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Measurements of the Minimum Bending Radius of Small Diameter Scintillating Plastic Fibres

LHCb SciFi Project

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Abstract

The minimum bending radius of plastic fibres is an important parameter as it determines the geometrical flexibility of the fibres during long-term storage or installation and usage inside detectors. The following document describes measurements of the minimum bending radius of round scintillating plastic fibres with small diameter performed in the context of the LHCb SciFi Tracker project. The experimental set-up is based on measuring the light output of a bent fibre in response to 1 MeV electrons over several days. The results suggest that the 250 μm diameter fibres can be bent to a radius of about 10 mm without damaging and losing light.

Contents

1 Introduction

Plastic scintillating fibres (PSF or SciFi) are heavily used as active elements of particle detectors or active targets in nuclear and high energy physics. The SciFi technology allows to build intrinsically fast, low mass detectors with a high degree of geometrical adaptability. Depending on the application it may be of special interest to determine the minimal bending radius of certain plastic fibres in order to estimate their mechanical flexibility that can be expected during handling, storage and installation inside detectors.

The LHCb SciFi Tracker [1] uses blue emitting plastic scintillating fibres of type SCSF-78MJ with circular cross section and 250 μm diameter produced by Kuraray[1]. The fibres are made from a polystyrene (PS) core, surrounded by a double cladding structure of polymethylmethacrylate (PMMA) and a fluorinated polymer. In the final configuration, the individual fibres will be 2.5 m long and placed straight and without bending inside the detector. However, it is still important to determine and respect the minimum bending radius for storage and handling during testing and installation. Bending the fibres beyond a certain radius will lead to cracking of core or cladding materials and subsequent light attenuation and losses. The fibre producer, Kuraray, suggests minimum bending radii for long-term usage of 200 mm, 100 mm and 50 mm (100 mm, 50 mm and 25 mm) for non-S type (S type) fibres with diameters of 2 mm, 1 mm and 0.5 mm[2]. For smaller diameter fibres it is no more possible to distinguish between S type and non-S type, respectively, due to more difficult production. However, considering the above values one could expect a minimum bending radius of about 12.5 mm to 25 mm for the fibres used in the SciFi Tracker.

2 Experimental set-up

Our method to determine the minimum bending radius is based on an experimental set-up which is also used to determine the light output of scintillating fibres created by minimum ionising particles in the context of quality assurance for the SciFi Tracker project. Such a set-up is motivated by superior stability compared to other methods, e. g. using an UV-LED to excite the fibre. A detailed description of the set-up and its components can be found in Ref. [2] and [3]. A picture of the set-up adapted for the measurement of the minimum bending radius is shown in Fig. 1. The whole set-up is placed inside a dark room at an ambient temperature of about 22 °C.

We determined the light output at the end of the bent fibres created by 1.1 ± 0.1 MeV electrons from a Sr-90 source traversing at a given distance from a Silicon Photomultiplier (SiPM type Hamamatsu S13360-1350CS). The SiPM was connected to a Hamamatsu C12332-01 driver board featuring a temperature compensation of the bias voltage and signal amplification. Three fibres were excited and read-out jointly to increase the measured light output and signal to noise ratio. The bending of the fibres was realised by passing them through small glass tubes for bending radii $r \geq 10$ mm and by simply coiling them around a small rod for smaller radii. The SiPM signal was readout with a LeCroy WaveRunner 104MXi-A digital oscilloscope and the measured signal charge was recorded about once an hour over a time period of several days, in order to see potentially slow

