



HSE  
Occupational Health & Safety  
and Environmental Protection unit



# Shielding update for AMBER Drell-Yan at EHN2

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HSE-RP

30/11/2021

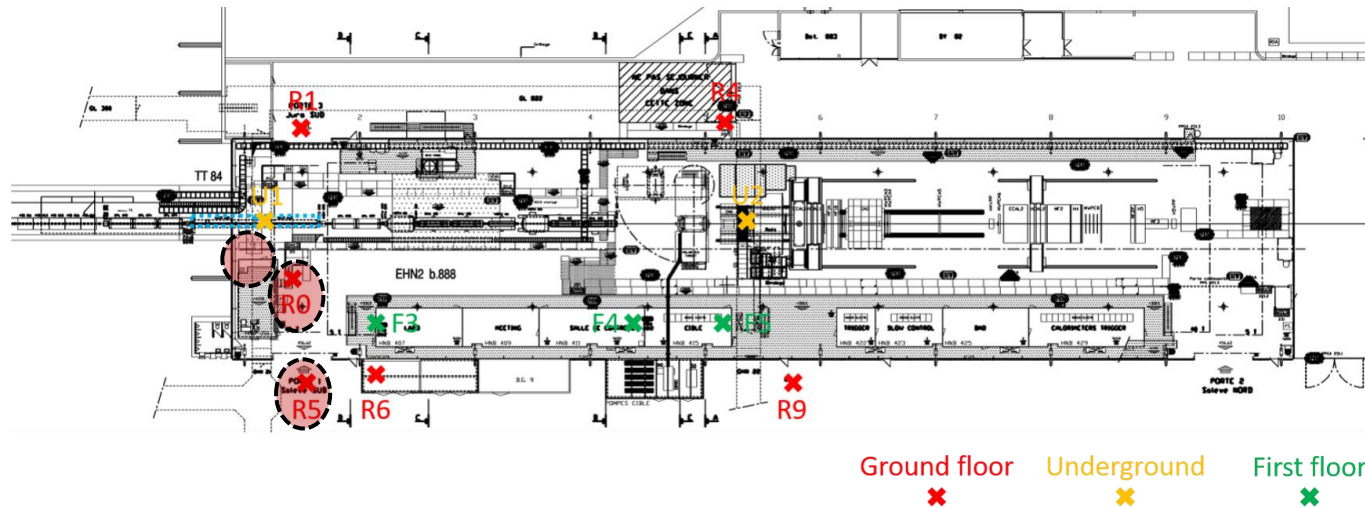
[EDMS 2667162](#)

# Outline

- Context
- Objective
- Shielding design
- Preliminary results
- Conclusions

# Context

- Preliminary studies available for EHN2 with geometry, source term and beam losses [1]
- High prompt dose rates measured in operation at several accessible EHN2 locations [2],[3]
- Optimization of environmental impact at CERN reference points [4]



# Objective

- Additional shielding at strategic EHN2 locations to comply with radiation area classification
- Design new shielding bunker for AMBER Drell-Yan
- Air activation assessment
- Skyshine optimization

Area	Annual dose limit (year)	Specific airborne radioactivity	Specific surface contamination
Non-designated	1 mSv	0.05 CA	1 CS
Supervised	6 mSv	0.1 CA	1 CS
Simple Controlled	20 mSv	0.1 CA	1 CS
Limited Stay	20 mSv	100 CA	4000 CS
High Radiation	20 mSv	1000 CA	40000 CS
Prohibited	20 mSv	> 1000 CA	> 40000 CS

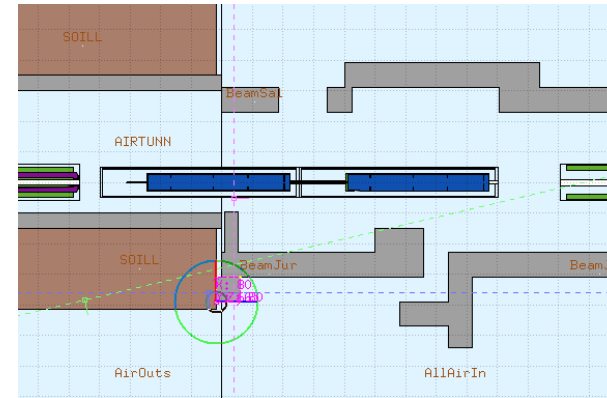
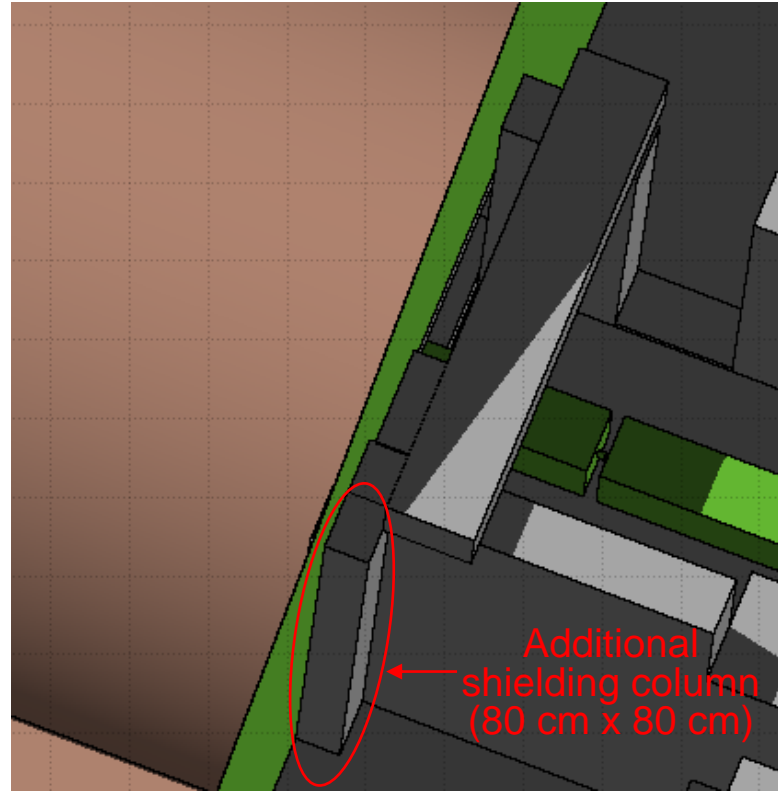
Radiation Area (left side) / Controlled Area (right side)

Area	Annual dose limit (year)	Ambient dose equivalent rate		Sign
		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 (left side) / Controlled Area (right side)

# Shielding design

- Junction EHN2/TT84 (*initial proposal simulated by RP*) :



To be discussed:

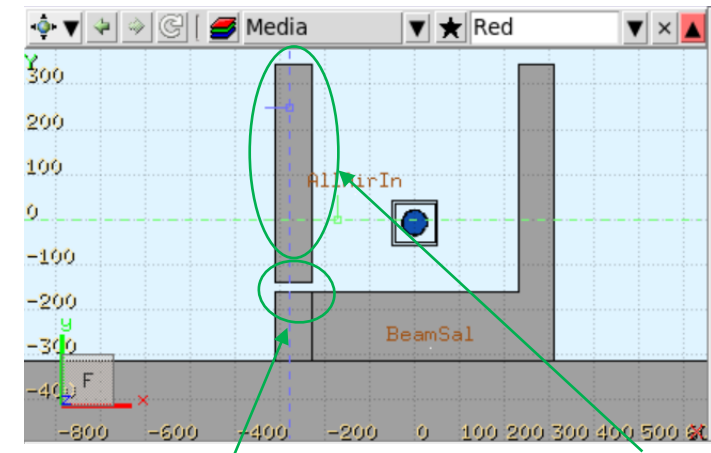
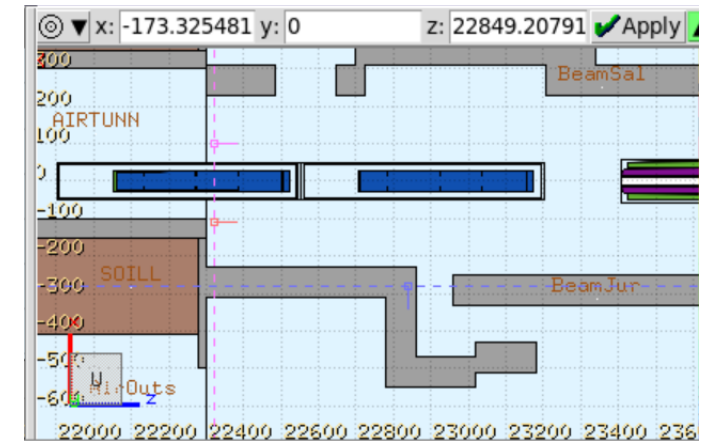
- ✓ Space constraint
- ✓ Mechanical constraint
- ✓ Shielding effectiveness

