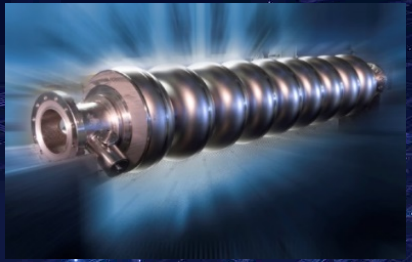
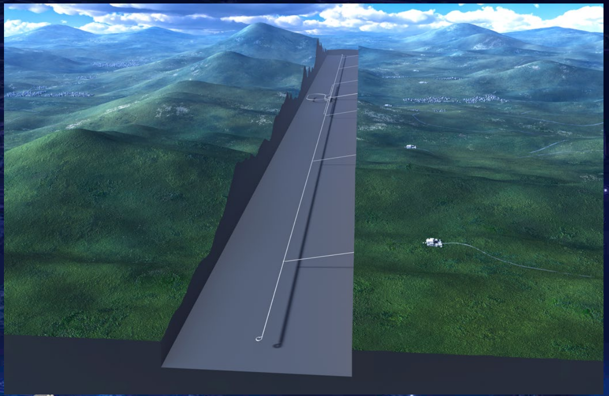
Evolution of the ILC Project & International Development Team





Maxim Titov, CEA Saclay, Irfu, France

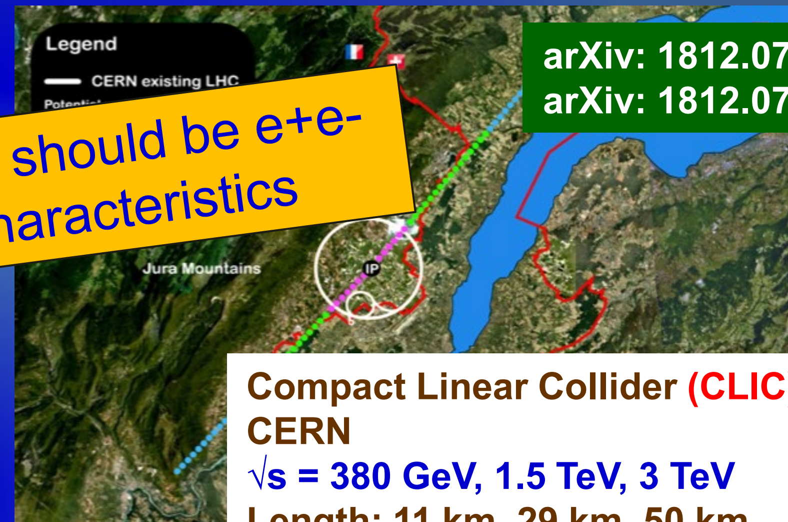
Future Electron-Positron Colliders: " Higgs Factory"

Linear colliders: *ILC, CLIC* (technical extendability to TeV regime)

arXiv: 1901.09829
arXiv: 1901.09825

General consensus: next "big machine" should be e+e- collider to scrutinize Higgs boson characteristics

International Linear Collider (ILC):
Japan (Kitakami)
$\sqrt{s}$ = 250 - 500 GeV, 1 TeV
Length: 21 km - 31 km (50 km)



arXiv: 1812.07987
arXiv: 1812.07986

Compact Linear Collider (CLIC):
CERN
$\sqrt{s}$ = 380 GeV, 1.5 TeV, 3 TeV
Length: 11 km, 29 km, 50 km

Circular colliders: *CEPC, FCC-ee*

arXiv: 1901.0316
arXiv: 1901.0317

- Ambitious Scope
- High Costs
- Long R&D Times

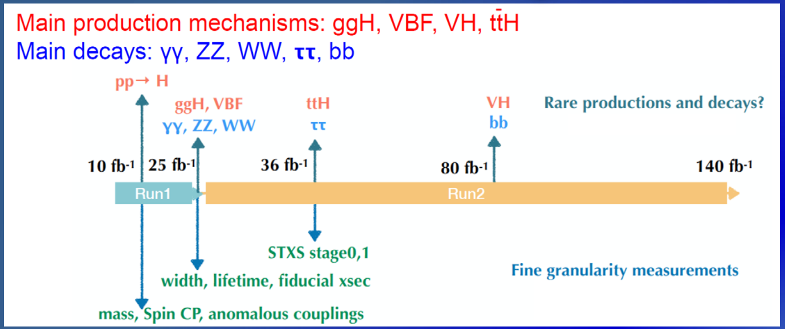
→ Global Projects (Politics!)

Circular Electr… Collider (CEPC):
China
$\sqrt{s}$ = 90 - 240 GeV
Circumference: 100 km

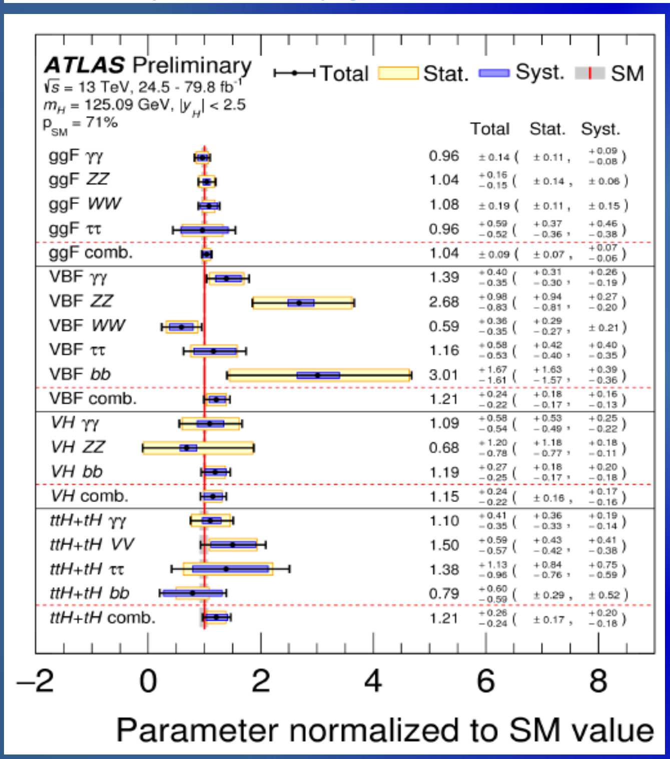
http://fcc-cdr.web.cern.ch/

Future Circular Collider (FCC-ee):
CERN
$\sqrt{s}$ = 90 - 350 GeV
Circumference: ~100 km

