LHCb looks to the future with SciFi detector

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The new device’s modules are being assembled at the LHCb site. Credit: CERN

For the LHCb detector at the Large Hadron Collider, the ongoing second long shutdown (LS2) of CERN's accelerator complex will be a period of metamorphosis. After two successful data-collection runs, the detector is being upgraded to improve the precision of its physics measurements, many of which are the best in the world. There will therefore be five times more collisions every time proton bunches cross within the detector after LS2 and the LHCb collaboration plans on increasing the data-readout rate from 1 megaHertz to the LHC's maximum interaction frequency of 40 megaHertz (or every 25 nanoseconds).

In addition to replacing nearly all of the electronics and data-acquisition systems to handle the enormous increase in data production, LHCb is replacing its tracking detectors with new ones, such as the scintillating-fiber tracker, or SciFi. It is the first time such a large tracker, with a small granularity and high spatial resolution, has been made using this technology. The SciFi will be placed behind the dipole magnet of LHCb.

Scintillating fibers, as the name suggests, are optical fibers—with a polystyrene base, in this case—that emit tens of photons in the blue-green wavelength when a particle interacts with them. Secondary scintillator dyes have been added to the polystyrene to amplify the light and shift it to longer wavelengths so it can reach custom-made silicon photomultipliers (SiPM) that convert optical light to electrical signals. The technology has been well tested at other high-energy-physics experiments. The fibers themselves are lightweight, they can produce and transmit light within the 25-nanosecond window and they are suitably tolerant to the ionizing radiation expected in the future.

Each scintillating fiber making up the sub-detector is 0.25 mm in diameter and nearly 2.5 m in length. The fibers will be packed into modules that will reside in three stations within LHCb, each made of four so-called "detection planes", with the photomultipliers located at the top and bottom of each plane. "The fibers have been painstakingly examined, wound into multi-layer ribbons, assembled into detector modules and thoroughly tested," explains Blake Leverington, who is coordinating part of the SciFi project for LHCb. "The fibers provide a single-hit precision better than 100 microns and the single-hit efficiency over the area of the detector is better than 99 percent." In total, over 10 000 km of precision-made scintillating fibers will adorn LHCb.

Unlike the other LHC detectors, LHCb is asymmetric in design and studies particles that fly very close to the beam pipe after being produced in proton–proton collisions. However, operating a sensitive detector this close to the beam pipe brings its own problems. Simulations show that radiation damage from collision debris would darken the fibers closest to the beam pipe by up to 40 percent over the lifetime of LHCb. This would make it harder for the produced light to be transmitted through the fibers, but the detector is expected to remain efficient despite this.

The photomultipliers located at the top and bottom of each SciFi detection plane will be bombarded by neutrons produced in the calorimeters that sit further downstream. The radiation damage results in so-called "dark noise", where thermally excited electrons cause the SiPMs to produce a signal that mimics the signal coming from individual photons. In addition to shielding placed between the SciFi and the calorimeters, a complex cooling system has been developed to chill the SiPMs. "Measurements have shown that the rate of dark noise can be reduced by a factor of two for every 10 degrees Celsius drop in temperature," points out Leverington. The SiPMs have been mounted on special 3-D-printed titanium cold-bars that are cooled to −40 degrees Celsius.

"The project has had contributions from more than a hundred scientists, students, engineers and technicians from 17 partner institutes in 10 countries," says Leverington. "We have worked together for seven years to bring SciFi to life." Currently, the SciFi modules, services and electronics are being assembled and installed in the 12 mechanical frames in the assembly hall at the LHCb site at Point 8 of the LHC ring. The first SciFi components are planned to be installed in spring next year.

Provided by CERN