# R2E radiation levels in RR/UJ/UL of P1 & P5

***HL-LHC integration meeting n51: R2E, update on CE***

Rubén García Alía, Markus Brugger, Francesco Cerutti, Salvatore Danzeca, Yacine Kadi, Corinna Martinella, Andrea Tsinganis

# Outline

- Introduction
- 2015 measurements and present machine calculations
  - RR
  - UJ
  - UL
  - UPS
- HL-LHC expected radiation levels: measurement scaling and calculations
- Summary and Conclusions

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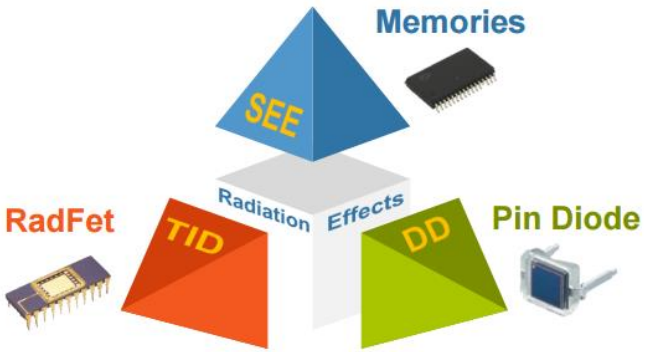
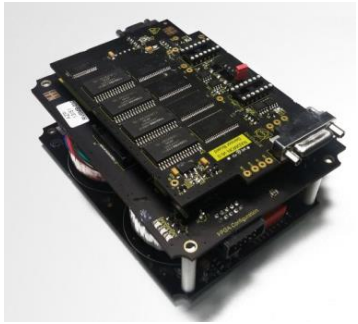
# RadMON system

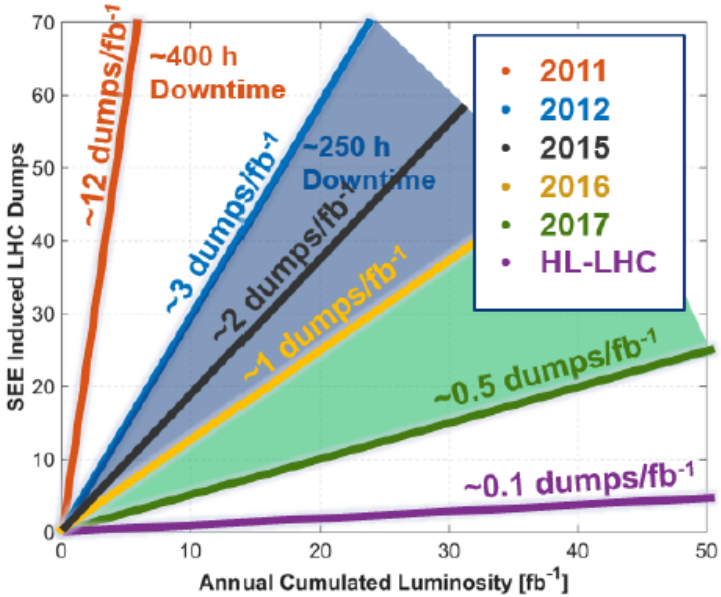


- CERN radiation level monitoring system for Displacement Damage (DD), Total Ionizing Dose (TID) and Single Event Effects (SEEs)
- For Commercial-Off-The-Shelf (COTS) components and the LHC shielded areas (RR/UJ/UL) **SEEs** are typically the **most critical effect**
- Therefore, this presentation mainly describes the radiation levels through the High Energy Hadron (**HEH**) **fluence**, relevant to SEE induction

*system responsible: Salvatore Danzeca*

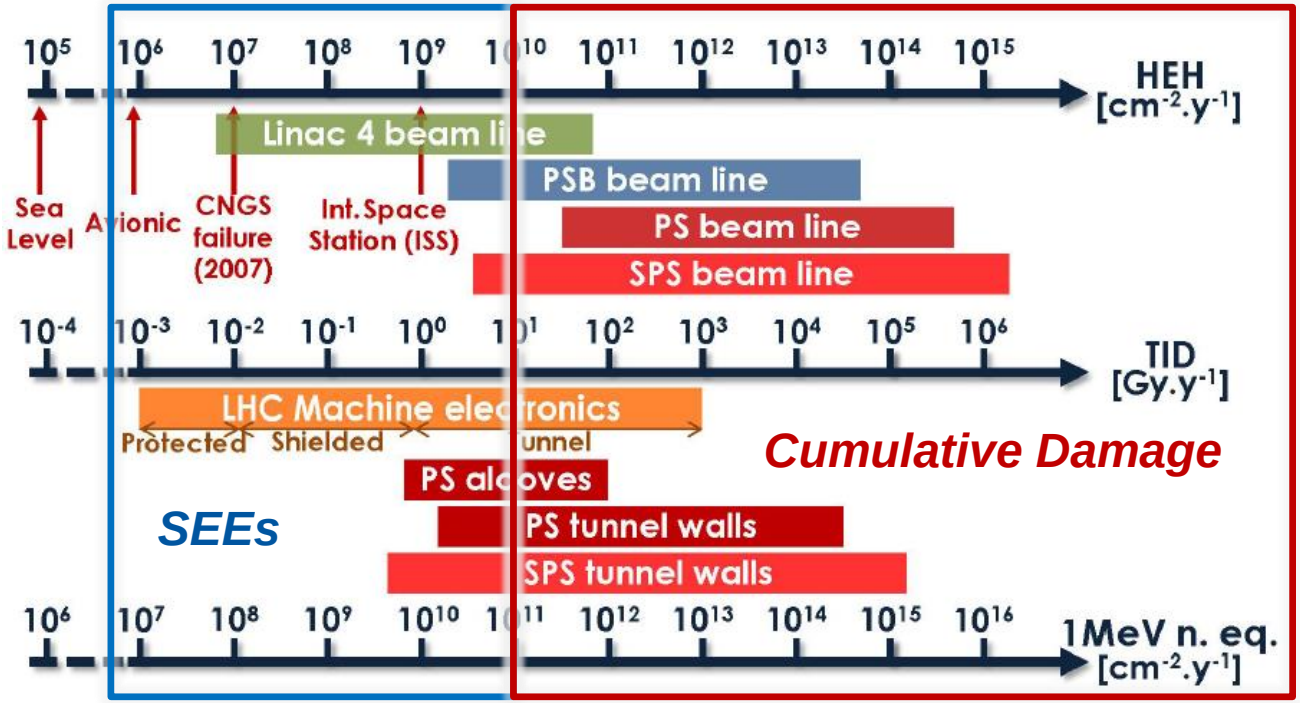
# R2E strategy: from mitigation to prevention




2011-2015
**Mitigation**
(shielding + relocation)

2015-2018
**Prevention**
(equipment upgrade)

# Annual radiation target levels



# Annual radiation target levels

- **$10^7$ HEH/cm$^2$** for optimization of presently installed equipment
- **$10^6$ HEH/cm$^2$** for future installations of non-qualified equipment
  - Non-qualified equipment *could* be exposed to larger levels if:
    - There is no safety concern
    - There is no impact on operation
    - It does not require access for reparation in case of damage

# HL-LHC radiation level request

- Interest in estimations of **HL-LHC radiation levels** in **shielded areas (UJ, UL, RR) of interaction points P1 and P5**
- Additional requests (following email to HL-LHC WP15 on June 2016):
  - Survey galleries in P1 and P5 (UPS14/16) [Helene Durand]
  - Regions underneath main quadrupole magnets and Dispersion Suppressor for BPM/BLM electronics beyond LS3 [Thibault Lefevre]
  - Galleries over the crab cavity areas where equipment will be installed due to cable length limitation [Mateusz Sosin]
  - Other areas of interest: UAs for kickers, etc.

