Radiation Protection and Safety Upgrade II

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30.3.2023*

*Evolution of what was presented a decade ago for Upgrade 1 by G.Corti

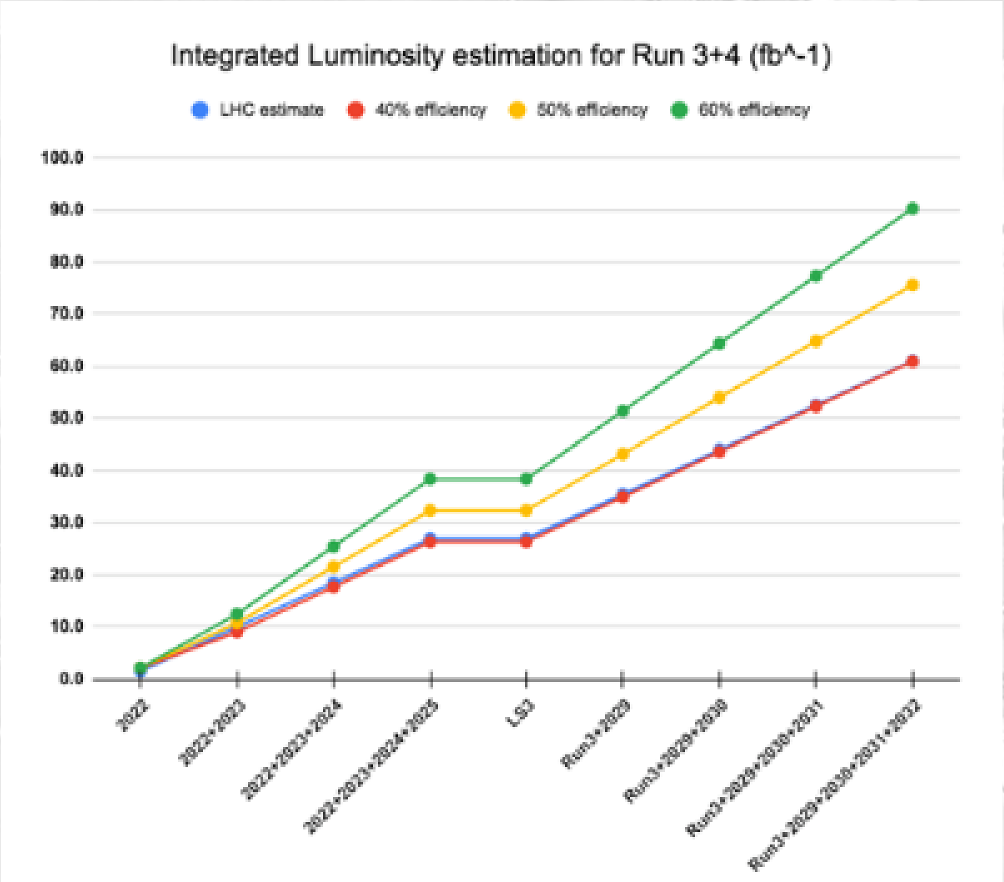
Radiation aspects for Future Upgrades

Increased luminosity -> Increased dose rates

Implications on:

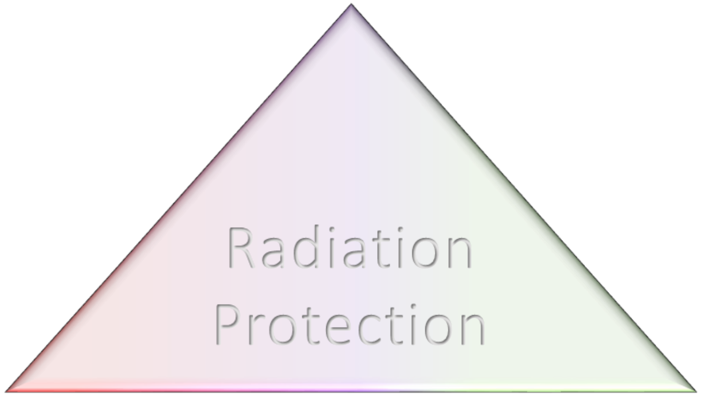
- **Prompt radiation environment**
- **Radiation Protection**
  - **Access procedures** (incl. required training)
  - **Preparation** time (Work and Dose Planning / DIMR)
  - **ALARA** Levels

Higher Dose -> Stronger implications



Radiation Protection at CERN

Justification



Limitation
(Legal Limits)

Optimization
(ALARA)

✓ Equité

For the same work(place), the reduction of the highest individual dose has priority.

✓ Equivalence

For equal activities, the effectiveness of RP measures set in motion is identical.

Personal and collective dose as well as **contamination of the environment** have to be kept

As Low As Reasonably Achievable

ALARA at CERN

Associated with conditions - 3 Levels

- ❑ ALARA Lv.1 (up to now for most activities)
- ❑ ALARA Lv.2 (>100 uSv individual, >500 uSv collective)
- ❑ ALARA Lv.3 (>1 mSv individual, >5 mSv collective)

