R2E in the HL-LHC Context

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HL-LHC Project Leader and Deputy Project Leader

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Reminder of the HL-LHC Goals

The main objective of HiLumi LHC Design Study is to extend the LHC lifetime by **another decade** and to determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

A peak luminosity of L_{peak} = **5×10^{34} $cm^{-2}s^{-1}$ with levelling**, allowing:

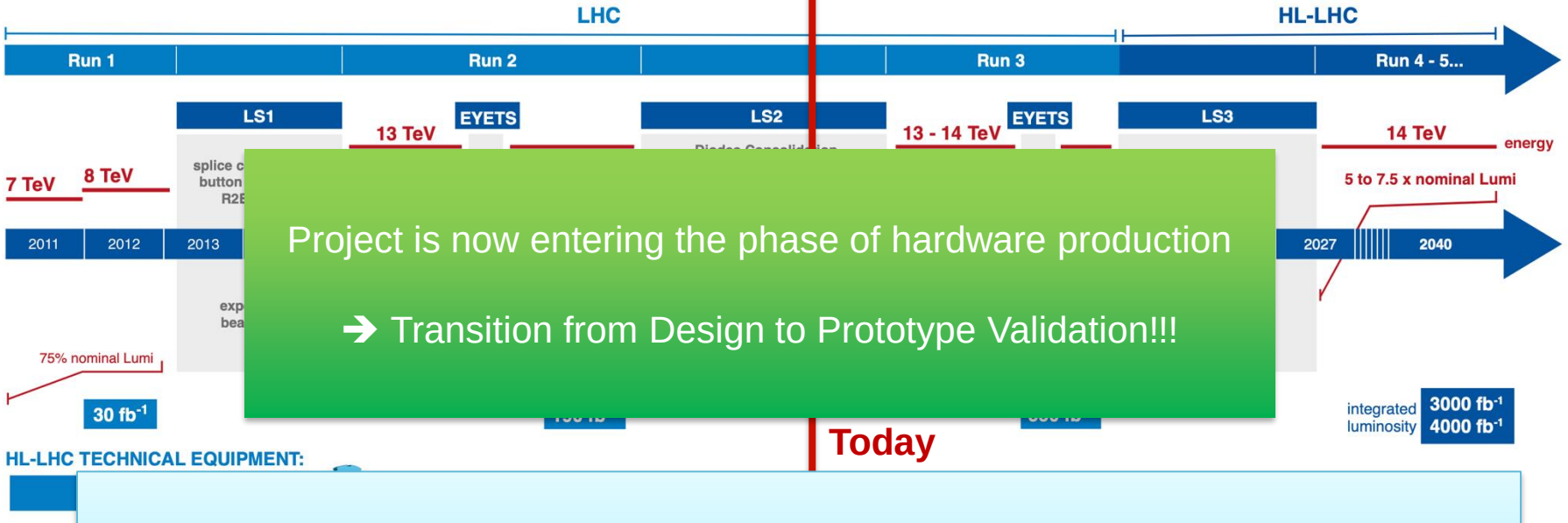
An integrated luminosity of **250 fb^{-1} per year**, enabling the goal of **L_{int} = 3000 fb^{-1}** twelve years after the upgrade.
This luminosity is **more than ten times the luminosity** reach of the first 10 years of the LHC lifetime.

Ultimate performance established 2015-2016. With same hardware and same beam parameters, by using **engineering margins:**
$L_{peak\ ult} \cong 7.5\ 10^{34}\ cm^{-2}s^{-1}$ and **Ultimate Integrated $L_{int\ ult} \sim 4000\ fb^{-1}$**
LHC should not be the limit, would Physics require more than nominal

From FP7 HiLumi LHC Design Study application in 2010

LHC / HL-LHC Plan

After November 2019 retreat: CERN has decided, upon request of LHC Experiments Collaborations, to shift LS3 by 1 year, starting in 2025.
EYTES in 2023/24 ahead of last operational year

