ECAL Radiation Environment
(Run2&3 – Prompt & Induced)

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12.12.2022

Prompt Dose and Fluence

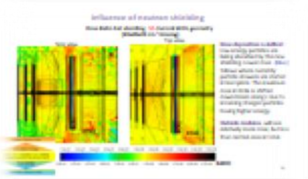
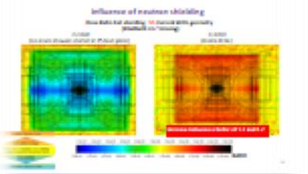
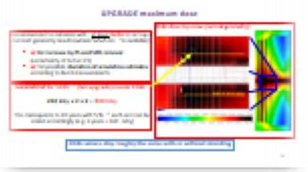
Currently available estimations (shown partially in earlier workshops or given privately):

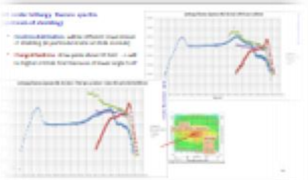
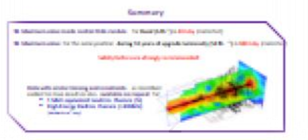
- Presentation from 2015 (dose)
- Update 2017 (1 MeV neutron fluence equivalent)

Results are based on **Approximate Run3 Geometry ("LHCb Upgrade")**
Reasonable applicability: same as Run2, but neutron shielding instead of PS/SPD/M1.

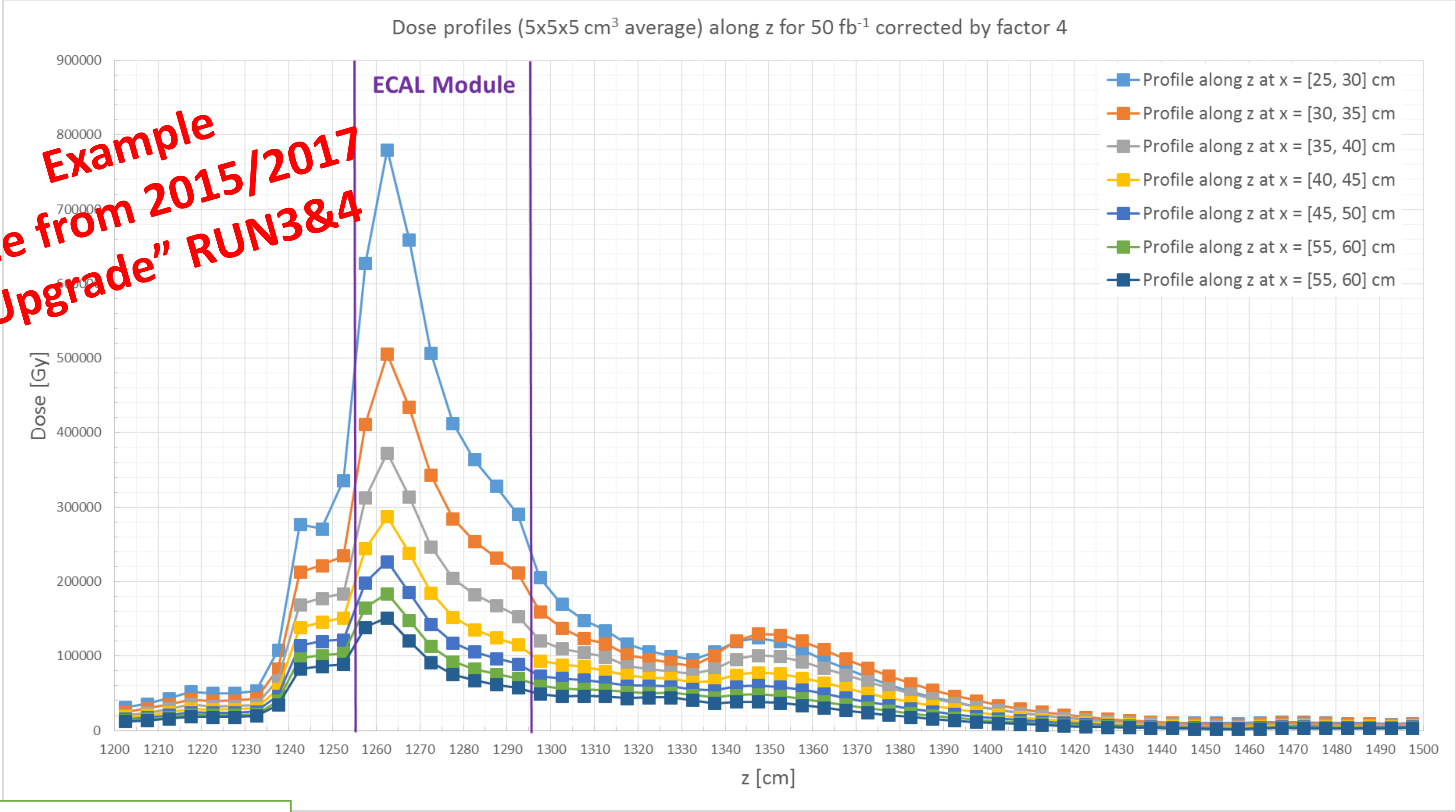
Prompt dose is mostly **scaled to 50 fb-1**
(scalable (linear) with integrated luminosity, e.g. individual LHC run or year,
as long as the beam energy and geometry (incl. materials) stay the same)

Example Slides Follow

Dose profiles along z for the upgrade (50 fb^{-1} at 14 TeV)

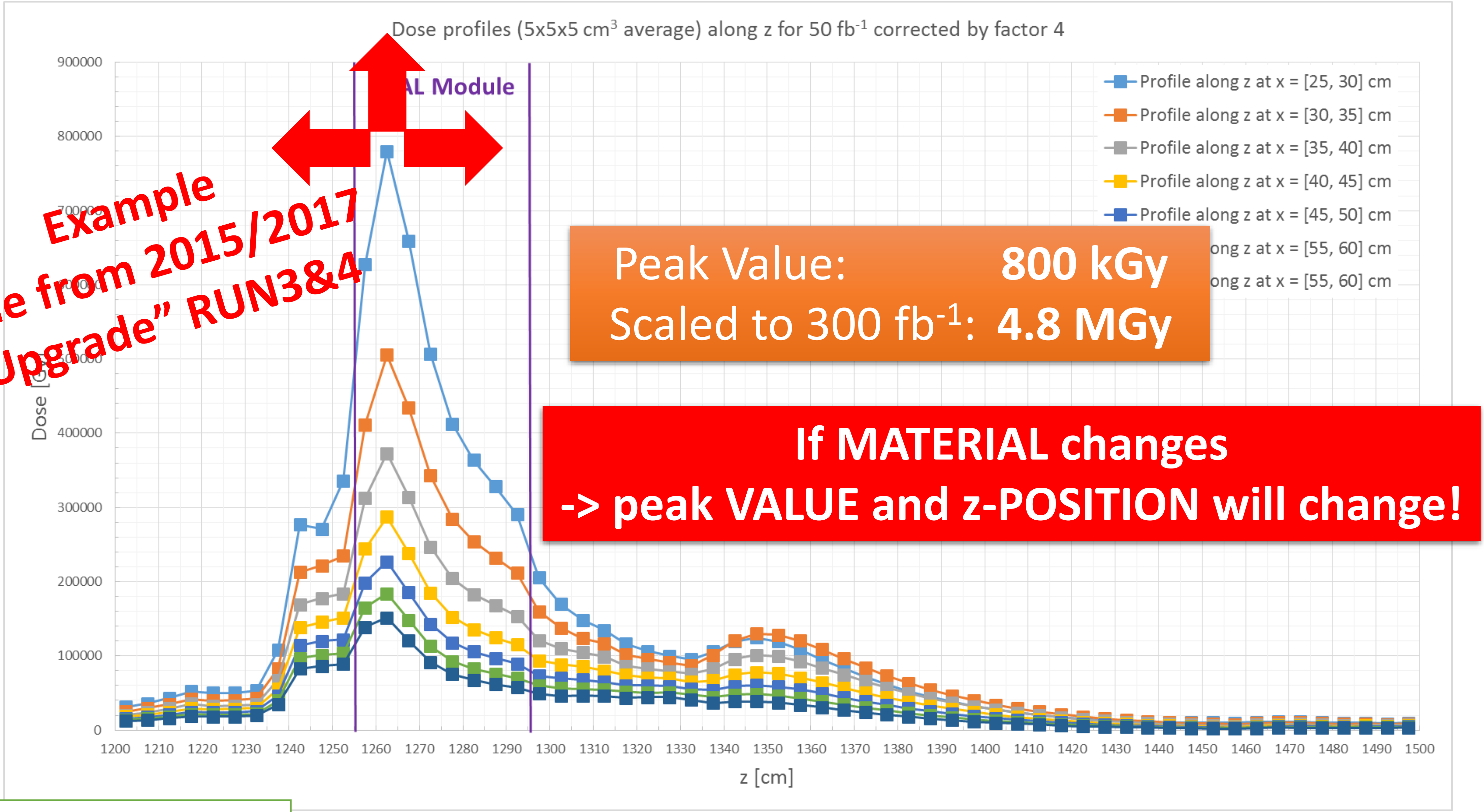


Example
Slide from 2015/2017
“Upgrade” RUN3&4

Each datapoint represents the average of a 5x5x5 cm^3 cubic bin

For infos on correction factor please see slides 5 and 12

Dose profiles along z for the upgrade (50 fb^{-1} at 14 TeV)



