Overview of the ILC, its significance and impact on the region

Iwate Collider School 2023

27 February - 4 March, 2023

Appi highland, Iwate, Japan (Hybrid)

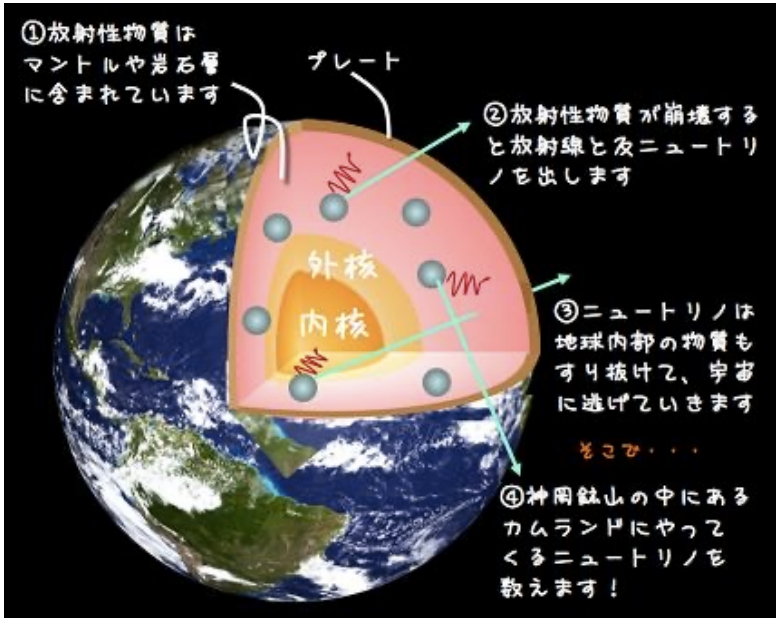
Masakazu Yoshioka

Iwate University, Iwate Prefectural University — Visiting Professor

High Energy Accelerator Research Organization KEK — Professor Emeritus

Last week, Professor Atsuto Suzuki asked me to give a lecture at this school !

Suzuki-sensei is a great physicist.
As far as I know, he has made many achievements in neutrino physics and trained many students.
I am sure you are well aware of his achievements at Kamiokande, Super-Kamiokande, and KamLAND.
Among them, my personal favorite achievement is that he opened the door to Earth neutrino science.



By detecting unti-neutrino from the earth at KamLAND, it was clarified that the reason why the Earth's interior is still hot today is that the energy of radiation emitted from unstable nuclear species is converted into heat.

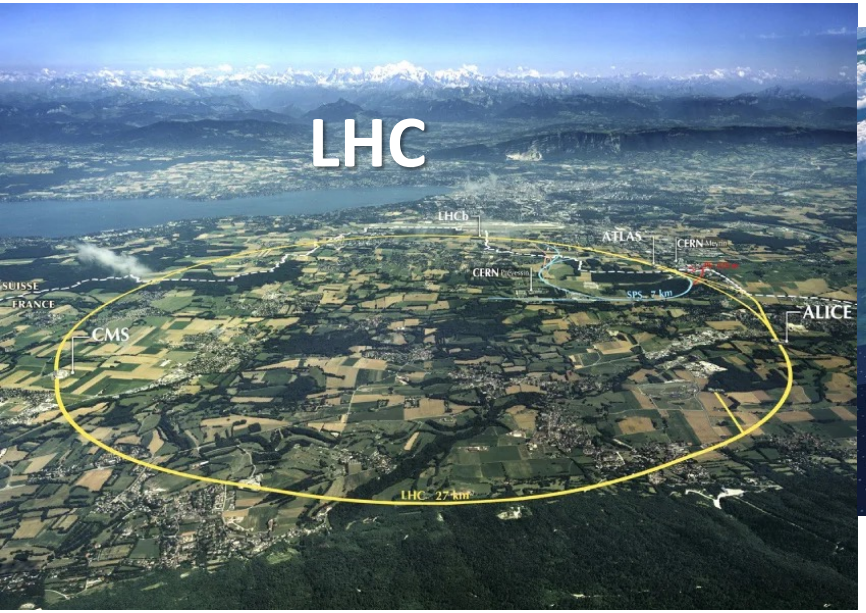
He was recently honored as a Person of Cultural Merit and was also appointed as a member of the Japan Academy of Sciences.

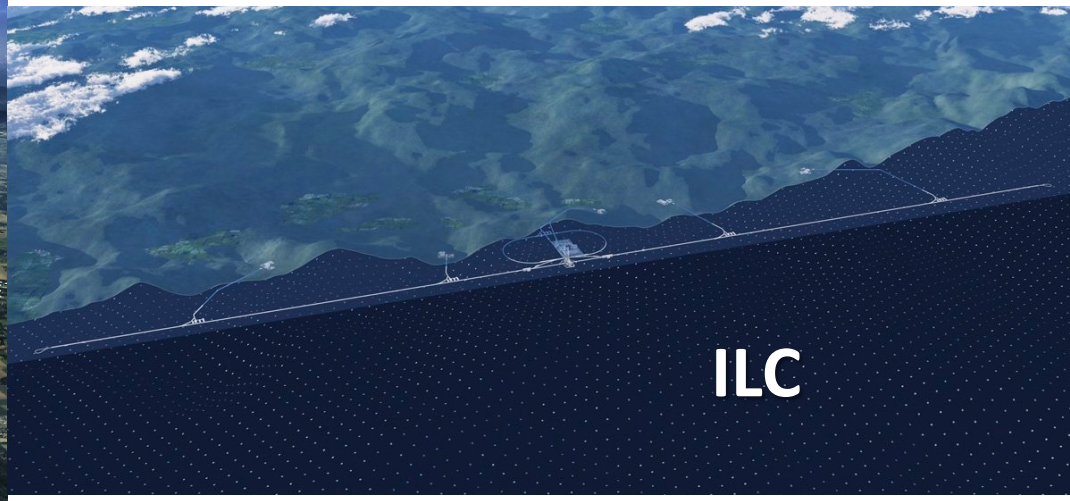
On the other hand, I specialize in accelerator science and have been responsible for the construction of Japan's large accelerators such as
TRISTAN, KEKB, and J-PARC,
and have also been involved in the R&D of linear colliders since early 1980s.
I also developed an accelerator-based cancer treatment system.

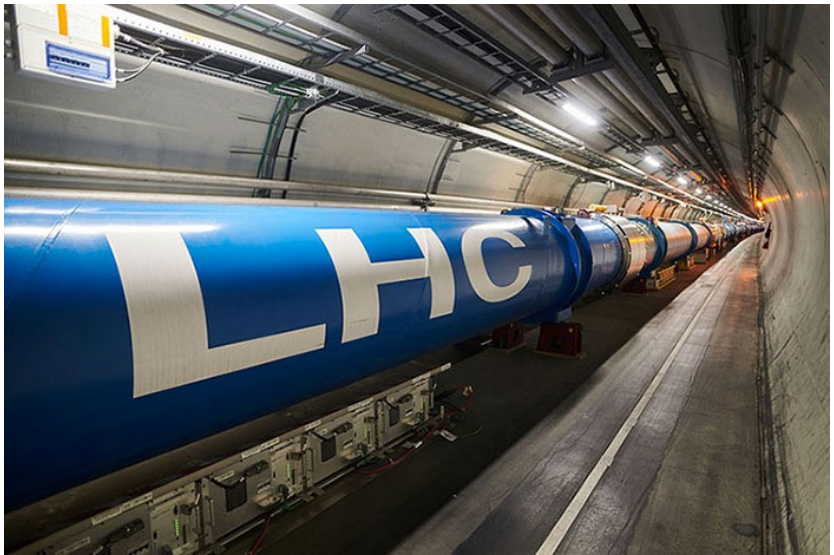
Although backgrounds of Suzuki-sensei and myself as researchers are very different, we share the same age and a love of Japanese sake in Iwate.

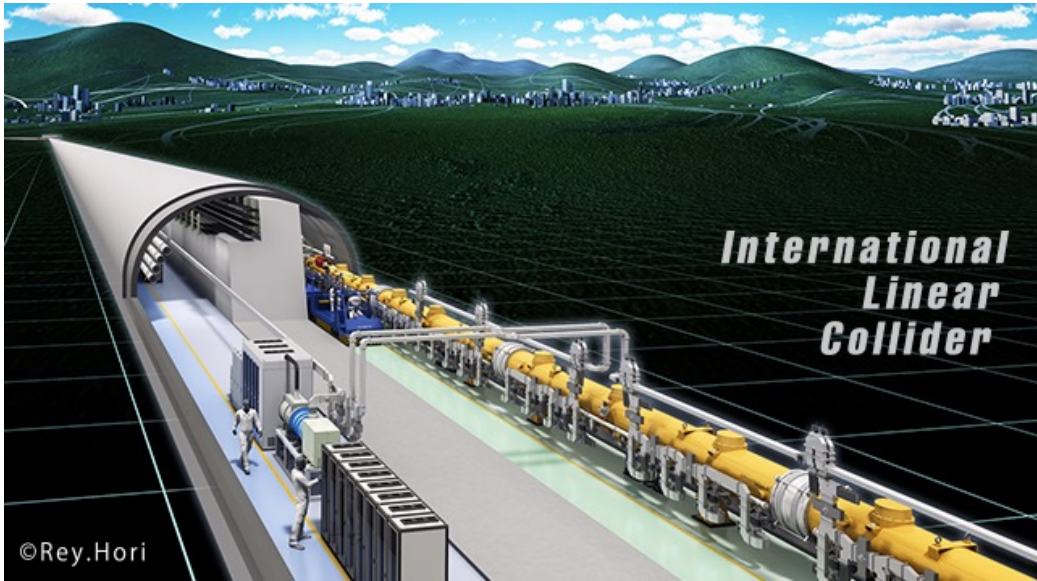
For these reasons, my lecture is not a substitute for Suzuki-san's, and the content will be biased toward accelerators.
From here, I will proceed the lecture in an interactive way.

