Simulation of the Radiation Field in GIF++

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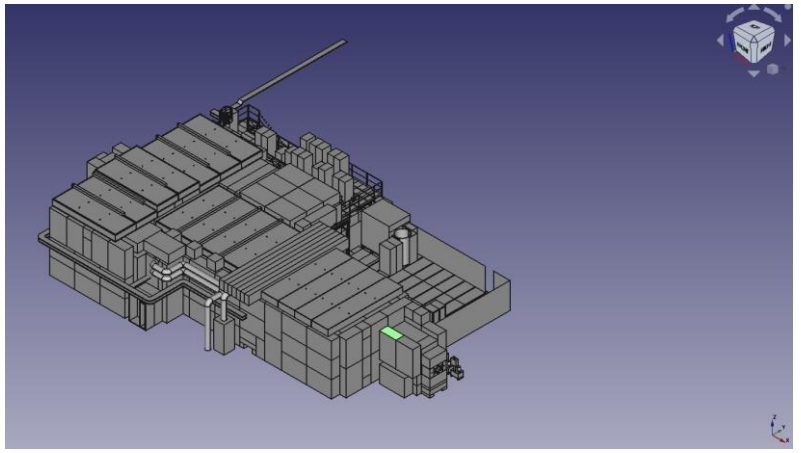
State of Art

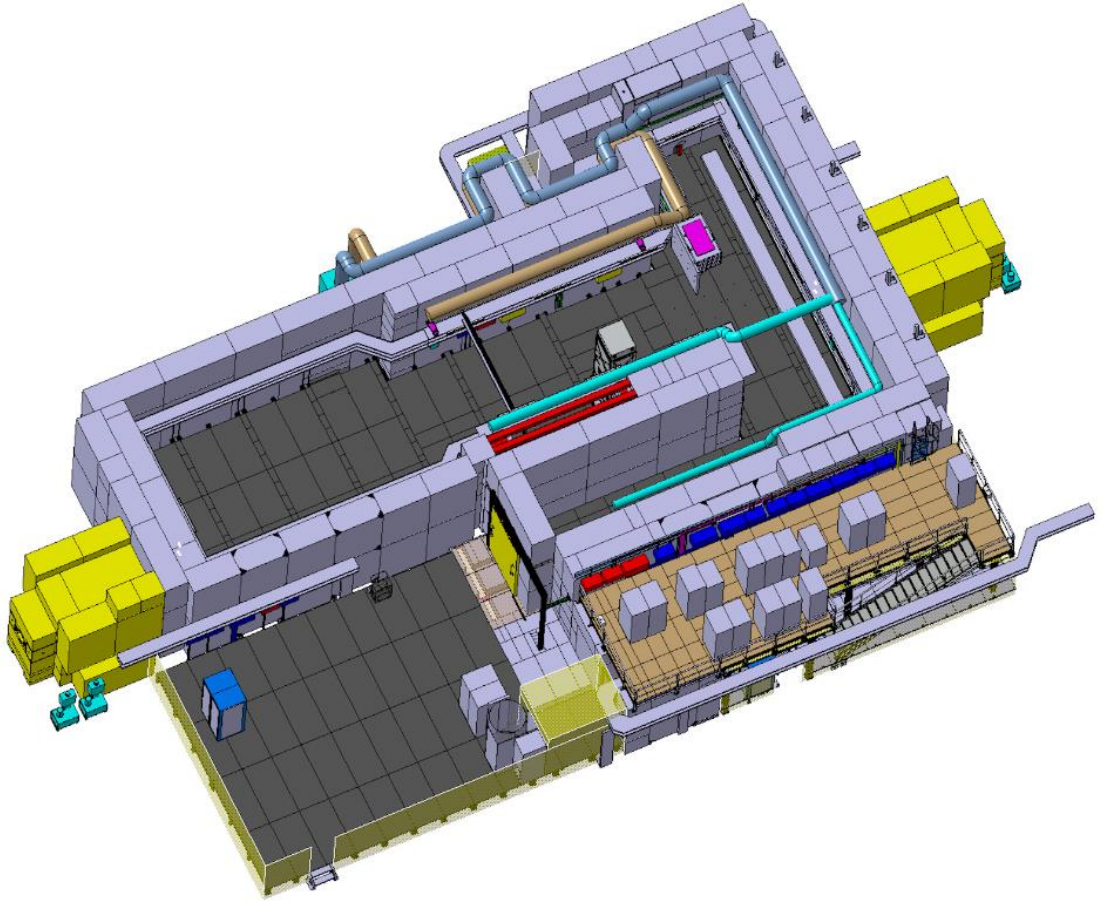


- Since 2014, test at Gamma Irradiation Facility at CERN has been extensively performed for Eco-gas, longevity, and R&D detector studies involving various detector technologies such as DT, MDT, CSC, RPC, iRPC, GEM, and more.
- A simulation study was developed by Pfeiffer Dorothea and published (“**The radiation field in the Gamma Irradiation Facility GIF++ at CERN”** [1]). It used GEANT4-10.0 to model the radiation background at GIF++ and it was performed without the detectors installed.
- Moreover, a new bunker geometry was implemented in 2018
- New simulation work is needed….

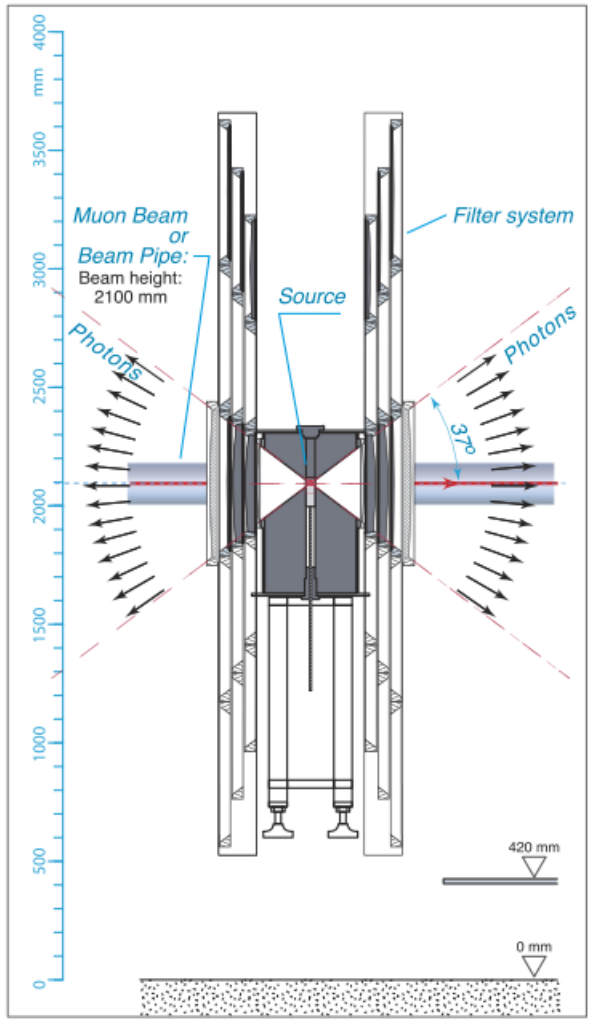
[1] http://dx.doi.org/10.1016/j.nima.2017.05.045

