Spatial-sensitive detector based on strong scattering scintillating medium

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Abstract

The opaque scintillator detector is a novel concept for a new generation of position-sensitive detectors. The main idea is to localize the light near the point of its scintillation via the scattering medium. The first published results by the LiquidO collaboration are based on the usage of an opaque liquid scintillator.

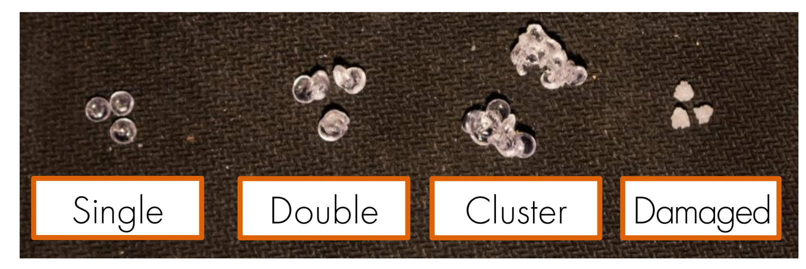
Our approach suggests the usage of media based on solid granular organic scintillator and an array of WLS fibers with SiPMs as photodetectors. The report describes the new results obtained during the beam test of different configurations of scintillating and scattering media with external proportional chambers as a tracking system. The results of media comparison and estimation of track reconstruction accuracy are presented.

0 Introduction

- Organic scintillators are widely used as easily scalable energy detectors. Many neutrino experiments, such as DANSS, SuperFGD, STEREO, PROSPECT etc., have organic scintillator counters as the segmented sensitive volume.
- The LiquidO collaboration suggested a new approach based on the scattering of scintillated light by adding special wax to the LAB liquid scintillator.

