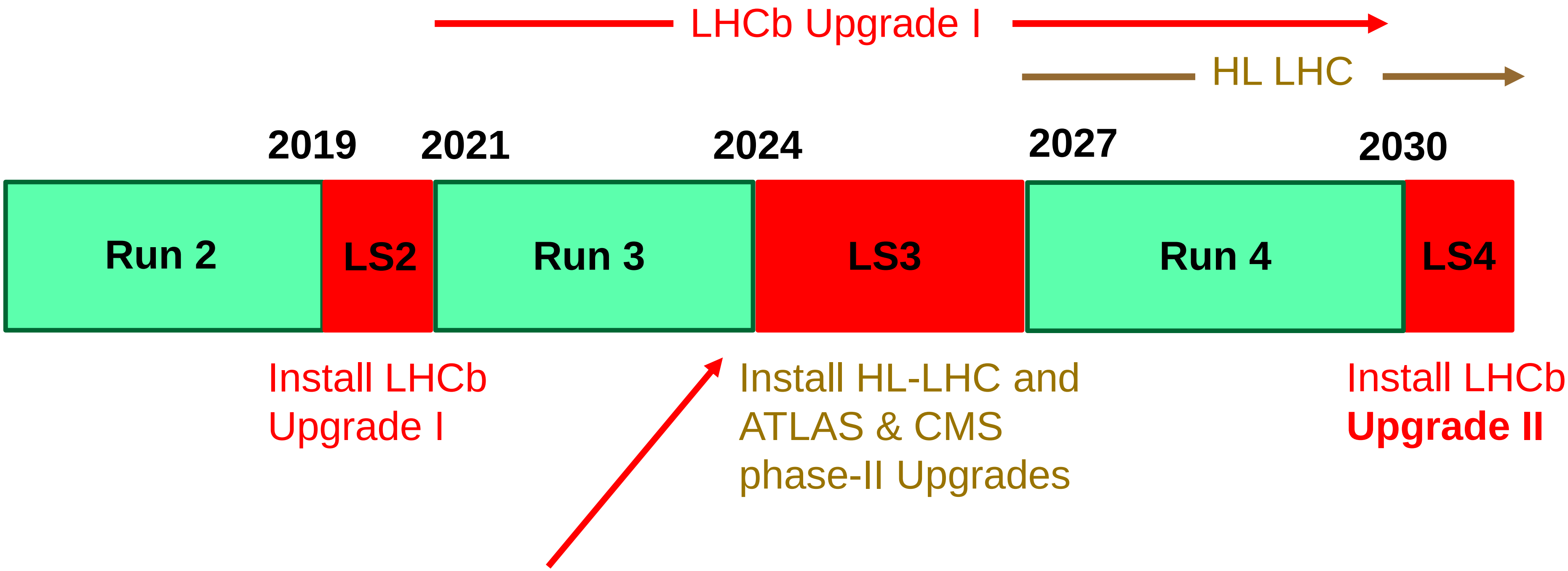
ECAL Upgrade Ib/II

Reminder of:
- Goals of Upgrade
- Scope and detector requirements
- Upgrade-Ib options
- Immediate goals and organisation

