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The development of a high-resolution scintillating fiber tracker with silicon photomultiplier array readout

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We present test results from a novel modular scintillating fiber tracker using silicon photomultiplier (SiPM) arrays for readout. The tracker modules are made up from 250µm thin scintillating fibers that are arranged in five tightly packed layers on top and on bottom of a light carbon fiber / Rohacell foam support structure. Novel, custom made SiPM arrays from Hamamatsu with a channel pitch of 250µm and a photon detection efficiency of approximately 50% are used for readout. From a full GEANT4 simulation the expected position resolution is 0.05 mm at a tracking efficiency of 99%. Several 860mm long and 32mm to 64mm wide tracker modules were tested at the PS facilities at CERN in summer 2008 and autumn 2009 achieving high light yields of more than 15 photons for a minimal ionizing particle. We will show details on the characterization of the SiPM arrays and the quality control of scintillating fibers, the construction of the fiber modules and the results in terms of tracking efficiency, noise and position resolution.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

The presented detector is a high-resolution scintillating fiber tracker with a modular design that is currently under development for use in balloon-borne experiments such as the Positron Electron Balloon Spectrometer (PEBS) and possible upgrades for the LHC experiments.

The tracker modules consist of thin scintillating fibers with a diameter of 0.250mm +/- 0.06mm. The fibers are compiled into 64mm wide and 860mm long ribbons of five tightly packed fiber layers fixed by an Epotek 301 adhesive. Within the ribbon, the fibers form an even lattice with a mechanical precision of approximately 20µm for each placed fiber. The fiber ribbons are produced in a workshop at the RWTH Aachen University achieving a high yield with detailed quality control during the full production process.

Two fiber ribbons are glued to light carbon fiber skin / Rohacell foam module carriers with a thickness of 10mm. Optical hybrids carrying eight 1.1mm high and 8mm wide silicon photomultiplier (SiPM) arrays are used for the readout. A linear 32-channel SiPM array that was specifically designed by us for the use in scintillating fiber trackers were produced by Hamamatsu. They have a readout pitch of 250µm with 80 micro-pixels per strip and a photon detection efficiency of 50% and are fixed on both ends of the fiber module. The SiPM arrays on the optical hybrids alternate with small aluminum mirrors in such a fashion that groups of 32 fibers are read out on one end, while the other is covered by a mirror. The next generation of the linear SiPM arrays has been ordered and is expected to be available end of 2009.

For the readout of the SiPM arrays a electrical frontend boards based on the IDEAS VA32-75 preamplifier chip and the new SPIROC preamplifier chip developed by IN2P3/LAL Orsay for SiPM readout were used. The VA32-75 was originally chosen for its low power consumption of 2mW per readout channel. A new version of the SPIROC chip that was designed for the presented fiber tracker will become available by the end of 2009 and feature a comparable power consumption.

Several prototype modules were tested at the PS facilities at CERN in summer 2008 and November 2009. The light yield of the modules, the spatial resolution, the tracking efficiency and the fake rate of the tracker modules have been measured. Among the tested modules the performance for different fibers of type Kuraray SCSF-78MJ with a peak emission wavelength at 437nm and of type Kuraray SCSF-81M are compared.

For the 2008 data a spatial resolution of 0.07 mm was found at a tracking efficiency of 99%. The 2009 tracker modules show a 50% improved light yield and we expect to find an improved spatial resolution. The results will be presented on the Vienna conference.

Primary authors: MAI, Carsten (I. Physikalisches Institut B - RWTH Aachen University); ROPER YEARWOOD, Gregorio (RWTH Aachen University); THOLEN, Heiner (I. Physikalisches Institut B - RWTH Aachen

University); Dr GAST, Henning (I. Physikalisches Institut B - RWTH Aachen University); GREIM, Roman (I. Physikalisches Institut B - RWTH Aachen University); Prof. SCHAEL, Stefan (I. Physikalisches Institut B - RWTH Aachen University); Dr KIRN, Thomas (I. Physikalisches Institut B - RWTH Aachen University)

Co-authors: BEISCHER, Bastian (RWTH Aachen University); Dr GAST, Henning (RWTH Aachen University); GREIM, Roman (RWTH Aachen University); Prof. SCHAEL, Stefan (RWTH Aachen University); Prof. NAKADA, Tatsuya (École Polytechnique Fédérale de Lausanne)

Presenter: ROPER YEARWOOD, Gregorio (RWTH Aachen University)

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