From Discovery to Precision: THE Higgs or A Higgs

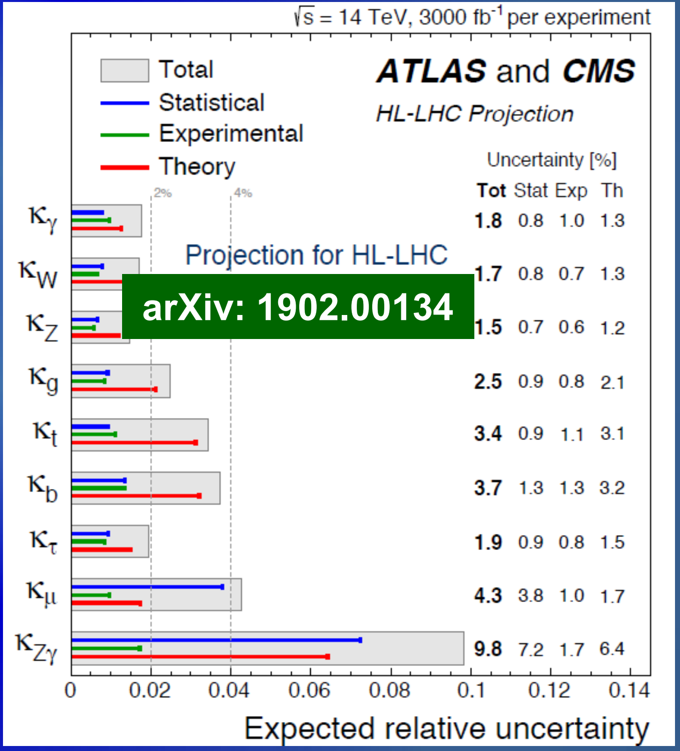


Measurements of Higgs properties with increasing precision are a **formidable tool to look for new-physics manifestations**
→ experimental precision approaching theory precision even before using full Run 2 statistics

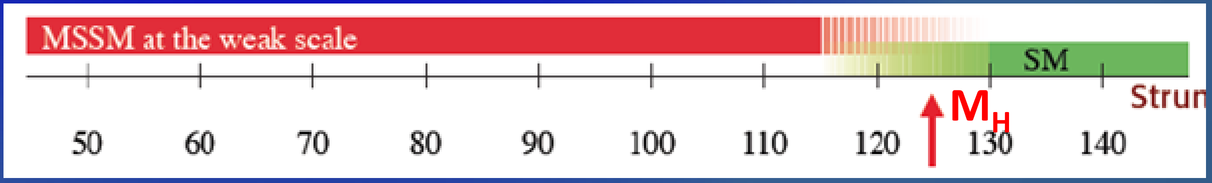


← **TODAY:** consistency so-far with the SM-like Higgs Boson

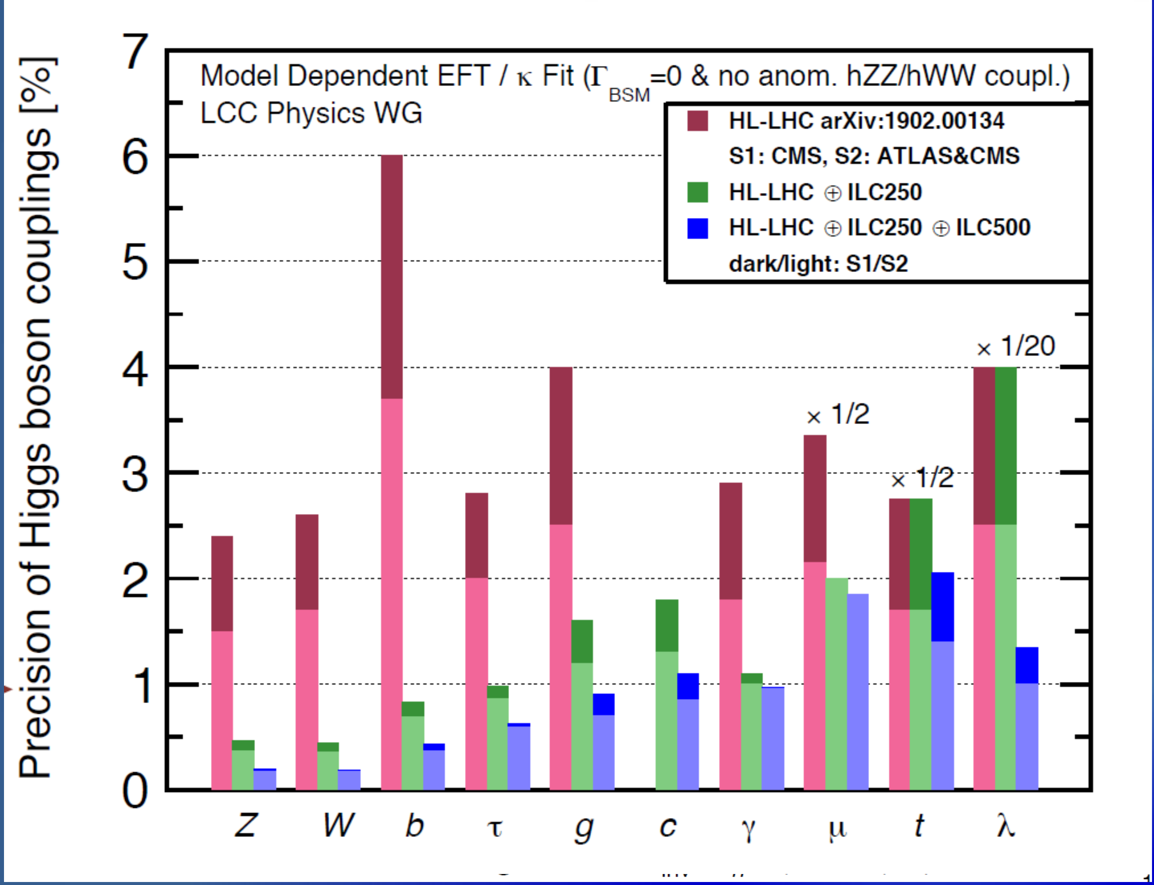
FUTURE: → 20x increase in statistics



Higgs is so simple and so unnatural
→ a "malicious choice"



Higgs Couplings Precision with ILC Model-Independent EFT Fit (22-parameters)



Highly model-independent analysis of EFT: Phys Rev D97, 053003 (2018)

Precision on Higgs Couplings and Synergy with HL-LHC:

~1 % required to access New Physics beyond HL-LHC direct search

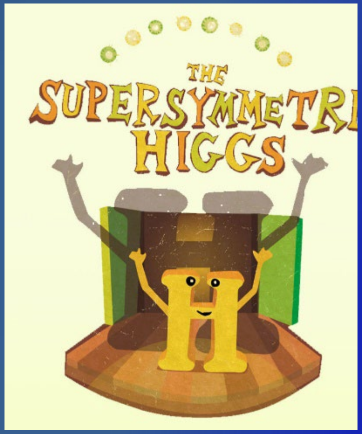
- ~ 1 % or better reached for many couplings → adding 500 GeV improves up to a factor of ~2
- ILC(250 GeV) offers quantitative *and* qualitative improvement beyond information accessible at hadron colliders → much better sensitivity to BSM !

Deviations Patterns to Reveal New Physics via Nature of Higgs

Precision has always been a window to new discoveries

Different BSM models predict different deviation patterns

=> Help discriminate between different Higgs models based on new physics possibilities beyond SM



The size of the deviation depends on the new physics scale (Λ)!

