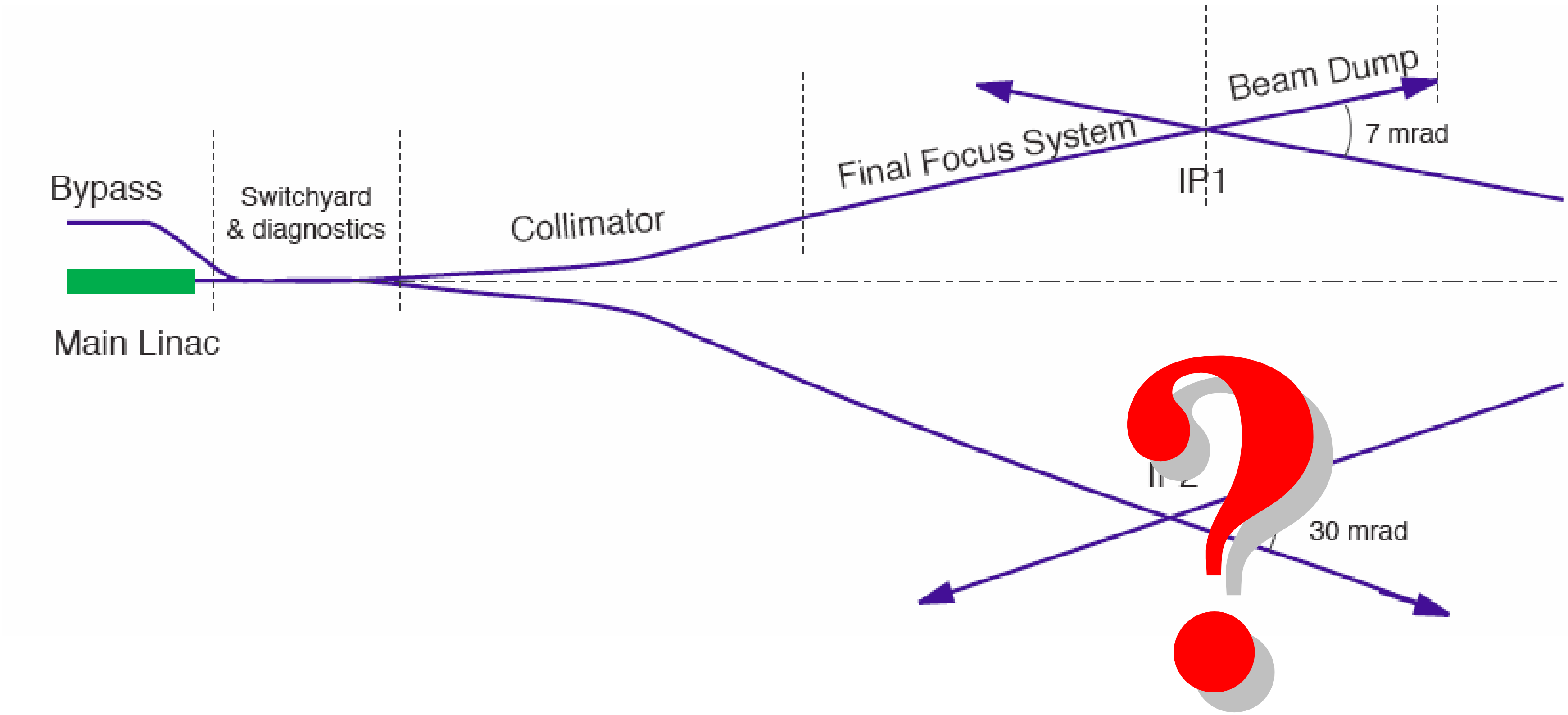
Why We Need Two Detectors?



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We will have one Linear Collider : ILC.

Two possibilities

i) One Interaction Region (1-IR)
(Naturally One Detector)

or

ii) Two Interaction Regions (2-IRs)
(Naturally Two Detectors)

1) We have to choose (i) or (ii).
2) In any case, we need justification.

