Purpose: Proton radiography and tomography was investigated in the early 1970s because of its low radiation dose, high density resolution and ability to image directly proton stopping power. Spatial resolution is still a limiting factor. therefore experimental methods and image reconstruction should be optimized to improve position resolution.
Methods: Spatial resolution of proton tomography is given by multiple scattering (MCS) of the protons. We employ an improved MCS model to study the impact of proton tomographic set-ups on spatial resolution, such as different combinations of entrance and exit coordinate and angle measurements, respectively, particle energy and angular confusion of the proton field.
Results: It was found that best spatial resolution is obtained by measuring in addition to the entrance and exit coordinates the entrance and exit angles. By applying partial backprojection and a perfect proton fan beam a sufficient spatial resolution can be achieved with less experimental complexity. It was also shown that it is essential to use the most probable proton trajectory to improve spatial resolution. A simple straight line connection for image reconstruction results in a spatial resolution which is not clinically sufficient. The percentage deterioration of spatial resolution due to the angular confusion of the incident proton field is less than the phase space in mrad.
Conclusions: Clinically sufficient spatial resolution can be either achieved with a full measurement of entrance and exit coordinates and angles, but also by using a fan beam with small angular confusion and an exit angle measurement. It is necessary to use the most probable proton path for image reconstruction. A simple straight line connection is in general not sufficient. Increasing proton energy improves spatial resolution of an object of constant size. This should be considered in the design of proton therapy facilities.