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A small detector could strike big in the search for dark matter

Low cost, spare parts, private money, and further serendipity converged to accelerate a new experiment at the LHC.

Toni Feder

An abandoned tunnel near the collision site of the Large Hadron Collider's ATLAS detector will house the new FASER experiment. Credit: FASER/CERN

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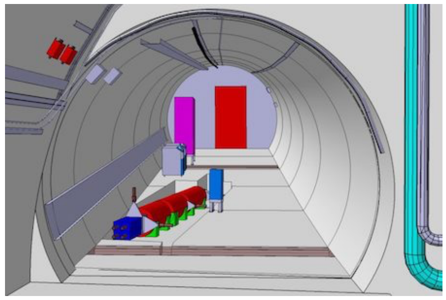
A detector for dark photons and other long-lived portals to the hidden sector is on the fast track to be built and installed at the Large Hadron Collider (LHC). CERN gave the green light to the Forward Search Experiment (FASER) on 5 March; it is scheduled to begin collecting data in the spring of 2021.

To be located 480 meters from the proton–proton collision site of the ATLAS detector, the piggybacking FASER will look for decays from particles that shoot out in the protons' direction of motion. That's a blind spot for ATLAS, says Jamie Boyd, a CERN scientist and FASER cospokesperson. ATLAS and the other LHC experiments look for heavy particles, which are produced at low velocities and decay almost isotropically. "For a light, weakly interacting particle, that's the wrong strategy," says Jonathan Feng, a theorist at the University of California, Irvine (UCI), and FASER cospokesperson. "The light particles are mainly produced along the beam pipe, and there could be millions of them."

Feng and three postdocs—Iftah Galon, Felix Kling, and Sebastian Trojanowski—had the idea for FASER in 2017. With particle physicists coming up empty-handed in discovering physics beyond the standard model, the four researchers were scratching their heads. "With 85% of the universe's matter unknown, there must be new particles out there," says Feng. The group's first aha moment was the realization that existing experiments might be missing collision products that could yield insight into the hidden sector. Then they looked at a map of CERN and saw that an abandoned tunnel from the former Large Electron–Positron Collider would be a good location for their experiment. "All of a sudden this theoretical idea became more realistic," says Feng.

The FASER detector will sit in the line of sight of the ATLAS collision point, slightly removed from the LHC's curvature. Impinging particles will pass through a scintillator into a 1.5-meter-long magnet, and then into tracking detectors and a calorimeter. The experiment will look for the appearance in the magnetic field of electrons and positrons, which could be the decay products of dark photons produced mainly by pions. The calorimeter would measure their energies.



FASER will detect particles that shoot out in the colliding protons' direction of motion. Credit: FASER collaboration

Dark matter interacts weakly—that's why it's hard to find—but it's not known how heavy a weakly interacting dark matter particle might be. FASER will tune in to dark particles with masses from about 10 MeV to 1 GeV, a range determined mainly by the distance between the collision site and the detector, says UCI experimental physicist Dave Casper. “No one has yet looked in the region of parameter space where FASER will be most sensitive.”

At 20 cm across, the detector will catch particles that do not spread out much in transit; that's why the initial “bread and butter” will be long-lived dark photons and other particles from pion decays, says Boyd. Dark photons—the putative dark-sector analogs of light, similarly neutral but having mass—may mediate between ordinary and dark matter. A later, larger version of FASER could look for signatures of dark Higgs bosons, sterile neutrinos, and other possible dark-sector particles that may be produced in the decay of heavier particles, like B mesons.

There is no guarantee that FASER will turn up anything, admits Feng. But if it does, “it would open the door to the next era of physics.”

FASER is part of the Physics Beyond Colliders program initiated in 2016 by CERN's director general, Fabiola Gianotti, to seek new ways to leverage the lab's facilities. Most of its proposals are being considered as part of the broader European Particle Physics Strategy, which will make recommendations in mid 2020. FASER's small price tag (roughly $1 million) and private funding let it sidestep that process.

The Simons Foundation and the Heising–Simons Foundation have each pledged $1 million over five years. Some of that money will go to pay for graduate students. “The timescale is such that a graduate student can be on the experiment from start to finish,” says Casper. “That’s an attractive selling point. Graduate students will be able claim parts of the experiment or analysis as their sole responsibility.” The FASER collaboration consists of about 40 scientists at institutions in the US, Europe, China, Israel, and Japan.

CERN is covering the costs of personnel for the simulations and design, infrastructure, installation, and excavation—the existing tunnel needs minor modifications to align the FASER detector. The tracking detectors and calorimeters are spares donated by the ATLAS and LHCb experiments. The 0.6 T permanent magnet, which needs neither power nor cooling, is being built at CERN. The lab gave the final approval for the experiment after making sure that FASER could be installed without disrupting other activities during the current LHC shutdown.