Q-1: As an energy-frontier accelerator why we need both hadron and lepton colliders?





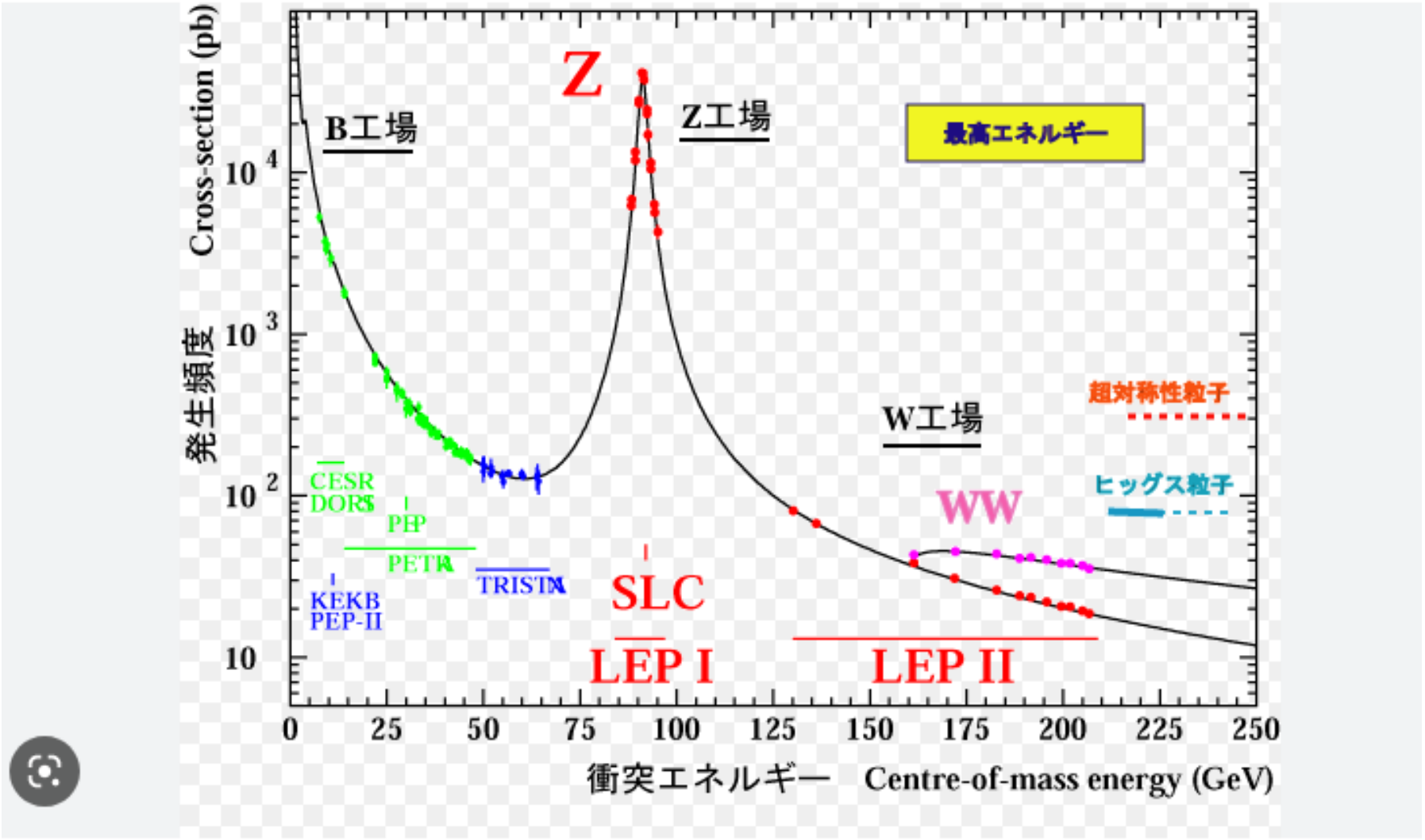




Q-2: Why ILC is the next generation Lepton Collider after LEP (predecessor of LHC)?

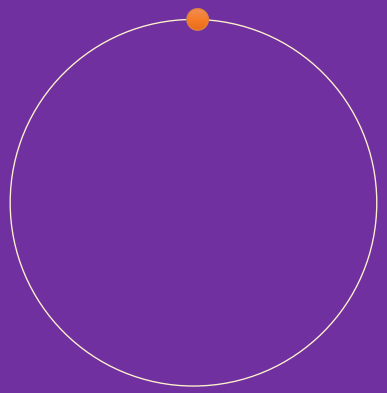
素粒子物理国際研究センター - 東京大学

©ICEPP Tokyo



Why is ILC linear? (LHC is circular)

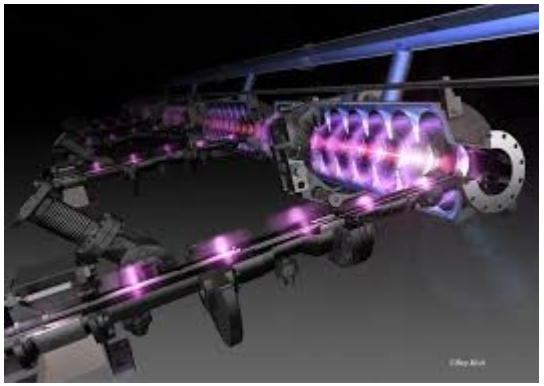
- If it's circular, the electrons emit a lot of synchrotron radiation and lose energy.
- Synchrotron radiation loss is inversely proportional to the fourth power of the particle mass.
- Since proton mass is 2000 times the electron mass, proton synchrotron radiation loss is not a problem
- If it's linear, it won't emit synchrotron radiation, so we're going to linearize the light electron-positron collider.
- However, there is a tradeoff. With a circular collider, the same particle has multiple opportunities to collide, but with a linear case, the collision of accelerated particles is a one-shot deal



Original slides by Professor Emeritus Hitoshi Yamamoto, Tohoku University

Q-3: Why the realization of the ILC will take more time than the LHC? (Not political but technical question)

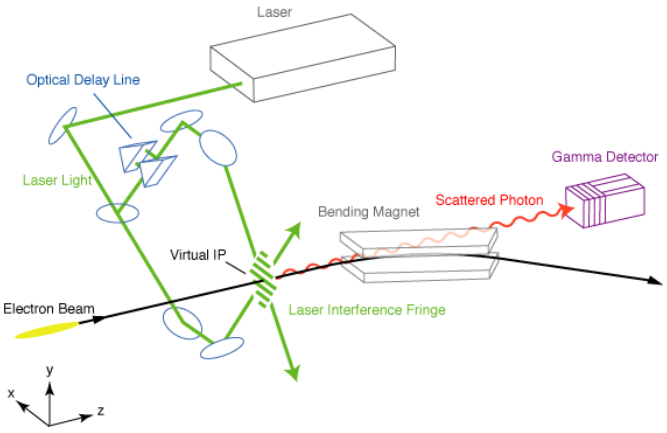
A-1: Issues are quality control, mass production and cost reduction of superconducting accelerators

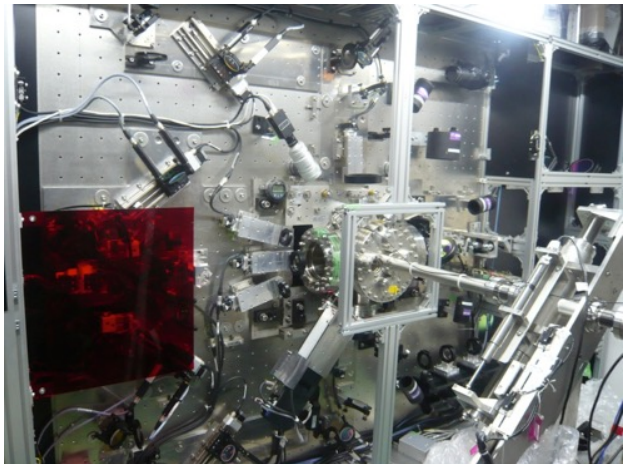


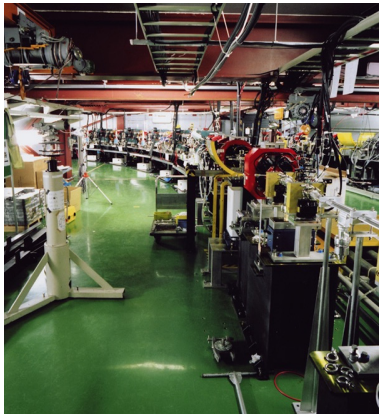
Yes, we can ! ➔ See next page (Euro-XFEL)