ALARA Level Examples

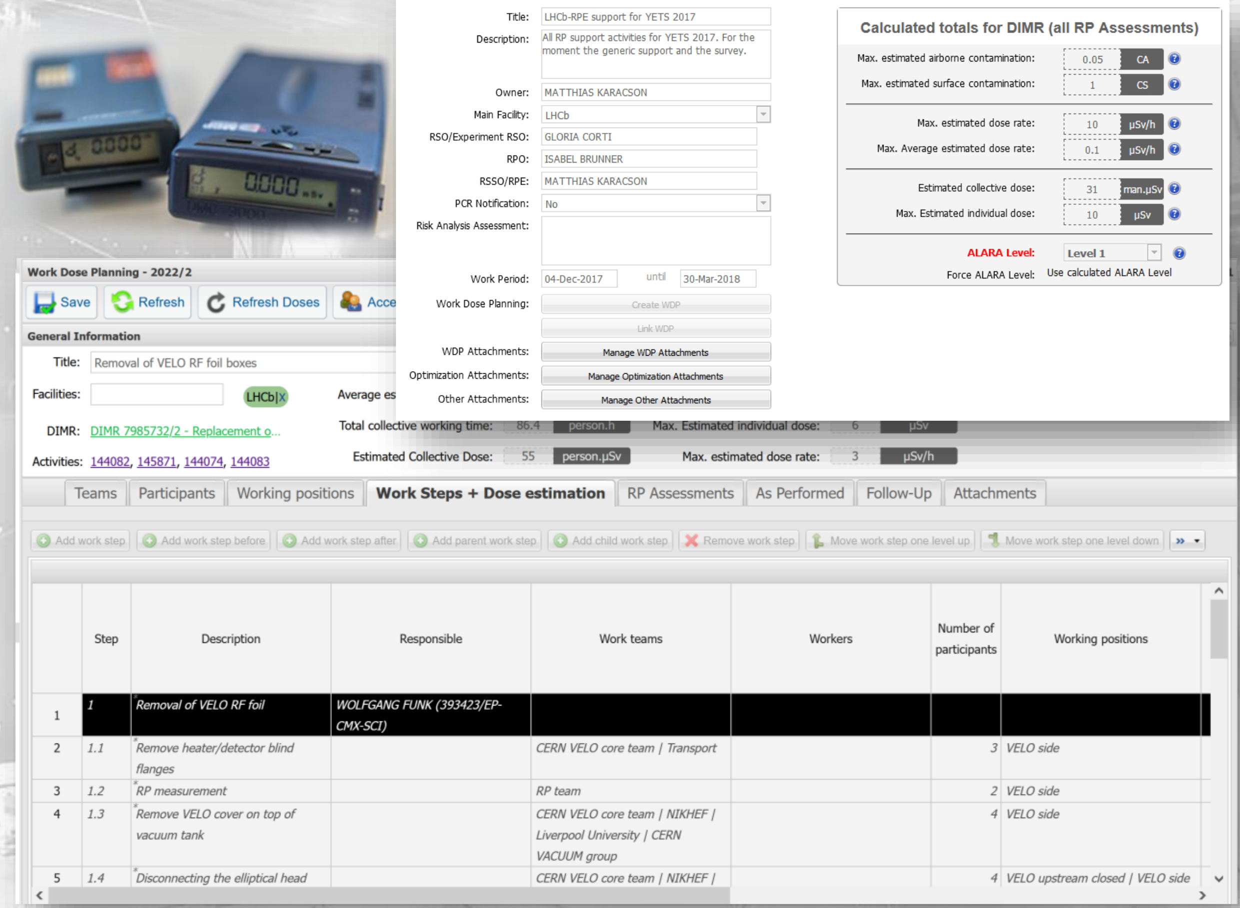
10 uSv/h for **2 days** (8h per day) (=160 uSv)
or
dose rate above **50 uSv/h**

ALARA Lv.2 (WDP required)

50 uSv/h for **3 days** (8h per day) (= 1.2 mSv)

ALARA Lv.3 (Committee required)
Several weeks to months of preparation!

Air/surface contamination can cause escalation!



ALARA Optimization – Safety Code F

2.3 Optimisation

2.3.1 The principle of optimisation of radiation protection is defined as a process to keep the magnitude of individual doses and the number of people exposed As Low As Reasonably Achievable (ALARA) below the appropriate dose limits, economic and social factors being taken into account.

2.3.2 ALARA must be applied by means of optimisation, which is the balancing of constraints on individual doses, risks, number of persons involved, cost of protection measures and consequences of potential failures.

2.3.3 A practice is considered as optimised when:

a) Different appropriate measures have been evaluated and judged against each other from the radiation protection viewpoint,

b) The decisional process leading to the chosen solution is documented,

c) The risk of failures has been taken into account and

d) The long-term consequences for activated material (re-use or final disposal) have been properly managed.

2.3.4 Optimisation can be considered as respected if the practice never gives rise to an annual dose above 100 μSv for persons exposed because of their own professional activity or 10 μSv for circumstances not linked with their own professional activity and for members of the general public.

Optimization is a legal requirement!
It starts with the design!

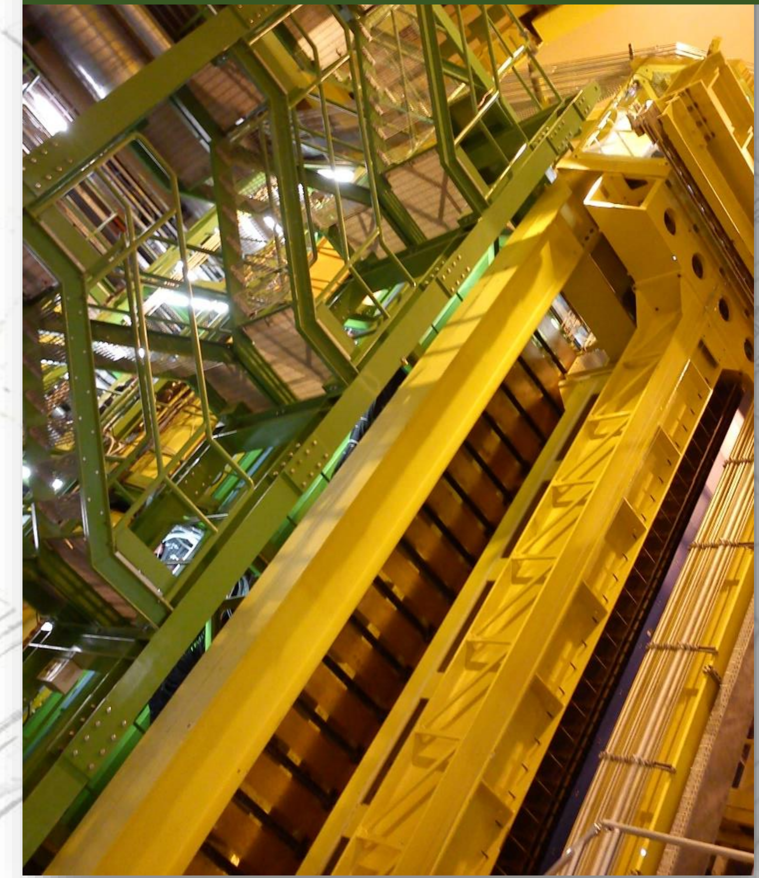
It also includes:

- Material in place
- Work coordination
- Work procedures
- Tools

Materials Matter

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

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



Considerate choices bring:

- ❑ **Safety Benefits**
  (lower committed dose rates)
- ❑ **Operational Benefits**
  (faster access, less restrictions)
- ❑ **End-Of-Life Benefits**
  (less and less costly radioactive waste)

Materials Matter

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

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

Often a choice between

Optimal (physics performance)
vs
Safest (for human intervention)

Once the choice is made, we can help with

- Preparation of interventions (ALARA)
- Rehearsing for time optimisation
- Looking for mobile shielding
- …

Subdetector groups can help by looking into

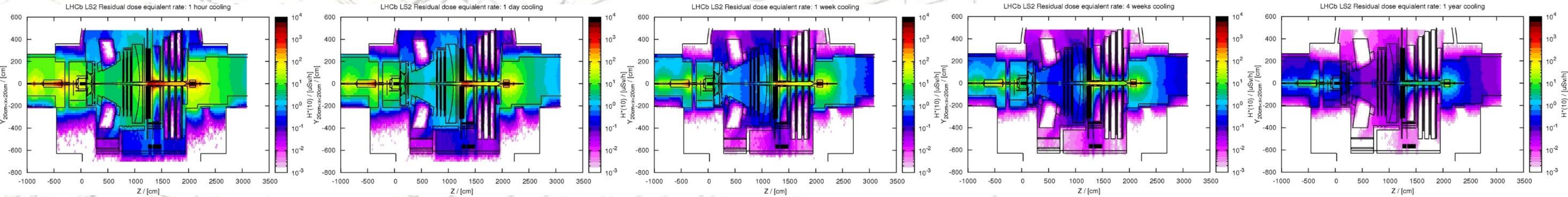
- Automation, remote maintenance
- Handling of fluids and potential contamination (+ easy sampling and retention)
- …

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 hours to weeks. **Determined by instantaneous luminosity**
  (increase by factor 5 (Run4 vs. Run2) to 25 (Run5 vs. Run2).

- **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.
  Determined by integrated luminosity (increase by more than an order of magnitude vs. Run2).



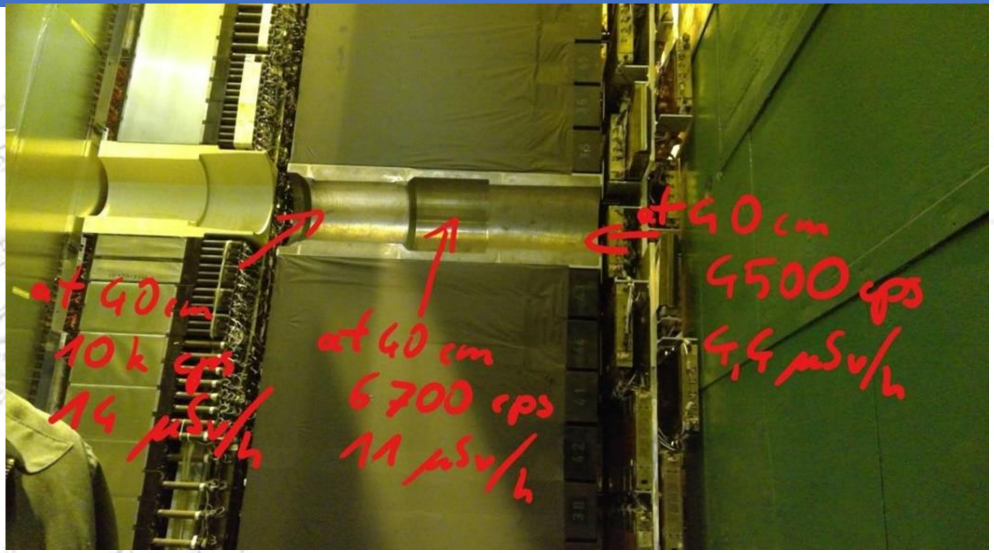
1h cooling 1d cooling 1w cooling 1m cooling 1y cooling

Residual dose rates (beam stop)

Activation Example – ECAL Center Implications

Example: LS2 survey

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

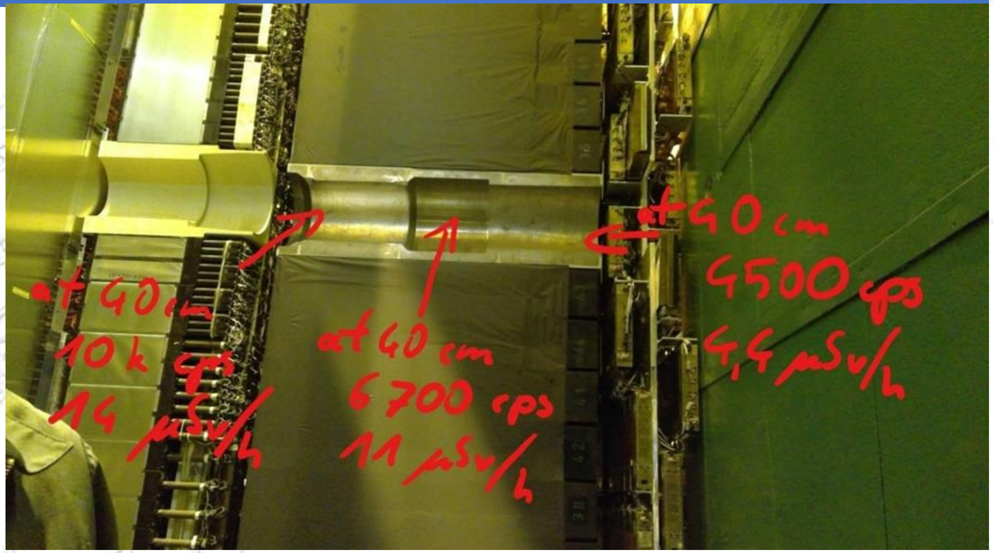


Already some difficulties in Run3.
Modifications of CALO central areas will influence opening scenarios with implications on RICH2 and MUON tower access.