Guy Wilkinson
13/12/17

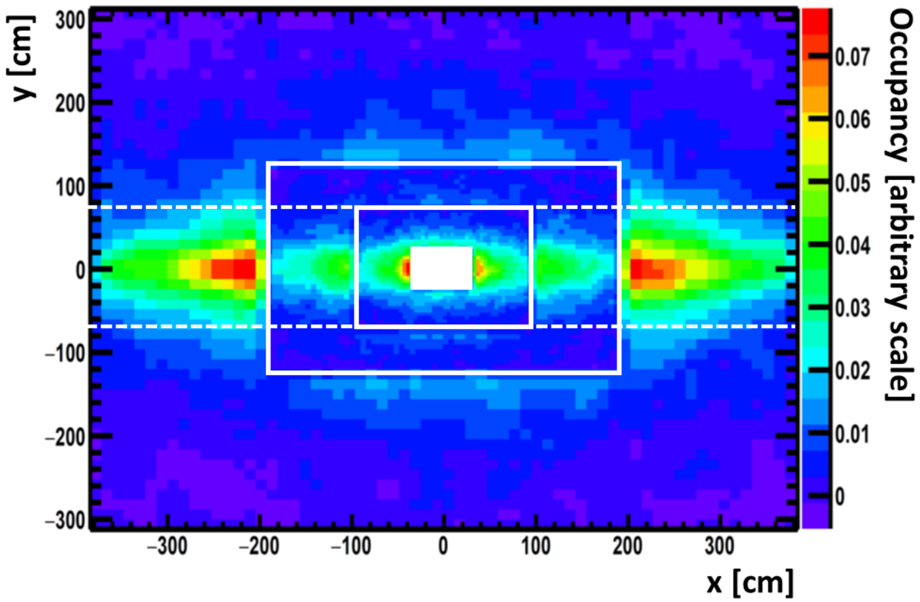
The LHC schedule up to 2030



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

LHCb 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.

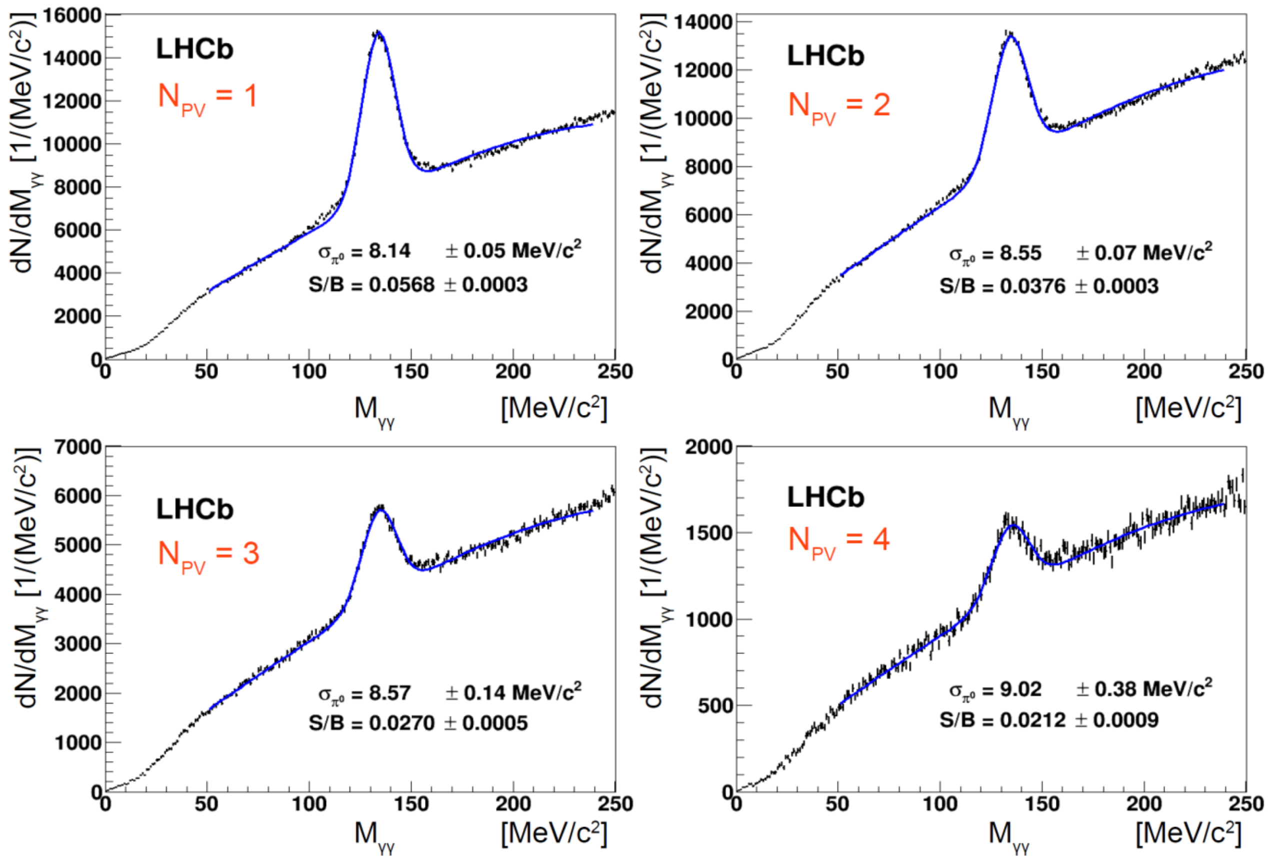
Main problems:

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

LHCb ECAL - reminder

Recall, lead shashlik calorimeter with three regions: inner, middle and outer, with current … x 12 cm^2.

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



In Upgr… PID TDR show th… …sumably not the… …er region.

Main pr…

- sh… …bjects
- increased number of candidates → high combinatoric background

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.

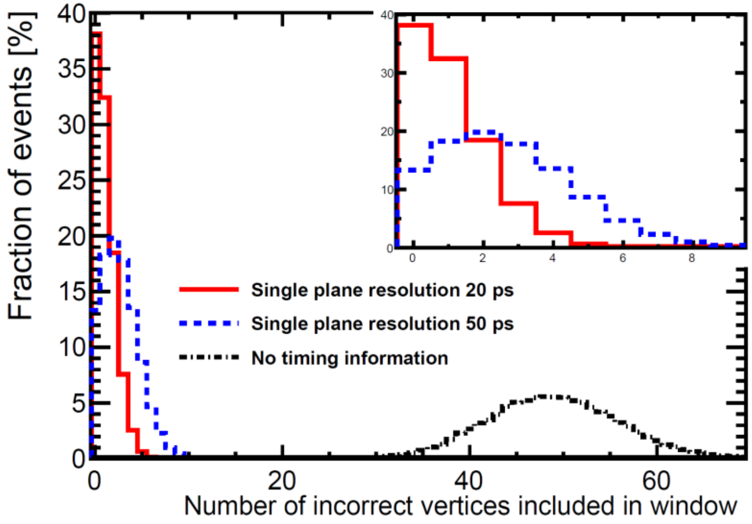
- Smaller Moliere radius and cell size in inner region, *e.g.* tungsten and 2 x 2 cm^2 cells.

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.
- 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

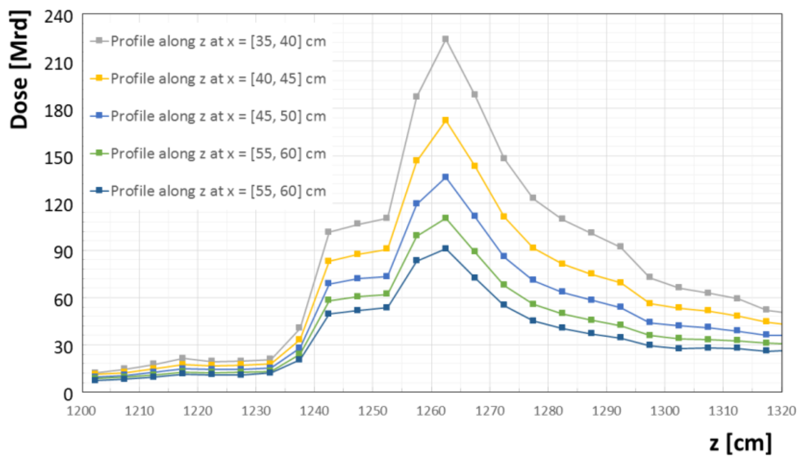
LHCb ECAL – Upgrade

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.
- 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.

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.

When to Upgrade ECAL ?

- Possible to conceive of a partial detector replacement already during Upgrade-I era *i.e.* in LS3 (‘Upgrade Ib’)

  - Plenty of time available for installation…
  - ...and replacement already foreseen for modules closet to beam pipe.
  - Improved detector probably necessary for a continued programme of calorimeter-based physics.
  - Work could be first step towards full Upgrade-II detector.