Decoupling Theorem:
Λ↑ → SM

example 1: **Minimal SUSY**
(MSSM : tanβ=5, radiative correction factor ≈ 1)

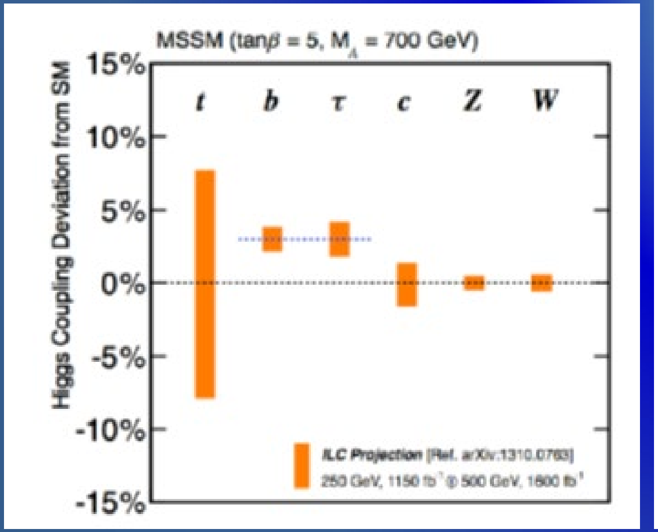
$$\frac{g_{hbb}}{g_{h_{SM}bb}} = \frac{g_{h\tau\tau}}{g_{h_{SM}\tau\tau}} \simeq 1 + 1.7\% \left(\frac{1\ \mathrm{TeV}}{m_A}\right)^2$$

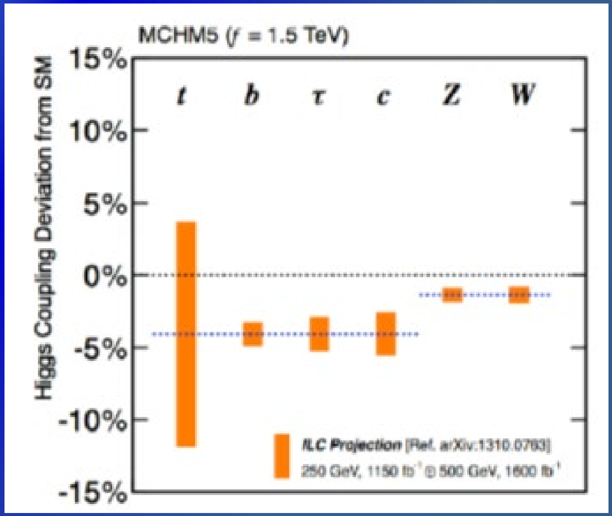
heavy Higgs mass

example 2: **Minimal Composite Higgs Model**

$$\frac{g_{hVV}}{g_{h_{SM}VV}} \simeq 1 - 8.3\% \left(\frac{1\ \mathrm{TeV}}{f}\right)^2$$

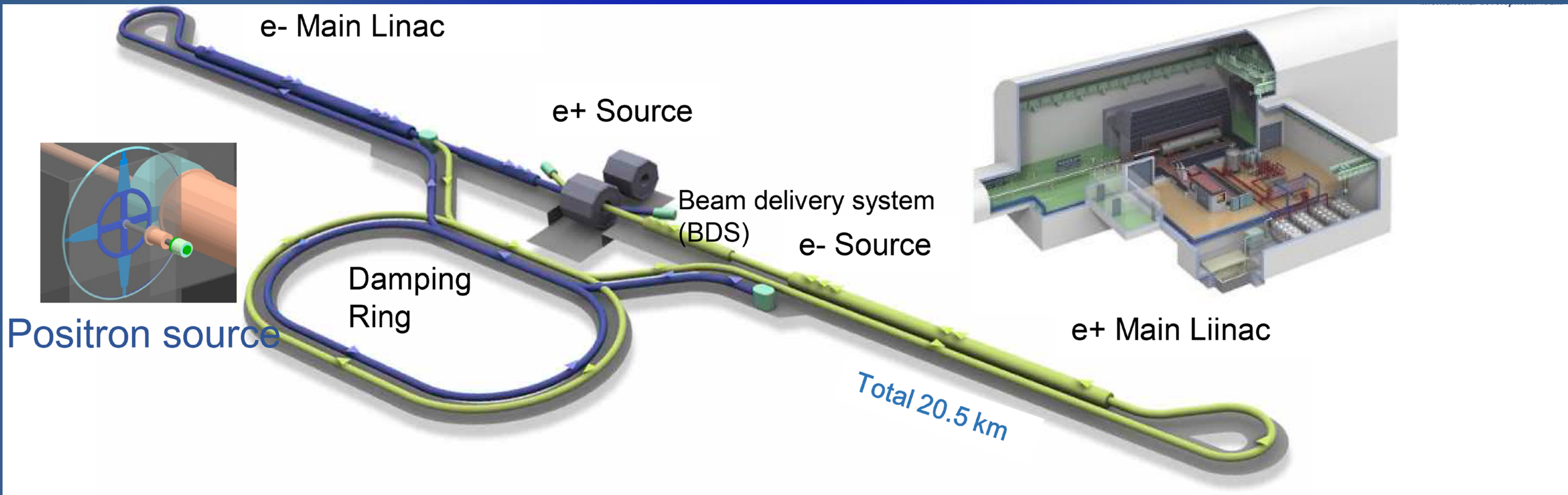
composite scale



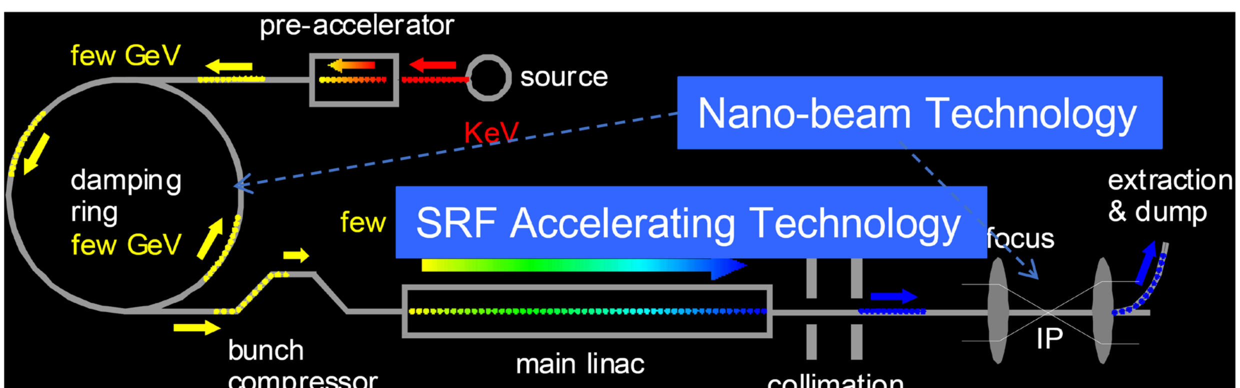


The ILC250 has the capability to tell the nature of the BSM from its deviation pattern!

