The International Linear Collider

Prospects and (possible) timeline

Joachim Mnich

LCWS 2018

Arlington, USA, 24 October 2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Outline

The International Linear Collider (ILC)

The European XFEL – a „10% prototype“ for ILC

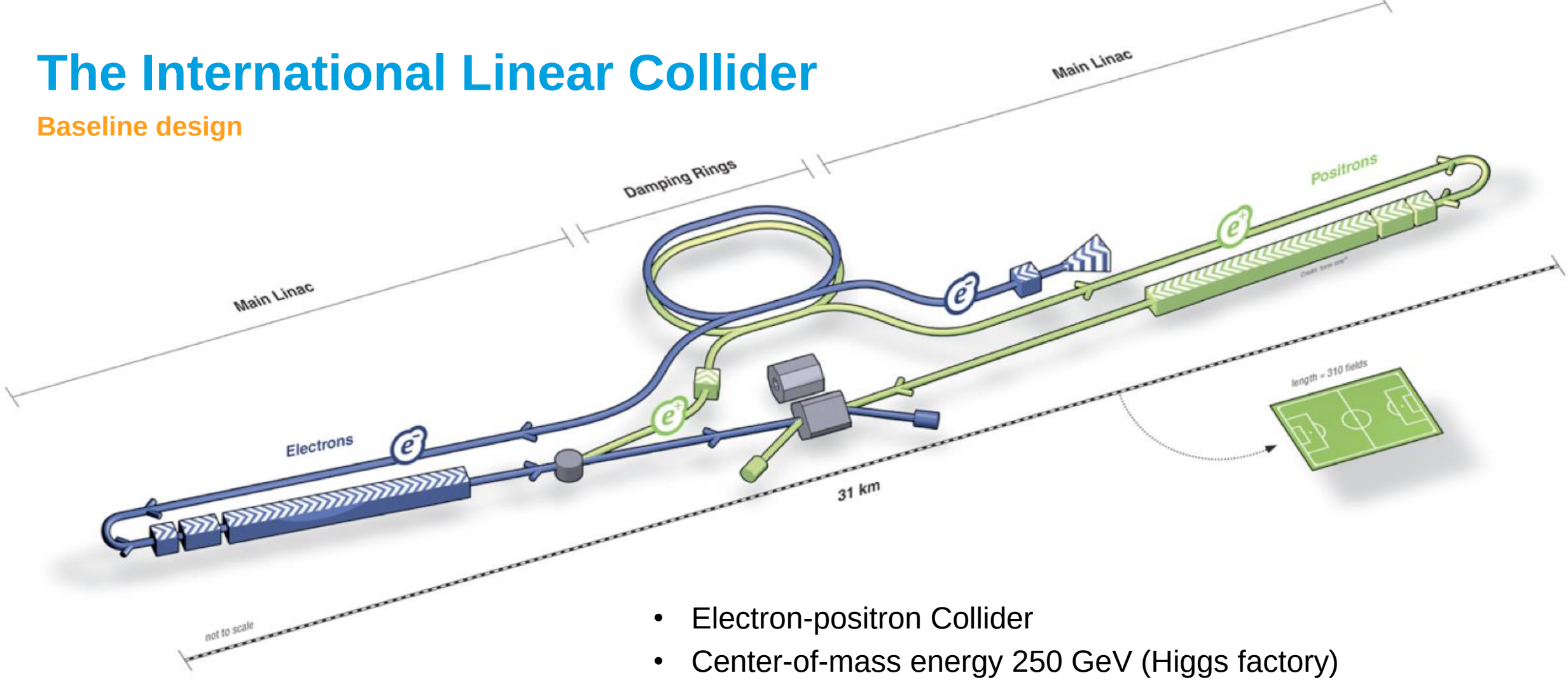
ILC – International Support

ILC – Status, Model and Possible Timeline

The International Linear Collider

The International Linear Collider

Baseline design



- Electron-positron Collider
- Center-of-mass energy 250 GeV (Higgs factory)
  Extendible to higher energies
- Based on superconducting RF niobium cavities
- Developed in an international framework
  Technical Design Report published 2012

The ILC Physics Case

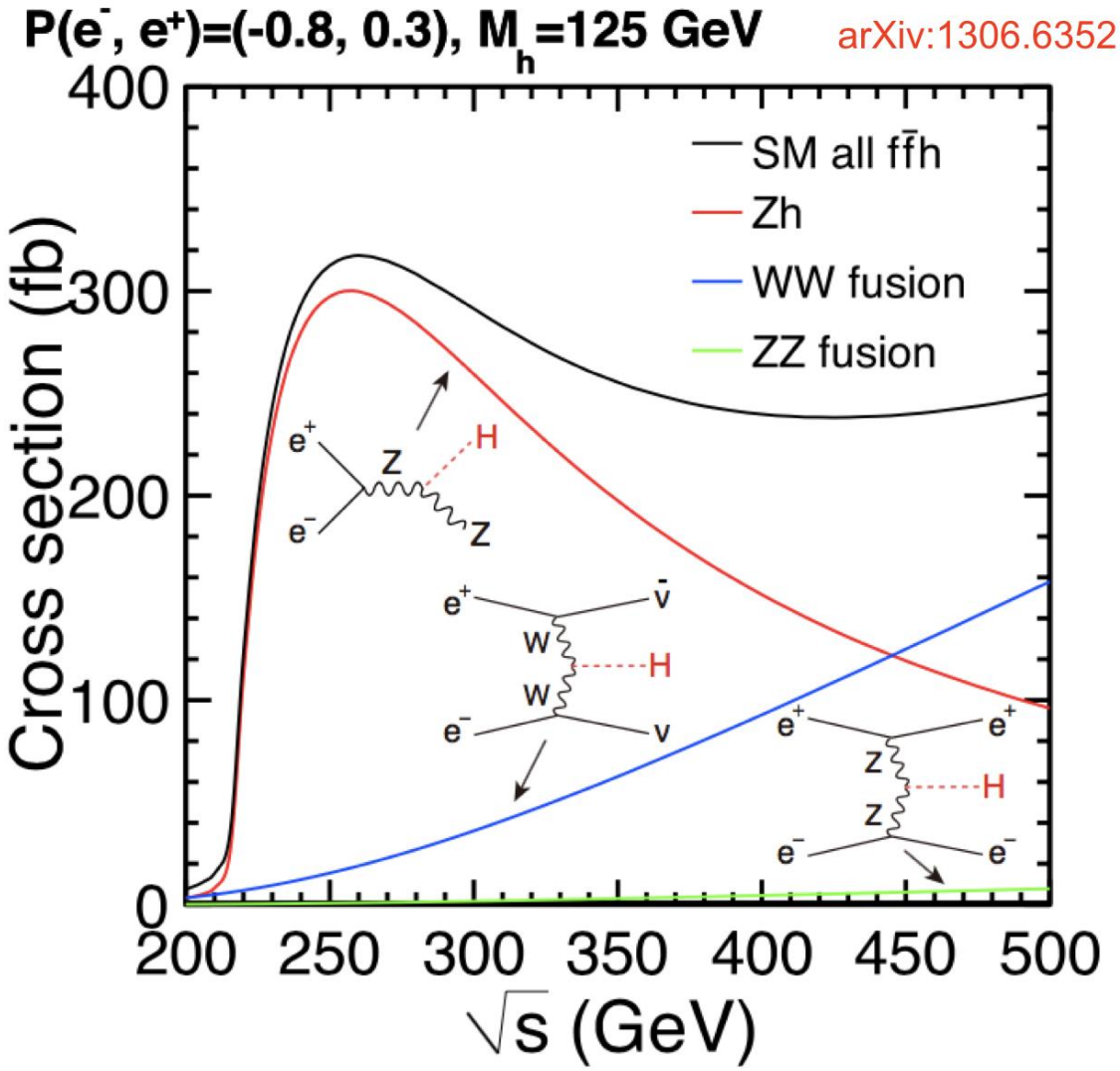
Higgs, top, BSM

ILC: a rich physics programme @ 250, 500, 1000 GeV
Higgs precision physics, top-quark physics, physics beyond the standard model

