

**Time-resolved Imaging of Secondary Gamma Ray Emissions for in vivo Monitoring of Proton Therapy  
Methodological and Experimental Feasibility Studies**

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**DOI**

[10.4233/uuid:3ba81eb3-3278-411b-abc2-efddb119991](https://doi.org/10.4233/uuid:3ba81eb3-3278-411b-abc2-efddb119991)

**Publication date**

2017

**Document Version**

Final published version

**Citation (APA)**

Cambráia Lopes Ferreira da Silva, P. (2017). *Time-resolved Imaging of Secondary Gamma Ray Emissions for in vivo Monitoring of Proton Therapy: Methodological and Experimental Feasibility Studies*. [Dissertation (TU Delft), Delft University of Technology]. <https://doi.org/10.4233/uuid:3ba81eb3-3278-411b-abc2-efddb119991>

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## Propositions

accompanying the doctoral thesis

“Time-resolved imaging of secondary gamma ray emissions for *in vivo* monitoring of proton therapy: methodological and experimental feasibility studies”

Patrícia Cambraia Lopes

1. Time-of-flight (TOF) neutron rejection in prompt-gamma (PG) imaging based on measurement of the ion arrival time (Testa *et al* *Radiat. Environ. Biophys.* 49 (2010) p.337–43) is unlikely to work with synchrotron beams. Even if a detector exists that can provide the exact arrival time of each ion, it is difficult to determine which ion gives rise to which gamma photon or neutron. In other words, the TOF information is ambiguous, considering a typical radiofrequency occupancy higher than 1 (particle per bunch) and a bunch width in the order of tens of nanoseconds (cf. Parodi *et al* *Nucl. Instr. Meth. Phys. Res. A* 545 (2005) p.446-58 and table 6.6 in Crespo Ph.D. Thesis (2005) Technischen Universität Darmstadt).
2. Prompt gamma imaging by means of mechanical collimation remains conceptually the simplest solution suggested so far.
3. Counting statistics is an insufficient measure for comparing the quality of information from PET and PG imaging techniques (Moteabbed *et al* *Phys. Med. Biol.* 56 (2011) p.1063–82; Dendooven *et al* *Phys. Med. Biol.* 60 (2015) 8923–47). The amount of information per count strongly depends on the process of image formation.
4. From simple mechanics, a small child of ca. 7-15 kg carried on the handlebars of a bicycle is in a situation of dynamic equilibrium. Considering that the risk of this practice is generally underestimated within the cultural context of The Netherlands, compulsory use of helmets would serve in the best interests of the child.
5. Transfer of knowledge through direct human interaction generally is far more effective than through self-study alone.
6. Quantity is overrated in current academic practice and comes at a cost of quality.
7. Efficient communication is a fundamental prerequisite for promoting collaboration, tolerance, and progress of Mankind as a whole. Therefore, we should adopt common languages. “Reading poetry in translation is like taking a shower with a raincoat on” (Paterson, 2016. Director: Jim Jarmusch).
8. The term “alternative medicine” is paradoxical, in the sense that there is no alternative to medicine; rather, there are alternative, potentially complementary, methods in medicine. The formulation “alternative medicine” should not be used, as it gives rise to interpretations and practices that do not benefit medicine in general.
9. To achieve success and happiness it is necessary to conjugate ambition and low expectations.

These propositions are regarded as opposable and defensible, and have been approved as such by the promotor Prof. dr. ir. H. van der Graaf and copromotor Dr. ir. D.R. Schaart.