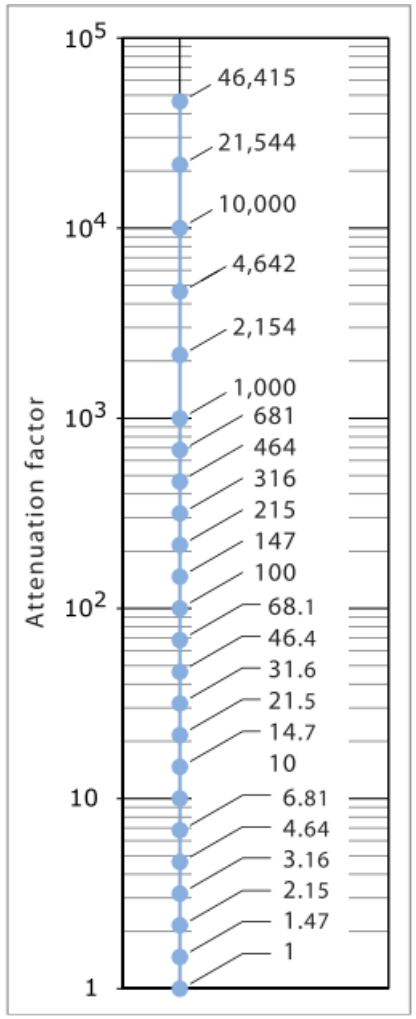
The GIF++ facility @ CERN

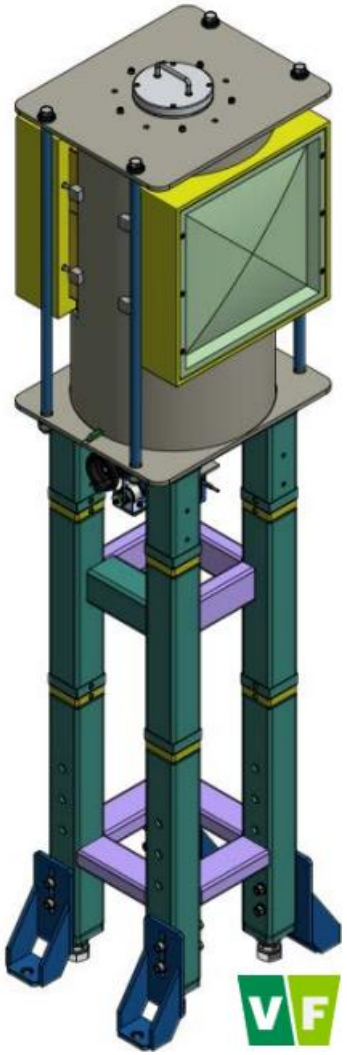
1. 12.5 TBq souce of ^{137}Cs emitting 662 keV photons
2. Beam from SPS (muons)
3. Radiation intensity controlled by a combination of attenuation filters, that shapes the radiation field from point-like to planar
4. Gas and electronics infrastructures
5. Unified control/monitoring system
6. Setups for beam & cosmic trigger, radiation monitoring, environmental monitoring, DAQ,…



Gamma Filters







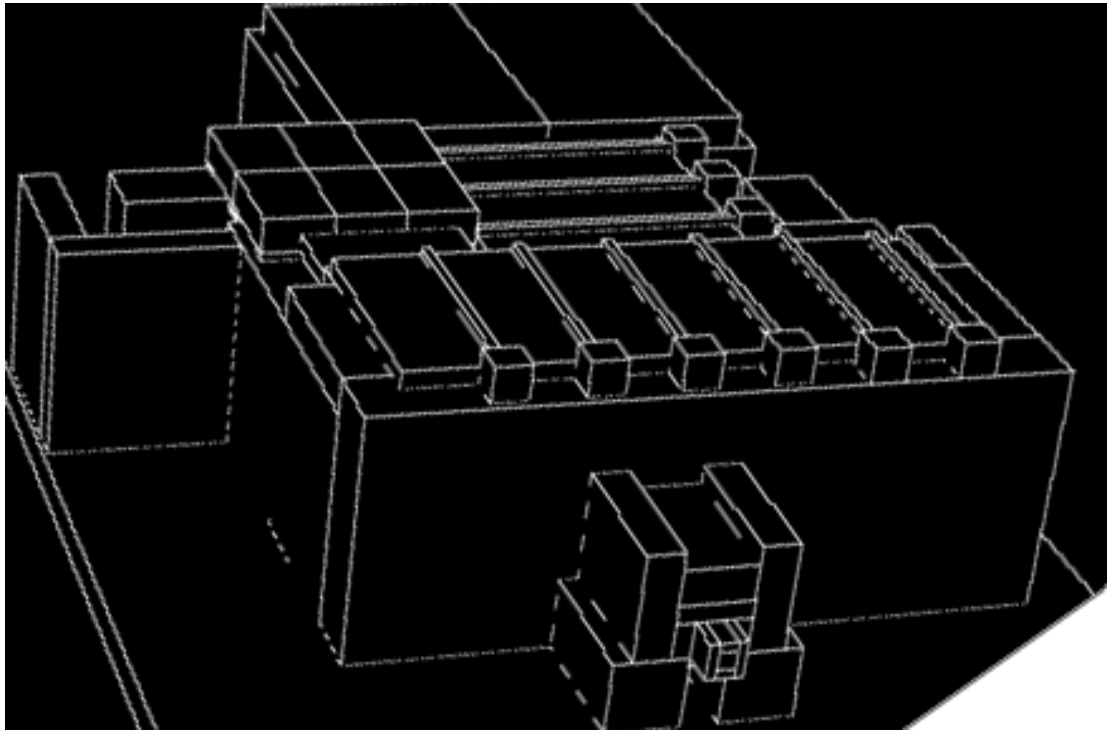
Array of 3 × 3 convex lead attenuation filters, to fine tune the photon flux for each irradiation field individually, upstream (UP) and downstream field (DOWN)

