Injection molded scintillator for future high granularity experiments – DUNE 3DST
Letter of Interest for Snowmass 2021

C. Ha,[1] S. Kwon,[1] K. Siyeon,[1] A. Bross,[2] J. Freeman,[2] A. Pla-Dalmau,[2] C. K. Jung,[3] C. McGrew,[3] C. Riccio,[3] and G. Yang[3]

[1] *Chung-Ang University, Seoul, Korea*
[2] *Fermi National Accelerator Laboratory, Batavia, IL 60510, USA*
[3] *SUNY Stonybrook, Stonybrook, NY 11794 USA*

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Several high energy physics experiments currently under design are considering the implementation of high granularity plastic scintillator detectors which will require the assembly of a large amount of small plastic scintillator units. Plastic injection-molding is the technique commercially pursued in these conditions. Development of high-quality injection-molded elements with holes for WLS fibers is directly applicable to the DUNE Near Detector (3DST), improving the quality of the detector, and saving substantial cost by eliminating the need to machine scintillator sheets and drill holes for fibers or to optically isolate each unit.

Plastic scintillator is a very important technology choice for detector builders. It is inexpensive, has fast response, and can be fabricated into many shapes. Future high granularity detectors can take advantage of these features. As future detectors increase anticipated granularity, it becomes more and more important to develop technology that allows for precise yet low-cost fabrication of detector elements. We are investigating using injection-molding to build the detector subunits. We will consider an explicit application to the DUNE three-dimensional scintillator tracker (3DST) [1].

Several high energy physics experiments currently under design are considering the implementation of high granularity plastic scintillator detectors. These detectors will require the assembly of a large number of small plastic scintillator units [1], [2]. The prospect of machining these cells from cast or extruded scintillator is expensive due to the amount of labor involved. For cost purposes, the ideal solution is to find an industrial process producing the small elements and to reduce post-manufacturing operations. Plastic injection-molding is the technique commercially pursued in these conditions. The CALICE detector is a pioneer in the use of injection-molded scintillator [3]. We will improve state-of-the-art by increasing light yield and incorporating key 3-D features into the injection-molded scintillator.

DUNE 3DST will be a scintillator-based tracking detector based on 3-D elements, "voxels". The voxel (volume pixel) is a cube of scintillator with reflective optical isolation on the outer faces, and 3 orthogonal holes through the body to be threaded with WLS fiber. It will create a 3-D volume element. The voxel element is planned to be approximately 1x1x1 cm. Figure 1 shows an artist conception of a voxel, threaded by orthogonal wavelength-shifting fibers. Readout of the 3 intersecting fibers provides the XYZ coordinates. We will develop technology to completely fabricate the voxel, with holes and opaque cladding. DUNE 3DST will use 11 million voxels, hence the extreme importance of reducing cost/labor per voxel. Injection molding is ideally suited for this application.

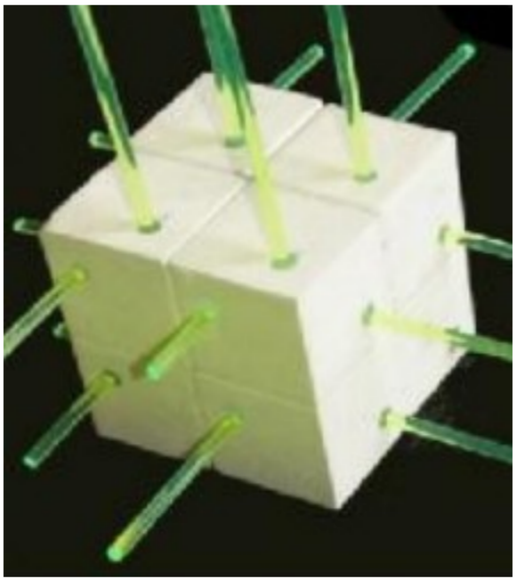

FIG. 1. The "voxel" concept for 3-D scintillator tracker using WLS fiber and SiPM readout. Eleven million $\sim$ 1 cm^3 voxels are foreseen for the DUNE experiment. [4]

The voxel unit cost will be reduced by creation of co-injection-molded holes through each face instead of drilling holes after injection molding. This part will not only save substantial time and money, it will also yield higher quality parts, with precise holes through their bodies (no drifting of the drill bit) and with optical quality surfaces (no drill marks in the holes).

An injection-molded reflective capstocking would be a significant development in the manufacture of injection-molded plastic scintillator. A reflective coating on the scintillator units is necessary for optical isolation of the voxels. Use of automated technology to create the coating would represent substantial cost and performance benefits.

There is already an injection-molding machine (Milacron ACT-100B) at Fermilab. It is equipped with a mold for a small scintillating tile (Figure 2). A new mold for a 1 cm^3 element featuring three orthogonal holes is currently being fabricated. This mold will allow us to test material more relevant to the DUNE 3DST detector.

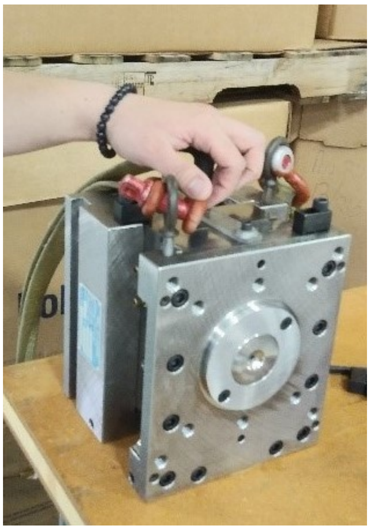

FIG. 2. Mold for small injection-molded scintillators.

[1] D. Martínez-Caicedo, "*The 3DST + KLOE spectrometer as part of the DUNE Near Detector*," DUNE doc-dB-16886-v2, presented at NNN19 (XX International Workshop on Next Generation Nucleon Decay and Neutrino Detectors, Medellín, Colombia, November 7-9, 2019 .

[2] M. Valentan, "*The CMS high granularity calorimeter for the high luminosity LHC*," Nucl. Instrum. Meth. A936 102-106 (2019) .

[3] R. Pöschl, "*Recent results of the technological prototypes of the CALICE high granularity calorimeters*," VCI2019 (Vienna Conference on Instrumentation, Vienna, Austria, February 18-22, 2019 .

[4] "*from https://indico.cern.ch/event/782953/contributions/3444520/attachments/1889314/3115389/DPF2019_DUNE3DST_gyang.pdf*," .