# HL-LHC
# Work and Dose Planning exercises for inner triplet interventions

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# Outline

- Optimization and ALARA principle implementation
- Dose rate outlook in the inner triplet area
  - Operational scenarios
  - Evolution until HiLumi era
- Work and Dose Planning exercises
  - Valve exchange intervention
  - PIM exchange intervention
- Summary and Conclusions

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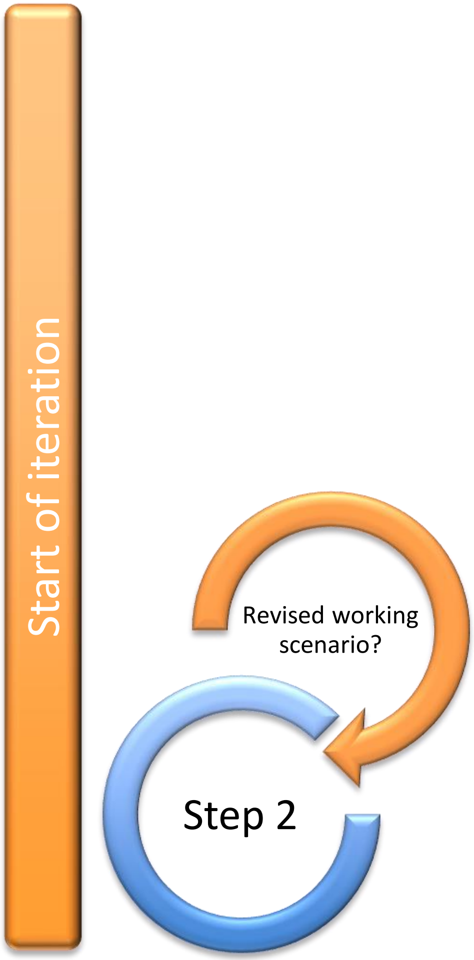
# Optimization during design

# Intervention doses

## Methodology



# Optimization during design

## Design options

### Material choice

- Low activation properties to reduce residual doses and minimize radioactive waste (optimization with ***ActiWiz*** code, Web-site: https://actiwiz.web.cern.ch)
- Avoid materials for which no radioactive waste elimination pathway exists (e.g., highly flammable metallic activated waste)
- Radiation resistant

### Optimized handling

- Easy access to components that need manual intervention or complex manipulation
- Provisions for fast installation/ maintenance/ repair, in particular, around beam loss areas (*e.g.,* plugin systems, quick-connect flanges, remote survey, remote bake-out)
- Foresee easy dismantling of components

### Limitation of installed material

- Install only components that are absolutely necessary, in particular in beam loss areas
- Reduction of radioactive waste

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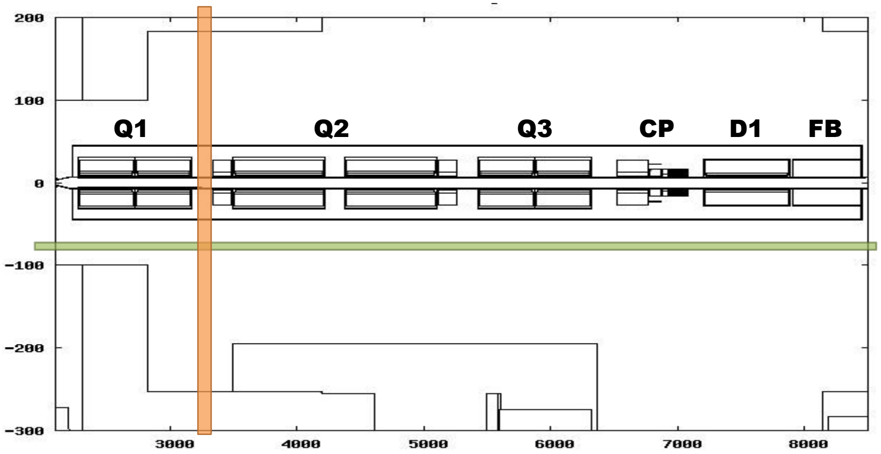
# Dose rate outlook