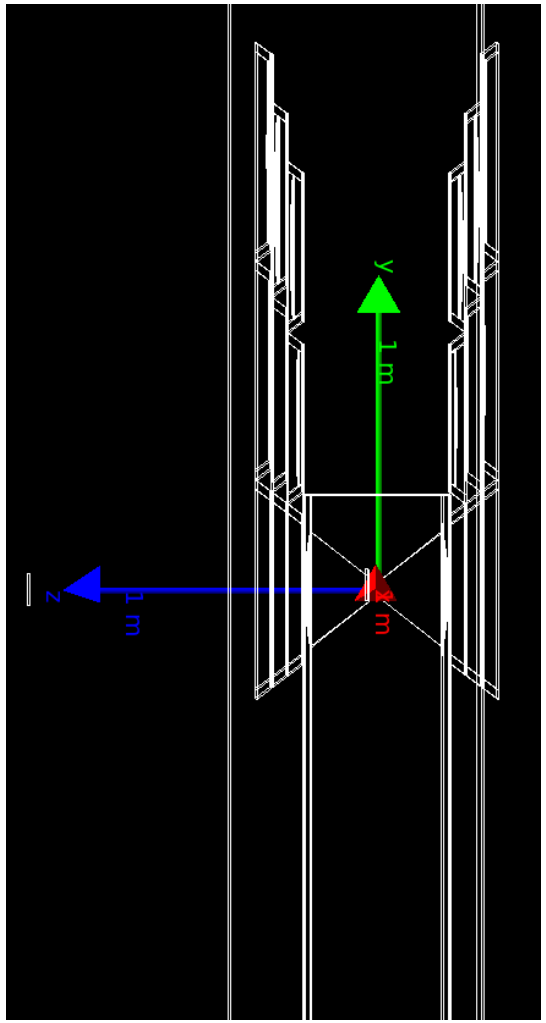
Systems of movable lead attenuators for large irradiation zone that allows attenuation factors (ABS) between 1 and 46000 in several steps

New simulation

New GDML Gif++ layout implemented for Geant4

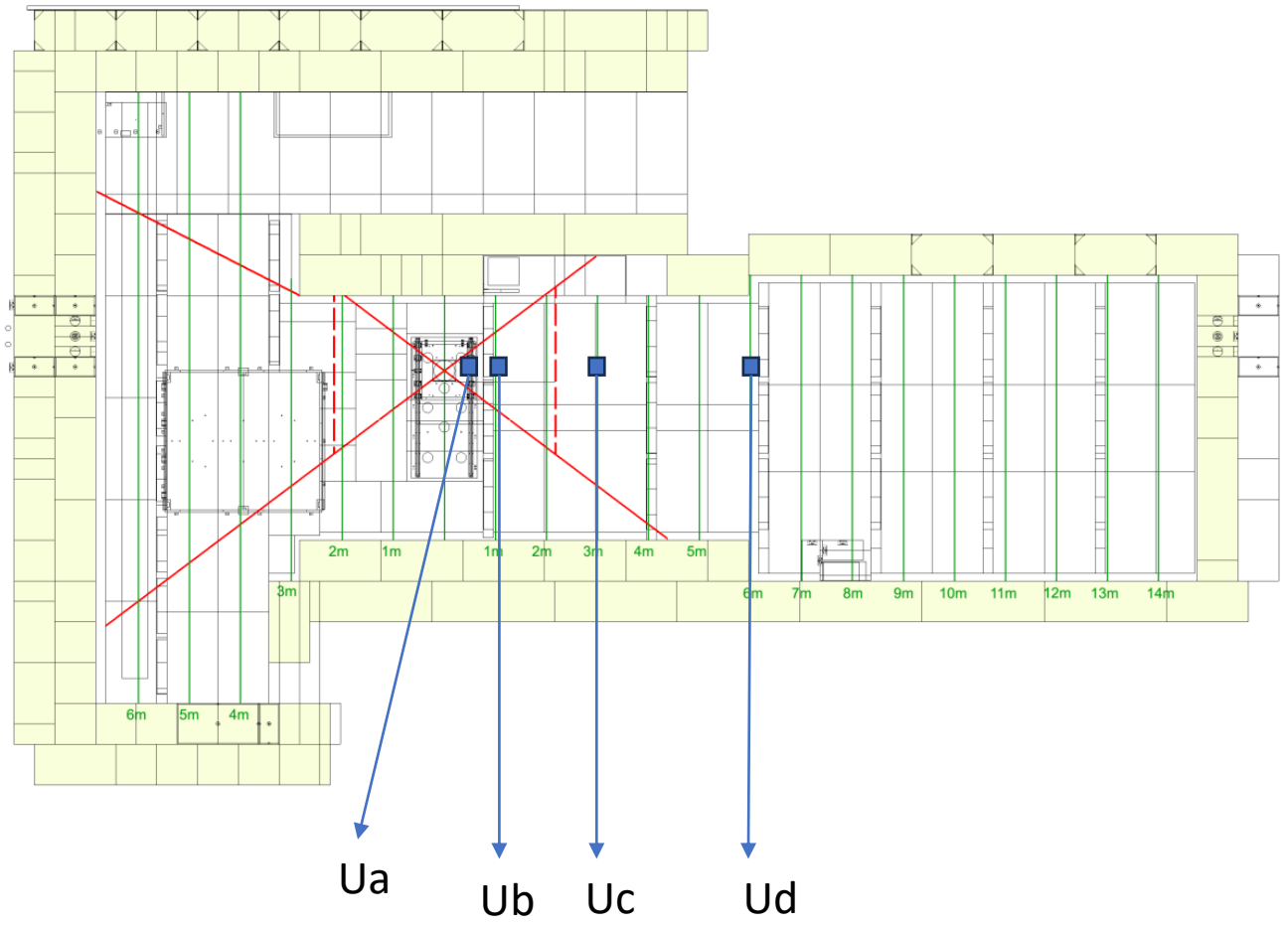
1. Bunker Geometry updated
2. Geant4 updated the version to 11.0
3. Physics List- G4EmLivermorePhysics
4. Filter implementation: mounted on aluminum support plates, the filters are positioned inside steel frames, as collimators.





