A cosmic muons test bench for the characterisation of GRAiNITA

Hervé Chanal
on behalf of the GRAiNITA Collaboration
Université Clermont Auvergne, CNRS/IN2P3, LPCA
F-63000 Clermont-Ferrand, France
herve.chanal@clermont.in2p3.fr

***Abstract*—The GRAiNITA project aims to develop a next-generation calorimeter. It uses grains of an inorganic crystal mixed with a high-density transparent liquid. This technology is expected to allow excellent energy resolution at a lower cost than existing technologies. To characterise its performance, a dedicated test bench has been developed. Its working principle is based on the track reconstruction of cosmic muons that cross the GRAiNITA prototype. Track length is directly related to the deposited energy. These measurements allow one to check detector light generation and its uniformity. The test bench uses a Timepix tracker to accurately reconstruct the muon trace and a set of scintillators to generate a trigger and a time stamp. This system is currently in operation and gives its first results which will be presented in the conference. These measurements provides a first step before producing finer studies in test beams.**

***Index Terms*—Muons, Calibration, Calorimeter**

I. Introduction

The development of new colliders in particle physics, such as the Future Circular Collider (FCC-ee) [1], triggered the development of new detector concepts. Intense research is aimed at improving the energy resolution of calorimeters. In this regard, GRAiNITA [2], a calorimeter made of small grains in a high z scintillating material in a high-density transparent liquid acting as an absorber, can bring a significant improvement over the typical shalshlick calorimeter architecture (Fig. 1). Multiple refraction due to the stochastic placement of the scintillator grain confines the light near its production, as in the LiquidO detection principle [3]. The preliminary simulation indicates that an energy resolution of $2\%/\sqrt{E}$ is achievable [2]. The scintillation light generated by the GRAiNITA grain is collected by wavelength shifting (WLS) fibres regularly spaced every 7 mm in the detection volume. The readout is performed by the Wavecatcher [4] or the ASM acquisition system [5].

This article presents the design and operation of a test bench using cosmic muons for a preliminary determination of the detector performance. The confinement of light demands an accurate reconstruction of the muon track in order to precisely study its collection by each of the WLS fibres.

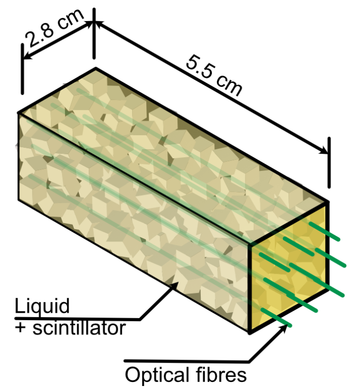

Fig. 1. The GRAiNITA prototype.

II. Working principle

The cosmic muon test bench provides two information needed for the characterisation of GRAiNITA : an accurate reconstruction of the muon track and a trigger (with a timestamp) for the GRAiNITA acquisition. The track reconstruction must provide a resolution better than 1 mm at the top of the detector. This helps to calculate the distance travelled by the muon dx in the tested device and the distance from the track to each WLS fibre. GRAiNITA acquisition is used to determine the deposited energy dE. The results give the dE/dx distribution.

It has been chosen to divide the test bench it in two stages (Fig. 2) :

- A Timepix tracker ;
- Two scintillators.

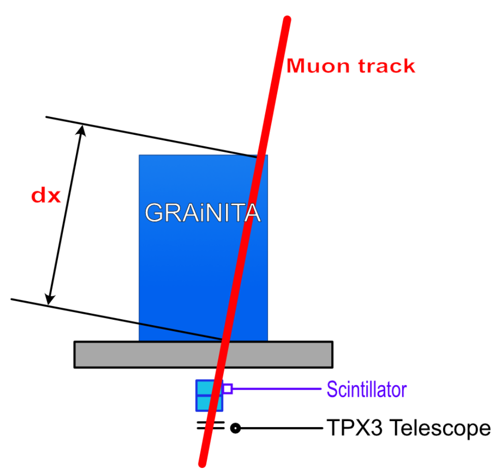

Fig. 2. The cosmic muon test bench.