A-2: Beam control technology, especially collision control by narrowing the beam size to nanometer size

Yes, we can ! ➔See ATF-II@KEK







Euro XFEL in Hamburg

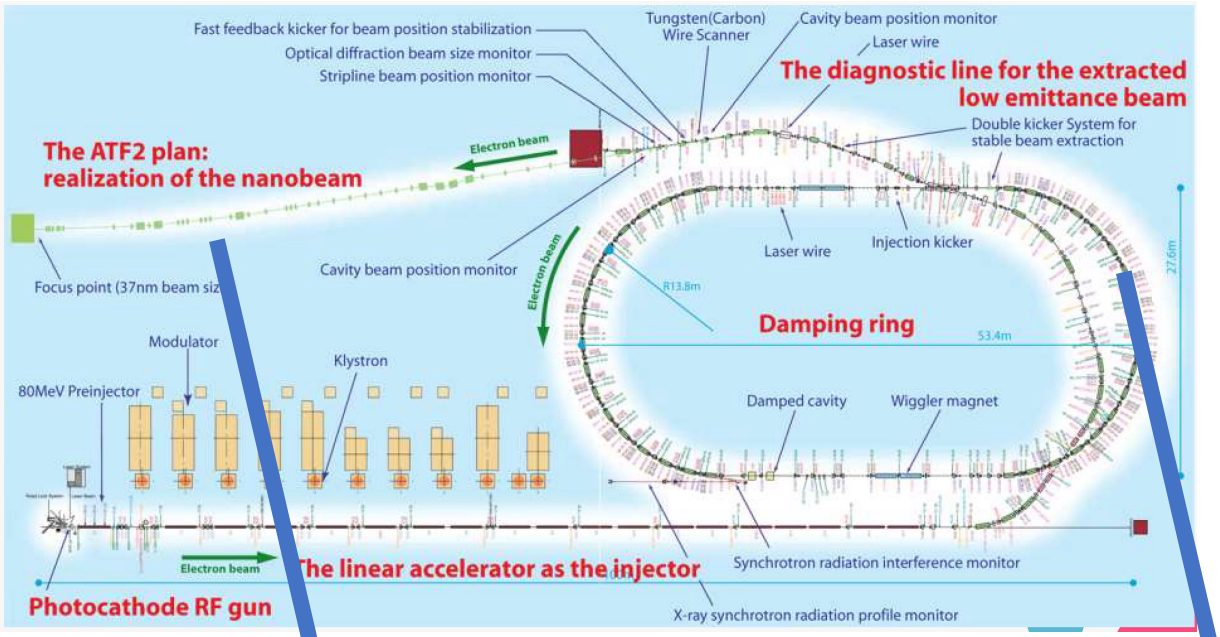
X-ray free electron laser (synchrotron radiation) facility in operation since 2017 in Hamburg, using exactly the same technology as the ILC, 10% the scale of the ILC … in other words, the basic technology of the ILC has been established.

Colliding particles in a single shot deal

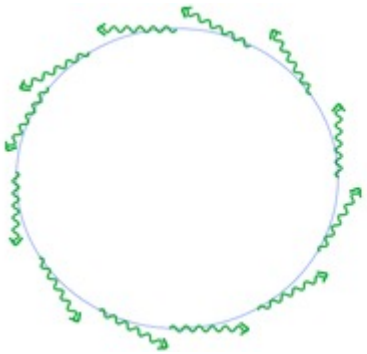
Beams of particles are bunched (swarmed).
Reducing the size of the bunch (narrowing the beam) makes collisions more likely.
Linear colliders especially need to narrow the beam size.

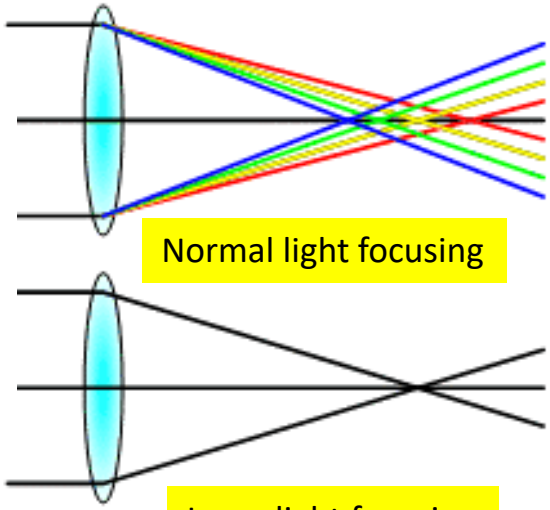
The role of the accelerator is all about accelerating and colliding well.

Original slides by Professor Emeritus Hitoshi Yamamoto, Tohoku University

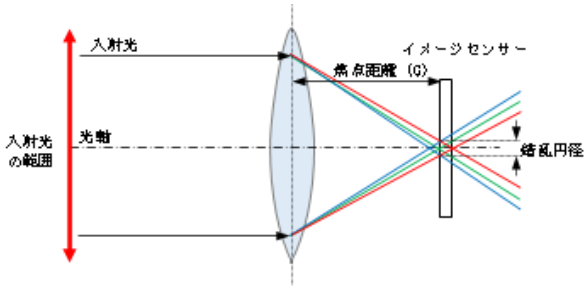

Fast feedback kicker for beam position stabilization
Optical diffraction beam size monitor
Stripline beam position monitor
Tungsten(Carbon) Wire Scanner
Cavity beam position monitor
Laser wire
The diagnostic line for the extracted low emittance beam
Double kicker System for stable beam extraction
The ATF2 plan: realization of the nanobeam
Electron beam
Cavity beam position monitor
Laser wire
Injection kicker
Focus point (37nm beam siz
Electron beam
R13.8m
Damping ring
53.4m
27.6m
Modulator
Klystron
80MeV Preinjector
Damped cavity
Wiggler magnet
Electron beam
The linear accelerator as the injector
Synchrotron radiation interference monitor
Photocathode RF gun
X-ray synchrotron radiation profile monitor

Let's understand the technology to focus beams to nanometer size and control collisions. (1) Realizing low beam emittance (radiation damping) and (2)good chromaticity correction.