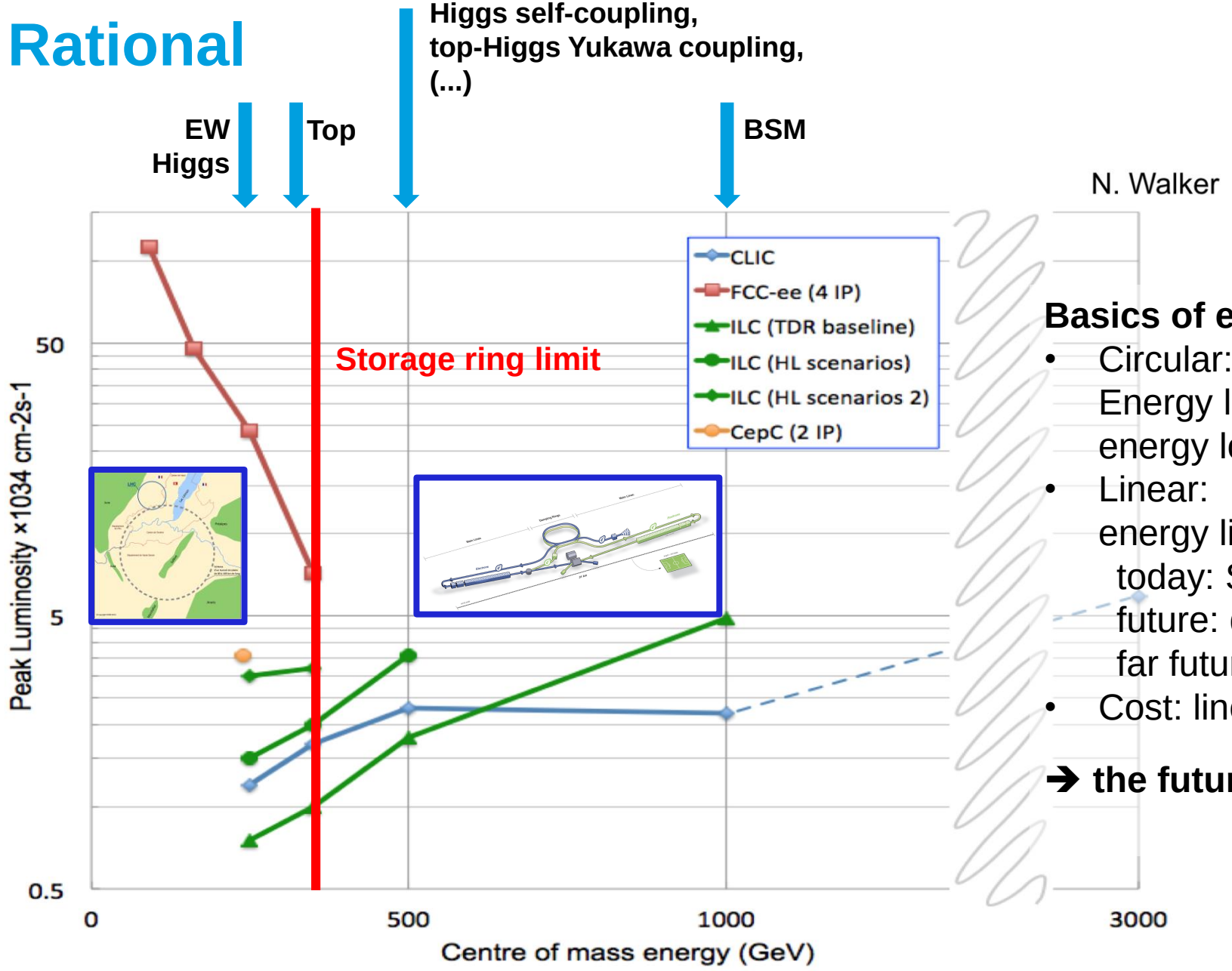
Discovery of a Higgs boson in 2012
Centennial event in particle physics; Nobel prize in 2013
Opening a new window into physics beyond the known
Use the new particle and its interactions as a handle

So far absence of new physics at the LHC
➔ precision is key to BSM physics; deviations of e.g. SM Higgs couplings are O(%); cannot be done at hadron collider!

The ILC is a Higgs factory at all energies!
At 250 GeV: Very clean and easy to reconstruct HZ final state.
Precision access to many Higgs properties



ILC Rational



Basics of electron-positron colliders:

- Circular:
  Energy limited by fundamental physics;
  energy loss $\propto E^4$
- Linear:
  energy limited by acceleration gradient
  today: SCRF O(35 MeV/m)
  future: drive beam O(100 MeV/m)
  far future: plasma accel. O(>GeV/m)
- Cost: linear $\propto E$; circular $\propto E^2$

