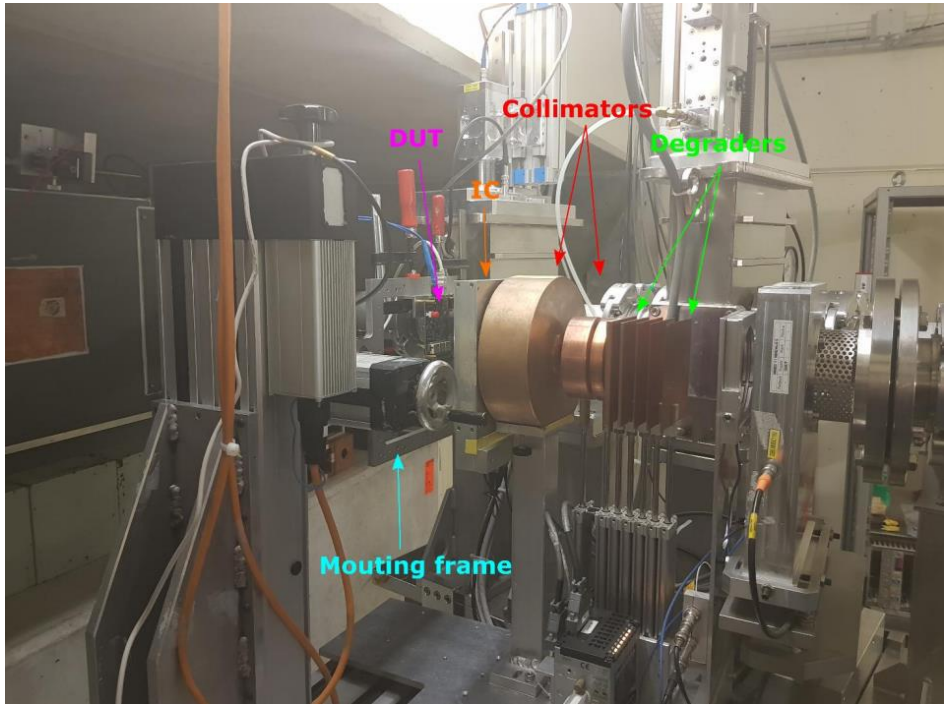
Exercise : Scoring II

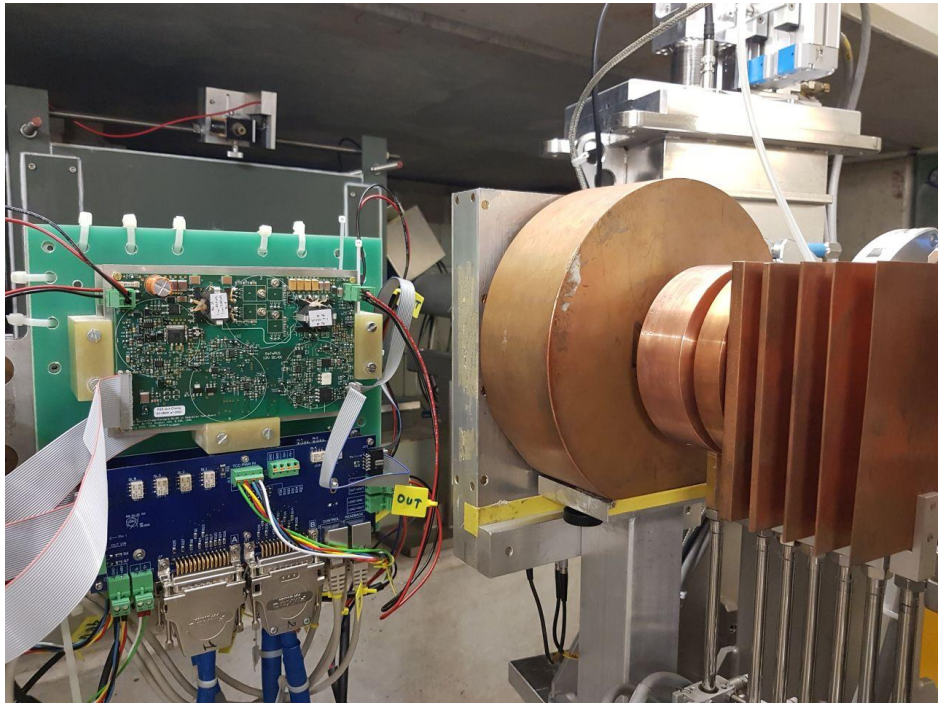
Aim of the exercise:

- Learn how to use **`USRTRACK`** and **`USRYIELD`** scoring cards
- Evaluate the impact of an energy degrader on a proton beam

Exercise inspiration



Credit: Daniel Söderström



Credit: Grzegorz Daniluk

Paul Scherrer Institute (PSI) Proton Irradiation Facility (PIF) degrader system (more info at http://pif.web.psi.ch/pif.htm).

