CERN High Energy Accelerator Mixed Field (CHARM) Facility

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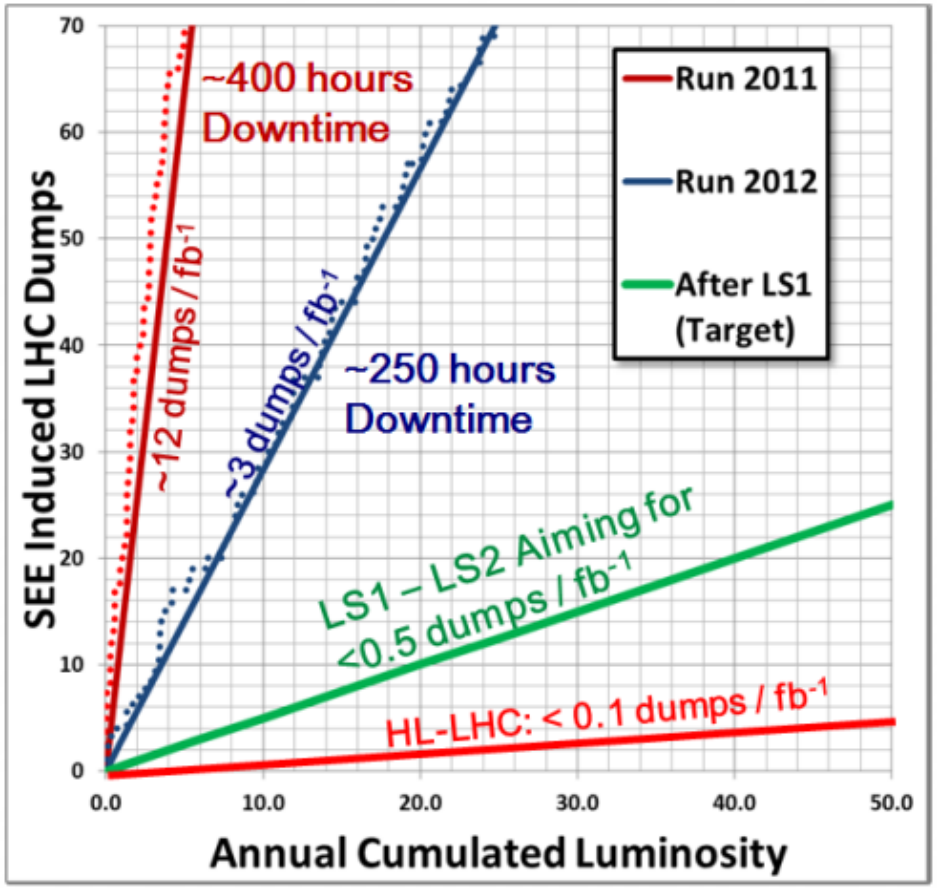
Motivation

- Objective of R2E project (Radiation2Electronics):
  ≤ 0.5 dumps per fb^{-1}
- Radiation test for electronic equipment (power converters, electronic devices)
- CHARM project to provide test locations with well understood, typical mixed radiation fields
  (in addition to existing facilities CNGS, CERF, H4IRRAD, IRRAD)
- Space in CERN–PS East Experimental Hall available due to decommissioning of DIRAC experiment
- Downstream of proton irradiation facility



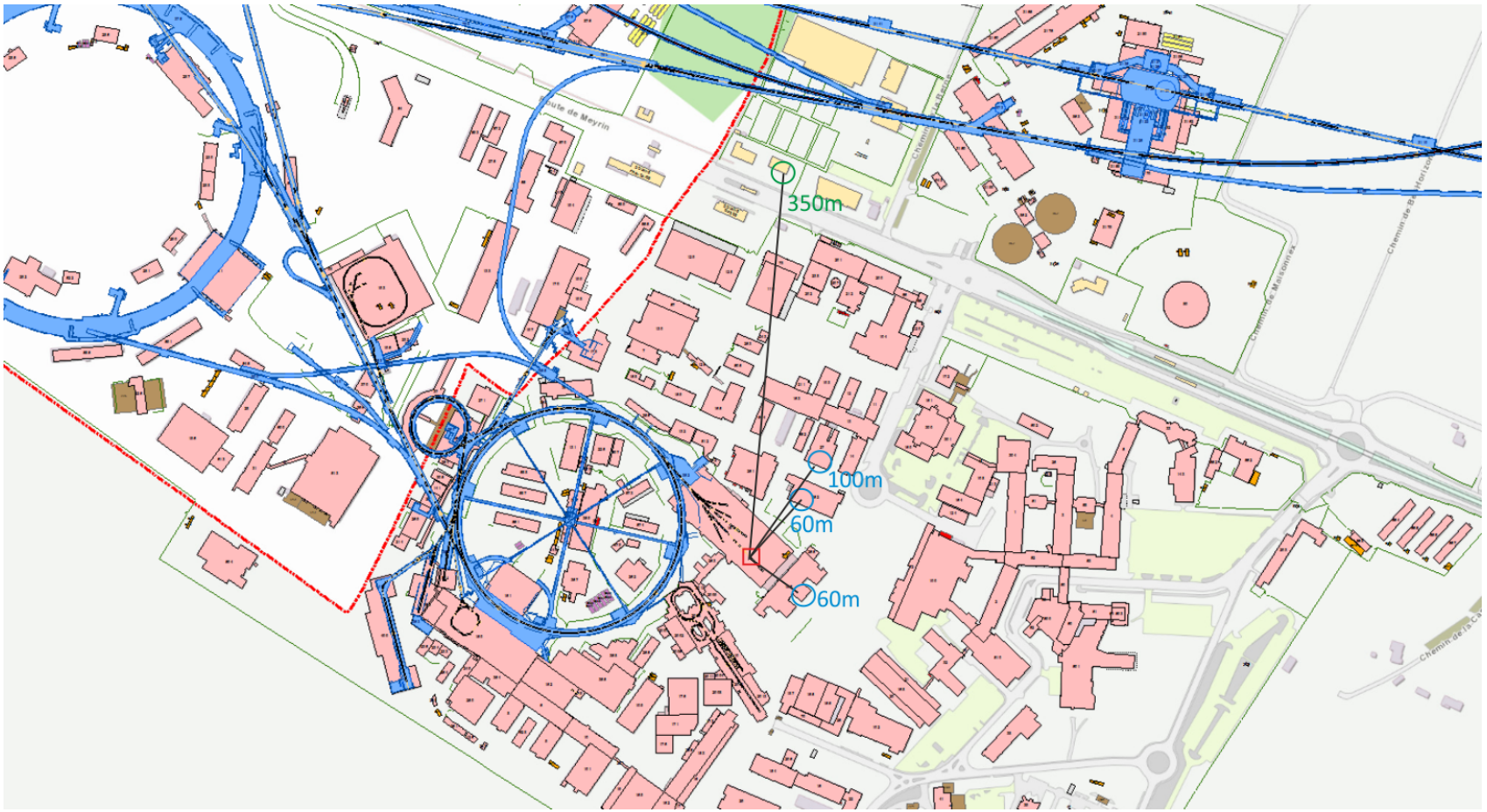
Motivation

- Interest/importance of testing in mixed fields
  - allows testing in real representative conditions, thus not requiring multiple tests
  - enables testing full systems (up to 1mx1mx2m)
  - field/intensity can be adopted over large ranges
- Spectrum and impact on electronics
  - high-energy tail of spectrum (for several applications) can be dominant in case of destructive failures (e.g, latch-up)
  - thermal neutrons also play a role
- High number of representative fields
  - high-energy accelerators/experiments
  - aviation and high-altitude
  - space (lower orbits)
  - ground applications (e.g, radiation impact on large distributed systems)

Motivation

- New installation conceived as real facility
  - Large number of cables and services pre-installed
  - Preparation and dry-run area (same layout)
  - Technical control room
  - Optimized for Radiation Protection using an integrated, iterative design approach
- Detailed monitoring
  - Available for all tests
  - Detailed benchmark during commissioning

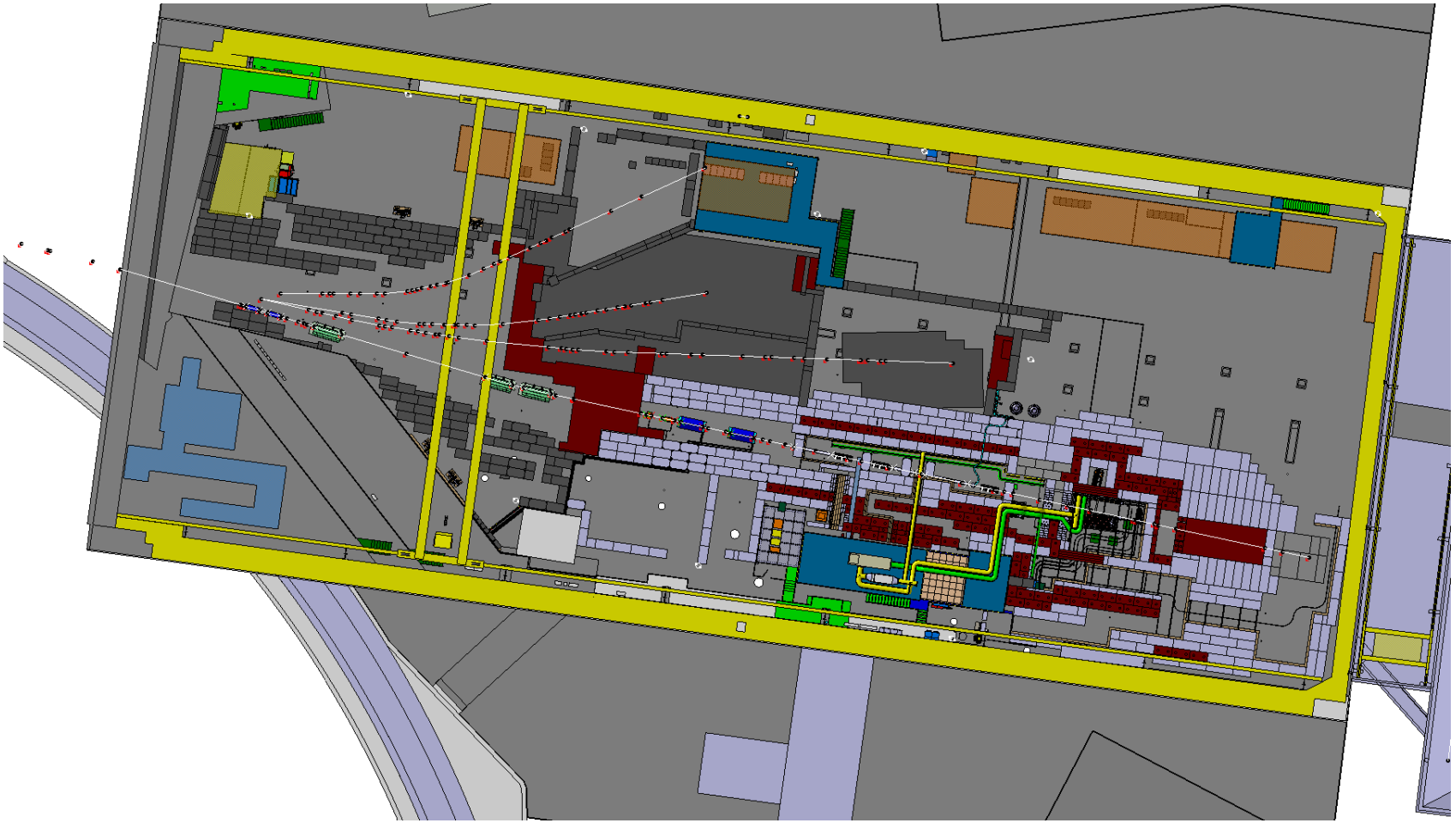
Location



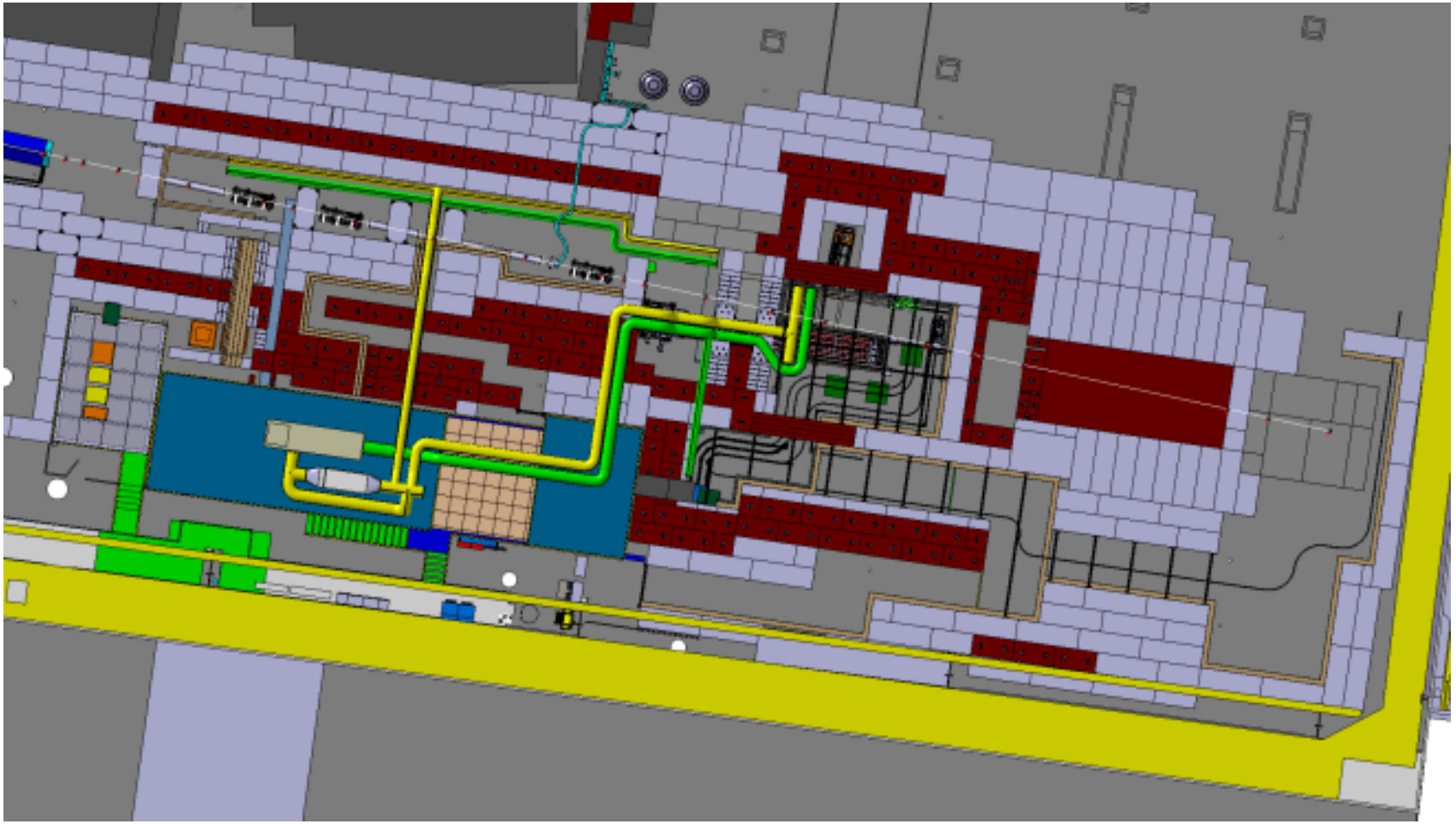
Parameters

- Proton beam from CERN–PS with 24 GeV/c on target
  - 5E11 protons/pulse
  - Pulse length 350 ms
  - 2.2E10 protons/s nominal average beam intensity
  - 6.7E10 protons/s maximum average beam intensity
  - 3.3E17 protons/y nominal annual protons on target
  - 1E18 protons/y maximum annual protons on target
- Three targets
  - Copper
  - Aluminum
  - Aluminum with longitudinal slits to reduce effective density
  - Diameter 8 cm, length 50 cm
- Four movable shielding walls (20 cm) to allow adjustment of radiation fields
  - Two concrete walls
  - Two cast-iron walls

