A suggestion for the critical question:
"How do we best express the need to make rapid progress with ILC in Japan and promote CLIC as the best machine option for CERN?"

The logic of the argumentation could be based on two facts which are already implicitly suggested in the text:

1. ILC in Japan remains the most promising path towards a fast implementation of a Higgs factory because the technology is the most industrially demonstrated, and the funding constraints are the smallest thanks to an acceptable overall cost and a worldwide sharing with an expected large Japanese contribution.
2. Any new large project at CERN (CLIC or FCC-ee) will have significantly longer implementation delays just because of the European/CERN funding constraints.

Hence:

- It is the short term interest of the physics community to support/boost the negotiations for a fast decision/implementation of the ILC in Japan.
- In case of no swift progress and convergence of the above process, CLIC remains the most attractive option for an upgradable Higgs factory at CERN and consolidation of the technology should be a priority to allow a timely decision process.

Wording of course subject to improvements to get the largest community support…

Mission statement for the next collider

Premise: The primary goal of the next collider is to provide inputs to a global fit of all Standard Model parameters AND the parameters of the EFT operator coefficients that represent high-scale new physics (including, but not limited to, the Higgs interactions)

Extensive simulation studies & EFT fits

Conclusion: e^+e^- collisions above 250 GeV are required, to provide precise measurement of the top mass and couplings and the two most interesting Higgs couplings

The e^+e^- programme we need:

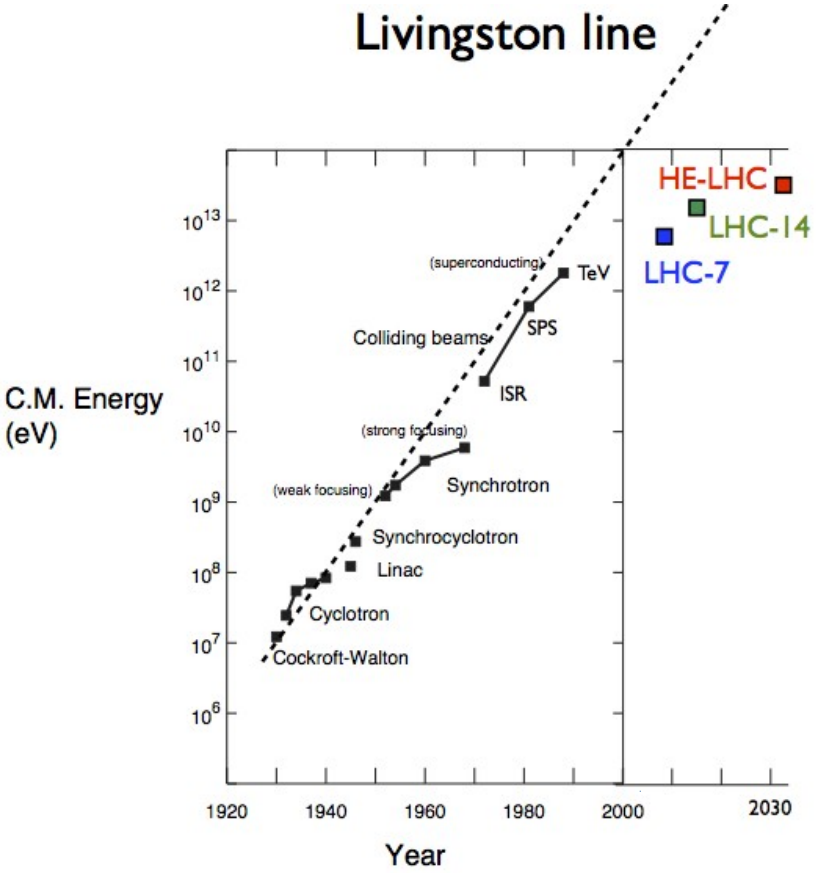
Physics	√s [GeV]
EW precision	m_Z
Higgs factory	250
Top physics	> $2m_t$
Higgs trilinear	> 500
Top Yukawa	> 550

Robust measurement ***requires*** > 500 GeV

The combination of the HL-LHC + Linear Collider provides the most cost-effective way to produce these inputs

Marcel Vos, IFIC (UV/CSIC) Valencia

A long-term vision for HEP



Livingston's law: a factor 10 increase every 6 years!

Not an adiabatic development of one technology; continued progress is the result of a sequence of breakthroughs: generator → cyclotron → synchrotron → collider → ?

Circular (hadron) colliders have dominated HEP in the last decades. It is hard to predict what will be the winning technology for the second half of this century.

What is more likely to exist by 2050; a 160 Tesla dipole magnet or a 300 MV/m accelerating structure?

Magnet → The future is circular

cavity → The future is linear

Comments on the draft document

Linear Collider Community Meeting, Lausanne, 04 / 2019

Georg Weiglein, DESY

What is needed from my point of view is a strategy document with a clear and convincing vision, behind which the worldwide Linear Collider community can unite. There is still quite some way to go from the present draft to achieve a document that fulfils this purpose.

Specific comments:

- Physics / main strategy (first two paragraphs):
  Our scientific goal is to understand the origin of mass of elementary particles by identifying the underlying dynamics of electroweak symmetry breaking. The exploration of the properties of the discovered Higgs boson provides us with access to this mechanism and to the non-trivial structure of the vacuum. We should not call the Higgs a SM particle and we should not phrase the goal of the LC that it is to discover violations of the SM predictions.
  From the perspective of funding agencies and people in other fields, a ``long term e+e- programme" is not necessarily something positive per se. Instead, we should argue with the great physics potential of future upgrades.

- Par 3: ``unrivalled accuracy": Can we justify this in comparison with FCC-hh?

- Par 4: ``affordable linacs" seems to imply that ILC and CLIC are not affordable

- Par 6: ``hadron and … muon colliders … can be built and operated in parallel with a LC installation" What??? Maybe if the LC installation is done in 30 years … .
  In its recent statement ICFA clearly states that there is an international consensus that the highest priority for the next global machine is a Higgs Factory. Our strategy document should emphasise this point! Furthermore, the national roadmaps that were submitted as input to the strategy process show a clear preference for an e+e- LC!

- Par 7: ``be ready for continuing the Higgs studies" is much too weak.

- Par 8, 9: The punchline of this document should be the strong support for an e+e- LC as the next big collider project of particle physics. I don't think that it is necessary to narrow this down to ``either ILC in Japan or CLIC at CERN".

Towards an LC Community statement for the European Strategy

LC Community Meeting, Lausanne, April 8/9 2019

Jenny List

- I very much support the idea of a joint “Lausanne statement” by the LC community as further input to the ESU process and the Open Symposium in Granada, and I thank the Program Committee for coming up with the idea and for preparing a first draft!

