Radiation protection of a proton beamline at ELI

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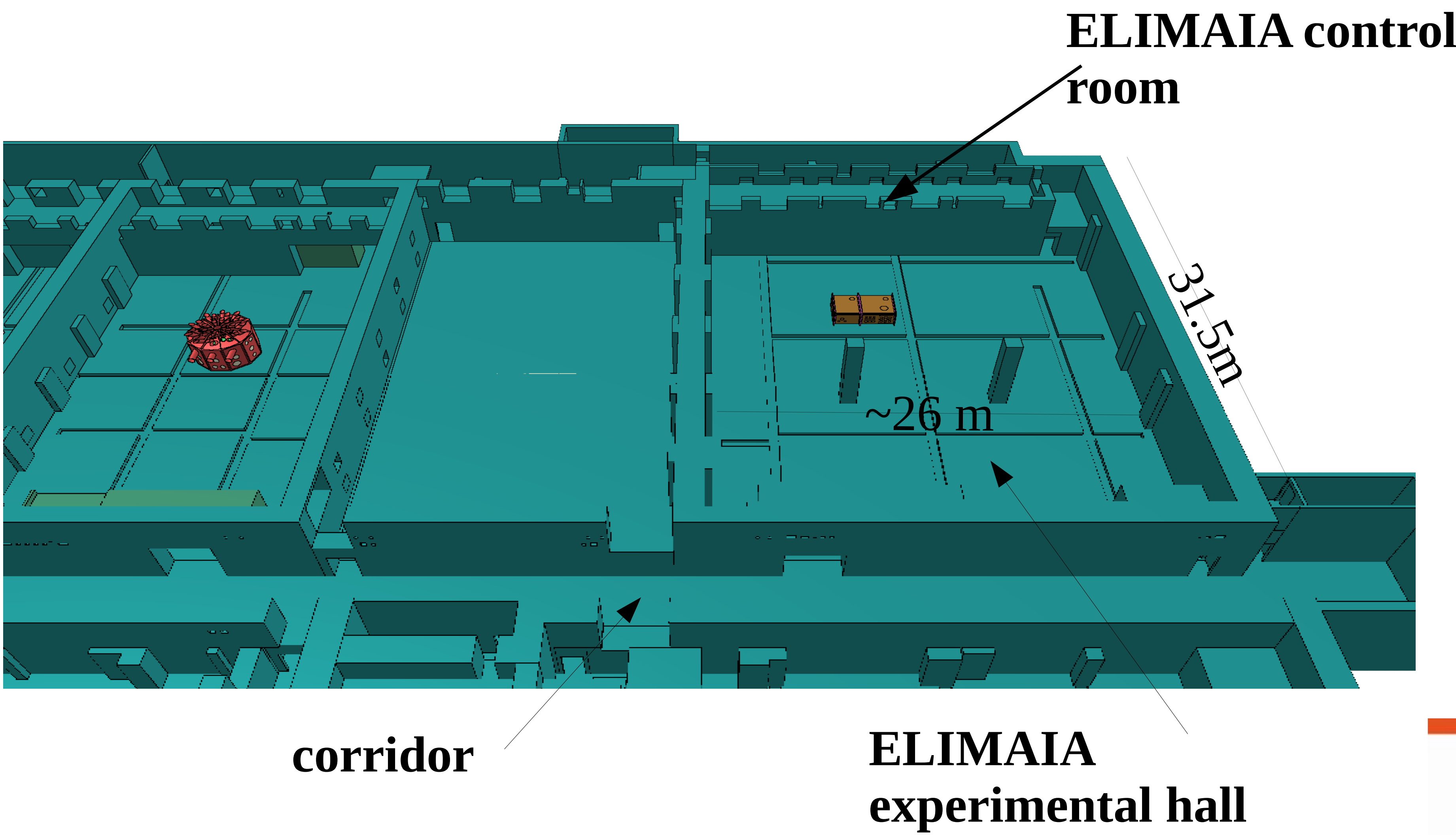
Outline

- ELI-beamlines and ELIMAIA
- Radiation protection objectives
- Source terms
- Fluka simulations
- Prompt ambient dose equivalent in the experimental hall
- Induced activity
- Conclusions

ELI-beamlines and ELIMAIA

ELI- beamlines : User facility for short-pulse high power laser

ELIMAIA : Multidisciplinary Application for ion acceleration



Radiation protection objectives

Prompt radiation

Only when the beam is on

Induced activity

Also when the beam is off

Ambient dose equivalent $H^*(10)$ [mSv]

