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DIRECTOR'S CORNER

IDT input to the European Strategy2025 is a crucial year for planning – and drafting – the future

by Tatsuya Nakada



As Europe updates its strategy for the future of high-energy physics with a special focus on the next flagship machine at CERN, there will be several input documents about linear collider facilities, says Tatsuya Nakada – both in Japan and in Europe.

FEATURE

Implementing a linear collider facility at CERN

by Michael Peskin

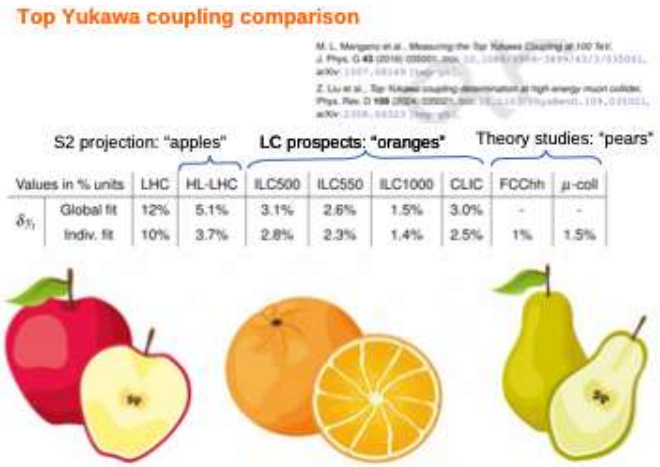


“The next flagship project at CERN should be an e+e− Linear Collider spanning the centre-of- mass energy range from the Z pole into the TeV regime.” The LC Vision idea, discussed in this article, builds on the well-developed Linear Collider concepts of ILC and CLIC, and proposes a new balance of performance and cost in a context appropriate for CERN. This collider meets all of the desired criteria: a rich physics programme attentive to discovery by precision measurements, affordability and the possibility of timely implementation, and flexibility in response to new physics advances or technical developments.

AROUND THE WORLD

Shaping the future at the Linear Collider Vision Community Event

by Jenny List and Steinar Stapnes



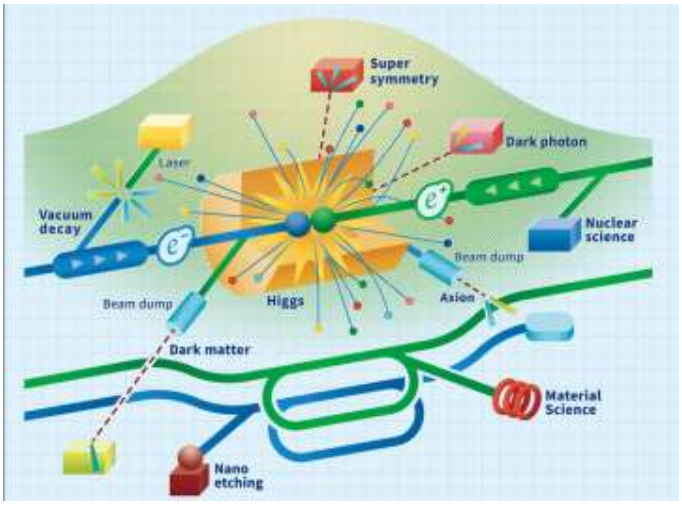
Values in % units		LHC	HL-LHC	ILC500	ILC550	ILC1000	CLIC	FCChh	μ-coll
δ_{y_t}	Global fit	12%	5.1%	3.1%	2.6%	1.5%	3.0%	-	-
	Indiv. fit	10%	3.7%	2.8%	2.3%	1.4%	2.5%	1%	1.5%

The Linear Collider Vision Community Event, held from 8 to 10 January at CERN and on zoom, took a fresh look at the physics case, extensions and technologies of a linear collider facility – and proposing such a facility for implementation at CERN. This article summarises the discussion and gives an outlook on the next steps towards the European Particle Physics Strategy Update.

