Simulation studies for ECAL Upgrade Ib/II

Guy Wilkinson
7/10/18

Introduction

We did not yet have an Upgrade Ib/II ECAL meeting for several months (since February). Various reasons for this:

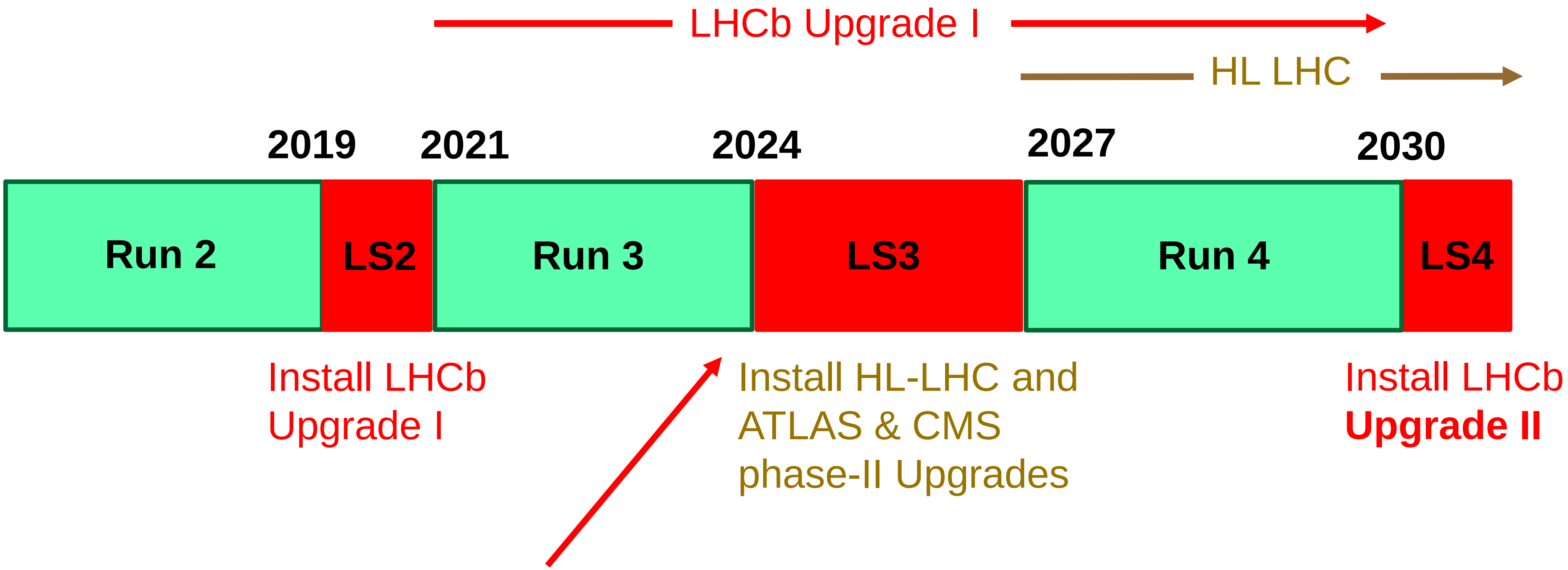
- A sub-set of interested people began self-sufficient, and are happily organising their own studies, focused on possible crystal-based solutions (SPACAL *etc.*)
- Many of us had to focus on the 'Physics case' document, now complete.

Important therefore that we meet again, particularly in light of other developments:

- UII is gathering momentum, with recent positive news from *e.g.* LHCC. The timescale is shorter that one might imagine (see next slides).
- Growing interest from other groups outside the SPACAL team.
- Hence, today's meeting is meant to be an opportunity for different groups to share news of progress, and for others to declare an interest.

Today's meeting focused entirely on simulation studies. This is a critical item which until recently has been slow in progressing, but where several groups are interested.

