Relative LET Measurement as a tool in Quality Assurance

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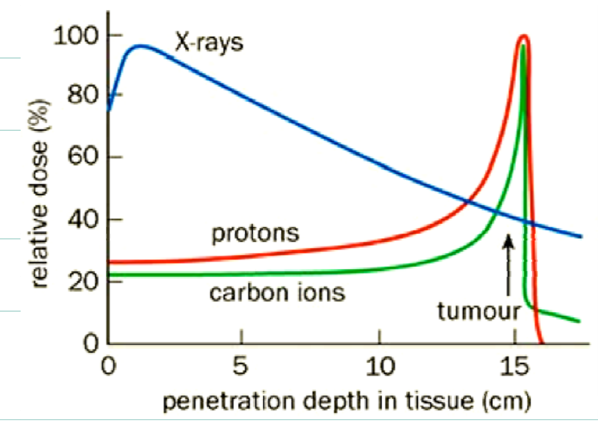
Introduction

The aim of radiotherapy is to use ionizing radiation to destroy tumor cells while sparing surrounding, healthy tissues. This requires maximizing the dose delivered in the tumor while minimizing it in healthy tissues. At the cellular level, the goal is to cause double strand breaks and therefore irreparable damage to the DNA of cancer cells, causing their destruction.

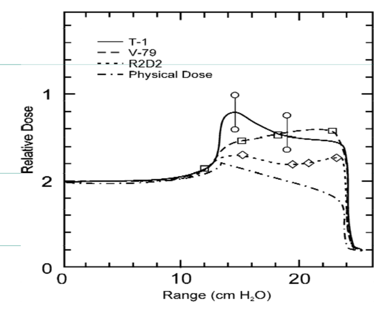


The main potential advantages of particle radiotherapy on conventional radiotherapy (x-ray) are the higher Relative Biological Effectiveness (RBE) and the change of RBE along the Bragg curve. Hadron therapy fields have higher linear energy transfer (LET) than x-ray, which means that for the same absorbed dose, the RBE and therefore the biological dose may be higher when compared to x-ray. As LET is the main physical quantity closely related to RBE, not only absorbed dose but also LET should be reported in clinical hadron therapy dosimetry.

A variation of the composition of the primary beam during the course of a treatment is expected to result in a change of the spatial distribution of the LET across the beam profile. The capability to detect such relative changes of LET could play an important part in the patient-specific quality assurance (QA).

$$D_{Bio} = RBE * D_{ph}$$

$$L_{\Delta} = \left.\frac{dE}{dx}\right|_{\Delta}$$



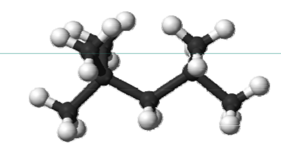
Material and Methods

The most widely used detectors in dosimetry are Ionization Chambers (IC). Liquid filled Ionization Chambers (LIC) have certain advantages over air filled IC. We use two multichannel detectors composed of a 2-D Array of LIC to study 2-D LET distributions at different depths along the Bragg Curves of electron, proton and carbon ion beams. Both of them are filled with isooctane (C_8H_{18}), a non-polar liquid, with a quite constant stopping power ratio to water.

Being that the liquid is more dense than air, recombination of e^-/ions in the sensitive volume after ionization can not be neglected.

It can be divided in two different components:

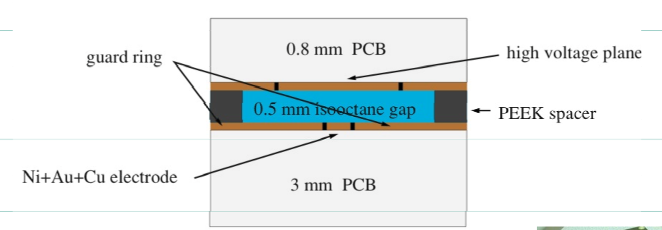
- Initial Recombination of electron/ions belonging to the same track: **LET dependent**
- General Recombination of electron/ions belonging to different tracks: dose rate dependent

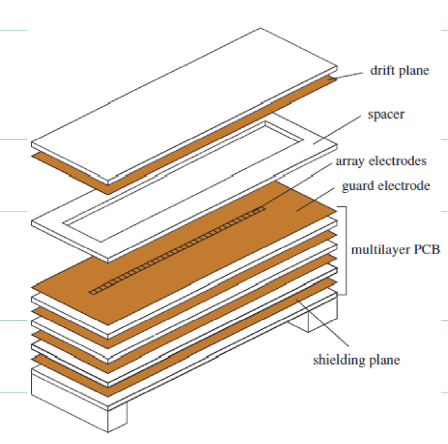


(C_8H_{18})

The evaluation of collected charges at different voltages provides the Voltage Curve. Its shape is characterized by a steeper part at low voltages followed by a linear one at higher voltages. The theory of Jaffe assess that under constant radiation and lower general recombination, the ionization current in a dielectric liquid will increase linearly with increasing the field strength (E). At low E the ionization current deviates from the linear relation due to general recombination, but at higher E its linear shape can be related to Initial Recombination, and therefore to LET, as the Initial Recombination is LET dependent.