- However, the proposed draft has several short-comings and is missing some important points

- On the following page lists the points which I think should be clearly expressed in such a “Lausanne statement”

- **To address the most urgent questions in particle physics and cosmology**, like i.e. the nature of dark matter, the origin of mass and of the matter-antimatter asymmetry in the universe, **we must elucidate the nature of electroweak symmetry breaking** by studying the Higgs boson, including its self-interaction, as well as the top quark, and search for new phenomena, in particular weakly interacting particles that may escape detection in hadron collisions.

- **ICFA recently re-confirmed the international consensus that the highest priority for the next global machine is a "Higgs Factory" capable of precision studies of the Higgs boson**.

- Among the input documents to the current Update of the European Strategy for Particles physics submitted by CERN member states, **a there is strong support for an e+e- linear collider, which can reach energies of at least 500 GeV.**

- **As Linear Collider Community, we therefore ask the European Strategy to adopt the following points:**

  - **A machine offering an *energy-upgradable* e+e- physics programme, starting with a Higgs factory at 250GeV, continuing at 350 and 500 GeV at the least, is the highest priority for a next global collider**

  - **Such an energy-upgradable e+e- program can only be offered by a Linear Collider**

  - **Europe and CERN should play a leading role in such a Linear Collider project, *wherever it is built***

  - **Thus Europe and CERN should further strengthen their Linear Collider activities and push for a worldwide consensual decision for construction within the next couple of years.**

  - **We are looking forward to an offer from Japan to host the ILC as a global project, for which CERN should take the role of a European hub, while continuing R&D for a far future project located at CERN.**

  - **For the case that Japan does not decide to host the ILC, Europe and CERN should aim to prepare a decision-ready European LC project within the next 3-5 years.**

3-minutes for the e^+e^- LC!

Gudi Moortgat-Pick (Hamburg University/DESY)

LINEAR COLLIDER COLLABORATION

What do we want?

- **Understanding the Universe from the 'smallest' to the 'biggest'**
- **The Higgs Sector plays a crucial role**
  - **explaining electroweak symmetry breaking 'smallest'**
  - **answering / triggering inflation period 'biggest'**
- **Physics case for a staged ILC is given, results guaranteed!**
  - **250 GeV-stage mandatory for Higgs sector**
  - **350 GeV-stage mandatory for Top and Higgs sector**
  - **500 GeV-stage mandatory for Yukawa+trilinear Higgs sector**
- **With pol. beams, tuneable cms, extendibility to higher cms**
  - **ideally prepared for the 'Expected'**
  - **well and comprehensively prepared for the 'Unexpected'**
  - **unique competitor at the precision ⊗ energy frontier!**

When do we need the ILC?

- ***The physics case is given NOW!***
  - **The precision results substantial to unravel the structure of the model**
    - ***Can be SM, can be BSM ……there is BSM (do not forget dark matter)***
  - **The precision results are substantial to outline even higher scales**
    - ***Can be multi TeV, can be inaccessible for all thinkable colliders***
- ***There are good chances to build the ILC at Japan…….!***
  - **But….we should prepare a European LC as well**
    - ***Why not an European LC? Maybe at CERN?***
- ***But now! Time is running, the physics case is given and***

we would like to analyze and interprete the results during life time!

Comments on the Draft Document

Linear Collider Community Meeting

Sven Heinemeyer, IFT/IFCA (CSIC, Madrid/Santander)

Lausanne, 04/2019

What we need (imho):

A united strategy for the whole European LC community (obviously, this is why we are here) that can be supported by the world-wide LC community

We should be clear about:
We want an LC, because of physics (see next slide)
LC should mean: $\sqrt{s} = 250$ GeV and more

We should not limit our options:
ILC@somewhere, CLIC@CERN, ...
ILC@Japan and CLIC@CERN are not mutually exclusive (depending on physics) $\Rightarrow$ we can support both
$\Rightarrow$ any LC offers great opportunities for CERN

We should not wait for/depend on Japan any longer
but we have to make clear that we support ILC@Japan "in case"!
We must continue our strong support for the japanese community.
The ILC@Japan is still the most promising opportunity for HEP (money-wise and physics-wise)

We should not mix the LC with other project (except HL-LHC)

We should make the following facts clear again to strengthen our case:
(We should not be defensive, but strong!)

- A Higgs factory (as given by an LC) should be the next big HEP project according to ICFA
- Many european countries made clearly favorable LC statements in their ESPP documents
- The physics goals of an LC are fully aligned with the overall goals of HEP:
  - direct and indirect search for new physics (that we know for sure to exist)
  - via precision Higgs measurements
  - via other precision measurements ($t\bar{t}$, other SM obs.)
  - via direct searches at 250 GeV and above

⇒ The european strategy (in the next 5 years) should be to put a world-wide LC project in motion

⇒ these points are not really given by the current version of the document

Requirements for ILC in Japan

Three necessary conditions to the next step for Japanese government

- Master plan of SCJ
- Some expectation on cost sharing
- Support in European strategy if ILC will go timely
  - Both in budget and in manpower
    - The better the clearer and more concrete support shown
  - Do not need to kill any other projects
  - Setting some deadline may push the government
    - But not too short - in a few months is not realistic

Update on RF Accelerator R&D

Emilio Nanni

4/8/2019

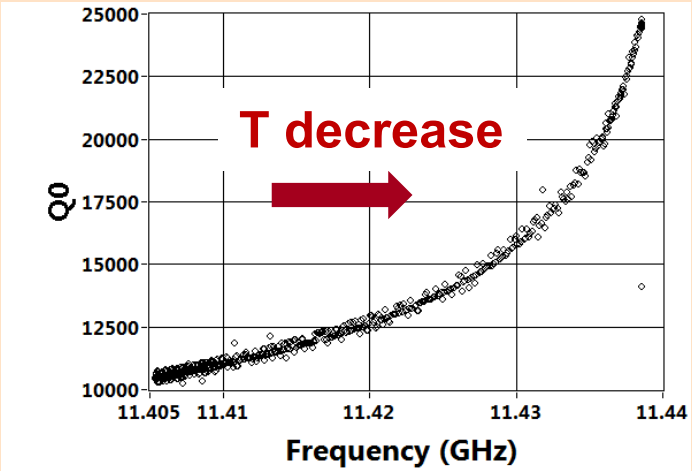
U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