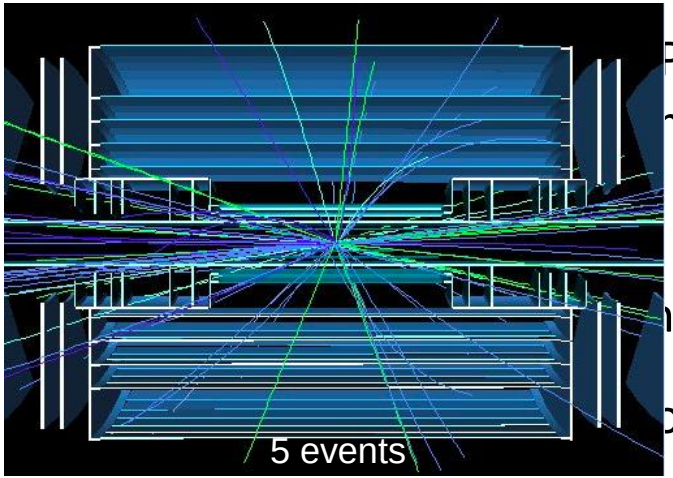


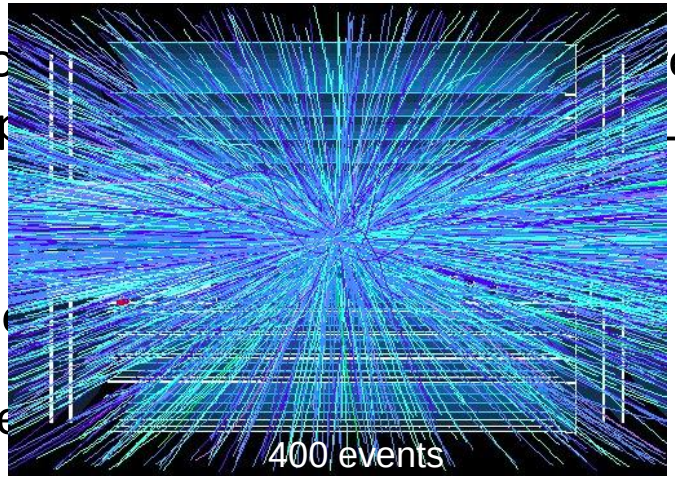
Project is now entering the phase of hardware production

➔ Transition from Design to Prototype Validation!!!

LS2 (extended by 2 months) coming to an end, with machine cooldown and hardware commissioning ongoing ➔ Covid-19 impact: Run3 start only in 2022!
HL-LHC maintains the construction schedule unchanged

Goal of High Luminosity LHC





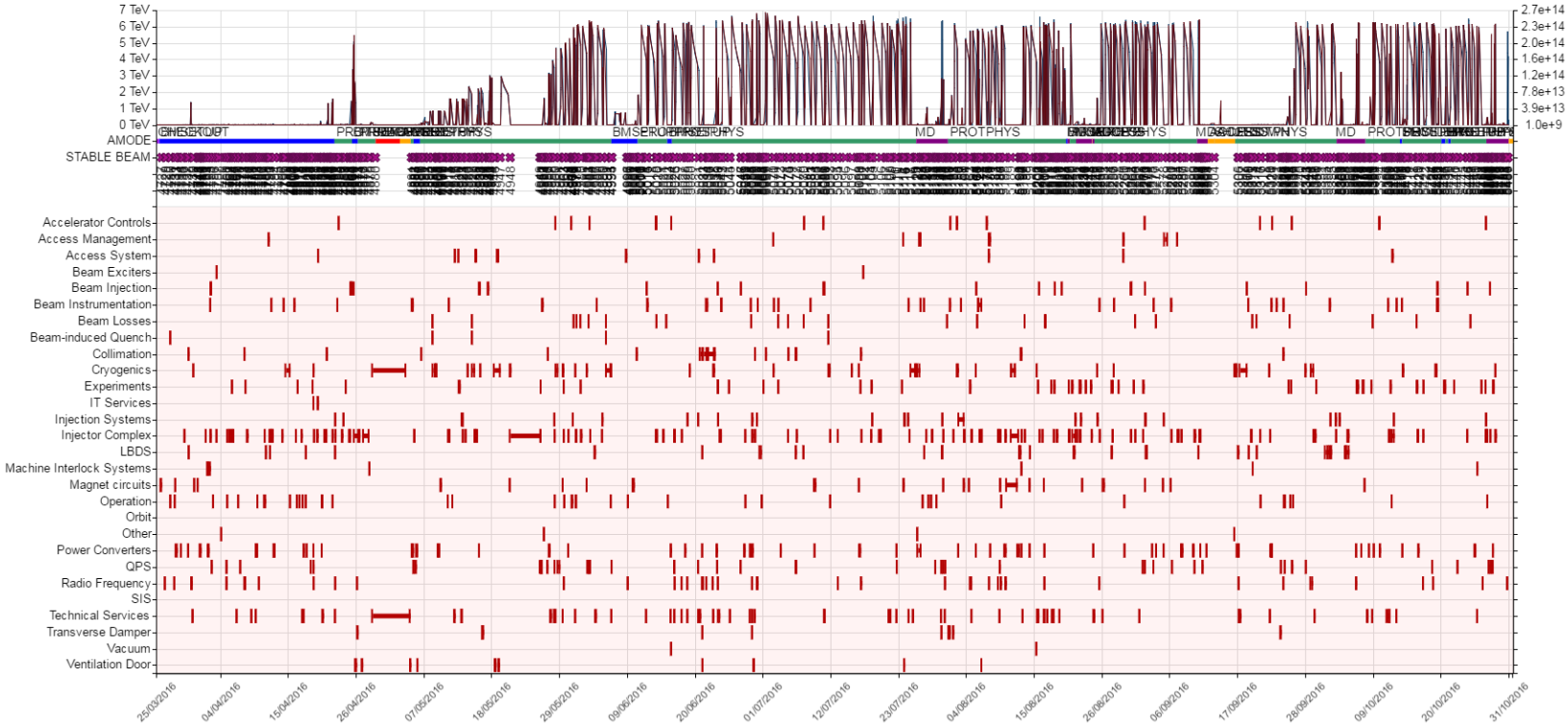
enabling at total integrated luminosity of **3000 fb^{-1}**
implying an integrated luminosity of **250 fb^{-1} per year**,
design operation for **μ < 140** (➔ peak luminosity **5 10^{34} cm^{-2} s^{-1}**)

