Exercise

Activation

Definition of problem

Goal

Plan an experiment for the activation of small material samples at an electron accelerator

Beam characteristics

- 28.5 GeV electron beam with a beam power of 20W
- Gaussian lateral profile with (σ_x,σ_y) = (0.5, 1.0) mm

Geometry

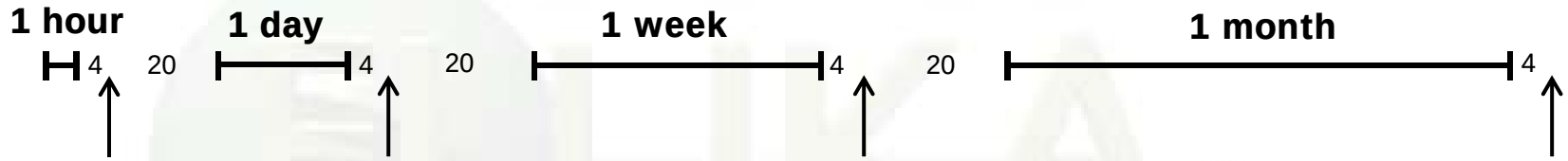
- cylindrical copper target (25cm long, 3cm in radius), beam incident on one of the circular planes aligned with the axis of the target
- cylindrical stainless steel sample (2cm long, 1cm in radius) placed immediately downstream of the target aligned with its axis
- cylindrical tunnel section (10m long, 2m in inner radius), assume a 20cm thick concrete wall, target and sample located in the center of the tunnel 1m downstream from its entrance

Problem

- determine approximate duration of irradiation such that the ambient dose equivalent of the sample (after having taken it out from the tunnel) after about 4 hours of cooling time at a distance of few tens of cm is in the order of 5-50 μSv/h
- calculate the effective dose that the experimenter receives next to the target, when she/he retrieves the sample (assume it takes about 2minutes)

...a few hints

- if you cannot guess whether the irradiation duration should be of the order of hours or months define a hypothetical irradiation profile with several irradiation periods of different lengths (e.g., one hour, one day, one week, one month) and sufficiently long gaps in between (e.g., 24 hours) and calculate the dose rates during these gaps at about 4 hours cooling from the last irradiation interval



- set electromagnetic interaction and transport thresholds such that CPU time is not wasted but calculation is still accurate, e.g., just above the photo-production threshold for the prompt cascade but still low enough for the radioactive decay radiation

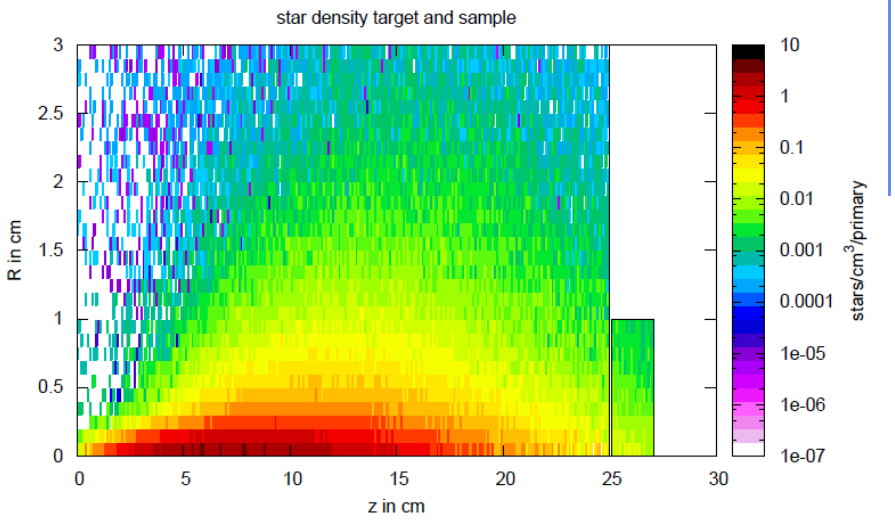
- enable photo-production (off by default) and reduce inelastic interaction length by photons by a factor of 0.02

