Review of the needs for a hollow e-lens for the HL-LHC
October 6th-7th, 2016
CERN, Geneva, CH

Loss and lifetime observations during nominal operation and their extrapolation to HL-LHC parameters

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on behalf of the collimation team

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

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Introduction

Performance of the machine is affected by

Maximum peak losses during the cycle and Lifetime drops

↪ Number of dumps due to losses

Continuos losses during the cycle

↪ Reduction of the beam intensity

Analysis of these quantities for relevant periods in Run I and Run II

	Energy	Beta Star	Bunch Spacing	Bunch Intensity	Total Number Bunches	IP7 Collimation Primary Cut @ Top Energy
2011	3.5 TeV	1.5 m	50 ns	1.40E+11	1374	5.7σ
2012	4 TeV	0.6 m	50 ns	1.50E+11	1374	4.3σ
2013	4 TeV	0.6 m	50 ns	1.50E+11	1374	4.3σ
2015	6.5 TeV	0.8 m	25 ns	1.20E+11	2244	5.5σ
2016	6.5 TeV	0.4 m	25 ns	1.10E+11	2220	5.5σ

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Beam Lifetime using BLMs - Run I

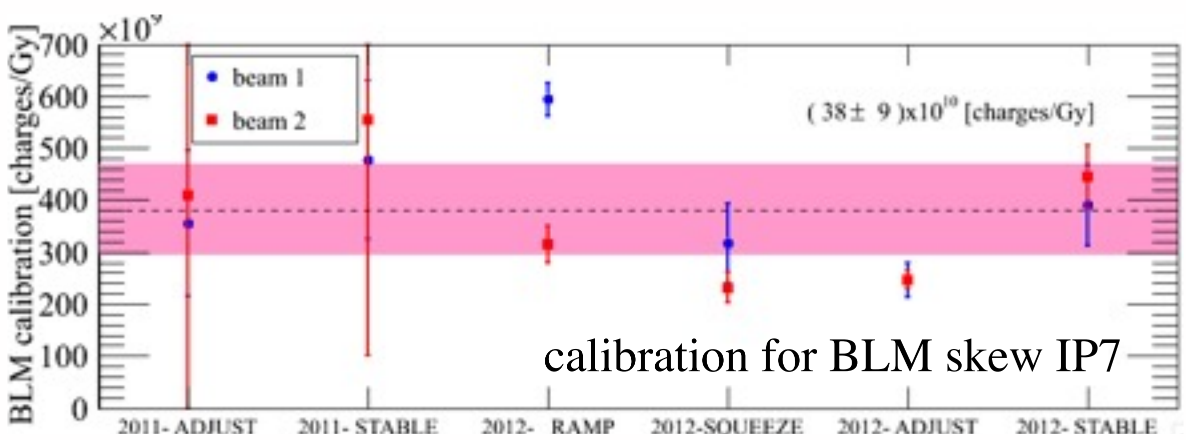
Primary losses occur at the collimators.

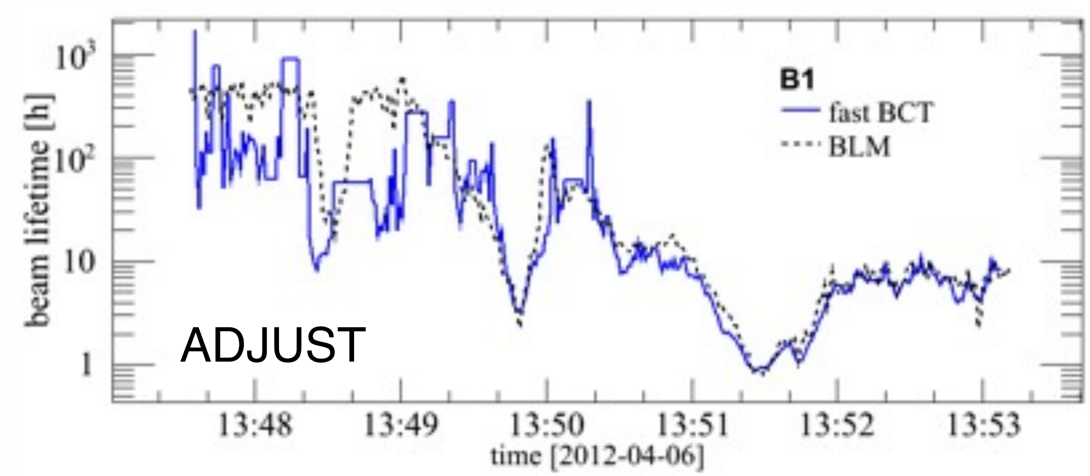
BLMs downstream each collimator have a direct measurement of the beam losses

BLMs had a wide range of integration times (we used 1.3sec) and are usually more sensitive to losses than the BCT

In 2012

We calculated a calibration of the BLMs downstream primary collimators in IP7. Previously done with beam scraping studies. This time by fitting the BLM signal to the Beam Current Measurement derivative over all the fills in 2012.





Belen et al. "Lifetime Analysis at High Intensity Colliders Applied to the LHC", IPAC2013

Previous studies by F. Burkart, PhD 2012 CERN-THESIS-2012-046 Beam Loss and Beam Shape at the LHC collimators.

Update of BLM calibration - Run II

Run II (2015-2016)

Previous method did not include primary losses in IP3

BLMs could provide information about the main plane of losses

A.Marsili PhD 2012

BLM decomposition

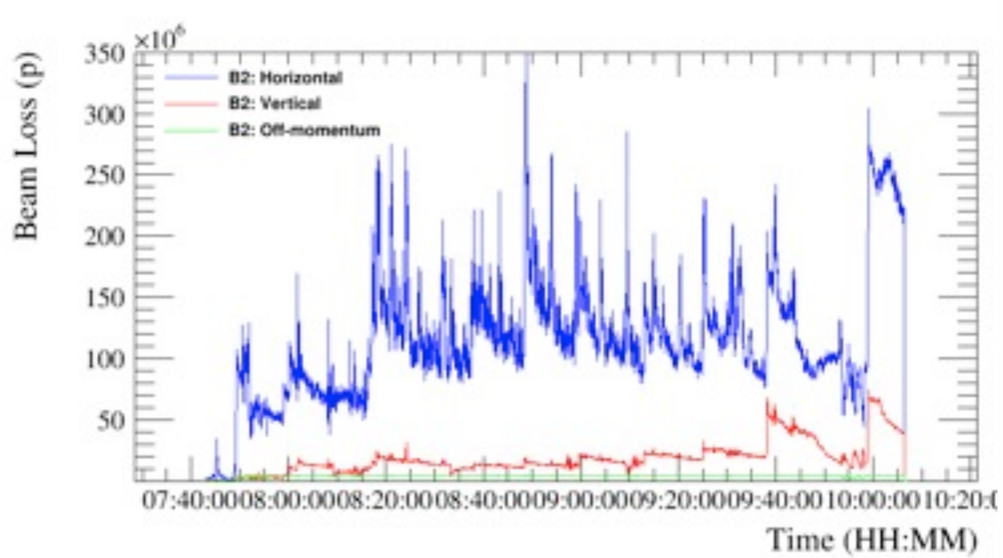
M.Wyszynski, Summer Student 2015 and Technical Student 2016

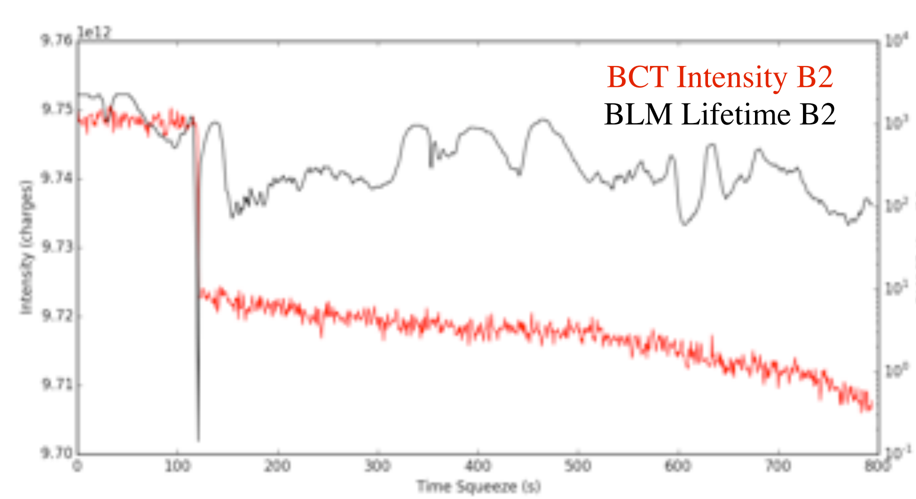
Define loss scenarios: longitudinal, horizontal and vertical → Validation Loss Maps

Calibration is not applied to 1 BLM but to a set of BLMs → Matrix

The result is the number of protons lost per second due to each loss scenario

$$\text{BiH} + \text{BiV} + \text{Bi off mom.} \approx -\frac{dI(\text{Bi})}{dt} \qquad i \in \{1, 2\}$$