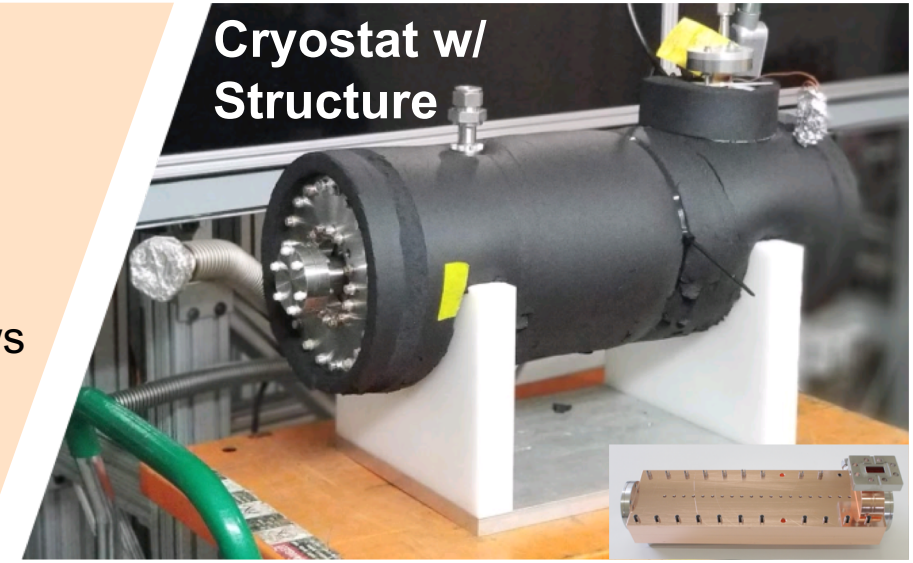
Cryogenic-Copper Accelerating Structures: New Frontier for Beam Brightness, Efficiency and Cost-Capability

SLAC

- Increased conductivity and hardness enables higher gradients
- Dramatic reduction in cost of system including cryogenics at 77K
- 2.5X less power establishing gradient allows for heavy beam loading even at high gradient – <u>improving system efficiency</u>

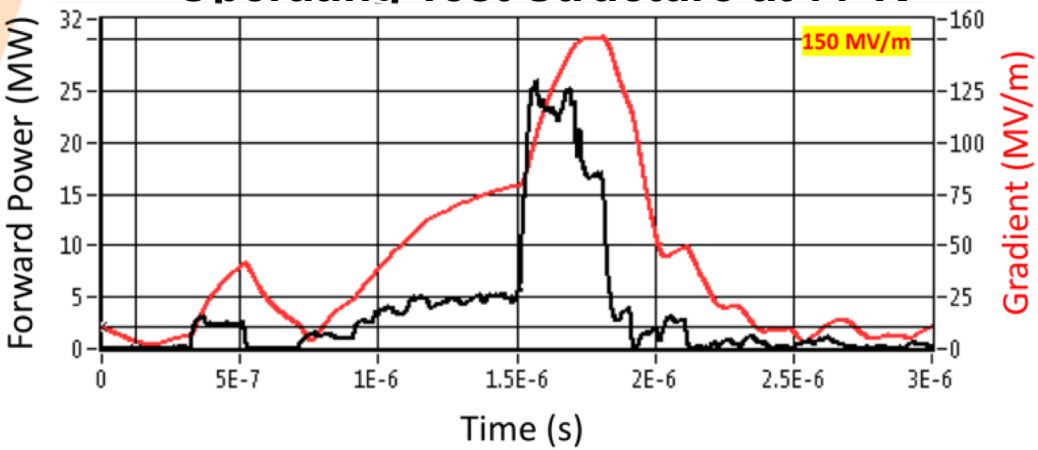


Increase in Q_0 by a factor of 2.5



M. Nasr, S. Tantawi, E. Nanni, et el.,

Operating Test Structure at 77 K



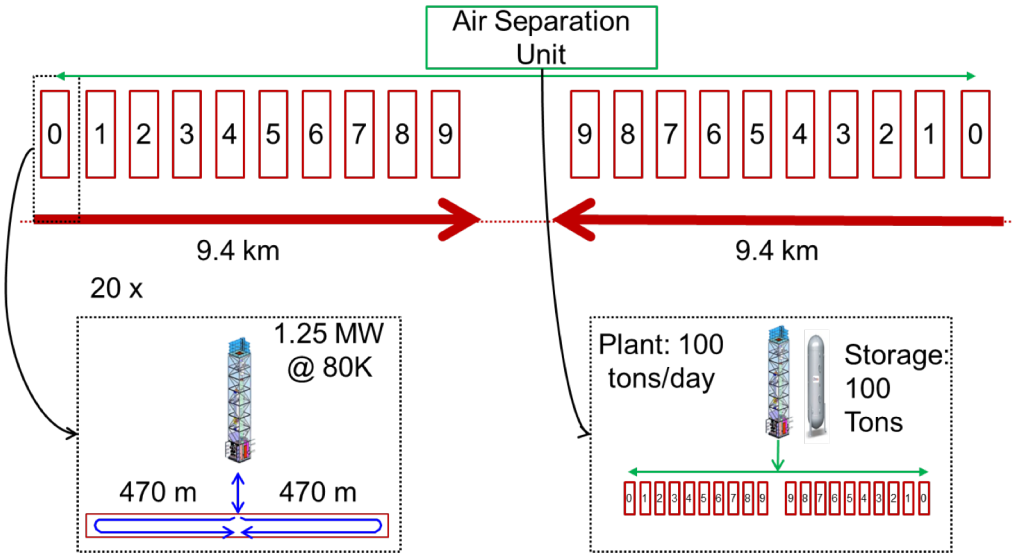
Tantawi et al., arXiv:1811.09925 (2018)

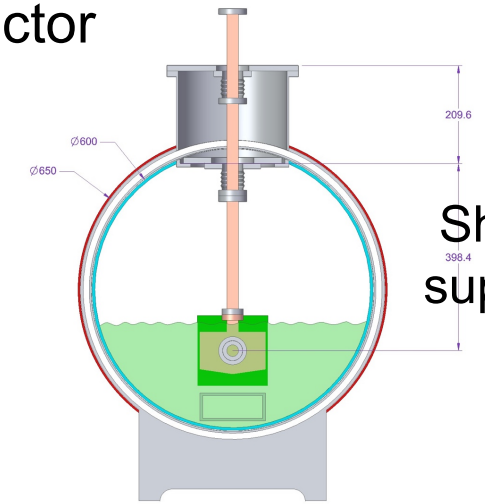
Impact of novel structures and temperatures → order of magnitude increased performance

An Advanced NCRF Linac Concept for Future High Energy Accelerators – Ongoing Study at 2 TeV CoM

