



Binning strategies for beam intensity data

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Abstract

The aim of this paper is to investigate the impact different binning strategies (time intervals) have when analysing real beam intensity data from the CHARM facility. In order to facilitate this task, the FLUKA Monte Carlo simulation code and the ActiWiz software are used. The irradiation profile from the beam intensity data is used in a simplified case of a proton beam on a gold target. FLUKA provides the particle fluence spectra which are used as input to ActiWiz, and the activation levels and ambient dose equivalent rate, $H^*(10)$, are obtained. The impact of using differently sized time interval bins from the beam intensity data allows a comparison of the corresponding irradiation profiles using ActiWiz.

1. Introduction

When dealing with accelerators operating at high energies, one must account for beam losses and the associated activation of material. Radionuclide production in accelerator equipment creates radiological hazards that have to be assessed which could impact future operations i.e. logistically, operationally and financially.

In the Radiation Protection group the goal is to find suitable materials that fulfill all required mechanical properties while keeping the radiological hazard to a justifiable minimum.

In order to predict the radionuclide production, one must understand the surrounding parameters. This includes the chemical composition of the material being irradiated and the actual conditions of the beam loss. The assessment of this hazard is difficult due to many different parameters and aspects. In Radiation Protection, a two-step approach is used to assess the radiological hazard linked to the activation of arbitrary materials. FLUKA [1, 2] is first used to calculate the particle fluence spectra (neutrons, protons and charged pions) for various energies of the primary proton beam interactions. FLUKA is a fully integrated Monte Carlo simulation program for the interaction and transport of particles and nuclei in matter. The aim of ActiWiz [3] is to then use the particle fluences to allow non-expert users to obtain comparisons of the radiological hazard for arbitrary materials in an easy yet flexible way. The same can be done directly from FLUKA, but ActiWiz provides faster calculations and a 'user friendly' interface for the non-expert.

Given in this paper are the results of comparing activity levels predicted by FLUKA and ActiWiz when using the same irradiation profile. In addition, various time intervals are applied independently to the beam data to find whether different irradiation profiles, due to differently sized bins, affects the $H^*(10)$ values calculated from ActiWiz.

2. FLUKA simulations

At CERN, the Large Hadron Collider (LHC) operates with beams of protons of 7 TeV. However the CHARM facility has a maximum beam momentum of 24 GeV/c from the Proton Synchrotron (PS). The work presented in this paper uses data from the PS therefore the beam momentum in FLUKA is set to 24 GeV/c. For simplicity, the geometry of the target material is 5cm x 5cm 1cm and the material used is gold. The density of gold is 19.32 g/cm³.

The irradiation profiles come from beam intensity data for a typical irradiation at the CHARM facility. The data is either un-binned or binned (10 minute bins and 5 minutes bins) therefore, depending on the binning (time interval used), there are different irradiation profiles. Using the simplest irradiation profile (un-binned data) the particle fluence spectra is calculated using FLUKA Monte Carlo simulations. Additionally FLUKA provides the activity and dose equivalent rate after several cooling down times. 20 cool-down times are chosen ranging from one hour to two weeks.

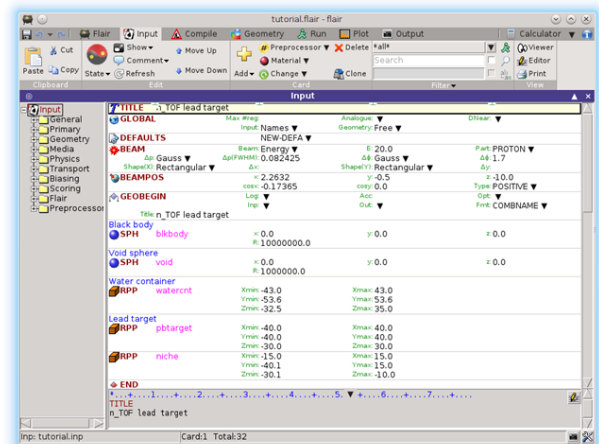


Figure 1. Screenshot of FLAIR [4]. This is the FLUKA advanced interface.

3. ActiWiz simulations

ActiWiz takes the particle fluences (calculated from FLUKA) and provides the total activity, total dose rate $H^*(10)$ and a list of the top contributors to the $H^*(10)$.

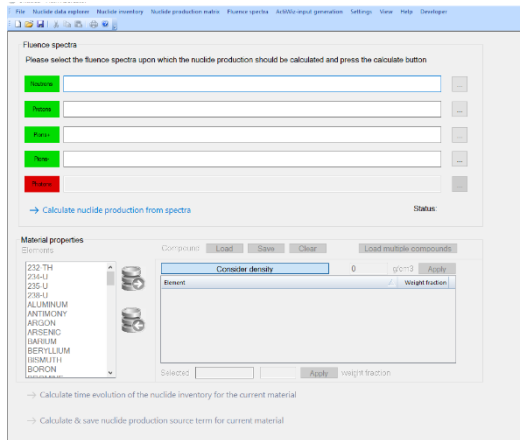


Figure 2. Screenshot of ActiWiz Creator. This is used as opposed to ActiWiz when using a complex irradiation profile.

