ILC Project

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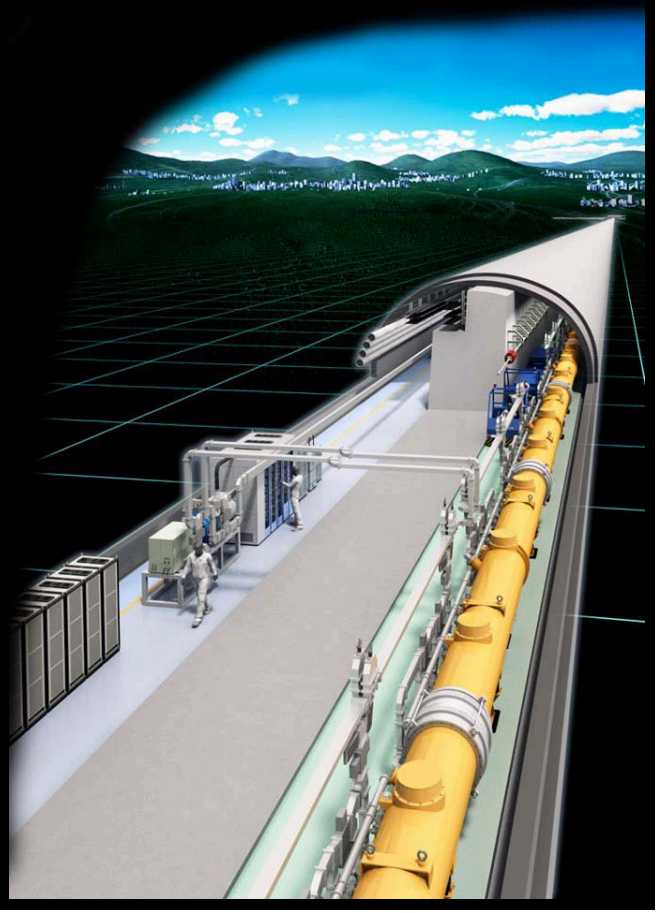
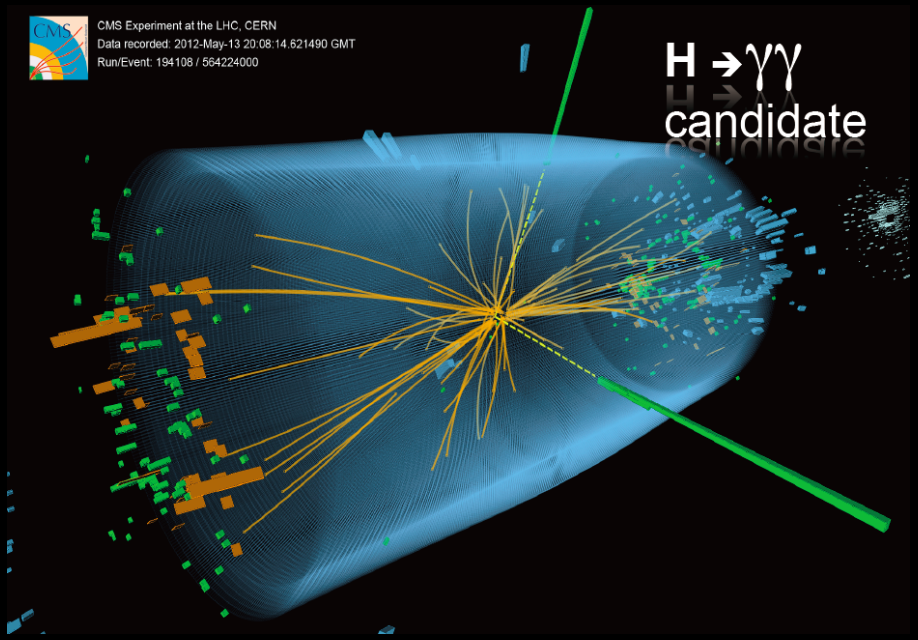
Tohoku University

PASCOS 2013
November 22, 2013, Taipei



ILC Physics

Discovery of Higgs particle

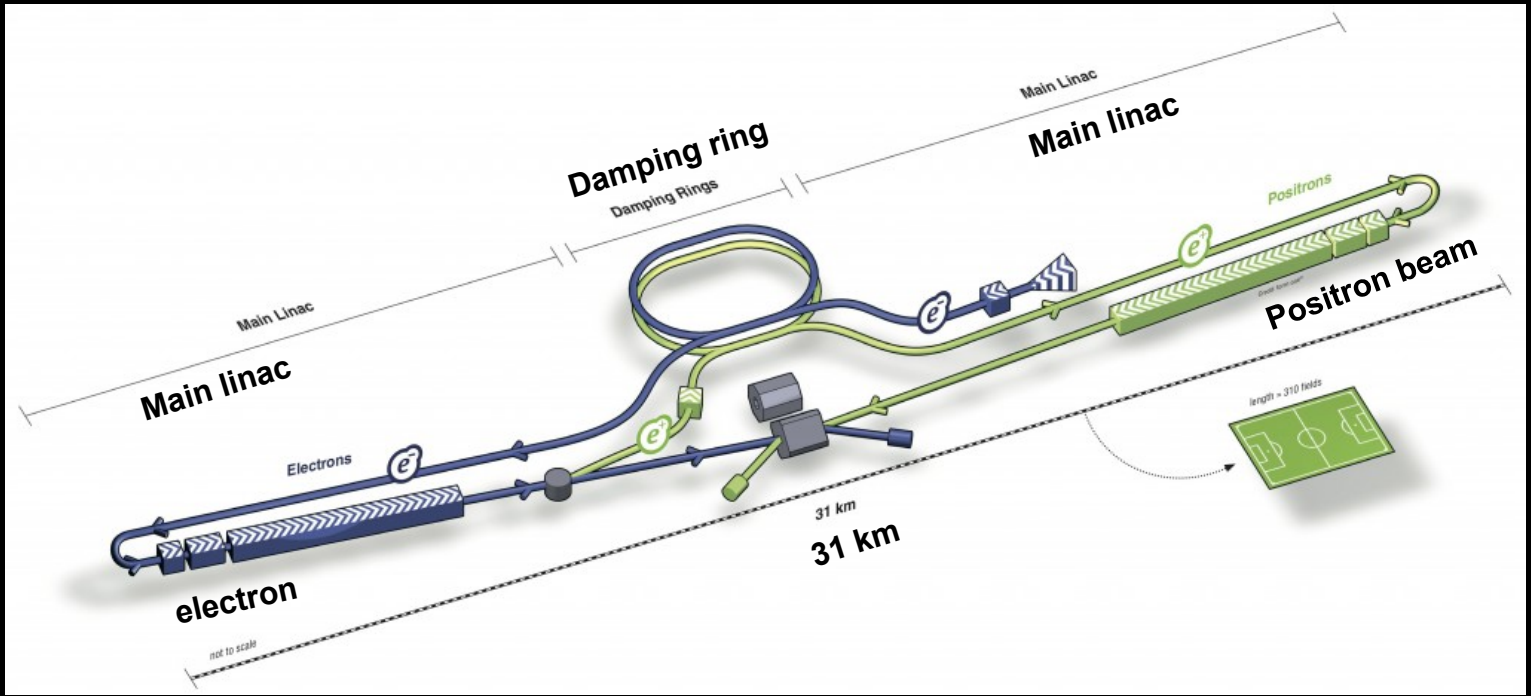


- The fine-tuning problem of the SM became real. (unless 'multiverse')
- The problem of missing dark matter in the SM became accute
- and more …
- : Compelling reasons for the next step.

