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ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

Upgrade of the GIF++ Radiation Field Simulation

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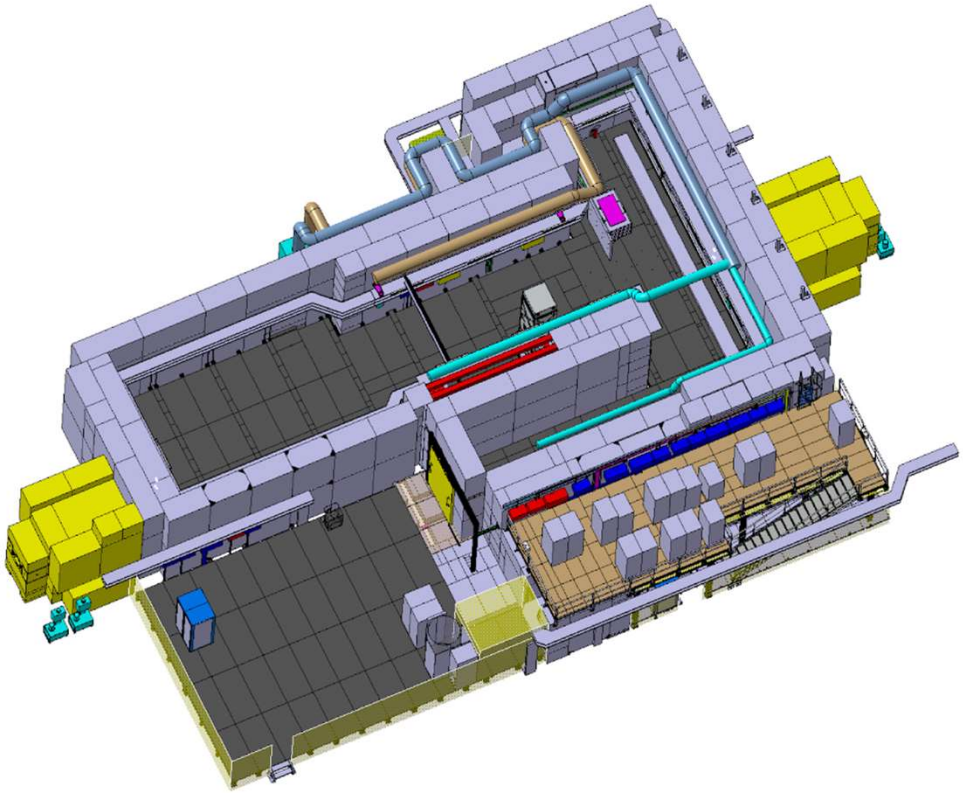
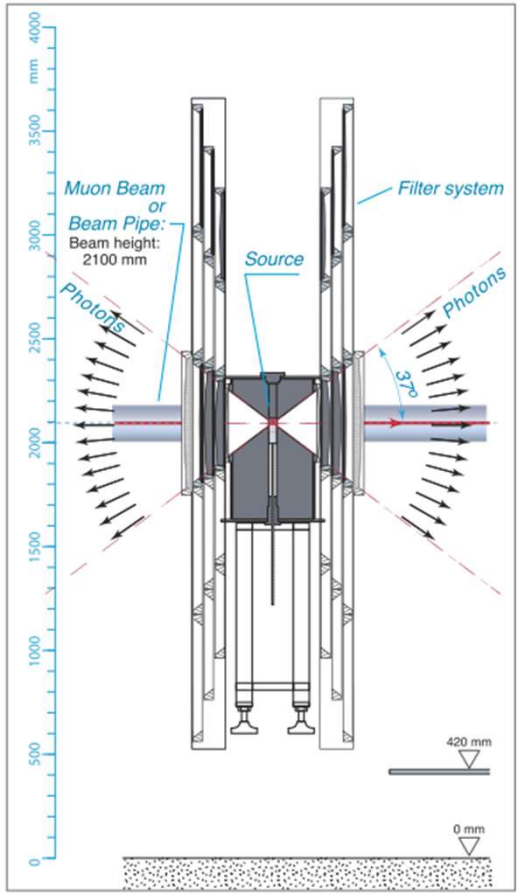
CMS Compact Muon Solenoid
GIF++
de' remi facemmo ali 1990 POLITECNICO DI BARI
Politecnico di Bari
INFN BARI