➔ Operation with levelled luminosity!

➔ Requires high Availability and Reliability of machine operation!!!

➔Minimize beam aborts through R2E!!!

(HL-) LHC exploitation



~ 780 faults registered in a normal operational year (=200 days)

Average LHC Turnaround time of 6h, Average LHC fill length ~ 6h

➔ 50% of scheduled physics time even with 100% availability!!!

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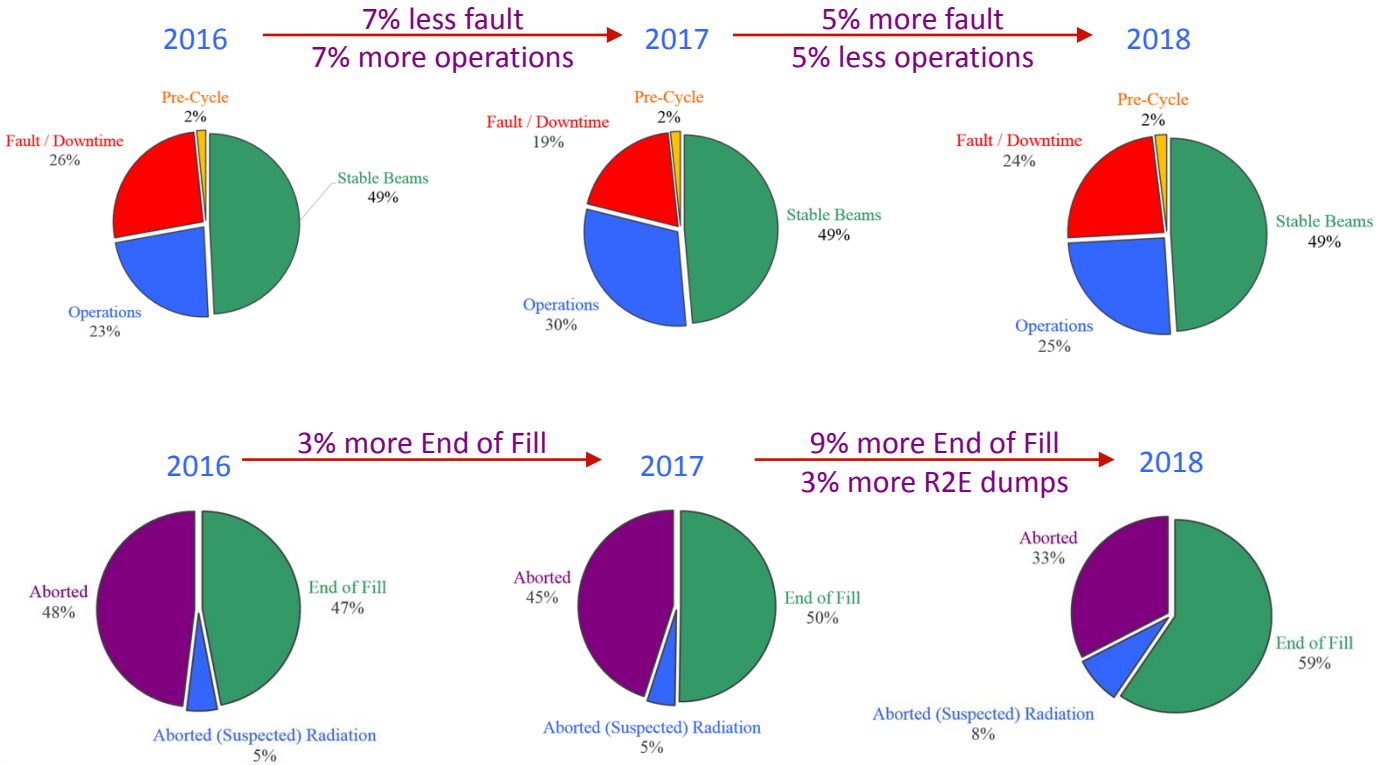
Machine Availability and R2E