Losses during the cycle

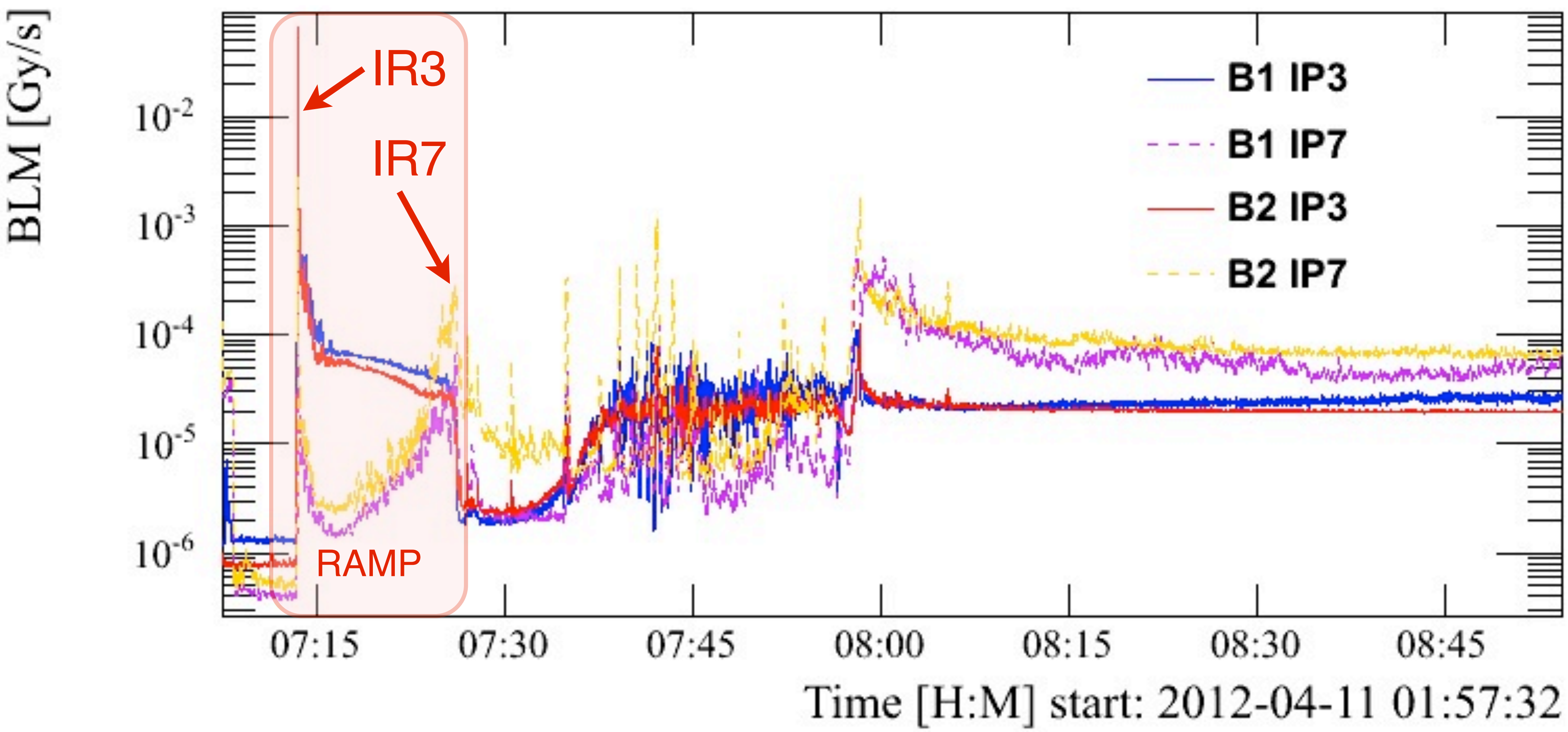
RAMP

Un captured beam at the start of the ramp is lost in IR3 collimation

↪ Energy ~ 450GeV no worrisome for quench but part of the intensity is lost

Smooth scraping of beam tails during the ramp in IR7 collimation

↪ Slow losses could be safely absorbed by the collimators



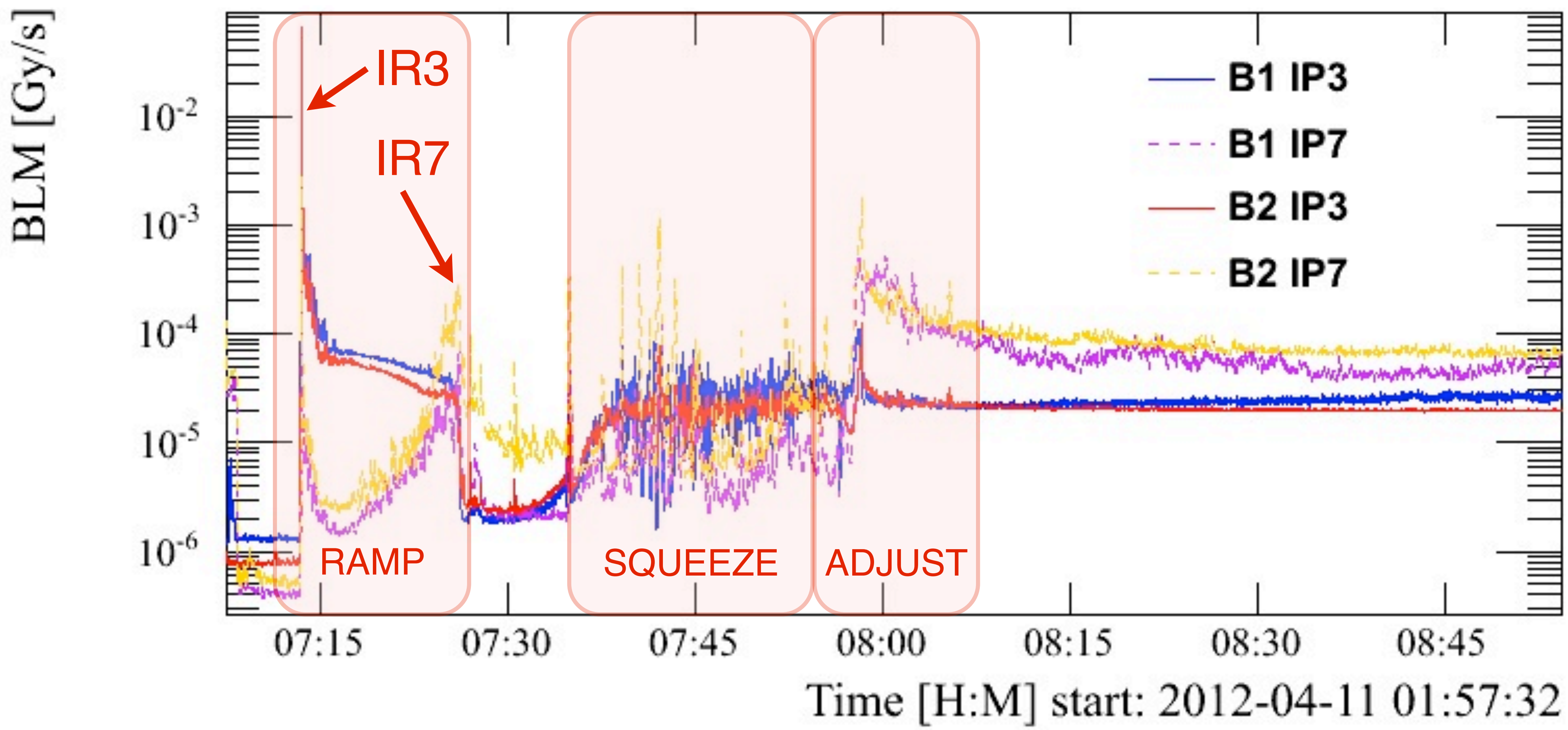
Losses during the cycle

SQUEEZE - Top Energy

Fast loss spikes that occur usually at well defined times during squeeze

ADJUST - Top Energy

Fast loss spike when the separation is collapsed



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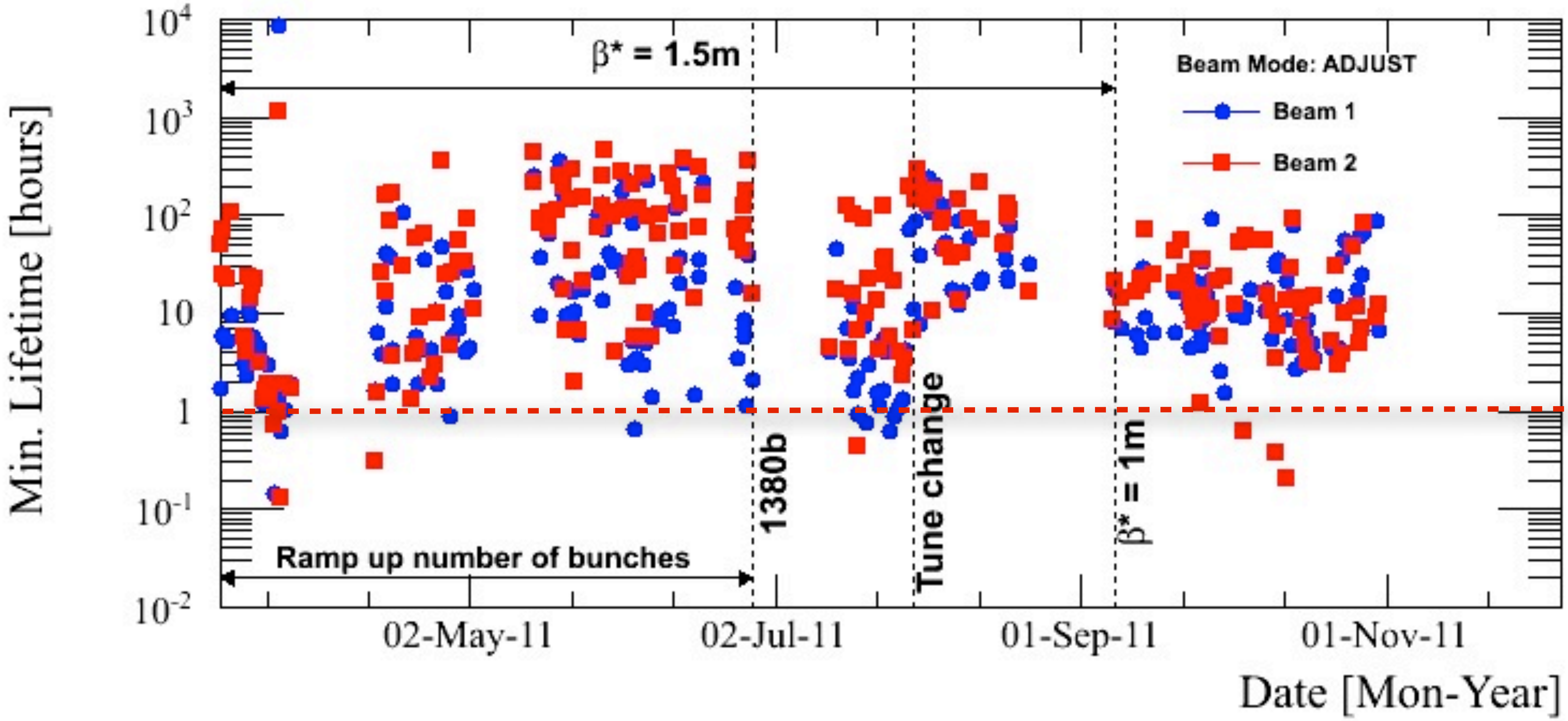
Lifetime in Run I - 2011

2011 - Minimum Beam Lifetime when beams are set into collisions

Clear correlation of machine parameters (tune, beta, etc.) with lifetime distribution

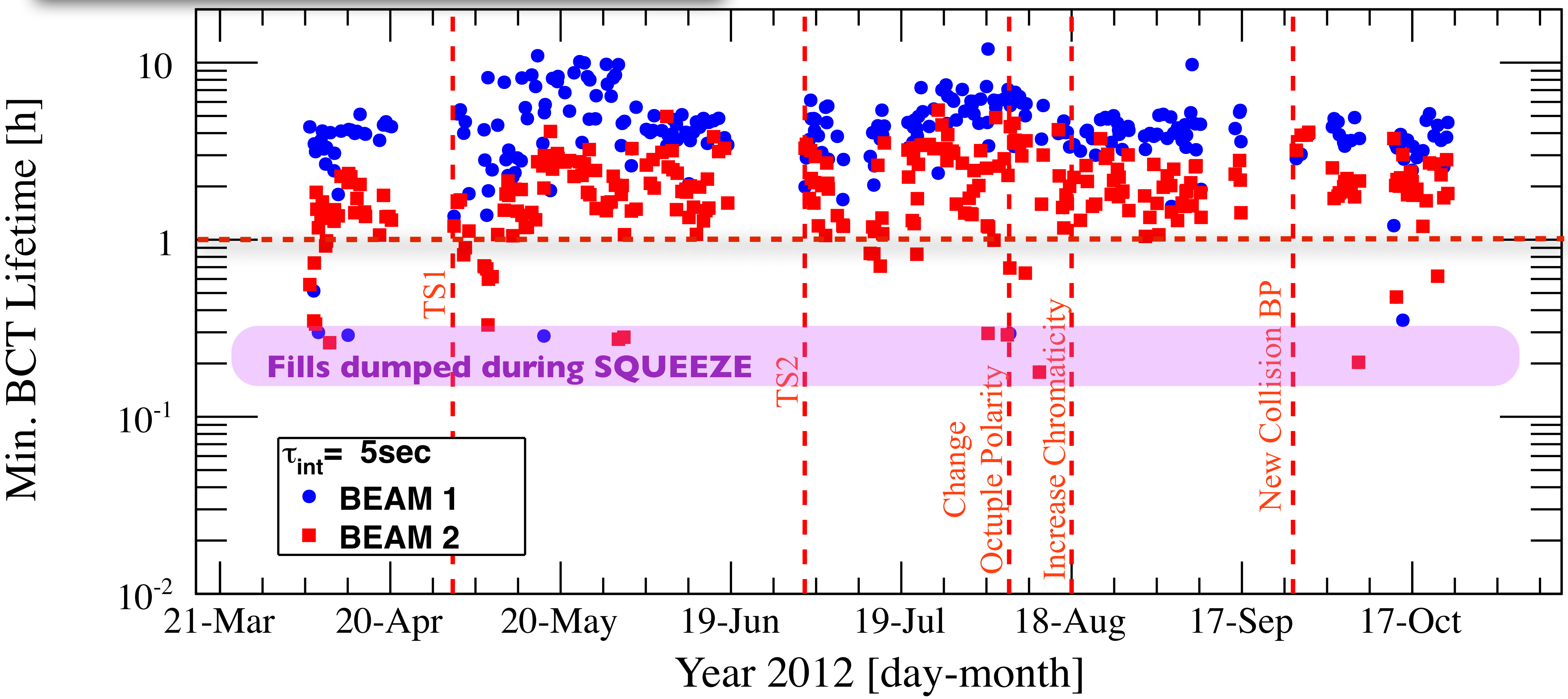


Lifetime in Run I - 2012

Including fills that dump during SQUEEZE

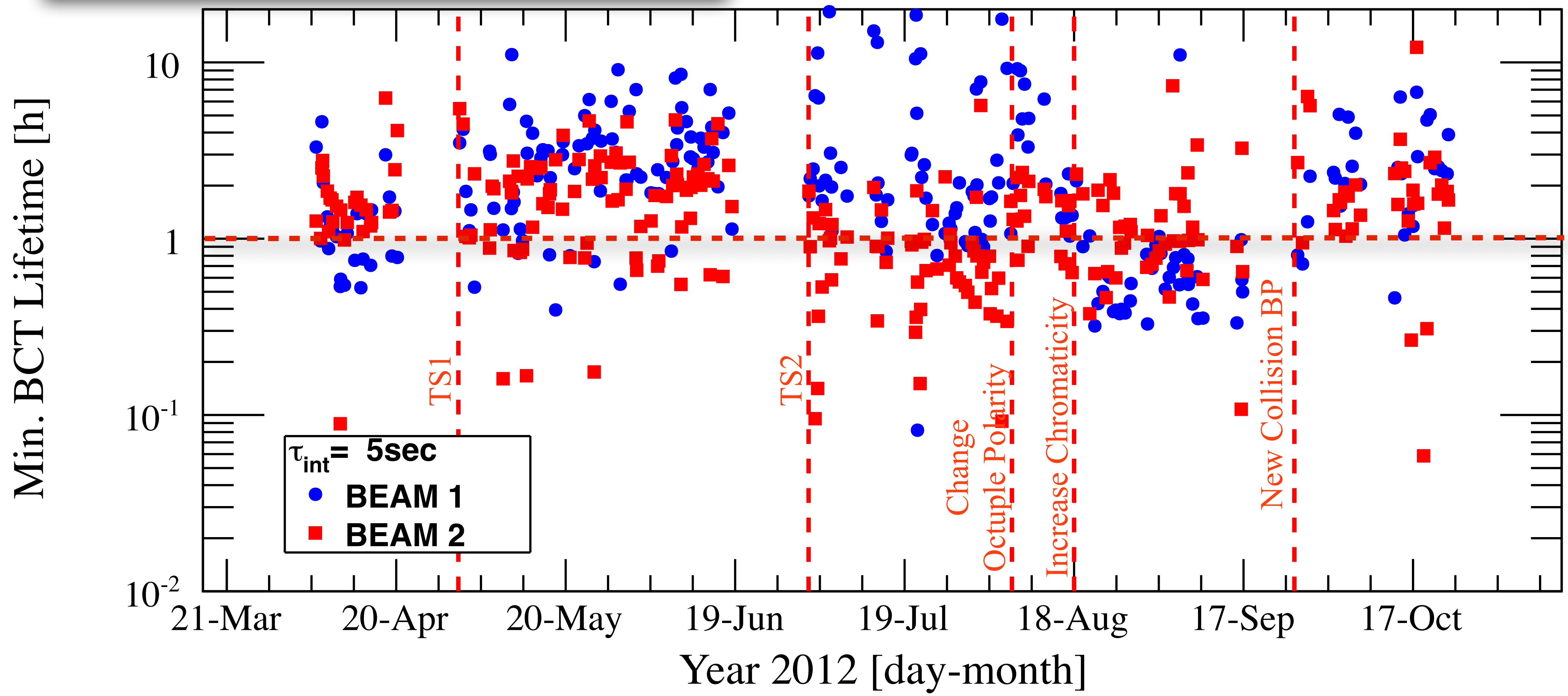
SQUEEZE

16 fills dump out of 283 analyzed during squeeze
19 fills with lifetime < 1h with no dump during squeeze
12 fills with lifetime < 1h made it to physics