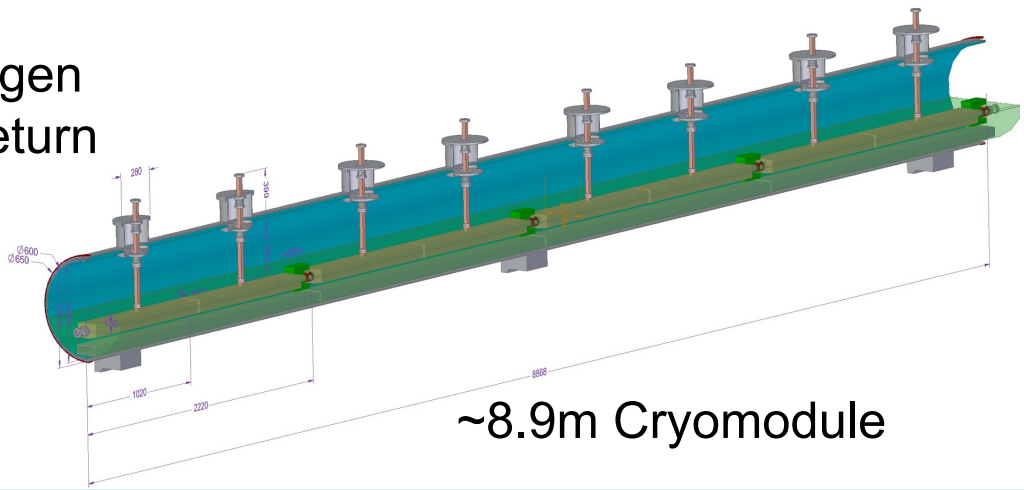
SLAC

- Cryomodule design developed for cryoplant layout to cool 24 MW/linac thermal load at 77K
- Optimizing for C-band (5.712 GHz) linac design w/ ~90% Fill Factor





Shared nitrogen supply and return



Bane et al., *ArXiv* 1807.10195 (2018)

~8.9m Cryomodule

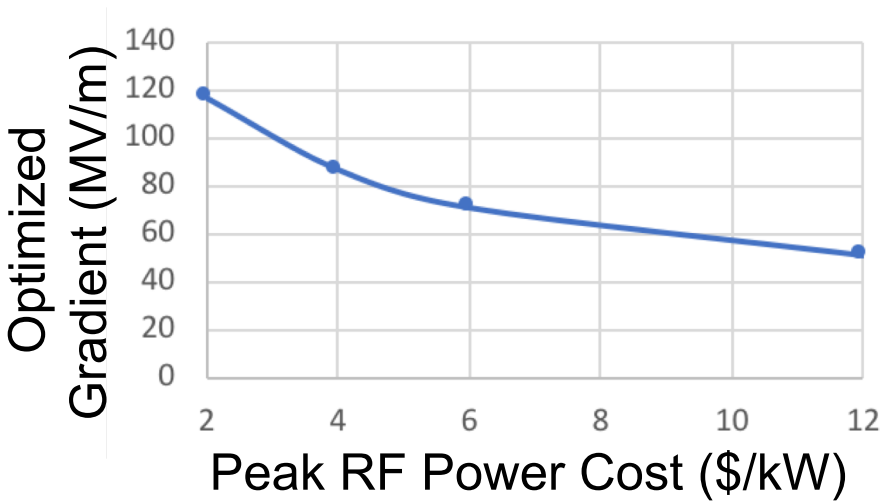
Moving Forward: Innovative NCRF Technologies Can Yield Major Advances in Cost-Capability

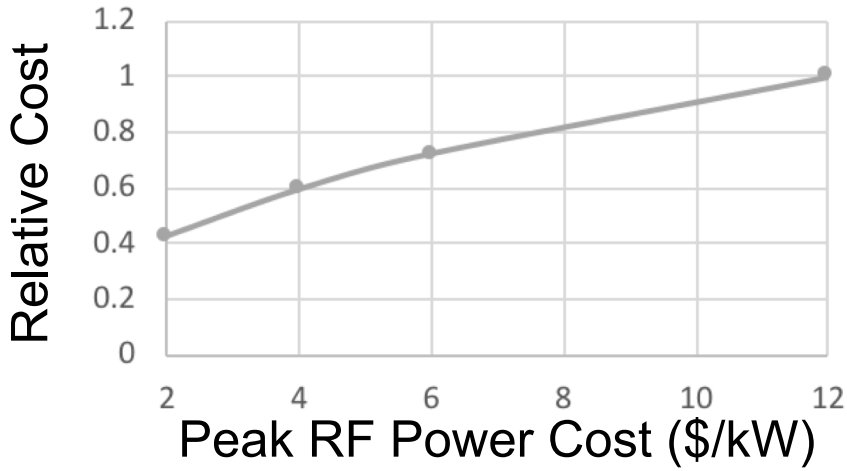
Efficient and Cost-Effective High-Gradient Normal Conducting Accelerators

SLAC

- Optimizing the cost of NCRF technology a fundamental requirement for its implementation for future facilities
- RF source cost is the key driver for gradient and cost – need to focus R&D on reducing source cost

Gradient/Cost Scaling vs RF Source Cost for 2 TeV CoM





Understand the Impact on Advanced Collider Concept Enabled by the Goals Defined in the DOE GARD RF Decadal Roadmap

https://science.energy.gov/~/media/hep/pdf/Reports/DOE_HEP_GARD_RF_Research_Roadmap_Report.pdf

Americas Linear Collider Committee

Jonathan Bagger (TRIUMF) Barry Barish (Caltech) Alain Bellerive (Carleton)

Jim Brau (Oregon) Marcel Demarteau (ANL) Dimitri Denisov (BNL)

Paul Grannis (Stony Brook) Mike Harrison (BNL) JoAnne Hewett (SLAC)

Steve Holmes (FNAL) Nigel Lockyer (FNAL) Joe Lykken (FNAL)

David MacFarlane (SLAC) Hugh Montgomery (Jefferson Lab, Chair)

Hitoshi Murayama (UC Berkeley, LBNL) Marc Ross (SLAC) David Rubin (Cornell)

Jan Strube (PNNL) Andy White (UT Arlington) Graham Wilson (Kansas)

Americas Linear Collider Committee stance concerning the International Linear Collider in the context of the European Strategy for Particle Physics (2020)

The Americas Linear Collider Committee supports the ICFA position confirming the international consensus that "*the highest priority for the next global machine is a 'Higgs Factory' capable of precision studies of the Higgs boson*." We remain convinced that the ILC best meets all of the requirements needed to probe detailed properties of the Higgs boson. The ILC has the potential for a future upgrade in energy, can sustain beam polarizations that increase its ability to do precision measurements, and is the most technically mature proposal for an electron-positron collider now available.