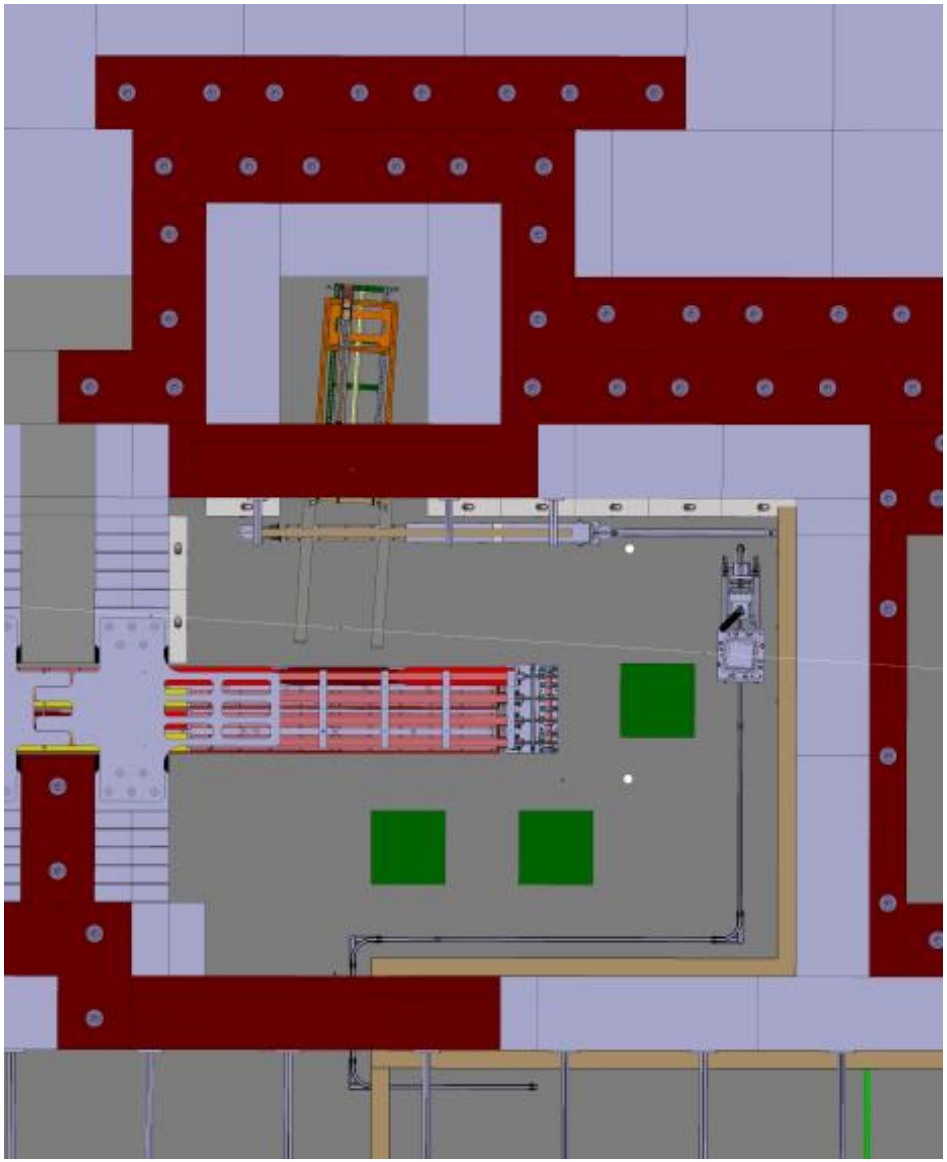
Integration – East Experimental Hall



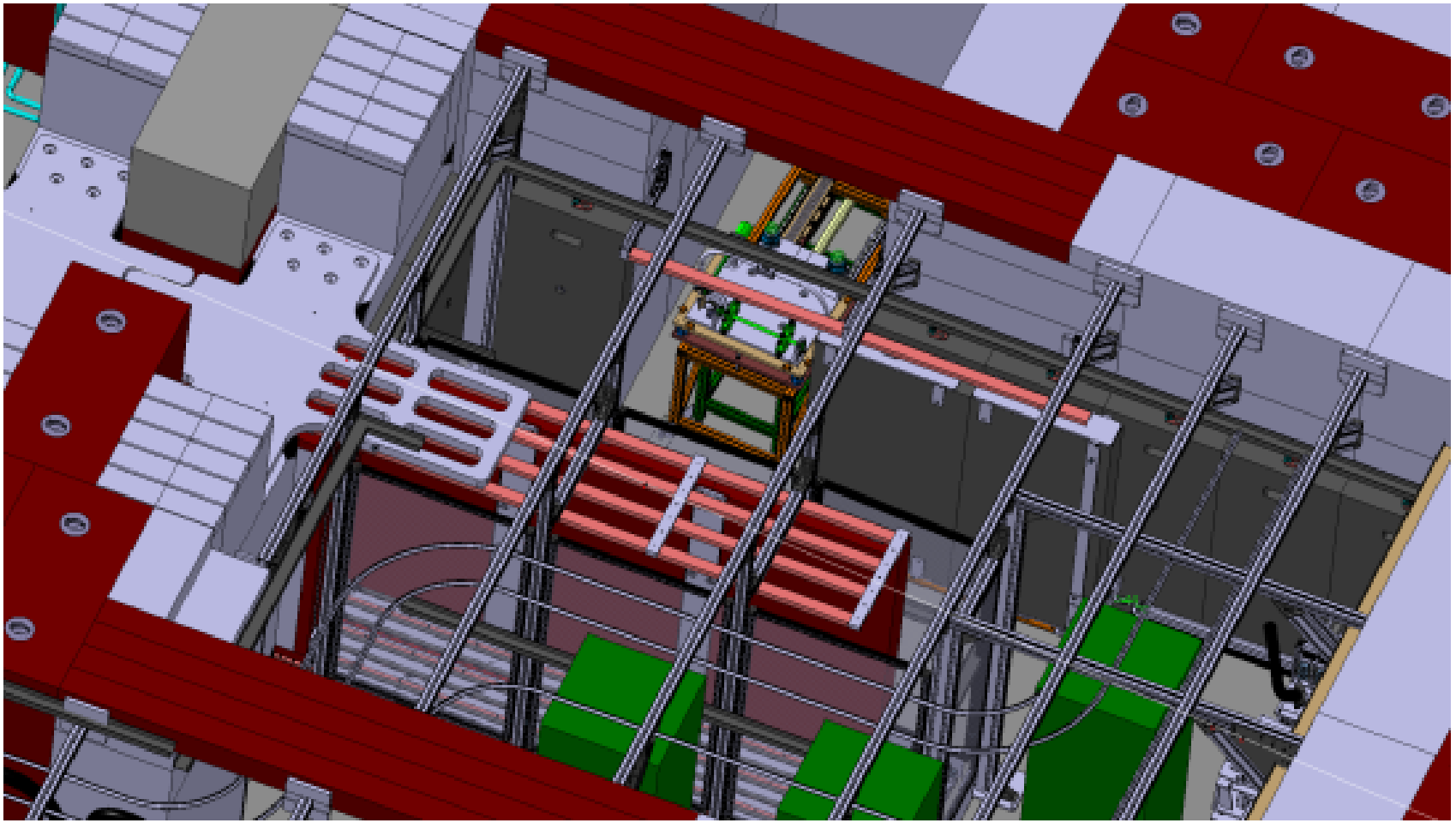
Integration – CHARM



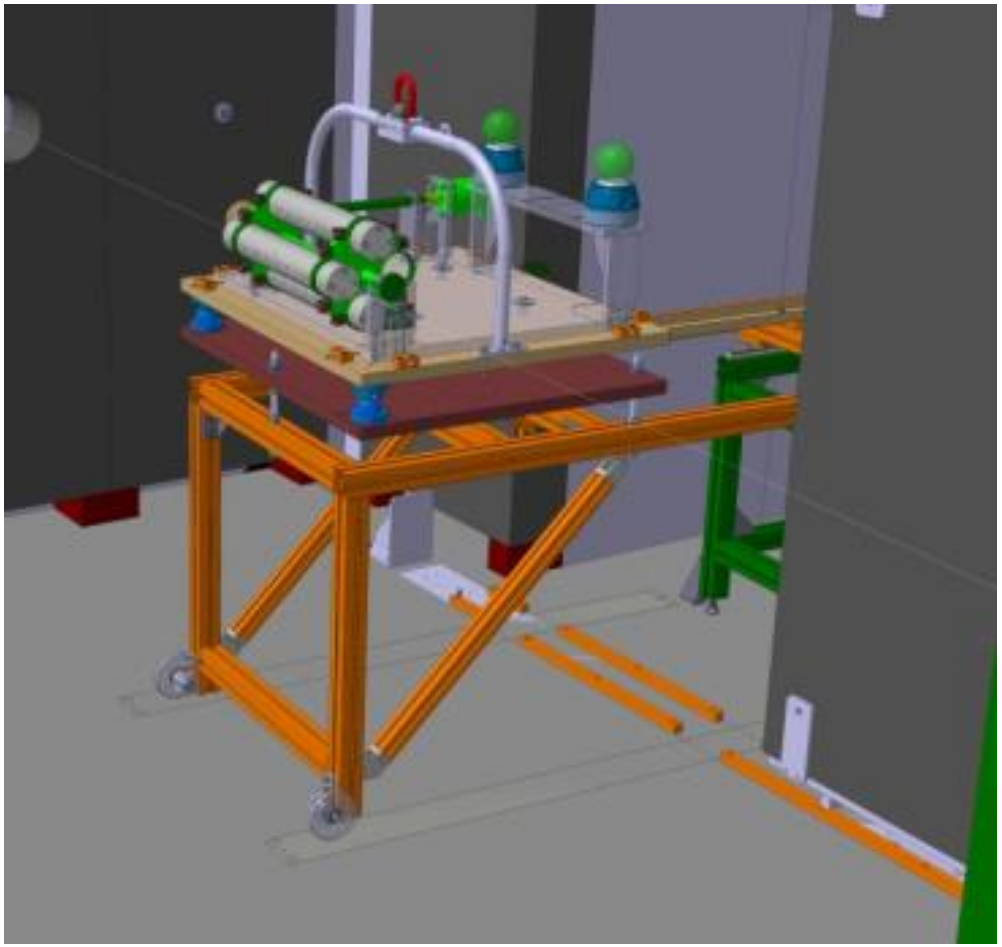
Integration – CHARM Target Zone

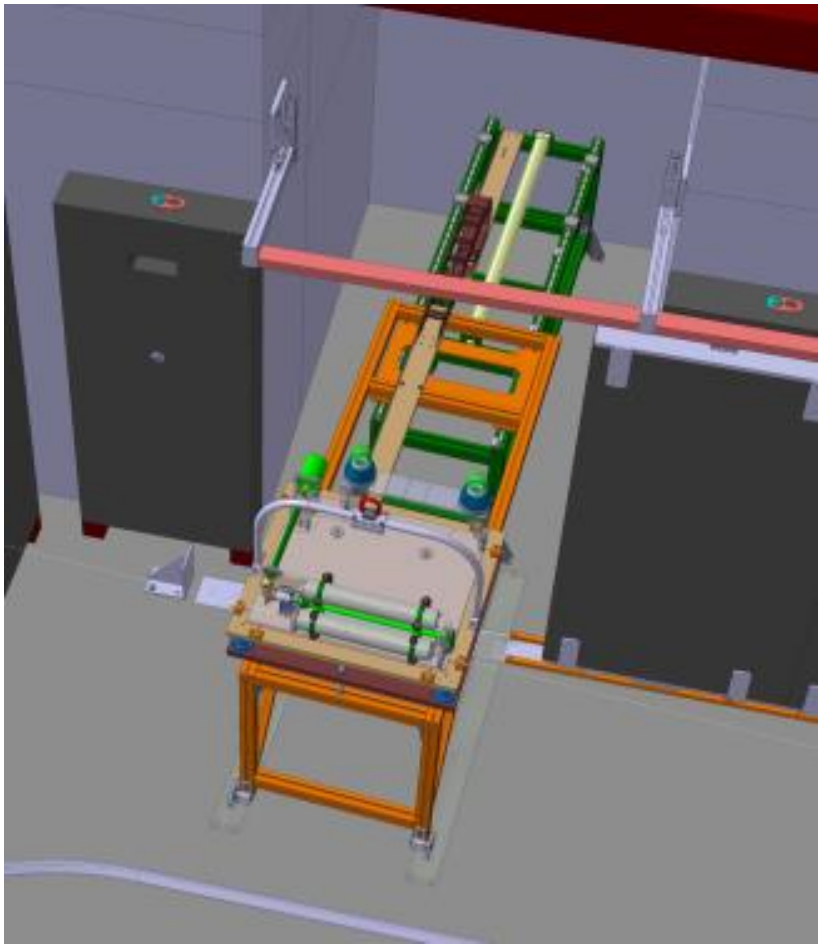


Integration – CHARM Target Zone

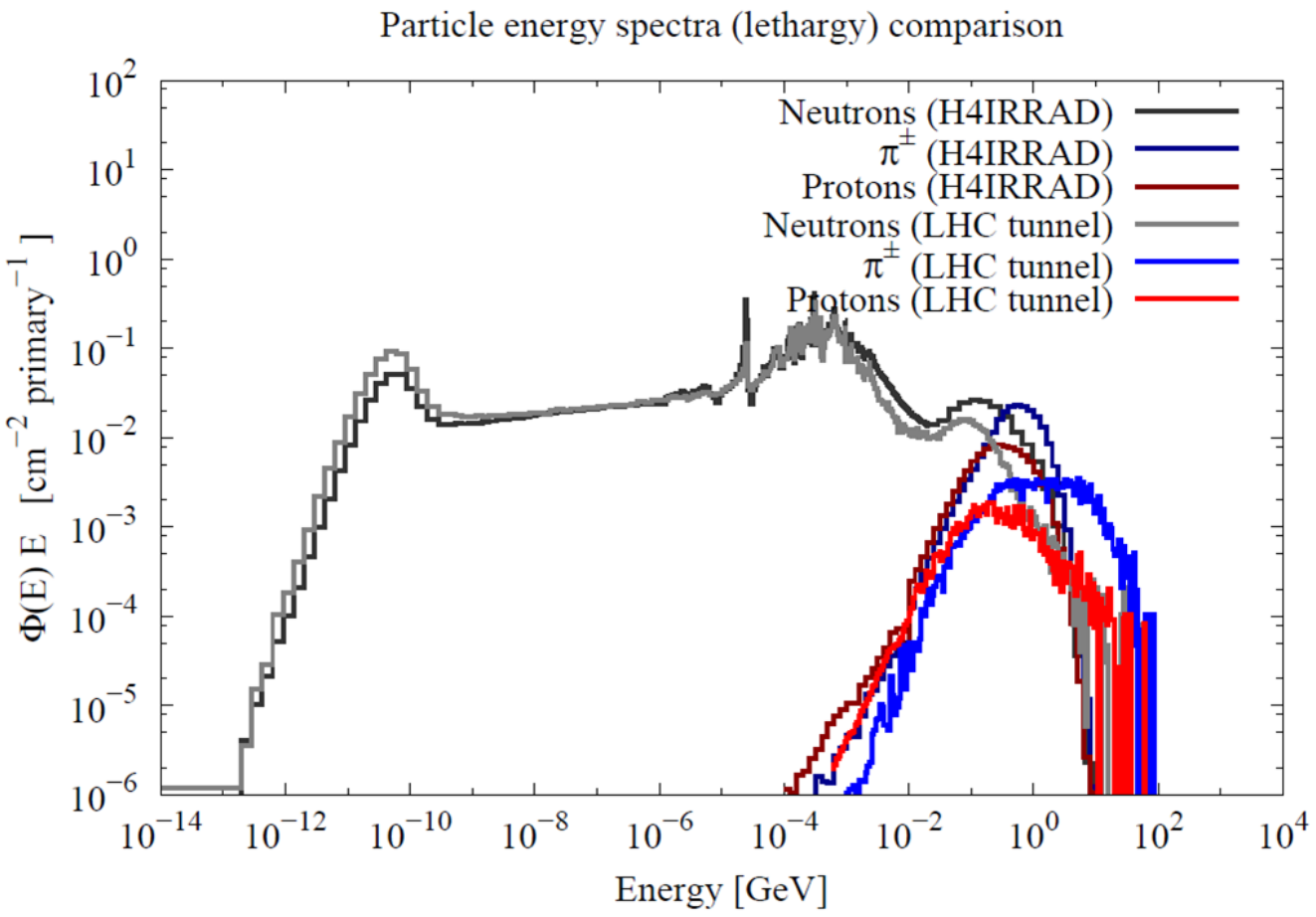


Integration – CHARM Target Alcove

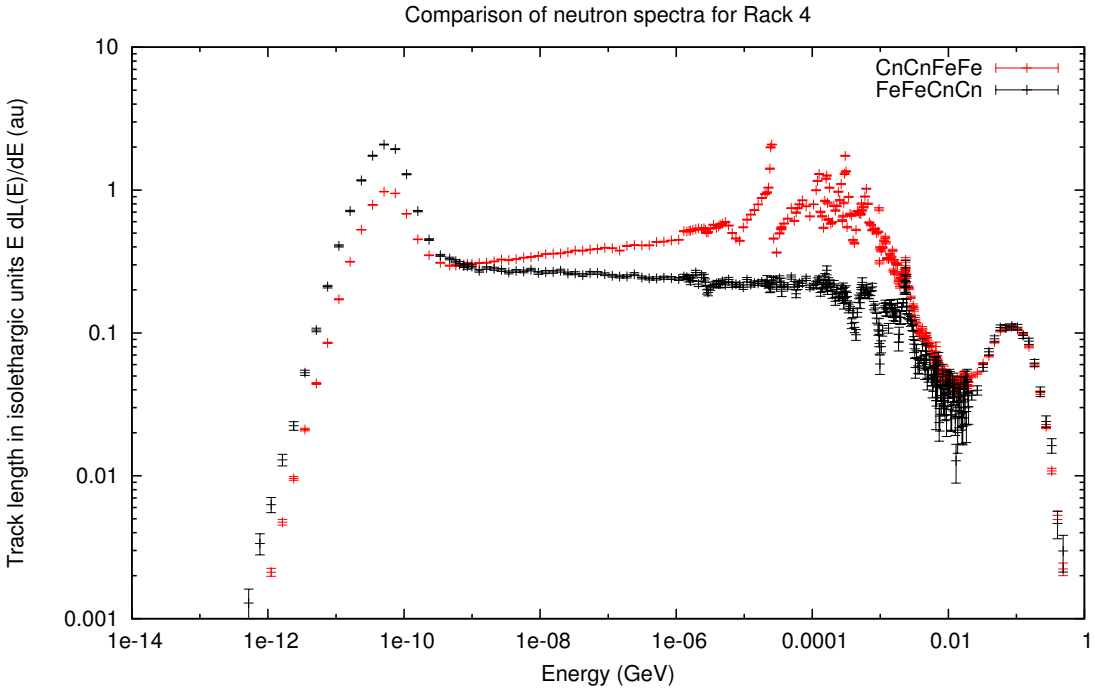


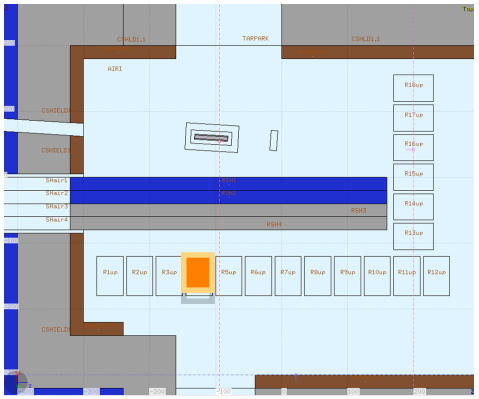


Radiation Fields

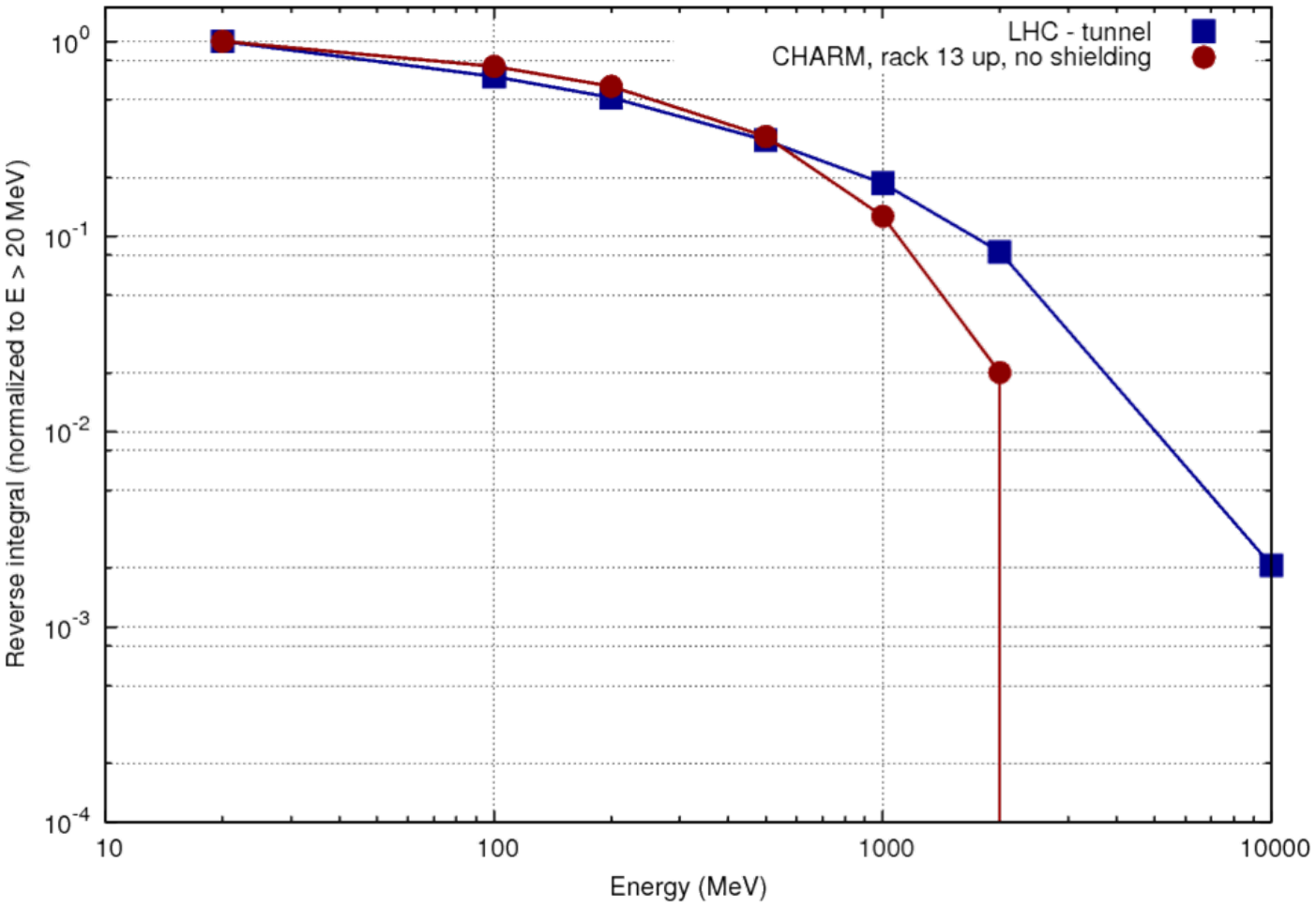


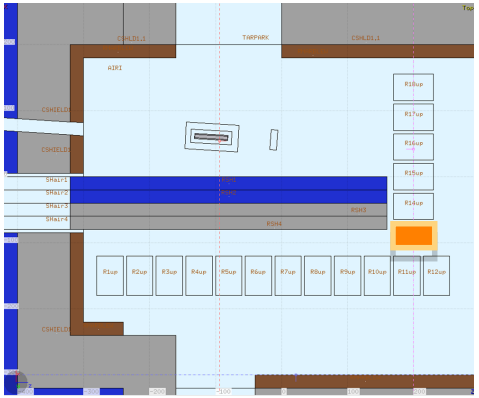
Radiation Fields



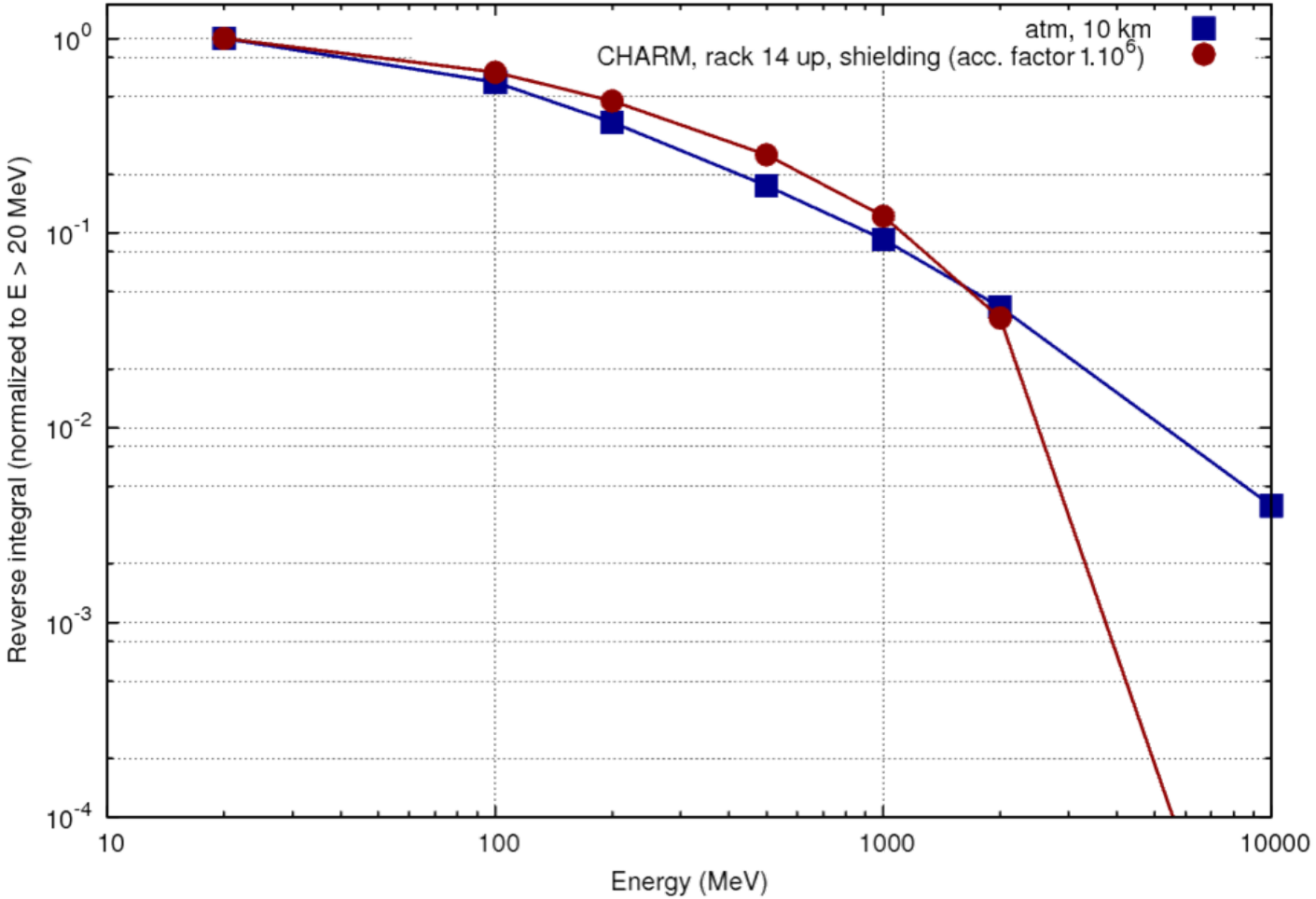


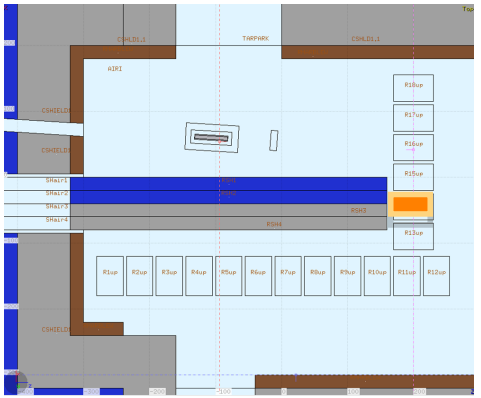
Radiation Fields





Radiation Fields

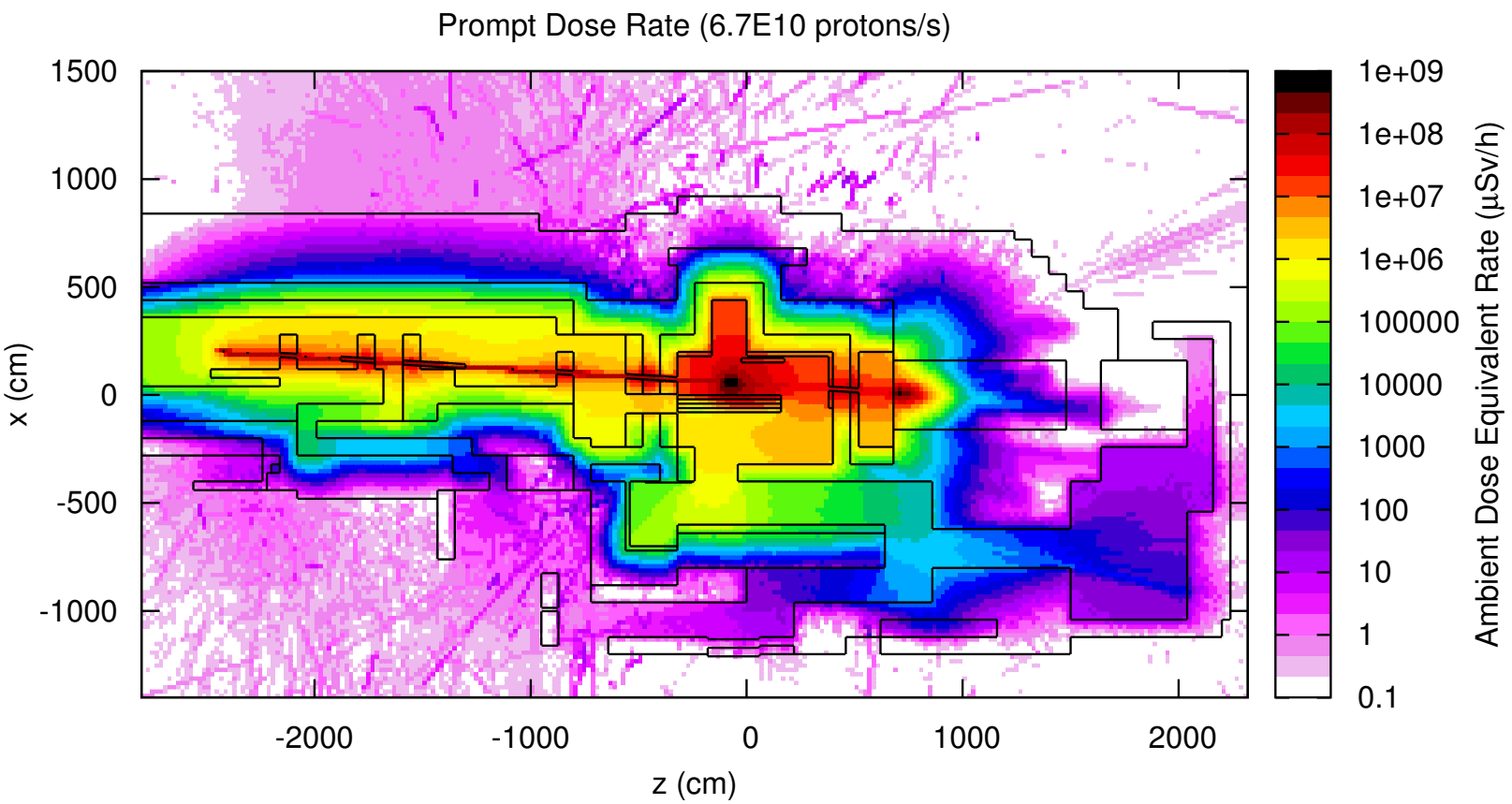




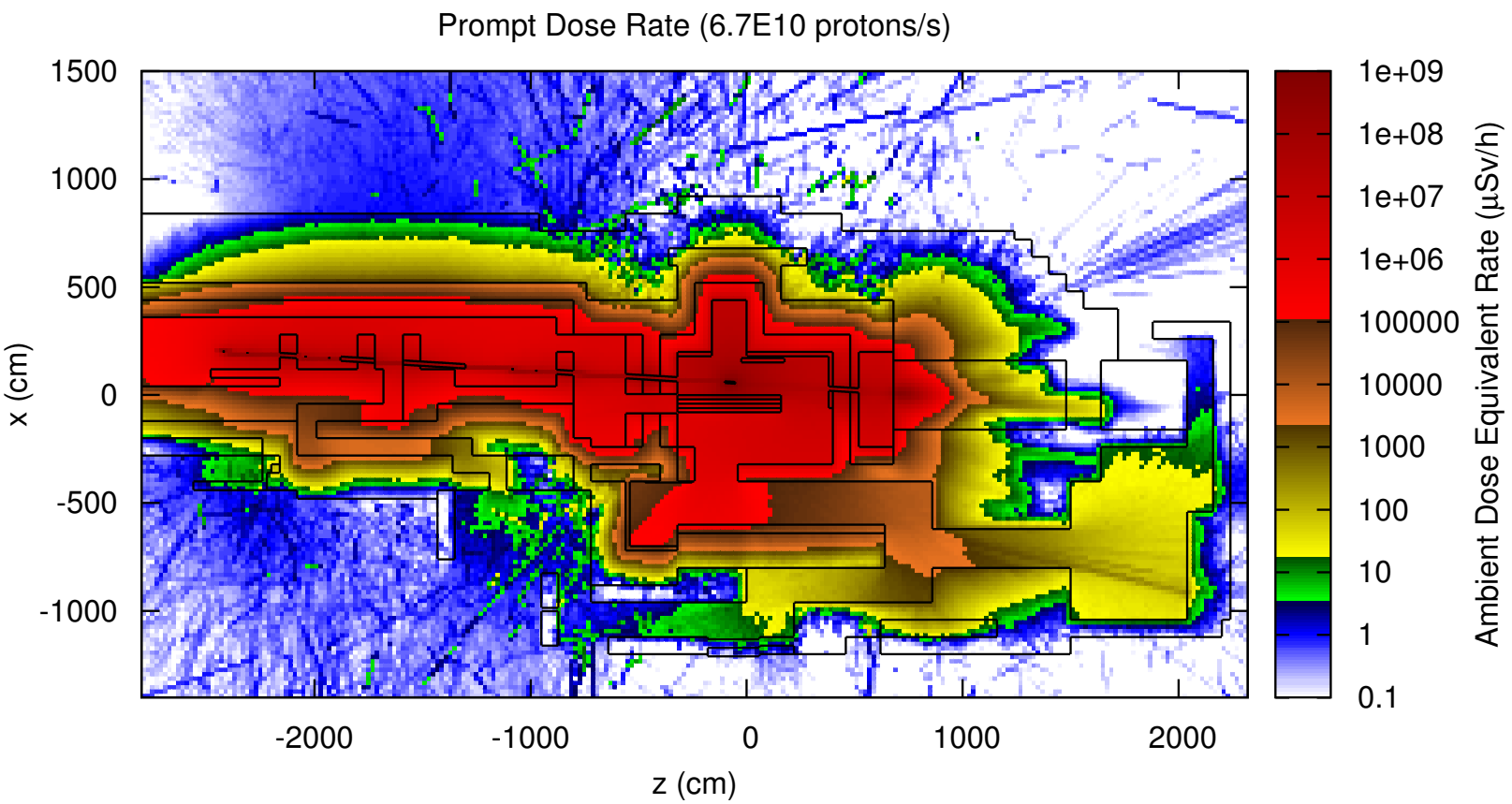
Prompt Radiation – Design Goals

- **Area Classification:**