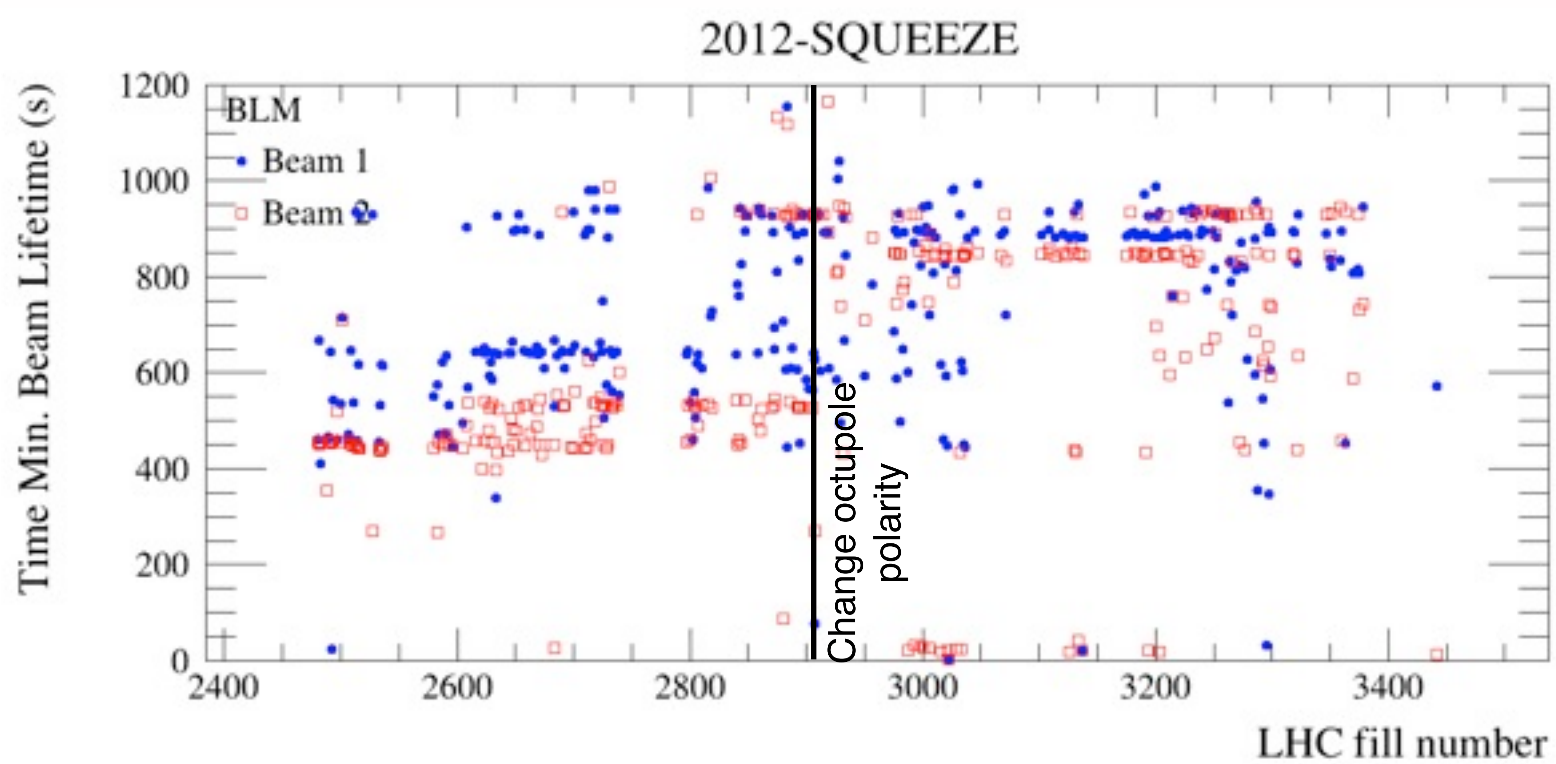


Lifetime in Run I - 2012

Including fills that dump during ADJUST



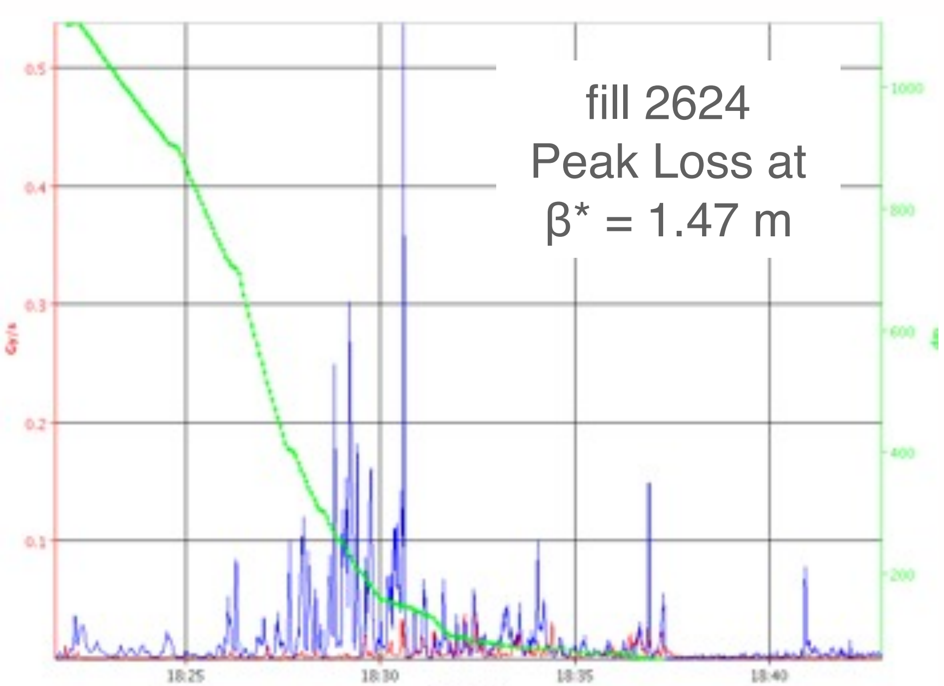
Time of lifetime drops

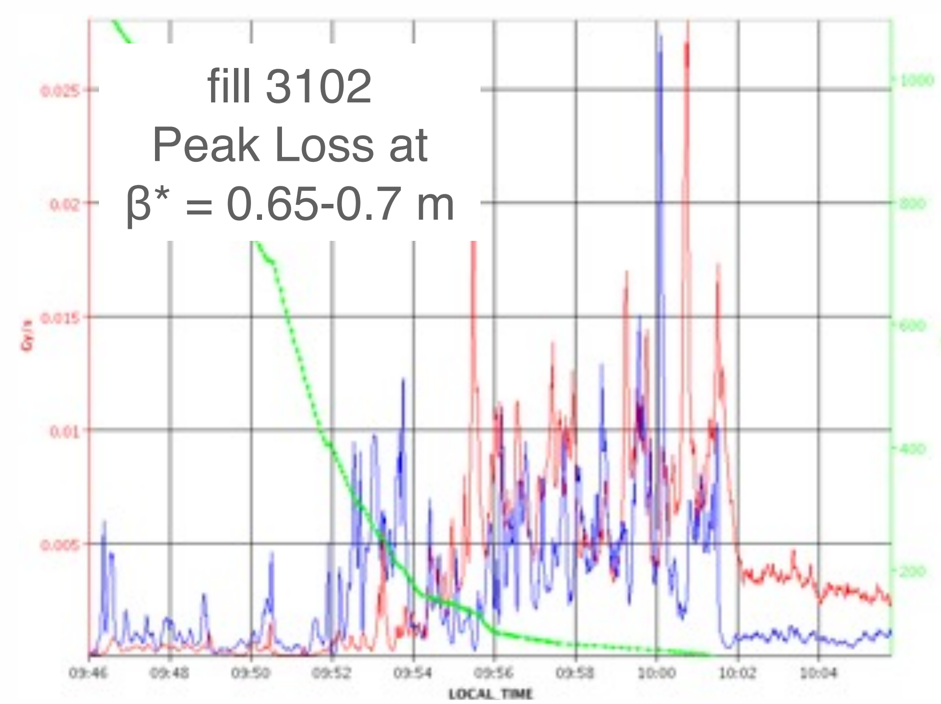


During squeeze loss spikes appear at well defined times.

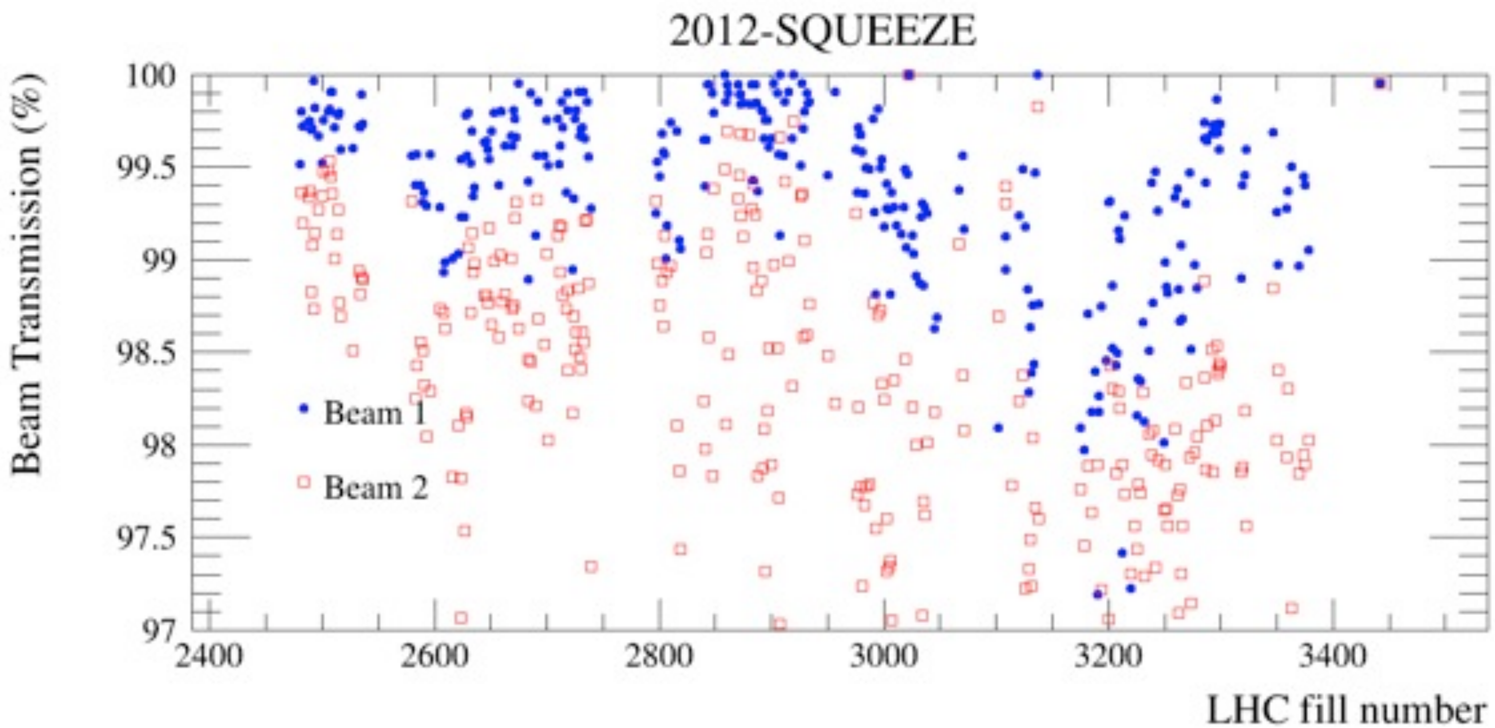
But pattern can change depending on the configuration of the machine

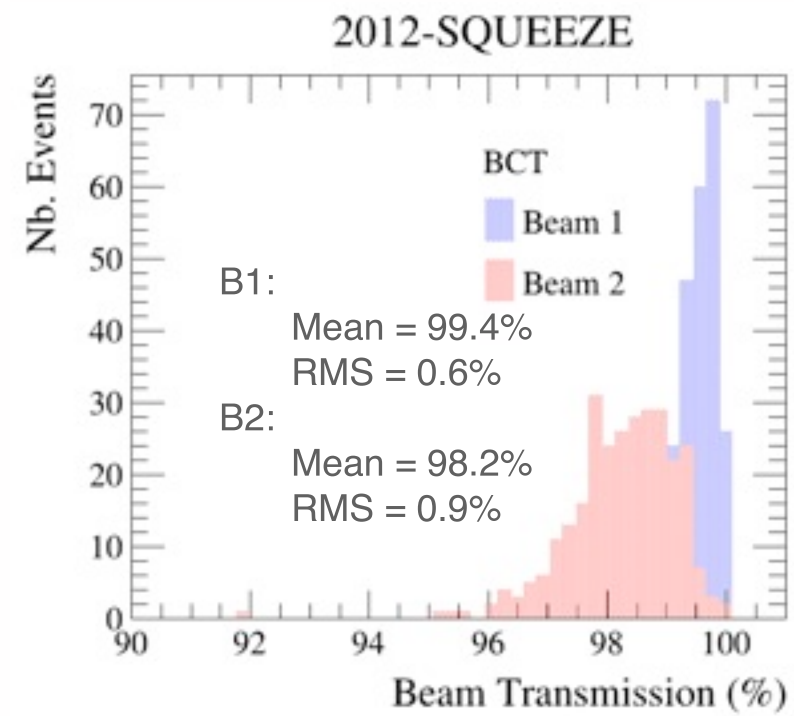
Around fill 2900 there was a change of octupole polarity