# Ambient Dose Equivalent Rates

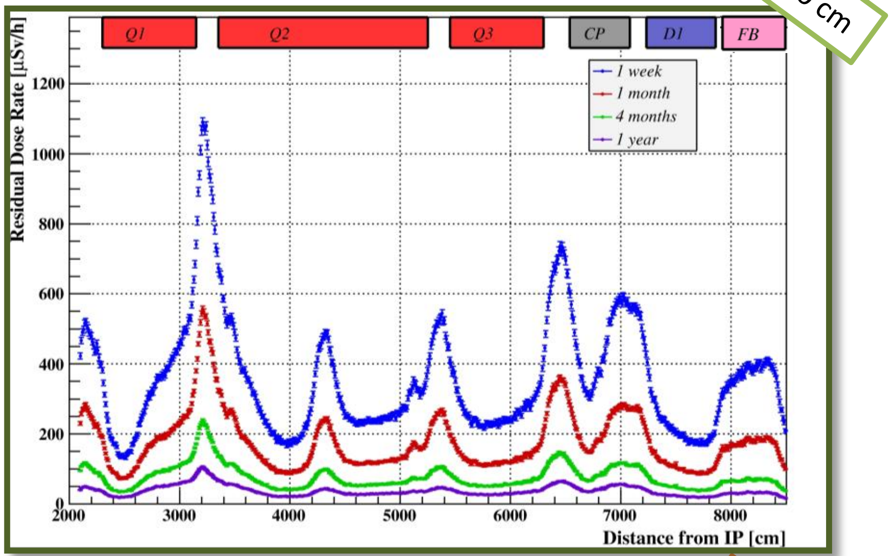
## *Cooling time dependence*

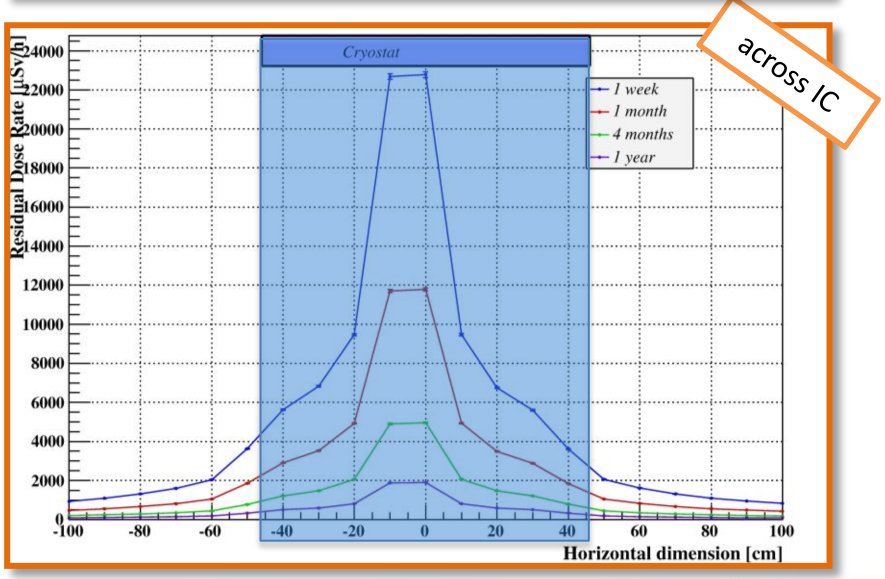
**Nominal scenario**
Total integrated luminosity 3060 $fb^{-1}$

**IR5 LHC Fluka geometry - Inner triplet area** (courtesy Fluka team)




| Cooling time | Scaling factor |
|---|---|
| 1 week | 2.0 |
| 1 month | 1.0 |
| 4 months | 0.4 |
| 1 year | 0.2 |