YOUNG PERSPECTIVE

Early Career Scientists discussing the future

by Jan Klamka, Krzysztof Mękała, Emanuela Musumeci and Leonhard Reichenbach



At the Linear Collider Vision Community Event, a special session was organised by Early Career Researchers to discuss their perspective on the future of linear colliders and of CERN among each other and with more senior colleagues. This article presents some of the main points of discussions and highlights the wishes of the ECR community.

IN THE NEWS

from *NHK*
23 December 2024
一ノ関駅近くのＮＥＣ跡地の活用方法 有識者会議が提言
市が優先的に誘致すべき事業として、▽ＩＬＣ＝国際リニアコライダーなどに応用可能な先端技術に関する産業のほか、▽健康福祉の分野や自動車関連産業などに活用できるＩＴ産業、それに▽市の歴史文化やファッションなどに関するカルチャー産業の３つを挙げています。(The city has identified three priority business areas to be attracted to the city: 1) industries related to advanced technologies that can be applied to the International Linear Collider (ILC), 2) IT industries that can be utilized in the health and welfare field and automobile-related industries, and 3) cultural industries related to the city's history, culture, fashion, etc.)

from *Iwate Nippo*
19 December 2024
ILC、自民政調で議論開始　大野戦略調査会長「ステージ上がった」
ＩＬＣ計画について、自民政調では近年議論することがなかった。同調査会は今後も定期的に議論を重ねる方針。終了後、大野会長は「議連から一つ上のステージに上がった。党の方針をしっかり出していくことが重要」と語った。(The ILC project has not been discussed in recent years by the policy research council of the Liberal Democratic Party. The study group intends to continue to discuss the issue regularly. After the meeting, Chairman Ohno said, "We have moved up one stage from the Diet members caucus. The party must put forth its policies firmly.)

from *IPMU*
2 December
Hitoshi Murayama elected to Vice Chair of Division of Particles and Fields under American Physical Society
Hitoshi Murayama, Professor at the Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU, WPI), has been named the incoming Vice Chair of the Division of Particles and Fields (DPF) under the American Physical Society, it was announced by the DPF executive committee.

from *ILC Tsushin*
2 November 2024
ILCマンガ「ILCの今」を公開しました
国際リニアコライダー（ILC）計画の「今」を描いたマンガ、「ILCの今 ー 取り組むべき課題と目指すべき未来」をILCウェブページにて公開いたしました。(A comic book depicting the current status of the International Linear Collider (ILC) project, "ILC Today – Issues to be tackled and the future we should aim for," is now available on the ILC webpage.)

PREPRINTS

ARXIV

2412.17876
Spin identification of the mono-Z′ resonance in muon-pair production at the ILC with simulated electron-positron collisions at s√ = 500 GeV

2412.13130
Higgs Factory options for CERN: A comparative study

2412.07125
Single production of singlet vector-like leptons at the ILC

2412.06125
The Development of Low-Q Cavity Type Beam Position Monitor with a Position Resolution of Nanometer for Future Colliders

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DIRECTOR'S CORNER

IDT input to the European Strategy2025 is a crucial year for planning — and drafting — the future

Tatsuya Nakada | 30 January 2025



Since this is the first Newsline of the year, let me start by wishing you all a happy new year. With the anticipated update of the European Strategy for Particle Physics, where the meeting of the European Strategy Group for drafting is planned in December this year, we will have an exciting and busy 2025 ahead of us.

The focus of the strategy update is the next flagship machine at CERN, which will inevitably have a large impact on the particle physics programme worldwide. Therefore, input from other regions, particularly on the large accelerator projects under consideration, have vital importance for Europe to construct a strategy in a global context. In this regard, the ILC International Development Team (IDT) will submit a document describing the status of the ILC project on the technical development with the ILC Technology Network (ITN), the updated ILC-250 (the machine operated at 250 GeV centre-of-mass energy) cost with an indication of additional cost for the second beam delivery system and increasing the energies up to 500 GeV, and the plan of Japanese High-Energy Physics community for promoting the realisation of the ILC in Japan.

