A cosmic muons test bench for the characterisation of GRAiNITA

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Abstract*—The GRAiNITA project aims to propose a novel design for a next-generation calorimeter. This innovative approach uses a mixture of submillimeter sized inorganic scintillating crystals (around 1-2 mm) dispersed within a high-density, transparent liquid. This technology is expected to achieve excellent energy resolution at a significantly reduced cost compared to existing technologies. This paper presents the development and operation of a test bench designed to characterise the performance of the GRAiNITA prototype. Its working principle is based on the reconstruction of the track of cosmic muons traversing the prototype. The length of the reconstructed track is directly correlated with the deposited energy within the detector. These measurements allow one to assess the light generation efficiency and its uniformity across the entire detector volume. The test bench incorporates a Timepix tracker to accurately reconstruct the muon trajectory within the detector. Additionally, a set of scintillators provides a trigger signal and a time stamp for each muon candidate event. This system is currently in operation and gives its first results, which will be presented in the upcoming conference. These measurements provide 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 about a significant improvement over the typical shashlik calorimeter architecture (Fig. 1). Multiple refraction due to the stochastic placement of the scintillator grains confines the light near its production, as in the LiquidO detection principle [3]. The first results indicate 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 what concerns the uniformity of the measurement and improved light-yield determination. 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.

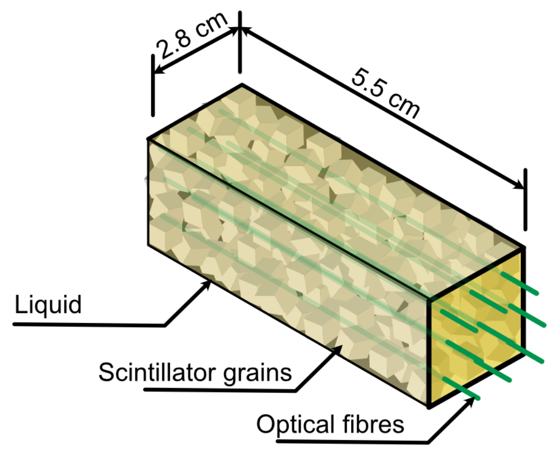

Fig. 1. The GRAiNITA prototype.

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.

The tracker consists of two planes of the timepix 3 chip separated by 4.5 mm developed by the ADVACAM company [6].

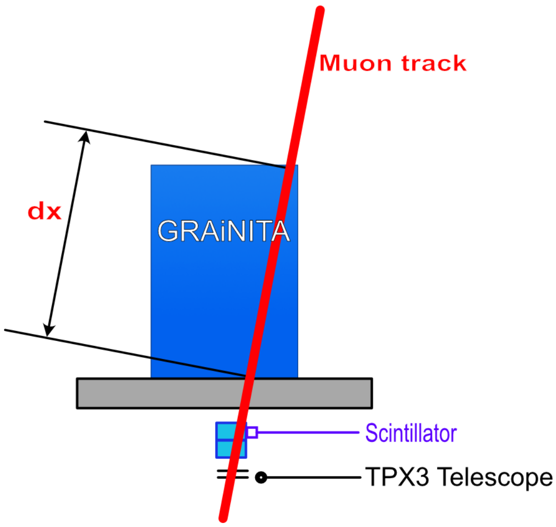

Fig. 2. The cosmic muon test bench.

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).

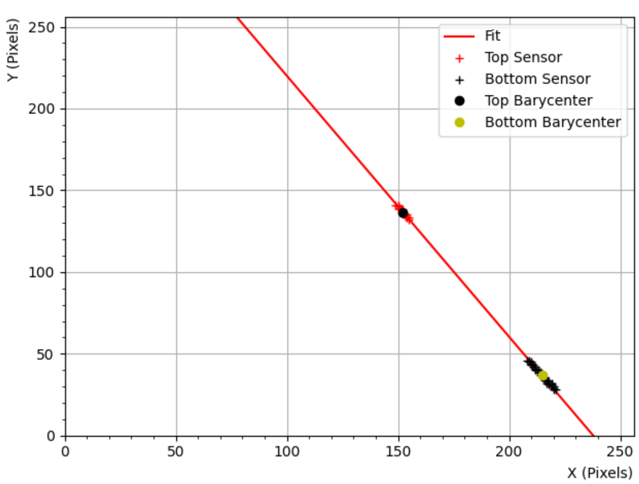

Fig. 3. A reconstructed track (red line).

The scintillators generate the trigger for the GRAiNITA acquisition system. They also provide an absolute time stamp to tag the muons. Data from the timepix and scintillators are merged to perform the final 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.

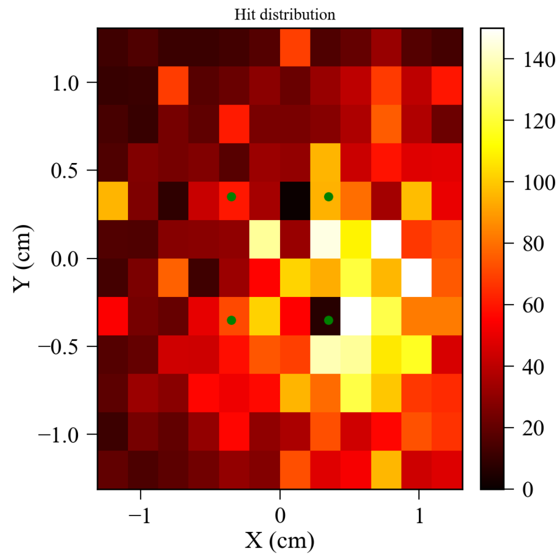

Fig. 4. Hit map of the mean number of detected photon depending on the reconstructed position at the top of GRAiNITA for one fibre of the detector. Green points represents the four centre fibres position.

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

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

The versatility of this test bench allows for its use in the test beam. It will also be available for the development needs of any other calorimeter developed by the community.

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