SciFi – Upgrading LHCb with a Scintillating Fibre Tracker

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The LHCb experiment is preparing for a major upgrade in order to run from 2021 onwards at a five times higher luminosity of 2×10^{33} cm^{-2}s^{-1} and a readout rate of 40 MHz. As part of the ambitious upgrade program, a large scintillating fibre (SciFi) tracker [1] is going to replace the current outer and inner trackers, consisting of straw tubes and silicon micro strip detectors, respectively, by using a single detector technology and more than 10,000 km of plastic scintillating fibres. Combining the SciFi technology with high performance Silicon Photomultiplier (SiPM) arrays allows to build an intrinsically fast, low mass high resolution tracking detector.

The 340 m^2 large active area is divided into three tracking stations with four independent stereo layers each (XUVX geometry, U and V with ± 5º stereo angle) with a size of about 6 × 5 m^2. The chosen blue emitting scintillating plastic fibres have a circular cross section and a diameter of 250 µm and are arranged in a 6-layer staggered pattern to form 1.35 mm thick fibre mats. 8 mats are combined to a single module, the basic unit of the SciFi tracker. The 2.4 m long fibre mats are read out at one end by linear 128-channel SiPM arrays, while the other end of the mats is equipped with mirrors. The trigger-less readout of 524k SiPM channels at a rate of 40 MHz is a major challenge and requires the usage of custom-designed front-end electronics. Six pairs of C-shaped frames (C-frames), arranged on either side of the beam pipe, will carry the 128 modules with photodetectors and front-end electronics as well as all services (see Fig. 1).

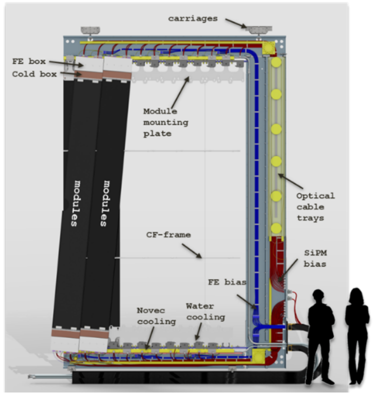

Figure 1: A model of one C-frame with 2 modules mounted on each side.

The LHCb tracker requirements and environment push both the SciFi and SiPM technology to the limits. During operation the SiPMs will be exposed to a total neutron fluence of up to 6×10^{11} n_{eq}/cm^2 and have to be cooled to -40 ºC to reduce the dark count rate and retain single photon counting capability. The fibres are required to have an attenuation length above 3 m, high light yield and should be radiation tolerant, since close to the beam pipe an ionizing dose of 35 kGy is expected. To reduce spill over into consecutive bunch crossings a fast signal generation and shaping is mandatory. The high demands on the quality of the fibres led to a R&D initiative aiming at the development of very fast and efficient scintillating fibres, which are based on a novel type of luminophores, called Nanostructured Organosilicon Luminophores (NOL), admixed to the polystyrene core [2]. In NOL fibres the activator and wavelength shifter complexes are arranged in close distance, allowing for fast and efficient, non-radiative energy transfer. The performance parameters of the NOL prototype fibres have already reached a competitive level, in particular the decay time constants are close to 1 ns, i.e. about 50% shorter than the fastest known fibres. Fig. 2 shows the time response of a NOL prototype fibre following excitation with short UV-LED pulses. The new fibres may be interesting for a future upgrade or replacement of the innermost regions of the SciFi tracker and in general for future fibre detectors.

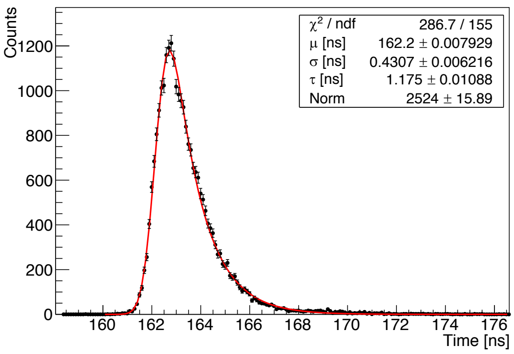

Figure 2: Time response of a NOL prototype fibre with a decay time of 1.2 ns.

The SciFi project is on track for the installation during the LHC long shutdown in 2019/2020. To produce the detector elements including spares, 12,000 km of scintillating fibre were tested and wound into fibre mats. The end of the module production is imminent. All photodetectors have been received and the serial production of front-end electronics has been started. A first prototype C-frame has been built and the assembly of the 12 serial C-frames will start in December 2018. All C-frames will be fully equipped and functionally tested above ground at LHC point 8 before being installed in the LHCb cavern. The talk will give a brief introduction to the SciFi tracker design, an overview about the production process and performance of the various detector components as well as a summary about the current status of C-frame assembly and testing. Furthermore, we will report on the most recent achievements on the NOL fibre development.

[1] The LHCb collaboration, *LHCb Tracker Upgrade*, Technical Design Report, CERN/LHCC 2014-001
[2] O. Borshchev et al., *Development of a New Class of Scintillating Fibres with Very Short Decay Time and High Light Yield*, 2017 JINST 12 P05013