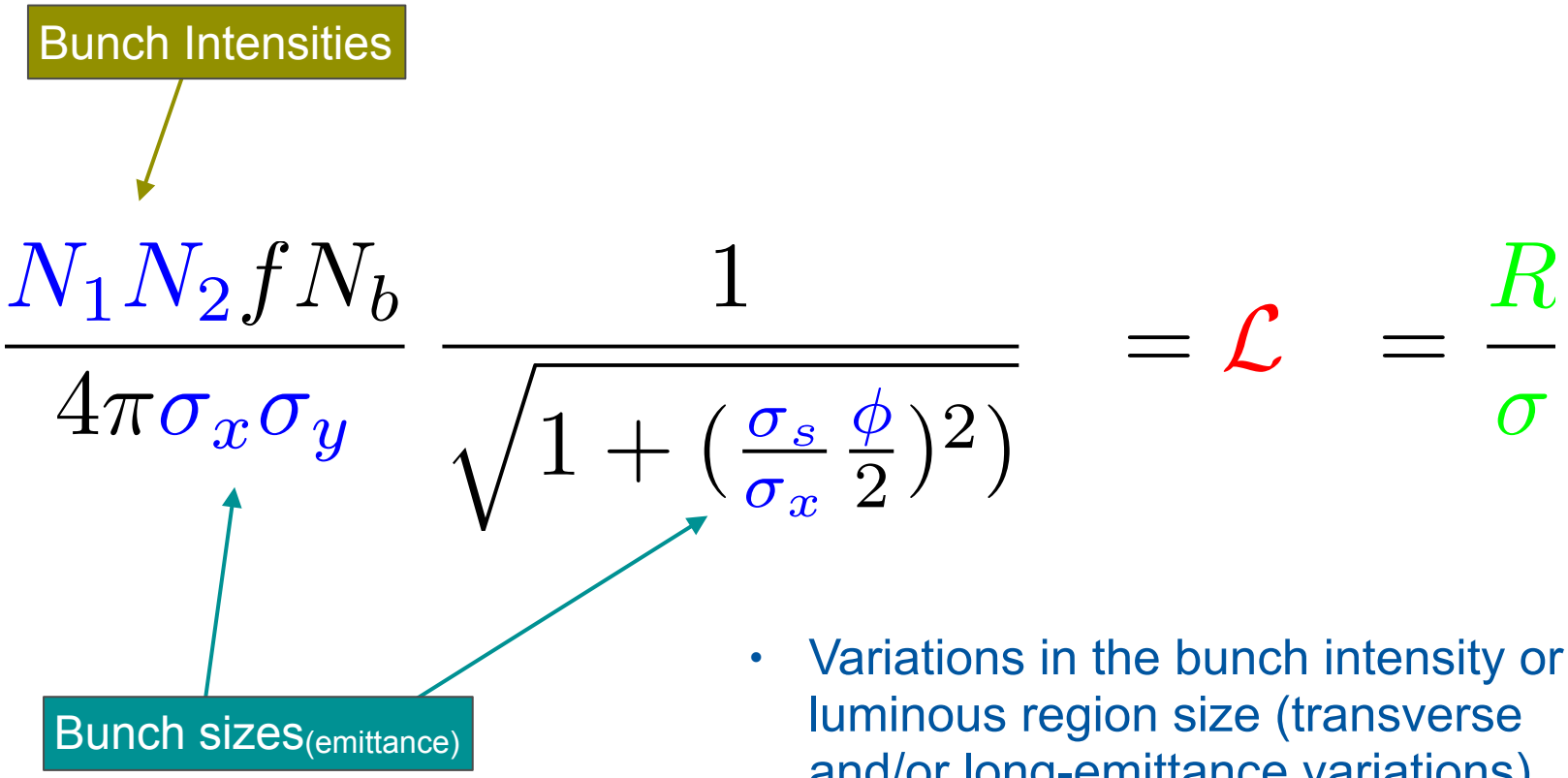
Buch-by-bunch Luminosity Variations in LHC

Study of the BbyB Luminosity variations in Run 2

Correlations and impact for LHC & HL-LHC

I. Efhtymiopoulos

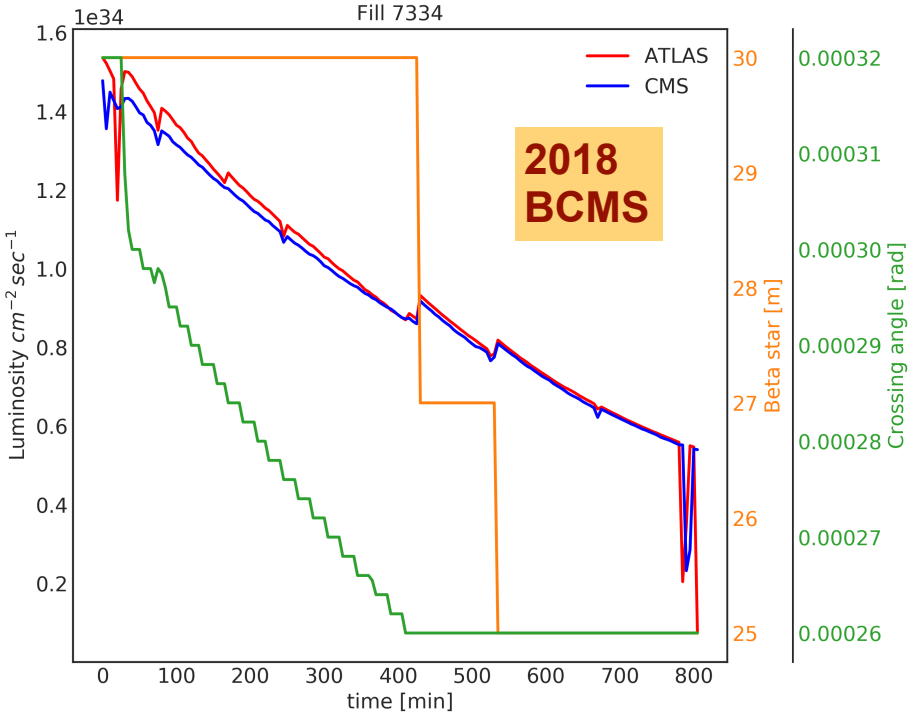
Bunch-by-Bunch Luminosity Variation

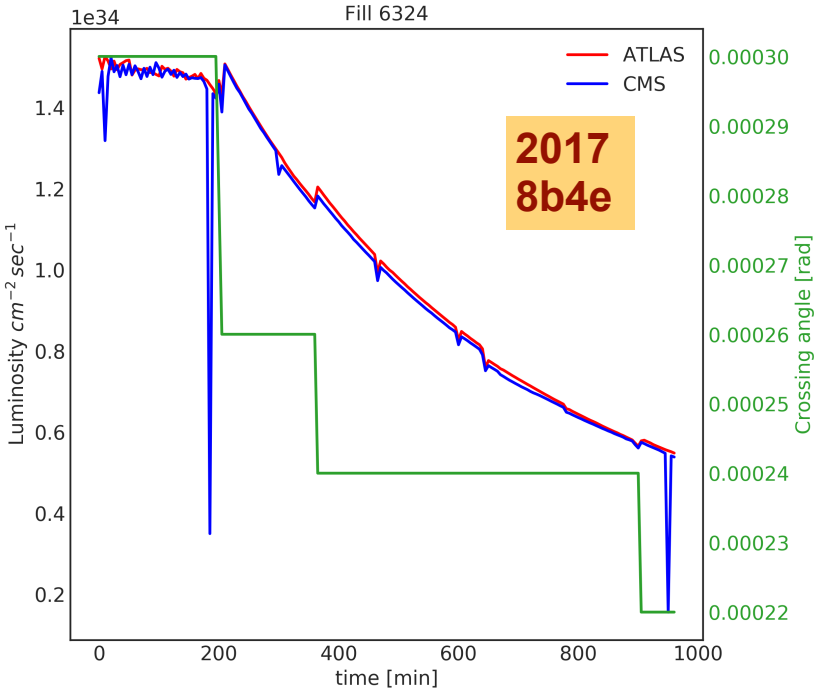


- Variations in the bunch intensity or luminous region size (transverse and/or long-emittance variations) result in Luminosity variations for the experiments or fluctuations to the event PU rate

Luminosity Variations in LHC

- Luminosity (integrated over all bunches) evolution in SB

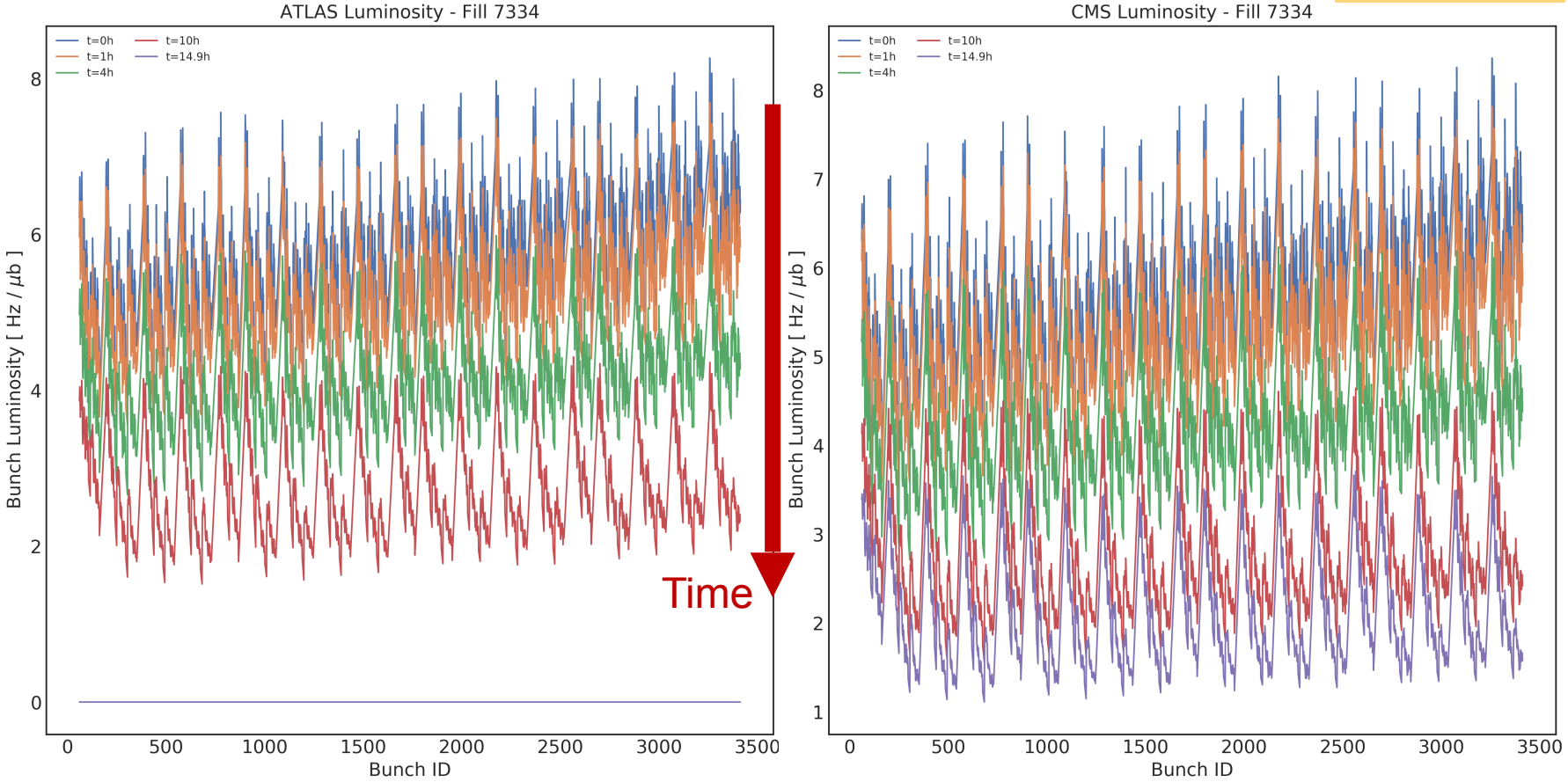




Luminosity Variations in LHC

- Bunch Luminosity evolution in SB

2018 BCMS



Luminosity Variations in LHC

- Compare several fills in 2017 and 2018 with BCMS and 8b4e beams and different polarities for LHCb dipole
- Fills considered:

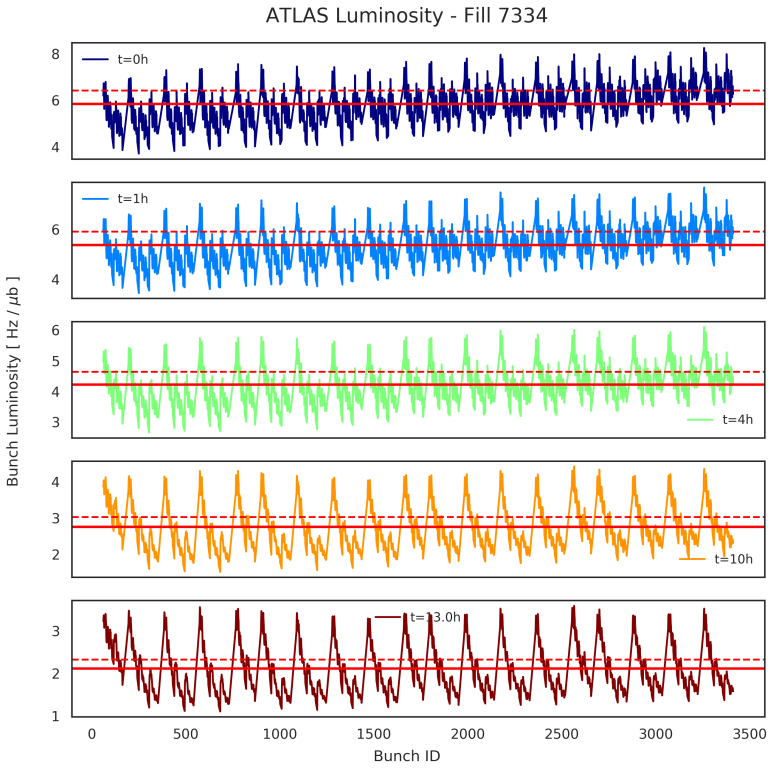
2017	Fill	SB duration	LHCb polarity
BCMS	5848	~20h	NEG
	5849	~1d2h	NEG
	5976	~14h	POS
8b4e	**6324**	~15h	POS
	6364	~15h	NEG
	6385	~14h	POS