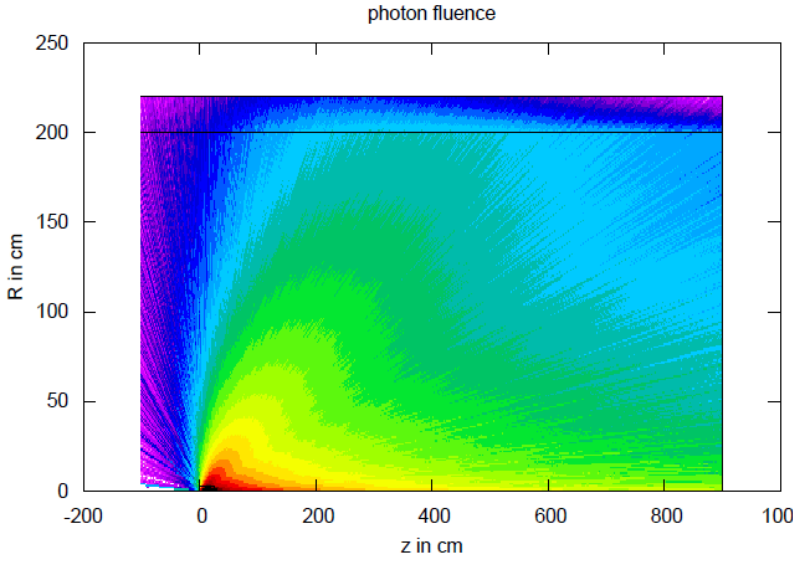
- don't forget special PHYSICS settings for activation calculations (generalized evaporation model and coalescence treatment) and to bias the hadronic interaction length of photons

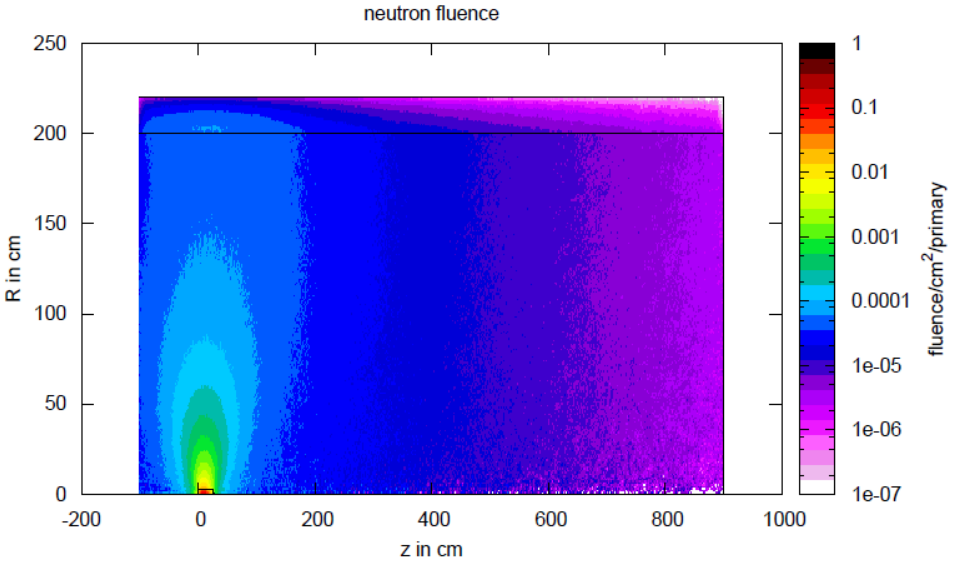
- convince yourself on the reliability results regarding the statistics in calculating radioactive nuclides (e.g., with star density maps in the target and steel sample)