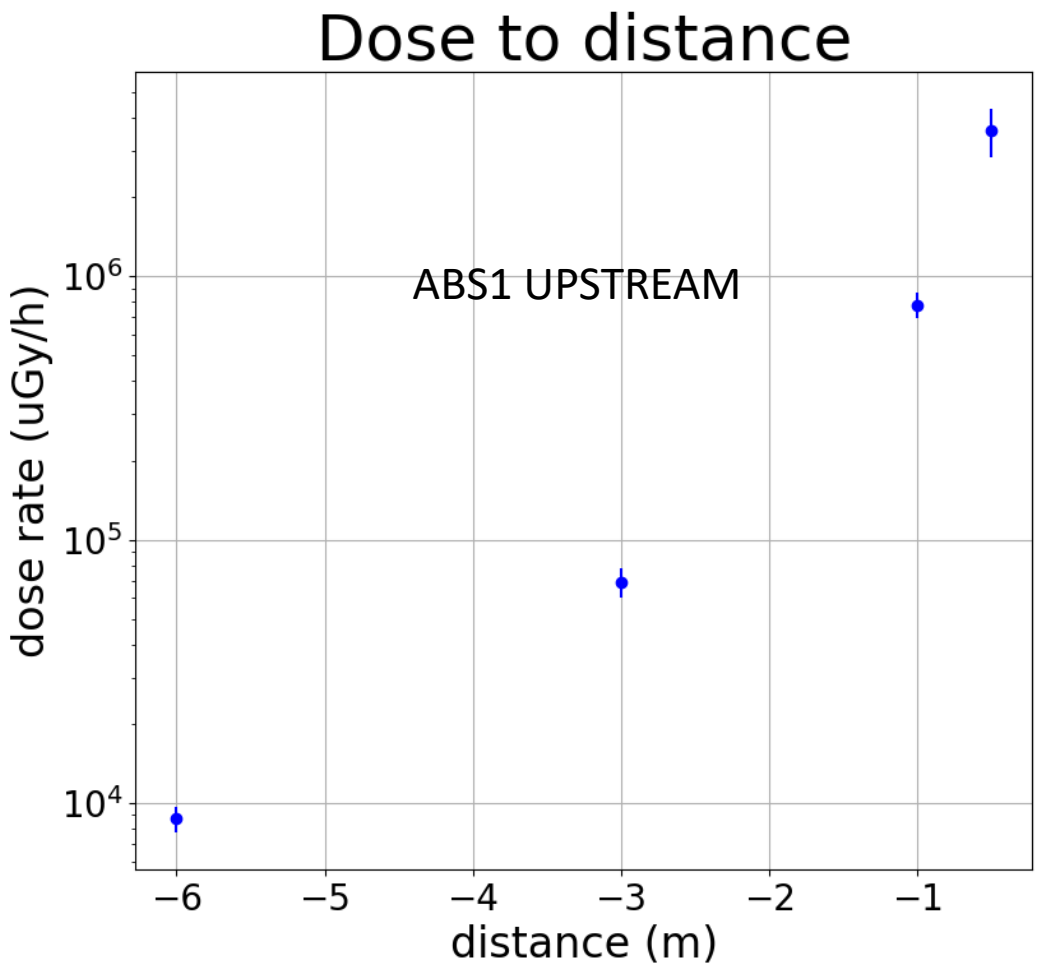
Simulation analysis

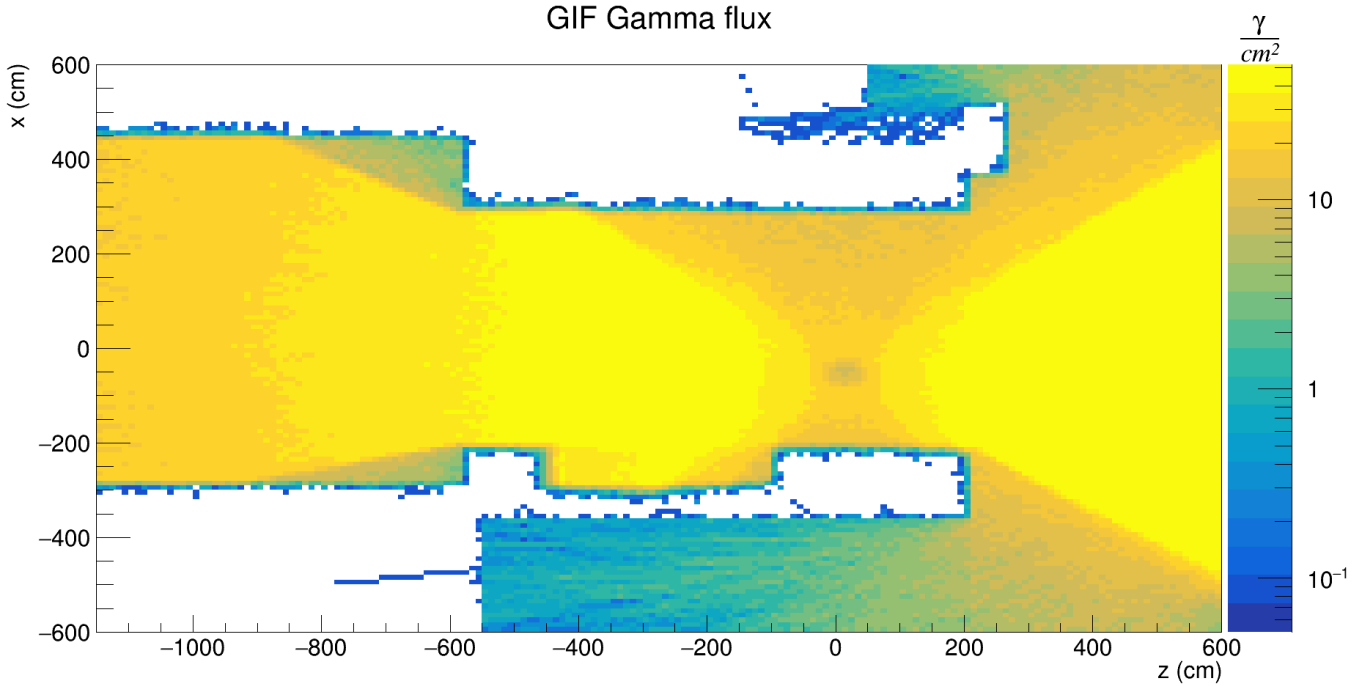
- 4 points were chosen (in the Upstream region) to study the dose and flux vs. the distance from the source
- In each point, a sensitive volume of air was considered for dose and flux estimation
- 12.5 TBq source ^{137}Cs of was considered
- Detectors and mechanical supports were not yet simulated