A new era of particle physics has begun!

The ILC is designed to lead the new era.

ILC (International Linear Collider)



- 500 GeV CM with 31 km → upgrade later to ~ 1TeV CM with 50 km
- IP beam size : 6 nm high, 500 nm wide 300 μm long (@500 GeV CM)
- Luminosity 1.8 x 10^{34} /cm^2s (@500 GeV CM)
- First stage : 250 GeV Higgs Factory

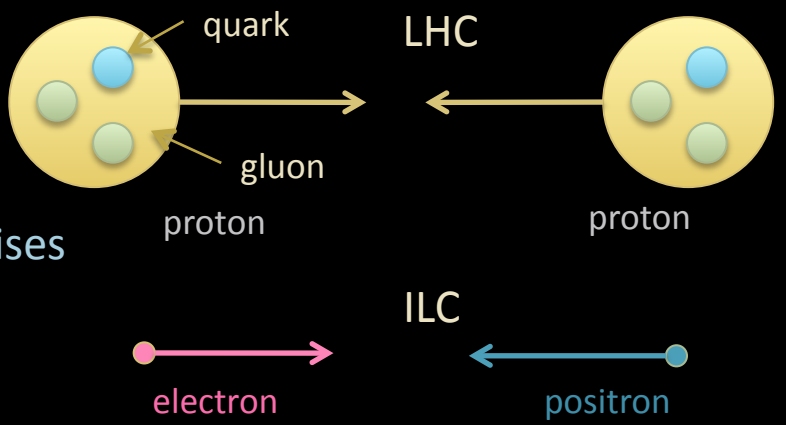
ILC features : cleanliness

- Collision of two elementary particles
  - proton + proton at LHC
    - Proton = 3 quarks + gluons
  - electron + positron at ILC

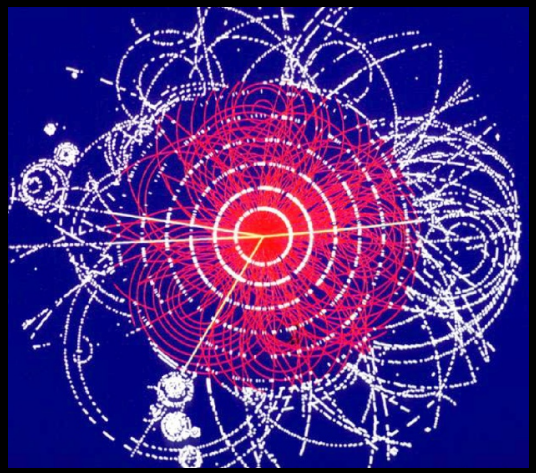
→ Signal is clearly seen without much noises

→ Trigger-less data taking

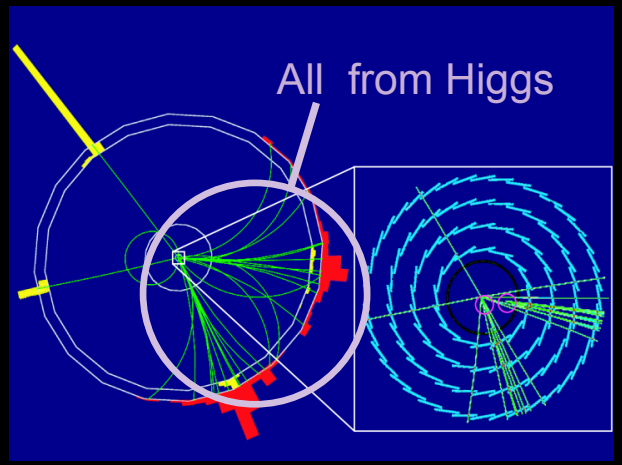
→ Theoretically clean
(less theoretical uncertainties)



LHC



ILC



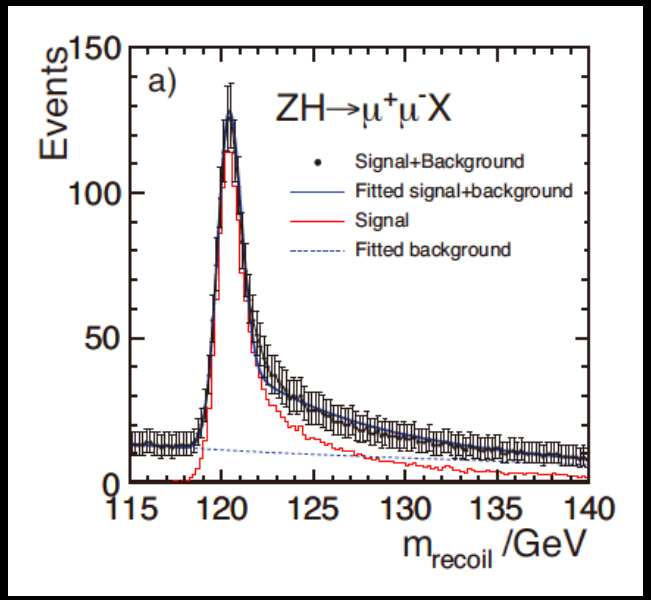
ILC features : control

- Initial state of electron-positron interaction :
  - Energy-momentum 4-vector is specified
  - Electron polarization (80%~90%) is specified
    - Positron polarization (60%) is optional (30% comes for free)

Energy-momentum 4-vector

→ e.g. recoil mass analysis: tagged Higgs

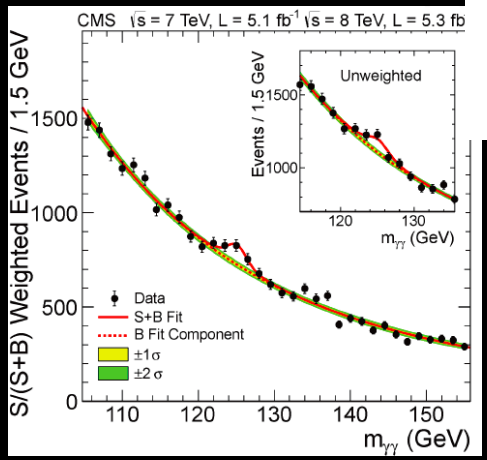
Higgs to ALL (including invisible final state)

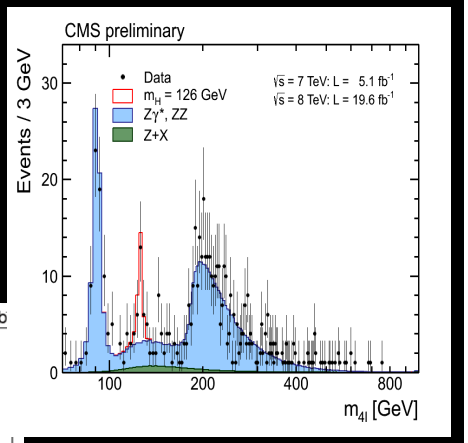


ILC

LHC

$H \to \gamma\gamma$





$H \to ZZ$

Electron polarization

Specify the intermediate state

- Right-handed e- turns off A^0
  - Information on the gauge structure of the final state

