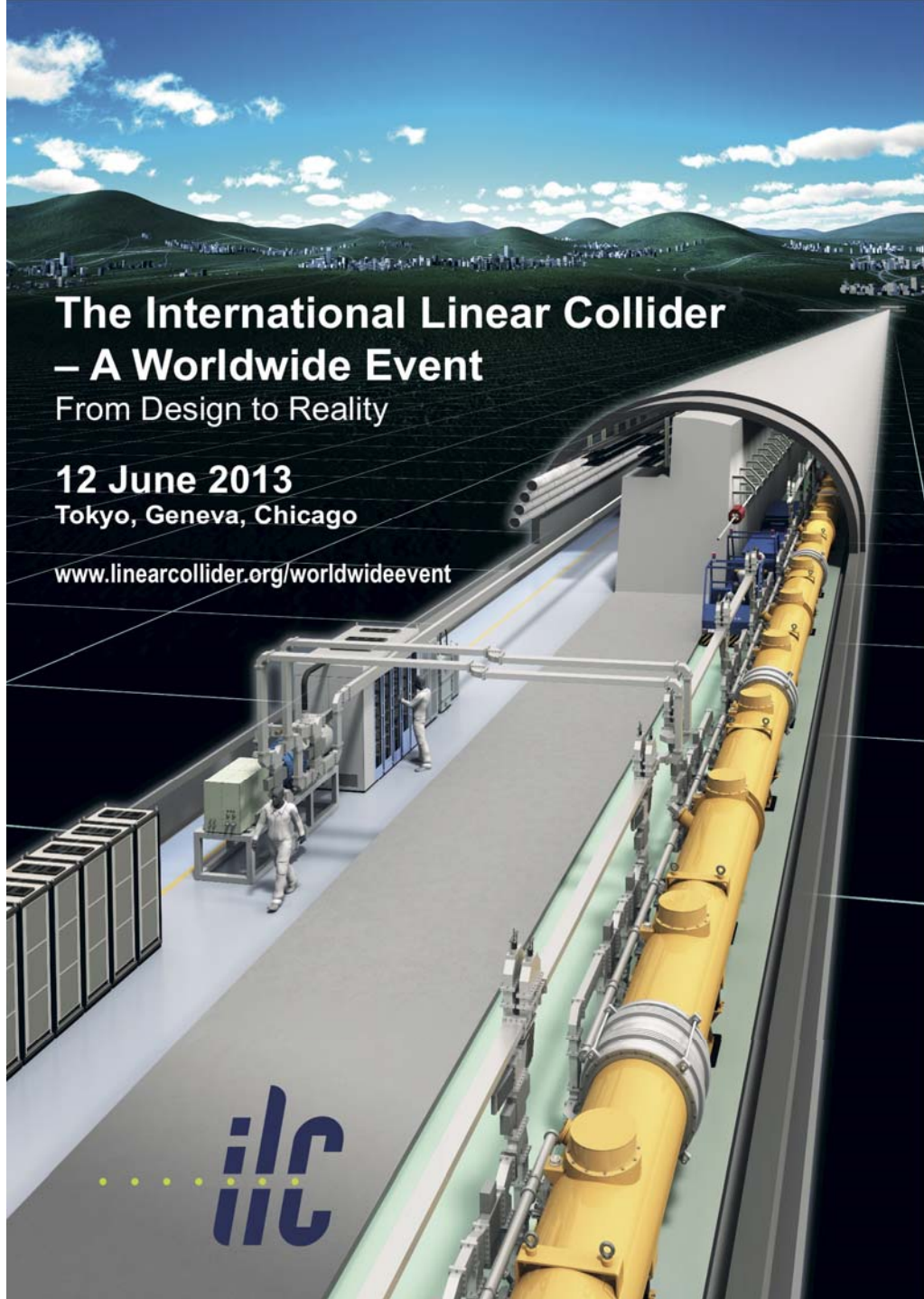
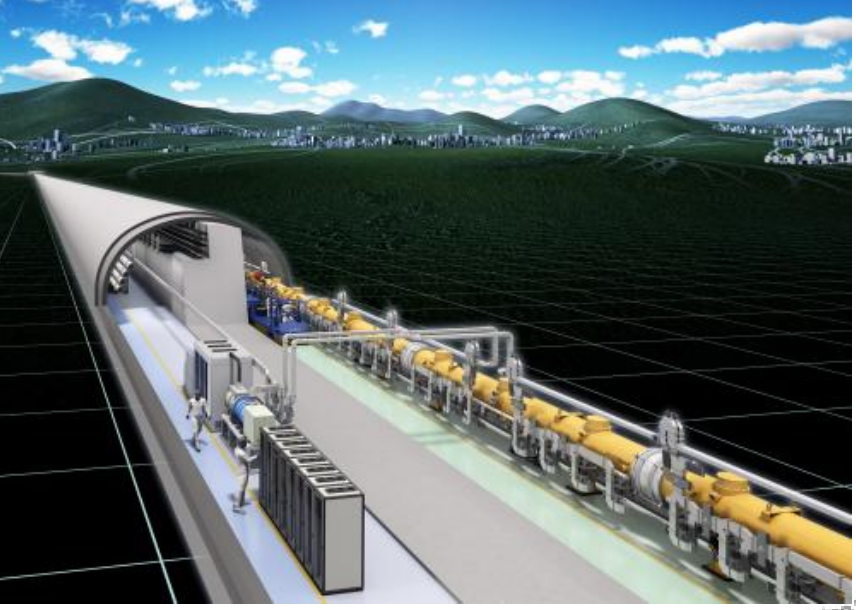