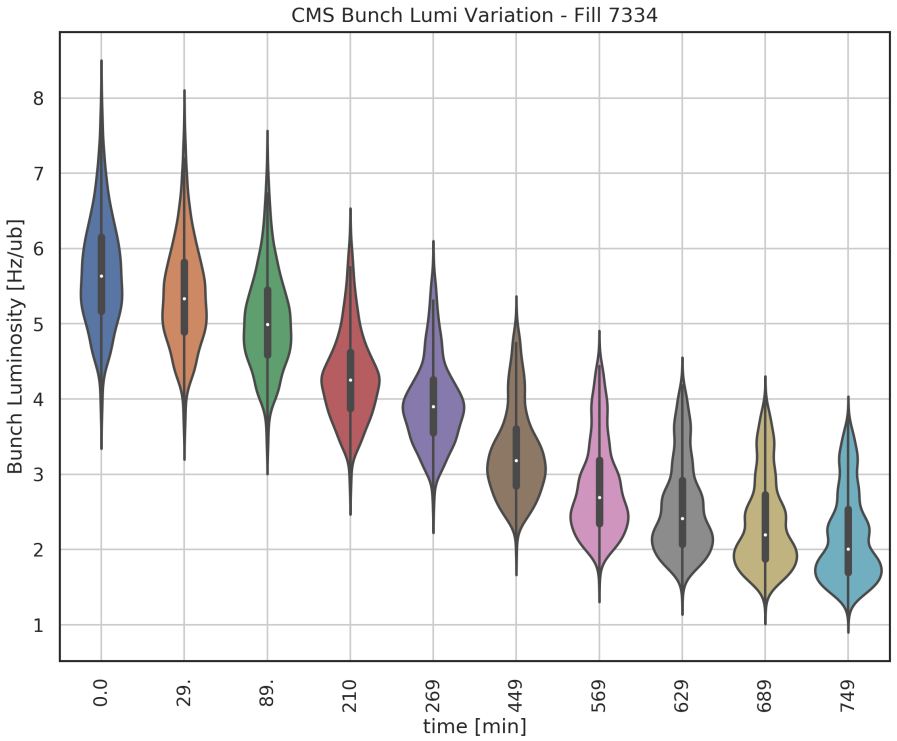
2018	Fill	SB duration	LHCb polarity	
BCMS	**6919**	~20h	NEG	ATLAS levelled
	7056	~1d2h	POS	
	7061	~14h	POS	
	7320	~15h	NEG	
	7314	~15h	NEG	
	7334	~14h	NEG	

Fill 7334 – 2018 BCMS LHCb/neg

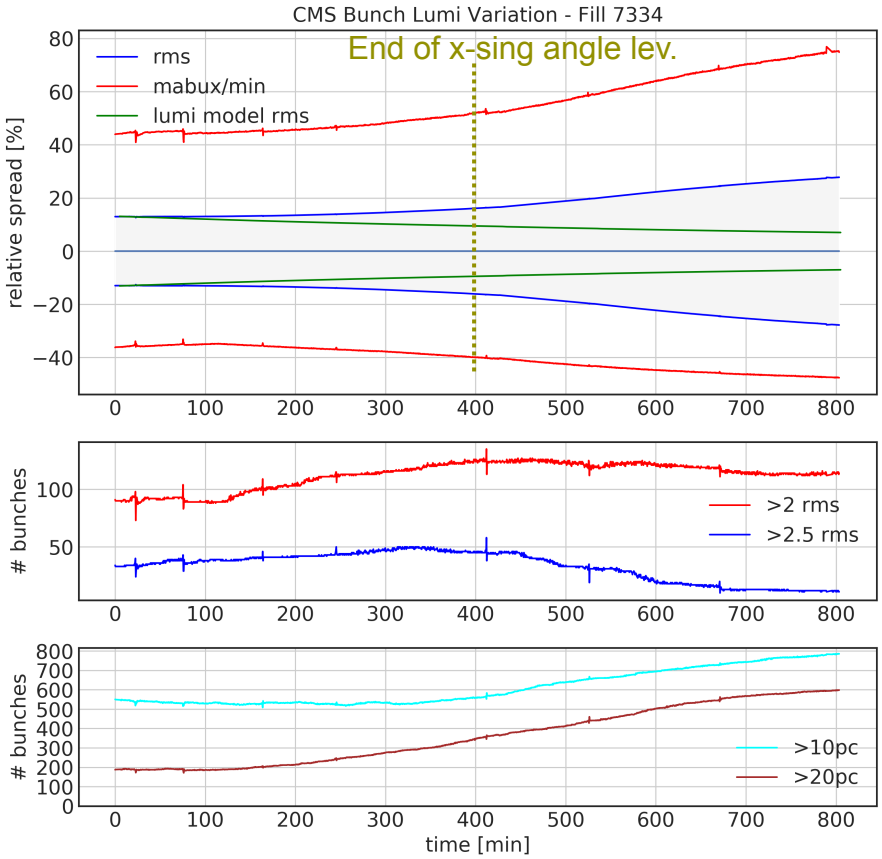
Bunch lumi vs time

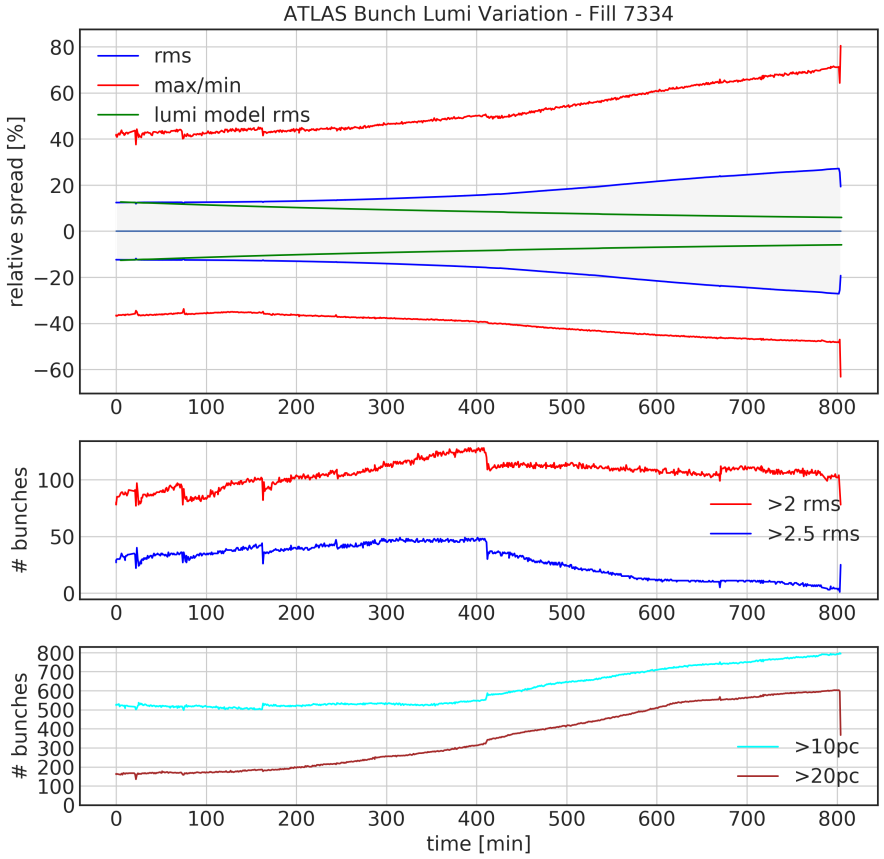
- red line = mean luminosity
- Dashed line = +10%