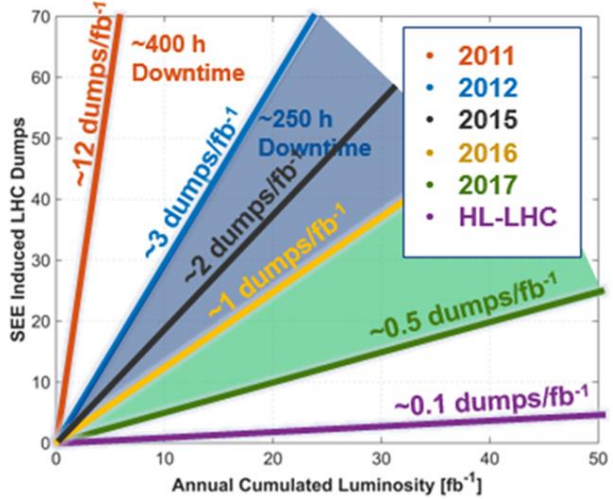
Courtesy B. Todd et al / AWG

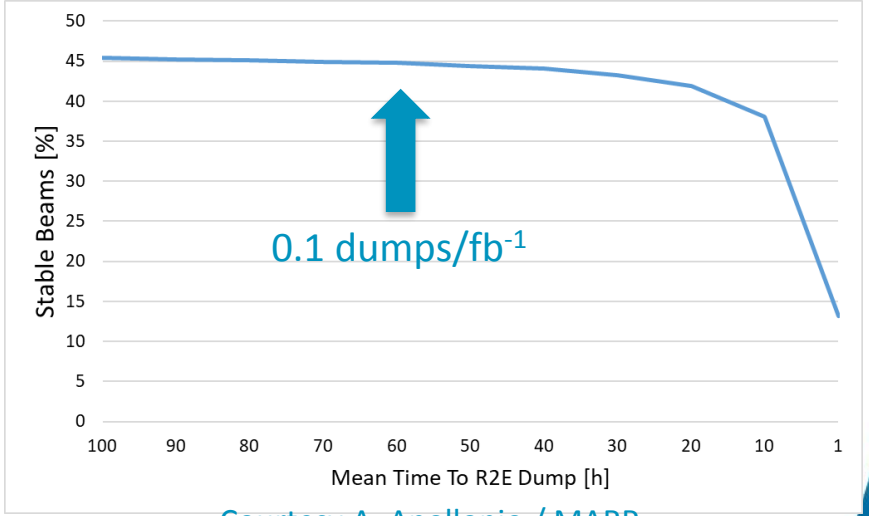


~ 40 fb^{-1} ~ 50 fb^{-1} ~ 68 fb^{-1} -> 250 fb^{-1}

R2E impact on HL-LHC availability

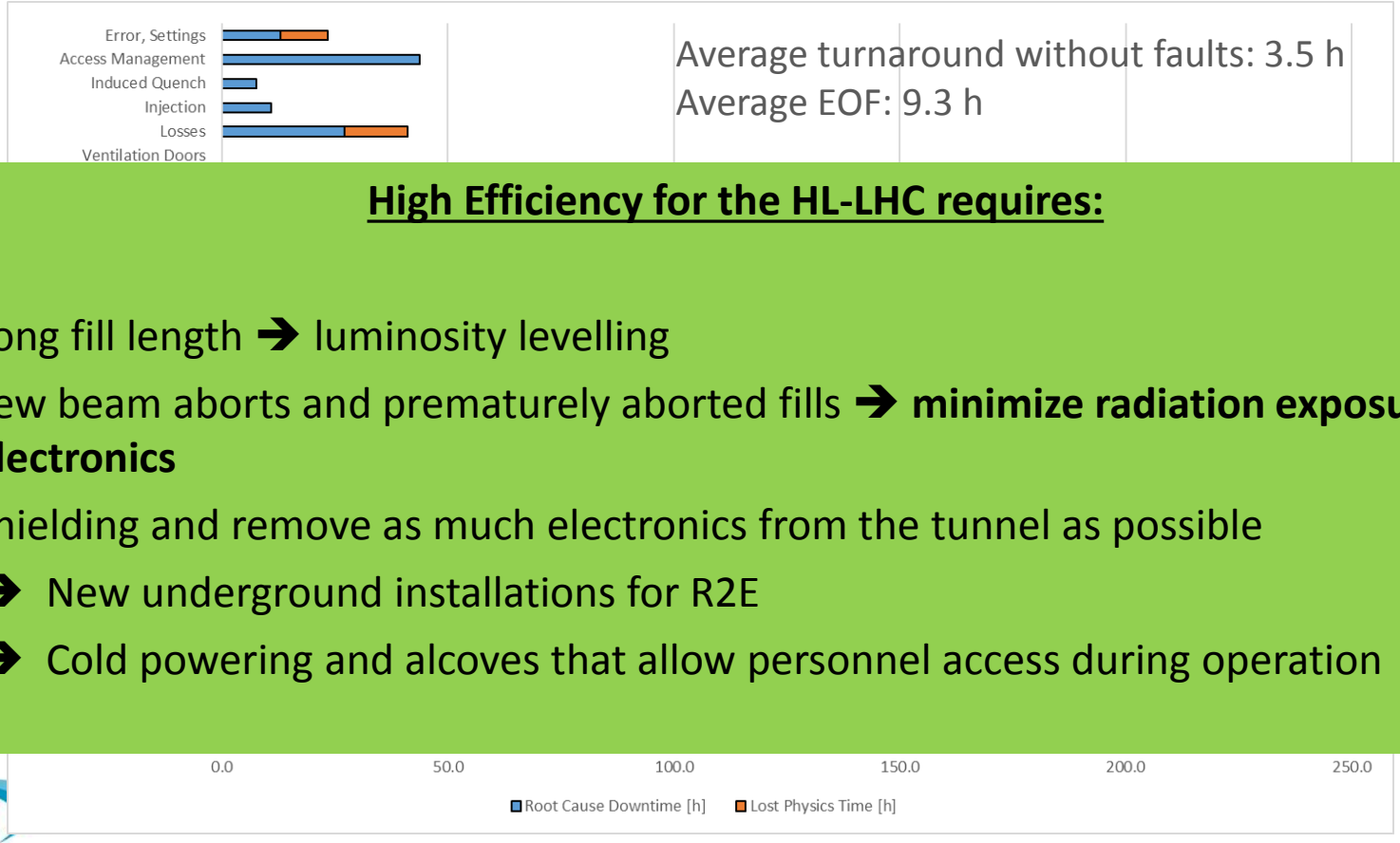
- R2E is transparent to operation if “in the shadow” of other failures (MTTF > 60h)
- Overall availability starts to be impacted for lower MTTF, and severely so below 30h
- **0.1 dumps per fb^{-1}** seems acceptable, with impact on the integral luminosity < ~1%
- Encouraging R2E figures in 2016 and 2017 (close to HL-LHC objective), HL-LHC will bring new and more complex equipment + larger radiation levels (in some areas, even per unit fb^{-1}), also for existing/remaining LHC equipment (-> CONS)





