Experimental Data Quality

HiLumi
HL-LHC PROJECT

l EDQ WG: https://indico.cern.ch/category/7932/

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and R. Tomas

CERN

Since 2017

Meenakshi Narain replaced P. Azzi as CMS EDQ co-chair

Simone Griso & Sarah Demers invited as new ATLAS Upgrade physics convenors.

New topics in 2018:

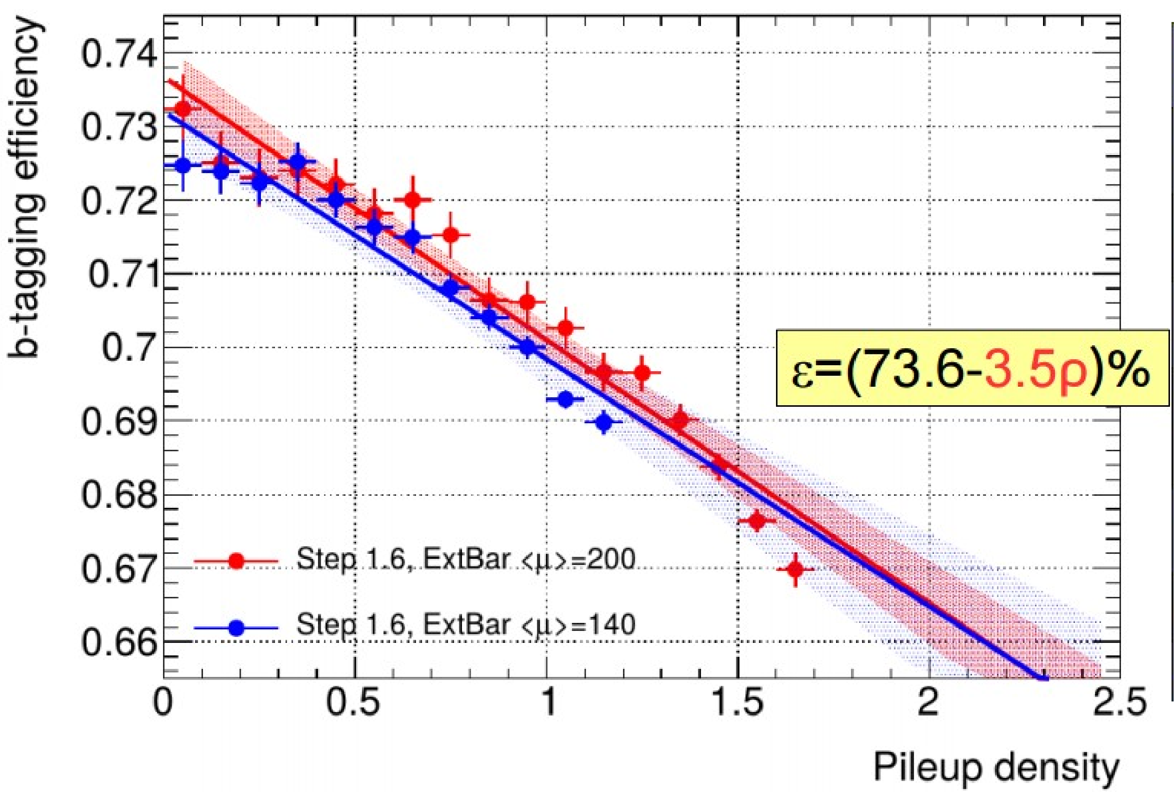
- Colliding Vs non-colliding bunches
- LHCb
- Time tagging
- Extreme pile-up density in ATLAS and CMS
- Luminosity calibration
- Bunch-by-bunch luminosity fluctuations

Status in 2017

Effective pile-up density

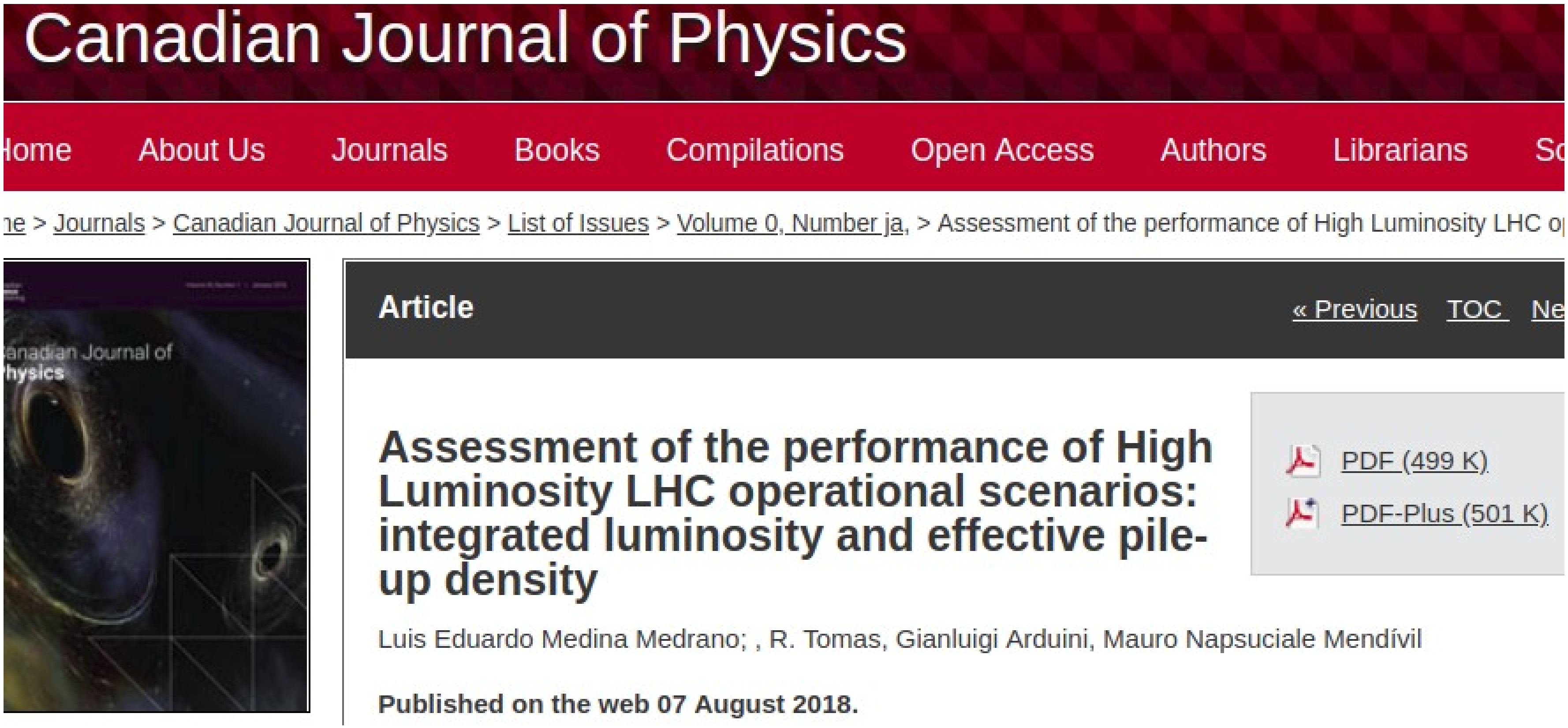
$$\bar{\rho} = \frac{\int_0^{t_{\mathrm{fill}}} \int \rho^2(s,t)\,\mathrm{d}s\,\mathrm{d}t}{\int_0^{t_{\mathrm{fill}}} \mu(t)\,\mathrm{d}t}$$