  - 3 μSv/h (control rooms) or 15 μSv/h (low occupancy area) at 40 cm outside from shielding walls for maximum average beam intensity
  - 2.5 μSv/h outside of the hall for maximum average beam intensity
  - Optimization of shielding passages (Access chicanes, ventilation ducts, cable ducts)
- **Sky-shine:** 1 μSv/y to members of the public (reference group) for nominal/maximum annual protons on target
- **Monitoring:** Define locations for area monitors
- **Shielding design:**
  - Re–use of existing concrete and iron blocks
  - Space constraints due to already existing facilities/crane
  - 2000 tons of iron, 4000 tons of concrete
- **Monte Carlo simulations:** performed with **FLUKA**

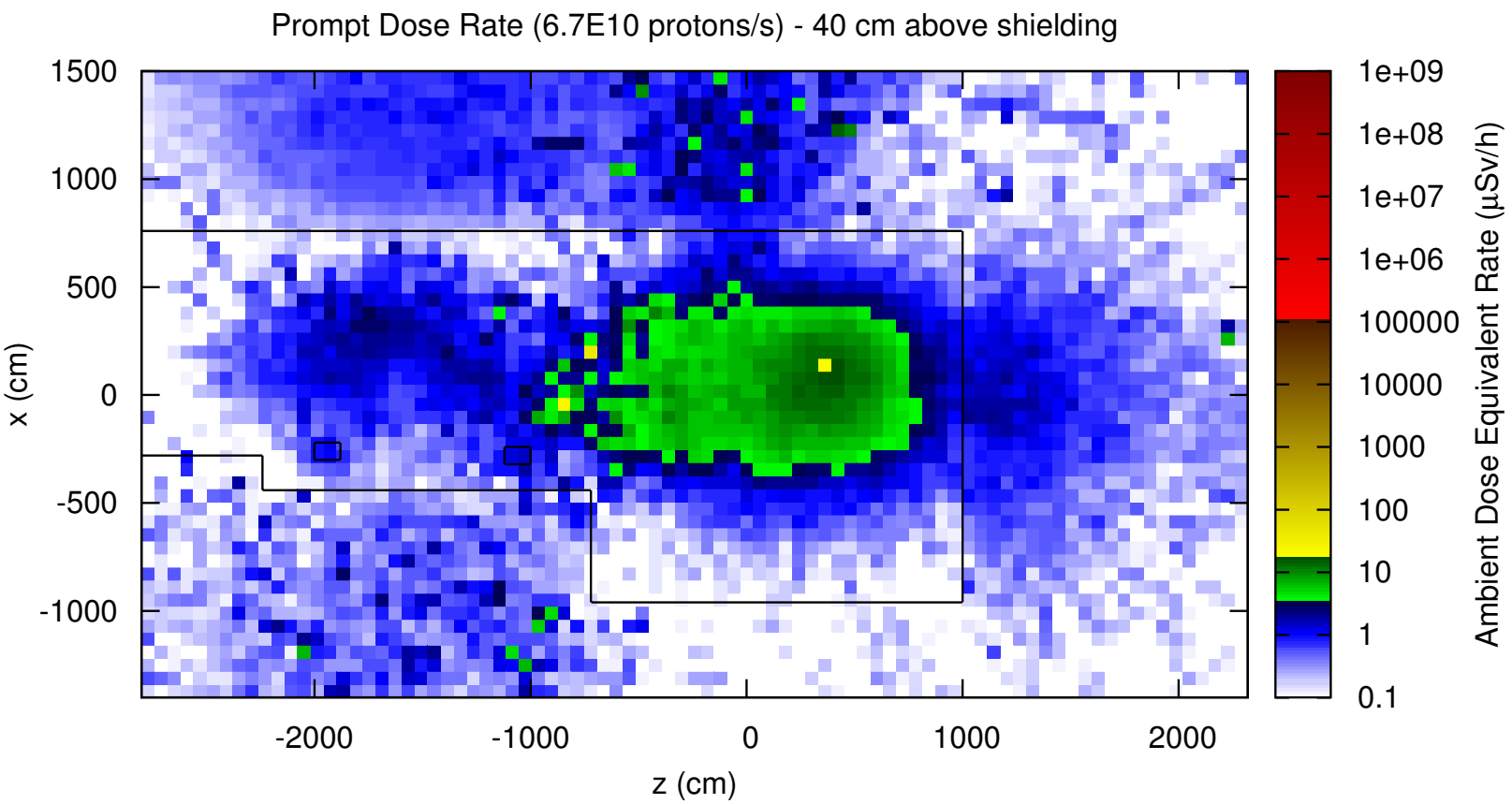
Prompt Radiation – Beam Line Level



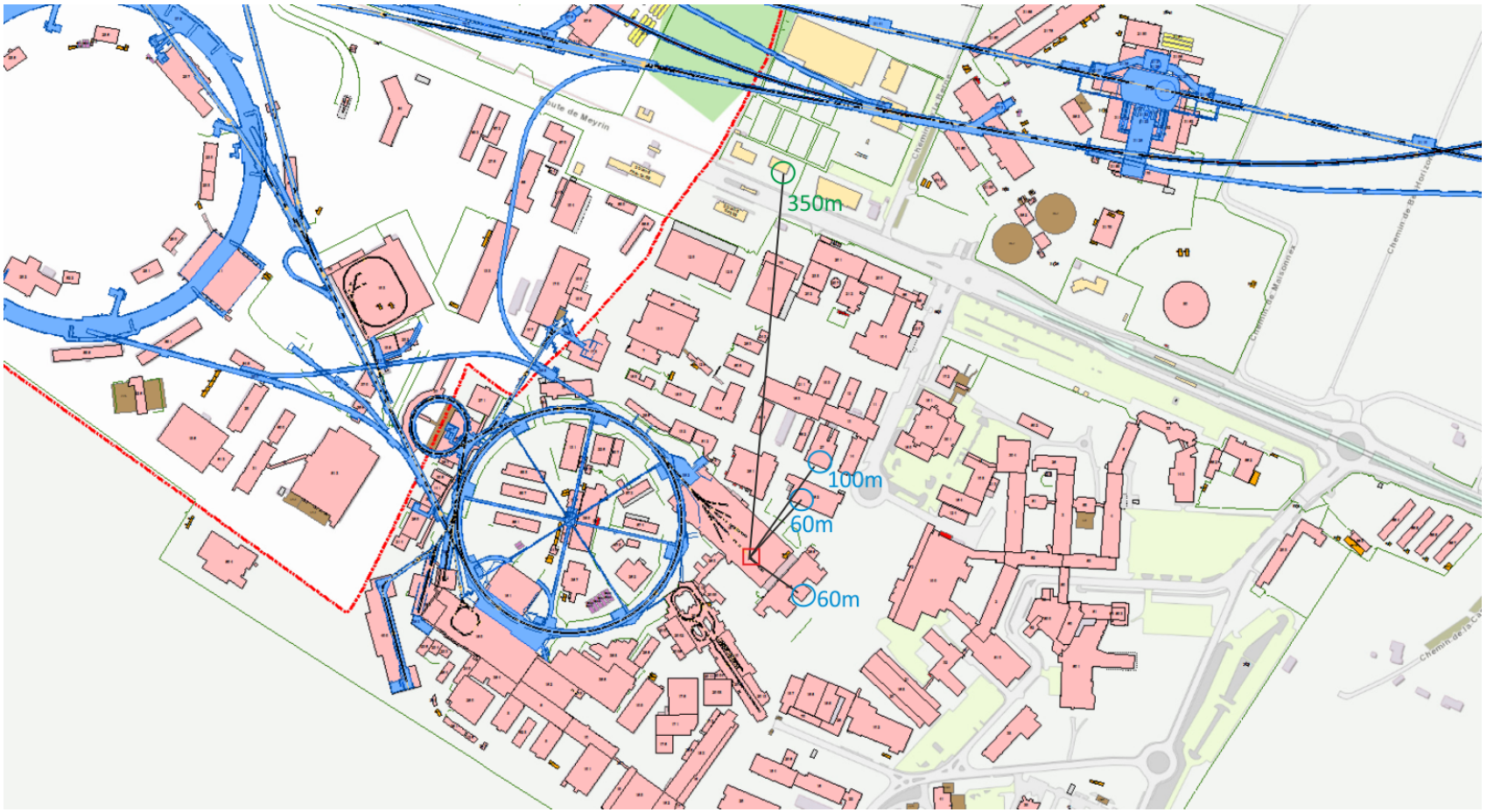
Prompt Radiation – Beam Line Level (Area Classification)



