

# Halo cleaning: What have we learned from 2017

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November 16, 2017



# Outline

## Introduction

- Sources of the halo data
- Experiments procedure

## Halo reconstruction

## Other beam observations

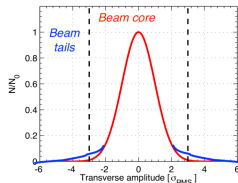
- Diffusion parameters
- Loss spectrum analysis

## Wrap up

- General loss observations

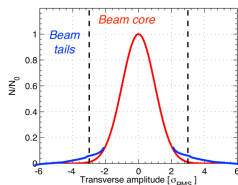
# Introduction

- ▶ From the previous years observations, overpopulated LHC beam halo consists of 5% of the stored energy.
- ▶ Is 2017 overpopulation (as well the one from the past years) scalable to the HL-LHC ?



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## Scope of this talk:

- ▶ End of Fills tests (including tests with 220MJ beam with 2550 bunches)
- ▶ Dedicated MD test with HL-LHC like beam ( $1.6e11$ /bunch, total 220 bunches)

# Collimator scraping campaign

Fill nb.	date	$n$	Beam1		Beam2		scans performed
			$I_{st}$	$I_s$ (% of $I_{st}$ )	$I_{st}$	$I_s$ (% of $I_{st}$ )	
5834	2017-06-15	900	8.8e13	5.9e12 (7%)	8.9e13	3.3e12 (4%)	B1/ B2 H/V
5848 <sup>1</sup>	2017-06-20	1741	1.2e14	1.2e13 (10%)	1.3e14	4.9e12 (4%)	B1/ B2 H
5849	2017-06-21	2029	1.3e14	9.8e12 (8%)	1.36e14	5.2e12 (4%)	B1H B2 V
6052	2017-08-06	2550	1.9e14	2.3e13 (12%)	2.1e14	2.3e13 (11%)	B1/B2 H/V
6194 <sup>2</sup>	2017-09-13	224	2.7e13	1.1e13 (40%)	2.7e13	1e13 (36%)	B1/B2 H/V
6199 <sup>3</sup>	2017-09-14	3	n/a				B2 H/V

**Table 1:** Summary of the End of fill scraping MD performed in 2017. Where  $n$  is the number of bunches,  $I_{st}$  is the total intensity at the the start of the scraping,  $I_s$  is the total intensity lost during scraping.

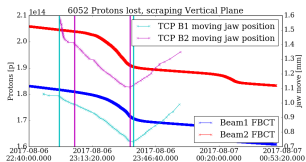


# Halo reconstruction

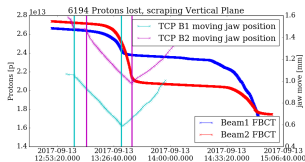
# Halo reconstruction 2017

Using the steps data we have reconstructed the beam halo (here shown for 2550b and 220b tests)

- ▶ Reconstructed both planes but only **first scraped plane can be trusted**
- ▶ Conversion factor was used (deducted from the BLM to FBCT,  $1.3e-13$  Gy/p)



(a) 2550b Vertical plane



(b) 220b Vertical plane

## Halo reconstruction comparison wrt to 2016 [1]

In 2016, reconstructed halo indicated overpopulation **reaching one order of magnitude** higher than expected.

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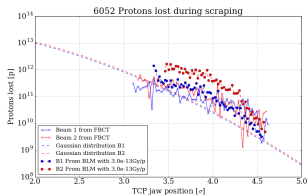
<sup>1</sup>Not the same configuration of the planes/beams was scanned through the campaign

# Halo reconstruction comparison wrt to 2016 [1]

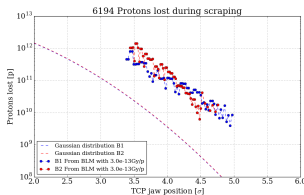
In 2016, reconstructed halo indicated overpopulation **reaching one order of magnitude** higher than expected.

In 2017 still present general overpopulation

- ▶ Some scans indicate reduction of the overpopulation wrt 2016<sup>1</sup>.



(a) 2550b Vertical plane



(b) 220b Vertical plane

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# Halo status – relative observations

## Caveat

Scans were done at the end of Stable Beams (reduced intensity), second plane may be affected by the first scan.