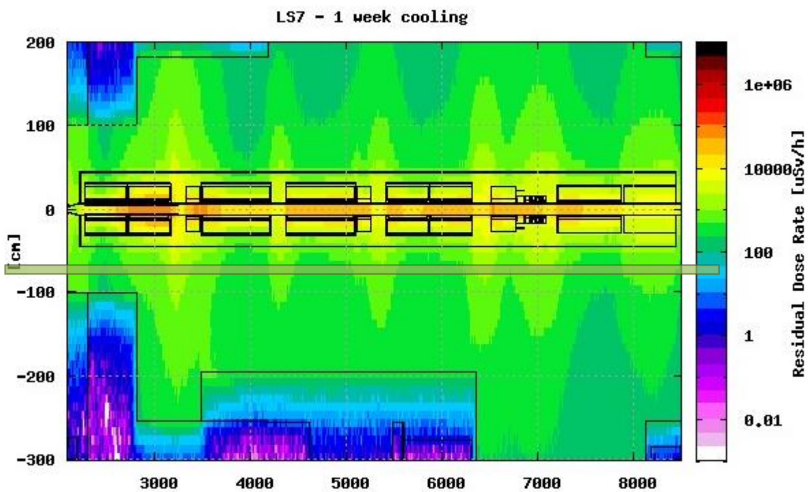


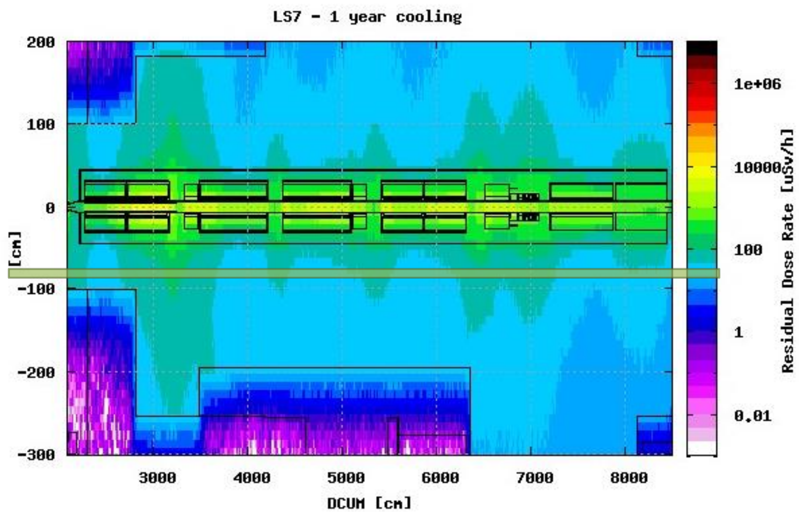



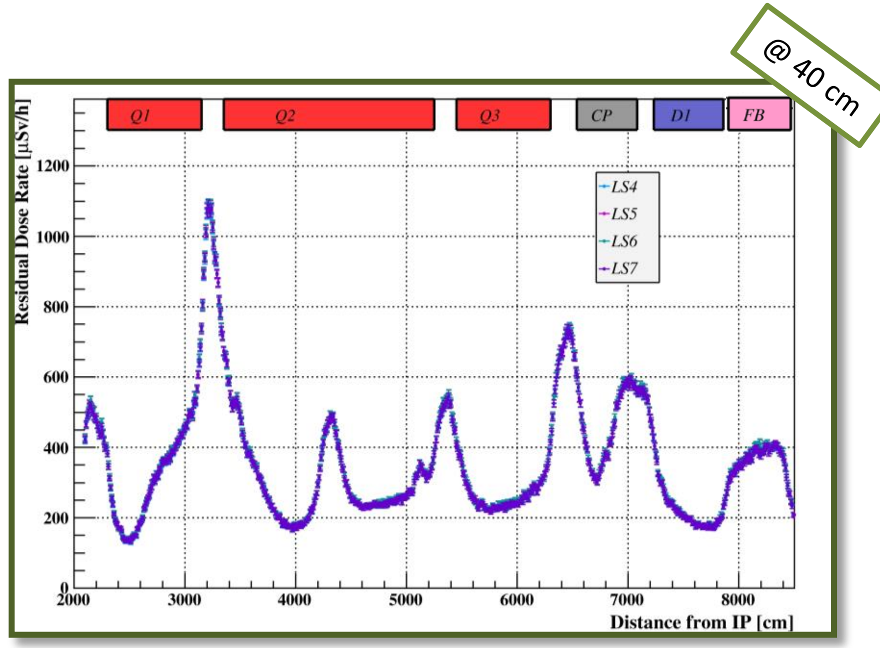
