A comprehensive theoretical comparison of proton imaging set-ups in terms of spatial resolution

Nils Krah*[1]

[1]CREATIS – CNRS – France

Abstract

We present a comprehensive analytical comparison of four types of proton imaging set-ups and, to this end, develop a mathematical framework to calculate the width of the uncertainty envelope around the most likely proton path depending on set-up geometry, detector properties, and proton beam parameters. As a figure of merit for the spatial resolution achievable with each set-up, we use the frequency f 10% at which the modular transfer function of a density step decreases below 10%. We verify the analytical results with Monte Carlo simulations. We find that set-ups which track the angle and position of individual protons in front of and behind the phantom would yield an average spatial resolution of 0.3-0.35 lp/mm assuming realistic geometric parameters (i.e., 30-40 cm distance between detector and phantom, 1520 cm phantom thickness). For set-ups combining pencil beam scanning with either a position sensitive detector, e.g., an X-ray flat panel, or with a position insensitive detector, e.g., a range telescope, we find an average spatial resolution of about 0.1 lp/mm for an 8 mm FWHM beam spot size. The pixel information improves the spatial resolution by less than 10%. In both set-up types, performance can be significantly improved by reducing the pencil beam size down to 2 mm FWHM. In this case, the achievable spatial resolution reaches about 0.25 lp/mm. Our results show that imaging set-ups combining double scattering with a pixel detector can provide sufficient spatial resolution only under very stringent conditions and are not ideally suited for computed tomography applications. We further propose a region-ofinterest method for set-ups with a pixel detector to filter out protons which have undergone nuclear reactions and discuss the impact of tracker detector uncertainties on the most likely path.

*Speaker