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bjorn.hans.filip.lindstrom@cern.ch

MD#2889: 16L2 Event Dynamics and UFO Nature Investigation

Bjorn Lindstrom, Andrea Apollonio, Philippe Bélanger, Martyna Dziadosz, Arkadiusz Andrzej Gorzawski, Laura Katharina Grob, Eva Barbara Holzer, Anton Lechner, Tatiana Medvedeva, Ruediger Schmidt, Matthieu Valette, Daniel Wollmann

UFO, dust particles, Machine Protection, Fast Failures

Summary

Micrometer sized particles (UFOs) entering the beam are a known cause of localized beam losses since the beginning of high intensity beam operation, however the origin of these particles is not fully known. Furthermore, during 2017 a new type of UFO events appeared around the 16L2 interconnection in the LHC, leading to beam instabilities resulting in major impact on beam availability. In MD#2036 a proof-of-concept method utilizing blown-up bunches and a fast loss detection system for studying the dynamics of UFOs, simulated by the wirescanners, was successfully attempted. In this MD it was shown that real UFO dynamics are possible to study employing this method.

The MD was done in parallel with MD#2934 and the procedure was adjusted for both MDs to profit as much as possible. In the end a single 16L2 induced beam dump occurred, but several conclusions about the UFO dynamics can already be drawn.

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1. Introduction

Micrometer sized dust particles intercepting the beam (UFOs) have been present in the LHC since the beginning of high intensity beam operation. While the typical UFO gives a sudden loss spike that quickly disappears, in 2017 a new type of UFO event emerged around an interconnection in 16L2, in which the beam becomes unstable resulting in a runaway of losses following the initial UFO loss spike. In total there were 66 of these events leading to dumps and even one quench during operations, plus one during this MD, having a major impact on availability.

The leading hypothesis about the origin of this new type of UFO event is that a dust particle consisting of frozen gas falls into the beam and evaporates **[1]**. The resulting gas cloud is ionized leading to a plasma of ions and electrons, causing the witnessed beam instability. In order to solve the problem, a beam screen flushing was first attempted, however with undesirable result. After this, during TS2, a solenoid as well as the diamond BLMs (dBLMs) used in this MD were installed. The purpose of the solenoid was to help prevent electron cloud effects **[2]**.

In MD#2036 **[3]** a proof-of-concept method for the study of UFO dynamics was employed in which a few bunches are blown-up by the ADT either vertically or horizontally. The wirescanners were then used to simulate a macroparticle intercepting the beam, with the resulting elastically scattered protons measured by the dBLMs installed in the collimation region in IR7. As the blown-up bunches have a larger beam size, the ones blown-up in the same plane as the wirescanner was moving gave rise to losses several turns earlier than the untouched bunches. Furthermore, by looking at the difference in signal between the bunches, it was possible to determine the speed of the wire.

This method was subsequently attempted for 16L2 events, however due to the relatively low level of elastically scattered protons from the interaction with these UFOs making them undetectable in the IR7 dBLMs, locally installed dBLMs were necessary.

2. Measurement setup

dBLMs were temporarily installed in 16L2 at the position of maximum signal expected from FLUKA simulations **[4]**. The MD consisted of one injection energy part, and one top energy part. In the injection energy part, the machine was filled with BCMS beams of 2460 bunches with 196 bunches blown up to 5 µm per plane and beam, whereas the top energy part used 8b4e beams of 1868 bunches, with 256 blown-up bunches per plane. The vertical emittance including the ADT excitation windows for the two planes can be seen in **Figure 1**. Due to coupling between the planes during excitation, horizontally blown-up bunches were also blown-up vertically and vice versa. The difference between the two groups of blown-up bunches was however enough for detecting differences in their interaction with the dust particles.

In both cases the solenoid was switched off and the 16L2 orbit bump removed after the bunches were blown-up but before ramp. For more details see the procedure **[5].**

