ILC

Open Questions & New Ideas

← "Bring ILC to Tohoku !"

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representing the
LCC Physics Working Group

Snowmass Energy Frontier
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Outline of this talk:

ILC run plan and potential

ILC political situation and timeline

“ILC Study Questions” arXiv:2007:03650

ILC Snowmass software and Monte Carlo data

2014 US P5 report:

"Use the Higgs boson as a new tool for discovery."

2017 JAHEP report:

"In light of the recent outcomes of the LHC Run 2, JAHEP proposes to promptly construct ILC as a Higgs factory with the center-of-mass energy of 250 GeV in Japan."

2020 European Strategy for Particle Physics:

"An electron-positron Higgs factory is the highest-priority next collider."

The couplings of the Higgs boson are absolutely predicted by the Standard Model. Searching for deviations from these predictions gives an approach to BSM physics different from and orthogonal to the search for new particles.

It is important to reach the sub-1% level of precision. Different BSM models predict deviations in different Higgs boson couplings, typically at the few-% level. The pattern of deviations can indicate the nature of the new interactions.

In order to understand any other question in particle physics — the fermion mass spectrum, CP violation, neutrino masses, even (in many models) dark matter — we need to understand the Higgs boson.

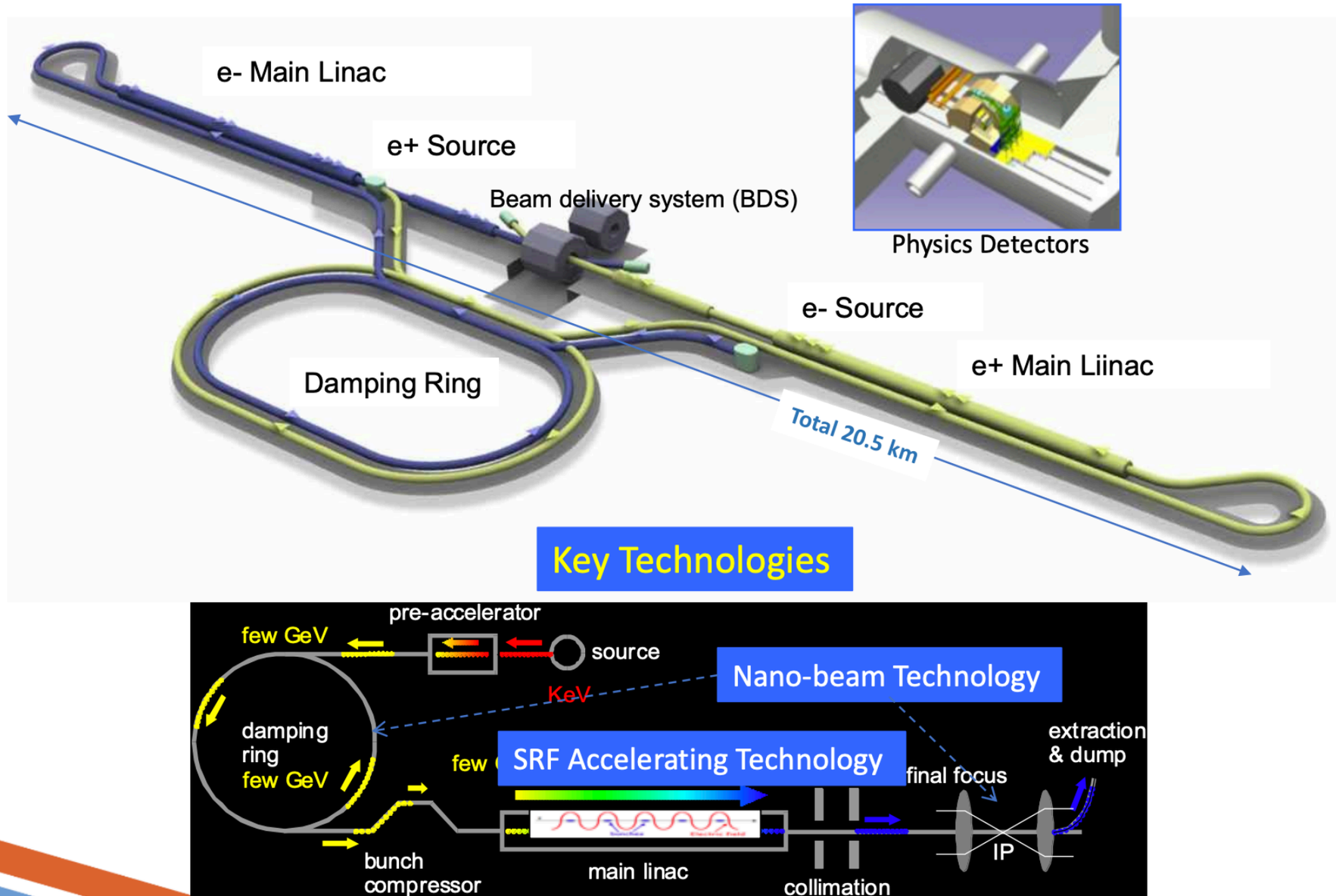
Our goal in collider physics is not to improve the error bars on Higgs measurements. It is to prove that the SM is violated.

