HSE
Radiation Protection

PBC Projects at LHC and SPS North Area

RP Seminar, 21 November 2024

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Supervisors:

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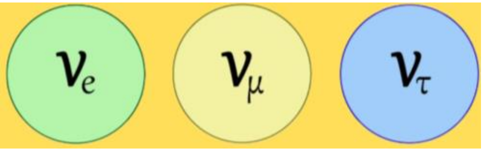
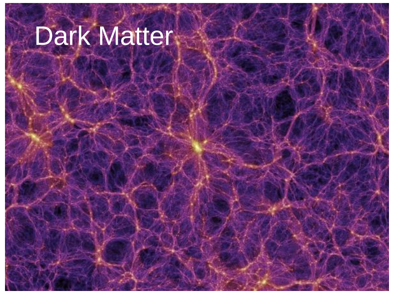
PBC: Physics Beyond Colliders

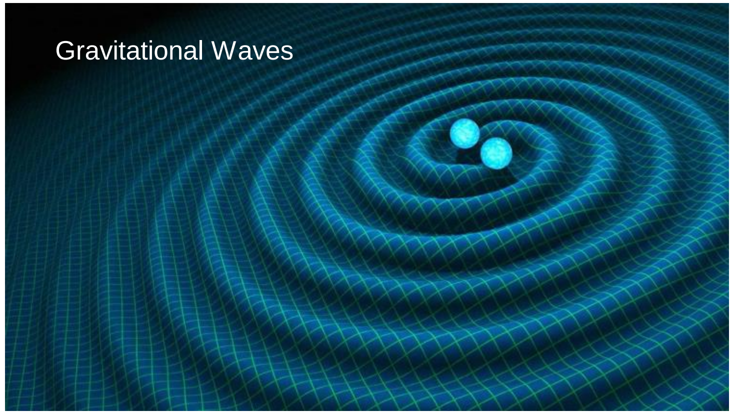
- PBC projects “explore the opportunities offered by the CERN accelerator complex and infrastructure to address some of today’s outstanding questions in particle physics through experiments complementary to high-energy colliders and other initiatives in the world”

- Projects I have worked on:

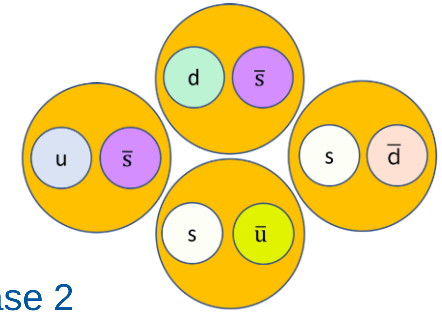
- LHC:
  - AdvSND-NEAR
  - AION100

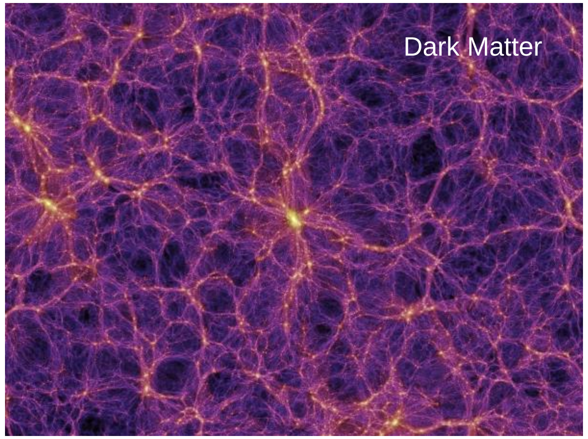






- SPS:
  - HIKE Phase 2
  - TCC8 Decommissioning





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PBC Projects at LHC

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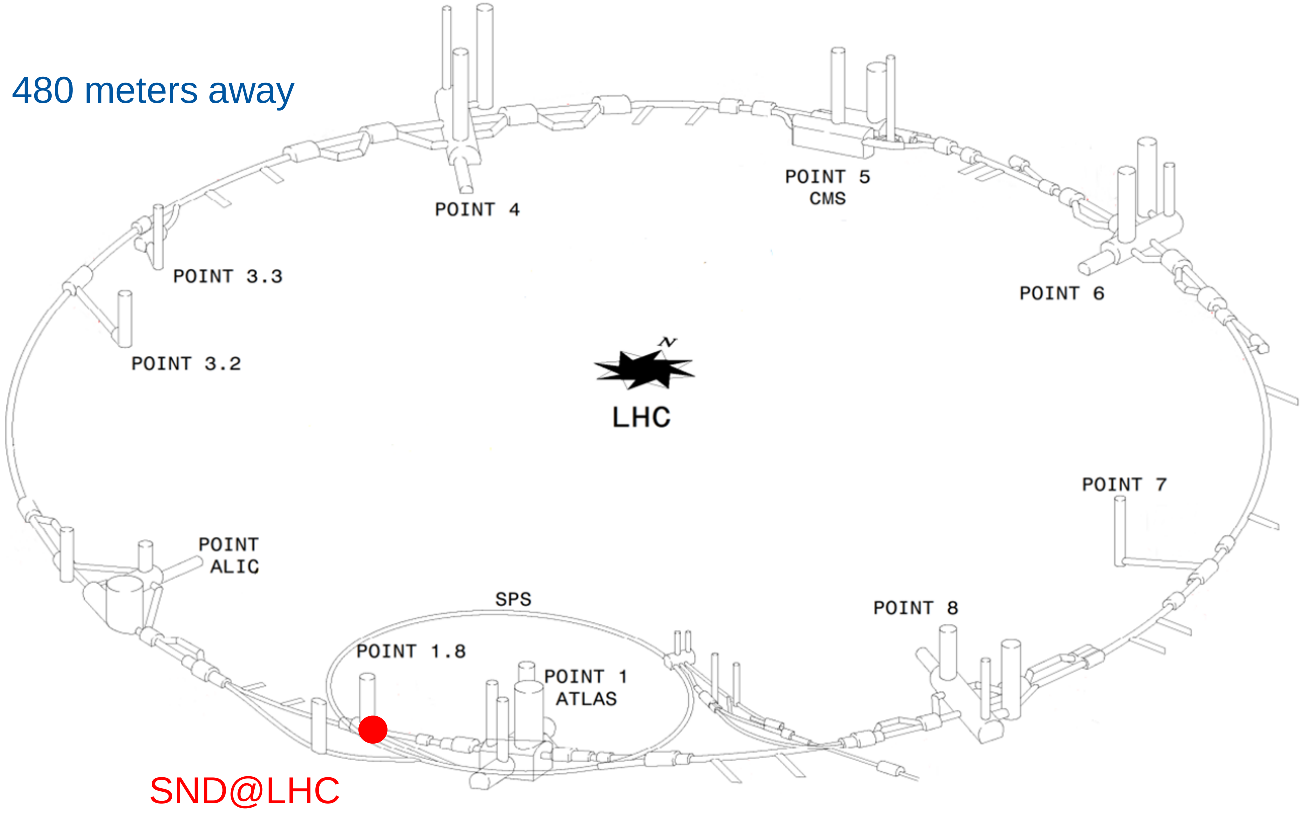
Scattering and Neutrino Detector (SND)

SND at LHC

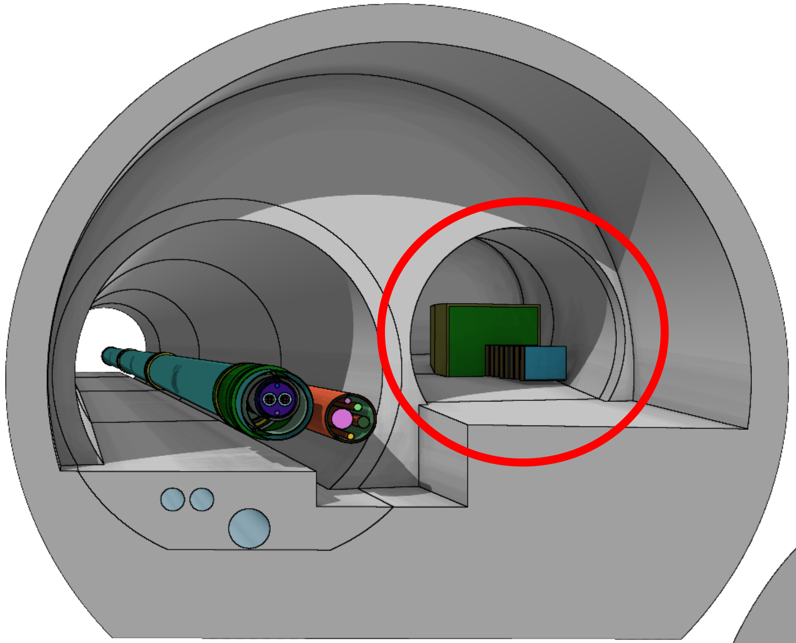
- The SND (Scattering and Neutrino Detector) at LHC (SND@LHC) is a stand-alone experiment to perform measurements with neutrinos of all three different flavours. They are produced at LHC Point 1 and they come from charmed-hadron decays. Additionally, SND@LHC is sensitive to feebly-interacting particles (dark matter).

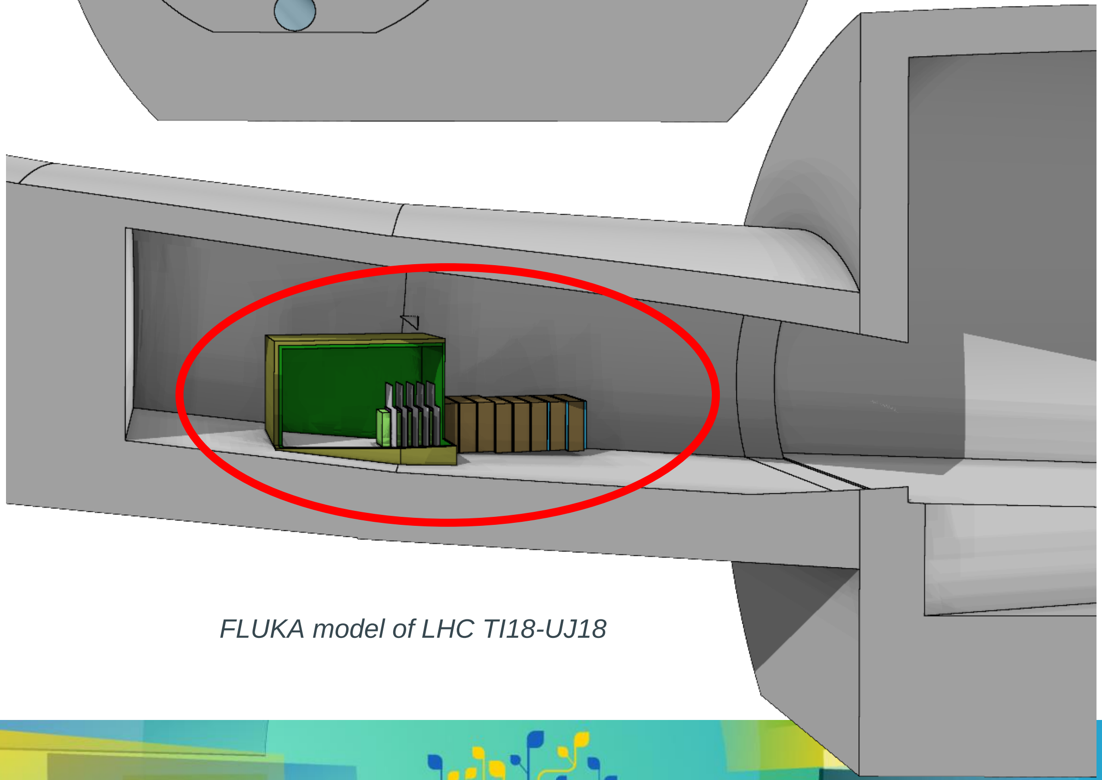
- SND@LHC is currently running and it is located in the TI18 tunnel, 480 meters away from IP1, on the right-hand side.



SND at LHC: FLUKA Geometry

- RP FLUKA simulations used all along the design process and for planning emulsion replacement.
- FLUKA model of the SND detector integrated in the LHC machine infrastructure (TI18).
- Modelling based on information provided by SND team (position, dimensions, materials, etc).



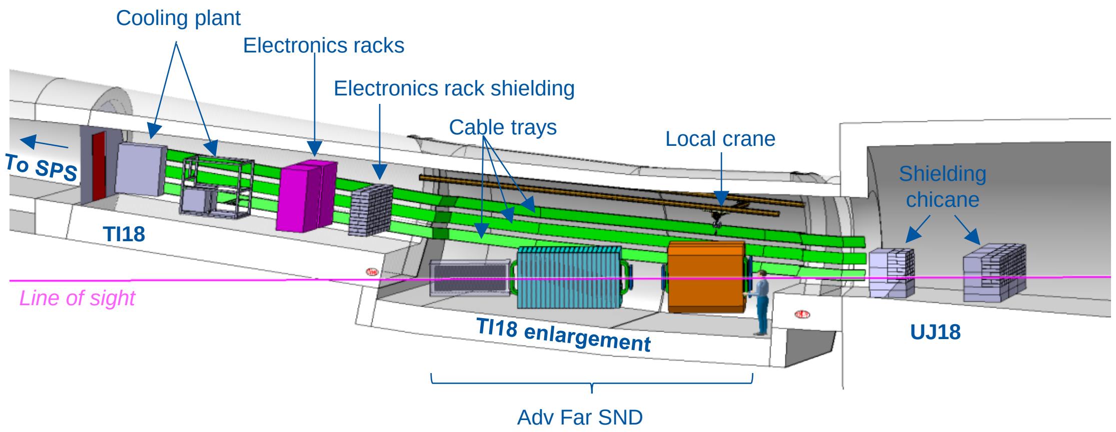


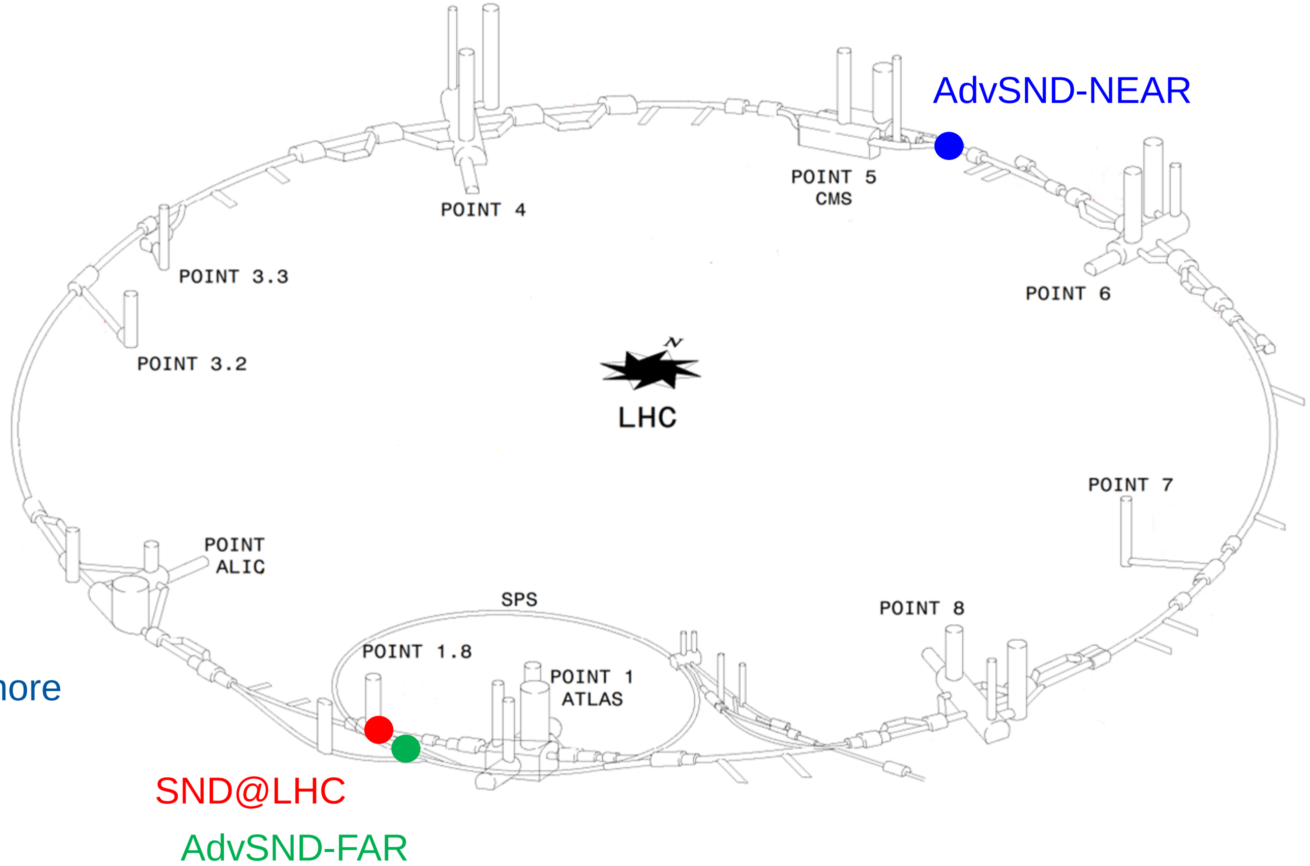
FLUKA model of LHC TI18-UJ18

AdvSND

- The newer generation of the SND detector is called AdvSND@LHC. It is an upgrade of the SND@LHC experiment. There are two projects for it:

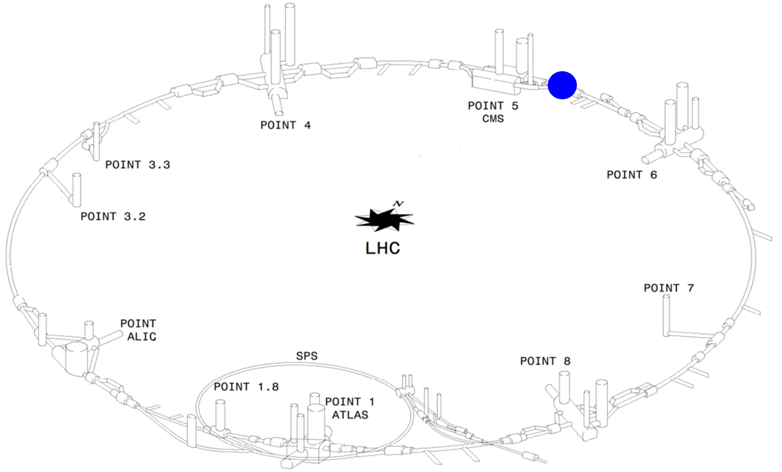
  - **AdvSND-FAR**: planned to replace the present SND detector, in the TI18 tunnel. This project has priority since it will start earlier, as it is easier to carry out.
    - CE works: LS3 , Foreseen Operation: Run 4



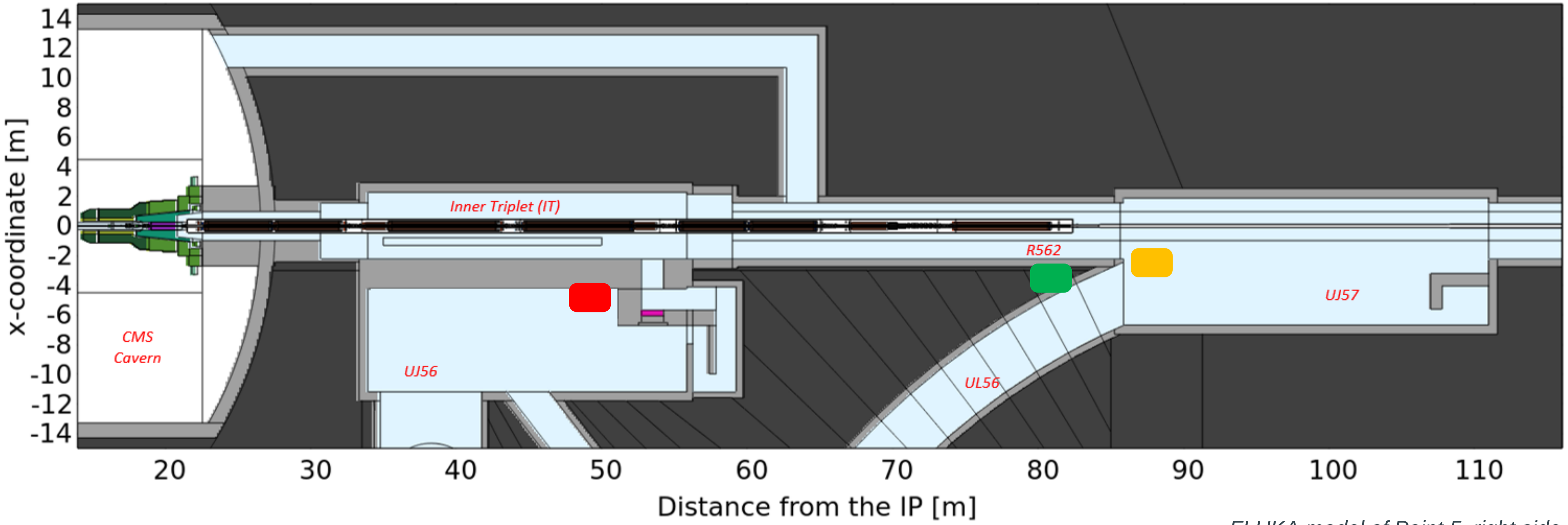


  - **AdvSND-NEAR**: planned to be placed near Point 5. It is a more challenging project.
    - Foreseen Operation: Run 5

AdvSND-NEAR



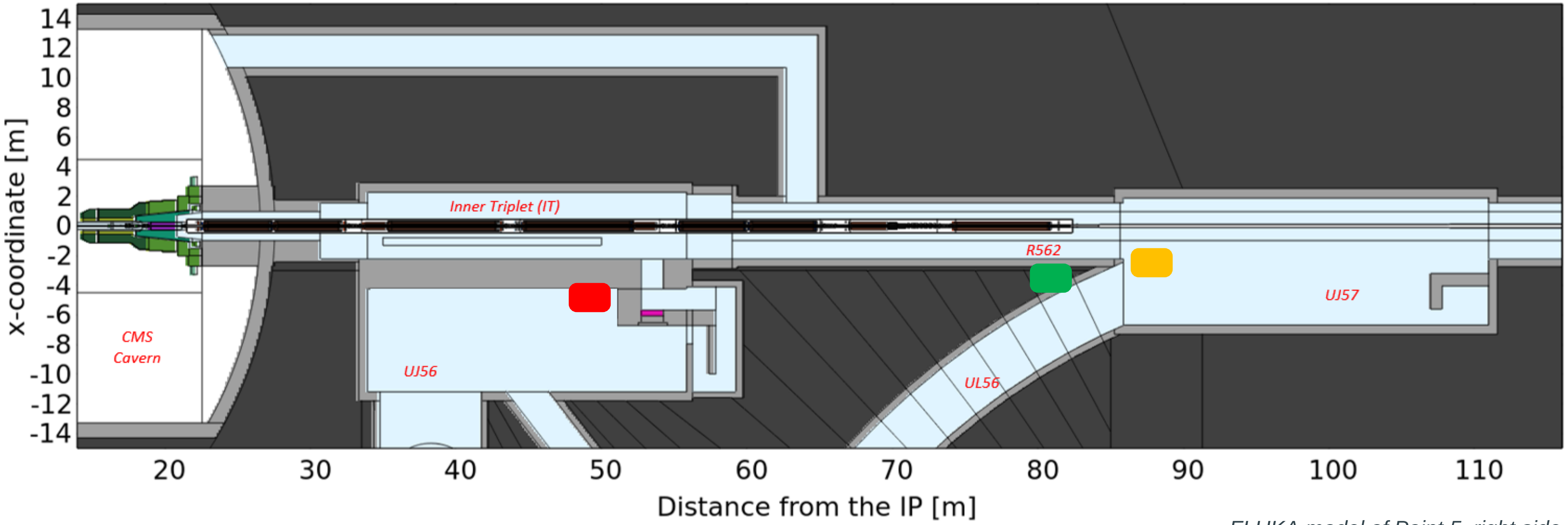
- Three different possible locations have been studied from an RP point of view:
  - UJ57
  - *Ad hoc* built alcove between UL56 and R562
  - UJ56



FLUKA model of Point 5, right side

AdvSND-NEAR: FLUKA Simulations

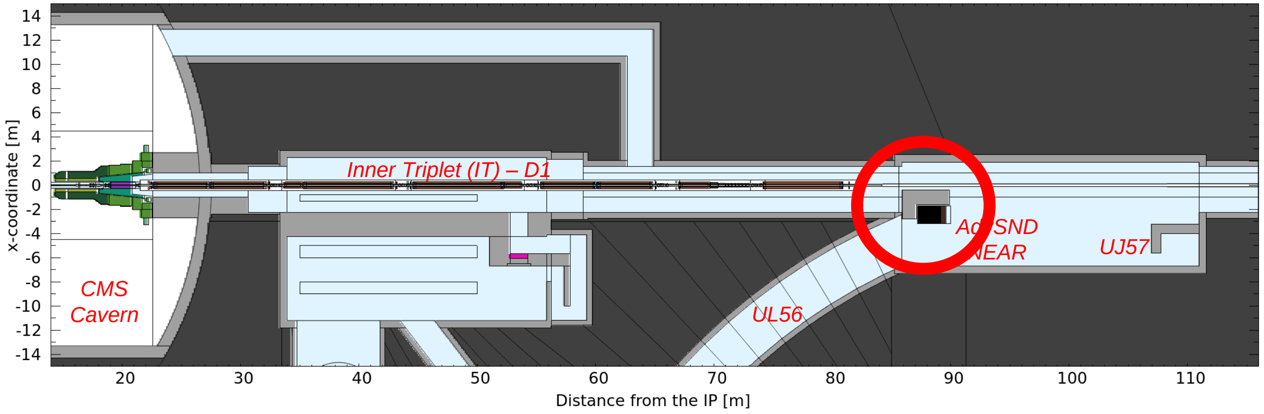
- HSE-RP FLUKA simulations consider a tentative model of the detector, a tentative shielding, and long-term projected HL-LHC performance.
- Source term: $\sqrt{s} = 14$ TeV pp collision debris in Point 5, in HL-LHC ultimate conditions.
- Full radiation transport along LSS5 – right side.
- Residual dose rate and detector activation are studied

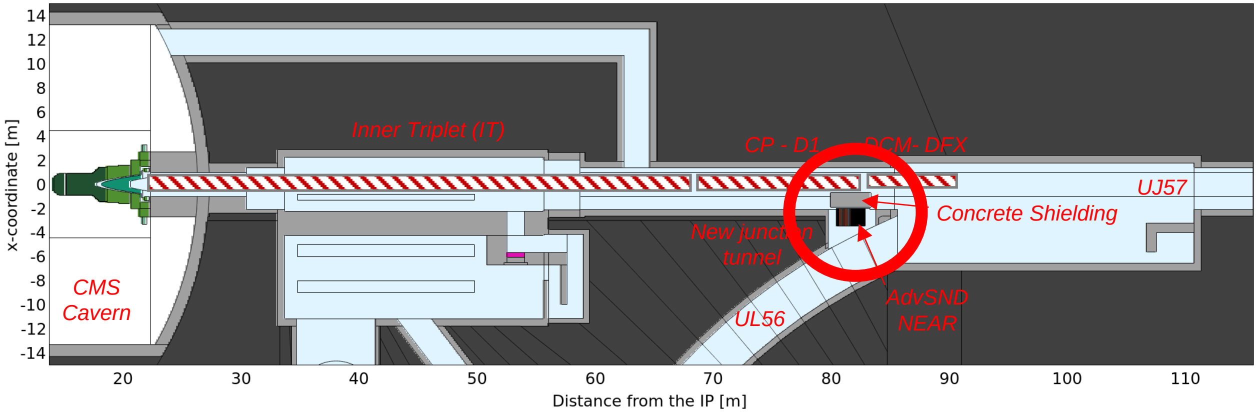


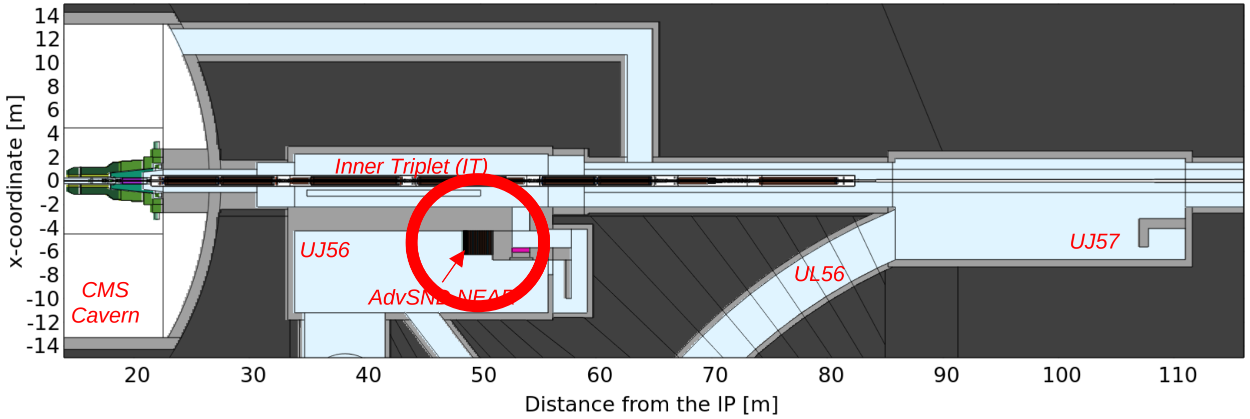
FLUKA model of Point 5, right side

AdvSND-NEAR: Geometries

FLUKA model of Point 5, right side



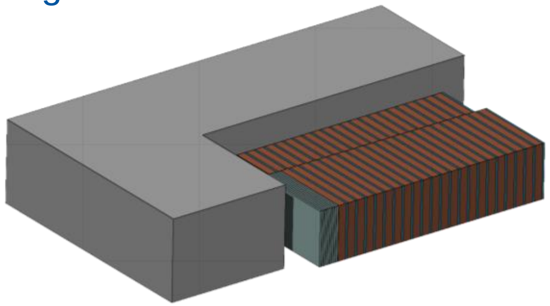


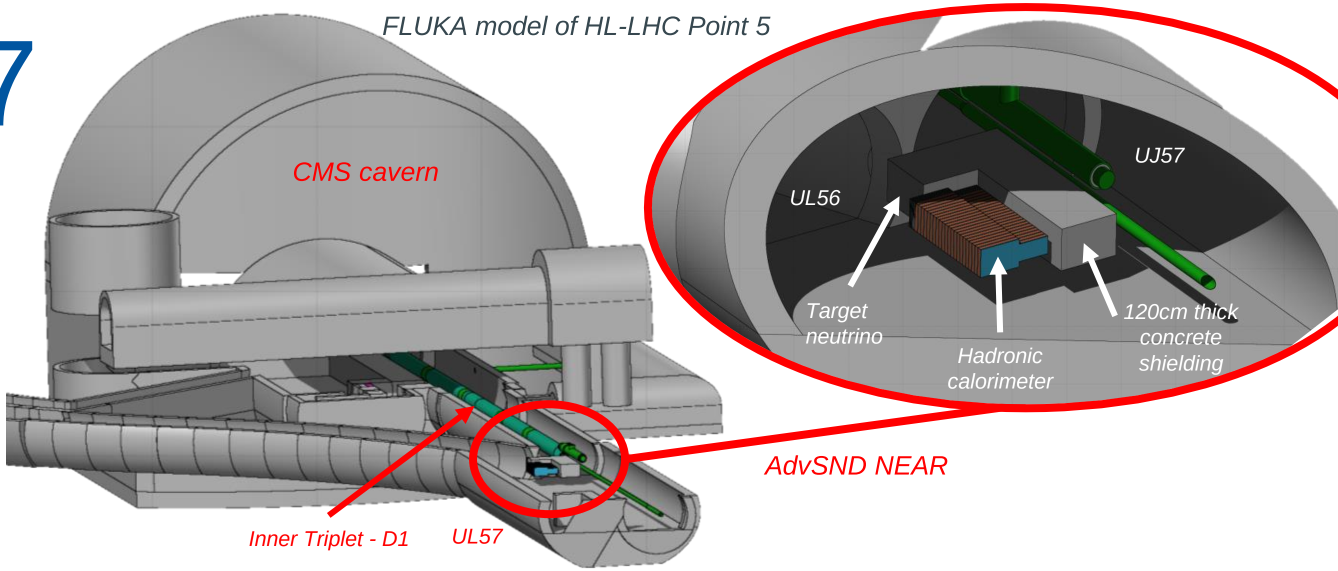


AdvSND-NEAR: UJ57

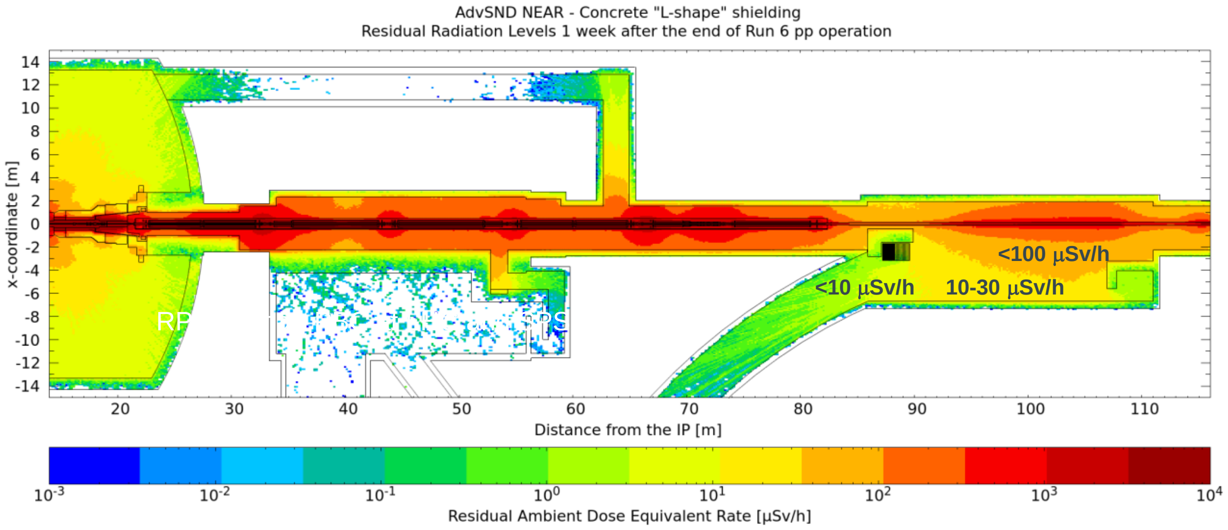
- HL-LHC FLUKA Geometry

- L-shaped shielding, designed to minimize detector background and NOT for RP purposes. Was this option to be chosen, an RP-oriented shielding should be designed.





- One week cooldown (e.g. Technical Stop):



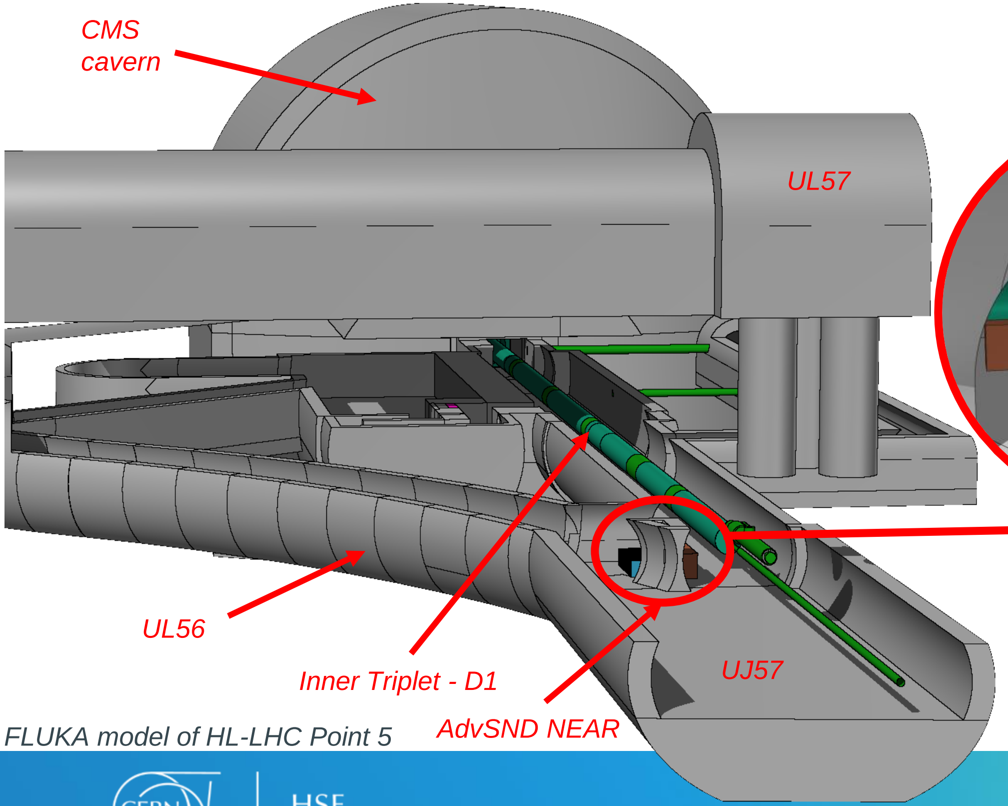
- Challenges and constraints:
  - Machine accessibility
  - Need to move the detector + cables + shielding during beam stop

- Residual radiation field in the UJ57 is significantly harsher than TI18 (<1uSv/h): detector + shielding expected to be, overall, above exemption limits.

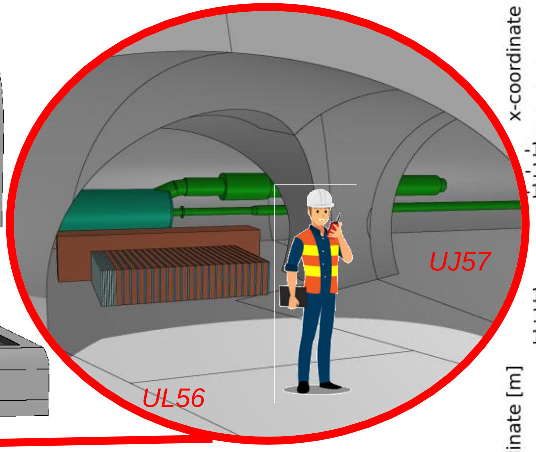
AdvSND-NEAR: Alcove

- Advantages:
  - Detector + Cables + Shielding do not need to be moved
  - Soil is partially used as shielding
- RP challenges and constraints:
  - Detector closer to the machine
  - Direct exposure to the D1/DCM radiation
  - Excavation spoils to be considered as radioactive waste

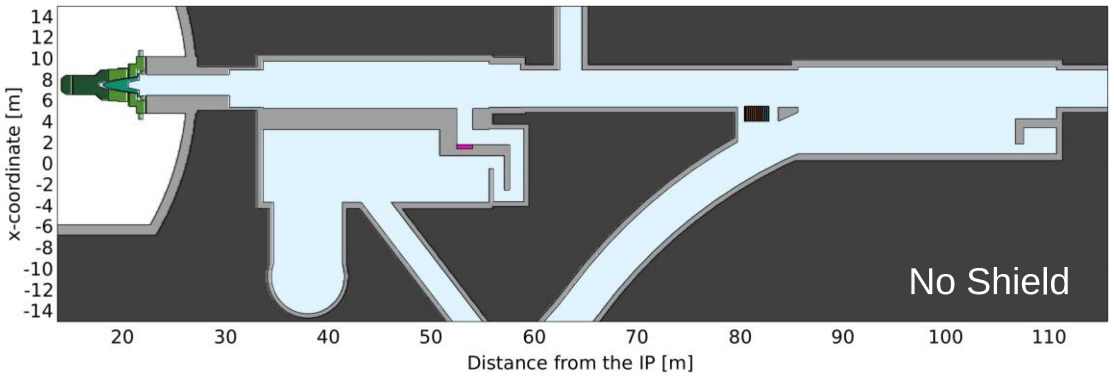
- FLUKA geometry modifications to create the alcove between UL56 and R562

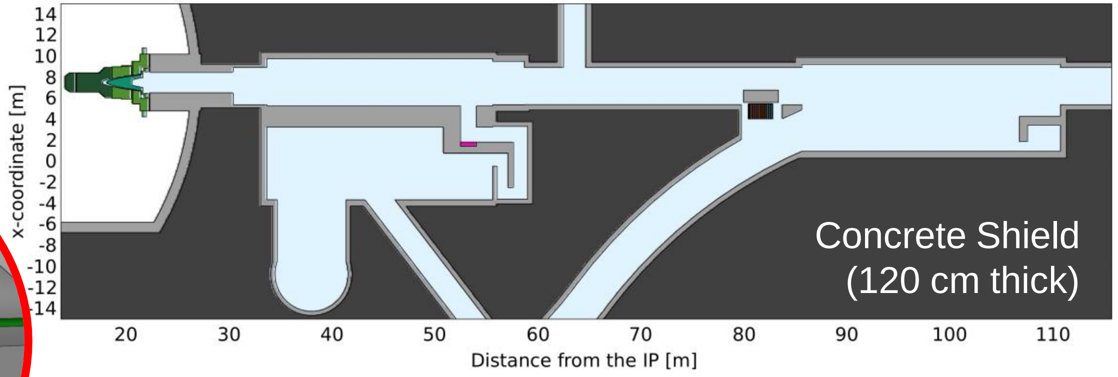


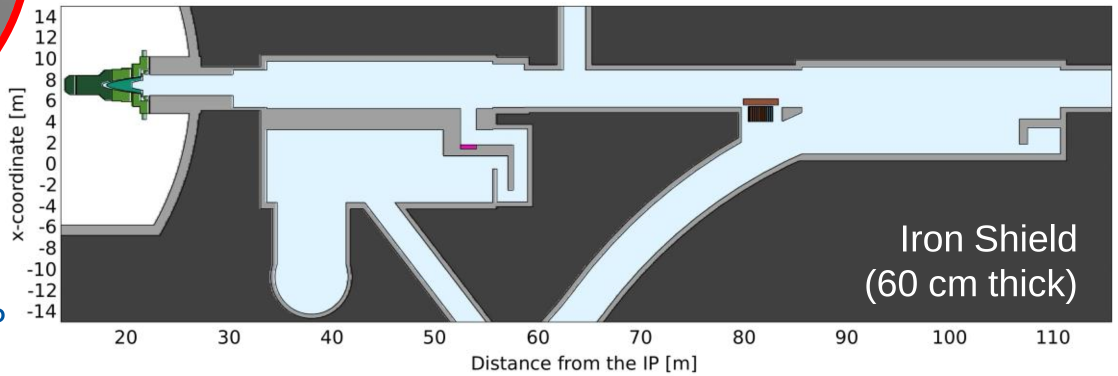
FLUKA model of HL-LHC Point 5



- Shielding shape optimized for detector background, not for RP



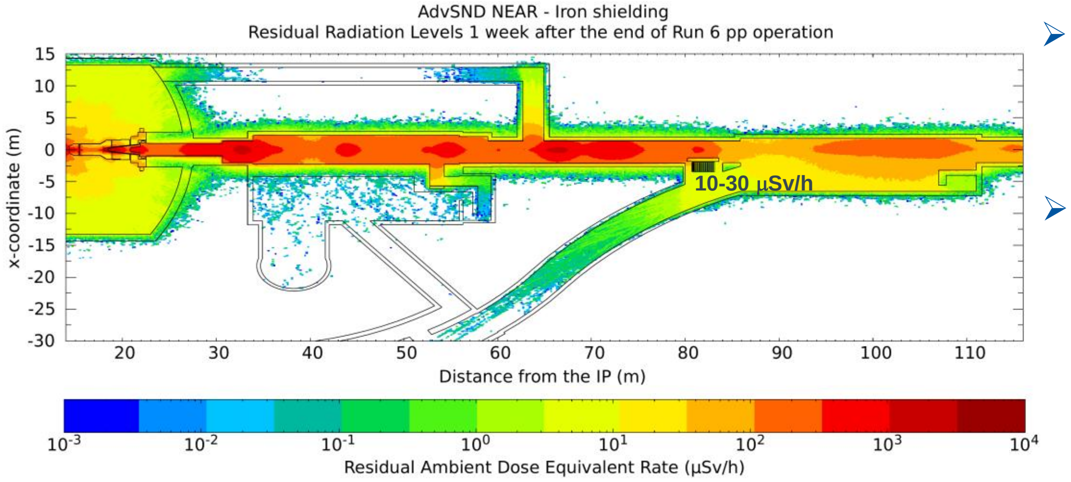


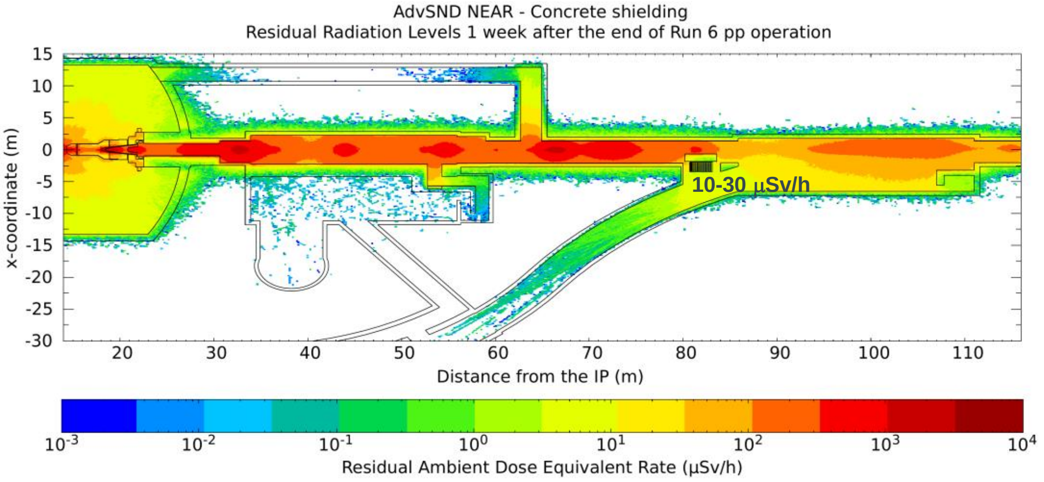


AdvSND-NEAR: Alcove

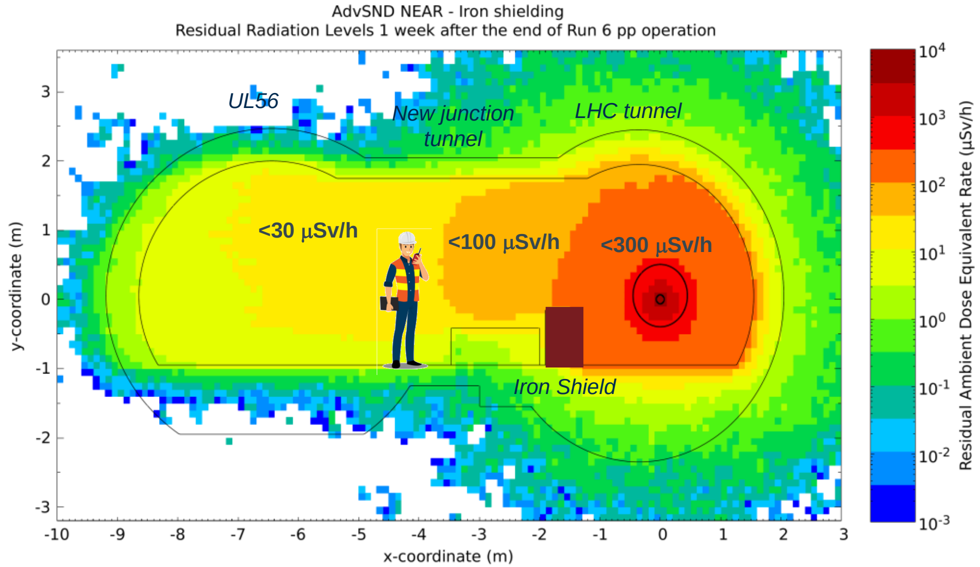
- FLUKA Results

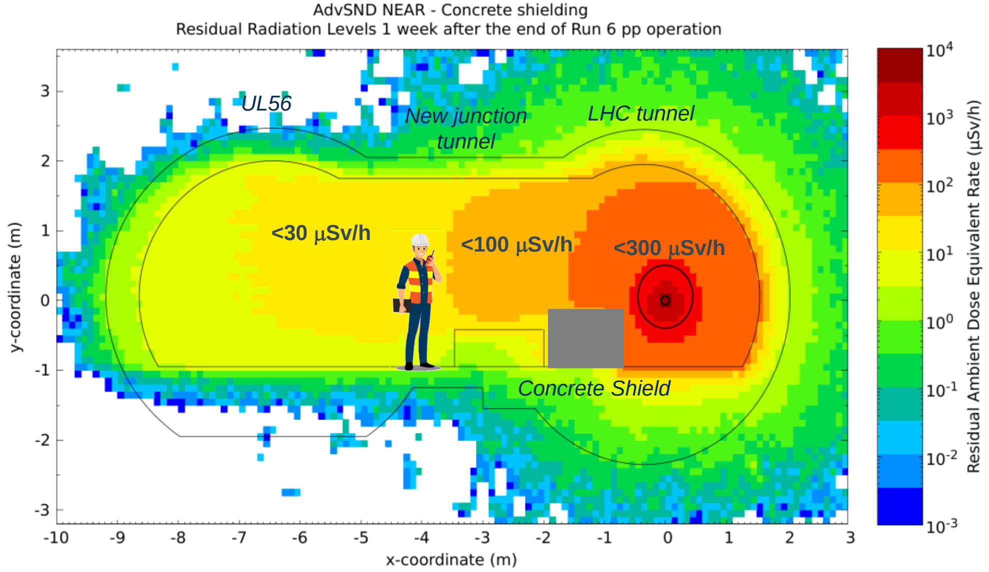
Detector height



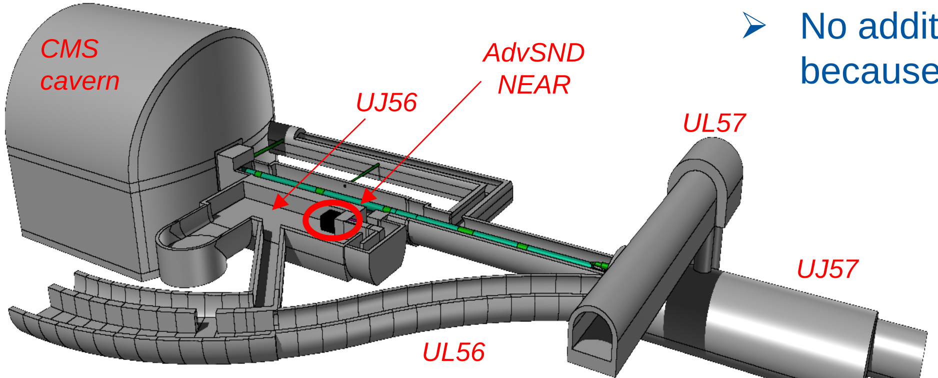


- No significant differences concerning area classifications
- Detector closer and in direct line-of-sight with the LHC machine → up to ~3x residual dose rate than in UJ57 for a person standing on the UL56 side, person standing in R562 potentially exposed to several hundreds of μSv/h
- Shielding presently not optimized for RP purposes → taller/ticker shielding would require an ad-hoc review together with HL-LHC integration & EN-HE teams.





