HSE-RP measurements on the HL-LHC RFD CM: preliminary results

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Experience from RFD CM tests at CERN II – 04/07/2024

HSE
Radiation Protection

With valuable inputs/discussion from:
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Pierre Carbonez (HSE-RP-DC)

Context and motivation

- RF cavities present an important radiation source both during the conditioning and during normal working conditions.
- The production of radiation is mainly caused by field emission of electrons from small impurities on the cavity surface.
- Two electron sources may be distinguished:
  i. a high intensity source of low energy electrons mainly producing transverse bremsstrahlung X-rays
  ii. a low intensity source of high energy electrons travelling parallel to the cavity axis and generating X-rays emitted along the axis → more important due to the much higher energy to which electrons can be accelerated to, up to the maximum field of the cavity.
- When these electrons strike the cavity walls or any other material, they produce intense bremsstrahlung radiation.

Silari et al., Nuclear Instruments and Methods in Physics Research A 432 (1999) 1-13

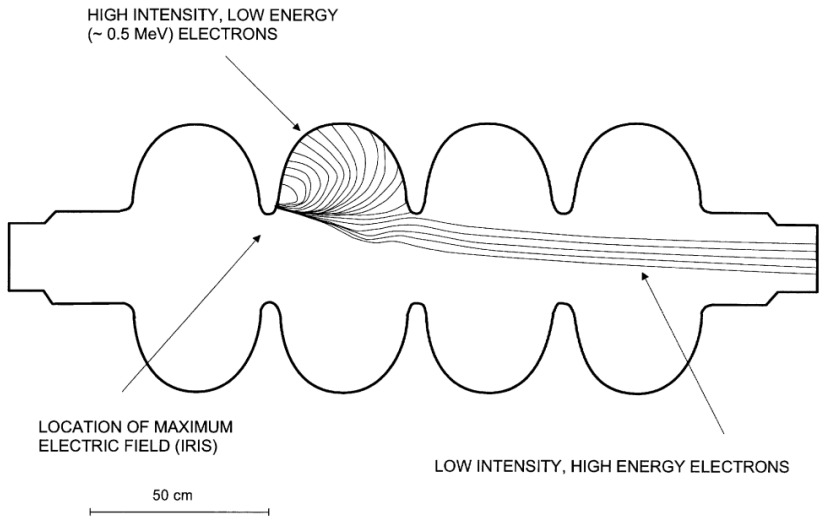


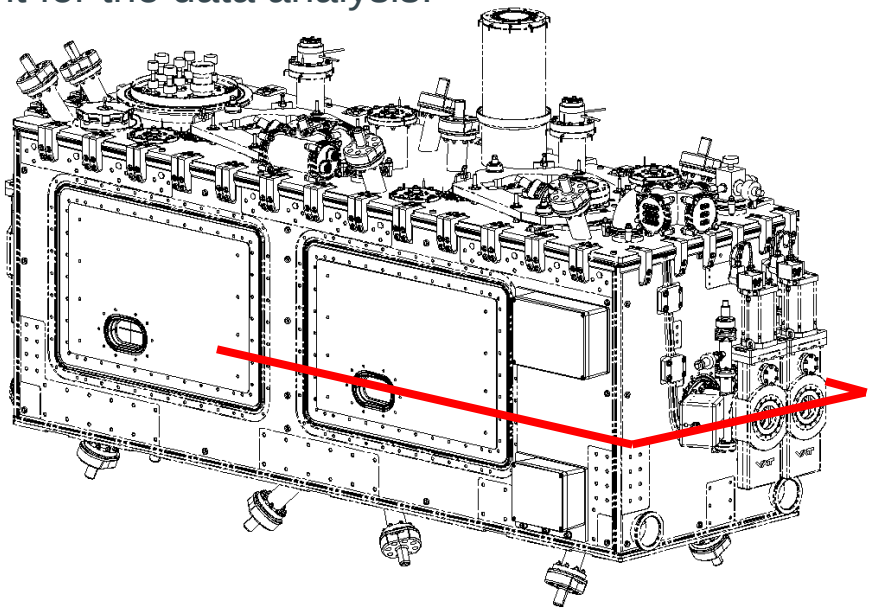
Fig. 1. Qualitative representation of trajectories of electrons produced by field emission and accelerated in the superconducting cavity.

Context and motivation

- HL-LHC crab cavities in Point 1 and Point 5 may limit the accessibility of the LSS during commissioning.
- An exclusion zone shall be defined and a potential modification to the LASS may be foreseen → active discussion between HSE-RP, HL-LHC PSO, WP4, EN-AA , and more.
- FLUKA simulations are a powerful tool, however, at present, RF cannot be directly simulated without the knowledge of the electron space/energy distribution within the cavity.
- Empirical formulas/models providing the electron current density (Fowler–Nordheim model) or the emitted photon spectrum can be found in literature. However, these models not always provide reliable results.
- A simple linear source (max. e^- energy) can provide a conservative envelope case; however, a scaling factor is needed to renormalize FLUKA simulations to a representative emission field.
- RP measurements in SM18 (RFD CM) can provide a good starting point.

