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Signal Shape and Time of Light Propagation in Scintillating Fibre SCSF-78MJ from Kuraray

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Abstract

This technical note describes Geant4 simulations and measurements to determine the signal shape and timing of the scintillating fibre SCSF-78MJ from Kuraray. After the scintillation process has been excited at discrete points of a 2.5 m long fibre, the light output at one fibre end is detected. A mirror is placed at the opposite fibre end to study its influence on the signal shape and timing.

1 Introduction

The current LHCb tracking stations (T1 to T3) will be replaced by a Scintillating Fibre Tracker (SciFi Tracker) for the upgrade of the LHCb detector. The SciFi Tracker will consist of layers of 2.5 m long scintillating fibres with Silicon-Photomultiplier (SiPM) read-out at one fibre end. Fibres with a diameter of 250 μm will be used to achieve the necessary hit resolution (< 100 μm). A mirror will be placed at the fibre end opposite to the SiPM to increase the light yield.

The time distribution of scintillation light reaching the photo-detector is investigated to estimate possible spill-over and evaluate constraints on the read-out electronics. The results are obtained from simulations and measurements of a 2.5 m long SCSF-78MJ fibre from Kuraray.

The main properties of this fibre can be found in the Kuraray catalogue and are shown in Table 1. Two different claddings surround the scintillating core to increase the trapping efficiency.

Table 1: Fibre properties of SCSF-78MJ from Kuraray catalogue.

Parameter	Value
Thickness of inner cladding	3 % of diameter
Thickness of outer cladding	3 % of diameter
Refractive index of core	1.59
Refractive index of inner cladding	1.49
Refractive index of outer cladding	1.42

2 Simulation

The Geant4 simulation of the fibre uses MIPs to excite the scintillation process at discrete positions on the fibre. Table 2 lists the fibre parameters used in the simulation. Photons leaving the inner cladding are considered lost and therefore the absorption length of the outer cladding was set to be 2 μm. An aluminium mirror at one end of the fibre is included in the simulation.

The arrival time of the photons at the opposite fibre end was simulated for different excitation points on the fibre. An example is shown in Fig. 1 for three different excitation points. There are two peaks visible in the signal distribution for the first two excitation points. The second peak is caused by reflection of the light from the mirror. The exponential tail of the peaks results from the decay time of the scintillation (2.8 ns). The

Table 2: Parameters used in the Geant4 simulation.

Parameter	Value
Decay time of scintillation	2.8 ns
Photon wavelength	443 nm
Absorption length of core	7 m
Rayleigh scattering length of core	7 m
Absorption length of inner cladding	10 m
Absorption length of outer cladding	2 μm
Reflectivity of Al mirror	0.9

photons can follow different paths in the fibre though the path length plays a minor role in the arrival time.

3 Measurement

Measurements of the time distribution for photons arriving at the photo-detector were made using an UV-LED to excite the scintillation in the fibre and a Hamamatsu SiPM to detect photons at one end of the fibre. A pulse generator was used to operate the UV-LED and trigger the sampling of the SiPM signal. Metallisation of one fibre end with aluminium acts as a mirror.

To retrieve the response function of the scintillation process and light propagation in the fibre, a further measurement was carried out where the UV-LED was shining directly onto the SiPM. A deconvolution of the data acquired with the fibre was computed using the signal shape from the measurement without fibre as the response function and results in the blue curves shown in Fig. 1. This method minimises the influence of the signal shape of the SiPM output, the LED pulse, and the trigger jitter on the presented data. The deconvolution was implemented using the TSpectrum class of the ROOT framework.

The measured signal shapes are in good agreement with the simulated data. However, the second peaks in the measured data are smaller than the simulated distributions as the reflectivity of the mirror used in the measurment was worse than that in the simulation. Figure 2 shows the time of arrival of signal peaks at the photo-detector as a function of the distance from the photo-detector. The simulation and measurement show the same trend except for a small offset. The fitted slope is 5.8 ns/m for measured and 5.9 ns/m for simulated data.

