Arguments for Two Complementary Detectors at the ILC

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The optimal experimental physics program of the International Linear Collider requires two complementary ILC detectors with full energy and luminosity reach. We discuss the arguments justifying this conclusion, and address counter-arguments.

1. INTRODUCTION

The optimal ILC experimental program would include two complementary high energy detectors at two separate interaction regions (IRs), designed for the full energy and luminosity reach of the collider, with operation of both scheduled to begin with the start of machine collisions. While the two detectors would split the integrated luminosity of the collider, the scientific productivity of the collider would be significantly expanded for many reasons. Scientific arguments for two detectors/IRs are summarized in the five categories below. These are supported by numerous historical examples where complementary experiments were critical to the scientific results. Counter-arguments can be made, especially if there is a limit in funding, and these are addressed below. Since two detectors/IRs will enhance the output of the ILC program and should attract more international participation and funding, this option should be included from the beginning. A summary of the detector options for the ILC is presented.

2. SCIENTIFIC REASONS

2.1. Cross-check and Scientific Redundancy

The ILC is expected to yield major discoveries on the nature of the universe. Such discoveries are accepted and integrated into the scientific paradigm only with sound confirmation. This will also be true at the ILC. Two complementary experiments, with differing detector approaches, will provide this required cross-check on discoveries and important physics measurements. While discoveries require confirmation; precision measurements require redundancy. Two collaborations will develop complementary analyses with detectors characterized by independent data sets and the differing systematic errors derived from differing detector designs. Two will ensure the most accurate assessment of new physics found by discoveries or by precision measurements.

Confirmation and redundancy have been a necessary condition for progress in high-energy physics, as demonstrated by many past fixed-target and collider experiments. For decades the ILC will be at the cutting edge of the unknown where confirmation and redundancy are imperative to a rapid, thorough understanding of the data and physics. In fact, cross-checks are an indispensable tool in all branches of science, a principle understood broadly.

2.2. Complementarity, future collider options

Ideally, given the unknowns of the experimental environment at future colliders, the program must be prepared with two detector philosophies in order to provide complementary sensitivity to physics, backgrounds and fake effects. There is no unique optimal design for an ILC detector, because it is not known what will be discovered, and what physics will prove to be the most important, and the backgrounds cannot be predicted with certainty. Two experiments open opportunities for some level of aggressiveness in experimental design. For similar reasons, the LEP/SLC detectors were designed with different strengths and weaknesses, arising from different assumptions on physics and technical advantages; their complementarity broadened the coverage. At the Tevatron, the top quark discovery benefited from the different detector approaches of CDF and D0. ATLAS and CMS at the LHC will provide this complementarity. It is important for the ILC detectors to provide similar breadth in detector response.

A second IR will allow future implementation of the gamma-gamma collider option if the science case becomes compelling, without disrupting the continuation of high energy e^+e^- studies.

A future upgrade to a much higher energy would require a large crossing angle at the IR. Two IRs make it possible to provide a small crossing angle experiment, as well, without closing off the large angle capability.

2.3. Competition

The competition between two detectors and IRs will drive the scientific productivity of both experiments, as has been demonstrated frequently. This important force in the scientific enterprise results in a more effective utilization of the program.

2.4. Efficiency, Reliability, Insurance

The efficiency of operation will be higher, since the maintenance of one detector and the associated final focus beamline elements, can be carried out while the other is accumulating data. Furthermore, unexpected problems with one detector will not stop the operations of the collider; the risk associated with the large concentration of hardware at the detector IR implies that a major failure could disable the program for a long time period without a second detector.

Experience with operating experiments at a linear collider is limited to Mark II and SLD at SLC. This experience raised unexpected issues with beam halos, 'fliers', beam-related EMI, and other effects. It is prudent to anticipate additional discoveries related to operation at the much higher currents and energy of the ILC. The design of the ILC will, of course, profit from the SLC experience, and be able to avoid most of these problems. But for a new machine, one must expect new effects, and complementary detector designs will insure the ability to deal with such technical uncertainties.

2.5. Sociology, Scientific Opportunity

A research facility for decades of exploration is being planned, meaning this facility will provide the opportunities for more than a generation of physicists. It is obvious that two detectors are better than one, by doubling the possibilities for meaningful contributions to the experimental program, and accommodating the research interests of twice as many physicists. With two detectors employing complementary technical solutions, the development and training opportunities, including those for young scientists and engineers, will be enhanced.

2.6. Historical examples

Multiple experiments have been important often in the past, either in establishing new physics, or providing the other aspects described above. Many examples are well known. A list of such examples is given in Reference [1].

3. COUNTER POINTS OF VIEW

Critics of this argument make a number of points, including the following:

1. In the absence of sufficient funding for two detectors/IRs, a single IR can provide a cross-check by "repeating a collider run".
2. Another often cited possibility is to organize two independent analysis chains within the same detector collaboration in order to promote competition and redundancy.
3. With proper organization, the visibility for young physicists, and the opportunities to make significant contributions, can be enhanced within a collaboration.
4. Reduced efficiency: the two-IR solution would mean that the tuning-for-two would require more effort than tuning-for-one would have, and the more complicated operation will yield less total luminosity than for one IR.

3.1. Comments on the counter arguments.

1. This is true (see next point).
2. This technique has been used in the past but is not be as effective as having two different detectors. There are many historical examples of effects not being resolved by parallel analyses in one experiment in high-energy physics: the Aleph 4-jet 105 GeV mass peak, the split-A2, leptoquarks, the zeta, etc. The degree of autonomy of multiple analyses within a single collaboration is limited by the desire to find a common answer. Two experiments will develop completely different approaches, potentially reaching different conclusions.
3. Visibility for young physicists and opportunities for significant contributions occur naturally if there are two detectors; they may or may not if there is only one.
4. Clearly this may be true, but the "insurance" addressed in item 2.4 above says the argument may cut the other way. This is the price one has to pay for a more attractive and robust scientific environment.

4. OPTIONS

Two detectors will cost more than one, but not twice as much, since the detector-optimization process would be different for two detectors than if there were only one being built. Many developments for the two IRs would be common to both experiments, e.g., bunch-to-bunch feedback, slow-control, DAQ architecture, magnetic-field-map ping gear, etc.

One approach to realizing two experiments is to stage one and to bring the second into full construction and operation the second or third year of the ILC. Other elements of the ILC complex might also be staged, with early commissioning of many elements providing the possibility to address some of the operational challenges, and the full potential of the scientific program realized a few years after start-up.

Since cost is a major issue and the financial basis for the ILC is not yet known, reliable estimates for the different options beyond the baseline are needed to fully evaluate the tradeoffs. The options, in order of our preference, are:

1. 2 Instrumented IRs / 2 detectors
2. 1 Instrumented IR / 2 detectors(in push-pull configuration) + 1 Non-Instrumented IR for future instrumentation
3. 1 Instrumented IR / 2 detectors(in push-pull configuration)
4. 1 Instrumented IR / 1 detector(with push-pull capability for a future additional detector)
5. 1 Instrumented IR / 1 detector + 1 Non-Instrumented IR for future instrumentation
6. 1 Instrumented IR / 1 detector (the minimal program)

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References

[1] http://physics.uoregon.edu/~lc/historical-examples.html