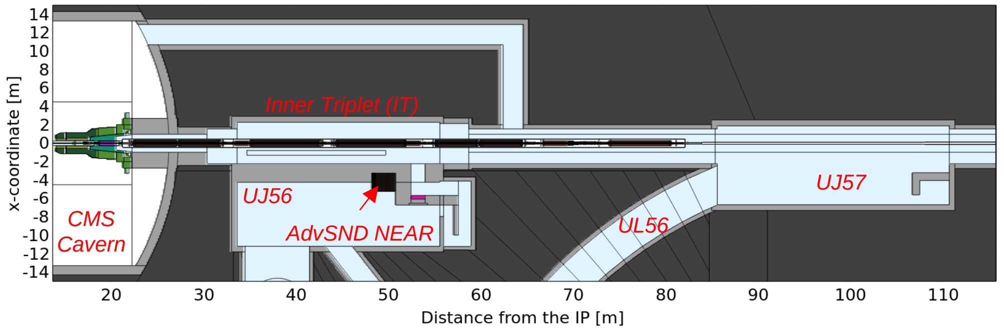
AdvSND-NEAR: UJ56



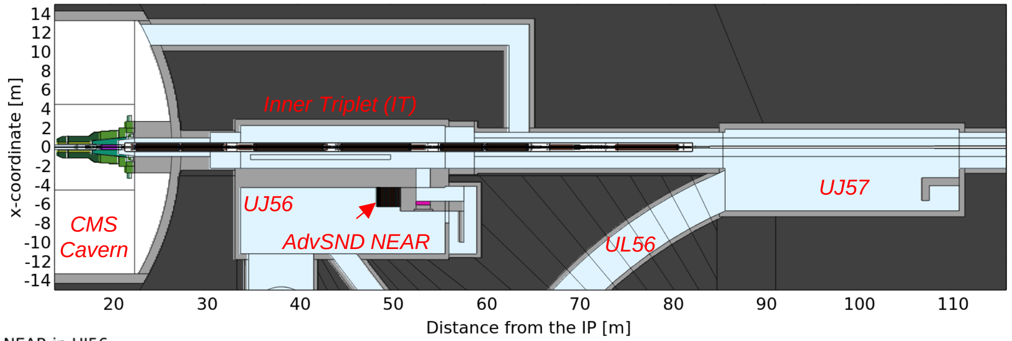
FLUKA model of HL-LHC Point 5

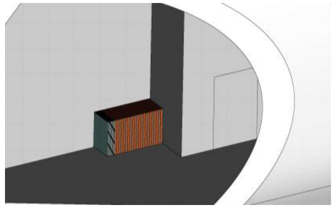
- No additional shielding required because of the UJ56 cavern wall
- Automatic Importance Biasing tool was used (one of the first plug-in versions)

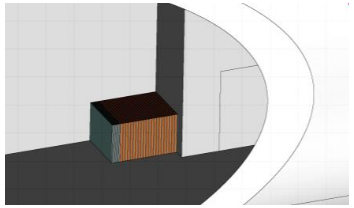
OPTION A: 3.25 m far away from the beamline, 1m excavation needed

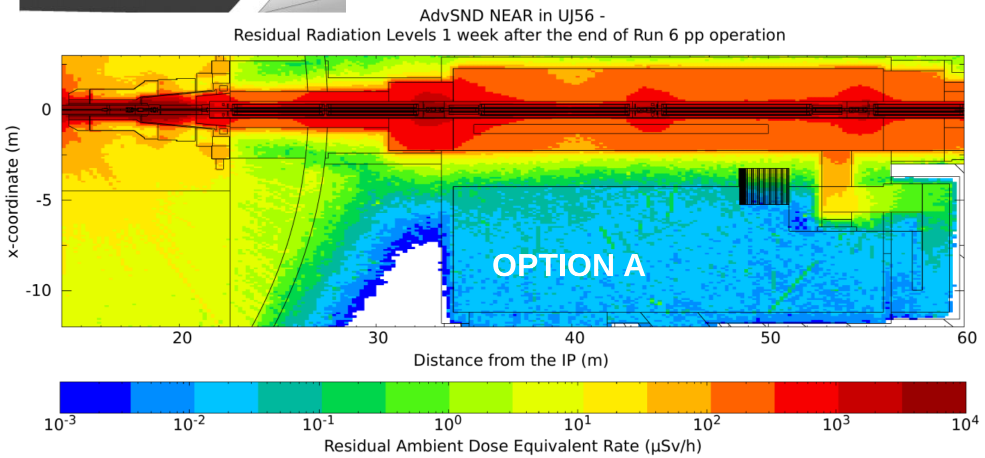


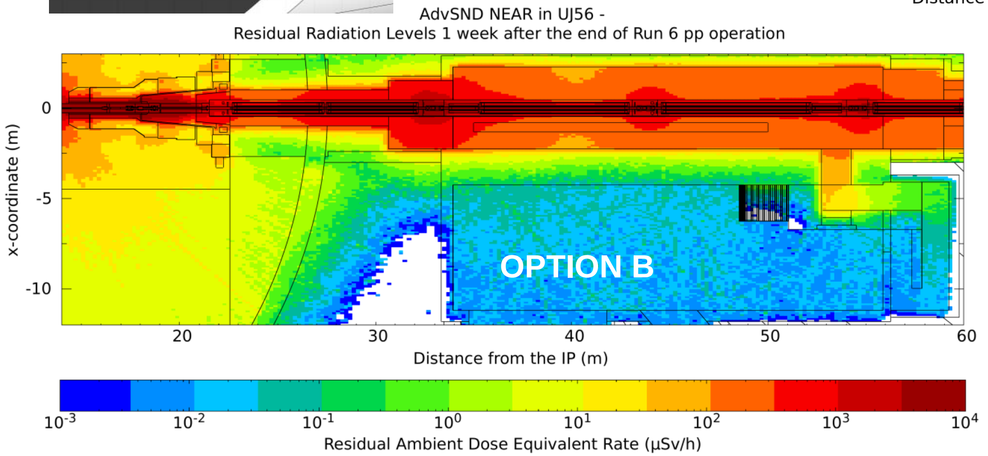
OPTION B: 4.25 m far away from the beamline, NO excavation needed





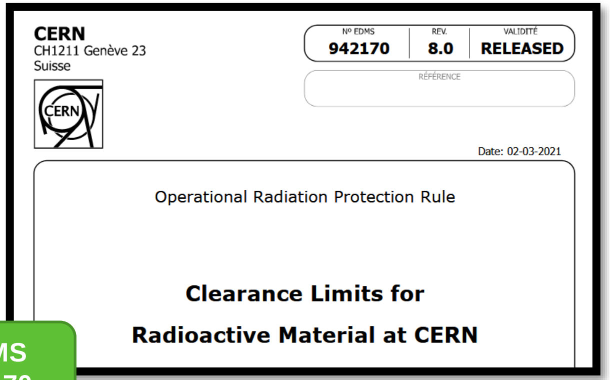






- No RP showstoppers have been identified, for either location.
- Residual radiation field in UJ56 does not require any reclassification of the area, for either location.

AdvSND-NEAR: Activation


CERN
CH1211 Genève 23
Suisse
N° EDMS 942170 | REV. 8.0 | VALIDITÉ RELEASED
RÉFÉRENCE
Date: 02-03-2021
Operational Radiation Protection Rule
Clearance Limits for
Radioactive Material at CERN

EDMS
942170

Accordingly to CERN regulation (EDMS 942170), any irradiated device/object *can be removed from regulatory control* if the following conditions are satisfied:

*To be measured on site**

i. the **ambient dose equivalent** rate measured at 10 cm distance from the item surface is **lower than 0.1 µSv/h** after subtraction of the background,

AND

FLUKA simulations (see next slides)

ii. the **specific activity** is below the **clearance limit (LL)**, i.e. for a mix of radionuclides if:

$$\sum_{i=1}^{n} \frac{a_i}{LL_i} < 1$$

AND

Contamination risk negligible (LHC tunnel)

iii. the **surface contamination** is below the surface **contamination limit (CS)**, i.e. for a mix of radionuclides if.

$$\sum_{i=1}^{n} \frac{c_i}{CS_i} < 1$$

Note: CERN adopted LL and CS from the Swiss Radiation Protection regulation (ORAP 814.501)

AdvSND-NEAR: ActiWiz Activation Studies

- UJ57

Concrete shielding - S_{LL} ± uncertainty %				
Cool down	Target Neutrino		Hadron Calorimeter	
	W	Si	Fe	Scintillator
1-day	47.1 ± 6.0%	9.4 ± 2.3%	30.9 ± 10.5%	0.16 ± 3.8%
1-week	14.3 ± 1.0%	8.8 ± 2.4%	30.0 ± 10.7%	0.15 ± 3.8%
1-month	11.7 ± 1.1%	8.7 ± 2.4%	28.1 ± 10.9%	0.11 ± 3.8%

- Alcove UL56/R562

Iron shielding - S_{LL} ± uncertainty %					
Cool down	Target Neutrino		Hadron Calorimeter		Shielding
	W	Si	Fe	Scintillator	
1-day	472 ± 2.08%	54.1 ± 0.94%	117 ± 4.00%	0.516 ± 1.63%	430 ± 1.15%
1-week	90.5 ± 0.38%	51.8 ± 0.99%	114 ± 4.07%	0.479 ± 1.63%	418 ± 1.16%
1-month	71.8 ± 0.38%	50 ± 0.99%	107 ± 4.15%	0.371 ± 1.66%	390 ± 1.19%
4-months	41.3 ± 0.39%	46.5 ± 1.00%	86 ± 4.20%	0.129 ± 2.25%	313 ± 1.21%

Concrete shielding - S_{LL} ± uncertainty %					
Cool down	Target Neutrino		Hadron Calorimeter		Shielding
	W	Si	Fe	Scintillator	
1-day	527 ± 1.96%	62.9 ± 0.95%	143 ± 3.67%	0.664 ± 1.35%	230 ± 0.73%
1-week	103 ± 0.36%	59.2 ± 1.01%	139 ± 3.73%	0.617 ± 1.35%	105 ± 0.47%
1-month	81.5 ± 0.37%	58.2 ± 1.01%	130 ± 3.81%	0.477 ± 1.36%	101 ± 0.48%
4-months	46.9 ± 0.38%	54.2 ± 1.01%	1.04 ± 3.87	0.165 ± 1.69%	91.3 ± 0.51%

- UJ56

OPTION A (1m excavation) - S_{LL} ± uncertainty %				
Cool down	Target Neutrino		Hadron Calorimeter	
	W	Si	Fe	Scintillator
1-day	5.05 ± 3.23%	1.72 ± 1.93%	8.16 ± 7.58%	0.0524 ± 2.54%
1-week	2.77 ± 0.88%	1.61 ± 2.06%	7.93 ± 7.7%	0.0487 ± 2.54%
1-month	2.29 ± 0.92%	1.58 ± 2.06%	7.39 ± 7.85%	0.0368 ± 2.57%
4-months	1.32 ± 0.94%	1.48 ± 2.06%	5.96 ± 7.96%	0.0132 ± 3.24%

OPTION B (no excavation) - S_{LL} ± uncertainty %				
Cool down	Target Neutrino		Hadron Calorimeter	
	W	Si	Fe	Scintillator
1-day	0.92 ± 4.7%	0.359 ± 3.48%	0.871 ± 14.45%	0.00516 ± 4.79%
1-week	0.60 ± 1.15%	0.337 ± 3.69%	0.846 ± 14.67%	0.0048 ± 4.79%
1-month	0.50 ± 1.19%	0.331 ± 3.7%	0.787 ± 14.98%	0.00362 ± 4.85%
4-months	0.29 ± 1.21%	0.31 ± 3.7%	0.636 ± 15.19%	0.0013 ± 6.19%

Factor 10

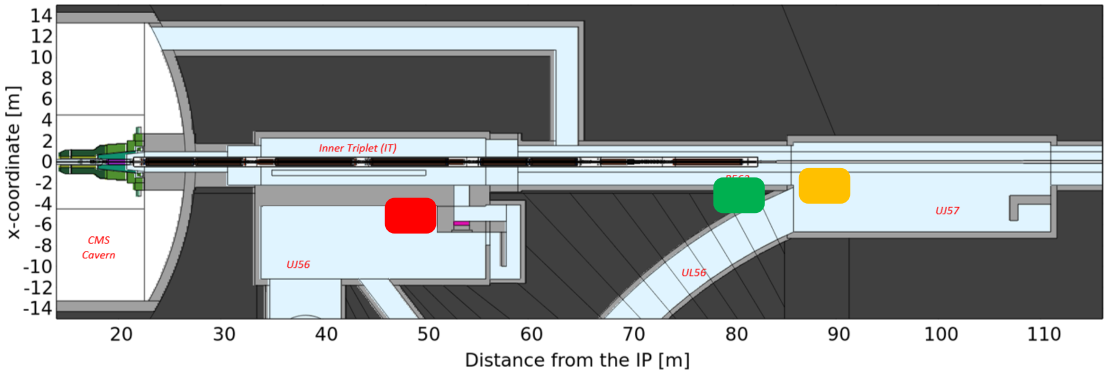
Factor 3

Factor 100

Factor 10

- Detector components to be considered as radioactive → manipulation of detector components to be performed in classified areas (in opposition to what is done today for SND@LHC), BUT
- For UJ56 - OPTION B, the sum of the LL fractions (S_{LL}) is below 1. *A priori*, the detector might be handled as non-radioactive material, as currently done for SND emulsions.

AdvSND-NEAR: Conclusions



- Results for all the different locations

Location	UJ57	Alcove R562/UL56	UJ56
Source Term	Collision debris	Collision debris	Collision debris
Residual radiation	High-residual radiations	High-residual radiations	Low-residual radiations
Activation	Above clearance limits (radioactive detector's equipment)	Above clearance limits (radioactive detector's equipment)	Depending on amount of shielding
References	EDMS 2937170	EDMS 3010676	EDMS 3033564

- TN under finalization (EDMS 3055063)

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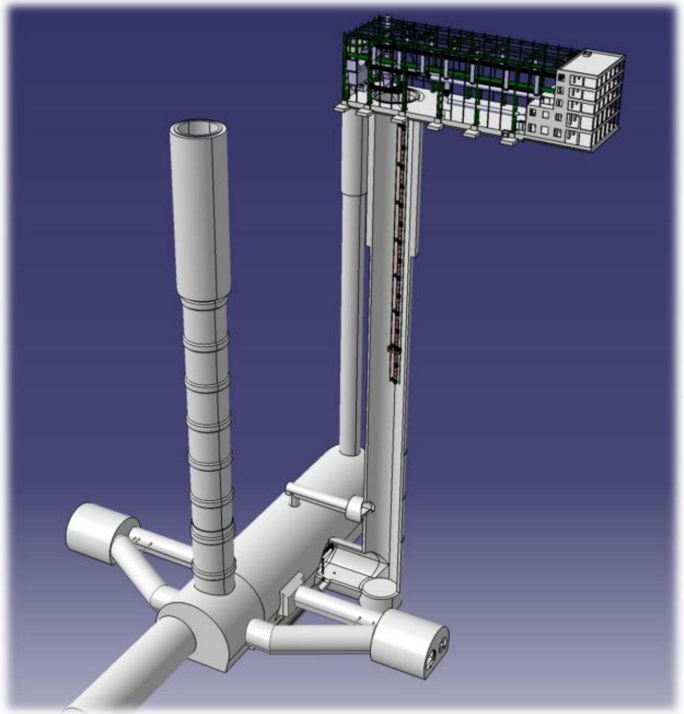
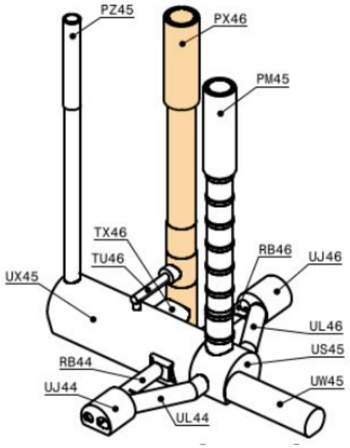
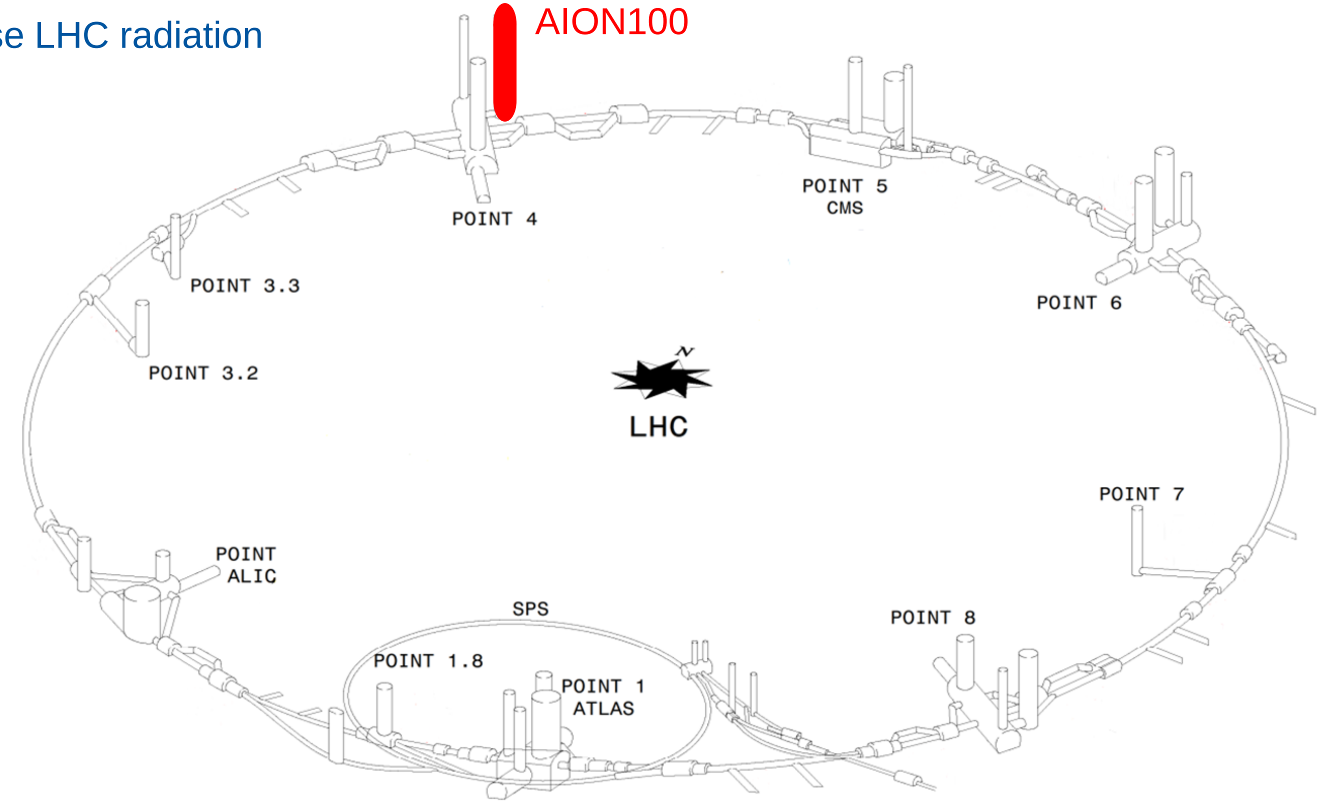
AION100 – a 100-Metre Atom Interferometer

AION100

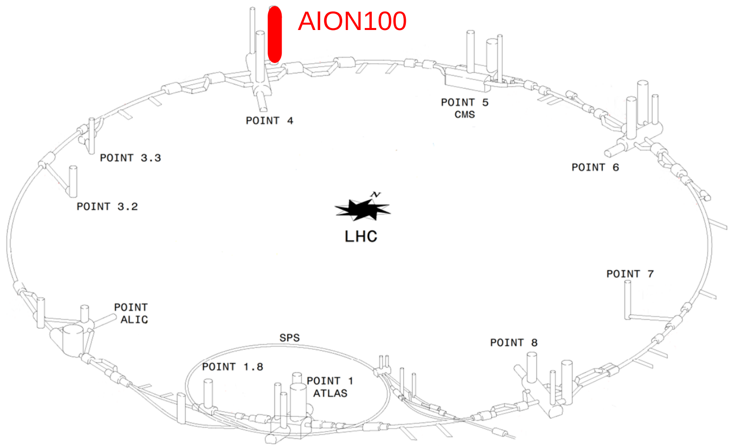
- The AION100 is a 100-metre-long vertical atom interferometer that searches for Ultralight Dark Matter and Gravitational Waves
- The AION collaboration is considering several different possible locations
- The PX46 shaft in Point 4 is among them, as it has a total height of 146m. It is currently used mainly by CV and transport.
- AION-100 would be part of the CERN complex, but it would NOT use LHC radiation



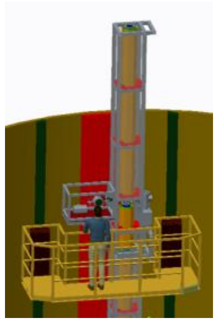




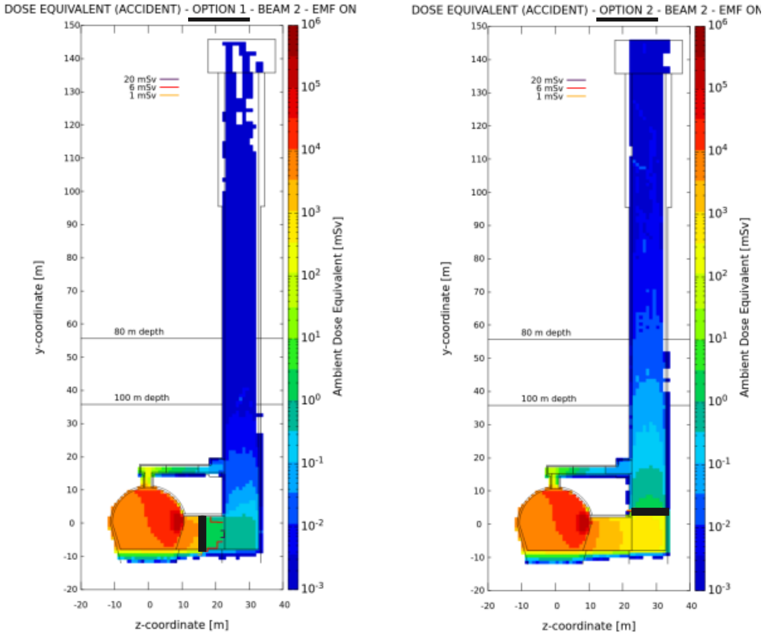
AION100: State of the Art



- The AION100 experiment wish to be installed during LS3 – ideal data taking during Run4
- The AION100 collaboration desires accessibility of the experiment during LHC operation
- Therefore, RP studies need to be performed
- Additional technical challenges:

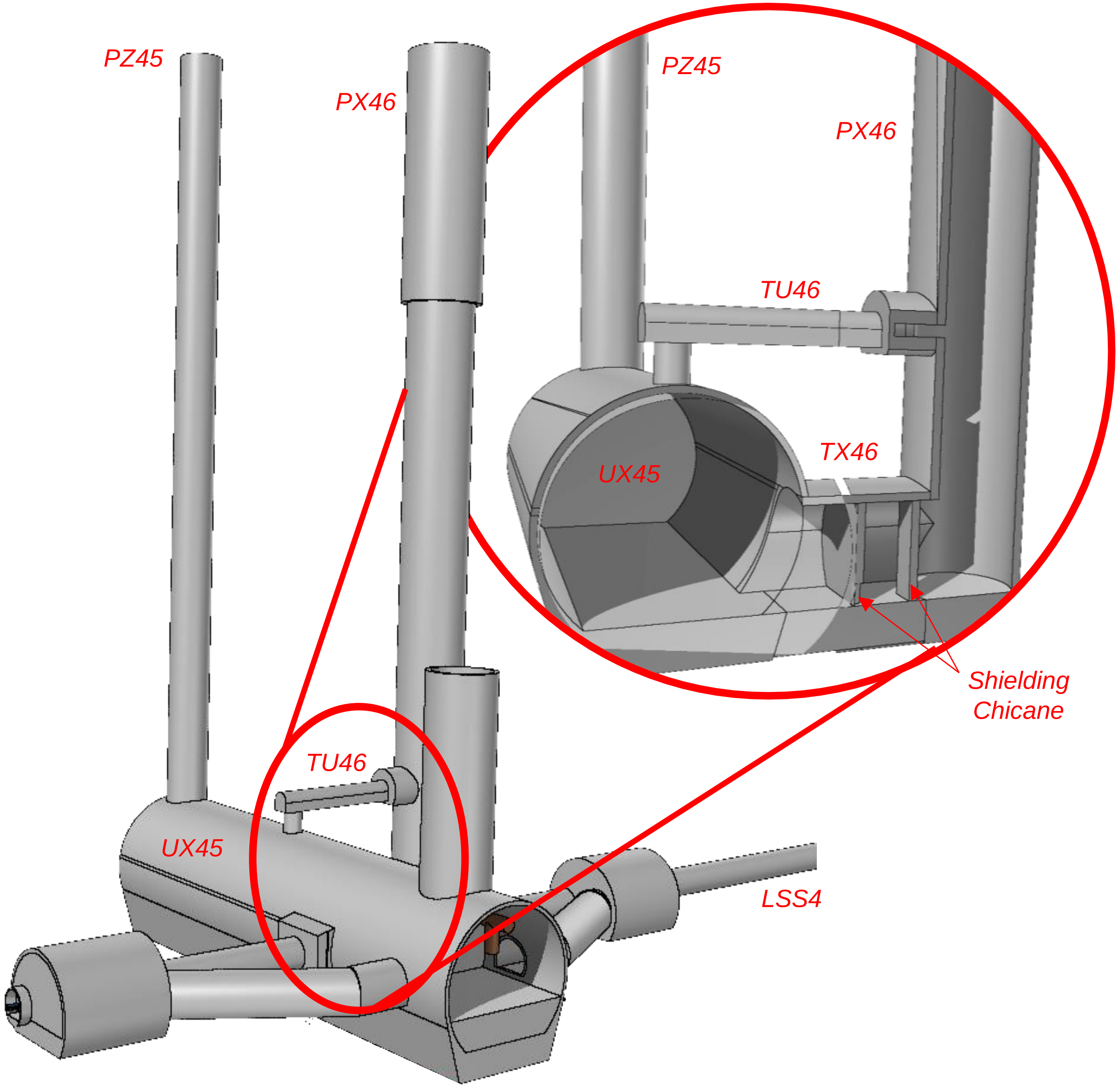


  - The PX46 shaft is also used for transport of materials inside and outside the machine tunnel
  - The PX46 shaft is also used for smoke extraction in case of fire
  - There is no other quick evacuation option and the current speed of the moving platform is lower than the minimum required by the fire-safety team
  - Masks would be needed because of the smoke



- Preliminary RP results were performed (EDMS 2333747 and 2635983) for two possible shielding configurations, in case of accidental scenario with complete beam loss (on fixed target)
- Using a model just involving the AION caverns and shafts, without the machine tunnel and line builder (LB, which is a FLUKA tool to create the machine geometry)
- Shielding option 1 was chosen so that AION-100 can be in contact with the floor of the PX46

AION100: Geometry

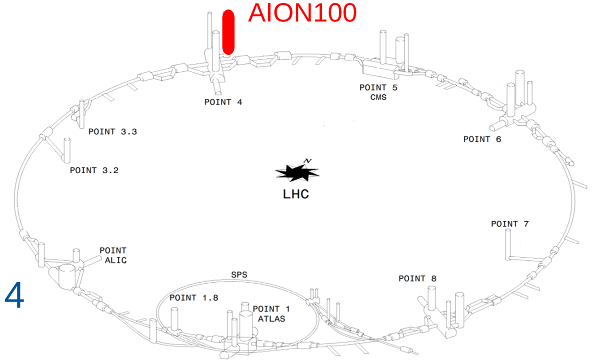


- STI model of Point4 adapted from Point6, not including the surrounding caverns and shaft (compatible with LB)

- RP model of Point4 merely for AION-100 studies, without machine tunnel (not compatible with LB)

- Need for RP to have a complete model of Point4, for AION-100 but also other RP LS3 studies
- Merge of the two with the result of a complete Point4 model, with cavern, shafts and tunnel machine, compatible with LB

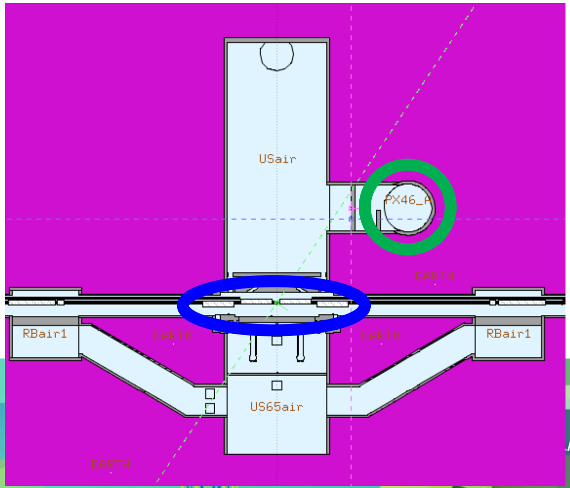
AION100: RP Studies

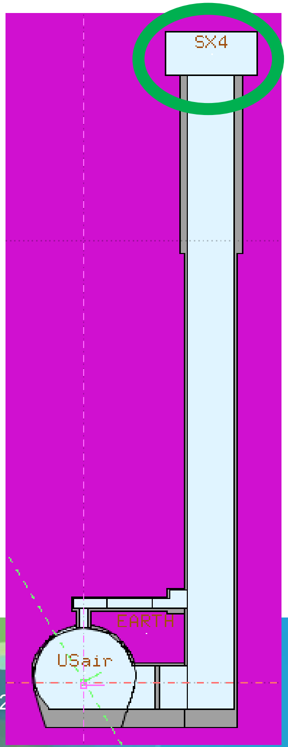


- Main goal of the performed study is to revise the source terms

- Two main radiation sources around Point 4 during normal operation:
  - X-ray emission from the RF cavities (even if no beam is circulating, only RF cavity commission periods)
  - Beam-gas interactions
- Beam-loss accidental scenarios need to be considered as well

Maximisation of radiation transport from the RF cavities (source) all the way up the PX46 shaft (region of interest for AION100)





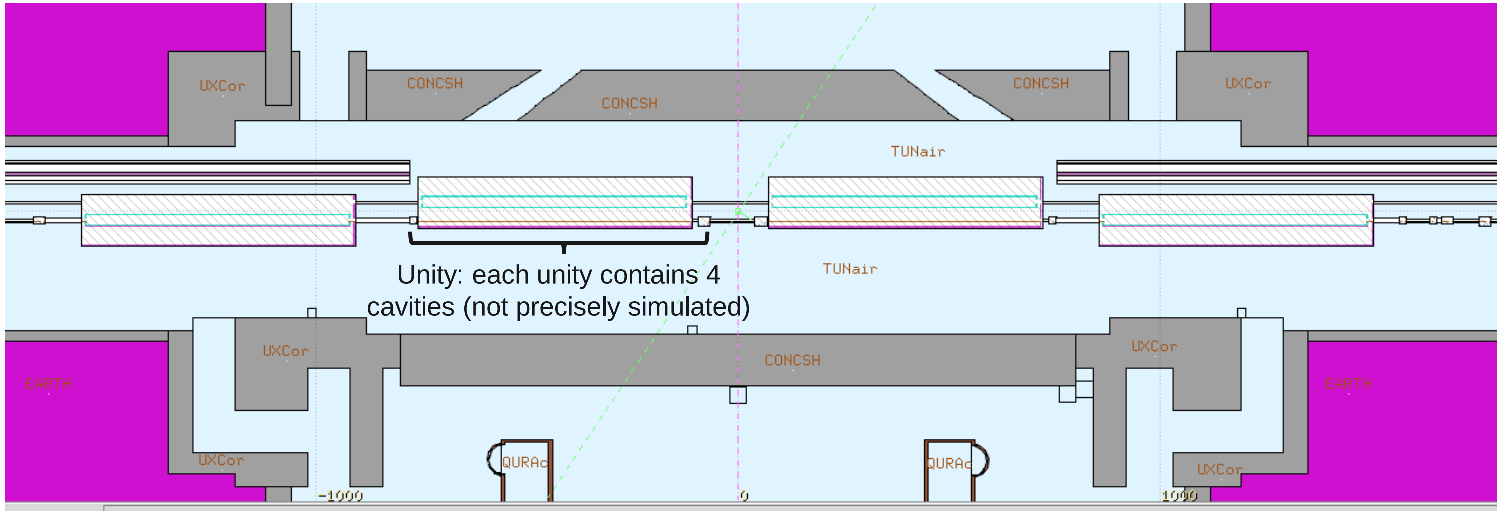
- Automatic Importance Biasing used and tested across the different source terms

AION100: RF X-ray Emissions

- X-ray emission from the RF cavities:

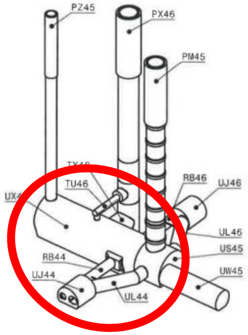
  Following the application of an electrical field to a cavity, electrons are emitted from the cavity inner surfaces, especially where impurities are present. The electric field accelerates the electrons and they collide with the cavity wall, causing the emission of secondary Bremsstrahlung photons, whose maximum energy corresponds to the electron energy. If this energy exceeds 10 MeV, the photons can produce neutrons through photonuclear reactions.

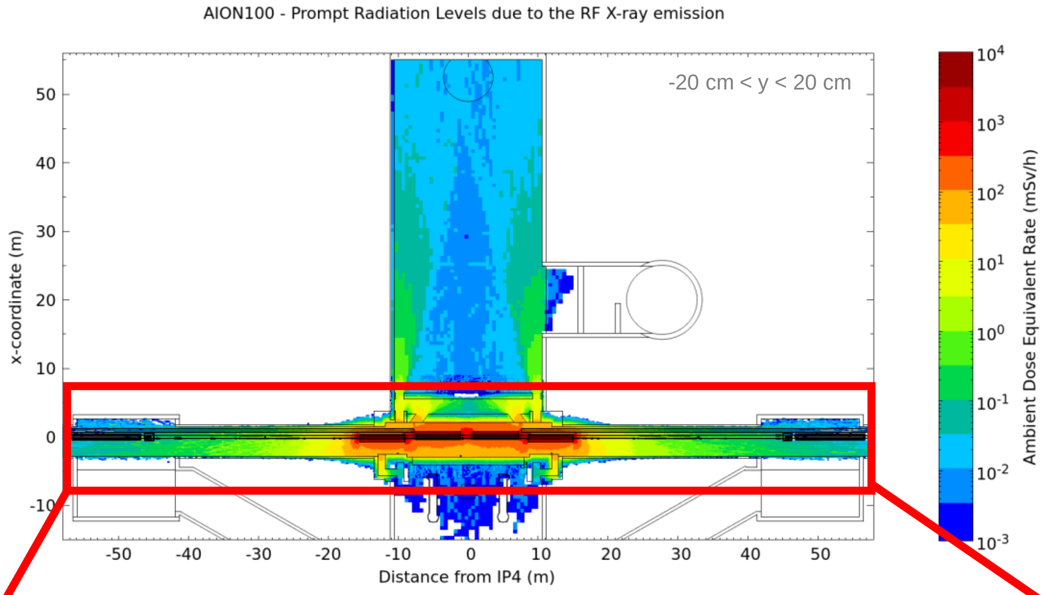
- Simplified RF geometry
- FLUKA simulation source: source routine that samples at the same time linear monoenergetic isotropic electron sources at the RF cavity centre in the four cryomodules
- Primary electron energy = 12MeV, as each cavity is operated at 1.5MV and there are 8 cavities per beam
- Ion operation (1.75MV) not studied → this study case needs to be followed up

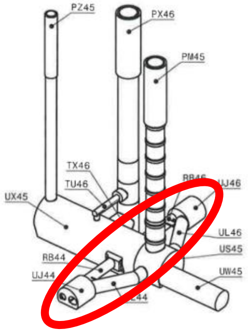


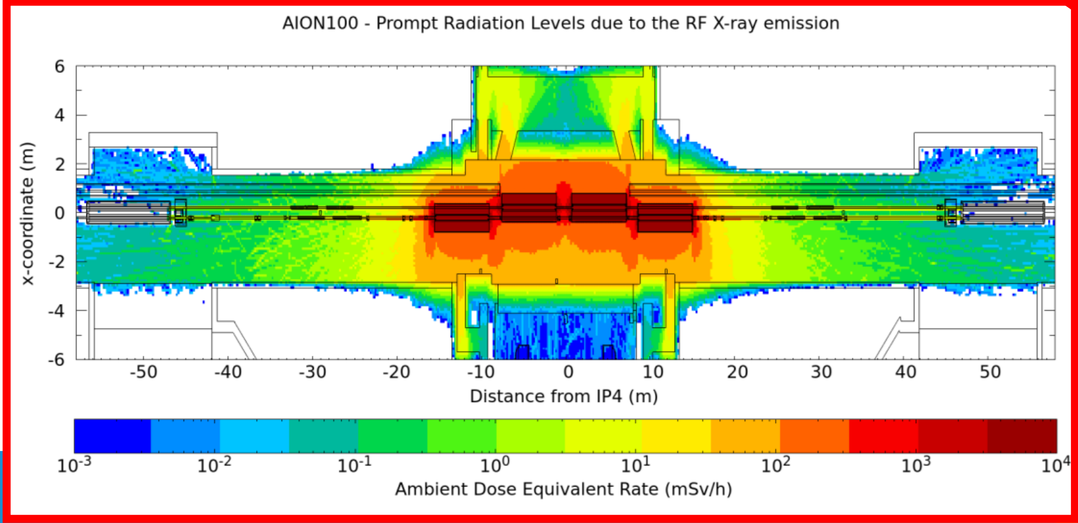
- Conservative normalisation factor such as the residual dose rates at ~2m from the cavities is 100mSv/h (EDMS 1822274)

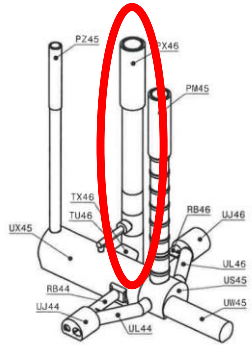
AION100: RF X-ray Emissions

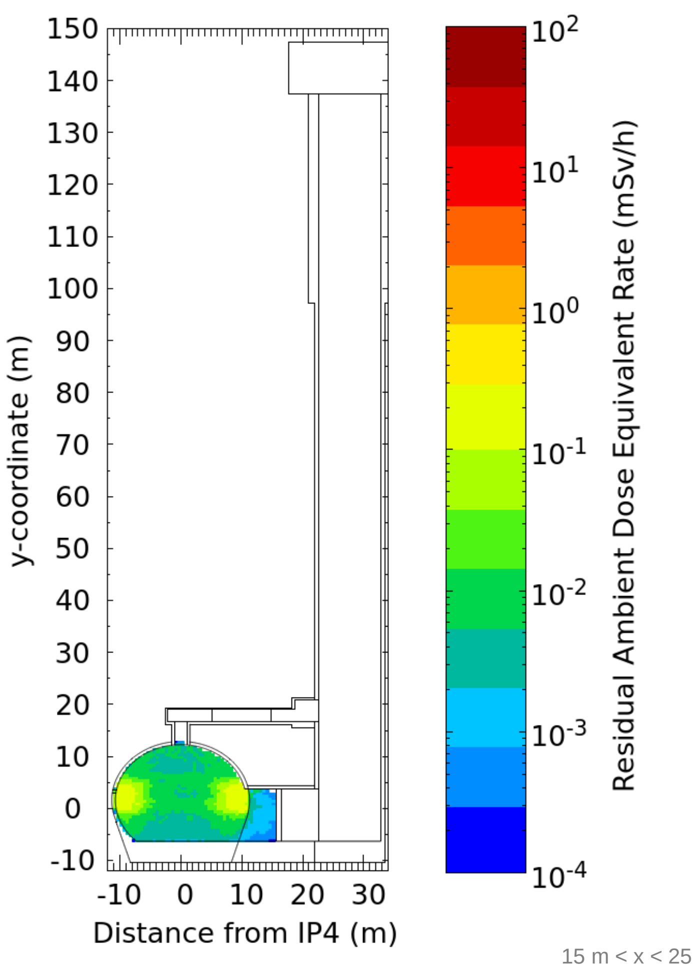












15 m < x < 25 m
Center of PX46 is 20 m (from IP4)

AION100: Beam-Gas Interactions

- FLUKA simulation in two steps:
  - Step 1: beam particle trajectory is followed long the beampipe
  - Step 2: the beam-gas interactions are simulated

- Starting point of the beam
- Description of the gas density profile in agreement with cooling and ventilation (CV) studies (uniform reasonable value of **10^7 H_2 equivalent molecules / cm^3 from CV**)

Step 1 Simulation

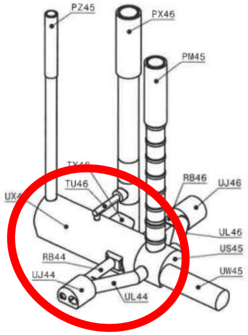
- Points of the particle trajectory
- Gas density values in those points
- Beam-gas interactions are forced along the particle trajectory

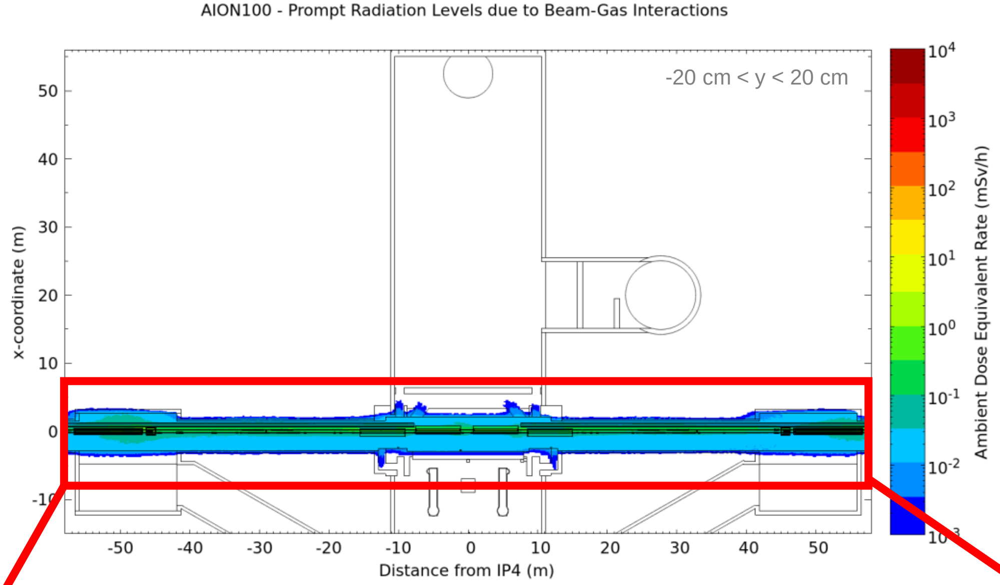
Step 2 Simulation

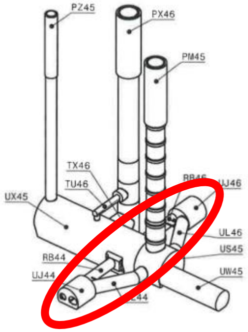
- Beam-gas collision probability
- Dose equivalent maps and particles fluences due to beam-gas interactions

