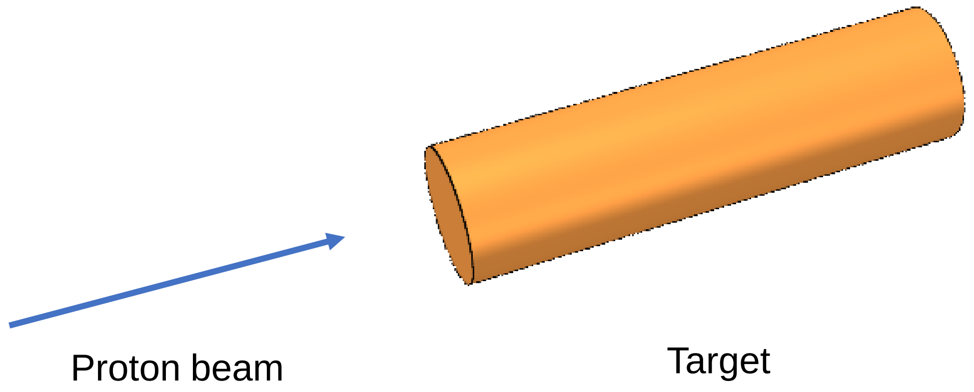
Exercise: Radiation Protection calculations

Goal of the exercise

Study of 4 Radiation Protection (RP) related quantities for proton beam on a copper target:

- Prompt ambient dose equivalent rate
- Residual ambient dose equivalent rate (12 hours cool-down time)
- Production Yields of residual nuclei
- Activity after 12 hours of cool-down time

- Prepare the input file in 5 tasks (*see the following slides*)



RP calculations exercise - Starting point

What is already contained in input file:

- Relevant `PHYSICS` cards
- Geometry
- Scoring for prompt ambient dose equivalent (in 2 meshes)
- Scoring for Nuclei Production Yield tables [#nuclei/g/primary] for the target
- Plots (without normalization)

RP calculations exercise - Task 1

Irradiation conditions and radiation settings

- Add a **`RADDECAY`** card:
  - Use defaults for residual transport (PRECISION: 100 keV for photons and electrons)
  - Switch off EMF for the prompt transport (prompt cut)
    - Check this point if your simulations runs slow!
  - Decay cut = 10.0 (no modification of PRECISION settings)
- Define the irradiation profile:
  - 180 days of irradiation, with 1e+10 primaries per second
- Define a cooling time:
  - 12 hour after the end of irradiation

RP calculations exercise - Task 2

Ambient dose equivalent rate maps

- Add one **USRBIN** for the cool-down time
- USRBIN should have the same R-Φ-Z as the prompt USRBIN
  - 20 radial bins, up to R=200 cm
  - 1 angular bin
  - 40 longitudinal bins in the range -200 cm ≤ Z ≤ 200 cm
  - Why is this a good choice?
- Associate the new USRBIN to the cool-down time (**DCYSCORE**)

RP calculations exercise - Task 3

Residual nuclei tables [Bq/g] for the target

- Add **RESNUCLE** for the target region
- Do not forget to include the mass normalization [Vol field]
  - Note: you should enter the mass in g; density of copper= 8.96 g/cm^3
  - Hint: See **RESNUCLE** scoring for Production Yields
- Associate the new RESNUCLE to the cool-down time (**DCYSCORE**)

RP calculations exercise - Task 4

Compile an executable and run the simulation!

- Executable:
  - Use FLUKA's default <flukadpm> (already available in the "Run" tab)
  - This is necessary to use DPMJET as the beam is made of high energy protons
- Use spawns and cycles to run a total of **100000** primaries
- Run and do not forget to merge the results