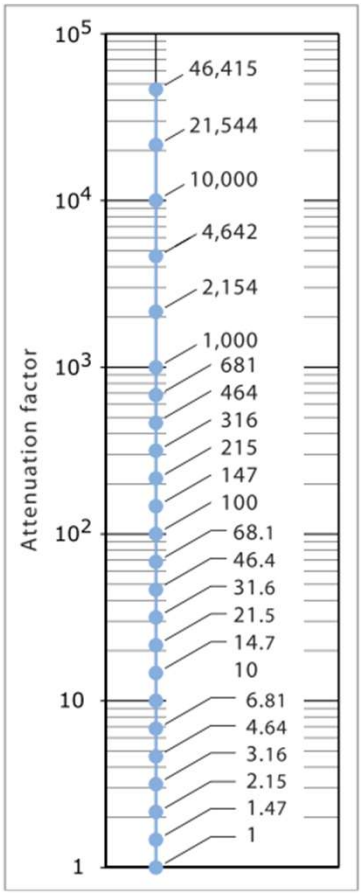
The GIF++ facility @ CERN

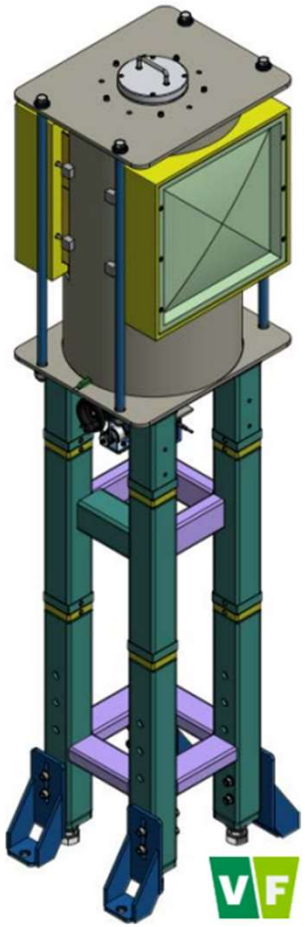
1. Source of ^{137}Cs of 662 keV photons at 11.5 TBq (January 2024)
2. Beam from SPS (muons)
3. Intensity controlled by a combination of attenuation filter
4. Field shaped from point-like to planar
5. Gas and electronics infrastructures
6. Unified control/monitoring system
7. Setups for beam & cosmic trigger, radiation monitoring, environmental monitoring, DAQ,…



Gamma Filters







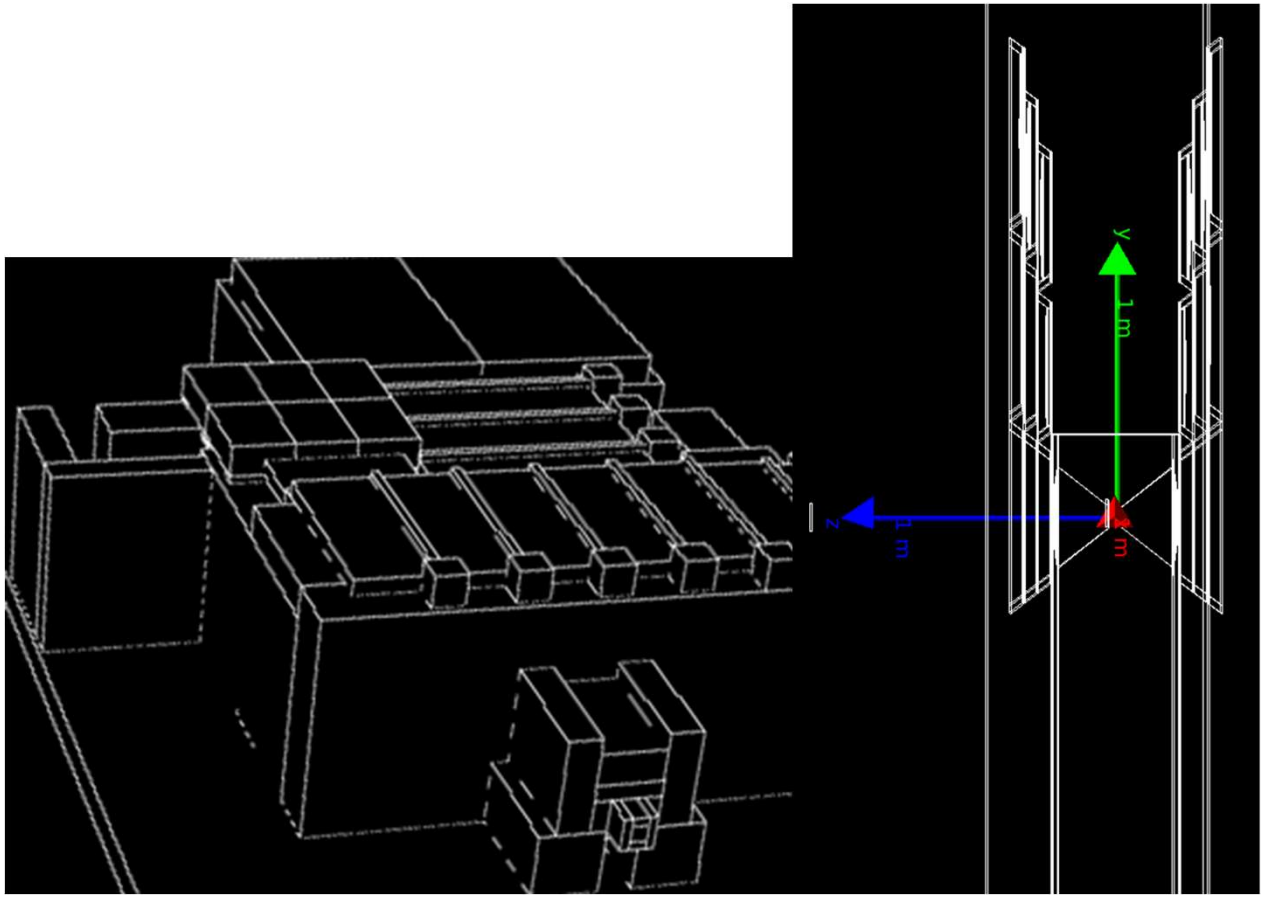
Array of 3 × 3 convex lead attenuation filters, to fine tune the photon flux for each irradiation field individually, upstream (UP) and downstream field (DOWN)

Systems of movable lead attenuators for large irradiation zone that allows attenuation factors (ABS) between 1 and 46420 in several steps

Simulation layout

New GDML Gif++ layout implemented for Geant4

1. Geometry updated to 15 m upstream
2. Version Geant4-11.0
3. Physics List- G4EmLivermorePhysics
4. Filter implementation: mounted on aluminum support plates, the filters are positioned inside steel frames, as collimators.
5. NO EXPERIMENTAL INSTALLATION INCLUDED IN THE SIMULATION LAYOUT