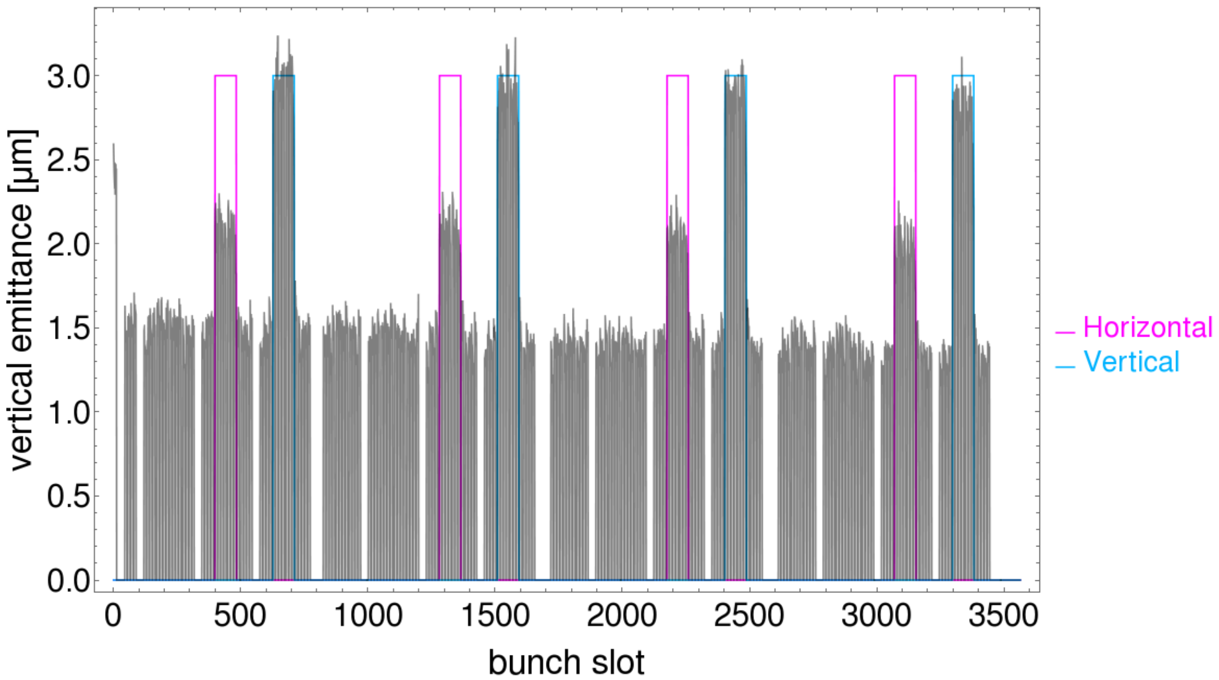

Figure 1 – The vertical emittance for all bunches as measured by the BSRT just before starting to ramp during the fill that was dumped by a 16L2 event. The windows used for vertical and horizontal blow-up are indicated. Due to coupling between the planes in the blow-up there was a leakage to the bunches being blown-up in the other plane. The horizontal emittance shows a similar, but reversed, image.

3. Main Results

A dump occurred at 5.5 TeV caused by a 16L2 event in b1. **Figure 2** compares the 40 µs integrated signal for the ICBLMs with the dBLMs in Gray/s for the time preceding the dump. The dBLM signal is scaled to the ICBLM signal. A very good linear correlation can be seen between the two, giving a high confidence in the dBLM data despite its much smaller active volume. The initial UFO spike was visible in this particular event, as can be seen in the beginning, covering roughly five LHC turns.

Splitting the integrated signal of the diamonds into the three different groups of bunches (see **Figure 3**), i.e. normal, vertically blown-up and horizontally blown-up bunches reveals that the vertically blown-up bunches are detected earlier than the horizontally blown-up and the normal bunches. Furthermore, the vertically blown-up bunches give rise to significantly more signal throughout the whole UFO-spike. First of all this implies that the dust particle was moving in the vertical plane, such that it started interacting with the vertically blown-up bunches first. Secondly, this data also implies that the dust particle never entered the beam core before either being repelled or evaporated, as then the signal from the normal bunches should have been the highest.

