Workshop on LHC / ILC Interplay: Introduction

Georg Weiglein

IPPP Durham

CERN 12/2005

Worldwide Study of the Physics and Detectors for Future Linear $e^+ e^-$ Colliders

www.ippp.dur.ac.uk/~georg/lhcilc

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⇒ LHC / ILC Study Group

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Meanwhile accepted for publication in *Physics Reports*

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- The issue of LHC / ILC synergy has found a lot of attention within and outside our field, of funding agencies, etc.

Examples from the U.S.

Presentation from M. Turner (NSF) to HEPAP, Sep. 23, 2004:

Complementarity

Inevitably, the question will arise of why we need a second, *less* powerful accelerator to explore the energy frontier. To educate us and to clarify this issue more generally, we would like HEPAP to form a subpanel to address complementarity, paying particular attention to the following aspects of LC/LHC complementarity:

- In the context of physics discoveries (e.g., low-energy supersymmetry) made at the Tevatron or early at the LHC, what is the role of a subTeV Collider?
- In the context of physics discoveries made an LC, what is the role of the LHC
- In the context of "known physics" (e.g., electroweak physics), what are the synergies and complementaries of these two machines?

You should assume that the LC and LHC (with possible upgrades) will have a significant period of overlapping operation.

We are looking for a short document (20 pages), accessible to knowledgeable non-experts (e.g., members of the EPP2010 Study, OSTP Staff and ourselves). We ask that the report be completed by April 2005.

Finally, to further educate us as well as giving us an opportunity to refine and discuss the charge with you in more detail, we suggest a half-day session at the next HEPAP meeting devoted to Complementarity.

HEPAP subpanel on LHC / ILC complementarities

- Official request from NSF (R. Staffin, M. Turner) to HEPAP on March 21, 2005:

  form subpanel, provide report by summer 2005

- Panel members:

  J. Lykken (Co-Chair), J. Siegrist (Co-Chair), J. Bagger, B. Barrish, N. Calder, A. De Roeck, J. Feng, F. Gilman, J. Hewett, J. Huth, J. Jackson, Y.-K. Kim, R. Kolb, K. Matchev, H. Murayama, R. Weiss

- Report to the Elementary Particle Physics (EPP) 2010 Committee from HEPAP (July 27, 2005):
  "Discovering the Quantum Universe"
  `www.science.doe.gov/hep/hepap.shtm`

EPP 2010 Decadal Survey

U.S. National Academy of Science reviews each field of physics every ten years
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EPP 2010 charge:

- Identify, articulate, and prioritize the scientific questions and opportunities that define elementary particle physics
- Recommend a 15-year implementation plan with realistic, ordered priorities to realize these opportunities

$\Rightarrow$ emphasis on ranking science priorities

Some of the EPP questions on the ILC:

- What are the physics arguments for operating a Linear Collider during the same time frame as the LHC?
- How would the combination of the LHC and a Linear Collider answer questions that could not be addressed by either machine alone?
- What physics would a Linear Collider address that would be impossible to probe at the LHC?

$\Rightarrow$ The LHC / ILC Study Group was approached by the EPP, asked to provide a response to these questions

Response of the LHC / ILC Study Group to the EPP questions

Document prepared, writing team: J. Conway, J. Gunion, H. Haber, S. Heinemeyer, G. Moortgat-Pick, G. W.

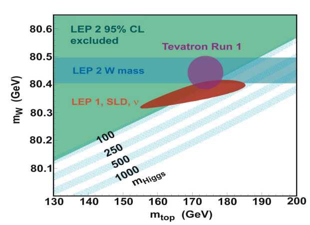
The EPP Questions

Response from the LHC/ILC Study Group

Ground-breaking discoveries are expected from the experiments under construction at the Large Hadron Collider (LHC) and those planned for the International Linear Collider (ILC). These high-energy particle accelerators will open up a new energy domain that will allow us to examine the very fabric of matter, energy, space and time. The experimental results should reveal how particles obtain the property of mass, whether the different forces that we experience in nature are in fact different manifestations of only one fundamental force, whether space and time are embedded into a wider framework of “supersymmetric” coordinates, and whether dark matter can be produced on Earth.

The LHC and ILC will probe this new TeV energy regime (roughly equivalent to 1000 proton masses) in very different ways, as a consequence of the distinct features of the two machines. Due to its high collision energy and luminosity, the LHC has a large mass reach for the discovery of new heavy particles. The striking advantages of the ILC are its clean experimental environment, polarized beams, and tunable collision energy. The ILC can thus perform precision measurements and detailed studies of directly accessible new particles, and also has exquisite sensitivity to quantum effects of unknown physics. Indeed, the fingerprints of very high-scale new physics (e.g. very high mass particles) will often only be manifest in small effects whose measurement requires the greatest possible precision.

The need for instruments that are optimized in different ways is typical in all branches of natural sciences, for example earth- and space-based telescopes in astronomy. In high-energy physics there has historically been a great synergy between hadron colliders, which can reach the highest energies, and lepton colliders, at which high-precision measurements are possible. As an example, the precise knowledge of the Z boson mass from LEP and precise measurement of its decay properties led to the prediction of a heavy top quark. Its mass was well beyond the energy reach of LEP but accessible to the Tevatron. Following the Tevatron’s discovery of the top quark, its mass was determined. Subsequently the Tevatron and LEP measured the W boson mass with high precision. In combination, these measurements point tantalizingly toward a light Higgs boson.