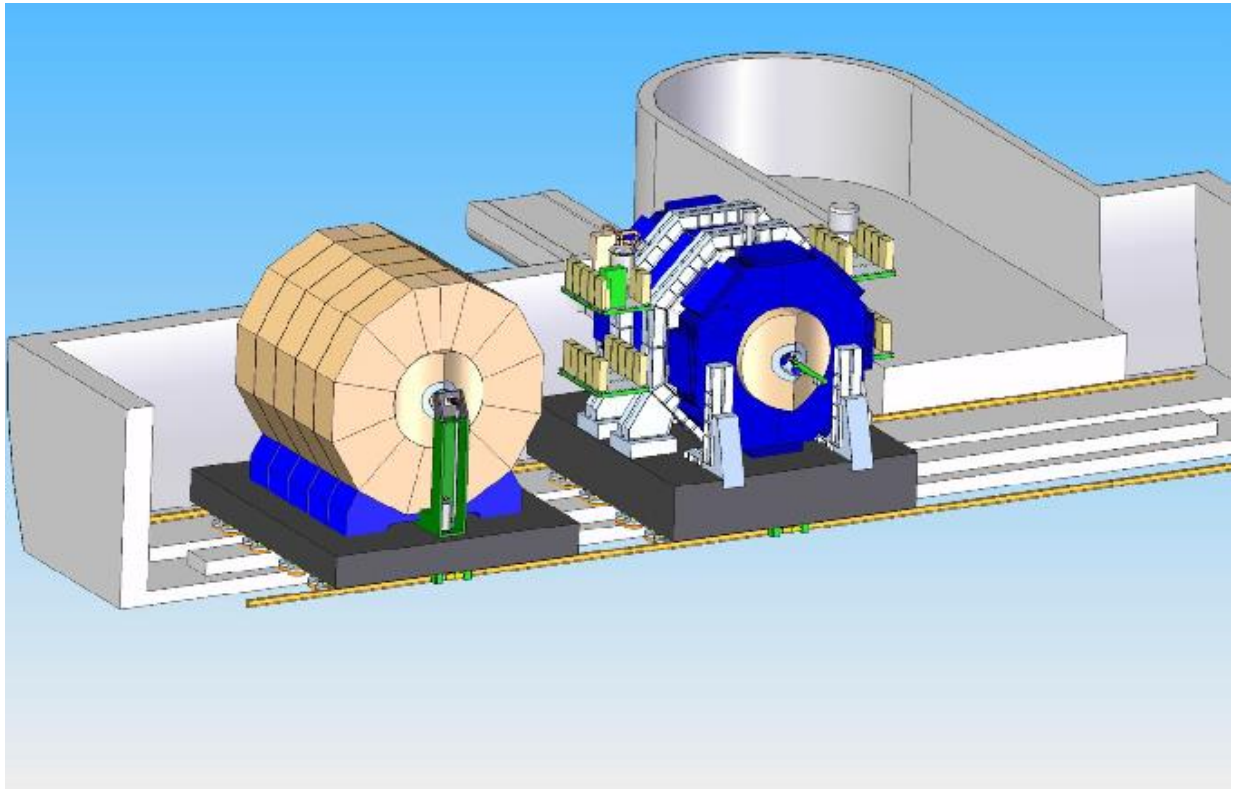
➔ **the future must be linear!**

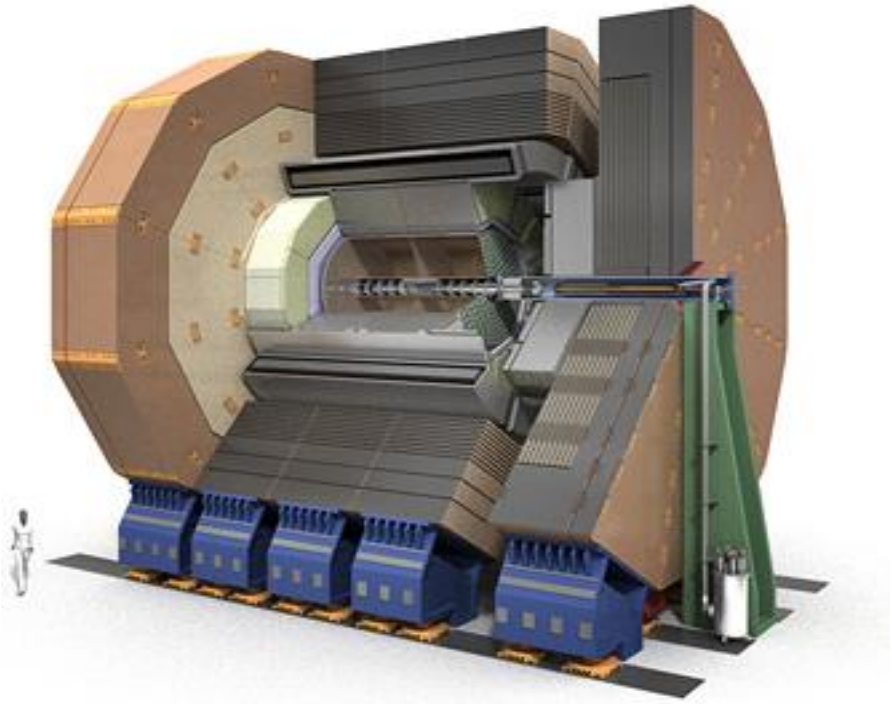
The International Linear Collider

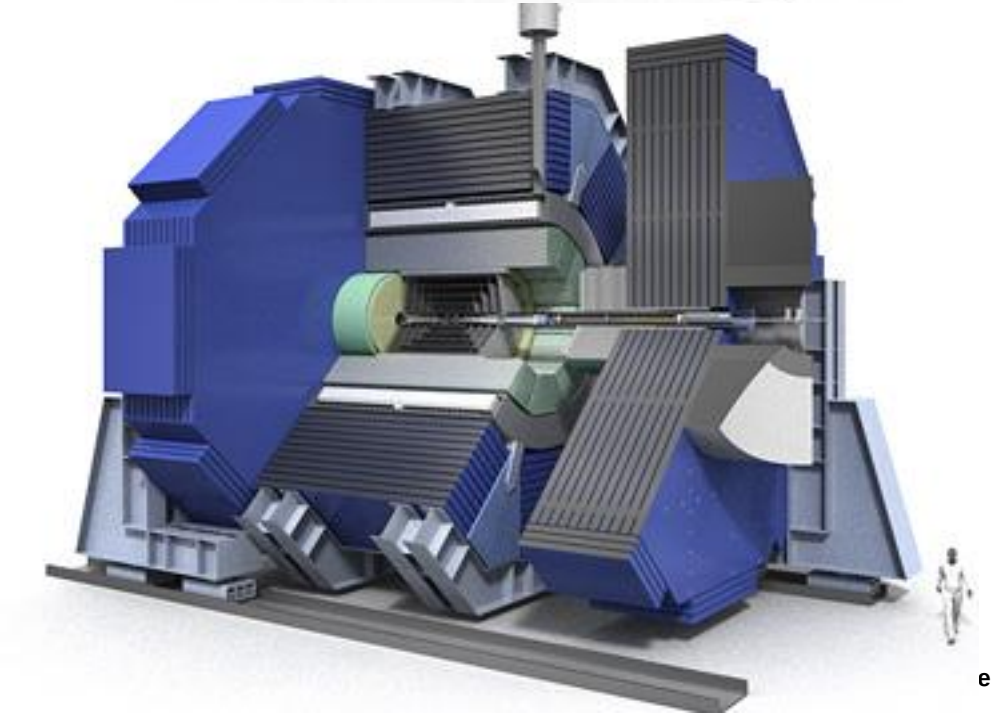
In the Kitakami mountain region in Tohoku, Iwate prefecture

ILC Detectors: ILD and SiD

Push-pull configuration







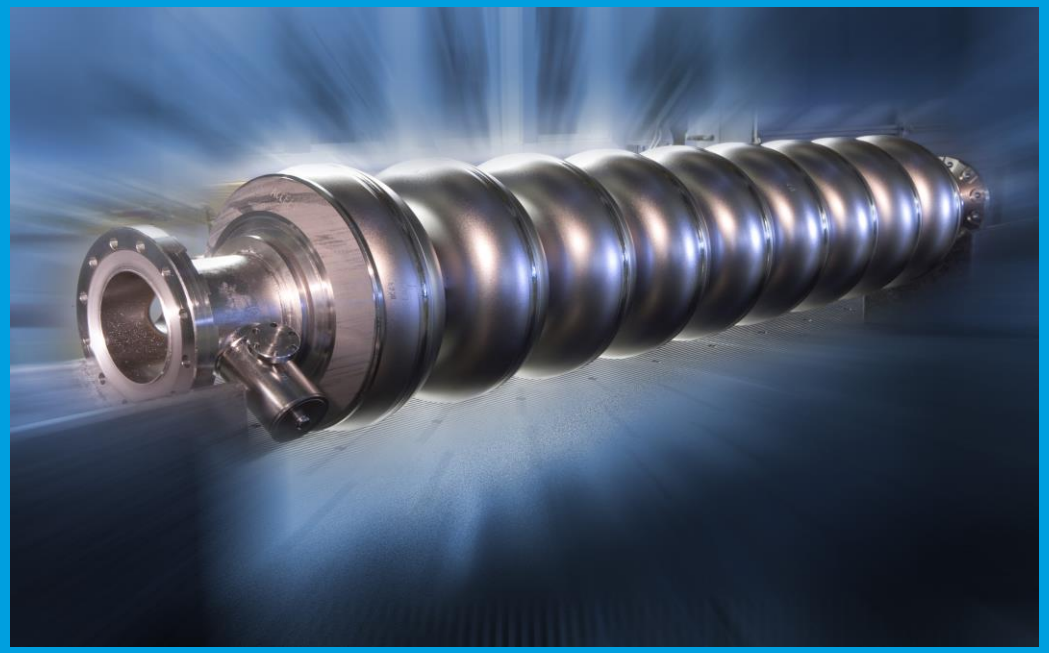
So far: two detector concept groups

- Foresee push-pull operation in one experimental cavern
- ILD: TPC-based tracking
- SiD: all-silicon solution

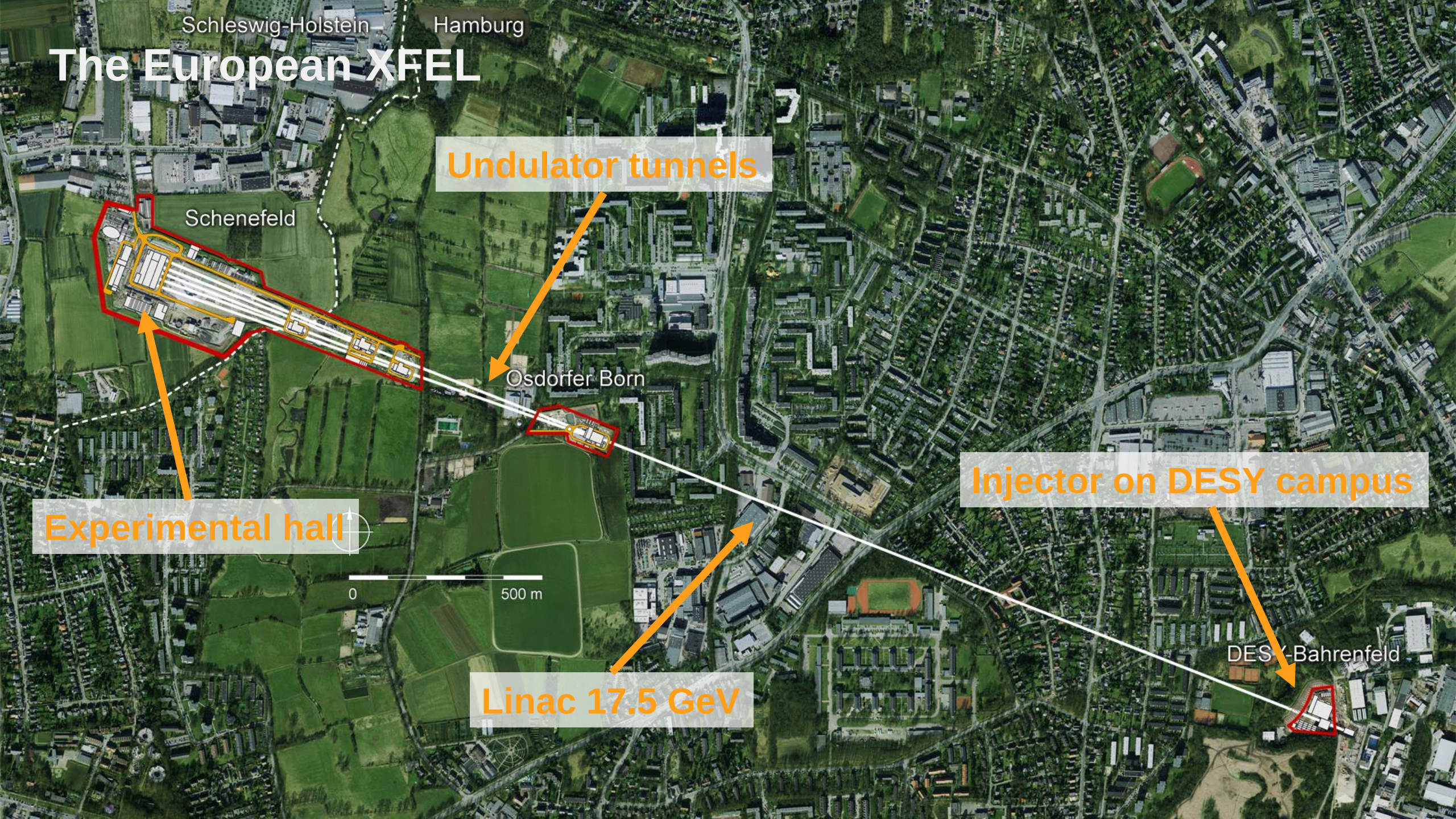
The European XFEL

The brighest X-ray light source in the world

Superconducting cavities – the heart of the linac



European XFEL:	800 cavities build by 2 European companies in 100 cryomodules a 10% prototype of the ILC!
ILC (250 GeV)	≈ 8.000 cavities ≈ 900 cryomodules


Schleswig-Holstein
Hamburg
The European XFEL
Undulator tunnels
Schenefeld
Osdorfer Born
Experimental hall
Injector on DESY campus
0
500 m
Linac 17.5 GeV
DESY-Bahrenfeld

The European XFEL

Magnets	103 dipoles, 495 quads, 59 multipoles, 403 correctors, 103 quad-movers, 2 solenoids
Modules	101 x 1.3 GHz, 1 x 3.9 GHz, 27 RF stations
Diagnostics	457 BPMs, 64 imaging stations, 36 toroids, 9 dark-current monitors, 7 beam arrival monitors, 4 beam halo monitors, 4 bunch compression monitors, 4 elector optical monitors, 3 coherent radiation detectors, 3 Faraday cups
Fast devices	34 kicker magnets, 3 transverse deflecting structure
Undulators	1 laser heater undulator, 91 SASE undulator segments
Vacuum	About 4200 m of cold & warm beam vacuum, collimators, beam stops, …
And many more ……	

The currently longest super-conducting accelerator in the world

The European XFEL

History

2000:

First laser light (109 nm) at the Tesla Test Facility (TTF);
today known as FLASH