Particles type and spectra

Radionuclides

Specific activity

General public limit: 1 mSv/year

Controlled area limit: 20 mSv/year

Legal maximum specific activity

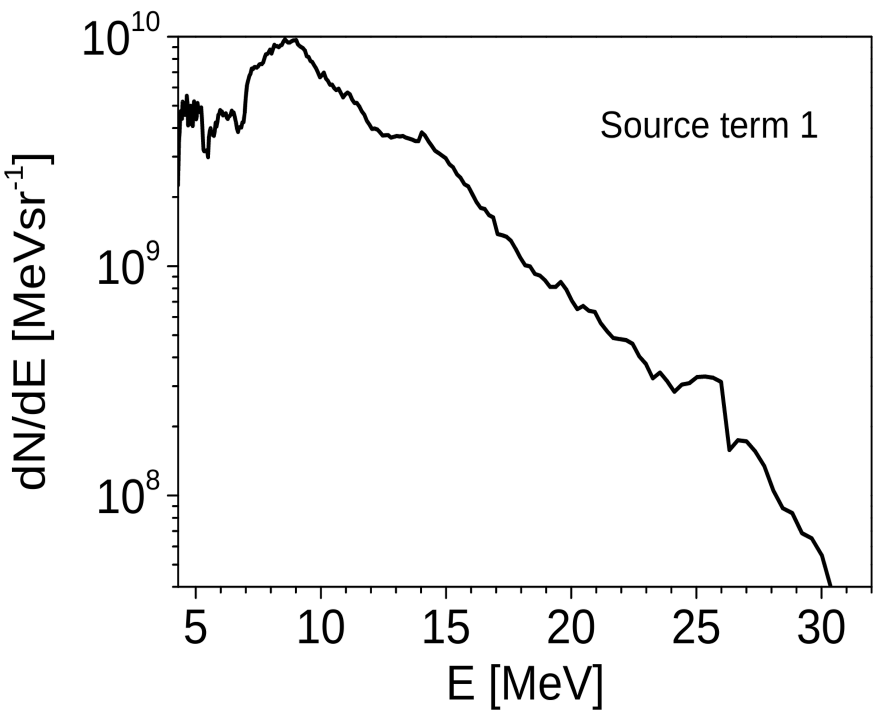
- Class 1 : 0.3 Bq/g
- Class 2 : 3 Bq/g
- Class 3 : 30 Bq/g
- Class 4 : 300 Bq/g

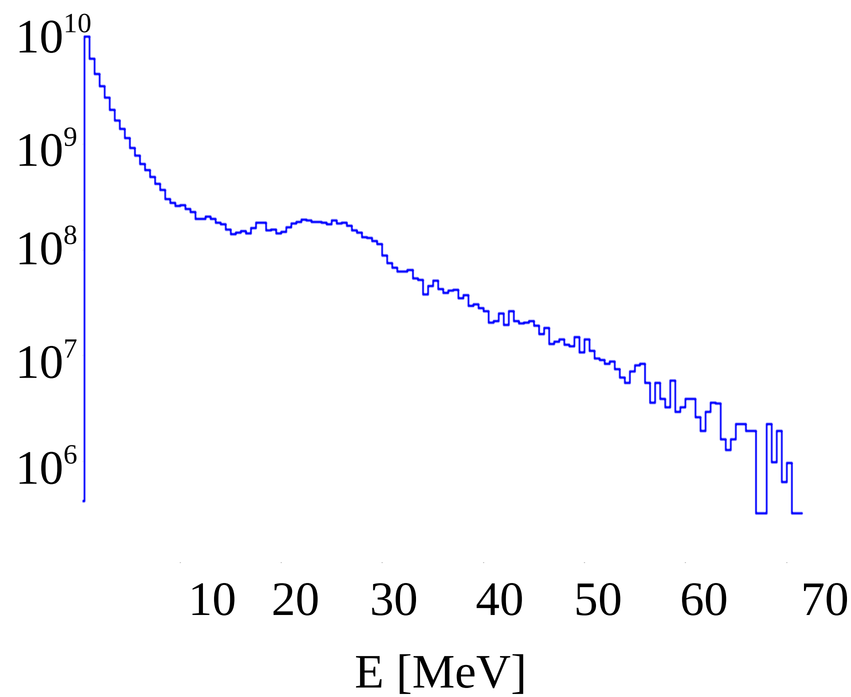
Source terms

Korean experimental data

PIC simulation data

Energy spectrum

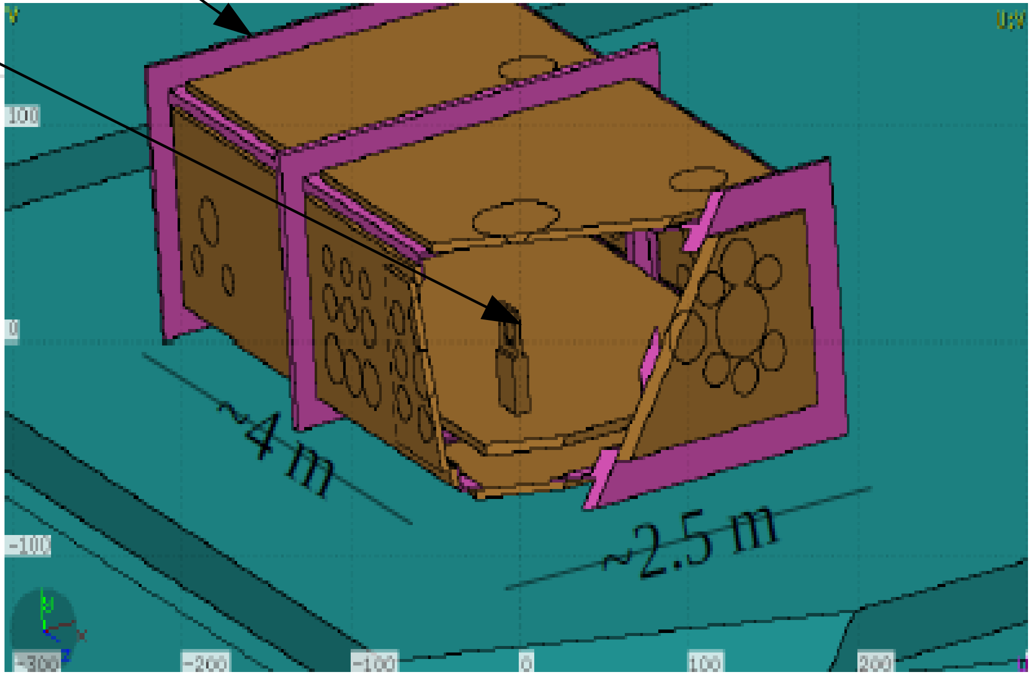




	Korean case	PIC simulation
#Primary/shot	$7\ 10^{10}$ protons	$2\ 10^{10}$ protons
Maximum energy	30 MeV	70 MeV
Divergence	25°	~10°
# shot/day	300	2000