Increase rates

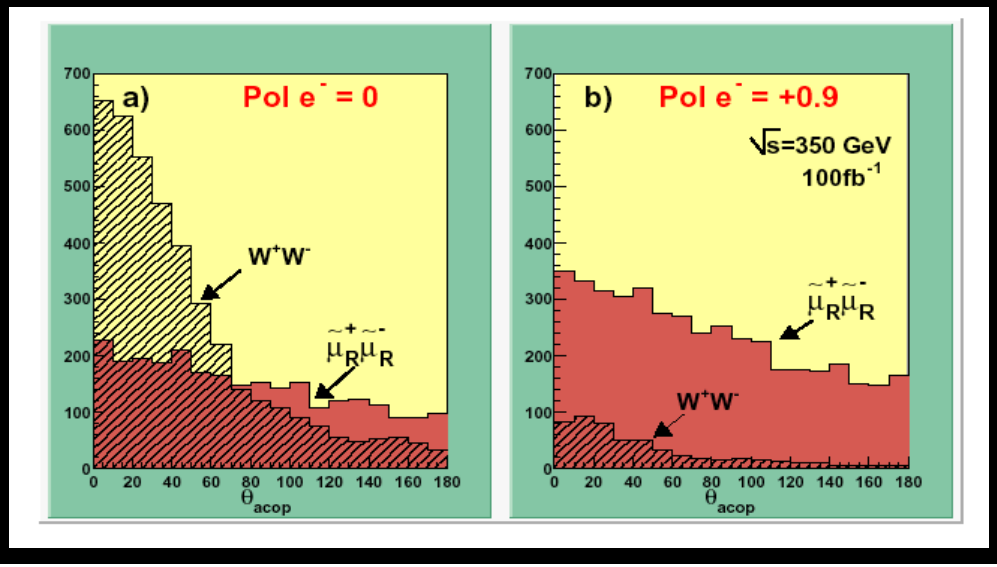
- e.g. $P^-/P^+ = -0.8/0.3$:

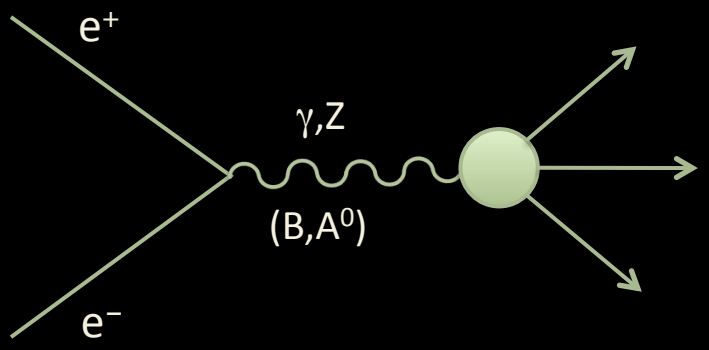
  Increases the H production mode

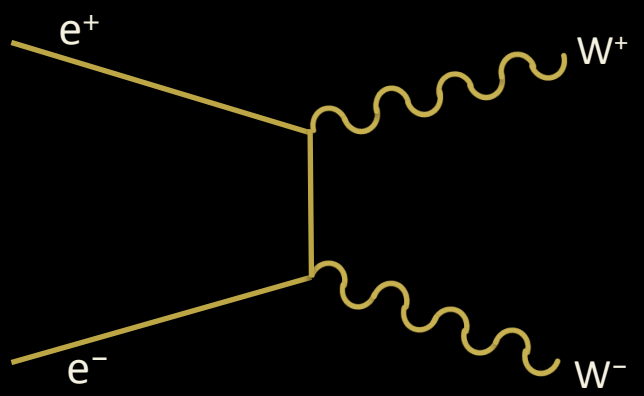
  $\sigma(\nu\nu H)$ by X 2.34 (=1.8 x1.3)

Background rejection

- Right-handed e- turns off W



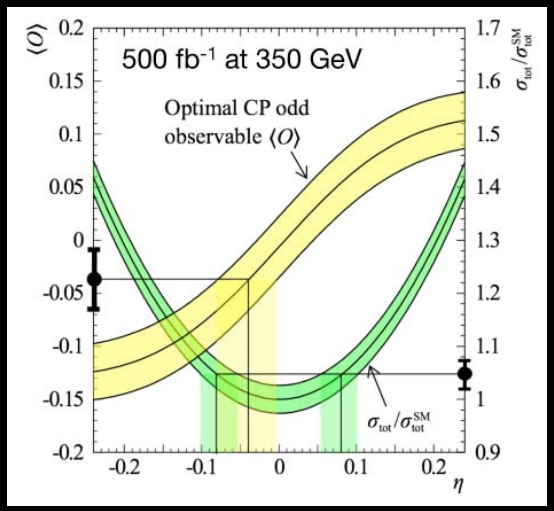


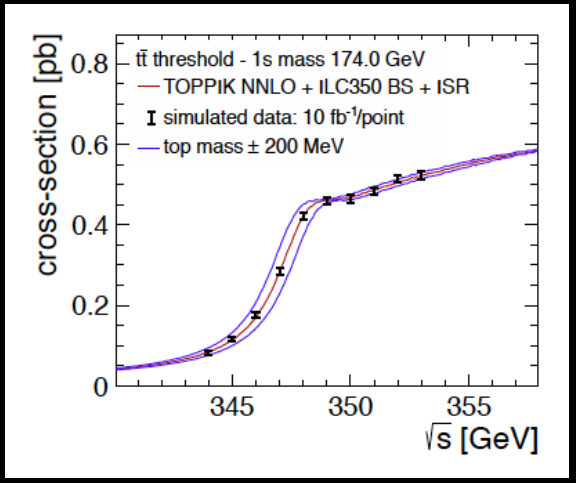


e.g. acoplanar muon pair produciton such as smuon pair production

ILC 250~500 GeV

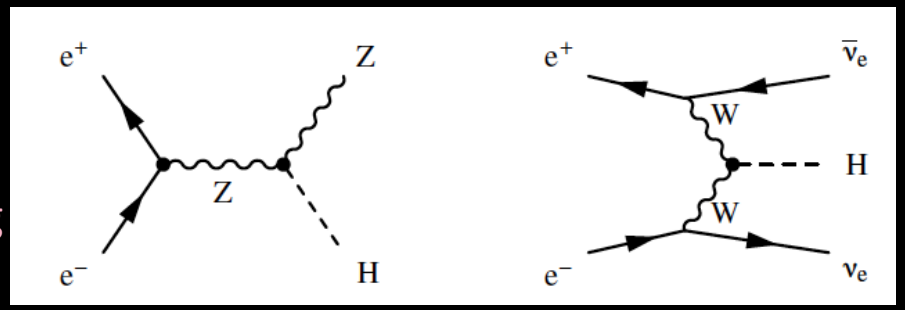
- Higgs
  - Generate 20K~30K Higgs every year
  - Higgs Brs (table later)
    - H → cc, invisible; & model independent
  - Γ_{tot} to 5%
    - Br(H → WW) & g(HWW) by e+e- → ννH
    - Br(H → ZZ) & g(HZZ) by e+e- → HZ
  - CP to 3~4% (on mixing coeff)
- top
  - m_t(msbar) to 100 MeV
  - Anomalous ttZ, tbW, ttg coupl
- New physics through SM
  - Composite Higgs scale to 45 TeV
  - Anomalous WWV coupl
- New unexpected particles!