This requires

* measurements that show SM violations at many σ
* measurements that are statistically dominated
* measurements that are improvable in a systematic program

e+e- collider experiments can meet these criteria.

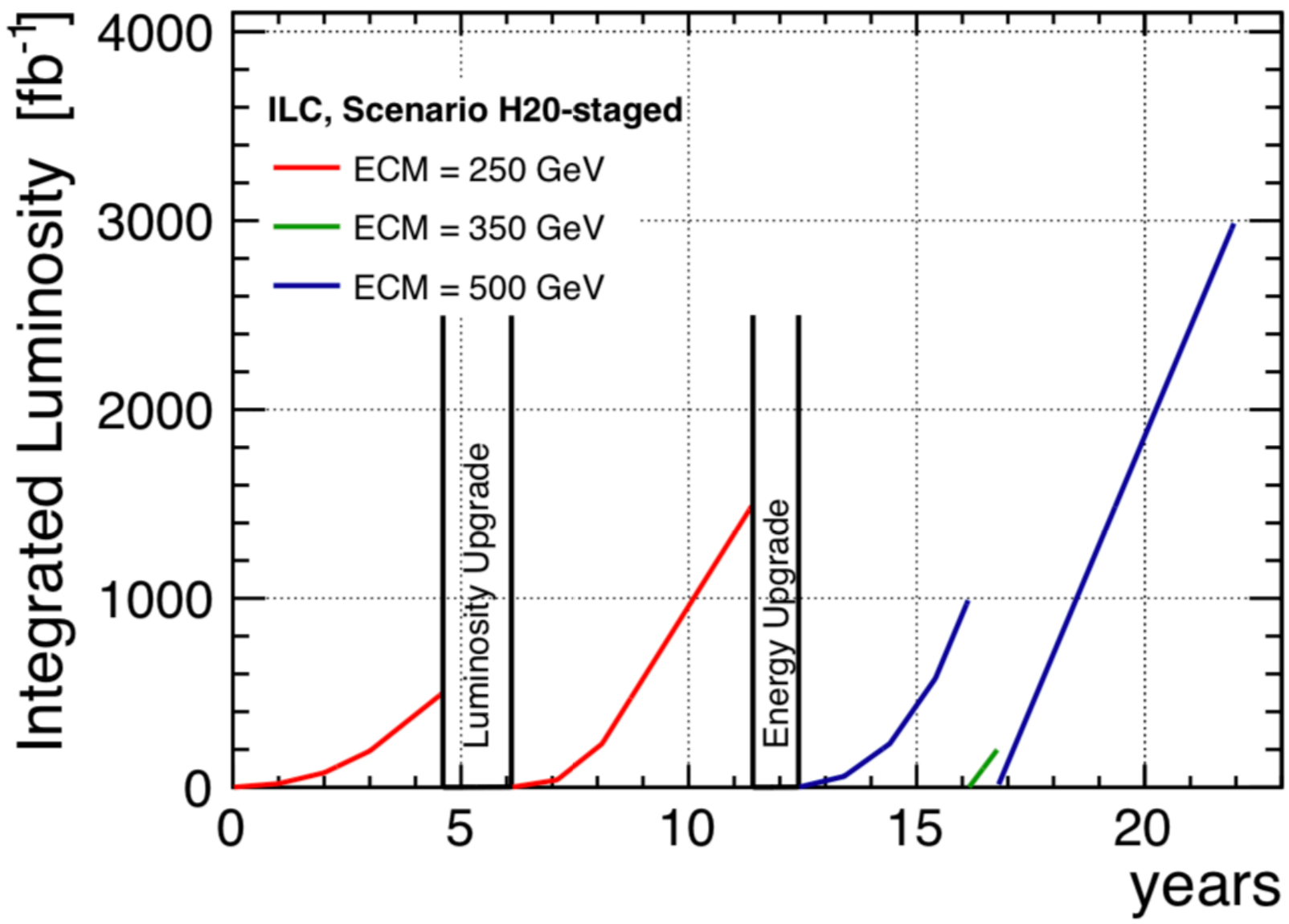
ILC250 accelerator facility



Item	Parameters
C.M. Energy	250 GeV
Length	20km
Luminosity	1.35 x10^{34} $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	**7.7** nm@250GeV