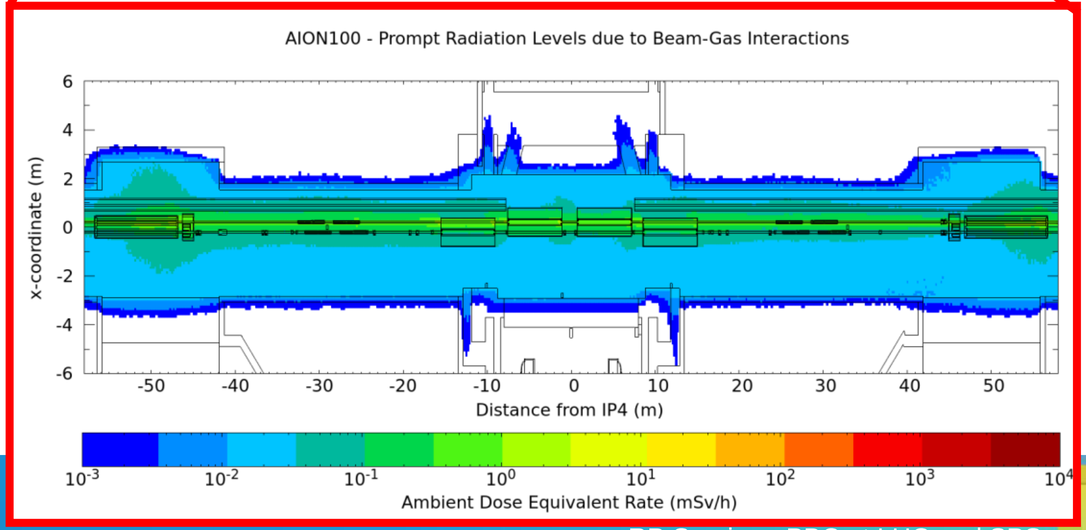
- Normalisation factor takes into account HL-LHC conditions and the beam-gas collision probability

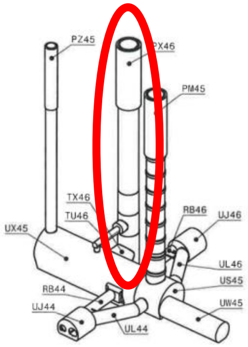
AION100: Beam-Gas Interactions

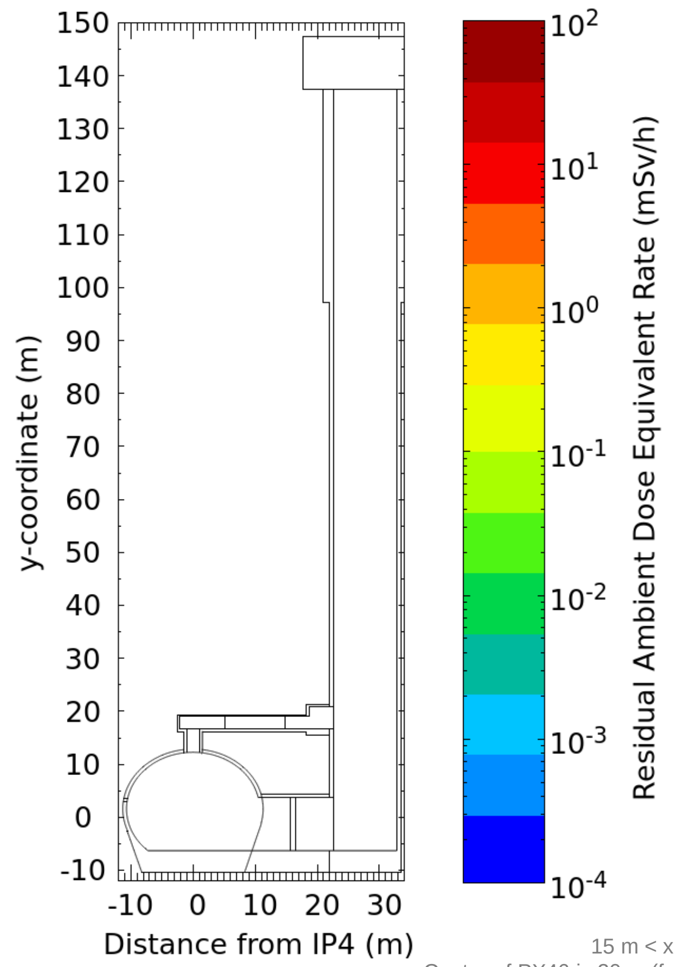






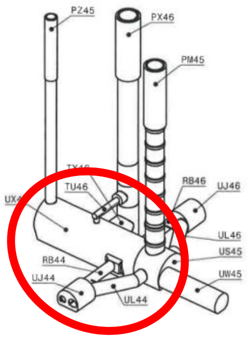


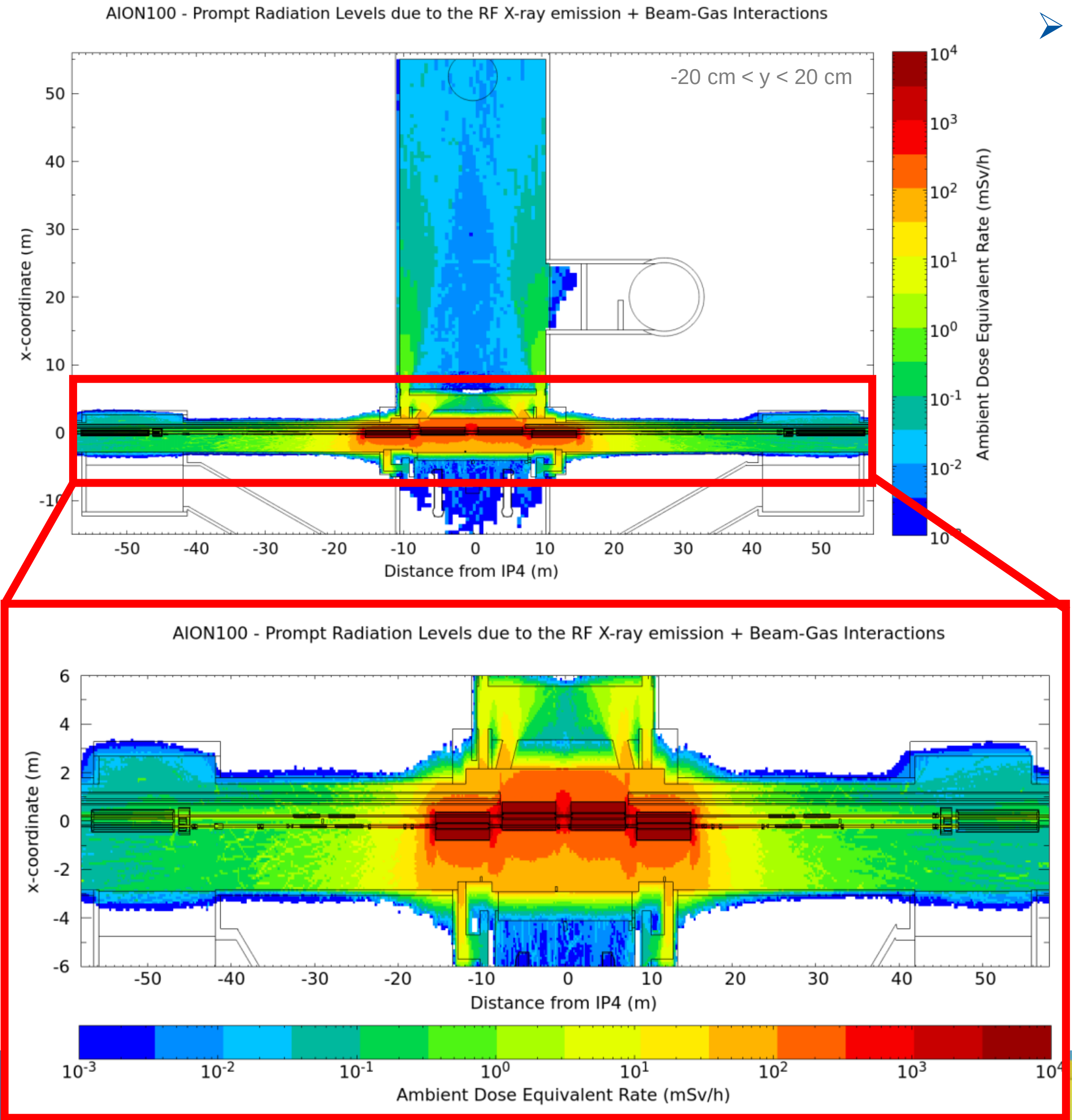


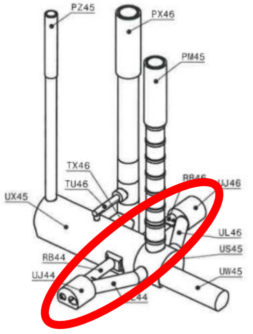


15 m < x < 25 m
Center of PX46 is 20 m (from IP4)

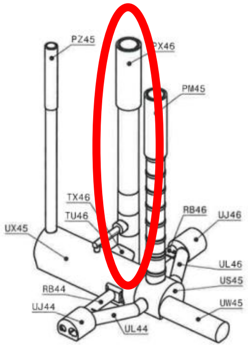
AION100: Nominal Operation Radiation Levels



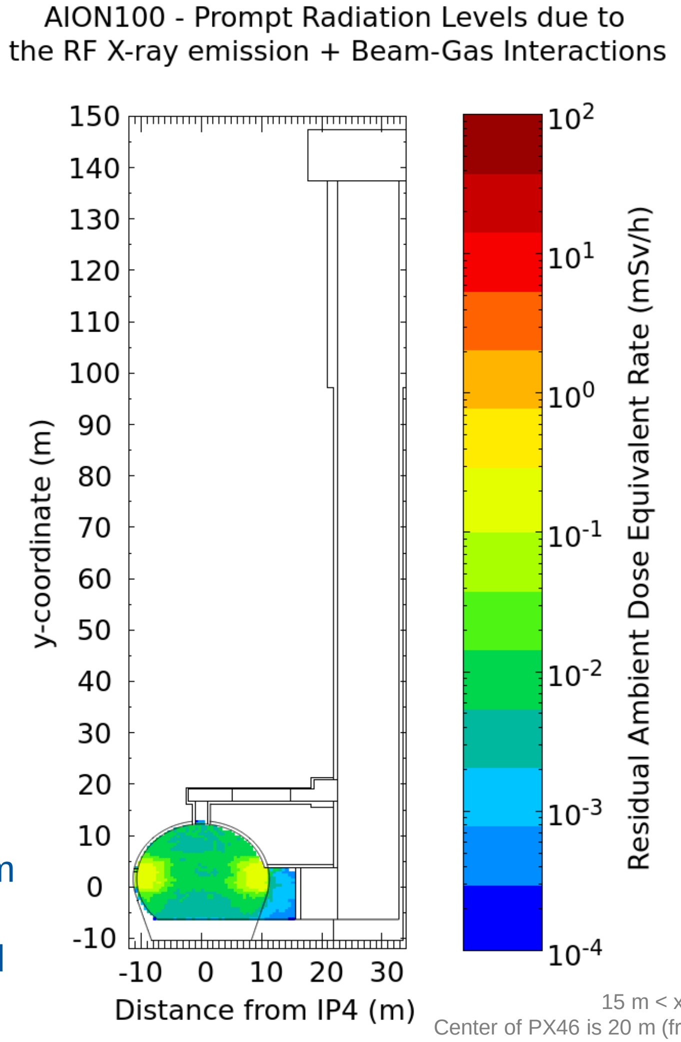




- Sum of RF X-ray emissions and beam-gas interactions



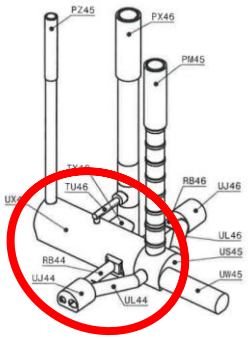
- Objective was to verify the radiation levels at the bottom of PX46: no radiological hazard

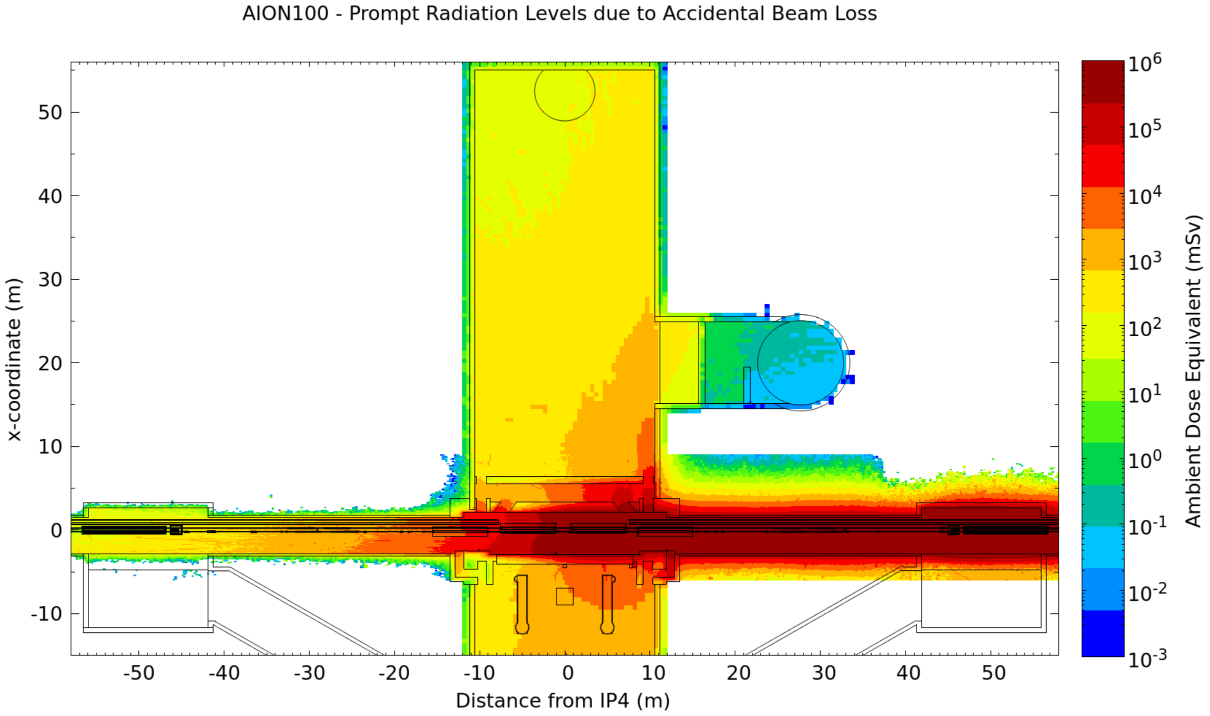


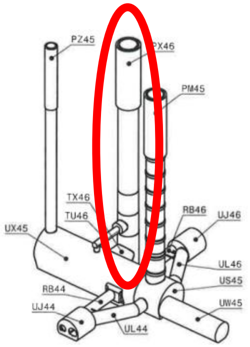
15 m < x < 25 m
Center of PX46 is 20 m (from IP4)

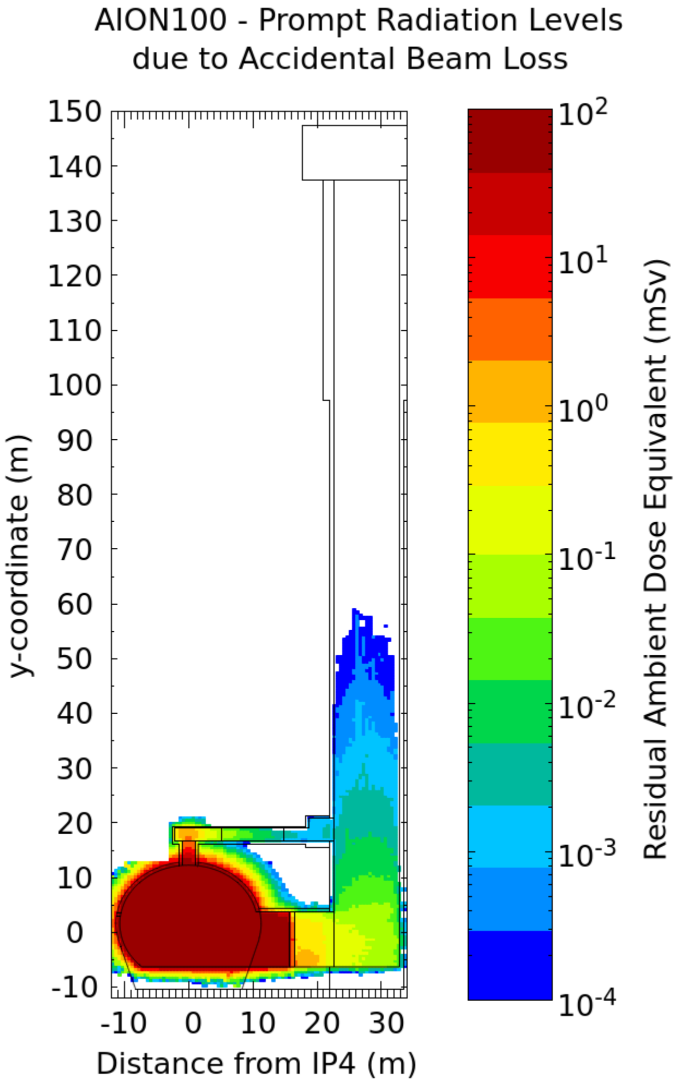
AION100: Accidental Scenario

- Scenario in which the dose rate could overcome safety limits at the bottom of the PX46 shaft
- Beam loss in Point4 is unlikely from a beam-optics point of view
- RP simulation of a beam loss assuming a missteering angle of 2urad (different than total beam loss on target of the preliminary studies)









- Experiment wish: whole PX46 as non-classified area
- RP goal: keeping PX46 as supervised radiation area

- It will need to be checked with technical shielding constraints if this is possible

AION100: Conclusions

- All radiation source terms in Point4 were revised
- A Point4 model was created that allows a realistic simulation of both RF X-ray and beam-gas interaction losses
- The nominal operation does not imply any radiological risk with the current shielding configuration
- The accidental scenario constraints the PX46 shaft accessibility, but it is very unlikely, as many things would need to go wrong before the beam is lost in the RF cavities
- It was simulated in a less unlikely way than in previous preliminary studies (beam missteering instead of complete beam loss on fixed target)

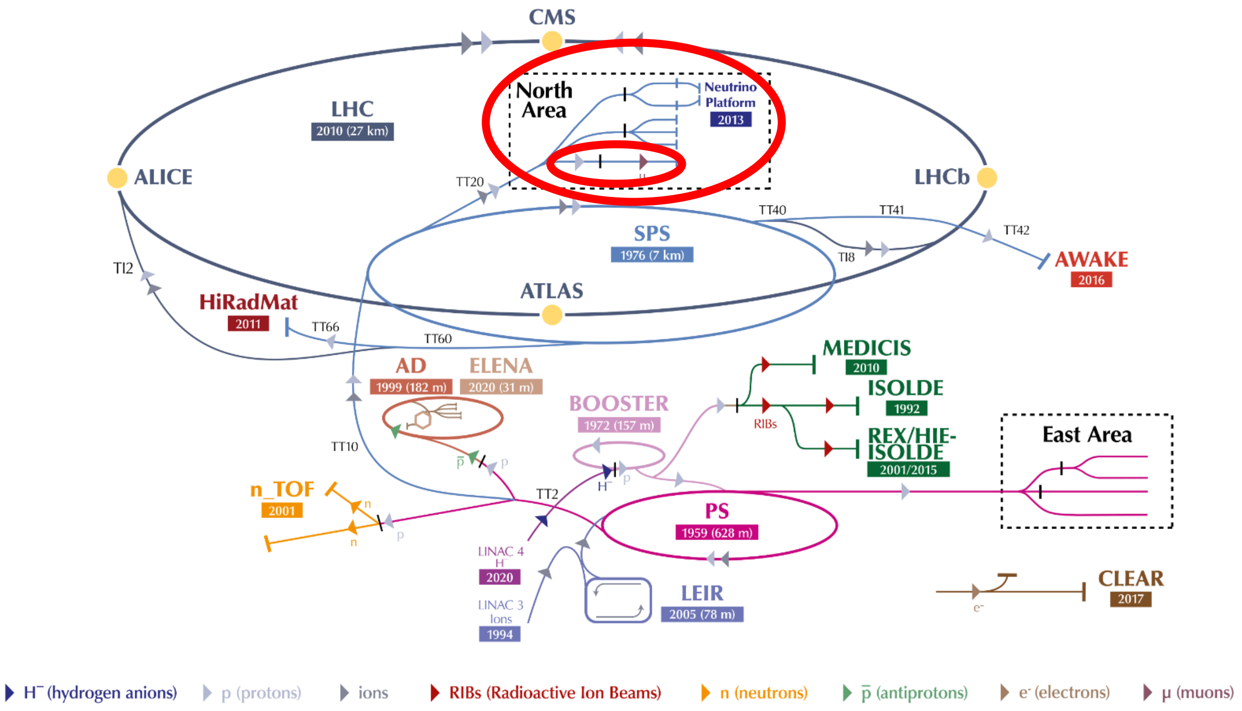
- Next steps:
  - Adaptation of shielding configuration to CE and other technical constraints (e.g. cable trails)
  - A new AION-100 letter of intent needs to be written: support RP studies will be needed
  - RF X-ray simulations: a more realistic normalisation factor needs to be computed with analysis of PMI data in UX45 (they detect less radiation than what our simulations foresee)

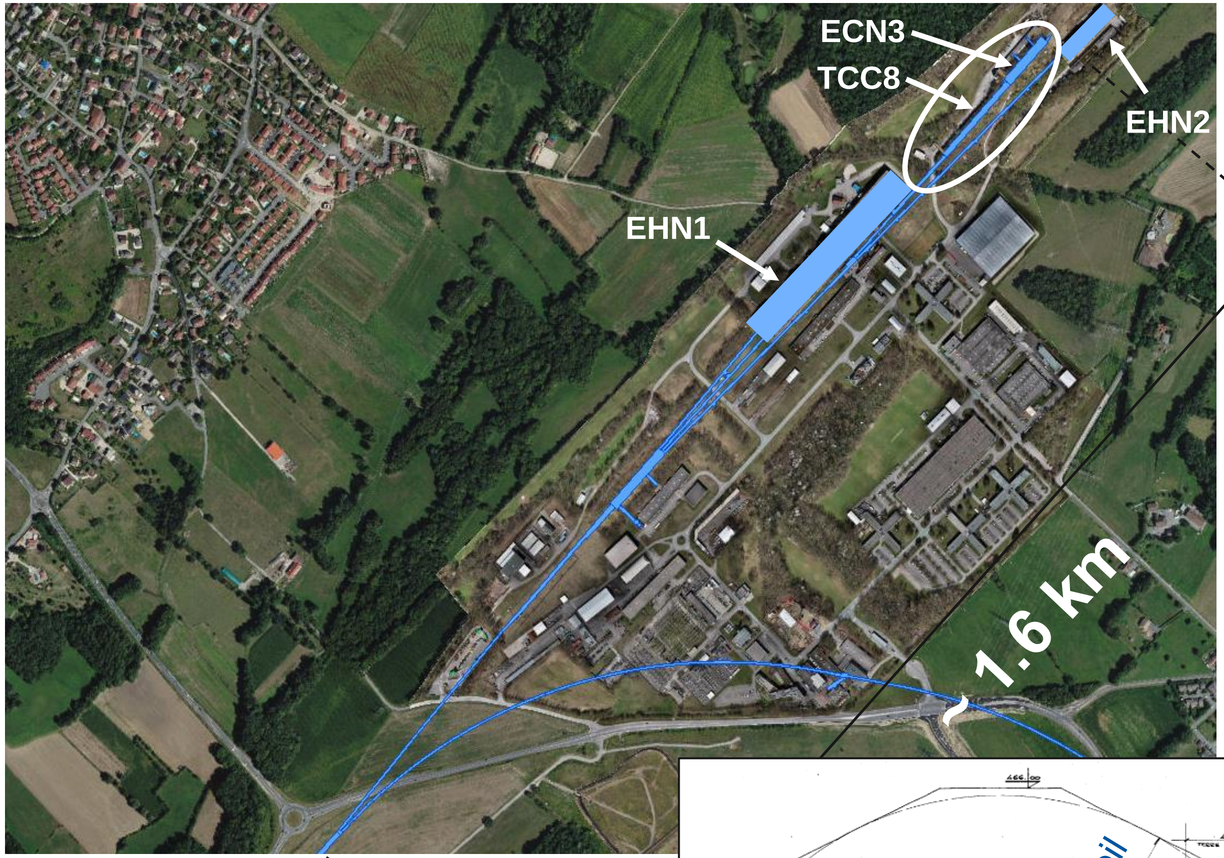
HSE
Radiation Protection

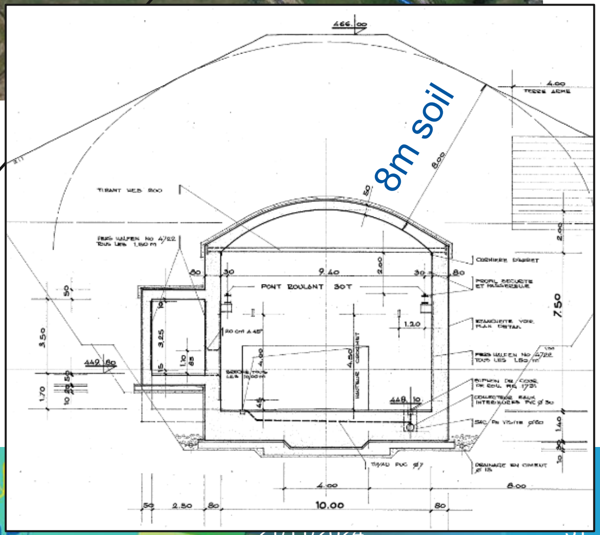
PBC Projects at SPS – North Area

SPS - North Area and ECN3

- TCC8 & ECN3 is SPS's only underground experimental cavern







Experiment currently being performed: NA62

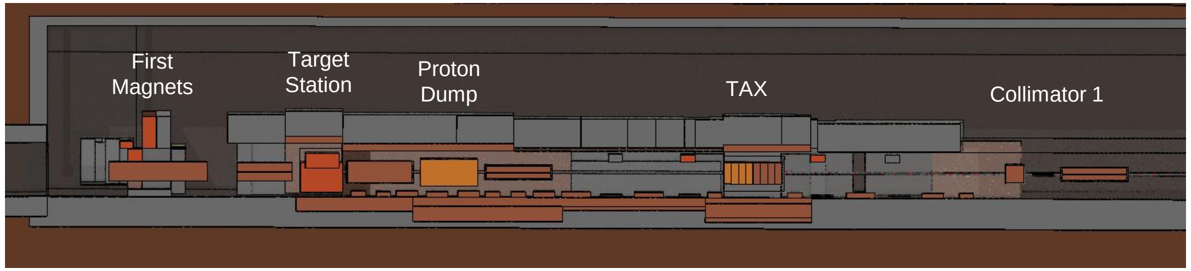
HSE
Radiation Protection

HIKE – Phase 2

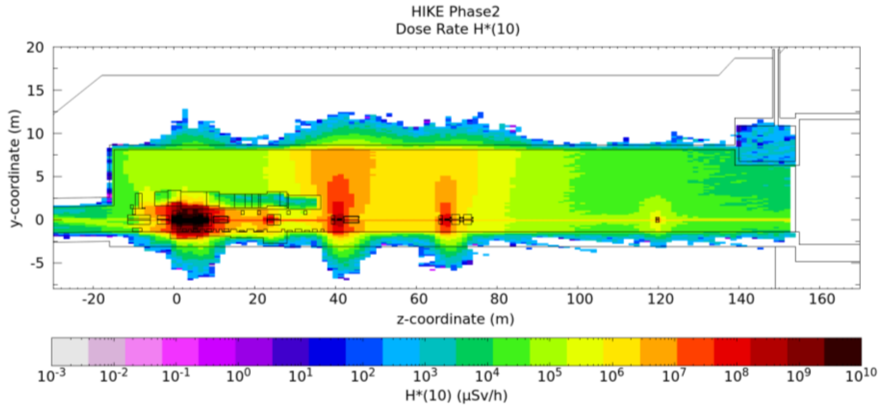
HIKE – Phase 2

Phase 1	Phase 2	Phase 3
Multi-Purpose K^+ Decay Experiment	Multi-Purpose K_L Decay Experiment	Measurement of the $K_L \rightarrow \pi^0 \nu \bar{\nu}$

- HIKE (High-Intensity Kaon Experiments) and the parasitic SHADOWS (Search for Hidden And Dark Objects With the SPS) were proposed to study rare kaon decay processes, CP violation, tests of the Standard Model, and search for feebly-interacting particles in ECN3, as follow-up of NA62
- Even if Phase 2 was supposed to be late (~2043), it was important to evaluate RP constraints impacting the feasibility, facility design, and costs required for the important decisional process
- HIKE – Phase 2 Foreseen Geometry:

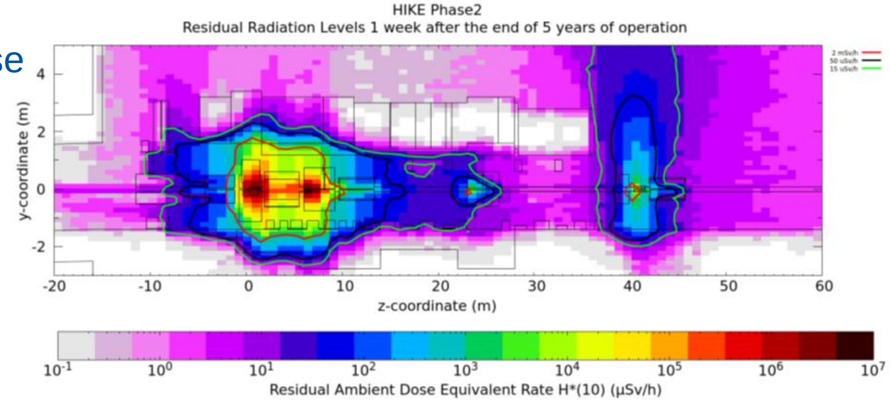


- Prompt Dose Rate:



- Prompt dose rates were investigated to obtain an overview of high-dose-rate regions inside the cavern
- Collimators are not sufficiently shielded
- In the surrounding accessible areas: dose rates compatible with a Non-Designated Area

- Residual Dose Rate:

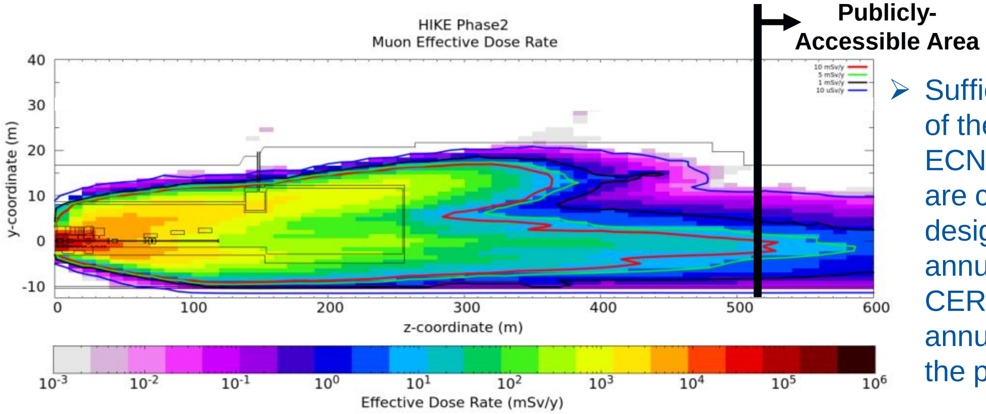


- Residual dose rates not well contained upstream of the target nor at the collimators
- Additional shielding in these areas is needed

- Annual Effective Muon Dose Rate:

CERN Fence

Publicly-Accessible Area



- Sufficiently contained inside of the soil downstream of ECN3 → radiation levels are compatible with a Non-designated Area, the annual dose limit at the CERN fence and the annual dose objective for the public

HIKE – Phase 2

Phase 1	Phase 2	Phase 3
Multi-Purpose K^+ Decay Experiment	Multi-Purpose K_L Decay Experiment	Measurement of the $K_L \rightarrow \pi^0 \nu \bar{\nu}$

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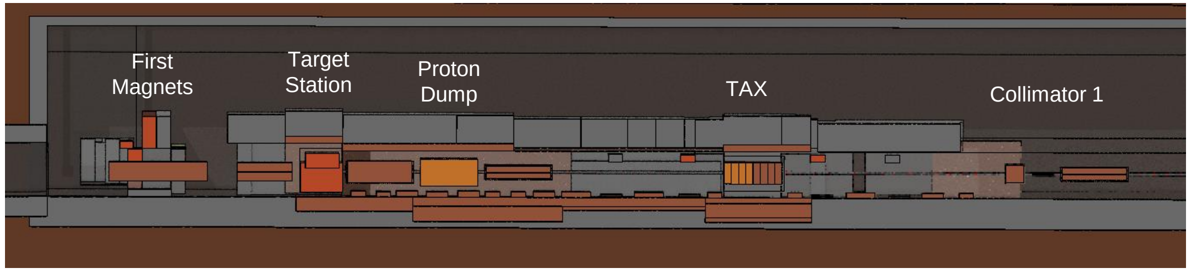
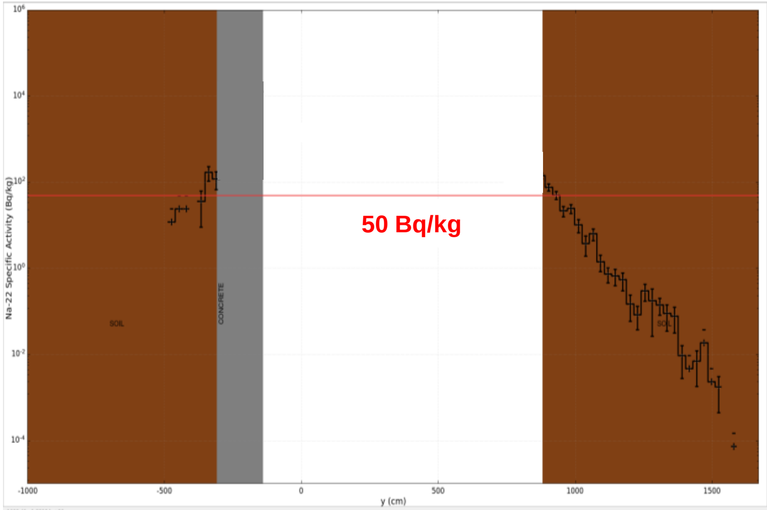


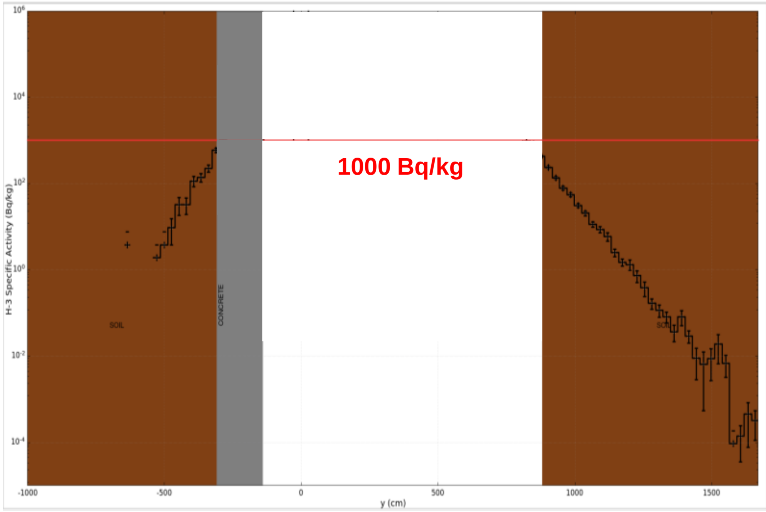
- The HIKE Phase 1 / BD shielding below the target station and proton dump was found to be sufficient
- However, additional shielding is required around collimators 1 and 2 as the Na-22 activity concentrations are exceeded

- Soil Activation Studies:
  - Example Case: around Collimator 1
  - Other Locations Studied: Target Area, Proton Dump, Collimator 2
- All of these studies are reported in EDMS 3015716

Na-22 specific activity in soil:



H-3 specific activity in soil:



- These considerations were made with very conservative soil activation limits
- A hydrogeological study is underway allowing to decrease these limits

- In March 2024, the SHiP (Search for Hidden Particles) experiment was chosen over HIKE/SHADOWS, therefore no further studies were performed

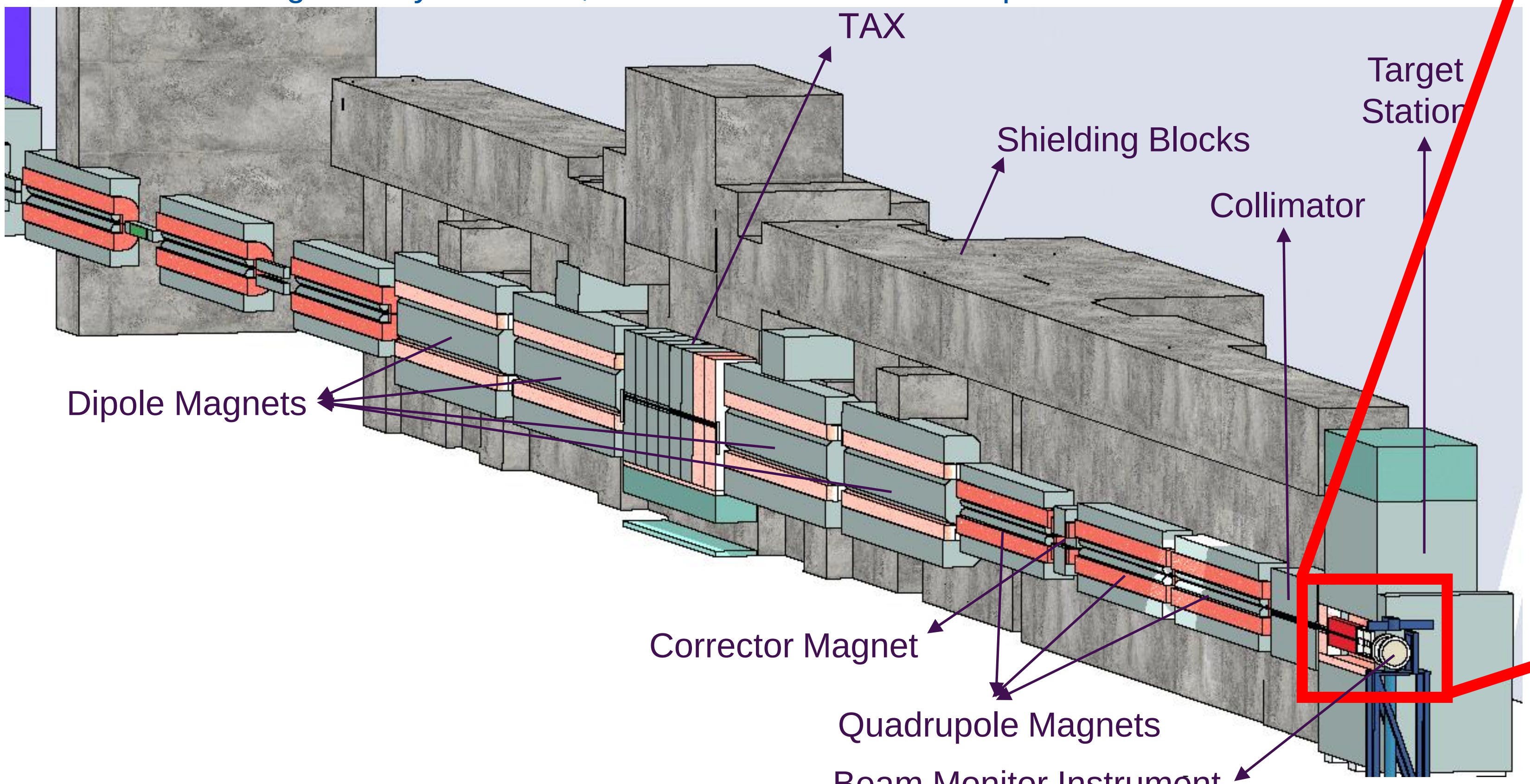
HSE
Radiation Protection

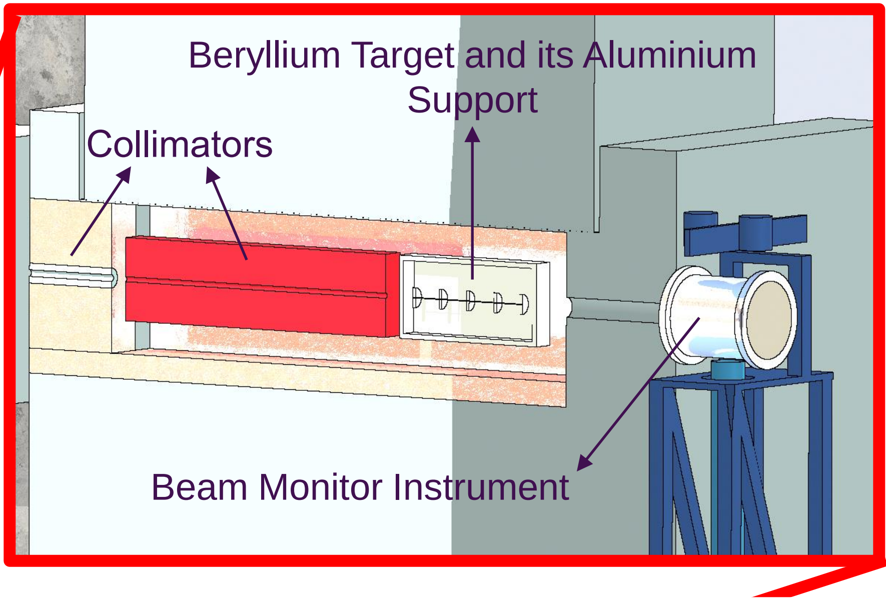
TCC8 Decommissioning

TCC8 Decommissioning

- After the approval of the SHiP Experiment, the whole current equipment of the TCC8 tunnel needs to be dismantled
- SHiP is supposed to take beam in 2032, the facility in 2031. Therefore, due to the many CE works and installation of BDF/SHiP, the cavern must be emptied during LS3 (including NA62)

- Latest FLUKA geometry of BE/EA, with several modifications performed:





- Study of hot TCC8 areas necessary to evaluate the impact on the dismantling personnel of the high residual dose rates

- Radionuclide inventory and equipment activation studies are necessary to organise transport, radioactive waste, and costs associated with them

TCC8 Decommissioning: Geometry

- Geometry modifications performed since the start of the work:
  1. Geometry updates performed based on STI input (EDMS 3086822)
  2. Refinement of the concrete compositions for tunnel wall, floor, and shielding blocks through XRF and gamma-spec measurements performed in February in TCC8 (EDMS 3156461)
  3. Correction of magnetic field maps performed with BE-EA (EDMS 3160904)

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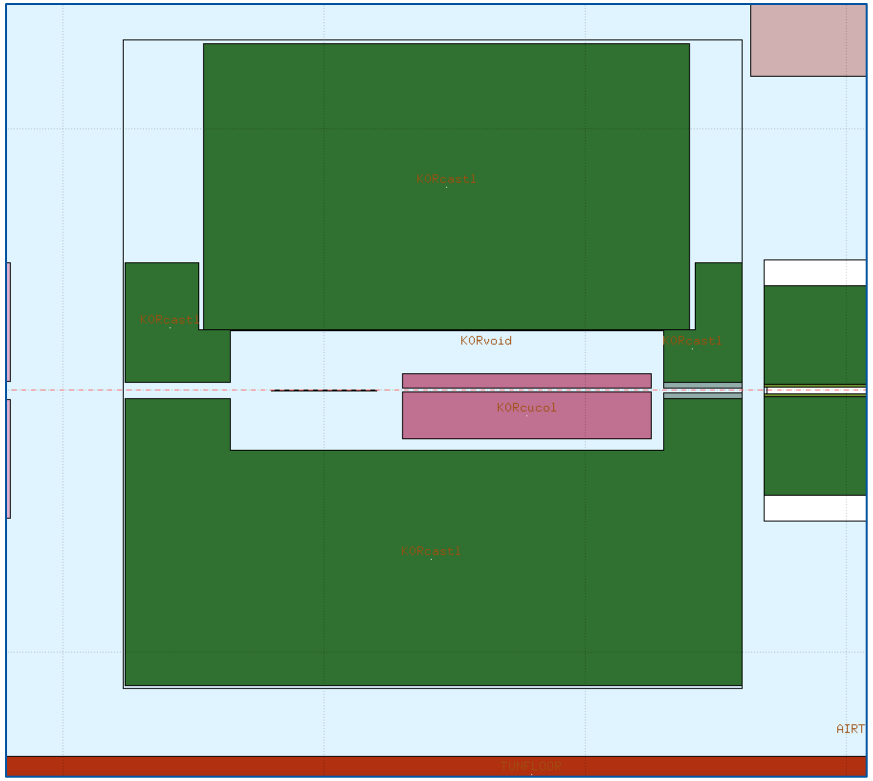
TCC8 Decommissioning: Geometry

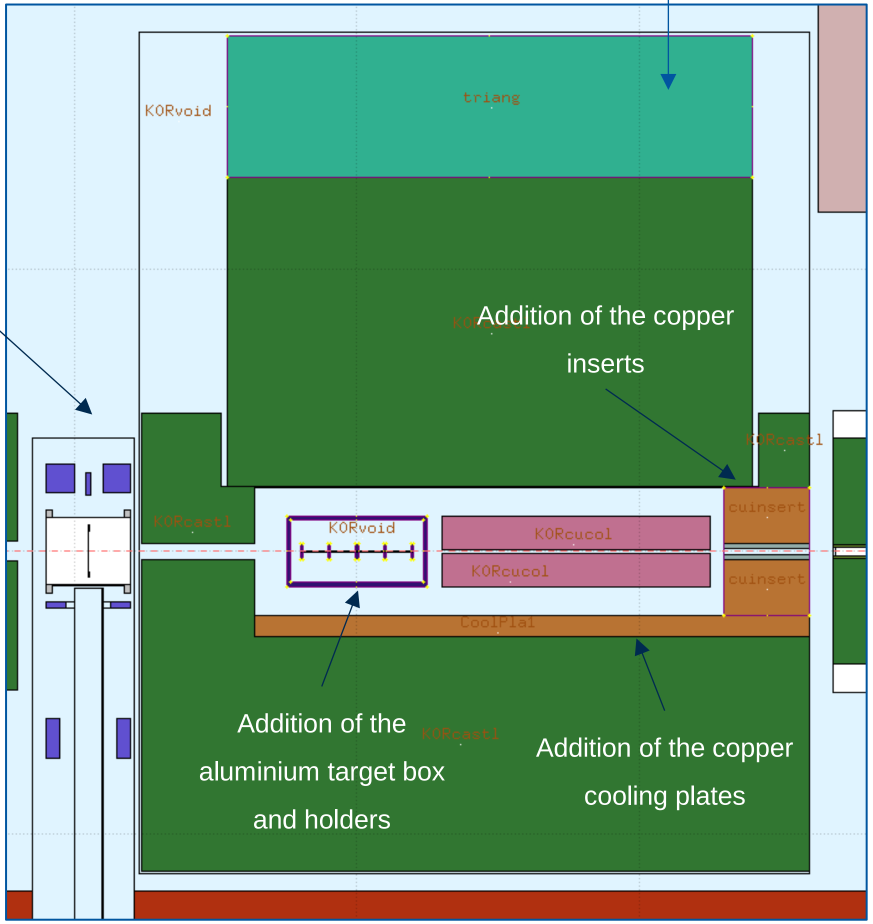
- Geometry modifications performed since the start of the work:
  1. **Geometry updates performed based on STI input (EDMS 3086822)**
- E.g.: Target Station
  - Previously:



- Currently:

Addition of this top part made of Fe360

Addition of Beam Instrument



Addition of the copper inserts

Addition of the aluminium target box and holders

Addition of the copper cooling plates

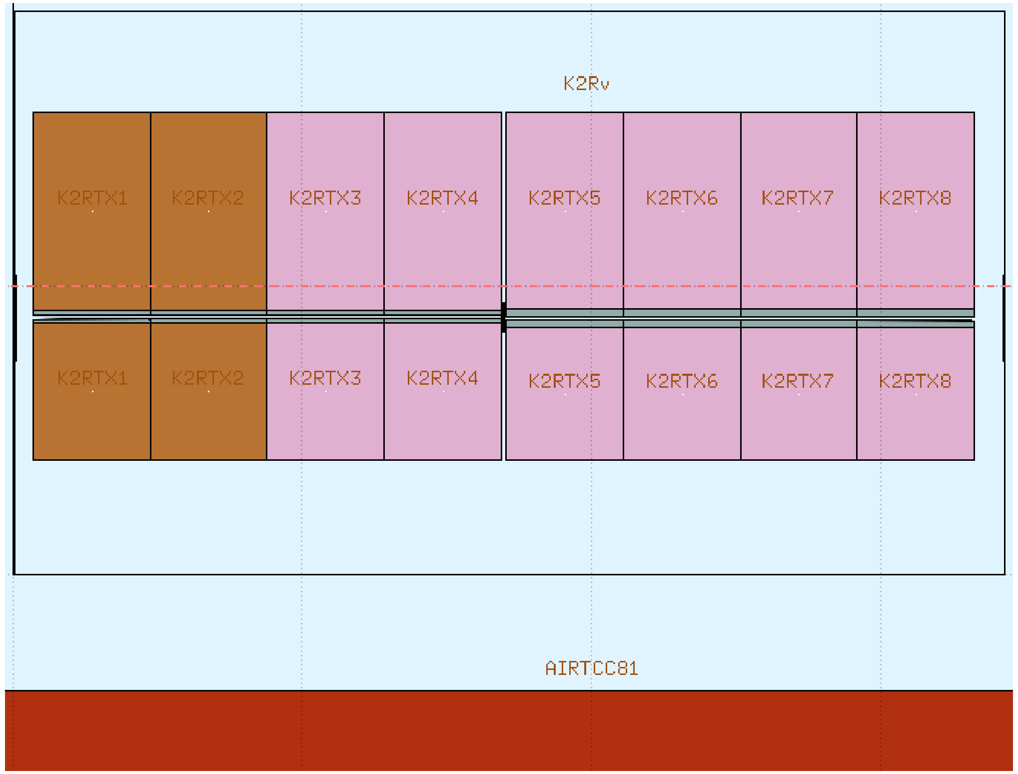
- GG20
- CuCrZr
- Beryllium
- Silafont30
- Copper
- Fe360
- Tungsten

TCC8 Decommissioning: Geometry

- Geometry modifications performed since the start of the work:
  1. **Geometry updates performed based on STI input (EDMS 3086822)**
- E.g.: TAX

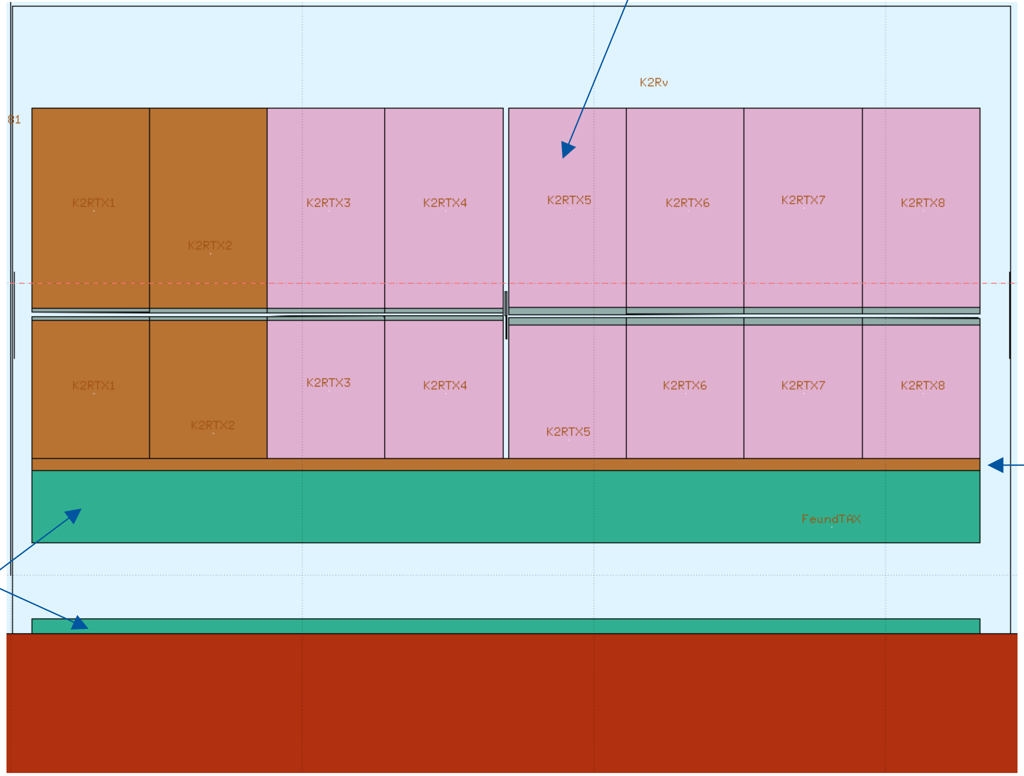
GG20
Concrete
Copper
Fe360
Tungsten

- Previously:



- Currently:

Modification of the GG20 composition



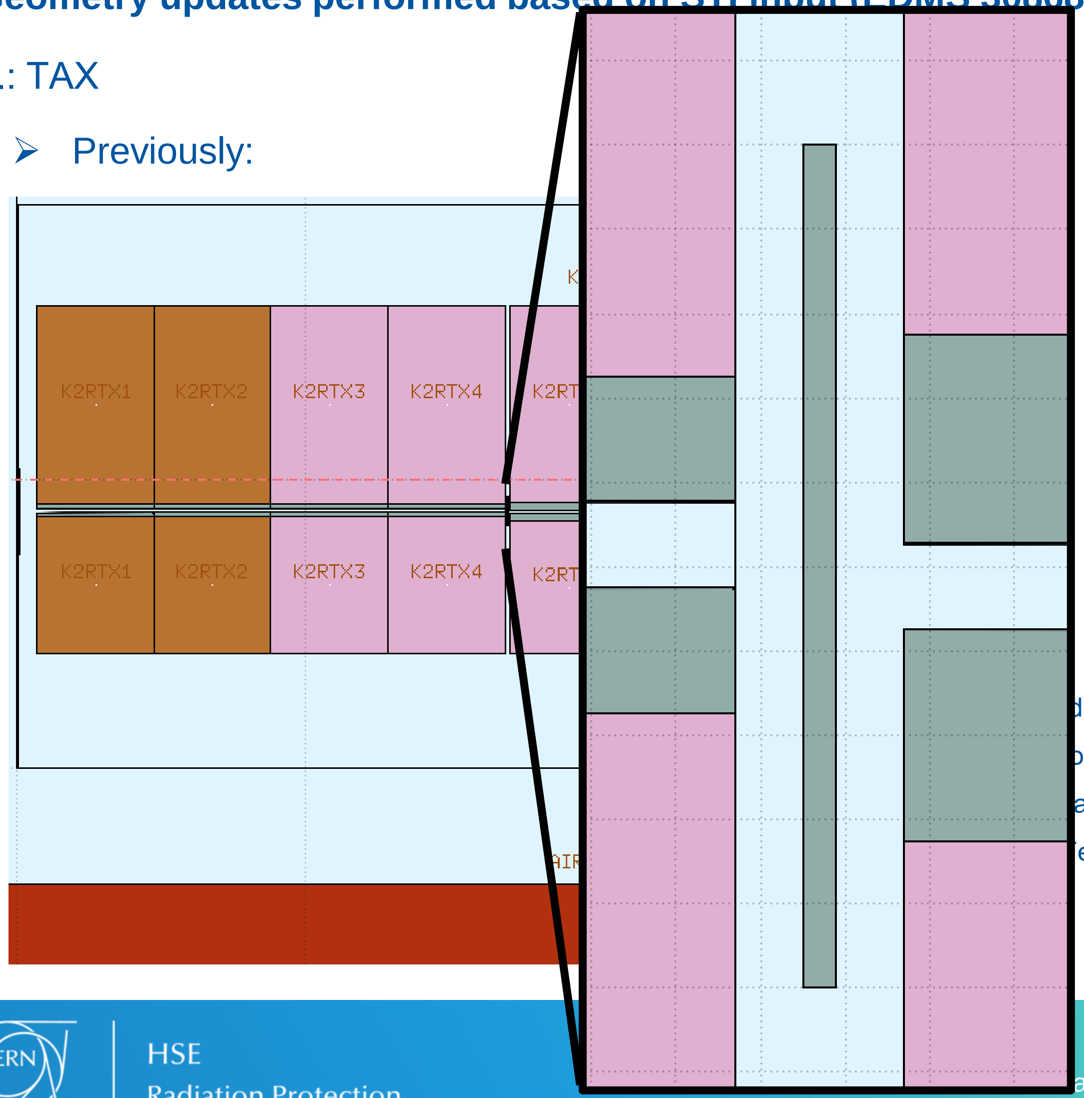
Addition of bottom parts made of Fe360

Addition of this copper plate

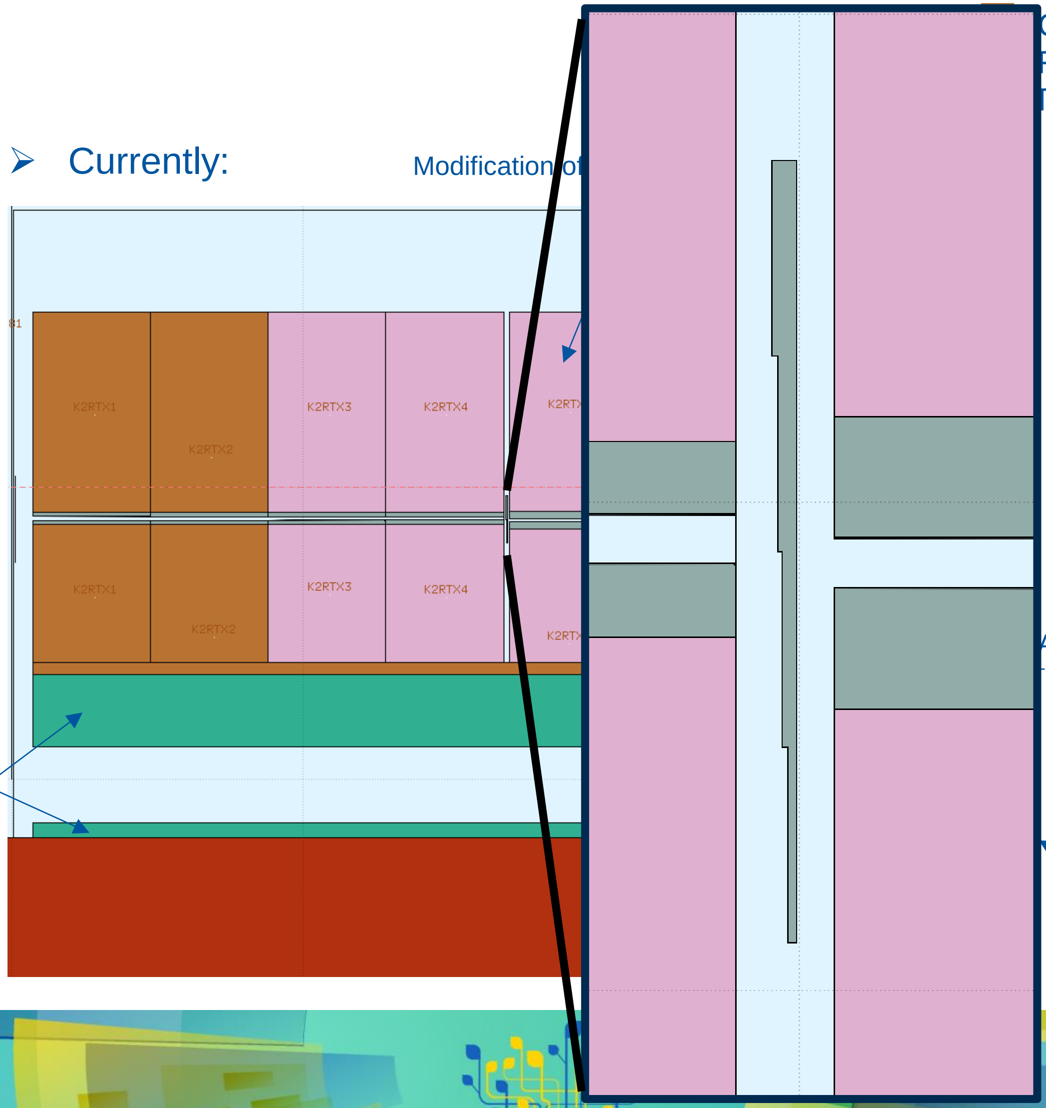
The floor is higher

TCC8 Decommissioning: Geometry

- Geometry modifications performed since the start of the work:
  1. **Geometry updates performed based on STI input (EDMS 3086822)**
- E.g.: TAX
  - Previously:



  - Currently:



TCC8 Decommissioning: Geometry

- Geometry modifications performed since the start of the work:
  1. **Geometry updates performed based on STI input (EDMS 3086822)**

- Refinement of material compositions: stainless steel, GG20, Fe360, Silafont30

MATERIAL Stainles — #: — ρ: 7.97 — Z: — Am: — A: — dE/dx: ▾

Material properties of SS316L

COMPOUND Stainles ▾ — Mix: Atom ▾ — Elements: 10..12 ▾

f1: 17.25	M1: CHROMIUM ▾	f2: 66.045	M2: IRON ▾
f3: 12.0	M3: NICKEL ▾	f4: 2.5	M4: MOLYBDEN ▾
f5: 1.0	M5: MANGANES ▾	f6: 1.0	M6: SILICON ▾
f7: 0.1	M7: COBALT ▾	f8: 0.03	M8: CARBON ▾
f9: 0.03	M9: SULFUR ▾	f10: 0.045	M10: PHOSPHO ▾
f11:	M11: ▾	f12:	M12: ▾

MATERIAL GG20 — #: — ρ: 7.15 — Z: — Am: — A: — dE/dx: ▾

COMPOUND GG20 ▾ — Mix: Mass ▾ — Elements: 16..18 ▾

f1: 92.69	M1: IRON ▾	f2: 2.8	M2: CARBON ▾
f3: 1.8	M3: SILICON ▾	f4: 0.75	M4: MANGANES ▾
f5: 1.1	M5: PHOSPHO ▾	f6: 0.4	M6: SULFUR ▾
f7: 0.08	M7: ALUMINUM ▾	f8: 0.04	M8: COPPER ▾
f9: 0.05	M9: NICKEL ▾	f10: 0.06	M10: CHROMIUM ▾
f11: 0.01	M11: MOLYBDEN ▾	f12: 0.01	M12: TUNGSTEN ▾
f13: 0.09	M13: VANADIUM ▾	f14: 0.06	M14: TITANIUM ▾
f15: 0.01	M15: NIOBIUM ▾	f16: 0.03	M16: COBALT ▾
f17: 0.02	M17: ARSENIC ▾	f18:	M18: ▾

MATERIAL SILAFO30 — #: — ρ: 2.65 — Z: — Am: — A: — dE/dx: ▾

COMPOUND SILAFO30 ▾ — Mix: Mass ▾ — Elements: 7..9 ▾

f1: 10.0	M1: SILICON ▾	f2: 0.15	M2: IRON ▾
f3: 0.02	M3: COPPER ▾	f4: 0.05	M4: MANGANES ▾
f5: 0.45	M5: MAGNESIU ▾	f6: 0.07	M6: ZINC ▾
f7: 0.15	M7: TITANIUM ▾	f8: 89.11	M8: ALUMINUM ▾
f9:	M9: ▾		

MATERIAL Fe360 — #: — ρ: 7.86 — Z: — Am: — A: — dE/dx: ▾

COMPOUND Fe360 ▾ — Mix: Mass ▾ — Elements: 7..9 ▾

f1: 0.17	M1: CARBON ▾	f2: 1.4	M2: MANGANES ▾
f3: 0.035	M3: PHOSPHO ▾	f4: 0.035	M4: SULFUR ▾
f5: 0.4	M5: SILICON ▾	f6: 97.96	M6: IRON ▾
f7:	M7: ▾	f8:	M8: ▾
f9:	M9: ▾		

TCC8 Decommissioning: Concrete Compositions

- Geometry modifications performed since the start of the work:
  1. Geometry updates performed based on STI input (EDMS 3086822)
  2. **Refinement of the concrete compositions for tunnel wall, floor, and shielding blocks through XRF and gamma-spec measurements performed in February in TCC8 (EDMS 3156461)**
  3. Correction of magnetic field maps performed with BE-EA (EDMS 3160904)

TCC8 Decommissioning: Concrete Compositions

- Geometry modifications performed since the start of the work:

2. **Refinement of the concrete compositions for tunnel wall, floor, and shielding blocks through XRF and gamma-spec measurements performed in February in TCC8 (EDMS 3156461)**

```
MATERIAL SHIELDbl                #:              ρ: 2.36
   Z:          Am:               A:              dE/dx: ▾
New composition added by F. Luoni (RP-AS) after the XRF and gamma-spec over samples collected in TCC8 in February 2024 with C. Ahdida, Y. Pira, and S.M. Boucly
COMPOUND SHIELDbl ▾              Mix: Mass ▾     Elements: 19..21 ▾
   f1: 50.048     M1: OXYGEN ▾      f2: 13.4       M2: CALCIUM ▾
   f3: 15.0       M3: SILICON ▾     f4: 8.0        M4: CARBON ▾
   f5: 1.515      M5: IRON ▾        f6: 7.9        M6: ALUMINUM ▾
   f7: 0.5        M7: MAGNESIU ▾    f8: 2.34       M8: POTASSIU ▾
   f9: 0.5        M9: SODIUM ▾      f10: 0.6       M10: HYDROGEN ▾
   f11: 0.2       M11: SULFUR ▾     f12: 6.4e-05   M12: EUROPIUM ▾
   f13: 0.26      M13: TITANIUM ▾   f14: 0.0005    M14: SCANDIUM ▾
   f15: 0.000495  M15: COBALT ▾     f16: 0.00027   M16: CESIUM ▾
   f17:           M17: ▾            f18:           M18: ▾
   f19:           M19: ▾            f20:           M20: ▾
   f21:           M21: ▾
MATERIAL TUNfloor                #:              ρ: 2.36
   Z:          Am:               A:              dE/dx: ▾
New composition added by F. Luoni (RP-AS) after the XRF and gamma-spec over samples collected in TCC8 in February 2024 with C. Ahdida, Y. Pira, and S.M. Boucly
COMPOUND TUNfloor ▾              Mix: Mass ▾     Elements: 19..21 ▾
   f1: 43.78      M1: OXYGEN ▾      f2: 20.7       M2: CALCIUM ▾
   f3: 12.0       M3: SILICON ▾     f4: 3.5        M4: CARBON ▾
   f5: 0.53       M5: SULFUR ▾      f6: 1.8        M6: ALUMINUM ▾
   f7: 0.65       M7: IRON ▾        f8: 0.0033     M8: ZINC ▾
   f9: 3.54       M9: POTASSIU ▾    f10: 3.2e-05   M10: TANTALUM ▾
   f11: 0.6       M11: HYDROGEN ▾   f12: 0.16      M12: TITANIUM ▾
   f13: 0.1       M13: PHOSPHO ▾    f14: 0.0004    M14: SCANDIUM ▾
   f15: 0.00053   M15: COBALT ▾     f16: 0.00015   M16: CESIUM ▾
   f17: 5.8e-05   M17: EUROPIUM ▾   f18: 0.11      M18: CHLORINE ▾
   f19:           M19: ▾            f20:           M20: ▾
   f21:           M21: ▾
MATERIAL TUNwall                 #:              ρ: 2.36
   Z:          Am:               A:              dE/dx: ▾
New composition added by F. Luoni (RP-AS) after the XRF and gamma-spec over samples collected in TCC8 in February 2024 with C. Ahdida, Y. Pira, and S.M. Boucly
COMPOUND TUNwall ▾               Mix: Mass ▾     Elements: 19..21 ▾
   f1: 50.98      M1: OXYGEN ▾      f2: 17.0       M2: CALCIUM ▾
   f3: 15.1       M3: SILICON ▾     f4: 6.5        M4: CARBON ▾
   f5: 0.95       M5: SULFUR ▾      f6: 1.4        M6: ALUMINUM ▾
   f7: 1.47       M7: IRON ▾        f8: 1.5        M8: MAGNESIU ▾
   f9: 0.85       M9: POTASSIU ▾    f10: 0.453     M10: SODIUM ▾
   f11: 0.6       M11: HYDROGEN ▾   f12: 0.08      M12: TITANIUM ▾
   f13: 0.0155    M13: ZINC ▾       f14: 5.8e-05   M14: TANTALUM ▾
   f15: 0.0004    M15: COBALT ▾     f16: 0.00036   M16: CESIUM ▾
   f17: 6.8e-05   M17: EUROPIUM ▾   f18: 0.00045   M18: SCANDIUM ▾
```

- Precise concrete compositions are important to predict as best as possible the residual dose rates coming from the concrete, which are particularly important for the re-usage of the concrete blocks and remaining residual dose rates in the emptied TCC8 cavern (e.g. for installation of new equipment)

TCC8 Decommissioning: Concrete Compositions

- Geometry modifications performed since the start of the work:

  2. **Refinement of the concrete compositions for tunnel wall, floor, and shielding blocks through XRF and gamma-spec measurements performed in February in TCC8 (EDMS 3156461)**

STEP 1: scoring particle fluences with FLUKA

STEP 2: Using ActiWiz to match the radionuclide production

- Iterative process:

Starting point = CNGS concrete compositions + XRF measurements in TCC8

X-RAY FLUORESCENCE

Iterations:

Manually fine-tuning the abundance of each element

End point = concrete compositions matching the Gamma Spec results

GAMMA SPECTROSCOPY

TCC8 Decommissioning: Concrete Compositions

- Example of results: TCC8 Floor

Final Composition:

```
# Density: 2.36  g/cm3
ALUMINUM          1.8
CALCIUM 20.7
CARBON  3.5
CESIUM  0.00015
CHLORINE          0.11
COBALT  0.00053
EUROPIUM          5.8e-05
HYDROGEN          0.6
IRON    0.65
OXYGEN  43.78
PHOSPHORUS        0.1
POTASSIUM         3.54
SCANDIUM          0.0004
SILICON 12
SULFUR  0.53
TANTALUM          3.2e-05
TITANIUM          0.16
ZINC    0.0033
```

SCANDIUM → Production of Sc-46

TANTALUM → Production of Ta-182

ZINC → Production of Zn-65

Elements added to CNGS compositions

N.B.: Na and Mg are not part of the composition because they led to a too-high Na-22 production

Comparison with XRF results:

% Mass	Ca	Si	Al	Fe	K	P	S	Ti	Cl
XRF:	20.9 ± 0.2	13.8 ± 0.3	2.5 ± 0.7	1.63 ± 0.03	3.54 ± 0.08	0.1 ± 0.06	0.53 ± 0.04	0.16 ± 0.02	0.11 ± 0.01

Ca: matching. Si: It was reduced to produce the measured Na-22 activity. Al: matching. Fe: It was reduced to produce the measured Mn-54 activity. K, P, S, Ti, Cl: matching.

Isotope production results obtained with the final composition:

(N.B.: Be-7 is not included in the gamma-spec results as its activity is under the MDA value. Therefore, the oxygen content is supposed to be less precise than in the following two compositions, since oxygen is the main source of Be-7)

Isotope	Activity (Bq/g) – Gamma Spec Results	Activity (Bq/g) – from our AW iterative process
Na-22	0.23 ± 0.02	0.25 ± 0.03
Sc-46	0.39 ± 0.02	0.38 ± 0.01
Mn-54	0.08 ± 0.01	0.08 ± 0.03
Fe-59	0.05 ± 0.01	0.022 ± 0.002
Co-60	0.77 ± 0.03	0.77 ± 0.03
Zn-65	0.08 ± 0.01	0.083 ± 0.002
Cs-134	0.36 ± 0.02	0.34 ± 0.04
Eu-152	0.86 ± 0.03	0.9 ± 0.1
Eu-154	0.13 ± 0.01	0.126 ± 0.009
Ta-182	0.05 ± 0.01	0.055 ± 0.009

The only radionuclide production that is not matched within the error bars is Fe-59 because both Fe-59 and Mn-54 are mainly produced through the activation of iron. Therefore, Mn-54 has been given priority since:

1. Mn-54 has higher activity
2. Mn-54 is well-benchmarked in AW

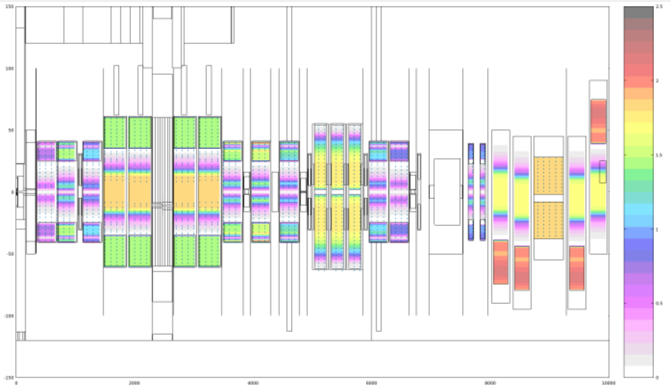
even if the measured XRF iron content is not matched like this. Priority was given to gamma-spec over XRF as the produced radionuclides are more critical for waste management

TCC8 Decommissioning: Magnetic Fields

- Geometry modifications performed since the start of the work:
  1. Geometry updates performed based on STI input (EDMS 3086822)
  2. Refinement of the concrete compositions for tunnel wall, floor, and shielding blocks through XRF and gamma-spec measurements performed in February in TCC8 (EDMS 3156461)
  3. **Correction of magnetic field maps performed with BE-EA (EDMS 3160904)**

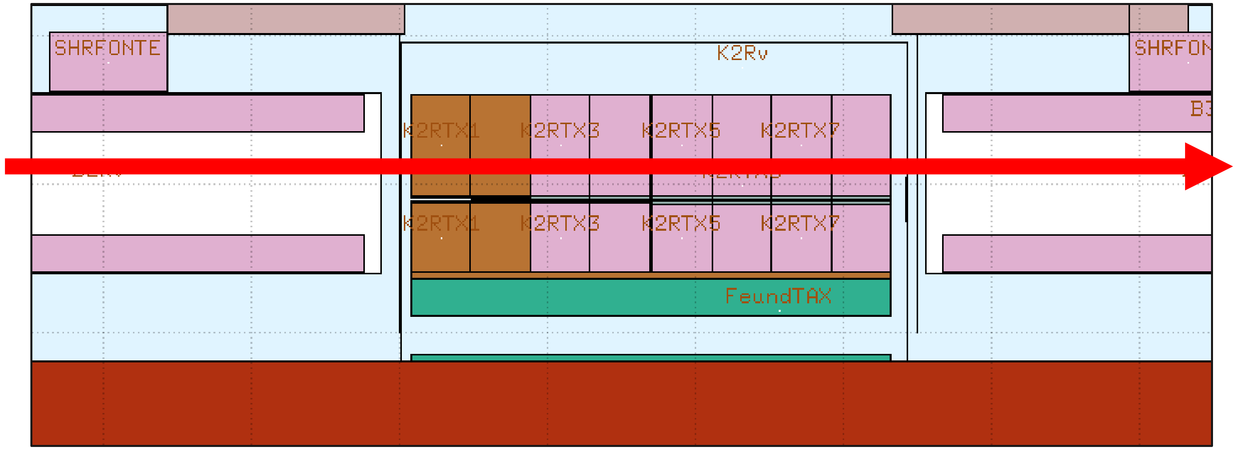
TCC8 Decommissioning: Magnetic Fields

- Geometry modifications performed since the start of the work:
  3. **Correction of magnetic field maps performed with BE-EA (EDMS 3160904)**

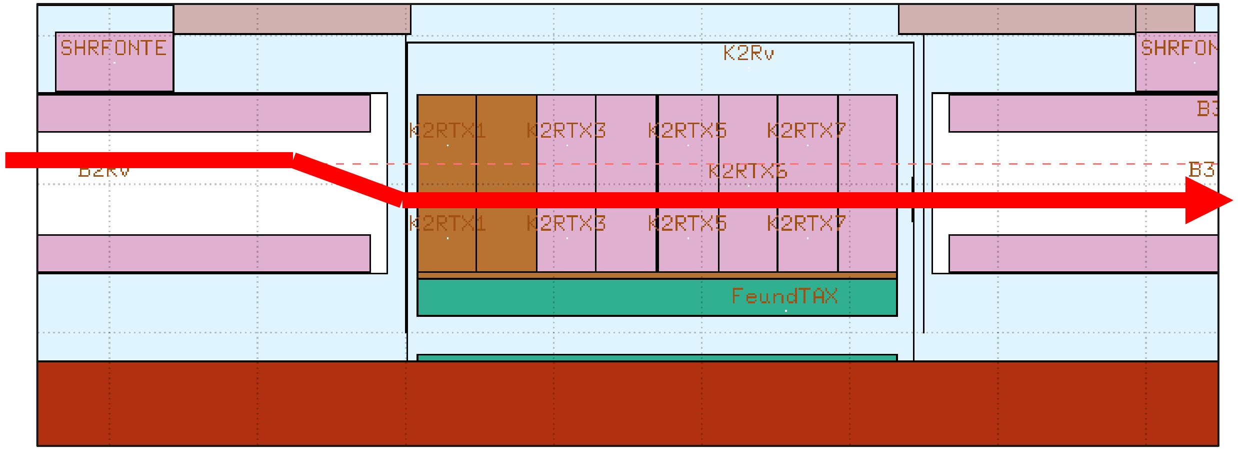


- Trajectory of 75 Gev/c positive particles:

- Before the correction of the magnetic fields: 75 GeV/c positive particles go straight and they are damped in the TAX



- After the correction of the magnetic fields: 75 GeV/c positive particles follow the magnetic chicane

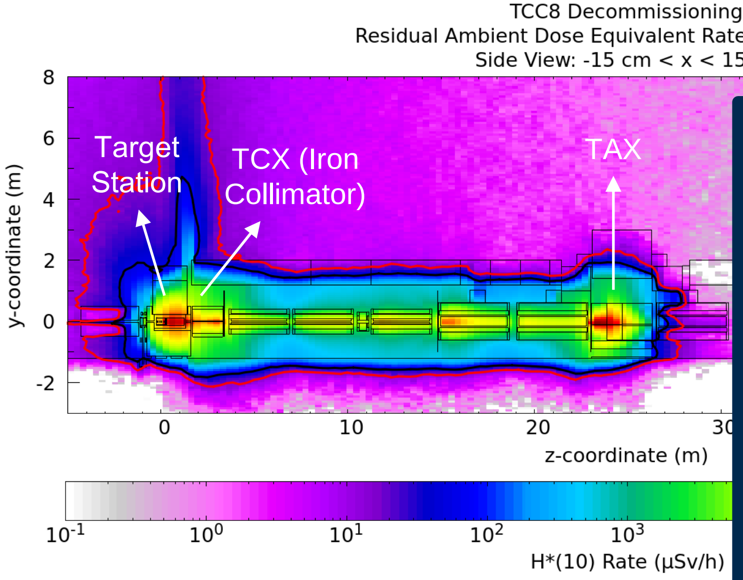


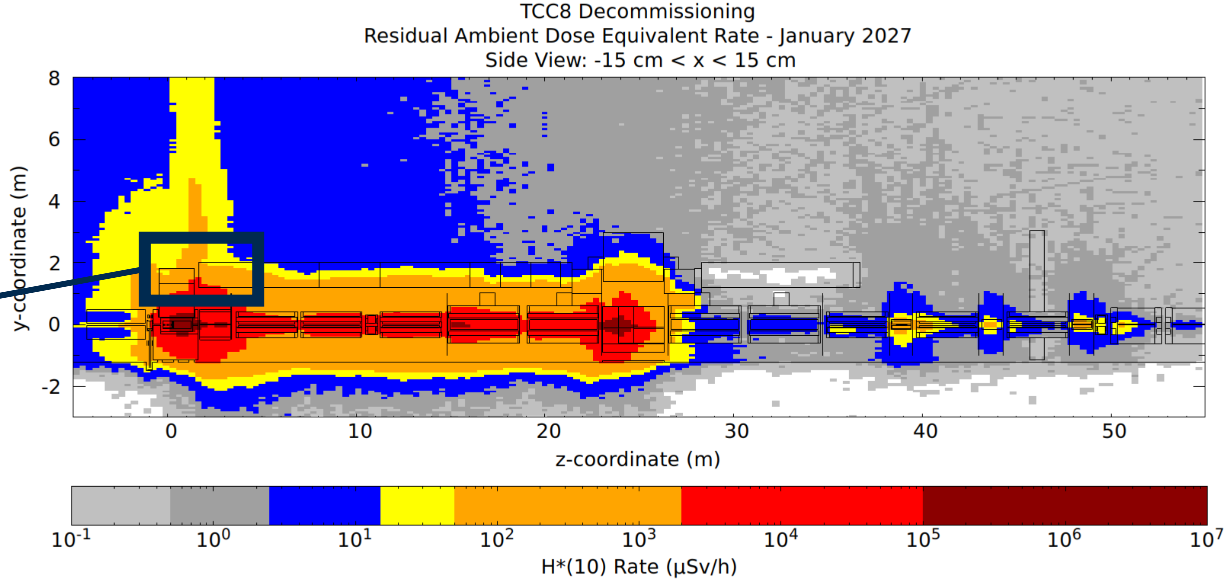
TCC8 Decommissioning: Residual Dose Rates

- Residual dose rate maps – January 2027 = 6 months after the updated (shifted) start of LS3, i.e. earliest date for TCC8 dismantling (data are available also for September 2027, latest date of TCC8 dismantling with goal to minimize the overlap with NA-CONS activities)
- The radiation levels are high in the location of the target station and TCX (on top especially because of a **gap** in the shielding blocks)
- The beamline area w/ 1m distance to components is compatible with a Limited Stay Controlled Area
- Outside of the shielded area, the levels are compatible with a Supervised Radiation Area, except around the target station and the TCX
- Hot areas are also around the collimators downstream of the TAX

Area	Annual dose limit (year)	Ambient dose equivalent rate	
		permanent occupancy	low occupancy
Non-designated	1 mSv	0.5 µSv/h	2.5 µSv/h
Supervised	6 mSv	3 µSv/h	15 µSv/h
Simple Controlled	20 mSv	10 µSv/h	50 µSv/h
Limited Stay	20 mSv	-	2 mSv/h
High Radiation	20 mSv	-	100 mSv/h
Prohibited	20 mSv	-	> 100 mSv/h

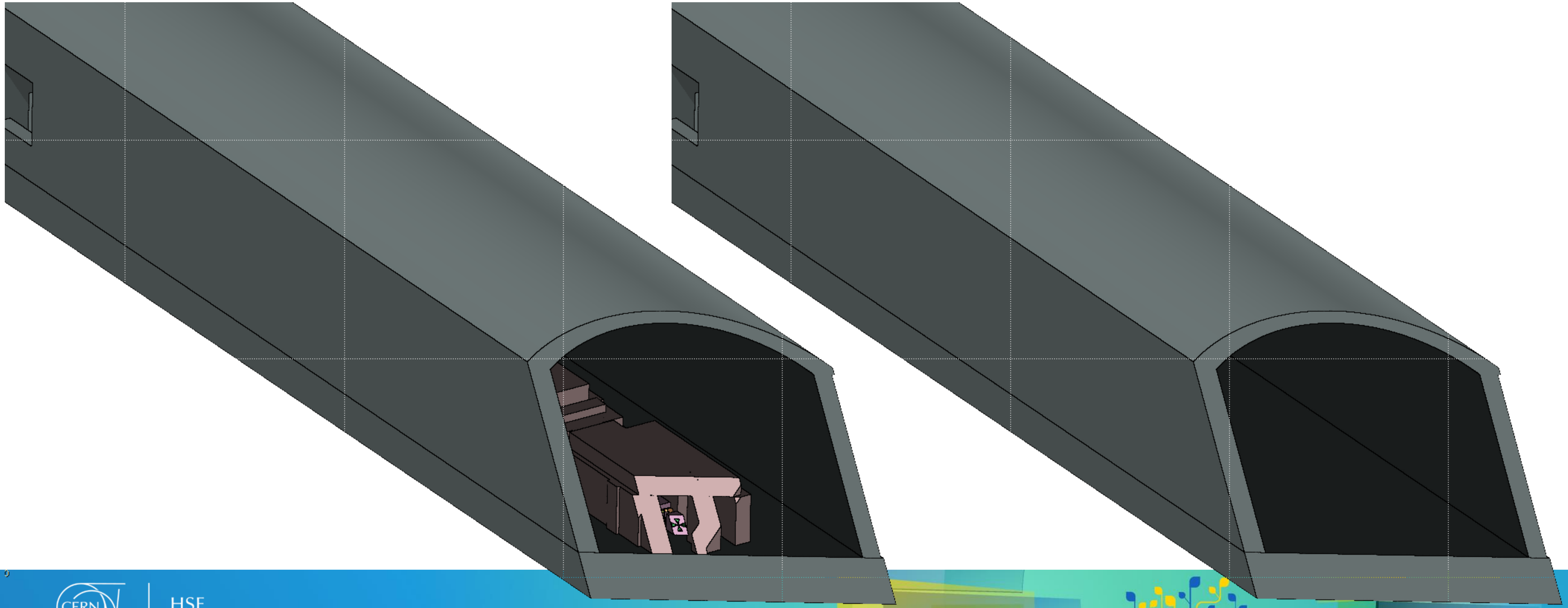
Radiation Area (Supervised to Prohibited); Controlled Area (Simple Controlled to Prohibited)





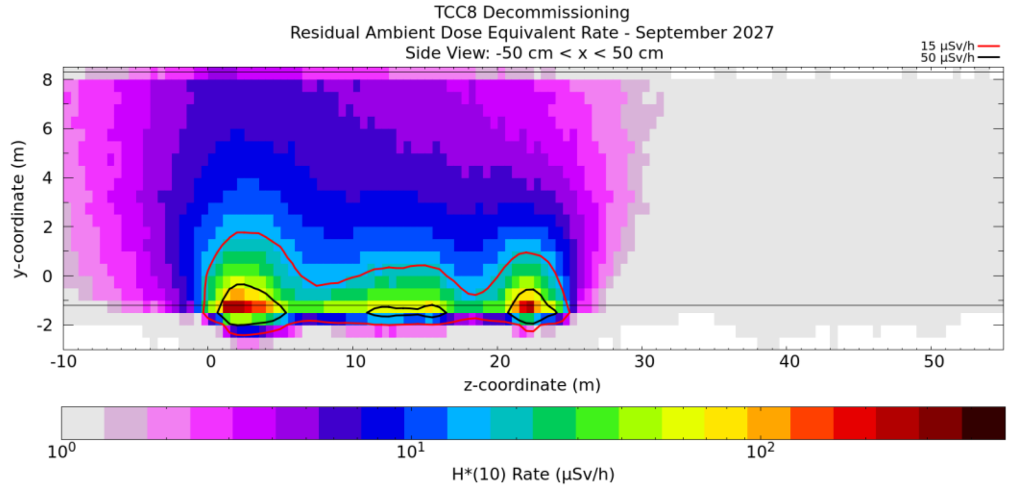
TCC8 Decommissioning: Residual Dose Rates

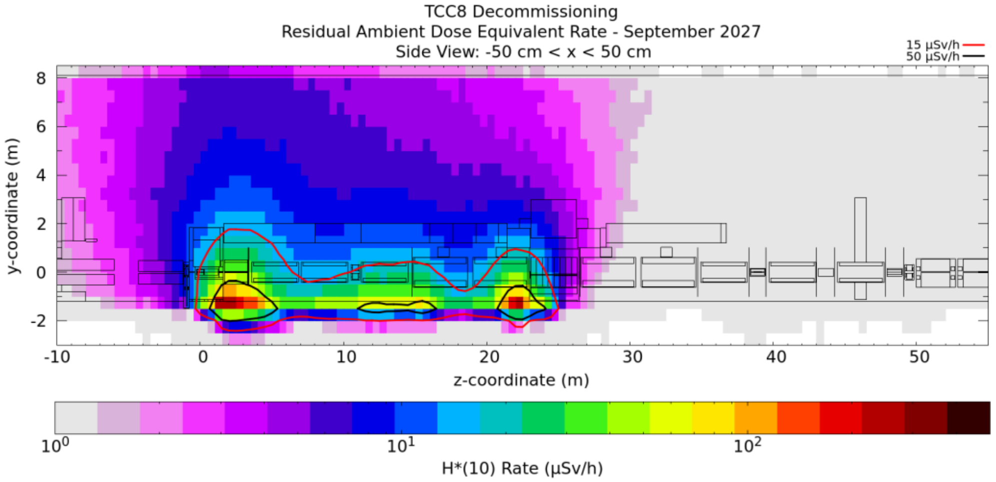
- Activation of the TCC8 tunnel walls and floor:
- The residual dose rates are solely from the activation of the cavern floor and walls, as all the beamline elements and the shielding block regions were set to air during the decay step

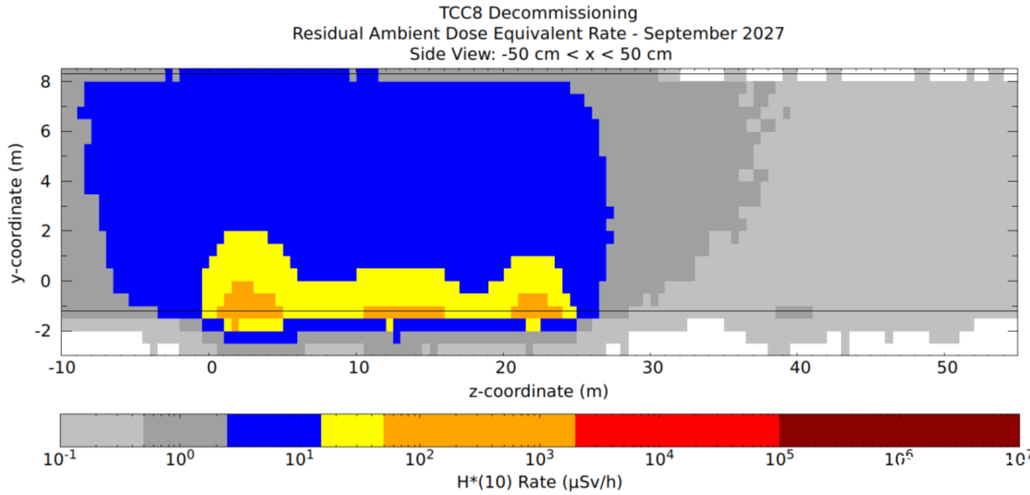


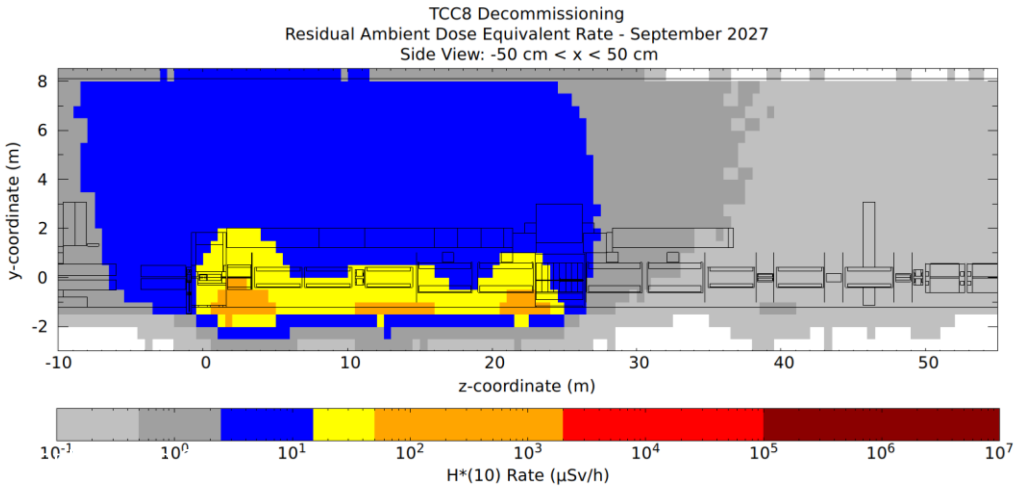
TCC8 Decommissioning: Tunnel Activation

- Activation of the TCC8 tunnel walls and floor:
- No Objects (as it actually is in the simulation and will be in reality):
- With Phantom Objects:







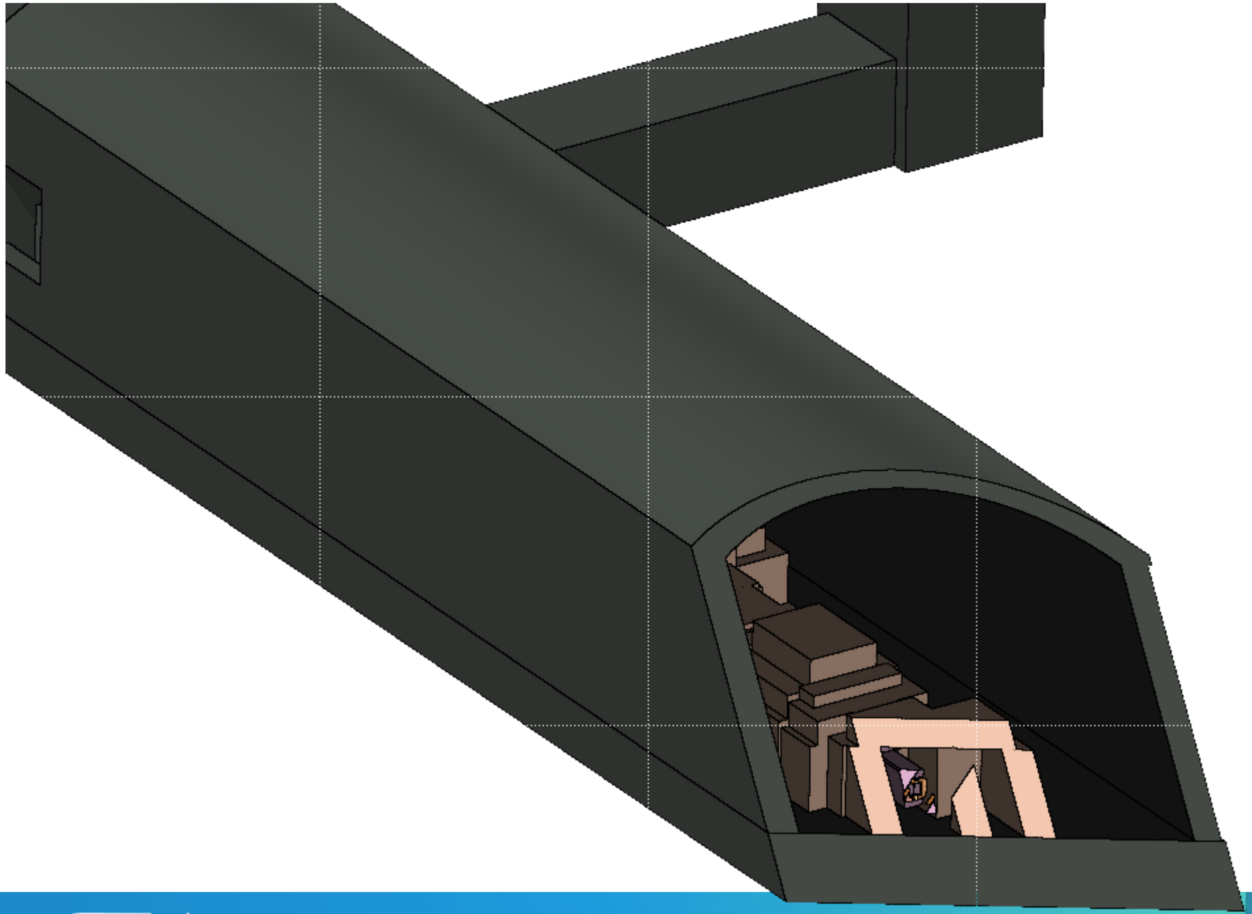


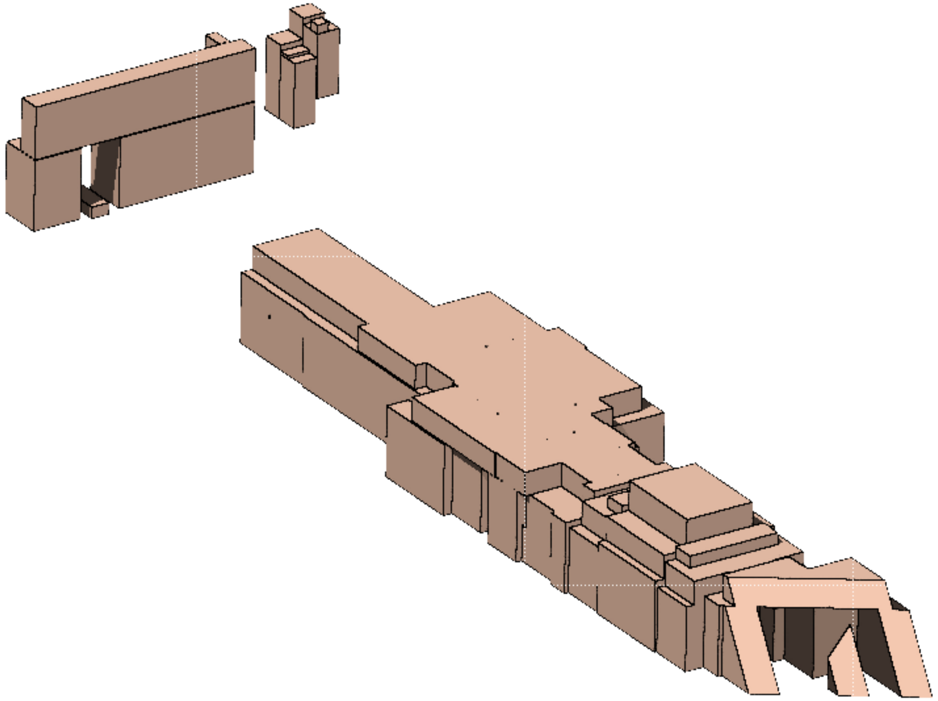
	Area	Annual dose limit (year)	Ambient dose equivalent rate: permanent occupancy	Ambient dose equivalent rate: low occupancy	
	Non-designated	1 mSv	0.5 µSv/h	2.5 µSv/h	
Radiation Area	Supervised	6 mSv	3 µSv/h	15 µSv/h	
Radiation Area	Simple Controlled	20 mSv	10 µSv/h	50 µSv/h	Controlled Area
Radiation Area	Limited Stay	20 mSv	-	2 mSv/h	Controlled Area
Radiation Area	High Radiation	20 mSv	-	100 mSv/h	Controlled Area
Radiation Area	Prohibited	20 mSv	-	> 100 mSv/h	Controlled Area

- The empty TCC8 tunnel between the target station and the TAX is compatible with a Limited Stay Radiation Area classification. The rest is compatible with a Non-Designated Area
- Max contact dose rate at the floor ~ 0.3 mSv/h
- Local shielding can be foreseen
- Main contributing isotopes: Co-60 (~40%), Eu-152 (~25%), Na-22 (~20%), Cs-134 (~10%)

TCC8 Decommissioning: Residual Dose Rates

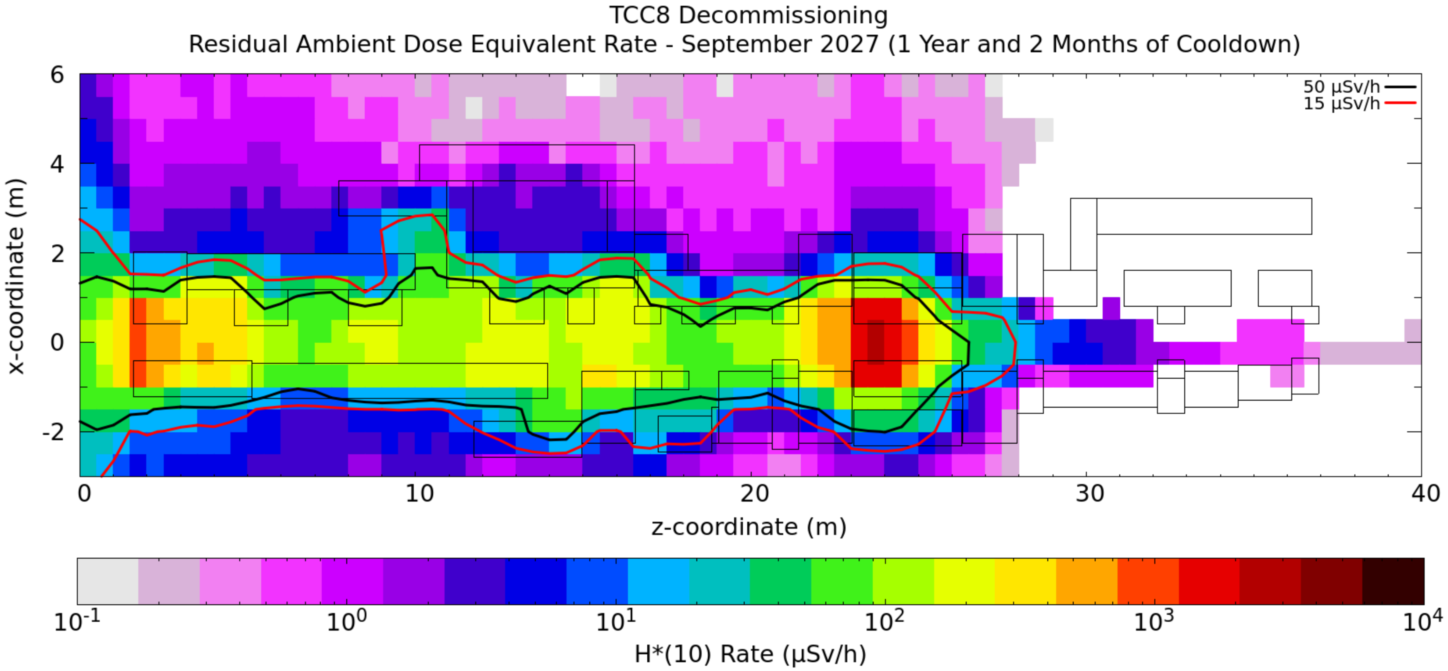
- Activation studies of the TCC8 shielding blocks to evaluate the re-usability of the shielding blocks in other experimental areas, compatibly with their area classification
- The residual dose rates are solely from the activation of the shielding blocks, as all the beamline elements, cavern floor and walls, were set to air during the decay step





TCC8 Decommissioning: Shield Activation

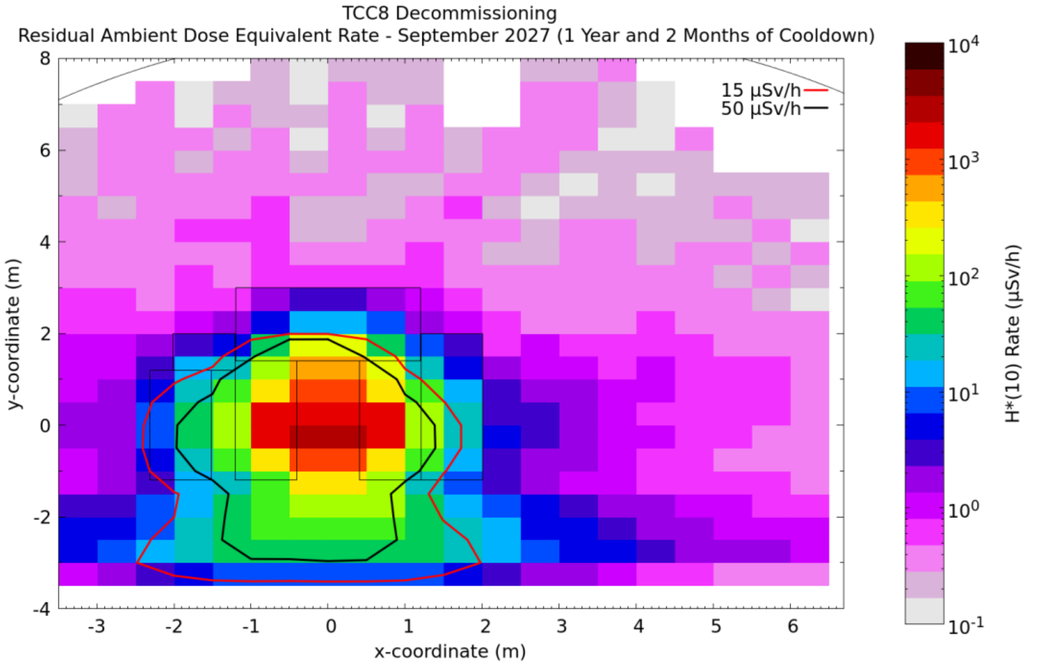
- No equipment parts, just shielding blocks:



Area	Annual dose limit (year)	Ambient dose equivalent rate	
		permanent occupancy	low occupancy
Non-designated	1 mSv	0.5 µSv/h	2.5 µSv/h
Supervised	6 mSv	3 µSv/h	15 µSv/h
Simple Controlled	20 mSv	10 µSv/h	50 µSv/h
Limited Stay	20 mSv	-	2 mSv/h
High Radiation	20 mSv	-	100 mSv/h
Prohibited	20 mSv	-	> 100 mSv/h

Radiation Area (Supervised to Prohibited); Controlled Area (Simple Controlled to Prohibited)

- Cross-view of the TAX shielding blocks:

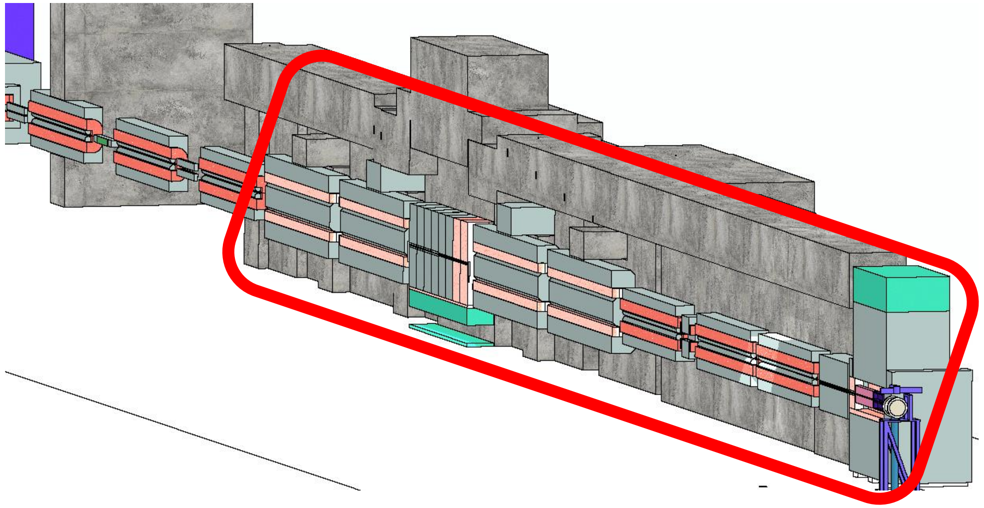


- The residual dose rates are due to the activation of all blocks together. Therefore, the same study should be performed again for single blocks or for the blocks of just one side of the beamline → to be followed up
- There is always a hotter side of the blocks, which can be put against the wall or floor in other facilities, or two hot sides can be placed against each other in a sandwich-type configuration

TCC8 Decommissioning: Radioactive Waste and transport

- Radionuclide inventory of all relevant regions that will become waste (e.g. TAX and target station regions) or will be transported to storage (e.g. magnets)

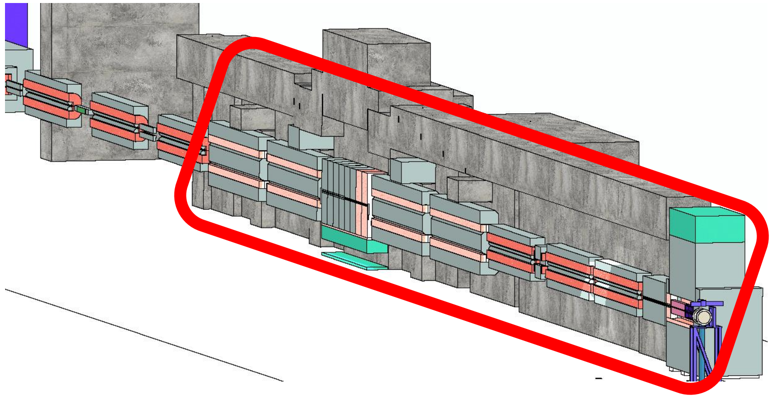
https://cernbox.cern.ch/s/bBl7JTP9PZqcbVc/Particle_fluences?items-per-page=100&view-mode=resource-table&tiles-size=1&sort-by=name&sort-dir=asc



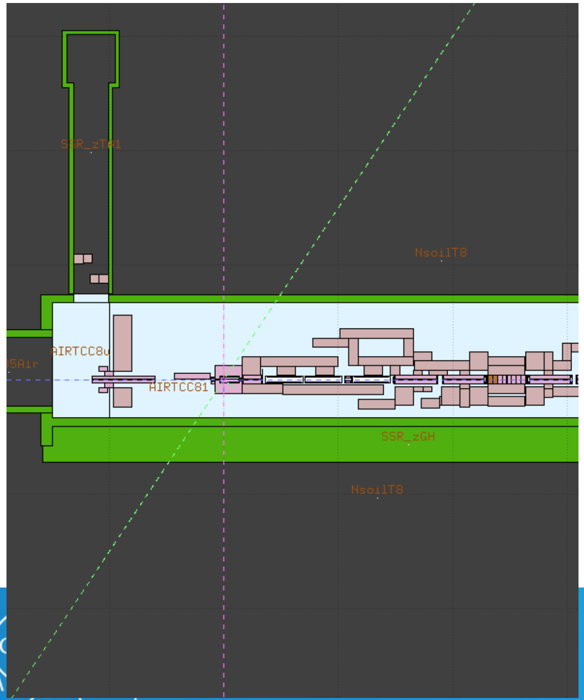
B1Rc	CoolPla3	K2RFOIL	TAXi1	tarbox
B1Ry	cuinsert	MCWFr	TAXi2	TAX1
B2Rc	CuundTAX	MgFro	TAXi3	TAX2
B2Ry	FeundTAX	Q1Ry	TAXi4	TAX3
B3Rc	K0Rcastl	Q2Ry	TAXi5	TAX4
B3Ry	K0Rcucol	Q3Ry	TAXi6	TAX5
B4Rc	K0Rins	RBIDup	TAXi7	TAX6
B4Ry	K0Rtrgt	RTBItop	TAXi8	TAX7
CoolPla1	K1Rtcx	T1Rb	TBIDsupp	TAX8
CoolPla2	K1Rtcxin	T1Ry	triang	TAXfloor

- RP-CS and RP-RWM were provided with the average neutron, positive-pion, negative-pion, and proton fluences out of the FLUKA simulations in **50** regions

TCC8 Decommissioning: Radioactive Waste and transport

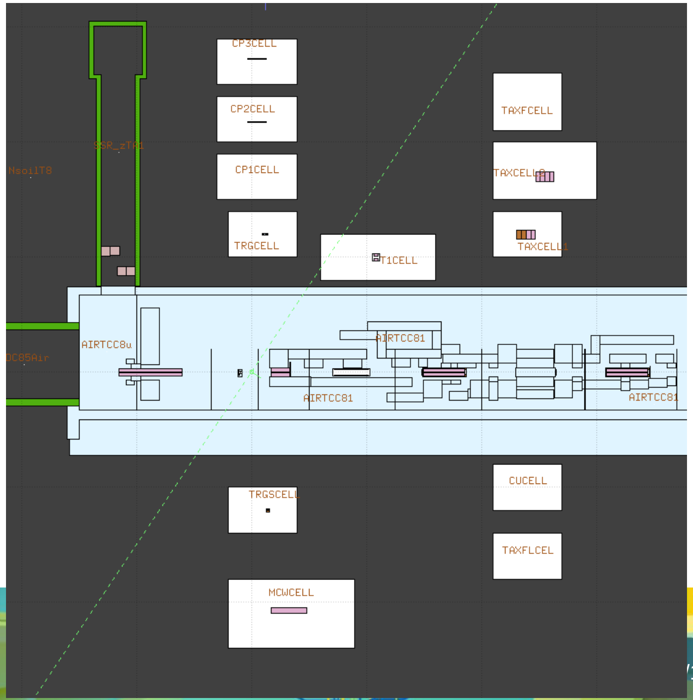


- For **25** groups of beamline equipment pieces, the dose rate at contact, at 10 cm, and at 40 cm, were provided, for 6 months after the updated (shifted) start of the LS3
- Residual dose maps around each region were provided too
- This was done using SESAME
- Irradiation Phase



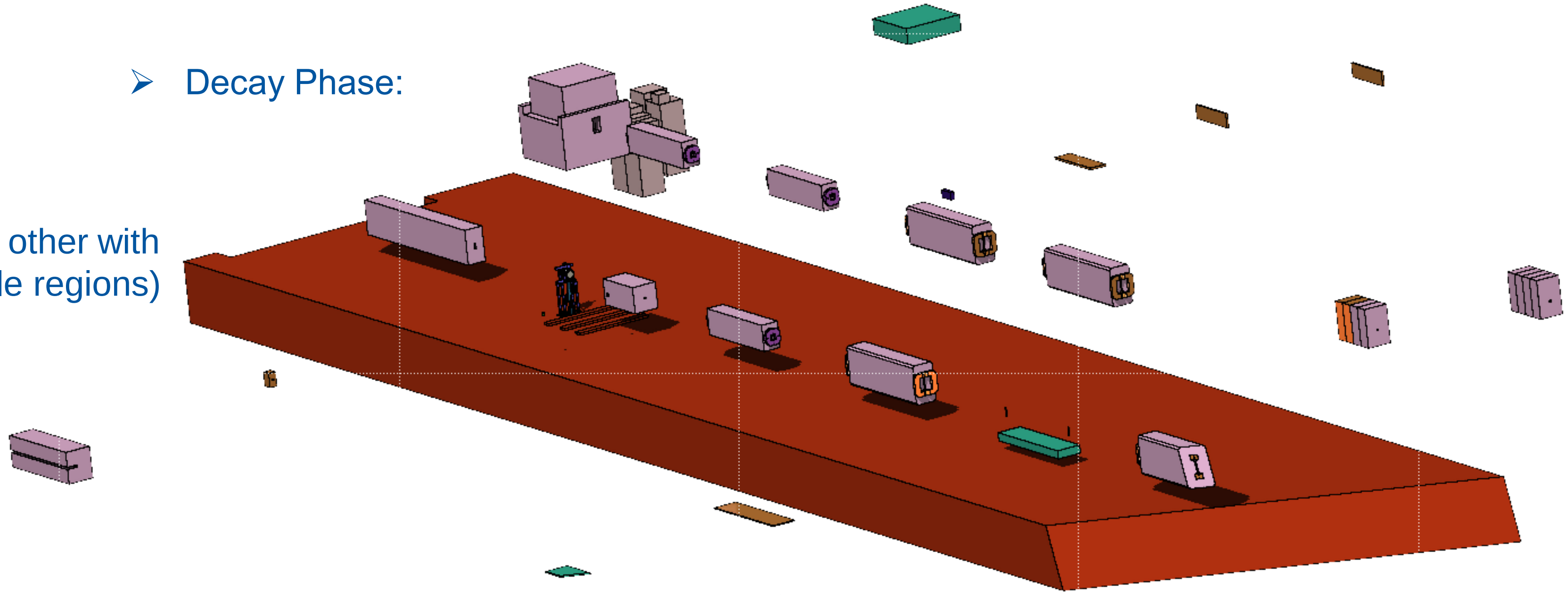
Objects are separated from each other (some are moved around the TCC8 tunnel and separated with thin black-hole walls, and some are isolated in single cells) during the decay phase so that the residual dose around each stand-alone object can be determined

- Decay Phase



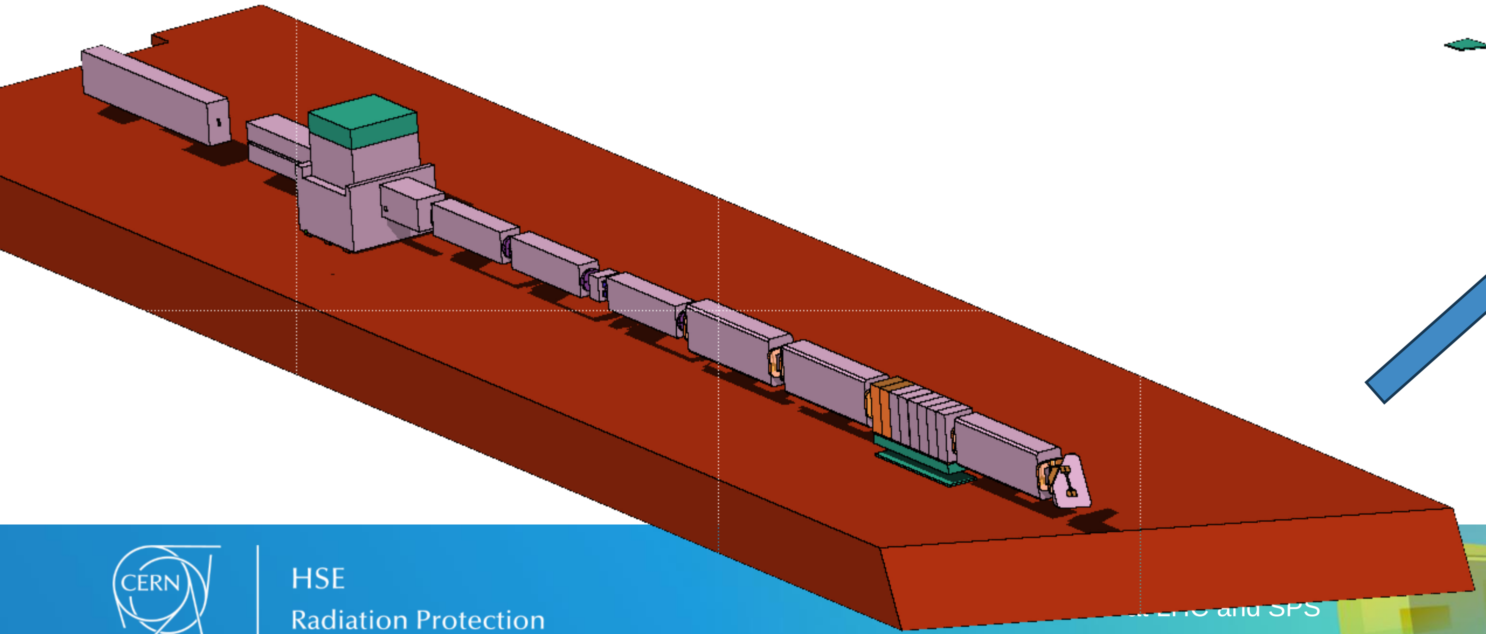
TCC8 Decommissioning: Radioactive Waste and transport

- Decay Phase:



(all separated from each other with black whole regions)

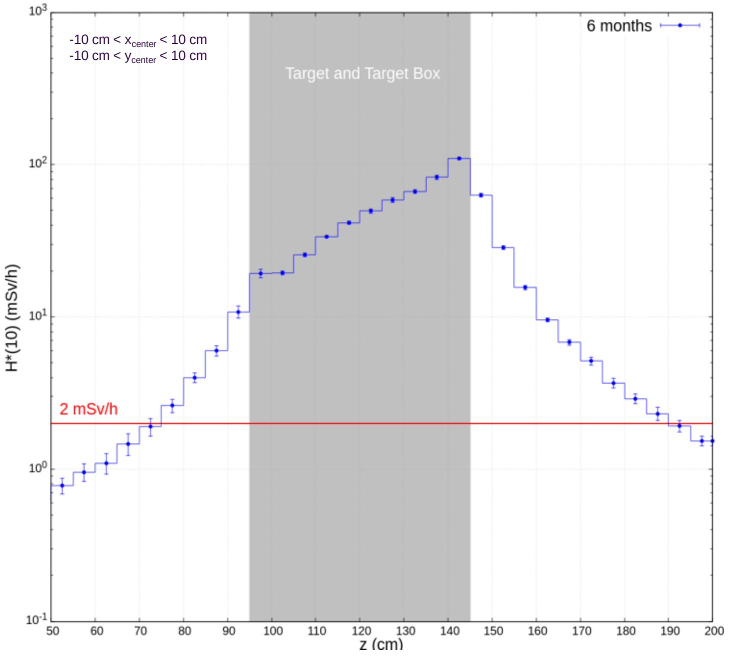
- Irradiation Phase:

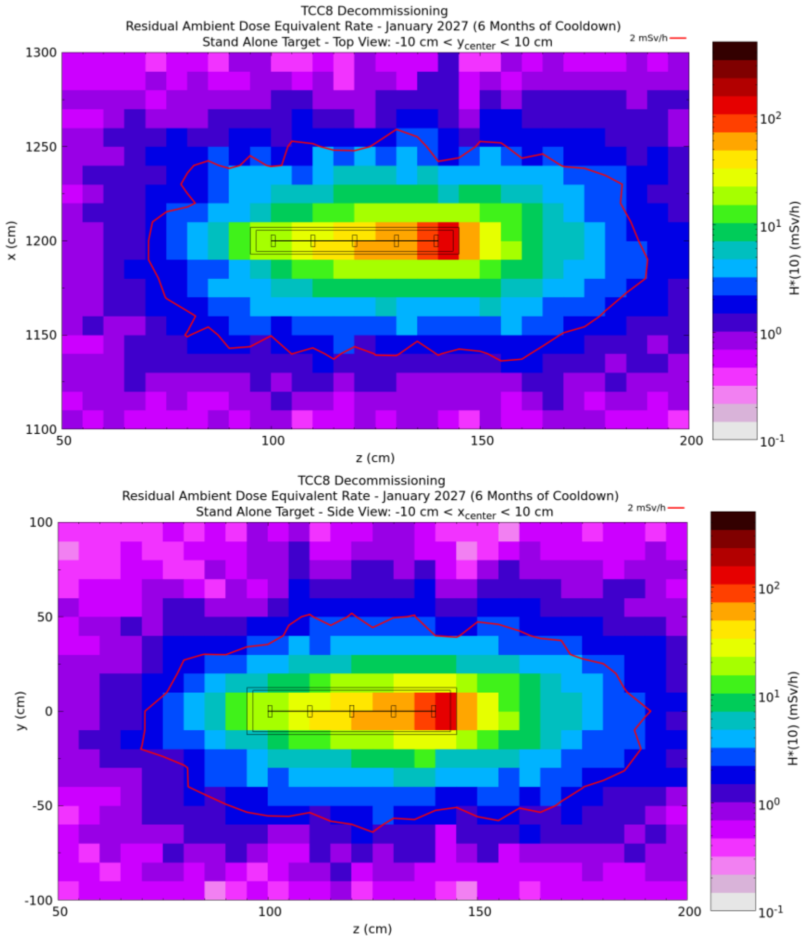


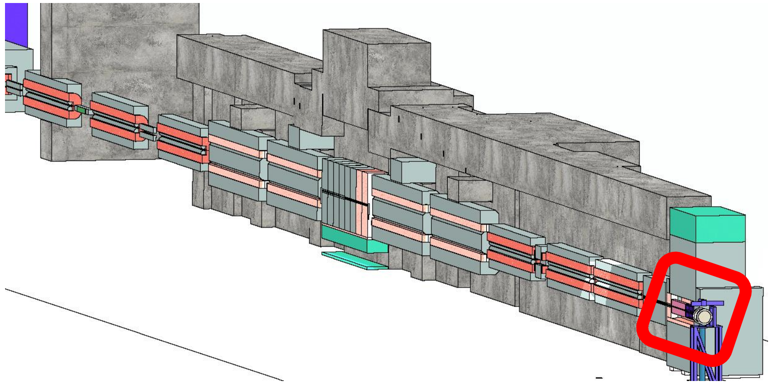
Objects are separated from each other (some are moved around the TCC8 tunnel and separated with thin black-hole walls, and some are isolated in single cells) during the decay phase so that the residual dose around each stand-alone object can be determined

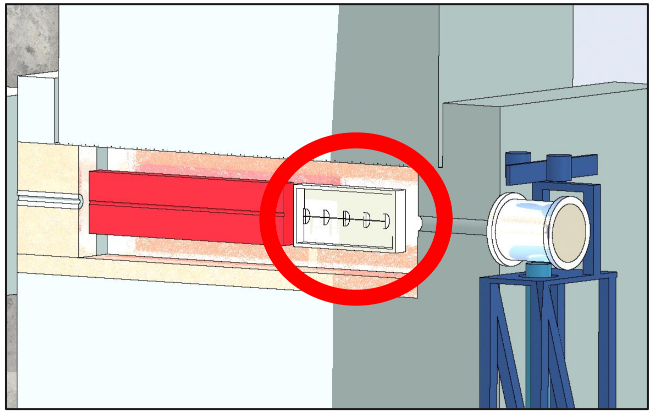
TCC8 Decommissioning: Radioactive Waste and transport

- Done for **25 groups of equipment pieces**
- Example: target and target box









- Max Dose Rate @contact ~ 80 mSv/h
- Max Dose Rate @10cm ~ 20 mSv/h
- Max Dose Rate @40cm ~ 3 mSv/h

- The 2 mSv/h transportation limit would be exceeded. Additional shielding is to be foreseen for many of the groups of equipment pieces studied.
- To be noticed: the 2 mSv/h limit is valid at the truck walls → for some objects, placing them the right way might be enough.

TCC8 Decommissioning: Conclusions

- The RP assessment for the TCC8 decommissioning in view of the installation of BDF/SHiP, was performed

- Several geometry corrections were made along the way:
  - Geometry updates performed based on STI input (EDMS 3086822)
  - Refinement of the concrete compositions for tunnel wall, floor, and shielding blocks through XRF and gamma-spec measurements performed in February 2024 in TCC8 (EDMS 3156461)
  - Correction of magnetic field maps performed with BE-EA (EDMS 3160904)
  - Update of the foreseen operation (LS3 shift)

- The residual dose rates were simulated and area classification considerations were made for:
  - TCC8 tunnel as it is right now: RP study for the start of the dismantling process
  - TCC8 tunnel empty: activation of tunnel floor and wall RP study for the end of the dismantling process
  - TCC8 shielding blocks: activation of the shielding blocks studied to evaluate the re-usability of the shielding blocks in other experimental areas, compatibly with their area classification (to be optimised for single blocks)

- Radionuclide inventory: the average fluences, irradiation profile, and details about the 50 equipment pieces were provided to RP-CS and RWM (https://cernbox.cern.ch/files/link/public/bBI7JTP9PZqcbVc?scrollTo=List_of_Beamline_elements_v2.xlsx&tiles-size=1&items-per-page=100&view-mode=resource-table&sort-by=name&sort-dir=asc)

- For **25** groups of beamline equipment pieces, the dose rate at contact, at 10 cm, and at 40 cm, were provided, for 6 months after the updated (shifted) start of the LS3 to RP-CS and RWM for transportation and radioactive waste management of all TCC8 equipment

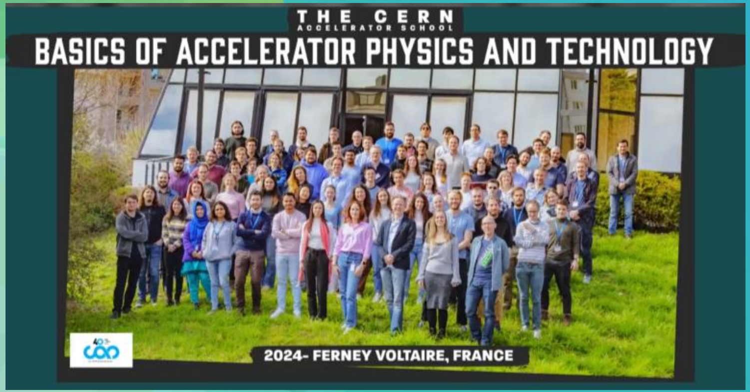
CERN | HSE Radiation Protection

Thank you for your attention!

And for giving me the opportunity to work here and learn about accelerator RP for 1 year and 3 months!

CERN

HSE
Radiation Protection



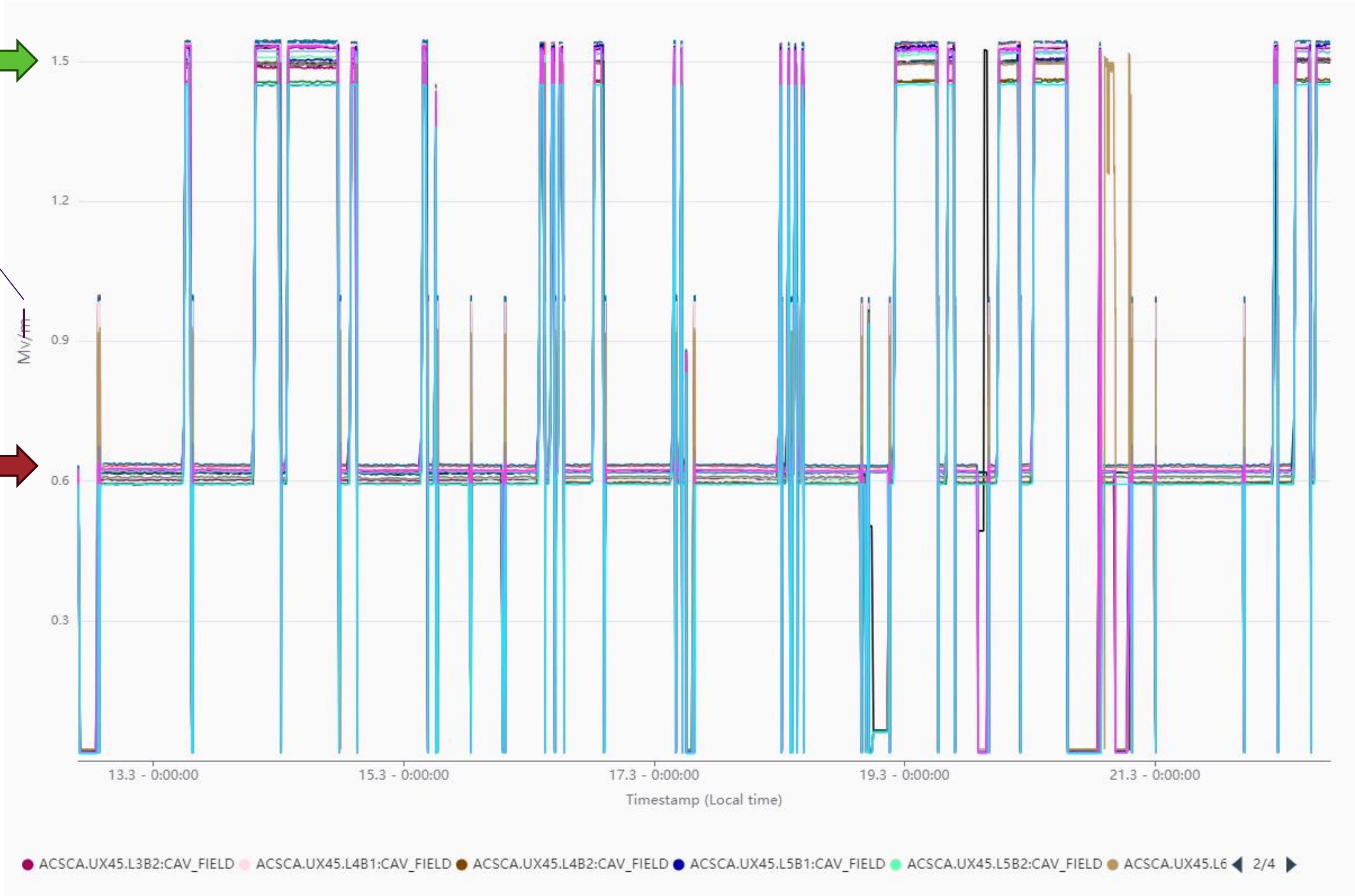
HSE
Radiation Protection

Backup Material

RF: Voltage

Timber (cern.ch) . There is a mistake : the cavity voltage should be in MV not in MV/m

From Katarzyna Turaj



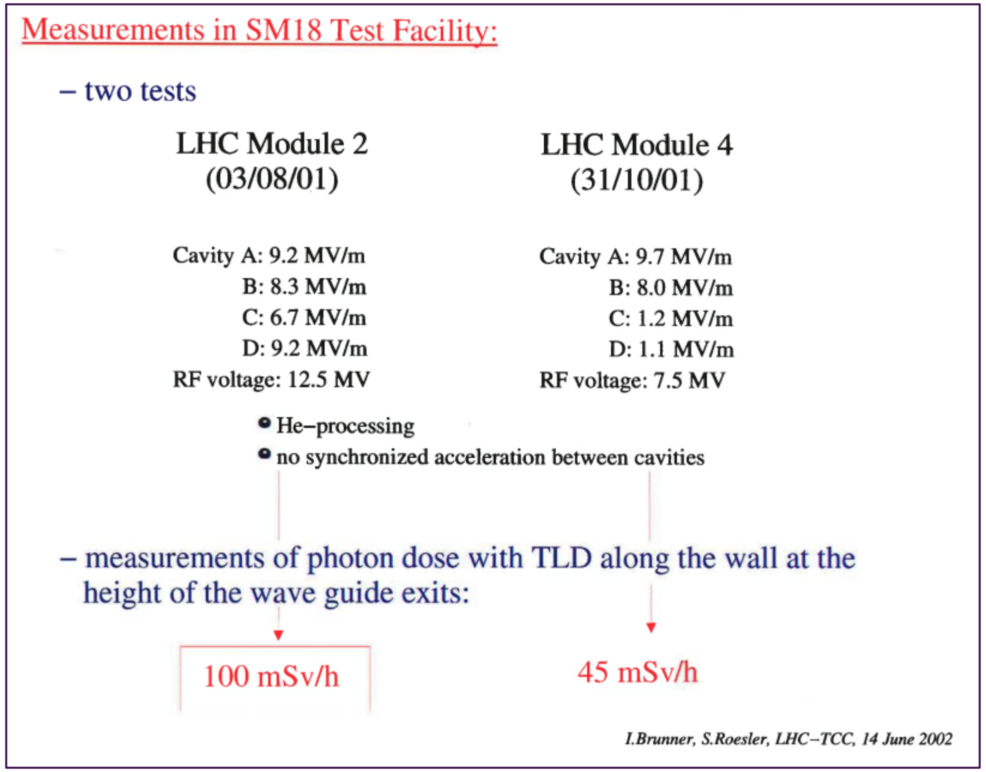
- Since each cavity applies a 1.5 MV potential maximum, for the FLUKA simulations we used as source 12 MeV electrons (1.5 MV x 8 cavities)

When are the RF cavities actually operating? When the LHC is being filled, when the beam is accelerated, or also when the beam is kept to 7TeV? → They are only switched off when the machine is in access mode or there is a long blocking problem in the LHC. The Rf cavities are used during filling, energy ramping and flat top (physics). They operate at different voltages. During injection the voltage across each cavity is 0.67 MV (protons) or 0.75 MV (ions), and in flat top they operate at 1.5 MV (protons) or 1.75 MV (ions). These values are correct for this year and may change slightly depending on operational requirements.