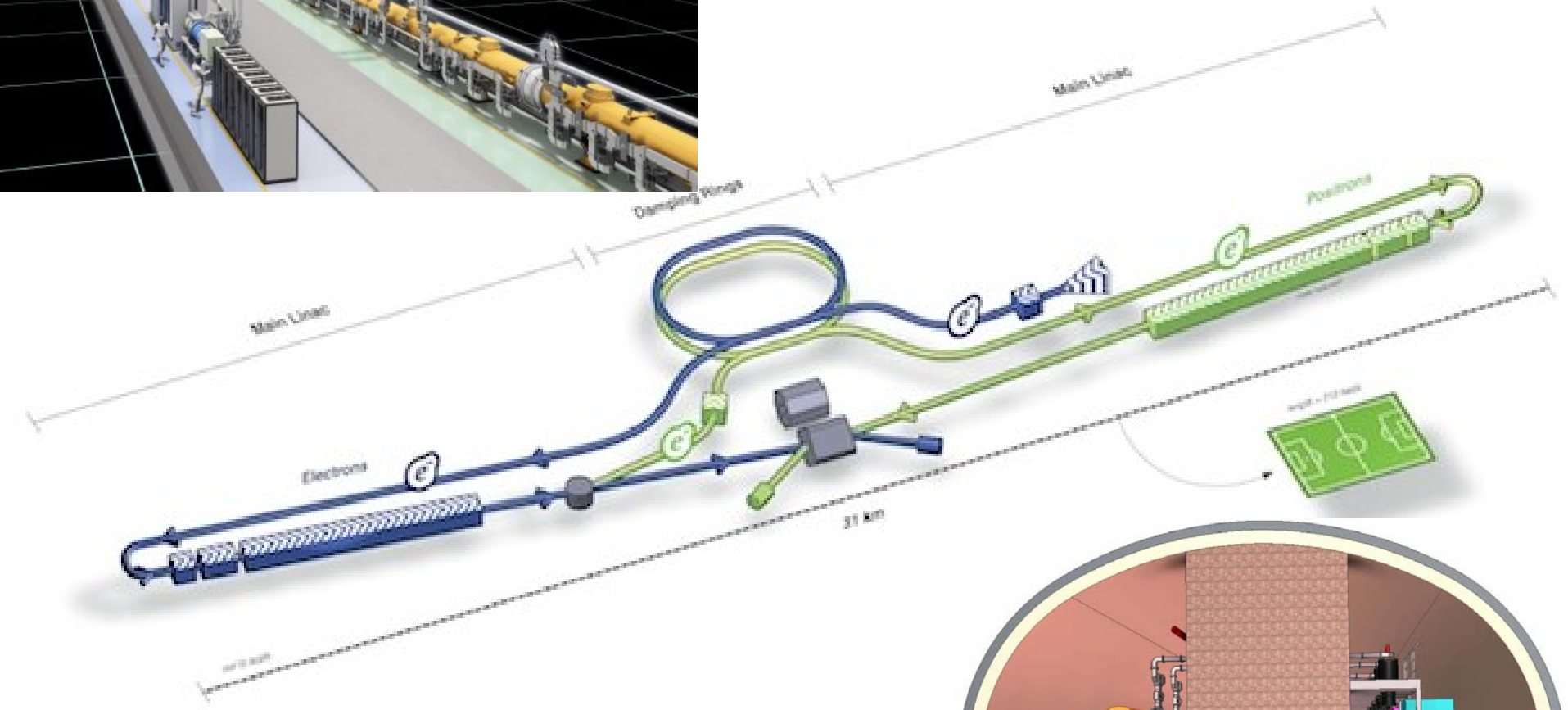
The ILC