The LHC schedule up to 2030

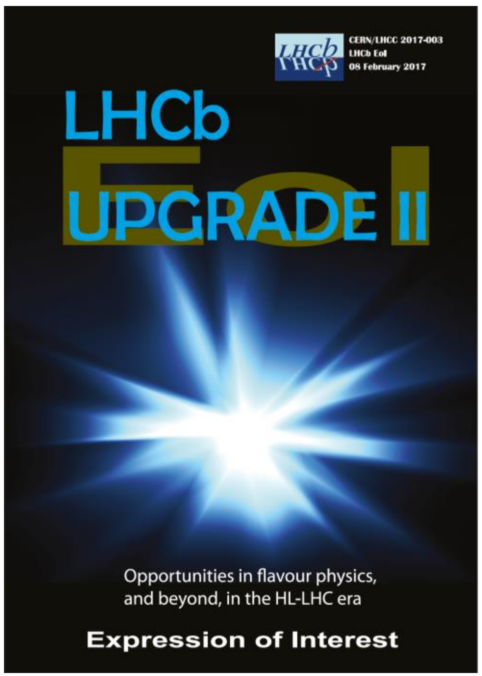


Extended shutdown of LS3 presents opportunity for an '**Upgrade Ib**': consolidation of UI & first steps towards U II

LHCb Upgrade II gathers momentum

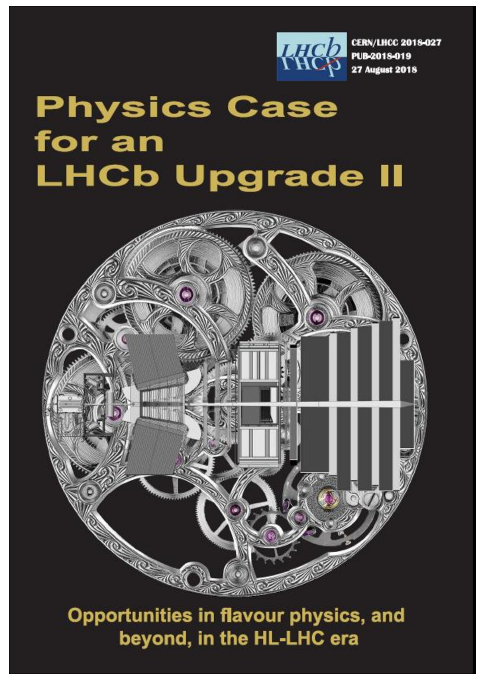
Begin after LS4 (2030). Operate at up to 2 x 10^{34} $cm^{-2}s^{-1}$ & collect (at least) 300 fb^{-1}.

EoI submitted to LHCC in early 2017



[CERN-LHCC-2017-003]

Full physics case submitted to Sept. LHCC



[CERN-LHCC-2018-027, also arXiv:1808.08865]

In parallel, many studies from the machine side, summarised in a report which identifies

"a range of potential solutions for operating LHCb Upgrade II at a luminosity of up to 2 x 10^{34} $cm^{-2}s^{-1}$ and permitting the collection of 300 fb^{-1} or more at IP8 during the envisaged lifetime of the LHC"

[CERN=ACC-NOTE-2018-038]

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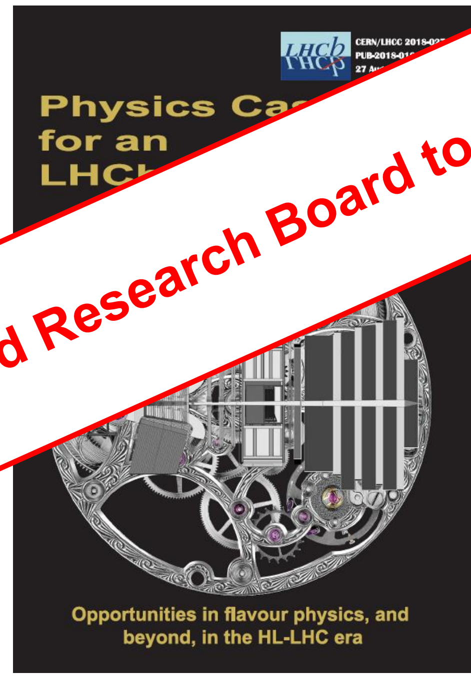