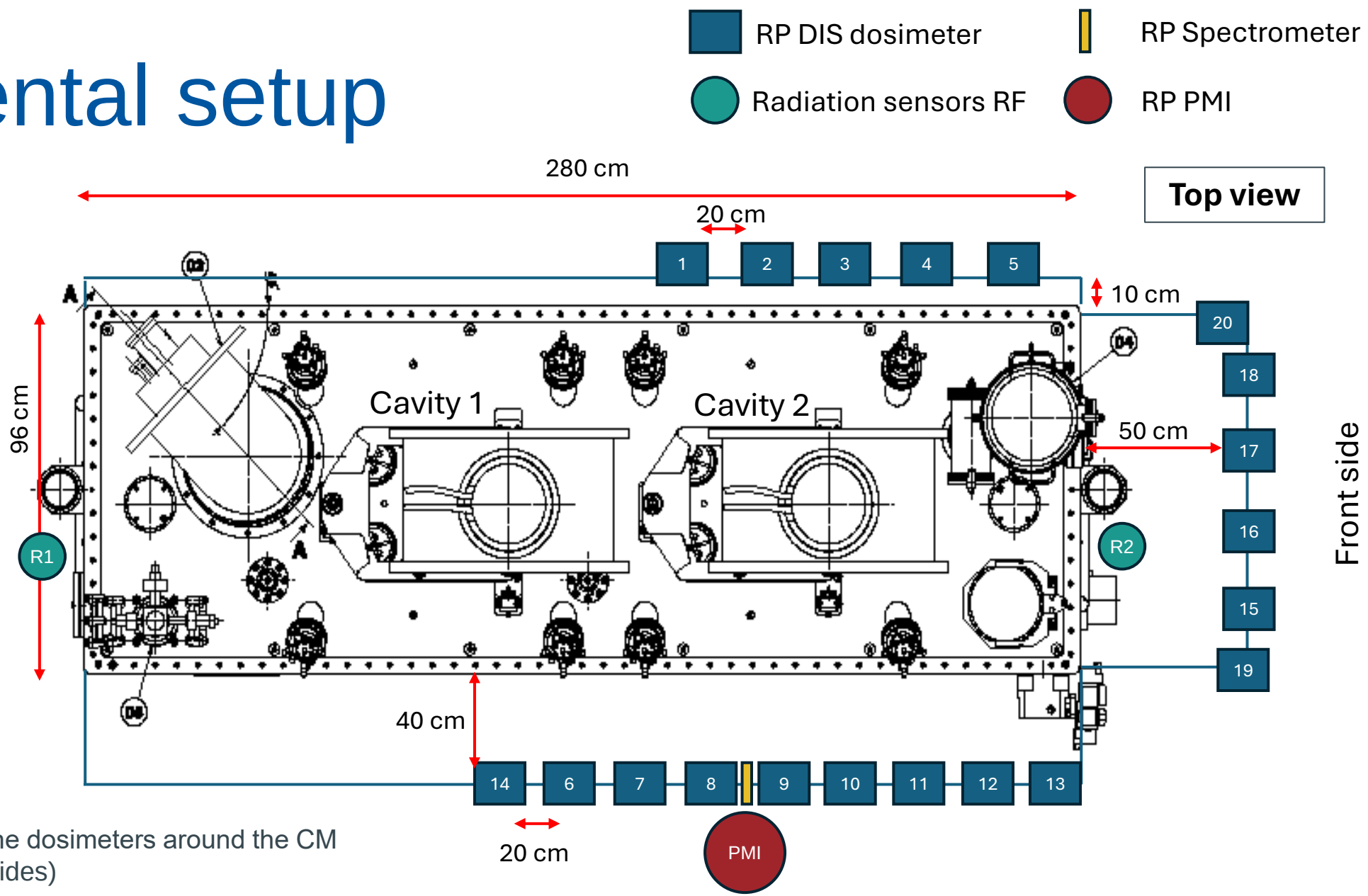
Experimental setup

- Measurements performed in the SM18 – M7 bunker, between 08/04/2024 to 14/06/2024 (67 days).
- 20 DIS dosimeters, calibrated in H*(10) and provided by HSE-RP-DC, have been used.
- The dosimeters have been numbered and read before installation (background measurement).
- NB: these are passive dosimeters, i.e. it is not possible to monitor online the cumulated dose → relevant for the data analysis!
- Passive dosimeters installed at "beam height", all around the CM (see next slides) + PMISMM71 + spectrometer.
- NB: only one cavity (cavity #2) was operational during the test, due to non-conformities discovered during tests in Oct 2023 → relevant for the data analysis!



Experimental setup

Dosimeter	Distance (cm)	Height (cm)
1-5	10	100
6-14	40	100
15-18	50	100
19	62	115
20	40	115

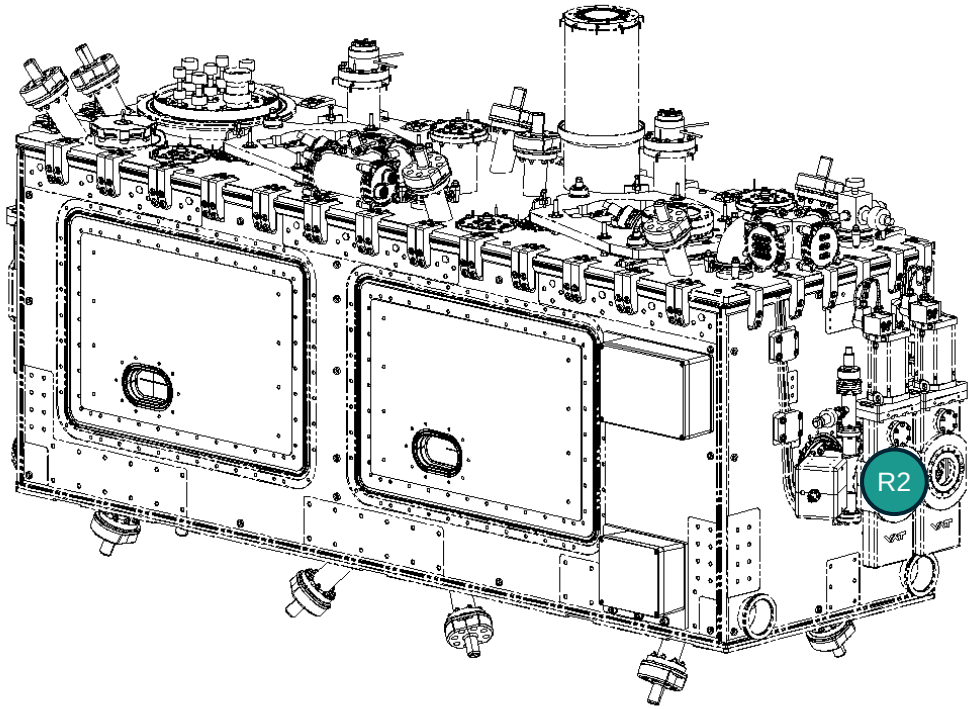


- Supports used to “hang” the dosimeters around the CM (see pictures in the next slides)