Simulation description

- Monte Carlo Simulation with FLUKA
- Source term :
  - Beam parameter (experimental data)
  - Input file from PIC simulation
- Geometry :
  - Complete description of the **experimental chamber (EC)**
  - Simple model for the **target holder**
  - Material used
    - AL6082 for aluminum
    - EN1.4306 for stainless steel

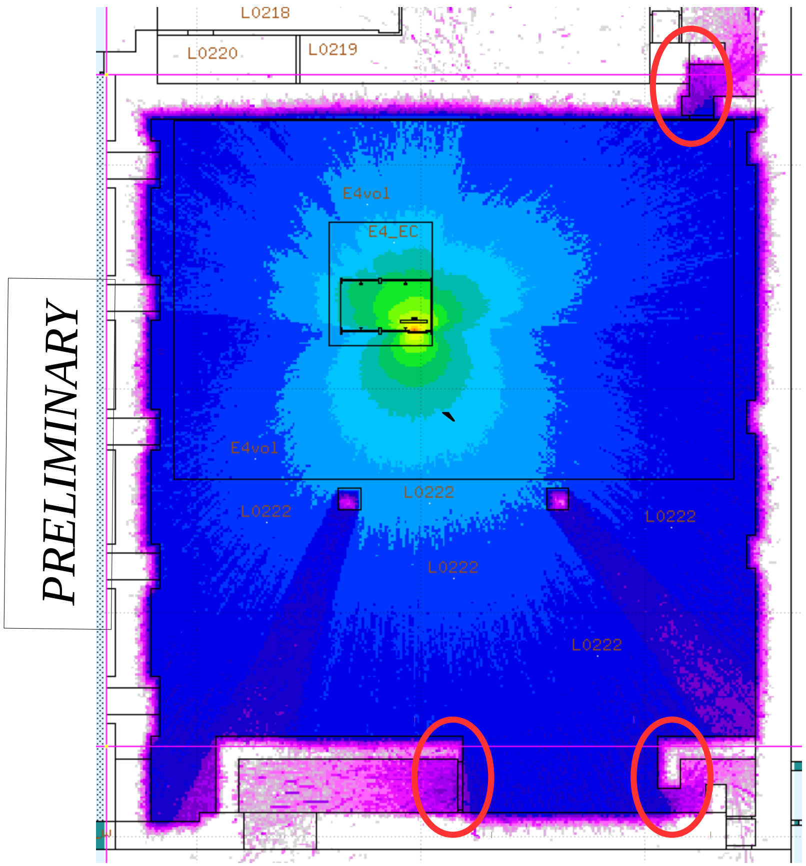


Prompt H*(10) in the experimental hall

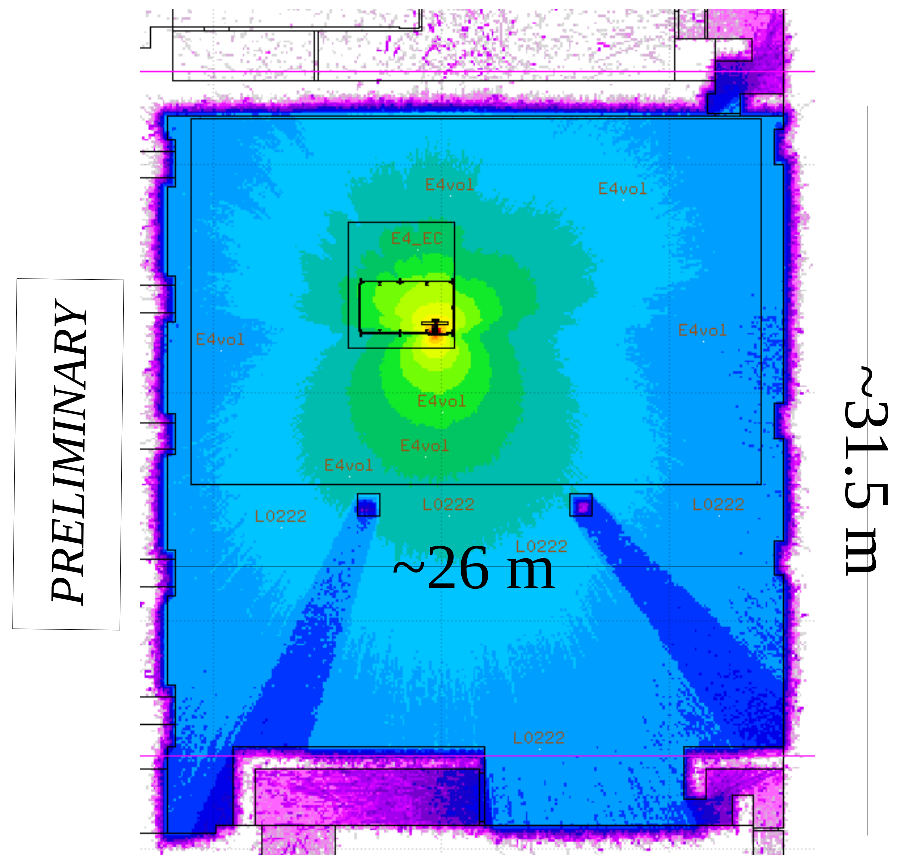
Horizontal view at beam height

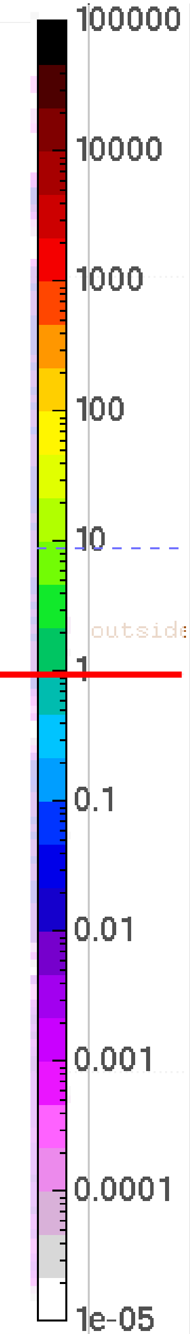
[mSv/year]