SRF Cavity G. Q_0	**31.5** MV/m (**35** MV/m) Q_0 = 1x10^{10}

accelerator: talk of Shinichiro Michizono at https://indico.fnal.gov/event/43871/

current ILC run plan: (basis of projections)

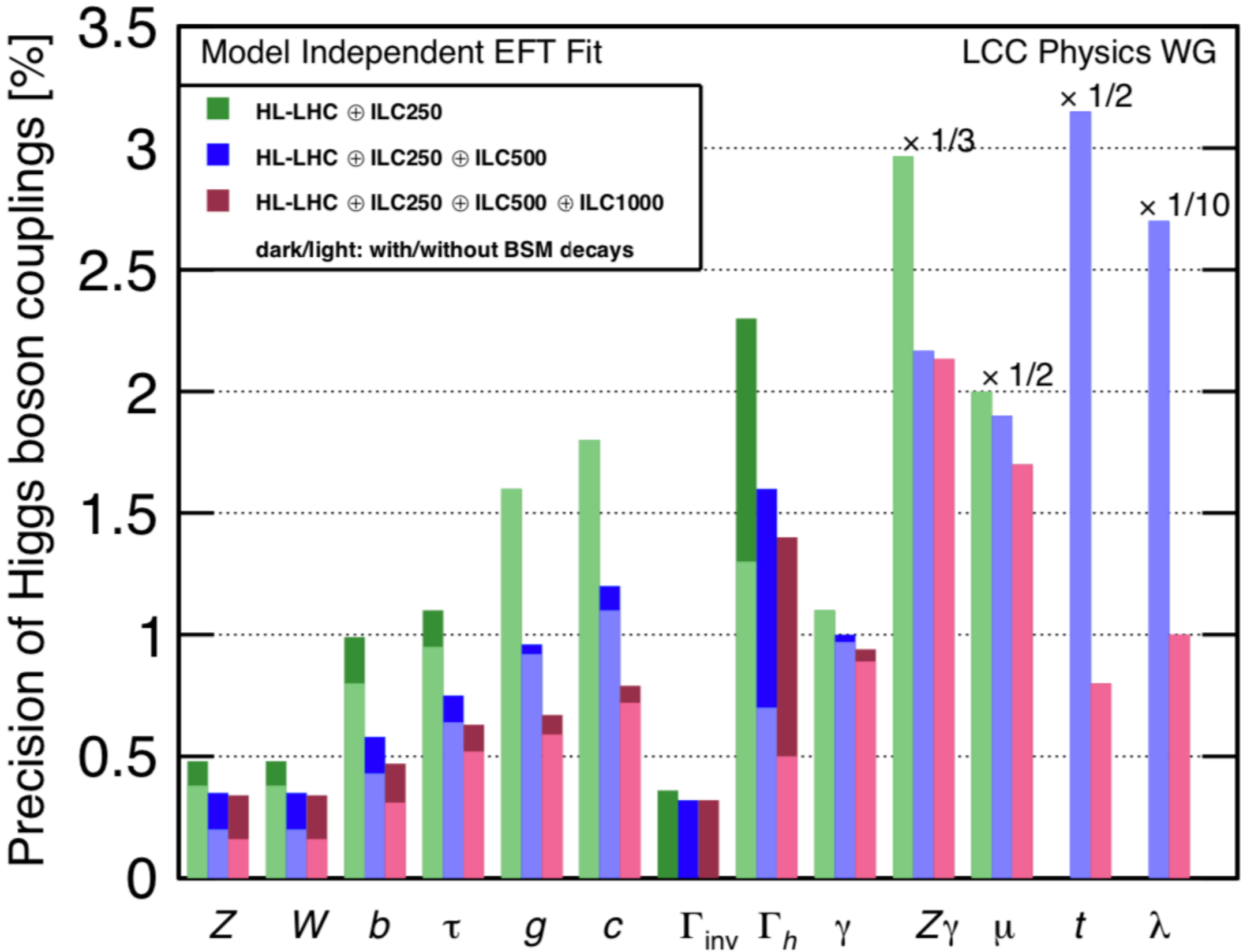


e- /e+ beam polarization at 80% / 30%

250 GeV: 2 ab-1, 500 GeV: 4ab-1, 350 GeV: 0.2 ab-1

also, runs at 91 GeV (5B Z's) and 1000 GeV (8 ab-1)