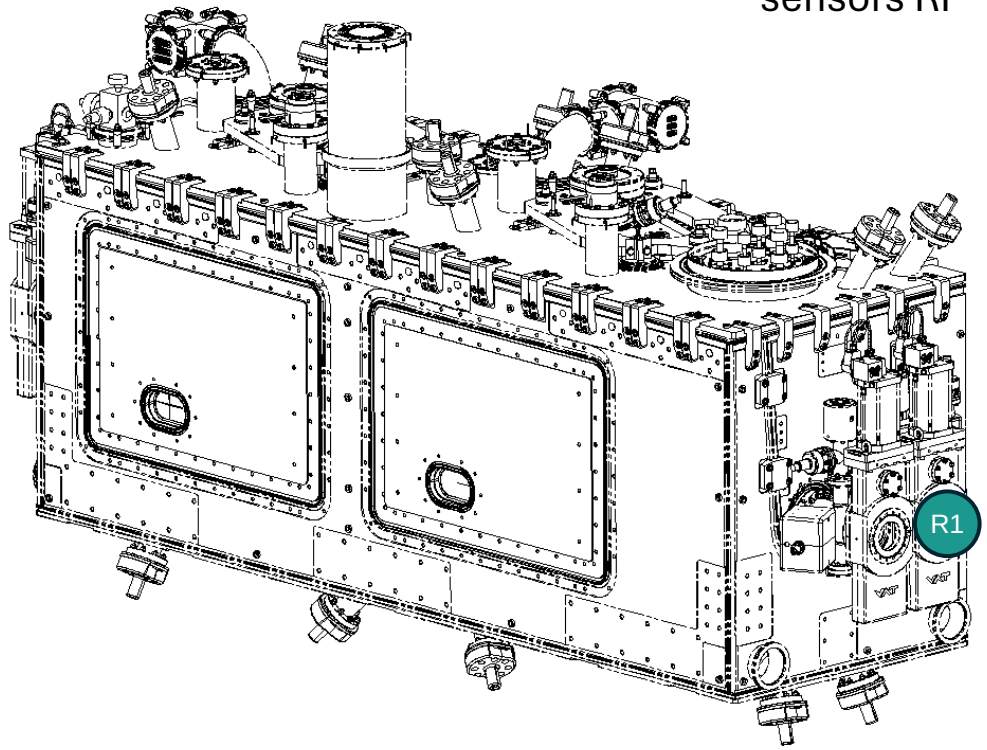
Experimental setup

R1 R2

Radiation sensors RF

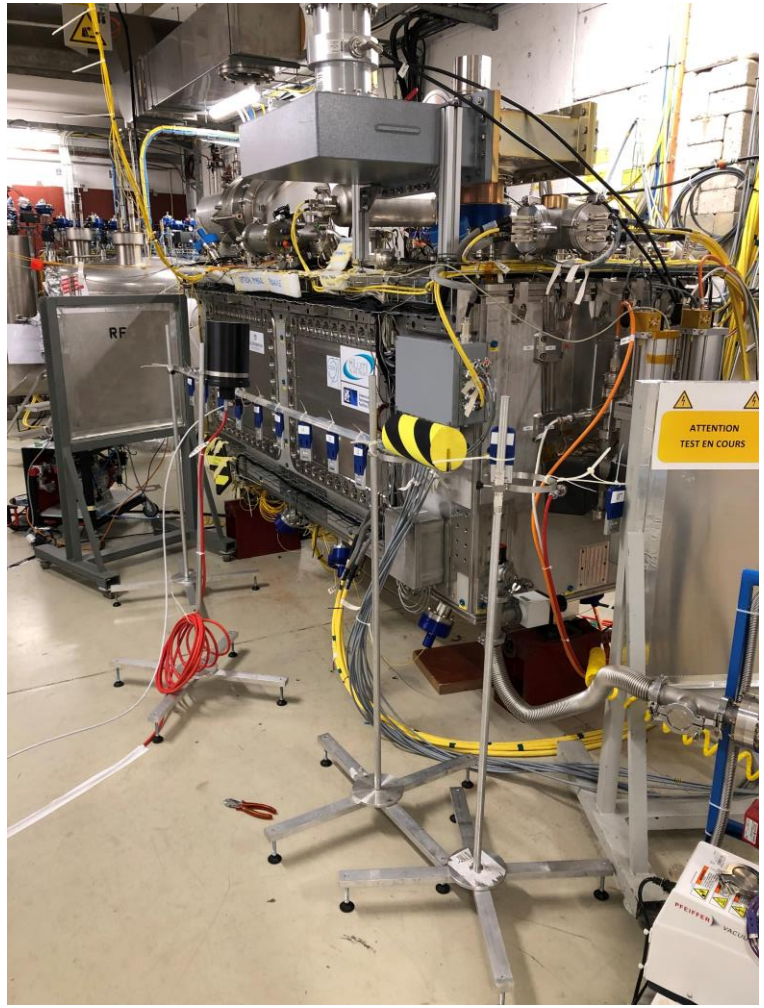


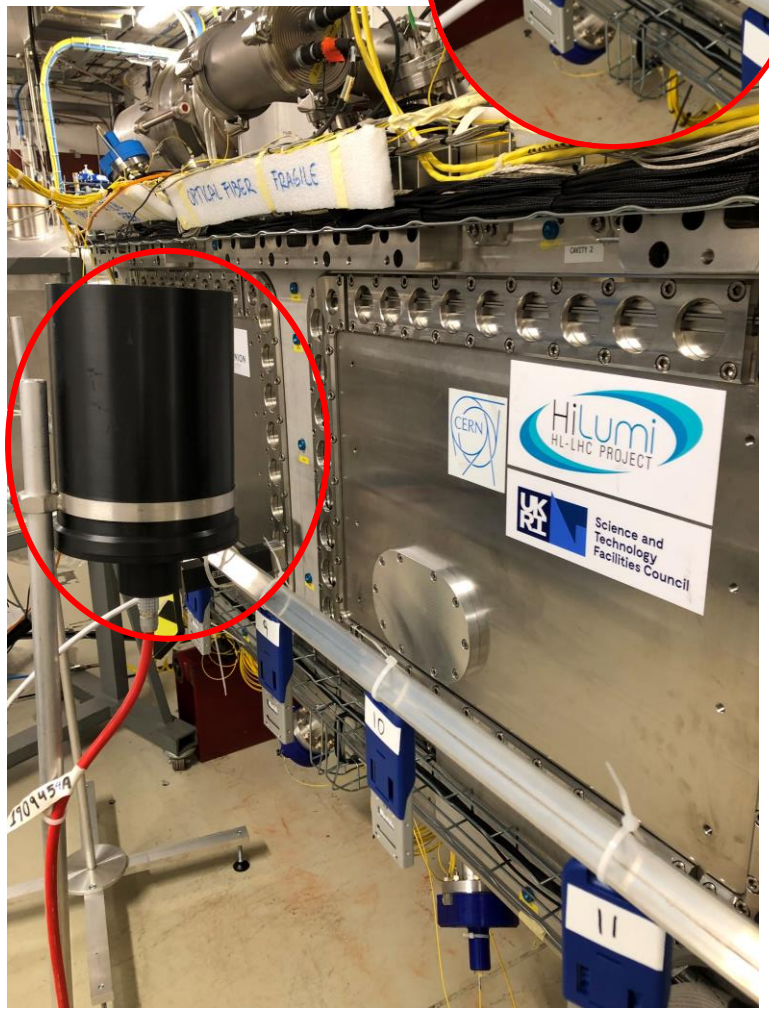
