8 October 2013

Canadian involvement in Higgs Search at the LHC and ATLAS

Background

The ATLAS and CMS experiments at the CERN (Geneva) Large Hadron Collider (LHC) reported a new particle discovery on July 4th, 2012, in the search for Higgs Boson, the missing link in our theories of particle physics that gives mass to energy and enables the existence of the matter we are made of. This is one of the leading scientific issues of the last century and resulted in the 2013 Nobel Prize in physics being awarded to Peter Higgs and Francois Englert. The Higgs particle itself is massive, more than 100 times the mass of the proton, and short lived so we must detect its decays into particle such as gamma-ray and electrons. Discovering the Higgs firstly required producing it in a high-energy collider, and then secondly detecting its decay products using sophisticated particle detectors similar to enormous digital cameras by finding the "needle" Higgs signal in the enormous "haystack" of background events. Canadian played critical roles in the Higgs discovery, with a large effort from Institute of Particle Physics scientists, members and institutes.

LHC Collider

The LHC accelerates two beams of protons to nearly the speed of light, and collides them together so that their large kinetic energies can be transformed into the Higgs or other heavy particles. While the beam energy is important, it is equally essential that the proton beams have enormous intensity to allow enough Higgs particle production rate for detection and also that the beams are very pure so that additional backgrounds that would mask the Higgs signal are not generated. The TRIUMF lab under the leadership of former IPP Director Alan Astbury worked with Canadian industry to upgrade the LHC beam injection systems to allow very high intensity running, and also to design and install very challenging beam-cleaning systems that insure that beam backgrounds for the Higgs search are kept at an absolute minimum.

ATLAS Detector

Key to Higgs observation is that it can decay into very clean signatures that allow us to detect it above the enormous backgrounds that are also produced in proton decays. Three critical Higgs decay modes were used to discovery the Higgs, in order of importance: (1) Higgs decays to pairs of gamma rays whose energies we measure by stopping them in devices called calorimeters; (2) Higgs decays to four electrons or muons which can be cleanly seen in particle detectors immersed in magnetic fields allowing their energies to be measured; (3) Higgs decaying to two electrons or muons plus the enigmatic neutrino who existence we infer by missing energy and momentum in our Calorimeters.

Canadians were leaders in the design, construction and operation of the ATLAS Calorimeters. Professor Michel Lefebvre from the University of Victoria, who led Canada into ATLAS, was instrumental in the design of the ATLAS gamma-ray detecting calorimeters in the early 90's. Canadians at IPP institutes TRIUMF and universities Alberta, Carleton, Toronto and Victoria went on to build other parts of the ATLAS calorimeter system that are used to precisely characterize the missing energy caused by neutrinos in other Higgs decay channels. In addition to building these detectors, Canadians, including CERN-resident Toronto IPP scientist Richard Teuscher, are also instrumental in operating and calibrating the ATLAS calorimeters whose data are used for Higgs analysis, with special emphasis on ensuring that we can robustly use the lower energy electrons expected in the four electron Higgs decay mode for discovery. The overall principal investigator of Canadian efforts on ATLAS is Rob McPherson, an IPP scientist at UVic.

Computing

ATLAS produces petabytes (millions of gigabytes) of data per year, which are streamed live to 10 Tier-1 centres including TRIUMF where the complex data is processed to the point where physicists can use them for the Higgs search. The processed data is distributed to Tier-2 sites, including five at Canadian universities where they are accessed by students, postdocs and faculty. UVic IPP Scientist Randall Sobie leads a team developing and deploying advanced computing grid tools for accessing the ATLAS data.

Data Analysis

ATLAS has independent teams working on the Higgs Search in each of its different Decay modes. Canadians work in each of these teams:

1) Higgs decays to gamma rays: the university of Victoria group has a postdoc central to the Higgs search in this channel, working primarily with Professor Bob Kowalewski.
2) Higgs decays to four electrons or muons: Carleton university faculty members Manuella Vincter and Thomas Koffas lead a team of postdocs and students in an effort to use lower energy electrons in the Higgs search.
3) Higgs decays to electrons or muons plus neutrinos: groups at TRIUMF, SFU and Toronto, led by faculty members Bernd and Oliver Stelzer and Pierre Savard, are principal analyzers of this channel.

Summary

LHC and ATLAS systems built in Canada are critical for the Higgs Boson search. About 30 (out of 150) Canadian work directly on the Higgs Boson analysis with ATLAS data, and probably more importantly a significant part of ATLAS-Canada maintains essential ATLAS detector systems for the Higgs search. Five of the eight IPP research scientists work on ATLAS, and continue to play critical roles in ATLAS Higgs studies, the search for physics beyond the Higgs and the Standard Model of Particle Physics, and ATLAS detector upgrades.