From design to reality

Mitsuaki Nozaki
(KEK/ACFA/AsiaHEP)





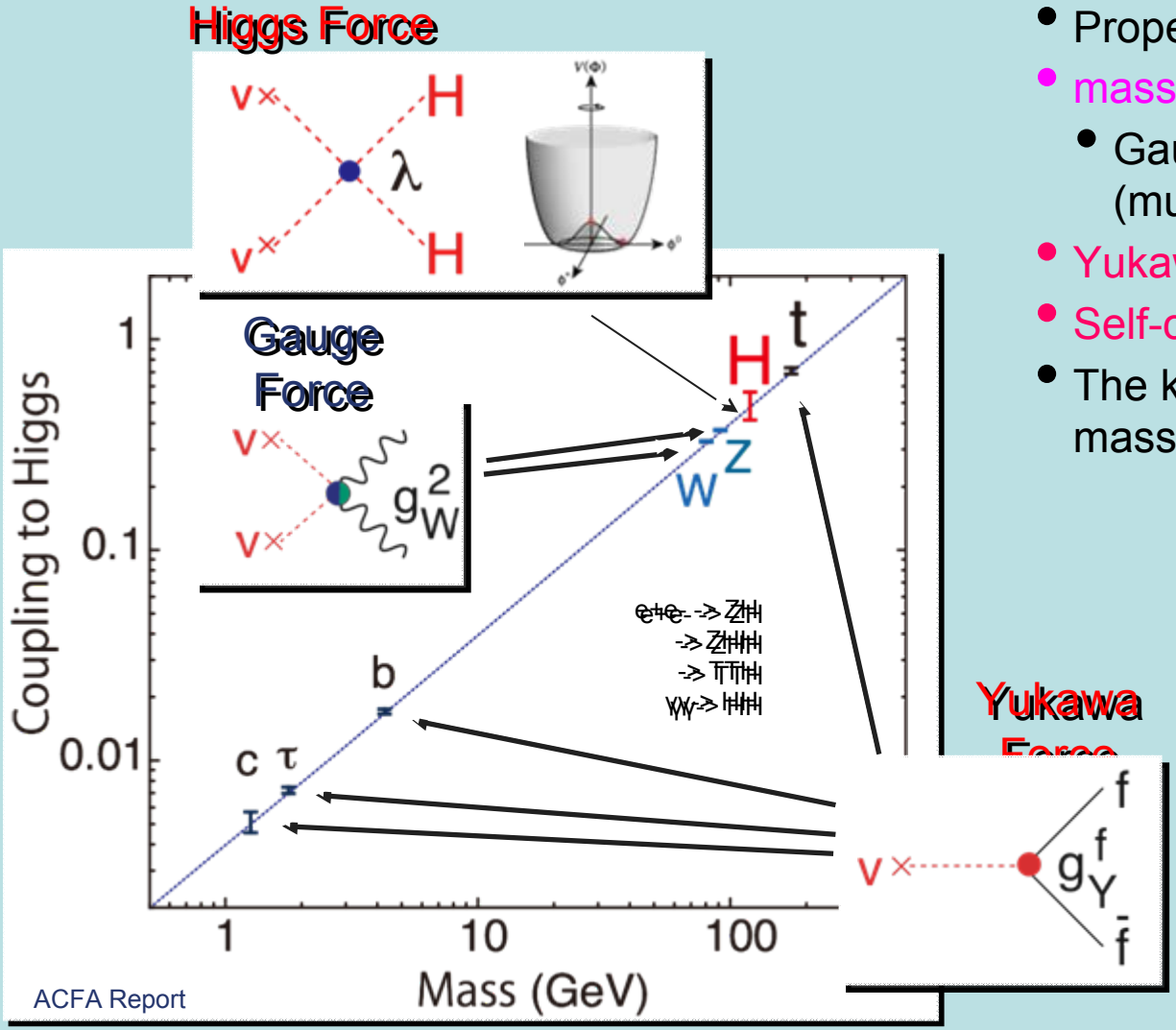

Main Linac
Damping Rings
Main Linac
Positrons
Electrons
31 km

Slides prepared by Keisuke Fujii

PHYSICS@ILC

What Properties to Measure?

The Key is the Mass-Coupling Relation



- Properties to measure are
- mass, width, J^{PC}
  - Gauge quantum numbers (multiplet structure)
- Yukawa couplings
- Self-coupling
- The key is to measure the mass-coupling relation

If the 125GeV boson is the one to give masses to all the SM particles, coupling should be proportional to mass.

Any deviation from the straight line signals BSM!

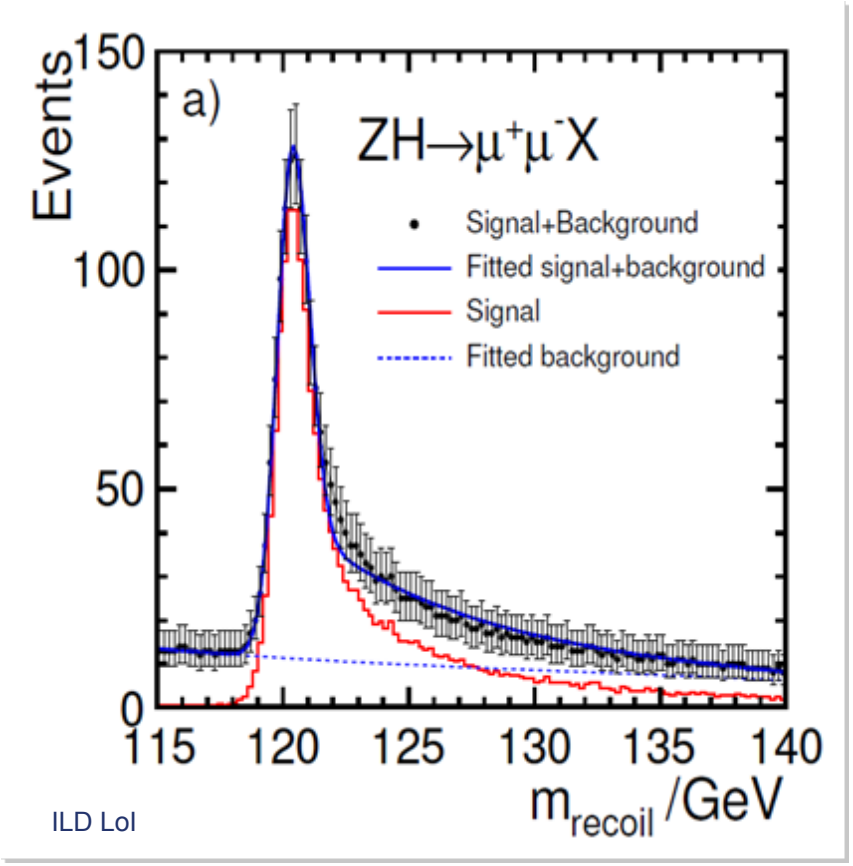
The Higgs is a window to BSM physics!

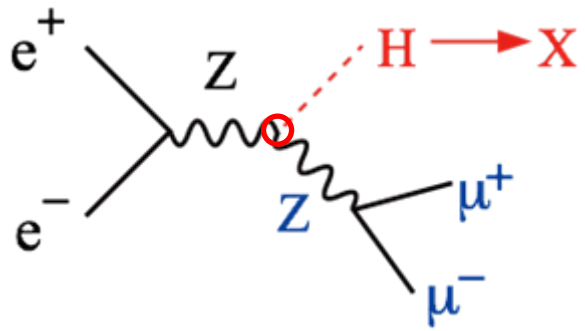
Recoil Mass Measurement

The flagship measurement of ILC 250

What we measure is not BR itself but σxBR. We need σ to extract BR!

Recoil Mass





$$M_X^2 = \left(p_{CM} - (p_{\mu^+} + p_{\mu^-})\right)^2$$

Invisible decay detectable!