Korean data



PIC simulation

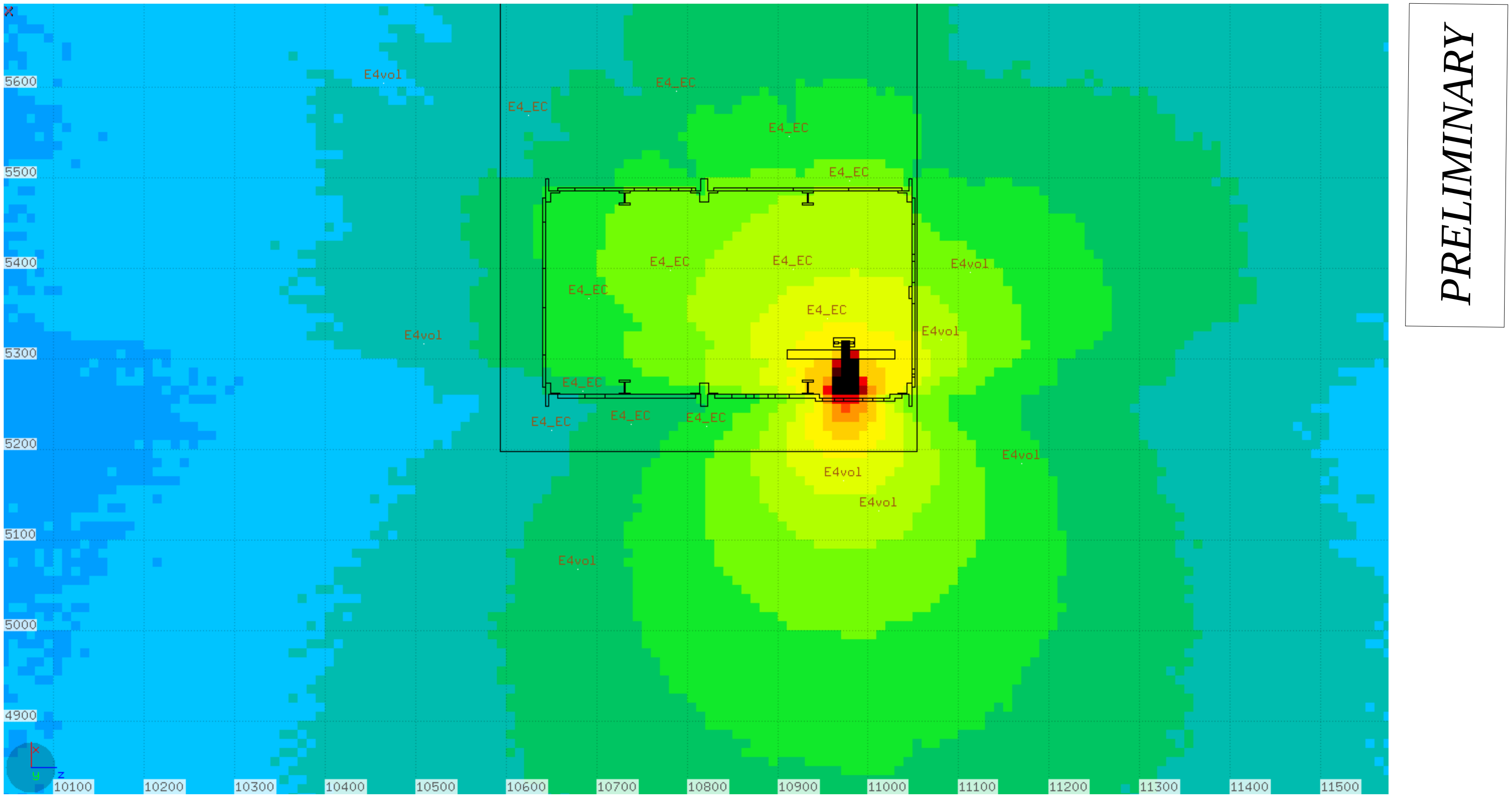


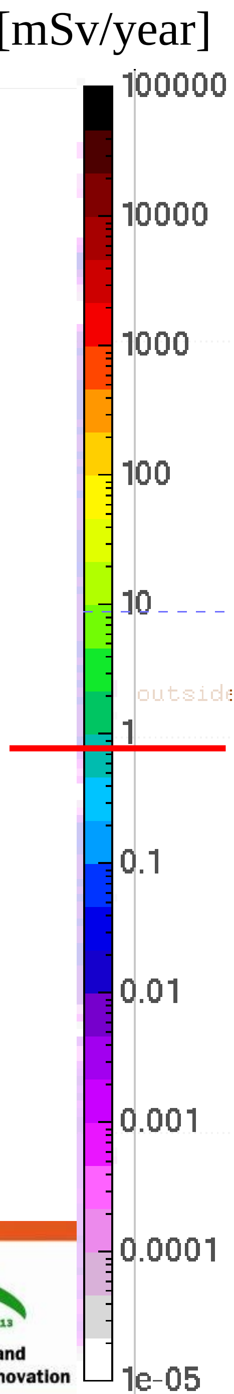


- Simulations configuration
  - 10^{10} primaries
  - Open doors in the geom model
  - Shot southward
  - Experimental chamber closed
- Observations
  - > 1 mSv/year → no one allowed inside during the run
  - Effect of the 2 concrete columns visible
  - Concrete walls shield control room and other areas
  - Detailed radiation shape explained on the next slide