L upgrade: 5 Hz → 10 Hz; E upgrade: extend the linac



arXiv:1908.11299

All of the proposed Higgs factories have similar capabilities, and their experimental programs have similar challenges.

You don’t have to choose.

But, frontier accelerators are expensive. It will be a challenge to get even one.

The ILC is now under serious discussion by governments:

2020 ESPP report:

“The timely realization of the electron-positron International Linear Collider would be compatible with this strategy and, in that case, the European particle physics community would wish to collaborate.”

Linear Collider Workshop Sendai Nov. 2019

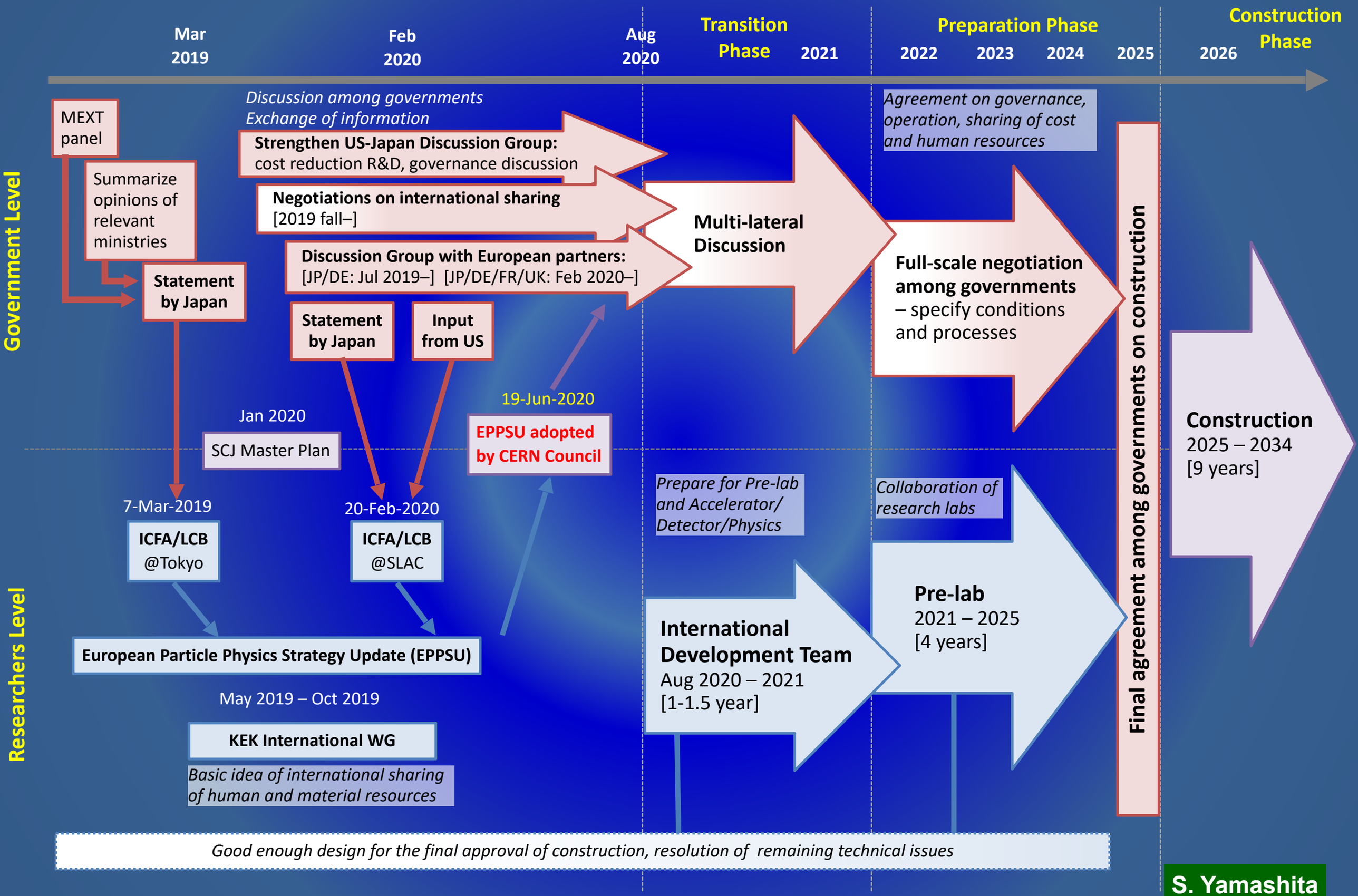
Ryu Shionoya, Chair, General Council, LDP

