Experimental Data Quality

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

P. Azzi, I. Efthymiopoulos, L. Medina, M. Narain,
B. Petersen and R. Tomas

Thanks to EDQ WG and WP2 for great discussions

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

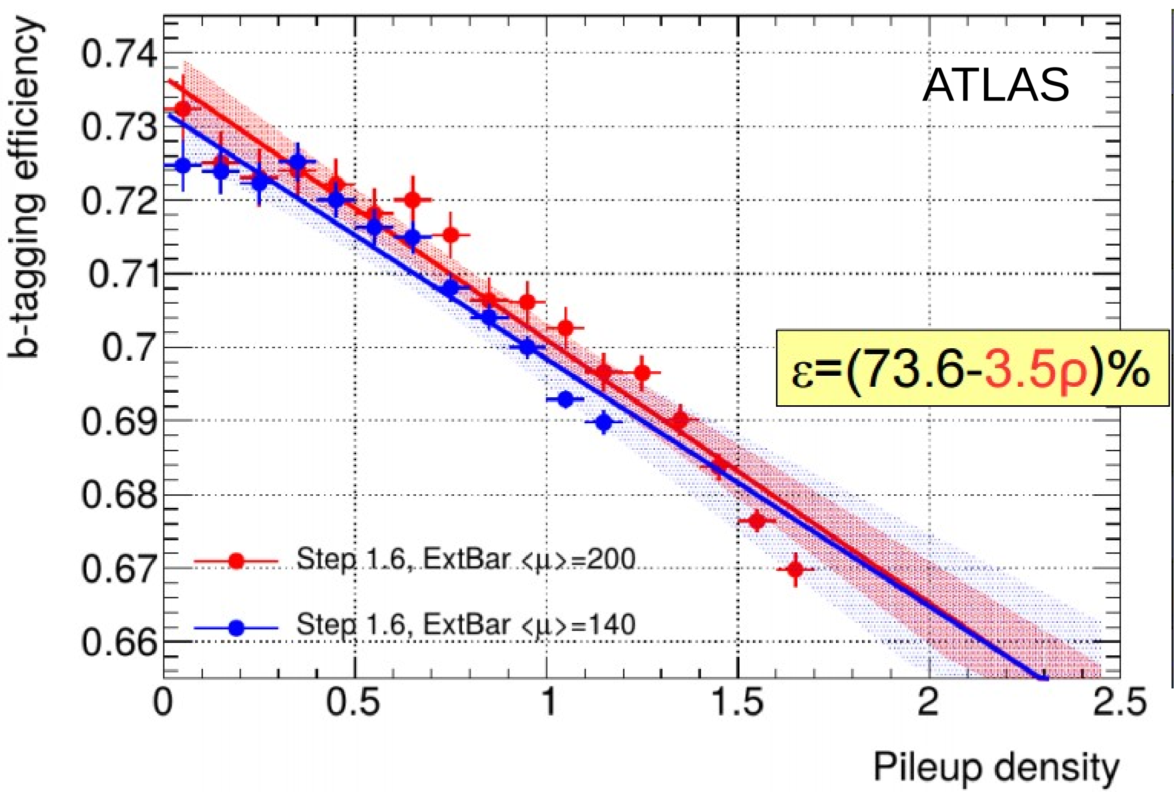
Status in 2017

The effective pile-up density
= Collision + Fill average

Effective pile-up density

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

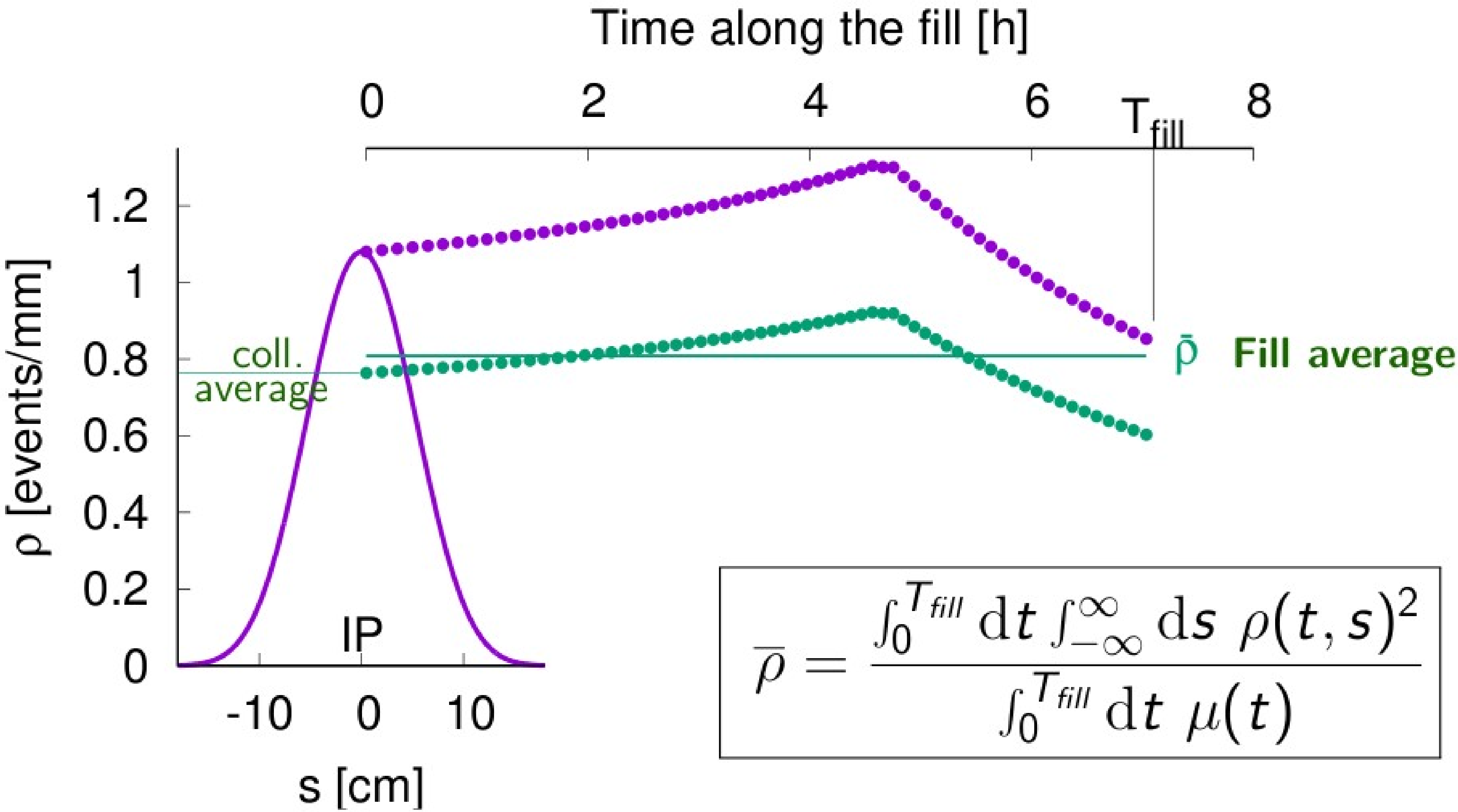
allows to estimate detector performance after parametrizing with simulations:



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

Scenarios' effective Pile-up density ranges between 0.8 – 2.1

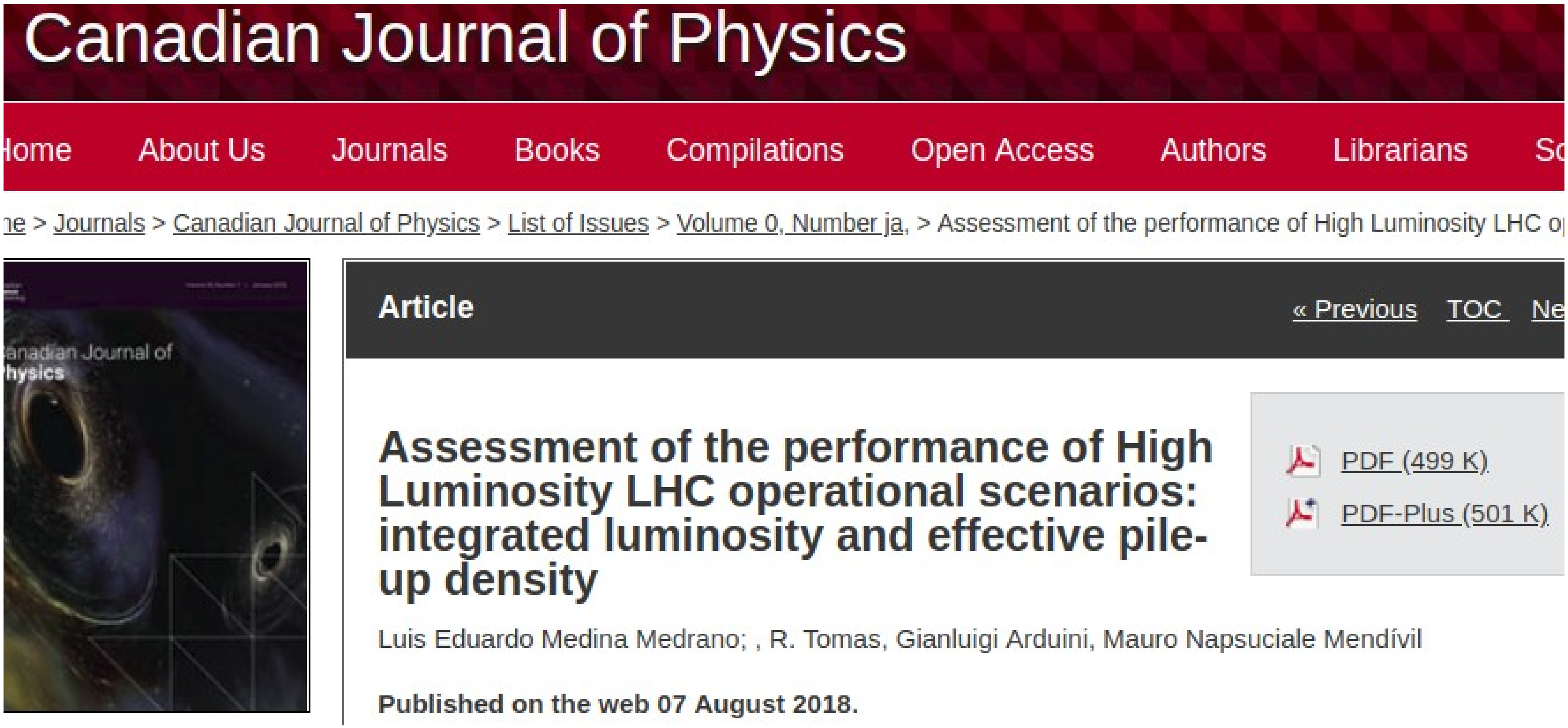
Effective pile-up density, $\overline{\rho}$,for a fill



$$\overline{\rho} = \frac{\int_0^{T_{fill}} \mathrm{d}t \int_{-\infty}^{\infty} \mathrm{d}s \ \rho(t,s)^2}{\int_0^{T_{fill}} \mathrm{d}t \ \mu(t)}$$

The larger $\overline{\rho}$ is, the larger the inefficiency.

Machine report



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Assessment of the performance of High Luminosity LHC operational scenarios: integrated luminosity and effective pile-up density

PDF (499 K)
PDF-Plus (501 K)

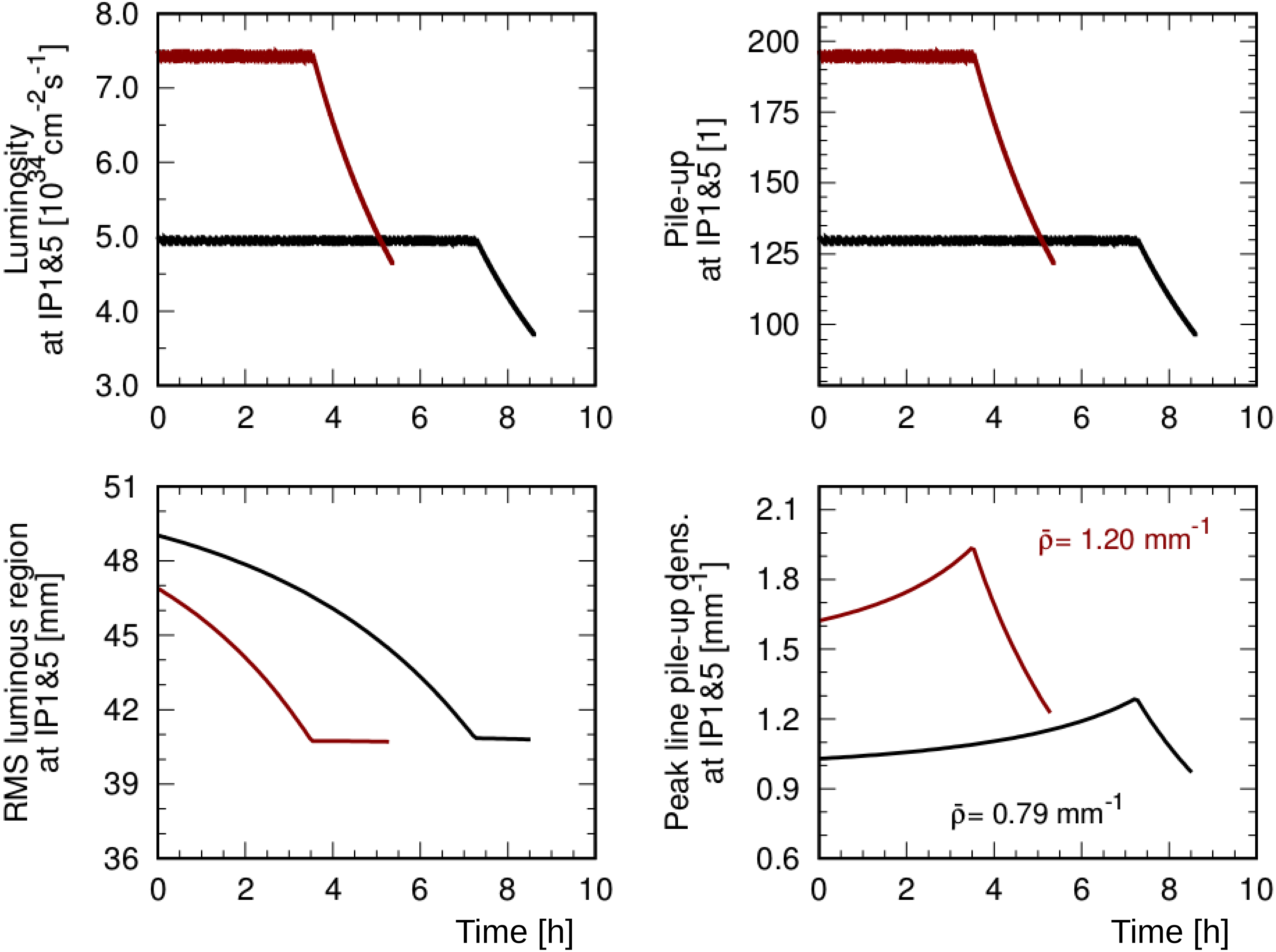
Luis Eduardo Medina Medrano; , R. Tomas, Gianluigi Arduini, Mauro Napsuciale Mendívil

Published on the web 07 August 2018.