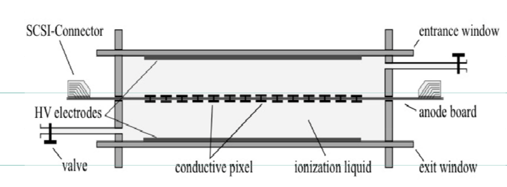
2-D Array

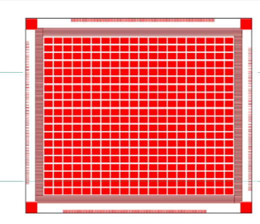


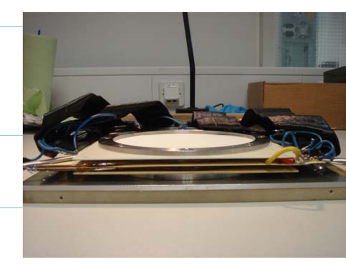


- 16x8 layout (128 pads)
- Pads: (2x2) mm^2
- Separation between the electrodes: 0.5 mm
- Individual read-out of single channels

K-LIC







- 24x20 layout (480 pads)
- Pads: (3.3x3.3) mm^2
- Separation between the electrodes: 5 mm
- Individual read-out of single channels

First Results

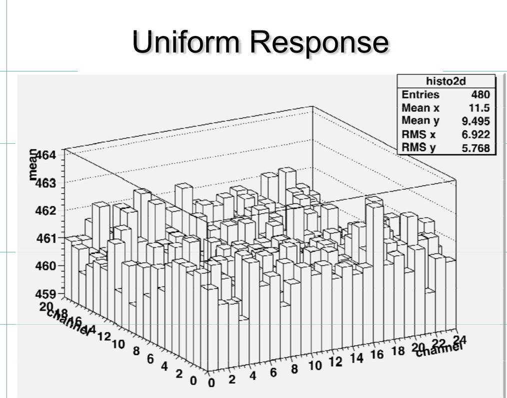
GAMMATRON MEASUREMENTS AT DKFZ

The main purpose of the first measurements was to check and compare the response of the two arrays. Therefore they have been irradiated with a Co-60 source (1.17 – 1.33 MeV Gamma Rays) in a flat field of 10x10 cm^2.

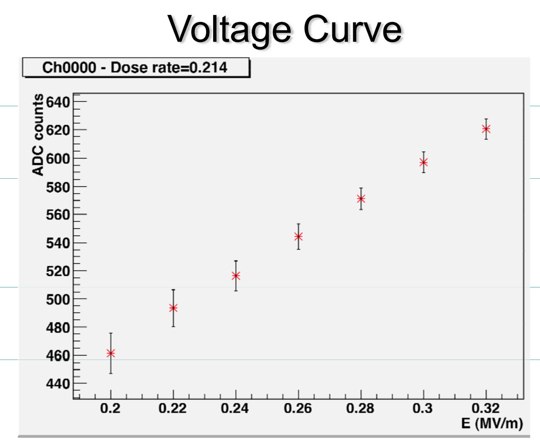
The response of the matrix, the leakage current and the Voltage Curve were evaluated.