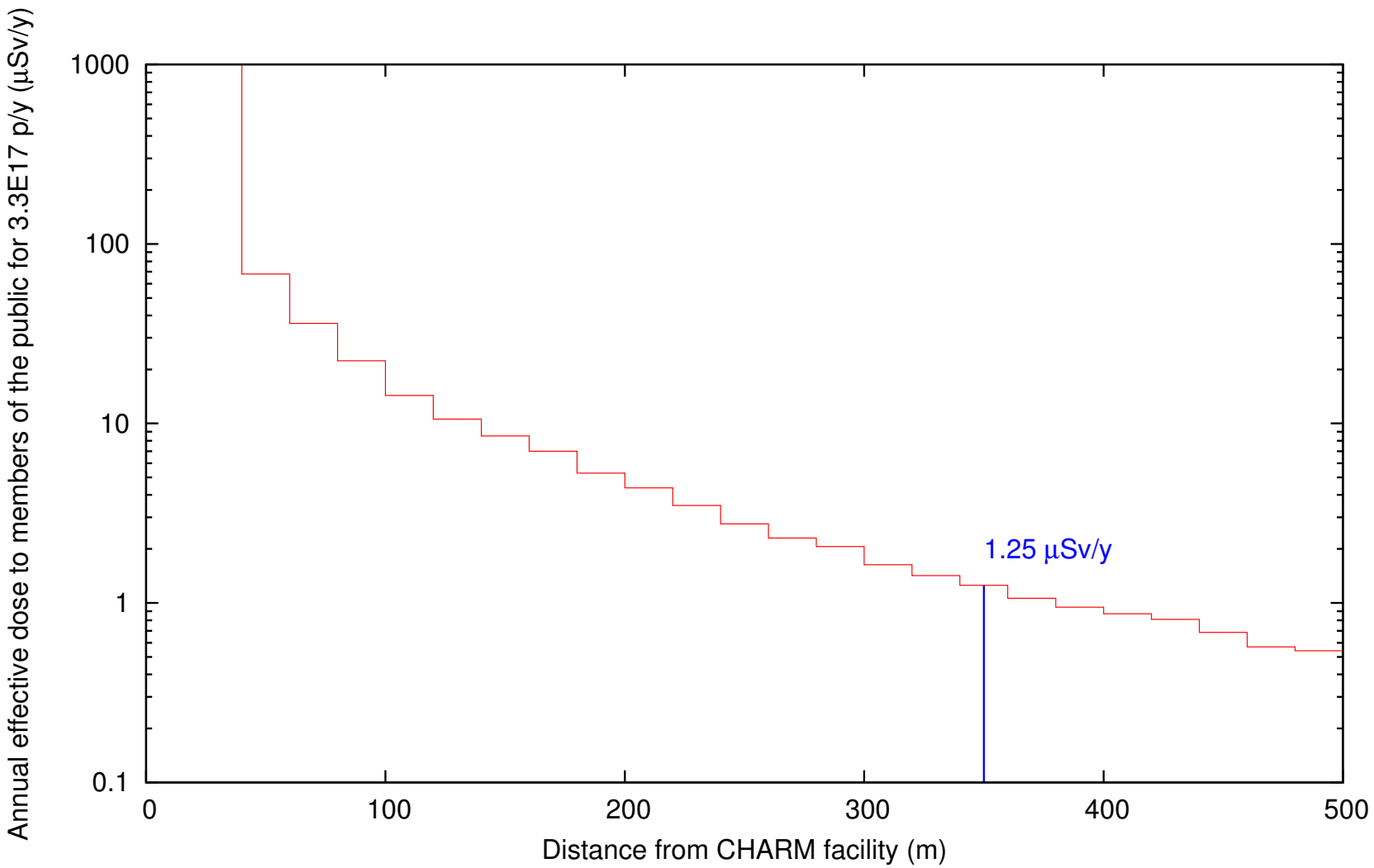
40 cm above top shielding – 720cm above target



Sky-shine



Sky-shine – Annual effective dose to members of the public



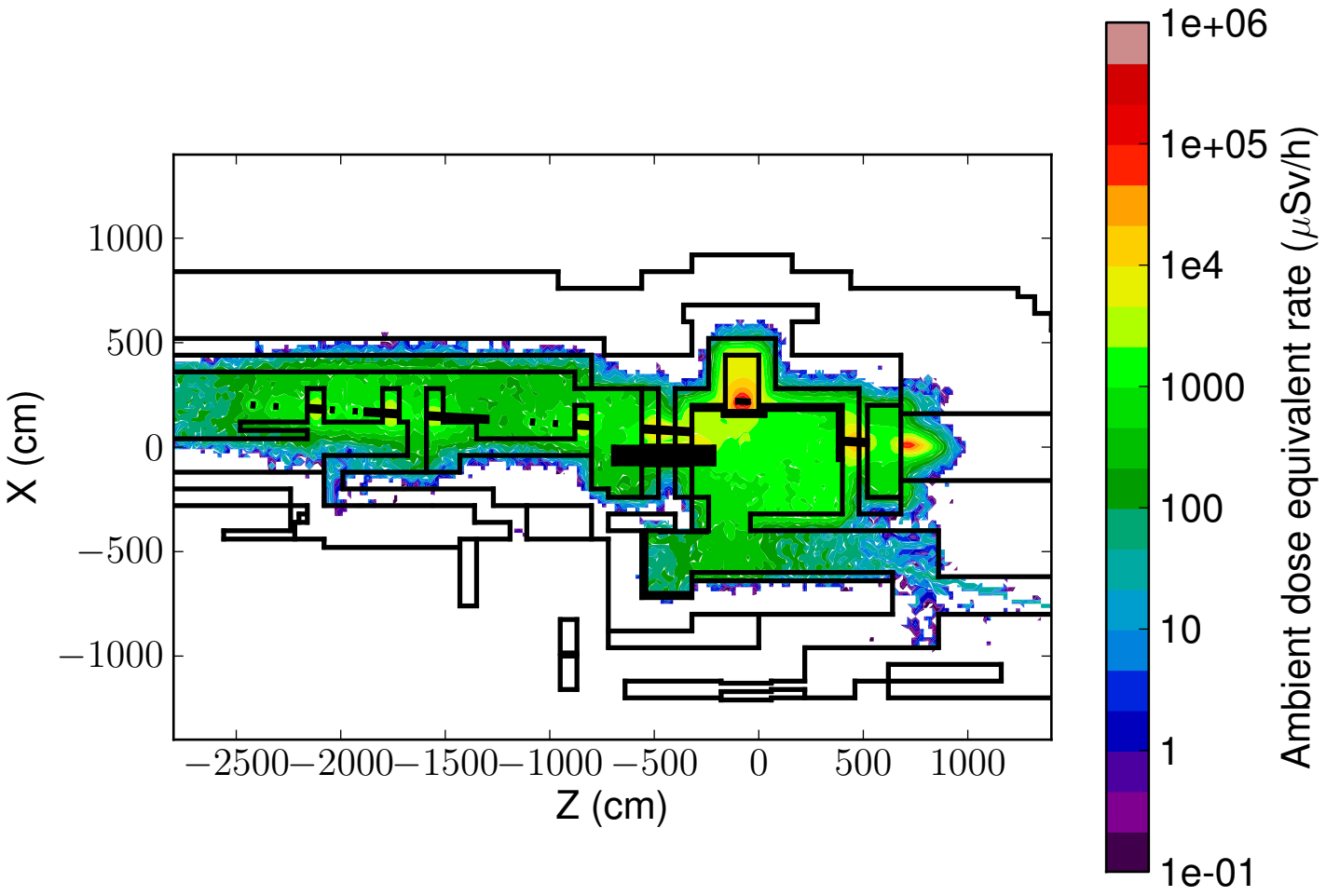
Residual Radiation – Design Goals

- Reduce ambient residual radiation
  - Optimization
  - More efficient exploitation of facility
- Marble cover for some wall parts and ceiling
- Target alcove
  - Target moved to alcove during access
  - Movable marble shielding to close alcove
- Studies for different shielding configurations to optimize procedures
- 100 μSv/h for the Patch Panel area (most frequent access)
- **Monte Carlo simulations:** performed with **FLUKA** and **DORIAN** code

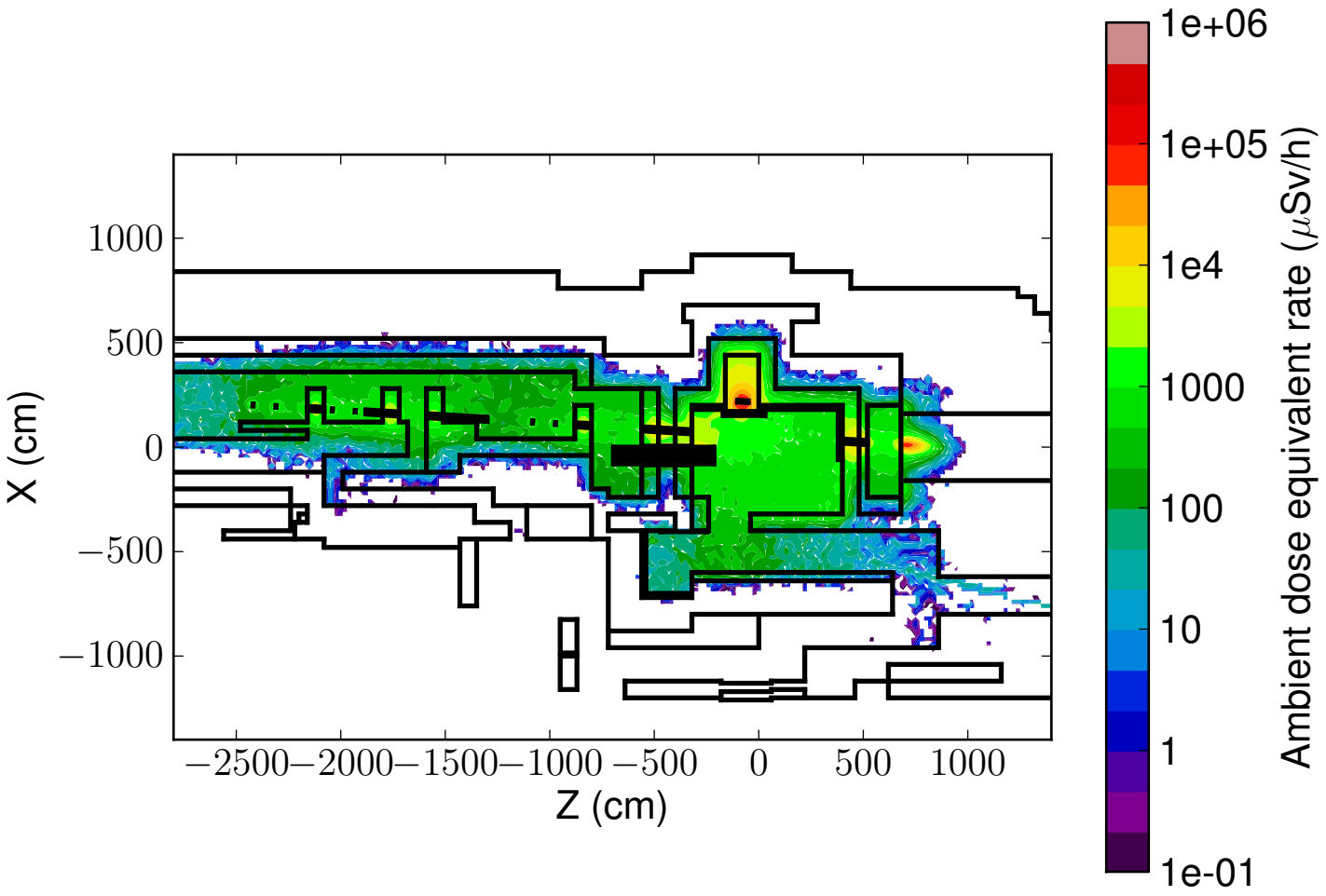
Residual Radiation

- Sequence of movable shielding walls still to be decided in the next weeks
- Experience for shielding configuration management with the **DORIAN** code gained
- Plots shown
  - for **FeCoFeCo** shielding walls sequence
  - walls inside zone during irradiation, retracted after beam stop
  - target moved into alcove
  - alcove marble shielding closed

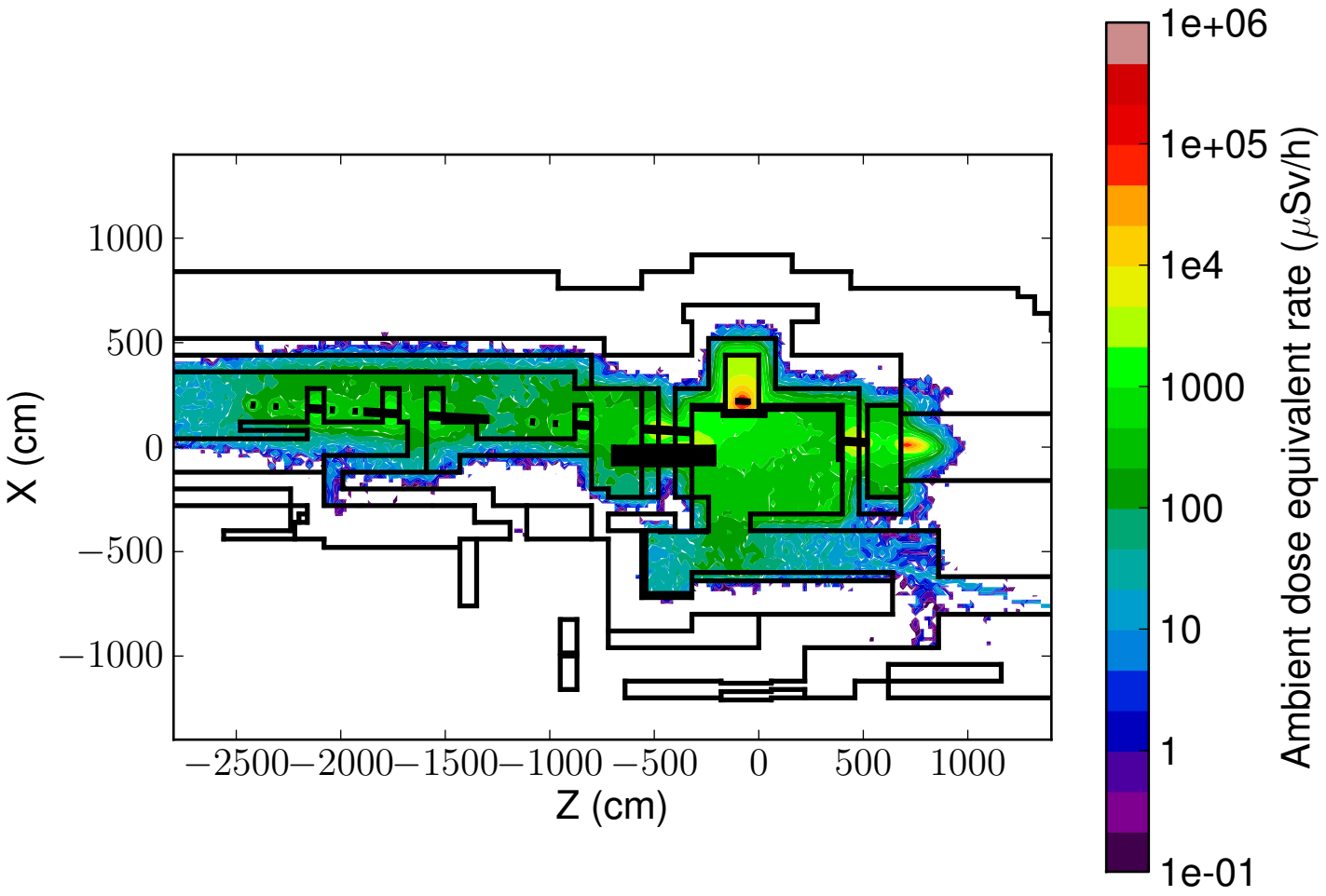
Residual DR after 200 days with 6.6E10 p/s and 1h of cool–down