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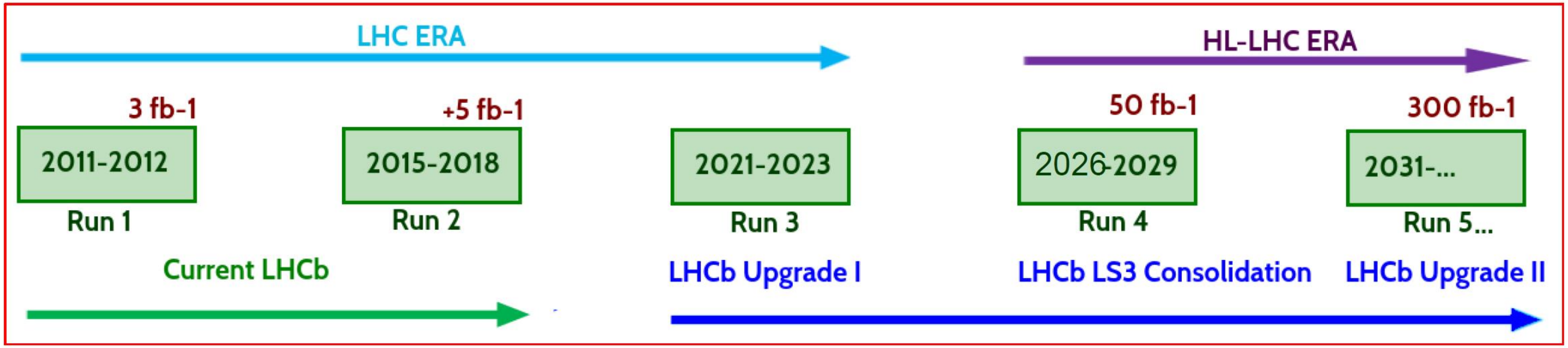
[CERN=ACC-NOTE-2018-038]

Approved by LHCC and Research Board to proceed to TDRs

(from Andreas, Valencia LHCb week)

LHCb ECAL Upgrades I(b) and II



LS2 in 2019/20: → LHCb Upgrade I

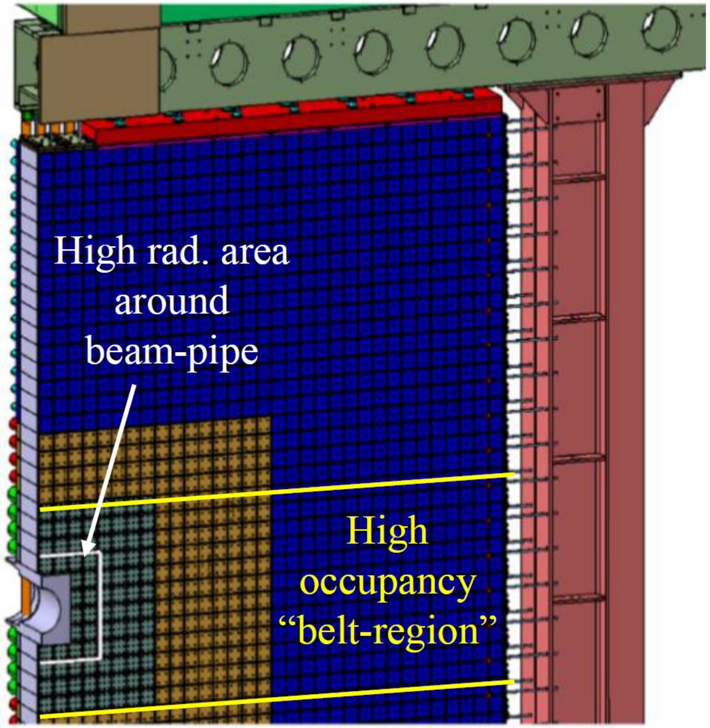
- Keep current ECAL Shashlik modules but **upgrade electronics to full 40 MHz readout**

