Proposition de sujet de stage M2 (2023) à l'Institut de Pluridisciplinaire Hubert Curien (IPHC)

Measurement of secondary particles produced in hadrontherapy treatments

The treatment of cancer by ion beam, or hadrontherapy, has demonstrated significant advantages in recent years compared to photon radiotherapy. Among these advantages, the most highlighted are the better conformation of the dose delivered to the tumor volume and the better efficiency of the high-LET particles against radioresistant cells (hypoxic tumor). However, during hadrontherapy treatments, primary ions undergo nuclear fragmentations that lead to the production of charged and neutral secondary particles. These particles, with very variable LET, will result in a dose deposition both in the tumour and in the surrounding healthy tissues before and after the tumour. Optimization of hadrontherapy treatments therefore implies being able to accurately estimate the spatial and energy distribution of these secondary particles, as well as the corresponding physical and biological doses. Unfortunately, this is still far from being possible in the softwares currently used for treatment planning, and research projects are needed to improve the calculations of secondary particle production and the associated radiobiological effects. Indeed, secondary particles (e.g. neutrons) are often pointed out as a potential source of secondary malignancies, which are of key importance for pediatric patients.

In this context, the DeSIs group of IPHC laboratory is developing an experimental setup allowing the measurements of the physical characteristics (energy, charge) of secondary particles produced by ions interacting with equivalent-tissue targets. This setup consists in a ΔE-E telescope, made by one plastic scintillator and a $CeBr_3$ crystal. The deposited energy (ΔE) is measured by the plastic detector, and the total residual energy (E) is given by the crystal. This telescope will achieve the secondary charged particles identification, as well as the measurement of the kinetic energy of the detected particle. The plastic scintillator can also be used as a "veto", in order to discriminate neutrals from charged particles. Thanks to this veto mode, the crystal scintillator will also be able to measure the high-energy secondary neutrons and γ-ray spectra. The secondary neutrons of low energy will be measured by a recoil proton telescope (RPT) developed by our group, placed at symmetrical angle from the ΔE-E apparatus. The system was fully characterized in 2022, and we plan to measure the first secondary particles yields in 2023, at CNAO hadrontherapy center (Pavia, Italy) and at GANIL (Caen, France).

This internship aims at preparing the experiments planned in spring 2023, and analyzing the obtained data. The candidate will have to work on Monte Carlo simulations carried out with Geant4 or GATE, in order to optimize the setup that will be used. She/he will also participate to the in-beam experiments, where the full setup will be used to evaluate the secondary particles produced by a 120 MeV/u ^{12}C ion beam (CNAO) and a 80 MeV/u ^{8}Li beam (GANIL). An important part of the work will also be the comparison between the obtained data with predictions given by MC simulation. This internship might be pursued by a PhD thesis.

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