While the ILC project is focusing on a machine at 250 GeV, the LC Vision effort has been developing a coherent linear collider roadmap that fully exploits the advantage of a linear collider, as demonstrated by the recently held meeting at CERN reported by Jenny List and Steinar Stapnes in this Newsline. It proposes a linear collider facility which starts as a machine with moderate cost and adequate physics performance as a Higgs (possibly also Top) Factory, can then evolve to higher energies up to one TeV and beyond, as well as one to two orders of magnitudes higher luminosities benefiting from the R&D effort that proceeds in parallel. Proposing such a facility at CERN with SRF technology for the baseline initial machine is also underway. The flexibility of such a facility, which can also accommodate science programmes beyond the core e+e- physics, makes it appropriate for the next high-energy collider to be constructed. The IDT will follow

very closely this effort and contribute to its activities through synergy with the work by the IDT Working Group 2 for accelerators and Working Group 3 for physics and detectors.

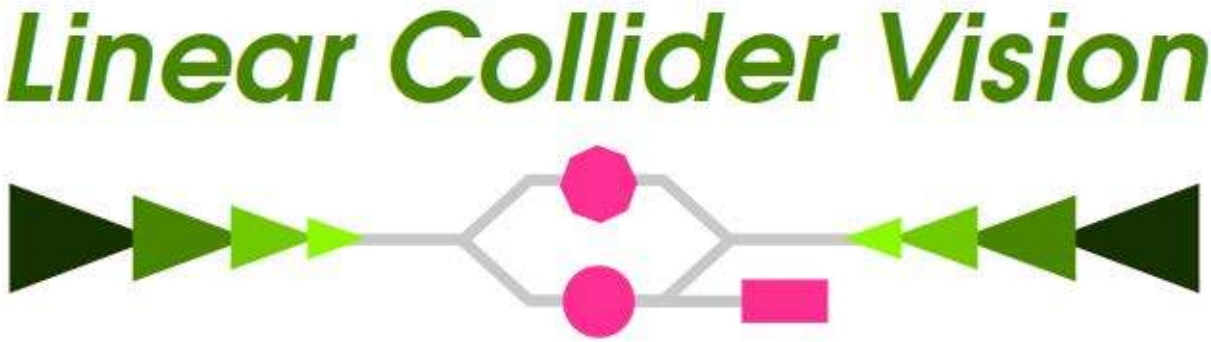
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FEATURE

Implementing a linear collider facility at CERN

Michael Peskin | **30 January 2025**



The previous iteration of the European Strategy for Particle Physics (ESPP) gave as its first recommendation: "An electron-positron Higgs factory is the highest-priority next collider." This recommendation is, in our view, best addressed by constructing an e^+e^- Higgs factory that meets all of the physics goals of such a collider in a way that is affordable for the global particle physics community and can be realistically implemented in the shortest possible timescale. With a solution based on an e^+e^- linear collider, all of these criteria can be met — while at the same time preserving the potential to react to results expected from the High-Luminosity LHC and other developments in global particle physics.

There is a reason why the study of the Higgs boson in e^+e^- reactions is considered the most urgent problem in particle physics. We have seen in experiments over the past three decades that the Standard Model provides an excellent description of the fundamental forces acting among elementary particles. This success highlights a set of problems in particle physics that the Standard Model is incapable of answering: What determines the spectrum of quark and lepton masses and mixings? Why is CP violated? What is the origin of the neutrino masses? In the Standard Model, all of these effects are due to the vacuum expectation value of the Higgs field, yet we have no understanding of why the Higgs field obtains a vacuum value in the first place. If these questions have explanations, they must come from new physics beyond the Standard Model that couples to the Higgs boson. Thus, the search for beyond-Standard-Model effects on the Higgs boson, using the highest precision that we can muster, is our best chance to discover new fundamental interactions beyond those currently known.