Example
Slide from 2015/2017
"Upgrade" RUN3&4

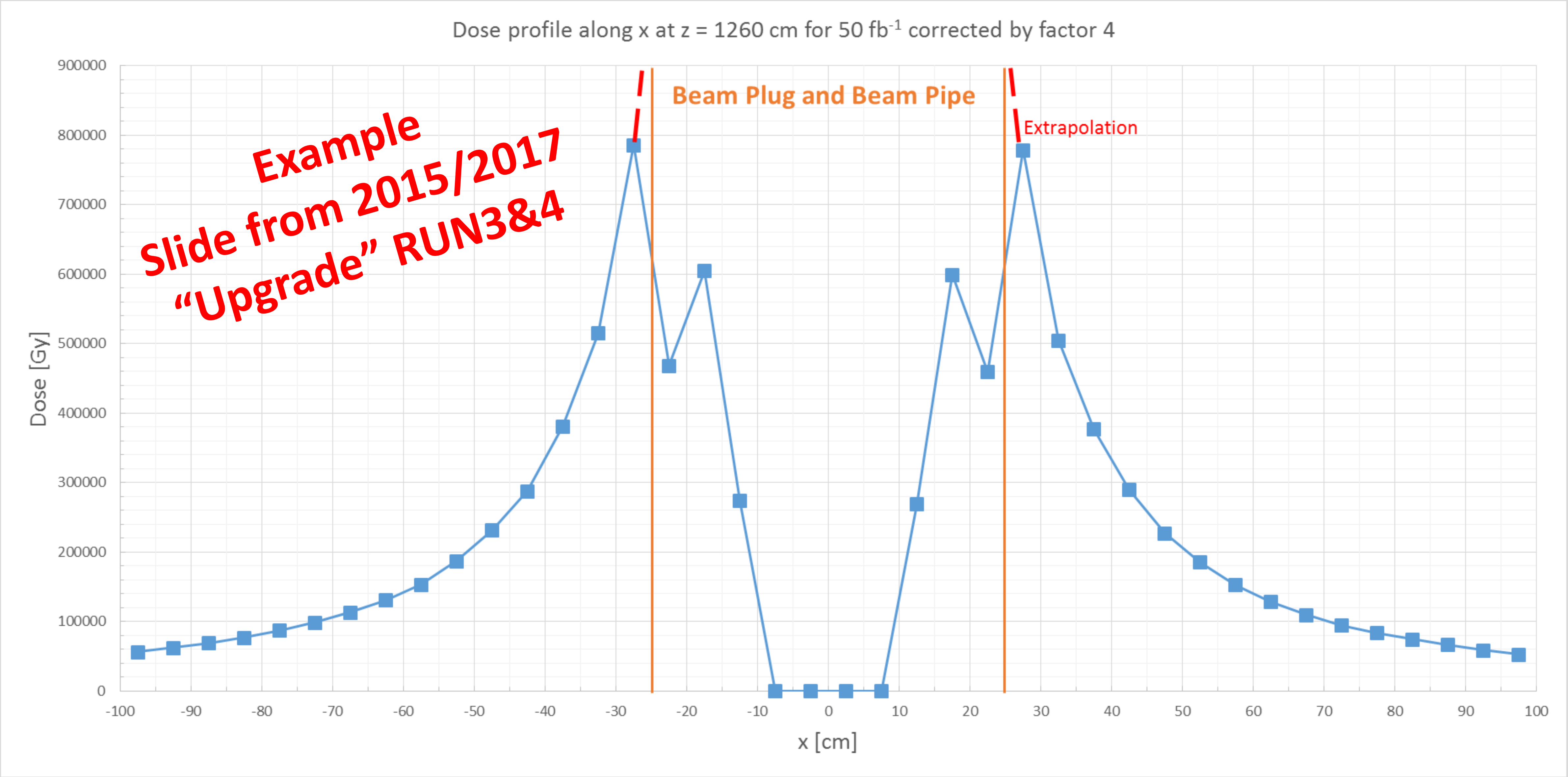
Peak Value: **800 kGy**
Scaled to 300 fb^{-1}: **4.8 MGy**

If MATERIAL changes
-> peak VALUE and z-POSITION will change!

Each datapoint represents the average of a 5x5x5 cm^3 cubic bin

For infos on correction factor please see slides 5 and 12

Dose profiles (max.) along x for the upgrade (50 fb^{-1} at 14 TeV)

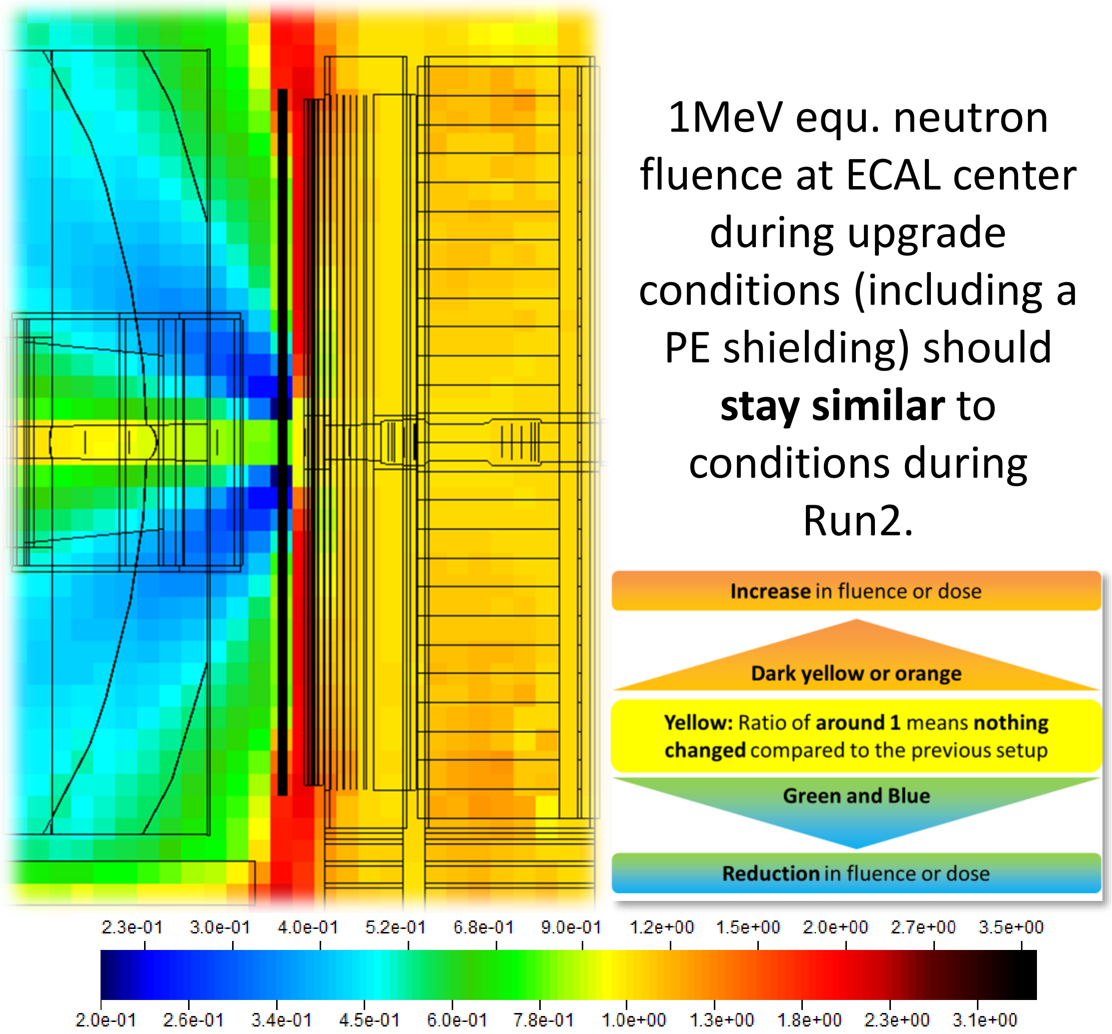


Each datapoint represents the average of a 5x5x5 cm^3 cubic bin

For infos on correction factor please see slides 5 and 12

1 MeV equivalent (Si) neutron fluence values for the upgrade

Ratio Full Shielding vs. Standard



1MeV equ. neutron fluence at ECAL center during upgrade conditions (including a PE shielding) should **stay similar** to conditions during Run2.

Increase in fluence or dose

Dark yellow or orange

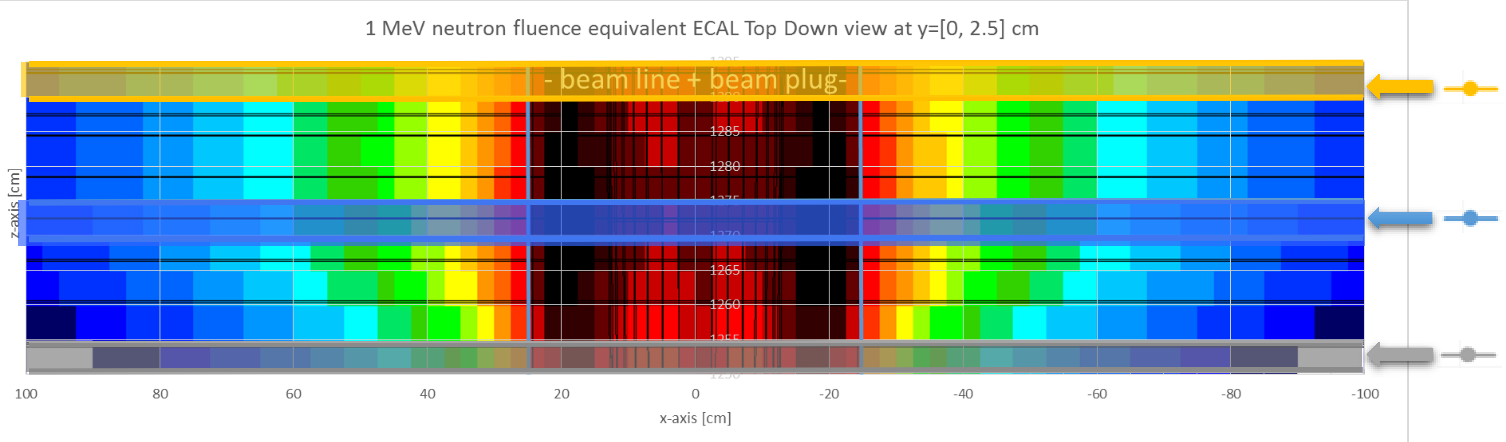
Yellow: Ratio of **around 1** means **nothing changed** compared to the previous setup