The recent statement by MEXT in Japan stated that further consideration by the Science Council of Japan and intergovernmental discussions are necessary before Japan would be in a position to make a bid to host the ILC. Unfortunately, this does not fit naturally into the timetable for finalizing the European Strategy recommendation. On the other hand, it appears that high-level interactions between the U.S. DOE and the Japanese principals, government and DIET, continue to be positive. We understand that the DOE remains interested in discussing with senior Japanese officials about ILC and the possibility of hosting it in Japan.

The ALCC is supportive of any electron-positron project that can distinguish the Standard Model from new physics models through precision measurements of the Higgs production and decay couplings. However, given the strengths of the ILC noted above and the recent progress in obtaining support for it within Japan, we urge that the European Strategy group support the completion of the process underway in Japan to decide on a bid to host the ILC.

Input to the European Strategy:

In total 164 submissions to the European Strategy process

- 18 national roadmaps from Cern MS
- 4 roadmaps from non-member states (CA, JP, RU, US)

Many individual projects
(including ILC/ CLIC/ ILD/ ..)

Ties Behnke, with material
also from Karsten Buesser

Scan the input for future collider projects (disclaimer: this is a non-exhaustive and probably incomplete survey, to the best of my knowledge)

1. Priorities

Type		MS (18)	NMS (4)
E+e- collider		12	2
	ILC, CLIC	9	2
	FCC(ee)	2	0
	Open	1	0
R&D accelerator		2	
Non-collider		1	
No priority		3	

MS: member state
NMS: non member state

2. Priorities

Type		MS (18)
R&D for collider		8
e+e- (ILC upgrade)		1
Neutrinos		1
Muon collider		1
Low energy precision		1
No priority		6

Some statements

Austria • „If the ILC is built, Austrian participation would be in line with HEPHY's tradition,(…)

France (IN2P3) • „In case of a positive announcement by the Japanese government regarding the ILC project, we recommend establishing a strong European participation in the experimental program (…).

Germany • „An electron-positron collider, upgradeable to a centre-of-mass energy of at least 500 GeV, should be realised, with the highest priority, as the next international high- energy project. (…)

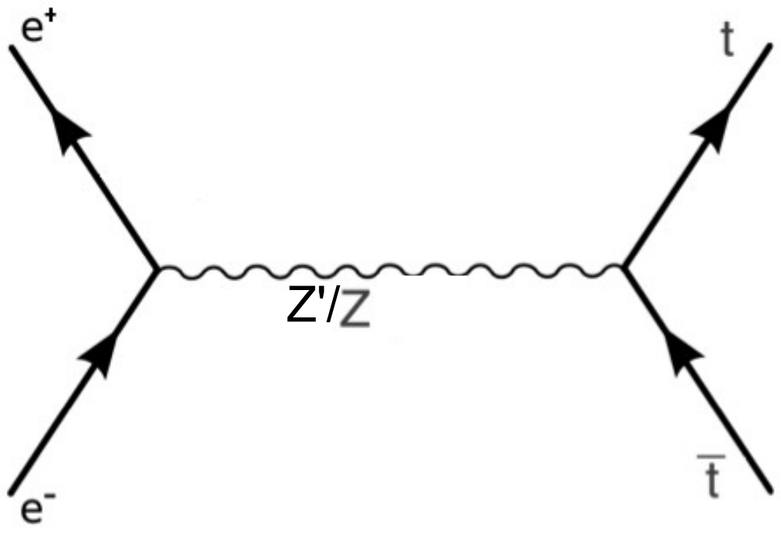
Israel • „Beyond the HL-LHC, the Israeli community is supportive of a future high-energy collider. (…)

Spain • „The present LC proposals, conceived as a Higgs factory at 250 GeV centre-of-mass energy with potential upgrades to higher energies, are positively seen by the community. (…)

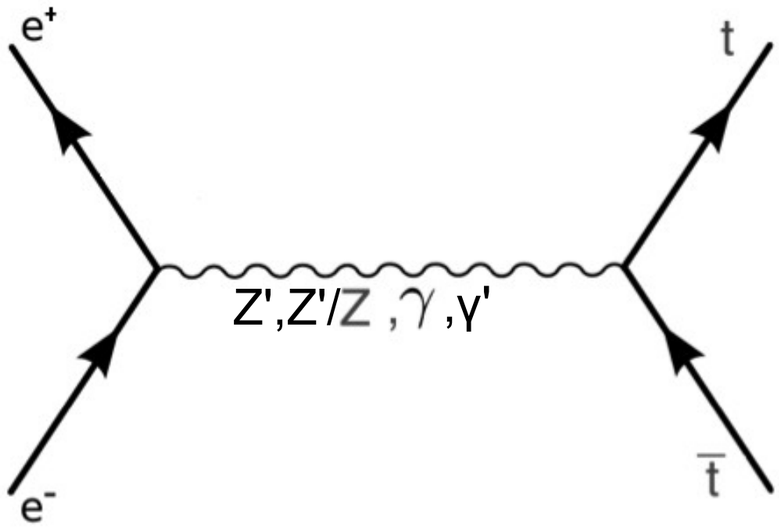
This is not a complete list, nor are the quotes complete.
Please visit the ESU page for the full statements.

Testing the chiral structure in 2-fermion processes

On the Z-pole



Above the Z-pole

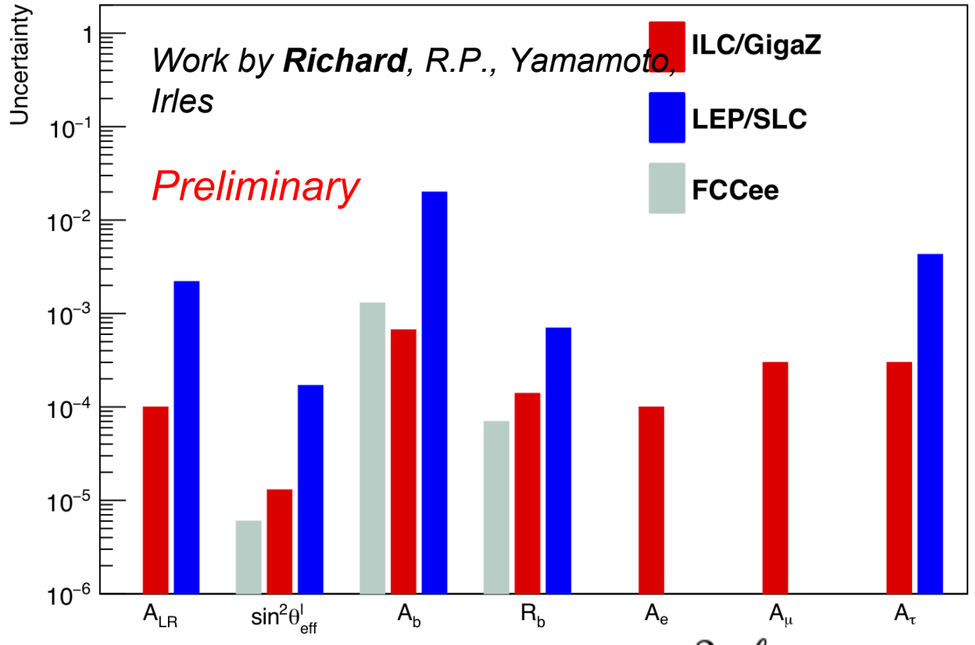


- GigaZ with ~10^9 Z
- Sensitivity to Z/Z' mixing
- Sensitivity to vector (and tensor) couplings of the Z
  - (the photon does not “disturb”)