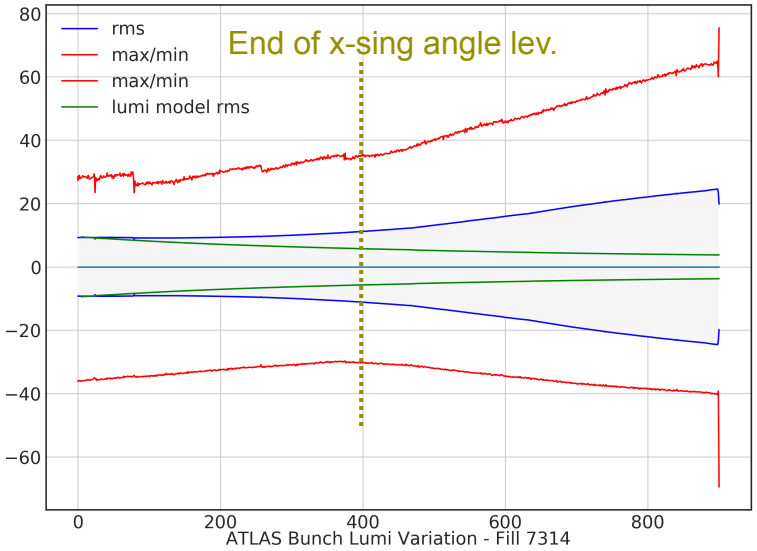


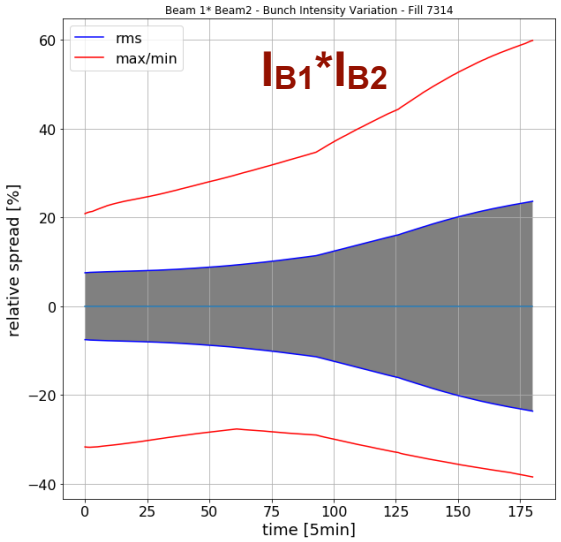
Fill 7334 – 2018 BCMS LHCb/neg

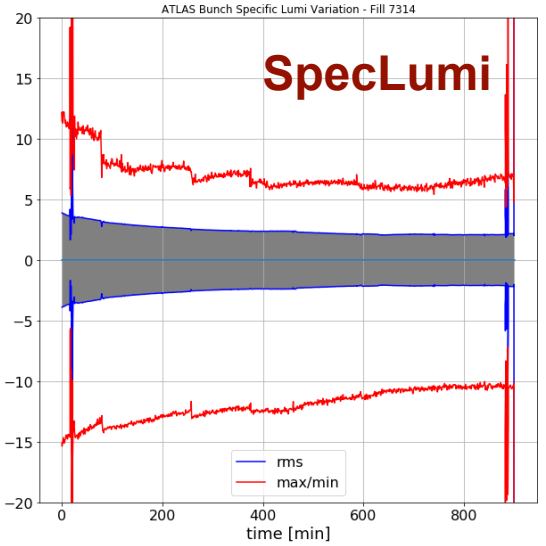


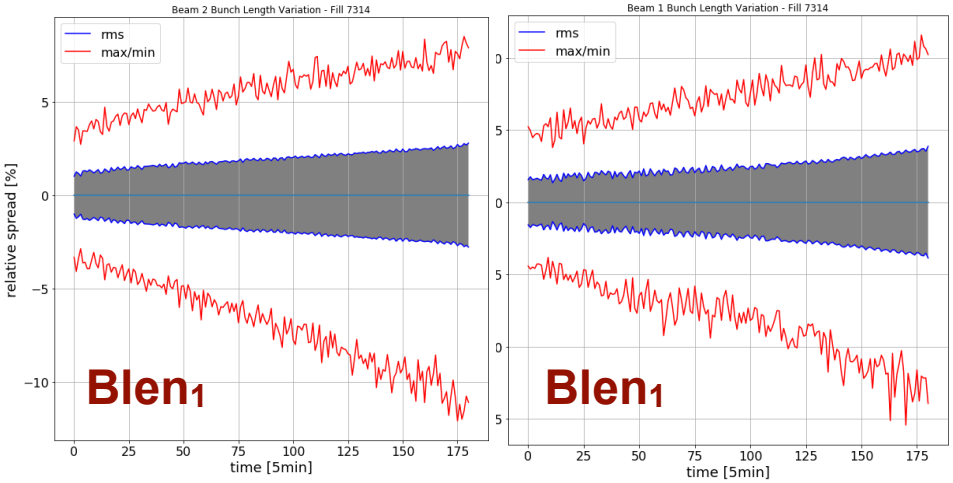


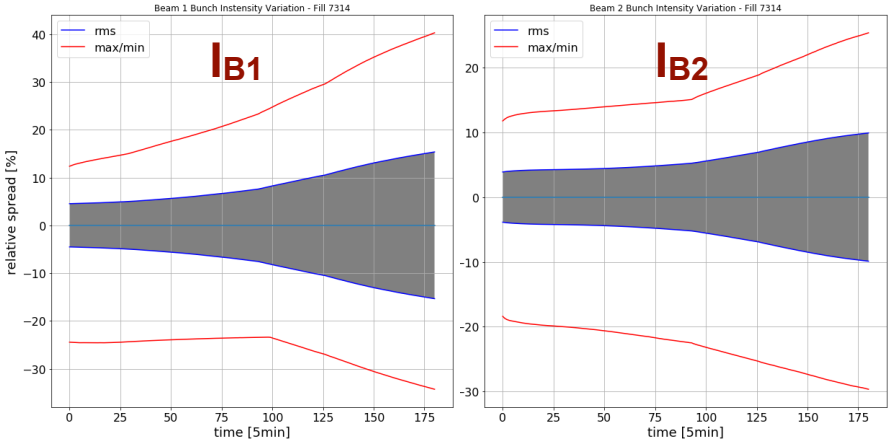
Fill 7314 - BCMS/LHCb=NEG





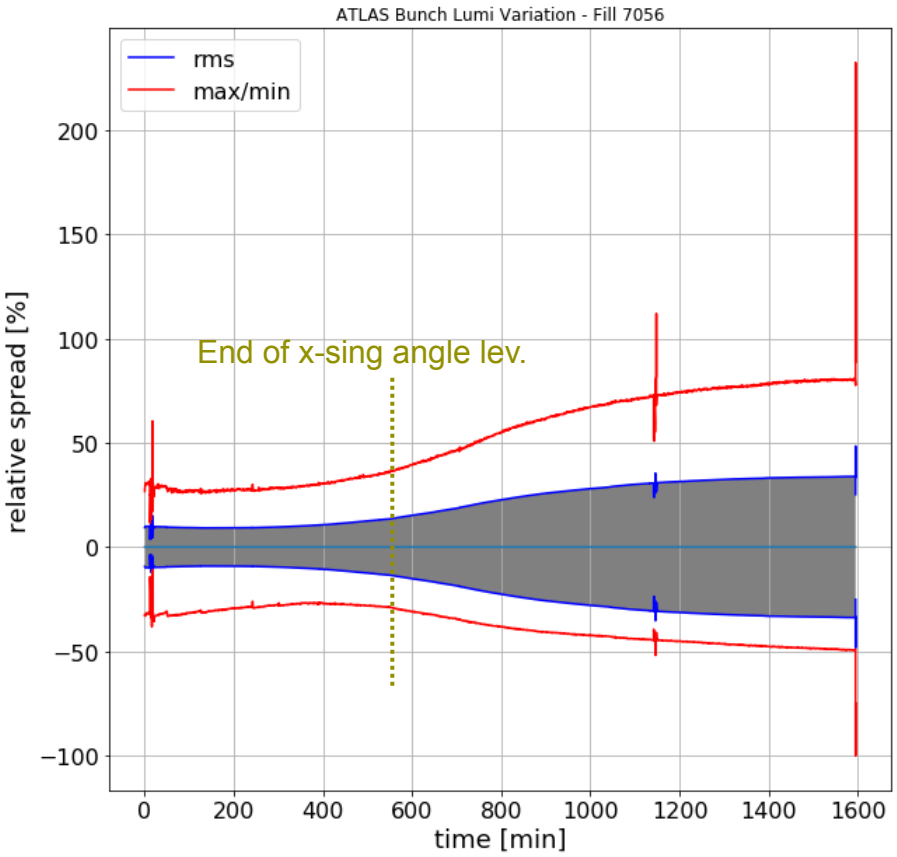






Fill 7056 - BCMS/LHCb=POS

2018



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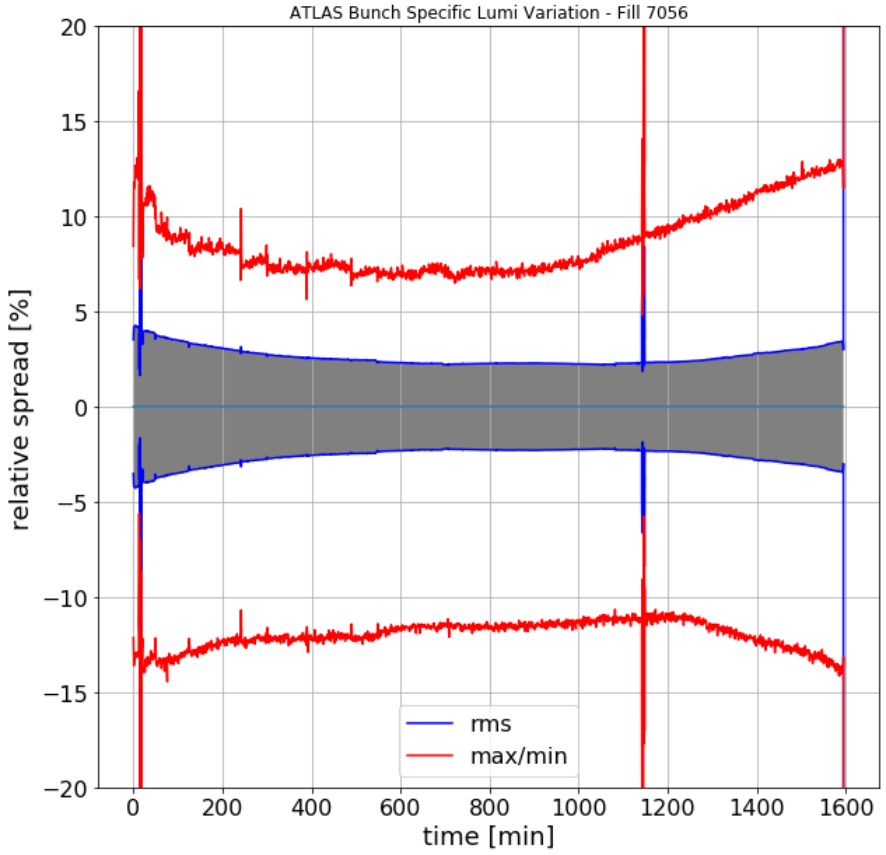
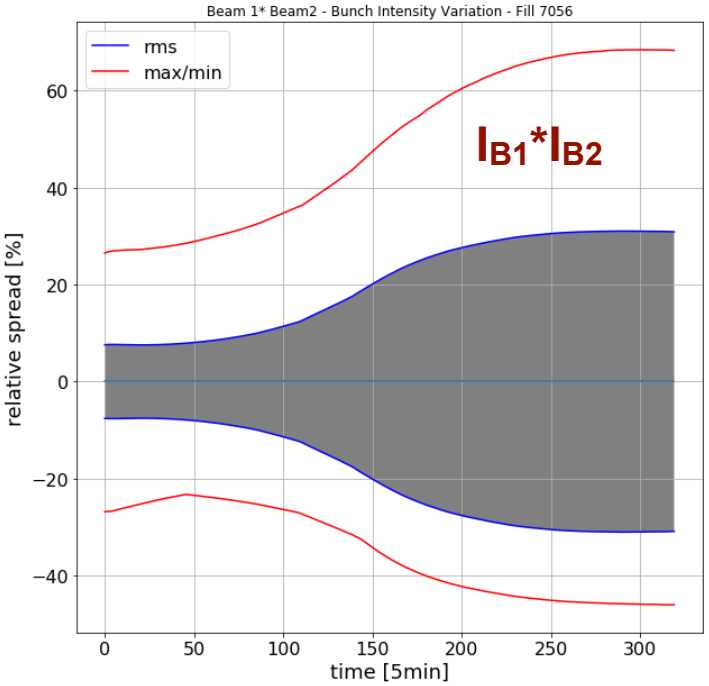
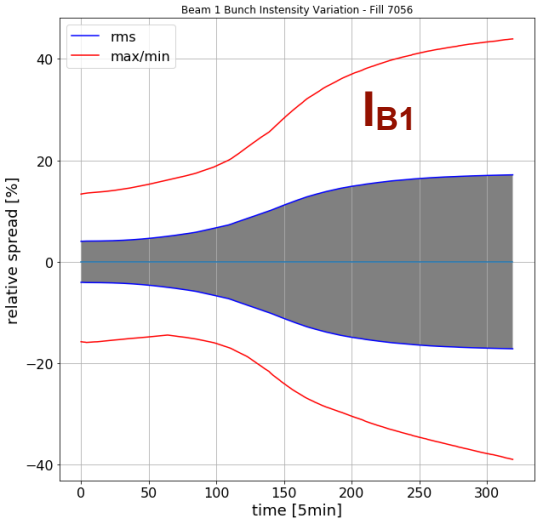
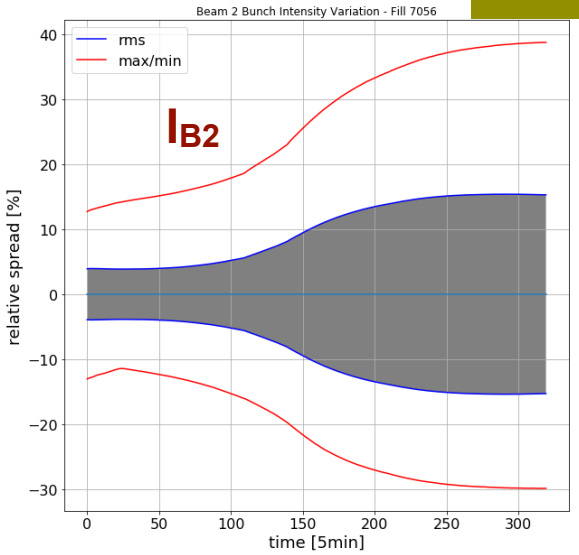


Fill 7056 - BCMS/LHCb=POS

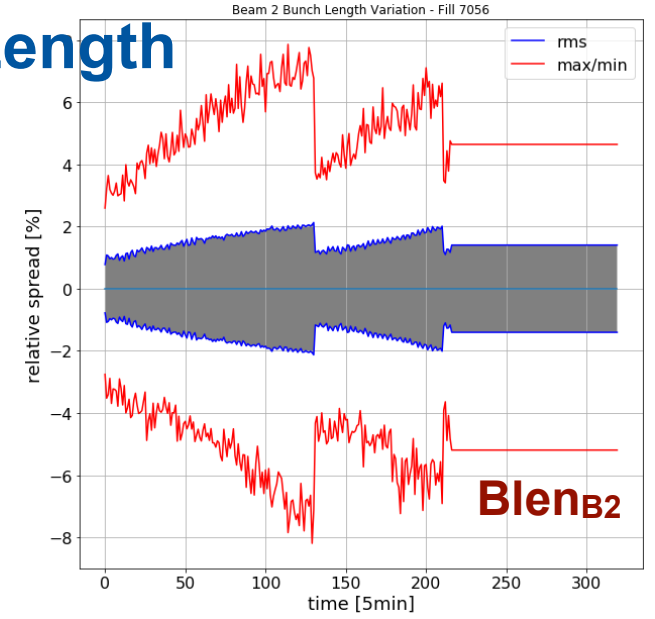
2018







Bunch Length

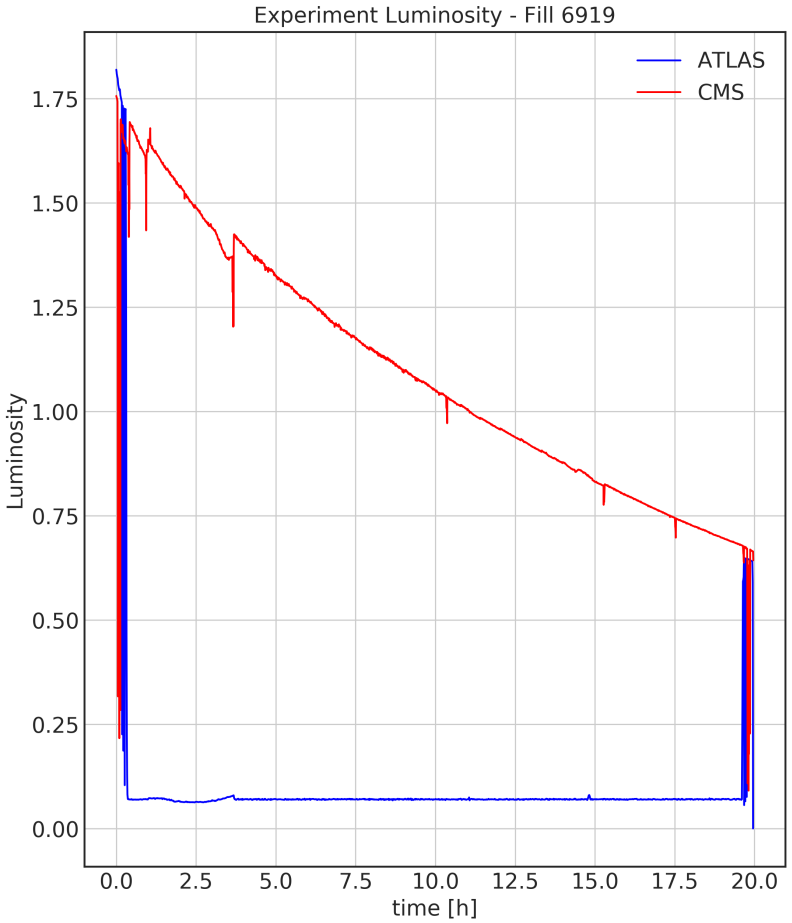


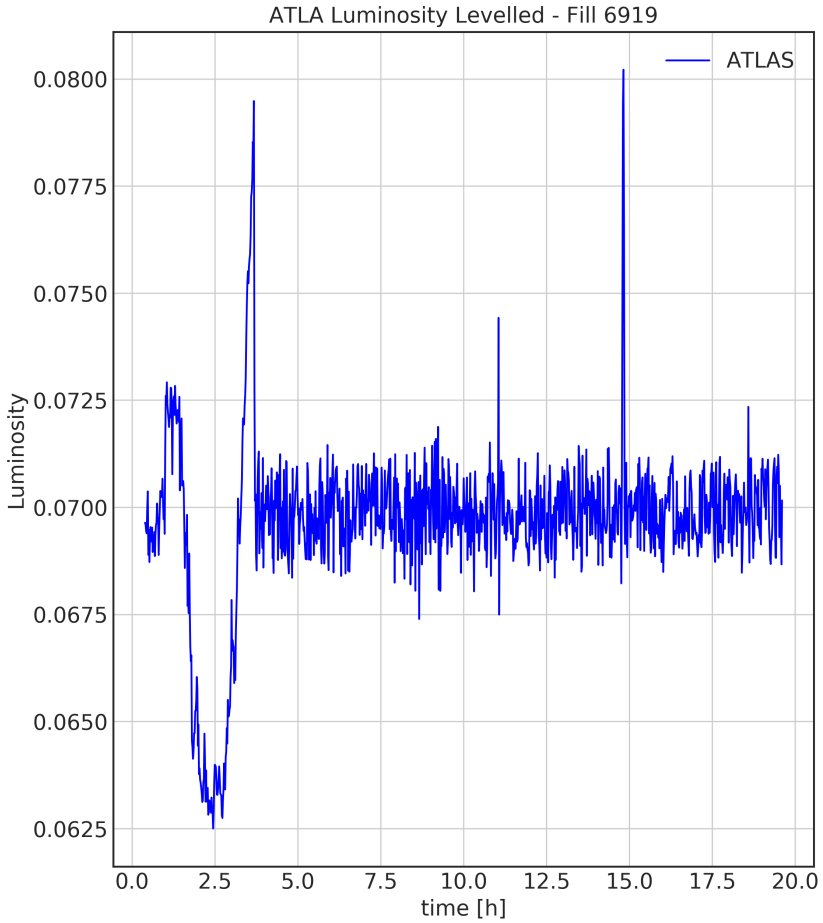
- The observed variations vs time in the bunch luminosity are mainly correlated to the beam intensity variations

