Dosimetry with Solid State Detectors - **Experiments at LEIR?**

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CERN, June 2012, LEIR Workshop



Signal quenching

Characteristic for any solid state detector.



Most solid state detectors (if not all?) respond **non-linear** to high-LET radiation.

Relative Effectiveness (RE or eta) is the deposited dose relative to Co-60 reference dose for iso-response. (perfect dosimeter has eta = 1) (Definition similar to RBE)

RE depends on **charge**, **energy** and sometimes also fluence.

Particle therapy: a mixed radiation field \rightarrow impossible to calibrate for all combinations of Z,E,Phi.

Instead a <u>detector model</u> is needed which describes RE for an arbitrary radiation field.

Example: GAFChromic film in Carbon lons (Martisikova et al)



RE example:

TLD-100



RE may **NOT** alone depend on single-valued parameter such as LET,

Its often also particle energy/amu, charge and fluence.

And even experimental findings of TLD relative efficiencies are ambiguous!



• One thing is to merely characterize the detector and fit models to the respective detector response

• But what we want is

– To actually understand what is happening in the detector on a less phenomenologically way

- Understanding this can lead to "detector design" (Workshop in Mainz on this topic, this week Thursday-Friday), e.g.

- decreasing unwanted effects such as quenching
- or increase it in order to be able to estimate LET



We need good Detector Models

And they should be thoroughly tested against experimental data



Detector models: the problem

• Typical situation:

- New article in <XXX> journal, presents <YYY> algorithm which describes detector response.
- Source code is not enclosed, and essential steps needed for reproduction are omitted or unclearly mentioned in article.
- "What is the purpose of presenting a model, which is closed-source, and neither can be reproduced nor verified?"



- **libamtrack** is a generic **AM**orphous **TRACK** structure based detector / radiobiology model **LIB**rary, which combines new and old algorithms for development, testing and benchmarking purposes.
- Open-source (GPL) will bring much needed transparency to detector and radiobiology models, and encourage future development to be GPL as well.
- Implemented by S. Greilich (DKFZ) and L. Granzka (IJF PAN) in collaboration with Aarhus.



libamtrack

- Libamtrack: An amorphous track structure library:
 - TST by Budz and Katz and derivates such as Hansen et Olsen
 - Local Effect Model derivates
 - Multiple radial dose distribution models
 - Scholz et al.
 - Katz
 - Hansen et Olsen
 - ...
- http://libamtrack.sf.net



AQURATE Project

AQURATE = Acquiring Response Data for Solid State Detectors

- Purpose: to establish a solid experimental data base for solid state detectors in ion beams
- Solid: only allow detectors with well established manufacture and readout protocols (typical pitfall)

Current detectors of interest:

- Alanine
- Lithium formate
- Liquid ionization chambers
- And to some extend in-vitro radiobiology
- So far we had beam time at low energy facility JYFL (Finland) in 2011



Alanine







AQURATE - Alanine

Why Alanine?

- Alanine saturates at high doses. According to TST theory, this means
 - Low LET dependency (relative to e.g. TLDs)
 - Low or negligible effects from overlapping particle tracks
- Alanine is a 1-hit detector
 - No supra-linearity
- Alanine readout protocol is well-defined, few parameters and well established (contrary to TLDs). We use service from primary dosimetry lab NPL, Teddington London (collaboration).
- => Alanine is simple to model, and in fact we get good agreement between model calculation and experimental values, shown in next slides (work by Rochus Herrmann, PhD student in our group).

Carbon ion pristine peak



ALANINE: SOBP Carbon ions



 $20~{\rm Gy}$ plateau- dose

- simulated dose
- simulated response
- + alanine response



- We would like to extend our experimental database for heavy charged particles.
- Mono-energetic beams out-side the medical range, for testing fundamental assumptions of track structure theory
 - Very low energies
 - Very high LET
 - Very high fluences (onset of track overlap) ← difficult, this means much beam time.



Alanine:



Lines represent various models from libamtrack.

Dots are experimental data.



Alanine - what we want from LEIR



Lines represent various models from libamtrack.

Dots are experimental data.

From this graph, you may see that we need two kinds of data:

1) Very low energies (there are data, but not with clear protocols)

2) higher-LET than for carbon ions



And a **third kind** of data set is needed: RE as a function of fluence, to study the exact nature of track overlaps.

Alanine is a nice detector:neglect non-linear effects from trackoverlap in therapeutic relevant dose levels.

But we want to understand the underlying physics, what happens if track's overlap, *because we can use this to test the fundamental assumptions in e.g. the Local Effect Model (LEM).*



Who are we?

- Aarhus Particle Therapy Group (APTG)
 - Research group with interest in radiobiology, detector models and dosimetry.
 - We consist of physicist (experimentalists, theorists, computer scientists) and loosely affiliated mathematicians, biologists and oncologists.
 - Denmark will get proton therapy, but our group is more involved with research with heavier ions
- http://www.phys.au.dk/aptg



http://www.phys.au.dk/aptg

anci.

THERAPY

BACKUP SLIDES



Simple Detector Response Modeling



Advanced Detector Response Modeling



Lithium Formate

Lithium Formate

- LiFo pellets have same dimensions as alanine pellets.
- Readout is similar to alanine.
- Only real difference is the lower saturation point for LiFo relative to alanine.
- Collaborative work with Oslo
 University Hospital (Norway)

- → LiFo is perfect to test the detector models where only the saturation parameter is changed (very nice!).
- → We want to apply testprotocol for alanine on Lithium formate.



Liquid Ionization Chambers

- Project with liquid ionization chambers (LICs) is related to this, since we think that *good track structure models can improve recombination models* (Jaffe / Onsager theory).
- Collaborative work with Heikki Tölli (Umeå, Sweden) and DKFZ, Heidelberg.

Again, testing our LICs in heavy ion beams with LETs higher than what can be reached with carbon ions, would be very interesting for us!