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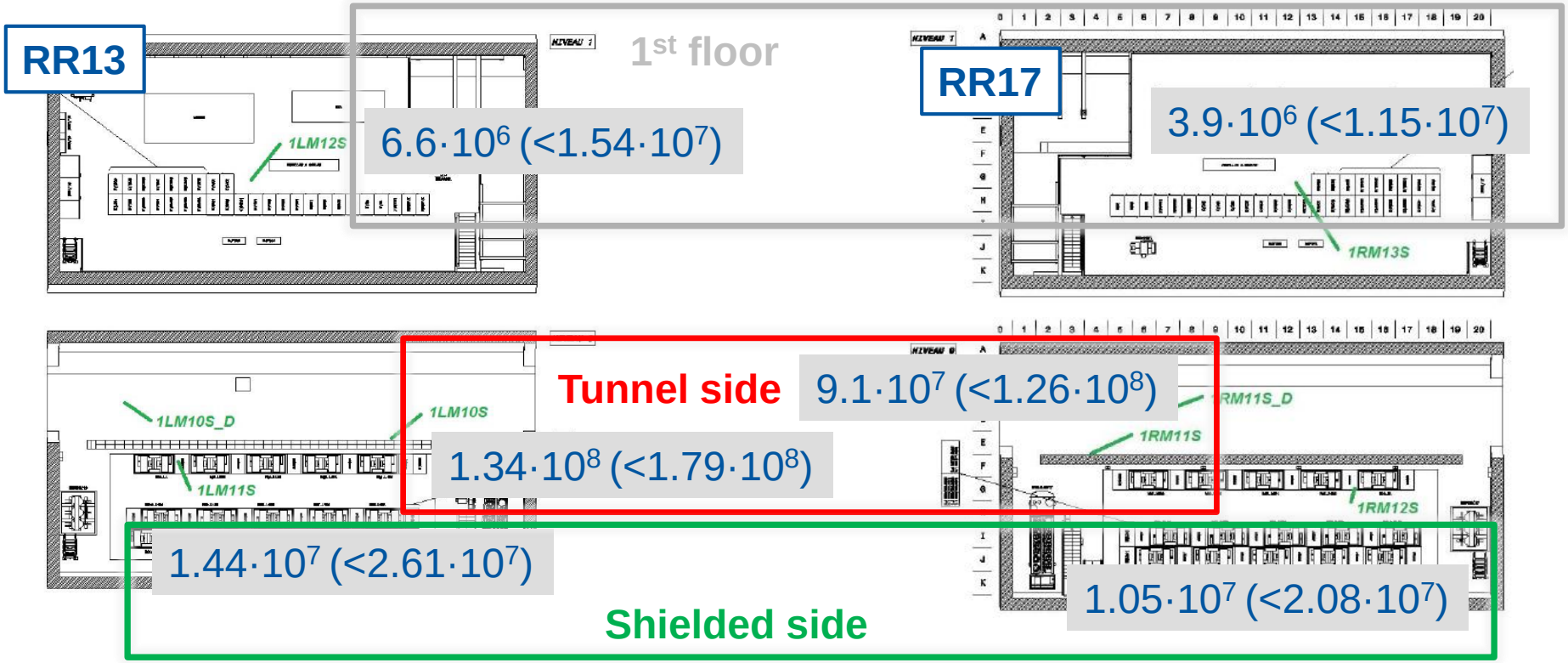
# Measurement considerations

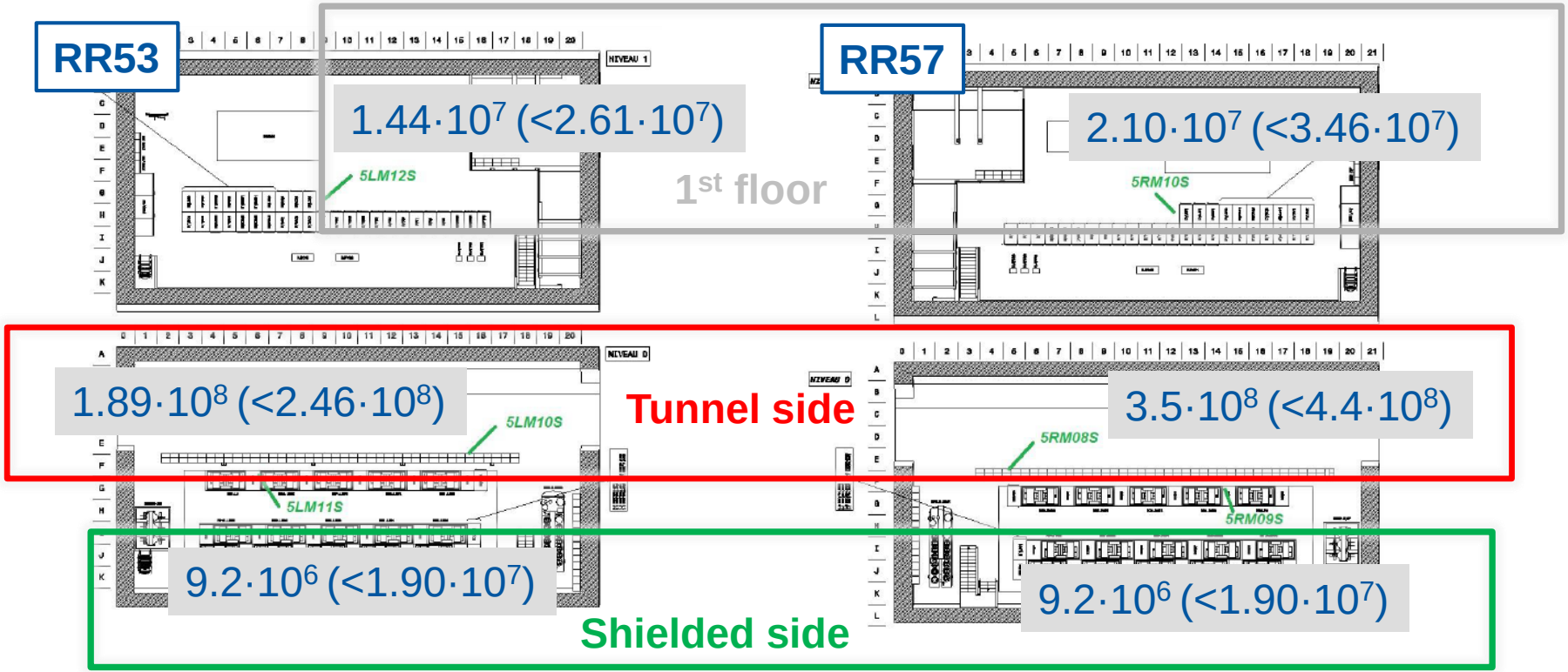
- 2015 values for **25 ns operation**
- Reported in units of **HEH/cm$^2$** and including **upper limit** (2-sigma count statistics, thermal neutron R-factor uncertainty and detector sensitivity spread)
- Presented in *"2015 LHC Radiation Levels"* Corinna Martinella, RadWG, May 2016 (link)
- When compared with calculations for present machine (HL-LHC) upper and lower limits of 2015 measurement are scaled by 100 fb$^{-1}$ (250 fb$^{-1}$)