Fill 6919 - BCMS/LHCb=NEG

2018

- ATLAS levelled at 0.7e34 for the whole fill

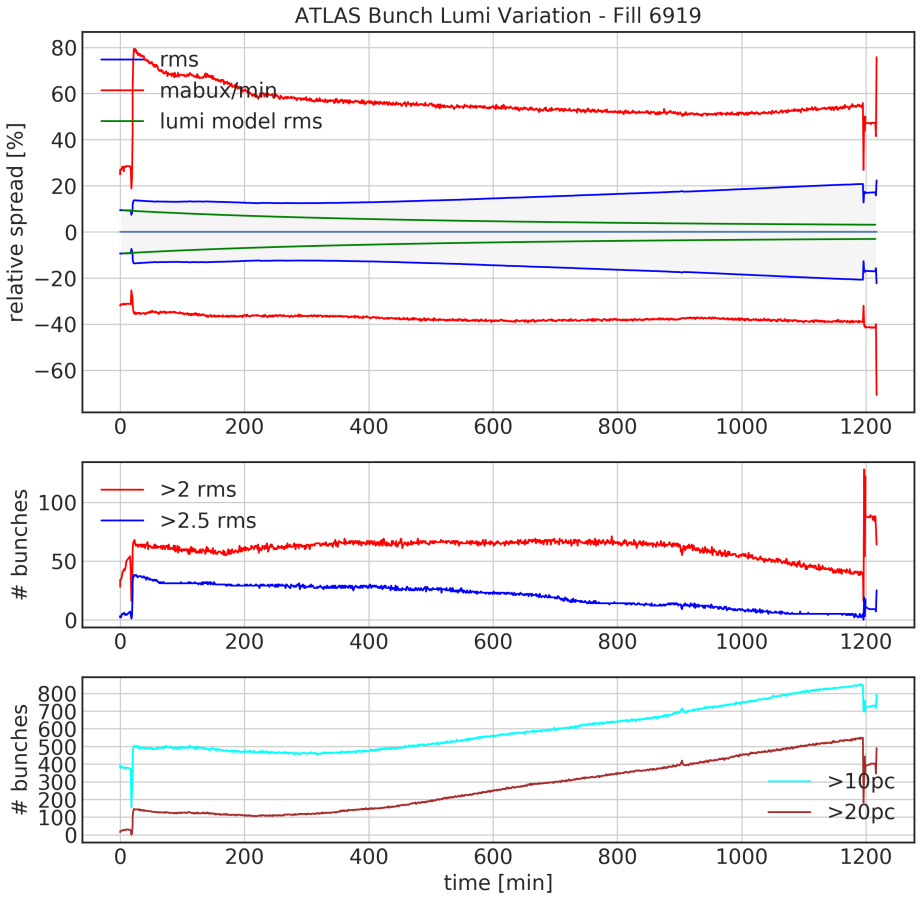


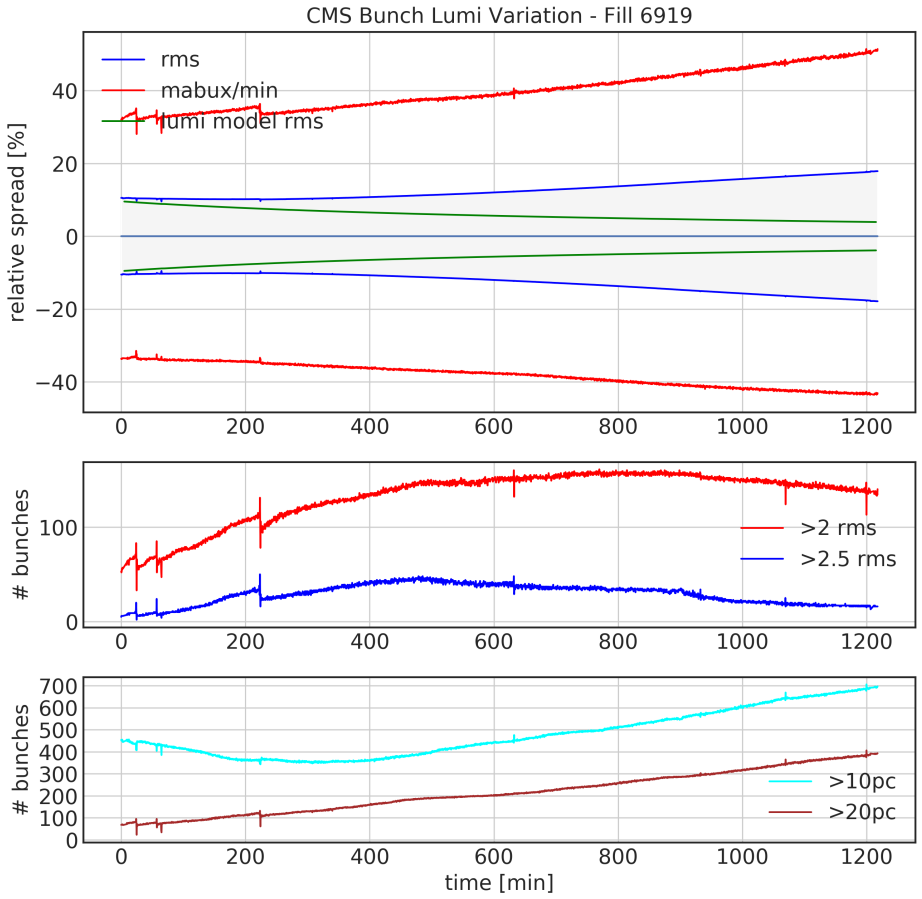


Fill 6919 - BCMS/LHCb=NEG

2018

- Bunch luminosity variation

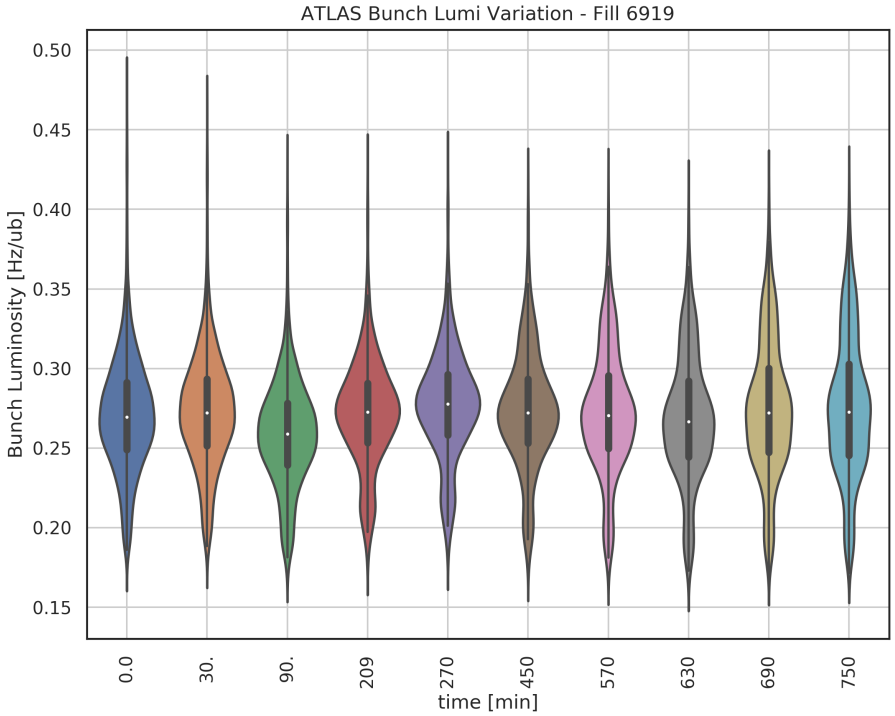


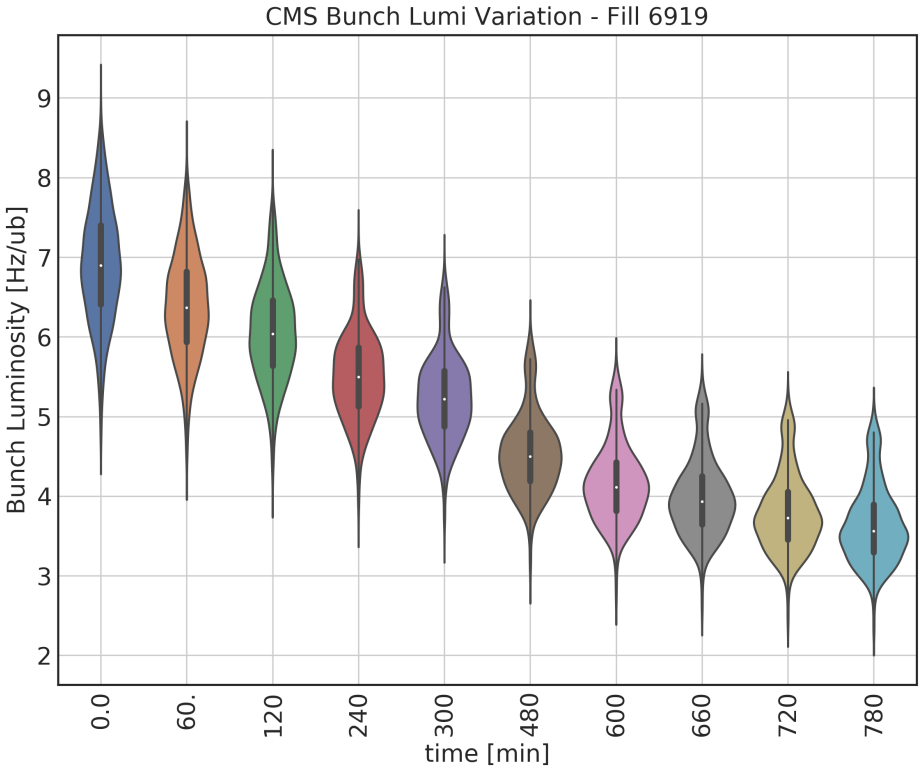


Fill 6919 - BCMS/LHCb=NEG

2018

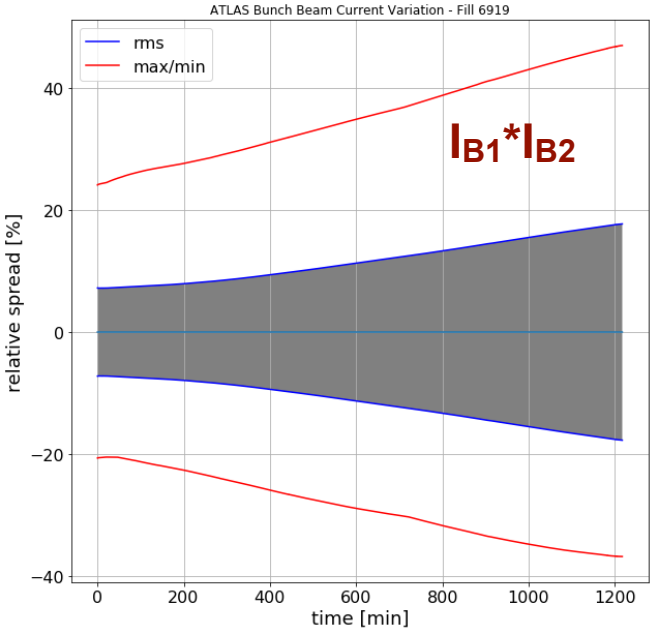
- Bunch luminosity variation

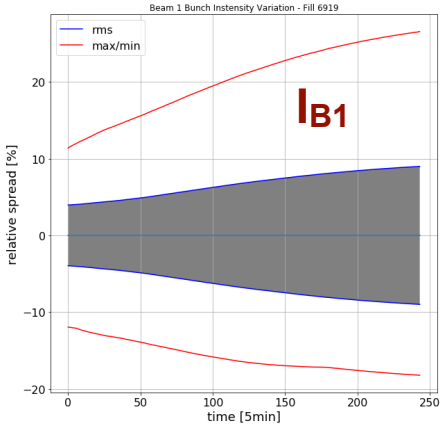


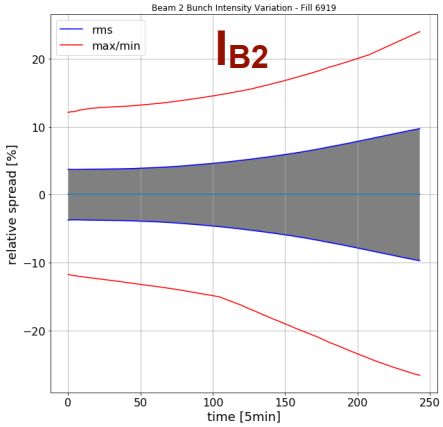


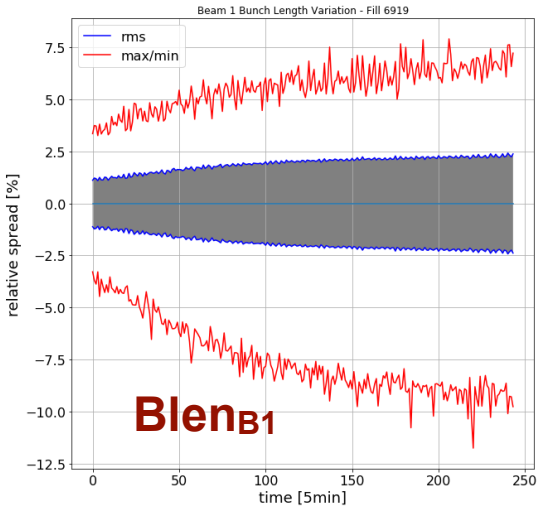
Fill 6919 - BCMS/LHCb=NEG

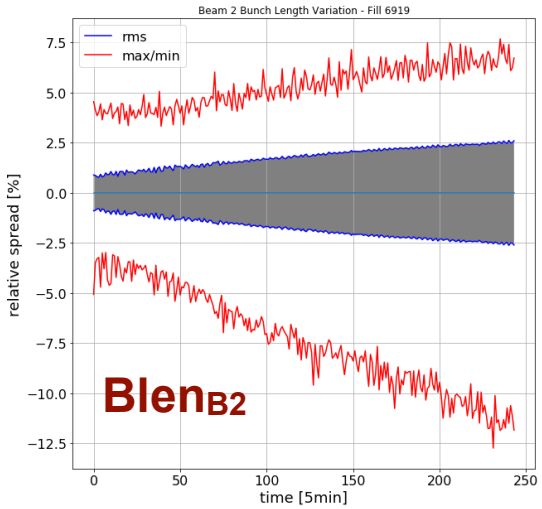
2018





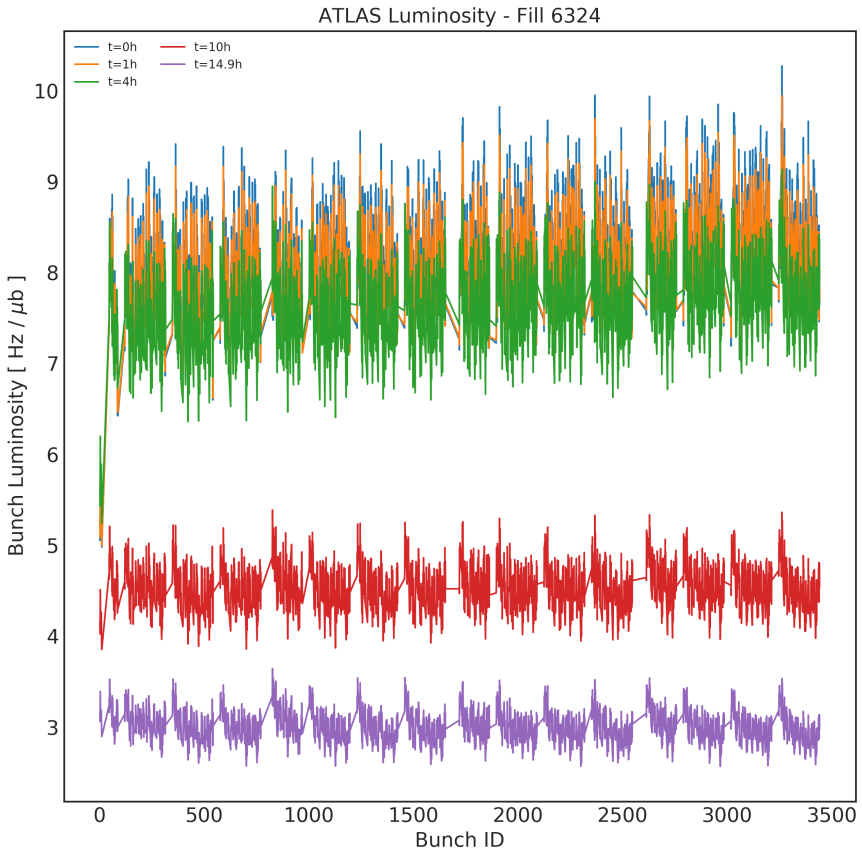


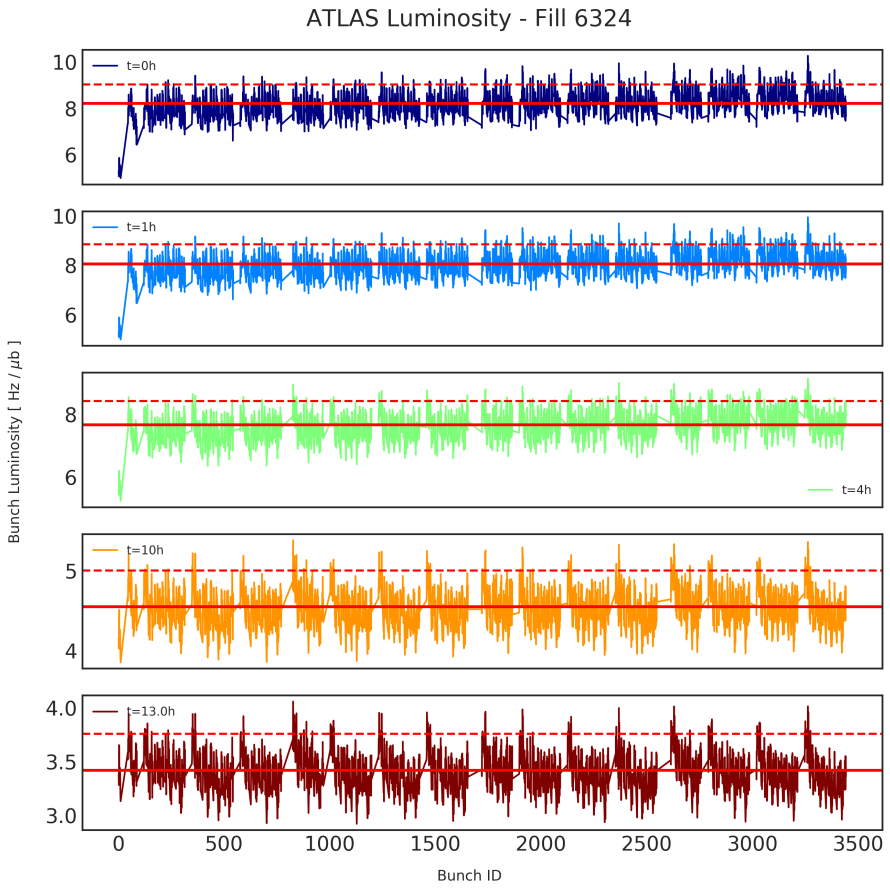




- The fact that ATLAS was levelled (by separation) had marginal effect on the bunch luminosity variations for both experiments
- As for other fills, the major contribution comes from the beam intensity fluctuations with both beams having equal share

