# Development of a TOF Compton camera prototype for ion therapy monitoring and medical imaging

Jean-Luc Ley

**Supervisors**: D. Dauvergne and N. Freud
**Institution**: Institut de Physique Nucléaire de Lyon
**Examiners**: S. Jan, G. Montarou, G. Chanfray, J.-P. Cussonneau, D. Dauvergne, V. Maxim, F. Peyrin and P. Thirolf

## I. Introduction

Hadrontherapy is one of the modalities available for treating cancer. Compared to conventional radiotherapy, this allows to spare the healthy tissue located adjacent downstream and upstream of the tumor. One of this modality's quality assurance challenges is to control the positioning of the dose deposited by ions in the patient. One possibility to perform this control is to detect the prompt gammas emitted during nuclear reactions induced along the ion path in the patient. A TOF Compton camera prototype is being developed under a regional collaboration and was the main focus of my thesis, and particularly the following points : i) studying, throughout Monte Carlo simulations, the operation of the prototype in construction, particularly with respect to the expected counting rates on the different types of accelerators in hadrontherapy ii) conducting simulation studies on the use of this camera in clinical imaging, iii) characterizing the silicon detectors (scatterer) iv) confronting Geant4 simulations on the camera's response with measurements on the beam with the help of a demonstrator.

## II. Material and Methods

### A. Monte Carlo simulation Geant4: hadrontherapy

The simulation consists of the irradiation of a patient by an ion beam and the detection of the secondary particles emitted by mean of the Compton camera prototype. The patient is replaced by a cylindrical PMMA phantom of 15 cm diameter and 20 cm length. The Compton camera prototype is composed by a scatterer, an absorber and a scintillating fiber hodoscope. The setup is described figure 1.

The Monte Carlo simulation parameters are as close to reality as possible in order to get relevant results. The detector resolutions are modelled in relation to the resolutions measured or estimated for each detector. Two time beam structures are applied to the simulation data: one of IBA cyclotron C230 for protons and one of synchrotron installed at the Heidelberg Ion Therapy Center (HIT) in Germany for carbon ions.

### B. Monte Carlo simulation Geant4: nuclear medicine

The Compton camera is modelled as in the hadrontherapy study. However, I remove the PMMA phantom and I use a point monoenergetic gamma source. The energy range for gammas is from 100 keV to 3 MeV.

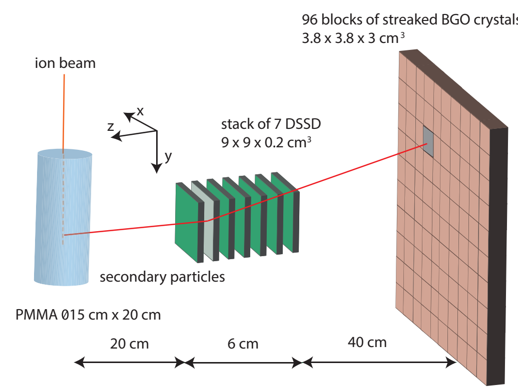


Fig. 1: Modelling of the patient (PMMA cylinder) and the Compton camera prototype. This configuration is used for all the results presented in this resume.

## III. Results

### A. Hadrontherapy

- Quality assurance with a Compton Camera is not possible at the current beam intensity used in clinic ($2 \times 10^{10}$ protons/s). The beam intensity has to be reduced by a factor of 200 to get 1 proton per bunch. The control for a carbon ions beam seems to be not achievable.
- In order to reconstruct the events detected by the Compton camera, the analytic algorithm gives a quick results, but the contrast at the falloff position is low. The LM-MLEM algorithm used provide a detection for the falloff with 20 iterations. However, this method is time consuming and some artefacts have to be corrected.
- The Compton Camera precision on the falloff position is estimated at 5 mm for 1 spot (protons).

### B. Nuclear Medicine

The performances of the Compton camera for a point source are:

- At low energy (100 keV), the camera is not adapted because of the Doppler effect and the equivalent noise charge (ENC) in the scatterer.
- For energies higher than 300 keV, the Compton Camera shows a better spatiale resolution and a better detection efficiency by a factor 100.
- Limitations come from the spatial resolution and the deep of the interaction of the absorber.

### C. Instrumentation

- The measurements of the leak current for the scatterer detectors in function of the temperature are done. The detectors show consistent results comparing to the manufacturer ones.
- The electronics is still under development and should be working in 2017.

## IV. Discussion

As a result, the Compton camera prototype developed makes a control of the localization of the dose deposition in proton therapy to the scale of a spot possible, provided that the intensity of the clinical proton beam is reduced by a factor 200 (intensity of 108 protons/s). An application of the Compton camera in nuclear medicine seems to be attainable with the use of radioisotopes of an energy greater than 300 keV. These initial results must be confirmed by more realistic simulations (homogeneous and heterogeneous PMMA targets). Tests with the progressive integration of all camera elements will take place during 2016.

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