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#### ► To cite this version:

O. Allegrini, J. P. Cachemiche, C. Caplan, B. Carlus, X. Chen, et al.. Test and characterization of the CLaRyS camera's absorber with its final acquisition chain. Young Investigator's Workshop on Photon Detection in Medicine and Medical Physics - 2019, Dec 2019, Siegen, Germany. hal-02408478

#### HAL Id: hal-02408478 https://hal.science/hal-02408478

Submitted on 13 Dec 2019  $\,$ 

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# Test and characterization of the CLaRyS camera's absorber with its final acquisition chain

O. Allegrini<sup>1</sup>, J.P. Cachemiche<sup>2</sup>, C.P.C Caplan<sup>2</sup>, B. Carlus<sup>1</sup>, X. Chen<sup>1</sup>, S. Curtoni<sup>3</sup>, D. Dauvergne<sup>3</sup>, R. Della Negra<sup>1</sup>, M. L. Gallin-Martel<sup>3</sup>, L. Gallin-Martel<sup>3</sup>, J. Hérault<sup>4</sup>, J. M. Létang<sup>4</sup>, S. Marcatili<sup>3</sup>, C. Morel<sup>2</sup>, É. Testa<sup>1</sup>, Y. Zoccarato<sup>1</sup>

<sup>1</sup>Université de Lyon, Université Claude Bernard Lyon 1, CNRS/IN2P3, Institut de Physique Des 2 Infinis de Lyon, 69622 Villeurbanne, France, <sup>3</sup>Université Grenoble Alpes, Laboratoire de Physique Subatomique et de Cosmologie, CNRS/IN2P3, Grenoble, France, <sup>4</sup>Centre Antoine Lacassagne, Cyclotron Biomédical, 227 Avenue de la Lanterne, F-06200 Nice, France, <sup>5</sup>CREATIS, Université de Lyon; CNRS UMR5220; INSERM U1044; INSA-Lyon; Université Lyon 1; Centre Léon Bérard, Lyon, France,

### **1.** Introduction

- > Ion-range uncertainties are currently a major concern in ion beam therapy. These are due to anatomical changes of the patient during the treatment and to uncertainties of imaging modalities (used for treatment planning) and of treatment planning systems.
- > As a consequence, the most widespread treatment planning techniques are based on the use of several beam incidences, which increases the healthy tissues irradiation and **additional margins** are applied around the tumor to ensure the whole tumor irradiation.
- > In order to fully take benefit from ballistic properties of ion beam therapy, in-vivo ion-range verification techniques are currently under development by several groups in the world. In this context, the CLaRyS collaboration (IP2I, CPPM, LPSC, CREATIS) develops gamma cameras prototypes coupled to a beam hodoscope [1] to perform prompt gamma (PG) detection with TOF measurement.

2. Material	3. Method	
ABSORBER HODOSCOPE	In-lab BGO blocks	In-beam test experimental setup:





**Collimator:** 

- $> 1.5 \times 120 \times 170 \text{ mm}^3$ tungsten alloy slabs
- Adjustable gap between slabs

Figure 1: View of the Compton camera assembly with the beam hodoscope



#### Hodoscope:

- 2 perpendicular planes for a 2D mapping
- > 128 BCF-12 scintillating fibers per plane
- $> 1 \text{ mm}^2$  squared section
- > 8 multi-anode PMs for a two side read-out
- Signal handling ensured by 8 FE cards including 64 input channels, 2 ASIC and 1 FPGA

# **Absorber:**

- > 32 BGO blocks  $(35 \times 38 \times 30 \text{ mm}^3)$  (BGO) particularly interesting for high energy photons [2])
- > 8×8 pseudo-pixels / block
- 4 photomultipliers (PMs) / block

#### characterization:

- **1** Manual equalization of PMs gain 2 High voltage (HV) adjustment to detect PG up to 6 MeV with low saturation rate.
  - Increase of HV (HV1) until signal saturation with  $^{22}$ Na source (0.511 and 1.275 MeV gammas)
  - Decrease of HV (HV2) by a factor of 4.7 (6/1.275) to ensure 6 MeV PG detection



Figure 4: Energy spectra with HV1 (left) and HV2 values(right).





Figure 6: Scheme of the experimental setup in top view

- Number of blocks used: 4
- **Trigger conditions:** 1 PM signal over an high threshold OR 2 PM signals over a low threshold
- **Beam intensity** = 3.5 nA (measured in a Faraday cage with  $\sim 10\%$  uncertainties)
- > System acquisition dead time rate = 90.8% (evaluated by successive acquisitions with various intensity and comparison to paralizable model)
- A calibration of the energy threshold has to be performed in-lab  $\Rightarrow$  Energy threshold not defined at this time





**BGO blocks performances:** 

**Spatial resolution:** Limited to pixel size (4.75mm)  $\Rightarrow$  A sub-pixel spatial resolution is not achievable [4]



Triggering: logical combination of thresholds applied on each block channel

**Energy resolution:** 

FWHM  $\sim 17\%$  at 511 keV and

 $\sim$  20-25% at 1275 keV



Figure 2: Distribution of arrival time differences between reference scintillator (a BaF<sub>2</sub> mono-block detector with 1 ns FWHM time resolution) and BGO block [4]

**Time resolution:** 

# 5. Conclusion and perspectives

> Physical results:

- First measurement of PG profile with the final acquisition system of the CLaRyS prototype at clinical beam intensity
- $\Rightarrow$  The PG profile corresponds to the expectations in terms of count rate (analytic model [5]) and profile length ( $\sim 3$  cm).

Figure 5: Picture of the experimental setup

## 4. In-beam test results

- **1** Acquisition without collimator **2** Acquisition with collimator Large variation of the efficiency within blocks  $\Rightarrow$  Need for normalization
- 3 Normalization of the acquisition with collimator with respect to the one without collimator
- $\blacktriangleright$  **N**<sub>B</sub>: Number of blocks
- $\succ$  C<sub>i</sub>: Mean value of the four pixels in the center of block *i*.
- > M: Average value of the mean values of the four pixels of the center of blocks

$$M = \frac{1}{N_B} \sum_{i=1}^{N_B} C_i$$

 $> N_{norm}$ : Counts in each normalized pixels



Figure 7: Assignment of events to pixels in a single block for acquisition without 1 and with 2 collimator.



contact: o.allegrini@ipnl.in2p3.fr

#### Perspectives:

- Physical analysis: Complete analysis and comparison with simulations
- Slow control improvements:
  - Make the BGO block calibration automatic
  - Tuning of the correlation between the beam hodoscope and the absorber
- Next experiment: Use of the beam hodoscope to perform TOF measurement and reduce the background induced by neutrons (of utmost interest for high energy proton beam)
- $\Rightarrow$  Absorber upgrade: High dead time with the current ASM board  $\Rightarrow$  Need for a new FE card



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