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

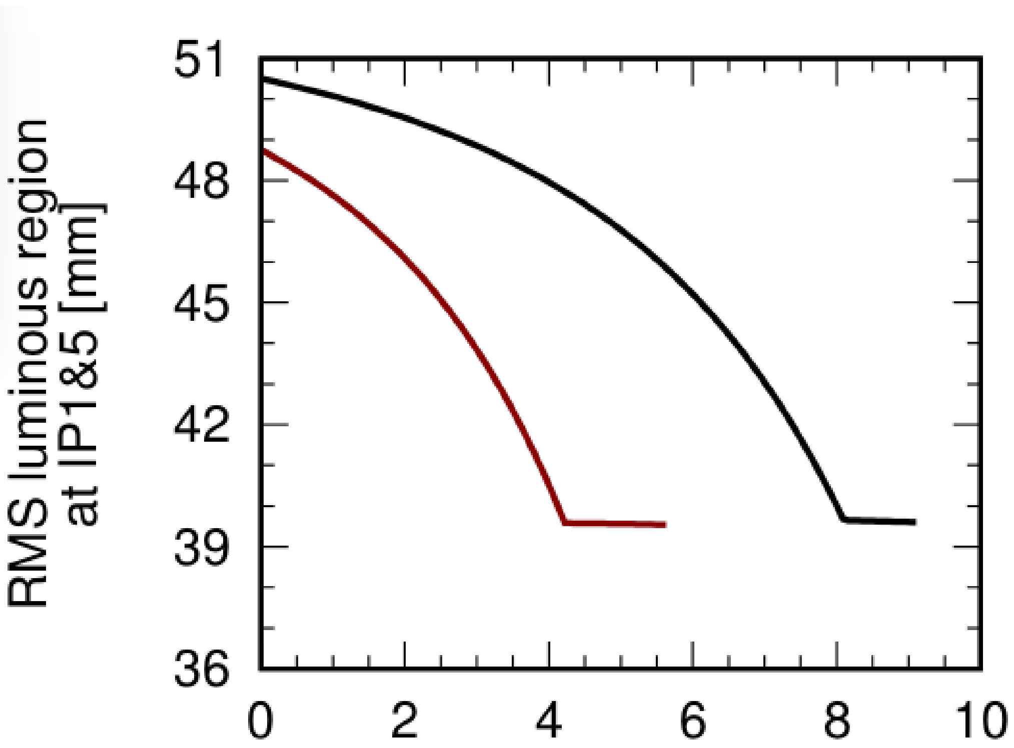


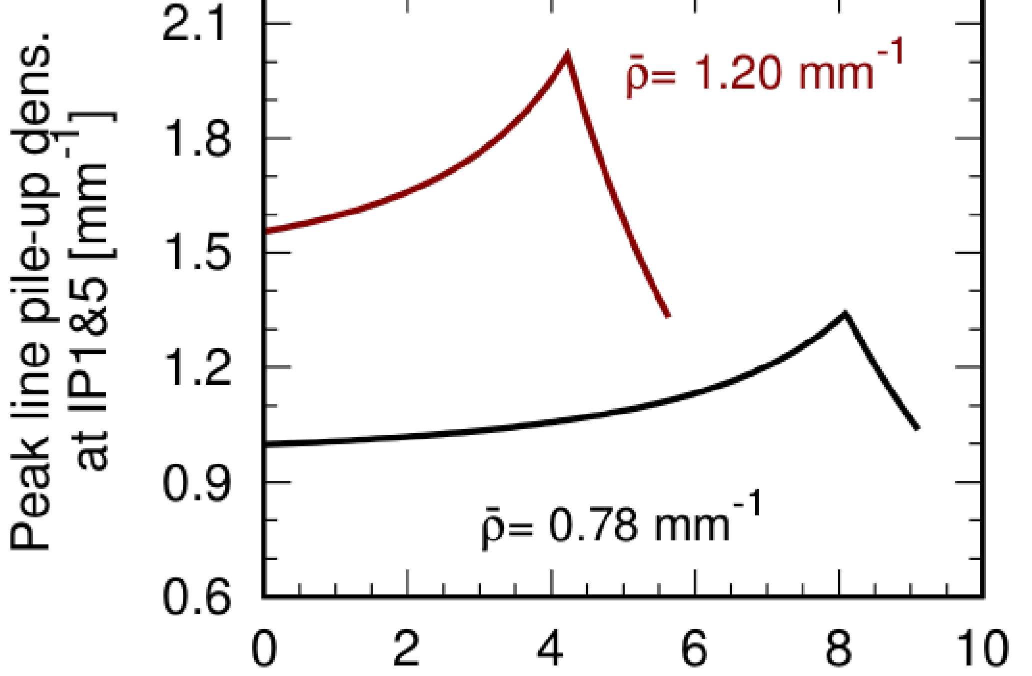
Baseline and 'No CC' scenario with round optics

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...

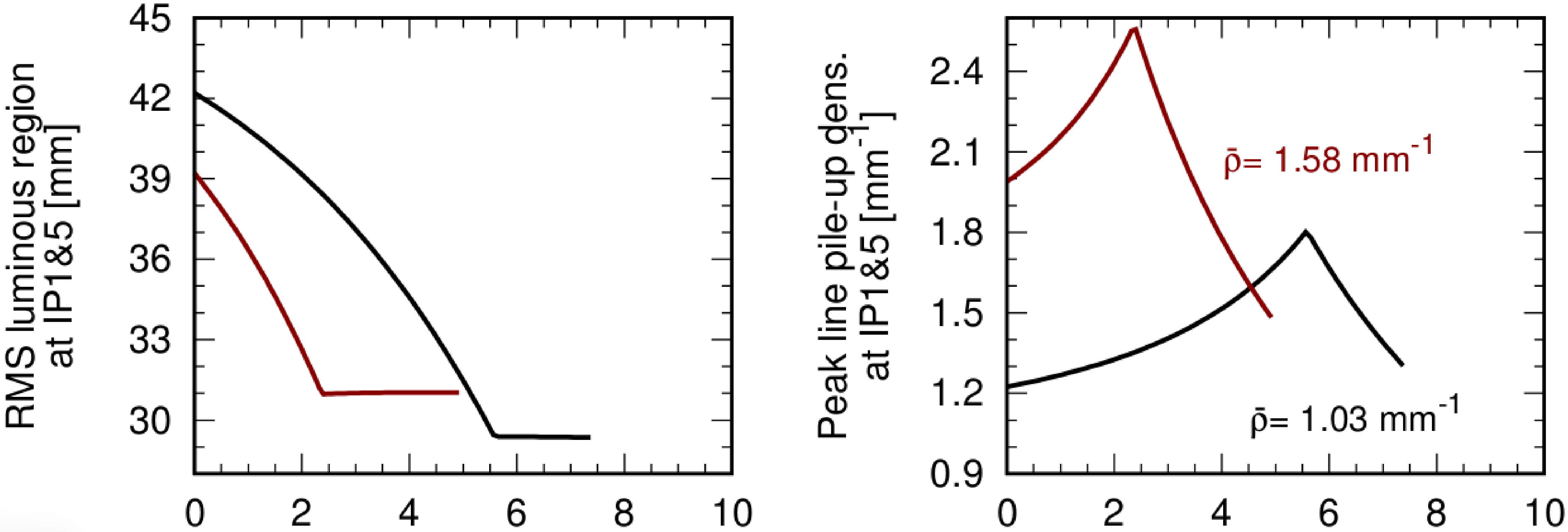
Flat & CC: Nominal and ultimate β*=7.5/18cm (490 μrad, 11.4σ)