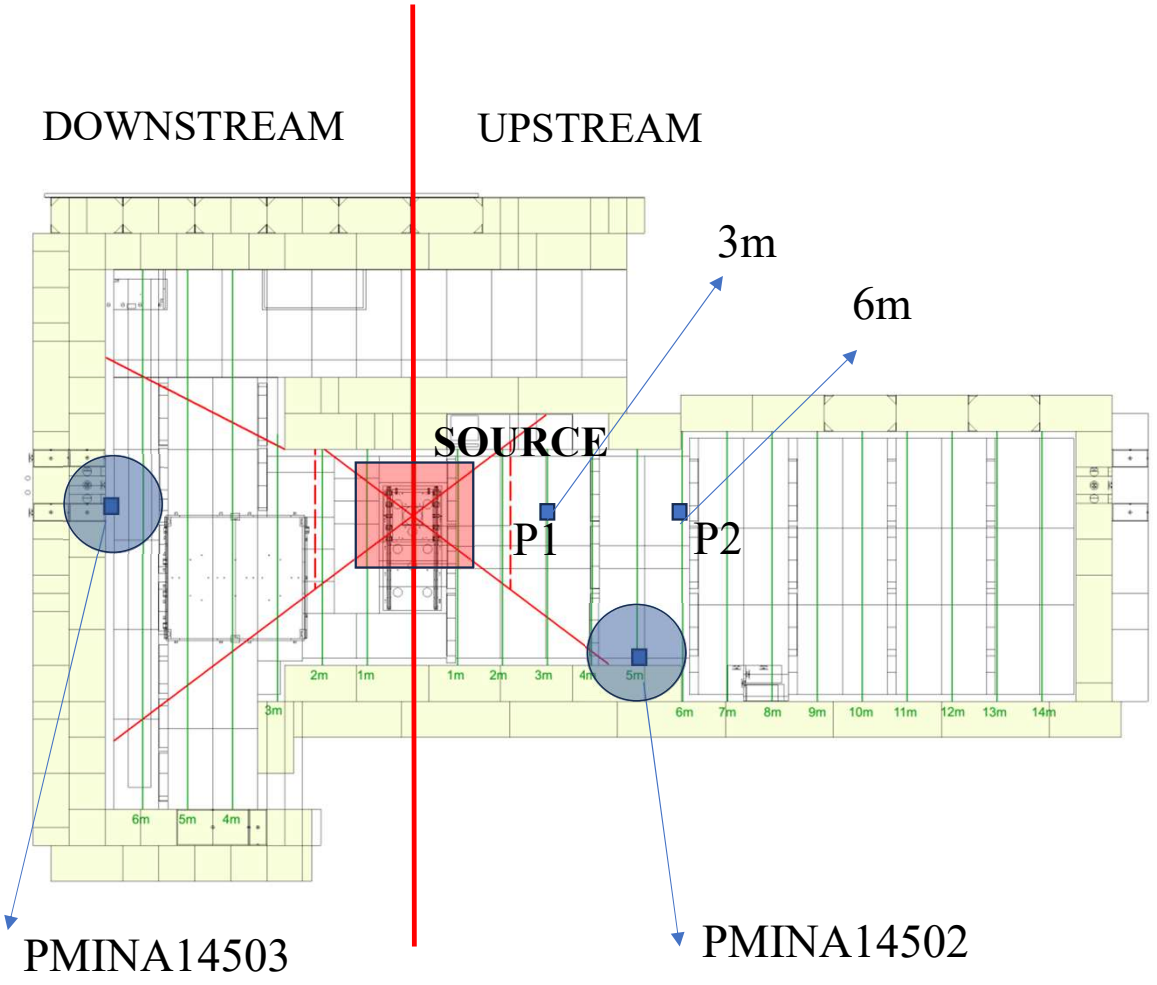
Simulation validation

- Two detectors (PMINA) are installed in the bunker at fixed position for dose rate measurements. PMINA are ionization chambers with a calibrated measurement range of 5 μSv/h–500 mSv/h.

- Measured dose rate is compared with simulation results at different filter set-up

- Additional ECOGAS measurements in points P1 and P2 are compared with simulation

- In each point a sensitive volume of TISSUE was considered in the simulation.



Ambient dose equivalent rate calculation

PROCEDURE:

Simulation of tissue equivalent phantom divided into 8 voxels

Simulated voxel dose **D(Sv)**

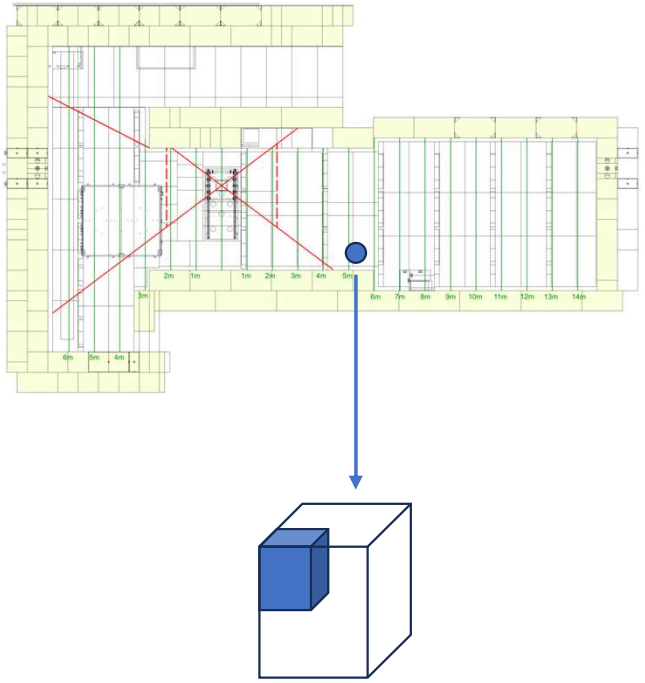
Source activity **A = 11,5 TBq**

Generated gammas $N_\gamma = 2\ 10^7$

Reference time **T (s)** $= \frac{N}{A} = 0{,}174 * 10^{-5}\ s$

Rate Dose $= \frac{D}{0{,}174 * 10^{-5}} * 3600 \frac{Sv}{h}$

Error calculation based on standard deviation of dose among different voxels.