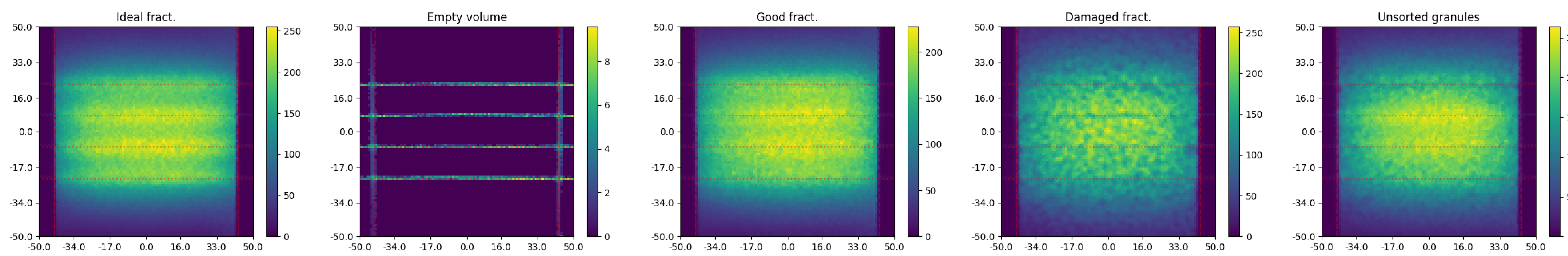
1 Prototype and Media configurations

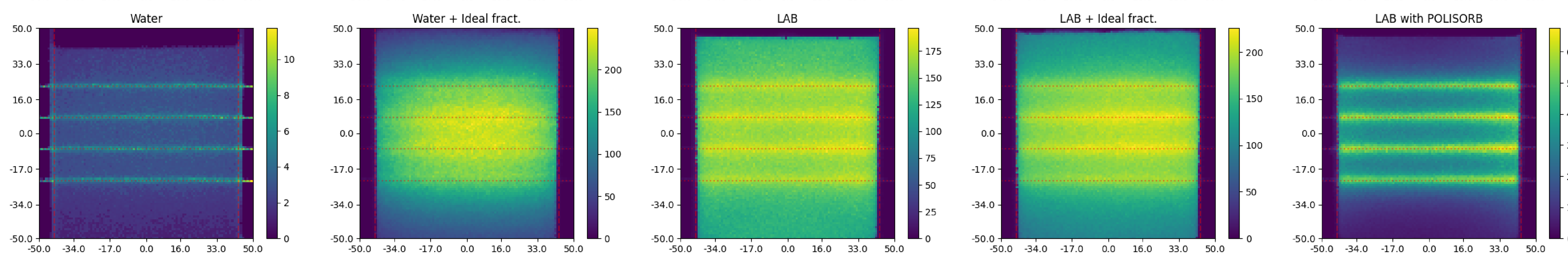
- Data collection was conducted on the almost horizontal parallel beam of pions with a momentum of 745 MeV. Three proportional chambers were used as an external tracking system: two 1 mm PCs were located 20 cm before and after the prototype along the beamline, and one 2 mm PC was located 150 cm before the prototype.
- Prototype's sensitive volume is (88x88x111) mm^3. The 4x4 array with a 15 mm step of WLS fibers Kuraray Y-11 is used for light collection. Each fiber is read by a SiPM on one end and is painted black on the other end.
- Solid organic scintillator granules are used as a medium component. A single granule has the form of a disc 3 mm in diameter and 1 mm in thickness.
- **Ideal fraction** consists of single granules; **Good fraction** combines single and double granules; **Damaged fraction** combines clusters and damaged granules; **Unsorted granules** are taken as is. **LAB** and **water** are used as the pure media and as the filling media for Ideal fraction. The solution of the **LAB and polisorb** is also studied as an example of colloidal suspension.



2 Integral pictures

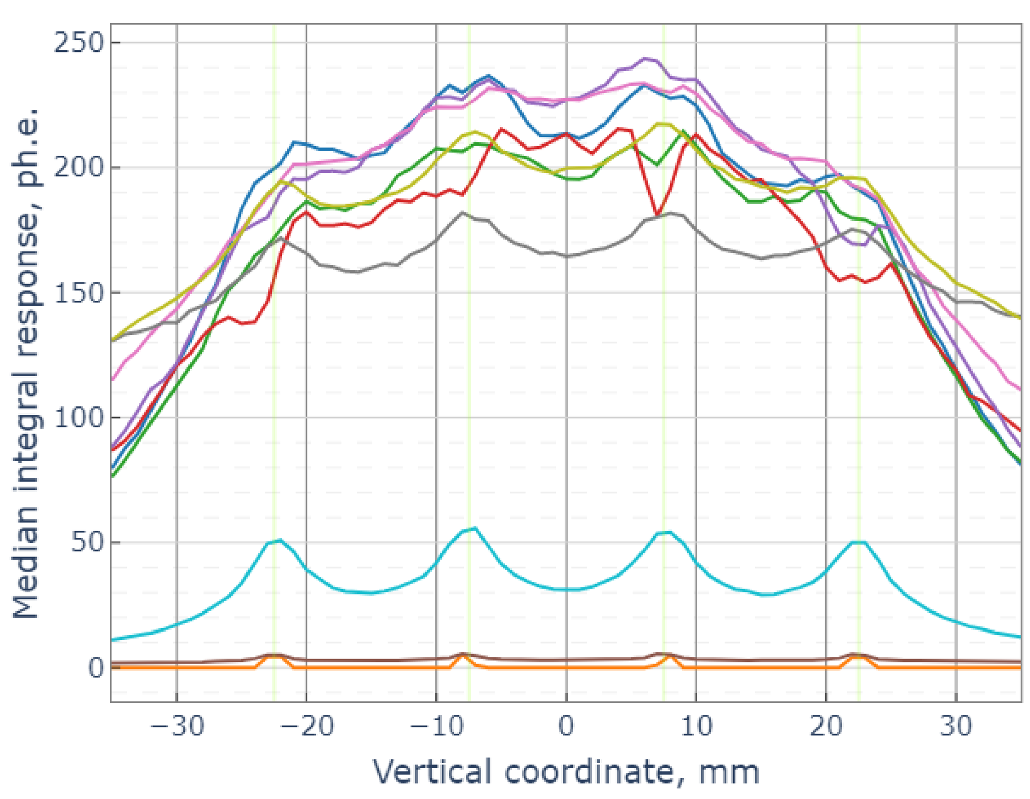
- The following 2D-histograms represent the distributions of the sum of signals from all channels in the plane transversal to the beamline for different medium configurations.
- Red lines mark the locations of the volume's edges and the fibers.

