CERN

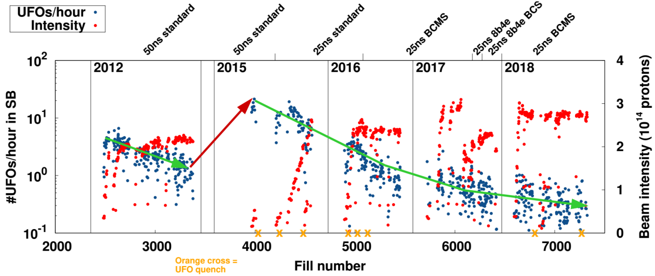
Update on UFO Dynamics Studies

Simulations and Run 2 events analysis

P. Bélanger, B. Lindstrom, R. Schmidt, C. Wiesner, D. Wollmann

A word on UFOs

From A. Lechner : "Update about (non-16L2) UFOs" (2018)



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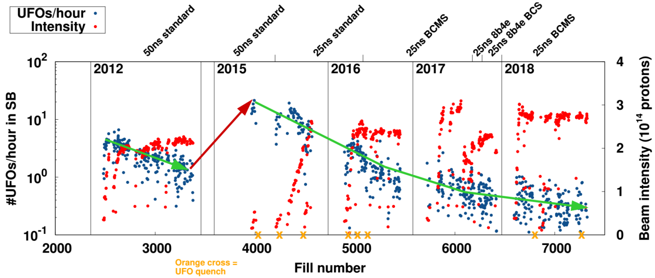


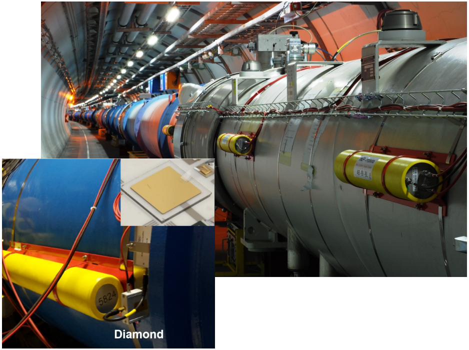
Why do we care?

- Beam dumps? Yes, 115 during Run 2
- Magnet quenches? Yes, 8 during Run 2
- Intensity drop? No, negligible during p-p physics (not an electron machine)

Data Collection

Instruments

- Beam Loss Monitors (BLM)
- Diamond BLMs (dBLM)



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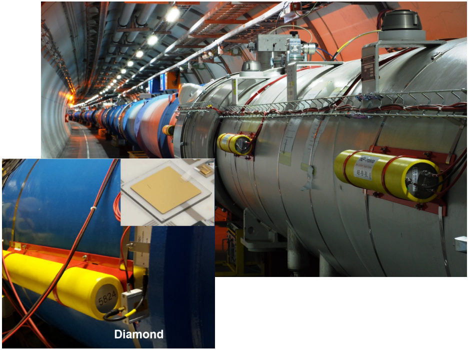
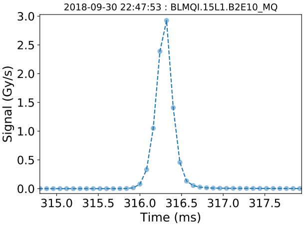


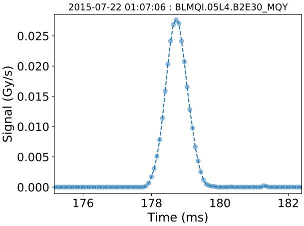
Databases

- UFO Buster :
  - Beam parameters
  - Triggers Capture Buffer : 80 μs resolution BLM signal
- Post-Mortem database : 40 μs resolution BLM signal
- dBLM database : 1.6 ns resolution diamond BLMs signal

Time profile examples

Some events with signal

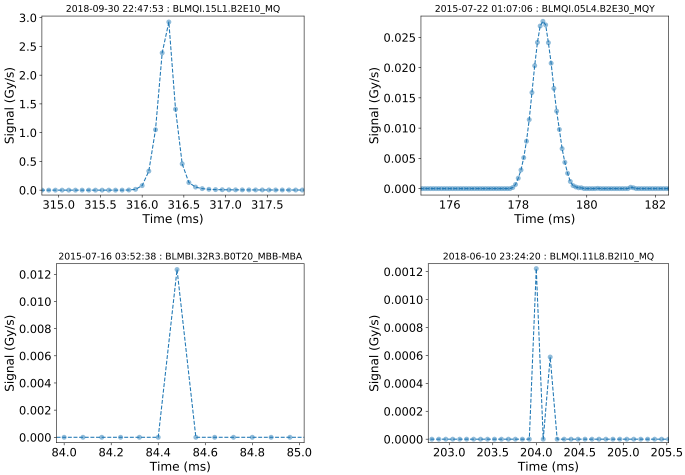




Time profile examples

Some events with signal

And some with not much information...