PHANTOM 20x20x20 cm3
Subdivided in 8 voxel

Extraction of PMINA experimental data

PMINA data available at:

https://timber.cern.ch/

Data and Time Dose rate value

18/04/24 10:33	0,0013967800
18/04/24 10:34	0,0013973500
18/04/24 10:35	0,0013957100
18/04/24 10:36	0,0013973200
18/04/24 10:37	0,0013961900
18/04/24 10:38	0,0013969200
18/04/24 10:39	0,0013967000
18/04/24 10:40	0,0013968100
18/04/24 10:41	0,0013970500
18/04/24 10:42	0,0013972400
18/04/24 10:43	0,0013972800
18/04/24 10:44	0,0013969400
18/04/24 10:45	0,0013973900
18/04/24 10:46	0,0013970200
18/04/24 10:47	0,0013963100
18/04/24 10:48	0,0013973500
18/04/24 10:49	0,0013963900
18/04/24 10:50	0,0013970100
18/04/24 10:51	0,0013956900
18/04/24 10:52	0,0013970700

Search in GIF database, https://epdt-rd-monitoring.web.cern.ch/

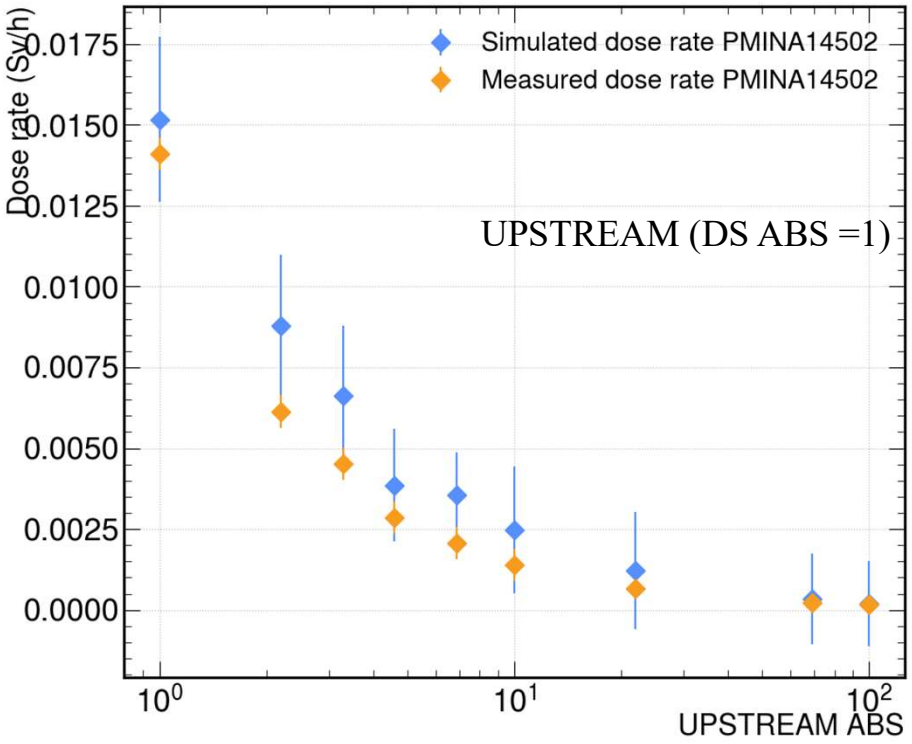
ABS values for the choosen data and times

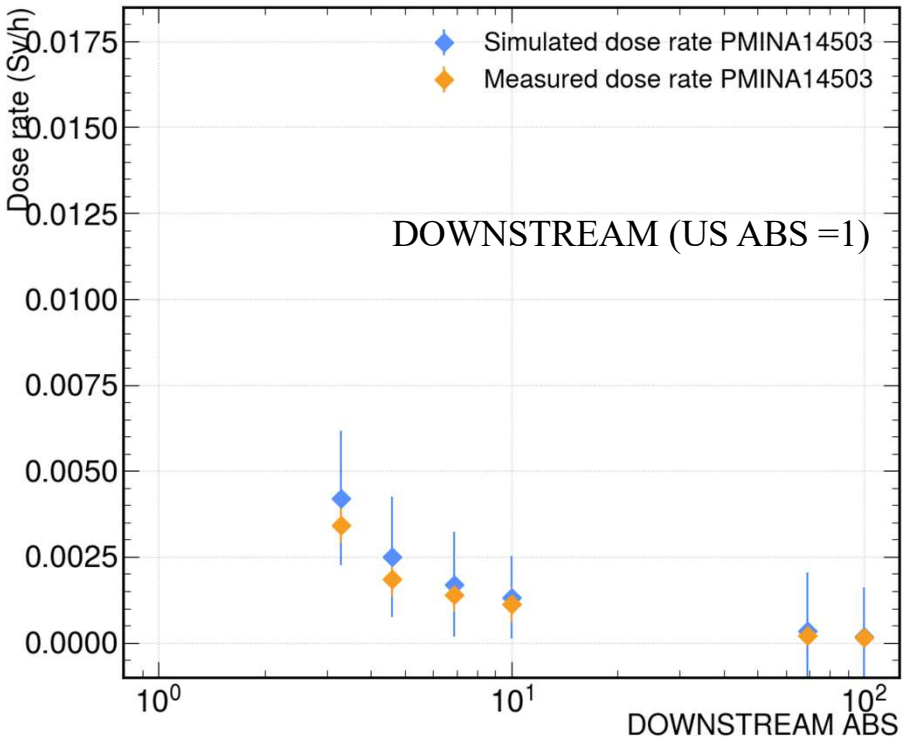
Data and Time ABS value

18/04/2024 12:55	10,0000000
18/04/2024 13:00	10,0000000
18/04/2024 13:05	10,0000000
18/04/2024 13:10	10,0000000
18/04/2024 13:15	10,0000000
18/04/2024 13:20	10,0000000
18/04/2024 13:25	10,0000000
18/04/2024 13:30	10,0000000
18/04/2024 13:35	10,0000000
18/04/2024 13:40	10,0000000
18/04/2024 13:45	10,0000000
18/04/2024 13:50	10,0000000
18/04/2024 13:55	10,0000000
18/04/2024 14:00	10,0000000
18/04/2024 14:05	10,0000000
18/04/2024 14:10	10,0000000
18/04/2024 14:15	10,0000000
18/04/2024 14:20	10,0000000
18/04/2024 14:25	10,0000000
18/04/2024 14:30	10,0000000
18/04/2024 14:35	10,0000000
18/04/2024 14:40	10,0000000