# Ambient Dose Equivalent Rates

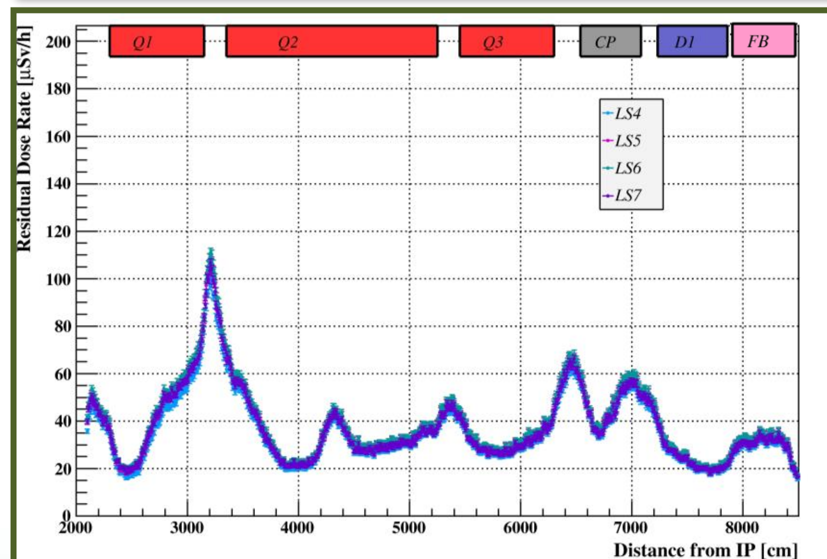
## *Time evolution*

**Nominal scenario**



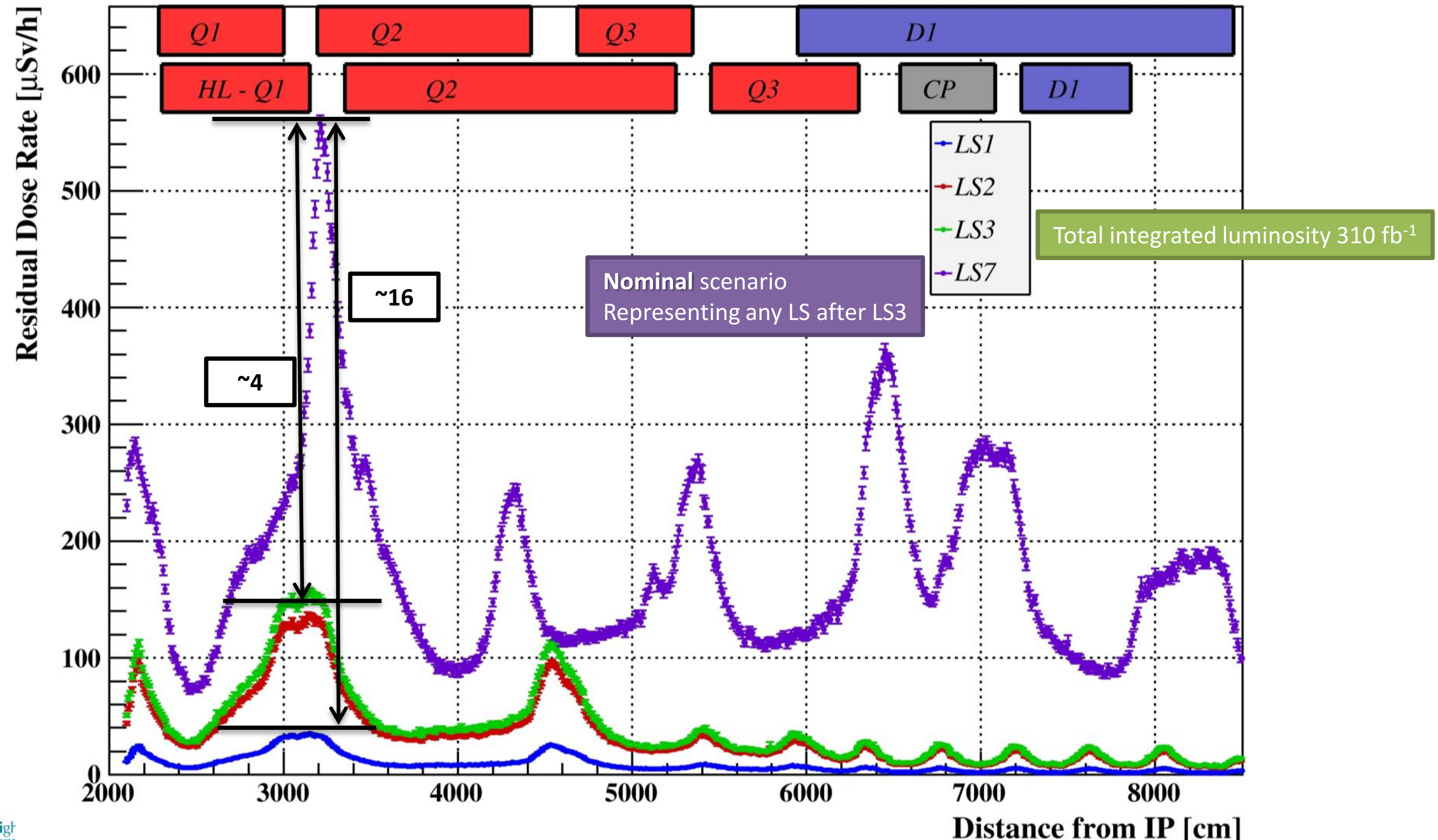