$250\,\mathrm{fb}^{-1}$@$250\,\mathrm{GeV}$ $m_H = 125\,\mathrm{GeV}$

$$\Delta\sigma_H/\sigma_H = 2.6\%$$

$$\Delta m_H = 30\,\mathrm{MeV}$$

$$BR(\mathrm{invisible}) < 1\%\,@\,95\%\,\mathrm{C.L.}$$

scaled from mH=120 GeV

Model-independent absolute measurement of σ_{ZH} (the HZZ coupling)

Impossible at LHC

Total Width and Coupling Extraction

One of the major advantages of the LC (impossible at LHC)

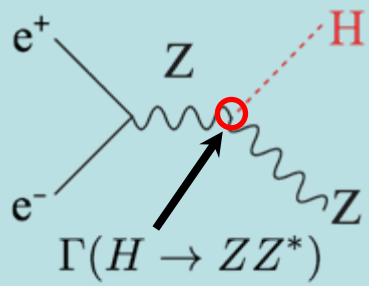
To extract couplings from BRs, we need the total width:

$$g^2_{HAA} \propto \Gamma(H \to AA) = \Gamma_H \cdot BR(H \to AA)$$

To determine the total width, we need at least one partial width and corresponding BR:

$$\Gamma_H = \Gamma(H \to AA)/BR(H \to AA)$$

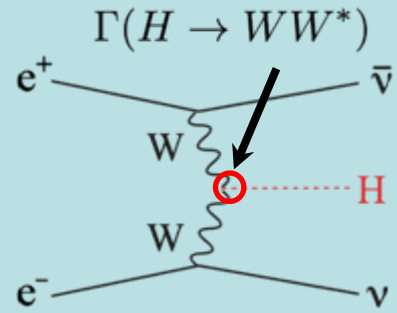
There are two possibilities: A=Z, or W for which we can measure both the BRs and the couplings:



$BR(H \to ZZ^*)$

BR=O(1%): precision limited by low stat. for H->ZZ* events

$250\,\mathrm{fb}^{-1}@250\,\mathrm{GeV}$
$\Delta\Gamma_H/\Gamma_H \simeq 20\%$



$BR(H \to WW^*)$

More advantageous but not easy at low E

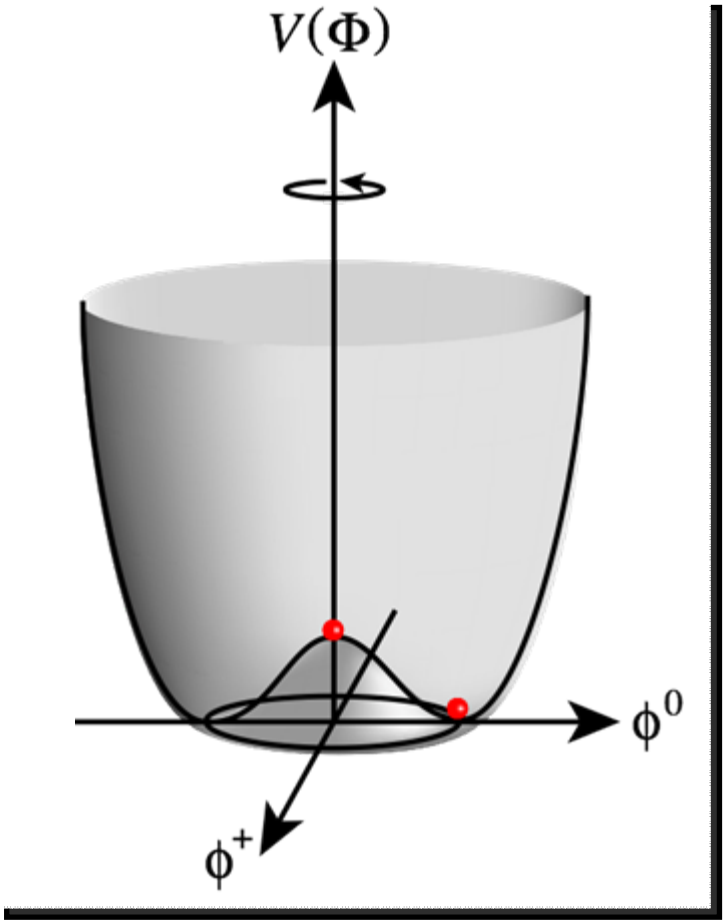
$250\,\mathrm{fb}^{-1}@250\,\mathrm{GeV}$
$\Delta\Gamma_H/\Gamma_H \simeq 11\%$

C.F.Durig, Helmholtz Alliance 6th WS, Dec. 2012

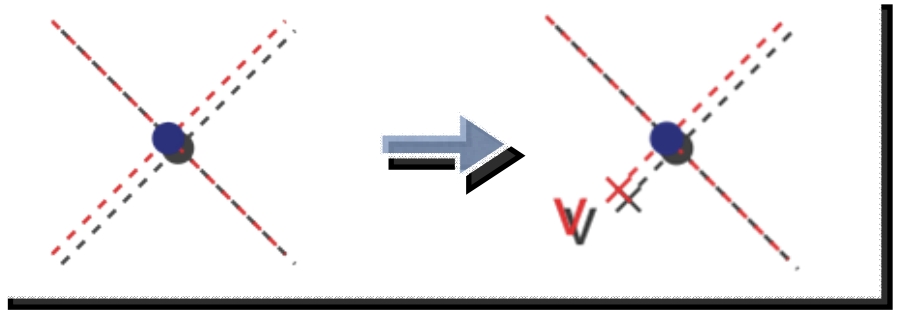
Higher energy (>350GeV) run needed !

Higgs Self-coupling

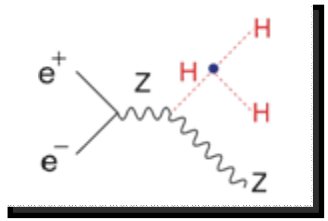
What force makes the Higgs condense in the vacuum?