Courtesy A. Apollonio / MARP

Machine Availability and R2E

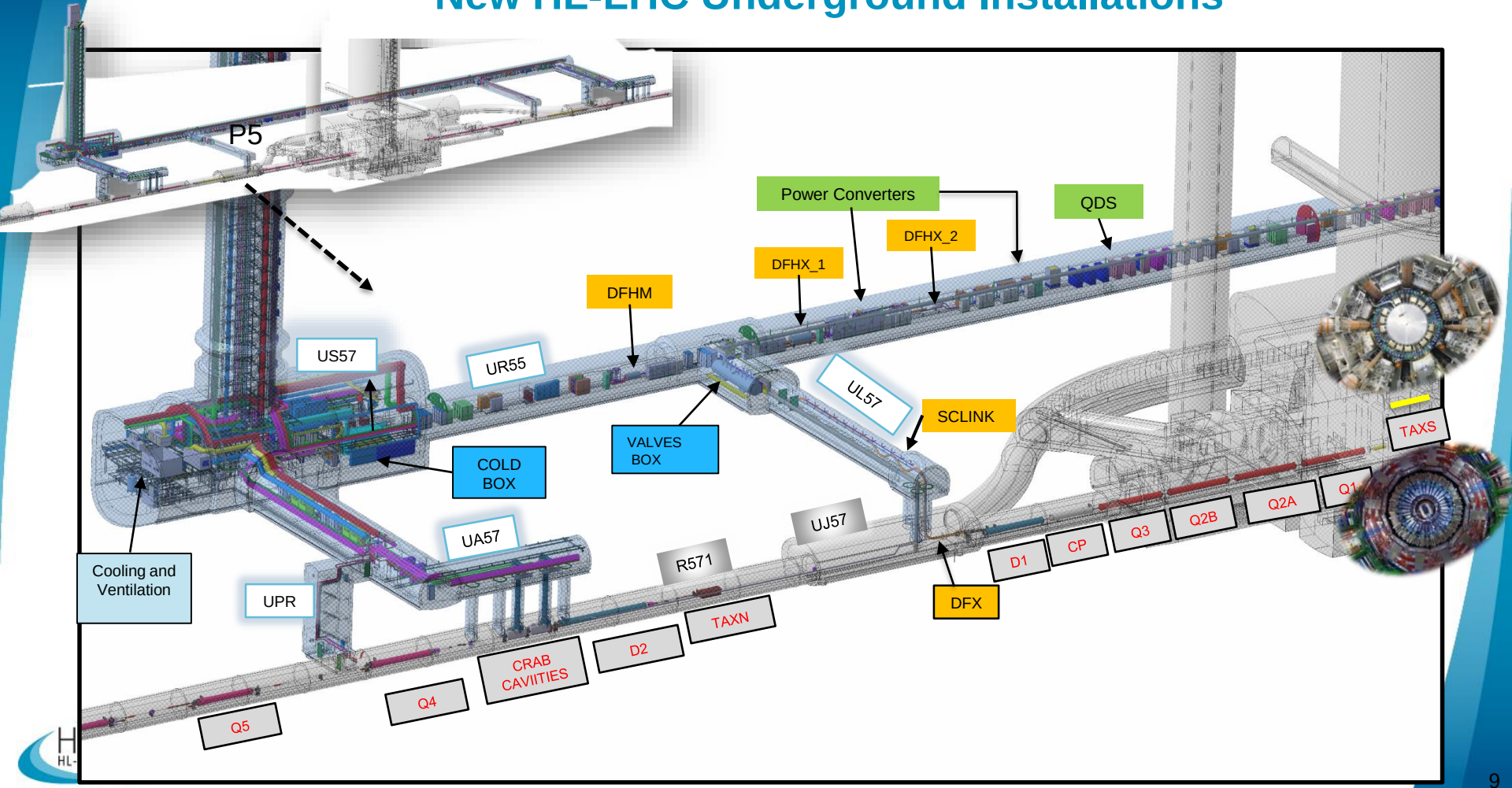


Average turnaround without faults: 3.5 h
Average EOF: 9.3 h

High Efficiency for the HL-LHC requires:

1. Long fill length ➔ luminosity levelling
2. Few beam aborts and prematurely aborted fills ➔ **minimize radiation exposure to electronics**
3. Shielding and remove as much electronics from the tunnel as possible
   - ➔ New underground installations for R2E
   - ➔ Cold powering and alcoves that allow personnel access during operation