An e^+e^- collider offers many observables that can be sensitive to beyond-Standard Model effects on the Higgs boson. First, there are the Higgs boson couplings giving decays to the fermions and bosons of the Standard Model, and also to unexpected final states, for example, through the Higgs portal to new sectors. In addition, there is the Higgs self-coupling, most robustly measured in HH production, the process of creating two Higgs particles. Finally, in models in which the Higgs boson is composite, the top quark must couple to the new compositeness interactions, and these become visible in the top quark Yukawa coupling, in the top quark electroweak couplings, and in top quark 4-fermion interactions. All of these observables can be explored by e^+e^- measurements, which will significantly improve upon the precisions available from the LHC. Measuring all of the observables, however, requires e^+e^- centre-of-mass energies up to 1 TeV.

It is important also to understand that the discovery of new interactions through precision measurements has a very substantial burden of proof. To convince the particle physics community, it is not enough to have one highly significant measurement of a deviation from the Standard Model. We will need complementary measurements of these effects, in reactions with different sources of systematic uncertainty. Fortunately, a complete study of the Higgs boson in e^+e^- reactions provides this. A deviation in Higgs couplings obtained in the reaction $e^+e^- \to ZH$ can be confirmed in Higgs production by WW fusion. Similarly, an effect in the Higgs self-coupling measured in $e^+e^- \to ZHH$ can be confirmed with a measurement in $WW \to HH$. The natural evolution of the physics of e^+e^- reactions with centre-of-mass energy gives many more examples. For this also, a large range of centre-of-mass energies must be studied.

In earlier ESPP updates both ILC in Japan and CLIC at CERN have submitted strong project proposals. These two projects will also be presented to the ESPP this time, including their latest parameters and technical developments. However, another very interesting and novel implementation path is possible for a linear collider, combining the unique industrial readiness and large linac project experience with Superconducting RF (SCRF) technology as proposed for ILC, with the upgrade possibilities offered by high gradient technologies as used in CLIC, C^3 and others.

Such a program can be implemented quickly with modest technology and financial risk, and remains very ambitious in its scientific goals and reach, including several possible paths for energy and luminosity upgrades. The remit for the ESPP encourages ambitious proposals for the next flagship project at CERN. CERN, after all, has constructed and operated the LHC, so it has the experience and capabilities needed to lead a new project of similar magnitude and technological breadth.

The LC Vision initiative thus proposes an ambitious Linear Collider Facility to be constructed at CERN. It will be executed in stages, where the first stage is an e^+e^- linear collider based on SCRF technology. SCRF is widely available today and would allow the fastest realisation of a new facility. Depending on the level of external contributions beyond the CERN budget that were to be acquired for the realisation of such a project, it could start at a centre-of-mass energy of 250, 380 or 550 GeV, with, respectively, tunnels of 21 km, 27 km, or 33 km in length. Likewise, the luminosity of such a machine can be staged depending on the resources, potentially offering four times the luminosity of the initial stage of the ILC as proposed for Japan. A rigorous costing of such a proposal is being prepared for the ESPP. After the initial technology has been fully exploited, the Linear Collider Facility would be upgraded in energy and other capabilities by introducing new technologies. This could be advanced SCRF with gradients of 40–45 MegaVolts per metre (MV/m), but several technologies capable of producing accelerating gradients of 70 MV/m and above are under study. These have very different levels of maturity but all target implementation readiness during the next decade. These are the CLIC two-beam accelerator mentioned above, the C^3 cold copper accelerator, and the HELEN advanced superconducting RF accelerator. With 70 MeV/m in a 21-km tunnel, the collider would reach centre-of-mass energies of at least 1 TeV, in a 33-km tunnel 2–3 TeV.

At a centre-of-mass energy of 250 GeV, such a machine can efficiently record 4 ab^{-1} of data, roughly 1 million Higgs bosons, each tagged by recoil against a Z boson. Using beam polarization, the precision on Higgs couplings is similar to that obtained with 10 ab^{-1} at an unpolarized collider. This stage would also include a two-year run at the Z^0 pole, achieving a precision measurement of $\sin^2\theta_w$ comparable to that expected from the FCC-ee TeraZ programme. The programme would be implemented with two interaction regions sharing the total luminosity.

