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The International Linear Collider A Polish perspective

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***Abstract*—The ILC is an immense e^+e^- machine planned since 2004 by a large international collaboration, to be potentially built in Japan [1]. The gigantic size of the whole research infrastructure, the involved human, technical and financial resources, and the pressure of new emerging and potentially soon to be competitive accelerator technologies, make the final building decision quite difficult. A vivid debate is carried on this subject globally by involved accelerator research communities. The European voice is very strong and important in this debate, and has recently been essentially refreshed by clear statements in a few official documents [2]. The final HEP European Strategy Document is just under preparation. This paper is a very modest and subjective voice in this debate originating from Poland, which around 50 researchers are present at the list of 2400 signatories for the original ILC TDR document published in 2013 [3].**

***Keywords*—particle accelerators, linacs, linear accelerators, superconducting accelerators, superconducting RF technology, large research infrastructures, European particle accelerator policy, SRF, ILC, LCC, CLIC**

I. Introduction

THE International Linear Collider idea is an offspring of some earlier plans and undertakings to build large warm or superconducting linear accelerators split in the middle with universal detectors there to catch the clean products of the high energy collisions of electrons and positrons. The real advanced predecessor to ILC was the TESLA – Teraelectronovolt Electron Superconducting Linear Accelerator planned on the break of the century in DESY. The famous, 5 volume TESLA TDR [4] showing the potency of the 1,3 GHz SRF technology, was a solid pedestal, actually in large extent a ready good example, for the ILC TDR [3]. ILC design is based on the superconducting TESLA technology, after the ITRP/ICFA advisory panel recommendation in 2004. TESLA technology is mature and ready for much larger implementation today.

All involved physicists and engineers, hundreds of them, active in preparation of the TESLA TDR remember the disappointment when a decision message arrived at DESY concerning the TESLA and was communicated by prof. Albrecht Wagner (Nachfolge von Bjorn Wiik) at a large gathering of the involved TESLA Technology Collaboration TTC staff. However, at this moment, a decision was taken to build there the European X-Ray Free Electron Laser E-XFEL. Originally, the XFEL was also planned in DESY as a part of the TESLA large accelerator and collider infrastructures.

Today, the International Linear Collider Collaboration (LCC) is a great promise for an unprecedented experiment involving building of a gigantic accelerator infrastructure for precision measurements of elementary particle interactions at never before reached energies. The promise has not yet been fulfilled, but the ILC Global Design Effort (GDE) Initiative headed by Barry Barrish tried to push hard this promise to the reality between 2005-2013, now followed by the Linear Collider Collaboration (LCC), the latter headed by Lyn Evens. The fate of the ILC seems to follow quite winding paths of good luck.

The ILC and the CLIC are very different designs, yet there is still a lot of common ideas and items. The LCC has a very challenging and subtle role to find synergies, to combine water and fire, and without any negative effects for both sides, but for the profit of the global accelerator community. Putting it in a different way, the LCC has a unique ability to seamlessly compare parameters of various solutions side by side. This combination makes it possible to highlight new unveiled aspects of both different projects and find their new advantages, real values, and application relevance.

II. Current status of the LCC Projects

Today's formal status of the International Linear Collider is somehow determined by the words of the LCC Director Lyn Evans from March 2019: "Not what we had hoped for but progress nevertheless". These words were a reaction to the Science Council of Japan SCJ report on ILC from December 2018. SCJ cannot reach a consensus to support hosting the 250 GeV ILC project in Japan. Roughly fifteen years ago, the German Authorities took also a decision concerning the TESLA collider and joined other regional proposals like the Next Linear Collider NLC and the Global Linear Collider GLC (JLC) to merge finally into a Global Design Effort GDE and the worldwide ILC project. The complicated path to the global linear collider was not closed, just the reverse remained luckily open till today.

The interest in Japan HEP research community to host ILC infrastructure is very strong. However, more than a decade has already passed since Japan announced the intention to be the host. Such a long decision time seems to be inevitable. Some of the factors influencing the decision process are listed below, including the impact of smaller partners. Now, the updated timing assumes approximately additional 5 years needed for obtaining final agreements, international negotiations to form legal institutional collaboration, detailed review of all aspects of the project, complete engineering design, and prepare for the construction. This period is expected to be followed by a decade of the construction phase. Taking into account the work done for the TESLA TDR, now the collider design is the effect of nearly twenty years of research and development.