**2015 measured value [HEH/cm$^2$] (2015 measured upper limit [HEH/cm$^2$])**

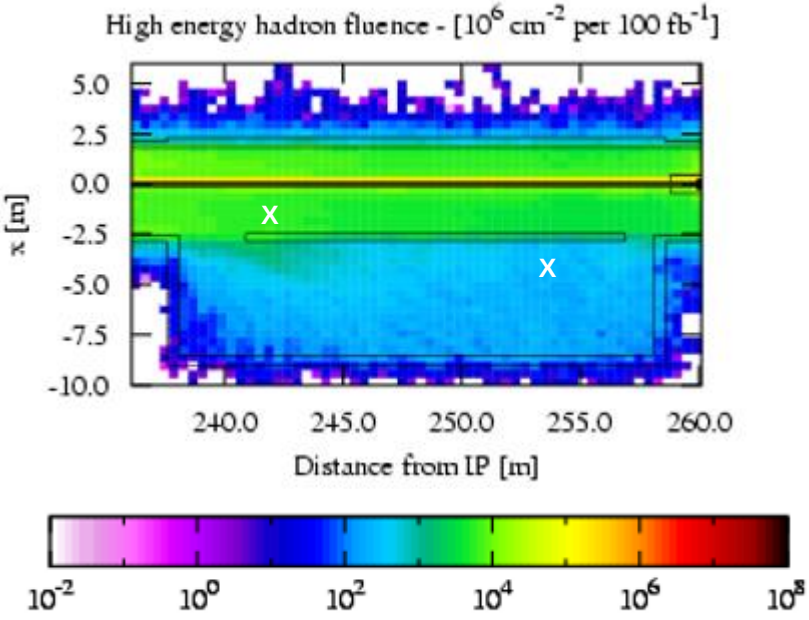
# 2015 RadMON measurements – RR13 & 17



# 2015 RadMON measurements – RR53 & 57



# FLUKA calculations for RR17 (present machine) [1]




Tunnel side: **~5·10⁹**
2015 measurement: **1.45-2.99·10⁹**

Shielded side: **~3·10⁸**
2015 measurement: **1.00-5.0·10⁸**

*in **HEH/cm²/100 fb⁻¹** units (2015 measurements are scaled from 4.2 fb⁻¹)*

*Note: simulation RR shielding is 40 cm concrete whereas cast iron is present since LS1. Also, TLC6 was not present (as is the case for 2015 and 2016 runs, where it is open).*

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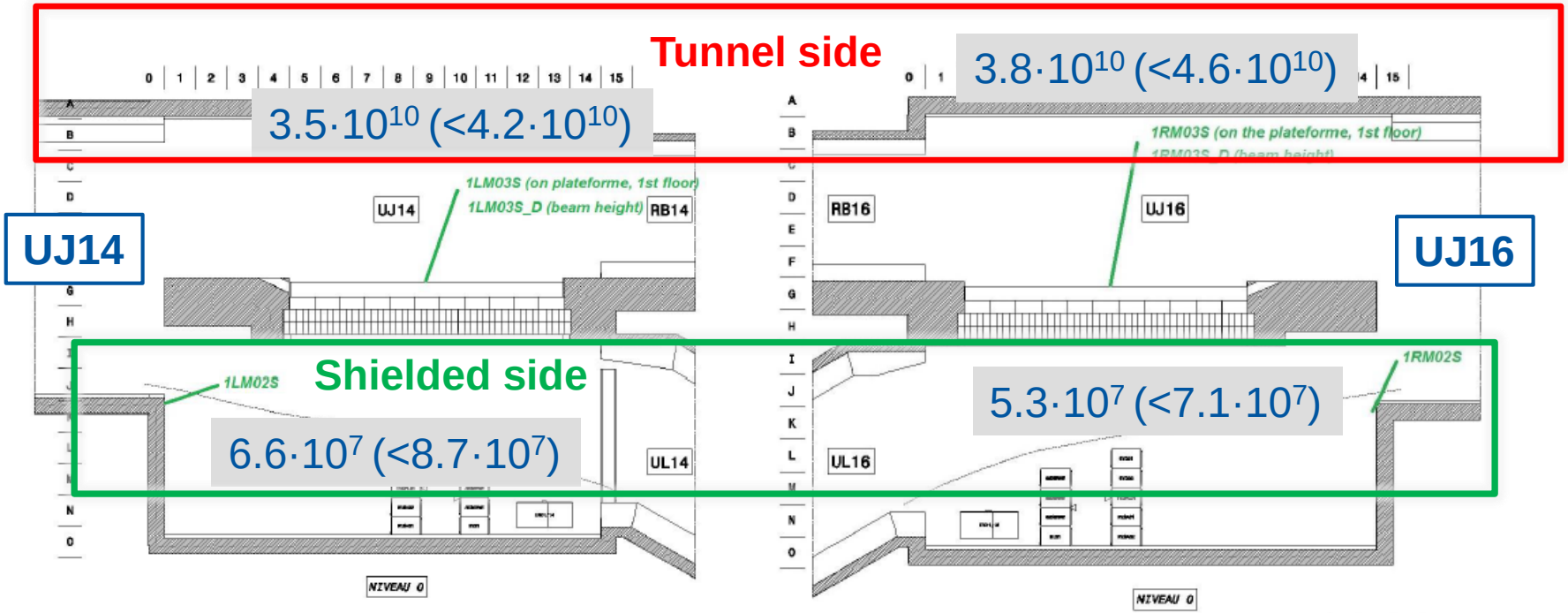
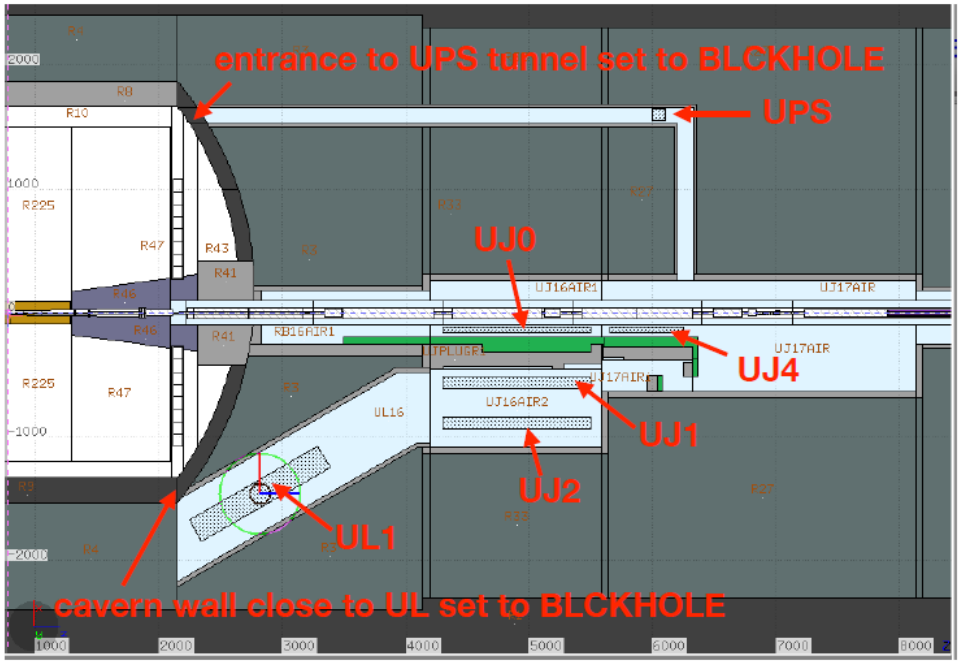
# 2015 RadMON measurements – UJ13, 14, 16 & 17