250 GeV International Linear Collider Overview



Key Technologies



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}

The International Linear Collider in a Nutshell

e+e- centre-of-mass energy:

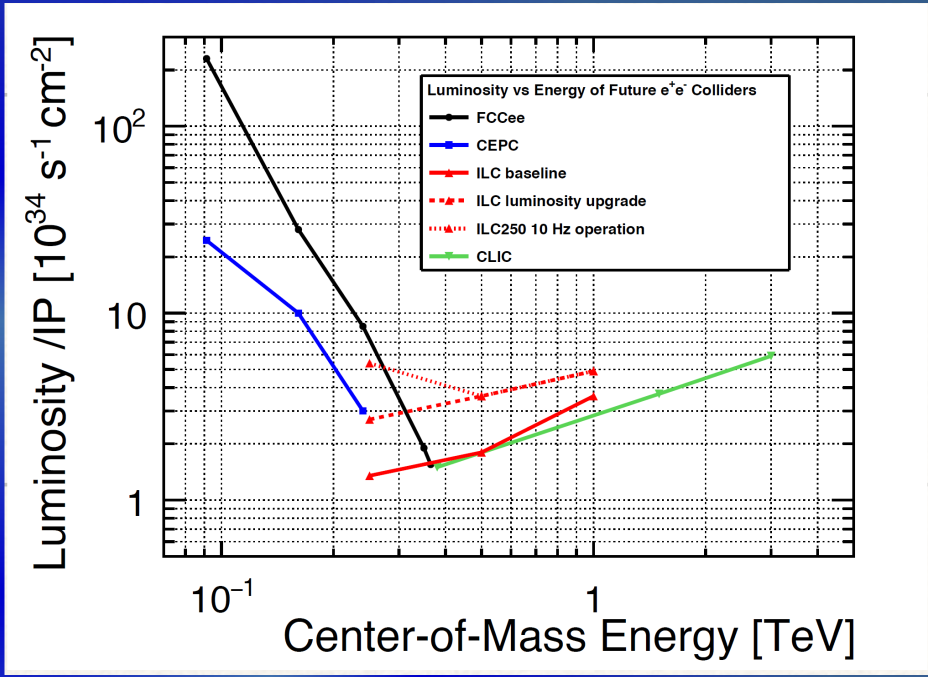
- first stage: 250 GeV (20 km tunnel)
- tunable; upgrades: 500 GeV, 1 TeV
- Other options: running at Z pole & WW threshold

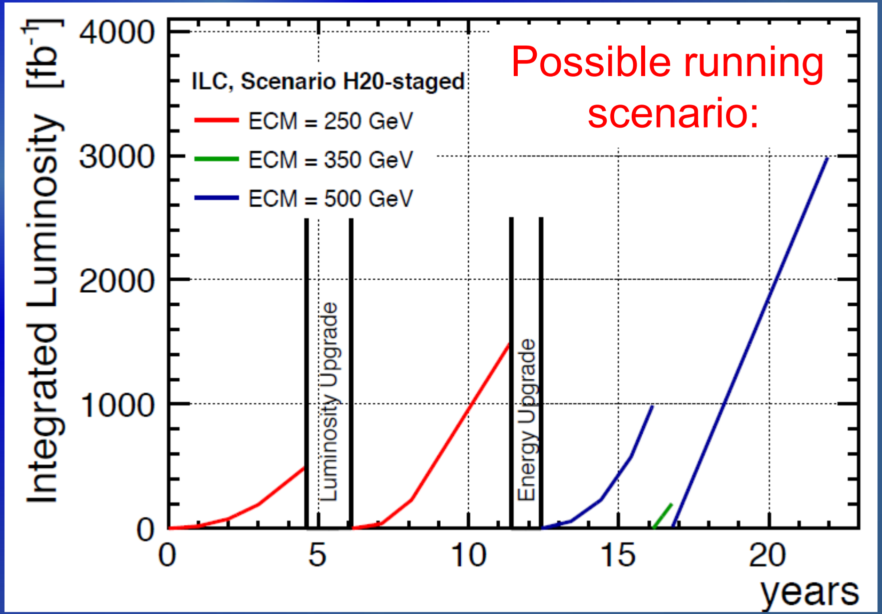
Luminosity:

- Initial design L ~ 1.35 x 10^{34} /cm2/s (400 fb-1 during the first 4 years)
- Upgrade 2.7 x 10^{34} /cm2 /s (doubling number of bunches per pulse – moderate cost (~10%));
- Upgrade 5.4 x 10^{34} /cm2 /s (repetiton rate 5 → 10 Hz (expensive));

Beam polarisation

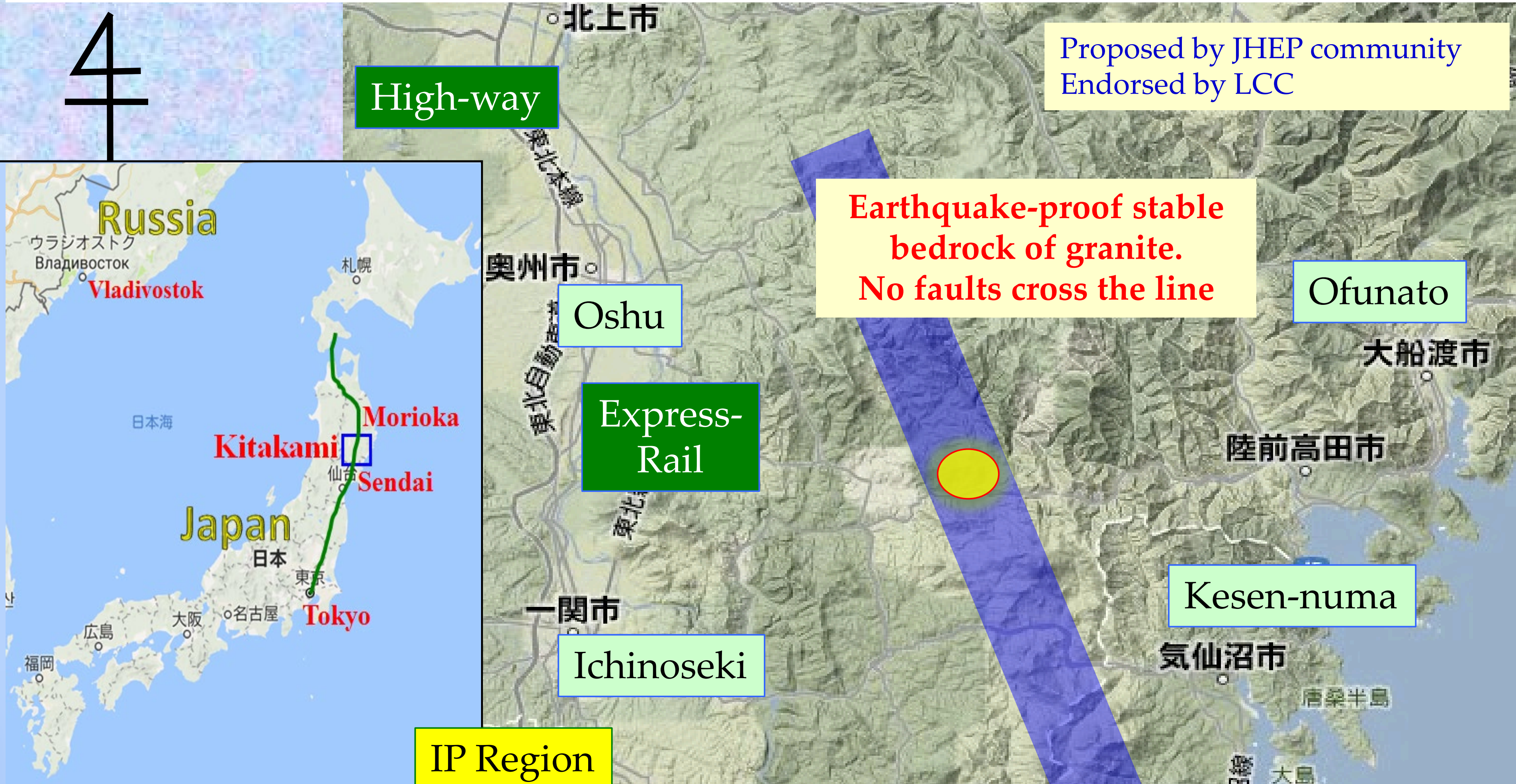
- P(e-) ≥ ±80%
- P(e+) = ±30%, at 500 GeV upgradable to 60%