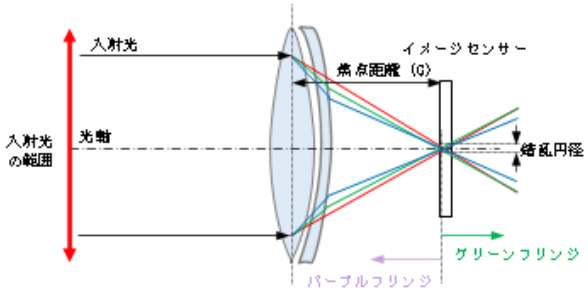




Minimize the beam emittance and realize strong focusing



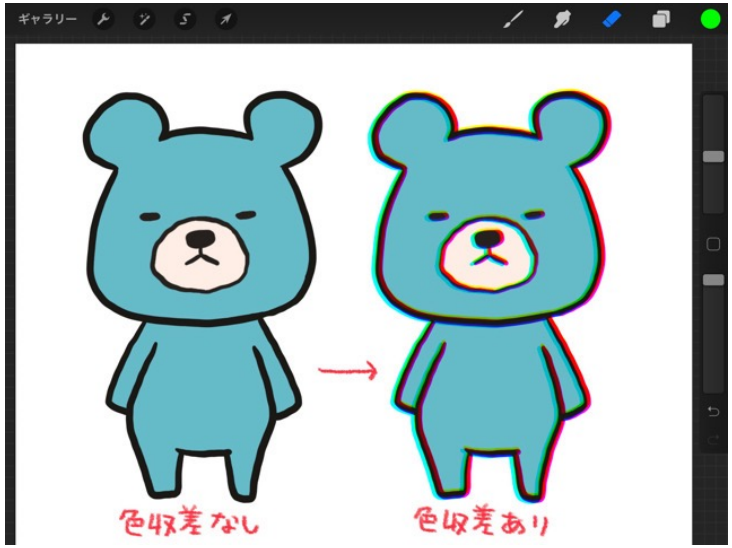
(a) レンズの軸上色収差

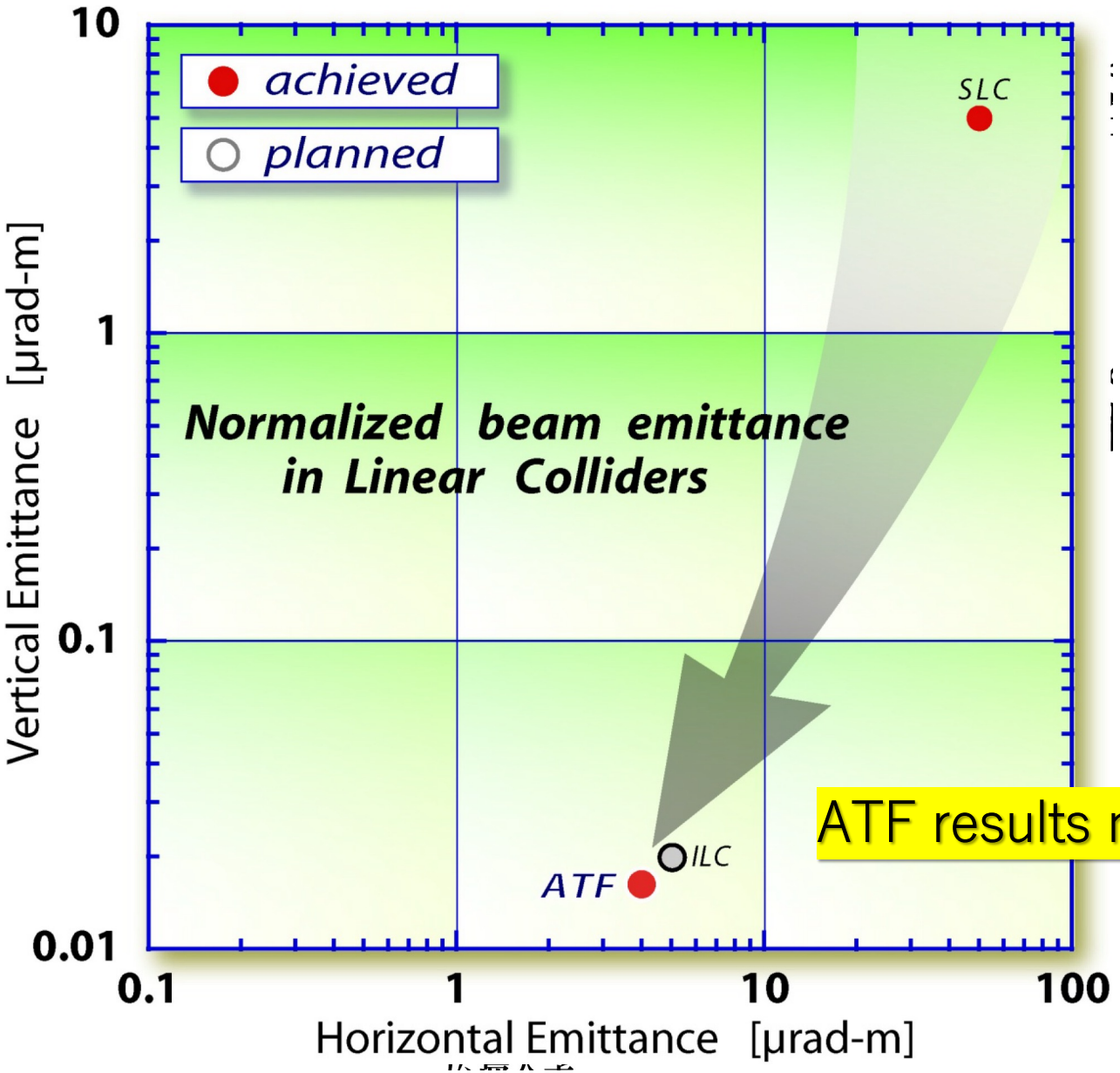


(b) 軸上色収差を補正したレンズ

Accelerator beam is not completely monochromatic.

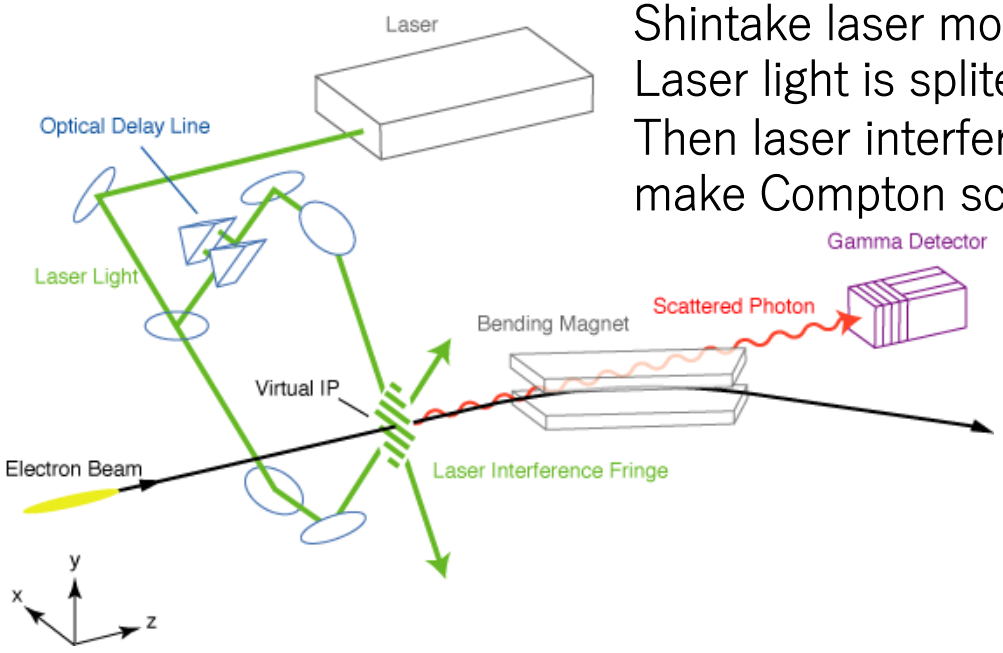
Need chromaticity correction

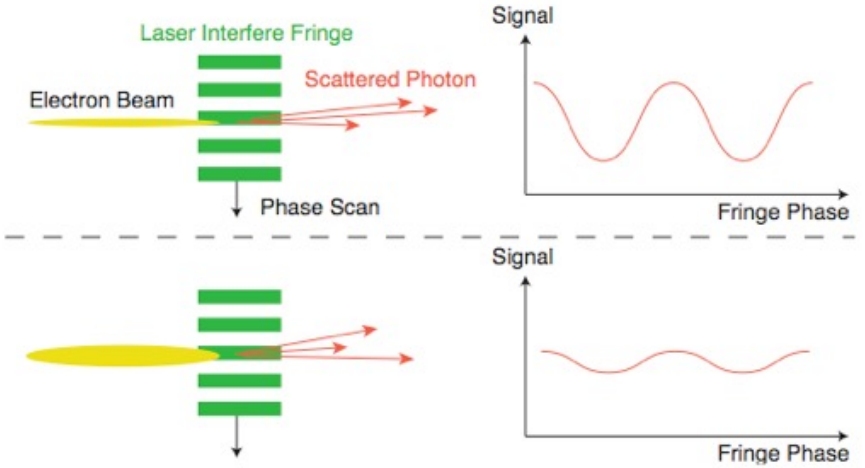




ATF results meet ILC's goals

Shintake laser monitor for beam size measurement
Laser light is splited and meet again.
Then laser interference fringe is made, which is a target to make Compton scattering.





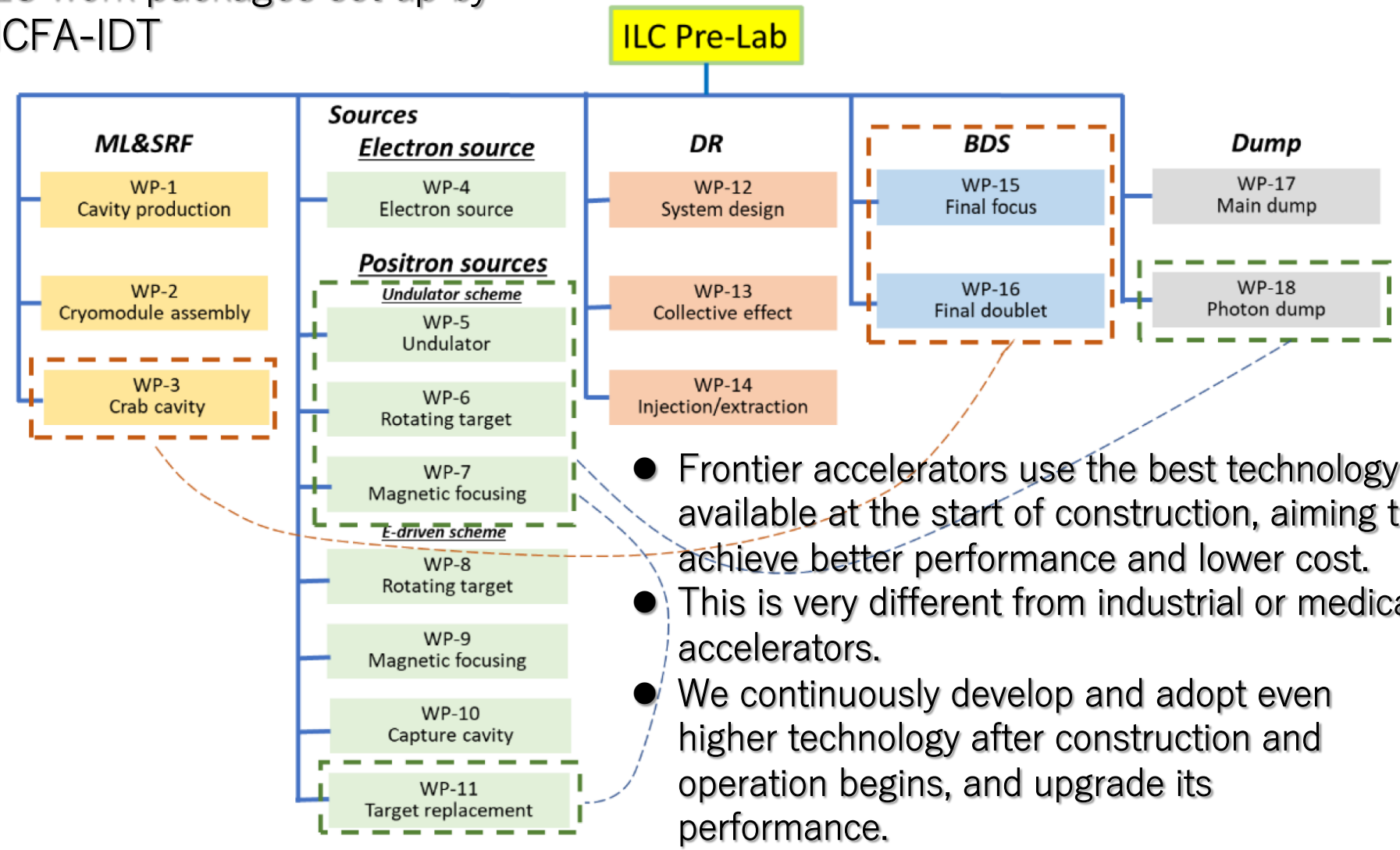
Beam Energy	ATF-II achieved	ILC design
1.3 GeV	41 nm	75.7 nm
125 GeV	4.2 nm	7.7 nm