2001 / 2002 / 2006:

TESLA Linear Collider TDR with XFEL Appendix (2001)
TESLA TDR Supplement with stand-alone XFEL (2002)
European XFEL TDR (2006)

2009:

Foundation of the European XFEL GmbH
Start civil construction

2010:

Foundation of the **Accelerator Consortium**
16 institutes coordinated by DESY

2012:

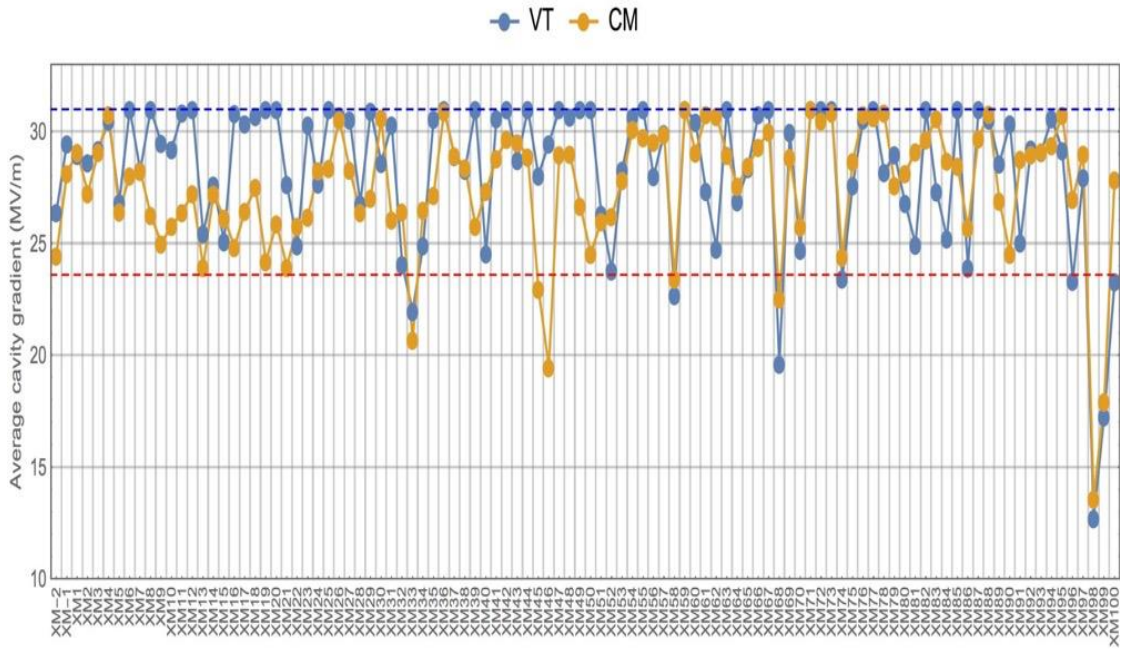
Tunnel finished
Start infrastructure installation

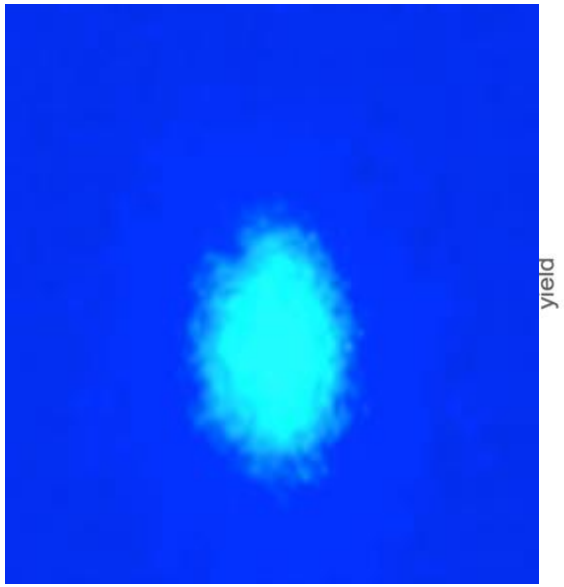
2016:

Accelerator finished
Start commissioning with cool down

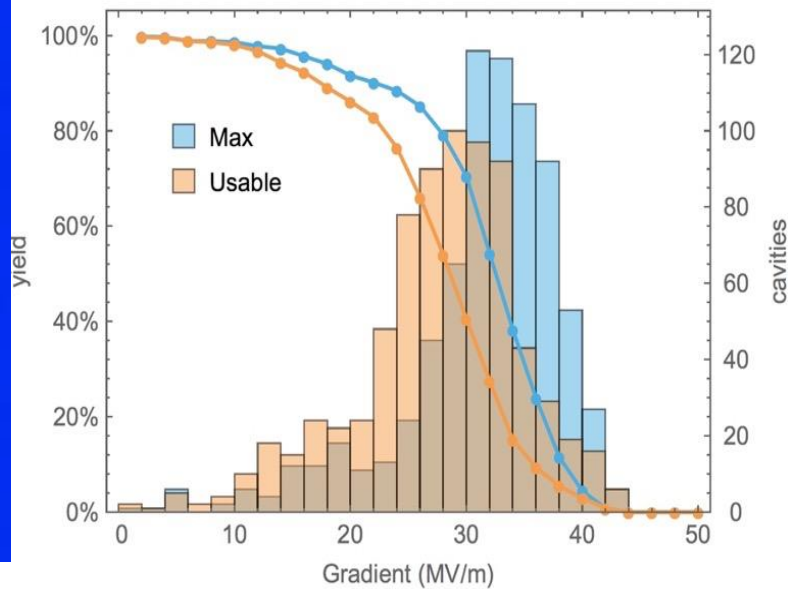
European XFEL Cavity / Module Performance

Process and results





N. Walker



Cavity and cryomodule tests for XFEL

- Tests of cavities („VT“) up to 31 MV
- Cryomodule tests („CM“)
- XFEL specifications easily achieved; extrapolation to ILC possible.

First lasing: May 2017

- User operations have started
- So far three beamlines
- Design energy achieved on 12 July 2018

ILC goal:

- 31.5 MeV/m @ 90% yield
- XFEL: 23.6 MeV/m
- Shown: „As received“ tests of XFEL cavities

XFEL cryomodule production

From: N. Walker

HP coupler production

Thales-RI

CPI

Coupler Processing (LAL)

Module Assembly (CEA Saclay)

Aperam / MecaMagnetic

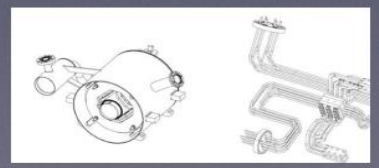
Magnetic shields

JEHIER

Multilayer insulation

CIEMAT

SC quad production



Niobium production

Tokyo Denkai

Ningxia

(Plansee)

Nb sheet QA/QC

Vertical test (AMTF, IFJ-PAN)

Cryostat QA/QC

SC magnet testing

Module test (AMTF, IFJ-PAN)

DESY

XFEL tunnel

INFN-Milan

ZANON

RI

Cavity production

IHEP

ZANON

Cryostat production

Not shown:

- cavity tuners
- BPMs
- Cavity bellows
- HOM absorberts

Production rate: 1 cryomodule / week

ILC – International Support

ICFA

And the ICFA mandate

ICFA: International Committee for Future Accelerators

Created in 1976 by the International Union of Pure and Applied Physics (IUPAP)

Mandate:

- **promote international collaboration on very high energy accelerators**
- **organize regularly world-inclusive meetings for the exchange of information on future plans**
- **organize workshops for the study of problems related to super high-energy accelerators**

ICFA is the recognised body to represent high energy physics on a global scale. Its aim is to facilitate international collaboration in the planning, construction and exploitation of accelerators for high energy physics and related fields.

HEP as a Global Endeavour

Towards a global strategy?

New machines are multi-billion Euro enterprises

- There will only be one of a kind
- Need international consensus

Co-ordinated strategy processes worldwide

- Last round concluded 2013.
- Different flavours in different regions of the world
- But looks like an emerging global, coherent strategy with ILC as high priority project

Next update of European strategy 2020 (see later slide); US to follow 2-3 years after.

Japan: Future HEP Projects
– „... Japan should take the leadership role in an early realisation of an e+e- linear collider.“

Update of European Strategy for by CERN Council (May 2013)
– LHC, incl. HL-LHC
– accelerator R&D
– strong support for ILC
– importance of theory

European Strategy for Particle Physics

USA: Snowmass conclusions and recommendations to P5 in line with worldwide strategy statements

ICFA and the ILC

... Since the 1990s

ICFA has been supporting and closely following the efforts for a linear electron-positron collider for many years

2002: ICFA created the International Linear Collider Steering Committee (ILCSC) to promote the construction of an electron-positron linear collider through world-wide collaboration

2003: ICFA created the International Technology Recommendation Panel (ITRP).