LS3 in 2024/25: → Consolidation (Upgrade Ib)

- **Replace modules around beam-pipe** (≥ 32 modules) compatible with **$L=2x10^{33}$ $cm^{-2}s^{-1}$**

LS4 in 2030/31: → LHCb Upgrade II

- **Rebuilt ECAL in high occupancy "belt-region"** compatible with luminosity up to **$L=2x10^{34}$ $cm^{-2}s^{-1}$**
- Include **timing information** to mitigate multiple interactions/crossing



ECAL simulation studies: two necessary approaches

Top-down approach

- Study calorimeter environment at ~10^{34}, and set boundary conditions on performance parameters
- Evaluation of requirements from canonical physics channels.
- Overall detector optimisation studies

Tools:
- GEANT
- DELPHES
- Machine Learning

Bottom-up approach

- Detailed GEANT simulations of different technologies and module designs, and careful comparison with test-beam evaluations.

Tools:
- GEANT
- Test beams

Both approaches are necessary to arrive at a satisfactory solution, although it is my impression (perhaps wrong) that the ‘top-down’ studies are less advanced.
I also suspect (perhaps wrongly) that we are almost wholly lacking studies on timing.

ECAL simulation studies: two necessary approaches

Top-down approach

Some examples of ‘top-down’ questions from Sheldon:

- The efficiency for detection of B->x y z, where one of the final state particles is a photon or π^0; the S/B required for a given efficiency.
- The resolution on the reconstructed B mass.
- The spatial resolution as it reflects in the B mass resolution, and/or π^0 mass resolution.
- The energy resolution.
- The time resolution for the needed S/B.

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- Test beams

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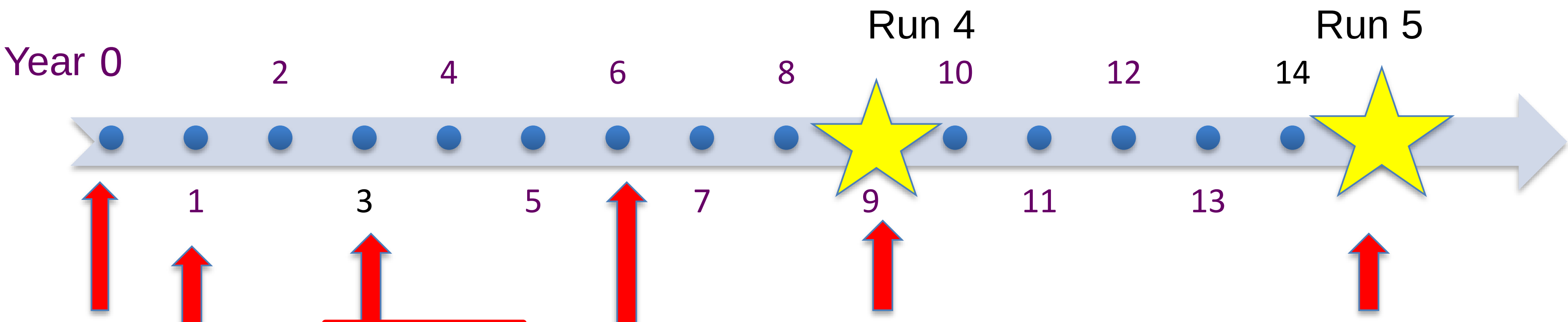
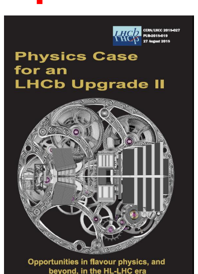
Documents & Timescales

LHCC informed of these timescales.