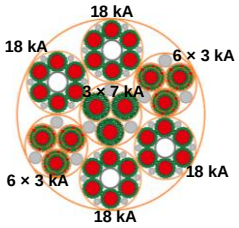
New HL-LHC Underground Installations

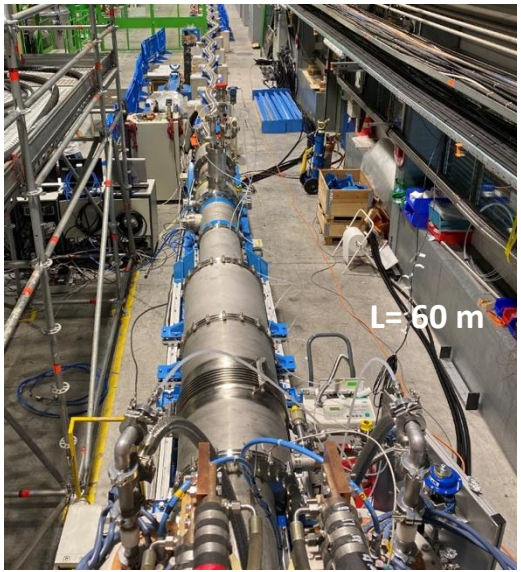


HL-LHC Civil Engineering Status

HL-LHC sc links for HL-LHC triplets and matching section

MgB_2 cable:
$\Phi \sim 90$ mm
$|Itot| > 100$ kA @ 25 K

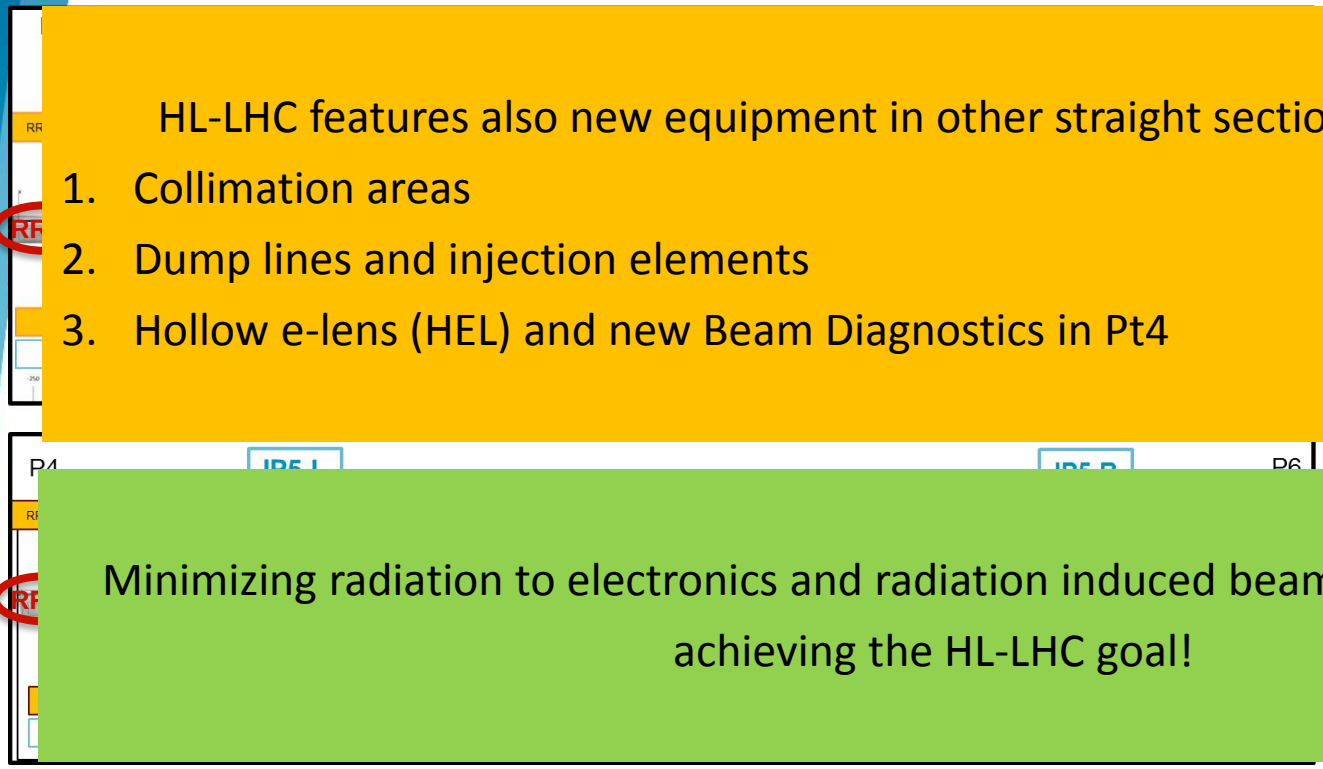




System demonstrator in SM 18 DEMO2/3
Demonstration of **2 x 20kA +**
2 x 7kA in June 2020