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The largest research experiments of a big discovery potential are built only in the places which provide appropriate human expert resources and sufficiently large financial support. Japan is the right place. It is one of the places where big high energy physics experiments are carried out with great successes. ILC is however an infrastructure which has to be built internationally. The investment and the responsibility has to be shared deeply internationally. Global infrastructure requires serious involvement by the global community. The host country could not be left alone only with a confined support of a narrowed research community.

European Strategy for Particle Physics is under official and recurring updating from 2019. The work on strategy includes considerations on the future of CLIC, ILC, but also HL-LHC and FCC. All large infrastructures, existing and planned, were expected to submit their views as input to the strategy. ILC documents have recently been presented to the European Strategy Process [5], the final one in March 2019. The document shows clearly the beauty of the planned infrastructure, its components including the detector [6] and its huge, irreplaceable by any other infrastructure, discovery power. European involvement in the ILC was supported formally by the Preparation Plan for European Participation in the International Linear Collider E-JADE – Europe – Japan Accelerator Development Exchange Programme, funded generously by the EU H2020 [7].

III. Smaller and Bigger Partners of LCC Projects

This article is a personal recollection of sometimes subjective thoughts concerning the role of the LCC, ILC, and CLIC in global, European and especially in local contexts for smaller research partners of wide research initiatives, like Poland. The article is a next part in a series of considerations concerning large, mainly accelerator based, research experiments and participation of Polish physics and engineering communities, especially young scientists. The series included papers published internationally on large experiments, infrastructures and projects: ILC [8], LCLS [9], EXFEL [10], CMS/LHC [11], ITER [12], POLFEL [13], plasma acceleration and fifth generation light sources [14], CARE and other European accelerator projects [15-16], TIARA [17], EuCARD [18-19], EuCARD2 [20], ARIES [21-22], CBM at FAIR/GSI [23-24], and other. Some of these publications were written in Polish for outreach purposes to disseminate the large experiment ideas among local physicists and engineers [25]. These publications play an important role for local communities in the communication, outreach and dissemination of knowledge on the largest research experiments and prepared infrastructures for the future activities. These publications also reach some of the local decision makers in this area to support the participation of smaller communities in global undertakings.

The views from numerable smaller partners of the global project like ILC cannot be neglected nor disregarded as they add considerably to the creation of an overall spirit and soft background surrounding the big decisions. The big picture is drawn in the paper on The International Linear Collider – A European Perspective [5]. The small, not exhaustive and very subjective local picture, which tries to be coherent with the big picture, but which is more oriented towards the research community issues, than on the research and technical sides of the ILC, is presented here.

IV. The ILC Infrastructure and Program

As early as in 2005 and 2006 there were published advanced considerations on the photon collider at ILC [26]. Availability of high energy electron and positron beams either creates the possibility to interact these beams with high energy, high intensity laser beam or with themselves. Photon beam can be provided from a separate high power laser infrastructure or the laser beam can be Compton back-scattered from the vicinity of the interaction point. The biggest advantage is that the types of reactions in gamma collider are different than from lepton colliders. Photon – photon and photon – lepton collider configuration was also considered as one of the options in the TESLA TDR.

The basic option is that the ILC is a Higgs factory. The initial high precision, and independent from model, measurements will concentrate on Higgs boson couplings. The basic assumption is that the basic ILC path of research is not covered by the LHC, but richly supplements it. Expected exotic Higgs decays and in pair production of weakly interacting particles WIPs will give the insight into the BSM physics. ILC can also operate polarized lepton beams which widens additionally the research space. There is an inbuilt plan in the TDR to upgrade ILC to higher energies by making the accelerator longer or by increasing the acceleration gradient.