2005 : ICFA set up Global Design Effort (GDE) to produce an ILC design and its cost

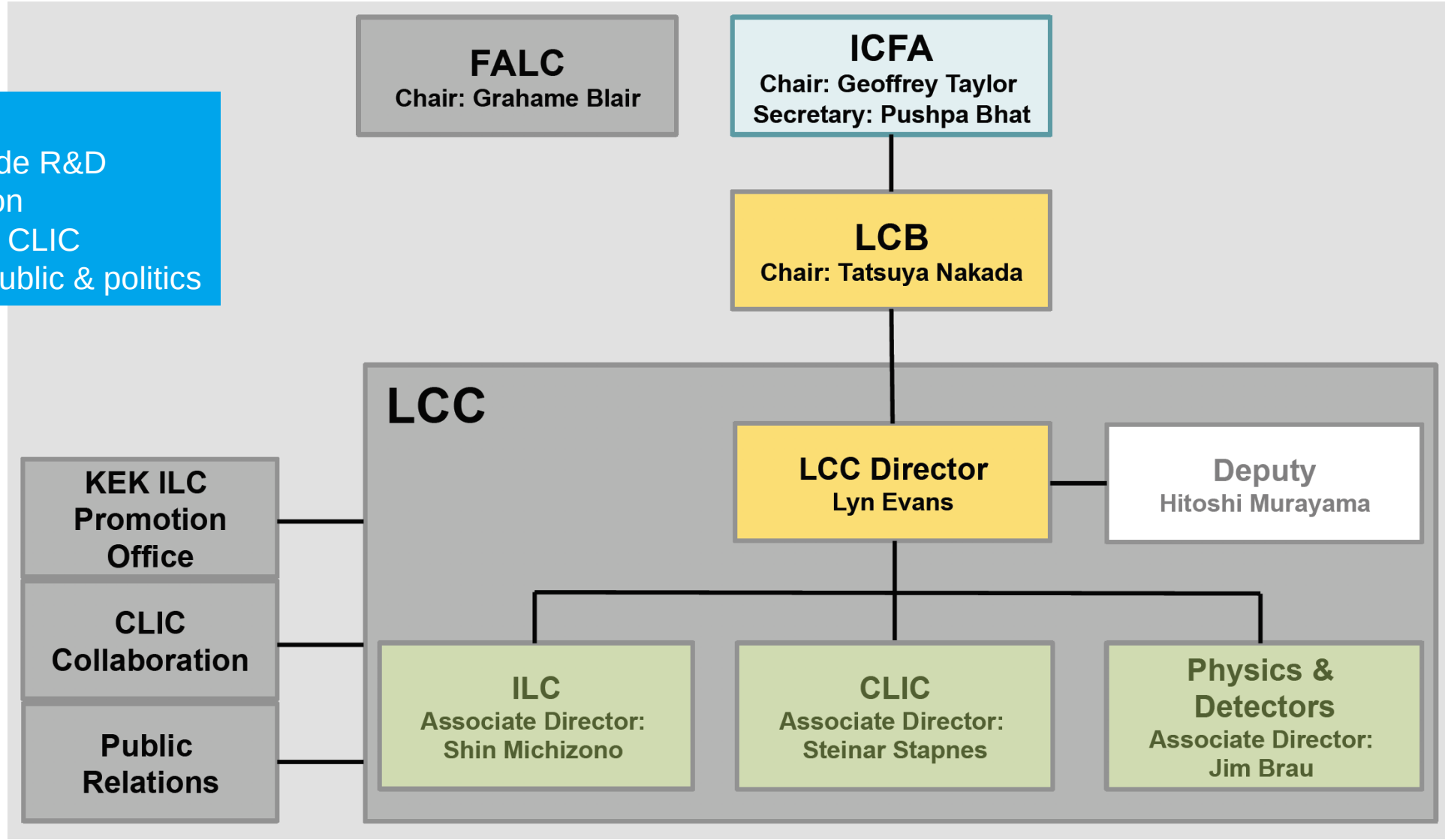
June 2013: Technical Design Report completed, including detectors, with costs

2013: ILCSC ended; Linear Collider Board (LCB) formed by ICFA, to oversee the Linear Collider Collaboration (LCC)
Note: this structure includes ILC and CLIC

ICFA

And the Linear Collider Board (LCB)

Tasks:
- Oversee worldwide R&D
- Keep collaboration between ILC and CLIC
- Promote ILC in public & politics



The Latest ICFA Statement on the ILC-250

Ottawa, November 2017

ICFA Statement on the ILC Operating at 250 GeV as a Higgs Boson Factory

The discovery of a Higgs boson in 2012 at the Large Hadron Collider (LHC) at CERN is one of the most significant recent breakthroughs in science and marks a major step forward in fundamental physics. Precision studies of the Higgs boson will further deepen our understanding of the most fundamental laws of matter and its interactions.

The International Linear Collider (ILC) operating at 250 GeV center-of-mass energy will provide excellent science from precision studies of the Higgs boson. Therefore, ICFA considers the ILC a key science project complementary to the LHC and its upgrade.

ICFA welcomes the efforts by the Linear Collider Collaboration on cost reductions for the ILC, which indicate that up to 40% cost reduction relative to the 2013 Technical Design Report (500 GeV ILC) is possible for a 250 GeV collider.

ICFA emphasizes the extendibility of the ILC to higher energies and notes that there is large discovery potential with important additional measurements accessible at energies beyond 250 GeV.

ICFA thus supports the conclusions of the Linear Collider Board (LCB) in their report presented at this meeting and very strongly encourages Japan to realize the ILC in a timely fashion as a Higgs boson factory with a center-of-mass energy of 250 GeV as an international project[1], led by Japanese initiative.

Statements on the ILC

From Europe, the US …

Germany („KET, own translation“): An e+e- collider shall be realised with highest priority, extendable to at least 500 GeV. ... We strongly support the Japanese initiative to realise the ILC as a Higgs factory with an initial energy of 250 GeV as an international project in Japan.

France: Strong interest for the ILC; very serous experience with the European XFEL and with detector R&D

Italy (INFN White Paper „What next?“, 2105): CSN1 supports INFN participation in studies and R&D related to future colliders. Our community must be part of the planning of the future.

US (J. Siegrist, Associate Director for HEP, DoE, May 2018): US looks forward to a decision this year by Japan to host the ILC as an international project. DoE efforts focused on cost reduction ...

US (Under-secretary Paul Dabbar, Kitakami Times 17 Oct 2018): „I hope for the Japanese government to proactively appraise the ILC project and move it forward.“

European Strategy 2013

European strategy update 2013 – outcome

a) *Europe should preserve this [European organisational] model in order to keep its leading role, sustaining the success of particle physics and the benefits it brings to the wider society.*

b) *The European Strategy takes into account the worldwide particle physics landscape and developments in related fields and should continue to do so.*

c) *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030.*

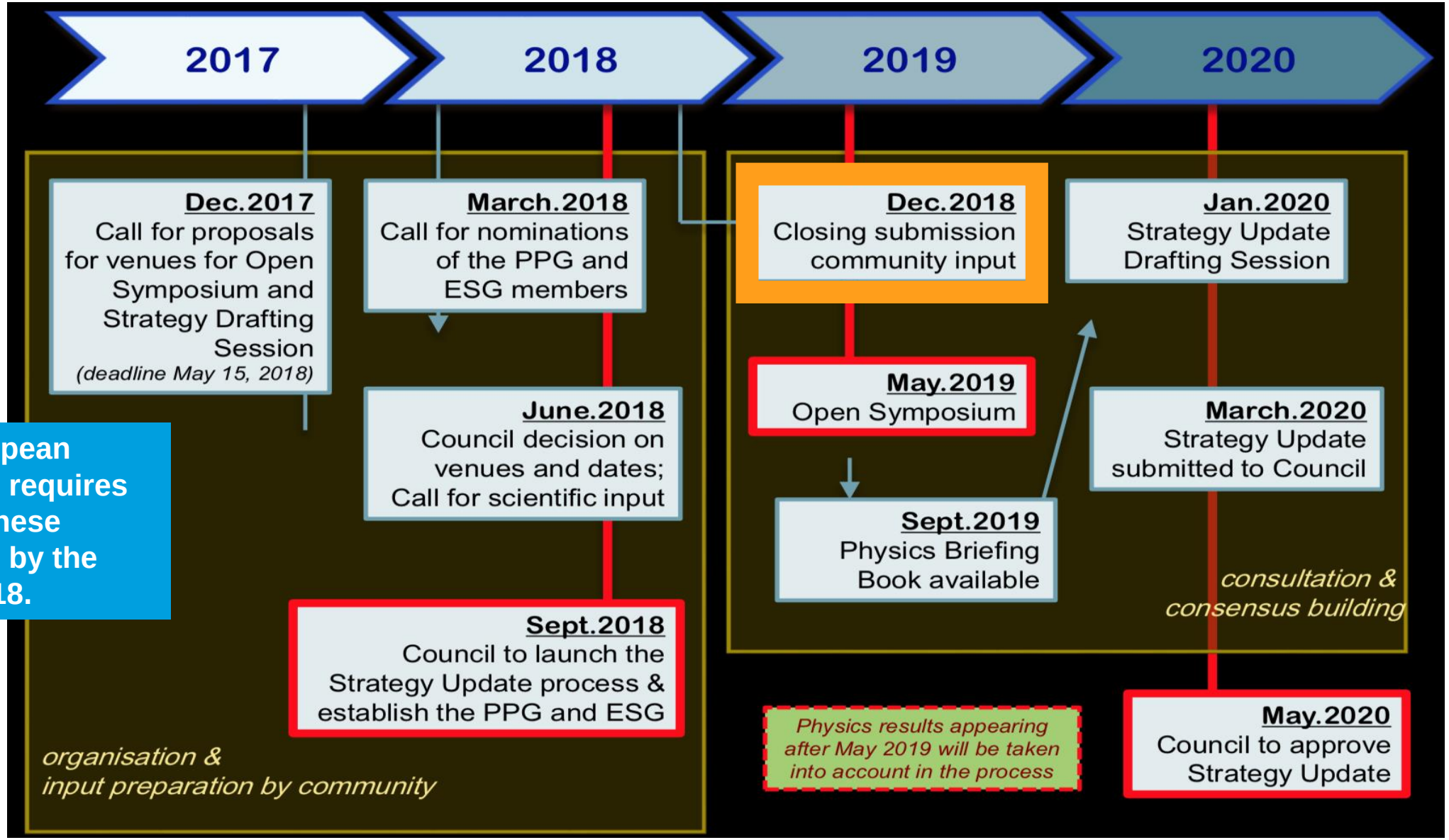
d) *CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures […]*

e) *There is a strong scientific case for an electron-positron collider, complementary to the LHC … The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. Europe looks forward to a proposal from Japan to discuss a possible participation.*

f) *CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.*

The Update of the European Strategy

Timeline



Firm European statement requires firm Japanese statement by the end of 2018.