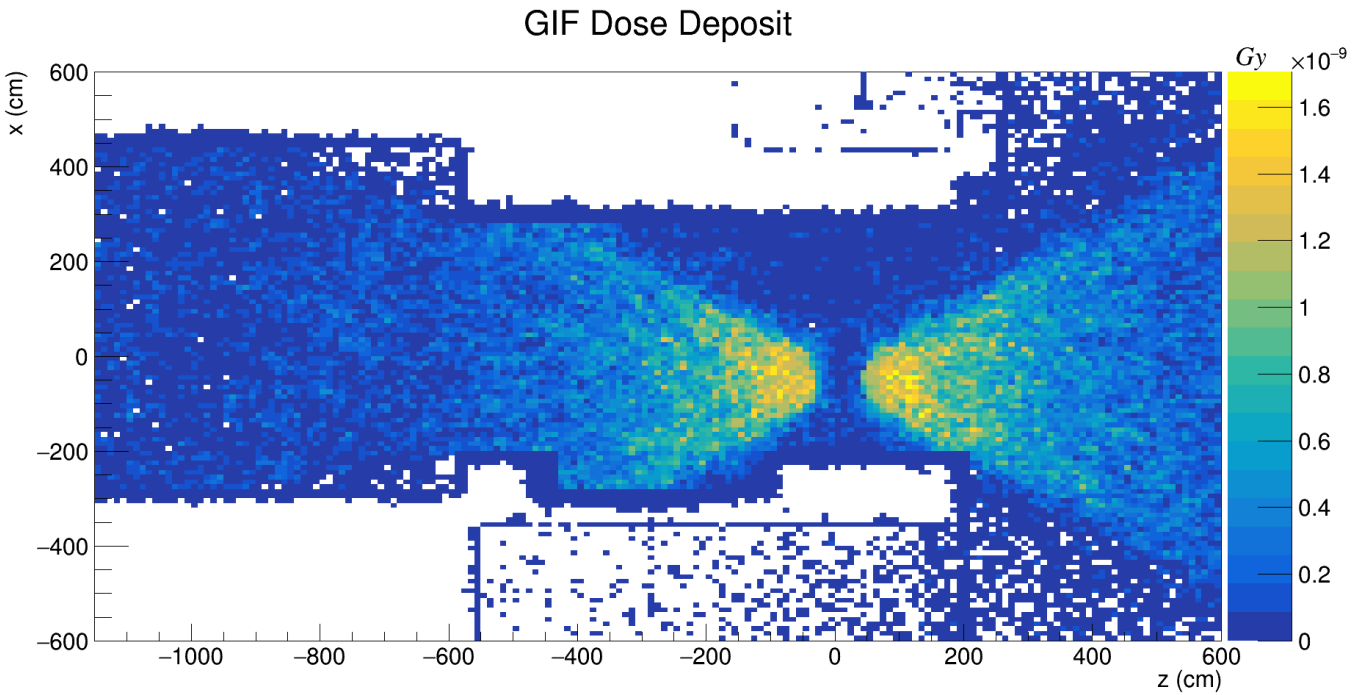


Box of 10 cm of size

Gamma flux and dose simulation (@ABS 1)