Activation Example – ECAL Center Implications

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

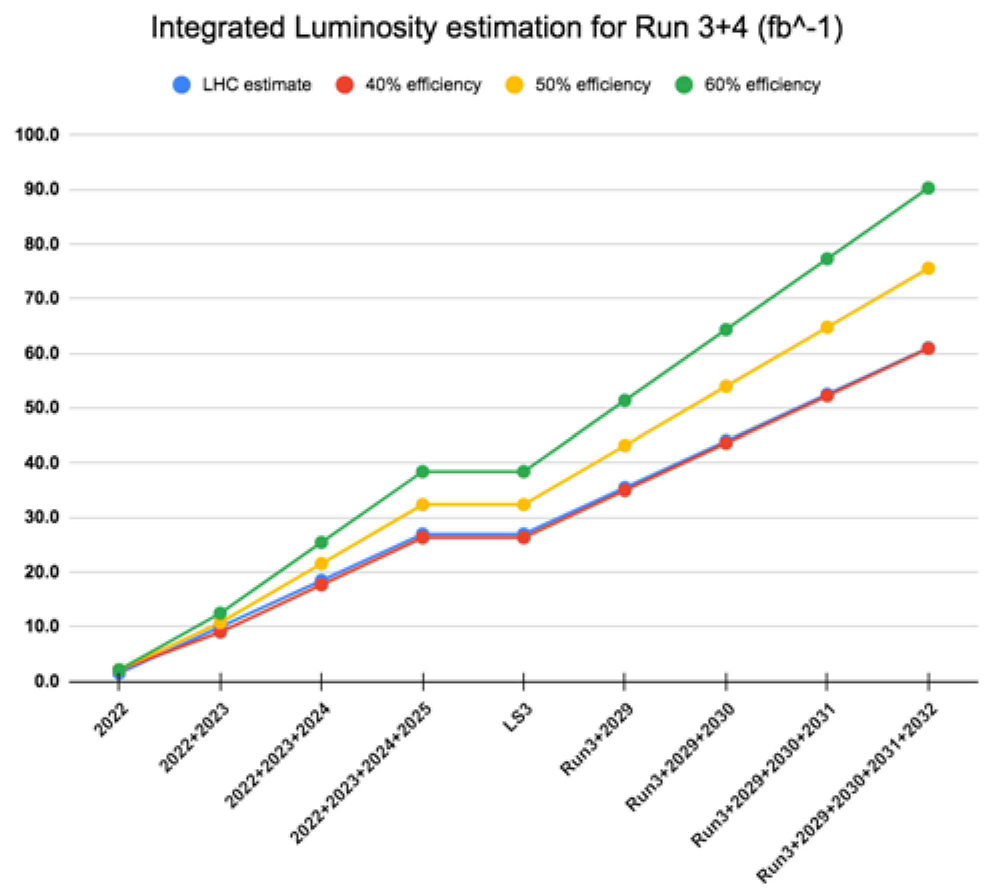
- **Dose rates at 1m** distance would increase by **factor of 3-4**.
- **Contact measurements** would be higher by **orders of magnitude** compared to lead.
- Dose rate **at 40 cm**, which defines **ALARA level**, would be somewhere in between.
- **Luminosity increase** (up to **factor of 7** for U2)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

For shorter cooling times, Tungsten is worse than lead!

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

Luminosity Increase - Addendum

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

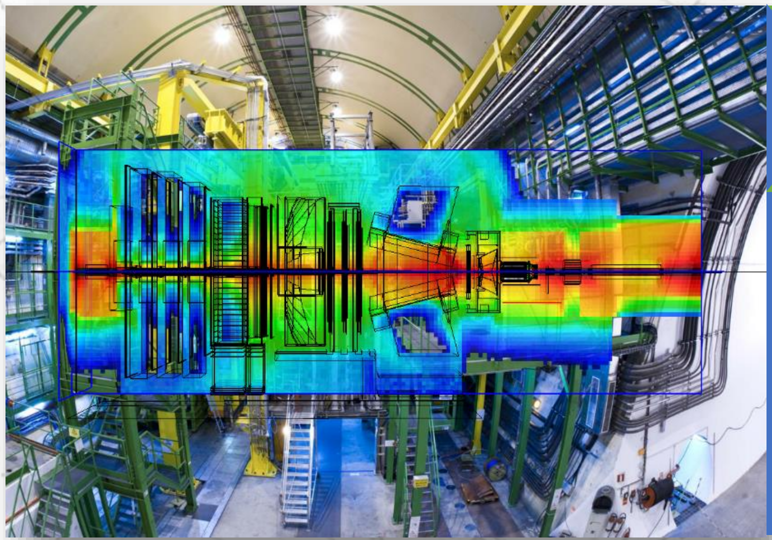


Run2	
Expected pp integrated luminosity:	5 fb^{-1}
Actually Recorded:	5.9 fb^{-1}
Actually Delivered:	6.6 fb^{-1}

Correction for delivered luminosity (350+X fb^{-1}) depending on:

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

Simulation Forecast – Upgrade II



Forecast is needed!
(Simulation and Measurements)

In order to asses the new situation once the choices are made, new FLUKA calculations (also for PROMPT) will be necessary.