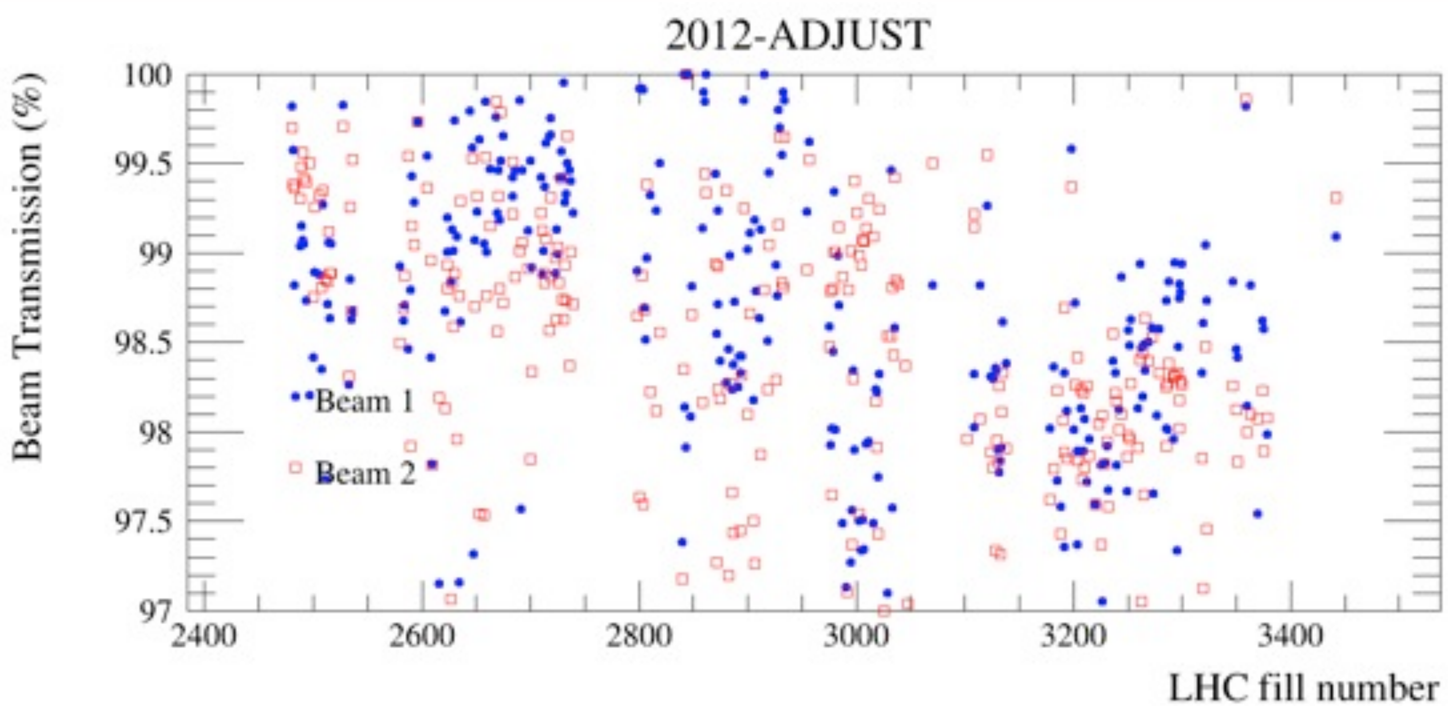


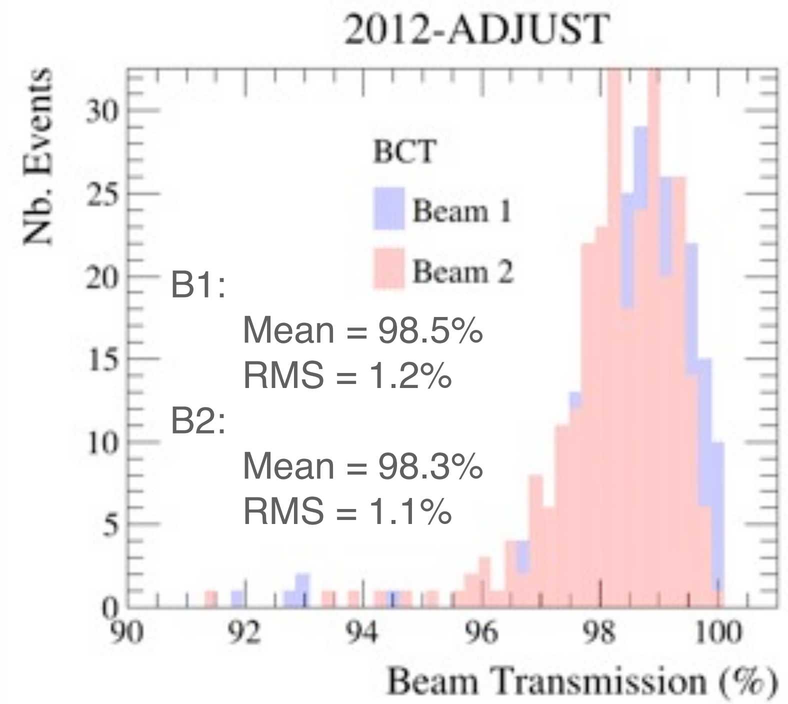


Beam Transmission - Run I (2012)

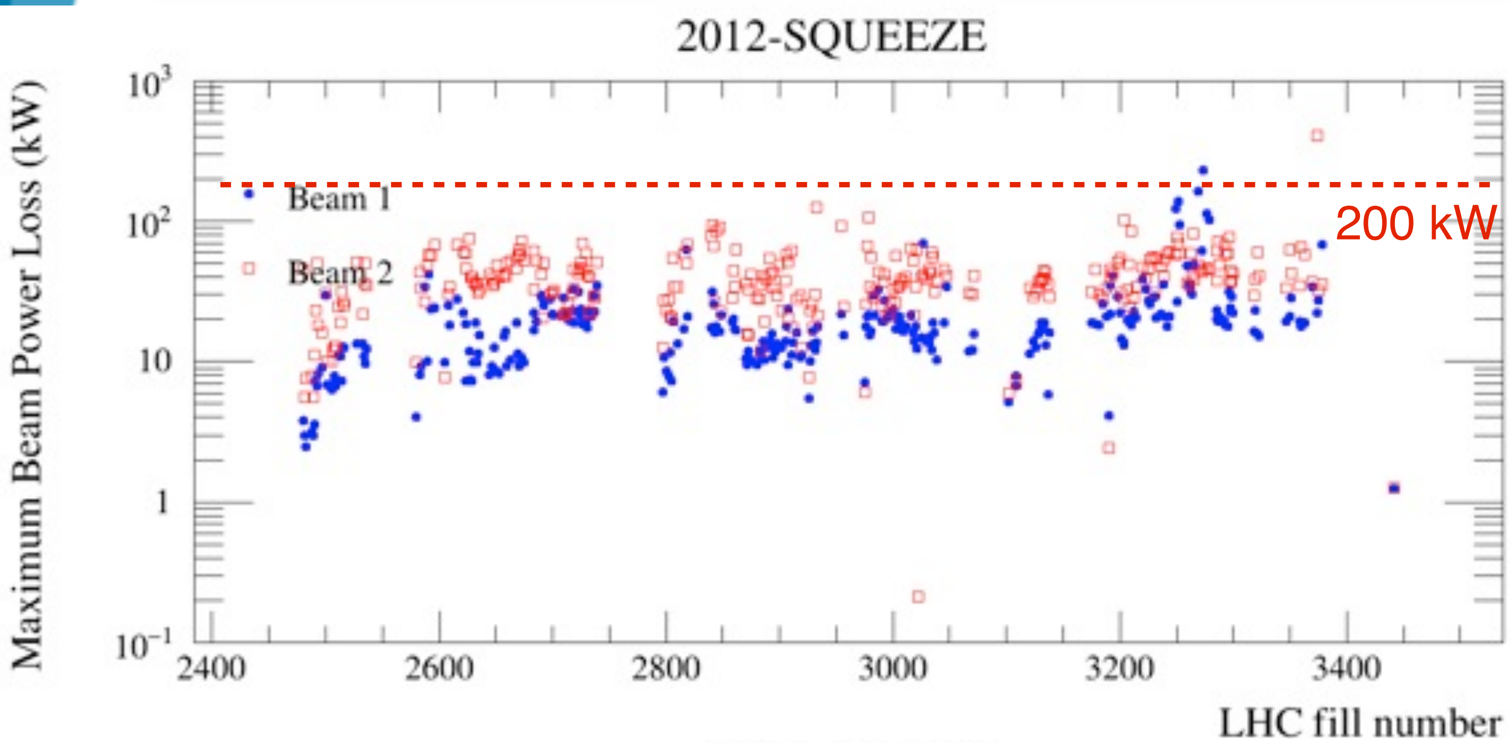


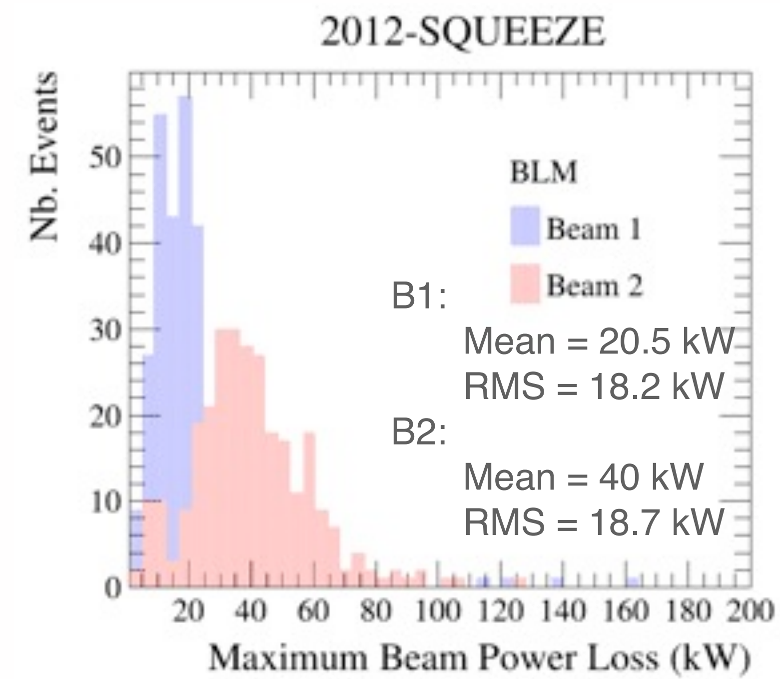


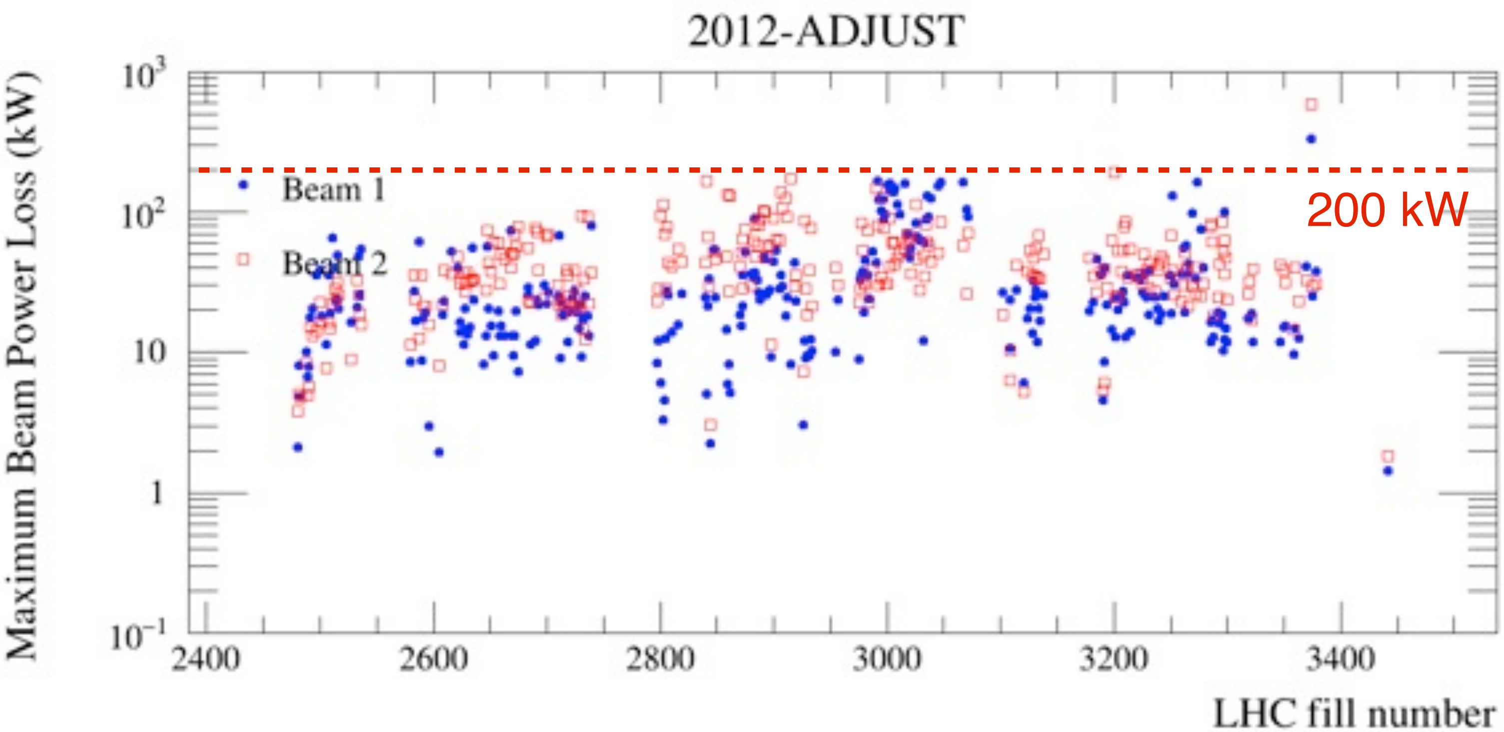


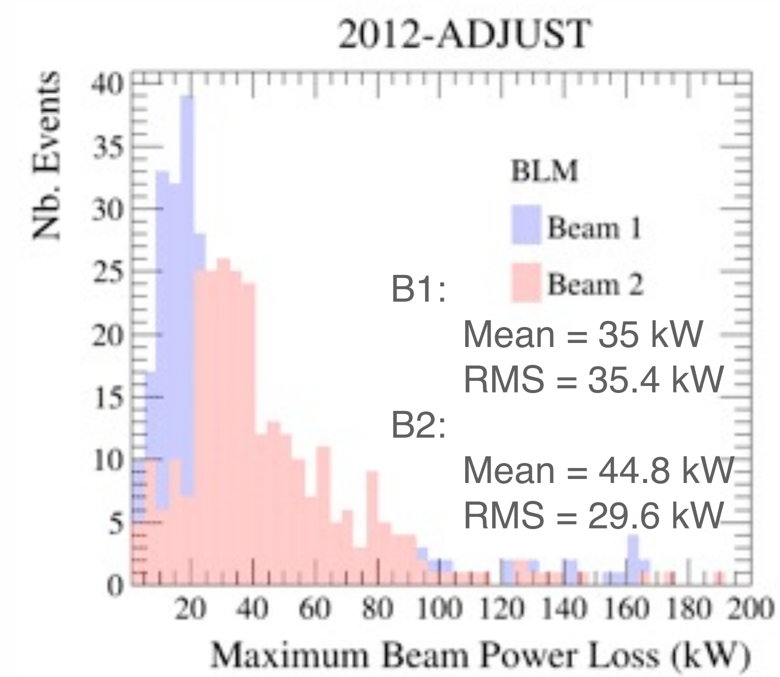


Maximum Peak Loss - Run I









Notice that BLM thresholds were adjusted in 2012 to allow up to 200 kW peak losses before requesting a beam dump