Beam size is inversely proportional to the square root of energy.
ATF-II results meet ILC goals.

ILC video courtesy of Rey.HORI

Q-4: The core technology of the ILC has been achieved, so why we continue further development and research?

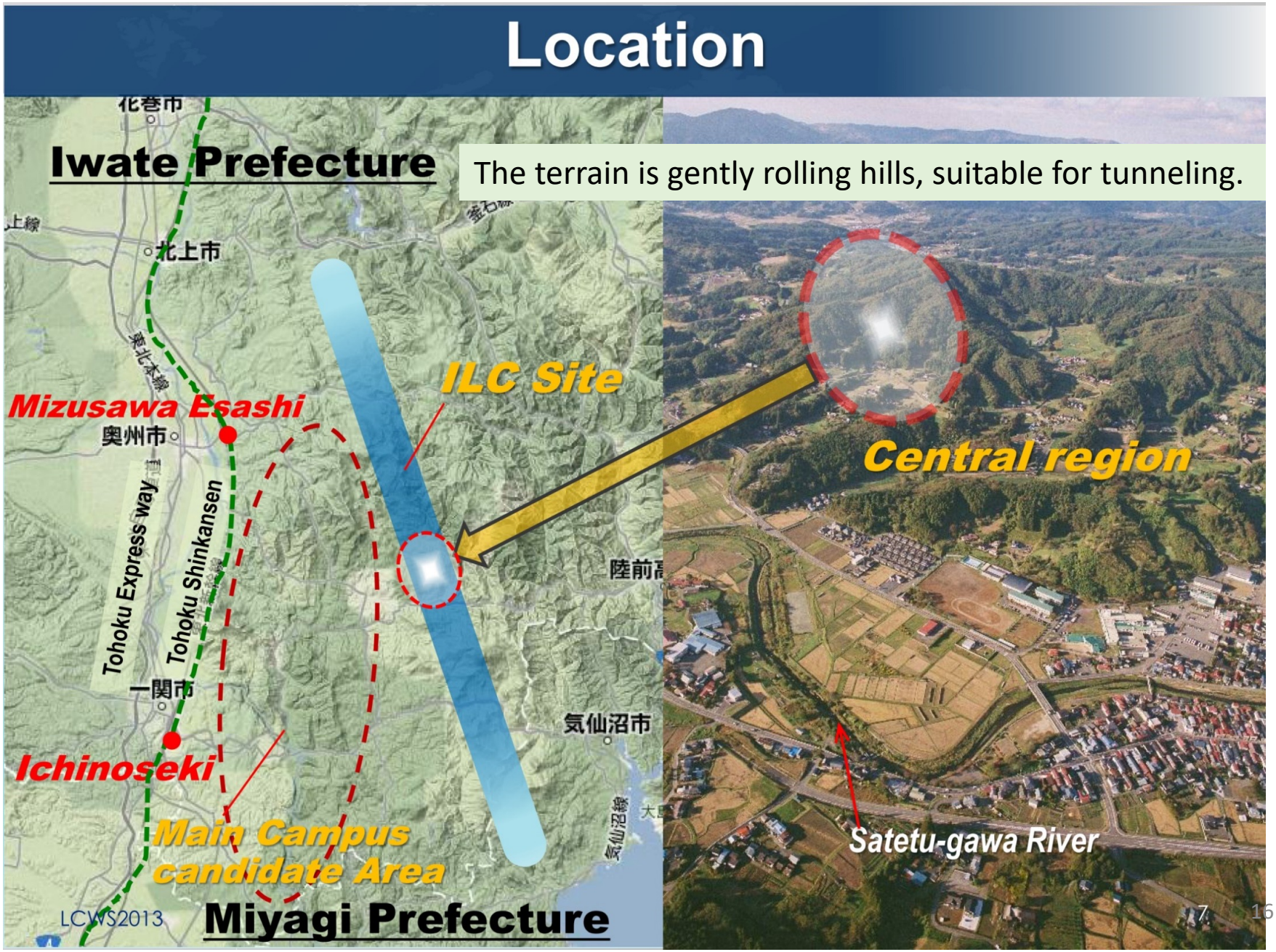
18 work packages set up by ICFA-IDT



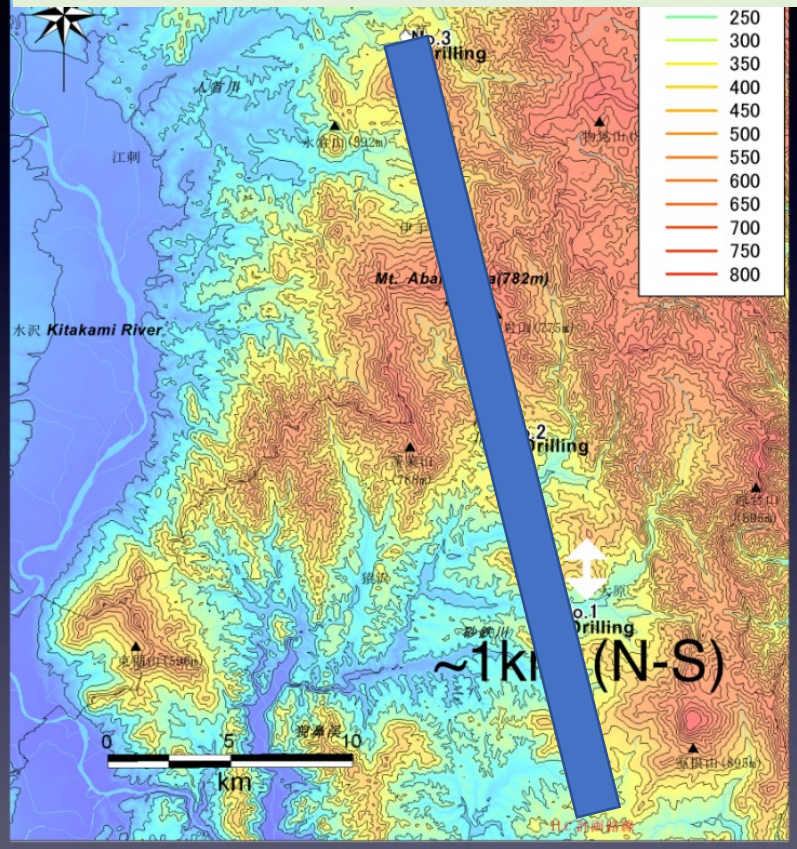
- Frontier accelerators use the best technology available at the start of construction, aiming to achieve better performance and lower cost.
- This is very different from industrial or medical accelerators.
- We continuously develop and adopt even higher technology after construction and operation begins, and upgrade its performance.
- Linear accelerators fit very well with this.