ILC – Status, Model and Possible Timeline

Recent ILC Costing

„Summary of the ILC Advisory Panel‘s Discussions to Date after Revision“

Costing of an ILC-250

Assumption 100 ¥ = 1$, 115¥ = 1€; uncertainty 25%

Accelerator in total: 6.35-7.03 G$; thereof

1.11-1,29 G$ civil engineering / construction

4.04-4.54 G$ accelerator material

1.20 G$ institutional labour (personnel in labs)

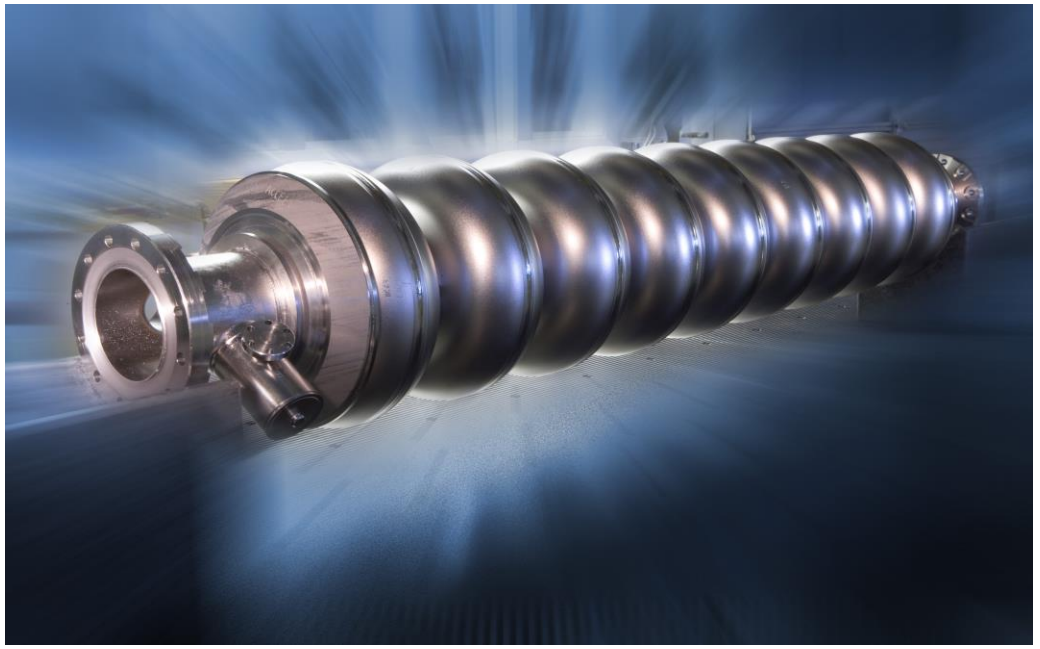
Detectors: 1.00 G$

0.77 G$ construction

0.24 G$ labour

Annual operations cost 366-392 M$/a

Costs in preparation phase: 233 M$ - without land purchase



A Realization Model for the ILC?

International sharing

A personal view
shared by many scientists

Recent international examples:
Majority contribution from host country

e.g. civil construction responsibility of host country

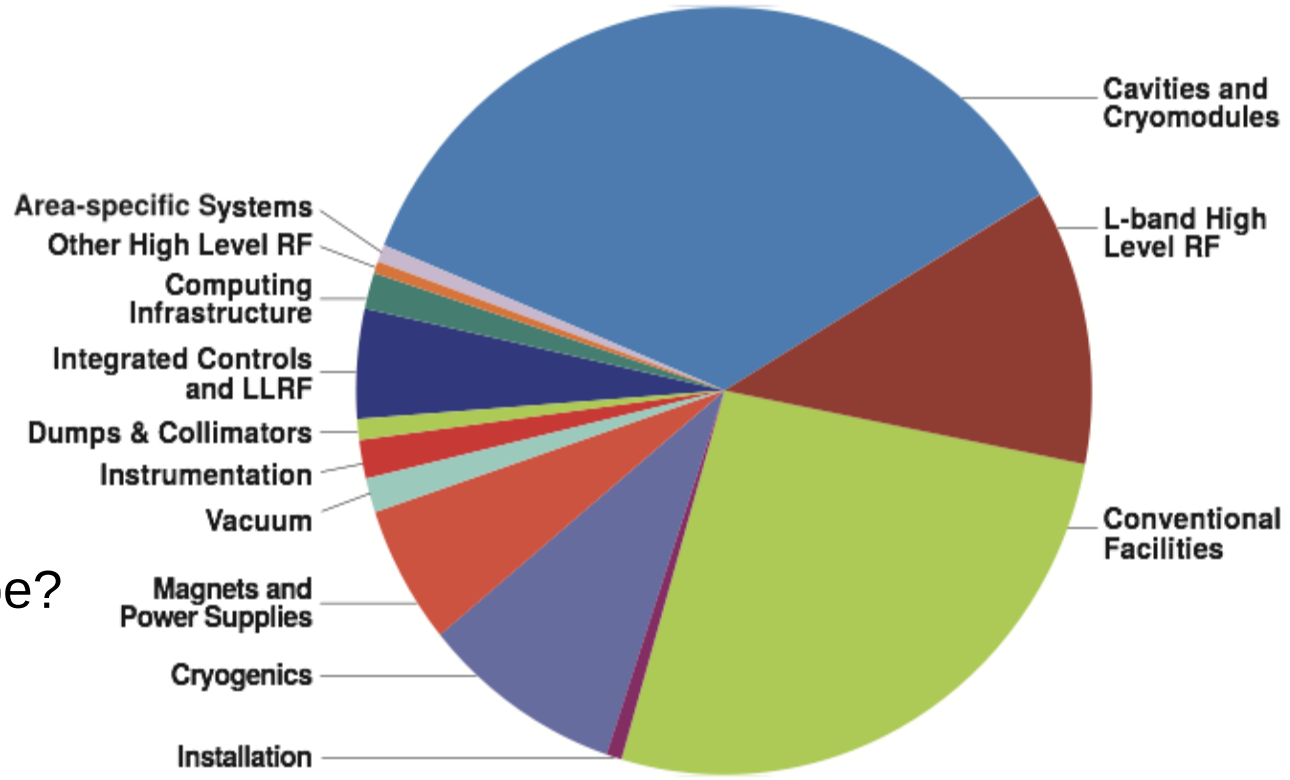
International sharing of accelerator costs
1/3 each for Japan (Asia), the Americas, Europe?

through in-kind contributions

Detectors funded by international collaborations)

A basis for starting discussions with governments world-wide?

ILC cost distribution (TDR)



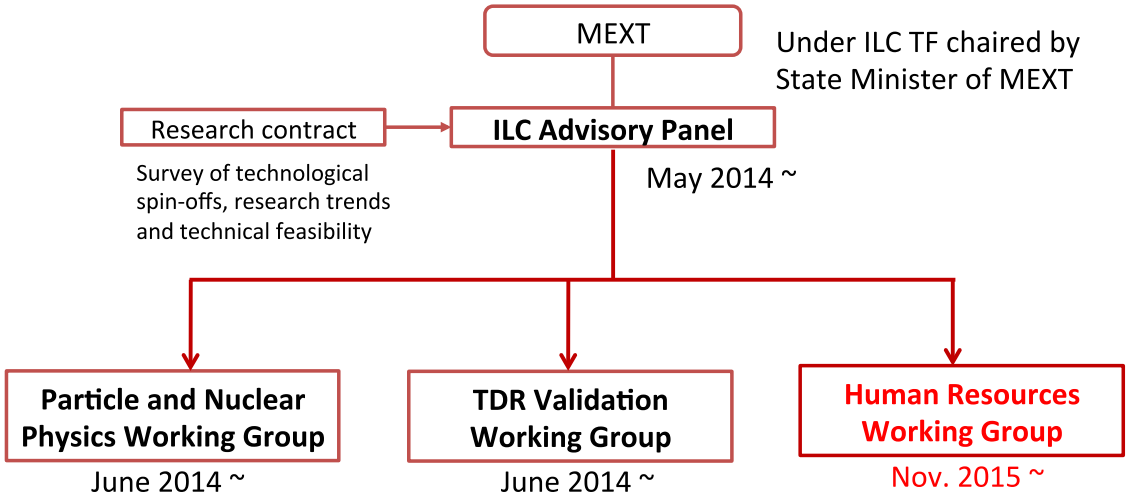
What Happened So Far?