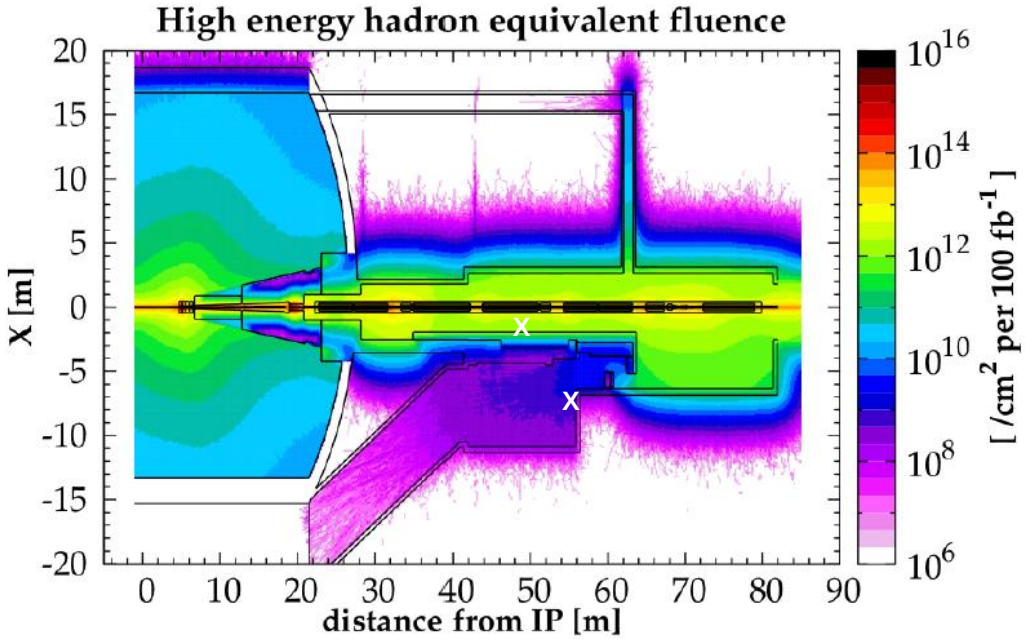


# FLUKA geometry for UJ, UL and UPS [5]




*Leakage from UX to UL and UPS not considered in simulation*

# FLUKA calculations for UJ16 & 17 (present machine) [5]



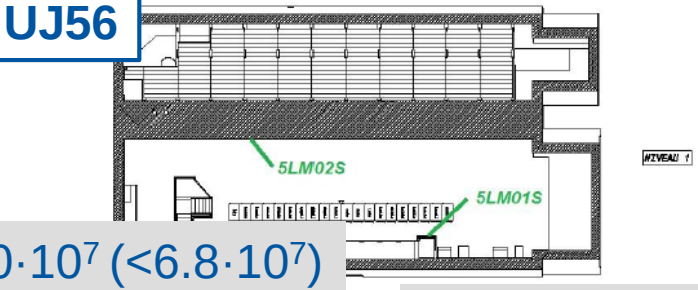

Tunnel side: **~2·10$^{12}$**
2015 measurement: **0.70-1.10·10$^{12}$**

Shielded side: **~1·10$^{9}$**
2015 measurement: **0.87-1.70·10$^{9}$**

*in **HEH/cm$^2$/100 fb$^{-1}$** units (2015 measurements are scaled from 4.2 fb$^{-1}$)*

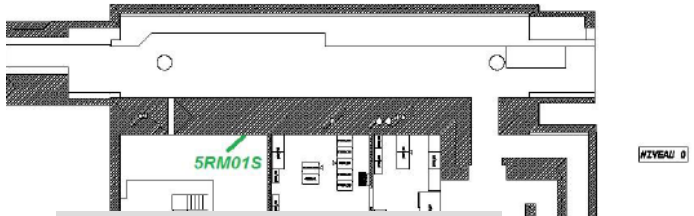
# 2015 RadMON measurements – UJ56

**UJ56**

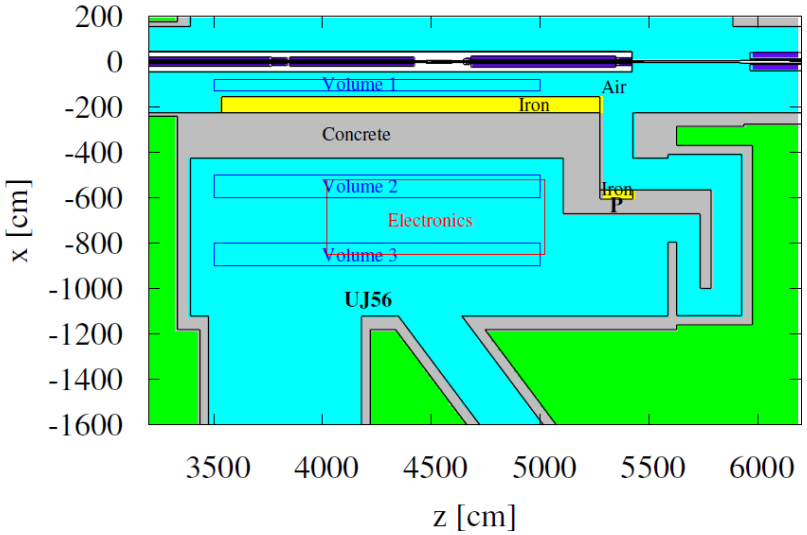



$5.0 \cdot 10^7$ ($<6.8 \cdot 10^7$)

$3.8 \cdot 10^6$ ($<4.6 \cdot 10^6$)



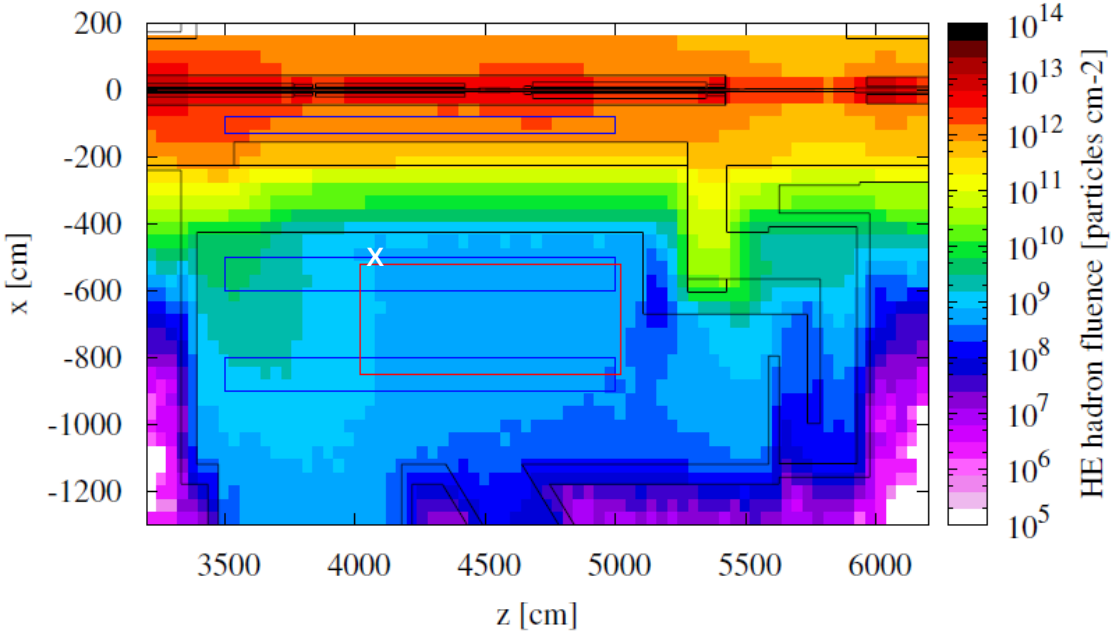

$9.0 \cdot 10^7$ ($<1.16 \cdot 10^8$)



