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Time and position resolution of the scintillator strips for a muon system at future colliders

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ABSTRACT

Prototype scintilator+WLS strips with SiPM readout for a muon system at future colliders were tested for light yield, time resolution and position resolution. Depending on the configuration, light yield of up to 36 photoelectrons per muon per SiPM has been observed, as well as time resolution of 0.45 ns and position resolution along the strip of 7.7 cm.

1. Introduction

Several concepts of future colliders, including e^+e^- colliders, are currently under study for the next generation of particle physics experiments [1–4]. Due to the well-defined initial state of the interactions, low backgrounds and radiation levels, e^+e^- colliders are an attractive option for precision measurements to test various theoretical extensions of the Standard Model in the areas where the predictions of the beyond Standard Model theories differ by a few percent, such as in the Higgs sector.

The detector concepts for the future e^+e^- colliders have been developed to a high level of detail over the past decade. Since the publication of the Letters of Intent of the two major concepts, the Silicon Detector (SiD) [5] and the International Large Detector (ILD) [6], numerous technical details have been specified to an advanced level. R&D prototypes of individual subsystems reach levels of complexity involving hundreds of thousands of readout channels (see e.g. Refs. [7,8]).

However, for the muon systems relatively few specific details are developed, and few experimental tests of detection technologies have been performed. The muon system is envisioned as several layers of position-sensitive detectors embedded in the iron flux-return yoke of the solenoidal magnet. The role of the muon system at an e^+e^- collider is primarily the identification of muons and track matching to the central tracker, besides serving as the tail catcher for the hadronic showers that penetrate beyond the hadron calorimetry. Examples of previous experimental studies dedicated to the muon-system include tests of a similar detection technique as presented here, but focusing on light yield and attenuation [9], and beam tests of a multi-layer prototype devoted to a study of the improvement of energy resolution of a hadronic calorimeter by using the muon system as tail catcher [10]. The analog hadronic calorimeter developed and prototyped by the CALICE collaboration uses square scintillator tiles in sizes ranging from 3×3 cm^2 to 12×12 cm^2 with WLS fibers and SiPM readout with the aim of reconstructing the hadronic showers with optimal energy resolution [11]. A detailed study of the detection technique similar to the one presented here, focusing on light yield and attenuation for excellent MIP detection efficiency in very long strips for long-baseline neutrino detectors is presented in Ref. [12].

The achievable precision of track matching is limited by the multiple scattering in the detector components before the muon system. The effect of the multiple scattering on track matching can be estimated using the formula by Highland [13]. The total thickness of material in the radial direction between the central tracker and the muon system corresponds to about 150–300 radiation lengths, depending on the polar angle. Muons in jets, if they have sufficient p_T to reach the muon system, typically have energies below 10 GeV. Muon spectrum in the process $e^+e^- \to Z \to q\bar{q}$ is shown in Fig. 1 as an example. At such energies, the contribution of the multiple scattering to the smearing of the muon system track position at the first muon-system layer is 5 cm or more.

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