The effective pile-up density
allows to estimate detector performance after parametrizing with simulations:



Object	μ=140→200	Pile-up density
b-jet	None	ε: -3.5% x ρ
jet	Resolution	ε: -2.5% x ρ
$E_{T,miss}$	Res.: +10%	Res: +5% x ρ
Electrons	ε: -1% Calo isol.: ?	Iso. ε: -2.5% x ρ
Muons	Calo isol.: ?	Iso. ε: -2.5% x ρ
Taus	TBD	TBD
Photons	TBD	TBD

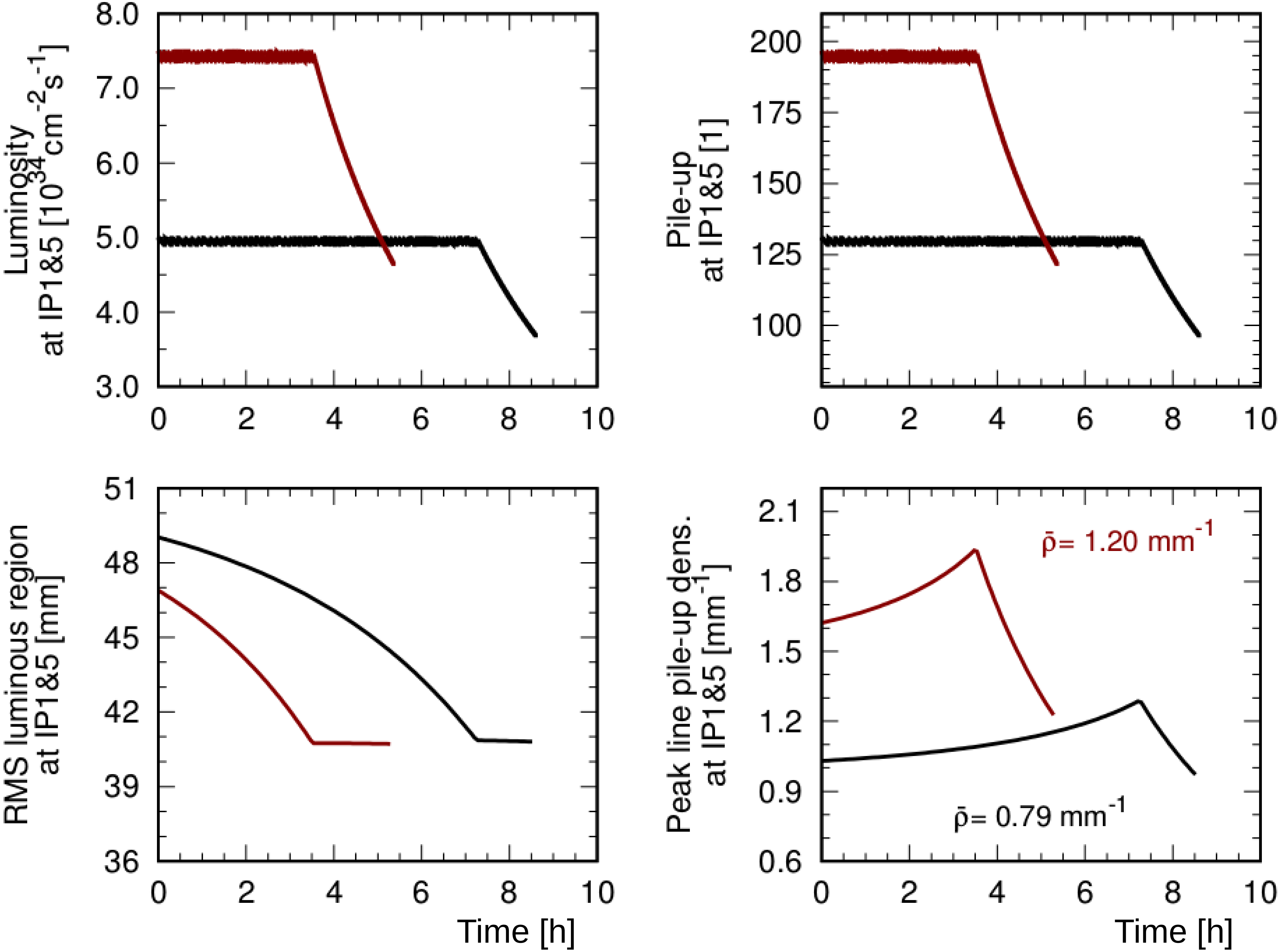
Machine report



http://www.nrcresearchpress.com/doi/abs/10.1139/cjp-2018-0291#.W7c8o2N_I8p

Preprint: https://cds.cern.ch/record/2301928/files/CERN-ACC-2018-0003.pdf

Baselines: Nominal and ultimate

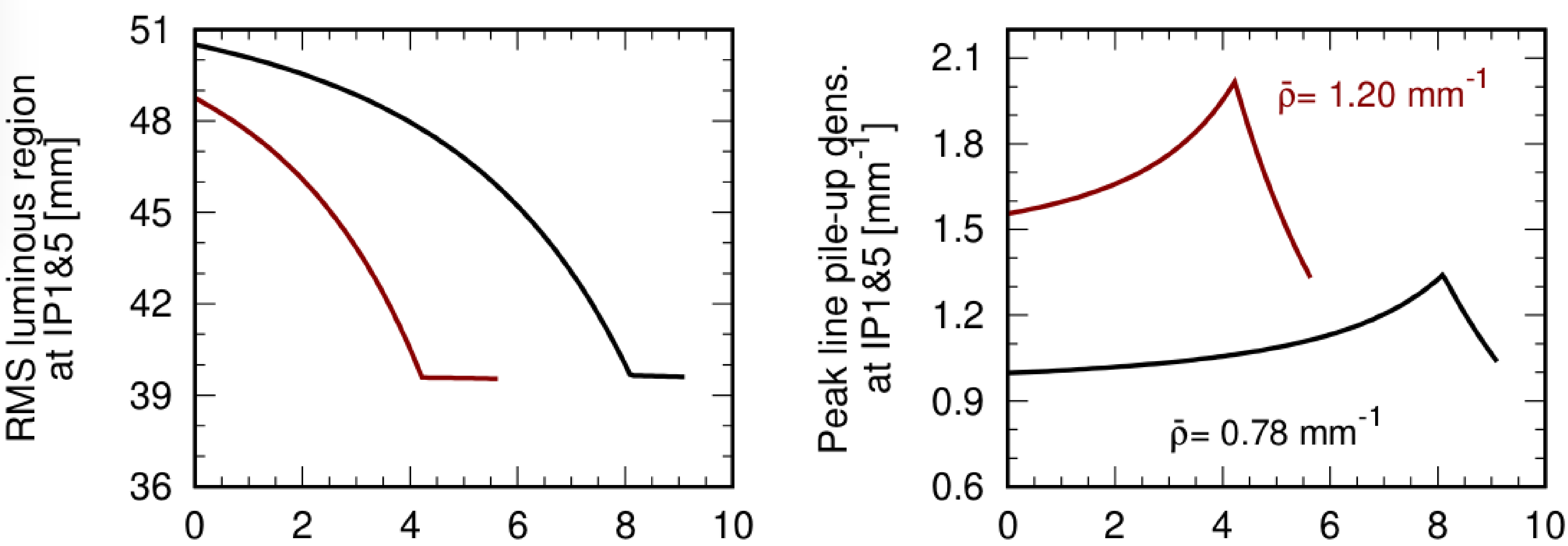


Baseline and 'No CC' scenario

Parameter	Unit	With CCs		Without CCs	
		Nominal	Ultimate	Nominal	Ultimate
Effective line pile-up density	mm^{-1}	0.79	1.20	1.55	2.13
Yearly integrated luminosity	fb^{-1}/160 days	**262**	**325**	228	247
Change w.r.t Baseline (w/CCs)	%	ref.	ref.	−13	−24