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## Relative comparison

Nominal Scanned	OP Beam (1.25e11) OP Beam (0.8e11)	HL-LHC (1.8e11) HL-LHC (1.1e11)
Beam 1	$H < \mathbf{V}$	$H \lesssim \mathbf{V}$
Beam 2	$H \lesssim \mathbf{V}$	$H < \mathbf{V}$

In **bold** the first scanned plane

## Halo status – extrapolation

- ▶ Visible difference wrt to the plane/beam configuration.
- ▶ Integrated charge ( $3\sigma - 5\sigma$ ) varies between  $4.2e12-4.5e12$  – 3%–5% of beam population
  - ▶ Above valid for the first scanned case (Vertical)
  - ▶ Spread comes from the different beam/plane and different filling scheme

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  - ▶ Above valid for the first scanned case (Vertical)
  - ▶ Spread comes from the different beam/plane and different filling scheme
- ▶ Extrapolating to the HL–LHC base parameters
  - ▶ 30 MJ (for 5% of full, fresh beam at 7 TeV)

Other beam observations  
Diffusion parameters

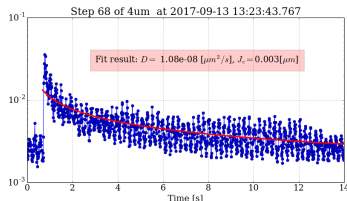
# Diffusion parameters methodology [2]

## Collimator scan

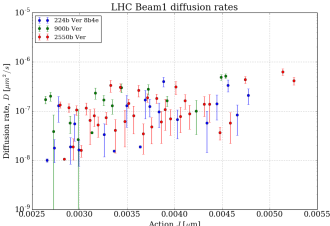
$$\partial_J f_l(J_c, t) \cong \underbrace{\frac{2(A_i J_{ci} - A_c J_c)}{\sqrt{4\pi Dt}}}_{\text{loss decay part}} \underbrace{\exp\left(-\frac{1}{2}\left(\frac{J_c}{\sqrt{2Dt}}\right)^2\right)}_{\text{loss rise part}}$$

$D$  diffusion coeff,  $J_x$  action for movement,  $A_x$  loss level,

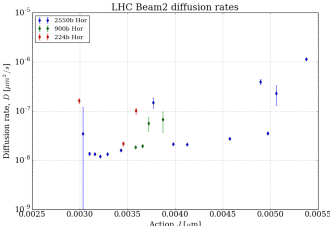
- ▶ Each step treated for fit,
- ▶ Error analysis by bootstrap of data subsets



# Diffusion parameters

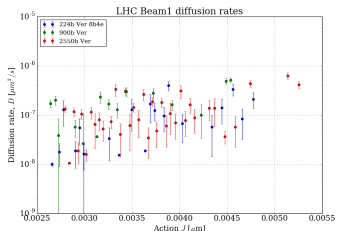


(a) Beam 1 Vertical

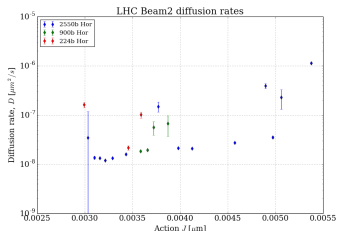


(b) Beam 2 Horizontal

# Diffusion parameters



(a) Beam 1 Vertical

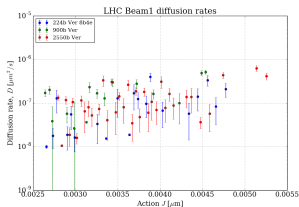


(b) Beam 2 Horizontal

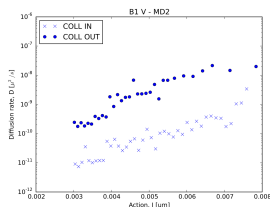
## Differences - study ongoing

- ▶ Amount of points depends on recorded/treated signal quality
- ▶ Order of magnitude difference between the extracted coefficients

# Diffusion parameters wrt 2016



(a) Beam 1 Vertical 2017



(b) Beam 1 Vertical 2016

## Visible change wrt 2016.

- ▶ Beam 1 growth of the diffusion speed ( $O(1-2)$ )
- ▶ Beam 2 growth (less than  $O(1)$ )

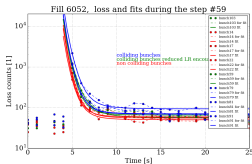
## Relative in 2017 (Preliminary!)

- ▶ Differences in planes of each beam are within the spread.

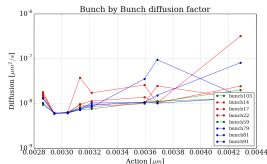
# Diffusion parameters bunch by bunch

Thanks to the diamond detectors (TCP), a similar analysis was done for the **bunch by bunch** case [4].

- ▶ While absolute loss is different for colliding/non bunches, the diffusion parameter does not vary (simplified plot below).



(a)



(b)

## Study on going!

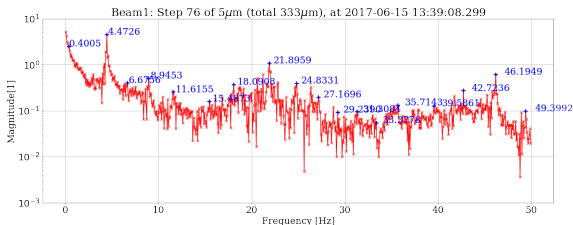
- ▶ Results Preliminary – ongoing work in usage in diamond loss detector data.
- ▶ Plane tangling involved – no dBLM per plane!