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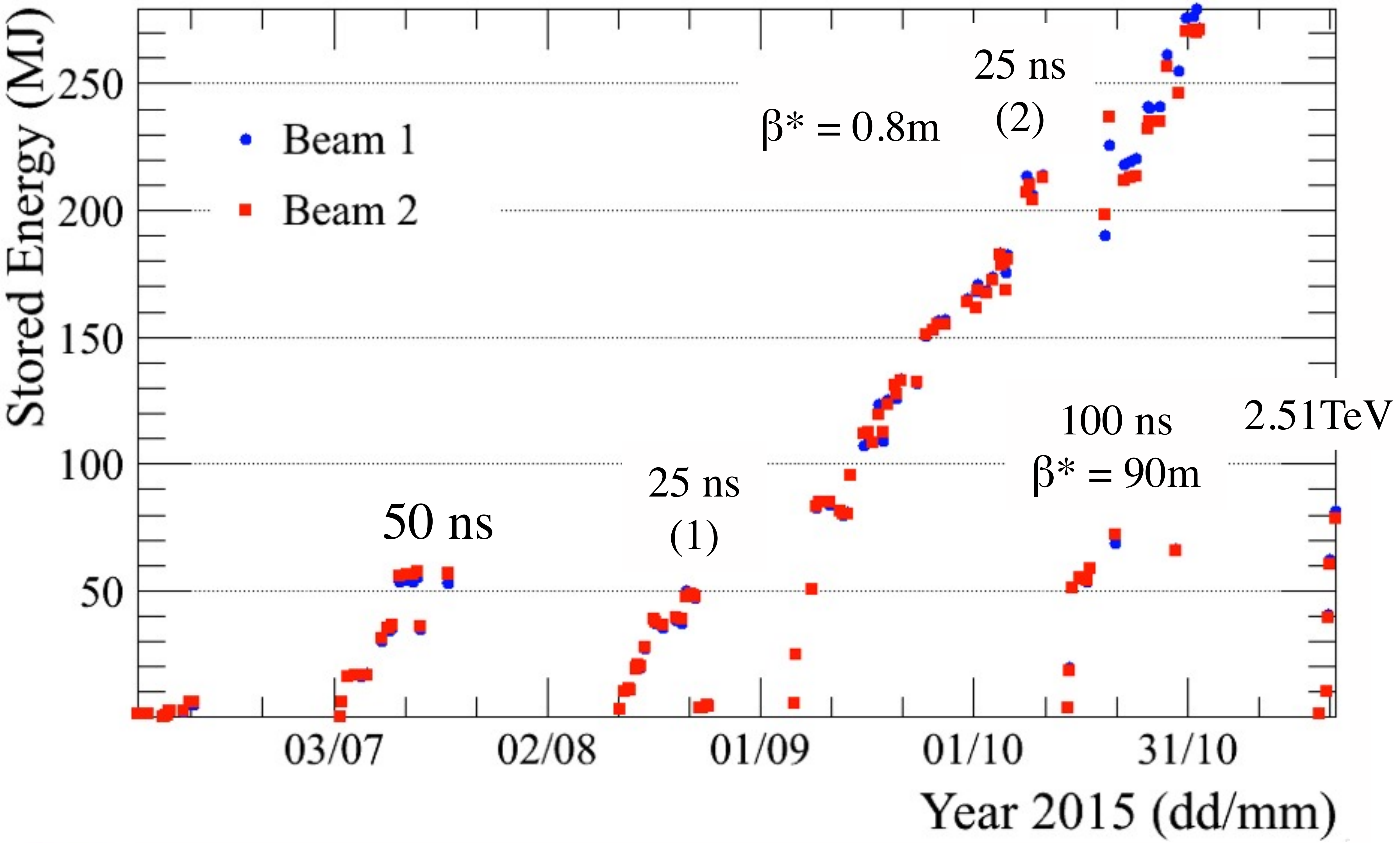
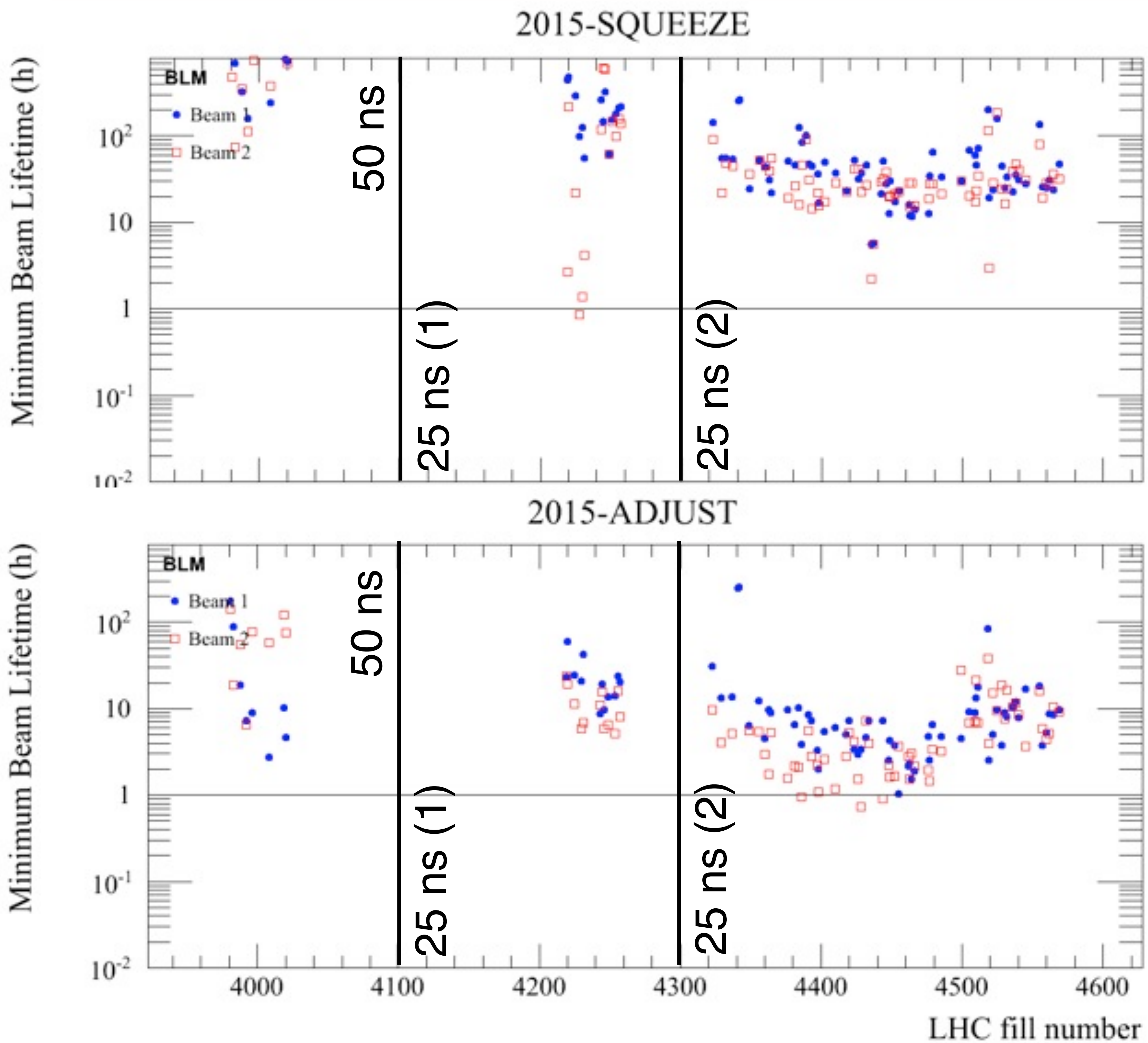
- Conclusions

2015 — stored beam energy



Lifetime in Run II - 2015

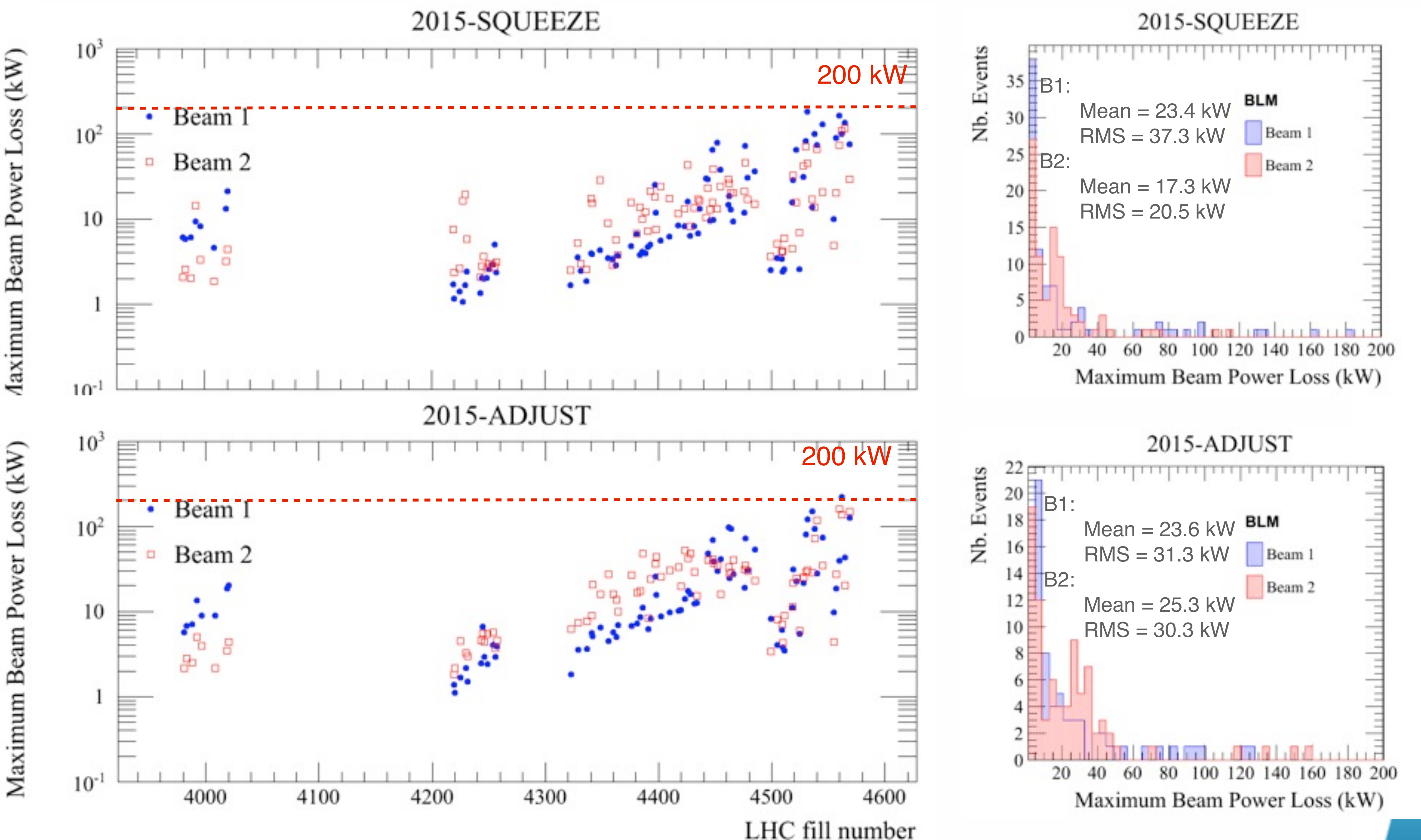


In 2015 lifetime drops where dramatically improved.

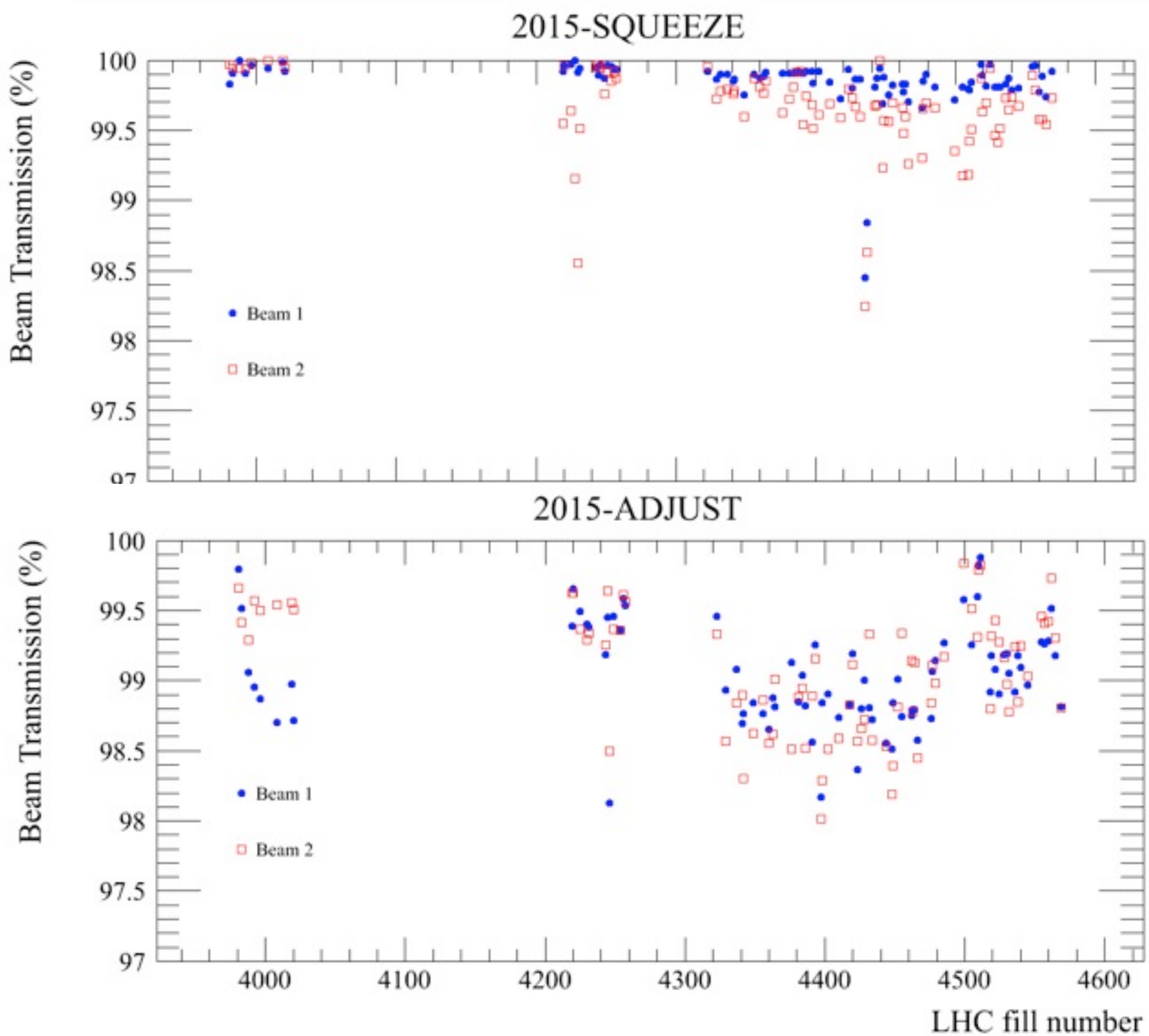
Few fills with lifetime peak close to 1hour in squeeze during the 1st intensity ramp up with the new bunch spacing of 25 ns.