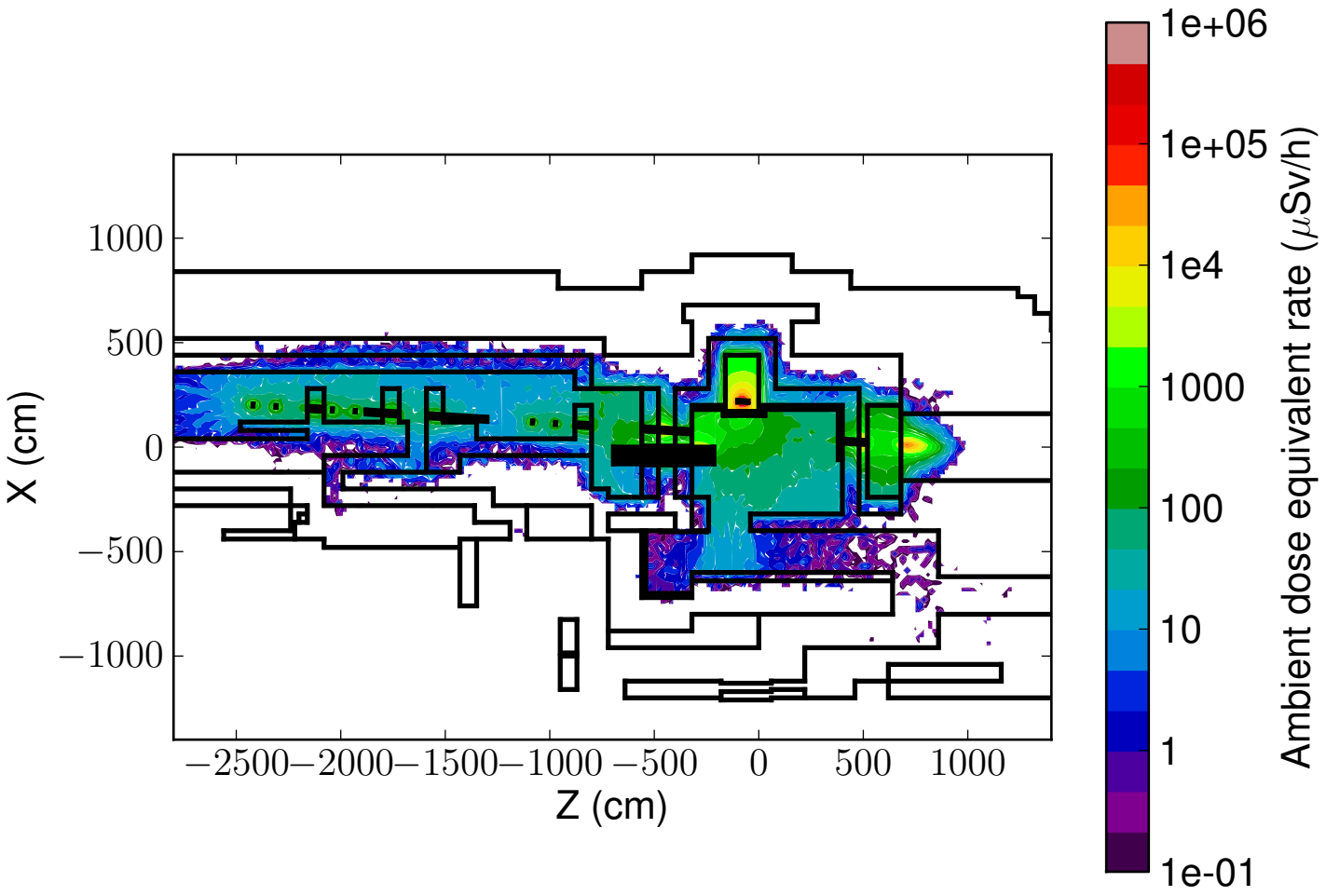
Residual DR after 200 days with 6.6E10 p/s and 8h of cool–down



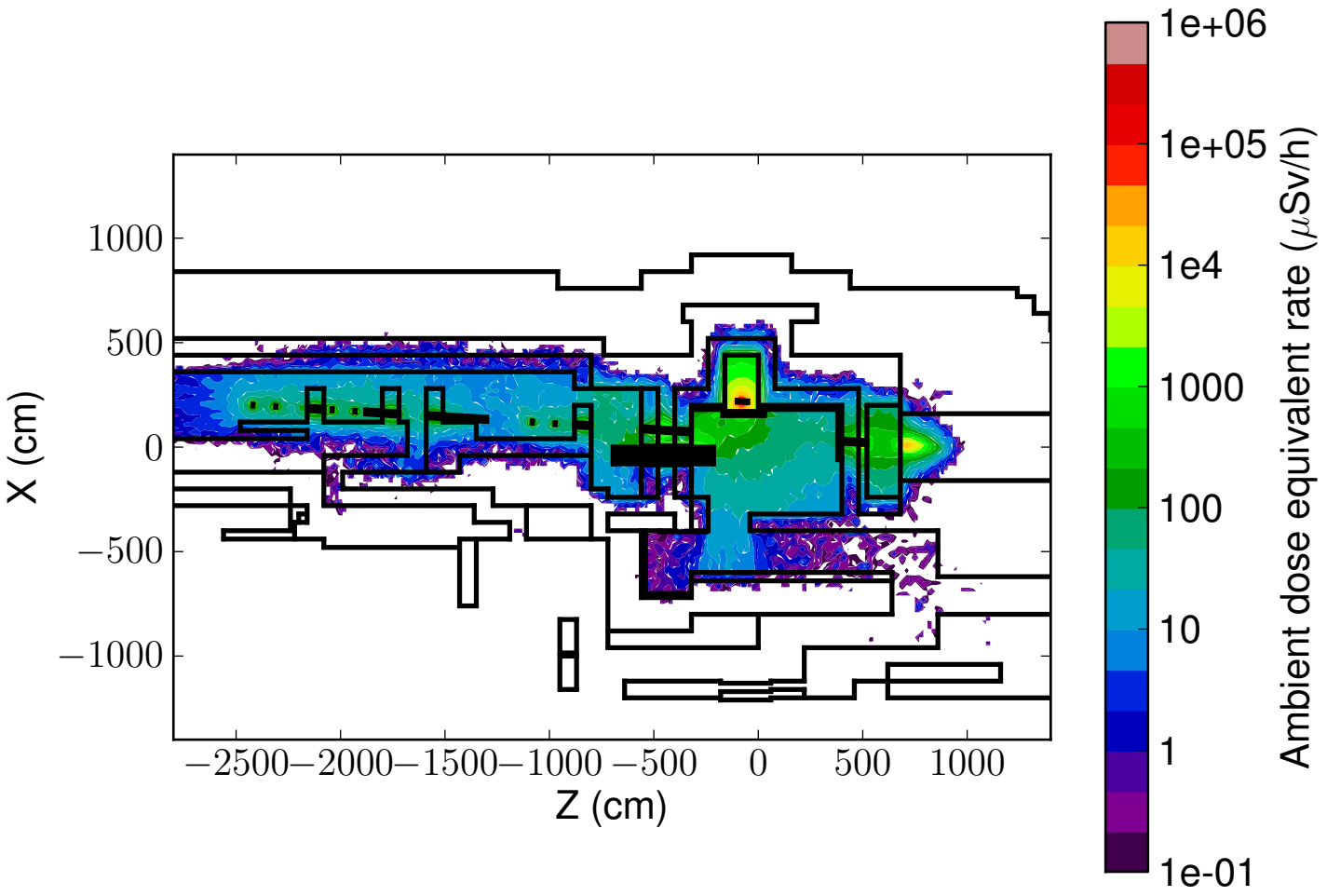
Residual DR after 200 days with 6.6E10 p/s and 1d of cool–down



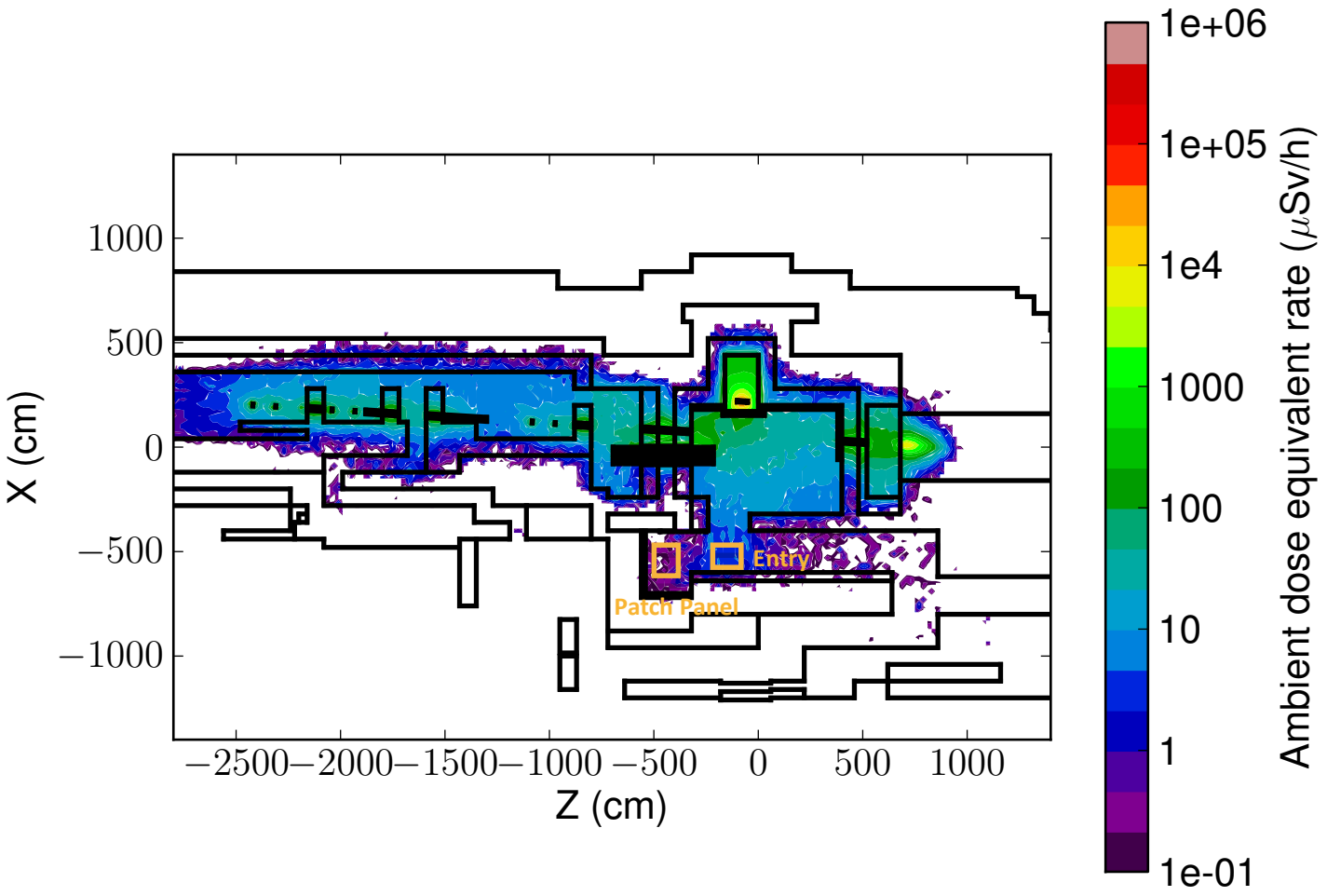
Residual DR after 200 days with 6.6E10 p/s and 7d of cool–down



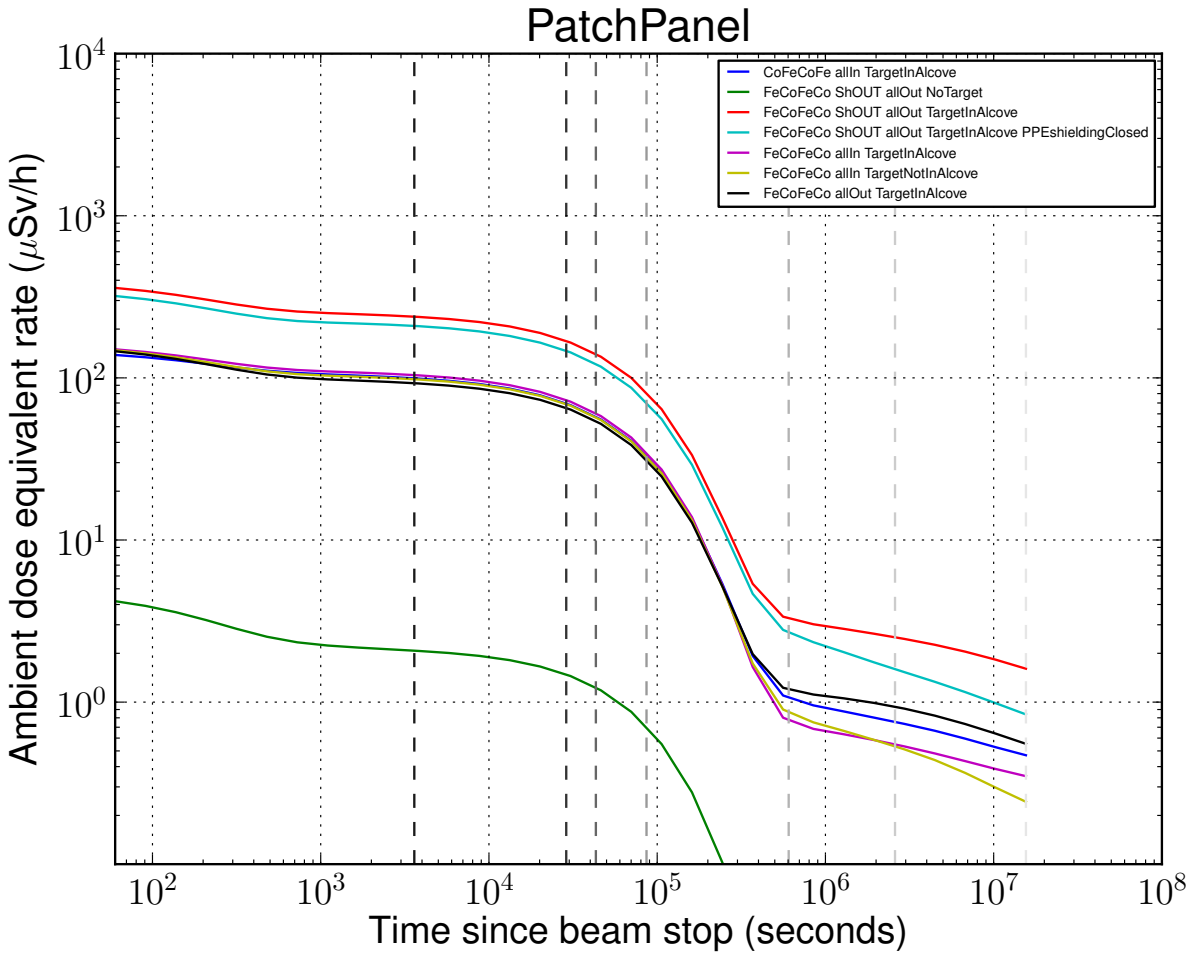
Residual DR after 200 days with 6.6E10 p/s and 30d of cool–down



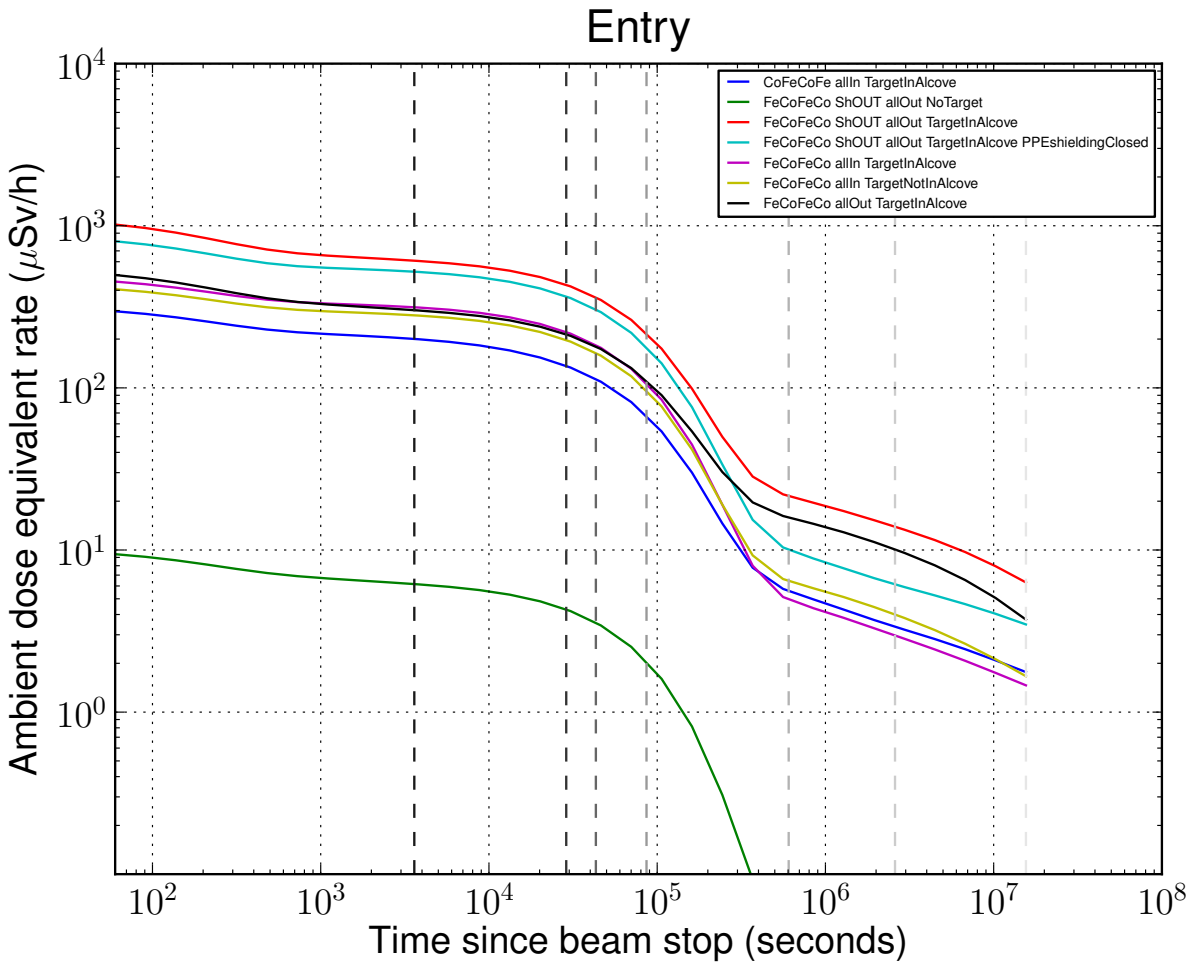
Residual DR after 200 days with 6.6E10 p/s and 180d of cool–down



Residual DR after 200 days with 6.6E10 p/s in the patch panel area



Residual DR after 200 days with 6.6E10 p/s in the entry area



Air Activation – Methodology

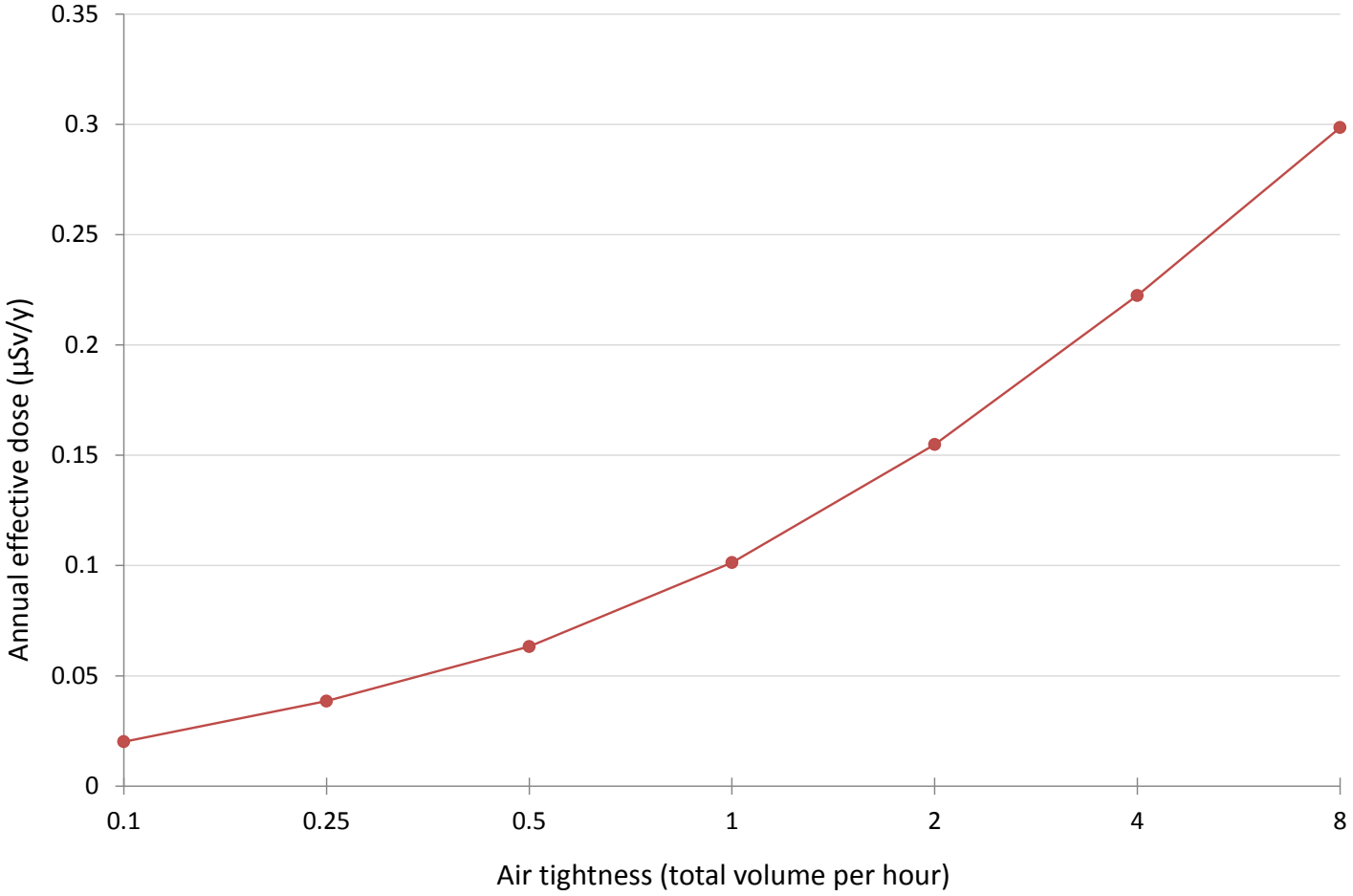
- Design goals
  1. Committed effective dose due to inhalation:
     $\leq 1\,\mu$Sv for 1 hour access
  2. Effective dose to members of the public (reference group):
     $\leq 1\,\mu$Sv/y
- Radionuclide concentrations and release
  - Track-length spectra scored in air volumes
  - Radionuclide production yields by weighting of spectra with dedicated air activation cross–sections
  - Dynamic confinement (controlled continuous release) to obtain release term
  - External effective dose to members of the public by dedicated Monte Carlo integration program (**EDARA**)