# FLUKA calculation for UJ56 [3]

Shielded side: **~1·10⁹**
2015 measurement: **1.58-2.76·10⁹**

*in **HEH/cm²/100 fb⁻¹** units (2015 measurements are scaled from 4.2 fb⁻¹)*



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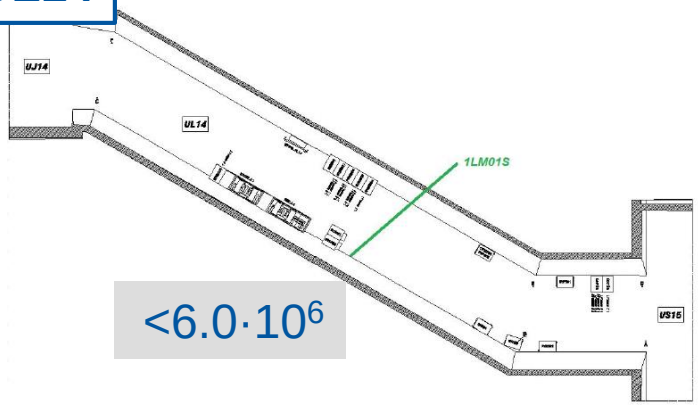
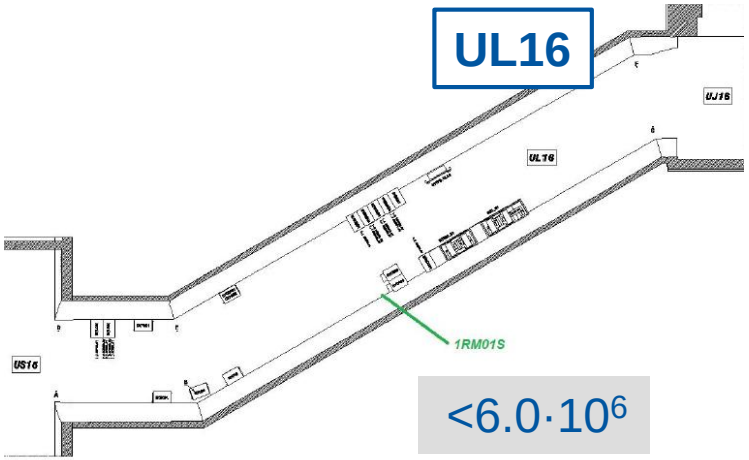
# 2015 RadMON measurements – UL14 & 16

**UL14**




<$6.0 \cdot 10^6$

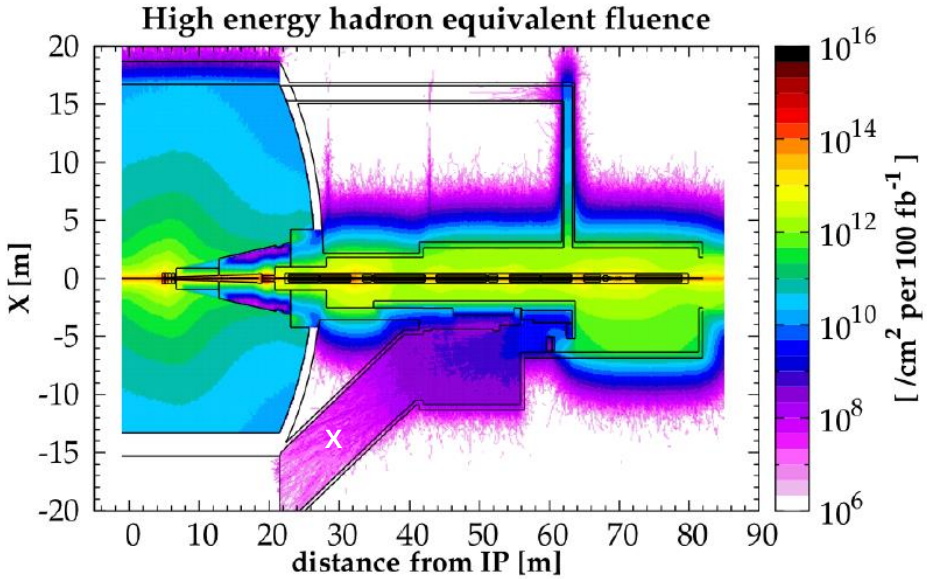
**UL16**




<$6.0 \cdot 10^6$

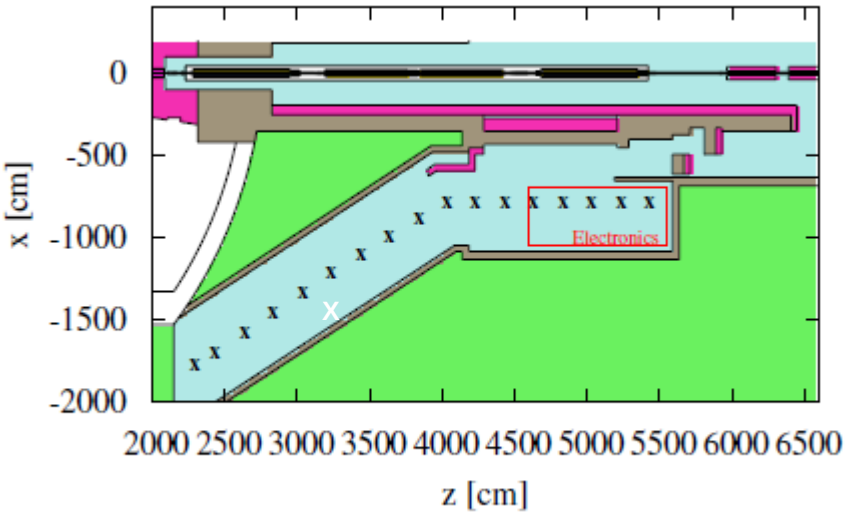
*Only upper limit is available (0 or 1 events per RadMon)*

# FLUKA calculations for UL16 (present machine) [5]

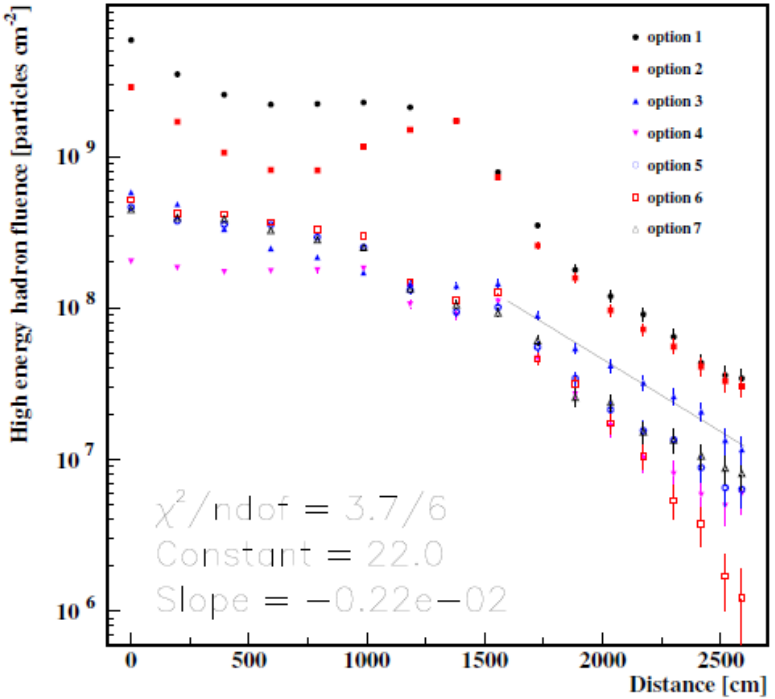



Mid-way UL:
**~2.1·10$^{7}$ HEH/cm$^{2}$/100 fb$^{-1}$**

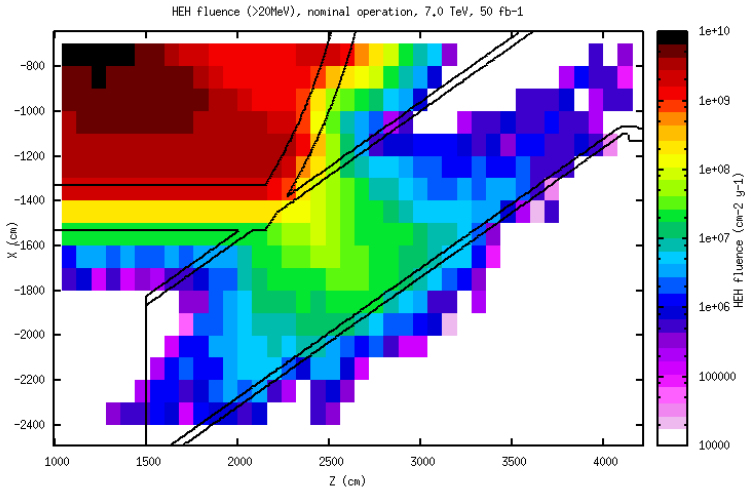
# FLUKA calculations for UL16 (present machine) [4]