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

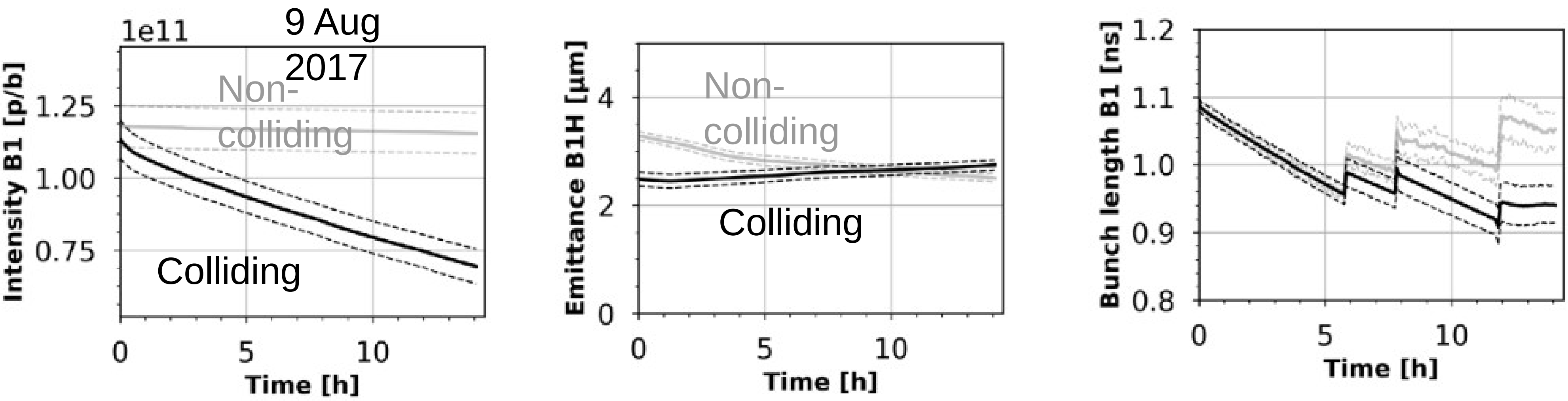
Flat without CC: β^*=7.5/31.5cm (410 μrad,12.6σ)



Integrated luminosity between 249 and 293 fb^{-1} with larger pile-up density by 20-30% w.r.t. baselines. Needs verification with beam-beam simulation.

Wire or octupoles would improve the performance.

Non-colliding bunches I



How different can non-colliding bunches be w.r.t. colliding bunches?

- 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

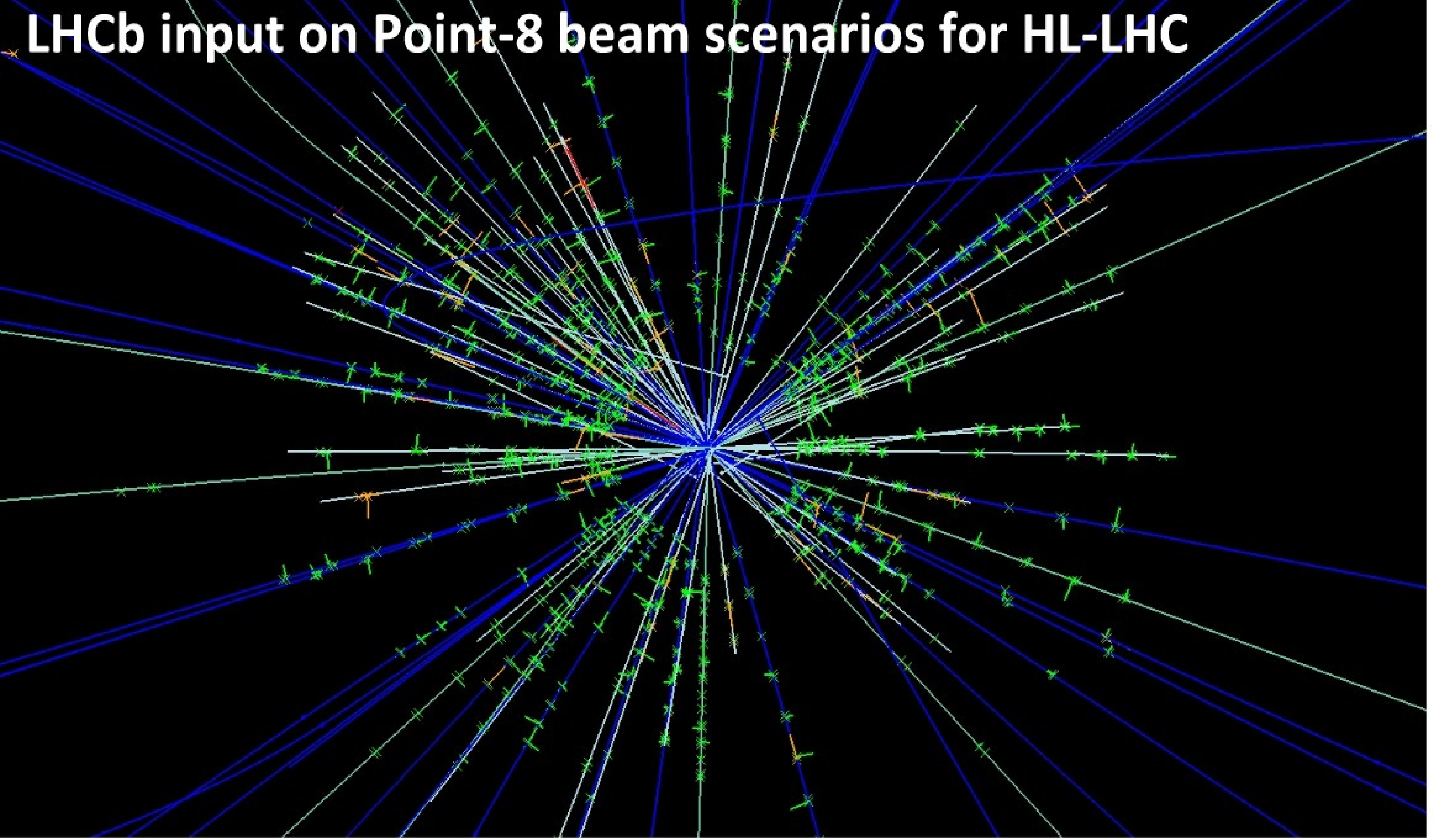
After albedo correction basic studies of the beam induced background can be done by studying first bunches in the colliding trains. So, once the intensity ramp-up is at the stage where non-colliding bunch trains start to compete for space in the machine with the colliding ones - our preference is to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