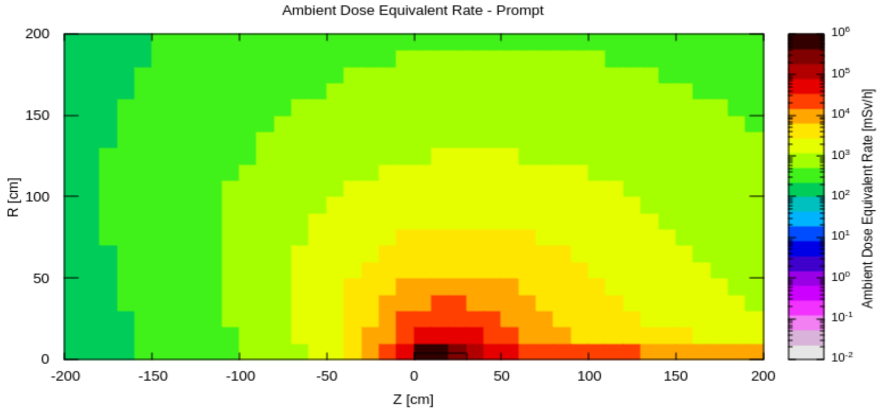
RP calculations exercise - Task 5

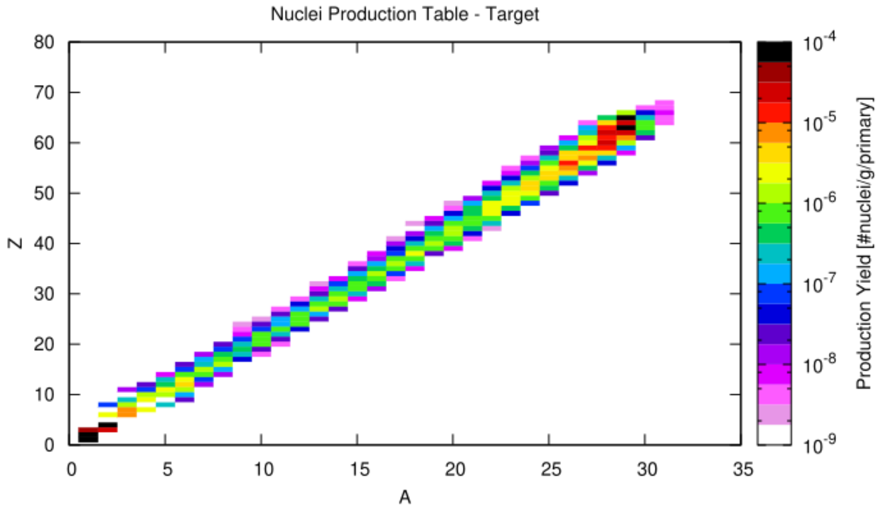
Plotting results – Flair Plot tab

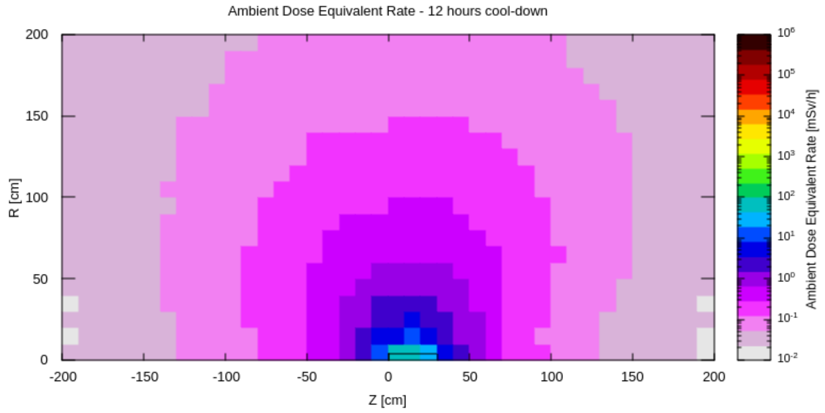
- 4 plots already exist in the flair file
- Link the plots to the processed output files
- Add the proper normalization for ambient dose equivalent rates to [mSv/h]
  - Hint: Irradiation profile already contains beam intensity
  - Hint: prompt scoring is per primary
- Create all 4 plots

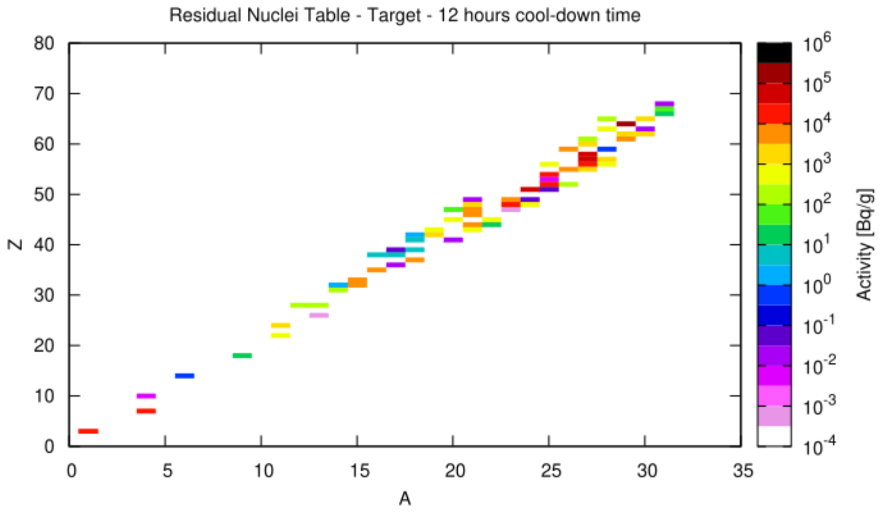
FLUKA

Activation exercise - Solutions









RP calculations exercise - Task 6 (BONUS)

Geometry modifications for residual radiation

- Not to lose your progresses, work on a copy of the exercise Flair project
- Define/import a new material: stainless-steel
- Modify the geometry to draw a simplified cylindrical container around the target
  - Example: use two RCCs, container with 2.5 cm thickness
  - Create a region for the container (modify accordingly the other regions)
  - Set the material to AIR
  - Set the material decay to stainless-steel
- Ideas: modify the Flair project, use FLUKA preprocessor, …
- Run again the simulation
  - Hint: check the statistical uncertainty; if needed, increase the number of primaries
  - One possible solution is provided (.flair)