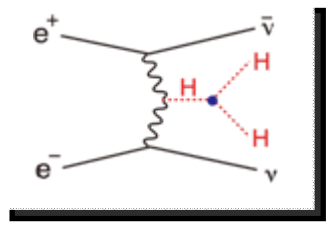


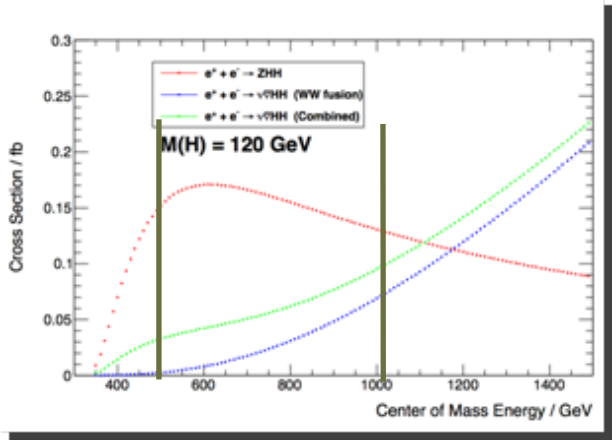
We need to measure the Higgs self-coupling



= We need to measure the shape of the Higgs potential







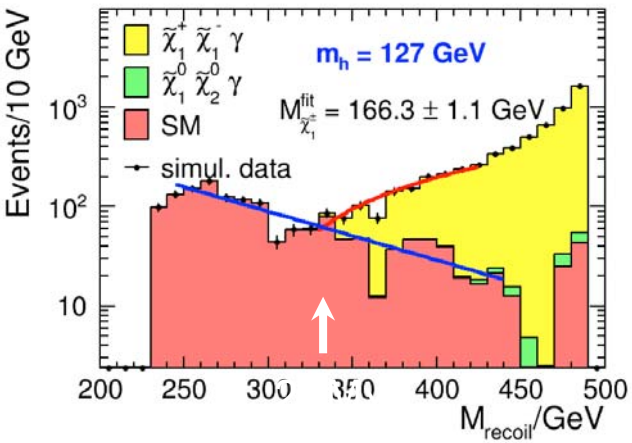
The measurement is very difficult even at ILC.

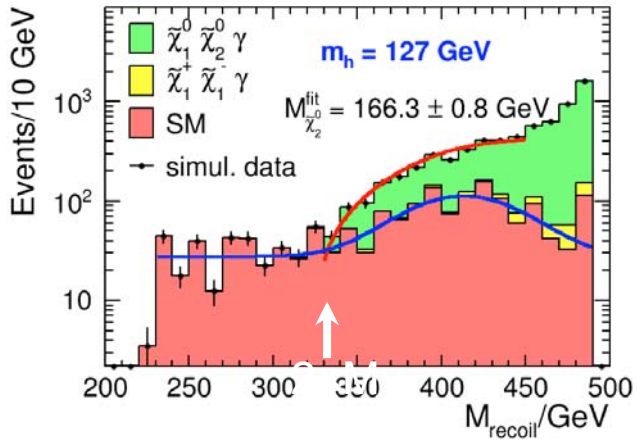
Higgsinos in Natural SUSY (ΔM<a few GeV)

Hale Sert
ECFA LCWS 2013, DESY

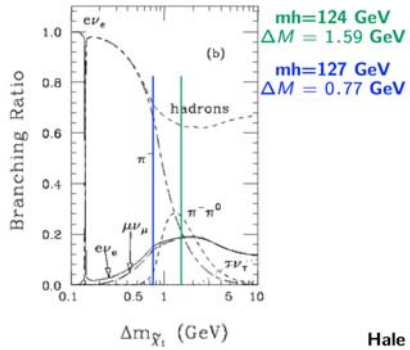
$$e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-\gamma$$
$$e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_1^0\gamma$$

ISR Tagging





Ref: C.-H. Chen et al. hep-ph:9512230



Only very soft particles in the final states → Require a hard ISR to kill huge two-photon BG!

Conclusion

Hale Sert

- Light Higgsinos are well motivated by naturalness
- It is a challenging scenario for LHC
- Separation of Higgsinos at the reconstructed level is possible at the ILC
- Assumed
  - $\sqrt{s} = 500$ GeV
  - $\int \mathcal{L}dt = 500\ fb^{-1}$ with $P(e^+,e^-) = (+30\%,-80\%)$ and $P(e^+,e^-) = (-30\%,+80\%)$ each
- Statistical uncertainities for $P(e^+,e^-) = (+30\%,-80\%)$

m_h=124 GeV

- $\delta(\sigma \times BR) \approx 3\ \%$ $\delta M_{\tilde{\chi}_1^\pm}(M_{\tilde{\chi}_2^0}) \approx 2.1(3.7)$ GeV $\delta\Delta M(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) = 70$ MeV

m_h=127 GeV

- $\delta(\sigma \times BR) \approx 1.5\ \%$ $\delta M_{\tilde{\chi}_1^\pm}(M_{\tilde{\chi}_2^0}) \approx 1.5(1.6)$ GeV $\delta\Delta M(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) = 20$ MeV

WHAT'S NEW

A Precursor in February 2012

JHEPC issued "A Report on Future Projects of High Energy Physics."

The committee makes the following recommendations concerning large-scale projects, which comprise the core of future high energy physics research in Japan.

- **Should a new particle such as a Higgs boson with a mass below approximately 1 TeV be confirmed at LHC, Japan should take the leadership role in an early realization of an e^+e^- linear collider.** In particular, if the particle is light, experiments at low collision energy should be started at the earliest possible time. In parallel, continuous studies on new physics should be pursued for both LHC and the upgraded LHC version. Should the energy scale of new particles/physics be higher, accelerator R&D should be strengthened in order to realize the necessary collision energy.
- **Should the neutrino mixing angle θ_{13} be confirmed as large, Japan should aim to realize a large-scale neutrino detector through international cooperation, accompanied by the necessary reinforcement of accelerator intensity, so allowing studies on CP symmetry through neutrino oscillations.** This new large-scale neutrino detector should have sufficient sensitivity to allow the search for proton decays, which would be direct evidence of Grand Unified Theories.

It all started on 4 July 2012

The discovery of Higgs accelerated the ILC promotion thereafter.

A Quick Follow-up in October 2012

Japan Association of High Energy Physicists (JAHEP, Japan's HEP Community)
Issued "A Proposal for a Phased Execution of the ILC."

On the basis of these developments and following the subcommittee's recommendation on ILC, JAHEP proposes that ILC be constructed in Japan as a global project with the agreement of and participation by the international community in the following scenario:

(1) Physics studies shall start with a precision study of the "Higgs Boson", and then evolve into studies of the top quark, "dark matter" particles, and Higgs self-couplings, by upgrading the accelerator. A more specific scenario is as follows:

(A) A Higgs factory with a center-of-mass energy of approximately 250 GeV shall be constructed as a first phase.