2017

Sep 2018



2020 !!

U II Technical Design Report

Run4 PID Technical Design Report

Run4 Tracking Technical Design Report

2023

2026

? ? ? ?

Upgrade II Detector TDRs

2031

(longer shutdown needed to install)

Other documents:
HL-LHC Machine Studies
European Strategy Group

Slightly updated version of old slide from Chris – everything remains pretty much valid.

Upgrade Ib/II checkpoints (an evolving plan)

For Upgrade Ib:

- All detector elements for UIb will be reviewed at Amsterdam UIb/II meeting (8-12 April next year), which requires documentation before then on physics performance (not to mention hardware aspects)….
- Then work towards an ECAL contribution to a UIb PID TDR, for completion in early 2020.

For Upgrade II:

- Need a fairly good idea by middle of next year (timescale to be confirmed by U2PG and management) what a UII ECAL would look like, and what its physics performance could be.

  → well before then need initial good guesstimates (guided by simulation) of main detector parameters.

- Some sort of 'framework TDR' (for whole UII) to be produced late 2020.

Goals of meeting

- To exchange information on recent work
- For new parties to declare an interest
- To agree on what needs doing, and timescale for next steps

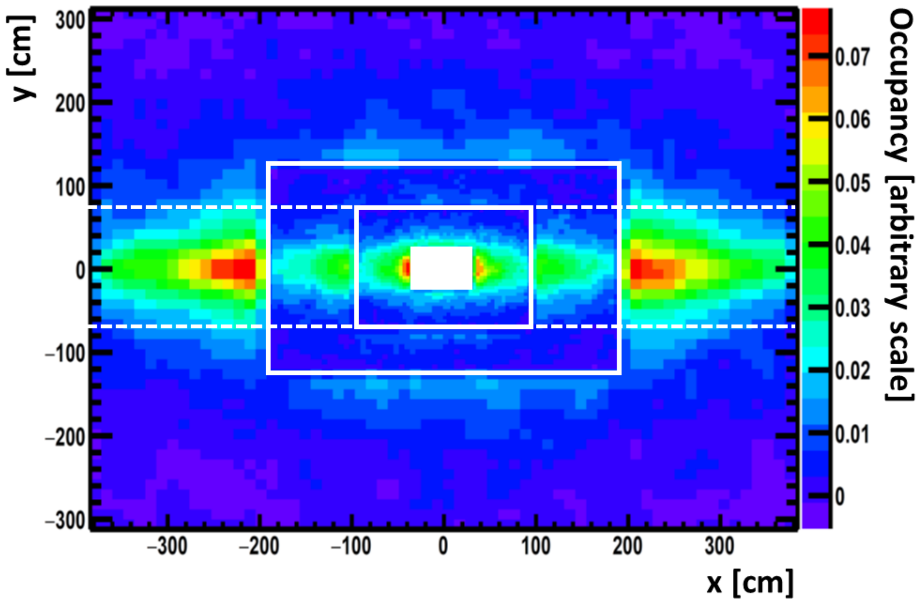
My view is that some dedicated organisation structure is now necessary, not just for software (although this is what we will be talking about today), but for project as a whole. Although I will continue to help out wherever needed, it is desirable that progress is overseen by people within the interested institutes. How this can be done we will discuss in the days ahead.

Backups

Guy Wilkinson
4/12/17

LHCb ECAL - reminder

Recall, lead shashlik calorimeter with three regions: inner, middle and outer, with current cell size 4 x 4 cm^2,6 x 6 cm^2 and 12 x 12 cm^2, within modules of 12 x 12 cm^2.



Even at Upgrade-I performance will degrade – studies performed for PID TDR show that some of loss can be recovered for high p_T rad. Penguins, but presumably not the case for other physics objects. And radiation damage will afflict inner region.