$H^*(10)$ in the experimental hall – PIC simulation

$H^*(10)$ in [mSv/year] - Horizontal view at beam height - ZOOM





- Back-scattering
- Shape depends on the geometrical structure of the experimental chamber

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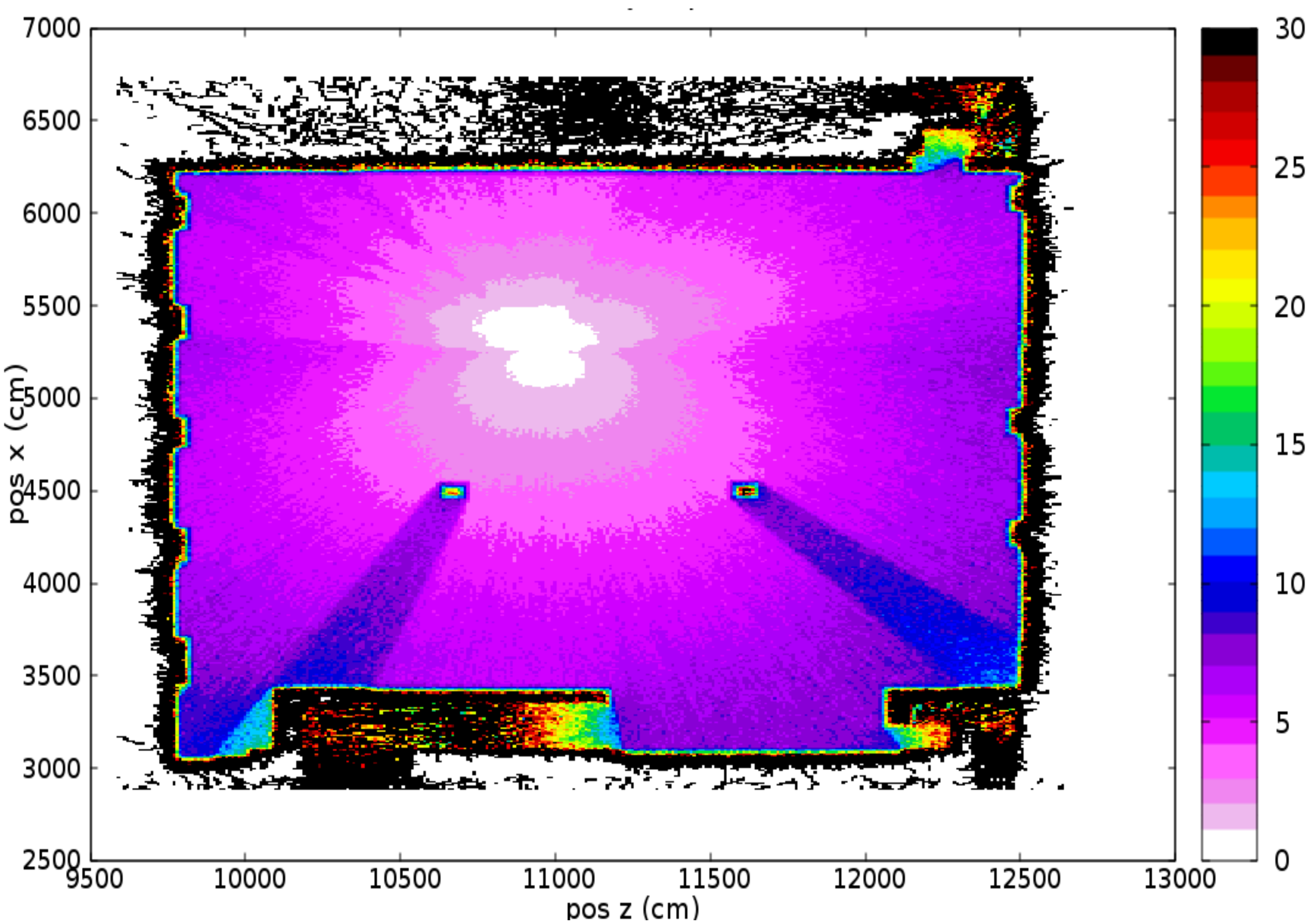
$H^*(10)$ in the experimental hall – PIC simulation

$H^*(10)$ in [mSv/year] - Horizontal view at beam height - statistical uncertainties



Less 10% → simulation reliable

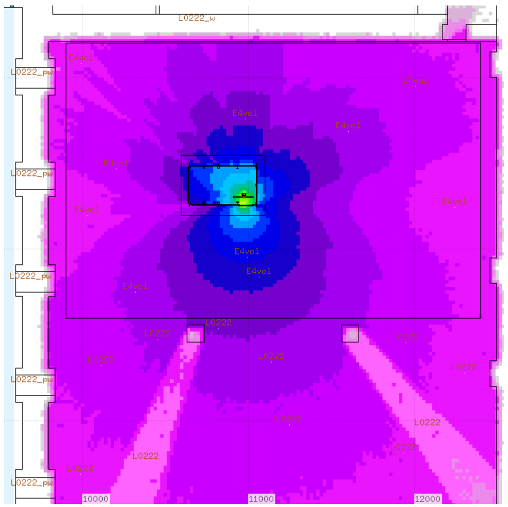
PRELIMINARY

H*(10) due to induced radioactivity - PIC

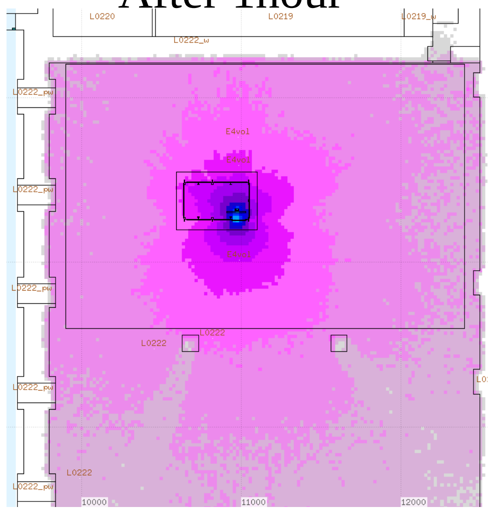
Horizontal view at beam height – **1 year of operation** for different cooling times