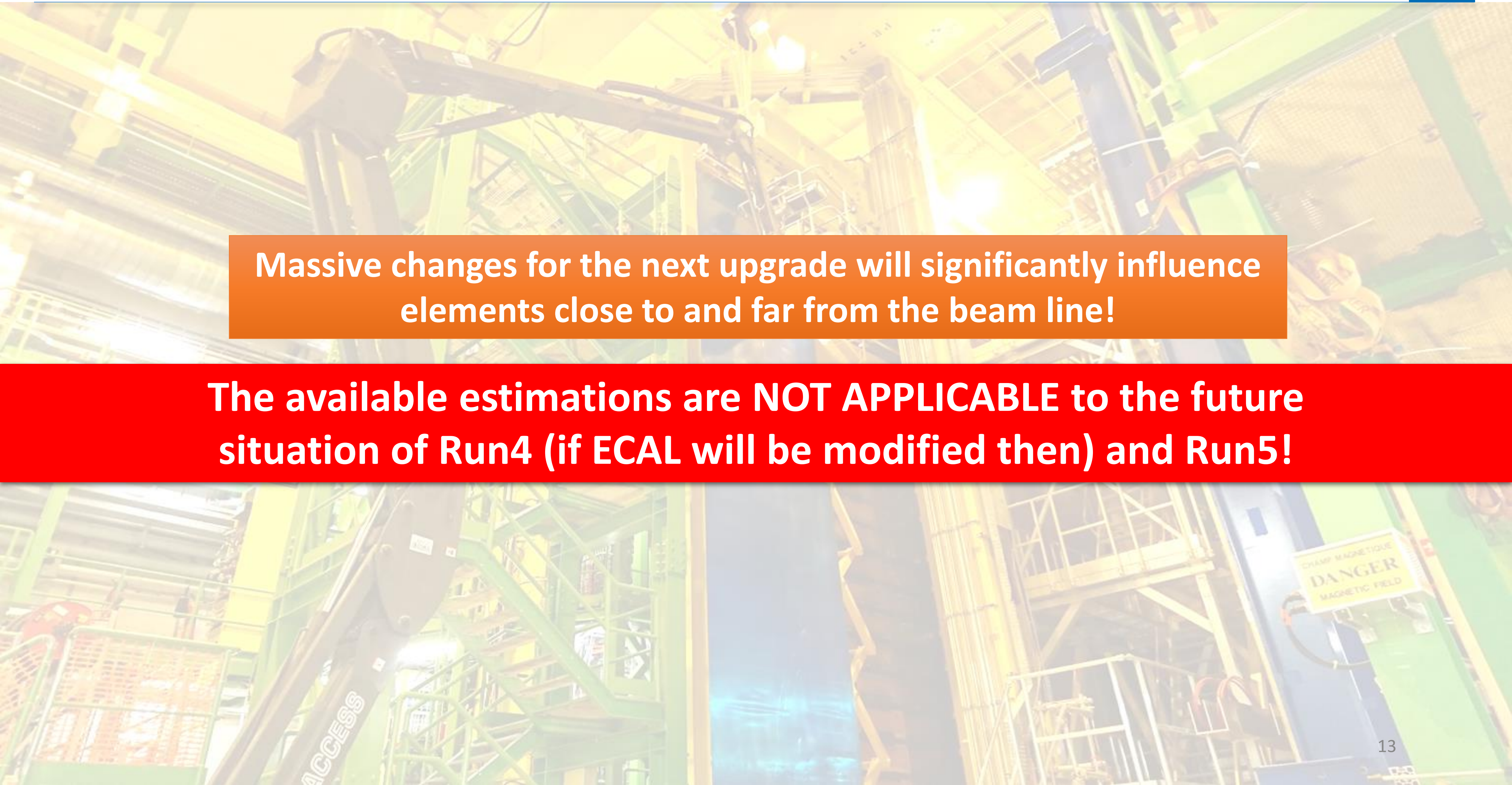
These must be redone with a realistic material estimate that incorporates new densities and geometries.

Activation 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!

Simulation Forecast – Upgrade II



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

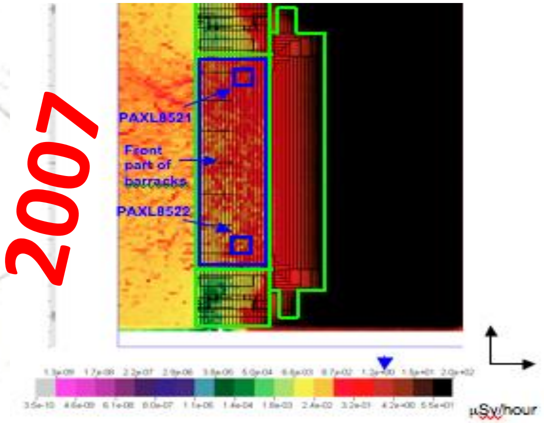
The available estimations are NOT APPLICABLE to the future situation of Run4 (if ECAL will be modified then) and Run5!

Simulation Forecast – Shielding of UX85A

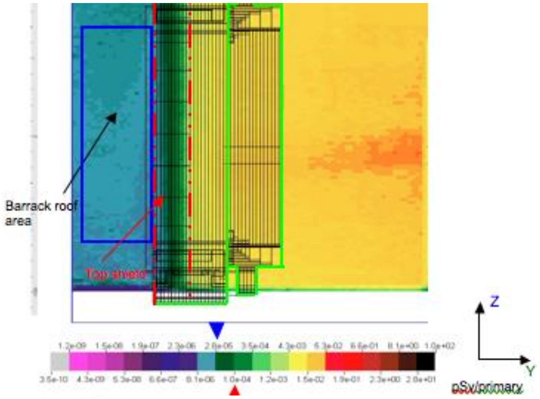
Shielding wall to comply with design limits of 20 mSv ambient dose equivalent in case of a full beam loss

Ambient-dose-in D2 [uSv/hour]

2007



Ambient-dose-equivalent on D3 [pSv/primary proton lost]



LHCb 'nominal' parameters used:

- Beam energy = 7 TeV
- luminosity L = 2 x 10^{32} cm^{-2} s^{-1},
- inelastic cross-section s = 80 mbarn
- collision rate of 1.6 x 10^{7} collisions/s

full beam loss of 4.7 x 10^{14} protons for 1 beam

For nominal Run1 LHCb operation average rate found to be 5.6 x 10^{-2} µSv/h ± 2% → Still supervised U2

For full beam loss average values in barracks ~4 mSv BUT part of D3 above.
→ May be an issue for HL-LHC if beam current increases

New openings in shielding wall require **re-evaluation**:

- New infrastructure pathways along sidewalls introduced in LS2
- New cable grooves below wall anticipated

CERN-SC-2007-035-RP-TN, EDMS no. 847155, C. Theis et al.