Fluence and star density

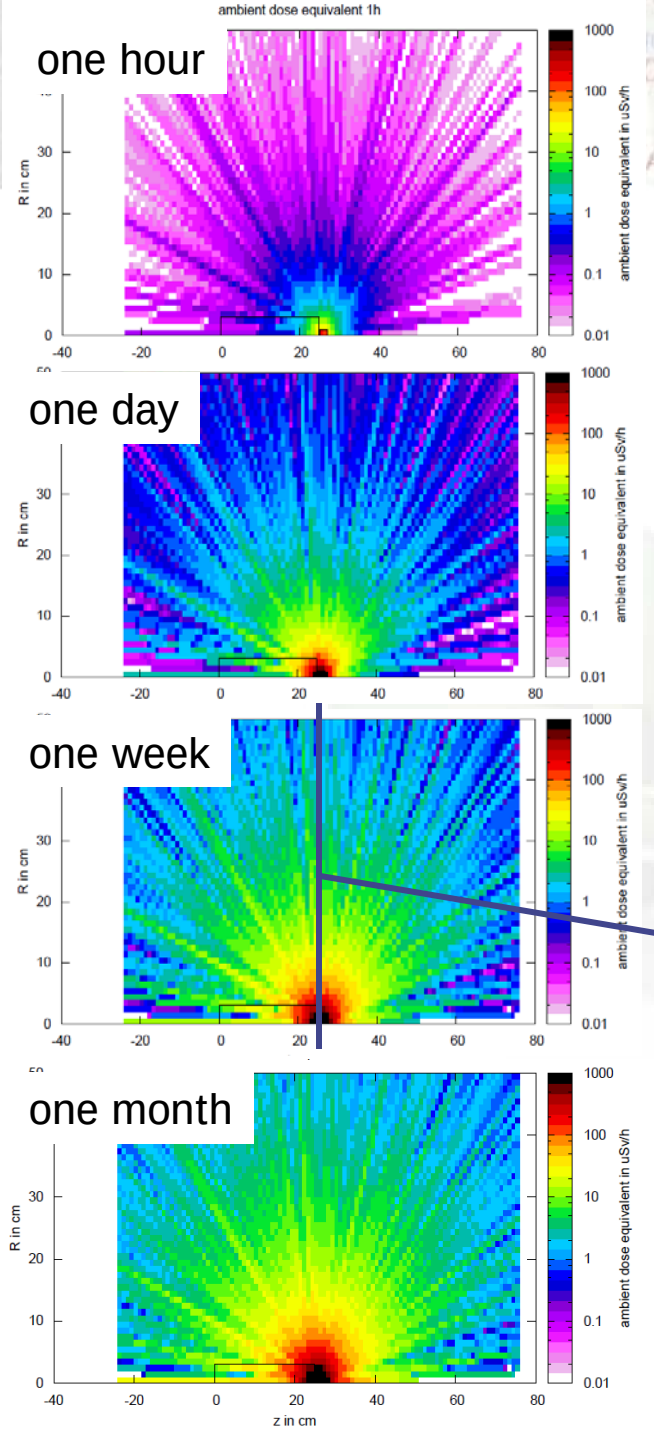
Always convince yourself on statistical uncertainties with contour plots!