At 550 GeV, an additional 4 ab^{-1} could be recorded, with, also, 200 fb^{-1} at the top quark pair production threshold. Then — noting that the luminosity of a linear collider increases linearly with the centre-of-mass energy — a further 8 ab^{-1} of data could be recorded at 1 TeV or beyond. In this regime, Higgs production is dominated by *WW* fusion, giving the independent precision measurements of Higgs couplings discussed earlier. Running at two distinct energies well above the top quark threshold also allows a complete exploration of the top quark couplings. Finally, this programme offers measurements of Higgs pair production in the two complementary reactions described above. All of these measurements are beyond the capabilities of circular Higgs factory colliders.

This proposal makes good sense for CERN. Any large project at CERN would require a preparatory phase of about five years and a construction period of about ten years. Starting today, this brings us to the last years planned for the operation of the HL-LHC. Starting the next programme within a short time after the end of the HL-LHC will allow young scientists to participate in the design and construction of the new detectors while gaining experience with data-taking and analysis on an operating collider. This will ensure that the next generation of particle physicists can acquire all of the skills that they will need to carry our field forward. Significant delays from this schedule would diminish our future capabilities.

Regarding the even farther future, particle physicists look forward to exploration of parton-parton or lepton-lepton centre-of-mass energies ten times greater than those available from the LHC. Today, we do not have a technology that can achieve this goal at reasonable cost. A proton-proton collider will always have the disadvantage that its very large footprint will require an expense many times that of the LHC, a level of cost that is unaffordable today, and remains a serious uncertainty and concern also in the future. New particle acceleration technologies — for example, the muon collider and plasma wakefield acceleration — are now under study. We expect that, in the next 20 years, fundamentally new designs for high energy colliders will give us a robust route forward.

Our proposal will encourage this route on the side of electron colliders and accelerator R&D, offering opportunities to extract a small fraction of the bunches for tests of new technologies. Possibilities for our linear collider facility include the demonstration of photon collider technology, energy recovery for dramatically increased luminosity, and a plasma wakefield “afterburner” to raise the energy of an e^+e^- collider.

We strongly believe that this novel Linear Collider Facility proposal is one that CERN needs to consider very carefully now.

- It is rooted in the need for precision studies of the Higgs boson as the next major goal in particle physics, while preserving at the same time also the potential to react to results from the HL-LHC.
- It can be constructed on a time scale appropriate for the successor to the HL-LHC.

- It is affordable for our community, with the possibility of designing a first stage to be consistent with the current CERN budget and an evolution that can also be funded within expectations.
- With global support, this project is compatible with the increased accelerator R&D, along multiple routes, that we will need to propose a 10 TeV parton or lepton centre-of-mass collider in the foreseeable future.
- And, our proposal itself incorporates technological innovation that will benefit many stakeholders outside of particle physics.

A set of documents laying out this proposal in detail is now being prepared by the LC Vision initiative for the ESPP. We encourage everyone to read these and to provide their support by signing **here**. The author thanks Masaya Ishino, Jenny List, Tatsuya Nakada, Roman Poeschl, Aidan Robson, Steinar Stapnes, and the participants in the LC Vision Community Meeting for many fruitful discussions to develop the ideas presented here, and for important comments and suggestions on this report.

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AROUND THE WORLD

Shaping the future at the Linear Collider Vision Community Event

Jenny List and **Steinar Stapnes** | **30 January 2025**

From January 8 to 10, about 200 particle and accelerator physicists met at CERN and on zoom for the **LC Vision Community Event**. The meeting started with a session organised by **Early Career Scientists**. It moved on to discussion physics case, luminosity and staging scenarios, advanced acceleration technologies, future perspectives on detectors and the implementation of a Linear Collider Facility in Japan – and at CERN.