# Shielding design

- Jonction EHN2/TT84 (Proposal BE-EA):

## Jonction EHN2/TT84

✓ Implemented in FLUKA model (V42)

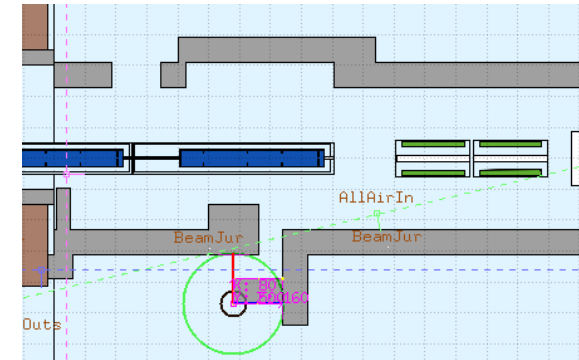
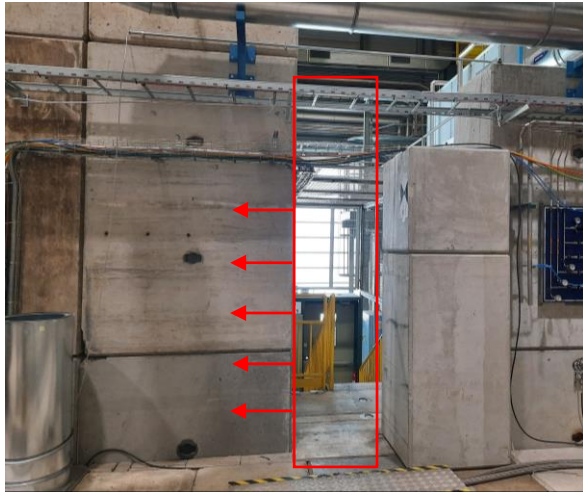


Opening for cables at inside ground level : 40 cm (width) x 20 cm (height)

Concrete bricks to fill gap according to proposal

# Shielding design

- Chicane access chicane (*initial proposal simulated by RP*):



To be discussed:

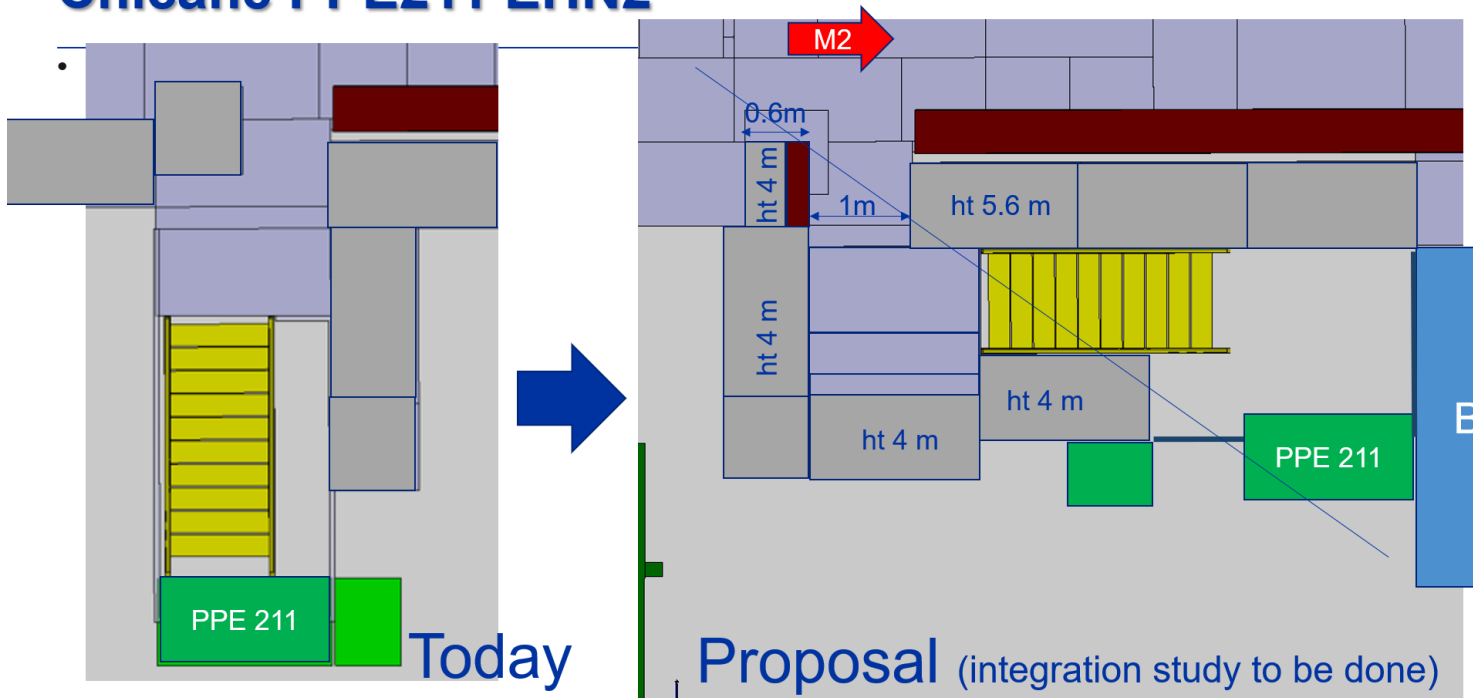
- ✓ Space constraint
- ✓ Mechanical constraint
- ✓ Shielding effectiveness



# Shielding design

- Chicane PPE211 (Proposal BE-EA)