Air Activation

Confinement type	Committed effective dose due to inhalation without flush for 1 hour access μSv	Release to environment TBq/y	Effective dose to members of public μSv/y
Static	60	-	-
Dynamic (1 volume/h)	1.9	2.4	0.10

- **Goal 1:** Dynamic confinement and flush before access
- **Goal 2:** Derived requirement on air tightness

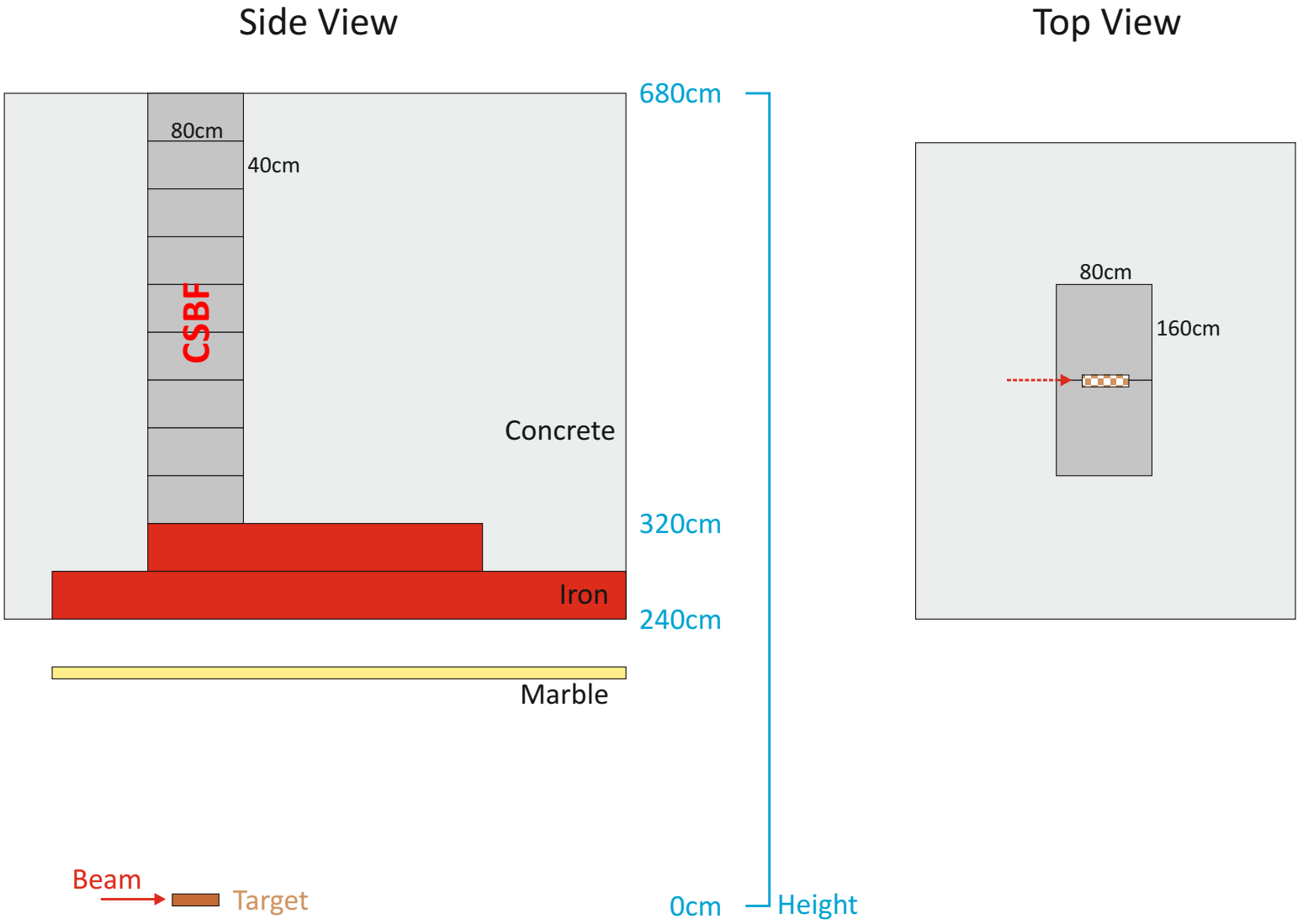
Derived Requirement on Air Tightness



CERN Shielding Benchmark Facility – Motivation

- Lateral spectra after deep shielding penetration
  - 80 cm of iron shielding downstream of CSBF
  - 360 cm of shielding material in CSBF itself
  - Spectra can be adjusted by the modifying shielding material in CSBF
  - FLUKA simulations for detailed characterization to be performed
- Characterization of shielding material
- Detector calibration
- Detector inter-comparison
- Parasitic use of beam on CHARM target
- Minimize operational impact on CHARM facility

CERN Shielding Benchmark Facility – Sketch



CERN Shielding Benchmark Facility - Integration

- Two independent stacks
  - Centered above the CHARM target
  - Four meter downstream
- Each stack
  - Available depth 360 cm, 160 cm$\times$80 cm area
  - 5 layers: 4$\times$80 cm + 1$\times$40 cm
  - Each layer is composed of 2 pieces, 80 cm$\times$80 cm area
  - Cable feed-throughs
- Integration and Commissioning plans on-going
  - PhD student planned

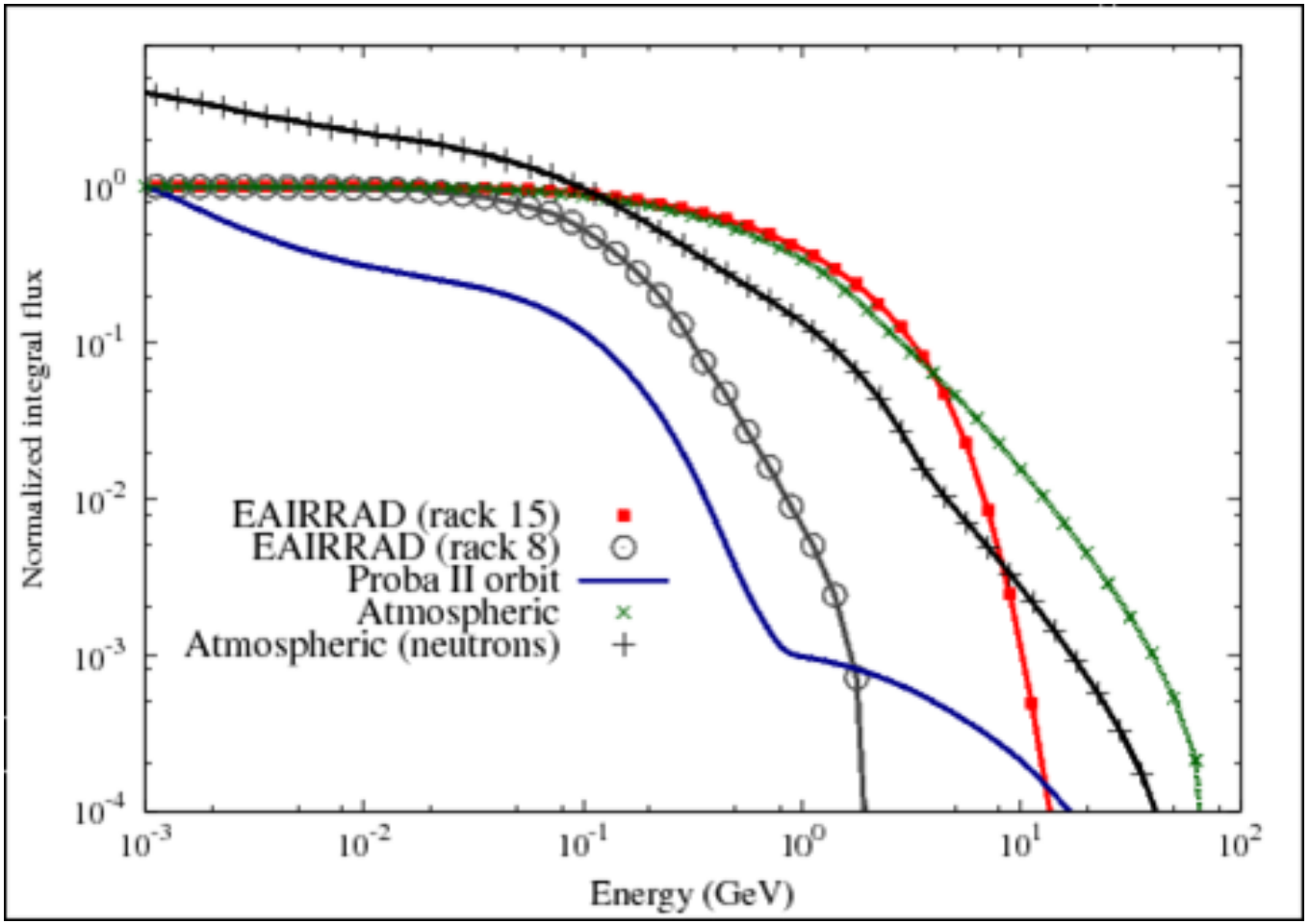
Conclusions

- CHARM Facility for
  - testing complex electronic systems in
  - representative radiation environments
- Radiation Protection assessment approach
- CSBF for deep lateral shielding penetration studies
- CHARM will start to receive beam mid-July 2014

