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Online Monitoring of Fibre Mat Winding

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Abstract

For the upgrade of the LHCb detector a scintillating fibre tracker is foreseen. The 250 µm fibres are arranged in multiple layer fibre mats and read out by silicon photomultipliers. This document describes an option of quality assurance during the production of fibre mats. A camera setup monitors the positioning of the fibres by looking tangential on the wheel. Defects in the fibre matrix will be detected by a pattern recognition software.

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1 Introduction

The Scintillating Fibre Tracker is part of the LHCb Upgrade to be installed in the LS2 which starts in 2018 (see LHCb Tracker Upgrade Technical Design Report [1]). The Tracker consists of scintillating fibres with a diametre of 250 µm and a length of 2.4 m. These fibres are stacked in six layers with a 275 µm horizontal pitch. To detect the scintillation light multichannel silicon photmultipliers (SiPM) with a channel width of 250 µm are used. Their height matches the height of the six layer fibre mat.

A fibre crossing particle generates a signal in more than one corresponding SiPM channel, so that the his position is calculated from the charge barycentre. The fibres are mirrored at the middle of the 5 m high acceptance and read out by the SiPMs at the outer edges. The readout electronics are to be based on a custom designed ASIC which includes pre-amplifier, shaper, ADC, clusterization and zero suppression.

This document describes the production of the fibre mat with a focus on the quality assurance during the production.

2 Fibre Mat Production

The scintillating fibre mats are the active component of the SciFi Tracker and must be assembled very precisely and with high quality. Single scintillating fibres with a 250 µm diameter are arranged to six layer fibre mats to receive a sufficient light yield at the photodectector. To produce these mats, the scintillating fibres are wound on a wheel with ≈1 m diametre. A machine has been developed to produce these mats, controlling the speed, tension and winding of the fibre onto the wheel (see Fig. 1)

This wheel has a milled screw to guide the fibres of the first layer and guarantee the correct pitch. At the end of the layer, the fibre is cut for starting the next layer. The layers are shifted by half the horizontal pitch with respect to each other, so that the fibres of the next layer are guided by the fibres of the respective layer before. The fibre is provided by a spool of 12.5 km of scintillating fibre and is pre-guided by means of a small spool which moves along the width of the winding wheel to define the position of the fibre precisely. A loose spool in between defines the tension of the fibre and regulates the speed of the feeding spool. TiO_2 loaded glue (two component epoxy) is placed between the layers. After curing the mat is cut perpendicular to the fibres and taken off the wheel to be flattenend. For more detailed informations about the fibre mat production see also [2].

3 Quality Requirements

To ensure a spatial resolution better than 100 µm, the fibres have to be accurately positioned. Due to many different influences problems occur during the winding process. The exclusive error is the wrong positioning of a fibre. This will manipulate the continuing fibre mat production, so that other fibres can't fit in their decided position. In the most situations

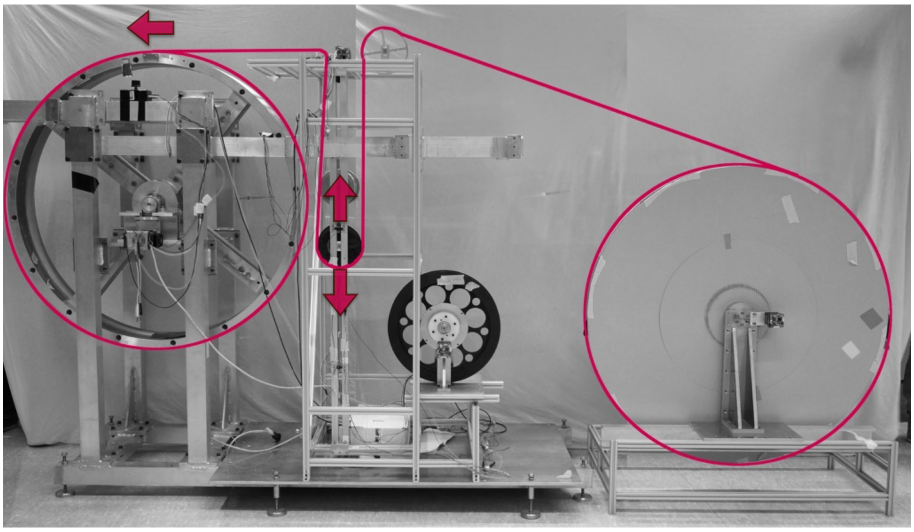

Figure 1: Prototype of a winding machine to produce scintillating fibre mats. The fibre is provided by a feeding spool (right) and moves over a loose spool to the winding wheel. The loose spool defines the tension of the fibre and regulates the speed of the feeding spool. A small spool is moving along the width of the winding wheel, for defining the correct position of the fibre.