[1]Kuraray Co. Ltd., Tokyo, Japan
[2]http://kuraraypsf.jp

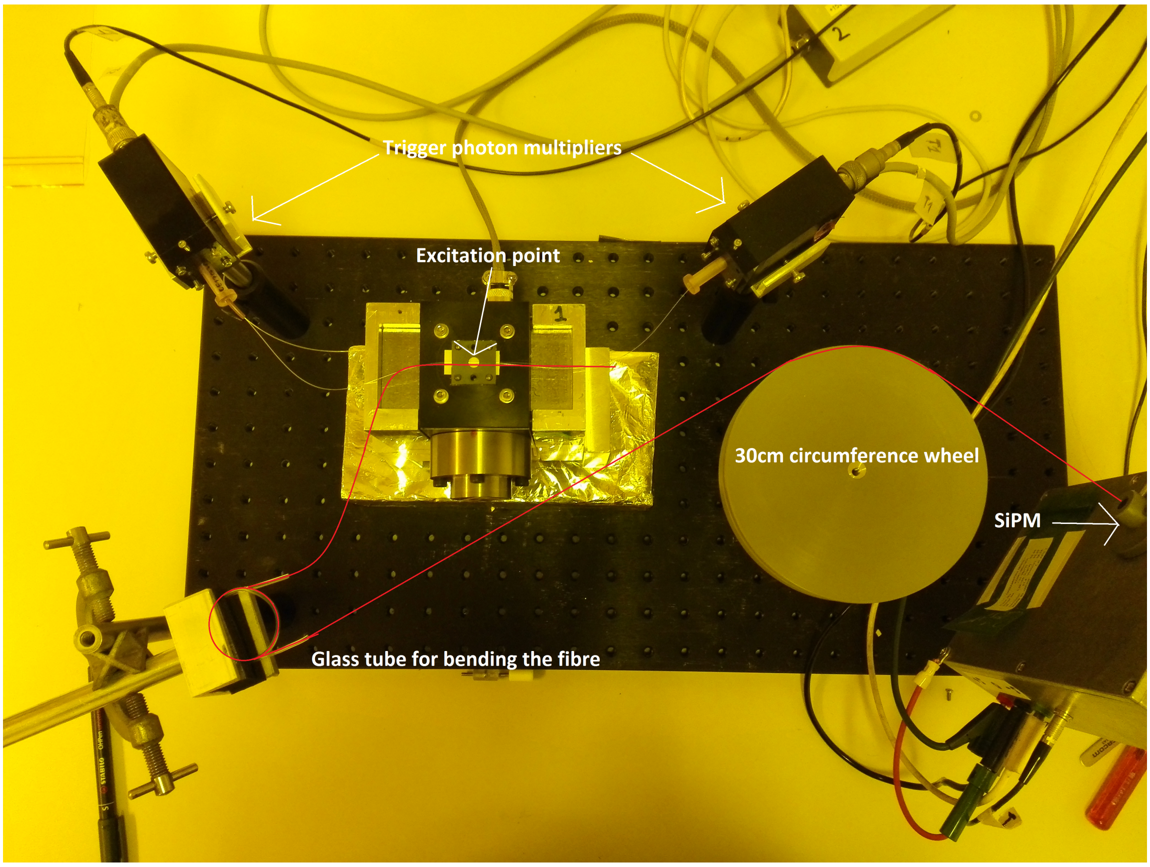

Figure 1: Picture of the bending test set-up. The fibre sample was typically about 2.6 m long and excited at about 2.4 m distance from the SiPM. The excess fibre was coiled around a 30 cm circumference wheel.

degradation of the fibre due to bending. The data taking of the oscilloscope was controlled by a Visual Basic script. The respective trigger signal was generated as a coincidence between two trigger fibres connected to PMTs, placed below and above the three fibres under test. The mean accumulated signal charge was then converted into photoelectrons after appropriate calibration using single photoelectron spectra.

3 Results and discussion

The results of the measurements of the minimum bending radius are shown in Fig. 2 to Fig. 5 for bending radii r of 15 mm, 10 mm, 6 mm and 4 mm. In general it can be seen that we observed no degradation of the light output for bending radii down to $r = 10$ mm within about two days of measurement time. Going beyond that radius seems to damage the fibre and leads to light loss, indicating that the minimum bending radius is below 10 mm. Especially for a bending radius of 4 mm it is clearly visible in the data that there is an effect due to the initial bending of the fibre at $t = 0$, which seems to damage the fibre mechanically and leads to a significant reduction in light yield within the first few hours. Such an effect may be also visible in the $r = 6$ mm data, however less pronounced. If we fit the data with a linear function for $t > 8$ h ($r = 6$ mm) and $t > 20$ h ($r = 4$ mm) we see almost no further change in the light yield after the initial loss, suggesting that a measurement time in the order of two days should be enough to see an effect due to bending. The data were also fitted with an exponential function (see Fig. 4 and Fig. 5).

4 Summary and conclusions

An experimental set-up for the determination of the light yield of 250 μm diameter plastic scintillating fibres for the LHCb SciFi Tracker was adapted to evaluate the minimum bending radius of the fibres. The measurement method is based on monitoring the light output of fibres bent to a certain radius after excitation by minimum ionising particles over many hours. The results indicate that the minimum bending radius is between 6 mm and 10 mm. For larger bending radii we didn't observe any degradation of the light output.