“"US-Japan relation is stronger than ever, and the political and administrative aspects are both working towards the realization of the ILC.”

Melinda Pavek, Director of Science, Innovation and Development, US Embassy, Tokyo

“the U.S. Department of State is ready to assist our partner agencies in developing the next major particle physics facility in Japan—the International Linear Collider.”

Processes and Approximate Timelines Towards Realization of ILC



S. Yamashita

* ICFA: international organization of researchers consisting of directors of world's major accelerator labs and representatives of researchers

* ILC pre-lab: International research organization for the preparation of ILC based on agreements among world's major accelerator labs such as KEK, CERN, FNAL, DESY, etc.

In my estimation, the corresponding timeline for detectors would be:

2020: physics and detector organization under the new International Development Team

2023: call for Letters of Intent from the ILC pre-Lab

2025: call for proposals, decision by the ILC PAC

2034: first data at 250 GeV

This schedule is by no means guaranteed. There are many political factors that we cannot control.

But, if there is no community, there will be no collider !

To join an e+e- Higgs factory initiative, or even to evaluate the prospects, it is essential that you get your hands dirty.

Over the past years, the ILC working groups have tried to make conservative, defensible projections for the physics capabilities.

But it is one thing to make estimates and quite another to control all sources of inefficiency and systematic error to realize 1% measurements at a collider. For this, we need your insight and effort.

With this in mind, we have put together

"ILC Study Questions for Snowmass 2021",
arXiv:2007.03650

This paper contains 90 questions for possible Snowmass projects covering all aspects of ILC physics, including Higgs, top, W, precision electroweak, QCD, and new particle searches — each with references to current work. It also lists contacts in the ILC physics community and detector and R&D groups.

Some sample questions:

6.3: To decrease the SM error on the hWW and hZZ coupling to 0.1%, we must measure the Higgs mass to 15 MeV. What are the sources of systematic error (e.g., tracking, luminosity spectrum, background subtraction) ? How can we mitigate them ?

6.13: What limits can ILC place on $h \to \tau\mu$, $h \to bs$, and other flavor-violating final states ?

8.3: There is an interesting theoretical literature on the measurement of a short-distance top quark mass from the kinematics of reconstructed jets in $e^+e^- \to t\bar{t}$. However, there is little experimental work on this measurement. What is the best strategy ?

8.8: The measurement of the top quark Yukawa coupling at 500 GeV is limited by the fact that this energy is very close to the threshold for $e^+e^- \to t\bar{t}h$. By simple cross section scaling, the precision on this coupling is expected to improve to about 2% at 550-600 GeV. Can this be confirmed by a full study ?

13.5: Just as the Higgs boson appears as a resonance in the missing mass in $e^+e^- \to Z + X$, a new scalar can also appear as such a resonance even if it has a small fraction of the standard Higgs boson coupling. What is the limit ? Can hadronic Z decays be used in this study ?

13.13: A possible effective Lagrangian term that gives a portal to dark matter is the coupling to photons $F_{\mu\nu}F^{\mu\nu}\chi\chi$. What limits can be placed by the photon-photon subprocess at e+e- colliders ?

14.2: There are at least two distinct mechanisms by which a theory with heavy SUSY particles can generate a large correction to the hbb coupling, one involving large b squark mixing, one involving h mixing with heavy Higgs bosons. Can one classify all mechanisms systematically ?