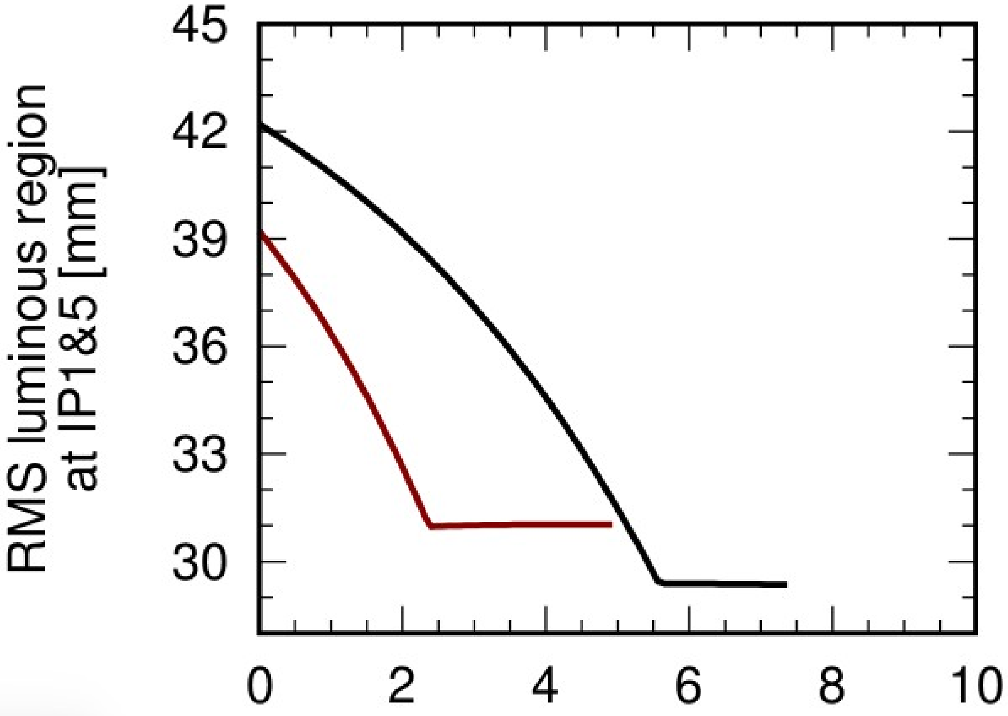
- Project goals comfortably reached
- Absence of CC doubles pile-up density and reduces integrated lumi by 13%-24%.
- Flat optics is a performance booster...

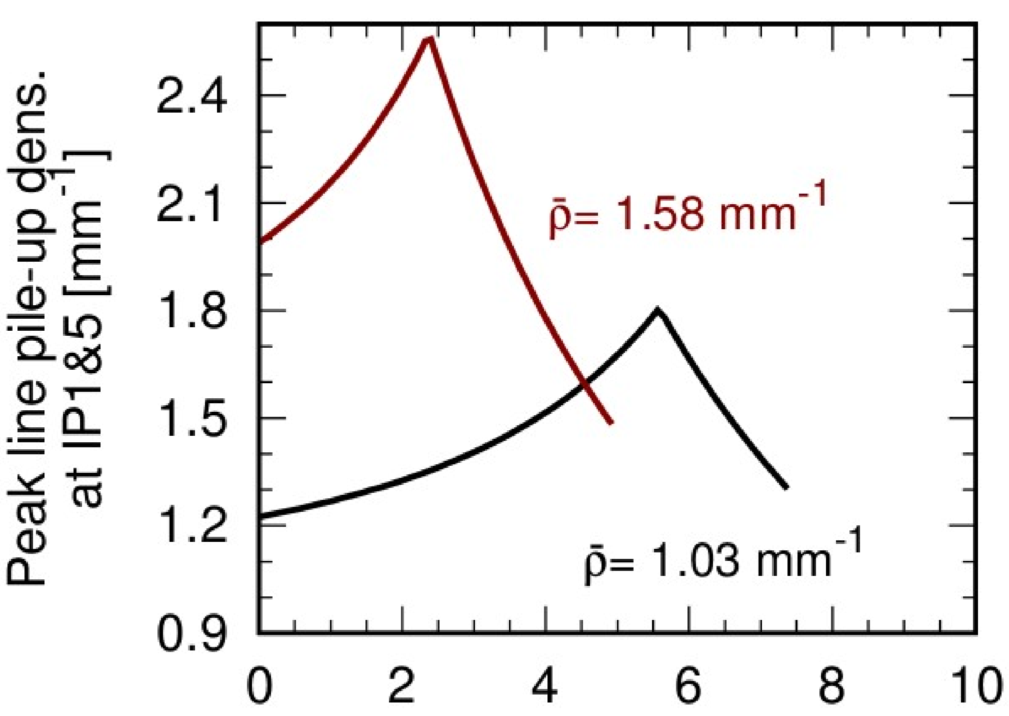
Flat & CC: Nominal and ultimate β^*=7.5/18cm (490 μrad)



Same pile-up density for 2-4% more integrated luminosity

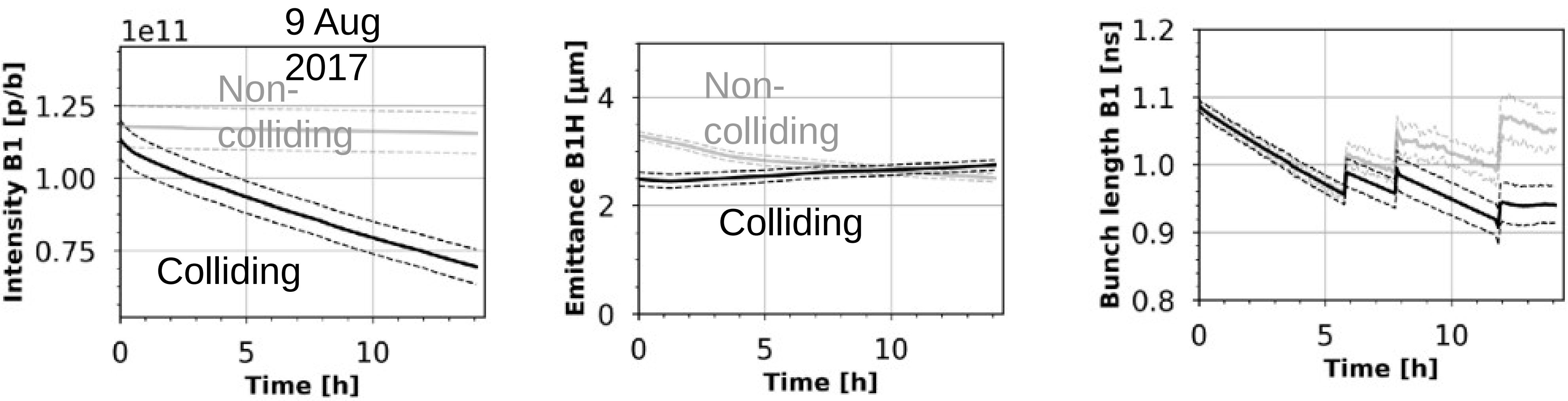
Flat without CC: β*=7.5/31.5cm (410 μrad)





Integrated luminosity between 249 and 293 fb^{-1} with larger pile-up density by 20-30% w.r.t. baselines.
Wire or octupoles would improve the performance.