  However:

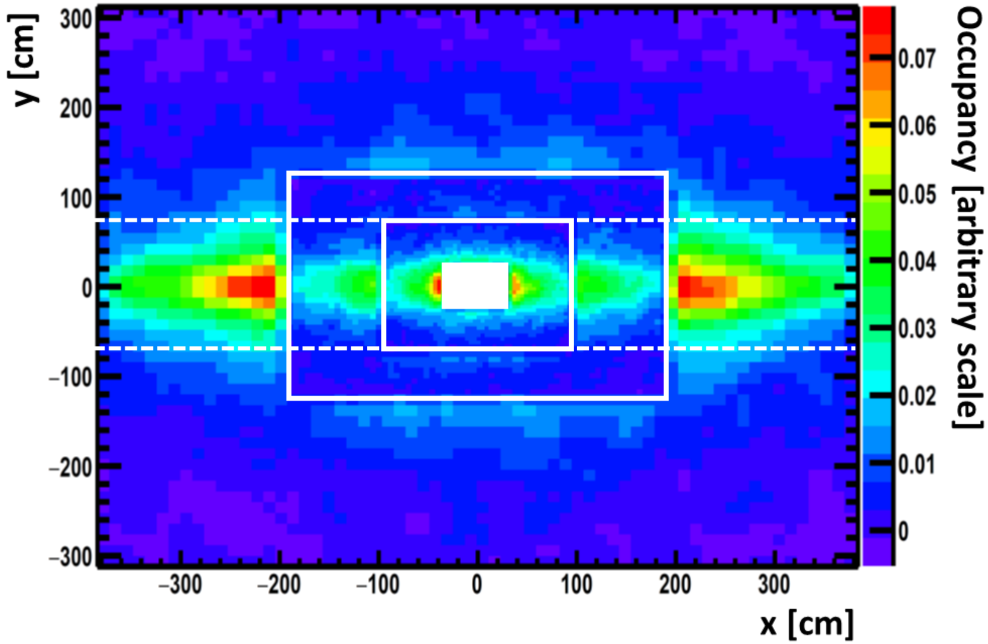
  - we have limited person power and the financial cost will be significant
  - the time for R&D, organisation and construction is also limited.

- Alternatively postpone everything until Upgrade II (*i.e*. LS4)

  - allows plenty of time for preparation…
  - …but then scope and cost of the project becomes intimidating as does constraints for installation (duration LS4 <(<) LS3).

Scope of Upgrade-Ib: options

Around ~1/3 of physics lies in inner region, and ~1/2 in horizontal band
(of course these numbers are channel dependent and require further study).



Options:

- Replace inner region (176 modules)
- Band out to edge of middle region
  (‘band A’ = 368 modules)
- Full horizontal band (‘band B’ = 752 modules)

Possible then to reuse existing inner + middle modules in middle + outer regions ?

And include fast-timing capabilities (*e.g.* ~3 planes of silicon).

Documents & Timescales

LHCC informed of these timescales at September meeting

Run 4 Run 5

Year 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

2017

May 2018

Physics Case

2020 !!

U II Technical Design Report

Run4 PID Technical Design Report

Run4 Tracking Technical Design Report

2023

? ? ? ?

Upgrade II Detector TDRs

2026

2031

(longer shutdown needed to install)

Other documents:
HL-LHC Machine Studies
European Strategy Group

A lot of talk about HE-LHC last week – impact on Run 6 operations and hence Upgrade II must be followed

Immediate goals & organisation

Simulation studies need to proceed on two fronts:

1. Full GEANT simulation of a straw-man design in some plausible technology to obtain detailed understanding of key performance parameters in Upgrade-I and Upgrade-II conditions.

2. Complementary above studies with fast-simulation to allow for fast detector optimisation and to analyse impact on key physics modes. (In ideal case this will also provide input for ongoing physics case for Upgrade II: both document to LHCC and HL-LHC workshop.)

Meanwhile, begin evaluation of candidate technologies with timescale of a possible Upgrade-Ib TDR firmly in mind (~2020).

(In parallel: continue discussions with funding agencies…)

Schedule these meetings with frequency of 1.5-2 months (?).