Front isometric view

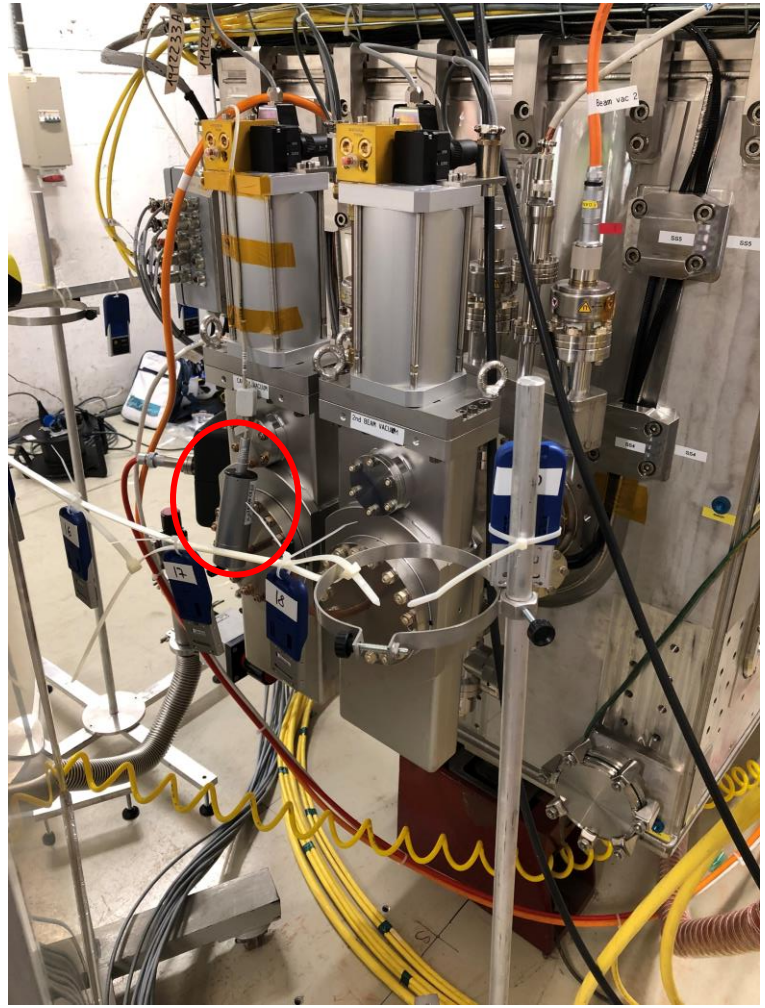


Rear isometric view

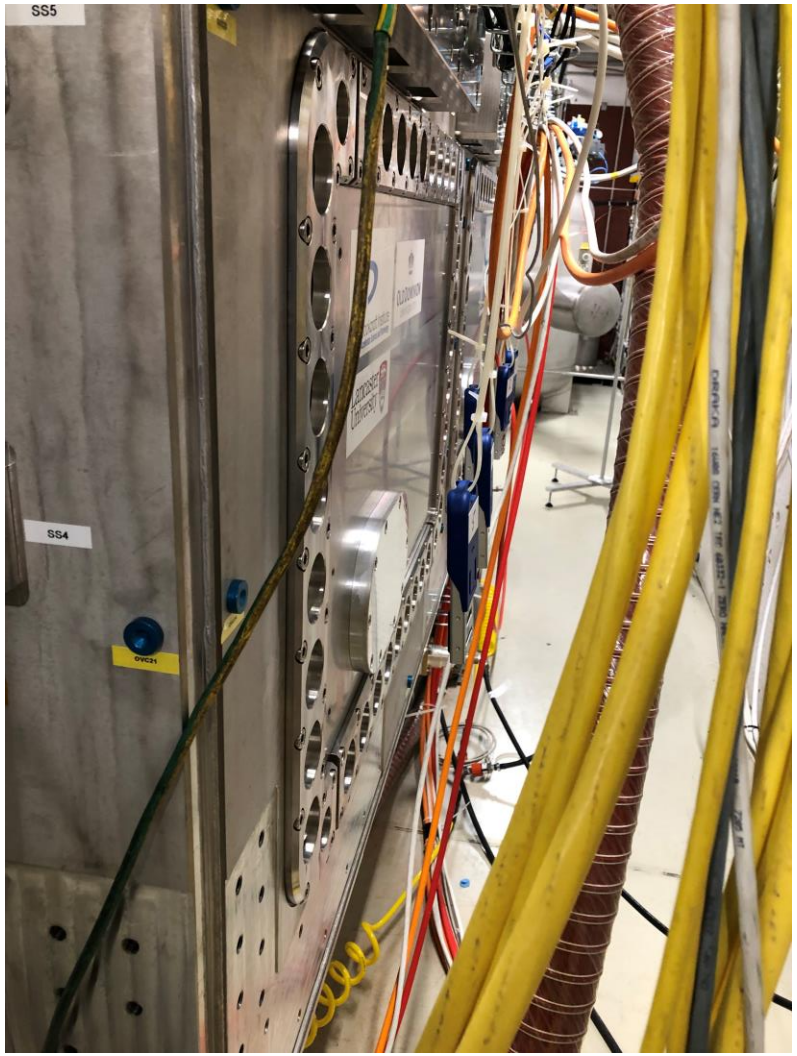
Experimental setup