Green and Blue

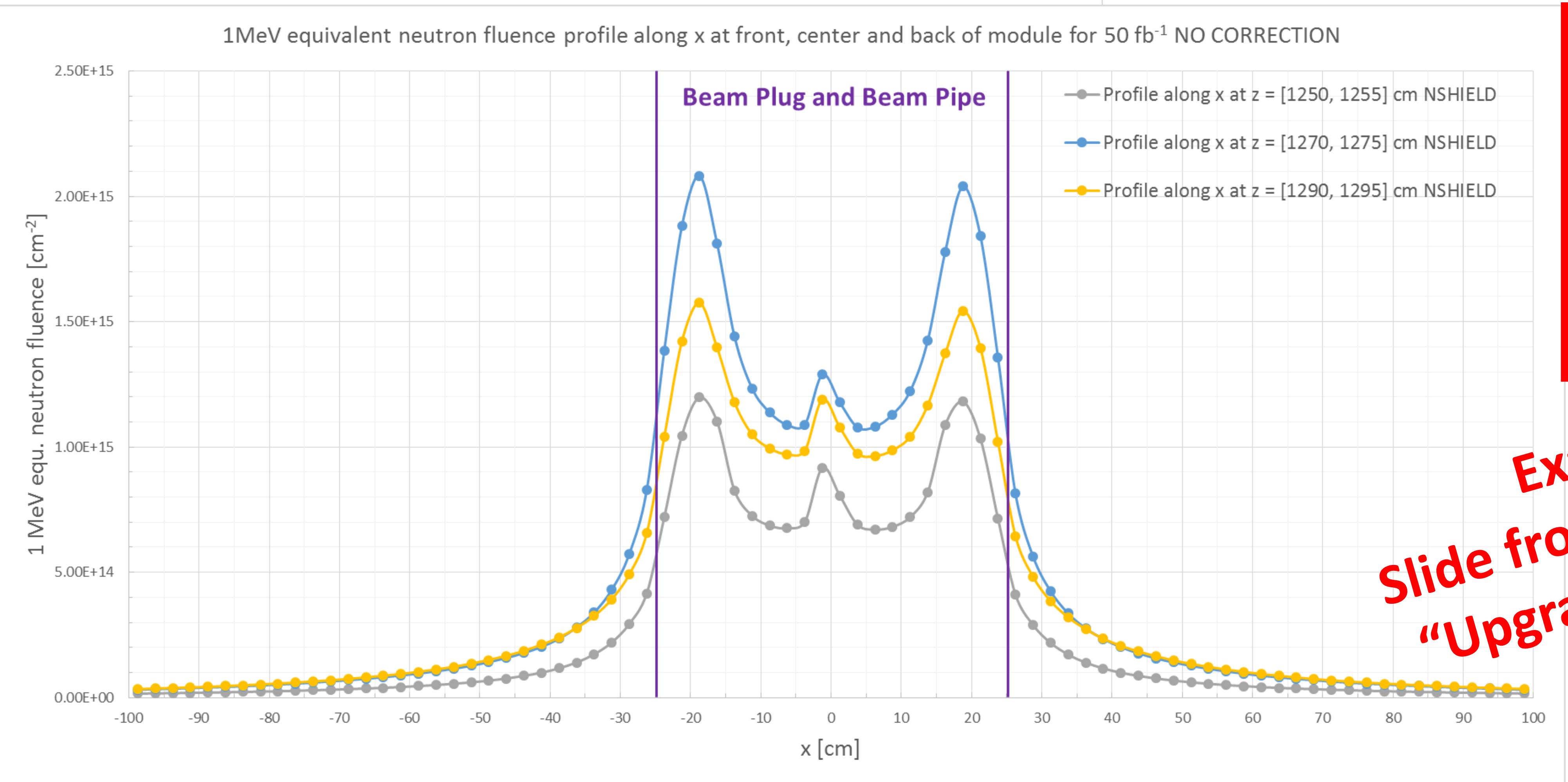
Reduction in fluence or dose

1 MeVne Simulation values for upgrade will be given without correction factors. However a **safety factor of at least 2 is strongly recommended**!

Example
Slide from 2015/2017
"Upgrade" RUN3&4


1 MeV neutron fluence equivalent ECAL Top Down view at y=[0, 2.5] cm

The expected maximum right at the edge of the plug at z = [1270, 1275] cm lies around **1.1E+15 cm^{-2}**.


1MeV equivalent neutron fluence profile along x at front, center and back of module for 50 fb^{-1} NO CORRECTION

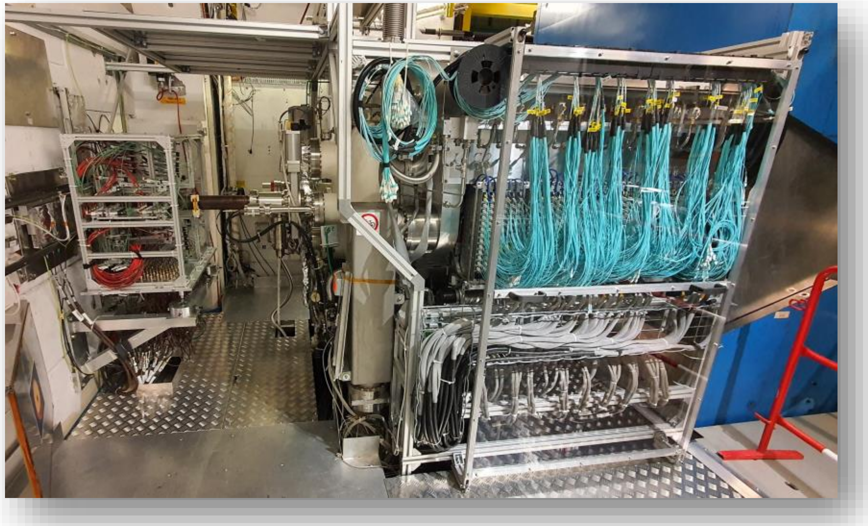
NO SAFETY FACTOR

Example
Slide from 2015/2017
"Upgrade" RUN3&4

Prompt Dose and Fluence – Differences (2015 to Today)

- **More recent FLUKA simulation code has increased cross sections** for certain interactions with consequences for **forward directed radiation.**
  (Increase of up to 30% of dose values in the central area)

- **Slight variation of final neutron shielding geometry compared to geometry used**
  (30 vs 20 cm in inner region as shown)
  (Increase and peak shift are minimal)

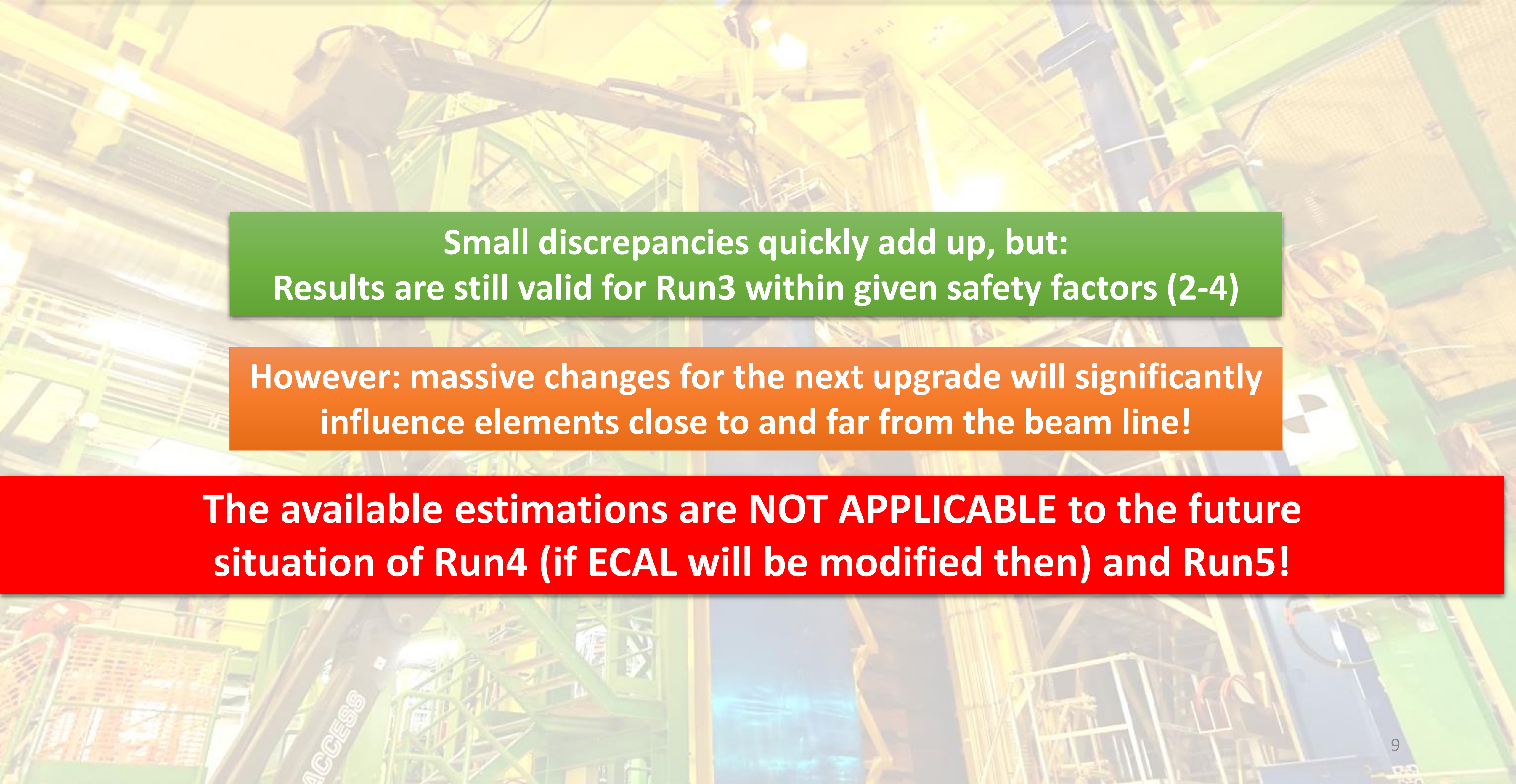


- **New Detectors not yet implemented**
  (Upstream detectors, VELO, UT, SciFi)

- **New beam plugs** (HCAL, Muon) **not yet implemented**

- Many **support structures** and detector details **missing**

Prompt Dose and Fluence – Upgrade II



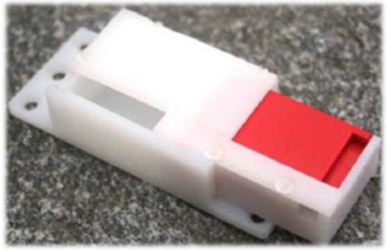
Small discrepancies quickly add up, but:
Results are still valid for Run3 within given safety factors (2-4)

However: massive changes for the next upgrade will significantly influence elements close to and far from the beam line!

