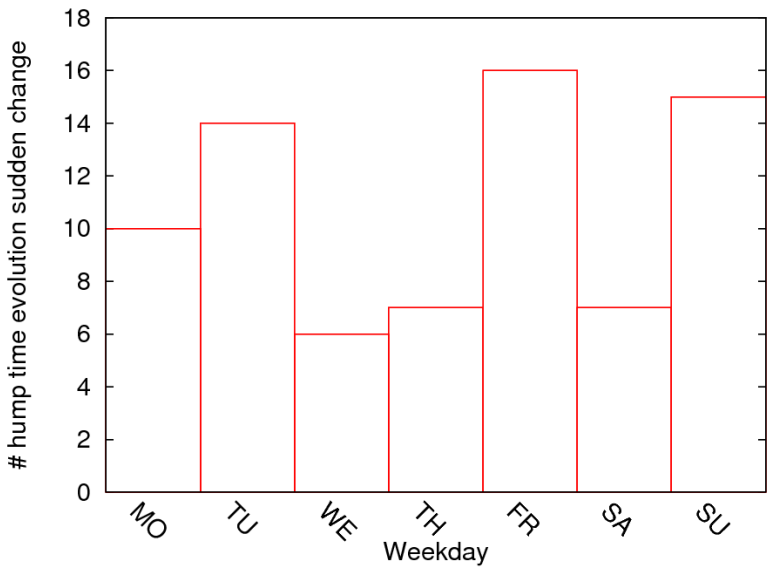
Distribution of the observed sudden changes of the time evolution of the hump frequency over the week



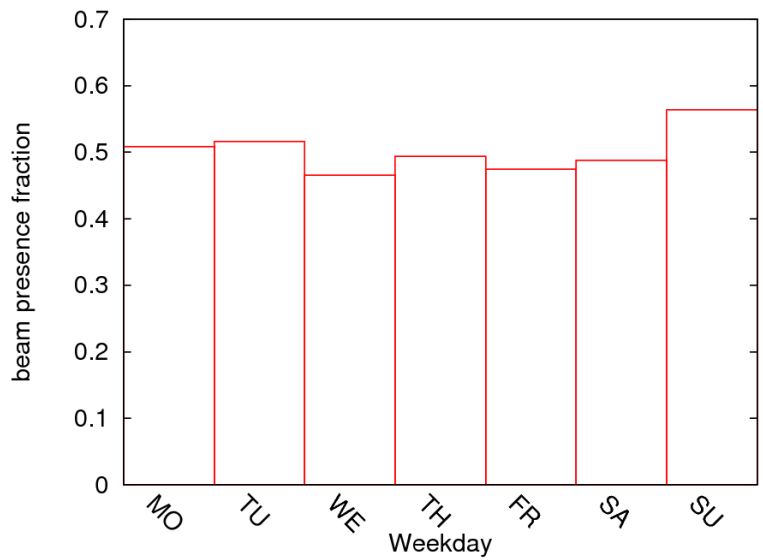
Analysis of the sudden changes over a week

Aim: to identify if the sudden changes occurs more frequently on certain days of the week

Distribution of the observed sudden changes of the time evolution of the hump frequency over the week