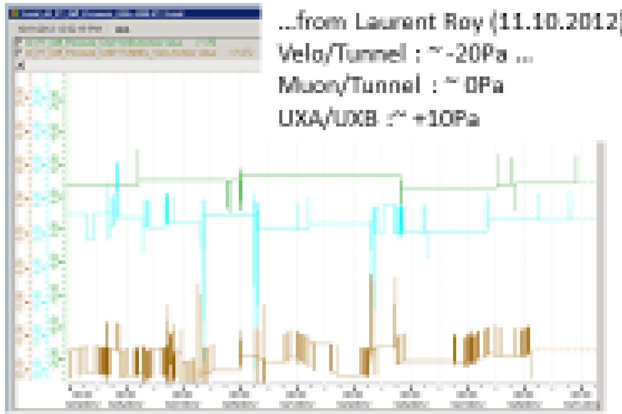
Simulation Forecast – Air Activation

Air activation

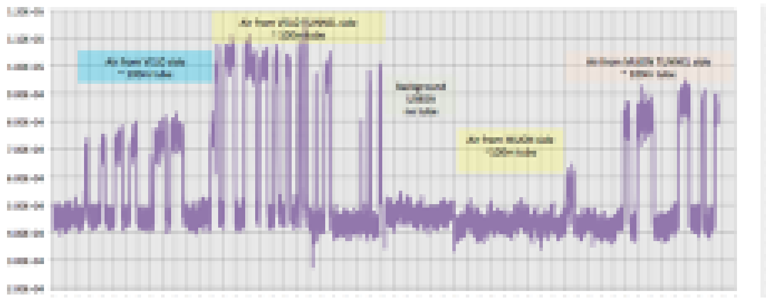
9

- Risk of exposure due to air activation investigated for all experiments by HSE-RP. Recommendation of 15'waiting before access.

CERN-SC-2008-067-RP-TN, EDMS no. 945045



...from Laurent Roy (11.10.2012):
Velo/Tunnel : ~-20Pa ...
Muon/Tunnel : ~ 0Pa
UXA/UXB :~ +10Pa



...from Isabel Brunner and Nadine Conan
Measurements made from 13 Oct to 7 Nov 2012 with special detector

- Re-evaluated end of 2012 for tunnel area adjacent to IR8 for two different air flow cases

For the current situation dose to personnel from air leaking into LHCb is negligible.
Re-assessment for LHCb upgrade is recommended

Hz. Vincke, HSE-RP, Private Comm.

2013

Re-assessment to be performed

Longer waiting times might be required in future

Activation – Handling of Radioactive Equipment

Radioactive material handling is subject to CERN RP rules!

- **Destructive work** (contamination risk)
- **Gas and Liquid** (inhalation / contamination risk)
- **Transport** (ADR regulations)
- **Shipping** (authorized recipients)

Classification of material may depend on **combination** of **measurements and calculations** (potentially simulations).

Not all relevant isotopes can be measured with available equipment (alpha, beta).

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LHCb-RP assisting with transport and shipping

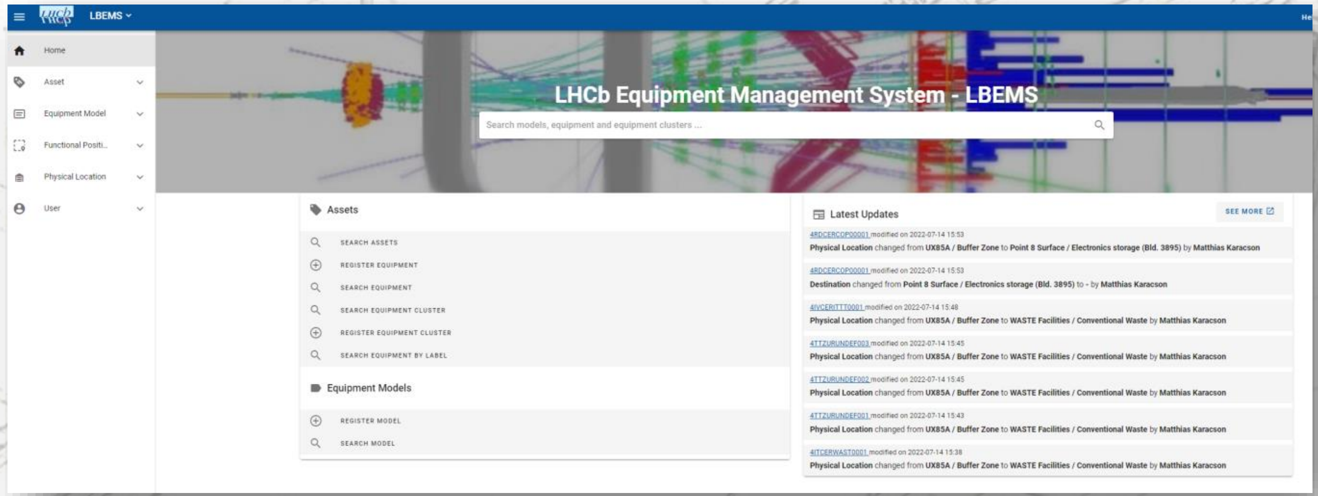
Dedicated RP workshops
available at P8 in UX85A (enough?)

LHCb-RP coordinates contaminating work and supervision in collaboration with HSE-RP

Activation – Handling of Radioactive Equipment

Tracing of (potentially) radioactive equipment is mandatory at CERN!
(almost 70k entries already only in LHCb database)

Registering during installation (optional early integration with subdetector production databases) can help to **minimize future workload**.



https://lbfence.cern.ch/lbems

- **New LHCb Equipment Management System (LBEMS)** introduced which is constantly improving!
- Features item histories and hierarchies, facilitating measurement and handling procedures.
- Connected to TREC for easier management of shipping and Measurements.
- People are gradually being introduced to it.

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 **ASAP**!