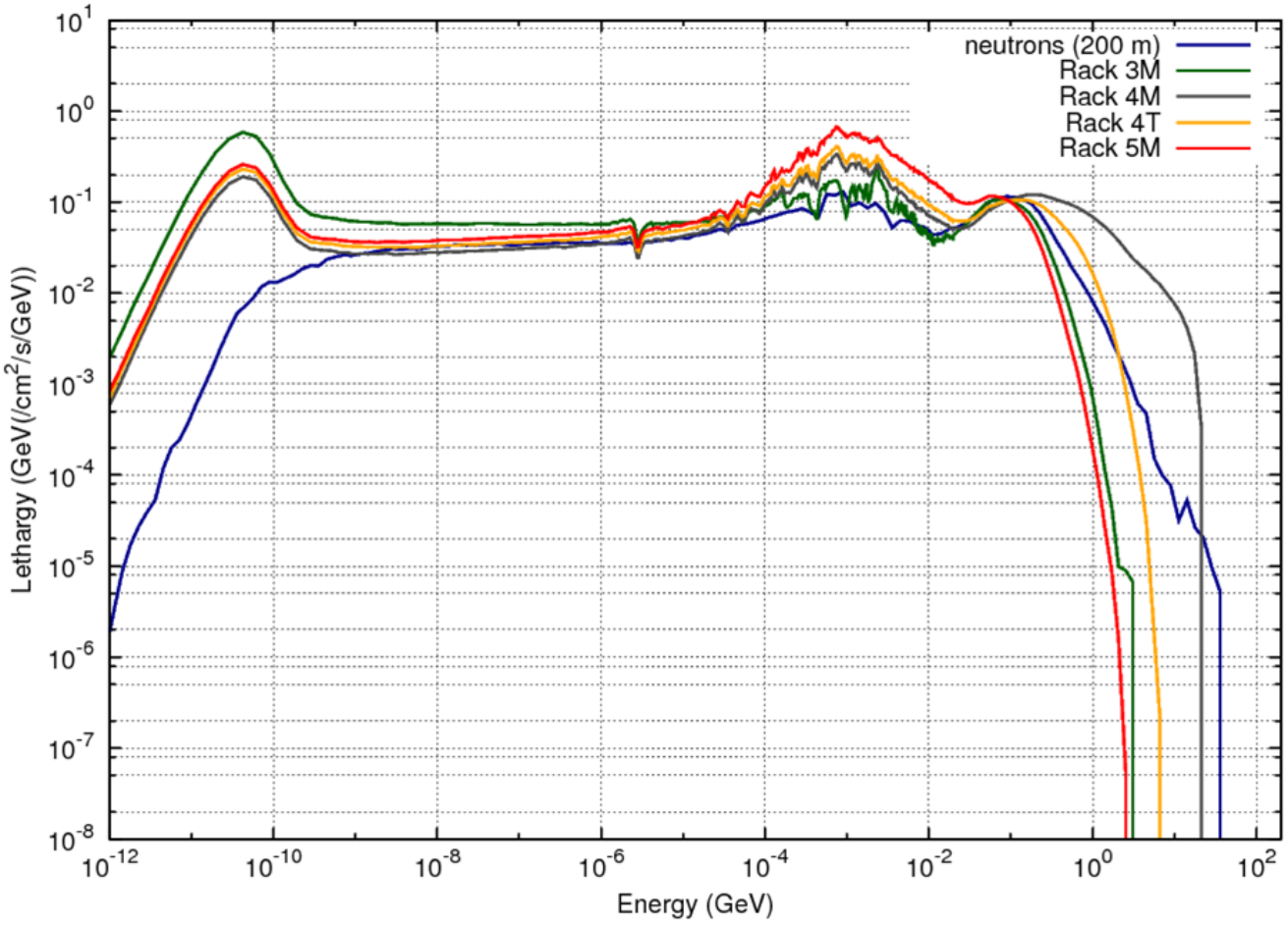
Backup

Backup

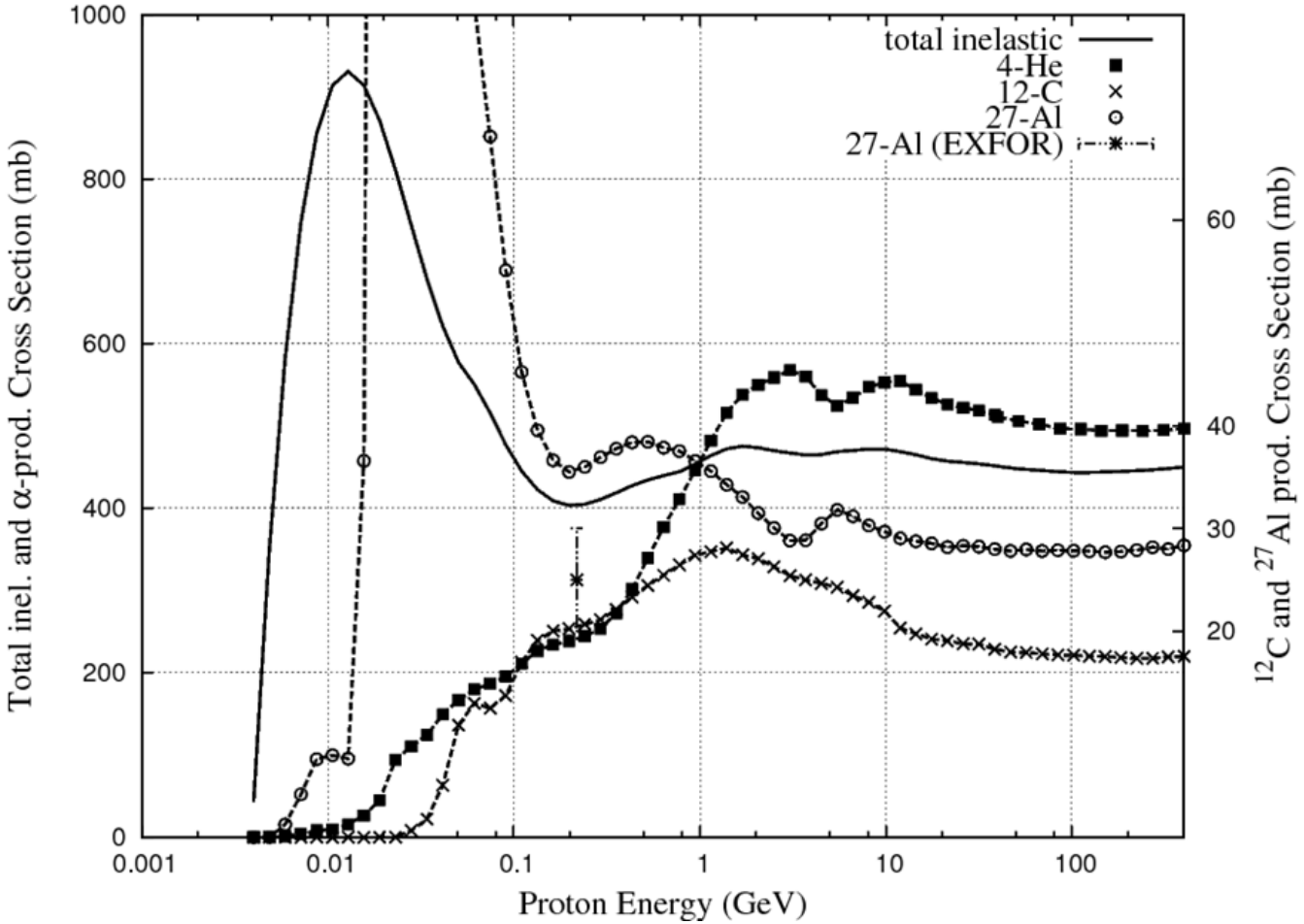
Radiation Fields



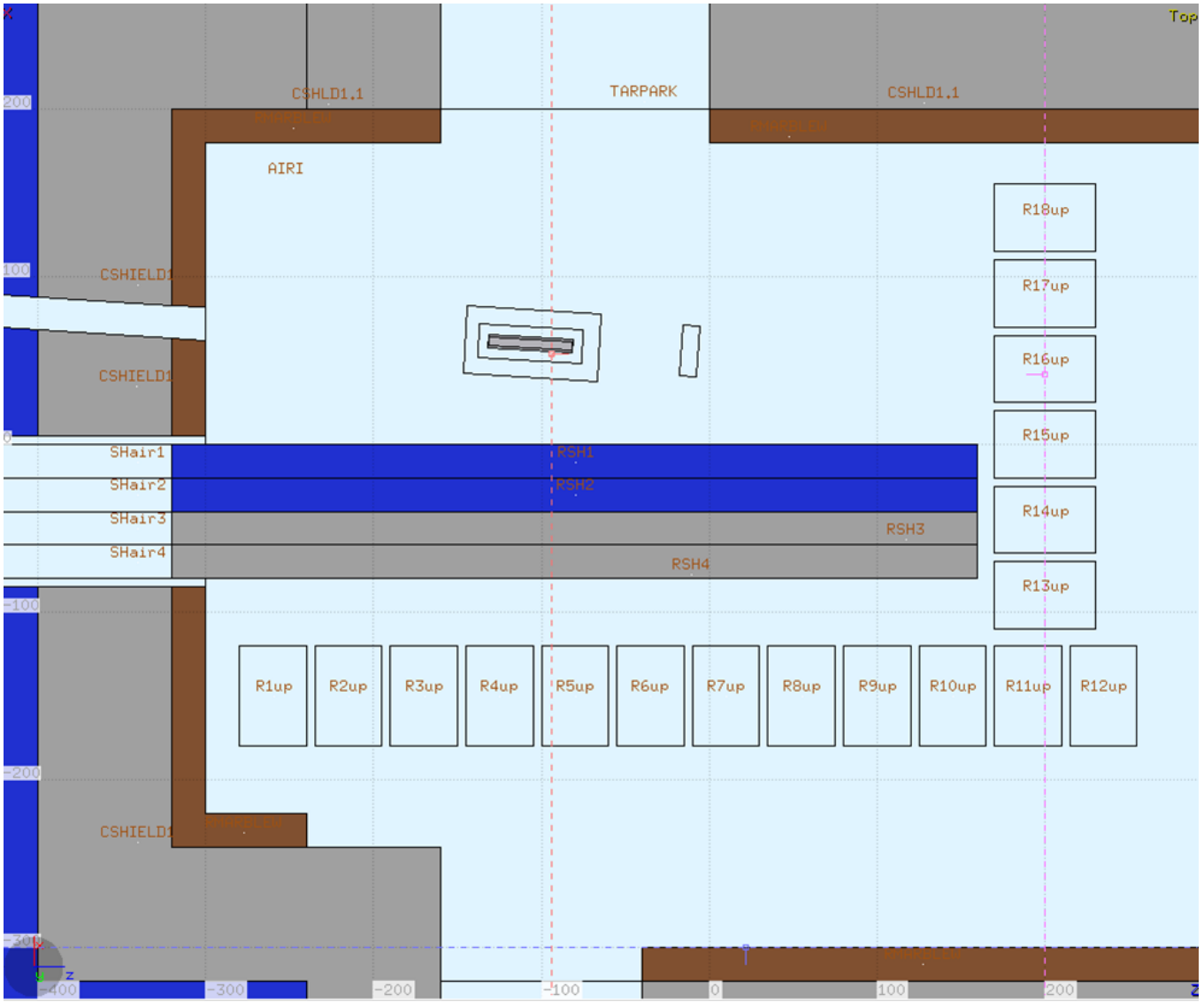
Radiation Fields



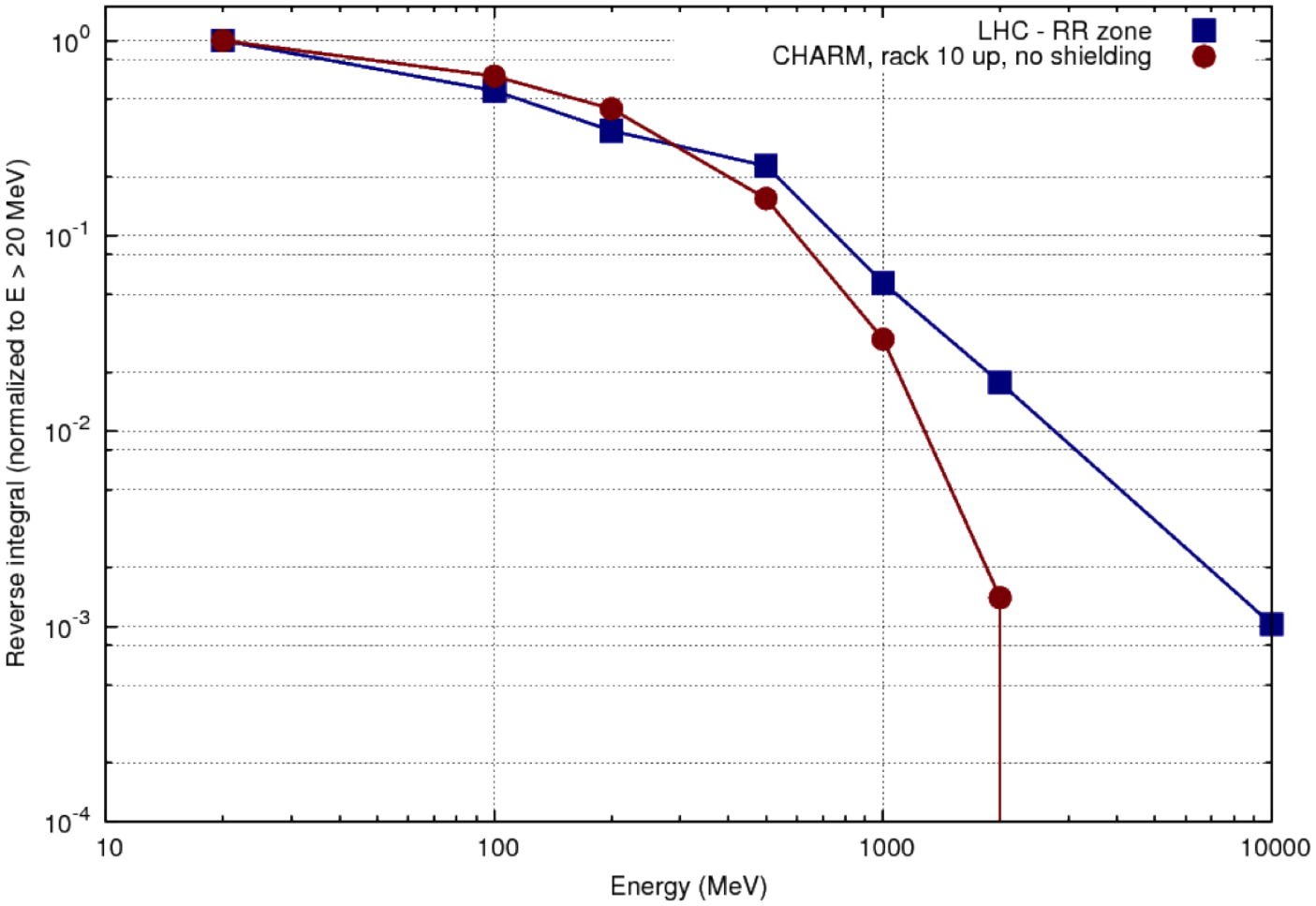
Cross-Sections for Al

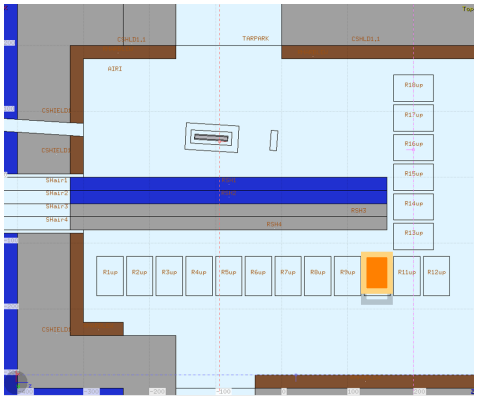


Test Locations



Radiation Fields





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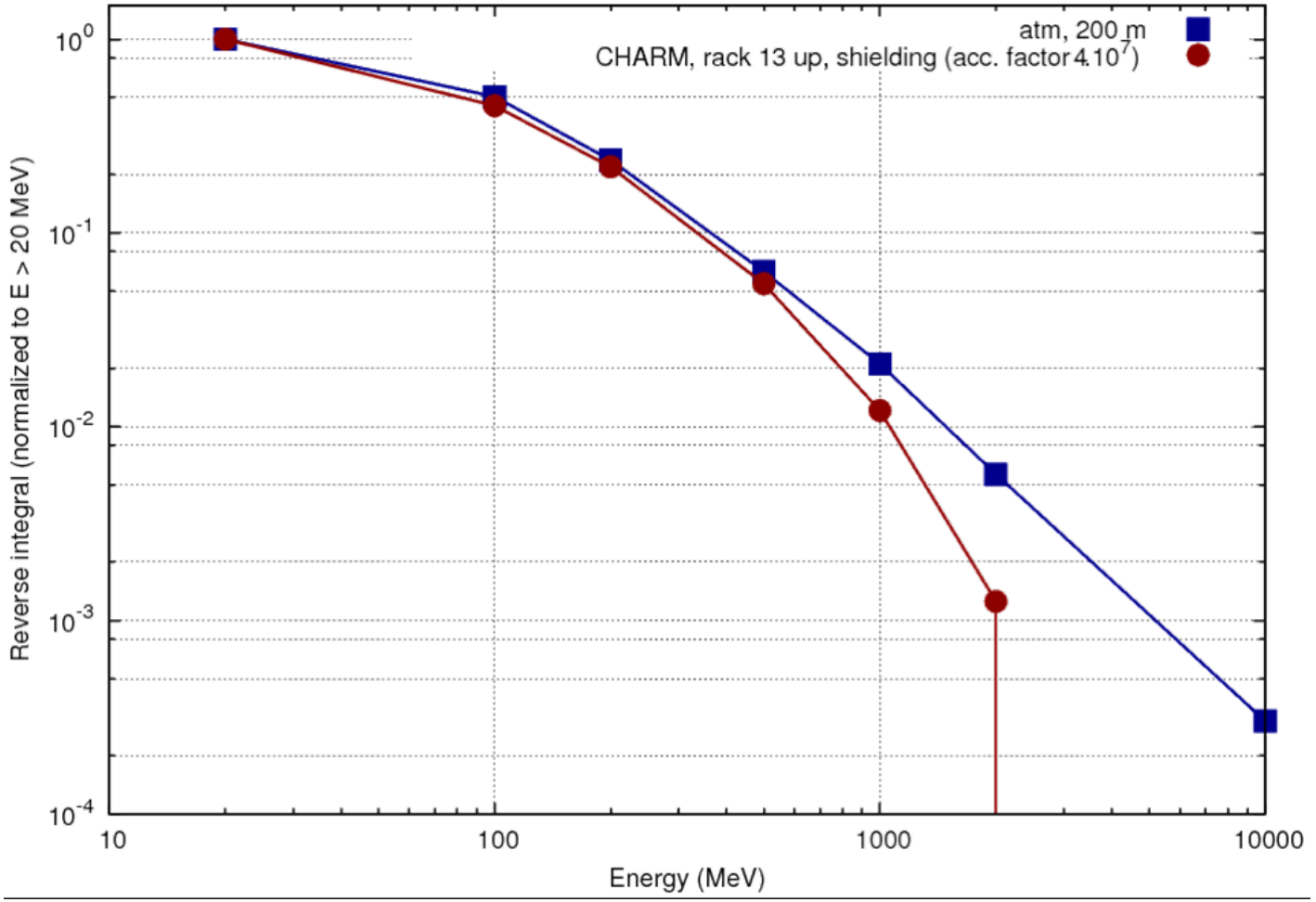
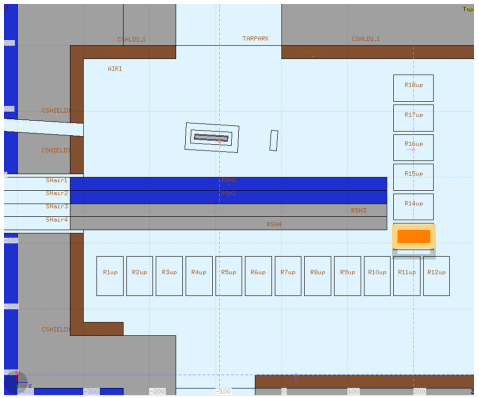
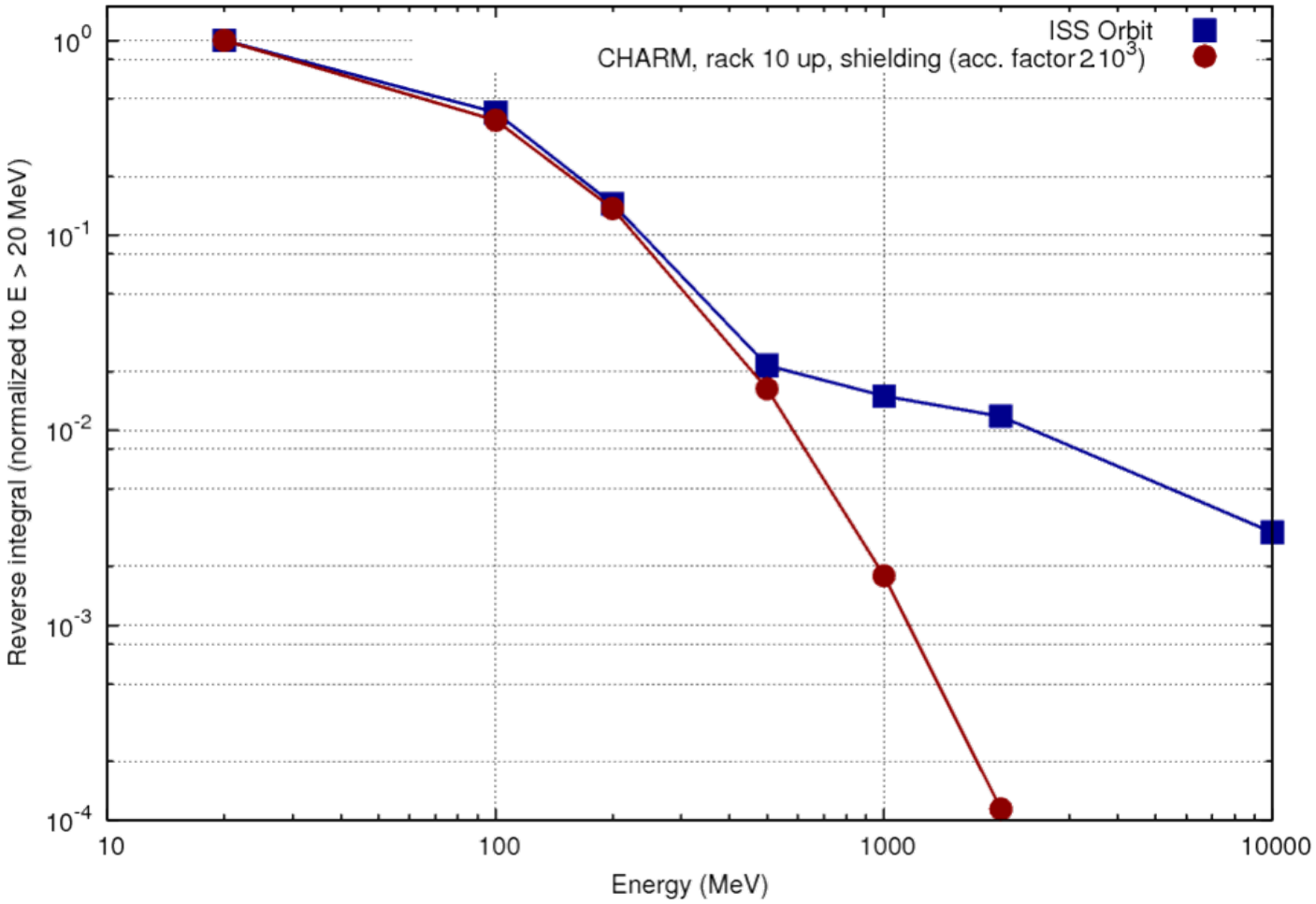
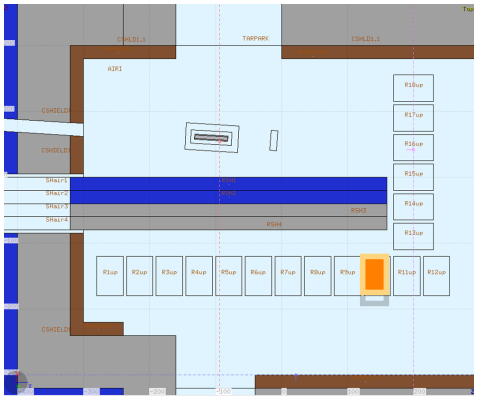