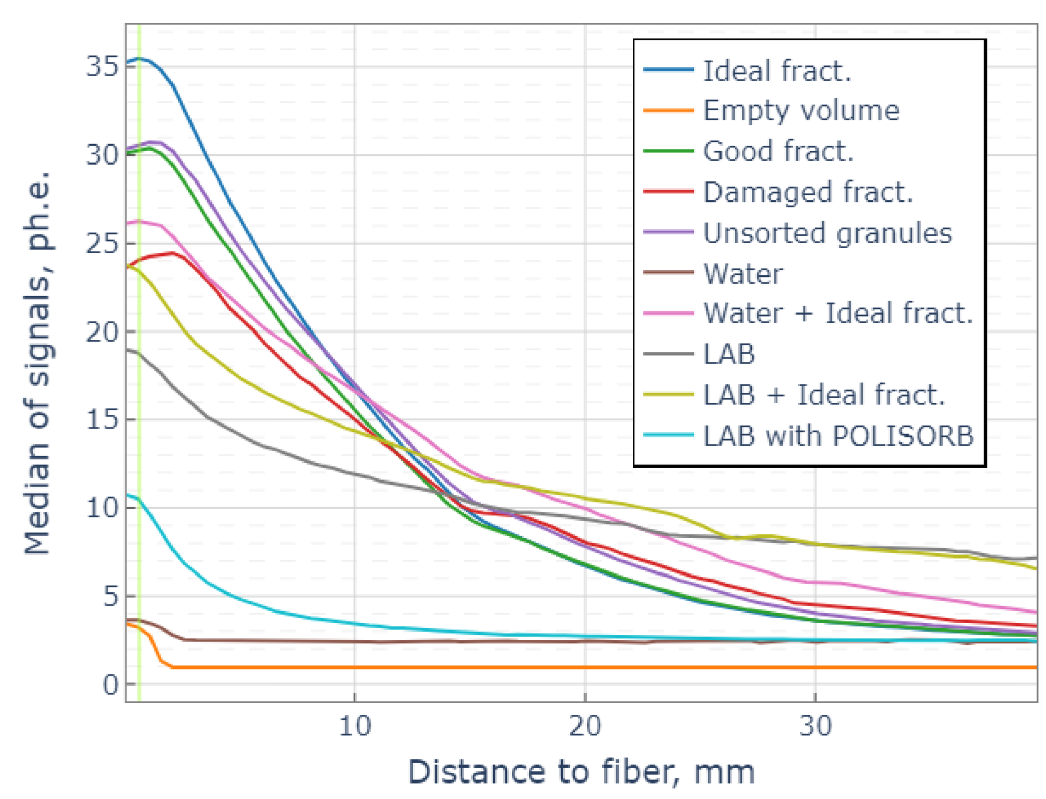




3 Detector response

- Integral detector response graphs represent the dependence of the median of the integrals in the central 30 mm horizontal window on vertical coordinate. Light green lines show the positions of the fibers.