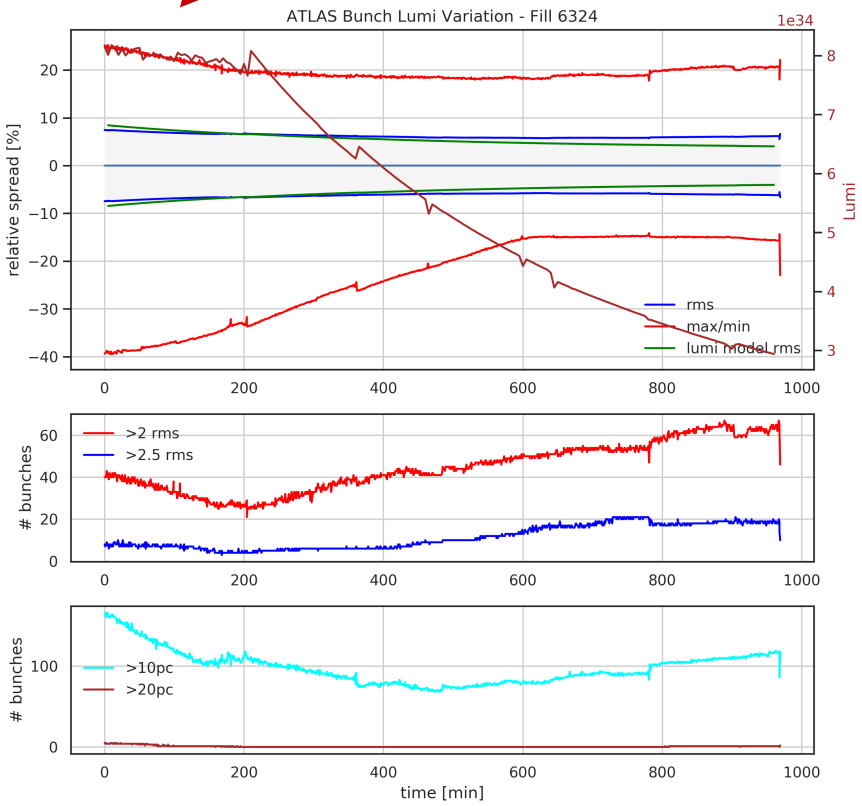
Fill 6324 – 2017 8b4e



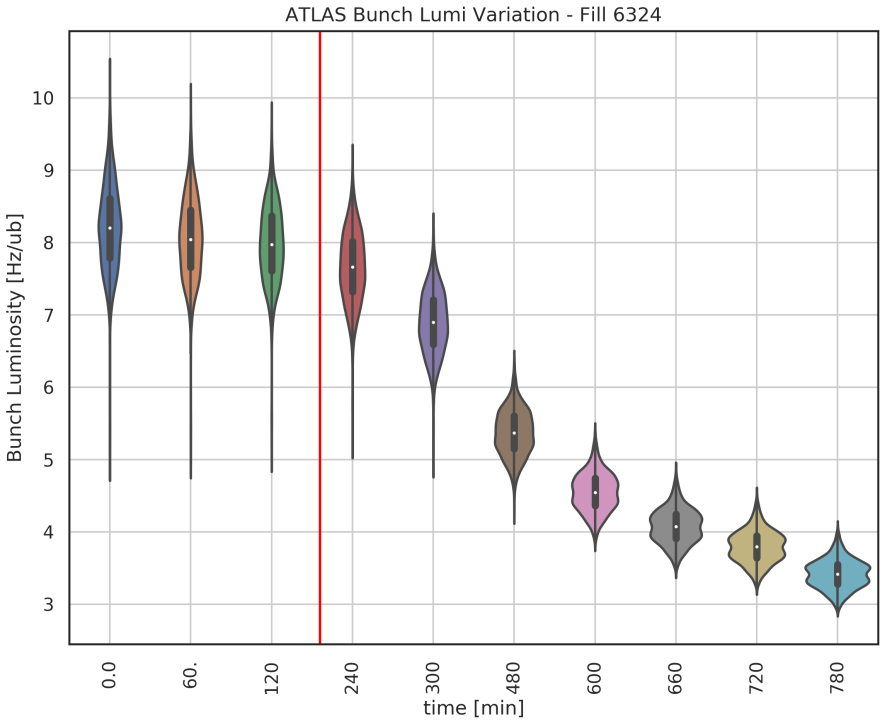


Fill 6324 – 2017 8b4e

Lumi leveling

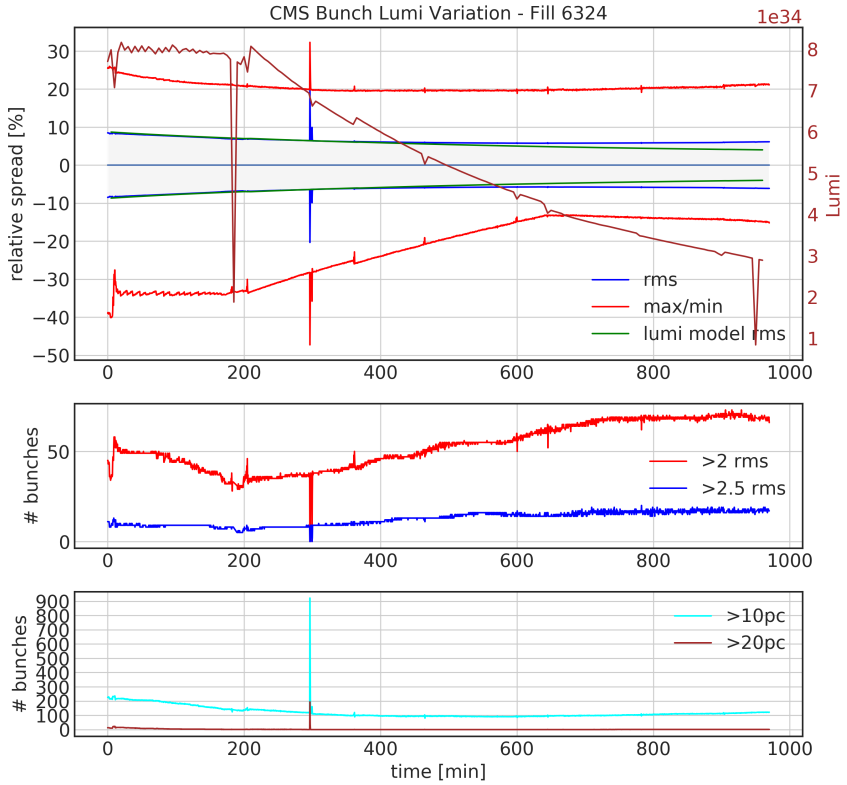


Lumi leveling

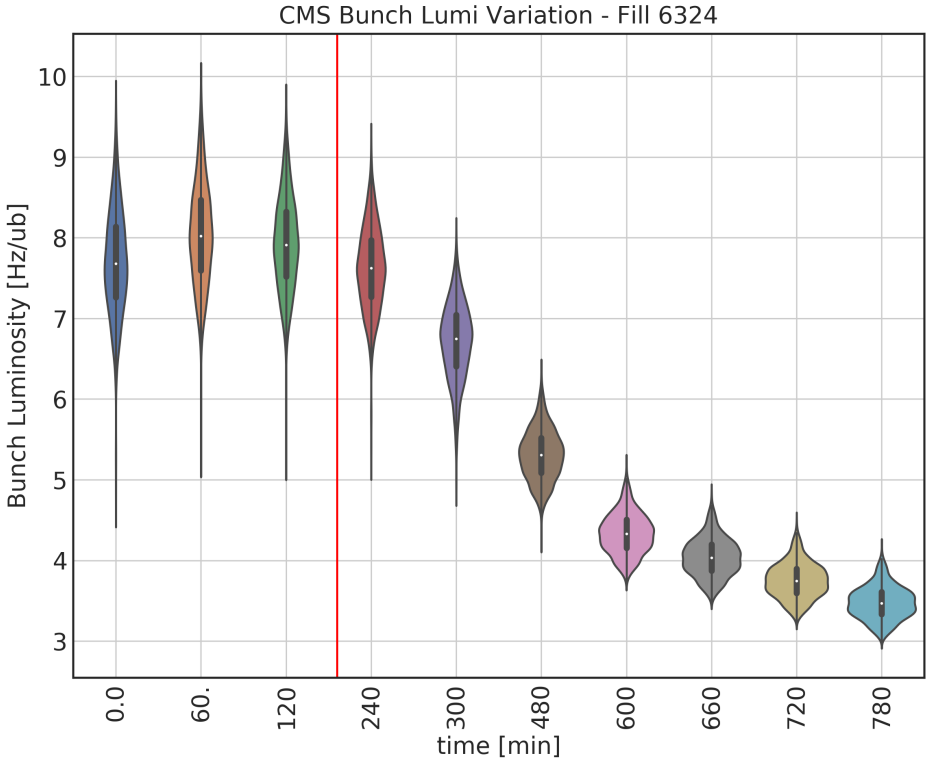


Fill 6324 – 2017 8b4e

- CMS data

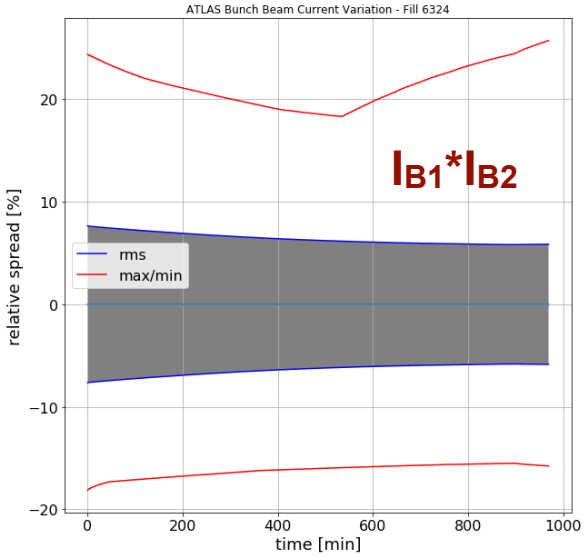


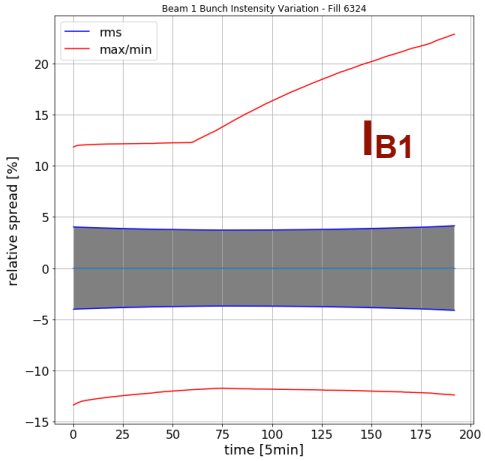
Lumi leveling

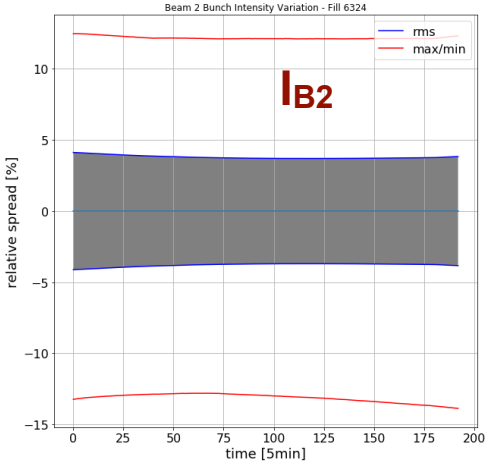


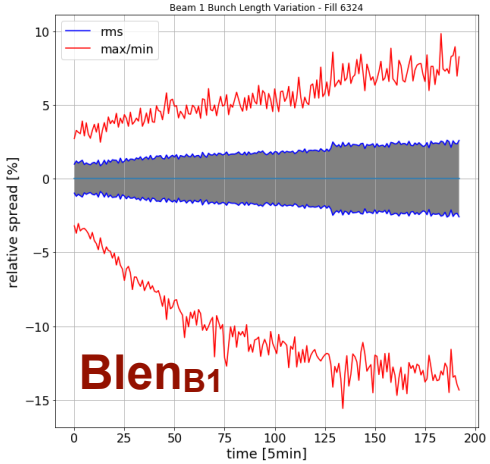
Fill 6324 - 8b4e/LHCb=POS

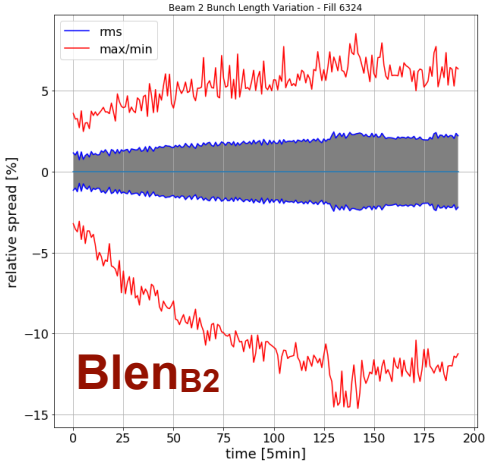
2017