Precise measurements from concurrent running of LEP and the Tevatron experiments have brought us to the threshold of discovering the Higgs boson.

We expect an even greater synergy between the LHC and ILC. Discoveries made at the LHC will guide the operation of the ILC, and the precision ILC measurements can make it possible for the LHC to extract subtle signals for new physics and particles that may have escaped detection. Ultimately both machines will be needed to definitively connect TeV-scale measurements with the underlying theoretical structure.

In general, the LHC can most readily discover the heavy states of new physics that are "strongly coupled" (that is, produced via the strong interaction). These strongly coupled states typically decay via complicated cascades into new “weakly coupled” particles. The ILC is ideal for directly producing and detecting these weakly coupled particles. Precision ILC measurement of the properties of these particles are essential in understanding the strongly coupled ones and their decay patterns. Moreover, ILC measurements of quantum effects can be combined with direct LHC and ILC measurements to infer the existence and properties of additional heavy states at first missed by the LHC and too massive to be directly produced at the ILC. In many cases, these could then be directly discovered using modified LHC procedures.

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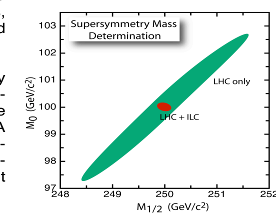
As an example, the existence and properties of heavy Higgs bosons and/or difficult-to-detect scalar Higgs-like particles associated with extra dimensions can be inferred from precision ILC Higgs measurements. A dedicated LHC search can then confirm their existence. In supersymmetry and extra-dimension theories, the LHC and the ILC will typically access different parts of the spectrum of new states.



Together the ILC and LHC can measure the unified supersymmetry masses much more precisely than either machine alone.

Summary

There will be a profound synergy between the physics results from the LHC and those from the ILC. The two machines complement and supplement one another in many ways, and concurrent operation will maximize the impact of both. Understanding the physics of the TeV scale will have an important impact on cosmology and other fields, as well as give timely guidance regarding future facilities. The sooner the ILC can be brought into operation, the sooner these benefits can be exploited. Optimal use of the capabilities of both machines will greatly improve our knowledge of the fundamental nature of matter, energy, space and time.

We urge the international high energy physics community and the governments of all the countries involved to strive to make the ILC a reality in the coming decade.

See the full report of the LHC/ILC Study Group at http://arxiv.org/abs/hep-ph/0410364

John Conway, Jack Gunion, Howard Haber, Sven Heinemeyer, Gudrid Moortgat-Pick, and Georg Weiglein

May 16, 2005

Released to the EPP members at the EPP meeting in May ’05 at Fermilab, see `www.ippp.dur.ac.uk/~georg/lhcilc`

Recent workshops on LHC / ILC interplay

- Workshop on LHC / ILC Synergies

  SLAC, March 23, 2005

- Les Houches Workshop

  Main meeting: May 2005

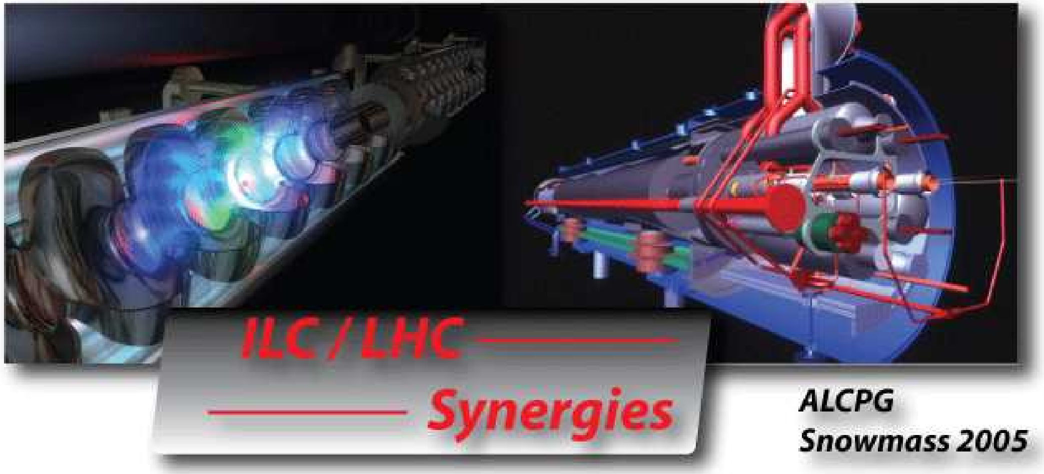
- Snowmass Workshop

  August 14–27, 2005

- Aspen Workshop

  August 14 – September 10, 2005

LHC / ILC activities at Snowmass, August 14–27, 2005



- Plenary talk: The HEPAP LHC / ILC Report, *J. Lykken*
- Coordination committee: "LHC / ILC Connections"
  Coordinators: *J. Conway, M. Nojiri, D. Rainwater, G. W., D. Zerwas*
- LHC – ILC debate: *"Does the ILC project have to wait for discoveries from the LHC?"*

`http://alcpg2005.colorado.edu:8080/alcpg2005/program`

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  $\Rightarrow$ Perfect "playground" for phenomenologists

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  Now is the time to start thinking about how this could be achieved!