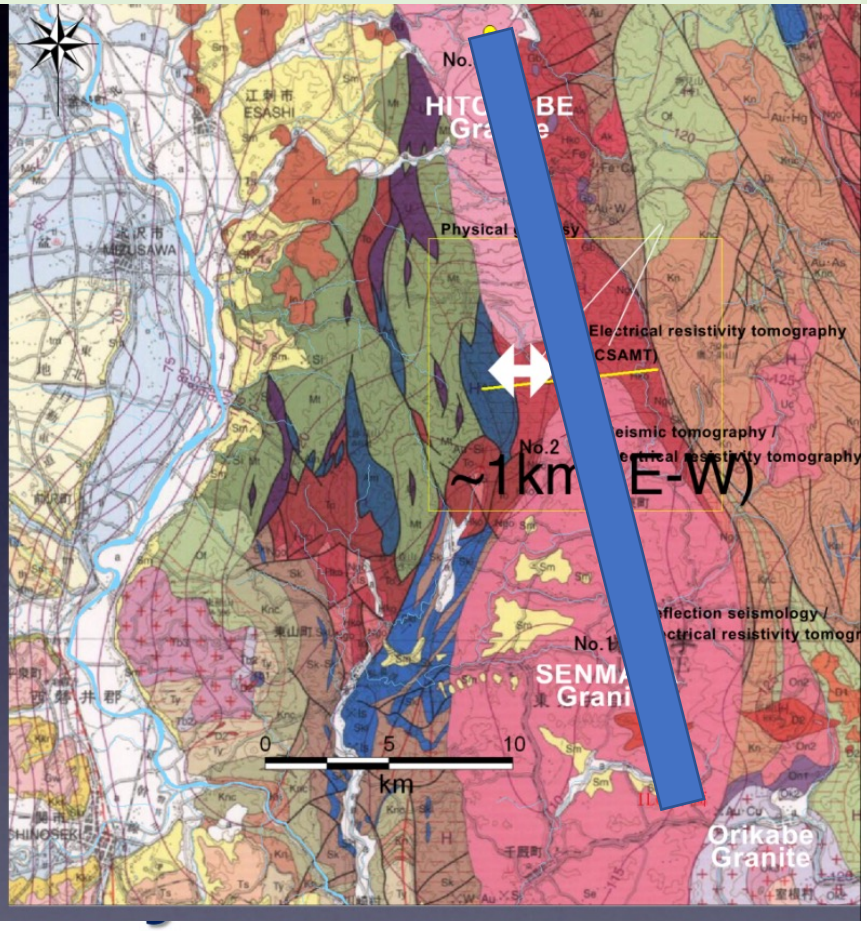
Figure 1: Summary of work packages.

Q-5: Why was the Kitakami Highlands chosen as a candidate site for the ILC?

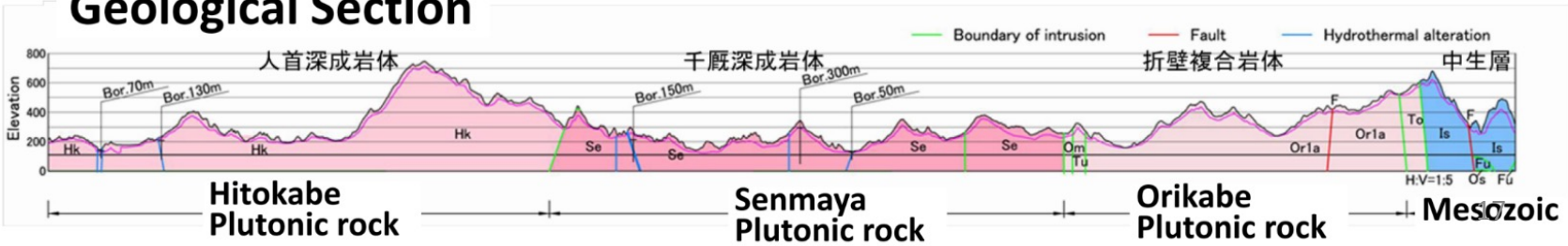


Granite is a deep-bearing igneous rock. Magma solidified over a long period of time and surfaced on the ground surface due to its slightly lower specific gravity.

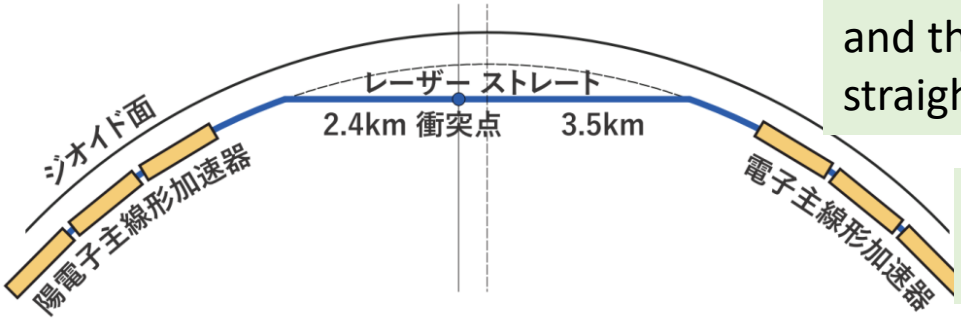




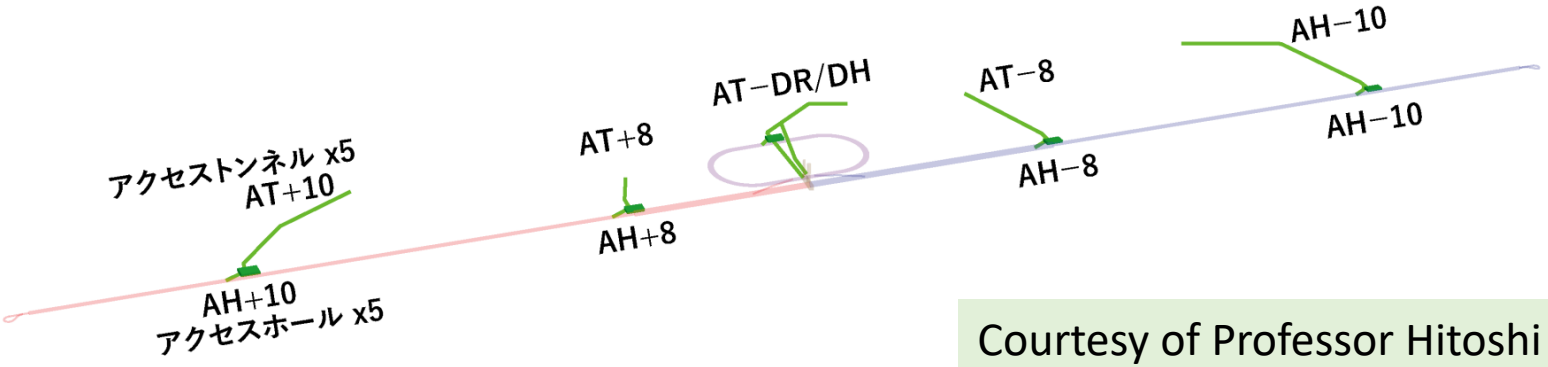
Geological Section



Accelerator tunnels are excavated along the geoid and the final focus tunnel is excavated in a laser-straight.