The tracker consists of two planes of the timepix 3 chip separated by 4.5 mm developed by the ADVACAM company [6]. Each is made up of a 256x256 matrix of 55 μm pixels. The sensitive detector on the top is a layer of 500 μm of silicium while the bottom use a 1000 μm one. Data are recorded by frames of 20 s. For each triggered pixel, the amplitude and time of arrival (TOA) of the charge are recorded. The resolution of the TOA time stamp is 1.56 ns. A muon candidate is generated when pixels on both planes are detected in a 350 ns windows.

For each muon candidate, the barycenter of the triggered pixels in each timepix detector is determined. The track is reconstructed from these two points (Fig. 3).

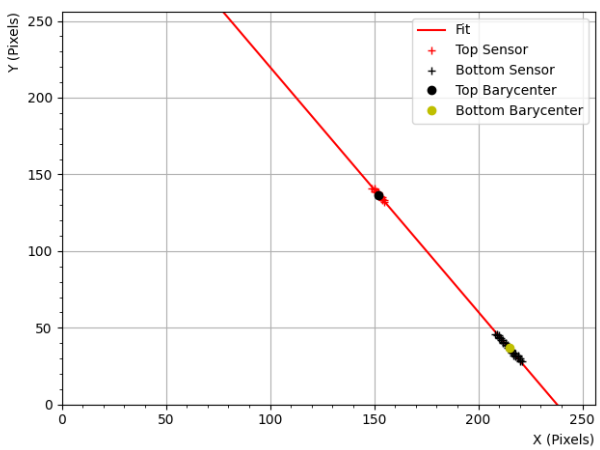

Fig. 3. A reconstructed track.

The scintillators generate the trigger for the Grainita acquisition system. It provides an absolute time stamp to tag the muons. Data from the timepix and scintillators are merged to perform the final reconstruction (Fig. 4).

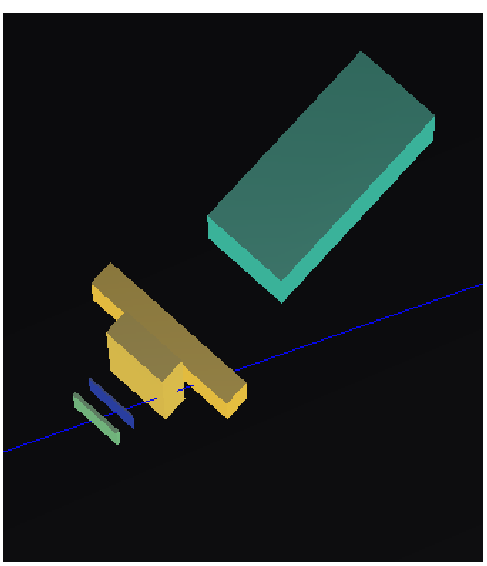

Fig. 4. 3D reconstruction.

III. Preliminary Results

The mean value of the number of photons detected for one of the GRAiNITA fibres was determined. The track reconstruction allows us to compute the expected interaction of the muon with the detector.

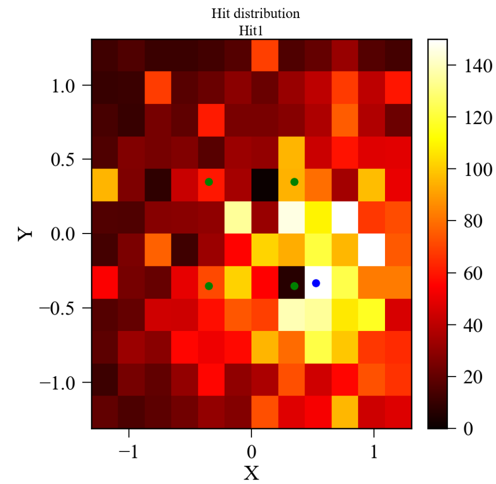

Fig. 5. Hit map (left) of the mean number of detected photon depending on the reconstructed position for one fibre of the detector.

One can observe the light confined near its production region, confirming the expectation. The light production yield was previously measured. The study of all the fibre responses with cosmic muons is ongoing.

IV. Conclusion

The design of a GRAiNITA test bench has been proposed and developed. Its operation has started, and it shows promising performance. The characterisation of the GRAiNITA prototype has begun and the first results are expected soon.

The versatility of this test bench allows one to foresee its usage in the test beam for a finer characterisation of GRAiNITA. It will also be available for the development needs of any other calorimeter developed by the community.

References

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