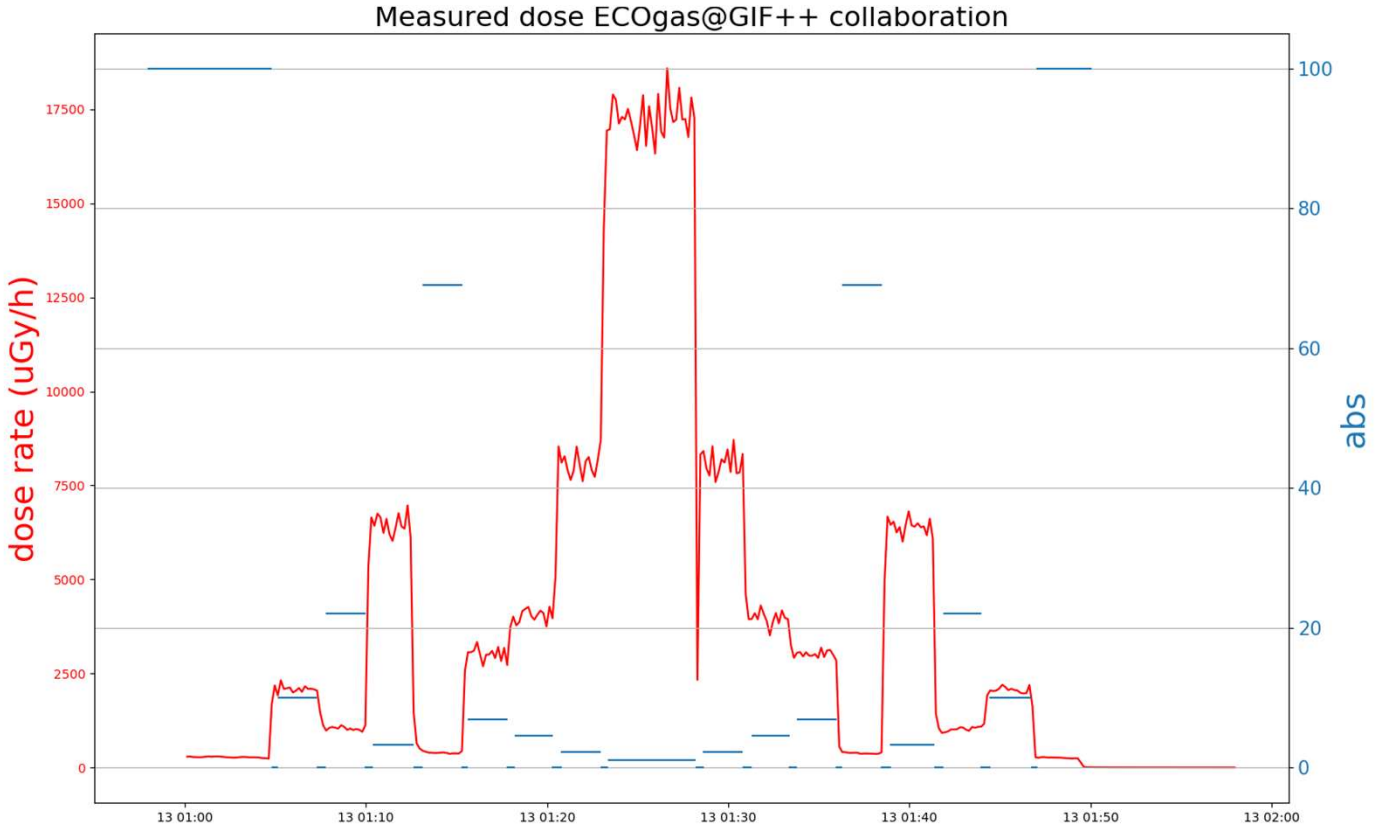
Gamma dose validation with PMINA dosimeters

- Upstream and Downstream validation
- **Simulated and measured values (test beam campaign 2024) in agreements inside error margin**
- NO SHADOW from experimental set-up on the PMINA response