The list of ILC advantages for the BSM research is very long and strongly justifying its construction. Let us repeat some of them after the TESLA and ILC TDRs. These are: extension and supplementation of LHC physics research, high potential to search for new BSM phenomena (new particles, new forces, SM deviations dark matter and energy, excess of matter over antimatter, mass scale of quarks, large mass ratio among particles), unprecedented measurement precision, much larger sensitivity to re-discover the SM, well defined collision energy, highly polarized beams, very low background levels, no spectator particles in collisions, simple hardware extendibility to higher energies and higher luminosities, etc. Ability for easy and cheap ILC energy scaling prolongs the youth of this machine for decades after the first commissioning, and first collisions.

Higgs boson remains unknown to very much extent till today. After the Higgs discovery, and determination of its mass, the ILC was rescaled down in energy to 250 GeV and considerably cut the costs, with keeping the option for 1 TeV upgrade. The ILC250 project parameters are: over 10^{34} $cm^{-2}s^{-1}$ luminosity, 400 fb^{-1} of integrated luminosity for the first four years, and around 2 ab^{-1} for the first decade. Beams polarization 80% for e^-, and 30% for e^+. Two complementary detectors are planned ILD and SiD.

ILC250 is expected to provide experimental method for observations of individual Higgs boson decays during the reaction e^+e^- - ZH, displaying all leptonic and hadronic final states, but also partially visible and invisible exotic modes. Supplementation to LHC embraces search for particles produced to electroweak interaction, which are dark matter candidates. The first ILC250 measurement aims are top-quark mass with a precision of 40 MeV, top-quark electroweak couplings to PPM level, Higgs coupling to top-quark to 2% accuracy, triple Higgs coupling to 10% accuracy. ILC500 or ILC1000 may be a place of discoveries of new particles with electroweak interactions. ILC tunnel may be in the future a place for colliders of much higher, multi TeV energies. Possession of such large infrastructure will give the host country additional handicap in contributing at the discovery level to the high energy frontier of the elementary particle physics for several next decades. Only few countries have this unique privilege.

The ILC interaction region will have two detectors in a push-pull geometry. The detectors were designed by two nondependent concept groups to address precision measurements for the SM and BSM [6]. The demands for LHC detectors included radiation hardness, high rate capability, and ability to dig out useful signal from below the large noise and complex, high level signal background. Some demands for future, large tracking detectors surrounding the interaction point IP in linear colliders are quite different, yet simple, though the list is still quite long: small size, low cost, low power consumption, the lowest possible material budget, acceptable speed, high reliability in complex radiation environments, high energy efficiency, very large granularity, large resolution in jet energy and space, use innovative concepts for radiation detection, at least an order of magnitude precision improvement when compared to the previous generation of particle detectors, new solutions to detector integration of sensors, electronics, photonics and smart lightweight mechatronics and mechanics, at least two orders of magnitude bigger channel density when compared to LHC detectors, silicon pixel tracking basing on monolithic devices and high level integration with readout electronics, micro-pattern gas amplification by using GEMs in time projection chambers, new technology particle flow calorimetry, etc.

High performance vertex detectors are at the heart of the physics program at both linear colliders ILC and CLIC. Vertex detectors see directly the hits from the collisions. They have to distinguish several primary interaction points to be able to reconstruct properly the events. There are numerable displaced decays during the event which also have to be reconstructed to remove the background. Small pixel CMOS silicon sensors used in vertex detectors are integrated in a smart way to use minimized support structures not to generate additional multiple radiation scattering.

Very low power silicon pixel detectors do not need any additional active cooling, which is typical for classical circuit solutions. Displaced vertices are determined from the perigee of a helical track originating from the IP. High accuracy, reaching a single micrometre, is needed for the perigee resolution to be able to reach high event reconstruction potential of the detector. Pixel size and the distance of the innermost detector layer from the IP are the deciding factors. The main background process close to the IP is production of electron-positron pairs during beam-beam interaction additionally to the primary physical events.

Several technological solutions are under research for vertex detector construction. The DEPFET ladder solution, proposed by topical collaboration, integrates the support structure with the sensor wafer using direct silicon processing and monolithic integration with signal amplifiers, read-out circuits and signal routing. The resulting all-silicon very thin ladder is fully self-supporting. The full DEPFET detector is tested at Belle II and consist of: silicon wafer pixels assembled and integrated at ladder mechanics, micro-channel cooling in the sensors, ancillary ASICs (read-out, control, on-detector DSP), and off-detector electronics for DAQ and trigger.