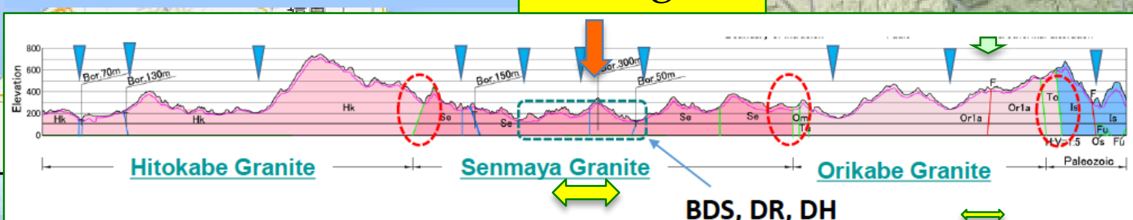




ILC Site Candidate Location in Japan: Kitakami Area

Establish a site-specific Civil Engineering Design - map the (site independent) TDR baseline onto the preferred site - assuming “Kitakami” as a primary candidate

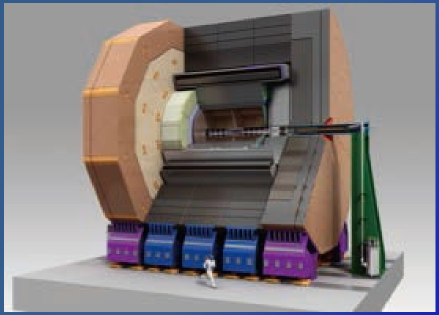


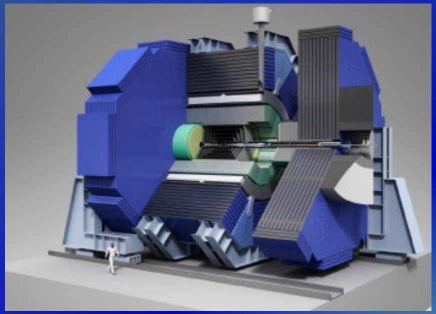


Need to finalize:

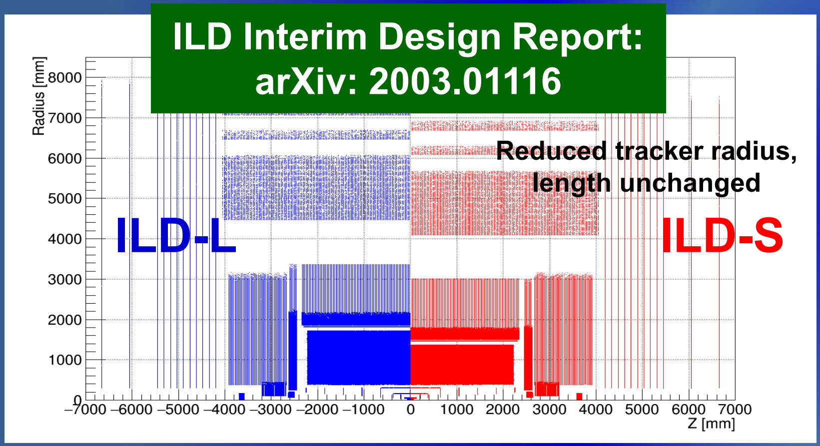
- IP / Linac orientation and length
- Access points and IR infrastructure
- Conventional Facilities and Siting (CFS)

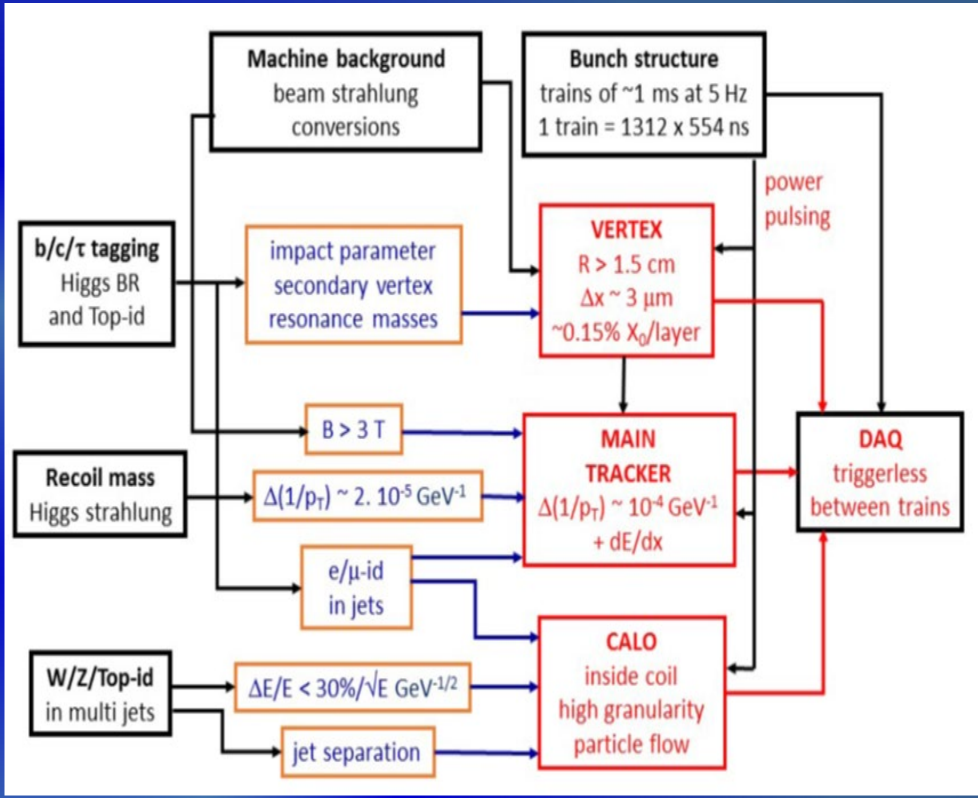
Two Validated Detector Concepts: ILD and SiD





Re-optimisation: Large (L) & small (S) options





ILD_L / ILD_S	SiD
Both optimized for PFA Performance: ~ $B \cdot R_{ECAL,inner}^2$ (two-track separation @ ECAL)	
B = 3.5 T / 4 T	B = 5 T
$R_{ECAL,inner}$ = 1.8 / 1.46 m	$R_{ECAL,inner}$ = 1.27 m
Si + TPC tracking Outer radius: 1.77 / 1.43 m	Silicon Tracking only Outer radius: 1.22 m

ILD vs SiD: Two Tracking Complementary Approaches

Gaseous Tracking (ILD):

- Si + Gaseous Tracking System:

- VXD: long barrel of 3 double layers

  0.3% X_0 / layer, $\sigma_{sp} \lesssim 3\ \mu m$

- Intermediate Si-tracker (SIT, SET, FTD)
  SIT/FTD: silicon pixel sensors (e.g. CMOS)
  SET: silicon strip sensors

- Time Projection Chamber with MPGD-readout
  High hit redundancy (200 hits / track)
  → 3D tracking / pattern recognition;
  → dE/dx information for PID

Silicon Tracking (SiD):