From Katarzyna Turaj

Normalisation: Reference

- Rooms in SM18 for the RF tests are R-A39 and R-A49



Measurements in SM18 Test Facility:

– two tests

LHC Module 2 (03/08/01)	LHC Module 4 (31/10/01)
Cavity A: 9.2 MV/m	Cavity A: 9.7 MV/m
B: 8.3 MV/m	B: 8.0 MV/m
C: 6.7 MV/m	C: 1.2 MV/m
D: 9.2 MV/m	D: 1.1 MV/m
RF voltage: 12.5 MV	RF voltage: 7.5 MV

- He–processing
- no synchronized acceleration between cavities

– measurements of photon dose with TLD along the wall at the height of the wave guide exits:

100 mSv/h	45 mSv/h

I.Brunner, S.Roesler, LHC–TCC, 14 June 2002

https://edms.cern.ch/ui/file/1822274/1/FLUKAstudy-LHC-RF.pdf

- Therefore, at the wall means ~ 2m (or a bit less) from the RF centre

AdvSND-NEAR: ActiWiz Calculations

- ActiWiz (AW) is an HSE-RP tool to calculate component activation

INPUT

- Particle fluences scored within a FLUKA simulation
- Irradiation profile
- Object material composition

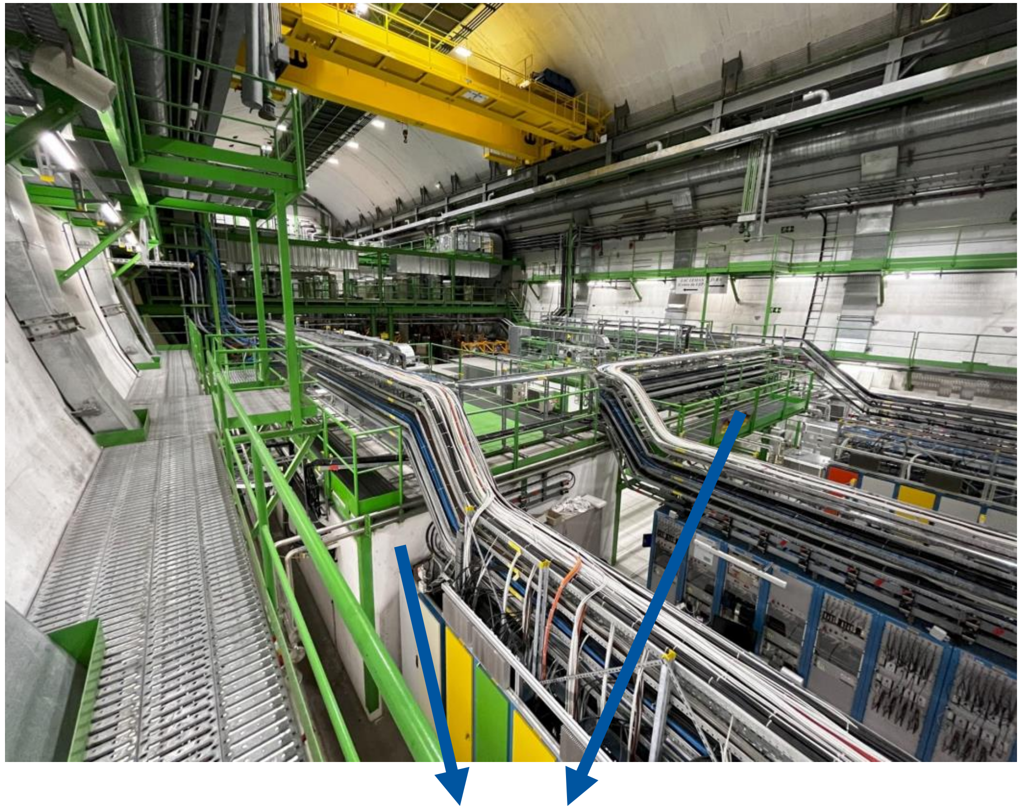
→ **ActiWiz** →

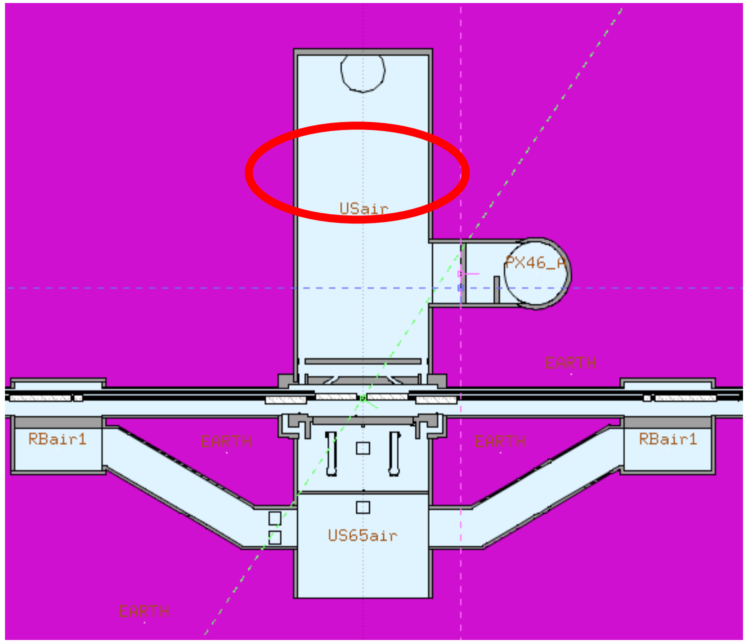
OUTPUT

- Object activation in terms of:
  - H*(10)
  - $\sum_{i=1}^{n} \frac{a_i}{LL_i}$ (s_{LL})
- Main isotope contributors

AION100: Geometry

- The real geometry is even more complicated and not everything could be taken into account





The UX45 cavern is modelled as empty in our geometry, but it has many objects in it, including 2 bunkers, which do not impact the RP evaluation, as they are in the back of the cavern

AION100: Geometry

- The real geometry is even more complicated and not everything could be taken into account




The integration of the UX Klystron waveguides in the shielding penetration is very complex, we used a conservative approach (direct line of sight)

AION100: Geometry

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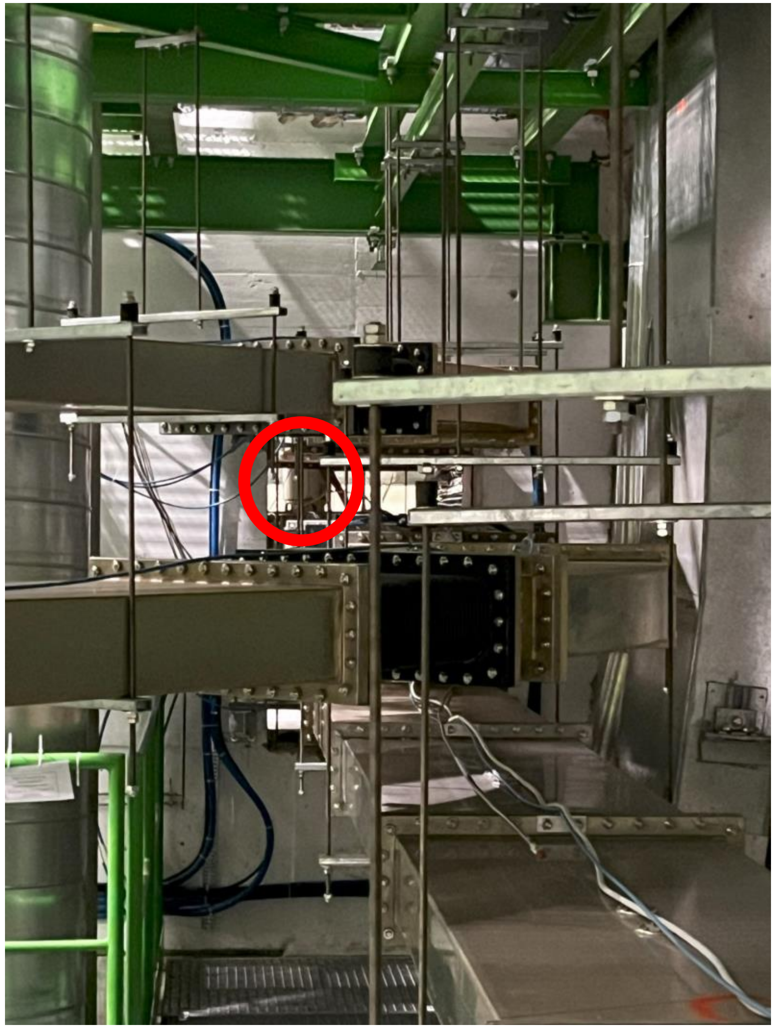
The integration of the UX Klystron waveguides in the shielding penetration is very complex, we used a conservative approach **(direct line of sight)**



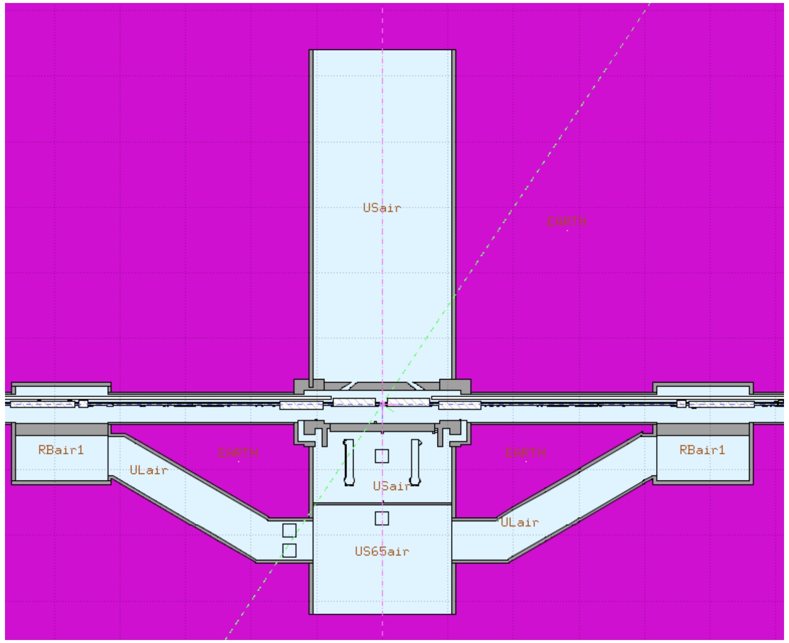
From the UX45

AION100: Geometry

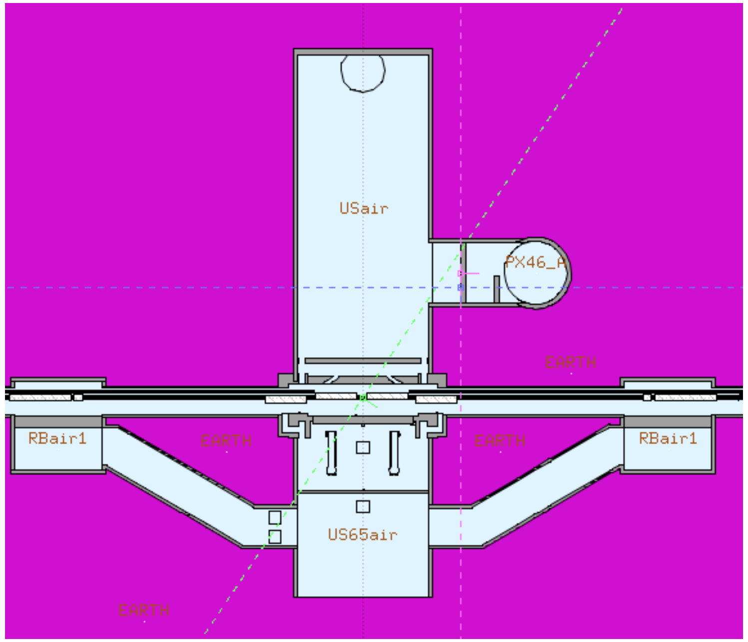
Main RP additions to STI initial geometry:

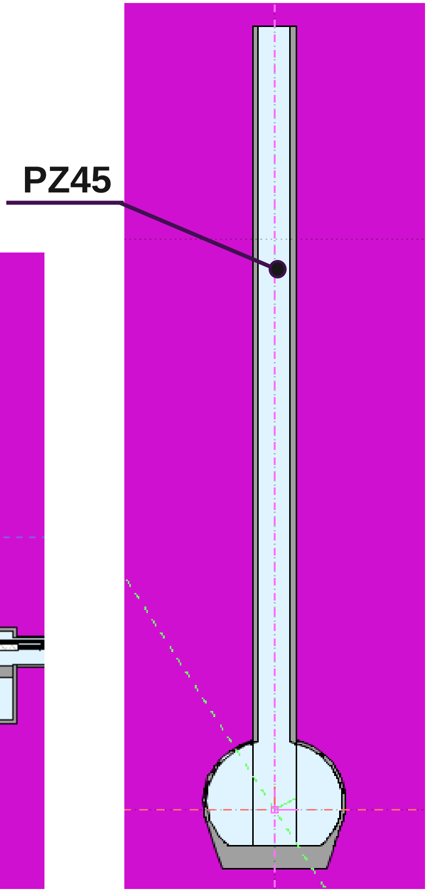
- PX46 shaft
- Its connections to the UX45 gallery:
  - TX46
  - TU46
- PZ45 shaft
- Shielding walls and holes in the walls

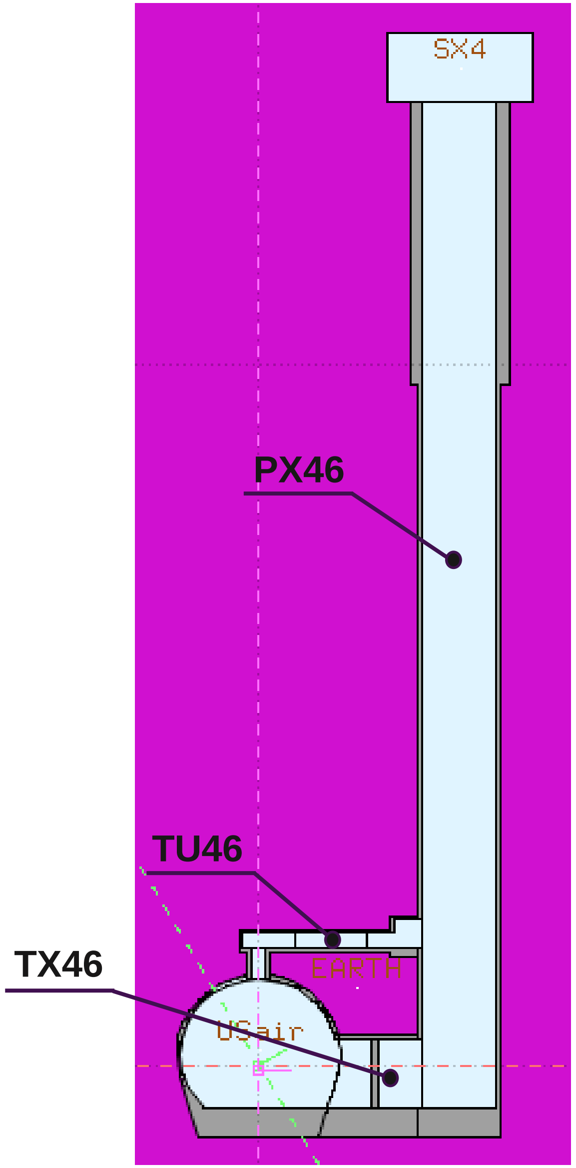
- STI starting model:



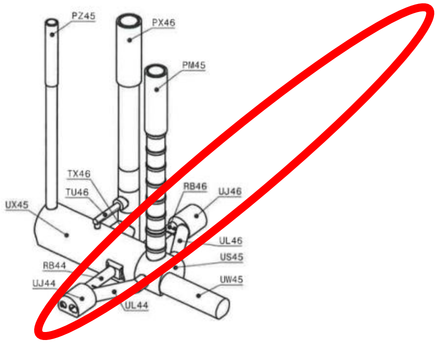
- RP expanded model:



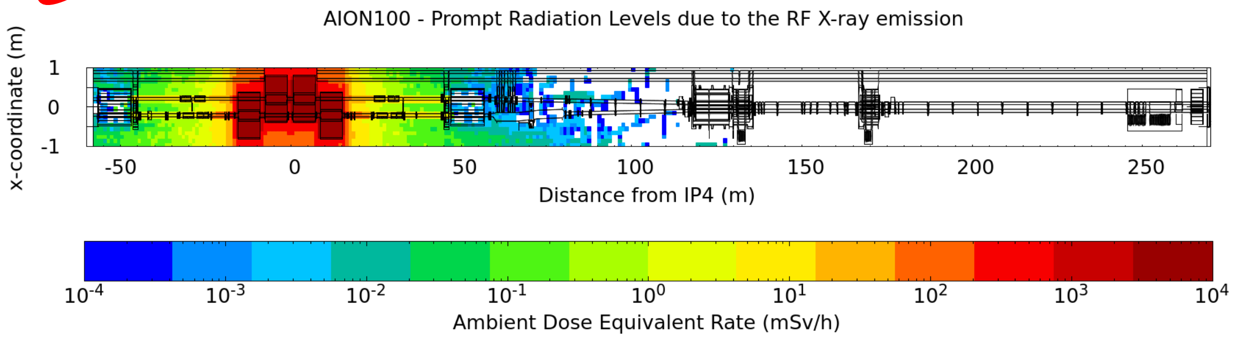


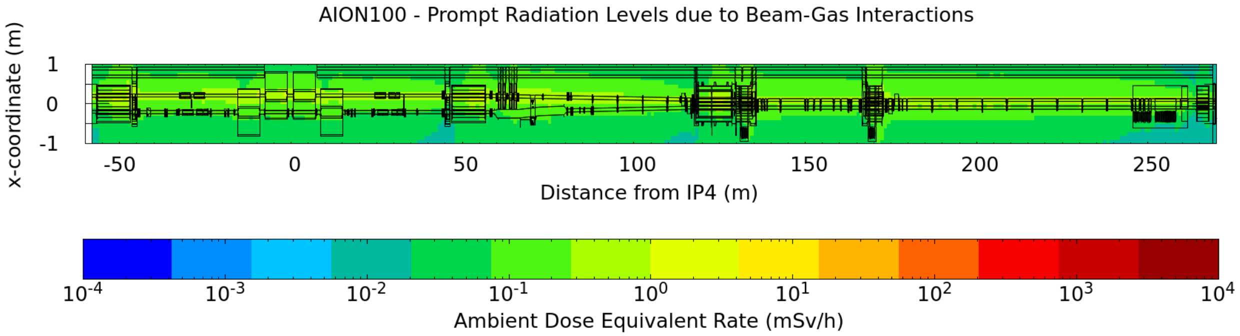


AION100: Nominal Operation Radiation Levels

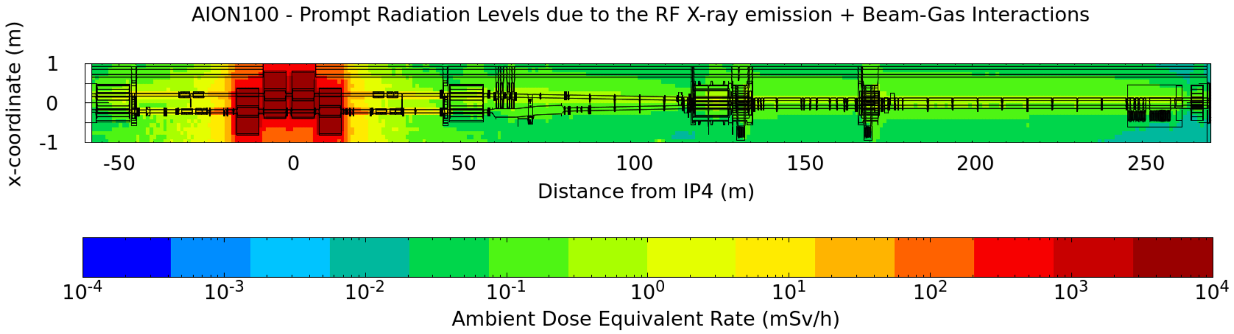


- ➢ Sum of RF X-ray emissions and beam-gas interactions in the whole LSS4 - right side



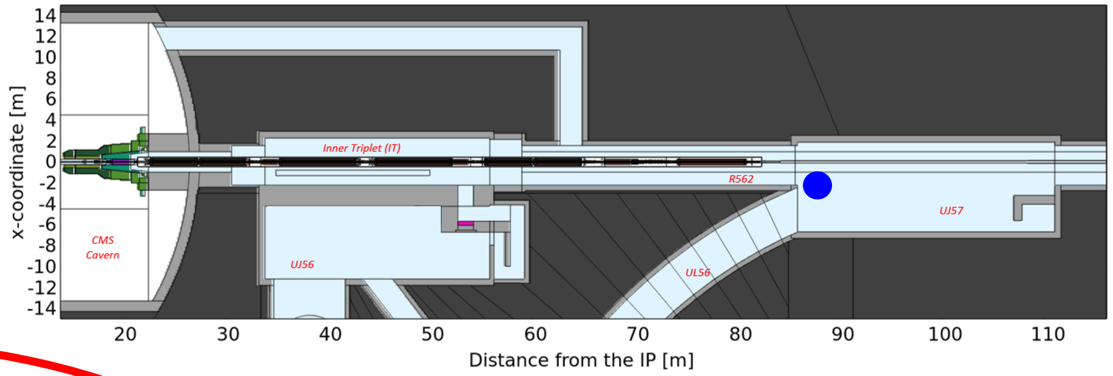


-20 cm < y < 20 cm

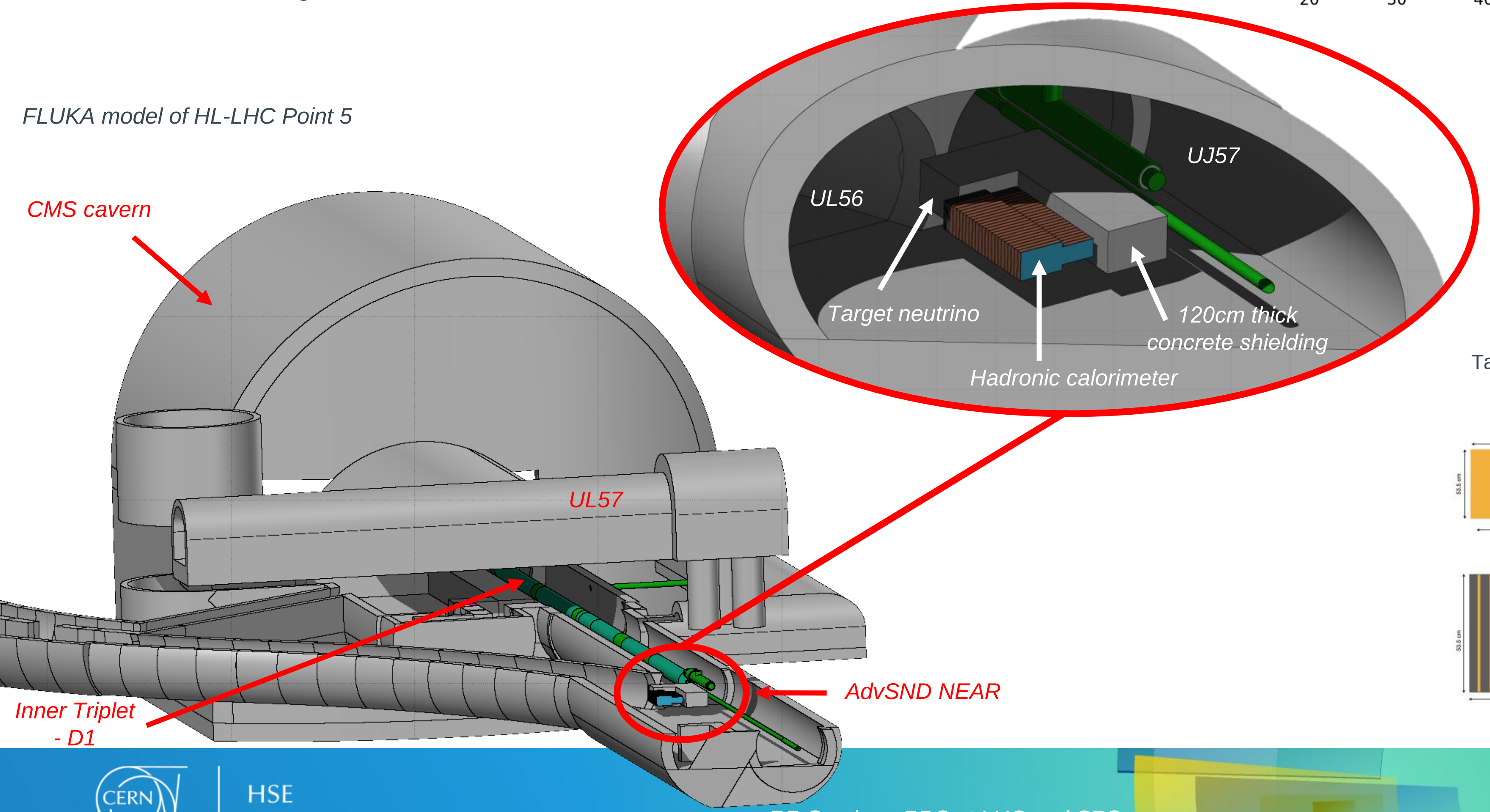


AdvSND-NEAR: UJ57

- HL-LHC FLUKA Geometry
- L-shaped shielding, designed to minimize detector activation and NOT for RP purposes. Was this option to be chosen, an RP-oriented shielding should be designed.

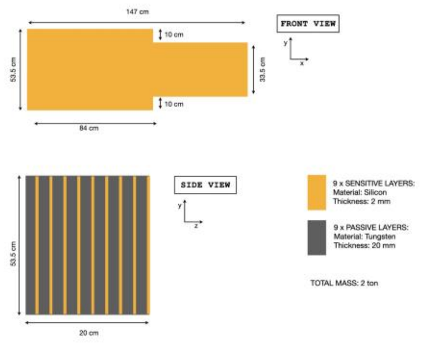


FLUKA model of HL-LHC Point 5

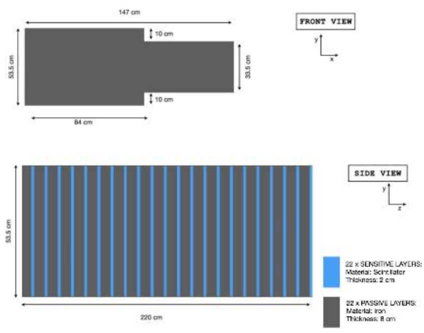


- Challenges and constraints:
  - Machine accessibility
  - Need to move the detector + cables + shielding during beam stop

Target region of the neutrino detector



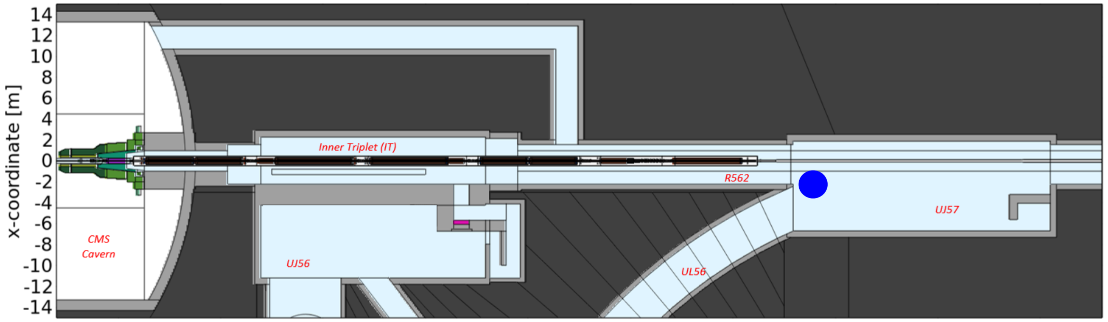
Hadronic calorimeter downstream of the target

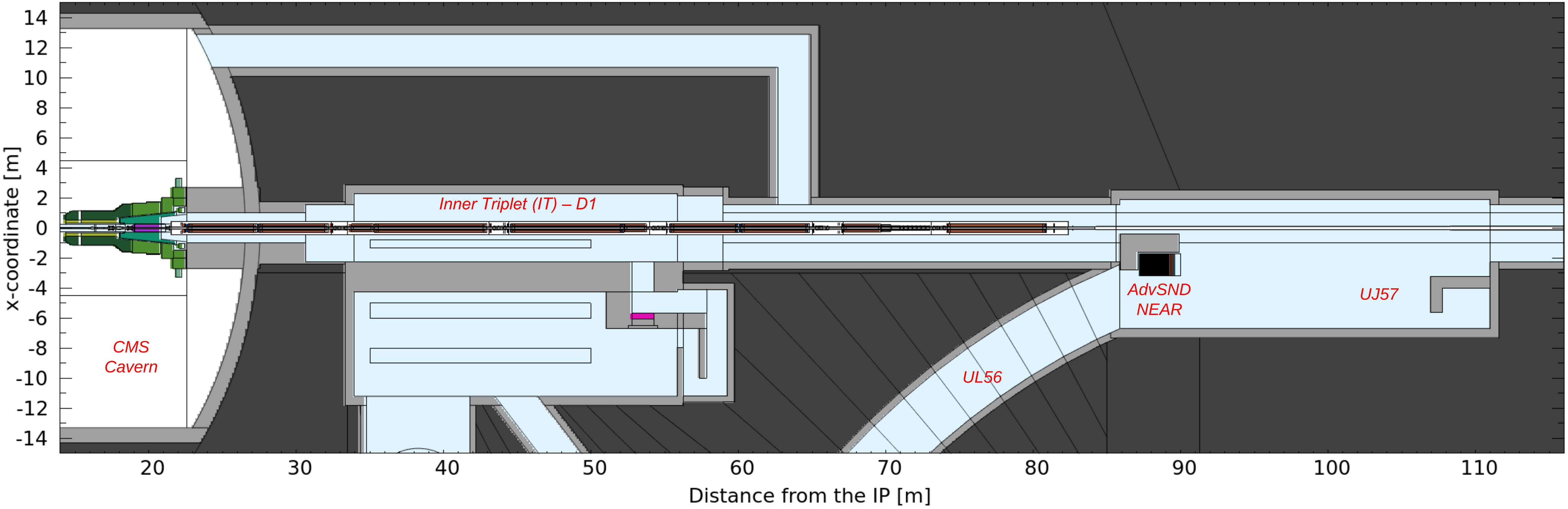


Detector data courtesy of G. De Lellis

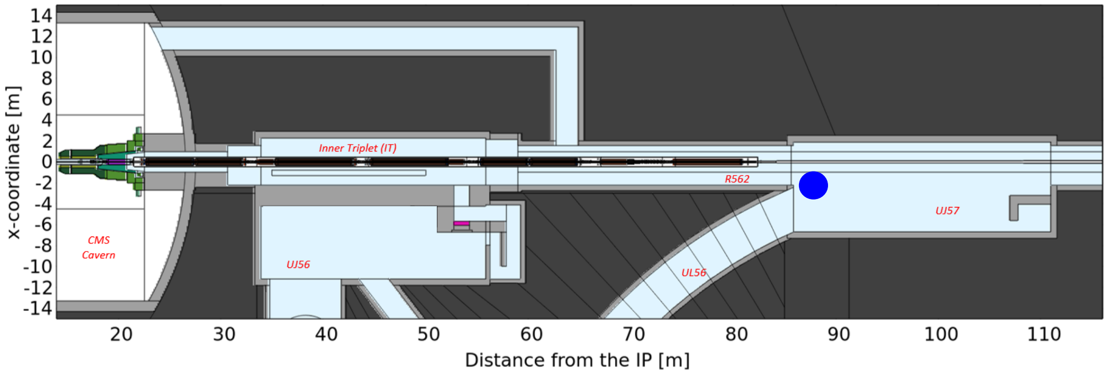
AdvSND-NEAR: UJ57

- HL-LHC FLUKA Geometry



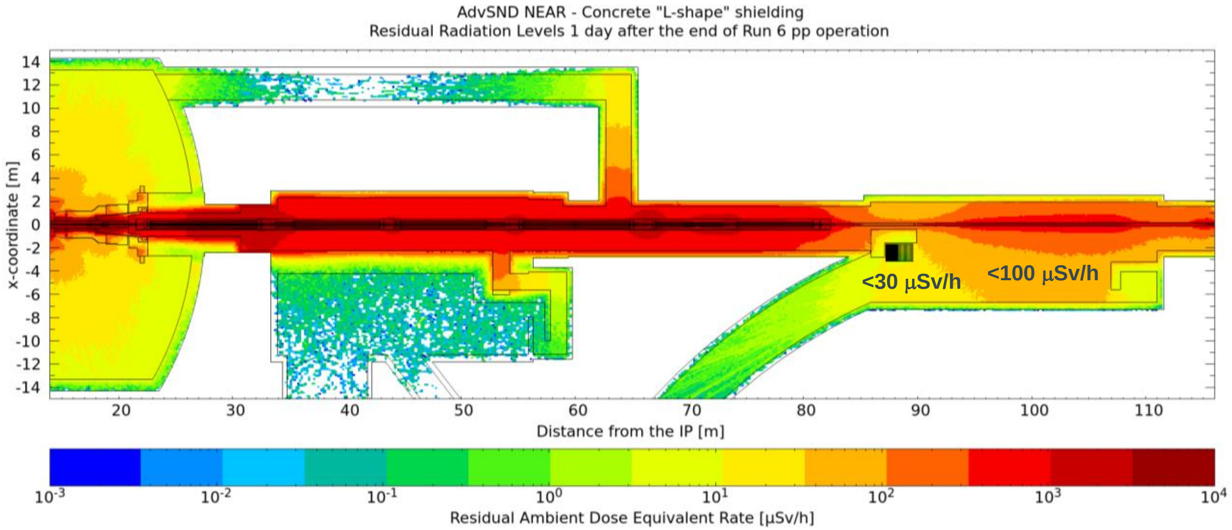


AdvSND-NEAR: UJ57

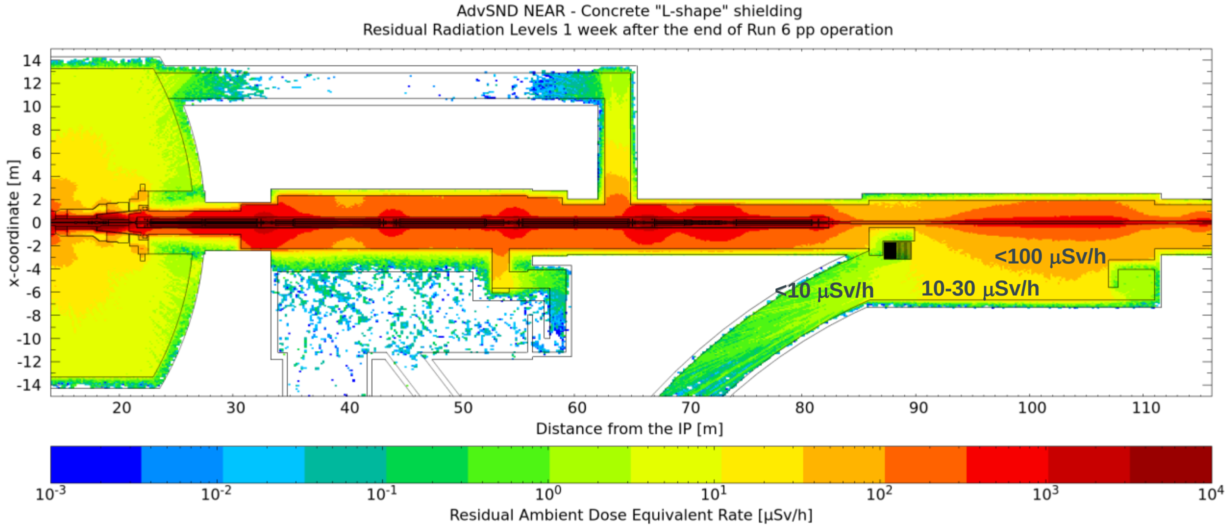


- FLUKA Results

- One day cooldown (e.g. short-term access):



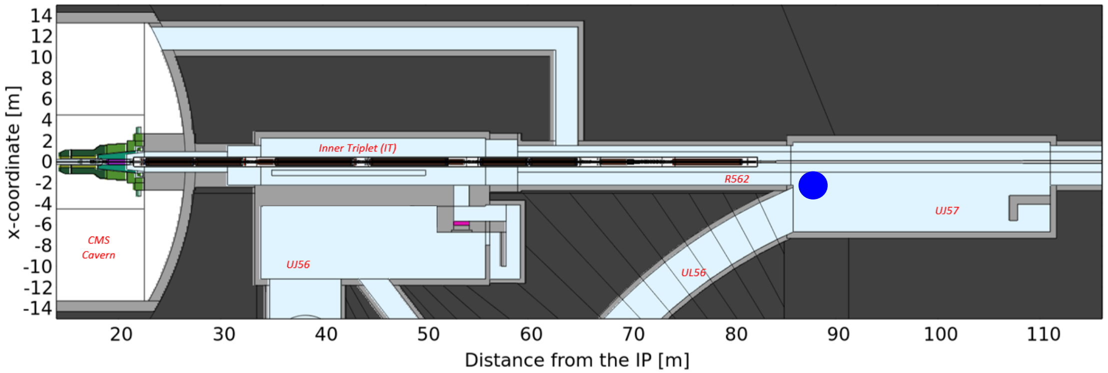
- One week cooldown (e.g. Technical Stop):



- Residual radiation field in the UJ57 significantly harsher than TI18: detector + shielding expected to be, overall, above exemption limits.

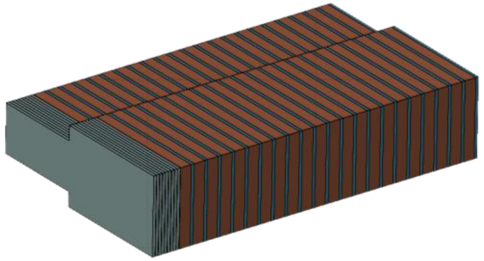
AdvSND-NEAR: UJ57

- AW Results



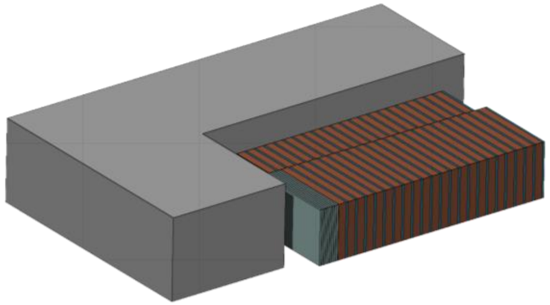
No shielding - S_{LL} ± uncertainty %												
Cool down	Target Neutrino						Hadron Calorimeter					
	W			Si			Fe			Scintillator		
1-day	238	±	2.9%	53.1	±	1.4%	134	±	4.3%	0.67	±	1.6%
1-week	72.7	±	0.5%	50.1	±	1.5%	130	±	4.4%	0.62	±	1.6%
1-month	59.2	±	0.5%	49.2	±	1.5%	121	±	4.5%	0.48	±	1.7%

Fe and Scintillator materials based on EDMS 2650049



Concrete shielding - S_{LL} ± uncertainty %												
Cool down	Target Neutrino						Hadron Calorimeter					
	W			Si			Fe			Scintillator		
1-day	47.1	±	6.0%	9.4	±	2.3%	30.9	±	10.5%	0.16	±	3.8%
1-week	14.3	±	1.0%	8.8	±	2.4%	30.0	±	10.7%	0.15	±	3.8%
1-month	11.7	±	1.1%	8.7	±	2.4%	28.1	±	10.9%	0.11	±	3.8%

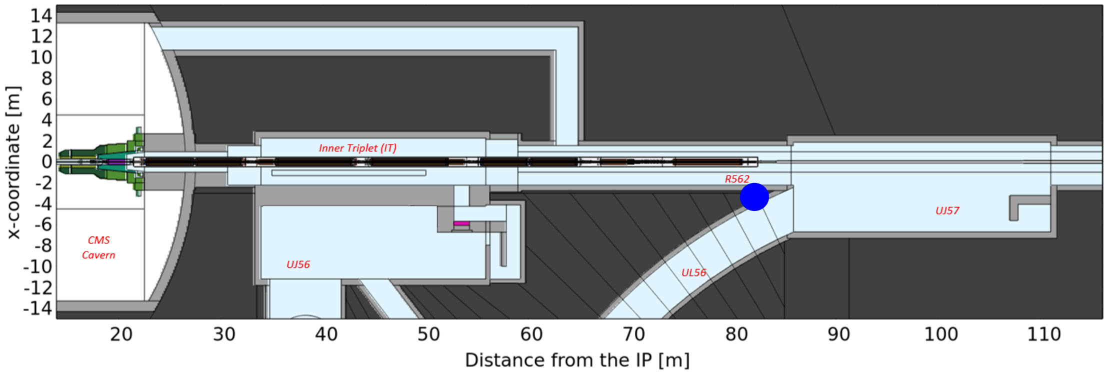
Fe and Scintillator materials based on EDMS 2650049

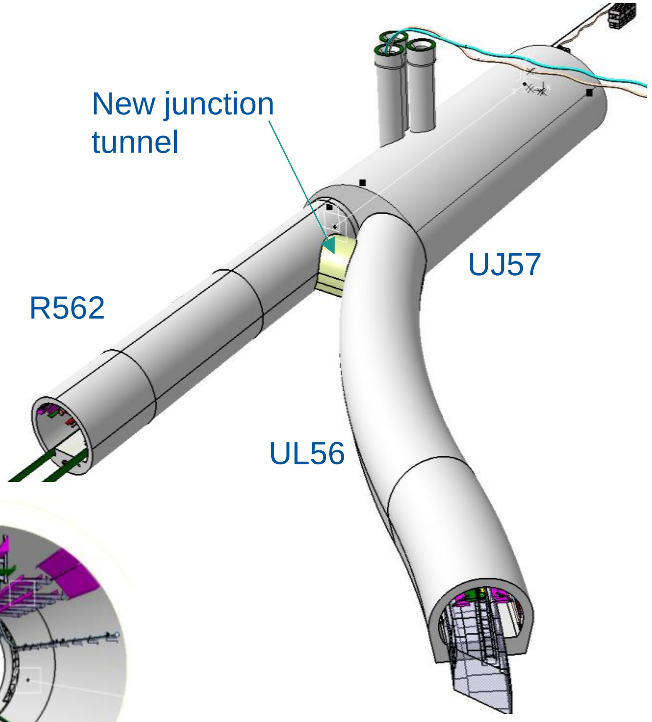


- Detector components to be considered as radioactive → Manipulation of detector components to be performed in classified areas (in opposition to what is done today for SND@LHC)

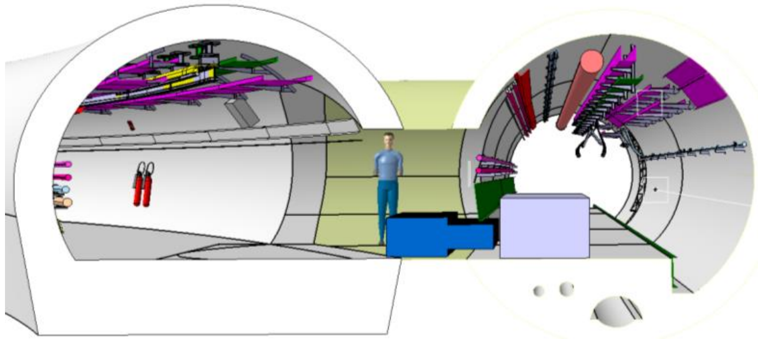
AdvSND-NEAR: Alcove

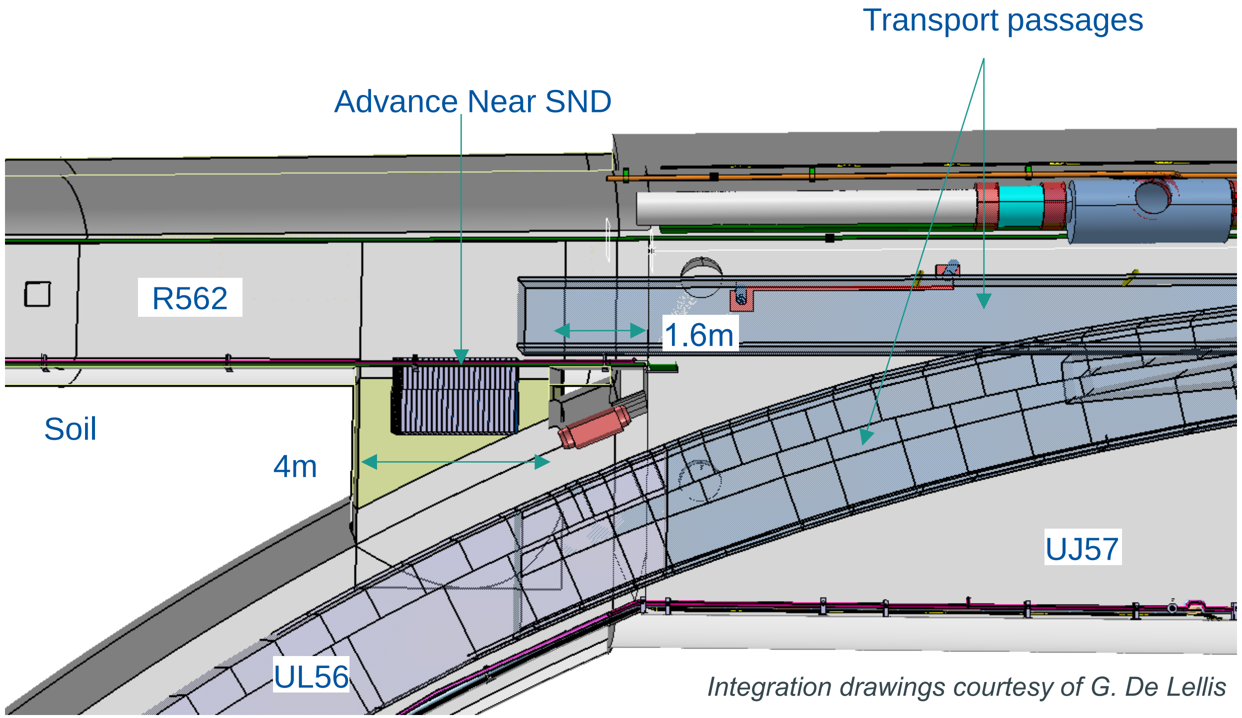
- Advantages:
  - Detector + Cables + Shielding do not need to be moved
  - Soil is partially used as shielding
- Challenges and constraints:
  - Even stronger exposure to the machine (D1) radiation than for the UJ57 option





Potential junction tunnel/alcove between UL56 and R562 (IT-D1 machine tunnel):

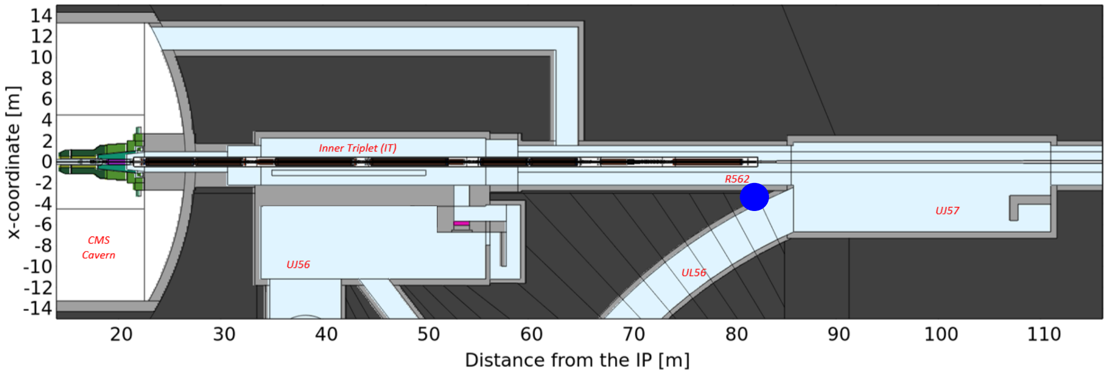


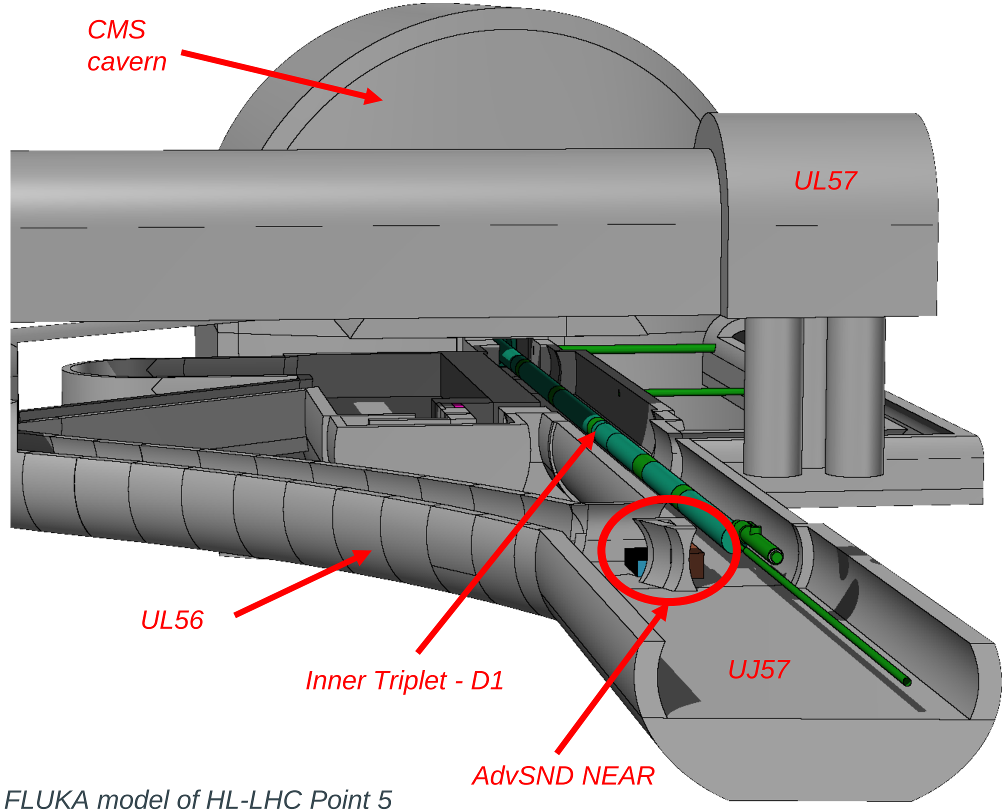


Integration drawings courtesy of G. De Lellis

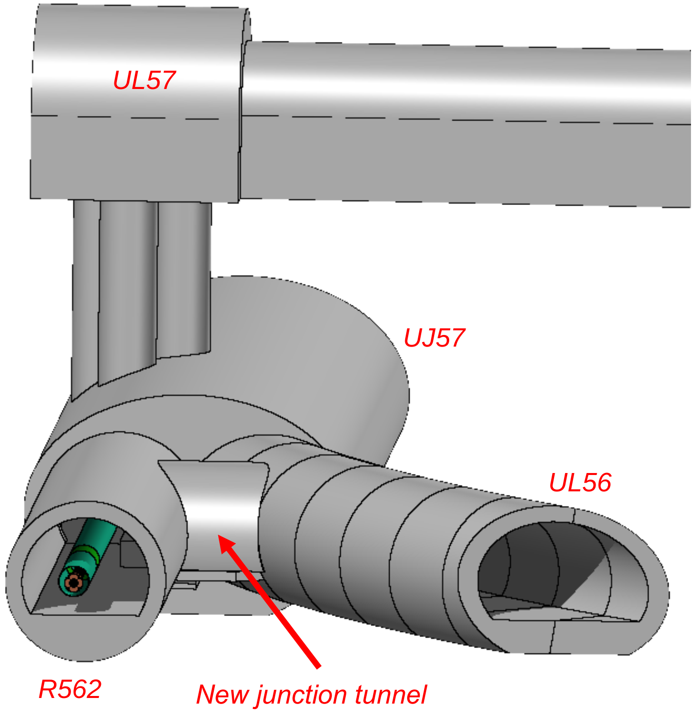
AdvSND-NEAR: Alcove

- FLUKA Geometry: the necessary geometry modifications to create the alcove between UL56 and R562 were performed