Short intro

- Protons up to 200 MeV are very popular for testing radiation effects on electronics, mainly due to:
  - The (relatively) high availability of ~200 MeV proton cyclotron facilities, linked primarily to proton therapy
  - Their capability of inducing all three type of effects on electronics (total ionizing dose, displacement damage and Single Event Effects - SEEs)
  - Their coverage of the trapped proton energy spectra in space
- Space standards require testing for SEEs in the 20-200 MeV proton energy range. Therefore, degraders are often used to modify the primary beam energy at cyclotron facilities and retrieve the so-called SEE cross section as a function of energy.
- The figure-of-merit for SEE induction is the linear energy transfer (LET) in silicon. Protons in general do not induce SEEs via direct ionization (LET < 0.54 MeVcm^2/mg) but rather indirect ionization (i.e. reaction products with LET > 1 MeVcm^2/mg).

The input file

- Simplified example of the two main parts of a radiation effects on electronics simulations:
  - Simulation of radiation environment
    (in this case, proton beam interacting with degrader – as performed in irradiation facilities)
  - Interaction with a micro-electronic component
    (in this case, a thin silicon layer)
- The input file contains a 230 MeV proton beam interacting with a **49.5 mm** copper degrader, and a thin silicon region representing a micro-electronic component under irradiation.
- Biasing of inelastic reactions is included in the silicon region to enhance the nuclear event statistics.
- EMF (photon and electron transport) is disabled, in order to optimize CPU time (given they are not relevant to the results of the exercise)
- Evaporation of heavy particles, the coalescence mechanism and heavy ion transport are also enabled.
- Heavy ion interactions at energies larger than 100 MeV/n requiring linking through the external event generators DPMJET and RQMD → select <flukadpm> in run tab

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!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!           ATTENTION PLEASE              !!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

