“LC Vision” and C3

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The update of the European Strategy for Particle Physics has begun.

There is a call for contributed papers, due on March 31, 2025.

The CERN management has made clear that its goal is approval for FCC. However, the CERN Council has requested an alternative plan with lower cost and, perhaps, alternative physics goals.

How should the international community developing e+e- linear colliders react to this call ?

Jenny List and Steinar Stapnes have laid out a strategy called

“LC Vision”

with the following goals:

create a plan that CERN can lead as an international project

address the need for construction of an e+e- Higgs factor urgently, with first data near the time of the conclusion of HL-LHC

study the Higgs boson with high precision, as much as it possible with current technologies

acknowledge and support the diversity of technologies being pursued for e+e- linear colliders

Our plan:

The first step is construction of the 250 GeV ILC at CERN.

This requires a 20 km tunnel in the plain near Lake Geneva, a plan already studied by CLIC. We envision 2 interaction regions sharing luminosity.

After 10 years construction and 10 years data-taking at 250 GeV (+ GigaZ ?), the accelerator will be upgraded in stages with different technologies to achieve higher energy and/or higher luminosity.

Many alternatives exist: higher gradient SRF, higher gradient copper, CLIC, energy recovery linac, gamma-gamma collider, plasma wakefield. We will ask, what is the best alternative at each stage.

In later stages, the 2 interaction regions can be used by sharing luminosity, by running parallel programs at higher and lower energy, or by using one as a testbed for technology development.

LC Vision is a direct competitor to FCC-ee. What are the advantages and disadvantages ?

advantages:

A 250 GeV e+e- ILC at CERN has approximately the same cost as the FCC tunnel, before you put an accelerator in it. The cost is much more certain, and the technology is mature. It can be achieved within the current CERN budget.

For Higgs, a 250 GeV LC has the same physics expectations at the 240 GeV FCC-ee. Already at this stage, LC Vision is doing frontier physics. FCC—ee has no physics until the project constriuction is complete.

In later stages, LC Vision can access important physics measurements beyond the scope of FCC-ee. In particular, at 1 TeV, it can measure the top Yukawa coupling to 1% and the Higgs self-coupling to 10%. For a list of addition physics measurements, see “Full Higgs Program” in the backup slides.

LC Vision is a flexible program that can respond to new discoveries from HL-LHC and from its earlier stages. For FCC, the program is set for the next 70 years.

disadvantages:

LC Vision will not have the flavor program of FCC-ee that is possible with 5×10^{12} Z bosons. However, by using beam polarization, a GigaZ run with 5×10^{9} Z bosons can test the electroweak theory at a level comparable to FCC-ee TeraZ.

LC Vision will not provide 4 interaction regions and will not draw to CERN a community of the size of the LHC program. This is an important consideration for many.

LC Vision will not provide a tunnel to host a 100 TeV proton collider. But, if the purpose of building the FCC tunnel is to host a proton collider, we must discuss the cost of the proton collider. At this time, the FCC-hh is completely unaffordable. Decades of R&D are needed to bring the cost down even to 4 x LHC. We are developing new technologies — muon collider and plasma wakefield accelerators — that, if successful, will give us 10 TeV parton CM colliders at a more acceptable cost. We need to postpone the discussion of how to realize 10 TeV pCM colliders until we have an affordable project — and a more precise physics case for the needed CM energy.

footnote on costs to be quoted for the European Strategy Study:

The ILC cost is being updated by the IDT WG1, headed by Tatsuya Nakada. The quoted cost will be for an ILC independent of site, and will be given in "ILC units".

A committee headed by Steinar Stapnes will translate that cost into the cost of an ILC at CERN in current CHF, based on costing experience with CLIC and FCC-ee.

LC Vision documents to be prepared for the European Strategy Study:

central documents:

eds: Jenny List, Roman Poeschl, Michael Peskin, Steinar Stapnes

Linear Collider Vision (~ 100 pp)

physics motivation for a linear collider Higgs factory, current status of the ILC, detector technologies for linear colliders, possible upgrade technologies, siting options in Japan and Europe.