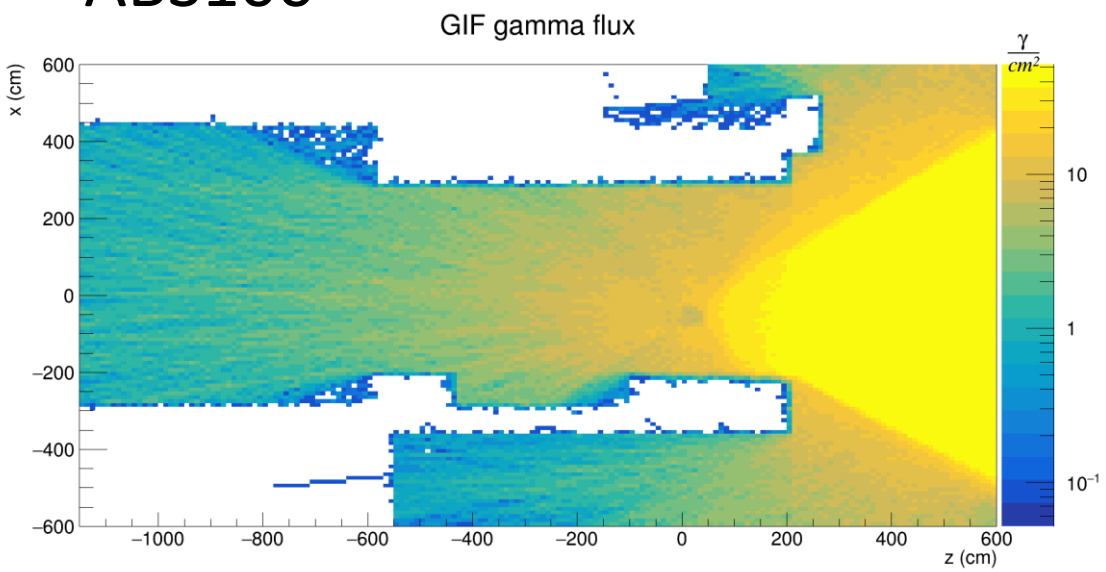


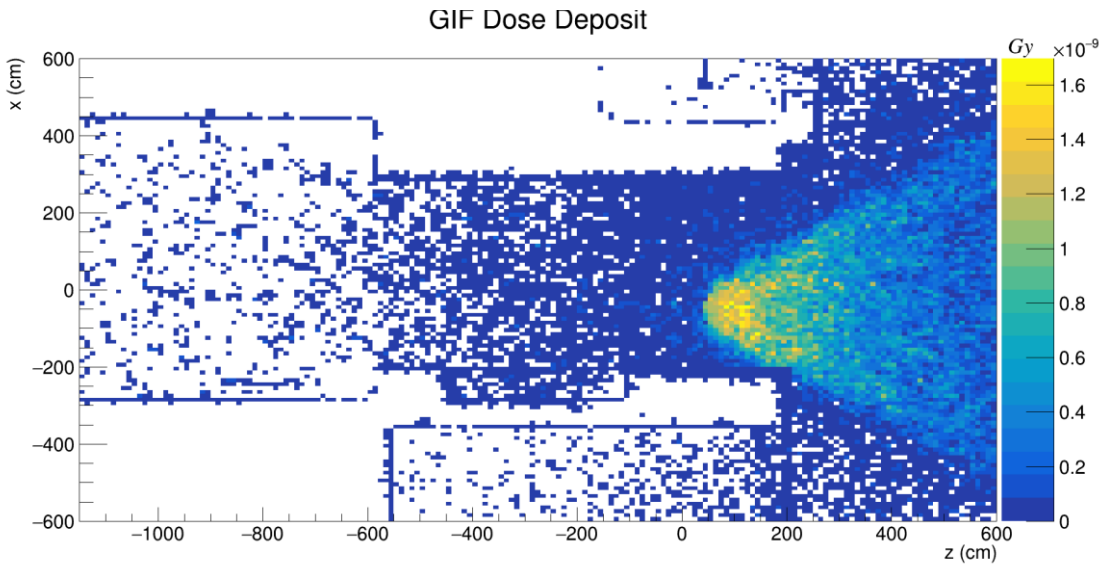




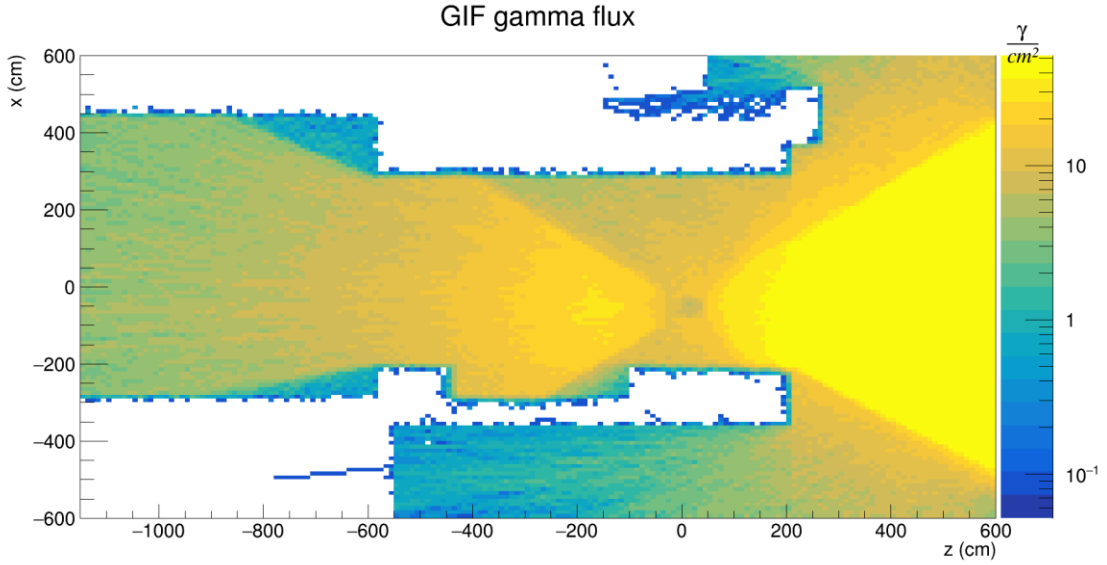
Gamma flux and dose simulation (ABS 100 and 10) UP stream region

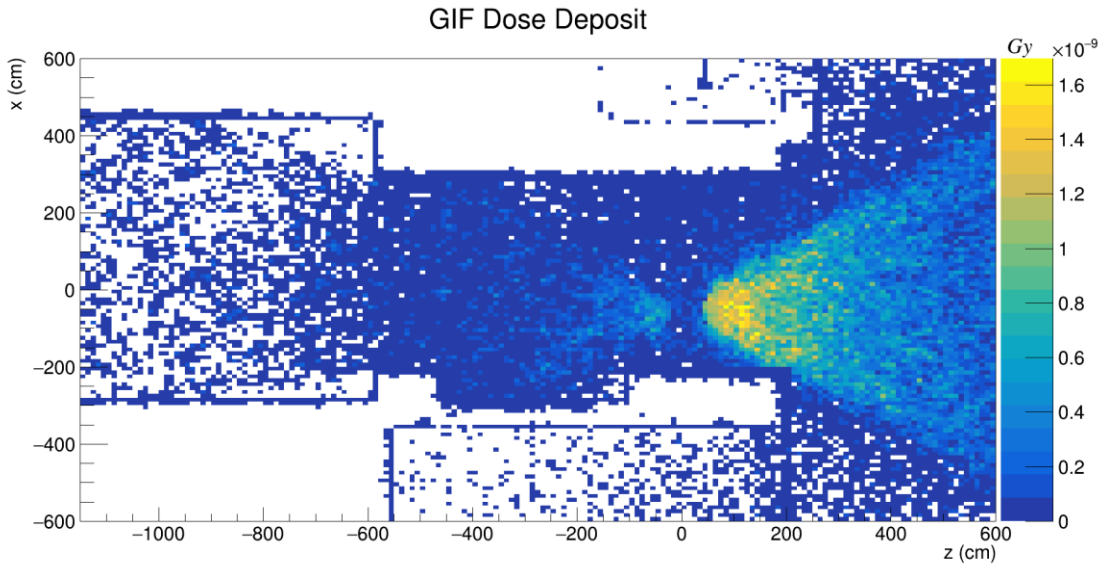
ABS100





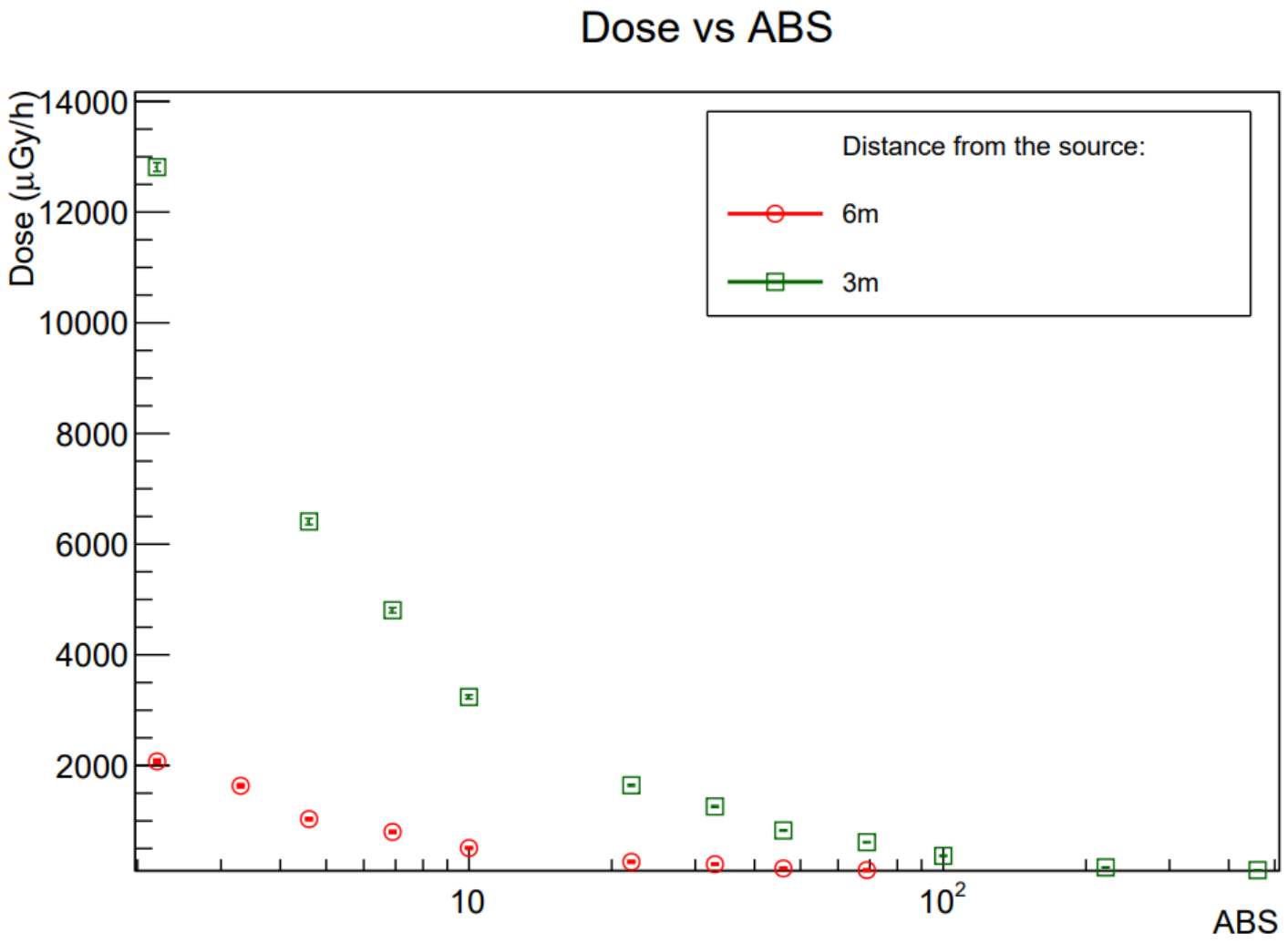
ABS10





Dose rate measurements by ECOgas@GIF++ Collaboration in 2021

- To validate the simulation, we used some dose campaign measurements performed in 2021 by the ECOgas@GIF++ collaboration and published [2].
- Two postions and several ABS were considered