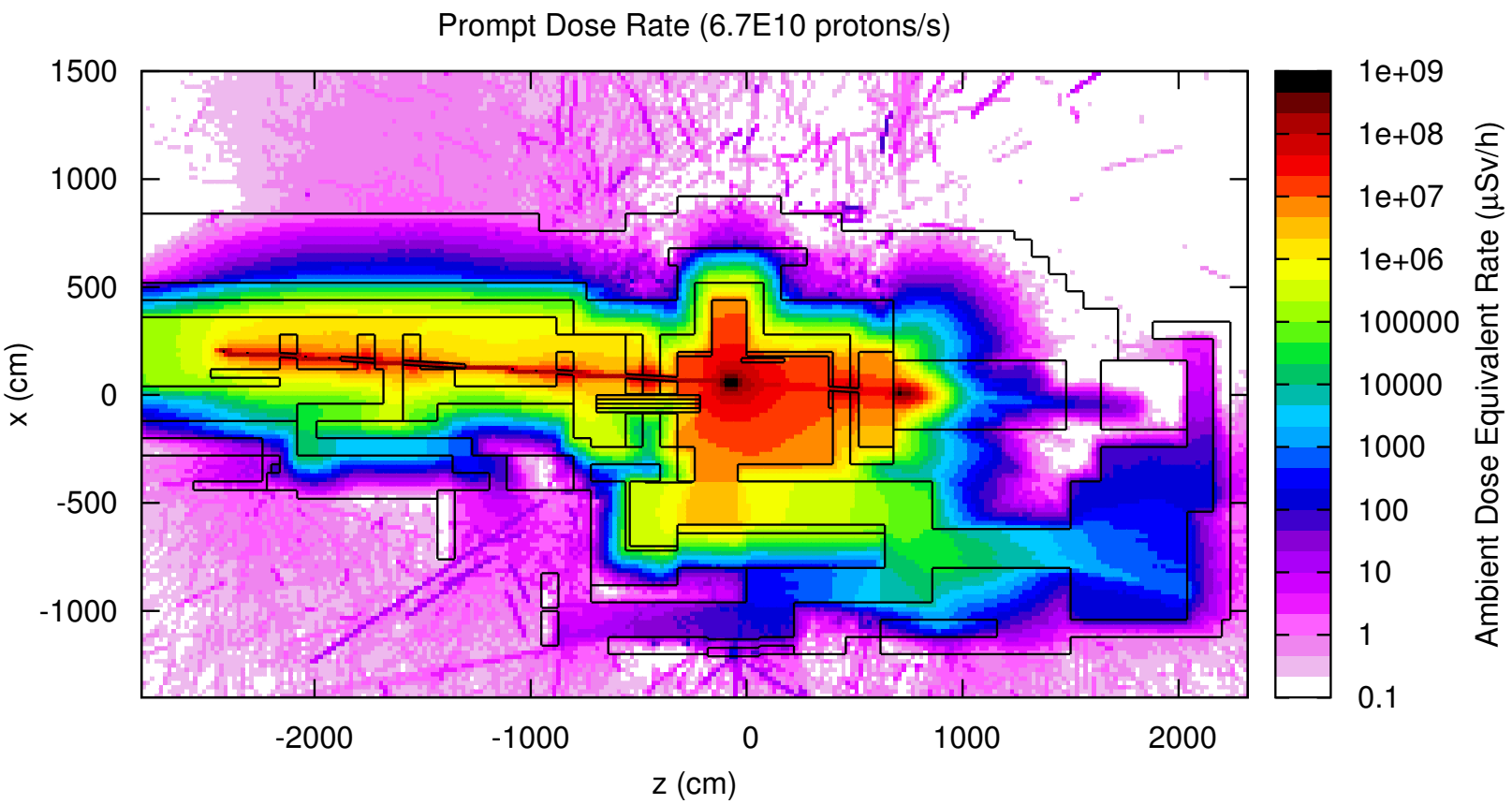


Radiation Fields

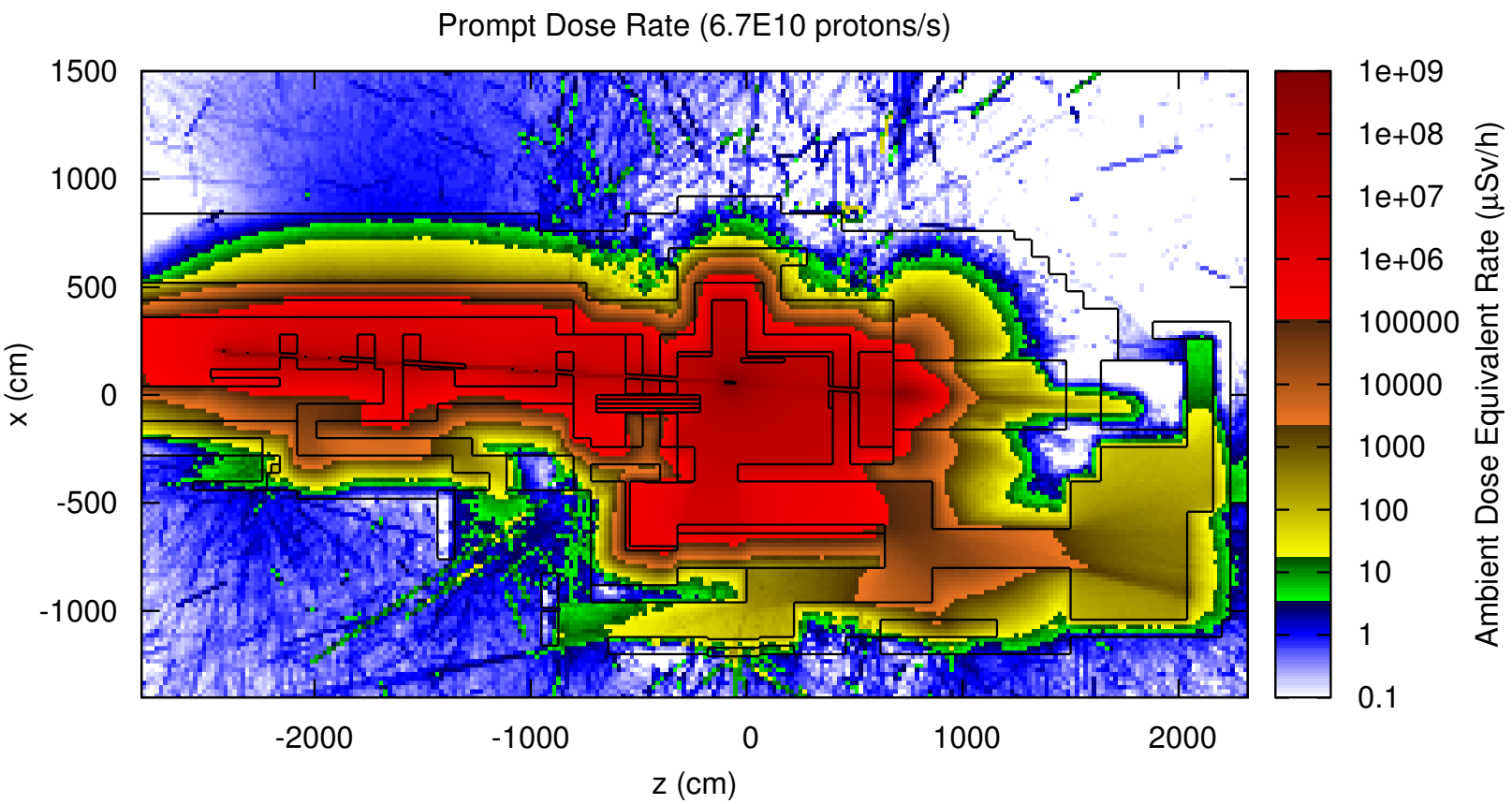




Prompt Radiation – Beam Line Level



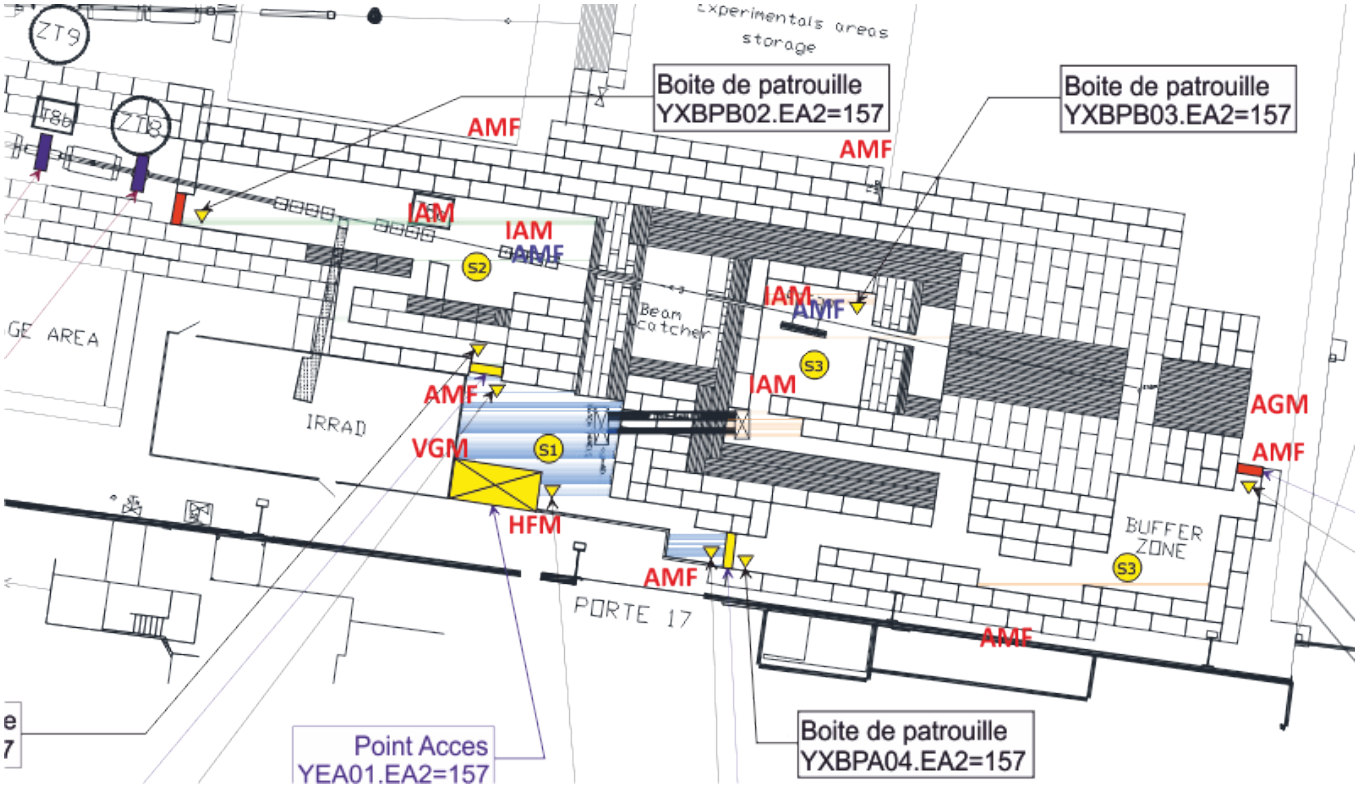
Prompt Radiation – Beam Line Level (Area Classification)



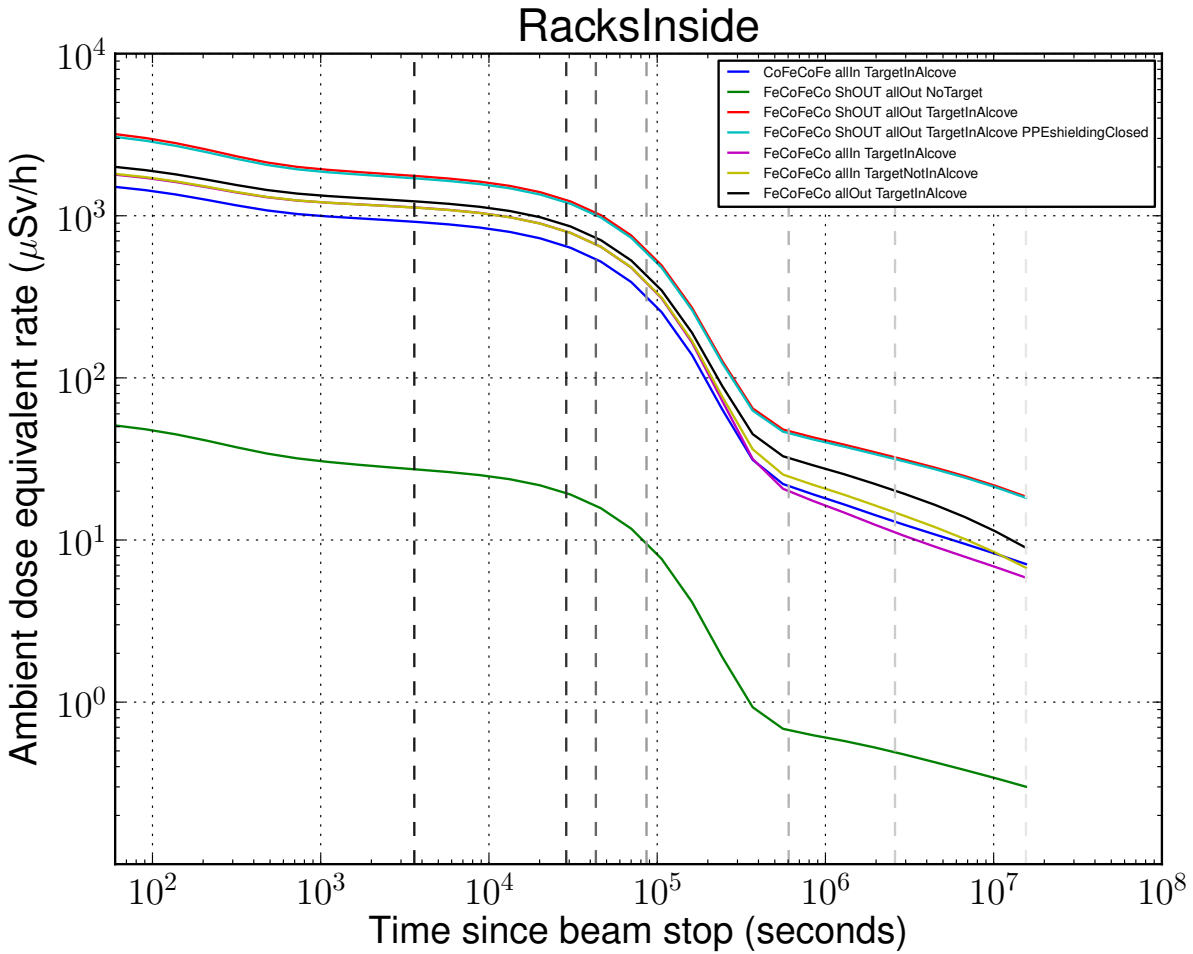
Monitoring

- Radiation Protection monitors
  - AMF/AGM for prompt radiation
  - IAM for residual radiation
  - VMS for monitoring the release to the environment
  - Mobile AMF/AGM during commissioning
- Radiation field monitoring
  - RadMon (active, TID, displacement damage, high energy hadron flux, thermal neutron flux)
  - Beam Loss Monitors (BLM)
  - Beam intensity and profile monitoring

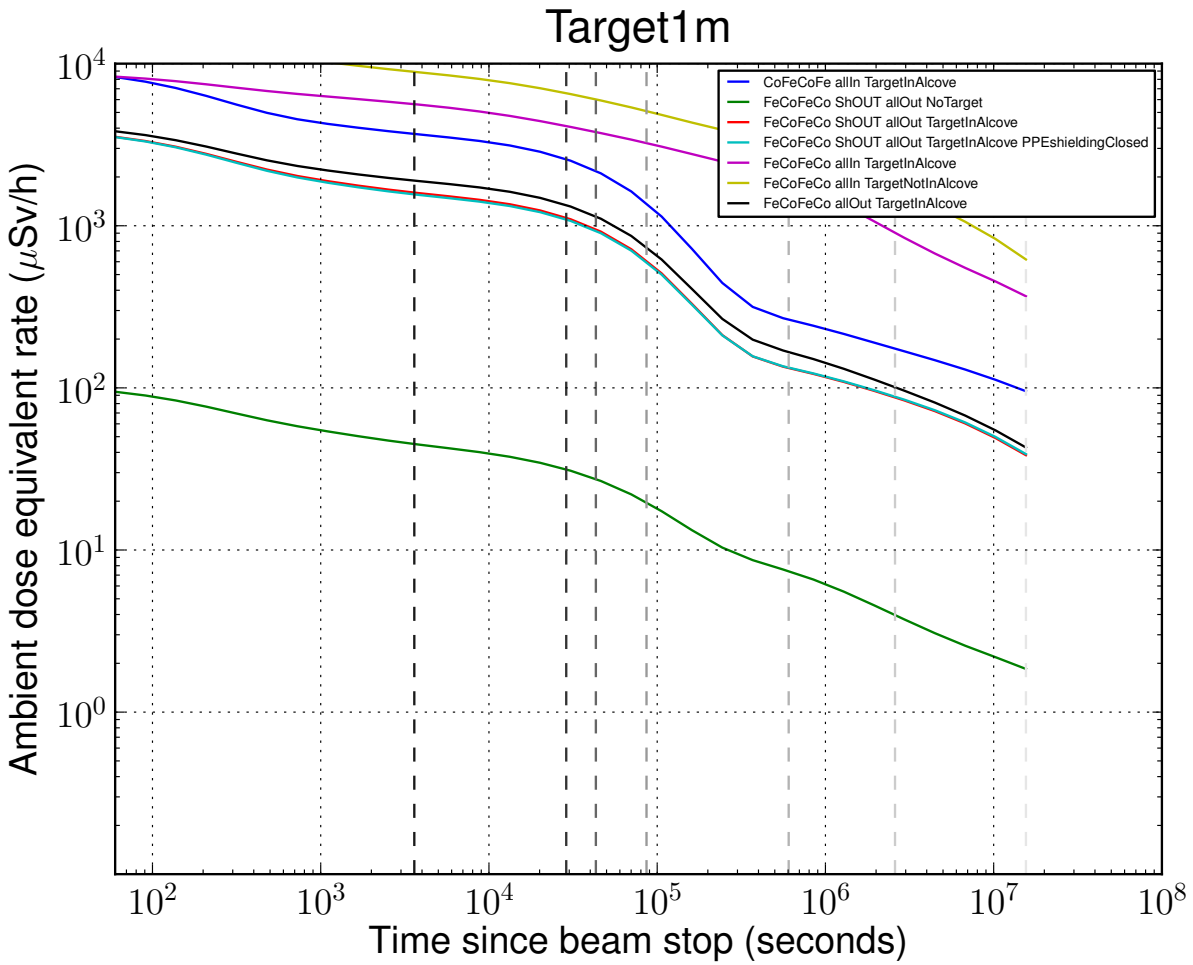
RP Monitoring



Residual DR after 200 days with 6.6E10 p/s in the rack area



Residual DR after 200 days with 6.6E10 p/s at 1m from the target position



Inhalation dose / Effective dose (1 volume per hour)

Radionuclide	Production yield nucl./primary	Total activity Bq	Committed effective dose due to inhalation without flush for 1 hour access μSv	Release environment TBq/y	Effective dose to members of public μSv/y
H-3	9.31E-03	3.14E+03	5.15E-04	1.66E-05	6.73E-07
Be-7	2.04E-03	5.81E+04	1.07E-02	3.07E-04	4.27E-03
C-11	2.80E-03	9.89E+07	5.40E-01	5.22E-01	2.77E-02
C-14	1.03E+00	7.48E+02	1.74E-03	3.95E-06	2.30E-05
N-13	4.08E-03	1.73E+08	5.23E-01	9.14E-01	3.50E-02
O-14	2.00E-04	1.02E+07	3.73E-03	5.40E-02	1.24E-03
O-15	2.63E-03	1.32E+08	8.27E-02	6.96E-01	9.26E-03
O-19	4.55E-07	2.37E+04	3.29E-06	1.25E-04	5.78E-07
F-18	7.52E-06	1.09E+05	3.37E-02	5.74E-04	3.32E-04
Ne-23	9.65E-07	5.02E+04	–	2.65E-04	1.41E-07
Ne-24	2.28E-07	1.11E+04	–	5.86E-05	6.44E-07
Na-22	2.42E-06	3.87E+00	3.10E-05	2.04E-08	1.20E-04
Na-24	3.63E-06	8.44E+03	1.75E-02	4.45E-05	5.88E-04
Na-25	1.58E-06	8.12E+04	–	4.29E-04	1.20E-06
Mg-27	2.05E-06	8.78E+04	–	4.64E-04	3.73E-04
Mg-28	5.85E-07	9.87E+02	6.60E-03	5.21E-06	6.99E-05
Al-26	3.25E-06	1.89E-05	1.06E-09	9.97E-14	6.93E-09
Al-28	7.40E-06	3.69E+05	–	1.95E-03	1.43E-03
Al-29	3.58E-06	1.63E+05	–	8.58E-04	5.82E-05
Si-31	4.34E-06	4.77E+04	1.85E-02	2.52E-04	5.82E-05
Si-32	2.39E-06	2.21E-02	4.86E-06	1.17E-10	2.45E-08
P-30	2.26E-06	1.12E+05	–	5.92E-04	2.35E-05
P-32	2.55E-05	2.71E+03	3.14E-02	1.43E-05	4.97E-04
P-33	1.91E-05	1.14E+03	5.93E-03	6.03E-06	3.37E-05
P-35	2.05E-06	1.06E+05	–	5.59E-04	3.39E-04
S-35	2.37E-05	4.12E+02	1.81E-03	2.17E-06	1.08E-05
S-37	7.61E-06	3.57E+05	–	1.88E-03	1.76E-04
S-38	4.53E-06	4.64E+04	–	2.45E-04	4.60E-04
Cl-34	9.72E-07	2.89E+04	–	1.53E-04	0.00E+00
Cl-36	5.68E-05	7.85E-04	1.60E-08	4.14E-12	1.94E-08
Cl-38	4.14E-05	1.15E+06	2.02E-01	6.07E-03	2.15E-03
Cl-39	7.71E-05	1.74E+06	3.72E-01	9.16E-03	4.10E-03
Cl-40	9.31E-06	4.74E+05	–	2.50E-03	8.78E-05
Ar-37	7.51E-05	3.26E+03	–	1.72E-05	1.48E-12
Ar-39	2.85E-04	4.41E+00	–	2.33E-08	7.59E-12
Ar-41	2.18E-03	3.15E+07	–	1.67E-01	1.29E-02
K-38	6.74E-07	3.00E+04	–	1.58E-04	5.24E-05
K-40	2.36E-06	7.67E-09	9.20E-14	4.05E-17	4.25E-13
SUM			1.85	2.38	0.101