(B) The machine shall be upgraded in stages up to a center-of-mass energy of ~500 GeV, which is the baseline energy of the overall project.

(C) Technical extendability to a 1 TeV region shall be secured.

A Milestone Achieved in December 2012

Technical Design Report (TDR) has been completed after 8 years of concerted efforts world wide led by Barry Barish and was handed-over to ILCSC chair Jonathan Bagger.

The hand-over ceremony took place in Tokyo and the media was invited to witness the ceremony.

A Step Forward in February 2013

The Linear Collider Collaboration (LCC) led by Lyn Evans has started working.

An eloquent Deputy and the Linear Collider Board (LCB) Chair.
The JINR Director is the member of LCB.

Access to Policy Makers in March/April 2013

A courtesy visit to Japan's Prime Minister

Takeo Kawamura, Chair of the Federation of Diet members in support of the ILC and former Chief Cabinet Secretary (right) and Daniel B. Poneman, Deputy Secretary of Energy (left) in Washington.

Japanese delegation visited Washington to "sell" the ILC.

KEK Roadmap in May 2013

A major revision of the KEK Roadmap

International Linear Collider (ILC)

KEK will play a central role in creating an international preparatory group
and will lead the effort on advanced R&D, the engineering design of the apparatus and facility, and the organizational design
toward groundbreaking for the linear collider project to be hosted in Japan,
within the framework of a global collaboration.

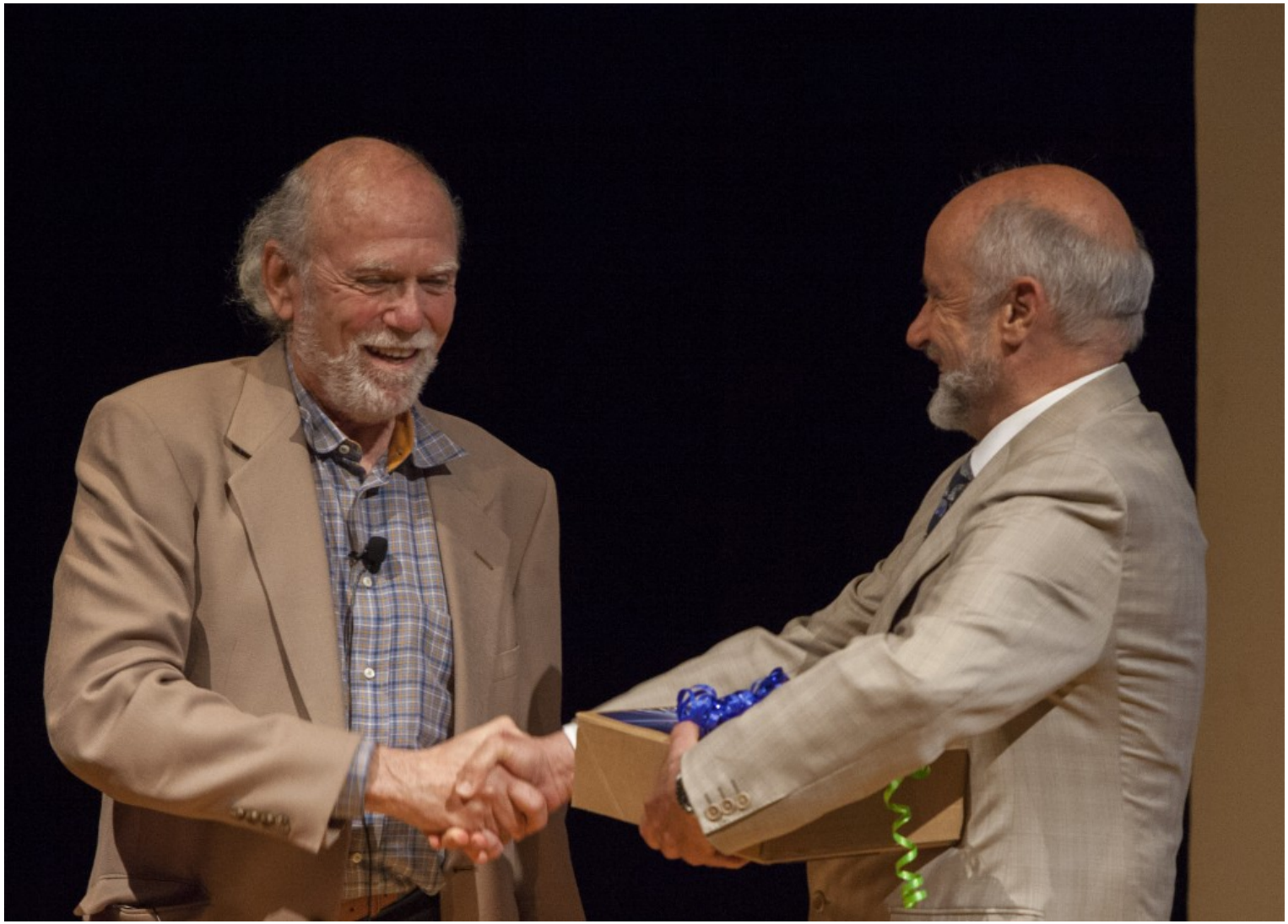
FYI;

At the neutrino facility, a significant improvement in the measurement precision of the T2K experiment will be pursued.
In addition, new research plans will be developed for the next generation of long-baseline neutrino oscillation experiments,
while relevant preparatory studies are pushed forward in parallel.

European Strategy in May 2013

e. There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. 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.*

Ready for Construction in June 2013



After reviews, ILC-TDR was handed over to ICFA Chair.