Non-colliding bunches I



How different can unpaired bunches can be from the colliding bunches in terms of intensity and emittance?

- ATLAS BIB currently dominated by Beam Gas interaction, which can be measured by NC-bunches with ***reduced intensity***.
- More difficult is to measure the Beam halo (betatron and off-momentum) cleaning losses reaching the TCTs upstream of ATLAS, which is dependent on emittance.
- HL-LHC will have larger TAS and tighter focusing: if other loss mechanisms are present at HL-LHC, a different emittance of the unpaired wrt paired can lead to wrong conclusions.

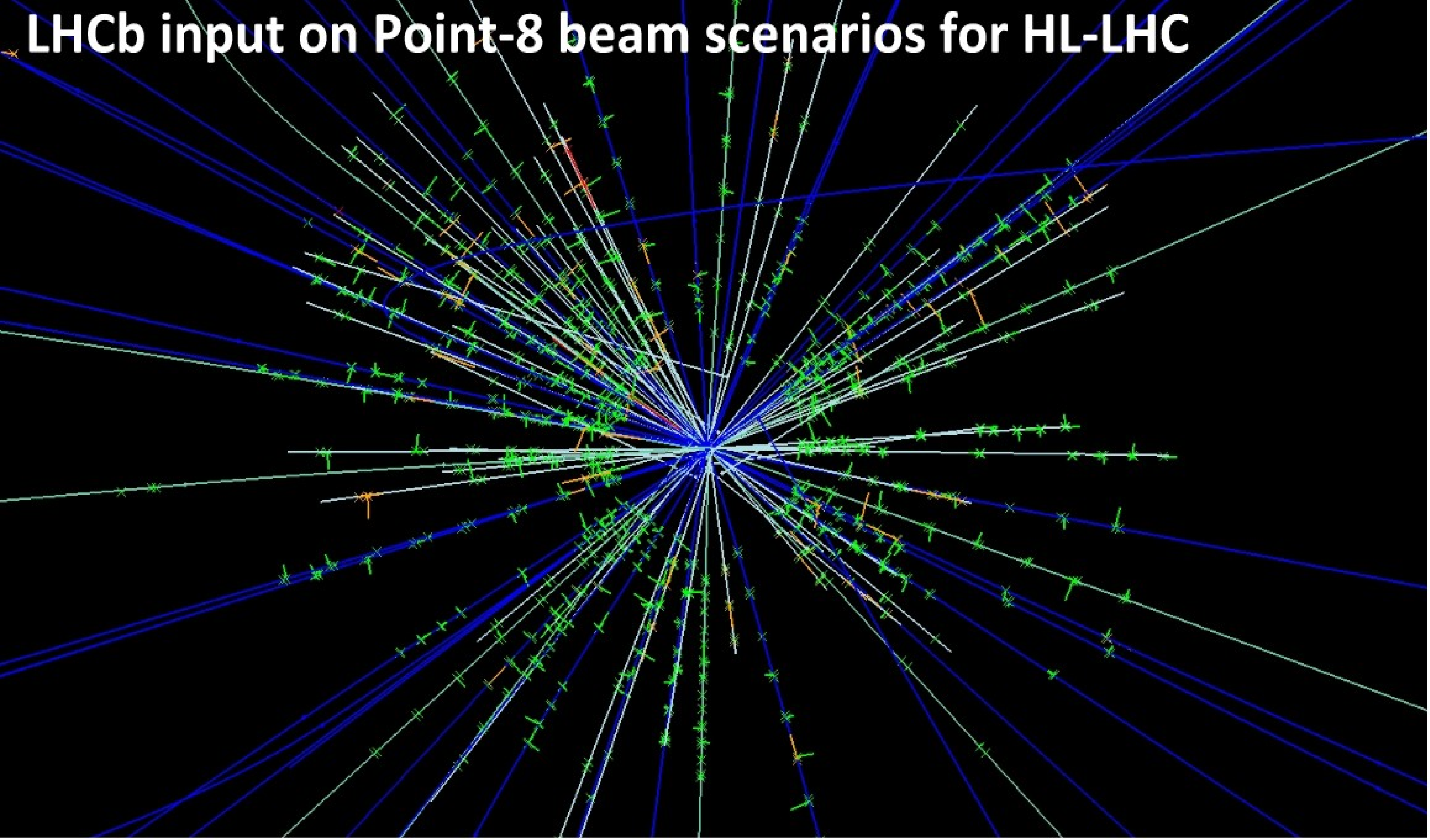
Non-colliding bunches II

In case of doubt: priority is to maximize the integrated luminosity

After albedo correction basic studies of the beam induced background can be done by studying first bunches in the colliding trains. So, once the intensity ramp-up is at the stage where non-colliding bunch trains start to compete for space in the machine with the colliding ones - our preference is to **increase luminosity!**

By then we should have a clear idea what are the sources of beam induced background!

LHCb input on Point-8 beam scenarios for HL-LHC



EDQ-WG Meeting   6 Nov 2017

Mark Williams, Marco Gersabeck,
Aditya Bhanderi, Biljana Mitreska

LHCb

MANCHESTER 1824
The University of Manchester

LHCb options

β^* [m]	230 µrad			770 µrad		
	$L_{\text{lev}} = 1.0$	1.5	2.0×10^{34}	$L_{\text{lev}} = 1.0$	1.5	2.0×10^{34}
1.4	[(a)	(b)	(c) $]_i$	[(A)	-	- $]_I$
2.0	[(d)	(e)	- $]_{ii}$	[(D)	-	- $]_{II}$
3.0	[(f)	-	- $]_{iii}$	[-	-	- $]_{III}$