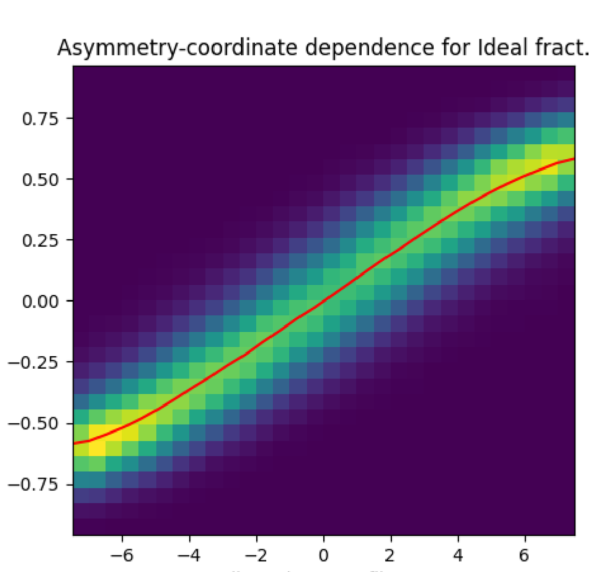


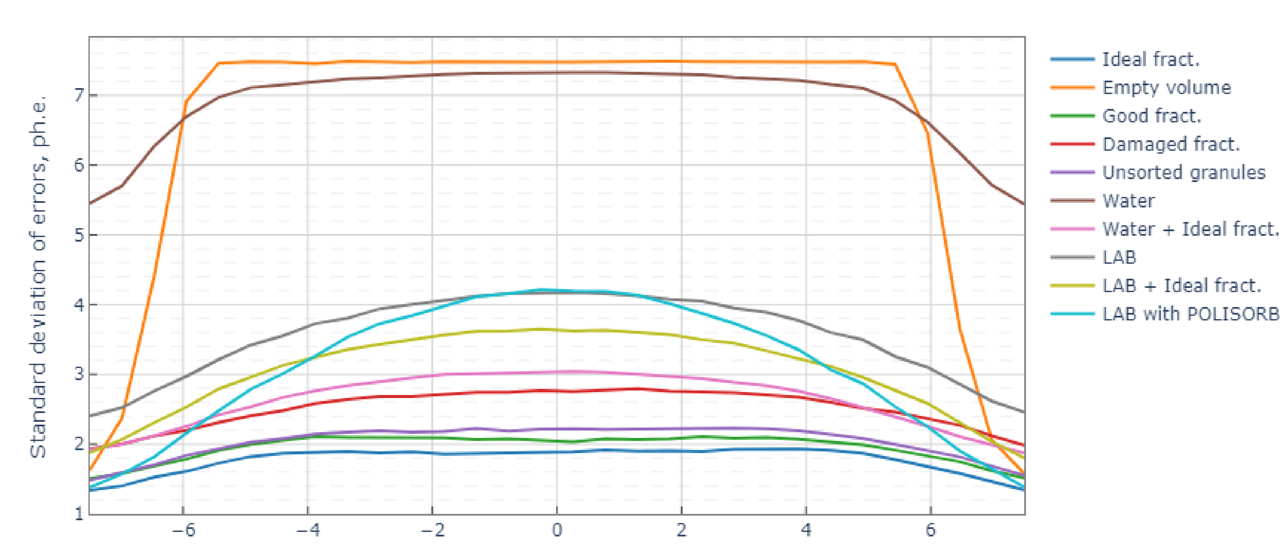
4 Channel profiles

- As the tracks' coordinates and channel positions are known, one can reconstruct the distance from the track to the fiber. Thus one can compare the light propagation for the different media configurations. Green line represent the edge of the fiber.

5 Asymmetry reconstruction

- In order to neglect the influence of the track's angle in the parallel to the fiber plane one can use the signal asymmetry: $asym = \frac{A_{up}-A_{down}}{A_{up}+A_{down}}$, where **A** is amplitudes of signals in vertical pair of channels.
- The asymmetry-coordinate function for the pair of the channels can be calculated via comparing the distributions of asymmetry and coordinate. It allows to reconstruct the track by 4 points obtained from 4 pair of the channels with the biggest signal in the vertical plane. The accuracy of this reconstruction method also depends on the coordinate.





6 Media comparison

- As it is seen in the integral pictures, scintillating granules can act as opaque medium, allowing to collect more light near the fibers, but making the distant areas less visible.
- The effective scattering light and mean density depend on the used fraction parameters and, also, on the filler – air, water, LAB. Filler makes the medium more dense, but at the same time it makes the medium more transparent as the filler's refraction index verges to the granule's one. The small effective scattering light leads to more steep asymmetry-coordinate dependence and better accuracy.
- Except scintillation in medium, the light can also be emitted via Cherenkov emission and scintillation in the fibers as it is seen in **Empty** and **Water**-filled configurations. Nevertheless, the intensities are small compared to scintillation of the medium even without scattering (**LAB**-filled).
- The table below summarizes the track reconstruction accuracies and total lightyield in the central area of the prototype for different configurations. The **Ideal fraction** shows the smallest effective scattering length and the most steep signal-distance profile, allowing the best accuracy. **Unsorted granules** lose a bit in accuracy, but allow to collect more light, what can be explained with more dense positioning of granules and clusters in the volume.

Configuration	Ideal frac.	Good frac.	Damaged	Unsorted	Water	Water + Id.f.	LAB	LAB + Id.f.	LAB+polisorb
Accuracy, mm	**1.82**	2.00	2.59	2.09	7.28	2.72	3.72	3.2	3.2
Median of spectrum, ph.e.	236.88	214.73	215.57	**243.83**	5.59	233.77	181.94	217.47	55.75

Conclusions

✓ Several configurations of the strong scattering scintillating media were tested and compared.

✓ Further investigations are planned: event identification and enhanced track reconstruction can be achieved with ML algorithms.

We keep working on the future tests and upgrades!