ActiWiz does not replace a full Monte Carlo study nor can it replace an assessment for very specific cases that cannot be generalized [3].

Whereas FLUKA generates the activation levels for all 20 cool-down times in one simulation, as it automatically adds each cool-down time at the end of the irradiation profile, ActiWiz requires this to be done manually.

This therefore means running 20 ActiWiz simulations using the same irradiation profile but changing the last cool-down time to the desired choice.

4. FLUKA and ActiWiz comparison

Both FLUKA and ActiWiz provide the total activity after each cool-down time. Figure 3 shows that there is greater difference between activation levels at shorter cool-down times. Figures 4 and 5 shown below further highlight the differences between the activation levels given from FLUKA and ActiWiz. Figure 3 indicates that it is the smallest cool-down times that give the greater ratios between the values. The ratio decreases rapidly between 1 – 72 hours before roughly flat-lining at a ratio of approximately 1.31. As seen below, this is not constant as for some of the later cool-down times there are slight increases in the ratio.

In order to find out why FLUKA and ActiWiz provide different activation levels, one may study the nuclide inventories of the FLUKA and ActiWiz outputs for each cool-down time to see which nuclides are mostly present. Contrasting nuclide inventories would be a reason for the activation levels to differ as they do.

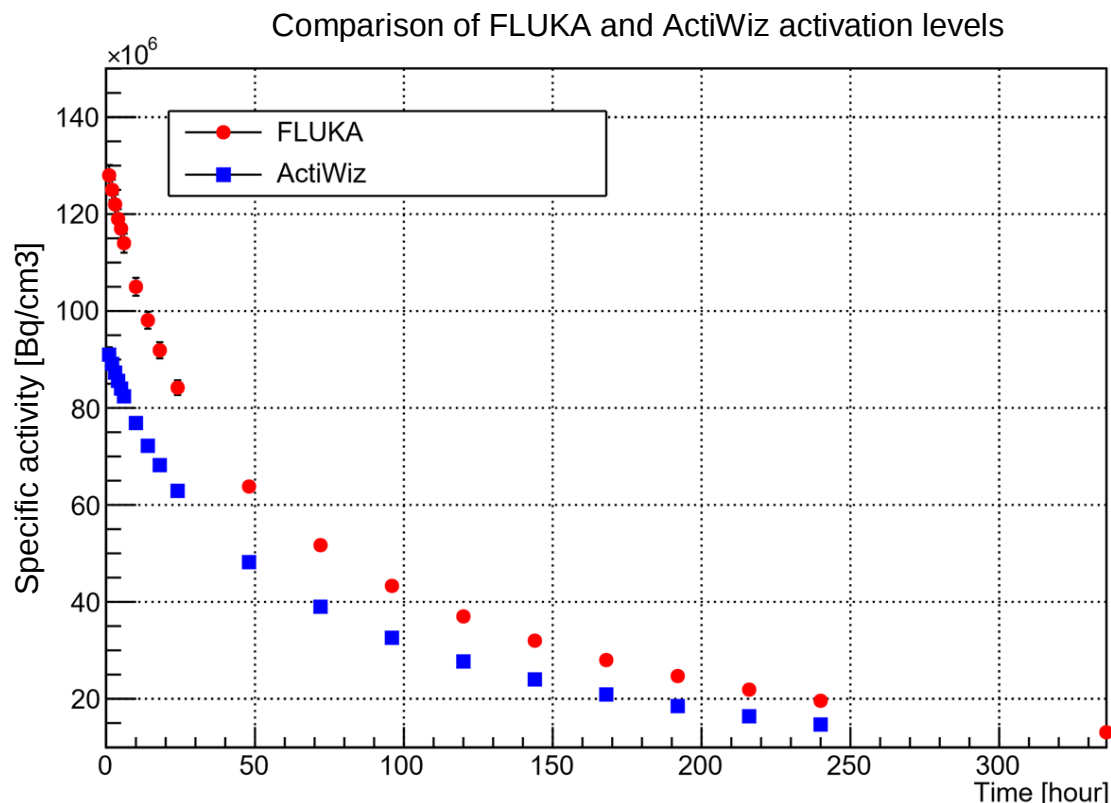


Figure 3. Comparison of specific activities between FLUKA and ActiWiz.