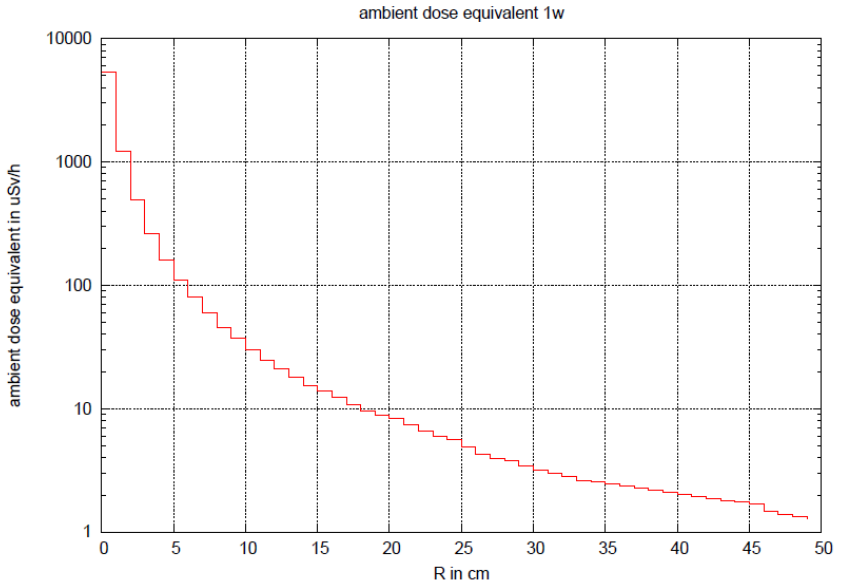




Ambient dose equivalent around sample



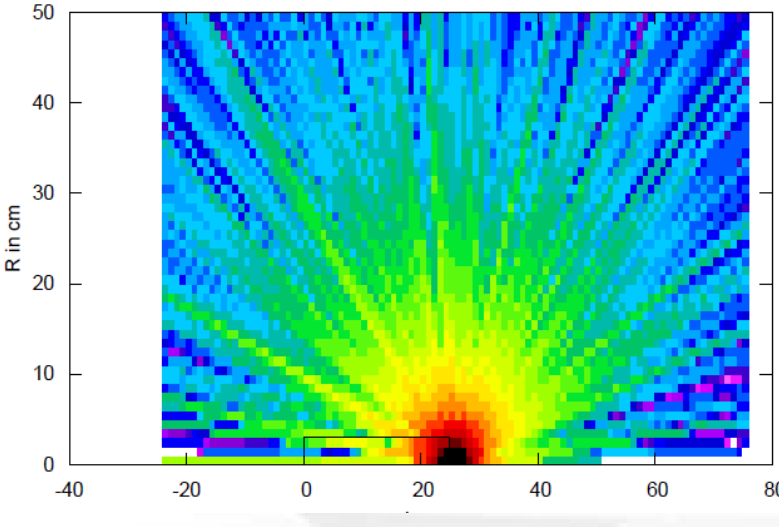
- This is for only 1000 primaries (we have only one hour for the exercise..) and thus statistics is terrible. Nevertheless, it is sufficient to roughly determine the irradiation duration.