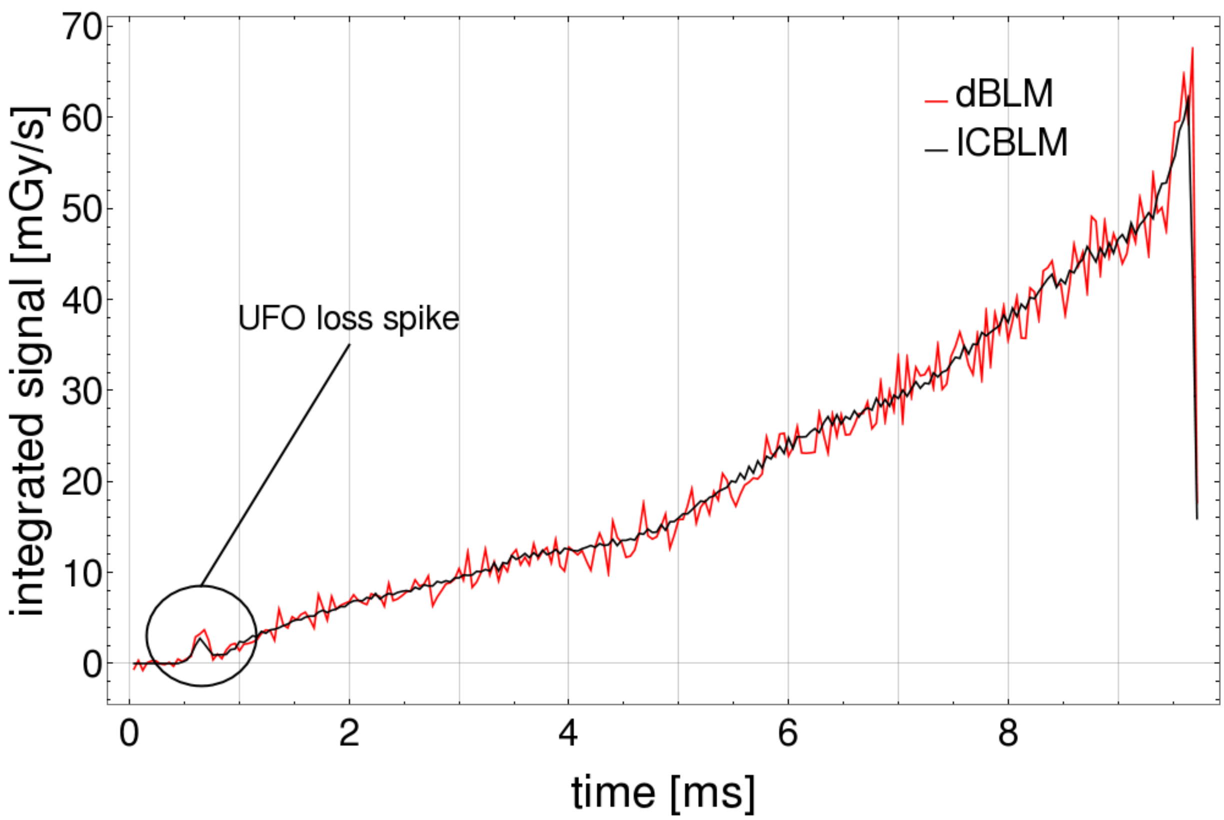

Figure 2 – Comparison between the ICBLM data with running sum 1 and the dBLM data integrated in 40 µs buckets scaled to the ICBLM data in Gray/s. The plot shows a very good linear correlation between the ICBLM and the dBLM.