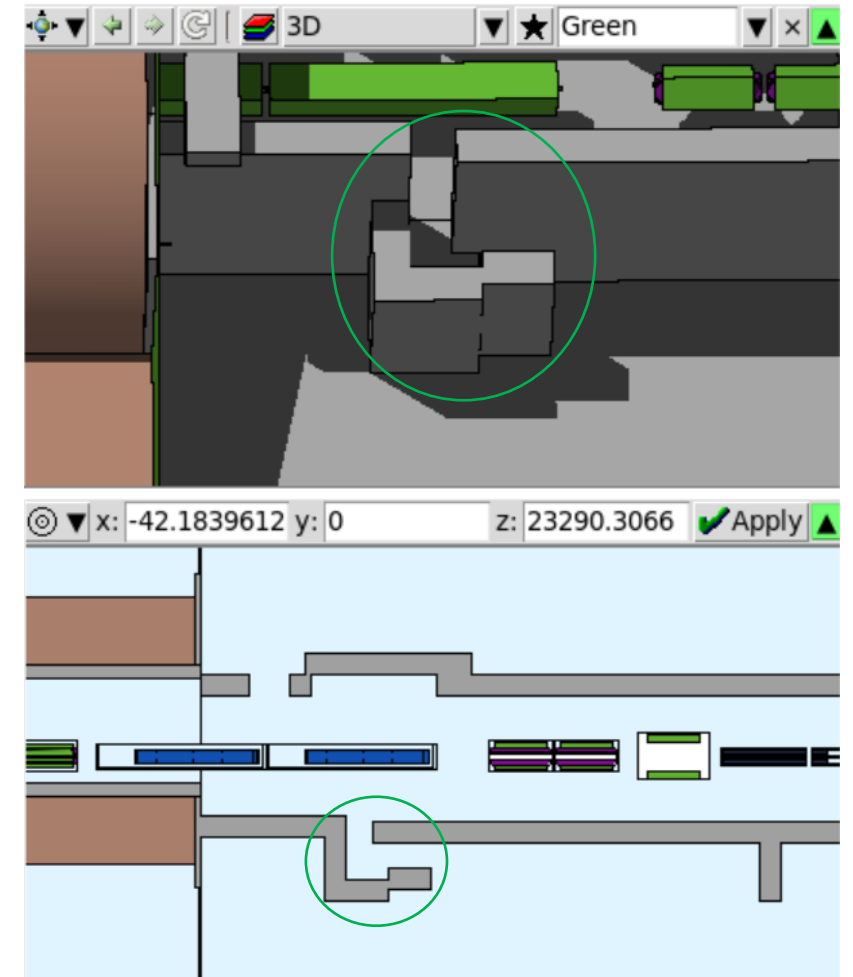
## Chicane PPE211 EHN2



DATE

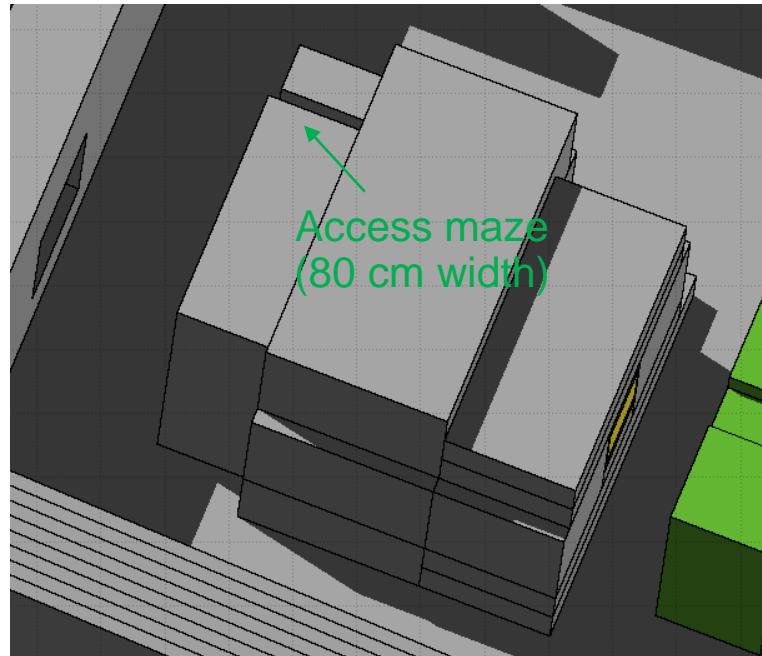
4

✓ Implemented in FLUKA model (V42)



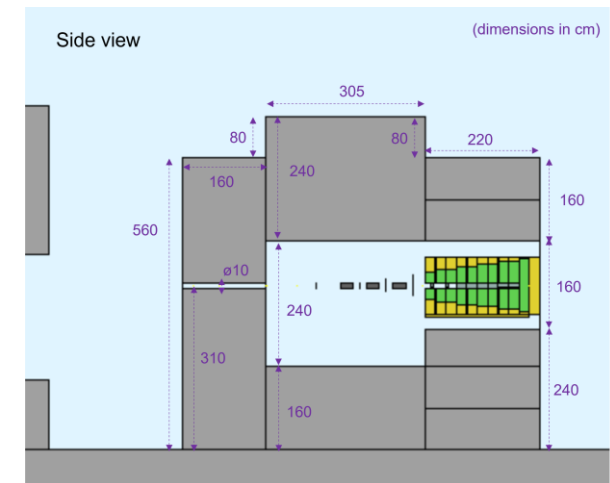
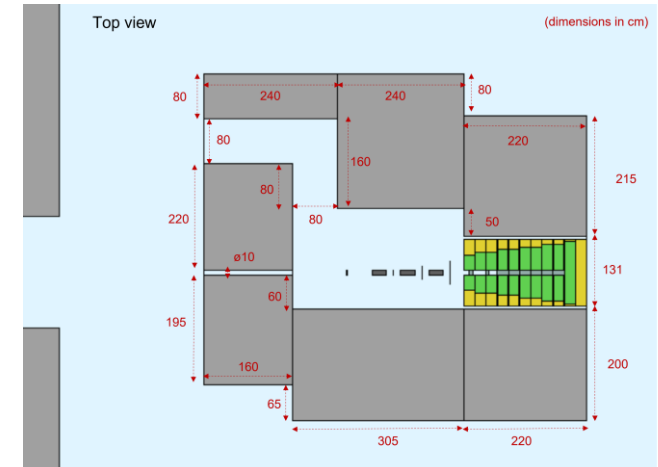
# Shielding design

- Bunker AMBER (initial proposal)



✓ Confirmation received from EP Safety Office on 26.11 that the access maze design width should be OK for emergency evacuation

✓ Discussion ongoing for integration



# Preliminary results

- Prompt radiation : losses improved at MBP

## Auxiliary files (V36) - old

- |           |            |
|-----------|------------|
| dist_px   | mbn_mea    |
| dist_py   | mbp        |
| dist_xxpr | qpl_qps_v2 |
| dist_yypr | qwl        |

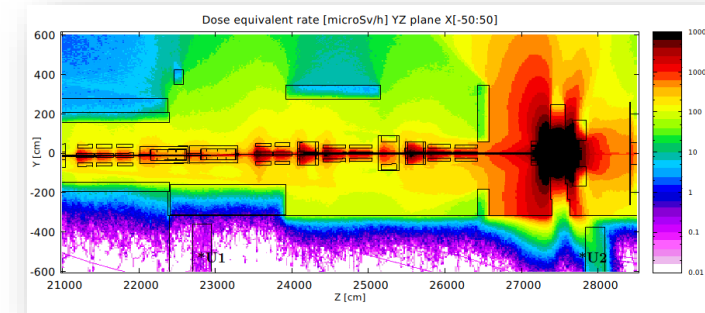
(files provided by M. Van Dijk on 04.11)