Table 1 : Possible optics at different levellings for high luminosity in IP8

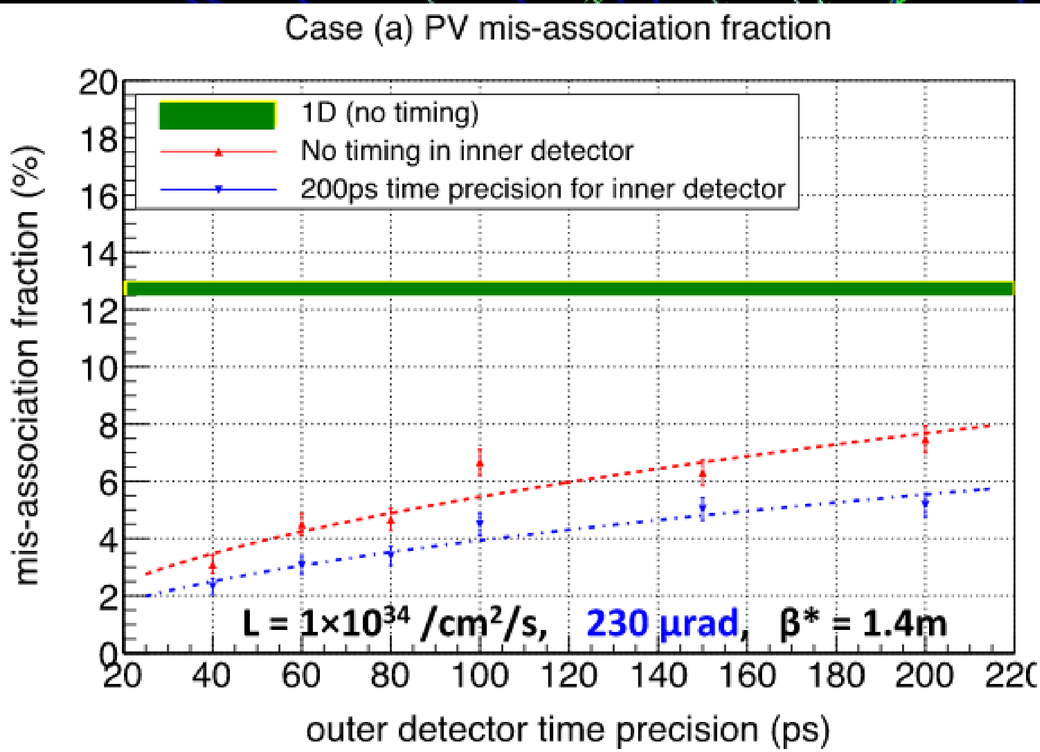
Case	mean N(PV)	σ(z) [mm]	σ(t) [ps]	σ(x,y) [µm]
(a)	27.5	51.9	190	26.6
(b)	41.25	51.9	190	26.6
(c)	55	51.9	190	26.6
(d)	27.5	53.1	189	26.6
(e)	41.25	53.1	189	26.6
~~(f)~~	~~27.5~~	~~?~~	~~?~~	~~26.6~~
(A)	27.5	32.7	202	26.6
~~(D)~~	~~27.5~~	~~?~~	~~?~~	~~26.6~~

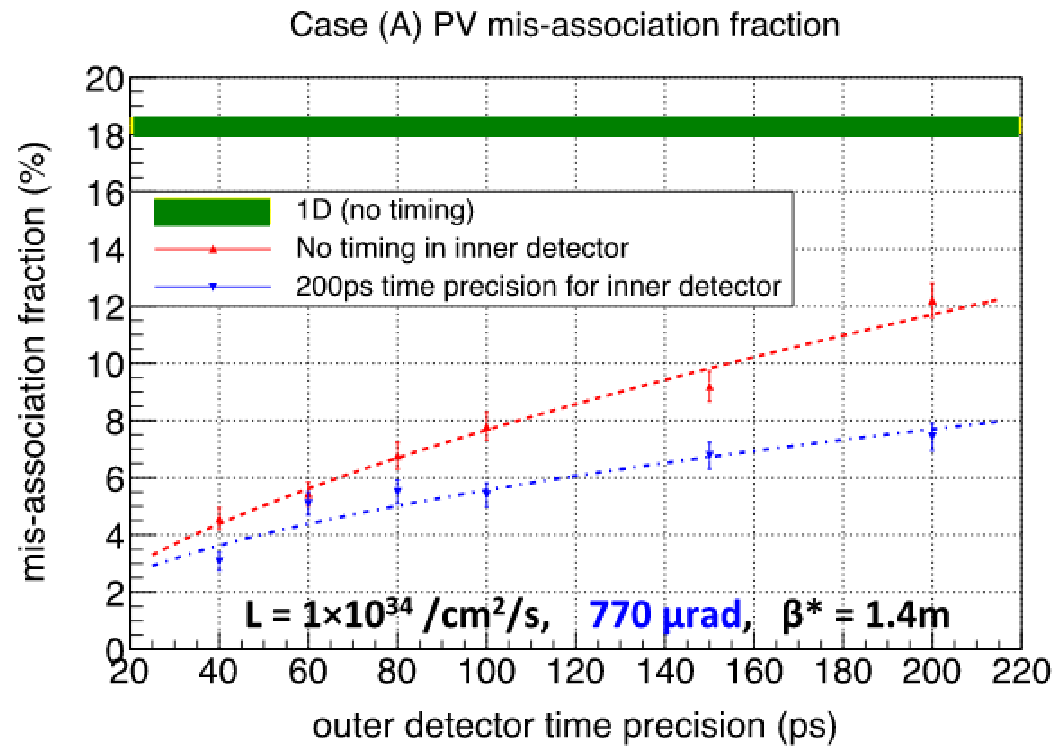
Assumptions

- N(PV) : Poisson
- Assume Gaussian PU density in (x,y,z,t)

Studies not yet ready for (f), (D)