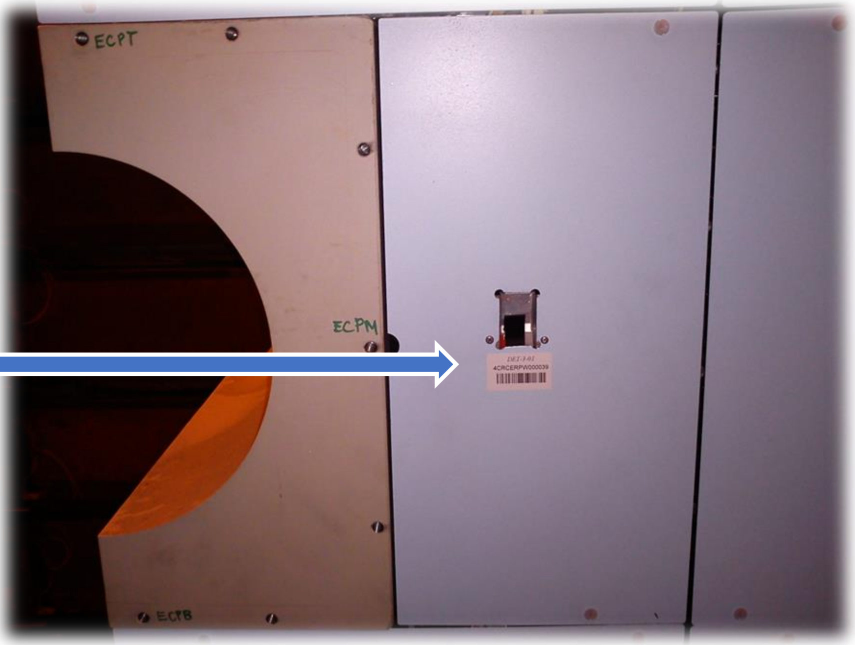
The available estimations are NOT APPLICABLE to the future situation of Run4 (if ECAL will be modified then) and Run5!

Prompt Dose and Fluence – Passive Dosimeters

Example Comparison ECAL front inner area



Measurement from YETS 2017:
(symmetrical position on Cside is pictured)



3.2 kGy for 2.269 fb^{-1} (delivered)
(scales to 9.3 kGy for Run2 total (6.607 fb^{-1}))

Same position, both scaled to 50 fb^{-1}

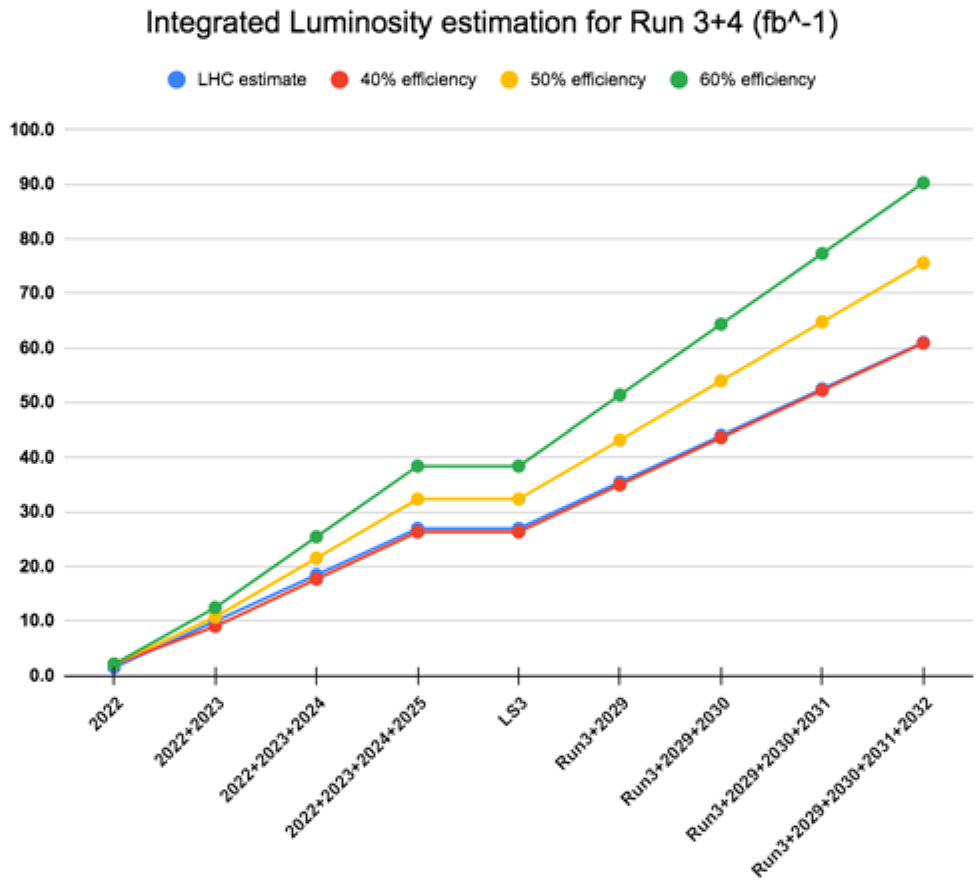
2017 FLUKA Simulation:	Alanine measurement:
45 kGy	70 kGy

Safety factor still necessary!

(LS2 measurements are not yet analysed and may need stronger corrections due to equipment age.)

Prompt Dose and Fluence – Safety Factor Addendum

50 fb^{-1} integrated luminosity always cited as Upgrade target
(based on expected recorded luminosity)



Run2	
Expected pp integrated luminosity:	5 fb^{-1}
Actually Recorded:	5.9 fb^{-1}
Actually Delivered:	6.6 fb^{-1}

Correction for delivered luminosity (50+X fb^{-1}) depending on:

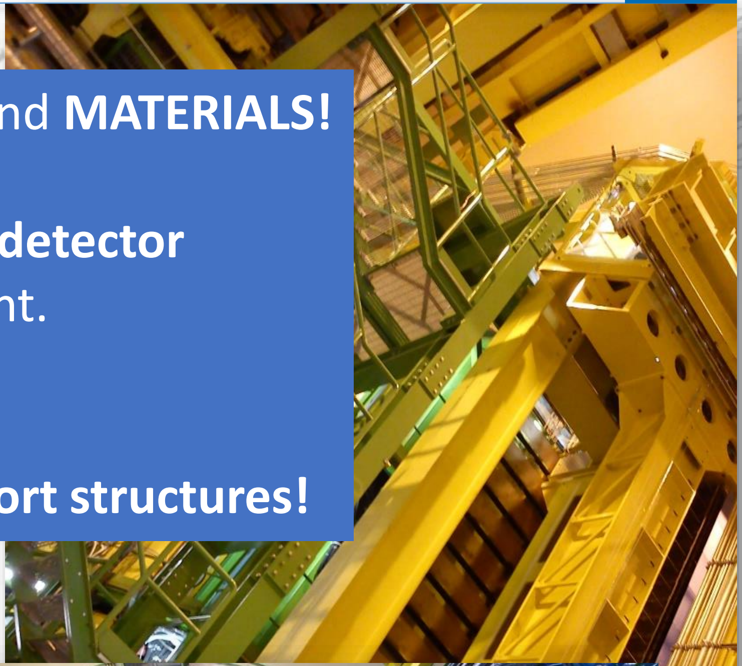
- **LHCb efficiency**
- **LHC performance**

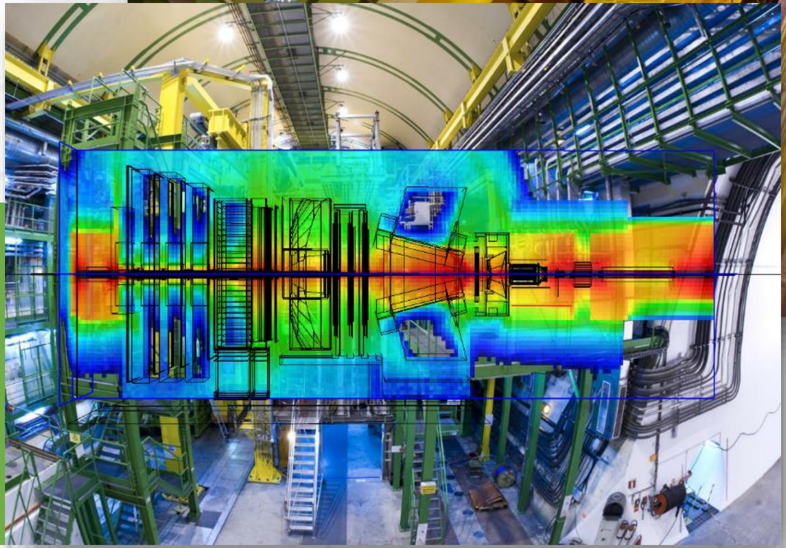
Materials Matter

Evolution of the radiation environment depends strongly on geometry and **MATERIALS!**

Calorimeters contribute a **very large part of the total mass of the detector**
and have a significant influence on the radiation environment.
(e.g. neutron showers between and from calorimeters)

NB: material choices not only important for detectors, but also for **support structures!**





In order to asses the new situation once the choices are made, new FLUKA calculations will be necessary.