The second session was dedicated to a fresh look on the Linear Collider physics case, from the Z pole to highest energies, covering the Higgs sector, the top quark, electroweak precision measurements, gauge boson interactions and direct searches for new particles and additional opportunities offered photon colliders as well as beam dump and extracted beam experiments. Key conclusions of the presentations comprise:

- Unraveling the dynamics behind electroweak symmetry breaking and the electroweak phase transition requires a multi-messenger approach based on all multi-boson production and scattering processes, including both gauge and Higgs bosons, measured at several centre-of-mass energies and polarised beams.
- An e+e- collider with a centre-of-mass energy of at least 500 GeV can measure the ZHH production cross-section which gives direct information on the triple-Higgs coupling with complementary beyond-the-Standard-Model (BSM) dependency to that of pp collisions: this is a qualitative game changer compared to lower-energy Higgs factories.
- The electroweak couplings of the top quark offer significant opportunities to discover BSM physics via effects intimately connected to top mass generation. These effects could be an independent source of information about the origin of electroweak symmetry breaking and the generation of the fermion mass hierarchy.
- While we today do not know the energy scale at which BSM physics would manifest itself, there are many opportunities left for discovering particles at e+e- colliders which are too elusive to be recognised at the LHC. It has still 90% of its data to come and the next flagship project of particle physics should be able to react to new discoveries in a timely manner.
- Very complementary opportunities for understanding electroweak symmetry breaking, discovering light new particles and studying QED in unexplored regimes arise from photon-photon collisions, beam-dump and extracted-beam experiments.

On the practical side, it was highlighted that across-collider comparisons of physics reach are often obtained under very different level of detail and very different assessment of future advances in reconstruction, analysis and theory. Work and discussions are needed to render future projections more comparable. Figure 1 illustrates this for the example of the top Yukawa coupling.

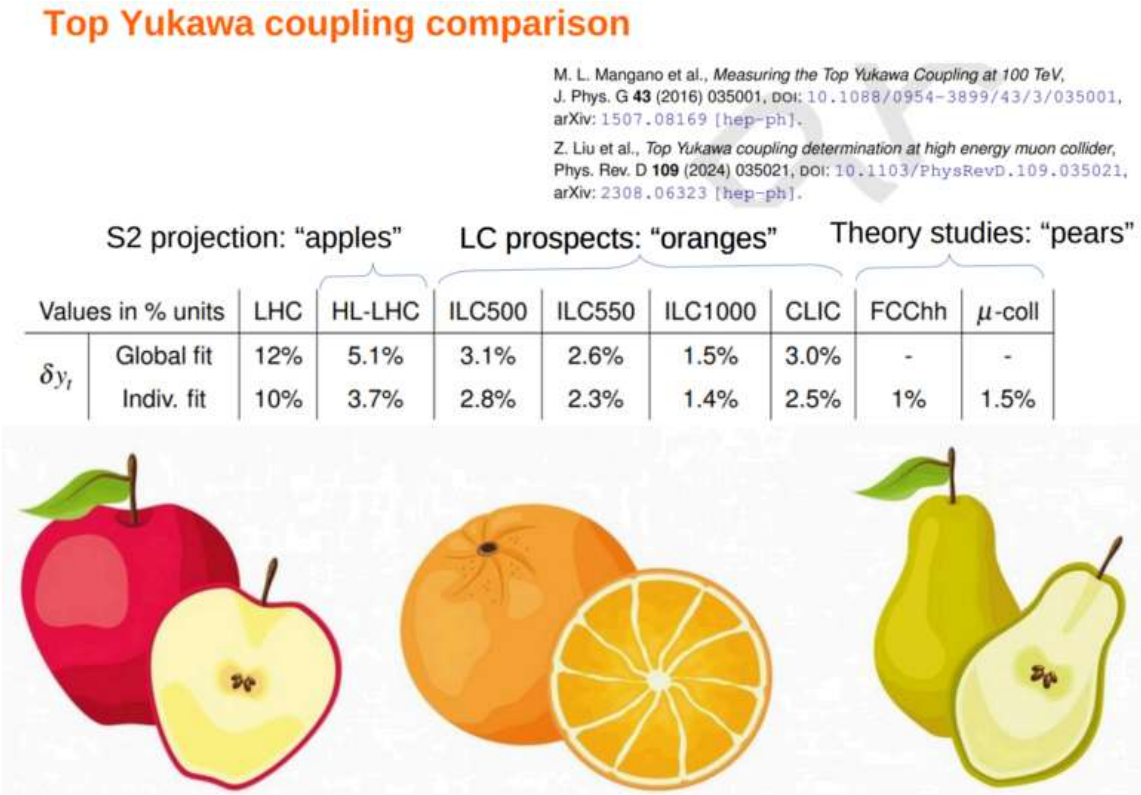


Figure 1: Illustrating different levels of detail in physics projections using the example of the top quark Yukawa coupling