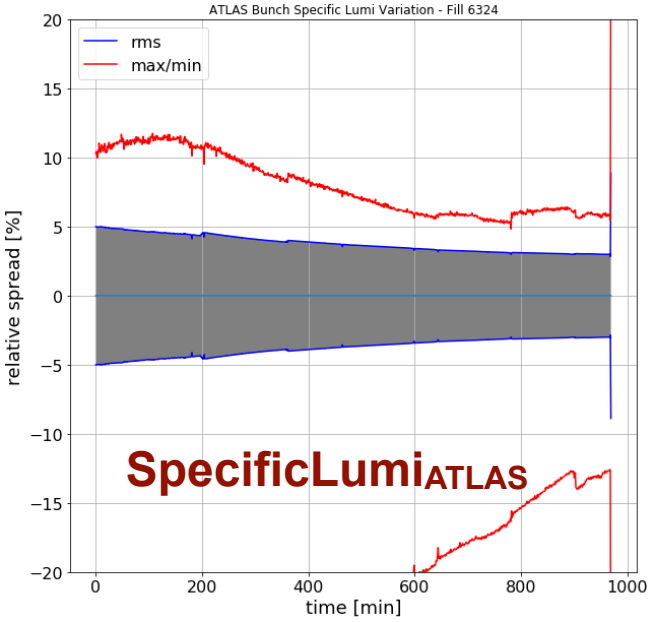






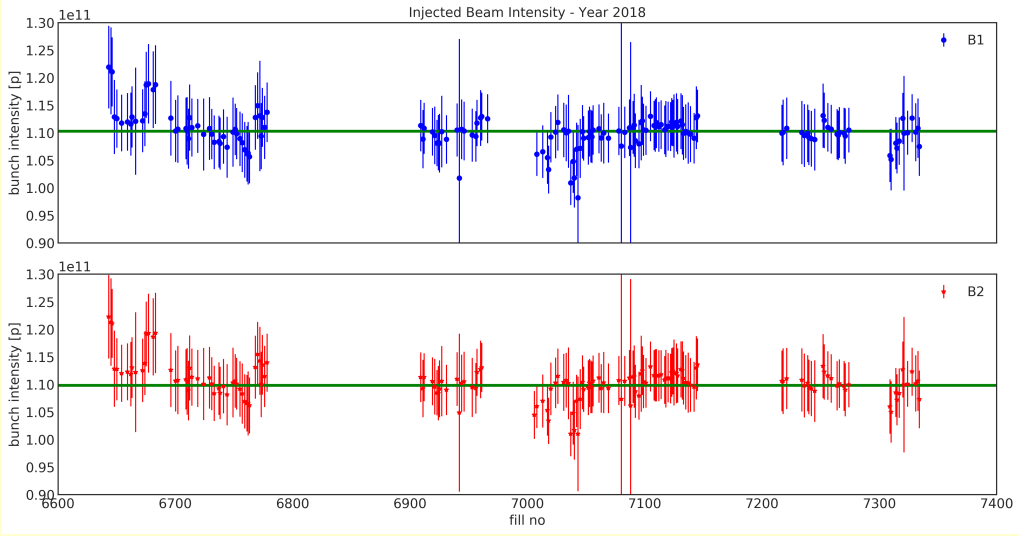


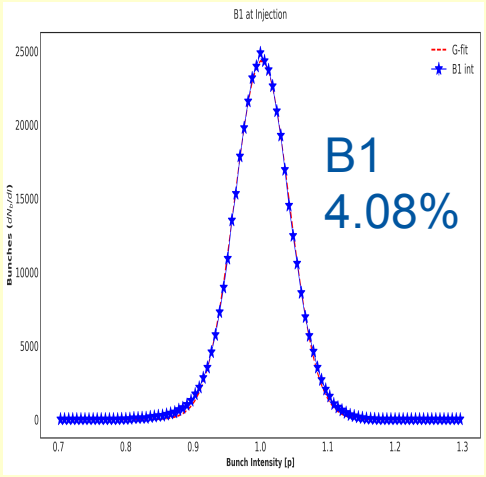


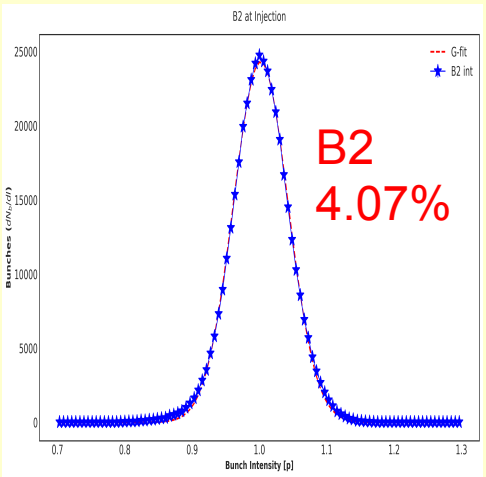


Intensity fluctuations in the cycle

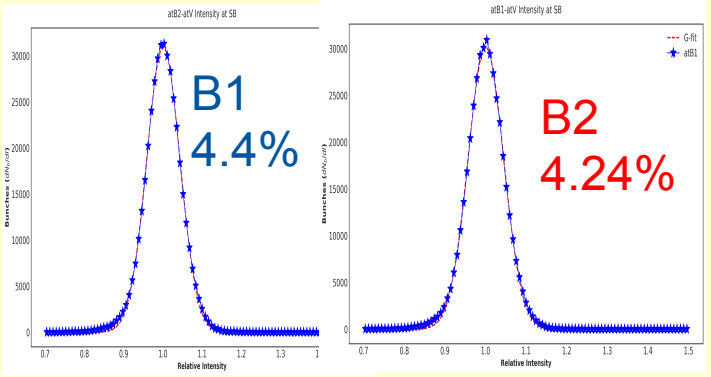
Injection – beam intensity 2018







Stable Beam – Intensity



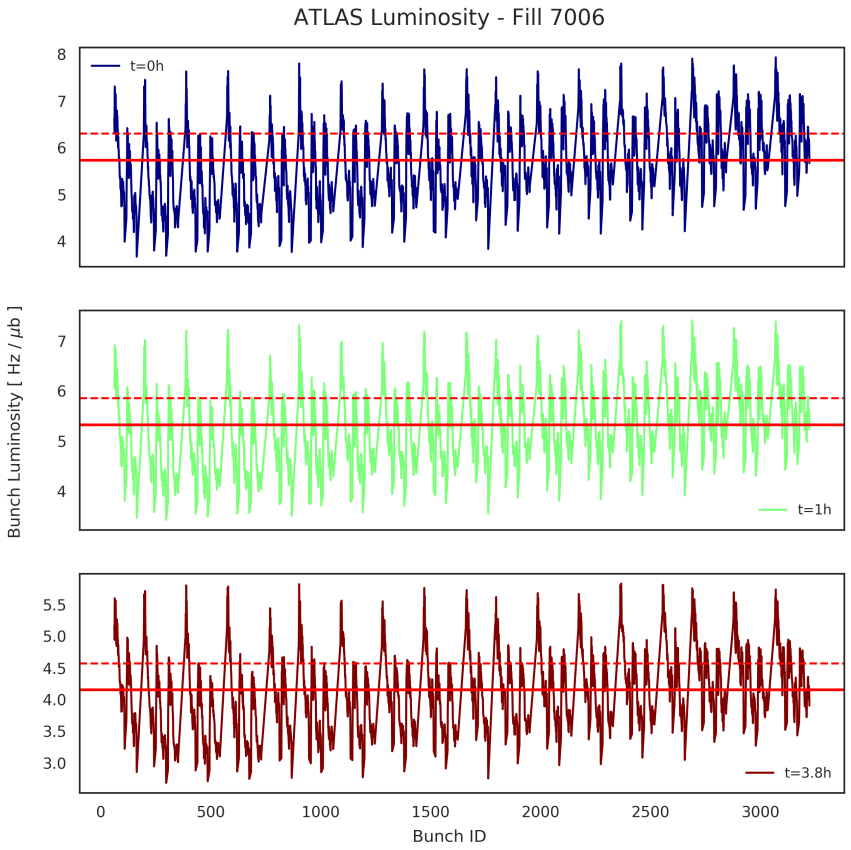
Emittance

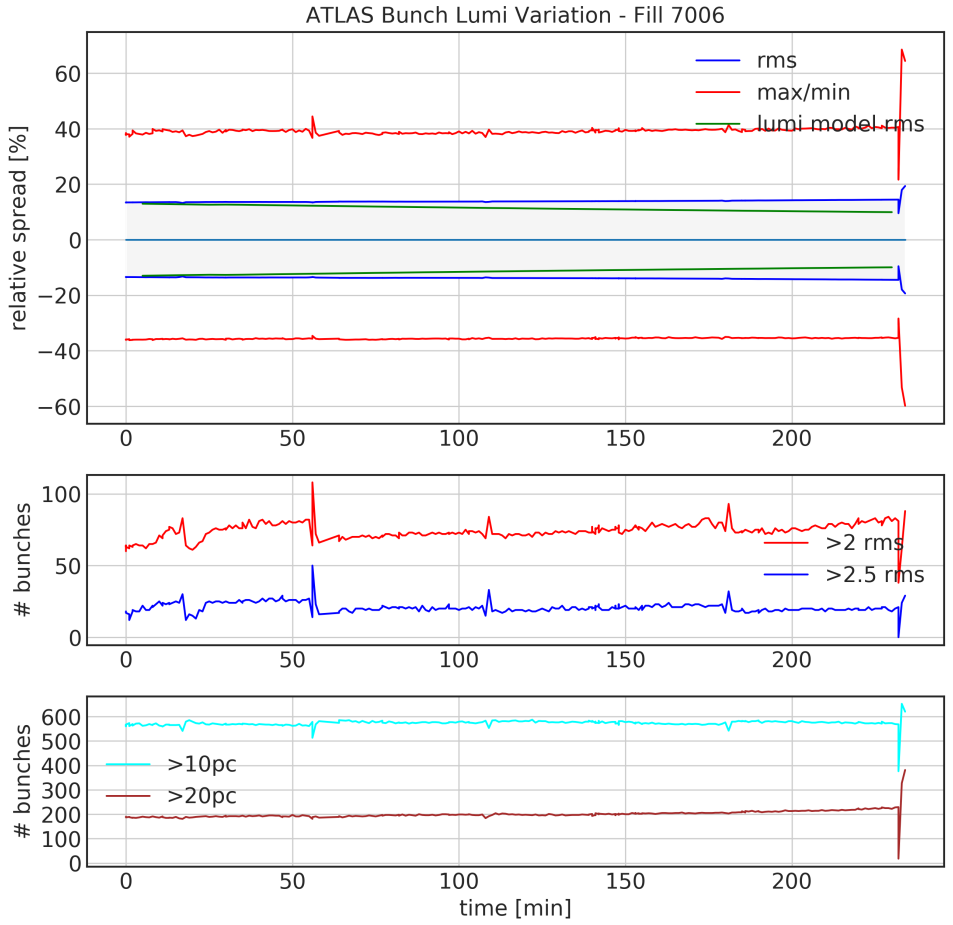
	B1H	B1V	B2H	B2V
Inj	4.78%	4.6%	4.96%	5.1%
SB	6.54%	7.78%	*13.64%*	9.86%

From BSRT data – all fills without any selection !