Other tested solutions for ILC ILD detector is the fine pixel FPCCD having 5 μm size in the innermost layer followed by a fully depleted epitaxial layer with thickness of 15 μm. ChronoPixel is a monolithic CMOS pixelated sensor proposed for the vertex detector. The sensors have to be thinned to below 50 μm to minimize the amount of material in the detector. Support structures have to be light, yet providing mechanical stability. Power dissipation is required to be low enough not to involve any active cooling but air. Sensor diode capacitance has to be low to minimize the SNR. The capacitance cannot be too low, at the same time, which may lead to larger inter-channel signal crosstalk between adjacent pixels. Optimal value for detector capacitance is to be found. The required ILC detector size is approximately 10 cm^2. The detector power supply has to avoid the Lorentz force interaction which may produce vibrations and decrease detector spatial resolution.

Alternative solution, reaching far into the future, are 3D pixel sensors designs. SOI pixel solution is also considered and developed practically. CLIXpix solution consisting of CMOS pixels and ASIC readout, originally developed for CLIC, is under consideration also for ILC. 3D electronics solutions provide no wasted area for interconnects, optimal delivery of power and ground, shortest paths of signal distribution and read-outs.

Vertex detectors are followed by silicon trackers farther away from the IP. Trackers measure the paths of charged particles in the magnetic field from the point of creation to where they enter the calorimeters. SiD detector uses two sets of micro strips to determine the longitudinal position of the track along the length of the sensor. Other researched solutions of solid state trackers are: KPIX – system on a chip, and Resistive charge distribution on thinned micro-strip. There are also researched gaseous trackers for construction of large time projection chambers. Polish groups successfully introduced GEM detector solutions for the tomographies of the plasma jet at several tokamaks. The technology seems to be adaptable for the LCC purposes. Several solutions of GEM and micromegas based readouts are considered for ILC originating from different laboratories in Japan, DESY and France.

The detectors are followed by front end readout electronics and DAQ. ILC requires high momentum resolution and two track separation. This imposes technical requirements on the small size of pads and high sampling rate.

ILC relevant expertise in building SRF accelerator and detectors originate from participation of Polish accelerator physicists and engineers in nearly all large European experiments in CERN, DESY, GSI/FAIR, ESS and others. They participate also in neutrino experiments in Japan and HEP experiments in USA (CEBAF, Fermilab, etc.).

V. European project ILC EIPP E-JADE

After Higgs discovery the JAHEP proposed to the ICFA to host the ILC in Japan in 2012. Relevant place was chosen for 50 km tunnel and a living place for a few thousand research staff. This was the beginning. Now, the EC is funding a Preparation Plan for European Participation in the International Linear Collider E-JADE project during the period 2015-2018, with plans beyond 2019-2022. The beneficiaries are among others: LAL Orsay, Oxford, IFIC Valencia, DESY, LAPP Annency, CEA Saclay, and CERN. At this stage no smaller partners are present. Though, possible participation of smaller partners would broaden and strengthen the European community interaction platform. E-JADE The Europe – Japan Accelerator Development Exchange Programme is a Maria Skłodowska Curie Research and Innovation Staff Exchange action coordinated by CERN and funded by EU under Horizon 2020. This project is not a simple gesture towards the European cooperation with ILC. It is a solid and clear support for the realization of this future project.

The aim of E-JADE is to define more formally the European capabilities and technical expertise put at a disposal for the ILC, while not defining precisely the extent of this involvement. E-JADE is expected to complement the relevant documents prepared by the Japanese side (KEK ILC Action Plan). Most of the European expertise relevant to ILC has been developed recently during the construction, commissioning and operation of the EXFEL in DESY.