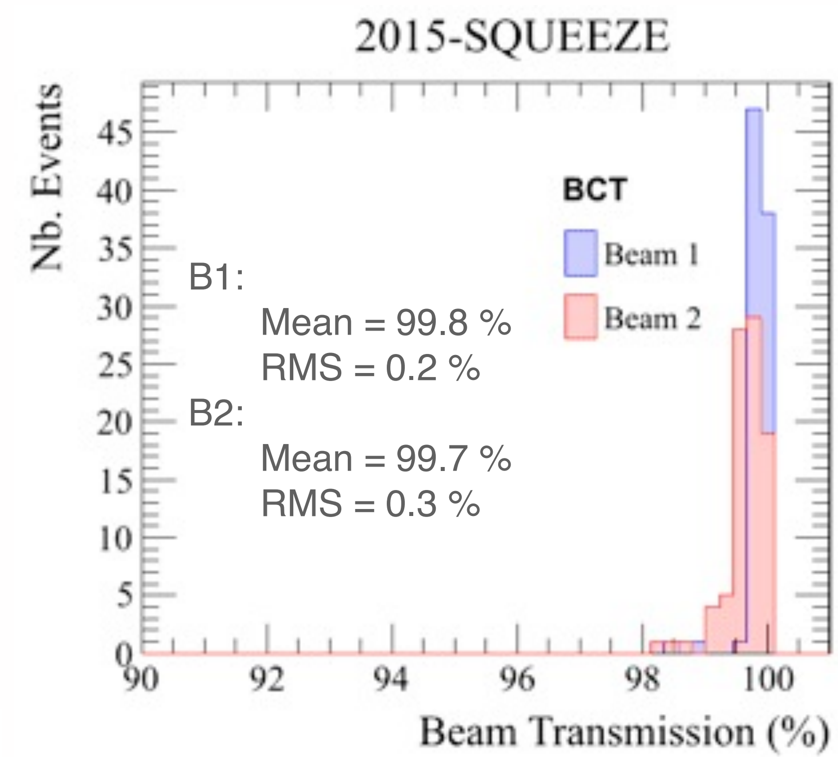
Set up of octuples and chromaticity settings to mitigate e-cloud effect

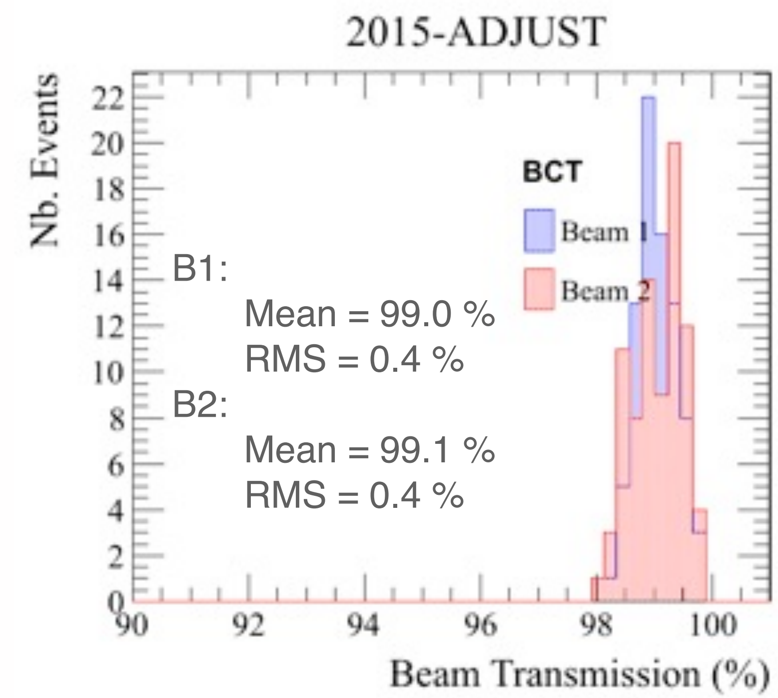
Maximum Peak Loss - Run II (2015)



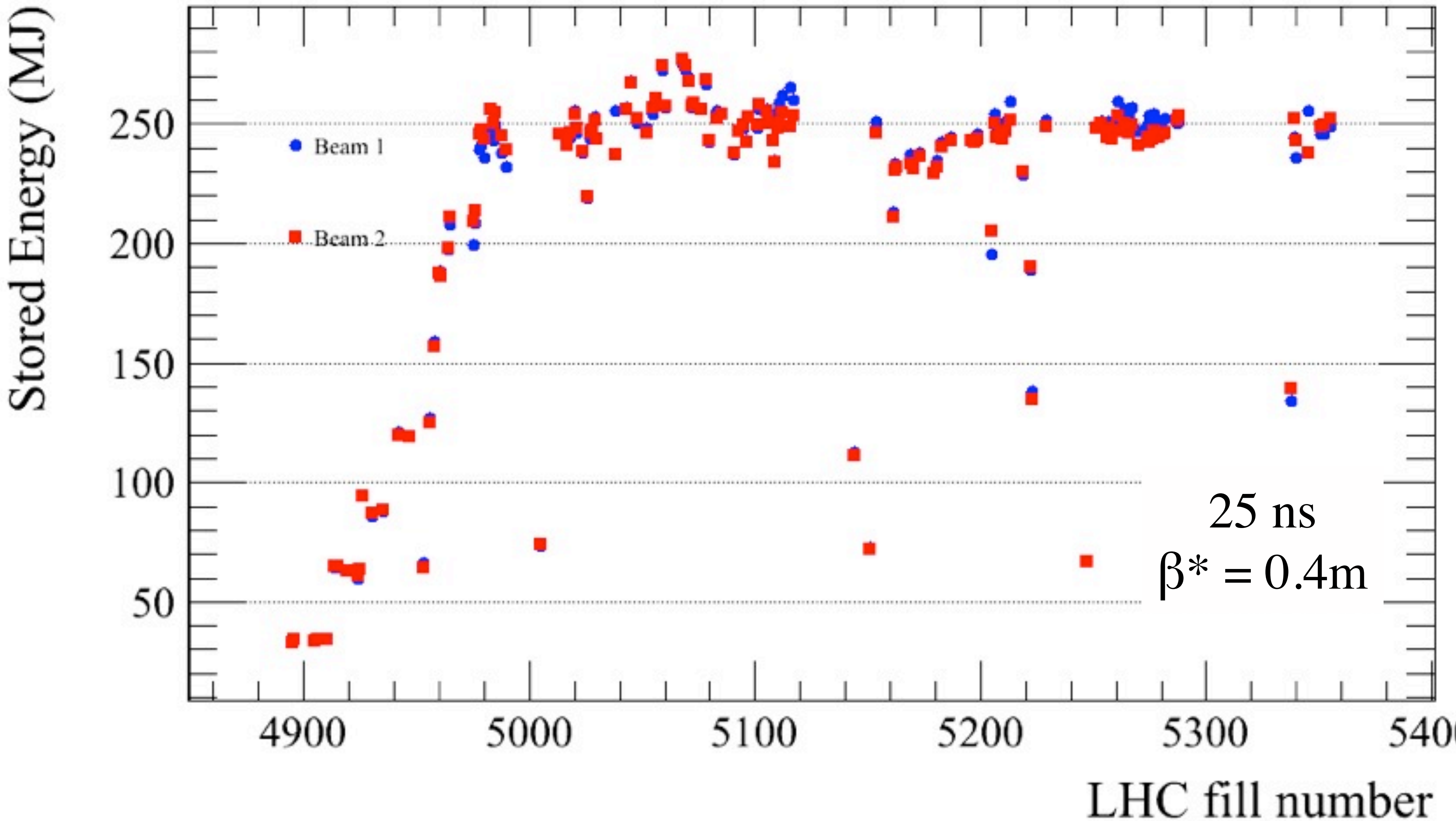
Beam Transmission - Run II (2015)







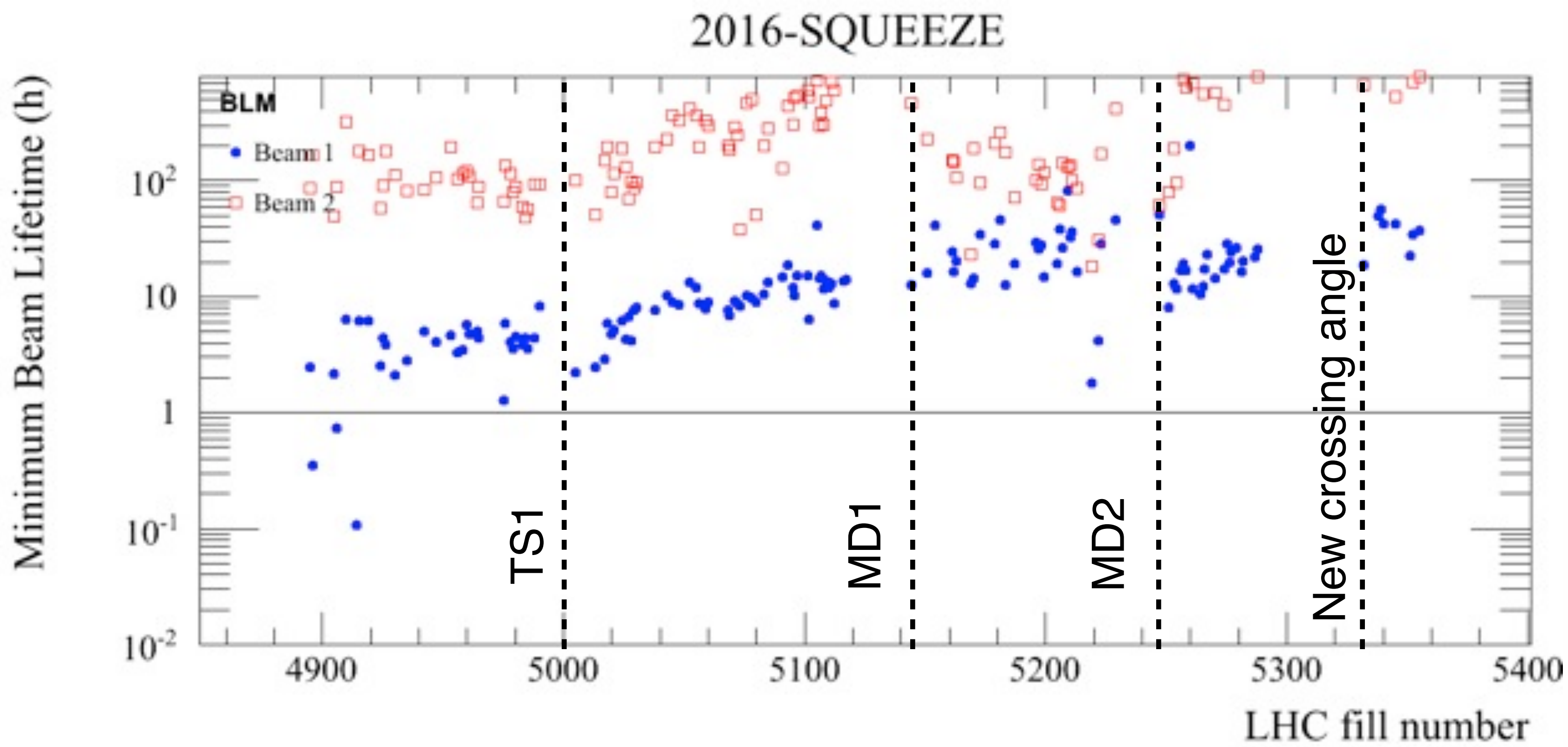
2016 — stored beam energy

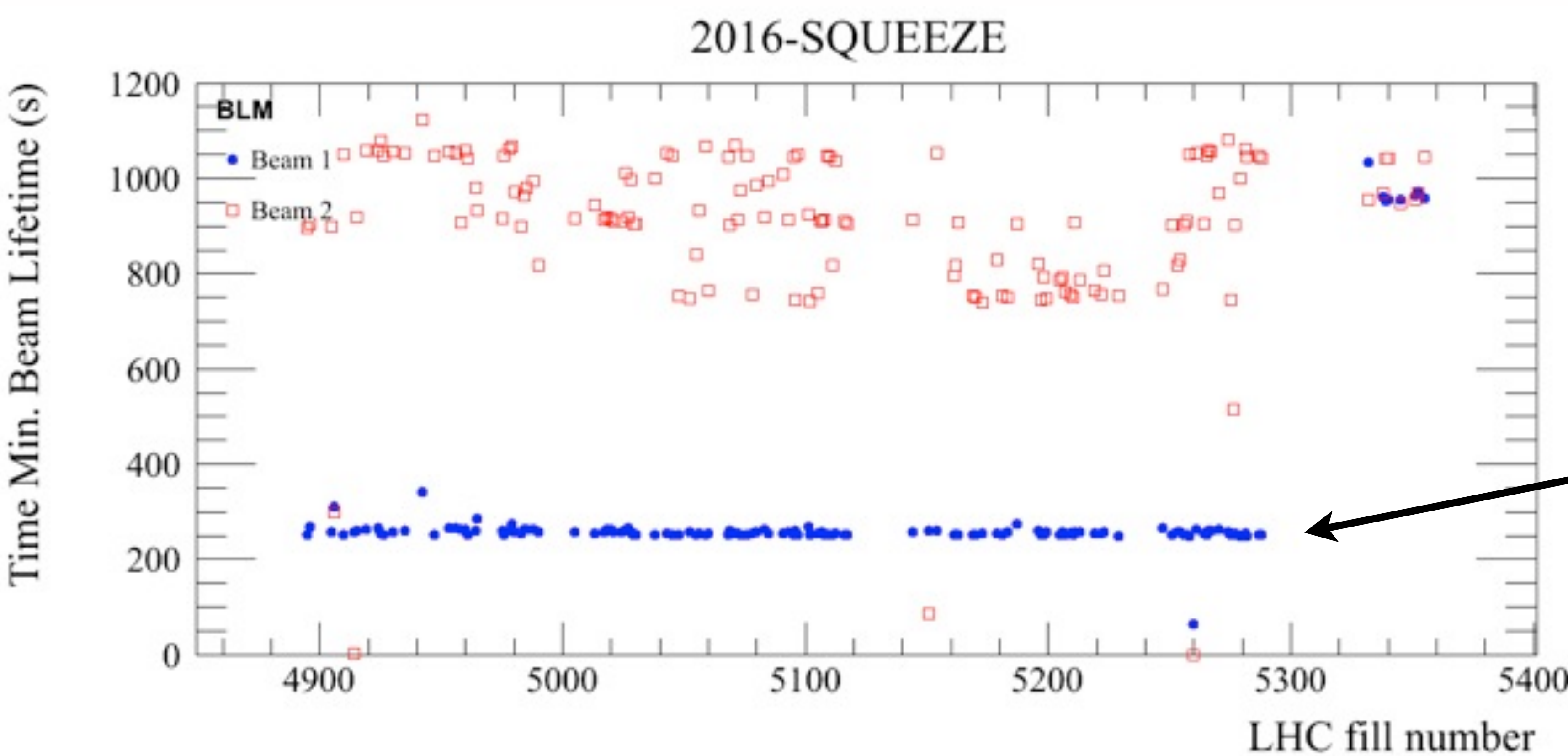


Very different profile ("second" commissioning at 6.5TeV)
BUT: betastar 2 times smaller (40cm vs 80cm in 2015)

Lower total stored beam energy — now limited by MKI and SPS dump (nb = 2220).