- Sensitivity to interference effects of Z and photon!!
- Measured couplings of photon and Z can be influenced by new physics effects
- Interpretation of result is greatly supported by precise input from Z

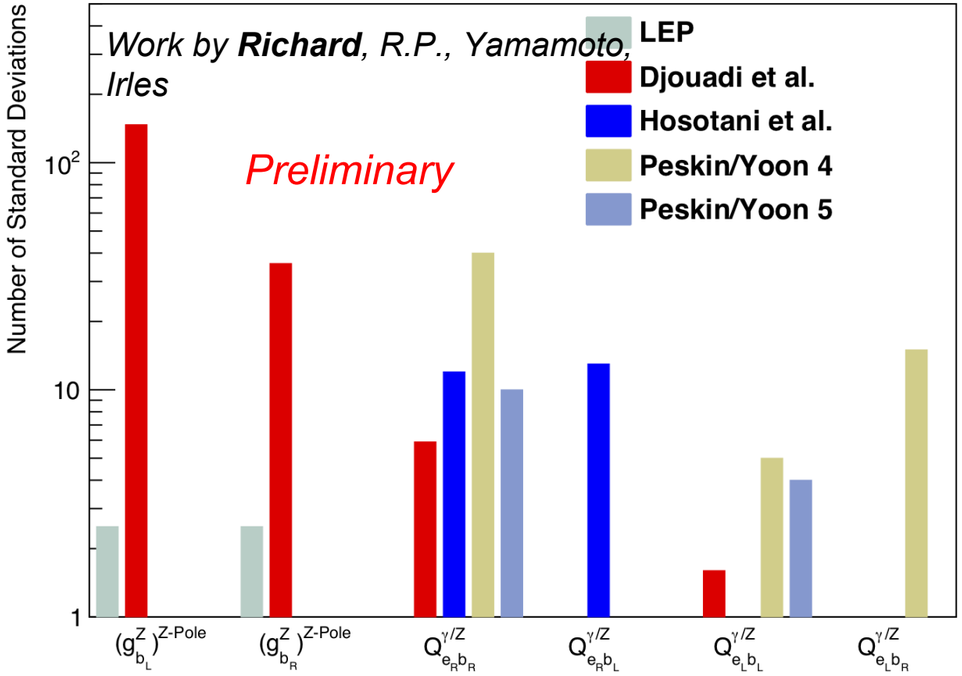
Precisions on Pole and Interplay with measurements above pole

Electroweak observables



- Precise measurement of $\sin^2\theta^{\ell}_{\rm eff}$.
  - Ten times better than LEP/SLD
  - Polarisation compensates for ~30 times luminosity
  - ... and ALR at LC can benefit from hadronic Z decays
  - **No assumption on lepton universality at LC**
- Complete test of lepton universality
  - Precisions of order 0.05%
- Excellent control of beam polarisation(dP/P ~ 5×10^{-4}) and beam energy (~MeV or better) required

Example: b couplings and helicity amplitudes



- Spectacular sensitivity to new physics in RS Models
  - Complete tests only possible at LC
- Pole measurements critical input
  - Only poorly constrained by LEP
- Pole measurements will (most likely) influence also top electroweak precision program
  - (t,b) doublet