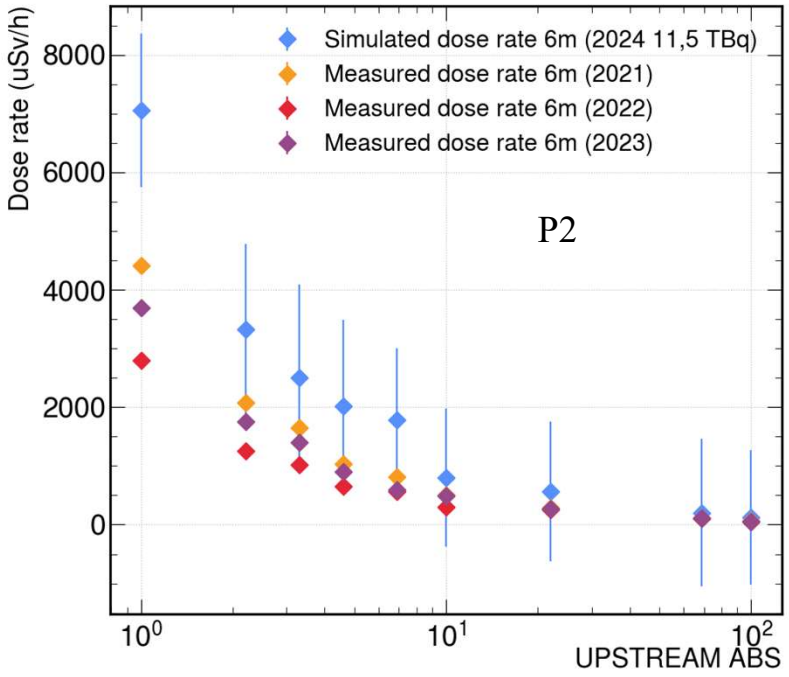
Dosimeter data from ECOGAS

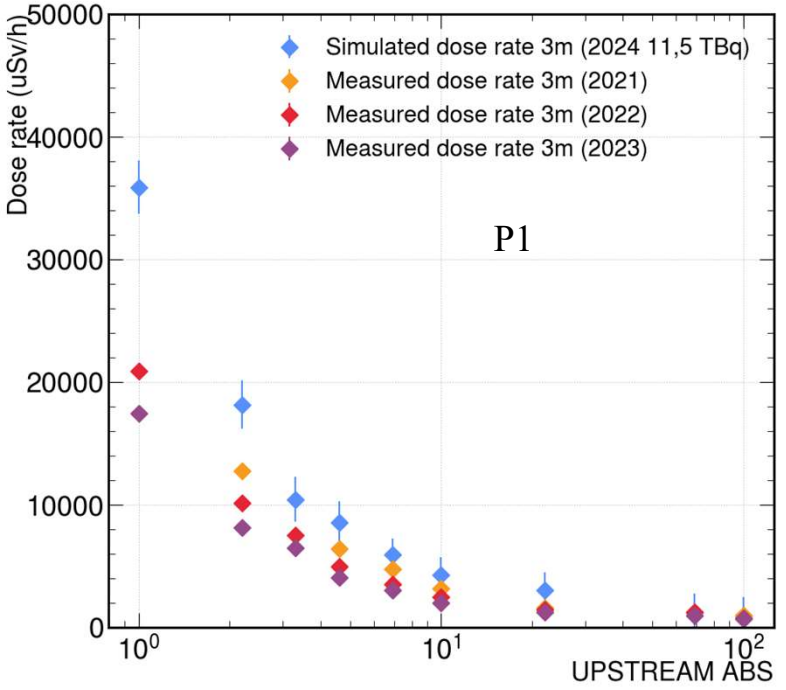


- Ecogas measurement at Trolley position P1
- Dose rate and ABS are shown
- Dose rate is the mean of experimental data for every ABS value
- Data from 2023

Dose rate comparison

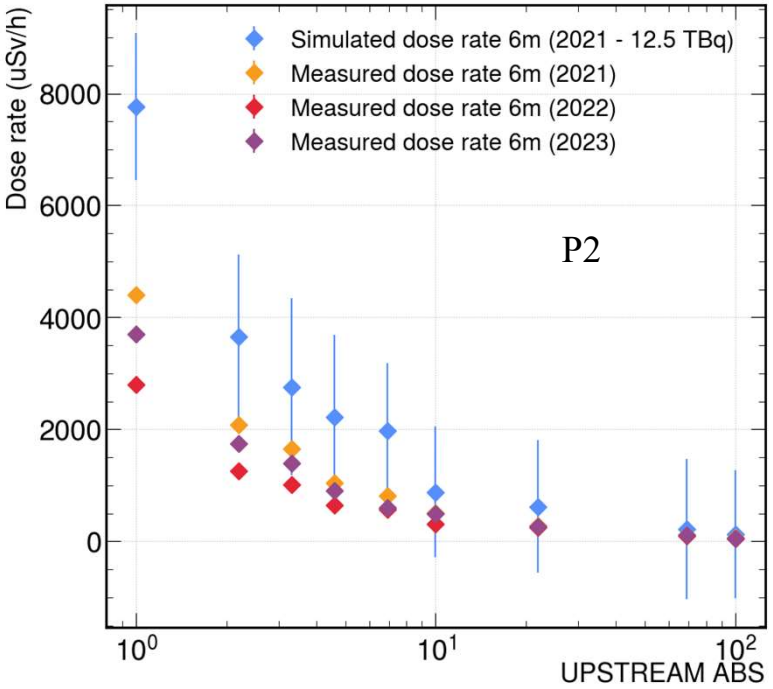
- Comparison at P1 and P2 with data provided by ECOGAS@GIF++ collaboration measured during 2021-2022-2023
- **Difference in dose rate due to presence of mechanical structure and setups in the bunker and difference of source activity**
- Comparison assuming activity of 11,5 TBq