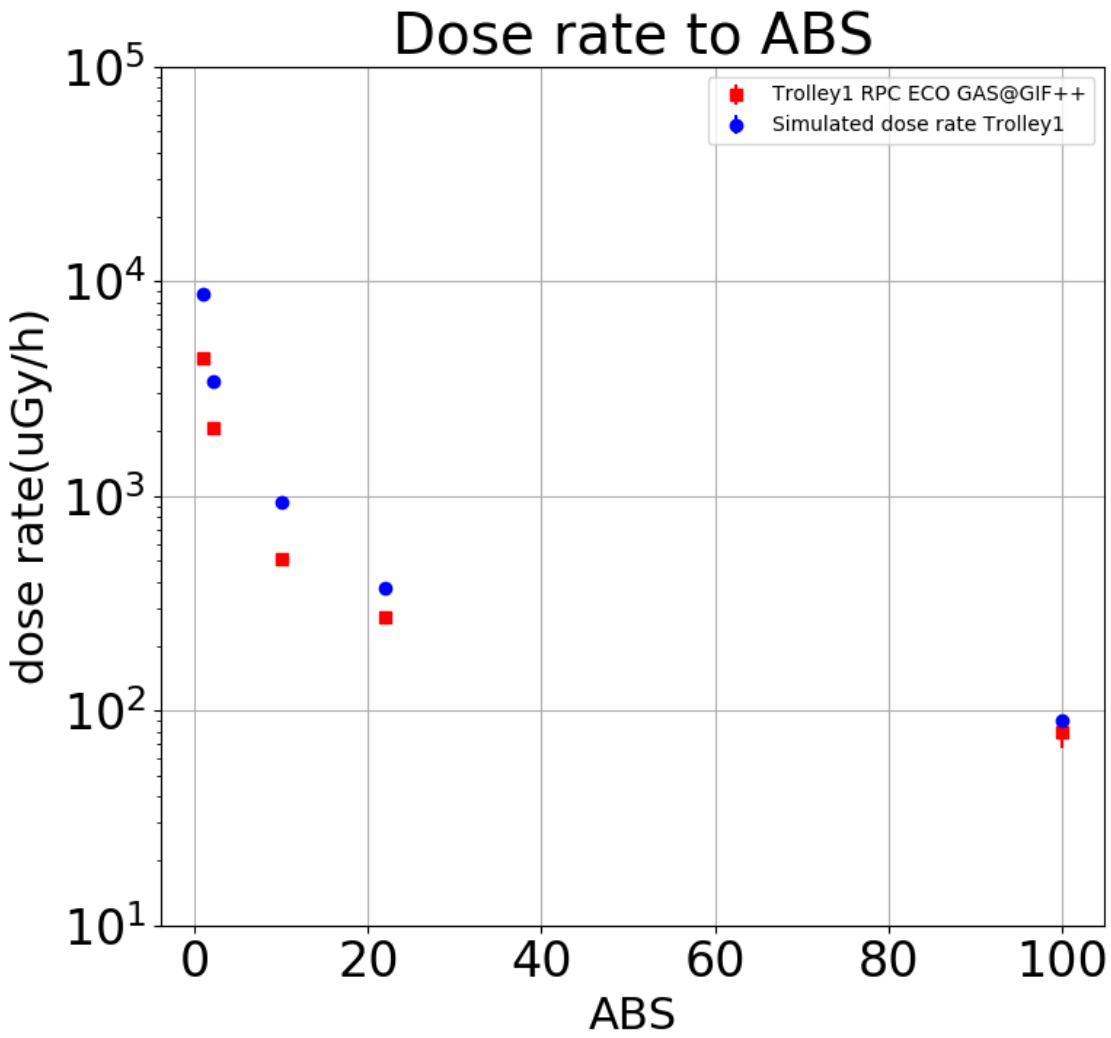


[2]High-rate tests on Resistive Plate Chambers operated with eco-friendly gas mixtures, RPC ECOGas@GIF++ collaboration,2023, https://doi.org/10.48550/arXiv.2311.08259

Simulation validation with data

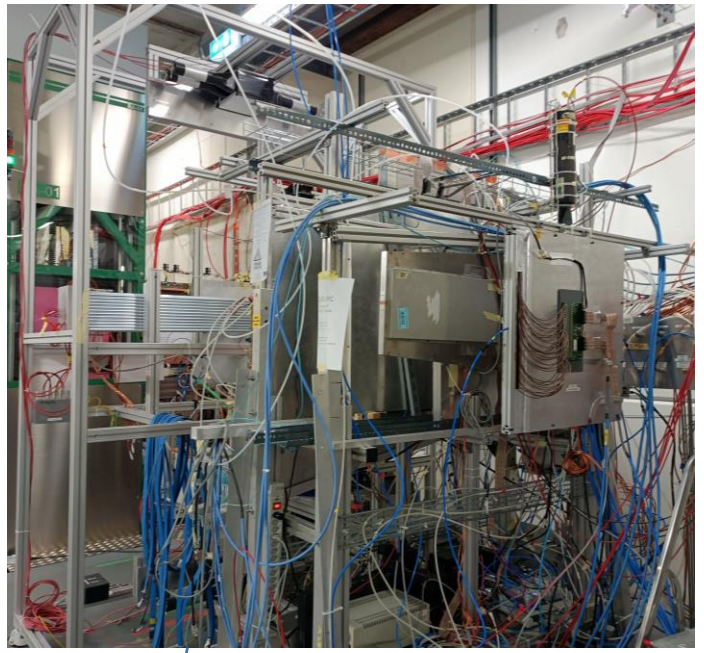
- For the validation the position at 6 m from source was considered
- Slightly discrepancies at lower ABS probably due to simulation setup