4 Conclusion

The time for light propagation over the full fibre length (2.5 m) is 15 ns. The effect of spill-over must be considered especially when using a mirror. For excitation points closer

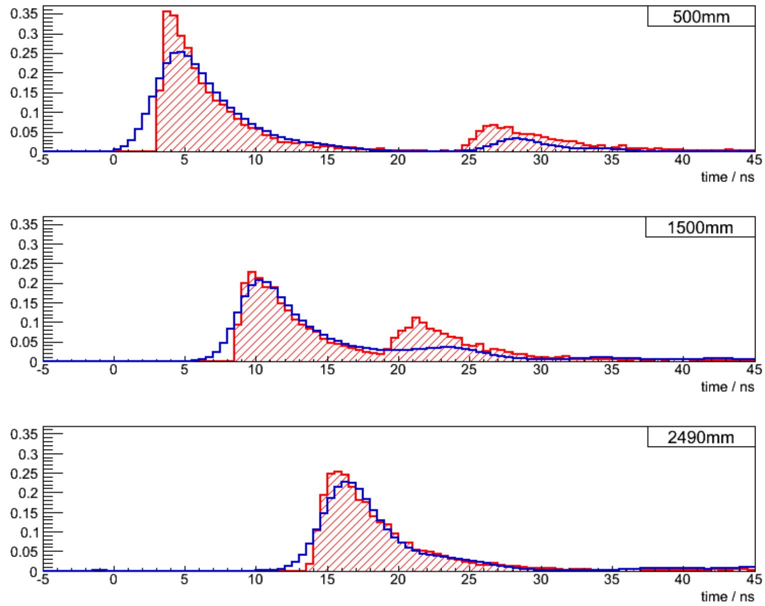

Figure 1: Time distribution of the photons leaving one end of a 2.5 m fibre with a mirror on the opposite side. The red curves show results from simulation, the blue curves show measured data for three different locations of the excitation point.

than about 1 m to the photo-detector, the arrival time of the mirrored signal is more than 25 ns after the scintillation. The arrival time of the photons at the photo-detector can be any time within an interval of 25 ns. Any electronic dead-time would reduce the already small number of photons collected per event. In addition, photons from a particular point of excitation are more likely to be lost than others in case of electronic dead-time. The results presented here only consider the signal shape from the scintillating fibre and do not include the signal shape from the photo-detector.

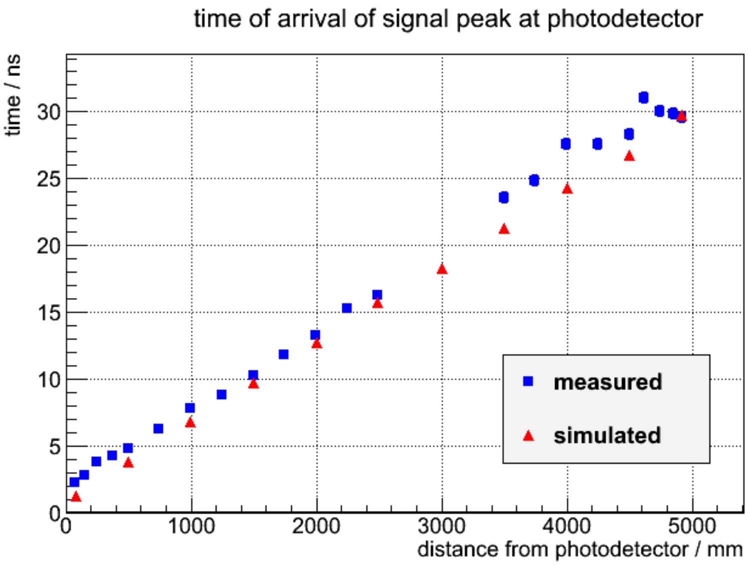

Figure 2: Arrival time of signal peak at the photo-detector as a function of the excitation point. Distances greater than 2500 mm represent the mirrored signal.