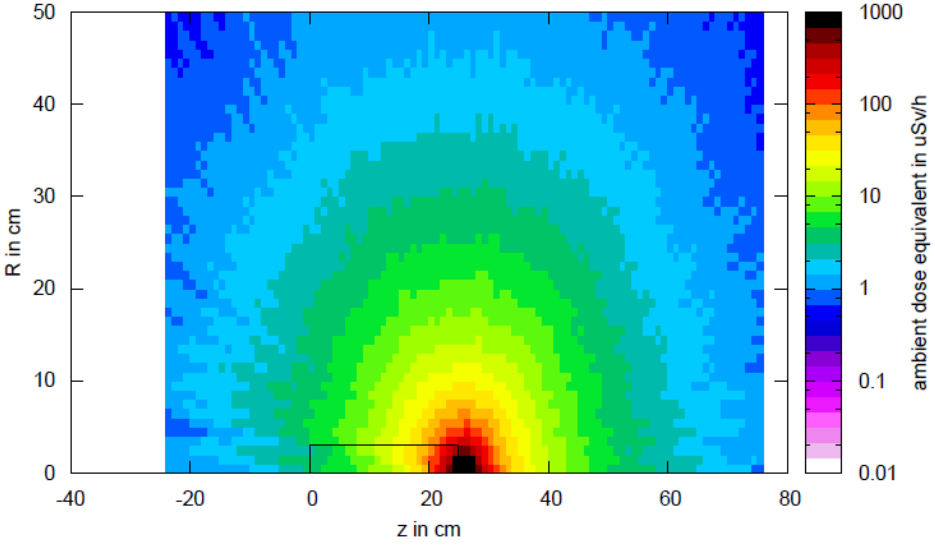
Ambient dose equivalent around sample

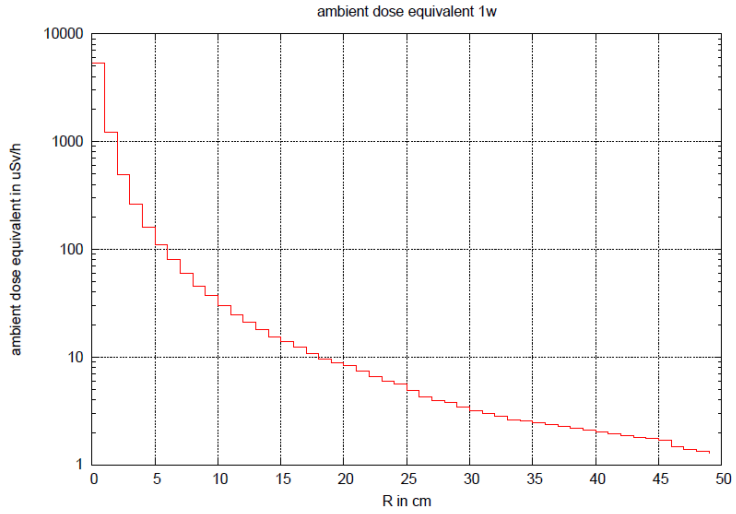
This is how it should look like

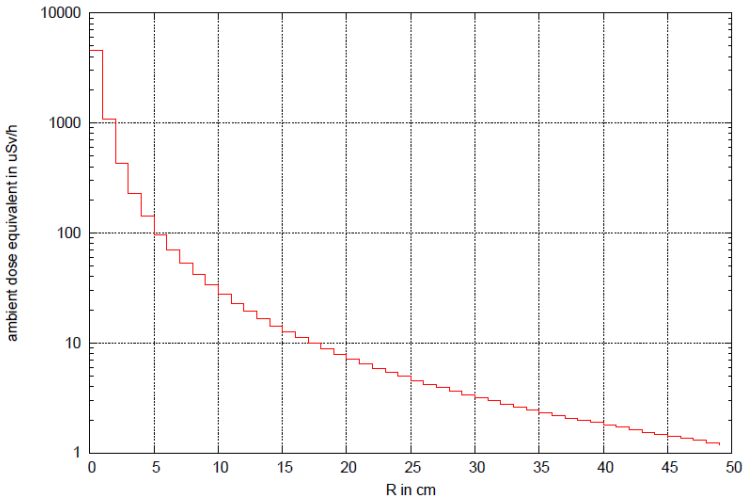
(1000 primaries)



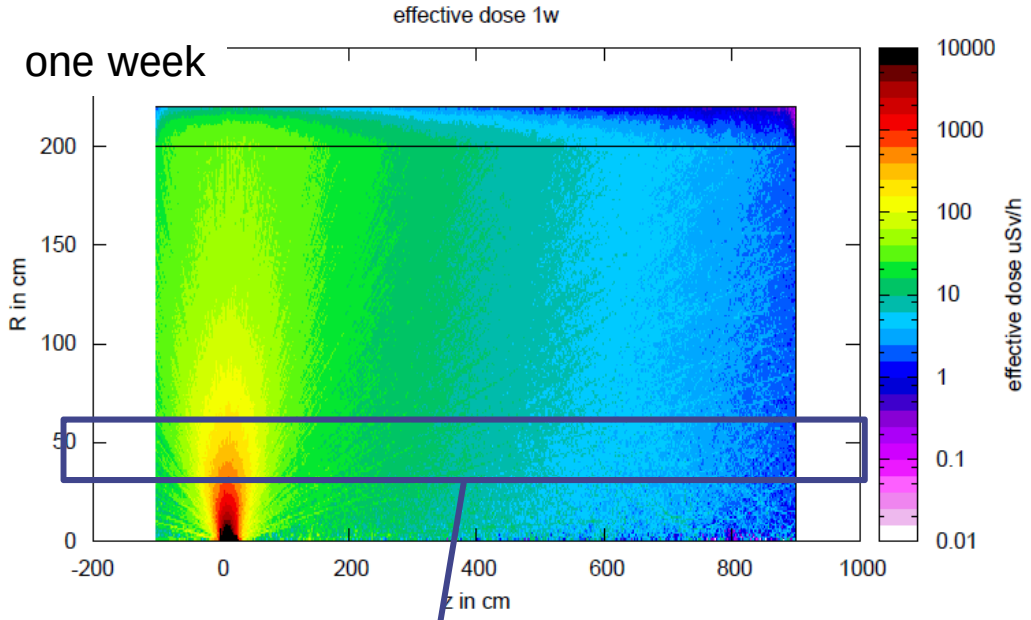
(16400 primaries)

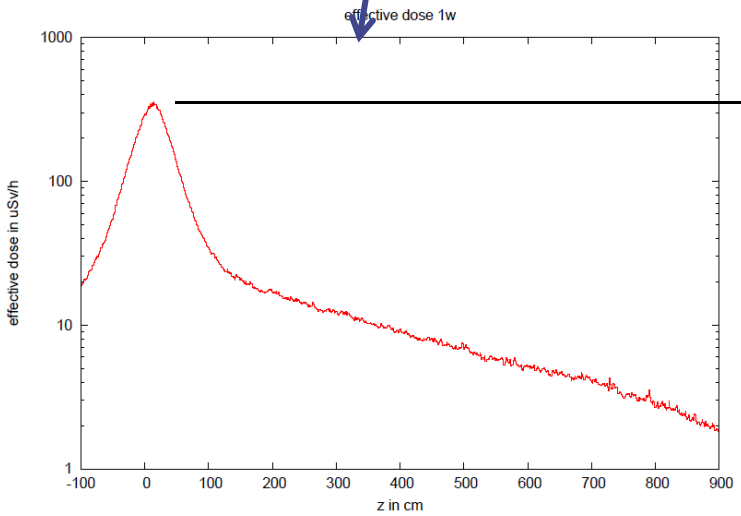






Effective dose next to target





~ 340 µSv/h

→ 11 µSv during two minutes