Visualization of $\pi^-$ and $\pi^+$ Stopping Density Distributions in One and Two Dimensions

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Summary. A technique suitable for mapping $\pi^\pm$ stopping density distributions in patients or phantoms is described. As a position sensitive detector a multiwire proportional chamber with a slit or a hole collimator in front was applied. Results using a water and a Rando phantom are presented for various momenta and momentum band widths of the $\pi^\pm$ beam. To our knowledge the two-dimensional visualization of a $\pi^-$ stopping density distribution was realized for the first time.

Introduction

It is one of the essential requirements to be met by radiotherapy that the irradiated volume has to match as precisely as possible the target volume previously determined by therapy planning. Due to the inhomogeneities of the human body this requirement turns out difficult to be fulfilled if one relies on calculations only.

In addition to the well known promising features which make pions attractive for use in therapy both negative as well as positive pions offer the unique advantage that their stopping density distribution can be visualized in beam by detecting those reaction products emitted from the stopping region that can escape from the human body or a phantom.

About 2% of negative pions coming to rest in tissue equivalent material undergo radiative capture on oxygen and carbon. This process is followed by the emission of photons with energies around 100 MeV. In order to use this reaction as a tool for visualization of the stopping density distribution the photons have to be converted into electrons and positrons. These particles have to be detected by a position sensitive detector after passage through a suitable device defining their direction of motion. This technique was developed by Sperinde et al. [3] and improved by Eaton et al. [2].

On the other hand stopped positive pions decaying via the $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ sequence lead to the emission of positrons. The energy of the positron spectrum has a

* SIN, CH-5234 Villigen
pronounced peak around 50 MeV and shows a steep decrease to the maximum energy of 53 MeV. In water this energy corresponds to a range of 20.5 cm. Therefore positive pions can be used with advantage at least for studying therapy plans with phantoms in those cases where the magnet polarities of the pion channel can be reversed easily and where the distance to be traversed by the positrons within the stopping material is considerably smaller than the given maximum range. The use of positive pions for testing therapy plans was studied for the first time by Daniel et al. [1].

**Experimental Technique**

A sketch of the experimental setup which was used for mapping the stopping density distributions of both negative and positive pions is shown in Fig. 1. Incoming pions from the biomedical channel $\pi E3$ at SIN were stopped either in the chest part of an anthropomorphic Rando phantom or in a water tank with lucite walls and a cross...