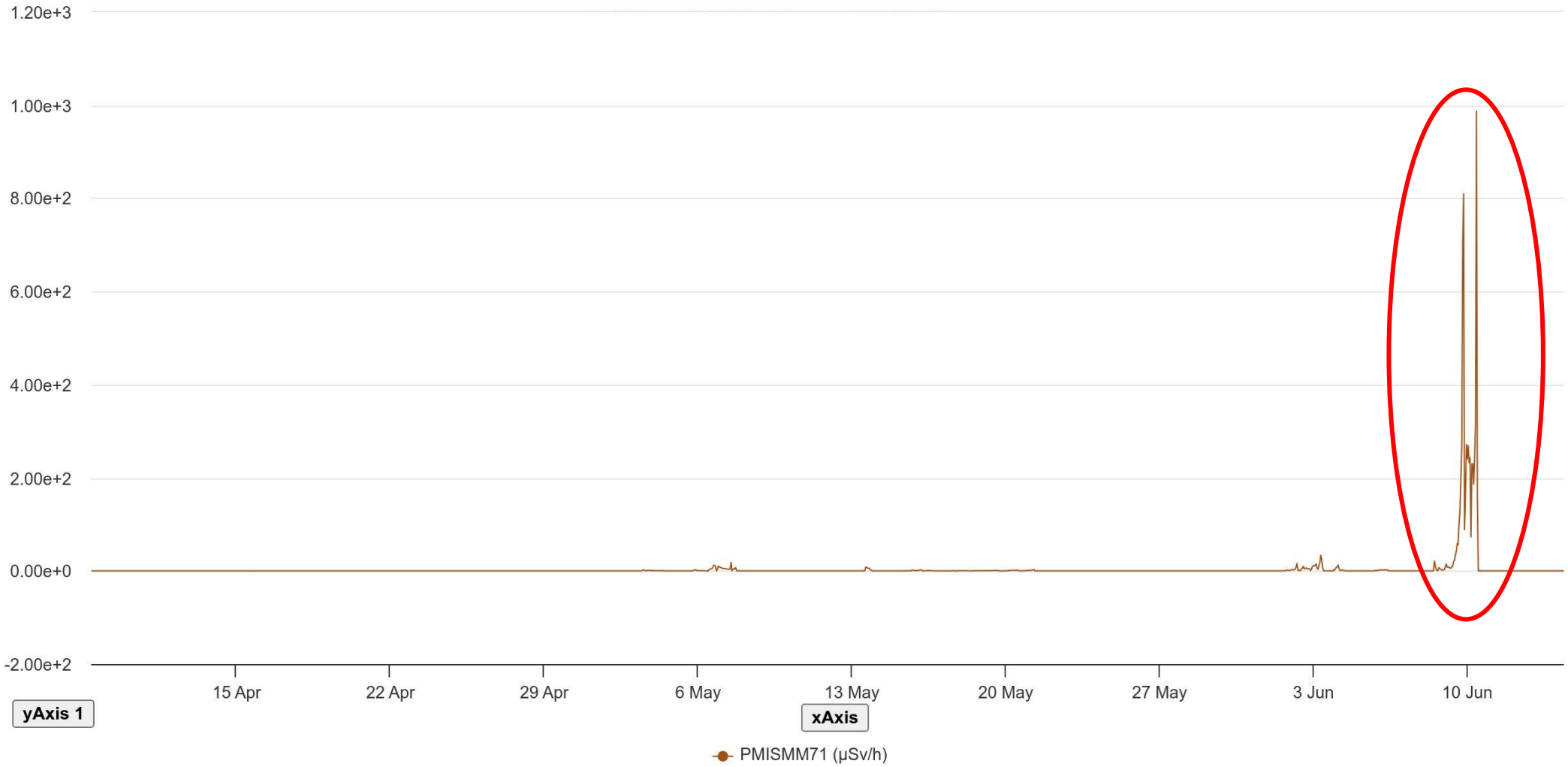


Experimental setup



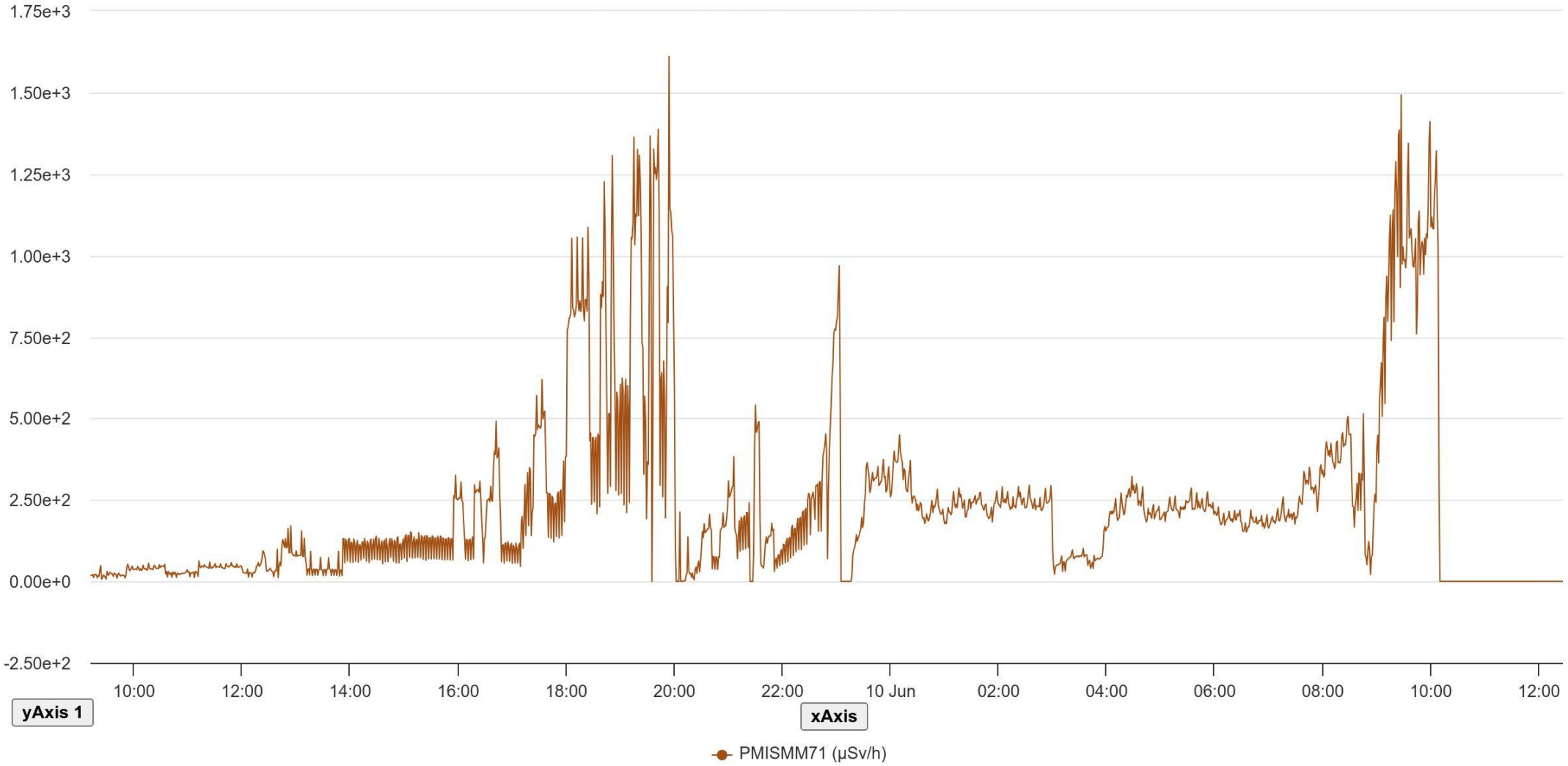
Measurements

- Plot from 08/04/2024 to 14/06/2024