in MgB_2 @ 30K
in flexible cryostat
over 60m [54kA total]

Courtesy of Amalia Ballarino [WP6a]

But Some Equipment still needs to remain in the Tunnel



HL-LHC features also new equipment in other straight sections than IR1 and IR5:

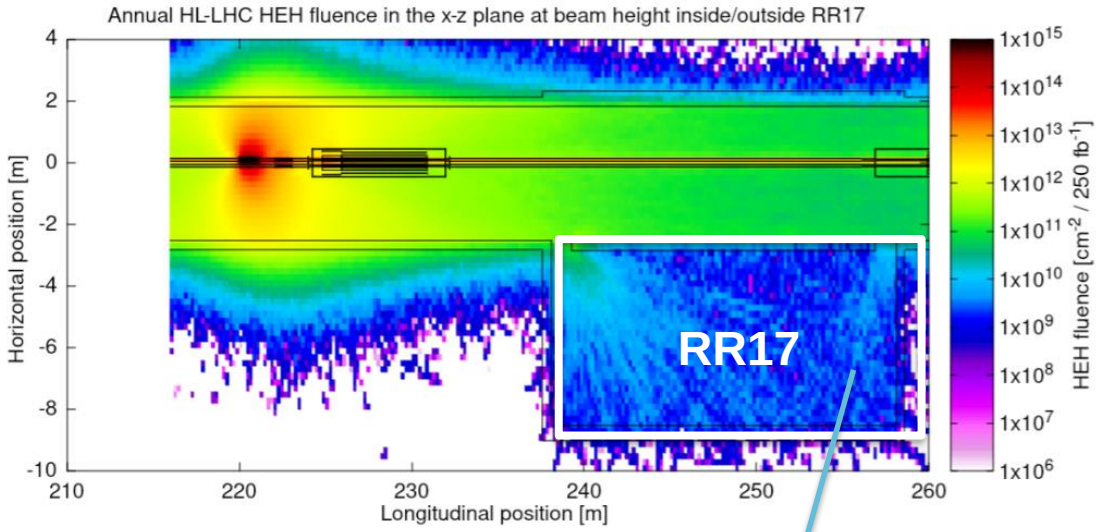
1. Collimation areas
2. Dump lines and injection elements
3. Hollow e-lens (HEL) and new Beam Diagnostics in Pt4