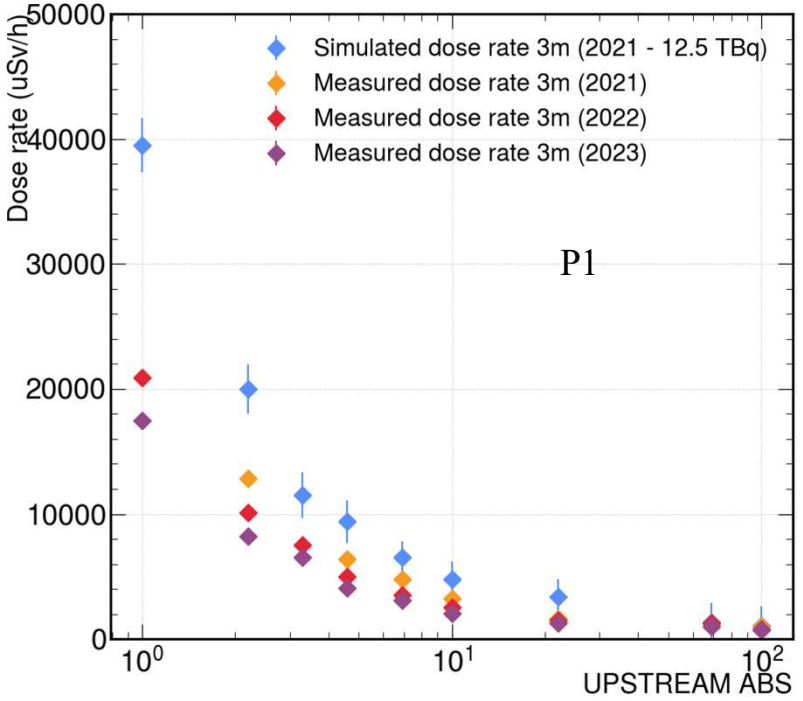




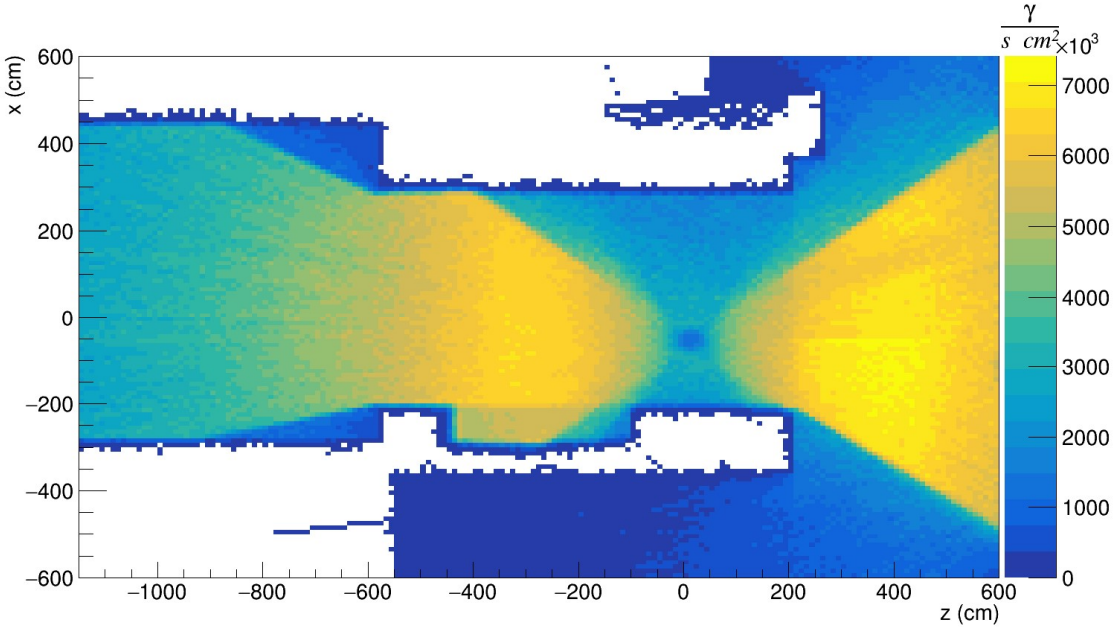
Dose rate comparison taking into account change of activity

- Comparison at P1 and P2 with data provided by ECOGAS@GIF++ collaboration measured during 2021-2022-2023
- Comparison assuming activity of 12,5 TBq (2021)