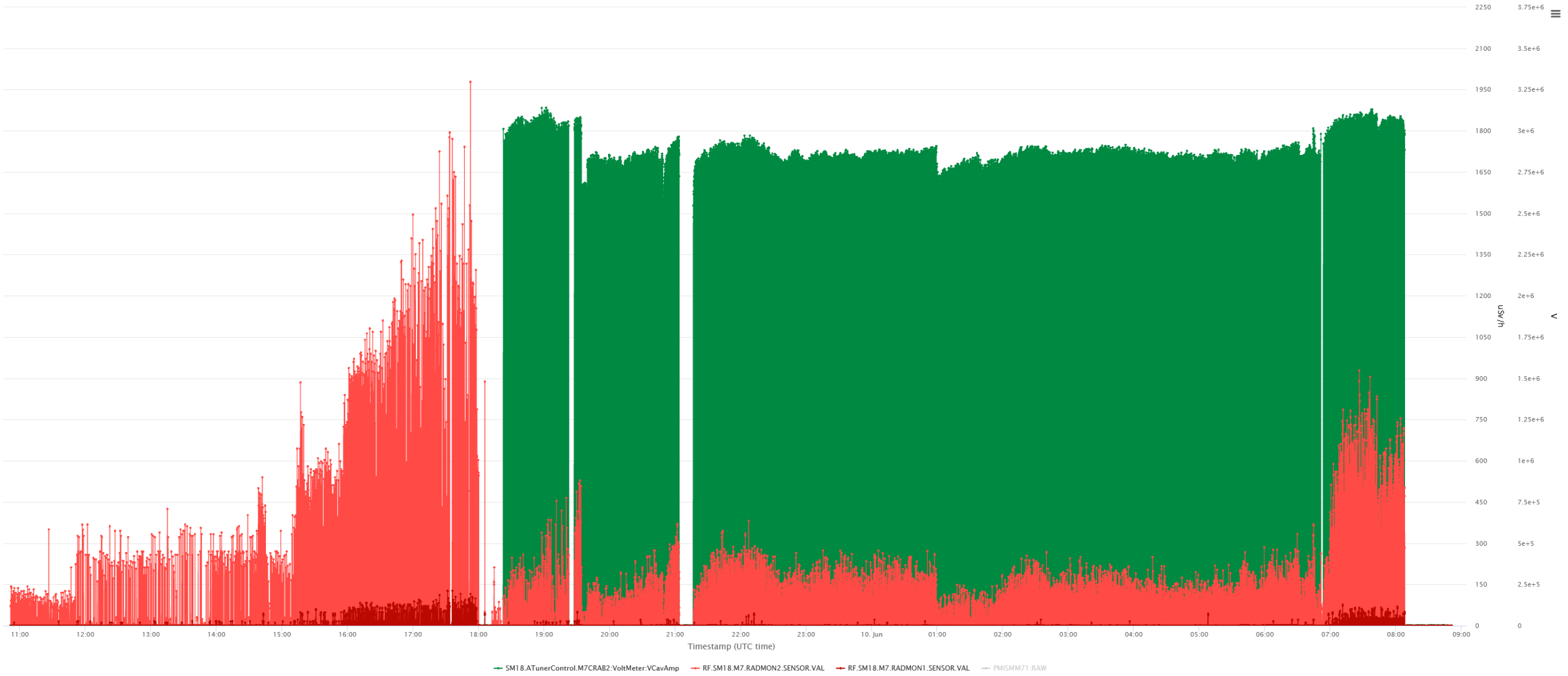
Measurements

- 88% of the total dose integrated over ~26h



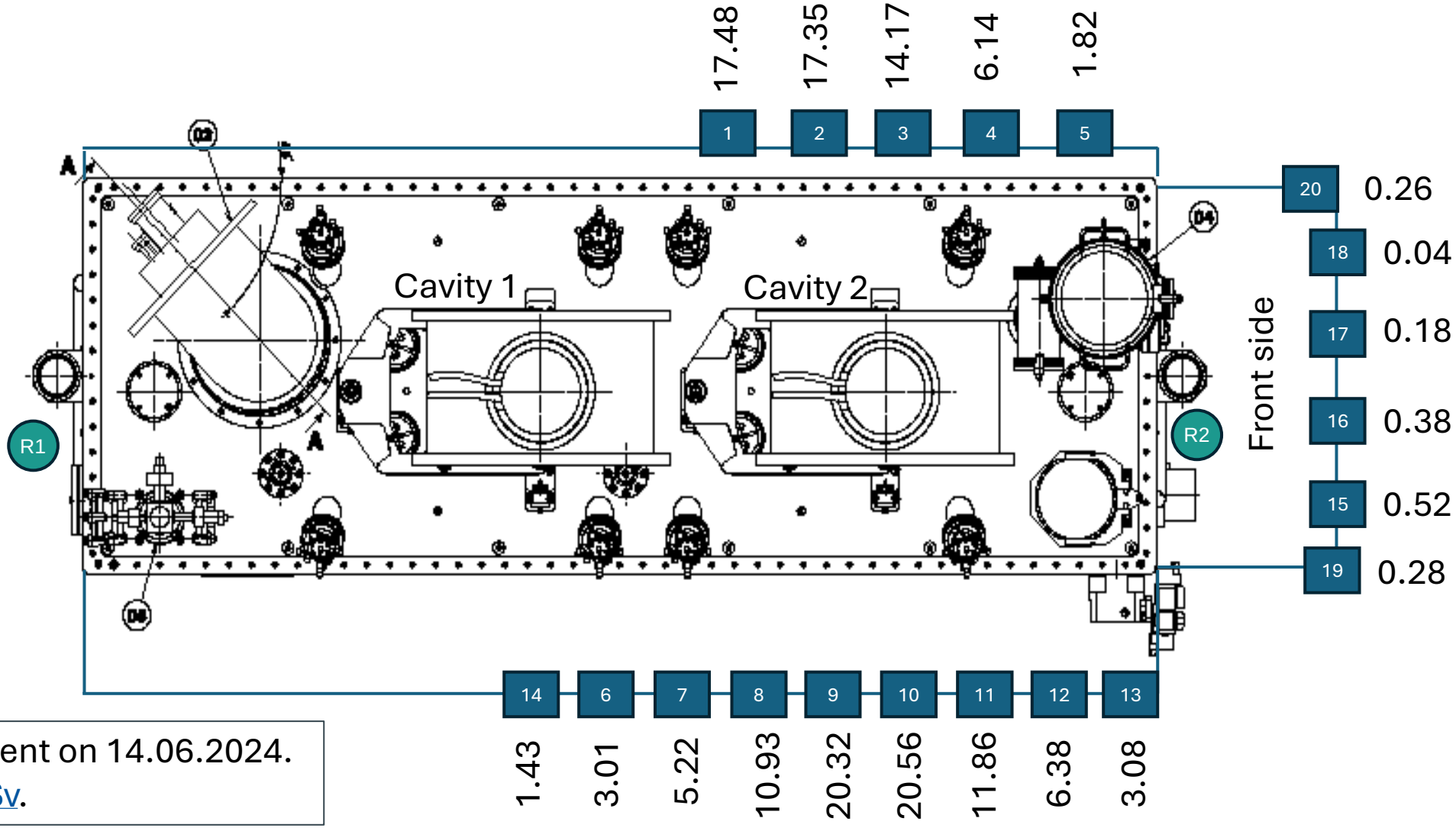
Measurements

- Tested up to 3.7 MV (nominal 3.4 MV) in short pulse
- Tested different pulse lengths (not all visible via TIMBER due to sampling rate) → WP4 to provide a more accurate dataset.