On Thursday, the interplay of beam energy, luminosity and construction/operation costs of Linear Colliders were outlined for different running scenarios, taking an "ILC-like" machine as an example. This was followed by an assessment of the expected evolution of key acceleration techniques. These have the potential to either upgrade or replace an initial version. The mission of LC Vision is to understand how to integrate these options into the overall science programme of a linear collider facility. The presentations covered the prospects of raising the gradient of superconducting accelerating structures up to the 70 MV/m region, as well as drive-beam and "cool copper" approaches, energy and particle recovery, plasma acceleration. While many of the presented ideas still need a lot more R&D, it became very clear that potentially game-changing developments could arrive in the next decades and a future facility should be designed to enable particle physics to profit from new technologies. The session also informed about the concepts for alternative collider modes and the implementation of beam dump experiments.

Detectors play a key role for the success of any facility: while the classic detector concepts for linear colliders have demonstrated that they can be built and do an excellent job, detector technologies are rapidly advancing, and any future detector should be designed to profit from current advancements and those to come over the next decades.

We also looked at actual implementations, both in Japan and at CERN. A first glimpse into the nearly finished cost update for the ILC in Japan was presented, showing the impressive level of detail at which this is being done, including new industry quotes on the major cost drivers. Another highlight was presentation of the ongoing work for CLIC, including improved luminosities, a cost update for the EPPSU and a life-cycle assessment for both the CLIC and the ILC accelerator components. Specifically for the implementation at CERN, a design of the conventional facilities and basic infrastructure compatible with hosting either CLIC or a superconducting collider is underway, including a second interaction region for complementary experiments or even complementary collider modes. Thanks to the inherent upgradability of linear colliders, such a facility could be designed with a cost-optimised initial stage, with many opportunities to upgrade in energy and luminosity depending on available ressources, physics and developments in more global partnership and cooperation.

A submission with a concrete proposal including an up-to-date costing is under preparation. Everybody interested to follow the developments is cordially invited to sign up **here** – and to mark their calendars for the week of October 20-24, when we are looking forward to LCWS2025 in Valencia!

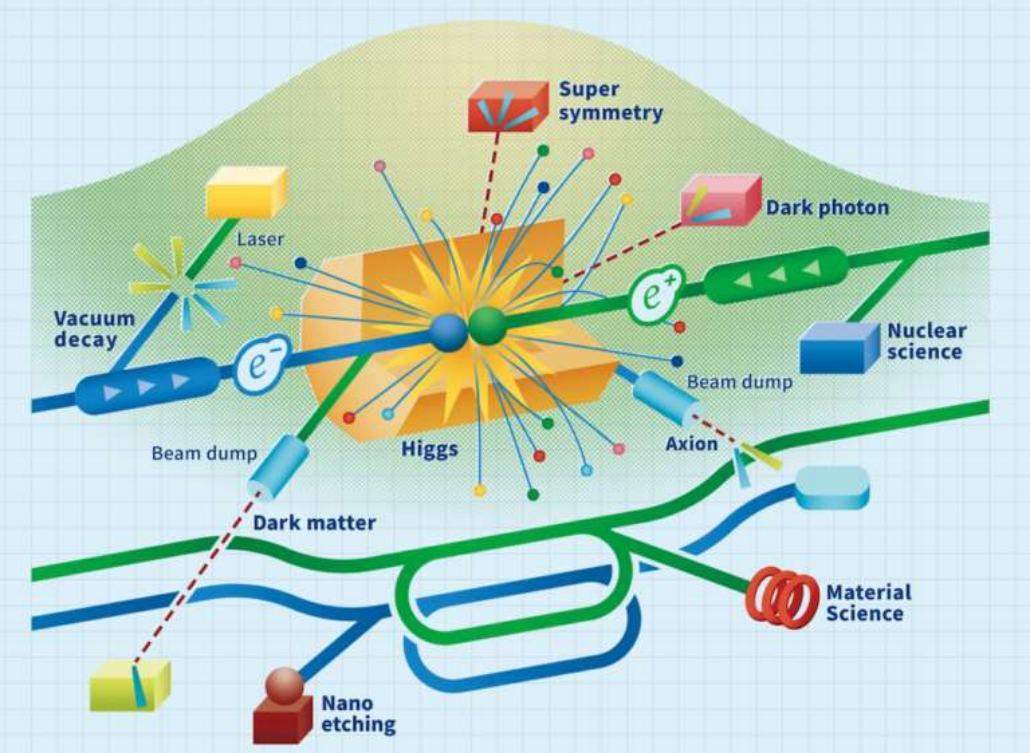
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YOUNG PERSPECTIVE