ILC @1 TeV

Higgsstrahlung



W fusion

	250 GeV	350 GeV	500 GeV	1 TeV
$\sigma(e^+e^- \to ZH)$	240 fb	129 fb	57 fb	13 fb
$\sigma(e^+e^- \to H\nu_e\bar{\nu}_e)$	8 fb	30 fb	75 fb	210 fb
Int. $\mathcal{L}$	250 fb^{-1}	350 fb^{-1}	500 fb^{-1}	1000 fb^{-1}
# ZH events	60,000	45,500	28,500	13,000
# $H\nu_e\bar{\nu}_e$ events	2,000	10,500	37,500	210,000

Luminosity
each energy for ~3 years

- At higher Ecm
  - W fusion dominant
  - More Higgs
  - New particles !
- Good for Higgs self coupling

  e+e- → ννHH
  - Effect of irreducible diagrams less important

  $\delta\lambda/\lambda = 0.76\ \delta\sigma/\sigma$ @ 1 TeV

  ($\delta\lambda/\lambda = 1.66\ \delta\sigma/\sigma$ @500 GeV)

  → $\delta\lambda/\lambda = 17\%$ (2 ab^{-1} @ 1 TeV)

ILC Luminosity Upgrade Options

- 250 GeV CM (Higgs factory)
  - X4 luminosity @ 3E34/cm^{2}s
  - x2 Nbunch, x2 rep rate; 120 → 200 MW wall plug
- 500 GeV CM
  - x2 luminosity @3.6E34/cm^{2}s
  - x2 Nbunch; 160 → 200 MW wall plug
- 1 TeV CM
  - x1.4 luminosity @5E34/cm^{2}s
  - Aggressive beam params;
    Same wall plug power

Recall the additional ~x2 luminosity by polarizations for Ecm > ~1 TeV (W-fusion)

Measurement errors of Higgs Couplings
(Snowmass study – Higgs WG)

Facility	LHC	HL-LHC	ILC500	ILC500-up	ILC1000	ILC1000-up
$\sqrt{s}$ (GeV)	14,000	14,000	250/500	250/500	250/500/1000	250/500/1000
$\int \mathcal{L}dt$ (fb^{-1})	300/expt	3000/expt	250+500	1150+1600	250+500+1000	1150+1600+2500
κ_γ	$5-7\%$	$2-5\%$	8.3%	4.4%	3.8%	2.3%
κ_g	$6-8\%$	$3-5\%$	2.0%	1.1%	1.1%	0.67%
κ_W	$4-6\%$	$2-5\%$	0.39%	0.21%	0.21%	0.2%
κ_Z	$4-6\%$	$2-4\%$	0.49%	0.24%	0.50%	0.3%
κ_ℓ	$6-8\%$	$2-5\%$	1.9%	0.98%	1.3%	0.72%
$\kappa_d = \kappa_b$	$10-13\%$	$4-7\%$	0.93%	0.60%	0.51%	0.4%
$\kappa_u = \kappa_t$	$14-15\%$	$7-10\%$	2.5%	1.3%	1.3%	0.9%

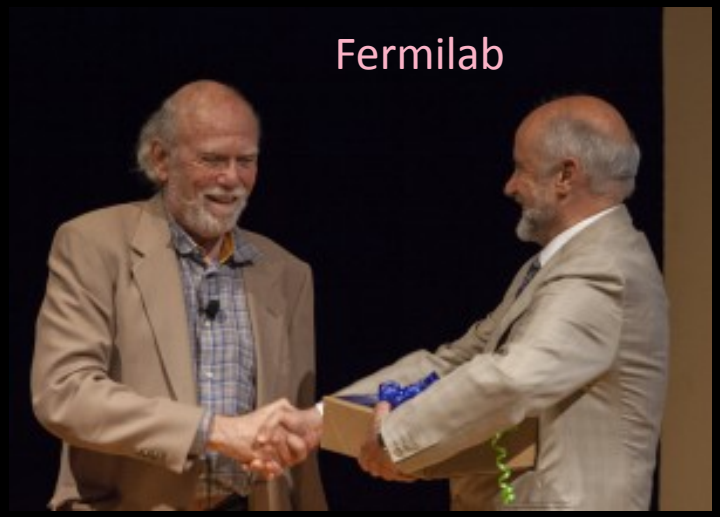
- All assume generation universality, no BSM → Fit
- Apart from γ, ILC is 1/3 ~ 1/10 of HL-LHC
- With luminosity upgrade, additional ~1/2
- ILC can measure model-independently w/o assumptions above.

ILC TDR Completion

June 12, 2013

'A World-wide Event – from design to reality'