Main problems:

- shower separation → degraded resolution & loss in efficiency finding objects
- increased number of candidates → high combinatoric background

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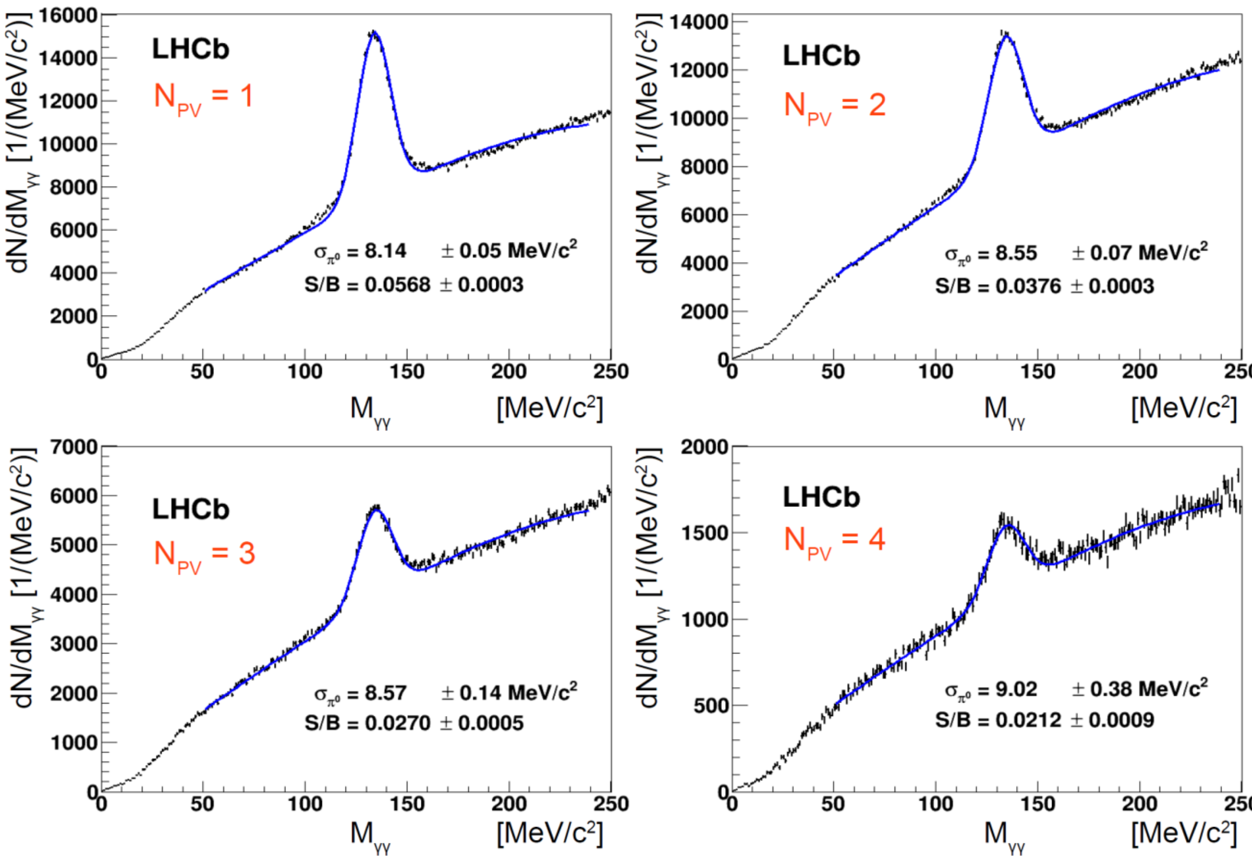
Performance degradation in run-2 data vs. number of PVs



In Upgr ... PID TDR
show th ... sumably
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LHCb ECAL – Upgrade

Even maintaining physics performance with calorimeter objects in Upgrade I will require some sort of ECAL upgrade during LS3. (Same argument)^2 for Upgrade II.