Results

- Measurements net of initial readout and background drift (~2.4 μSv/day).
- Results confirming the lateral preference direction of the produce X-rays.
- Note the position of the R1/R2 sensors, wrt the peak dose location.



NB: Measurement on 14.06.2024.
All doses in mSv.

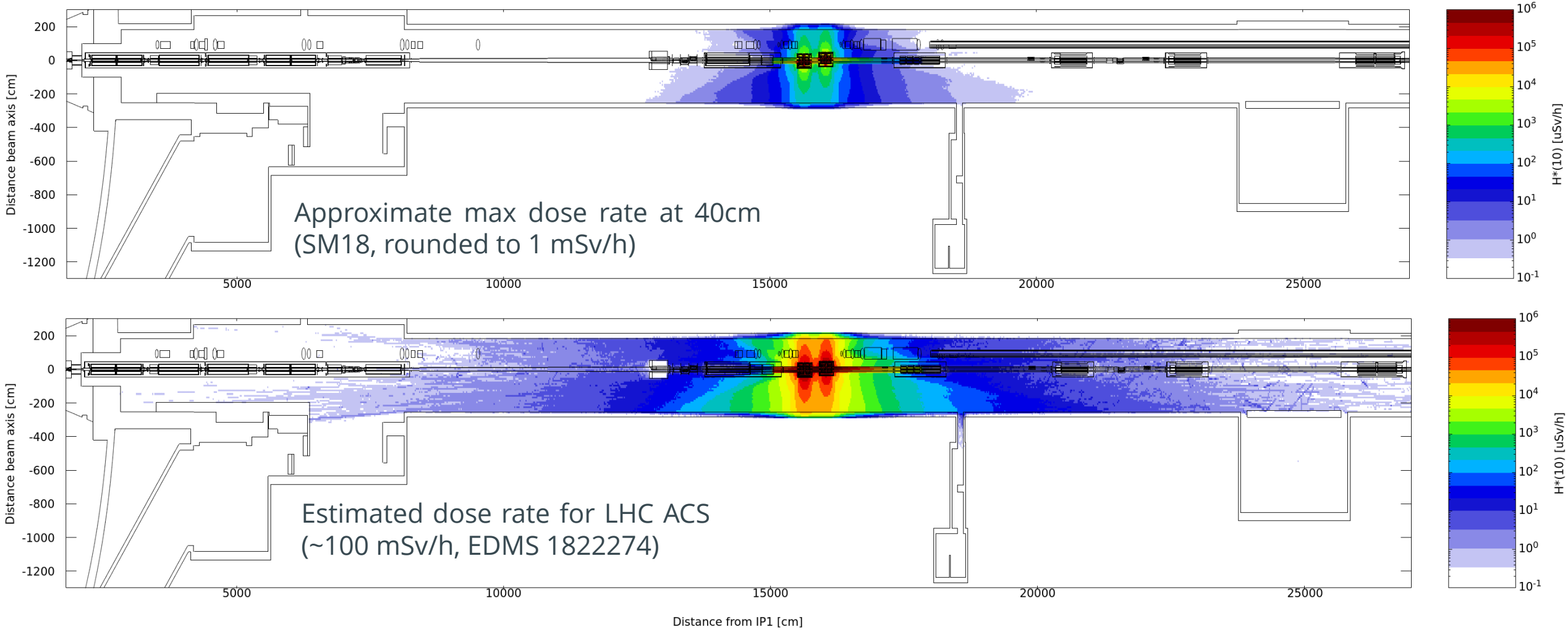
Results

Dosimeter	Serial Number	Background (mSv)	Net Dose (mSv)	Average Dose Rate (mSv/h)
1	21800702	0.01	17.48	0.589
2	21800571	0.01	17.35	0.585
3	21602118	0.01	14.17	0.478
4	21200264	0.01	6.14	0.207
5	21403844	0.01	1.82	0.061
6	21402975	0.00	3.01	0.101
7	21200153	0.00	5.22	0.176
8	22006054	0.00	10.93	0.368
9	21200705	0.00	20.32	0.685
10	21500472	0.01	20.56	0.693
11	21201643	0.01	11.86	0.400
12	21203779	0.01	6.38	0.215
13	21801957	0.01	3.08	0.104
14	21201381	0.00	1.43	0.048
15	21203188	0.01	0.52	0.018
16	22200114	0.01	0.38	0.013
17	21800027	0.00	0.18	0.006
18	22006234	0.00	0.04	0.001
19	21201273	0.00	0.28	0.009
20	21203393	0.01	0.26	0.009

- NB: Preliminary results! Data analysis still ongoing.
- Approximate average dose rate estimate over 26h operation → actual operation time of the cavity still to be evaluated.
- Waiting for more data from RF team, to couple with RP measurements.
- Spectrometer removed on 15.05.2024 → no spectrum available at present (open point for an upcoming experimental campaign).

Results

- Very preliminary results!
- Plots below for discussion only.
- Approximative scaling factor.



Take home message

- ✓ First attempt to measure the x-ray emission from the HL-LHC RFD CM.
- ✓ Successfully tested the experimental setup → relevant for future experimental campaign.
- ✓ Results confirming the lateral preference direction of the produce X-rays.
- ✓ FLUKA scaling factor: very preliminary results, which need a deeper analysis (still ongoing).
- ✓ Coming next:
  - Finalize the data analysis, also profiting of data from WP4 (voltage, pulse length,etc)
  - Start planning a new experimental campaign in September 2024 (with both cavities)
    - Get a few more dosimeter to fully cover the CM
    - X-ray spectrum measurement
    - Coordination between RP and WP4
  - FLUKA simulations for HL-LHC Point 5.