[μSv/hour]

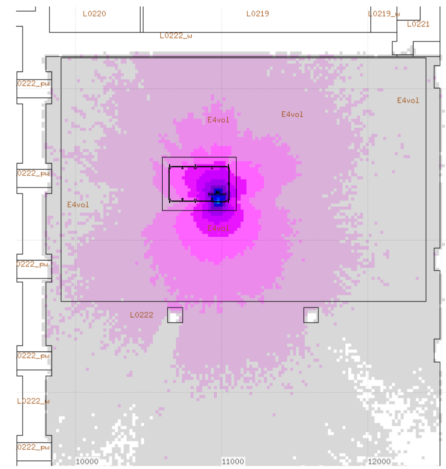
End of irradiation (EoI)



After 1hour

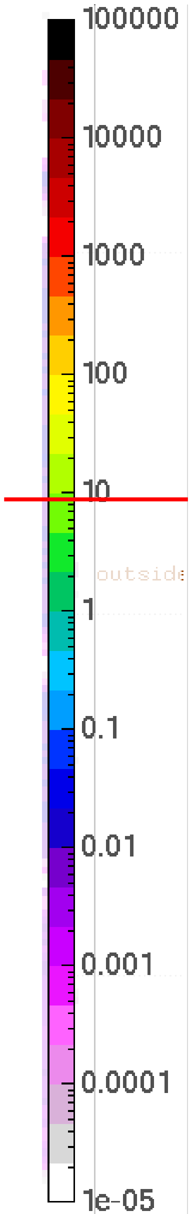


After 1 day

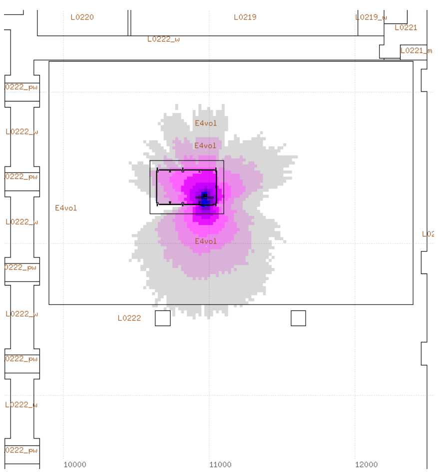


PRELIMINARY

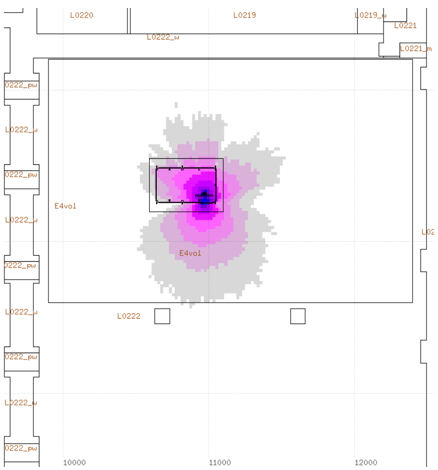
100 hours /man/year



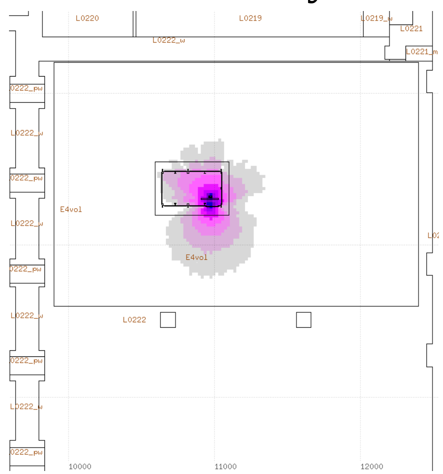
After 1 week



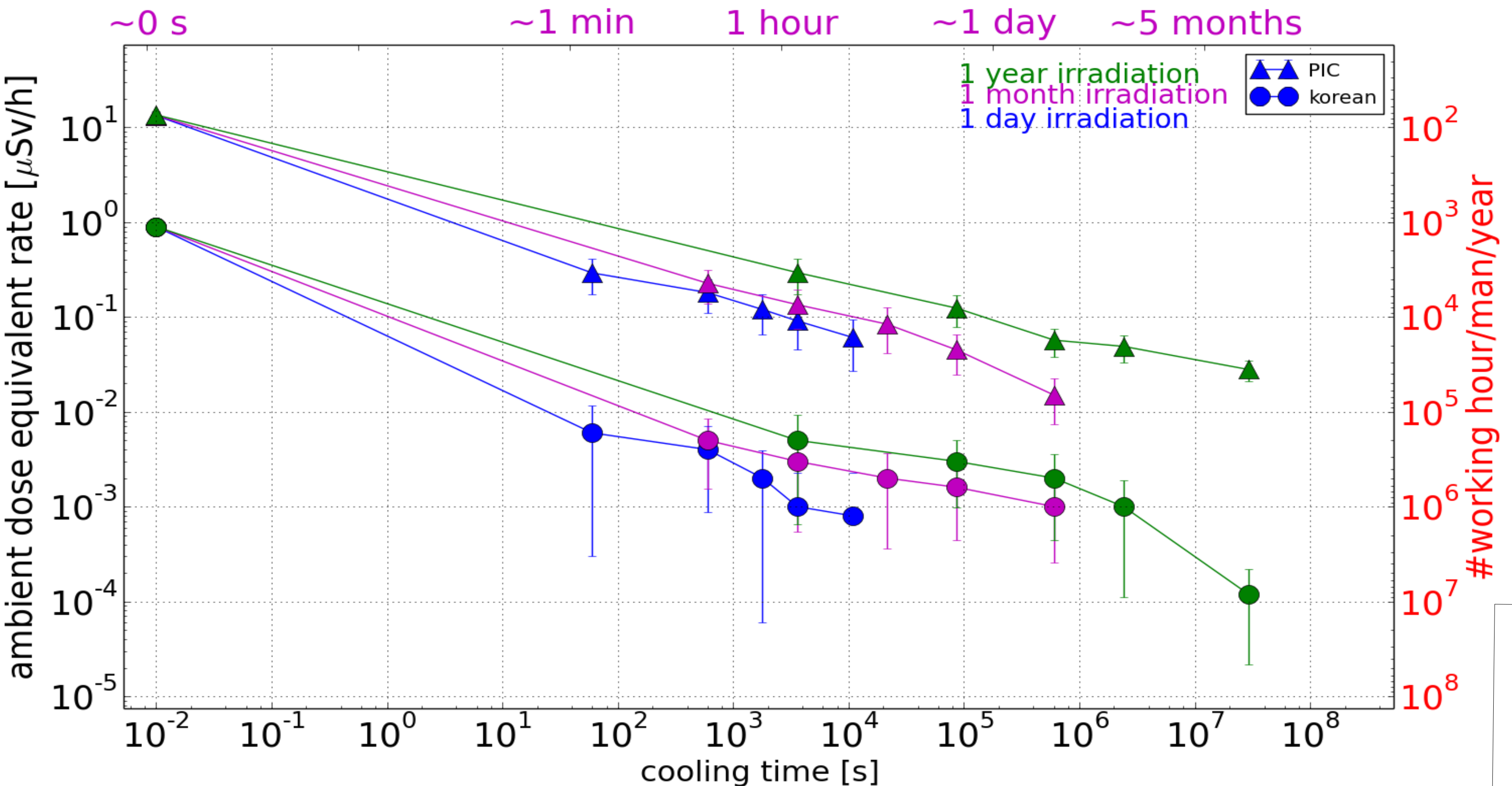