A Message from US in August 2013

A Snowmass summary

We welcome the initiative for ILC in Japan

- U.S. accelerator community is capable to contribute
  - Supported by the physics case as part of a balanced program
- ILC design is technically ready to go
  - TDR incorporates leadership U.S. contributions to machine physics & technology
    - SRF, high power targetry (e+ source), beam delivery, damping rings, beam dynamics
- Important that there is an upgrade path of ILC to higher energy & luminosity (> 500 GeV, > 10^{34} $cm^{-2}s^{-1}$)

We are experienced & ready to do it

A Message from Asia in August 2013

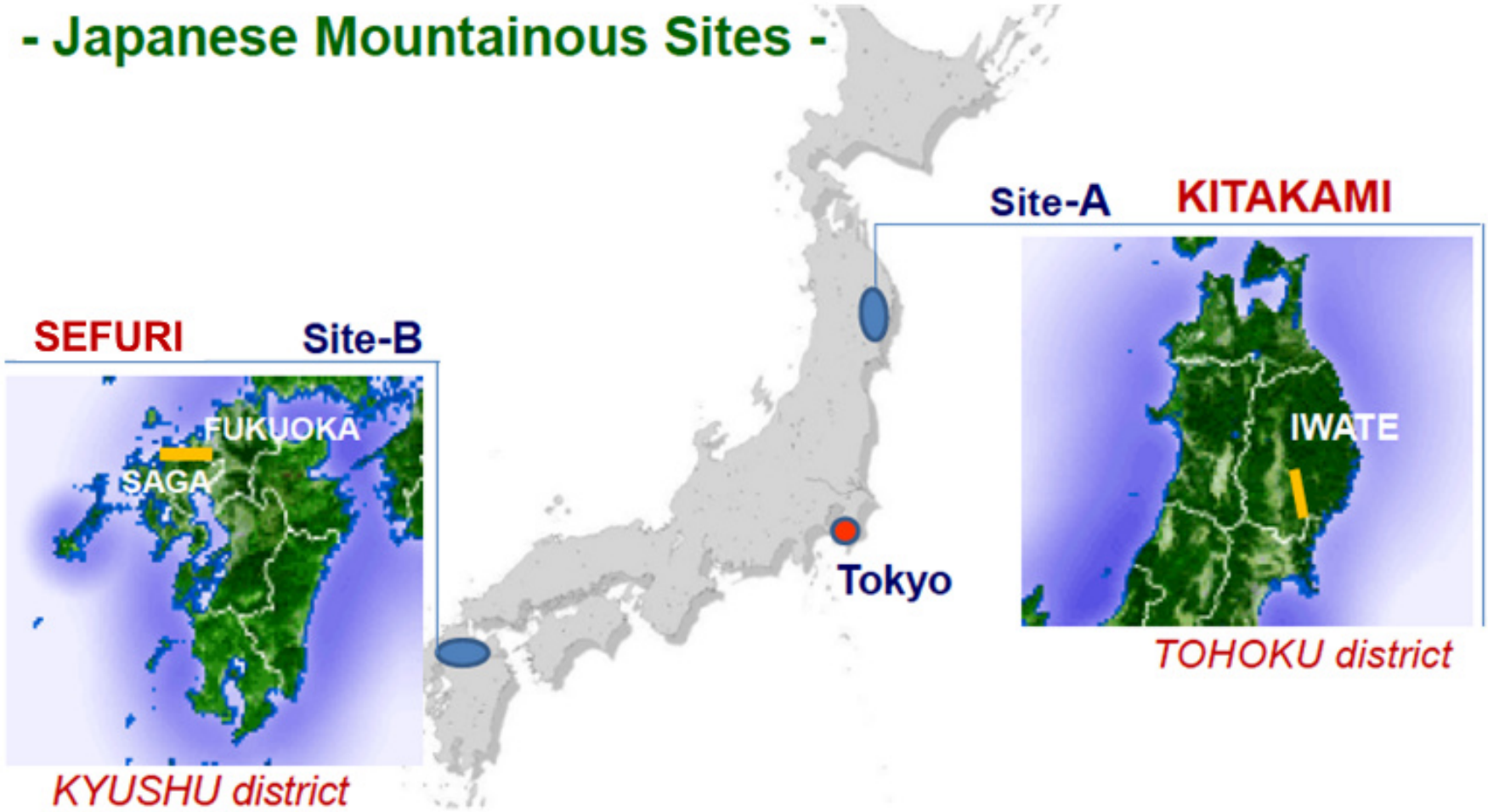
AsiaHEP/ACFA welcomes the proposal by the Japanese HEP community for the ILC to be hosted in Japan. AsiaHEP/ACFA looks forward to a proposal from the Japanese Government to initiate the ILC project.

To be public soon.

AsiaHEP: Asia-Pacific High Energy Physics Panel, consisting of representatives from HEP communities and major HEP labs in Australia, China, India, Japan, Korea, Russia and Taiwan.
(c.f. Vladimir Blinov (BINP) from “Asian part of Russia”)

ACFA: Asia Committee for Future Accelerators, consisting of particle/nuclear physics, photon/neutron science and accelerator communities in Australia, Bangladesh, China, India, Indonesia, Japan, Korea, Malaysia, Pakistan, Russia, Singapore, Taiwan, Thailand, and Vietnam.
(c.f. Oleg Mashkov (BINP) and Grigori Shirkov (JINR))