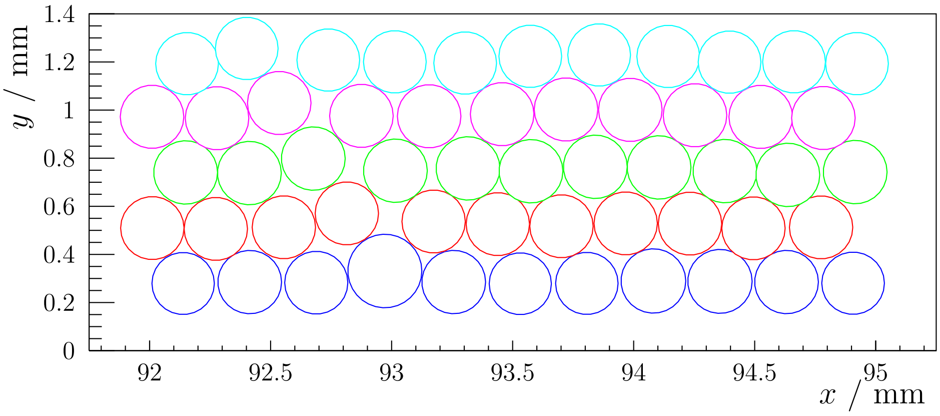

Figure 2: Effect of a bump to the fibre matrix. A bump at x =93 mm (ca. 300 µm) in the first layer causes errors, which propagate till the highest layer.

the error is limited to a small region, but a small error can get worse in higher layers. Plots shown here are the result of a winding simulation. For more Informations see [3].

One important point is the fluctuating diameter of the scintillating fibre. The trend of the diameter shows thick regions up to 500 µm. These thick regions, called bumps, cause a wrong positioning of the neighbouring fibres. An example of such a error is showed in Fig. 2.

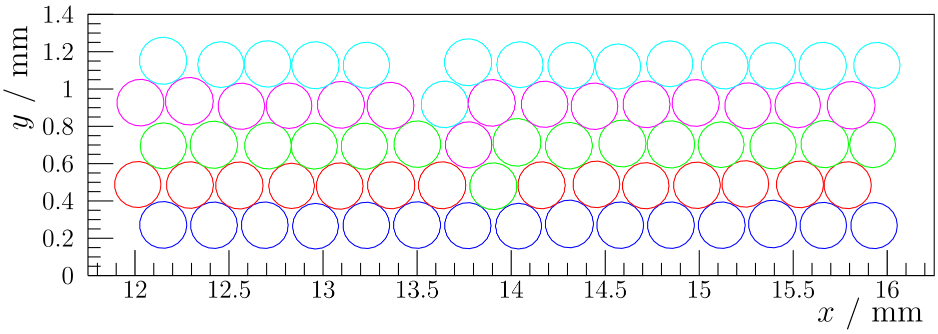

Figure 3: Cantle of a cross section of a fibre mat (12 to 16 mm). Due to a missing fibre in the second layer, fibres from the higher layers fill up the empty space.

Another problem are fibres, who skip a notch and create therefore an empty space. These empty spaces will be filled up by fibres belong to a higher layer actually. This will cause there an empty space too (see Fig. 3).

On the basis of this influences (and many more) a good positioning of the fibres during the winding process has to be guaranteed to receive a good fibre mat. Unfortenuately a scintllating fibre without bumps can't be delivered by the manufacturer. As a result of this bumps which cause problems have to be cut out. To make a statement about the positioning of the fibres and if a bump has to be cut out, a camera system will be used to monitor the fibres exactly.

4 Hardware

To ensure a right positioning of the fibres in the fibre mat a setup consisting of an industrial camera and a lens with a big magnification is used. A scheme of the setup can found in Fig. 4. Die Camera system is mounted on the same slide as the positioning spool. As a result the camera is moving along the width of the wheel and monitors always the current fibre. Furthermore the camera will have a tangential look an the wheel. A schematic picture of the camera is shown in Fig. 5. The fibres of the first layer are guided by the threat in the wheel and are well positioned. The dark blue fibre is the current one and should be monitored very precisely.

Despite of the many influences which have a bearing on the fibre positioning, there are only two different effects which can be observed during the winding process. On the one hand a fibre can jump in the wrong threat an leave an empty space (see Fig. 6(a))).On the other hand a fibre is able to lie down in the next layer (see Fig. 6(b)).

A picture of the current hardware setup is shown in Fig. 7. The camera can be adjusted by a ball head. Unfortunately the lens has no possibilty to adjust the focus, so that another slide is used for this.