World-Wide-Study set
A Panel on 1-IR vs 2-IRs

Panel Members

- N-America: Jim Brau
- Europe : Ron Settles
- Asia : TO

Reviewer : Joel Butler

Report:
Arguments for Two Complementary Detectors (draft v1.3a)

http://physics.uoregon.edu/~lc/wwstudy/concepts/draft_1.3.doc

Quick Introduction of the report

The ILC program should ideally include
i) two interaction regions (IRs) and two detectors,
ii) both designed for the full energy and luminosity,
iii) both scheduled to begin at the first collision.

Two detectors split liminosity. Nevertheless the scientific productity will be significantry expanded

Two detectors/IRs
i) enhance the output of the ILC,
ii) attract more international participation and hence more funding.
-> two detectors should be included from the beginning.

Report discusses following items

- Scientific reasons for two detectors/IRs : (1) - (6)
- Counter auguments: (7)
- list of the detector/IR options : (8)
- Recommendation for next step

Scientific Reasons for Two Detector/Irs: (1)-(6)

(1) Cross-check and Scientific Redundancy

Two experiments provide a cross-check.
Scientific redundancy is a key for progress of physics.

(2) Complementarity, future collider options

(i) Unknowns of the experimental environment.
We have to prepare with two detector philosophies, to provide complementary sensitivity.

(ii) 2-nd IR adds to the scientific flexibility, it will allow for an easier implementation of an increase in CMS energy and/or of the - (or e-) option.

(3) Competition

Competition drives productivity of both experiments.

(4) Efficiency, Reliability, Insurance

(i) Maintenance of one detector and one final focus beamline can be carried out while the other is accumulating data.

(ii) Risk associated with the large concentration of hardware at/near the IR --> If we have tow IRs, then unexpected problems with one detector will not stop the operation.

(5) Sociology, Scientific Opportunity

Doubling the possibilities for meaningful contributions, especially for young scientists and engineers.

(6) Historical examples :

multiple experiments was important

(7) Counter points of view

(i) a cross-check by "repeating a collider run".

Limited budget !!!

(ii) organize two independent analysis with one detector.

Limited budget !!!

(iii) Proper organization --> visibility/opportunity potential can be enhanced in one detector.

Limitted budget !!

(iv) Reduced efficiency:

tuning-for-two would require more effort than tuning-for-one.

L(sum of two) < L(one)

(8) Options

(i) 2-Instrumented-IRs/2-detectors

(ii) 1-Instrumented-IR/2-detectors(push-pull)
+
1-Non-Instrumented-IR

(iii) 1-Instrumented-IR/2-detectors(push-pull)

(vi) 1-Instrumented-IR/1-detector(push-pull capable)

(v) 1-Instrumented-IR/1-detector
+
1-Non-Instrumented-IR

(vi) 1-Instrumented-IR/1-detector

(i) is the best, and (vi) is the minimum.
(i) is most expensive, but not the double of (vi), because there are many common efforts.

Recommendation:
We ask the costing committee to provide relative cost estimates of (i) to (vi).

Full Text of the Draft

Arguments for Two Complementary Detectors

DRAFT 1.3a - 16 August, 2005

Introduction

The ILC experimental program should ideally include at least two 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 start of machine collisions. It is understood that the two detectors will split the integrated luminosity of the collider. Nevertheless, the scientific productivity of the collider will be significantly expanded.

Scientific reasons for two detectors/IRs are summarized in the first five points that follow. Historical examples, illustrating the importance of complementary experiments, follows as point six. Counter-arguments can be made, especially if there is a limit to the finances, and these are addressed in a seventh point. Since two detectors/IRs will enhance the output of the ILC facility and should attract more international participation and funding, this option should be included from the beginning. Since we have to know what the different options mean financially, a summary of all of the detector options for the ILC and a recommendation for the next step are presented in a eighth and final point.

(1) Cross-check and Scientific Redundancy

The ILC is expected to yield major discoveries of 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 experiments 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 differing systematic errors. 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) 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.

(3) Competition

The competition between two 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.

(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.

(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, doubling the possibilities for meaningful contributions to the experimental program, and accomodating 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.

(6) Historical examples

Multiple experiments have been important often in the past, either in establishing new physics, or providing the other aspects described above.