The final positive results of E-JADE depend on the positive decision of Japanese authorities about hosting the ILC and next appropriate intergovernmental agreements. This decision should be followed by European strategy update. In such positive conditions, the update is expected to position the ILC in the highest priority, probably next to the HL-LHC. CERN is playing a central role in coordination of the European effort on behalf of the ILC. European ILC partners work on detailed finalization of the design, define initially their deliverables fabricated in cooperation with European industry, including in particular the in-kind contributions.

E-JADE digests considerable past contributions of Europe to the linear collider development projects. Total contribution to ILC GDE during the period 2007-2012 was over 700 PY (FTE). The fields of conceptual work, followed by extended technical activities, were: accelerator design and integration ADI, superconducting RF technology development SCRF, and detectors for linear colliders. This contribution was then split to particular subjects, which is more less continued till now: SCRF, Controls - LLRF, Beam Delivery, Positron Source, Damping Rings, Electron Source, Simulations, Ring to Main Linac, ML Integration, CFS, and other. Superconducting RF was split further to cavities, cryogenics, cryomodule and high level HLRF. The design results on SiD and ILD detectors concepts submitted to the ILC TDR [3] were practically applied in other infrastructures and experiments including HL-LHC, FAIR, RHIC and other. Poland is listed in the past contributions for the ILC TDR, in ADI area, at the level of over 20 FTE. SCRF contribution was somehow omitted, despite large input of Polish teams to the development of the controls, interlocks, precision synchronization and LLRF system at CMS/LHC, TESLA TTF and FLASH during these years. Polish teams are also involved in building the European Spallation Source ESS in Lund. The most active Polish accelerator technology groups are from AGH University in Kraków, Warsaw University of Technology WUT, Institute of Nucelar Physics IFJ PAN in Kraków, National Centre of Nuclear Research in Świerk NCBJ, and some other places.

The main aim of E-JADE is however to show the massive European input to the development plans of ILC in the coming near future. The European expertise relevant to ILC stems from realization of several large conceptual, design and infrastructural projects. Among them there are: superconducting liniac for the ESS/Lund, TESLA technology liniac at the European XFEL at DESY, CLIC study at CERN, LCC R&D study on detectors, participation in accelerator test facility at KEK. Nearly in all of these efforts participate actively physicists and engineers from Poland.

VI. The CLIC Infrastructure and Program

The compact linear collider CLIC is a TeV scale high-luminosity linear electron-positron collider under development by international collaborations hosted by CERN. Thinking subjectively, one of very strong arguments for CLIC would be its clear and profitable synergy with the planned FCC, if any. CLIC web page at the LCC Home says that it would collide electrons and positrons and is currently the only mature option for a multi-TeV linear collider. CLIC own home page at clic.cern refers intentionally, carefully and conservatively, to the update of the European Strategy for Particle Physics, and presents the infrastructure as a compelling opportunity for the post-LHC era. The past and current effort invested in CLIC is huge and probably overcomes the one invested in ILC. CLIC would be between 11 and 50 km long and is proposed to be built at CERN, with first beams around 2035. This date corresponds somehow with the time schedules for the FCC. Seeking a synergy is thus justified.

CLIC is based on a two-beam warm acceleration technique at an acceleration gradient of 100 MV/m or more. The best cavities support fields up to 200 MV/m. The tested CLIC Cu cavity resonant frequencies, related to mm cavity dimensions, were around 30 GHz and now are X-band 12 GHz. TESLA uses 1,3 GHz Nb cold cavity assembled in nine sets of around 1m in length. The operation field intensity is around 30 MV/m. The best cold cavities are near to 50 MV/m/. CLIC is expected to work at up to 3 TeV centre-of-mass energy. CLIC global project is composed of two collaborations for detector and physics CLICdp, and accelerator study CLICas. CLIC GP gathers more than 70 institutes in more than 30 countries.

CLIC is, no doubt, a very important planned infrastructure for CERN. Even more, it may be somehow treated as, a scalable in energy, lifesaving project. The scalability steps are 380 GeV, 1500 GeV and 3000 GeV. The wise scalability stems from economic purposes and technology testing. A similar scalability was applied by ILC in 250 GeV, 500 GeV and 1000 GeV energy steps. CLIC has not yet a 10:1 demonstrator of the double beam acceleration technology. ILC has this sort of demonstrator which is the successful European XFEL accelerator. The competition tightens and will continue in the coming future.