Time profile examples - Measurements

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UFO Buster	337,217

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Following slides: → Filter 2 (min. 5 points signal)

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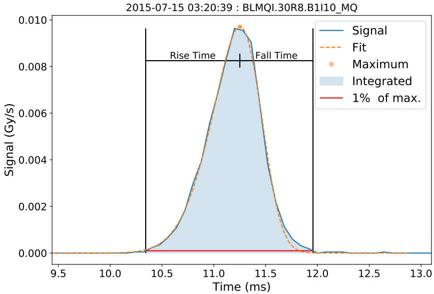
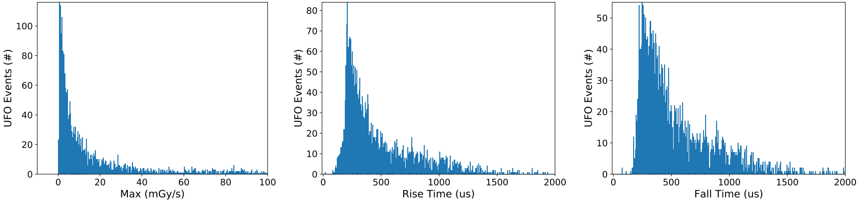
Following slides: (Filter 2 row)



Measurements overview

Parameter		Min.	-	Max.
Maximum Losses	(Gy/s)	9.05×10^{-5}	-	3.16
Integrated Signal	(Gy)	2.90×10^{-8}	-	2.02×10^{-3}
Rise Time	(μs)	91	-	4241
Fall Time	(μs)	109	-	3876
Full length	(μs)	317	-	7118

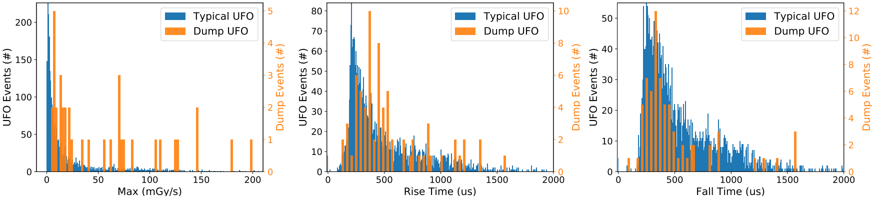


Normal UFOs v.s. Dump UFOs

Dump UFOs seem to have :

- Higher losses
- Longer rise time
- Shorter fall time

However, not a lot of statistics... In-depth analysis of the dump UFOs is still to be done.



Dynamics Simulation Tool

Tool developed (starting in 2010, F. Zimmermann, B. Auchmann *et al.*) to simulate UFO dynamics :

1. UFO begins to fall and/or be attracted toward the proton beam
2. UFO-beam interaction knocks-off electrons in the UFO (ionization) and lead to proton losses
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Recently translated in Python by R. Schmidt, and under continuous development

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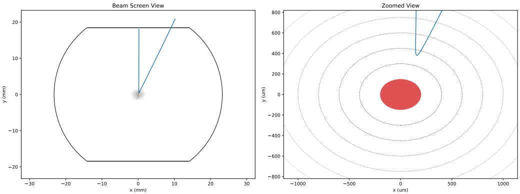
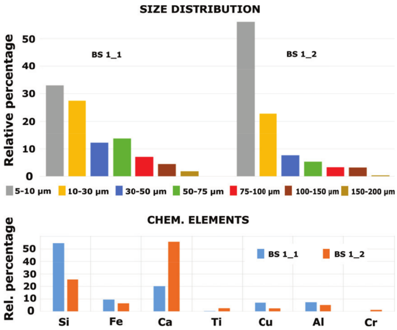


Simulations - Parameter scan

- Range of parameters is based on past studies:
  - FLUKA simulations (A. Lechner)
  - Dust collection in the beam pipe (L. Grob)

From L. Grob : "Dust Analysis From LHC Vacuum System to Identify the Source of Macro Particle-Beam-Interactions" (2019)