After 1 month



After 1 year



Dose rate due to induced radioactivity on the EC

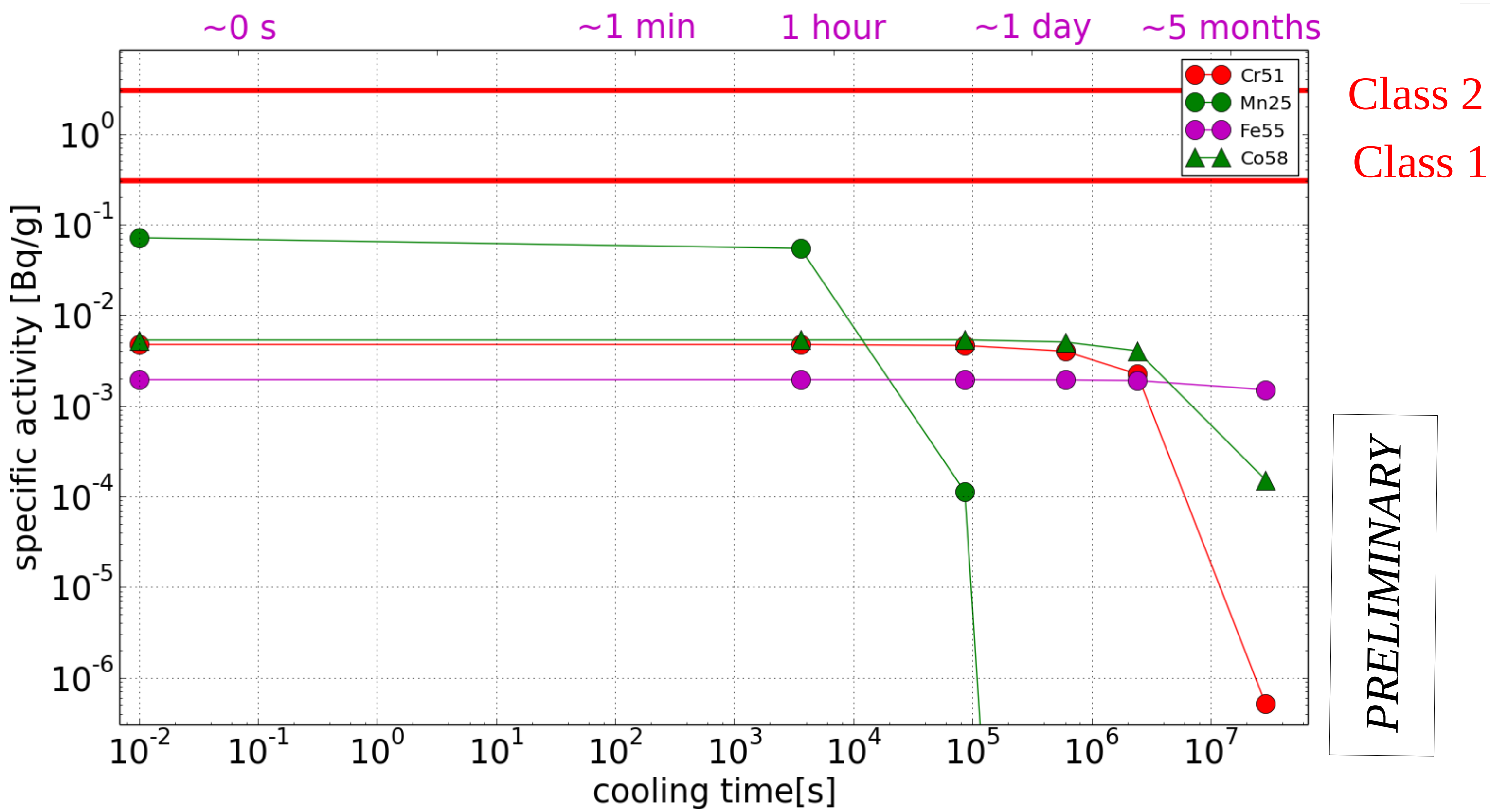


PRELIMINARY

- Observations
  - One order of magnitude difference between Korean and PIC due to energy differences
  - Dose 1 year > dose 1 month > dose 1 day due to the nuclides build-up
  - At the EoI, low dose → 100 – 1000 hours/year for one man