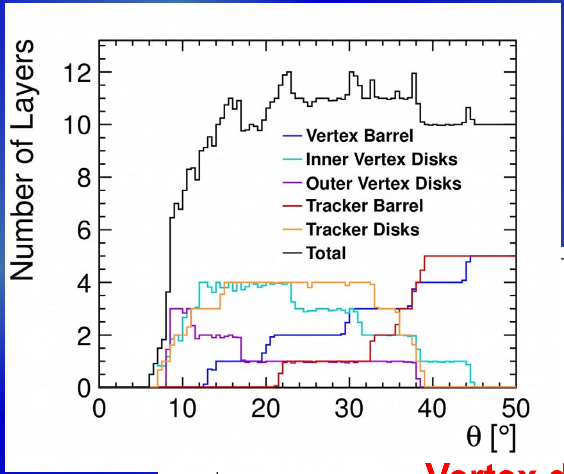
- All Si-Tracking (concept proven by CMS)

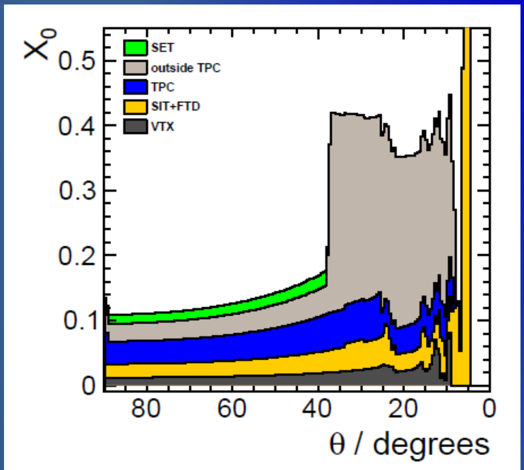
- VXD: short barrel of 5 single layers

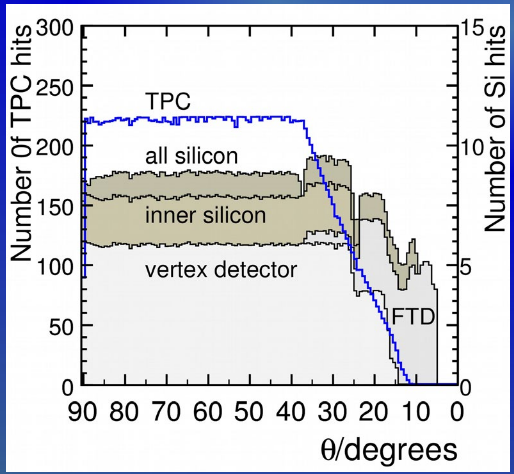
  0.15% X_0 / layer, $\sigma_{sp} \lesssim$ 3-5 μm

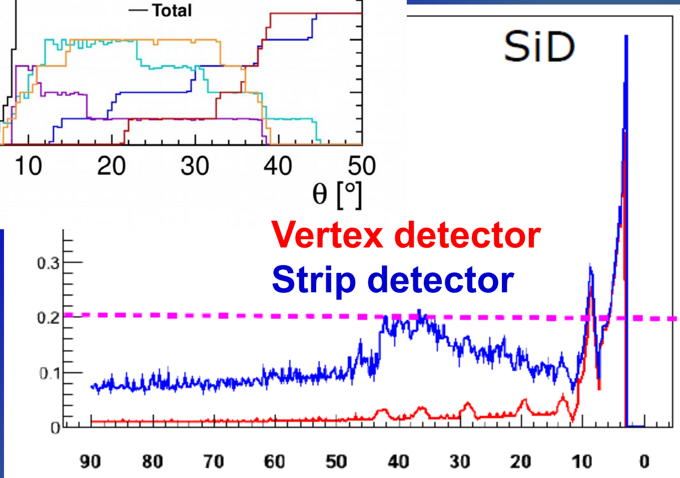
- 5 layers Silicon-strip tracker
  (25um strips, 50 um readout pitch)

- Few highly precise hits (max. 12)
- Robustness, single bunch time stamping









RPC DHCAL

Scintillator ECAL

Collaborations

FCAL

CLICPix

SPiDeR

LCTPC

SOI

DEPFET

ChronoPixel

SDHCAL

LC-TPC

TPAC

RPC Muon

GEM DHCAL

KPIX

Silicon ECAL (ILD)

VIP

Dual Readout

Silicon ECAL (SiD)

CMOS MAPS

Many forms of Linear Collider Detector R&D efforts:

DEPFET Active Pixel Detector

CALICE Calorimeter for ILC

- Large collaborations: CALICE, LCTPC, FCAL
- Collection of many efforts such as vertex R&Ds
- Individual group R&D activities
- Efforts currently not directly included in the concept groups (ILD, SiD, CLICdp), which may become important for LC in future

FPCCD

FCAL Collaboration High precision design

Scintillator HCAL

RPC DHCAL

Scintillator ECAL

Collaborations

FCAL

CLICPix

SPiDeR

LCTPC

SOI

DEPFET

ChronoPixel

SDHCAL

LC-TPC

TPAC

GEM DHCAL

Silicon ECAL (ILD)

Silicon ECAL (SiD)

CMOS MAPS

DEPFET Active Pixel Detector

CALICE Calorimeter for ILC

FPCCD

FCAL Collaboration High precision design

Scintillator HCAL

LINEAR COLLIDER COLLABORATION

Detector R&D Report

FINAL VERSION

doi:10.5281/zenodo.3749461

https://doi.org/10.5281/zenodo.3749461 (DOI:10.5281/zenodo.3749461)