This will mainly be based on the ILC report to Snowmass, with appropriate updates

Linear Collider Facility at CERN (~ 30 pp, with a 10 p summary)

physics arguments for a linear collider e+e- Higgs factory at CERN, description of an ILC250@CERN project, brief discussion of upgrade paths, brief discussion of road to 10 TeV.

We hope that all members of the LC community will sign these documents current table of contents of the “LC at CERN” document:

Each proposal will have a brief description in the document and links to longer documents available on the arXiv.

Each proposal group will have the responsibility of writing its article(s) in a manner compatible with the overall vision.

There will be a meeting at CERN on Jan. 8 -10 to discuss and revise these documents and begin the signature-gathering process.

There is an LC Vision mailing list. To add yourself to it, go to

http://simba3.web.cern.ch/simba3/SelfSubscription.aspx?groupName=LCVision-General

What documents does C3 need to write ?

Focus on the technology description, accelerator design, specific experimental considerations, and cost. The physics motivation will be given in the central documents.

The C3 report should cover two different options for C3:

1. As the second stage after ILC 250 at CERN, reusing as much as possible of the infrastructure.

2. As a stand-alone project beginning at 250 GeV. This is to emphasize that such a C3 design is possible and attractive, after the C3 technology is considered to be “ready for prime time”.

A 10-page summary of the C3 report should be submitted to the European Strategy Study.

Here is a sample table of contents:

1. Introduction
2. What is C3 ?   Why C3 ?
3. C3 in the LC Vision program
   design of a C3 collider, reaching 1 TeV,
   in the 20 km LC Vision tunnel
4. C3 as a Stand-Alone Higgs Factory
   design of a C3 Higgs factor on a green field site, up to 1 TeV
5. C3 beyond 1 TeV
   design of a C3 collider in the LC Vision tunnel
   reaching 2 TeV and beyond
6. Current status of the C3 Technology, and Anticipated R&D
7. Experimentation at C3
7. Cost estimates for the C3 colliders presented here
8. Conclusion

Backup:

The “Full Program” of Precision Higgs Measurements

91 GeV: Z resonance

enhanced precision EW tests, also needed for SMEFT fitting

SM PEW closure test error : GigaZ w. pol.: 1.3 , TeraZ no pol: 1.0 $\times 10^{-5}$

160 GeV: WW threshold

W mass, precision EW test for LC only useful for enhanced luminosity upgrades

SM PEW closure test error: ILC 250 : 5.3 FCC-ee: 1.7 $\times 10^{-5}$

250 GeV: peak of the tagged Higgs cross section $e^+e^- \to ZH$

Higgs couplings to W, Z, b, τ, g, c to 1% (absolutely normalized)

search for exotic Higgs decays to BR ~ 10^{-4} invisible to BR ~ 10^{-3}

W mass to 2 MeV (see above)

precision study of $e^+e^- \to W^+W^-$, $e^+e^- \to f\bar{f}$ for global SMEFT fits, multi-TeV BSM sensitivity, CP violation probes

350 GeV: top quark threshold

a short run (200 fb-1) gives m(t) to < 50 MeV

550 - 600 GeV: above the ttH, ZHH thresholds

Higgs couplings to 1% in $WW \to H$ 2nd!

top quark EW form factors (SMEFT parameters) to parts per mil

measurement of top Yukawa in $e^+e^- \to t\bar{t}H$ to 3%

measurement of triple H coupling in $e^+e^- \to ZHH$ to 20%

precision study of $e^+e^- \to W^+W^-$, $e^+e^- \to f\bar{f}$ for global SMEFT fits,
10's -TeV BSM sensitivity, CP violation probes 2nd!

800 - 1000 GeV: final Higgs Factory stage

Higgs couplings to <1% in $WW \to H$ 3rd!

top quark EW form factors (SMEFT parameters) to parts per mil 2nd!, resolution of degeneracies in SMEFT fit

measurement of top Yukawa in $e^+e^- \to t\bar{t}H$ to 1% 2nd!

measurement of top Yukawa in $WW \to t\bar{t}$ to few % 3rd!

measurement of triple H coupling in $e^+e^- \to \nu\bar{\nu}HH$ to 10% 2nd!

precision study of $e^+e^- \to W^+W^-$, $e^+e^- \to f\bar{f}$ for global SMEFT fits, 100 -TeV BSM sensitivity, CP violation probes 3rd!