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Parameter	Values
UFO Charge	$0 - 10^8 \cdot (-e)$
UFO Position	Top of beam screen
UFO Radius	$1\ \mu m - 50\ \mu m$
UFO Material	Cu, Si, Al
Beam Energy	6.5 TeV
Beam Intensity	$3 \times 10^{10} - 3 \times 10^{14}$
Beam σ_x	$50\ \mu m - 500\ \mu m$
Beam σ_y	$50\ \mu m - 500\ \mu m$

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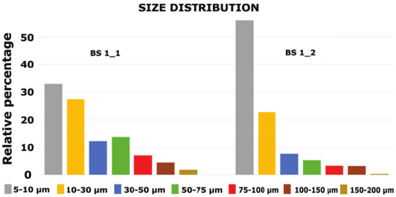
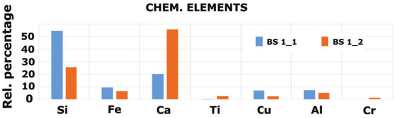
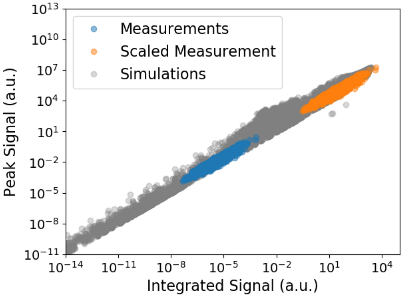




Simulations - Results



Log-Log axis

- Expected "calibration" constant (BLM response to incoming particles)
- Can be calculated with FLUKA
- Scaled measurements move along the simulated line : compatible with the need for this BLM calibration

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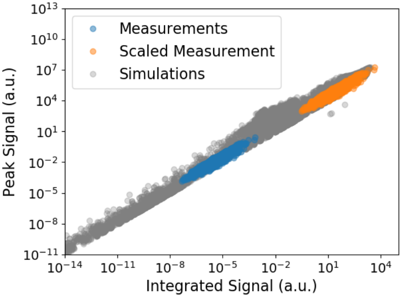

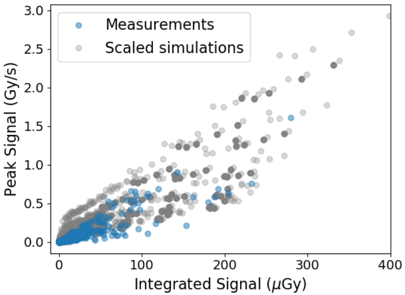

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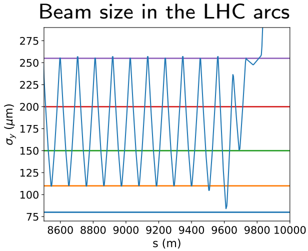
Regular axis

- Range of σ_y influences the thickness of the simulation band (left figure) and the slope (right figure)
- Coverage is compatible with measurements for same σ_y range

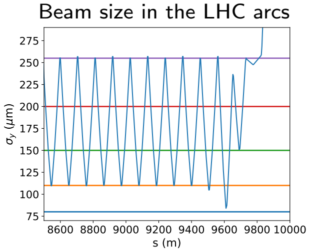
Simulations - Beam size



Simulations - Beam size

Let's look at the ratio (Integrated signal)/(Peak Signal)

- Units of seconds
- Independent of the BLM calibration
- Equivalent to time spent in the beam by the UFO
- From previous slide : highly dependant on σ_y



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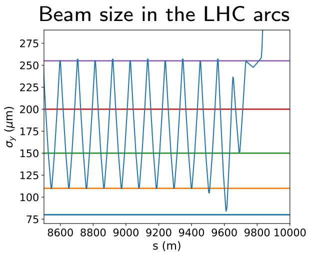

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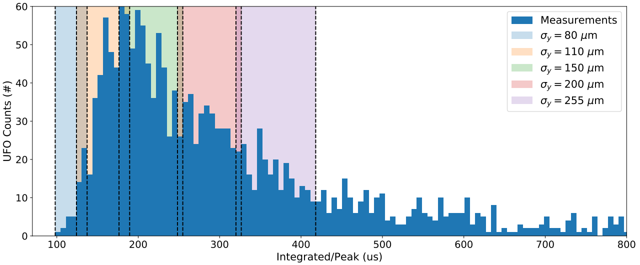

Simulations - UFO Charge

- Since 2010, it is hypothesized that the fall of UFOs is not only driven by gravity
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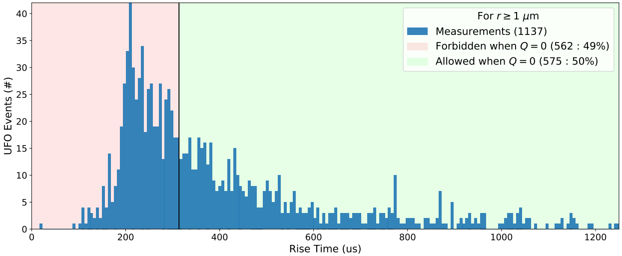

UFO dynamics driven by gravity alone is incompatible with measurements!