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

Non-colliding bunches: Machine view

- In the current baseline non-colliding bunches are stable with same beam parameters as colliding bunches
- Nevertheless having lower intensity non-colliding bunches might be useful for future baselines or for buying margins

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



EDQ-WG Meeting   6 Nov 2017

Mark Williams, Marco Gersabeck,
Aditya Bhanderi, Biljana Mitreska

The University of Manchester

LHCb options

β^* [m]	230 µrad			770 µrad		
	$L_{lev} = 1.0$	1.5	2.0×10^{34}	$L_{lev} = 1.0$	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

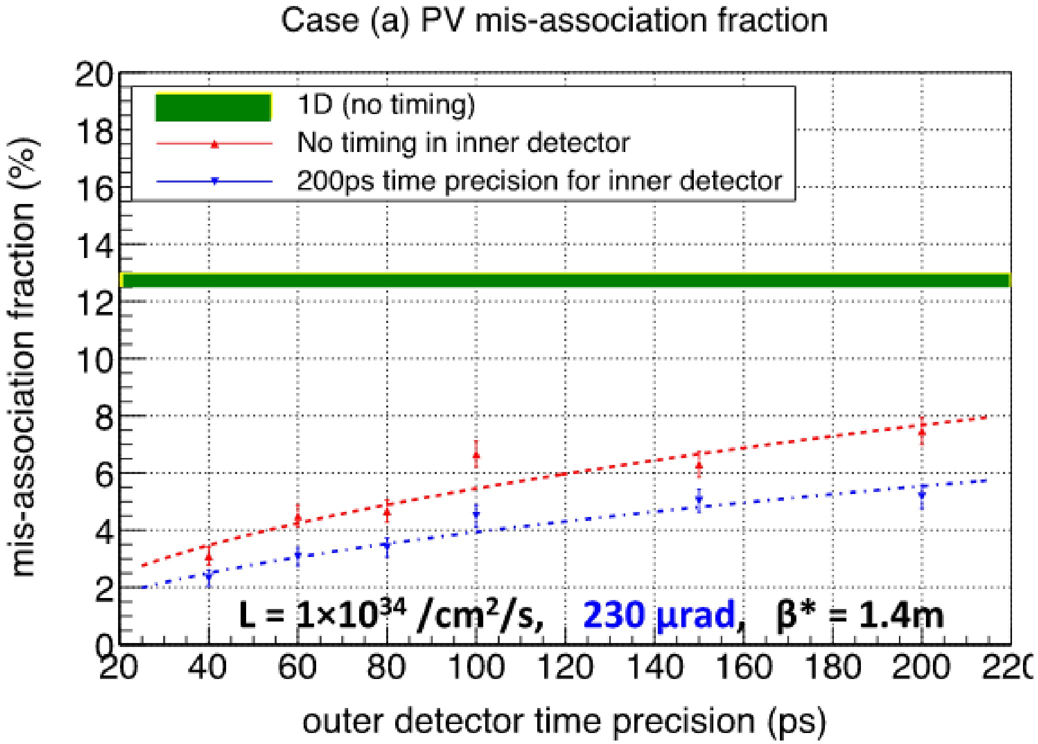
Case	mean N(PV)	σ(z) [mm]	σ(t) [ps]	σ(x,y) [µm]
(a)	27.5	51.9	190	26.6
(b)	41.25	51.9	190	26.6
(c)	55	51.9	190	26.6
(d)	27.5	53.1	189	26.6
(e)	41.25	53.1	189	26.6
~~(f)~~	~~27.5~~	~~?~~	~~?~~	~~26.6~~
(A)	27.5	32.7	202	26.6
~~(D)~~	~~27.5~~	~~?~~	~~?~~	~~26.6~~