Fill 7006 – 2018 BCMS

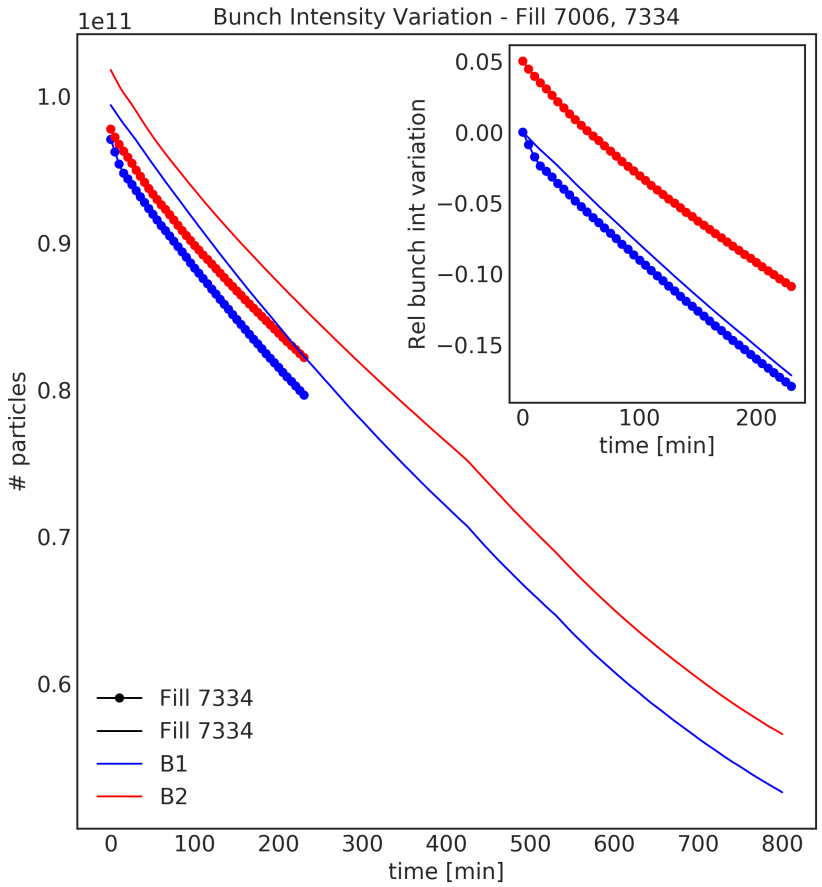
- "nominal" BCMS fill as all others in 2018, except of the missed last injection of B1

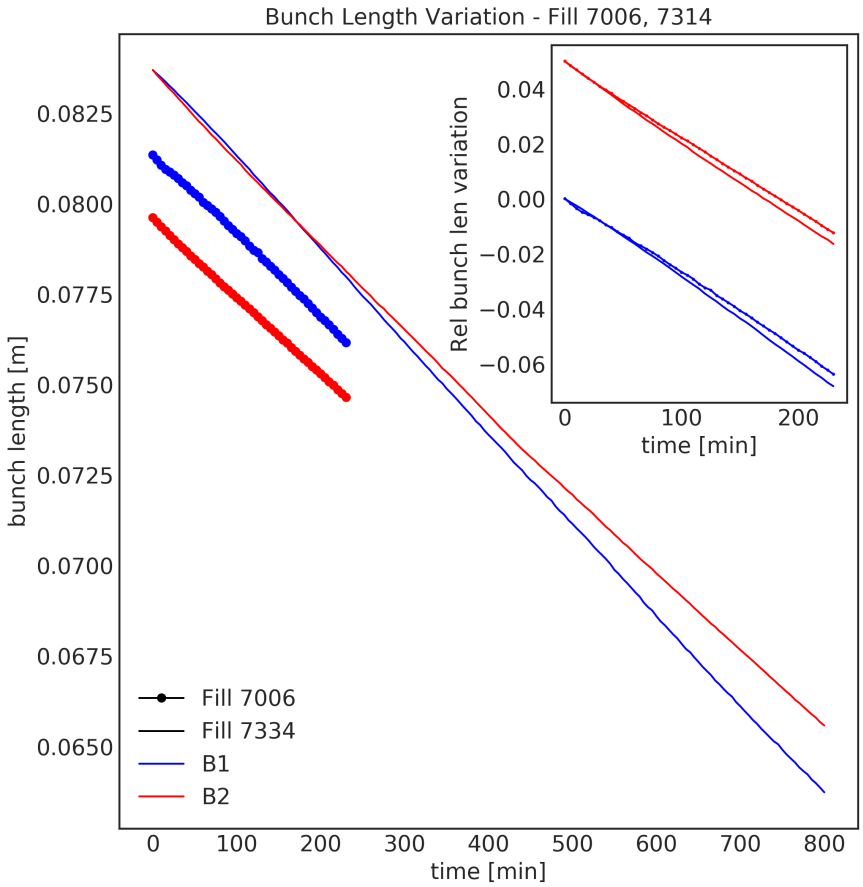




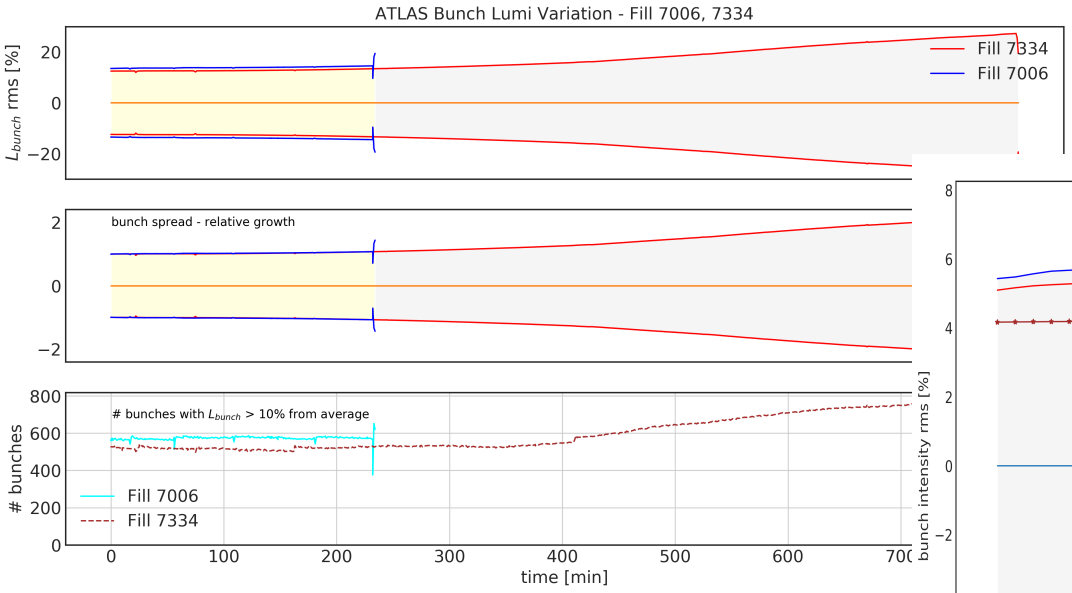
Fill 7006 – 2018 BCMS

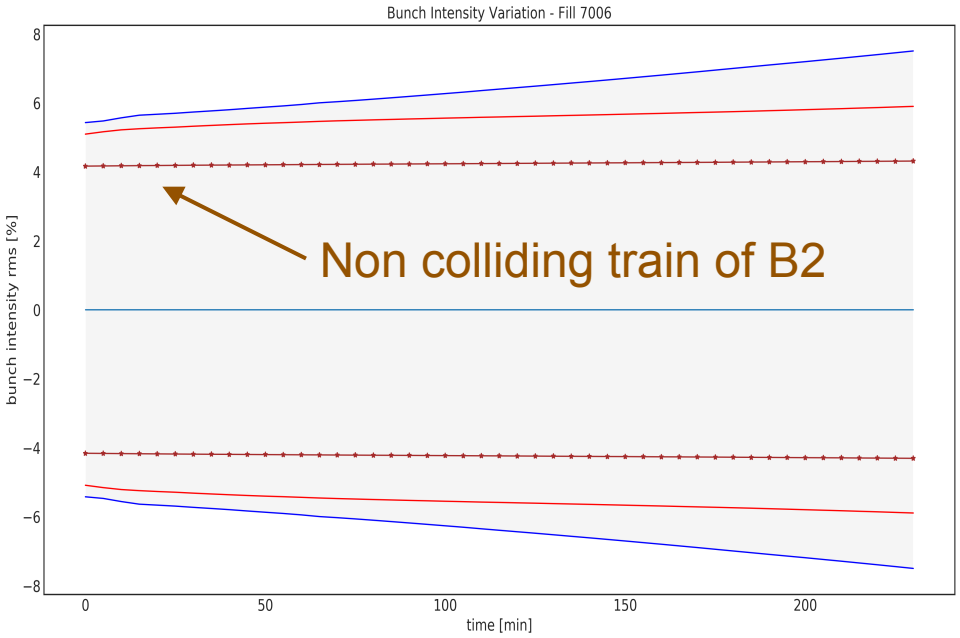
- Compare colliding bunches with another fill
  - good agreement for the duration of the fill





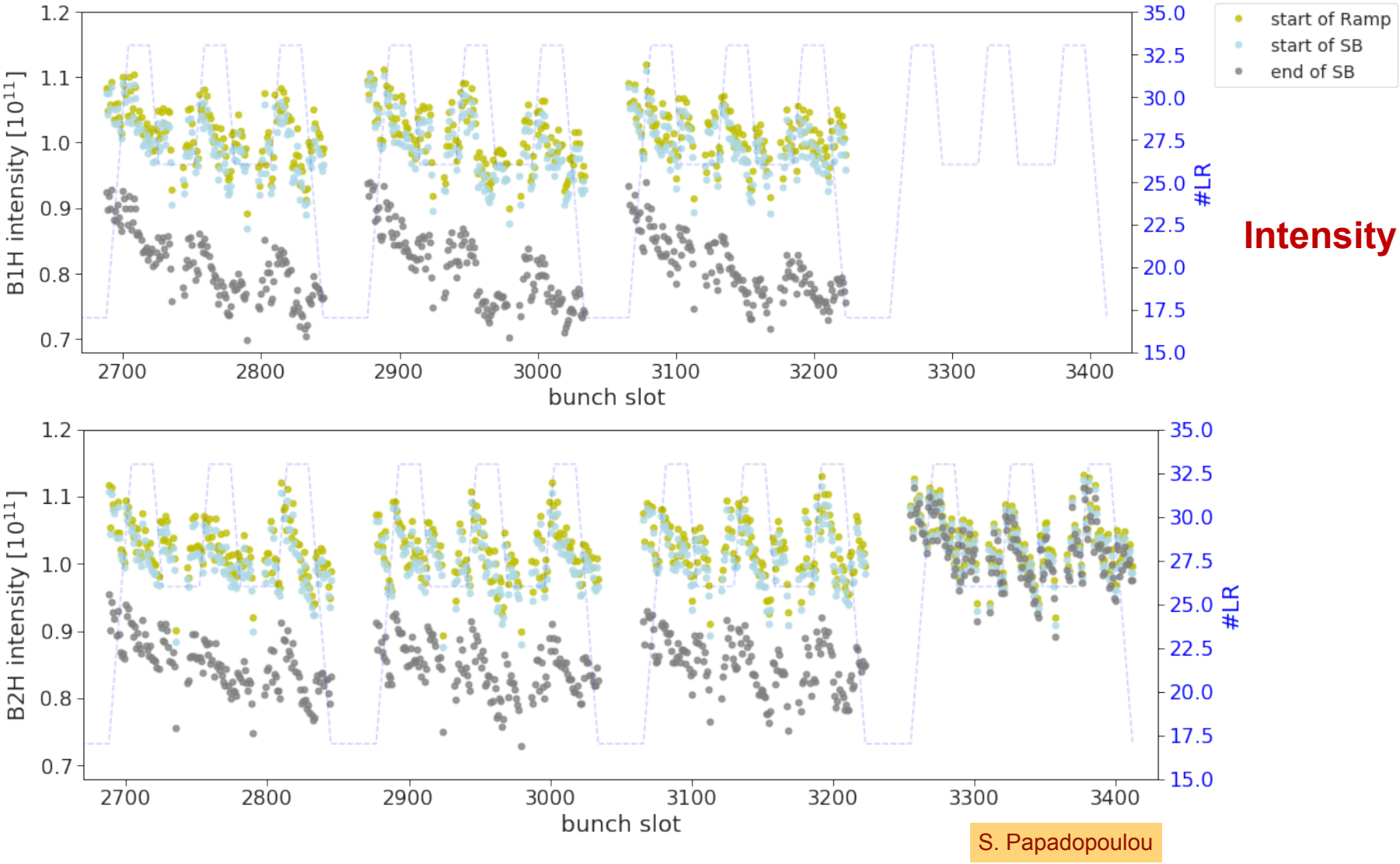
Fill 7006 – 2018 BCMS





- No RMS growth of the non-colliding train bunches, while the colliding trains show the same increase as in all other BCMS fills.

