Monte-Carlo simulation with FLUKA for liquid and solid targets

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Introduction

Monte-Carlo simulations can be used to assess isotope production on small medical cyclotrons. These simulations calculate the particle interactions with electric and magnetic fields, as well as the nuclear reactions. The results can be used to predict both yields and isotopic contaminations and can aid in the optimum design of target material and target geometry [1,2].

FLUKA is a general-purpose tool widely used in many applications from accelerator shielding to target design, calorimetry, activation, dosimetry, detector design, neutrino physics, or radiotherapy [3,4]. In this work, we applied the Monte-Carlo code FLUKA to determine the accuracy of predicting yields of various isotopes as compared to experimental yields.

Material and Methods

The proton beam collimation system, as well as the liquid and solid target of the TR13 cyclotron at TRIUMF, has been modeled in FLUKA. The proton beam parameters were initially taken from the cyclotron design specifications and were optimized against experimental measurements from the TR13. Data from irradiations of different targets and with different beam currents were collected in order to account for average behavior see FIG. 1. Yields for a pencil proton beam as well as a beam spread out in direction and energy have been calculated and have been compared to experimental results obtained with the TR13.

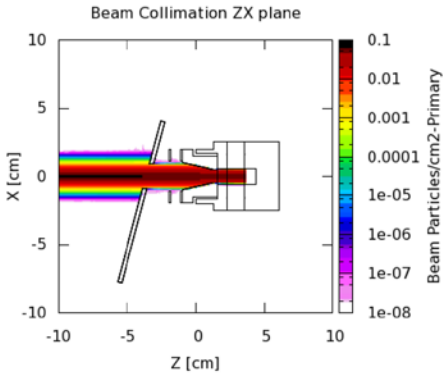

FIGURE 1: Optimized proton beam propagation through the collimation system into the liquid target.

Results and Conclusion

The reactions listed in Table 1 were assessed. For most reactions a good agreement was found in the comparison between experimental and simulated saturation yield. Table 1 only shows the yields simulated with a proton beam with a spread in both direction and energy. In most cases, the simulated yield is slightly larger or comparable. Only the calculated yield for ^{55}Co was significantly lower by a factor of 4.2. This is still a good agreement considering that FLUKA was originally a high-energy physics code. It may indicate that the FLUKA internal cross-section calculation for this isotope production needs some optimization. In summary, we conclude that FLUKA can be used as a tool for the prediction of isotope production as well as for target design.

reaction	Y_{exp} (MBq/μA)	Y_{FLUKA} (MBq/μA)	Y_{exp}/ Y_{FLUKA}
^{nat}Mo(p,x)^{94}Tc	50±6	60.2±0.2	0.8
^{nat}Y(p,x)^{89}Zr	346±2	238.4±0.4	1.5
^{nat}Sr(p,x)^{86}Y	36±1	26.0±0.1	1.4
^{nat}Zn(p,x)^{68}Ga	138±2	112.6±0.3	1.2
^{nat}Zn(p,x)^{61}Cu	130±20	322.2±0.4	0.4
^{nat}Fe(p,x)^{56}Co	1400±200	792.4±0.7	1.8
^{nat}Ni(p,x)^{55}Co	180±20	42.7±0.2	4.2
^{nat}Cr(p,x)^{52}Mn	880±100	3292±1	0.3
^{nat}Ca(p,x)^{44}Sc	4.9±0.3	9.20±0.08	0.5
^{18}O(p,n)^{18}F	4930±60	6493±2	0.8
^{nat}O(p,x)^{13}N	259±3	1237.2±0.9	0.2

TABLE 1. Measured (Y_{exp}) and simulated (Y_{FLUKA}) saturation yields at a proton energy of 13 MeV.

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