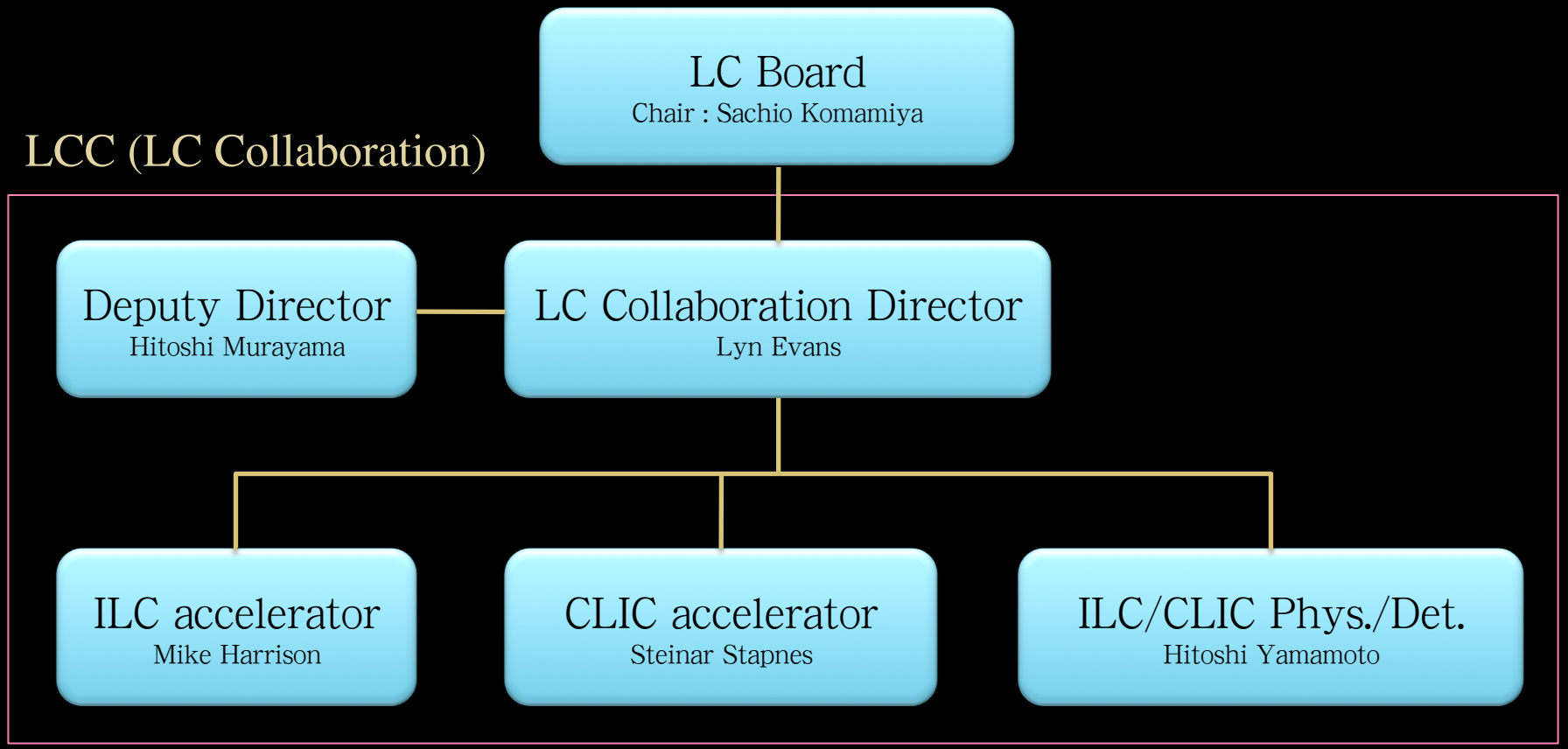
Fermilab



Tokyo

CERN

New International LC Organization

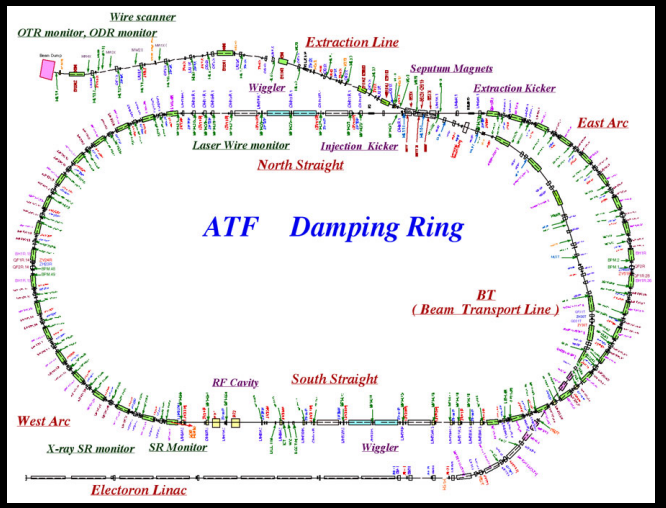


In full operation since June, 2013

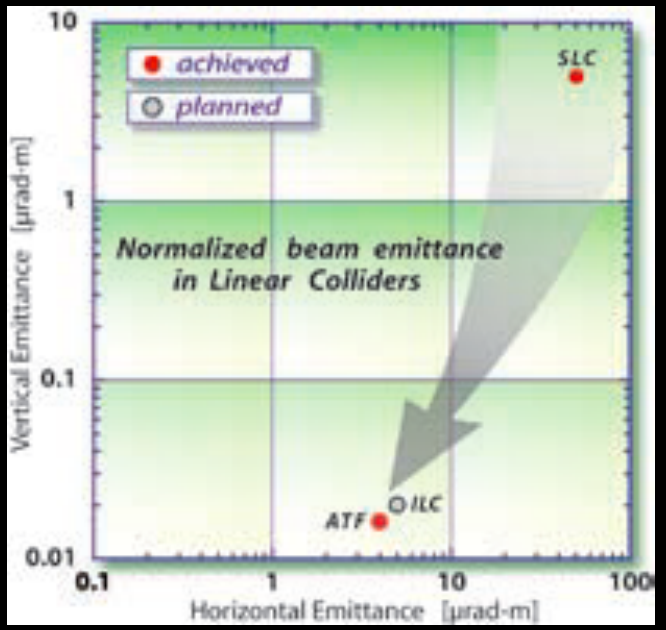
ILC Accelerator

ILC Accelerator

1. Ultra-Small Beam



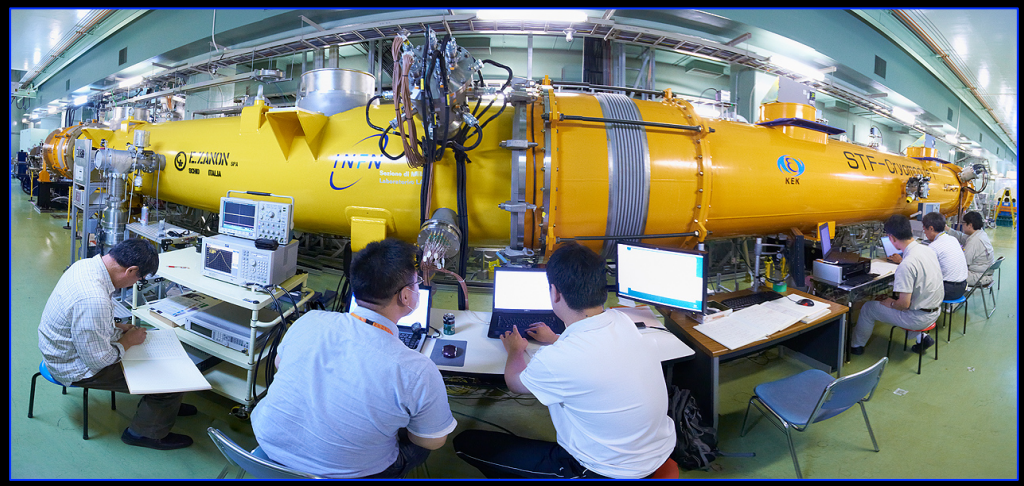
- Low emittance : KEK ATF (Accelerator Test Facility)
  - Achieved the ILC goal.
- Small vertical beam size : KEK ATF2
  - Goal = 37 nm, 65 nm achieved
    - Limit is in measurement. No basic problem seen.
- Stabilize the beam at nm scale: KEK ATF2
  - Feedback system successful (FONT)



ILC Accelerator

2. Main Acceleration

- Accelerating cavity
  - Spec: 31.5 MV/m ±(<20%)
  - >80% yield achieved (RDR goal achieved)
- Cryomodule assembly
  - Combine cavities from all over the world
    - KEK S1-global successful



TDR completed: ILC technology is now 'ready'