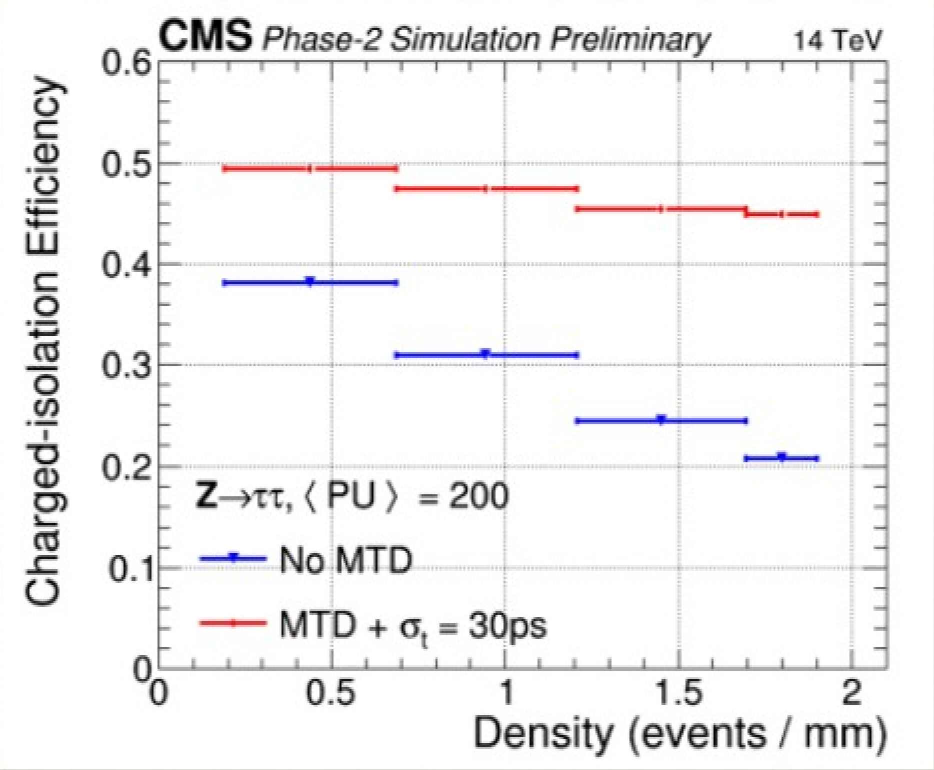
Results: Influence of crossing angle

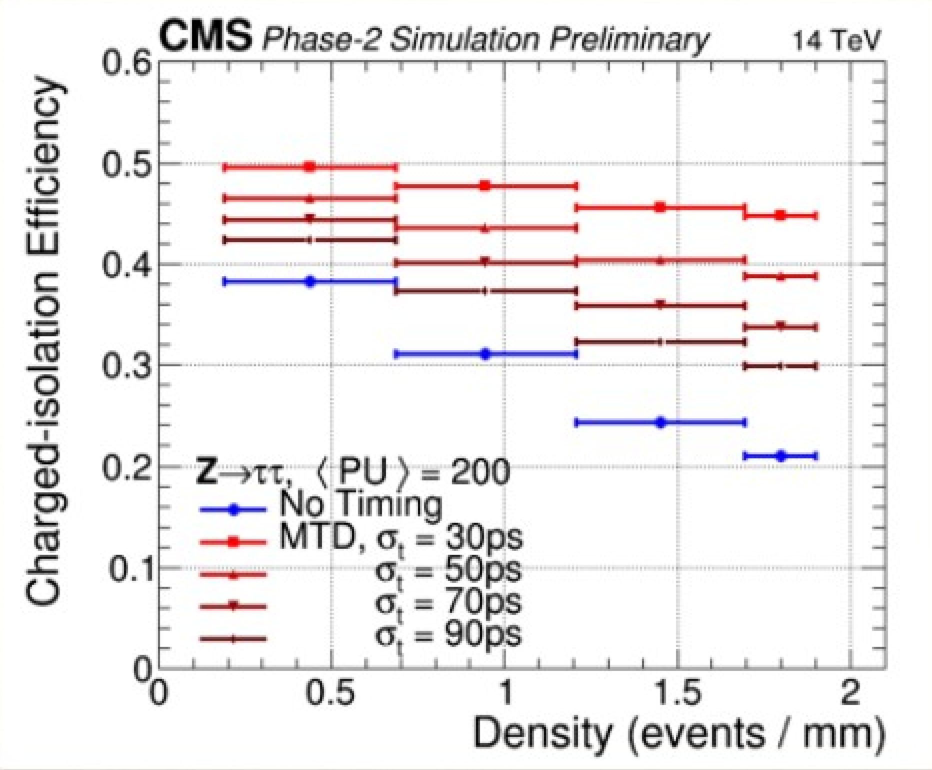




Larger crossing angle gives ~**30-50%** larger PV mis-association fraction
(again, neglecting possible effects on transverse PU distribution)

tau-ID performance vs PU density

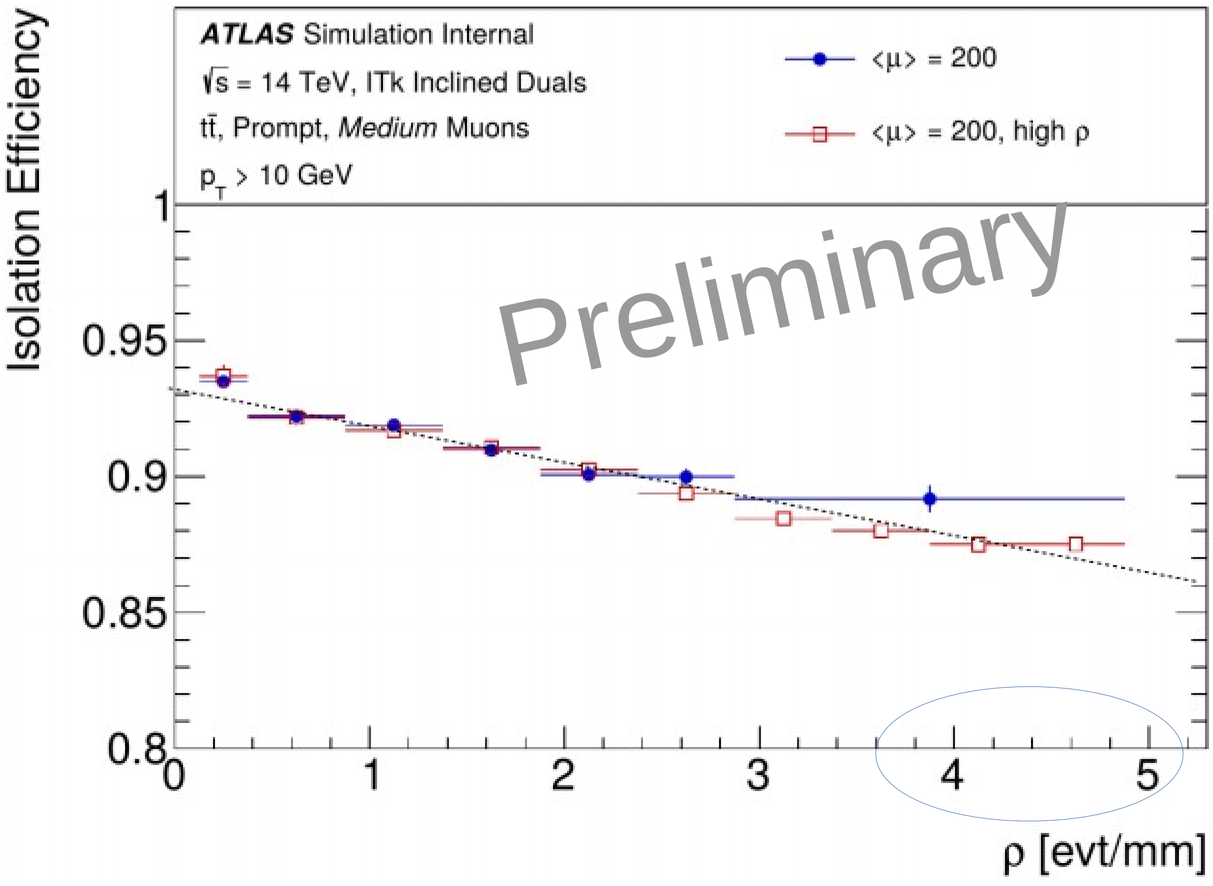




- Significant impact of PU density on tau-ID, similarly for muons, jets and missing energy.
- CMS timing system allows to reduce impact of PU density.

ATLAS: Muon isolation at high density

- Studied isolation in high pile-up density sample
- Still see a roughly linear dependence of the efficiency on pile-up density
  - Note not directly comparable to previous plot as it is different sample ($t\bar{t}$ vs $Z \rightarrow \mu\mu$) and plotting vs local pile-up density