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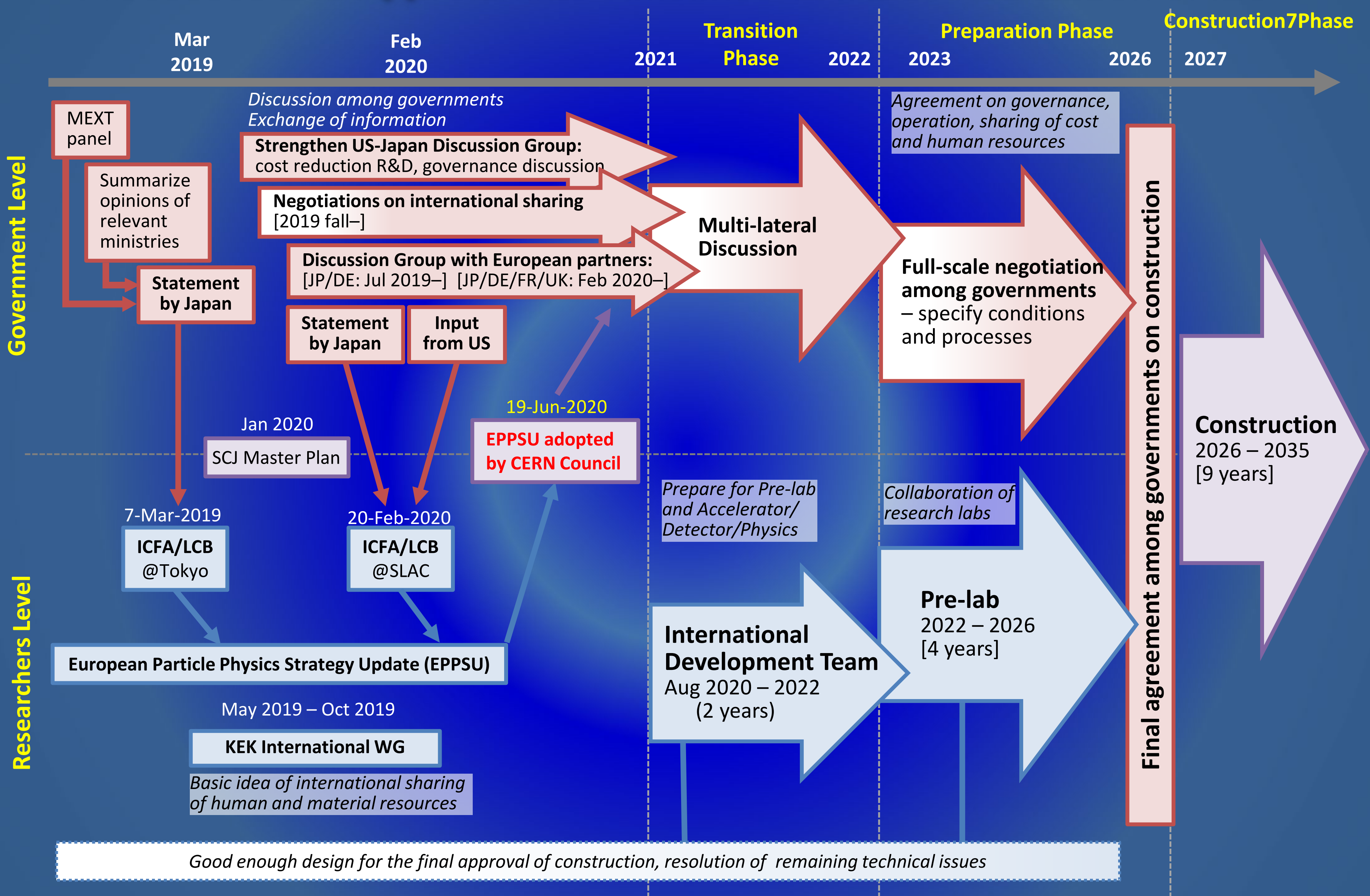
February 2, 2021

LINEAR COLLIDER COLLABORATION
Designing the world's next great particle accelerator

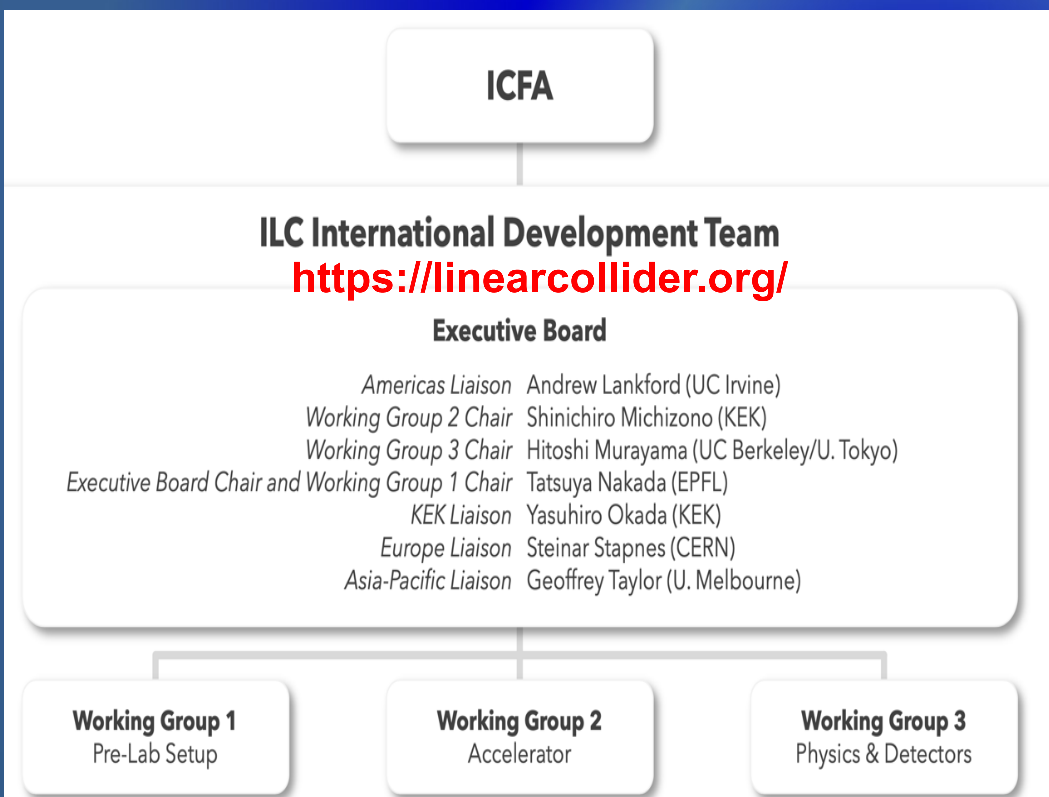
Processes and Approximate Timelines Towards Realization of ILC

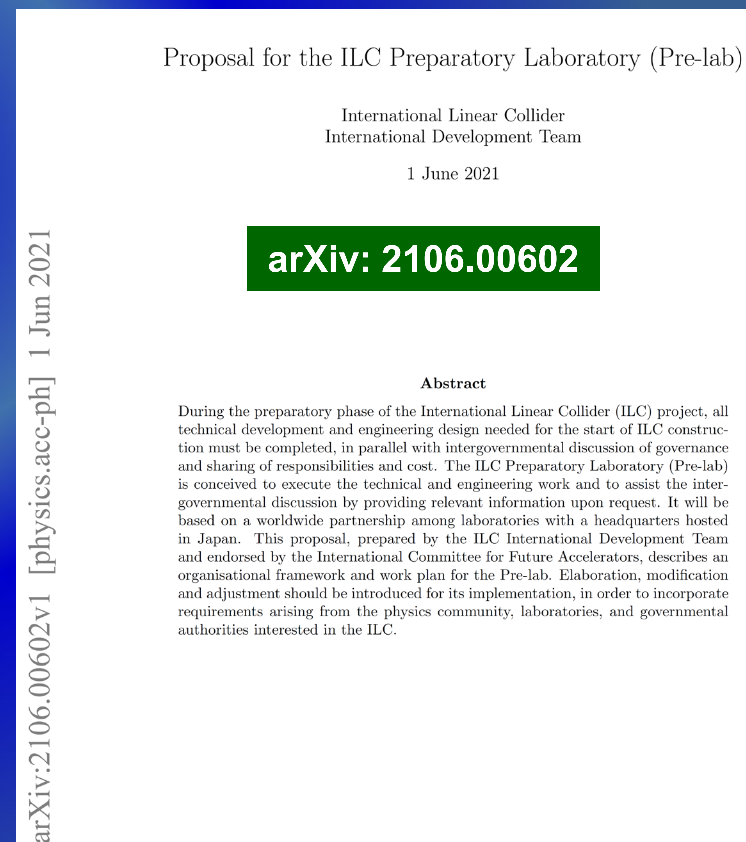


* ICFA: international organization of researchers consisting of directors of world's major accelerator labs and representatives of researchers
* ILC pre-lab: International research organization for the preparation of ILC based on agreements among world's major accelerator labs such as KEK, CERN, FNAL,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