Machine Parameters

https://arxiv.org/abs/1903.01629

ILC250 Higgs Factory

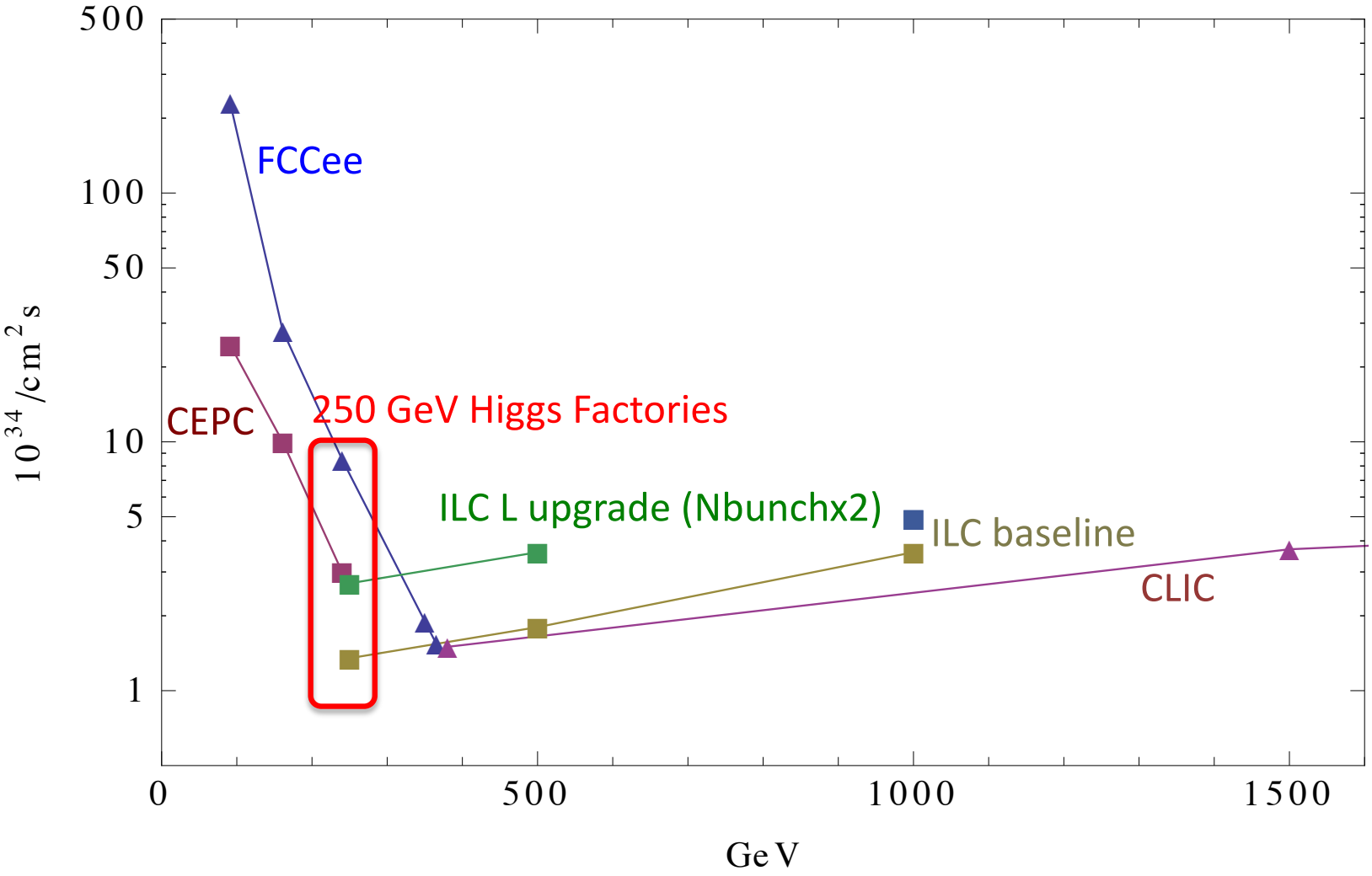
Quantity	Symbol	Unit	Initial	$\mathcal{L}$ Upgrade	TDR	Upgrades	
Centre of mass energy	$\sqrt{s}$	GeV	250	250	250	500	1000
Luminosity	$\mathcal{L}$	$10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	1.35	2.7	0.82	1.8/3.6	4.9
Polarisation for $e^-(e^+)$	$P_-(P_+)$		80 %(30 %)	80 %(30 %)	80 %(30 %)	80 %(30 %)	80 %(20 %)
Repetition frequency	f_{rep}	Hz	5	5	5	5	4
Bunches per pulse	n_{bunch}	1	1312	2625	1312	1312/2625	2450
Bunch population	N_{e}	10^{10}	2	2	2	2	1.74
Linac bunch interval	Δt_{b}	ns	554	366	554	554/366	366
Beam current in pulse	I_{pulse}	mA	5.8	5.8	8.8	5.8	7.6
Beam pulse duration	t_{pulse}	μs	727	961	727	727/961	897
Average beam power	P_{ave}	MW	5.3	10.5	10.5	10.5/21	27.2
Norm. hor. emitt. at IP	$\gamma\epsilon_{\mathrm{x}}$	μm	5	5	10	10	10
Norm. vert. emitt. at IP	$\gamma\epsilon_{\mathrm{y}}$	nm	35	35	35	35	30
RMS hor. beam size at IP	σ^*_{x}	nm	516	516	729	474	335
RMS vert. beam size at IP	σ^*_{y}	nm	7.7	7.7	7.7	5.9	2.7
Luminosity in top 1 %	$\mathcal{L}_{0.01}/\mathcal{L}$		73 %	73 %	87.1 %	58.3 %	44.5 %
Energy loss from beamstrahlung	δ_{BS}		2.6 %	2.6 %	0.97 %	4.5 %	10.5 %
Site AC power	P_{site}	MW	129		122	163	300
Site length	L_{site}	km	20.5	20.5	31	31	40

TABLE I: Summary table of the ILC accelerator parameters in the initial 250 GeV staged configuration (with TDR parameters at 250 GeV given for comparison) and possible upgrades. A 500 GeV machine could also be operated at 250 GeV with 10 Hz repetition rate, bringing the maximum luminosity to $5.4 \cdot 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ [10].

Cost of $\mathcal{L}$ upgrade (2.7×10^{34}): ~6% of initial construction cost

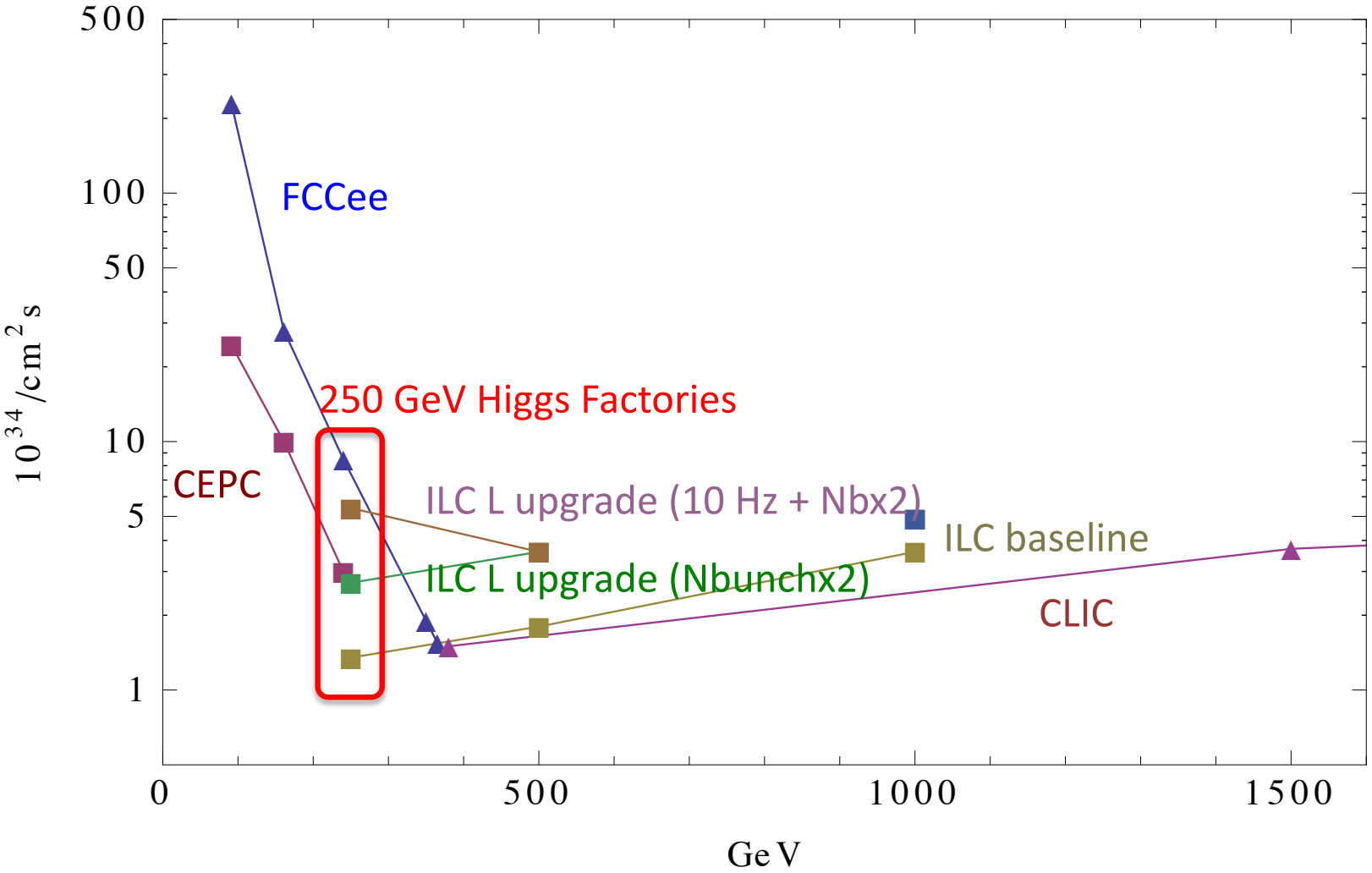
10 Hz repetition rate upgrade requires ~ ILC500

