Crunching Large Hadron COLLIDER DATA to Speed Dark Matter Quest

With the discovery and later confirmation last March of the Higgs boson—the last missing piece of the standard model of particle physics—scientists are now setting their sights on discovering new physics beyond the standard model. The next big thing is to search for dark matter, according to Frank Wuerthwein, a professor of physics at UC San Diego.

"For the Higgs, we knew exactly how to search for it given theoretical predictions based on past experimental results," said Wuerthwein, part of the research team for the Compact Muon Solenoid (CMS), one of two large general-purpose particle detectors at the Large Hadron Collider (LHC) used by researchers in Switzerland to find the elusive Higgs boson.

"For dark matter, the situation is much hazier," Wuerthwein added. "We hope to produce dark matter at the LHC in cascade decays of a whole spectrum of new fundamental particles, the lowest mass of which is dark matter. But the details of this spectrum of masses are unknown. To have sensitivity to a large range of possible mass spectra, we needed to write more data to tape so we would be able to carefully analyze it later."

Toward that end, a team of UC San Diego physicists including Wuerthwein, and the Open Science Grid (OSG), a multi-disciplinary research partnership funded by the U.S. Department of Energy and the National Science Foundation, used SDSC's *Gordon* to rapidly process raw data from almost one billion particle collisions generated by the CMS. The project represented the single most data-intensive exercise to date for *Gordon* since completing its large-scale acceptance testing in early 2012.

The UC San Diego-OSG collaboration (see page 41) came as the LHC was shut down in February 2013 to make numerous upgrades during the next two years. One major activity during the shutdown included the development of plans for efficient, effective searches once the LHC was back in operation. To do that—and to have time enough to upgrade equipment—researchers had to sift through massive amounts of stockpiled data to help scientists define future research agendas, such as the search for dark matter.

"Access to *Gordon*, and its excellent computing speed due to its flash-based memory, really helped push forward the processing schedule for us," said Wuerthwein. "With only a few weeks' notice, we were able to gain access to *Gordon* and complete the runs, making the data available for analysis in time to provide crucial input toward international planning meetings on the future of particle physics."

"Giving us access to the *Gordon* supercomputer effectively doubled the data processing compute power available to us," added Lothar Bauerdick, OSG's executive director and the U.S. software and computing manager for the CMS project. "This gave CMS scientists precious months to get to their science analysis of the data reconstructed at SDSC."

UC San Diego researchers and CMS team members, in addition to Wuerthwein, included Jim Branson, Vivek Sharma, and Avi Yagil, all of whom played major roles in the discovery of the Higgs boson particle.

"UC San Diego has been one of the most successful institutions in the global hunt for the Higgs particle discovery at the LHC," said Wuerthwein, who is leading the university's search for dark matter.

Amit Majumdar is interim director of SDSC's Data Enabled Scientific Computing (DESC) division, which assisted researchers in using *Gordon* to process data on almost one billion particle collisions.

This image of a supersymmetry event shows the transverse momentum imbalance due to dark matter particles escaping the detector (direction indicated by red arrow). Red and blue rectangles indicate energy deposited in the electromagnetic and hadronic calorimeter respectively; green tracks in the center show charged particles with transverse momentum larger than 2GeV. Yellow-outlined triangles indicate jet cones or the presence of subatomic particles called quarks. Image courtesy of Matevz Tadel, UC San Diego/CMS