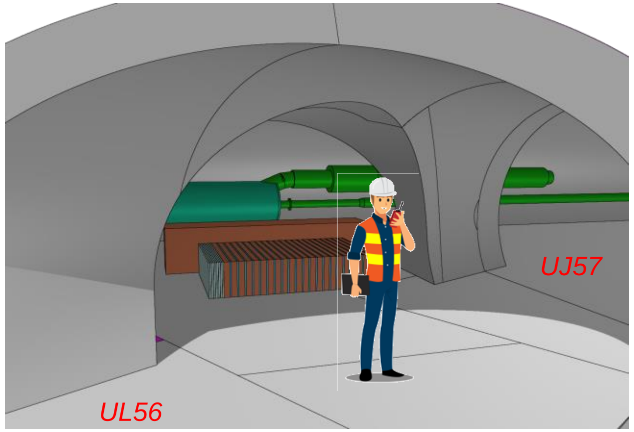


FLUKA model of HL-LHC Point 5

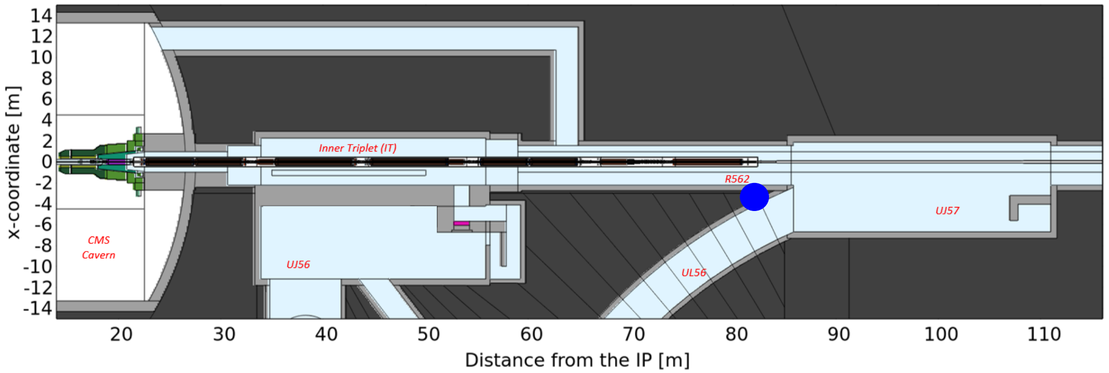


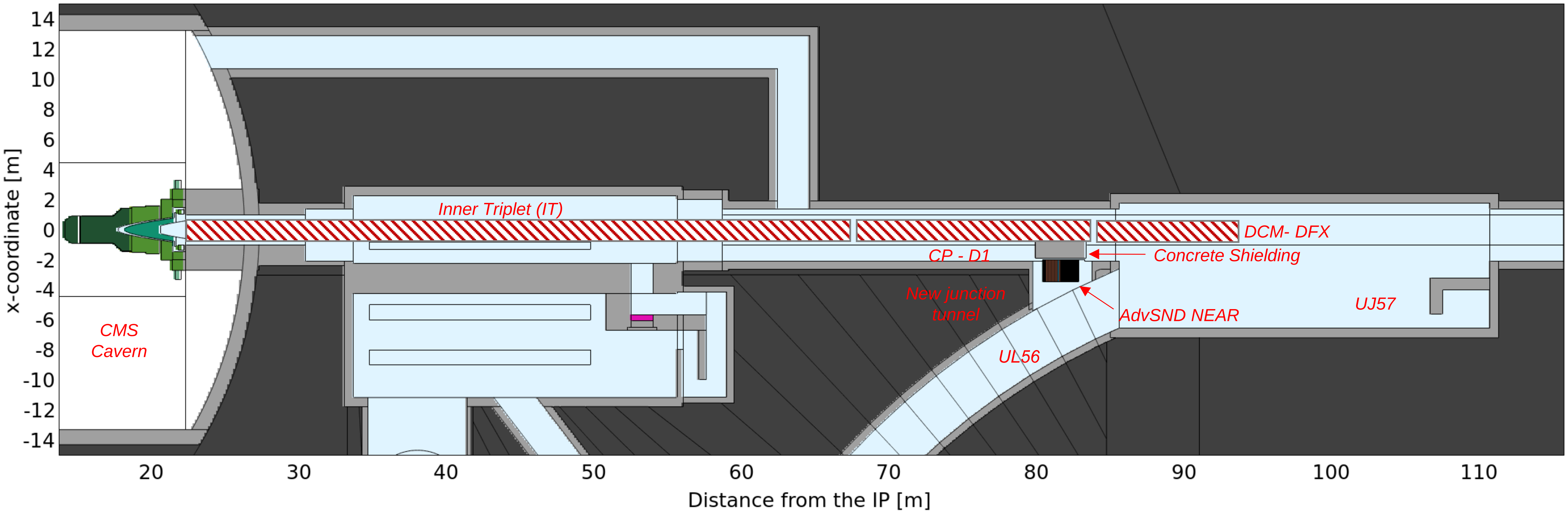
RP challenges during access to the LHC tunnel:

- Detector closer to the machine
- Direct exposure from the D1-DCM
- Excavation spoils to be considered as radioactive waste



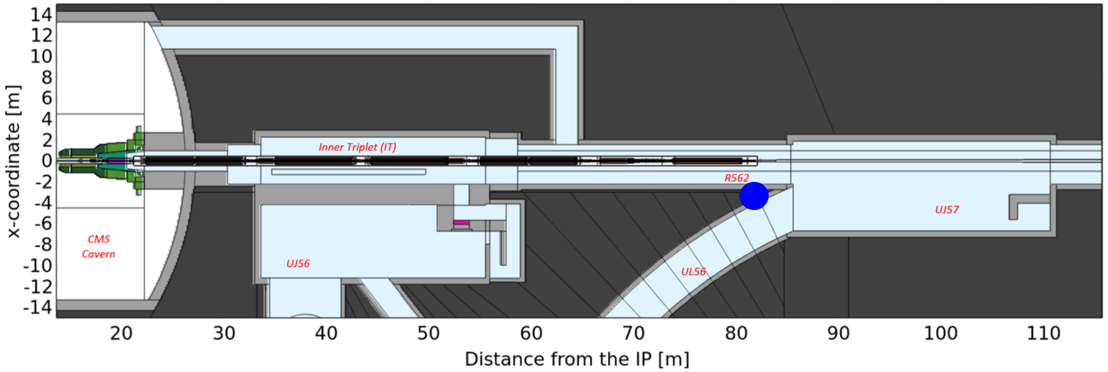
AdvSND-NEAR: Alcove





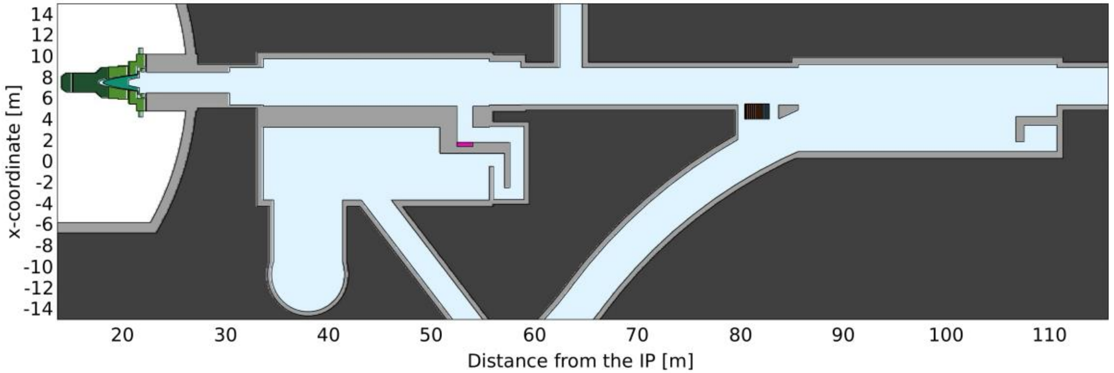
AdvSND-NEAR: Alcove

- Three different shields considered:
  - concrete (120cm-thick)
  - iron (60cm-thick)
  - no shielding

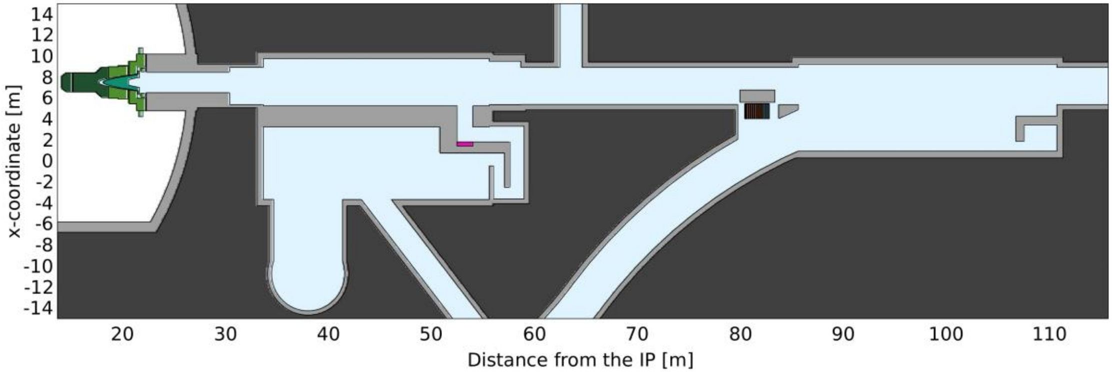


- Shielding shape optimized for detector protection, not for personnel protection (RP)

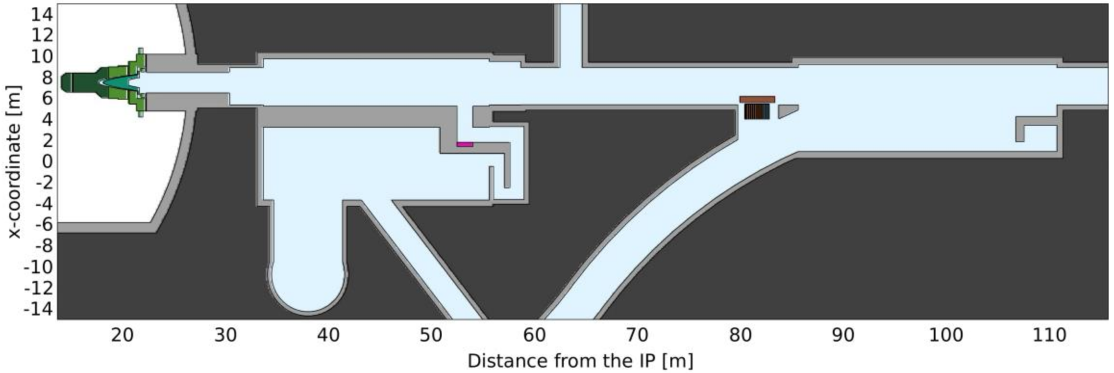
No Shield



Concrete Shield

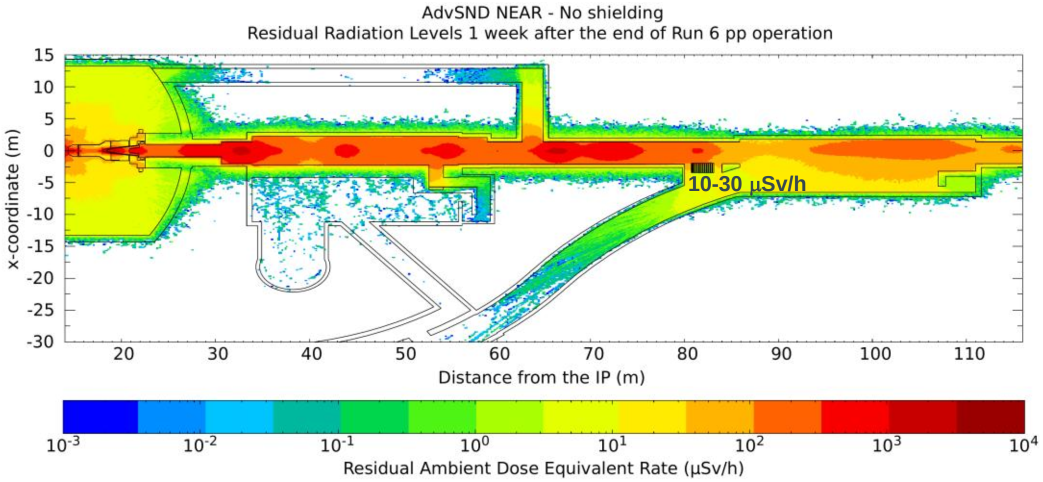


Iron Shield

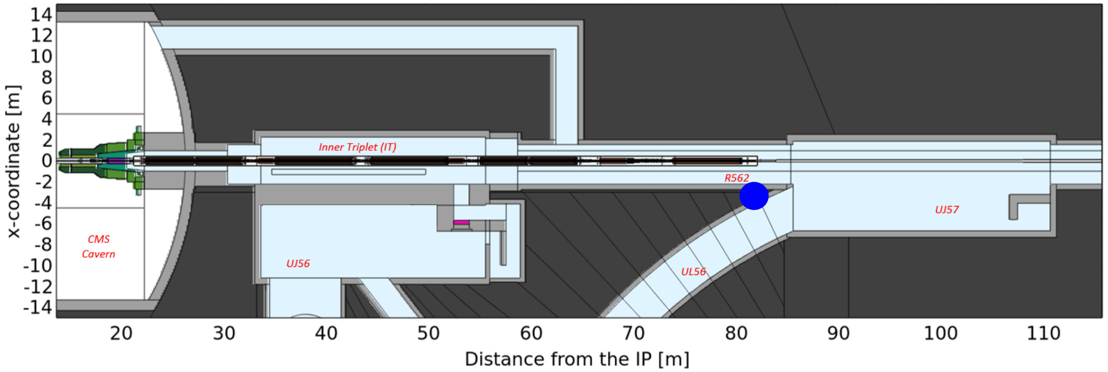


AdvSND-NEAR: Alcove

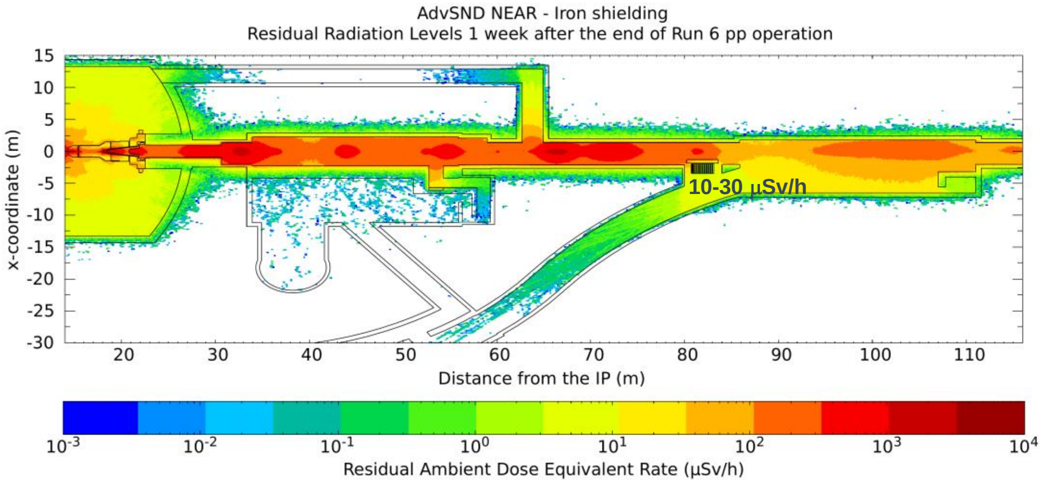
- FLUKA Results

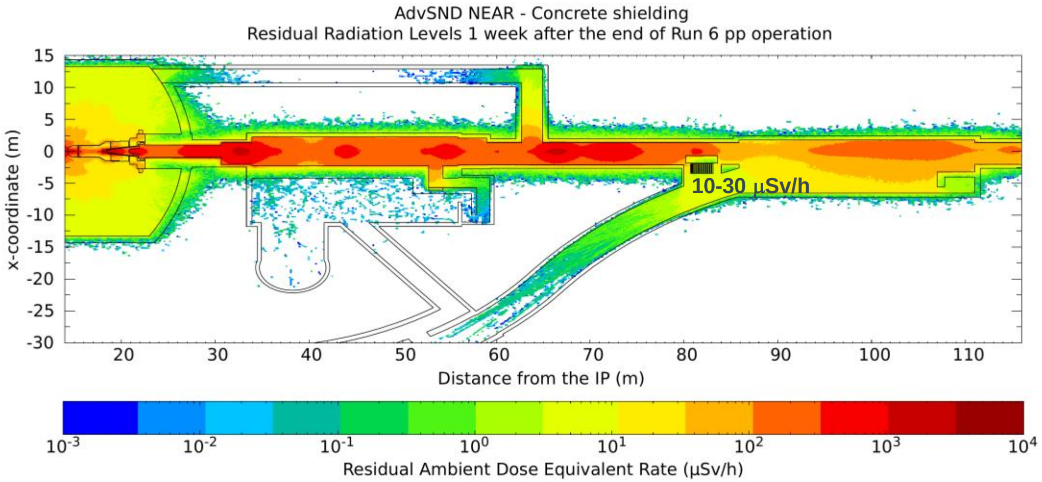


Detector height



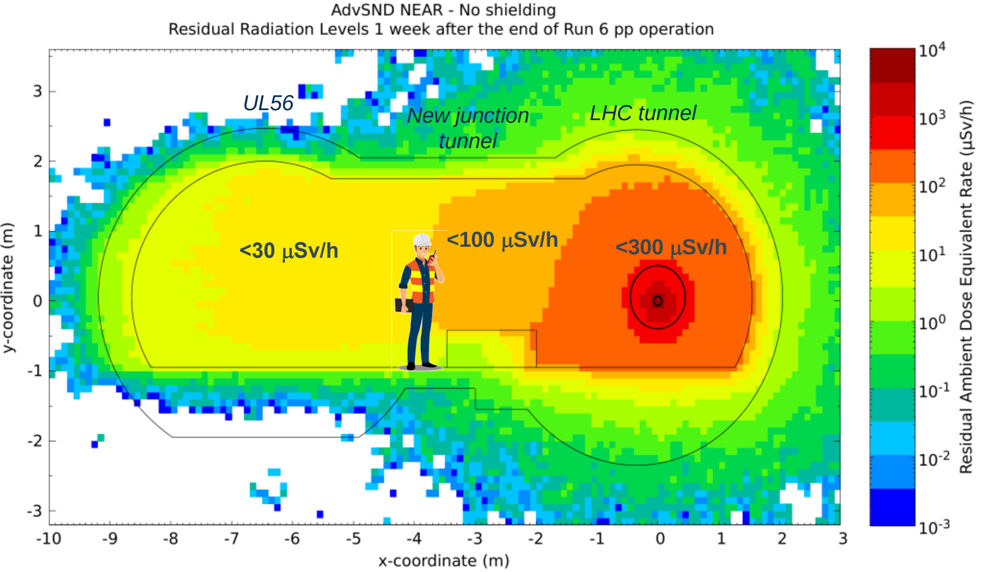
- No significant differences overall concerning area classifications

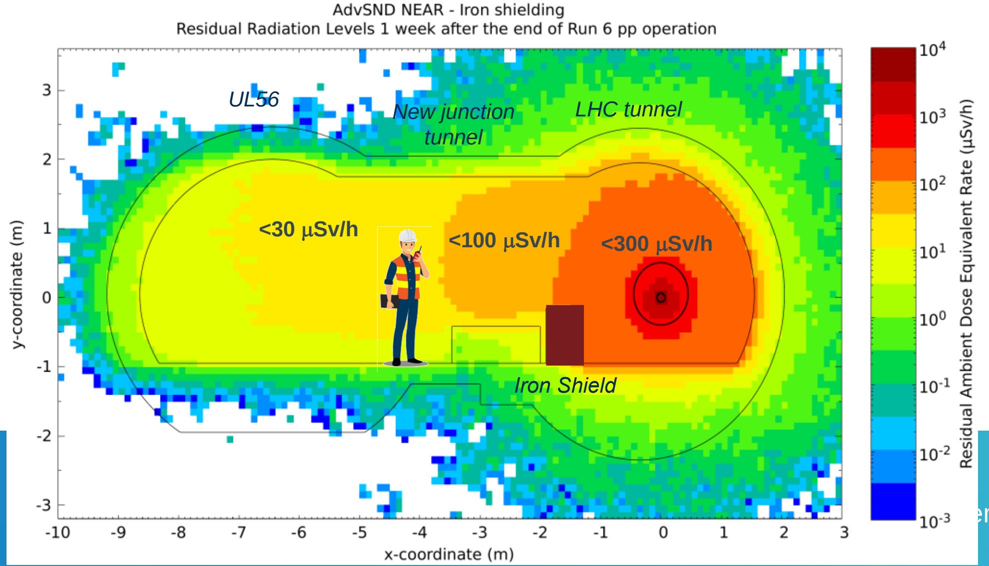


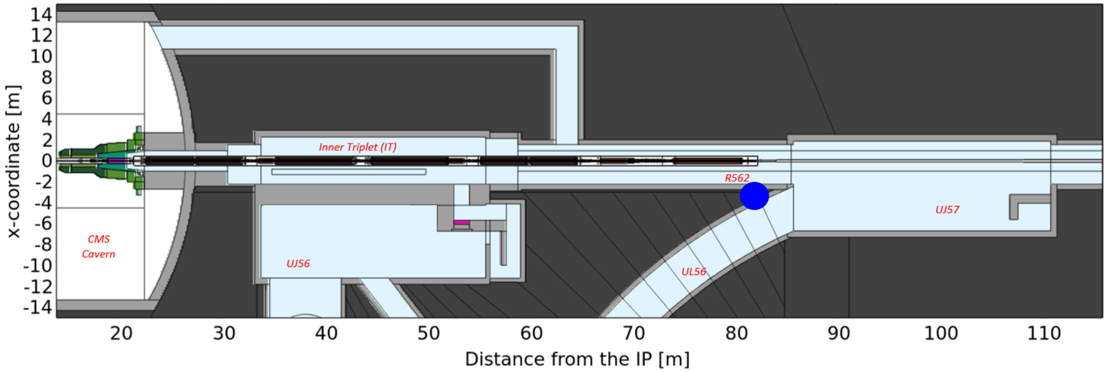


AdvSND-NEAR: Alcove

➢ FLUKA Results

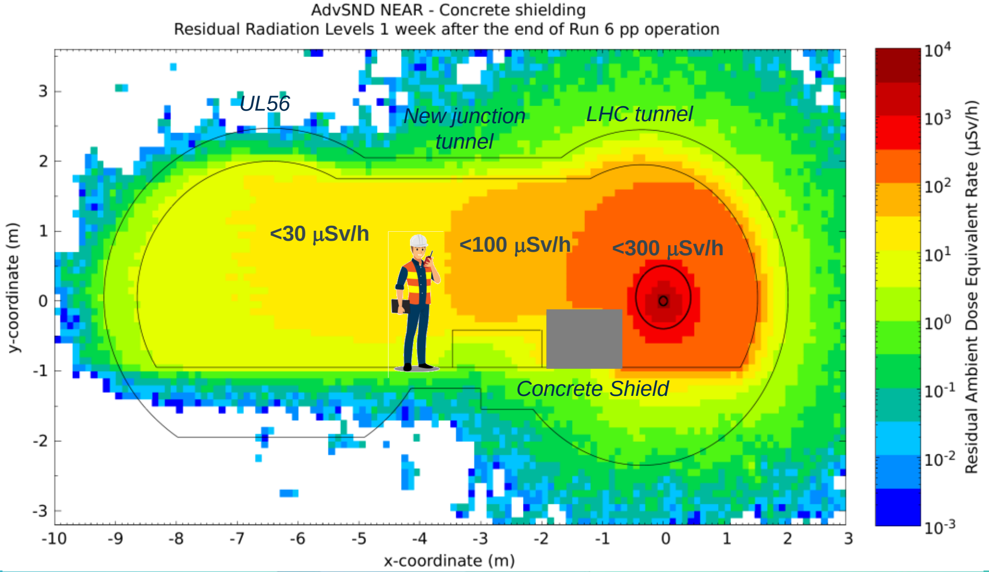






➢ Detector closer to the machine and in direct line-of-sight with the LHC machine → up to ~3x residual dose rate for a person standing on the UL56 side, person standing in R562 potentially exposed to several hundreds of μSv/h.

➢ No significant differences overall concerning area classifications



➢ Shielding presently not optimized for RP purposes → taller/ticker shielding would require an ad-hoc review together with HL-LHC integration & EN-HE teams.

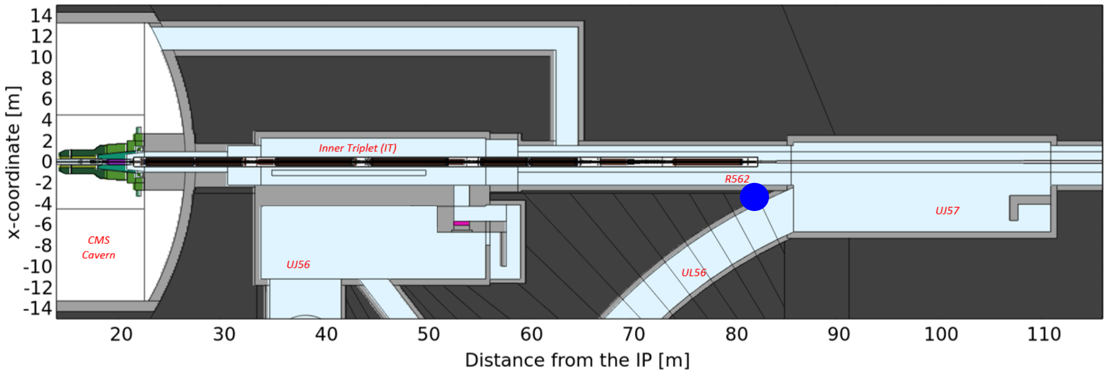
AdvSND-NEAR: Alcove

- AW Results

No shielding - S_{LL} ± uncertainty %					
Cool down	Target Neutrino		Hadron Calorimeter		Shielding
	W	Si	Fe	Scintillator	
1-day	649 ± 1.80%	75.3 ± 0.91%	235 ± 2.95%	1.14 ± 1.24%	n.a.
1-week	129 ± 0.35%	70.7 ± 0.96%	228 ± 3.00%	1.06 ± 1.24%	
1-month	104 ± 0.35%	69.5 ± 0.96%	213 ± 3.06%	0.82 ± 1.26%	
4-months	59.2 ± 0.36%	64.8 ± 0.97%	172 ± 3.10%	0.29 ± 1.64%	

Iron shielding - S_{LL} ± uncertainty %					
Cool down	Target Neutrino		Hadron Calorimeter		Shielding
	W	Si	Fe	Scintillator	
1-day	472 ± 2.08%	54.1 ± 0.94%	117 ± 4.00%	0.516 ± 1.63%	430 ± 1.15%
1-week	90.5 ± 0.38%	51.8 ± 0.99%	114 ± 4.07%	0.479 ± 1.63%	418 ± 1.16%
1-month	71.8 ± 0.38%	50 ± 0.99%	107 ± 4.15%	0.371 ± 1.66%	390 ± 1.19%
4-months	41.3 ± 0.39%	46.5 ± 1.00%	86 ± 4.20%	0.129 ± 2.25%	313 ± 1.21%

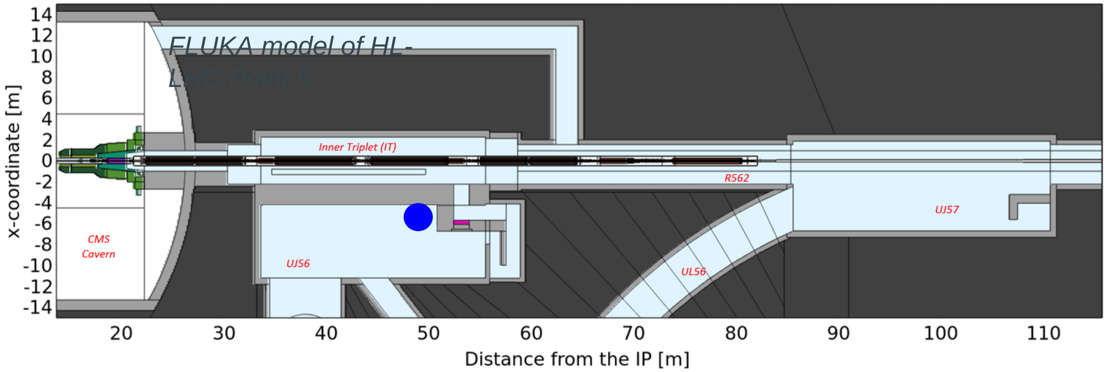
Concrete shielding - S_{LL} ± uncertainty %					
Cool down	Target Neutrino		Hadron Calorimeter		Shielding
	W	Si	Fe	Scintillator	
1-day	527 ± 1.96%	62.9 ± 0.95%	143 ± 3.67%	0.664 ± 1.35%	230 ± 0.73%
1-week	103 ± 0.36%	59.2 ± 1.01%	139 ± 3.73%	0.617 ± 1.35%	105 ± 0.47%
1-month	81.5 ± 0.37%	58.2 ± 1.01%	130 ± 3.81%	0.477 ± 1.36%	101 ± 0.48%
4-months	46.9 ± 0.38%	54.2 ± 1.01%	1.04 ± 3.87	0.165 ± 1.69%	91.3 ± 0.51%

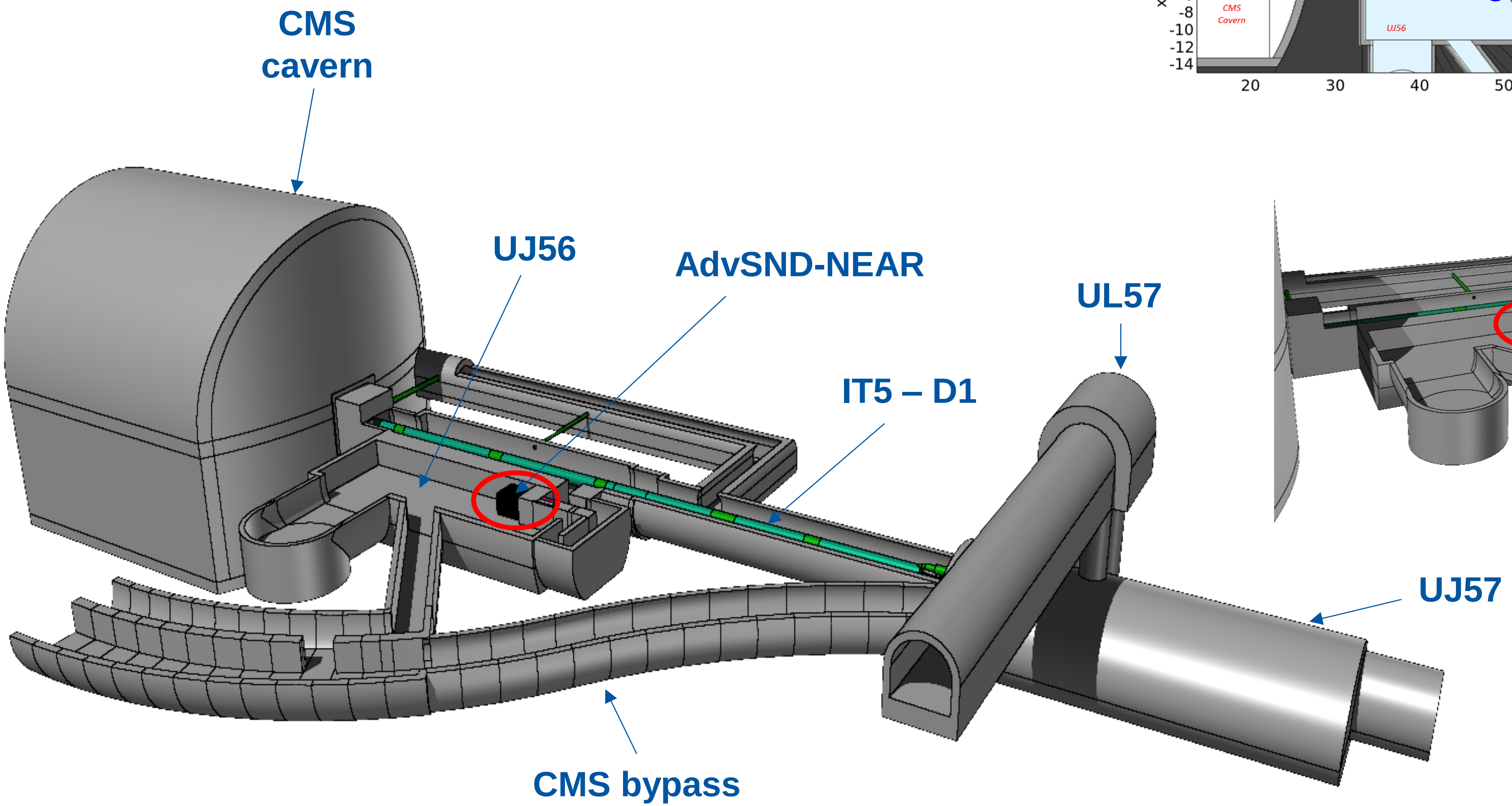


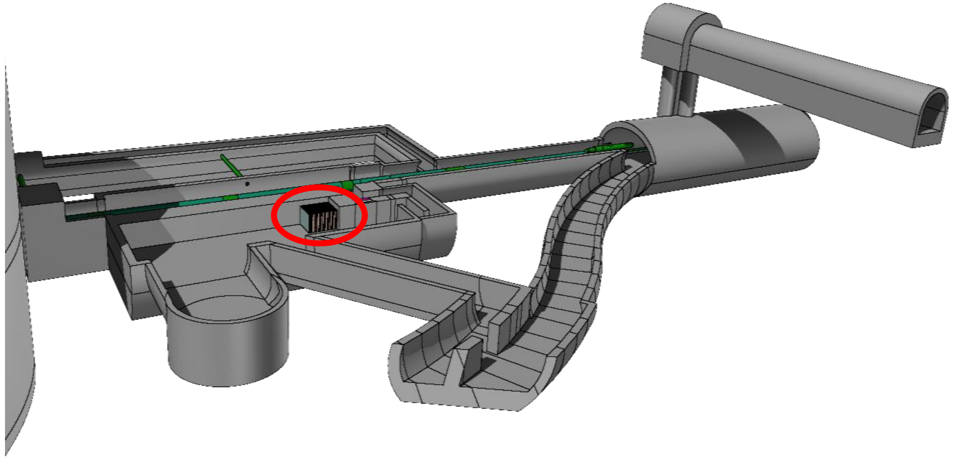
- Detector components to be considered as radioactive (activation levels in general higher than in UJ57) → manipulation of detector components to be performed in classified areas (in opposition to what is done today for SND@LHC)

AdvSND-NEAR: UJ56

- FLUKA Geometry



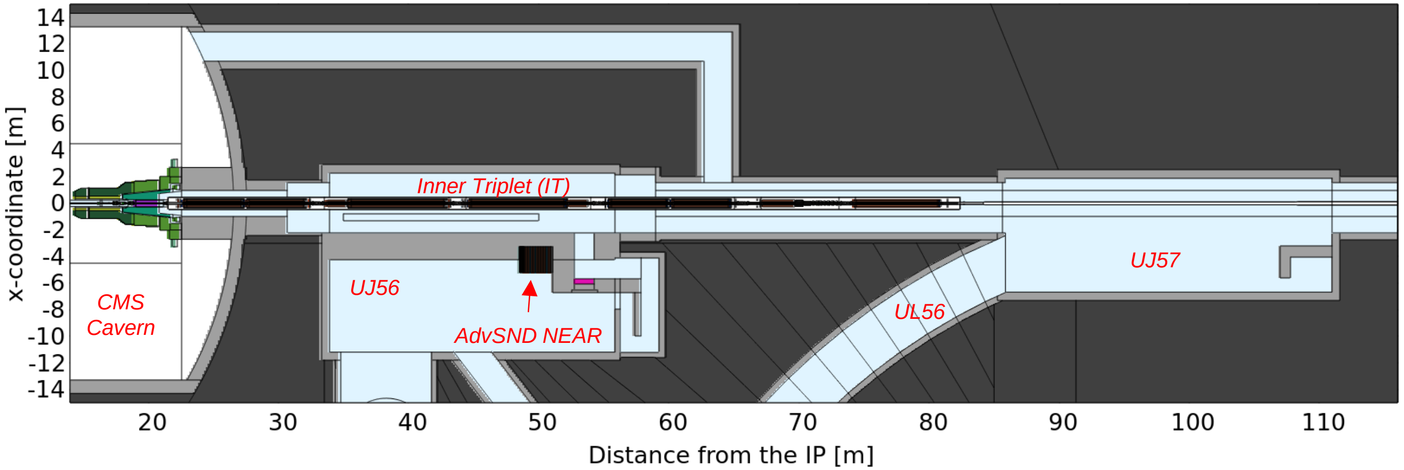




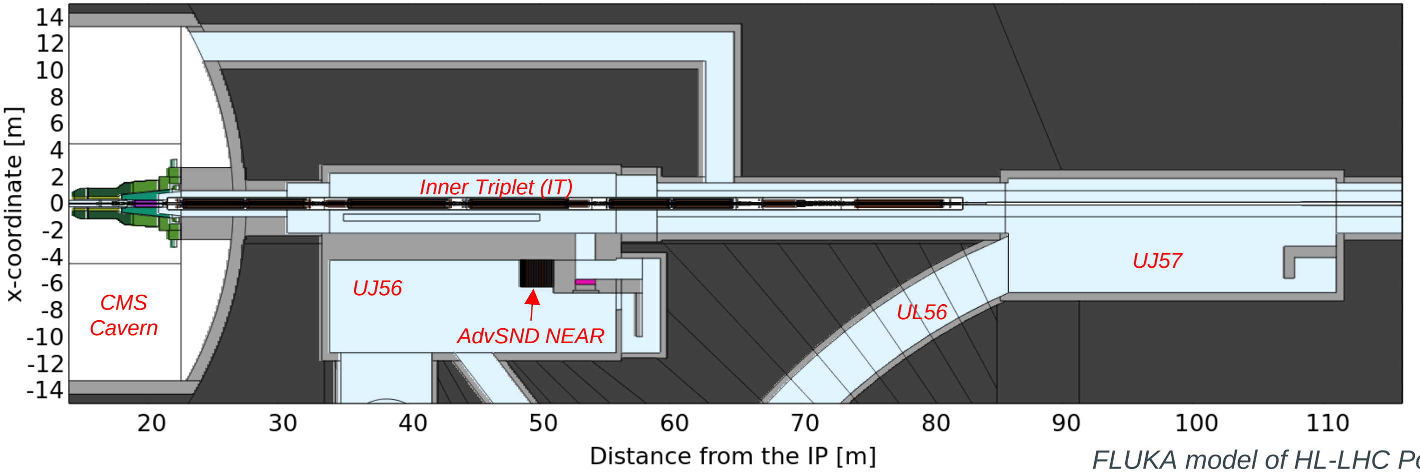
FLUKA model of HL-LHC Point 5

AdvSND-NEAR: UJ56

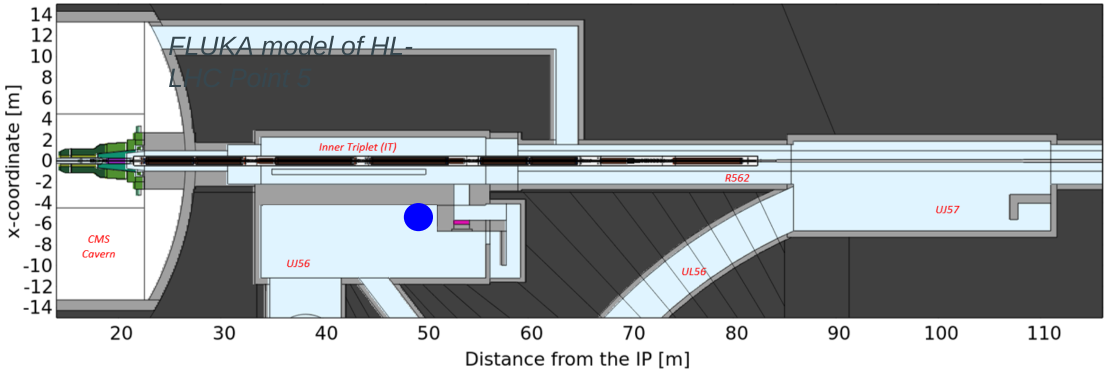
OPTION A: 3.25 m far away from the beamline, 1m excavation needed



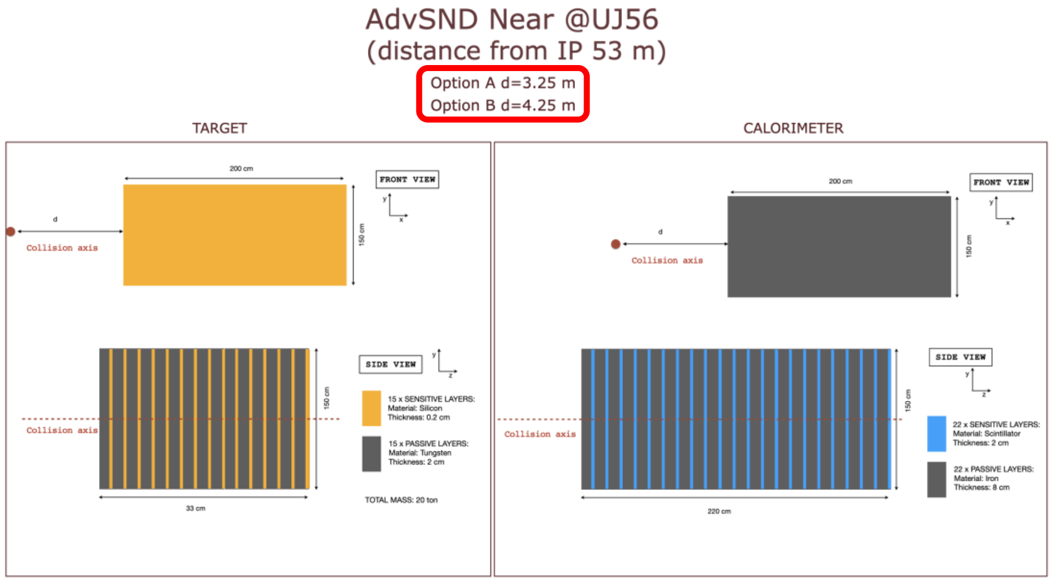
OPTION B: 4.25 m far away from the beamline, NO excavation needed



FLUKA model of HL-LHC Point 5

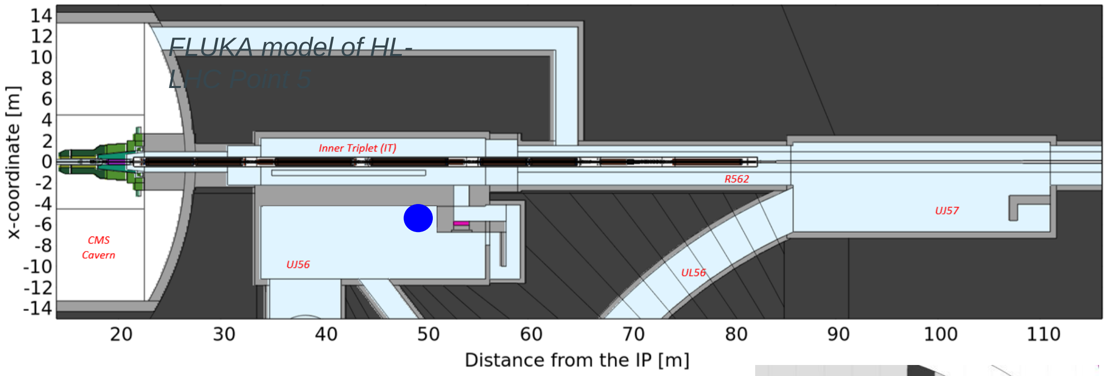


- No additional shielding required because of the UJ56 cavern wall

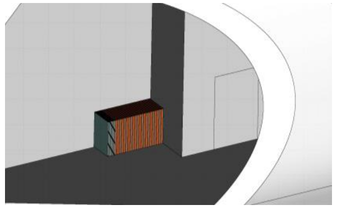


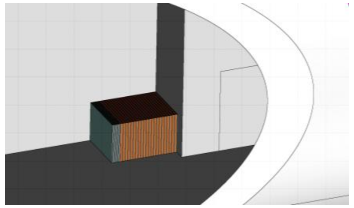
Detector data courtesy of G. De Lellis and A. di Crescenzo

AdvSND-NEAR: UJ56

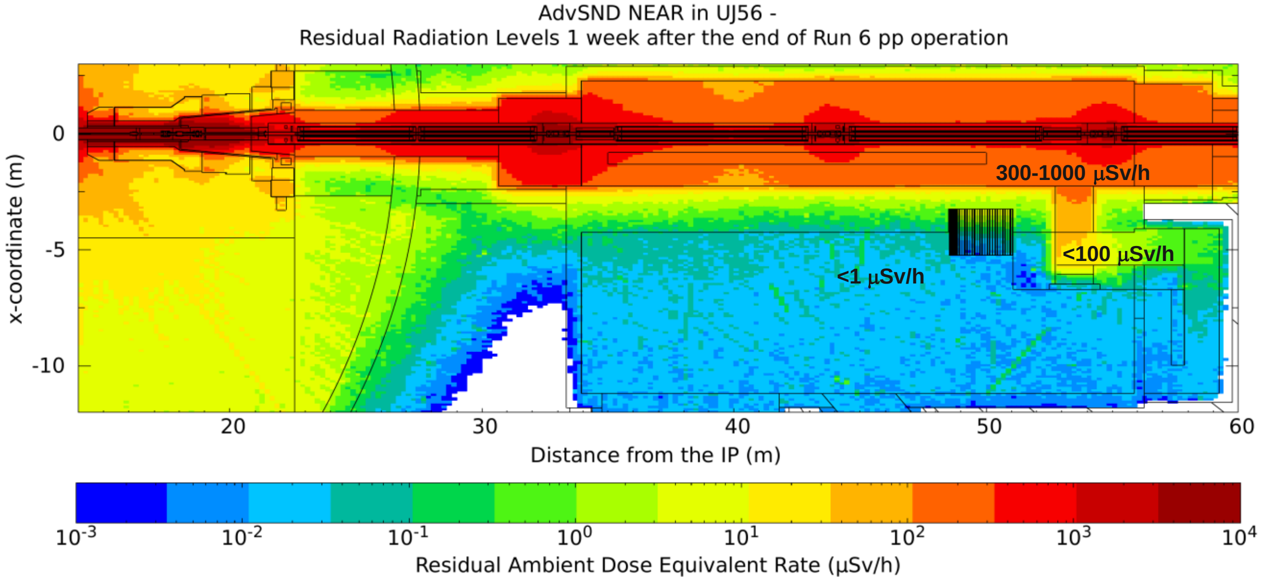


- Automatic Importance Biasing tool was used (one of the first plug-in versions)
- FLUKA Results:
  - No RP showstoppers have been identified, for either location.
  - Residual radiation field in UJ56 does not require any reclassification of the area, for either location.