ILC Detectors

ILC Detector Performances

- Vertexing $(h \to b\bar{b}, c\bar{c}, \tau^+\tau^-)$
  - ~1/5 $r_{beampipe}$, 1/50~1/1000 pixel size, ~1/10 resolution (wrt LHC)

$$\sigma_{IP} = 5 \oplus \frac{10}{p \sin^{3/2}\theta} (\mu m)$$

- Tracking $(e^+e^- \to Zh \to \ell^+\ell^- X; \quad \text{incl. } h \to \text{nothing})$
  - ~1/6 material, ~1/10 resolution (wrt LHC)

$$\sigma(1/p) = 2 \times 10^{-5} (\text{GeV}^{-1})$$

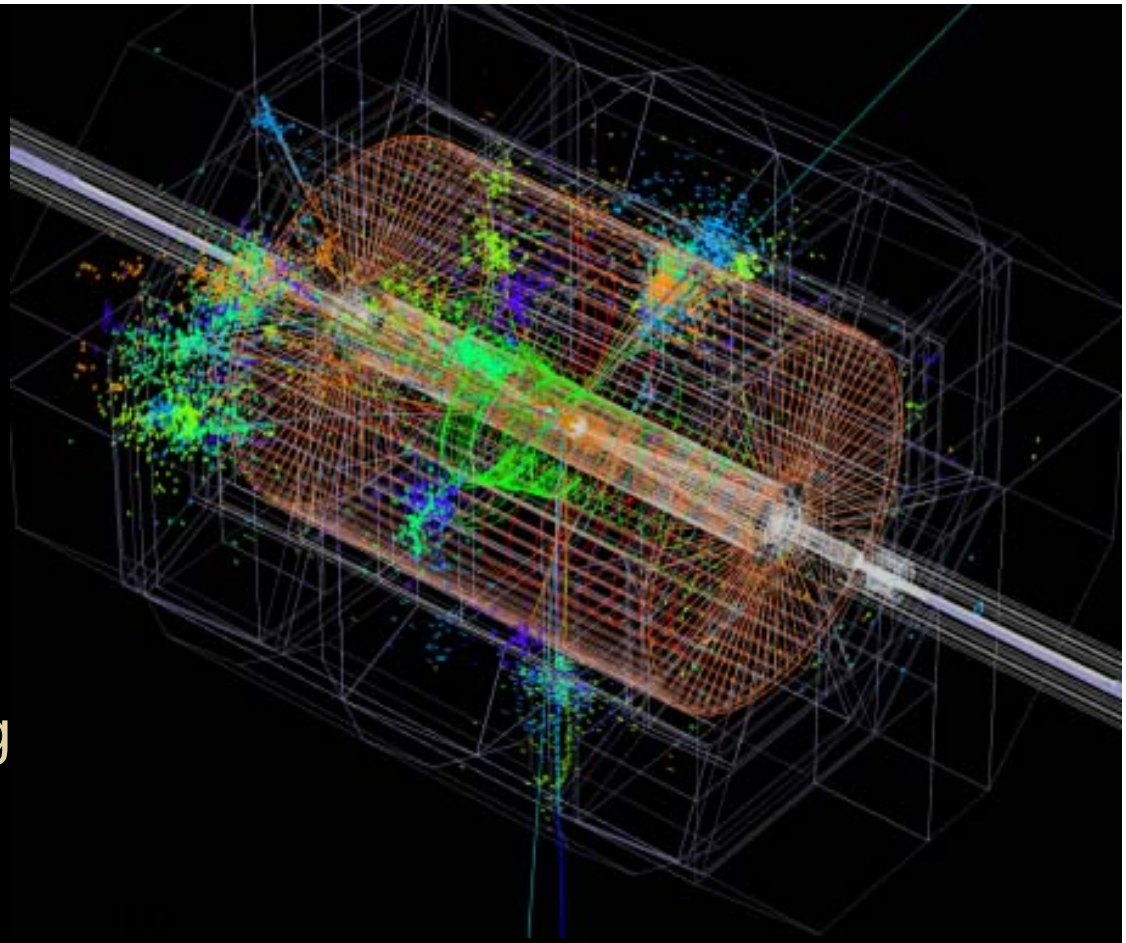
- Jet energy (quark reconstruction by PFA)
  - 1000x granularity, ~1/2 resolution (wrt LHC)

$$\sigma_E / E = 0.3 / \sqrt{E(\text{GeV})}$$

Above performances achieved in realistic simulations based on actual detector R&Ds.

PFA

(particle flow algorithm)



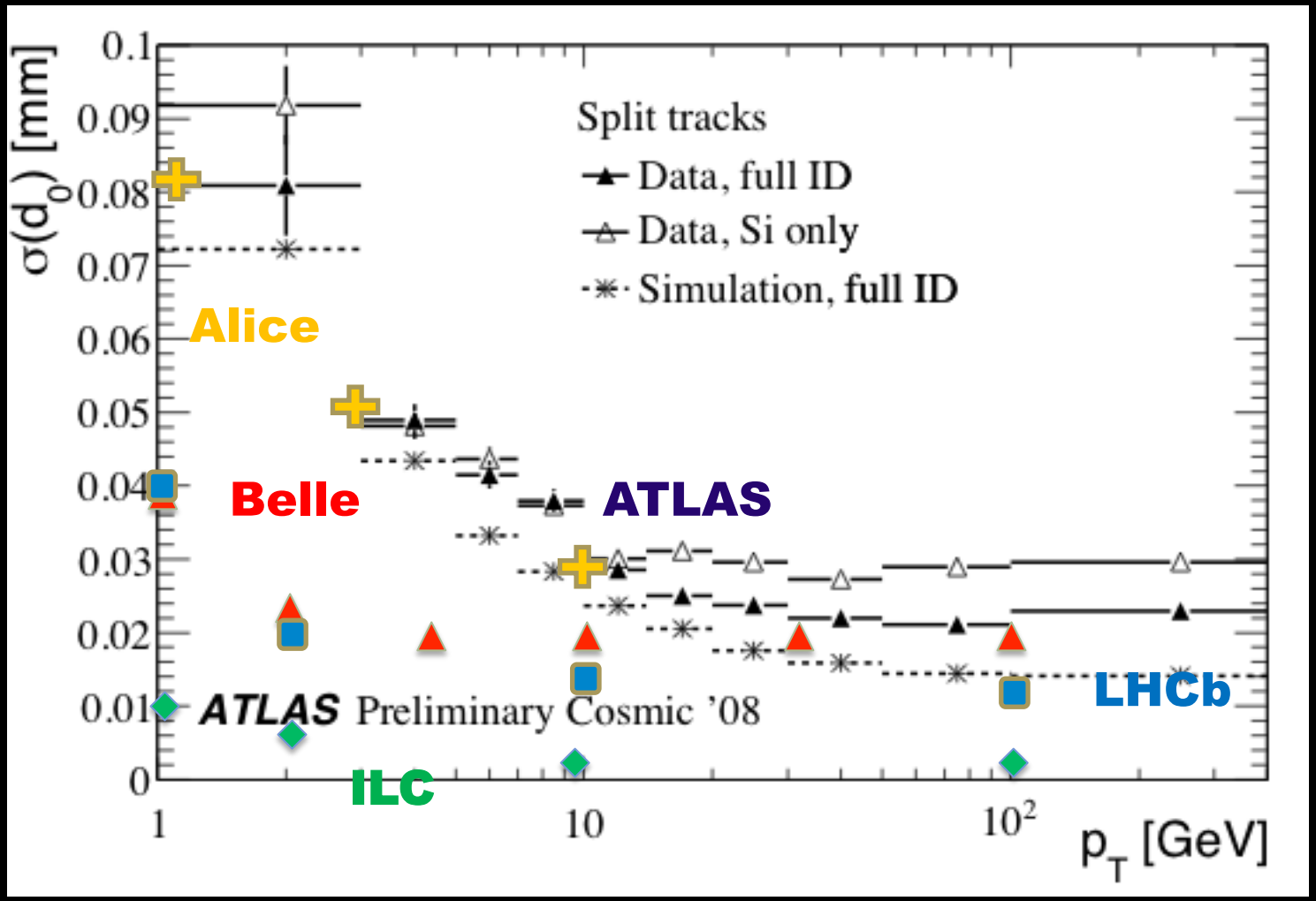
- Charged particles
  - Use trackers
- Neutral particles
  - Use calorimeters
- Remove double-counting of charged showers
  - Requires high granularity