Political process in Japan – past, present, future

2012: Japanese HEP community expresses interest to host ILC

Realisation of ILC in Japan part of the LDP's election programme

2013: TDR published; European strategy supports ILC in Japan; Japanese site proposal; MEXT starts evaluation process

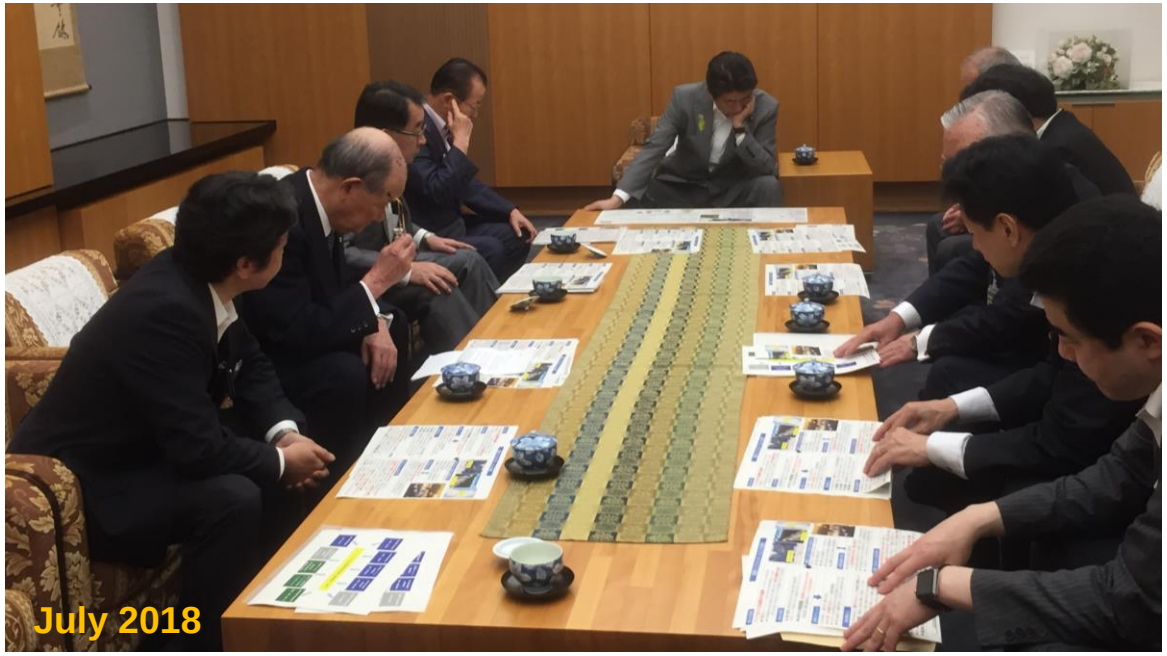


Discussions in MEXT ILC Advisory Panel concluded; Japanese report ready. Now passed to Japanese Science Council.

Statement from Japan expected in time for ESU.

International negations have started; very subtle process ...

- Recommendation 1: **Share the cost internationally** and **Find a clear vision on the discovery potential of new particles.**
- Recommendation 2: **Closely monitor and analyze the development of the LHC experiments** and **Mitigate cost risk.**
- Recommendation 3: **Obtain general understanding by the public and science communities.**



ILC Decision Timeline in Japan

From S. Yamashita (FCCJ)

2013 2017

US・EU・Labs. in the world Support ILC in Japan

2018

Japan-France・Japan-Germany Established Government – Politic- Academic Body

July 2018

Expert Committee in MEXT

by fall 2018

Discussion in Science Council of Japan

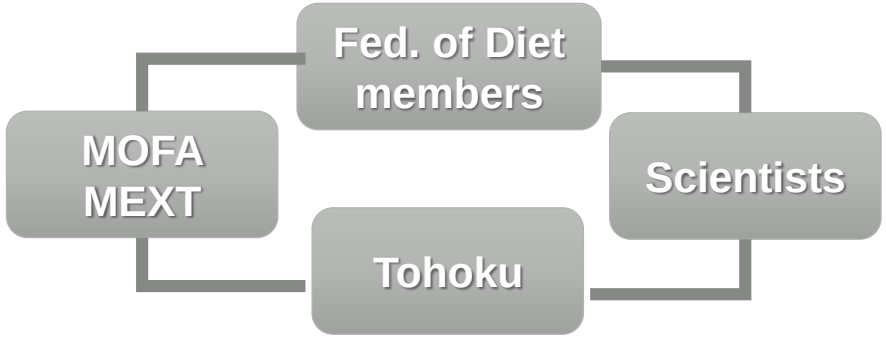
by the end of Dec. 2018

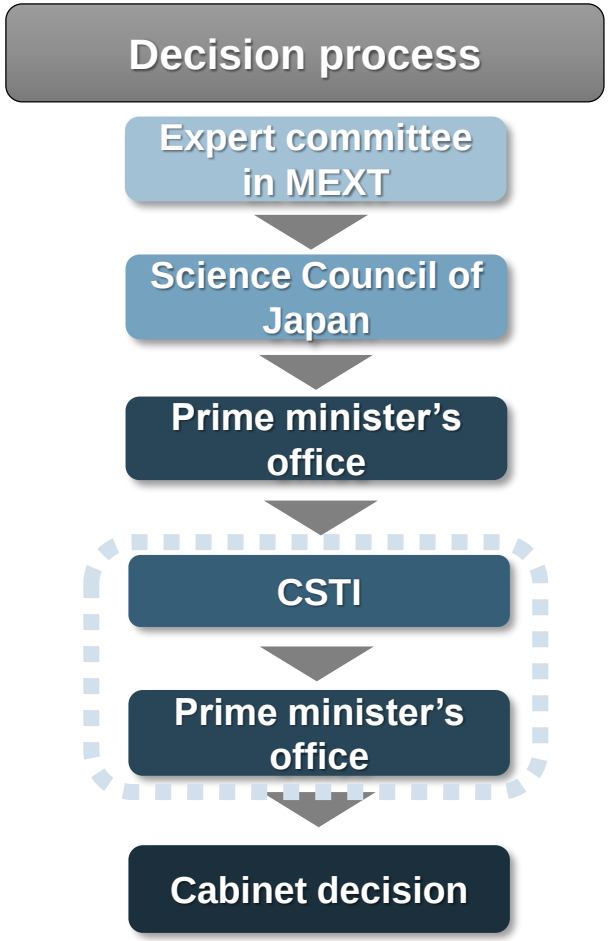
Expression of Interest from Japanese government

2019

Japan-US intergovernmental discussion

Discussion of 5 year European Strategy





The Preparation Phase (2019-2022?)

A European view

Preparations in Europe will start only
IF Japan sends a sufficiently strong positive signal („green light“) AND
IF the European strategy ranks European participation as a high priority

Preparation phase focuses on
Preparation for construction
Agreement on the definition of deliverables and their allocation to the regions
Foundation of ILC international laboratory

In Europe specifically:
Technical preparation of European deliverables for the construction phase
European design office at CERN (satellites elsewhere?) + EDMS documentation
Final European negotations on contributions / organisation / governance

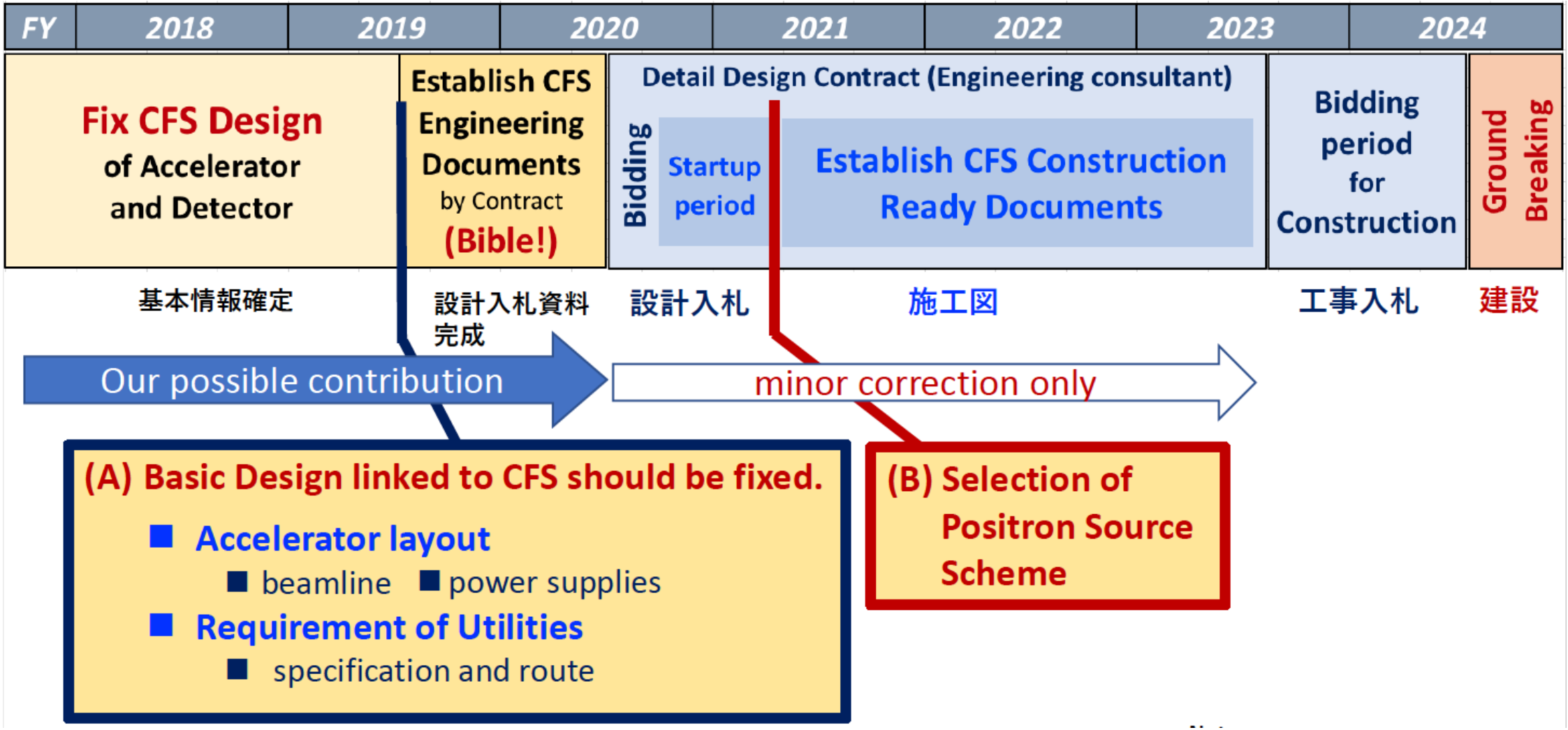
Potential fields of European interest
(from: The European International Linear Collider Preperation Plan)