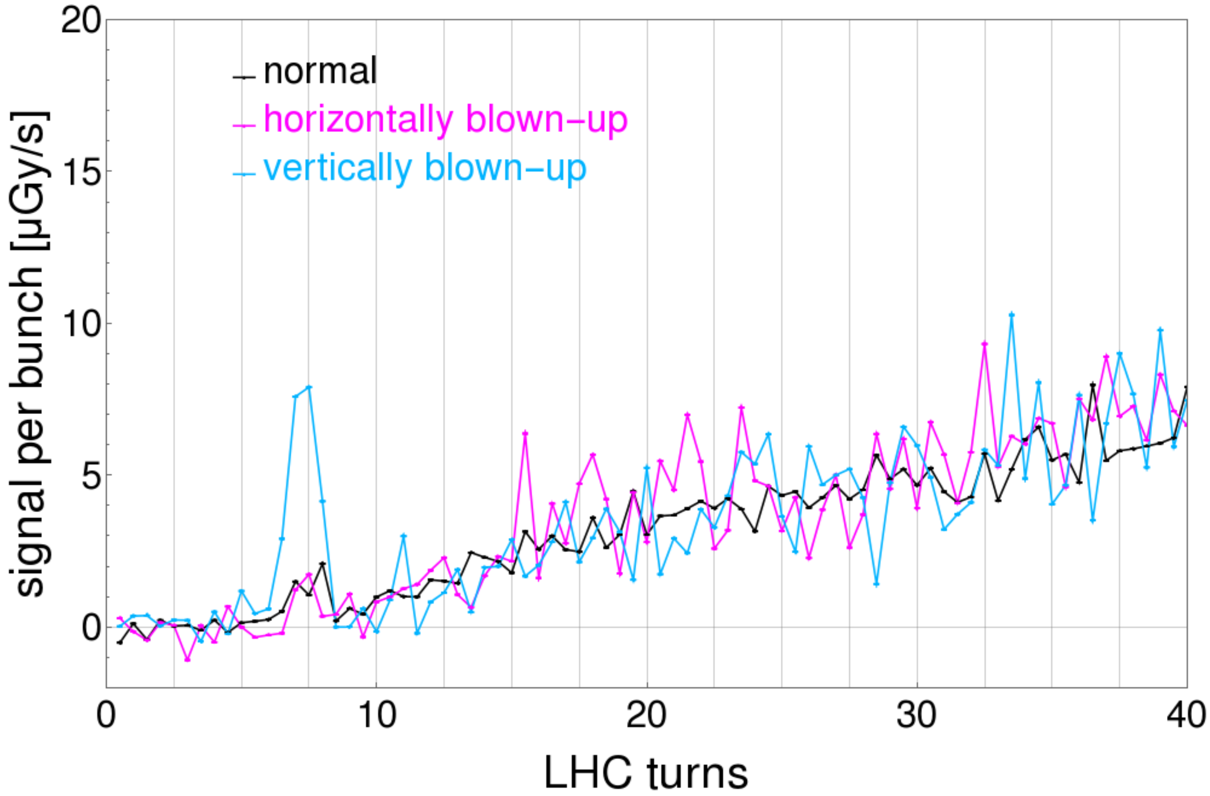

Figure 3 – This plot shows the ratio of detected bunches per turn, split into the three groups of bunches (normal, horizontally blown-up and vertically blown-up). For visibility a zoom on the UFO-spike is included, where one can see that the vertically blown-up bunches were detected earlier than the others. One can also see that the vertically blown-up bunches gave more losses throughout the whole UFO-spike, and were thus detected with a higher probability.

4. Ongoing analysis

As there are still many unknowns surrounding UFOs in general and 16L2 events in particular, the analysis on the data from this MD as well as 16L2 events in general is still ongoing. The problem is approached from two perspectives; a deterministic simulation model of dust particles interacting with the beam capable of calculating movement of the dust particle, energy deposition and ionization, as well as a statistical simulation based on FLUKA. The goal is then to benchmark the simulations with the data in order to be able to make extrapolations to future beam parameters, such as the HL-LHC, as well as to estimate what kind of materials can lead to this type of fast failures observed in 16L2.

While the conditions necessary for vaporization of the dust particle is best simulated by the deterministic model, the transverse position at various moments in time can be estimated in three independent ways; by looking at the ratio of measured losses between the blown-up bunches and the normal bunches, from the deterministic simulations, and lastly from FLUKA simulations in combination with ICBLM data. However, assumptions on e.g. the bunch distributions need to be made in all cases, giving a certain uncertainty. Furthermore, the data from the dBLMs is subject to significant noise in this particular MD due to the low local losses.

Important input is also taken from the instability simulations in BE-ABT group.

5. Conclusions

5.1 Initial Results

This MD successfully demonstrated the viability of the scheme for studying UFO dynamics using blown-up bunches and a fast loss detection system. Initially it can be concluded that the dust particle was moving in the vertical plane and did not enter the beam before being repelled or vaporized, but with further data analysis, as well as comparison with simulations, it should be possible to give more quantitative answers on the turn-by-turn evolution of the dust particle.

5.2 Further studies in 2018

Aside from the ongoing analysis of the current data as well as improvement of the simulation models, since only one single event has been recorded using blown-up bunches and a fast loss detection system, it is also important to gather more data. While the position of normal UFOs is not as predictable as the 16L2 types were, their UFO loss spikes are visible in the IR7 dBLMs, making the study of normal UFOs with the scheme used in this MD feasible. It is therefore proposed to have a set of non-colliding bunches blown-up vertically and horizontally respectively during the machine recommissioning which is usually a time of intense UFO activity. With that data it would be possible to further refine the understanding of beam-dust particle interaction and to learn what their impact could be in future machines, where the end goal is to learn how to limit their frequency and impact on beam availability, and more importantly to prevent any potential damage to the machine.

References

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[3] MD#2036: UFO dynamics studies and UFO fast detection, CERN MD note (2018), P. Bélanger

[4] 16L2 – proton interactions with UFOs, 64th BLM Thresholds WG Meeting, Feb 6th 2018, A. Lechner

[5] MD#2889: 16L2 Event Dynamics and UFO Nature Investigation Procedure, M. Valette