Monte Carlo (MC) codes are increasingly spreading in the hadrontherapy community due to their detailed description of radiation transport and interaction with matter. MC methods are being utilized at several institutions for a wide range of activities spanning from beam characterization to quality assurance and dosimetric/radiobiological studies. The suitability of a MC code for application to hadrontherapy demands accurate and reliable physical models for the description of the transport and the interaction of all components of the expected radiation field (ions, hadrons, electrons, positrons and photons). This becomes extremely important for correctly performing not only physical but also biologically-based dose calculations especially in cases where ions heavier than protons are involved. In addition, accurate prediction of emerging secondary radiation is of utmost importance in emerging areas of research aiming to in-vivo treatment verification.

This contribution will address the specific case of the general-purpose particle and interaction code FLUKA. Validations and applications at several experimental sites as well as proton/ion therapy facilities with active beam delivery systems will be presented:

- Generation of synchrotron accelerator library of proton/carbon ion beam energies and foci (i.e., lateral widths at the isocentre of the treatment unit).
- Physical database generation: laterally integrated depth-dose profiles, lateral-dose distributions at different depths, secondary fragments yields and fragment energy spectra at different depths.
- Forward MC re-calculations of physical/RBE-weighted dose distributions of proton and carbon ion treatment plans.
- MC-based treatment planning in proton therapy.

The satisfactorily agreement of FLUKA against several dosimetric/nuclear yields data indicates that the code already represents a valuable choice for supporting a large variety of applications in proton and ion beam therapy.