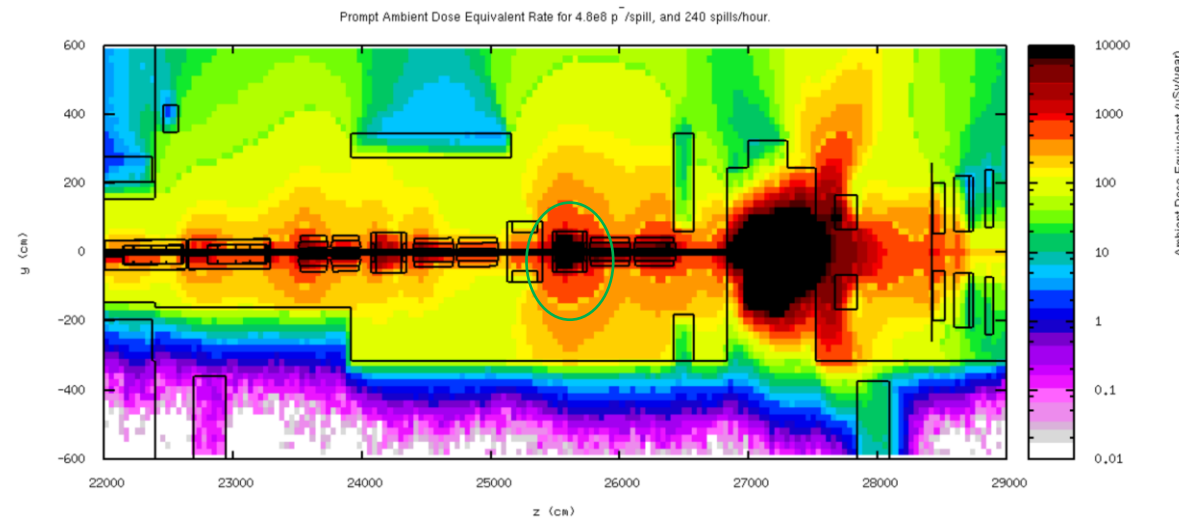
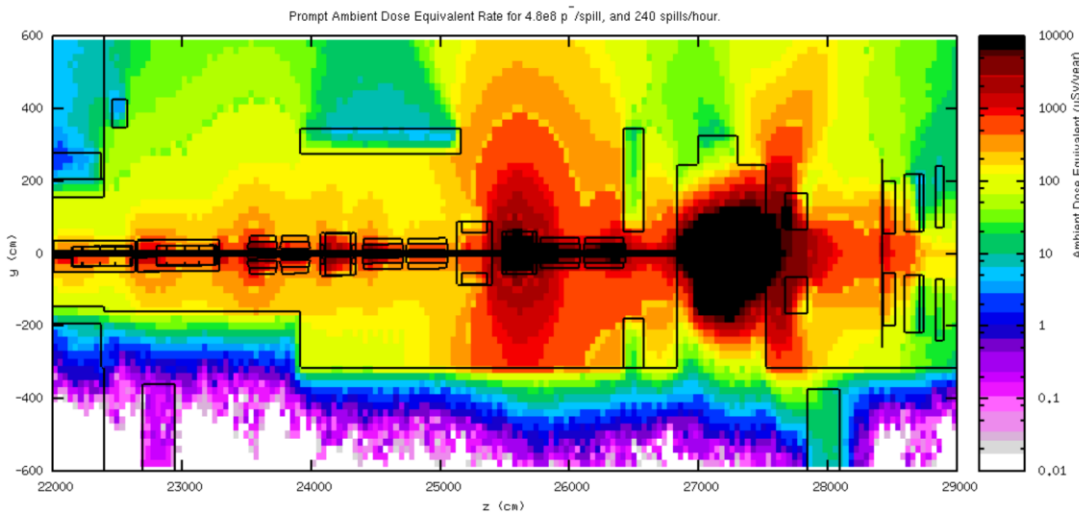
## Auxiliary files (V42) - new

- |           |            |               |
|-----------|------------|---------------|
| dist_px   | mbn_mea    |               |
| dist_py   | mbp        | RP_MBP_B8_MBP |
| dist_xxpr | qpl_qps_v2 |               |
| dist_yypr | qwl        |               |

- ✓ New map file provided by BE-EA on 26.11 for MBP
- ✓ Magnet aperture MBP corrected from 11 cm to 14 cm according to Magnet Database









Results from previous study [1]

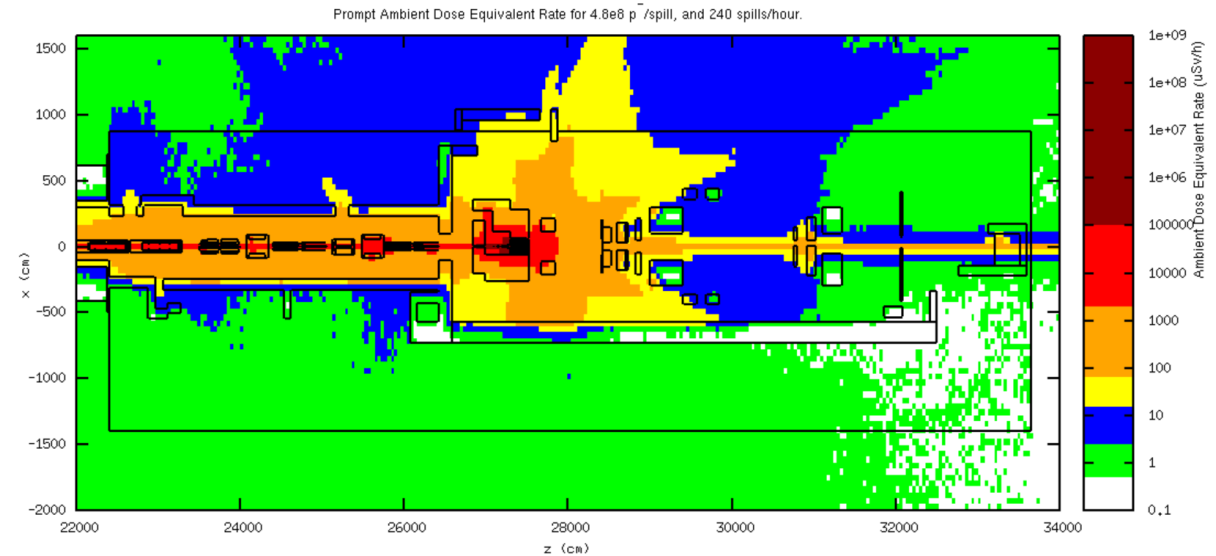
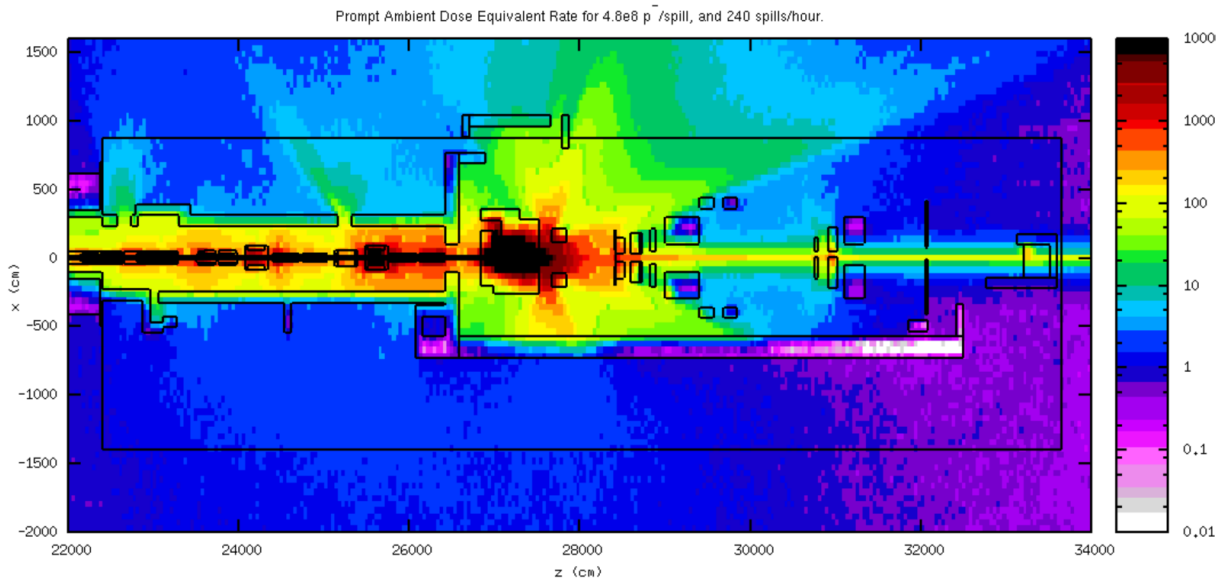


# Preliminary results

- Prompt radiation at **beam level Y[-30;30] – V42**







- Source: source.for (190 GeV/c  $\pi^-$  beam from [1])
- Magnetic field: magfld.for (magnets maps from [1] & modified MBP)
- Intensity:  $4.8 \times 10^8 \pi^-$ /spill and 240 spills/h

Area	Annual dose limit (year)	Ambient dose equivalent rate		Sign 
		permanent occupancy	low occupancy	
Non-designated	1 mSv	0.5 $\mu$ Sv/h	2.5 $\mu$ Sv/h	
Radiation Area	Supervised	6 mSv	3 $\mu$ Sv/h	
	Simple Controlled	20 mSv	10 $\mu$ Sv/h	
	Limited Stay	20 mSv	-	
	High Radiation	20 mSv	-	
	Prohibited	20 mSv	-	
				Controlled Area

