Fast Trigger and Position Detector Based on a Single Solenoid-Shaped Scintillating Fibre

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A light pulse is induced in a finite length scintillating fibre by the energy deposit of a traversing charged particle. A detectable fraction of this light pulse can reach each end of the fibre depending on the hit position with respect to one of the two ends. The difference in time arrival Δt of the two signals between the two ends of the fibre is an indication of the hit position z along the fibre. However, a 1 mm precision on the position measurement requires better than 5 ps precision on the measurement of Δt. Here, the idea is to roll the fibre to form a solenoid with adjacent spires. The diameter of a spire is chosen to be 10 cm such as to have about 1.5 ns total spire length. Thus an easily achievable precision of $\simeq$ 500 ps on Δt is enough to distinguish in which spire a hit occured for a charged particle emitted from inside the solenoid. The precision on the position measurement along the solenoid axis is therefore about the fibre diameter.

Various types of scintillating fibres can now be found in the market. As a suitable compromise between mechanical properties, light output yield, attenuation length and desired position resolution we choose the 1 mm diameter fibre of type BCF 10 manufactured by BICRON. It has the following properties: Emission peak = 432 nm; Decay time = 2.7 ns; 1/e length > 2 m; Number of photons per MeV deposit $\simeq$ 8000. To test the feasibility of the detector, we use a 2.15 m long fibre mirrored from one end and coupled to a photo-multiplier (PMT) of type XP2262B manufactured by RTC. The PMT quantum efficiency is about 22% and it has a gain of 3×10^7 for a supply voltage of 1.9 kV. The optical coupling between the fibre and the PMT photo-cathode is done through a soft silicone cylindrical piece (39 mm in diameter and 5 mm thick) that holds from one side to the PMT photo-cathode by simple mechanical pressure. From the other side the fibre is pushed deep inside the silicon piece, penetrating it by 3 to 4 mm, and fixed with optical cement. The scintillation is induced by a Ru^{106} source. Its β^- rays are analysed in a small magnetic spectrometer made of 2 kG permanent magnets. The β^- rays reaching the highest energy focalisation point have an energy of 3.5 MeV and are able to cross the fibre. The fibre is layed on a table such as to ease the control of the source position along the fibre length. The PMT output signal is fed into passive 1/3, 2/3 splitter. The first part is used to generate the integration gate for a LECROY 2249A 10 bit dynamic range analog to digital converter (ADC), the second part is used as the ADC input charge signal. With this simple self triggering system, we measure the ratio of the trigger rate with the source over the trigger rate without the source as a function of the source position on the fibre. The slope of the obtained curve is a measure of the fibre attenuation from which we extract an attenuation length(1/e) = 1.8 ± 0.2 m in agreement with the manufacturer quotation.

To measure the time resolution, each end of the fibre is coupled, as in the previous case, to a PMT. The PMT outputs are discriminated with constant fraction discriminators (CFD) of type FCC8 from GANIL/IPNO laboratory that have only 40 ps output jitter for a -50 mV input signal. The discriminated signal from one end of the fibre is used to start a LCROY 2228A time to digital converter (TDC) and the discriminated signal from the other end, delayed such that it arrives always later than the first one independently of the source position, is used as the stop signal of the TDC. The TDC least significant bit (LSB) is set from the manufacturer to 50 ps, we re-measured it and found 48.8 ps. The fibre length is scanned with the source by steps of 10 cm. At each source position the TDC spectrum is fitted to a Gaussian shape. The width of the Gaussian, which is our precision on Δt, varies from 150 ps to 200 ps depending on the source position. This is much better than our requirement for the solenoid shaped detector. The peak position is perfectly linear with the source position on the fibre as shown on Figure 1.At the end, the above fibre is rolled to form a a 0.7 cm long (7 spires) solenoid build on a thin carbon-fibre cylinder (10 cm diameter) removed after gluing the spires to an outer carbon-fibre cylinder. The two ends of the fibre were connected to clear fibres as used in [1] and then coupled to PMTs with the soft silicon pieces. The Ru^{106} is fixed to a micrometer screw that moves inside the solenoid parallel to the cylinder axis but close to the scintillating fibre. The β^- rays are focused with thin lead shielding that leaves a small exit hole, pointing to only one spire at a time. Here again we obtain as in Figure 1, a linear response of the TDC counts versus the source position and the spire position is measured unambiguously.

We conclude that a detector based on scintillating fibres rolled in a solenoidal shape is feasible. The detector can achieve fast triggering and 1 mm position resolution along the solenoid axis. The detector needs 2 readout channels per cm length (10 spires). The acceptance is limited by the fibre shape to about 85%. This can be compensated by constructing a double layer solenoid that will also increase the accuracy on the position measurement. Such a a detector, equipped with multi-hit TDC's, can be used in a collider environment.

References

[1] G. Aguillion *et al.*, Nucl. Inst. and Meth. A 417 (1998) 266.

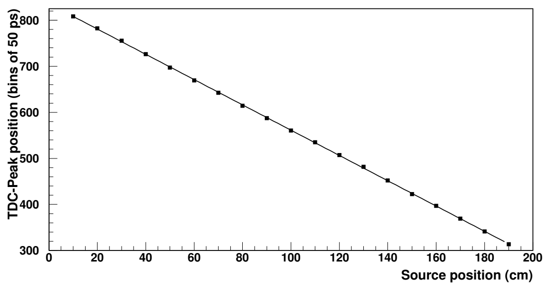

Fig. 1: TDC peak position versus the source position on the fibre