These MUST be redone with a realistic material estimate that incorporates new densities and geometries.

Activation – Maintenance and Waste Scenarios

Activation-related scenarios are primarily influenced by materials in the region of interest.

- **Short term maintenance** scenarios:
  Short lived isotopes determine radiation levels and therefore **access (time) restrictions** for the first couple of weeks/months.

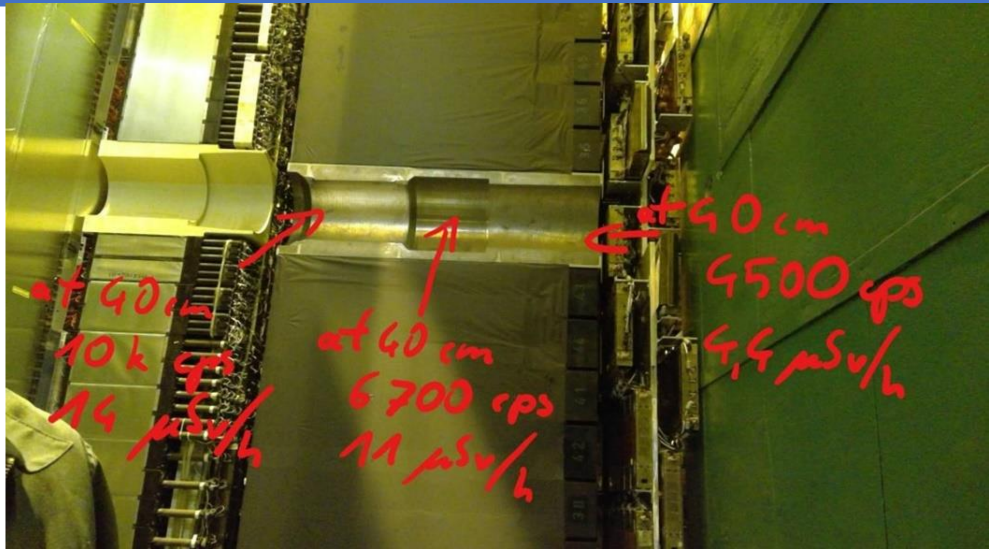
- **Long term maintenance and waste** scenarios for Upgrade II detector:
  Long lived isotopes add up for maintenance access (YETS) and have a large impact on dismantling.

Modifications of ECAL or HCAL central areas will influence opening scenarios with implications on RICH2 and MUON towers. Higher luminosity already creates difficulties with present lead and iron. E.g. tungsten would amplify those difficulties.

Activation – Maintenance and Waste Scenarios

Example: LS2 survey

Roughly 1 month after beam stop in LS2 with ECAL and HCAL open



Assumption: Tungsten instead of Lead in ECAL after 1 month cooling

- **Dose rates at 1m** distance would increase by **factor of 3-4**.
- **Contact measurements** would be higher by **orders of magnitude** compared to lead.
- Dose rate **at 40 cm**, which defines **ALARA level**, would be somewhere in between.
- **Luminosity increase** (up to **factor of 7** for U2) has to be taken into account **on top!**

For shorter cooling times, Tungsten is even worse!

Short ACTIWIZ studies sent
to Andreas et al. (email)

Activation – Maintenance and Waste Scenarios

High dose rates (e.g. above 50 uSv/h for limited stay areas) bring about:

- **Stricter access procedures** (incl. required training)
- **Longer preparation** time (Work and Dose Planning, more signatures)
- Potentially **higher ALARA** Levels for activities causing all of the above to a greater extent

- **Changing PM tubes in inner areas might become a challenge even during YETS.**
- **Work on RICH2 towers when CALOs are open might also become more restrictive.**

Studies for different materials can be done for various scenarios using ACTIWIZ, based on particle fluences calculated by FLUKA.

ACTIWIZ provides recommendations on material preferences and some relative, but no absolute dose rate values in vicinity (too many components and no complex geometrical input)

Material changes-> fluence calculations have to be redone with FLUKA!

Activation – Decommissioning, Storage and Waste

CERN requests forecast of waste from design of project

(should come with TDR, done with final design)

In case of installation of new ECAL in **LS3**, we need to tell them our requirements **NOW**!

	Traceability			Component origin			Component type				Single component dimensions					Total quantities			Component risks						
ID	Owner	Contact person	Date of input	Facility	Subarea or room	Position or process	Component	Description	Waste family	Material type	Mass/ component (kg)	Volume/ component (m^3)	Length (m)	Width (m)	Height (m)	Nb. of components	Total mass (kg)	Total volume (m^3)	Flammable	Contaminated	Highly radio	Toxic	Material Safety Data Sheet	Photos, technical documentation	
	DPT-GP-SECT*	First name Name	dd.mm.yyyy	Select from list			Select from list		Select from list		[kg]	[m3]	[m]	[m]	[m]				x	x	x	x	Link to MSDS	Link to photos or EDMS document	
1	PH-LBD	G. Corti K. Rinnert	30/11/2015	LHCb	VELO	Tank	Detector	Vertex detector - VELO halves	Electronic/Electrical	C, Fe, Ni, Cu, Si, O + traces	150.00	0.19	1.20	0.40	0.40	2	300.00	0.4							
						Tank	Other	2 open boxes with 0,3 to few mm thick RF foil	Metallic	Aluminium	4.073	0.30	1.20	0.50	0.50	2	8.15	0.6							Send to wa upon remo
						Wakefield suppressor		0.075 mm thick CuBe foils	Metallic	CuBe		0.000					0	0							Send to wa upon remo
						Outside Tank	Electronic and Electrical Equipment (WEEE)	Vertex detector - Repeater Boards	Electronic/Electrical	Al, G10 (glass fiber, epoxy), Cu, Si, Solder							20.00	1.2							Keep in sto then dispo
						Outside Tank	Electronic and Electrical Equipment (WEEE)	Vertex detector - Repeater Boards	Electronic/Electrical	Al, G10 (glass fiber, epoxy), Cu, Si, Solder							0.50	0.04							Removed d Run2 ?
						Alcove	Cable		Cables	Copper, Plastic, Steel		0.000				352	5000	3.50							Gross over precise to b
						Alcove	Cooling circuit	Cooling pipes	Other	Steel and insulation		0.000					150	0.227							Cylinders 2 radius
						In gas enclosure	Support	Aerogel support boxes	Other	Carbon, araldite, Al	0.5	0.017				2	1.00	0.034							Kept until 2 expected to given the m
						In gas enclosure	Support	Aerogel support boxes (new design)	Other	Carbon, araldite, Al	0.5	0.017				2	1.00	0.034							Kept until LS expected to given the m
						In gas enclosure	Support	Glass panels	Inert	Glass D263	0.075	0.0001	0.36	0.40	0.0005	4	0.30	0.0003							Kept until 2 expected to given the m
						In gas enclosure	Support	Glass panels (new design)	Inert	Glass D263	0.075	0.0001	0.36	0.40	0.0005	4	0.30	0.0004							Kept until LS expected to given the m
							Detector	Aerogel tiles	Other	Silica SiO2	0.28	0.0020	0.20	0.20	0.05	3	0.84	0.01							To be sent to waste if co radioactive
							Detector	Aerogel tiles	Other	Silica SiO2	0.28	0.0020	0.20	0.20	0.05	16	4.48	0.03							Only the clo pipe are exp radioactive material
							Support	Magnetic shielding shelves	Metallic	AMRCO iron	475	0.079	1.85	0.43	0.10	2	950.00	0.16						CDD drawing LHBRUM__0007	
						Gas enclosure	Support	Gas enclosure	Metallic	Aluminium 6061-T651	600	3.500				1	600	3.5						Photo	The volume in reality it is mocoque m mm thick so crashed it is volume
						Gas enclosure	Support	Exit window	Other	Carbon, epoxy, foam, aluminium	20	0.039	1.50	0.017	1.50	1	20	0.04							
						Gas enclosure	Detector	Flat mirrors planes	Other	Borosilicate glass, coated with Al+SiO2+HfO2	70	0.007	1.392	0.007	0.760	2	140	0.014						Photo	
						Shielding doors		steel magnetic shielding doors	Metallic			0.000				4	0	0							To be reuse in RP works out)
19	PH-LBD	G. Corti A. Papanestis	12/08/2018	LHCb	RICH2	HPDs	Detector	HPD support frame	Metallic	Aluminum	1.94	0.720	1.00	0.60	1.20	2	3.89	1.44							likely to be Christoph F dimensions
20	PH-LBD	G. Corti A. Papanestis	12/08/2018	LHCb	RICH2	HPDs	Detector	Profiles	Metallic	Aluminum	0.68	0.250	1.00	0.50	0.50	1	0.68	0.25							

We need to estimate space requirements for

- BUFFER area handling&checks of radioactive material
- Intermittent storage (modules, supports…)

- incoming material storage (non-designated)
- Handling and tool space during and after installation

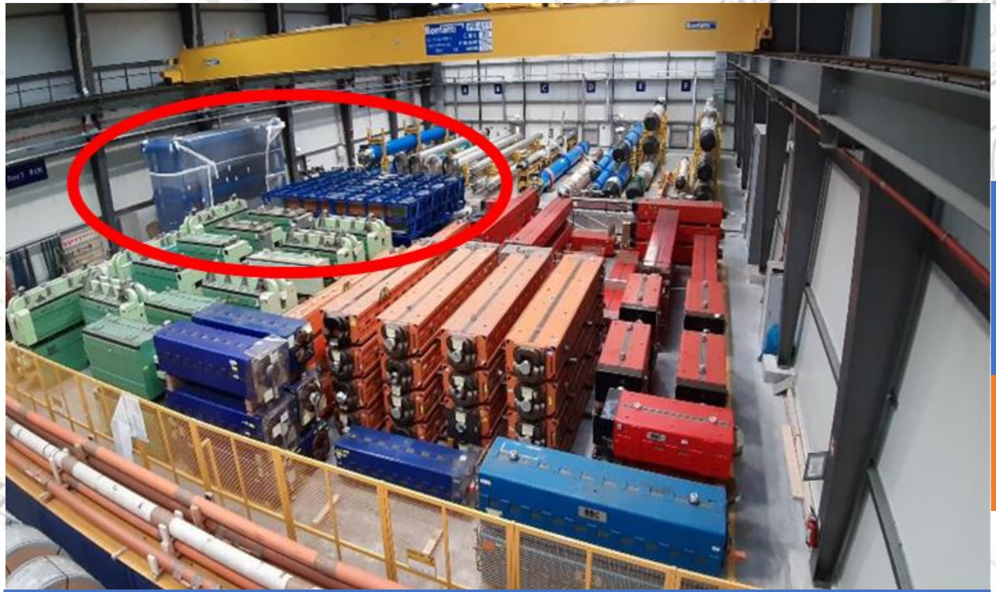
In addition, ECAL modules might need **special environment** (humidity, temperature) to keep them in **working condition**!