Building at CERN a straight tunnel of 50 km or more in length opens a myriad of other possibilities to extend the machine, and scale the lepton and other research beyond 10 TeV and beyond 2050. Combining the 50 km CLIC project with the 80/100 km FCC project keeps CERN safely at the cutting edge of the HEP experiments for many decades. And this is the fundamental interest of the European and the World science.

VII. The European and Global Strategies

As of June 2019 there were published several documents at the page of the ILC- European Strategy Document [2]. The first document The International Collider - A Global Project is in two parts.. One part is short and fulfills a role of an extended abstract. The second part is extensive and embraces fully all aspects of the machine and physics. The set of authors and institutions in these two documents is different. The longer document is signed by the representatives of 18 big institutions from Japan, USA, France, Germany, UK, and Italy. No smaller partners were included at all. The shorter part adds smaller partners: Canada, Serbia, Norway, Poland, and Israel. The second document concentrates directly on the European competences for individual infrastructures of the ILC i.e. accelerator and detectors, and is signed only by the representatives of European institutions from France (LAL-Orsay/CNRS, IRFU, U.Paris–Saclay, LAPP/CNRS, IPHC/SNRS), Germany (DESY), Norway (U.Bergen), CERN, Italy (INFN, ISIC, U.Valencia), Poland (AGH and IFJ PAN Kraków), Israel (U.TelAviv), and UK (U.Glasgow).

The input documents are quite declarative, strong and technically exhausting showing the European potential to participate in the global ILC initiative. They, however do not cross the red line, which depends on the position of the host country. The European declaration should be open, attracting all relevant and interested partners, including smaller ones like numerable distributed university groups, and essentially it has just this character.

VIII. Arguments and Scenarios

The most important arguments for concentration of the biggest and very large research infrastructures are quite strong, yet not filling the full decision space.

- Construction price and maintenance costs get prohibitively big for any single partner, rather than for the global effort,
- Required expert pool counts in thousands persons rather than in hundreds,
- Exchangeability and flow of experts through the experiment, its careful planning, construction, maintenance and inevitable upgrades, during several decades,
- Continuous training of experts directly involved in particular experiment,
- Today there are only a few sites fulfilling the requirements for being the sites for next global experiments, and the global community has to think about the continuation of their active life during several next decades,
- Returning to life neglected, outdated, or obsolete research centres may sometimes be more difficult than to build a new one from the scratch,
- Centre of the world now for HEP experiments is currently in the CERN. To provide safe future for this centre planning should embrace several decades, not just one or two.

Forgetting for a while the following deconcentrating arguments, the decision is simple. With the increase in size and costs of the global experiments, the World should forget the competitiveness at this global level of research, concentrate at the competency development level, reserve the competiveness for infrastructure components, and possibly invest strongly in a single versatile research and infrastructure centre.

The most important arguments for deconcentrating the global research experiments are perhaps of nearly equal weight. Though, the balance between concentration and deconcentrating arguments is more a matter of general politics, including individual country abilities and ambitions, than the science itself.

- Reasonably weighted dissipation of ultimate research effort among the most relevant large local communities,
- More equal distribution of knowledge and experts training across the globe,
- A chance to involve much more research talent in reasonably distributed global experiments.

The concentration versus the deconcentrating policy will always be present in the research policy of building large infrastructures. ILC, and its predecessor TESLA, are ideal examples of this complex decision process. The deciding factors in the future, with even bigger infrastructures to be built, will be associated with the size, costs, complexity, maintenance, expert human force, need for particular geographical location on the Globe, etc.

What sort of input can be expected from smaller partners, taking into account the possible, above mentioned, arguments and scenarios. A large number of signatories from the Polish HEP experiments community for the ILC shows a big interest for the participation in this activity. The activity is covering the machine and physics. The infrastructural part is embracing machine construction, testing of components, commissioning, fine tuning, maintenance, exploitation, and machine studies during the research phase. The research phase embraces doing physics at all levels, which includes simulations, measurements, data acquisition, evaluation and processing, but also hardware changes to fit to the appearing new needs. The listed tasks are finely granular. There is a lot of work for many interested and small research groups.