# Ambient Dose Equivalent Rates

## *Time evolution*

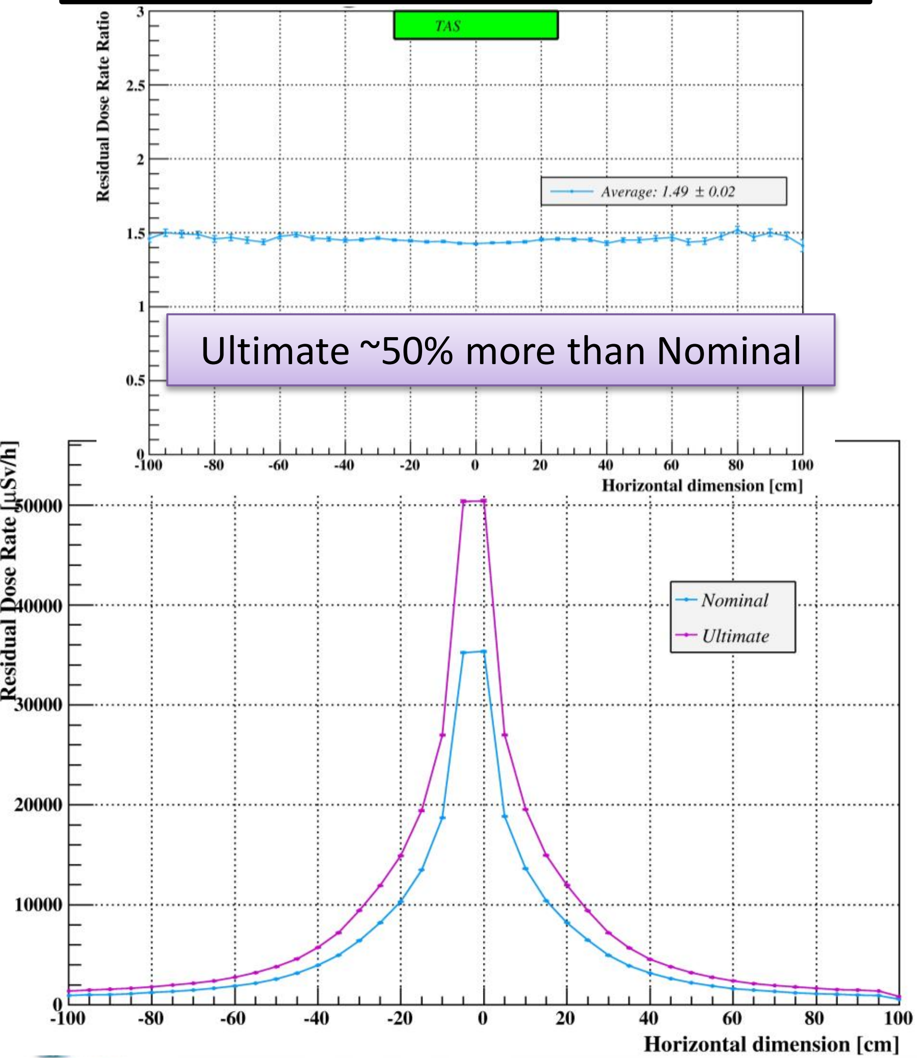
1 month cooling time, dose rates at 40 cm from the cryostat