Inventory was equally essential for planning of STORAGE REQUIREMENTS for LS2

Activation – Decommissioning, Storage and Waste

We need a plan of **what to keep, what to throw, and when**

It is already difficult to find space at P8
(RP tent was setup as a temporary solution for LS2)



OT/SPD/PS in FLEX building in Prevessin

For material with high dose rate (>50 uSv/h) storage at P8 might become very difficult. (large **shielded** areas will be required)

Transport to other CERN areas require lots of administration and can involve delays!

Activation – Storage and Waste

Even if things are declared waste immediately, time from declaration to disposal can be **weeks to months!** (depends on signature availability as well as CERN transport and (RP) waste group capacities)

CERN already asked for the radioactive waste estimate of LHCb for LS3 1 year ago.
We should let them know ASAP!

Please start talking to us about it, we are late!
(normally we would start 5 years in advance)

Conclusions

- **Don’t rely on RUN2 calculations for dose and fluence estimates for Run4&5**
  (in particular for modules and PMTs)

- **Don’t rely (solely) on Run2 Surveys for estimating access scenarios for Run4&5**

- **We need information from you on hardware and storage**
  (detector module, support and electronics modifications for LS3 and also LS4)

- **FLUKA and ACTIWIZ simulations need to be done based on that information**
  (material choices need to be made or at least limited beforehand)

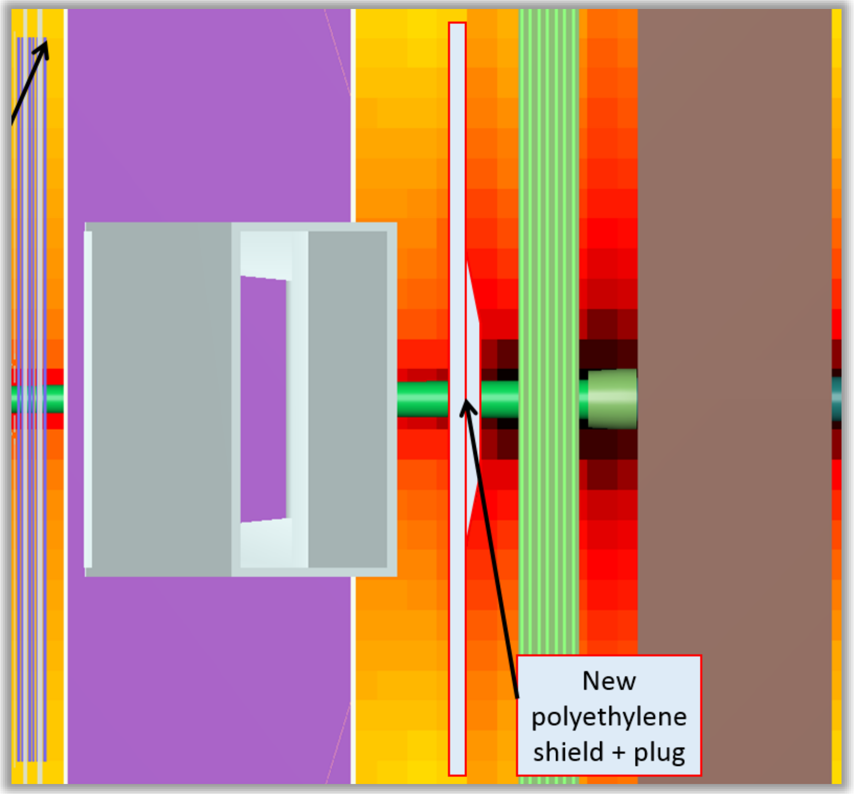
We are currently **lacking time and manpower** to do these, as the system (LHCb farm) and software used for the old calculations went out of date or even commission during LS2.

We would appreciate some help to get simulations on track.

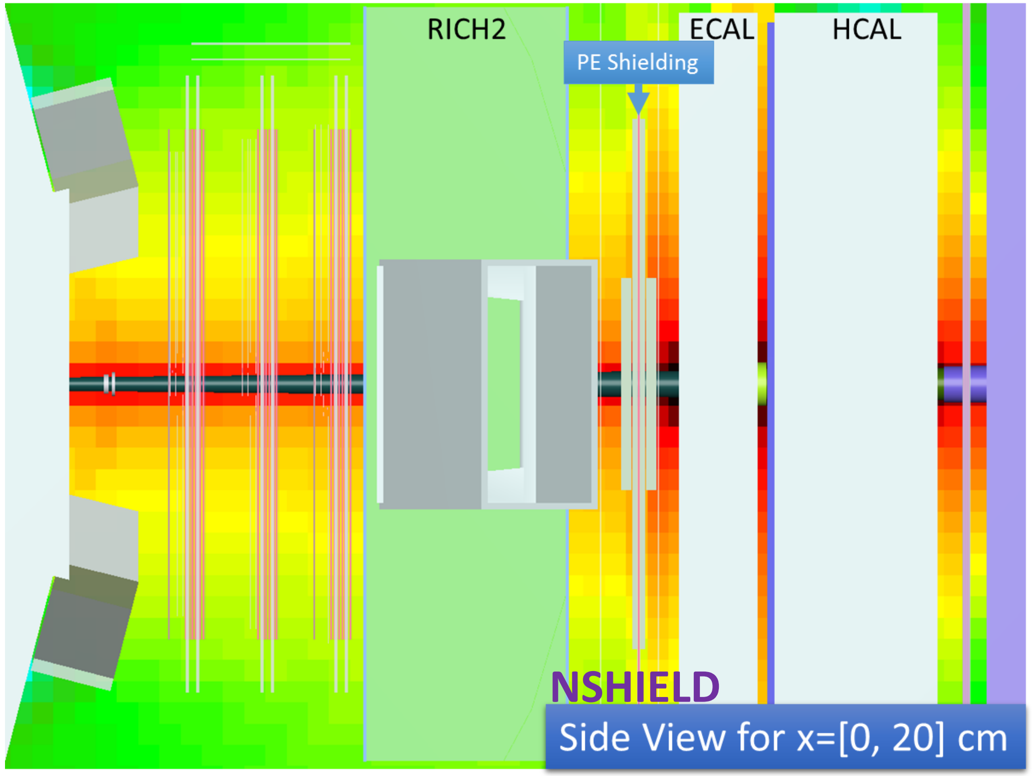
Backup

Prompt Dose and Fluence – Differences (2015 to Today)

2015 expected option:
20 cm thick shielding in front of ECAL.
"Position along z will be closer to ECAL in final configuration, but its influence on the radiation field will stay almost the same."



1MeVne fluence results from more recent (2017) FLUKA simulations, where PS/SPD and M1 are replaced by a polyethylene neutron shielding (without Alu coating) with 30 cm thickness in the inner part at the position of M1.



Side View for x=[0, 20] cm

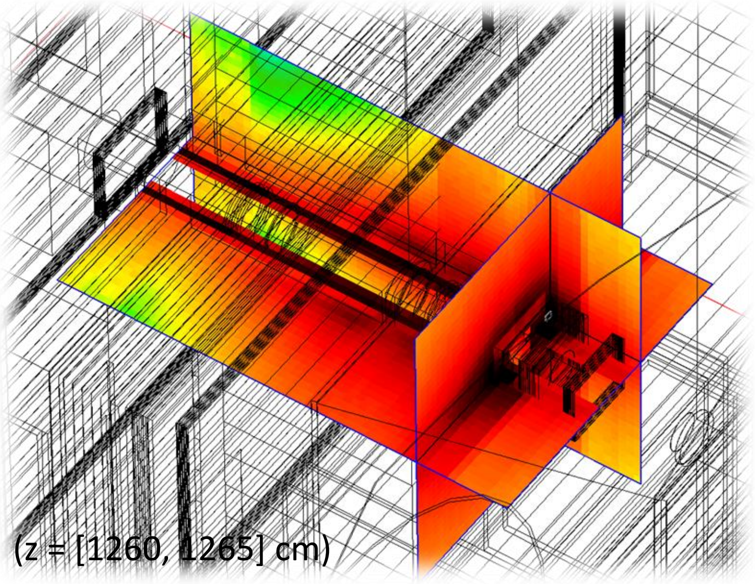
Dose values for Run1 (3.47 fb-1)

Highest alanine measurements on **ECAL front**:

3600 Gy (**in total for Run1**)

Corresponding **simulation estimate** on **ECAL front (same spot)**:

2814 Gy (**in total for Run1, no correction**)



(z = [1260, 1265] cm)

Simulation estimates inside ECAL (max.) for Run1:

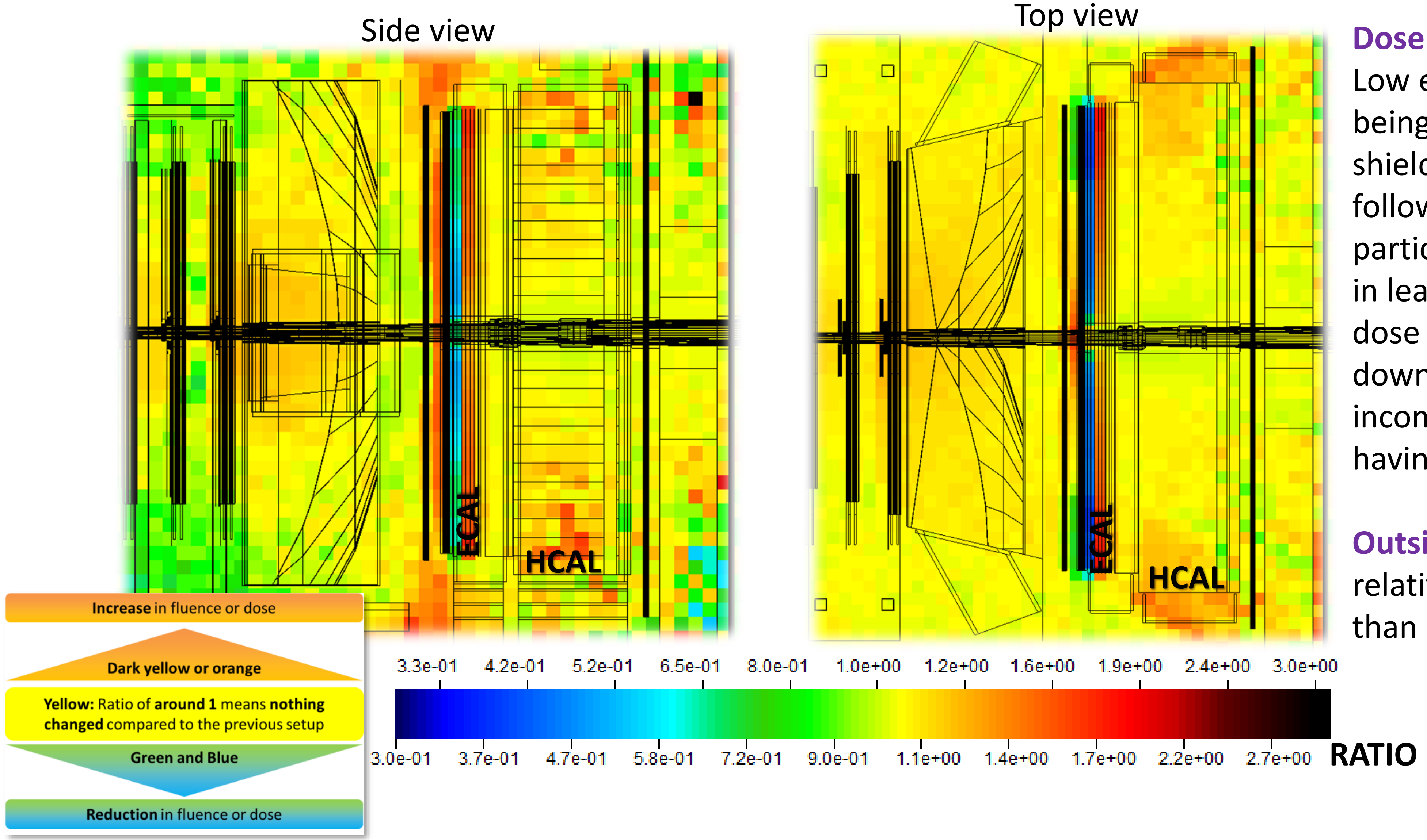
3700 Gy for 1.26 fb-1 at 7 TeV c.m.
6800 Gy for 2.21 fb-1 at 8 TeV c.m.

10500 Gy in total for Run 1

21 kGy when applying correction factor of 2

Influence of neutron shielding

Dose Ratio Full shielding VS Current LHCb geometry
(20x20x20 cm^3 binning)



Increase in fluence or dose

Dark yellow or orange

Yellow: Ratio of **around 1** means **nothing changed** compared to the previous setup

Green and Blue

Reduction in fluence or dose

Dose deposition is shifted: Low energy particles are being absorbed by the new shielding. Lower dose (blue) follows where currently particle showers are started in lead plate. The maximum dose in ECAL is shifted downstream along z due to incoming charged particles having higher energy.

Outside modules will see relatively more dose, but less than central ones in total.

Prompt Dose and Fluence – Differences (2015 to Today)

Slides from 2015/2017

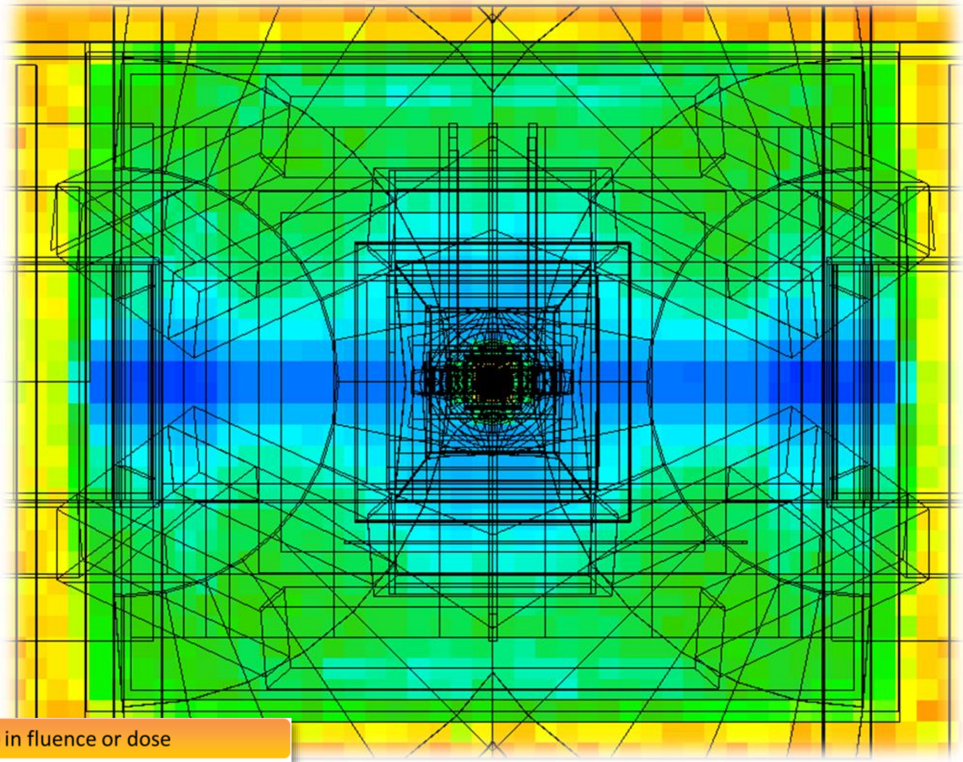
Influence of neutron shielding

Dose Ratio Full shielding VS Current LHCb geometry

(20x20x20 cm^3 binning)

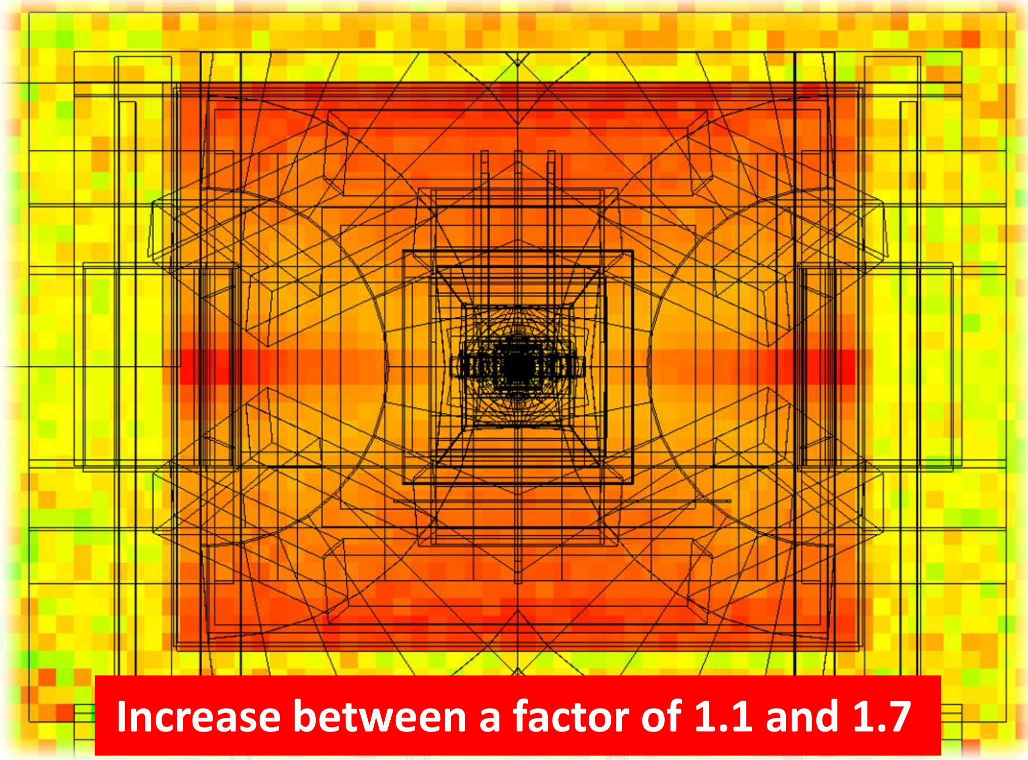
Z=1240

(no more showers started in PS lead plate)

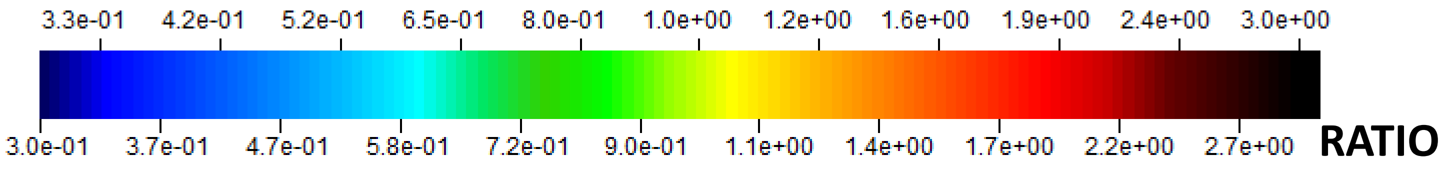


Z=1260

(Inside ECAL)