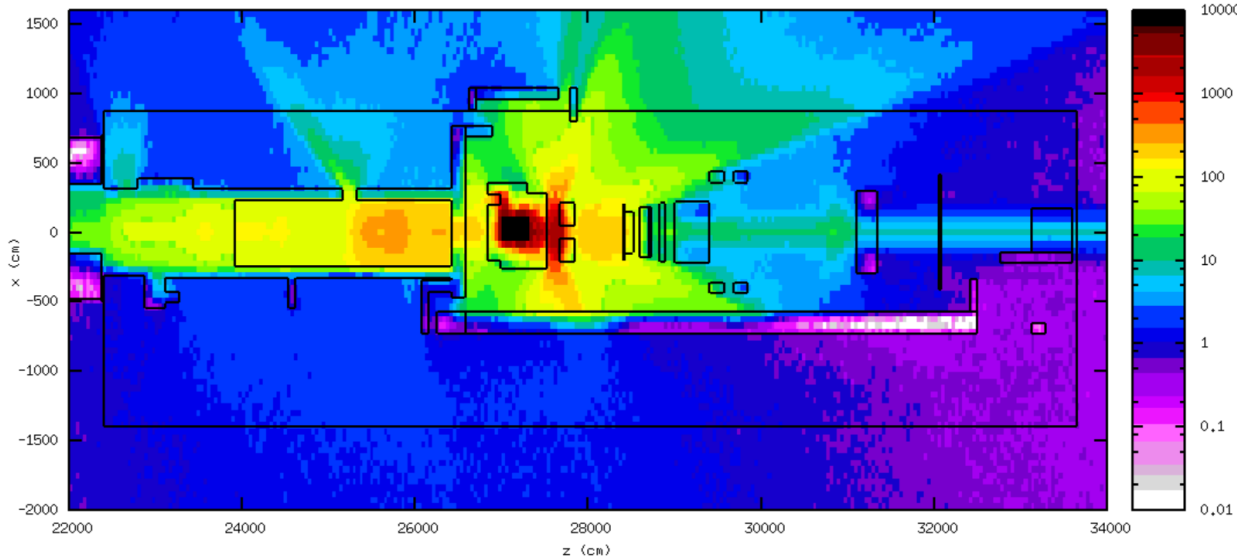


# Preliminary results

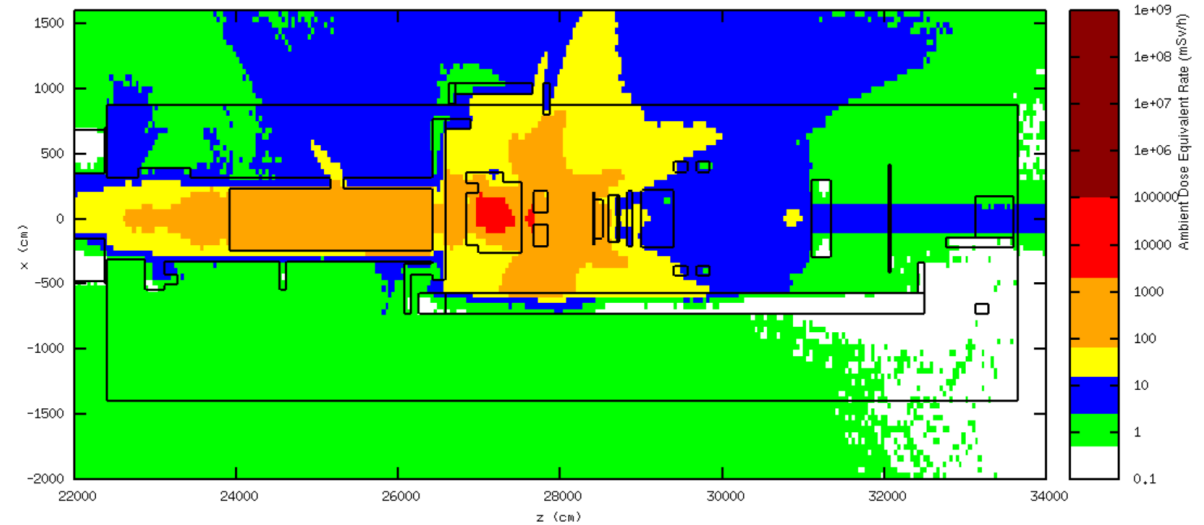
- Prompt radiation at **floor level Y[-230;-130] – V42**
  - Source: source.for (190 GeV/c  $\pi^-$  beam from [1])
  - Magnetic field: magfld.for (magnets maps from [1] & modified MBP)
  - Intensity:  $4.8 * 10^8 \pi^-$ /spill and 240 spills/h

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

Prompt Ambient Dose Equivalent Rate for  $4.8e8 \pi^-$ /spill, and 240 spills/hour.



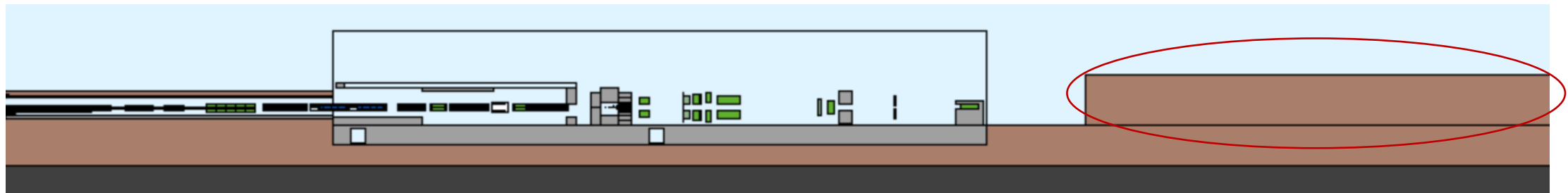
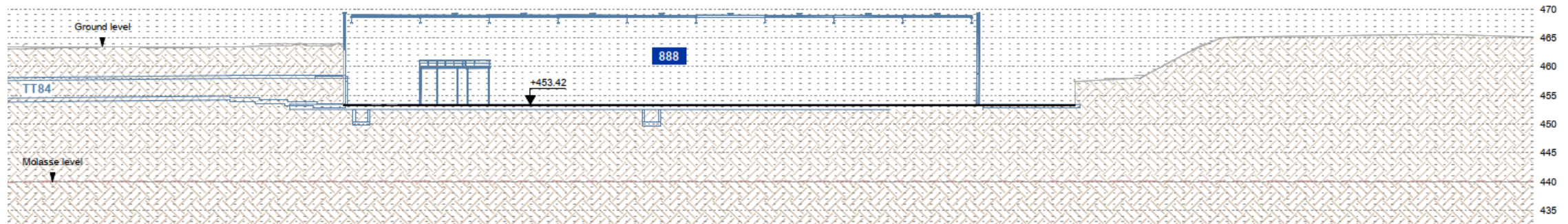
Prompt Ambient Dose Equivalent Rate for  $4.8e8 \pi^-$ /spill, and 240 spills/hour.