A Site in Japan was Chosen Recently



A Site was Announced Last Week

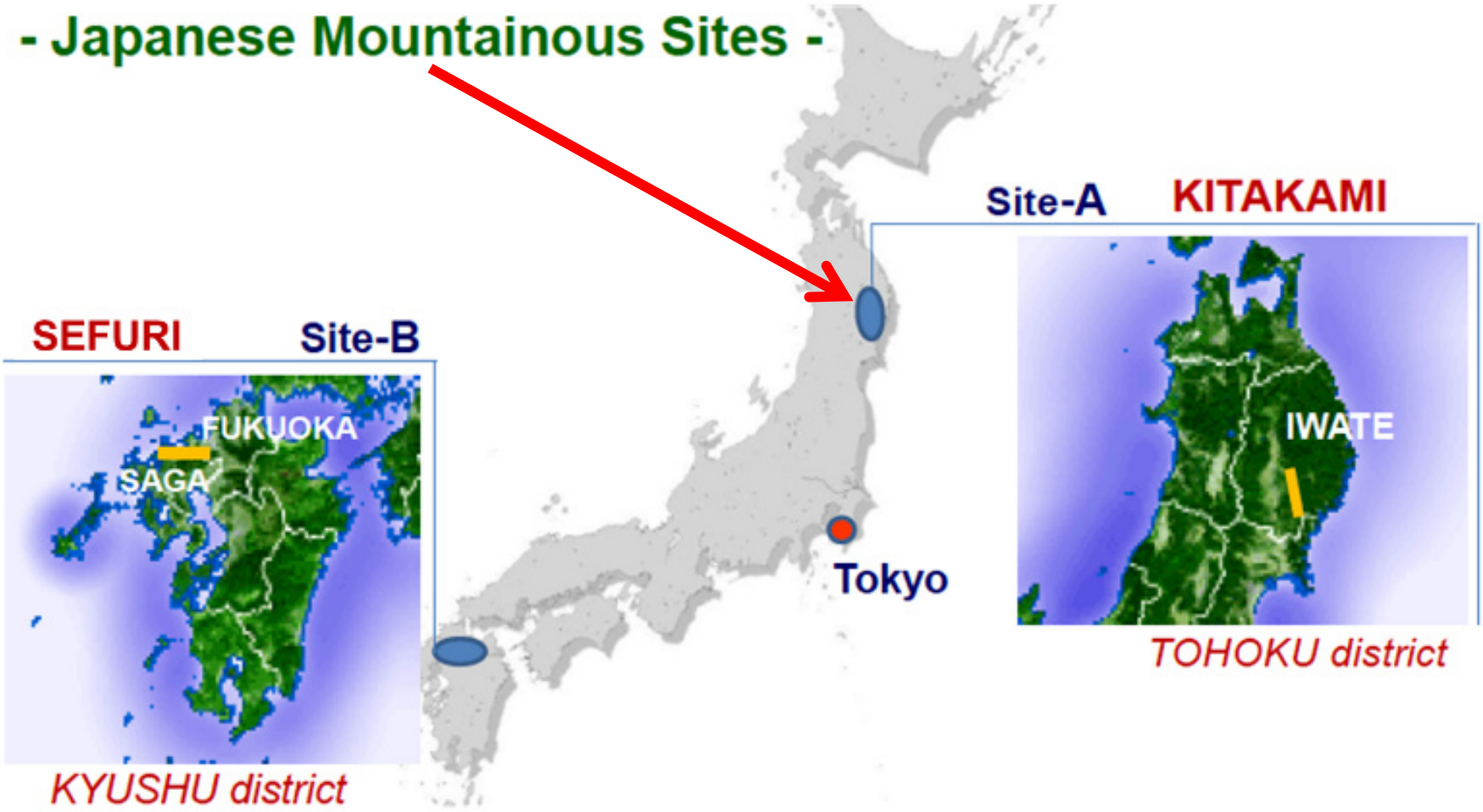
August 17, 2013

The ILC site evaluation committee of Japan has assessed the two candidate sites based on technical and socio-environmental criteria and unanimously concluded as follows:

The Kitakami site is evaluated to be the best domestic candidate site for the ILC.

In addition, the committee strongly recommends the central campus of the Kitakami site to have a good environment for living and research and to be located near the Shinkansen line for convenient access to Sendai and Tokyo.

Kitakami Site



The Local City has Already been Prepared

まちづくりのイメージ（ゾーニング）

エントランスゾーン

一関市の玄関口として、研究等で訪れる方と市民が交流し、回遊性の高いまちの形成を図るとともに多様な情報発信機能や交通結節機能の強化など高次都市機能の集積を誘導するなど、質の高い都市空間の形成が必要となります。


東北新幹線


仙台空港

居住ゾーン

研究者等やその家族の新たな住宅地として、みどり豊かで潤いある田園生活を可能とする自然・環境共生型の住宅地や一ノ関駅に近接し最も交通の利便性を享受できる都市型の住宅地などの形成が必要となります。


住宅団地（サンヒル柴宿）


一ノ関駅東口


セルン（CERN）※の街並み

※スイスのジュネーヴにある世界最大規模の素粒子物理学の研究所


一関東工業団地

実験・観測ゾーン

ILC研究施設を核とし、素粒子・加速器関係の大学研究施設や企業の研究施設、産業用の放射光施設など研究施設の集積が想定されます。


岩手県南技術研究センター


一関工業高等専門学校

産業集積ゾーン

ILCによる実験、研究から派生するさまざまな産業をはじめ、仙台と盛岡の中間に位置する優位性を生かした幅広い産業の集積が想定されます。


江刺フロンティアパーク


一関東第二工業団地

A Message from Science Council Soon

- In response to an inquiry from MEXT about ILC, SCJ set up an ad-hoc committee to answer.
- A statement will be issued (probably) in September.
  - Reportedly the statement will include;
    - Science case for the ILC is OK.
    - ILC should not affect other science research in Japan.
    - The government should start preparatory negotiation with potential partners to draft a detailed plan in a few years.

    - MEXT: Ministry of Education, Culture, Sports, Science and Technology
    - SCJ: Science Council of Japan, the highest level institution representing Japan's science community.

A Message from ACFA/AsiaHEP Chair

- LCC will start shortly the engineering design for the ILC in Japan.
- The Government of Japan may initiate a preparatory work by making a initial approach to a potential partner, hopefully.
- Considering the achievements in HEP and accelerator science, there is no doubt that Russia is an important partner of the ILC project.
- From Asia, Russia is too large to identify a single point of contact.
  - CERN member states are supposed to collaborate through CERN.
  - Major partners in Asia are expected to collaborate separately.
  - Minor partners in Asia-Oceania are considering a way to join. A consortium?
  - What about Russia?
- Exciting years ahead of us!

THANK YOU