Main radionuclides in the target holder

1 year irradiation with PIC source term

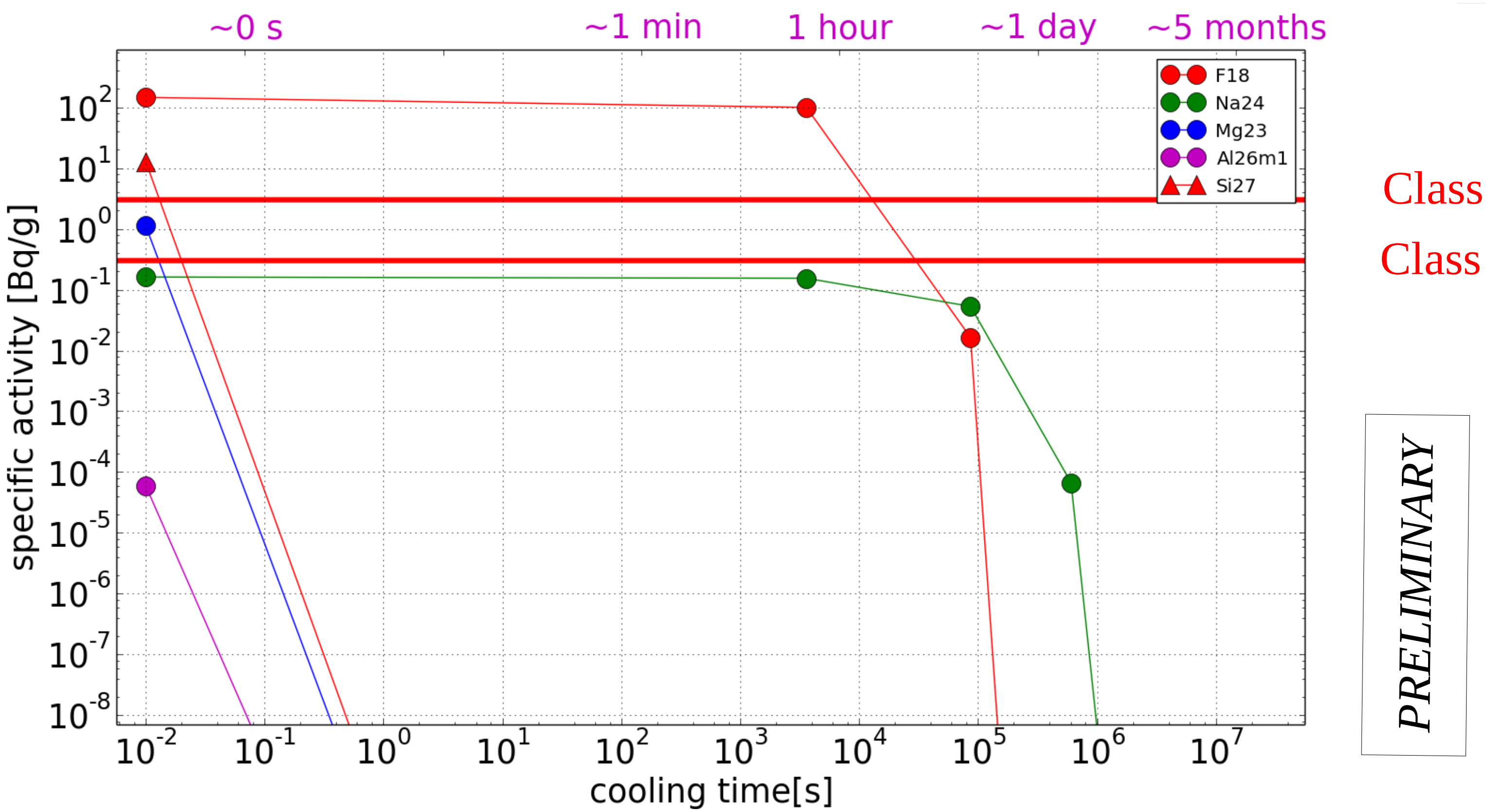


- Observations
  - Error of the order few %
  - Nothing above the most restrictive class

name	class	Lifetime
Cr51	3	27.7 days
Mn56	1	2.58 h
Fe55	4	2.73 year
Co58	1	70.8 days

Main radionuclides in the steel structure

1 year irradiation with PIC source term



- Observations
  - Error of the order few %
  - Preliminary result : need a better normalization
  - High specific activity for F18, Mg23 and Si27 but they are short-lived nuclides

name	class	Lifetime
F18	2	109.8 min
Na24	1	14.9 h
Mg23	unclassified	11.3 s
Al26m-1	1	6.3 s
Si27	unclassified	4.2 s

Conclusions

- Beam and geometry implemented in FLUKA

  → useful for next simulations with new configurations
- Prompt dose
  - **> 1 mSv/year** close to EC

  → no one allowed during the run in the experimental hall
- Induced activity
  - ≃ 1 μSv/h → ~ 1000 hours/man/year → **“safe”**
  - Some radionuclides have high specific activities but also short life-time → after one day no need for radioactive waste procedure
- **Preliminary** results **not worrying** for the radiation protection