Early Career Scientists discussing the future

Jan Klamka, Krzysztof Mękała, Emanuela Musumeci and Leonhard Reichenbach | 30 January 2025



The Early Career Researchers (ECRs) community has been very active since the last 2020 Update of the European Strategy for Particle Physics (ESPPU), e.g. by conducting an extensive survey on career prospects and diversity. In September 2024 the ECFA ECR panel initiated a process to prepare a dedicated input from ECRs to the 2026 ESPPU, inviting all European ECRs to contribute. Following the workshop organised at CERN on 14 November 2024, the preparation of the ECR White Paper is ongoing. The report will be largely based on a topical survey distributed within the community. In parallel, an ECR session was organised within the linear collider (LC) community during the LCWS24 in Tokyo, providing a platform for ECRs to share their perspectives on the future of linear colliders.

Following this trend, the LC Vision Community Event, held on 8-10 January 2025 at CERN, began with an ECR session. Its purpose was to give younger representatives of the community an opportunity to discuss their perspectives on different aspects of a future LC. The session started with a live survey among the ECR participants followed by a discussion; in the second part, senior scientists joined the ECRs to discuss the main points raised.

The live survey shed light on the ECR community's perspective on the assets of the LC Vision project. There is strong support for the physics programme, which is seen as broad and attractive. Additionally, due to the advanced technical design of the linear colliders, they appear as a more timely option compared to other proposals. The project timeline and its technical feasibility have been highlighted as primary strengths, reflecting the essential needs of ECRs, along with the flexibility to future challenges and evolving priorities.

At the same time, participants identified points where additional focus is needed. One of the key issues brought up during the session was the conservative character of the LC proposals. Some participants pointed out that the projects should aim higher, and highlight also a long-term vision and perspective, not only a guaranteed low-budget option. In order to be competitive, the future collider proposals should bring enthusiasm to the whole community, the ECRs in particular. The linear machines, with a possibility of future upgrades based on new technologies (such as cool copper, beam energy recovery, or plasma wakefield), have both the potential to pose an exciting

option for the (far) future, and the flexibility to remain competitive even if the necessary funding is not available right away. The former of these strengths needs to be further underlined and promoted.

There was a call for increased efforts to engage more ECRs in LC studies, promoting broader involvement and collaboration within the community. Participants also suggested that CERN would profit from diversifying its funding policy for future collider studies by providing more resources to explore the LC options. Moreover, establishing a clear and well-defined strategy for the LC's position in the global landscape is seen as crucial and should be further developed. The community needs a clear strategy to move forward for the case that another major Higgs factory project is pursued.

Another aspect emphasised during the session was the need for unity within the LC Vision community itself. Given the existence of several linear collider proposals, participants stressed the importance of consolidating efforts and presenting a cohesive strategy. Aligning on common goals and priorities will not only strengthen advocacy for an LC but also provide a clear and unified message to decision-makers and the whole particle physics community, increasing the chances of success. These reflections underline the young researchers' dedication to further enhancing the LC Vision project while recognising the exciting features already in place. The choices made for the ESPPU will significantly shape the opportunities and direction available to the next generation of scientists.

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