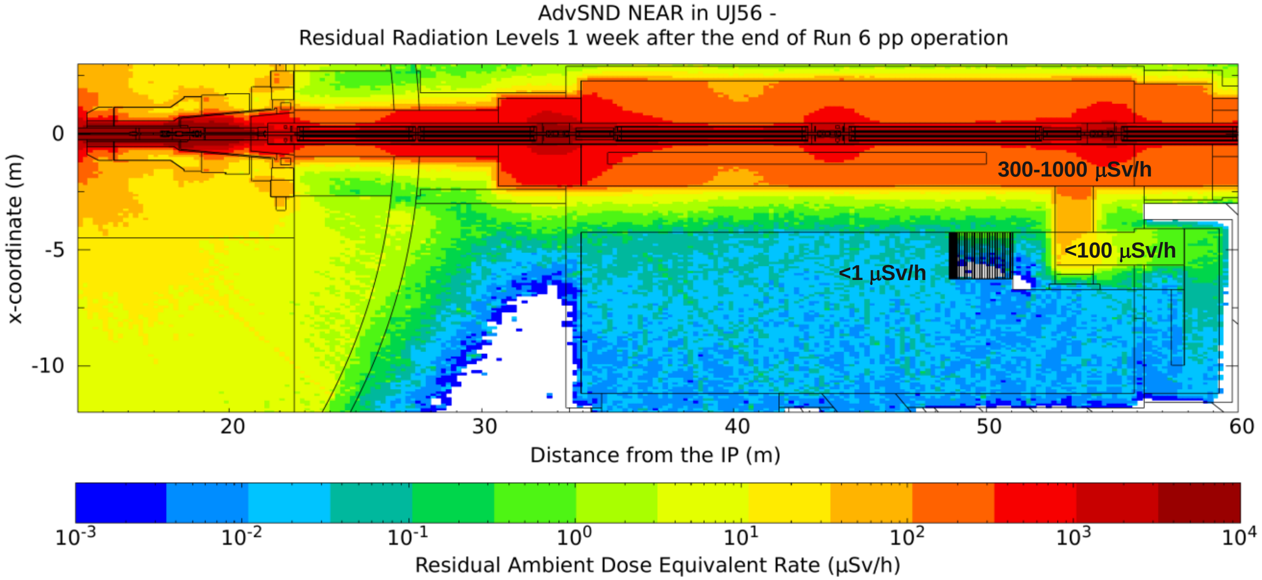




OPTION A: 3.25 m far away from the beamline, 1m excavation needed



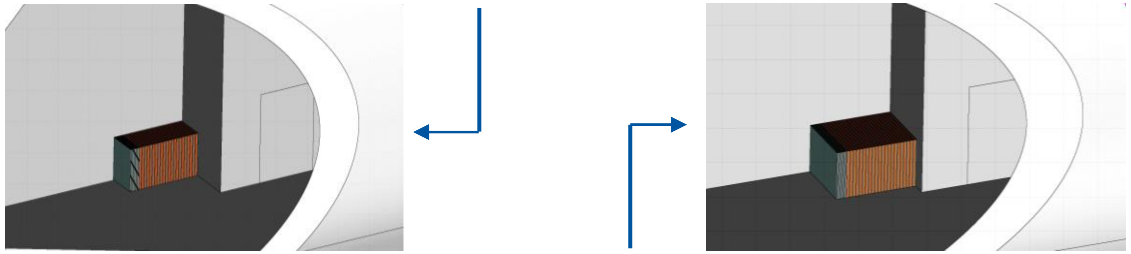
OPTION B: 4.25 m far away from the beamline, NO excavation needed



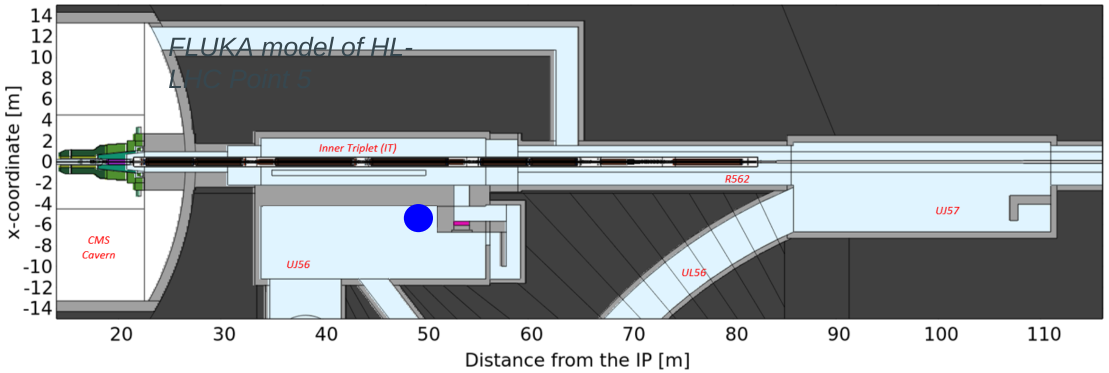
AdvSND-NEAR: UJ56

- AW Results:

OPTION A (1m excavation) - S_{LL} ± uncertainty %				
Cool down	Target Neutrino		Hadron Calorimeter	
	W	Si	Fe	Scintillator
1-day	5.05 ± 3.23%	1.72 ± 1.93%	8.16 ± 7.58%	0.0524 ± 2.54%
1-week	2.77 ± 0.88%	1.61 ± 2.06%	7.93 ± 7.7%	0.0487 ± 2.54%
1-month	2.29 ± 0.92%	1.58 ± 2.06%	7.39 ± 7.85%	0.0368 ± 2.57%
4-months	1.32 ± 0.94%	1.48 ± 2.06%	5.96 ± 7.96%	0.0132 ± 3.24%



OPTION B (no excavation) - S_{LL} ± uncertainty %				
Cool down	Target Neutrino		Hadron Calorimeter	
	W	Si	Fe	Scintillator
1-day	0.92 ± 4.7%	0.359 ± 3.48%	0.871 ± 14.45%	0.00516 ± 4.79%
1-week	0.60 ± 1.15%	0.337 ± 3.69%	0.846 ± 14.67%	0.0048 ± 4.79%
1-month	0.50 ± 1.19%	0.331 ± 3.7%	0.787 ± 14.98%	0.00362 ± 4.85%
4-months	0.29 ± 1.21%	0.31 ± 3.7%	0.636 ± 15.19%	0.0013 ± 6.19%



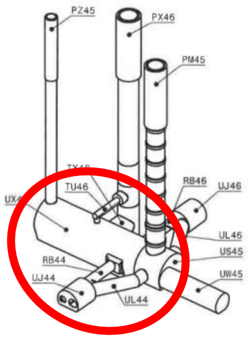
- Activation of detector components lower than in the UJ57 or junction UL56/R562.

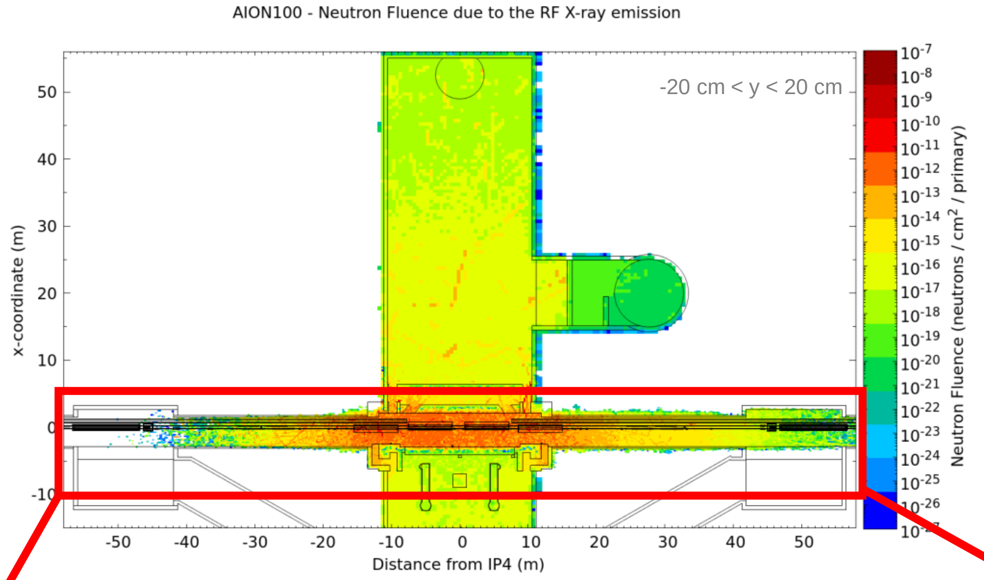
- For OPTION A:
  - Wrt UJ57 (with concrete L–shaped shielding), reduction factors range between 10 (for W) and 3 (for the scintillator material)
  - Wrt junction UL56/R562 (with concrete shielding), reduction factors range between 100 (for W) and 10 (for the scintillator material)

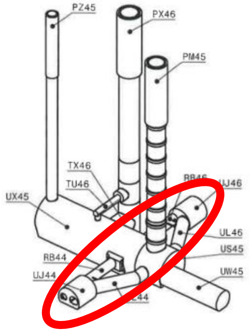
- Activation of detector components higher of around a factor 5 to 10 for OPTION A than for OPTION B

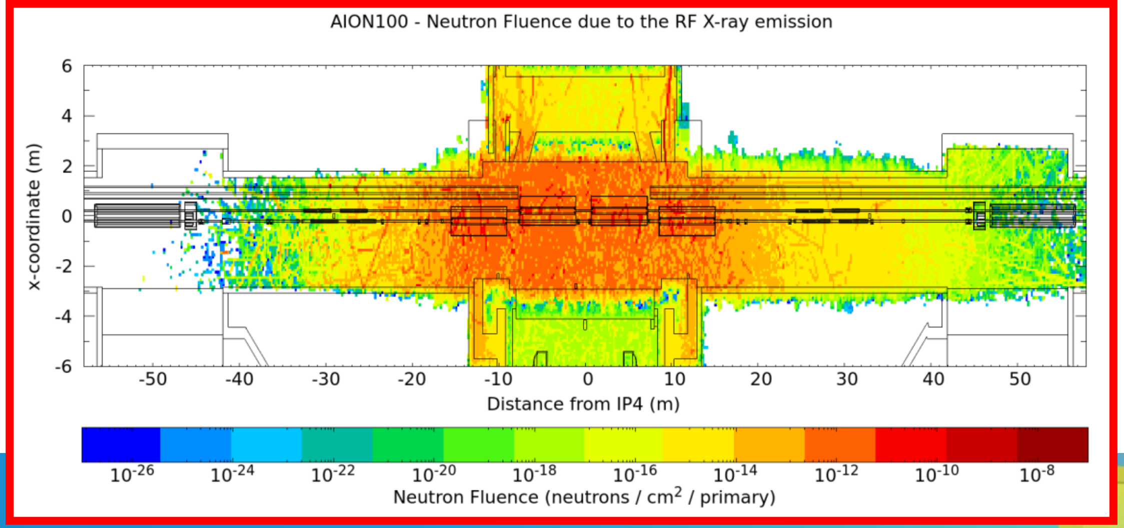
- For OPTION B, the sum of the LL fractions (S_{LL}) is below 1. *A priori*, the detector might be handled as non-radioactive material, as currently done for SND emulsions.

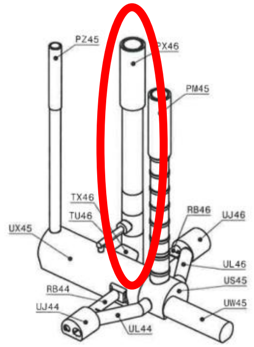
AION100: RF X-ray Emissions, n Fluence

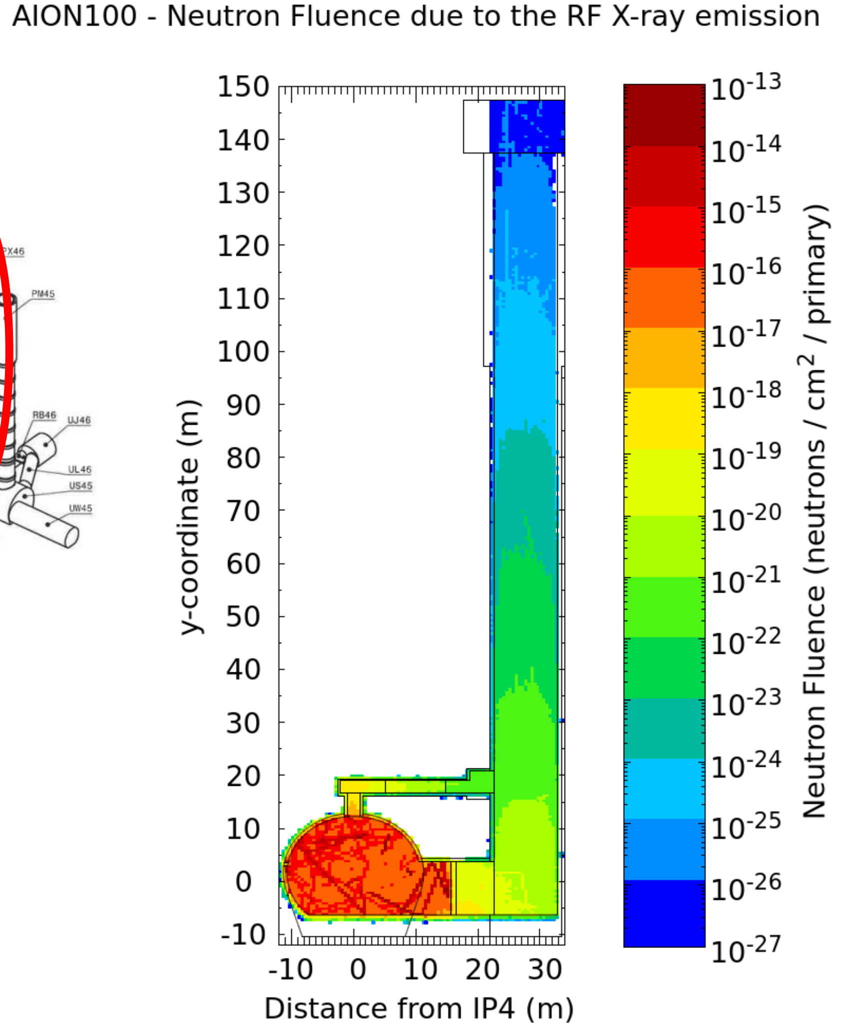






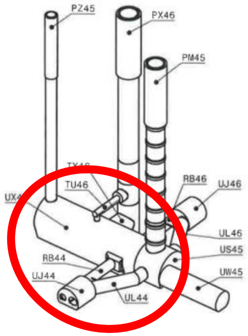


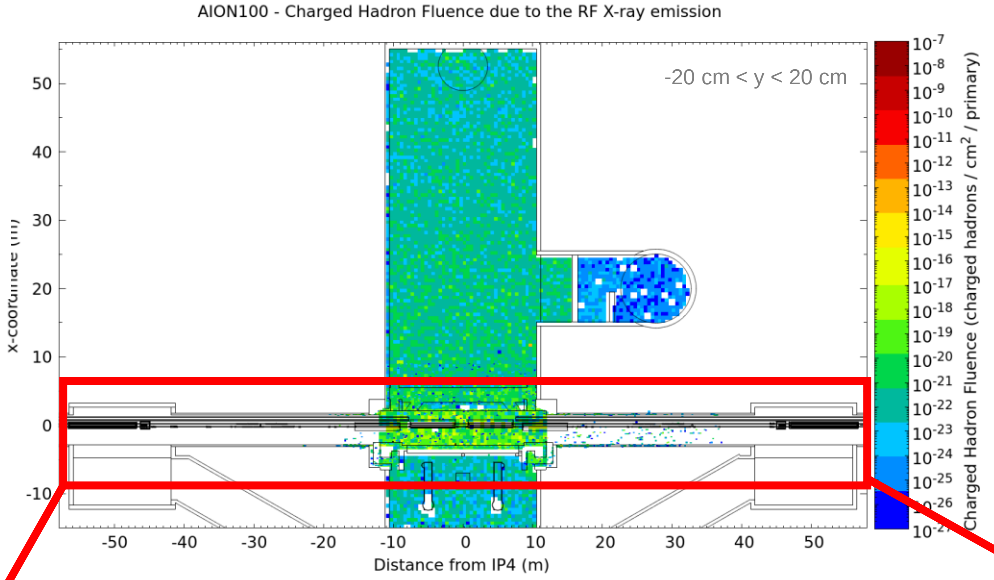


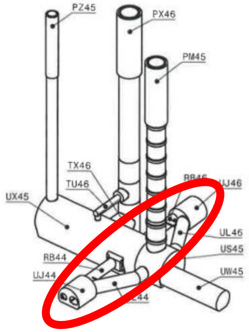


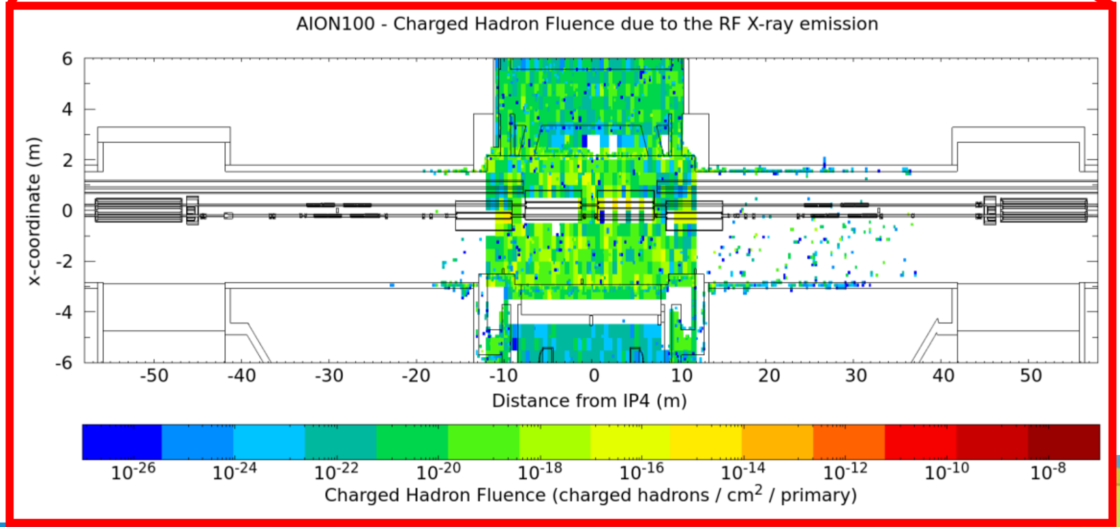
15 m < x < 25 m
Center of PX46 is 20 m (from IP4)

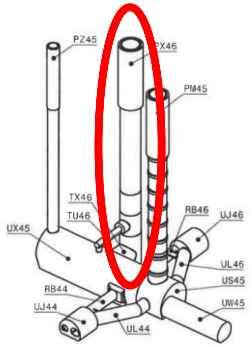
AION100: RF X-ray Emissions, ch Fluence

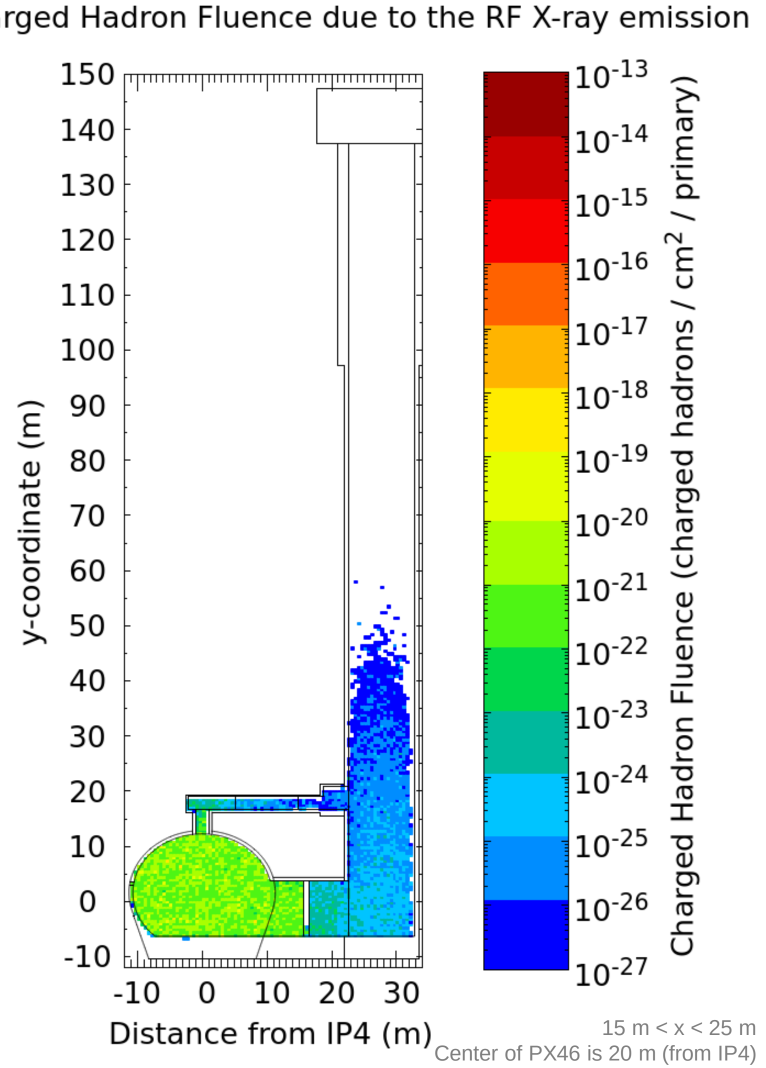






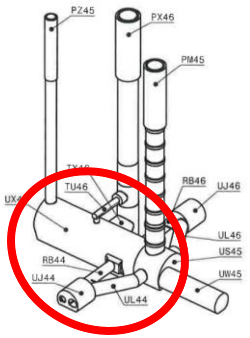


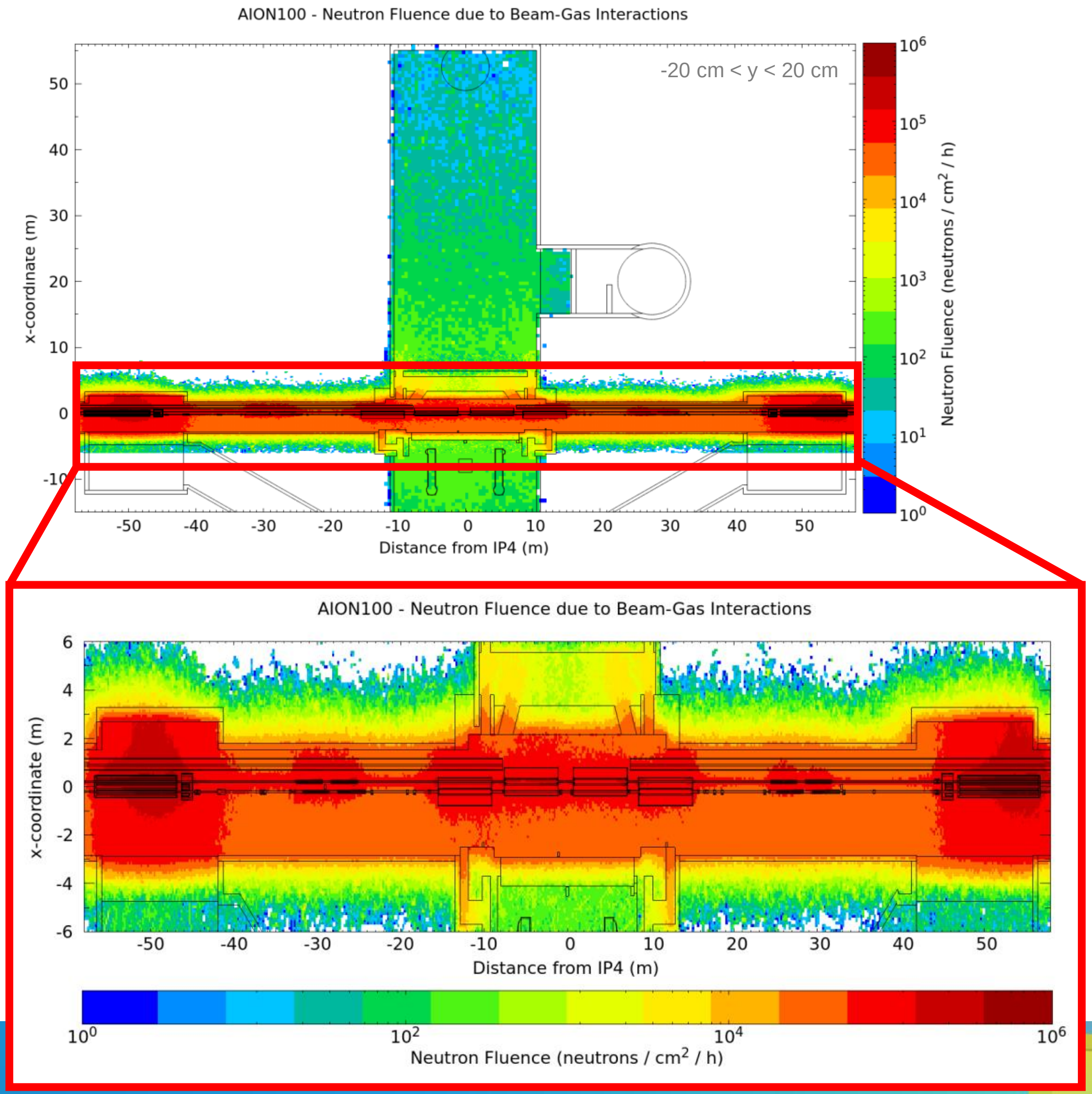


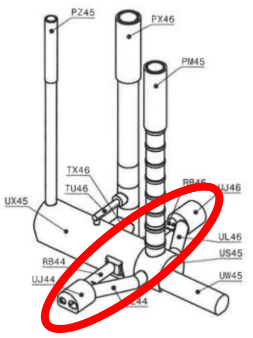


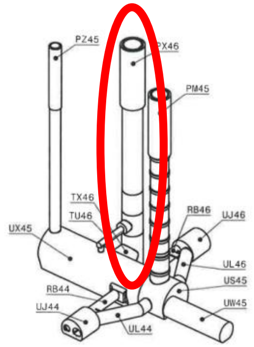
15 m < x < 25 m
Center of PX46 is 20 m (from IP4)

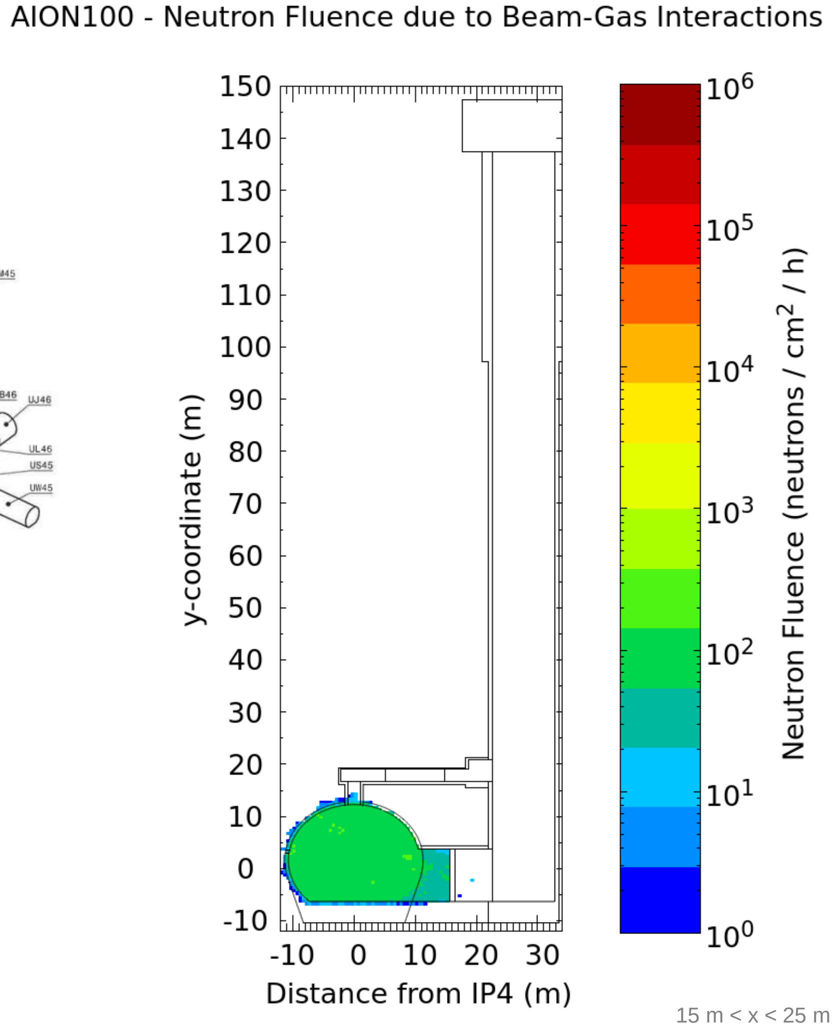
AION100: Beam-Gas Emissions, n Fluence





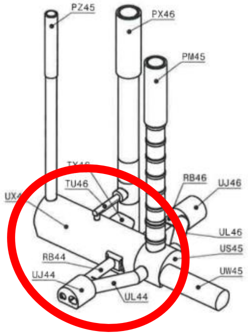


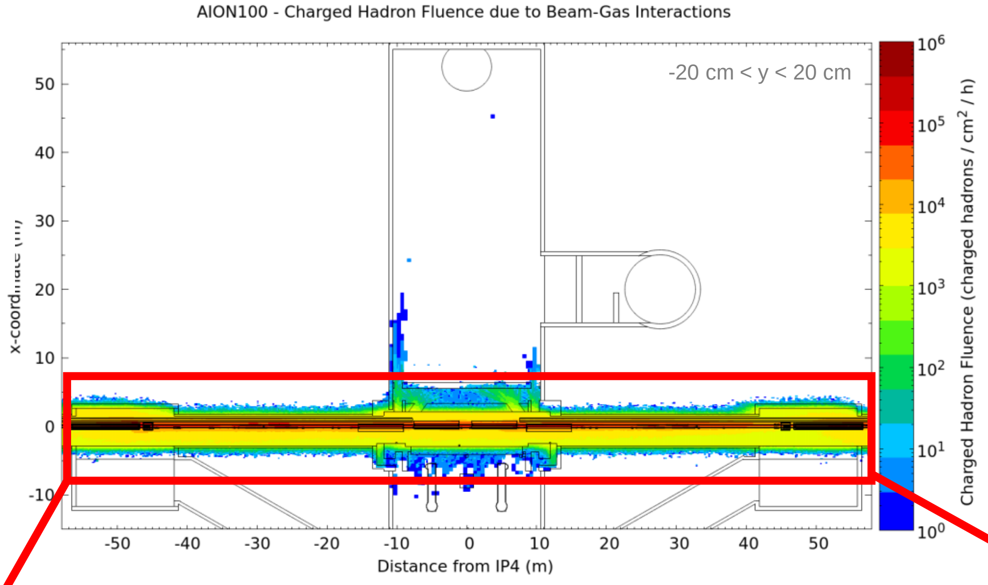


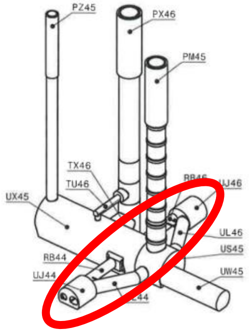


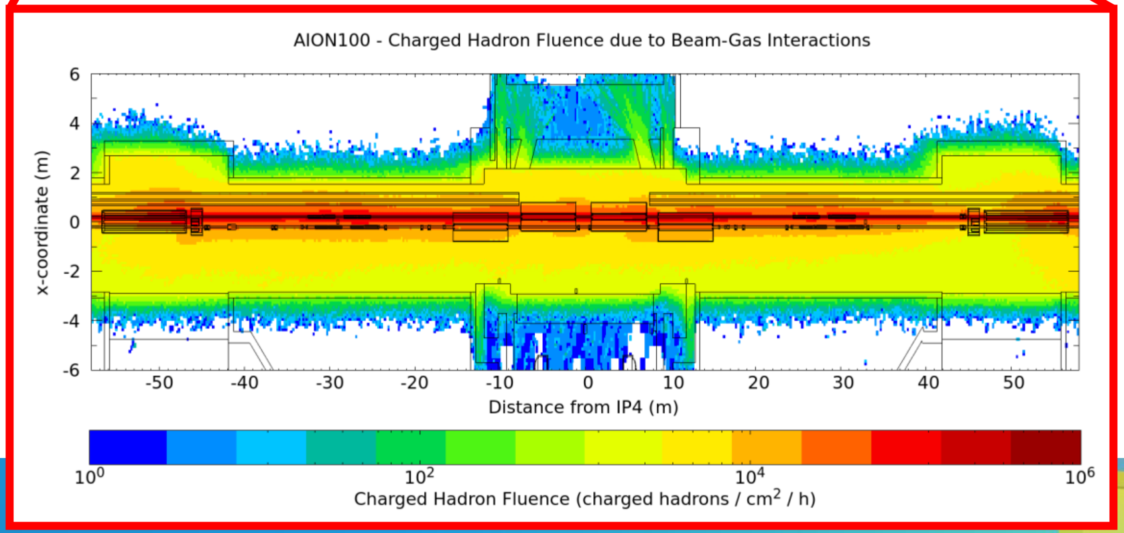
15 m < x < 25 m
Center of PX46 is 20 m (from IP4)

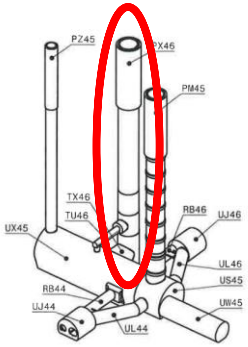
AION100: Beam-Gas Emissions, ch Fluence

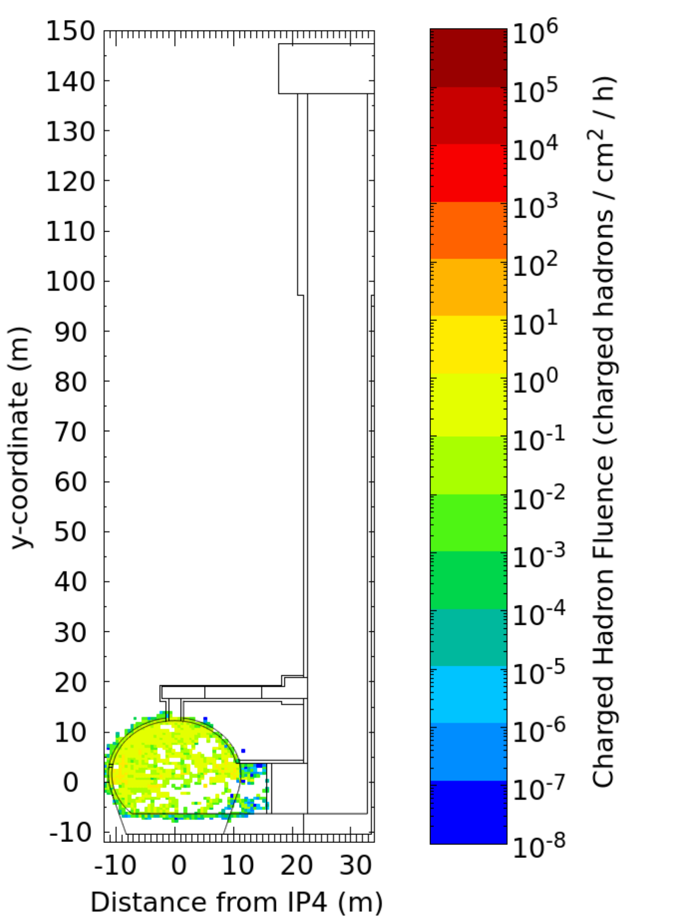






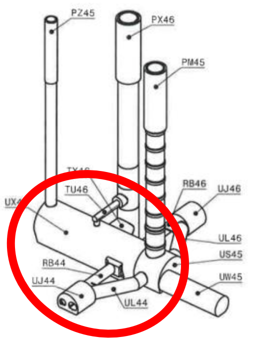


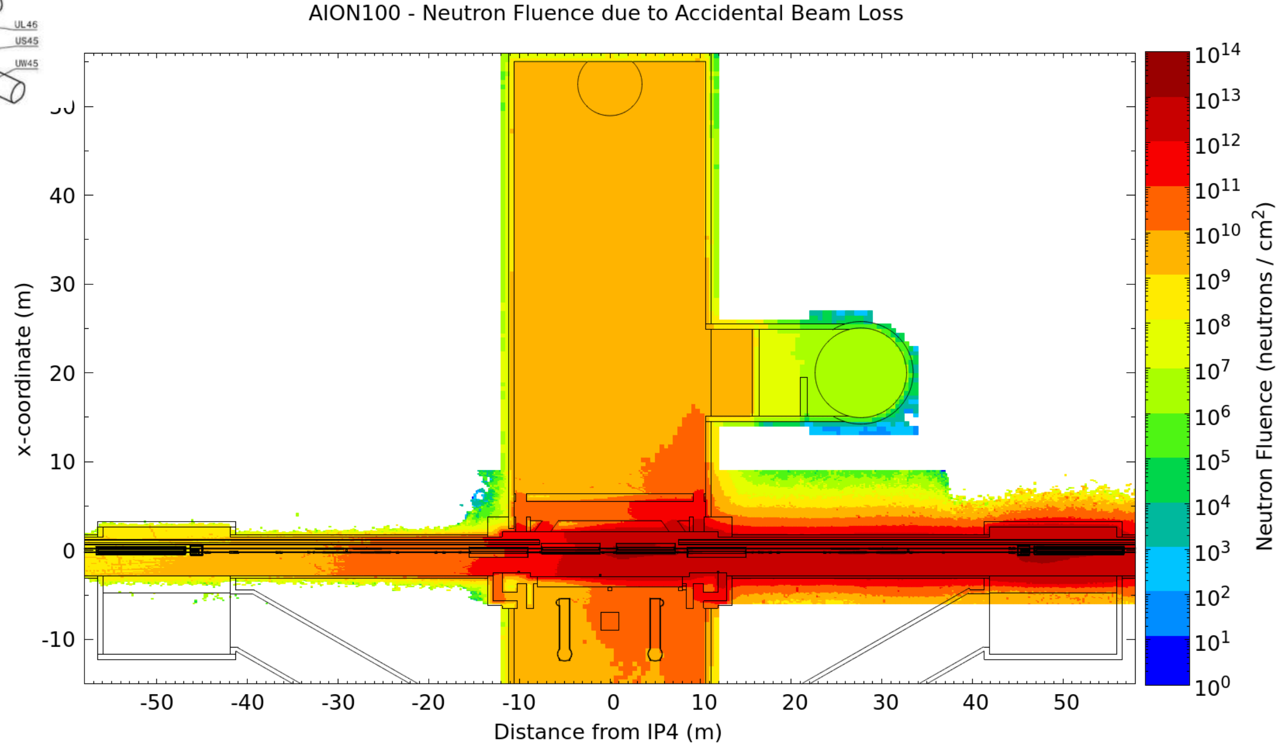


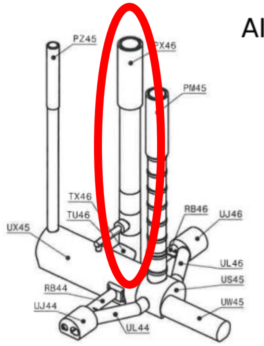


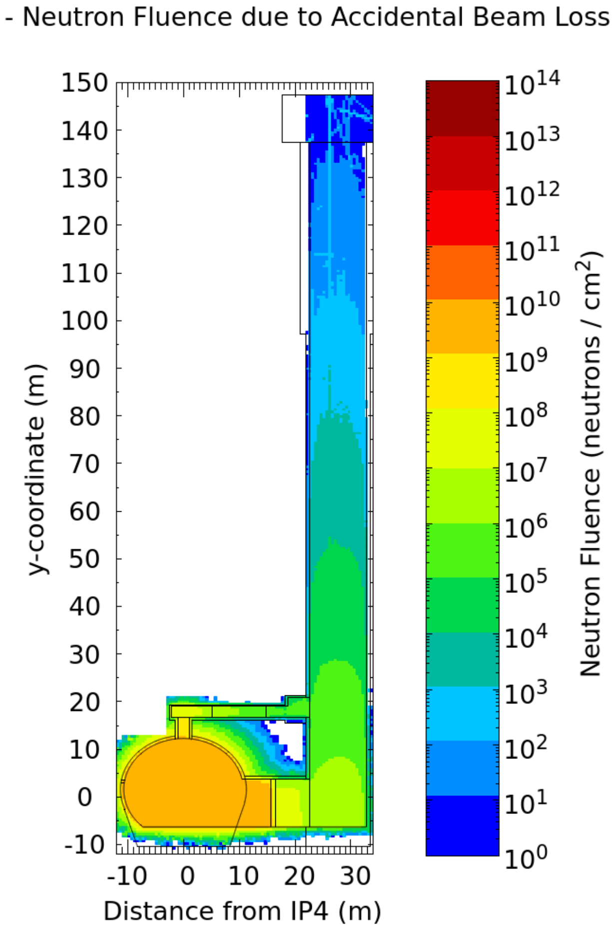
15 m < x < 25 m
Center of PX46 is 20 m (from IP4)

AION100: Accidental Scenario, n Fluence

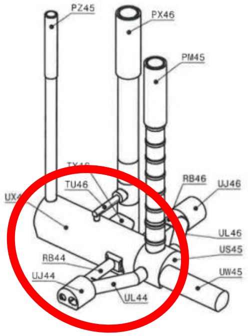


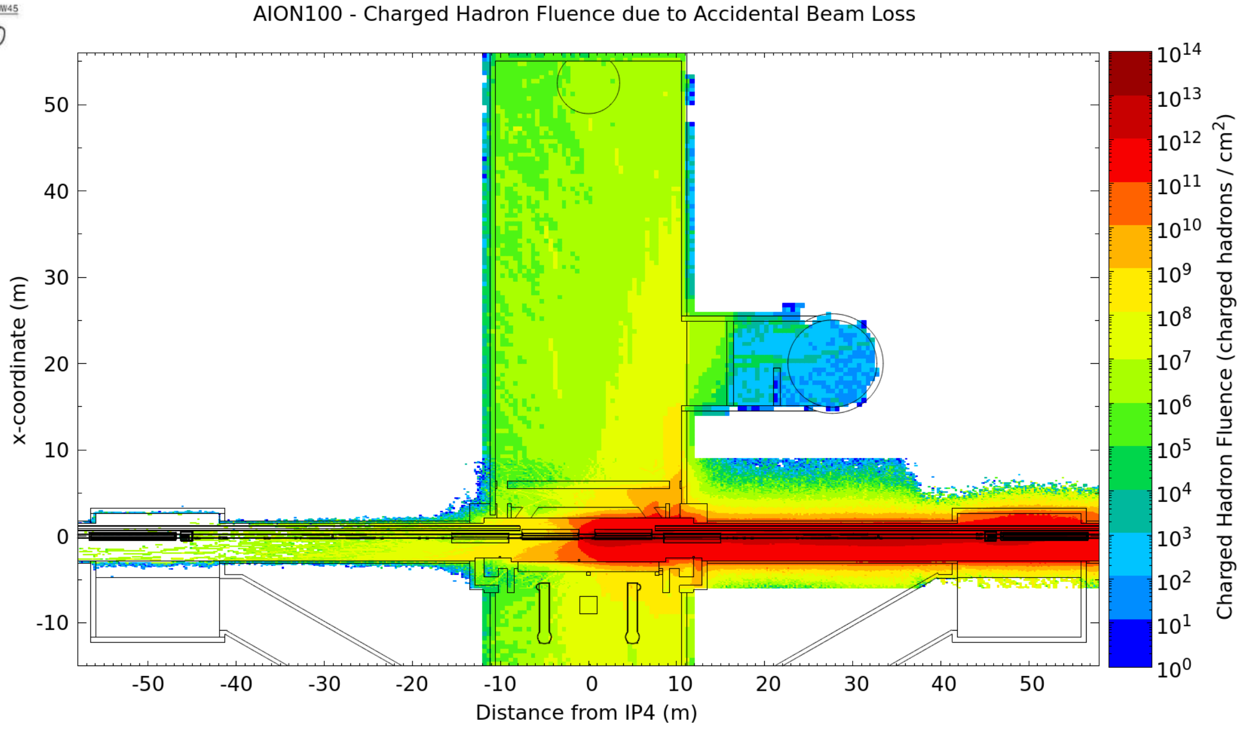




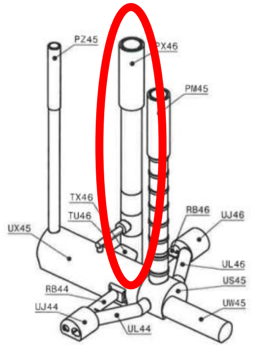


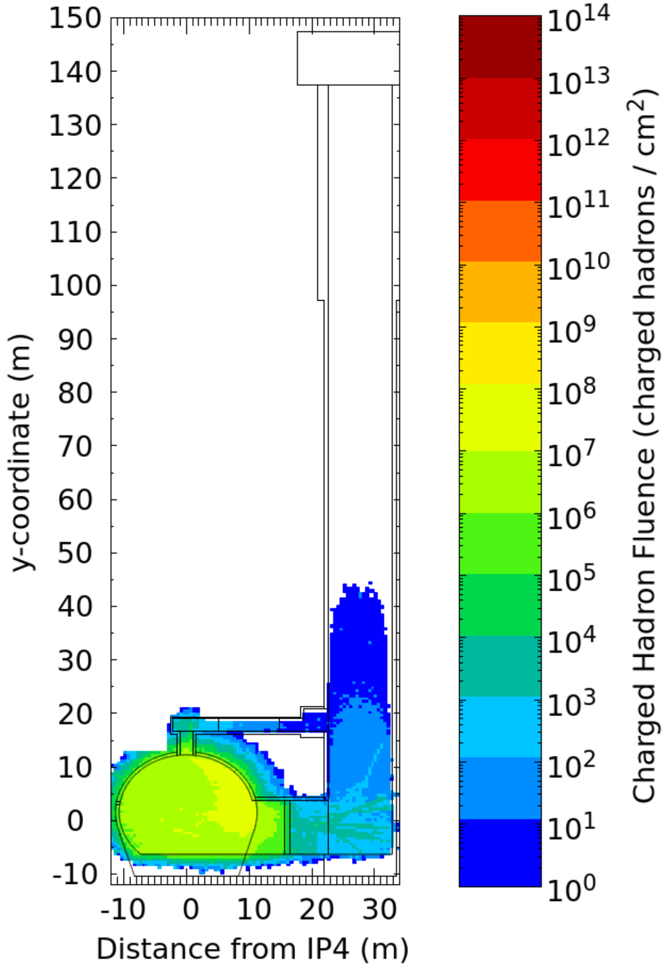
AION100: Accidental Scenario, ch Fluence





AION100 - Charged Hadron Fluence due to Accidental Beam Loss





LHC Residual Gas Parameters

GAS	Nuclear scattering cross section(cm^2)	Gas density (m^{-3}) for a 100 hour lifetime	Pressure (Pa) at 5 K, for a 100 hour lifetime
H_2	$9.5\ 10^{-26}$	$9.8\ 10^{14}$	$6.7\ 10^{-8}$
He	$1.26\ 10^{-25}$	$7.4\ 10^{14}$	$5.1\ 10^{-8}$
CH_4	$5.66\ 10^{-25}$	$1.6\ 10^{14}$	$1.1\ 10^{-8}$
H_2O	$5.65\ 10^{-25}$	$1.6\ 10^{14}$	$1.1\ 10^{-8}$
CO	$8.54\ 10^{-25}$	$1.1\ 10^{14}$	$7.5\ 10^{-9}$
CO_2	$1.32\ 10^{-24}$	$7\ \ 10^{13}$	$4.9\ 10^{-9}$