Lifetime in Run II (2016)





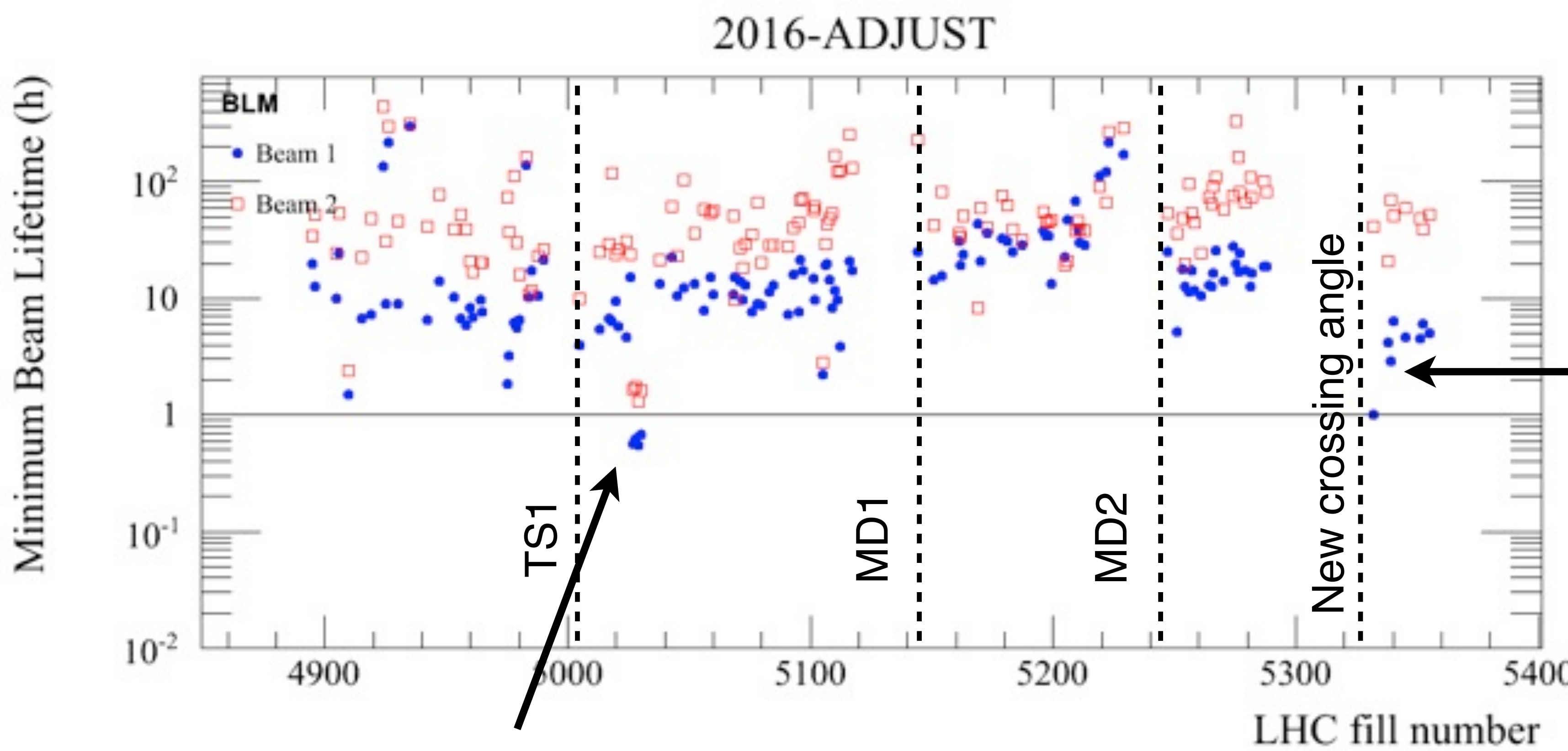
Very good lifetime in 2016, only few cases below 1 hour in the first intensity ramp up

B1: Lifetime drops occurs during squeeze to $\beta^* = 1.3$ m systematically.

Several attempts to cure this losses by tuning the orbit feedback.

Cured after small coupling corrections.

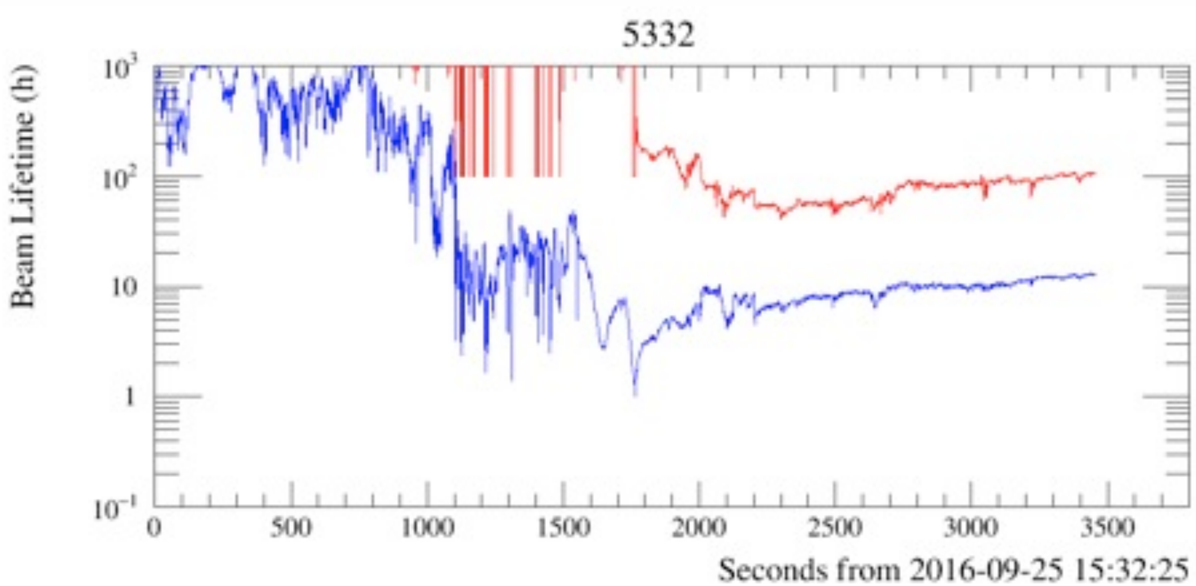
Lifetime in Run II (2016)

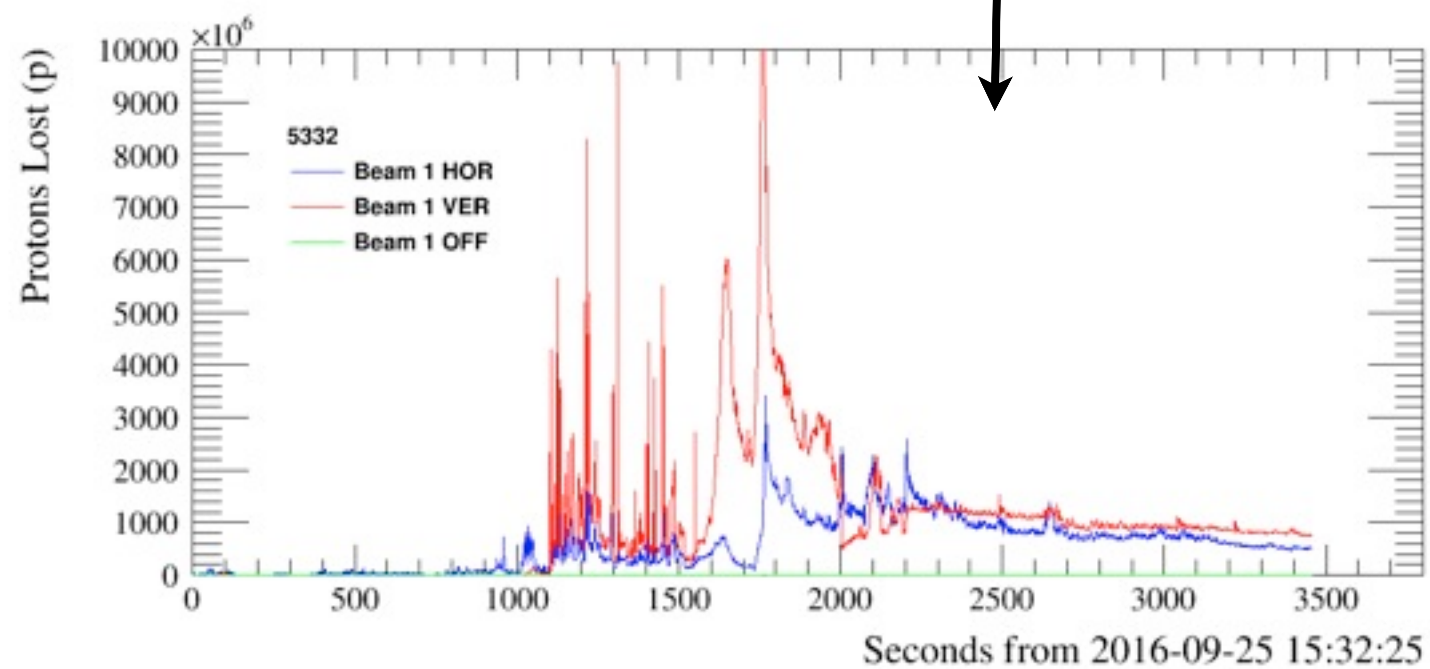


B1 lifetime drop after reduction of crossing angle. Correction in place after 3-4 fills that mitigates the losses.

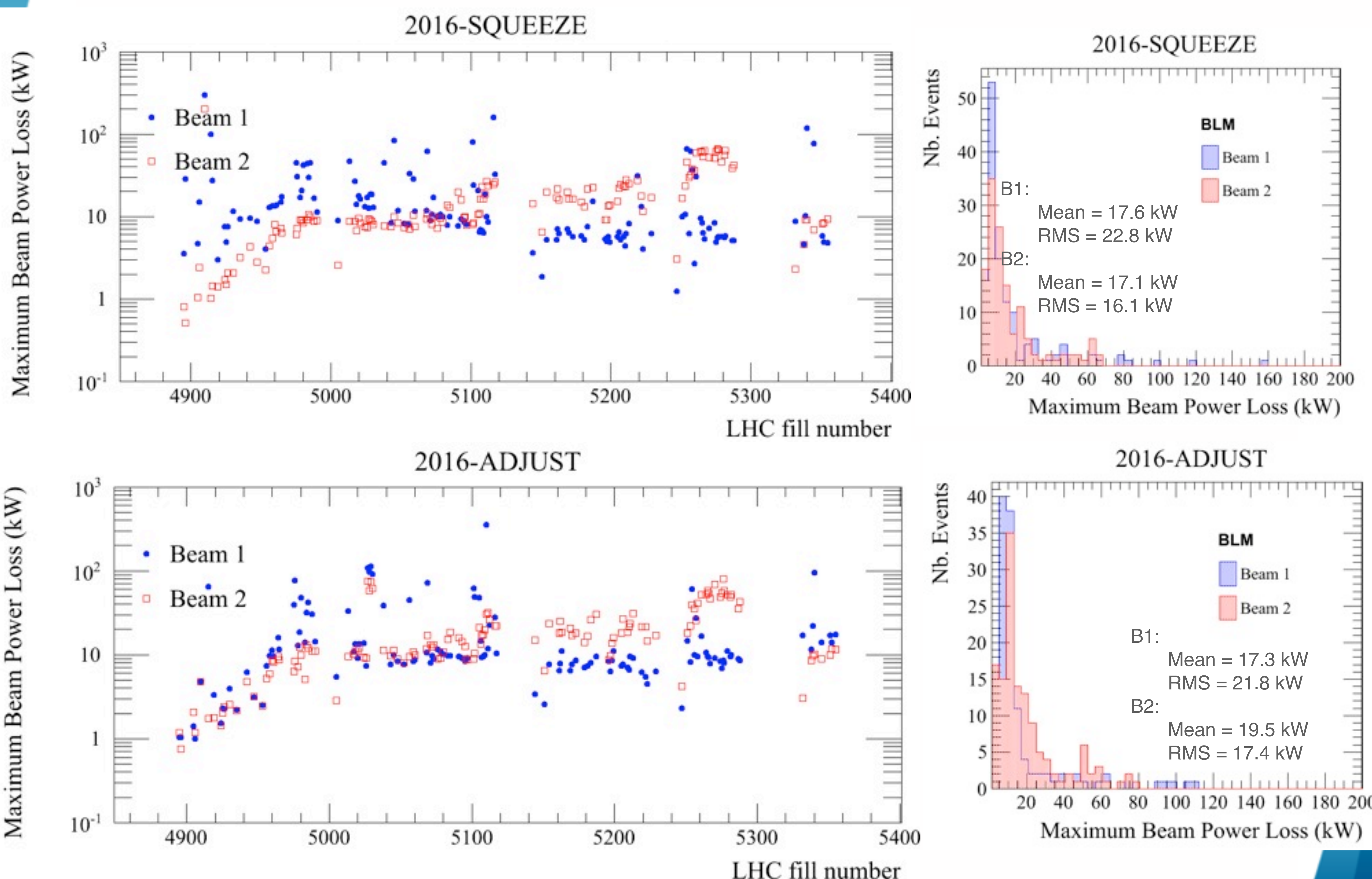
Isolated case during intensity ramp up

B1 Vertical is excited during the change of crossing and this also results in higher losses when collapsing the beams.