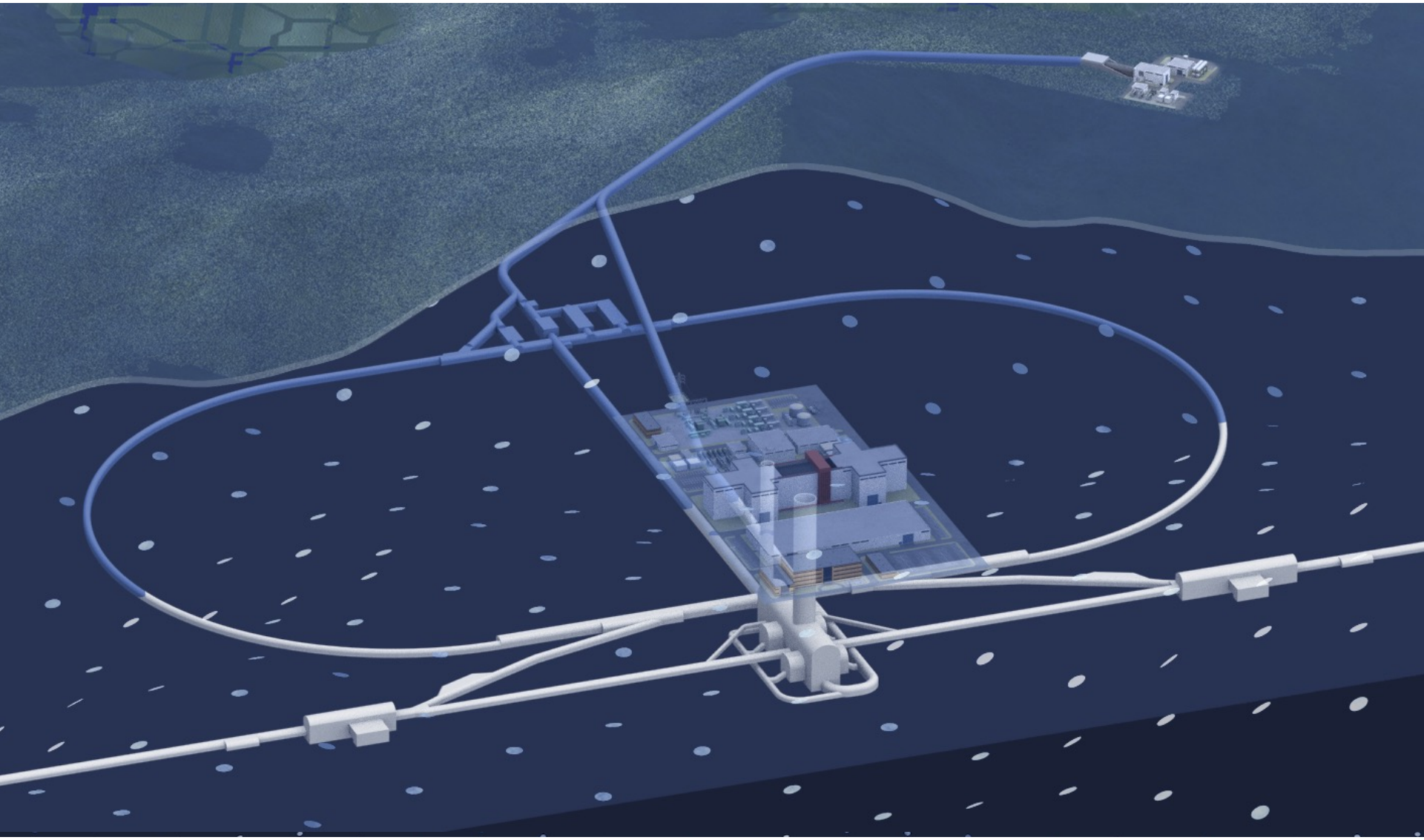


Excavate five access tunnels first, then proceed to the main tunnel



Courtesy of Professor Hitoshi Hayano

Bird's eye view of ILC Kitakami candidate site



Tunnel design for ILC Kitakami candidate site (ILC 250GeV 20.5km)

Courtesy of Professor Hitoshi Hayano

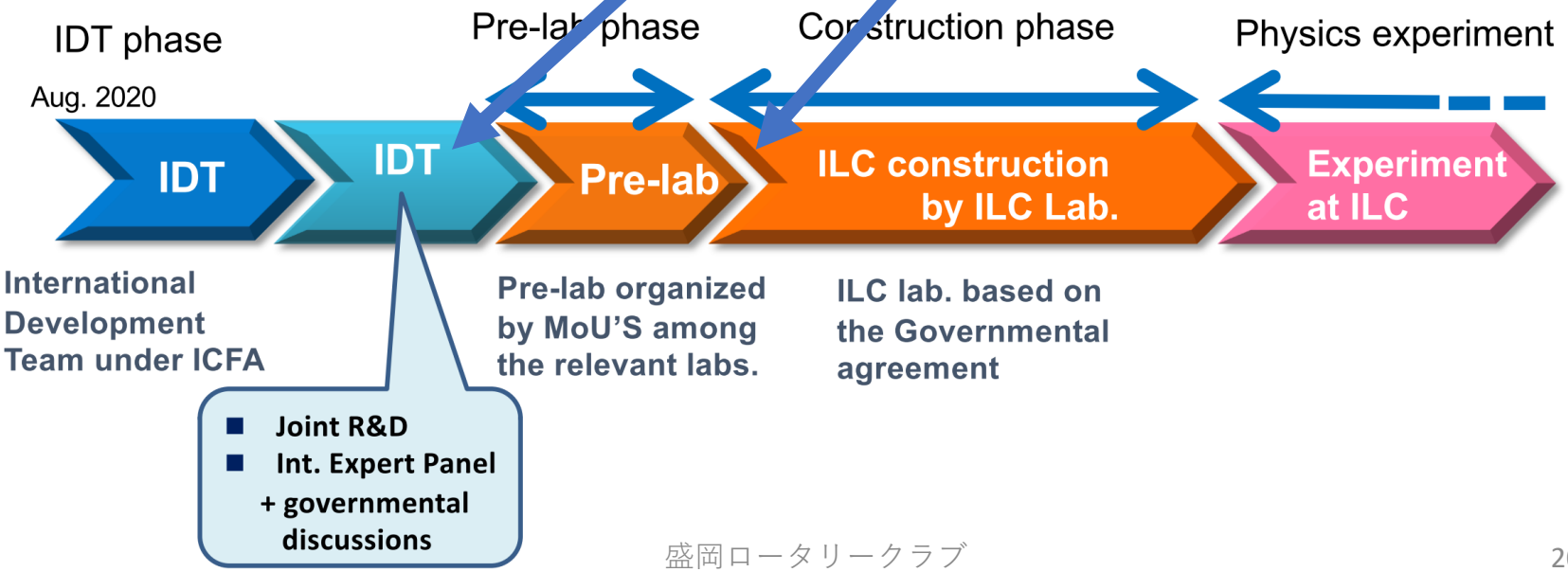
KEK, High Energy Accelerator Research Organization

Particle Physics Program in Japan

July 25, 2022
Snowmass Meeting in Seattle

M.Yamauchi
KEK

- Timeline shown by KEK Director General
- The IDT phase, shown in light blue, was added to the previous timeline
- We will strive to start construction as soon as possible !!!



7 Environmental and societal impact

A. The energy efficiency of present and future accelerators, and of computing facilities, is and should remain an area requiring constant attention. Travel also represents an environmental challenge, due to the international nature of the field. ***The environmental impact of particle physics activities should continue to be carefully studied and minimised. A detailed plan for the minimisation of environmental impact and for the saving and re-use of energy should be part of the approval process for any major project. Alternatives to travel should be explored and encouraged.***

B. Particle physics, with its fundamental questions and technological innovations, attracts bright young minds. Their education and training are crucial for the needs of the field and of society at large. ***For early-career researchers to thrive, the particle physics community should place strong emphasis on their supervision and training. Additional measures should be taken in large collaborations to increase the recognition of individuals developing and maintaining experiments, computing and software. The particle physics community commits to placing the principles of equality, diversity and inclusion at the heart of all its activities.***

C. Particle physics has contributed to advances in many fields that have brought great benefits to society. Awareness of knowledge and technology transfer and the associated societal impact is important at all phases of particle physics projects. ***Particle physics research centres should promote knowledge and technology transfer and support their researchers in enabling it. The particle physics community should engage with industry to facilitate knowledge transfer and technological development.***

D. Exploring the fundamental properties of nature inspires and excites. It is part of the duty of researchers to share the excitement of scientific achievements with all stakeholders and the public. The concepts of the Standard Model, a well-established theory for elementary particles, are an integral part of culture. ***Public engagement, education and communication in particle physics should continue to be recognised as important components of the scientific activity and receive adequate support. Particle physicists should work with the broad community of scientists to intensify engagement between scientific disciplines. The particle physics community should work with educators and relevant authorities to explore the adoption of basic knowledge of elementary particles and their interactions in the regular school curriculum.***

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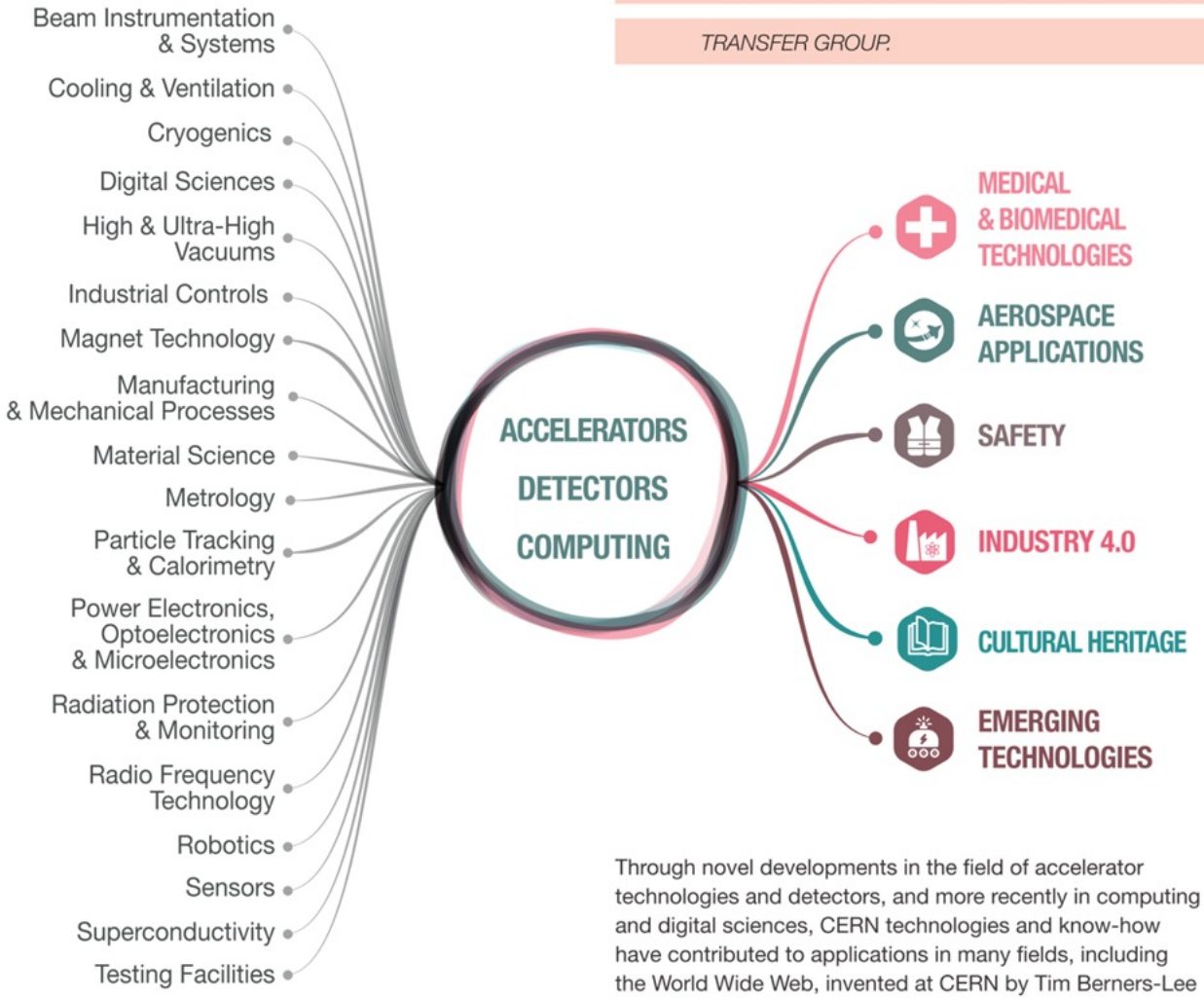
The ILC should also base its policy on this strategy