Worthwhile to establish a timeframe with internal milestones to encourage convergence & obtain initial answers to key questions? (Discuss with management.)

Backups

Guy Wilkinson
4/12/17

Cost guesstimates: modules

Number of modules under consideration

modules per region	x	y	x*y
beamplug	4	4	16
inner + beam plug	16	12	192
middle + inner + plug	32	20	640
outer + middle + inner + plug	64	52	3328
inner			**176**
middle			448
outer			2688
band A: X(middle) * Y(inner) - plug	32	12	**368**
band B: X(outer) * Y(inner) -plug	64	12	**752**

Cost guesstimates: modules

Indicative estimates made by Andreas (treat with caution), but ball-park correct.

							Inner	band A	band B
					CHF		MCHF	MCHF	MCHF
Cost per module: Tungsten 2x2	~18	g/cm^3	1.25mm sheets		**28802**		**5.1**	**10.6**	**21.7**
Converter					4086				
Tungsten raw sheets	31	kg	130	CHF/kg	3981				
machining sheets and holes	75	pieces	1.4	CHF/piece	105				
Scintillator					7346				
BASF 164 H	5.4	kg	10.2	CHF/kg	56				
molding+coating+quality	2700	tiles	2.7	CHF/tile	7290				
Fibers (Y11)	0.1	km	4500	CHF/km	450				
Photomultiplier					7920				
PM	36	channels	140	CHF/channel	5040				
PM Base + HV	36	channels	80	CHF/channel	2880				
Readout electronics					9000				
FE-card (12bit ADC)	36	channels	196	CHF/channel	7056				
crate	36	channels	54	CHF/channel	1944				

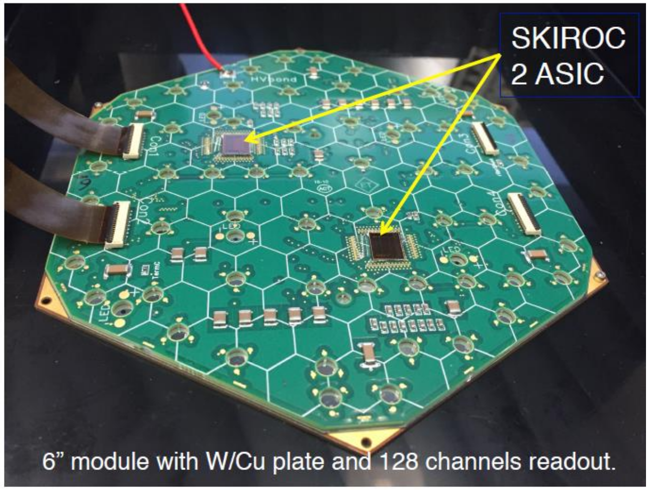
Remark: 2 x 2 cm^2 cells would be overkill in outer region, so 'band B' number probably an overestimate

Cost guesstimates: silicon planes

Naïve scaling from CMS HGCAL

Cell size ~0.5 cm², 1 cm²

Area to cover ~600 m²



LHCb	area / plane	cost, with 3 planes
Inner region	2.5 m^2	0.4 MCHF
Band A	5.3 m^2	0.7 MCHF
Band B	10.8 m^2	1.6 MCHF

Main challenge probably lies in development of ASIC.

Estimated cost (as quoted by Virdee at Manc. TTFU) ~ 28.7 MCHF for modules

Cost of CMS HGCAL

(from Virdee, Manchester, 2016)

Table 3.10: CORE cost estimate for the endcap calorimetry system.

Estimated CORE cost in MCHF (2014)	
Mechanical Structures	5.4
Silicon Modules	28.7
On-detector electronics and services	3.4
BE Electronics and Controls	2.5
Power System	5.0
Cooling System	7.5
Assembly and Installation	1.4
Total HGCAL	**54**
Absorber	6.6
Scintillating Tiles and WLS fibers	1.3
Readout and on-detector electronics	1.2
BE Electronics and Controls	0.3
Power System	0.1
Assembly and Installation	0.3
Total Back HE	**10**
Total Endcap Calorimeters	**64**

28 layers, of ~20 m^2