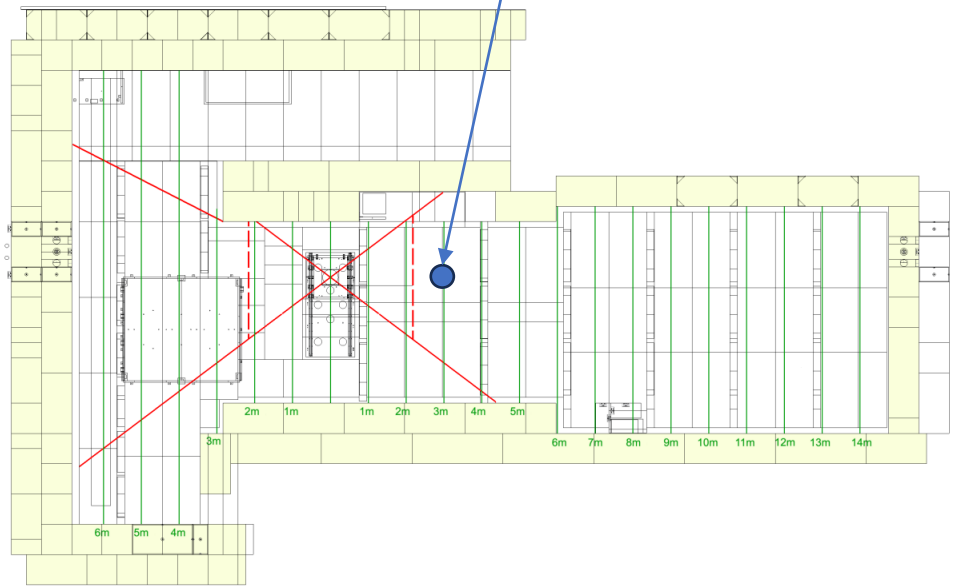
Note: the simulation is done in air **without detectors inside GIF++ bunker**



Next steps

1. Simulation of different detectors installed inside the GIF
2. Extensive dose campaign of measurements for further validation
3. Deeply study with different ABS **upstream and downstream** and analysis of influence of **backscattering** between Up stream and Down stream regions





Backup

Dose and Flux UPSTREAM for abs 10,100

Filter US100DS1

Position	Simulated Dose Rate	Simulated Flat Surface Current	Attenuation factor
Uc (-3m)	$0{,}6\,\frac{mGy}{h}$	$182\,\frac{10^3}{s * cm^2}$	37.
Ud (-6m)	$0{,}09\,\frac{mGy}{h}$	$91\,\frac{10^3}{s * cm^2}$	29.

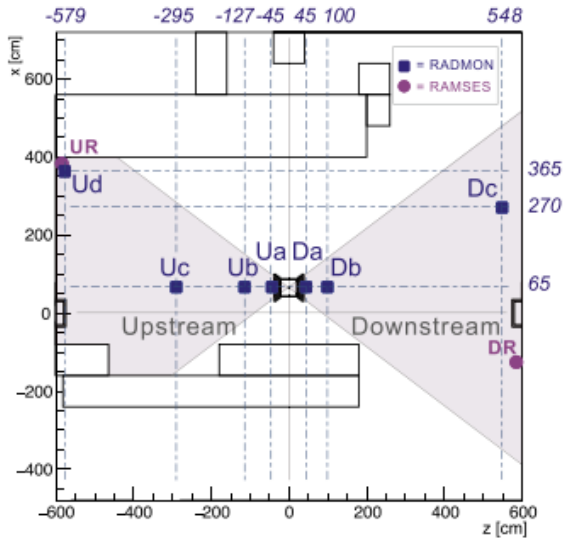
Filter US10DS1

Position	Simulated Dose Rate	Simulated Flat Surface Current	Attenuation factor
Uc (-3m)	$8{,}7\,\frac{mGy}{h}$	$75{,}5\,\frac{10^4}{s * cm^2}$	9,00
Ud (-6m)	$0{,}93\,\frac{mGy}{h}$	$32\,\frac{10^4}{s * cm^2}$	8,43

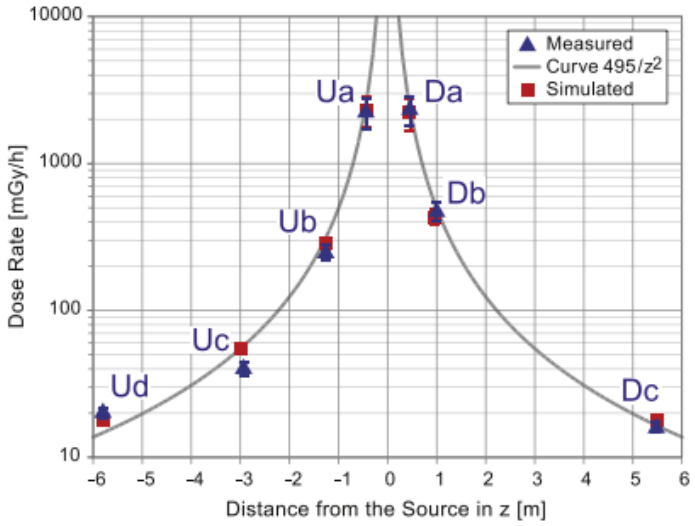
Dose comparison

New Rate Dose with detector $= \frac{69mGy}{h}$

Rate Dose $U_c = \frac{55mGy}{h}$



(a) RADMON measurement positions.



(b) Measured and simulated data.

Fig. 8. RADMON measurements of absorbed dose [mGy/h].

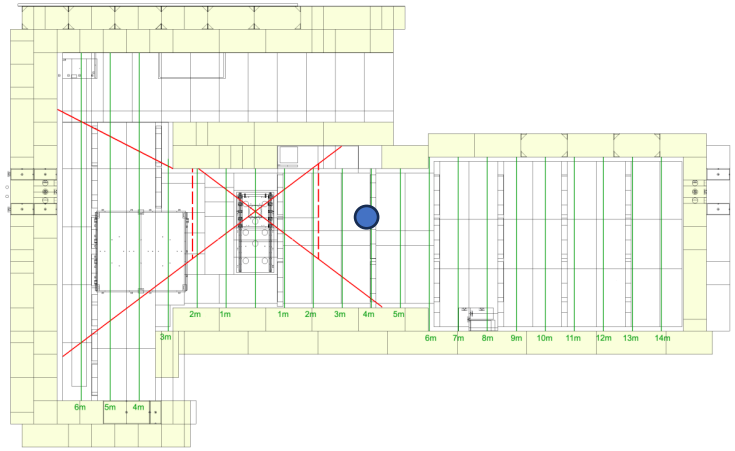
Dose calculation

Simulation with SD in AIR : 1,35*10^{-11} Gy

Calculation of time:

1*10^{7} gamma correspond to $\frac{N}{A}$

$$= \frac{1 * 10^{7}\ gamma}{14 * 10^{12}\ Bq} = 0{,}07 * 10^{-5} s$$



Calculation of Rate Dose:

Rate Dose: $\frac{1{,}35*10^{-11}\ Gy}{0{,}07*10^{-5} s} = 19{,}3 * \frac{10^{-6} Gy}{s} =$

$$69{,}4\ * 10^{-3} Gy/h$$