List of elemental technologies for accelerators, detectors, and computing

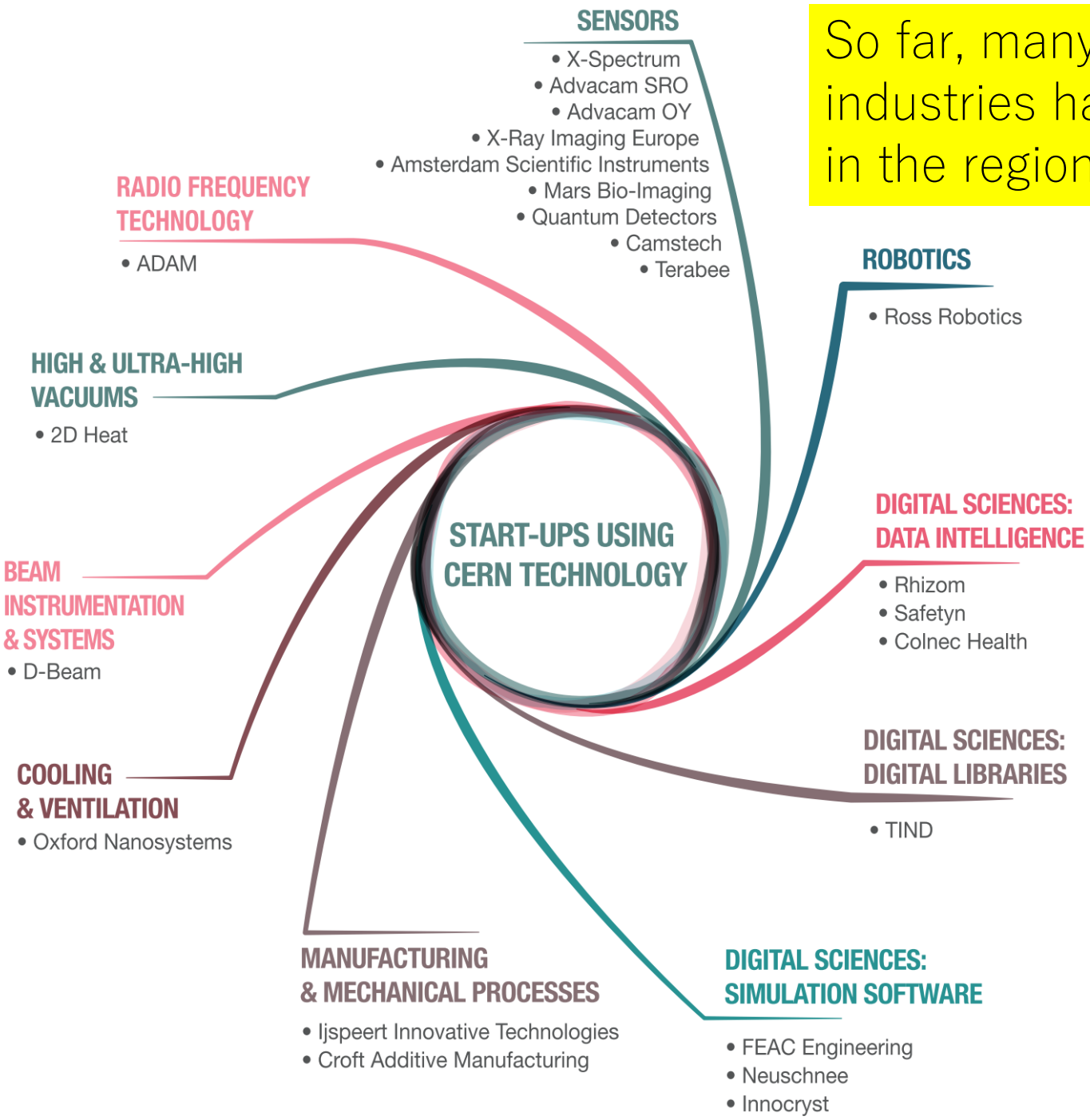
"CERN NATURALLY CREATES NEW OPPORTUNITIES FOR INNOVATION THAT BENEFIT SOCIETY."

GIOVANNI ANELLI, HEAD OF THE CERN KNOWLEDGE TRANSFER GROUP.



Through novel developments in the field of accelerator technologies and detectors, and more recently in computing and digital sciences, CERN technologies and know-how have contributed to applications in many fields, including the World Wide Web, invented at CERN by Tim Berners-Lee in 1989. Behind these three pillars of technology lies a great

Create a new industry in the private sector



So far, many new industries have sprung up in the region.

- My last topic is about town planning/development triggered by the ILC.
- We need wide-area planning with Sendai and Morioka as the dipoles
- Ecosystem already under construction in Sendai, triggered by the construction of a synchrotron radiation facility
- As a community of researchers and engineers, it should be designed as a community of 200-300 units, each with its own local characteristics.

ILCを契機とした広域エコシステム構築

NTTファシリティーズ・平井さん作成

ILC契機で「いち早く」モビリティ改革を進める／社会実装に向けたシナリオ検討

今後の課題

中山間地域の交通課題解決に向けた導入シナリオ(自動運転・e-VTOL特区)

現時点でサイトを特定しているものではありません

地域交通
(地域間鉄道・バス、自動運転車)

東北新幹線

50km

盛岡

■花巻空港

中央衝突点
サテライトキャンパス

メインキャンパス
・研究開発拠点
・先端産業集積拠点

agriculture
biotechnology
science

物流拠点

100km

住居コミュニティサイト

docomo 5G→6G

NTT東日本
光ブロードバンド環境

①フェーズ1(2025年) 先行エリア(特区)
・レベル5実験場を含む小さな区画で
レベル4以上の**自動車専用エリアを設定**
・自動運転車の街づくりの利便性を実感、課題の解決

②フェーズ2(2030年) エリア拡大
・レベル4以上の**自動車専用エリアを**
「メインキャンパス」や「衝突地点」に拡大
・山間部の居住者に自動運転車による各種サービス開始

③フェーズ3(2035年) 自動運転専用道の供用開始
・自動車優先の街づくりから, **人間優先の街づくりに転換**

50km

広域交通
(新幹線、高速道路、eVTOL)

仙台

■仙台空港

0 10 20 30 40 50km

(出典)「ILCを契機とした東北・北上エリアグランドデザイン」にNTTファシリティーズが加工
NTT Facilities,INC. / Advanced Accelerator Association Promoting Science and Technology(AAA)

Figure3: Community-driven town planning triggered by the construction of the ILC.

Summary

- ILC is the most sustainable and economical accelerator as Higgs Factory, which is based on the superconducting technologies.
- ILC is the most advanced Higgs Factory in terms of technology development, and I personally believe that we are at the point where construction can begin as soon as the green light is given.
- ILC is the most energy extendible accelerator in future.
- We hope that the IDT/Pre-Lab process will lead to international discussions on the structure and cost burden of the ILC, and that construction will begin as soon as possible.
- The ILC's relationship with society can be learned from the CERN's experience.
- We are considering town planning together with the local community in the Tohoku region, using the ILC as a trigger.
- Establishment of Asia's first large-scale international research institute is a symbol of "Science for Peace".

Science for peace

CERN's convention states: "The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available."

French physicist Louis de Broglie put forward the first official proposal for the creation of a European laboratory at the European Cultural Conference, which opened in Lausanne on 9 December 1949.

First proposal was only 4 years after the end of WW-II

In the present era of war and infectious diseases, we must realize the ILC in Japan, the first large-scale international research institute in Asia, and use it as a symbol of Science for peace and world wide brain exchange.