Minimizing radiation to electronics and radiation induced beam aborts is essential for achieving the HL-LHC goal!

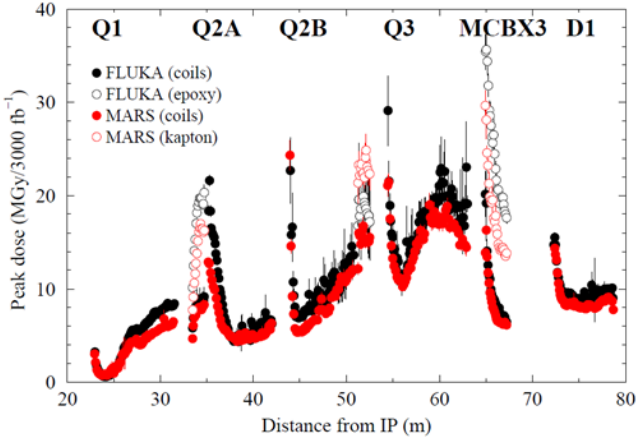
- Area Integration Reports are
- USC55 – EDMS 1836699
- UL557 – EDMS 1836818
- UJ56 – EDMS 2113496
- RR53/57 – EDMS 1758152

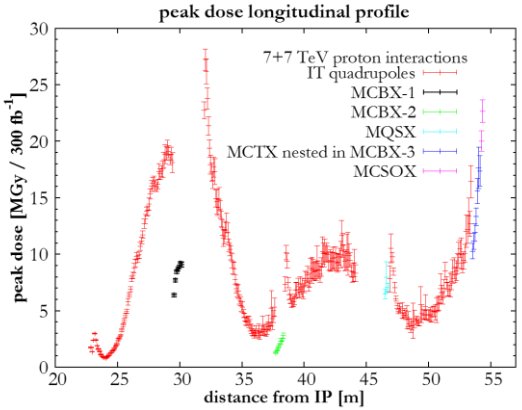
Knowing your radiation levels and energy deposition

- Radiation levels in IP1-5 RRs (for 250 fb^{-1}/yr)



HEH fluence: $6 \cdot 10^9$ cm^{-2}/yr (L0), $1 \cdot 10^{10}$ cm^{-2}/yr (L1).
Thermal neutron fluence: $6 \cdot 10^{10}$ cm^{-2}/yr (L0), $8 \cdot 10^{10}$ cm^{-2}/yr (L1).
TID: 8 Gy/yr (L0), 16 Gy/yr (L1).
1MeVn-eq fluence: $5 \cdot 10^{10}$ cm^{-2}/yr (both L0 and L1).





Courtesy FLUKA/R2E (WP10)

Knowing your radiation levels and energy deposition

- Comprehensive summary of all analysis summarized in HL-LHC Radiation level specification document (EDMS Doc 2302154)

- Few recent baseline changes might require updates of some simulations and radiation profiles
  - Non installation of 11T during LS2, now planned to be mitigated for Run3 through installation of crystal collimators in IR7
  - Increase of TAXN aperture from 85 to 88 mm - ECR in preparation
  - Machining of JFC3 shielding to be completed in LS3 (partially done in LS2)

Conclusions

HL-LHC goals will require to maintain Run2 machine efficiency despite added complexity and more stringent radiation environments

R2E considerations have been fundamental input to HL-LHC design at all levels

Detailed understanding of radiation environment (FLUKA team / WP10) and R2E effects allows aedequat equipment design as well optimisation for cost (60A converters in arc, no rotation of Q4…)

HL-LHC fully supports continued efforts of R2E project considered vital to assure machine efficency throughout entire (HL-)LHC era

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R2E