Ratio of Fluka and ActiWiz values

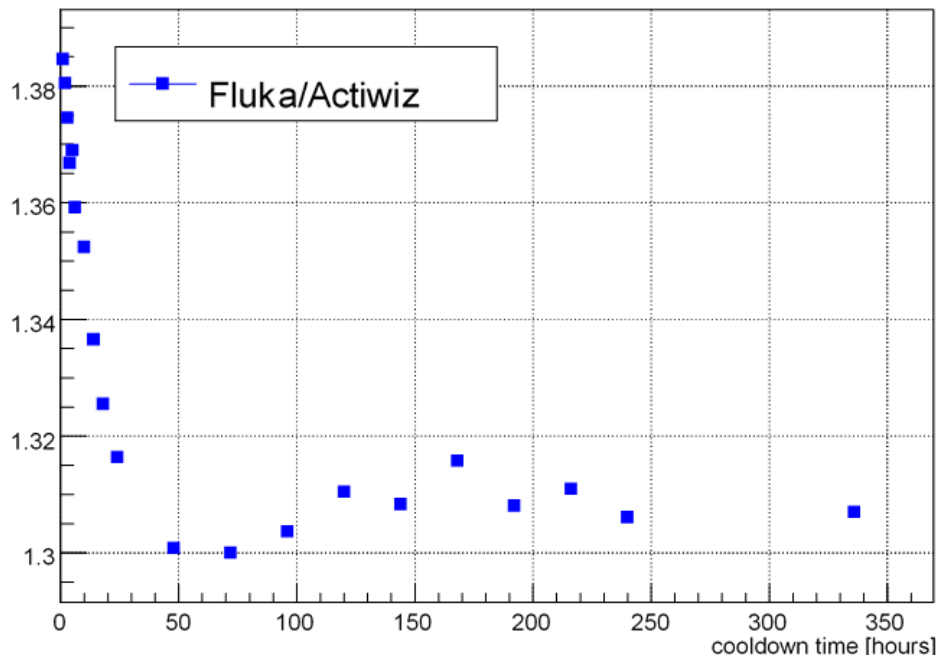


Figure 4. Ratio between the FLUKA and ActiWiz activation levels varies as a function of the cool-down time.

Difference between Fluka and ActiWiz values

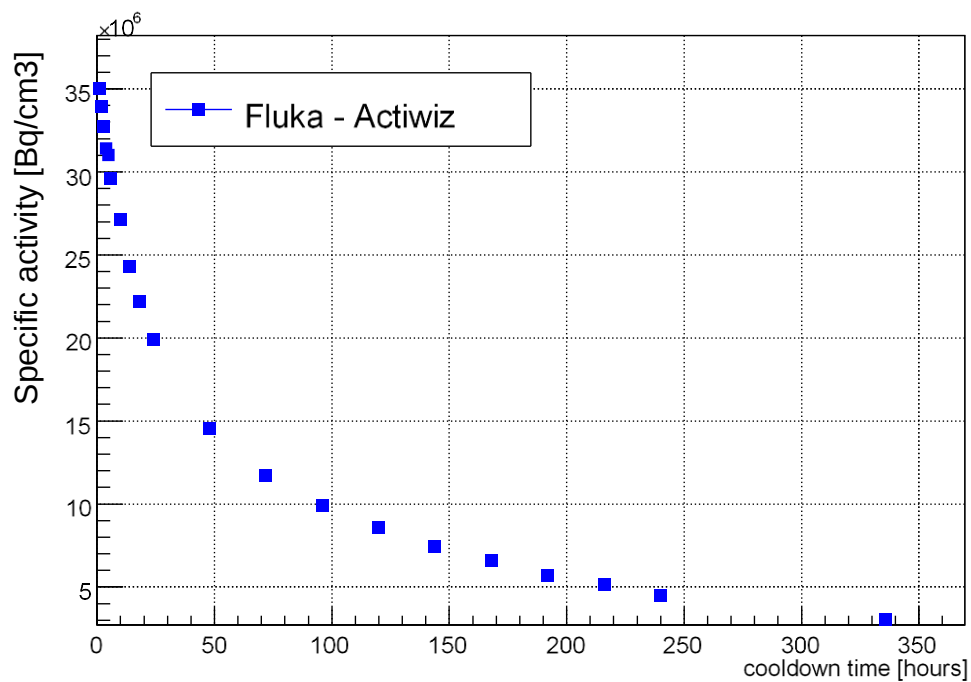


Figure 5. Difference between the FLUKA and ActiWiz activation levels decreases exponentially as a function of the cool-down time.

5. Different binning strategies

Different irradiation profiles are formed from the same beam data using different time intervals when binning the original beam data. This means changing the bin size accordingly. To investigate how this affects the ActiWiz output, five irradiation profiles are formed from the CHARM beam data, each with different bin size. Each bin size constitutes of 20 different irradiation profiles in correspondence with the 20 cooling times chosen previously. Figure 6 shows how the $H^*(10)$ varies with bin size for different cooling times. This graph indicates that the largest bins provide the smallest $H^*(10)$ values.