# Ambient Dose Equivalent Rates

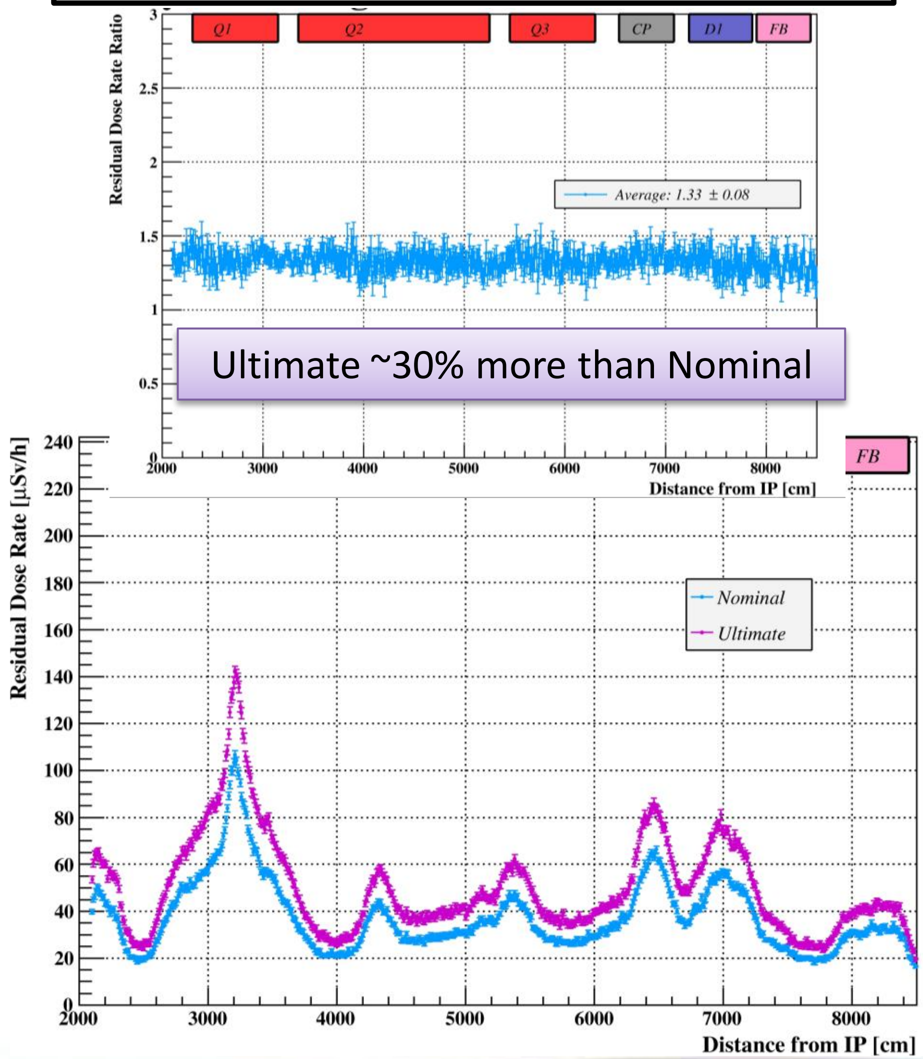
## *Nominal vs Ultimate*

**1 hour cooling time @ contact**




Ultimate ~50% more than Nominal

**1 year cooling time @** 40cm from cryostat surface




Ultimate ~30% more than Nominal

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# Work and Dose Planning exercises