#ch	ECAL	HCAL
ILC (ILD)	100M	10M
LHC	76K(CMS)	10K(ATLAS)

X10^3 for ILC

Need new technologies !

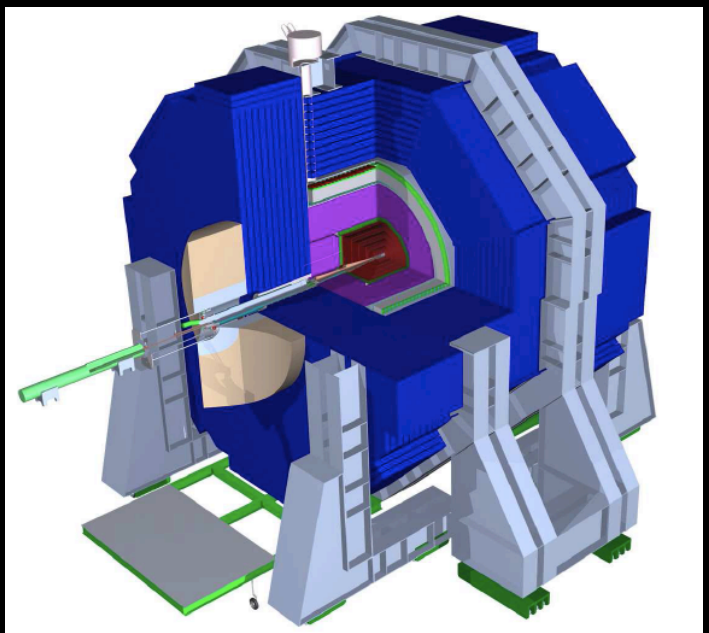
Impact parameter resolution

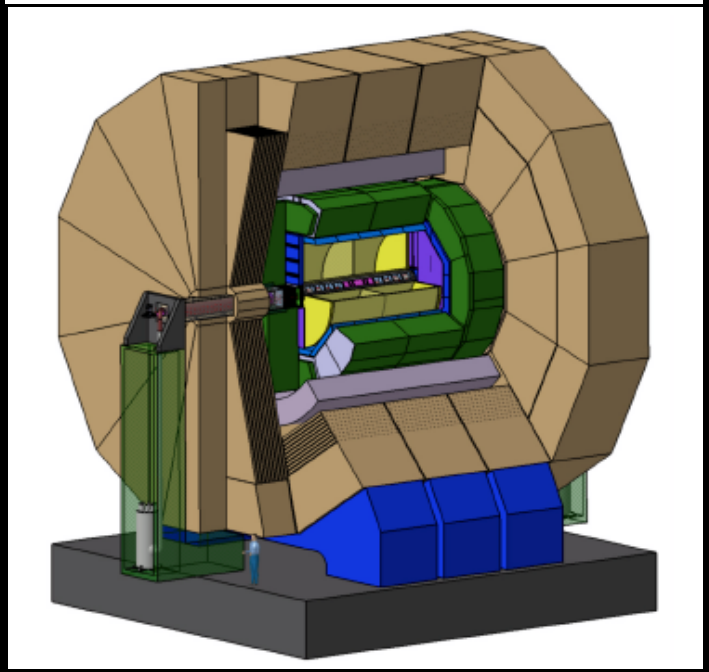


Design Strategies

ECAL/HCAL within SC coil

- SiD
  - High B field (5 Tesla)
  - Small ECAL ID
  - Small calorimeter volume
    - Finer ECAL granularity
  - Silicon main tracker
- ILD
  - Medium B field (3.5 Tesla)
  - Large ECAL ID
    - Particle separation for PFA
  - Redundancy in tracking
  - TPC for main tracker

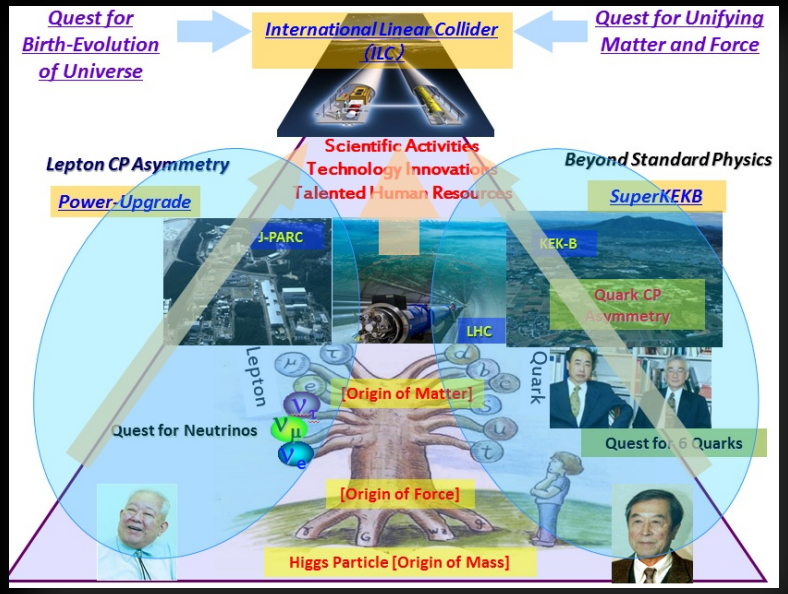




Status in Japan

KEK roadmaps

- 2007
  - ILC at the top of the pyramid



- 2013
  - 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.

JAHEP (Japan Association of High Energy Physicists)

- A report on large projects (March 2012)
  - On ILC:

    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.

  (Now, Higgs particle has been found and it is 'light')

- A proposal for staging of ILC (October 2012)
  - Staging
    - A Higgs factory with a CM energy of ~250 GeV to start
    - Upgraded in stages to ~500 GeV (TDR baseline)
    - Technical expandability to ~1 TeV to be secured
  - Guideline for cost sharing
    - The host country to cover 50% of the expenses (construction) of the overall project of the 500 GeV machine. The actual contributions left to negotiations among the governments.