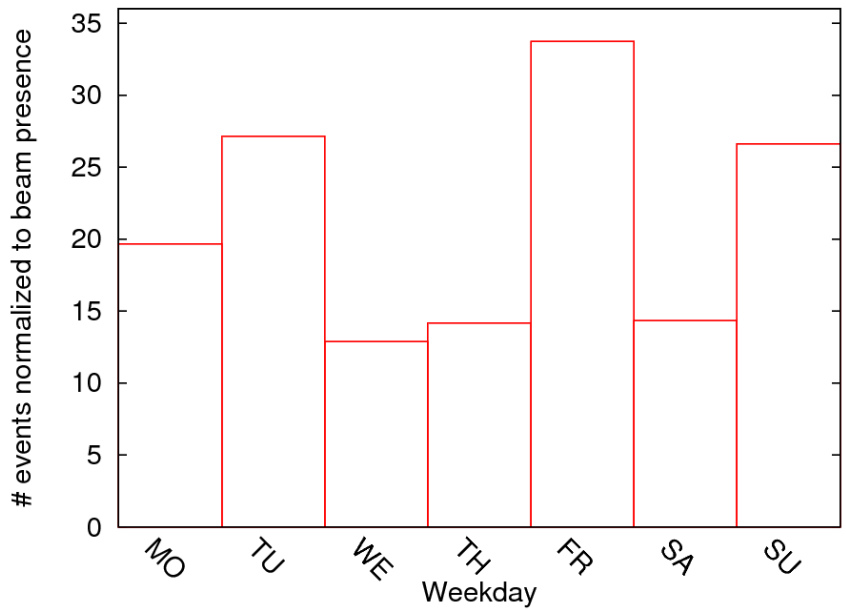


Beam presence fraction over the day of the week



Analysis of the sudden variations over a week

Distribution of the sudden changes over the week normalized to the beam presence fraction

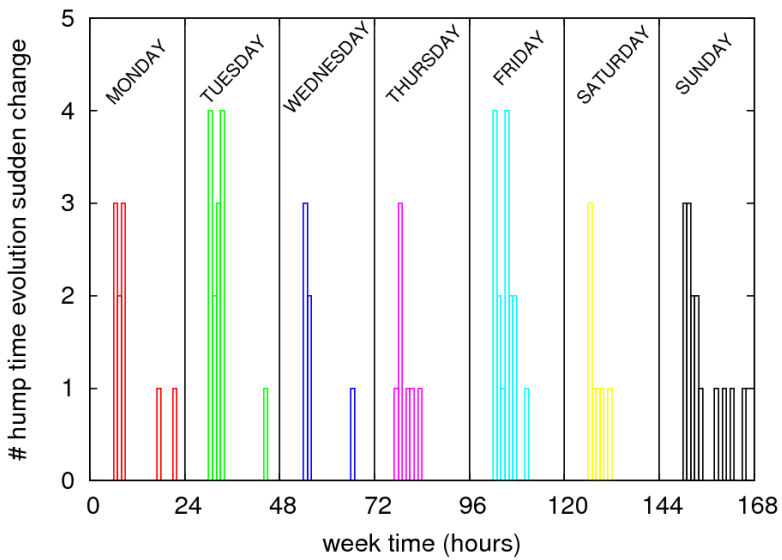


→ The probability to have a sudden change varies significantly from one day to another one

Differences over the day of the week

Aim: to identify if the sudden changes use to happen at different times on the different days of the week

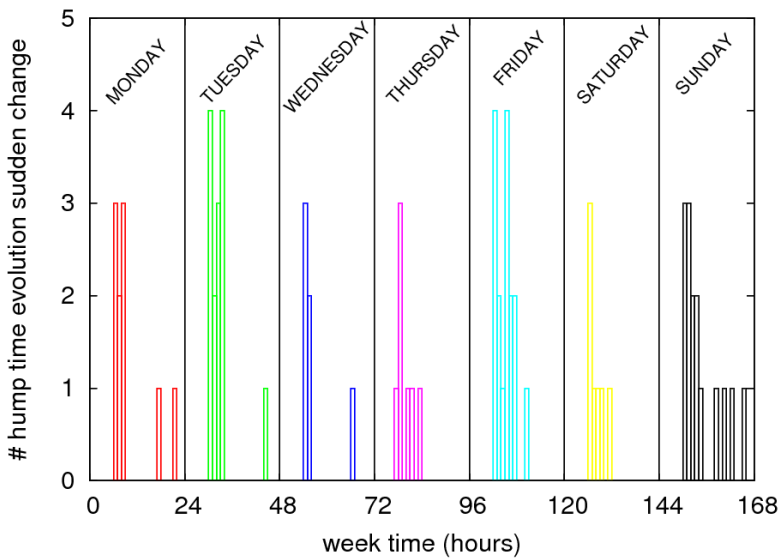
Distribution of the observed sudden changes versus time of the day for the different days of the week