# WDP example 1: **Valve exchange intervention**

- WHEN: any LS during HL-LHC (Ultimate scenario)
- WHERE: **region in between TAS and Q1**

*Intervention description and timing from Cedric Garion*

*Estimations done using simulation data*

| team | # person | action description | distance from the beam pipe (cm) | Duration (minutes) | dose per action (man μSv) | individual dose (μSv) | dose per action (man μSv) | individual dose (μSv) |
|---|---|---|---|---|---|---|---|---|
| | | | | | **1 month cooling time** | | **4 months cooling time** | |
| T0 | 2 | Valve investigation | 40 | 60 | 747 | 374 | 290 | 145 |
| A | 1 | Jacket and cabling removal | in contact | 30 | 283 | | 103 | |
| B | 2 | Pneumatic system disconnection | 40 | 10 | 125 | **1162** | 48 | **427** |
| B | 2 | Flanges disconnection | in contact | 20 | 377 | | 138 | |
| B | 2 | valve removal | in contact | 30 | 566 | | 206 | |
| B | 2 | valve re-installation | in contact | 30 | 566 | | 206 | |
| B | 2 | Flanges reconnection | in contact | 30 | 566 | | 206 | |
| B | 2 | Pneumatic system reconnection | 40 | 10 | 125 | | 48 | |
| A | 1 | Jacket and cabling installation | in contact | 45 | 425 | 708 | 155 | 258 |

| | Collective dose (man mSv) | |
|---|---|---|
| Ultimate scenario | **3.8** | **1.4** |
| **Nominal** scenario | **2.8** | **1.0** |

3 different teams
5 workers involved

# Lesson learnt from WDP example 1

- ½ working day could cost (**Ultimate/1 month cooling**)
  - ~4 mSv in terms of collective dose
  - ~1.2 mSv individual dose for the most exposed worker

    i.e. 1/5 (1/16) of the annual dose for a Category B (A) worker,

    **~1/2 of the dose design criterion (2 mSv/intervention/year)**

- More exercises needed in a more refined/realistic description

# WDP example 2: **PIM exchange intervention** (1/2)

*Intervention description and timing from Herve Prin*

- WHEN: any LS during HL-LHC (Ultimate scenario)
- WHERE: inner triplet – **Q1Q2 interconnection** (IC with the highest residual dose rate)

*Estimations done using simulation data*

| team | # person | action description | distance from cryostat (cm) | Duration (minutes) | dose per action (man µSv) | individual dose (µSv) | dose per action (man µSv) | individual dose (µSv) |
|---|---|---|---|---|---|---|---|---|
| | | | | | **1 month** | | **4 months** | |
| A | 1 | BLM removal | 40 | 30 | 351 | 820 | 147 | 343 |
| C | 3 | Open W bellow and thermal screen (including tie-rods disassembly) | 40 | 180 | 6325 | 4217 | 2643 | 1762 |
| D | 1 | Environment protection | in contact | 30 | 1057 | **9861** | 426 | **3973** |
| D | 1 | PIM cutting | in contact | 240 | 8452 | | 3405 | |
| E | 1 | Inspection | 40 | 20 | 234 | 234 | 98 | 98 |
| F | 1 | PIM installation and welding | in contact | 120 | 4226 | 4226 | 1703 | 1703 |
| G | 1 | Welding inspection | 40 | 10 | 117 | 117 | 49 | 49 |
| D | 1 | Environment protection removal | in contact | 10 | 352 | | 142 | |
| C | 3 | Closing W bellow and thermal screen (including tie-rods assembly) | 40 | 180 | 6325 | | 2643 | |
| A | 1 | BLM installation | 40 | 40 | 469 | | 196 | |

| Collective dose (man mSv) | |
|---|---|
| **28** | **11** |

6 different teams
8 workers involved

**Nominal** scenario

| Collective dose (man mSv) | |
|---|---|
| **21** | **8** |

Survey HLS and WPS removal and installation and magnet realignment NOT TAKEN into account in this estimation.