Luminosity vs Energy



- FCCee/CEPC are for 1 IP (their CDR have 2 IPs)
- ILC Higgs Factory numbers do not include effective x～2.5 by polarization

Luminosity vs Energy



- FCCee/CEPC are for 1 IP (their CDR have 2 IPs)
- ILC Higgs Factory numbers do not include effective x～2.5 by polarization
- ILC 10 Hz collision reaquires ~ILC500

Input from Lucie Linssen, Aidan Robson, Ulrike Schnoor, Dominik Dannheim, Andre Sailer, Philipp Roloff, Eva Sicking

Referring to the recent ICFA statement:

"… ICFA notes with satisfaction the great progress of the various options for Higgs factories proposed across the world. All options will be considered in the European Strategy for Particle Physics Update and by ICFA. …"

From this statement it is clear that all proposed facilities will be taken into account. There is an interest that each facility is reviewed according to objective scientific standards.

Weakening our statements on the physics capabilities of one LC facility out of respect for another LC facility does not fit within such a scientific scrutiny process.

Very likely, at this European Strategy process the next large collider facility for CERN will be chosen.
Two facilities, FCC and CLIC, are in strong competition.

We are convinced that CLIC is the best option for CERN.
So we shall say this explicitly in our conclusions.

Input from Lucie Linssen, Aidan Robson, Ulrike Schnoor, Dominik Dannheim, Andre Sailer, Philipp Roloff, Eva Sicking

About the draft document, posted on indico for this discussion (1):

The purpose and the extent of the document need to be discussed.

Advantages and risks need to be assessed carefully.

Not easy to cover two facilities (in two very different situations) in one document.
It may be better to have one general statement in support of Linear Colliders
(e.g in line with the main text at the top).

In fact, both ILC and CLIC have already documented all their work in recent publications and ESPPU input documents:
ILC: https://ilchome.web.cern.ch/content/ilc-european-strategy-document
CLIC: https://clic.cern/european-strategy
All our findings are already carefully documented and summarised there.

Input from Lucie Linssen, Aidan Robson, Ulrike Schnoor, Dominik Dannheim, Andre Sailer, Philipp Roloff, Eva Sicking

About the draft document, posted on indico for this discussion (2):

- Therefore, preference for a short feedback text of support for Linear Colliders
- However, in case a longer document style is maintained, several aspects of CLIC are missing or need further adjustments:
  - “CLIC is the best option for the future of CERN”
  - Access to measuring the top quark (already at the first accelerator stage)
  - The multi-TeV reach of CLIC
  - Stronger statements are needed about the complementarity between the CLIC stages, and the resulting gain in sensitivity to various BSM phenomena
  - For the CLIC accelerator the roadmap for to reaching readiness in the next few years is still missing. The draft document only refers to “building smaller machines with X-band facilities … to be pursued with high priority”. Though very important, this is a secondary rather than a primary aspect. Information on the CLIC roadmap can be found in recent reports.

Input from Lucie Linssen, Aidan Robson, Ulrike Schnoor, Dominik Dannheim, Andre Sailer, Philipp Roloff, Eva Sicking

About future organisation of Linear Colliders:
The LCC organisation was defined top-down (by ICFA) some ~7 years ago for ILC and CLIC.
LCC was a follow-up on the GDE, which was a dedicated organisation for the ILC.

The LCC organisation is not sufficiently well adapted to the needs, as the context for ILC and CLIC are very different.

Both the CLIC accelerator and the CLIC detector and physics study have well-defined collaboration structures, hosted by CERN.

Despite the uncertain situation around the ILC, there is a need for a dedicated ILC organisation structure hosted by a Japanese institute, in order to serve the ILC interests at best.

In a situation where ILC and CLIC each have well-defined organisational structures, suitable modalities for cooperation between ILC and CLIC can easily be found. These shall be defined bottom-up by the participants involved in the studies, rather than imposed top-down.

Support Document for the KEK-DG's talk: 9.4.2019 Sachio Komamiya

(1) In Japan the ILC project is more active than it has ever been.

Report from the SCJ's ILC committee made some negative effects in Japan, in the same time however, ILC became more visible in the public, and many media became sympathetic and supportive to ILC.

At the ICFA/LCB meeting on March 7th in the University of Tokyo, MEXT officially showed an interest in the ILC project in the first time. Dr. Keisuke Isogai, the Director-General of the Research Promotion Bureau of the MEXT, announced that MEXT recognized not only the scientific significance of ILC in particle physics particularly in the precision measurement of Higgs Boson, but also technological advancement and its effect on the local community. MEXT will continue to discuss the ILC project with other governments while having an interest in the ILC project. I heard that Dr. Isogai pushed very hard over the positive wording of the announcement against a Finance Ministry bureaucrat. I think this is a major progress of the project, since MEXT finally has come to our side.

In September last year LDP established Coordination Council for Realization of ILC which includes leaders of Head-Quarters and Councils of policy groups related to different ministries and agencies. Correspondingly MEXT organized meetings on the ILC with participations of high level government officials of other ministries and agencies.

(2) Financial issue is the key of the project

Both Federation of the Diet Members to Promote a Construction of ILC (supra-partisan organization) and the LDP's Coordination Council for ILC mention that "to secure the financial resources for realization of ILC (beyond the Olympic Games) outside of the ordinary science and technology, academic or university budget ".
Politicians take initiatives to study the financial scheme for the ILC along the above arrangement. Once this scheme has been more or less established, then real negotiation of the ILC budget with other countries can be officially started.
"Negotiation" and "discussion" are very different within their terminology. Discussions group of ILC is established in 2016 between US-DOE and MEXT. MEXT want to establish similar organization with European countries, starting with France and Germany.

I hope these activities will be competed on time so that they be considered in the discussion of the European Strategy on Particle Physics Update.