International Development Team (IDT) Goals for 2021-2022

- ✓ Establish a preliminary list of the ILC Pre-lab tasks and deliverables (through WG2) and national/regional laboratories which might be interested in contributing to those;
- ✓ Establish Pre-lab resources needs for the regional activities and central office (a few % of ILC cost);
- ✓ Prepare a preliminary proposal for the ILC Pre-lab organization and governance:
- ✓ Finalise all the inputs needed to set-up the Pre-lab;





Proposal for the ILC Preparatory Laboratory (Pre-lab)

International Linear Collider
International Development Team

1 June 2021

arXiv: 2106.00602

arXiv:2106.00602v1 [physics.acc-ph] 1 Jun 2021

Abstract

During the preparatory phase of the International Linear Collider (ILC) project, all technical development and engineering design needed for the start of ILC construction must be completed, in parallel with intergovernmental discussion of governance and sharing of responsibilities and cost. The ILC Preparatory Laboratory (Pre-lab) is conceived to execute the technical and engineering work and to assist the intergovernmental discussion by providing relevant information upon request. It will be based on a worldwide partnership among laboratories with a headquarters hosted in Japan. This proposal, prepared by the ILC International Development Team and endorsed by the International Committee for Future Accelerators, describes an organisational framework and work plan for the Pre-lab. Elaboration, modification and adjustment should be introduced for its implementation, in order to incorporate requirements arising from the physics community, laboratories, and governmental authorities interested in the ILC.

IDT - WG1: Approximate Timeline of the ILC Realisation

Pre-preparatory Phase		Main Preparatory Phase		Construction Phase	
2020.8	(2022)	About 4 years	(2026)	About 9 years	(2035)
LCB/LCC	International Development Team	ILC Pre-Lab		ILC Laboratory	

ILC IDT (~2 years):

- Prepare the work and deliverables of the ILC Pre-laboratory and work out, with national and regional laboratories, a scenario for their contributions;
- Prepare a proposal for the organisation and governance of the ILC Pre-laboratory;

ILC Pre-laboratory (~4 years)

- Complete all the technical preparation necessary to start the ILC project (infrastructure, environmental impact and accelerator facility) :
- Prepare scenarios for the regional contributions to and organisation for the ILC;

ILC laboratory

- Construction and commissioning of the ILC (~9-10 years);
- Followed by the operation of the ILC;
- Managing the scientific programme of the ILC;

Positive "signs" from the host country (Japan) government and agreements by the national/regional laboratories for providing their contributions

Positive « outcomes « of the inter-governmental negotiations for the responsibility and cost sharing among the host (Japan) and partner countries

Set up four WG1 subgroups:

i. Pre-Lab organization
ii. Preferred legal base for the Pre-Lab
iii. Necessary condition to start the Pre-Lab
iv. Process to start the Pre-Lab

Members of IDT Working Group 1

Paul Collier	CERN	Switzerland
Bruce Dunham	SLAC	United States
Eckhard Elsen	DESY	Germany
Brian Foster	U. Oxford	United Kingdom
Juan Fuster	IFIC – U. Valencia	Spain
Stuart Henderson	Jefferson Lab	United States
Reiner Kruecken	TRIUMF	Canada
Joseph D. Lykken	Fermilab	United States
Maksym Titov	Irfu – CEA/Saclay	France
Satoru Yamashita	U. Tokyo	Japan

IDT – WG2: Technical Preparation Document

IDT-WG2 summarized the technical preparation as Work Packages (WPs) for the Pre-Lab stage in the Technical preparation Document

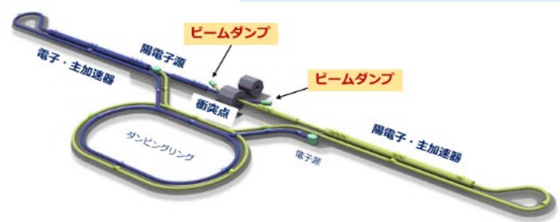
Actual cavity /CM manufacturing

ILC Pre-lab

- ***SRF*** ~41MILCU, 285 FTE-yr
  - WP-1 Cavity production
  - WP-2 Cryomodule assembly
  - WP-3 Crab cavity
- ***e- source*** ~2.5MILCU, 6 FTE-yr
  - WP-4 Electron source
- ***e+ source*** ~6MILCU, 15FTE-yr
  - ***Undulator scheme***
    - WP-5 Undulator
    - WP-6 Rotating target
    - WP-7 Magnetic focusing
  - ***e-Driven scheme***
    - WP-8 Rotating target
    - WP-9 Magnetic focusing
    - WP-10 Capture cavity
    - WP-11 Target replacement
- ***DR*** ~2.5MILCU, 30FTE-yr
  - WP-12 System design
  - WP-13 Collective effect
  - WP-14 Injection/extraction
- ***BDS*** ~2MILCU, 16FTE-yr
  - WP-15 Final focus
  - WP-16 Final doublet
- ***Dump*** ~3MILCU, 12FTE-yr
  - WP-17 Main dump
  - WP-18 Photon dump

SRF technology is energy-efficient, and its applications are increasing around the world.
These WPs will contribute to the promotion of SRF accelerators in each region.

For detail,
http://doi.org/10.5281/ zenodo.4742018



- The technical preparation document was reviewed by the international review committee (chair:Tor Raubenheimer (SLAC)).
- The total global cost of the project is about 60 MILCU and about 360 FTE-year. (This does not include the cost of the infrastructure for the WPs.)
- The cost will be shared internationally as in-kind contribution.

ILC - WG3: Physics and Detectors Timeline

- ✓ Oct. 25-29, 2021: ILC Workshop on Potential Experiments (ILCX2021)
- ✓ 2022-2023: The **IDT calls for EoIs,** to be presented in a workshop after Pre-lab start
- ✓ 2022-2023: Potential start of the Pre-lab. EoI presentations in dedicated workshop. The process of moving from EoI presentations towards LoI documents is community driven. Initial dedicated ILC R&D funds will be needed.
- ✓ **2023: LoI submissions and presentations.** The ILCXAC will initiate its evaluation of the LoIs. R&D continues.
- ✓ **2024: ILCXAC recommendations of initial ILC experiments to proceed towards TPs.** R&D towards the TPs.
- ✓ **2025: TP submissions and presentations**. Continuation of R&D and recommendations by the ILCXAC based on the submit-ted TPs.
- ✓ **2026-27: Approval of the experiments,** based on the TP and ILCXAC recommendations, by a committee set up by the ILC Laboratory. Recommendations to proceed towards Technical Design (TDR) Reports. Funding requests for construction are being prepared.
- ✓ **2027: The ILC laboratory allows construction to start** and construction funding spending for experiments or experimental subsystems based on TDRs approvals.

"ILC as a Global Project"
→ international project, led by Japanese initiative

- Today, ILC is technically sound and is the only mature technology for future accelerator, ready for construction start

- Staged ILC offers excellent science from first stage (250 GeV) → higher energy upgrades will extend physics program → All LHC scenarios leave a compelling ILC discovery potential

Important conditions for ILC realization:

- Reach common understanding of the ILC Laboratory ("a-la CERN-II') and model of cost-sharing between Japan (and Asia), US and Europe
- Global Context → ILC has to be Coexisting and Synergistic with CERN
- Create a Basis for International Cooperation in the Industrial Sector

Tentative timeline for the ILC Project:

→ Commissioning mid-2030