Other beam observations  
Loss spectrum analysis

# Loss spectra

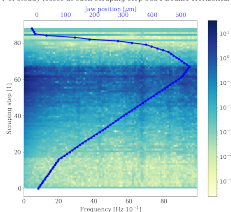
In the view of understanding different population reconstruction and different diffusion coefficients, a **frequency analysis** of the loss signal was performed.

Below an example from the  $3\sigma$  scan position.



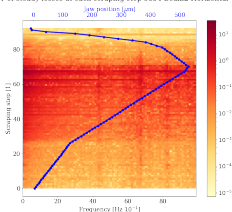
# Loss spectra - collimator scans

FFT of steady losses at each scraping step 5834 Beam1 Horizontal



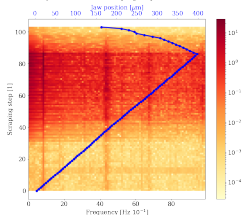
(a) Beam 1 Horizontal

FFT of steady losses at each scraping step 5834 Beam2 Horizontal



(b) Beam 2 Horizontal

FFT of steady losses at each scraping step 6052 Beam2 Vertical

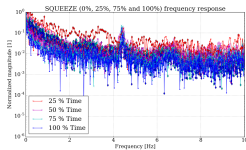


(c) Beam 2 Vertical

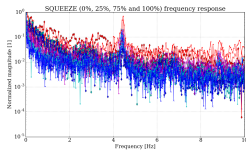
Visible **difference between** Beam 1 and Beam 2 in the low frequency response.

- ▶ strong 4.4 Hz contribution missing for Beam 1 Horizontal
- ▶ strong 1 Hz peak visible only for Beam 2 Vertical

# Loss spectra - operation cycle losses<sup>2</sup>



(a) Beam 1 Horizontal



(b) Beam 2 Horizontal



(c) Beam 1 Vertical



(d) Beam 2 Vertical

Loss frequency spectrum different than for the dedicated scan!

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<sup>2</sup> selected 10 fills from Oct-Nov 2017, Normalized to the strongest frequency

# Frequency analysis – conclusions

## Loss spectra indications:

- ▶ Frequency pattern is not halo scraping test dependent, occurs any time during the cycle
- ▶ Except few characteristic frequencies (4.4 Hz, 22 Hz, etc ) Beam 2 Vertical shows some activity at 1 Hz that is not visible in other beam plane configuration.

## Ongoing study

- ▶ Difference in the beam loss response may contribute:
  - ▶ to the general loss difference
  - ▶ halo reconstruction and diffusion analysis

# Conclusions and outlook

## Halo population similar as in 2016

- ▶ Present LHC beam halo carries less than 12 MJ
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## Computed diffusion parameters indicate growth wrt 2016

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## Halo population similar as in 2016

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- ▶ HL– LHC beam halo extrapolated to less than 30 MJ

## Computed diffusion parameters indicate growth wrt 2016

- ▶ Different beams, higher intensity and smaller emittance.

Spectrum analysis of the loss data indicates different frequency components acting differently wrt beam plane configuration

# The End

Thank you!

# References



G. Valentino, *et al.*

"What did we learn about HALO population during MDs and regular operation?", Review of the needs for a hollow e-lens, CERN, Geneva (2016).



G. Stancari,

textit "Diffusion model for the time evolution of particle loss rates in collimator scans: a method for measuring stochastic transverse beam dynamics in circular accelerators", FERMILAB-FN-0926-APC, arXiv:1109.5010v3



G. Valentino, R. Bruce, A. Gorzawski, S. Redaelli, G. Trad, J. Wagner, C. Xu,

"End-of-Fill Diffusion and Halo Population Measurements with Physics Beams at 6.5 TeV", Tech. Rep. LHC , CERN, Geneva.



A. Gorzawski,

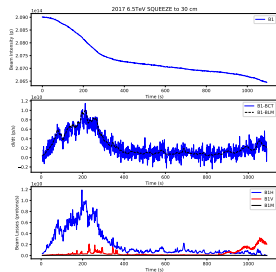
"Loss studies with IR7 diamond BLMs", Tech. Rep. LHC Collimation Working Group #220

Backup slides

# Beam and plane of increased losses

## From the LHC operation in 2017

- ▶ Loss decomposition tool available in the CCC
  - ▶ Calibration done for scraping test without collisions (21/Oct)
- ▶ Beam 1 (in Figure)
  - ▶ Horizontal losses dominating,
  - ▶ Has worst lifetime than Beam 2,
- ▶ Beam 2
  - ▶ No signature of difference in planes until reaching low  $\beta^* \leq 40$  cm



Not the same moment in cycle as the other presented

- ▶ to be followed up!