Luminosity calibration for HL-LHC

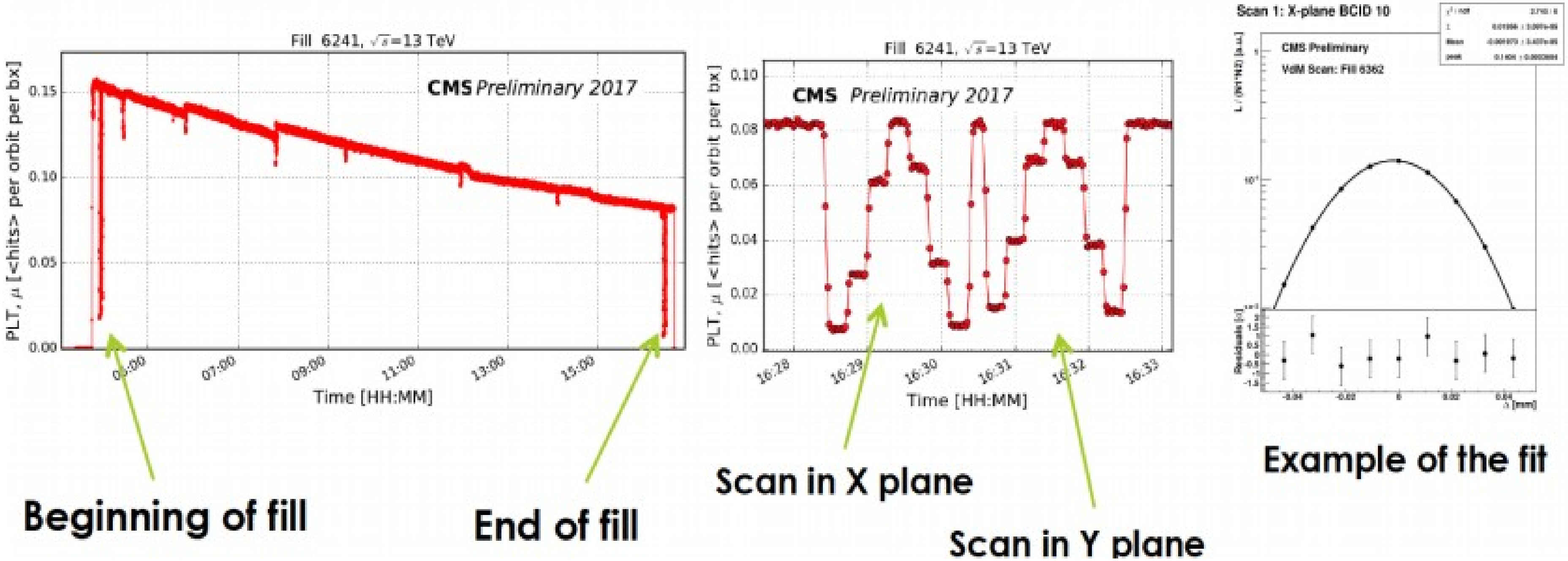
Anne Dabrowski, David Stickland CERN

Goal: Reach 1.5% systematic errors in luminosity

Approach: Reduce uncertainties where possible and perform emittance scans regularly.

Emittance scans

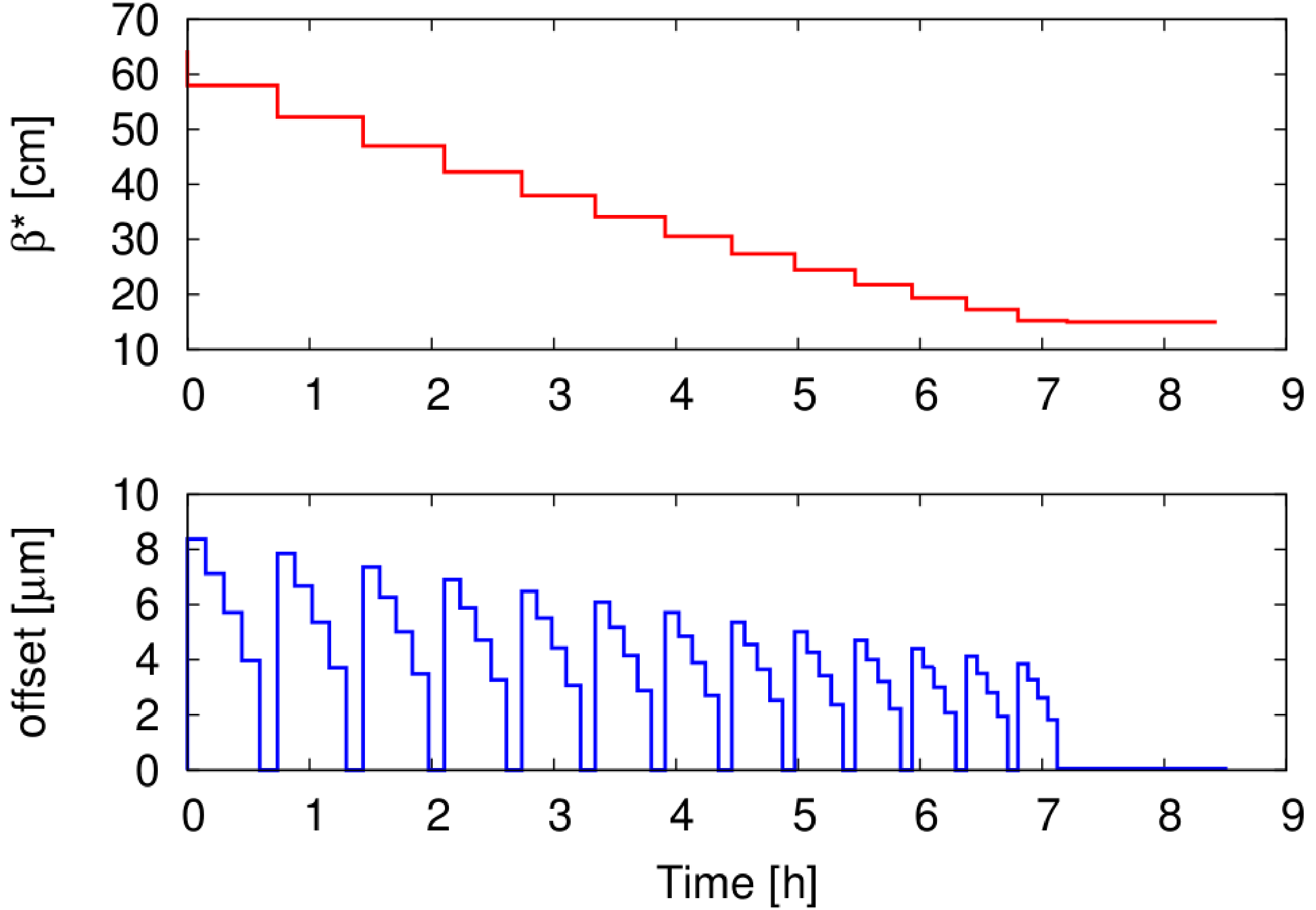
- **Emittance scans** are short Van der Meer type scans performed at the beginning and at the end of LHC fills.
  - Beams are scanned in 7 displacement steps (19-25 steps in VdM);
  - 10 s per step (30 s per step in VdM);
  - The same beams as in physics data taking (in VdM fill special beam optics is used);
  - Filling scheme with 25 ns separated bunches, “bunch trains” (well separated bunches in VdM);
  - Single Gaussian fit is used to fit the emittance scan shape and to extract Peak and beam overlap in X and Y.



Lumi-levelling

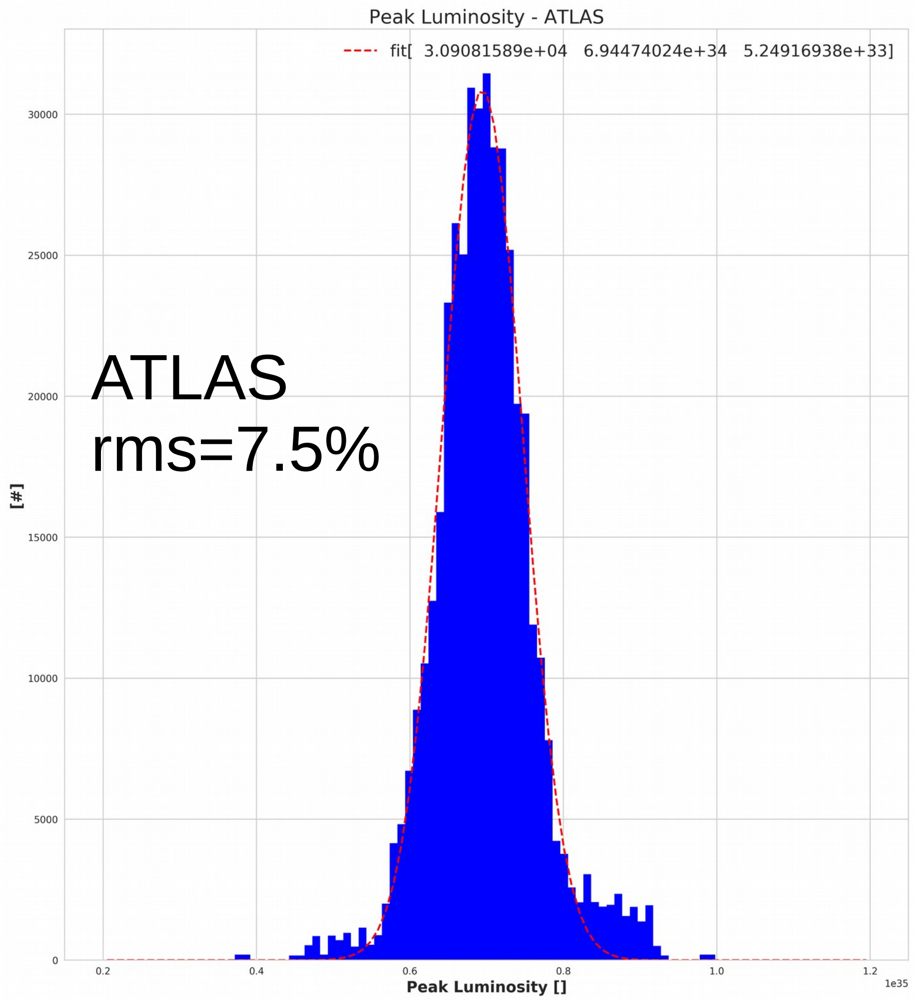
- Emittance scans should be at the same peak pileup that we are taking physics data
- Require lumi levelling with beta*; and not by separation.
  - This is because emittance scans pass the beams through "head on". For the moment we don't have a procedure for calculating the sig_visable for the detectors if the beams remain separated in one plane during the scan.