References

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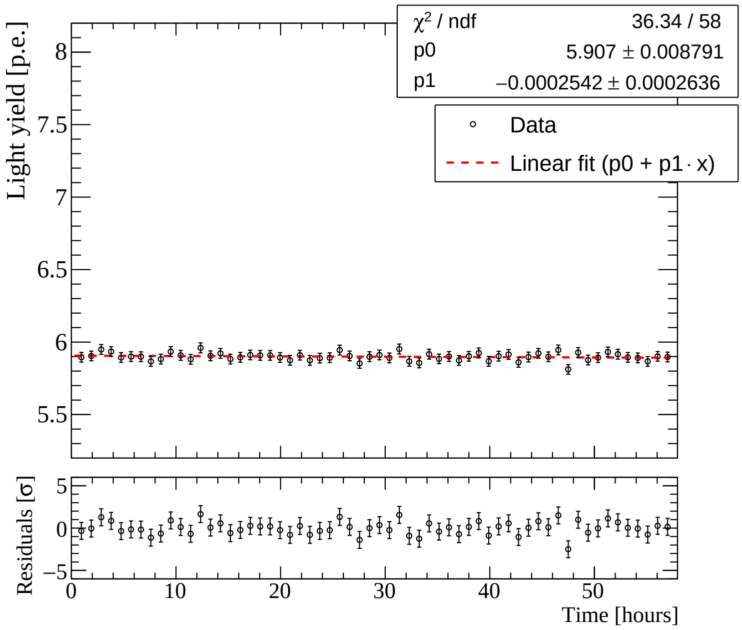


Figure 2: The plot shows the result of the fibre bending test using a bending radius of 15 mm. Within the accuracy of the fit, the slope is compatible with zero.

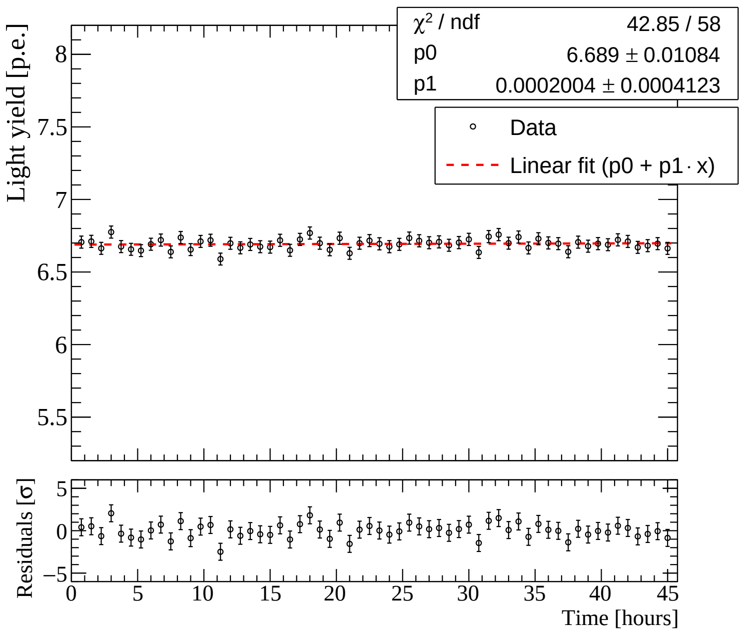
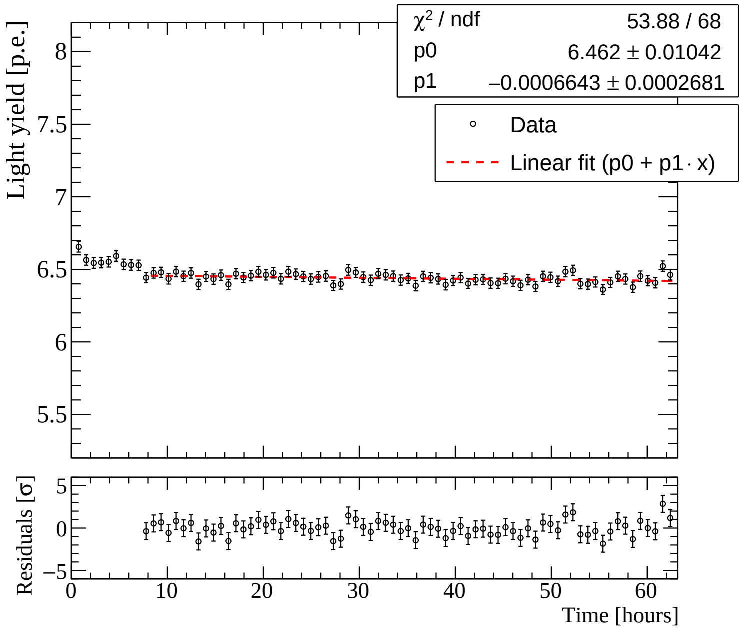


Figure 3: The plot shows the result of the fibre bending test using a bending radius of 10 mm. As for $r = 15$ mm, the slope is compatible with zero.