# Preliminary results

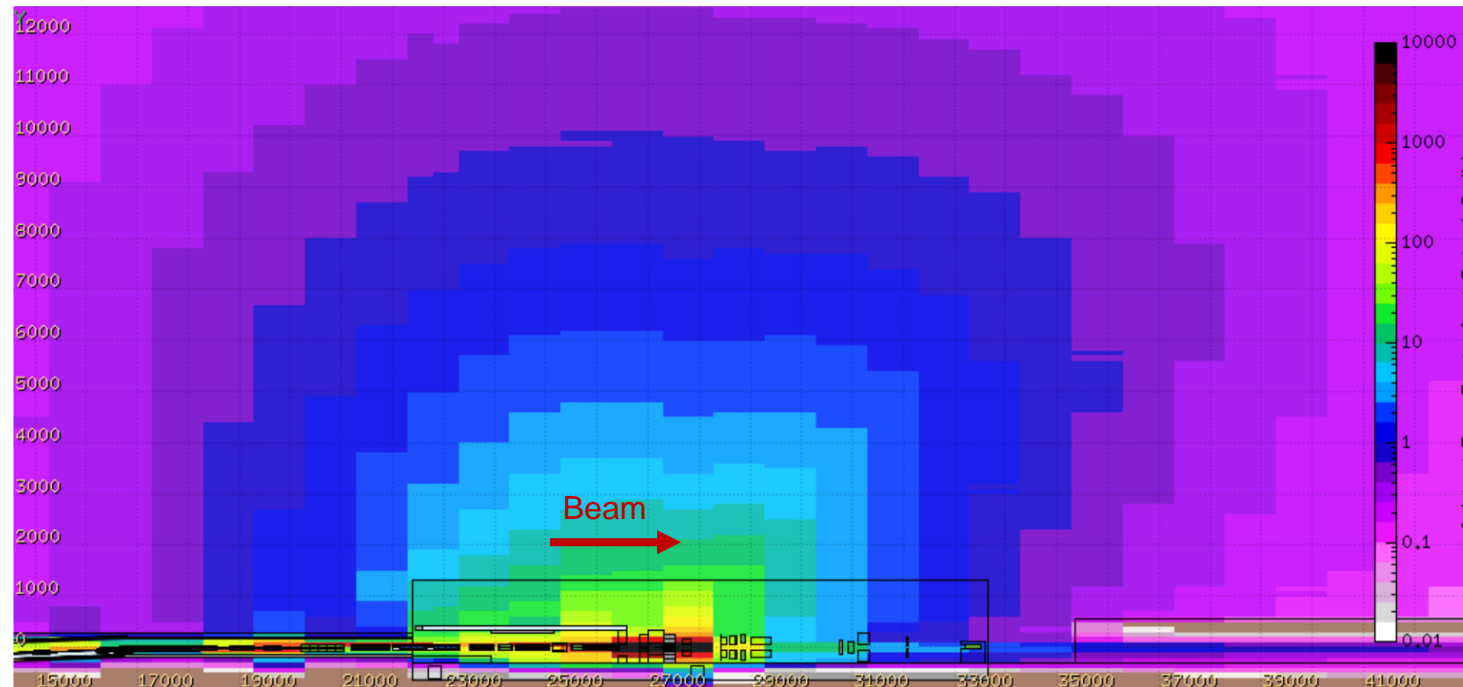
- Prompt radiation– V42

- EHN2 ground profile obtained from SCE-SAM-TG
- Simplified model with Soil region included for prompt radiation downstream EHN2 (to be completed)



# Preliminary results

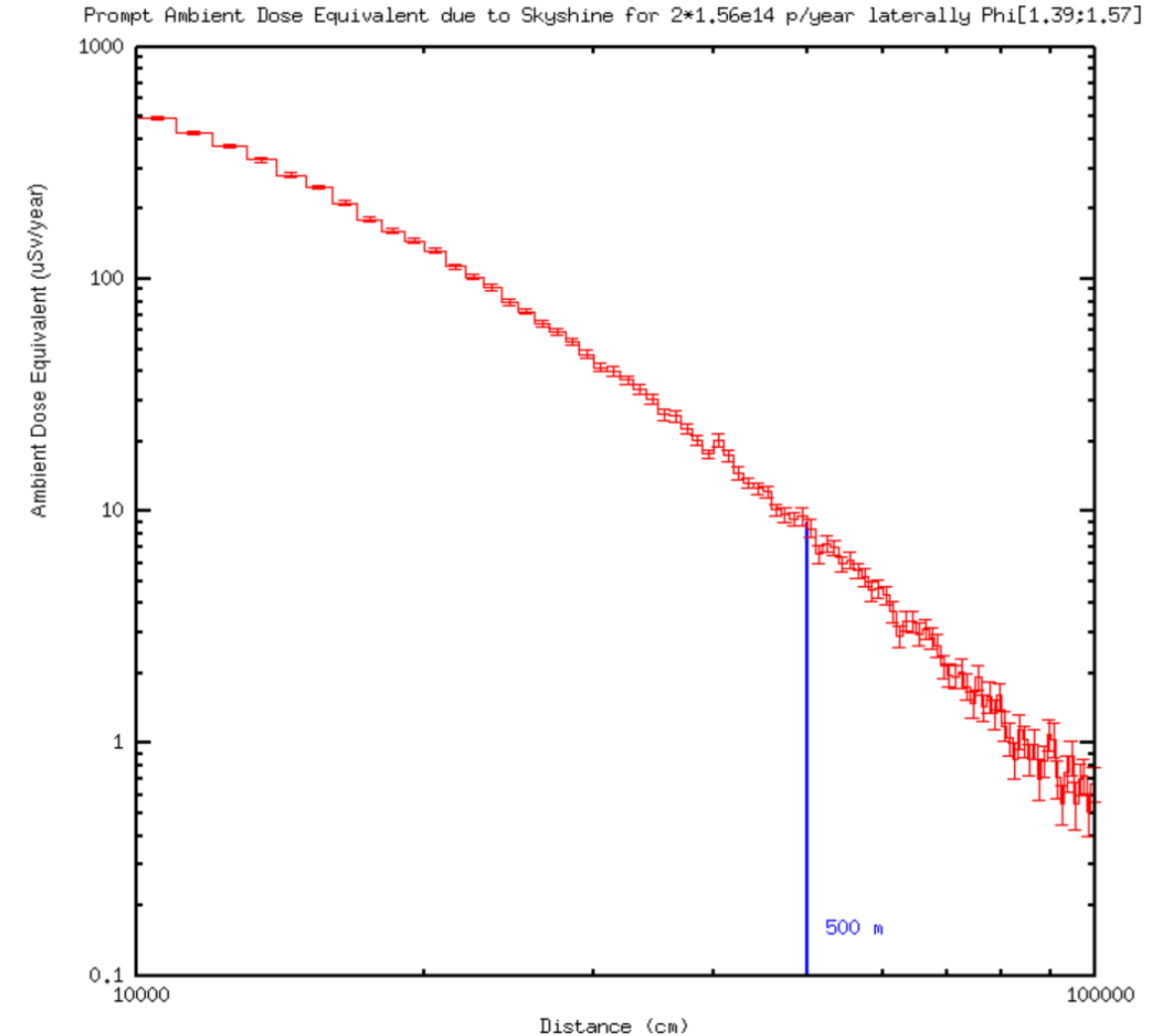
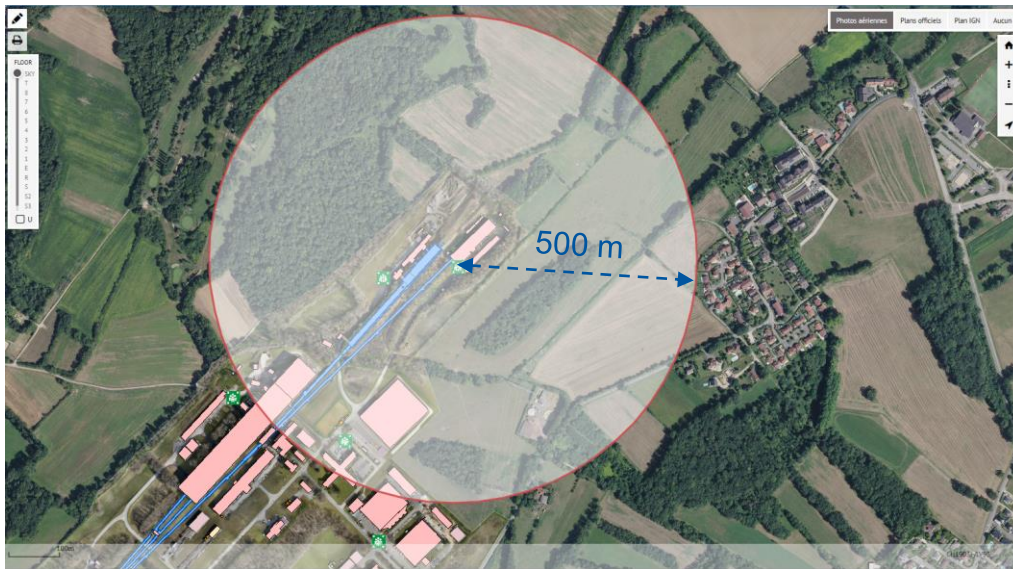
- Prompt radiation– V42
  - Ambient Dose Equivalent rate longitudinally to EHN2 with soil ground region downstream:



Ambient Dose Equivalent rate ( $\mu\text{Sv/h}$ ). Intensity:  $4.8 \times 10^8 \pi^-/\text{spill}$  and 240 spills/h

# Preliminary results

- Skyshine contribution – V42
  - Intensity:  $3.07e14$  p/year
  - Below  $10 \mu\text{Sv/year}$  at 500 m distance
  - To be re-assessed with final design

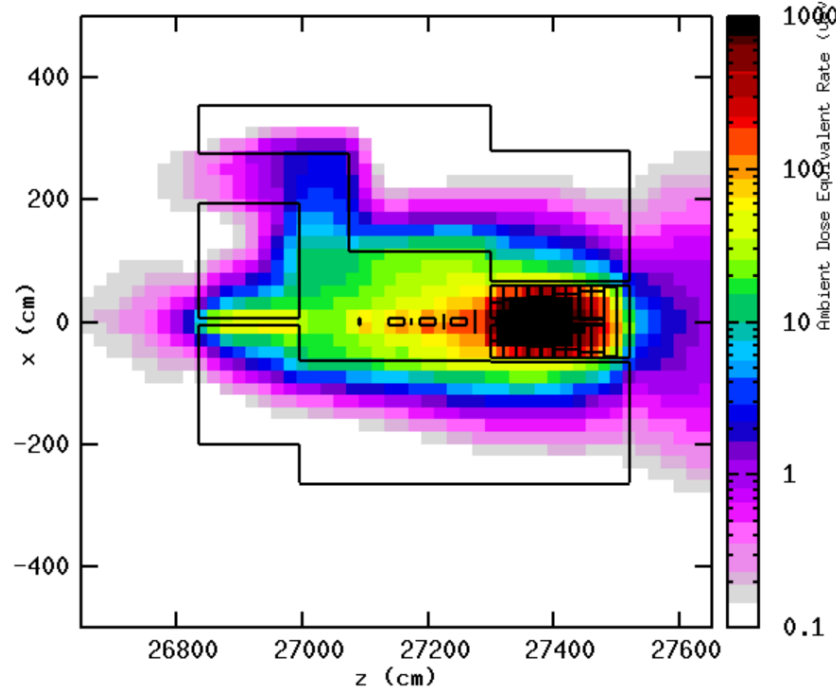




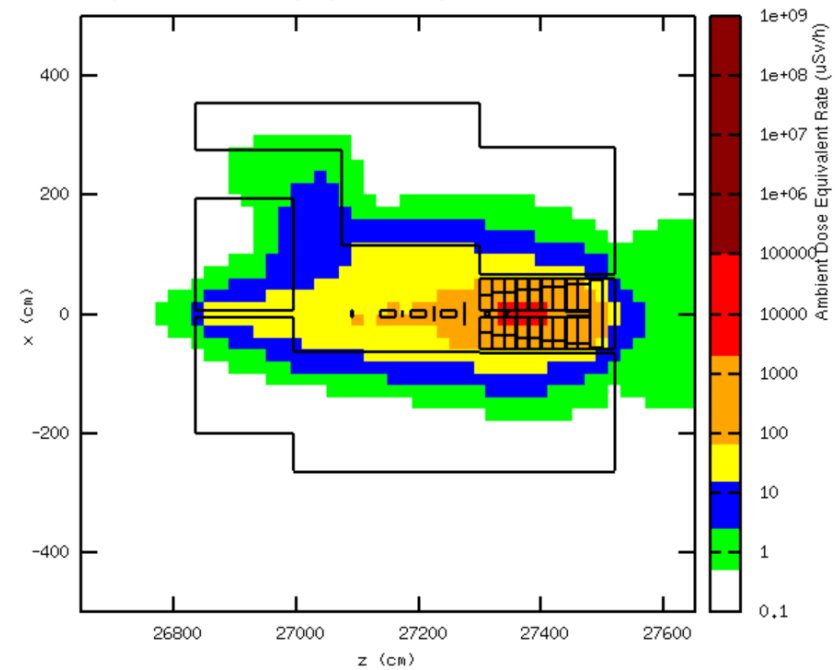
# Preliminary results

- Residual radiation – V42
  - 6 months irradiation. 2 mn cool-down (minimum time from access system)

Residual Ambient Dose Equivalent Rate for  $4.8e8$  p<sup>-</sup>/spill, and 240 spills/hour. 6 month irradiation and 2 mn cool-down time.



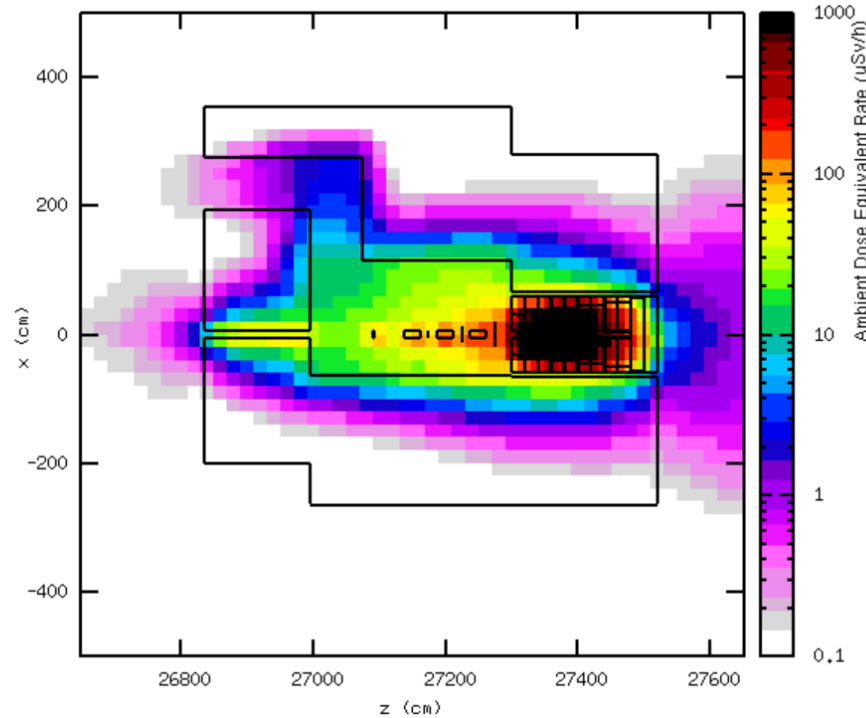
Residual Ambient Dose Equivalent Rate for  $4.8e8$  p<sup>-</sup>/spill, and 240 spills/hour. 6 month irradiation and 2 mn cool-down time.