Increase between a factor of 1.1 and 1.7



Increase in fluence or dose

Dark yellow or orange

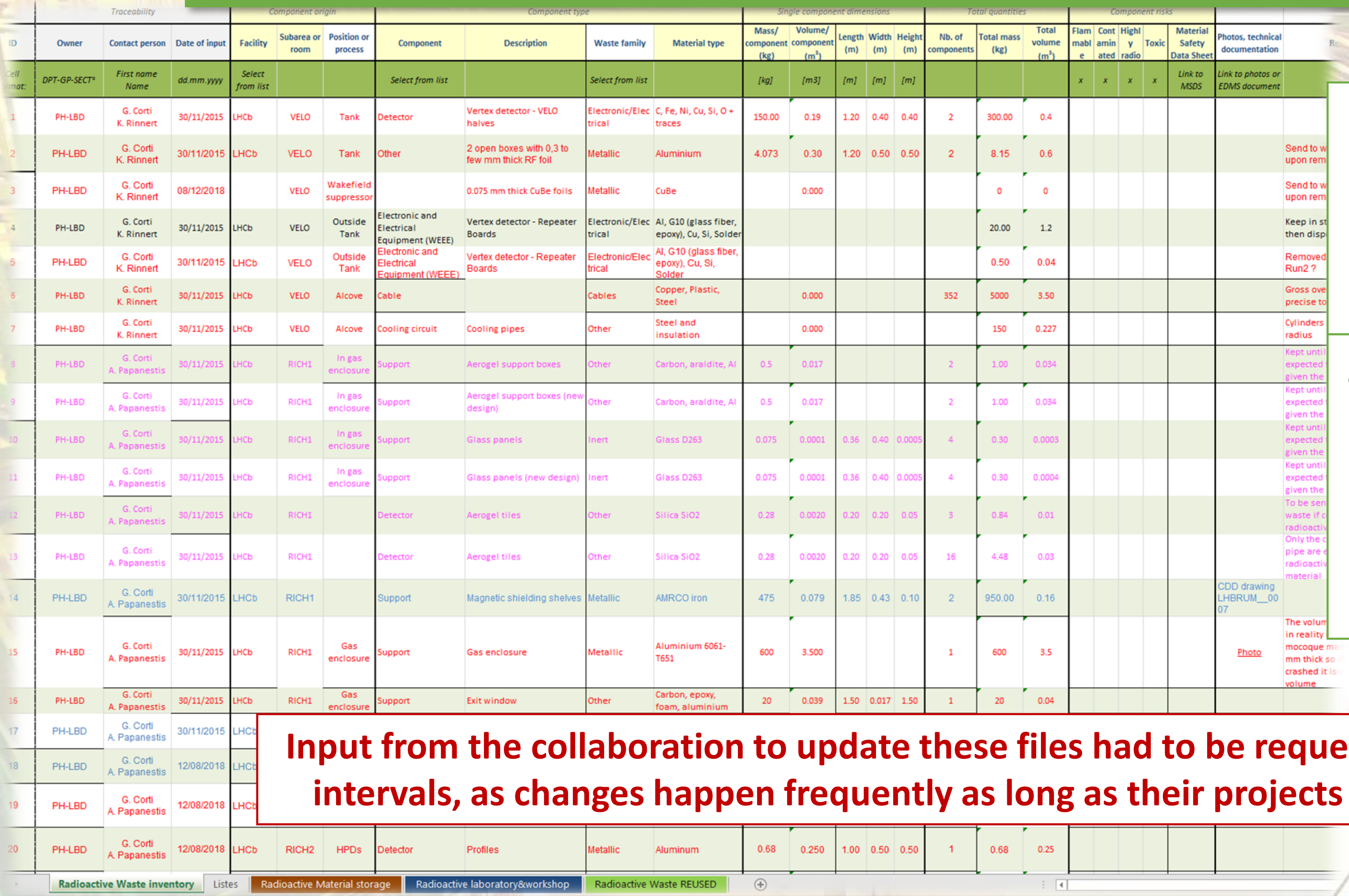
Yellow: Ratio of **around 1** means **nothing changed** compared to the previous setup

Green and Blue

Reduction in fluence or dose

Preparation - LHCb dismantling in LS2

Based on Zoning considerations:
Inventory of expected radioactive and conventional Waste/Storage



	Traceability			Component origin			Component type				Single component dimensions					Total quantities			Component risks						
ID	Owner	Contact person	Date of input	Facility	Subarea or room	Position or process	Component	Description	Waste family	Material type	Mass/ component (kg)	Volume/ component (m^3)	Length (m)	Width (m)	Height (m)	Nb. of components	Total mass (kg)	Total volume (m^3)	Flammable	Contaminated	Highly radio	Toxic	Material Safety Data Sheet	Photos, technical documentation	Re
Cell rmat:	DPT-GP-SECT°	First name Name	dd.mm.yyyy	Select from list			Select from list		Select from list		[kg]	[m3]	[m]	[m]	[m]				x	x	x	x	Link to MSDS	Link to photos or EDMS document	
1	PH-LBD	G. Corti K. Rinnert	30/11/2015	LHCb	VELO	Tank	Detector	Vertex detector - VELO halves	Electronic/Electrical	C, Fe, Ni, Cu, Si, O + traces	150.00	0.19	1.20	0.40	0.40	2	300.00	0.4							
2	PH-LBD	G. Corti K. Rinnert	30/11/2015	LHCb	VELO	Tank	Other	2 open boxes with 0,3 to few mm thick RF foil	Metallic	Aluminium	4.073	0.30	1.20	0.50	0.50	2	8.15	0.6							Send to w upon rem
3	PH-LBD	G. Corti K. Rinnert	08/12/2018		VELO	Wakefield suppressor		0.075 mm thick CuBe foils	Metallic	CuBe		0.000					0	0							Send to w upon rem
4	PH-LBD	G. Corti K. Rinnert	30/11/2015	LHCb	VELO	Outside Tank	Electronic and Electrical Equipment (WEEE)	Vertex detector - Repeater Boards	Electronic/Electrical	Al, G10 (glass fiber, epoxy), Cu, Si, Solder							20.00	1.2							Keep in st then disp
5	PH-LBD	G. Corti K. Rinnert	30/11/2015	LHCb	VELO	Outside Tank	Electronic and Electrical Equipment (WEEE)	Vertex detector - Repeater Boards	Electronic/Electrical	Al, G10 (glass fiber, epoxy), Cu, Si, Solder							0.50	0.04							Removed Run2 ?
6	PH-LBD	G. Corti K. Rinnert	30/11/2015	LHCb	VELO	Alcove	Cable		Cables	Copper, Plastic, Steel		0.000				352	5000	3.50							Gross ove precise to
7	PH-LBD	G. Corti K. Rinnert	30/11/2015	LHCb	VELO	Alcove	Cooling circuit	Cooling pipes	Other	Steel and insulation		0.000					150	0.227							Cylinders radius
8	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1	In gas enclosure	Support	Aerogel support boxes	Other	Carbon, araldite, Al	0.5	0.017				2	1.00	0.034							Kept until expected given the
9	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1	In gas enclosure	Support	Aerogel support boxes (new design)	Other	Carbon, araldite, Al	0.5	0.017				2	1.00	0.034							Kept until expected given the
10	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1	In gas enclosure	Support	Glass panels	Inert	Glass D263	0.075	0.0001	0.36	0.40	0.0005	4	0.30	0.0003							Kept until expected given the
11	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1	In gas enclosure	Support	Glass panels (new design)	Inert	Glass D263	0.075	0.0001	0.36	0.40	0.0005	4	0.30	0.0004							Kept until expected given the
12	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1		Detector	Aerogel tiles	Other	Silica SiO2	0.28	0.0020	0.20	0.20	0.05	3	0.84	0.01							To be sen waste if c radioactiv
13	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1		Detector	Aerogel tiles	Other	Silica SiO2	0.28	0.0020	0.20	0.20	0.05	16	4.48	0.03							Only the c pipe are e radioactiv material
14	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1		Support	Magnetic shielding shelves	Metallic	AMRCO iron	475	0.079	1.85	0.43	0.10	2	950.00	0.16						CDD drawing LHBRUM__0007	
15	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1	Gas enclosure	Support	Gas enclosure	Metallic	Aluminium 6061-T651	600	3.500				1	600	3.5						Photo	The volum in reality mocoque ma mm thick so crashed it is volume
16	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb	RICH1	Gas enclosure	Support	Exit window	Other	Carbon, epoxy, foam, aluminium	20	0.039	1.50	0.017	1.50	1	20	0.04							
17	PH-LBD	G. Corti A. Papanestis	30/11/2015	LHCb																					
18	PH-LBD	G. Corti A. Papanestis	12/08/2018	LHCb																					
19	PH-LBD	G. Corti A. Papanestis	12/08/2018	LHCb																					
20	PH-LBD	G. Corti A. Papanestis	12/08/2018	LHCb	RICH2	HPDs	Detector	Profiles	Metallic	Aluminum	0.68	0.250	1.00	0.50	0.50	1	0.68	0.25							

In 2012 the RP Waste group initiated requests for future radioactive waste deposits.
LHCb produced spreadsheet for expected inventories.

2-3 years before the start of LS2:
LHCb updated the **latest version of this spreadsheet** and added a more **in-detail descriptive document** about the planned modifications (explaining **WHAT**, **WHY** and **HOW**).

Input from the collaboration to update these files had to be requested in regular intervals, as changes happen frequently as long as their projects are ongoing.

Run2 Lumi pp delivered:
2.462 fb-1 (2018)
1.876 fb-1 (2017)
1.906 fb-1 (2016)
0.363 fb-1 (2015)

6.607 fb-1 (TOTAL RUN2) plus negligible ion run contribution
(5 fb-1 recorded originally planned for LHCb)