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- Next logical step : what is the minimum charge which allows to explain the measurements?

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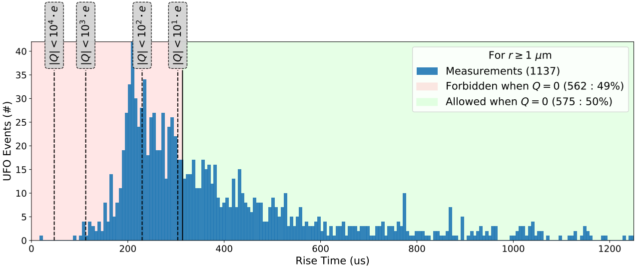
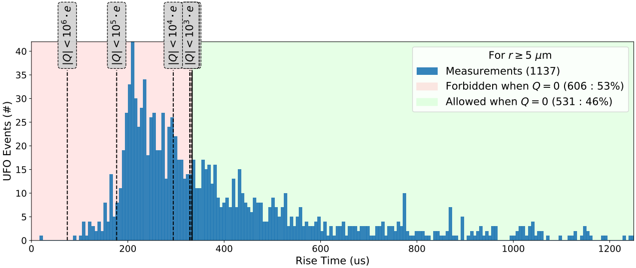


UFOs are generally charged with $|Q| > 1000 \cdot e$ $(-1.6 \times 10^{-16}$ C)

Simulations - UFO Charge

- With increasing UFO radius, more and more charges are needed to explain the measurements



UFOs with $r \geq 5$ μm are generally charged with $|Q| > 10^6 \cdot e$ $(-1.6 \times 10^{-13}$ C)

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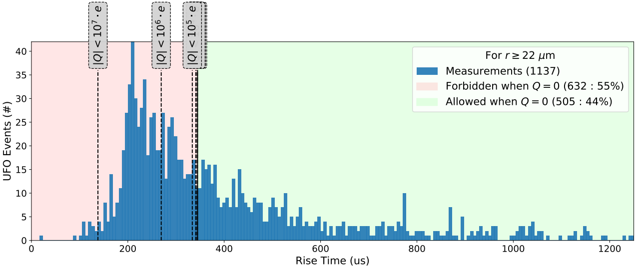

UFOs with $r \geq 22$ μm are generally charged with $|Q| > 10^7 \cdot e$ $(-1.6 \times 10^{-12}$ C)

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- Overall : gathered important statistics which could help understand release mechanism!

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- Monte-Carlo simulations with appropriate distributions for the input parameters of the dynamics simulation is needed to further our understanding.

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Summary of work done

Since January 2019 :

- Literature review of previous UFO studies.
- Development of a more accurate description of the electric field around the LHC proton beam.
- Upgrade of the UFO Dynamics Simulation Tool
- Development of new methods of analysis for studying UFO bunch-by-bunch signals.
- Gathering of all available data from standard beam operation between 2015 and 2018. First look and direct conclusions.
- Started an in-depth analysis of the data mentioned above.

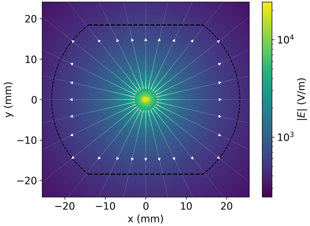
E-field around the LHC proton beam

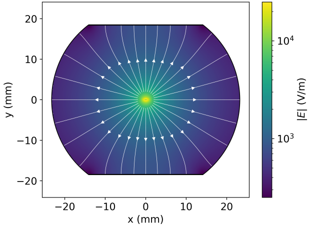
- Original approximation considered the Houssais E-field in free space (i.e. no beam screen)

- A new method to solve Laplace's equation for complex boundary conditions was developed and allowed to find a more accurate description of the E-field

Bélanger, P. (2019). Generalizing the Method of Images for Complex Boundary Conditions : Application on the LHC Beam Screen.

https://arxiv.org/abs/1905.03405





E-field around the LHC proton beam

Conclusion : ignoring the beam screen accounts for an error of 1% in the E-field at 1σ from the center of the beam and 10% at 30σ

The method developed can also be used for off-centered beam, at really low computing cost.