International Supports

- Europe : 'European Strategy' (March 22, 2013)
  - 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 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.
- US : HEPAP facilities subpanel report (March 22, 2013)
  - The initiative from the Japanese particle physics community to host the ILC in Japan is very welcome, and the U.S. particle physics community looks forward to a proposal from Japan to discuss possible participation.
  - For the final US strategy, wait for the HEPAP subpanel (P5) report (March-May, 2014)

Political support :

LDP (Liberal Democratic Party : New Ruling Party) election platform

'ILC' appears twice explicitly

32 Rebuilding true command tower functions that strongly advance science and technology policies

- …We will actively promote the critical fields of energy creation, energy conservation, energy storage, etc. as knowledge-concentrated national strategies - for example, our country should be able to play a leading role in creation of international centers for scientific innovations such as the ILC (the international linear collider) project which is a grand project in the field of particle physics.

92 Creation of globally top-class centers for research and development

- …We will significantly strengthen supports for universities and public research facilities that perform studies at levels above the intentional standards, such as significant expansion of WPIs and playing a leading role in creation of international centers for scientific innovations such as the ILC (the international linear collider construction) project which is a grand project in the field of particle physics.

Press conference by the MEXT minister Shimomura

Jan 18, 2013

‘(On ILC) We would like to consider the plan for the near future, while as the government actively negotiating with relevant countries in the first half of this year … we are now studying the legal framework.’

Support by Industries:

A report by the Association of Corporate Executives (経済同友会: one of the two such groups in Japan）

‘… The Japanese government should announce the intention to site the ILC in Japan, and propose to related countries to begin discussions toward its realization. ‘

Science Council of Japan

Report submitted : Sep 30, 2013

(Unofficial translation)

- …we fully acknowledge the necessity and academic value of an electron-positron collider that is complementary to the LHC.

- …the Science Council of Japan proposes that the Japanese government appropriate necessary fund to study various issues toward deciding the implementation of the ILC project, and intensively conduct examinations and studies for 2 to 3 years by a group including experts outside of the relevant field and related government offices.

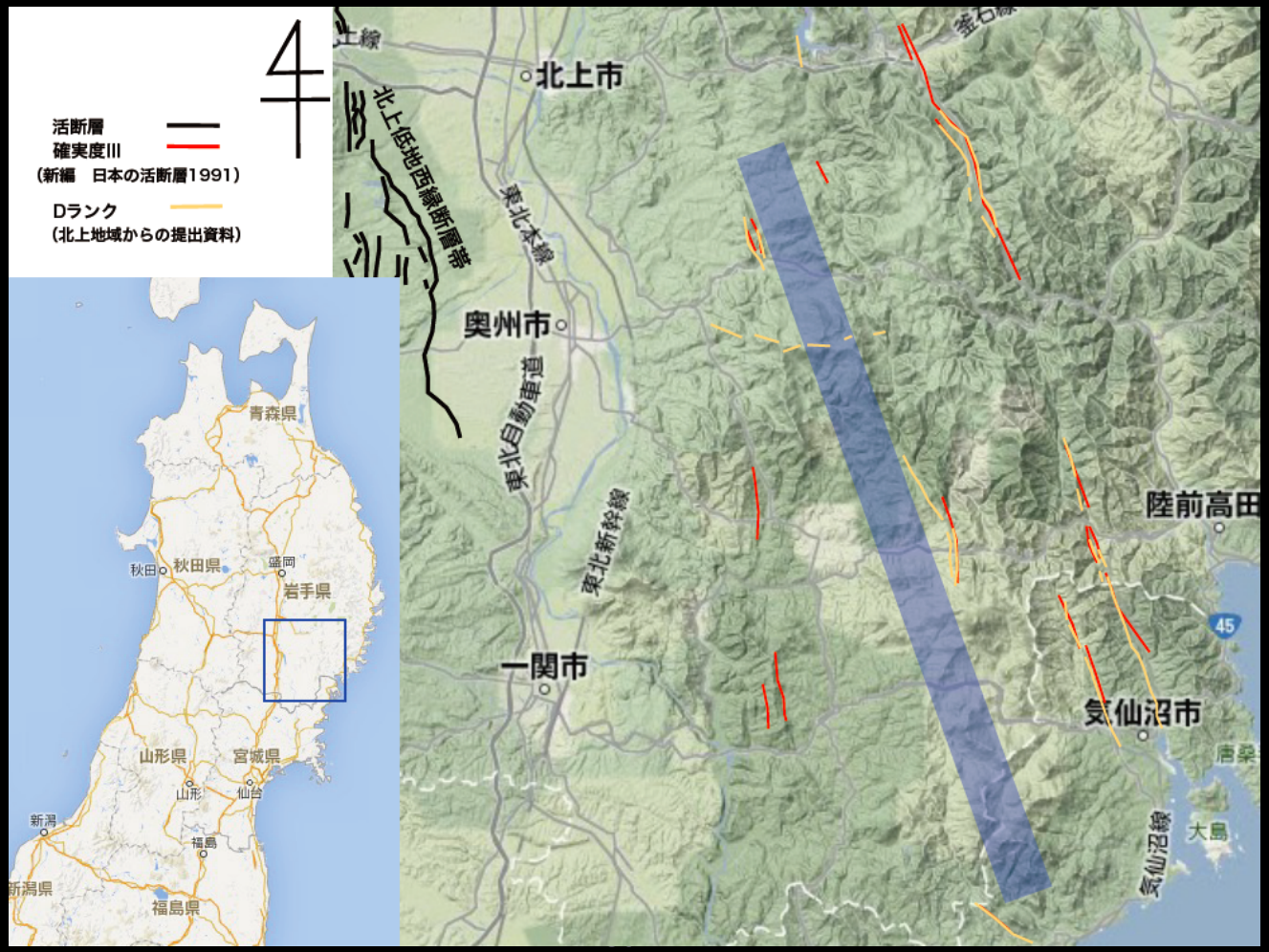
- In parallel with the above study and examination, negotiations should be conducted with research laboratories and funding authorities of relevant countries and regions to clarify the issues such as the international cost sharing.

MEXT has requested ~$0.5M for the investigatory study

Japanese Candidate Site

Chosen by the ILC site evaluation committee (JAHEP) (Aug 23, 2013)

- Kitakami site (north of Sendai)
- Based on geological/technical and socio-evironmental aspects



ILC Timeline
Proposed by LCC

- 2013 - 2016
  - Negotiations among governments
  - Accelerator detailed design, R&Ds for cost-effective production, site study, CFS designs etc.
  - Prepare for the international lab.
- 2016 – 2018
  - 'Green-sign' for the ILC construction to be given (in early 2016)
  - International agreement reached to go ahead with the ILC
  - Formation of the ILC lab.
  - Preparation for biddings etc.
- 2018
  - Construction start (9 yrs)
- 2027
  - Construction (500 GeV) complete, (and commissioning start)

    (250 GeV is slightly shorter)

Summary

- With the discovery of Higgs, the physics case for the ILC is now stronger than ever
- ILC accelerator design is ‘ready’ with the completion of TDR
- The ILC detectors are pushing the state of the art of particle detection technologies
- Japanese government is now willing to negotiate with other governments toward siting the ILC in Japan (when will be the official announcement?)
- There are strong supports from the international scientific community. (will they translate to real commitments?)

Backups