The graph shows the 5, 10, 30, large and mixed (90, 30 and 10 minute) binned irradiation profiles. The $H^*(10)$ values for the 5, 10 and 30 minute bin irradiation profiles are identical. Theoretically, making smaller bin sizes should lead to more accurate values but in this case the graph shows that there is no benefit in making the bin size smaller than 30 minutes. Irradiation profiles with smaller bin sizes are bigger and slower to run than other irradiation profiles with larger bins. For reasons of efficiency, it would therefore make more sense to use the 30 minute bin irradiation profile as opposed to the 5 or 10 minute bin irradiation profile.

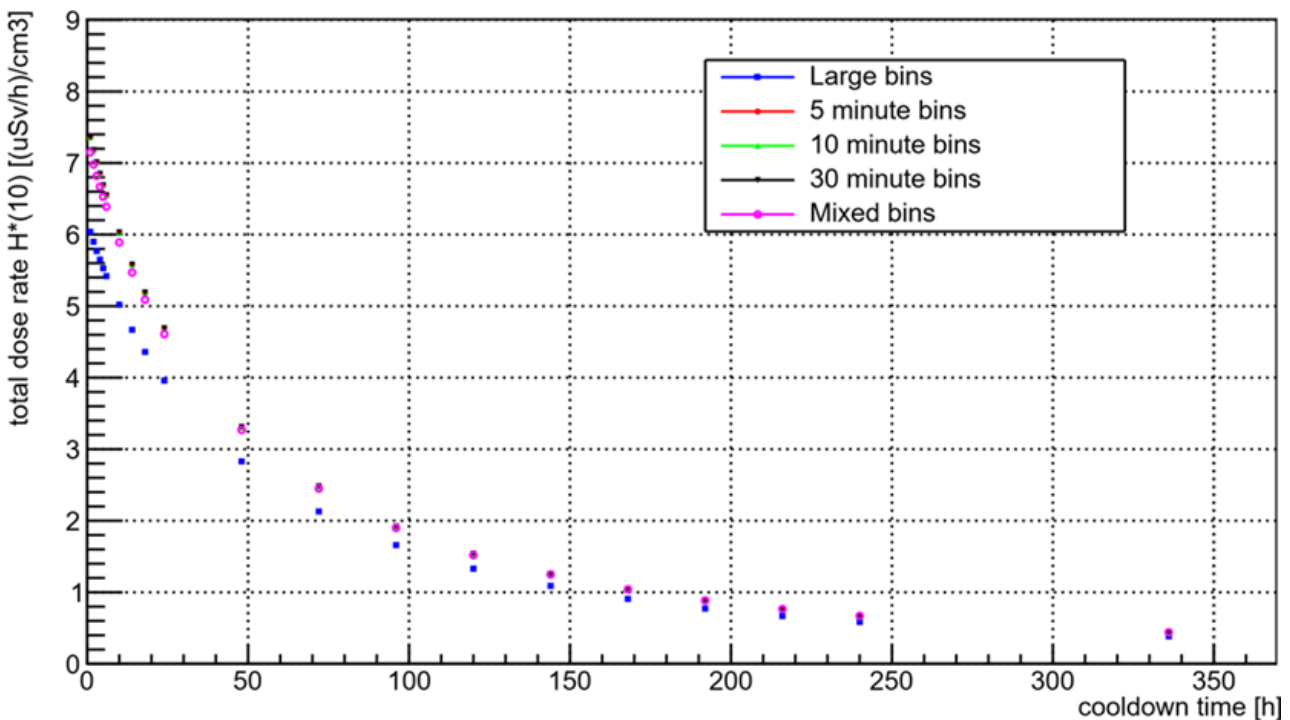
6. Summary

In order to examine the role different binning strategies play when analysing beam intensity data from the CHARM facility, the FLUKA Monte Carlo simulation code and the ActiWiz software have been used. This enables relatively quick and easy access to the activation levels and $H^*(10)$ values for multiple cool-down times.

A simple yet effective comparison of the activation levels produced from FLUKA and ActiWiz shows some variation at short cool-down times. Given more time, it would be beneficial to repeat the FLUKA/ActiWiz comparisons but with different targets. This would allow a more extensive investigation when comparing the nuclide inventories.

Using the $H^*(10)$ values provided from ActiWiz, a comparison between different irradiation profiles concludes that there is no advantage in making the bin sizes smaller than 30 minutes for the selected cool-down times. It is also clear that having bin sizes too large affects the $H^*(10)$ values. For reasons of accuracy and efficiency, the irradiation profile with the 30 minute bins is the most practical when dealing with the beam intensity data provided from the CHARM facility for the selected cool-down times.

Total dose rate $H^*(10)$ vs cooling time for all irradiation profiles



7. References

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