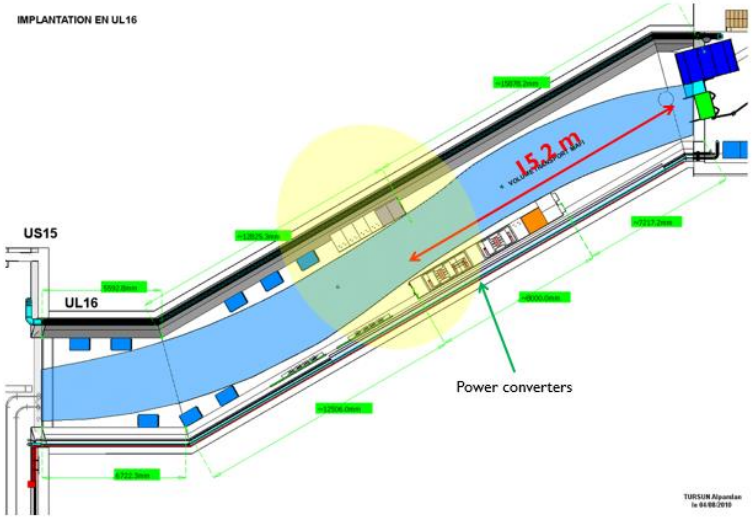

*Strong HEH fluence gradient*



# UL exclusion zone from UX leakage [2]




*Only for relative comparison*




*Exclusion Zone in UL*

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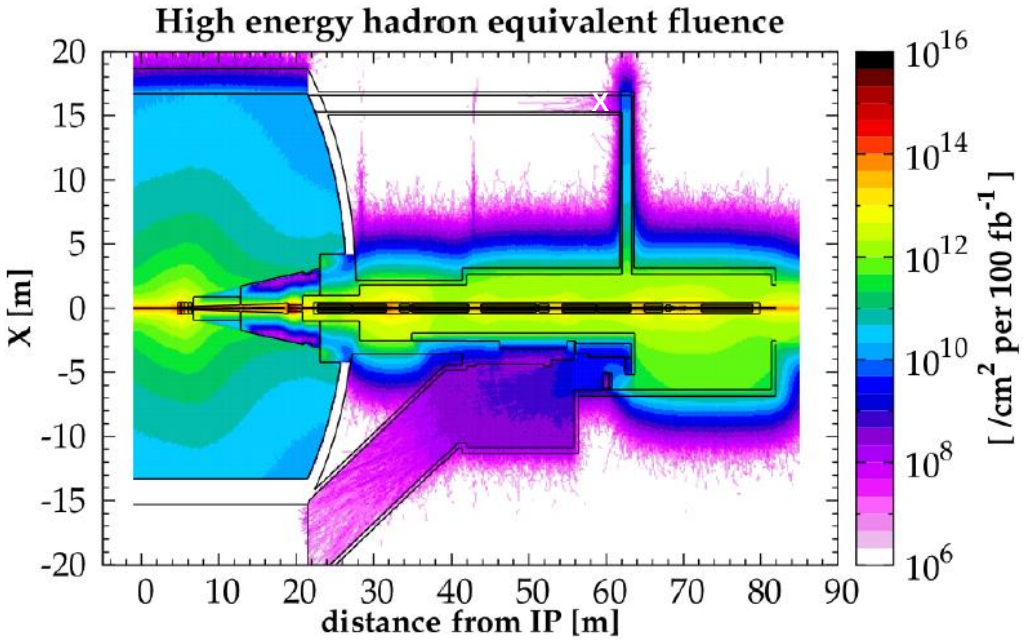
# FLUKA calculations for UPS16 (present machine)




UPS (after corner):
**~5.7·10⁷ HEH/cm²/100 fb⁻¹**

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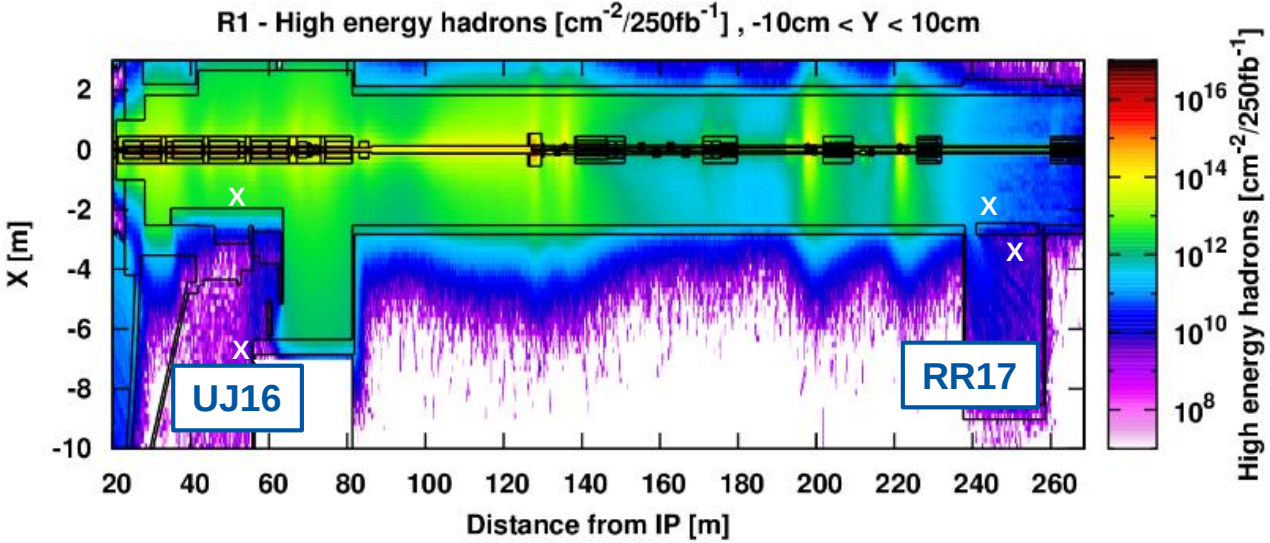
# FLUKA calculations for UJ & RR P1 (HL LHC)