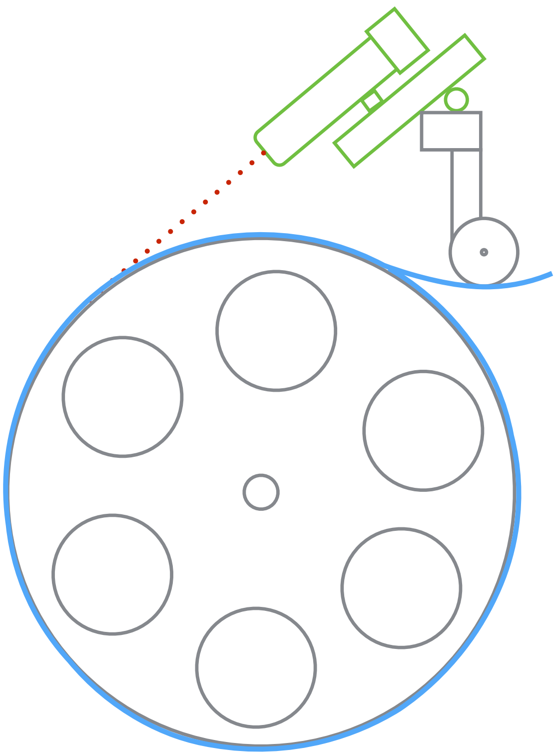

Figure 4: Scheme of the camera setup on the winding maschine. The camera (green) will be placed on the same slide as the positioning spool and look tangential on the wheel.

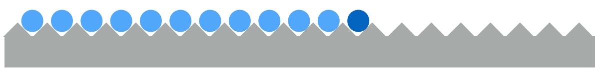

Figure 5: Scheme of the view if the camera looks tangential on the wheel. Fibres in the first layer are guided by the threat in the wheel. The current fibre is marked in dark blue.

5 Software

The picture of the camera is supposed to be analysed with a pattern recognition software. This insures that no person has to be present during winding time supervising the winding process. For this purpose a pattern recognition software based on the open source library *OpenCV* has been developed. The main idea was to apply a background substraction of the frame at the position of the current fiber such as gaussian mixture models [4–6]. This results in a binary image that, besides fluctuations that can be thresholded, resembles if there was a notable change in the picture, i.e. the current fiber not being in place.

This method can't be applied to the whole camera frame due to expected vibrations of

(a) (b)

Figure 6: Two different defects which can occur during the winding process. In (a) the current fibre jumped in the wrong threat and leave an empty space. (b) shows a fibre lying in the wrong layer.

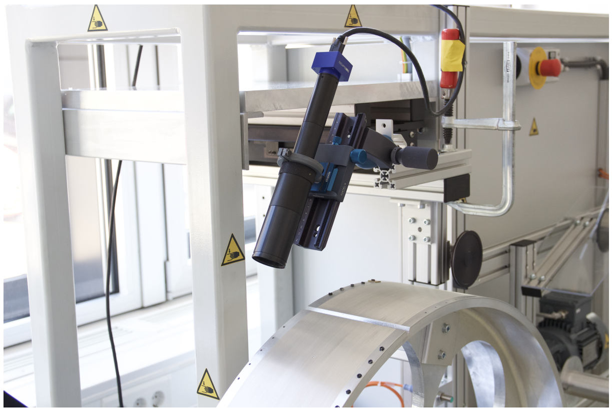

Figure 7: Camera setup mounted on the winding machine.

the camera and a possibly unbalanced winding wheel which would trigger the background substraction over the threshold. Therefore the approximate position of the current fiber and a window around that position need to be estimated. This is done on the basis of a hough transformation into the parameter space of circles [7] that gives a set of found circles. The reason why this can't directly be used to assure the right positon of the current fiber is, as can later be seen, that it is difficult to find and to find only those circles that correspond to a fiber on the winding wheel. In fact there are much more circles found in the frame than there are fibers on the wheel and these need to be filtered somehow. In the current implementation this is easily be done through taking the mean position of all circle centers and taking only those circles into account that lie in a small window around that position. But another implementation including e.g. clustering could be applied here. Given the filtered circles and say they all correspond to a fiber on the winding wheel the current fiber window and the foreground image can be computed.

The problem arises that there is no given point to place the window relative to. Placing it relative to the outermost found circle will more or less result in an error once this circle isn't found in one of the frames. The solution here is measuring the position und the distances of the fibers over an initial range of frames, i.e an initial period of time, while after that time the video feed gets stabilized, i.e. it gets moved back according to an estimated movement between two frames. This is done employing the feature detector described in [8] to get prominent features that are trackable well and track them with the pyramidial Lucas-Kanade feature tracker [9, 10]. The matching pairs of feature points can then be used to estimate the movement between two frames, which is done using a simple least squares algorithm. After that the camera feed should be stabilized and the current fiber should always appear to be locked inside the current fiber window.

The goal is to measure the signal inside the computed foreground images or combinations of them, which are binary images that can be normed, and trigger an alarm and possibly bring the winding process to a stop if the signals rise above a given threshold.

6 Results

Show results of the working software.

7 Summary

Short summary

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