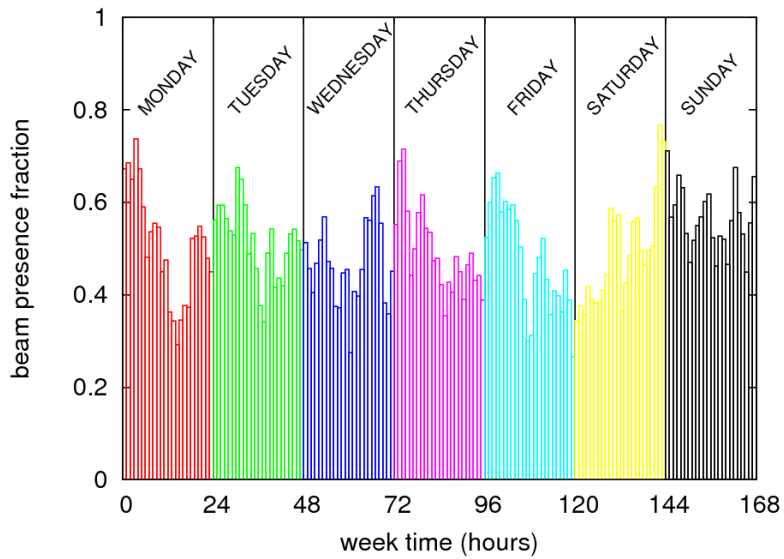
Differences over the day of the week

Aim: to identify if the sudden changes use to happen at different times on the different days of the week

Distribution of the observed sudden changes versus time of the day for the different days of the week

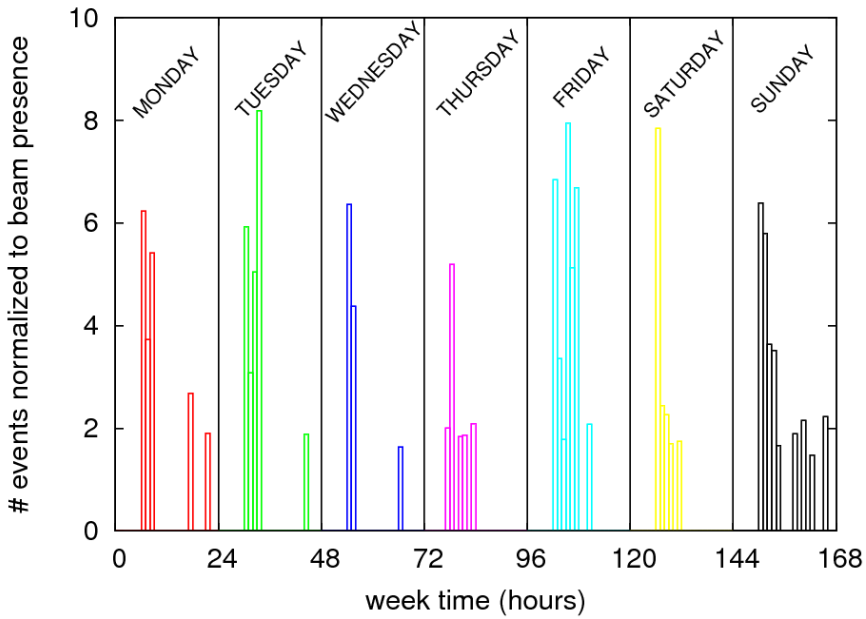


Beam presence fraction over the time of the day for the different days of the week



Differences over the day of the week

Distribution of the sudden changes over the time of the day normalized to the beam presence fraction, for the different day of the week



→ the distribution of the event versus the time of the day is independent on the day of the week

→ there is not a different pattern during the week days or during the weekend

Conclusions (1/2)

● The so-called hump signal has been present all the time in the frequency spectrum since the LHC started operation, varing in frequency slowly with time and sweeping different frequency spans.

● One of the observed characteristics of the hump is that the time evolution of the frequency is subject to sudden changes.

● These sudden variations of the frequency time evolution have been investigated for a period of the operation (from 22nd May to the end of August):

→ They occurred often in the morning (specially from 7 to 8 AM), passing from a stable oscillation of the frequency in time to sweep a broad frequency span.

→ About one or two hours later, another sudden change was normally observed passing to a situation where the hump frequency was more stable in time.

→ A few cases where observed in the afternoon and the evening.

→ No sudden changes were observed during the night.

Conclusions (2/2)

- No correlation of the temporal pattern with external factors or actions on any system of the machine has been identified yet.

- Although during the operation in 2011 the hump signal is more stable in frequency and far away from the tunes normally, and its intensity seems to be reduced, the identification of its source is still important.