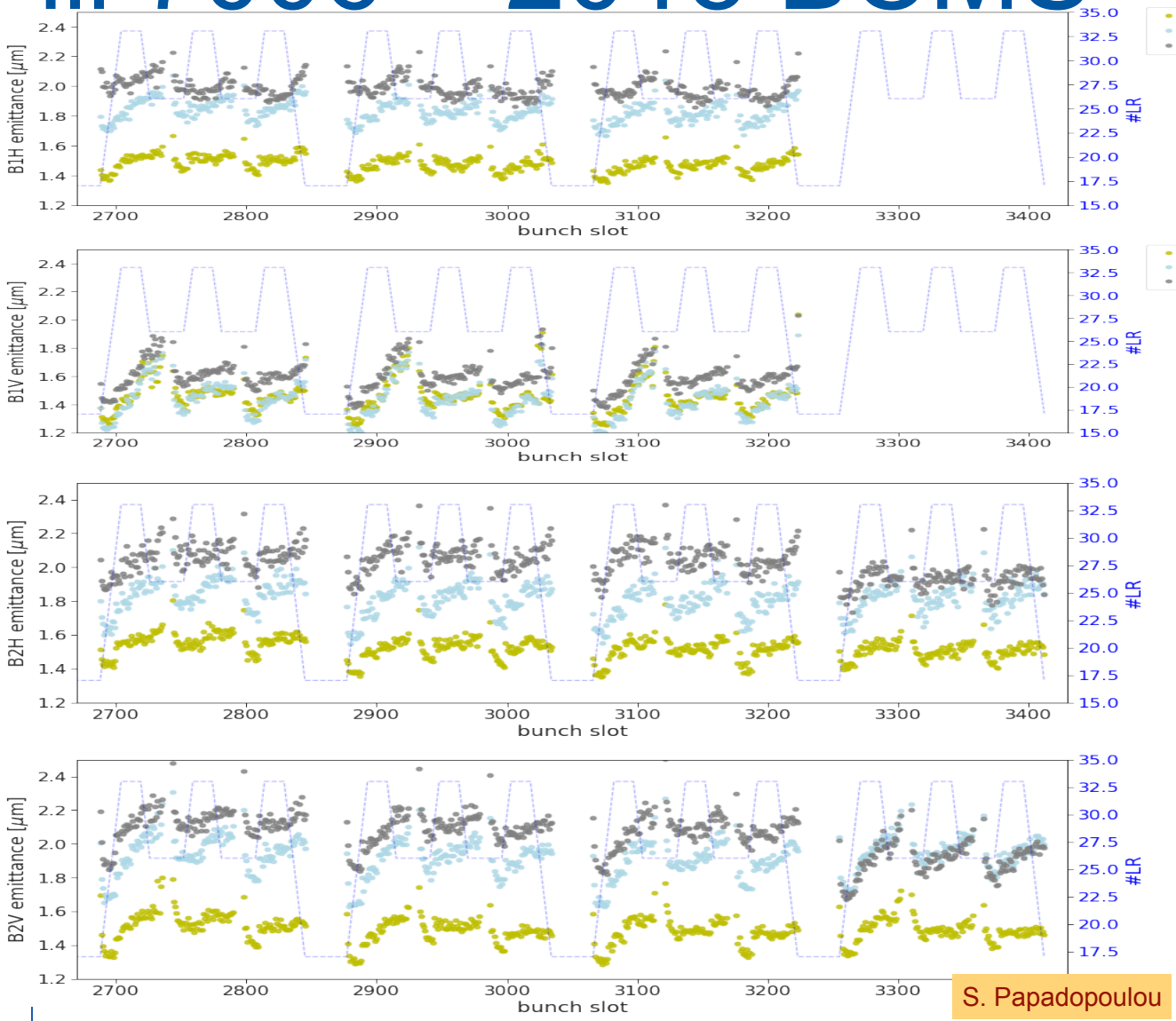
Fill 7006 – 2018 BCMS



Intensity

S. Papadopoulou

Fill 7006 – 2018 BCMS



Emittance

Non colliding train:

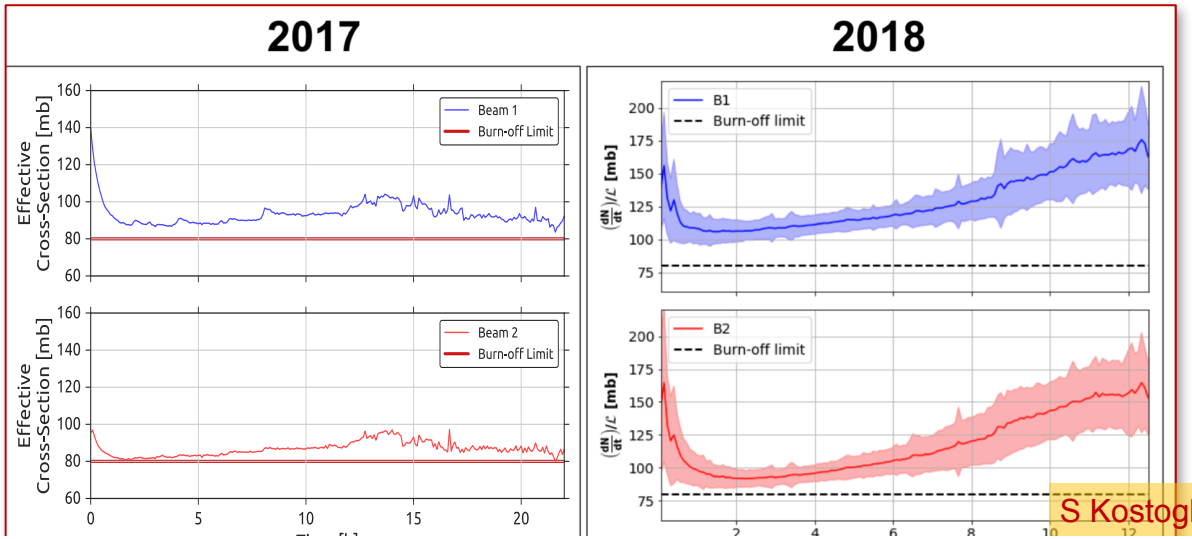
- E-growth in H-plane as expected
- No (or minimal) growth in the V-plane

Check with the lumi model ongoing…

S. Papadopoulou

Fill 7006 – 2018 BCMS

- Reminder : additional losses (above burn-off limit) observed in the 2018 for the BCMS beams, correlated to the e-cloud pattern in the trains



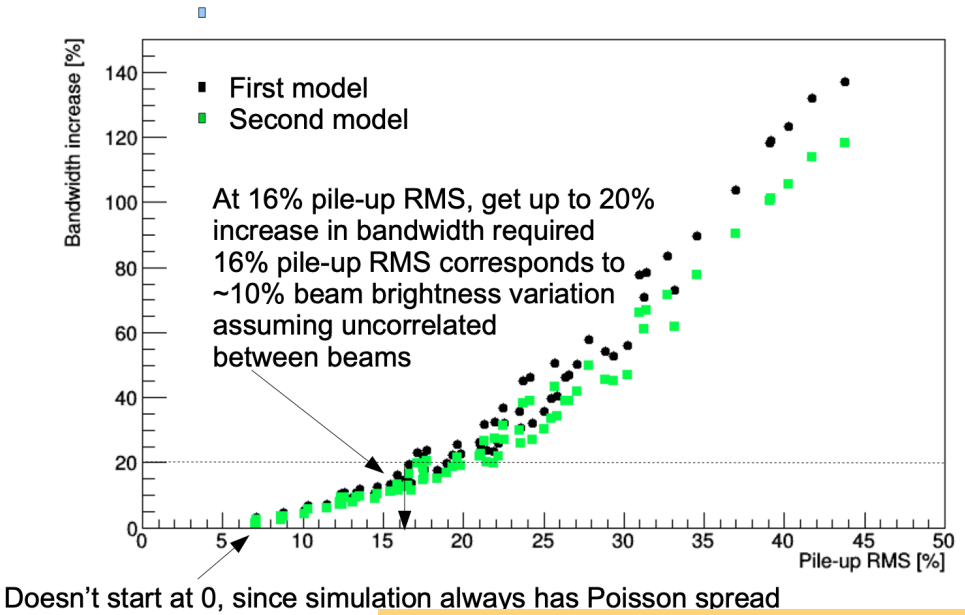
- From fill 7006 it seems the non-colliding train that exhibits e-cloud, shows no(?) losses and no(?) e-growth
- *Could be the source of the observed losses are around the IP (e-cloud in the triplets or combined effect of e-cloud + BBLR)* – to investigate further

Bunch-by-Bunch Luminosity Variation

$$\frac{N_1 N_2 f N_b}{4\pi\sigma_x\sigma_y}\,\frac{1}{\sqrt{1+\left(\frac{\sigma_s}{\sigma_x}\frac{\phi}{2}\right)^2}} = \mathcal{L} = \frac{R}{\sigma}$$

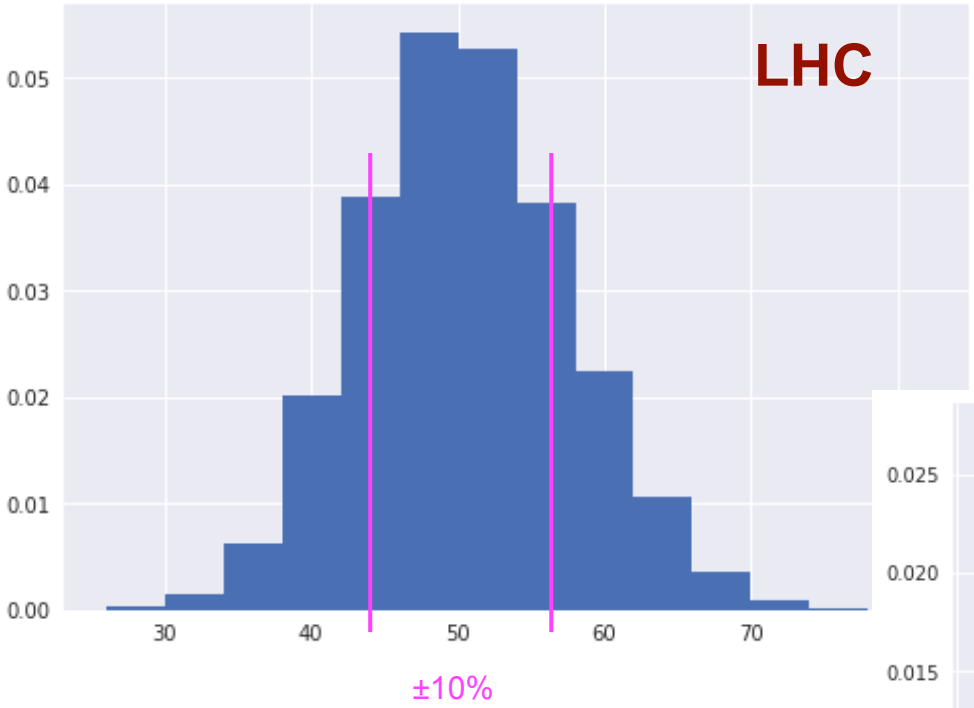
Impact to the experiments:

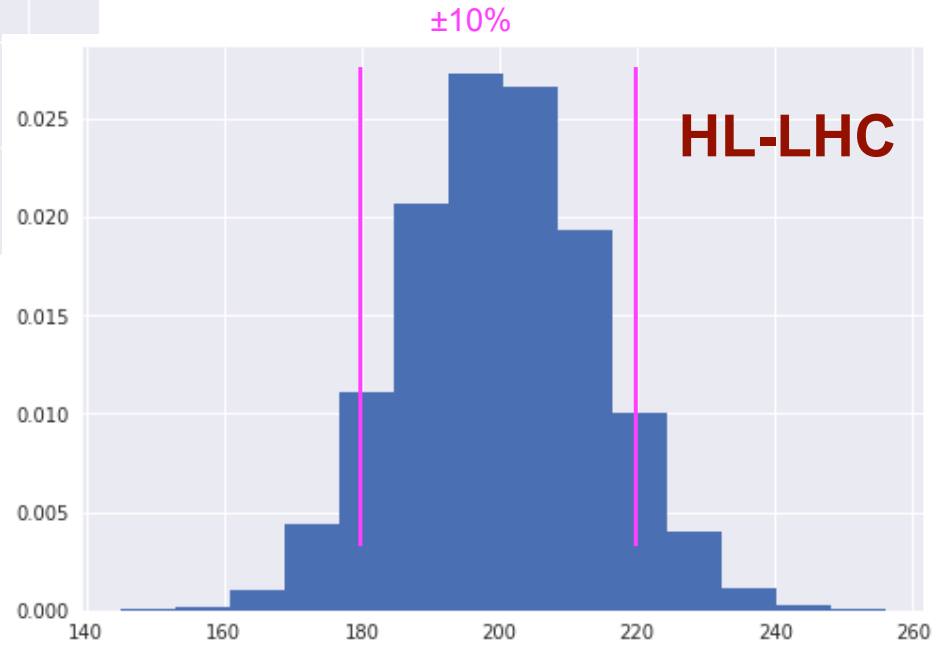
- Trigger limitations due to maximum event bandwidth
  - Would need to adjust trigger levels, trigger menu thresholds to remain optimal and at maximum read-out capacity during levelling
- Variable PU distribution, beyond the nominal from Poisson
  - Challenging to apply calibration factors globally
- First feedback from the experiments (EDQ WG meetings: : a variation < 10% would be easily acceptable, further studies ongoing also for Run 3



B. Petersen - 19th EDQ WG meeting (https://indico.cern.ch/event/790362/)

Bunch variations & PU





Summary

- Highlight results from a study of **BbyB Luminosity fluctuation** in LHC for BCMS and 8b4e fills presented
  - the fluctuations manifest during SB while a small growth is observed during FB and the ramp
- A general growth of up to **20% RMS** observed for the BCMS fills of 2018, mainly due to fluctuations in the **bunch intensities**.
  - The maximum spread for the bunch luminosities goes up to **60%** for a sizeable fraction of the bunches in the fill, typically for the ~10 head bunches of the trains
- For **8b4e fills** that show no (major) signs of e-cloud, **no rms spread increase** (could even be a small dumping) is observed
- From fill 7006 having a **full non-colliding train during SB** no (sizeable) increase in BbyB rms is observed. This result points to the the intensity losses and thus fluctuations in BCMS beams originate mainly form the IP regions, where the e-cloud adds on top of the BB and BBLR effects. Further studies are ongoing to further understand it.
- If not mitigated, the BbyB luminosity fluctuations at the levels observed would have an impact to the overall strategy for the experiments to configure trigger rates and optimise the available bandwidth to maximise the recorded luminosity for Run 3 and HL-LHC
  - Further studies are ongoing, to follow in the EDQ WG meetings

Spare slides

Luminosity Variations in LHC

- Luminosity (integrated over all bunches) evolution in SB