Coalescence activated and beam above BME  limit with no  rQMD
Execution terminated.
```

Add these scorings and run

1. Proton and neutron fluence:
   - Add a **USRTRACK** to score the energy spectrum of protons and neutrons in the DETECT region (e.g. linear, up to 250 MeV, with 500 bins)
2. LET distribution in silicon
   - Add a **USRYIELD** to score LET of particles travelling from DEVICE to VOID (e.g. up to 5000 keV/(μm×g/cm^3), which corresponds to 50 MeVcm^2/mg)
     - Scoring kind needs to be set to **d2N/dx$_1$dx$_2$**, and material to **silicon**
   - Use the range of the 2nd variable to score (i) the total LET distribution (i.e. all particles), and (ii) the LET for a charge (i.e. Z) of 2, and 12 (use half-integers as limits!)
3. Run 10 cycles of 10^4 primaries each
4. Plot the **USRTRACK** results for protons in linear y-axis scale, and protons and neutrons in logarithmic y-axis scale, in units of differential flux.
   (reminder: divide by detector volume if the value is not explicitly included in scoring card!)
5. Plot the **USRYIELD** results in logarithmic y-axis, including the total, Z=2 and Z=12 distributions (reminder: multiply by the bin width of the second variable of USRYIELD).
6. Bonus: run same simulation but with different degrader thickness (e.g. **41.4 mm, 53.5 mm**) and check the impact on the results.

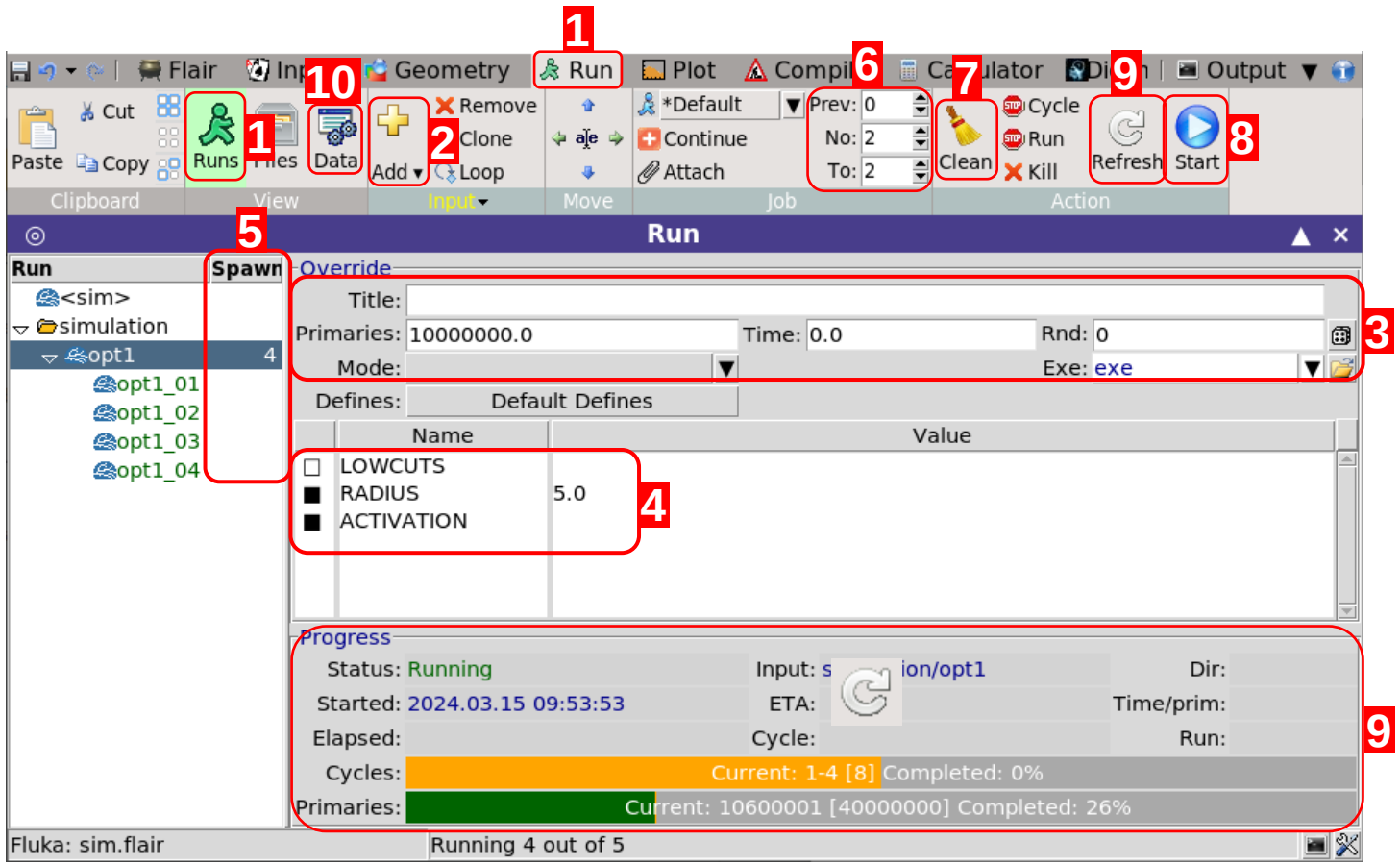
Questions that can be answered from looking at generated plots

- What is the impact of the degrader in terms of:
  (i) the shift of the average beam energy?
  (ii) the introduction of beam energy spread?
  (iii) the generation of secondary neutrons?

- What is the LET (in silicon) distribution of fragments leaving the DEVICE region?
  What is the maximum LET value produced?

- What is the contribution from Z=2 and Z=12 particles to the total distribution?

Flair Cheat Sheet



Remember!

- You can **STOP** or **KILL** the run.
- You can edit your input while the simulation runs.

!!! WARNING !!!

- Mind the memory and CPU usage of your simulations!

1. Go to the ***Run* tab**, select ***Runs* view**.
2. Add **new folder** + Add **new run**.
3. Override the input run info:
   - **Number of primaries**
   - Title / Max. time per cycle / Seed / Exec.
4. Override/Define variables.
5. **Recommended:** Increase number of spawns
6. Set number of cycles per spawn
   - Recommend at least 5 cycles in total.
   - `num_cycles_tot = num_cycles_per_spawn * num_spawns`
7. ***Clean*** run files after change to input or run settings.
8. Click ***Start*** to launch the simulations.
9. Monitor the progress. Click ***Refresh*** to force update.
10. After all cycles end:
    - Go to the ***Data*** ( ) tab.
    - Click ***Process*** ( ) to combine all cycles and create simulation data files.
    - You may need to refresh ( ) and scan ( ) if detectors are missing.

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