(Note – this list of historical examples will be expanded with detailed explanations of how each example makes the point for two complementary detectors at the ILC)

One important set of historical examples illustrates the importance of confirming results with a second experiment

- **The Nobel Prize for the discovery of the W and Z (1984) was awarded within two years (data 1982/83), thanks to two experiments getting clean signals (the prize was only awarded to one, but without the other, it would not have been awarded so fast)**
- **The Nobel Prize (2002) for the observation of solar neutrinos (initially a one experiment show) was only awarded decades later after the observations had been confirmed by several experiments.**
- **The Nobel Prize for the J/psi discovery (1976), again observed simultaneously by two experiments, was awarded within two years (data 1974)**
- **The Nobel Prize for the discovery of CP violation, originally observed by only one experiment in 1964, was awarded only many years later (1980), despite the very clear initial observation.**

Other historical examples:

(i) TPC and Mark II magnet coils shorted -- other PEP experiments were able to take data while the coils were repaired
(ii) When Jade's wires broke Petra was able to continue running
(iii) High backgrounds in H1 at HERA are not troubling ZEUS
(iv) UA1 and UA2 at SppS
(v) BaBar and Belle have greatly exceeded expectations; would this have happened if there had been just one
(vi) LSND has an anomalous observation; experiment repeated with MINIBOONE
(vii) Hi-Q^2 jet distributions of CDF and D0 needed both experiments
(viii) Crystal Ball saw Zeta -> repeat experiment at DESY
(ix) charm and B lifetimes have needed multiple experiments to sort out observations
(x) Ab has a history requiring multiple experiments
(xi) Leptoquark signals at ZEUS and H1 were compared and found to be inconsistent
(xii) Pentaquark signals cannot be judged by one experiment alone.
(xiii) Epsilon-prime.
(xiv) At LEP, Aleph found a 4-jet mass peak at 105 GeV/c^2. It was not confirmed by the other experiments, an important check.

(xv) Kl -> mu+ mu-
(xvi) QED violation (Pipkin)
(xvii) ARGUS-CLEO competition reduced cost and increase physics
(xviii) CDF and D0 provided significant complementary roles in top quark discovery
(xix) Rising total proton-proton cross section observed directly in Pisa-Stony Brook experiment, confirmed by complementary indication in CERN-Rome experiment measuring elastic scattering at zero angle (optical theorem).
(xx) Eta-c discovered by DASP, rediscovered at different mass by Crystal Ball
(xxi) Unconfirmed top and Higgs discoveries

There are more. Making the case for two detectors does not mean trouble is foreseen as part of the program, but that the ILC should be prepared in case it arises.

(7) Counter points of view

---Counter arguments.

(i) In the absence of sufficient funding for two detectors/IRs, a single IR can provide a cross-check by "repeating a collider run".

(ii) Another often-cited possibility is to organize two independent analysis chains within the same detector collaboration in order to promote the competition and redundancy.

(iii) With proper organization the visibility for young physicists, and the opportunities to make significant contributions can be enhanced within one collaboration.

(iv) 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.

---Comments on the counter arguments.

(i) This is true (see next point).

(ii) 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...
The degree of autonomy of multiple analysis 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.

(iii) 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.

(iv) Clearly this may be true, but the "insurance" addressed under item (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.

(8) Options

Two detectors will cost more than one, but not double since the detector-optimization process would be different. Many developments for the two IRs could be in common, e.g., bunch-to-bunch feedback, slow-control, DAQ architecture, magnetic-field-map ping gear, etc.

Another approach to realizing two experiments is to stage one, bringing the second into full construction and operation the second or third year of the ILC.

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. In the following list the symbols mean: IIR=Instrumented IR and NIR=Non-Instrumented IR.
The options are in order of our preference:

- **2 IIRs/ 2 detectors would entail a cost increase of A%,**
- **1 IIR/ 2 detectors(push-pull) + 1 NIR of B%,**
- **1 IIR/ 2 detectors(push-pull) of C%,**
- **1 IIR/ 1 detector(push-pull capability) of D%**
- **1 IIR/ 1 detector + 1NIR of E%, relative to**
- **1 IIR/ 1 detector = the minimal program.**

Recommendation for the next step:

We ask the Snowmass machine+detector costing committee to provide estimates of A, B, C, D, and E