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**UJ tunnel:**

$\Phi_{HEH}^{FLUKA} \sim 4.5 \cdot 10^{12}$

$\Phi_{HEH}^{2015} = 1.77\text{-}2.76 \cdot 10^{12}$

**UJ shielded:**

$\Phi_{HEH}^{FLUKA} \sim 3 \cdot 10^{9}$

$\Phi_{HEH}^{2015} = 2.18\text{-}4.3 \cdot 10^{9}$

**RR tunnel:**

$\Phi_{HEH}^{FLUKA} \sim 1.5 \cdot 10^{11}$

$\Phi_{HEH}^{2015} = 3.6\text{-}7.5 \cdot 10^{9}$

**RR shielded:**

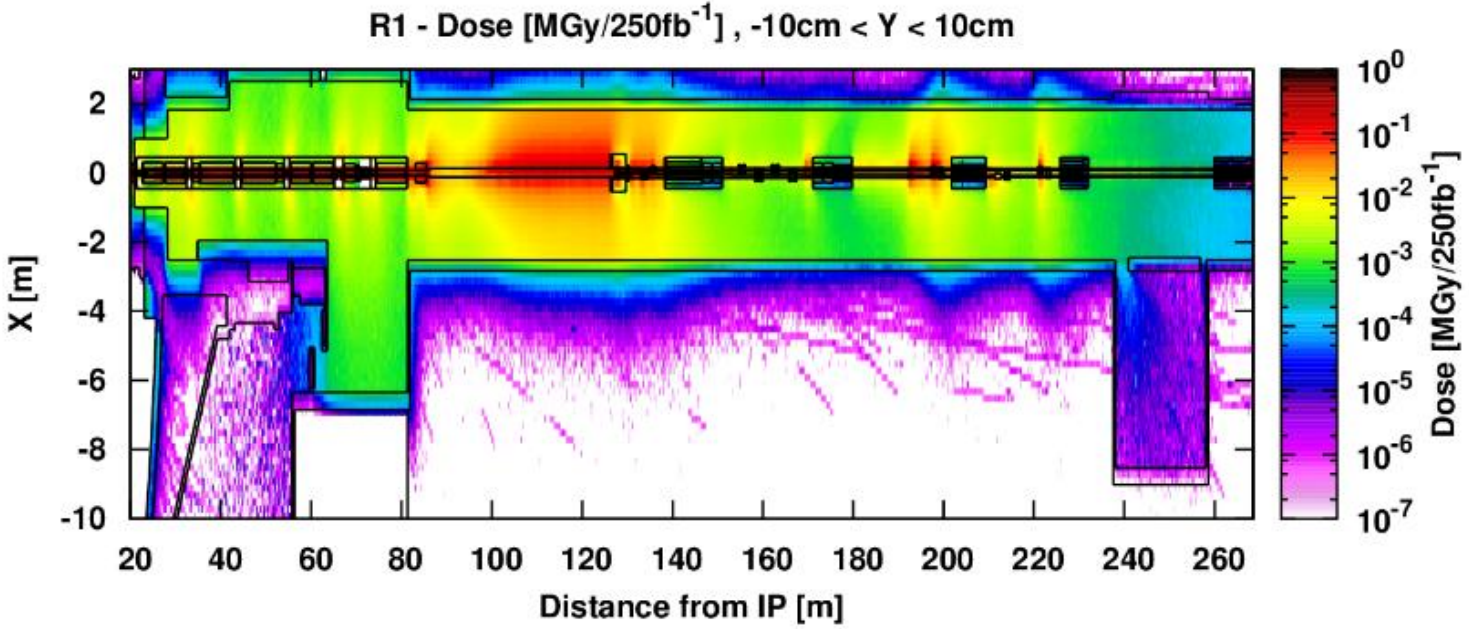
$\Phi_{HEH}^{FLUKA} \sim 1 \cdot 10^{10}$

$\Phi_{HEH}^{2015} = 0.25\text{-}1.24 \cdot 10^{9}$

# FLUKA calculations for UJ & RR P1 (HL LHC)

- For the UJs near P1 and P5, the scaling of the 2015 HEH fluence measurements with luminosity is compatible with what is expected in FLUKA
- For the RRs however, FLUKA predicts a **factor 10 larger fluence** as compared with the 2015 measurement scaling – which can in principle be attributed to the different machine layout (e.g. stronger leakage in this area, dependence on TLC settings, etc.)

# FLUKA calculations for UJ & RR P1 (HL LHC)

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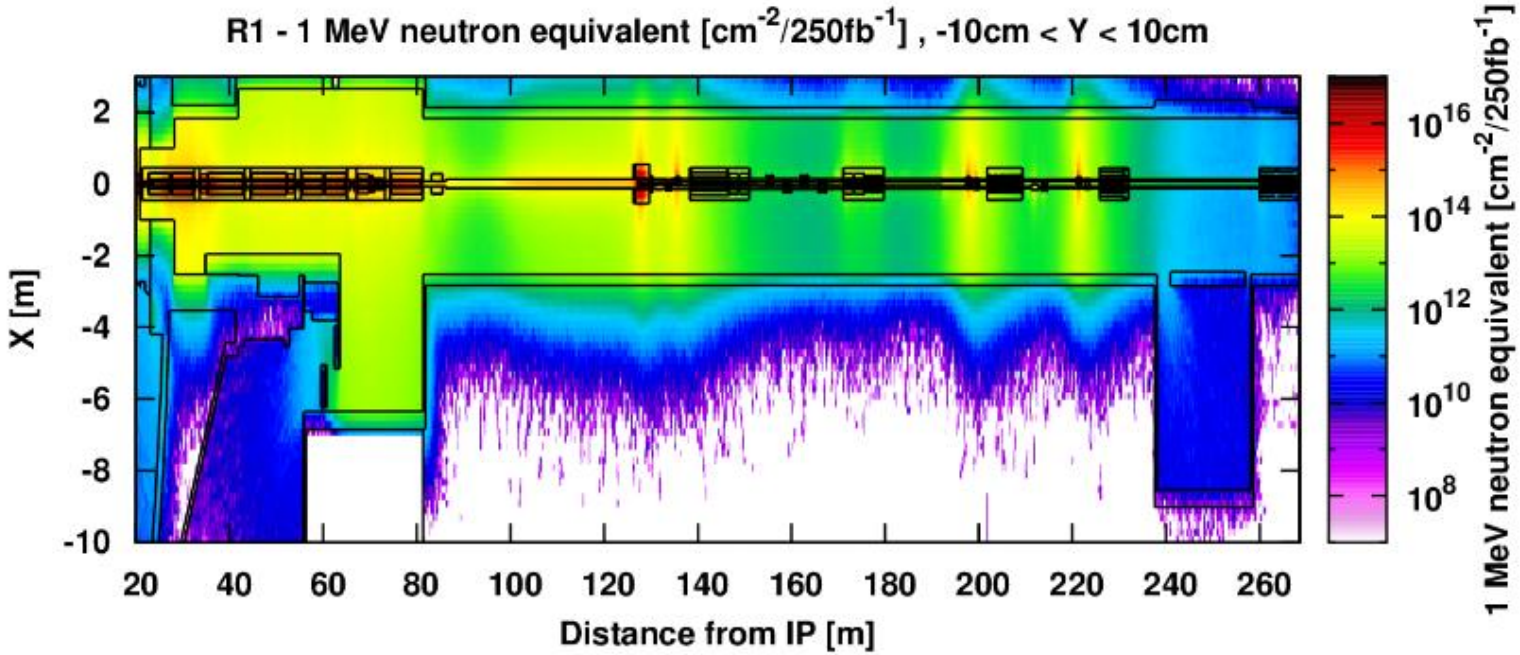
# FLUKA calculations for UJ & RR P1 (HL LHC)

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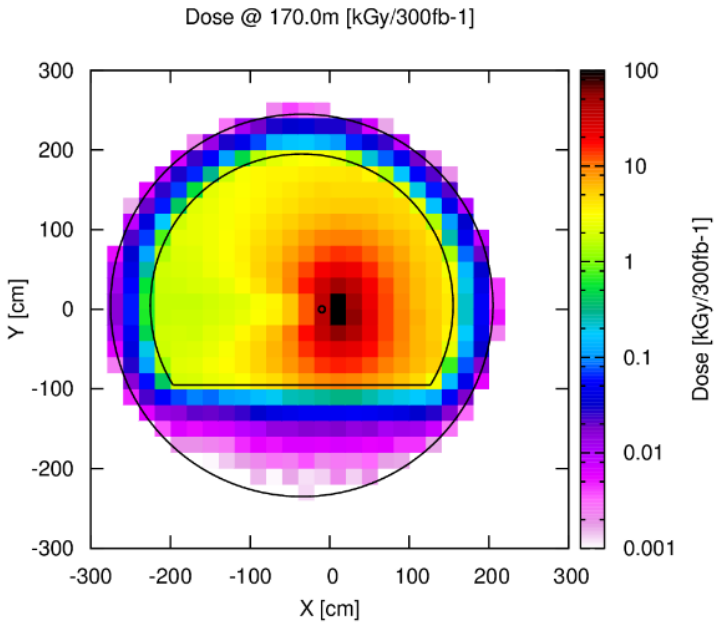
# FLUKA calculations for UJ & RR P5 (HL LHC)