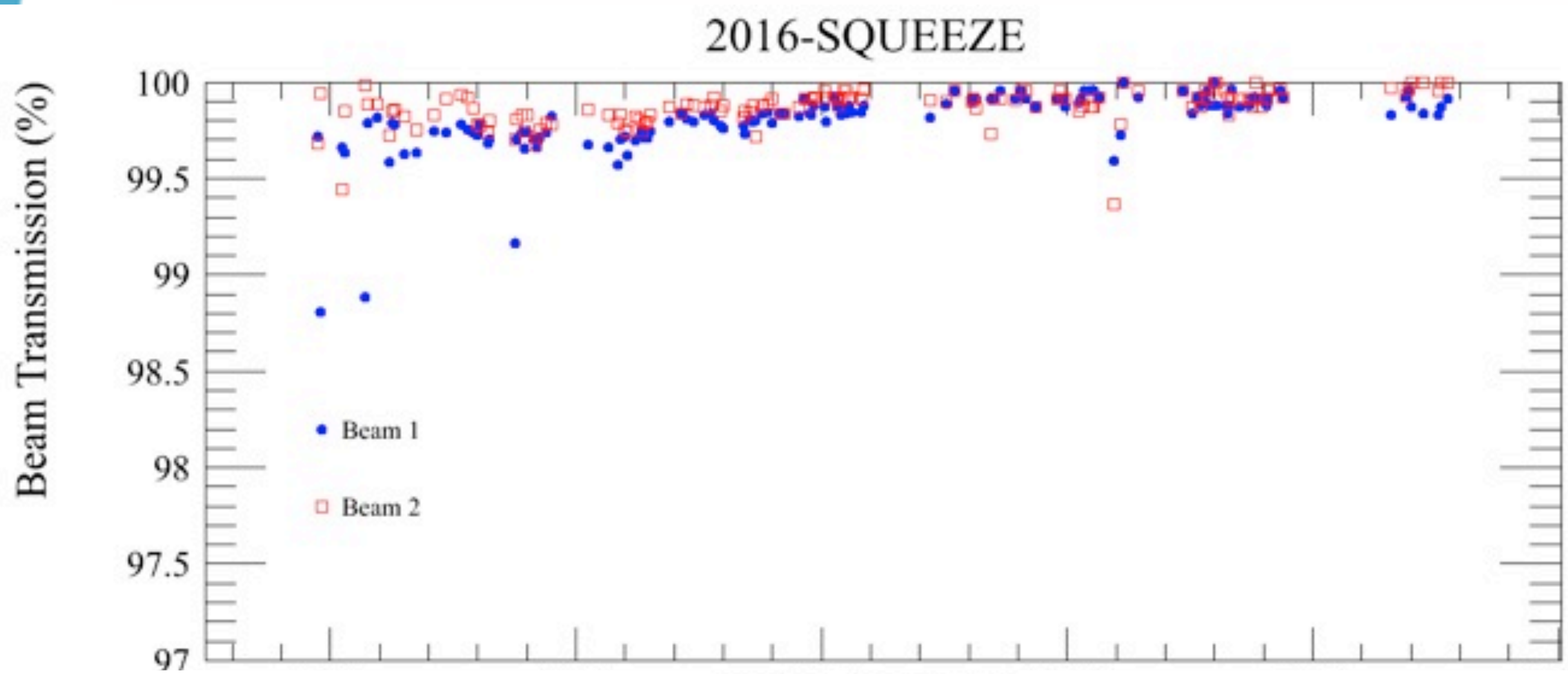


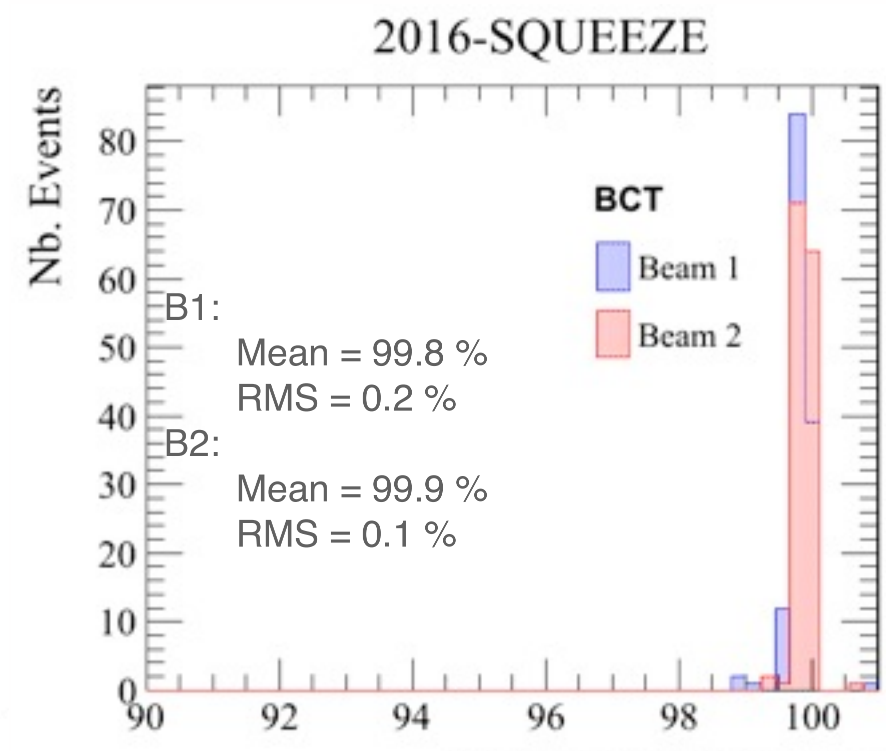


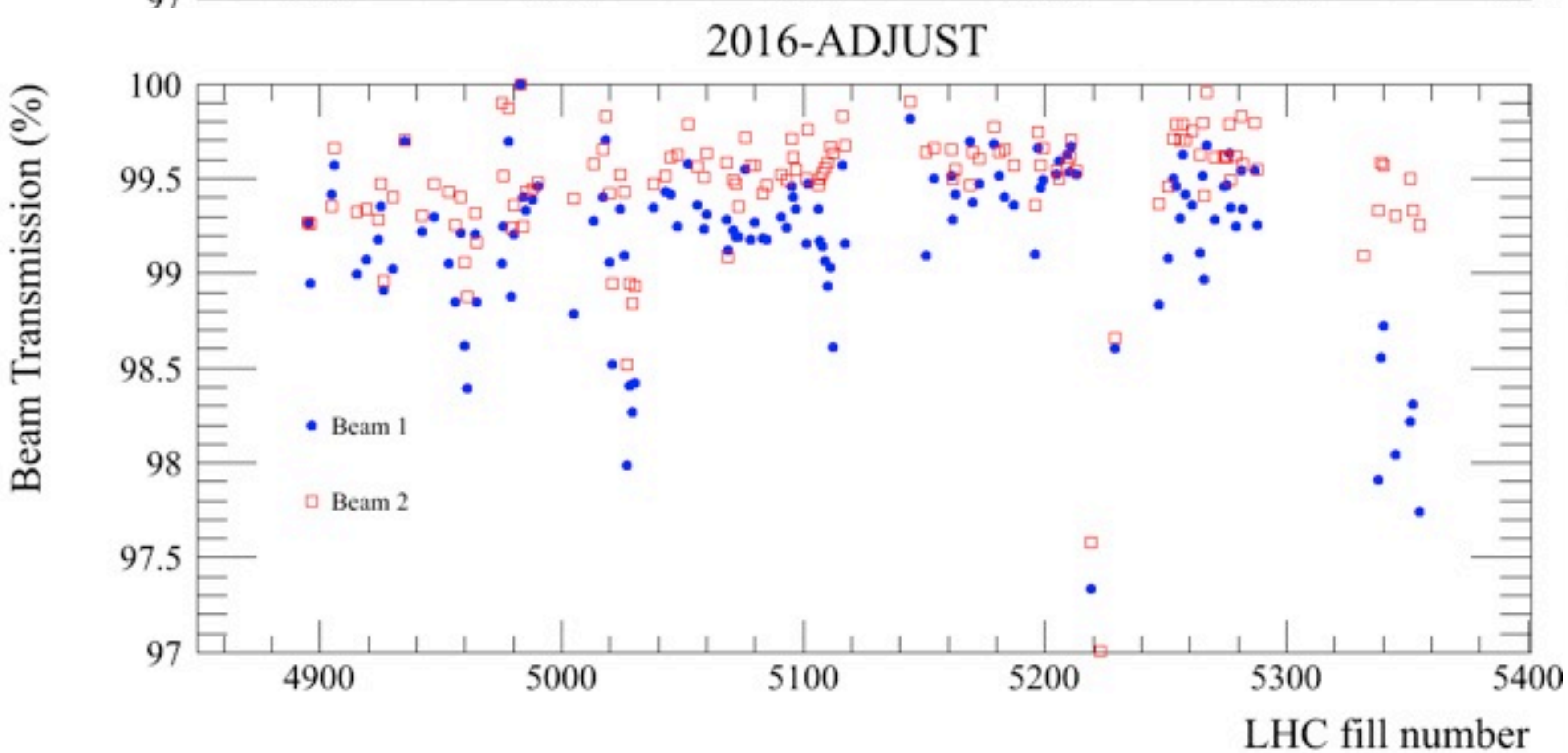
Maximum Peak Loss - Run II (2016)

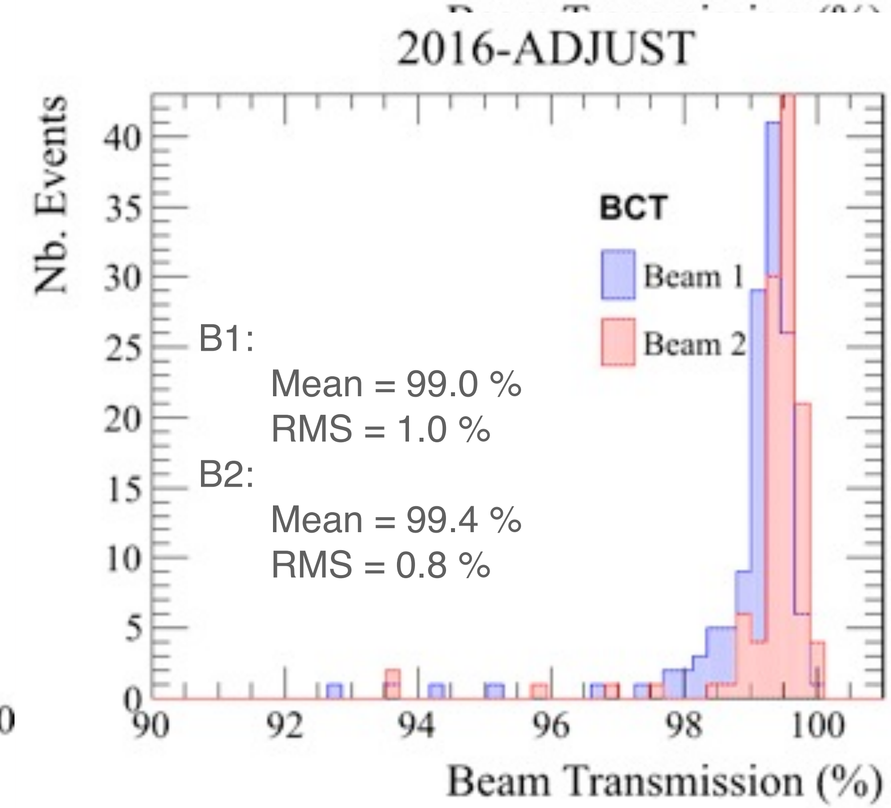


Beam Transmission in Run II (2016)









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Trying to scale to HL-LHC

HL-LHC

Beam Intensity: 2 x Nominal LHC

Energy: 7 TeV

Scaling from 2012

Beam Intensity: 0.5 x Nominal LHC

Energy: 4 TeV

Over simplified scaling factor of maximum losses of 7

Assuming the same lifetime (as this will not scale with intensity)

How many fills did we have with 500 kW HL-LHC equivalent in 2012?

This corresponds to 70kW in 2012 --> 45 out of 282 fills in ADJUST (15% of fills)

How many fills did we have with 200 kW HL-LHC equivalent in 2012?

This corresponds to 35kW in 2012 --> 157 out of 282 fills in ADJUST (55 % of fills)

Trying to scale to HL-LHC

HL-LHC

Beam Intensity: 2 x Nominal LHC

Energy: 7 TeV

Scaling from 2016

Beam Intensity: 0.8 x Nominal LHC (due to reduction of number of bunches)

Energy: 6 TeV

Over simplified scaling factor of maximum losses of 3

Assuming the same lifetime (as this will not scale with intensity)

How many fills did we have with 500 kW HL-LHC equivalent in 2016?

This corresponds to 166kW in 2016 --> 1 out of 135 fills in ADJUST (<1% of fills)

How many fills did we have with 200 kW HL-LHC equivalent in 2016?

This corresponds to 66kW in 2016 --> 22 out of 135 fills in ADJUST (15 % of fills)

Summary of Average Losses

Beam Transmission

	SQUEEZE		ADJUST	
(%) MEAN / RMS	B1	B2	B1	B2
2012	99.4 / 0.6	98.2 / 0.9	98.5 / 1.2	98.3 / 1.1
2015	99.8 / 0.2	99.7 / 0.3	99.0 / 0.4	99.1 / 0.4
2016	99.8 / 0.2	99.9 / 0.1	99.0 / 1.0	99.4 / 0.8

Maximum Peak Loss

	SQUEEZE		ADJUST	
(kW) MEAN / RMS	B1	B2	B1	B2
2012	20.5 / 18.2	40 / 18.7	35 / 35.4	44.8 / 29.6
2015	23.4 / 37.3	17.3 / 20.5	23.6 / 31.3	25.3 / 30.3
2016	17.6 / 22.8	17.1 / 16.1	17.3 / 21.8	19.5 / 17.4

HL-LHC

Scaling the average peak loss

300 kW
74 kW
58 kW

Conclusions

- Clearly, lifetime is very good in Run II
- Can we conclude that there will be no issue for HL-LHC?

  Many lifetime drops and peak losses depend on machine optimization and some of them can be solved but clearly if we have more margin to control the losses the performance of the machine benefits directly.
- Scale losses to HL-LHC

  Not obvious how to scale the losses. In Run II we had much better lifetimes than in 2012 but this could depend on many factors: orbit stability, collimator settings, e-cloud, optics corrections, etc.