We need to estimate space requirements for

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

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

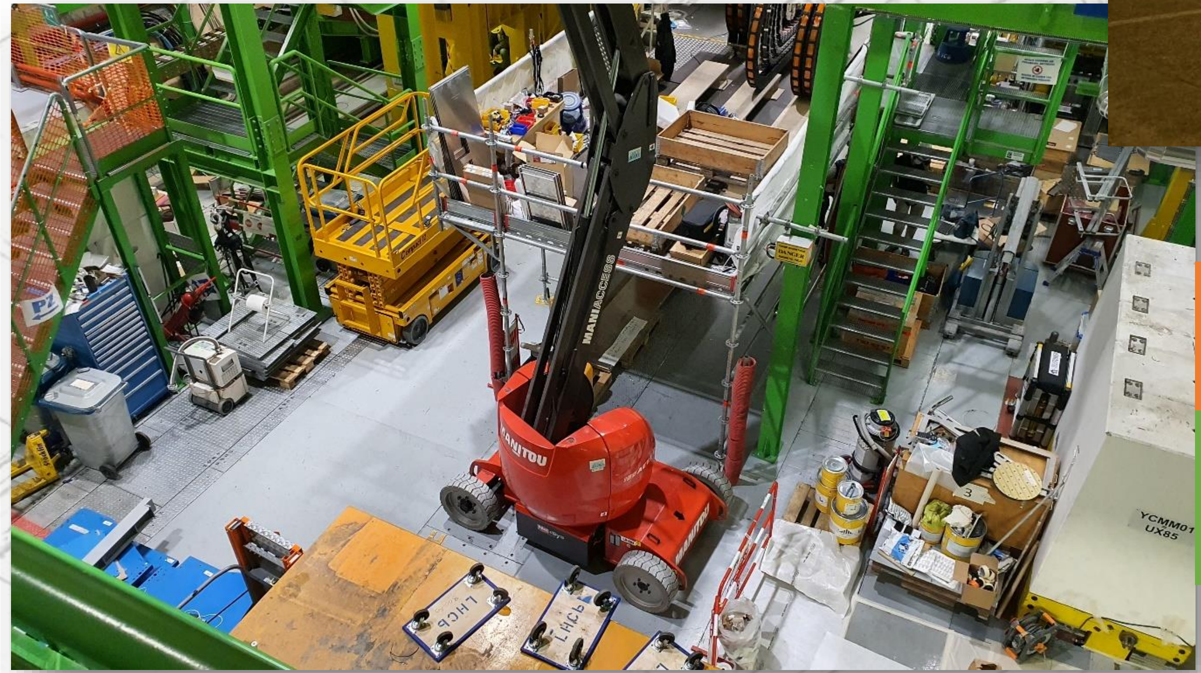
In addition, some equipment might need **special environment** (humidity, temperature) to keep them in **working condition**!

Traceability			Component origin			Component type				Single component dimensions					Total quantities			Component risks						
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	
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…
					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… expected… given the…
					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…
					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…
					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…
						Detector	Aerogel tiles	Other	Silica SiO2	0.28	0.0020	0.20	0.20	0.05	3	0.84	0.01							To be sent… 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 ex… 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… mocoque… mm thick s… crashed it… 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 reus… in RP work… out)
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… dimension…
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							

Inventory was equally essential for planning of STORAGE REQUIREMENTS for LS2

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.

Please start talking to us about it as soon as you possibly can!

Conclusions

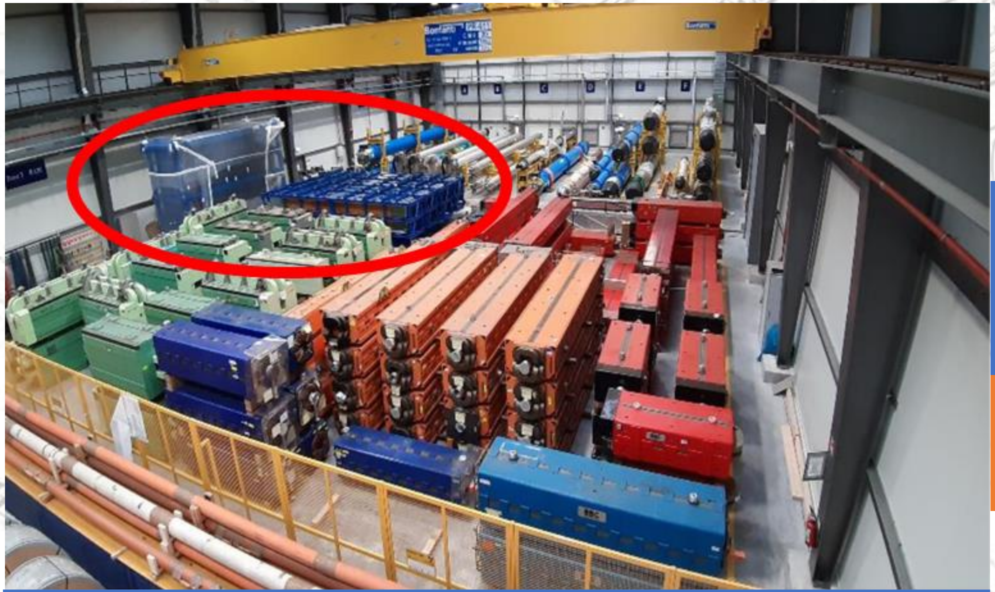
- **Activation and residual dose rates will increase heavily after LS3/4.**
  - We need to work together to devise means of mitigation of committed dose for activities.
- **We need to be prepared for more constraints and restrictions** on activities during access.
- **Material choices** can heavily influence the **radiological hazards** for different scenarios incl. PROMPT.
  - Consider material impact already during **design** phase. Let us help you in finding solutions.
- **We need information from you on hardware and storage as soon as possible.**
  (detector module, support and electronics modifications for LS3 and also LS4)
- **FLUKA and ACTIWIZ simulations will have to be performed based on this information.**
- **Please contact us early on, we will be happy to hear from you!** ☺

Backup

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)