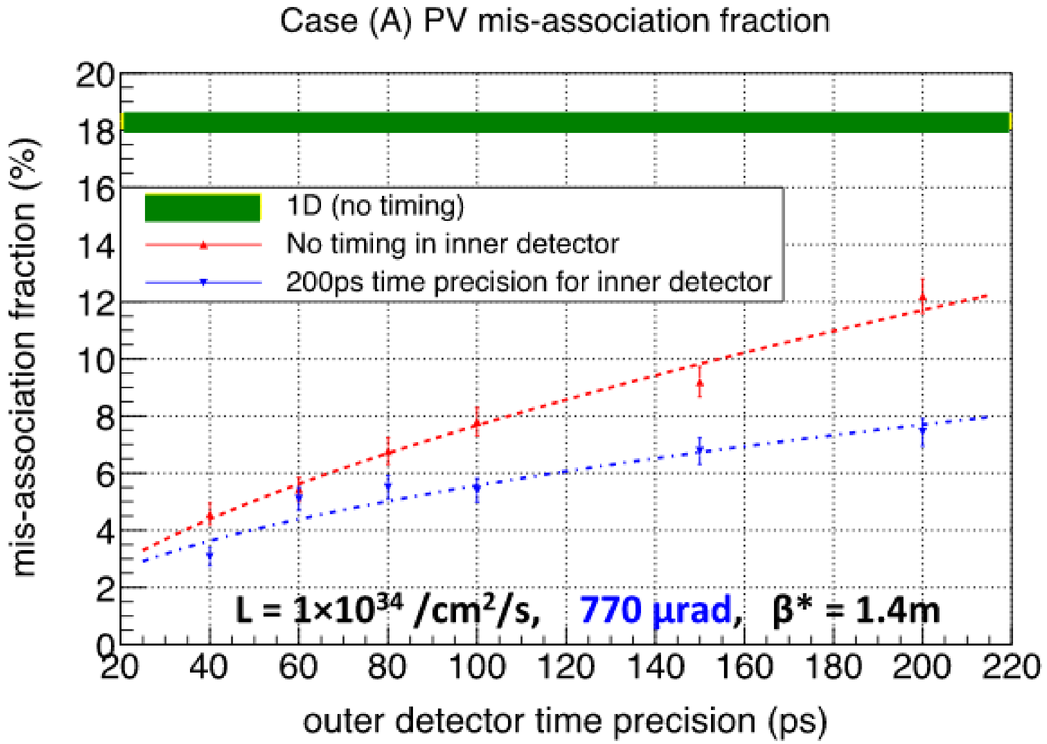
Assumptions

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

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

Results: Influence of crossing angle

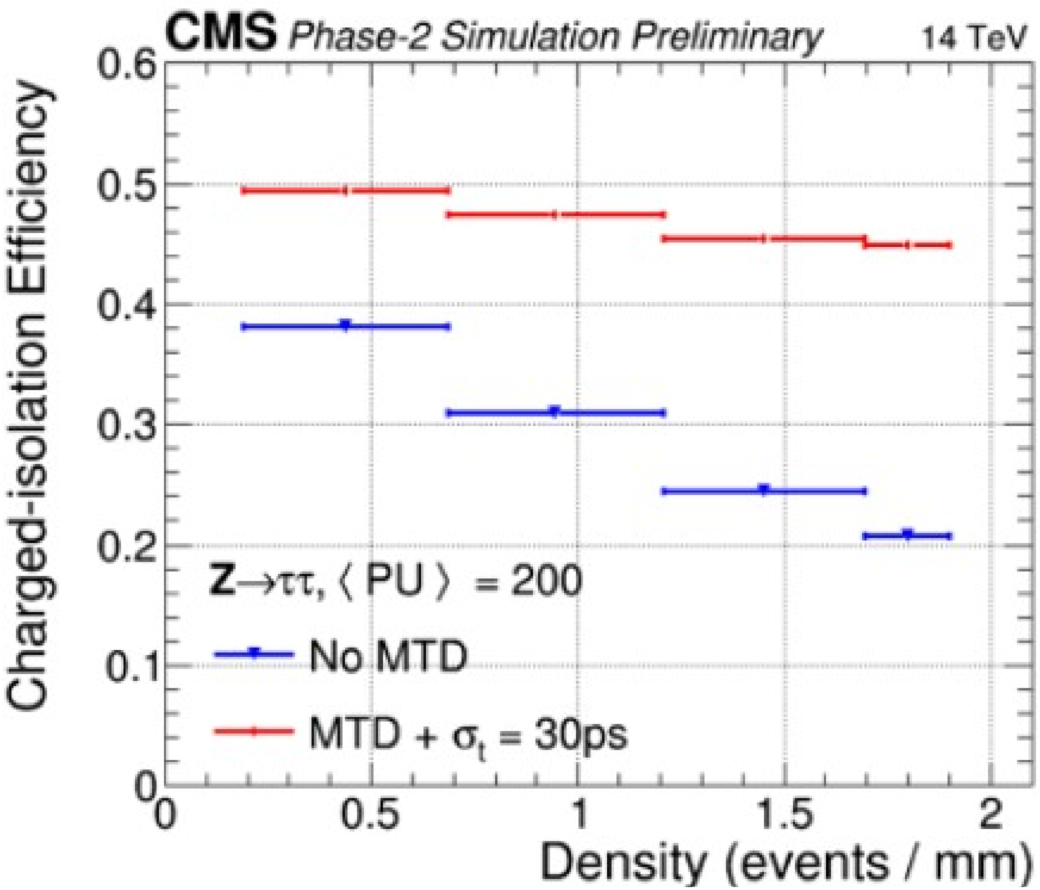




Larger crossing angle gives ~**30-50%** larger PV mis-association fraction
(again, neglecting possible effects on transverse PU distribution)

From machine side: External crossing angles can be optimized to reduce differences between the 2 cases.