# WDP example 2: **PIM exchange intervention** (2/2)

*Intervention description and timing from Herve Prin*

- WHEN: any LS during HL-LHC (Ultimate scenario)
- WHERE: inner triplet – **Q2Q3 interconnection** (IC with the lowest residual dose rate)

*Estimations done using simulation data*

| team | # person | action description | distance from cryostat (cm) | Duration (minutes) | dose per action (man $\mu$Sv) | individual dose ($\mu$Sv) | dose per action ($\mu$Sv) | individual dose (man $\mu$Sv) |
|---|---|---|---|---|---|---|---|---|
| | | | | | **1 month cooling time** | | **4 months cooling time** | |
| A | 1 | BLM removal | 40 | 30 | 153 | 357 | 59 | 138 |
| C | 3 | Open W bellow and thermal screen (including tie-rods disassembly) | 40 | 180 | 2755 | 1837 | 1068 | 712 |
| D | 1 | Environment protection | in contact | 30 | 434 | **4049** | 163 | **1525** |
| D | 1 | PIM cutting | in contact | 240 | 3470 | | 1307 | |
| E | 1 | Inspection | 40 | 20 | 102 | 102 | 40 | 40 |
| F | 1 | PIM installation and welding | in contact | 120 | 1735 | 1735 | 654 | 654 |
| G | 1 | Welding inspection | 40 | 10 | 51 | 51 | 20 | 20 |
| D | 1 | Environment protection removal | in contact | 10 | 145 | | 54 | |
| C | 3 | Closing W bellow and thermal screen (including tie-rods assembly) | 40 | 180 | 2755 | | 1068 | |
| A | 1 | BLM installation | 40 | 40 | 204 | | 79 | |
| | | | | | Collective dose (man mSv) | | | |
| | | | | | **12** | | **5** | |

6 different teams
8 workers involved

| **Nominal** scenario | Collective dose (man mSv) | |
|---|---|---|
| | **9** | **3** |

Survey HLS and WPS removal and installation and magnet realignment NOT TAKEN into account in this estimation.

# Lesson learnt from the WDP example 2

- Survey HLS and WPS removal/re-installation and magnet realignment have **not been taken** into account
- 2 working days could cost (**at worst IC / Ultimate / 4 months cooling**)
  - ~11 mSv in terms of collective dose
  - ~4 mSv individual dose for the most exposed worker

  → **do not match the design criterion of 2 mSv/intervention/year**

| Individual dose (mSv) – intervention at worst IC (Q1Q2) | | | |
|---|---|---|---|
| Cooling time | **1 month** | **4 months** | **1 year** |
| Nominal scenario | 7.3 | 2.9 | 1.3 |
| Ultimate scenario | 9.9 | 4.0 | 1.7 |

→ estimated individual dose (4 months cooling time) exceeds the design criterion by 50% (nominal) or a factor two (ultimate)

- The results of this estimation exercise show that the intervention cannot be done accordingly to the present working description (coming from actual experience) and the necessity of **revising the working scenario in order to optimize the dosed to personnel**

High Luminosity LHC

# Summary and Conclusions

- 4 months VS 1 month cooling time: a factor 2.5 less
- Nominal VS Ultimate: a factor 1.35 less
- The estimation is done using residual dose rate maps from **simulation study** based on nominal and ultimate operational parameters and on the last available geometry
- Doing more exercises in this phase of the project is important for the optimization of the design of the component and for the optimization of the future working scenario
- Estimation of WDP can also be done for LS3 and the removal of the present inner triplet magnets to optimize the work-methods

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# THANK YOU FOR YOUR ATTENTION!