The basis requirement for active participation of international community, especially young researchers, in the machine construction and its research program of such large initiative like ILC is its unconditional and indiscriminative openness. It is evident that young researchers are fascinated by large experiments and their participation is more than necessary. Forgetting this will lead the project to collapse in longer terms. Big science in the current world has a different position than one or two generations of researchers before.

Most of the mysticism and mysterious character of big science has recently disappeared altogether. Though older scientists still believe in this spiritual power of science and even more try to keep this sort of atmosphere around themselves. Young scientists want just simply to participate in something interesting and very challenging. If well organized by current managers of the science, and large long lasting projects like the ILC and CLIC, this participation may change to an interesting long life research career.

Conclusion

International Linear Collider ILC is a global project pursued in Japan. Compact Linear Collider CLIC is a global project pursued in CERN. Linear Collider Collaboration LCC is a non-governmental organization, founded by the International Committee on Future Accelerators, that tries to unite the research efforts of ILC and CLICK by finding not only a common denominator but also beneficial synergies, and trying to make profit out of this. ILC and CLIC use different, even competing, some even say orthogonal, acceleration technologies, warm versus cold, klystron based versus two-accelerator acceleration-deceleration transformer like. Linear Collider Consortium LCC tries to unite global development work for a next-generation linear particle collider. Creation of the LCC was a natural reasonable step for better cooperation of the global accelerator community. Without the LCC the global linear accelerator cooperation would be not so perfectly and seamlessly coordinated.

Only one linear collider of this global size and cost is expected to be built. No final decisions have yet been taken for building any of these two ILC and CLIC gigantic competitors. However, we have been observing the ups and downs of the ILC (and CLIC, although to a lesser extent) projects for several years. CLIC has a second serious competitor for large finances at home, which is the FCC.

Future Circular Collider is a global project, a direct continuation of the Large Hadron Collider LHC, after exhausting all possible LHC upgrades and modifications. Time scales of the above development and building processes are decades, many decades. There are several factors which prevent to begin the construction work tomorrow. These perhaps are: gigantic building costs, no sufficiently encouraging results obtained after the Higgs discovery from the LHC accelerator complex, and new acceleration technologies like plasma wake not only emerging but fast developing in several large laboratories.

The latter technology has the chance to efficiently combine several advanced technologies like high-power, high-intensity lasers, plasma, accelerator, precision photonics, and ultra-precision, atto-second time synchronization. In the meantime, the FCC community proceeds very actively with preparations of the requirements for the Technical Design Report, TDR document, sometimes even overshadowing the ILC and CLIC. It shows that a success of any big project depends on the activity of the initiators.

The global high-energy, high-luminosity accelerator community is facing a chess pat situation? Or perhaps, this situation opens up new fascinating possibilities for the far reaching future? ILC infrastructure will be finally built by global collaboration in which large and small partners are equally important. Especially important is the participation of numerable small university groups dissipated around the globe but actively contributing toward common construction or research effort at the ILC. These groups train experts for the ILC and ILC like experiments in numbers far bigger than any single experiment itself. Are there any essential risks of stopping the ILC project basing on TESLA technology? The international accelerator community already uses very effectively a 1:10 scale accelerator propelling the largest FEL today in the world, which is the EXFEL in DESY.

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The author is very grateful to the European community of large accelerator infrastructures in which he could actively participate for the last two decades. Such European projects like TESLA Test Collaboration TTC, Coordinated Accelerator Research in Europe CARE, followed by TIARA, EuCARD, EuCARD2, and ARIES has seriously integrated and consolidated this community, adding to it also numerable representatives of smaller partners and university groups specializing in narrow subjects relevant to accelerator infrastructures and research.

This participation enabled the author to contribute actively to the community as an editor of an Editorial Series on Accelerator Science and Technology, which has recently published its 50th volume [27-29], now within the EU ARIES H2020 project.

This also enabled a number of young scientists from Poland to be accepted as team members in the largest accelerator experiments in Europe and across the World.

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