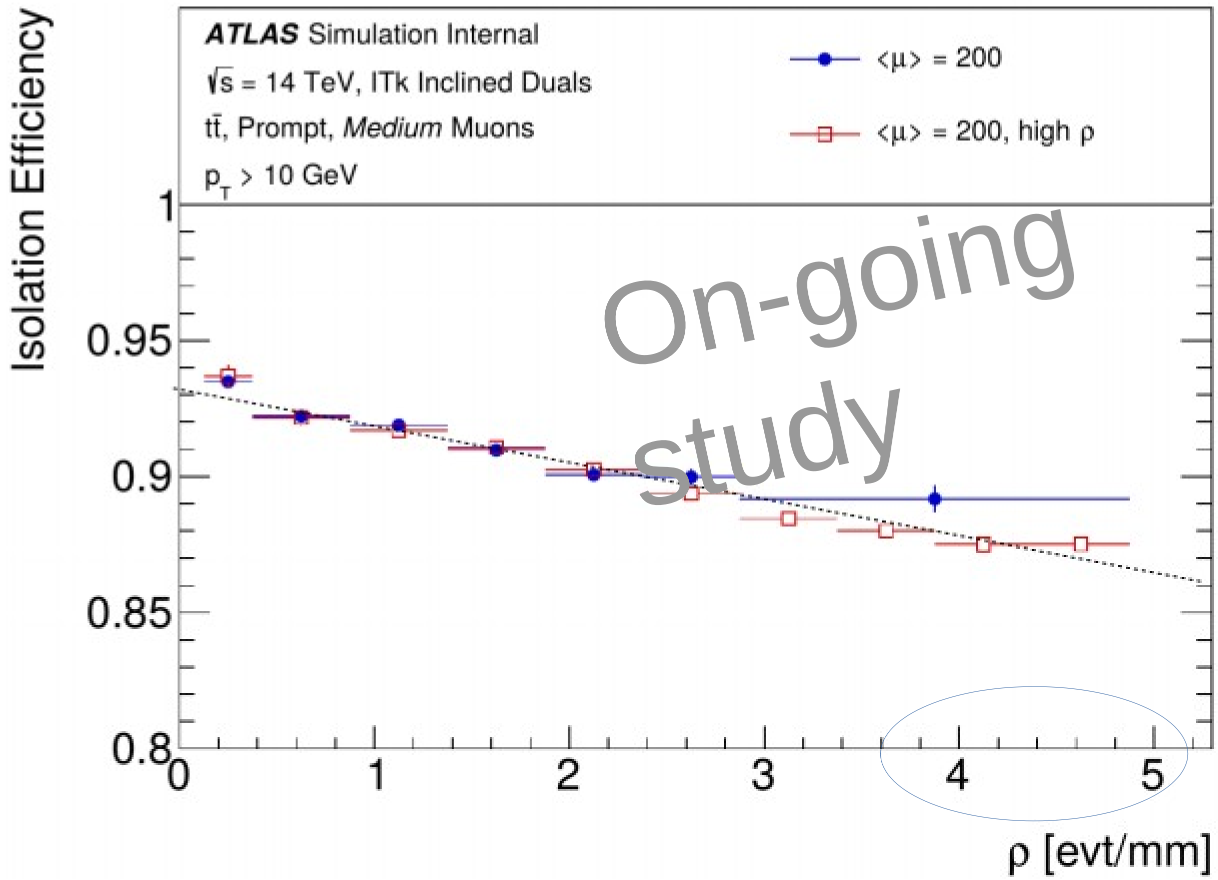
CMS: Benefit of time tagging



- 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

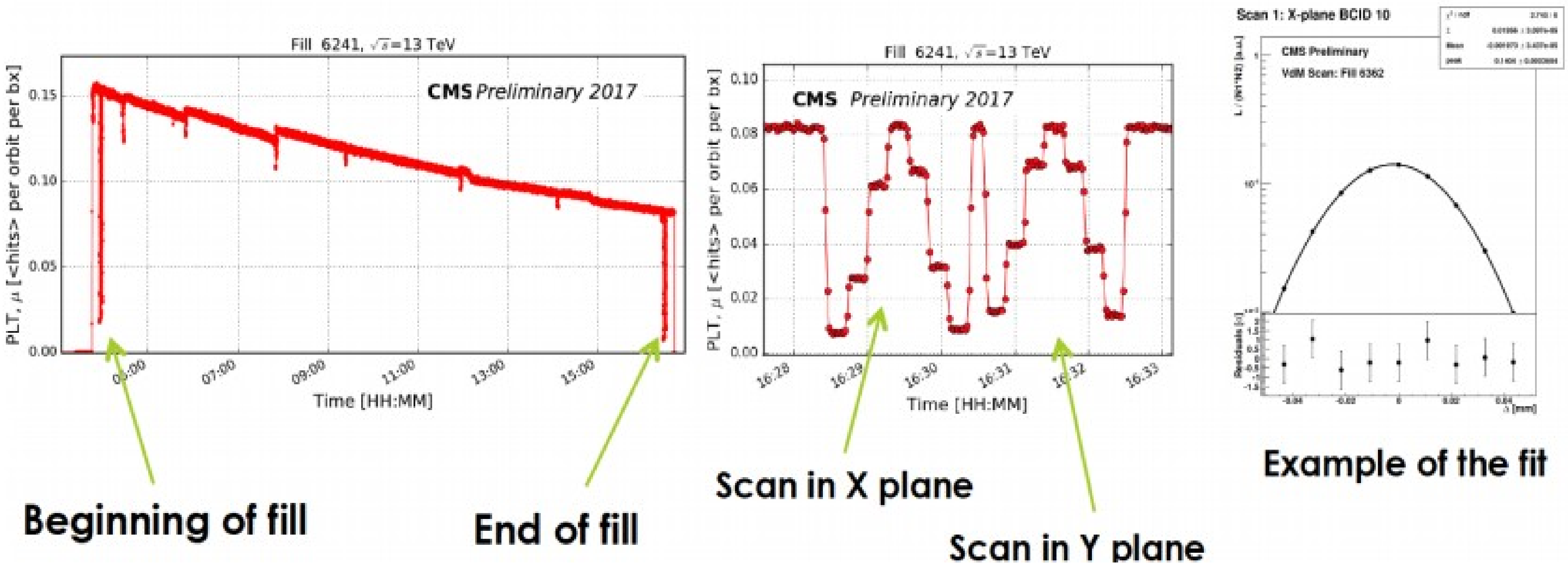
Goal: Reach 1.5% systematic errors in luminosity

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

Current assumption for β* in VdM is about 20m. Today's 20% uncertainty on β* could be improved to 5%.

Emittance scans

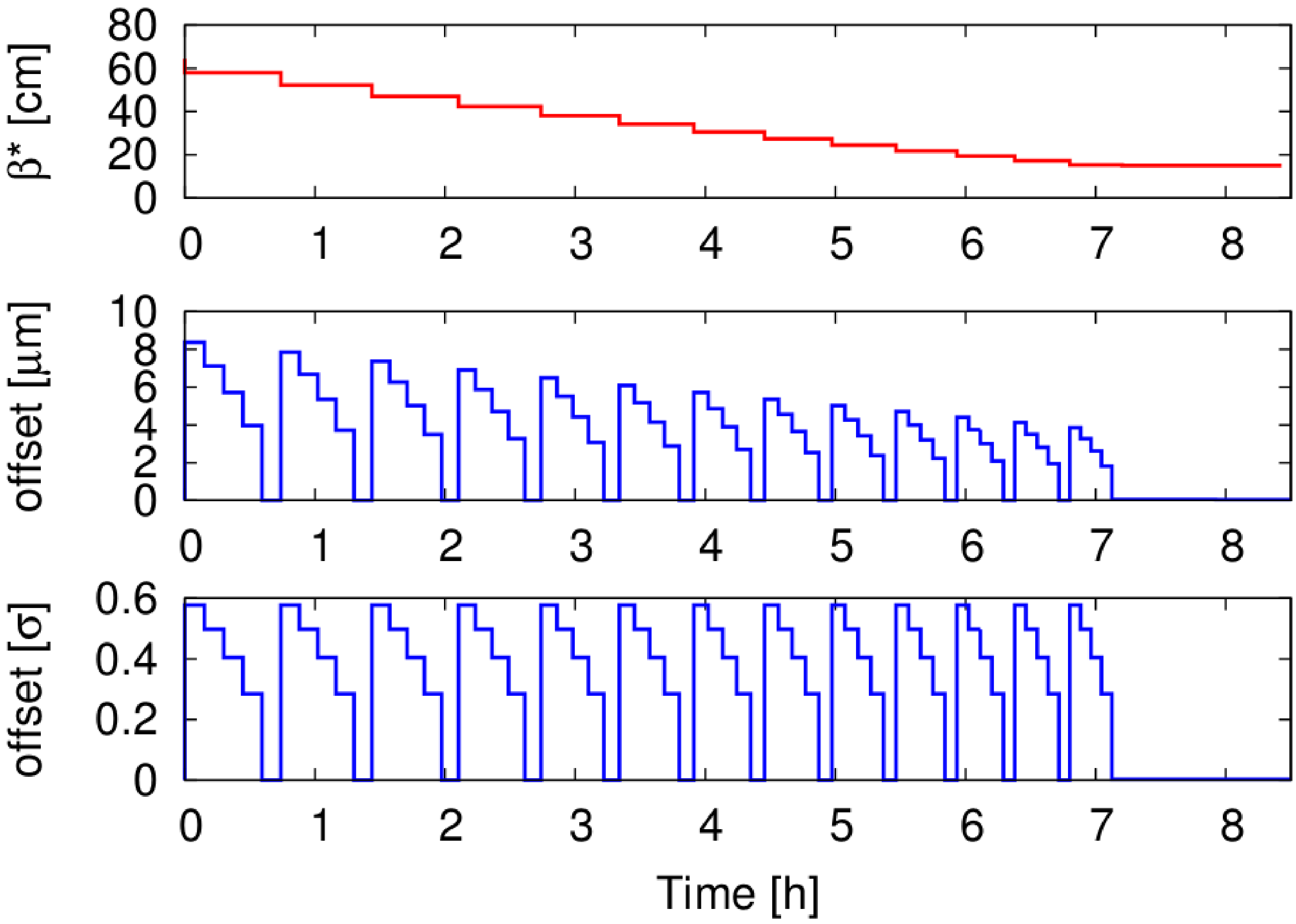
- **Emittance scans** are short Van der Meer type scans performed at the beginning and at the end of LHC fills.
  - Beams are scanned in 7 displacement steps (19-25 steps in VdM);
  - 10 s per step (30 s per step in VdM);
  - The same beams as in physics data taking (in VdM fill special beam optics is 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

HL-LHC bunch-to-bunch luminosity variations

- Detectors assume up to ±5% lumi variation
- Tolerances do not exist in HL-LHC or LIU
- LIU has assumed to provide similar relative beam parameter variations as for present LHC beams
- What is this today? Previous references?
  Is it an issue?