This can be seen as an opportunity – one to improve ECAL-related physics beyond current capabilities – well motivated by growing importance of e, π^0 and γ analyses.

- Smaller Moliere radius and cell size in inner region, *e.g.* tungsten and 2 x 2 cm^2 cells.

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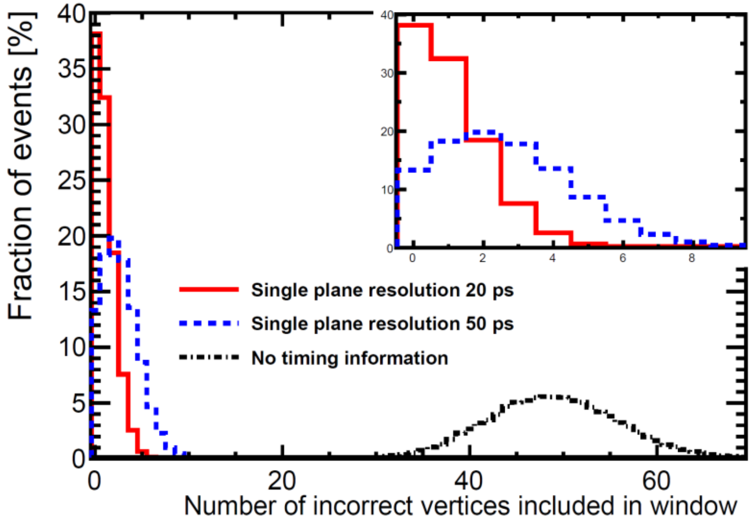
- Smaller Moliere radius and cell size in inner region, *e.g.* tungsten and 2 x 2 cm^2 cells.
- Fast timing information, *e.g.* provided by a few silicon planes with a few 10s of ps timing precision (as aimed at by CMS HGCAL).
- Improved spatial resolution, *e.g.* provided by silicon planes.



	Spatial information from clusters		Perfect spatial knowledge	
	σ_C		σ_C	
σ_S	1%	2%	1%	2%
7%	7.5	8.2	4.2	5.2
10%	8.5	9.3	5.5	6.5
15%	10.5	11.3	8.0	8.9

π^0 resolution [MeV]
σ_s = stochastic term
σ_c = constant term

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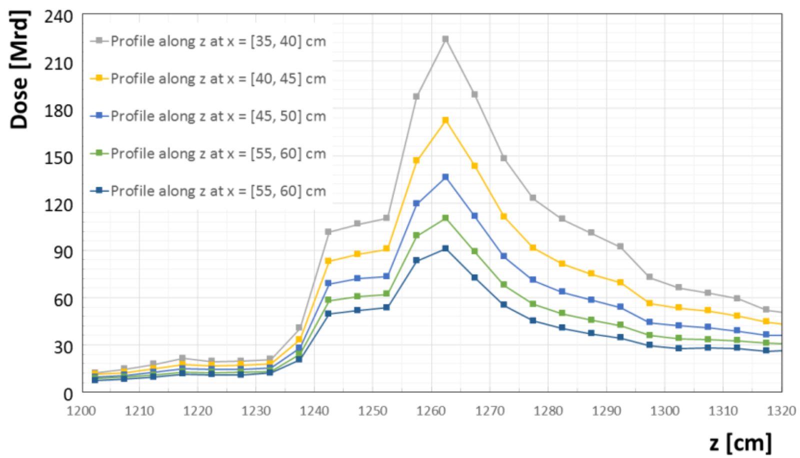
Radiation dose for 300 fb^{-1}



- High radiation-tolerance (although exposure varies steeply with radius, so different technology &/or replacement schemes can be envisaged in different regions.)

Some realism is necessary. Very difficult to envisage affordable solution meeting above requirements that will also improve upon current intrinsic energy resolution.