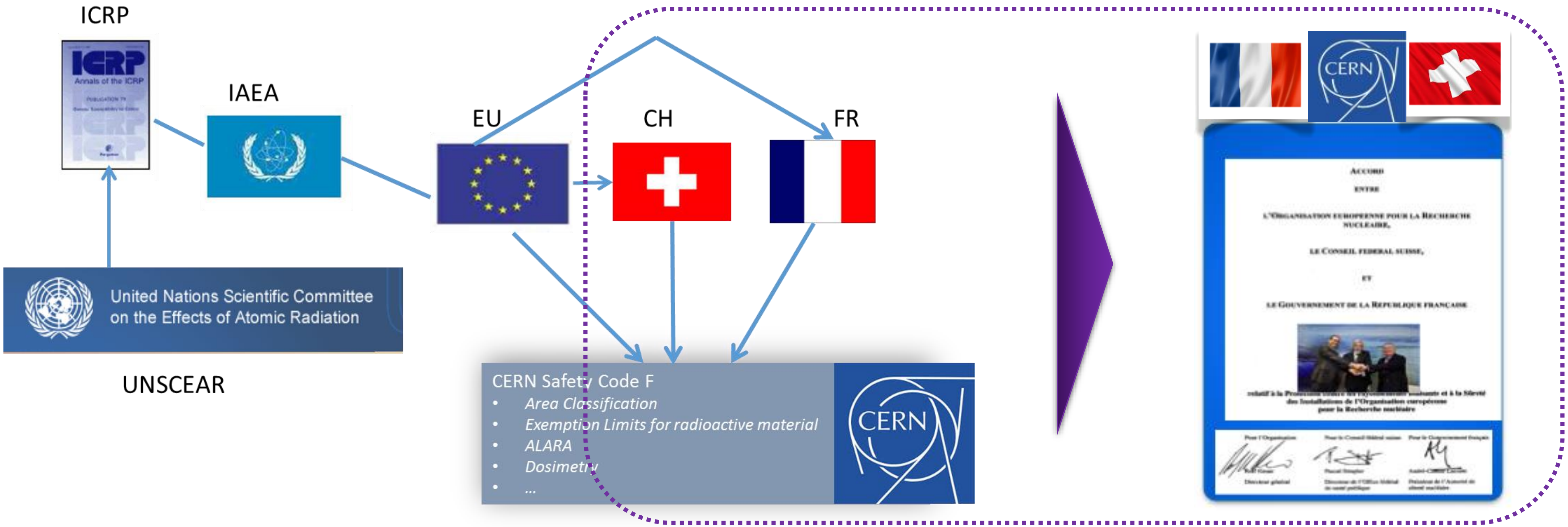


OT/SPD/PS in FLEX building in Prevessin

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!

Radiation Protection at CERN



The tripartite agreement on radiation protection and radiation safety

A legal framework to discuss CERN wide radiation safety and radiation protection issues in a transparent and collaborative way with the host states authorities.

Matters covered:

- Radioactive Waste
- Transport of radioactive materials
- Incident declaration
- Export/import and handling of radioactive materials
- Dosimetrie
- Environmental monitoring

Radiation Protection rules at CERN

CODE DE SÉCURITÉ
SAFETY CODE
Mandatory as defined in SAPOCO/42

F
Rev.

Issued by: Director-General

Date of issue: November 2006
Original: English

Radiation Protection

- **Safety Code F 2006 [EDMS 335729]** – same level as ORAP
- General (RP) Safety Notes and Instructions (2006)
  - Area Classification [EDMS 810149]
  - ALARA rule applied to interventions at CERN [EDMS 1751123]
    (replaces *Approach to ALARA [825353], ALARA criteria [EDMS 810176], ALARA committee [EDMS 810178]*)
  - Dosimetry Service [EDMS 810330]
  - Operational Dosimetry [EDMS 810327]
  - Exemption limits for radioactive materials [EDMS 942170]
  - Radiological control of material from CERN's radiation areas [EDMS 942171]
  - CERN acceptance criteria for radioactive waste [EDMS 1364231]
  - Guide CERN des declarations des evenements significatifs [EDMS 1359615]
  - Organisation of Radiation Protection (RGE9) [EDMS 699284]
  - Organisation of Operational Radiation Protection for CERN's Experiments (RPE) [EDMS 941627]
  - Radiation Safety Support Officer [EDMS 1114705]

Completed by
- Swiss and French RP regulations

Radiation Protection at CERN

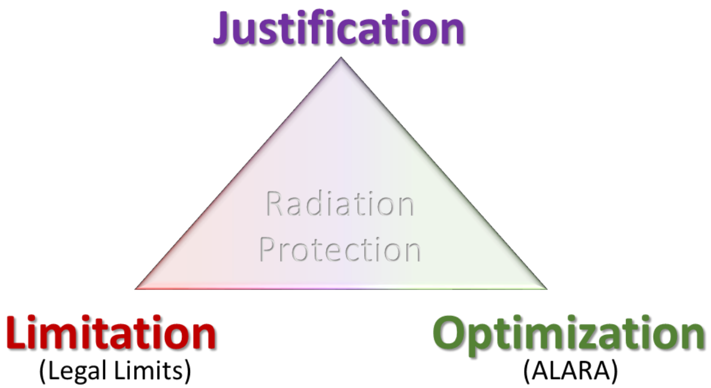
Radiation Protection
(HSE-RP)

advising, authorising, monitoring, checking compliance with RP rules, treating accidents

Radiation Safety
(RSO Dept & LEX)

Safe operation of accelerators, detectors… = Safety of a « source »

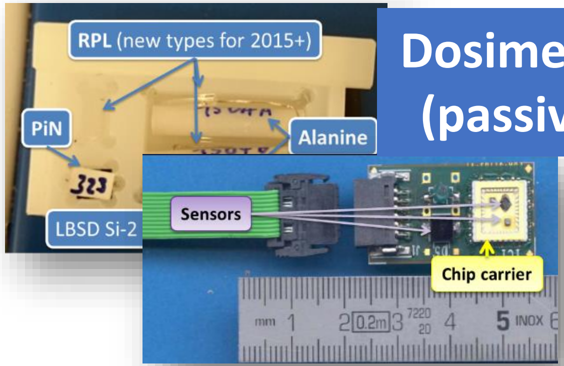
Who is doing what?	Dept/LEX	HSE/RP
Justification	x	
Limitation		x
Optimisation	x	(x)
Control and follow-up	(x)	x



RP aspects of access scenarios

- **Short term maintenance** scenarios (day-month)
- **Long term maintenance and waste** scenarios (>3months, waste up to decades)

will require preparation of **procedures**, also considering the need for local shielding, remote handling, etc.



Dosimetry for future upgrades (passive, active, locations,…)

New ZONING studies (RP support for LS) need to be performed based on new situation