*©A. Tsinganis*

- Vertical tunnel cut at 170m from IP5 (i.e. most exposed longitudinal position in the crab-Q4 region)

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# Summary and Conclusions

- Expected shielded area HL-LHC annual radiation levels for P1 & P5:
  - **UJ: ~5·10$^{9}$ HEH/cm$^{2}$** (can be scaled from present machine)
  - **RR: ~1·10$^{10}$ HEH/cm$^{2}$** (scaling from present machine can lead to one order of magnitude underestimation)
  - **UL: ~1·10$^{9}$ HEH/cm$^{2}$** near UJ (to be further analysed through calculations, also considering the exclusion zone due to leakage from UX)

# Summary and Conclusions

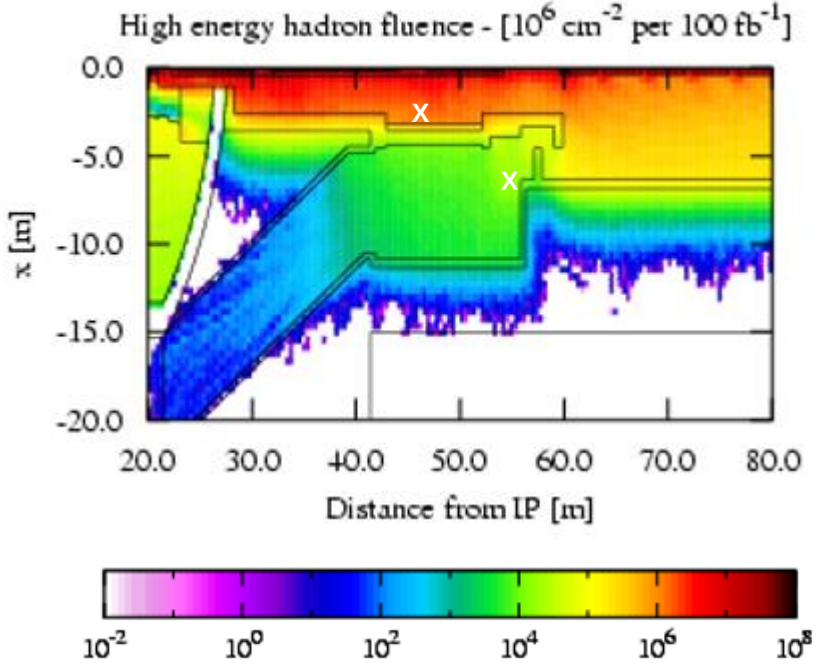
- In calculations, **UPS** currently set to black-hole (i.e. no radiation level scoring) however can be enabled to try to obtain statistically meaningful radiation level results
- For areas below main quadrupoles (**BPM/BLM electronics**) present in P1 & P5 simulation, radiation levels can be extracted. Present results cover up to Q7 but DS model is available and can be added. Values for P7 (collimation) are also available (A. Lechner)
- For the **technical alcoves** in P5 (**crab cavities**) attenuation approximations are available, however dedicated simulations can be implemented/run

# Links to simulation reports and presentations


- [1] *"Expected radiation conditions in IR1 and IR5",* F. Cerutti for the FLUKA Team, 2009
- [2] *"ATLAS-UX/UL junction hadron fluence evaluation"* M. Calviani, 1st MCWG meeting, 2010
- [3] *"R2E FLUKA studies for Point 1 and Point 5"* R. Versaci et al, CERN-ATS-Note-2010-046 PERF (link)
- [4] *"Updates on R2E FLUKA studies for Point 1 and Point 5",* R. Versaci et al, ATS-Note-2011-008 PERF (link)
- [5] *"Fluence estimation in UJ, UL, UPS for HL-LHC Point 1"* L. Esposito, 2013
- [6] *"Debris impact in the TAS-triplet D1 region"* F. Cerutti, L. Esposito, 4th Joint HiLumi LHC-LARP Annual meeting, 2014 (link)
- [7] "Energy deposition in the Matching Section (v1.2)", A. Tsinganis, F. Cerutti, ColUSM #67, 2016 (link)
- [8] *"V1.2 reevaluation of collision debris impact on the IT region – and matching section -. The role of the interconnections and BPM."* F. Cerutti, A. Tsinganis, 5th HL-LHC TCC, 2016 (link)

# Backup/Annex

# FLUKA calculations for UJ16 & 17 (present machine*) [1]

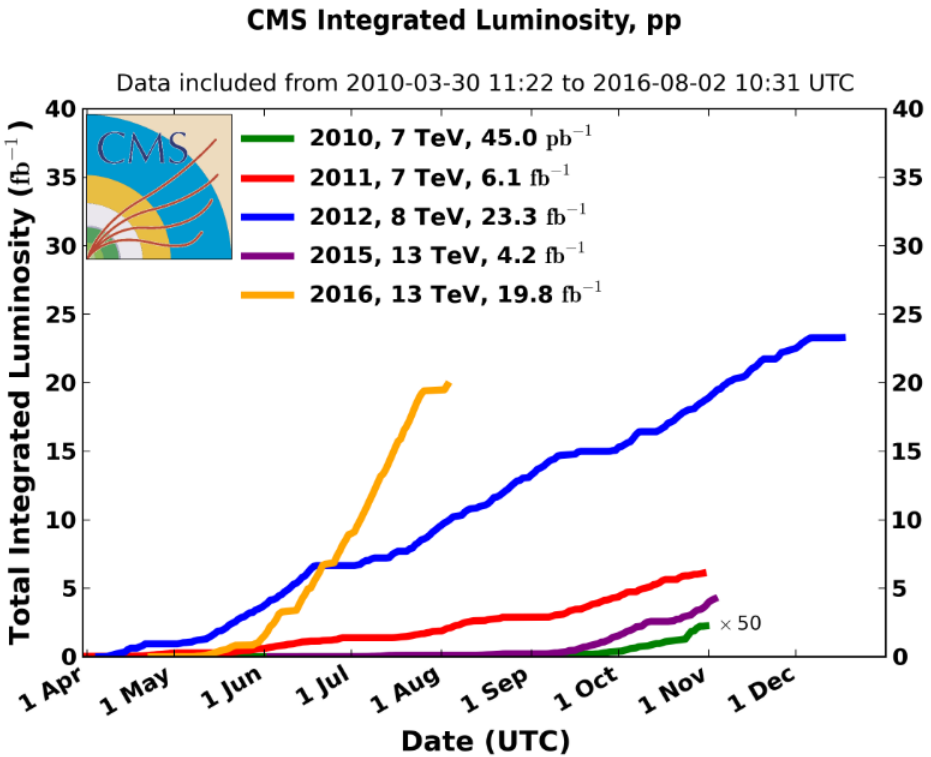



Tunnel side: **~3·10$^{12}$**
2015 measurement: **0.73-1.14·10$^{12}$**

Shielded side: **~1·10$^{10}$**
2015 measurement: **0.87-1.70·10$^{9}$**

*in **HEH/cm$^2$/100 fb$^{-1}$** units (2015 measurements are scaled from 4.2 fb$^{-1}$)*

** Before reinforcement of UJ16 shielding in EYETS 2011-2012*




Considered 2015 luminosity:
**4.2 fb$^{-1}$**

http://cms-service-lumi.web.cern.ch/cms-service-lumi/publicplots/int_lumi_cumulative_pp_2.png

# CHARM test facility

- Mixed-field test facility representative of the high-energy accelerator environment