R&D for SiPM based scintillating fibre tracker in high energy physics

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On behalf of LHCb SciFi Tracker and BGV collaborations

Two SciFi applications

LHCb SciFi tracker

For the LHCb upgrade, the current Inner Tracker and Outer Tracker will be replaced with a scintillating fibre (SciFi) tracker [1,2].

Fibre mat

SiPMs and FE electronics

LHC beam monitoring

Using beam imaging technique, the LHC beam gas vertex (BGV) detector will provide real-time beam size measurements for other LHC experiments [3].

Cooling system

SiPMs and FE electronics

Working principle

A crossing particle deposits energy through ionisation in the fibres (250μm-diameter) producing visible scintillation light.

Channels (1) are made of several pixels (2) which are put in parallel.

The signal is generated in several SiPM channels. A clustering algorithm is applied in order to calculate the crossing position of the particle (weighted mean of cluster) and suppress noise.

Experimental setup for SciFi characterisation

Electron-gun

The electron-gun generates signal in the fibre mat. It comprises:

- β sources emitting β-particles (continuous energy spectrum)
- Solenoid coil to induce a magnetic field for energy selection
- Trigger system made of short plastic scintillating fibres, placed at the exit of the collimator
- Mounted on an X-Y table in order to scan the module

1 MeV electrons deposit very small amount of energy in the mat, similar to minimum ionising particle (MIP). However, they undergo multiple scattering which results in wide signal clusters.

UV LED can also be used to inject light but it produces large spot and inhomogeneous intensity due to the TiO₂ loaded glue in the fibre mat.

Irradiated SiPMs with BGV SciFi module

In high energy physics experiments, SciFi trackers will have to withstand radiation. The effect of radiation on the fibres is increased attenuation and a shift of the emission spectrum. For the SiPMs, a large increase of the dark count rate (DCR) is observed.

Light detection

Noise cluster rate

The number of photons per cluster follows the distribution of particle energy deposit (Landau), unchanged with irradiated SiPMs.

![Graph showing light detection and noise cluster rate](image)

Cooling

The SiPMs can be cooled down to -40°C. They are in contact with a cooling pipe connected to a liquid circulating chiller. An enclosure allows for their thermal isolation and dry air injection prevents water condensation. SiPMs are equipped with thermistor which allows temperature monitoring during measurements.

Read-out electronics

Different FE electronic chips are used to read out multi-channel SiPMs:

- The Beetle [6] designed to read out silicon strip detectors of LHCb. For the BGV SciFi modules, SiPM signals are adapted to the Beetle inputs using attenuator circuits. DAQ is done with TELL [7].

CERN test beam

High energy pions are produced at CERN from the SPS proton beam and used to fully characterise 2.5 m long 6-layer SciFi modules (resolution, hit detection efficiency and light yield). The energy deposit of 180 GeV pions and 1 MeV electrons are within 20% of the MIP.

![Diagram showing CERN test beam setup](image)

Conclusions

The detector test facility installed in the lab allows characterisation of SciFi modules. An electron-gun enables to perform fast measurement of light yield and attenuation length. Moreover, using a cooling system, irradiated SiPMs can be operated for the read-out of fibre module.

Test beam facility at the SPS at CERN is however indispensable for the full characterisation of SciFi modules in particular for the measurement of resolution and hit detection efficiency.

References