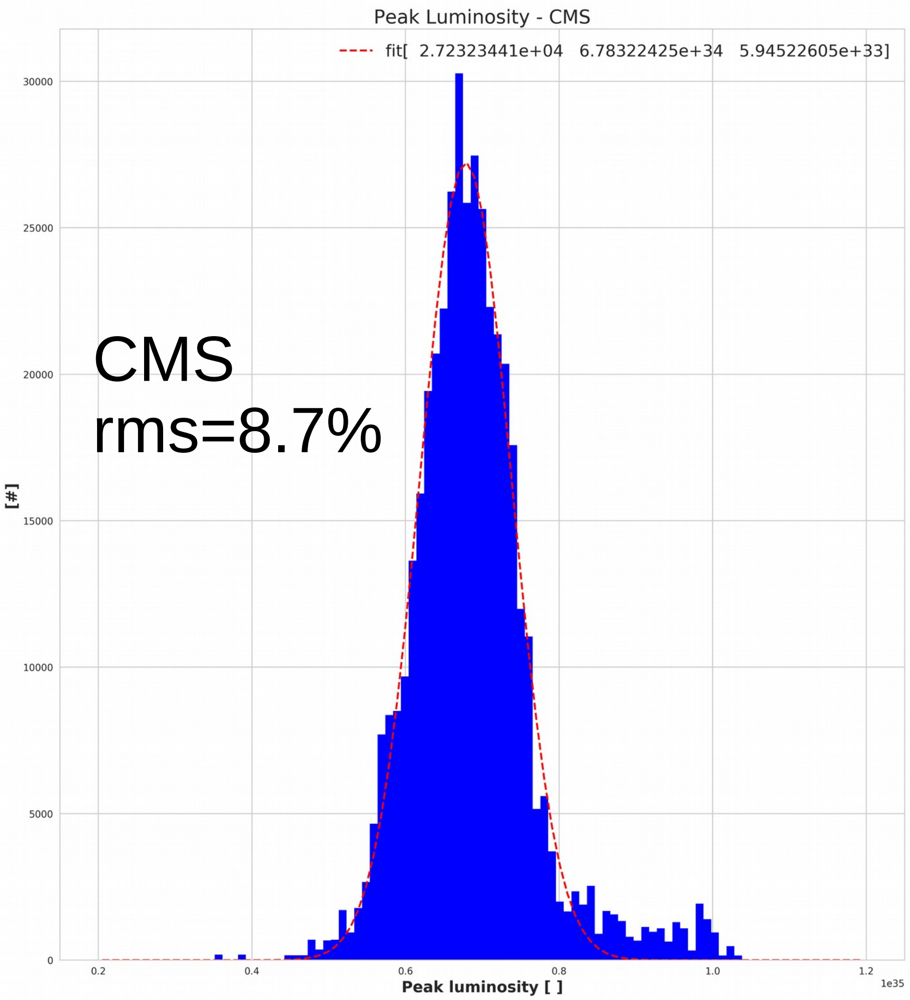
Combined β* and offset leveling to alleviate optics commissioning?



Compatible with emittance scans when offset=0

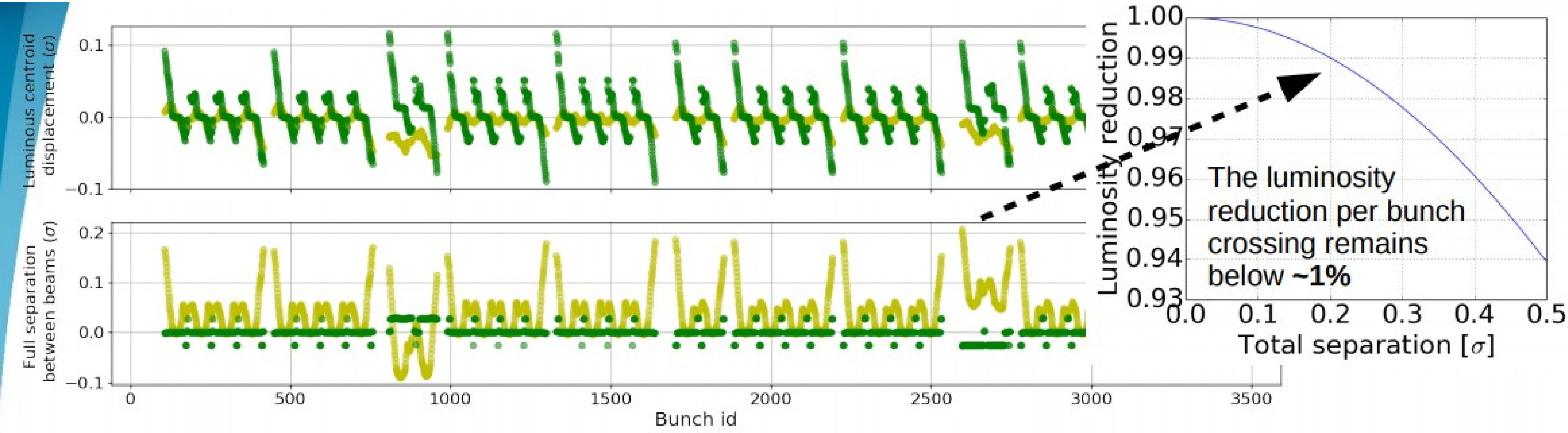
LHC bunch-to-bunch lumi variations





- Detectors are accounting for ±5% flat distribution
- Potential problems with trigger/DAQ at PU=200

Bunch-to-bunch lumi variations from Beam-Beam long range in HL-LHC



- Beam-beam long-range effects in bunch-to-bunch luminosity will be in the shadow of bunch intensity and emittance variations.

Summary and outlook

- Machine report is out
- Non-colliding bunches: accepted different bunch charge and emittance
- Detector performance still linear at extreme pile-up density values
- LHCb also observes pile-up density effects
- Bunch-by-bunch luminosity fluctuations could affect trigger/DAQ
- Common report based on ATLAS, CMS, LHCb and machine publications in 2019