Gamma Flux estimation



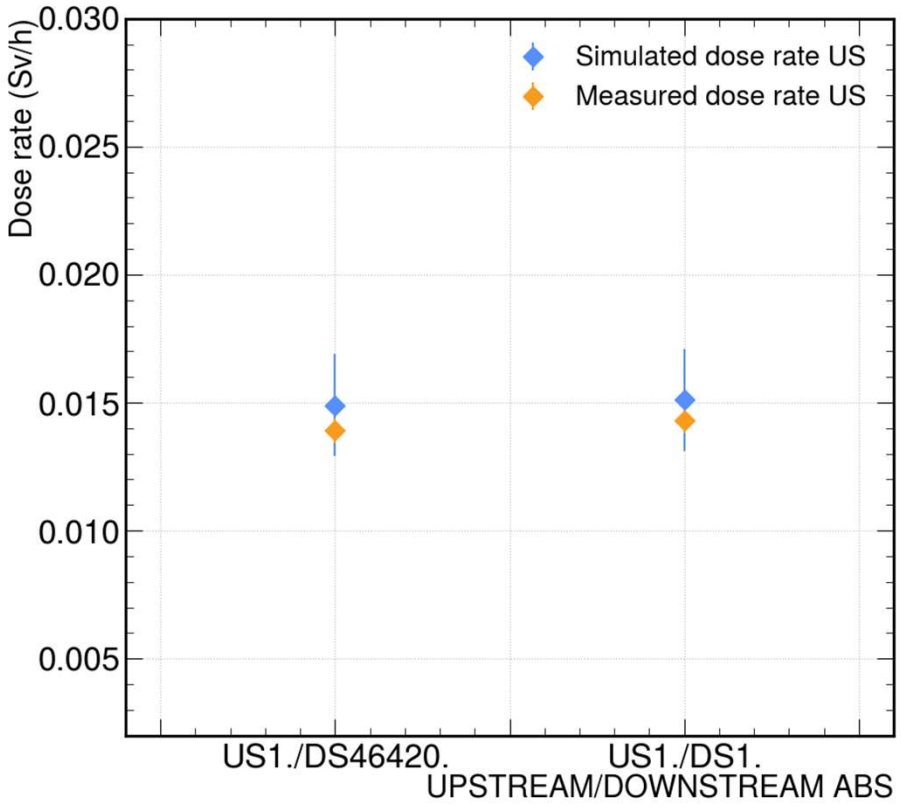
At ABS 2.2

Around 6 10^6 gamma/ s cm2

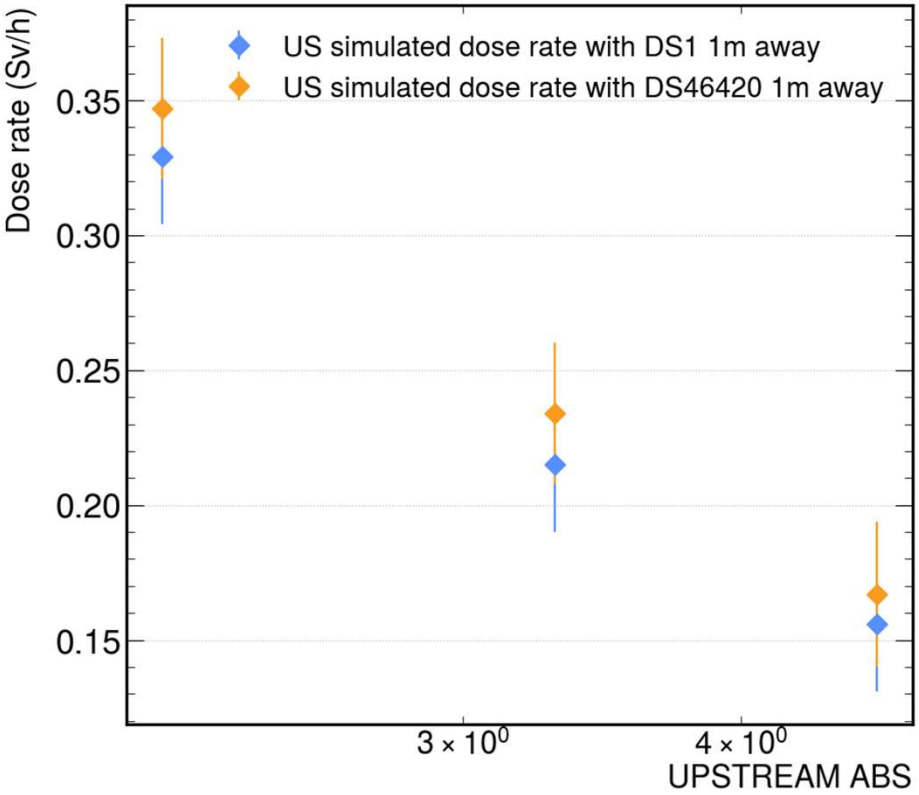
Estimated gamma from plot at 3m from the source

Backscattering study

Dose rate of PMINA detectors used for backscattering measure, no evident difference



Simulation at 1m for backscattering investigation with 2.2 , 3.3 and 4.6 filters



Conclusions and Next steps

1. The simulation has been validated by the comparison of the dose rate with the measurements done with PMINA sensors
2. The validated simulation provides results in agreement with the measured dose rate taken at 6 m and 3 m from the source.

1. The simulation tool can be enriched including all detectors installed inside the GIF.
2. Extensive dose campaign are planned to improve the simulation validation
3. Increase number of generated gammas to improve precision

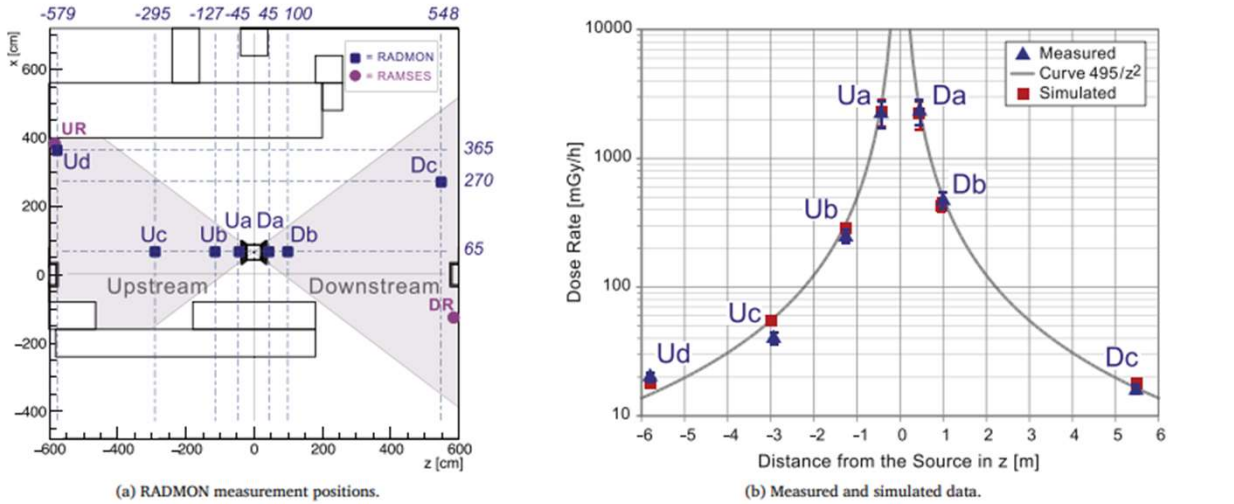
THANKS

Backup

Dose comparison

New Rate Dose with detector $= \frac{37mGy}{h}$

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].

State of Art

- Since 2014 the Gamma Irradiation Facility at CERN is extensively used for: Eco-gas, longevity and R&D detector studies involving several Detector technology: DT, MDT ,CSC ,RPC, iRPC, GEM…

- One simulation study is available (without detectors) done on by Pfeiffer Dorothea. She developed simulation Software in GEANT4-10.0 to simulate GIF++ radiation background: "**The radiation field in the Gamma Irradiation Facility GIF++ at CERN"** [1]

- New bunker geometry was implemented in 2018 → new simulation work is needed

- 8 – 09 - 2020 dose activity measure 12.15 TBq

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