To help you explore these questions, we are making available a large number of MC events at the relevant ILC energies. Index at: http://ilcsnowmass.org

250 fb-1 at 250 GeV , 350 fb-1 at 350 GeV
500 fb-1 at 500 GeV , 1000 fb-1 at 1000 GeV

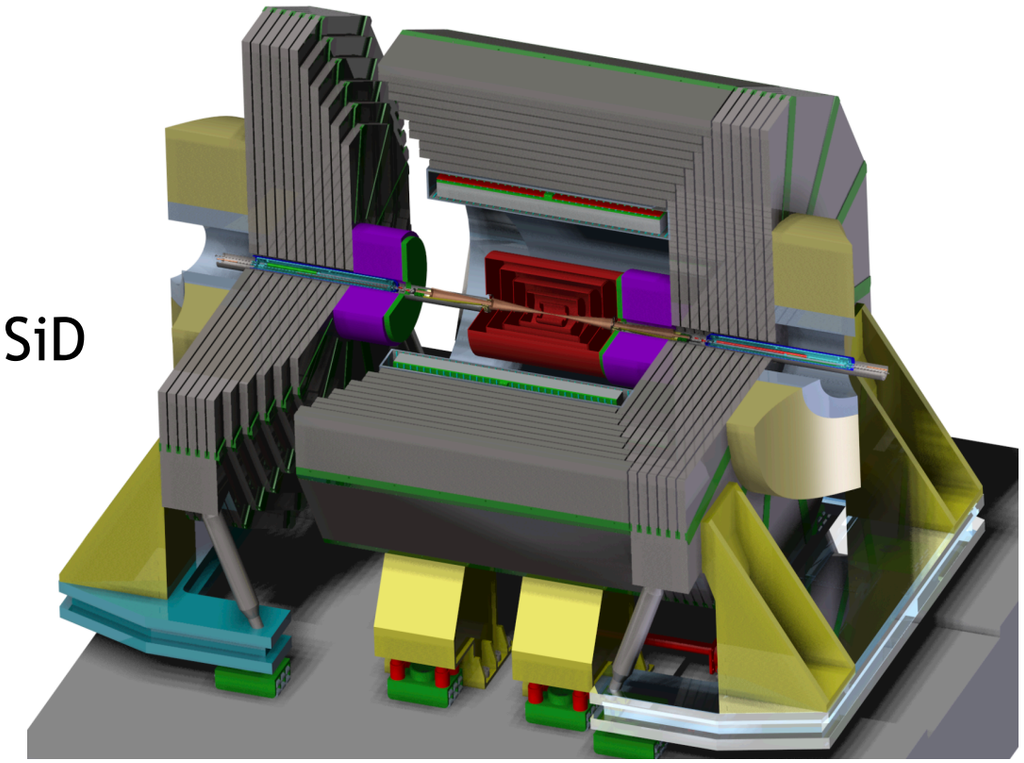
(thanks to JoAnne Hewett for server space at SLAC)

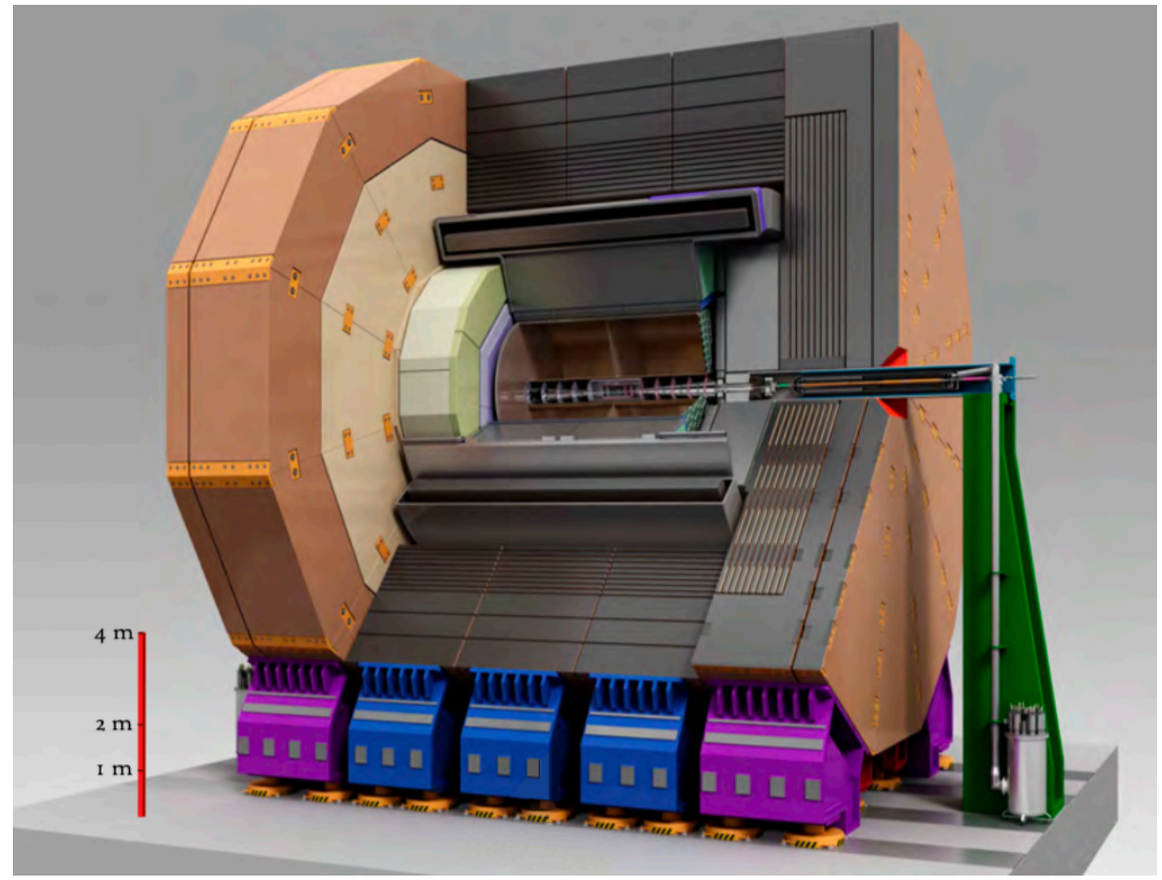
being set up now: SM events in stdhep format, generated by Whizard 1.95, for all 4 combinations of 100% polarized e- and e+ beams, using the ILC TDR design luminosity spectra