	CERN	DESY	Czech Republic	France	Germany	Israel	Netherlands	Norway	Poland	Serbia	Spain	UK
Vertexing	✓	✓	✓	✓	✓				✓		✓	✓
Tracking	✓	✓		✓	✓		✓				✓	✓
Calorimetry	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
MDI	✓	✓						✓				✓
System Integration	✓	✓		✓							✓	

Timelines

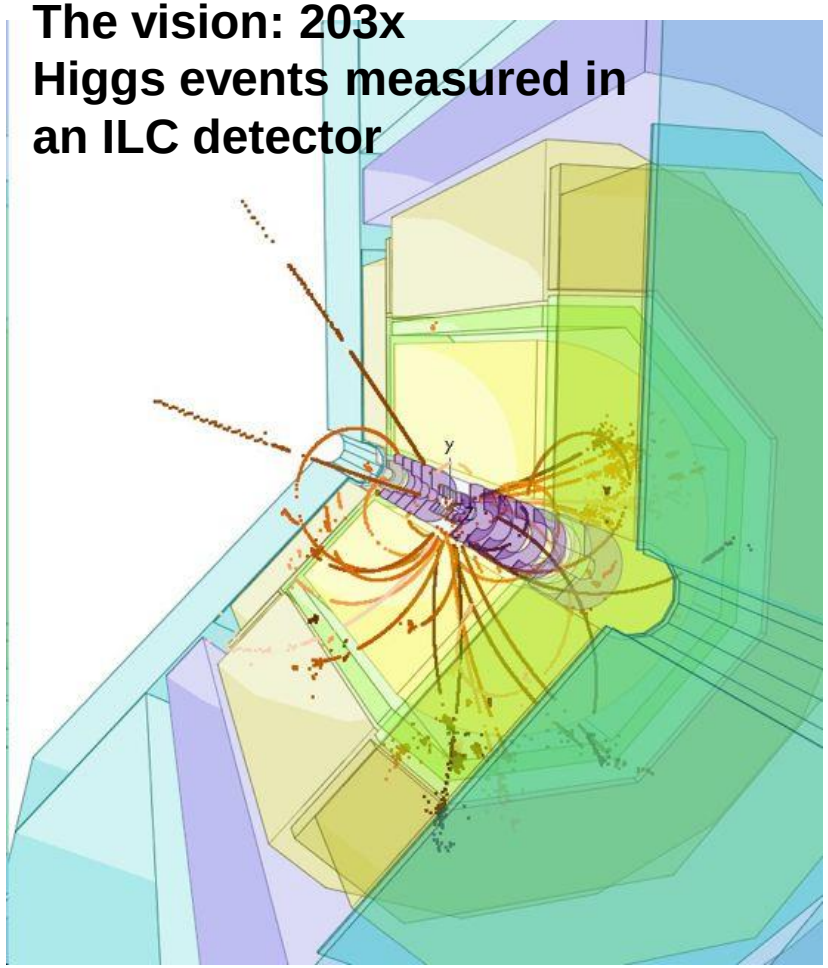
Approved by ILC-CFS team at KEK

N. Terunuma, ALCWS'18



Conclusions

- **Strong international support for the ILC**
  - The next big collider after the LHC
  - Initially operating as Higgs factory
- **Project is scientifically exiting and technically sound**
  - Based on proven technologies
  - But a lot of technological and industrial challenges (accelerator and detector)
- **High level political discussions in Japan**
  - Community is waiting for a positive signal very soon
  - to realize the ILC as international project under Japanese leadership
- **We hope that high-level inter-governmental discussions on the ILC can start soon**
  - Will require continous enthusiasm and support from scientists and industrial partners
- **2019 will be a decisive year for the ILC**



Backup

Timelines

A personal view / wish

K. Buesser, Jan. 2018

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
European Strategy	Discussions	Decision	Publication			Discussions	Decision	Publication			Discussions	Decision	Publication			Discussions	Decision	Publication
US P5	???	Discussion	Decision	Publication	???													
Japanese Government	"Green Light"																	
	Local and International Negotiations							Supervision										
ILC International Lab				Foundation	Call for LoIs	LoI		TDR	Construction Supervision/Support									
ILC Machine/Project	Pre-Prep Phase	Preparatory Phase						Machine Construction									Commissioning	
																	Data Taking	
Detector Collaborations	Preparatory Phase/ R&D					LoI		TDRs									Commissioning	

The Update of the European Strategy

Relevance and scope

https://council.web.cern.ch/en/content/european-strategy-particle-physics:

*The Convention bestows **two missions** upon the Organization, namely the **operation of laboratories** and the **organisation and sponsoring of international co-operation in the field of elementary particle physics**.*

*[…] In this context, the **Council has assumed full responsibility for defining the strategic orientations of European particle physics**, a bottom-up process that starts with the broad consultation of all stakeholders in Europe's particle physics community and culminates in a dedicated meeting of the European Strategy Group, which brings together representatives of the CERN's Member States and of the major European laboratories active in the field, particle physicists from outside Europe and specialists in related fields of physics. The Strategy updates are drafted at this special "drafting" session of the European Strategy Group and are then validated at a dedicated "European Strategy Session" of the Council.*
The last one of these was held on 28 May 2013 in Brussels.

➔ Strategy process defines long-term commitments of European community. CERN strategy as necessary condition for access to EU FP funds.

➔ ILC competing with large CERN projects (and others; note that CERN needs a future after LHC)

The International Linear Collider

Status - Summary

Machine design technically mature ✓

Site defined ✓

Detectors ~ready to be built ✓

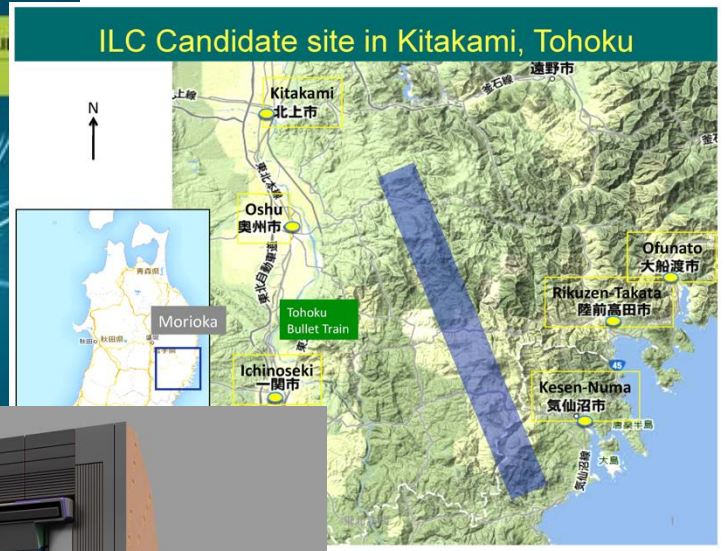
Large international community ✓

European strategy ☐

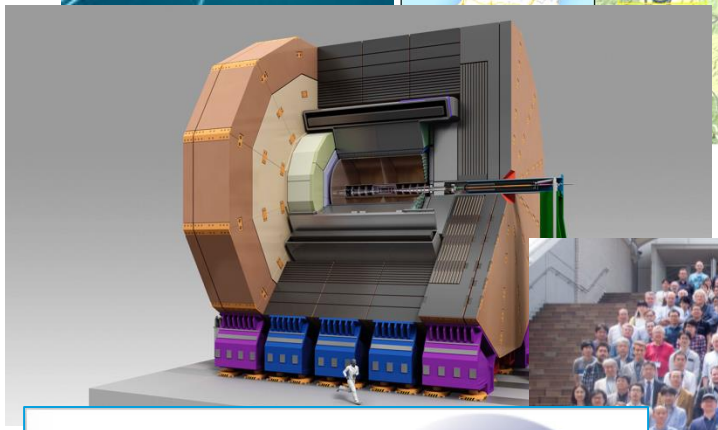
Japanese decision ☐

ILC TDR 2013

Kitakami site, Iwate prefecture



ILD detector



ALCWS18

ESU2018-20