K-LIC

Uniform Response

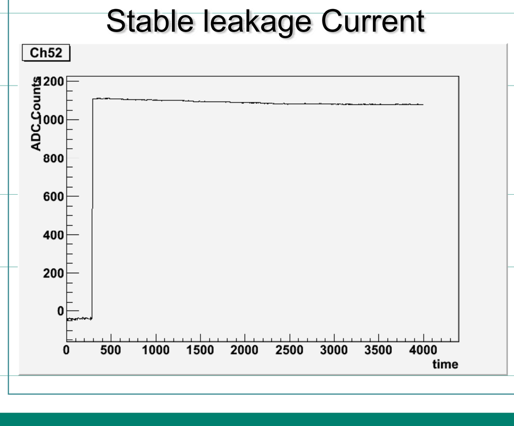


Voltage Curve

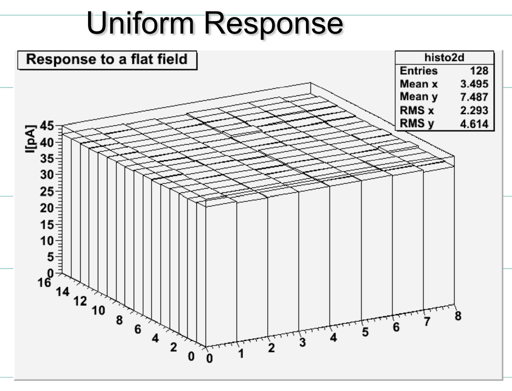


2-D Array

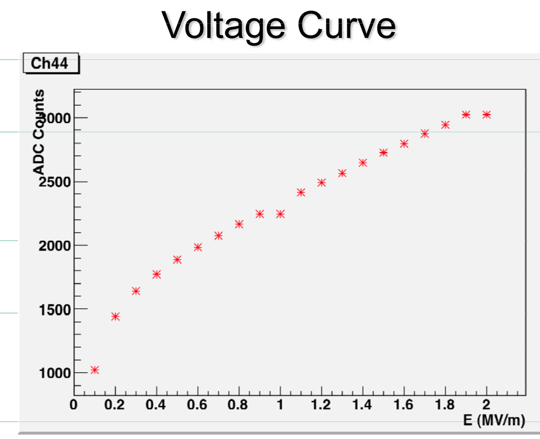
Stable leakage Current



Uniform Response

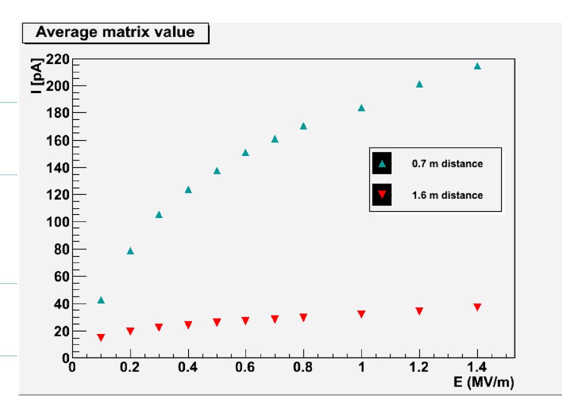


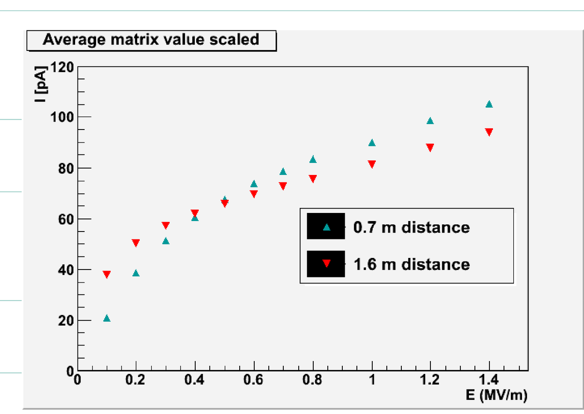
Voltage Curve

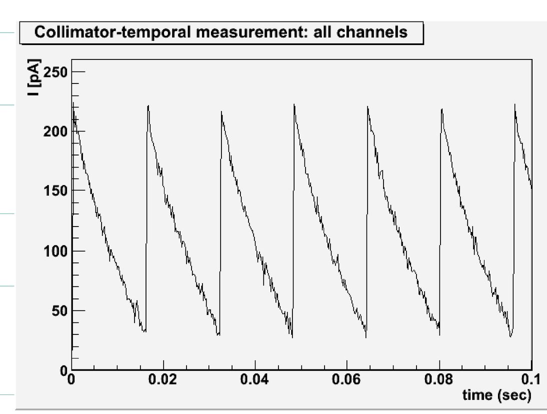


SIEMENS ARTISTE LINAC MEASUREMENTS AT DKFZ

The beam provided by the LINAC is an electron pulsed beam. The dose rate was set to a value of 50 MU/min, the pulse period was 15 msec and the pulse length was about 2 msec. Two voltage curves have been performed at two different distances from the accelerator. As the dose is scaling as r^2 and the LET of the beam does not change, the two scaled curves are expected to match.







We measured a temporal sequence to evaluate the charge collection time of the detector: data are continuously collected and averaged every 100 µsec. The whole charge ionized in the volume is collected before the arrival of the next pulse. The residual charge (20 pA) is a background level.

Conclusions and Outlook

We observed a uniform behaviour of the two matrices under a flat field irradiation. The leakage current is constant during time, therefore it can be easily subtracted.

The space between the electrodes is smaller in the 2-D Array, therefore we expect less General Recombination Effects. Moreover, it is possible to reach higher electric fields in its volume. The 2D-Array seems to be more suitable for LET measurements.

The Voltage curves measured at the LINAC shows a typical linear shape at higher electric fields: its extrapolation value on the y-Axis is related to the initial recombination and therefore gives information about LET.

The next steps are a comparison of the Voltage Curves of different LET beams (proton and carbon beams at the HIT facility in Heidelberg and antiproton beams at CERN) to get information about relative changes in the LET.

Acknowledgements

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