Galileo Galilei Institute Workshop
"Interpreting LHC Discoveries"

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1 Motivation

The Large Hadron Collider wlll provide direct access to new physics at the TeV scale that may be responsible for electroweak symmetry breaking, dark matter, and the mysterious flavor structure of the Standard Model.

The LHC has resumed operation in November 2009. The present plan foresees a run at 7 TeV for up to 2 years corresponding to a significant integrated luminosity, before a long shut down to prepare an increase of the energy up to 14 TeV. A signal could appear in this first run in one or more collider signatures in several scenarios for new TeV scale physics. This defines the first opportunity for particle theorists to help interpret LHC discoveries.

This unique moment presents special challenges and will require new ways of thinking. In particular, it will be necessary to go beyond the "top-down" approach in which the experimental consequences of a given theory model are worked out and translated into searches for the predicted signatures. With early LHC signals in hand, theorists will be called upon to assist in the "bottom-up" problem of mapping the signals to their underlying theory. Early discovery analyses will suffer from limited statistics and ambiguities due to imperfectly understood Standard Model backgrounds and detector effects. The excitement of discovery might be tempered by uncertainty over what is actually being seen.

This intense, four week GGI workshop will take place at the end of the first run and will be devoted to interpreting the first signals from the LHC, making the most of the data available. The workshop will therefore gather a critical mass of the theorists and experimentalists most engaged in this challenge at a time at which hopefully the dust will start to settle. A conference in the first part of the workshop will present the status of the experiment and the analyses to provide the latest input for the subsequent work.

Since it is hard to predict what the data will bring, the topical organization of the workshop will be kept flexible. However some considerations are sufficiently broad that they apply in any discovery scenario:

- Electroweak symmetry breaking: any discovery of new physics at the TeV scale is likely to be tied to electroweak symmetry breaking and to the hierarchy between the electroweak and the Planck scales, but this connection may be unclear, ambiguous, or involve a mechanism not yet imagined. Besides studying the consistency of the existing theoretical scenarios with the first data, the possibility to apply model-independent analyses should also be investigated and model degeneracies should be identified together with the possibility to resolve them.

- Data interpretation: since mapping theory to LHC signatures involves QCD and detailed Monte Carlo simulations, the theoretical interpretation of discoveries will require a solid understanding of the most promising discovery channels and the validation of our simulations. We will invite leading experts on QCD applied to collider physics and MC to focus on the challenge of closing the gap between new theory ideas and LHC data.

- Data analysis: the complete understanding of the new detectors (ALICE, ATLAS, CMS, LHCb) is an essential ingredient for the correctness of the data analysis. Interesting techniques have been developped using physics signals. For example the abundant production of W and Z bosons and the clean experimental signature of the leptonic decays, make W and Z bosons a very useful tool for the detector calibration and alignment and essential to tune the generators. In addition they could complement and extend the tests of the EW theory performed so far at the e^+e^- and $p\overline{p}$ colliders.

- Higgs boson search: Discovery of a Standard Model-like Higgs is not expected with the integrated luminosities currently projected for the first year of running, with the possible exception of the $H \to WW$ signature. Observation of excesses in Higgs-motivated search channels in the first data would therefore require an exhaustive discussion between theorists and experimenters to properly interpret such signals. In the (not unlikely) absence of signals there will remain the major challenge of relating the results of the startup-strength analyses to the already-existing Tevatron exclusion.

- Rare decays: the very first data would allow the study of rare decays with muons (easy to detect) in the final state. These decays are highly suppressed in the Standard Model and are therefore excellent probes of new physics. For example the expected branching ratio for the rare decay $B_s \rightarrow \mu^+\mu^-$ in the Standard Model is $\sim 3\times 10^{-9}$. In the Minimal Supersymmetric Standard Model the branching fraction for this decay can be enhanced by orders of magnitude, especially at large $\tan\beta$. Hints from these searches could be seen even with few hundred inverse picobarns.
- Dark matter: any missing energy signal at the LHC is potentially related to dark matter, but with limited data sets it is not yet known how to extract the first unambiguous steps towards revealing the identity of dark matter. This opportunity may be heightened in the near future by direct or indirect signals of astrophysical dark matter particles.