INTRODUCTION (8/13) SPS BEAM PARAMETERS

Tolerance in bunch intensity: 10%

Tolerance in trans. emittance: 20%

Tolerance in long. emittance: 20%

Table 12.1: Nominal LHC beam parameters

	Injection	Extraction
Proton momentum [GeV/c]	26	450
Number of bunches/PS batch	72	72
Number of PS batches/SPS batch	2-4	2-4
Number of particles per bunch [10^{11}]	1.3	1.15
Circulating beam current [A]	0.13-0.26	0.12-0.23
Bunch spacing [ns]	24.97	24.95
Bunch train spacing	224.7	224.6
Transverse normalised emittance (H/V) [μm.rad]	3.0/3.0	3.5/3.5
Longitudinal emittance [eV.s]	0.35	<0.8
Rms. bunch length [cm]	30	<15
Rms. energy spread [10^{-4}]	10.7	<2.8

Table 12.6: Ultimate LHC beam parameters

	Injection	Extraction
Proton momentum [GeV/c]	26	450
Number of bunches/PS batch	72	72
Number of PS batches/SPS batch	2-4	2-4
Number of particles per bunch [10^{11}]	1.9	1.7
Circulating beam current [A]	0.19-0.39	0.17-0.34
Bunch spacing [ns]	24.97	24.95
PS batch spacing	224.7	224.6
Transverse normalised emittance (H/V) [μm.rad]	3.0/3.0	3.5/3.5
Longitudinal emittance [eV.s]	0.35	<0.8
Rms. bunch length [cm]	30	<15
Rms. energy spread [10^{-4}]	10.7	<2.8

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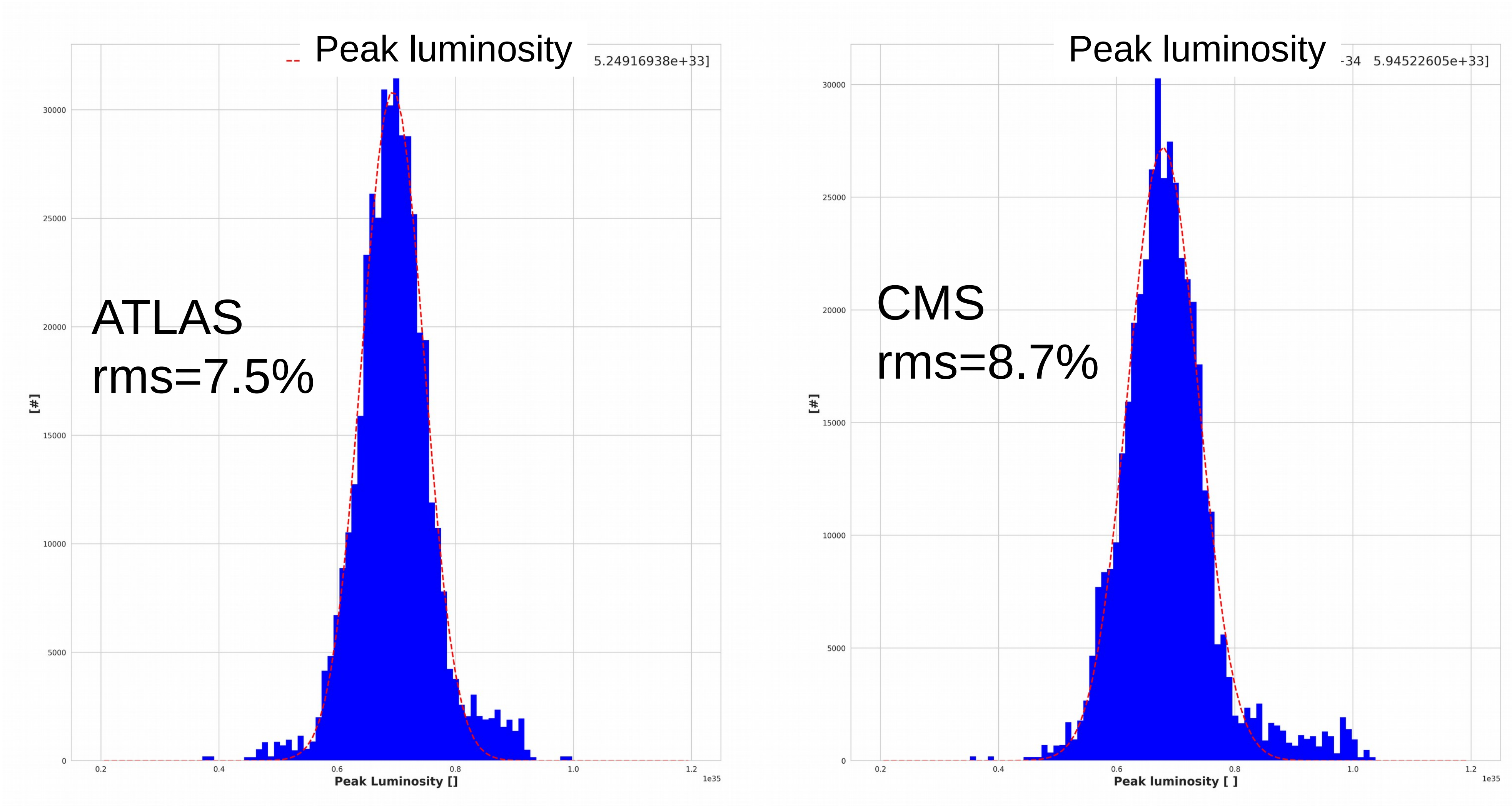
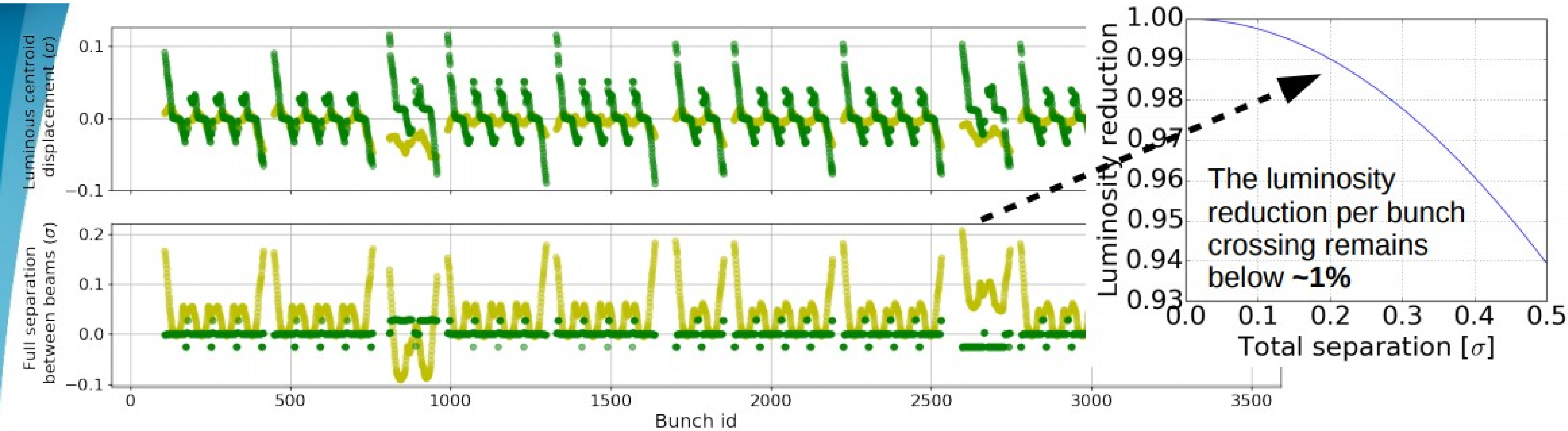
OP Shutdown
Lecture 3/4/2008

LHC bunch-to-bunch lumi variations



Larger variation than ±5% could increase trigger rate requirements at PU=200. To be followed-up.

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

- Different non-colliding bunches OK if needed
- So far detector performance still degrades linearly at extreme pile-up density values → Effective pile-up density is a good figure of merit.
- LHCb also observes pile-up density effects
- Bunch-by-bunch luminosity fluctuations issues to be followed up
- Common report based on ATLAS, CMS, LHCb and machine publications in 2019