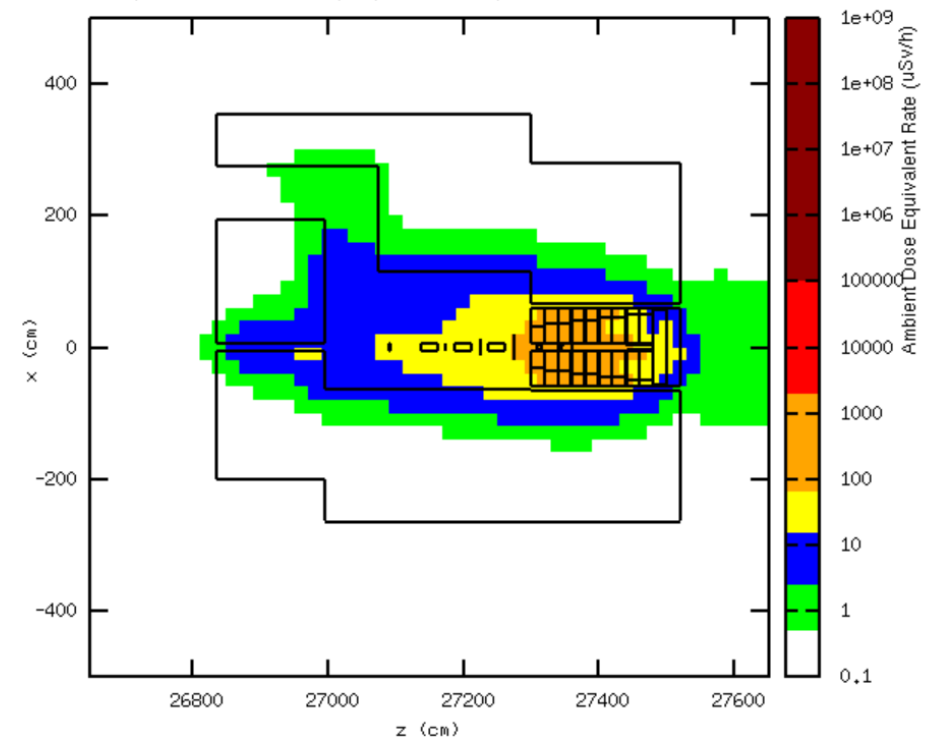
# Preliminary results

- Residual radiation – V42
  - 6 months irradiation. 1h cool-down.

Residual Ambient Dose Equivalent Rate for  $4.8e8 \text{ p}^-$ /spill, and 240 spills/hour. 6 month irradiation and 1h cool-down time.



Residual Ambient Dose Equivalent Rate for  $4.8e8 \text{ p}^-$ /spill, and 240 spills/hour. 6 month irradiation and 1h cool-down time.



# Preliminary results

- Air activation in AMBER bunker area:
  - ✓ 1 year irradiation, no cool-down time
  - ✓ Results show values below 0.1 CA
  - ✓ Main contributors N-13, O-15, C-11, Ar-41

Area	Annual dose limit (year)	Specific airborne radioactivity	Specific surface contamination
Non-designated	1 mSv	0.05 CA	1 CS
Supervised	6 mSv	0.1 CA	1 CS
Simple Controlled	20 mSv	0.1 CA	1 CS
Limited Stay	20 mSv	100 CA	4000 CS
High Radiation	20 mSv	1000 CA	40000 CS
Prohibited	20 mSv	> 1000 CA	> 40000 CS

Controlled Area

- Air activation in EHN2 Hall (negligeable)

Isotop	t 1/2 [s]	Total yield/pp	Error (%)	Activity (Bq)	Activity/CA
H-3	3.89E+08	6.36E-03	0.13%	1.11E+04	1.08E-04
Be-7	4.61E+06	1.70E-03	0.11%	5.38E+04	1.04E-03
Be-10	5.05E+13	1.27E-03	0.11%	1.76E-02	3.80E-07
C-11	1.22E+03	2.08E-03	0.09%	6.67E+04	1.85E-03
C-14	1.81E+11	1.12E+00	0.09%	4.33E+03	8.41E-04
N-13	5.98E+02	4.40E-03	0.13%	1.41E+05	3.91E-03
O-14	7.10E+01	1.94E-04	0.15%	6.20E+03	-
O-15	1.22E+02	2.12E-03	0.13%	6.77E+04	1.88E-03
O-19	2.71E+01	4.21E-07	0.35%	1.35E+01	-
F-18	6.59E+03	1.30E-06	0.36%	4.17E+01	1.16E-06
Ne-23	2.80E+01	6.34E-07	0.36%	2.03E+01	-
Ne-24	2.03E+02	2.19E-07	0.64%	7.00E+00	-
Na-22	8.21E+07	1.63E-06	0.26%	1.22E+01	5.90E-06
Na-24	5.40E+04	1.16E-06	0.25%	3.73E+01	2.41E-06
Na-25	6.00E+01	1.08E-06	0.32%	3.46E+01	-
Mg-27	5.70E+02	1.79E-06	0.26%	5.71E+01	-
Mg-28	7.53E+04	4.54E-07	0.45%	1.45E+01	4.70E-06
Al-26	2.26E+13	1.02E-06	0.23%	3.17E-05	1.54E-10
Al-28	1.34E+02	6.20E-06	0.17%	1.98E+02	6.42E-05
Al-29	3.96E+02	3.34E-06	0.21%	1.07E+02	-
Si-31	9.44E+03	5.43E-06	0.17%	1.74E+02	3.37E-06
Si-32	1.42E+10	2.34E-06	0.24%	1.15E-01	7.45E-06
P-30	1.50E+02	2.78E-06	0.19%	8.89E+01	-
P-32	1.23E+06	1.47E-05	0.13%	4.72E+02	4.58E-04
P-33	2.19E+06	1.35E-05	0.13%	4.31E+02	8.38E-05
P-35	4.74E+01	1.78E-06	0.27%	5.68E+01	-
S-35	7.55E+06	2.18E-05	0.10%	6.58E+02	1.28E-04
S-37	3.04E+02	4.87E-06	0.13%	1.56E+02	-
S-38	1.03E+04	1.81E-06	0.28%	5.78E+01	-
Cl-34	1.92E+03	1.04E-06	0.22%	3.31E+01	-
Cl-36	9.50E+12	4.13E-05	0.09%	3.04E-03	5.90E-09
Cl-38	2.23E+03	1.65E-05	0.11%	5.29E+02	2.57E-05
Cl-39	3.34E+03	4.66E-05	0.11%	1.49E+03	1.45E-05
Cl-40	8.40E+01	5.94E-06	0.17%	1.90E+02	-
Ar-37	3.03E+06	8.55E-05	0.07%	2.73E+03	5.31E-11
Ar-39	8.49E+09	1.74E-04	0.10%	1.43E+01	3.98E-09
Ar-41	6.58E+03	2.37E-03	0.09%	7.59E+04	2.95E-03
K-38	4.58E+02	7.90E-08	0.49%	2.53E+00	-
K-40	4.04E+16	1.31E-06	0.37%	2.27E-08	1.47E-14
				Total	0.01

Results obtained using FLUKA 4.1.0 and Actiwiz 3.5

# Conclusions

- Shielding design for EHN2 – AMBER Drell-Yan should be in agreement with radiation area classification
- Additional shielding elements and new designs: Junction EHN2/TT84 , Chicane PPE211 , AMBER Bunker.
- Preliminary results showed for prompt and residual radiation, skyshine contribution and air activation
- **Open points:**
  - *Improve source term (updated source routine)*
    - *Implemented using user routines from [1]. Update auxiliary files and MBP geometry. Investigate vertical beam offset.*
  - *Complete study skyshine and air activation*
    - *Machinery prepared for skyshine and air activation. Pending final design and ground profile for accuracy.*
  - *Discuss possible mechanical and/or integration constrains*
    - *Discussion ongoing with BE-EA. Proposal for Junction EHN2/TT84 and Chicane PPE211. Pending feedback bunker.*
  - *Verifications to be done on Jura side shielding*

# References

- [1] Shielding studies for EHN2 with FLUKA, S. Cholak. Internal report (2018)
- [2] COMPASS - 2018 Radiation Protection Survey, C. Ahdida, M. Casolino, H. Morimoto. Survey Note (2019)
- [3] COMPASS - 2018 Radiation Protection Survey 2, C. Ahdida, H. Morimoto (2021)
- [4] Report on Annual Radiation levels calculations for Amber experiment, P. Correia (2020)



[www.cern.ch](http://www.cern.ch)