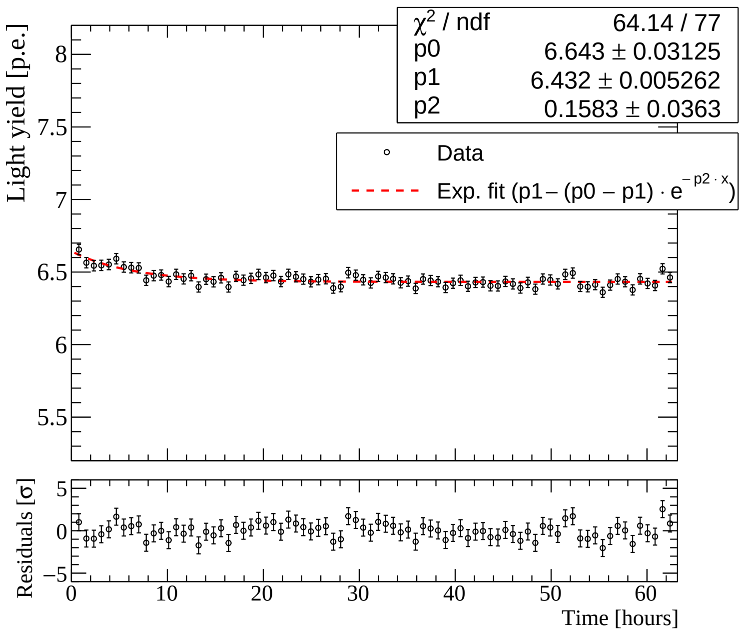


Figure 4: The plot shows the result of the fibre bending test using a bending radius of 6 mm. The data are fitted with a linear function (top) for $t > 8$ h and with an exponential function (bottom).

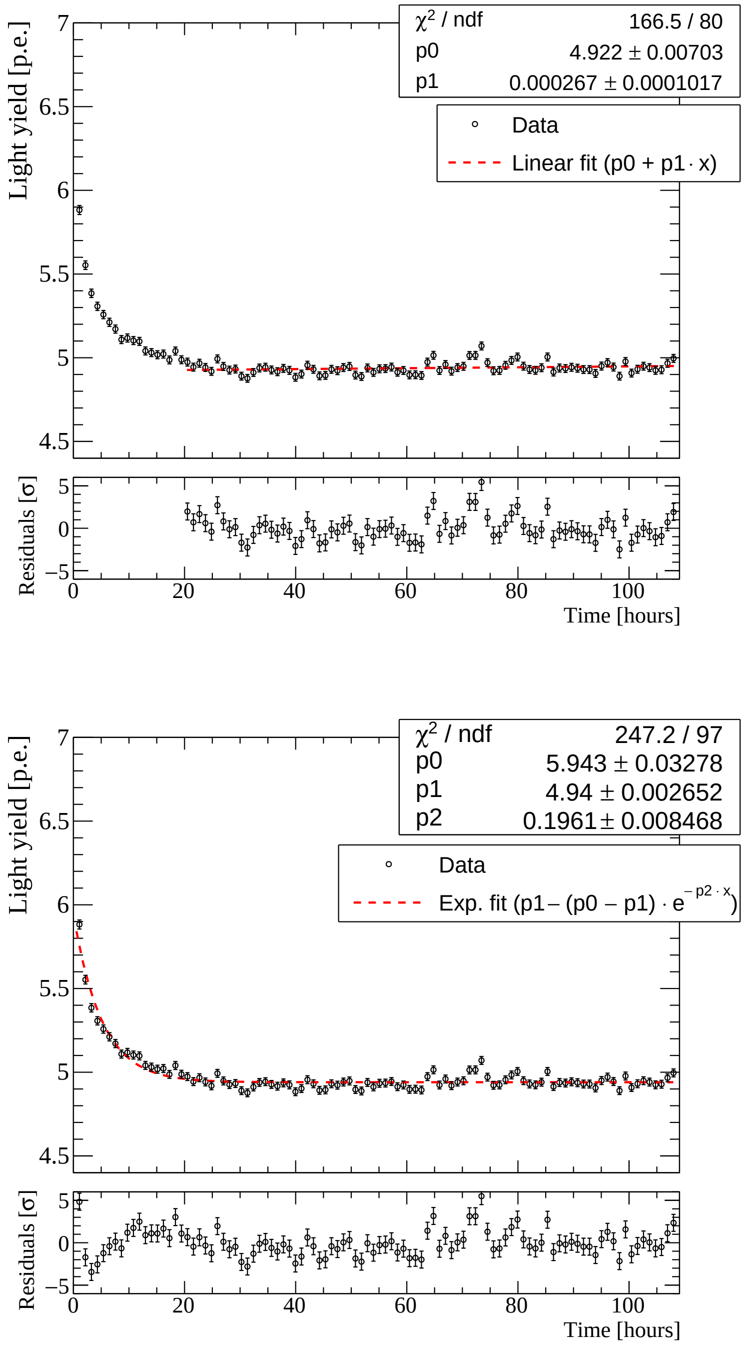


Figure 5: The plot shows the result of the fibre bending test using a bending radius of 4 mm. The data are fitted with a linear function (top) for $t > 20$ h and with an exponential function (bottom).