expected soon: SM events in other formats (see below); a larger MC event sample at 250 GeV

Published ILC physics analyses are generally done with full simulation of the SiD and ILD detectors,

SiD





ILD

Full description: ILC TDR vol. 4, arXiv:2003.01116

Simulation, reconstruction, and analysis tools in iLCSoft, data stored in LCIO format.

These tools and data format are also used by CLIC and CEPC.

For Snowmass, we are creating some new tools that hopefully will be simpler to start out with:

ILCDelphes:

New Delphes card that approximately models the performance of ILD and SiD. It includes:

- b and c tagging
- hadronic event description as n = 2, .., 6 jets
- 3-d momentum balance
- forward and very forward detectors

current version available now for testing:

https://github.com/ILCSoft/ILCDelphes

But, please do not try to study reconstruction and jet substructure using Delphes objects. The ILC detectors are designed to achieve high-precision hadron calorimetry using particle flow based on high granularity in 3 dimensions. The Delphes “tower” model does not provide these objects as a starting point.

Delphes also lacks other needed features:

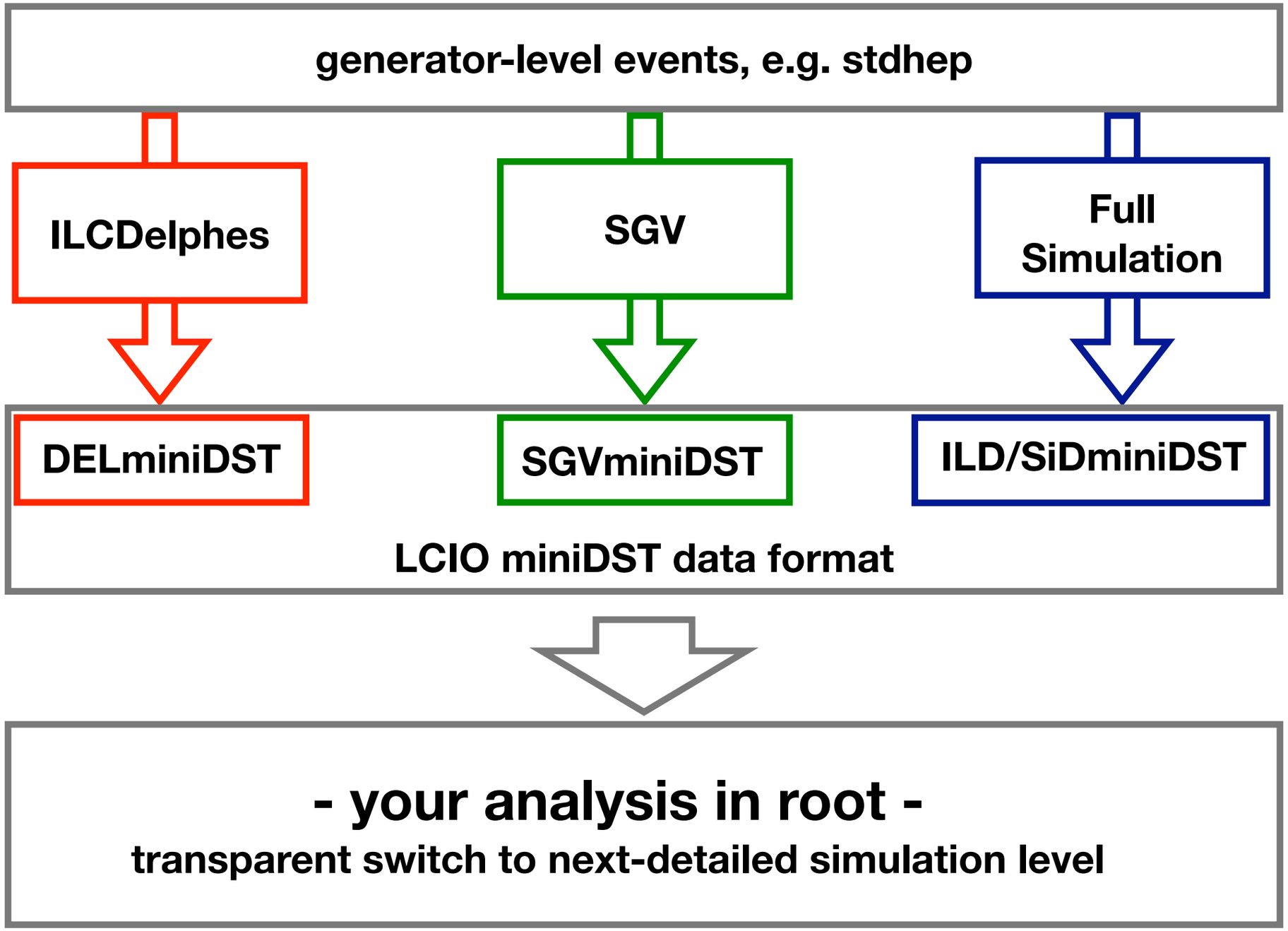
- b and c tagging information for a given jet is uncorrelated
- there is no particle ID information
- there is no beam crossing angle
- tau-tagging is very conservative

SGV:

SGV is the fast simulation tool used by ILD. Tracks are drawn from the full pdf of track parameters computed from the detector design. Calorimetry is parametrized using the exact point of entry of each particle. SGV can fill the data sets of the miniDST adequately for reconstruction studies.

miniDST:

The miniDST is a new high-level file-type that contains a subset of the information in LCIO and is readable in Root. It contains reconstructed particle flow objects, isolated leptons and photons and jets, with links to the MC truth. The miniDST is designed so that analyses based on this format can be ported seamlessly between Delphes, SGV, and full simulation.


generator-level events, e.g. stdhep
ILCDelphes
SGV
Full Simulation
DELminiDST
SGVminiDST
ILD/SiDminiDST
LCIO miniDST data format
- your analysis in root -
transparent switch to next-detailed simulation level

Full simulation:

To use full-simulation data, please contact one of the detector groups, SiD or ILD.

The SiD and ILD groups have established full simulation and reconstruction chains, based on iLCSoft and LCIO, for their respective detector models. To contribute to these groups, or even just to learn the tools, we recommend that you join SiD or ILD. Both groups offer zero-cost guest memberships during Snowmass.

Software (and physics) support:

Documentation for ILCDelphes, miniDST, and the layout of the stdhep files is now being prepared.

Support for all elements of the ILC Snowmass data and tools can be obtained from the contacts listed in the "ILC Questions" document, or from

ilc-snowmass@slac.stanford.edu
or ilc-snowmass on Slack

We will offer tutorials on the ILC Snowmass tools as a part of the program described by John Stupak this morning.

Please refer to the report

"ILC Study Questions for Snowmass 2021",
arXiv:2007.03650

for more details.

We hope you will have fun at Snowmass learning about the capabilities for precision physics at e+e- colliders!

I thank the members of the LCC Physics Working Group, the members of the American Linear Collider Committee, the authors of arXiv:2007.03650, and Norman Graf, Akiya Miyamoto, Andre Sailer, and Maxim Titov for contributions to this talk and the associated materials.